GEM TN-92-64

Workshop on Vibration Control and Dynamic Alignment Issues at the SSC

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SSCL

February 11-14, 1992

Abstract:

Report to GEM on the Workshop on Vibration Control and Dynamic Alignment Issues at the SSC.

Workshop on Vibrational Control and Dynamic Alignment Issues at the SSC

Feb 11 - 14, 1992

The SSCL has recognized that its mission success is dependent on the capability to properly align accelerator and detector components and to ensure that subsequent movements are acceptable or correctable. Hence it organized a workshop to address vibrational and alignment issues. Members of the GEM collaboration engineering team attended most workshop sessions. The following reports are organized in the approximate order of the speakers' presentations. Some of the comments and observations were from private conversations between the speakers and GEM engineers. The comments are labelled by the speakers' titles and their names.

- Overview of Collider Project and Purpose of this Workshop; Rainer Meinke (SSC). See appended viewgraphs.
- Earthquake concerns in Texas; Bob Murray (LLNL) Bob pointed out that there are earthquake requirements imposed on the Comanche Peaks power plant being designed for Fort Worth, and that there is no reason to expect SSC to not have minimal requirements as well. He leads a group that has been doing earthquake designs and calculations for DOE Headquarters for the past 15 years and his group has many tools that could help us satisfy these concerns. Joel Bowers, of Gary Deis' group, has sent us a memo about the same requirements. Joel will follow up with Bob.
- Ground Motion Effects on the SSC; Jack Peterson (LBL/SSC) Jack's conservative calculations indicate that random vibrations with amplitudes as low as one micron would degrade the beam emittance completely in one minute. A later talk with Mike Syphers we heard that this estimate may be overly conservative but he had not done enough detailed calculations to say.
- Lessons Learned from the NOVA Laser Spaceframe Design; Chuck Hurley (LLNL) Chuck described the automated alignment system that was required to operate before each of the 7 or 8 shots per day. He described the difficulties of getting a 225 foot long frame built to within 1/4 inch. He then designed a laser fiducial system to position the 600 critical elements. He had several specific warnings: anything that has tight requirements on location should not be on a concrete base (comment from audience - SLAC successfully uses a mixture of sand and epoxy); no alignment sensitive devices should be on vacuum structures; and that temperature variation or drift over a day can produce major alignment changes, he controlled his to 1/4 degree
- Overview of Alignment Concerns and Requirements for Low Beta Magnets; David Veal (SSCL). This was mostly a repeat of presentations Veal has made at GEM meetings. He stated that initial alignment methods may not be repeatable after machine operation commences due to radiation exposure limits. Is this true???
- Prognosis for an Automated Alignment System; Robert Ruland (SLAC). Ruland described a system for automatically maintaining alignment of (dipole?) magnets to tens of microns.
- On-line 3D Control of LHC Low Beta Quadrupoles; Preliminary Approach of Possible Solutions: Michel Mayoud (CERN). Mayoud described some alignment methods being studied at CERN to address various alignment problems. A Fresnel lens system was described which facilitates periodic alignment verification with the beam pipe intact. It has achieved 100 micron resolution in tests in a 40 mm diameter pipe > 100 m long with no vacuum.
- Kinematic Cam Positioning Mounts; Gordon Bowden (SLAC). Bowden described an interesting and ingenious design for kinematically supporting the section of the beam just outside the detector (analogous to SSCL quad triplet section at the IR). Time spent consulting with Bowden would be well spent if a similar task arises here.
- Beam Steering Concepts and Capabilities; Mike Syphers (SSC) Mike described the complex way that the beam is changed to effect the interaction location or angle. His bottom line was that moving the IP more than a couple of mm in the X-Y plane would require large changes, and CCB action. He expects to have a BPM at the end of each low beta quad that is closest to the IP. He indicated that requests for moving the end of the quads from Z=20m to 22 or 23m would

not be totally out of line if well justified and soon enough (both unquantified). Current design concepts accommodate a maximum beam crossing half-angle of ~100 microradians (5.7×10^{-3} degrees), with the normal crossing angle being about 40 - 50 microradians ($2.3 - 2.9 \times 10^{-3}$ degrees). Beam separation is 4 mm at $Z = 20$ m and 90 cm at $Z = \infty$. The beam aperture/collimator located between the detector and quad triplet is present simply to protect the quads from collision products; it does nothing to the beam. Syphers does not know how much space is required for the beam aperture/collimator, nor who is responsible for its design and cost (GEM may be!!). SDC is assuming that it requires an extra two meters of space inside the quad, i.e., it protrudes to $Z = 18$ m.

- Summary Sessions

A. Vibration suppression Frequency ranges of concern are 1- 30 Hz, and 600 - 1200 Hz. Passive isolation, active isolation, passive damping, active damping, active structural control, and beam control were measures considered. Passive damping is highly recommended; active isolation and active structural control are promising but complex, expensive, and immature; passive isolation is not recommended because it introduces low frequency mode as well as creep and alignment difficulties; active damping is not recommended; beam control depends on beam position monitor accuracy, magnet design, etc... Recommendations include designing for vibration suppression from the beginning; accurate beam position monitors for beam control; additional testing to determine whether 600 - 1200 Hz frequency band is a real problem; tests for flow- or boiling-induced vibration, particularly in quads; isolation or removal of vibration sources (beware high frequency acoustic noise here!).

B. Vibrational concerns Closed orbit distortions separate beams at interaction points. Train crossing results in < 1% luminosity loss; however, this is for a west campus location. It is probably worse on the east campus, since it is closer to a railroad trestle, with pilings driven into the Austin Chalk. Midlothian quarry blasting causes ~67% loss for a few seconds 2-3 times/week. Freeway effects on luminosity are negligible. Ground diffusion motions are of order 6 microns/hr, 0.5 mm/year, 2-3 mm/20 years; annual realignment may be necessary! 1 micron = 1 sigma shift in beam position at IR. Emittance growth is not serious at low frequency. Because of excitation of frequencies with harmonic relation to betatron frequencies, emittance growth can be serious at high frequencies even though power spectrum is proportional to 1/f**4. More data is needed.

C. Design of stable structures Recommends supporting quads on spaceframe with 20 - 40 Hz resonant frequency. The question was raised whether the spaceframe must be temperature-controlled; the session chairman responded affirmative and suggested hall ventilation to control temperature within 0.3 °C. Dipole magnets could be on a C frame support. Recommended detector support is a saddle structure, adjustable by hydraulic jacks but permanently supported on shims, which could be wedge-shaped. Grease bearings are recommended for coil translation. Steel sheet can be laid over grease path to mitigate the mess and keep grease from contaminating clean surfaces.

D. Dynamic alignment Initial alignment spec is currently not known. If quad alignment (relative to each other) tolerance > 1 mm, alignment is marginally achievable by traversing the detector. If tolerance < 1 mm, an optical path through the detector is required; presumably this is the beam pipe. The clear diameter should be 40 - 50 mm; 30 mm diameter is marginal, anything less is unacceptable. The alignment group needs information on the beam pipe design ASAP. Individual quads are sensitive to movements at the micron level. For frequencies of a few minutes and amplitudes < 30 microns, electrical correction is preferred.

Tunnel Construction and Magnet Installation

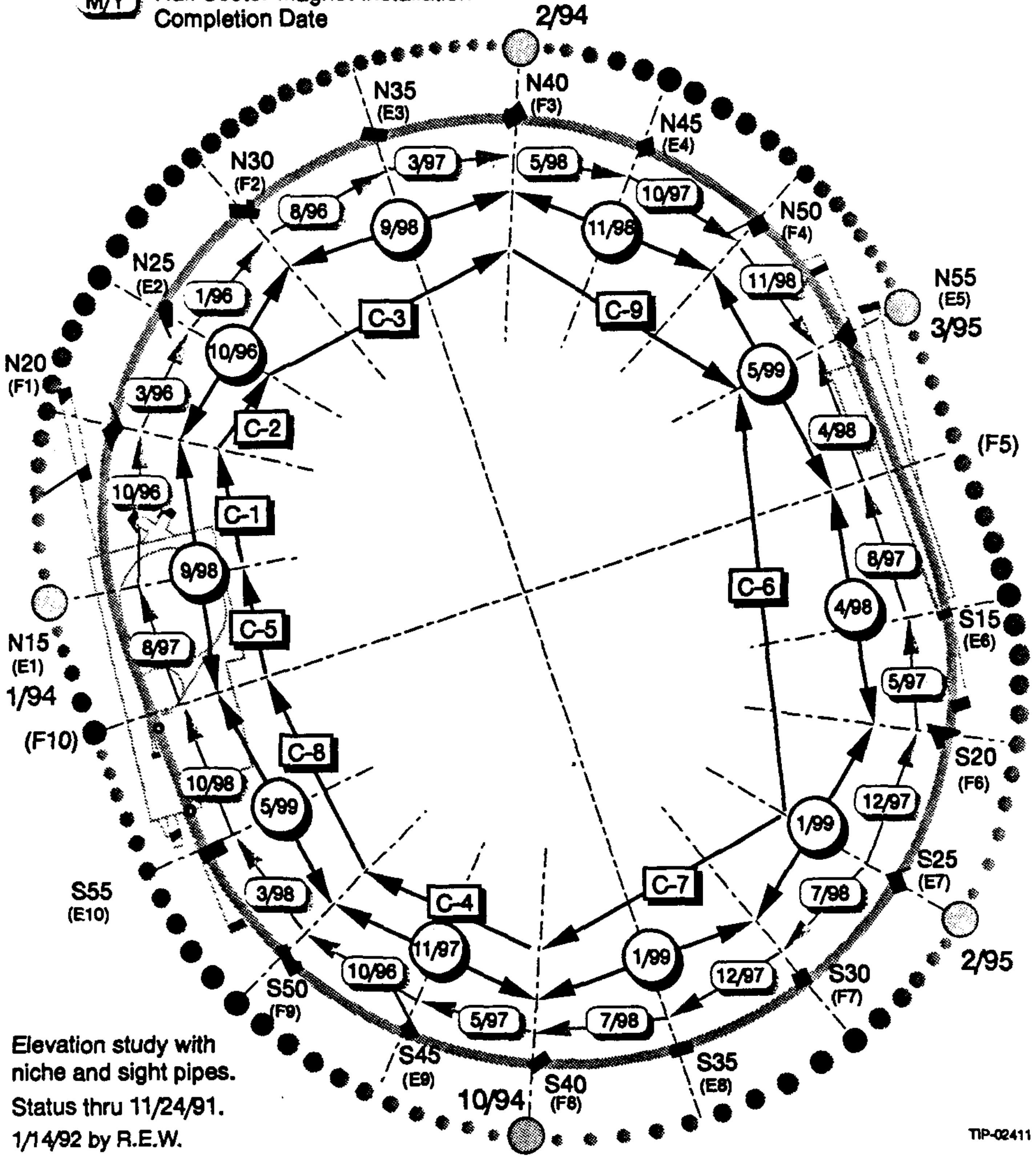
○ Magnet Shaft Locations

C-# Tunnel Contract Identification

M/Y Half Sector Magnet Installation Completion Date

M/Y Full Sector Test Completion Date

• • ● ● Backfill Concept Portrayal

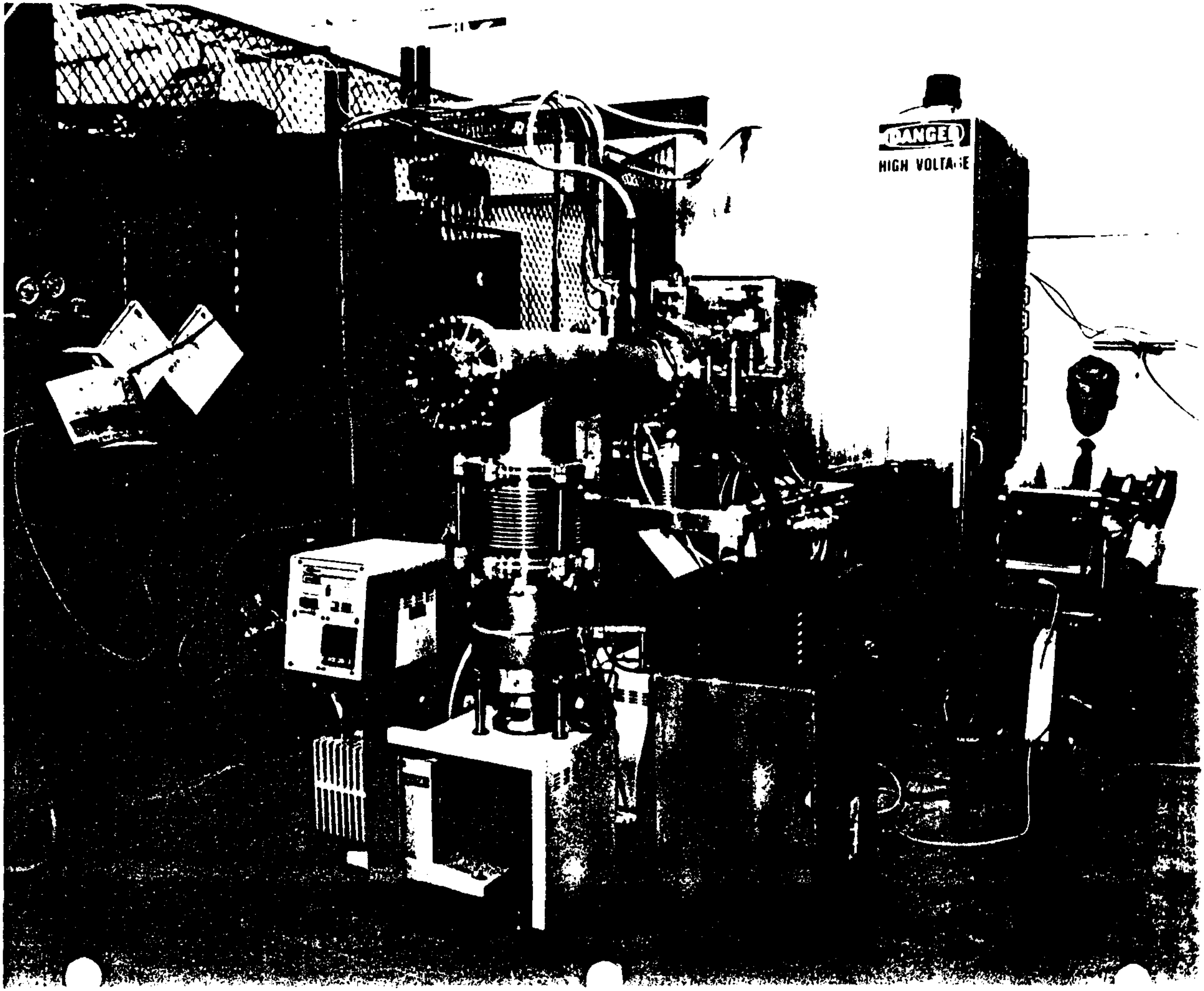


Elevation study with niche and sight pipes.

Status thru 11/24/91.

1/14/92 by R.E.W.

TIP-02411


DANGER
HIGH VOLTAGE

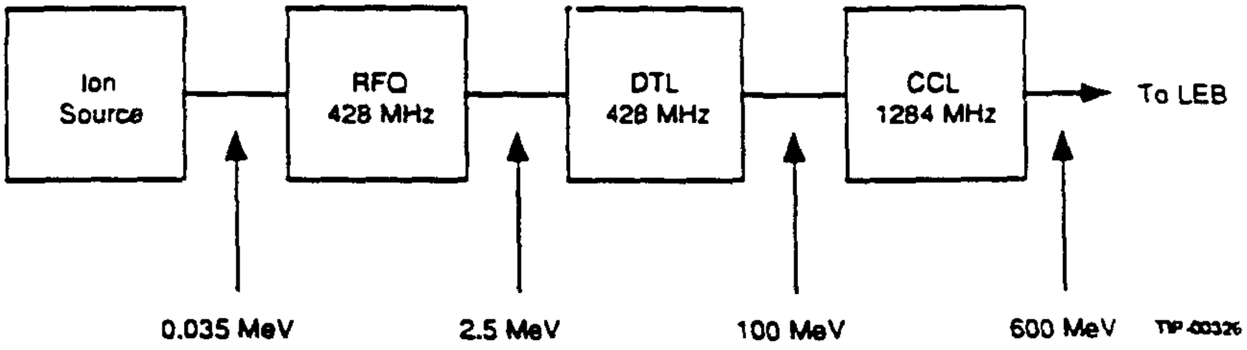
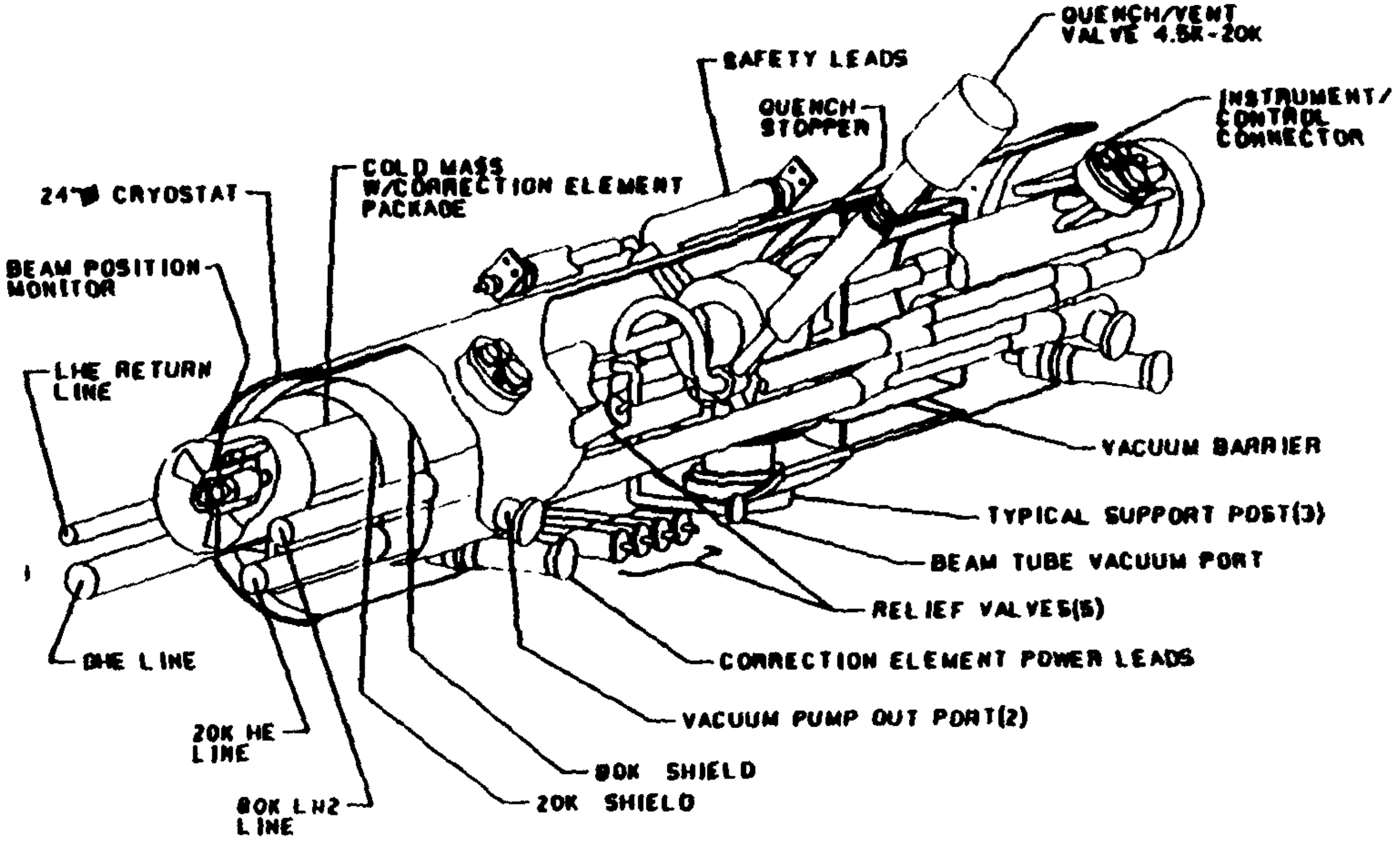


Figure 4.1.1.2-16. Linac block diagram.


QUENCH/VENT VALVE 4.5K-20K
SAFETY LEADS
QUENCH-STOPPER
INSTRUMENT/CONTROL CONNECTOR
COLD MASS W/CORRECTION ELEMENT PACKAGE
24"Ø CRYOSTAT
BEAM POSITION MONITOR
LHE RETURN LINE
SHE LINE
VACUUM BARRIER
TYPICAL SUPPORT POST(3)
BEAM TUBE VACUUM PORT
RELIEF VALVES(5)
CORRECTION ELEMENT POWER LEADS
VACUUM PUMP OUT PORT(2)
80K SHIELD
20K SHIELD
20K HE LINE
80K LH2 LINE

Alignment Tolerances of Accel. Components

Ideal accelerator has all components in one plane with axes of magnets on design orbit.

Allowable deviations from design orbit:

ARCs

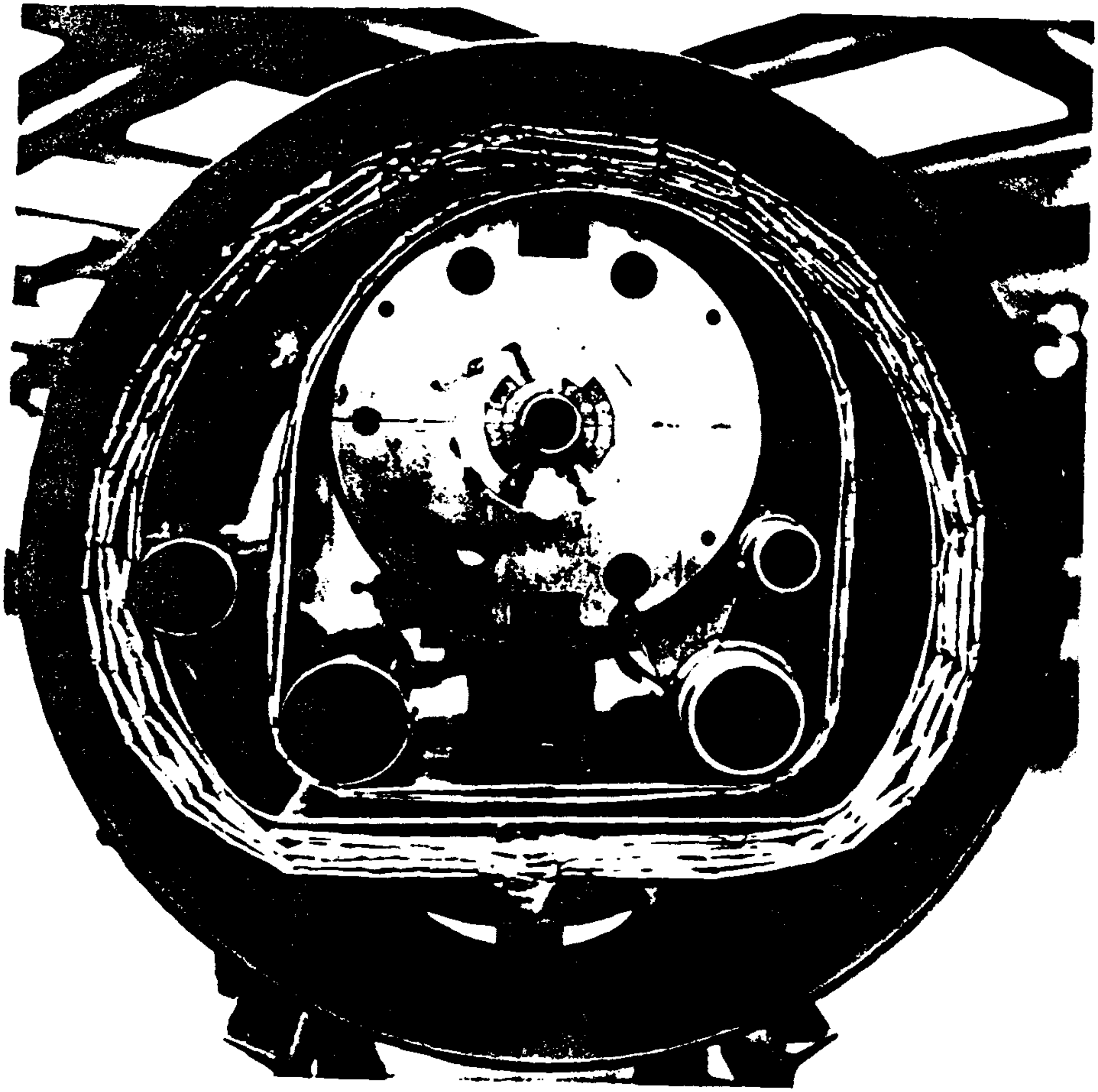
Dipoles: 1 mm

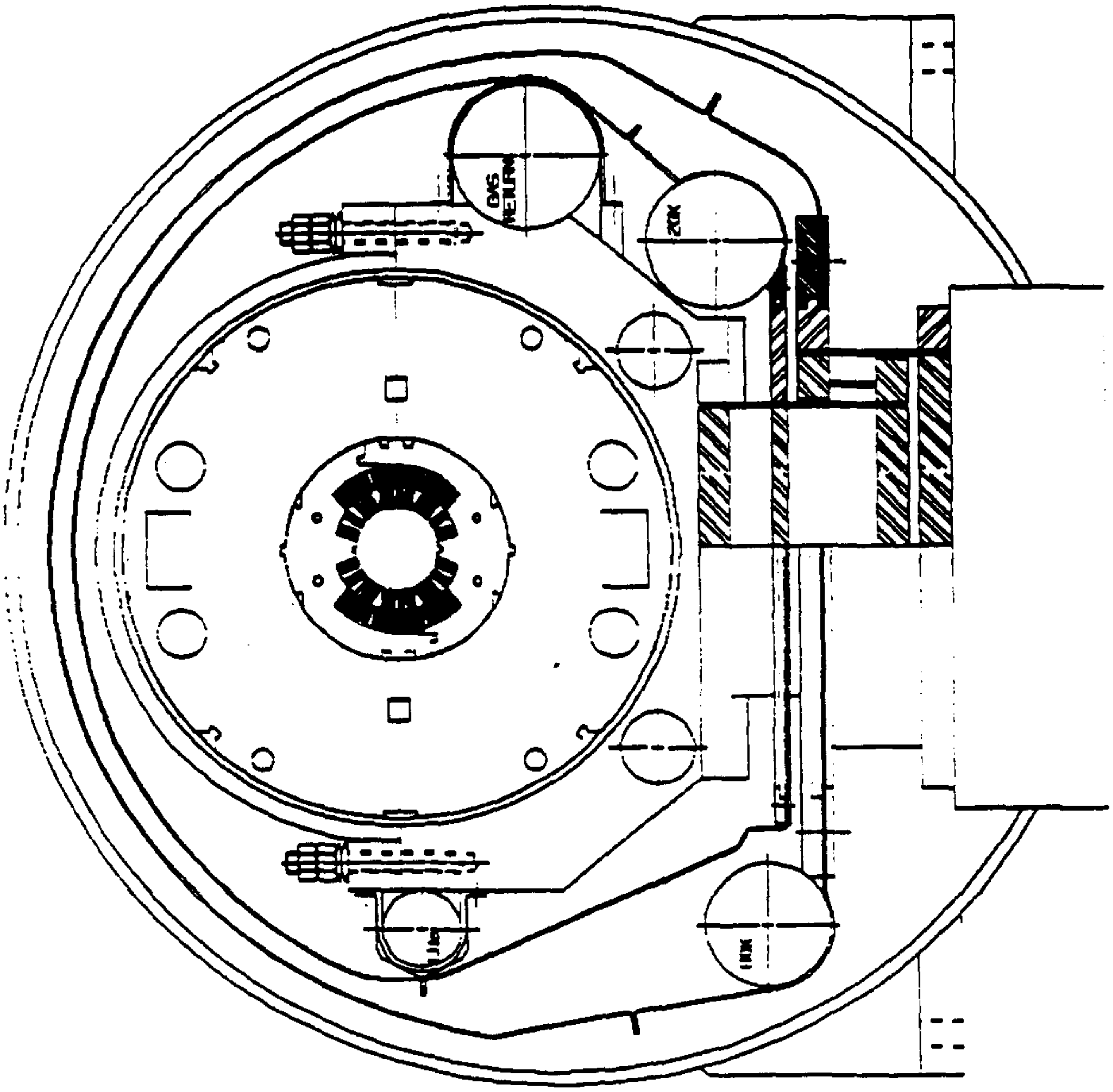
Quadrupoles: 0.5 mm

BPM's: 0.3 mm

IRs

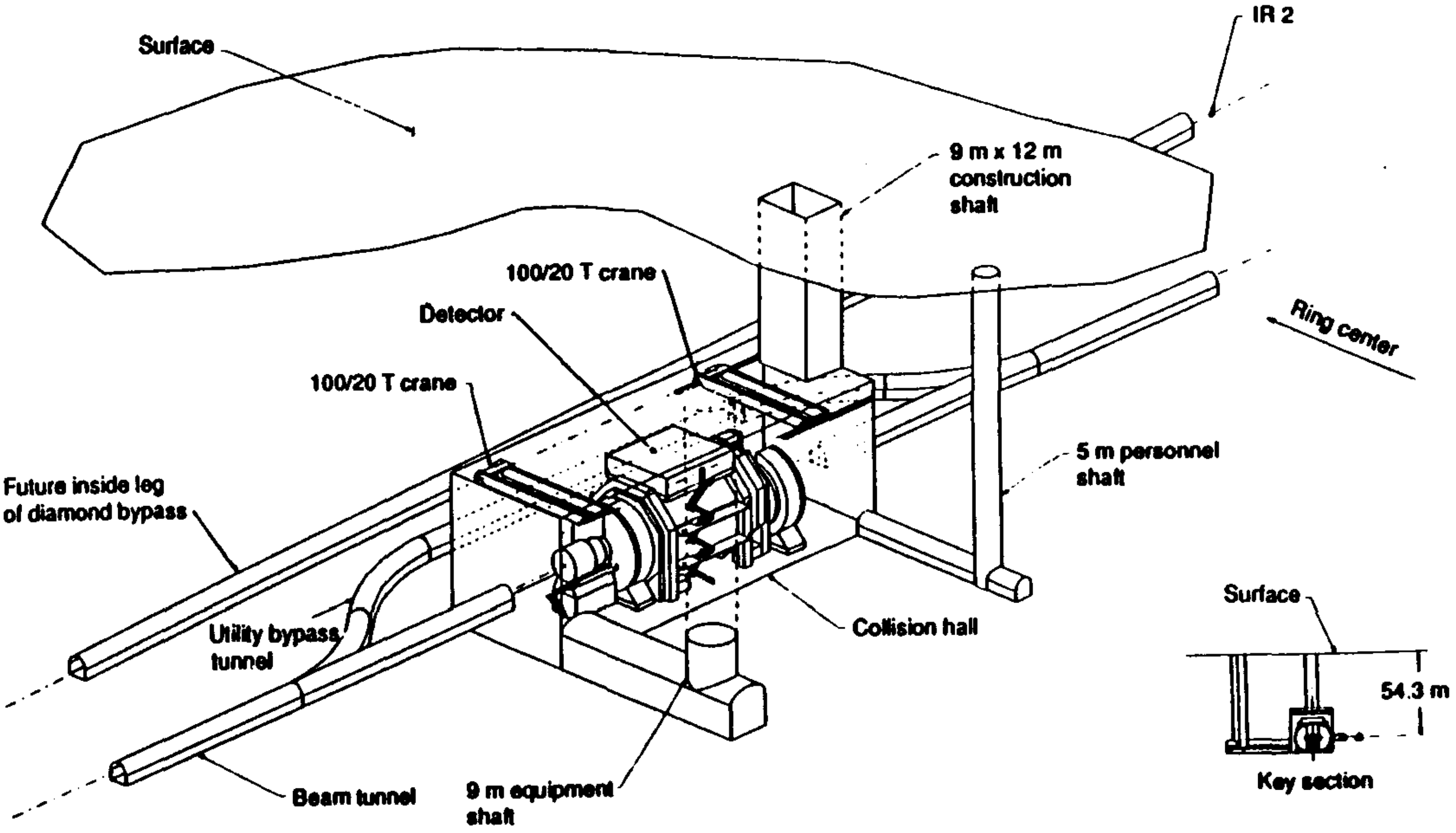
Final focus quads: 0.001 mm

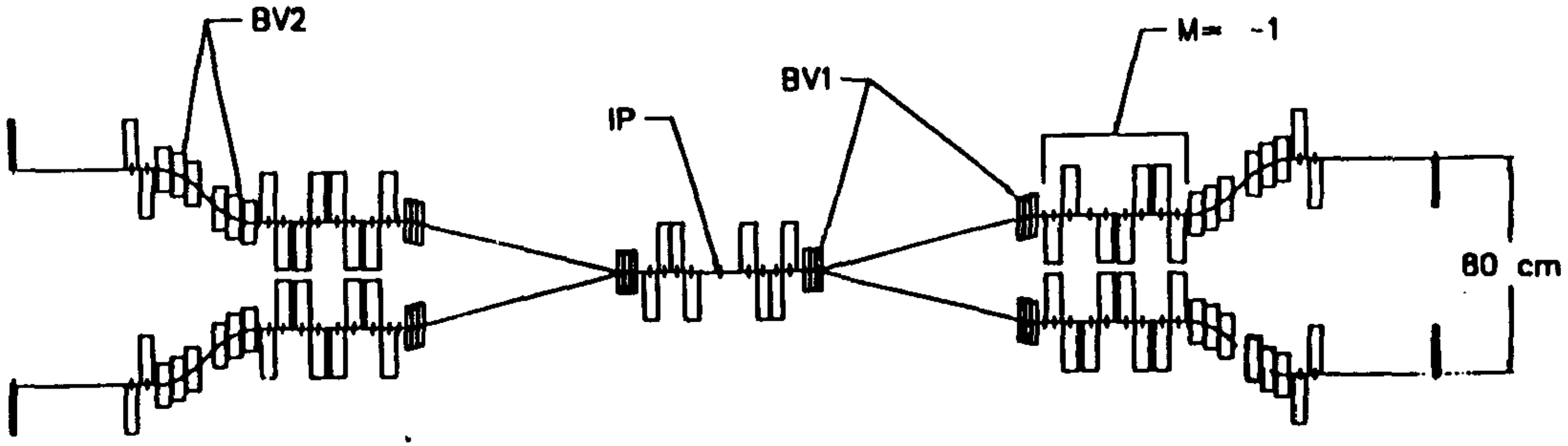


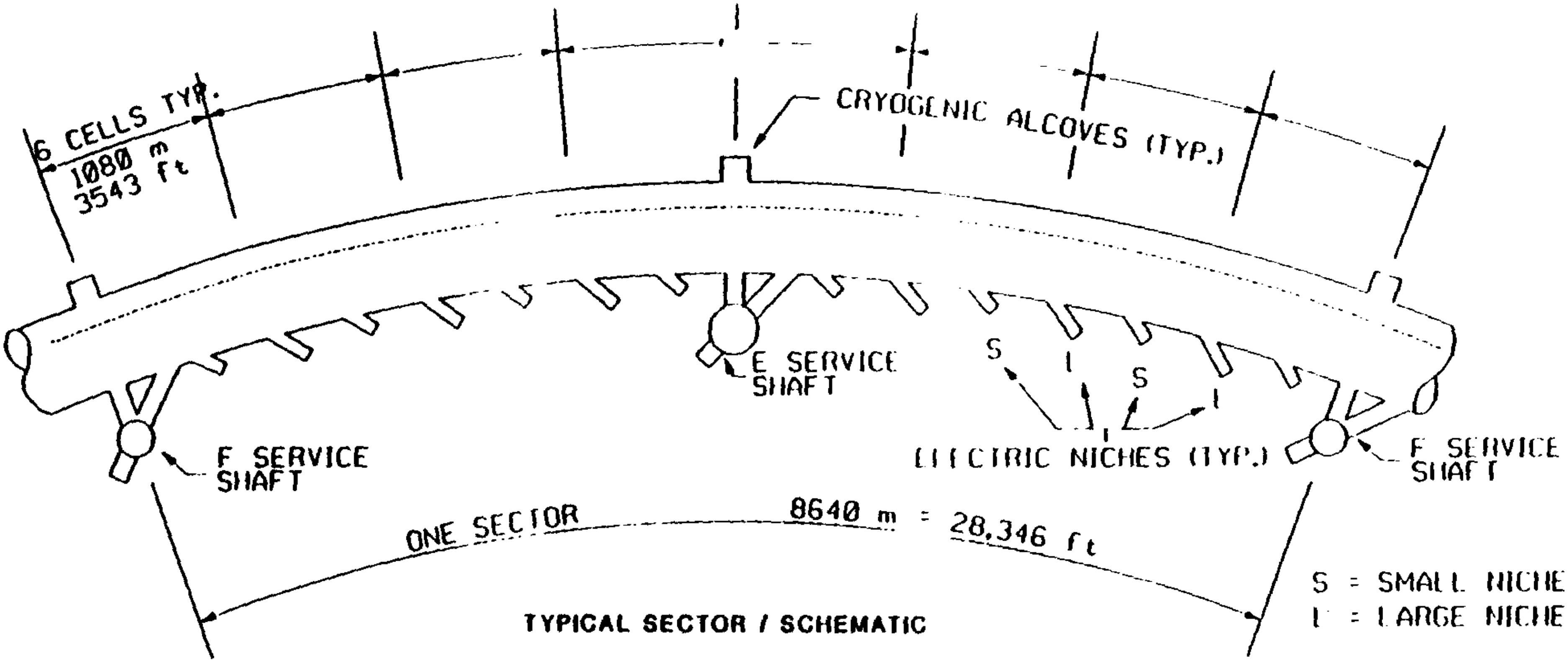

GAS HELIUM
20K
100K

Isometric View of LSD Detector in Hall (WBS 2.2.1.1.1)

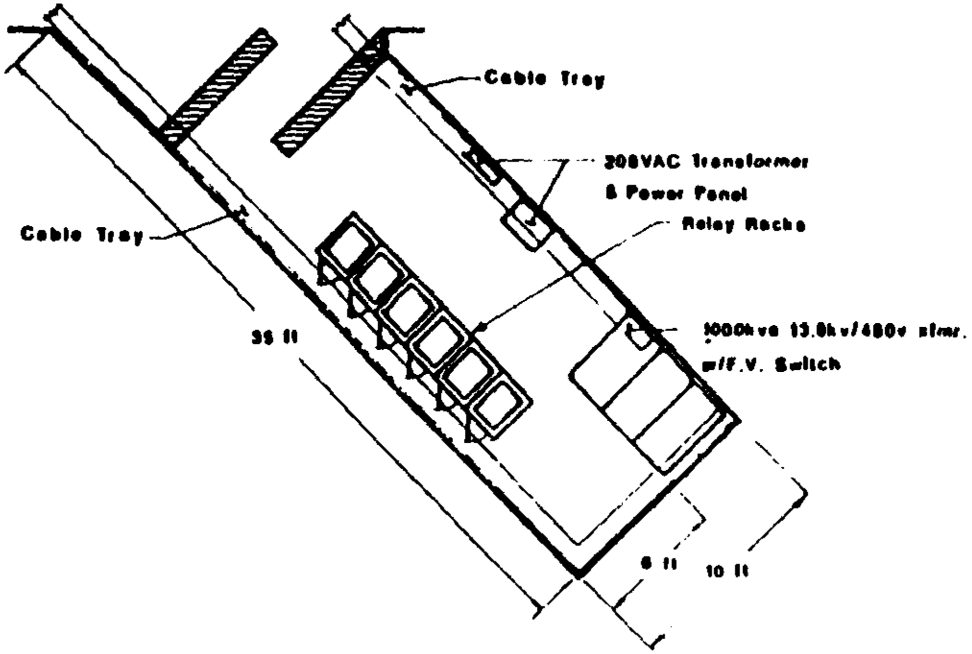
West North Interaction Region IR1 Underground (WBS 2.2.1.1.1)



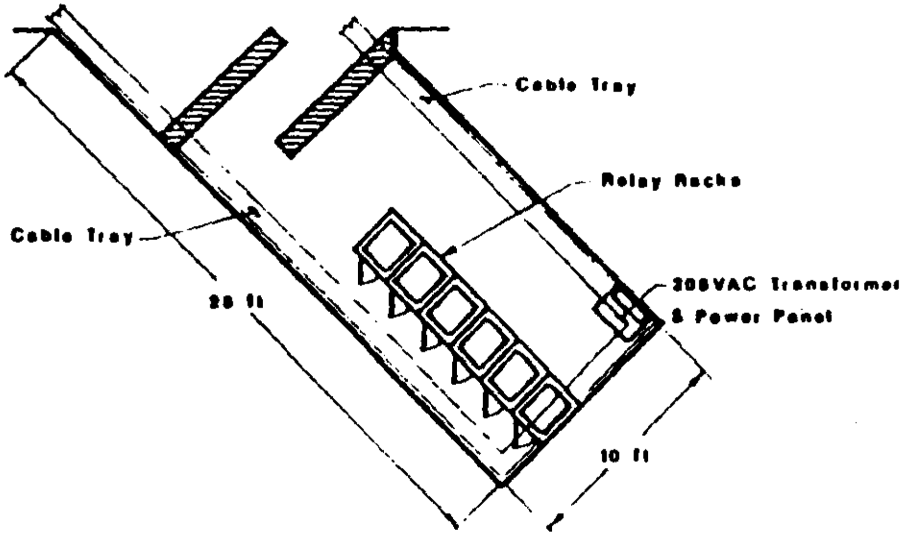

BV2
IP
BV1
M= -1
80 cm



TYPICAL SECTOR / SCHEMATIC



OF TYPE L NICHE

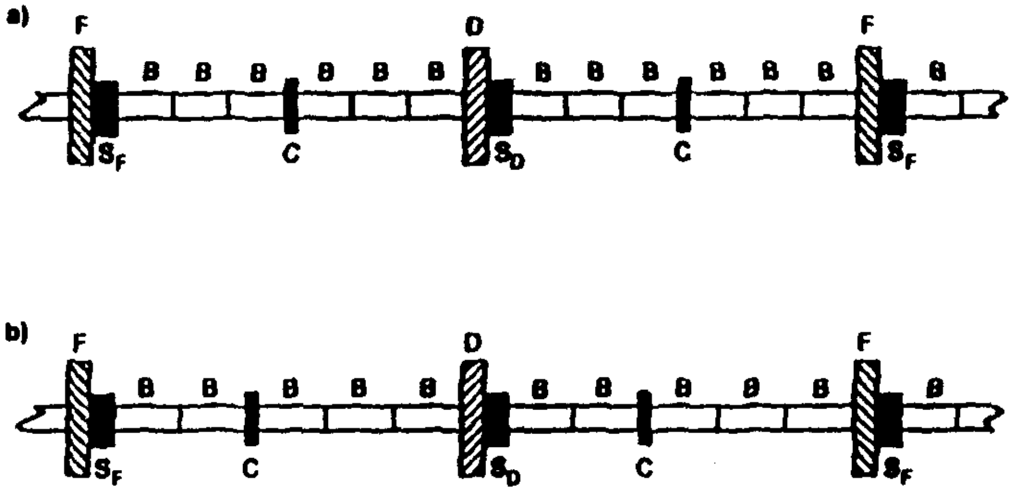


PLAN VIEW OF TYPE S NICHE

CONVENTIONAL CONSTRUCTION
BY OTHERS

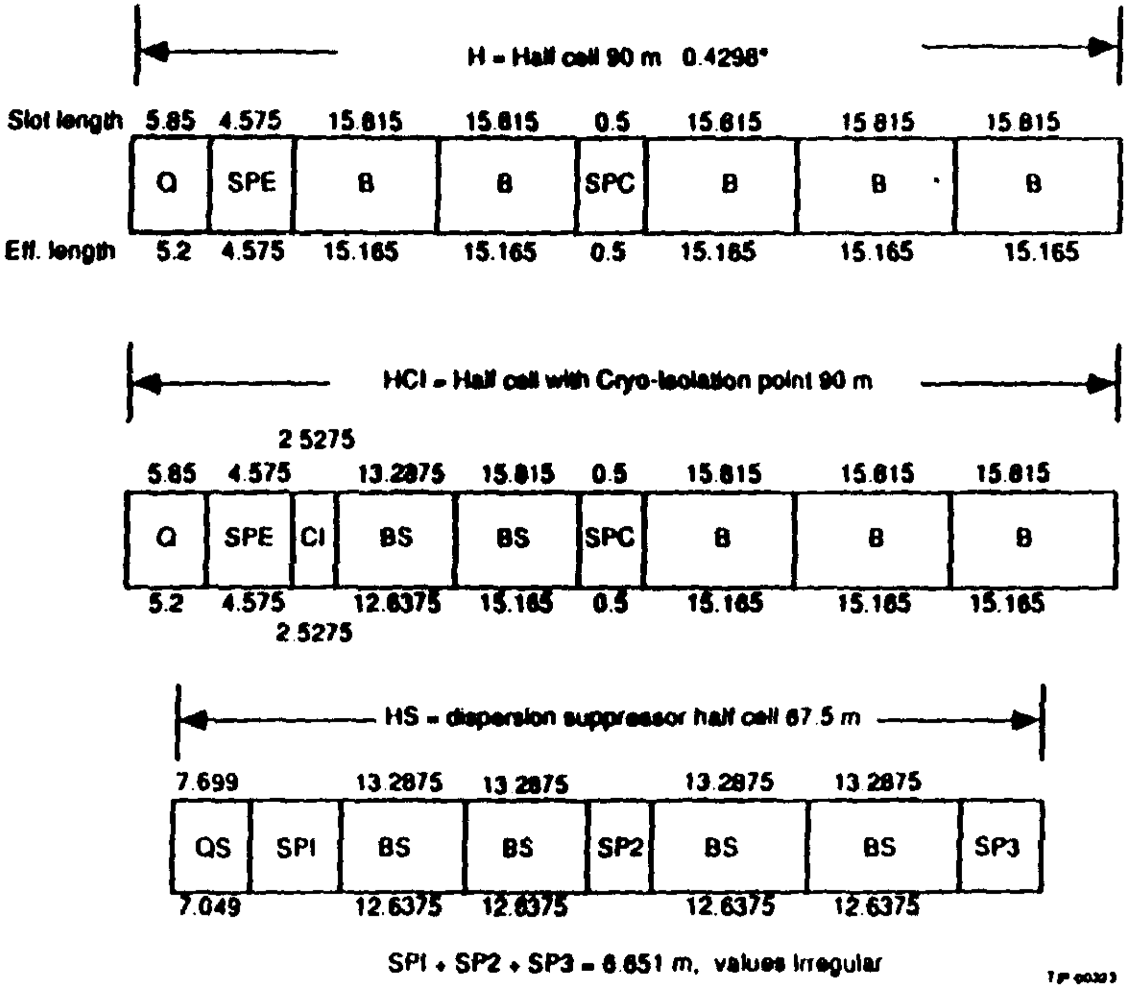
Primary Corrector Magnet Strengths

B*L, T-m at $r = 1.00$ cm



Pole	F	C	D
Dipole	2.50	—	2.50
Quadrupole	0.53	—	0.53
Sextupole	0.13	0.09	0.21
Octupole	0.007	0.016	0.007
Decapole	0.004	0.009	0.004

Alternate Dipole Layout of Footprint Configuration



H = Half cell 90 m 0.4298°

Slot length	5.85	4.575	15.815	15.815	0.5	15.815	15.815	15.815
	Q	SPE	B	B	SPC	B	B	B
Eff. length	5.2	4.575	15.165	15.165	0.5	15.165	15.165	15.165

HCI = Half cell with Cryo-isolation point 90 m

5.85	4.575	2.5275	13.2875	15.815	0.5	15.815	15.815	15.815
Q	SPE	CI	BS	BS	SPC	B	B	B
5.2	4.575	2.5275	12.6375	15.165	0.5	15.165	15.165	15.165

HS = dispersion suppressor half cell 67.5 *m*

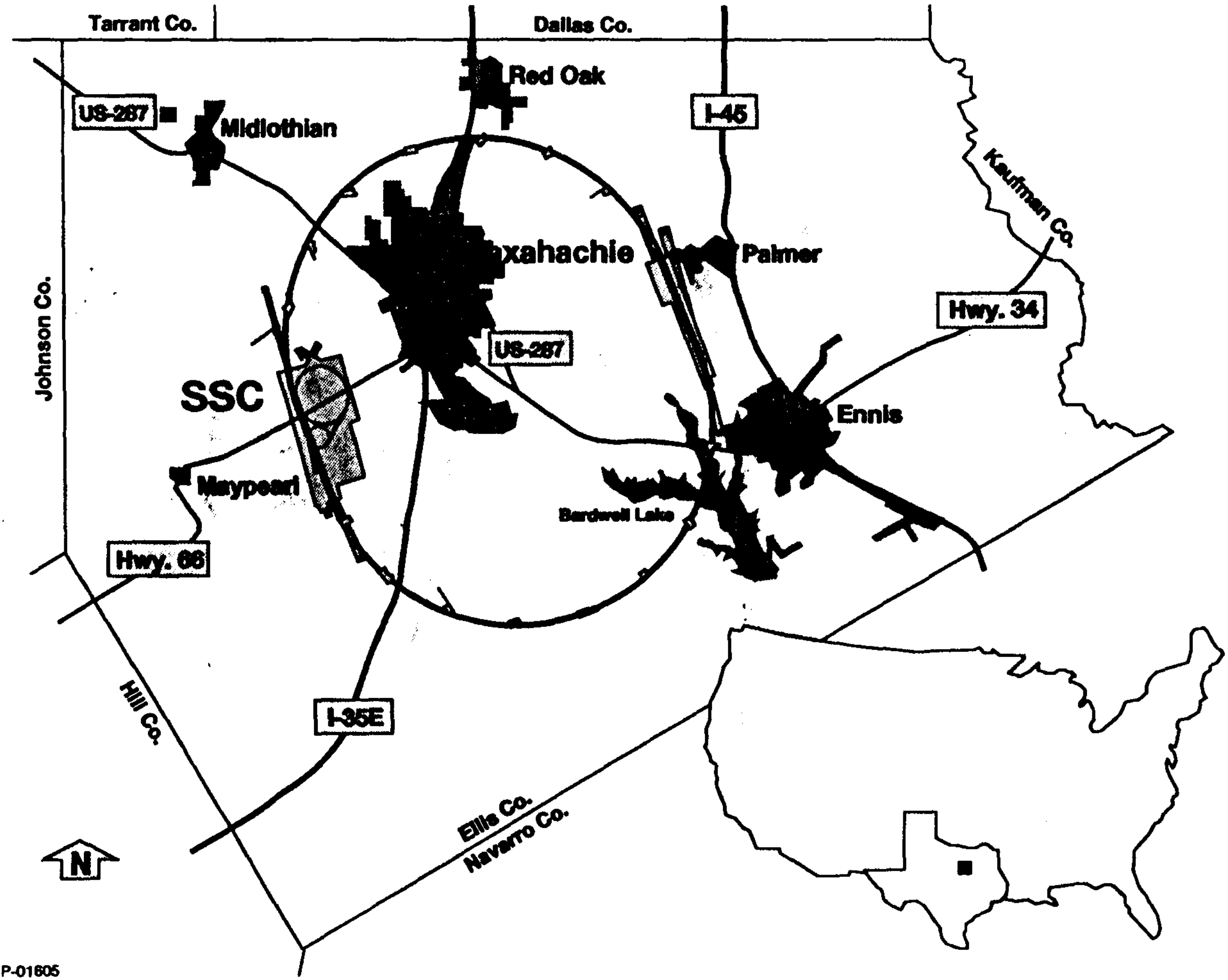
7.699		13.2875	13.2875		13.2875	13.2875	
QS	SP1	BS	BS	SP2	BS	BS	SP3
7.049		12.6375	12.6375		12.6375	12.6375	

SP1 + SP2 + SP3 = 6.651 *m*, values irregular

TP-00323

SSC Parameters

Proton Energy	20 TeV
Circumference of rings	87 KM
Protons per r.f. bunch	0.75×10^{10}
Bunch spacing	5 meters
Number of bunches/ring	17,424
Total particle energy/ring	418 megajoules
Emittance (RMS)	1π millimeter-milliradian
Interaction region focal spot size RMS radius, ($\beta^* = 0.5$ M)	5 micrometers
Proton-proton collision rate	60 MHz
Luminosity	1×10^{33} cm^{-2} sec^{-1}
Sychrotron radiation power	8.75 kilowatts/ring


Tarrant Co.
Dallas Co.
Red Oak
US-287
Midlothian
I-45
xahachie
Palmer
Kaufman Co.
Hwy. 34
US-287
Johnson Co.
SSC
Ennis
Maypearl
Bardwell Lake
Hwy. 66
I-35E
Hill Co.
Ellis Co.
Navarro Co.
N

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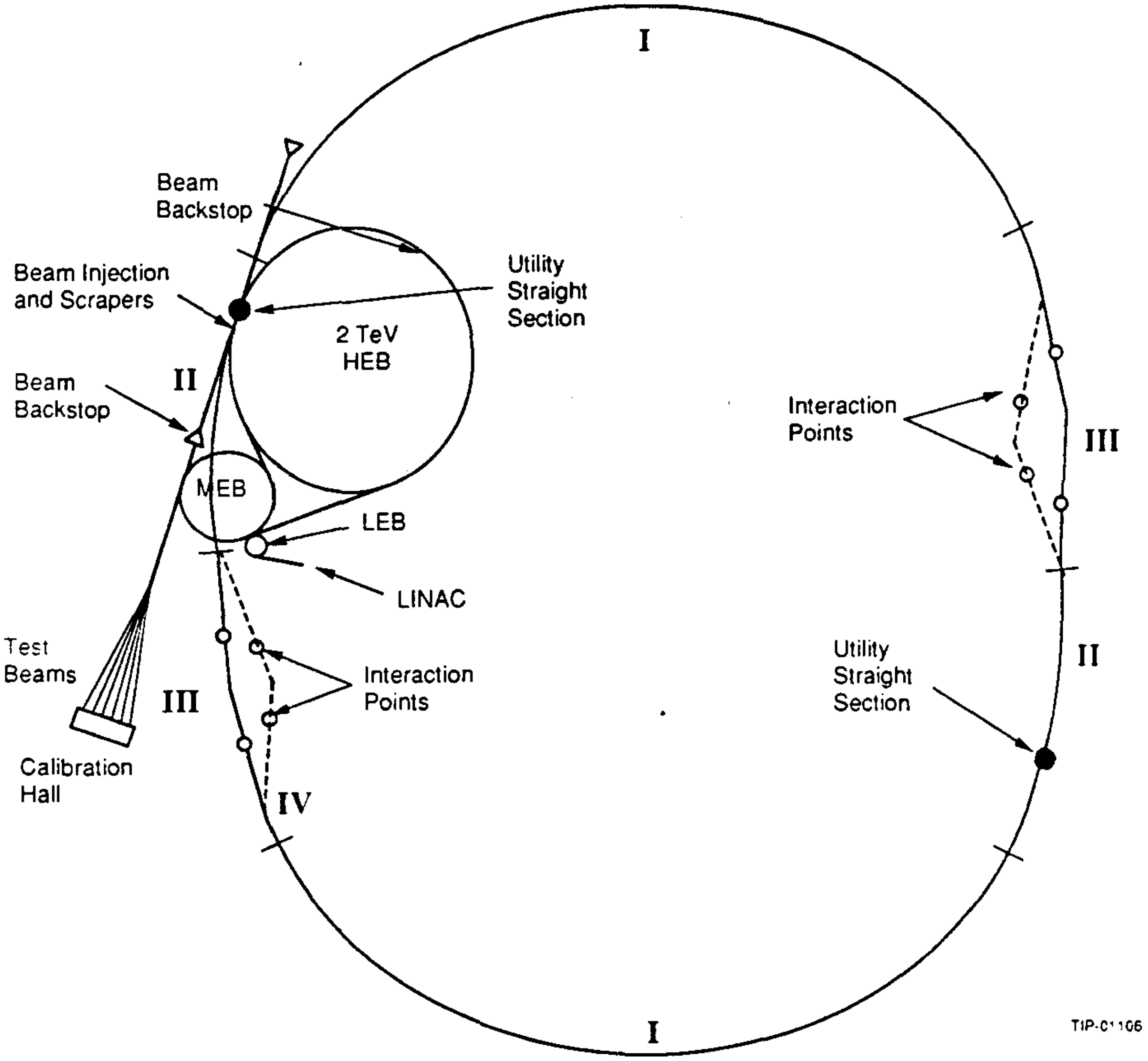
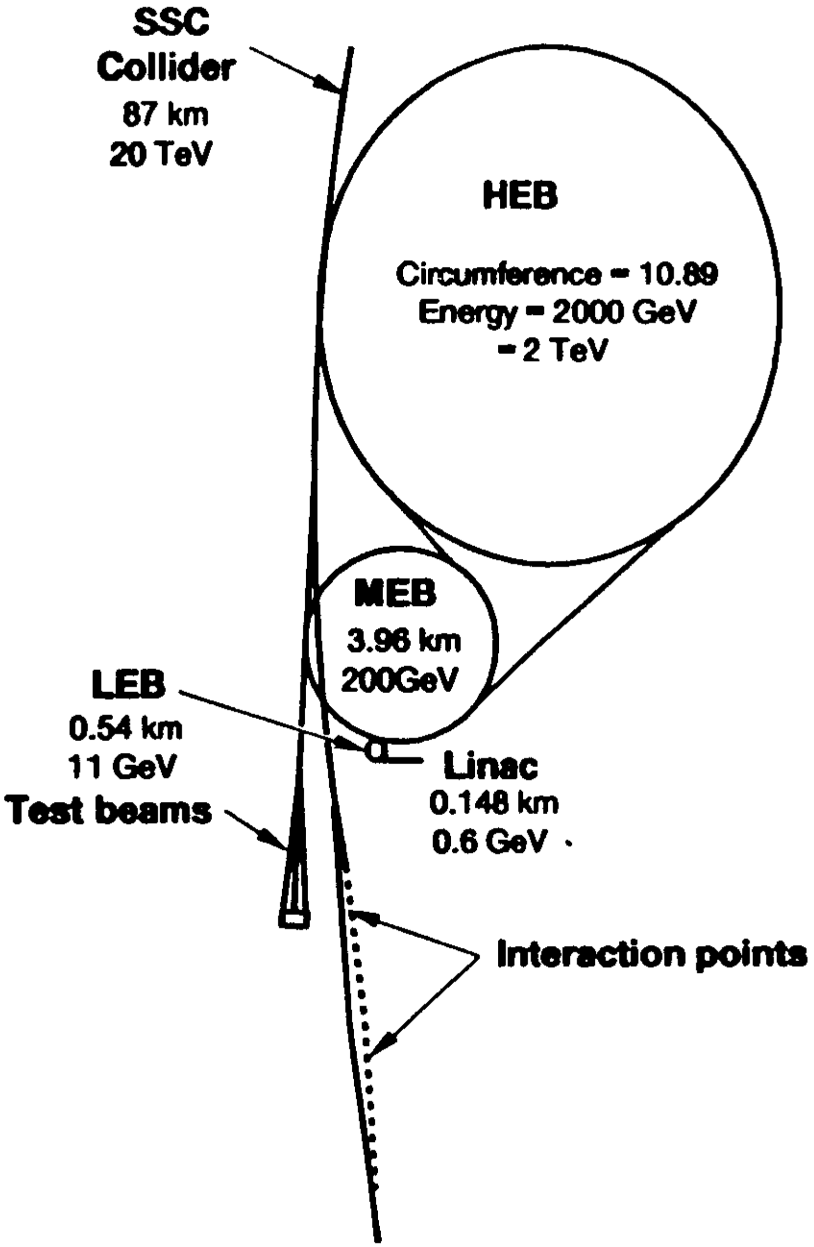
Overall Arrangement of Collider Ring





5 Stages of Acceleration

Linac	0 – 0.6 GeV
LEB	0.6 – 11 GeV
MEB	11 – 200 GeV
HEB	200 – 2000 GeV
Collider	2 TeV – 20 TeV

Schematic layout of the injector complex, a portion of the collider ring and test beam area. The dashed line indicates a future beam bypass.

TIP-[illegible]

H. Edwards, 6/90

SSC Accelerator

Scope

proton-proton collider

20 TeV x 20 TeV

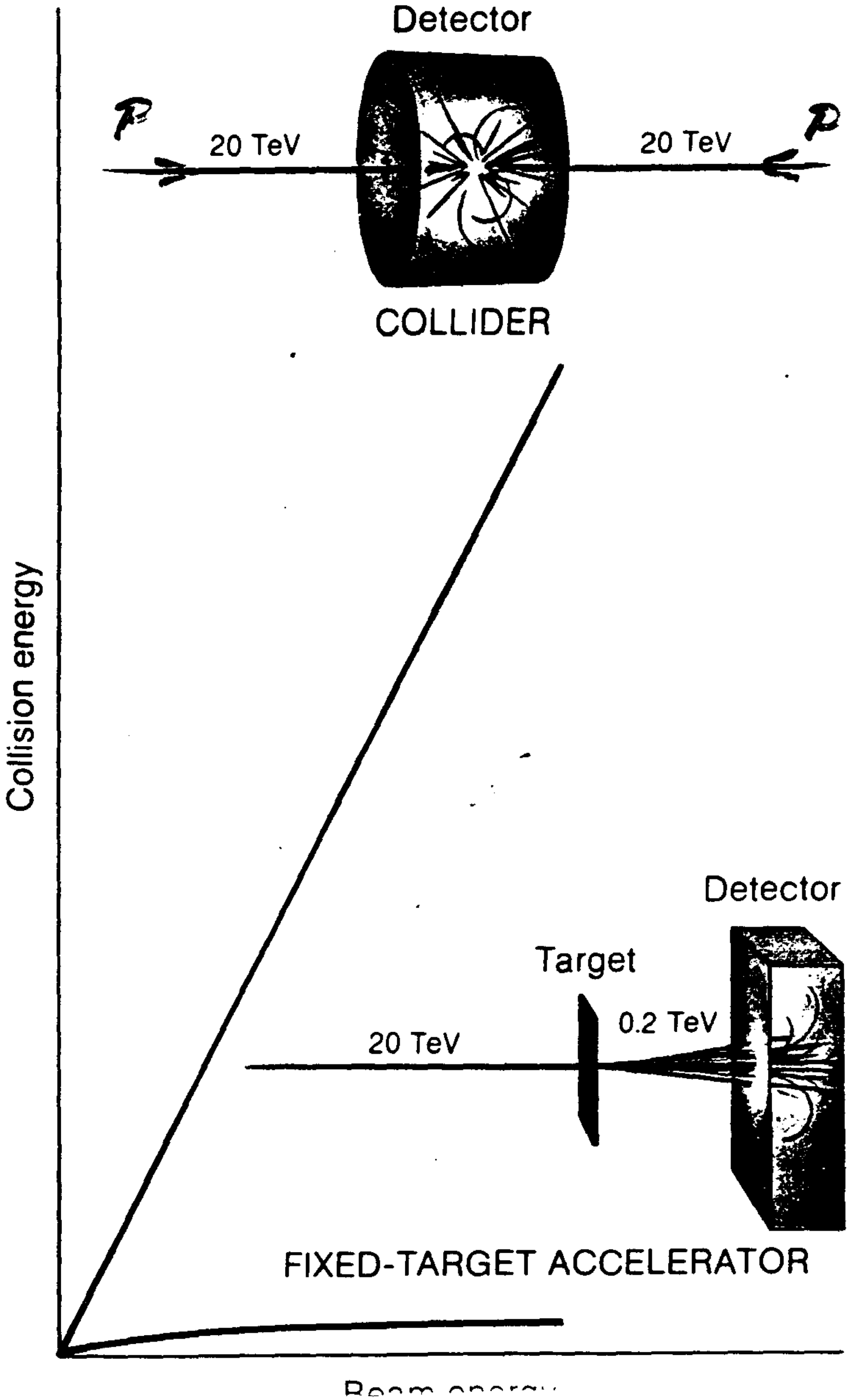
L ≈ $10^{33} cm^{-2} sec^{-1}$

injectors - with energy up to 2TeV

up to four interaction regions

initial set of detectors

Laboratory & infrastructure


Detector
P
20 TeV
20 TeV
P
COLLIDER
Collision energy
Detector
Target
0.2 TeV
20 TeV
FIXED-TARGET ACCELERATOR
Beam energy

C.M. Energy:

Energy available for initiating new elementary processes, creating new particles, and probing subnuclear distances *

Luminosity:

Rate of Occurrence of Process
= Probability of Process
x Luminosity

or

Rate = Cross section x Luminosity

* For Fixed-Target Operation:

$$E_{CM} = \sqrt{2EM_P}$$

E = Beam Energy
M_P = Proton Mass
~ 0.938 GeV

For Colliding Beams:

$$E_{CM} = 2\sqrt{E_1 E_2}$$

If $E_1 = E_2 = E$

$$= 2E$$

SSC Laboratory Goals

Create a premier international laboratory for high energy physics by the year 2000.

Create a major resource for science and education.

Understand the ultimate building blocks of matter and the basic forces which govern the transformation of matter and energy.

Understand electro-weak symmetry breaking.

What is the origin of mass??