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GEM Magnet

Purpose

- Provide magnetic field for muon momentum measurement
- Provide help in separation of electrons from photons
- Separate charges of electrons and muons

Physics performance of the GEM magnet:

- Muon momentum resolution $\Delta p/p = 5\%$ for tracks with $p_T = 500$ GeV/c at $|\eta| < 1.35$

- Muon momentum resolution $\Delta p/p < 13\%$ for tracks with $p_T = 500$ GeV/c at $1.35 < |\eta| < 2.5$

- Momentum resolution in the central tracker $\Delta p/p^2 = 1.15 \cdot 10^{-3}$ (Gev/c)$^{-1}$

- Charge separation
  - up to 600 GeV/c in the central tracker at $\eta = 0$
  - up to 1.25 TeV/c in the central tracher at $\eta = 1.5$
  - up to 6.5 TeV/c for muons at $\eta = 0$
  - up to 15.0 TeV/c for muons at $|\eta| = 2.5$

GEM Magnet

Concept

Large solenoid with moderate field enclosing <u>all</u> detector components

Choice

Superconducting solenoid with no return yoke.

- Resistive magnet technology required high operating cost. (About 20 MW for 0.8 T magnet with return yoke, more without return yoke.)
- Field return is expensive (about $100M for external solenoid or for iron yoke), it is technologically risky (large forces involved) and would take extra year to install.
- Fringe field mitigation presents no major problem

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GEM Magnet

Searches for new particles impose requirements on the muon momentum resolution and charge separation.

- Resolution requirements were not fulfilled by the LOI design with simple solenoid.

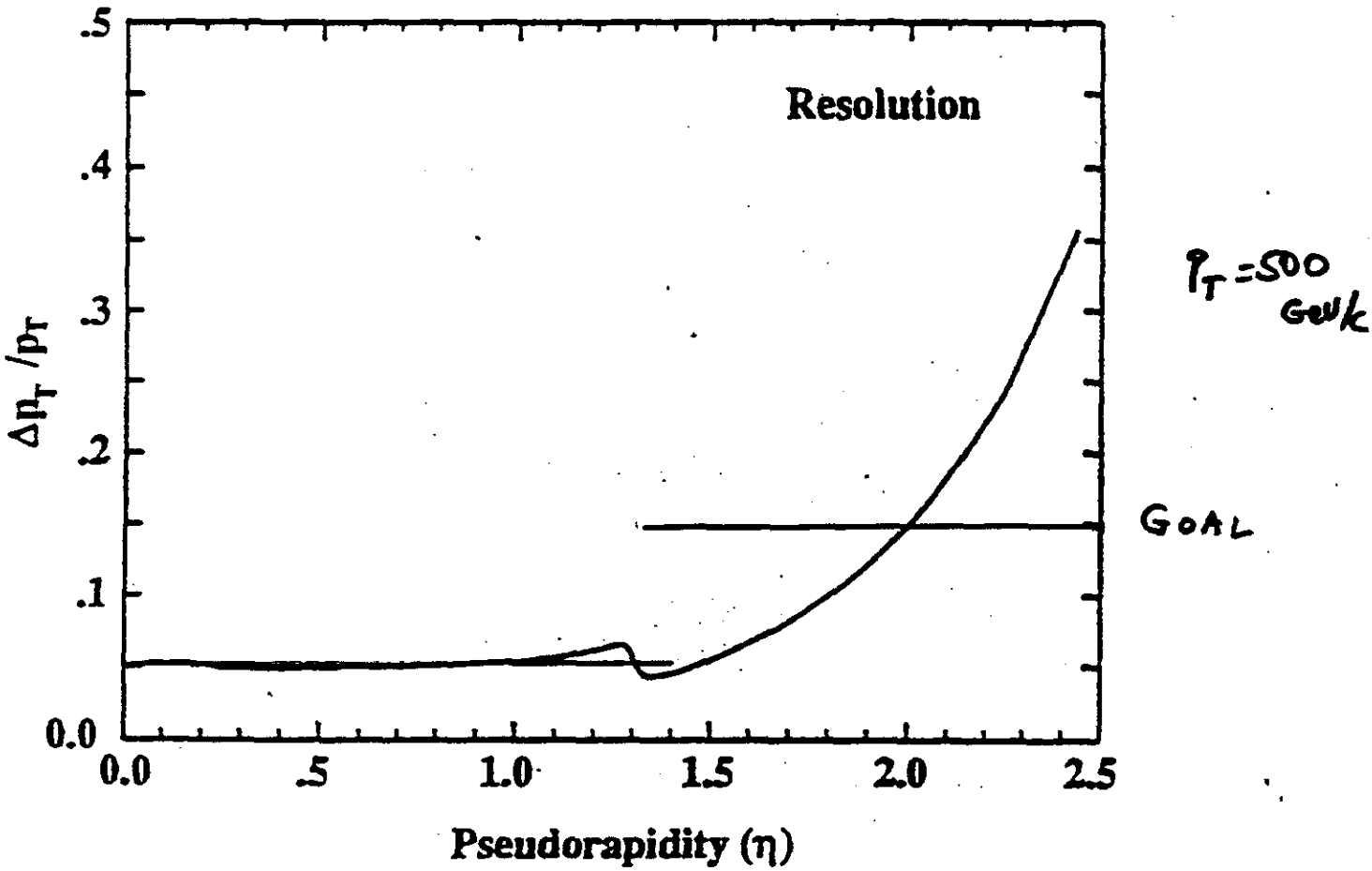
  $\Delta p_T/p_T \sim 40\%$ at $\eta = 2.5$ for $p_T = 500$ GeV/c

- Field modification in the forward region is necessary.

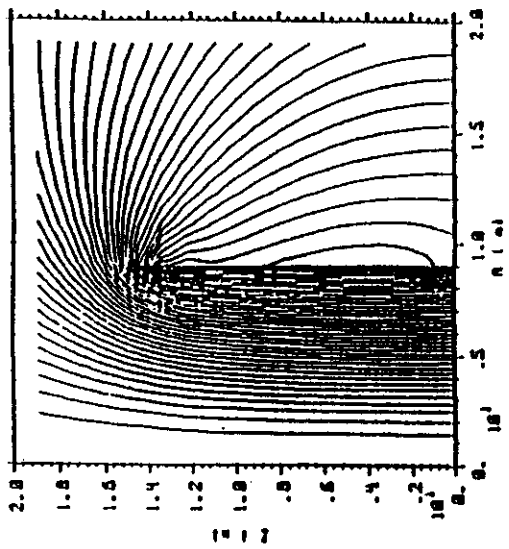
  $\Delta p_T/p_T < 15\%$ at $\eta = 2.5$ for $p_T = 500$ GeV/c.

- Options studied included various poles, pinch coils, opposing field coils etc. Solution chosen consists of a simple, passive iron flux concentrator - Forward Field Shaper.

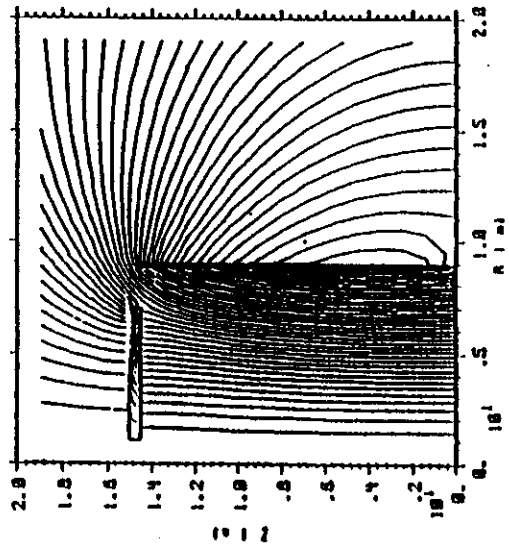
L01


Resolution
$\Delta p_T / p_T$
.5
.4
.3
.2
.1
0.0
0.0
.5
1.0
1.5
2.0
2.5
Pseudorapidity (η)
p_T = 500 GeV/c
GOAL

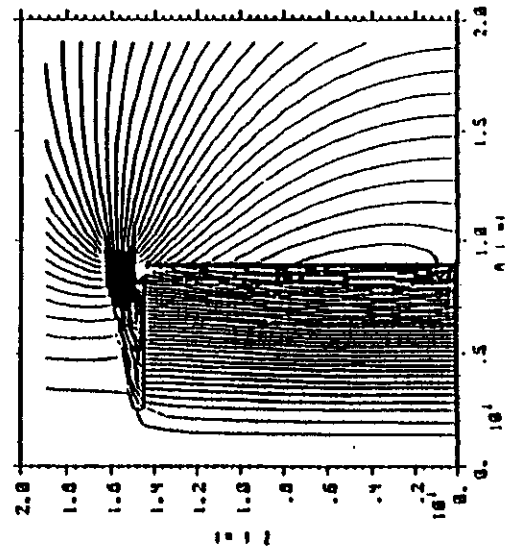
No pole



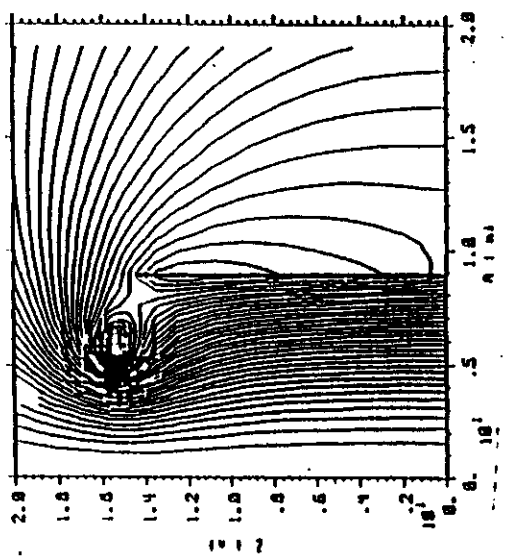
Thin pole



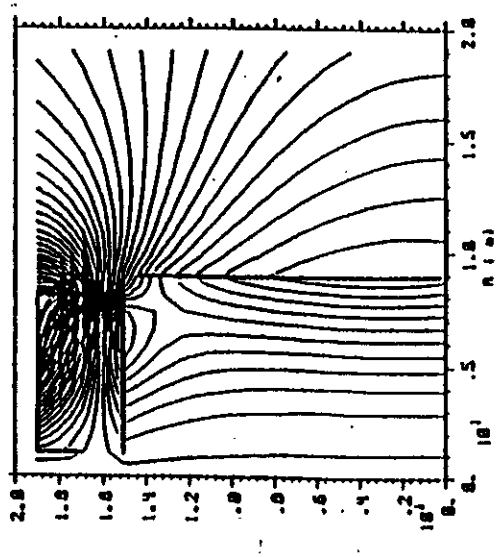
Thick pole



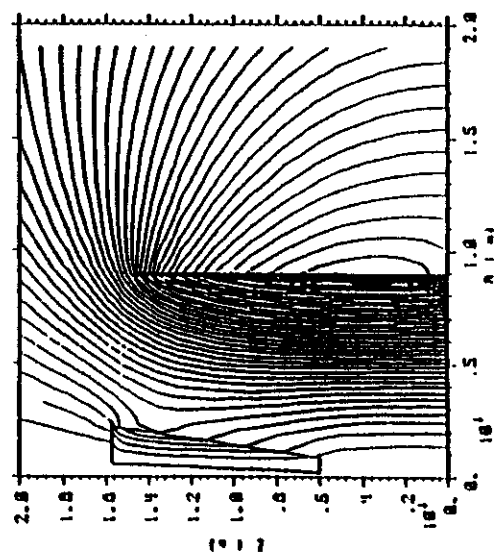
"Pinch" coil



"Opposing-field" coil



Iron cone



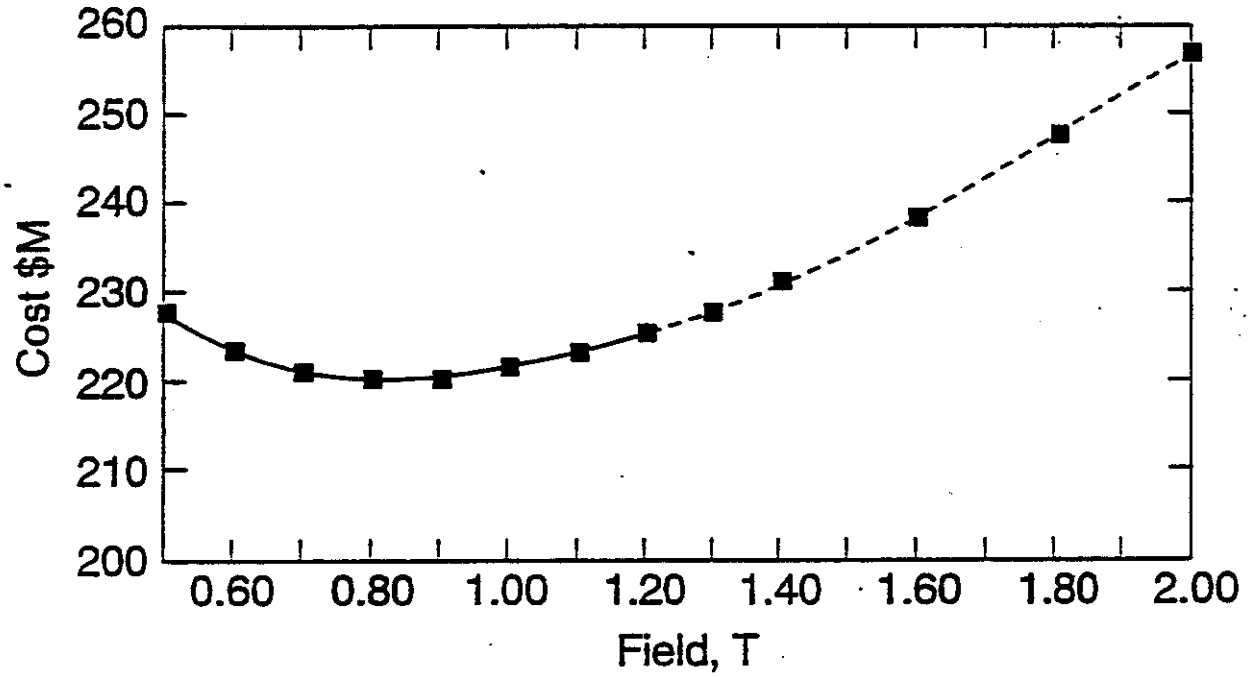
GEM Magnet - optimization

Size and field strength of the magnet were optimized using a parametric model of combined magnet and muon systems.

The model included cost of the magnet components, generic cost of the muon system (number of planes, channel count etc.), realistic alignment criteria, and precision of individual measurements.

Not included in the model but taken into considerations were sizes and costs of experimental hall and support facilities (assembly buildings, shafts, cranes etc.).

- For a fixed momentum resolution in the central rapidity region, there is a broad minimum at a field of about 0.8 T and inner radius of 9.0 m.


260
250
240
230
220
210
200
Cost $M
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Field, T

TIP-04106

GEM Magnet

Dominant aspect of all decisions concerning the magnet is its overall size. It is too large to be built in a factory and shipped to SSCL, it has to be built on site.

Example - choice of the conductor.

- Many choices available: indirectly cooled (Rutherford, Kurchatov) used for HEP magnets, Cable-in-conduit (MIT) designed for plasma fusion devices.
- Selection process included workshop with international participation, comparison of costs and risks, etc.
- Cable-in-conduit conductor with superconducting strands in contact with liquid helium was chosen for the GEM magnet.
  - It has a very large stability margin.
  - It allowes for pretesting of critical components.
  - It reduces sensitivity to small imperfections in manufacturing and winding.

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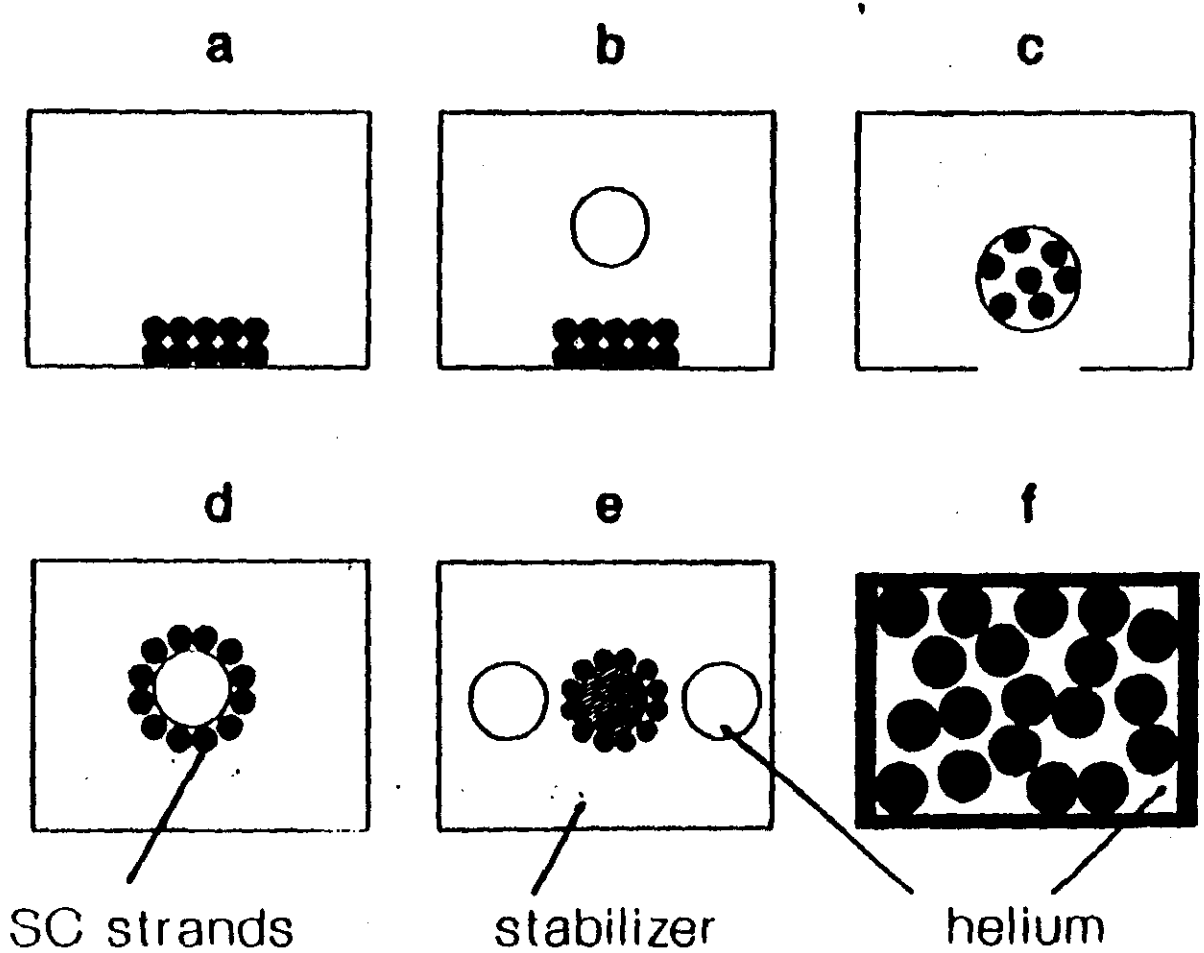
Different types of conductors for the GEM magnet



GEM Magnet - special features

Split coil halves.

- Magnet is too large to be built and lowered into the experimental hall in one piece.
  Split coil halves allow for a free standing central detector support structure (CDS) and access to central detector components.

Mobility

- Coil halves and forward field shapers are independently movable along the beam axis.
  Mobility is needed for initial installation of the magnet.
  It allowes for easy access to all detector components and provides flexibility in installation and access scenarios.

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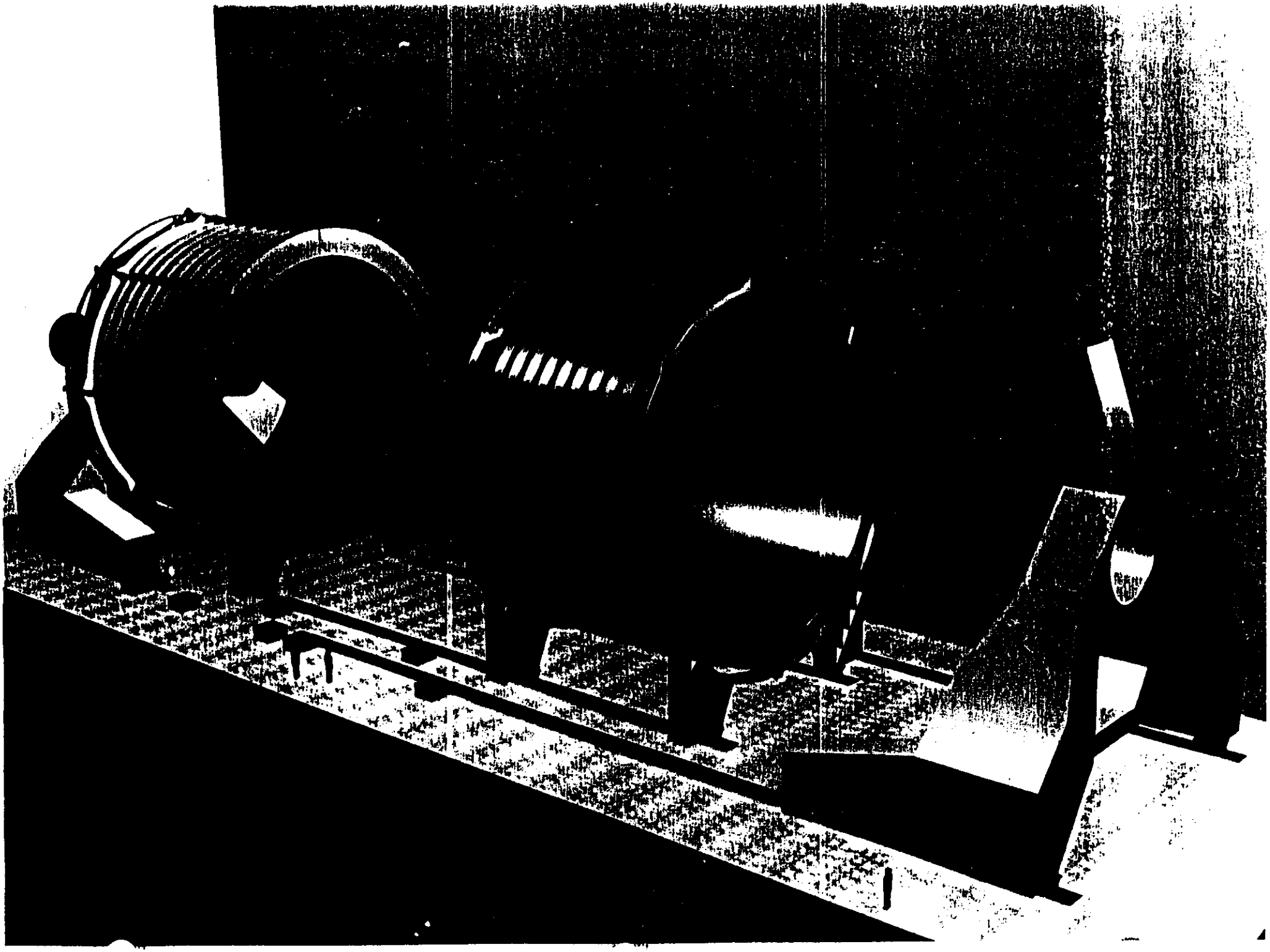


GEM DETECTOR MAGNET SYSTEM

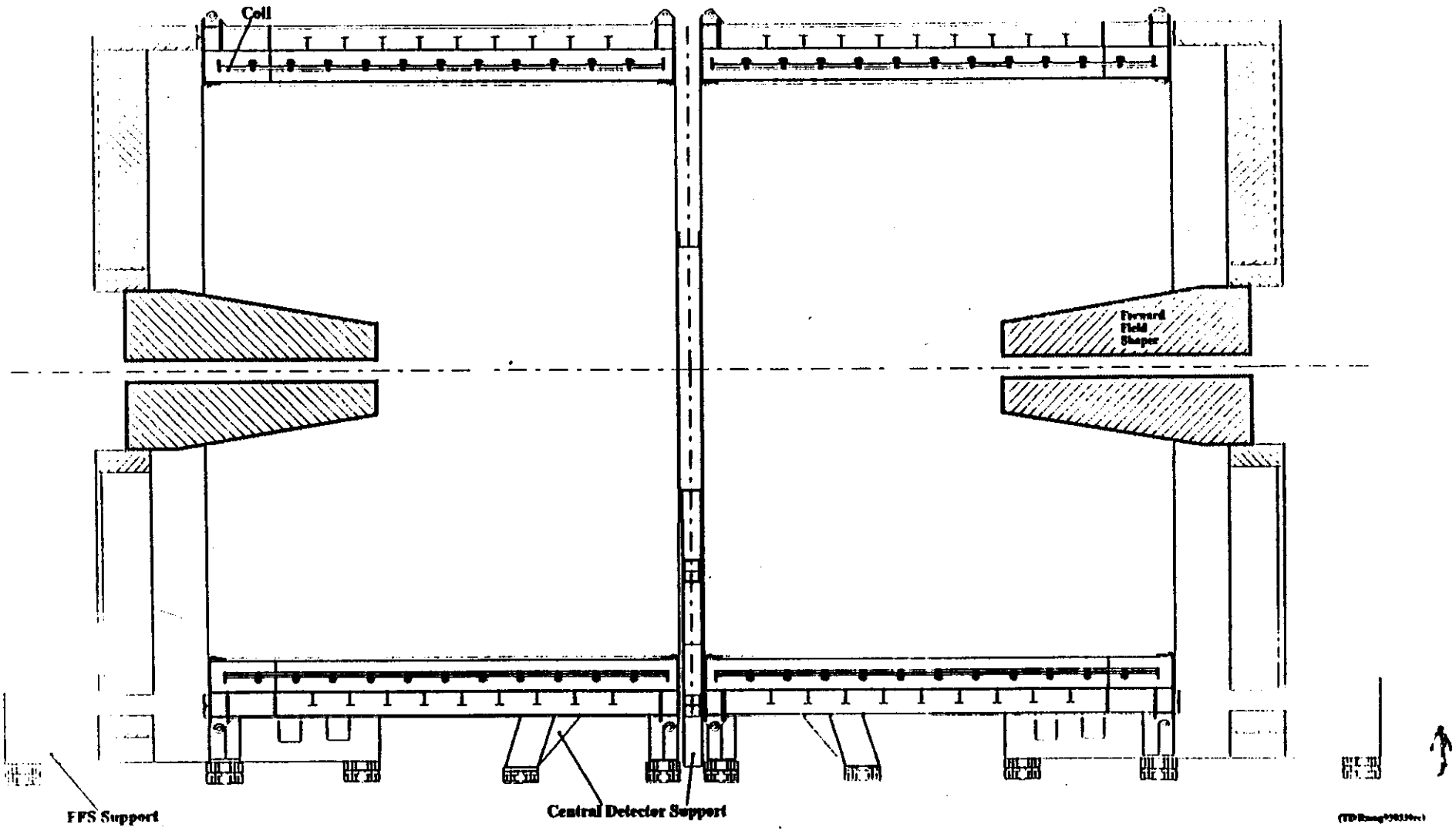
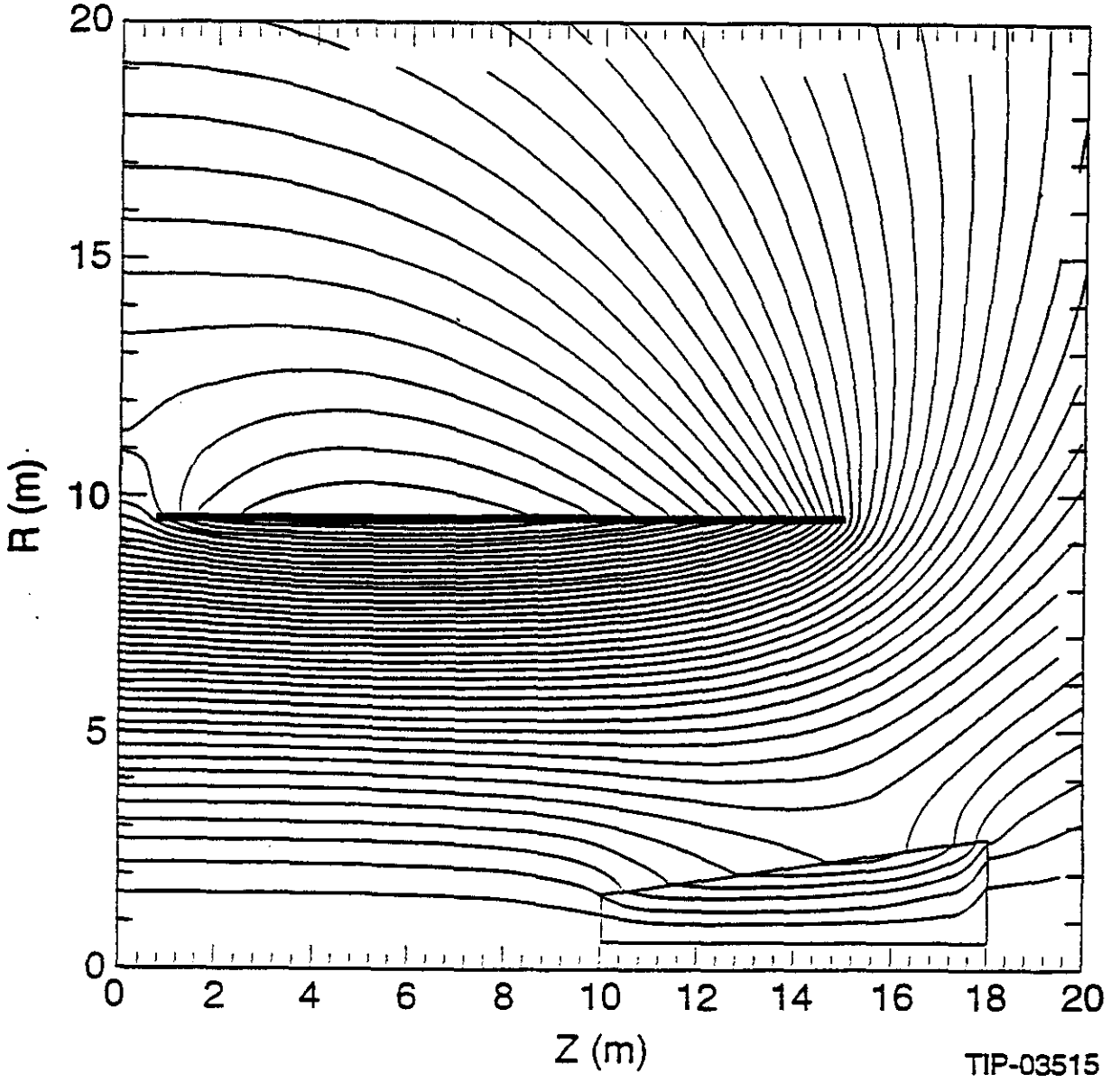


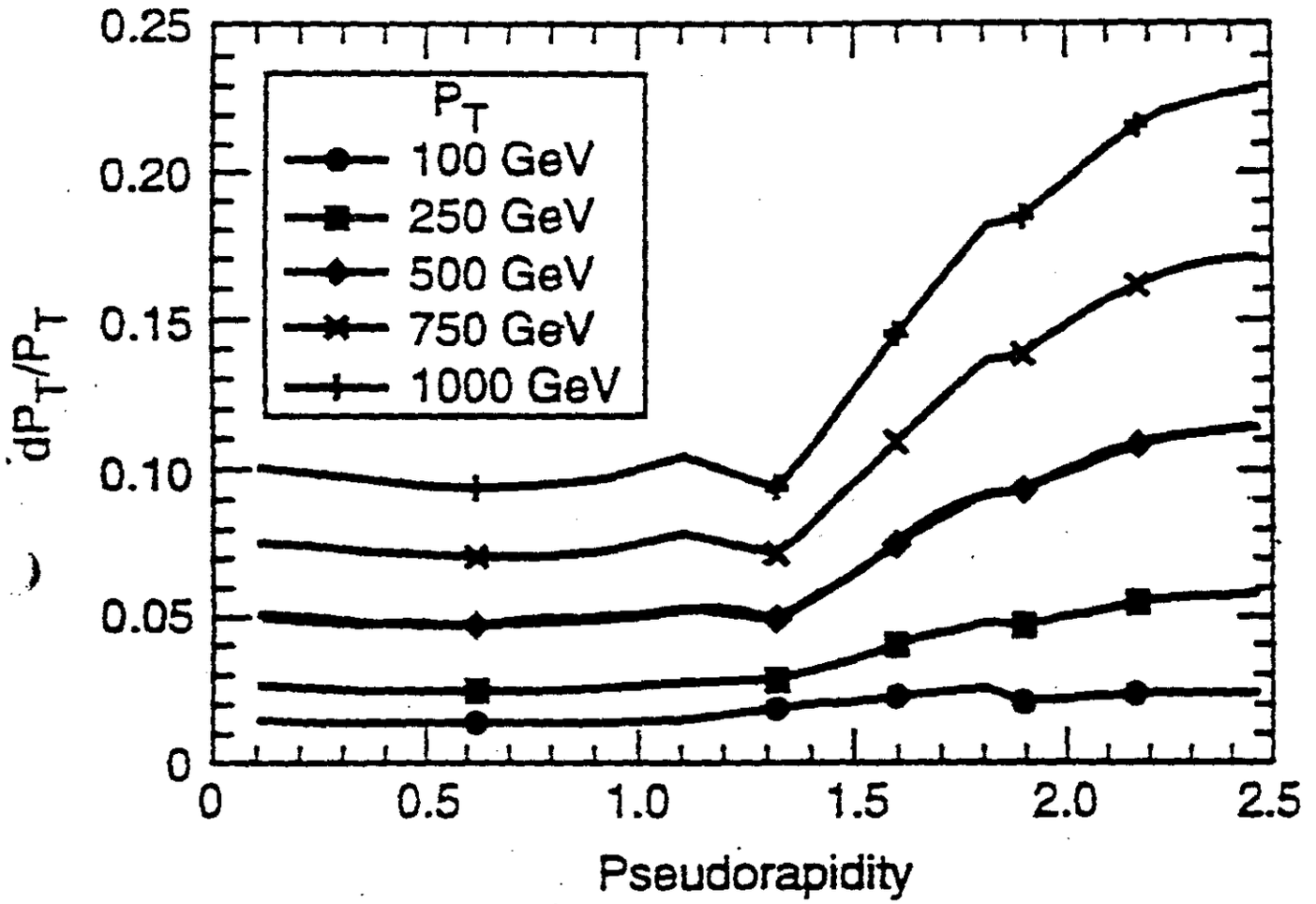
Table 3-2. Major parameter list for the GEM magnet.

Central field	0.8	T
Mean radius of windings	9.5	m
Inner radius of the vacuum vessel	9.0	m
Overall outer radius, including structural ribs	10.9	m
Coil length (per half)	14.25	m
Number of turns (per half)	228	
Central gap between windings	1.5	m
Magnet axis height above floor level at interaction point.	13.0	m
Operating current	50.2	kA
Stored energy	2.5	GJ
Inductance	1.98	H
Total magnet assembly mass (per half)	1500	Mg
Forward field shaper minimum z	10.0	m
Forward field shaper maximum z	18.0	m
Forward field shaper included angle	18.8°	
Forward field shaper mass (each)	1265	Mg
Charge time	8	h
Dump time constant	100	s

Table 3-3. Cold mass parameters.

Mean radius of windings	9.5	m
Cold mass length (per half)	14.25	m
Conductor length (total)	27 219	m
Conductor and insulation mass (per half)	158 000	kg
Mass of 4 K structure (per half)	525 000	kg
Operating current	50 200	A
Stored energy	2.5	GJ
Inductance	1.98	H
Number of turns (per half)	228	
Peak voltage to ground	500	V
Turn insulation thickness	1.25	mm
Ground insulation thickness	6	mm

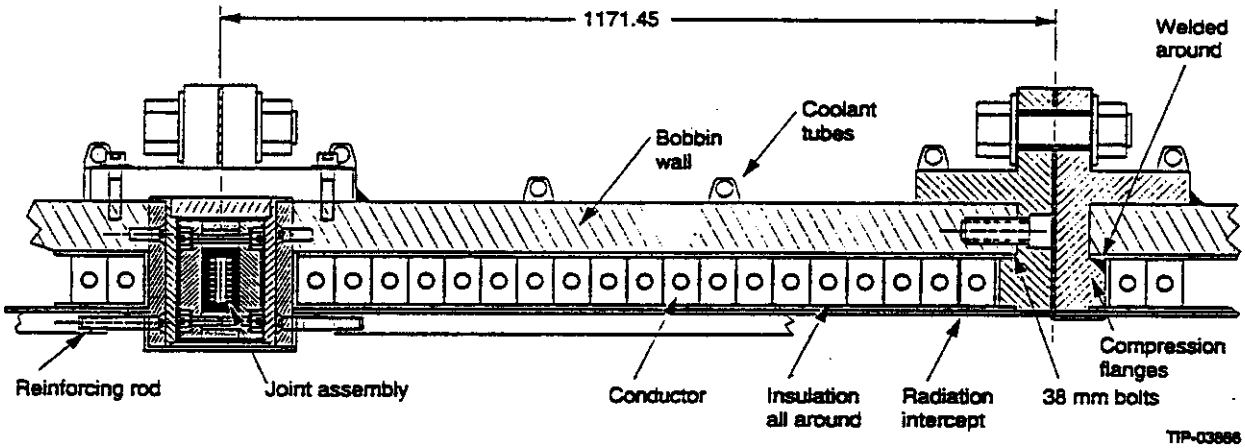

20
15
10
5
0
R (m)
0
2
4
6
8
10
12
14
16
18
20
Z (m)
TIP-03515


0.25
0.20
0.15
0.10
0.05
0
dP_T/P_T
P_T
100 GeV
250 GeV
500 GeV
750 GeV
1000 GeV
0
0.5
1.0
1.5
2.0
2.5
Pseudorapidity

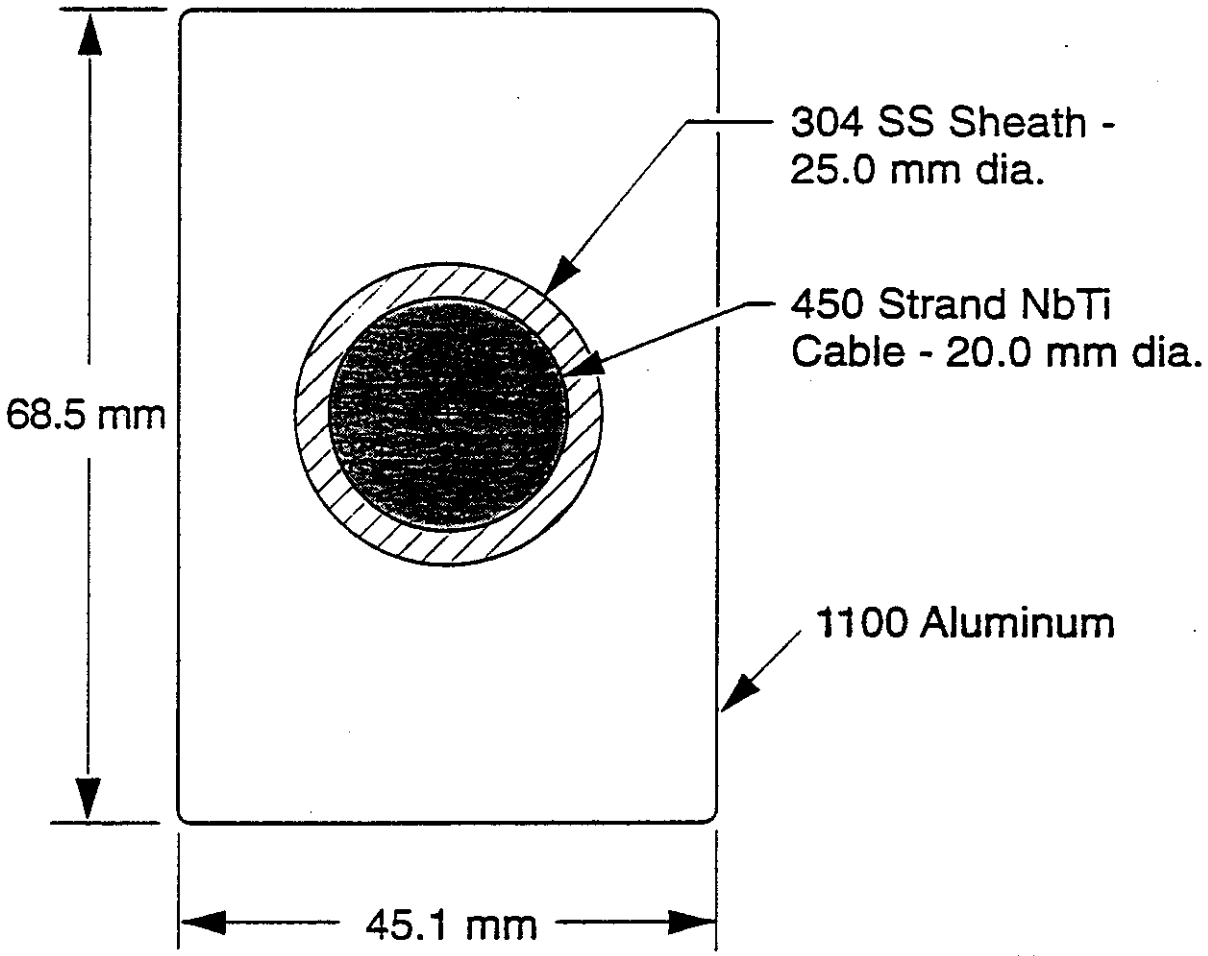
GEM Magnet

Design:

- Each coil half consists of 12 sections of windings (19 turns each) on the inside of the aluminum bobbin.
- Sections are joined mechanically (flanges) and electrically (conductor joints).
- Conductor consists of 450 NbTi-copper twisted strands enclosed in a 2cm diameter stainless steel tube. Conductor sheath is made from aluminum.
- Conductor joints are resistive with separated cooling system.
- Coil is supported by "radial" rods attached to end flanges and by axial flexures. The support preserves the alignment of the coil and counteracts the magnetic forces.
- Thermosiphon provides cooling for the bobbin, conductor and joint circuits.

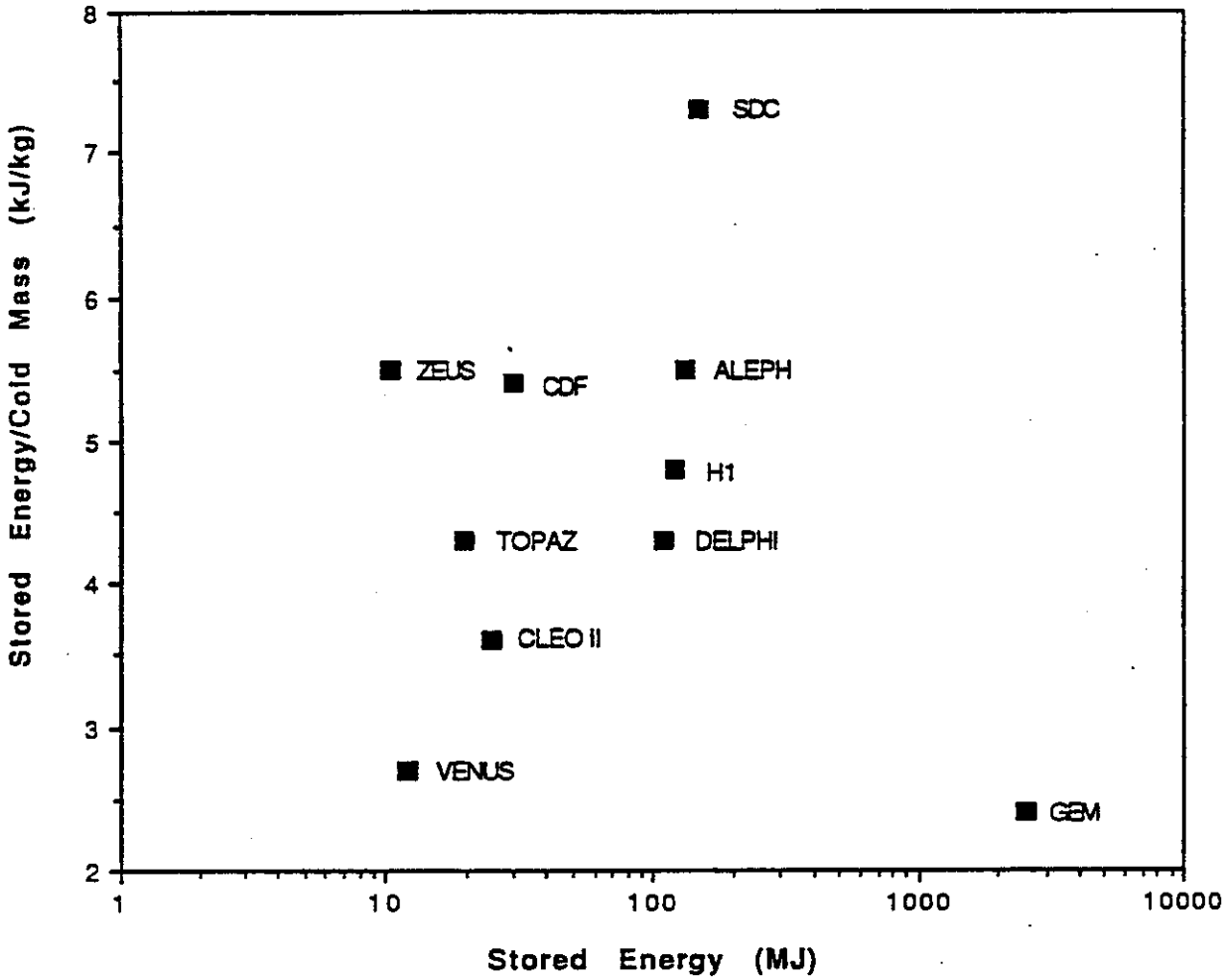

1171.45
Welded around
Coolant tubes
Bobbin wall
Reinforcing rod
Joint assembly
Conductor
Insulation all around
Radiation intercept
38 mm bolts
Compression flanges
TIP-03866

beam axis


304 SS Sheath -
25.0 mm dia.
450 Strand NbTi
Cable - 20.0 mm dia.
68.5 mm
1100 Aluminum
45.1 mm

TIP-03753

All dimensions in mm


Stored Energy/Cold Mass (kJ/kg)
8
7
6
5
4
3
2
SDC
ZEUS
CDF
ALEPH
H1
TOPAZ
DELPHI
CLEO II
VENUS
GEM
1
10
100
1000
10000
Stored Energy (MJ)

	Field, T	Bore Diameter, m	Length, m	Stored Energy, Mj	E/m, kJ/kg
CDF	1.5	2.86	5.07	30	5.4
TOPAZ	1.2	2.72	5.40	19.5	4.3
VENUS	0.75	3.40	5.64	12	2.7
CLEO II	1.5	2.90	3.80	25	3.6
ALEPH	1.5	5.00	7.00	130	5.5
DELPHI	1.2	5.20	7.40	109	4.3
H1	1.2	5.20	5.75	120	4.8
ZEUS	1.8	1.72	2.85	10.5	5.5
SDC	2.0	1.70	8.72	146	7.3
GEM	0.8	18.00	28.50	2500	2.4

GEM Magnet - organization

Design team:

- Talented experts from LLNL/MIT/SSCL+Y12

Consulting:

- Rutherford-Appleton Laboratory/Kurchatov Institute/ABB and others.

Reviewing:

- Internal reviews - LLNL/MIT/SSCL
- External reviews - industry

Conceptual design is complete, work on the preliminary design is progressing.

Management team is in place.

- Paul Reardon - Magnet Project Manager (extensive experience in large and successful projects)
- Gary Deis - Magnet Project Chief Engineer
- Experts from SSCL/MIT/LLNL - subproject managers and technical overseers.

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Requests for proposals to the industry were sent out in March. Bids were received in April and are evaluated by Source Selection Board appointed by SSCL.

We feel that the proper action on the magnet is to move forward with the indstrial participation.

- Industry involvement is crucial for development of the production processes.
- Excellent team has been assembled.
- Magnet is on the critical path of GEM. The construction facilities are for multipurpose use and magnet has to be finished before the assembly of calorimeters and muon systems. Early verification of the design by industry is necessary.

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5/21/91