SSCL-N-745

THE INJECTOR WORKSHOP REPORT

Superconducting Super Collider Laboratory*
2550 Beckleymeade Avenue
Dallas, TX 75237

December 3–December 6, 1990

* Operated by the Universities Research Association, Inc., for the U.S. Department of Energy under Contract No. DE-AC02-89ER40486.

INTRODUCTION

Consistent with the Superconducting Super Collider (SSC) construction plans, an Injector Workshop was held at the SSC Laboratory on December 3–6, 1990 to discuss the issues of the Injector chain. The charge to the workshop is described in the letter of invitation to the participants, reproduced as Appendix A. The non-SSCL participants were L. Teng, M. Furman, S. Penner, M. Craddock, U. Wienands, S. Koscielniak, S. Pruss, J. Griffin, and E. Courant.

Nine working groups were formed. They are listed below together with the group coordinators:

space charge effects (L. Teng)

High gamma-t lattices (R. York)

RF (M. Craddock, W. Funk)

LEB-to-MEB bucket matching (J. Peterson)

transition crossing (R. Gerig)

MEB beampipe (S. Pruss)

bunch spacing (J. Griffin)

circumferences and fills (S. Penner)

parameters consistency (M. Furman, C. Manz)

The workshop agenda was as follows:

Monday, December 3, 9:00 a.m.–12:00 p.m.

welcoming remarks (D. Edwards)

status of LEB (R. York)

status of MEB (R. Gerig)

status of HEB (D. Johnson)

discussion of tasks and specific assignments (A. Chao)

Wednesday, December 5, 9:00 a.m.–10:00 a.m.

working group coordinators meeting

Thursday, December 6, 2:00 p.m.–5:00 p.m.

working group summary reports

This document is the collection of the summary reports by the working groups. It serves as the reference of work in the next several months.

–Alex Chao

SPACE CHARGE EFFECT IN LEB

L. Teng

Space Charge Effect in LEB

Maximum tune shift (core of Gaussian beam)

	600 MeV / 1.22 GeV/c	1000 MeV / 1.70 GeV/c
$0.6\pi\ \mu$m	0.4	0.16
$0.25\pi\ \mu$m	1.0	0.4

0.16 looks o.k. but 0.4 (perhaps even 1.0) may still be o.k.

Computation by Machida

1. $0.6\pi\ \mu$m 600 turns $\rightarrow$ $0.65\pi\ \mu$m (reaching asymp.)
   (See plot on p.5)
2. $0.25\pi\ \mu$m 1000 turns $\rightarrow$ $0.3\pi\ \mu$m (still rising)
   (See plot on p.6)

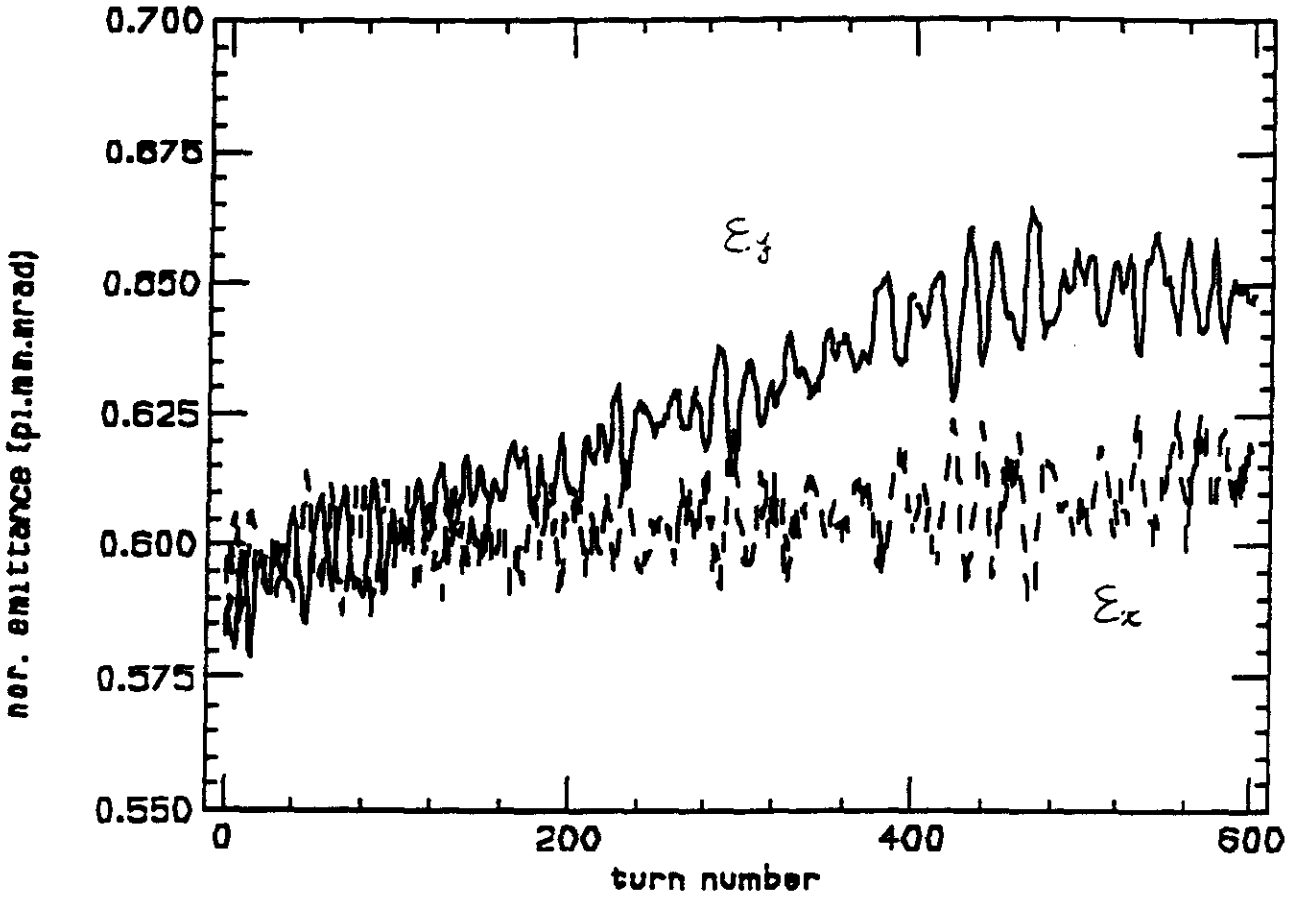
Improvements:

1. Continue $0.25\pi\ \mu$m calculation to asympsatic value.
   Overshoot formula should apply.

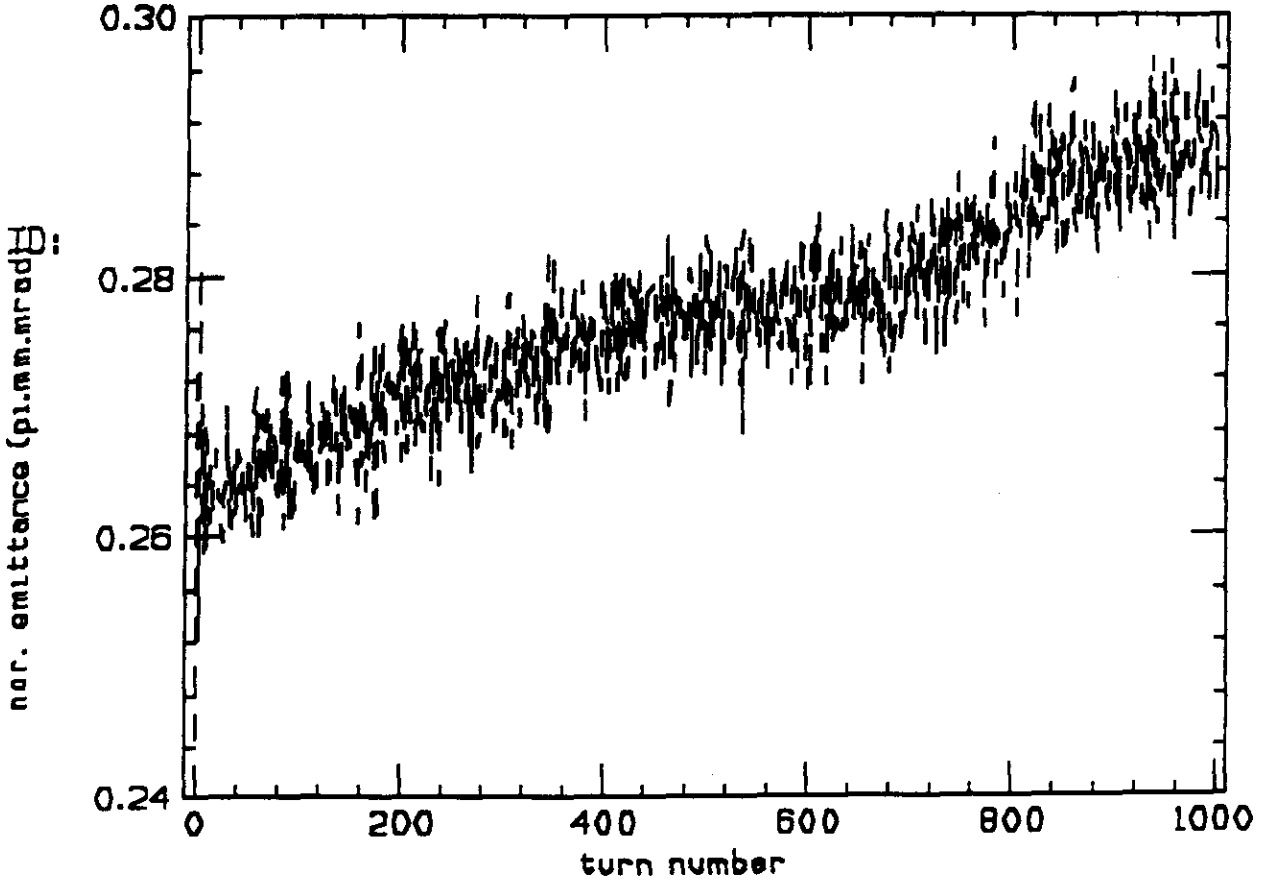
$$\varepsilon_{\text{init.}} \times \varepsilon_{\text{asymp.}} = \varepsilon_{\text{thresh.}}{}^2$$

2. So far only radial (r) binning is included. Driving of coupling resonances is not given correctly. Should add section (φ) binning—computer time may be too long!
3. Add acceleration (work by Talman and Bourianoff).
   In 1000 turns:
   At bottom of Cos, momentum = 1.22–1.28 GeV/c
   At fastest slope, momentum = 1.9 GeV/c
   Effect is significant.

PRELIMINARY



PRELIMINARY



4. Emittance budget by S. Penner.

   a. Injection blowup—steering errors, focusing mismatch, foil scattering

$$0.25\pi\ \mu\text{m} \rightarrow 0.41\pi\ \mu\text{m} \quad \text{(in LEB)}$$

   b. Extraction blowup-steering errors

$$0.55\pi\ \mu\text{m} \leftarrow 0.60\pi\ \mu\text{m} \quad \text{(in LEB)}$$

   Hence all self-field effects should cause no more emittance growth than

$$0.4\pi\ \mu\text{m} \rightarrow 0.55\pi\ \mu\text{m}$$

5. Some Machida results still have to be understood physically.

6. Add vacuum chamber wall effects. Negligible?

Conclusions:

1. With $\left\{\begin{array}{c}\text{sector binning}\\ \text{accelerations}\\ \text{wall effect}\\ \text{synch. osc.}\end{array}\right\}$ added

   and with bin size, step size, convergence, precision etc. all checked; the computer calculation is perhaps the best and only thing one can rely upon.

2. 600 MeV is likely o.k. But going up to 1000 MeV is always a fallback position.

3. Space charge neutralization may be considered, but it is not reliable.

4. Octupoles?

Improvements on Machida's Space Charge Simulation

1. Use two degree-of-freedom bins (r, φ) instead of a single degree-of-freedom (r).
2. Add acceleration and vacuum chamber wall effect.
3. Add synchrotron oscillation. The synchrotron oscillation modulation on the tune shift can be 100%. But this would expand the problem to 3 degrees-of-freedom and one should also consider longitudinal space charge!!!
4. Minimum convergence studies required.
   a. Bins size
   b. Step-size
5. This is a different problem and I do not know how to do it any other way!

HIGH γ_t LATTICES

R. York

REPORT OF THE HIGH γ_{tr} LEB WORKING GROUP

December 6, 1990

Working Group Members

Richard York
Ernest Courant
Mike Craddock
Al Garren
Sam Penner
Fulvia Pilat
Ulie Wienands

LEB Design Issues

- Lattice
  - γ_{tr}
  - Dynamic Aperture
  - Linear Aperture

- Circumference
  - Space Charge Tune Shift
  - RF Design Gap Voltage—HDWR space
  - Polarized Beam Transport—HDWR space
  - Detailed Parts Inventory—HDWR space

- Trans. Emittance (0.6π mm mrad)
  - Space Charge Tune Shift
  - Hardware Tolerances
  - Collective Effects

High γ_t Lattice Subjects Considered

- Space—M. Craddock, R. York
- General Parameters—U. Wienands
- Alternative Lattices—A. Garren, U. Wienands
- Dynamic Aperture—F. Pilat
- Polarized Beam—E. Courant, U. Wienands
- Transverse Emittance Budget—S. Penner

Preliminary Conclusions

Space

The longitudinal space for a 12 GeV/c, high γ_t lattice will require a circumference of at least 540 m *if* significant care is taken and probably at the expense of some engineering complexity.

General Parameters

The general parameters stipulated at the beginning of the report are reasonably appropriate. Space charge tune shift considerations would tend to decrease the 540 m circumference and to increase injection momentum. Longitudinal space considerations would tend to increase the 540 m circumference and to decrease the extraction momentum.

Alternative Lattices

The two lattices presented support the preliminary conclusion that a suitable ($\gamma_t \approx 20$) lattice with a triangular shape and a circumference of approximately 540 m is feasible.

Dynamic Aperture

Evaluation of the perturbed Garren lattice and the unperturbed Wienands lattice, support the preliminary conclusion that a suitable dynamic aperture may

be achieved though probably not without significant care and therefore, engineering expense.

Polarized Beam

A high lattice symmetry in the vertical plane may be necessary in order to effectively avoid or otherwise compensate depolarizing resonances under the basic LEB design conditions of repetition rate and momentum range.

Transverse Emittance Budget

The transverse emittance growth budget of $\epsilon_n = 0.6\pi$ mm·mrad after extraction will be marginally adequate given the fact that preliminary estimates for contributions *other than* those attributable to space charge tune shifts, lattice perturbations, and collective effects account for all but $\approx 0.15\pi$ mm·mrad.

Specified LEB Design Parameters

- $\mathbf{P}_{\text{injection}}$
  - Baseline $\rightarrow$ 1.2 GeV/c
  - Potential $\rightarrow$ 1.7 GeV/c
- $\epsilon_{N-injection} = 0.25\pi$ mm mrad
- $\mathbf{P}_{extraction} \rightarrow$ 12 GeV/c
  - $\gamma = 12.8$
- $\epsilon_{N-extraction}$
  - Collider $= 0.6\pi$ mm mrad
  - Test Beam $= 4\pi$ mm mrad
- Circumference = 540 m
- Repetition Rate = 10 Hz
- Particles/bunch
  - Collider $= 1 \times 10^{10}$
  - Test Beam $= 5 \times 10^{10}$
- Bunch Spacing
  - Baseline $\rightarrow$ 5 m
  - Potential $\rightarrow$ 10, 20, 30, ?? m

LEB Space

M. Craddock

Machine	p_{max} (GeV/c)	C (m)	N_Q	N_{st}	L_{st} (m)	$N_{st}{*}L_{st}$ (m)	%
LEB SCDR	12	540	90	24	4	96	18
LEB AAG (11/90)	12	540	84	12 48	5.8 2	70 96	13 18
LEB UW (12/90)	12	540	108	24	5.4	130	24
FNAL Booster	8	474	(96)	24	6	144	30
MOSCOW KF Booster	8.4	470	68	24	6	144	30
KAON Booster	3.9	216	48	24	4.1	98	45

A **SPACE INVENTORY** should be compiled, to include:

	KOAN Booster
- magnets (2, 4, 6 ... pole)	has 24 straights
- rf cavities–fundamental	6
–harmonic	-
- dampers	3
- injection	2
- extraction and abort	
(kickers, septa, bumps)	$3\frac{1}{2}$
- beam instrumentation	$2\frac{1}{2}$
- polarimeter	$\frac{1}{2}$
- snakes, pulsed quads	$\frac{1}{2}$
- scrapers, collimaters	$4\frac{1}{2}$
- correction magnets } distributed	
- pumping ports } distributed	
- bellows and flanges } distributed	
- spare	$\frac{1}{2} + \frac{1}{2} + \frac{1}{2}$

Straights Space Budget

- 12 Short Straights (SS) $\approx 5.8\,\mathrm{m}$
- Space Available for non-lattice $\approx 5.0\,\mathrm{m}$
    - Injection, Extraction, RF, Polarization Hardware, etc.
- Inject. (1) & Ext. (4) HDWR $\rightarrow$ 5 SS (SCDR)
- RF Hardware $\rightarrow$ 2–5 SS
    - Length per Structure $= 1.25\,\mathrm{m}$ (SCDR)
        - Assume 4 Structures/SS
    - SCDR $\rightarrow$ 8 structures $=$ 2 SS
        - $n = 8$, $(n-2) \times 117\,\mathrm{kV} = 700\,\mathrm{kV}$
        - $n = 8$, $n \times 88\,\mathrm{kV} = 700\,\mathrm{kV}$
    - A Contingency Plan $\rightarrow$ 16 structures $=$ 4 SS
        - $n = 16$, $(n-2) \times 50\,\mathrm{kV} = 700\,\mathrm{kV}$
        - $n = 16$, $n \times 43.75\,\mathrm{kV} = 700\,\mathrm{kV}$
    - A Longitudinal Emittance Blowup Scheme $\rightarrow$ 20 structures $=$ 5 SS
        - $n = 20$, $(n-2) \times 50\,\mathrm{kV} = 900\,\mathrm{kV}$
        - $n = 20$, $n \times 45\,\mathrm{kV} = 900\,\mathrm{kV}$

Short Straight (SS) Allocation

Allocation	# Short Straights
Injection	1
Extraction	4
RF	5
Polarization Snake	1
Diagnostics, Contingency	1
TOTAL	12

- MUST Complete CAREFUL Inventory
  - primary lattice magnets, correction magnets
  - dampers, pulsed quads, beam instrumentation
  - pumping ports, bellows, flanges
  - scrapers, collimators
  - rf cavities (fundamental, harmonic)
  - injection, extraction hardware
  - snakes, polarimeter
  - spare ???????

Matching of Accelerators

U. Wienands

$$T_0 \longrightarrow (\mathrm{Ac1}) \longrightarrow T_1 \longrightarrow (\mathrm{Ac2}) \longrightarrow T_2$$

To optimize T_1, make space charge (S-C) tune shift the same in both rings.

Matching of radii and repetition rates

$$R_1 f_1 = R_2 f_2, \quad \frac{N}{R} = \text{constant implies } N_1 f_1 = N_2 f_2.$$

Matching of S-C tune shift (d-v)

$$d\nu_1 = \frac{N_1}{\beta_0 \gamma_0^2}, \quad d\nu_2 = \frac{N_2}{\beta_1 \gamma_1^2}.$$

$$d\nu_1 = d\nu_2$$

$$\Rightarrow \frac{N_1}{N_2} = \frac{\beta_0 \gamma_0^2}{\beta_1 \gamma_1^2} = \frac{R_1}{R_2} = \frac{\beta_1 \gamma_1}{\beta_2 \gamma_2} \qquad (R \propto p)$$

$$\Rightarrow \beta_1^2 \gamma_1^3 = \beta_0 \gamma_0^2 \beta_2 \gamma_2$$

For LEB; MEB: $T_2 = 180\,\mathrm{GeV}$, $T_0 = 0.6\,\mathrm{GeV}$.

$$\beta_1^2 \gamma_1^3 = \beta_0 \gamma_0^2 \beta_2 \gamma_2$$

$$\Rightarrow \gamma_1 \approx 7.4, \qquad T_1 \approx 6\,\mathrm{GeV}$$

For LEB; MEB: $T_2 = 180\,\mathrm{GeV}$, $T_0 = 1\,\mathrm{GeV}$

$$\beta_1^2 \gamma_1^3 = \beta_0 \gamma_0^2 \beta_2 \gamma_2$$

$$\Rightarrow \gamma_1 \approx 9, \quad T_1 \approx 7.5\,\mathrm{GeV}$$

Pick:

$$T_1 = 8\,\mathrm{GeV}, \quad p_1 = 8.889\,\mathrm{GeV/c}, \quad \gamma_1 = 9.5264$$
$$\Rightarrow f_{\mathrm{rep}} : 15\,\mathrm{Hz}, \quad R = 360\,\mathrm{m}, \quad \nu \approx 8$$

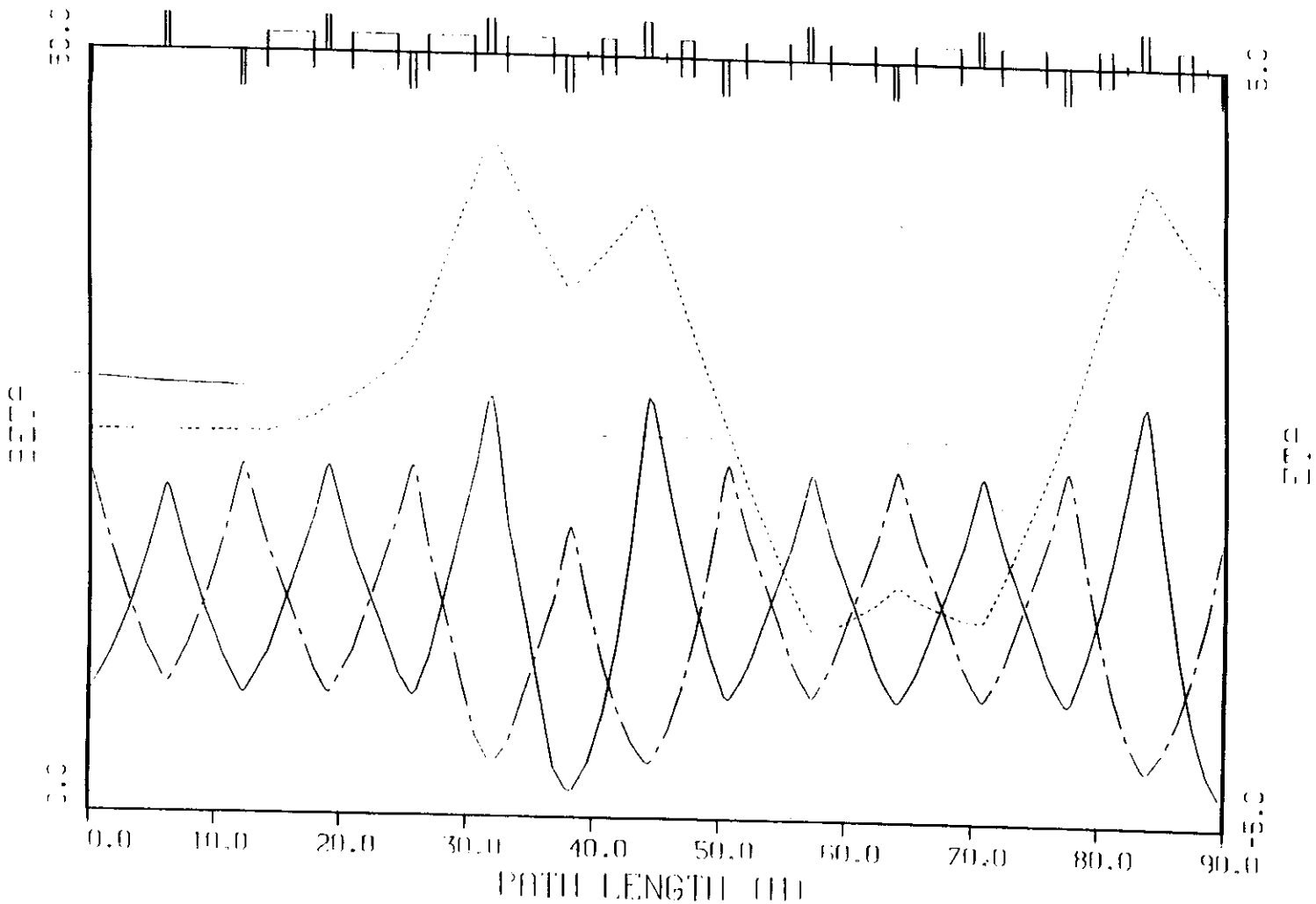
To achieve same value of η at extraction (0.00276) as in present scenario ($p_1 = 12\,\mathrm{GeV/c}$, $\gamma_t \simeq 20$) requires that $\gamma_t \simeq 11$.

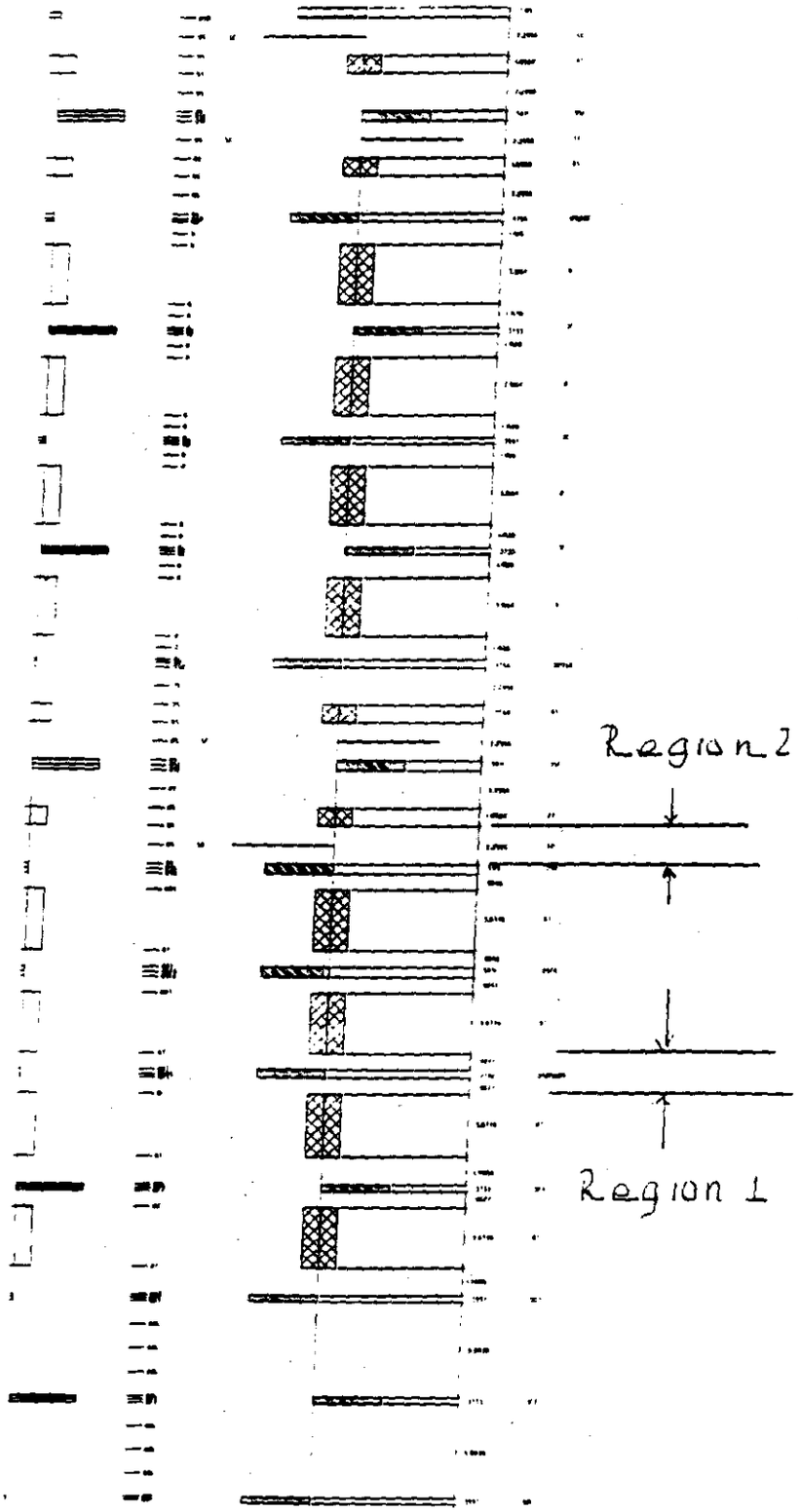
High γ_{tr} LEB Lattice

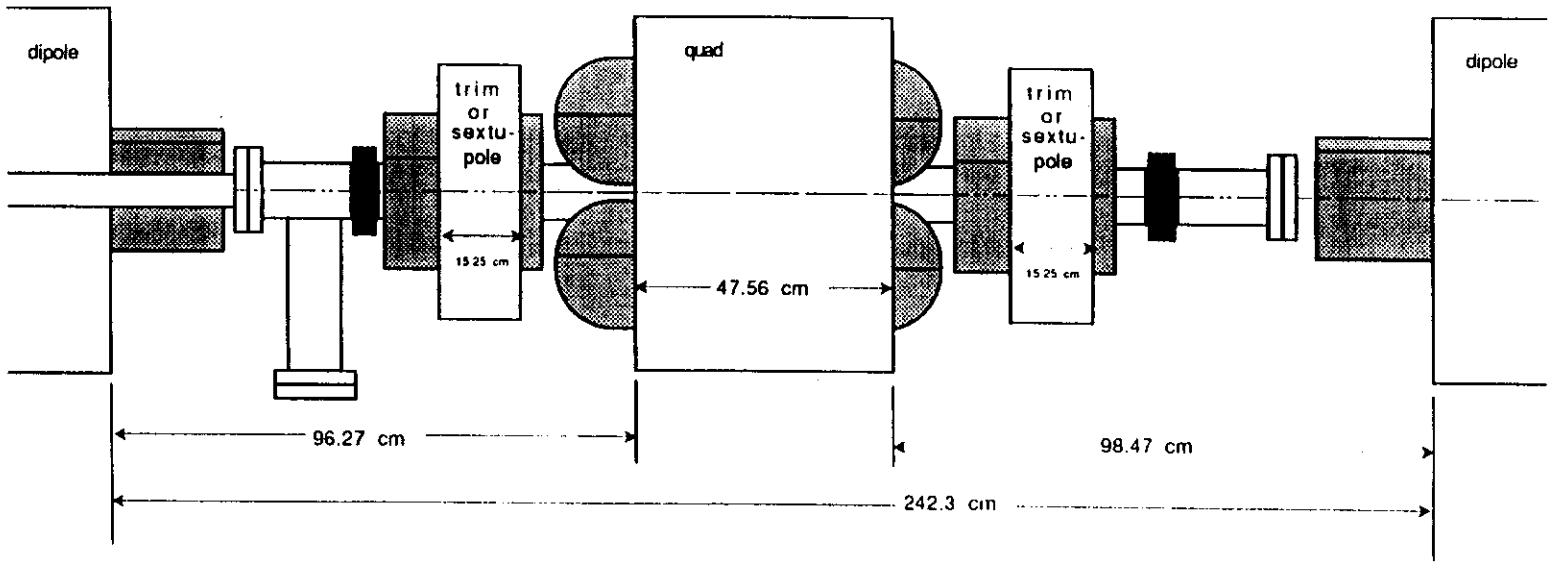
Garren

- At: USER5:[YORK.LEB]LEB_18NOV.X
- Machine Function Values
  - Circumference = 540 m
  - $\nu_x \approx 8.43$, $\nu_y \approx 8.42$
  - $\gamma_{tr} \approx 21.3$
  - β_x (max/min) = 27.6/1.71 [m]
  - β_y (max/min) = 23.2/3.53 [m]
  - η_x (max/min) = 3.95/ − 2.53 [m]
  - $\chi_{x/y}$ (natural) = −11.42/ − 10.03
- Magnetic Elements
  - Dipoles → 3 types, 72 total
  - Quadrupoles → ≈ 5 types, 84 total
  - Sextupoles → 2 types, 24 total

LEB_13NOV.X

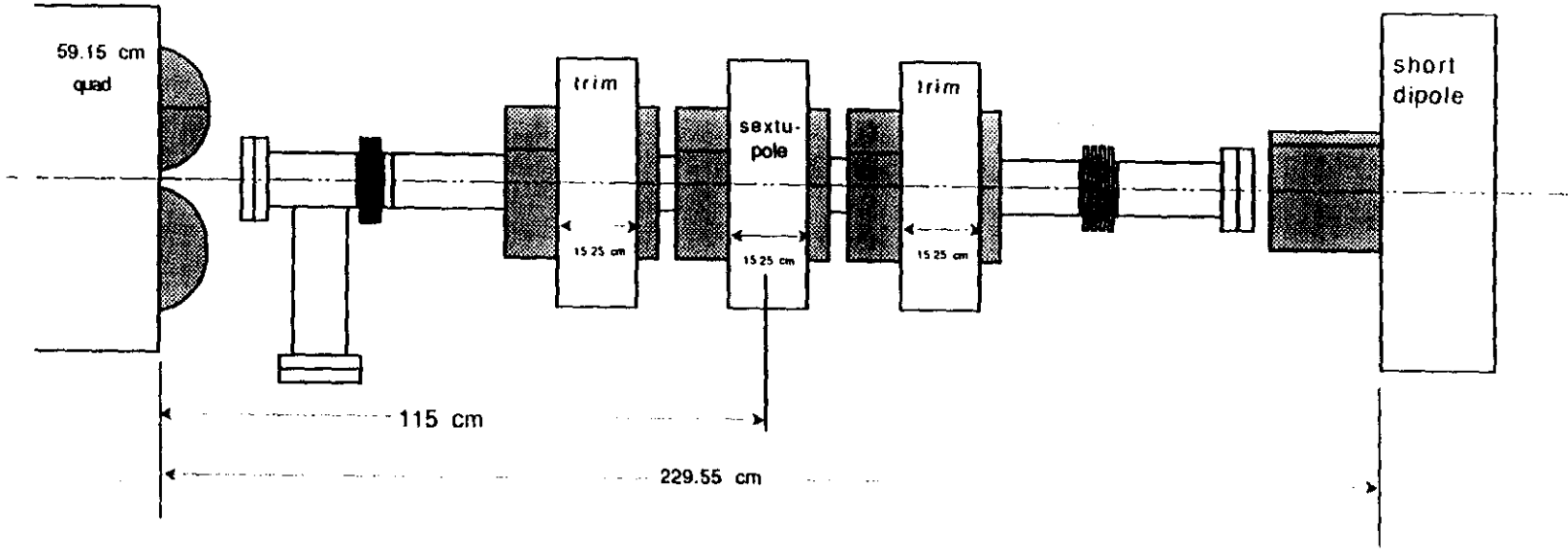



Region 2
Region 1



Region 1

revised lattice #3 (11/30/90)
dipoles shown similar to BNL with 1.5 inch added to coil overhang
quads shown as BNL
sextupoles shown as BNL with 6 inches iron
trims shown as identical to sextupoles



Region 2

revised lattice #3 (11/30/90)
dipoles shown similar to BNL with 1.5 inch added to coil overhang
quads shown as BNL
sextupoles shown as BNL with 6 inches iron
trims shown as identical to sextupoles

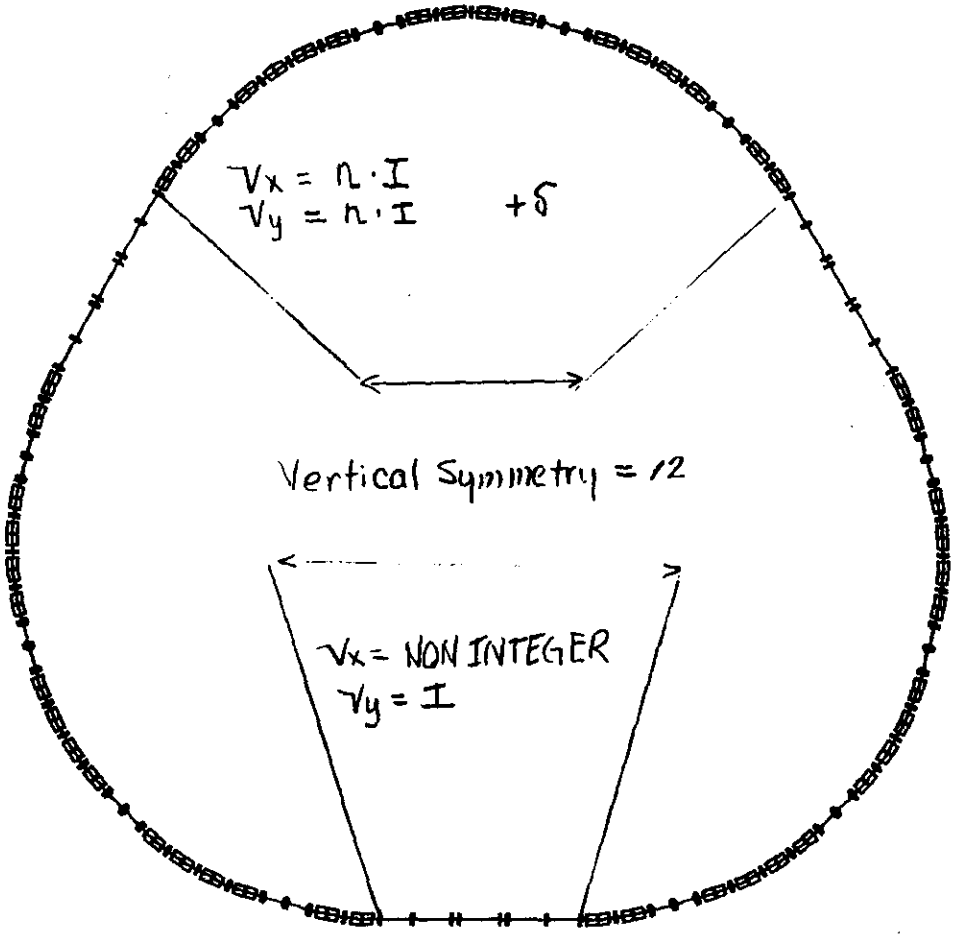
High γ_{tr} LEB Lattice

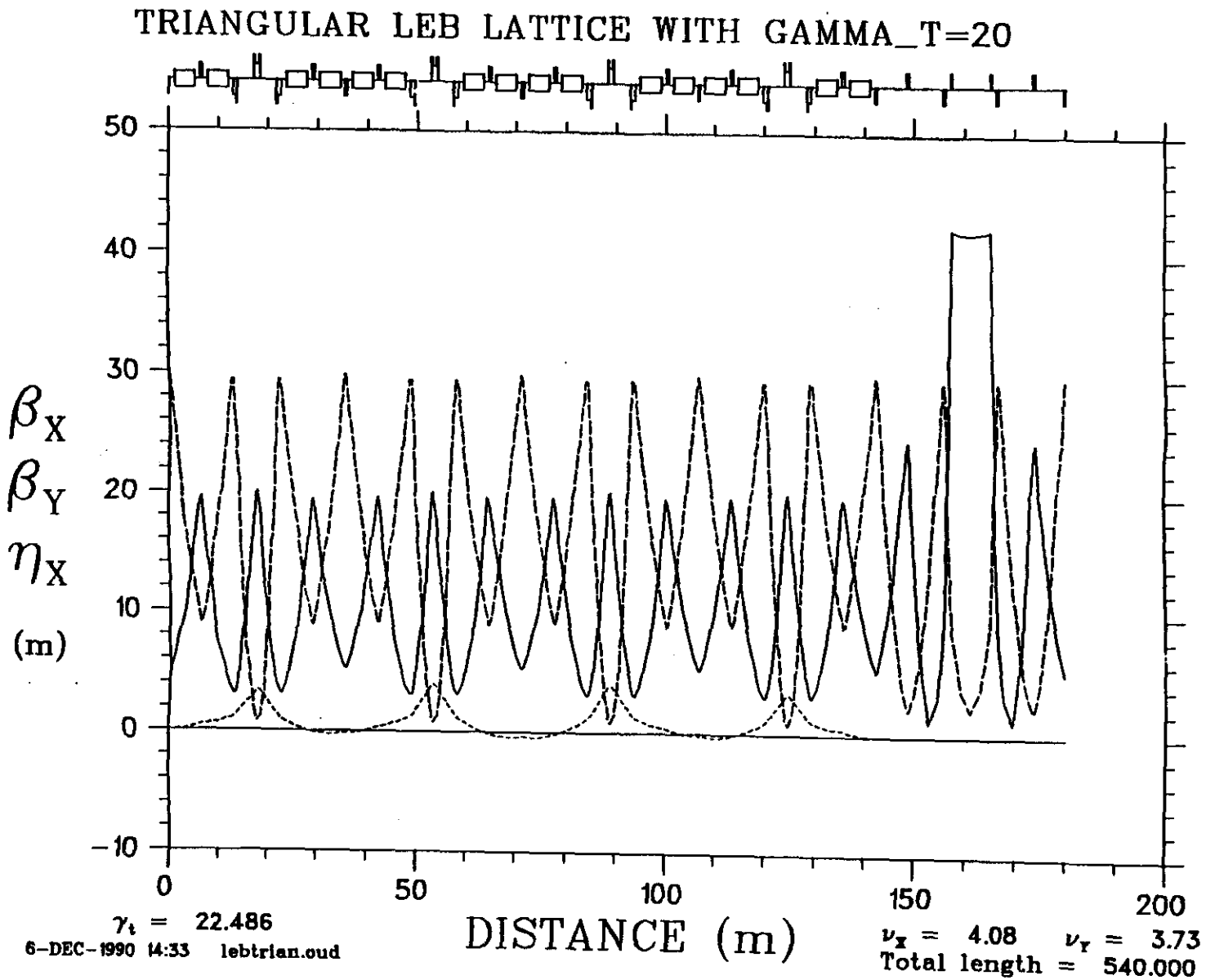
Wienands

- At: USER5:[YORK.LEB]LEBTRIAN.DAD
- Machine Function Values
  - Circumference = 540 m
  - $\nu_x \approx 12.2$, $\nu_y \approx 11.2$
  - $\gamma_{tr} \approx 22.5$
  - β_x (max/min) (arc) = 20/3 [m]
  - β_y (max/min) = 30/0.7 [m]
  - η_x (max/min) = 3.95/ − 0.2 [m]
  - $\chi_{x/y}$ (natural) = −20.35/ − 23.93
- Magnetic Elements
  - Dipoles → 1 type, 48 total
  - Quadrupoles → ≈ 8 types, 91 total
  - Sextupoles → 2 types, 36 total

TRIANGULAR LEB LATTICE WITH GAMMA_T=20

U. Wienands




TRIANGULAR LEB LATTICE WITH GAMMA_T=20
β_X
β_Y
η_X
(m)
50
40
30
20
10
0
−10
0
50
100
150
200
DISTANCE (m)
γ_t = 22.486
6-DEC-1990 14:33 lebtrian.oud
ν_X = 4.08 ν_Y = 3.73
Total length = 540.000

Past Transverse Optics Efforts

Pilat

- Dynamic Aperture Determined
  - Perfect Machines
    - Chromaticity corrected to zero
  - $\sigma = [4 \times 10^{-6} \times \beta_{x,y}/(\beta_\gamma)_L]^{1/2}$ m at 0.6 GeV
  - Vacuum Chamber $\approx 6\sigma$
  - Bench Mark
    - 480 M FODO with $\gamma_{tr} \approx 6.3$
    - Dynamic Aperture $\approx 28\,\sigma$
  - LEB_18NOV.X with $\gamma_{tr} \approx 21.3$
    - Dynamic Aperture $\approx 14\,\sigma$

Emittance Aperture

- Beam Size
  - $6 \times \epsilon_{\text{testbeam}} = 24\,\pi\mu\text{m}$
- Beam Steering [5 mm with $\beta \approx 10$ m]
  - $2.5\,\pi\mu\text{m}$
- Total $\Rightarrow \approx 27.5\,\pi\mu\text{m}$

Present Transverse Optics Efforts

Pilat

- "Quick" Stability Analysis
  - Use $\pm 4\sigma$ Gaussian distribution
  - Set Conservative (Easy to Achieve) Values
  - Set Misalignments
    - $\sigma_{x,y} = 0.5\,\mathrm{mm}$
    - $\sigma_{x',y'} = 2\,\mathrm{mrad}$ ($\rightarrow 0.2\,\mathrm{mrad}$ dipoles)
    - $\sigma_z = 5\,\mathrm{mm}$
    - $\sigma_{z'} = 2\,\mathrm{mrad}$
    - BPM's $\rightarrow \sigma_{x,y} = 1\,\mathrm{mm}$
    - BPM (x & y) per quadrupole
    - Corrector (plane of focus) per quadrupole
  - Set Multipoles
    - Quadrupoles [B1]... B2–B5 multipoles added
    - Sextupoles [B2]... B3–B6 multipoles added
    - Dipoles [B0]... B1–B2 multipoles added
    - Include eddy current contributions
  - Set Mispowering
    - Systematic $\sigma = 3 \times 10^{-3}$
    - Random $\sigma = 1 \times 10^{-3}$
- Determine Dynamic Aperture/Linearity
  - Misaligned (Corrected)
  - Multipoles
  - Mispowered

Tracking Status

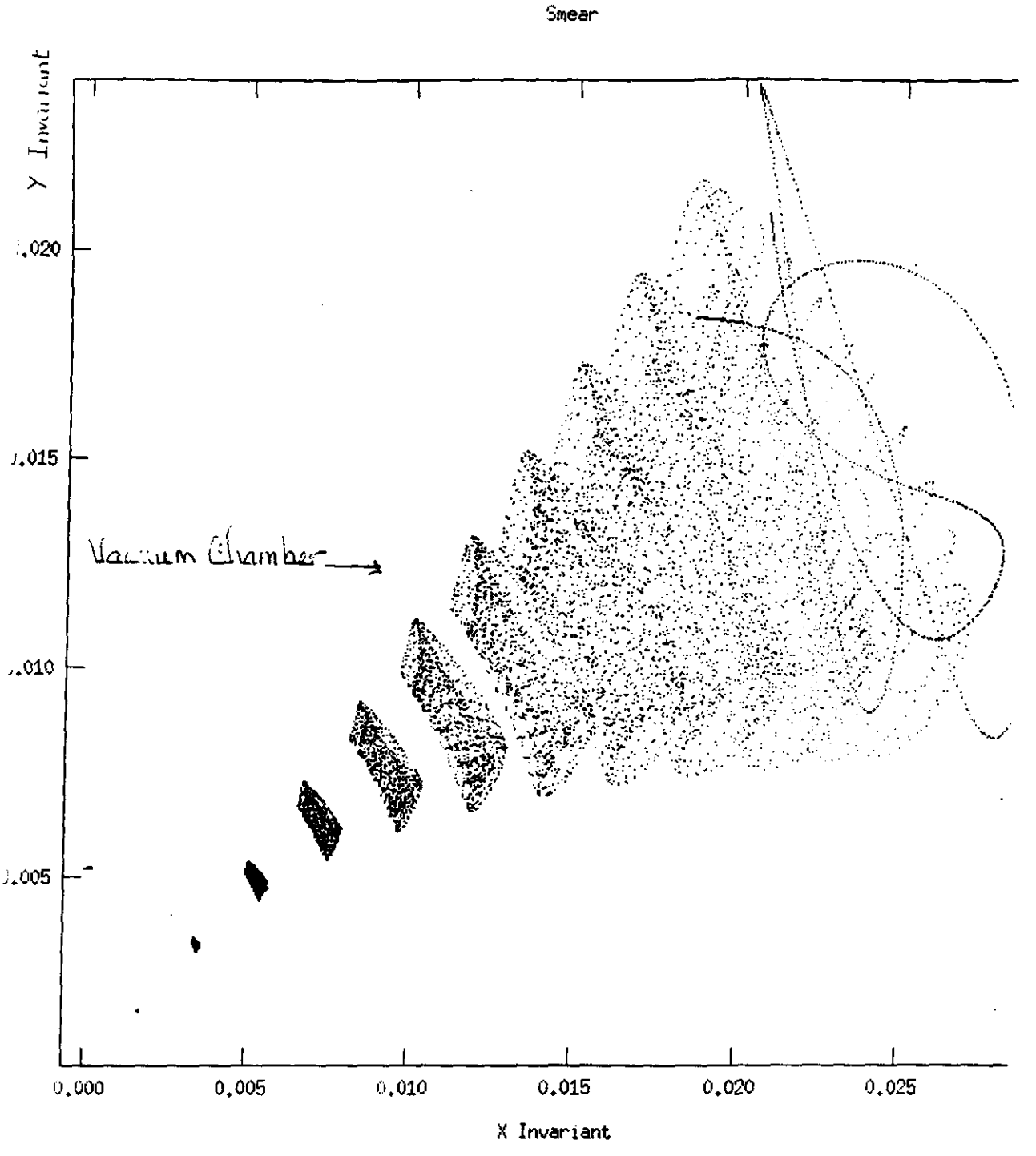
Garren LEB Lattice

18_Nov

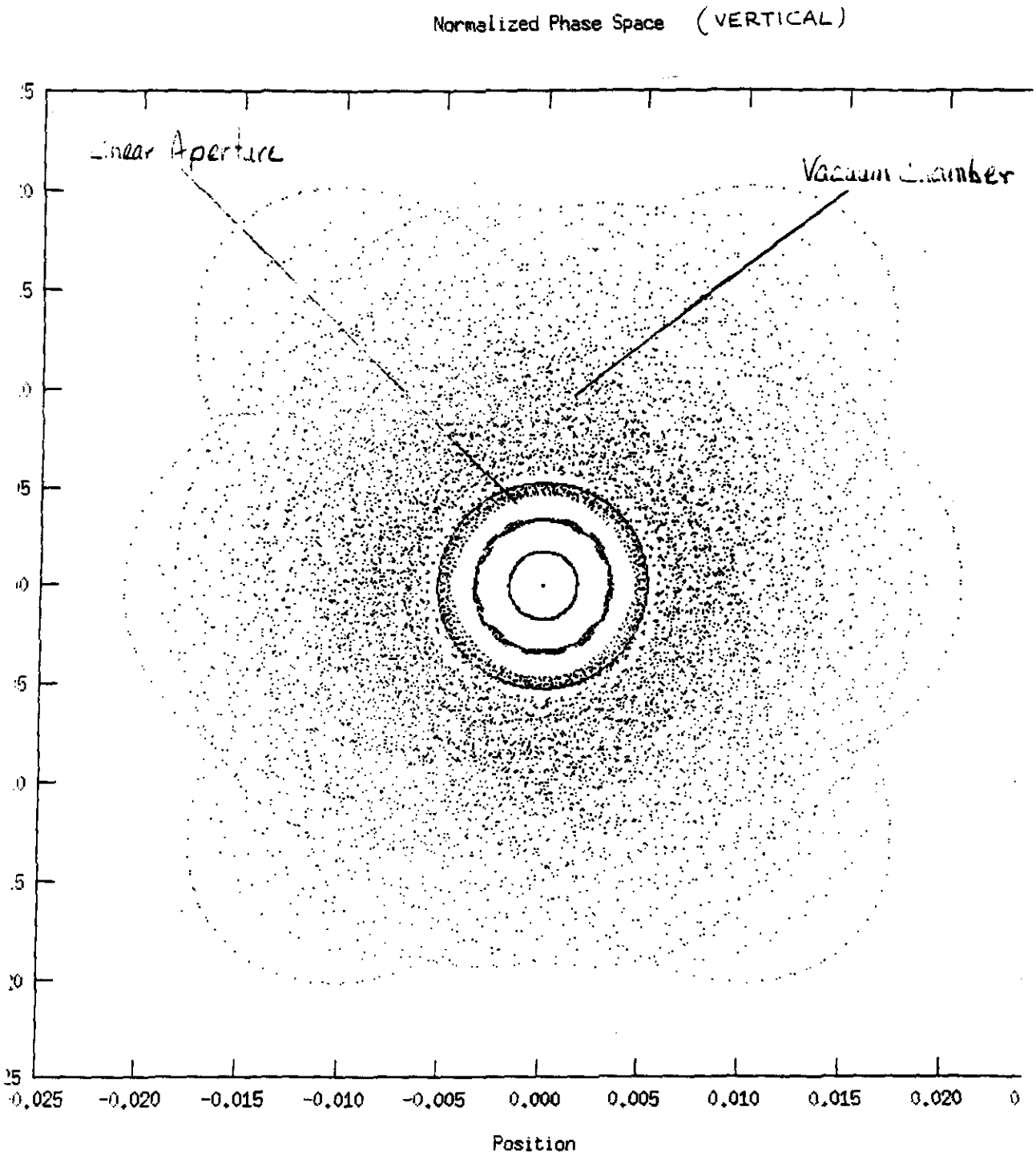
Pilat

Case	A	B	C
Chromaticity Sextupoles	Yes	Yes	Yes
misalignment (*all* elements $\sigma = 0.5\,\mathrm{mm}$ BPMs $\sigma = 1\,\mathrm{mm}$	No	Yes	Yes
errors in bends (multipoles & mispowering random & systematic)	No	Yes 10^{-4} at 5 cm	Yes 10^{-3} at 5 cm
errors in quads	Not yet	Not yet	Not yet
dynamic aperture	14σ	11σ	7σ
equivalent maximum emittance (mm·mrad)	600π	360π	150π

A


Smear
Y Invariant
.020
.015
.010
.005
Vacuum Chamber
0.000
0.005
0.010
0.015
0.020
0.025
X Invariant

A


Normalized Phase Space (VERTICAL)
Linear Aperture
Vacuum Chamber
-0.025
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-0.015
-0.010
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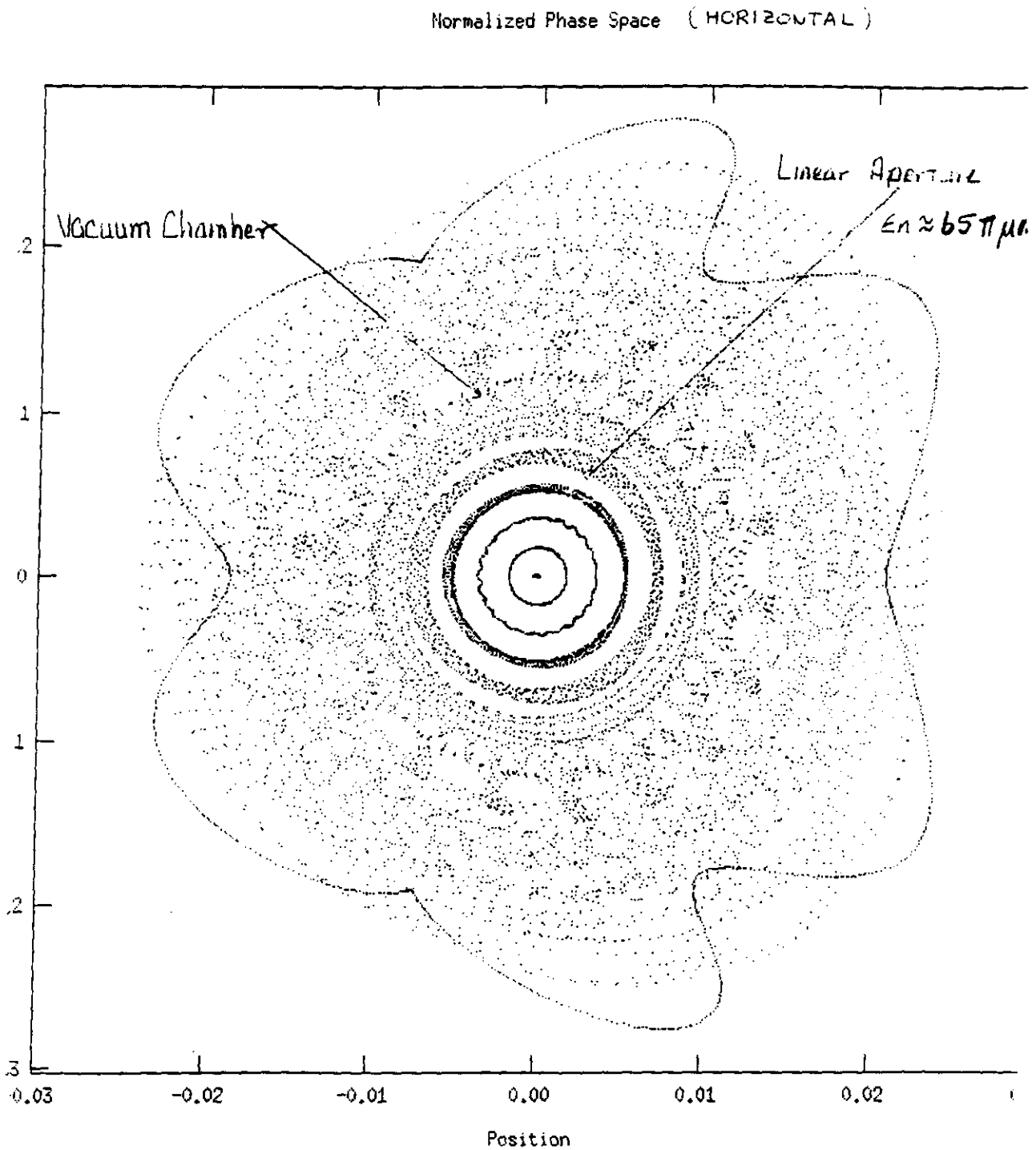
Position

A


Normalized Phase Space (HORIZONTAL)
Vacuum Chamber
Linear Aperture
En ≈ 65 π μr
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-0.02
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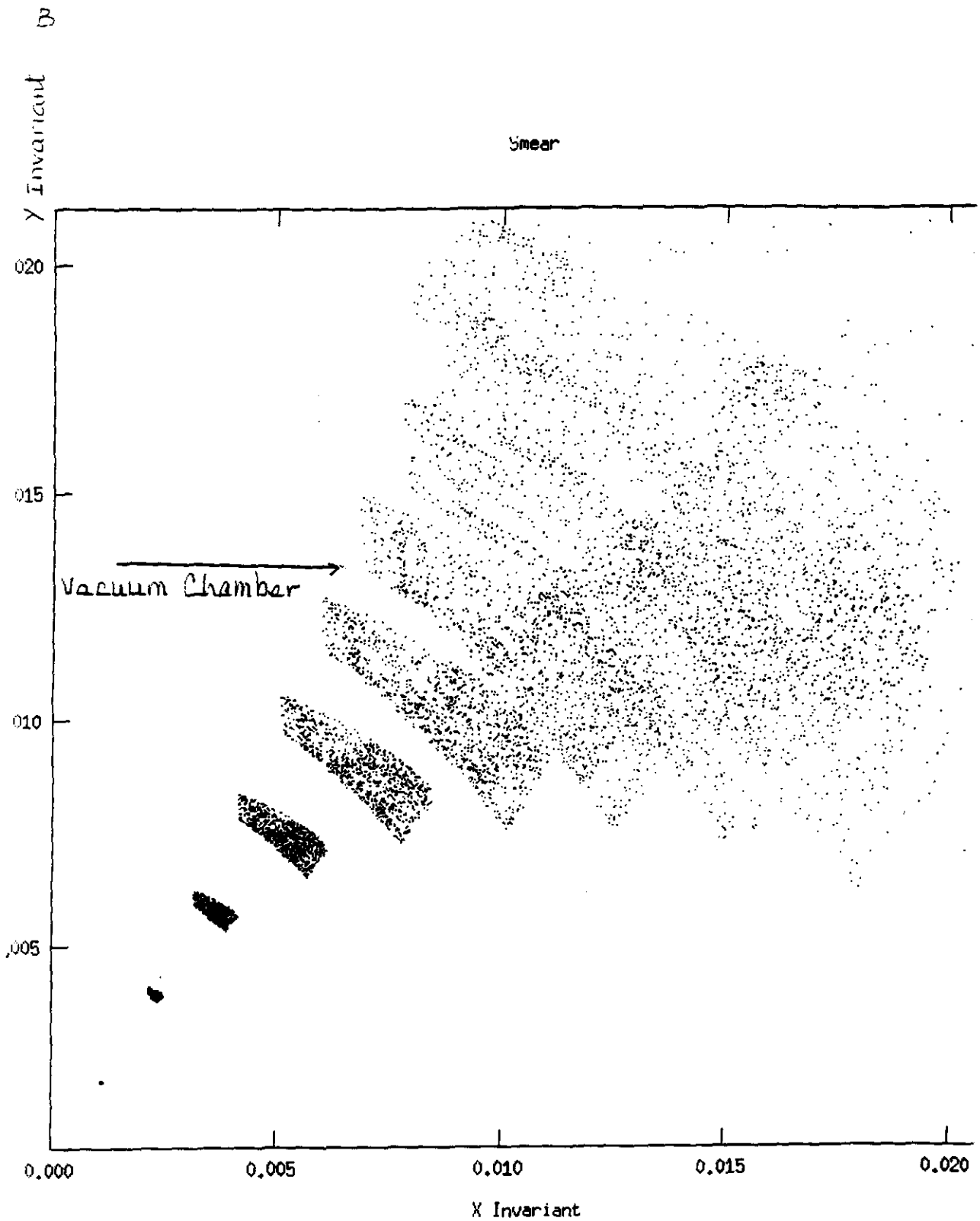
Position


B
Y Invariant
Smear
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Vacuum Chamber
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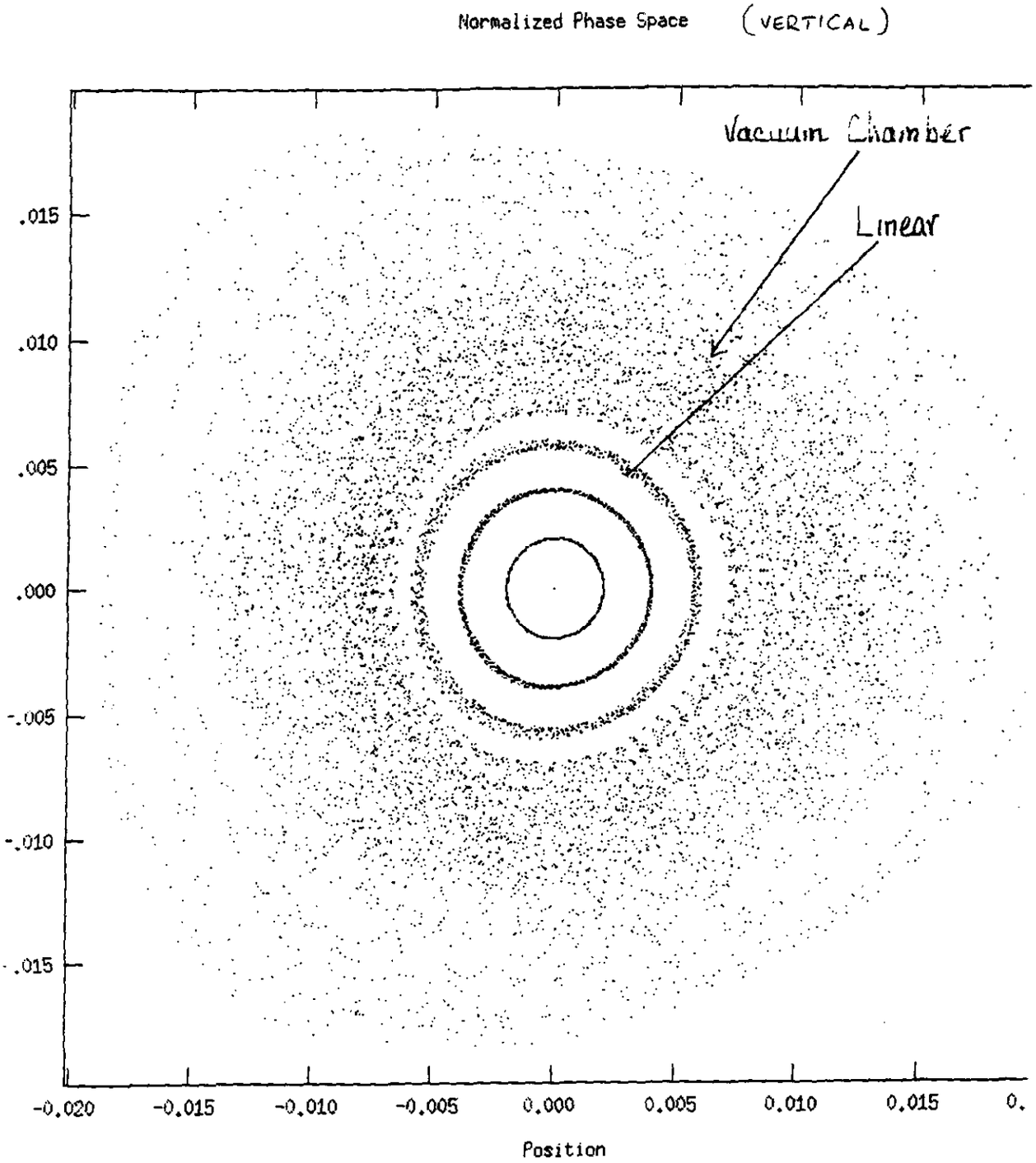
0.020
X Invariant

3


Normalized Phase Space (VERTICAL)
Vacuum Chamber
Linear
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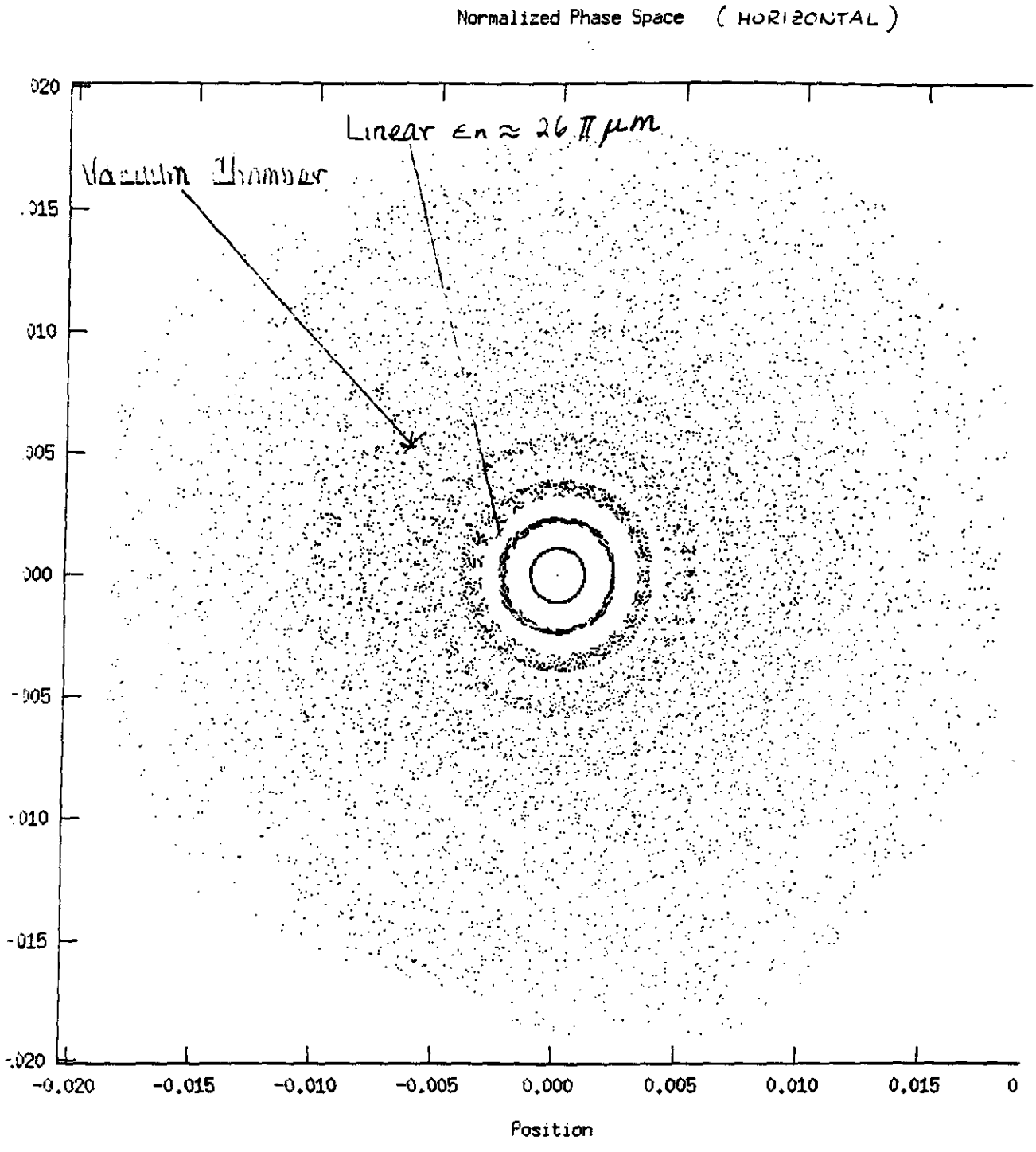
0.015
0.
Position

3


Normalized Phase Space (HORIZONTAL)
Linear $\epsilon_n \approx 26\pi\,\mu m$
Vacuum Chamber
.020
.015
.010
.005
.000
-.005
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-0.015
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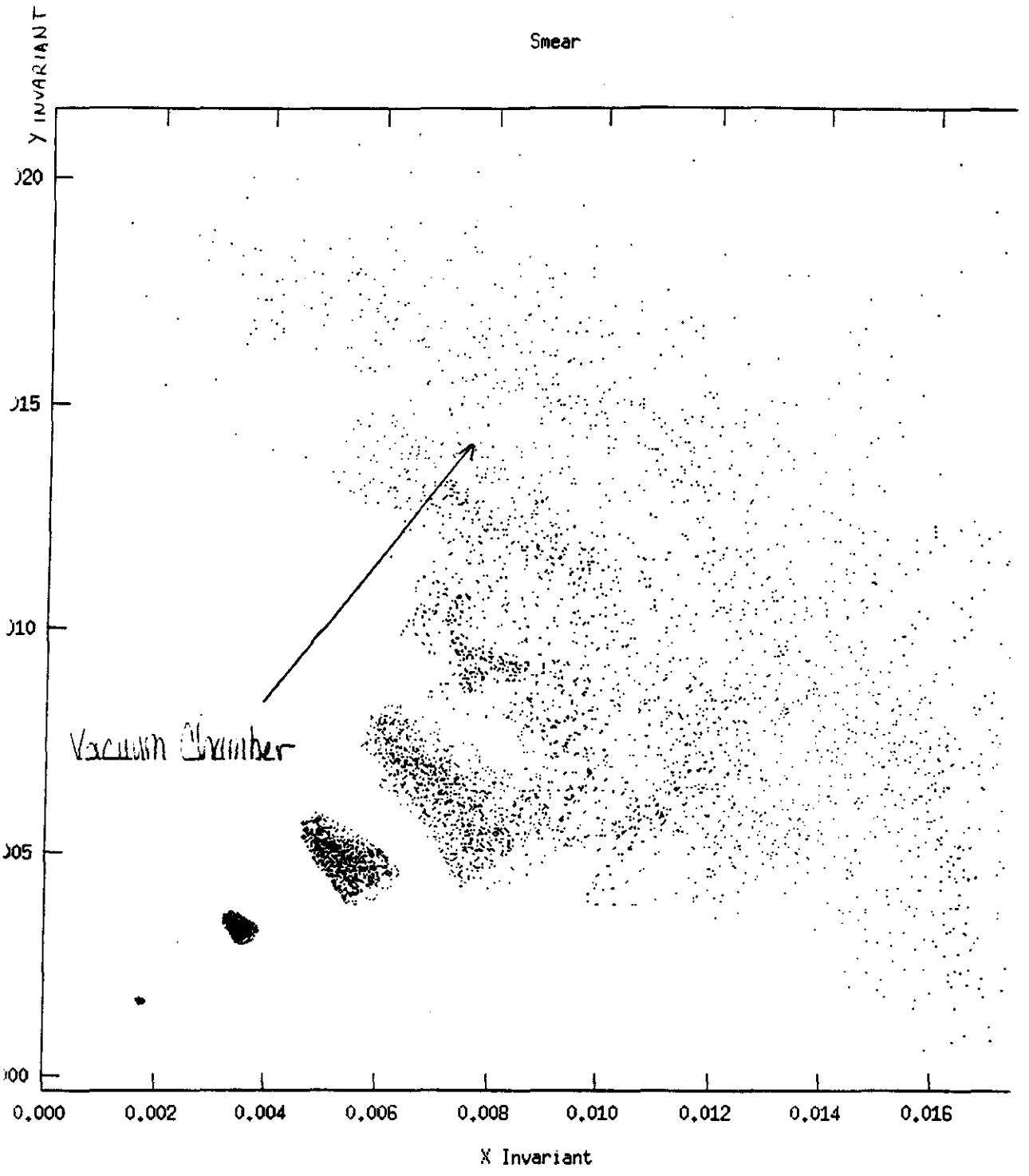
0
Position

C


Smear
Y INVARIANT
020
015
010
005
000
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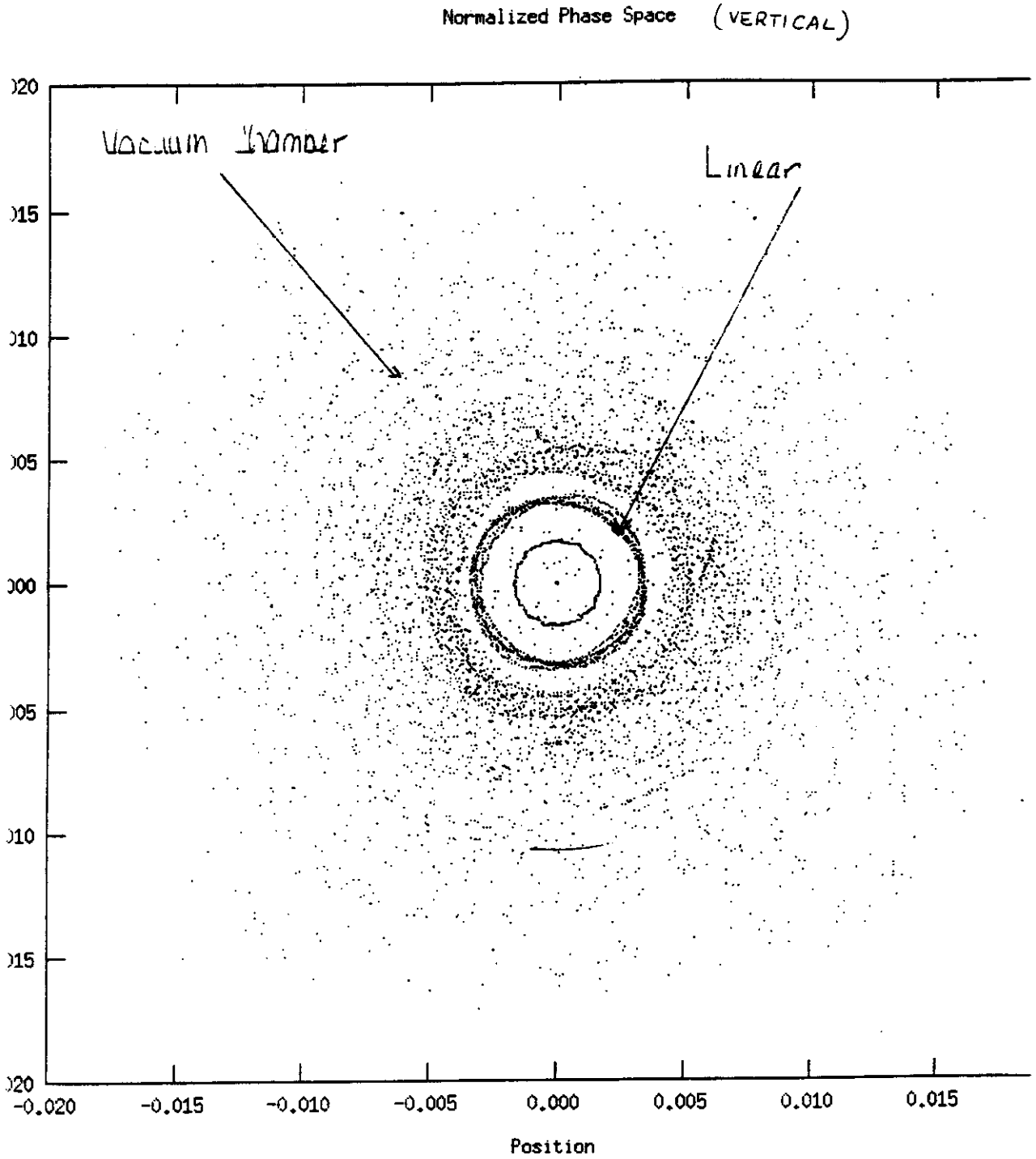
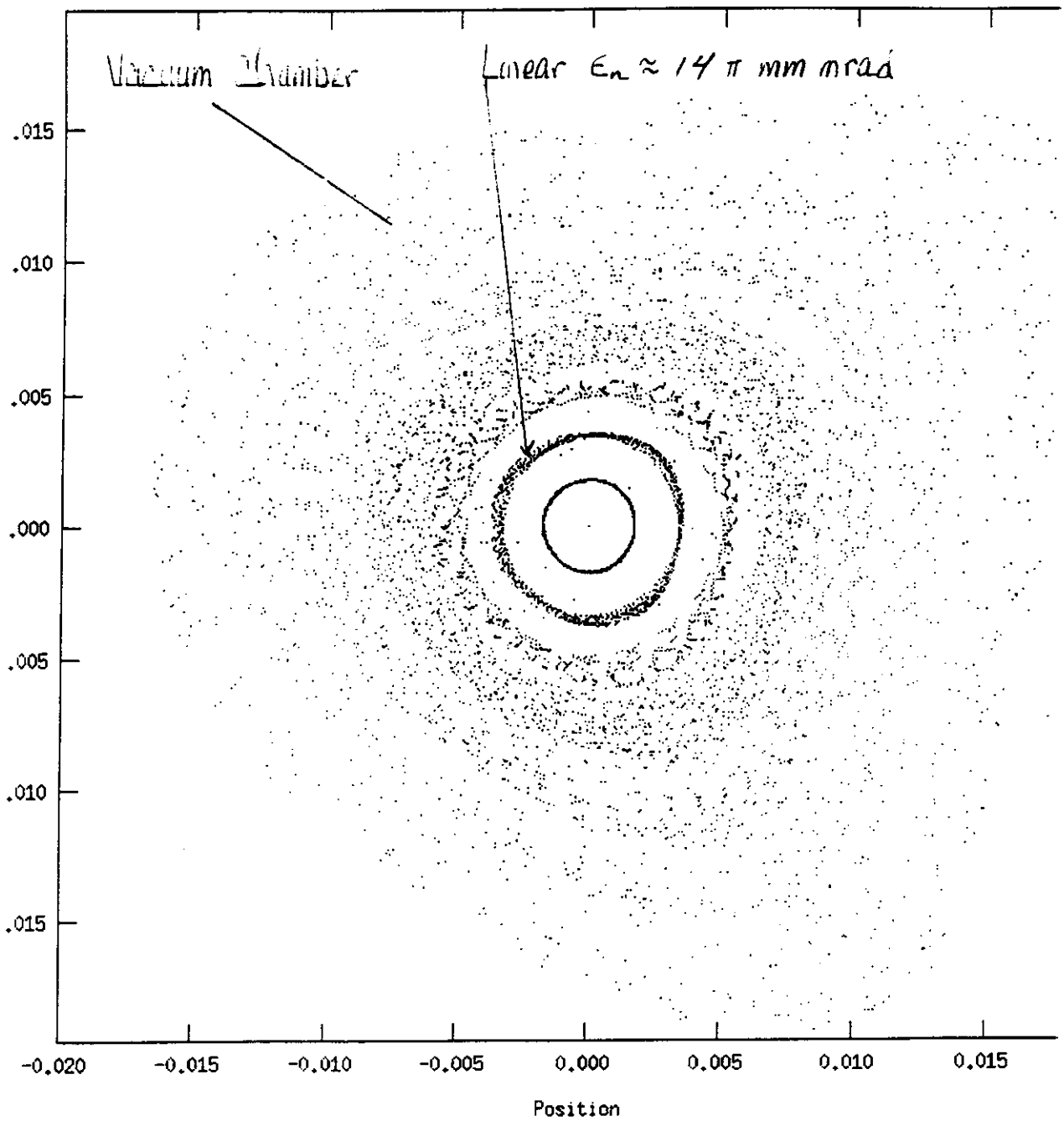
0.004
0.006
0.008
0.010
0.012
0.014
0.016
X Invariant
Vacuum Chamber

C


Normalized Phase Space (VERTICAL)
Vacuum Chamber
Linear
020
015
010
005
000
005
010
015
020
-0.020
-0.015
-0.010
-0.005
0.000
0.005
0.010
0.015
Position

Normalized Phase Space (HORIZONTAL)



Transverse Emittance Budget

Penner

- LINAC $\rightarrow 0.25\,\pi\mu$m
- With Injection Errors $\rightarrow 0.41\,\pi\mu$m
  - Steering $\rightarrow \Delta = 0.02\,\pi\mu$m
  - Bump Field $\rightarrow \Delta = 0.02\,\pi\mu$m, $B(t) = 1.2 \times 10^{-3}$
  - Septum Field $\rightarrow \Delta = 0.02\,\pi\mu$m, $B(t) = 4 \times 10^{-4}$
  - Foil Scatter $\rightarrow \Delta = 0.06\,\pi\mu$m
  - Matching $\rightarrow \Delta = 10\%$ of above
- With Ext. Errors $\rightarrow 0.45\,\pi\mu$m
  - Bump $\rightarrow \Delta = 0.0005\,\pi\mu$m, $B(t) = 1 \times 10^{-3}$
  - Fast Kicker $\rightarrow \Delta = 0.02\,\pi\mu$m, $B(t) = 1.2 \times 10^{-2}$
  - Septum #1 $\rightarrow \Delta = 0.0008\,\pi\mu$m, $B(t) = 1 \times 10^{-3}$
  - Septum #2 $\rightarrow \Delta = 0.026\,\pi\mu$m, $B(t) = 4 \times 10^{-4}$
- Not Included
  - Space Charge, Collective Effects
  - Lattice Magnetic Tolerances, Acceleration
- Budget Remaining $\rightarrow \Delta = 0.15\,\pi\mu$m

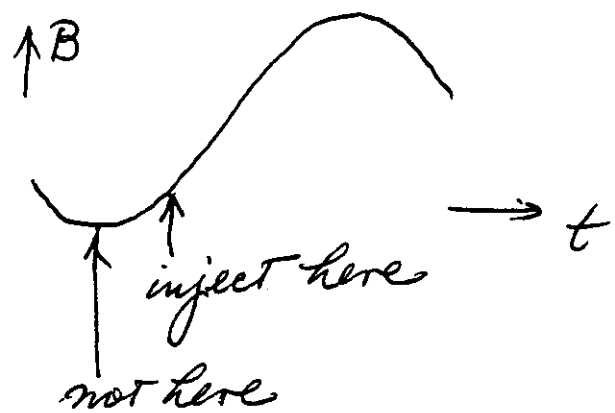
General Remarks on LEB Lattice

L. Teng

1. High γ_t lattice looks o.k. The advantage of not crossing transition in a rapid-cycling machine is worth the trouble. But the present lattice does look very crowded. One may like to have a larger circumference.

2. If the dipoles and quadrupoles are all in series, why not use combined function lattice? This will save space and money.

3. One might consider injection on the rising part of the sinusoidal ramp instead of on the bottom. This accelerates faster and is good for reducing space charge effect fast.

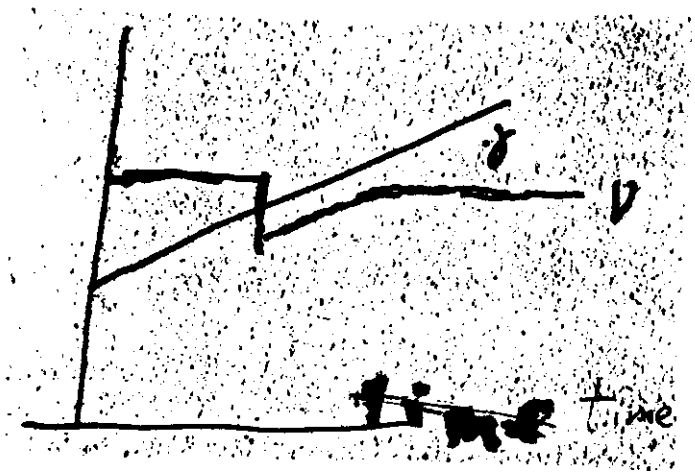


LEB POLARIZATION

E. Courant

Cure (AGS, ZGS)

Very fast pulsed Quadrupoles
modulate v_y ***rapidly*** through resonance



Must make $\Delta v \sim 0.1$ to 0.2 in a few turns ($\sim 5\,\mu$sec), then decay back. Need expensive ferrite quadrupoles, power supplies.

Worse in LEB than AGS because of timing: Some resonances only a few milliseconds apart.

LEB Polarization

Depolarizing resonances whenever

$$v_s = \gamma G = |v_y \pm kP|$$

P = periodicity of lattice

$G = 1.793$ = anamalons momat factor

Garron LEB

γG	γ	ε	Depol Factor
$v + 0$	4.695	0.0059	0.50
$24 - v$	8.69	0.0062	0.48
$9 + v$	9.71	0.0033	0.82
$27 - v$	10.36	0.0094	− .03
12	11.39	0.032	0.83
$33 - v$	13.71	0.0100	− .12

With the partial snake, spin flips by > 99.9% at every integer value of γG.

Fast pulse quads for "intrinsic" resonances still work (but partial snake does not help those).

Higher energy machines (MEB, HEB, SSC): "Siberian Snake" technique should be capable of eliminating resonances.

Alternate lattice $\Rightarrow$ U. Wienands:

Lattice where effective periodicity for polarization is 12. Only 2 of these resonances exist—easier to cope with.

Imperfections:

Resonances whenever $\gamma G = k$ (any integer). With orbit errors down to $\sim 2\,\mathrm{mm}$, these have width $\lesssim 0.005$—but still depolarize.

Cure:

"Partial Snake" Solenoid, 18° spin rotation

(4 T − M @ 12 GeV/c.)

1 depolarization components for LEB-18NV with NU = 8.4178, $G = 1.7930$

Invariant Emittance 1.500 mrad-mm

Imperfection resonances computed with rms orbit displacement 0.2255E−02 meters

RESONANCE	KP	GAMMA	EPSR	EPSI	WIDTH	DEPOL FACTOR
2.42 =	NU − 6	1.348	−0.000271	0.000000	0.00027070	
3.58 =	12 − NU	1.998	0.000580	0.000000	0.00057992	
5.42 =	NU − 3	3.022	−0.000149	0.000000	0.00014928	
6.58 =	15 − NU	3.671	−0.000033	0.000000	0.00003272	
8.42 =	NU + 0	4.695	0.005900	−0.000001	0.00590023	$< x[0.5]$
9.59 =	18 − NU	5.344	−0.000800	0.000000	0.00080019	
11.42 =	NU + 3	6.368	0.000052	0.000000	0.00005193	
12.58 =	21 − NU	7.017	0.000576	0.000000	0.00057649	
14.42 =	NU + 6	8.041	−0.000207	0.000000	0.00020722	
15.58 =	24 − NU	8.691	0.006243	0.000000	0.00624347	$< x[0.48]$
17.42 =	9 + NU	9.714	0.003253	0.000001	0.00325315	$<$ [0.82]
18.58 =	27 − NU	10.364	−0.009389	−0.000001	0.00938942	$<$ [0.03]
20.42 =	12 + NU	11.387	0.003284	−0.000001	0.00328435	$< x[0.83]$
21.58 =	30 − NU	12.037	0.001183	0.000000	0.00118295	
23.42 =	15 + NU	13.061	0.002226	0.000000	0.00222590	
24.58 =	33 − NU	13.710	−0.009954	−0.000001	0.00995402	$<$ [0.12]

L LEB IQ NOV LATTICE

X LEB TRIAN LATTICE

RF

W. Funk and M. Craddock

rf Working Group

Members

J. Griffin
S. Koscielniak
M. Craddock
J. Rogers
C. Friedrichs
G. Schaffer
D. Coleman
Y. Goren
W. Funk
N.K. Mahale

rf Working Group

Issues:

- eddy currents in the tuner manageable?
- what limits on rf $|V|$ and ϕ are allowed? How accurately does the cavity resonance have to track the rf drive?
- what is the maximum cavity operating voltage achievable?
- what alternative cavity designs are available?
- how severe is beam loading during LEB $\Longrightarrow$ MEB longitudinal matching maneuver?
- do we need more voltage capability?
- could 2nd or 3rd harmonic cavities be built for damping or capture voltage linearizing (or even transition crossing)?
- could we build sub-harmonic cavities to address the question of variable bunch spacing, as an alternative to bunch coalescing?

Tuner Eddy Currents

(Shane Koscielniak, TRIUMF)

- experiment : in the absence of a readily available 3-D eddy current program, an approximate analysis was carried out, and the conducting surfaces in the tuner modified. After experimentation, some improvements were found to be necessary. These have been implemented, and the eddy current behavior of the tuner at 50 Hz is now acceptable.
  - theory : a 2-D model has been developed, using PSPICE, which is now being fitted to the experimental data.
- conclusion : the LANL/TRIUMF style cavity tuner should work on the LEB without eddy current problems

Controls: Gap Voltage and Cavity Resonance

(Shane Koscielniak, TRIUMF)

- rf noise : analytic studies suggest (and experience at CERN confirms) that phase locking the rf drive to the beam greatly improves tolerance to phase noise. Similarly, a damping system for longitudinal quadrupole oscillations greatly reduces the sensitivity to amplitude noise.

  simulation studies should be pursued to confirm these analyses and to examine the effect of real systems with errors.
- resonance : proposed characteristics of the LEB rf system lead to a tuner bandwidth requirement of 20 kHz. Including the effects of a fast feedback loop of modest gain (10) reduces this to about 2 kHz, which is readily achievable.

Beam Loading during LEB $\Longrightarrow$ MEB Matching Exercise

(Jim Griffin, FNAL)

- this *will* be a problem, but operational modes have been devised which will minimize the effect and hold it to acceptable levels.

  Are there better ways to achieve the required match?

Maximum Achieved Gap Voltages in Prototype Cavities

- no existing broadband cavity has *demonstrated* accelerating gradients in excess of 30 kV/m cw in this frequency range. The LANL/TRIUMF cavity has supported > 100 kV at reasonable duty factors, but only at the top end of the bias curve, and "corona/imperfect discharge" effects were encountered. At the power levels and frequencies tested, this did not limit operation. Experiments at TRIUMF which will attempt to extend the operating envelope have not yet begun, but are expected in the first quarter of calendar '91. The LANL "Main Ring" cavity illustrated some additional factors which have to be taken into consideration in the design of the tuner.

Alternative Cavity Designs

- Friedrichs : a variant of the LANL/TRIUMF cavity with a tuner design incorporating flood or bath cooling to eliminate "imperfect discharge" and optimize heat transfer.
  $\Longrightarrow$ high gradient/R_{shunt}
- Schaffer : a variant of the FNAL Booster cavity with a stripline tuner configuration
  $\Longrightarrow$ low gradient/high R_{shunt}

- Griffin : a variant of the FNAL Main Ring cavity modified for larger coupling of the tuner to the cavity
  $\Longrightarrow$ high gradient/low R_{shunt}
- Conclusion : a decision requires detailed engineering studies. These are now beginning. We wish to make a decision by the end of January, 1991.

Will more voltage capability be required?

- implementation of a scheme to blow up the longitudinal emittance in the first half of the LEB acceleration cycle will demand about 25% greater voltage capability, *no matter how the blowup is done*, and require the additional voltage at an earlier time in the cycle, when the ferrite bias is lower, and the stored energy and dissipation is higher.
- We *can't* get lower voltage requirements by slowing the rep rate or reducing the ring circumference, and the demands on the rf are stringent enough even without this addition, so if it is demanded, what can we do?

⟨⟨ LATTICE DESIGNERS: MORE SPACE!! ⟩⟩

Harmonic and Sub-harmonic Cavities

- although these pose some technical challenges, they do not appear to be show-stoppers. If such cavities were considered to be necessary or useful, they could be built.

Final Concerns (non-technical)

- Given that the MEB must be available shortly after the LEB, and that TRIUMF is performing "prototype" studies appropriate to the LEB rf system, is the present distribution of effort in-house at SSC the best one could hope for? Shouldn't there be more effort directed at the MEB rf from within SSCL?
- Should more space be created in the lattice for rf to allow for the additional demands now being proposed?

Eddy Currents

Shane Koscielniak, TRIUMF

We have solved our eddy current loss problems. We have learned that there is no 3-D program readily available to predict the problems we ran into; and we are now trying to make a 2-D model based on PSPICE and our measurements. Our problems were solved by putting our structure in an AC magnetic field, measuring the effect of eddy currents and making appropriate changes to minimize the effect. Now we are in a process of fitting the model to the measurements.

Status Report on TRIUMF Booster Cavity

Roger Poirier
Shane Koscielniak, TRIUMF

The cavity is assembled with no ferite rings and operated at a fixed frequency of 65 MHz. A 50 ohm load is capacitively coupled to the cavity from below the tube coupling. The cavity has been conditioned through multipactoring and reached a pulsed (2% duty cycle) gap voltage of 65 kV; and is limited by the power supply.

In cw mode a gap voltage of 50 kV is reached; limited by the capability of the temporary anode power supply which can produce only 11 kV dc. Given 50 kV and 50 ohm load, 25 kW is dumped into the load and 7 kW into the rf structure.

At present, the main problem is with dc power supplies; these are with the manufacturer and should be back within a week or so.

LEB RF-Noise Evaluation

Shane Koscielniak, TRIUMF

1) Consider what fraction emittance increase, $\Delta\epsilon/\epsilon_L$, is allowed during the accelerating cycle or storage time, ΔT. Be wary of periods when bucket fill-factor

is close to unity. Be aware that noise stimulates faster growth at the periphery of the bunch than at the core.

2) Spectral density, S, per turn as seen by beam:

$$S \lesssim \frac{2}{\omega_s^2 \Delta T} \frac{\Delta\epsilon}{\epsilon}$$

If parameters vary, then compute several values and average.

From here, there are two questions one might ponder:

i) What are the specifications for S at the phase and amplitude sources? The answer depends on modulation transfer functions of system components; and on whether these are beam feed-back loops.

ii) What are $\Delta\psi_{\rm rms}$ and $(\Delta V/V)_{\rm rms}$ in terms of S_ψ and S_a, respectively? The problem is that one must compute the integral $\int_0^\infty S(\omega)d\omega$ and so, a complete knowledge of the spectral density function is required; or at least some realistic cutoff $\widehat{\omega}$.

I have sketched a few results in the accompanying note. The tolerances are comparable (or less severe) than those achieved at CERN. Basically, the storage time is short.

N.B. The analysis assumes uncorrelated noise. So, for instance, the effect of the voltage perturbation due to beam current revolution harmonics is *not* included.

Reference: TRI-DN-89-K68 "RF Noise Tolerances for KAON Factory."

RF Noise Calculation (Background)

Shane Koscielniak, TRIUMF

Bunch $\equiv$ harmonic oscillator.

Hence express motion in action angle variables, J, ψ.

Noise $\Rightarrow$ perturbed Hamiltonian ΔH.

$$\overset{\circ}{J} = -\delta\Delta H/\delta\beta$$
$$\overset{\circ}{\beta} = +\delta\Delta H/\delta J$$

Find $J(t)$, $\beta(t)$ to 2nd order as integral over time $\int_0^t dt'$. Find ensemble average by integrating over initial phases $\int_0^{2\pi} d\psi_0$. Can reverse the integration order (over phases then over time) and find that what is left is the Fourier Transform of the (time-dependent) disturbance (i.e. noise) evaluated at the synchrotron frequency.

RF Noise Tolerances for LEB

Shane Koscielniak, TRIUMF

Phase-space density $\rho\left(\frac{J}{\omega_s}, t\right)$ obeys diffusion equation. J = "Action" and ω_s = synchrotron angular frequency. Solutions are of the form $\rho(x)\exp\left(\frac{t}{\tau}\right)$.

For frequency noise alone:

$$\tau_f \gtrsim \frac{2}{S_f(\omega_s)} = \frac{2}{\omega_s^2 s_\psi(\omega_s)}.$$

$S_f(\omega_s)$ is the spectral density of frequency noise appearing *at the gap* $*$ in the neighborhood of the synchrotron frequency (incoherent); S_ψ is the spectral density of phase noise.

For amplitude noise alone:

$$\tau_a \gtrsim \frac{1}{\omega_s^2 S_a(2\omega_s)}.$$

$S_a(\omega_s^2)$ is the spectral density of amplitude noise appearing *at the gap** at the incoherent quadrupole mode frequency.

$*$ Though I've said at the gap, the formalism assumes the plural discrete cavity interactions have been replaced by a continuous force acting over one revolution about the ring. What I was trying to stress is that this noise is not necessarily the same as that at the frequency source or amplitude source. For instance, an high Q cavity acts as a filter and will attenuate sidebands of the carrier; so that noise at the gap is less than that at source.

We have assumed *un*-correlated noise.

Noise present at higher-order side-bands $3\omega_s$, $4\omega_s$, $5\omega_s$, $6\omega_s \ldots$ is not so effective at bunch dilution except for long bunches. For phase noise, "long" means $> 120° \frac{1}{2}$ length. For amplitude noise, "long" means $> 160° \frac{1}{2}$ length.

Above inequalities are rewritten:

$$S_\psi(\omega_s) \lesssim \frac{2}{\omega_s^2 \tau_f} \qquad \text{and} \qquad S_a(2\omega_s) \lesssim \frac{1}{\omega_s^2 \tau_a}$$

What is a suitable value for the e-folding time τ?
The answer depends on how full the rf-bucket is and hence $\sqrt{\text{voltage}}$. The synchrotron frequency also depends on $\sqrt{\text{voltage}}$. Parameters for LEB are given on pages 184–187 of SSCP. The answer also depends on what diffusive emittance growth can be accepted.

Looking at the LEB cycle, the noise tolerance is dominated by the first 30 milli-sec, when synchrotron frequency is large and ratio of bucket-to-bunch area is small.

$$\overline{\omega_s} \simeq 2\pi(10 \text{ kHz}) \qquad \frac{\text{Bucket}}{\text{Bunch}} = \frac{0.06}{0.04} = \frac{3}{2} \text{ or } 66\% \text{ filling.}$$

Just suppose the filling can rise to 83%,

$$\frac{\langle a^2(t)\rangle}{\langle a^2(0)\rangle} = \exp\left(\frac{t}{\tau}\right) = \frac{0.05}{0.04} = 1.25 \text{ at } t = 30 \times 10^{-3} \text{ sec.}$$

Hence, $\tau \leq \frac{3\times10^{-2}}{\ln(1.25)} = 0.134$ seconds.

Finally, the spectral density is $S < 2/\omega_s^2\tau$. $S \lesssim 4 \times 10^{-9}$ sec (for both types of noise) at the appropriate frequency.

Let us translate the spectral densities into more intuitive quantities, $\Delta\psi_{\text{rms}}$ and $\frac{\Delta V}{V}$rms.

To make any *realistic* progress, *we need* the frequency spectrum of the noise $\Rightarrow$ and this should be pursued. For the moment, we make some *gross* approximations. From Wiener–Khintchine,

$$\langle g(t)^2 \rangle = \frac{1}{\pi} \int_0^\infty S_g(\omega) d\omega.$$

Suppose S_g is constant up to some frequency $\widehat{\omega}$ and falls rapidly to zero afterwards. (This is *very* unrealistic). Then, $\langle g(t)^2 \rangle = S_g^0 \widehat{\omega}/\pi$.

<u>Phase Noise</u>

$$\langle \Delta\psi^2 \rangle = S_\psi^0 \widehat{\omega}/\pi.$$

Suppose

$$S_\psi^0 = 4 \times 10^{-9} \text{ sec.}$$
$$\widehat{\omega} = 2\pi(25 \text{ kHz})$$

then, $\Delta\psi_{\text{rms}} = 0.014$ radian $= 0.8°$ for the whole ring. *If* cavities are noise-correlated, then

$$\Delta\psi_{\text{rms}} \text{ per cavity} = 0.8°/\text{Ncav} = 0.08° \text{ for ten cavities.}$$

<u>Amplitude Noise</u>

$$\langle (\Delta V/V)^2 \rangle = S_a^0 \widehat{\omega}/\pi.$$

Make similar suppositions $\frac{\Delta V}{V}\Big|_{\text{rms}}$ per cavity $= 1.4 \times 10^{-3}$. These values look very daunting BUT feedback loops will increase the tolerance to noise by 1 to 2 cycles of magnitudes, also historically speaking, the amplitude noise has been found to be much smaller than phase noise in rf systems constructed so far. The noise reduction due to a dipole mode damping loop (i.e. beam phase loop) is given in TRI-DN-89-K68 section 3. The noise reduction due to a quadrupole mode damping loop is sketched out in an accompanying note.

Phase Noise

Let G_{U_e} be spectral density of voltage noise at input to VCO. Let M_1 be the radian-to-voltage gain in the phase-detector. Then $\langle \Delta\psi^2 \rangle \approx 2\pi\omega_s G_{U_e}/M_1^2$ and $\frac{G_{U_e}}{M_1^2} \lesssim \frac{128}{\omega_s^2[1-\cos\hat{\phi}]^2} \times \frac{1}{\tau}$. $\hat{\phi}$ is the rms half bunch-length. τ is the required life-time as given on page 2.

Values:

$$\overline{\omega_s} = 2\pi(10 \text{ kHz}); \ \tau \approx 0.13 \text{ sec}, \ \hat{\phi} \approx 25^\circ.$$

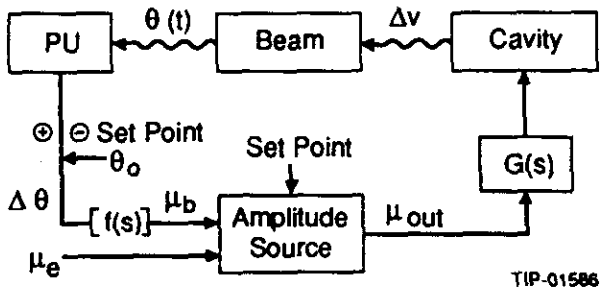
Hence:

$$[\Delta\phi_{\text{rms}}]^2 = \frac{128}{f_s[1-\cos\hat{\phi}]^2} \times \frac{1}{\tau} = 11.2$$
$$\Delta\phi_{\text{rms}} = 3.3 \text{ radian.}$$

Hence, $\Delta\phi_{\text{rms}}$ per cavity ~ 0.3 radian or 19°.

Effect of Quadrupole-Mode Damping Loop

Shane Koscielniak, TRIUMF



$U_{\text{out}} =$ voltage error out
$U_e =$ voltage noise at input
$U_b =$ voltage from beam which is zero in absence of bunch length oscillator.

Bunch-length Oscillation Equation
(from 1971 PAC W. Lee and L.C. Tang)

$$\frac{d}{dt}\left(\frac{1}{a}\frac{d\theta}{dt}\right) + b\theta - \left(\frac{s}{\pi}\right)^2 \frac{a}{\theta^3} = 0$$

$$a = \frac{h^2}{mR^2\gamma}\left[\frac{1}{\gamma_t^2} - \frac{1}{\gamma^2}\right] \qquad b = \frac{eV}{2\pi h}\cos\phi_s.$$

Let θ_0 be the steady state value. Then $\left(\frac{s}{\pi}\right)^2 \frac{a}{\theta_0^4} = b$.

Let $\Delta\theta$ be the change in rms envelope, then

$$\frac{1}{a}\frac{d^2\Delta\theta}{dt^2} + b\Delta\theta + \theta_0\Delta b(t) + \left(\frac{s}{T}\right)^2 \frac{a}{\theta_0^4} 3\Delta\theta = 0.$$

Hence, $\Delta\ddot{\theta} + 4ab\,\Delta\theta = -\theta_0\, a\Delta b(t)$ or $\Delta\ddot{\theta} + (2\omega_s)^2\Delta\theta = -\theta_0\,\omega_s^2 \frac{\Delta V}{V}(t)$. Hence $[-s^2 + (2\omega_s)^2]\Delta\theta = -\theta_0\,\omega_s^2 \frac{\Delta V(s)}{V}$ with s = complex frequency.

$$\begin{aligned} U_{\text{out}} &= M_1(U_b + U_e) \\ U_b &= f(s)\Delta\theta \end{aligned} \quad \Longrightarrow \quad U_{\text{out}} = M_1[f(s)\Delta\theta + U_e] \tag{1}$$

$\Delta V = G(s)U_{\text{out}}$; and steady state $V = G(0)U_0$. Hence,

$$[-s^2 + (2\omega_s)^2]\Delta\theta = -\theta_0\omega_s^2 \frac{G(s)}{G(0)}\frac{U_{\text{out}}}{U_0} \tag{2}$$

Substitute Eq. 2 into Eq. 1:

$$U_{\text{out}} = M_1\left[\frac{-f(s)\theta_0\omega_s^2}{-s^2 + (2\omega_s)^2}\frac{G(s)}{G(0)}\frac{U_{\text{out}}}{U_0} + U_e\right]$$

Hence,

$$\frac{U_{\text{out}}}{U_e} = 1 \Bigg/ \left[1 + \frac{f(s)\omega_s^2}{s^2 + (2\omega_s)^2}\frac{G(s)}{G(0)}\frac{\theta_0}{U_0}\right].$$

For case $s = \pm 2\omega_s + \alpha$ with α small cf ω_s,

$$\frac{U_{\text{out}}}{U_e} \approx \frac{\pm 4\alpha}{f(\omega_s)\omega_s} \frac{G(0)}{G(\omega_s)} \frac{U_0}{G_0} \rightarrow \text{ zero as } \alpha \rightarrow \text{ zero.}$$

Hence the noise is reduced to zero at frequency $2\omega_s$. When there is a non-rigid bunch and some spread of incoherent frequency, the noise suppression by the loop is incomplete and a dispersion integral must be calculated.

N.B. From above equations we can write down the transfer function from U_e (total noise at input of amplitude source) to $\Delta\theta$.

$$[-s^2 + (2\omega_s)^2]\Delta\theta = -{\omega_s}^2 \frac{G(s)}{G(0)} \frac{\theta_0}{U_0} M_1 (U_b + U_e)$$

and $U_b = f(s)\Delta\theta$.

Let ${\omega_s}^2 \frac{G(s)}{G(0)} \frac{\theta_0}{U_0} M_1 \equiv \beta(s)$, then

$$[-s^2 + f(s)\beta(s) + (2\omega_s)^2]\Delta\theta = \beta(s) U_e \, .$$

Hence,

$$\Delta\theta = \frac{\beta(s)}{-s^2 + f(s)\beta(s) + (2\omega_s)^2} U_e$$

provided that $f(s)\beta(s) \neq 0$ at $s = \pm 2\omega_s$, the response to excitation at the quadrupole mode frequency is no longer infinite.

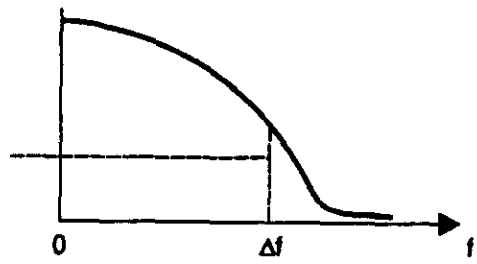
LEB Tuner Spec

Shane Koscielniak, TRIUMF

We calculate

1) The error in the cavity resonance frequency allowable for no bunch distortion at all.

2) The resonance-controller time-constant, ΔT and hence $\frac{1}{2}$ bandwidth of the *tuning controller*, Δf.



The expressions are taken from TRI-DN-90-K126 "Calculation of Required Tuner Accuracy and Time Constant."

Tuner Accuracy and Time Constant for LEB

$$\overset{\circ}{\omega} = \omega_\infty \frac{\Omega_B}{2}\left\{\Delta\beta + \frac{\bar{\beta}\,\overline{\tan\psi}}{Q}\left[\frac{\Delta I_b}{\langle I_b\rangle} - \frac{\Delta I_0}{\langle I\rangle}\right]\right\}$$

$$\Omega_B = 2\pi(10\text{ Hz})$$

$$\Delta\beta = 0.9970 - 0.7924 = 0.2046$$

$$\text{Tan }\psi = \frac{I_b}{I_0}\cos\phi_b \qquad \bar{\beta} = 0.8947$$

$$I_b = 0.2\text{ Amp}$$

$$\text{Ten gaps } I_0 = 70\text{ kV}/100\text{ k}\Omega = 0.7\text{ Amp}$$

$$\cos\phi_b = 0.6$$

$$Q \sim 3000$$

Hence, $\bar{\beta}\,\frac{\overline{\tan\psi}}{Q} = 2.6 \times 10^{-5}$.

Find the relativistic β change dominates.

$$\overset{\circ}{\omega}_\theta \approx \omega_\infty \Delta\beta\Omega/2 \qquad \text{and} \qquad \frac{\overset{\circ}{\omega}_0}{\omega} \approx \frac{\Delta\beta}{\langle\beta\rangle}\frac{\Omega}{2} = 7.18$$

Estimate of Allowable Tuning Error

Allowable tuning error:

$$\frac{\Delta\omega_0}{\omega_0} \approx \frac{(1 + H + \tan\psi \tan\phi_b)}{2Q} \left.\frac{\text{Reactive}}{\text{resistive}}\right|_{\text{max}}$$

$H = 0$ is case of no fast feedback. The power ratio depends on the absolute power, the allowed dissipation at the anode; and non-linearity of the tube when operated far from the manufacturer's specifications. However, the maximum permitted value of the ratio lies in the range 1–2 for the intended Eimac 4CW15000 tube. We shall take 1–5; non-linearity starts to enter in at 3

$$\frac{\Delta\omega}{\omega_0} \approx \left[\frac{1 + (0.171)(1.192)}{2 \times 2900}\right] 1.5 = 3 \times 10^{-4}$$

$$\text{for } \overline{d_b} = 50°.$$

Hence, we may estimate required Tuner time-constants

$$\Delta T = \left.\frac{\Delta\omega}{\overset{\circ}{\omega}}\right|_{\text{min}} = \frac{\Delta\omega/\omega_0}{\overset{\circ}{\omega}_0/\omega_0} = \frac{3 \times 10^{-4}}{7.0} = 4.3 \times 10^{-5} = 43 \text{ sec!}$$

This is a "middling-good" estimate; if $\Delta T \leq 50$ sec, we shan't go far wrong. Hence, $\Delta f = 20$ kHz. This is a bit daunting! However, fast feedback will make the voltage (amplitude and phase) much less sensitive to tuning errors. Taking an arbitrary open-loop gain of $H = 10$,

$$\frac{\Delta\omega}{\omega_0} = \frac{[11 + 0.2]}{2 \times 2900} \times 1.5 = 3 \times 10^{-3}$$

$\Delta T \Rightarrow 430$ sec and $\Delta f = 2$ kHz which is easily feasible with tuner controller.

LEB Cavity Voltage Requirements and R&D Plans

Jimmy Rogers

The present baseline requirements are 700 kV max to be supplied in normal operation by eight cavities operating at 87.5 kV each. For reliability, the cavities and RF systems are to be designed to provide the 700 kV with six operating cavities; 117 kV per cavity. The present design requires that the cavities be operated in "back-to-back" pairs in order to minimize longitudinal magnetic bias fields. Hence, the present design assumes that two cavities will be turned off if one fails. The baseline design assumes each cavity is 1.2 meters in length. (The 800 kV being discussed in the workshop this week would result in adding more cavities.)

Liquid Submergence Approach

The design approach that is receiving the most effort at this time is very similar to the orthogonally biased configuration that was designed by LANL for TRIUMF. The major difference is that the present design submerges the ferrites in liquid, either water or flourinert, to cool the ferrites and to eliminate corona discharge. (The TRIUMF cavity maximum voltage requirement is 75 kV whereas the SSC maximum operating voltage is 117 kV.)

The R&D program includes design and manufacture of a liquid cooled 2 ring ferrite tuner which will be tested in the SSC RF test stand using the LANL TEE cavity configuration. This test will stress the ferrites at the same voltage and dissipation levels that are anticipated for the LEB 4-ring tuner. This test will be completed in time to incorporate its results into the 4-ring design which will be in progress.

The lead design engineers for this approach are Carl Friedrichs, RF engineer, and Billy Cambell, mechanical engineer.

Alternate Approaches

Georg Schaffer is investigating alternative orthogonally biased designs, including designs that use striplines partially filled with small ferrite bricks "epoxied" to water cooled copper plates, a technique developed by ANT for high power circulators.

Jim Griffin is investigating the use of a modified FNAL cavity that has the potential for achieving 120 kV with a combination of parallel and perpendicular bias.

Schedule

A design review/workshop is planned for the end of January 1991. The objective of the review will be to examine in detail the candidate design approach(es). The review board will be responsible for recommending the design(s) that should be pursued, short range R&D activities that are required to support the selected design(s), and to identify a low-risk back-up approach in the event that the selected approach is not successful or the schedule cannot be met.

The liquid cooled 2-ring tuner is scheduled to begin test in May 1991.

The final design review for the prototype cavity and tuner is scheduled to be held in October 1991.

The prototype is scheduled for test beginning March 1993.

Low Risk Back-up Cavity/Tuners

At the present time the LEB lattice design has room for twenty-four 1.2 meter cavities. Based on a projected worse case requirement of 850 kV and two failed cavities (two pairs of cavities out of service), the required voltage per cavity would be (850 kV/20) 42.5 kV, a level which is well within the state-of-art that could probably be met by the TRIUMF cavity, the proposed liquid cooled design, or a modified FNAL design.

A more likely scenario would be the use of 16 cavities. With only 14 in operation, the voltage per cavity (worse case) would be $850\,\mathrm{kV}/14 = 61\,\mathrm{kV}$, a level that should be readily achieved.

LEB-TO-LEB BUCKET MATCHING

J. Peterson

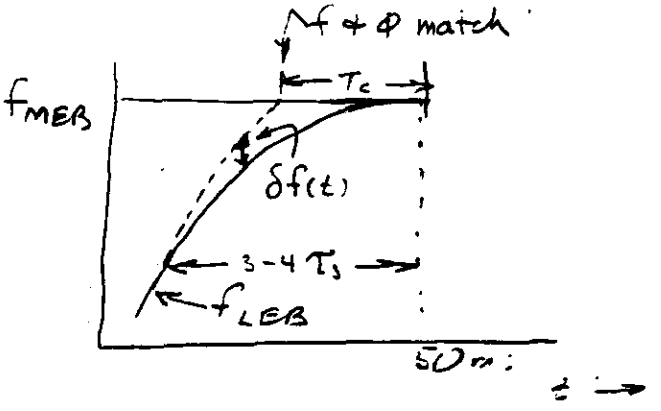
CONSIDERED AND COMPARED
COGGING METHODS AND BUCKET MATCHING

Beam Transfer Working Group

Jim Griffin	FNAL
Lee Teng	ANL
Shane Koscielniak	TRIUMF
Bob Webber	SSC
Jack Peterson	SSC

COGGING METHODS:

1. Frequency and Phase Lock, Late in LEB Cycle



Requirements:

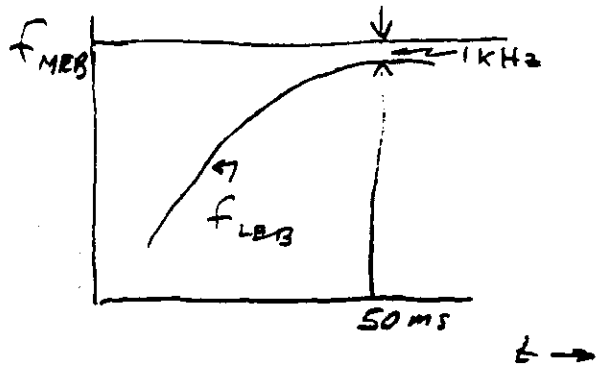
(a) $\delta f(t)$ such that $\Delta\widehat{R} \leq 1\,\text{cm}$.
$\Delta\widehat{R} = \widehat{D}\,(\delta f/f)/\eta$.

(b) $T_c \geq 1\,\tau_s$.

For $\gamma_t = 21.3$ lattice, $T_c \cong 1.5\,\tau_s$.

Conclusion: Good method, but should be simulated.

2. 1 kHz Δf on Central Orbit



Requirement:

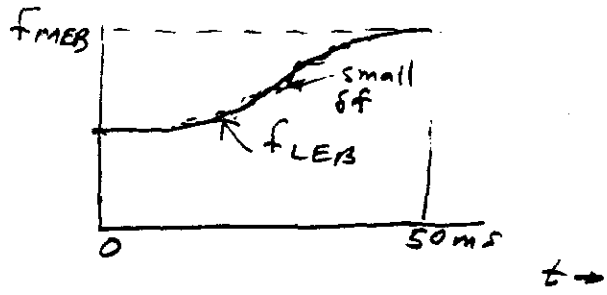
$$\begin{aligned} C_{\mathrm{LEB}} &\Rightarrow 540\,\mathrm{m}\,(1 + \Delta f/f) \\ &= 540\,\mathrm{m} + 9\,\mathrm{mm} \end{aligned}$$

Feature: Method works with any γ_t.

Conclusion: Good method. Griffin suggested $\Delta C = 9\,\mathrm{mm}/2$, so as to better accommodate alternative cogging methods as well.

3. Frequency and Phase Control, throughout Cycle

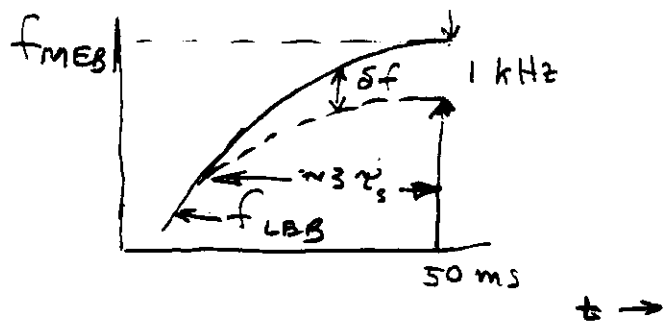
(Proposed by L.K. Mestha)



Basically the same frequency and phase control as Method 1, but has the advantages of smaller δf and δR excursions and greater range of phase adjustments, which might be needed if a gap were introduced in the LEB beam train and if the LEB/MEB circumference ratio were not favorable for automatic coarse cogging.

Conclusion: Should work, but the effects of radial beam controls, radial errors, magnetic errors, and beam dynamics have not yet been analyzed.

4. 1 kHz Δf through ΔR



Problem:

$$\Delta\widehat{R} = \gamma_t^2 \widehat{D} \Delta f / f$$
$$= 3\,\text{cm for } \gamma_t = 21.3 \text{ lattice}$$

Conclusion: Recommend against.

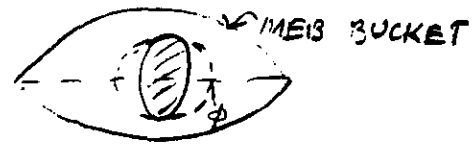
BUCKET MATCHING:

In order to match the LEB beam into the MEB with the desired bunch length (about 0.85 ns) (wanted for acceptable space-charge tune shift in the MEB), a relatively low voltage is required in the LEB (4 kV for $\gamma_t = 14.5$, 12 kV for $\gamma_t = 21.3$). Such low voltages are difficult to control under the beam-loading conditions expected.

Three alternatives were considered by the working group:

1. Deliberate Mismatch

If a voltage of 80 kV is used in the LEB at extraction, the rms bunch length is reduced to $(12/80)^{1/4}$ 0.85 ms = 0.62×0.85 ms. Then in the (unchanged) MEB bucket, the beam is mismatched.



Eventually the beam smears out, resulting in dilution in the longitudinal phase space. If the LEB beam is Gaussian, the resulting increase in the variance is $(\sigma/\sigma_0)^2 = 1.50$ and the increase in the phase-space area containing 95% of the beam is 1.75 (using Syphers' analysis, FN-458, June 1987).

A serious consequence of this mismatch scenario is the increased and time-dependent space-charge tune shift in the MEB. Initially the tune-shift oscillates between 1.62 and 0.62 times the "matched" tune shift at twice the MEB synchrotron frequency, finally settling at the 0.62-times value when the smearing is complete. The smearing time is approximately $8[f_s(1 - \cos\phi)]^{-1}$ (formula due to Koscielniak), which for this situation ($\phi \sim 29°$), evaluates to 65 synchrotron periods.

Conclusion: Unsatisfactory scenario.

2. Match through Non-adiabatic Phase-space Shaping

(Method due to Maschke and Mahale)

A simulation using the $\gamma_t = 14.5$ parameters, and LEB rf voltage of 80 kV, that it is feasible to double the adiabatic beam length (σ_t) [and halve its energy width (σ_E)] in the 1-ms time interval 49 to 50 ms of the LEB cycle. The method involves jumping the rf phase to the unstable synchronous phase for a fraction

of a millisecond and then back to the synchronous phase. Since the beam is now mismatched in the LEB bucket, the timing of the rf manipulations must be coordinated with the cogging scheme.

Conclusion: Looks ok in principle. The hardware problems in accomplishing the phase jump need verification.

3. Longitudinal Emittance Enlargement

The voltages in both the LEB and the MEB at beam-transfer time would be increased by increasing the longitudinal emittance ϵ_L. For the same bunch length, $V \propto \epsilon_L^2$. Thus if the emittance were doubled, the LEB voltage for adiabatic matching would increase from 12 to 48 kV.

Emittance enlargement can be accomplished either by off-energy injection and adiabatic pick-up, or by modulation of the rf bucket (voltage modulation seems to be more effective than phase modulation... Koscielniak)—or by some combination.

Enlargement through off-energy injection is favorable in that it decreases the space-charge tune shift substantially. Emittance enlargement reduces the tune shift both by decreasing the bunching factor and by increasing the horizontal beam width, as pointed out by Furman. The penalty is a higher rf voltage. A factor of two in emittance raises the maximum required LEB voltage from 700 to about 900 kV (Funk and Griffin), if done early in the LEB cycle.

Such a voltage increase could be avoided if the emittance enlargement were accomplished through bucket manipulations during the second half of the LEB cycle, because there, the bucket area is adequate without any increase in voltage. However, such enlargement is difficult to do in the second half of the acceleration cycle because of the low synchrotron frequency there (Maschke and Mahale). The synchrotron frequency in the first half of the cycle looks adequately high, but this should be verified by simulations.

Conclusion: Recommend increasing the longitudinal emittance and the rf voltage capability.

TRANSITION CROSSING

R. Gerig

TRANSITION CROSSING IN MEB

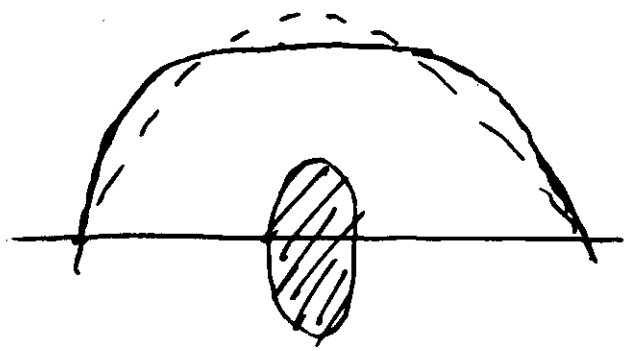
Rod Gerig
Jim Griffin
Stan Pruss
Shane Koscielniak
Warren Funk
M.K. Mahale
Shengi Machida
Lee Teng

Transition Crossing in MEB

To avoid tight longitudinal bunching at transition which may cause Transverse blow up.

Method 1 (Jim Griffin)

Crossing transition at neutral phase stability—reduce restoring force by flat-topping the rf wave form (add 3rd harmonic)



- Isochronous cyclotron
- Computer simulation looks good
- Will test on Fermilab MR (Summer 1991)

  Advantages:

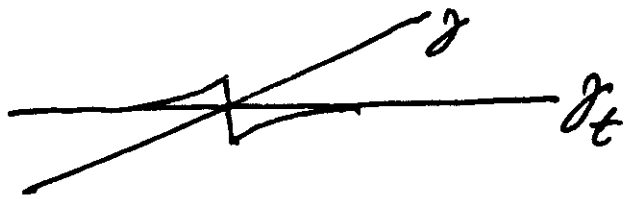
  1. Solves problem at the source—no side effect (transverse effect)
  2. Cheap

  Disadvantage:

  1. Neutral stability aggrevates negative mass instability lumping

Method 2

γ_t-jump



Effectively converts rings into 2 machines, one operating totally below transition, the other totally above. The transition is "sudden" for longitudinal motion but "adiabatic" for transverse motion.

<u>Advantages:</u>

1. Tested successful at PS and FNAL.
2. Suppresses negative mass lumping.

<u>Disadvantages:</u>

1. More costly.
2. Affects transverse motion (but "adiabatically").

Conclusion

With 2 cures available—one proven and one to be proved—there is no need to consider no-transition-crossing lattices. Discussions by Rod Gerig showed no desirable such lattice anyway.

MEB SPACE BUDGET CONSIDERATIONS

S. Pruss

We considered the space left in the present MEB lattice design in the arcs for interconnection of components, for chromaticity correcting sextupoles and trim dipoles. The present slot length between dipoles is 0.375 m. This is consistent with the present Fermilab Main Injector design, and allows for an ion pump for each dipole. The total slot length for the main quads and other stuff also seems adequate. There is now a possible design for a chromaticity correcting sextupole which will fit in the slot length allocated to it. The horizontal correcting dipole also seems quite reasonable, but the vertical dipole needs a real design. Its requirements do not seem excessive. It may be feasible to assemble the main quad, the chromaticity correcting sextupole, the trim dipole and the location specific devices all onto a beam outside the tunnel and then transport them as a unit. This will require a real mechanical design to evaluate the best design, but since there is adequate space, this is not urgent.

A comment may be made about the exact choice of tune. The first design for the main quads indicates a small octopole component developed at 200 GeV/c as the magnet starts to saturate. Since the present concept is to transfer to the HEB at 180 GeV/c and only accelerate to 200 GeV/c occasionally for test beam slow spill, if the tune is above the half integer, rather than below, a small zeroth harmonic octupole might actually help. A thorough study of slow extraction would need to be done to determine the magnitude of octupole that would be tolerable.

BUNCH SPACING

J. Griffin

Bunches Separated by $5 \times N$ meters

$(N = 2, 3, \ldots ? \ldots)$

If *same* luminosity is required

$$P \equiv [\text{Protons per bunch}] \propto P_o\sqrt{N}$$

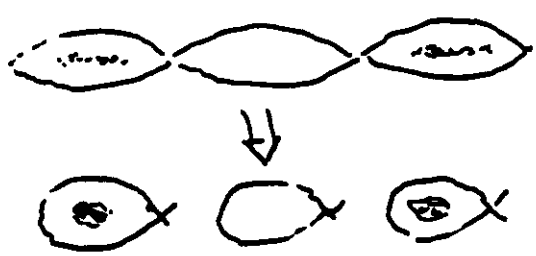
$$T \equiv [\text{Total number of protons}] \propto \frac{P_h}{N} = \frac{P_o h}{\sqrt{N}}$$

(in LEB for example)

It is necessary (maybe not sufficient) that h/N = integer, h = "normal" harmonic number

First Method

Gate Linac somewhere so that selected buckets in LEB are filled. Increase intensity (number of turns) by $\sqrt{N}$. Accelerate normally. Additional rotational sub-harmonics will be introduced in beam Fourier components. Not a serious problem.



Second Method (For $N = 2$, maybe 3)

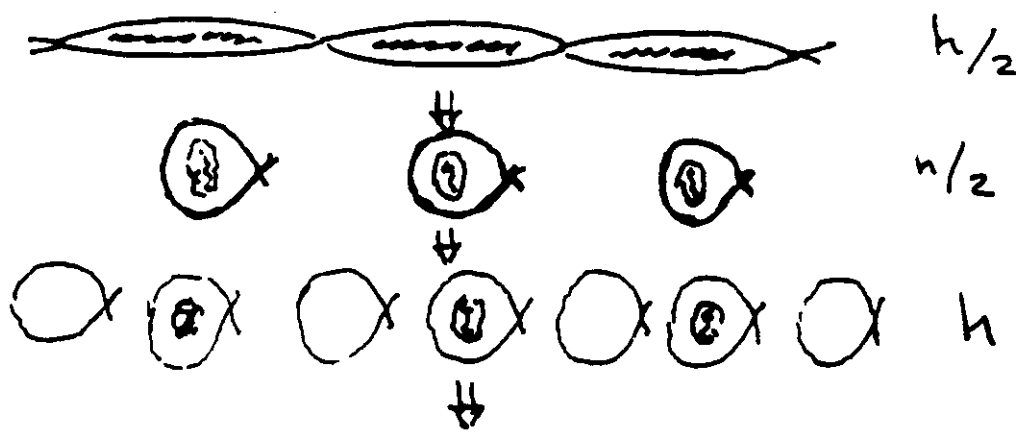
Install in LEB an additional rf system at h/N (say, 23.5 MHz).

It must be tunable part way up.

Inject normally from linac, maybe 3 turns instead of 4 (i.e., $\sim 75\%$).

Adiabatically capture at h/N.

Accelerate at some (large) rate consistent with space charge tune shift limitation. At some point β_{γ^2} is <u>large</u> enough so that bunching factor B can be made <u>small</u> enough so that bunches can be matched to "normal" rf system at h. Continue with acceleration ....



Third Method

Bunch coalescing at 180 GeV in MEB.

Flat-top MEB.

Adiabatically Debunch (somewhat) at h.

Turn off h. Turn on h/N (Proper phase; ampl.)

Bunch rotate in h/N.

Recapture in h.

Linearize voltage wave in h/N with h for $N = 2$, or 3.

$N = 2$:

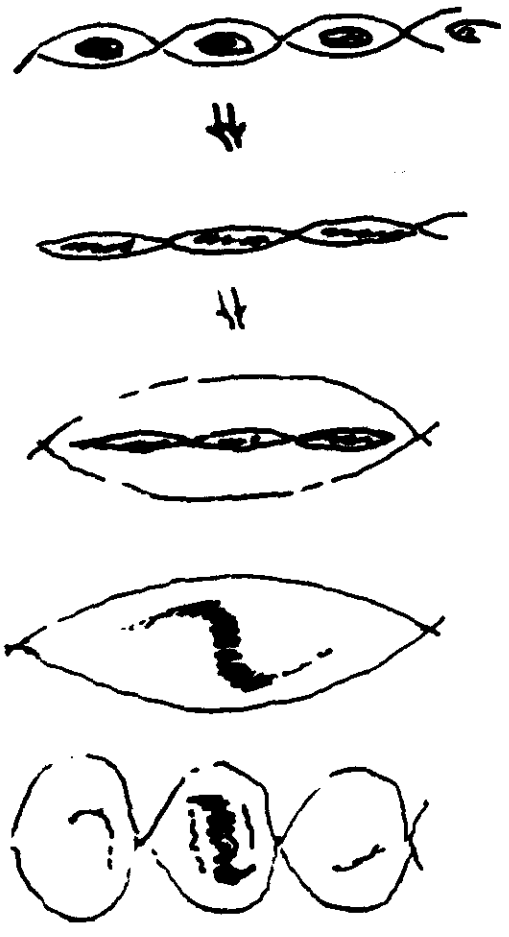
$V(\varphi) = \sin\varphi - \frac{1}{4\sqrt{2}}\sin 2\varphi$

$N = 3$:

$V(\varphi) = \sin\varphi - \frac{1}{12}\sin 3\varphi$

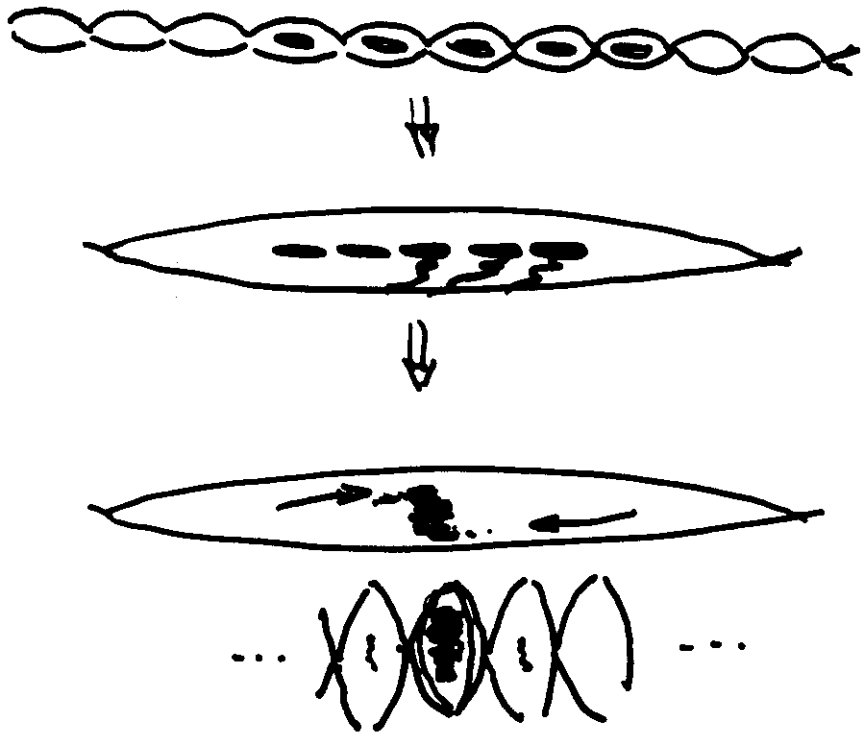
Comment:

Coalescing with *all* original buckets occupied is not neat. Charge too near unstable fixed points. Large longitudinal blow-up. i.e. $3 \times 0.1 \Rightarrow 4\,\mathrm{eV\text{-}Sec}$.



For larger values of N, coalescing in MEB appears attractive, i.e., $N = 9$.

But, some method should be implemented to provide the correct ratio of occupied to empty buckets initially.



This implies an additional <u>kicker</u> <u>to</u> <u>dump</u> system in LEB or LEB-MEB transfers.

Sub-harmonic voltages are usually not large, i.e., 20–30 kV because of low harmonic numbers.

Final longit. emittances $\sim$ 4–5 eV-sec.

$\Delta P/P \sim \pm 0.8\%$

Some method must be employed to get rid of satellite bunches in adjacent buckets; transverse anti-damping?

All promising scenarios should be extensively simulated (ESME...).

	At Fermilab we routinely and successfully
cf. NOVA TV	coalesce 10–11 bunches into one in a
starring	subharmonic bucket spanning 21 "normal" buckets.
D. Finley	
FNAL	But only one ensemble per cycle.
	We propose to do ~ 3 in MR and 6 in M.I. simultaneously.

Subharmonic spurious resonances, arising possibly from kickers is a problem.

cf. Fermilab M.I. Instability Workshop July, 1990.

Finally—My comment in that proceeding about "eliminating coalescing" was unique to M.I. project. It requires existence of anti-proton source Debuncher and Accumulater Rings. Not applicable here.

CIRCUMFERENCES AND FILLS

S. Penner

Circumferences and Filling

Issues:

Collider Filling Factor $F = \frac{\text{bunches}}{\text{buckets}}$

Average luminosity reduced by:

$$F^2\mathcal{L}_o \leq \overline{\mathcal{L}} \leq F\mathcal{L}_o$$

Operational Ease simple care of all equal cycles of every ring gives poor F for baseline circumferences and risetimes.

Flexibility—for commissioning, future upgrades, etc.

Transient Beam Loading—a non-issue in this context since we must cope with the problem anyway.

F vs. Filling Sequence

Sequence	Risetimes	F
Uniform $6 \times 3 \times 8$	Baseline	87.6%
Partial Fill $[(6+f)+6+6] \times 8$	Baseline	91.4
Non-Uniform $[7+6+6] \times 8$	Fast	92.5

BASELINE

	Kicker Rise Times				Circumference
	Injections		Extractions		
	μs	bunches	μs	bunches	Meters
LEB			0.047	2	540
MEB	0.047	2	0.40	24	3960
HEB	0.400	24	1.70	102	10890
SSC	1.7	102	2.4	144	87120

SCENARIO FOR $F = 92.5\%$

	Circumference	Kicker Rise Times			
		Injections		Extractions	
	Meters	buckets	μs	buckets	μs
LEB	540	–	–	2	0.047
MEB	$\geq$ 3890	2	0.047	24	0.40
HEB	$\geq$ 10860	16	0.267	94	1.57
SSC	87120	94	1.57	142	2.37

Sequence $[7 + 6 + 6] \times 8$

Conclusions

- Baseline case with uniform filling $F = 87.6\%$. MEB, HEB circumferences do not limit anything.
- F can be increased to $\sim 93\%$ by using partial fills and/or faster kickers.
- Slightly smaller HEB makes sense.
- Try for faster risetimes in HEB injection, extractions and abort kickers and collider injection and abort kickers.
- Provide way of transferring partial LEB fills to the MEB.

CIRCUMFERENCES AND FILLS

We want to determine the effect on the performance of the collider of the circumferences of the booster synchrotrons. The circumference ratios among the machines affect the filling factor, F, of the collider. Different ratios will result in different values of F, and will affect the details of the filling sequence and the rise times needed for efficient injection, extraction, and abort capability.

We also considered any possible effect of the circumferences on the flexibility of operation (e.g., for commissioning, future upgrades, etc.) and on transient beam loading of the RF systems. The former is clearly not an issue, and it is necessary for the RF systems to cope with essentially the same transient effects regardless of the specific filling times.

Another issue related to the exact values of the circumferences is preserving the capability of operating the collider with increased bunch spacing. This issue may impose additional constraints on the circumferences, but this can, and has been, considered separately.

The average luminosity, L, available to collider experiments is in the range

$$F^2 L_o \leq L \leq F L_o, \tag{1}$$

where L_o is the luminosity that would be obtained if every bucket of both collider rings were filled, and

$$F = \frac{\text{full buckets}}{\text{total buckets}}. \tag{2}$$

The upper limit of L occurs when the fill patterns of both rings are identical and properly synchronized for one particular interaction point. Since there is only one abort gap per ring, L will necessarily be lower at all other interaction points.

F depends on the circumferences C_L, C_x, C_B, and C_c of the LEB, MEB, HEB, and collider respectively, on the number of cycles of each ring used to fill the next ring, and on the rise (or fall) times of the injection, extraction, and

abort kickers. The number of buckets in the collider circumference, B_o, is 17424. We need to calculate the number of filled buckets, B_c, for a particular filling sequence.

When N_L complete bunch trains plus a partial transfer of b bunches are transferred to the MEB, the number of bunches in the MEB is

$$B_M = N_L(C_l - \tau_L) + b, \tag{3}$$

where τ_L is the number of LEB bunches lost due to the LEB extraction kicker and the MEB injection kicker (assuming the two kickers are properly synchronized).[1] For a rise time between 20 and 47 ns, $\tau_L = 2$.

When the MEB is filled as described by equation (3), the abort gap in the MEB is

$$\tau_{MX} = C_M - N_L C_L - b + 2\delta_{b0}, \tag{4}$$

where $\delta_{b0} = 1$ if $b = 0$, and zero otherwise. The MEB fill described by equation (4) is acceptable if τ_{MX} is equal to or greater than the (minimum) rise times of the MEB extraction and abort kickers.

For the entire range of parameters under consideration, the only practical way to fill the HEB is with three MEB cycles.[2] Each of the three can have different values of N_L, which we label N_{L1}, N_{L2}, and N_{L3}. The three fills could also have different values of b, but the highest fill factor will always occur when there is, at most, one non-zero value of b. With this restriction, the number of

[1] Throughout this note, all circumferences and rise times are in units of bunches, except where specifically stated otherwise. The bunch length is 5.0 meters, and the time per bunch is $5\,\mathrm{m}/(B_c)$.

[2] If the MEB circumference could be in the range of 5 km, instead of less than 4 km, the HEB could be filled with just two MEB cycles. This would approximately halve the dwell time of the HEB at its injection energy. Together with the increased MEB extraction energy made possible by an increased circumference might decrease the HEB aperture requirement. This possibility has not been studied.

bunches in an HEB fill is

$$B_H = (N_{L1} + N_{L2} + N_{L3})(C_L - 2) + b. \tag{5}$$

The corresponding abort gap in the HEB is

$$\tau_{HX} = C_H - (N_{L1} + N_{L2} + N_{L3})C_L - b + 4 + 2\delta_{b0} - 2\,\tau_{H1}, \tag{6}$$

where τ_{H1} is the HEB injection kicker rise time.

Each collider ring will be filled with N_H HEB cycles, all assumed identical. Then

$$B_c = N_H B_H, \tag{7}$$

and the abort gap in the collider is

$$\tau_{CX} = C_c - N_H(C_H - \tau_{HX} + \tau_{C1}) + \tau_{C1}. \tag{8}$$

The baseline configuration, described in Table 1, has $C_c = 8C_H$, exactly. The natural choice is $N_H = 8$. Then, if $\tau_{HX} = \tau_{C1}$, which results in maximum filling of the HEB, $\tau_{CX} = \tau_{C1}$. It is probably not reasonable to require the collider abort kicker to be as fast as its injection kicker, and therefore the HEB circumference could be reduced slightly (i.e., $\leq 30\,\mathrm{m}$) without reducing F. Furthermore, C_c exactly equal to $8C_H$ is awkward for cogging the transfer.

Table 1. SCDR Rise Times and Circumferences

			Kicker Rise Times			
	Circumference		Injection		Extraction	
Machine	meters	buckets	μs	buckets	μs	buckets
LEB	540	108	–	–	0.047	2
MEB	3960	792	0.047	2	0.40	24
HEB	10890	2178	0.40	24	1.7	102
SSC	87120	17424	1.7	102	2.4	144

Using equation (4) and the circumferences in Table 1, the largest value of N_L which gives an allowable value of τ_{HX} (i.e., not less than the corresponding rise time in Table 1) with $b = 0$ is $N_L = 7$. However, the largest value of $N_{L1} + N_{L2} + N_{L3}$ which gives an allowable value of τ_{HX} is 18, according to equation (6). Then, the largest possible value of F, using the parameters in Table 1 and $b = 0$ is $F = 0.8760$. The simplest way to achieve this result is, obviously, $N_{L1} = N_{L2} = N_{L3} = 6$. We can improve on this by using $b > 0$. For $b = 83$, $\tau_{CX} = 142$, just 32 ns under the rise time limit of 144 buckets or 2.4 μs. Assuming this to be allowable, the result is $F = 0.9141$. The MEB abort gap is still much larger than needed (61 buckets) and the HEB abort gap is 107 buckets, which would allow the slight HEB circumference reduction mentioned above.

Finally, we find the rise times needed for a filling sequence with $N_{L1} = 7$, $N_{L2} = N_{L3} = 6$, and $b = 0$. The values obtained are not unique because of the relationships among rise times embodied in equations (6) and (8). Any set of rise times that satisfy these equations will yield the same filling factor, $F = 0.9247$. Table 2 summarizes these examples, including some cases that have different LEB and/or HEB circumferences. The MEB circumference is never a limiting factor.

Table 2. Filling Scenarios. $C_M = 792$ buckets, $N_H = 8$, $\tau_L = 2$ buckets are fixed. Rise times printed in bold type are less than the nominal values given in Table 1.

C_L	C_M	N_{L1}	$N_{L2,3}$	b	τ_{MX}	τ_{H1}	τ_{HX}	τ_{C1}	τ_{CX}	F
108	2178	6	6	0	144	24	192	102	822	0.8760
108	2178	6	6	83	61	24	107	102	142	0.9141
108	2178	7	6	0	38	16	100	94	142	0.9247
108	2172	7	6	0	38	16	94	94	142	0.9247
120	2178	5	6	0	74	22	100	94	142	0.9210
120	2172	5	6	0	74	19	100	100	148	0.9210

Our conclusion is that in order to obtain a filling factor above 91 percent with a 540 meter (108 bucket) LEB circumference, it is necessary to allow either partial LEB to MEB transfers, or to reduce the kicker rise times. It is not possible to go beyond about 93 percent with feasible rise times. The conclusion would be similar for different LEB circumferences, except that by numerical chance, some circumferences give F around 91 percent without partial fills or reduced rise times.

We recommend providing the capability of partial LEB to MEB transfers, which will prove useful for other purposes besides maximizing F. In principal, there are many ways to accomplish this. In practice, we are limited by the premium on space in the LEB, the necessity to avoid all possible sources of emittance growth, and the difficulty of realizing a kicker with both fast rise and fall times and adjustable pulse length. The straightforward solution appears to be an auxiliary kicker in the LEB to MEB transfer line, which guides the unwanted beam into the normal beam dump in this transfer line.

The largest sources of filling losses are the collider and HEB injection kickers which, for the rise times in Table 1, cause reductions in F of 4.1 and 2.2 percent, respectively. (The LEB extraction kicker and MEB injection kicker together account for 1.9 percent, which probably cannot be reduced further.) Reducing all kicker rise times, but especially these two, is the best way to improve F, independently of the specific circumferences.

PARAMETERS CONSISTENCY

M. Furman, C. Manz

Report of the Parameter Consistency Group

Miguel Furman and Cleon Manz

SUMMARY

Under a set of assumptions listed below, we examined the following items:

(1) Choice of injection and extraction voltages for MEB.

(2) A sample ramping cycle for the LEB, assuming a substantially larger longitudinal emittance than in the SCDR and conventional matching into the MEB (i.e., no bunch rotation at the end of the LEB cycle).

The results presented here are a first pass, and substantially more work is needed. However, we offer the following tentative conclusions:

(1) Injection and extraction voltages of several hundred kV are desirable for the MEB (in the sample presented here we have chosen 700 kV at injection and 860 kV at extraction).

(2) The conventional adiabatic matching of the beam in the LEB $\rightarrow$ MEB transfer probably will not work very well, and some kind of gymnastics will be necessary, such as bunch rotation, or the Maschke-Mahale scheme of going to the unstable phase for a while followed by recapture into a shorter (vertically) bucket.

ASSUMPTIONS

(1) The new peak acceleration rate for the MEB is 56 (GeV/c)/sec, and the peak MEB voltage is 1.1 MV (the corresponding old values were 80 (GeV/C)/sec (approx.) and 2.3 MV, respectively).

(2) The new longitudinal beam emittance in and out of the LEB is 0.08 eV-sec (95% bunch area $= 6\pi\epsilon_L$) and the peak voltage is 1 MV (the corresponding SCDR values were 0.038 eV-sec and 0.8 MV, resp.).

(3) The injection and extraction momenta and the cycle time in the LEB are the same as the old values ($p = 1.219\,\mathrm{GeV/c}$ at inj., $p = 12\,\mathrm{GeV/c}$ at extr., and cycle time $= 0.1\,\mathrm{sec}$ with simple sinusoidal excitation).

(4) The extraction momentum in the MEB is $180\,\mathrm{GeV/c}$ instead of the old value of $200\,\mathrm{GeV/c}$. The MEB cycle time is the same as the old value, $4.5\,\mathrm{sec}$.

(5) The HEB lattice and RF is as in the SCDR.

(6) The MEB $\rightarrow$ HEB transfer is a conventional matched transfer.

(7) The LEB and MEB lattices and bunches are such that the relevant parameters for our purposes have the following values:

Table 1

	LEB	MEB
Circumference [m]	540	3960
harmonic no.	108	792
av. beta-function [m]	10	27.5
av. dispersion**2 [m**2]	2	2.5
transition gamma	21	24
tr. emittance [mm-mrad]	0.6	0.7 (rms area/pi, normalized)
particles/bunch	le10	le10

DISCUSSION

(A) MEB Extraction Voltage

The MEB $\rightarrow$ HEB matching condition implies a certain HEB/MEB voltage ratio at transfer,

$$\frac{V_{\mathrm{HEB}}}{V_{\mathrm{MEB}}} = \frac{|h_\eta|_{\mathrm{HEB}}}{|h_\eta|_{\mathrm{MEB}}} = \frac{2.369}{1.353} = 1.751$$

From this and the appropriate lattice parameters we obtain Table 2, which shows the MEB voltage at extraction, synchrotron frequencies and the (common) bucket area, listed by injection voltage into the HEB.

Since the maximum voltage in the HEB is 1.6 MV, the maximum voltage at extraction from the MEB is 914 kV, as seen in the last entry in Table 2.

Because of our desire to stay comfortably above 60 Hz in the MEB synchrotron frequency we chose a fairly large value for the extraction voltage from the MEB, namely $V = 860\,\mathrm{kV}$, corresponding to an HEB voltage $V = 1.506\,\mathrm{MV}$. From Table 2, the corresponding MEB and HEB synchrotron frequencies are, approximately, 77 Hz and 49 Hz, respectively (***Last minute note: this choice may mean that the HEB crosses 60 Hz later on during its cycle—this needs to be checked).

Clearly, one can go down to $V = 528\,\mathrm{kV}$ in the MEB, at which point the synchrotron frequency in the MEB is just over 60 Hz, and the HEB voltage is 925 kV.

We did not consider any other issues in the MEB extraction voltage question.

(B) MEB Injection Voltage (and LEB Extraction Voltage)

Assuming a matched LEB $\rightarrow$ MEB transfer at $p = 12\,\mathrm{GeV/c}$ (gamma = 12.828) and the parameters assumed above, we obtain the following MEB/LEB voltage ratio:

$$\frac{V_{\mathrm{MEB}}}{V_{\mathrm{LEB}}} = \frac{|h_\eta|_{\mathrm{MEB}}}{|h_\eta|_{\mathrm{LEB}}} = \frac{3.438}{0.411} = 8.365$$

This is an uncomfortably large number, and tends to imply low voltages for the LEB at extraction (however, it's better than the ratio of 12 in the SCDR case). Table 3 shows the LEB extraction voltage, the MEB synchrotron frequency and the (common) bucket area, listed by MEB injection voltage (we don't show the LEB synchrotron frequency because it falls rapidly towards the end of the LEB cycle; this is discussed later).

We used 2 criteria in order to choose the MEB injection voltage:

(*i*) The voltage should be as large as possible so that the LEB extraction voltage is also as large as possible; a low LEB voltage at extraction is considered undesirable for several reasons. It seems impossible not to cross 120 Hz later on during the MEB cycle (we don't know whether crossing 240 Hz is bad or not, but this seems to be unavoidable also). We also wanted to stay below 480 Hz, although we don't know whether this ought to be a constraint or not.

(*ii*) However, the voltage should not be so large than the space-charge tune spread in the MEB at injection gets too large. We take 0.7 to be a value that the space-charge tune spread should not exceed. This is a somewhat arbitrary number. We do not believe that anything besides the hunch of certain PEEFs (Personally-Established Experts in the Field) has gone into this number. The hunch of WEEFs (Well-Established Experts in the Field) should be welcome. It would be even better if physical arguments, such as simulations, were provided.

These criteria allow a certain leeway, especially since the space-charge tune spread scales like Voltage**(1/4). Anyway, using assumption (2) above for the value of the longitudinal emittance, we arrive at $V = 700\,\mathrm{kV}$ for the MEB injection voltage; for this voltage, the tune spread is just over 0.7, including the Laslett image-charge enhancements. From Table 3, the LEB voltage is $V = 83.7\,\mathrm{kV}$, and the MEB synchrotron frequency is 427 Hz.

It would be nice if the LEB extraction voltage were higher. In choosing 700 kV for the MEB we payed more attention to criterion (ii) than (i). If the 0.7 "limit" on the tune-spread could be shown to be exceeded without detrimental effect on the transverse emittance, the voltage could be pushed up. However, the peak voltage of 1.1 MV does not allow much room, especially since RF people

do not like to inject into voltage that is too close to maximum when a frequency swing is required during the ramp.

Still, these numbers are a lot better than in the SCDR, where the LEB and MEB voltages at transfer were 4 and 48 kV, respectively. However, the SCDR numbers are so low that this comparison may not be particularly meaningful.

(C) Longitudinal Emittance of 0.08 eV-sec (95% Bunch Area)

In the SCDR we assumed a long. emittance of 0.038 eV-sec (95% bunch area, or $6\pi\epsilon_L$). This value of the emittance was obtained by injecting the linac beam with an energy spread sigma_E = 0.15 MeV into pre-existing LEB buckets of low voltage (if this beam were allowed to spread uniformly through the LEB, with no voltage, it would lead to a longitudinal emittance of 0.015 eV-sec (95% area) per "virtual" bunch). The voltage was then increased nonadiabatically in order to achieve good capture and long bunches with smoothly distributed particles. This process blows up the emittance from 0.015 eV-sec to the above-mentioned value of 0.038 eV-sec. This process also yielded the maximum value for the space-charge tune spread of 0.33 in the LEB, which is reached some 3 msec after injection. All this was verified by longitudinal multiparticle simulations by Mahale.

Since several people voiced concerns over the low previous value of 0.038 eV-sec, we decided to study a case with higher emittance. Of course the limited scope of the workshop did not allow any possibility for simulations. Therefore, we have made reasonable guesses as to how to achieve the longitudinal emittance of 0.08 eV-sec (95% bunch area), corresponding to assumption #2. The reasoning is the following: this value of 0.08 is perfectly within the range of the linac capabilities, since the bunch at the end of the RF compressor cavity at the exit of the linac allows an adjustable energy spread sigma_E from 0.14 MeV to 1.25 MeV. Thus, the previous value of 0.038 eV-sec corresponded to the low end of the range (since it is obtained from a beam with energy spread of 0.15 MeV). The present value of 0.08 is a factor of 2.1 greater, so it ought to be obtainable

with an energy spread sigma_E = 0.3 MeV, which is not even half-way in the range.

We assume a mechanism similar to the SCDR's: we assume that beam is injected such that the initial longitudinal emittance is 0.064 eV-sec, and then this is blown up by the nonadiabatic capture to 0.08 eV-sec at $t = 15$ msec (we allow more time for the blowup than the 10 msec in the SCDR (just a hunch)). At least one member of our group feels certain that simulations will show that this scenario is realistic, and will provide good capture and long, smooth bunches, leading to an acceptable space-charge tune spread.

Obviously, the penalty of a higher longitudinal emittance is a larger peak voltage, since the bucket has to be large enough to contain the bunch. We assume an occupancy fraction of 80% (bunch-to-bucket area ratio). Thus, the bucket area should be tailored to reach 0.1 eV-sec at $t = 15$ msec. The corresponding peak voltage turns out to be 1 MV, which is what Warren Funk and Jim Griffin were talking about.

(D) Excitation Curves for the LEB and MEB

Under the assumptions and choices stated above, we have calculated the excitation curves for the LEB and MEB with the program RAMPRF. The results are attached (plots plus tables of values).

In the case of the LEB, the input to RAMPRF are the momentum, the bucket area, and the 95% bunch area as a function of time. Thus, our assumptions about capture and longitudinal emittance dilution are explicitly stated in the plot entitled "Bucket area and 95% bunch area." For the case of the MEB, the inputs to RAMPRF are the momentum, voltage and 95% bunch area. We assume that the longitudinal emittance is constant throughout the MEB ramp, even though there is transition crossing.

(E) Remarks about the Excitation Curves and Conclusions

(1) We assumed 0.5 sec parabolas in the MEB ramp, just before and just after the linear part of the ramp. We simply made up the 0.5 sec number; it's quite possible that the parabolas should be a lot shorter than this.

(2) The MEB bucket area dips just after ramping starts; these are the result of the interplay between the energy parabola and the linear voltage increase. One should be able to tailor these so that the dip disappears—this is no big deal, probably.

(3) The MEB synchrotron frequency drops monotonically (except for the glitch near transition crossing) from 427 to 77 Hz. The value 120 Hz is crossed around transition. This doesn't smell good, but one can probably tailor the voltage curve to avoid this.

(4) The MEB space-charge tune spread drops monotonically from its injection value of 0.073 (except for the glitch near transition crossing).

(5) The LEB voltage curve looks weird on account of the hump at $t = 6$ msec; we don't know if this is bad. In any case, the initial hump at $t = 6$ msec is caused by the input bucket-area-vs.-time curve. The voltage drops monotonically after $t = 6$ msec, thus giving the appearance of "wasted voltage." If it were possible to start out with a lower bucket area than our assumed 0.064 eV-sec, the peak voltage of 1 MV could be decreased. This would presumably necessitate injection of beam with lower longitudinal emittance followed by a faster blowup by a larger factor. Simulations then become more important in order to ascertain the feasibility of this scenario.

(6) The peak LEB space-charge tune spread occurs at $t = 1$–2 msec, reaching a value of 0.28, including the Laslett image-charge enhancements. This value is lower than the SCDR's 0.33, but it is a soft number because there are no simulations to back up our capture and long. emittance blow-up assumed scenario.

(7) The LEB synchrotron frequency varies over a wide range (as in the SCDR case). It peaks at 31.6 kHz at $t = 2.5$ msec, then it drops monotonically. It drops quickly towards the end of the ramp, from 729 Hz at $t = 47$ msec to a minimum of 375 Hz at extraction time, $t = 50$ msec. This is a lot better than the SCDR's value of 48 Hz at $t = 50$ msec. It remains to be studied whether this is high enough to perform successful adiabatic fine-cogging.

(8) The relative momentum spread sigma_p/p and bunch length sigma_t vary sharply by about a factor of 2 (in opposite directions) during the last 5 msec or so of the LEB ramp. However, this depends on the assumption that the bunches remain matched to the buckets (in our calculation we do assume that the bunches remain exactly matched to the bucket at all times). This may not happen in reality due to the smallness of the synchrotron frequency (simulations should decide the question). (This issue was raised by Phil Martin last year). In this case the bunches will not be matched to the MEB, and they will tumble in longitudinal phase space after transfer.

(9) This behavior (point 8 above) is qualitatively similar to the SCDR. We suspect it's generic of resonant excitation ramps. If indeed simulations show that the bunches do not turn around as quickly as our calculation shows, it seems to us that a deliberate bunch rotation should be performed prior to transfer, in order to ensure that the matching is achieved, and is under control.

SUGGESTIONS

(1) Examine more closely the MEB ramp parabolas, probably they should be a lot shorter. Examine the voltage ramp, perhaps the voltage should rise and fall more quickly.

(2) Do the excitation curves for the HEB and look at the synchrotron frequency; does it cross a bad value? If so, readjust the MEB extraction voltage.

(3) Do some kind of gymnastics prior to transfer out of the LEB (talk to experts, say at FNAL). In this case, you don't need a 1 MV RF system in the LEB. If you don't want to do gymnastics, be sure to do simulations on the

simplest method we've shown here. We suspect this no-gymnastics matching method, shown here and in the SCDR, does not work well.

(4) Find out what the space-charge tune spread limit is in the MEB at injection; adjust the MEB injection voltage accordingly.

(5) We have not looked at the transverse beam sizes in the LEB or the MEB with this kind of longitudinal emittance. The numbers are in the attached tables, after the pictures. Somebody should look at them.

Program [MIGUEL.TUNEBOO]MEBHEB
matching MEBTINMAN --> HEBSCDR at p=180 GeV/c

Vheb [kV]	Vmeb [kV]	fsheb [Hz]	fsmeb [Hz]	Area [eV-s]
100.000	57.110	12.600	19.792	1.477
125.000	71.388	14.087	22.128	1.651
150.000	85.665	15.432	24.240	1.809
175.000	99.943	16.668	26.183	1.954
200.000	114.220	17.819	27.990	2.089
225.000	128.498	18.900	29.688	2.215
250.000	142.776	19.922	31.294	2.335
275.000	157.053	20.895	32.822	2.449
300.000	171.331	21.824	34.281	2.558
325.000	185.608	22.715	35.681	2.663
350.000	199.886	23.572	37.028	2.763
375.000	214.163	24.400	38.327	2.860
400.000	228.441	25.200	39.584	2.954
425.000	242.718	25.976	40.803	3.045
450.000	256.996	26.729	41.985	3.133
475.000	271.274	27.461	43.136	3.219
500.000	285.551	28.174	44.257	3.303
525.000	299.829	28.870	45.349	3.384
550.000	314.106	29.550	46.417	3.464
575.000	328.384	30.214	47.460	3.542
600.000	342.661	30.864	48.481	3.618
625.000	356.939	31.500	49.480	3.692
650.000	371.216	32.124	50.460	3.766
675.000	385.494	32.736	51.421	3.837
700.000	399.772	33.336	52.365	3.908
725.000	414.049	33.927	53.292	3.977
750.000	428.327	34.507	54.203	4.045
775.000	442.604	35.077	55.099	4.112
800.000	456.882	35.638	55.981	4.178
825.000	471.159	36.191	56.849	4.242
850.000	485.437	36.735	57.703	4.306
875.000	499.714	37.271	58.546	4.369
900.000	513.992	37.800	59.376	4.431
925.000	528.270	38.321	60.195	4.492
950.000	542.547	38.836	61.003	4.552
975.000	556.825	39.343	61.801	4.612
1000.000	571.102	39.845	62.588	4.671
1025.000	585.380	40.340	63.366	4.729
1050.000	599.657	40.829	64.134	4.786
1075.000	613.935	41.312	64.893	4.843
1100.000	628.212	41.789	65.643	4.899
1125.000	642.490	42.262	66.385	4.954
1150.000	656.768	42.729	67.118	5.009
1175.000	671.045	43.191	67.844	5.063
1200.000	685.323	43.648	68.562	5.116
1225.000	699.600	44.100	69.272	5.169
1250.000	713.878	44.548	69.976	5.222
1275.000	728.155	44.991	70.672	5.274
1300.000	742.433	45.430	71.362	5.325
1325.000	756.710	45.865	72.044	5.376
1350.000	770.988	46.295	72.721	5.427
1375.000	785.266	46.722	73.391	5.477
1400.000	799.543	47.145	74.055	5.526
1425.000	813.821	47.564	74.714	5.576
1450.000	828.098	47.979	75.366	5.624
1475.000	842.376	48.391	76.013	5.673
1500.000	856.653	48.800	76.655	5.720
1525.000	870.931	49.205	77.291	5.768
1550.000	885.208	49.606	77.922	5.815
1575.000	899.486	50.005	78.548	5.862
1600.000	913.764	50.400	79.168	5.908

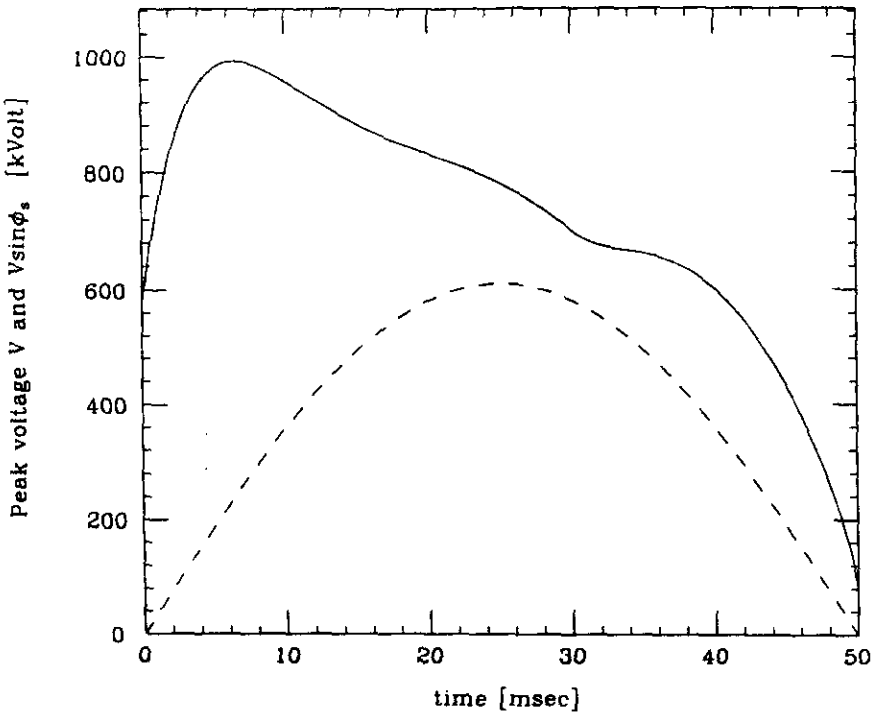
Table 2

program [MIGUEL.TUNEBOO]LEBMEB
matching LEBAAGRE --> MEBTINMAN at p=12 GeV/c

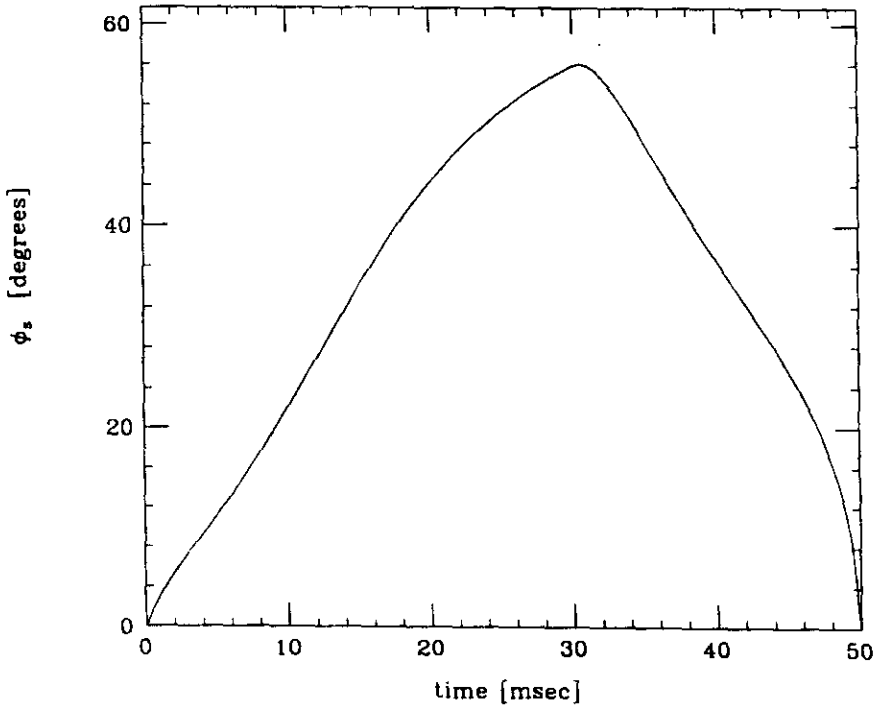
Vmeb [kV]	Vleb [kV]	fsmeb [Hz]	Area [eV-s]
100.000	11.955	161.403	0.317
125.000	14.943	180.454	0.354
150.000	17.932	197.678	0.388
175.000	20.921	213.516	0.419
200.000	23.909	228.258	0.448
225.000	26.898	242.105	0.476
250.000	29.886	255.201	0.501
275.000	32.875	267.657	0.526
300.000	35.864	279.558	0.549
325.000	38.852	290.973	0.571
350.000	41.841	301.957	0.593
375.000	44.830	312.556	0.614
400.000	47.818	322.806	0.634
425.000	50.807	332.741	0.654
450.000	53.796	342.387	0.672
475.000	56.784	351.770	0.691
500.000	59.773	360.908	0.709
525.000	62.762	369.821	0.726
550.000	65.750	378.524	0.743
575.000	68.739	387.031	0.760
600.000	71.727	395.355	0.776
625.000	74.716	403.508	0.793
650.000	77.705	411.499	0.808
675.000	80.693	419.337	0.824
700.000	83.682	427.032	0.839
725.000	86.671	434.591	0.854
750.000	89.659	442.020	0.868
775.000	92.648	449.327	0.882
800.000	95.637	456.517	0.897
825.000	98.625	463.595	0.911
850.000	101.614	470.567	0.924
875.000	104.603	477.437	0.938
900.000	107.591	484.209	0.951
925.000	110.580	490.888	0.964
950.000	113.568	497.477	0.977
975.000	116.557	503.981	0.990
1000.000	119.546	510.401	1.002
1025.000	122.534	516.742	1.015
1050.000	125.523	523.005	1.027
1075.000	128.512	529.195	1.039
1100.000	131.500	535.313	1.051

Table 3

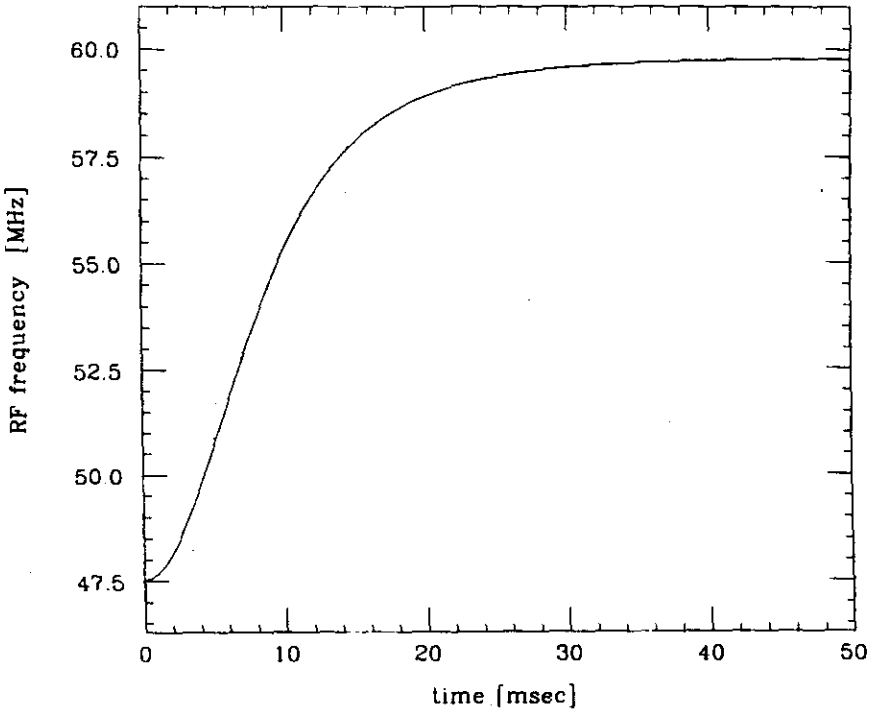
LEBAAGRE matched into MEBTINMAN dec 8, 1990



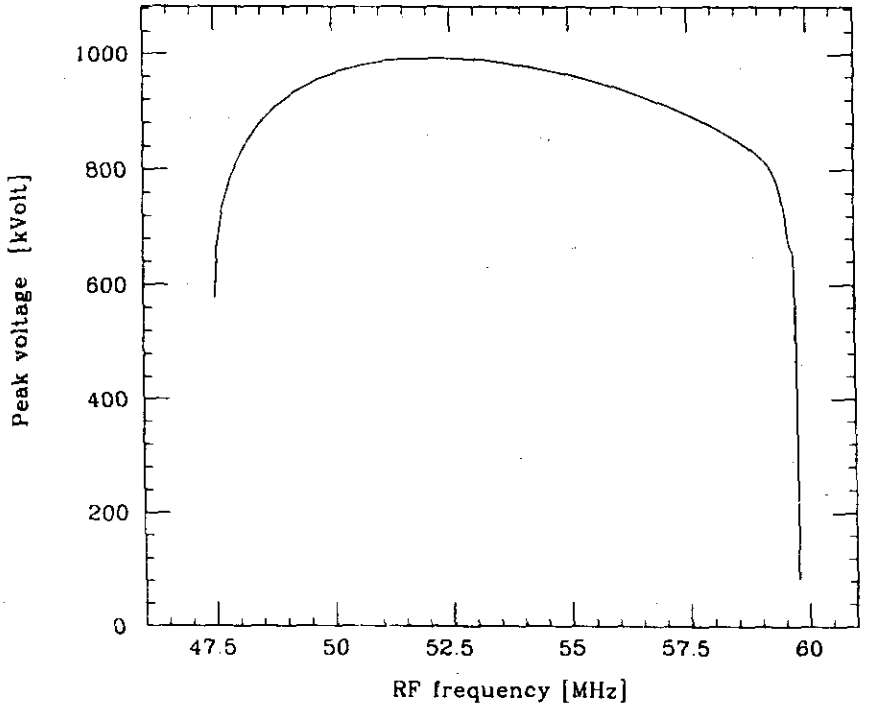
LEBAAGRE matched into MEBTINMAN dec 8, 1990

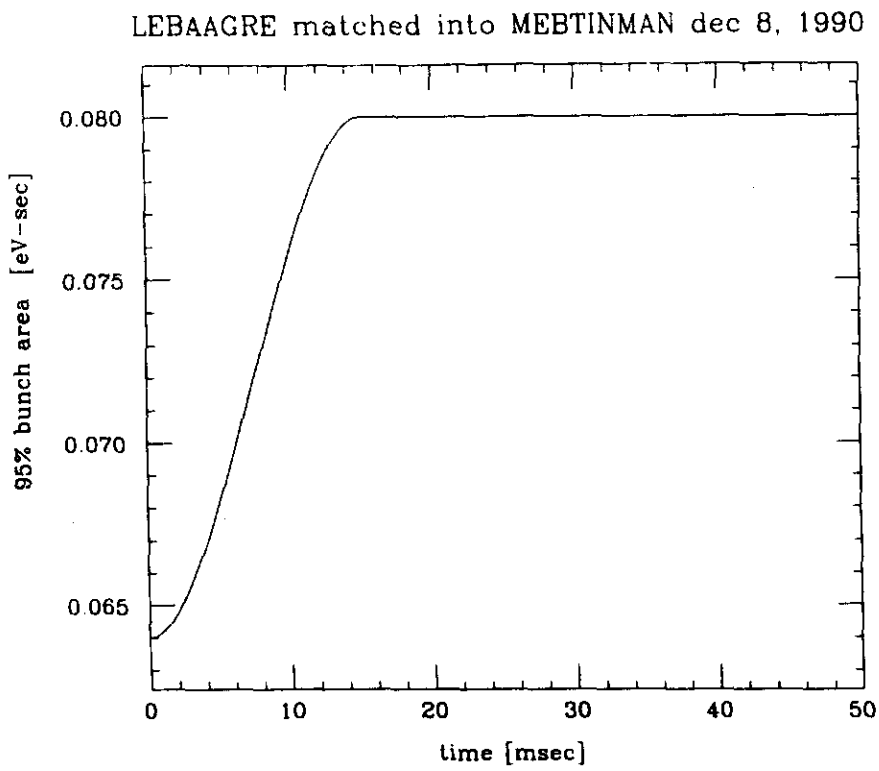


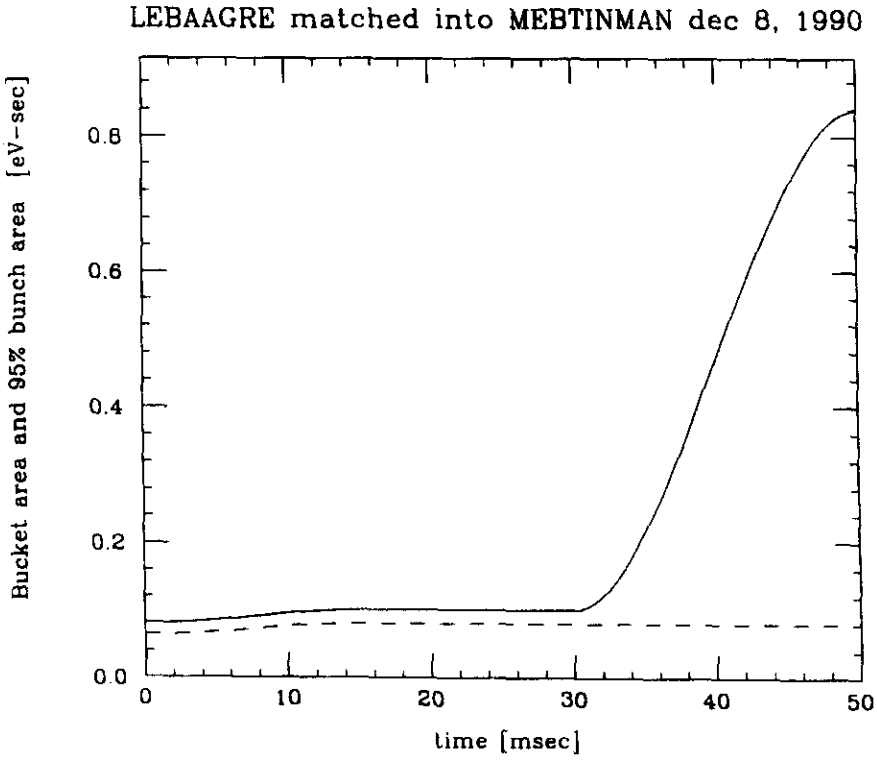
LEBAAGRE matched into MEBTINMAN dec 8, 1990

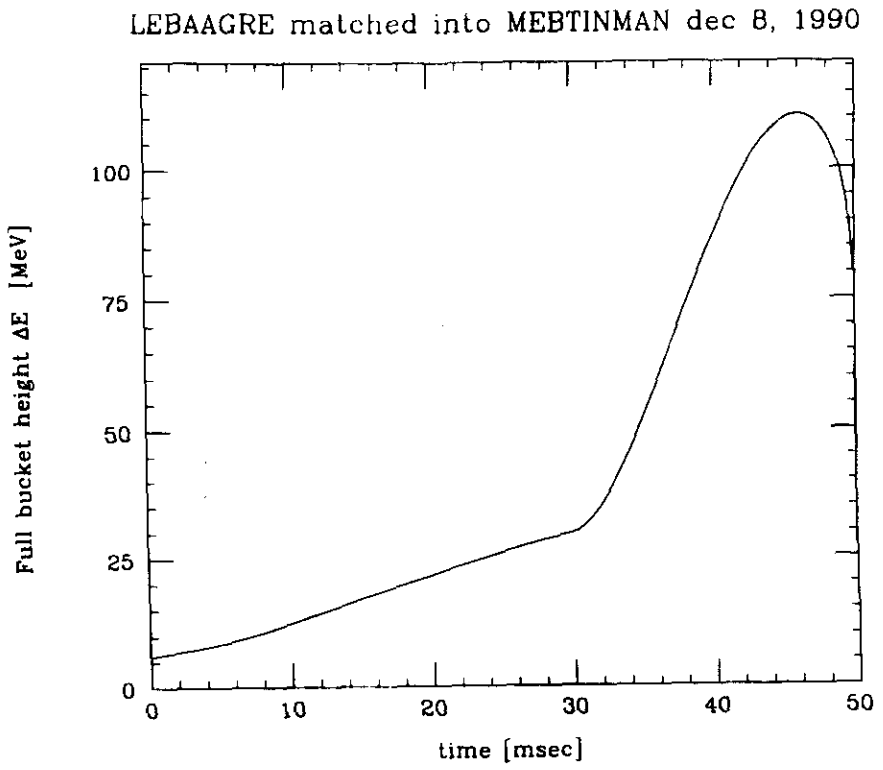


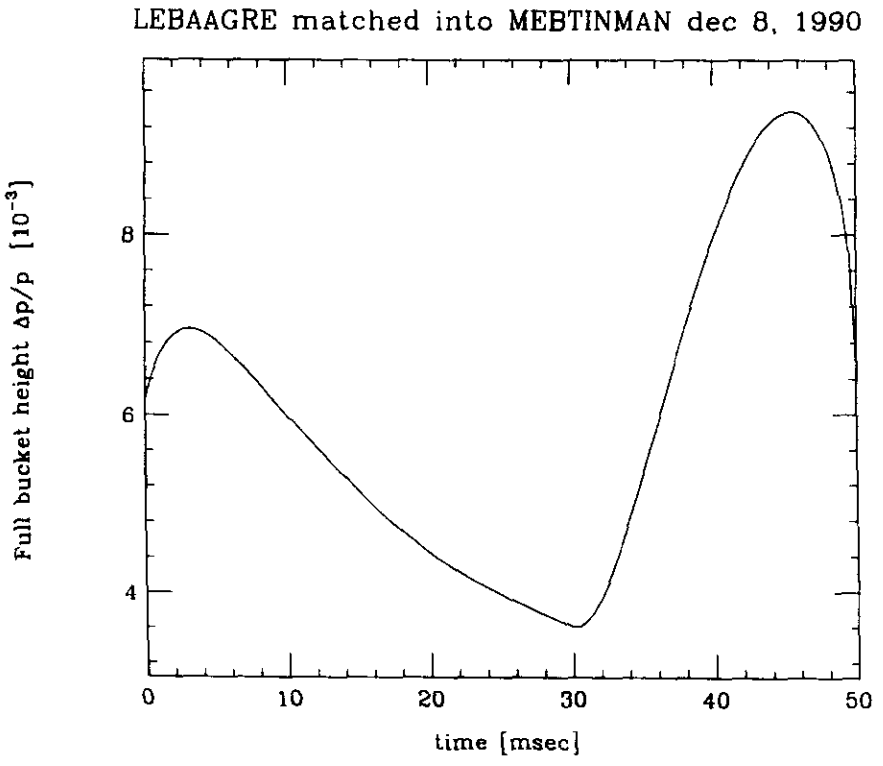
LEBAAGRE matched into MEBTINMAN dec 8, 1990



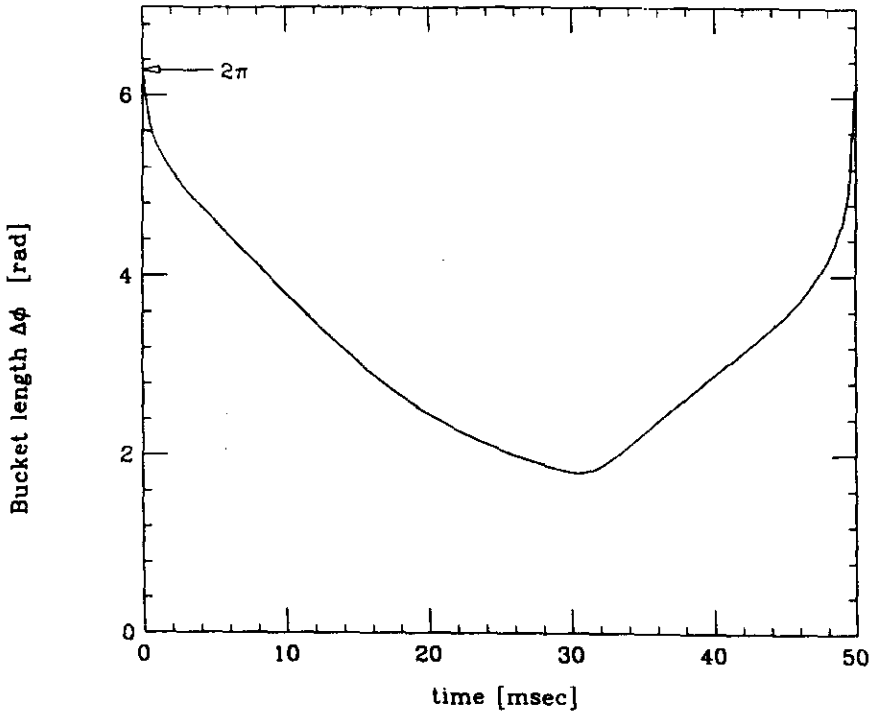

LEBAAGRE matched into MEBTINMAN dec 8, 1990
95% bunch area [eV-sec]
0.080
0.075
0.070
0.065
0
10
20
30
40
50
time [msec]


LEBAAGRE matched into MEBTINMAN dec 8, 1990
Bucket area and 95% bunch area [eV-sec]
0.8
0.6
0.4
0.2
0.0
0
10
20
30
40
50
time [msec]

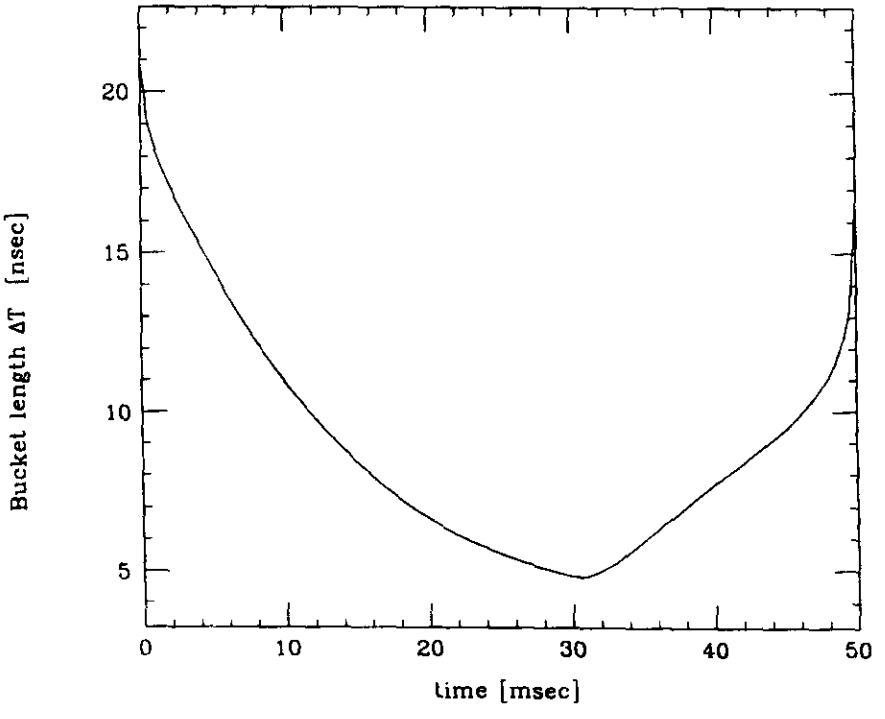

LEBAAGRE matched into MEBTINMAN dec 8, 1990
Full bucket height ΔE [MeV]
0
25
50
75
100
0
10
20
30
40
50
time [msec]


LEBAAGRE matched into MEBTINMAN dec 8, 1990
Full bucket height Δp/p [10^-3]
4
6
8
0
10
20
30
40
50
time [msec]

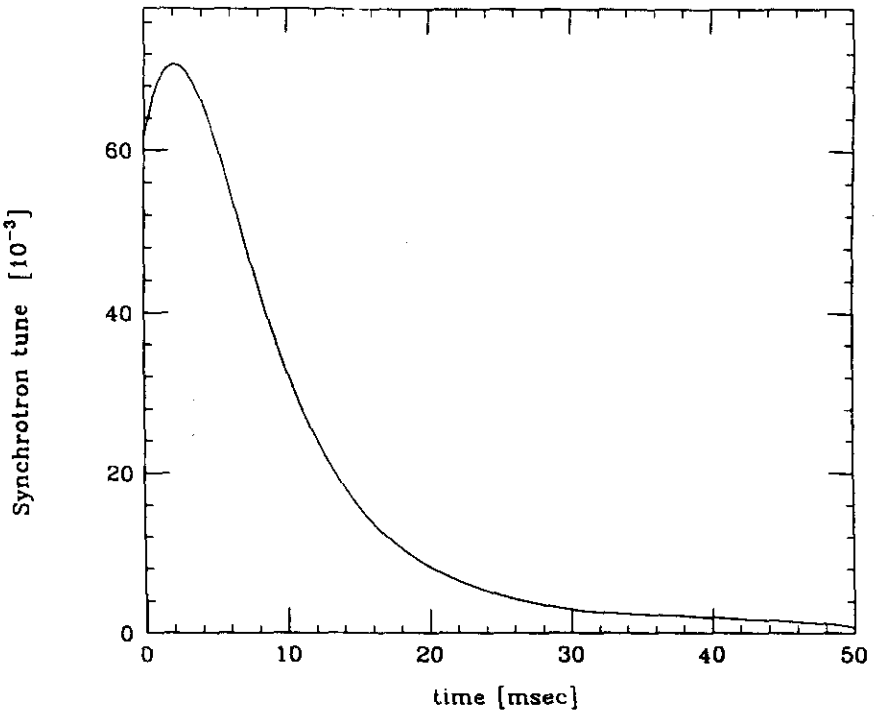
LEBAAGRE matched into MEBTINMAN dec 8, 1990



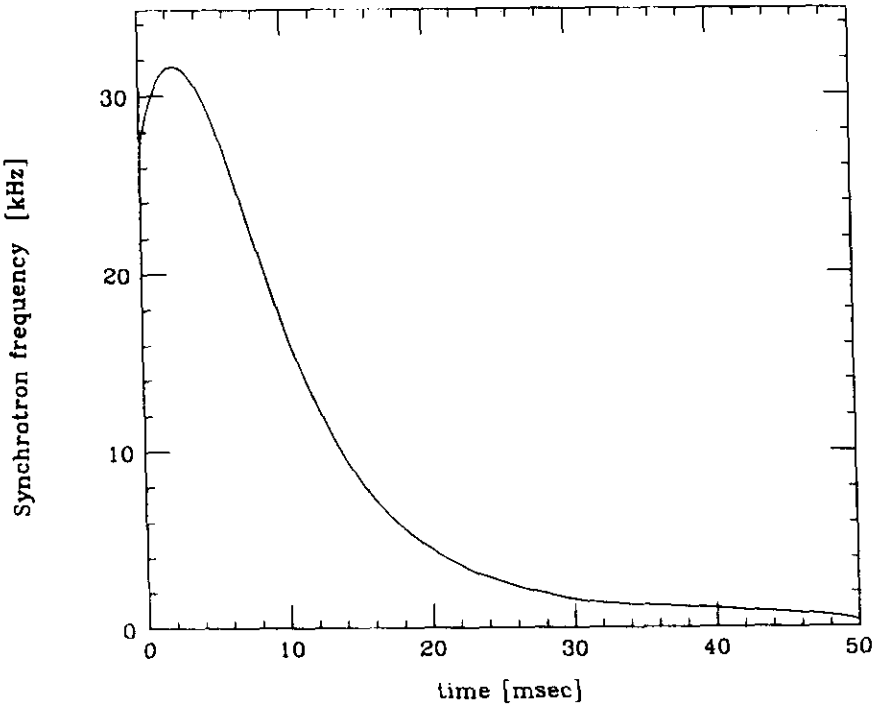
LEBAAGRE matched into MEBTINMAN dec 8, 1990

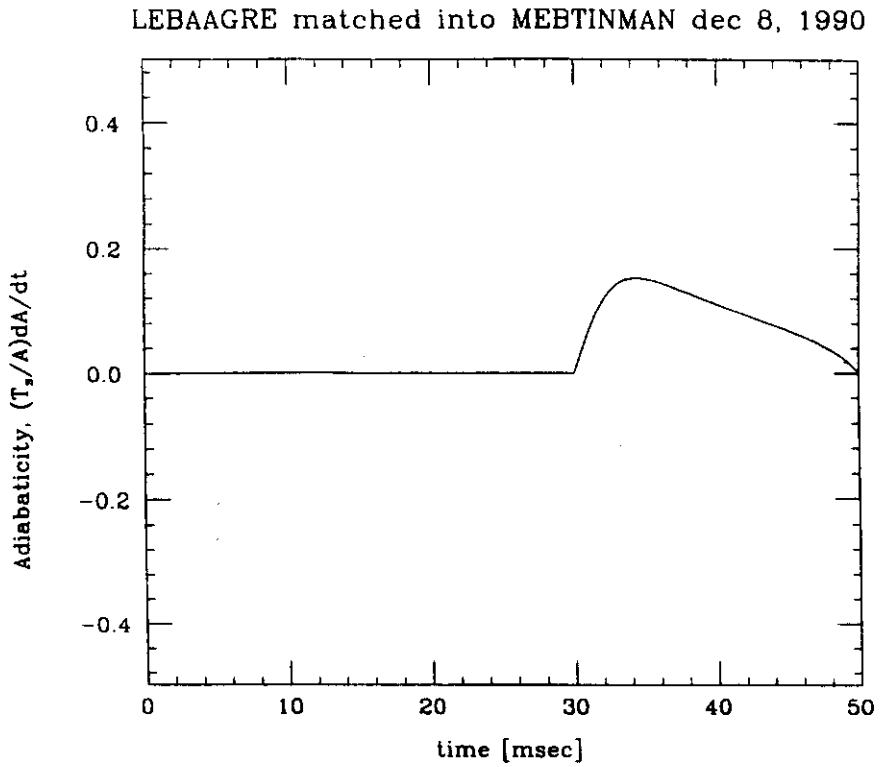


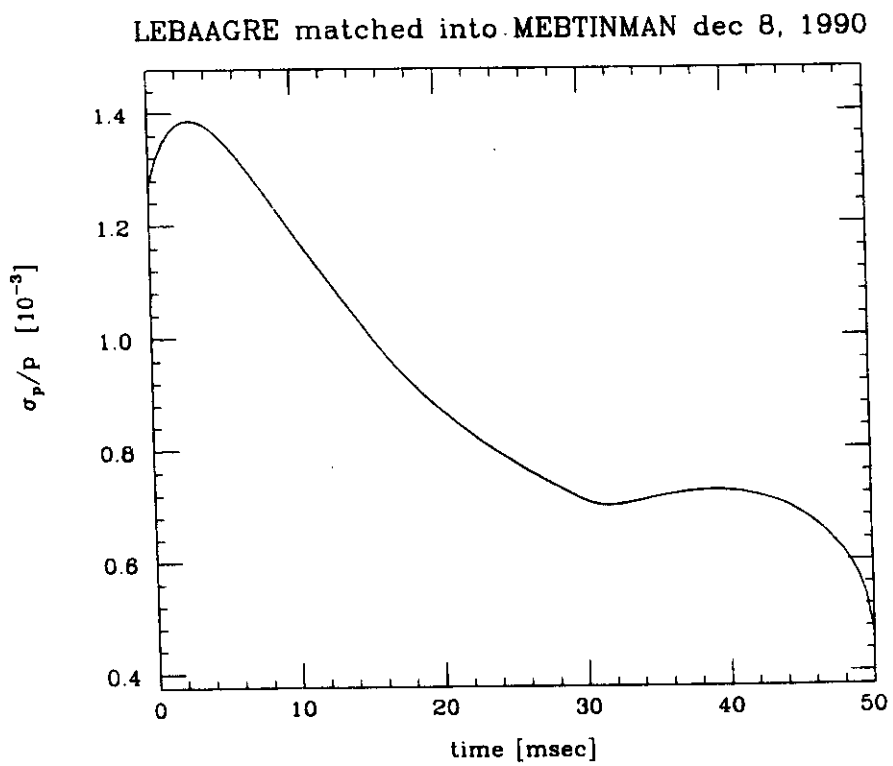
LEBAAGRE matched into MEBTINMAN dec 8, 1990



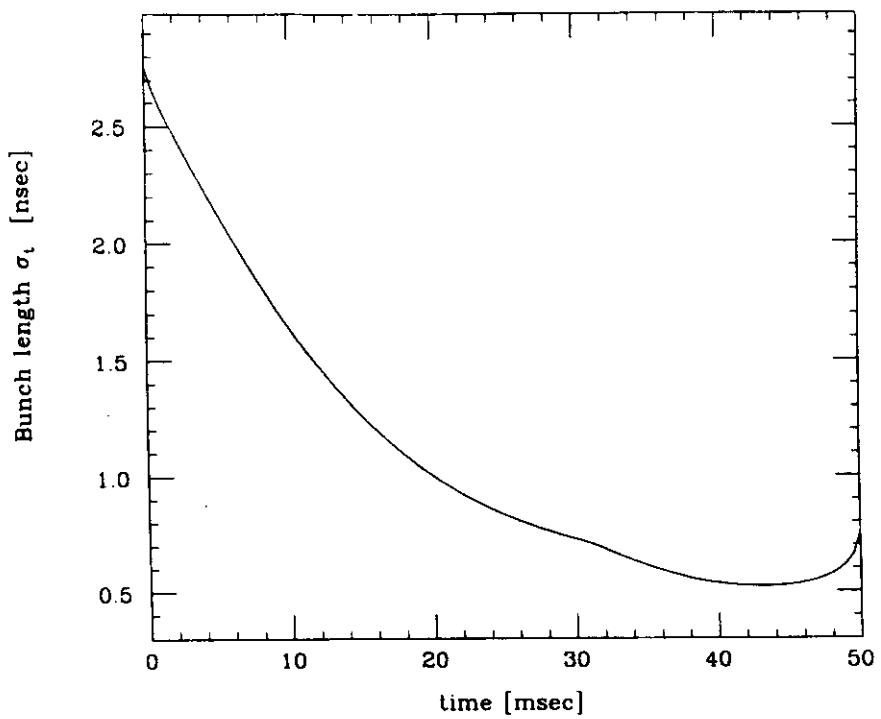
LEBAAGRE matched into MEBTINMAN dec 8, 1990



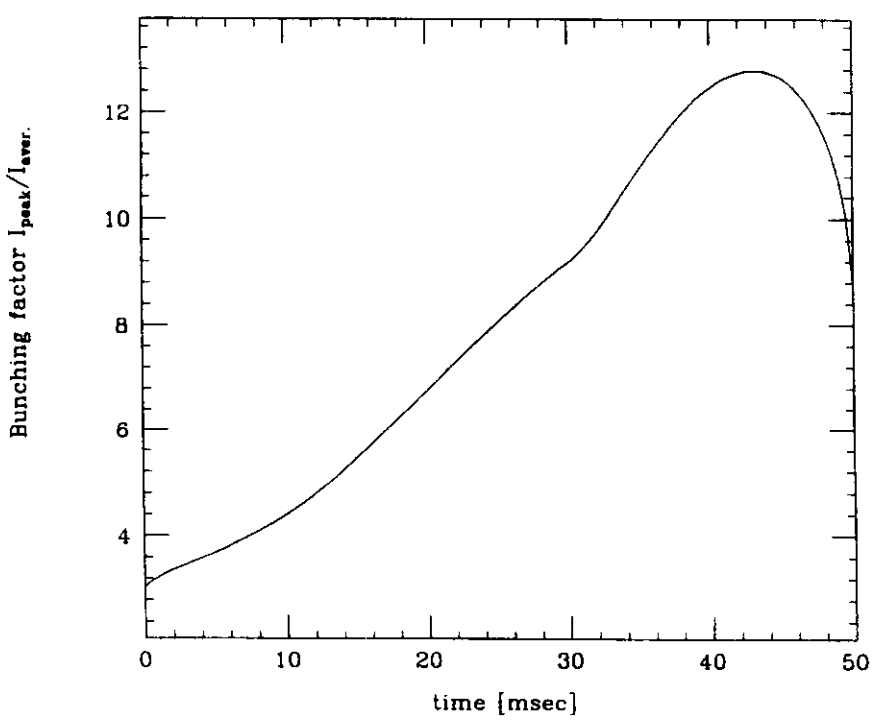

LEBAAGRE matched into MEBTINMAN dec 8, 1990
Adiabaticity, $(T_s/A)dA/dt$
0.4
0.2
0.0
−0.2
−0.4
0
10
20
30
40
50
time [msec]

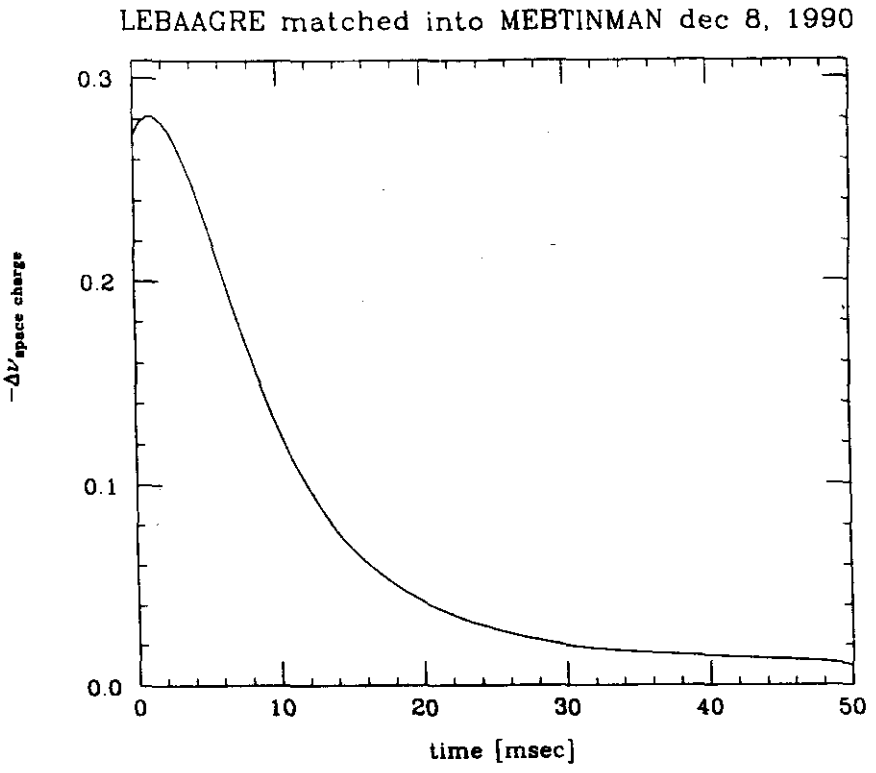

LEBAAGRE matched into MEBTINMAN dec 8, 1990
σ_p/p $[10^{-3}]$
1.4
1.2
1.0
0.8
0.6
0.4
0
10
20
30
40
50
time [msec]

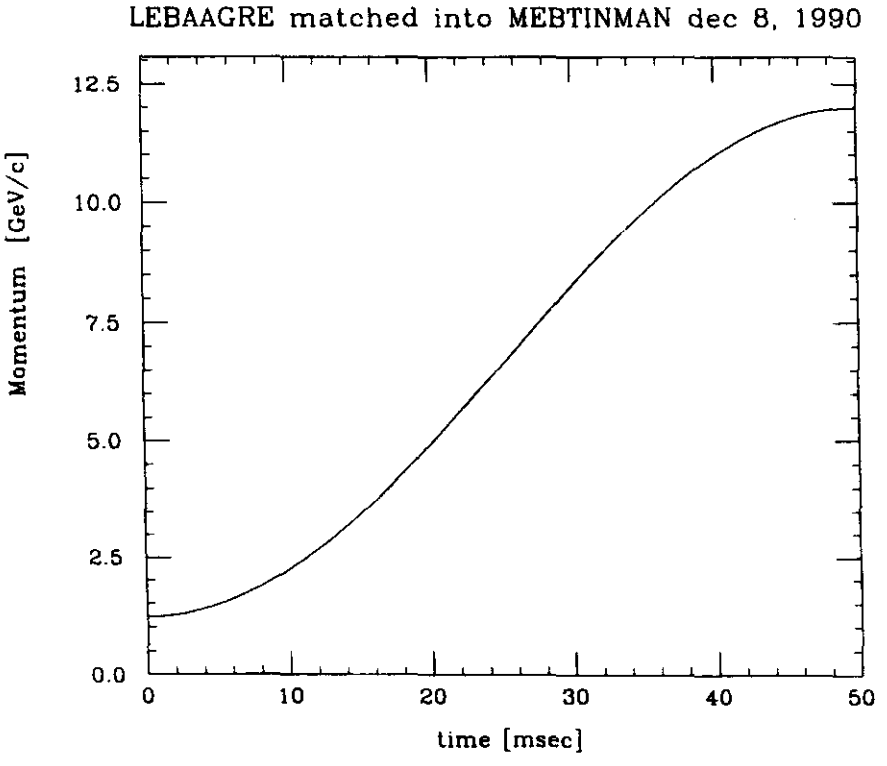
LEBAAGRE matched into MEBTINMAN dec 8, 1990

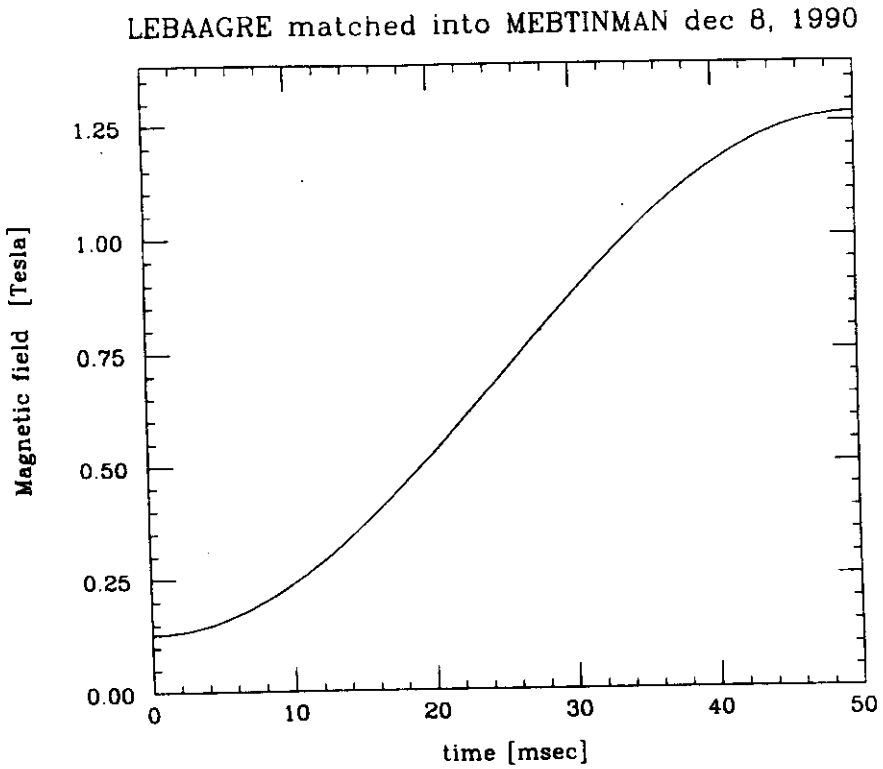


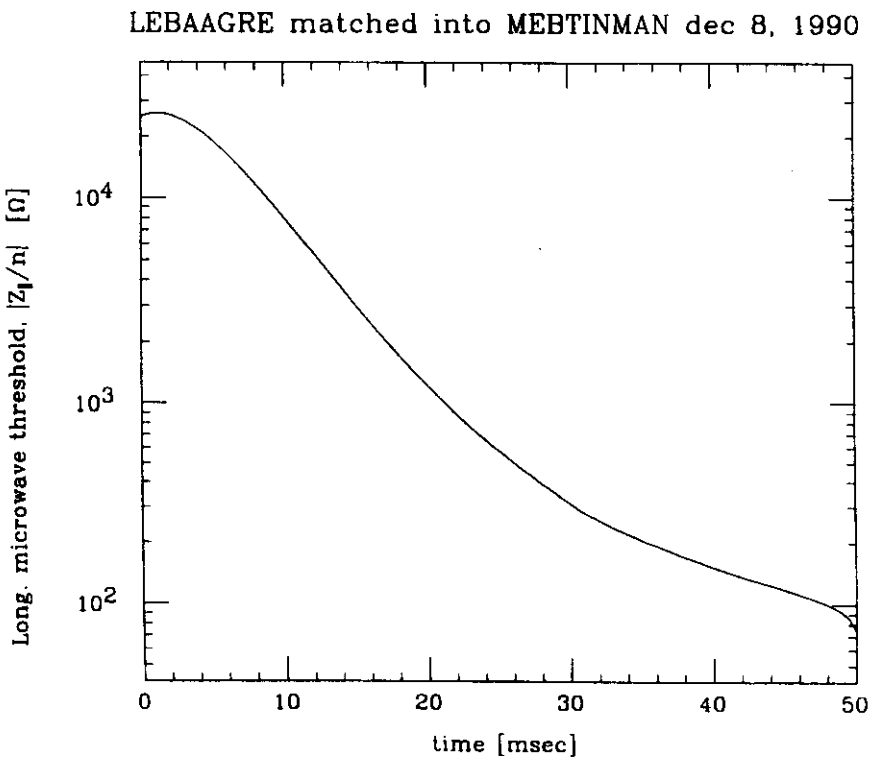
LEBAAGRE matched into MEBTINMAN dec 8, 1990

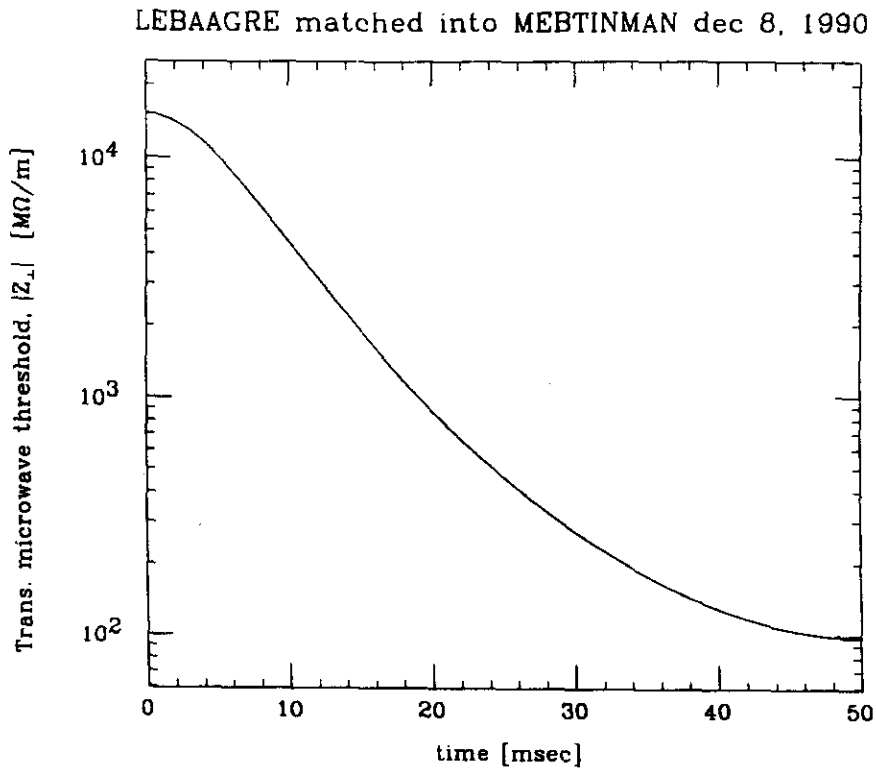


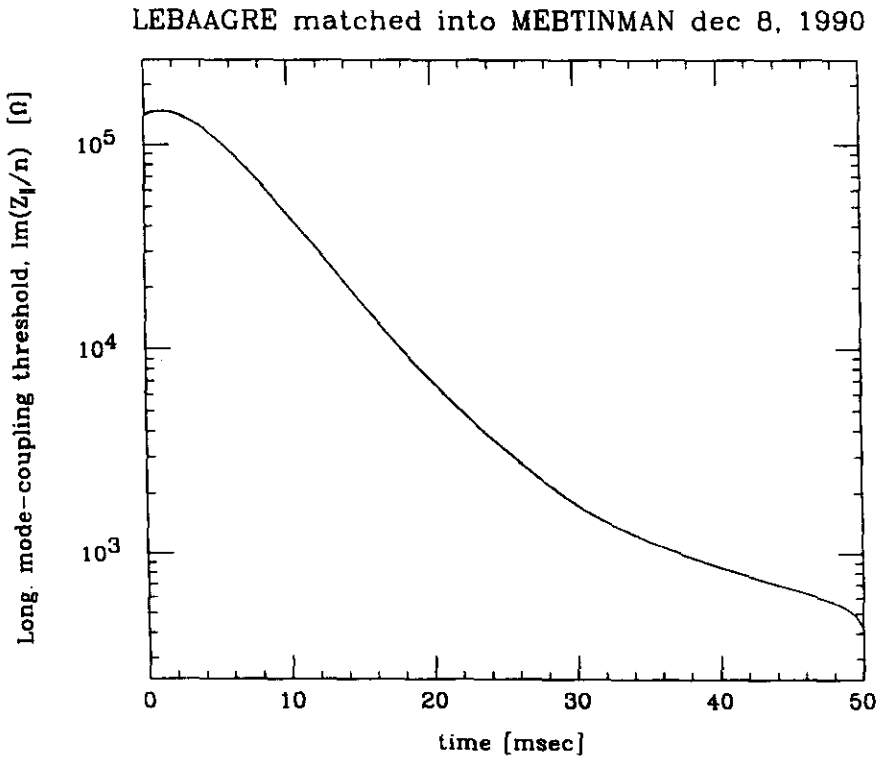

LEBAAGRE matched into MEBTINMAN dec 8, 1990
0.3
0.2
0.1
0.0
$-\Delta\nu_{space\ charge}$
0
10
20
30
40
50
time [msec]

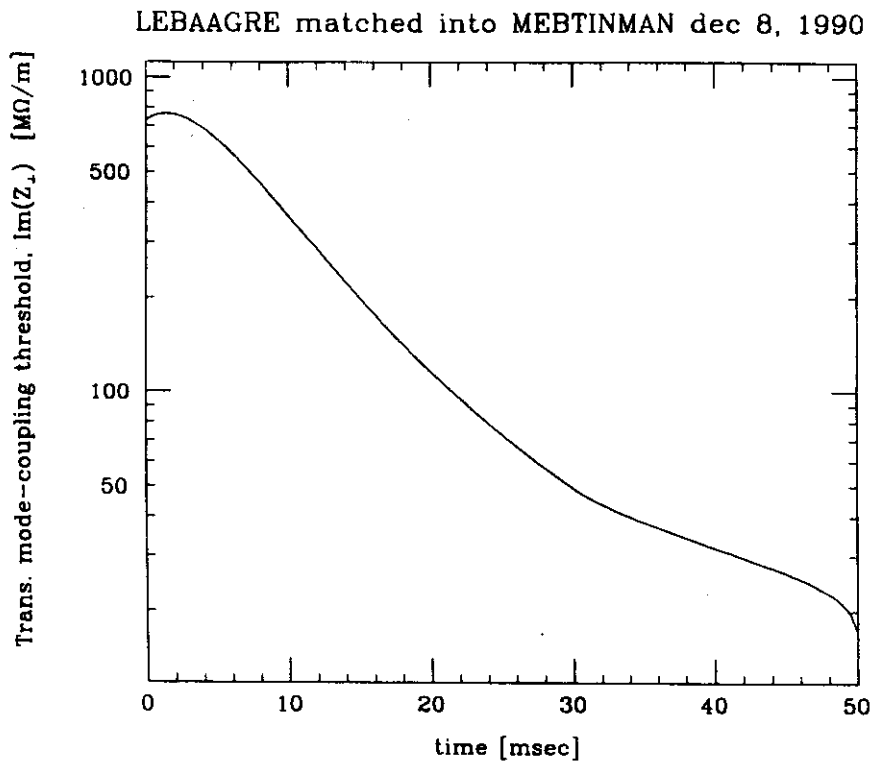

LEBAAGRE matched into MEBTINMAN dec 8, 1990
12.5
10.0
7.5
5.0
2.5
0.0
Momentum [GeV/c]
0
10
20
30
40
50
time [msec]


LEBAAGRE matched into MEBTINMAN dec 8, 1990
Magnetic field [Tesla]
1.25
1.00
0.75
0.50
0.25
0.00
0
10
20
30
40
50
time [msec]


LEBAAGRE matched into MEBTINMAN dec 8, 1990
Long. microwave threshold, |Z||/n| [Ω]
10^4
10^3
10^2
0
10
20
30
40
50
time [msec]


LEBAAGRE matched into MEBTINMAN dec 8, 1990
Trans. microwave threshold, |Z⊥| [MΩ/m]
10^4
10^3
10^2
0
10
20
30
40
50
time [msec]


LEBAAGRE matched into MEBTINMAN dec 8, 1990
Long. mode-coupling threshold, Im(Z∥/n) [Ω]
10^5
10^4
10^3
0
10
20
30
40
50
time [msec]


LEBAAGRE matched into MEBTINMAN dec 8, 1990
Trans. mode-coupling threshold, Im(Z⊥) [MΩ/m]
1000
500
100
50
0
10
20
30
40
50
time [msec]

8 DEC 90 15:46:41USER2:[MIGUEL.RAMPRF.LEB12]RAMPRF1.DAT;6

p0 1.219E+09, pe= 1.200E+10 [eV/c]; Bmax= 1.270E+00 [T]; Brho= 4.003E+01 [T-m]

time [sec]	momentum [eV/c]	energy [eV]	B-field [Tesla]	dE/dt [eV/s]	dp/dt [eV/c/s]	dB/dt [T/sec]	beta	gamma	b*g**2
0.000E+00	1.219E+09	1.538E+09	1.290E-01	0.000E+00	0.000E+00	0.000E+00	7.924E-01	1.639E+00	2.130E+00
5.000E-04	1.222E+09	1.540E+09	1.293E-01	8.437E+09	1.064E+10	1.126E+00	7.931E-01	1.642E+00	2.138E+00
1.000E-03	1.230E+09	1.547E+09	1.301E-01	1.691E+10	2.127E+10	2.251E+00	7.950E-01	1.648E+00	2.160E+00
1.500E-03	1.243E+09	1.557E+09	1.315E-01	2.544E+10	3.187E+10	3.373E+00	7.981E-01	1.660E+00	2.199E+00
2.000E-03	1.262E+09	1.572E+09	1.335E-01	3.406E+10	4.245E+10	4.493E+00	8.024E-01	1.676E+00	2.253E+00
2.500E-03	1.285E+09	1.591E+09	1.360E-01	4.279E+10	5.298E+10	5.607E+00	8.077E-01	1.696E+00	2.323E+00
3.000E-03	1.314E+09	1.615E+09	1.391E-01	5.166E+10	6.347E+10	6.717E+00	8.139E-01	1.721E+00	2.411E+00
3.500E-03	1.349E+09	1.643E+09	1.428E-01	6.065E+10	7.388E+10	7.819E+00	8.209E-01	1.751E+00	2.517E+00
4.000E-03	1.388E+09	1.676E+09	1.469E-01	6.979E+10	8.423E+10	8.914E+00	8.285E-01	1.786E+00	2.643E+00
4.500E-03	1.433E+09	1.713E+09	1.517E-01	7.905E+10	9.449E+10	1.000E+01	8.366E-01	1.826E+00	2.788E+00
5.000E-03	1.483E+09	1.755E+09	1.569E-01	8.844E+10	1.047E+11	1.108E+01	8.450E-01	1.870E+00	2.956E+00
5.500E-03	1.538E+09	1.801E+09	1.627E-01	9.794E+10	1.147E+11	1.214E+01	8.536E-01	1.920E+00	3.146E+00
6.000E-03	1.598E+09	1.853E+09	1.691E-01	1.075E+11	1.247E+11	1.320E+01	8.623E-01	1.975E+00	3.362E+00
6.500E-03	1.662E+09	1.909E+09	1.759E-01	1.171E+11	1.345E+11	1.424E+01	8.709E-01	2.034E+00	3.604E+00
7.000E-03	1.732E+09	1.970E+09	1.833E-01	1.268E+11	1.442E+11	1.526E+01	8.793E-01	2.099E+00	3.875E+00
7.500E-03	1.807E+09	2.036E+09	1.912E-01	1.365E+11	1.538E+11	1.627E+01	8.874E-01	2.170E+00	4.177E+00
8.000E-03	1.886E+09	2.106E+09	1.996E-01	1.461E+11	1.632E+11	1.727E+01	8.953E-01	2.245E+00	4.512E+00
8.500E-03	1.970E+09	2.182E+09	2.085E-01	1.557E+11	1.724E+11	1.825E+01	9.028E-01	2.325E+00	4.881E+00
9.000E-03	2.058E+09	2.262E+09	2.178E-01	1.651E+11	1.815E+11	1.921E+01	9.099E-01	2.411E+00	5.288E+00
9.500E-03	2.151E+09	2.347E+09	2.277E-01	1.745E+11	1.904E+11	2.015E+01	9.166E-01	2.501E+00	5.734E+00
1.000E-02	2.248E+09	2.436E+09	2.380E-01	1.837E+11	1.991E+11	2.107E+01	9.229E-01	2.597E+00	6.223E+00
1.050E-02	2.350E+09	2.531E+09	2.487E-01	1.928E+11	2.076E+11	2.197E+01	9.287E-01	2.697E+00	6.755E+00
1.100E-02	2.456E+09	2.629E+09	2.599E-01	2.017E+11	2.159E+11	2.285E+01	9.342E-01	2.802E+00	7.335E+00
1.150E-02	2.566E+09	2.732E+09	2.716E-01	2.104E+11	2.240E+11	2.370E+01	9.392E-01	2.912E+00	7.964E+00
1.200E-02	2.680E+09	2.839E+09	2.836E-01	2.188E+11	2.319E+11	2.454E+01	9.438E-01	3.026E+00	8.644E+00
1.250E-02	2.798E+09	2.951E+09	2.961E-01	2.271E+11	2.395E+11	2.535E+01	9.481E-01	3.145E+00	9.378E+00
1.300E-02	2.919E+09	3.067E+09	3.090E-01	2.351E+11	2.469E+11	2.613E+01	9.520E-01	3.268E+00	1.017E+01
1.350E-02	3.045E+09	3.186E+09	3.222E-01	2.428E+11	2.541E+11	2.689E+01	9.557E-01	3.396E+00	1.102E+01
1.400E-02	3.173E+09	3.309E+09	3.359E-01	2.503E+11	2.610E+11	2.762E+01	9.590E-01	3.527E+00	1.193E+01
1.450E-02	3.306E+09	3.436E+09	3.498E-01	2.575E+11	2.676E+11	2.832E+01	9.620E-01	3.662E+00	1.290E+01
1.500E-02	3.441E+09	3.567E+09	3.642E-01	2.644E+11	2.740E+11	2.900E+01	9.648E-01	3.801E+00	1.394E+01
1.550E-02	3.580E+09	3.701E+09	3.788E-01	2.710E+11	2.801E+11	2.965E+01	9.673E-01	3.944E+00	1.505E+01
1.600E-02	3.721E+09	3.838E+09	3.938E-01	2.773E+11	2.860E+11	3.027E+01	9.697E-01	4.090E+00	1.622E+01
1.650E-02	3.866E+09	3.978E+09	4.091E-01	2.833E+11	2.915E+11	3.085E+01	9.718E-01	4.239E+00	1.747E+01
1.700E-02	4.013E+09	4.121E+09	4.247E-01	2.890E+11	2.968E+11	3.141E+01	9.737E-01	4.392E+00	1.878E+01
1.750E-02	4.162E+09	4.267E+09	4.405E-01	2.944E+11	3.018E+11	3.194E+01	9.755E-01	4.547E+00	2.017E+01
1.800E-02	4.314E+09	4.415E+09	4.566E-01	2.995E+11	3.065E+11	3.243E+01	9.772E-01	4.706E+00	2.164E+01
1.850E-02	4.469E+09	4.566E+09	4.729E-01	3.042E+11	3.108E+11	3.290E+01	9.787E-01	4.866E+00	2.318E+01
1.900E-02	4.625E+09	4.719E+09	4.895E-01	3.086E+11	3.149E+11	3.333E+01	9.800E-01	5.030E+00	2.479E+01
1.950E-02	4.784E+09	4.875E+09	5.063E-01	3.127E+11	3.187E+11	3.373E+01	9.813E-01	5.195E+00	2.649E+01
2.000E-02	4.944E+09	5.032E+09	5.232E-01	3.165E+11	3.221E+11	3.409E+01	9.825E-01	5.363E+00	2.826E+01
2.050E-02	5.106E+09	5.191E+09	5.403E-01	3.199E+11	3.252E+11	3.442E+01	9.835E-01	5.533E+00	3.011E+01
2.100E-02	5.269E+09	5.352E+09	5.576E-01	3.230E+11	3.281E+11	3.472E+01	9.845E-01	5.704E+00	3.203E+01
2.150E-02	5.434E+09	5.514E+09	5.751E-01	3.257E+11	3.305E+11	3.498E+01	9.854E-01	5.877E+00	3.403E+01
2.200E-02	5.599E+09	5.677E+09	5.926E-01	3.281E+11	3.327E+11	3.521E+01	9.862E-01	6.051E+00	3.611E+01
2.250E-02	5.766E+09	5.842E+09	6.103E-01	3.302E+11	3.345E+11	3.540E+01	9.870E-01	6.226E+00	3.826E+01
2.300E-02	5.934E+09	6.008E+09	6.280E-01	3.319E+11	3.360E+11	3.556E+01	9.877E-01	6.403E+00	4.049E+01
2.350E-02	6.102E+09	6.174E+09	6.458E-01	3.333E+11	3.372E+11	3.569E+01	9.884E-01	6.580E+00	4.279E+01
2.400E-02	6.271E+09	6.341E+09	6.637E-01	3.343E+11	3.380E+11	3.577E+01	9.890E-01	6.758E+00	4.517E+01
2.450E-02	6.440E+09	6.508E+09	6.816E-01	3.350E+11	3.385E+11	3.583E+01	9.896E-01	6.936E+00	4.761E+01
2.500E-02	6.610E+09	6.676E+09	6.995E-01	3.353E+11	3.387E+11	3.585E+01	9.901E-01	7.115E+00	5.012E+01
2.550E-02	6.779E+09	6.843E+09	7.174E-01	3.353E+11	3.385E+11	3.583E+01	9.906E-01	7.294E+00	5.269E+01
2.600E-02	6.948E+09	7.011E+09	7.353E-01	3.350E+11	3.380E+11	3.577E+01	9.910E-01	7.472E+00	5.533E+01
2.650E-02	7.117E+09	7.178E+09	7.532E-01	3.343E+11	3.372E+11	3.569E+01	9.914E-01	7.651E+00	5.803E+01
2.700E-02	7.285E+09	7.345E+09	7.710E-01	3.333E+11	3.360E+11	3.556E+01	9.918E-01	7.828E+00	6.078E+01
2.750E-02	7.453E+09	7.512E+09	7.888E-01	3.319E+11	3.345E+11	3.540E+01	9.922E-01	8.006E+00	6.359E+01
2.800E-02	7.620E+09	7.677E+09	8.064E-01	3.302E+11	3.327E+11	3.521E+01	9.925E-01	8.182E+00	6.645E+01
2.850E-02	7.785E+09	7.842E+09	8.240E-01	3.282E+11	3.305E+11	3.498E+01	9.928E-01	8.358E+00	6.935E+01
2.900E-02	7.950E+09	8.005E+09	8.414E-01	3.258E+11	3.281E+11	3.472E+01	9.931E-01	8.532E+00	7.229E+01
2.950E-02	8.113E+09	8.167E+09	8.587E-01	3.231E+11	3.252E+11	3.442E+01	9.934E-01	8.705E+00	7.527E+01
3.000E-02	8.275E+09	8.328E+09	8.758E-01	3.201E+11	3.221E+11	3.409E+01	9.936E-01	8.876E+00	7.828E+01

3.050E-02	8.435E+09	8.487E+09	8.928E-01	3.167E+11	3.187E+11	3.373E+01	9.939E-01	9.046E+00	8.132E+01
3.100E-02	8.594E+09	8.645E+09	9.095E-01	3.131E+11	3.149E+11	3.333E+01	9.941E-01	9.214E+00	8.439E+01
3.150E-02	8.750E+09	8.800E+09	9.261E-01	3.091E+11	3.108E+11	3.290E+01	9.943E-01	9.379E+00	8.747E+01
3.200E-02	8.905E+09	8.954E+09	9.424E-01	3.048E+11	3.065E+11	3.243E+01	9.945E-01	9.543E+00	9.057E+01
3.250E-02	9.057E+09	9.105E+09	9.585E-01	3.002E+11	3.018E+11	3.194E+01	9.947E-01	9.704E+00	9.367E+01
3.300E-02	9.206E+09	9.254E+09	9.743E-01	2.953E+11	2.968E+11	3.141E+01	9.948E-01	9.863E+00	9.677E+01
3.350E-02	9.353E+09	9.400E+09	9.899E-01	2.901E+11	2.915E+11	3.085E+01	9.950E-01	1.002E+01	9.988E+01
3.400E-02	9.498E+09	9.544E+09	1.005E+00	2.846E+11	2.860E+11	3.027E+01	9.952E-01	1.017E+01	1.030E+02
3.450E-02	9.639E+09	9.685E+09	1.020E+00	2.788E+11	2.801E+11	2.965E+01	9.953E-01	1.032E+01	1.060E+02
3.500E-02	9.778E+09	9.823E+09	1.035E+00	2.728E+11	2.740E+11	2.900E+01	9.954E-01	1.047E+01	1.091E+02
3.550E-02	9.913E+09	9.958E+09	1.049E+00	2.664E+11	2.676E+11	2.832E+01	9.956E-01	1.061E+01	1.121E+02
3.600E-02	1.005E+10	1.009E+10	1.063E+00	2.598E+11	2.610E+11	2.762E+01	9.957E-01	1.075E+01	1.151E+02
3.650E-02	1.017E+10	1.022E+10	1.077E+00	2.530E+11	2.541E+11	2.689E+01	9.958E-01	1.089E+01	1.181E+02
3.700E-02	1.030E+10	1.034E+10	1.090E+00	2.459E+11	2.469E+11	2.613E+01	9.959E-01	1.102E+01	1.210E+02
3.750E-02	1.042E+10	1.046E+10	1.103E+00	2.385E+11	2.395E+11	2.535E+01	9.960E-01	1.115E+01	1.239E+02
3.800E-02	1.054E+10	1.058E+10	1.115E+00	2.309E+11	2.319E+11	2.454E+01	9.961E-01	1.128E+01	1.267E+02
3.850E-02	1.065E+10	1.069E+10	1.127E+00	2.231E+11	2.240E+11	2.370E+01	9.961E-01	1.140E+01	1.294E+02
3.900E-02	1.076E+10	1.080E+10	1.139E+00	2.151E+11	2.159E+11	2.285E+01	9.962E-01	1.151E+01	1.321E+02
3.950E-02	1.087E+10	1.091E+10	1.150E+00	2.068E+11	2.076E+11	2.197E+01	9.963E-01	1.163E+01	1.347E+02
4.000E-02	1.097E+10	1.101E+10	1.161E+00	1.984E+11	1.991E+11	2.107E+01	9.964E-01	1.173E+01	1.372E+02
4.050E-02	1.107E+10	1.111E+10	1.171E+00	1.897E+11	1.904E+11	2.015E+01	9.964E-01	1.184E+01	1.396E+02
4.100E-02	1.116E+10	1.120E+10	1.181E+00	1.808E+11	1.815E+11	1.921E+01	9.965E-01	1.194E+01	1.420E+02
4.150E-02	1.125E+10	1.129E+10	1.191E+00	1.718E+11	1.724E+11	1.825E+01	9.965E-01	1.203E+01	1.442E+02
4.200E-02	1.133E+10	1.137E+10	1.199E+00	1.626E+11	1.632E+11	1.727E+01	9.966E-01	1.212E+01	1.464E+02
4.250E-02	1.141E+10	1.145E+10	1.208E+00	1.532E+11	1.538E+11	1.627E+01	9.966E-01	1.220E+01	1.484E+02
4.300E-02	1.149E+10	1.153E+10	1.216E+00	1.437E+11	1.442E+11	1.526E+01	9.967E-01	1.228E+01	1.504E+02
4.350E-02	1.156E+10	1.159E+10	1.223E+00	1.341E+11	1.345E+11	1.424E+01	9.967E-01	1.236E+01	1.522E+02
4.400E-02	1.162E+10	1.166E+10	1.230E+00	1.243E+11	1.247E+11	1.320E+01	9.968E-01	1.243E+01	1.539E+02
4.450E-02	1.168E+10	1.172E+10	1.236E+00	1.144E+11	1.147E+11	1.214E+01	9.968E-01	1.249E+01	1.555E+02
4.500E-02	1.174E+10	1.177E+10	1.242E+00	1.043E+11	1.047E+11	1.108E+01	9.968E-01	1.255E+01	1.570E+02
4.550E-02	1.179E+10	1.182E+10	1.247E+00	9.419E+10	9.449E+10	1.000E+01	9.968E-01	1.260E+01	1.583E+02
4.600E-02	1.183E+10	1.187E+10	1.252E+00	8.397E+10	8.423E+10	8.914E+00	9.969E-01	1.265E+01	1.595E+02
4.650E-02	1.187E+10	1.191E+10	1.256E+00	7.365E+10	7.388E+10	7.819E+00	9.969E-01	1.269E+01	1.605E+02
4.700E-02	1.190E+10	1.194E+10	1.260E+00	6.327E+10	6.347E+10	6.717E+00	9.969E-01	1.273E+01	1.615E+02
4.750E-02	1.193E+10	1.197E+10	1.263E+00	5.282E+10	5.298E+10	5.607E+00	9.969E-01	1.276E+01	1.623E+02
4.800E-02	1.196E+10	1.199E+10	1.266E+00	4.232E+10	4.245E+10	4.493E+00	9.969E-01	1.278E+01	1.629E+02
4.850E-02	1.198E+10	1.201E+10	1.267E+00	3.178E+10	3.187E+10	3.373E+00	9.969E-01	1.280E+01	1.634E+02
4.900E-02	1.199E+10	1.203E+10	1.269E+00	2.120E+10	2.127E+10	2.251E+00	9.970E-01	1.282E+01	1.638E+02
4.950E-02	1.200E+10	1.203E+10	1.270E+00	1.061E+10	1.064E+10	1.126E+00	9.970E-01	1.283E+01	1.640E+02
5.000E-02	1.200E+10	1.204E+10	1.270E+00	1.488E-05	-1.493E-05	-1.580E-15	9.970E-01	1.283E+01	1.641E+02

8 DEC 90 15:46:41USER2:[MIGUEL.RAMPRF.LEB12]RAMPRF4.DAT;6

time [sec]	sync. tune	Thresholds: microwave inst. sync. freq. [Hz]	|Zl/n| [Ohm]	|Zt| [Ohm/m]	mode-coupl. inst. Im(Zl/n) [Ohm]	Im(Zt) [Ohm/m]	V*sin(phis) [Volts]	bunarea [eV-s]
0.000E+00	6.171E-02	2.715E+04	2.503E+04	1.513E+10	1.416E+05	7.285E+08	0.000E+00	6.400E-02
5.000E-04	6.598E-02	2.905E+04	2.580E+04	1.506E+10	1.460E+05	7.522E+08	1.916E+04	6.405E-02
1.000E-03	6.865E-02	3.030E+04	2.609E+04	1.487E+10	1.476E+05	7.638E+08	3.831E+04	6.420E-02
1.500E-03	7.018E-02	3.109E+04	2.600E+04	1.455E+10	1.471E+05	7.665E+08	5.741E+04	6.445E-02
2.000E-03	7.076E-02	3.152E+04	2.560E+04	1.412E+10	1.448E+05	7.619E+08	7.646E+04	6.478E-02
2.500E-03	7.055E-02	3.164E+04	2.492E+04	1.359E+10	1.410E+05	7.510E+08	9.544E+04	6.519E-02
3.000E-03	6.965E-02	3.147E+04	2.402E+04	1.299E+10	1.359E+05	7.348E+08	1.143E+05	6.566E-02
3.500E-03	6.817E-02	3.107E+04	2.294E+04	1.233E+10	1.298E+05	7.144E+08	1.331E+05	6.621E-02
4.000E-03	6.620E-02	3.045E+04	2.174E+04	1.163E+10	1.230E+05	6.905E+08	1.517E+05	6.681E-02
4.500E-03	6.385E-02	2.965E+04	2.045E+04	1.091E+10	1.157E+05	6.641E+08	1.702E+05	6.746E-02
5.000E-03	6.120E-02	2.871E+04	1.912E+04	1.019E+10	1.082E+05	6.360E+08	1.885E+05	6.815E-02
5.500E-03	5.835E-02	2.765E+04	1.778E+04	9.478E+09	1.006E+05	6.067E+08	2.067E+05	6.888E-02
6.000E-03	5.537E-02	2.650E+04	1.646E+04	8.784E+09	9.309E+04	5.770E+08	2.246E+05	6.963E-02
6.500E-03	5.232E-02	2.529E+04	1.517E+04	8.118E+09	8.580E+04	5.473E+08	2.423E+05	7.041E-02
7.000E-03	4.926E-02	2.405E+04	1.393E+04	7.485E+09	7.883E+04	5.181E+08	2.598E+05	7.120E-02
7.500E-03	4.625E-02	2.279E+04	1.277E+04	6.889E+09	7.221E+04	4.896E+08	2.770E+05	7.200E-02
8.000E-03	4.331E-02	2.153E+04	1.167E+04	6.331E+09	6.601E+04	4.620E+08	2.939E+05	7.280E-02
8.500E-03	4.048E-02	2.029E+04	1.065E+04	5.813E+09	6.023E+04	4.355E+08	3.106E+05	7.359E-02
9.000E-03	3.776E-02	1.908E+04	9.700E+03	5.333E+09	5.487E+04	4.103E+08	3.269E+05	7.437E-02
9.500E-03	3.519E-02	1.791E+04	8.827E+03	4.891E+09	4.994E+04	3.863E+08	3.429E+05	7.512E-02
1.000E-02	3.276E-02	1.678E+04	8.027E+03	4.484E+09	4.541E+04	3.637E+08	3.586E+05	7.585E-02
1.050E-02	3.048E-02	1.571E+04	7.294E+03	4.111E+09	4.126E+04	3.423E+08	3.739E+05	7.654E-02
1.100E-02	2.834E-02	1.470E+04	6.624E+03	3.769E+09	3.747E+04	3.221E+08	3.889E+05	7.719E-02
1.150E-02	2.635E-02	1.374E+04	6.014E+03	3.456E+09	3.402E+04	3.032E+08	4.034E+05	7.779E-02
1.200E-02	2.450E-02	1.284E+04	5.459E+03	3.169E+09	3.088E+04	2.854E+08	4.176E+05	7.834E-02
1.250E-02	2.278E-02	1.199E+04	4.953E+03	2.908E+09	2.802E+04	2.688E+08	4.314E+05	7.881E-02
1.300E-02	2.119E-02	1.120E+04	4.494E+03	2.668E+09	2.542E+04	2.531E+08	4.447E+05	7.922E-02
1.350E-02	1.971E-02	1.046E+04	4.076E+03	2.449E+09	2.305E+04	2.384E+08	4.576E+05	7.955E-02
1.400E-02	1.835E-02	9.767E+03	3.695E+03	2.249E+09	2.090E+04	2.246E+08	4.701E+05	7.980E-02
1.450E-02	1.708E-02	9.123E+03	3.349E+03	2.065E+09	1.895E+04	2.117E+08	4.821E+05	7.995E-02
1.500E-02	1.592E-02	8.525E+03	3.035E+03	1.897E+09	1.717E+04	1.995E+08	4.936E+05	8.000E-02
1.550E-02	1.484E-02	7.969E+03	2.751E+03	1.744E+09	1.556E+04	1.881E+08	5.046E+05	8.000E-02
1.600E-02	1.385E-02	7.456E+03	2.498E+03	1.606E+09	1.413E+04	1.776E+08	5.151E+05	8.000E-02
1.650E-02	1.294E-02	6.982E+03	2.272E+03	1.480E+09	1.285E+04	1.678E+08	5.251E+05	8.000E-02
1.700E-02	1.210E-02	6.543E+03	2.070E+03	1.367E+09	1.171E+04	1.587E+08	5.346E+05	8.000E-02
1.750E-02	1.133E-02	6.137E+03	1.890E+03	1.264E+09	1.069E+04	1.503E+08	5.436E+05	8.000E-02
1.800E-02	1.062E-02	5.761E+03	1.728E+03	1.170E+09	9.772E+03	1.424E+08	5.520E+05	8.000E-02
1.850E-02	9.964E-03	5.414E+03	1.582E+03	1.085E+09	8.949E+03	1.351E+08	5.599E+05	8.000E-02
1.900E-02	9.357E-03	5.091E+03	1.451E+03	1.007E+09	8.208E+03	1.282E+08	5.672E+05	8.000E-02
1.950E-02	8.796E-03	4.792E+03	1.333E+03	9.368E+08	7.541E+03	1.218E+08	5.740E+05	8.000E-02
2.000E-02	8.277E-03	4.515E+03	1.227E+03	8.723E+08	6.940E+03	1.159E+08	5.802E+05	8.000E-02
2.050E-02	7.796E-03	4.257E+03	1.131E+03	8.133E+08	6.396E+03	1.103E+08	5.858E+05	8.000E-02
2.100E-02	7.350E-03	4.017E+03	1.044E+03	7.593E+08	5.904E+03	1.051E+08	5.909E+05	8.000E-02
2.150E-02	6.936E-03	3.795E+03	9.649E+02	7.099E+08	5.458E+03	1.002E+08	5.954E+05	8.000E-02
2.200E-02	6.551E-03	3.587E+03	8.933E+02	6.645E+08	5.053E+03	9.557E+07	5.993E+05	8.000E-02
2.250E-02	6.193E-03	3.394E+03	8.283E+02	6.227E+08	4.686E+03	9.125E+07	6.026E+05	8.000E-02
2.300E-02	5.860E-03	3.213E+03	7.691E+02	5.844E+08	4.351E+03	8.719E+07	6.053E+05	8.000E-02
2.350E-02	5.549E-03	3.045E+03	7.152E+02	5.490E+08	4.046E+03	8.338E+07	6.074E+05	8.000E-02
2.400E-02	5.260E-03	2.888E+03	6.659E+02	5.165E+08	3.767E+03	7.978E+07	6.089E+05	8.000E-02
2.450E-02	4.989E-03	2.741E+03	6.209E+02	4.864E+08	3.512E+03	7.639E+07	6.098E+05	8.000E-02
2.500E-02	4.736E-03	2.603E+03	5.797E+02	4.586E+08	3.279E+03	7.320E+07	6.101E+05	8.000E-02
2.550E-02	4.499E-03	2.474E+03	5.419E+02	4.329E+08	3.065E+03	7.018E+07	6.098E+05	8.000E-02
2.600E-02	4.278E-03	2.353E+03	5.072E+02	4.091E+08	2.869E+03	6.733E+07	6.089E+05	8.000E-02
2.650E-02	4.070E-03	2.240E+03	4.754E+02	3.870E+08	2.689E+03	6.464E+07	6.074E+05	8.000E-02
2.700E-02	3.875E-03	2.133E+03	4.461E+02	3.665E+08	2.523E+03	6.209E+07	6.053E+05	8.000E-02
2.750E-02	3.692E-03	2.033E+03	4.191E+02	3.475E+08	2.371E+03	5.967E+07	6.026E+05	8.000E-02
2.800E-02	3.519E-03	1.939E+03	3.942E+02	3.298E+08	2.230E+03	5.739E+07	5.993E+05	8.000E-02
2.850E-02	3.358E-03	1.851E+03	3.712E+02	3.134E+08	2.100E+03	5.522E+07	5.954E+05	8.000E-02
2.900E-02	3.205E-03	1.767E+03	3.500E+02	2.981E+08	1.980E+03	5.316E+07	5.909E+05	8.000E-02
2.950E-02	3.061E-03	1.688E+03	3.304E+02	2.838E+08	1.869E+03	5.121E+07	5.858E+05	8.000E-02
3.000E-02	2.926E-03	1.614E+03	3.122E+02	2.705E+08	1.766E+03	4.935E+07	5.802E+05	8.000E-02

3.050E-02	2.807E-03	1.549E+03	2.958E+02	2.580E+08	1.673E+03	4.766E+07	5.740E+05	8.000E-02
3.100E-02	2.710E-03	1.496E+03	2.814E+02	2.464E+08	1.592E+03	4.620E+07	5.672E+05	8.000E-02
3.150E-02	2.632E-03	1.453E+03	2.686E+02	2.356E+08	1.520E+03	4.491E+07	5.599E+05	8.000E-02
3.200E-02	2.567E-03	1.417E+03	2.572E+02	2.255E+08	1.455E+03	4.376E+07	5.520E+05	8.000E-02
3.250E-02	2.512E-03	1.387E+03	2.469E+02	2.160E+08	1.397E+03	4.273E+07	5.436E+05	8.000E-02
3.300E-02	2.464E-03	1.361E+03	2.375E+02	2.071E+08	1.344E+03	4.178E+07	5.346E+05	8.000E-02
3.350E-02	2.422E-03	1.338E+03	2.289E+02	1.988E+08	1.295E+03	4.090E+07	5.251E+05	8.000E-02
3.400E-02	2.382E-03	1.316E+03	2.208E+02	1.910E+08	1.249E+03	4.006E+07	5.151E+05	8.000E-02
3.450E-02	2.345E 03	1.296E+03	2.132E+02	1.838E+08	1.206E+03	3.927E+07	5.046E+05	8.000E-02
3.500E-02	2.308E-03	1.276E+03	2.061E+02	1.769E+08	1.166E+03	3.850E+07	4.936E+05	8.000E-02
3.550E-02	2.273E-03	1.256E+03	1.994E+02	1.705E+08	1.128E+03	3.776E+07	4.821E+05	8.000E-02
3.600E-02	2.237E-03	1.237E+03	1.930E+02	1.645E+08	1.092E+03	3.705E+07	4.701E+05	8.000E-02
3.650E-02	2.202E-03	1.217E+03	1.870E+02	1.589E+08	1.058E+03	3.635E+07	4.576E+05	8.000E-02
3.700E-02	2.166E-03	1.197E+03	1.812E+02	1.537E+08	1.025E+03	3.567E+07	4.447E+05	8.000E-02
3.750E-02	2.130E-03	1.178E+03	1.758E+02	1.487E+08	9.944E+02	3.500E+07	4.314E+05	8.000E-02
3.800E-02	2.093E-03	1.158E+03	1.706E+02	1.441E+08	9.650E+02	3.435E+07	4.176E+05	8.000E-02
3.850E-02	2.057E-03	1.137E+03	1.656E+02	1.398E+08	9.369E+02	3.371E+07	4.034E+05	8.000E-02
3.900E-02	2.019E-03	1.117E+03	1.609E+02	1.358E+08	9.102E+02	3.309E+07	3.889E+05	8.000E-02
3.950E-02	1.982E-03	1.096E+03	1.564E+02	1.320E+08	8.847E+02	3.248E+07	3.739E+05	8.000E-02
4.000E-02	1.944E-03	1.075E+03	1.521E+02	1.285E+08	8.604E+02	3.188E+07	3.586E+05	8.000E-02
4.050E-02	1.905E-03	1.054E+03	1.480E+02	1.252E+08	8.372E+02	3.129E+07	3.429E+05	8.000E-02
4.100E-02	1.866E-03	1.032E+03	1.441E+02	1.222E+08	8.150E+02	3.072E+07	3.269E+05	8.000E-02
4.150E-02	1.827E-03	1.011E+03	1.403E+02	1.194E+08	7.938E+02	3.016E+07	3.106E+05	8.000E-02
4.200E-02	1.786E-03	9.884E+02	1.367E+02	1.167E+08	7.734E+02	2.960E+07	2.939E+05	8.000E-02
4.250E-02	1.746E-03	9.659E+02	1.333E+02	1.143E+08	7.540E+02	2.906E+07	2.770E+05	8.000E-02
4.300E-02	1.704E-03	9.430E+02	1.300E+02	1.121E+08	7.352E+02	2.852E+07	2.598E+05	8.000E-02
4.350E-02	1.662E-03	9.196E+02	1.268E+02	1.100E+08	7.172E+02	2.799E+07	2.423E+05	8.000E-02
4.400E-02	1.618E-03	8.955E+02	1.237E+02	1.082E+08	6.997E+02	2.746E+07	2.246E+05	8.000E-02
4.450E-02	1.573E-03	8.707E+02	1.207E+02	1.065E+08	6.827E+02	2.693E+07	2.067E+05	8.000E-02
4.500E-02	1.527E-03	8.451E+02	1.178E+02	1.049E+08	6.661E+02	2.640E+07	1.885E+05	8.000E-02
4.550E-02	1.479E-03	8.184E+02	1.149E+02	1.036E+08	6.498E+02	2.587E+07	1.702E+05	8.000E-02
4.600E-02	1.428E-03	7.903E+02	1.120E+02	1.023E+08	6.336E+02	2.532E+07	1.517E+05	8.000E-02
4.650E-02	1.374E-03	7.606E+02	1.091E+02	1.013E+08	6.173E+02	2.475E+07	1.331E+05	8.000E-02
4.700E-02	1.317E-03	7.287E+02	1.062E+02	1.003E+08	6.006E+02	2.415E+07	1.143E+05	8.000E-02
4.750E-02	1.254E-03	6.941E+02	1.031E+02	9.958E+07	5.832E+02	2.350E+07	9.544E+04	8.000E-02
4.800E-02	1.185E-03	6.558E+02	9.979E+01	9.895E+07	5.645E+02	2.280E+07	7.646E+04	8.000E-02
4.850E-02	1.106E-03	6.123E+02	9.611E+01	9.846E+07	5.437E+02	2.199E+07	5.741E+04	8.000E-02
4.900E-02	1.013E-03	5.607E+02	9.175E+01	9.811E+07	5.190E+02	2.102E+07	3.831E+04	8.000E-02
4.950E-02	8.928E-04	4.942E+02	8.602E+01	9.790E+07	4.866E+02	1.972E+07	1.916E+04	8.000E-02
5.000E-02	6.770E-04	3.747E+02	7.487E+01	9.784E+07	4.235E+02	1.716E+07	3.921E-03	8.000E-02

8 DEC 90 15:46:41USER2:[MIGUEL.RAMPRF.LEB12]RAMPRF3.DAT;6
bunch assumed gaussian

time [sec]	voltage [Volts]	RF freq [Hz]	adiab	B factor	delnu	sigp/p	sigz [m]	sigx [m]	sigy [m]
0.000E+00	5.788E+05	4.751E+07	0.000E+00	3.042E+00	-2.724E-01	1.273E-03	6.558E-01	2.804E-03	2.149E-03
5.000E-04	6.656E+05	4.755E+07	1.108E-04	3.152E+00	-2.789E-01	1.318E-03	6.329E-01	2.843E-03	2.147E-03
1.000E-03	7.339E+05	4.767E+07	2.047E-04	3.235E+00	-2.815E-01	1.347E-03	6.166E-01	2.865E-03	2.140E-03
1.500E-03	7.900E+05	4.785E+07	2.874E-04	3.305E+00	-2.811E-01	1.366E-03	6.036E-01	2.875E-03	2.128E-03
2.000E-03	8.368E+05	4.811E+07	3.622E-04	3.367E+00	-2.783E-01	1.378E-03	5.925E-01	2.875E-03	2.113E-03
2.500E-03	8.757E+05	4.843E+07	4.310E-04	3.424E+00	-2.735E-01	1.385E-03	5.825E-01	2.866E-03	2.093E-03
3.000E-03	9.079E+05	4.880E+07	4.955E-04	3.479E+00	-2.669E-01	1.386E-03	5.733E-01	2.850E-03	2.069E-03
3.500E-03	9.338E+05	4.922E+07	5.566E-04	3.533E+00	-2.588E-01	1.383E-03	5.646E-01	2.828E-03	2.043E-03
4.000E-03	9.543E+05	4.968E+07	6.152E-04	3.587E+00	-2.496E-01	1.376E-03	5.561E-01	2.800E-03	2.014E-03
4.500E-03	9.698E+05	5.016E+07	6.719E-04	3.641E+00	-2.396E-01	1.367E-03	5.478E-01	2.768E-03	1.982E-03
5.000E-03	9.809E+05	5.067E+07	7.269E-04	3.697E+00	-2.289E-01	1.355E-03	5.396E-01	2.733E-03	1.948E-03
5.500E-03	9.882E+05	5.118E+07	7.803E-04	3.754E+00	-2.179E-01	1.341E-03	5.313E-01	2.694E-03	1.913E-03
6.000E-03	9.921E+05	5.170E+07	8.323E-04	3.814E+00	-2.067E-01	1.325E-03	5.230E-01	2.653E-03	1.877E-03
6.500E-03	9.932E+05	5.222E+07	8.824E-04	3.876E+00	-1.955E-01	1.309E-03	5.146E-01	2.610E-03	1.840E-03
7.000E-03	9.919E+05	5.272E+07	9.303E-04	3.941E+00	-1.845E-01	1.292E-03	5.062E-01	2.567E-03	1.803E-03
7.500E-03	9.888E+05	5.321E+07	9.753E-04	4.009E+00	-1.737E-01	1.274E-03	4.976E-01	2.522E-03	1.765E-03
8.000E-03	9.841E+05	5.368E+07	1.016E-03	4.080E+00	-1.633E-01	1.256E-03	4.889E-01	2.478E-03	1.728E-03
8.500E-03	9.783E+05	5.413E+07	1.053E-03	4.155E+00	-1.534E-01	1.238E-03	4.801E-01	2.434E-03	1.691E-03
9.000E-03	9.717E+05	5.456E+07	1.083E-03	4.233E+00	-1.440E-01	1.219E-03	4.713E-01	2.389E-03	1.654E-03
9.500E-03	9.645E+05	5.496E+07	1.105E-03	4.314E+00	-1.350E-01	1.201E-03	4.623E-01	2.346E-03	1.618E-03
1.000E-02	9.569E+05	5.533E+07	1.117E-03	4.400E+00	-1.266E-01	1.183E-03	4.534E-01	2.303E-03	1.582E-03
1.050E-02	9.491E+05	5.568E+07	1.117E-03	4.488E+00	-1.187E-01	1.166E-03	4.444E-01	2.261E-03	1.548E-03
1.100E-02	9.412E+05	5.601E+07	1.103E-03	4.581E+00	-1.113E-01	1.148E-03	4.354E-01	2.220E-03	1.514E-03
1.150E-02	9.334E+05	5.631E+07	1.071E-03	4.677E+00	-1.045E-01	1.131E-03	4.265E-01	2.179E-03	1.481E-03
1.200E-02	9.256E+05	5.659E+07	1.018E-03	4.777E+00	-9.811E-02	1.113E-03	4.176E-01	2.140E-03	1.449E-03
1.250E-02	9.180E+05	5.685E+07	9.406E-04	4.880E+00	-9.221E-02	1.096E-03	4.087E-01	2.101E-03	1.419E-03
1.300E-02	9.105E+05	5.708E+07	8.337E-04	4.988E+00	-8.675E-02	1.079E-03	3.999E-01	2.063E-03	1.389E-03
1.350E-02	9.031E+05	5.730E+07	6.924E-04	5.099E+00	-8.170E-02	1.062E-03	3.912E-01	2.026E-03	1.360E-03
1.400E-02	8.959E+05	5.750E+07	5.110E-04	5.214E+00	-7.705E-02	1.045E-03	3.826E-01	1.990E-03	1.332E-03
1.450E-02	8.889E+05	5.768E+07	2.827E-04	5.333E+00	-7.277E-02	1.028E-03	3.740E-01	1.954E-03	1.305E-03
1.500E-02	8.819E+05	5.785E+07	0.000E+00	5.456E+00	-6.883E-02	1.011E-03	3.656E-01	1.919E-03	1.279E-03
1.550E-02	8.753E+05	5.800E+07	0.000E+00	5.582E+00	-6.518E-02	9.948E-04	3.573E-01	1.885E-03	1.254E-03
1.600E-02	8.693E+05	5.814E+07	0.000E+00	5.710E+00	-6.177E-02	9.789E-04	3.493E-01	1.852E-03	1.230E-03
1.650E-02	8.637E+05	5.827E+07	0.000E+00	5.840E+00	-5.861E-02	9.637E-04	3.416E-01	1.820E-03	1.207E-03
1.700E-02	8.585E+05	5.838E+07	0.000E+00	5.970E+00	-5.565E-02	9.491E-04	3.341E-01	1.790E-03	1.184E-03
1.750E-02	8.536E+05	5.849E+07	0.000E+00	6.102E+00	-5.290E-02	9.351E-04	3.269E-01	1.761E-03	1.163E-03
1.800E-02	8.489E+05	5.859E+07	0.000E+00	6.234E+00	-5.032E-02	9.218E-04	3.199E-01	1.733E-03	1.142E-03
1.850E-02	8.444E+05	5.868E+07	0.000E+00	6.368E+00	-4.792E-02	9.089E-04	3.133E-01	1.706E-03	1.122E-03
1.900E-02	8.401E+05	5.876E+07	0.000E+00	6.501E+00	-4.568E-02	8.966E-04	3.068E-01	1.681E-03	1.103E-03
1.950E-02	8.358E+05	5.884E+07	0.000E+00	6.635E+00	-4.359E-02	8.847E-04	3.006E-01	1.656E-03	1.085E-03
2.000E-02	8.315E+05	5.891E+07	0.000E+00	6.768E+00	-4.163E-02	8.733E-04	2.947E-01	1.632E-03	1.067E-03
2.050E-02	8.272E+05	5.897E+07	0.000E+00	6.902E+00	-3.980E-02	8.623E-04	2.890E-01	1.609E-03	1.050E-03
2.100E-02	8.229E+05	5.903E+07	0.000E+00	7.035E+00	-3.809E-02	8.517E-04	2.835E-01	1.587E-03	1.034E-03
2.150E-02	8.184E+05	5.908E+07	0.000E+00	7.168E+00	-3.648E-02	8.415E-04	2.783E-01	1.566E-03	1.018E-03
2.200E-02	8.138E+05	5.913E+07	0.000E+00	7.300E+00	-3.498E-02	8.316E-04	2.732E-01	1.546E-03	1.003E-03
2.250E-02	8.090E+05	5.918E+07	0.000E+00	7.432E+00	-3.356E-02	8.221E-04	2.684E-01	1.526E-03	9.881E-04
2.300E-02	8.040E+05	5.922E+07	0.000E+00	7.562E+00	-3.224E-02	8.129E-04	2.638E-01	1.507E-03	9.740E-04
2.350E-02	7.988E+05	5.926E+07	0.000E+00	7.691E+00	-3.099E-02	8.040E-04	2.593E-01	1.488E-03	9.605E-04
2.400E-02	7.933E+05	5.930E+07	0.000E+00	7.819E+00	-2.982E-02	7.954E-04	2.551E-01	1.471E-03	9.475E-04
2.450E-02	7.875E+05	5.933E+07	0.000E+00	7.946E+00	-2.872E-02	7.870E-04	2.510E-01	1.454E-03	9.350E-04
2.500E-02	7.814E+05	5.936E+07	0.000E+00	8.071E+00	-2.769E-02	7.789E-04	2.472E-01	1.437E-03	9.229E-04
2.550E-02	7.750E+05	5.939E+07	0.000E+00	8.194E+00	-2.671E-02	7.710E-04	2.435E-01	1.421E-03	9.113E-04
2.600E-02	7.683E+05	5.942E+07	0.000E+00	8.315E+00	-2.579E-02	7.633E-04	2.399E-01	1.406E-03	9.001E-04
2.650E-02	7.612E+05	5.944E+07	0.000E+00	8.433E+00	-2.493E-02	7.559E-04	2.365E-01	1.391E-03	8.894E-04
2.700E-02	7.537E+05	5.947E+07	0.000E+00	8.550E+00	-2.411E-02	7.486E-04	2.333E-01	1.376E-03	8.791E-04
2.750E-02	7.459E+05	5.949E+07	0.000E+00	8.664E+00	-2.334E-02	7.416E-04	2.302E-01	1.362E-03	8.691E-04
2.800E-02	7.377E+05	5.951E+07	0.000E+00	8.776E+00	-2.261E-02	7.347E-04	2.273E-01	1.348E-03	8.596E-04
2.850E-02	7.290E+05	5.953E+07	0.000E+00	8.885E+00	-2.192E-02	7.279E-04	2.245E-01	1.335E-03	8.504E-04
2.900E-02	7.200E+05	5.955E+07	0.000E+00	8.991E+00	-2.126E-02	7.214E-04	2.219E-01	1.322E-03	8.415E-04
2.950E-02	7.106E+05	5.956E+07	0.000E+00	9.093E+00	-2.065E-02	7.149E-04	2.194E-01	1.310E-03	8.330E-04
3.000E-02	7.007E+05	5.958E+07	1.312E-16	9.193E+00	-2.006E-02	7.086E-04	2.170E-01	1.298E-03	8.248E-04

3.050E-02	6.918E+05	5.959E+07	3.441E-02	9.304E+00	-1.953E-02	7.035E-04	2.144E-01	1.287E-03	8.169E-04
3.100E-02	6.849E+05	5.960E+07	6.680E-02	9.439E+00	-1.906E-02	7.006E-04	2.113E-01	1.279E-03	8.094E-04
3.150E-02	6.797E+05	5.962E+07	9.463E-02	9.596E+00	-1.864E-02	6.995E-04	2.079E-01	1.274E-03	8.021E-04
3.200E-02	6.756E+05	5.963E+07	1.166E-01	9.770E+00	-1.826E-02	6.998E-04	2.042E-01	1.270E-03	7.951E-04
3.250E-02	6.725E+05	5.964E+07	1.326E-01	9.956E+00	-1.793E-02	7.012E-04	2.004E-01	1.267E-03	7.884E-04
3.300E-02	6.700E+05	5.965E+07	1.433E-01	1.015E+01	-1.762E-02	7.033E-04	1.965E-01	1.265E-03	7.820E-04
3.350E-02	6.679E+05	5.966E+07	1.495E-01	1.035E+01	-1.733E-02	7.058E-04	1.927E-01	1.264E-03	7.758E-04
3.400E-02	6.658E+05	5.967E+07	1.524E-01	1.055E+01	-1.705E-02	7.085E-04	1.891E-01	1.264E-03	7.699E-04
3.450E-02	6.637E+05	5.968E+07	1.527E-01	1.075E+01	-1.680E-02	7.113E-04	1.856E-01	1.263E-03	7.642E-04
3.500E-02	6.613E+05	5.968E+07	1.512E-01	1.094E+01	-1.655E-02	7.140E-04	1.823E-01	1.263E-03	7.588E-04
3.550E-02	6.585E+05	5.969E+07	1.485E-01	1.114E+01	-1.632E-02	7.165E-04	1.791E-01	1.263E-03	7.536E-04
3.600E-02	6.552E+05	5.970E+07	1.450E-01	1.132E+01	-1.609E-02	7.188E-04	1.762E-01	1.262E-03	7.486E-04
3.650E-02	6.513E+05	5.971E+07	1.410E-01	1.150E+01	-1.588E-02	7.208E-04	1.735E-01	1.262E-03	7.439E-04
3.700E-02	6.466E+05	5.971E+07	1.366E-01	1.167E+01	-1.567E-02	7.226E-04	1.710E-01	1.261E-03	7.393E-04
3.750E-02	6.412E+05	5.972E+07	1.322E-01	1.183E+01	-1.546E-02	7.239E-04	1.687E-01	1.260E-03	7.350E-04
3.800E-02	6.349E+05	5.972E+07	1.276E-01	1.198E+01	-1.527E-02	7.249E-04	1.665E-01	1.259E-03	7.309E-04
3.850E-02	6.277E+05	5.973E+07	1.231E-01	1.212E+01	-1.508E-02	7.255E-04	1.646E-01	1.257E-03	7.270E-04
3.900E-02	6.195E+05	5.973E+07	1.186E-01	1.224E+01	-1.490E-02	7.256E-04	1.629E-01	1.255E-03	7.232E-04
3.950E-02	6.102E+05	5.974E+07	1.142E-01	1.236E+01	-1.472E-02	7.254E-04	1.614E-01	1.253E-03	7.197E-04
4.000E-02	6.000E+05	5.974E+07	1.098E-01	1.246E+01	-1.455E-02	7.247E-04	1.600E-01	1.250E-03	7.164E-04
4.050E-02	5.886E+05	5.974E+07	1.055E-01	1.255E+01	-1.438E-02	7.235E-04	1.589E-01	1.247E-03	7.132E-04
4.100E-02	5.760E+05	5.975E+07	1.013E-01	1.263E+01	-1.422E-02	7.219E-04	1.579E-01	1.244E-03	7.102E-04
4.150E-02	5.624E+05	5.975E+07	9.712E-02	1.269E+01	-1.406E-02	7.197E-04	1.572E-01	1.239E-03	7.074E-04
4.200E-02	5.475E+05	5.975E+07	9.299E-02	1.274E+01	-1.390E-02	7.170E-04	1.566E-01	1.235E-03	7.048E-04
4.250E-02	5.314E+05	5.976E+07	8.889E-02	1.277E+01	-1.375E-02	7.137E-04	1.562E-01	1.230E-03	7.023E-04
4.300E-02	5.141E+05	5.976E+07	8.479E-02	1.278E+01	-1.360E-02	7.098E-04	1.561E-01	1.224E-03	7.001E-04
4.350E-02	4.956E+05	5.976E+07	8.068E-02	1.278E+01	-1.345E-02	7.052E-04	1.561E-01	1.217E-03	6.980E-04
4.400E-02	4.757E+05	5.976E+07	7.652E-02	1.275E+01	-1.330E-02	6.999E-04	1.564E-01	1.210E-03	6.960E-04
4.450E-02	4.545E+05	5.977E+07	7.230E-02	1.271E+01	-1.315E-02	6.938E-04	1.570E-01	1.202E-03	6.942E-04
4.500E-02	4.320E+05	5.977E+07	6.798E-02	1.264E+01	-1.300E-02	6.868E-04	1.578E-01	1.193E-03	6.926E-04
4.550E-02	4.080E+05	5.977E+07	6.353E-02	1.254E+01	-1.285E-02	6.789E-04	1.590E-01	1.183E-03	6.911E-04
4.600E-02	3.826E+05	5.977E+07	5.889E-02	1.242E+01	-1.269E-02	6.698E-04	1.606E-01	1.172E-03	6.898E-04
4.650E-02	3.557E+05	5.977E+07	5.402E-02	1.227E+01	-1.252E-02	6.594E-04	1.626E-01	1.159E-03	6.887E-04
4.700E-02	3.271E+05	5.977E+07	4.885E-02	1.208E+01	-1.234E-02	6.474E-04	1.651E-01	1.145E-03	6.877E-04
4.750E-02	2.966E+05	5.977E+07	4.327E-02	1.185E+01	-1.215E-02	6.335E-04	1.683E-01	1.129E-03	6.868E-04
4.800E-02	2.641E+05	5.977E+07	3.718E-02	1.157E+01	-1.193E-02	6.171E-04	1.724E-01	1.110E-03	6.862E-04
4.850E-02	2.291E+05	5.978E+07	3.037E-02	1.121E+01	-1.166E-02	5.973E-04	1.779E-01	1.088E-03	6.856E-04
4.900E-02	1.907E+05	5.978E+07	2.253E-02	1.076E+01	-1.133E-02	5.723E-04	1.854E-01	1.060E-03	6.852E-04
4.950E-02	1.468E+05	5.978E+07	1.305E-02	1.011E+01	-1.087E-02	5.376E-04	1.973E-01	1.023E-03	6.850E-04
5.000E-02	8.376E+04	5.978E+07	0.000E+00	8.810E+00	-9.874E-03	4.683E-04	2.264E-01	9.527E-04	6.849E-04

8-DEC-90 14:30:48USER2:[MIGUEL.RAMPRF.MEB12]RAMPRF1.DAT;30

pi= 1.200E+10, pe= 1.800E+11 [eV/c]; Bmax= 1.600E+00 [T]; Brho= 6.004E+02 [T-m]

time [sec]	momentum [eV/c]	energy [eV]	B-field [Tesla]	dE/dt [eV/s]	dp/dt [eV/c/s]	dB/dt [T/sec]	beta	gamma	b*g**2
0.000E+00	1.200E+10	1.204E+10	1.067E-01	0.000E+00	0.000E+00	0.000E+00	9.970E-01	1.283E+01	1.641E+02
1.000E-01	1.200E+10	1.204E+10	1.067E-01	0.000E+00	0.000E+00	0.000E+00	9.970E-01	1.283E+01	1.641E+02
2.000E-01	1.200E+10	1.204E+10	1.067E-01	0.000E+00	0.000E+00	0.000E+00	9.970E-01	1.283E+01	1.641E+02
3.000E-01	1.200E+10	1.204E+10	1.067E-01	0.000E+00	0.000E+00	0.000E+00	9.970E-01	1.283E+01	1.641E+02
4.000E-01	1.200E+10	1.204E+10	1.067E-01	0.000E+00	0.000E+00	0.000E+00	9.970E-01	1.283E+01	1.641E+02
5.000E-01	1.200E+10	1.204E+10	1.067E-01	0.000E+00	0.000E+00	0.000E+00	9.970E-01	1.283E+01	1.641E+02
6.000E-01	1.200E+10	1.204E+10	1.067E-01	0.000E+00	0.000E+00	0.000E+00	9.970E-01	1.283E+01	1.641E+02
7.000E-01	1.200E+10	1.204E+10	1.067E-01	2.125E-05	2.132E-05	1.895E-16	9.970E-01	1.283E+01	1.641E+02
7.250E-01	1.203E+10	1.207E+10	1.070E-01	2.792E+09	2.800E+09	2.489E-02	9.970E-01	1.287E+01	1.650E+02
7.500E-01	1.214E+10	1.218E+10	1.079E-01	5.583E+09	5.600E+09	4.978E-02	9.970E-01	1.298E+01	1.679E+02
7.750E-01	1.231E+10	1.235E+10	1.095E-01	8.376E+09	8.400E+09	7.467E-02	9.971E-01	1.316E+01	1.728E+02
8.000E-01	1.256E+10	1.259E+10	1.116E-01	1.117E+10	1.120E+10	9.956E-02	9.972E-01	1.342E+01	1.797E+02
8.250E-01	1.287E+10	1.291E+10	1.144E-01	1.396E+10	1.400E+10	1.244E-01	9.974E-01	1.376E+01	1.888E+02
8.500E-01	1.326E+10	1.329E+10	1.179E-01	1.676E+10	1.680E+10	1.493E-01	9.975E-01	1.417E+01	2.002E+02
8.750E-01	1.371E+10	1.375E+10	1.219E-01	1.955E+10	1.960E+10	1.742E-01	9.977E-01	1.465E+01	2.142E+02
9.000E-01	1.424E+10	1.427E+10	1.266E-01	2.235E+10	2.240E+10	1.991E-01	9.978E-01	1.521E+01	2.308E+02
9.250E-01	1.483E+10	1.486E+10	1.319E-01	2.515E+10	2.520E+10	2.240E-01	9.980E-01	1.584E+01	2.505E+02
9.500E-01	1.550E+10	1.553E+10	1.378E-01	2.795E+10	2.800E+10	2.489E-01	9.982E-01	1.655E+01	2.734E+02
9.750E-01	1.623E+10	1.626E+10	1.443E-01	3.075E+10	3.080E+10	2.738E-01	9.983E-01	1.733E+01	2.999E+02
1.000E+00	1.704E+10	1.707E+10	1.515E-01	3.355E+10	3.360E+10	2.987E-01	9.985E-01	1.819E+01	3.303E+02
1.025E+00	1.791E+10	1.794E+10	1.592E-01	3.635E+10	3.640E+10	3.236E-01	9.986E-01	1.912E+01	3.651E+02
1.050E+00	1.886E+10	1.888E+10	1.676E-01	3.915E+10	3.920E+10	3.484E-01	9.988E-01	2.013E+01	4.045E+02
1.075E+00	1.987E+10	1.990E+10	1.767E-01	4.195E+10	4.200E+10	3.733E-01	9.989E-01	2.121E+01	4.492E+02
1.100E+00	2.096E+10	2.098E+10	1.863E-01	4.476E+10	4.480E+10	3.982E-01	9.990E-01	2.236E+01	4.995E+02
1.125E+00	2.211E+10	2.213E+10	1.966E-01	4.756E+10	4.760E+10	4.231E-01	9.991E-01	2.359E+01	5.560E+02
1.150E+00	2.334E+10	2.336E+10	2.075E-01	5.036E+10	5.040E+10	4.480E-01	9.992E-01	2.490E+01	6.193E+02
1.175E+00	2.463E+10	2.465E+10	2.190E-01	5.316E+10	5.320E+10	4.729E-01	9.993E-01	2.627E+01	6.899E+02
1.200E+00	2.600E+10	2.602E+10	2.311E-01	5.596E+10	5.600E+10	4.978E-01	9.993E-01	2.773E+01	7.684E+02
1.300E+00	3.160E+10	3.161E+10	2.809E-01	5.598E+10	5.600E+10	4.978E-01	9.996E-01	3.369E+01	1.135E+03
1.400E+00	3.720E+10	3.721E+10	3.307E-01	5.598E+10	5.600E+10	4.978E-01	9.997E-01	3.966E+01	1.572E+03
1.500E+00	4.280E+10	4.281E+10	3.804E-01	5.599E+10	5.600E+10	4.978E-01	9.998E-01	4.563E+01	2.081E+03
1.600E+00	4.840E+10	4.841E+10	4.302E-01	5.599E+10	5.600E+10	4.978E-01	9.998E-01	5.159E+01	2.661E+03
1.700E+00	5.400E+10	5.401E+10	4.800E-01	5.599E+10	5.600E+10	4.978E-01	9.998E-01	5.756E+01	3.313E+03
1.800E+00	5.960E+10	5.961E+10	5.298E-01	5.599E+10	5.600E+10	4.978E-01	9.999E-01	6.353E+01	4.035E+03
1.900E+00	6.520E+10	6.521E+10	5.796E-01	5.599E+10	5.600E+10	4.978E-01	9.999E-01	6.950E+01	4.829E+03
2.000E+00	7.080E+10	7.081E+10	6.293E-01	5.600E+10	5.600E+10	4.978E-01	9.999E-01	7.546E+01	5.694E+03
2.100E+00	7.640E+10	7.641E+10	6.791E-01	5.600E+10	5.600E+10	4.978E-01	9.999E-01	8.143E+01	6.631E+03
2.200E+00	8.200E+10	8.201E+10	7.289E-01	5.600E+10	5.600E+10	4.978E-01	9.999E-01	8.740E+01	7.638E+03
2.300E+00	8.760E+10	8.761E+10	7.787E-01	5.600E+10	5.600E+10	4.978E-01	9.999E-01	9.337E+01	8.717E+03
2.400E+00	9.320E+10	9.320E+10	8.284E-01	5.600E+10	5.600E+10	4.978E-01	9.999E-01	9.934E+01	9.867E+03
2.500E+00	9.880E+10	9.880E+10	8.782E-01	5.600E+10	5.600E+10	4.978E-01	1.000E+00	1.053E+02	1.109E+04
2.600E+00	1.044E+11	1.044E+11	9.280E-01	5.600E+10	5.600E+10	4.978E-01	1.000E+00	1.113E+02	1.238E+04
2.700E+00	1.100E+11	1.100E+11	9.778E-01	5.600E+10	5.600E+10	4.978E-01	1.000E+00	1.172E+02	1.374E+04
2.800E+00	1.156E+11	1.156E+11	1.028E+00	5.600E+10	5.600E+10	4.978E-01	1.000E+00	1.232E+02	1.518E+04
2.900E+00	1.212E+11	1.212E+11	1.077E+00	5.600E+10	5.600E+10	4.978E-01	1.000E+00	1.292E+02	1.669E+04
3.000E+00	1.268E+11	1.268E+11	1.127E+00	5.600E+10	5.600E+10	4.978E-01	1.000E+00	1.351E+02	1.826E+04
3.100E+00	1.324E+11	1.324E+11	1.177E+00	5.600E+10	5.600E+10	4.978E-01	1.000E+00	1.411E+02	1.991E+04
3.200E+00	1.380E+11	1.380E+11	1.227E+00	5.600E+10	5.600E+10	4.978E-01	1.000E+00	1.471E+02	2.163E+04
3.300E+00	1.436E+11	1.436E+11	1.276E+00	5.600E+10	5.600E+10	4.978E-01	1.000E+00	1.530E+02	2.342E+04
3.400E+00	1.492E+11	1.492E+11	1.326E+00	5.600E+10	5.600E+10	4.978E-01	1.000E+00	1.590E+02	2.529E+04
3.500E+00	1.548E+11	1.548E+11	1.376E+00	5.600E+10	5.600E+10	4.978E-01	1.000E+00	1.650E+02	2.722E+04
3.600E+00	1.604E+11	1.604E+11	1.426E+00	5.600E+10	5.600E+10	4.978E-01	1.000E+00	1.710E+02	2.922E+04
3.700E+00	1.660E+11	1.660E+11	1.476E+00	5.600E+10	5.600E+10	4.978E-01	1.000E+00	1.769E+02	3.130E+04
3.800E+00	1.710E+11	1.710E+11	1.520E+00	4.480E+10	4.480E+10	3.982E-01	1.000E+00	1.823E+02	3.323E+04
3.900E+00	1.750E+11	1.750E+11	1.555E+00	3.360E+10	3.360E+10	2.987E-01	1.000E+00	1.865E+02	3.477E+04
4.000E+00	1.778E+11	1.778E+11	1.580E+00	2.240E+10	2.240E+10	1.991E-01	1.000E+00	1.895E+02	3.589E+04
4.100E+00	1.794E+11	1.794E+11	1.595E+00	1.120E+10	1.120E+10	9.956E-02	1.000E+00	1.912E+02	3.657E+04
4.200E+00	1.800E+11	1.800E+11	1.600E+00	0.000E+00	0.000E+00	0.000E+00	1.000E+00	1.918E+02	3.680E+04
4.300E+00	1.800E+11	1.800E+11	1.600E+00	0.000E+00	0.000E+00	0.000E+00	1.000E+00	1.918E+02	3.680E+04
4.400E+00	1.800E+11	1.800E+11	1.600E+00	0.000E+00	0.000E+00	0.000E+00	1.000E+00	1.918E+02	3.680E+04
4.500E+00	1.800E+11	1.800E+11	1.600E+00	0.000E+00	0.000E+00	0.000E+00	1.000E+00	1.918E+02	3.680E+04

8-DEC-90 14:30:48USER2:[MIGUEL.RAMPRF.MEB12]RAMPRF2.DAT;30
Circ.= 3960.0 [m]; harmonic no.= 792, bunch spacing= 5.000 [m], gammat=(24.000, 0.000)

time [sec]	phis [deg]	Delphi [rad]	DelE [eV]	bucarea [eV-s]	phileft [rad]	phiright [rad]	Delt [sec]	Delz [m]	Delp/p
0.000E+00	0.000E+00	6.283E+00	7.876E+07	8.388E-01	-3.142E+00	3.142E+00	1.673E-08	5.000E+00	6.584E-03
1.000E-01	0.000E+00	6.283E+00	7.876E+07	8.388E-01	-3.142E+00	3.142E+00	1.673E-08	5.000E+00	6.584E-03
2.000E-01	0.000E+00	6.283E+00	7.876E+07	8.388E-01	-3.142E+00	3.142E+00	1.673E-08	5.000E+00	6.584E-03
3.000E-01	0.000E+00	6.283E+00	7.876E+07	8.388E-01	-3.142E+00	3.142E+00	1.673E-08	5.000E+00	6.584E-03
4.000E-01	0.000E+00	6.283E+00	7.876E+07	8.388E-01	-3.142E+00	3.142E+00	1.673E-08	5.000E+00	6.584E-03
5.000E-01	0.000E+00	6.283E+00	7.876E+07	8.388E-01	-3.142E+00	3.142E+00	1.673E-08	5.000E+00	6.584E-03
6.000E-01	0.000E+00	6.283E+00	7.876E+07	8.388E-01	-3.142E+00	3.142E+00	1.673E-08	5.000E+00	6.584E-03
7.000E-01	2.305E-14	6.283E+00	7.876E+07	8.388E-01	-3.142E+00	3.142E+00	1.673E-08	5.000E+00	6.584E-03
7.250E-01	2.945E+00	5.462E+00	7.707E+07	7.572E-01	-2.372E+00	3.090E+00	1.454E-08	4.347E+00	6.423E-03
7.500E-01	5.737E+00	5.117E+00	7.624E+07	7.060E-01	-2.075E+00	3.041E+00	1.362E-08	4.072E+00	6.298E-03
7.750E-01	8.395E+00	4.851E+00	7.622E+07	6.726E-01	-1.856E+00	2.995E+00	1.291E-08	3.860E+00	6.207E-03
8.000E-01	1.093E+01	4.626E+00	7.702E+07	6.512E-01	-1.675E+00	2.951E+00	1.231E-08	3.681E+00	6.149E-03
8.250E-01	1.337E+01	4.428E+00	7.862E+07	6.390E-01	-1.520E+00	2.908E+00	1.179E-08	3.524E+00	6.123E-03
8.500E-01	1.570E+01	4.250E+00	8.107E+07	6.345E-01	-1.382E+00	2.868E+00	1.131E-08	3.382E+00	6.129E-03
8.750E-01	1.795E+01	4.086E+00	8.443E+07	6.370E-01	-1.258E+00	2.828E+00	1.087E-08	3.251E+00	6.171E-03
9.000E-01	2.012E+01	3.934E+00	8.882E+07	6.464E-01	-1.143E+00	2.790E+00	1.046E-08	3.130E+00	6.251E-03
9.250E-01	2.223E+01	3.791E+00	9.440E+07	6.631E-01	-1.038E+00	2.754E+00	1.008E-08	3.017E+00	6.376E-03
9.500E-01	2.426E+01	3.657E+00	1.014E+08	6.880E-01	-9.385E-01	2.718E+00	9.724E-09	2.910E+00	6.557E-03
9.750E-01	2.625E+01	3.529E+00	1.104E+08	7.230E-01	-8.452E-01	2.684E+00	9.382E-09	2.808E+00	6.811E-03
1.000E+00	2.817E+01	3.407E+00	1.219E+08	7.714E-01	-7.569E-01	2.650E+00	9.057E-09	2.711E+00	7.167E-03
1.025E+00	3.006E+01	3.290E+00	1.374E+08	8.394E-01	-6.727E-01	2.617E+00	8.744E-09	2.618E+00	7.679E-03
1.050E+00	3.190E+01	3.177E+00	1.593E+08	9.400E-01	-5.922E-01	2.585E+00	8.444E-09	2.528E+00	8.455E-03
1.075E+00	3.370E+01	3.068E+00	1.938E+08	1.104E+00	-5.149E-01	2.553E+00	8.154E-09	2.442E+00	9.760E-03
1.100E+00	3.546E+01	2.963E+00	2.613E+08	1.438E+00	-4.404E-01	2.523E+00	7.873E-09	2.358E+00	1.248E-02
1.125E+00	3.720E+01	2.861E+00	5.397E+08	2.867E+00	-3.683E-01	2.492E+00	7.600E-09	2.276E+00	2.442E-02
1.150E+00	1.411E+02	2.761E+00	3.760E+08	1.927E+00	-2.983E-01	2.463E+00	7.334E-09	2.197E+00	1.612E-02
1.175E+00	1.394E+02	2.663E+00	2.428E+08	1.200E+00	-2.302E-01	2.433E+00	7.075E-09	2.119E+00	9.862E-03
1.200E+00	1.377E+02	2.568E+00	1.948E+08	9.280E-01	-1.637E-01	2.404E+00	6.820E-09	2.043E+00	7.496E-03
1.300E+00	1.377E+02	2.568E+00	1.532E+08	7.300E-01	-1.637E-01	2.404E+00	6.819E-09	2.043E+00	4.852E-03
1.400E+00	1.377E+02	2.568E+00	1.466E+08	6.982E-01	-1.637E-01	2.404E+00	6.818E-09	2.043E+00	3.942E-03
1.500E+00	1.377E+02	2.568E+00	1.472E+08	7.010E-01	-1.637E-01	2.404E+00	6.818E-09	2.043E+00	3.440E-03
1.600E+00	1.377E+02	2.568E+00	1.504E+08	7.162E-01	-1.637E-01	2.404E+00	6.817E-09	2.043E+00	3.108E-03
1.700E+00	1.377E+02	2.568E+00	1.547E+08	7.367E-01	-1.637E-01	2.404E+00	6.817E-09	2.043E+00	2.866E-03
1.800E+00	1.377E+02	2.568E+00	1.596E+08	7.598E-01	-1.637E-01	2.404E+00	6.817E-09	2.043E+00	2.678E-03
1.900E+00	1.377E+02	2.568E+00	1.647E+08	7.840E-01	-1.637E-01	2.404E+00	6.817E-09	2.043E+00	2.526E-03
2.000E+00	1.377E+02	2.568E+00	1.698E+08	8.087E-01	-1.637E-01	2.404E+00	6.817E-09	2.043E+00	2.399E-03
2.100E+00	1.377E+02	2.568E+00	1.750E+08	8.335E-01	-1.637E-01	2.404E+00	6.817E-09	2.043E+00	2.291E-03
2.200E+00	1.377E+02	2.568E+00	1.802E+08	8.582E-01	-1.637E-01	2.404E+00	6.816E-09	2.043E+00	2.198E-03
2.300E+00	1.377E+02	2.568E+00	1.853E+08	8.825E-01	-1.637E-01	2.404E+00	6.816E-09	2.043E+00	2.116E-03
2.400E+00	1.377E+02	2.568E+00	1.904E+08	9.066E-01	-1.637E-01	2.404E+00	6.816E-09	2.043E+00	2.043E-03
2.500E+00	1.377E+02	2.568E+00	1.954E+08	9.302E-01	-1.637E-01	2.404E+00	6.816E-09	2.043E+00	1.977E-03
2.600E+00	1.377E+02	2.568E+00	2.003E+08	9.535E-01	-1.637E-01	2.404E+00	6.816E-09	2.043E+00	1.918E-03
2.700E+00	1.377E+02	2.568E+00	2.051E+08	9.764E-01	-1.637E-01	2.404E+00	6.816E-09	2.043E+00	1.864E-03
2.800E+00	1.377E+02	2.568E+00	2.098E+08	9.989E-01	-1.637E-01	2.404E+00	6.816E-09	2.043E+00	1.815E-03
2.900E+00	1.377E+02	2.568E+00	2.144E+08	1.021E+00	-1.637E-01	2.404E+00	6.816E-09	2.043E+00	1.769E-03
3.000E+00	1.377E+02	2.568E+00	2.190E+08	1.043E+00	-1.637E-01	2.404E+00	6.816E-09	2.043E+00	1.727E-03
3.100E+00	1.377E+02	2.568E+00	2.235E+08	1.064E+00	-1.637E-01	2.404E+00	6.816E-09	2.043E+00	1.688E-03
3.200E+00	1.377E+02	2.568E+00	2.279E+08	1.085E+00	-1.637E-01	2.404E+00	6.816E-09	2.043E+00	1.651E-03
3.300E+00	1.377E+02	2.568E+00	2.322E+08	1.106E+00	-1.637E-01	2.404E+00	6.816E-09	2.043E+00	1.617E-03
3.400E+00	1.377E+02	2.568E+00	2.365E+08	1.126E+00	-1.637E-01	2.404E+00	6.816E-09	2.043E+00	1.585E-03
3.500E+00	1.377E+02	2.568E+00	2.407E+08	1.146E+00	-1.637E-01	2.404E+00	6.816E-09	2.043E+00	1.555E-03
3.600E+00	1.377E+02	2.568E+00	2.448E+08	1.166E+00	-1.637E-01	2.404E+00	6.816E-09	2.043E+00	1.526E-03
3.700E+00	1.377E+02	2.568E+00	2.489E+08	1.185E+00	-1.637E-01	2.404E+00	6.816E-09	2.043E+00	1.499E-03
3.800E+00	1.458E+02	3.036E+00	3.077E+08	1.734E+00	-4.923E-01	2.544E+00	8.060E-09	2.416E+00	1.799E-03
3.900E+00	1.538E+02	3.529E+00	3.660E+08	2.394E+00	-8.457E-01	2.684E+00	9.369E-09	2.809E+00	2.092E-03
4.000E+00	1.620E+02	4.080E+00	4.240E+08	3.187E+00	-1.253E+00	2.827E+00	1.083E-08	3.247E+00	2.385E-03
4.100E+00	1.706E+02	4.761E+00	4.819E+08	4.170E+00	-1.783E+00	2.978E+00	1.264E-08	3.789E+00	2.685E-03
4.200E+00	1.800E+02	6.283E+00	5.397E+08	5.730E+00	-3.142E+00	3.142E+00	1.668E-08	5.000E+00	2.998E-03
4.300E+00	1.800E+02	6.283E+00	5.397E+08	5.730E+00	-3.142E+00	3.142E+00	1.668E-08	5.000E+00	2.998E-03
4.400E+00	1.800E+02	6.283E+00	5.397E+08	5.730E+00	-3.142E+00	3.142E+00	1.668E-08	5.000E+00	2.998E-03
4.500E+00	1.800E+02	6.283E+00	5.397E+08	5.730E+00	-3.142E+00	3.142E+00	1.668E-08	5.000E+00	2.998E-03

8-DEC-90 14:30:48USER2:[MIGUEL.RAMPRF.MEB12]RAMPRF3.DAT;30
bunch assumed gaussian

time [sec]	voltage [Volts]	RF freq [Hz]	adiab	B-factor	delnu	sigp/p	sigz [m]	sigx [m]	sigy [m]
0.000E+00	7.000E+05	5.978E+07	0.000E+00	8.810E+00	-6.886E-02	4.683E-04	2.264E-01	1.480E-03	1.281E-03
1.000E-01	7.000E+05	5.978E+07	0.000E+00	8.810E+00	-6.886E-02	4.683E-04	2.264E-01	1.480E-03	1.281E-03
2.000E-01	7.000E+05	5.978E+07	0.000E+00	8.810E+00	-6.886E-02	4.683E-04	2.264E-01	1.480E-03	1.281E-03
3.000E-01	7.000E+05	5.978E+07	0.000E+00	8.810E+00	-6.886E-02	4.683E-04	2.264E-01	1.480E-03	1.281E-03
4.000E-01	7.000E+05	5.978E+07	0.000E+00	8.810E+00	-6.886E-02	4.683E-04	2.264E-01	1.480E-03	1.281E-03
5.000E-01	7.000E+05	5.978E+07	0.000E+00	8.810E+00	-6.886E-02	4.683E-04	2.264E-01	1.480E-03	1.281E-03
6.000E-01	7.000E+05	5.978E+07	0.000E+00	8.810E+00	-6.886E-02	4.683E-04	2.264E-01	1.480E-03	1.281E-03
7.000E-01	7.000E+05	5.978E+07	-2.402E-17	8.810E+00	-6.886E-02	4.683E-04	2.264E-01	1.480E-03	1.281E-03
7.250E-01	7.200E+05	5.978E+07	-1.002E-02	8.894E+00	-6.904E-02	4.714E-04	2.243E-01	1.481E-03	1.280E-03
7.500E-01	7.400E+05	5.978E+07	-6.767E-03	9.021E+00	-6.873E-02	4.740E-04	2.211E-01	1.478E-03	1.274E-03
7.750E-01	7.600E+05	5.979E+07	-4.712E-03	9.193E+00	-6.796E-02	4.761E-04	2.170E-01	1.472E-03	1.265E-03
8.000E-01	7.800E+05	5.979E+07	-3.210E-03	9.413E+00	-6.677E-02	4.780E-04	2.119E-01	1.463E-03	1.253E-03
8.250E-01	8.000E+05	5.980E+07	-1.950E-03	9.683E+00	-6.523E-02	4.797E-04	2.060E-01	1.451E-03	1.237E-03
8.500E-01	8.200E+05	5.981E+07	-7.668E-04	1.001E+01	-6.340E-02	4.814E-04	1.993E-01	1.437E-03	1.219E-03
8.750E-01	8.400E+05	5.982E+07	4.491E-04	1.039E+01	-6.135E-02	4.833E-04	1.919E-01	1.422E-03	1.199E-03
9.000E-01	8.600E+05	5.983E+07	1.792E-03	1.084E+01	-5.916E-02	4.857E-04	1.840E-01	1.405E-03	1.176E-03
9.250E-01	8.800E+05	5.984E+07	3.376E-03	1.137E+01	-5.692E-02	4.889E-04	1.754E-01	1.388E-03	1.152E-03
9.500E-01	9.000E+05	5.985E+07	5.360E-03	1.199E+01	-5.468E-02	4.933E-04	1.664E-01	1.371E-03	1.127E-03
9.750E-01	9.200E+05	5.986E+07	8.011E-03	1.272E+01	-5.253E-02	4.996E-04	1.569E-01	1.356E-03	1.102E-03
1.000E+00	9.400E+05	5.987E+07	1.181E-02	1.359E+01	-5.056E-02	5.087E-04	1.468E-01	1.343E-03	1.075E-03
1.025E+00	9.600E+05	5.988E+07	1.773E-02	1.467E+01	-4.886E-02	5.222E-04	1.360E-01	1.335E-03	1.049E-03
1.050E+00	9.800E+05	5.988E+07	2.803E-02	1.606E+01	-4.758E-02	5.432E-04	1.242E-01	1.335E-03	1.022E-03
1.075E+00	1.000E+06	5.989E+07	4.907E-02	1.802E+01	-4.701E-02	5.782E-04	1.107E-01	1.352E-03	9.957E-04
1.100E+00	1.020E+06	5.990E+07	1.068E-01	2.128E+01	-4.797E-02	6.476E-04	9.374E-02	1.410E-03	9.696E-04
1.125E+00	1.040E+06	5.990E+07	4.920E-01	3.111E+01	-5.512E-02	8.974E-04	6.411E-02	1.704E-03	9.439E-04
1.150E+00	1.060E+06	5.991E+07	-3.488E-01	2.642E+01	-4.544E-02	7.222E-04	7.549E-02	1.466E-03	9.188E-04
1.175E+00	1.080E+06	5.992E+07	-2.915E-01	2.161E+01	-3.597E-02	5.596E-04	9.230E-02	1.258E-03	8.943E-04
1.200E+00	1.100E+06	5.992E+07	-1.182E-01	1.971E+01	-3.041E-02	4.836E-04	1.012E-01	1.159E-03	8.705E-04
1.300E+00	1.100E+06	5.993E+07	-2.151E-02	1.748E+01	-1.914E-02	3.529E-04	1.141E-01	9.669E-04	7.896E-04
1.400E+00	1.100E+06	5.994E+07	-3.449E-03	1.710E+01	-1.375E-02	2.932E-04	1.167E-01	8.629E-04	7.278E-04
1.500E+00	1.100E+06	5.994E+07	3.053E-04	1.713E+01	-1.051E-02	2.553E-04	1.164E-01	7.895E-04	6.785E-04
1.600E+00	1.100E+06	5.995E+07	1.648E-03	1.732E+01	-8.368E-03	2.282E-04	1.152E-01	7.330E-04	6.380E-04
1.700E+00	1.100E+06	5.995E+07	2.232E-03	1.756E+01	-6.853E-03	2.075E-04	1.136E-01	6.874E-04	6.041E-04
1.800E+00	1.100E+06	5.995E+07	2.505E-03	1.784E+01	-5.736E-03	1.909E-04	1.118E-01	6.494E-04	5.750E-04
1.900E+00	1.100E+06	5.995E+07	2.632E-03	1.812E+01	-4.885E-03	1.772E-04	1.101E-01	6.170E-04	5.497E-04
2.000E+00	1.100E+06	5.995E+07	2.682E-03	1.840E+01	-4.219E-03	1.658E-04	1.084E-01	5.891E-04	5.275E-04
2.100E+00	1.100E+06	5.995E+07	2.691E-03	1.868E+01	-3.687E-03	1.560E-04	1.068E-01	5.645E-04	5.078E-04
2.200E+00	1.100E+06	5.995E+07	2.676E-03	1.895E+01	-3.254E-03	1.474E-04	1.052E-01	5.428E-04	4.902E-04
2.300E+00	1.100E+06	5.996E+07	2.647E-03	1.922E+01	-2.897E-03	1.400E-04	1.038E-01	5.234E-04	4.743E-04
2.400E+00	1.100E+06	5.996E+07	2.611E-03	1.948E+01	-2.598E-03	1.333E-04	1.024E-01	5.058E-04	4.598E-04
2.500E+00	1.100E+06	5.996E+07	2.570E-03	1.973E+01	-2.345E-03	1.274E-04	1.011E-01	4.899E-04	4.466E-04
2.600E+00	1.100E+06	5.996E+07	2.528E-03	1.998E+01	-2.129E-03	1.221E-04	9.984E-02	4.754E-04	4.344E-04
2.700E+00	1.100E+06	5.996E+07	2.484E-03	2.022E+01	-1.943E-03	1.172E-04	9.866E-02	4.620E-04	4.232E-04
2.800E+00	1.100E+06	5.996E+07	2.441E-03	2.045E+01	-1.782E-03	1.128E-04	9.754E-02	4.498E-04	4.129E-04
2.900E+00	1.100E+06	5.996E+07	2.399E-03	2.067E+01	-1.640E-03	1.088E-04	9.648E-02	4.384E-04	4.032E-04
3.000E+00	1.100E+06	5.996E+07	2.358E-03	2.089E+01	-1.516E-03	1.051E-04	9.547E-02	4.278E-04	3.942E-04
3.100E+00	1.100E+06	5.996E+07	2.318E-03	2.111E+01	-1.406E-03	1.017E-04	9.451E-02	4.179E-04	3.858E-04
3.200E+00	1.100E+06	5.996E+07	2.279E-03	2.131E+01	-1.308E-03	9.851E-05	9.359E-02	4.087E-04	3.779E-04
3.300E+00	1.100E+06	5.996E+07	2.241E-03	2.151E+01	-1.220E-03	9.557E-05	9.272E-02	4.001E-04	3.704E-04
3.400E+00	1.100E+06	5.996E+07	2.205E-03	2.171E+01	-1.142E-03	9.282E-05	9.188E-02	3.919E-04	3.634E-04
3.500E+00	1.100E+06	5.996E+07	2.171E-03	2.190E+01	-1.071E-03	9.025E-05	9.107E-02	3.843E-04	3.568E-04
3.600E+00	1.100E+06	5.996E+07	2.137E-03	2.209E+01	-1.006E-03	8.785E-05	9.030E-02	3.770E-04	3.505E-04
3.700E+00	1.100E+06	5.996E+07	2.105E-03	2.227E+01	-9.480E-04	8.559E-05	8.956E-02	3.701E-04	3.445E-04
3.800E+00	1.052E+06	5.996E+07	3.999E-02	2.281E+01	-9.138E-04	8.506E-05	8.746E-02	3.651E-04	3.394E-04
3.900E+00	1.004E+06	5.996E+07	3.460E-02	2.313E+01	-8.856E-04	8.434E-05	8.623E-02	3.611E-04	3.356E-04
4.000E+00	9.560E+05	5.996E+07	3.134E-02	2.328E+01	-8.634E-04	8.353E-05	8.570E-02	3.582E-04	3.329E-04
4.100E+00	9.080E+05	5.996E+07	3.001E-02	2.324E+01	-8.465E-04	8.263E-05	8.581E-02	3.562E-04	3.314E-04
4.200E+00	8.600E+05	5.996E+07	3.546E-02	2.303E+01	-8.339E-04	8.160E-05	8.663E-02	3.551E-04	3.309E-04
4.300E+00	8.600E+05	5.996E+07	0.000E+00	2.303E+01	-8.339E-04	8.160E-05	8.663E-02	3.551E-04	3.309E-04
4.400E+00	8.600E+05	5.996E+07	0.000E+00	2.303E+01	-8.339E-04	8.160E-05	8.663E-02	3.551E-04	3.309E-04
4.500E+00	8.600E+05	5.996E+07	0.000E+00	2.303E+01	-8.339E-04	8.160E-05	8.663E-02	3.551E-04	3.309E-04

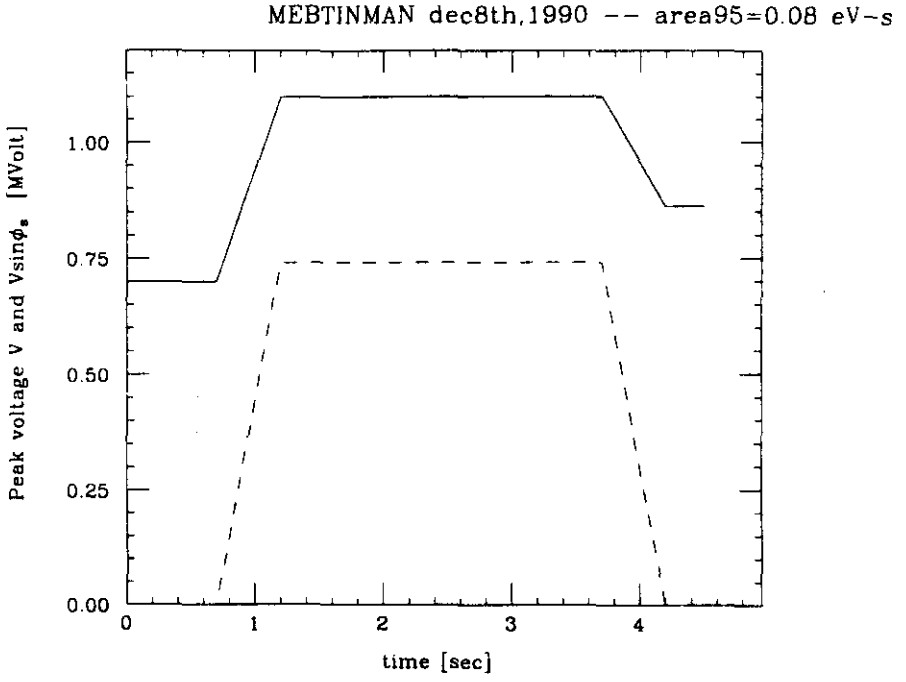
8-DEC-90 14:30:48USER2:[MIGUEL.RAMPRF.MEB12]RAMPRF4.DAT;30

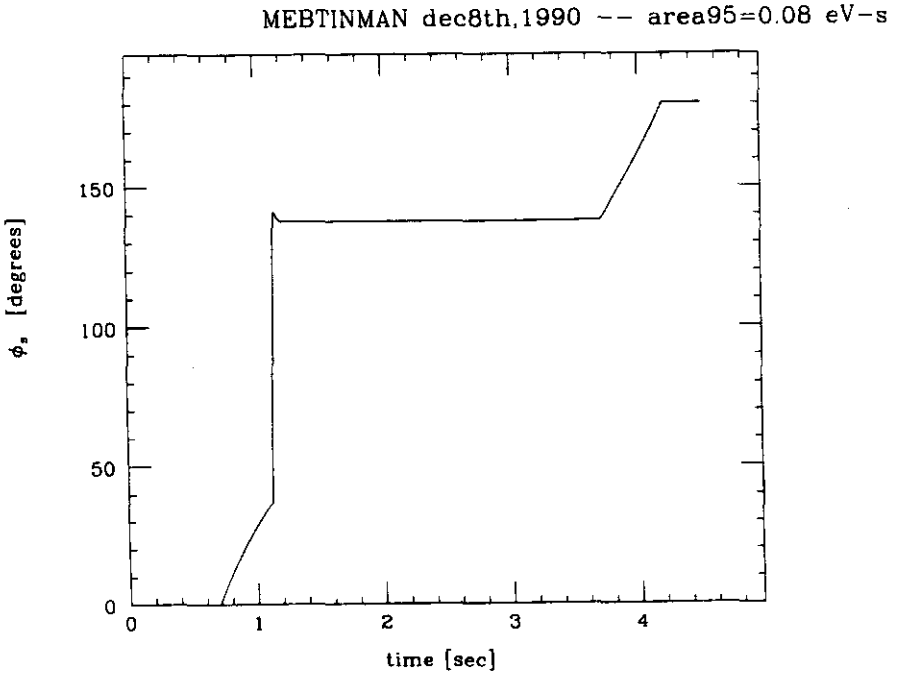
time [sec]	sync. tune	Thresholds: microwave inst. sync. freq. [Hz]	|Zl/n| [Ohm]	|Zt| [Ohm/m]	mode-coupl. inst. Im(Zl/n) [Ohm]	Im(Zt) [Ohm/m]	V*sin(phis) [Volts]	bunarea [eV-s]
0.000E+00	5.658E-03	4.270E+02	8.532E+01	2.725E+08	4.826E+02	4.781E+07	0.000E+00	8.000E-02
1.000E-01	5.658E-03	4.270E+02	8.532E+01	2.725E+08	4.826E+02	4.781E+07	0.000E+00	8.000E-02
2.000E-01	5.658E-03	4.270E+02	8.532E+01	2.725E+08	4.826E+02	4.781E+07	0.000E+00	8.000E-02
3.000E-01	5.658E-03	4.270E+02	8.532E+01	2.725E+08	4.826E+02	4.781E+07	0.000E+00	8.000E-02
4.000E-01	5.658E-03	4.270E+02	8.532E+01	2.725E+08	4.826E+02	4.781E+07	0.000E+00	8.000E-02
5.000E-01	5.658E-03	4.270E+02	8.532E+01	2.725E+08	4.826E+02	4.781E+07	0.000E+00	8.000E-02
6.000E-01	5.658E-03	4.270E+02	8.532E+01	2.725E+08	4.826E+02	4.781E+07	0.000E+00	8.000E-02
7.000E-01	5.658E-03	4.270E+02	8.532E+01	2.725E+08	4.826E+02	4.781E+07	2.816E-10	8.000E-02
7.250E-01	5.703E-03	4.304E+02	8.518E+01	2.703E+08	4.819E+02	4.788E+07	3.699E+04	8.000E-02
7.500E-01	5.676E-03	4.284E+02	8.358E+01	2.638E+08	4.728E+02	4.739E+07	7.397E+04	8.000E-02
7.750E-01	5.581E-03	4.213E+02	8.062E+01	2.532E+08	4.561E+02	4.637E+07	1.110E+05	8.000E-02
8.000E-01	5.421E-03	4.093E+02	7.648E+01	2.393E+08	4.326E+02	4.486E+07	1.479E+05	8.000E-02
8.250E-01	5.206E-03	3.930E+02	7.136E+01	2.224E+08	4.037E+02	4.291E+07	1.849E+05	8.000E-02
8.500E-01	4.942E-03	3.732E+02	6.552E+01	2.035E+08	3.706E+02	4.058E+07	2.219E+05	8.000E-02
8.750E-01	4.638E-03	3.503E+02	5.921E+01	1.831E+08	3.349E+02	3.792E+07	2.589E+05	8.000E-02
9.000E-01	4.305E-03	3.252E+02	5.264E+01	1.620E+08	2.978E+02	3.501E+07	2.959E+05	8.000E-02
9.250E-01	3.949E-03	2.983E+02	4.604E+01	1.407E+08	2.604E+02	3.190E+07	3.329E+05	8.000E-02
9.500E-01	3.578E-03	2.704E+02	3.955E+01	1.198E+08	2.238E+02	2.863E+07	3.699E+05	8.000E-02
9.750E-01	3.197E-03	2.416E+02	3.331E+01	9.960E+07	1.884E+02	2.526E+07	4.068E+05	8.000E-02
1.000E+00	2.810E-03	2.124E+02	2.739E+01	8.042E+07	1.549E+02	2.180E+07	4.438E+05	8.000E-02
1.025E+00	2.419E-03	1.829E+02	2.183E+01	6.244E+07	1.235E+02	1.827E+07	4.808E+05	8.000E-02
1.050E+00	2.020E-03	1.527E+02	1.665E+01	4.576E+07	9.417E+01	1.466E+07	5.178E+05	8.000E-02
1.075E+00	1.605E-03	1.214E+02	1.179E+01	3.044E+07	6.669E+01	1.094E+07	5.548E+05	8.000E-02
1.100E+00	1.149E-03	8.687E+01	7.142E+00	1.646E+07	4.040E+01	6.991E+06	5.918E+05	8.000E-02
1.125E+00	5.357E-04	4.052E+01	2.278E+00	3.789E+06	1.288E+01	2.352E+06	6.288E+05	8.000E-02
1.150E+00	7.394E-04	5.593E+01	3.701E+00	7.649E+06	2.094E+01	4.034E+06	6.657E+05	8.000E-02
1.175E+00	1.099E-03	8.313E+01	6.724E+00	1.793E+07	3.803E+01	7.735E+06	7.027E+05	8.000E-02
1.200E+00	1.311E-03	9.922E+01	8.797E+00	2.715E+07	4.976E+01	1.068E+07	7.397E+05	8.000E-02
1.300E+00	1.667E-03	1.261E+02	1.260E+01	5.328E+07	7.129E+01	1.860E+07	7.397E+05	8.000E-02
1.400E+00	1.743E-03	1.319E+02	1.347E+01	6.852E+07	7.618E+01	2.339E+07	7.397E+05	8.000E-02
1.500E+00	1.735E-03	1.313E+02	1.338E+01	7.818E+07	7.570E+01	2.675E+07	7.397E+05	8.000E-02
1.600E+00	1.699E-03	1.286E+02	1.296E+01	8.469E+07	7.330E+01	2.929E+07	7.397E+05	8.000E-02
1.700E+00	1.651E-03	1.250E+02	1.242E+01	8.928E+07	7.024E+01	3.132E+07	7.397E+05	8.000E-02
1.800E+00	1.601E-03	1.212E+02	1.186E+01	9.263E+07	6.706E+01	3.300E+07	7.397E+05	8.000E-02
1.900E+00	1.551E-03	1.174E+02	1.131E+01	9.516E+07	6.397E+01	3.444E+07	7.397E+05	8.000E-02
2.000E+00	1.504E-03	1.139E+02	1.079E+01	9.711E+07	6.106E+01	3.569E+07	7.397E+05	8.000E-02
2.100E+00	1.459E-03	1.105E+02	1.032E+01	9.865E+07	5.836E+01	3.681E+07	7.397E+05	8.000E-02
2.200E+00	1.417E-03	1.073E+02	9.875E+00	9.989E+07	5.586E+01	3.782E+07	7.397E+05	8.000E-02
2.300E+00	1.378E-03	1.043E+02	9.469E+00	1.009E+08	5.356E+01	3.874E+07	7.397E+05	8.000E-02
2.400E+00	1.342E-03	1.016E+02	9.095E+00	1.017E+08	5.145E+01	3.958E+07	7.397E+05	8.000E-02
2.500E+00	1.308E-03	9.898E+01	8.750E+00	1.024E+08	4.949E+01	4.037E+07	7.397E+05	8.000E-02
2.600E+00	1.276E-03	9.657E+01	8.431E+00	1.030E+08	4.769E+01	4.111E+07	7.397E+05	8.000E-02
2.700E+00	1.246E-03	9.431E+01	8.136E+00	1.035E+08	4.603E+01	4.180E+07	7.397E+05	8.000E-02
2.800E+00	1.218E-03	9.218E+01	7.863E+00	1.039E+08	4.448E+01	4.245E+07	7.397E+05	8.000E-02
2.900E+00	1.191E-03	9.019E+01	7.609E+00	1.043E+08	4.304E+01	4.307E+07	7.397E+05	8.000E-02
3.000E+00	1.167E-03	8.831E+01	7.373E+00	1.046E+08	4.171E+01	4.366E+07	7.397E+05	8.000E-02
3.100E+00	1.143E-03	8.654E+01	7.152E+00	1.049E+08	4.046E+01	4.422E+07	7.397E+05	8.000E-02
3.200E+00	1.121E-03	8.487E+01	6.946E+00	1.051E+08	3.929E+01	4.476E+07	7.397E+05	8.000E-02
3.300E+00	1.100E-03	8.328E+01	6.752E+00	1.054E+08	3.819E+01	4.528E+07	7.397E+05	8.000E-02
3.400E+00	1.080E-03	8.178E+01	6.570E+00	1.056E+08	3.717E+01	4.578E+07	7.397E+05	8.000E-02
3.500E+00	1.061E-03	8.035E+01	6.399E+00	1.057E+08	3.620E+01	4.626E+07	7.397E+05	8.000E-02
3.600E+00	1.043E-03	7.900E+01	6.238E+00	1.059E+08	3.528E+01	4.672E+07	7.397E+05	8.000E-02
3.700E+00	1.026E-03	7.770E+01	6.085E+00	1.060E+08	3.442E+01	4.717E+07	7.397E+05	8.000E-02
3.800E+00	1.046E-03	7.917E+01	6.054E+00	1.061E+08	3.425E+01	4.836E+07	5.918E+05	8.000E-02
3.900E+00	1.053E-03	7.968E+01	6.008E+00	1.062E+08	3.398E+01	4.909E+07	4.438E+05	8.000E-02
4.000E+00	1.049E-03	7.944E+01	5.953E+00	1.063E+08	3.367E+01	4.942E+07	2.959E+05	8.000E-02
4.100E+00	1.037E-03	7.851E+01	5.891E+00	1.063E+08	3.332E+01	4.937E+07	1.479E+05	8.000E-02
4.200E+00	1.014E-03	7.680E+01	5.818E+00	1.063E+08	3.291E+01	4.891E+07	9.840E-12	8.000E-02
4.300E+00	1.014E-03	7.680E+01	5.818E+00	1.063E+08	3.291E+01	4.891E+07	9.840E-12	8.000E-02
4.400E+00	1.014E-03	7.680E+01	5.818E+00	1.063E+08	3.291E+01	4.891E+07	9.840E-12	8.000E-02
4.500E+00	1.014E-03	7.680E+01	5.818E+00	1.063E+08	3.291E+01	4.891E+07	9.840E-12	8.000E-02

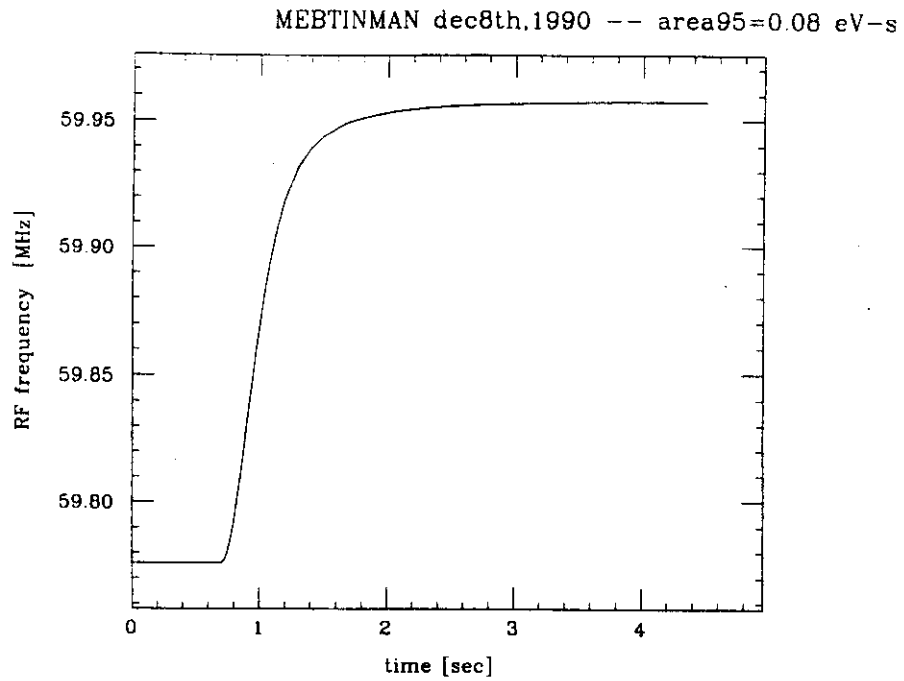
8-DEC-90 15:46:41USER2:[MIGUEL.RAMPRF.LEB12]RAMPRF2.DAT;6
Circ.- 540.0 [m]; harmonic no.= 108, bunch spacing= 5.000 [m], gammat=(21.000, 0.000)

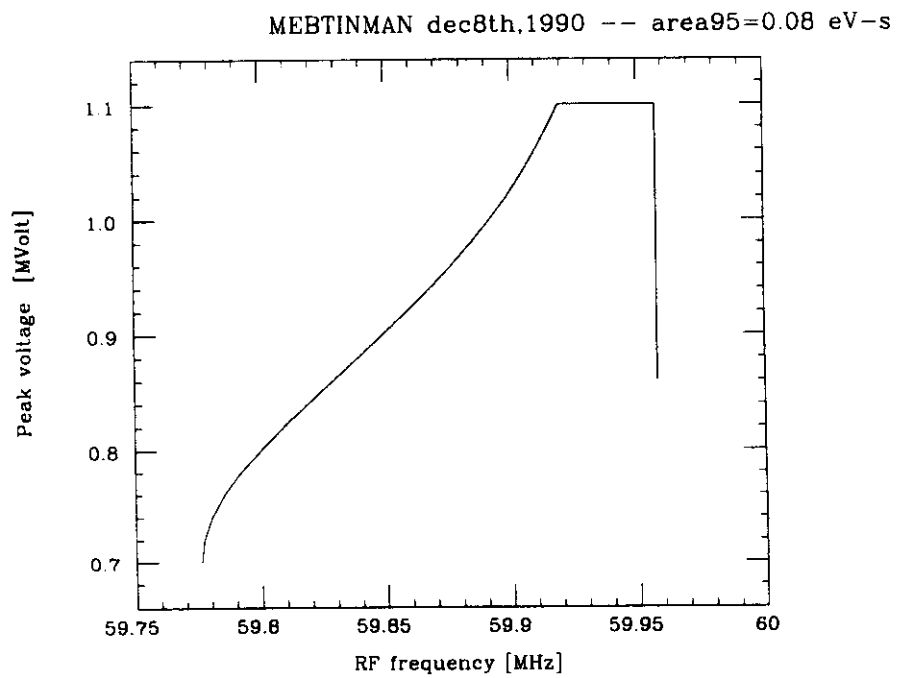
time [sec]	phis [deg]	Delphi [rad]	DelE [eV]	bucarea [eV-s]	phileft [rad]	phiright [rad]	Delt [sec]	Delz [m]	Delp/p
0.000E+00	0.000E+00	6.283E+00	5.971E+06	8.000E-02	-3.142E+00	3.142E+00	2.105E-08	5.000E+00	6.181E-03
5.000E-04	1.650E+00	5.674E+00	6.276E+06	8.007E-02	-2.561E+00	3.113E+00	1.899E-08	4.515E+00	6.478E-03
1.000E-03	2.992E+00	5.455E+00	6.521E+06	8.025E-02	-2.366E+00	3.089E+00	1.821E-08	4.341E+00	6.671E-03
1.500E-03	4.168E+00	5.299E+00	6.746E+06	8.056E-02	-2.230E+00	3.069E+00	1.762E-08	4.216E+00	6.800E-03
2.000E-03	5.243E+00	5.172E+00	6.969E+06	8.097E-02	-2.121E+00	3.050E+00	1.711E-08	4.115E+00	6.885E-03
2.500E-03	6.256E+00	5.062E+00	7.198E+06	8.148E-02	-2.029E+00	3.032E+00	1.663E-08	4.028E+00	6.934E-03
3.000E-03	7.234E+00	4.962E+00	7.439E+06	8.208E-02	-1.947E+00	3.015E+00	1.618E-08	3.949E+00	6.953E-03
3.500E-03	8.193E+00	4.870E+00	7.694E+06	8.276E-02	-1.871E+00	2.999E+00	1.575E-08	3.875E+00	6.949E-03
4.000E-03	9.148E+00	4.782E+00	7.965E+06	8.351E-02	-1.800E+00	2.982E+00	1.532E-08	3.805E+00	6.924E-03
4.500E-03	1.011E+01	4.697E+00	8.253E+06	8.432E-02	-1.732E+00	2.965E+00	1.490E-08	3.738E+00	6.883E-03
5.000E-03	1.108E+01	4.614E+00	8.557E+06	8.519E-02	-1.666E+00	2.948E+00	1.449E-08	3.672E+00	6.829E-03
5.500E-03	1.207E+01	4.532E+00	8.879E+06	8.609E-02	-1.601E+00	2.931E+00	1.409E-08	3.606E+00	6.764E-03
6.000E-03	1.308E+01	4.451E+00	9.217E+06	8.704E-02	-1.537E+00	2.913E+00	1.370E-08	3.542E+00	6.691E-03
6.500E-03	1.412E+01	4.370E+00	9.571E+06	8.801E-02	-1.474E+00	2.895E+00	1.332E-08	3.477E+00	6.611E-03
7.000E-03	1.518E+01	4.289E+00	9.941E+06	8.900E-02	-1.412E+00	2.877E+00	1.295E-08	3.413E+00	6.527E-03
7.500E-03	1.627E+01	4.208E+00	1.033E+07	9.000E-02	-1.350E+00	2.858E+00	1.259E-08	3.349E+00	6.440E-03
8.000E-03	1.738E+01	4.127E+00	1.072E+07	9.100E-02	-1.289E+00	2.838E+00	1.224E-08	3.284E+00	6.352E-03
8.500E-03	1.851E+01	4.046E+00	1.113E+07	9.199E-02	-1.228E+00	2.819E+00	1.190E-08	3.220E+00	6.262E-03
9.000E-03	1.966E+01	3.966E+00	1.156E+07	9.296E-02	-1.167E+00	2.798E+00	1.157E-08	3.156E+00	6.172E-03
9.500E-03	2.083E+01	3.886E+00	1.199E+07	9.391E-02	-1.108E+00	2.778E+00	1.125E-08	3.092E+00	6.082E-03
1.000E-02	2.201E+01	3.806E+00	1.244E+07	9.481E-02	-1.048E+00	2.757E+00	1.095E-08	3.029E+00	5.993E-03
1.050E-02	2.320E+01	3.726E+00	1.289E+07	9.568E-02	-9.897E-01	2.737E+00	1.065E-08	2.965E+00	5.905E-03
1.100E-02	2.440E+01	3.648E+00	1.335E+07	9.649E-02	-9.319E-01	2.716E+00	1.036E-08	2.903E+00	5.817E-03
1.150E-02	2.561E+01	3.569E+00	1.381E+07	9.724E-02	-8.749E-01	2.695E+00	1.009E-08	2.840E+00	5.731E-03
1.200E-02	2.682E+01	3.492E+00	1.428E+07	9.792E-02	-8.187E-01	2.674E+00	9.821E-09	2.779E+00	5.645E-03
1.250E-02	2.803E+01	3.416E+00	1.475E+07	9.852E-02	-7.634E-01	2.652E+00	9.563E-09	2.718E+00	5.560E-03
1.300E-02	2.924E+01	3.340E+00	1.522E+07	9.903E-02	-7.090E-01	2.631E+00	9.313E-09	2.658E+00	5.475E-03
1.350E-02	3.045E+01	3.266E+00	1.569E+07	9.944E-02	-6.556E-01	2.610E+00	9.071E-09	2.599E+00	5.391E-03
1.400E-02	3.165E+01	3.192E+00	1.615E+07	9.975E-02	-6.030E-01	2.589E+00	8.836E-09	2.540E+00	5.307E-03
1.450E-02	3.284E+01	3.120E+00	1.661E+07	9.993E-02	-5.514E-01	2.568E+00	8.608E-09	2.483E+00	5.222E-03
1.500E-02	3.403E+01	3.048E+00	1.706E+07	1.000E-01	-5.007E-01	2.548E+00	8.387E-09	2.426E+00	5.138E-03
1.550E-02	3.520E+01	2.979E+00	1.750E+07	1.000E-01	-4.514E-01	2.527E+00	8.174E-09	2.370E+00	5.054E-03
1.600E-02	3.634E+01	2.911E+00	1.795E+07	1.000E-01	-4.039E-01	2.507E+00	7.970E-09	2.317E+00	4.975E-03
1.650E-02	3.744E+01	2.846E+00	1.840E+07	1.000E-01	-3.582E-01	2.488E+00	7.775E-09	2.265E+00	4.899E-03
1.700E-02	3.852E+01	2.784E+00	1.886E+07	1.000E-01	-3.143E-01	2.469E+00	7.588E-09	2.215E+00	4.826E-03
1.750E-02	3.956E+01	2.723E+00	1.931E+07	1.000E-01	-2.720E-01	2.451E+00	7.410E-09	2.167E+00	4.756E-03
1.800E-02	4.056E+01	2.665E+00	1.977E+07	1.000E-01	-2.315E-01	2.434E+00	7.240E-09	2.121E+00	4.689E-03
1.850E-02	4.153E+01	2.609E+00	2.022E+07	1.000E-01	-1.926E-01	2.417E+00	7.077E-09	2.076E+00	4.625E-03
1.900E-02	4.247E+01	2.556E+00	2.068E+07	1.000E-01	-1.553E-01	2.400E+00	6.922E-09	2.034E+00	4.563E-03
1.950E-02	4.338E+01	2.504E+00	2.114E+07	1.000E-01	-1.195E-01	2.385E+00	6.774E-09	1.993E+00	4.503E-03
2.000E-02	4.425E+01	2.455E+00	2.159E+07	1.000E-01	-8.524E-02	2.369E+00	6.632E-09	1.953E+00	4.446E-03
2.050E-02	4.509E+01	2.407E+00	2.205E+07	1.000E-01	-5.238E-02	2.355E+00	6.496E-09	1.915E+00	4.391E-03
2.100E-02	4.590E+01	2.361E+00	2.250E+07	1.000E-01	-2.090E-02	2.341E+00	6.367E-09	1.879E+00	4.338E-03
2.150E-02	4.668E+01	2.318E+00	2.295E+07	1.000E-01	9.242E-03	2.327E+00	6.243E-09	1.844E+00	4.286E-03
2.200E-02	4.742E+01	2.276E+00	2.340E+07	1.000E-01	3.810E-02	2.314E+00	6.125E-09	1.811E+00	4.237E-03
2.250E-02	4.814E+01	2.236E+00	2.384E+07	1.000E-01	6.572E-02	2.301E+00	6.012E-09	1.779E+00	4.189E-03
2.300E-02	4.883E+01	2.197E+00	2.428E+07	1.000E-01	9.215E-02	2.289E+00	5.905E-09	1.748E+00	4.142E-03
2.350E-02	4.950E+01	2.160E+00	2.471E+07	1.000E-01	1.174E-01	2.278E+00	5.802E-09	1.719E+00	4.097E-03
2.400E-02	5.013E+01	2.125E+00	2.514E+07	1.000E-01	1.416E-01	2.267E+00	5.703E-09	1.691E+00	4.054E-03
2.450E-02	5.074E+01	2.091E+00	2.557E+07	1.000E-01	1.647E-01	2.256E+00	5.610E-09	1.664E+00	4.012E-03
2.500E-02	5.133E+01	2.059E+00	2.598E+07	1.000E-01	1.868E-01	2.246E+00	5.520E-09	1.639E+00	3.971E-03
2.550E-02	5.188E+01	2.028E+00	2.639E+07	1.000E-01	2.078E-01	2.236E+00	5.435E-09	1.614E+00	3.931E-03
2.600E-02	5.242E+01	1.999E+00	2.680E+07	1.000E-01	2.280E-01	2.227E+00	5.354E-09	1.591E+00	3.892E-03
2.650E-02	5.293E+01	1.971E+00	2.720E+07	1.000E-01	2.471E-01	2.218E+00	5.276E-09	1.568E+00	3.855E-03
2.700E-02	5.342E+01	1.944E+00	2.759E+07	1.000E-01	2.654E-01	2.209E+00	5.202E-09	1.547E+00	3.818E-03
2.750E-02	5.389E+01	1.918E+00	2.797E+07	1.000E-01	2.828E-01	2.201E+00	5.132E-09	1.527E+00	3.782E-03
2.800E-02	5.433E+01	1.894E+00	2.834E+07	1.000E-01	2.994E-01	2.193E+00	5.065E-09	1.507E+00	3.747E-03
2.850E-02	5.475E+01	1.871E+00	2.870E+07	1.000E-01	3.152E-01	2.186E+00	5.002E-09	1.489E+00	3.713E-03
2.900E-02	5.516E+01	1.849E+00	2.905E+07	1.000E-01	3.301E-01	2.179E+00	4.942E-09	1.471E+00	3.680E-03
2.950E-02	5.554E+01	1.828E+00	2.940E+07	1.000E-01	3.443E-01	2.172E+00	4.885E-09	1.455E+00	3.647E-03
3.000E-02	5.590E+01	1.808E+00	2.973E+07	1.000E-01	3.577E-01	2.166E+00	4.831E-09	1.439E+00	3.615E-03

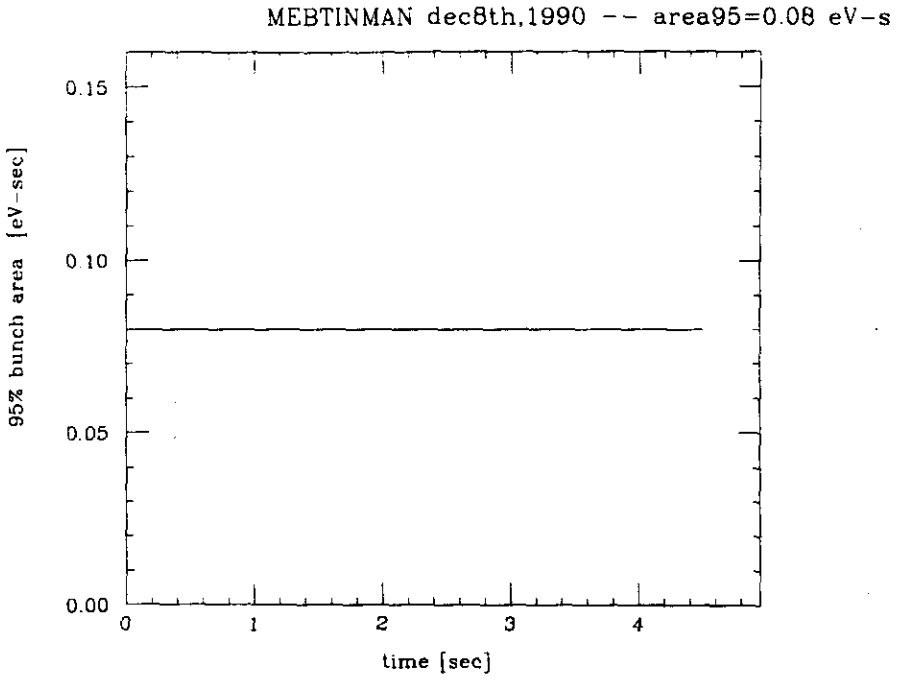
3.050E-02	5.607E+01	1.799E+00	3.030E+07	1.014E-01	3.641E-01	2.163E+00	4.804E-09	1.431E+00	3.614E-03
3.100E-02	5.591E+01	1.808E+00	3.135E+07	1.054E-01	3.581E-01	2.166E+00	4.827E-09	1.438E+00	3.669E-03
3.150E-02	5.547E+01	1.832E+00	3.284E+07	1.118E-01	3.416E-01	2.174E+00	4.891E-09	1.458E+00	3.774E-03
3.200E-02	5.479E+01	1.869E+00	3.473E+07	1.207E-01	3.164E-01	2.185E+00	4.989E-09	1.487E+00	3.922E-03
3.250E-02	5.393E+01	1.916E+00	3.698E+07	1.317E-01	2.843E-01	2.200E+00	5.113E-09	1.525E+00	4.105E-03
3.300E-02	5.293E+01	1.971E+00	3.954E+07	1.449E-01	2.471E-01	2.218E+00	5.258E-09	1.568E+00	4.317E-03
3.350E-02	5.184E+01	2.031E+00	4.236E+07	1.600E-01	2.061E-01	2.237E+00	5.418E-09	1.616E+00	4.551E-03
3.400E-02	5.068E+01	2.095E+00	4.539E+07	1.768E-01	1.625E-01	2.257E+00	5.587E-09	1.667E+00	4.803E-03
3.450E-02	4.949E+01	2.161E+00	4.861E+07	1.954E-01	1.172E-01	2.278E+00	5.762E-09	1.719E+00	5.067E-03
3.500E-02	4.828E+01	2.228E+00	5.197E+07	2.154E-01	7.083E-02	2.299E+00	5.942E-09	1.773E+00	5.339E-03
3.550E-02	4.706E+01	2.296E+00	5.544E+07	2.369E-01	2.399E-02	2.320E+00	6.123E-09	1.827E+00	5.618E-03
3.600E-02	4.584E+01	2.364E+00	5.899E+07	2.596E-01	-2.300E-02	2.341E+00	6.304E-09	1.882E+00	5.898E-03
3.650E-02	4.464E+01	2.432E+00	6.259E+07	2.834E-01	-6.990E-02	2.362E+00	6.484E-09	1.936E+00	6.178E-03
3.700E-02	4.345E+01	2.500E+00	6.622E+07	3.082E-01	-1.165E-01	2.383E+00	6.663E-09	1.989E+00	6.456E-03
3.750E-02	4.228E+01	2.566E+00	6.985E+07	3.338E-01	-1.628E-01	2.404E+00	6.840E-09	2.042E+00	6.730E-03
3.800E-02	4.113E+01	2.632E+00	7.346E+07	3.601E-01	-2.087E-01	2.424E+00	7.015E-09	2.095E+00	6.998E-03
3.850E-02	4.000E+01	2.698E+00	7.702E+07	3.869E-01	-2.542E-01	2.443E+00	7.188E-09	2.147E+00	7.258E-03
3.900E-02	3.888E+01	2.762E+00	8.052E+07	4.142E-01	-2.993E-01	2.463E+00	7.360E-09	2.198E+00	7.510E-03
3.950E-02	3.779E+01	2.826E+00	8.393E+07	4.417E-01	-3.441E-01	2.482E+00	7.530E-09	2.249E+00	7.751E-03
4.000E-02	3.671E+01	2.890E+00	8.723E+07	4.694E-01	-3.887E-01	2.501E+00	7.698E-09	2.300E+00	7.980E-03
4.050E-02	3.564E+01	2.953E+00	9.040E+07	4.971E-01	-4.332E-01	2.520E+00	7.866E-09	2.350E+00	8.197E-03
4.100E-02	3.457E+01	3.016E+00	9.342E+07	5.246E-01	-4.777E-01	2.538E+00	8.034E-09	2.400E+00	8.400E-03
4.150E-02	3.352E+01	3.079E+00	9.626E+07	5.519E-01	-5.224E-01	2.557E+00	8.201E-09	2.450E+00	8.587E-03
4.200E-02	3.247E+01	3.142E+00	9.892E+07	5.787E-01	-5.676E-01	2.575E+00	8.370E-09	2.501E+00	8.758E-03
4.250E-02	3.141E+01	3.207E+00	1.014E+08	6.050E-01	-6.133E-01	2.593E+00	8.540E-09	2.552E+00	8.911E-03
4.300E-02	3.035E+01	3.272E+00	1.036E+08	6.306E-01	-6.599E-01	2.612E+00	8.714E-09	2.604E+00	9.046E-03
4.350E-02	2.927E+01	3.338E+00	1.055E+08	6.554E-01	-7.076E-01	2.631E+00	8.891E-09	2.657E+00	9.160E-03
4.400E-02	2.817E+01	3.407E+00	1.072E+08	6.792E-01	-7.570E-01	2.650E+00	9.073E-09	2.711E+00	9.252E-03
4.450E-02	2.704E+01	3.478E+00	1.085E+08	7.019E-01	-8.084E-01	2.670E+00	9.262E-09	2.768E+00	9.321E-03
4.500E-02	2.588E+01	3.552E+00	1.096E+08	7.234E-01	-8.624E-01	2.690E+00	9.460E-09	2.827E+00	9.365E-03
4.550E-02	2.465E+01	3.631E+00	1.102E+08	7.434E-01	-9.200E-01	2.711E+00	9.669E-09	2.890E+00	9.381E-03
4.600E-02	2.336E+01	3.716E+00	1.105E+08	7.620E-01	-9.820E-01	2.734E+00	9.894E-09	2.957E+00	9.367E-03
4.650E-02	2.197E+01	3.808E+00	1.103E+08	7.788E-01	-1.050E+00	2.758E+00	1.014E-08	3.030E+00	9.320E-03
4.700E-02	2.046E+01	3.911E+00	1.096E+08	7.939E-01	-1.126E+00	2.785E+00	1.041E-08	3.112E+00	9.235E-03
4.750E-02	1.877E+01	4.028E+00	1.083E+08	8.071E-01	-1.214E+00	2.814E+00	1.073E-08	3.205E+00	9.107E-03
4.800E-02	1.683E+01	4.167E+00	1.064E+08	8.181E-01	-1.319E+00	2.848E+00	1.109E-08	3.316E+00	8.926E-03
4.850E-02	1.451E+01	4.339E+00	1.036E+08	8.270E-01	-1.451E+00	2.888E+00	1.155E-08	3.453E+00	8.677E-03
4.900E-02	1.159E+01	4.572E+00	9.959E+07	8.334E-01	-1.632E+00	2.939E+00	1.217E-08	3.638E+00	8.332E-03
4.950E-02	7.502E+00	4.936E+00	9.341E+07	8.374E-01	-1.925E+00	3.011E+00	1.314E-08	3.928E+00	7.810E-03
5.000E-02	2.682E-06	6.282E+00	7.876E+07	8.388E-01	-3.141E+00	3.142E+00	1.673E-08	4.999E+00	6.583E-03

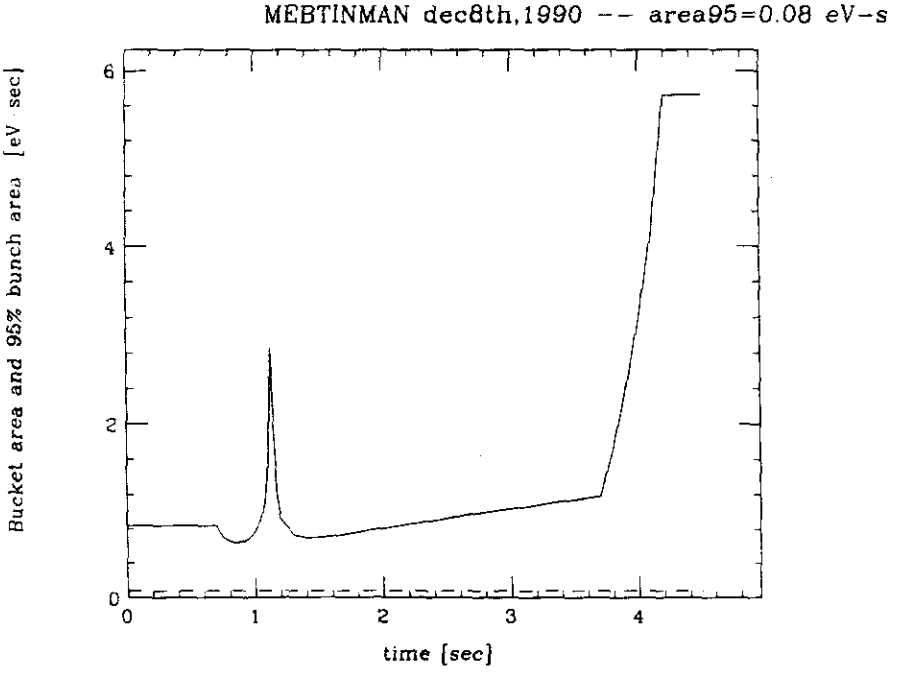

MEBTINMAN dec8th,1990 -- area95=0.08 eV-s
Peak voltage V and Vsinφs [MVolt]
1.00
0.75
0.50
0.25
0.00
0
1
2
3
4
time [sec]

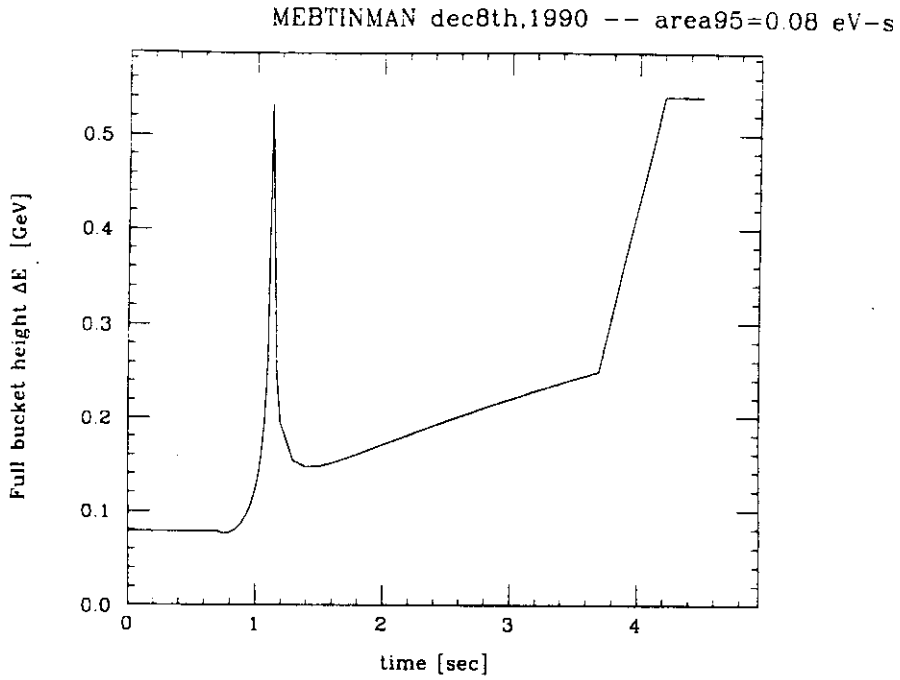

MEBTINMAN dec8th,1990 -- area95=0.08 eV-s
φs [degrees]
150
100
50
0
0
1
2
3
4
time [sec]

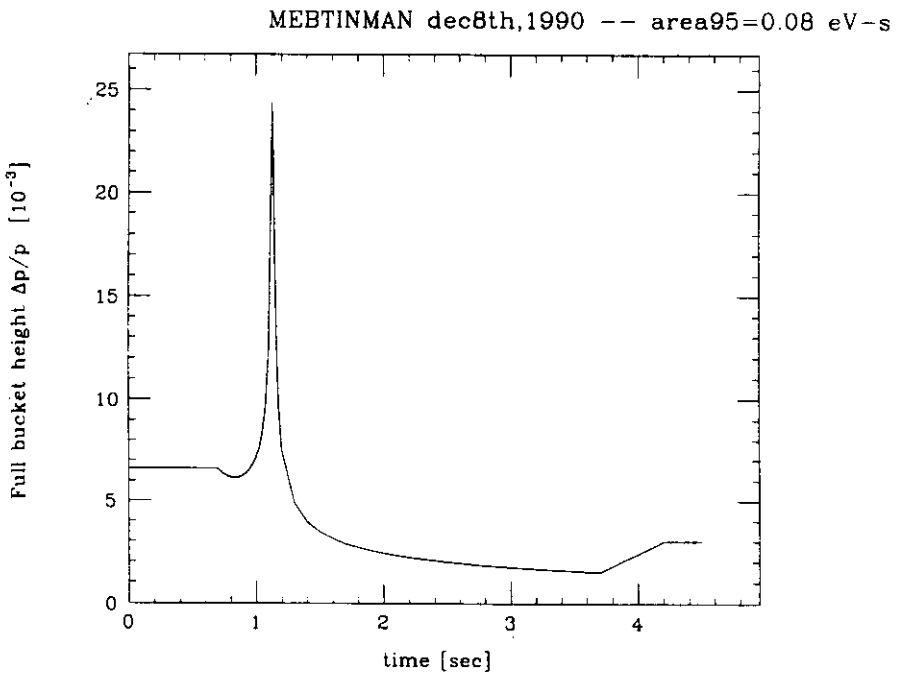

MEBTINMAN dec8th,1990 -- area95=0.08 eV-s
RF frequency [MHz]
59.95
59.90
59.85
59.80
0
1
2
3
4
time [sec]

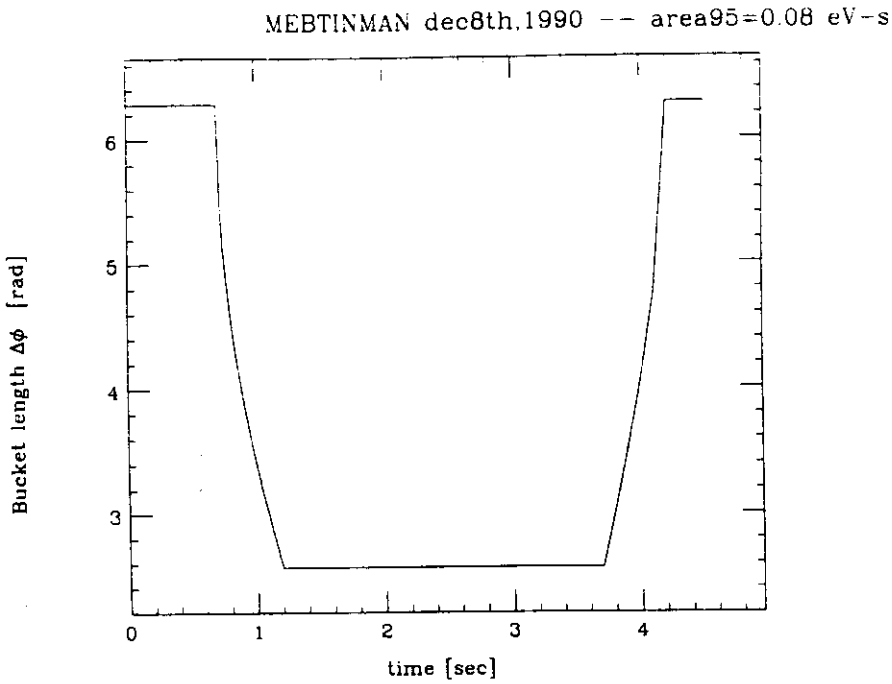

MEBTINMAN dec8th,1990 -- area95=0.08 eV-s
Peak voltage [MVolt]
1.1
1.0
0.9
0.8
0.7
59.75
59.8
59.85
59.9
59.95
60
RF frequency [MHz]

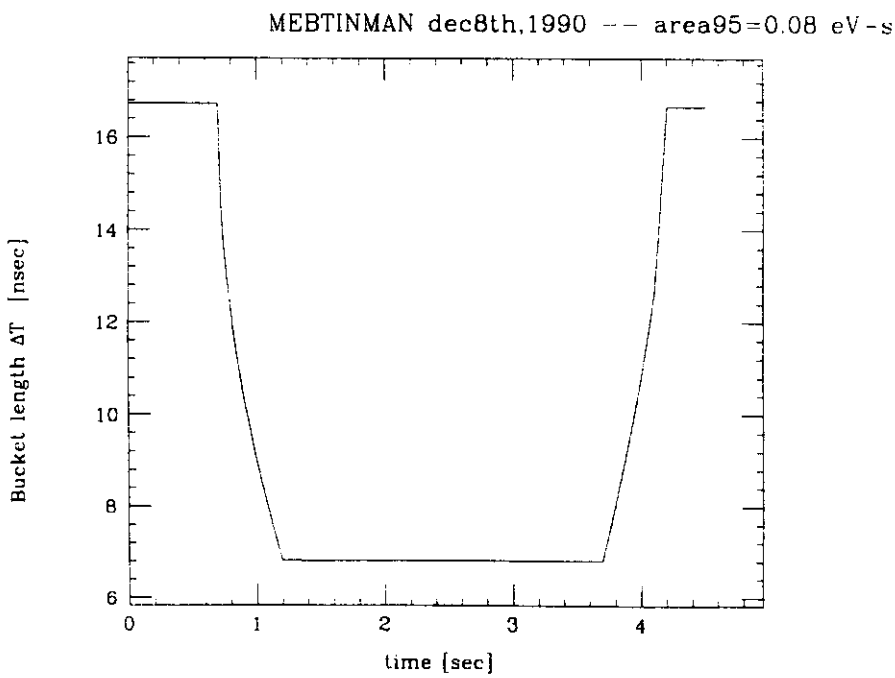

MEBTINMAN dec8th,1990 -- area95=0.08 eV-s
95% bunch area [eV-sec]
0.15
0.10
0.05
0.00
0
1
2
3
4
time [sec]

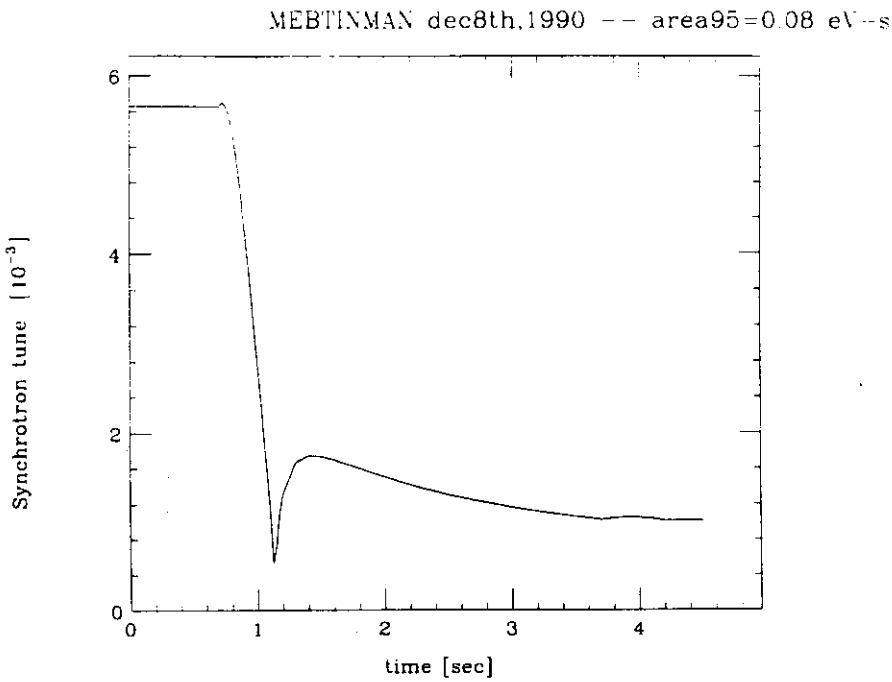

MEBTINMAN dec8th,1990 -- area95=0.08 eV-s
Bucket area and 95% bunch area [eV sec]
6
4
2
0
0
1
2
3
4
time [sec]

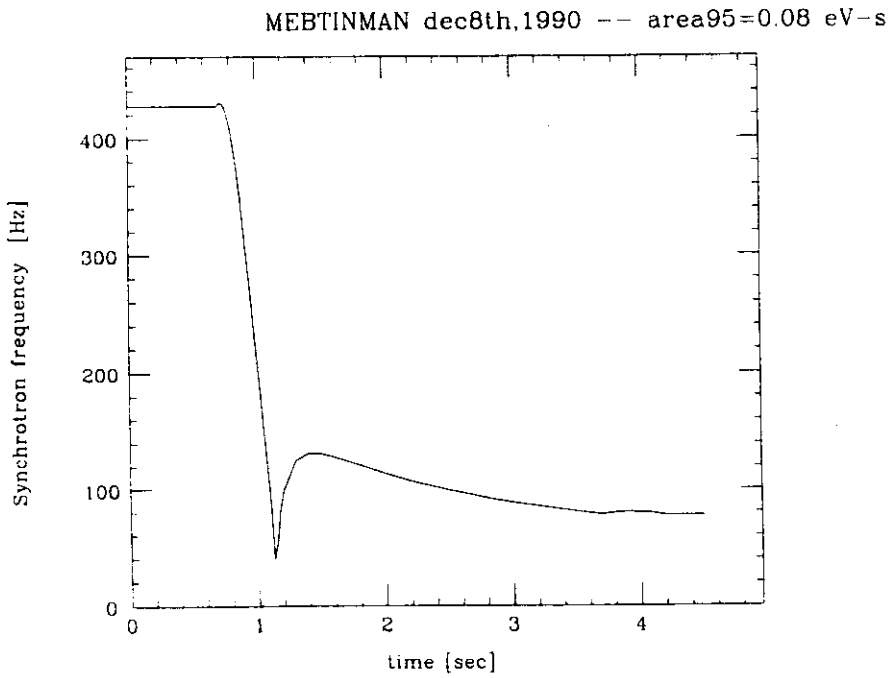

MEBTINMAN dec8th,1990 -- area95=0.08 eV-s
Full bucket height ΔE [GeV]
0.0
0.1
0.2
0.3
0.4
0.5
0
1
2
3
4
time [sec]

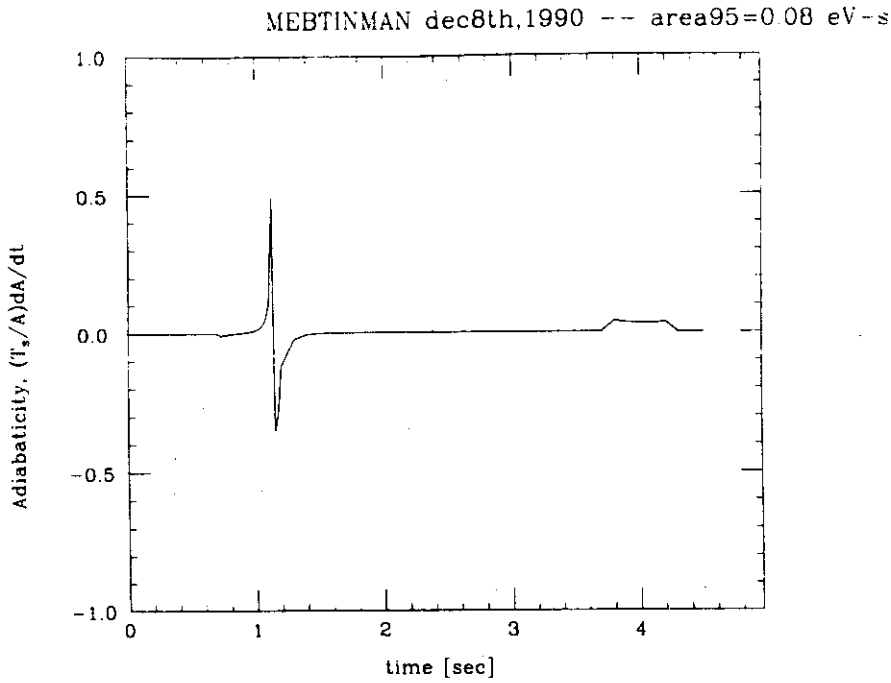

MEBTINMAN dec8th,1990 -- area95=0.08 eV-s
Full bucket height Δp/p [10^-3]
0
5
10
15
20
25
0
1
2
3
4
time [sec]

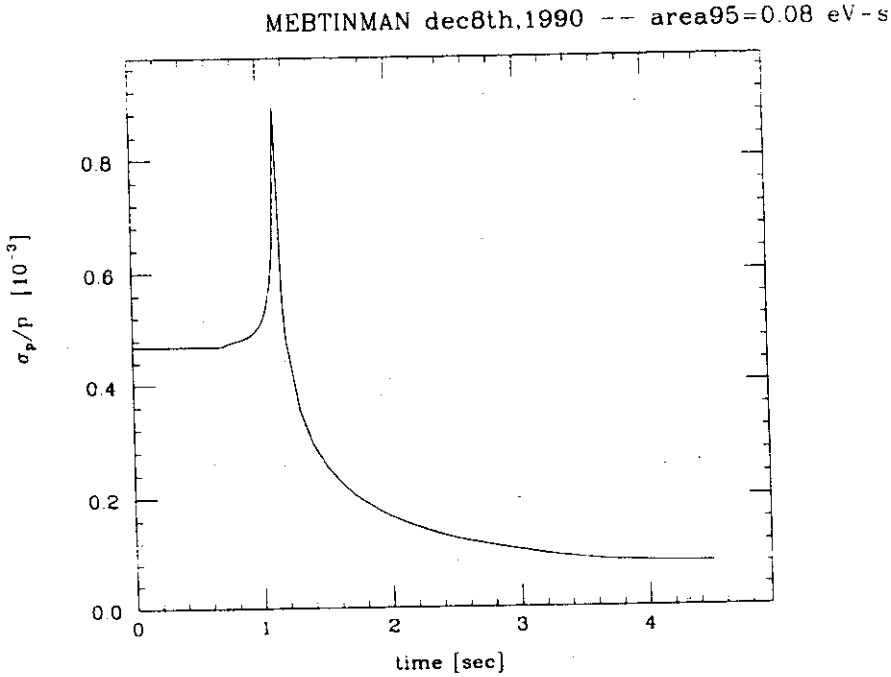

MEBTINMAN dec8th,1990 -- area95=0.08 eV-s
Bucket length Δφ [rad]
6
5
4
3
0
1
2
3
4
time [sec]

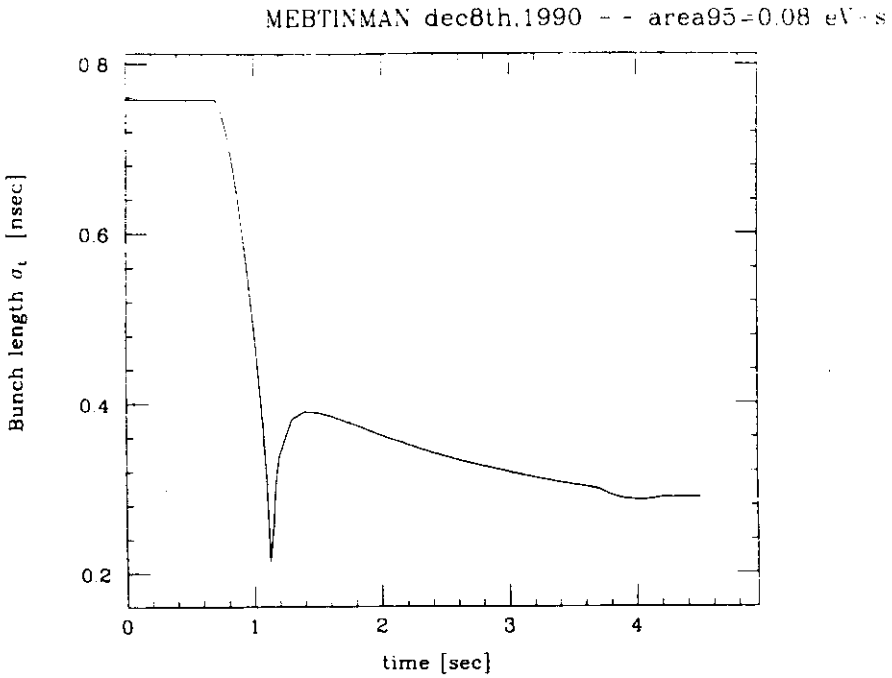

MEBTINMAN dec8th,1990 -- area95=0.08 eV-s
Bucket length ΔT [nsec]
16
14
12
10
8
6
0
1
2
3
4
time [sec]

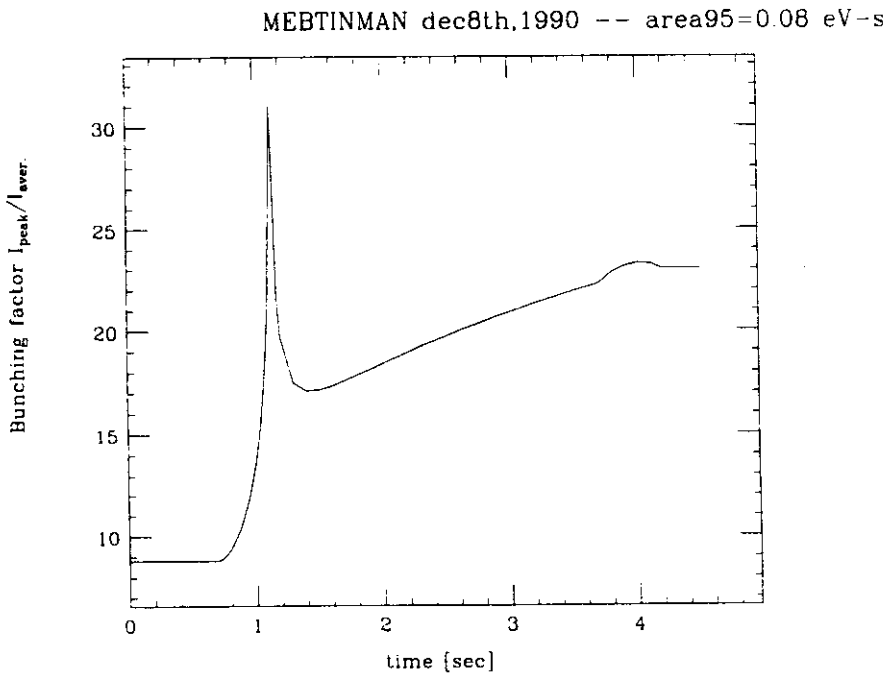

MEBTINMAN dec8th,1990 -- area95=0.08 eV-s
Synchrotron tune [10^{-3}]
time [sec]
0
2
4
6
0
1
2
3
4

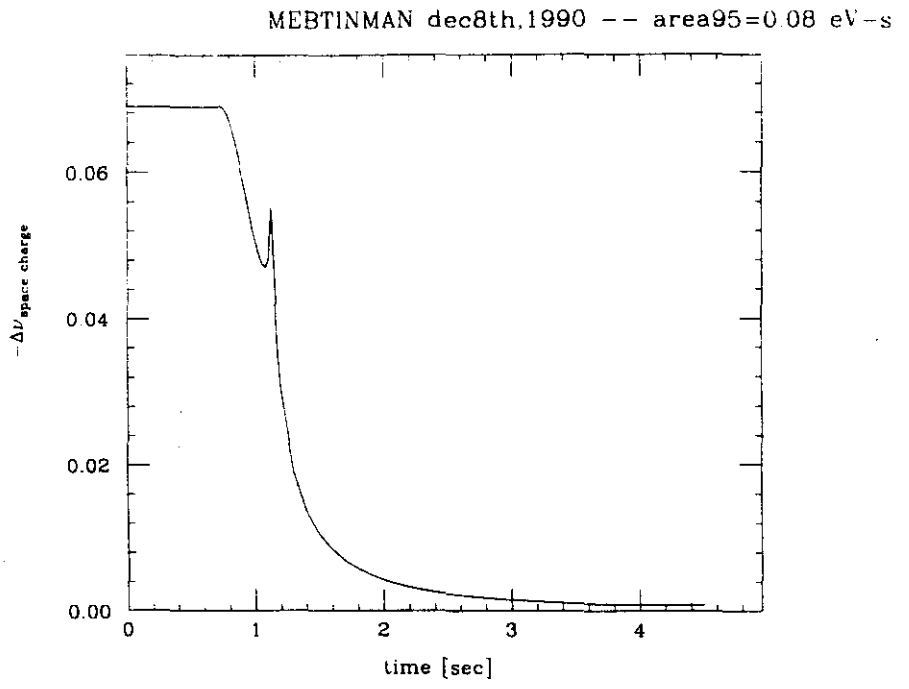

MEBTINMAN dec8th,1990 -- area95=0.08 eV-s
Synchrotron frequency [Hz]
time [sec]
0
100
200
300
400
0
1
2
3
4

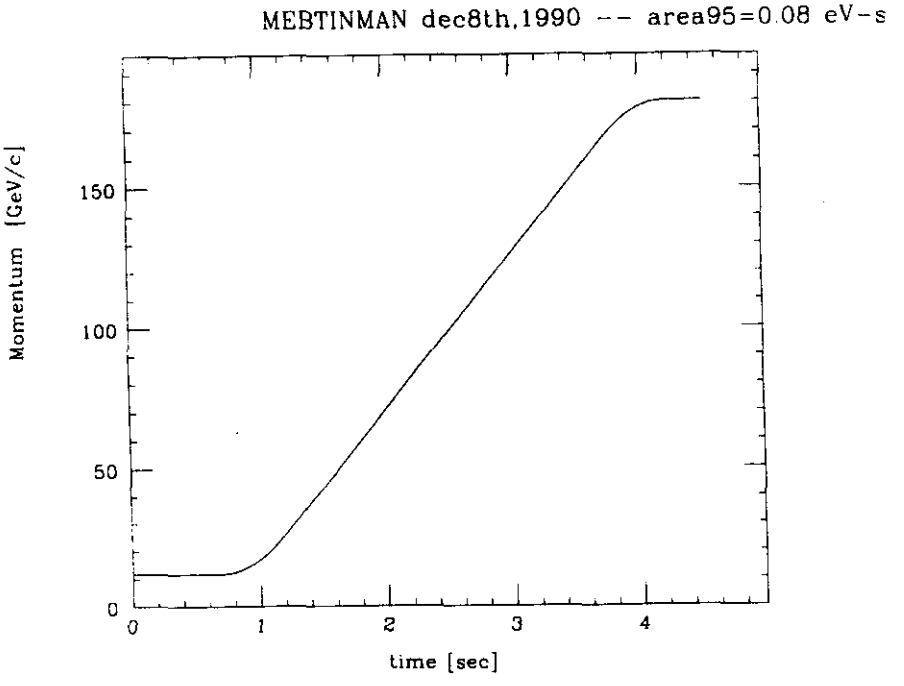

MEBTINMAN dec8th,1990 -- area95=0.08 eV-s
1.0
0.5
0.0
-0.5
-1.0
Adiabaticity, (Γ_s/A)dA/dt
0
1
2
3
4
time [sec]

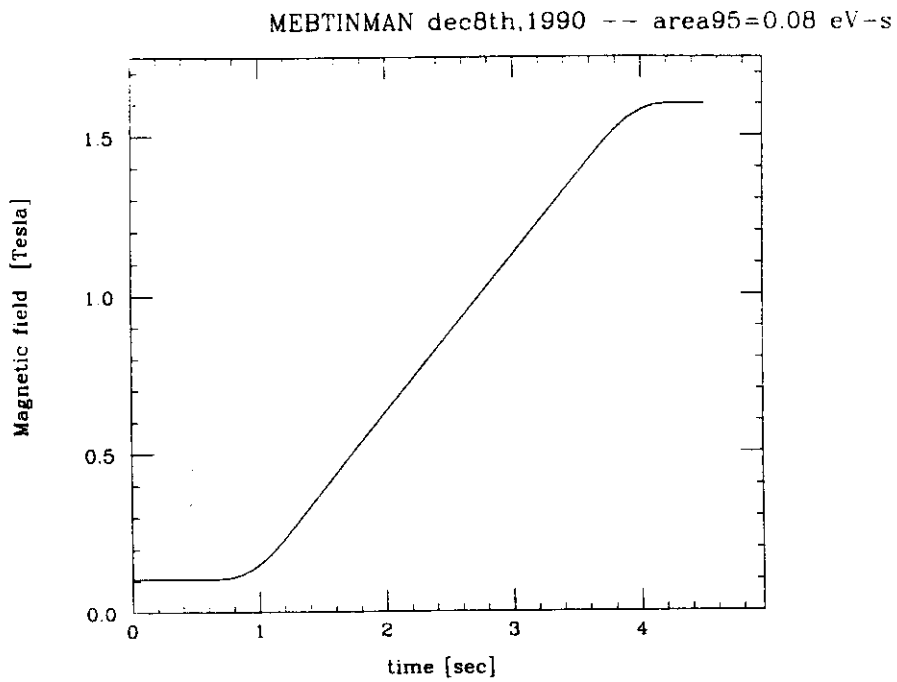

MEBTINMAN dec8th,1990 -- area95=0.08 eV-s
0.8
0.6
0.4
0.2
0.0
σ_p/p [10^{-3}]
0
1
2
3
4
time [sec]

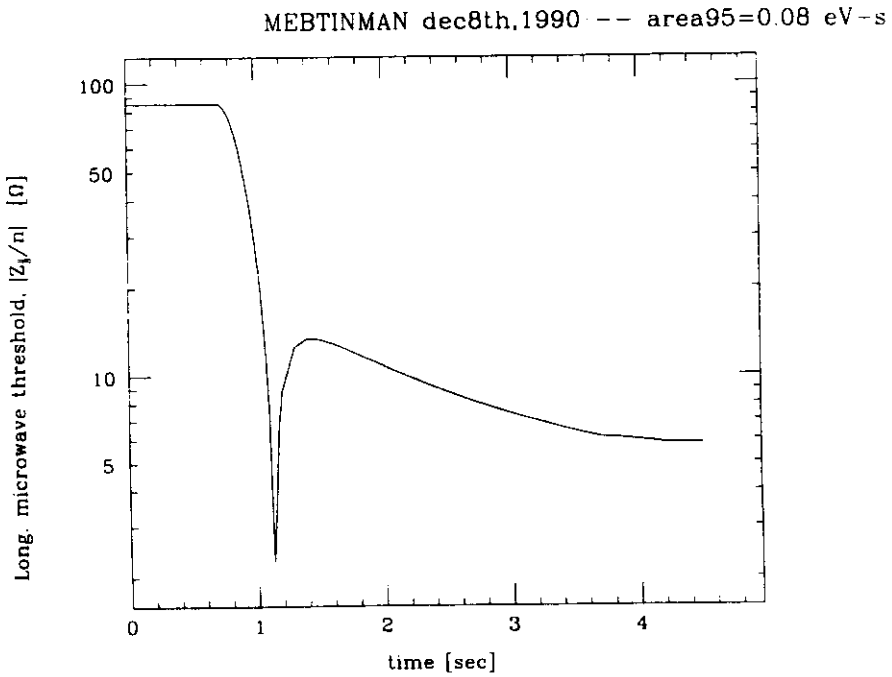

MEBTINMAN dec8th,1990 - - area95=0.08 eV-s
Bunch length σ_t [nsec]
0.8
0.6
0.4
0.2
0
1
2
3
4
time [sec]

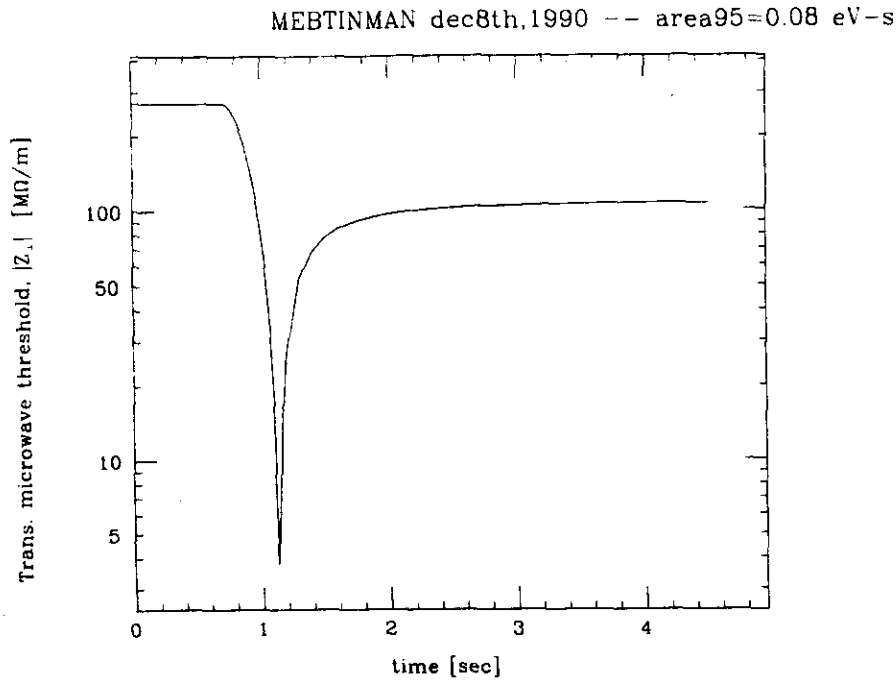

MEBTINMAN dec8th,1990 -- area95=0.08 eV-s
Bunching factor $I_{peak}/I_{aver.}$
30
25
20
15
10
0
1
2
3
4
time [sec]

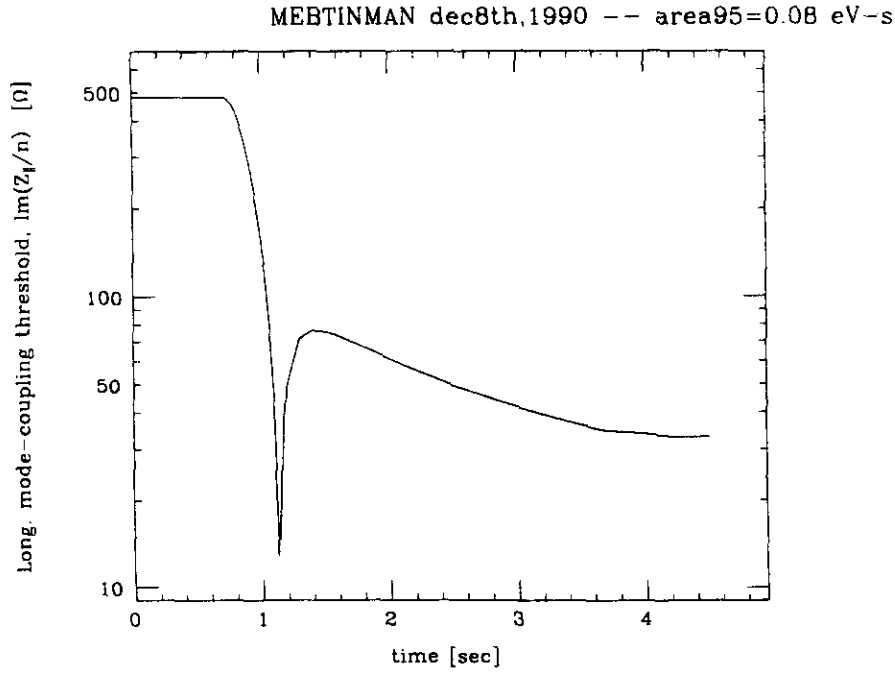

MEBTINMAN dec8th,1990 -- area95=0.08 eV-s
0.06
0.04
0.02
0.00
$-\Delta\nu_{\text{space charge}}$
0
1
2
3
4
time [sec]

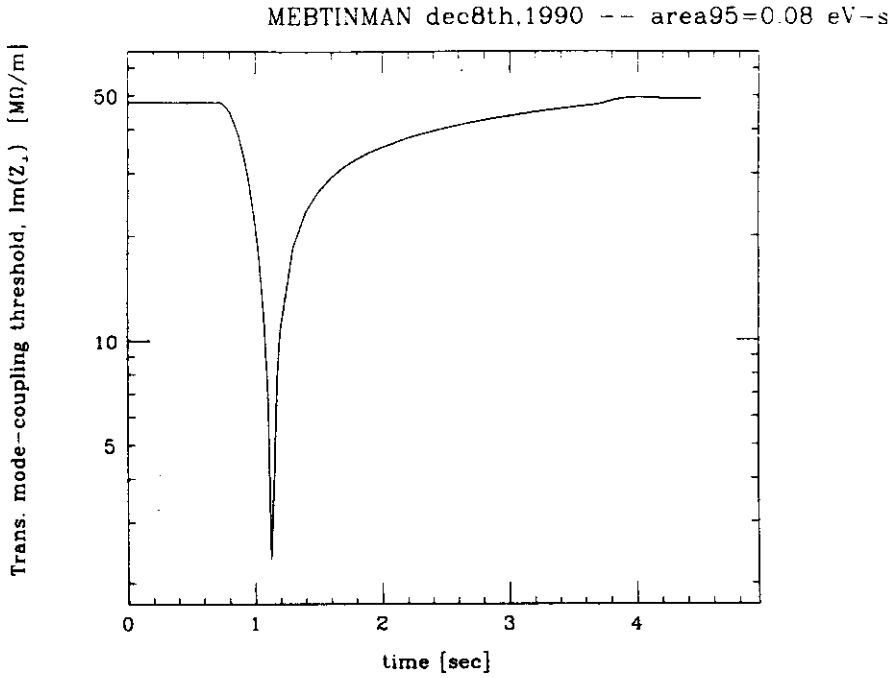

MEBTINMAN dec8th,1990 -- area95=0.08 eV-s
150
100
50
0
Momentum [GeV/c]
0
1
2
3
4
time [sec]

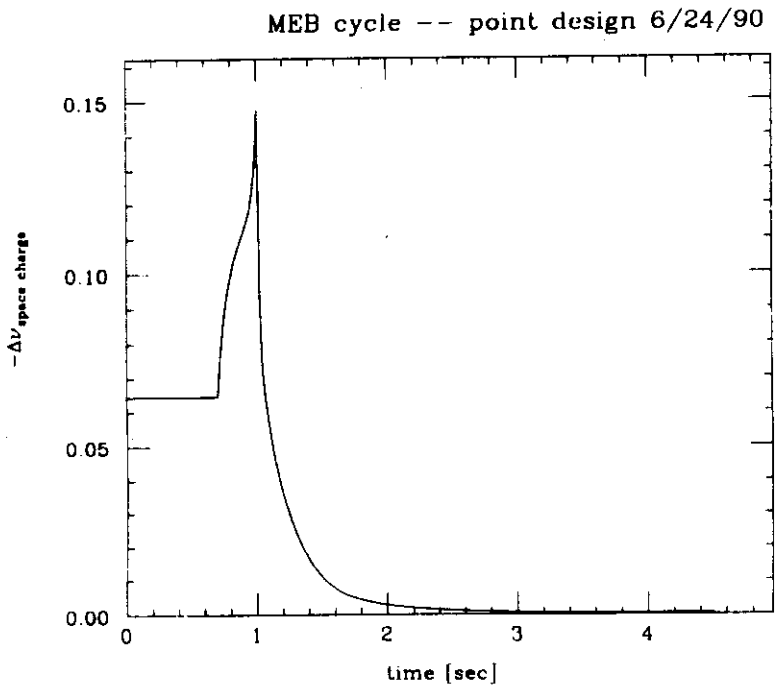

MEBTINMAN dec8th,1990 -- area95=0.08 eV-s
Magnetic field [Tesla]
1.5
1.0
0.5
0.0
0
1
2
3
4
time [sec]


MEBTINMAN dec8th,1990 -- area95=0.08 eV-s
Long. microwave threshold, |Z_l/n| [Ω]
100
50
10
5
0
1
2
3
4
time [sec]

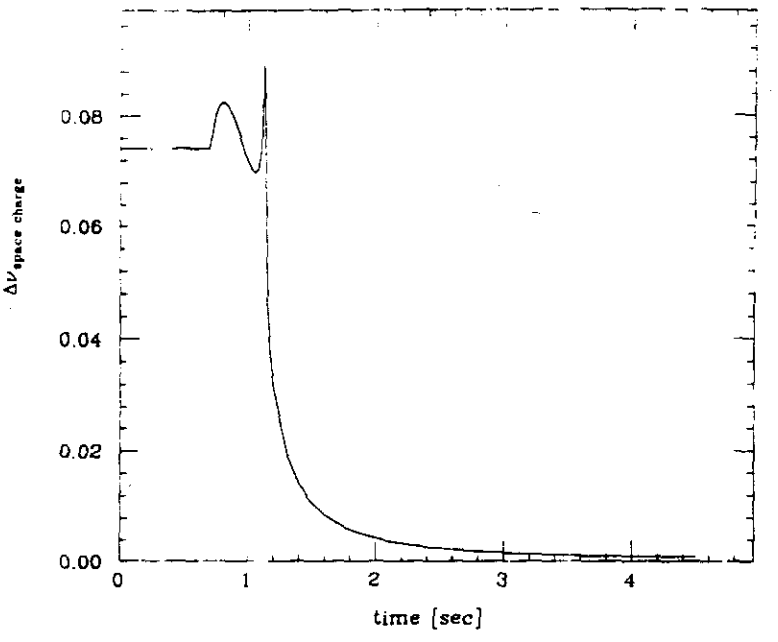

MEBTINMAN dec8th,1990 -- area95=0.08 eV-s
Trans. microwave threshold, |Z⊥| [MΩ/m]
100
50
10
5
0
1
2
3
4
time [sec]


MEBTINMAN dec8th,1990 -- area95=0.08 eV-s
Long. mode-coupling threshold, Im(Z∥/n) [Ω]
500
100
50
10
0
1
2
3
4
time [sec]

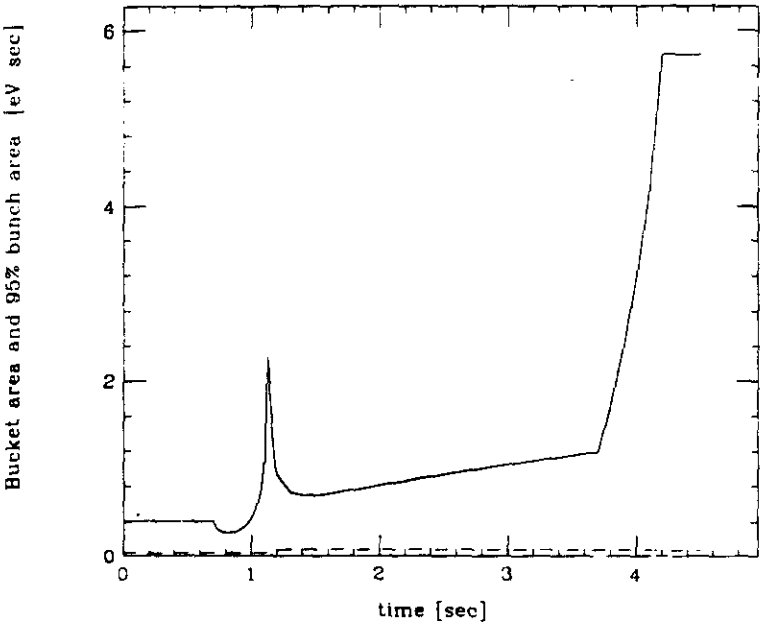

MEBTINMAN dec8th,1990 -- area95=0.08 eV-s
Trans. mode-coupling threshold, Im(Z⊥) [MΩ/m]
50
10
5
0
1
2
3
4
time [sec]

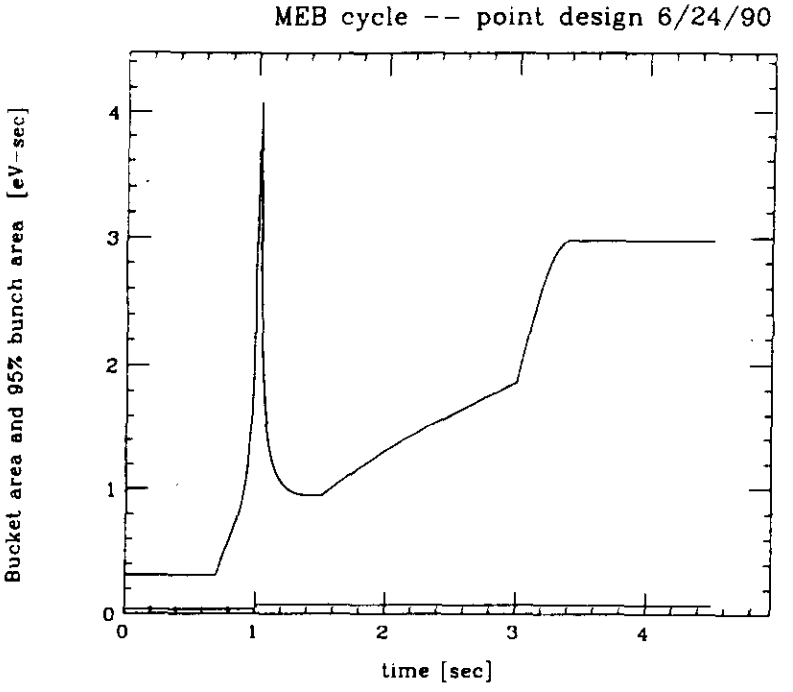

MEB cycle -- point design 6/24/90
$-\Delta\nu_{space\ charge}$
0.15
0.10
0.05
0.00
0
1
2
3
4
time [sec]

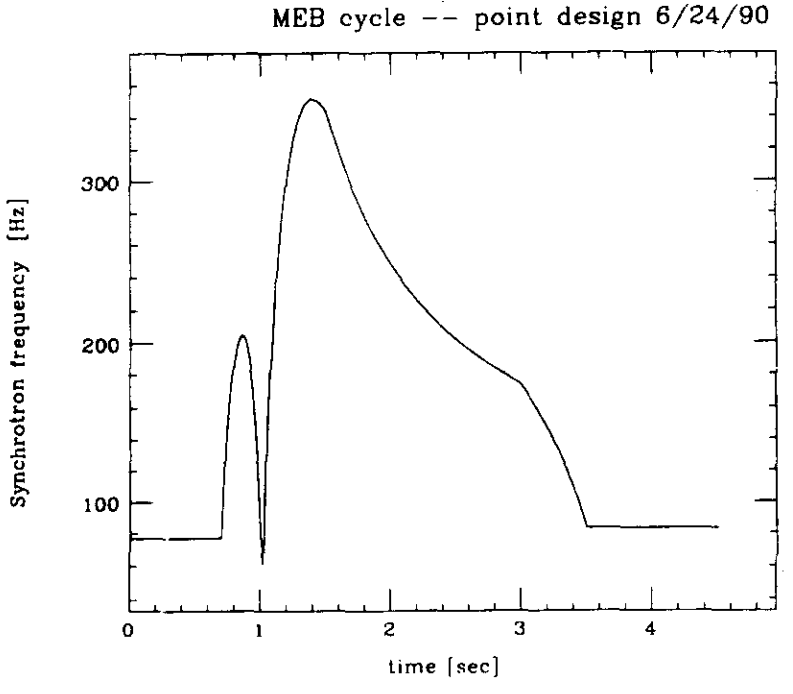
MEBTINMAN

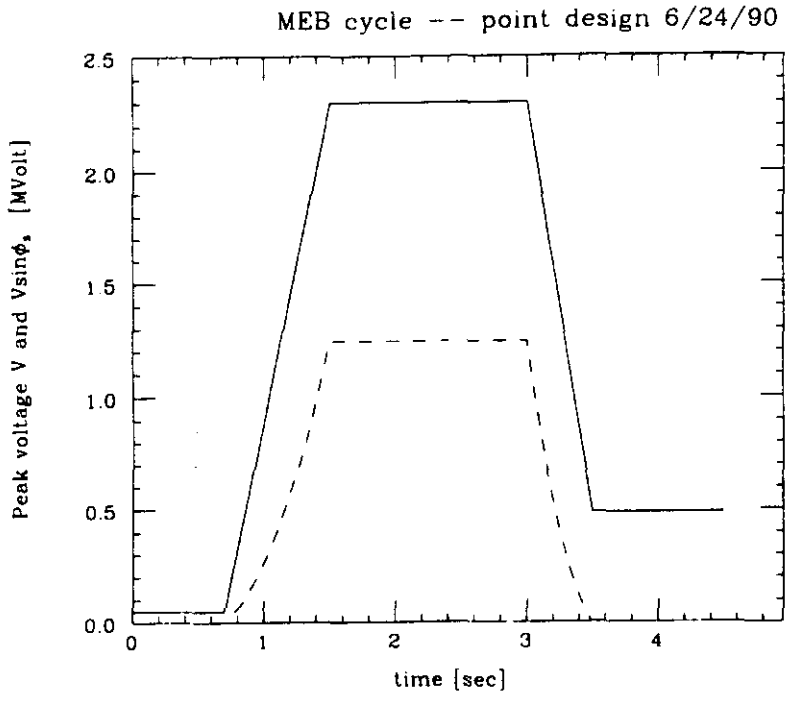


MEBTINMAN



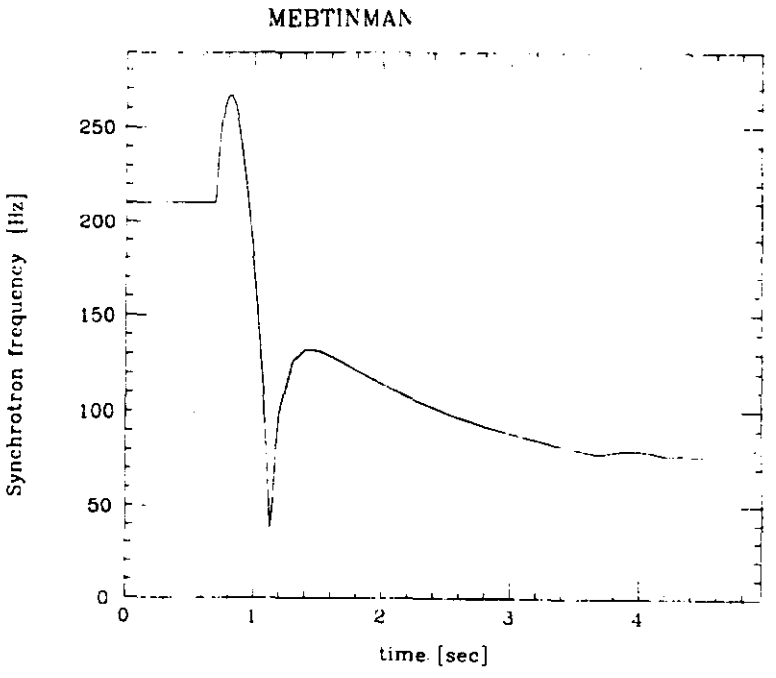

MEB cycle -- point design 6/24/90
Bucket area and 95% bunch area [eV-sec]
0
1
2
3
4
0
1
2
3
4
time [sec]

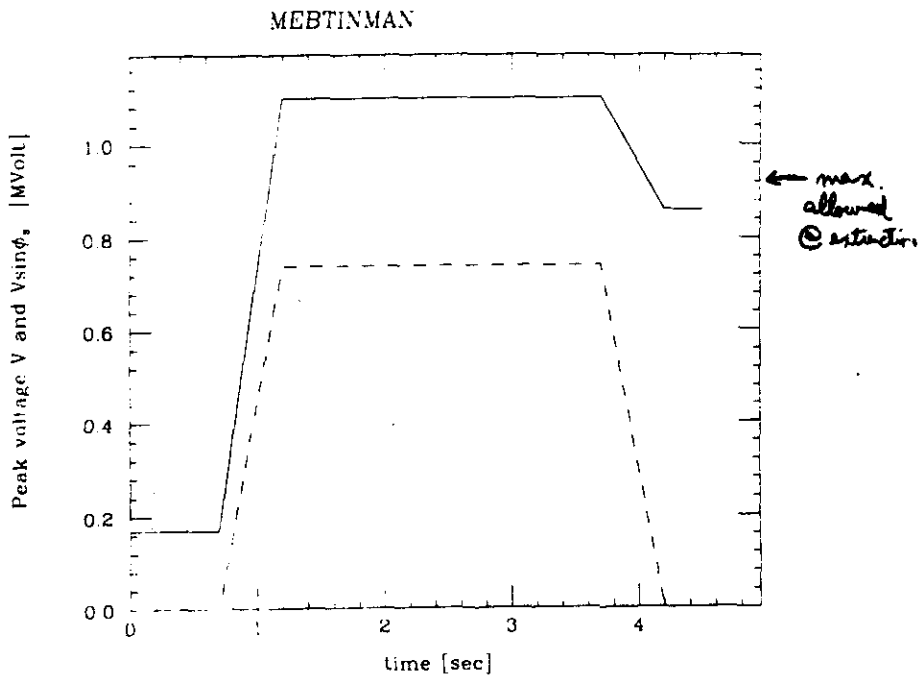

MEB cycle -- point design 6/24/90
Synchrotron frequency [Hz]
100
200
300
0
1
2
3
4
time [sec]

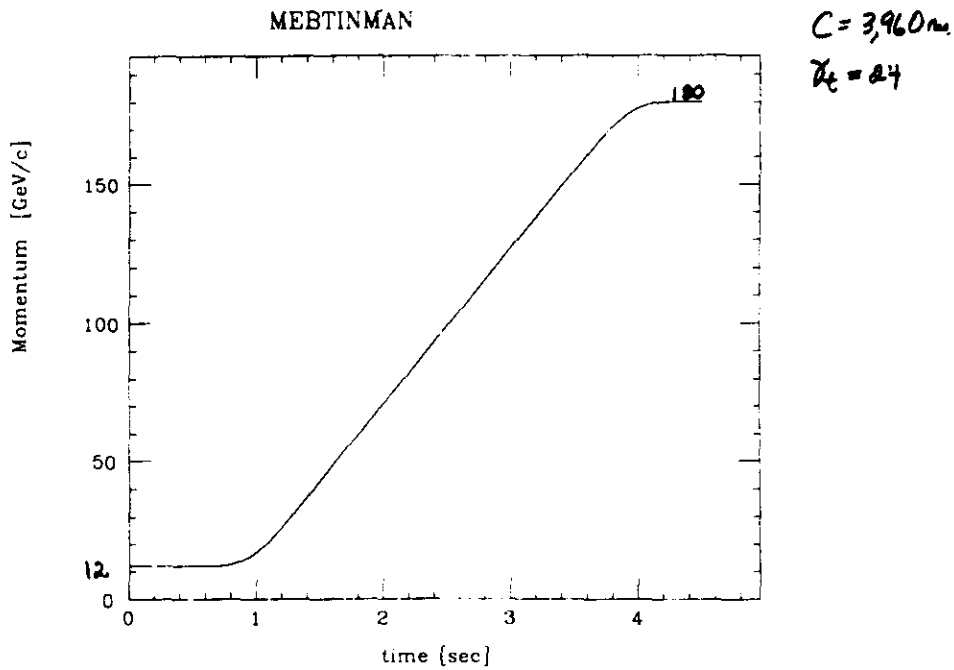


$C = 3,960$

$\gamma_t = 16$




MEBTINMAN
Peak voltage V and Vsinφs [MVolt]
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
time [sec]
← max. allowed @ extraction


MEBTINMAN
C = 3,960 m
γt = 24
Momentum [GeV/c]
150
100
50
12
0
180
0
1
2
3
4
time [sec]

APPENDIX A

TO: DISTRIBUTION

FROM: Alex Chao, Richard York

DATE: 14-November-1990

Dear Colleagues:

We invite you to attend and participate in a workshop on the injector machine systems for the SSC collider to take place on December 3 through December 7, 1990 at the SSCL. The topics listed below are those which are considered to have a high priority for the efforts during this workshop.

Please find enclosed a preliminary agenda. Note that there will be an overlap between the close out for the workshop and the Machine Advisory Committee (MAC).

The following topics are to be covered.

Low Energy Booster (LEB) Topics

The present working design parameters are given in Table 1. With a circumference of 540 m, a normal FODO lattice will provide a transition gamma of ≈ 7 which would therefore, require transition crossing. The alternative is a more complex lattice which would not require transition crossing by providing a transition gamma of ≈ 20 or of ≈ 15 depending on the detailed lattice values, but which may have higher sensitivities to perturbations. The following topics will be addressed.

(1) **LATTICE:** Evaluation of the wisdom of avoiding transition crossing at the cost of a more operationally complex lattice. This evaluation must be compared to item 2.

(2) **TRANSITION CROSSING: Quantitative** evaluation of possible methods and their effects on beam quality in the circumstance of a rapid (10 Hz) cycling synchrotron.

(3) **BEAM TRANSFER TO Medium Energy Booster (MEB):** Detailed evaluation of the necessary bucket matching and cogging to

transfer beam from the **LEB** to the **MEB**. There are presently at least three possible methods of cogging and two possible methods of bucket matching.

Table 1. Working Injector Design Parameters

Machine	Circumference (m)	Pinj. (GeV/c)	Pext.
LEB	540	1.2	12
MEB	3,960	12	180
HEB	10,890	180	1,800

Medium Energy Booster (MEB) Topics

The present working design prarmeters are given in Table 1. With a circumference of 3960 m, a normal FODO lattice will provide a transition gamma of ≈ 25 which would therefore, require transition crossing. The alternative is a more complex lattice which will not require transition crossing by providing an imaginary transition gamma, but which may have higher sensitivities to perturbations and be less efficient in terms of dipole space available. The present design criteria calls for a dipole magnetic field less than 1.55 T at 180 GeV/c. The following topics will be addressed.

(1) **LATTICE:** Evaluation of the wisdom of avoiding transition crossing at the cost of a more operationally complex lattice. This evaluation must be compared to item 2.

(2) **TRANSITION CROSSING: Quantitative** evaluation of possible methods and their effects on beam quality.

(3) **SLOW EXTRACTION:** The implications of the new lattice are to be evaluated in the presence of the saturation sextupole in the dipoles.

High Energy Booster (HEB) Topic

The present working design parameters are given in Table 1. The following topics will be addressed:

(1) **MEB to HEB FILLING SEQUENCE:** A possible **HEB** filling sequence as specified in the SCDR requires that a sequence of 1 full **MEB**, 1 full **MEB**, 2/3 full **MEB** be followed. Examination of possible consequences of this scenario with respect to, for example, the rf systems should be done. See numerology below.

General Numerology Topic

The present working design parameters are given in Table 1. However, an evaluation of the specified circumferences should be undertaken to finalize and document the impact of these choices and to identify, if appropriate, preferable circumferences with respect to the effective and efficient filling of the collider.