GEM TN-91-00006

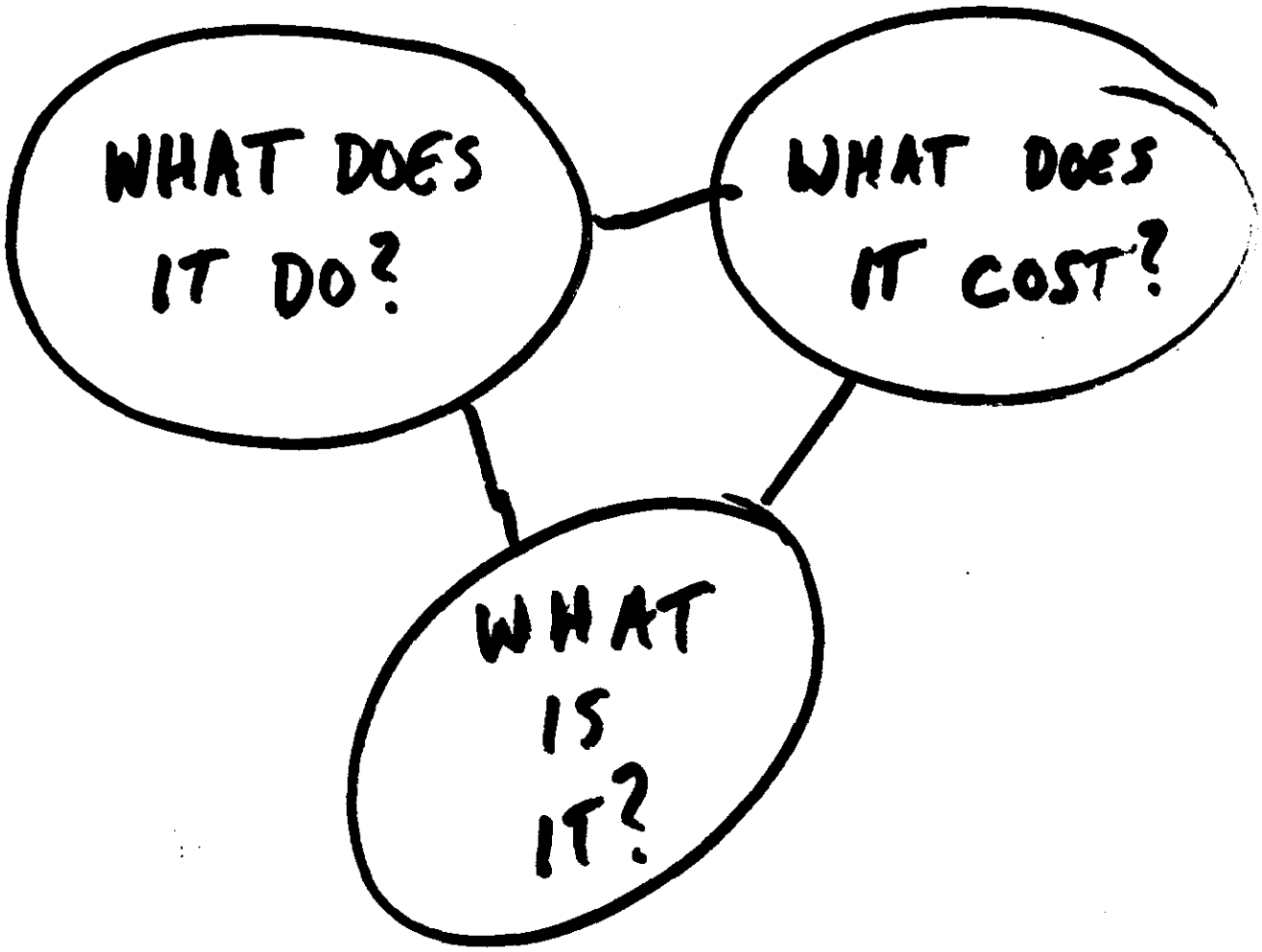
GEM Calorimetry Meeting
SSCL

August 8-9, 1991

Abstract:
Transparencies from the Calorimetry Meeting held at the SSC Lab on August 8 and 9, 1991.

BRAU

GEM CALORIMETRY



LOI PREPARATION

(NOV 30)

- FOCUS GOALS

  PHYSICS REQUIRES:

  excellent EM (?/$\sqrt{E}$ + ?)

  good hadronic

  (hermetic / SDC competitin

- NARROW OPTIONS

  CONCENTRATE LIMITED RESOURCES

- DEFINE R+D PLAN

- PLAN PROPOSAL PREPARATION

  SPECIFICATIONS

  PHYSICS OPTIMIZATION

  ENGINEERING DETAIL

PROPOSAL PREPARATION
(NOV '92)

- FULFILL R+D PLAN

- ACHIEVE ENGINEERING DESIGN

- RETAIN FLEXIBILITY

  BALANCE NEED FOR SPECIFICITY WITH OPTION TO RESPOND TO BREAKTHROUGHS

NARROWING PROCESS IS DIFFICULT

1. COST CONSTRAINTS/TRADEOFFS
2. IMPACT ON OTHER SUBSYSTEMS
3. LIMITS PERFORMANCE
4. KNOWLEDGE OF ALL OPTIONS IS LIMITED

NEVERTHELESS,

WE MUST MOVE FORWARD

FORWARD CALORIMETRY

IS <u>VERY</u> IMPORTANT FOR

THE <u>CEM</u> PHYSICS GOALS

$H \to \ell \ell \nu \nu$

strong VV scattering

$W' \to \ell \not{E}_T$

SUSY searches

⋮

I.E. POTENTIAL FOR <u>DISCOVERY</u>

WE MUST <u>CAREFULLY</u> HANDLE

MEASUREMENTS OF $\not{E}_T$

BEWARE OF THE $\eta = 3$ TRANSITION

AND "CRACKS"

PRE-RADIATOR, ANOTHER COMPLICATION FOR CALORIMETRY

e i.d./trigger

π^0/γ separation?

integrate into EM cal?

comparison of technologies

e.g. sci-fi vs. silicon

PRISCA CUSHMAN IS PREPARING DISCUSSION FOR SEPT 4 MEETING.

TASK FORCES WE NEED

RAD HARD POLICE FORCE

SIMULATION GROUP

PROPOSAL FOR PROCESS
(TO BE DISCUSSED)

1. AUG 8-9

2. REMAINDER OF AUGUST

   CRITICS PREPARE WRITTEN
   NOTES TO ADAIR + BRAU.
   (BY AUG 16 - REMAIN ANONY

   ADAIR + BRAU SYNTHESIZE
   CRITICISM AND PREPARE
   QUESTIONS FOR PROPONENTS
   BY AUGUST 23

3. SEPTEMBER 4

   PROPONENTS BRING <u>WRITTEN</u>
   RESPONSES TO CRITICISM
   TO GEM-CAL MEETING
   AT SSCL

GEM council meeting Sept 5
Reconvene GEMCAL - Sep 6

4. THROUGH SEPTEMBER.

RESPONSES ARE DIGESTED, DISCUSSED, REVIEWED, ETC.

5. OCTOBER 2 (GEM-CAL MEET)

DECISIONS MADE

1. ULTRA HIGH RES EM VS. INTEGRATED CAL.

- GO FOR UHR-EM
- DEFER (MODEST R+D SUPPORT)
- DROP UHR-EM
- NO CHOICE

2. NARROW OPTIONS SUPPORTED

SO –

THIS MEETING SHOULD

- EXPAND OUR UNDERSTANDING OF THE OPTIONS, THEIR RISKS, THEIR LIMITATIONS, ETC

- DEFINE IN GENERAL THE R+D GOALS OF FY92

  WHAT DO WE NEED, GENERALLY TO PRODUCE PROPOSAL?

Physics Requirements to the Precisions of Electromagnetic calorimeter at SSC

Ren-yuan Zhu
Caltech

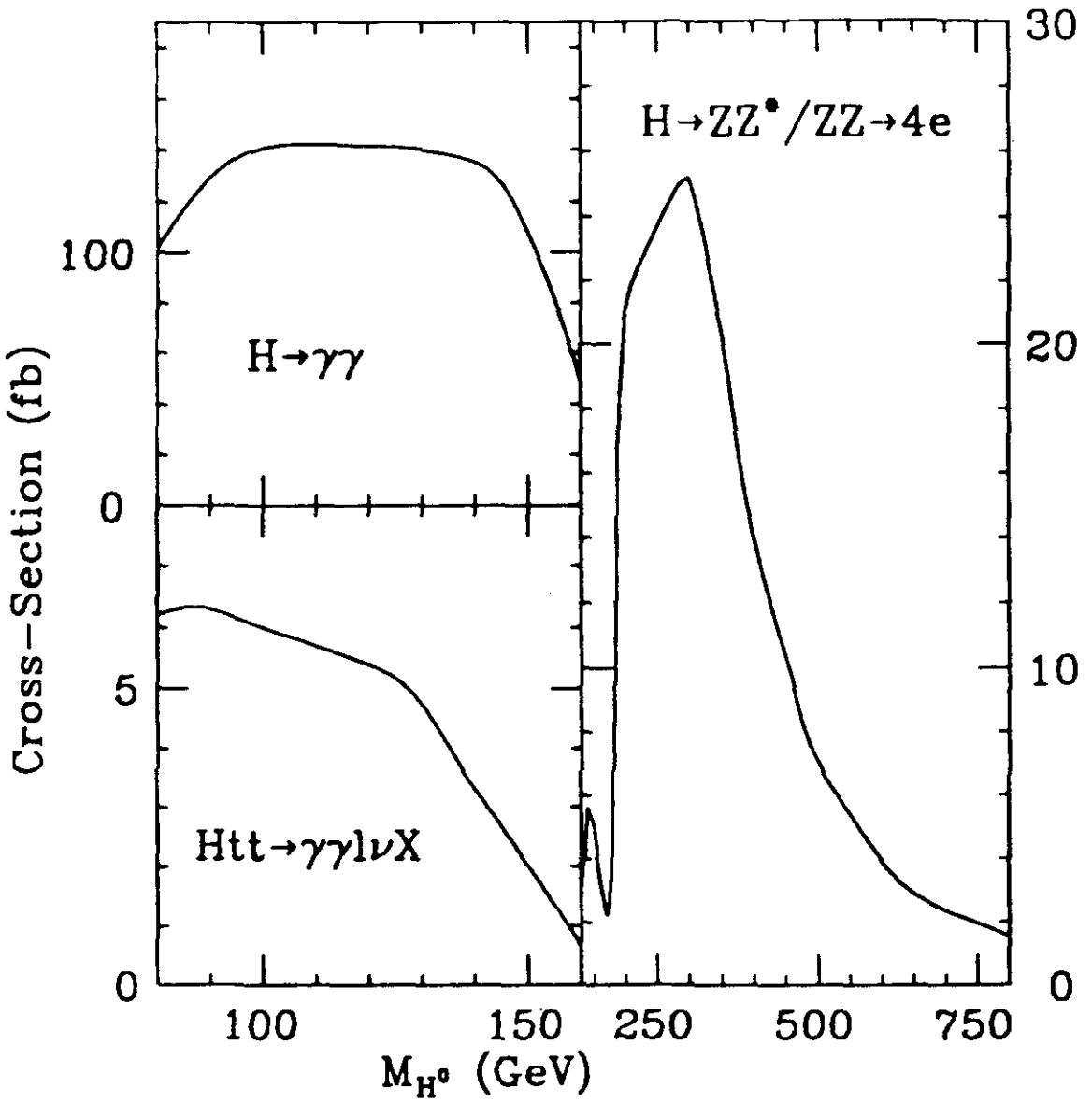
GEM Calorimeter Workshop

SSCL, August 8, 1991

- Physics Requirements on Precision of EMC:
  - $H \rightarrow \gamma\gamma$ Physics;
  - $Ht\bar{t} \rightarrow l\gamma\gamma$ Physics.
- Discussion on Performance of Precision EMC:
  - Energy Resolution;
  - Position resolution;
  - time Resolution.

Higgs Production at the SSC

PYTHIA5.5 (M_{top}=140 GeV)



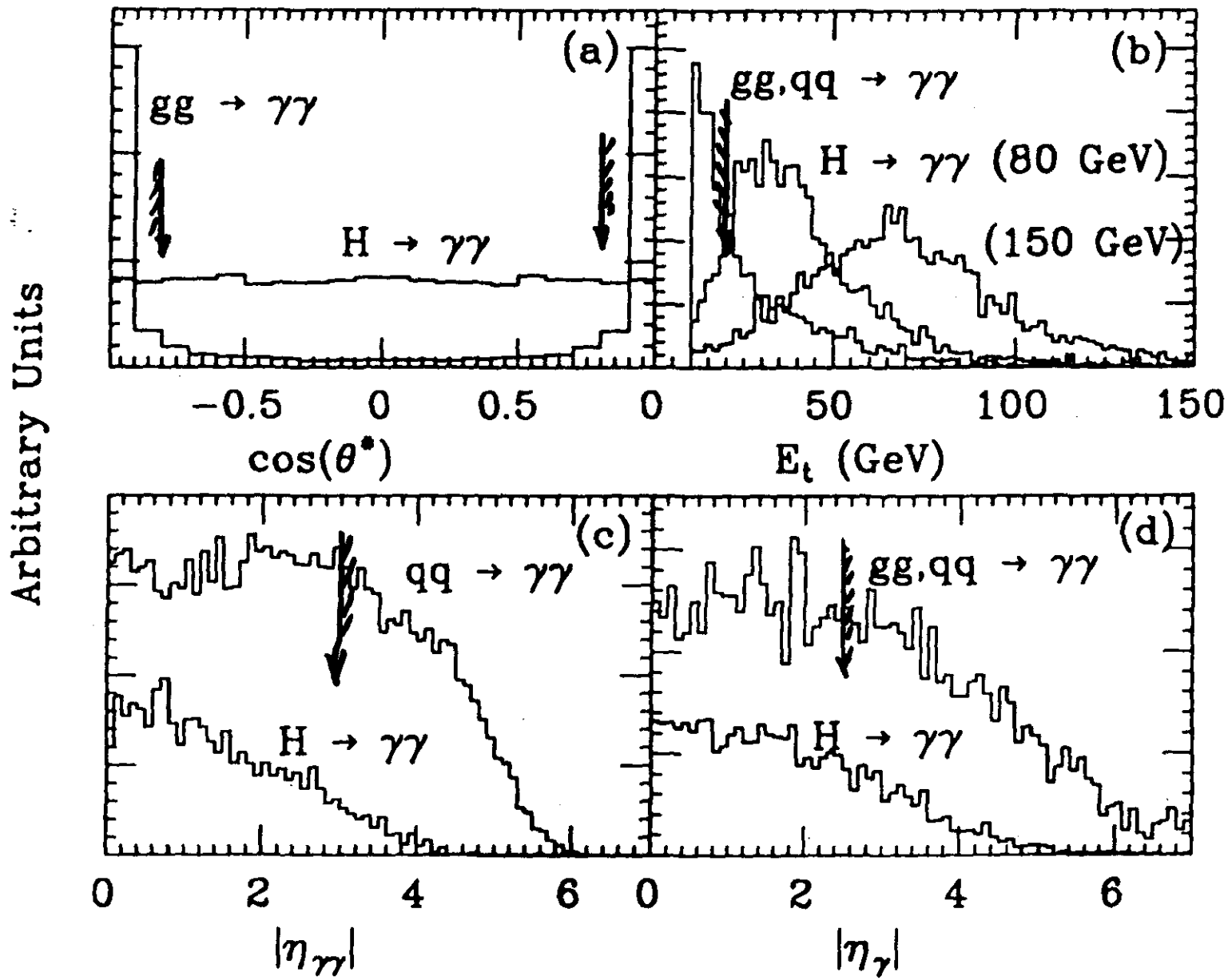
Production Cross-Section and Events/SSCY
Calculated with PYTHIA 5.5

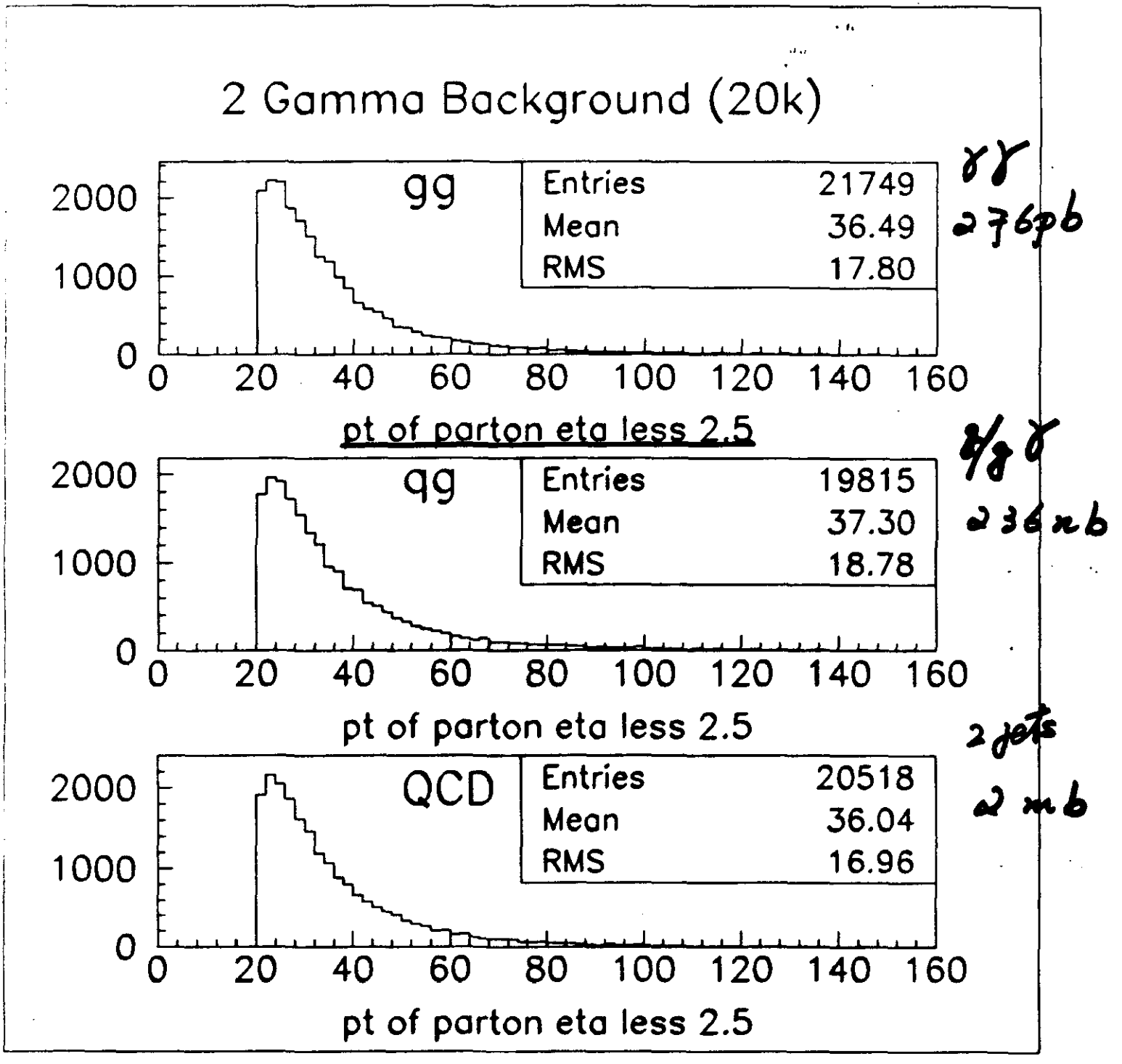
M_H(GeV)	$\sigma_{H(\gamma\gamma)}$	$N_{\gamma\gamma}$	$\sigma_{ttH(\gamma\gamma)}$	$N_{l\gamma\gamma}$	$\sigma_{H(4e)}$	N_{4e}
80	102fb	503	15.5fb	16		
90	124fb	610	15.6fb	24		
100	153fb	751	15.0fb	22		
120	193fb	949	13.5fb	20		
140	171fb	830	8.3fb	15	5.6fb	24
150	124fb	604	5.0fb	8	7.4fb	33
160	47.8fb	264	1.6fb	3	3.2fb	13
170					2.2fb	9
180					5.6fb	28
200					21.2fb	99
400					14.0fb	85
600					3.9fb	26
800					1.5fb	10

$H^0 \rightarrow \gamma\gamma$ Signal/Background

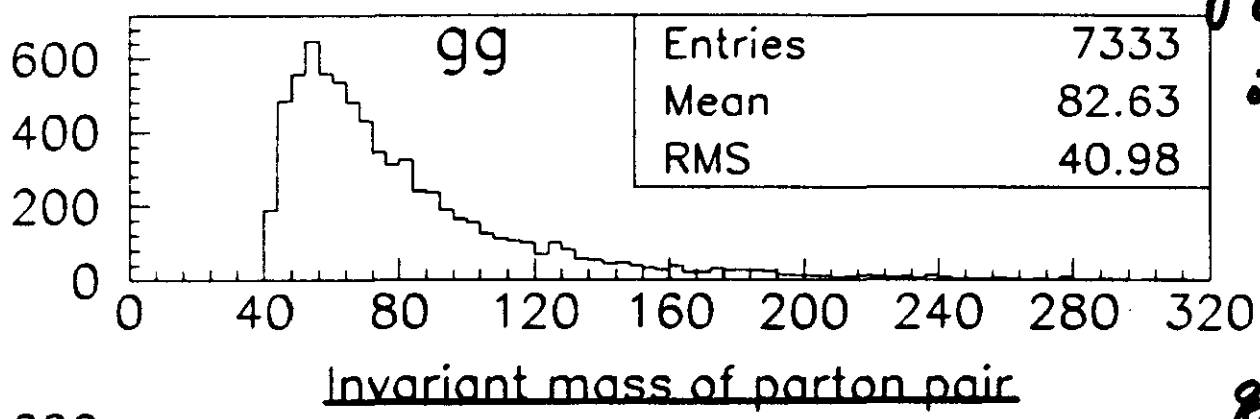
- Signal: 0.05–0.2 pb for $M_H \in (80,160)$GeV:
  - $|\eta_\gamma| < 2.5$;
  - $E_T > 20$ GeV;
  - $|cos\theta^*_\gamma| < 0.8 \Rightarrow$ reduce gg $\rightarrow \gamma\gamma$;
  - $|\eta_{\gamma\gamma}| < 3 \Rightarrow$ reduce qq $\rightarrow \gamma\gamma$.
- Direct Photon Production Background (gg$\rightarrow \gamma\gamma$ and qq $\rightarrow \gamma\gamma$):
  - Production x-section: 276 pb (198 and 78);
  - After selection with $M_{\gamma\gamma} > 70$ GeV: 43 pb;
- QCD Background: (2 Jets and $qg \rightarrow q\gamma$, $qq \rightarrow g\gamma$)
  - Production x-section: 2 mb and 236 nb;
  - Isolation cut:
    γ/jet $= 2 \times 10^{-4}$, γ^2/jet$^2 = 4 \times 10^{-8}$,
  - After isolation: 80 pb and 47 pb;
  - After selection with $M_{\gamma\gamma} > 70$ GeV: 38 pb and 18 pb.

$H \to \gamma\gamma$ selection

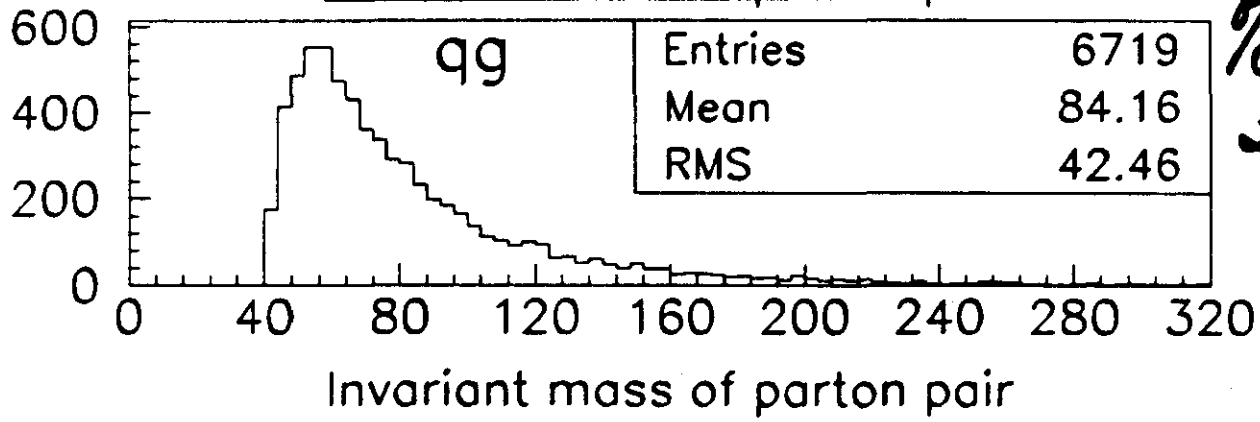



2 Gamma Background (20k)
gg
Entries 21749
Mean 36.49
RMS 17.80
2000
1000
0
0 20 40 60 80 100 120 140 160
pt of parton eta less 2.5
γγ
276pb
qg
Entries 19815
Mean 37.30
RMS 18.78
2000
1000
0
0 20 40 60 80 100 120 140 160
pt of parton eta less 2.5
q/g γ
236nb
QCD
Entries 20518
Mean 36.04
RMS 16.96
2000
1000
0
0 20 40 60 80 100 120 140 160
pt of parton eta less 2.5
2 jets
2 mb

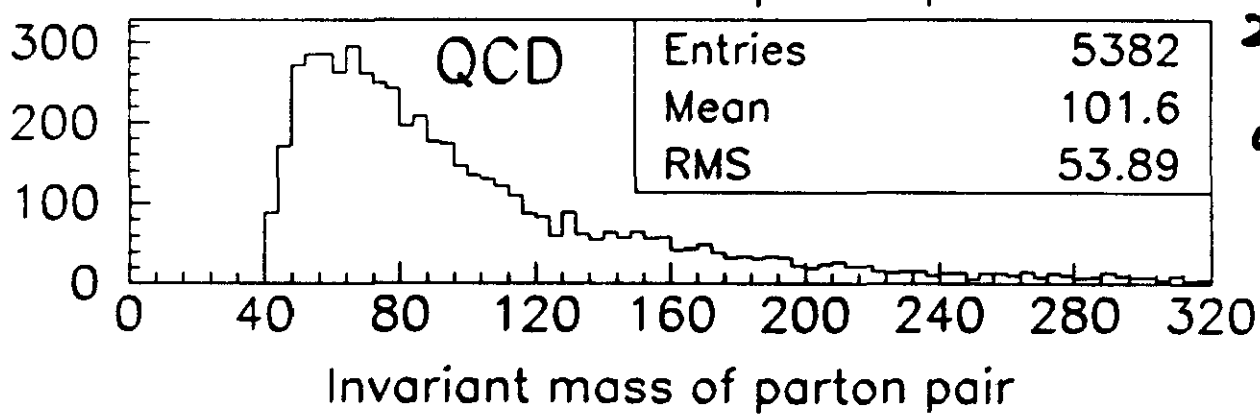
2 Gamma Background (20k)



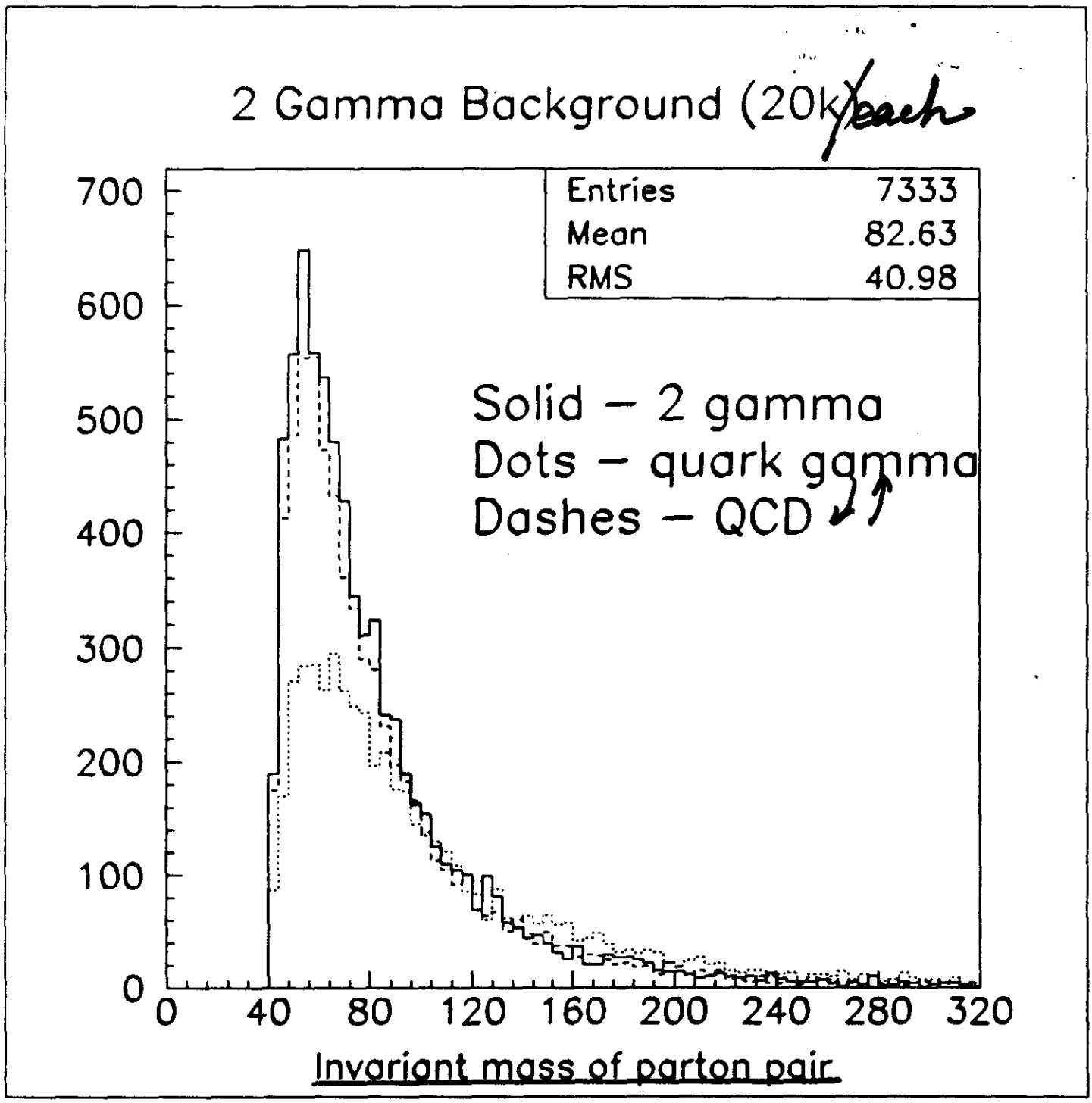
γγ
276pb



q/g γ
236nb



2 jets
2 mb


2 Gamma Background (20k/each
Entries 7333
Mean 82.63
RMS 40.98
Solid – 2 gamma
Dots – quark gamma
Dashes – QCD
700
600
500
400
300
200
100
0
0
40
80
120
160
200
240
280
320
Invariant mass of parton pair

Isolation Cut PYTHIA 5.5

- Generate QCD jets, deposit all EM energy and part of hadron energy (from GEANT) in calorimeter cells with parametrized shower spread. Record cell numbers hitted by charged track with 8 kG field.

- Search through all cells ($\Delta\eta \times \Delta\phi$=0.04 × 0.04) to identify all cells hit by photons only, find E_T^{cell}.

- Charge Veto: if there is a charged track hitting neighboring 8 cells ⇒ **Reject**;

- Define the sum of E_T^{cell}'s of these 9 cells ($\sum_{9cells} E_T^{cell}$) as the E_T^{photon};

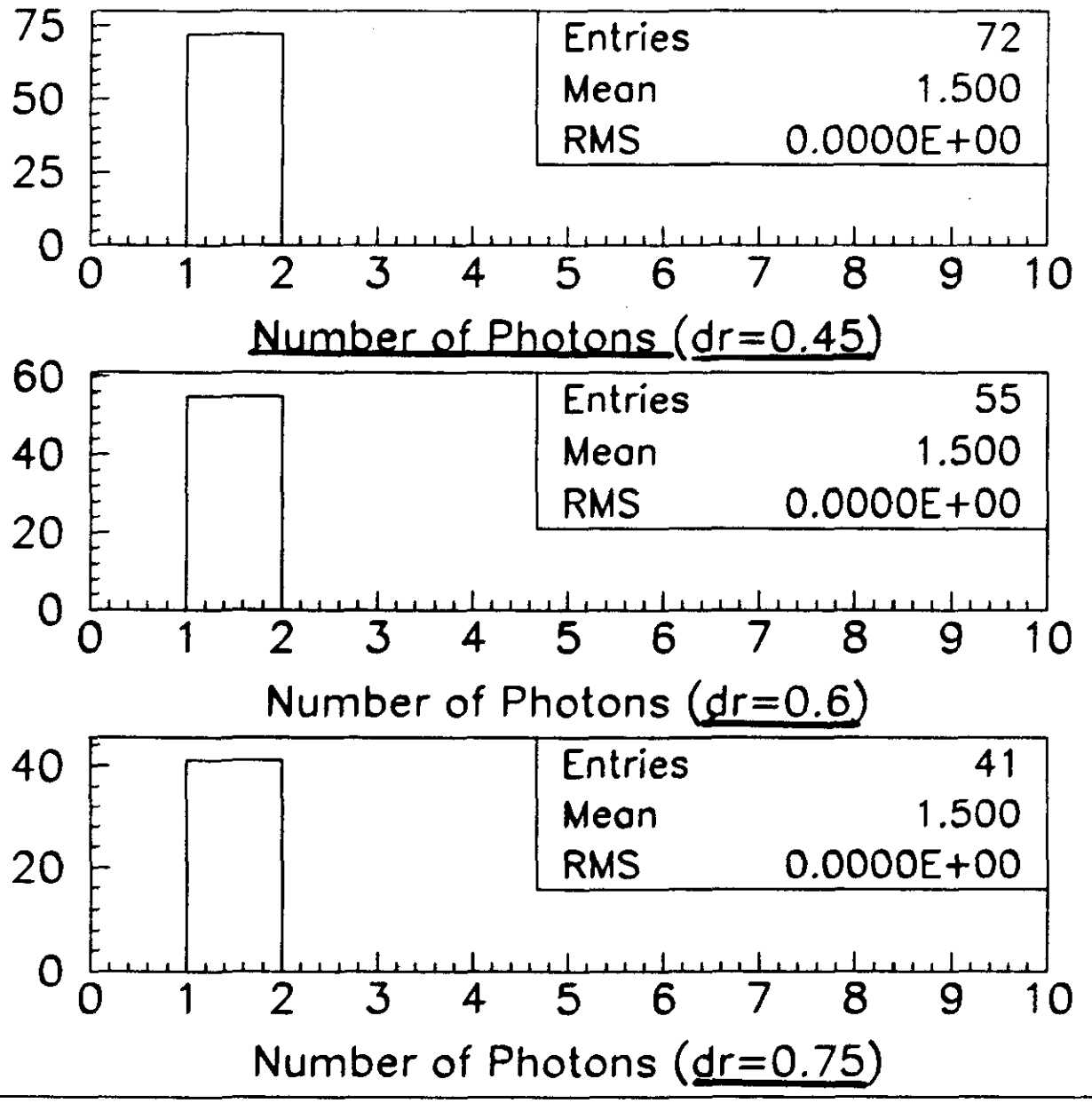
- Isolation Veto: if the sum of the transverse energies in a cone of radius R ($R=\sqrt{\Delta\eta^2+\Delta\phi^2}$), excluding the E_T^{photon}, is larger than 10% of the E_T^{photon} plus an isolation energy cut (E_T^{cut}):

$$\sum_{r<R} E_T - E_T^{photon} > (E_T^{cut} + 0.1 E_T^{photon}) \Rightarrow \textbf{Reject};$$

- Continue for all cells, define the probability (F) of a jet faking an isolated photon as the number of cells passing all above cuts normalized to the number of jets generated.

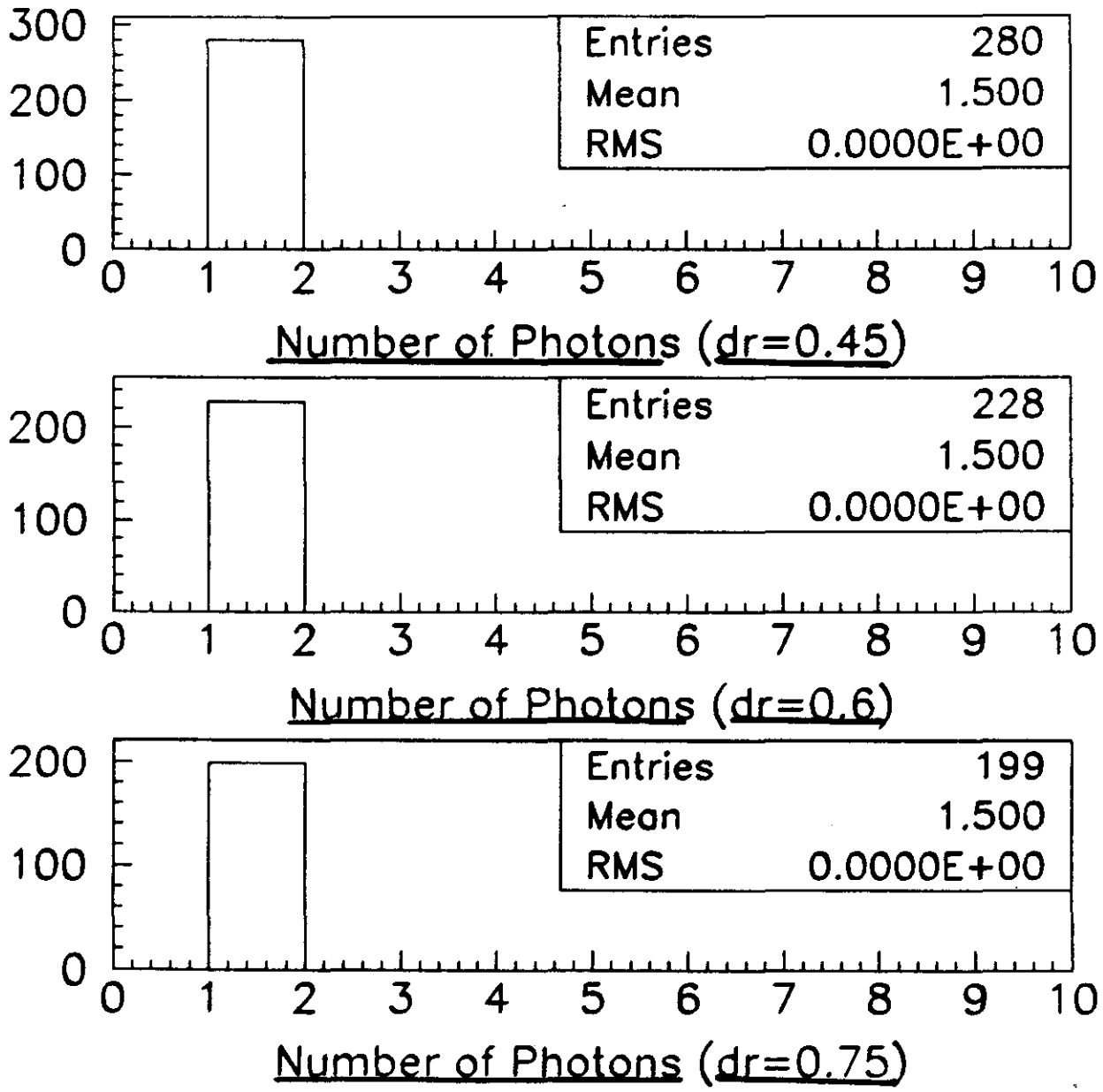
100 K events

QCD Background(5GeV cut) 2.0 mb



100K events

QCD Background (15GeV) 2.0 mb



Isolation Cut (Cont.)

- Isolation Cut Rate (10^{-4}):

E_T^{cut}	R=0.45	R=0.60	R=0.75
5 GeV	3.6	2.8	2.0
10 GeV	9.5	7.8	6.2
15 GeV	14	11	9.9
20 GeV	19	16	15

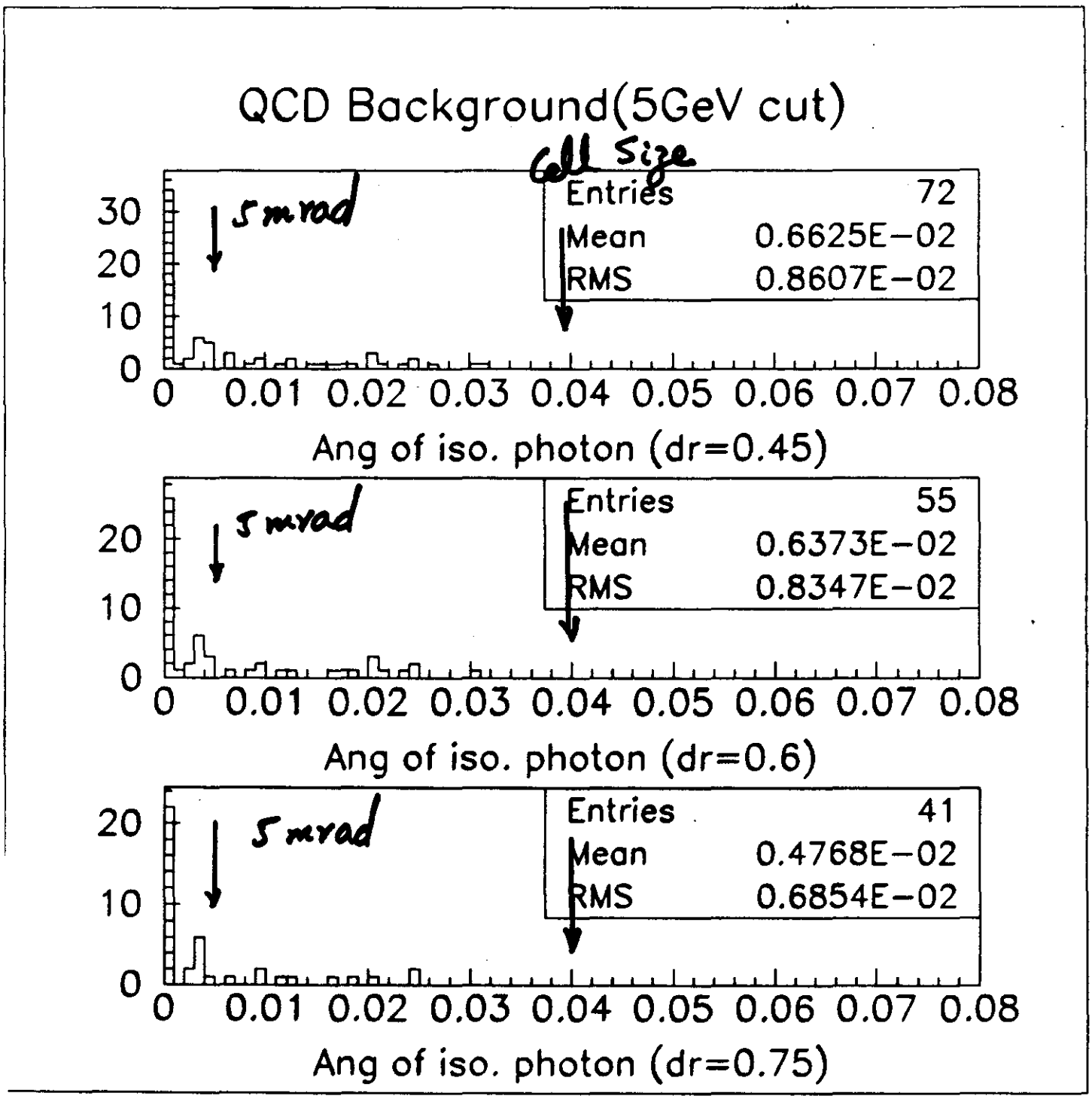
- Total QCD Background Cross-Section (pb): $M_{\gamma\gamma} > 70$ Ge

E_T^{cut}	R=0.45	R=0.60	R=0.75
5 GeV	160	100	56
10 GeV	940	650	420
15 GeV	2000	1200	1020
20 GeV	3600	2600	2300

While Direct photon $q\bar{q}/gg \to \gamma\gamma$

43 pb for $M_{\gamma\gamma} > 70$ GeV

Max. Angle of γ's in take isolated photon



Maximum Possible

Potential Rejection with position detector

R_{cut}	0.45	0.6	0.75
< 1 mrad	53 %	53 %	46 %
< 2 mrad	51 %	51 %	46 %
< 5 mrad	33 %	31 %	24 %

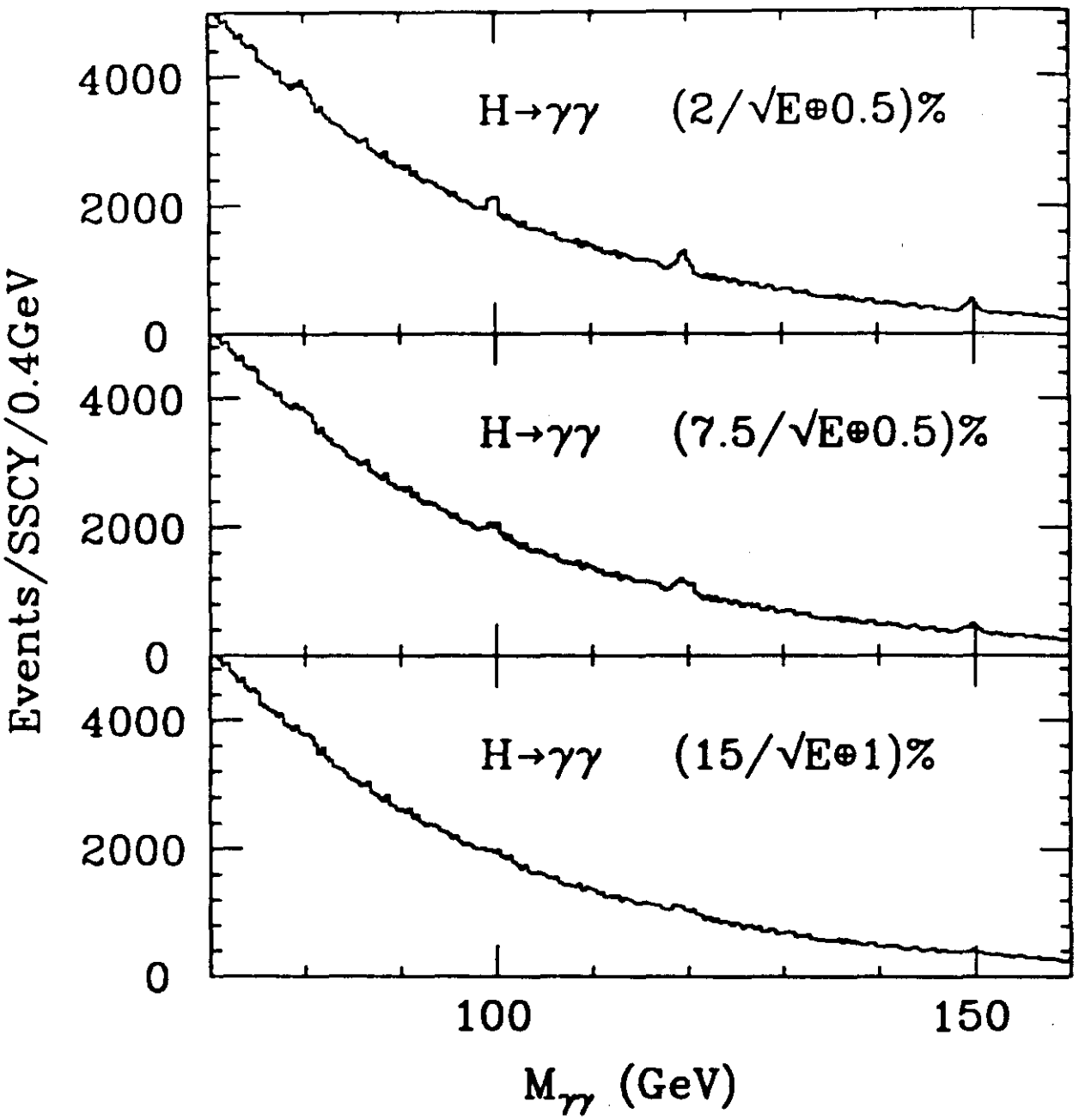
For $E_T^{cut} = 5$ GeV

up to 50% QCD Background

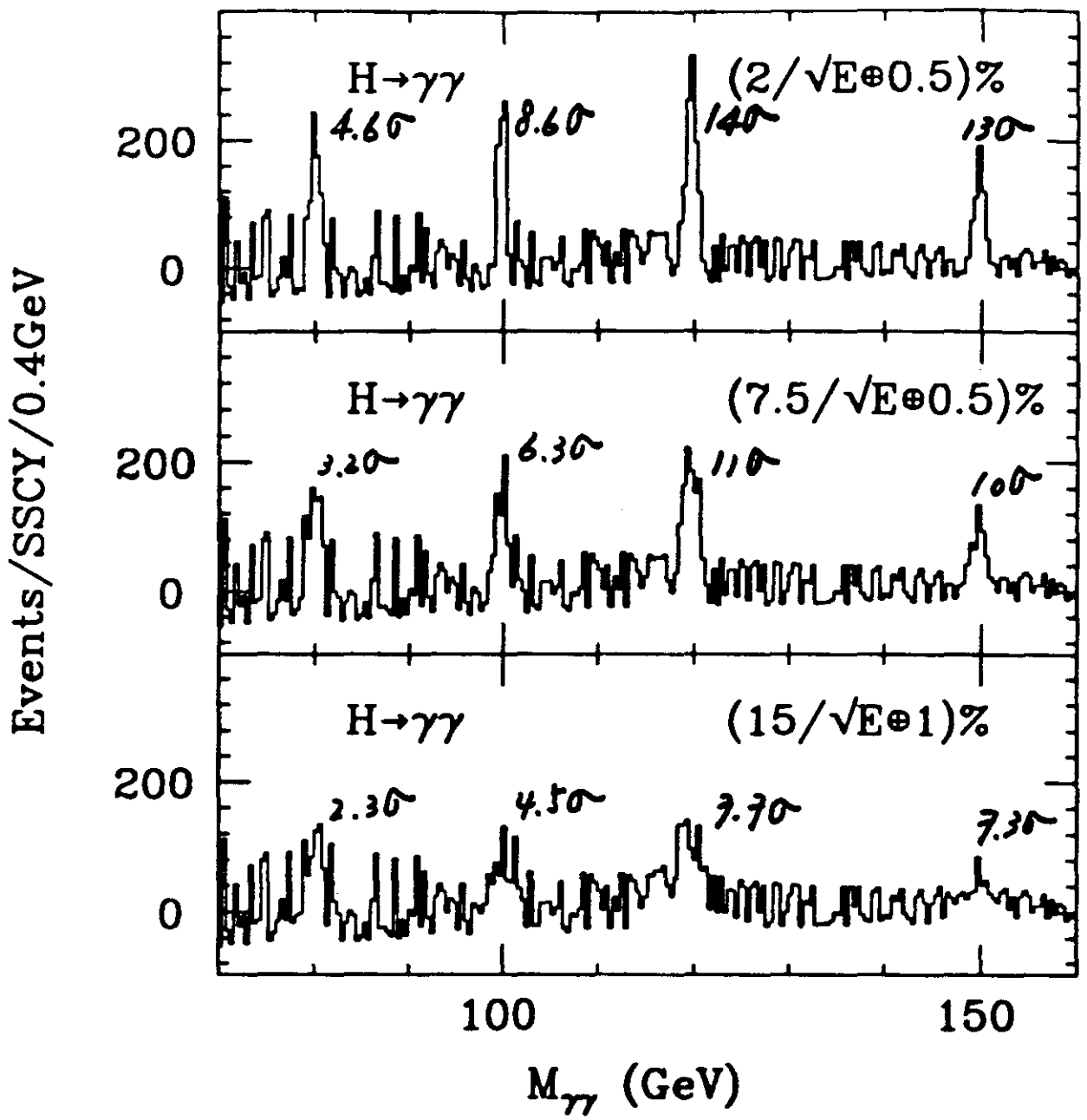
may be rejection with position detector inside EMC. (1 mrad precision

For $E_T^{cut} = 10$ GeV 65%

$H \to 2\gamma$ with Direct Photon Background



Higgs → γγ Detection with D-L*



$H^0 \rightarrow \gamma\gamma$

Production Cross-Section and Events/(SSC Year)
Calculated with PYTHIA 5.5 and M_{top} = 140 GeV

For a **Fast** EM Calorimeter with
$(2/\sqrt{E} \oplus 0.5)$ % Energy Resolution,
1 mm Position Resolution at r = 75 cm
and 0.5 mm Z_{vetex} Resolution

M_H(GeV)	$\sigma_{\gamma\gamma}$(fb)	$\sigma_{M_{\gamma\gamma}}$(GeV)	N_B(k)	N_S	$S/\sqrt{N_B}$
80	102	0.34	6.0	352	4.6
90	124	0.37	4.8	427	6.1
100	153	0.40	3.7	526	8.6
120	193	0.45	2.1	664	14
140	171	0.53	1.3	581	16
150	124	0.58	1.0	423	13
160	47.8	0.65	0.8	168	5.9

$H^0 \rightarrow \gamma\gamma$

Production Cross-Section and Events/(SSC Year)
Calculated with PYTHIA 5.5 and M_{top} = 140 GeV

For a **Fast** EM Calorimeter with
$(7.5/\sqrt{E} \oplus 0.5)$ % Energy Resolution,
1 mm Position Resolution at r = 75 cm
and 0.5 mm Z_{vetex} Resolution

M_H(GeV)	$\sigma_{\gamma\gamma}$(fb)	$\sigma_{M_{\gamma\gamma}}$(GeV)	N_B(k)	N_S	$S/\sqrt{N_B}$
80	102	0.66	12	352	3.2
90	124	0.70	9.2	427	4.5
100	153	0.73	6.8	526	6.3
120	193	0.77	3.7	664	11
140	171	0.89	2.2	581	12
150	124	0.95	1.7	423	10
160	47.8	1.1	1.3	168	4.7

$H^0 \rightarrow \gamma\gamma$

Production Cross-Section and Events/(SSC Year)
Calculated with PYTHIA 5.5 and M_{top} = 140 GeV

For a **Fast** EM Calorimeter with
$(15/\sqrt{E} \oplus 1.0)$ % Energy Resolution
1 mm Position Resolution at r = 75 cm
and 0.5 mm Z_{vetex} Resolution

M_H(GeV)	$\sigma_{\gamma\gamma}$(fb)	$\sigma_{M_{\gamma\gamma}}$(GeV)	N_B(k)	N_S	$S/\sqrt{N_B}$
80	102	1.3	24	352	2.3
90	124	1.4	18	427	3.2
100	153	1.45	14	526	4.5
120	193	1.5	7.3	664	7.7
140	171	1.7	4.2	581	8.9
150	124	1.9	3.3	423	7.3
160	47.8	2.0	2.5	168	3.4

$pp \rightarrow Ht\bar{t}X \rightarrow \gamma\gamma l\nu X$

Production Cross-Section and Events/(SSC Year)
PYTHIA 5.5 (M_{top} = 140 GeV)

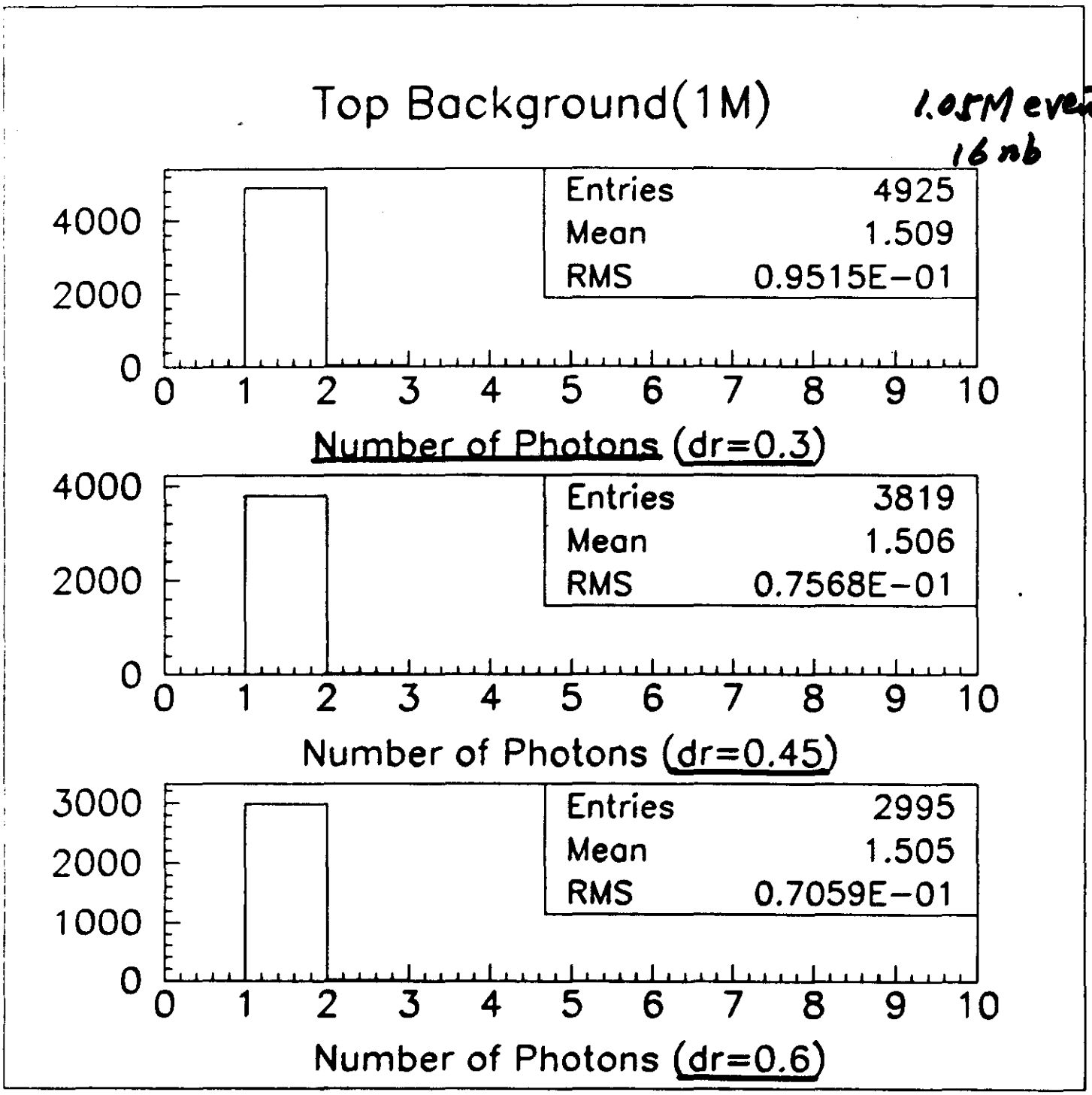
M_H(GeV)	$\sigma_{\gamma\gamma t\bar{t}X}$(fb)	$N_e(0.3)$	$N_e(0.45)$	$N_e(0.6)$
80	15.5	16	9.8	6.7
90	15.6	24	16	12
100	15.0	22	15	11
120	13.5	20	15	11
140	8.3	15	9	4
150	5.0	8	6	4
160	1.6	3	2	0.5

- Selection:
  - $|\eta_\gamma| < 2.5$, $P_T^\gamma > 20$ GeV
  - $|\eta_l| < 2.5$, $P_T^l > 20$ GeV
  - isolation cut: R_{cut} = 0.3, 0.45 and 0.6.

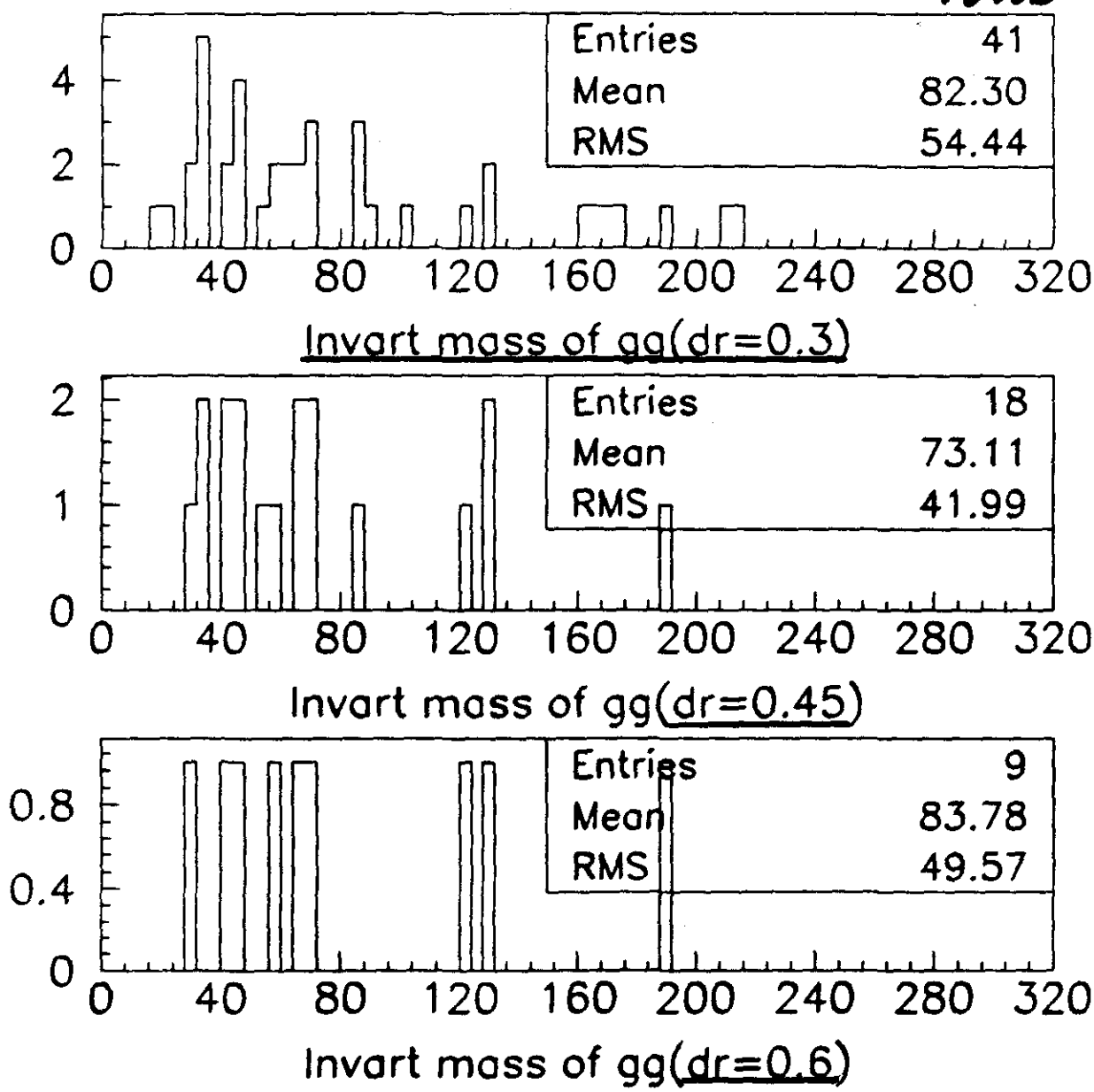
    $$\sum_{R<R_{cut}} E_T - E_T^{photon} > (5GeV + 0.1E_T^{photon}) \Rightarrow \text{Reject}$$

  - <u>Major background $t\bar{t}$ itself</u>.

Isolation Cut : 5 GeV



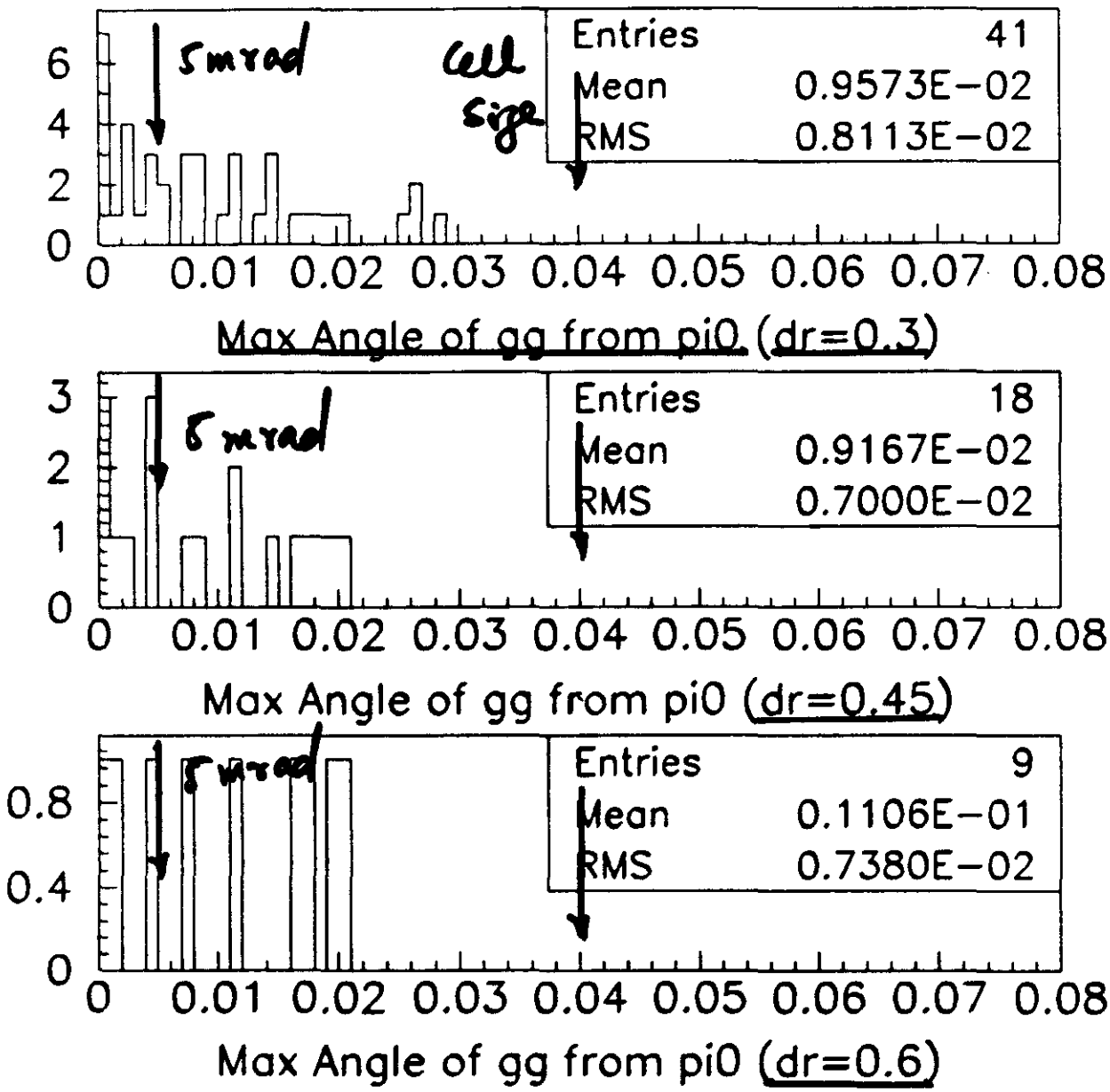
Top.Background(1M) 88 events from 1.05 M gen. 16 nb



Max. Opening angle of γ's in iso. photo

1.05M events
16 nb

Top Background(1M)



$pp \to Ht\bar{t}X \to \gamma\gamma l\nu X$ (Cont.)

- $t\bar{t}$ background calculation with 1.05M top pair events:

R_{cut}	0.3	0.45	0.6
$Rate_{\gamma}$ (10^{-4})	8.2	6.4	5.0
$Rate_{\gamma\gamma}$ $M_{\gamma\gamma} > 70$ GeV (10^{-5})	2.3	1.3	0.4
X-section (fb)	370	210	64
Events/SSCY	3700	2100	640
	5	5	5

- Ability of distiguashing π^0 vs. 2γ:
  - 1 mrad: reject 83%;
  - 2 mrad: reject 78%.
  - 5 mrad: reject 63%.

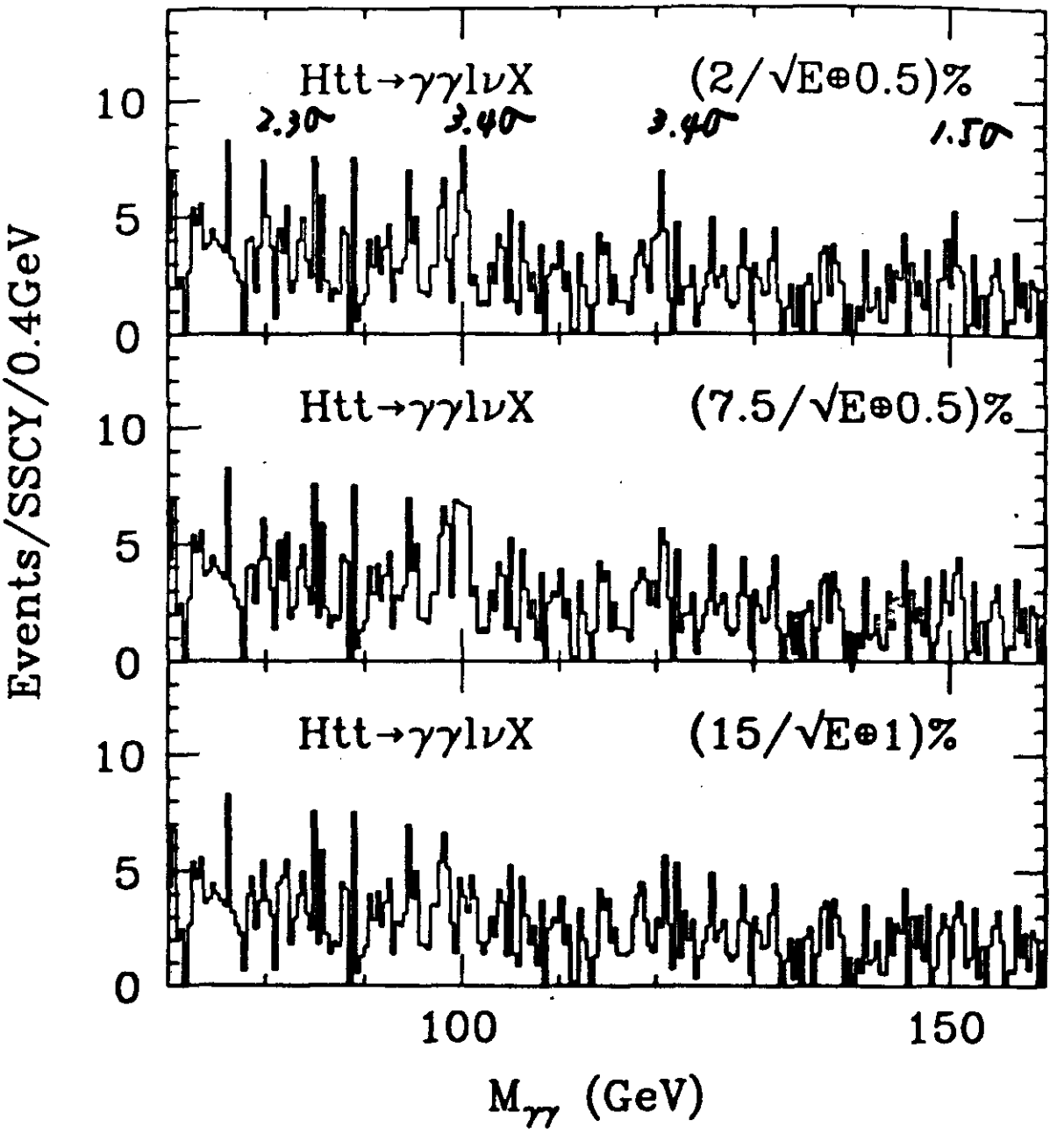
  } might be able achieved.

  background

Detailed study is under way. This is the maximum one can achieve.

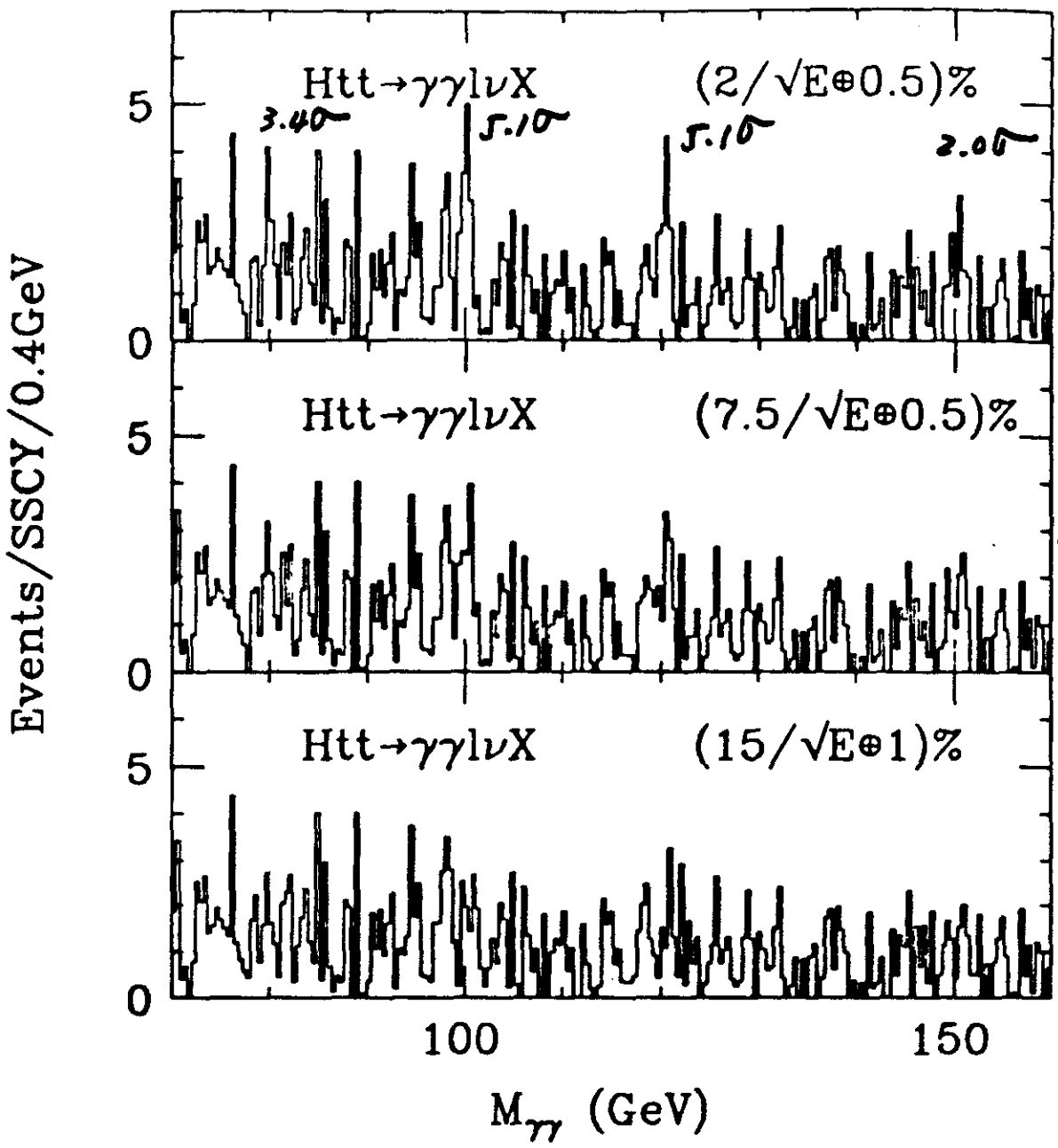
$Htt \to \gamma\gamma l X$ ($l = e/\mu$)

$R_{cut} = 0.45$



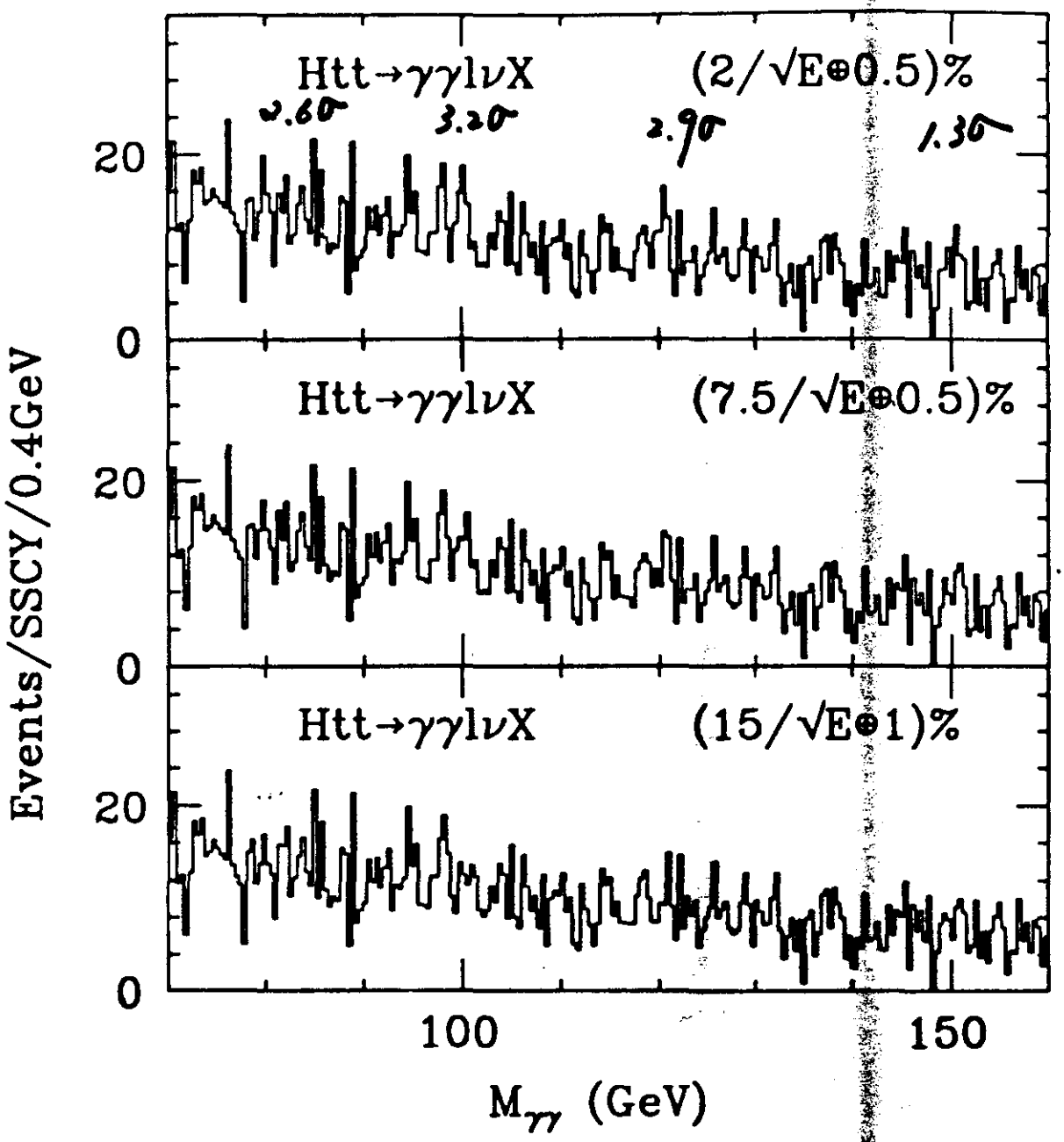
$Htt \to \gamma\gamma l X \quad (l = e/\mu)$

$R_{cut} = 0.6$

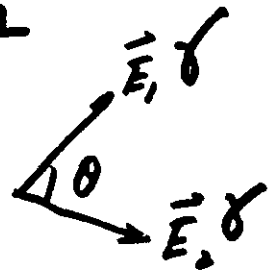


$Htt \to \gamma\gamma l X$ $(l = e, \mu)$

$R_{cut} = 0.3$



Physics Requirements on EMC for $pp \to H + X \to \gamma\gamma + X$ Detection



$$\frac{\delta M}{M} = \frac{1}{2}\sqrt{(\frac{\delta E_1}{E_1})^2 + (\frac{\delta E_2}{E_2})^2 + (cot\frac{\theta}{2}\delta\theta)^2}$$

- Best possible energy resolution:

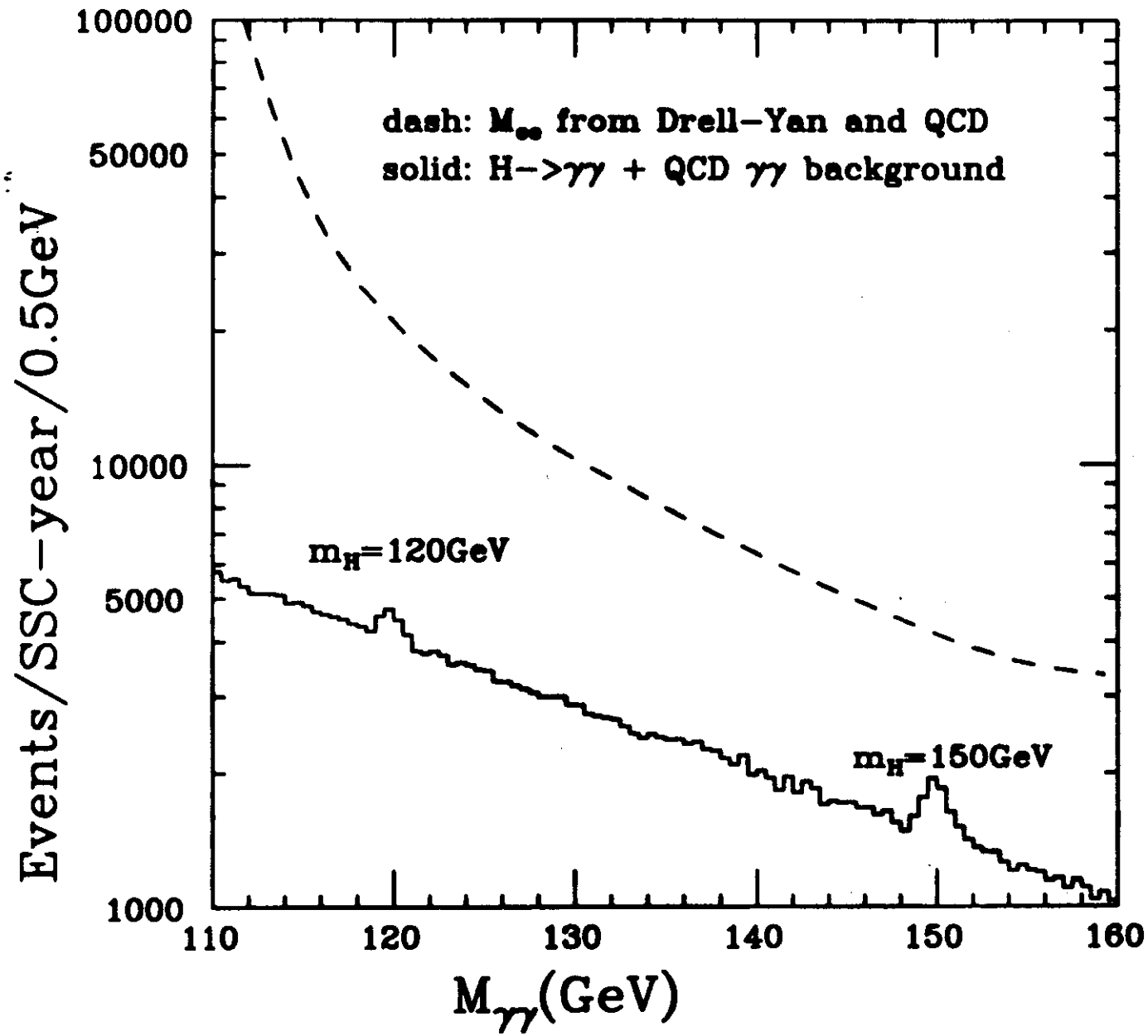
$$\frac{\delta E}{E} = \frac{\mathbf{a\%}}{\sqrt{E}} \oplus \mathbf{b\%}$$

  - **a** < 3, **b** < 0.5 needed.

- Good position resolution:
  - better than 2 × r(cm)/75 mm resolution for a calorimeter consisting of a barrel with an inner radius of r and two endcaps at z=±2r, and a central tracker with adequate momentum resolution, to determine photon vectors at the SSC;
  - use built-in position detectors to measure photon vectors at the LHC.

- Excellent time resolution: gate in a single beam crossing to reduce the pile-up (multi vertex), and to apply isolation.

- Need central tracker to reject electron pair background: 2 Hz.


dash: $M_{\gamma\gamma}$ from Drell–Yan and QCD
solid: H–>$\gamma\gamma$ + QCD $\gamma\gamma$ background
m_H=120GeV
m_H=150GeV
100000
50000
10000
5000
1000
110
120
130
140
150
160
Events/SSC–year/0.5GeV
$M_{\gamma\gamma}$(GeV)

Time Factor in Discovering an 80 GeV Higgs

As function of energy resolution (**a** and **b**)

a	1.0	2.0	3.0	5.0	7.5	10	15
b=0	0.33	0.48	0.68	1.1	1.6	2.2	3.3
b=.25	0.53	0.63	0.83	1.2	1.7	2.2	3.3
b=0.5	0.94	**1.0**	1.07	1.4	1.8	2.3	3.4
b=.75	1.3	1.4	1.5	1.7	2.1	2.6	3.6
b=1.0	1.8	1.8	1.9	2.1	2.4	2.9	3.7

- Note: Different detectors have different background rate. This table is for detectors with the same background rate.

Energy Resolution of Electromagnetic Calorimeter

$$(\frac{\sigma}{E})^2 = (\frac{\mathbf{a_0}}{E})^2 + (\frac{\mathbf{a_1}}{\sqrt{E}})^2 + \mathbf{b}^2$$

- $\mathbf{a}_0$: Electrical noise, sum over few Moliere radii.
- $\mathbf{a}_1$: Photon statistics.
- $\mathbf{b}$: Constant term: $\mathbf{b}^2 = \mathbf{b}_G^2 + \mathbf{b}_n^2 + \mathbf{b}_C^2$
  - $\mathbf{b}_G$ (Geometry effect): shower leak (front, side and rear) and inactive material between cells.
  - $\mathbf{b}_n$ (Physics noise): light collection uniformity etc.
  - $\mathbf{b}_C$ (Intercalibration error): 0.4% is the best for a large system?

L3 Experience and L* Design:

$$\frac{2\%}{\sqrt{E}} \oplus 0.5\%$$

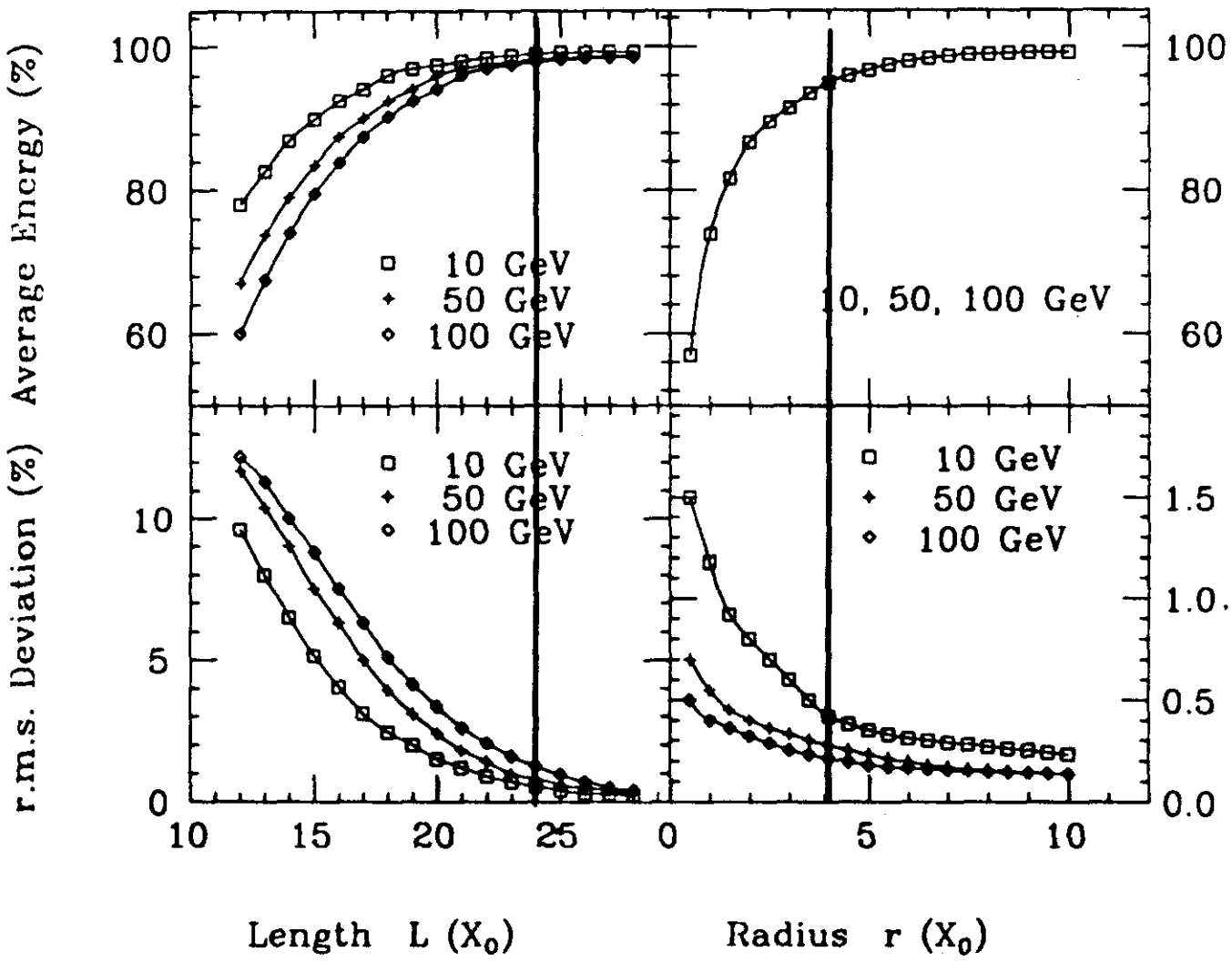
Energy Resolution of EMC (Cont.)

- Sampling Calorimeters:
  - Good Dynamic Range has been achieved for a fine-sampling device, such as ARGUS.
  - The resolution, however, is not enough to do $\gamma\gamma$ physics: best **a** = 7.5; **b** = ???, presumably 1.
- Homogeneous Calorimeters:
  - L3 experience: be tter than $2\%/\sqrt{E} \oplus 0.5\%$ at test beam for 8000 crystals.
  - Monte Carlo simulation result is promising, such as BaF_2.
- The **key issue**: Keep intercalibration term down at 0.4% level for a large system: wait and see L3 RFQ calibration experience.

Energy Resolution of EMC (Cont.)

- a_0: ~2000 electrons/channel when sum 9 channels;
- a_1: $\sim 1\%/\sqrt{E} \Rightarrow >$ 10,000 p.e./GeV;
- **b**: Constant term: $\mathbf{b}^2 = \mathbf{b}_G^2 + \mathbf{b}_n^2 + \mathbf{b}_C^2$
  - $\mathbf{b}_G$ (Geometry effect):
    - length > 24 r.l.;
    - proper lateral segmentation: 0.04 × 0.04 for the SSC and 0.02 × 0.02 for the LHC;
    - Minimum dead material inside calorimeter.
  - $\mathbf{b}_n$ (Physics noise):
    - Good light uniformity along the EMC cell axis.
  - $\mathbf{b}_C$ (Intercalibration error):
    - Need a good calibration, such as RFQ for high energy calibration: 0.4% seems feasible; and/or
    - MIP calibration.

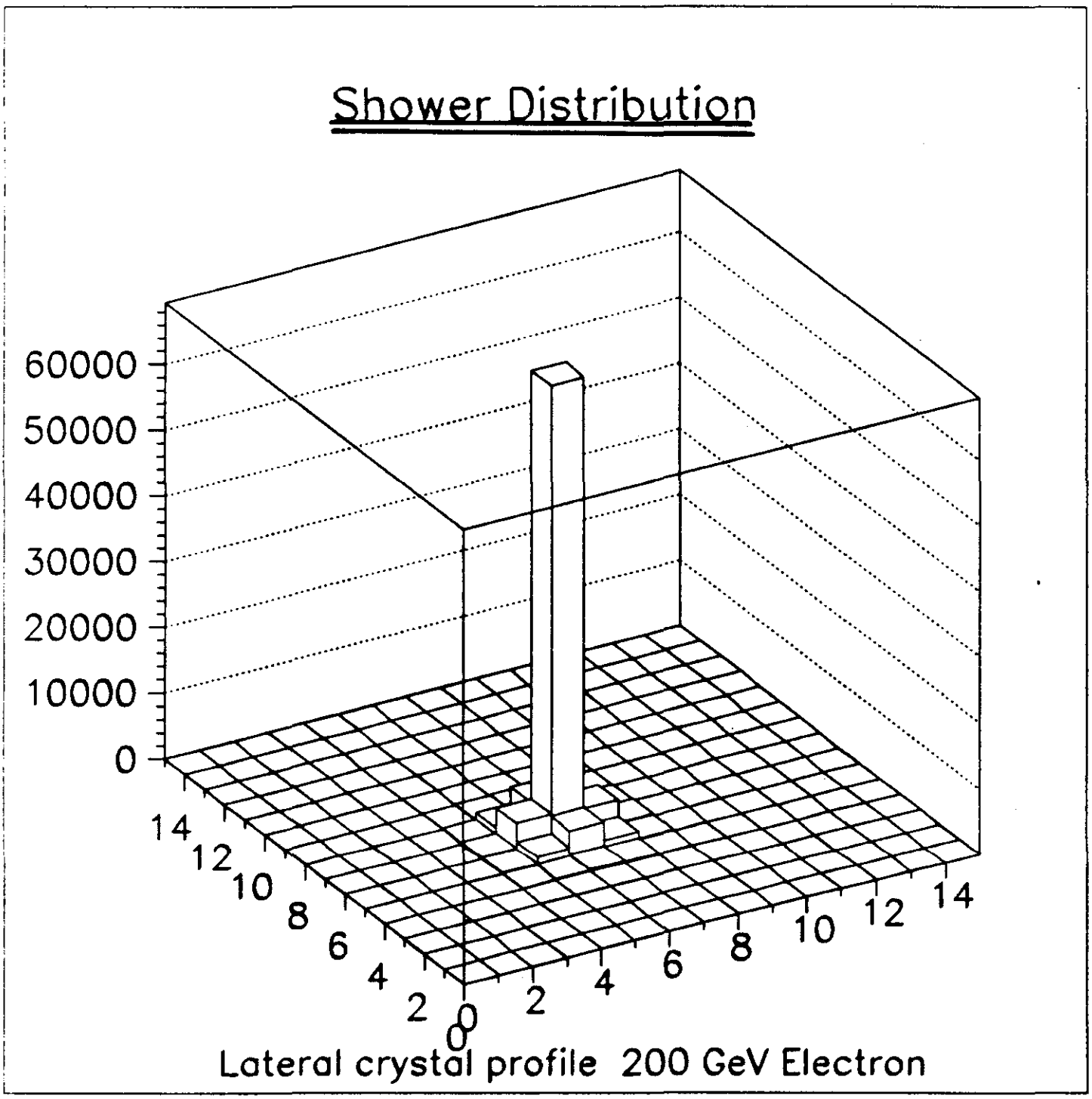
Geant Simulation



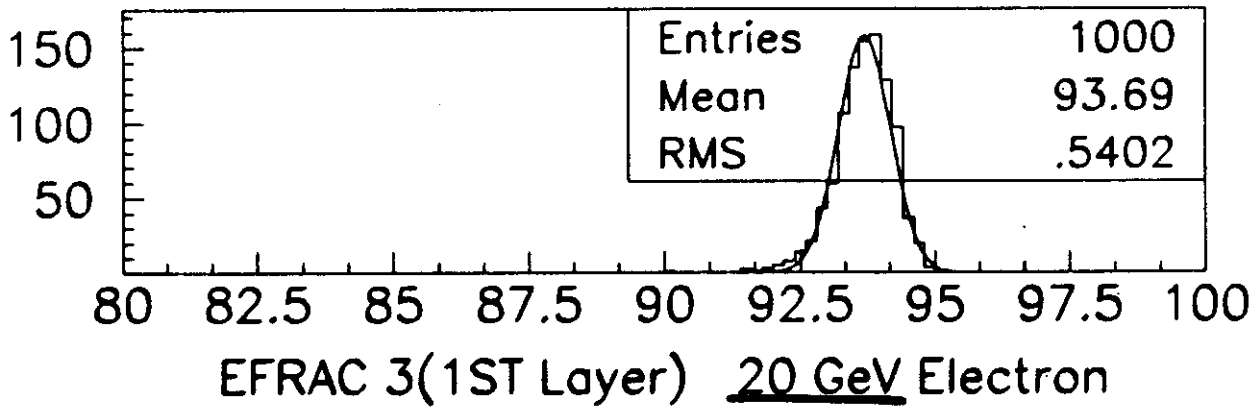
GEANT SIMULATION
Fraction Energy Deposited in BaF_2 with Deviated Light Uniformity

- Number of BaF_2 crystals: 11 x 11
- BaF_2 Crystal length: 50 cm
- Front (rear) face of BaF_2 :
  3 cm x 3 cm (5 cm x 5 cm)
- Carbon fiber wall thickness between any two crystal faces: 0.025 cm
- Particle is hitting over the front face of central BaF_2 crystal.
- One centimeter Aluminium placed just before the crystals and two 0.5 cm Aluminium placed between track origin and midway point to crystals (i.e., total 2 cm Al, whose $X_0 = 9$ cm)
- No magnetic field.
- Light yield response (Y) is parametrized with deviation (δ):

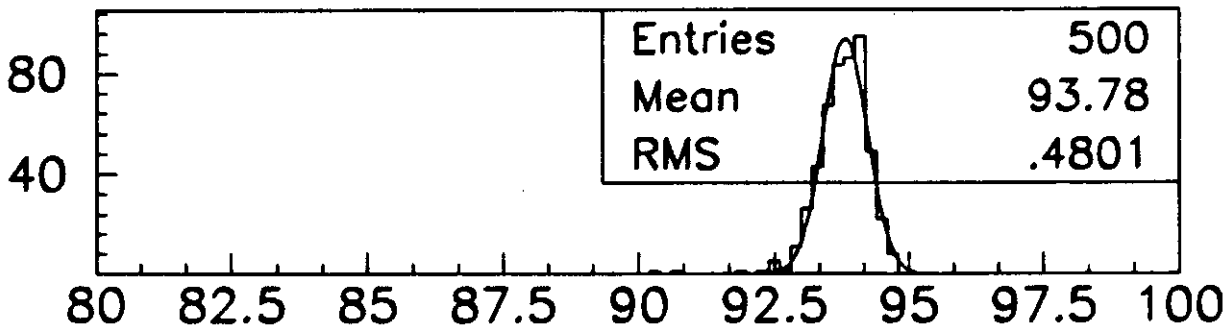
$$Y = Y_{25}[1 + \delta(Z/25 - 1)]$$


Shower Distribution
60000
50000
40000
30000
20000
10000
0
14
12
10
8
6
4
2
0
0
2
4
6
8
10
12
14
Lateral crystal profile 200 GeV Electron

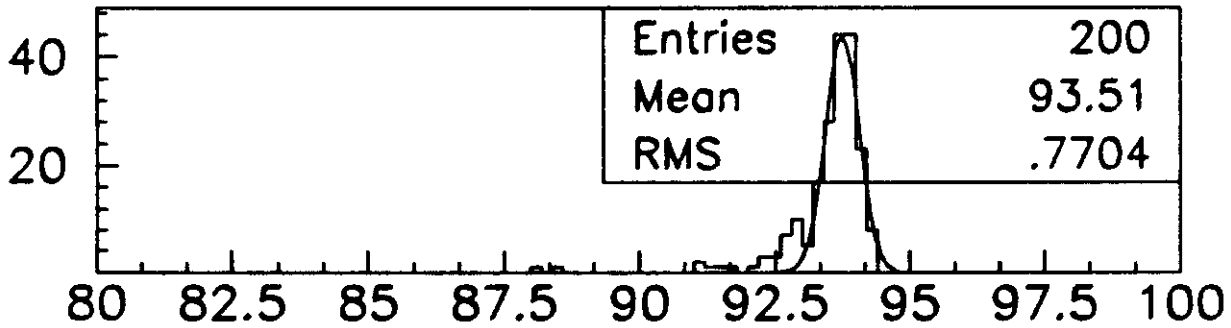
Energy Fraction in 3x3 Crystals



EFRAC 3(1ST Layer) 20 GeV Electron



EFRAC 3(1ST Layer) 50 GeV Electron



EFRAC 3(1ST Layer) 500 GeV Electron

Fraction Energy Deposited in BaF_2 with Deviated Light Uniformity

$\delta = 0\%$

E(GeV)	10	20	50	100	200	500
NEVT	1000	1000	500	500	500	200
1 x 1	71.0	72.5	73.5	74.0	74.4	74.9
(σ)	(4.2)	(4.2)	(5.5)	(4.4)	(3.8)	(3.4)
3 x 3	93.5	93.7	93.8	93.7	93.8	93.5
(σ)	(.63)	(.49)	(.41)	(.36)	(.34)	(.32)
5 x 5	97.2	97.3	97.3	97.1	97.0	96.7
(σ)	(.43)	(.32)	(.30)	(.31)	(.30)	(.29)
7 x 7	98.4	98.4	98.3	98.2	98.0	97.6
(σ)	(.35)	(.29)	(.26)	(.47)	(.33)	(.39)

Fraction Energy Deposited in BaF_2 with Deviated Light Uniformity

$\delta = 5\%$

E(GeV)	10	20	50	100	200	500
NEVT	1000	1000	500	500	500	200
1 x 1	69.6	71.2	72.5	73.2	73.8	74.5
(σ)	(4.0)	(4.2)	(3.9)	(4.3)	(3.9)	(3.6)
3 x 3	92.0	92.3	92.7	92.9	93.2	93.2
(σ)	(.76)	(.62)	(.53)	(.47)	(.38)	(.31)
5 x 5	95.6	95.9	96.2	96.3	96.5	96.4
(σ)	(.51)	(.43)	(.36)	(.29)	(.27)	(.25)
7 x 7	96.8	97.1	97.3	97.4	97.5	97.4
(σ)	(.41)	(.37)	(.30)	(.20)	(.26)	(.35)

Fraction Energy Deposited in BaF_2 with Deviated Light Uniformity

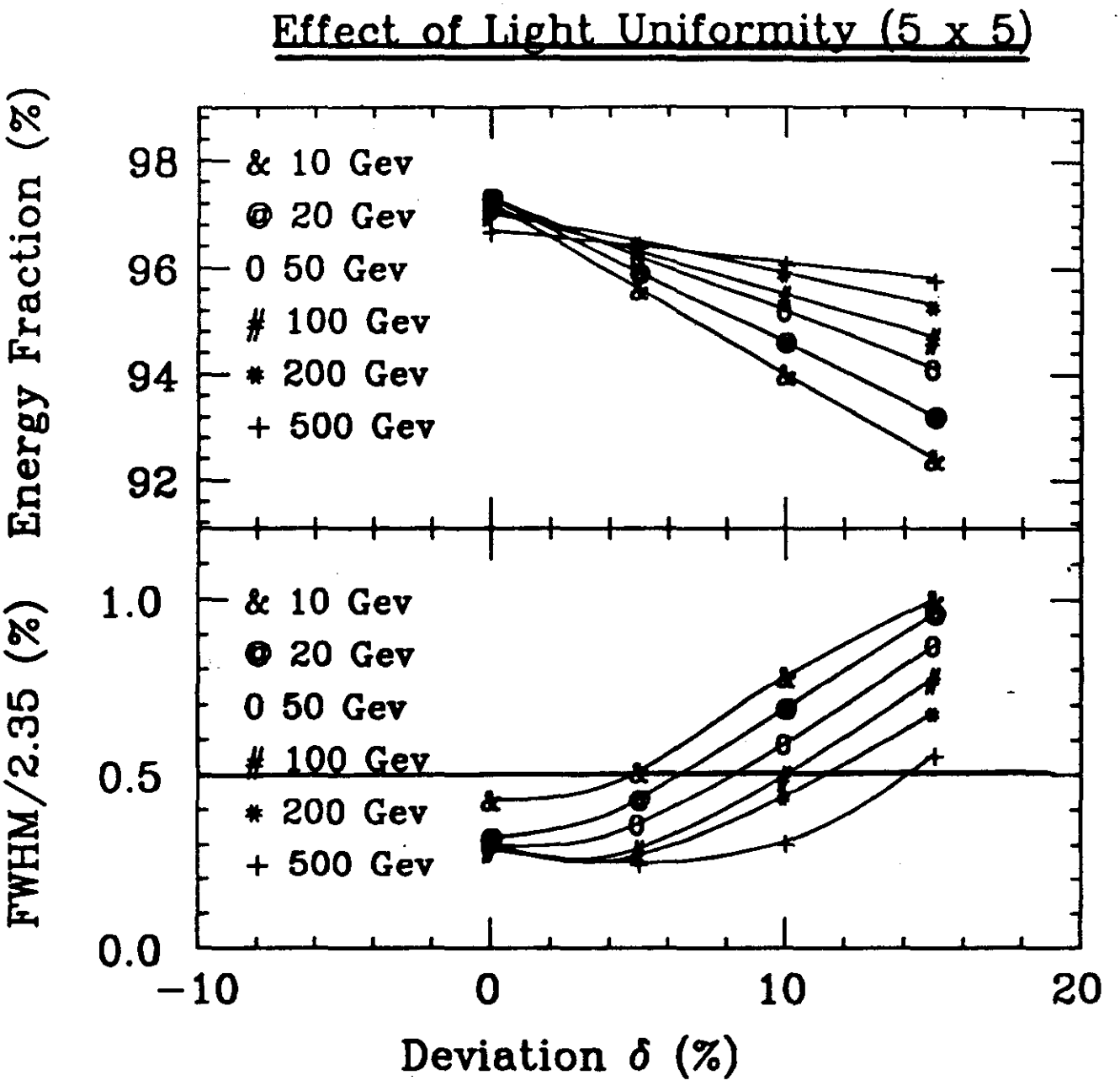
$\delta = 10\%$

E(GeV)	10	20	50	100	200	500
NEVT	1000	1000	500	500	500	200
1 x 1	68.2	70.0	71.6	72.4	73.2	74.1
(σ)	(4.2)	(4.6)	(4.3)	(4.2)	(3.9)	(3.6)
3 x 3	90.4	91.0	91.7	92.1	92.6	92.9
(σ)	(1.0)	(.86)	(.76)	(.66)	(.56)	(.45)
5 x 5	94.0	94.6	95.2	95.5	95.9	96.1
(σ)	(.78)	(.69)	(.59)	(.50)	(.44)	(.31)
7 x 7	95.2	95.7	96.2	96.6	96.9	97.1
(σ)	(.69)	(.62)	(.55)	(.45)	(.39)	(.30)

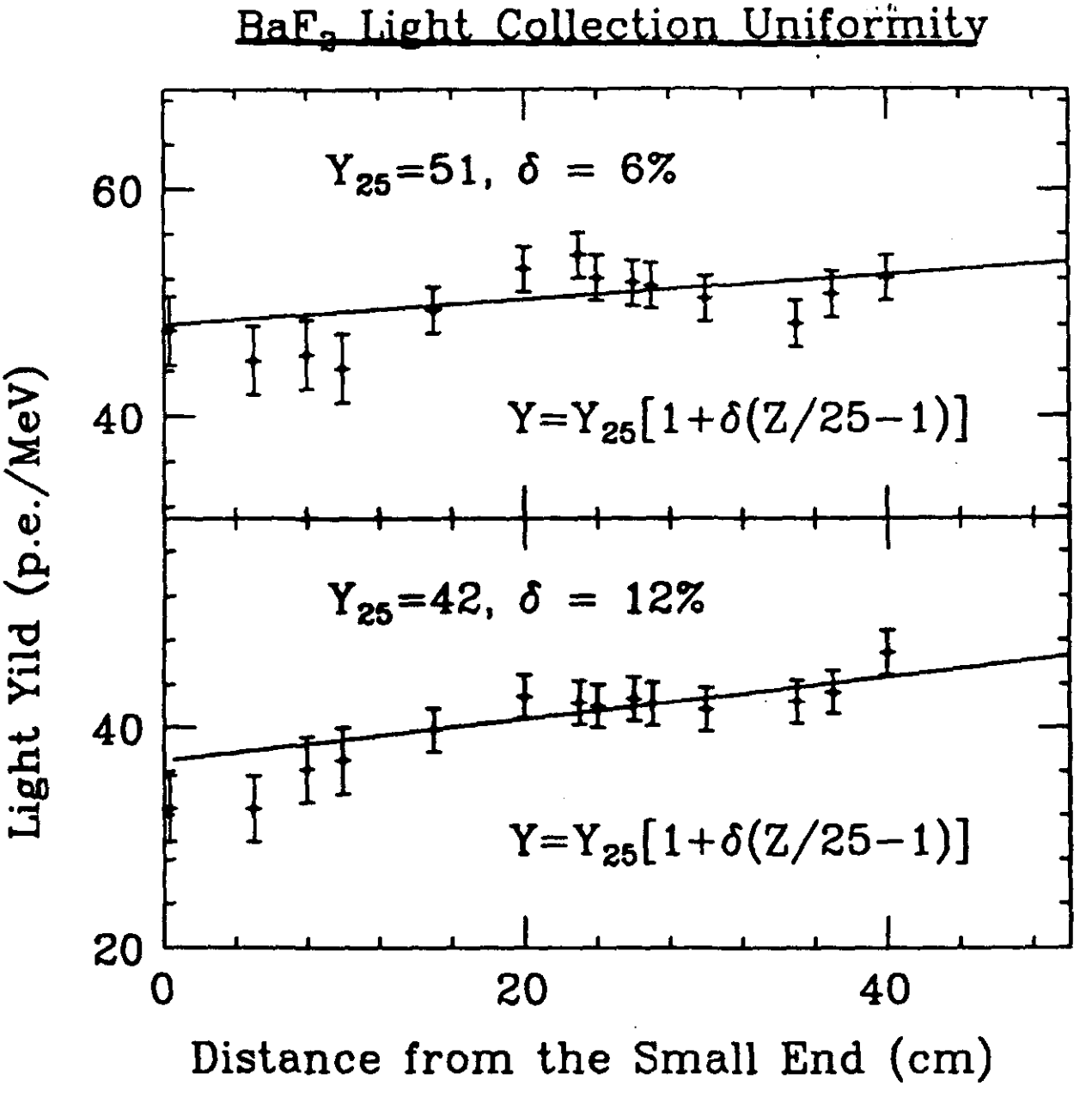
Fraction Energy Deposited in BaF_2 with Deviated Light Uniformity

$\delta = 15\%$

E(GeV)	10	20	50	100	200	500
NEVT	1000	1000	500	500	500	200
1 x 1	66.8	68.8	70.6	71.6	72.6	73.7
(σ)	(4.1)	(4.3)	(4.5)	(4.0)	(3.7)	(3.5)
3 x 3	88.8	89.6	90.6	91.3	92.0	92.6
(σ)	(1.2)	(1.1)	(.97)	(.90)	(.81)	(.72)
5 x 5	92.4	93.2	94.1	94.7	95.3	95.8
(σ)	(1.0)	(.96)	(.87)	(.78)	(.68)	(.56)
7 x 7	93.6	94.3	95.2	95.8	96.3	96.8
(σ)	(.96)	(.90)	(.82)	(.73)	(.63)	(.48)


Effect of Light Uniformity (5 x 5)
Energy Fraction (%)
98
96
94
92
& 10 Gev
@ 20 Gev
0 50 Gev
100 Gev
* 200 Gev
+ 500 Gev
FWHM/2.35 (%)
1.0
0.5
0.0
& 10 Gev
@ 20 Gev
0 50 Gev
100 Gev
* 200 Gev
+ 500 Gev
−10
0
10
20
Deviation δ (%)

Data measured with Cs^{137} source



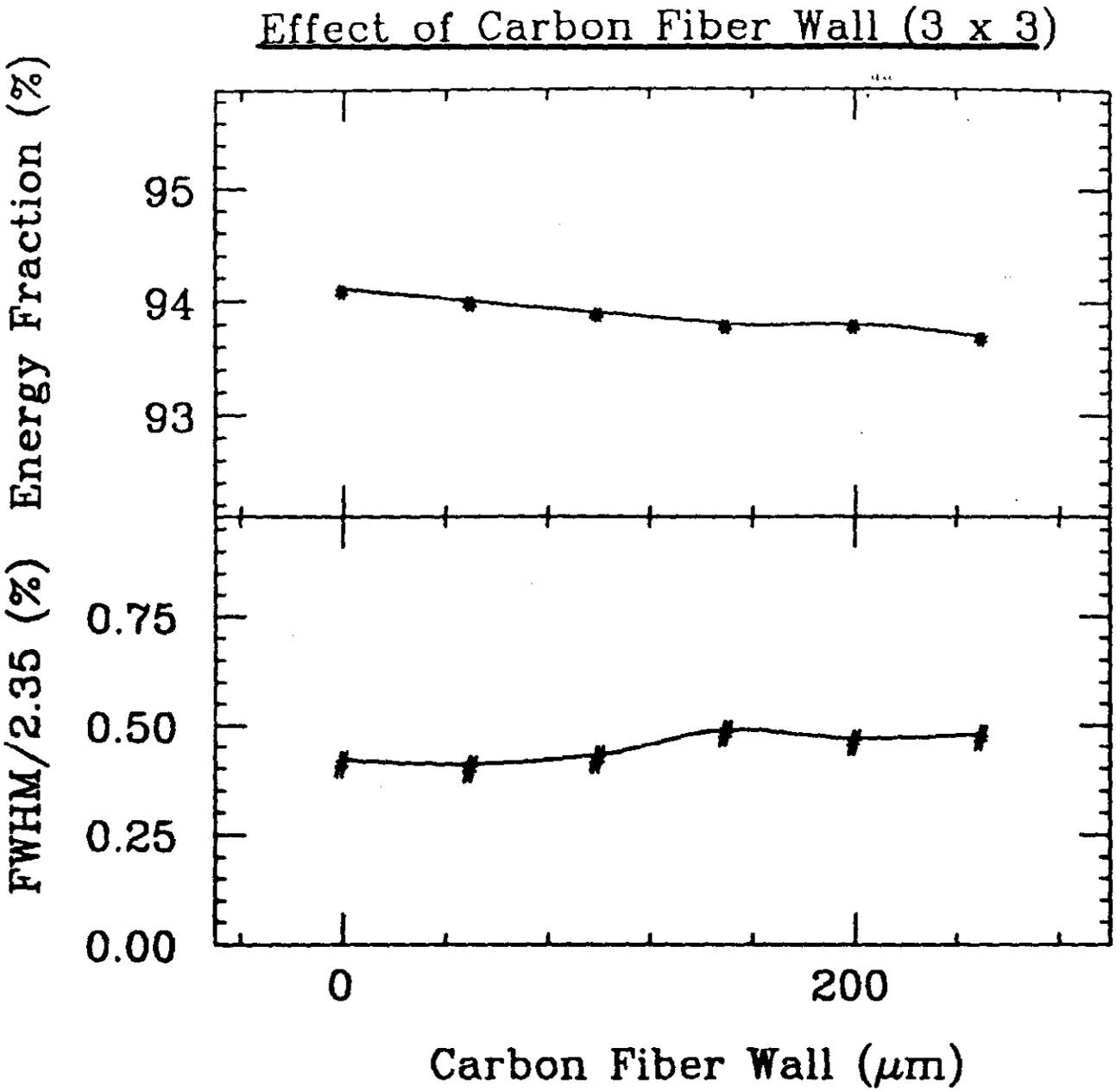
GEANT SIMULATION

Fraction Energy Deposited in BaF_2 as Function of Carbon Fiber Wall

- Charge Particle : 20 GeV Electron
- Carbon fiber wall thickness between any two crystal faces: from 0 to 250μm
- Number of BaF_2 crystals: 11 x 11
- BaF_2 Crystal length: 50 cm
- Front (rear) face of BaF_2 :
  3 cm x 3 cm (5 cm x 5 cm)
- Particle is hitting over the front face of central BaF_2 crystal.
- One centimeter Aluminium placed just before the crystals and two 0.5 cm Aluminium placed between track origin and midway point to crystals (i.e., total 2 cm Al, whose $X_0 = 9$ cm)
- No magnetic field.

Fraction Energy Deposited in BaF_2 as Function of Carbon Fiber Wall

Carbon(μ)	0	50	100	150	200	250
1 x 1	73.0	73.0	72.8	72.7	72.7	72.9
(σ)	(5.4)	(5.8)	(7.0)	(4.8)	(4.1)	(4.7)
3 x 3	94.1	94.0	93.9	93.8	93.8	93.7
(σ)	(.42)	(.41)	(.43)	(.49)	(.47)	(.48)
5 x 5	97.7	97.6	97.5	97.4	97.4	97.3
(σ)	(.23)	(.28)	(.30)	(.35)	(.30)	(.31)
7 x 7	98.8	98.7	98.7	98.6	98.5	98.4
(σ)	(.20)	(.22)	(.20)	(.28)	(.25)	(.26)
9 x 9	99.2	99.1	99.1	99.0	98.9	98.8
(σ)	(.15)	(.15)	(.18)	(.27)	(.27)	(.24)

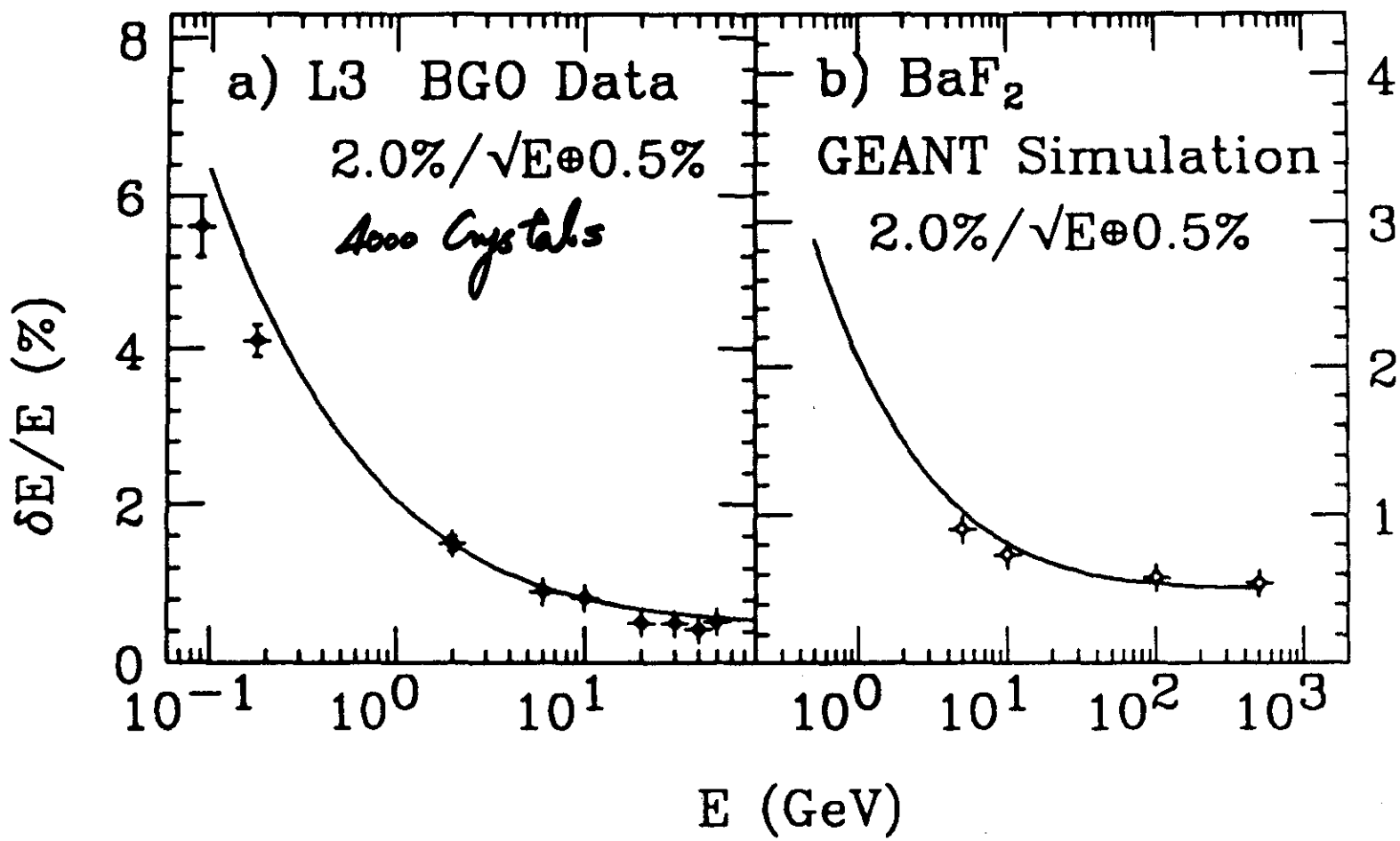

Effect of Carbon Fiber Wall (3 x 3)
Energy Fraction (%)
95
94
93
FWHM/2.35 (%)
0.75
0.50
0.25
0.00
0
200
Carbon Fiber Wall (μm)

Energy Resolution (%)

of BaF_2 Calorimeter

GEANT Simulation

E (GeV)	5	10	100	500
Electrical Noise	0.8	0.40	0.04	0.008
Photoelectrons	0.2	0.1	0.04	0.02
GEANT	0.67	0.56	0.42	0.36
Intercalibration	0.40	0.40	0.40	0.40
Total	1.1	0.80	0.58	0.54


a) L3 BGO Data
2.0%/√E⊕0.5%
4000 Crystals
b) BaF2
GEANT Simulation
2.0%/√E⊕0.5%
δE/E (%)
E (GeV)
0
2
4
6
8
1
2
3
4
10^-1
10^0
10^1
10^2
10^3

Position Resolution for γ vectors.

- Tower structure:

$$\delta_x(mm) \approx \frac{3}{\sqrt{E}} \quad e^{0.4D}$$

where $3/\sqrt{E}$ is signal/noise term, $e^{0.4D}$ is the lateral shower distributions: D is cell size in X_0. Requesting $\delta x \approx 1.5$ mm for 20 GeV photon:

$$\Rightarrow D < 2X_0$$

- Position detector at the middle of shower:
  - Increase the accuracy of shower center determination:
    - UA1 4 mm/$\sqrt{E}$: 7 mm wide strips in TMP at shower max;
    - UA2 3.5 mm/$\sqrt{E}$: preshower detector with ϕ1 mm fibres;
    - COSICA 1 mm/$\sqrt{E}$: 500 μm pitch silicon at shower max.
  - ~~However, it seems pay the price of resolution, so is not applicable to Homogeneous calorimeter.~~ It seems ok to put position detector at $5X_0$ or before.

Time Factor in Discovering an 80 GeV Higgs

to discover 80 GeV Higgs

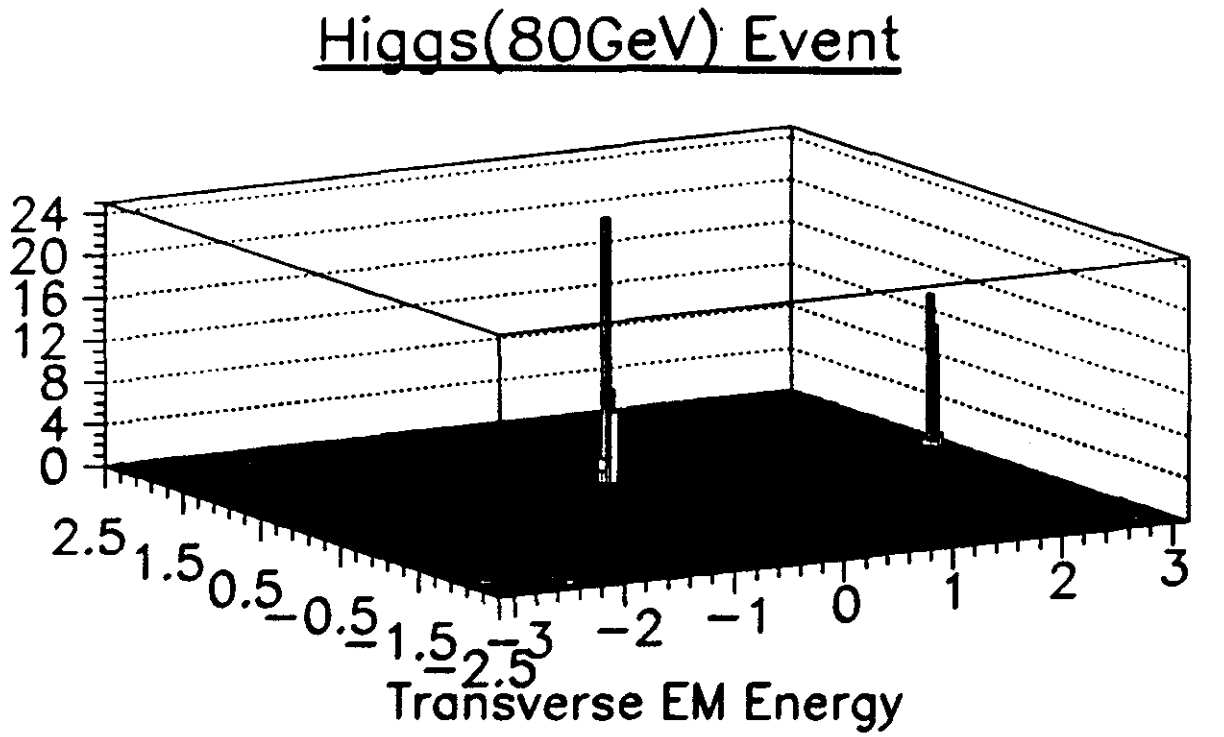
As function of position resolution (δx) and a

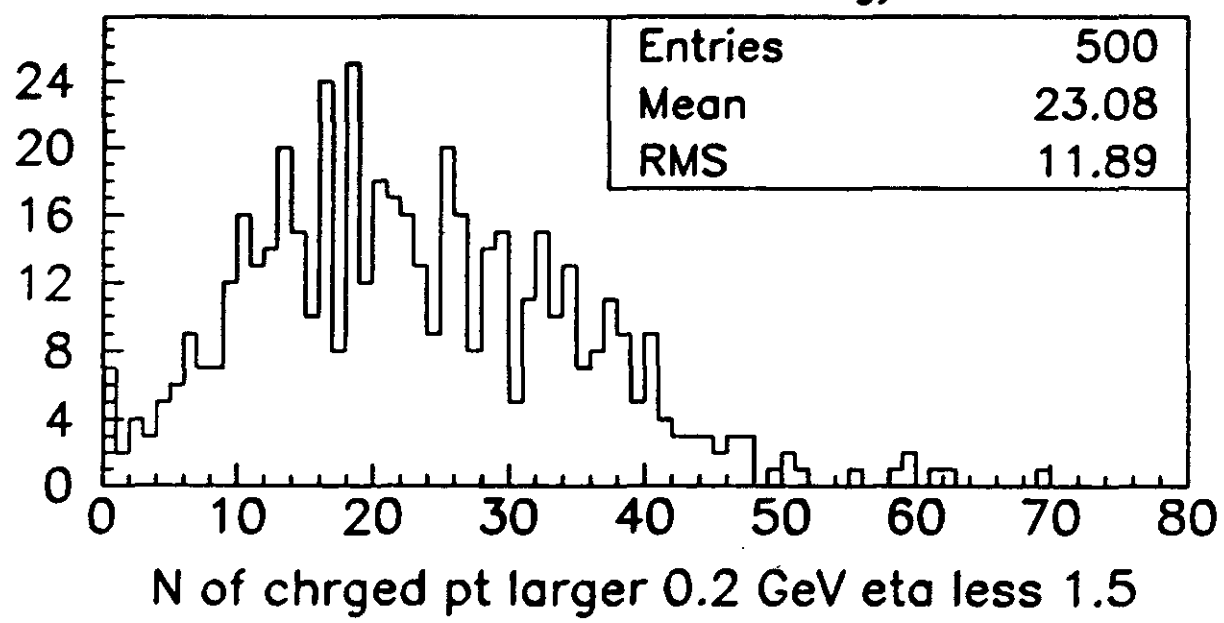
b=0.5

δx(mm)	0.	0.5	1.0	1.5	2.0	3.0	5.0
a=1	0.94	0.94	0.95	0.97	1.0	1.1	1.4
a=2	1.0	**1.0**	1.01	1.0	1.1	1.2	1.4
a=3	1.09	1.1	1.1	1.1	1.2	1.3	1.5
a=5	1.4	1.4	1.4	1.4	1.4	1.5	1.7
a=7.5	1.8	1.8	1.8	1.8	1.9	1.9	2.1

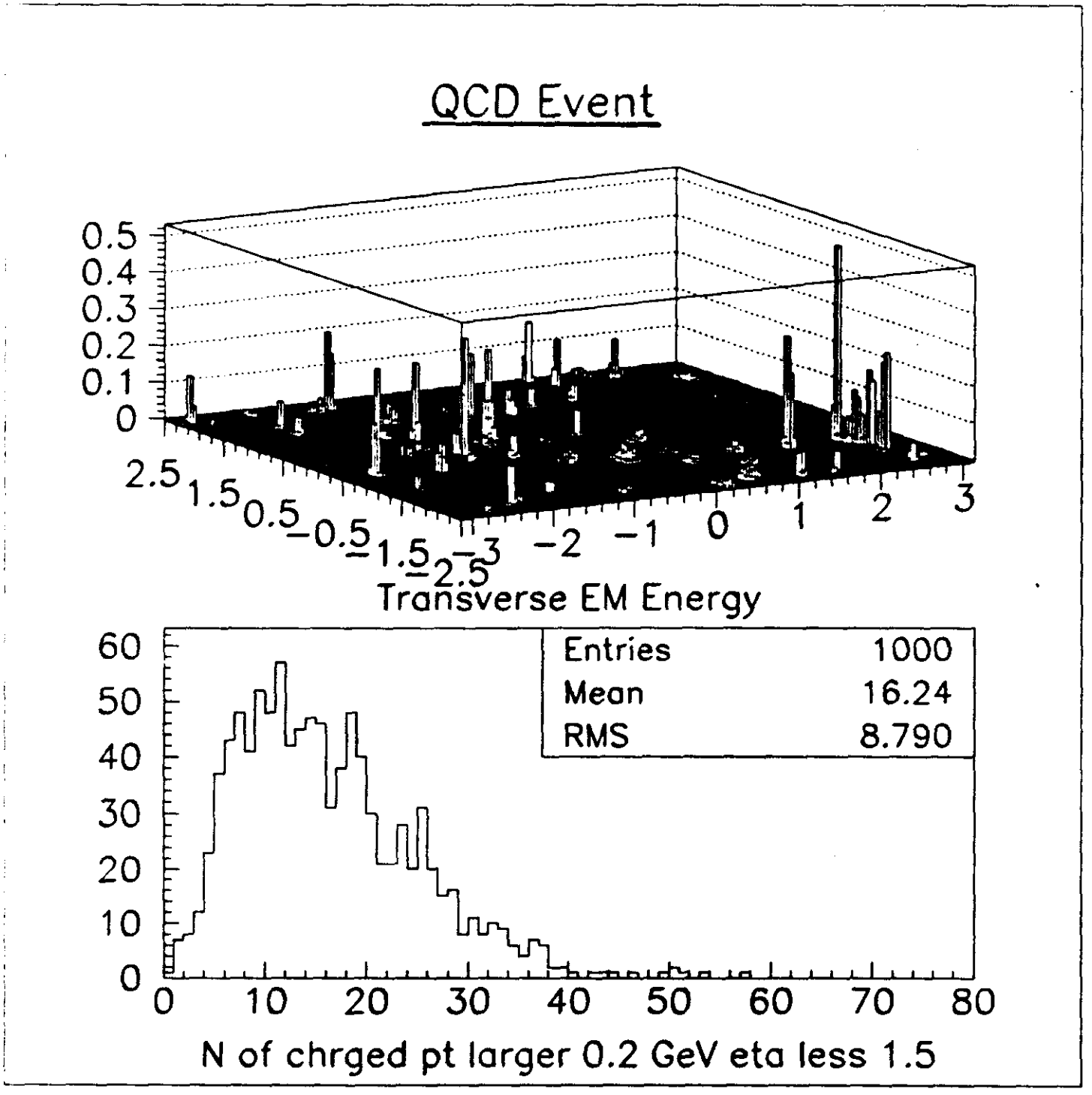
- Note: Different detectors have different background rate. This table is for detectors with the same background rate.

Vertex with high charge multiplicity

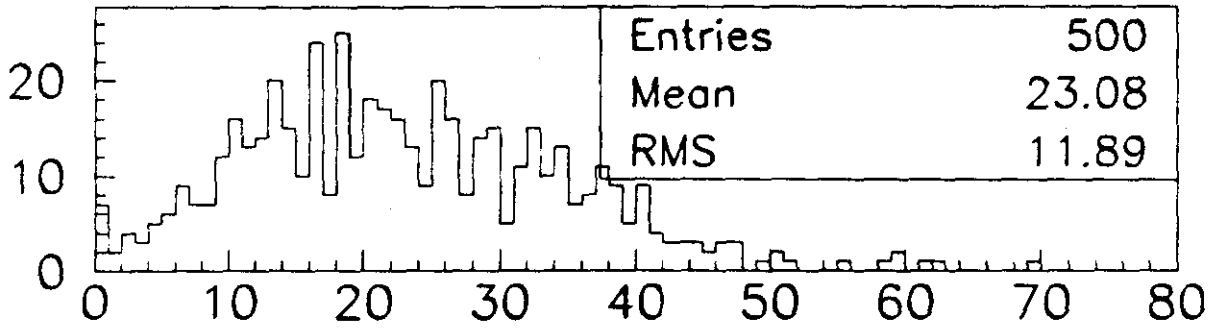




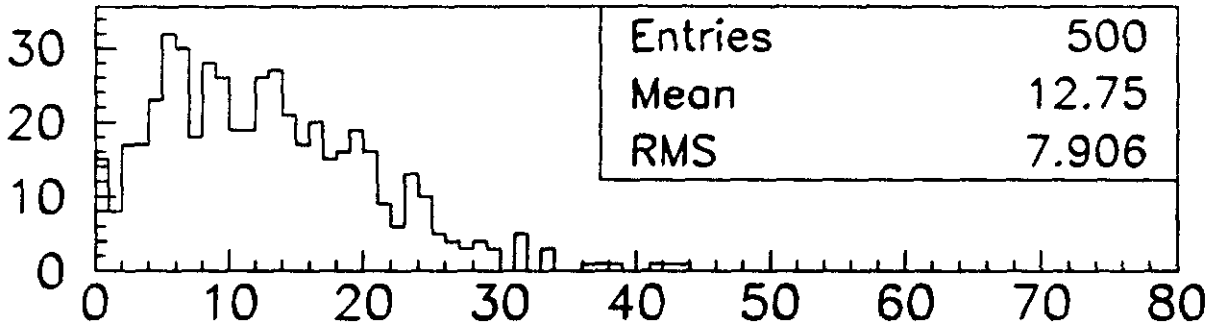
Vertex' with low charge multiplicity



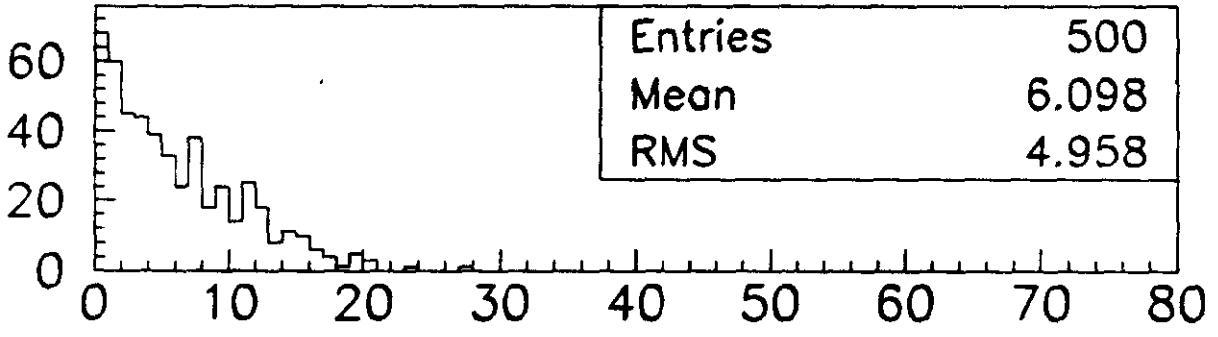
Higgs(80GeV) to 2 Photons



N of chrged pt larger 0.2 GeV eta less 1.5

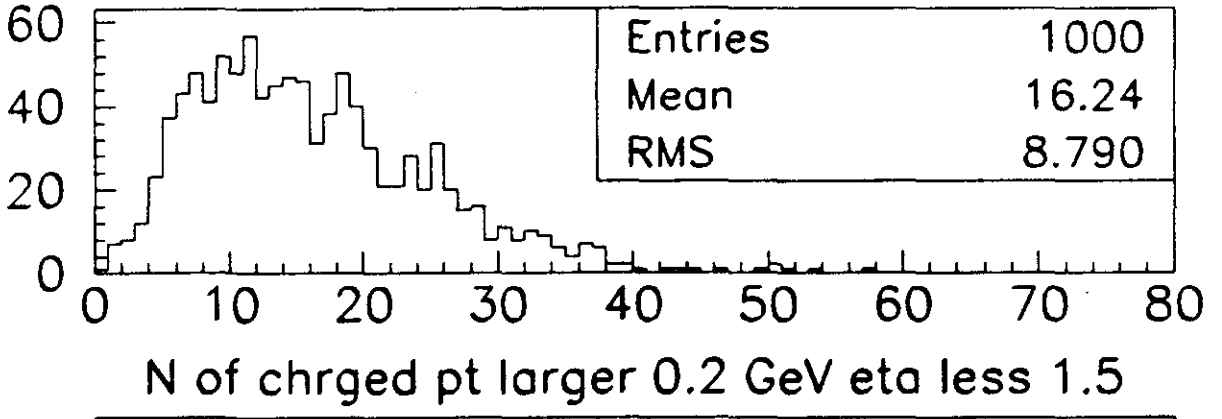


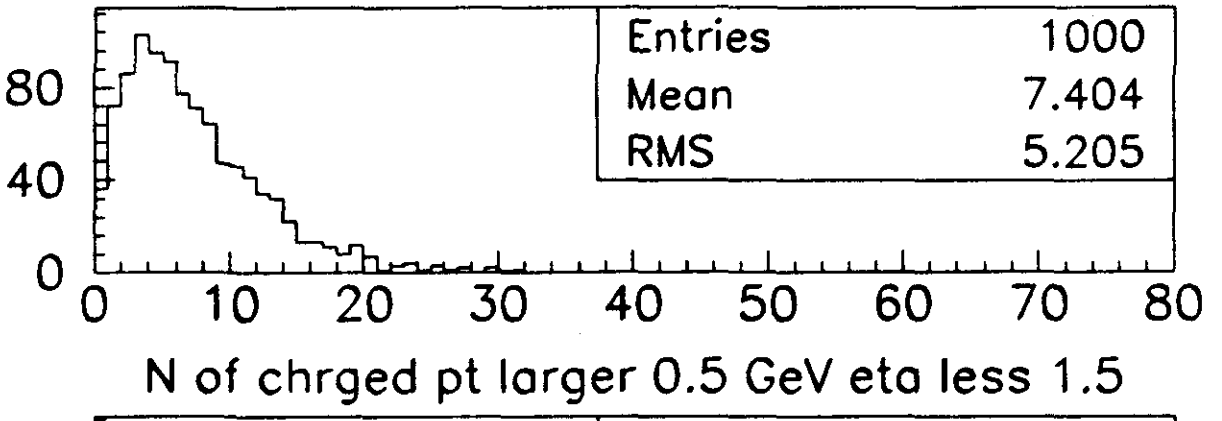
N of chrged pt larger 0.5 GeV eta less 1.5

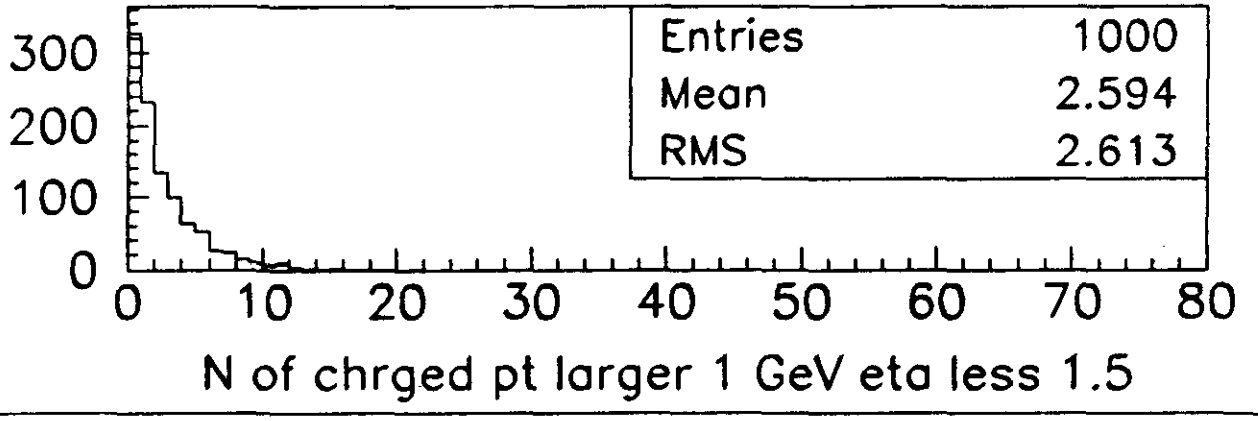


N of chrged pt larger 1 GeV eta less 1.5

QCD Events


Entries 1000
Mean 16.24
RMS 8.790
0
20
40
60
0 10 20 30 40 50 60 70 80
N of chrged pt larger 0.2 GeV eta less 1.5


Entries 1000
Mean 7.404
RMS 5.205
0
40
80
0 10 20 30 40 50 60 70 80
N of chrged pt larger 0.5 GeV eta less 1.5


Entries 1000
Mean 2.594
RMS 2.613
0
100
200
300
0 10 20 30 40 50 60 70 80
N of chrged pt larger 1 GeV eta less 1.5

Crystal Clear Collaboration at CERN

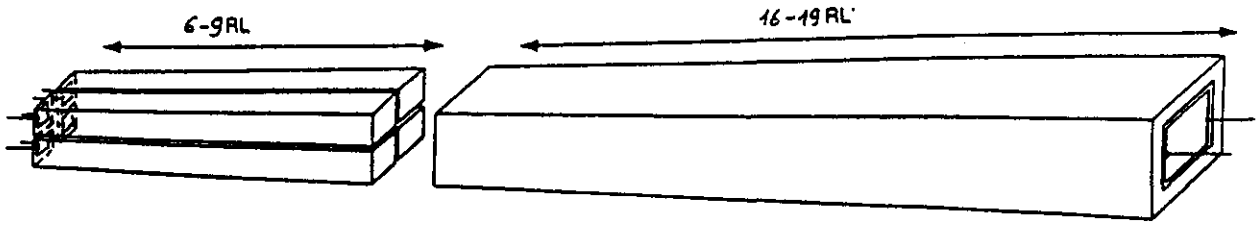


Fig. 1: PROPOSED CRYSTAL LAYOUT

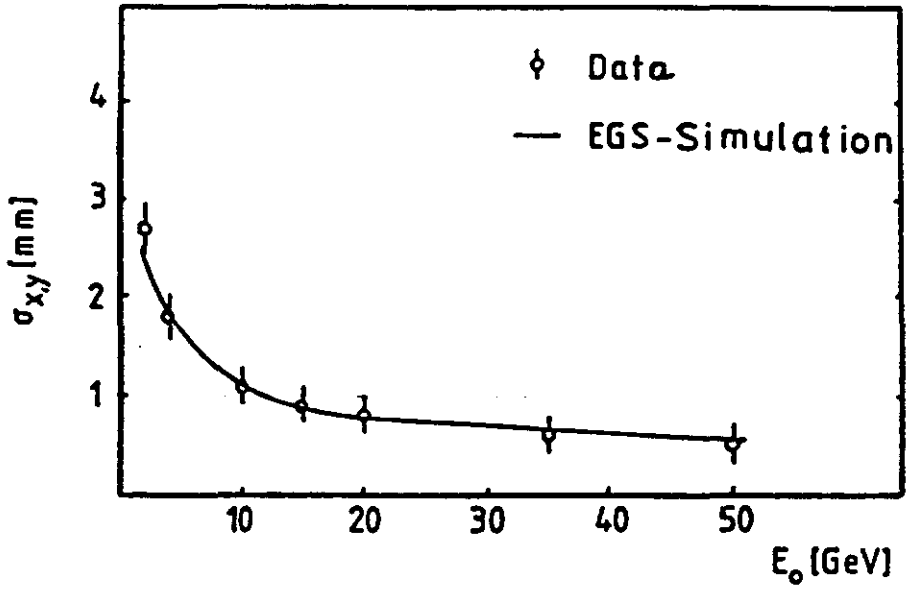
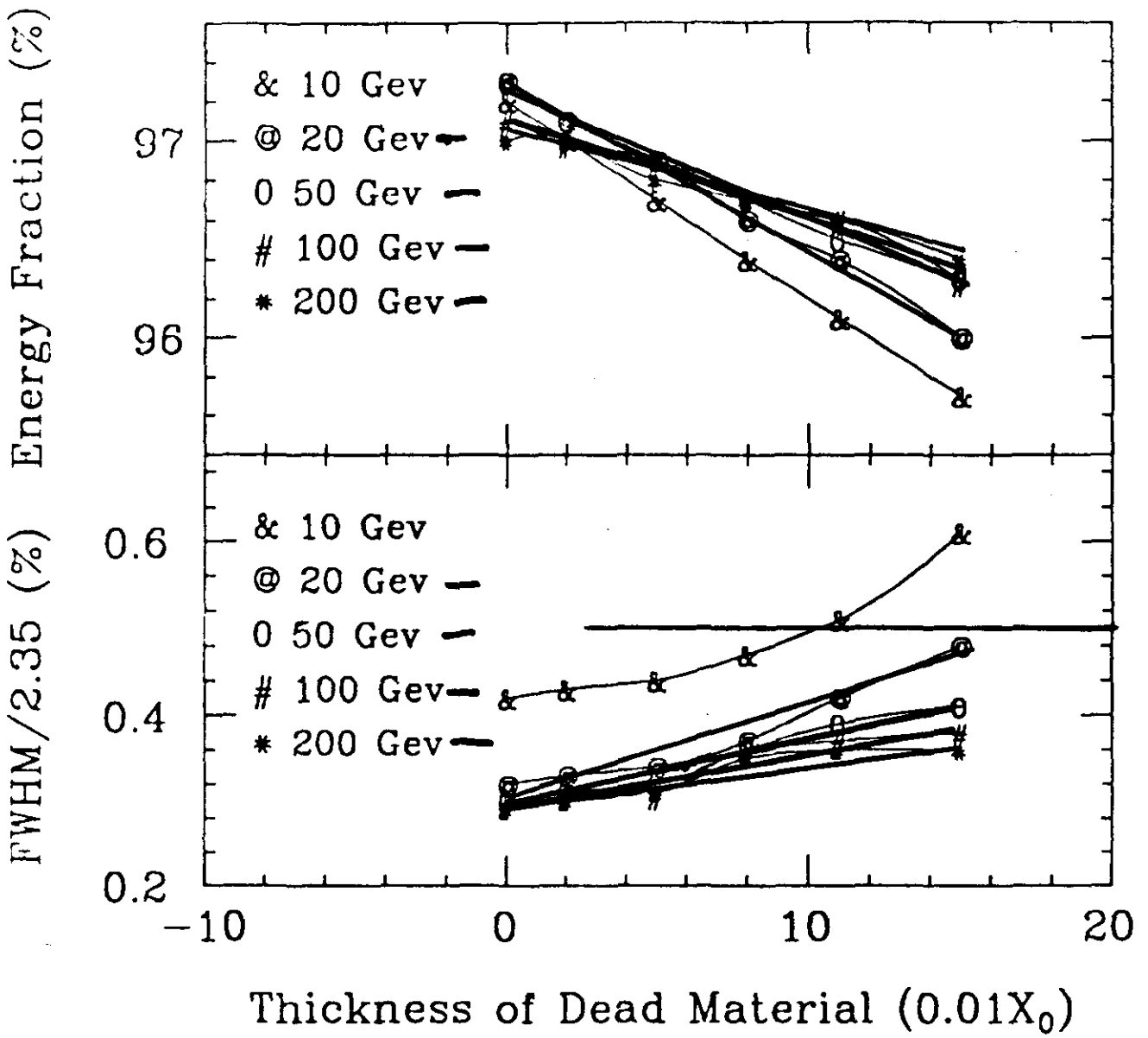


Fig. 2

Effect of Dead Material at $5X_0$ (5 x 5)



Why Time Resolution

- Higgs vertex determination with associate charge multiplicity:
  A slow detector may have bad vertex information.

- QCD background rejection:
  Need isolation cut with E_T^{cut}=**5 GeV** in large R cone to reduce background;

- Time Factor for Discovery:

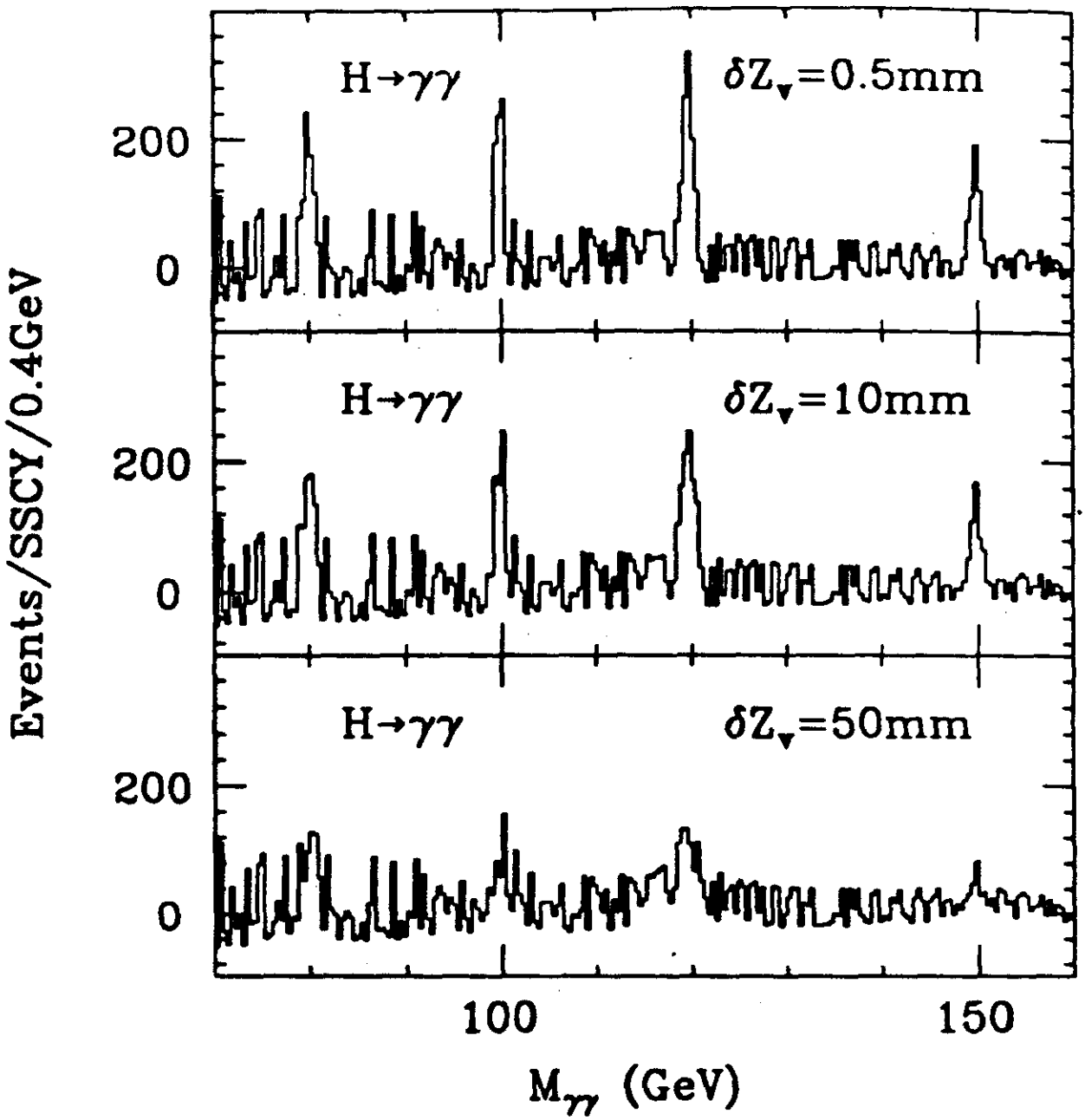
E_T^{cut}	R=0.45	R=0.60	R=0.75
5 GeV	2	1.4	1.0
10 GeV	9.8	6.9	4.6
15 GeV	20	12	11
20 GeV	36	26	23

- It is important for a precision EMC & HC to have a low noise in a large isolation cone.

Effect of Vertex Z (δZ_v) Resolution in discovering an 80 GeV Higgs through $\gamma\gamma$

a	b	0.5 mm	10 mm	50 mm
2	0.5	1	1.6	5.0
7.5	0.5	1.9	2.3	5.2
15	1	3.8	4.0	6.1

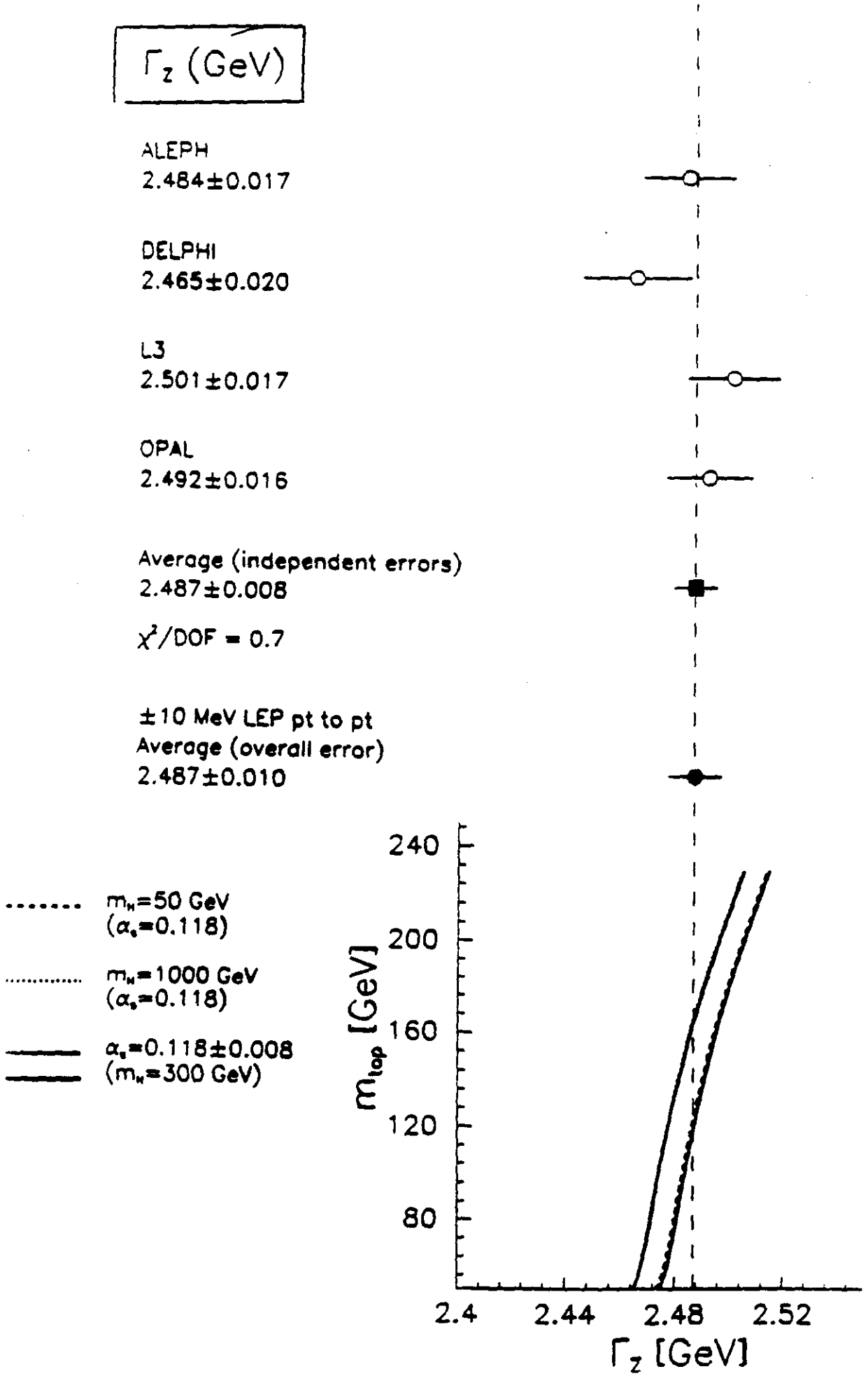
Effect of Vertex (δZ_v) Resolution

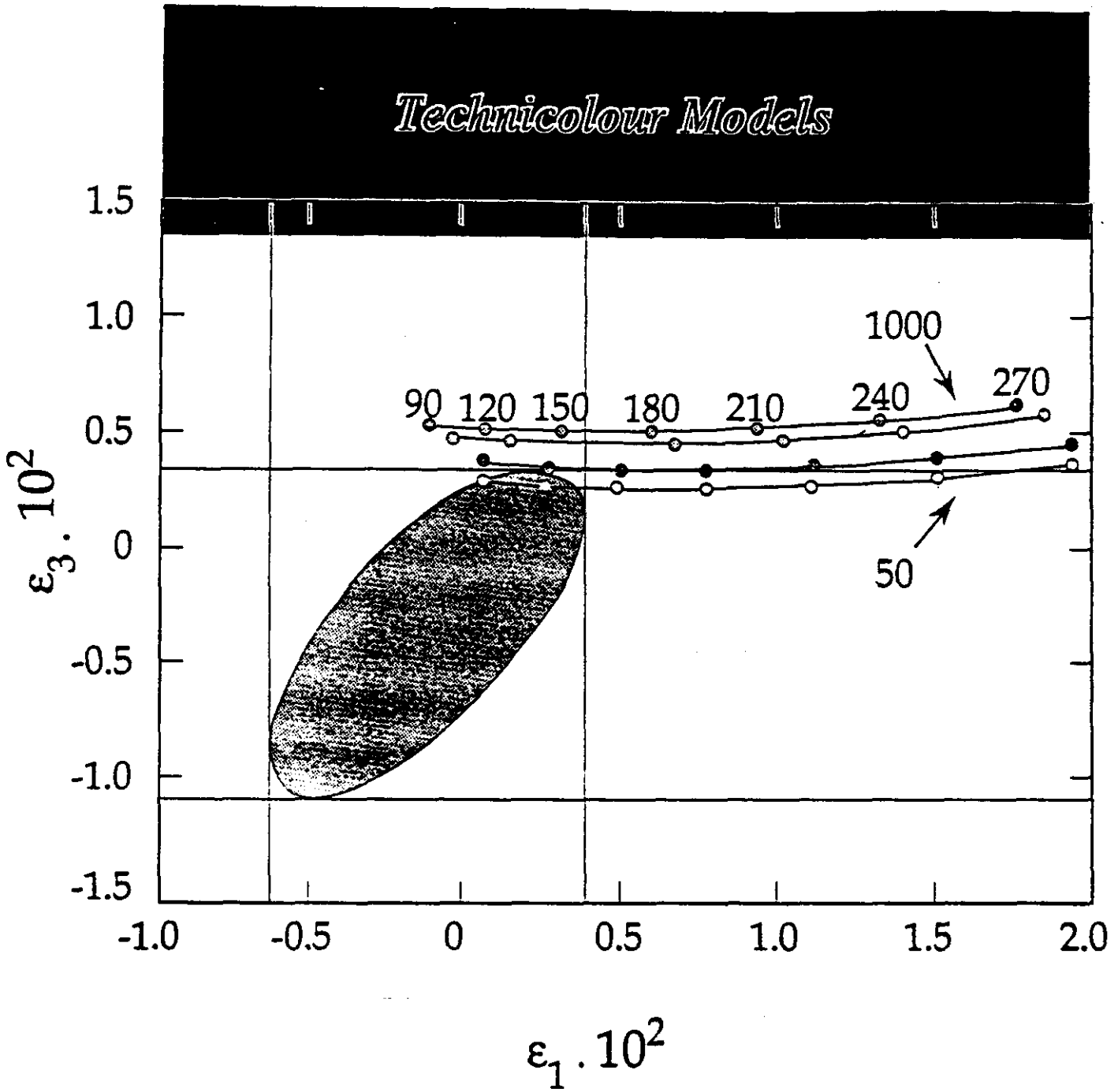


HIGGS DETECTION: PHYSICS IMPLICATIONS

Experiment	M_H Range	Implications
LEP Phase I (1992)	$\leq$ 50 GeV	Minimal SUSY
LEP Phase II (1996)	$\leq$ 80 GeV	Req'd By Minimal SUSY
BaF_2 at SSC: $H \rightarrow \gamma\gamma$	$\leq$ 200 GeV	Req'd By Nonminimal SUSY; OR: New Physics below M_{Planck}
Lepton Detector at the SSC	200 GeV To 1 TeV	Standard Model

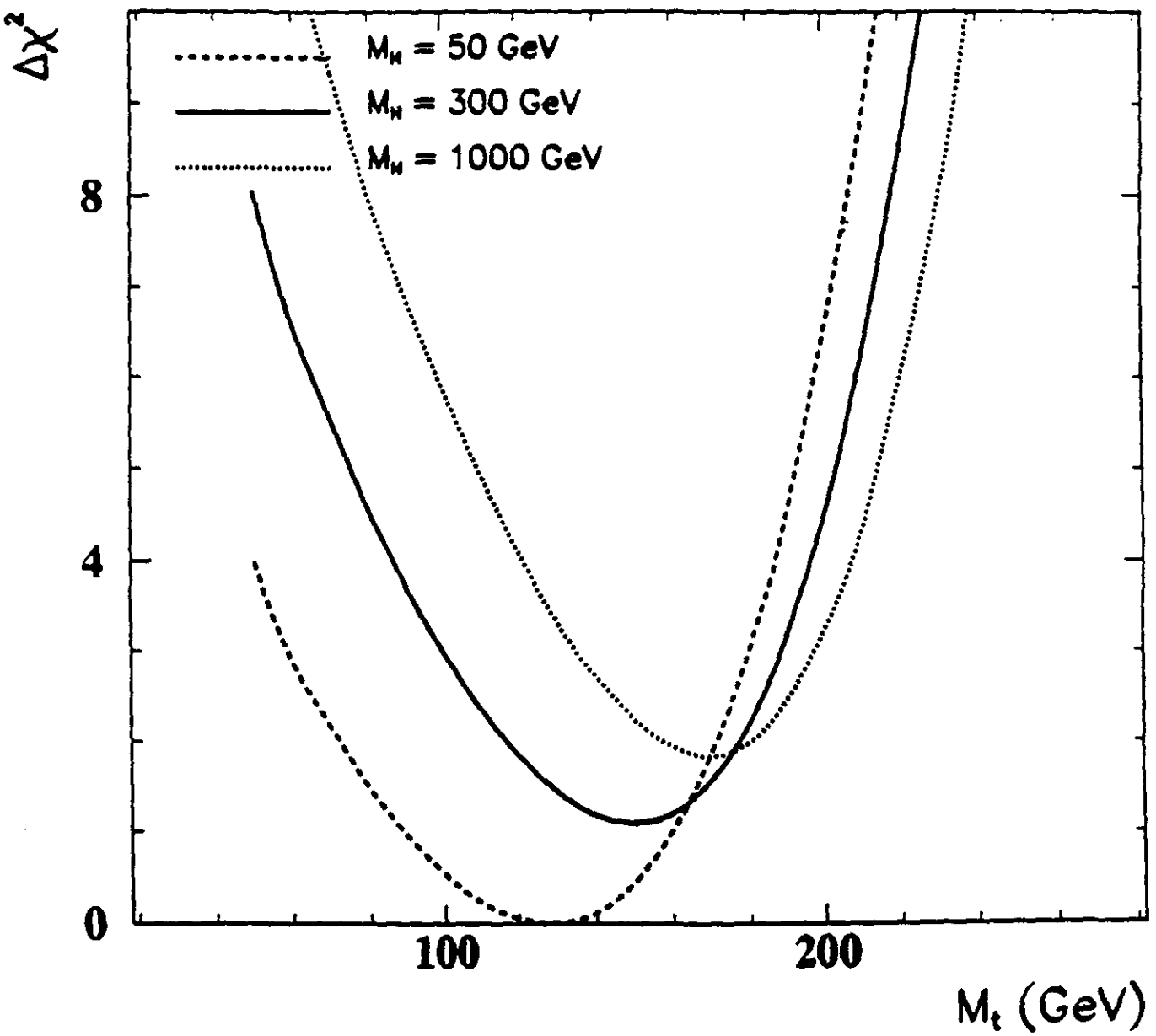
IMPORTANCE of $M_H \in (80, 150)$ GeV


Γ_Z (GeV)
ALEPH
2.484±0.017
DELPHI
2.465±0.020
L3
2.501±0.017
OPAL
2.492±0.016
Average (independent errors)
2.487±0.008
χ^2/DOF = 0.7
±10 MeV LEP pt to pt
Average (overall error)
2.487±0.010
m_H=50 GeV
(α_s=0.118)
m_H=1000 GeV
(α_s=0.118)
α_s=0.118±0.008
(m_H=300 GeV)
240
200
160
120
80
m_{top} [GeV]
2.4
2.44
2.48
2.52
Γ_Z [GeV]


Technicolour Models
1.5
1.0
0.5
0
-0.5
-1.0
-1.5
-1.0
-0.5
0
0.5
1.0
1.5
2.0
1000
270
90
120
150
180
210
240
50
$\varepsilon_3 \cdot 10^2$
$\varepsilon_1 \cdot 10^2$

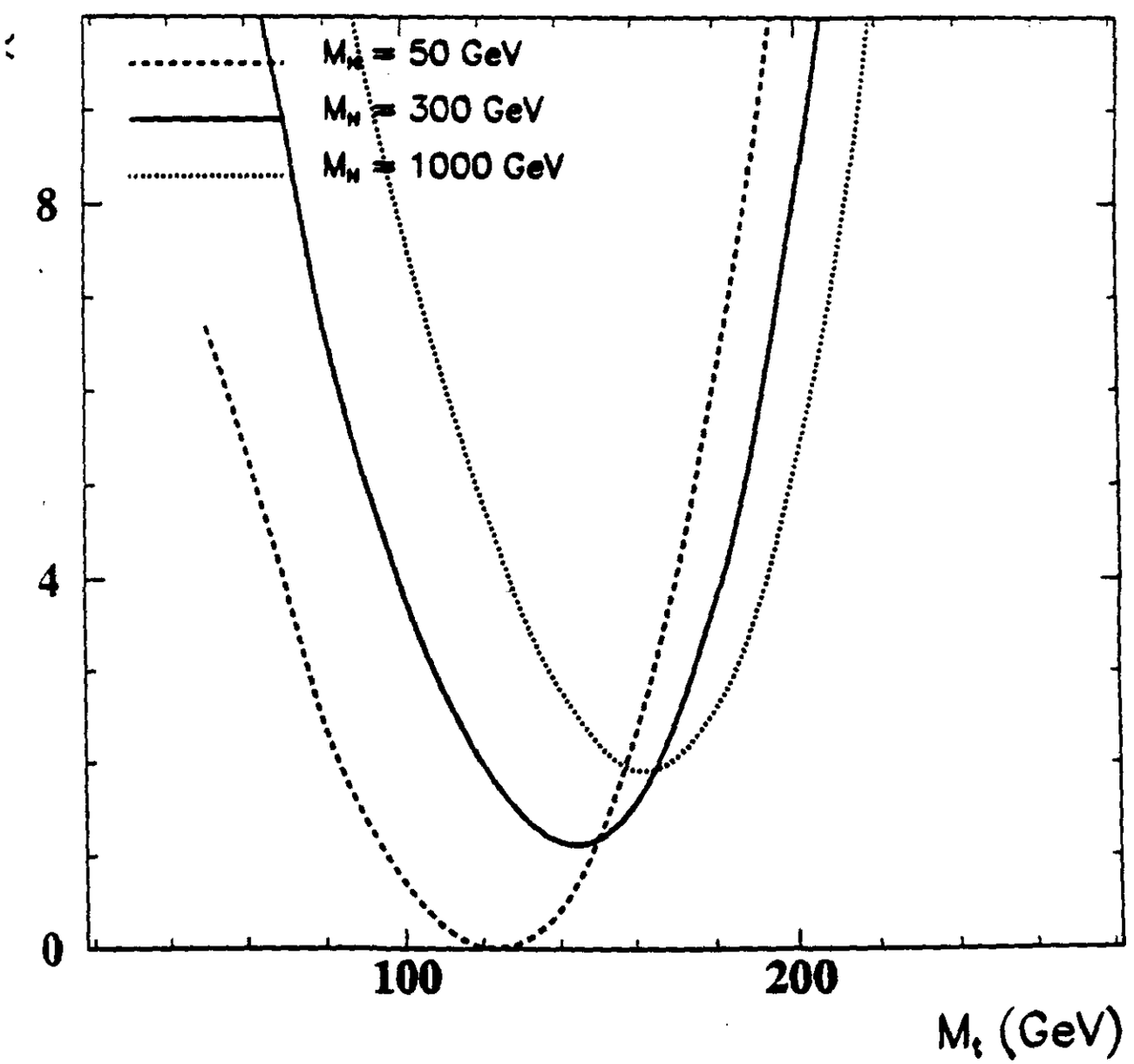
M_t

LEP $\sigma^{had} + \sigma^{lept} + A_{FB}^{lept} + A_{POL}^{\tau} + A_{FB}^{bb} + A_{FB}^{qq}$



M_t

LEP $\sigma^{had} + \sigma^{lept} + A_{FB}^{lept} + A_{POL}^{\tau} + A_{FB}^{bb} + A_{FB}^{qq}$
$+ M_W$ (UA2/CDF) $+ \sin^2\vartheta_w$ (CHARM/CDHS)



RESULTS FOR M_t, COMBINED DATA

Input data	M_t (GeV)	95% upper confidence limit (GeV)
$\sigma^{had}\,\sigma^{lept}\,A_{FB}^{lept}$	$123^{+37}_{-47}{}^{+22}_{-23}$	186
$+A^{pol}(\tau),\ A_{FB}^{pol}(\tau)$	$129^{+35}_{-44}{}^{+22}_{-22}$	188
$+A_{FB}^{b\bar{b}}$	$146^{+31}_{-38}{}^{+21}_{-22}$	192
$+A_{FB}^{q\bar{q}}$	$150^{+29}_{-34}{}^{+20}_{-22}$	193
$+M_W$	$149^{+24}_{-28}{}^{+19}_{-21}$	187
$+\sin^2\theta_W\,\nu N$	$144^{+23}_{-26}{}^{+19}_{-21}$	181

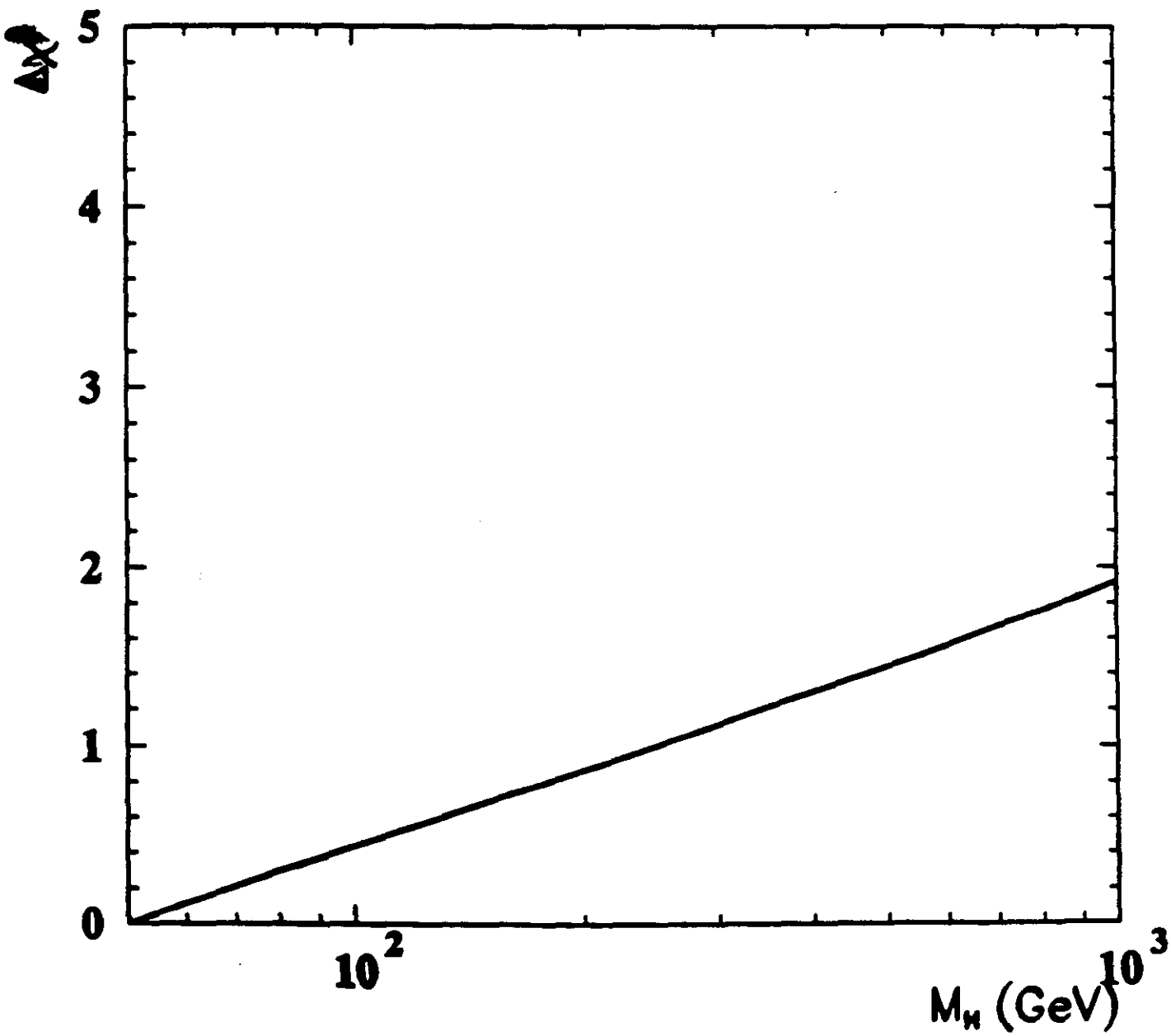
HIGGS

$50 < M_H < 1000$ GeV

CENTRAL VALUE 300 GeV

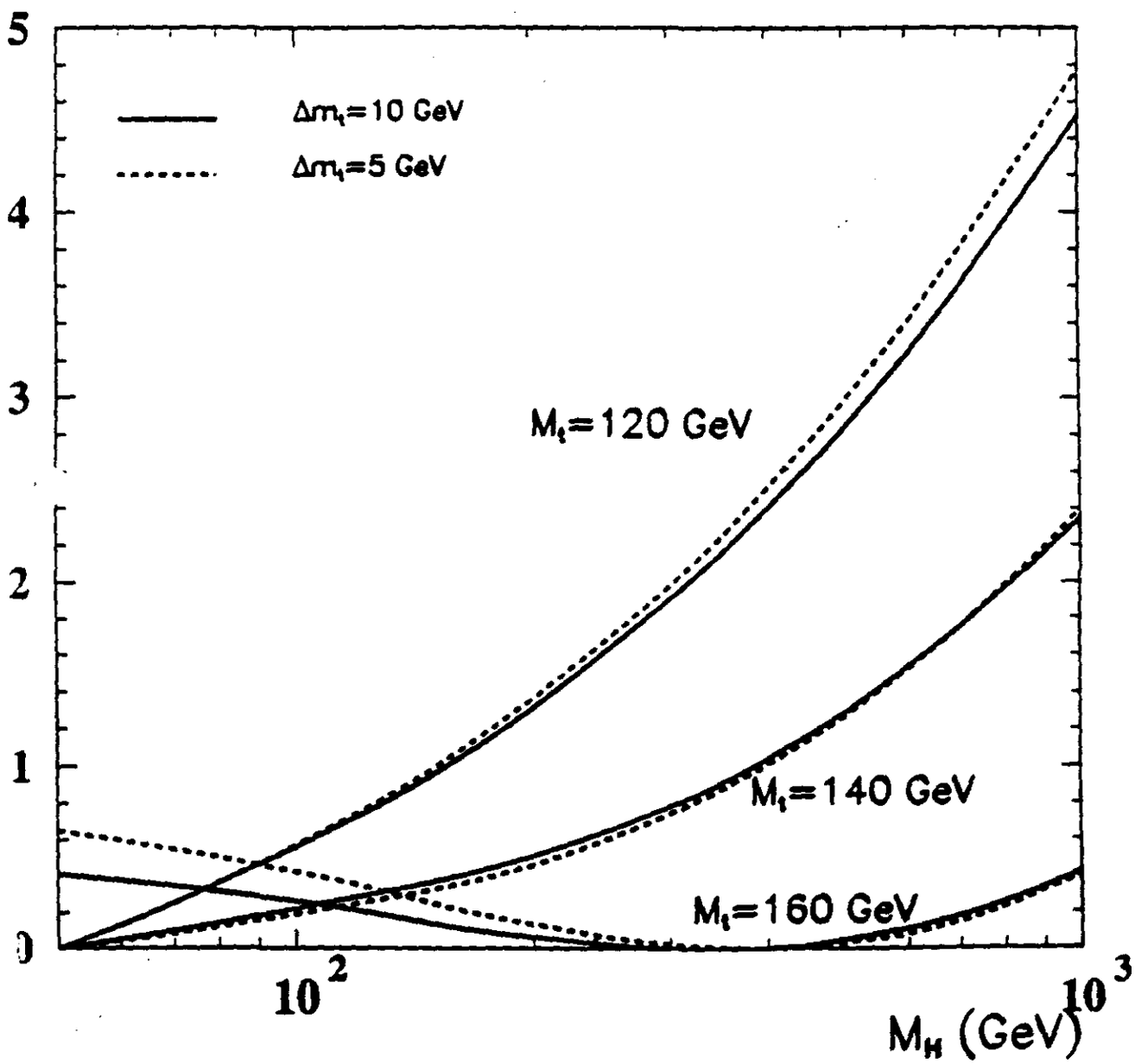
SENSITIVITY TO M_H

LEP $\sigma^{had} + \sigma^{lept} + A_{FB}^{lept} + A_{POL}^{\tau} + A_{FB}^{bb} + A_{FB}^{qq}$
$+ M_W$ (UA2/CDF) $+ \sin^2\vartheta_W$ (CHARM/CDHS)

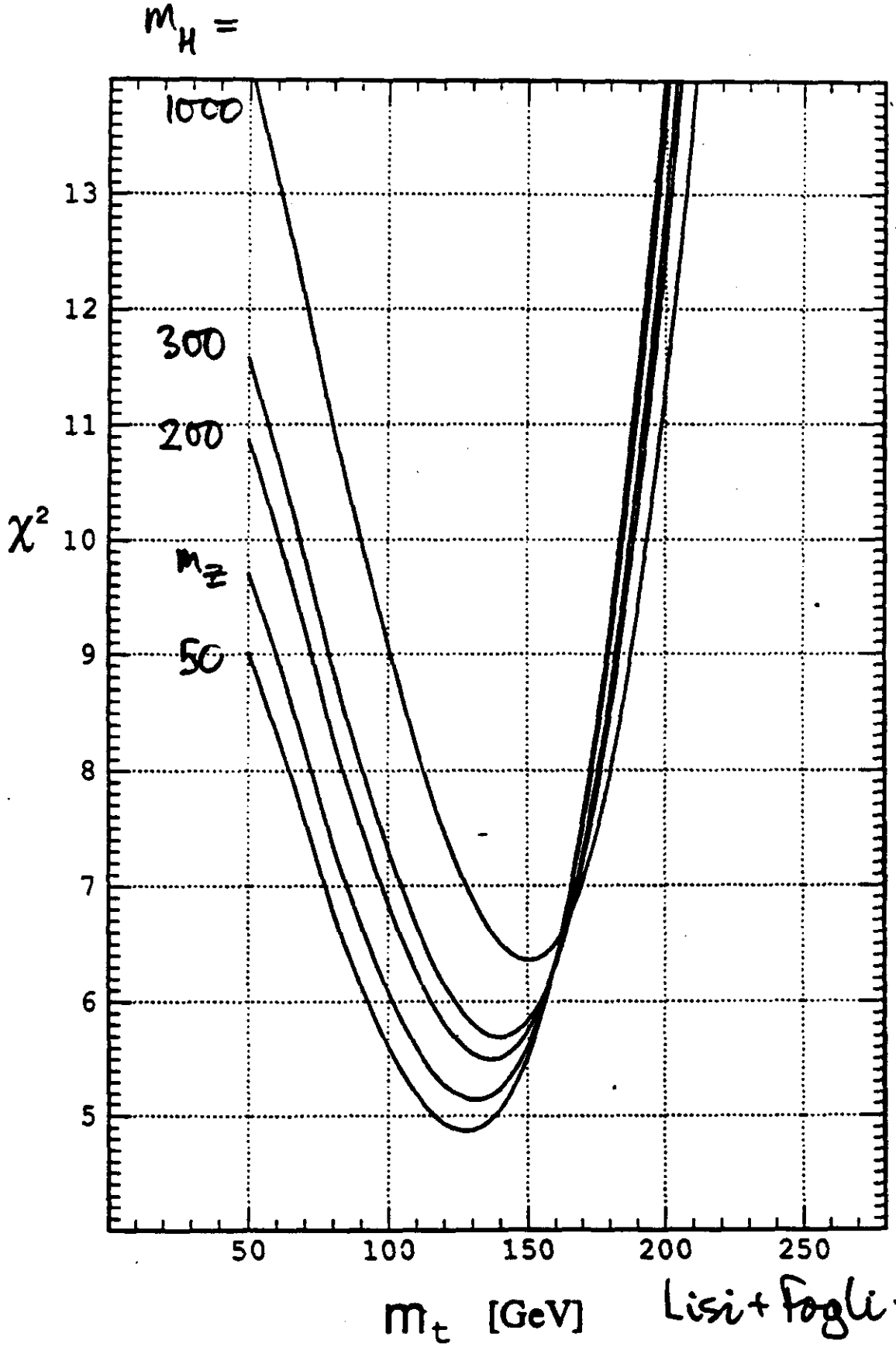


... AND IF M_t IS MEASURED AT CDF

LEP $\sigma^{had} + \sigma^{lept} + A_{FB}^{lept} + A_{POL}^{\tau} + A_{FB}^{bb} + A_{FB}^{qq}$
$+ M_W$ (UA2/CDF) $+ \sin^2\vartheta_w$ (CHARM/CDHS)

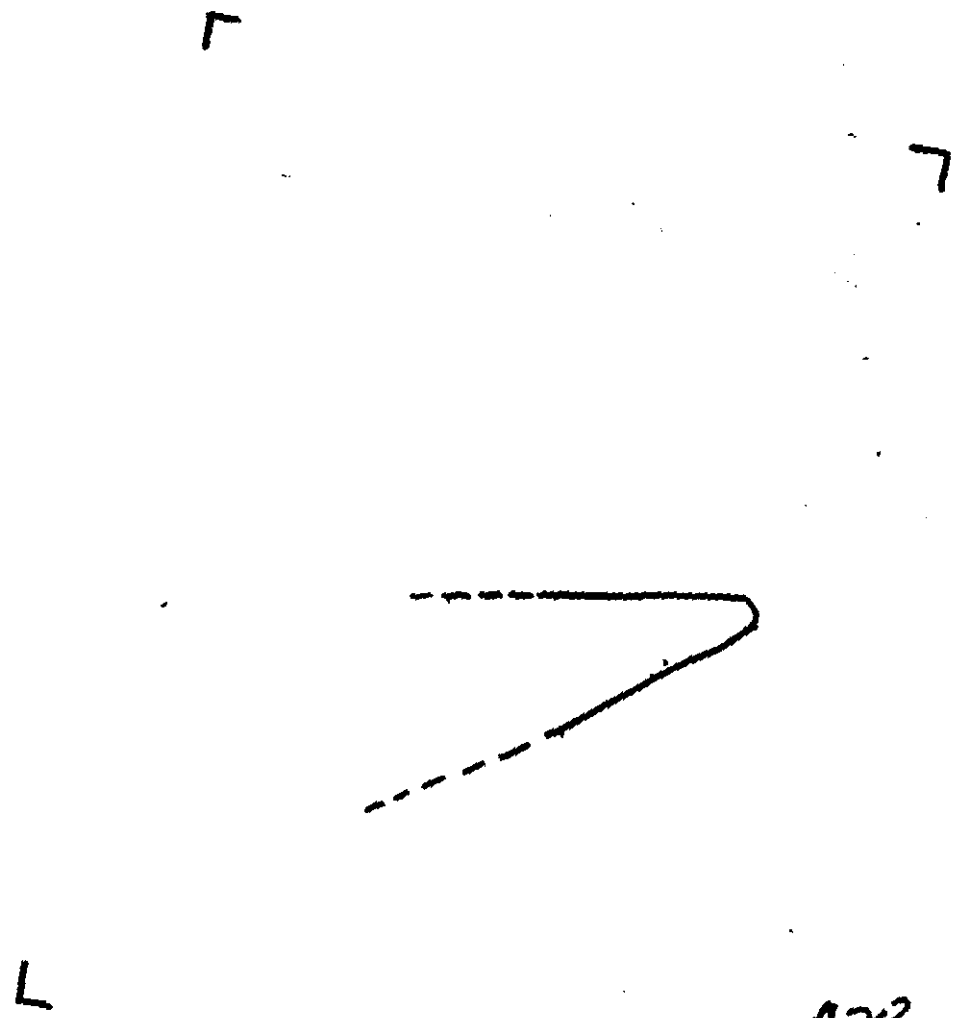


Total $\chi^2(m_t)$ for different m_H



Lisi + Fogli + J.E.

$m_t = 125 \pm 30$ GeV



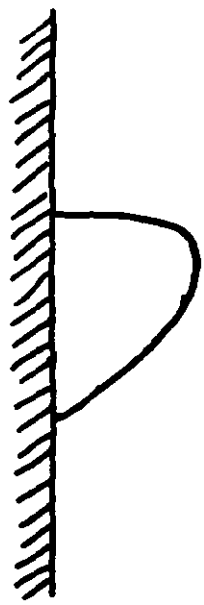
$\Delta\chi^2 = 1$
relative
$m_H = 50$
Passarin
(my interp

$\Delta\chi^2 = 1$

relative

$m_H = 50$

Lisi+Foglio



$\Delta\chi^2 = 1$
relative
$m_H = 50$
Carter

Allowed region of (m_t, m_H) plane

Summer 1990: $\Delta\chi^2 = 1$ relative to $m_H = 40$ GeV

J.E. + Fogli

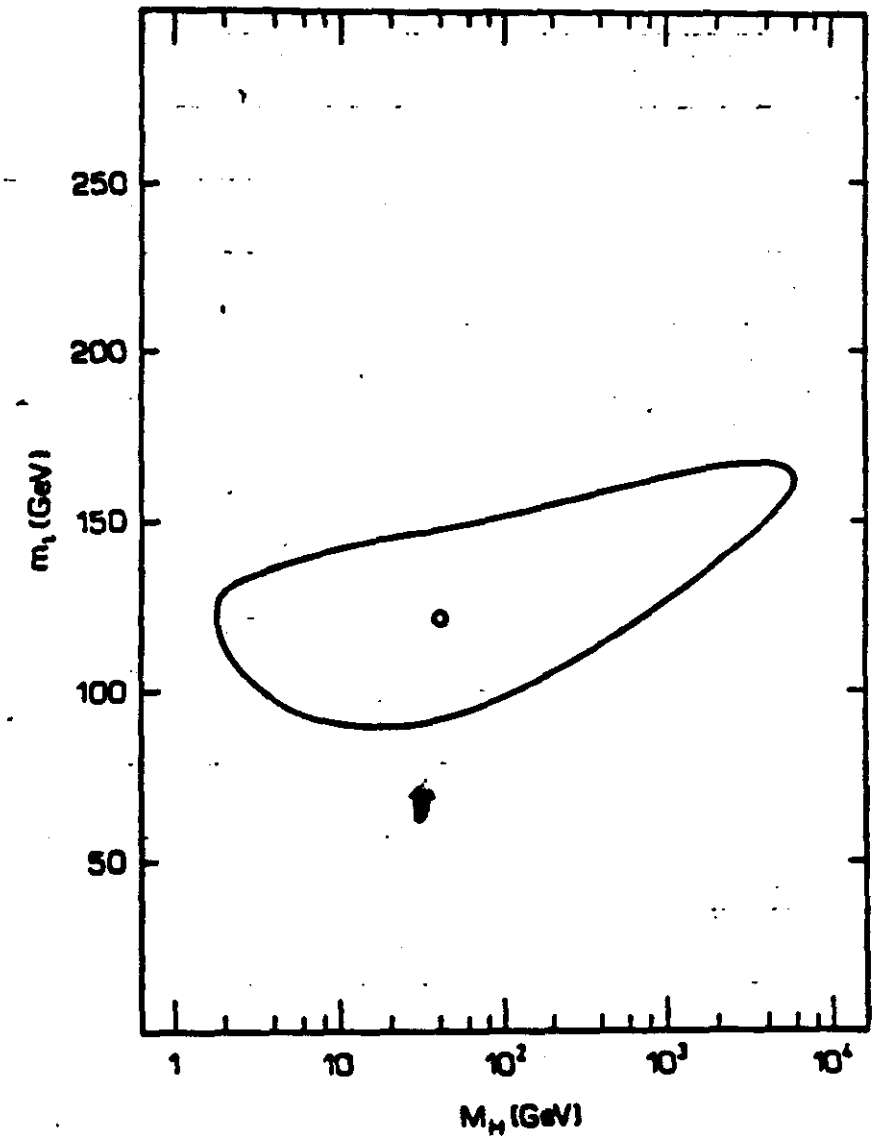


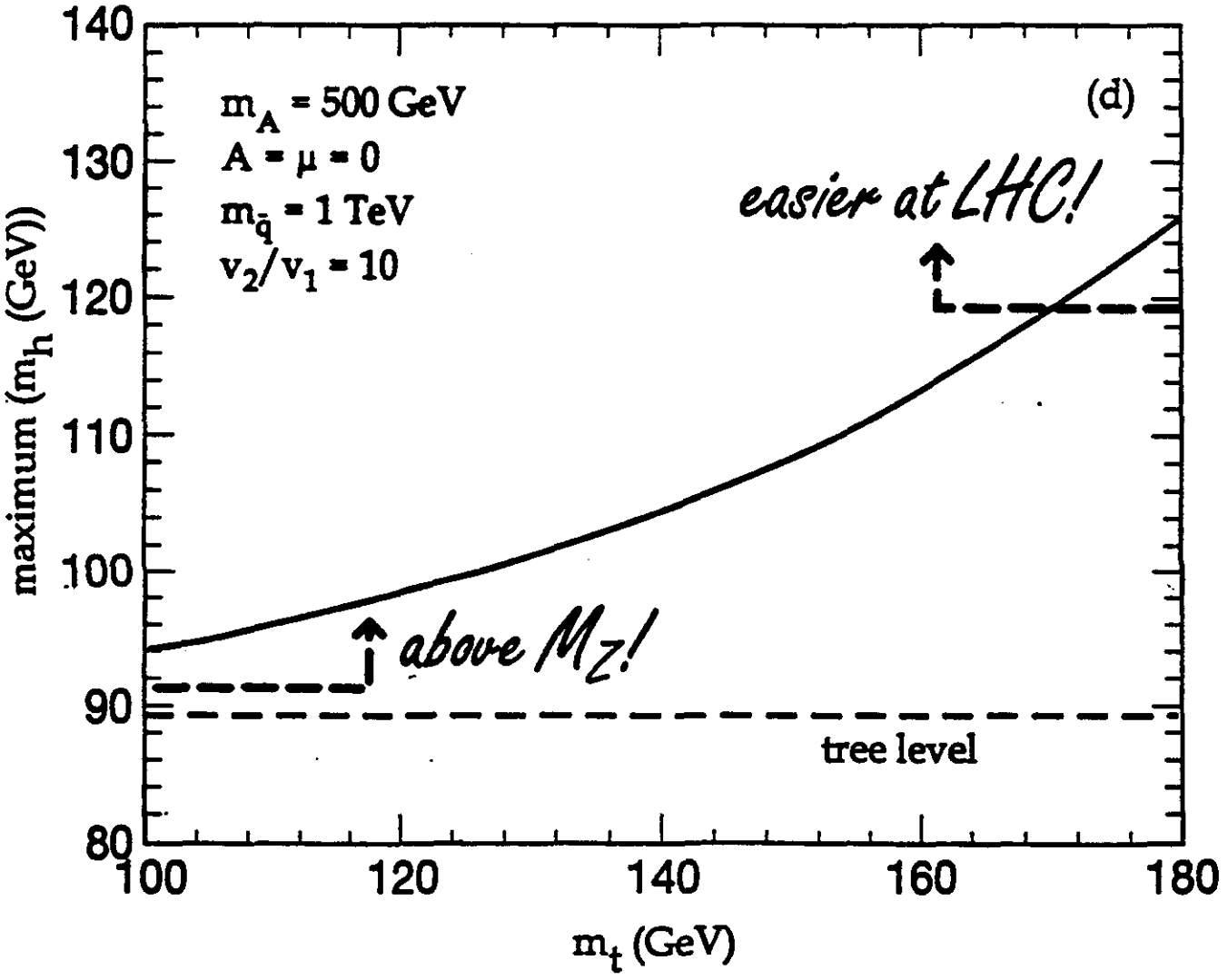
Fig. 6 — $\Delta\chi^2 = 1$ **contour in the** (M_H, m_t) **plane: note the 68.3 % C.L. lower and upper limits on** M_H **of 1.8 GeV and 6 TeV, respectively. All the data are included.**

Imprimé au CERN. Prix : 0.35 Fr

Minimal SUSY & Tree level:

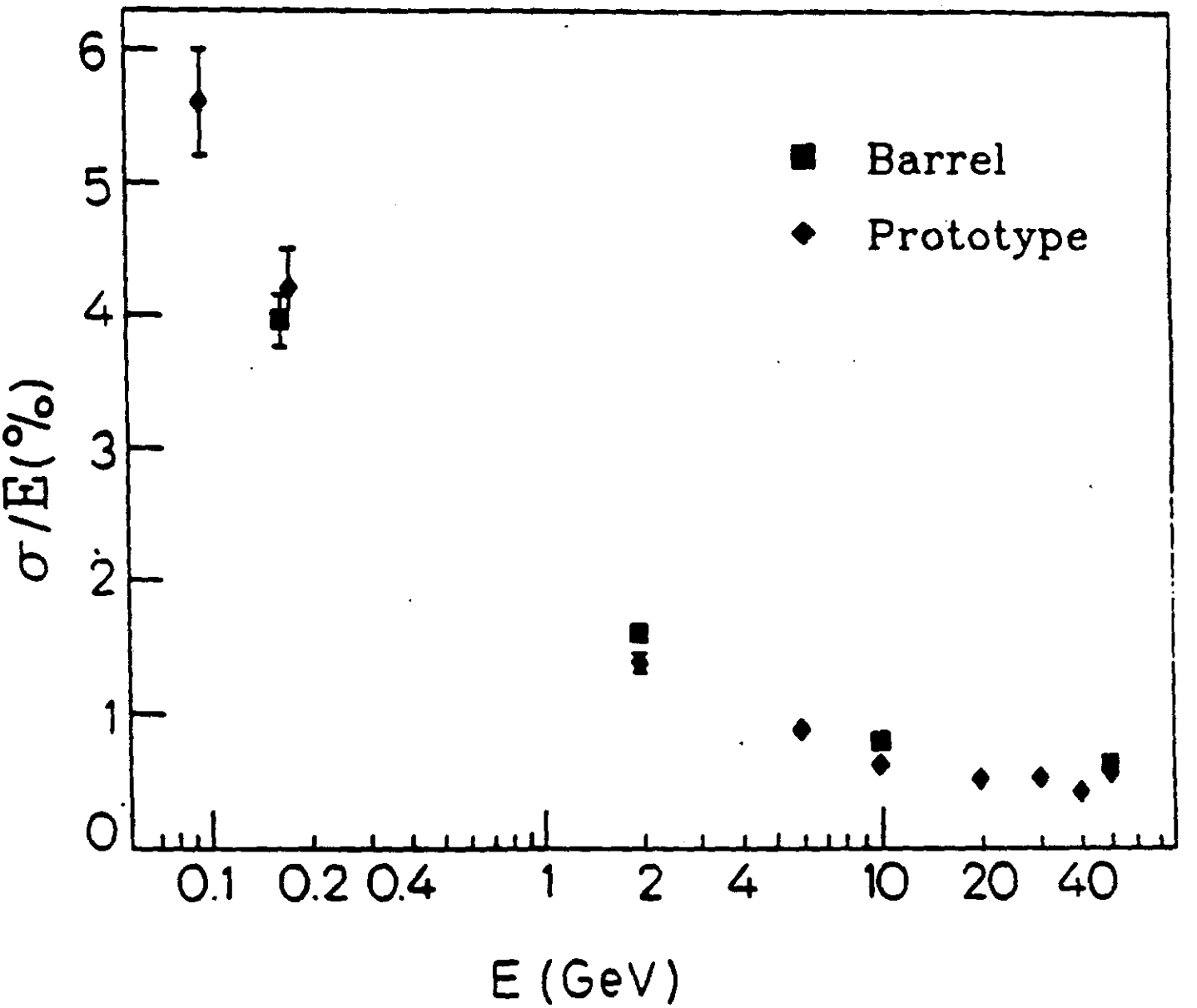
At least one $\tilde{H}^0$ with mass $\ll Z^0$, hence within LEP 200 range

but Radiative Corrections to Supersymmetric Higgs Mass

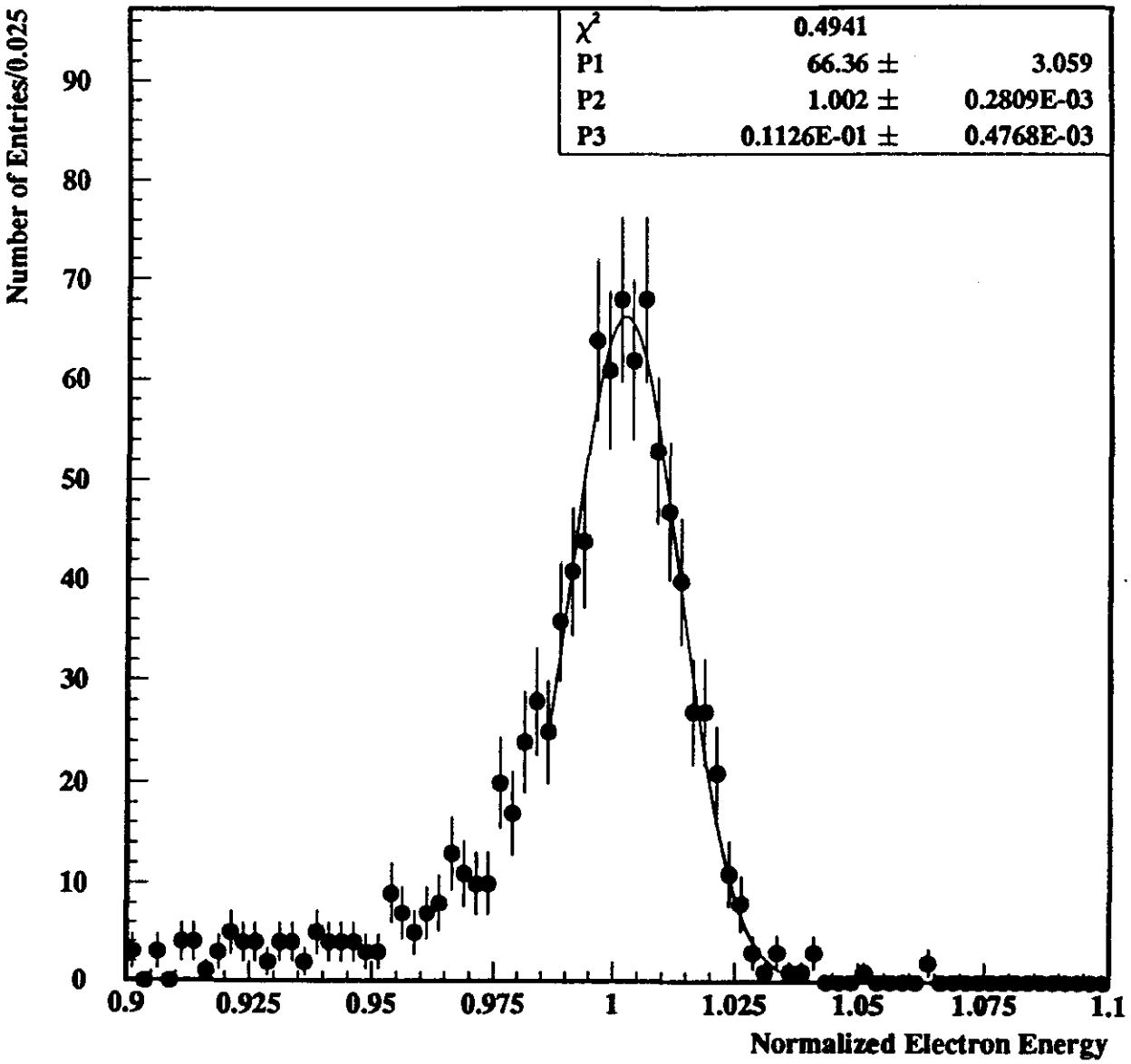


H. Newman
8/7/91
GEM Calorimeter Workshop

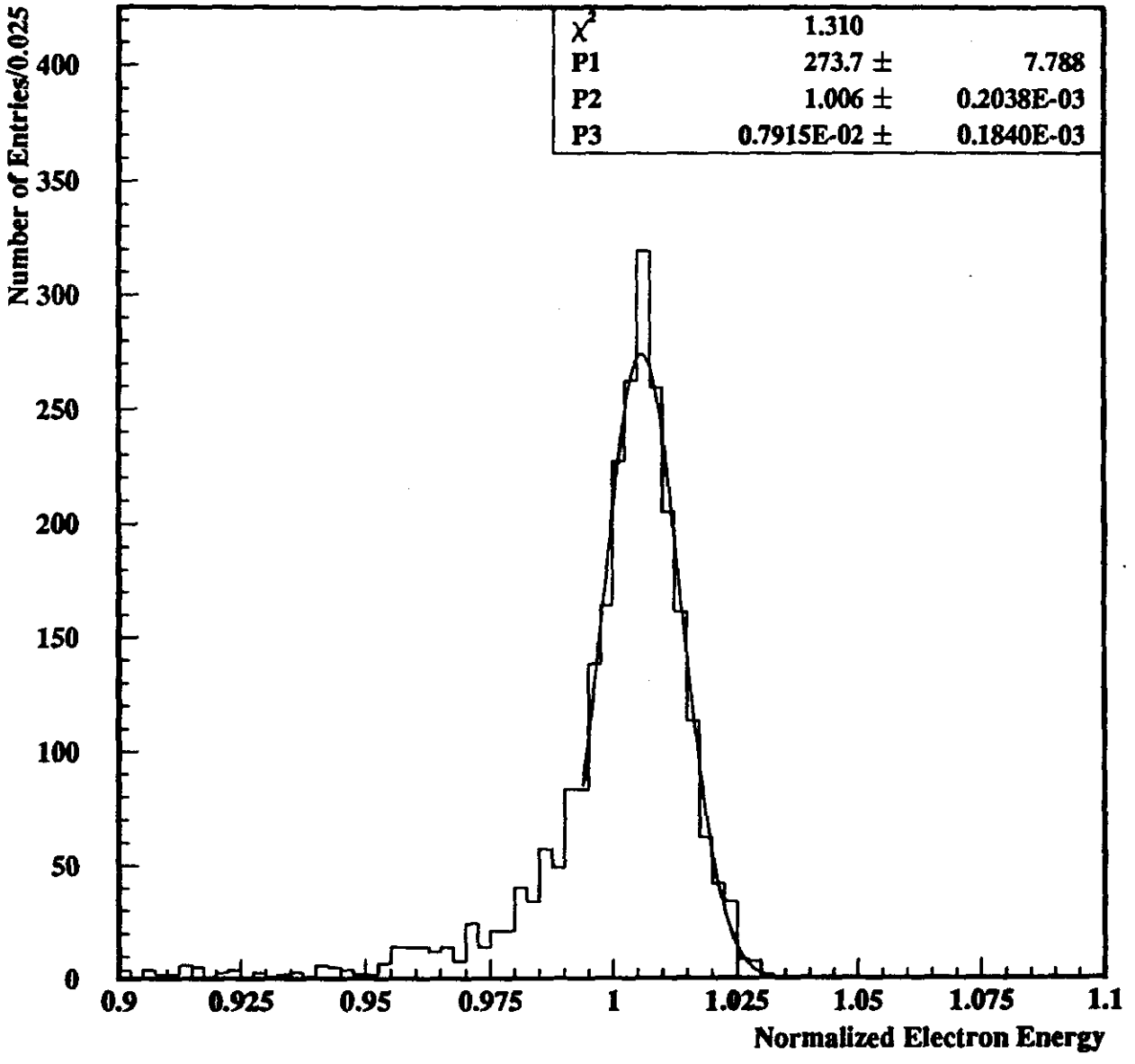
BGO energy measurement resolution



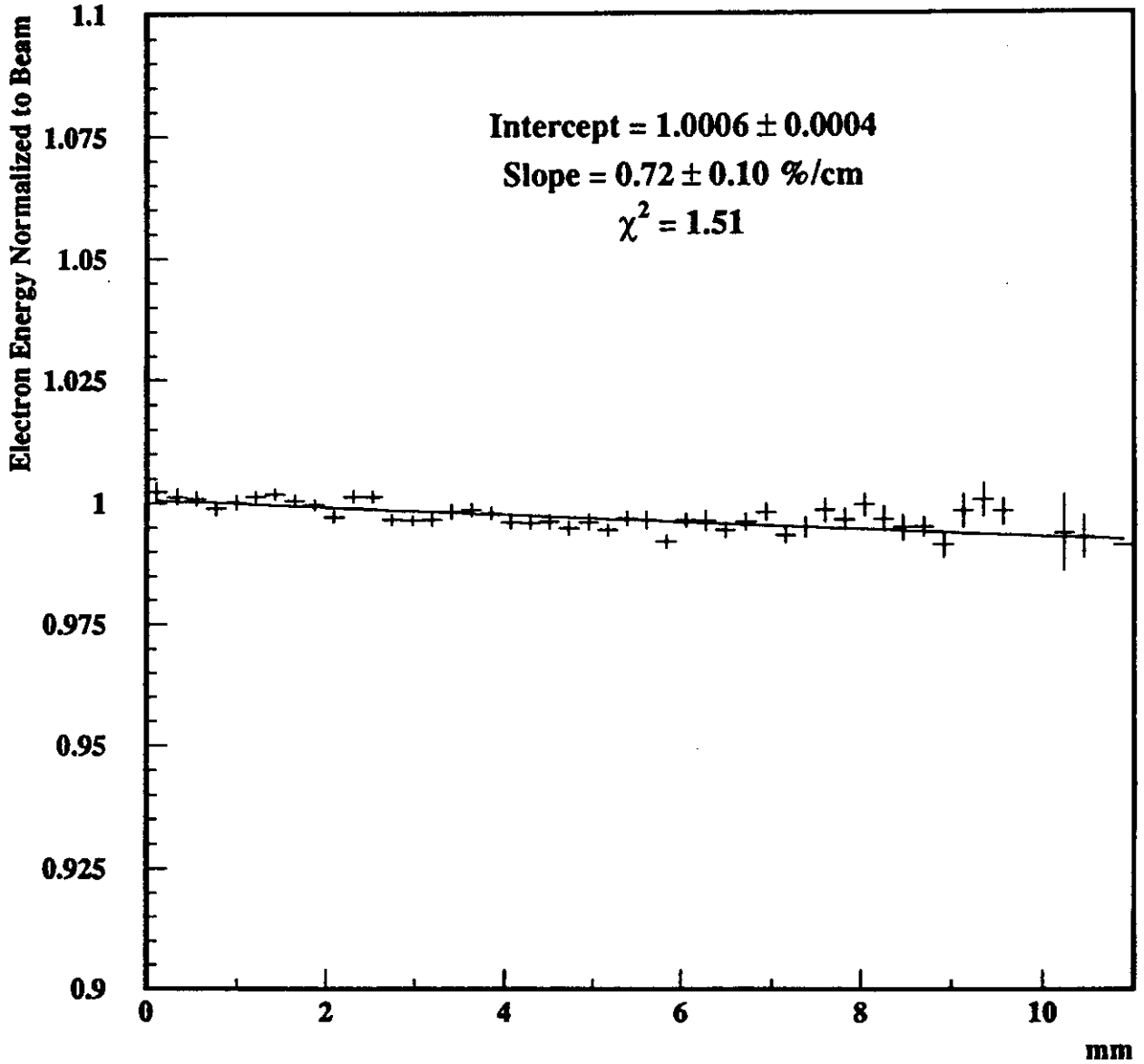
Electron Energy Measured in L3 BGO Calorimeter

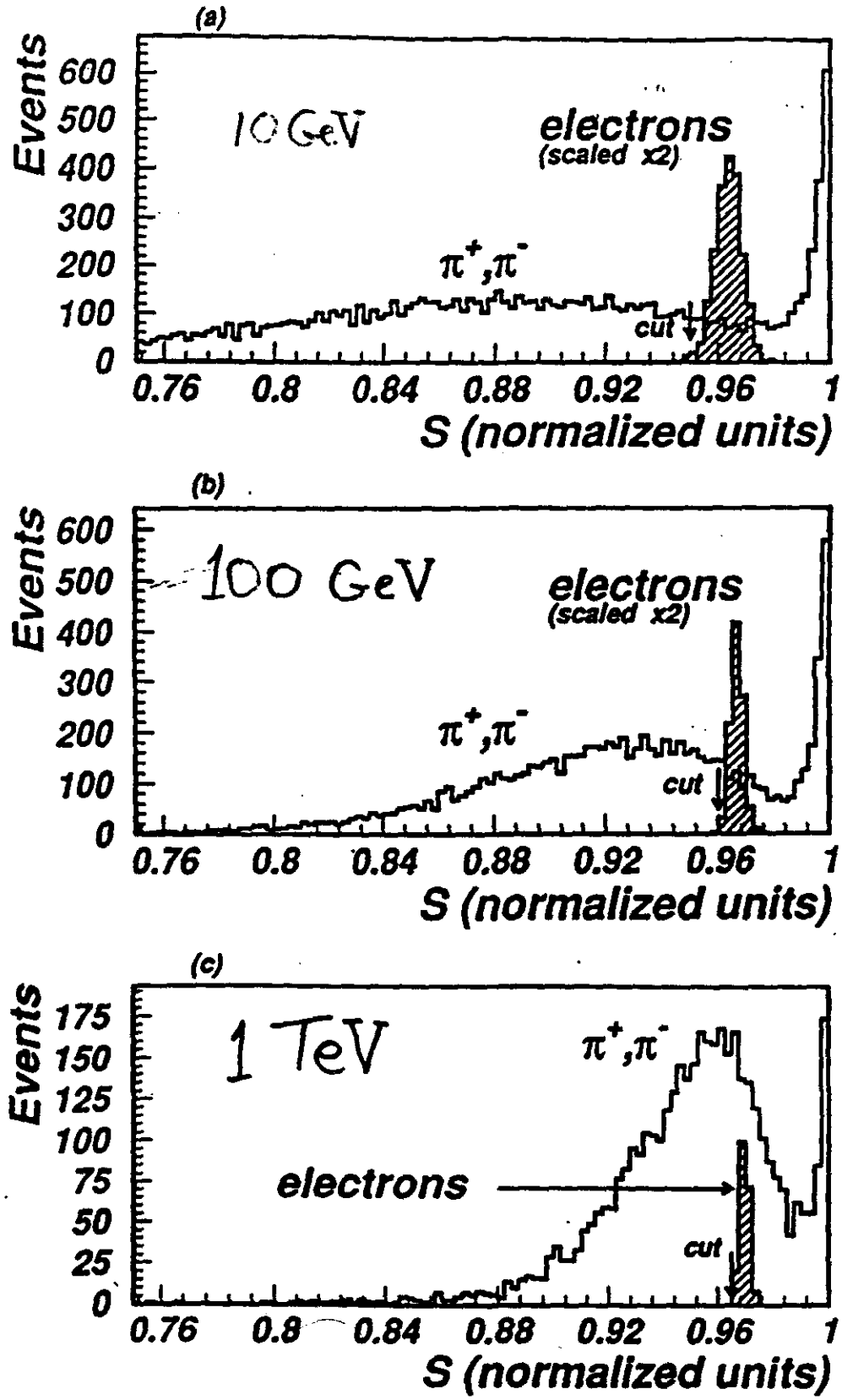


Electron Energy Simulated in L3 BGO Calorimeter



Position Dependence for 90ab and 91a Data



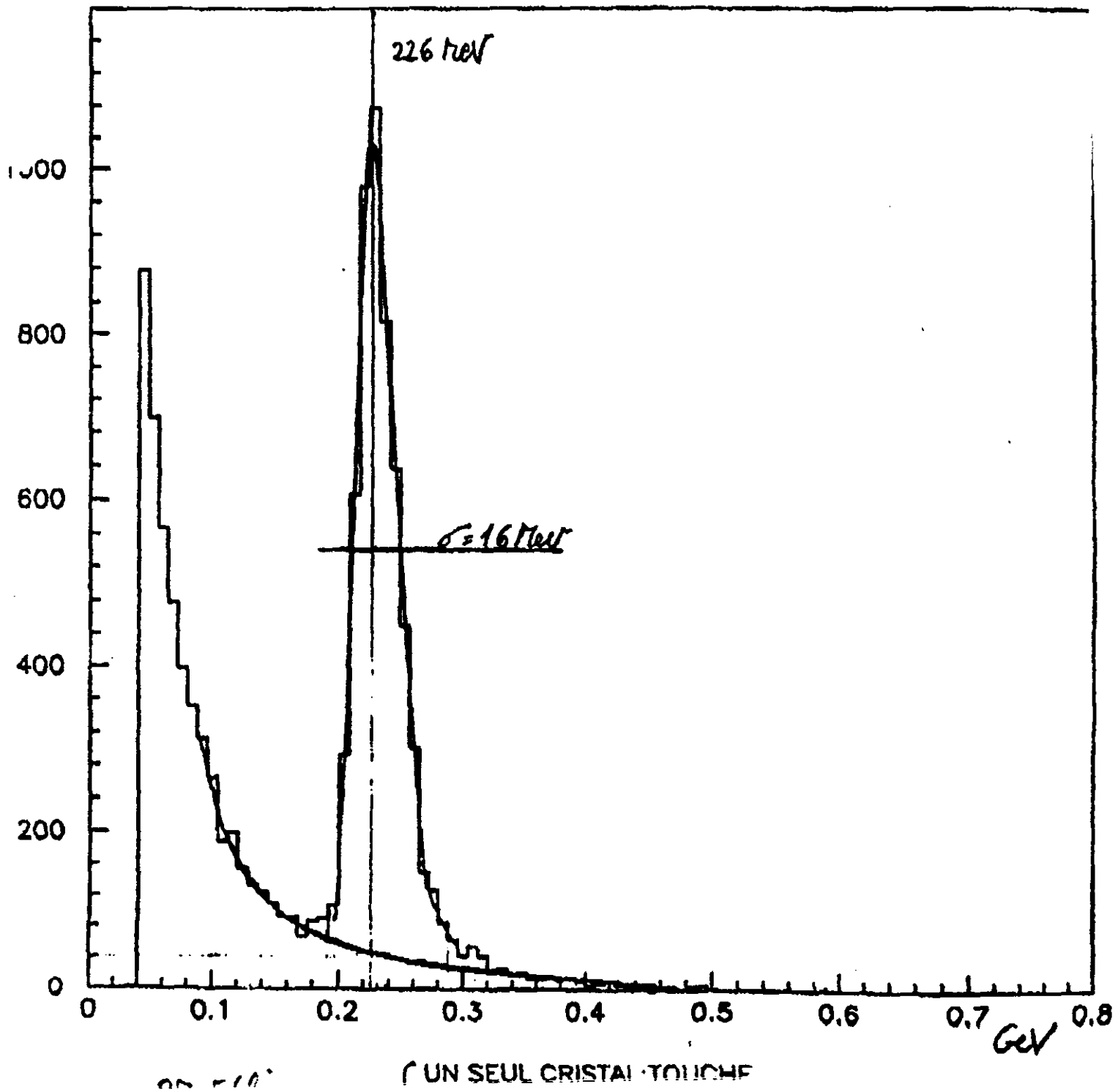


The transverse shower shape distribution in $S \equiv \sum_{3\times3} E_{EM}^{cell} / \sum_{5\times5} E_{EM}^{cell}$, for electrons and charged pions at (a) 10 GeV, (b) 100 GeV, and (c) 1 TeV.

Peak at 226 MeV ⇒ 9.42 MeV/cm
Δ ≈ 5 bin of 8 MeV ⇒ 38 MeV
σ ≈ 16 MeV σ⁻ ≈ 13.6 MeV
σ/E ≈ 7.1% σ⁻/E ≈ 6.0%

L3 / BGO
JULY 90
S. Y. + D. B.

~ 30 000 γγ Events
~ ½ of 1990
~ 5100 MIP



BARIUM FLUORIDE CALORIMETER CALIBRATION

- **Minimum Ionizing Particles (MIPs) from pp Collisions**
  - Pass Through Crystals Longitudinally
  - Calibrate to 0.4% in 12 Hours

- **Verify With Inclusive** e^+e^- From Z^0, Υ, J
  - Reconstruct Mass: Use RFQ + MIP Results
  - 200 e^+ or e^- from Υ, 20 from Z^0 Per Crystal Per Week

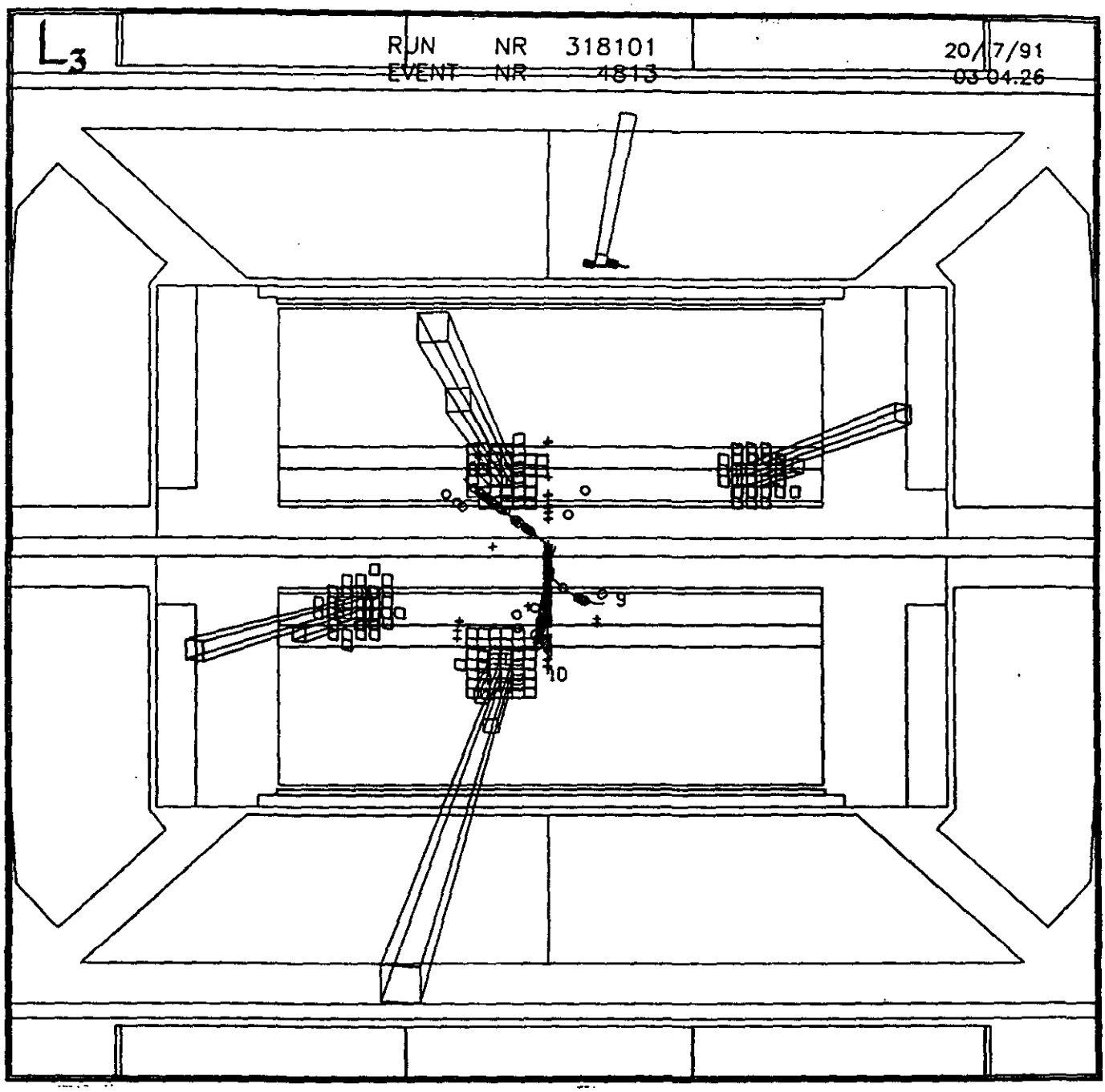
PHYSICS of ELECTRONS and PHOTONS At The TeV SCALE

ISOLATE NEW PHYSICS SIGNALS

from "Standard" Physics Backgrounds

- **Cleanly Separate Leptons and Photons from Jets and Single Hadrons.**
- **Reconstruct Multilepton, Multiphoton, and Lepton-Photon Invariant Masses Precisely**

Run # 318101 Event # 4813 Total Energy : 88.32 GeV

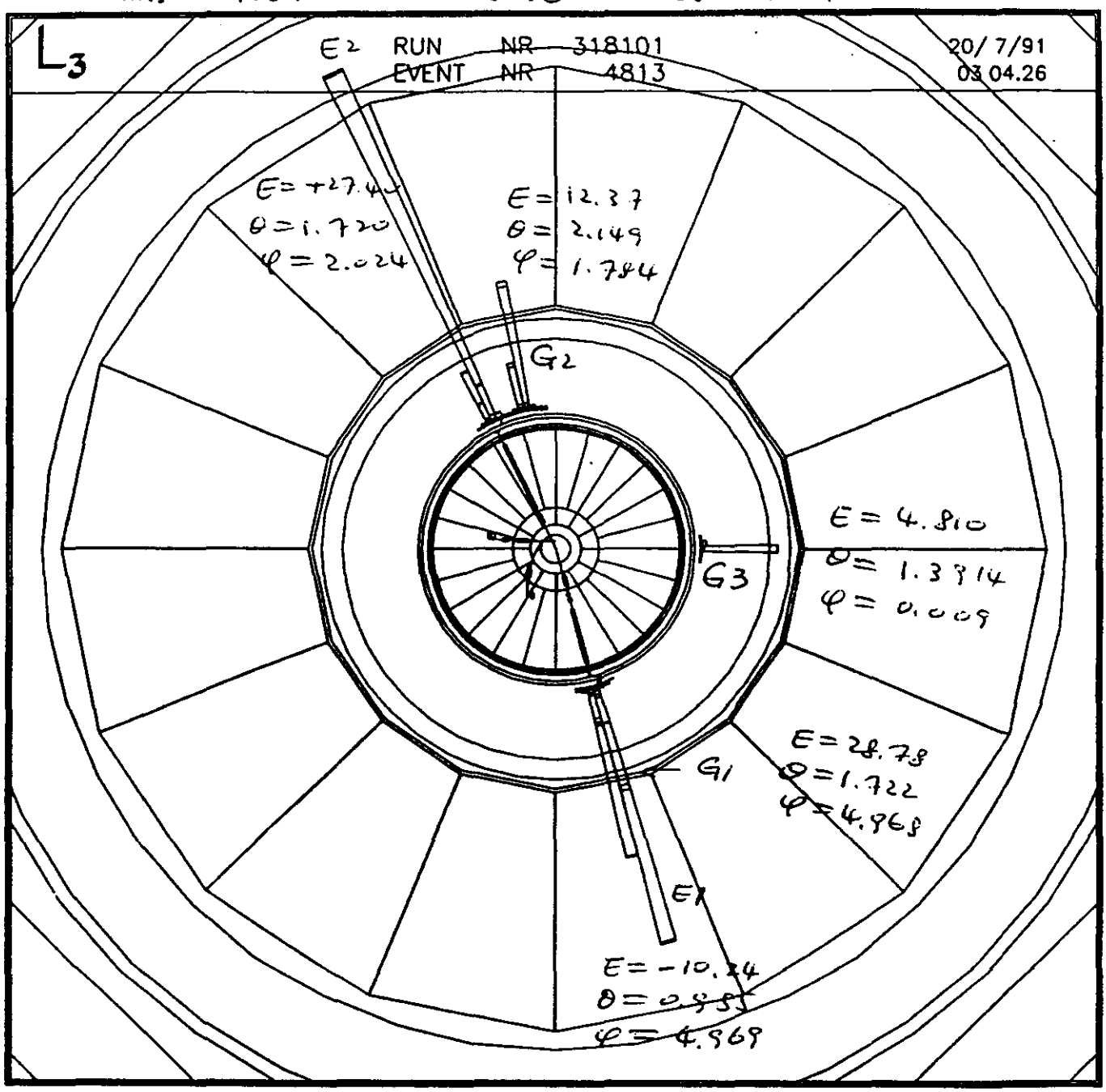


Transverse Imbalance :	94.05 GeV	**Longitudinal Imbalance :**	0.01 GeV
Thrust : -.0965	**Major :** 0.9182	**Minor :** 0.2396	
Printed Date :	*Saturday, July 27, 1991 15:17:28*		

M(G1, G2) = 35.26 M(G1, G3) = 14.78 M(G2, G3) = 12.27

Run # 318101 Event # 4813 Total Energy : 88.32 GeV

E_{mis} = 7.59 P_{mis} = 8.46 θ_{mis} = 0.127

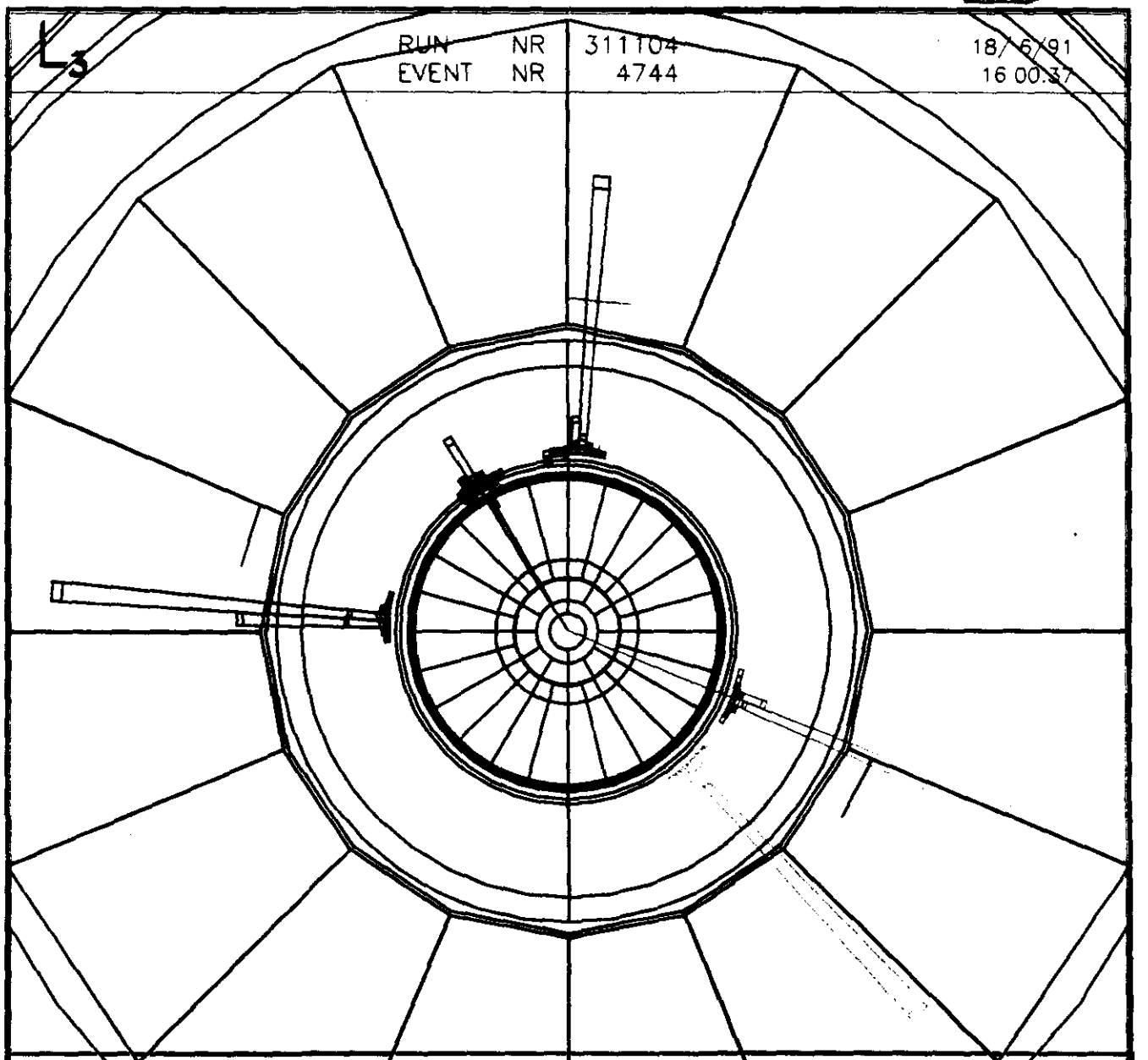


Transverse Imbalance :	94.05 GeV	**Longitudinal Imbalance :**	0.01 GeV
Thrust : -.0965	**Major :** 0.9182	**Minor :** 0.2396	
Printed Date :	*Saturday, July 27, 1991 15:19:29*		

M(G1, G2, G3) = 40.15 M(E1, E2) = 32.46

Miss(G1, G2, G3) = 38.31 Miss(E1, E2) = 50.06

Run # 311104 Event # 4744 Total Energy : 105.18 GeV

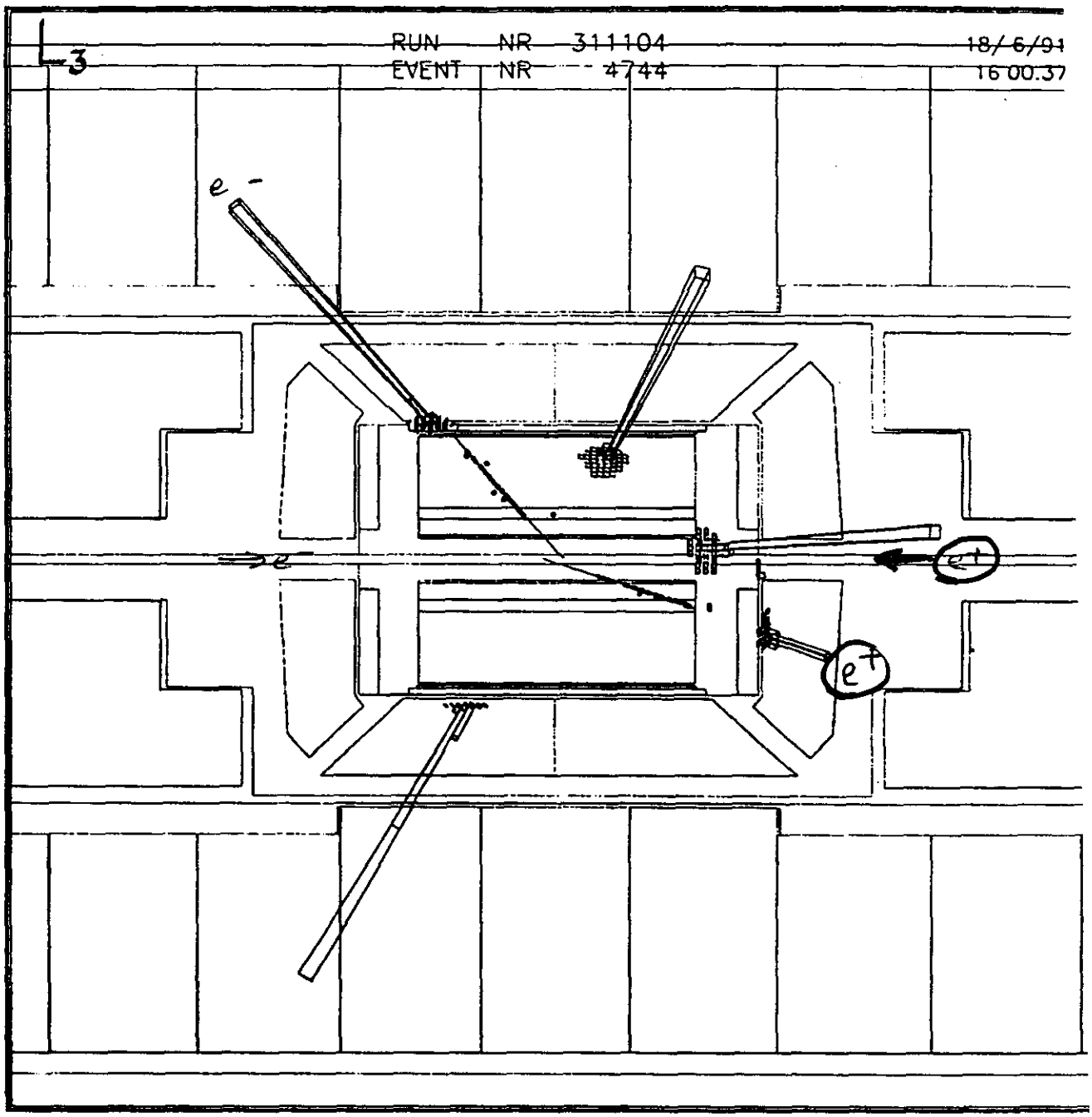


Transverse Imbalance :	**97.77 GeV**	**Longitudinal Imbalance :**	**0.04 GeV**

Thrust : -.0323	**Major :** 0.5993	**Minor :** 0.5846

Printed Date : *Friday, June 28, 1991 17:23:18*

Run # 311104 Event # 4744 Total Energy : 97.68 GeV



Transverse Imbalance :	0.03 GeV	**Longitudinal Imbalance :**	0.01 GeV
Thrust : 0.6932	**Major :** 0.5962	**Minor :**	0.3037
Printed Date :	*Sunday, June 23, 1991 17:34: 2*		

$\mu^+\mu^-\gamma\gamma$ Events in L3

(WITH BGO ENDCAPS in '91)

→ 2 in 220 K Hadrons

→ $m_{\gamma\gamma}$ = 58.8 GeV; 58.9 GeV
$\sigma \sim 0.6$ GeV

- MC Study $E_{\gamma_1}, E_{\gamma_2} > 1$ GeV
  Isolation Cut $> 5^\circ$

- YFS (3.02) (JADACH & WARD): Prelim.
  Predict 19.3 Events
  See 19 Events
  } $M_{\gamma\gamma}^{MAX} < 25$ GeV

- $P_1(M_{\gamma\gamma} > 50) = 1\%$ Expect (0.15 ev)
  $P_2(M_{\gamma\gamma} > 40) = 5.6\%$ Expect (0.38 ev)

- Expectation: 0.035 events Per 1 GeV Bin

- STRANGE: NOTHING in $ee\gamma\gamma$ channels
  $q\bar{q}\gamma\gamma$

- But if get 3rd & 4th events:
  EFFECT ESTABLISHED

- $m_{\nu\nu}$ Crucial

8/8/91

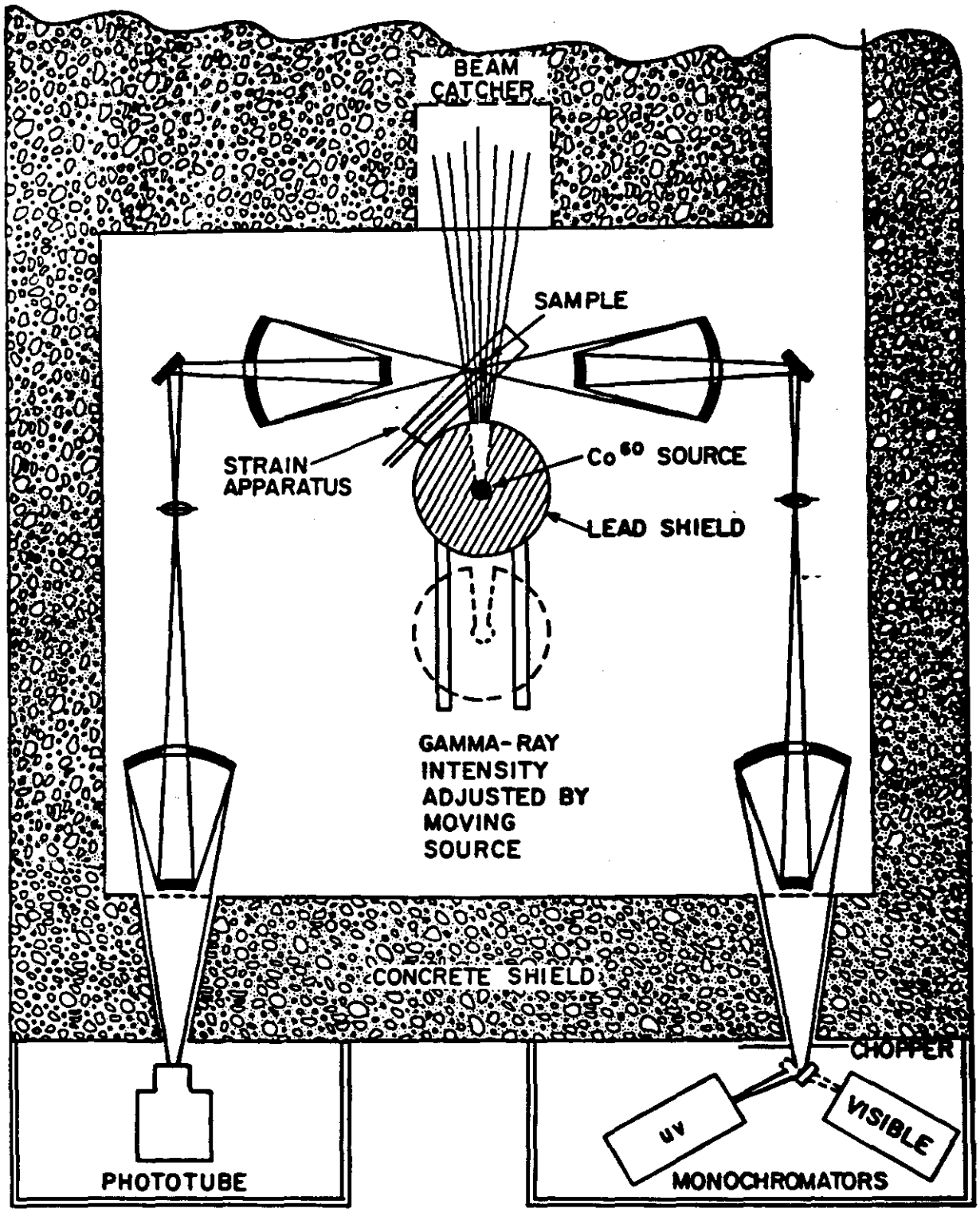
RADIATION INDUCED Effects IN BaF_2

C. Woody, J. Kierstead, P. Levy, S. Stoll

BNL

BNL ^{60}Co RADIATION FACILITY

$10^6 - 10^7$ R/week



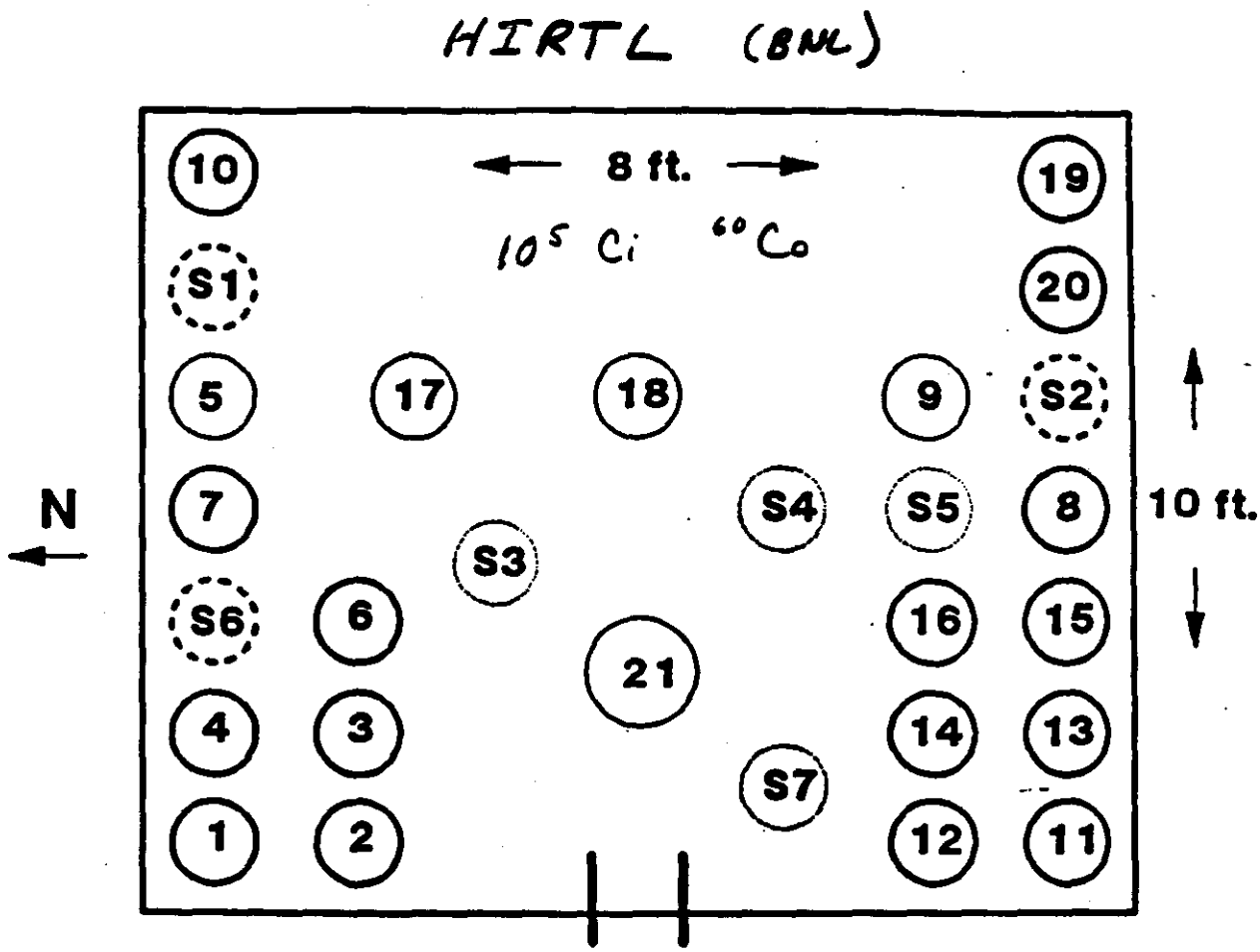


Figure 2. Gamma Source and Airtube Locations

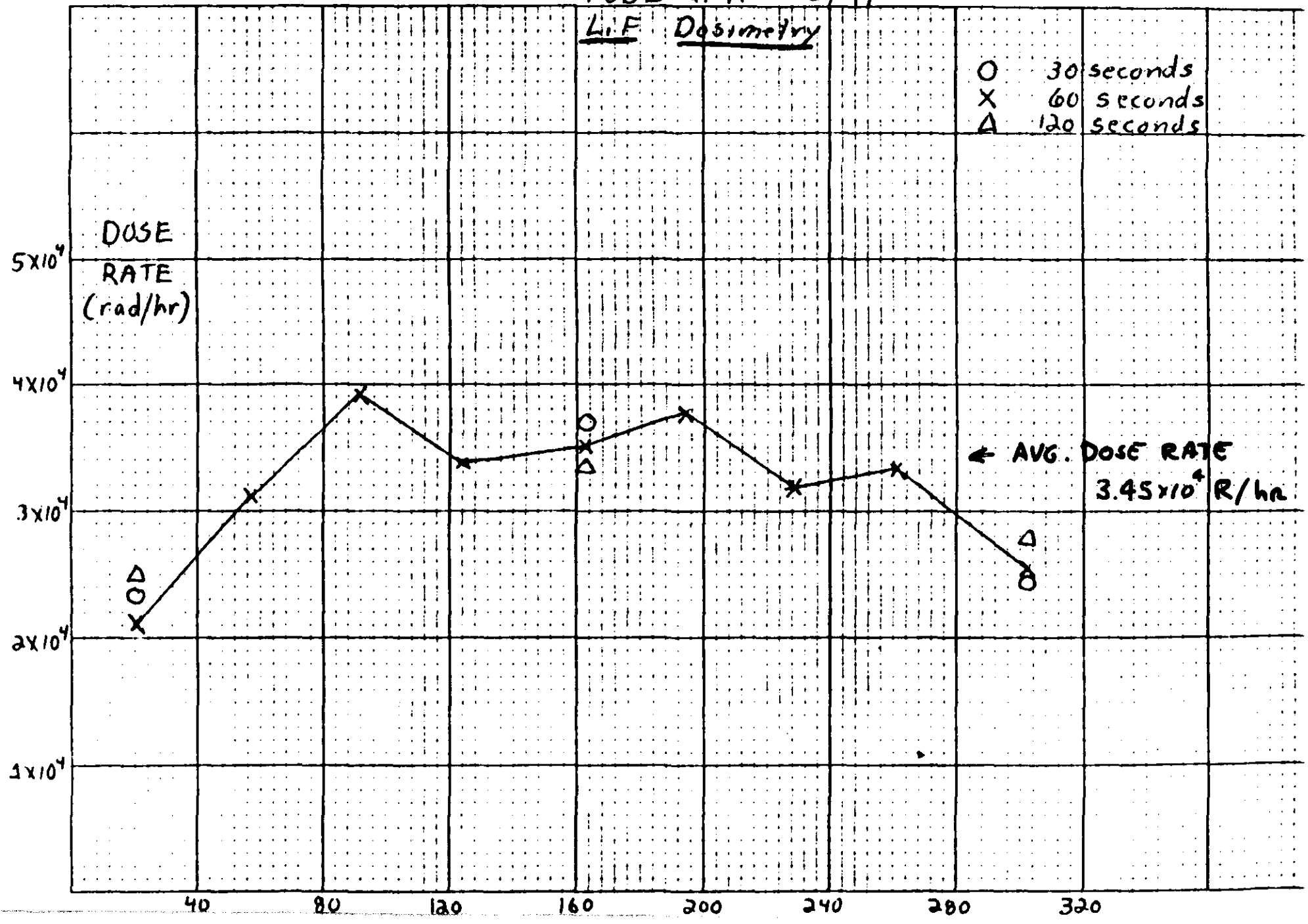
KEY:

10	Airtube with Source (in cask)
5	Airtube with no Source
S1	Source in Cask (no airtube)
S3	Source (rack only, no air tube or cask)
| |	Chiller supply/return pipes and Autofill

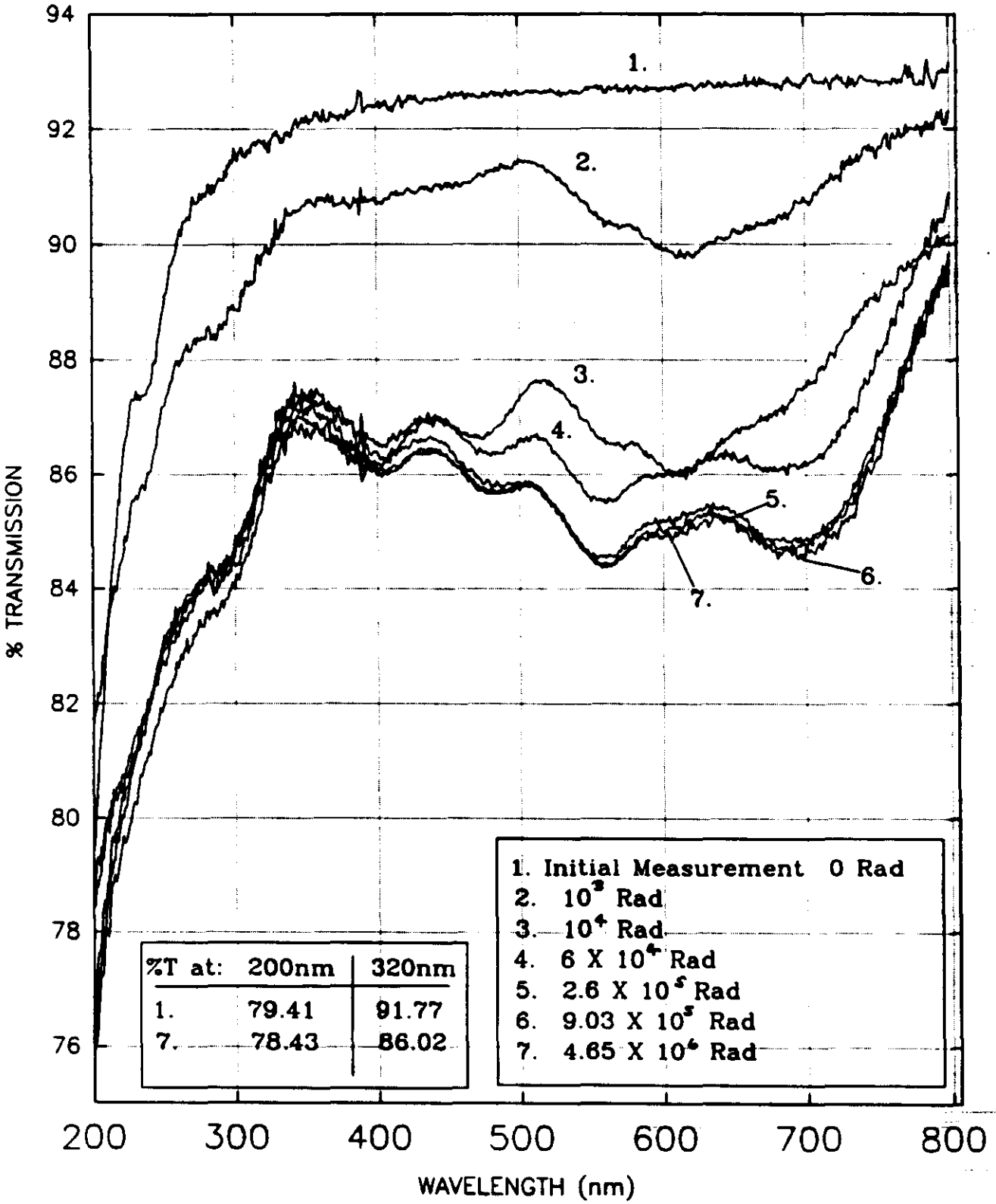
GRAPHING PAPER NO. 1780-10
TRACING PAPER NO. 1787-10
CROSS SECTION-10X10 TO 1 INCH
AMPARCO
MADE IN USA

TUBE #11 6/91

LiF Dosimetry

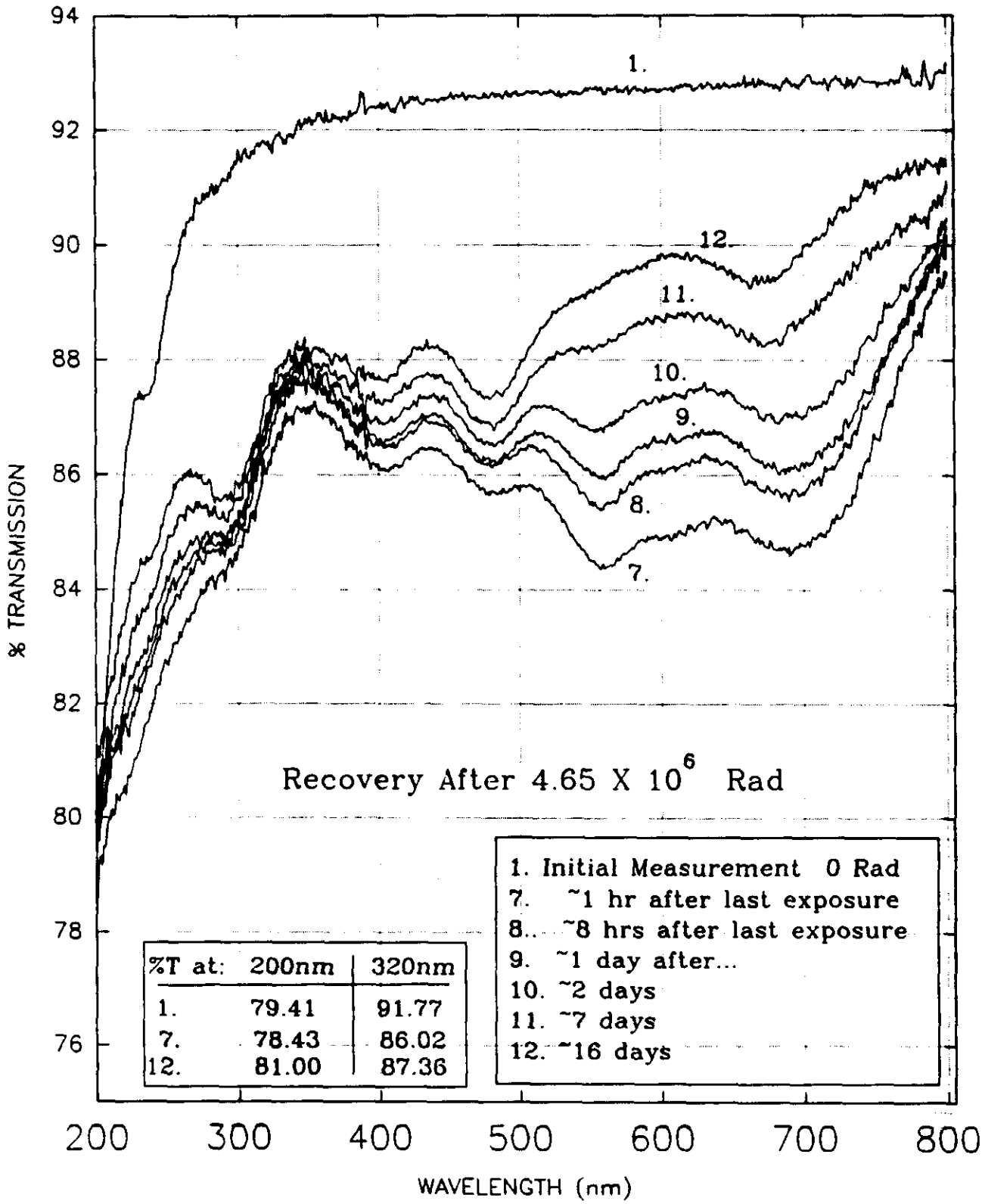


Hitachi Transmission Scans of BaF2 samples.
7/91 Radiation Damage Study
Sample: K458484B (samp1) 1 " CYLINDER



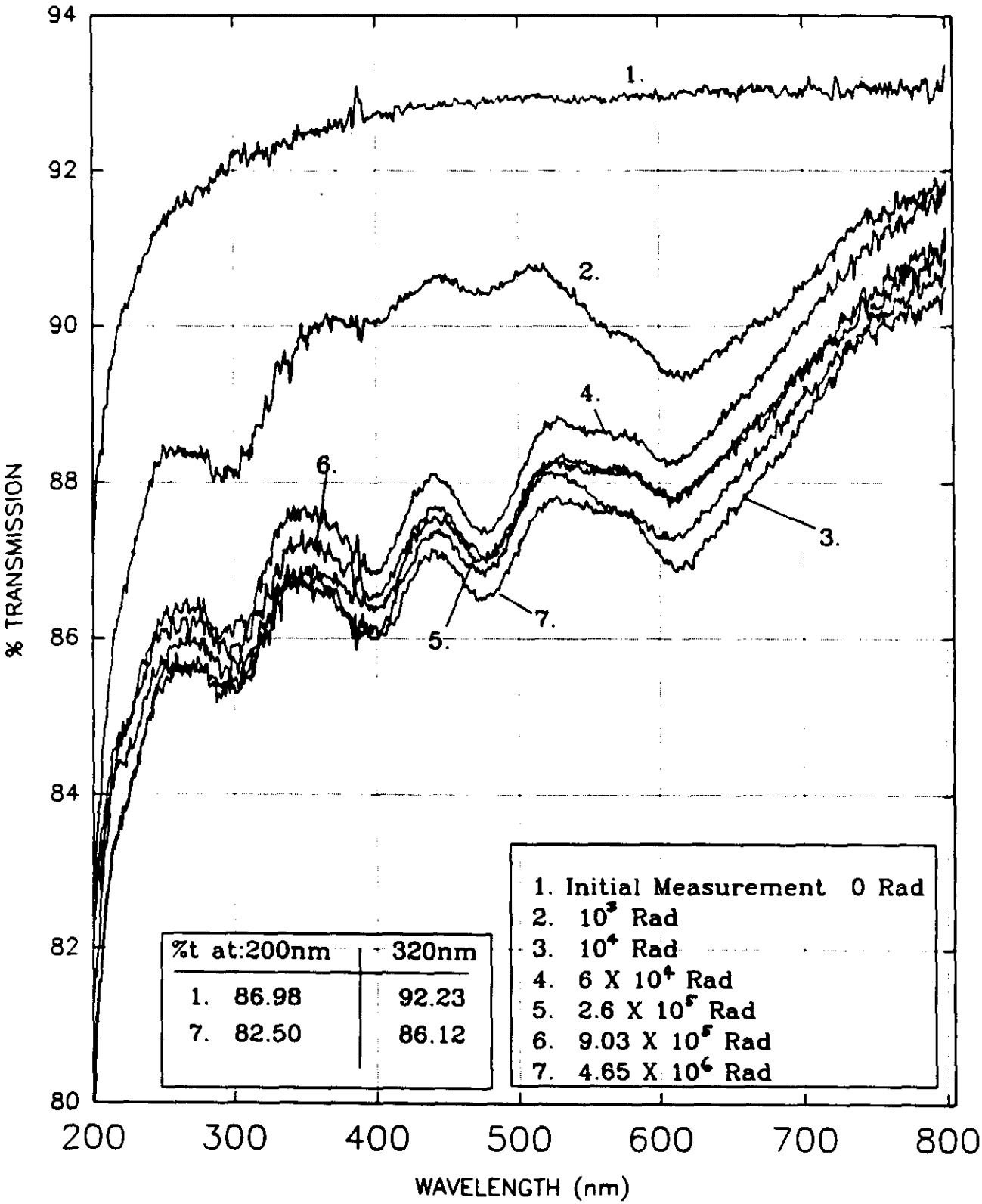
%T at:	200nm	320nm
1.	79.41	91.77
7.	78.43	86.02

Hitachi Transmission Scans of BaF2 samples.
7/91 Radiation Damage Study
Sample: K458484B (samp1) 1 " CYLINDER

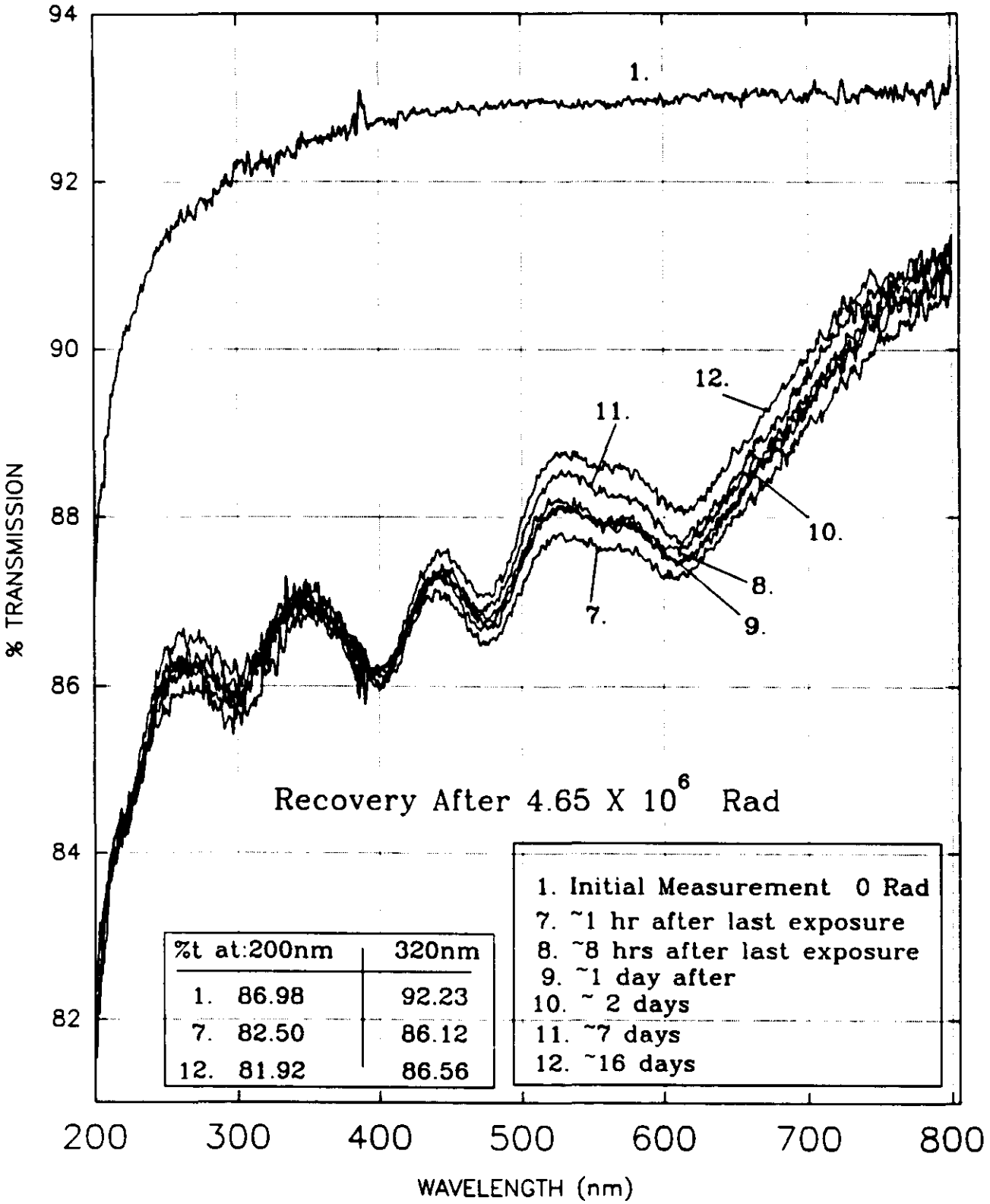


%T at:	200nm	320nm
1.	79.41	91.77
7.	78.43	86.02
12.	81.00	87.36

Hitachi Transmission Scans of BaF2 samples.
7/91 Radiation Damage Study
Sample: K14417B (samp2) 1 " CYLINDER

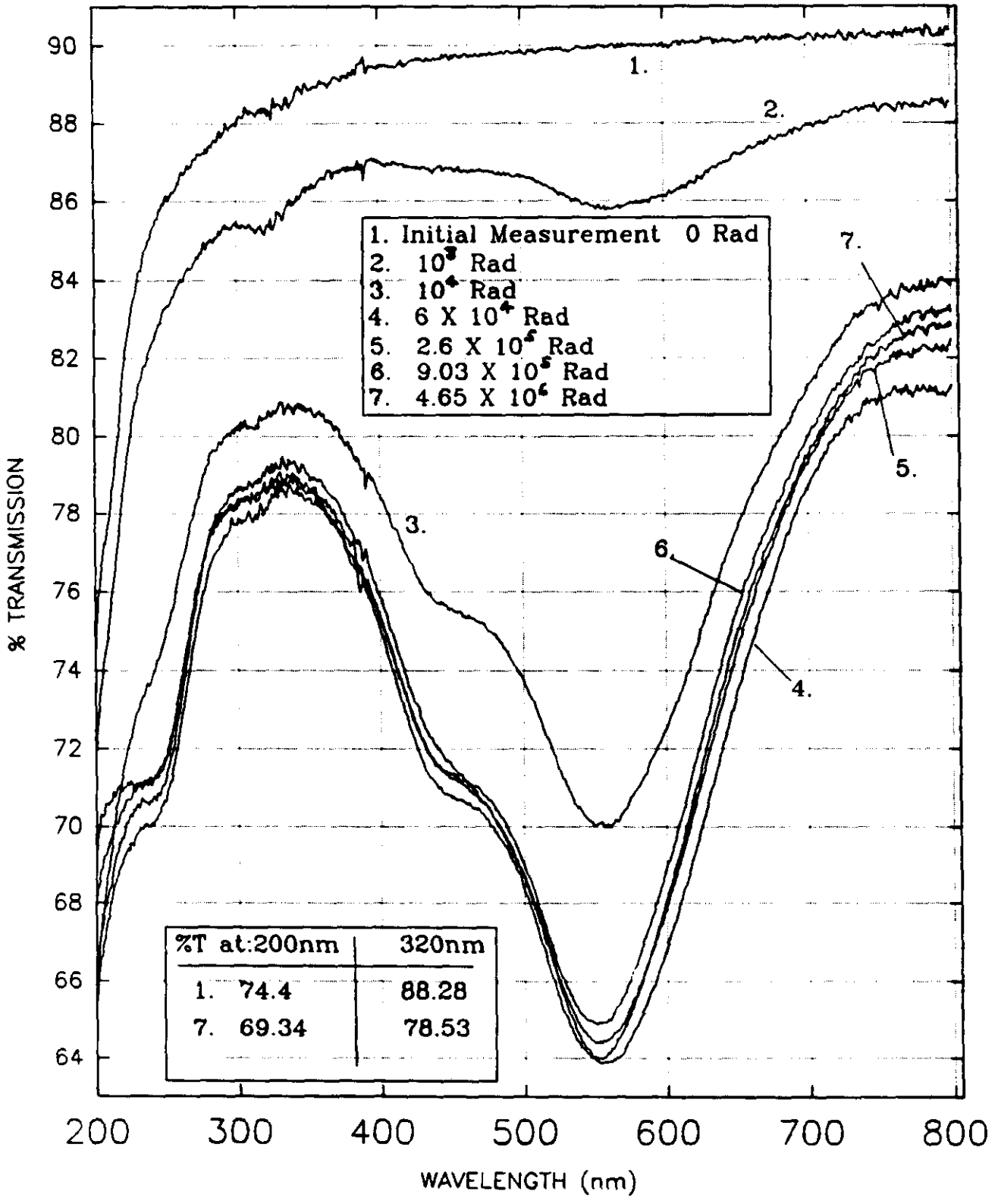


Hitachi Transmission Scans of BaF2 samples.
7/91 Radiation Damage Study
Sample: K14417B (samp2) 1 " CYLINDER

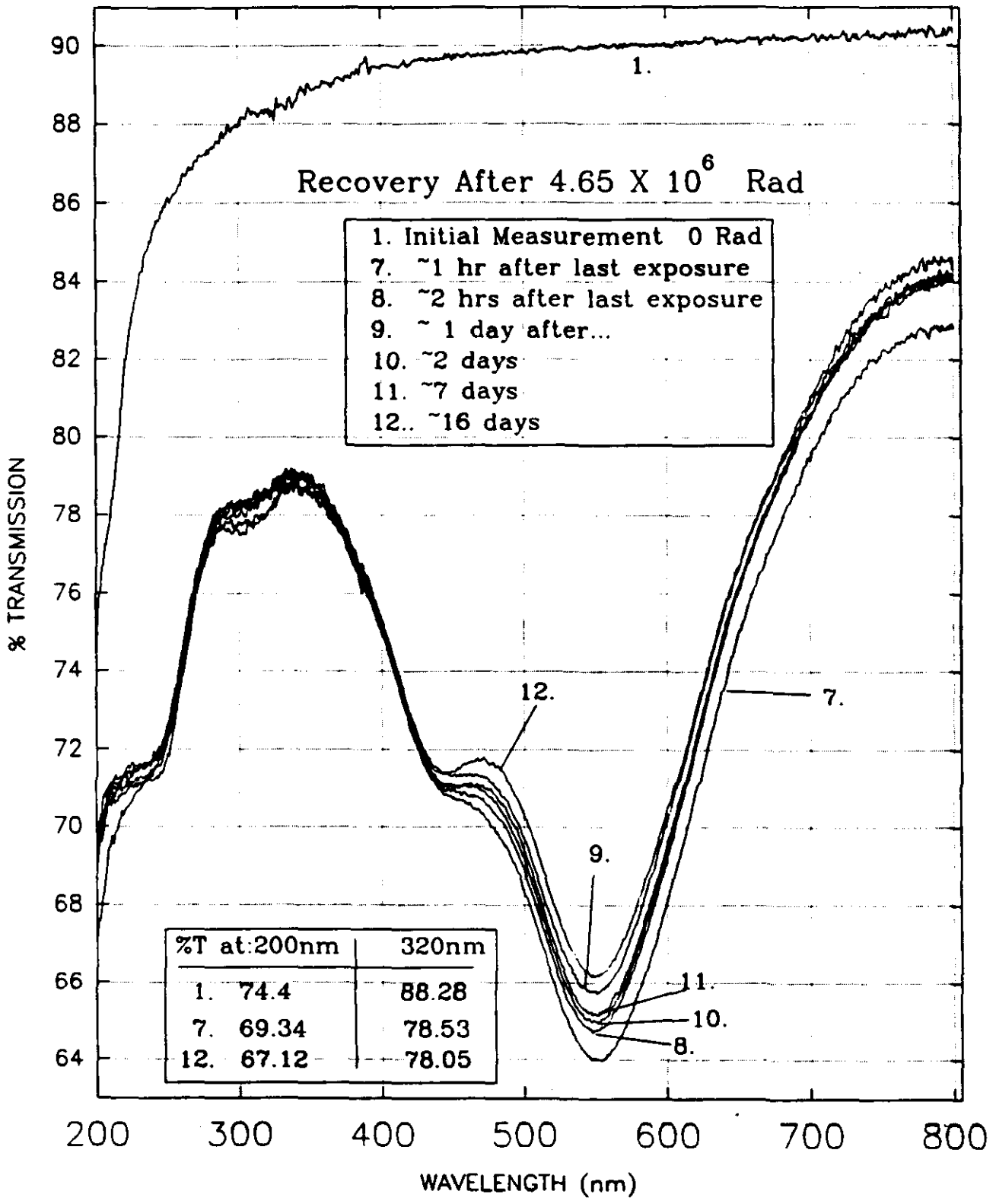


%t at:	200nm	320nm
1.	86.98	92.23
7.	82.50	86.12
12.	81.92	86.56

Hitachi Transmission Scans of BaF2 samples.
7/91 Radiation Damage Study
Sample: Harshaw Slab (samp3) 1 " CYLINDER



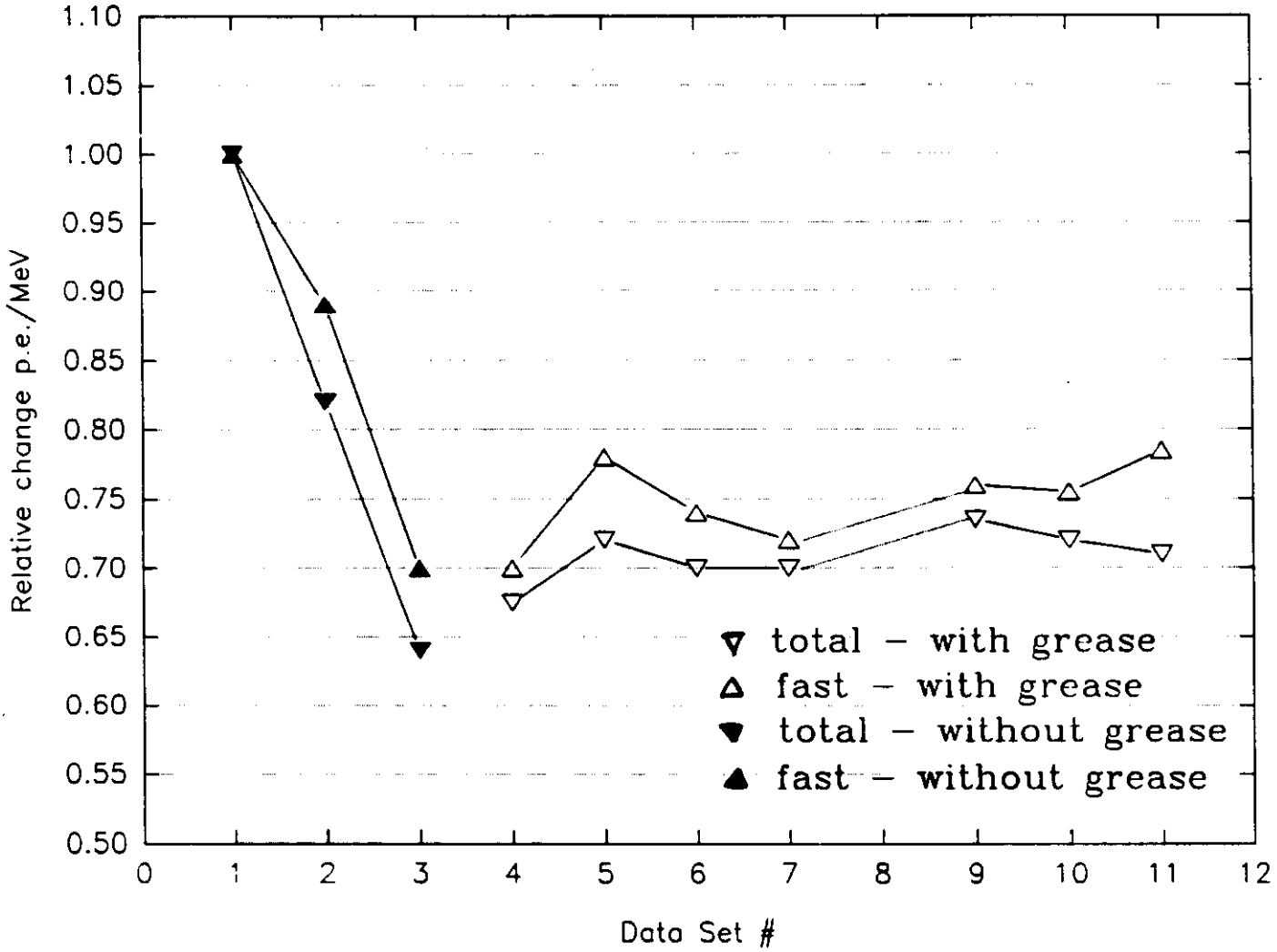
Hitachi Transmission Scans of BaF2 samples.
7/91 Radiation Damage Study
Sample: Harshaw Slab (samp3) 1 " CYLINDER



Light Output

PMT: BA98 (CsTe) at 1980V, with and without grease

K458484B (samp1)

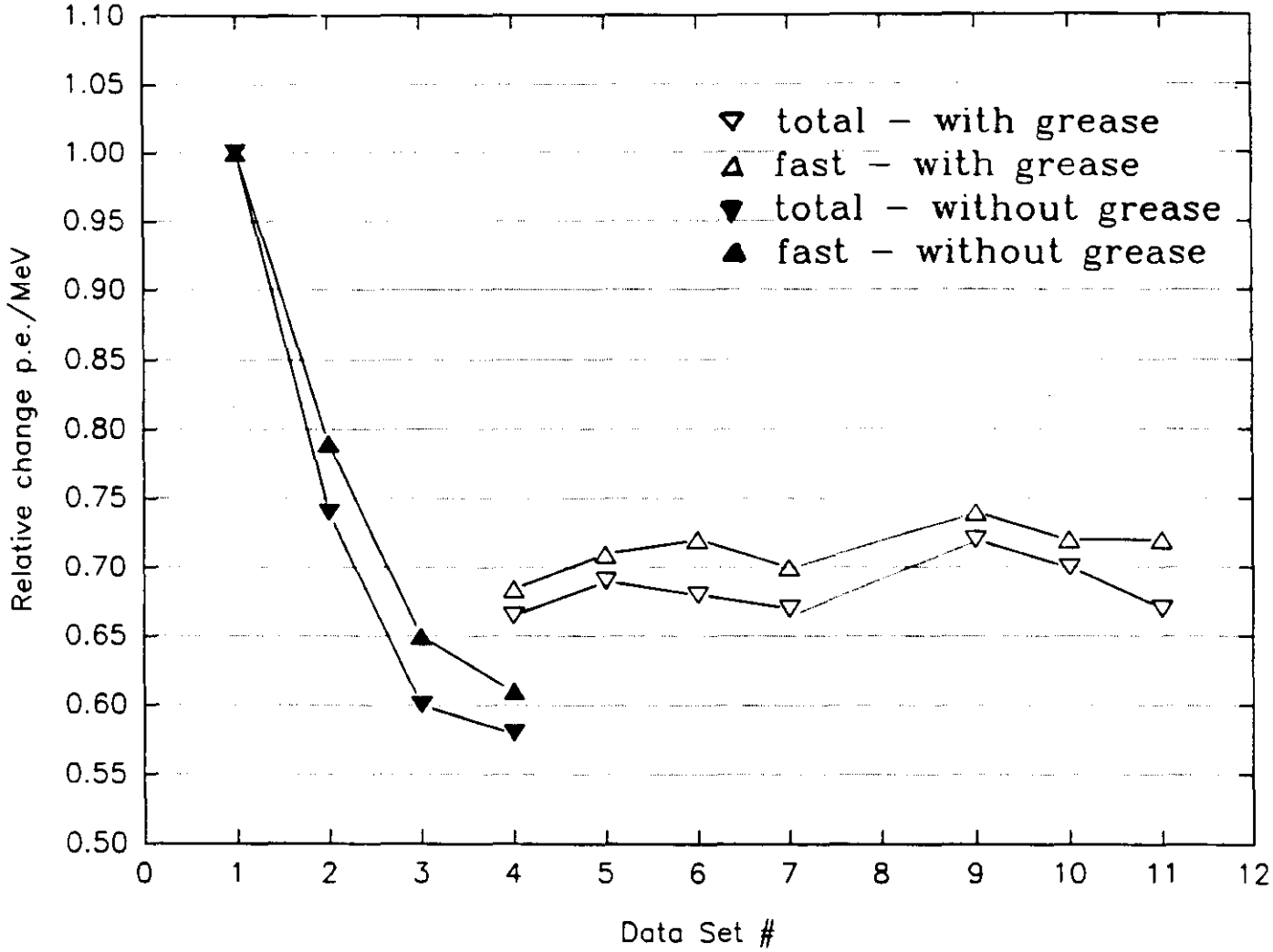


1. 7/2 Initial Measurements 0 Rad.
2. 7/8 10^3 Rad.
3. 7/8 10^4 Rad.
4. 7/9 6×10^4 Rad.
5. 7/9 2.65×10^5 Rad
6. 7/10. 9.03×10^5 Rad
7. 7/15 4.65×10^6 Rad.
8. 7/15 4.65×10^6 Rad.
9. 7/16 no additional radiation exposure
10. 7/17
11. 7/22

Light Output

PMT: BA98 (CsTe) at 1980V, with and without grease

K14417B(samp2)

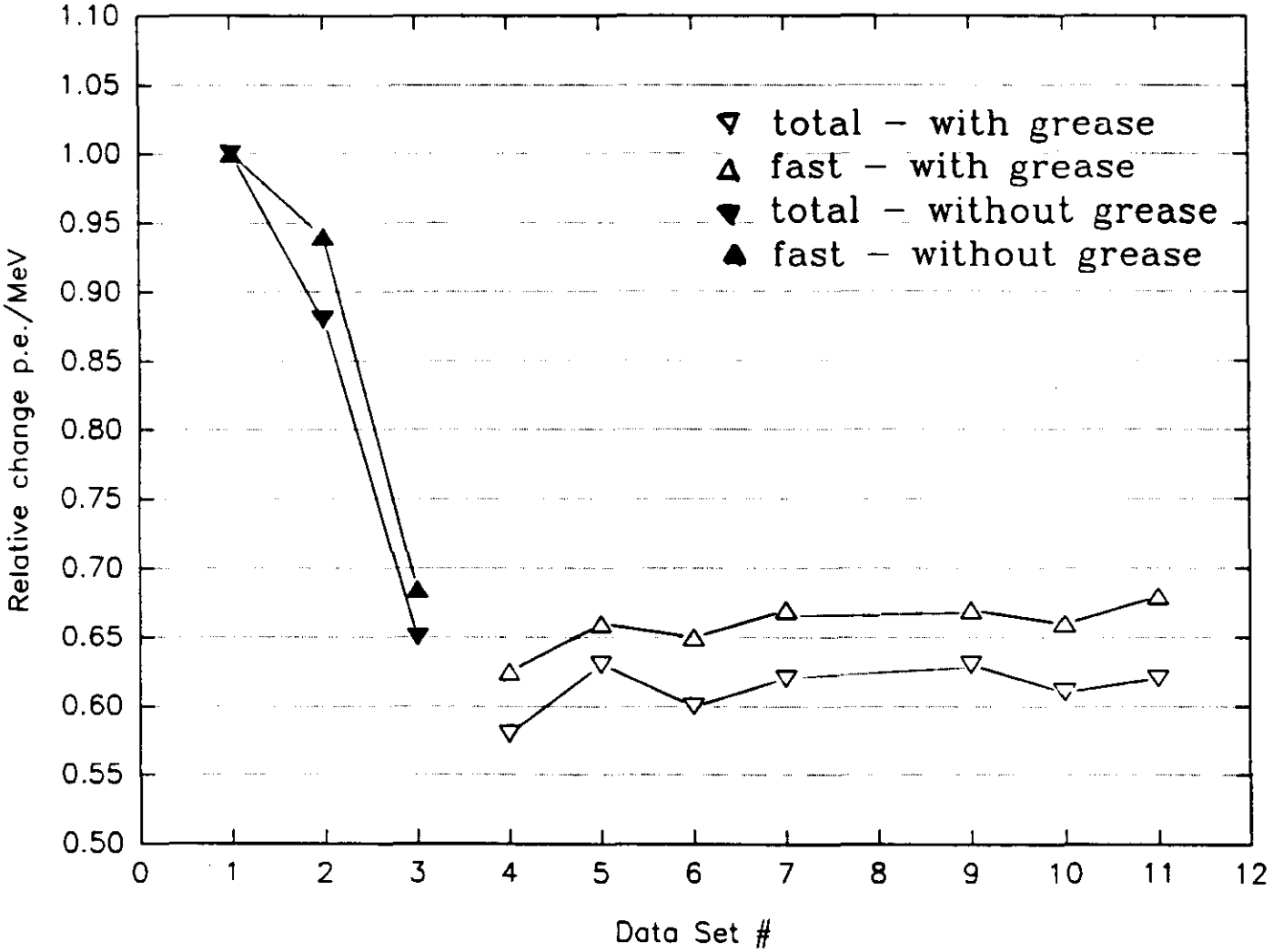


1. 7/2 Initial Measurements 0 Rad.
2. 7/8 10^3 Rad.
3. 7/8 10^4 Rad.
4. 7/9 6×10^4 Rad.
5. 7/9 2.65×10^5 Rad
6. 7/10. 9.03×10^5 Rad
7. 7/15 4.65×10^6 Rad.
8. 7/15 4.65×10^6 Rad.
9. 7/16 no additional radiation exposure
10. 7/17
11. 7/22

Light Output

PMT: BA98 (CsTe) at 1980V, with and without grease

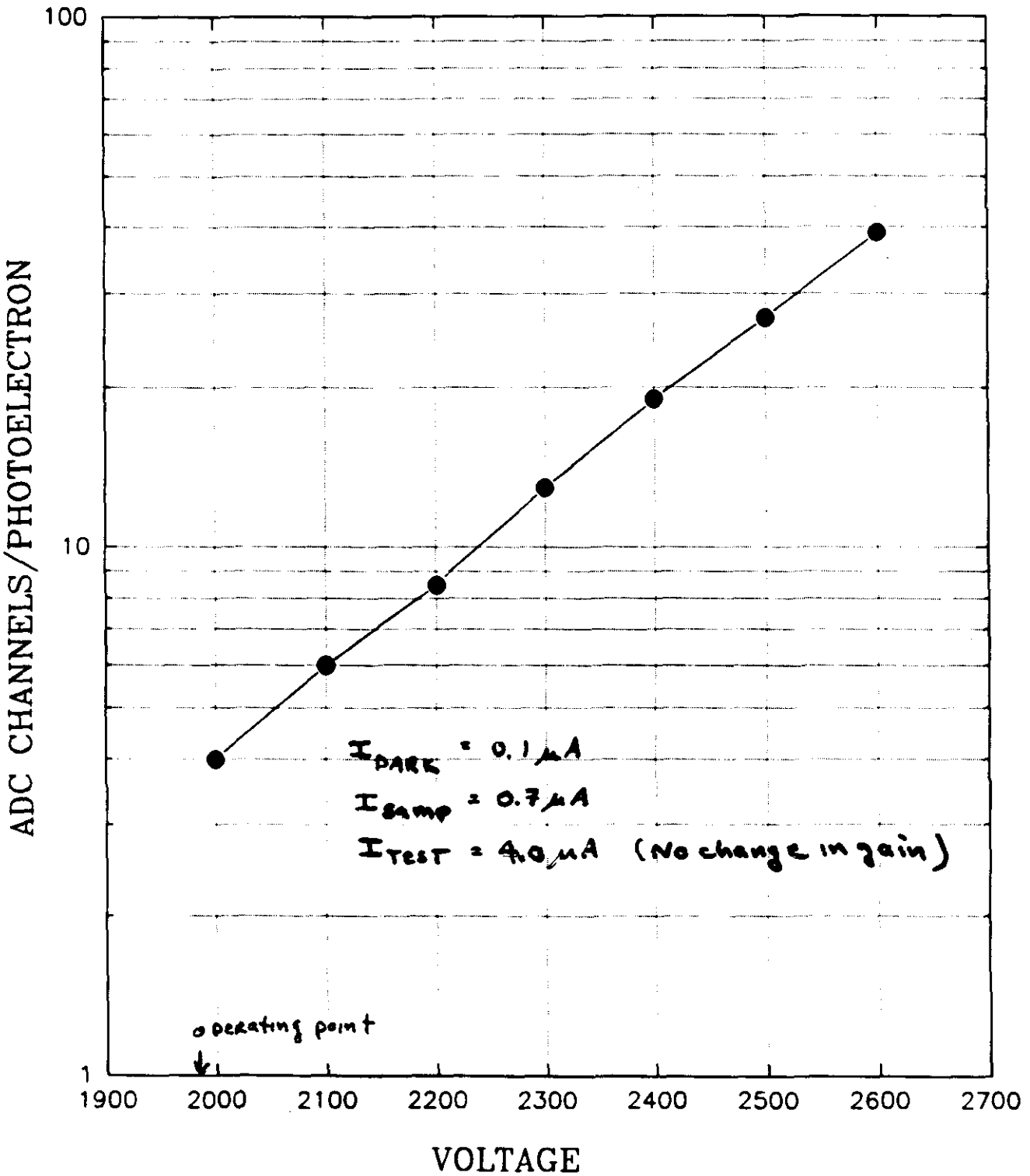
Harshaw Slab (samp3)



1. 7/2 Initial Measurements 0 Rad.
2. 7/8 10^3 Rad.
3. 7/8 10^4 Rad.
4. 7/9 6×10^4 Rad.
5. 7/9 2.65×10^5 Rad
6. 7/10. 9.03×10^5 Rad
7. 7/15 4.65×10^6 Rad.
8. 7/15 4.65×10^6 Rad.
9. 7/16 no additional radiation exposure
10. 7/17
11. 7/22

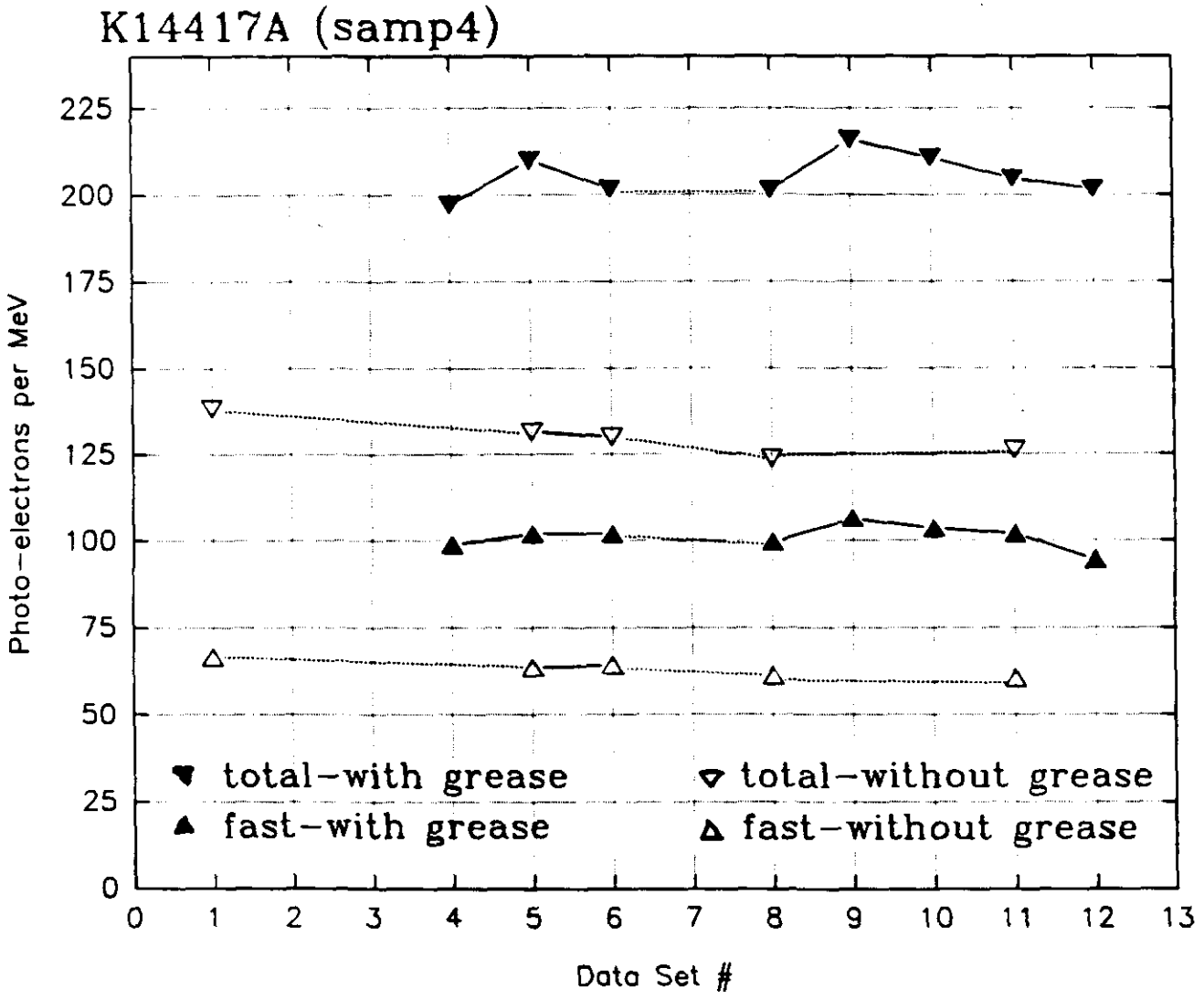
CALIBRATION OF PMT# BA98 8/6/91

R2059 (Cs-Te)



Light Output

PMT: BA98 (CsTe) at 1980V, with and without grease

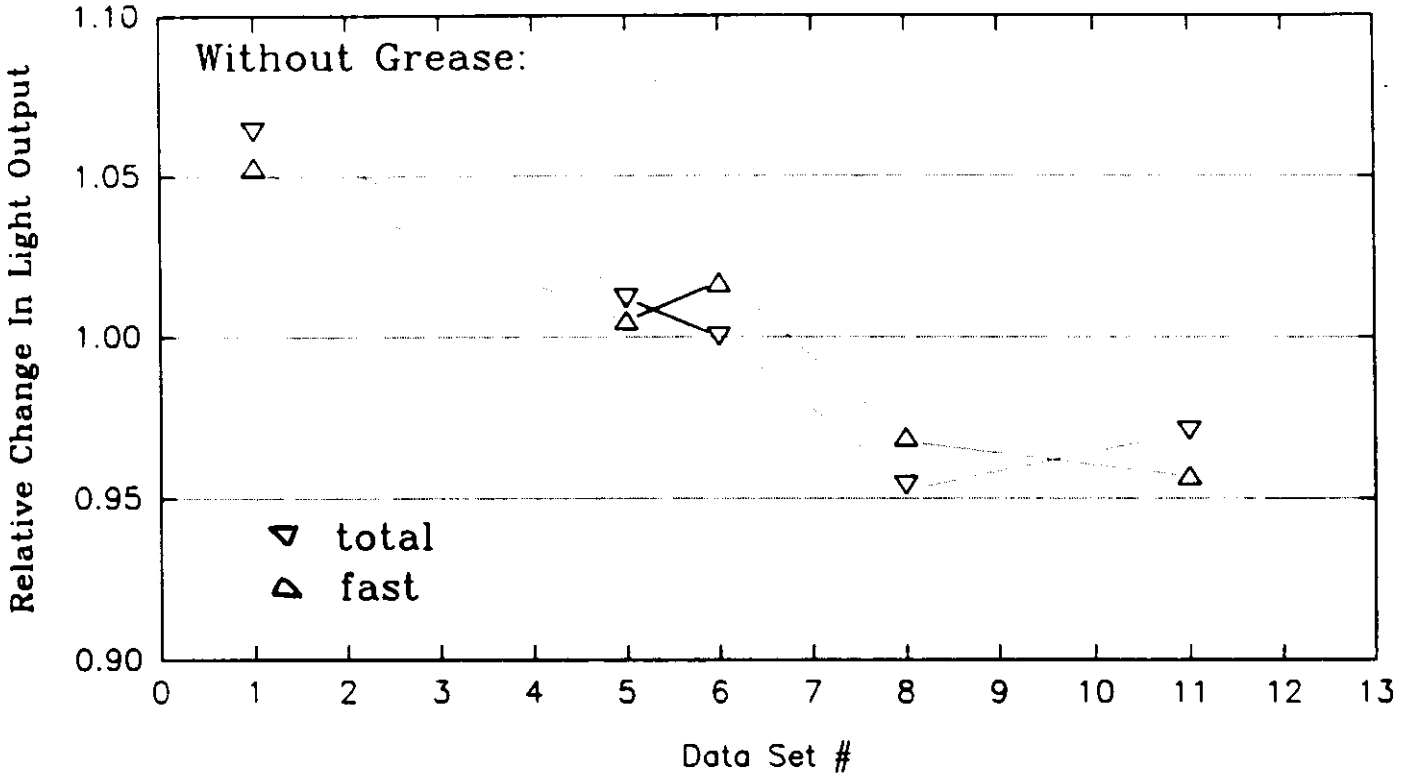


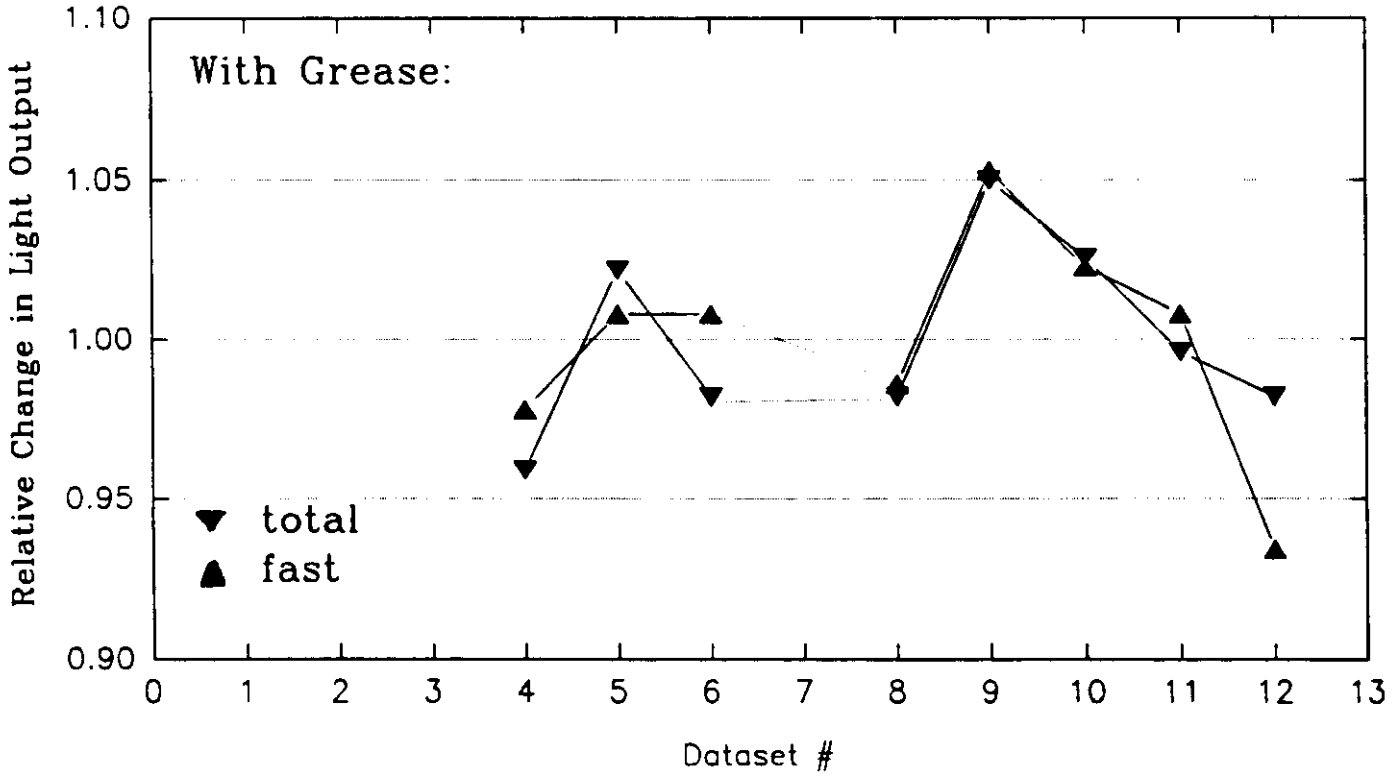
1. 7/2 Initial Measurements 0 Rad.
2. 7/8 10^3 Rad.
3. 7/8 10^4 Rad.
4. 7/9 6×10^4 Rad.
5. 7/9 2.65×10^5 Rad
6. 7/10. 9.03×10^5 Rad
7. 7/15 4.65×10^6 Rad.
8. 7/15 4.65×10^6 Rad.
9. 7/16 no additional radiation exposure
10. 7/17
11. 7/22
12. 7/31

Light Output

PMT: BA98 (CsTe) at 1980V, with and without grease

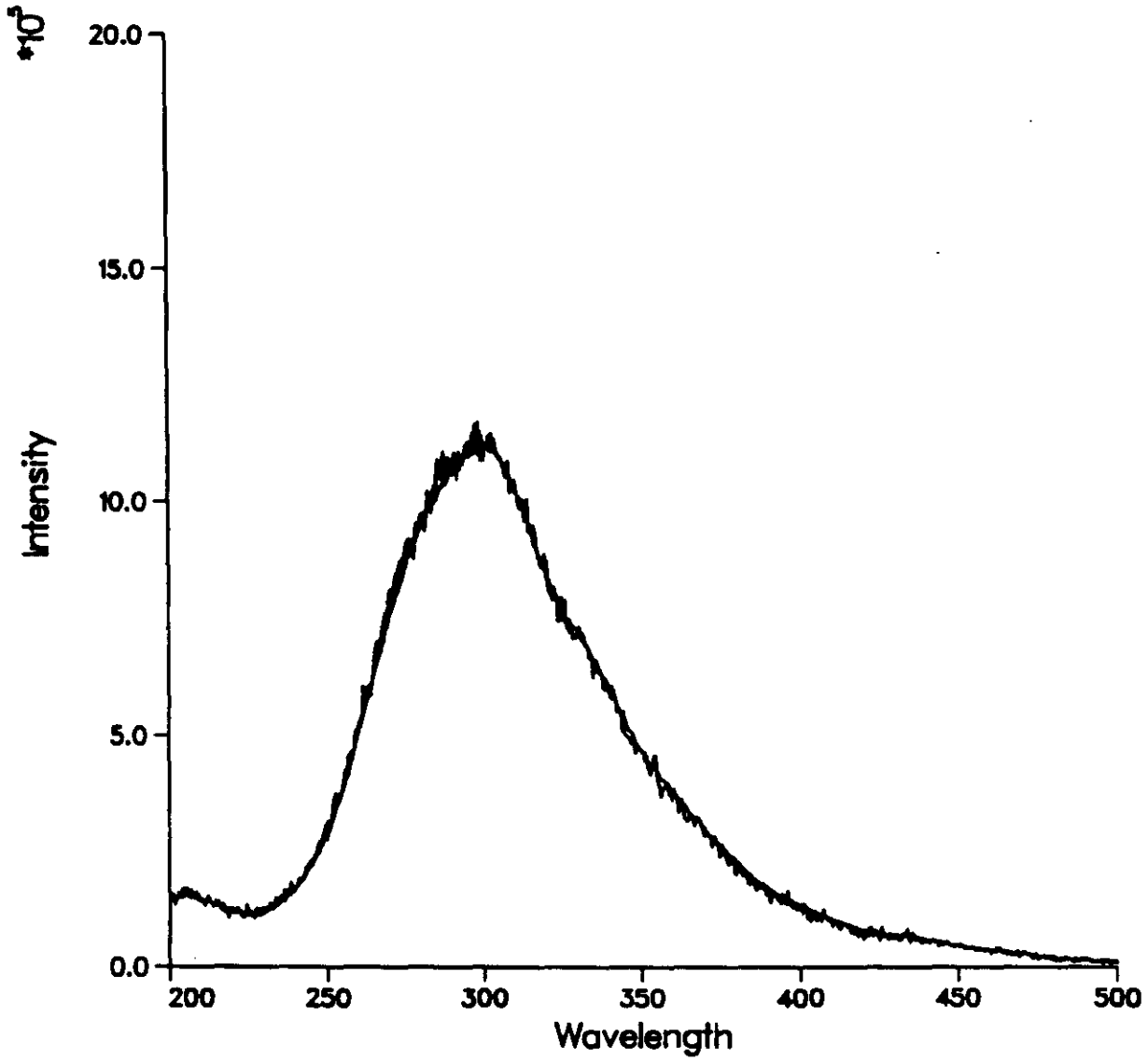
K14417A (samp4) – control

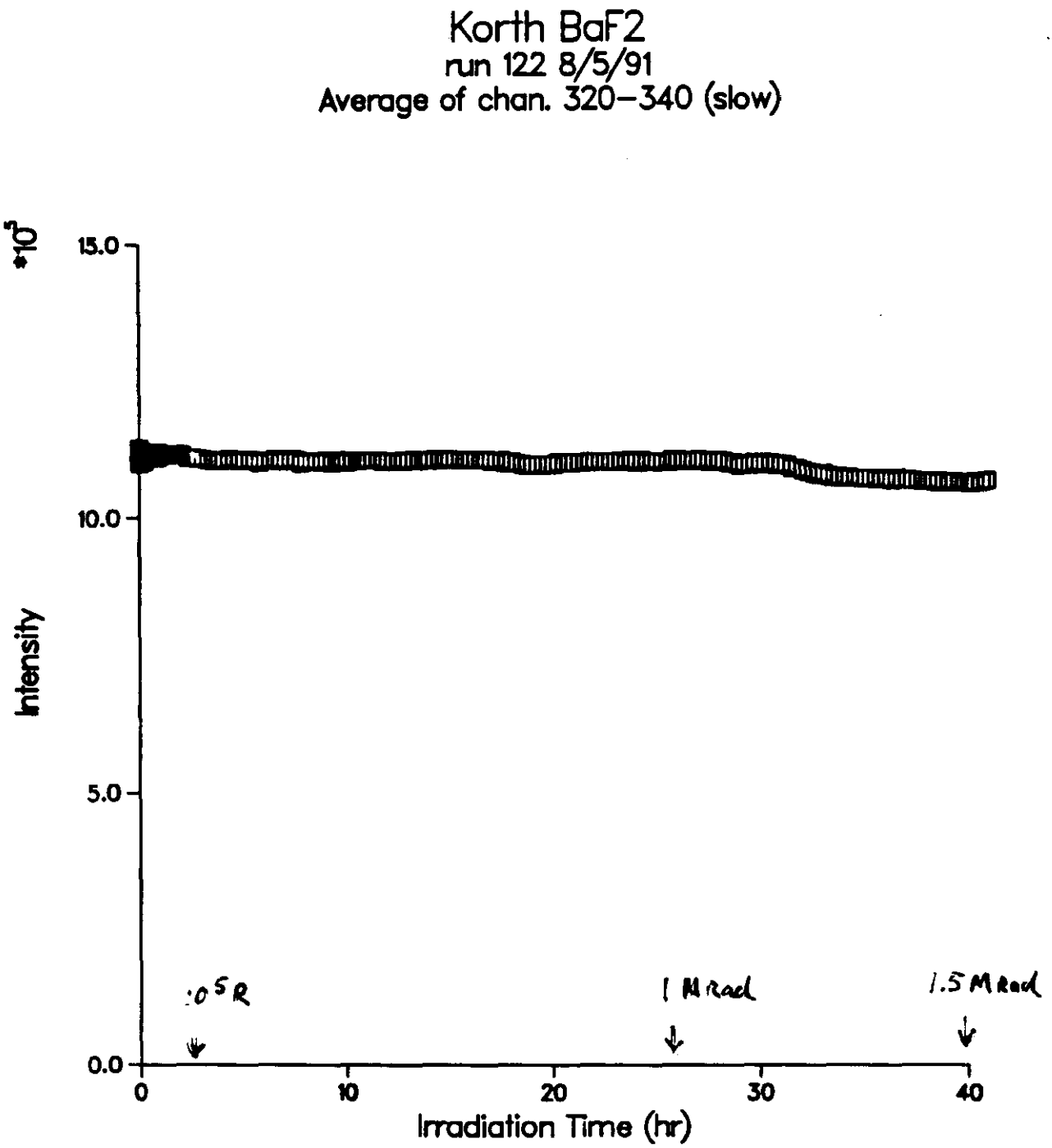


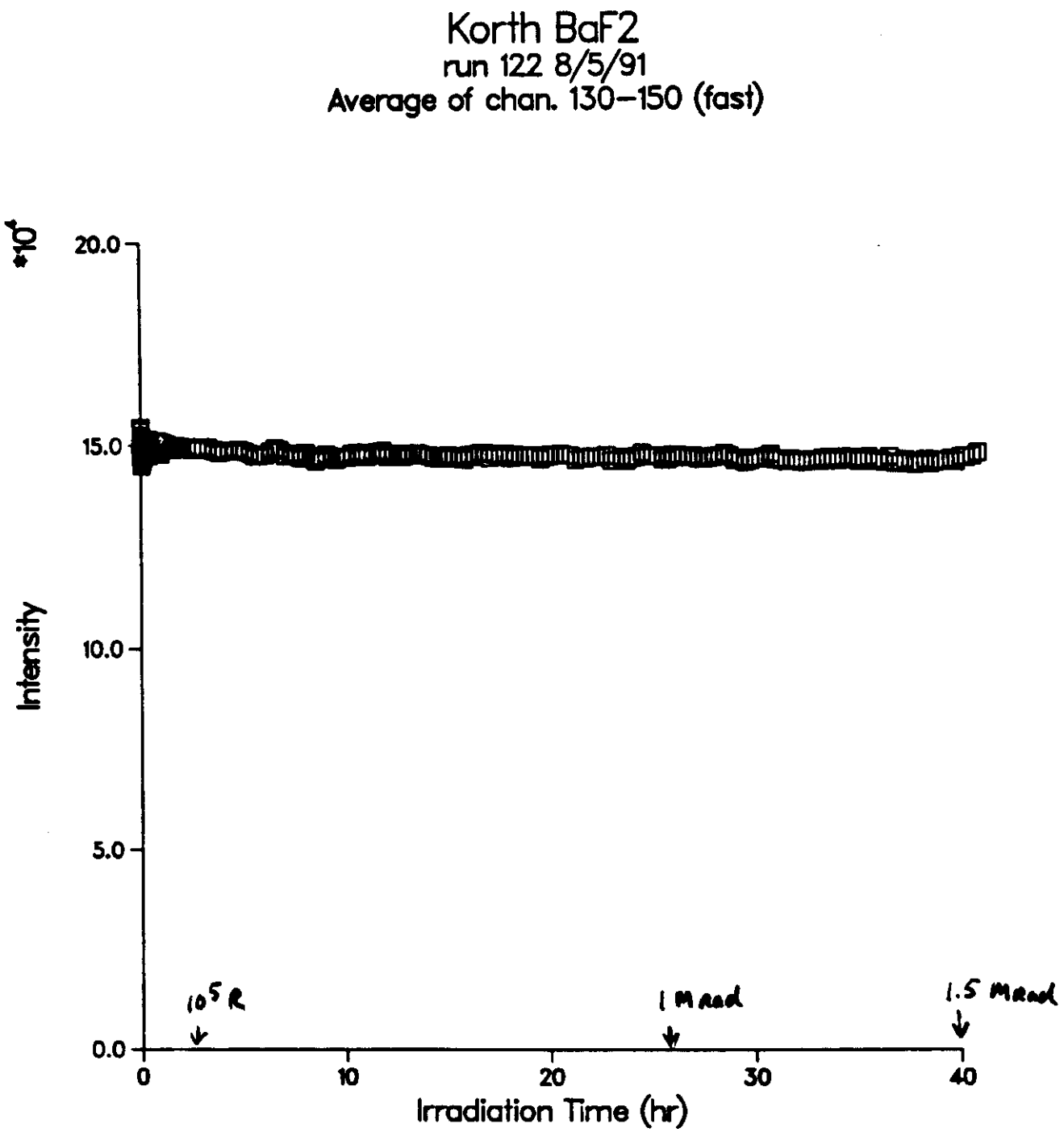


Scintillation Emission Spectrum
measured during irradiation
(uncorrected for Q.E. of PM)

Korth BaF2 (K14429C)
Run 122
100 rad, 1Mrad



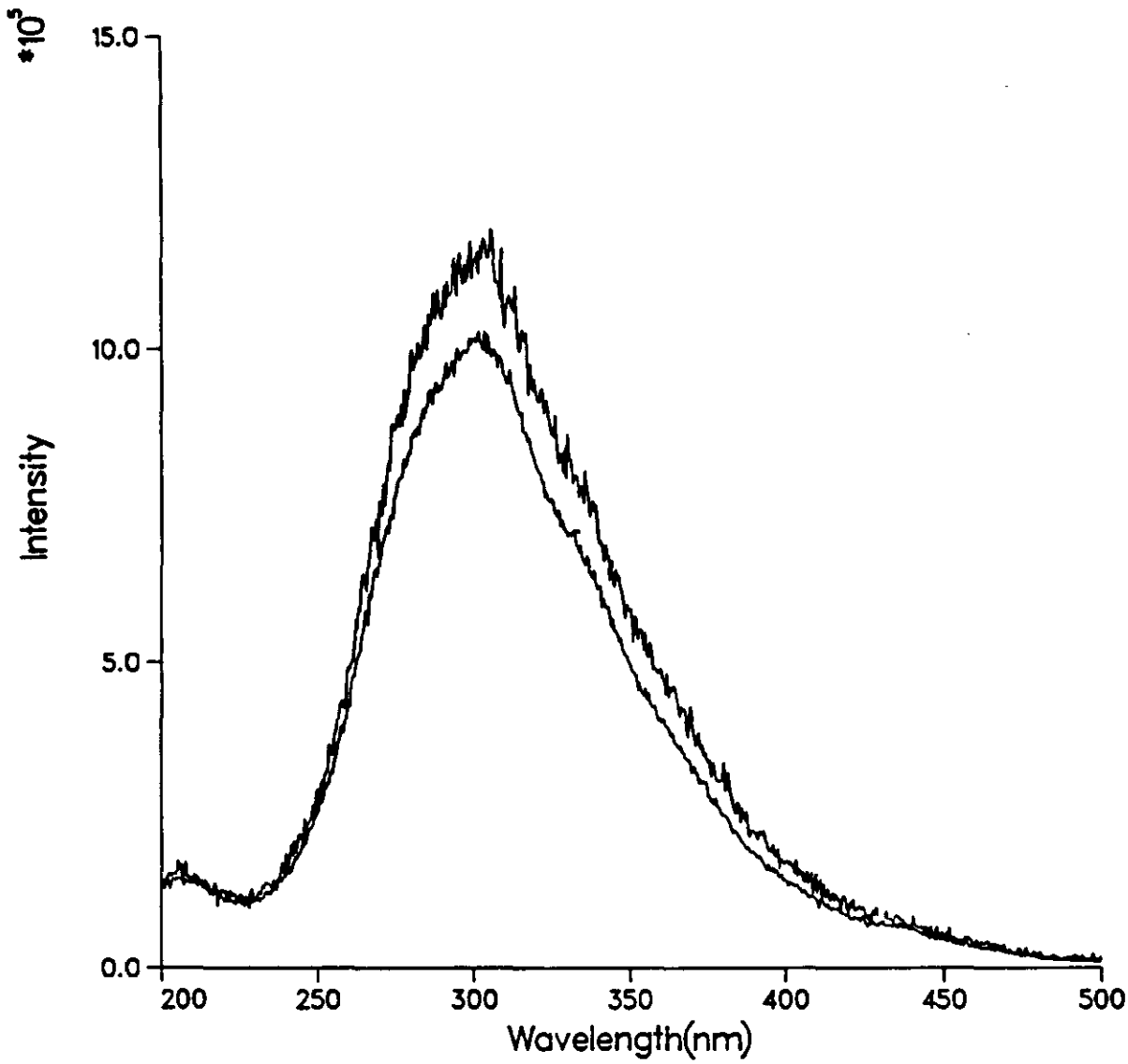

Korth BaF2
run 122 8/5/91
Average of chan. 320–340 (slow)
*10^5
15.0
10.0
5.0
0.0
Intensity
:0^5 R
1 M Rad
1.5 M Rad
0
10
20
30
40
Irradiation Time (hr)

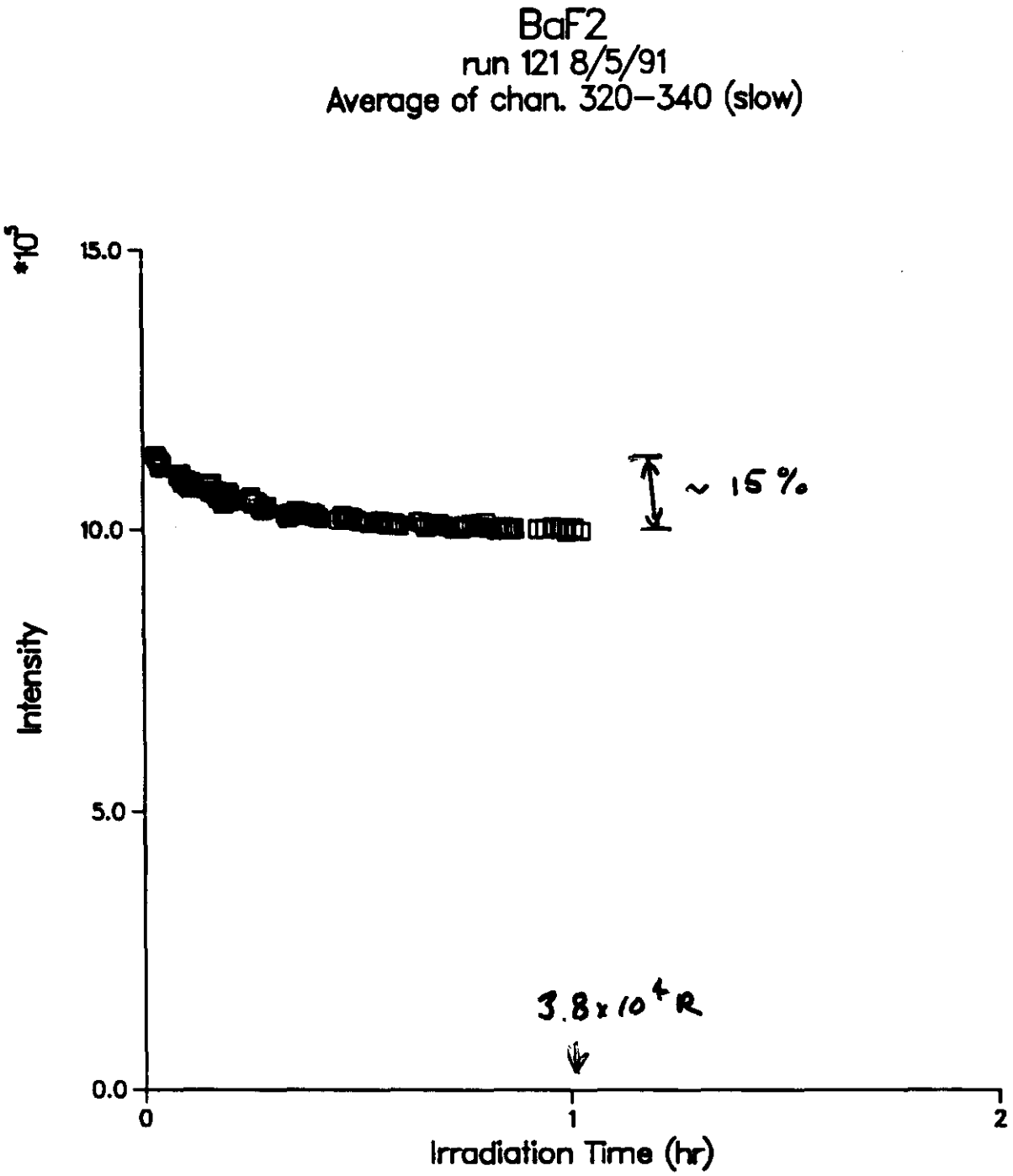

Korth BaF2
run 122 8/5/91
Average of chan. 130–150 (fast)
*10⁴
20.0
15.0
10.0
5.0
0.0
Intensity
10⁵ R
1 Mrad
1.5 Mrad
0
10
20
30
40
Irradiation Time (hr)

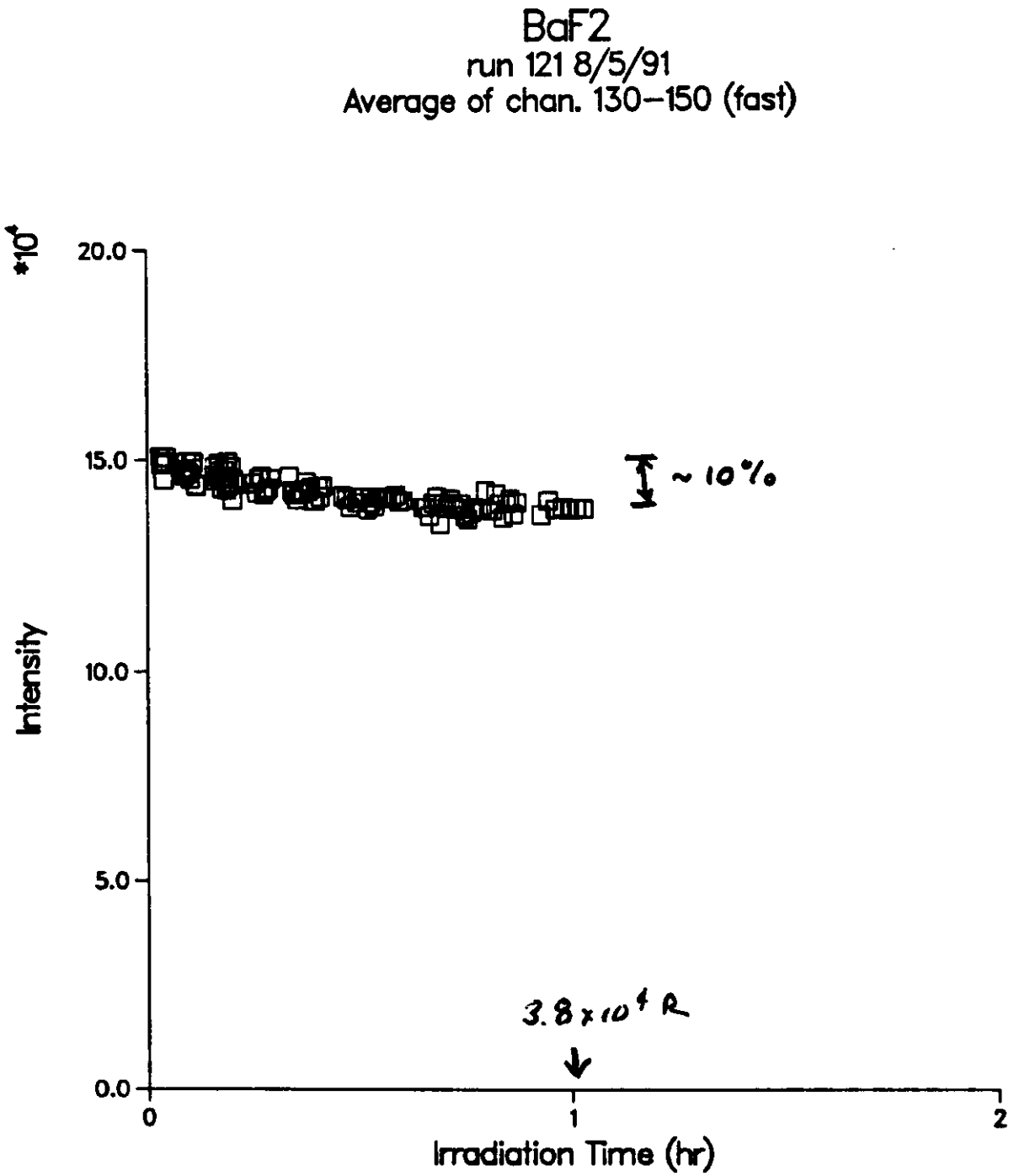
Scintillation Emission Spectrum

measured during irradiation (interrupted)
(uncorrected for Q.E. of pm)

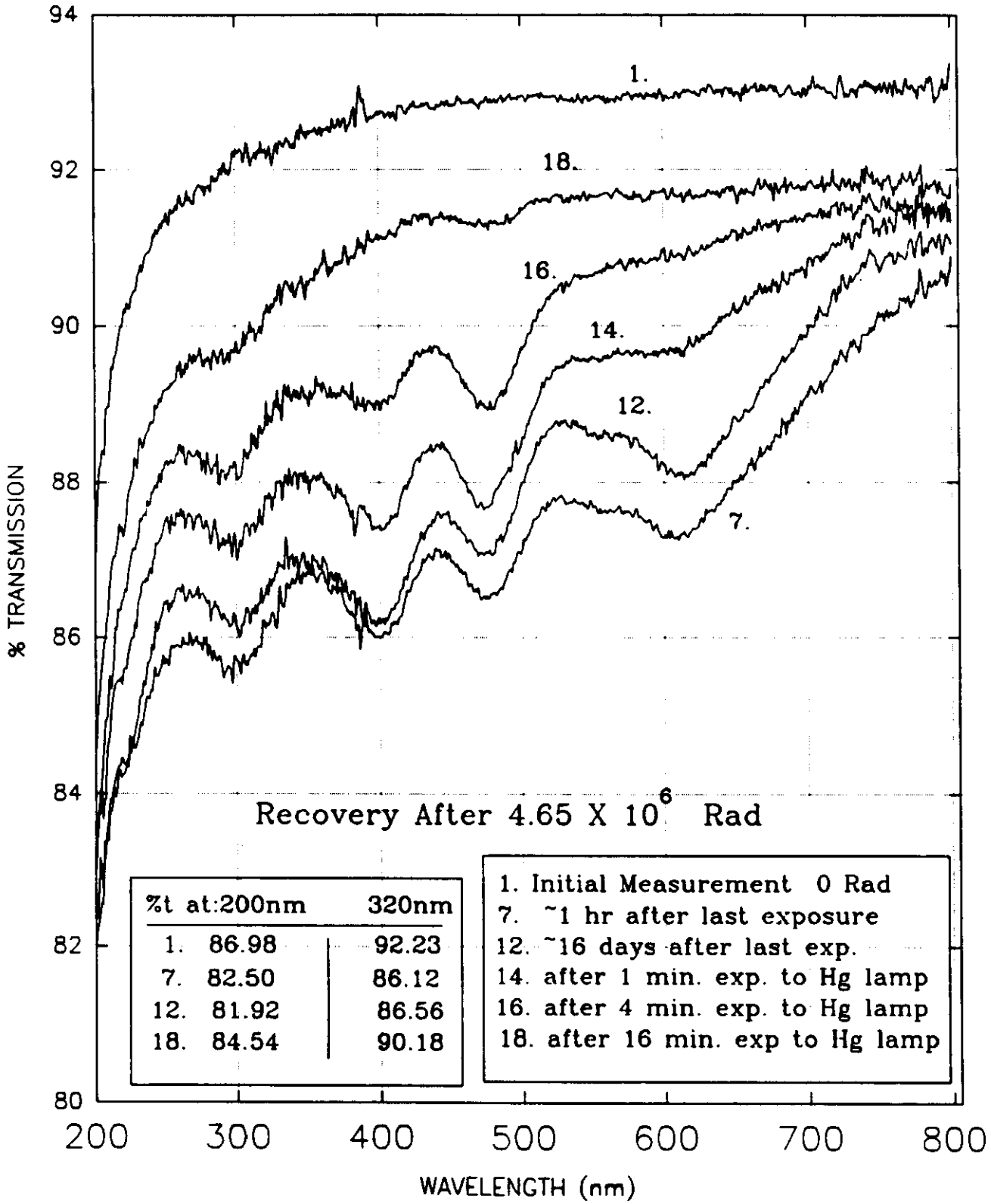
BaF2 (K14417C)
Lumin. Run 121
1.2e3, 3.8e4 rad




BaF2
run 121 8/5/91
Average of chan. 320–340 (slow)
*10^5
15.0
10.0
5.0
0.0
Intensity
~ 15 %
3.8 x 10^4 R
0
1
2
Irradiation Time (hr)


BaF2
run 121 8/5/91
Average of chan. 130–150 (fast)
*10⁴
20.0
15.0
10.0
5.0
0.0
Intensity
~ 10%
3.8 x 10⁴ R
0
1
2
Irradiation Time (hr)

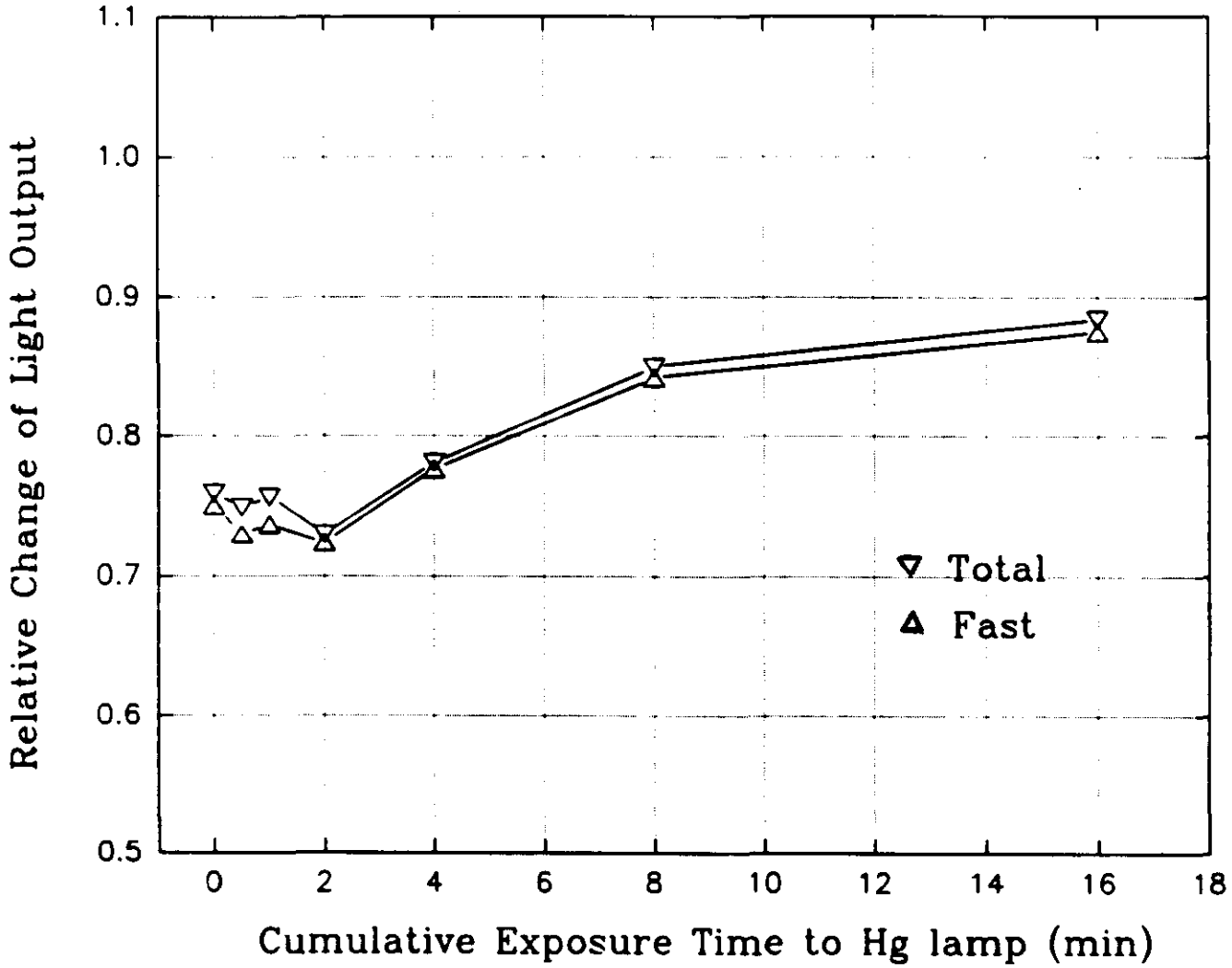
Hitachi Transmission Scans of BaF2 samples.
7/91 Radiation Damage Study
Sample: K14417B (samp2) 1 " CYLINDER



Recovery Study 7/91

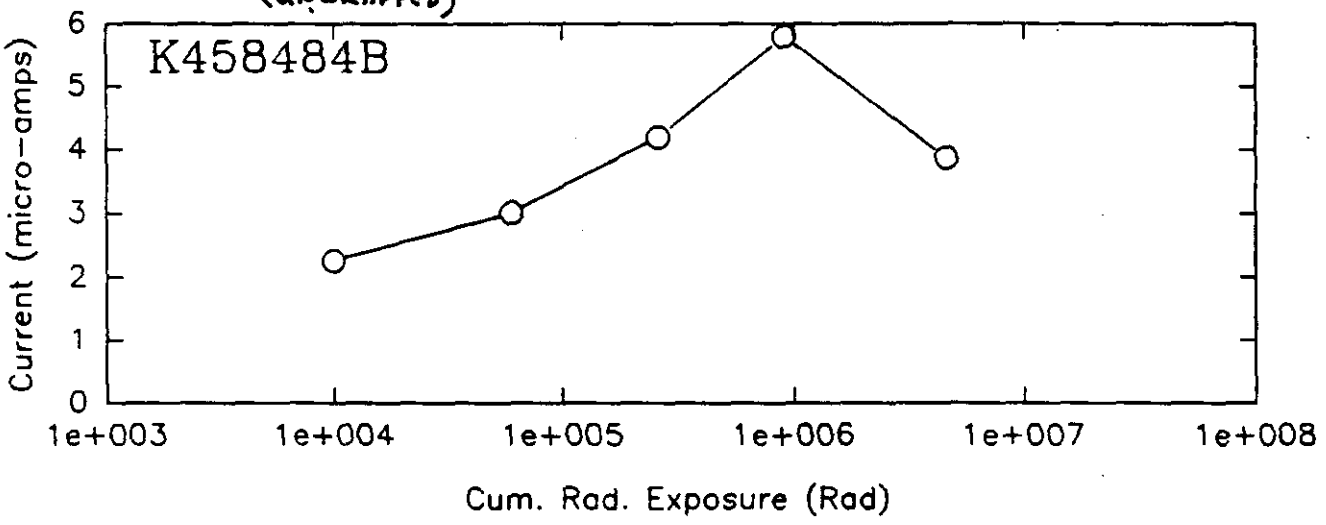
Sample K14417B

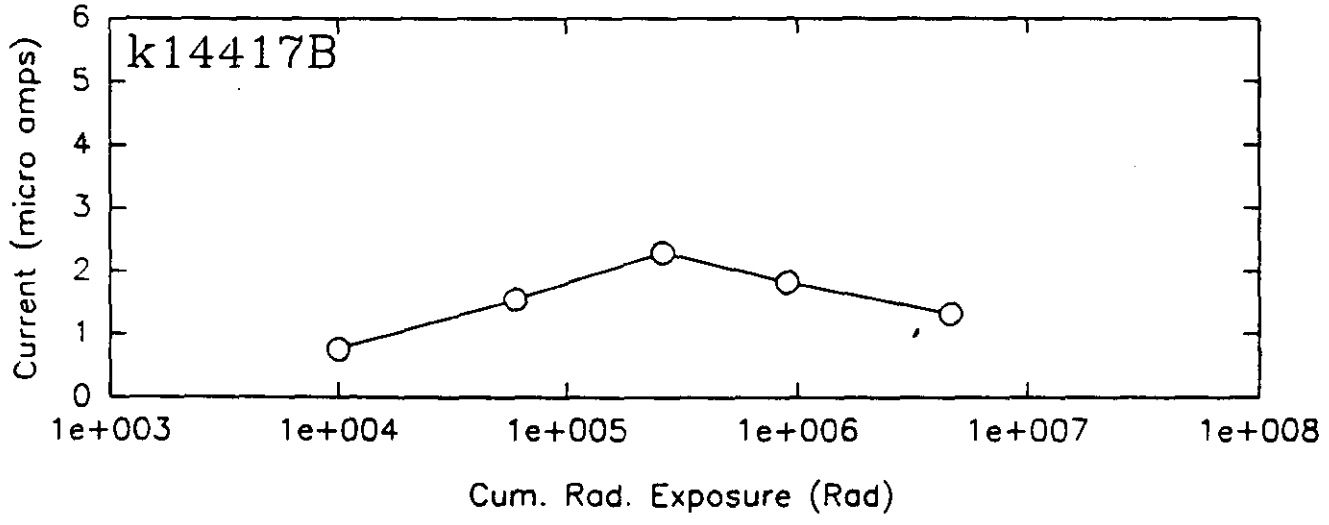
Light output measured with PMT BA98 (CsTe) at 1980V.
Sample was attached to PMT with grease.

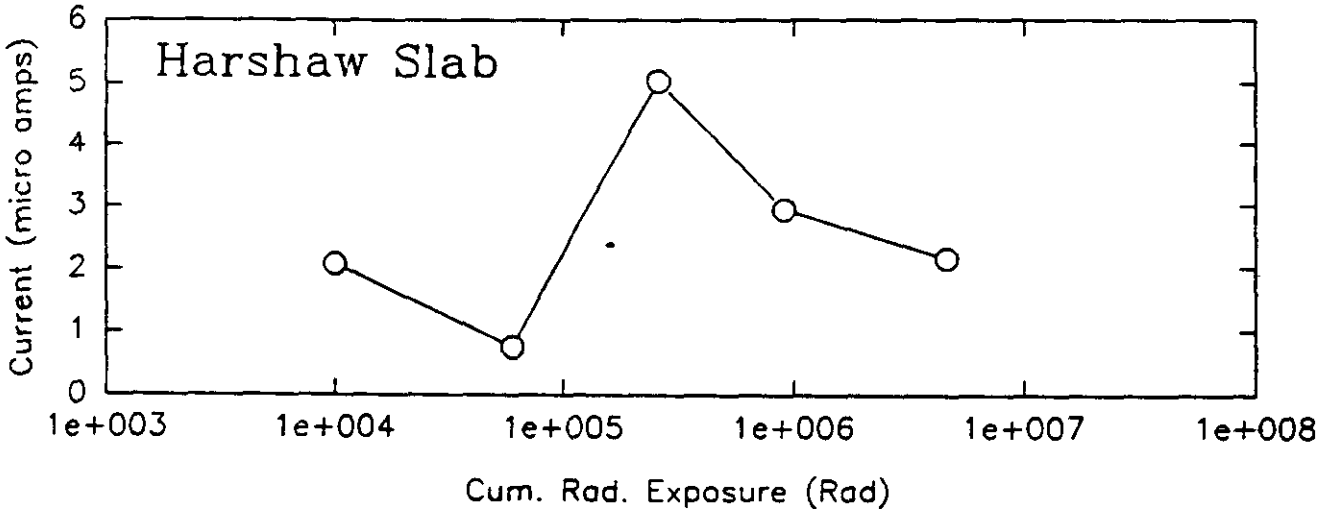


Current measured with PMT: BA289 at 2000V

DISTANCE: CRYSTAL - PMT = 20 cm (Bialkali)
(UNWRAPPED)



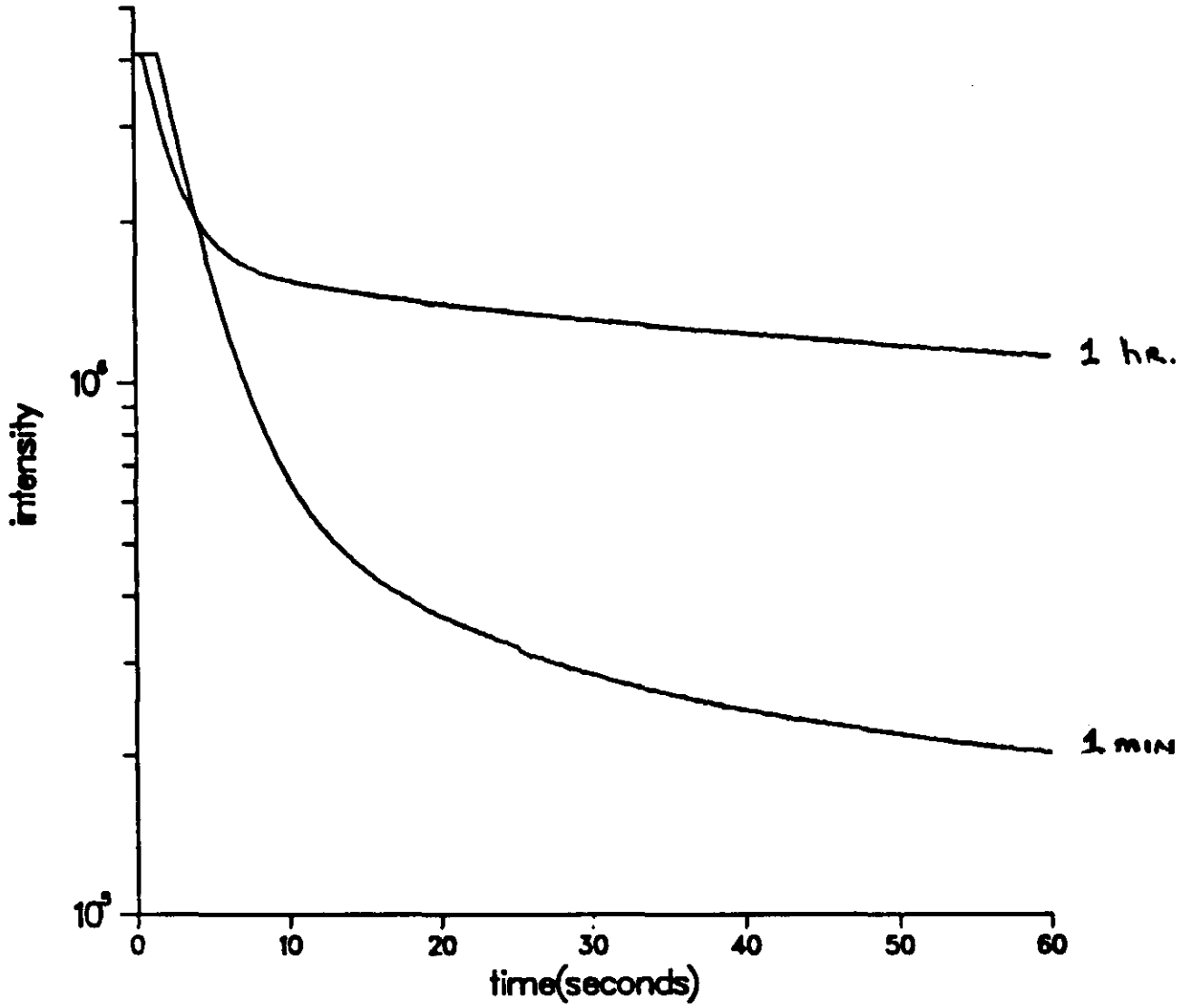




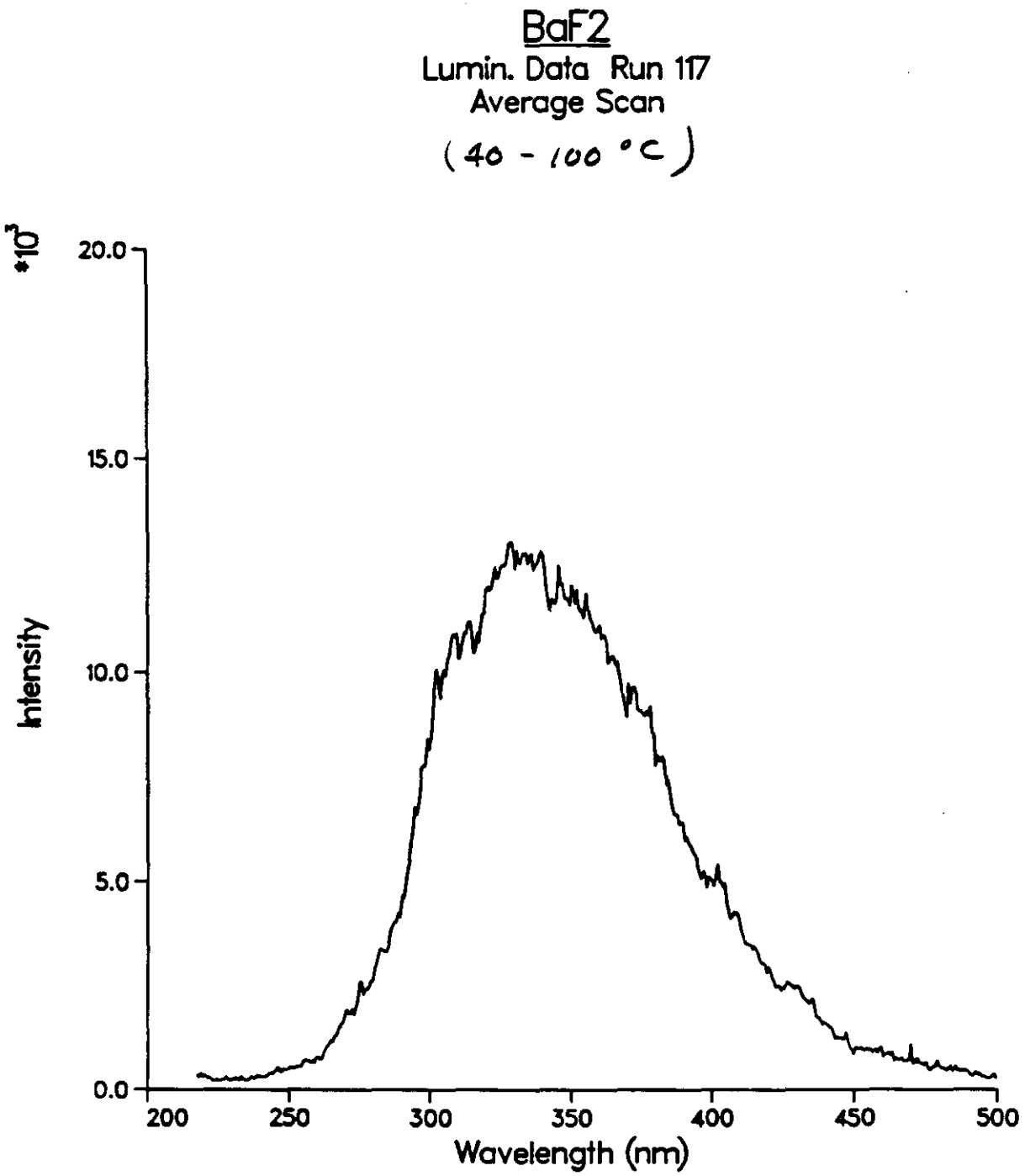
BaF2 (K14417C)

Phosphorescence

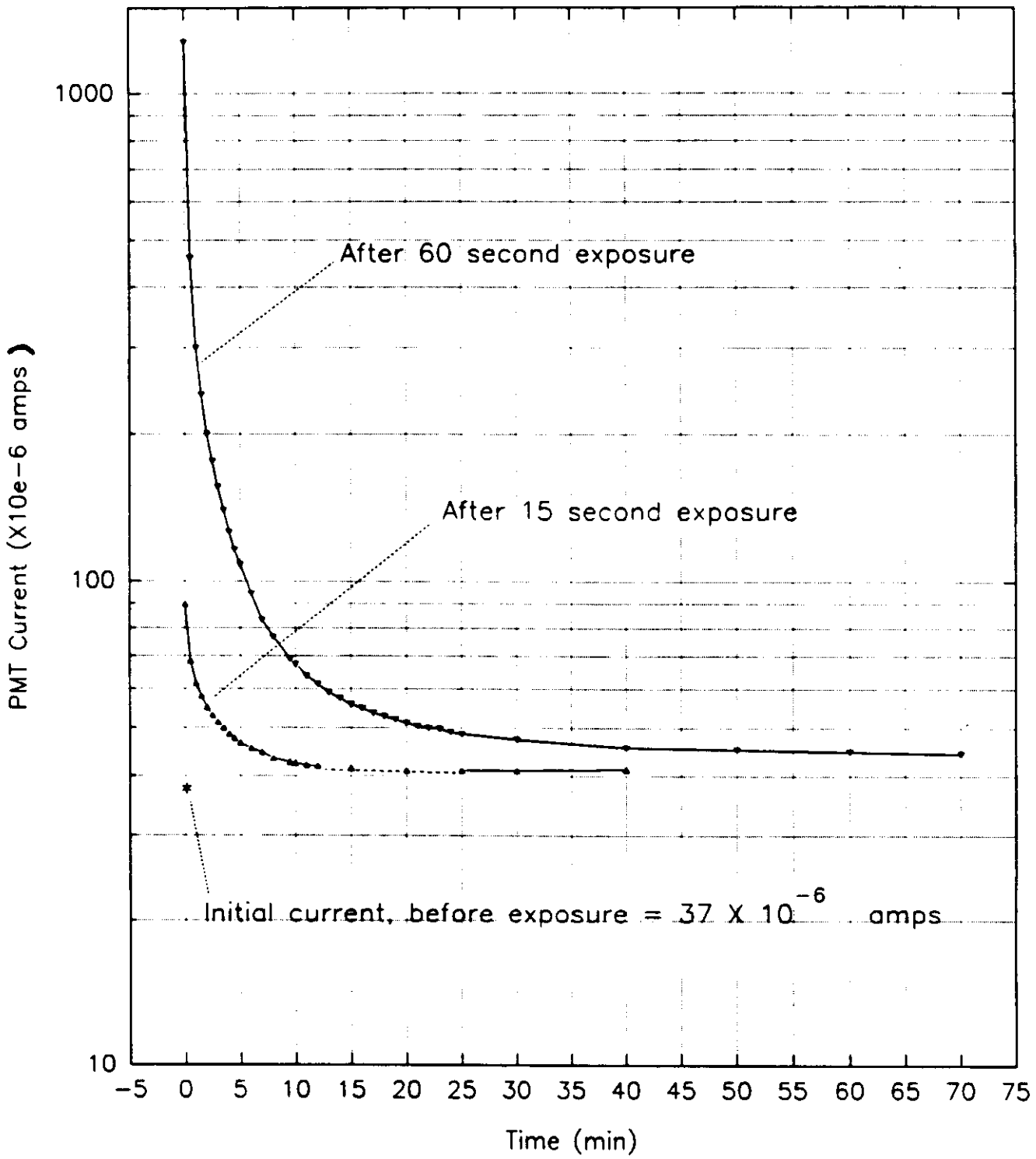
1 minute, 1 hour irradiations



Phosphorescense Emission Spectrum



Reactivation of BaF2 sample: K14417D with room light.
Sample exposed to 15 then 60 seconds of room light.
PMT: BA289 (bi-alkali) at HV:2400V 1/30/91



Summary

- We have seen radiation induced effects on the UV light transmission and scintillation light output in a few, small BaF_2 crystals

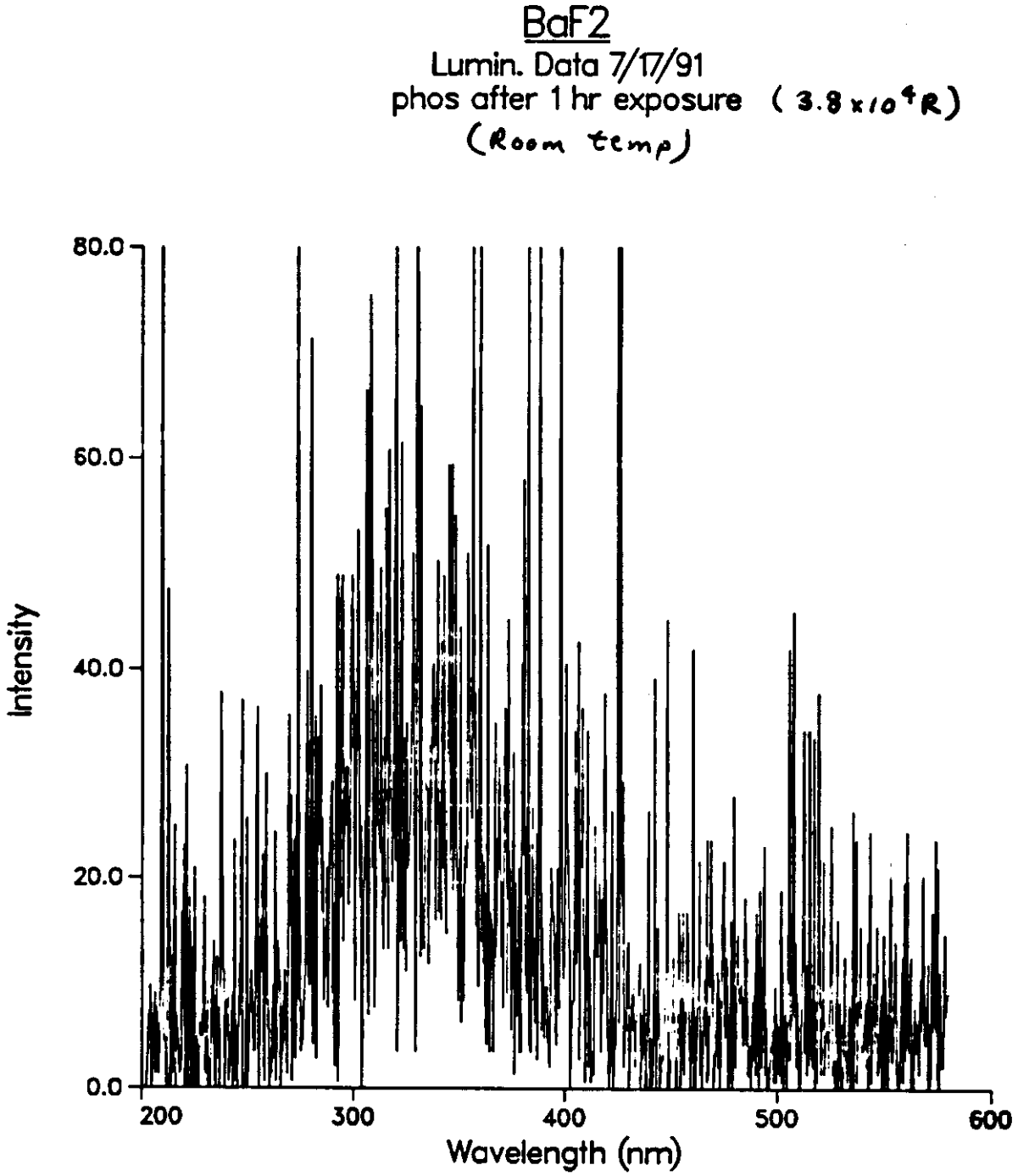
- It seems unlikely that the observed loss in transmission can fully account for the loss in light output, but this requires a detailed simulation of the light loss due to multiple reflections in the crystal

- We have observed an intense phosphorescense in all of the samples we have measured which emitted near the wavelength of the slow component

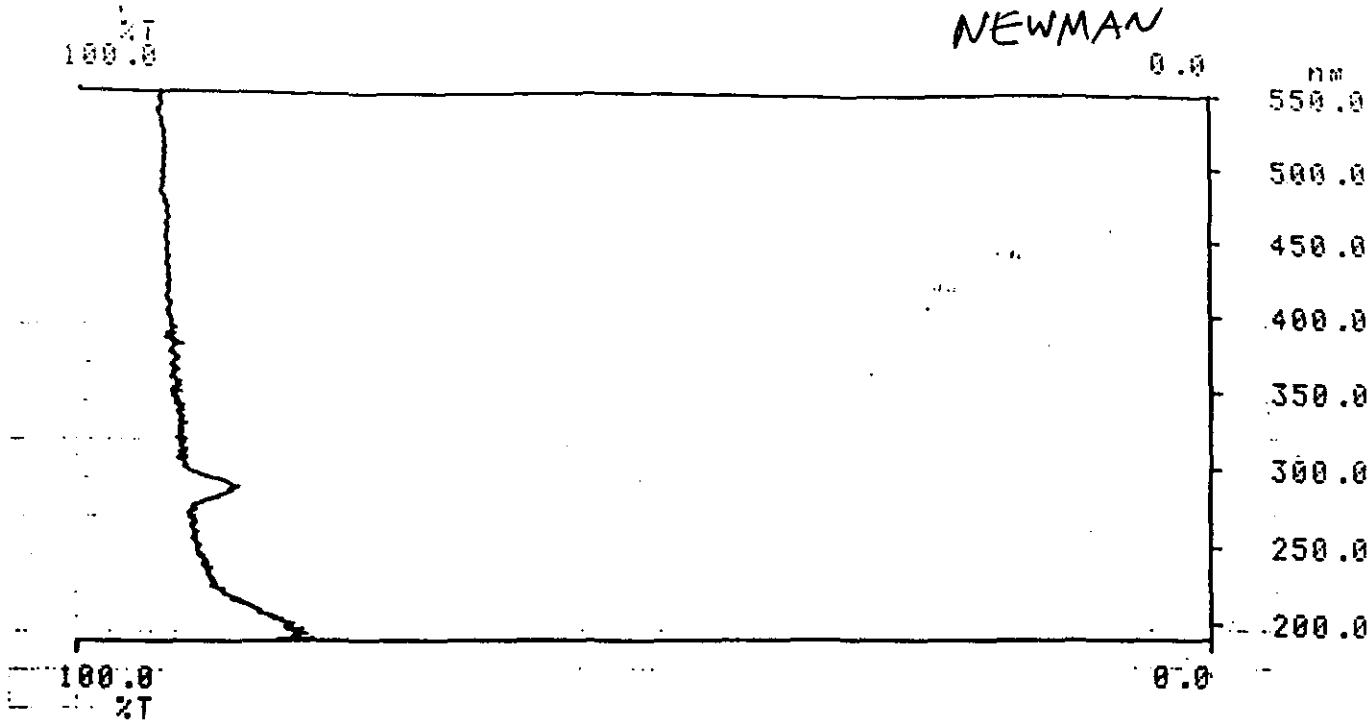
- All three effects (transmission loss, loss in light output and phosphorescense) can be recovered by exposure to light

Phosphorescense Emission Spectrum

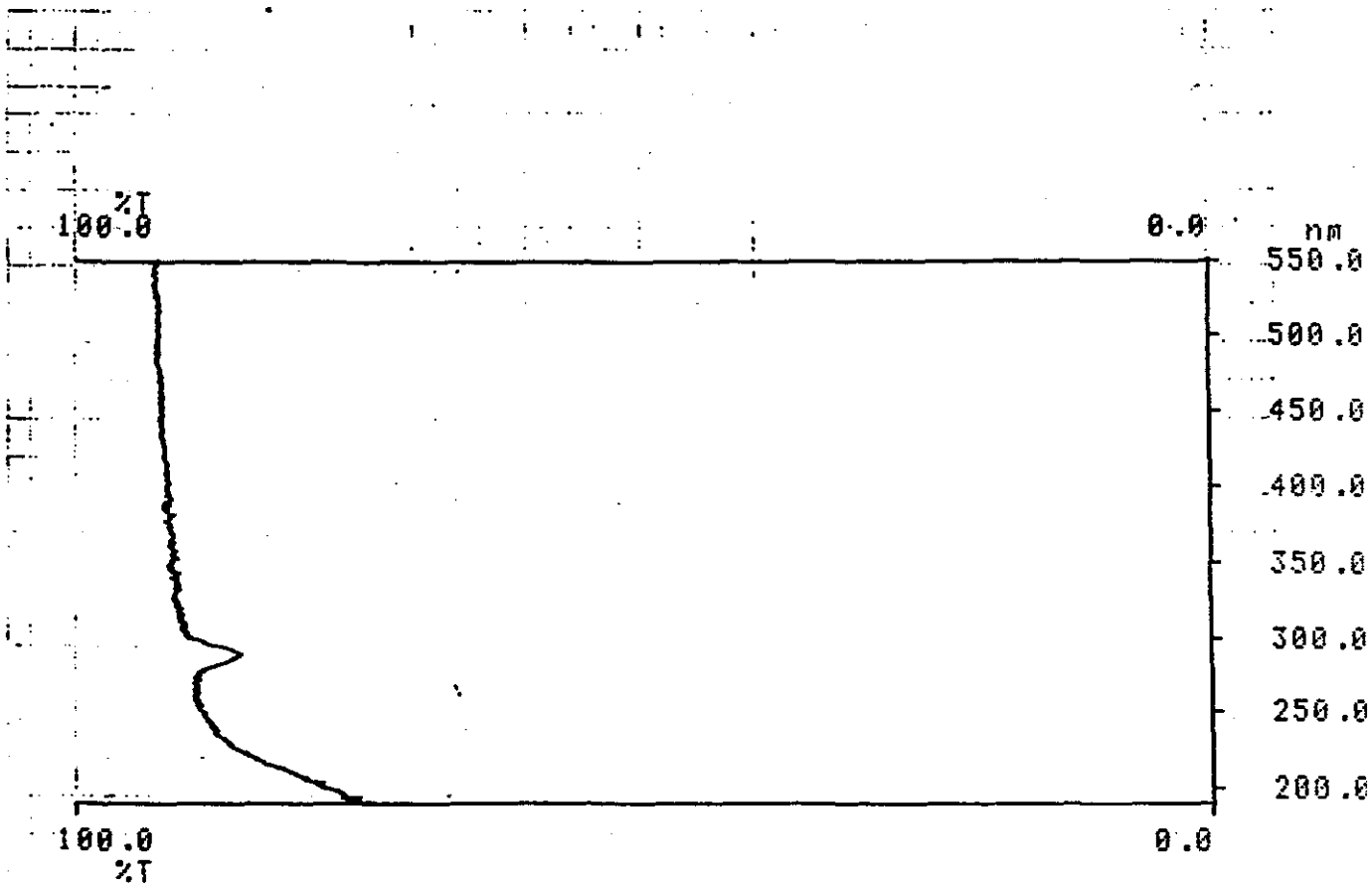
measurments started seconds after exposure
integrated for 2 min.



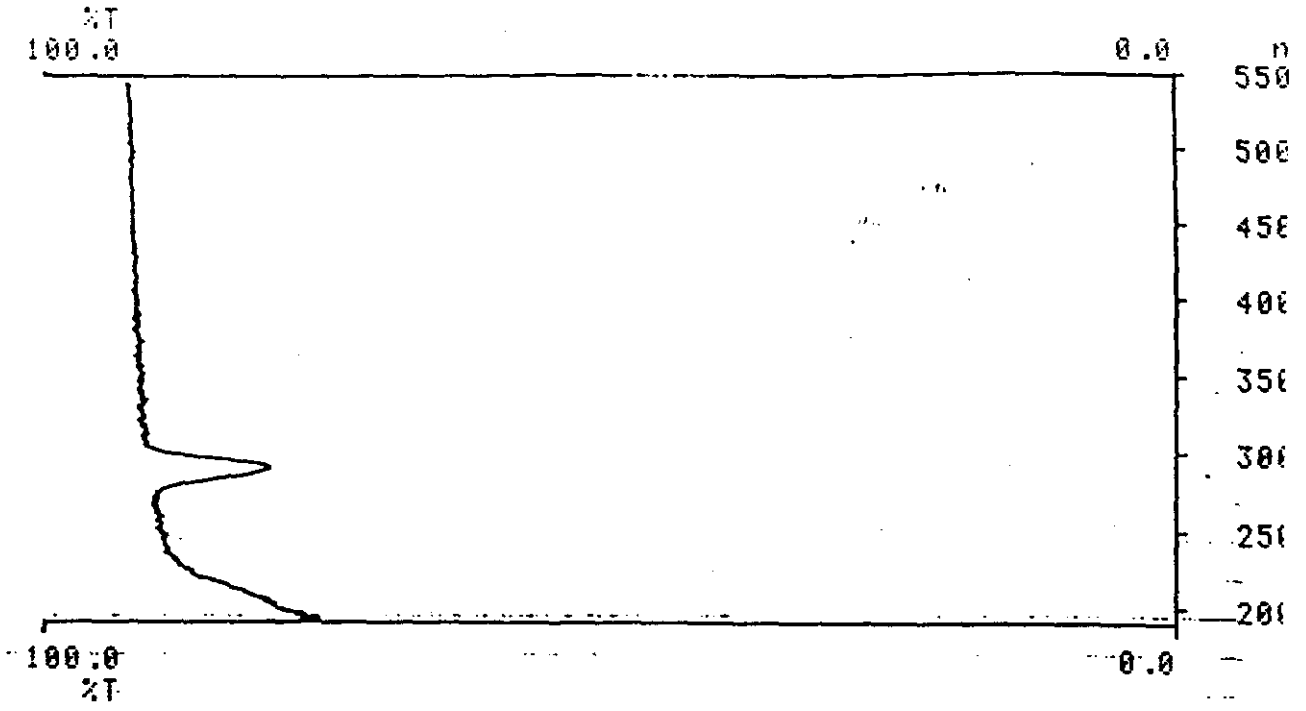
NEWMAN



TITLE: S1A002.DT 2:58 PM 5/16/91
SCAN SPEED: 60.0 nm/min RESPONSE: MEDIUM
BANDPASS: 5.00nm

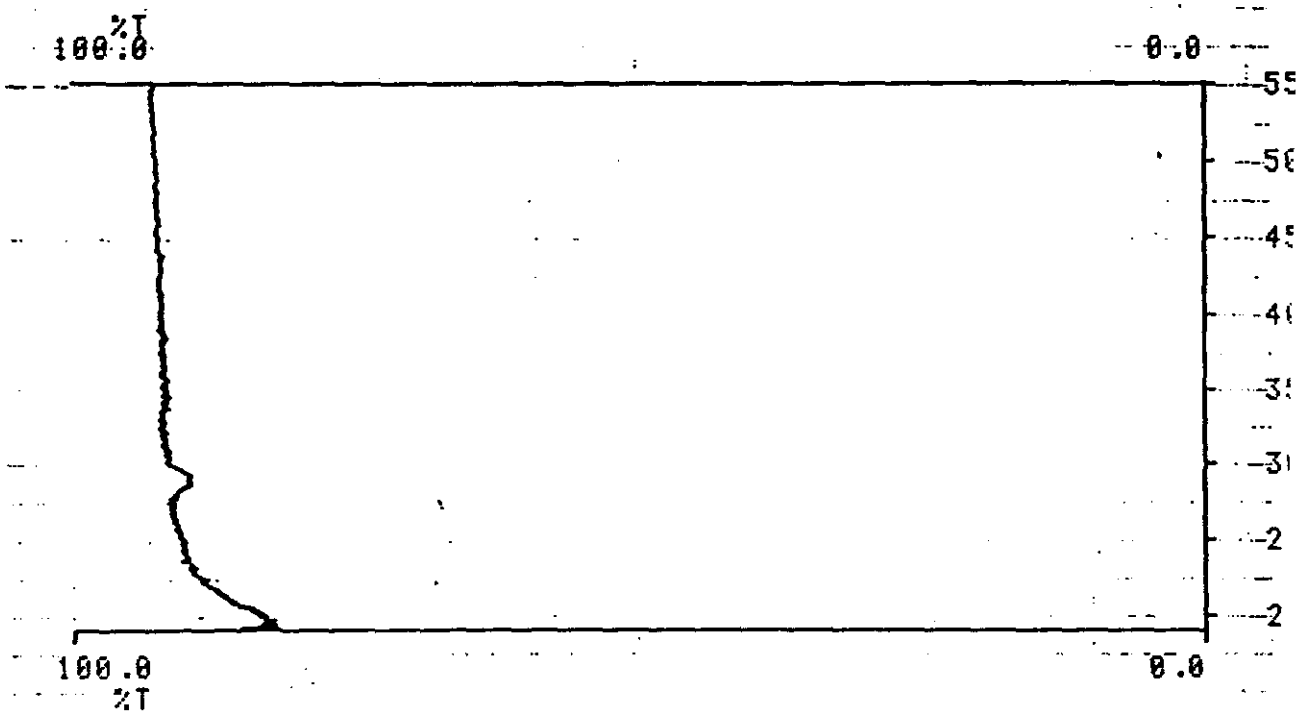


TITLE: S1A001.DT 2:48 PM 5/16/91
SCAN SPEED: 60.0 nm/min RESPONSE: MEDIUM
BANDPASS: 5.00nm



TITLE: S2A007.DT
SCAN SPEED: 60.0 nm/min
BANDPASS: 5.00nm

5:26 PM 5/13/91
RESPONSE: MEDIUM



TITLE: S2A006.DT
SCAN SPEED: 60.0 nm/min
BANDPASS: 5.00nm

6:33 PM 5/13/91
RESPONSE: MEDIUM

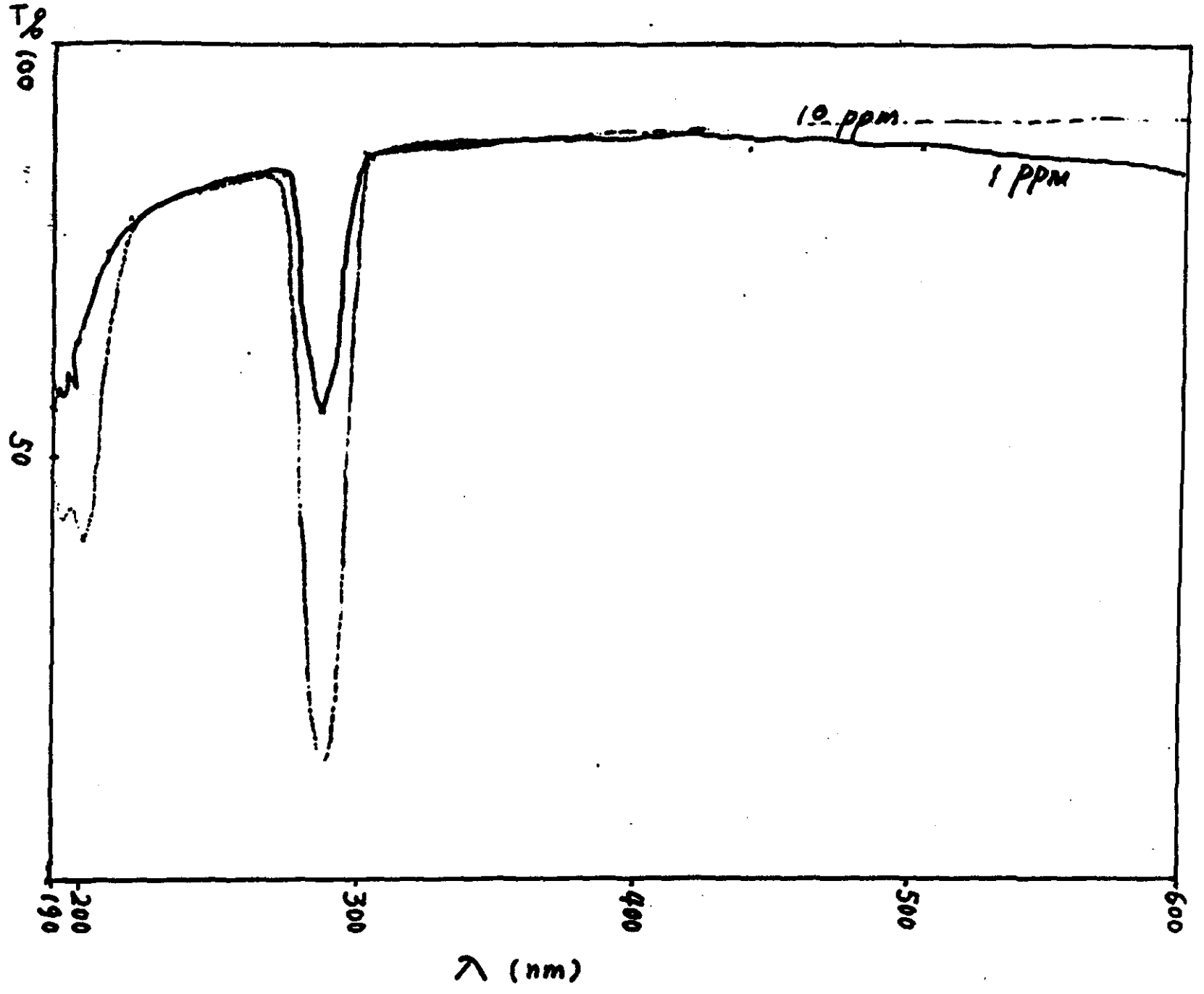
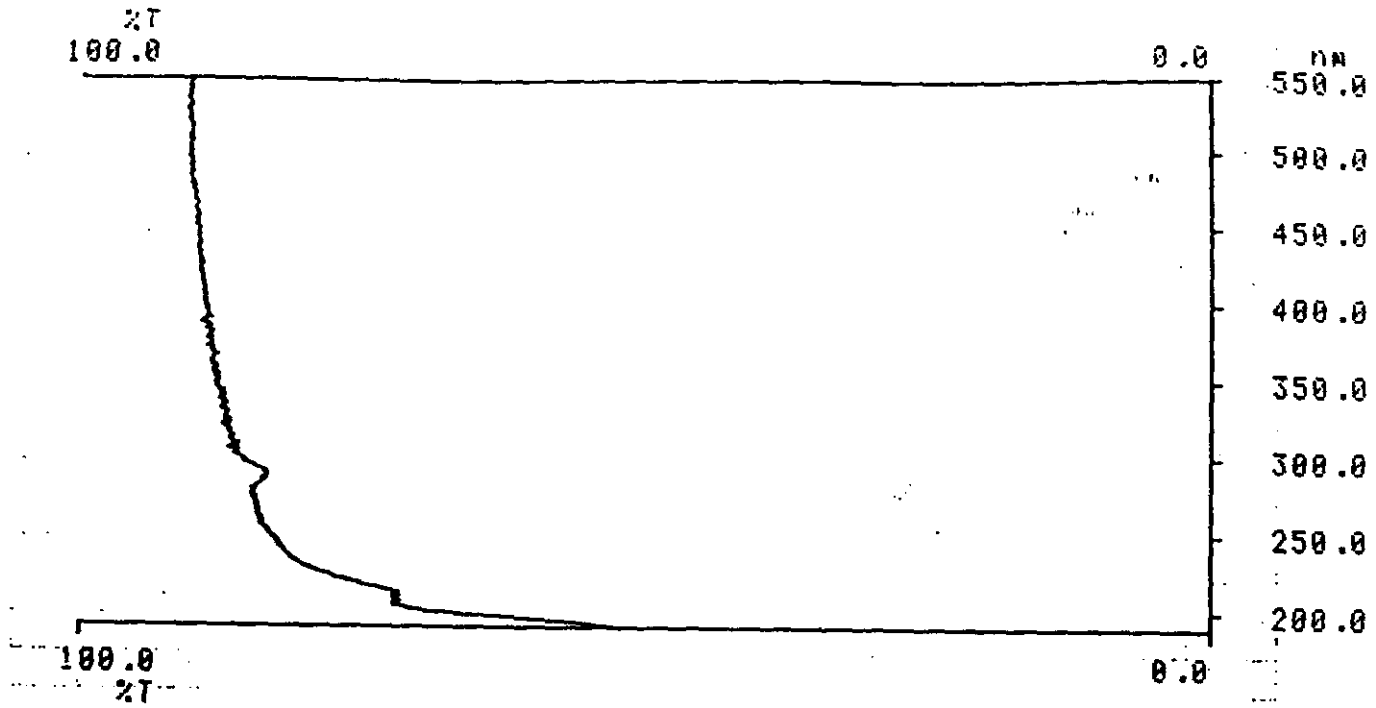
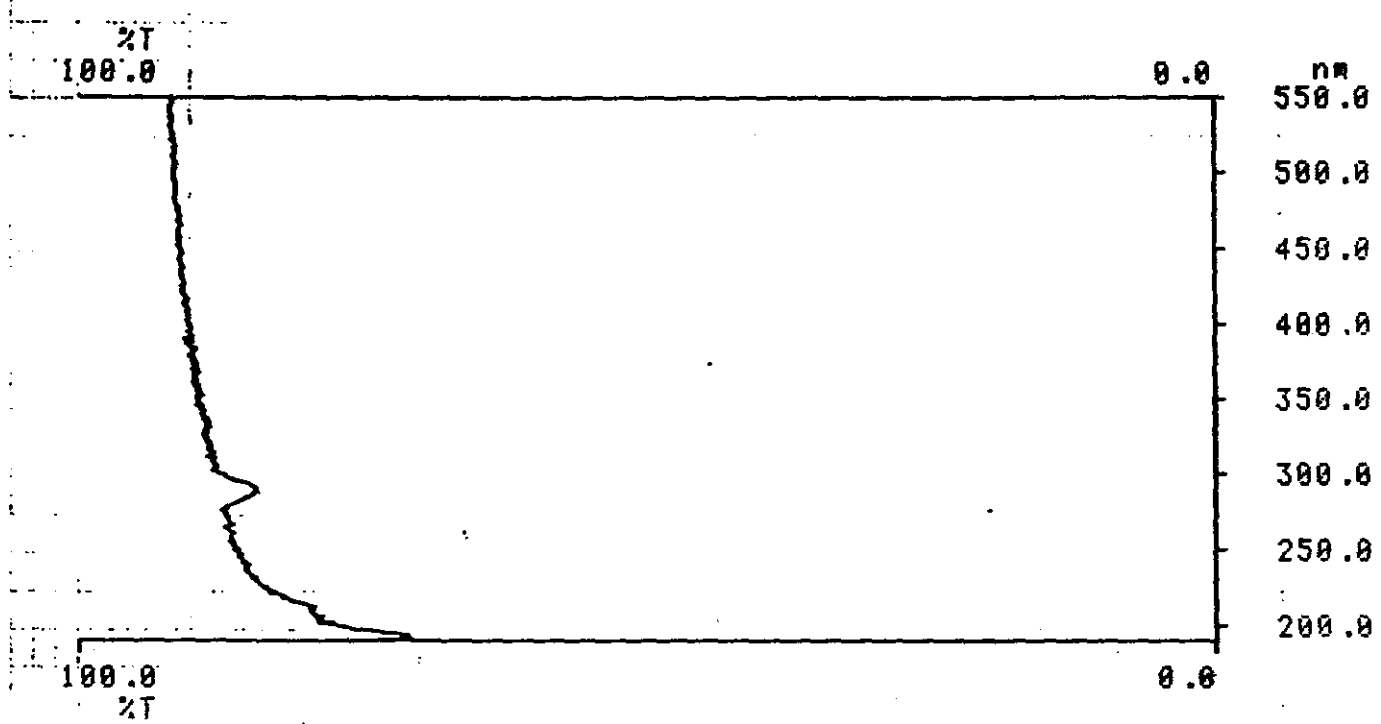


Fig 8 Transmittance of Ce doped BaF crystal



TITLE: S18006.DT
SCAN SPEED: 60.0 nm/min
BANDPASS: 5.00nm

12: 2 PM 5/16/91
RESPONSE: MEDIUM



TITLE: S18005.DT
SCAN SPEED: 60.0 nm/min
BANDPASS: 5.00nm

11:21 AM 5/16/91
RESPONSE: MEDIUM

Impurity	Crystal	Raw Material
NiO	1.7×10^{-6}	8.3×10^{-6}
MnO	1.5×10^{-7}	5.2×10^{-7}
CaO	3.6×10^{-7}	2.8×10^{-7}
Cr_2O_3	8.4×10^{-7}	1.4×10^{-5}
Fe_2O_3	9.2×10^{-6}	2.0×10^{-5}
MgO	1.9×10^{-6}	1.0×10^{-5}
CoO	1.0×10^{-5}	1.3×10^{-6}

Table.1. Impurity quantities of raw material and crystal respectively

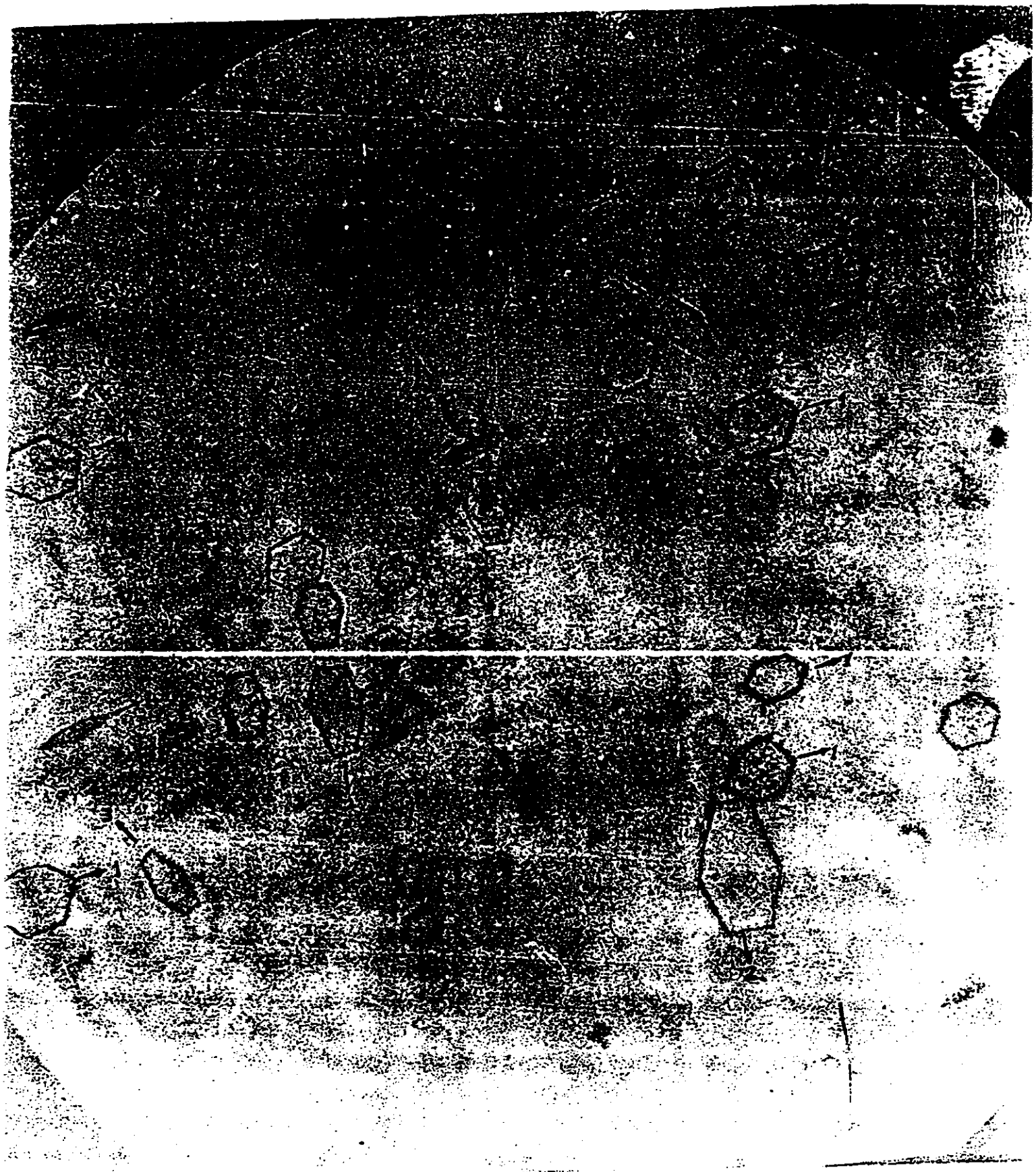


Fig.7. Crystal photograph under microscope.

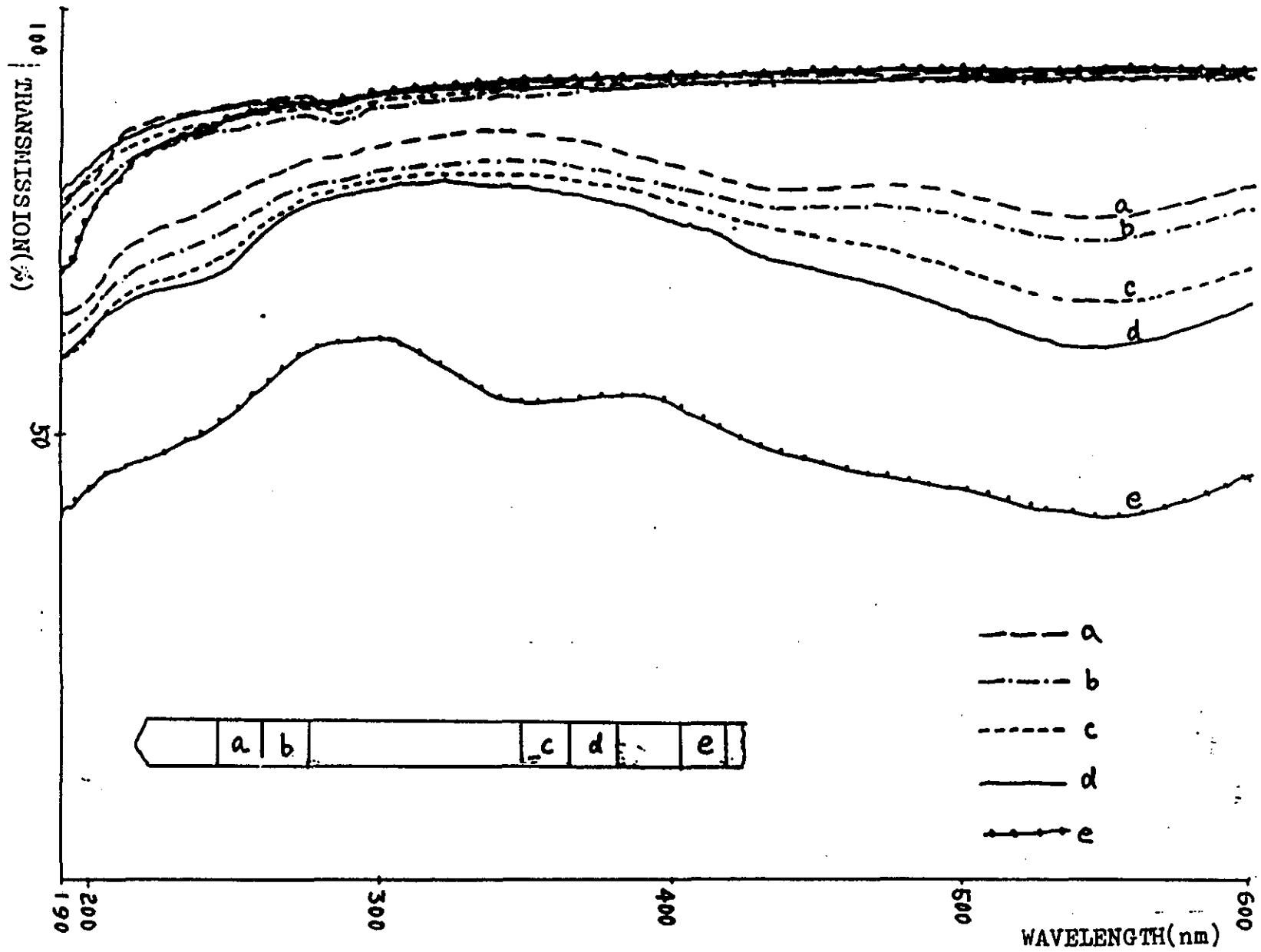
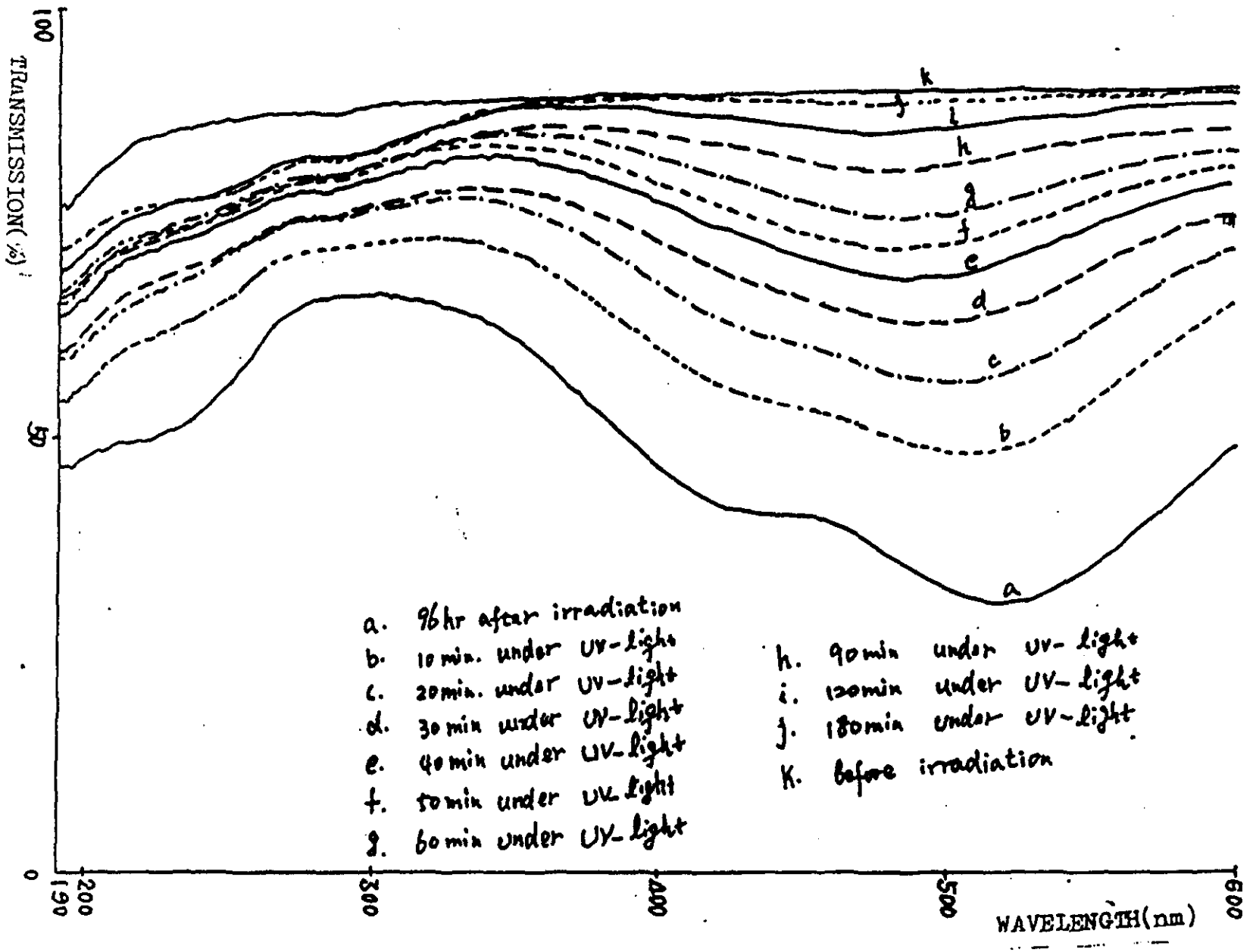


Fig.2 25 mm long crystal, r-ray irradiation: 1.6 MRad.
BaF_2 crystal cut from different sites of a 300 mm crystal


TRANSMISSION(%)
100
50
0
190
200
300
400
500
600
WAVELENGTH(nm)
a
b
c
d
e
f
g
h
i
j
k
a. 96hr after irradiation
b. 10 min. under UV-light
c. 20min. under UV-light
d. 30 min under UV-light
e. 40 min under UV-light
f. 50 min under UV-light
g. 60 min under UV-light
h. 90 min under UV-light
i. 120 min under UV-light
j. 180 min under UV-light
K. before irradiation

* Oxygen containing fluorides can be considered as a mixed crystal of MF_2 and MO, for example, can consider oxygen containing SrF_2 crystal as a mixed crystal of SrF_2 and SrO. It was known that the UV absorption band of SrO is located at 215-217 nm[7], and it is 205-209 nm (about 6 e.V) for BaO. They are due to the transition from O_{2p} state to conduction band of Ba^{+2} or Sr^{+2} ions.

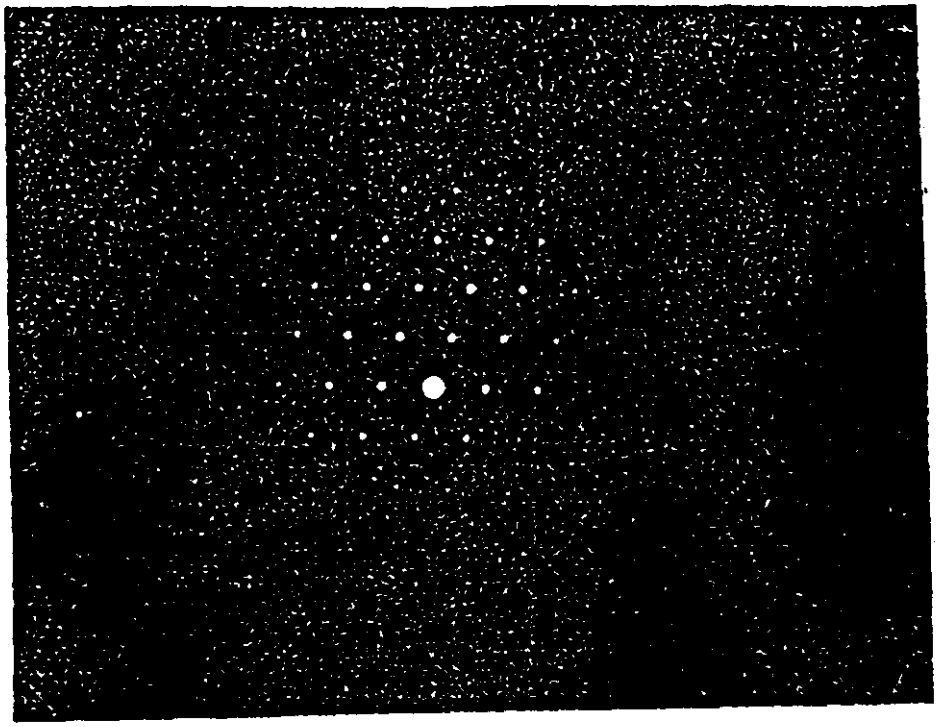
* When oxygen containing BaF_2 crystals were irradiated by r-ray radiation, O^{-2}-F^{+} dipoles decomposed:

$$O^{-2}\text{-}F^{+} \longrightarrow O^{-2} + F^{+}$$

which will increase the concentration of lone O^{-2} ions and O^{-2} ion pairs so as to increase the absorption in the 190-250 nm region. F^{+} vacancies are easy to capture electrons to form F centers which are responsible to the absorption in the visible region. In the mean time, the hollow at 290 nm was reduced or disappeared due to the decomposition of O^{-2}-F^{+} dipoles.

* When the damaged crystal was irradiated by UV, the electrons trapped in the F centers are easily escaped from the F^+, the crystal was bleached due to the destroy of F centers. The F^+ could associate again with O^{-2} ion to form O^{-2}-F^+ dipoles so as to decrease the concentration of O^{-2} ions and O^{-2} ion pairs in the crystal. The absorption in the 190-250 nm region also decreased.

* An experimental result of electron diffraction study (Fig.15) gave us an idea that probably there is a certain amount of oxygen (either in atom or molecule state) dissolved in the BaF_2 crystals.
Figure shows that just after the electron beam hitting the crystal, a very pure BaF_2 pattern was shown, however, after certain times, BaO rings appeared associated with the BaF_2 diffraction pattern. We assume that is the result of oxygen atoms or molecules transforming to oxygen ions during the electron beam bombardment.



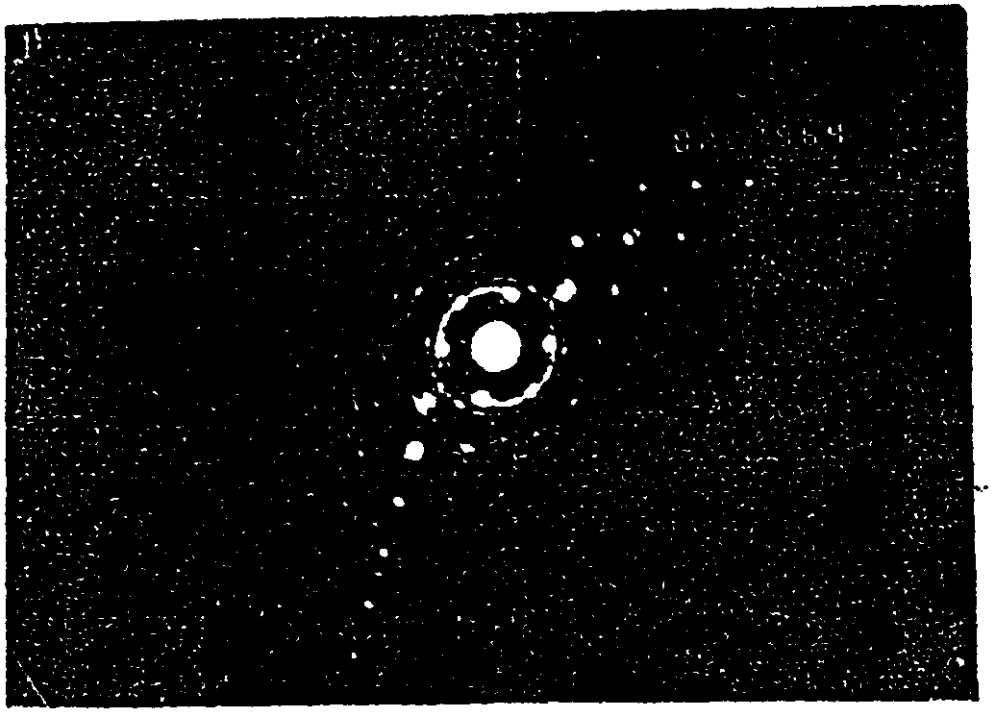
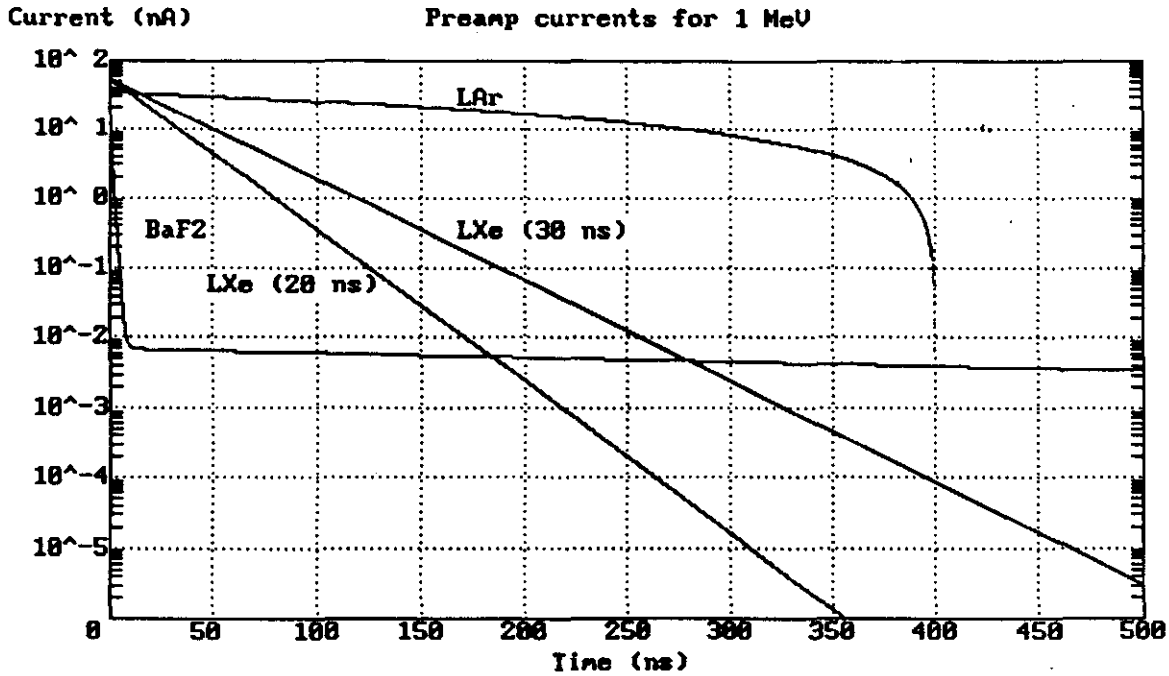


Fig.12 Electron diffraction patterns of BaF_2 crystal

(a) Just start bombardment of electron beam on crystals
(b) After certain time of bombardment of electron beam, pattern shows appearance of BaO rings

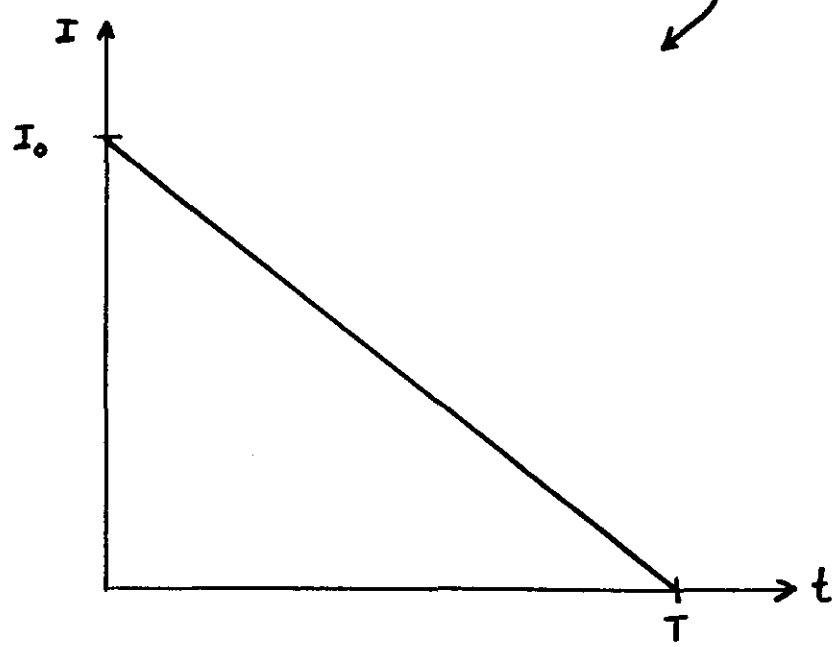
DENES

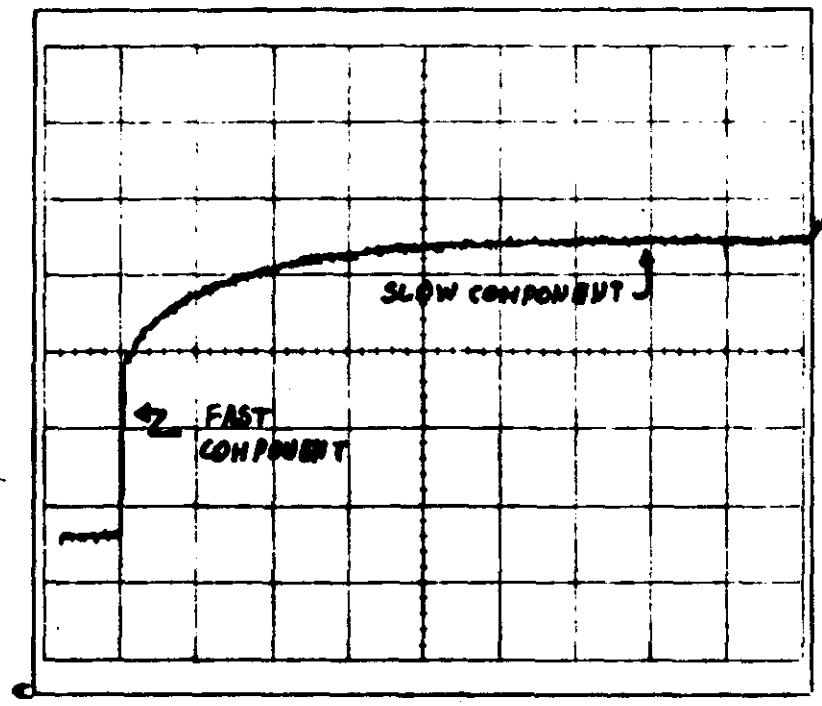


$$BaF_2: \quad I = \frac{Q_f}{\tau_f} e^{-t/\tau_f} + \frac{Q_s}{\tau_s} e^{-t/\tau_s}$$

$$LXe: \quad I = \frac{Q}{\tau} e^{-t/\tau}$$

$$LAr: \quad I = I_0 \left(1 - \frac{t}{T}\right) \qquad t < T$$

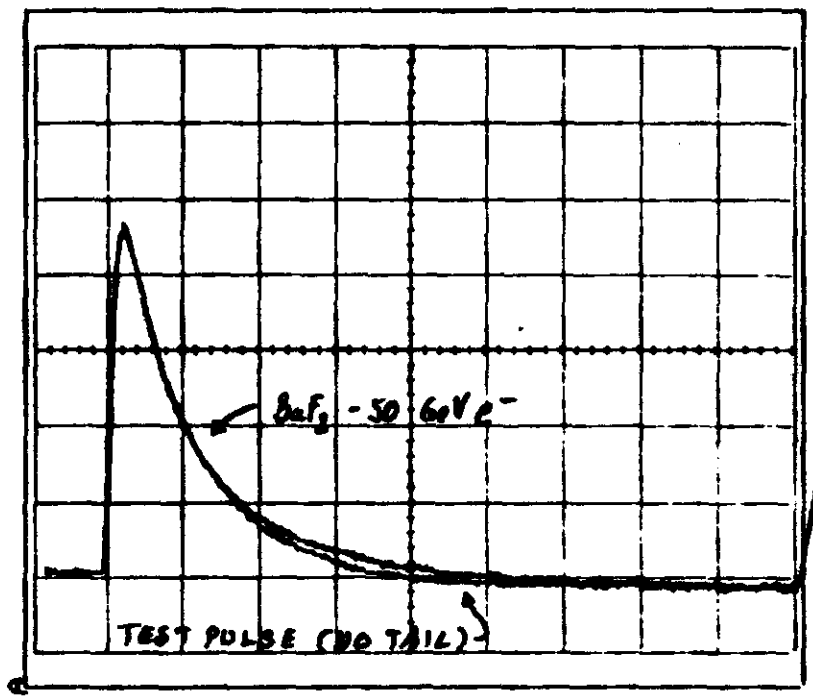




DATE:Jun 14/91
TIME:16:58:38

TR1A: 10.0mV :500ns

Integrated BaF_2 charge

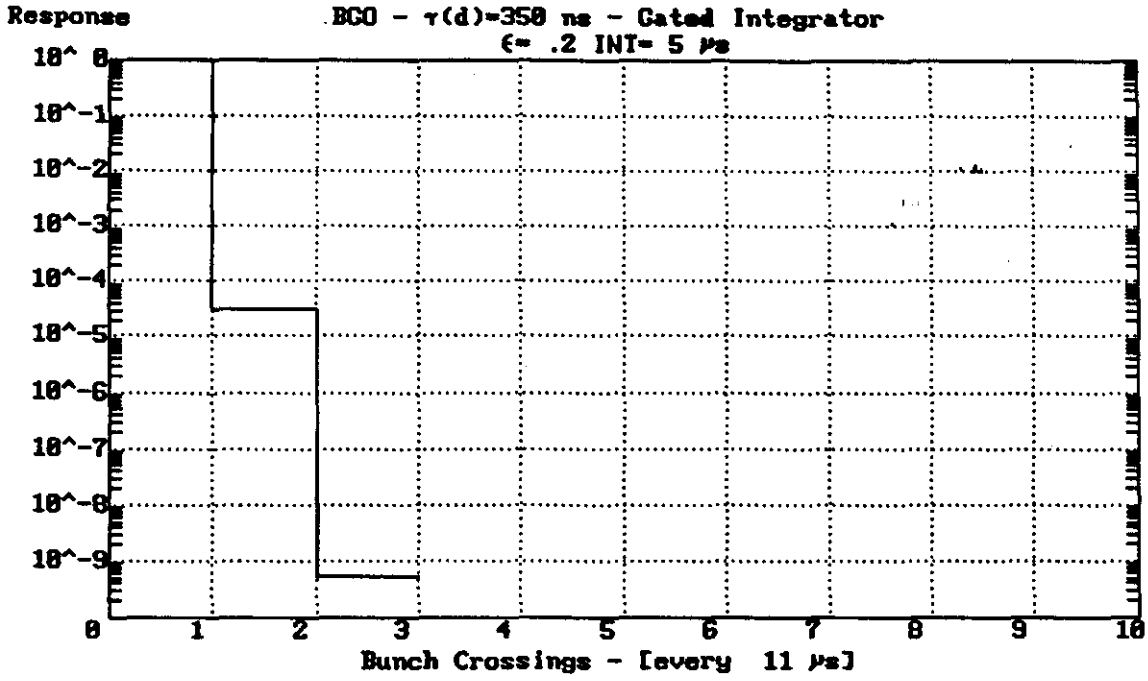


DATE:Jun 12/91
TIME:09:37:24

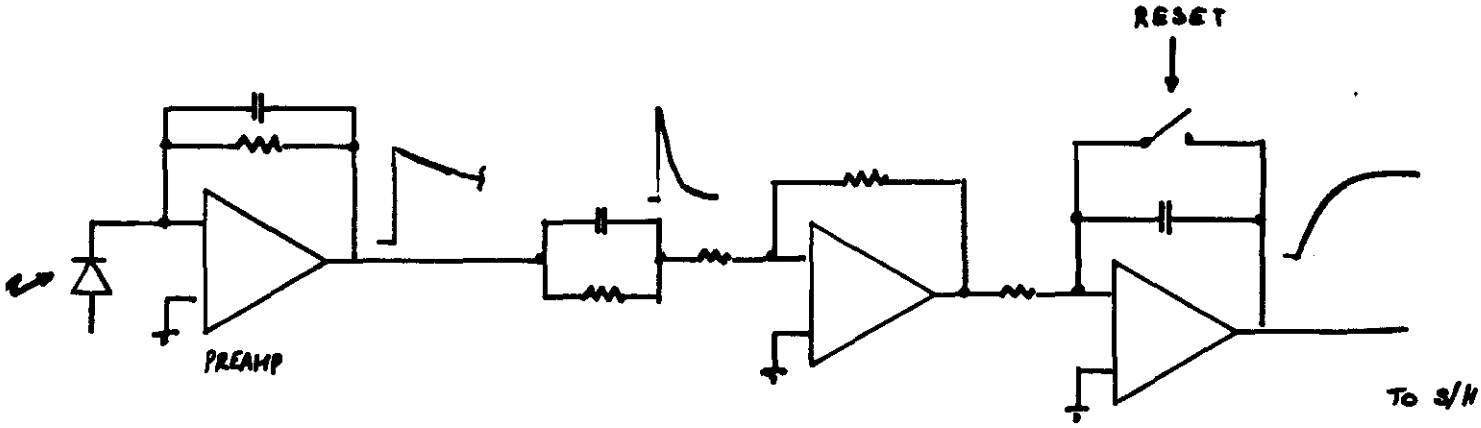
TR1A:> 10.0mV :250ns

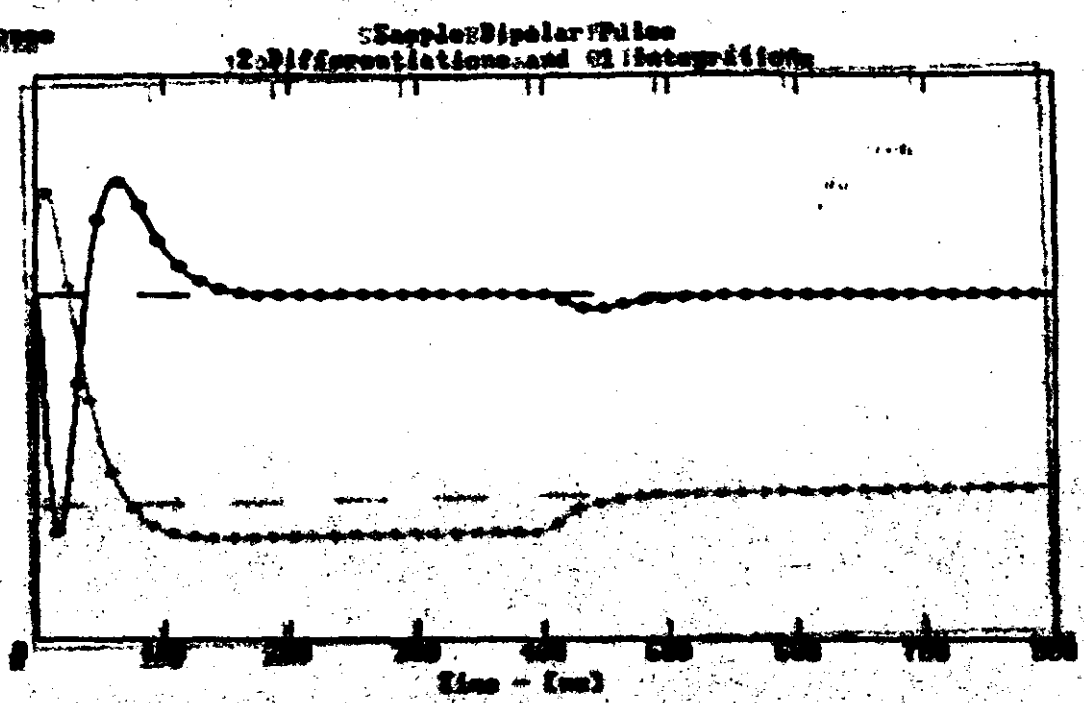
TR2A: 10.0mV :250ns

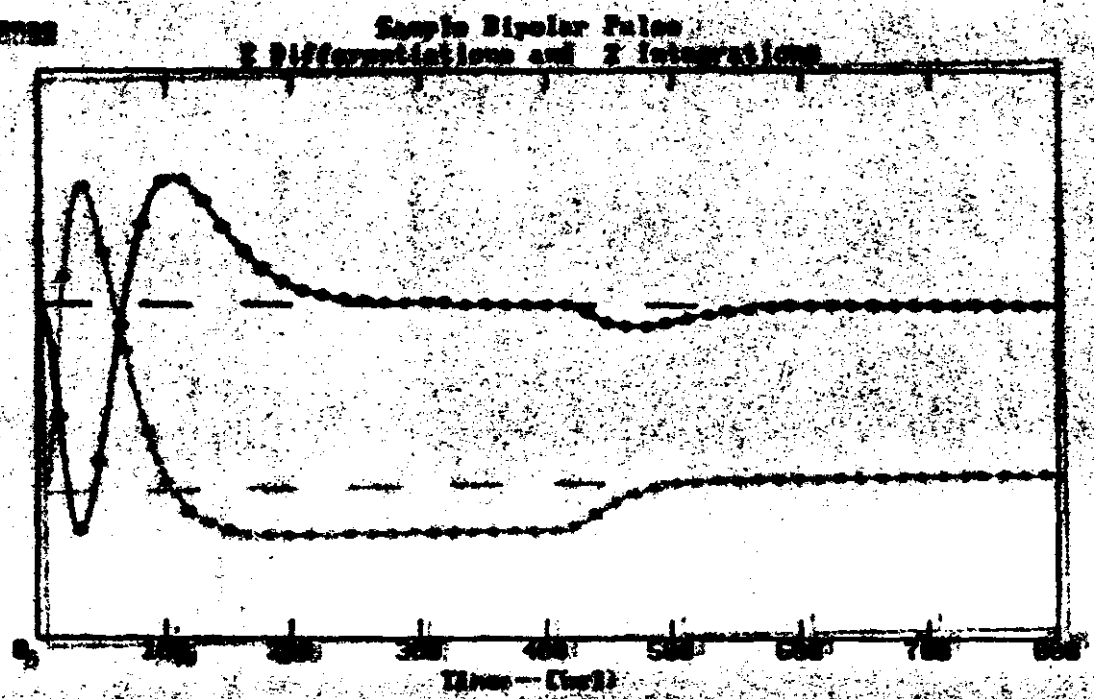
Slow component - small effect.


Response
BGO - τ(d)=350 ns - Gated Integrator
ε= .2 INT= 5 μs
10^ 0
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7
10^-8
10^-9
0
1
2
3
4
5
6
7
8
9
10
Bunch Crossings - [every 11 μs]

BGO Readout

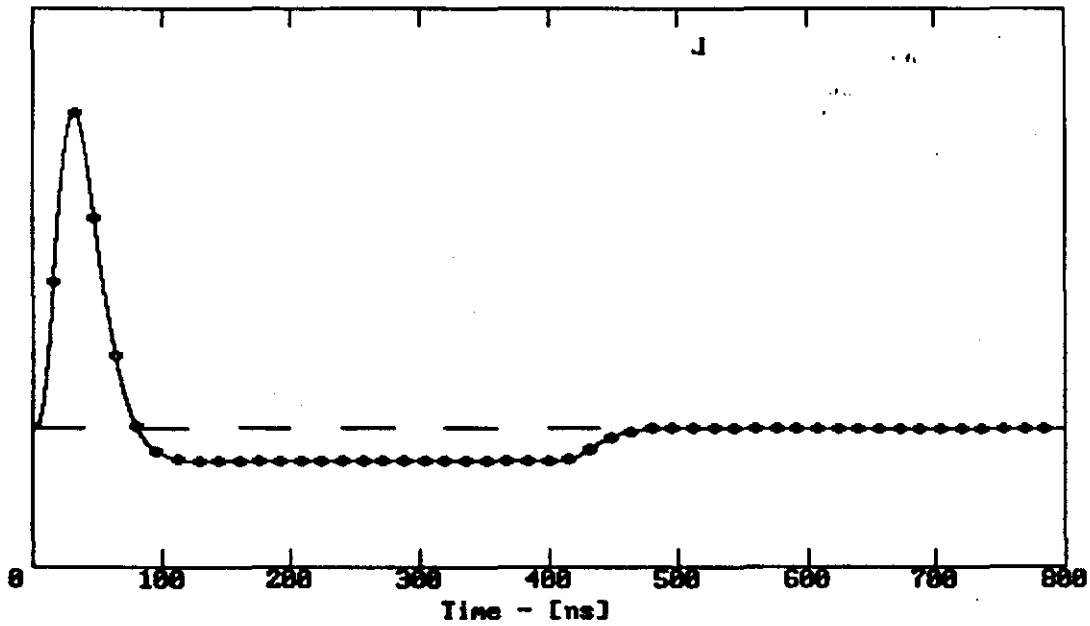

RESET
PREAMP
To S/H


Response
Sample Bipolar Pulse
2 Differentiations and 2 Integrations
0
Time - (us)

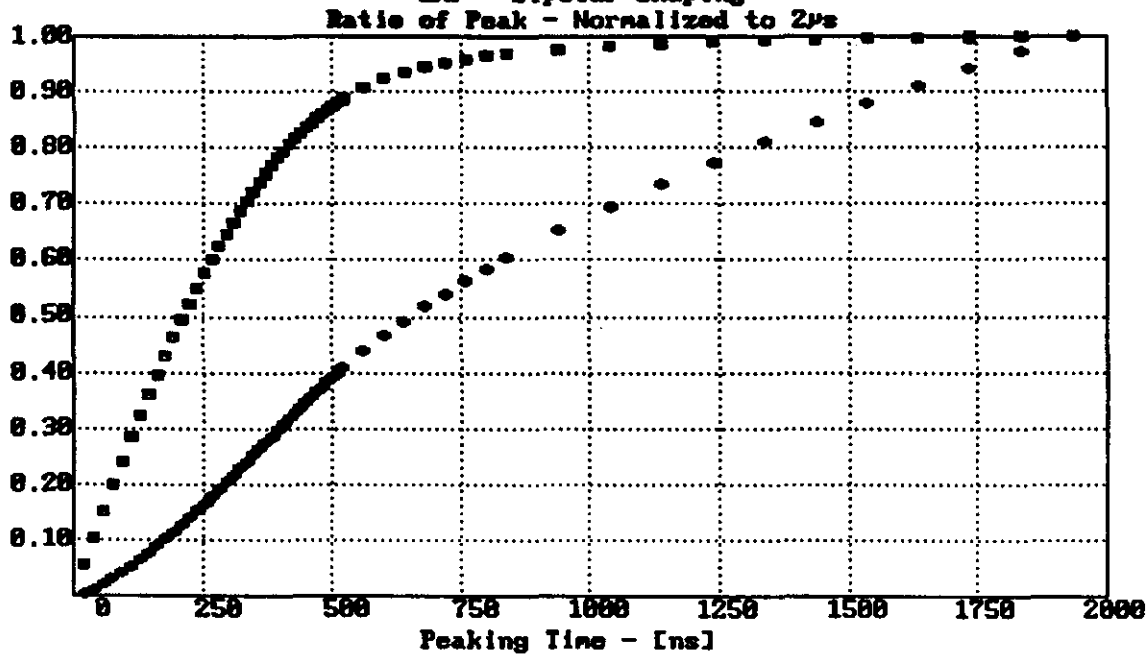

Response
Sample Bipolar Pulse
2 Differentiations and 2 Integrations
Time -- (us)

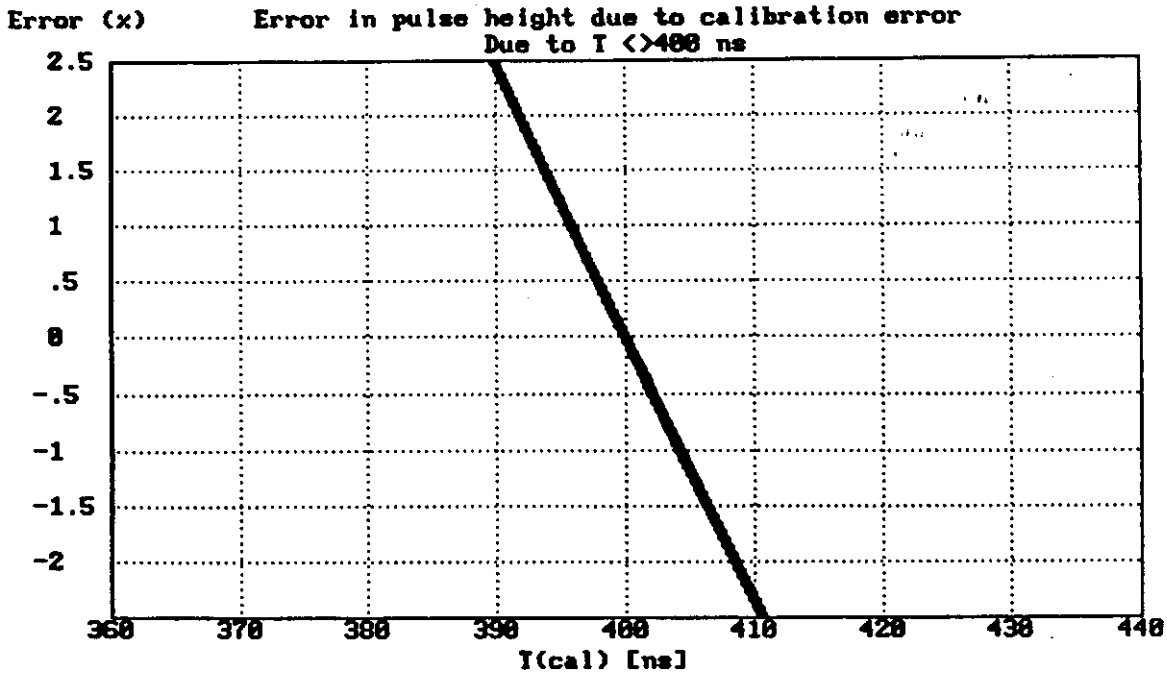
Response

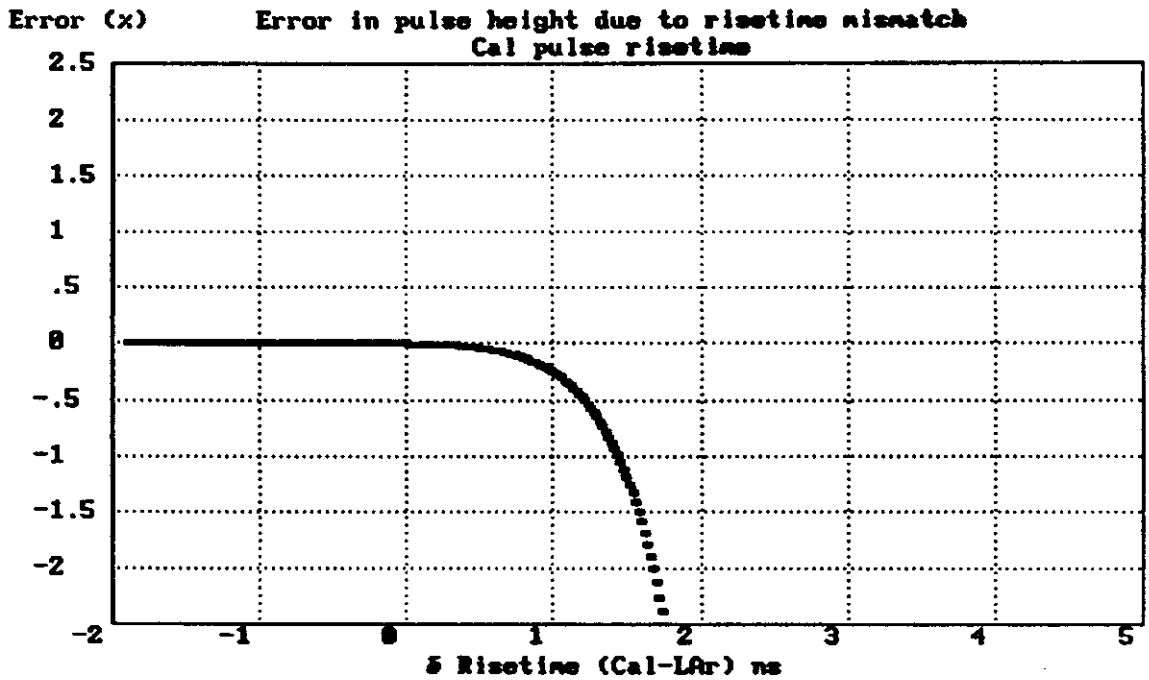
Sample Bipolar Pulse

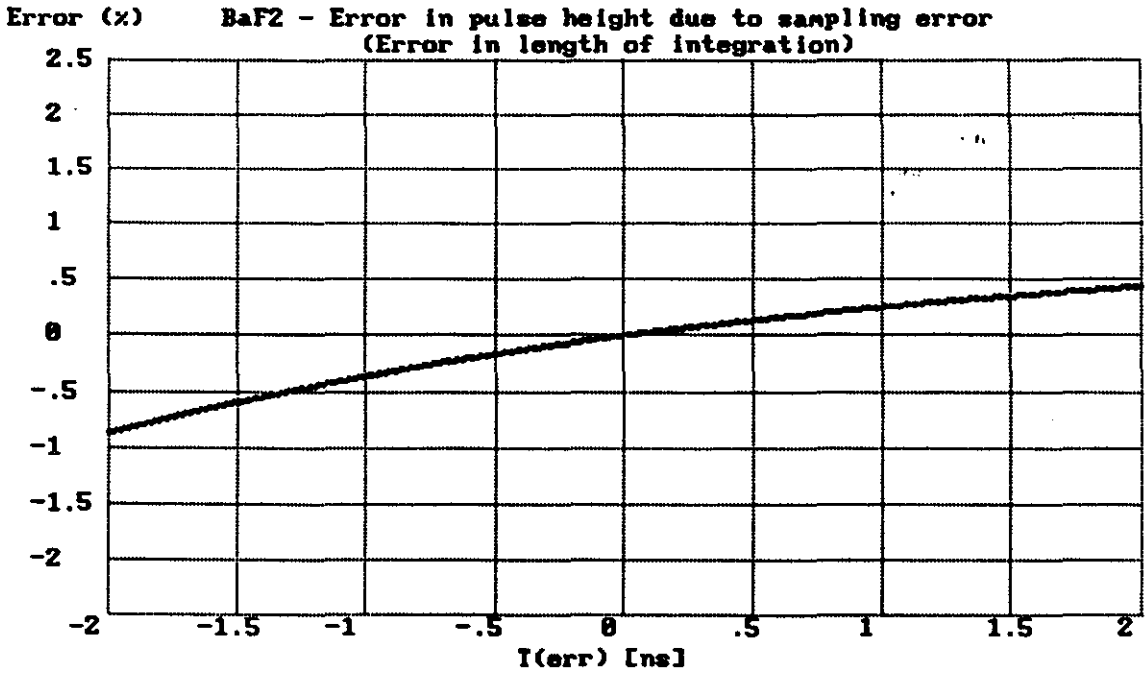


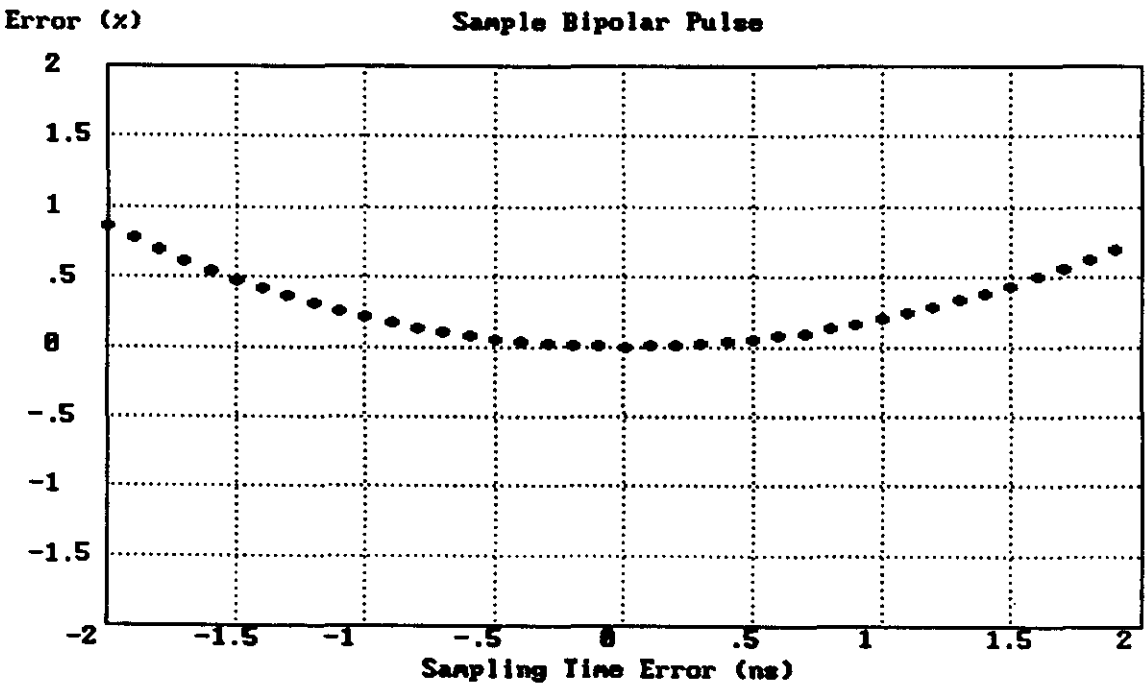
LAr - Bipolar Shaping
Ratio of Peak - Normalized to 2μs




Error (%)
Error in pulse height due to calibration error
Due to T <>400 ns
2.5
2
1.5
1
.5
0
-.5
-1
-1.5
-2
360
370
380
390
400
410
420
430
440
T(cal) [ns]

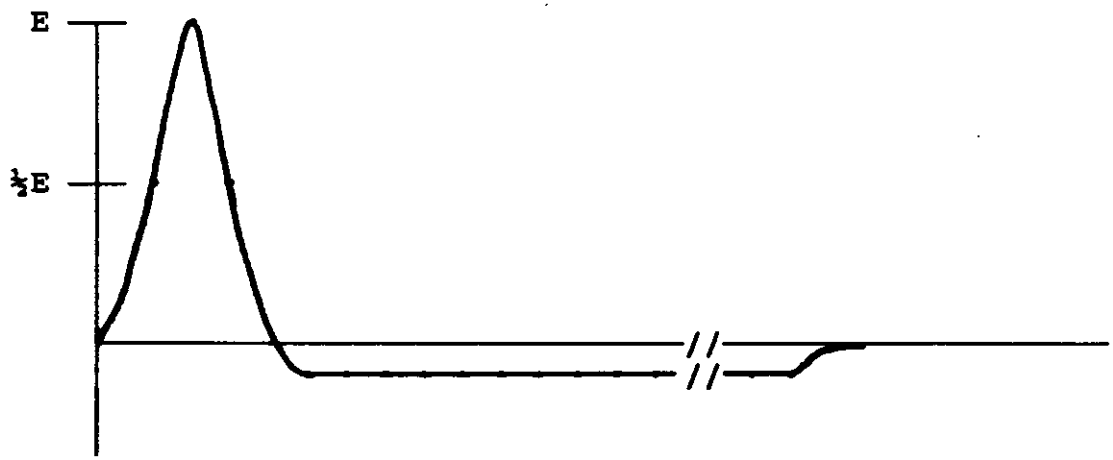

Error (%)
Error in pulse height due to risetime mismatch
Cal pulse risetime
2.5
2
1.5
1
.5
0
-.5
-1
-1.5
-2
-2
-1
0
1
2
3
4
5
δ Risetime (Cal-LAr) ns


Error (%)
BaF2 - Error in pulse height due to sampling error
(Error in length of integration)
2.5
2
1.5
1
.5
0
-.5
-1
-1.5
-2
-2
-1.5
-1
-.5
0
.5
1
1.5
2
T(err) [ns]


Error (%)
Sample Bipolar Pulse
2
1.5
1
.5
0
-.5
-1
-1.5
-2
-2
-1.5
-1
-.5
0
.5
1
1.5
2
Sampling Time Error (ns)

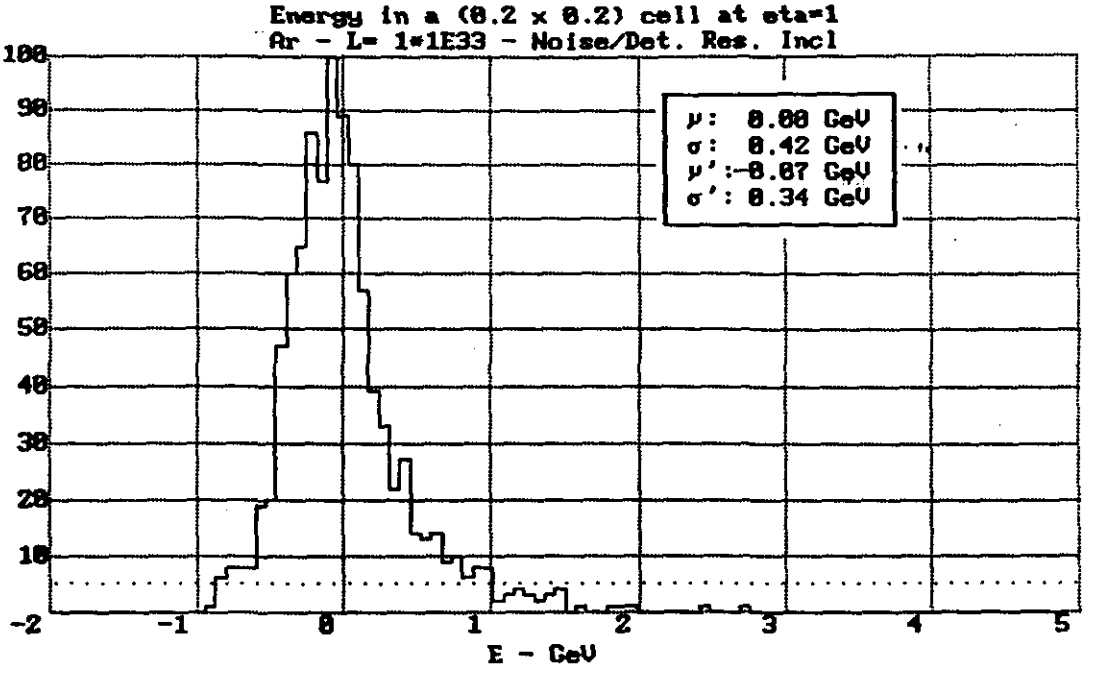
Pileup

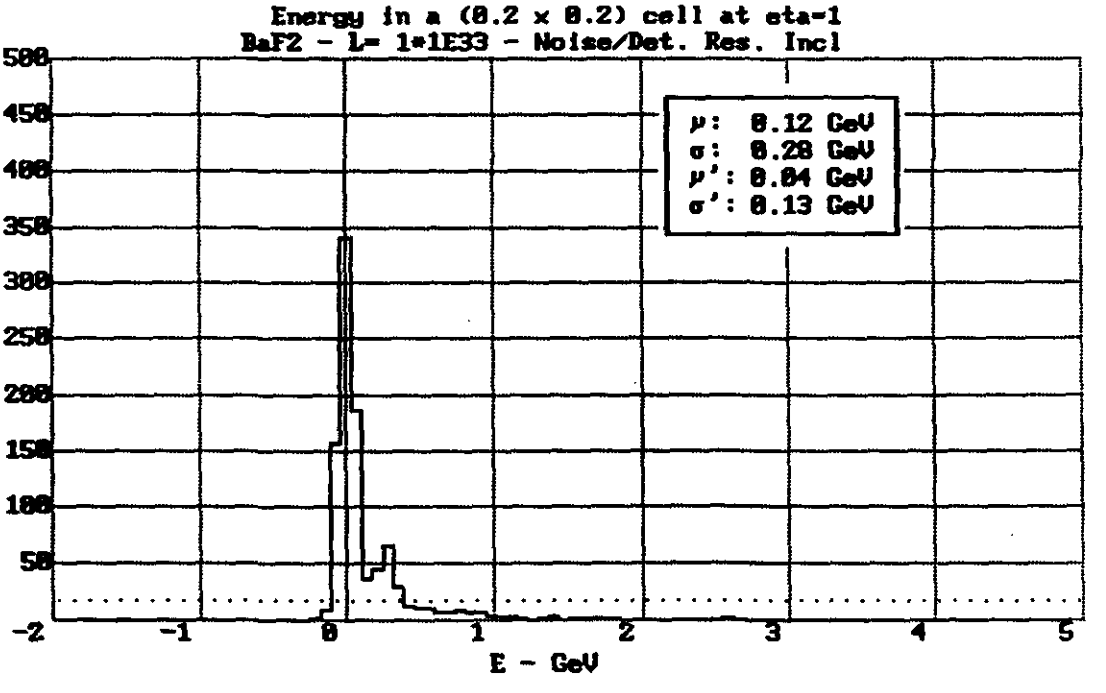
Consider an input of energy E at time t=0, and imagine that the bipolar shaper has the (idealized) response below. As the pulse peaks in two bunches (dots represent bunches) at t=2 bunches, the pulse height is equivalent to energy E. For this pulse shape, we have arranged that the pulse height is ½E at t=1 and 3 bunches, and zero at t=4 bunches.

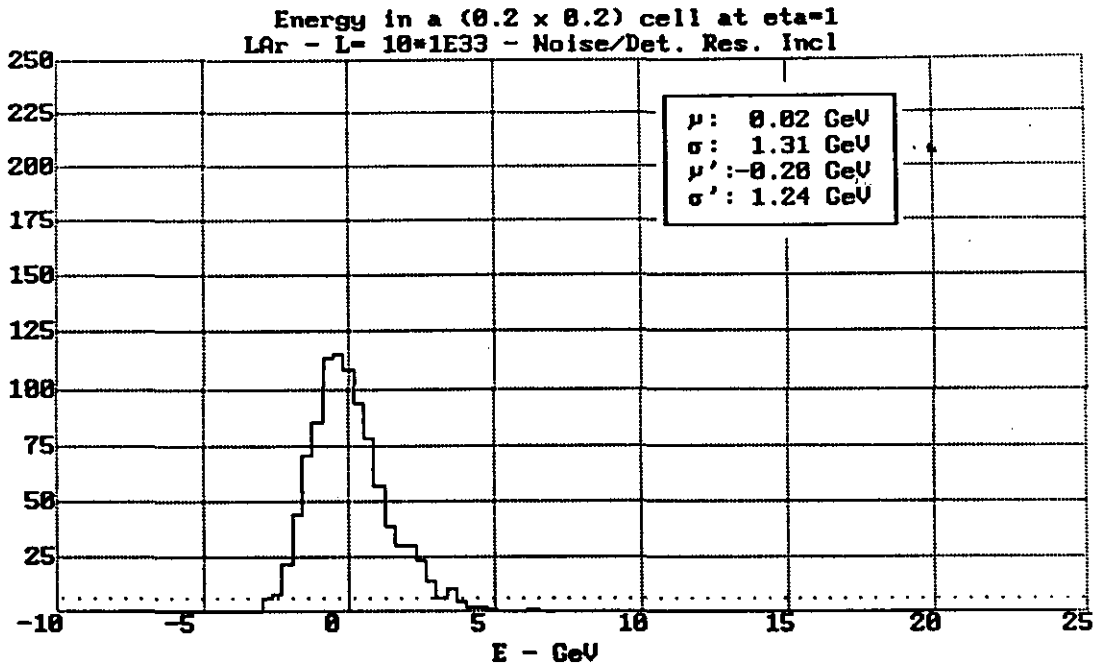


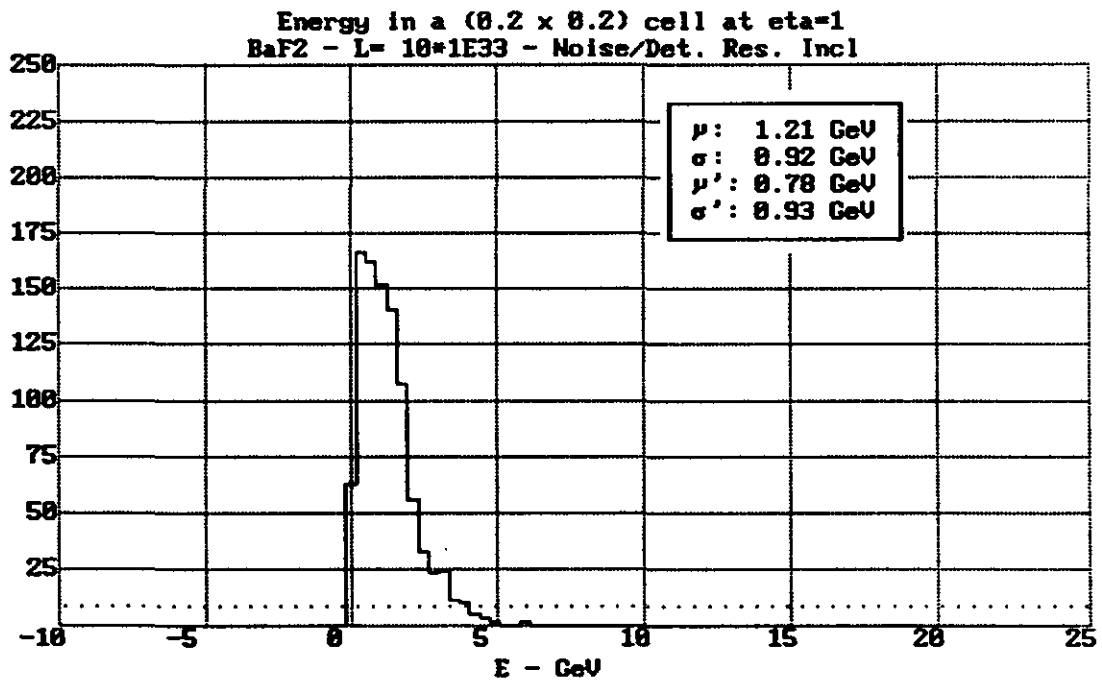
<--------><----------//------>
This Area + This Area = 0

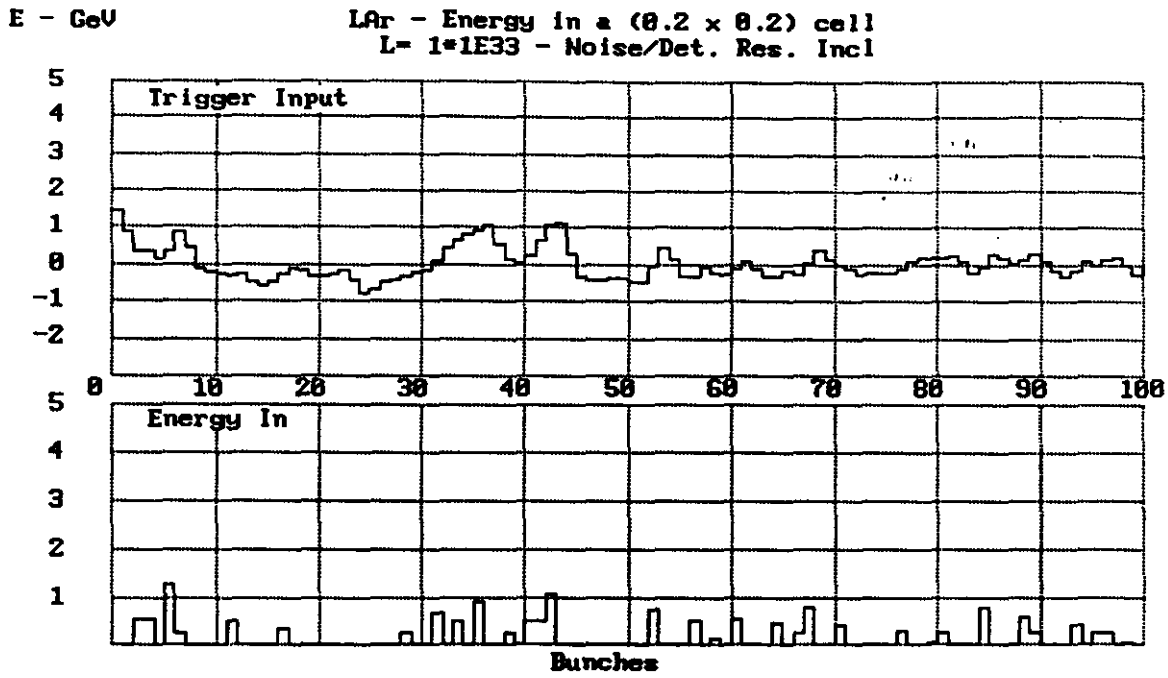
As the positive area (½ + 1 + ½) E • t_{bunch} must be the same as the negative area ϵ • E • 20 t_{bunch}, $\epsilon \approx -0.1$ E. Now, if a_i is the gain of for the ith bunch (0, ½, 1, ½, 0, -ϵ etc.) and E_j is the energy deposited in the jth bunch, the measured energy at bunch k is $E_{Meas} = \Sigma a_i E_{k-i}$. As the energy of each bunch is statistically independent, $\langle E_{Meas}\rangle = \langle E\rangle \Sigma a_i \equiv 0$. Similarly, $\langle E^2_{Meas}\rangle = \langle E^2\rangle \Sigma a^2_i \approx \langle E^2\rangle(½^2+1^2+½^2+20\epsilon^2)$ so that we will observe (statistically) $\sigma_{Meas} = 1.3\ \sigma_E$.
This factor of 1.3 is the "pileup".

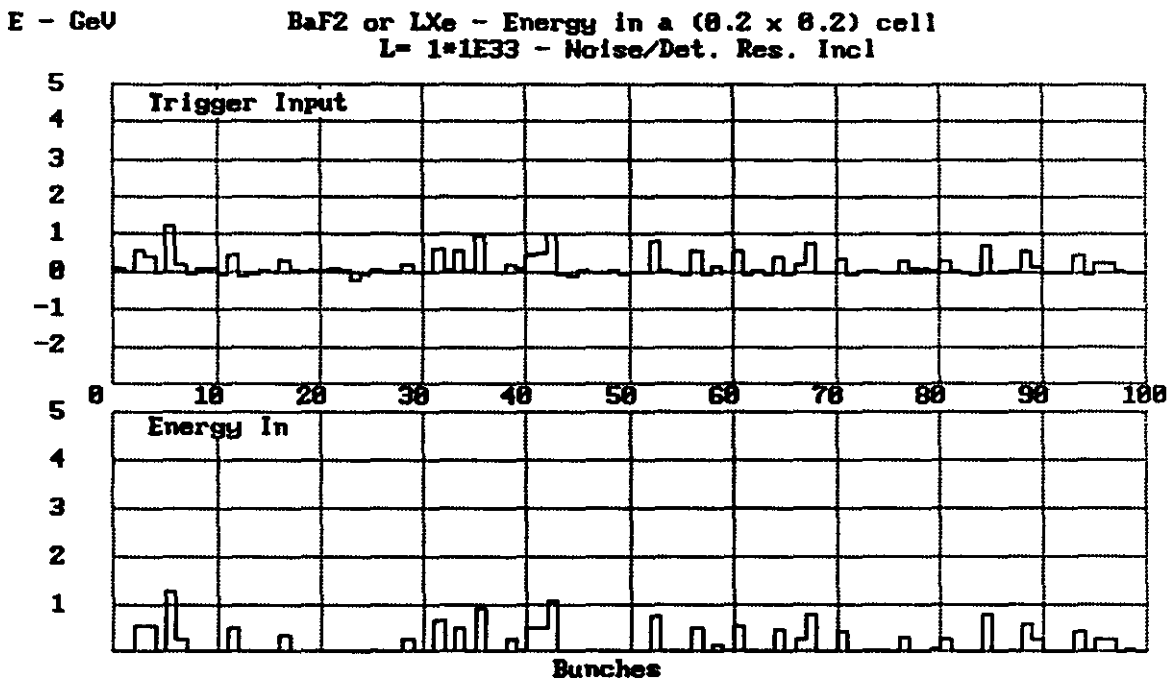

Energy in a (0.2 x 0.2) cell at eta=1
Ar - L= 1*1E33 - Noise/Det. Res. Incl
μ: 0.00 GeV
σ: 0.42 GeV
μ': -0.07 GeV
σ': 0.34 GeV
E - GeV

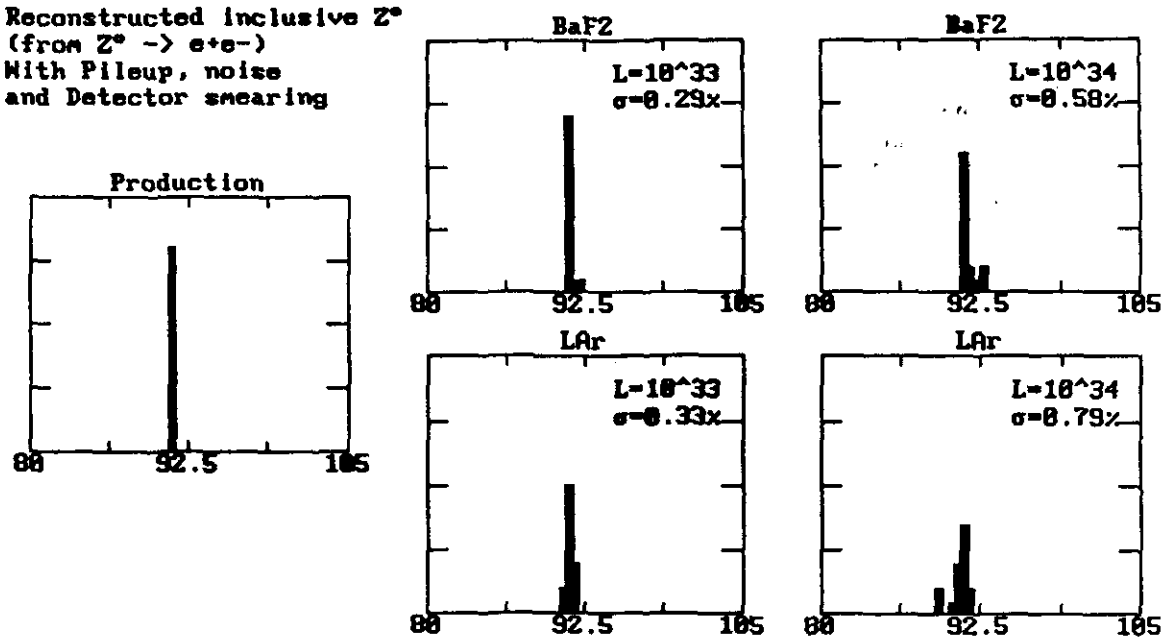

Energy in a (0.2 x 0.2) cell at eta=1
BaF2 - L= 1*1E33 - Noise/Det. Res. Incl
μ: 0.12 GeV
σ: 0.28 GeV
μ': 0.04 GeV
σ': 0.13 GeV
E - GeV

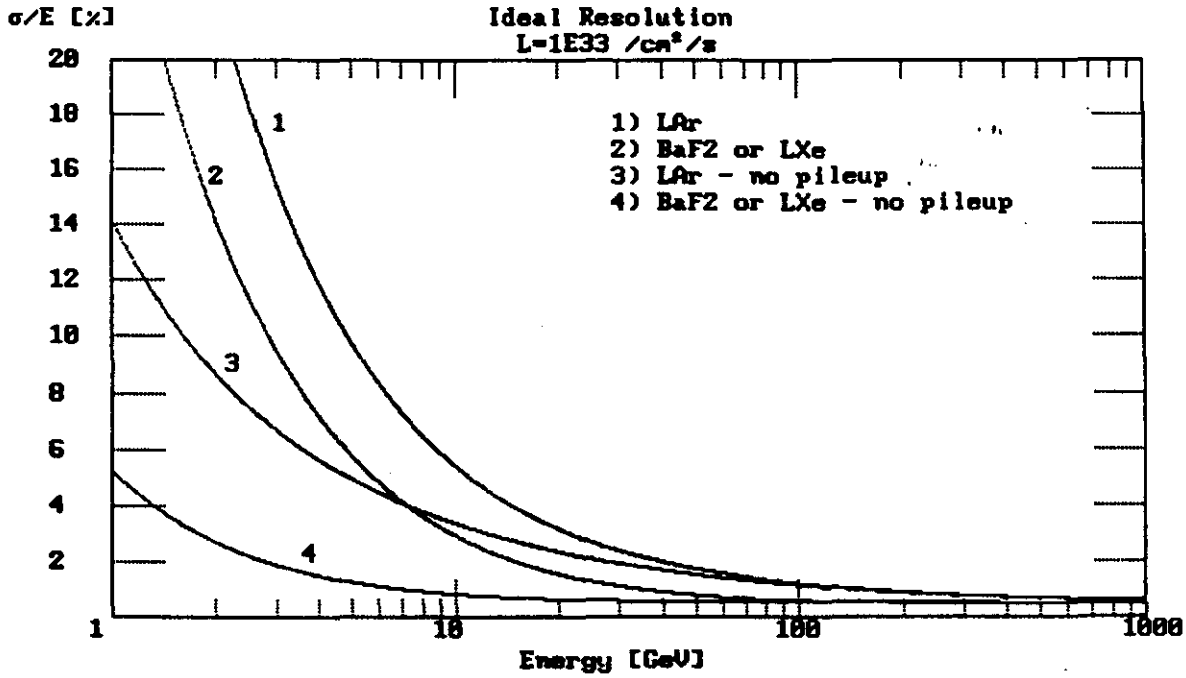

Energy in a (0.2 x 0.2) cell at eta=1
LAr - L= 10*1E33 - Noise/Det. Res. Incl
μ: 0.02 GeV
σ: 1.31 GeV
μ':-0.20 GeV
σ': 1.24 GeV
250
225
200
175
150
125
100
75
50
25
-10
-5
0
5
10
15
20
25
E - GeV

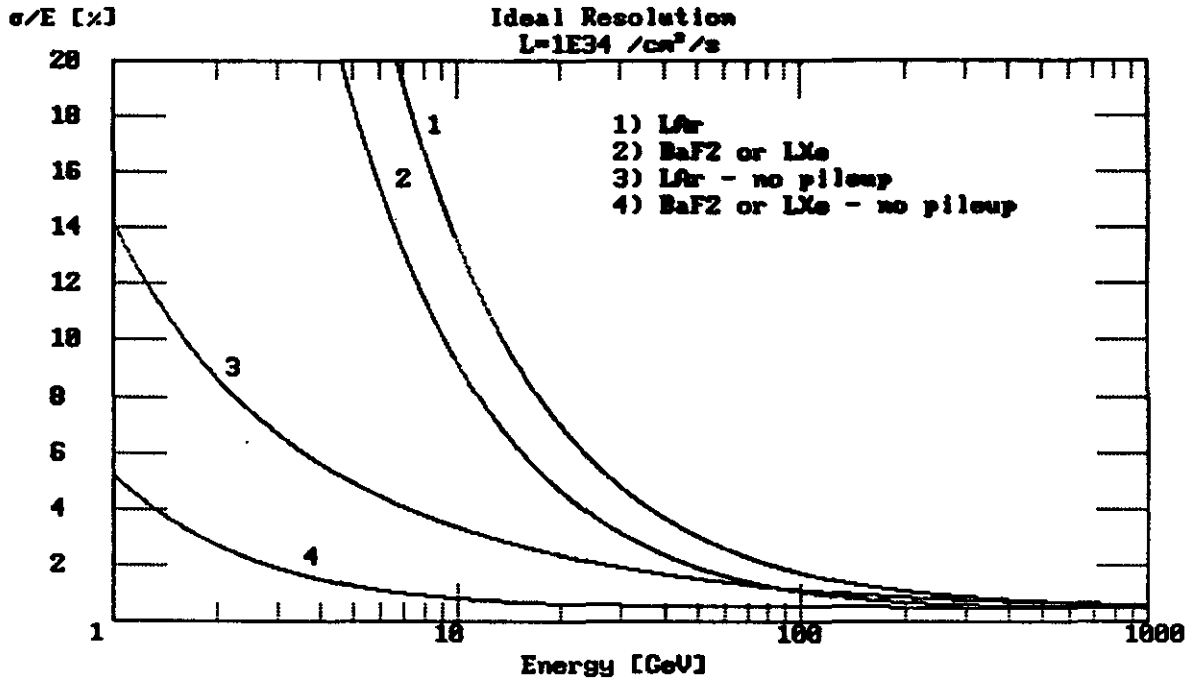

Energy in a (0.2 x 0.2) cell at eta=1
BaF2 - L= 10*1E33 - Noise/Det. Res. Incl
μ: 1.21 GeV
σ: 0.92 GeV
μ': 0.78 GeV
σ': 0.93 GeV
250
225
200
175
150
125
100
75
50
25
-10
-5
0
5
10
15
20
25
E - GeV


E - GeV
LAr - Energy in a (0.2 x 0.2) cell
L= 1*1E33 - Noise/Det. Res. Incl
Trigger Input
Energy In
Bunches


E - GeV
BaF2 or LXe - Energy in a (0.2 x 0.2) cell
L= 1*1E33 - Noise/Det. Res. Incl
Trigger Input
Energy In
Bunches


Reconstructed inclusive Z°
(from Z° -> e+e-)
With Pileup, noise
and Detector smearing
Production
80
92.5
105
BaF2
L=10^33
σ=0.29%
80
92.5
105
BaF2
L=10^34
σ=0.58%
80
92.5
105
LAr
L=10^33
σ=0.33%
80
92.5
105
LAr
L=10^34
σ=0.79%
80
92.5
105


σ/E [%]
Ideal Resolution
L=1E33 /cm²/s
1) LAr
2) BaF2 or LXe
3) LAr - no pileup
4) BaF2 or LXe - no pileup
Energy [GeV]


σ/E [%]
Ideal Resolution
L=1E34 /cm²/s
1) LAr
2) BaF2 or LXe
3) LAr - no pileup
4) BaF2 or LXe - no pileup
Energy [GeV]

Some Details...

Fraction of Charge in 16 ns

BaF_2 - All
LXe - 41% (τ_{Xe}=30 ns), 55% (τ_{Xe}=20 ns)
LAr - 8%

Thermal Noise out of preamp (based on capacitance...)

$\sigma_{LXe} = 30 \bullet \sigma_{BaF2}$
$\sigma_{LAr} = 22 \bullet \sigma_{BaF2}$

Signal-to-Noise

$S/N_{LXe} = 2 \bullet S/N_{BaF2}$ (30 ns), $3 \bullet S/N_{BaF2}$ (20 ns)
$S/N_{LAr} = ½ \bullet S/N_{BaF2}$

Pileup

σ_{Pileup} (LAr) = 1.4 σ_{Pileup} (BaF_2 or LXe)

E_T^{cut} (LAr) = E_T^{cut} (BaF_2 or LXe) + 1 GeV

σ_E/E for reconstructed Z^o (from e^+e^-) (With pileup, noise and detector smearing; but "constant term" = 0)

BaF_2 or LXe: 0.29% at $L=10^{33}$, 0.58% at $L=10^{34}$
LAr: 0.33% at $L=10^{33}$, 0.79% at $L=10^{34}$

GORDON

MEASUREMENT OF π^0 FRAGMENTS FROM JETS PRODUCED IN pp COLLISIONS AT THE CERN ISR

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Received 18 June 1979

The jet fragmentation function into π^0, $f(z)$ has been measured using the away side high p_t π^0 or η mesons as a measure of the jet momentum. The fragmentation function is found to have an excess of events near $z \approx 1$ compared with the exponential fall-off observed at lower z values. The data behaves like $1/z^3$ up to $z \approx 1$, but deviates sharply from it for $z > 1$. Possible explanations of this effect are the single particle fragmentation mode of the quark or gluon jet, or quark fusion.

The correlation between two high p_t particles can be analysed using different variables. In this letter we report on new measurements of the fragmentation variable $z = (p_2/p_1)\cos\phi$, where p_1 is either a very high transverse momentum (p_t) π^0 or η meson and p_2 is a π^0. The hard scattering of the proton constituents produces high p_t jets [1–5], which usually fragment into several particles. The selection of single high p_t particles introduces a "trigger bias" [2] due to the rapidly falling p_t spectrum, which allows one to use the approximation that the direction and momentum of the high p_t meson are a measure of these quantities for the scattered constituents in the transverse plane. The variable z, while defined relative to the momentum of a single high p_t π^0 or η meson (p_1), is expected to provide a measure of the fragmentation into π^0's of the second scattered constituent.

The apparatus used (fig. 1) in this experiment consisted of four identical liquid-argon calorimeters. Each calorimeter module covered a solid angle of approximately 1 sr, 50° to 130° in polar angle and 40° in azimuth. The energies and position of the electromagnetic showers were measured in the segmented lead–liquid-argon calorimeter. Discrimination between hadrons and electromagnetic showers was provided by measurement of shower development in the calorimeter. Energy

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[4] Permanent address: Tel-Aviv University, Israel.
[5] On leave of absence from the University of Pisa and INFN, Sezione di Pisa, Italy.
[6] Work supported by the US National Science Foundation.

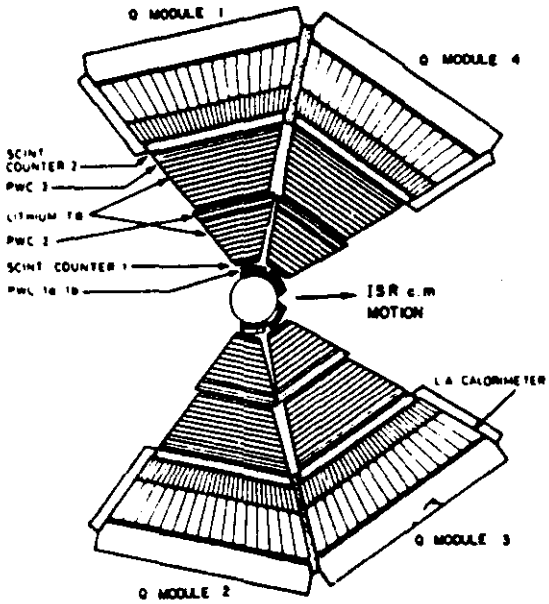


Fig. 1. The apparatus arrangement in the ISR.

resolution in the calorimeter was found to be $\sigma(E) = 10\%/\sqrt{E}$. A more detailed description of the apparatus is found elsewhere [6–12].

The trigger for this experiment was based on a large energy deposit in a single calorimeter module. The trigger efficiency rises from near zero at 4 GeV/c to a constant value of 95% for p_t above 6–7 GeV/c. The η production [10] was detected via $\eta \to 2\gamma$. The η acceptance increases as a function of p_t, because of both increasing trigger efficiency and geometrical acceptance. Note that in this experiment low-energy π^0's ($p_t \leq 3$ GeV) were resolved in the calorimeter and were detected as two separate electromagnetic showers. With increasing p_t the two showers overlap and the π^0 is reconstructed as a single shower. Thus one could not distinguish a single photon from π^0's in this analysis, and all showers were assumed to be π^0's.

The analysis is done in the plane transverse to the proton–proton interactions (fig. 2). The data can be described by the variables p_1, p_2 and ϕ, the azimuthal difference between the two particles. The azimuthal acceptance of the apparatus being poor in the region where $\phi < 110°$, events in that region were not used. In this analysis the events were grouped in bins of fixed p_t of one of the particles (p_1). For the analysis of the η–π^0 correlation, p_1 pertains to an η meson. For π^0–

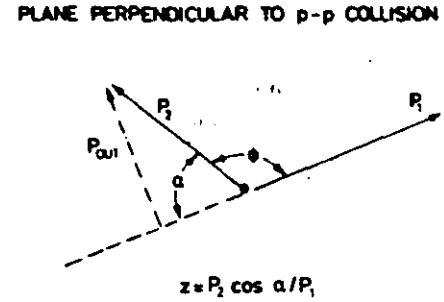


Fig. 2. The definitions of the variables p_1, p_2 and z.

π^0 studies the symmetry of the correlation between two identical particles is recognized by treating each pion both as p_1 and p_2 in turn. Thus events may appear twice in the plots.

In fig. 3 we show the constituent fragmentation function $f(z)$ into π^0. The constituent energy is estimated using the high p_t π^0 on the away side. A rapid fall-off in the distribution is observed for all p_1 bins.

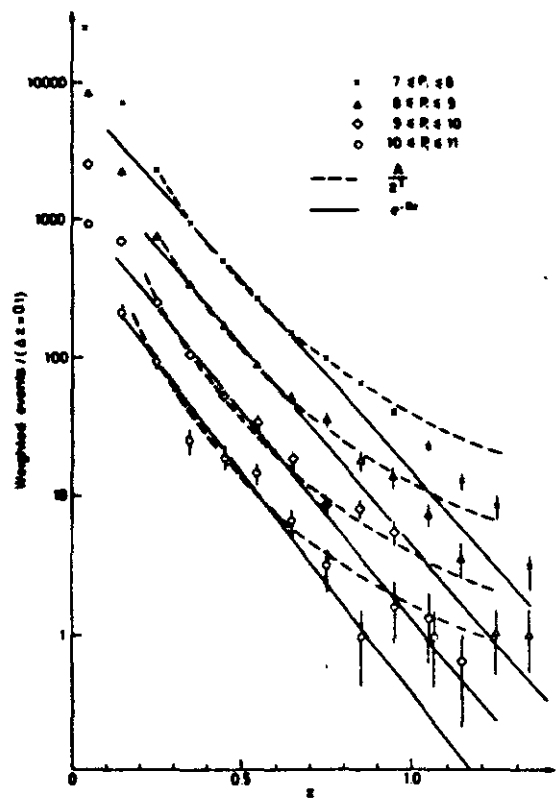


Fig. 3. The constituent fragmentation distribution into π^0 for π^0–π^0 events.

A more detailed investigation shows that for the region $0.8 \geq z \geq 0.2$ the fall-off is approximately exponential with a slope of $b \approx 7$. An even steeper exponential fall-off is observed for events with lower z values ($z < 0.2$). This might be due to the fact that at lower momentum transfer, π^0's not directly related to the scattered constituent are included. A more interesting feature of the data is the excess of events with respect to the exponential fit observed near $z \approx 1$. Note that the functional form $1/z^3$ (dotted line) describes the data well in the region up to $z \approx 1$, but the data show a sharp deviation from this form beyond $z = 1$. The data could also be described as the sum of two exponentials, a steep one for the $z \lesssim 0.5$ region and a flatter one for the $z \gtrsim 0.5$ region. This however implies a change in the shape of the fragmentation function from the one observed with a lower triggered momentum, where a single exponential was observed.

In fig. 4 we show the constituent fragmentation function $f(z)$ when the estimator of the constituent momentum is an η meson on the away side. The fragmentation function using the $\eta-\pi^0$ events shows the same features as were discussed in the $\pi^0-\pi^0$ events. While observation of a structure near $z \approx 1$ for the $\eta-\pi^0$ case indicates that the effect is not due to $\gamma-\gamma$ events, a γ–meson correlation is not ruled out.

The exponential fall-off of the fragmentation function has been observed earlier. It is worth while to note that the slope observed at FNAL [13] using lower p_t jets was 4.6 compared with our 7. This might be due to the fact that as the energy of the scattered constituent increases, the number of fragments also increases; thus $\langle z \rangle$ is decreased, resulting in a steeper slope. The deviation from single exponential fall-off or alternatively the change in the $1/z^3$ behaviour at $z \geq 1$ could be the result of a number of effects, e.g. a large single particle fragmentation mode of the quark or gluon jets either in the meson–meson or γ–meson mode; a CIM [14] process favouring quark meson scattering or quark fusion. If we assume that the excess of events near $z \approx 1$ is due to a single particle fragmentation mode its ratio to the total number of fragments is $R \approx 2 \times 10^{-3}$. Assuming the average number of fragment in this $\hat{s}$ range ($\hat{s} \approx 2p_1$) to be 5, the probability of a constituent to show up as a single particle is about 1%. A recent phenomenological analysis of high mass dihadron data from FNAL [15] concludes that R is smaller than our measured value and is consistent with being zero. That

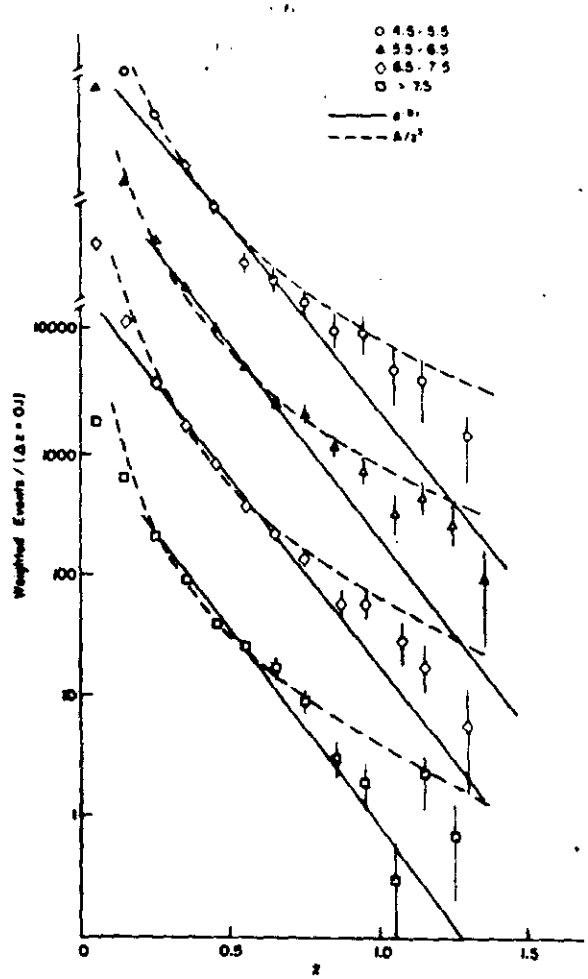


Fig. 4. The constituent fragmentation distribution into π^0 for $\pi^0-\eta$ events.

analysis is based primarily on the p_t dependence of the dihadron pairs rather than on direct measurements of the fragmentation function, and may be sensitive to other assumptions used in the analysis. An observation of this effect with pairs of mesons in different charge states may allow the identification of the mechanism involved. This effect can be an important tool for studying constituent scattering, as it implies that this region is dominated by two-body kinematics, and it would seem reasonable that the constituent characteristics such as quantum numbers would be more easily detected.

We would like to thank M. Jacob and R. Horgan for helpful discussions.

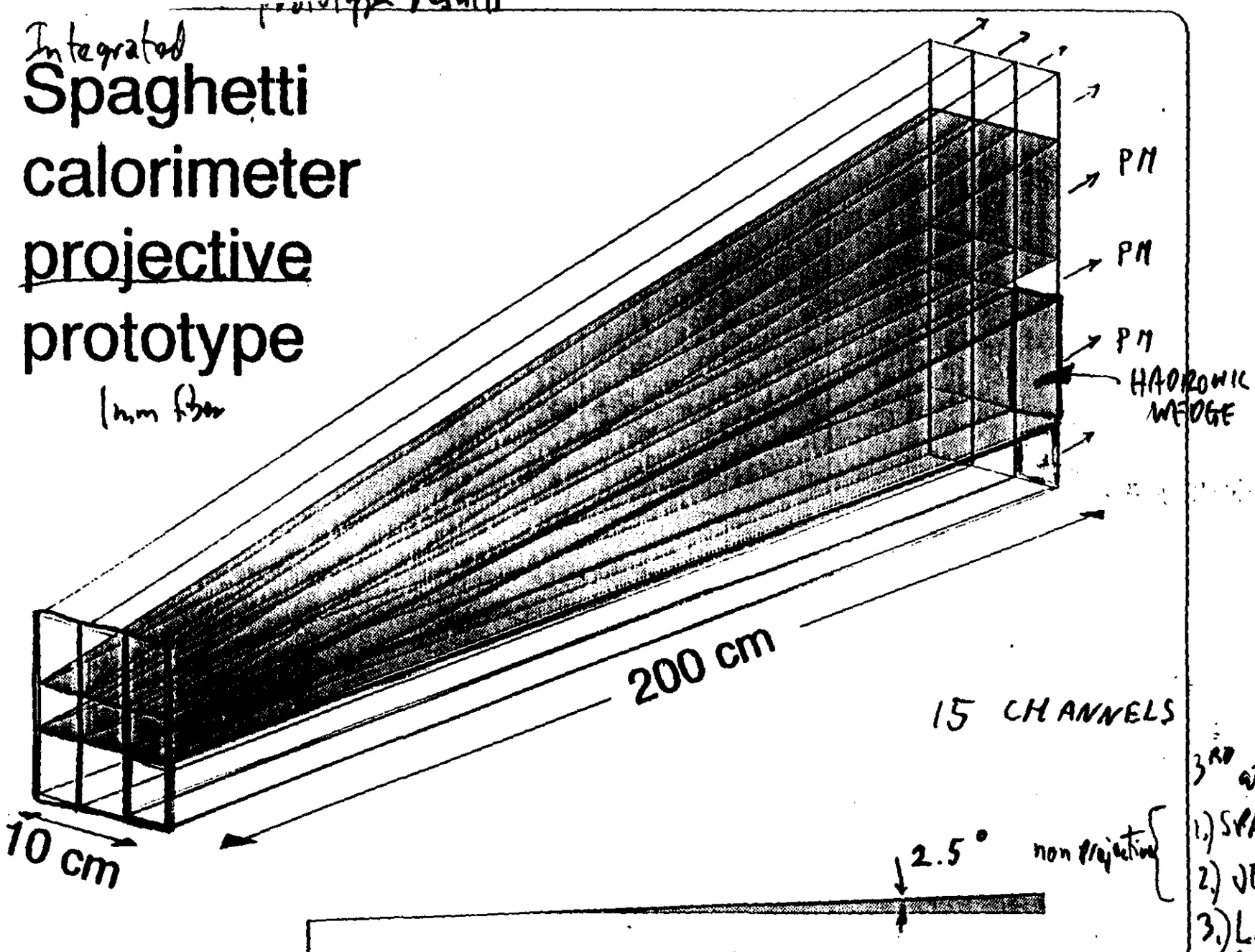
Ricardo Orsaluo

R.D.6

An Integrated

Spaghetti calorimeter projective prototype

1mm fiber



15 CHANNELS

3RD at CERN

non projective { 1.) SPACAL e/π
2.) JETSET
3.) LAA 2b

projective & ζ em constant term

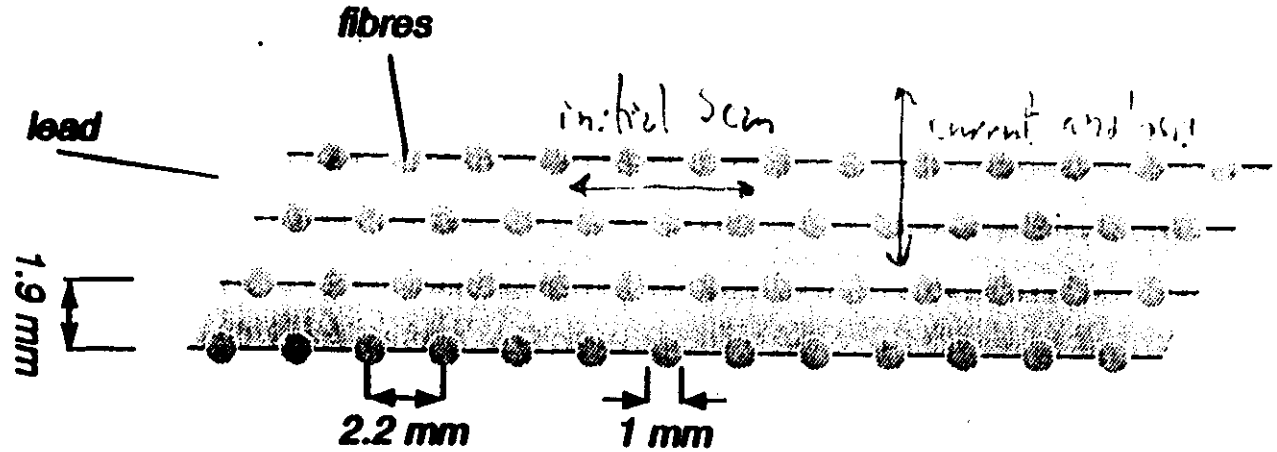
2.5°

20 cm

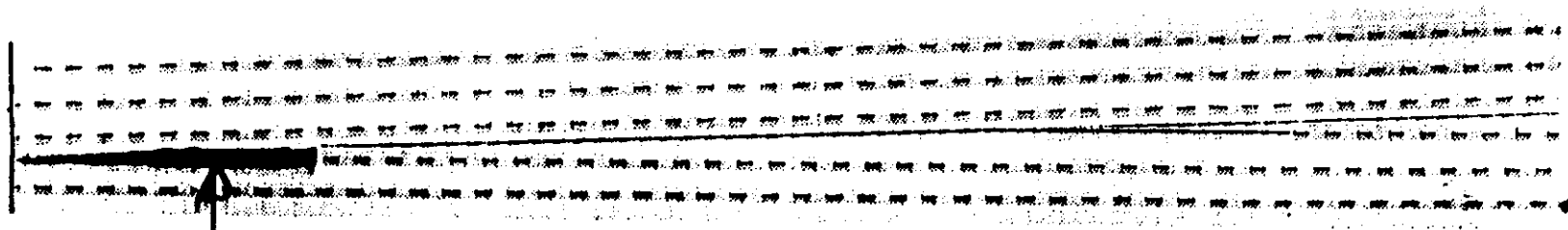
L. Sulak

GEM Calorimeter Meeting - SSCL 8/9-10/91

EM front end



Top view

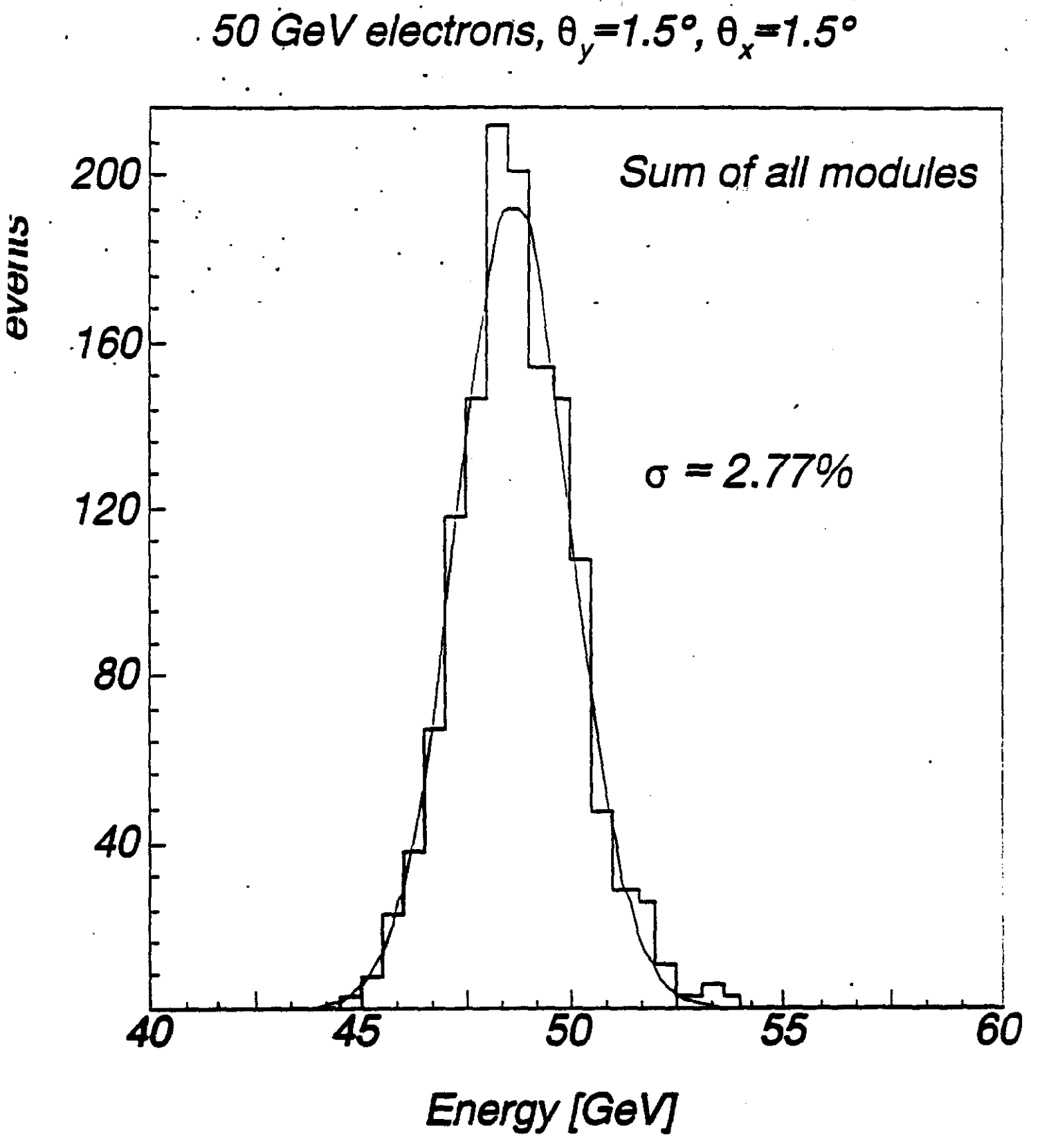


side view

(CURRENTLY) UNDER SAMPLED VOLUME

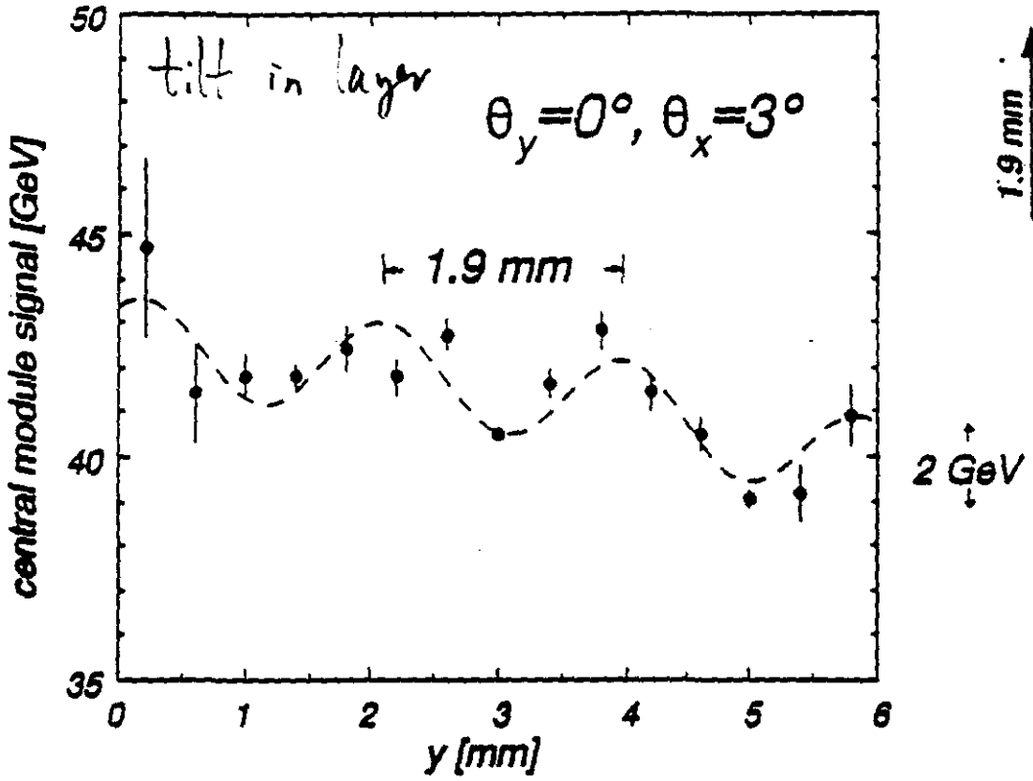
... with fibers turned down at end

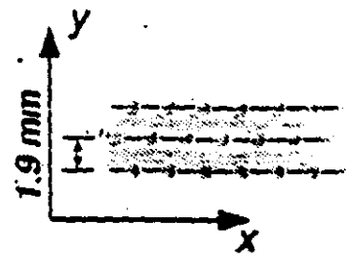
RD =

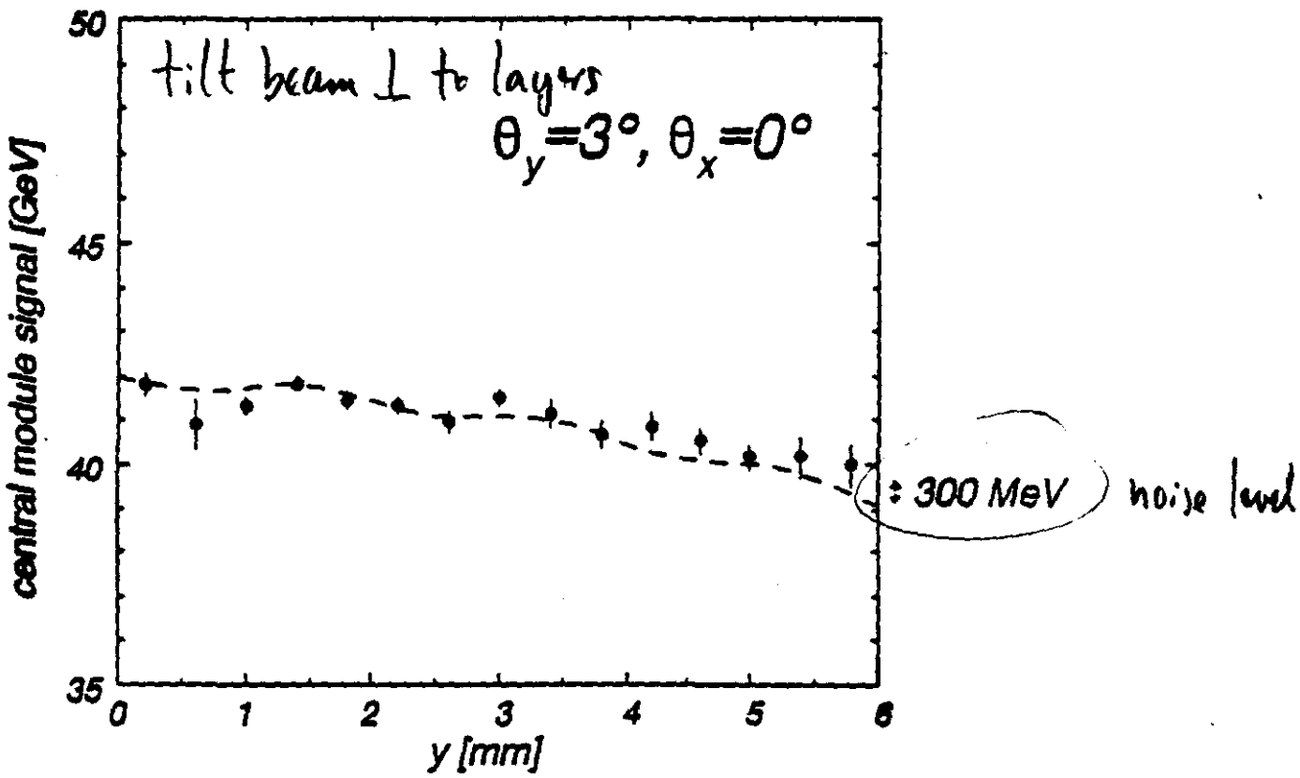

50 GeV electrons, θy=1.5°, θx=1.5°
Sum of all modules
σ = 2.77%
events
200
160
120
80
40
40
45
50
55
60
Energy [GeV]

RD 12

50 GeV electrons







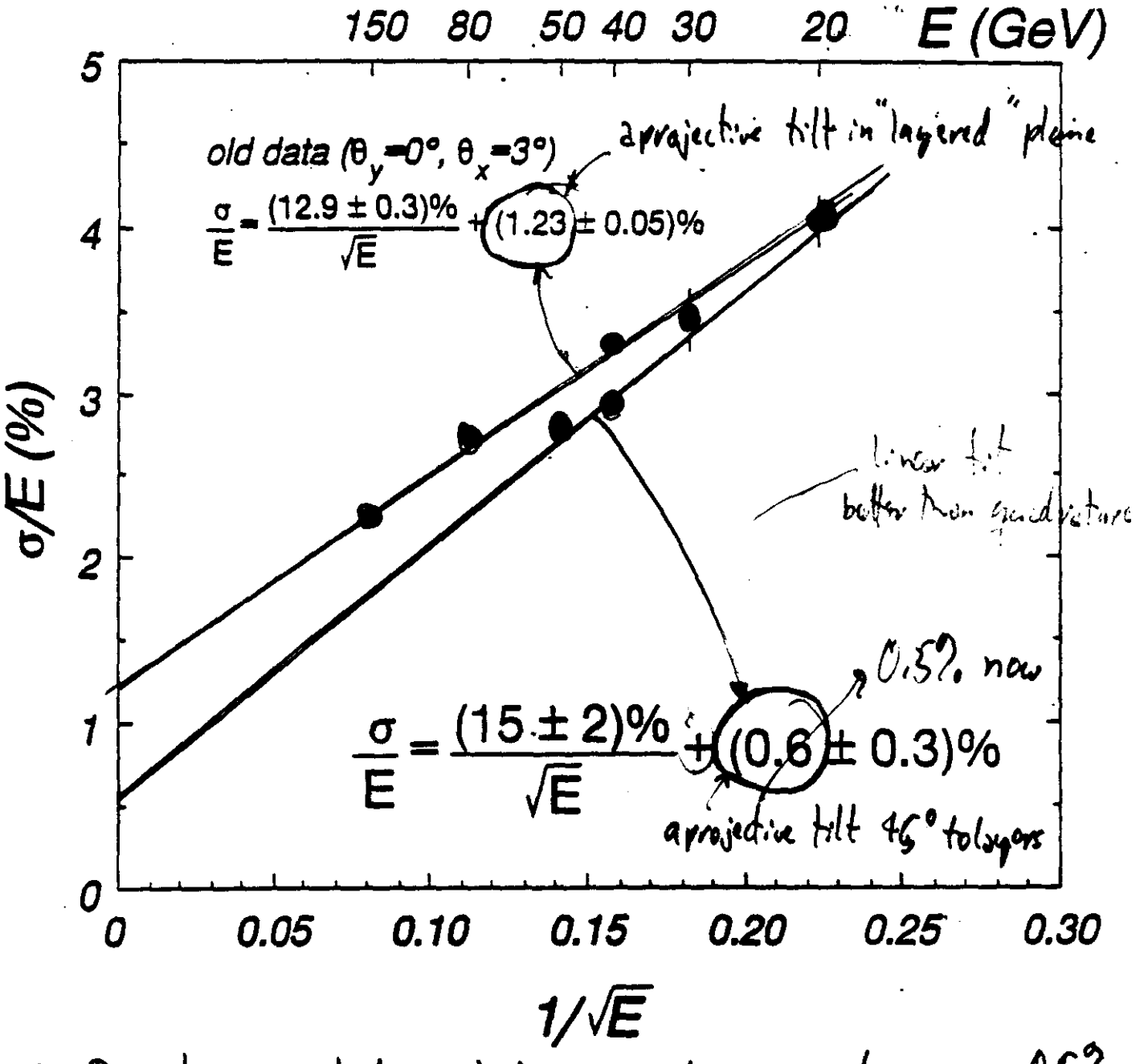
... idea tilt neither

RD16

Evaluation of constant term ...

Energy resolution electrons

$\theta_y = 1.5°, \theta_x = 1.5°$



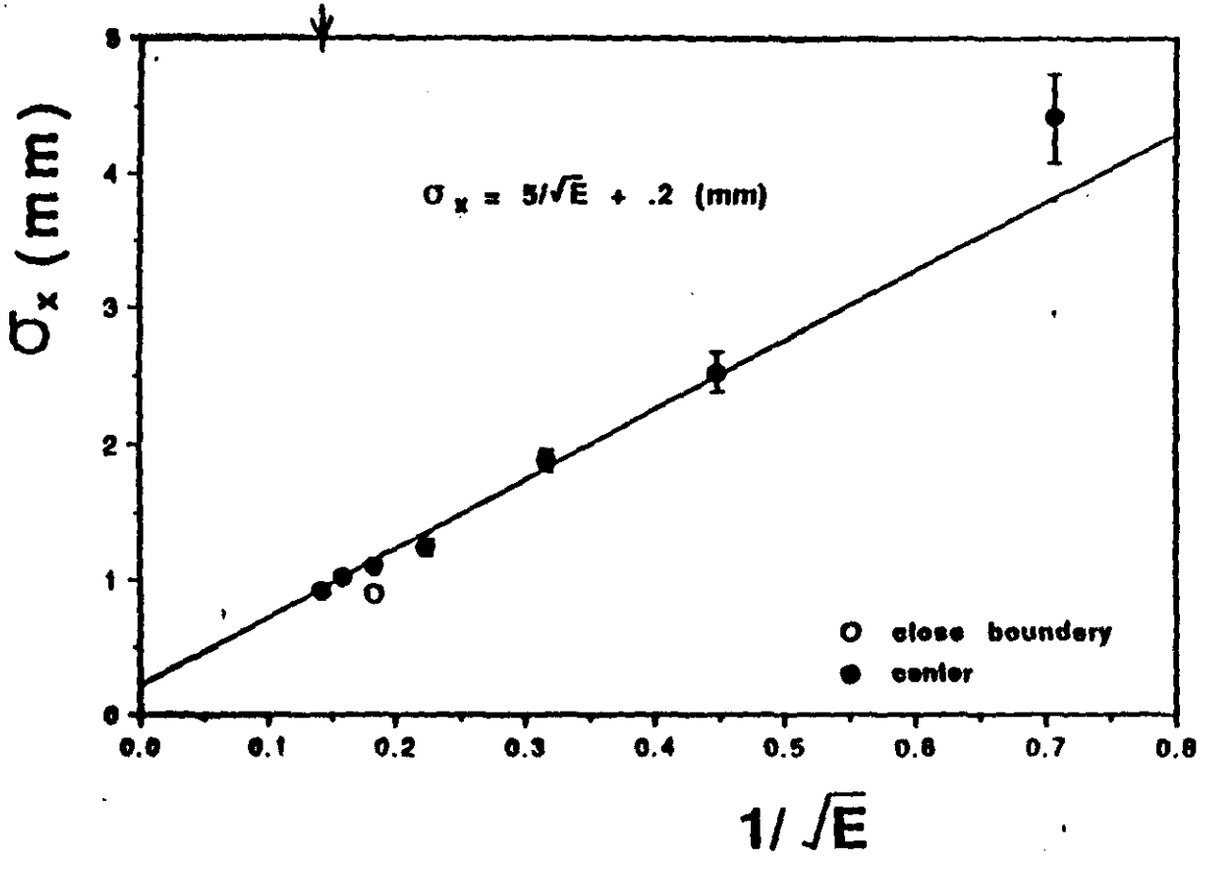
...may 0.6% term includes
1.) beam spread ... correction gives 0.5%
2.) no selection on fibers ... from two beams
3.) idea channeling tilt at 30°
4.) under sampled region

RD 14

POSITION RESOLUTION

RD33

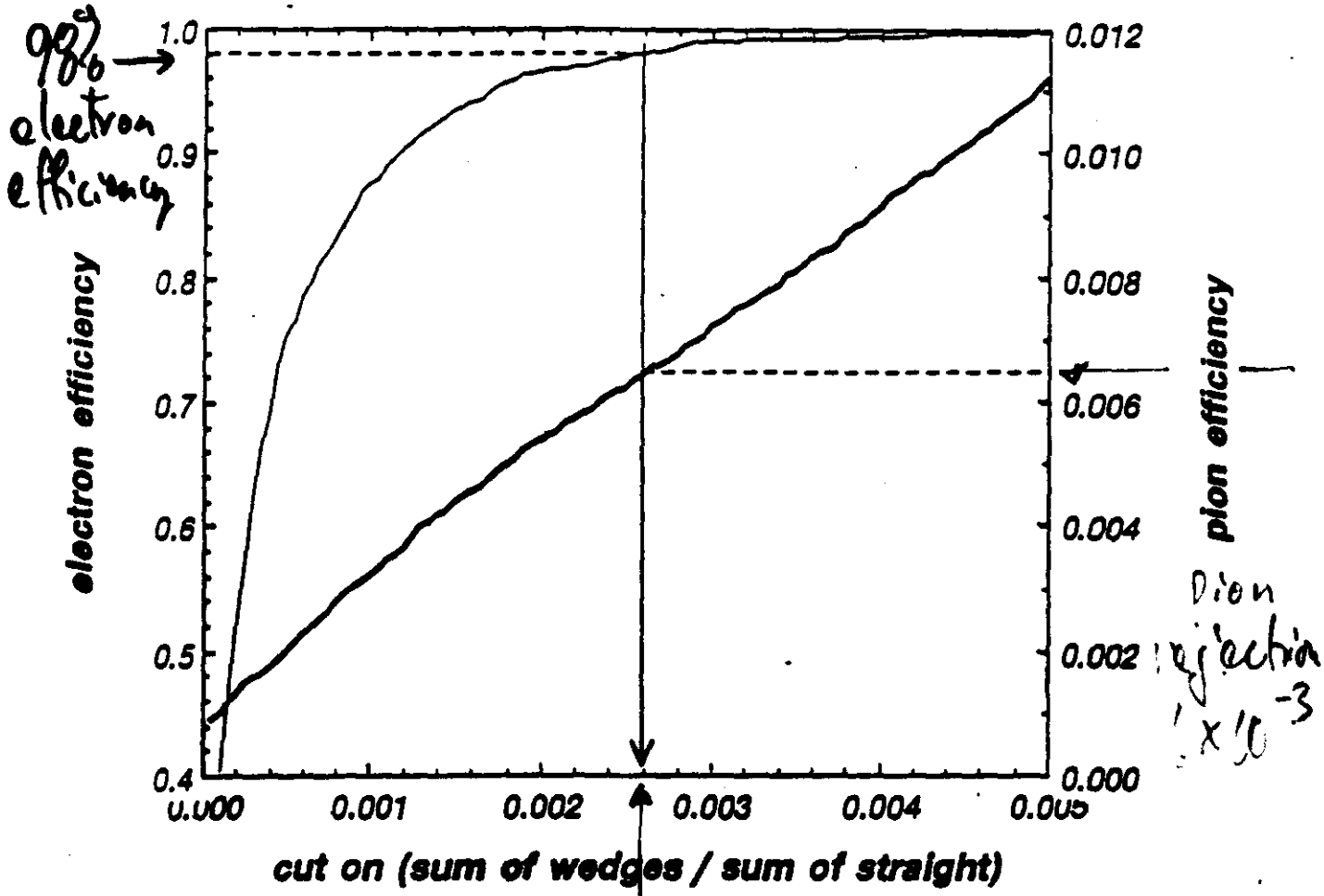
50GeV 0.2 mm @ 50GeV EM center of gravity



$$\sigma_x = \frac{5\,mm}{\sqrt{E}} + 0.2\,mm$$

1) e/π Separation

... compare { hadronic wedge / electromagnetic tower ...



0.25% goes into wedge

2) Muon Sampling ...

for 3° tilt, μ's measured 9 times by crossing straight and wedge towers (~4 times for E/T design) RP 36

Analysis under way

Vasoluo - CERN preprint

CALIBRATION WITH ISOLATED γ's

1.) "γ" ≡ a) no energy > threshold in layer outside 3 (50 MeV)
b) no charged particles entering 3x3
⇒ 1 MHz in total calorimeter

2.) normalize EM modules to ≈1% using $p_\perp^\gamma$

3.) Need 3×10^4 "γ"'s for 1% ... get in ~1/4 hr

but 4.) ~10^2 Hz/tower @ SSC ⇒ dedicated local calibration with 5 Threshold

5.) fit either 1.) 3x3 (97% of energy) but need recursive procedure
2) central tower alone (70% of en

$$\frac{dN}{dp_\perp} = Ae^{k p_\perp^\gamma}, \quad 0.1 < p_\perp^\gamma < 1$$

Calibrate on min bias γ's ... use [illegible] charges veto

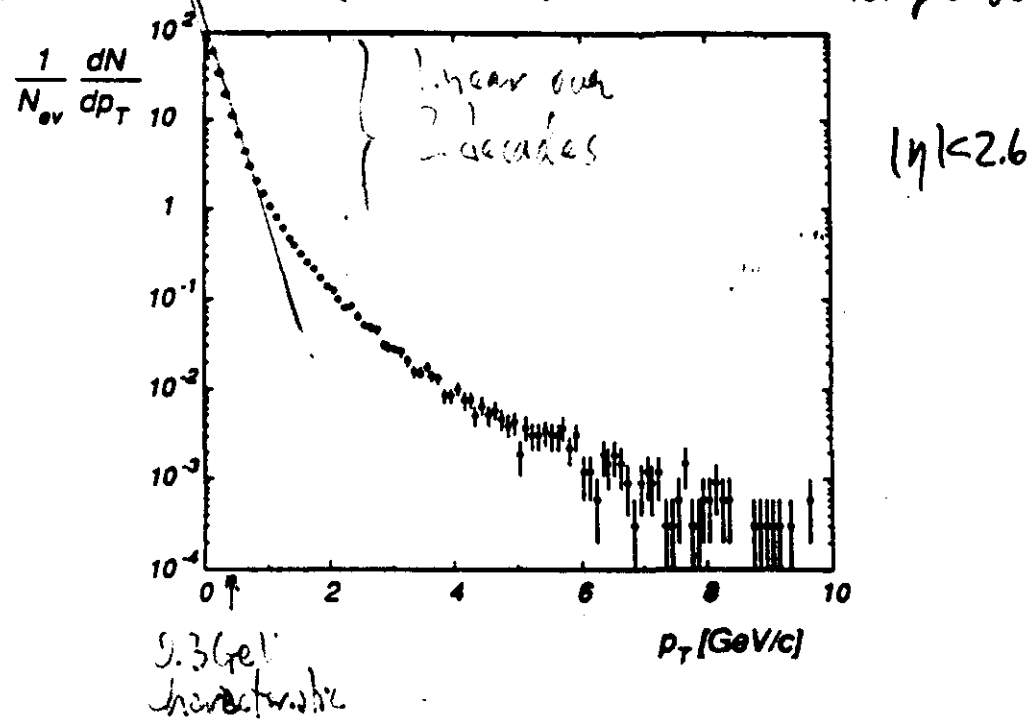
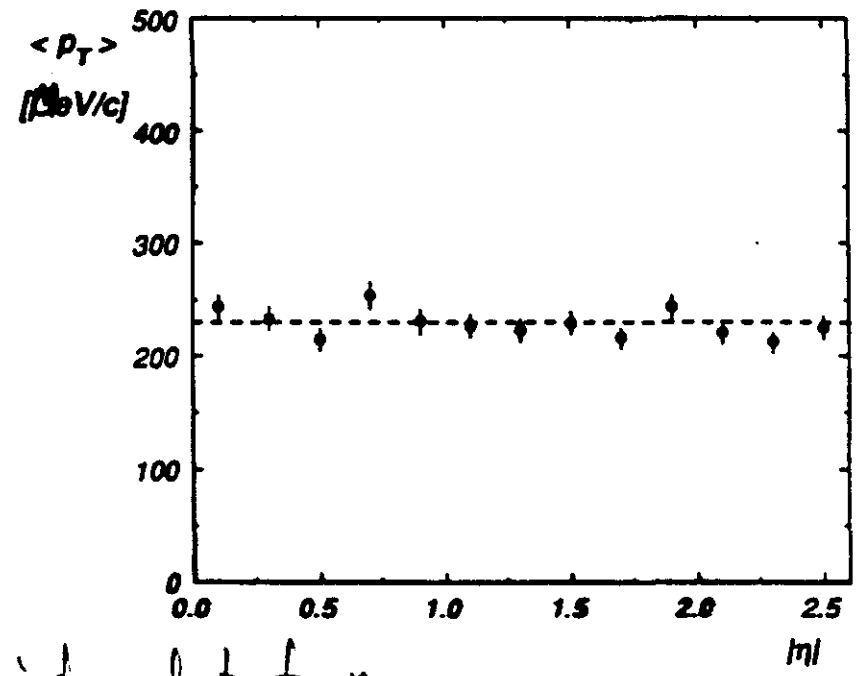


Fig. 1. Transverse momentum distribution of γ's produced in the interval $|\eta| \leq 2.6$.



independent of η

Fig. 2. Average transverse momentum of γ's as function of η.

... use "γ" light as calibration / monitor standard

Muon punch thru after 9.5 λ ...

Y. Wang
EPS/LP'91
SPACAL

Muon Production in Hadronic Shower Development at Spacal

E_π (GeV)	Events	Muons	Acceptance	Muons (corr.)	μ-rate (%)
10	2751	4 ± 1	0.749	5 ± 2	0.18 ± 0.04
20	2352	5 ± 1	0.749	7 ± 2	0.30 ± 0.04
40	2805	10 ± 2	0.749	13 ± 2	0.46 ± 0.11
80	3272	30 ± 6	0.749	40 ± 8	1.22 ± 0.24
150	3255	51 ± 5	0.749	68 ± 7	2.09 ± 0.20

... using a second calorimeter after the firs

For 80 Gev pion Showers

The ' muon ' event distribution clearly exhibits a low energy tail, that is consistent with an exponentially falling E_{miss} distribution.

Average value of E_{miss} :	5.2 ± 0.6 Gev
Average value of E_ν (for K-decay):	3.2 Gev
Energy of escaping muon (for k-decy) :	2.0 Gev
Average value of E_ν (for π-decay):	1.5 Gev
Energy of escaping muon (π-decay) :	3.7 Gev

So the muons produced in the hadronic shower development and escaping the 9.5 λ_I deep spaghetti calorimeter had an average momentum of

$\langle E_\mu \rangle$ = 2.8 ± 0.9 Gev/c for 80 GeV π's

Higgs searches, Colly Bunzst, EPS/LP'91

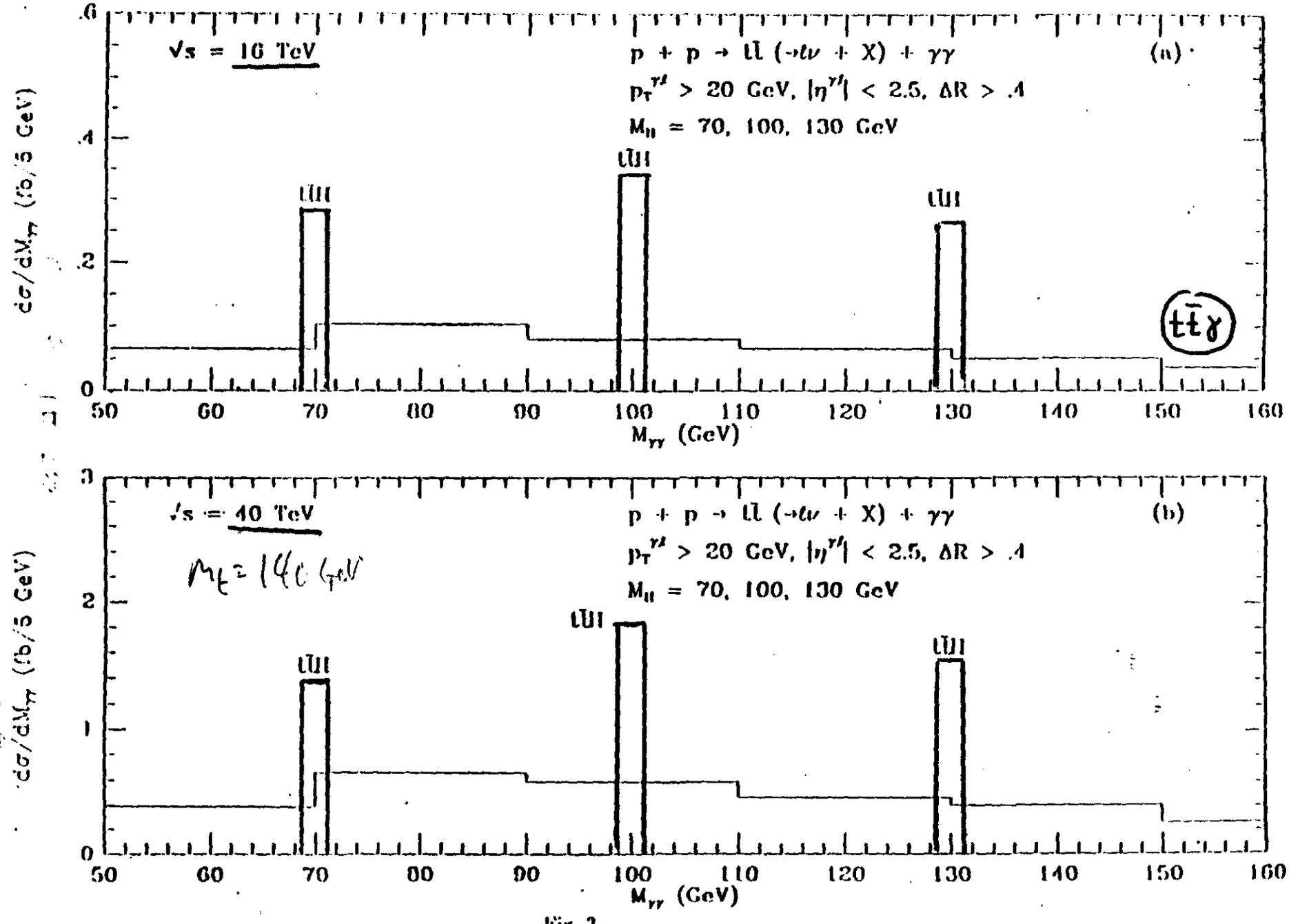


Fig. 3

L. Sulak

$t\bar{t}H \to \gamma\gamma$

Z. Trócsányi
W. J. Stirling
Z. Kunszt

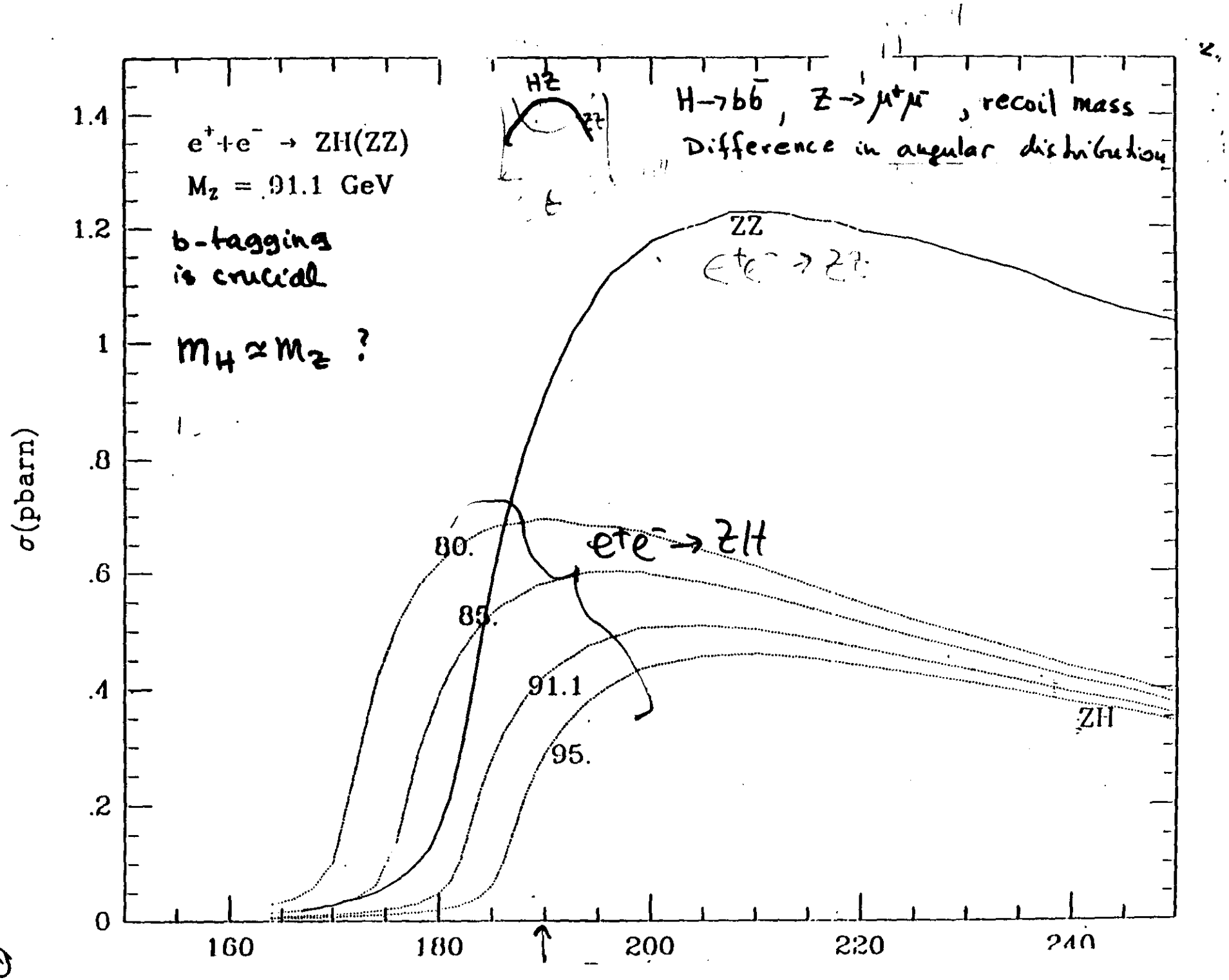
$m_{t_{top}} = 140\,GeV$

Table 1: Event numbers of signals for Higgs boson production and that of the most important background processes. The background yields are computed assuming 3% mass resolution. The cuts are the same as specified in the figures. The numbers reflect 10^5pbarn^{-1} integrated luminosity at LHC and 10^4pbarn^{-1} integrated luminosity at SSC energies.

CM energy (TeV)	M_H (GeV)	Signal (# of events)			Background (# of events/Δm)					
		WH	$t\bar{t}H$	total	Δm ($\frac{GeV}{c^2}$)	$W\gamma\gamma$	$t\bar{t}\gamma\gamma$	$b\bar{b}\gamma\gamma$	$b\bar{b}\gamma$	total
~~SSC~~ 16 (LHC)	70	26	28	54	2.1	8.4	4.3	4.3	0.45	17
	80	30	32	62	2.4	8.4	5.0	4.4	0.48	18
	90	32	35	67	2.7	8.3	4.3	4.3	0.51	17
	100	33	35	68	3.0	7.6	4.8	4.0	0.53	17
	110	31	33	64	3.3	6.6	4.4	3.6	0.53	15
	120	28	30	58	3.6	6.0	4.8	3.1	0.52	14
	130	23	25	48	3.9	6.2	4.0	2.6	0.48	13
	140	18	19	37	4.2	3.6	4.3	2.5	0.42	13
	150	12	12	24	4.5	4.5	5.1	3.3	0.32	13
~~LHC~~ 40 (SSC)	70	5.1	15	20	2.1	1.6	2.8	1.8	0.15	6.4
	80	5.9	17	23	2.4	1.5	3.2	1.7	0.16	6.6
	90	6.3	18	24	2.7	1.6	3.2	1.7	0.17	6.7
	100	6.5	19	26	3.0	1.3	3.2	1.6	0.17	6.3
	110	6.2	18	24	3.3	1.1	3.1	1.4	0.16	5.8
	120	5.6	17	23	3.6	1.1	3.4	1.3	0.15	6.0
	130	4.7	15	20	3.9	1.2	3.2	1.3	0.13	5.8
	140	3.7	12	16	4.2	0.9	3.4	1.4	0.13	5.8
	150	2.5	8	11	4.5	0.9	2.3	1.2	0.13	4.5

($m_t = 140$; $m_t = 100$)

m_{Higgs} # events/year # bkgnd/year


$e^+ + e^- \to ZH(ZZ)$
$M_Z = 91.1$ GeV
b-tagging is crucial
$m_H \simeq m_Z$?
$H\to b\bar{b}$, $Z\to\mu^+\mu^-$, recoil mass
Difference in angular distribution
$e^+e^- \to ZZ$
$e^+e^- \to ZH$
ZZ
ZH
80.
85.
91.1
95.
σ(pbarn)
1.4
1.2
1
.8
.6
.4
.2
0
160
180
200
220
240

NEWMAN

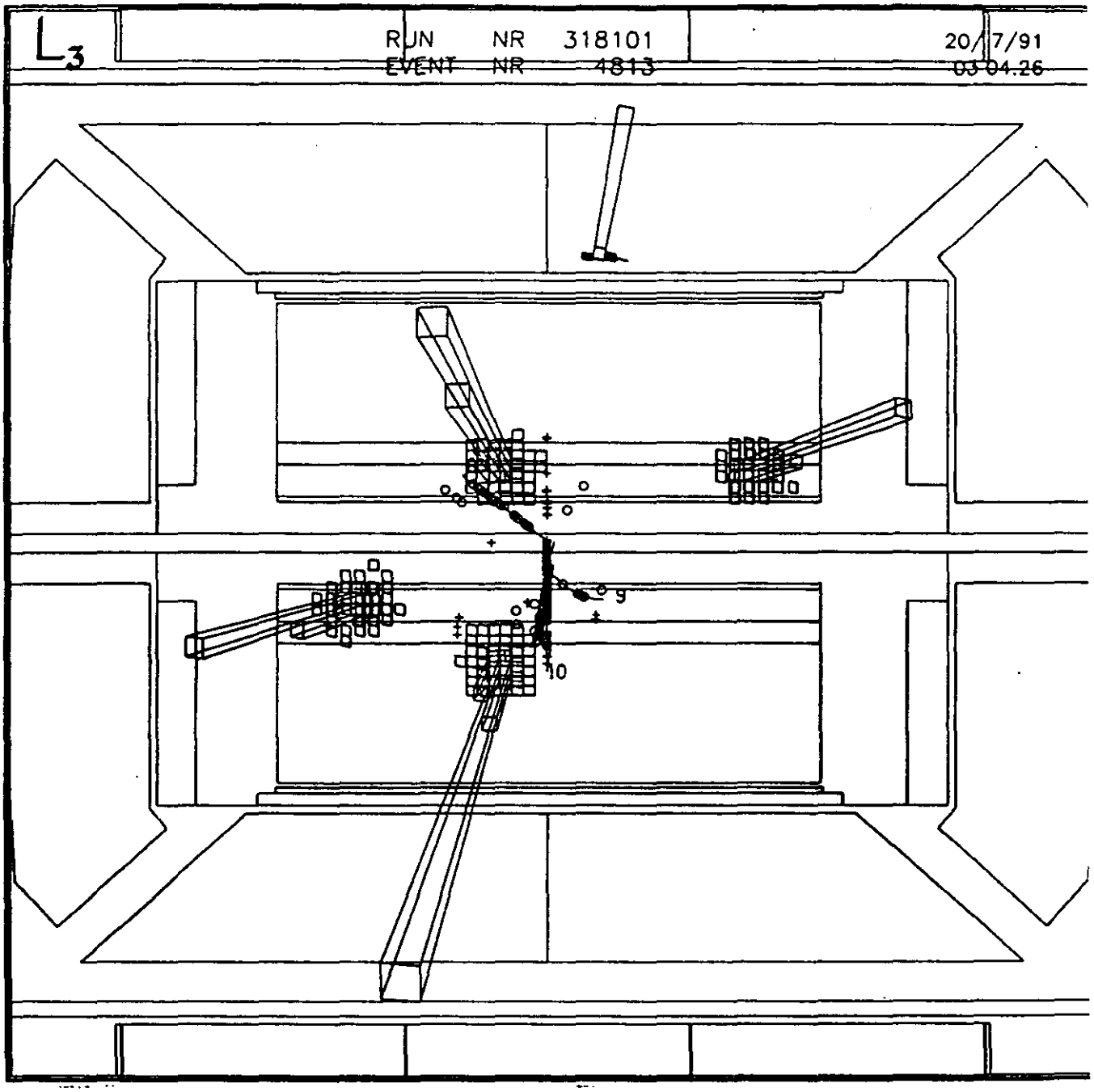
PHYSICS of ELECTRONS and PHOTONS At The TeV SCALE

ISOLATE NEW PHYSICS SIGNALS

from "Standard" Physics Backgrounds

- **Cleanly Separate Leptons and Photons from Jets and Single Hadrons.**
- **Reconstruct Multilepton, Multiphoton, and Lepton-Photon Invariant Masses Precisely**

Run # 318101 Event # 4813 Total Energy : 88.32 GeV

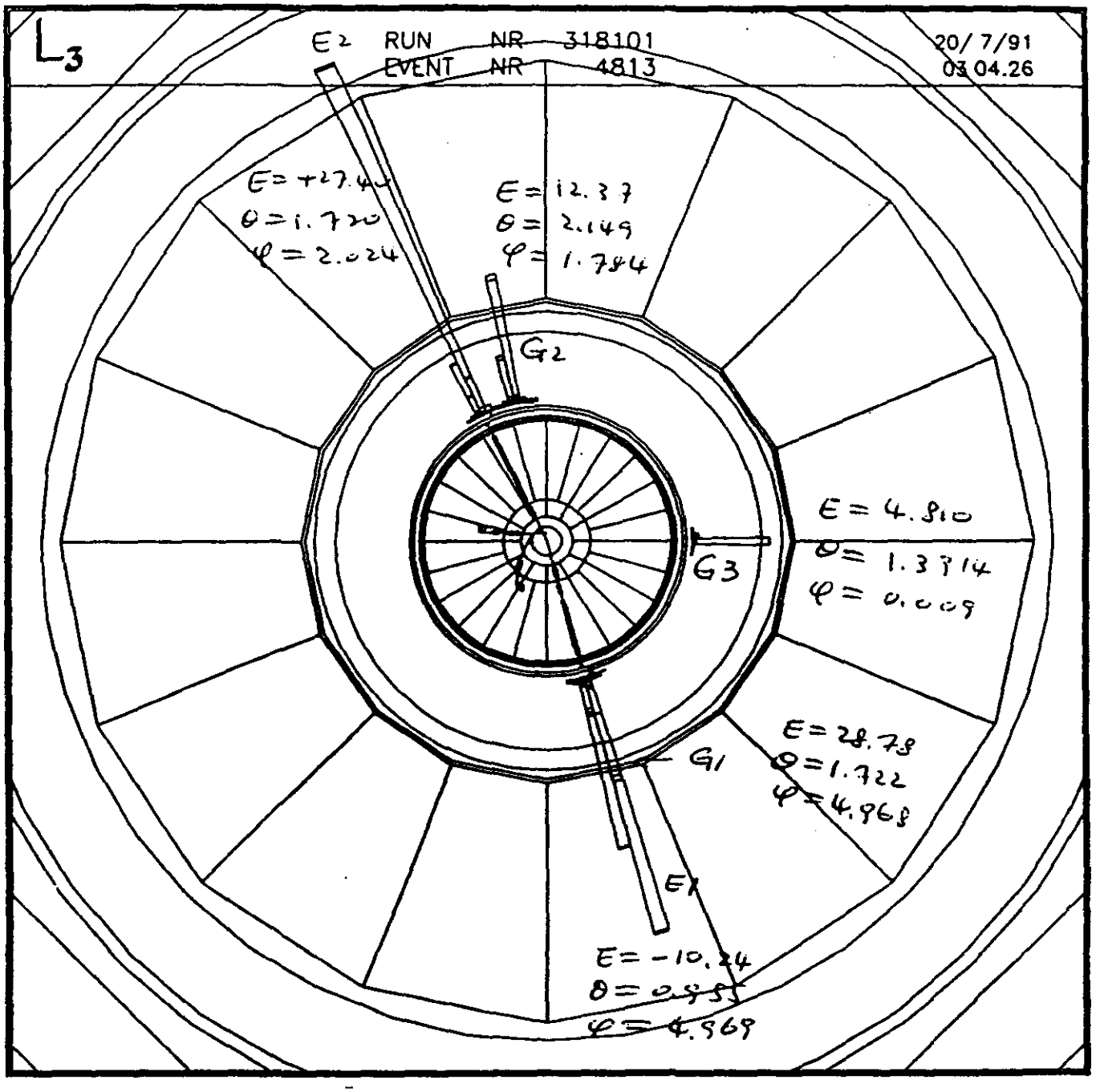


Transverse Imbalance :	94.05 GeV		**Longitudinal Imbalance :**	0.01 GeV	
Thrust : -.0965		**Major :** 0.9182		**Minor :** 0.2396	
Printed Date :	*Saturday, July 27, 1991 15:17:28*				

$M(G1, G2) = \cancel{4.5}\ 35.26$ $M(G1, G3) = 14.78$ $M(G2, G3) = 12.27$

Run # 318101 Event # 4813 Total Energy : 88.32 GeV

$E_{mis} = 7.59$ $P_{mis} = 8.46$ $\theta_{mis} = 0.127$

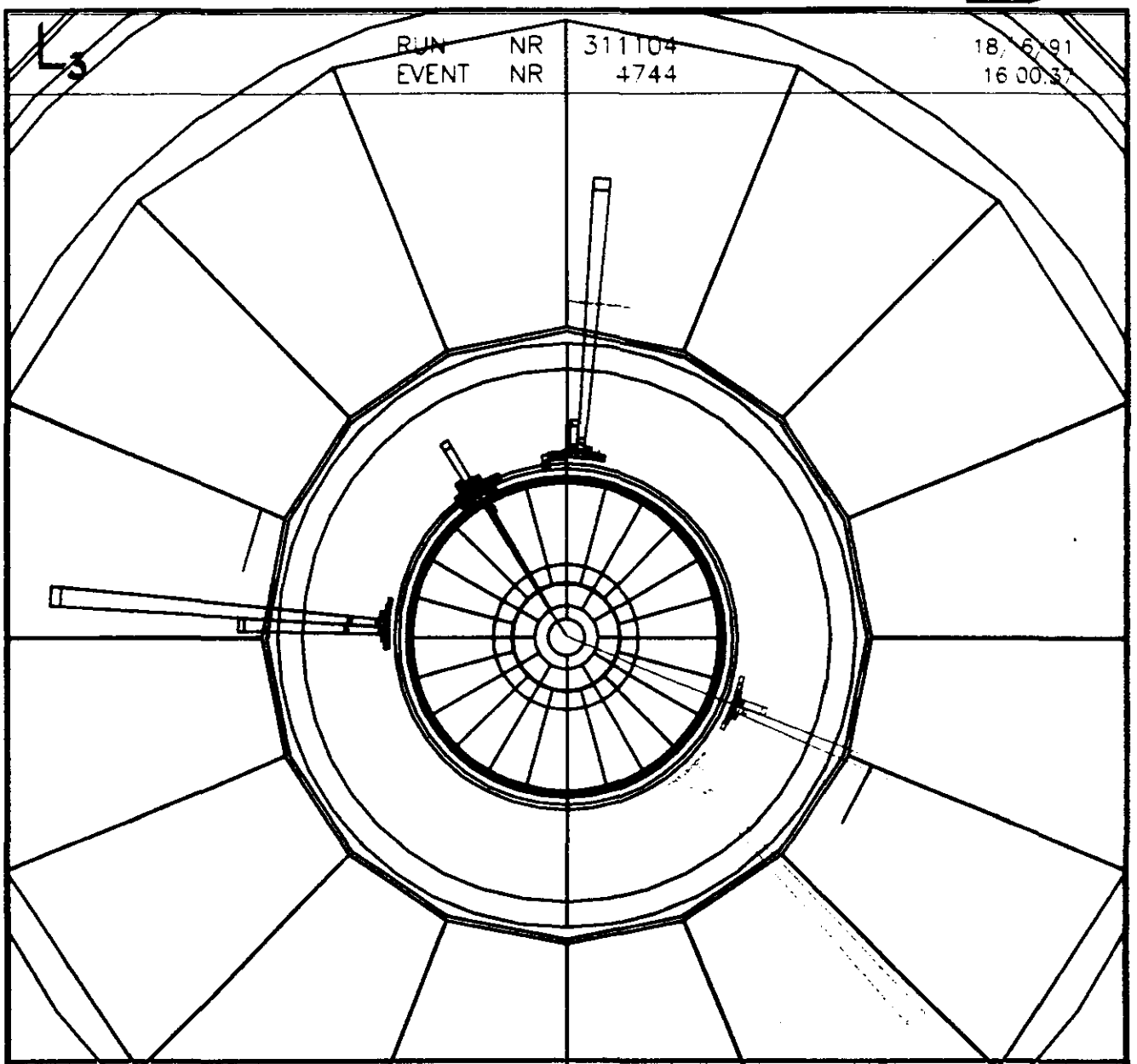


Transverse Imbalance :	**94.05 GeV**	**Longitudinal Imbalance :**	**0.01 GeV**
Thrust : -.0965	**Major :** 0.9182	**Minor :** 0.2396	
Printed Date :	*Saturday, July 27, 1991 15:19:29*		

$M(G1, G2, G3) = 40.15$ $M(E1, E2) = 32.46$

$M_{iss}(G1, G2, G3) = 38.31$ $M_{iss}(E1, E2) = 50.06$

Run # 311104 Event # 4744 Total Energy : 105.18 GeV

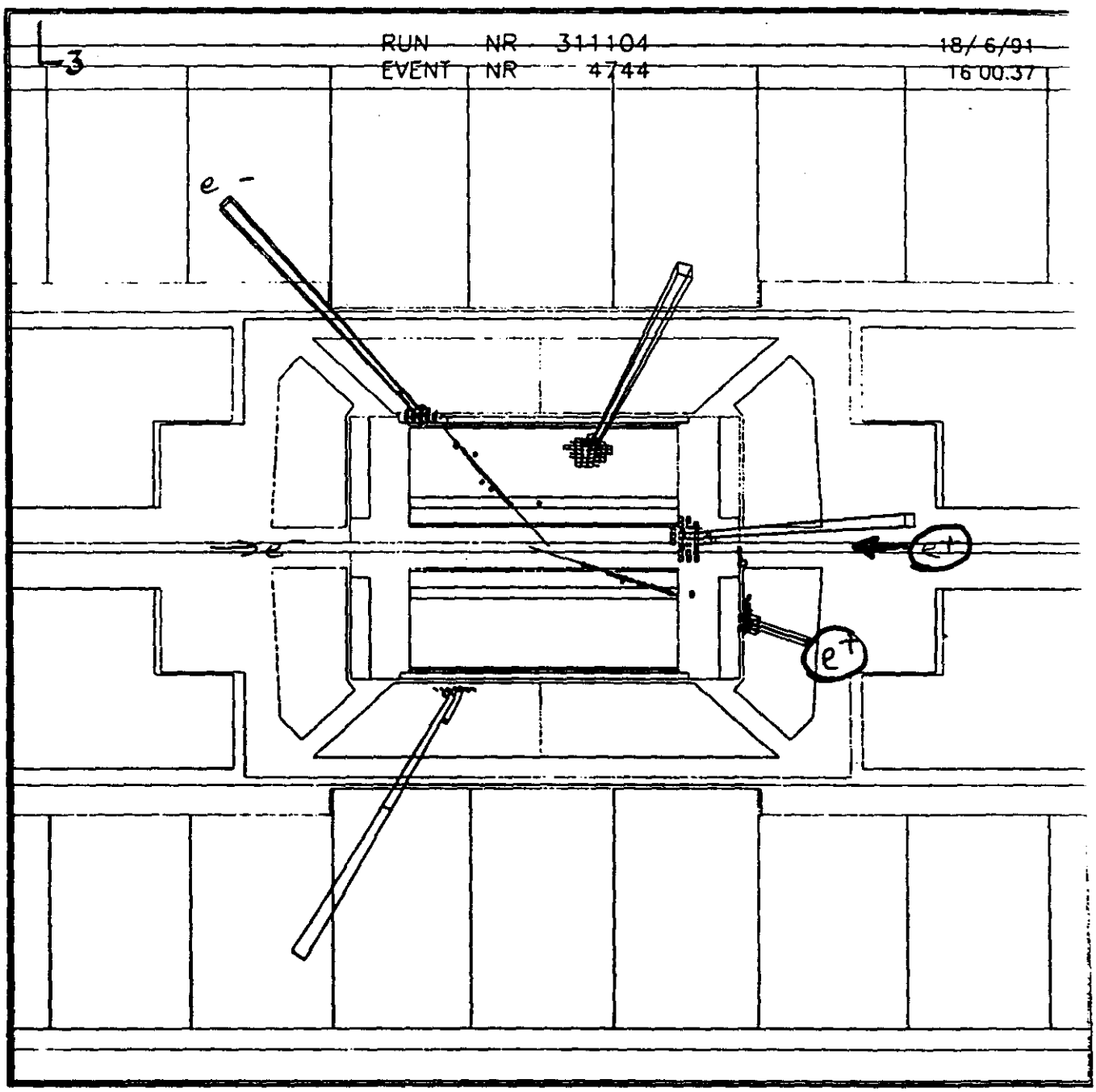


Transverse Imbalance :	97.77 GeV	**Longitudinal Imbalance :**	0.04 GeV

Thrust : -.0323	**Major :** 0.5993	**Minor :** 0.5846

Printed Date : *Friday, June 28, 1991 17:23:18*

Run # 311104 Event # 4744 Total Energy : 97.68 GeV



Transverse Imbalance :	0.03 GeV	**Longitudinal Imbalance :**	0.01 GeV
Thrust : 0.6932	**Major :** 0.5962	**Minor :** 0.3037	
Printed Date :	*Sunday, June 23, 1991 17:34: 2*		

$\mu^+\mu^-\gamma\gamma$ Events in L3

(WITH BGO ENDCAPS in '91)

→ 2 in 220 K Hadrons

→ $m_{\gamma\gamma}$ = 58.8 GeV; 58.9 GeV
$\sigma \sim 0.6$ GeV

- MC Study $E_{\gamma_1}, E_{\gamma_2} > 1$ GeV
  Isolation Cut $> 5^\circ$

- YFS (3.02) (JADACH & WARD): Prelim.
  Predict 19.3 Events
  See 19 Events
  } $M_{\gamma\gamma}^{MAX} < 25$ GeV

- $P_1(M_{\gamma\gamma} > 50) = 1\%$ Expect (0.15 ev)
  $P_2(M_{\gamma\gamma} > 40) = 5.6\%$ Expect (0.38 ev)

- Expectation: 0.035 events Per 1 GeV Bin

- STRANGE: NOTHING in $ee\gamma\gamma$ channels
  $q\bar{q}\gamma\gamma$

- But if get 3rd & 4th events:
  EFFECT ESTABLISHED

- $m_{\gamma\gamma}$ Crucial

from Prince Cushman with child @ home...

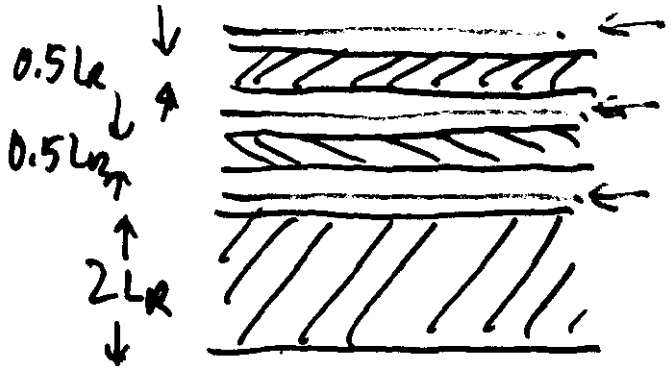
SULAK

FIBER PRERADIATOR FOR GEM

L. Sulak / GEM 8/9/91

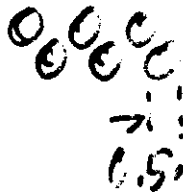
1.) EGS/GEANT MC
2.) reconstruction routine to get π^0/γ rejection & γ efficiency

} check: final e test beam data of last year



each 2Z, 2U, 2V

@ 3" shec



0.5mm

loose packed ribbon

central tracker rejects charged particle

$\sigma = 430\mu$ on 50GeV shower

@ $2L_R$ $\sigma = 150\mu$ on min ionizing particle

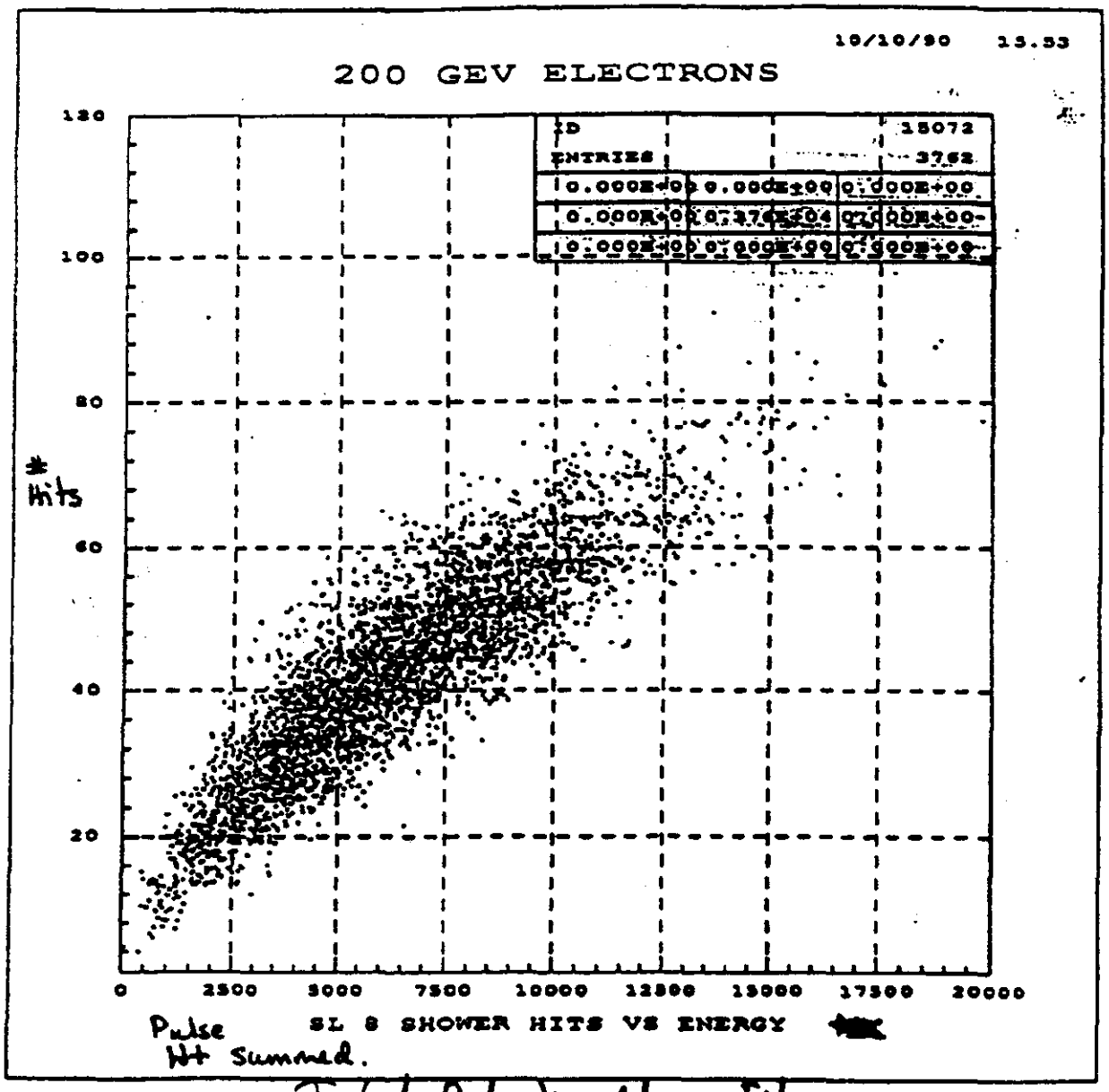
$3L_R$ total optimum

correction to $7\%/\sqrt{E}$ + 0.5% device gives no effect

using either 1.) # fibers hit (as long as ½ mm)
2.) flash ADC (on board pixel table) for each fiber

She will be here Sept. 4

NAL e^- test beam data prototype preradiator: Cushman (4)



Total Pulse Height in fibers
500μ fibers.

Shows correlation between shower energy and number of hits for one super layer at 1.75 X_0 of Pb

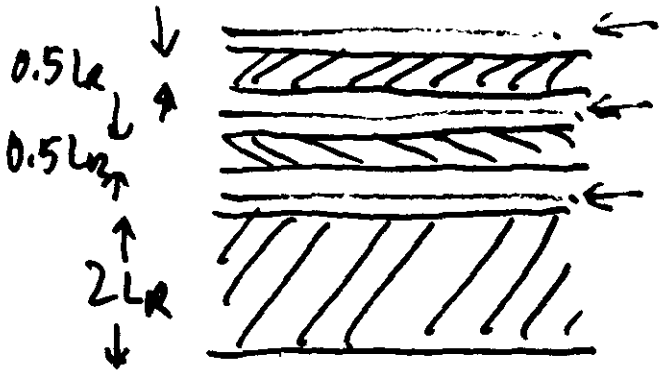
from Prince Cushman with child @ home...

FIBER PRERADIATOR FOR GEM

L. Sulak/GEM 8/9/91

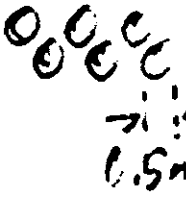
1.) EGS/GEANT MC
2.) reconstruction routine to get π^0/γ rejection & γ efficiency

} check: FNAL e test beam data of last year



each
2Z, 2U, 2V
@ 3° stereo

central tracker
rejects charged particle



loose packed ribbon

$\sigma = 430\mu$ on 50GeV shower

@ $2L_R$ $\sigma = 150\mu$ on min ionizing particle

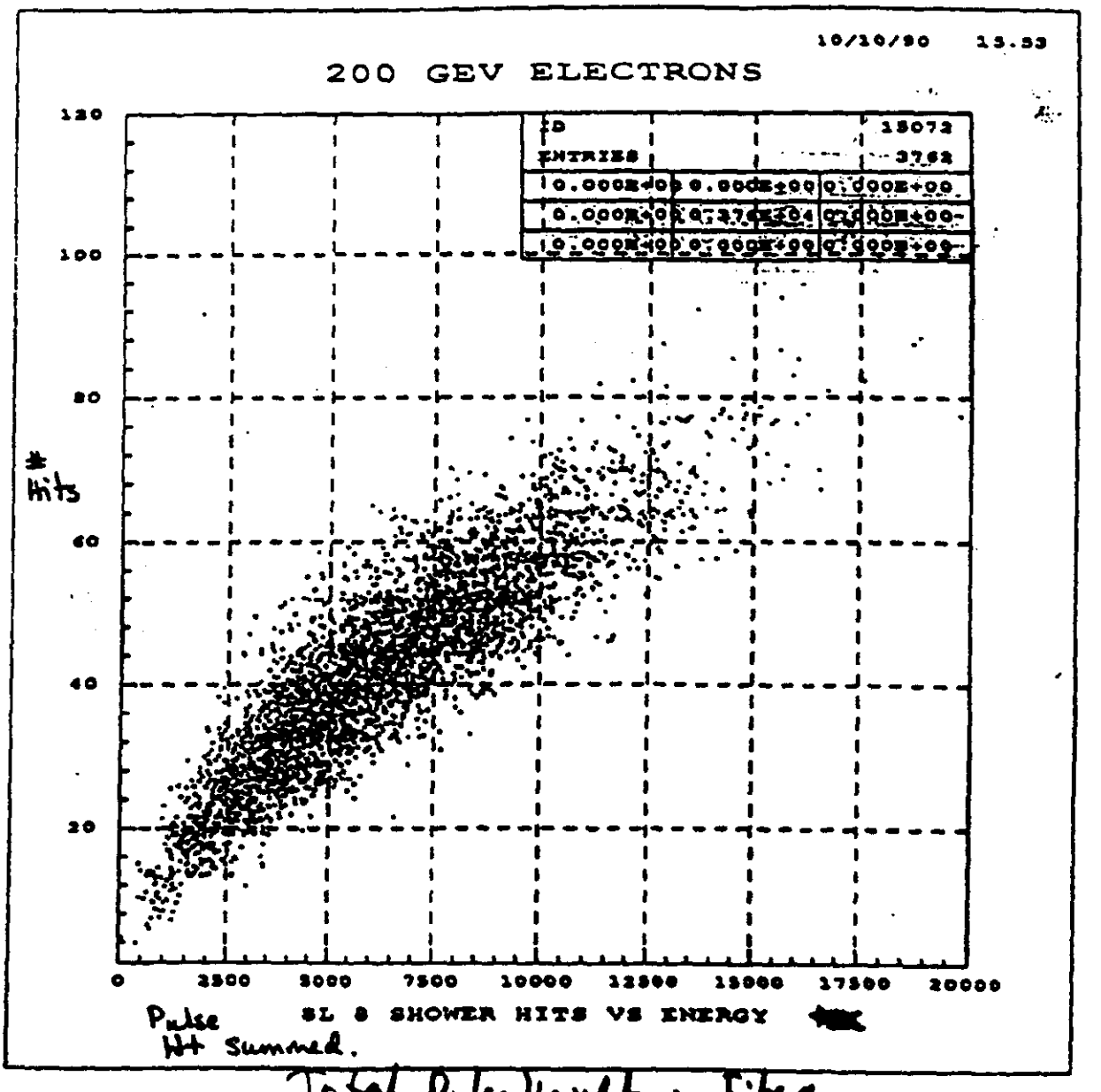
$3L_R$ total optimum

correction to $7\%/\sqrt{E} + 0.5\%$ device gives no effect

using either
1.) # fibers hit (as long as 1/2 mm)
2.) flash ADC (on board pixel table) for each fiber

She will be here Sept. 4

WAL e^- test beam tale prototype preradiator: Cudeman (5)



fiber hits

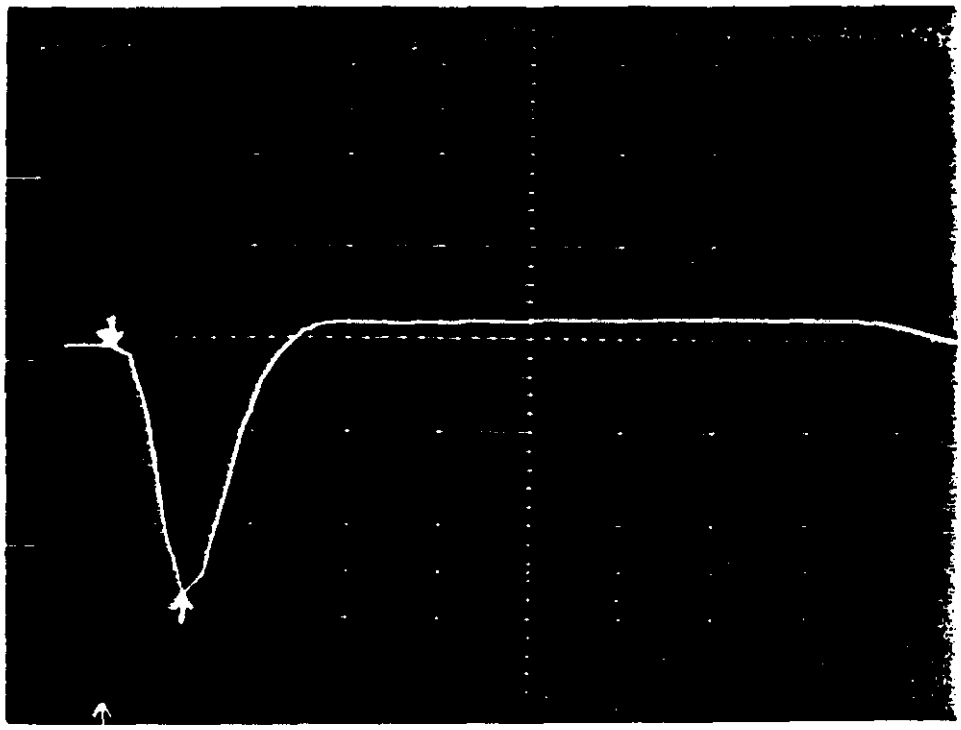
Total Pulse Height in Fibers
500μ fibers.

Shows correlation between
Shower energy and number of hits
for one super layer at 1.75 X_0 of Pb

** TOTAL PAGE.005 **

Accordion Waveforms 1991 Data

GORDON



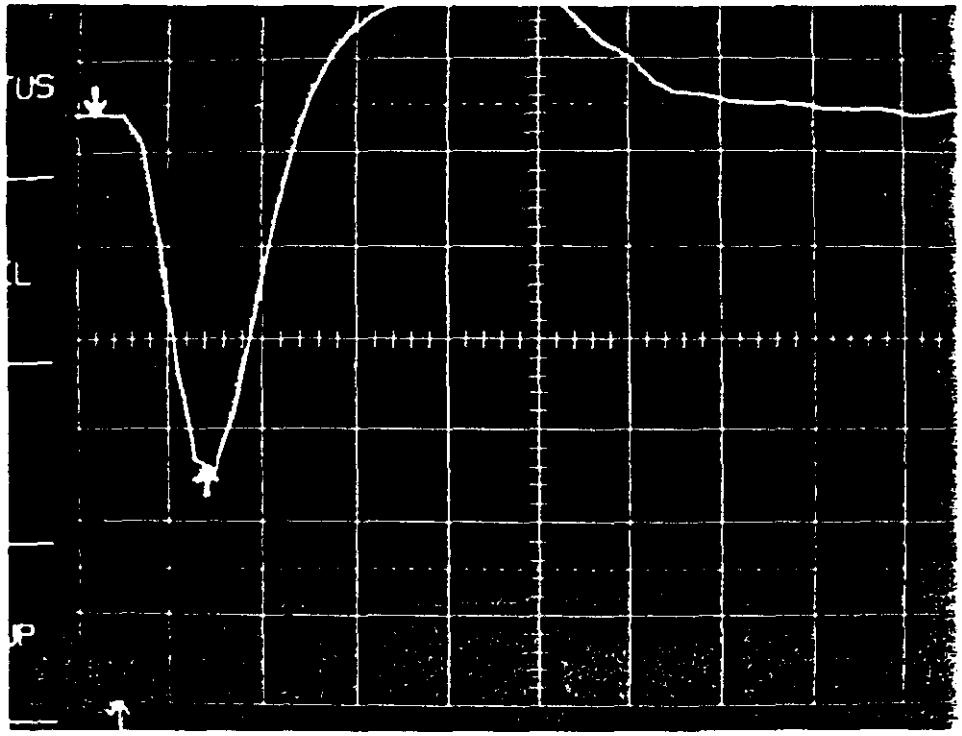
60GeV

2mm ga

tp = 20u

single trace

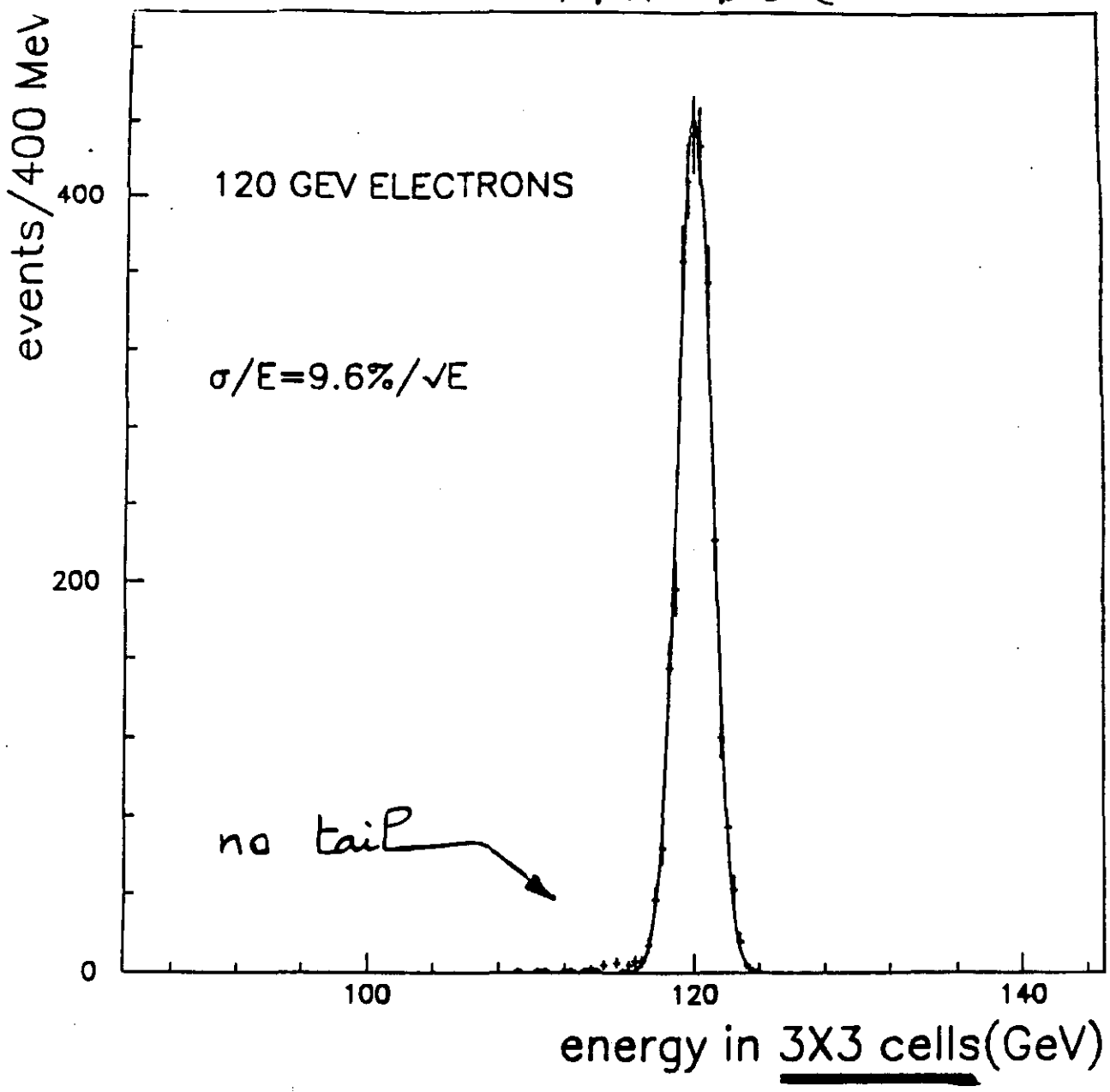
50nsec



Preshower

1mm ga

1171 Data



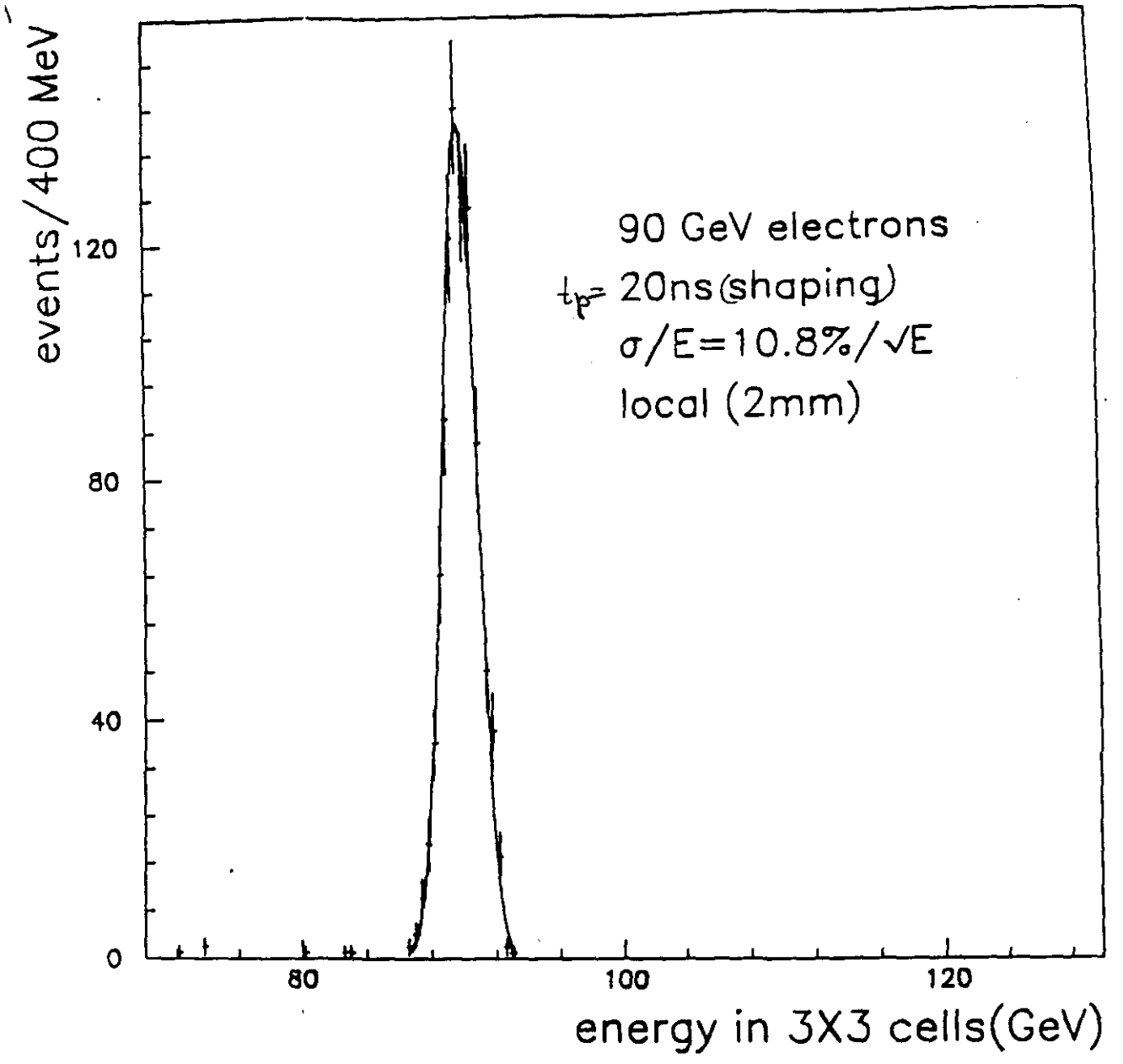
beam in 1 cell

$\frac{\sigma}{E} = 0.88\ \%$ at 120 GeV

$t_p = 100\,\mu sec$

-91

1991 Data



90 GeV

$$\begin{cases} \dfrac{\sigma(E)}{E} = 1.14\ \% \\[2ex] \sigma(x) \simeq 450\ \mu \end{cases}$$

1.026 GeV

CALORIMETRY

ORNL

Costing Perspective

$ Cost Estimate Quality Is Directly Proportional To Design Quality.

$ Detailed Designs (Concepts?) Do Not Exist For GEM Calorimeters

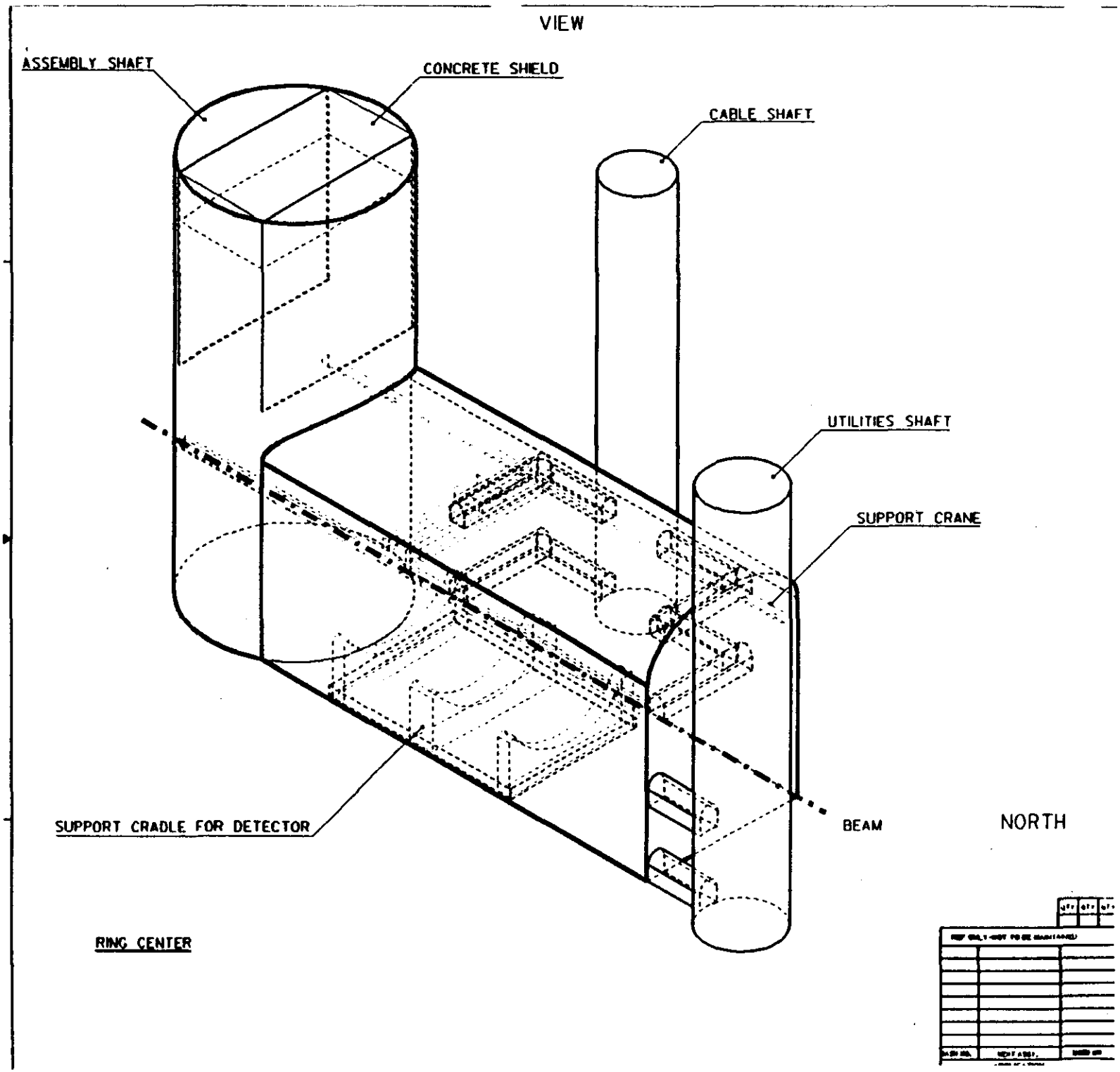
Therefore

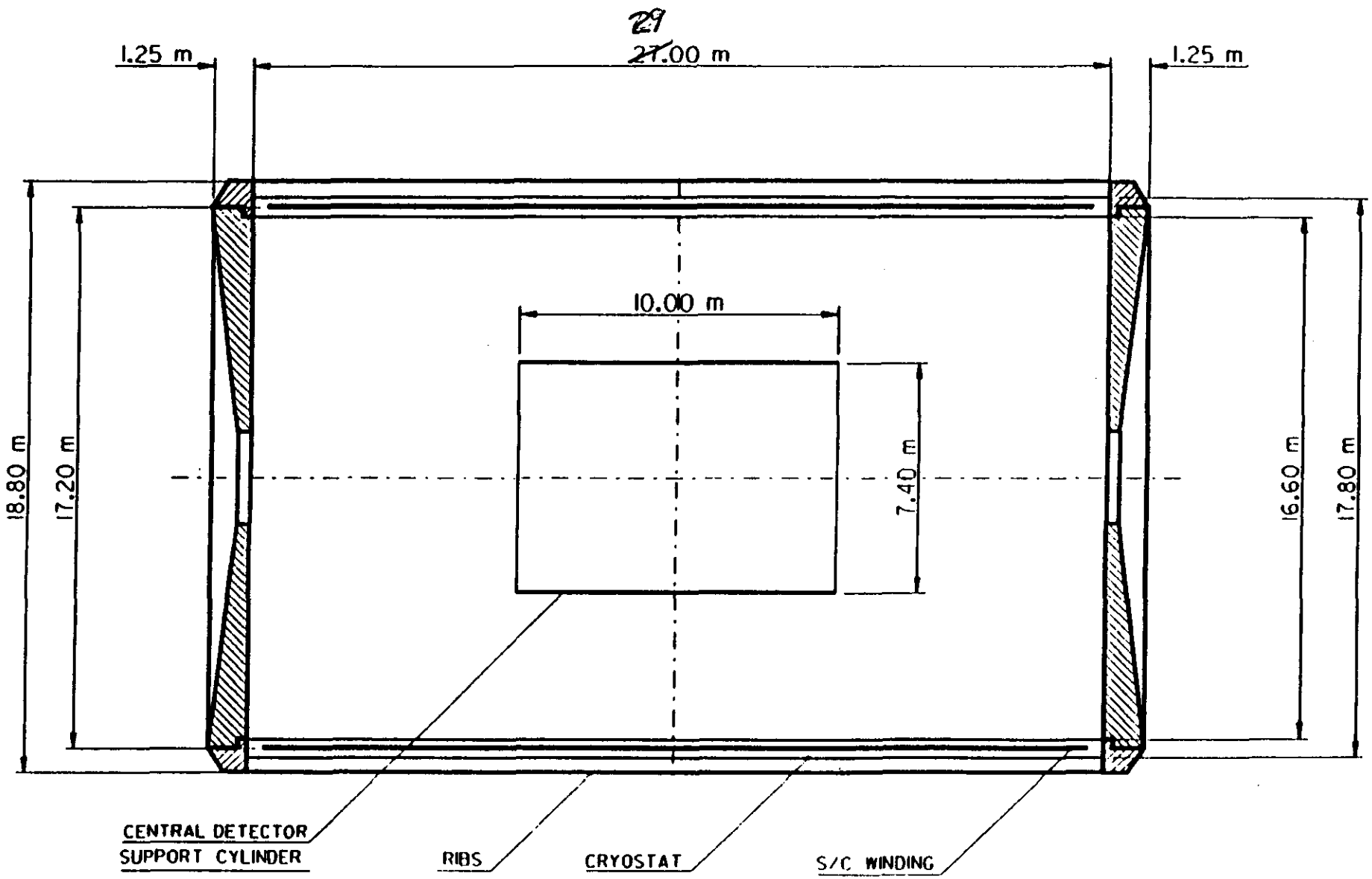
$ Costing Must Be Based On:

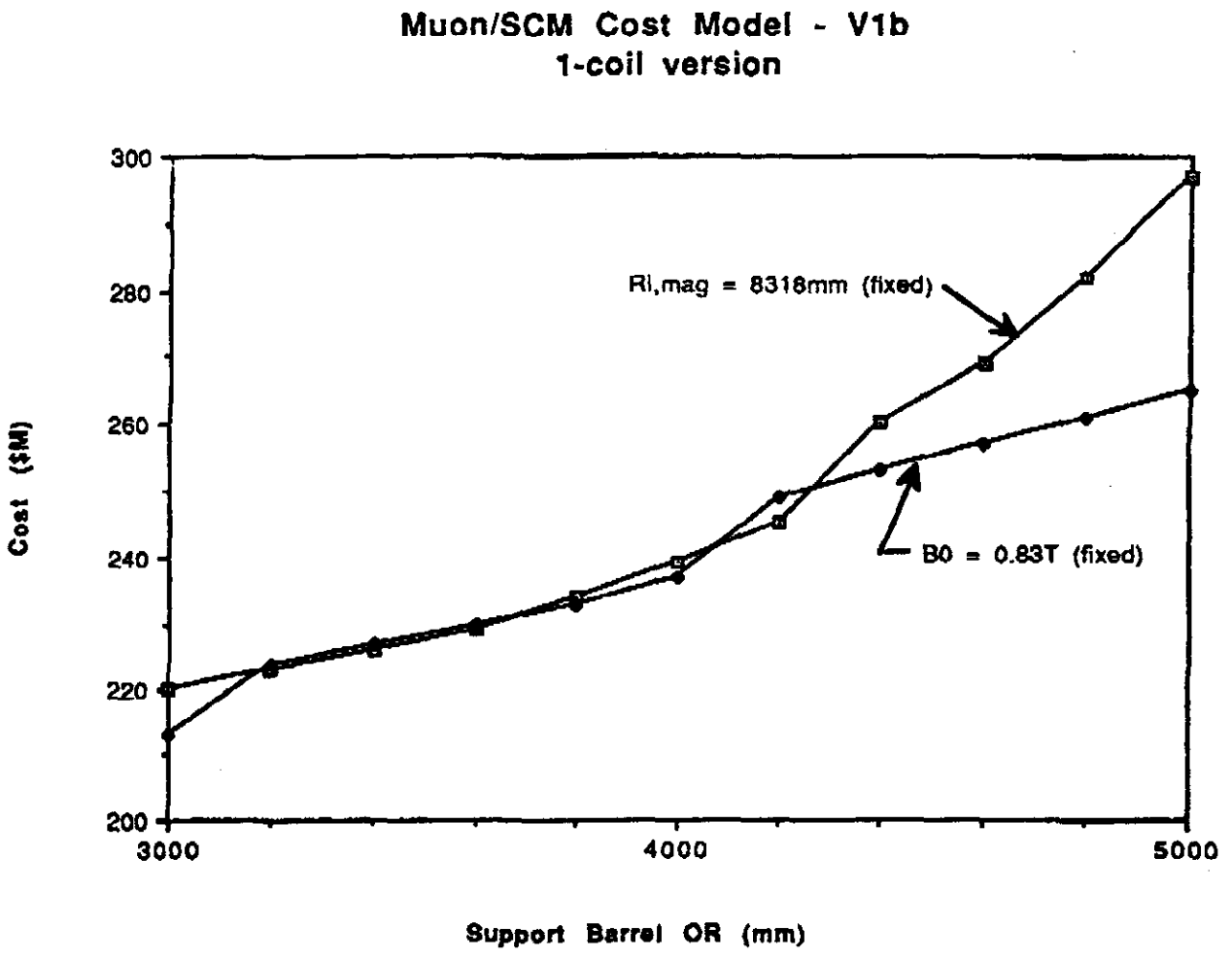
A) Vendor Estimates For Known Items (ie PMT's)

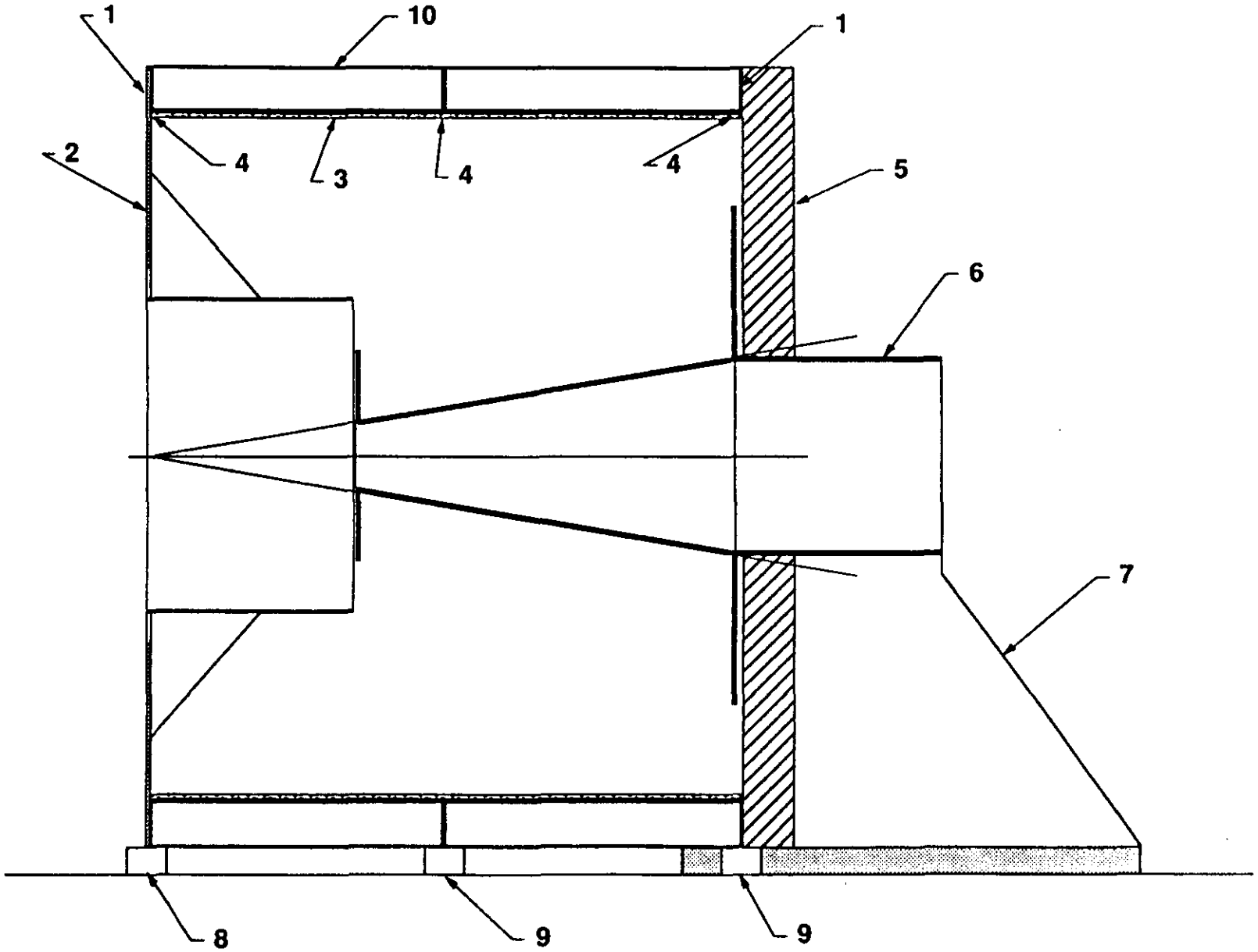
B) Enlightened Approximation For Unknown Items (ie Ass. And Test)

$ Theriot Numbers Must Be The Basis Of All Approximations


VIEW
ASSEMBLY SHAFT
CONCRETE SHIELD
CABLE SHAFT
UTILITIES SHAFT
SUPPORT CRANE
SUPPORT CRADLE FOR DETECTOR
BEAM
NORTH
RING CENTER


29
1.25 m
27.00 m
1.25 m
10.00 m
18.80 m
17.20 m
7.40 m
16.60 m
17.80 m
CENTRAL DETECTOR
SUPPORT CYLINDER
RIBS
CRYOSTAT
S/C WINDING


Muon/SCM Cost Model - V1b
1-coil version
Ri,mag = 8318mm (fixed)
B0 = 0.83T (fixed)
Cost ($M)
300
280
260
240
220
200
3000
4000
5000
Support Barrel OR (mm)



Magnet/ Muon/Structures
Design Integration

CALORIMETRY

ORNL

Comments On Manufacturing and Maintenance of GEM Calorimeters

Off-Site, Modular Fabrication is Desirable

Rapid Assembly in Experimental Hall is Required

Maintenance will be Annual

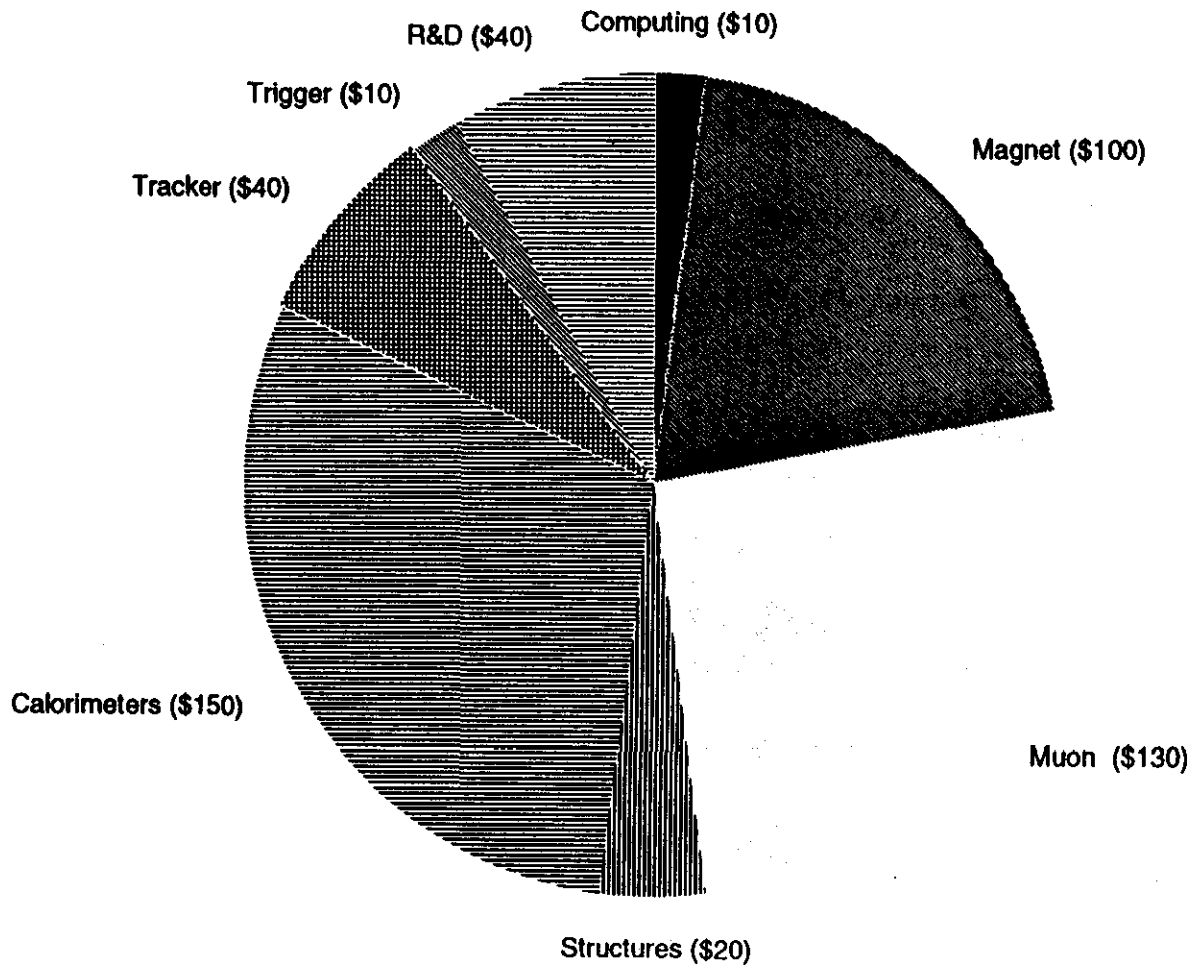
Removal of Calorimeter Requires Removal of All End Cap Assemblies

GEM Calorimeter Comparison-Segmentation and Channel Count

		Electromagnetic				Hadron				
Type	Coverage	Segmentation		Layers	Channels	Segmentation		Layers	Channels	Total Chan.
		n=0.0	n=3.0			n=0.0	n=3.0			
Theoretical	0 to 3.0	0.05	0.05	1	15,120	0.05	0.05	1	15,120	15,120
	0 to 3.0	0.04	0.04	1	23,550	0.04	0.04	1	23,550	23,550
	0 to 3.0	0.035	0.035	1	30,780	0.035	0.035	1	30,780	30,780
Liquid Argon	0 to 3.0	0.035	0.035	2?	56,400	0.07	0.07	4?	61,920	118,000
Spaghetti	0 to 3.0	0.05	0.14	1	13,232	0.05	0.14	1	13,232	26,464
Liquid Scint.	0 to 3.0	-	-	-	-	0.05	0.07	4	40,000	40,000
Barium Fluor.	0 to 2.87	0.04	0.11	1	16,560	-	-	-	-	16,560
Liquid Xenon	0 to 3.0?	0.04?	0.11?	3	42,786	-	-	-	-	42,786

Mark Rennich/ Oak Ridge National Laboratory/8-5-91

GEM COST TARGETS (29 JULY 1991)
($ MILLIONS)



CALORIMETRY

ORNL

COMMENTS ON ELECTRONICS COSTING

$ TRIGGER DESIGN DOES NOT EXIST

$ CABLING ARRANGEMENT IS UNKNOWN

$ NOT ALL CALORIMETER ELECTRONICS ARE THE SAME

$ THERIOT AND DETECTOR HISTORY HAVE ESTABLISHED A BASIS FOR ELECTRONICS COSTS

THEREFORE:

A BASIC CALORIMETER CHANNEL COST SHOULD BE ESTABLISHED BASED ON THE THERIOT REVIEW AND FACTORS APPLIED (BY DAN MARLOW?) TO ACCOUNT FOR DIFFERENCES IN CALORIMETER READOUTS.

COST TO WEIGHT RATIOS FOR MAJOR DETECTOR PROPOSALS

	Weight	Total Cost	Cost/Ton	Cost/Pound
L*- Liq Scintill**	1945	$89,112	$46K	$21
E/T-Spghetti	2378	$103,000	$43K	$20
E/T-Liq Argon	3075	$156,750	$51K	$23
SDC-Liq Argon				
SDC-Pla. Tile	5300	$198,300	$37K	$17
GEM -Spaghetti	2100	$123,400	$59K	$27
GEM-Liquid Arg	2900	$147,600	$51K	$23
GEM-Liq Scint.**	1945	$81,800	$42K	$19
CDF-Pb/Scint.				$14
ZEUS-Ur/Scint.				$29

Costs include Electronics
Costs include Therio Adjustment
GEM estimates are preliminary
****Does not include EM calorimeter**
Items included in CDF and ZEUS calorimeters unknown

Mark Rennich/Oak Ridge National Laboratory/7/24/91

EM CALORIMETER			HADRON CALORIMETER	
L*	**BaF2 EM CAL**	**LX EM CAL**	**LIQUID SCINT**	
SIGNALS	18,044	42,786	50,000	
CHANNELS	18,044	42,786	50,000	
MULTIPLEX RATIO	1	1	1	
FRONT END ELECT.	6,748	10,840	15,625	
CABLE	-	-	-	
INSTALLATION	-	-	-	
DAQ	-	-	-	
COMPUTING	843	1,999	2,336	
TOTAL	7,591	12,839	17,961	
COST/CHANNEL	$421	$300	$359	
THERIOT CONT.	25.00%	30.00%	25.00%	
LOI EDIA	10.70%	10.70%	14.64%	
THERIOT EDIA/R&D	36.00%	36.00%	36.00%	
TOTAL C/C	517	479	426	
E/T			**SPAGHETTI**	**LIQ ARGON**
SIGNALS			26,464	120,320
CHANNELS			26,464	120,320
MULTIPLEX RATIO			1	1
ELECTRONICS			5,009	14,569
CABLE			-	-
INSTALLATION			-	-
TRIGGER			1,574	3,250
DAQ			102	465
COMPUTING			81	369
TOTAL			6,767	18,652
COST/CHANNEL			$256	$155
SDC			**PLASTIC TILE**	**LIQ ARGON**
SIGNALS			66,000	87,400
CHANNELS			66,000	87,400
MULTIPLEX RATIO			1	1
FRONT END ELECT.			6,308	3,900
CABLE			-	-
INSTALLATION			-	-
TRIGGER			13,839	13,839
DAQ			3,737	4,948
COMPUTING			1,856	2,458
TOTAL			25,739	25,145
COST/CHANNEL			$390	$288
THERIOT CONT.			100.00%	100.00%
LOI EDIA			17.00%	17.00%
THERIOT EDIA/R&D			43.00%	43.00%
TOTAL C/C			477	352

	MUON	FOR. CAL	SYSTEM
L*	**WIRE**	**TMS**	
SIGNALS	398,000	33,124	
CHANNELS	110,000	33,124	278,233
MULTIPLEX RATIO	3.60	1.00	
FRONT END ELECT.	22,669	14,005	
CABLE	-	-	
INSTALLATION	-	-	
DAQ	-	-	
COMPUTING	5,140	1,548	13,000
TOTAL	27,809	15,553	101,560
COST/CHANNEL	$253	$470	$365
THERIOT CONT.	20.00%	50.00%	
LOI EDIA	10.46%	19.80%	11.00%
THERIOT EDIA/R&D	36.00%	36.00%	36.00%
TOTAL C/C	311	533	447
E/T	**WIRE**	**?**	
SIGNALS	410,000		
CHANNELS	410,000		756,983
MULTIPLEX RATIO	1		
ELECTRONICS	26,456		
CABLE	-		
INSTALLATION	-		
TRIGGER	13,620		13,514
DAQ	1,584		2,924
COMPUTING	1,256		2,319
TOTAL	42,915		79,543
COST/CHANNEL	$105		$105
SDC	**WIRE/SC**	**?**	
SIGNALS	108,400	7,000	
CHANNELS	108,400	7,000	494,558
MULTIPLEX RATIO	1.00	1.00	
FRONT END ELECT.	15,675	765	
CABLE	-		
INSTALLATION	-		
TRIGGER	30,001	259	18,286
DAQ	6,137	396	28,000
COMPUTING	3,048	197	13,906
TOTAL	54,861	1,617	143,341
COST/CHANNEL	$506	$231	$290
THERIOT CONT.	40.00%	50.00%	
LOI EDIA	8.00%	17.00%	29.00%
THERIOT EDIA/R&D	43.00%	43.00%	43.00%
TOTAL C/C	670	282	321

COMPARISON OF ELECTRONICS COSTS: L/SDC/E-T*

	TRACKING			
L*	**SI TRACK**	**FIBER**	**STRAW-TUBE**	
SIGNALS	3,200,000	36,000	52,000	
CHANNELS	5,065	10,000	52,000	
MULTIPLEX RATIO	632	3.60	1	
FRONT END ELECT.	16,440	1,390	11,683	
CABLE	-	-	-	
INSTALLATION	-	-	-	
DAQ	-	-	-	
COMPUTING	237	467	2,430	
TOTAL	16,677	1,857	14,113	
COST/CHANNEL	$3,293	$186	$271	
THERIOT CONT.	100.00%	30.00%	30.00%	
LOI EDIA	17.88%	17.88%	17.88%	
THERIOT EDIA/R&D	36.00%	36.00%	36.00%	
TOTAL C/C	3,799	214	313	
E/T	**TRD**	**LAr SI PADS**	**SPA. SI PADS**	**PRESHOWER**
SIGNALS	290,000	62,000	30,000	467,000
CHANNELS	290,000	62,000	30,000	519
MULTIPLEX RATIO	1	1	1	900
ELECTRONICS	19,424	4,618	2,235	260
CABLE	-	-	-	-
INSTALLATION	-	-	-	-
TRIGGER	5,177	1,107	536	9
DAQ	1,120	239	116	2
COMPUTING	888	190	92	2
TOTAL	26,610	6,154	2,978	273
COST/CHANNEL	$92	$99	$99	$526
SDC	**SILICON**	**STRAW-TUBE**	**WIRES**	
SIGNALS	47,500,000	188,000	50,000	
CHANNELS	75,158	188,000	50,000	
MULTIPLEX RATIO	632	1	1	
FRONT END ELECT.	8,446	20,860	8,510	
CABLE	-			
INSTALLATION	-			
TRIGGER	2,779	6,951	1,849	
DAQ	4,255	10,644	2,831	
COMPUTING	2,113	5,286	1,406	
TOTAL	17,593	43,741	14,595	
COST/CHANNEL	$234	$233	$292	
THERIOT CONT.	100.00%	30.00%	100.00%	
LOI EDIA	34.00%	34.00%	34.00%	
THERIOT EDIA/R&D	43.00%	43.00%	43.00%	
TOTAL C/C	250	248	312	

E/T Estimates have not received an SSC review
Theriot Contingency Included
Readout Devices (PMT's) not included
Total C/C cost not exact since DAQ and Computing did not have same contingency as local electronics
Shaded numbers are assumed

Costing Of GEM Calorimeters

- $ Cost Estimates Cannot Be Ready Until Concepts Complete
- $ Concepts Will Not Be Complete Until After Sept. Meeting

Mechanical Engineering (Costing) Definition

Barium Fluoride	*9*
Liquid Scintillator - Hadron	*9*
Spaghetti - Hadron	*8*
Liquid Xenon	*8*
Fiber Preradiator	*8*
Silicon Preradiator	*7*
Spaghetti - EM	*6*
Silicon Drift Preradiator	*5*
Liquid Scintillator - EM	*5*
Liquid Argon	*4*

BIG Engineering Issues

- *! Total Thickness*
- *! Active Thickness*
- *! Separate EM*
- *! Replacable EM*
- *! Electronics Costing Methodology*
- *! Uniform Physics Criteria*
- *! PreRadiator Requirement*

WORSTELL

CERN-PPE/91-45
March 6th 1991

EFFECTS OF RADIATION DAMAGE ON SCINTILLATING FIBRE CALORIMETRY

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Abstract

We report on measurements of radiation hardness of plastic scintillating fibres to be used for scintillating fibre calorimetry. Fibres were irradiated by a ^{60}Co γ-source and the effects on the emission and on the attenuation of scintillation light in a number of different fibre types were studied. Results are given on the changes in the wavelength spectrum induced by ionising radiation. The influence of optical filters, glue and surrounding gas were investigated. A Monte Carlo study is described that simulates radiation damage in a compensating lead-fibre calorimeter and predicts the impact on the performance. By combining the results of the radiation hardness measurements of the fibres and the results of the Monte Carlo, a limit is set on the acceptable dose level. If we define a contribution of 0.8% to the constant term of the electromagnetic energy resolution due to radiation damage as an acceptable performance degradation, we determine, with the best fibres that are presently commercially available, an acceptable dose limit of 7 Mrad.

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(Submitted to Nucl. Instr. and Meth. in Physics Research)

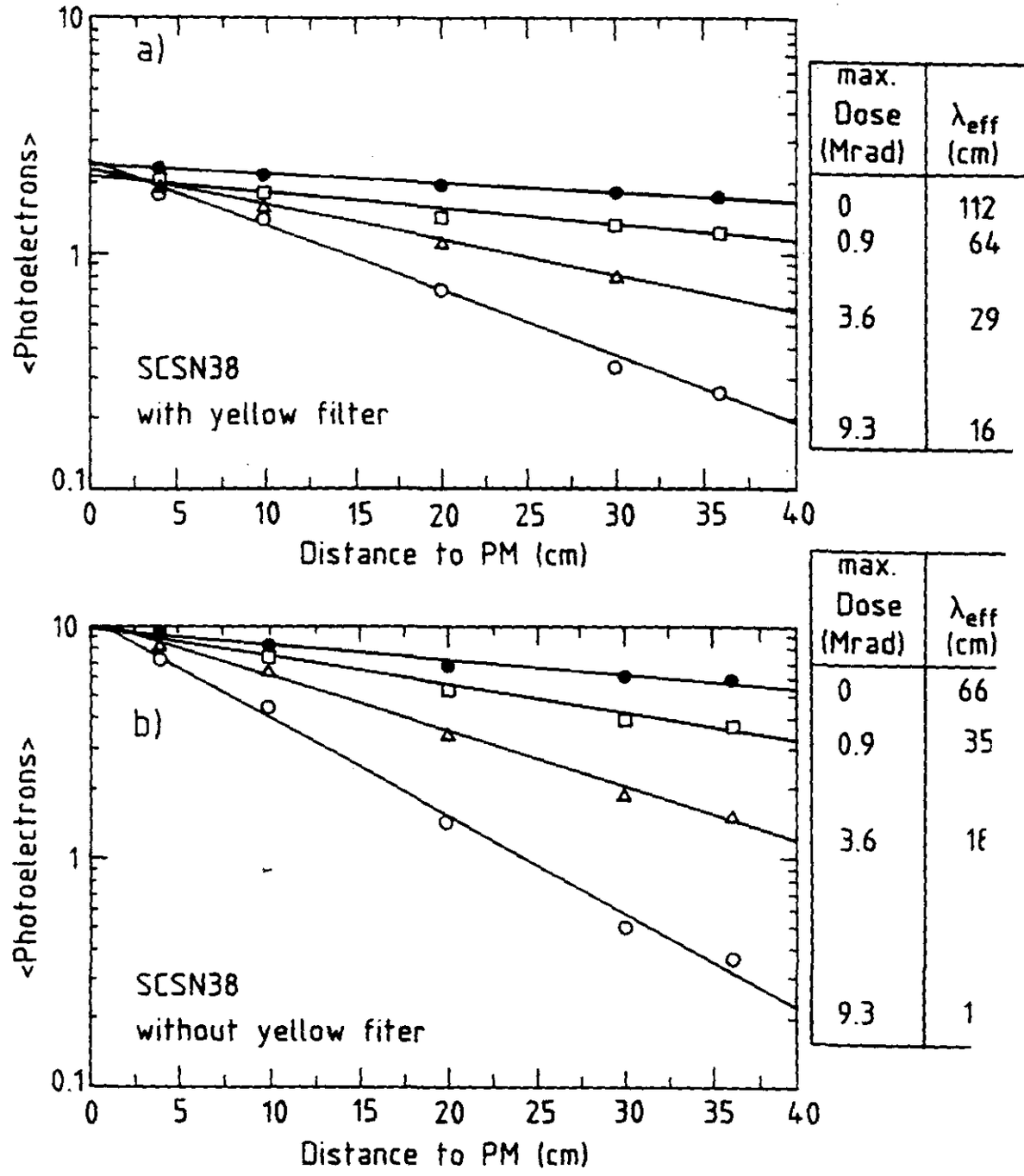
a)
SCSN38
with yellow filter
<Photoelectrons>
Distance to PM (cm)
max. Dose (Mrad)
λeff (cm)
0 112
0.9 64
3.6 29
9.3 16
b)
SCSN38
without yellow fiter
<Photoelectrons>
Distance to PM (cm)
max. Dose (Mrad)
λeff (cm)
0 66
0.9 35
3.6 18
9.3 1

Fig. 6

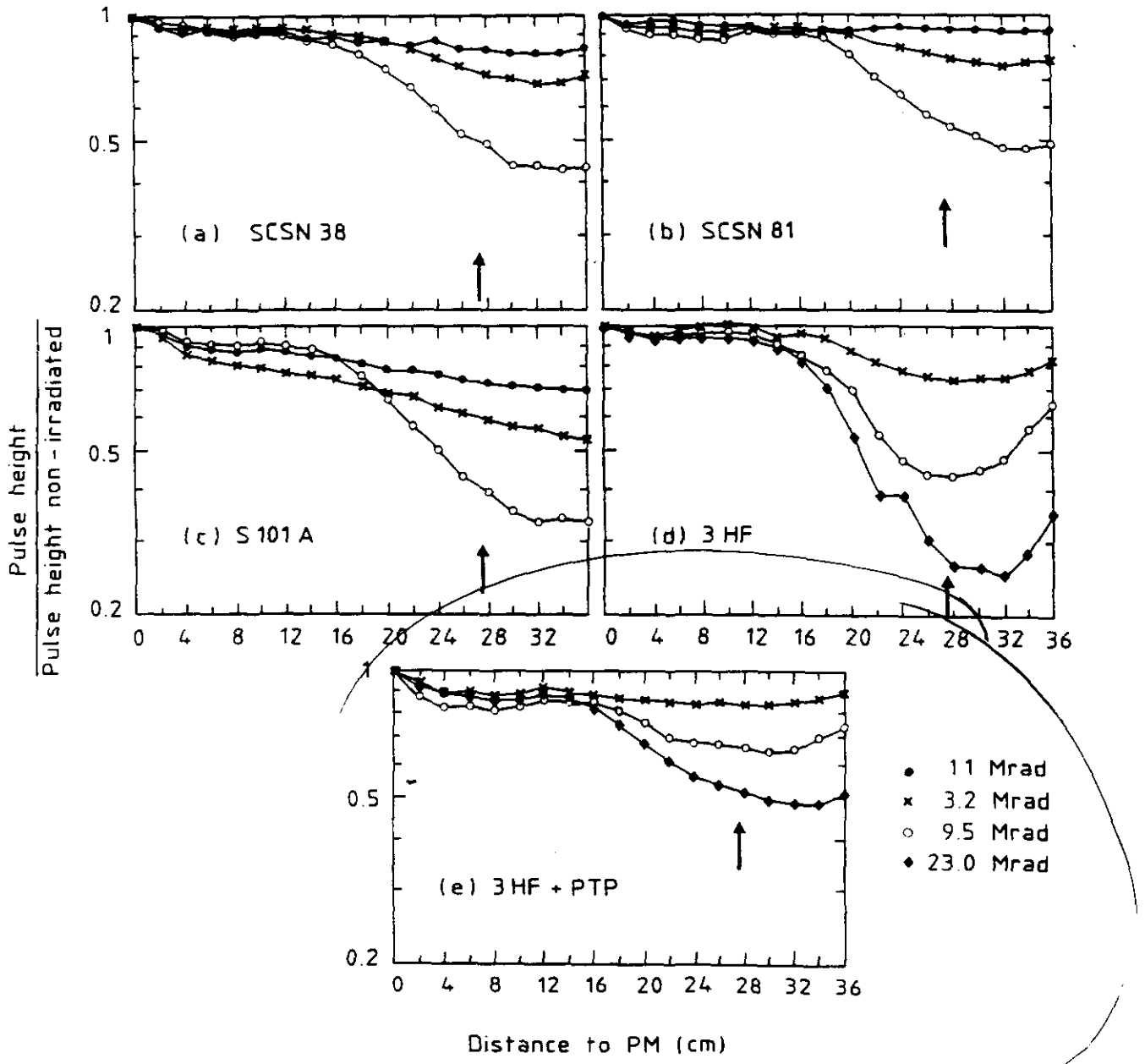
Pulse height / Pulse height non-irradiated
(a) SCSN 38
(b) SCSN 81
(c) S 101 A
(d) 3 HF
(e) 3 HF + PTP
1
0.5
0.2
0 4 8 12 16 20 24 28 32 36
11 Mrad
3.2 Mrad
9.5 Mrad
23.0 Mrad
Distance to PM (cm)

Fig. 9