GEM TN-92-50
GDT-000012

GEM Muon Meeting
SSCL

November 8, 1991

Abstract:

Agenda, list of participants and transparencies contributed to the Muon Meeting held at the SSCL on November 8, 1991.

11/8/91 GEM MUON MEETING

NAME	E-MAIL	PHONE
Orrin Fackler	FACKLER@NEU.LLNL.GOV	(510) 423-1766
Frank Taylor	MITLNS::FET	(617) 253-7249
Louis S. Osborne	OSBORNE @MITLNS	(617) 253-2398
Richard Todd	TODDRA@VLSI01.IC.ORNL.GOV	(615) 574-5650
Robert Miller	MILLER@MSUPA	(517) 353-1697
Craig Wuest	WUEST@LLNL.GOV	(510) 423-2909
Chiaki Yanagisawa	SBHEP::CHIAKI CHIAKI@SBHEPNY	(516) 632-8295
Mohammad Mohammadi	SBHEP::MOHAMMADI	(516) 632-8107
Luis Villasenor	VILLASENOR@SSCVX1	(214) 708-6209
Gena Mitselmakher	MITSELMAKHER@SSCVX1	(214) 708-6001
Frank Stocker	STOCKER@SSCVX1	(214) 708-6025
Trivan Pal	TRIVAN@CERNVM	
Brian Smith	BSMITH@SSCVX1	(505) 665-2666
Emmitt Nelms/ASD		(214) 708-3009
Coleman Johnson	JOHNSON@TROY.LLNL.GOV	(510) 422-8748
Carl Bromberg	BROMBERG@MSUPA	(517) 353-1809
Kwong Lau	LAU@UHOU	(713) 749-4385
George Yost	YOST@SSCVX1	(214) 708-6028
Vinnie Polychronakos	POLYCHRON@BNLDAG	(516) 282-3982
Steve Ahlen	AHLEN@BUPHYC	(617) 353-8940
A. Vaniachiae	VANYASHIN@SSCVX1	(214) 708-6211

Muon Group Meeting - Nov. 8, 1991

1) R+D Status - Ahlen (15 min)

2) LoI Status - Taylor (15 min)

3) Engineering - Nimblett (30 min)

4) Texas Test Rig - Mitselmakher (30 min)

5) 10 min updates on plans for:

   PDT (Ahlen)
   LSDT (Osborne)
   CSC (Polychronakos)
   RPC (Wuest)

11:30 - Separate into subgroups (PDT, LSDT, CSC, RPC, LSM, ENG) to begin modifying R+D plan

2 PM - Reconvene to discuss R+D proposal and simulations (McNeil)

Ahlen

[redacted]

MUON GROUP R+D PROPOSAL

Original Requests:

ENG (2.7M), PDT (613k), LSDT (680k),
RPC (739k), CSC (799k), LSP (350k)

$5.9M

Barish's Oct. 3 PAC presentation:

MAGNET	6M
CALORIMETRY	6M
MUONS	3M
TRACKING	1M
ELECTRONICS	1M
COMPUTING	
	17M

SA/FT Modifications:

ENG (700k), PDT (500k), LSDT (600k)
RPC (531k), CSC (785k), LSP (350k)

3.47M

Morning of Nov. 7

MAGNET	6.2 M
CALORIMETRY	7.8M
MUONS	3.5M
TRACKING	1.3M
ELECTRONICS	0.9M
COMPUTING	0.1M
INTEGRATION	1.0M
	20.8M

Now expectations are:

SSC Lab	$\lesssim$ 10M
TNLRC	$\lesssim$ 5M
SSC Integration	$\lesssim$ 1M

NEED TO CUT AT LEAST 4.8M !!

R+D Meeting, Evening of Nov. 7

	REQ	PLAN A	THE END	PAC	
MAG	6.2	5	5	6	(83%)
CAL	7.8	4.6	4.6	6	(77%)
μ	3.5	2.5	2.7	3	(90%)
TRACK	1.3	1.2	1.1	1	(110%)
ELEC.	0.9	0.8	0.8	1	(80%)
COMP.	0.1	0.1	0.1		
RESERVE		0.8	0.7		
	19.8	15	15	17	

SUGGESTED BREAKDOWN *

		ORIGINAL REQUEST	
PDT	400	(613)	65%
LSDT	500	(680)	74%
RMC	300	(739)	41%
CSC	550	(799)	69%
LSP	250	(350)	71%
ENG	700	(2.7M)	26%
	2.7M		

* R+D group was most concerned that ENG was too low (they'd be happier if
(1) RMC work descoped/delayed
(2) Decision on DT's now
(3) All one technology, for barrel + endcap)

10 page R+D request for muon system due Nov. 21.

- Each subgroup needs to write 2 page description of R+D plan consistent with final breakdown, including a separate page for detailed budget These should get to Ahlen by Nov. 14 !!!

- Also - a separate page with text and budget for development of electronics beyond preamp and shaper - this will be examined by electronics group

GUIDANCE ON R+D PLANS / BUDGETS

① We must be project oriented;

- Focus sharply on goals necessary for development of muon system
- Only equipment required for prototypes will be permitted (except SSC L)

② Before funds are allocated, all R+D plans will be very closely scrutinized by GEM management

- Optimize work done by national labs
- Check for double counting
- Avoid "diluted" R+D tasks
- Avoid set up of labs other than at SSC (equipment should eventually appear at SSC for LSP work)

1.0 INTRODUCTION AND OVERVIEW

2.0 GEM DETECTORS

2.1 Hall and Surface Facilities

2.2 Magnets

2.3 Muons

2.3.1 Introduction

The detection and momentum analysis of muons provide a important access to rare and potentially important physics at the SSC. Reactions where the muon system can contribute are: Higgs scalar production, production of sequential Z bosons,gauge boson scattering, high mass Drell-Yan process, technicolor, and SUSY. The expectation is that all of these processes, if real, will occur at a low rate.

To gain access to this important physics the GEM Muon System will furnish the following: (1) muon identification, (2) charge assignment, (3) Pt trigger - both Levels 1 and 2, (4) beam crossing time marker, (5) muon momentum determination from a few GeV/c to a few TeV/c.Muons, as distinct from electrons, photons and hadrons, are unique in their great penetrating power, providing a distinct advantage in carrying out searches for new physics at the SSC. With sufficient material in the electro-magnetic and hadron calorimeters, particle rates in the muon system are low enough to enable triggering and momentum measurements to be made reliably with luminosities at the $10^{34}/cm^{2}$-s level. The GEM muon system is designed to detect muons over nearly full solid angle coverage with high precision measurements of muon momentum.

Our design goal of a muon system with large background rejection and good momentum resolution, which can be triggered selectively on large transverse momentum muons, requires that the muon detection elements be placed outside the hadron calorimeter. Figure 2.3-1 shows a schematic of the GEM muon system. Muon chambers are located in three superlayers between the calorimeter and the magnetic coil or endplate in both the central and endcap regions. The amount of material within the muon tracking system is kept to a minimum so that multiple scattering is small. A trigger based on transverse momentum of the muon is generated by trigger chambers located in each of the three superlayers. Thus the GEM muon system is complementary in concept and operating characteristics to that of the SDC detector.

The following table summarizes the baseline design of the GEM Muon System.

Table 2.3-1: Configuration of GEM Muon System*

Dimensions of solenoid:		
Length of magnet		29m
Inside diameter of magnet		16.6m
Calorimeter length		10m
Calorimeter diameter		7.4m
Calorimeter thickness at 90 degrees		12 λ
Uniform magnetic field		0.8 T
General characteristics of muon chambers:		
Intrinsic single layer resolution		100 um
Layer-to-layer within a superlayer		25 um
Superlayer-to-superlayer		25 um
Global alignment systematics		200 um
An 8 layer superlayer is <10% Xo.		
Barrel region:		
Angle region: 30 to 90 degrees ($1.32>\eta>0$)		
For momentum reconst. and Lvl.. 2 trigger:		
Three superlayers:	Bend plane	8-16-8 layers
	Nonbend plane	2-4-4 layers
Channel segmentation		3cm
Channel count:	Bend plane	225 k
	Nonbend plane	25 k
For Level 1 trigger:		
Three superlayers:	Bend plane	2-2-2 layers
	Nonbend plane	2-2-2 layers
Channel count:	Bend plane	18 k
	Nonbend plane	21 k
Endcaps:		
Angle region: 10 to 30 deg. ($2.44>\eta>1.32$)		
For momen. reconst. and Lvl 1 & 2 trigger:		
Three superlayers:	Bend plane	4-4-3 layers
	Nonbend plane	2-2-2 layers
Channel segmentation		5 um
Channel count:	Bend plane	231 k
	Nonbend plane	21 k

*** All quoted values are considered "typical", and are not to be taken as the final design.**

Momenta are reconstructed by the SAGITTA METHOD in which the sagitta is related to the momentum of the muon by the relation for a trajectory at 90 degrees to beam: $S = 0.3\ B\ L^2/8p$, where L is the length traversed in the magnetic field of magnitude B, and p is the muon momentum. In order to achieve good momentum resolution, the sagitta must be made as large as practically possible. Thus $B\ L^2$ is the term to maximize and a large radius magnet of moderate field can provide a high resolution.

Various studies have been done to determine, based on physics criteria, the technology independent specifications for the GEM muon system.

(a) Momentum resolution. In order to evaluate the physics requirements on the momentum resolution, we find it convenient to parameterize

the muon momentum resolution, dp/p, as dp/p = ap + b, where the "+" symbol denotes addition in quadrature. The "b" term, dependent on multiple scattering in the middle module and pseudorapidity, limits the resolution at low momentum. The "a" term, which depends primarily on pseudorapidity, is determined by systematic alignment errors and module spatial resolution (for a given magnetic field and tracking lever arm). This term limits high momentum measurements.

Low momentum specification for muon measurement come from consideration of the intermediate mass Higgs search (140 < MH < 180 GeV/c*c) through the process H -> ZZ* -> 4 muons, which is expected to have a very small line width. To achieve clean detection of the Higgs through this channel we require for the discovery process N(signal)/N(background)**.5 > 6, implying that b < 1%. Thus the number of radiation lengths in the middle superlayer must be less than or equal to 10%. Figure 2.3-2 illustrates the point.

For large momentum, the most stringent constraint for resolution arises from the requirement of being able to assign charge to each of the two muons from the decay of a Z', so that accurate measurements of the forward/backward asymmetry can be made. As statistics limit Z' searches even at the highest luminosity, only a small fraction of decay muons should be allowed to have charge misidentified, implying dp/p < 30% for about 3 sigma confidence level charge assignment. The heaviest Z' accessible at the SSC has mass of about 6 TeV/c*c, implying that a = dp/p^2 < 30%/3000 GeV = 1.0 x 10**(-4)/GeV.

Several things contribute to the momentum resolution in an actual system. There is the intrinsic muon chamber spatial resolution, the alignment errors, and the multiple scattering smearing. Given the baseline design outlined in Table I, the momentum resolution as a function of angle and momentum for the baseline muon system is shown in Figure 2.3-3. At 90 degrees dP/P = 4.5 % for p = 500 GeV/c. With the parameters as indicated we find that over most of the momentum range, the resolution is limited by the spatial resolution of the tracking chambers. Note that for η < 1.3, the multiple scattering limited resolution is about 1%. Note also that the charge sign can be determined at the 4 to 7 sigma level for 1 to 3 TeV/c muon.

Various improvements to the resolution can be effected at relatively low cost. For example, the vertex can be constrained in the fits to the muon trajectory which results in an improvement for high energy muons in the TeV range. The resolution can be further improved by adding muon tracking chambers external to the coil in the central region In addition, the B-field can be shaped to give larger radial component in the endcap region While we believe that our baseline performance i quite good, we are evaluating these enhancement in terms of cost versus benefit. It is a characteristi of our open field solenoid design that suc improvements can be made.

(b) Rapidity coverage. In order to obtain goo statistics for the Higgs to 4 muon channel (eithe through ZZ* or ZZ channels) requires good soli angle (i.e. pseudorapidity) coverage for the muo chambers. The goal is to maximize N(sigma) = N(signal)/N(background)**.5. From our studies o Higgs production and detection we found tha N(sigma) is roughly constant, having the value o about 6, for maximum rapidity of about 2.5. And rapidity coverage of -2.5 < η < 2.5 provides greate than 90% acceptance for a 4 TeV/c*c Z' and eve greater acceptance for a heavier Z'. (See Fig. 2.3-4.

(c) Chamber Occupancy. We take as a desig goal to limit the occupancy at $10^{34}/cm^{2-s}$ belov 1%, in order to guarantee the unambiguous muo track finding efficiency at nearly 100%. From ou detailed simulations, the inner muon chamber hi rate is about 3 Hz/cm^2 at 10^{34} in the barrel. Figur 2.3-5 shows the rate as a function of η for the inner middle and outer modules, assuming 12 λ in th barrel calorimeter, and 14 λ in the end ca calorimeter. For a 4m by 3cm diameter drift tube with a 1 microsecond maximum drift time, th occupancy would be 0.4% in the barrel. In th endcap region, the rate increases to about 15(Hz/cm^2 in the inner modules at η = 2.5. For a on meter long and 5mm wide cathode strip chamber having integration time of 1 microsecond, th occupancy would be less than 1%.

Such occupancies are a hundred times lowe than would be the case for tracking element located inside of the calorimeter. Benefits of th relatively low rate outside the calorimeter extend t triggering as well. Figure 2.3-6 shows that the rat of muons above 5 GeV/c is a factor 100 lower tha the total muon particle rate, implying that the P muon trigger is not seriously challenged by th background.

(d) Pattern Recognition Capability. The mos reliable way to tag a b-jet is through inclusive muo detection: b -> muon + x, where the muon is ver near (within) a hadronic jet. The major backgroun comes from hadron punch-throughs. To reject suc background, an inner tracker is required to provid redundant momentum measurements to match th exterior muon tracks. Based on simulations o heavy top quark searches, we have found tha

satisfactory background suppression requires 85% of the punch-through events to be rejected to eliminate fake muons (pt > 5 GeV/c). Detailed studies, including consideration of matching tracks inside the calorimeter with those outside, have shown that a momentum resolution of 1 x 10**(-3)/GeV is required for the central tracker.

(e) Energy Loss in the Calorimeter. Proper correction of muon energy loss in the calorimeter is very important for high energy muon measurements. As shown in Figure 2.3-7, the high energy muon loss spectrum has a significant high energy tail due to muon radiation processes. One requirement for the calorimeter is the ability to satisfactorily measure this energy loss to permit muon measurement accuracy at the level specified in the first section above. Another requirement of the calorimeter is that it provide adequate shielding for the muon system. Figure 2.3-8 shows the sensitivity of particle rate in the muon system to calorimeter thickness. To preserve a conservative safety margin regarding particle rates in the barrel, even at the highest luminosities, requires at least 12 λ for the barrel calorimeter.

2.3.1 Description of Technologies:

In this section we discuss the technology options we are considering for the final design of the GEM muon system. These technologies were considered in a recent GEM internal review to be worthy of further R&D. For the central (barrel) region pressurized drift tubes (PDT) and limited streamer drift tubes (LSDT) are being investigated for the muon momentum reconstruction and Level 2 trigger. In the central region the Level 1 trigger and the beam cross tagging will be provided by resistive plate counters (RPC). For the endcaps, cathode strip chambers (CSC), operated in the proportional mode, seem to be the most attractive candidate technology. These chambers can be adapted to the radial geometry of that region and will also provide both the muon reconstruction as well as the beam tagging and Levels 1 and 2 trigger signals.

(a) Pressurized Drift Tubes. Pressurized metal wall tubes, with drift time measurement, have been used successfully in the past in large solenoidal magnetic fields as precision tracking devices at both proton-antiproton and electron-positron colliders.

The symmetry of cylindrical tubes, operated with axes parallel to the magnetic field, enables precise tracking due to the simple electric field configuration and the independence of the time-to-distance function on angle of incidence. Furthermore, the cylindrical geometry of tubes enables improvement of resolution through pressurization as 1/P**.5 by the reduction of the diffusion coefficient, and improved statistics of cluster formation.

The GEM PDT's would be aluminum tubes with 300 micron wall thickness, and about 3cm diameter. A possible configuration of the tubes would be for the inner and outer modules each to consist of 8 layers of staggered tubes, and the outer modules to have 4 staggered layers. The number of radiation lengths in the central modules would be 8.5% X0, consistent with the technology independent specifications of the muon system (so as not to degrade the H to ZZ* peak). This configuration is based on an estimate of cost-versus-resolution optimization.

The PDT alignment philosophy is based on accurate placement of wire ends relative to end plate fiducials. Accurate alignment can be achieved with precision machined reference end plates, and precision fabricated end plugs, pins and ferrules. The PDT design does not utilize wire bridges inside the tubes. It is believed that greater alignment precision is possible by calculating wire position from resonant frequency measurements which provide the ratio of wire tension to wire radius squared, exactly the quantity needed to calculate sag. Such measurements can be made non-invasively with current-magnetic field excitation, and phase shift analysis. Wire holding through crimp and solder techniques will enable long term stability. Measurements have been made by GEM members which have demonstrated that wire position can be predicted correctly within a few microns (for 4m wire tensioned at 80% of the yield strength, sag will be about 230 microns, with an electrostatic component of about 3 microns). At the sector level, alignment will be achieved with straight-line monitoring techniques such as have been utilized successfully at L3.

(b) Limited Streamer Drift Tubes System. The chambers are envisaged as rectangular boxes containing multiple layers (4) of wires each running through its own U-profiled cathode operated in the limited streamer mode. The positioning of the wires is achieved by supporting them on accurately machined insulating bridges running across the width of the chamber and through slots in the cathode at this support point. The bridge, in turn, is held against a reference point on the wall of the chamber which can be monitored or aligned from outside. The cathodes are to be made of thin aluminum, possibly coated to minimize secondary electron emission, and a cover over the open side. The cathodes are held in place by a mechanical

system separate from the bridges; precision is not required and the weight of the cathodes must not bear or distort the wire support. At present, we have chosen Mycalex for the bridge material; it is stable and machinable.

This chamber design has the flexibility of being made to any length with wire supports at any point of choice to minimize sag, and thus not rely on calculating a large correction. The wires can be laid down multiply (as done with Iarocci tubes), inspected, and tested for positioning and tension before being covered. All chamber parts can be manufactured by state of the art machine shops.

We will operate the wires in limited streamer mode. We had expected that the combination of large and fast pulses so produced would give good drift time measurements; this was the case and our results on small prototype chambers have been reported(1). In these tests we have used LASER beams, cosmic rays, and the 0.5 TeV/c beam at Fermilab. The use of aluminum cathodes makes the tube itself a good transmission line that preserves the rise time of the streamer pulse for drift time measurement and gives a coarse spatial measurement along the wire using instrumentation at both ends of the wire. Because the wires lie in cathodes open at the top we can place instrumented strips over this open side to obtain a measurement of position orthogonal to the drift time measurement and correlated with it by the common timing signal. In this way we obtain an x-y coordinate for each track all in one chamber.

The electronics system for drift time and z measurement is being considered by the LeCroy Corp.(2). They base their design on their discriminator chip, MVL407 and their TDC chip, MTD132; the latter achieves sub-nanosecond time resolution. These will be used for prototype measurements; however, it is expected that even faster electronics will be available for the final system.

We will start testing 2 full length chambers in January 1992 and a full width (1 meter), full length chamber in the spring of '92.

(c) Resistive Plate Counters. The RPCs will perform the following functions for the GEM detector: (1) the first level muon trigger, (2) the event beam crossing tag, (3) the Z-coordinate for the muon tracks in the PDT option, (4) the muon tracking "roads" for the precision tracking elements, (5) an anti-coincidence trigger to veto cosmic rays, (6) a cosmic ray coincidence trigger to test GEM subsystems.

The original Resistive Plate Counters (RPC developed in Rome ten years ago, work at uniform electric field of about 40 kV/cm betwe parallel electrode plates of plastic phenol (bakelite) with a resistivity about 10^{11} ohm-cr The 2mm thick plates are separated by 2mm usi PVC spacers. The sensitive volume is filled with gas mixture of 60% argon, 38% isobutane, and 2 freon. The field electrodes are a graphite varni (about 500 kohms per square) coating the out surfaces of the bakelite. RPCs have a measur time resolution of about 1 nanosecond. Spati readout is made via pick up strips insulated fro the field electrodes by a 0.3mm thick polyethyle film. The voltage induced on these pickup strips about 0.5 volts into 50 ohms.

RPCs have been used in many experiments wi the largest having dimensions 0.5 × 6.0 meters. It planned that the GEM RPCs will have dimensio of up to 3.3 × 4.0 meters.

The RPC system will be deployed in all thre superlayers and will completely shadow th precision muon measuring components as see from the interaction point. (Refer to Figure 2.3-1 RPCs will furnish three-dimensional space poin for particles passing through the system. Short RP strips running perpendicular to the magnetic fiel lines will give the X-coordinate while long RP strips running parallel to the magnetic field line will give the Y-coordinate.

The logic for the trigger has four component (1) three-fold coincidence timing in the non-ben plane, (2) straight-line space fit to three points i the non-bend plane.(3) three-fold timing in the ben plane, and (4) three-point sagitta measurement i the bend plane. The coincidence timing and space point fitting in the non-bend plane eliminates mos punch-throughs, low energy tracks, and randon pick-up noise. The coincidence timing in the ben plane placed in coincidence with the coincidence i the non-bend plane further reduces the randor pick-up noise problem. The sagitta measurement i the bend plane determines which momentun activates the trigger.

The proposed trigger will be able to select fou ranges: 10, 30, 50 and 100 GeV/c transvers momentum, under computer control. We believe that the Level 1 trigger decision time can be mad less than 100 nanoseconds. The logic for furnishin the event beam crossing tag must be fast enough t cope with the 16 nanosecond beam crossing time We have designed for a 10 nanosecond decisio time. We note the X-strip on the inner RP cylinder has a length of 1.5 meters.

The propagation time down this strip is less than 8 nanoseconds. If the RPC jitter time is less than 2 nanoseconds, we can use the pulse from these strips as a simple and inexpensive beam crossing tag.

Several R&D issues have to be resolved before RPCs can be a technique of choice for the GEM Detector. These concern their operating characteristics in the high rate environment of the SSC. Furthermore, construction techniques have to be devised for the large size and quantity of chambers needed in this effort.

(d) Cathode Strip Chambers. The high rate environment of the endcap region makes considerable demands on the triggering and tracking technology employed there. Hence, we are considering cathode strip chambers (CSC) which has a high flexibility in terms of channel segmentation, pattern recognition capability, and trigger speed.

In the endcap application there will be 3 superlayers at z=6, 10, and 14m. Each superlayer features modular construction with trapezoidal modules, each of which spans 18 degrees of azimuth, resulting in a structure with 20-fold symmetry. The first two superlayers have chamber modules containing four chambers. The superlayers at ±14 have only three planes in order to reduce the total channel count. (See Figure 2.3-1 for the chamber layout.)

Each chamber consists of two cathode planes (only one segmented) with an anode plane between them. The anode wires have a pitch of 2.5mm and the distance between the cathodes is 5mm. The precision azimuthal coordinate is obtained by charge interpolation between neighboring strips. Measurements made for this configuration indicate a resolution of order 50 um per strip plane.

For a maximum occupancy of 10 Hz the total number of channels is 231k with an additional 21k of anode readout channels. (It is assumed that each channel reads a group of 20 wires for a resolution of 2cm along the radius.) The superlayers closest to the absorber cover a relatively small area and more planes could be added if necessary for pattern recognition with a relatively modest increase in the total channel count.

The spatial resolution of these chambers in the azimuthal direction is limited by the dynamic range of the charge signal referenced to the rms noise which is proportional to the capacitance of the cathode strip and inversely proportional to the square root of the integration time. In order to operate the chambers at a relatively low gain (~2-3 $\times 10^4$) we intend to use an integration time of about 1 usec. After a preamplifier the signal is split in two. One branch feeds a 1 usec shaping amplifier whose output goes to a track-and-hold circuit. Due to the long integration time a local hold can be generated and thus avoid the use of analog pipelines. Through an analog multiplexer a single ADC can digitize a large number of channels. Monolithic circuits developed for reading out silicon detectors already very nearly meet the requirements for such a readout system. A parallel branch feeds a discriminator and the resulting signal is used for the formation of the Level 1 trigger.

The plan for R&D during the next year or two will include detailed physics simulation as well as punch-through, pattern recognition; engineering studies of module configuration, support, and alignment; gas studies in order to choose a gas which is safe, has drift velocity about 50-60mm/usec and a Lorentz angle ← 6 degrees; and construction of a set of prototype chambers to test large scale fabrication techniques and evaluate electronics in realistic situations.

2.3.2 Mechanical Engineering of Muon System

The central region muon support system is arranged into 16 measurement modules per end as shown in Figure 2.3-1. These modules utilize an aluminum truss structure to support the muon chambers. Each module is attached with kinetic hardware to the superconducting magnet near the endplates of the magnet cryostat.

The support structure design will utilize pinned clevis joints. This design permits the layered assembly of the truss joints to be disassembled and reassembled with accuracy. The maximum deflection will be less than 2mm in any orientation and the stresses less than 2 ksi for a central module weight of 10 tons.

The structure of the endcap region will be similar in concept to the central region but will be constructed of lighter cross section tubing appropriate for the 1 ton per module weight expected for the trapezoidal-shaped CSC design. The same 16-fold symmetry of the central region will be translated to the endcap regions and the endcap modules will be attached kinematically to the respective central region module structure.

In both regions there will be interface structures between the chambers and the support structure which will direct the support load through the truss nodes. The interface between the chambers and

these interface structures will be flexual elements which permit predictable translation of the chambers in a plane.

Alignment of the muon chambers within a module will be accomplished with the use of multiple straight-line monitors similar to those successfully used to monitor and maintain alignment of the L3 muon system to an accuracy of 10 microns RMS. Actuators will be available to control this alignment either in a closed loop or manually. Initial alignment will be accomplished with precision surveying techniques.

Generic to all of the muon structures will be accommodations for services, cables, access space for maintenance of electronics and appropriate rigging hardware, to permit safe passage of personnel within the support structure.

We are engaged in an engineering R&D program in order to fully develop the design of the support structure with such demanding tolerances. We intend to (1) develop the conceptual design of a complete muon system, with installation procedures and chamber support fixtures, (2) fabricate and evaluate prototype structural elements, straight-line monitors, and interface hardware, and (3) perform a preliminary design, with a cost estimate, for the selected muon chamber technology as an engineering basis for the Technical Proposal.

2.3.3 Summary:

The design of the GEM Muon System is based on a large solenoid with muon tracking chambers placed outside the hadron calorimeter and inside the magnet coil. In this way, high precision reconstruction of muon tracks is possible, even in the highest rates being envisioned for the SSC. The system will provide a trigger dependent on the transverse momentum of the muon. An active R&D program is envisioned to determine which tracking and triggering technology is to be used, and to develop support structures which will satisfy our demanding alignment criteria.

References:

PDT applications

Toroidal Spectrometer Group Progress Report, SSC

Progress Report No.218 (Sept.15, 1991).

EMPACT/TEXAS Tech. Note #338, from LeCroy Corp.

Nov.26, 1990 (Revised Feb.26, 1991).

Figure Captions:

Figure 2.3-1 **Overview of the GEM Muon System. The dimensions of the large solenoidal magnet are indicated. Shown are the placement of the muon chambers in both side and end view.**

Figure 2.3-2 **The reconstructed Higgs mass distribution is shown for various resolutions of the muon system, quantified by the number of radiation lengths in the middle superlayer. The mass is reconstructed from the 4 muon final state.**

Figure 2.3-3 **The muon momentum resolution of the baseline system is shown versus polar angle. Refer to Table I for the assumed system.**

Figure 2.3-4 **The pseudorapidity coverage for Z' production is shown.**

Figure 2.3-5 **The muon rate per sqcm versus polar angle for the three superlayers.**

Figure 2.3-6 **The muon rate as a function of pseudorapidity for various Pt cuts.**

Figure 2.3-7 **Energy loss of muon in the calorimeter. Note the high energy tail corresponding to radiative energy losses.**

2.4 Calorimetry

2.5 The Central Tracker

The Central Tracker in the Gem detector will operate in the 8 kilogauss magnetic field of the large GEM superconducting solenoid. It is envisioned to be of modest size: 75 cm outer radius with a total length of 300 cm. At present we are considering two options for the design of this device. The first uses a silicon microstrip inner tracker surrounded by an outer tracker consisting of layers of strawtubes and scintillating fibers. This design was presented in our Expression of Interest and the cost estimates in this Letter of Intent are based on this design. An alternate design, employing a somewhat smaller silicon microstrip inner detector surrounded by an Interpolating Cathode Pad Chamber, is being considered because is has potentially much lower occupancy and the outer detector would operate well at luminosities of $10^{34}/cm^2/sec$. One of the criteria for this alternate design is to keep its cost at or below the cost estimate presented for the EOI design.

2.5.1 Physics Goals and Design Parameters

The physics goals for the central tracking in GEM can be divided into two categories. The first are those features that are required to support the primary objectives of GEM, namely the detection

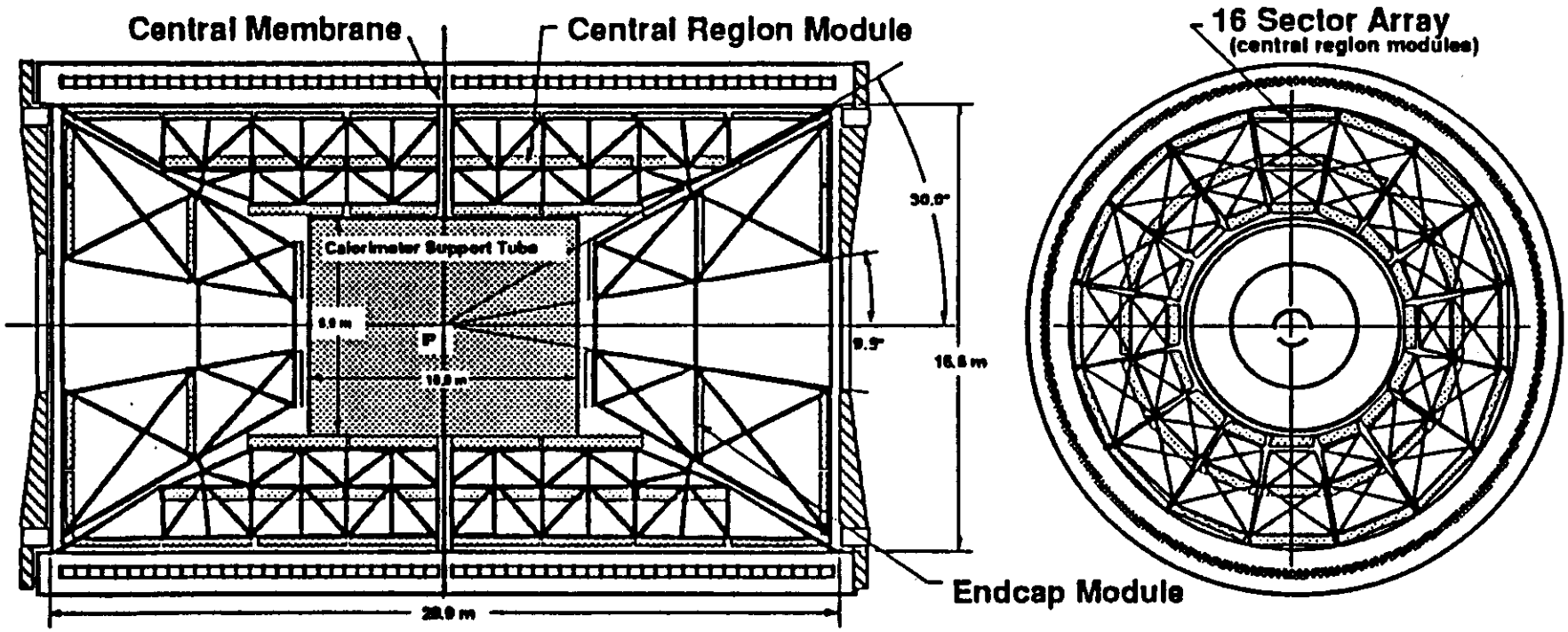

Central Membrane
Central Region Module
16 Sector Array
(central region modules)
Calorimeter Support Tube
IP
30.0°
9.5°
16.6 m
Endcap Module

Figure 1

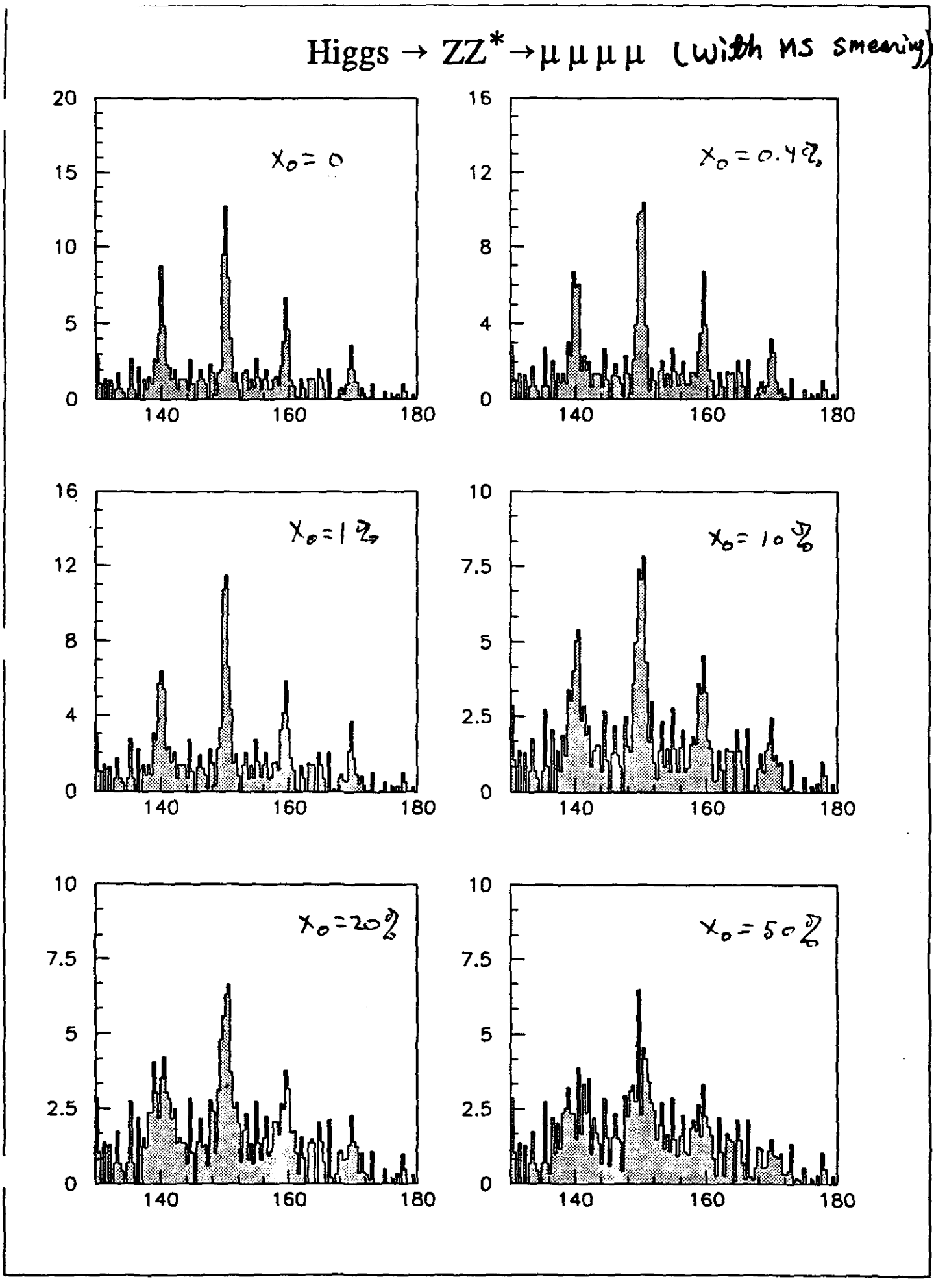

Higgs → ZZ* → μμμμ (with MS smearing)
$X_0 = 0$
$X_0 = 0.4\%$
$X_0 = 1\%$
$X_0 = 10\%$
$X_0 = 20\%$
$X_0 = 50\%$
140
160
180

Figure 2

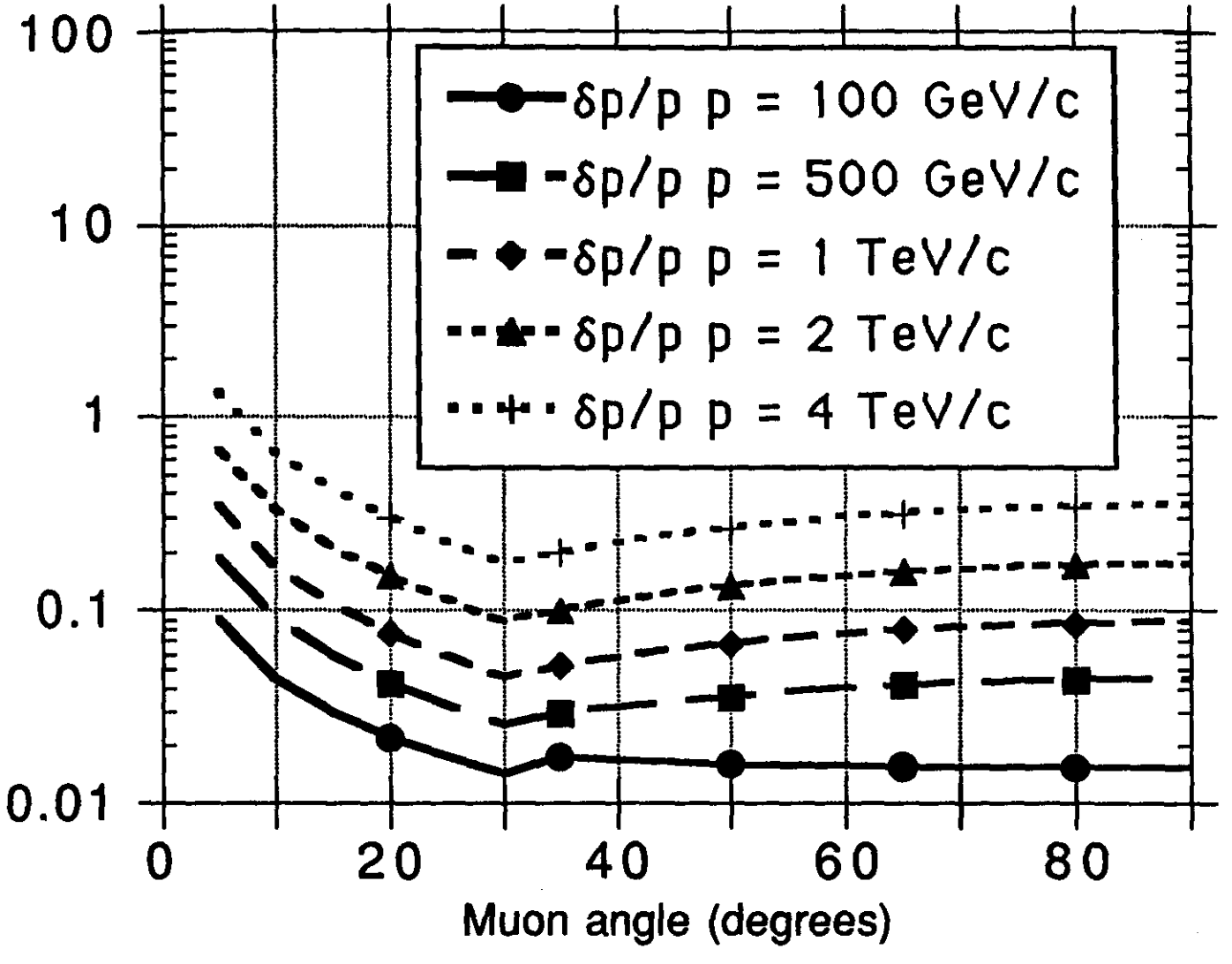

100
10
1
0.1
0.01
0
20
40
60
80
Muon angle (degrees)
δp/p p = 100 GeV/c
δp/p p = 500 GeV/c
δp/p p = 1 TeV/c
δp/p p = 2 TeV/c
δp/p p = 4 TeV/c

Fig. 3

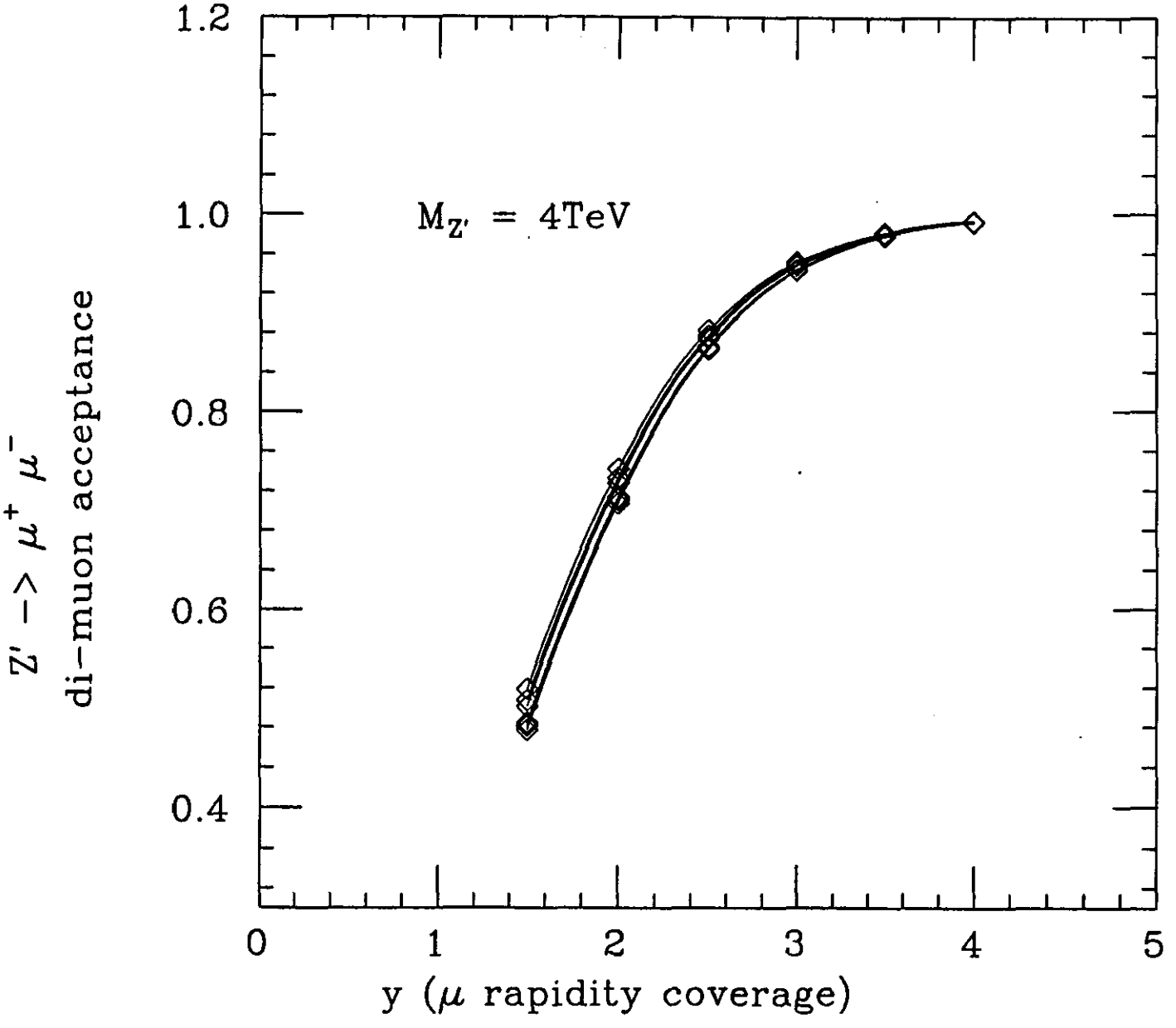

1.2
1.0
0.8
0.6
0.4
0
1
2
3
4
5
$M_{Z'}$ = 4TeV
$Z' \to \mu^+ \mu^-$
di-muon acceptance
y (μ rapidity coverage)

Figure 4

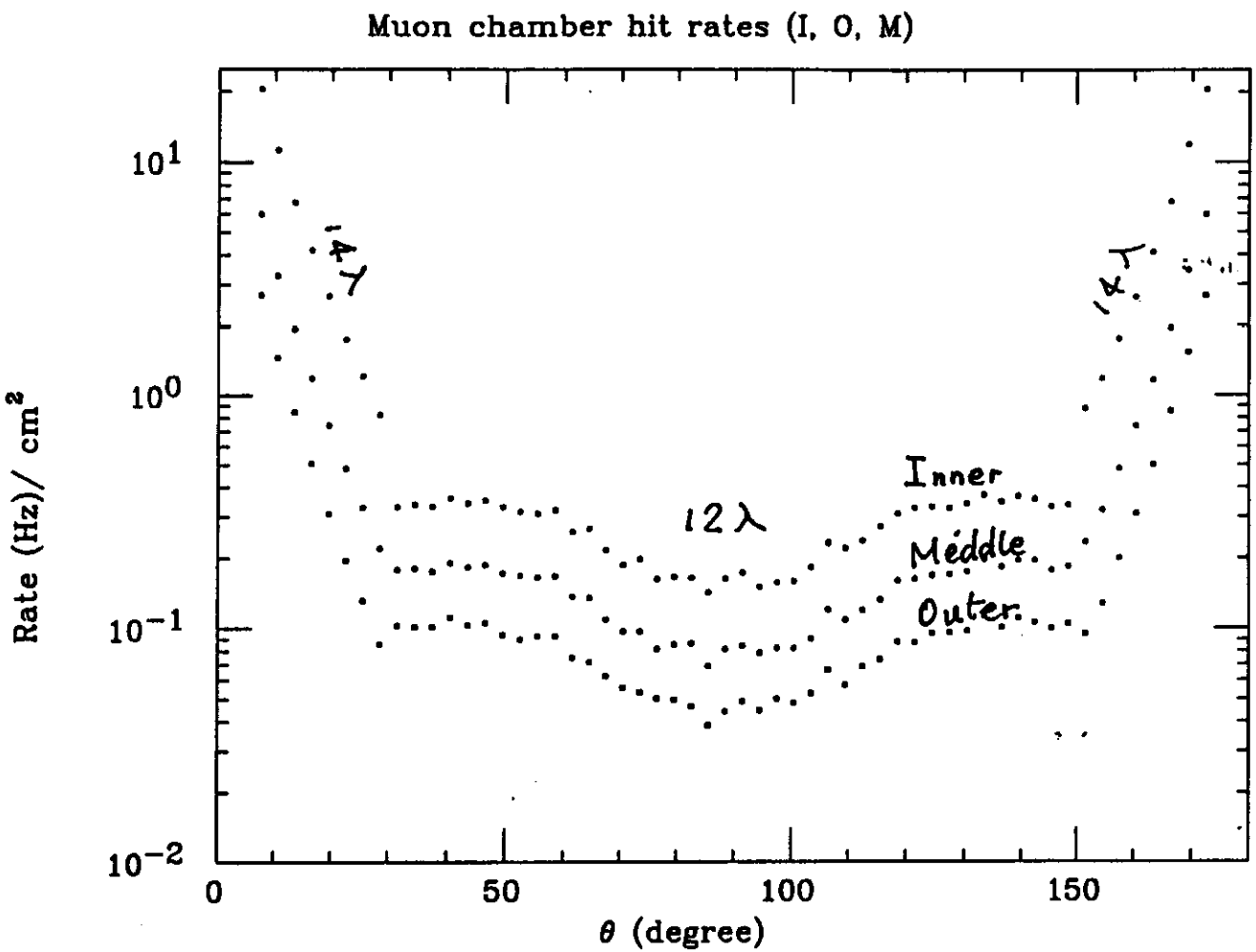

Muon chamber hit rates (I, O, M)
Rate (Hz)/ cm²
θ (degree)
10¹
10⁰
10⁻¹
10⁻²
0
50
100
150
14λ
12λ
14λ
Inner
Middle
Outer

Figure 5

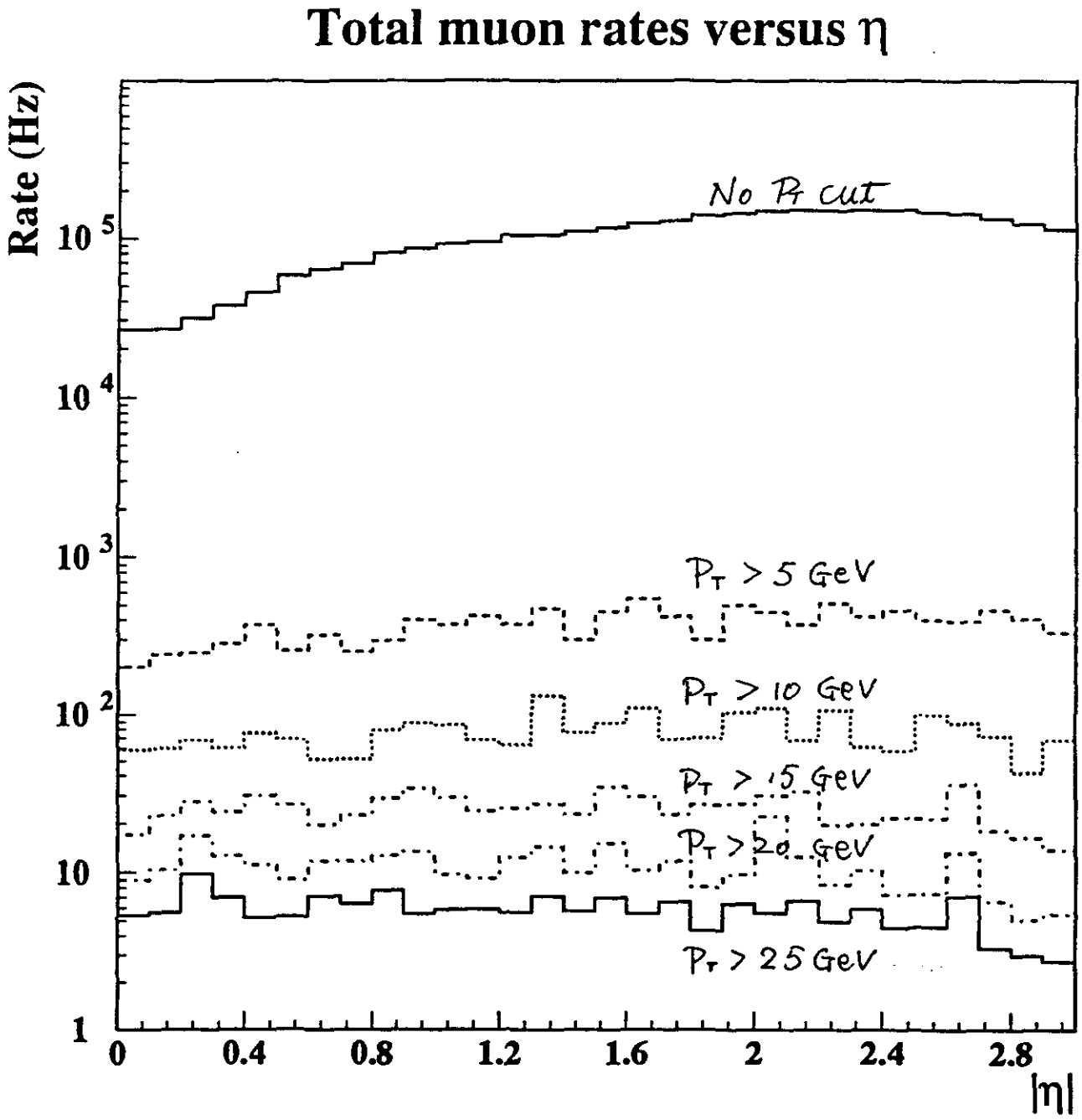

Total muon rates versus η
Rate (Hz)
10 5
10 4
10 3
10 2
10
1
0
0.4
0.8
1.2
1.6
2
2.4
2.8
|η|
No Pt cut
PT > 5 GeV
PT > 10 GeV
PT > 15 GeV
PT > 20 GeV
PT > 25 GeV

Figure 6

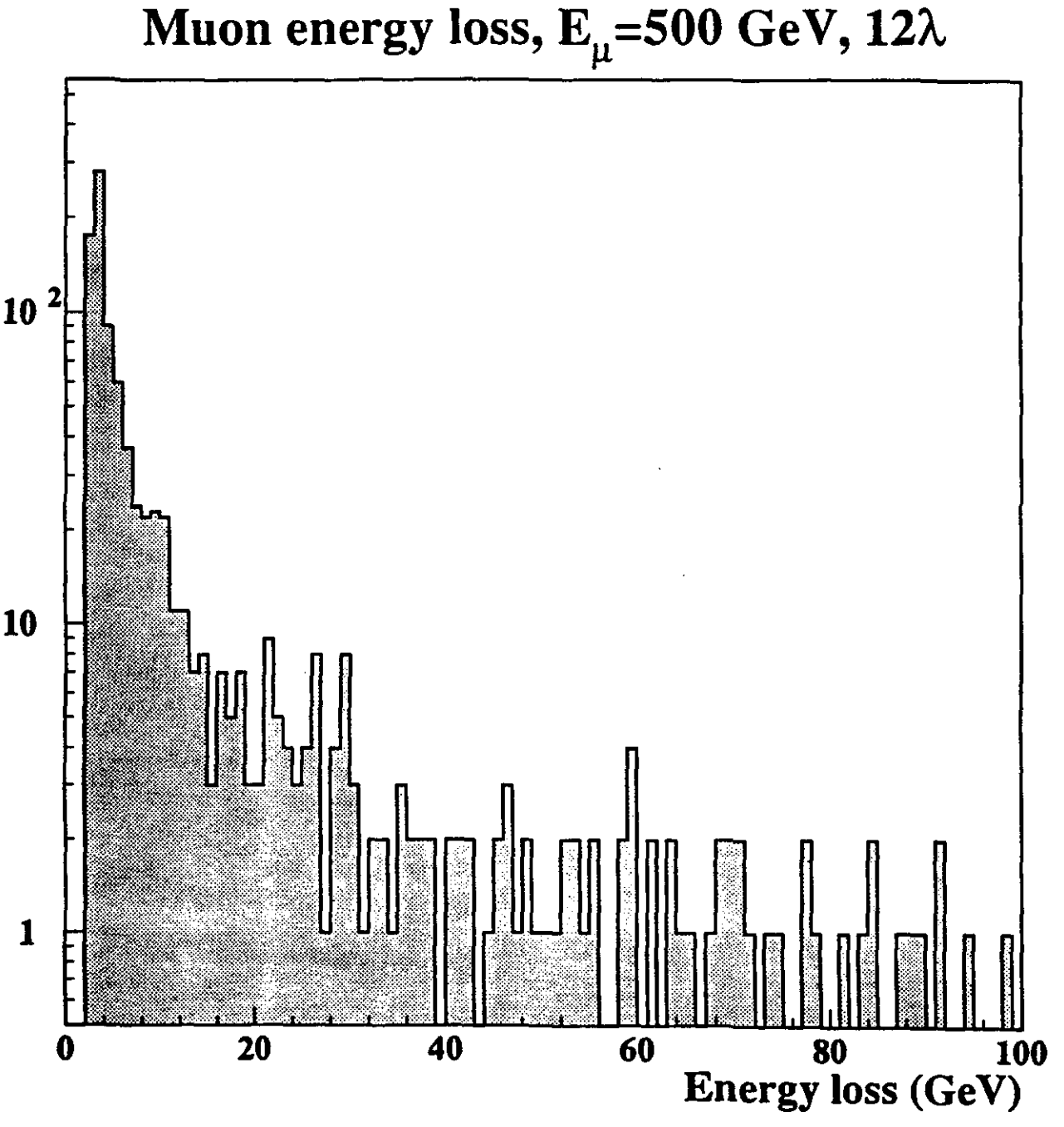

Muon energy loss, E_μ=500 GeV, 12λ
10^2
10
1
0
20
40
60
80
100
Energy loss (GeV)

Figure 7

GEM MUON SYSTEM ENGINEERING GFY92

Frank Nimblett
08 November 1991

- **Engineering Categories**
  - Subgroup Engineering
    (Engineering Effort required to complete R&D activities) ; Dec. '91-Sept. '92
  - Conceptual Design Engineering
    (Complete a conceptual design of the entire muon system)
  - Muon System Engineering
    (Engineering Effort required to produce a credible Technical Proposal; or Engineering Design Report(EDR))

- **Cost Estimates**
  - Initial estimate for Conceptual design plus Muon System Engineering ,$ 2.7 M for GFY92 (This was probably LIGHT !!)
  - Current cost estimate for these two engineering areas is $0.79 M (30% of what I consider a LIGHT estimate)

    THIS INCLUDES MANAGEMENT, M&S,AND TRAVEL
  - Final numbers are not yet settled !!

Subgroup Engineering

- **Design, fabricate and evaluate component elements and or small prototype chambers for the the various subsystem chamber options or the hardware for the TTR.**

- **Design and develop assembly procedures and fixturing for large scale prototypes to be tested on the Texas Test Rig (TTR) at SSCL in May of '92.**

- **As designs mature, maintain active cost books to facilitate and improve the EDR cost estimate.**

- ***Recommend reserving an appropriate % of funds to participate in preliminary design phase for the individual chambers. (KEEP LSP EFFORT TO A MINIMUM or POINT THE LSP EFFORT MORE IN THE DIRECTION OF A PRELIMINARY CHAMBER DESIGN)***

PDT SUBGROUP

BOSTON UNIVERSITY (BU):
AHLEN**, EARLE, HAZEN, MARIN, VARNER, ZHOU
MICHIGAN STATE UNIVERSITY (MSU):
BROMBERG, JOY, MILLER, RICHARDS, YOSUF
INSTITUTE OF ATOMIC PHYSICS (IAP), BUCHAREST, ROMANIA:
DOROBANTU, STAN-SION, ZIMMER
INSTITUTE OF HIGH ENERGY PHYSICS (IHEP), BEIJING, CHINA:
XU
JOINT INSTITUTE FOR NUCLEAR RESEARCH (JINR), DUBNA, USSR:
ALEXEEV, BONYUSHKIN, FIALOVSKI, GORNUSHKIN, HOVANSKI, KARPENKO,KOTOVA, MALYSHEV, PROHOROV, TOKMENIN, VERTOGRADOV
LOS ALAMOS NATIONAL LABORATORY (LANL):
SANDERS, SMITH
SSC LABORATORY (SSCL):
MITSELMAKHER, STOCKER, VILLASENOR, YOST

LSDT SUBGROUP

MIT:
KENDALL, OSBORNE**, ROSENSON, ROSS, TAYLOR, VERDIER, WADSWORTH,
LSU:
MCNEIL, METCALF
UNIVERSITY OF HOUSTON (UH):
LAU, MAYES, PINSKY, WEINSTEIN
DRAPER LABORATORY:
NIMBLETT
JINR:
BONYUSHKIN, KHOVANSKY, KORYTOV, MALYSHEV, SEDYKH, TOKMENIN
LAWRENCE LIVERMORE LABORATORY (LLNL):
FACKLER, WEANUS, CAPELL
LECROY:
HOFTIEZER, SUMNER
VANDERBILT/SLAC:
VENUTI, MARKIEWICZ

CSC SUBGROUP

BROOKHAVEN NATIONAL LABORATORY (BNL):
HARDER, O'CONNOR, PAFFRATH, POLYCHRONAKOS**, RADEKA, RESCIA, ROGERS,SMITH, STEPHANI, YU

BU:
EARLE, HAZEN, JOHNSON, ORLOV, OSBORNE, SHANK, WARNER, WHITAKER,WILSON

UH:
LAU, MAYES, PYRLIK, WEINSTEIN

JINR:
ALEXEEV, BONYUSHKIN, OLSHEVSKY

LENINGRAD NUCLEAR PHYSICS INSTITUTE (LNPI), LENINGRAD, USSR:
GRATSHEF, PROKOVIEF, SMIRNOFF, TERENTIEF, VOROBYOV

OAK RIDGE NATIONAL LABORATORY (ORNL):
BAUER, BRITTON, TODD, WINTENBERG

SSCL:
MITSELMAKHER, STOCKER, VILLASENOR

RPC SUBGROUP

MIT:
CHANG, HAFEN, HARIDAS, PLESS**(co)

LLNL:
ABLES, VAN BIBBER, BIONTA, FACKLER, MAKOWIEKI, WUEST**(co)

BROWN UNIVERSITY:
WIDGOFF

INDIANA UNIVERSITY:
ALYEA

UNIVERSITY OF TENNESSEE:
BERRIDGE, BUGG, DU

TTR SUBGROUP

SSCL:
MITSELMAKHER, STOCKER, VILLASENOR, YOST**

ENG SUBGROUP

DRAPER:
NIMBLETT, HAMILTON, ANTKOWIAK, ELDER, HANSBERRY**
LANL:
HANLON, SMITH

CONCEPTUAL DESIGN ENGINEERING

TASK DESCRIPTION:

Complete conceptual design of entire muon system for two barrel region options (PDTs and LSDTs). This effort will include conceptual layouts of proposed chambers, electronics racks and cable routing, interfaces to structure, interfaces to the magnet support points or other attachment options, respective structural support concepts and assembly procedures, alignment hardware concepts (local and global), installation hardware and fixtures, installation procedures and schedules, allotment of appropriate space for our own and other subsystem service requirements, safety air venting, temperature control and air routing through the muon system, gas system desing concepts, surface facility requirements, and last but not least, initial cost book entries and cost estimates on all of the above.

Staffing: --- Three Engineers for 5 months; 1 at LANL working the global alignment problems and 2 at Draper working the rest plus the routine program management needs of such an effort.

(WISH US LUCK, WE WILL NEED IT!!)

PREPARATION OF GEM TECHNICAL PROPOSAL
(Engineering Design Report)

Task Description: This is very simply an extension of everthing listed above except that now we will be doing REAL DRAWINGS with REAL COSTS (BOTTOMS-UP COSTING)!! In addition, we have the prototype design fabrication and evaluation of structure components, interface hardware and straight-line monitors.

This effort must provide the basis for a muon system design and cost estimate that WE WILL HAVE TO LIVE WITH !!

STAFFING: 5 ENGINEERS AND 2 DESIGNERS FOR 5 MONTHS.

HELP FROM THE SUBGROUP ENGINEERS IS VITAL IF WE ARE TO HAVE A PRAYER OF ACHIEVEING THIS !!!

THERE IS ONE SAVING GRACE: THE "EDR" IS NOT DUE UNTIL NOVEMBER!! IF WE ACTUALLY GET FUNDED SO THAT THIS EFFORT PROCEEDS IN DECEMBER, THEN THERE CAN STILL BE ADDITIONAL TIME AND GFY93 DOLLARS TO HELP COMPLETE THIS EFFORT (ONE ADDITIONAL MONTH).

G. M. McCracken 11/8/91
SSCL

Texas Test Rig

1. List of assumptions and questions sent to proponents –
   – EXPECT DISCUSSIONS TODAY AND ANSWERS

2. Work started at the SSCL.
   People involved:

SSCL
- F. Stocker
- L. Villasenor
- A. Vanyashin
- G. Kost
- E. Zimmer-Nixdorf
- T. Prosapio

expect visitors from USSR (Dubna, ITEP, MEPI, MSU)

Univ. of Houston: K. Law, R. Weinstein et al expect more help from the Lab.

Various options for the absorber-magnet ~~considered~~. and DAS considered.

Expect final choice to be done by the end of November

(Optimization: performance, cost, schedule)

TTR should be ready by April

F. Stocker

A. Vanyashin

E. Zimmer-Nixdorf

} magnet optimisation

L. Villasenor DAS

R. Lay - chambers (comment)

From: SSCVX1::MITSELMAKHER 21-OCT-1991 19:11:16.47
To: JNET%"FET@MITLNS",BUPHYC::AHLEN
CC: STOCKER,VILLASENOR,YOST,MITSELMAKHER
Subj: LSP: assumptions and questions

Dear Frank and Steve,

We have updated our list of assumptions and questions.Please make your comments and advise us to whom we should send it(we need the mailing list of contactmen of technologies).

Gena,Frank,Luis,George

List of Assumptions for the Muon System Evaluation

1. Each technology proponent should provide us, as soon as possible, with a description of the equipment they are going to ship to SSCL, including a tentative schedule.

2. Each prototype should have enough layers to allow to estimate the resolution without the use of external (i. e., other modules) information.

3. We assume that only one acquisition electronics standard (either CAMAC, FASTBUS or VME) will be used in the DAQ system of the Large Scale Prototype (LSP). This standard will have to be selected by the GEM Muon Group as soon as possible. We propose to use CAMAC.

4. We assume the front-end electronics, the ADC's and/or TDC's, crate(s), power supplies and cables necessary for each prototype will be provided by the corresponding institution.The SSCL will provide the crate controllers if necessary.

5. We assume that each institution will make its own gas system (in

compliance with SSCL safety regulations) available to use at SSCL during the evaluation period.

6. We assume that each institution will be responsible for proper transportation of its prototype to SSCL and for making it operational at SSCL.

7. We assume all the involved institutions will take part in the data taking and analysis. The SSCL will participate by making computing resources available and helping with the design and construction of the software. However, each proponent will be responsible for providing any technology-specific software, including any necessary calibration software.

8. We will assume responsibility for the construction of the LSP.

9. We will assume full responsibility for the trigger system.

10. We will assume full responsibility for the DAQ system with equipmer provided by SSCL.

11. All prototype modules should be at SSCL ready for installation into the LSP fixture by May 1, 1992.

12. Data taking will start June 1, 1992, and it will last for about one month.

List of Questions Concerning the Muon System Evaluation at SSCL

1. What are the dimensions, number of layers, number of wires/strips, etc., of your prototype?

2. What gas mixture do you need? With what tolerance? What flow? Please describe in detail the gas system you want to use. We will check compliance with SSCL safety regulations.

3. How many ADC and/or TDC channels do you need to read out?

4. Do you have any special requirements of SSCL?

5. Are there any volunteers willing to participate in any of the various activities at SSCL? When?

Luis Villasenor
11/8/91

DAQ for TTR

We propose to use CAMAC

DAQ System

*** Workstation — VME – CAMAC

OR

*** PC – CAMAC

OR

*** Other (VAX station)

Need Information!

1) Number of ADC/TDC channels for each technology

2) Average number of channels with non-zero data per event

3) Monitoring scheme

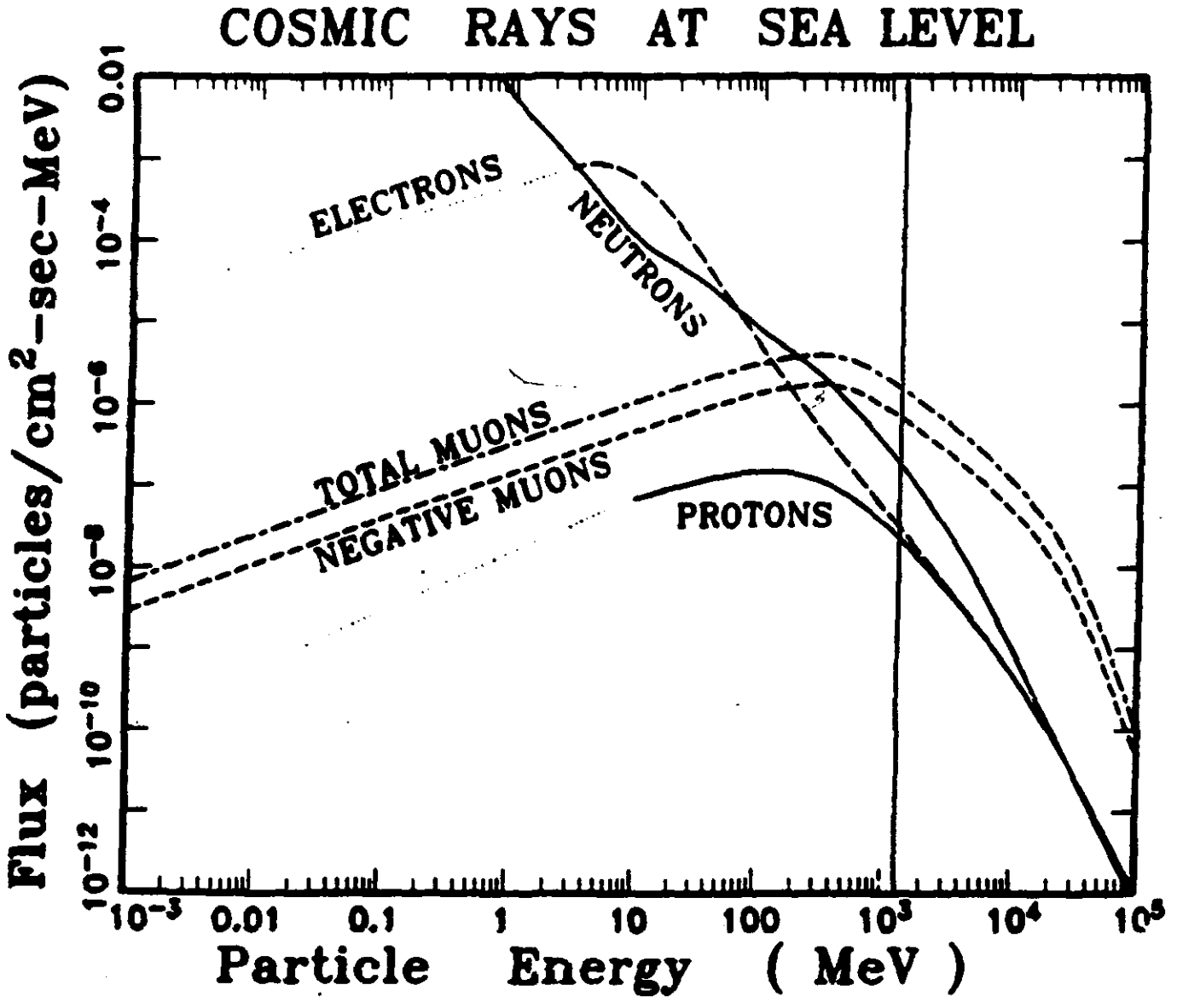
We still assume

Proponents → Bring ADC and/or TDC Modules with CRATES

→ DataTaking & Analysis

SSCL → Provides DAQ system (software, host, crate controllers)

Figure 4.11 Flux of cosmic ray particles at sea level at 40° N geomagnetic latitude. The low energy electron and proton spectra can differ significantly from the dotted lines depending on local conditions in the atmosphere. (J. Ziegler, Nuc. Instr. Meth. 191: 419, 1981.)



1 m of Fe ⇒ $P_{muon} \geq 1.4$ GeV

or ~ 60 μ's/m² s

for A = 4 m² ⇒ R ~ 240 Hz

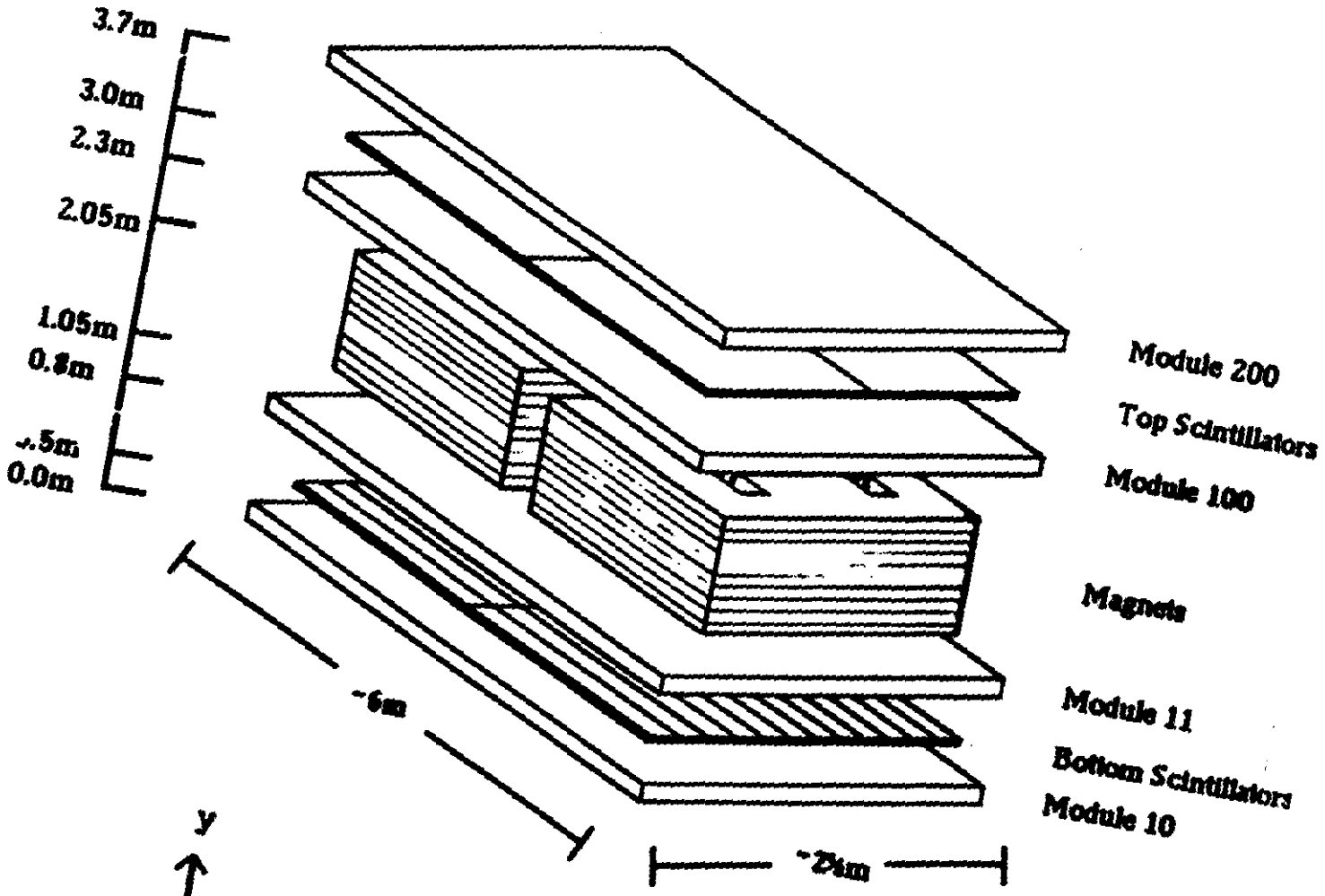
Geometric Acceptance ⇒ Rates O(10-1

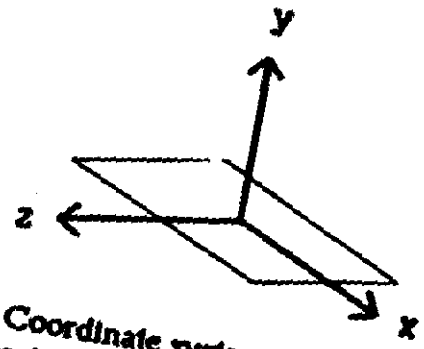
F. Stocker
11/8/91

Texas Test Rig Magnet

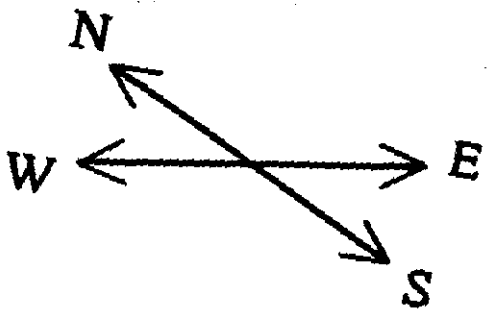
1. Modified DØ-magnet
2. New magnet
3. Poor mans magnet

COSMIC-RAY TELESCOPE

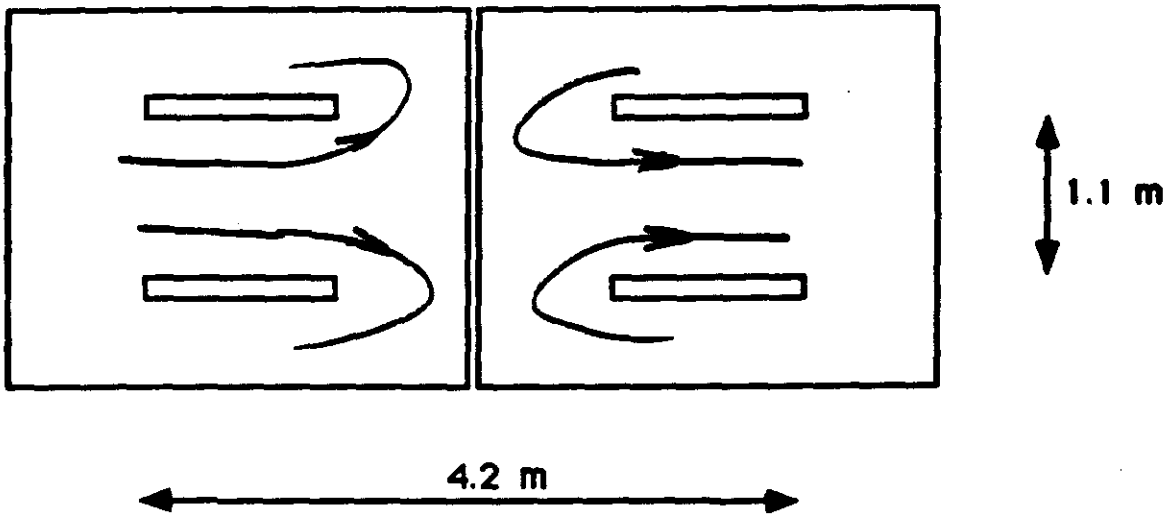




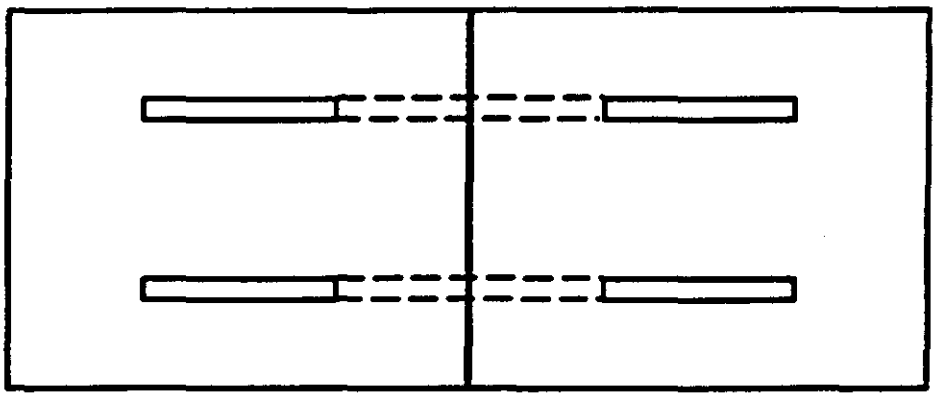
Coordinate system with the origin just below the bottom of Module 10, near the center of the chamber.



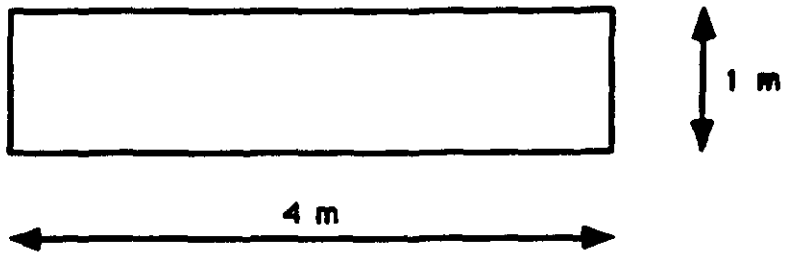
DO Muon Test Stand Magnet



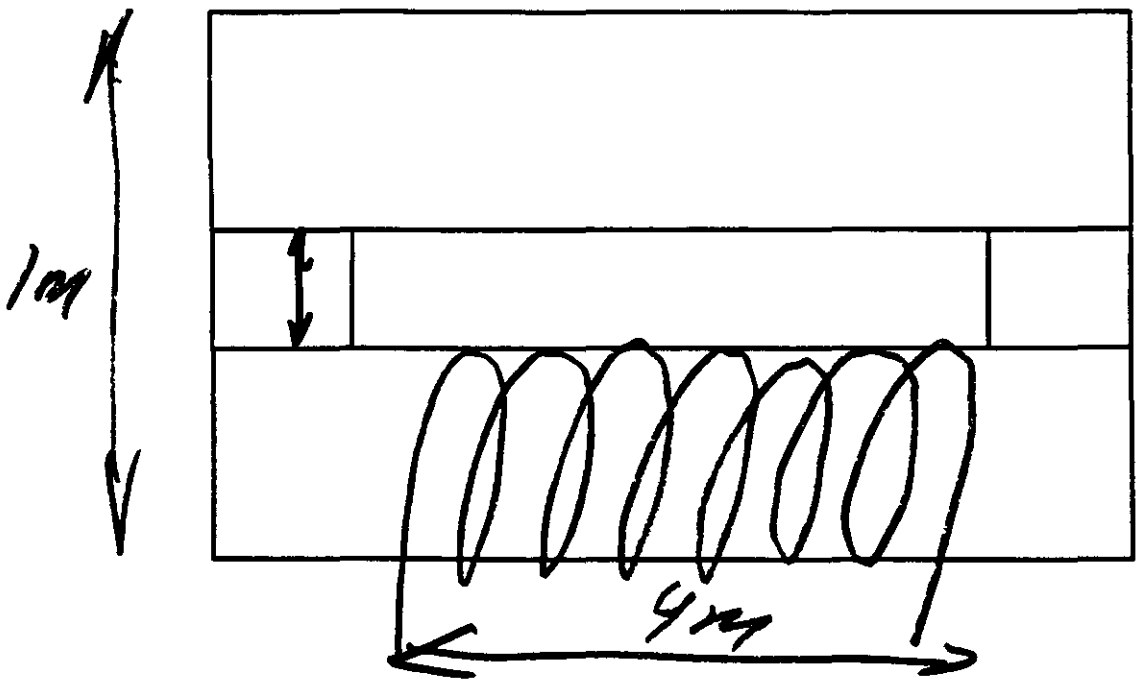
Modified D0 Muon Test Stand Magnet



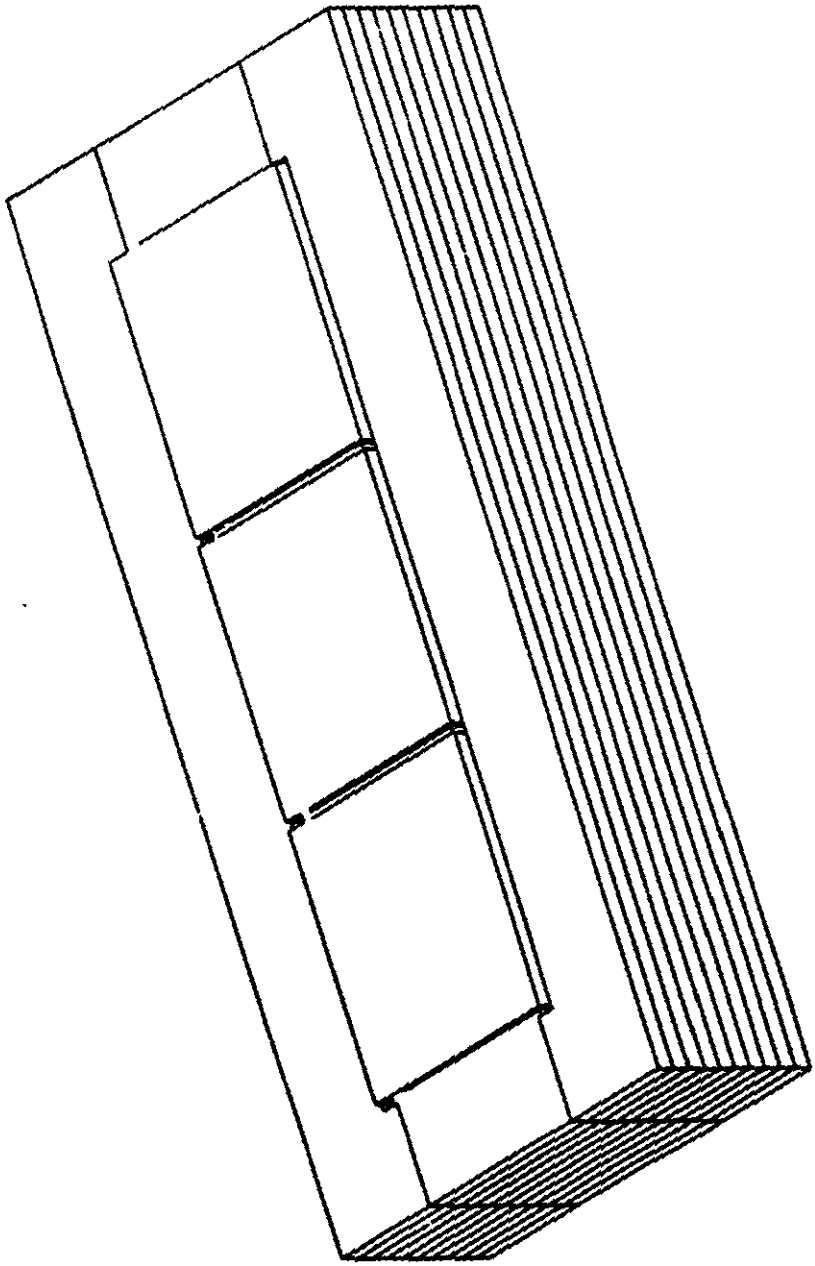
Dimensions of Technologies

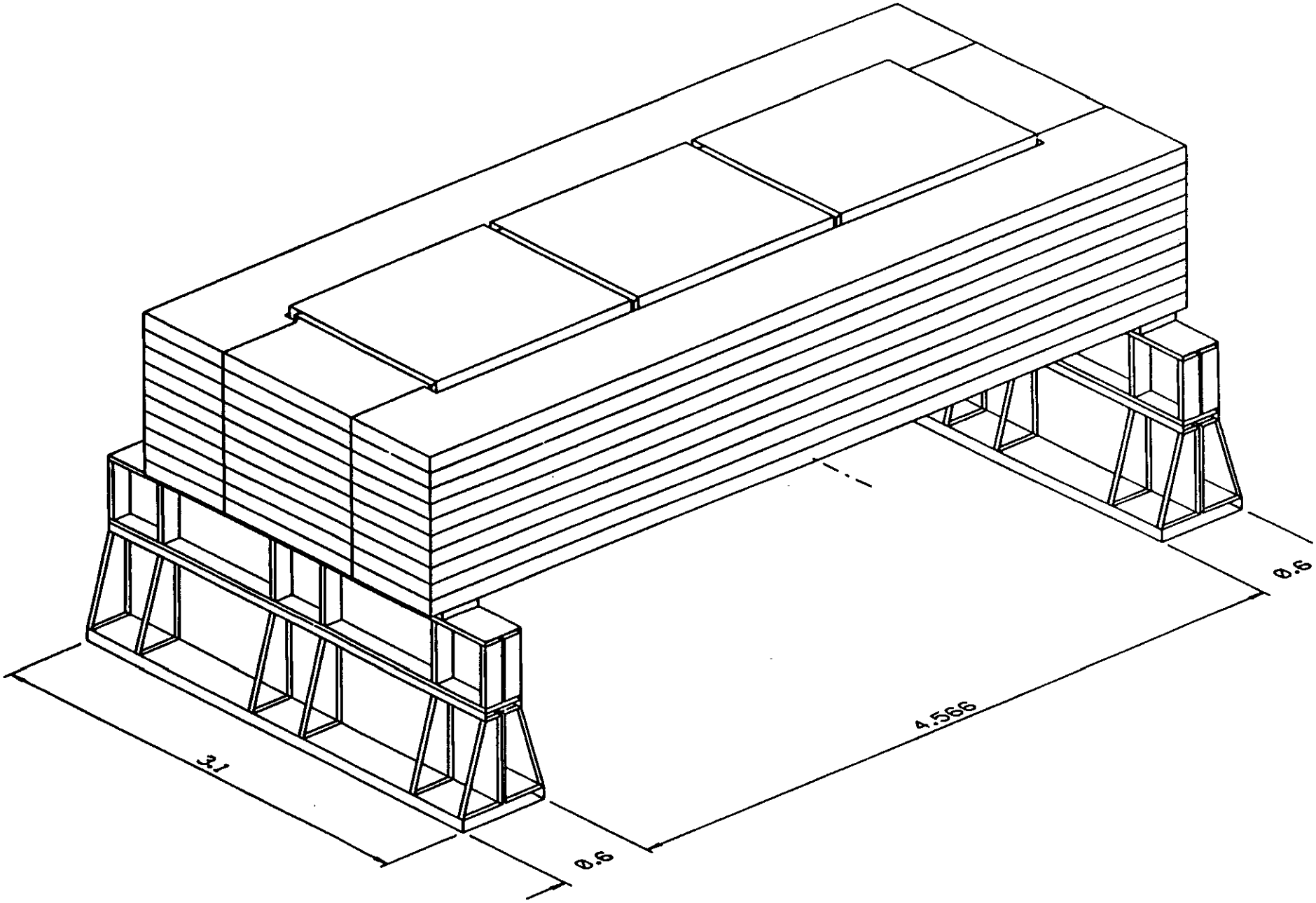


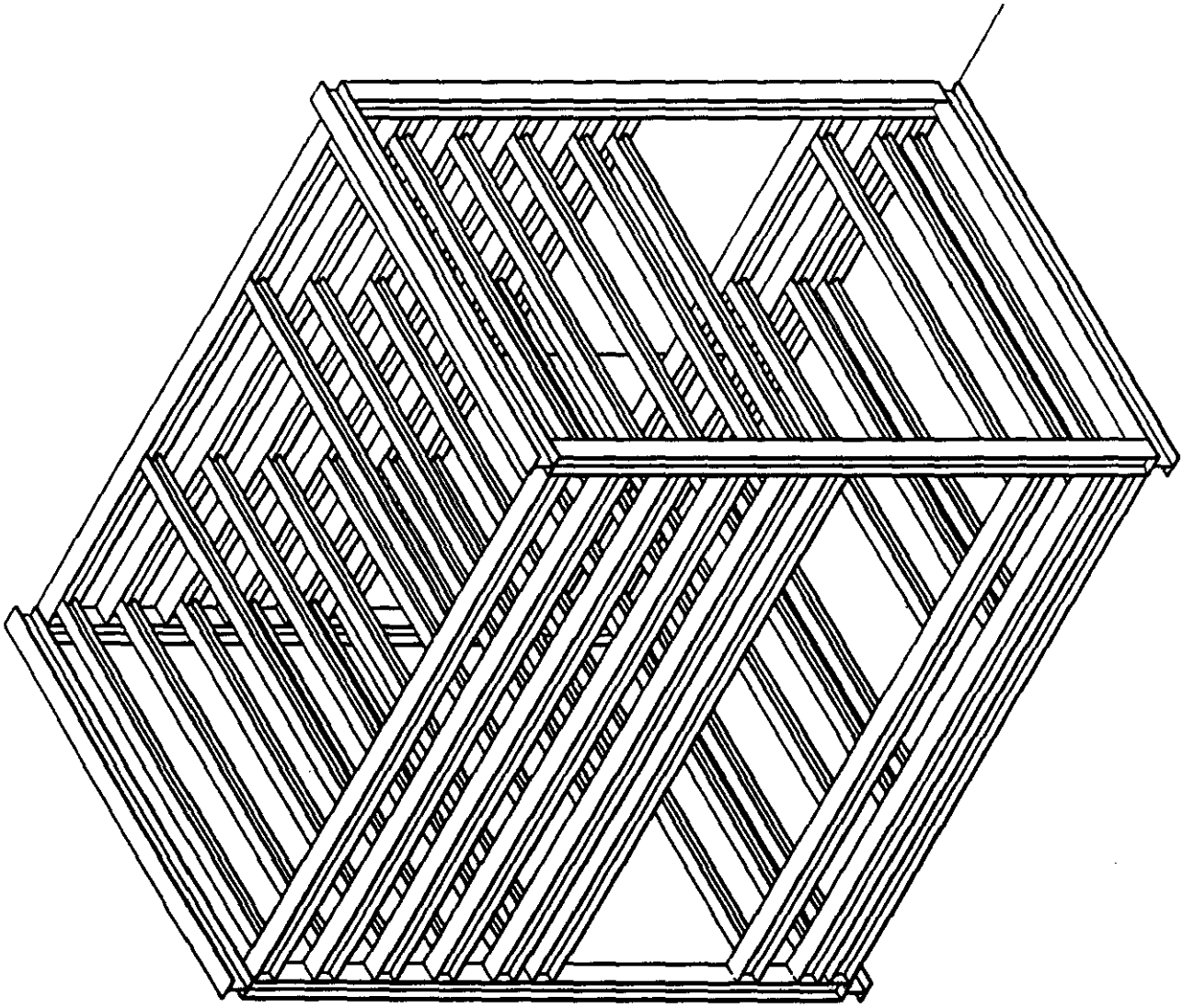
Toroid Magnet

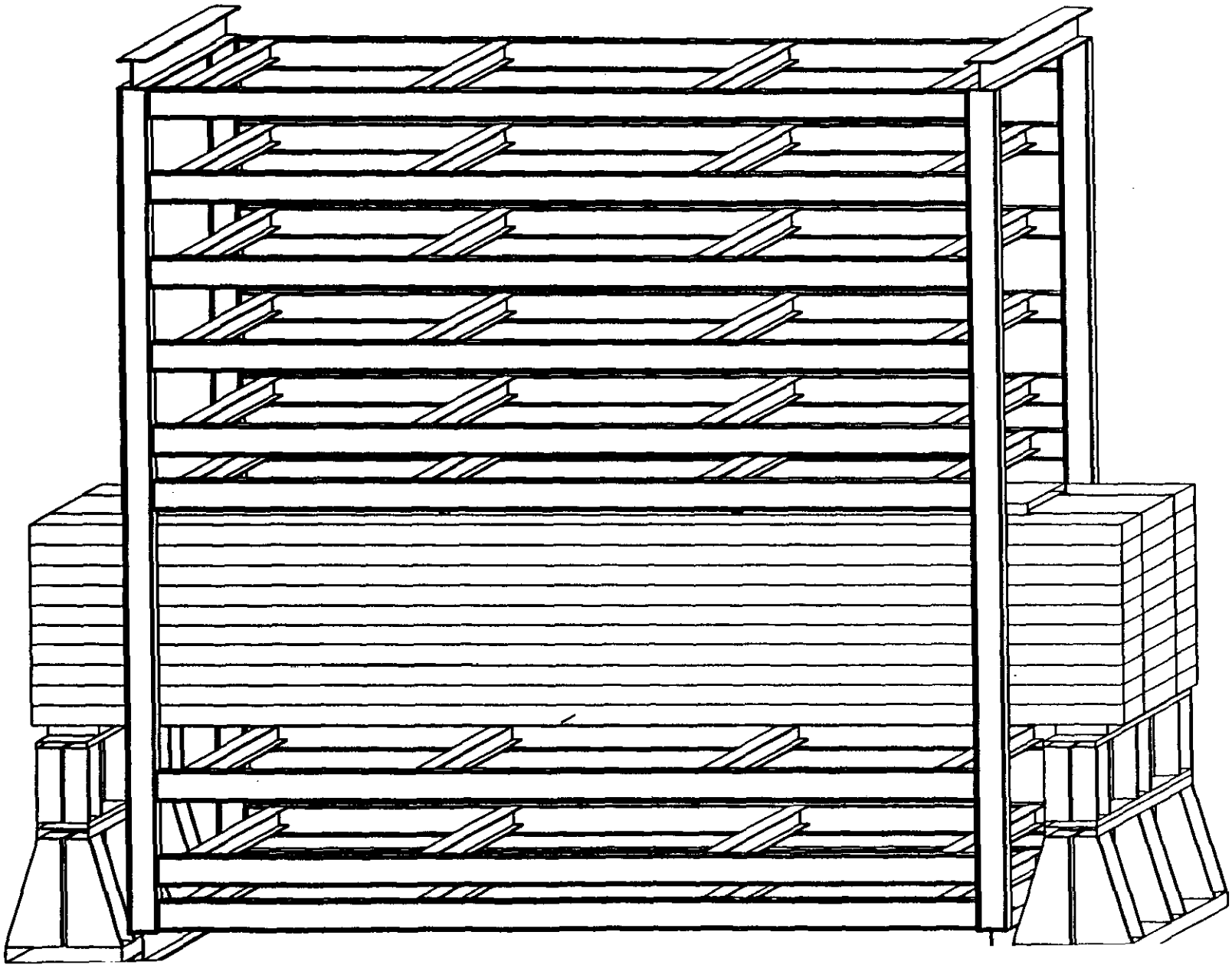


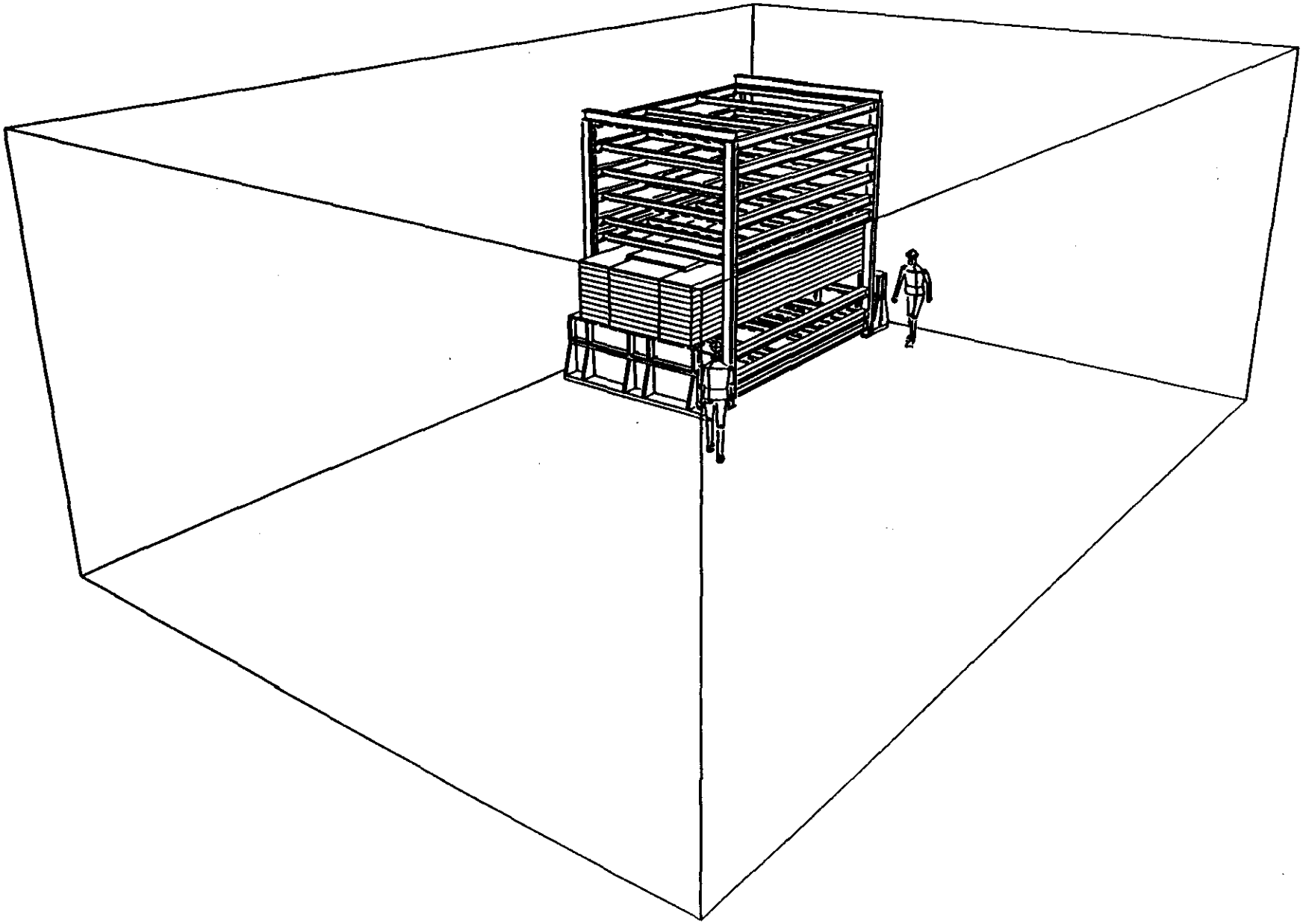
Ewald Zimmer - Mix dor-

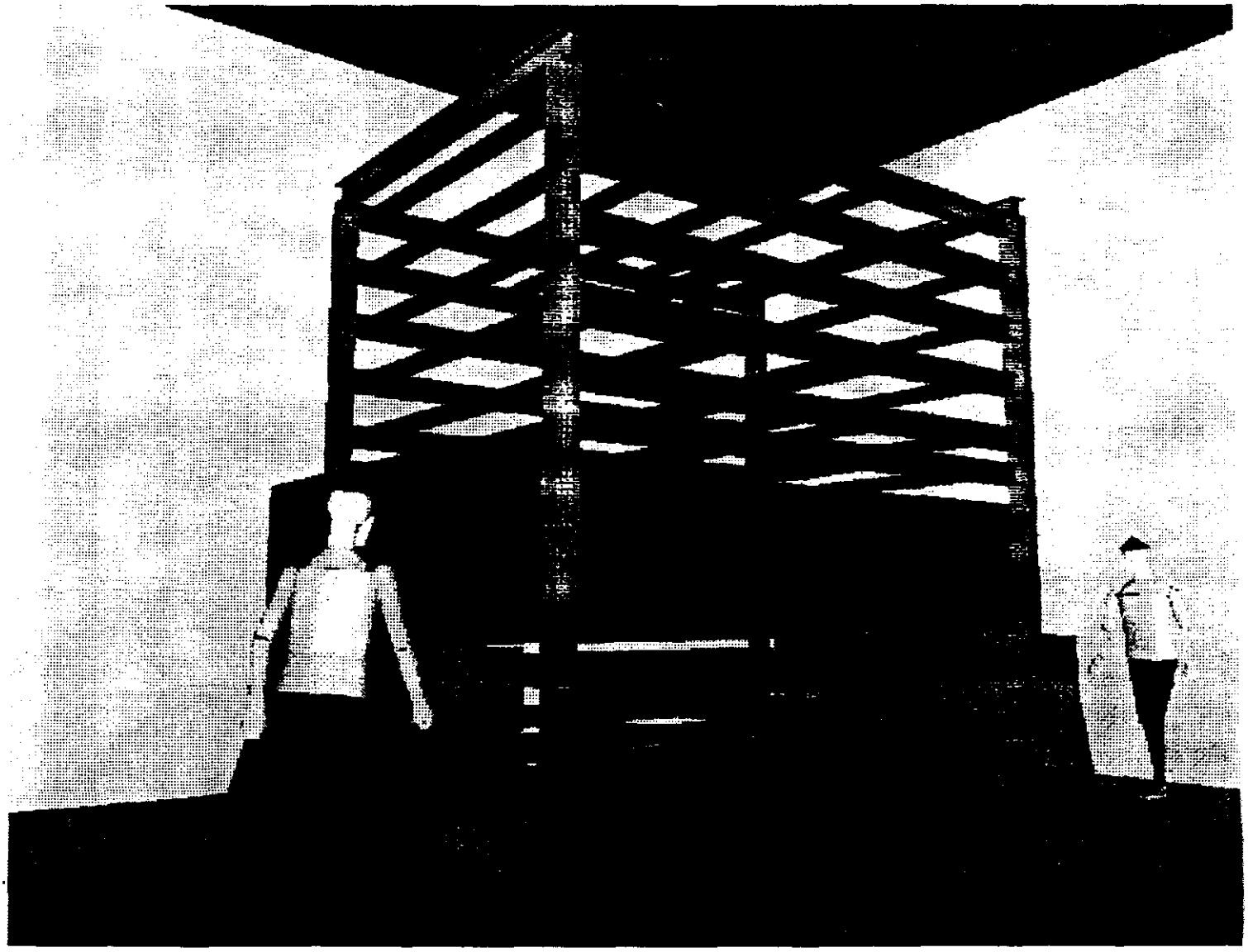



3.1
0.6
4.568
0.6









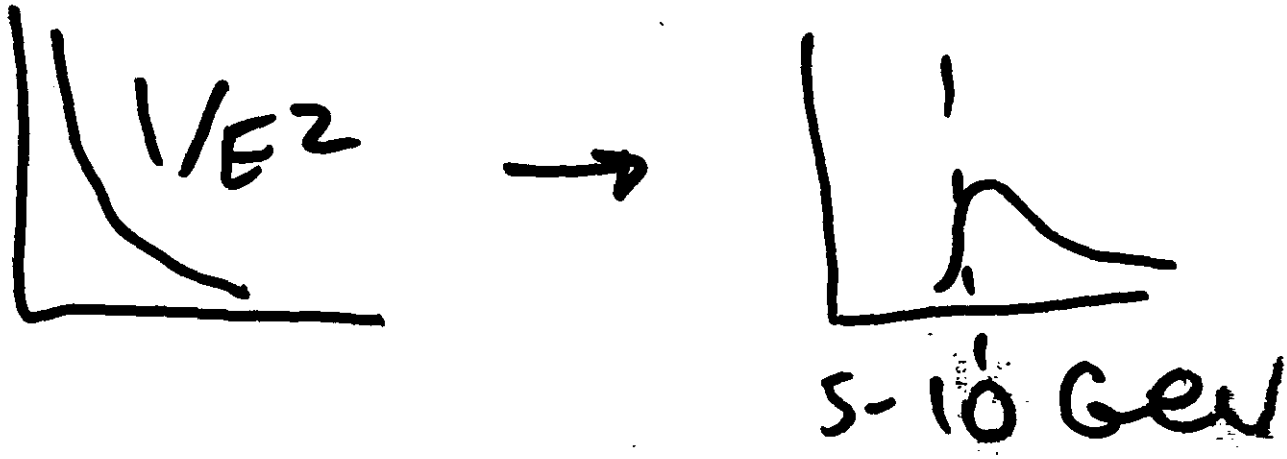
cosmic ray studies with muon multiple scattering effects included (A. Vanyas)

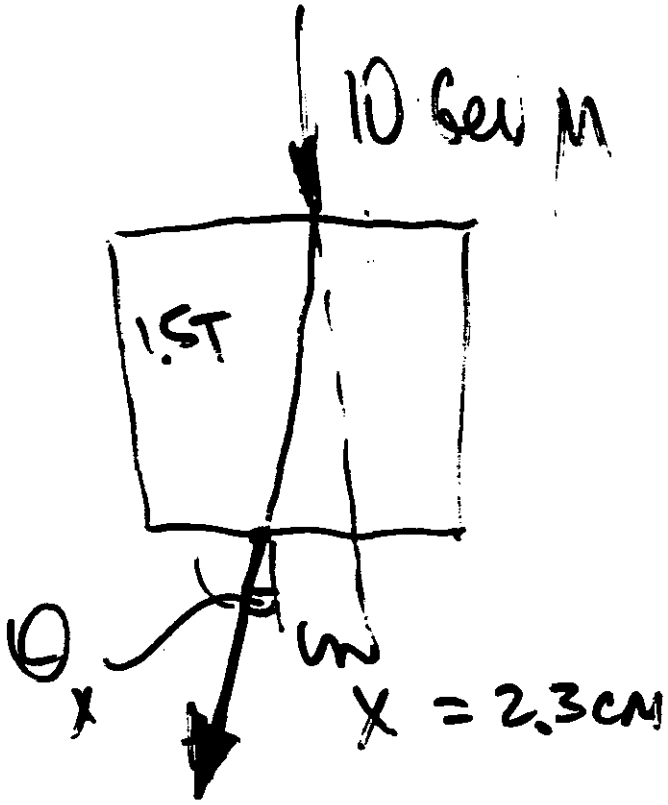
Nov. 8
SSC L muon meeting

Full Geant (of Block Iron)
(Yu. Yarba)

4 telescope configurations:
(Gena M.)

1m Iron thickness, field = 1.5T
no chamber resolution included

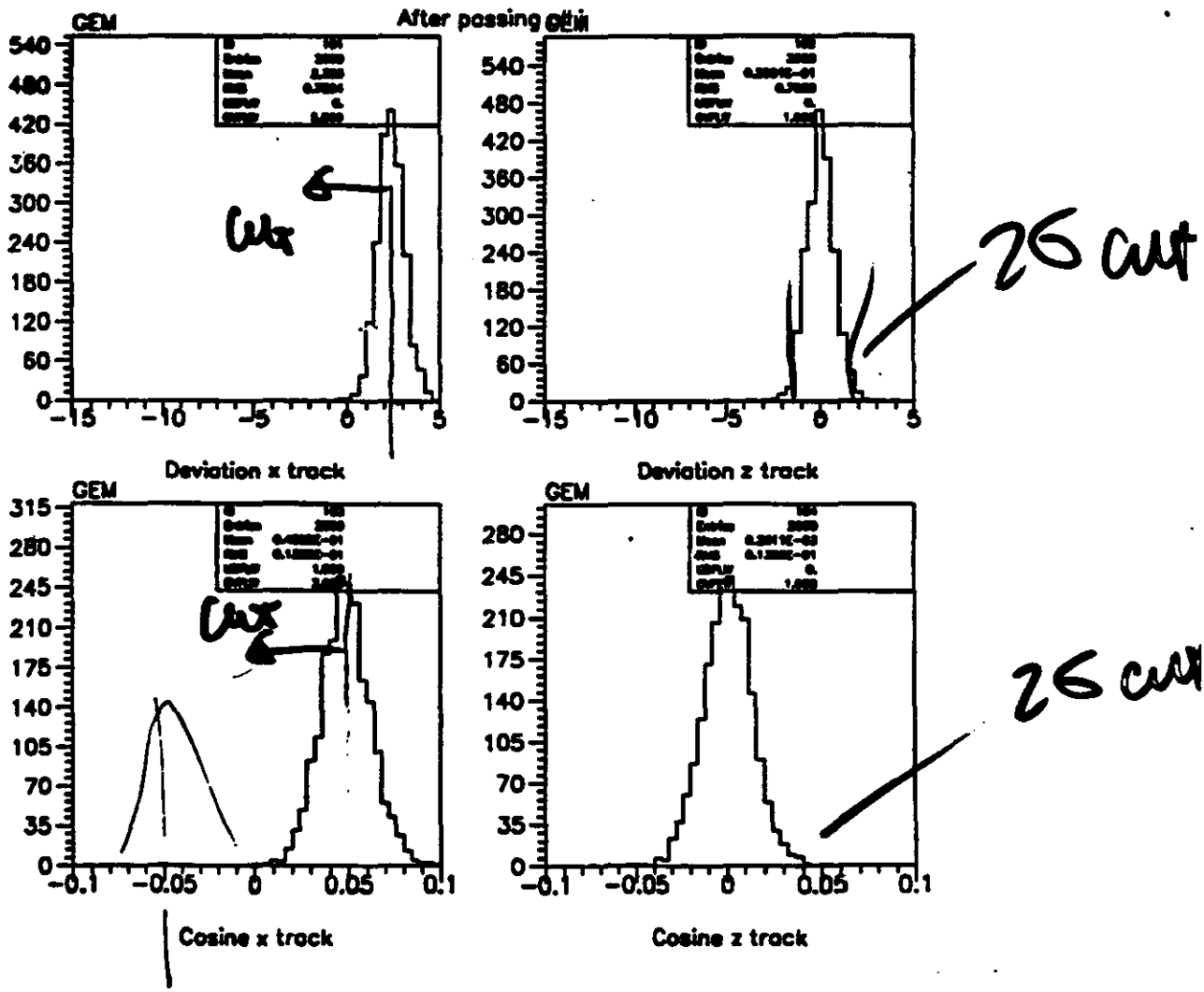


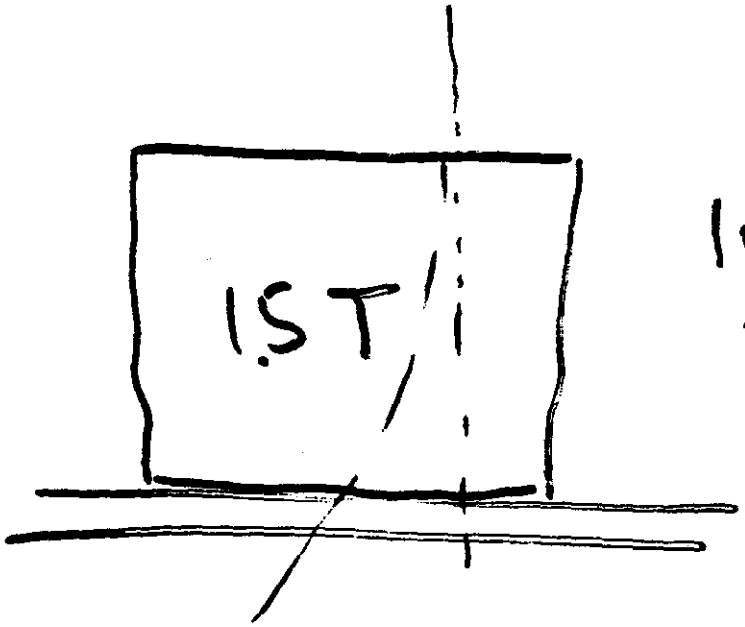


1m Fe Magn

10 GeV

91/11/06 20.01



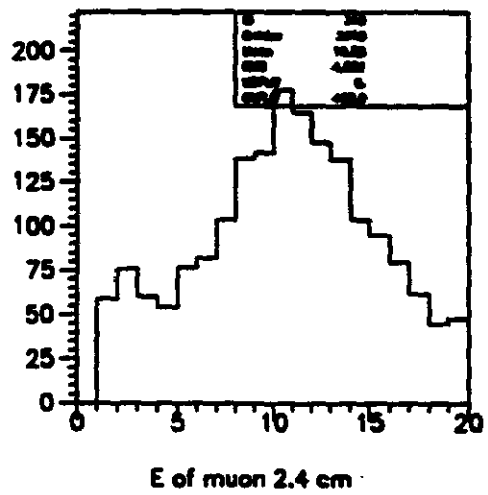


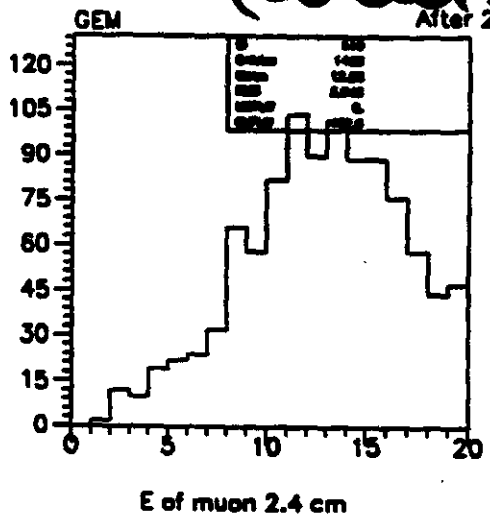
1m Fe magnet

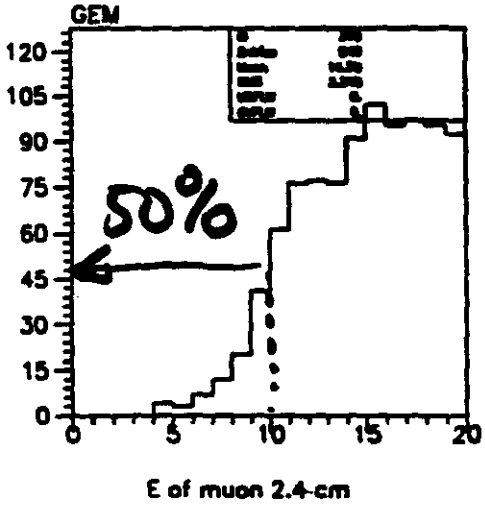
2 projection: (25 cuts)

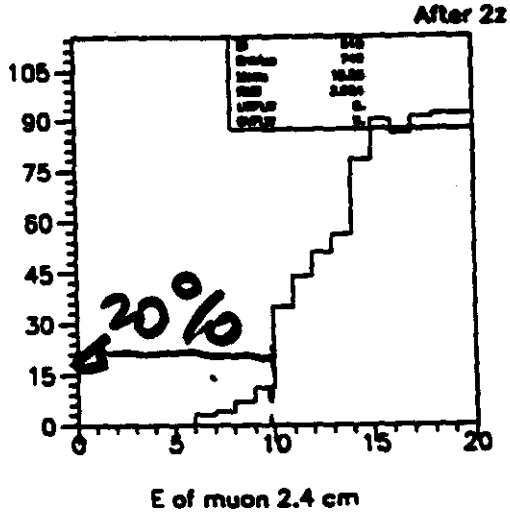
spect.

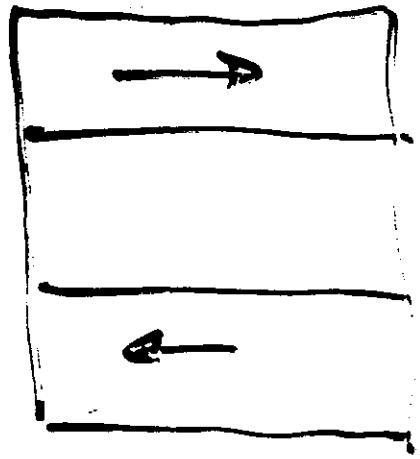
effic.







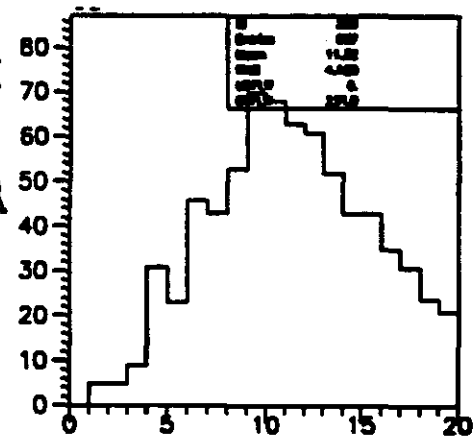


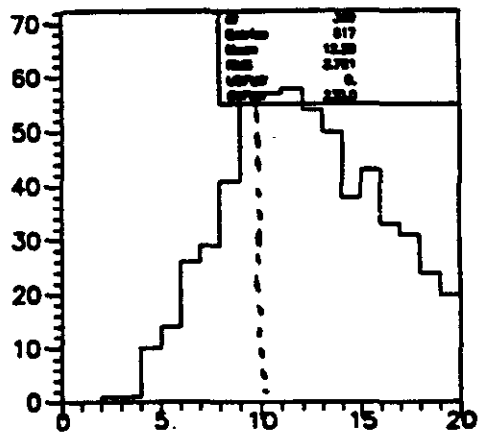


1m air gap

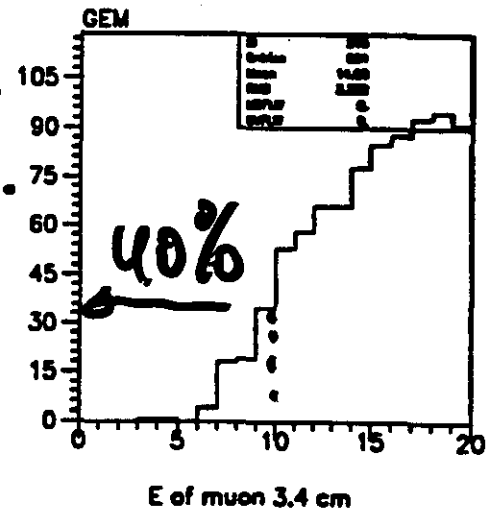
2 projection

Energy: Spectra





eff.

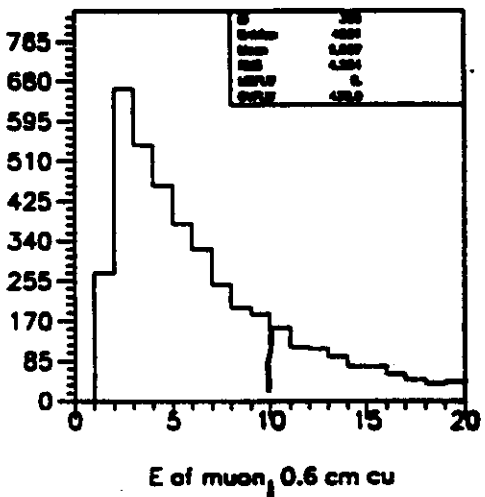


about the same effic ~ 3%

no field

1m iron

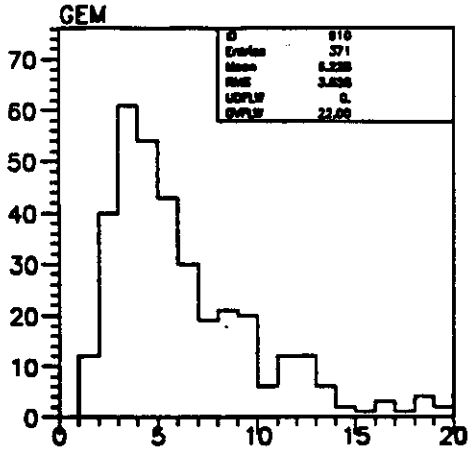
0.8 σ cuts



50% effic.

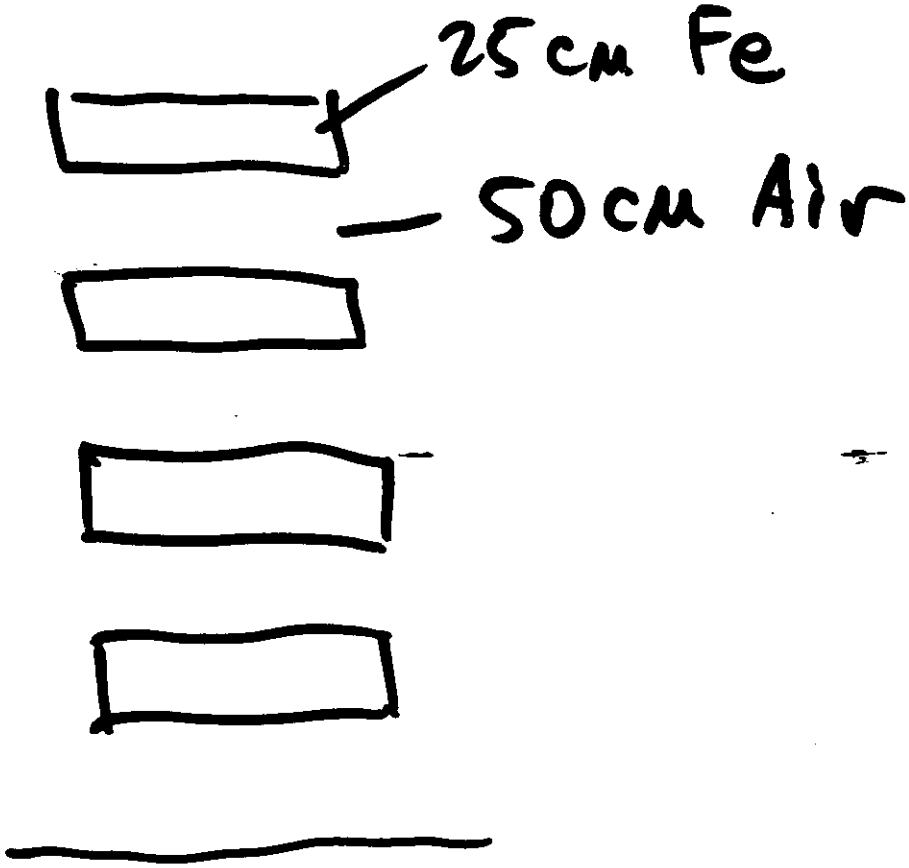
40% eff. at

2σ cut in both projections in 4 chambers



E of muon 5. cm cut

no field



PRESSURIZED DRIFT TUBE SUBGROUP

TASK: BUILD 4m × 1m × 4 layers PROTOTYPE FOR LSP TEST IN JUNE, 1992

GOALS:

- LEAK RATE AT 30psia OK?
- WIRE SAG CORRECTABLE?
- CONSTRUCTION RELIABLE AND AFFORDABLE?
- MODULE ALIGNABLE?
- SUITABLE GAS:
  - SAFE?
  - 100μm at 30psia?
  - <1μs drift time?
  - environmental sensitivity OK?

BOSTON UNIVERSITY

Electronics (EDF at BU)

MICHIGAN STATE UNIVERSITY

Mechanical Design (LANL)

SSC LAB

Assembly/Production of parts at SSCL

IHEP (BEIJING) (Ahlen, Zhou and Rongsheng Xu, Oct. 10)

2 Physicists to assist with assembly and operation of PDT-LSP

5 Physicists to work on GEANT LEVEL DETECTOR SIMULATIONS

JINR (DUBNA) GROUP (LNP)

Names to be on LoI:

G. Alexeev †
A. Bannikov
L. Barabash
S. Baranov
Y. Bonyushkin
★ G. Chelkov †
B. Fialovszky
Y. Gornushkin
V. Kalinnikov
M. Kazarinov
B. Khomenko
N. Khovansky
O. Klimov
A. Korytov
Z. Krumstein
P. Kulinich
V. Malyshev
Y. Merekov
A. Nozdrin
A. Olshevski
Y. Petukhov
A. Popov
Y. Sedykh
L. Tkatchev
V. Tokmenin
L. Vertogradov
V. Frolov

★ SPOKESMAN

† AHLEN MET WITH AT CERN ON NOV. 25

JINR - LNP R+D on PDT's

PRIORITORIZED LIST:

- Study performance at Hi P (10 atm)
- Search for right gas
- Study cathodes (stainless steel, Al)
- Study performance in $\vec{B}$
- End plug design
- Resolution vs P (LS and prop. modes)
- Study of hybrid system (PDT + LST)
- Trigger schemes
- Assembly techniques
- Monte Carlo work
- Wire position accuracy with x-ray source
- Front end electronics

TIME SCHEDULE:

February or
March 1992

Meeting of GEM muon representatives with LNP group at Dubna to compare progress + coordinate future work

BY APRIL or MAY, 1992

Beam test of small (1m x 1m) prototype

BY JUNE or JULY 1992

Arrival of DUBNA people at SSCL to participate in tests

ROMANIAN SITUATION

Sept. 24, 1991

Telefax from G. Pascovici, Director of Institute of Atomic Physics, Bucharest:

Groups to work on GEM:

Physics + Detector Simulations:

4 physicists (K. Zimmer)

Detector Systems:

3 physicists, 2 engineers (C. Stan-Sion)

Dynamical Systems (Data processing/acq.):

3 physicists, 3 engineers (A. Dorobantu)

INTERESTED IN PDT's and RPC's

Nov. 26 meeting at CERN:
S. Ahlen and A. Marin with:

Serban Constantinescu:
Head of Computer Lab at IAP

Venera Baldea
+ Sanda Mita of
High Energy Lab at IAP

They will:

1. Have Bitnet capabilities within 3 mo.

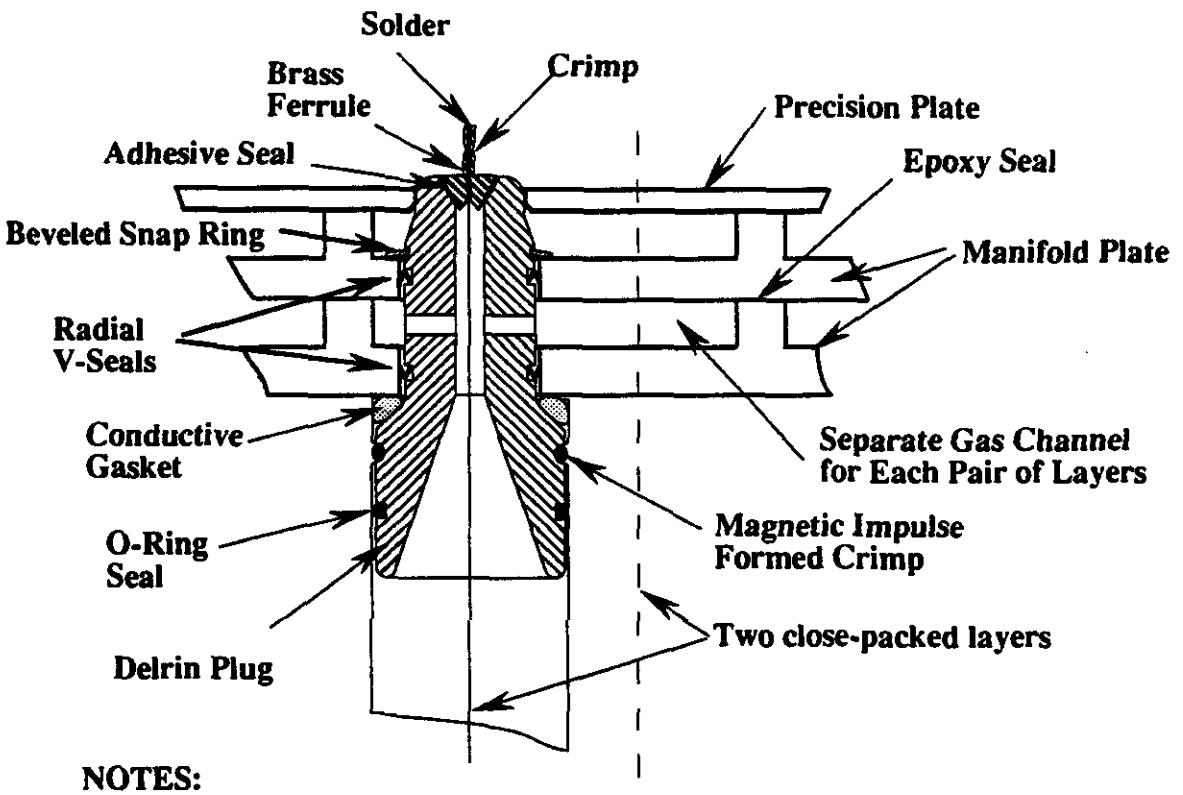
2. Have full list of names sent for LoI

3. Identify physicists interested in spending some time at SSC

4. Visit to Bucharest in Feb. to check out facilities/capabilities

Assembly Sequence- Captured Plug Version

1. Cut tubes to length, clean
2. Attach seals to plugs, insert into tubes
3. Crimp tubes onto plugs
4. Pressure test each tube
5. Attach conductive gaskets, insert tubes into one manifold plate and secure with snap rings
6. Test tube-to-plate resistance
7. Attach mainifold plate to other end of tubes and secure with snap rings
8. Pressure test each gas volume, temporarily sealing feedthrough holes
9. Assemble precision plates over tube ends and secure
10. Feed wires through tubes and ferrules, seat ferrule with epoxy, tension and crimp wires
11. Fill ends of ferrules with solder
12. Test wire continuity and HV resistance, replace any bad ones
13. Pressure test each gas volume

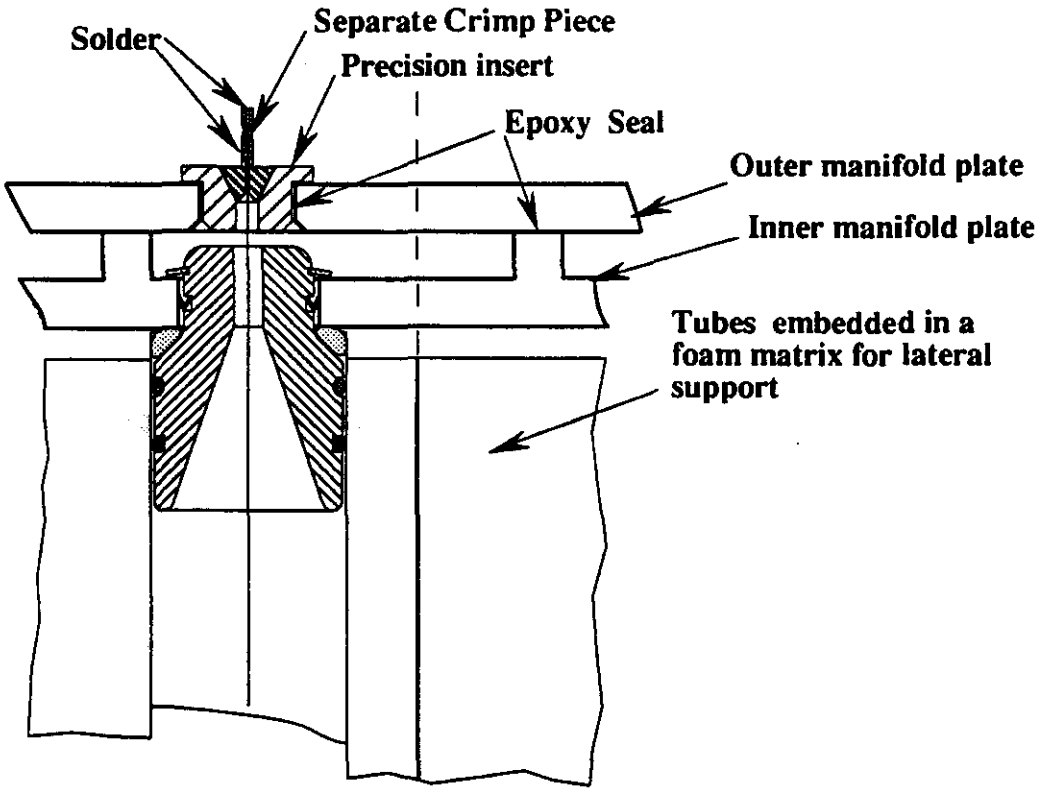


NOTES:

1. **The manifold plate is made from two identical pieces epoxied together to form the gas volumes**
2. **Sealing the ferrules into the precision plate after the wire has been threaded may be awkward**
3. **Wires can pobably be fed with a pneumatic system**
4. **Plastic tubes will require metal bands for crimping to the plugs, metal tubes may not need these**
5. **Tube lengths and plug positions will require close tolerance to insure good electical contact with the manifold plate. This can be achieved by holding the tubes and plugs in a jig while crimping the tubes**

Assembly Sequence- Captured Plug Version-Alternatives

1. Cut tubes to length, clean
2. Attach O-ring seals to plugs, insert into tubes
3. Crimp tubes onto plugs
4. Pressure test each tube
5. With tubes held in a temporary fixture, laminate with foam
6. Attach conductive gaskets and V-seals, insert tubes into manifold plates and secure with snap rings
7. Test tube-to-plate resistance
8. Epoxy inserts into outer manifold plates, align and epoxy outer to inner plates
9. Pressure test each gas volume, temporarily sealing feedthrough hole
10. Feed wires through tubes and ferrules, seat ferrule with epoxy, tension and crimp wires
11. Fill ends of ferrules with solder
12. Test wire continuity and HV resistance, replace any bad wires
13. Pressure test each gas volume



NOTES:

1. **Each alternative is independent of the others**
2. **A precision plate is not needed; the precision inserts which could be molded from glass, ceramic or plastic, are epoxied into the outer manifold plate in precise positions located from a jig plate**

GEM Prototype Full Scale Chambers
28x(6 m. X 0.5 M.) chambers

R and D Group

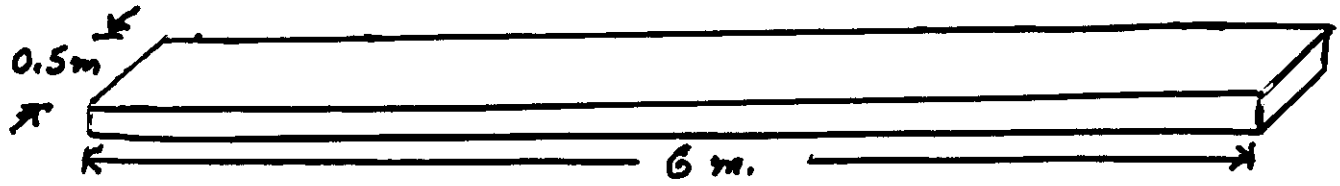
Dubna- Design and Test
Houston- Wire Placement Techniques
LeCroy- Timing Electronics
Louisiana ~~Houston-~~ Simulation,Data Analysis
MIT- Design, Construction, Tests
Livermore - Design Review, Costs
Stonybrook - Data Analysis

Schedule:

Design- Spring '91
Parts Ordered- Summer '91
Assembly- Fall '91
Tests- Winter '91-'92

Build, Wire and Test;

2 6m x 0.5m x 0.15m Chambers



Schedule:

Parts and Delivery :	Nov. and Dec.
Assemble :	Jan and Feb.
Test :	March

Measure Lorentz Angle in various gasses	Nov.
Test Tubes in Magnetic Field	Dec.

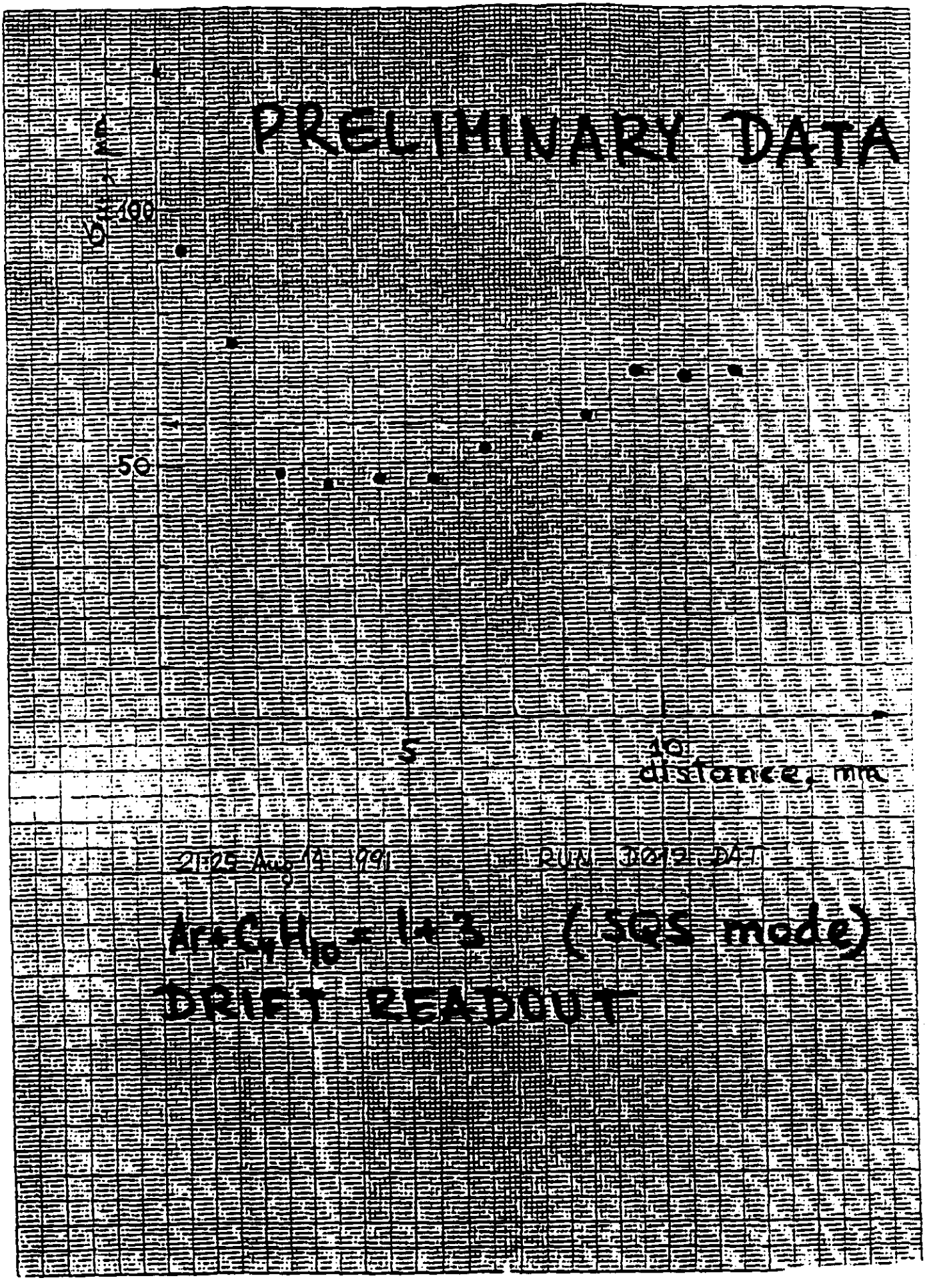

PRELIMINARY DATA
100
50
5
10
distance, mm
2:25 Aug 14 1991
RUN 3012 DAT
Ar+C4H10 = 1+3 (SGS mode)
DRIFT READOUT

Fig. V.1

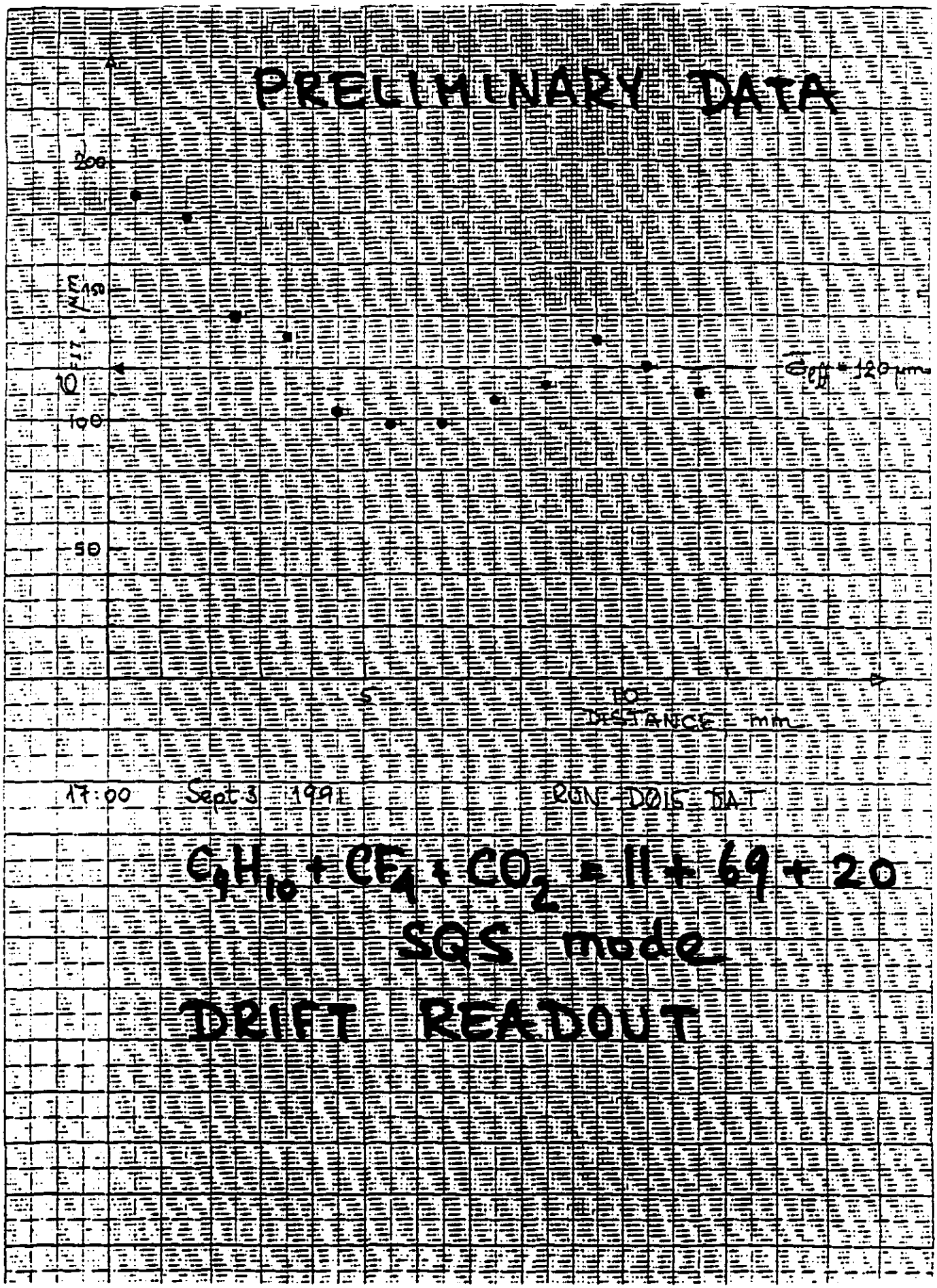
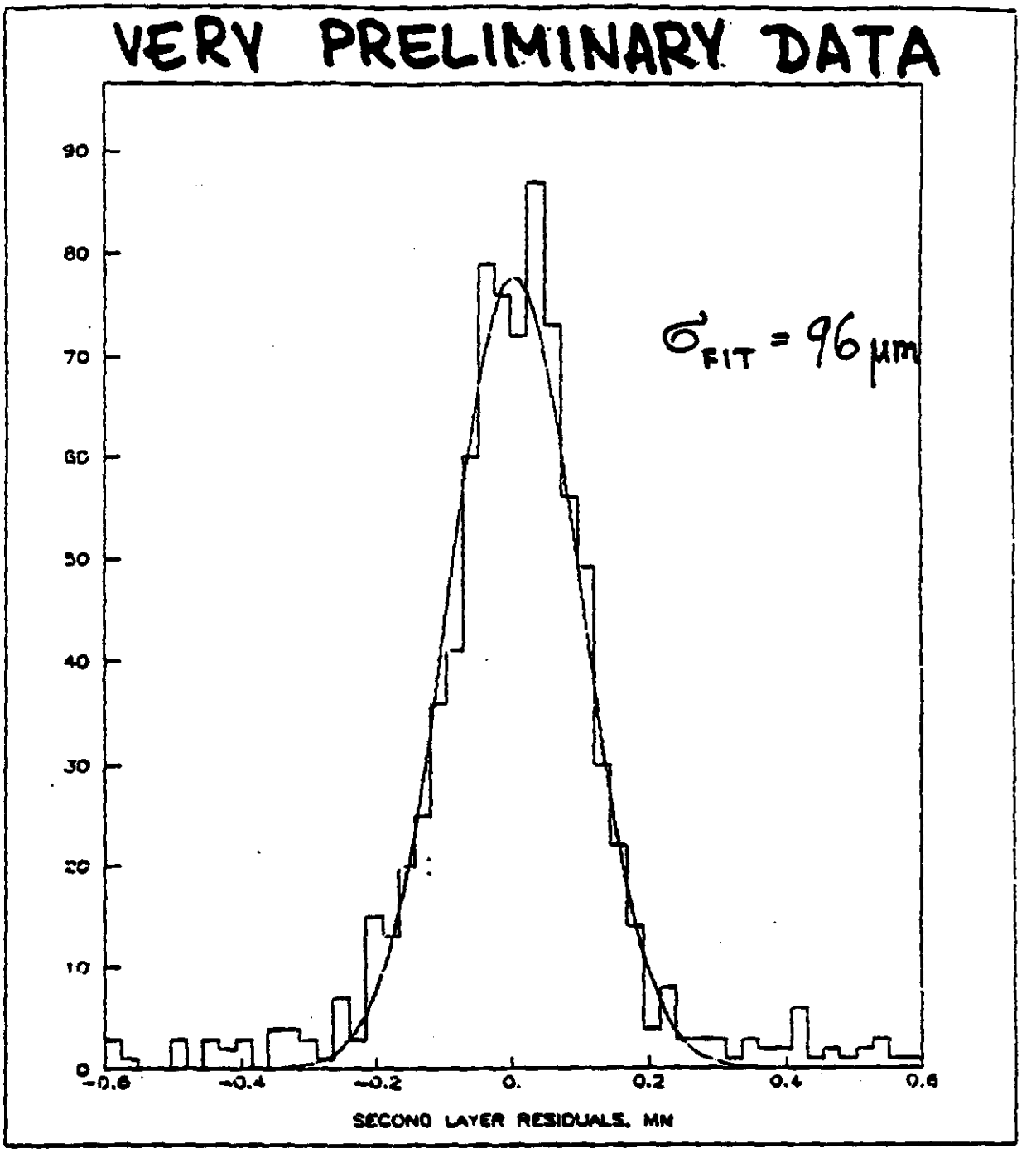

PRELIMINARY DATA
200
150
100
50
10
σ_{eff} = 120 μm
5
10
DISTANCE mm
17:00
Sept 3 1991
RUN D015 DAT
C_4H_{10} + CF_4 + CO_2 = 11 + 69 + 20
SQS mode
DRIFT READOUT

Fig. V.2

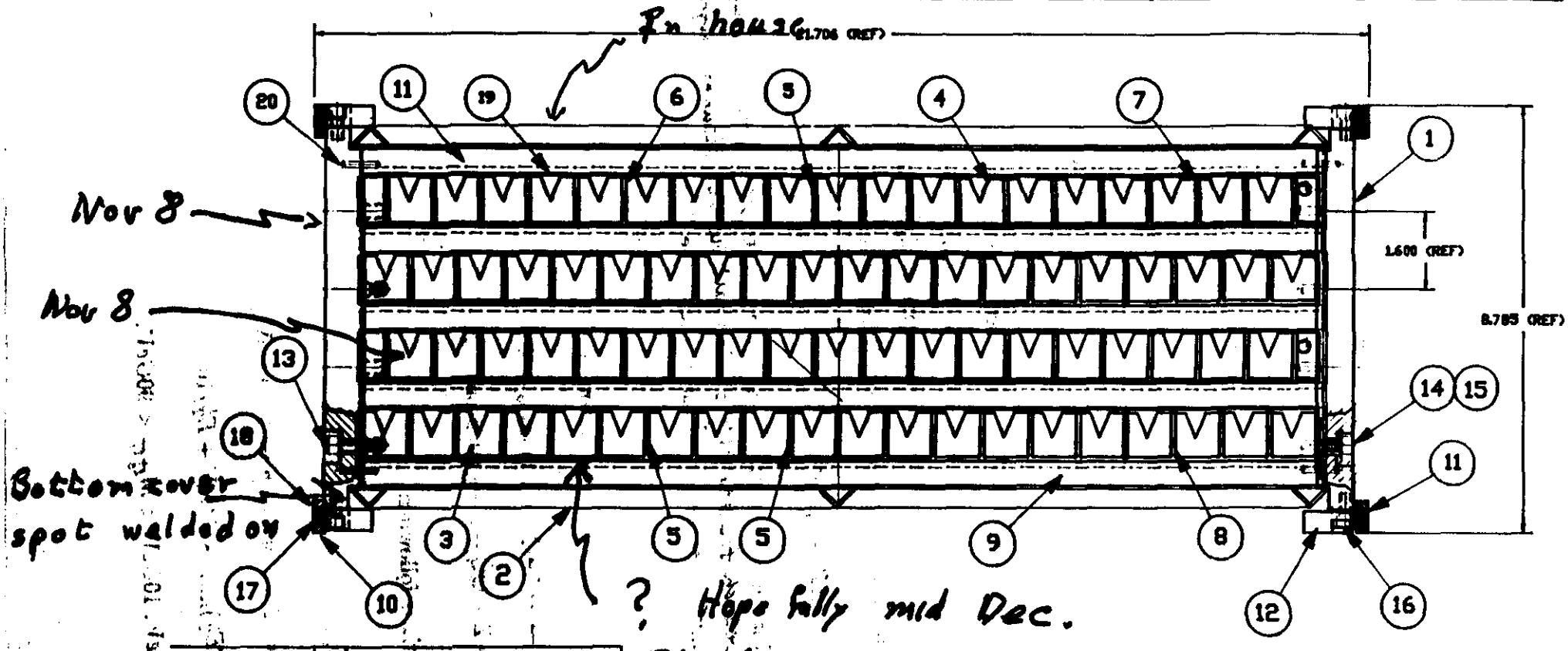


RUN - S001. DAT (STRIPS)

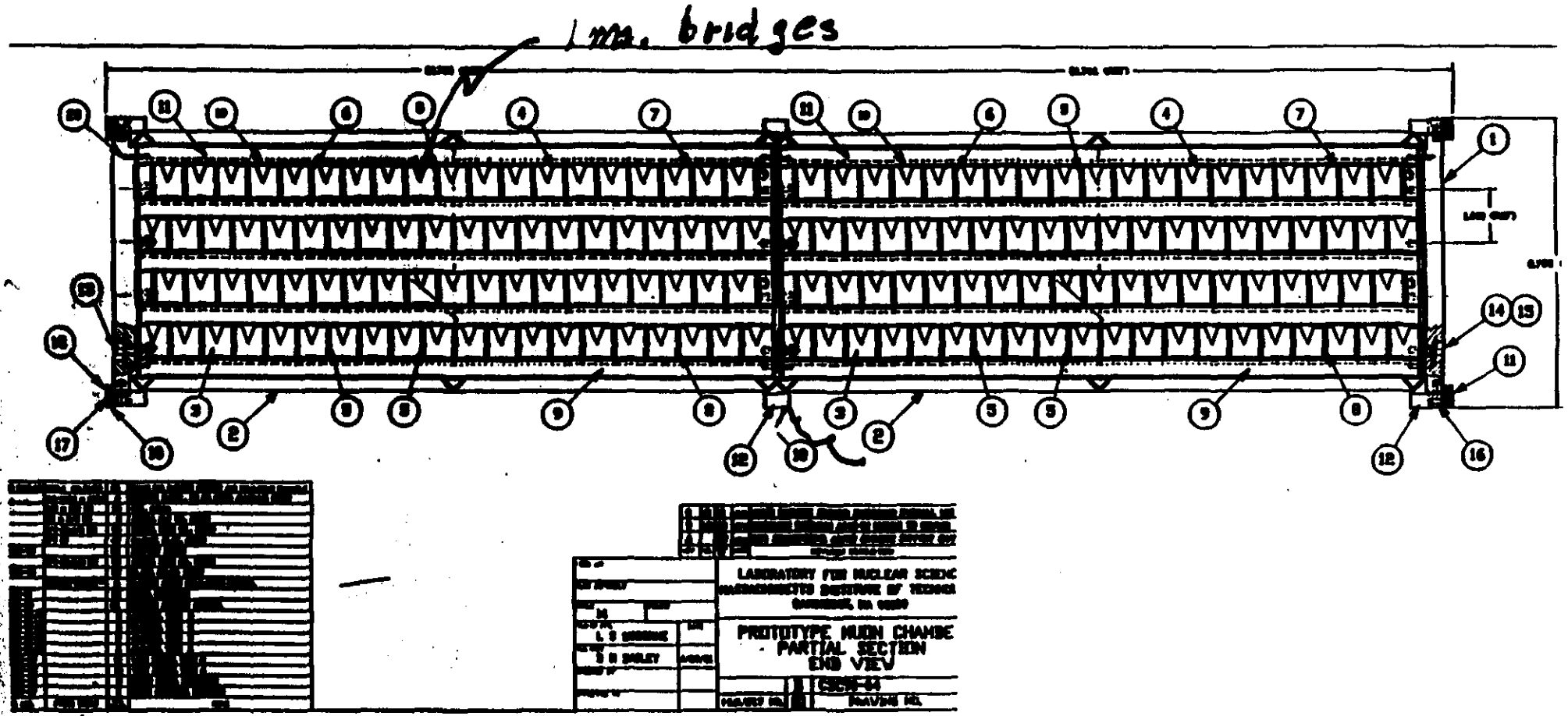
PROP. MODE ($Ar + C_4H_{10} = 1+3$, $U = 3.1$ kV)

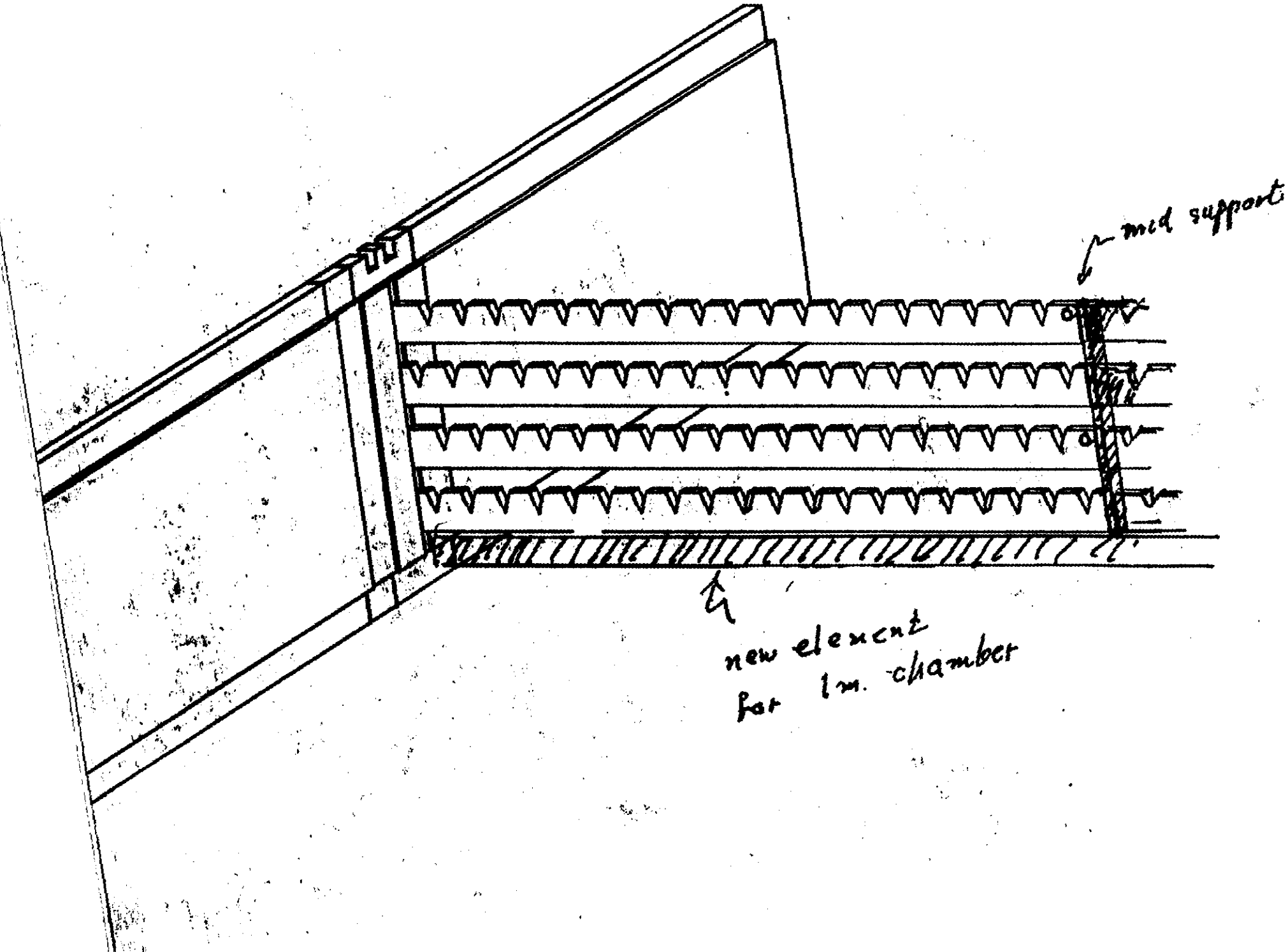
$\alpha \approx 1°$ $Q_{anode} \sim 1$ pC

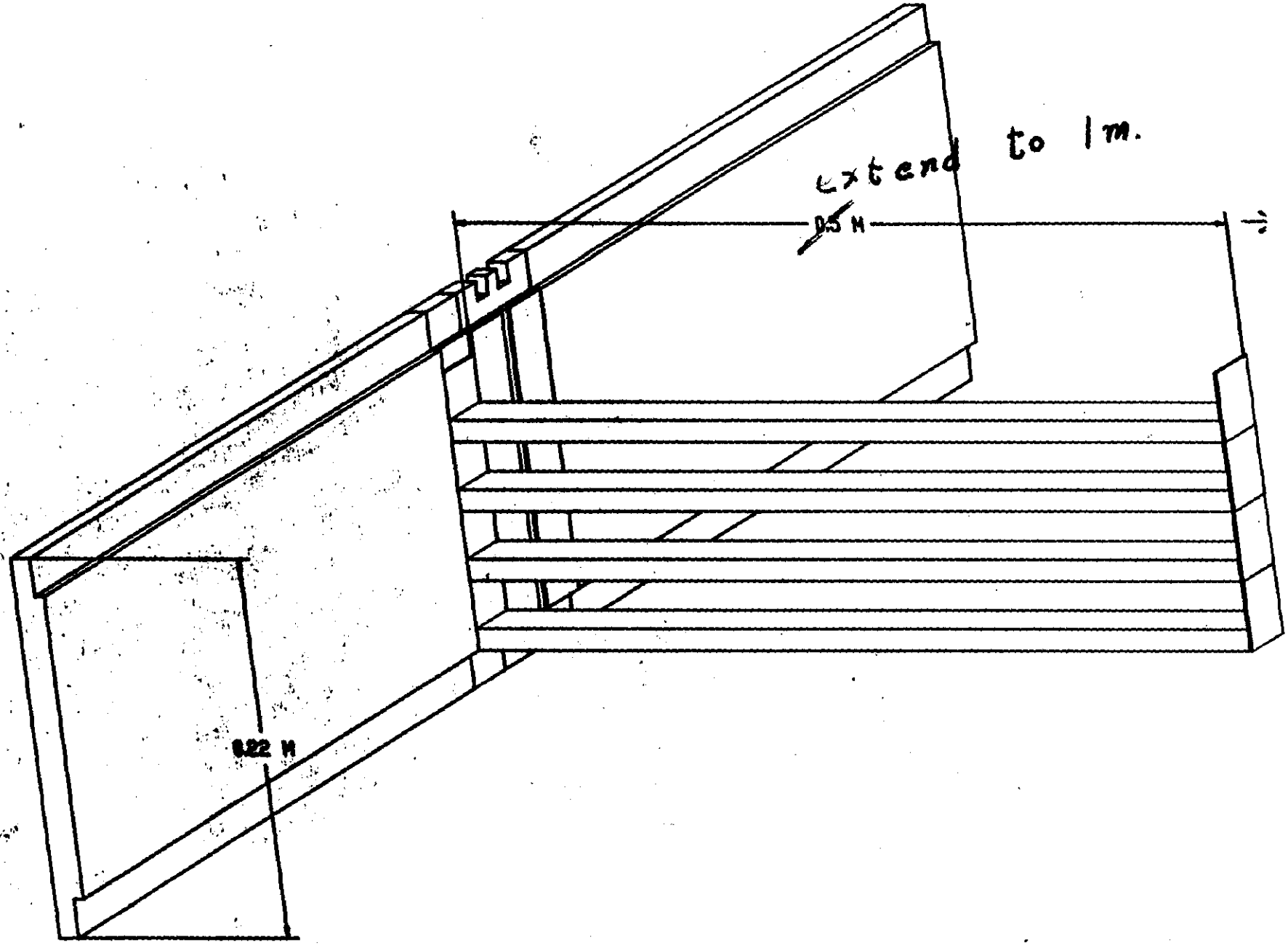
Fig. V.3


Pin house
21.706 (REF)
1.600 (REF)
8.785 (REF)
Nov 8
Nov 8
Bottom cover spot welded on
? Hopefully mid Dec.
Electronics; MIT Dec. 1
LeCroy Jan 1
LABORATORY FOR NUCLEAR SCIE
MASSACHUSETTS INSTITUTE OF TECHN
CAMBRIDGE, MA 02139
PROTOTYPE MUON CHAMB
PARTIAL SECTION
END VIEW
L S OSBORNE
D H BAILEY
4/29/91
D
CSC91-04

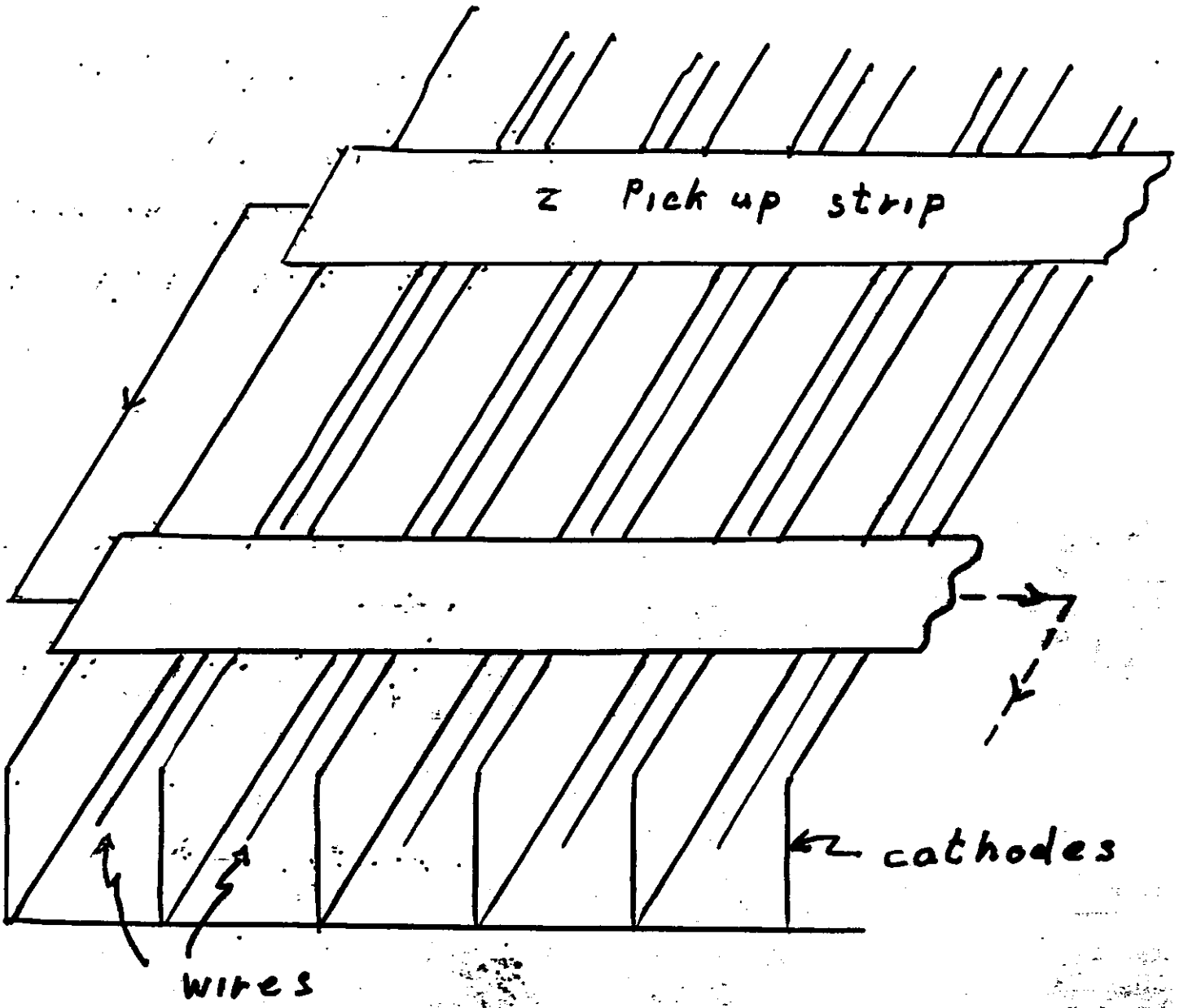
1 meter chamber




mid support
new element
for 1m. chamber


extend to 1m.
0.5 H
0.22 H

Z Measurement with Pickup Strips



Pickup strips make a vernier z-measurement within the timing measurement along the wire.
Several strips which bridge the accuracy of the timing measurement can be ganged in series.

Design, Build, and Test

2 (?) 4 m × 1 m × 0.2 m chambers

4 layers - 40 wires / layer

Schedule:

Design:		Nov. '91
Parts Delivery		Feb. '92
Assemble		March, April
Test	MIT	May →
	SSCL	May →

Cathode Strip Chambers

Participants:

BNL: J. Harder, P. O'Connor, L. Paffrath, V. Polychronakos, V. Radeka, S. Rescia, L. Rogers, G. Smith, D. Stephani, B. Yu

BU: W. Earle, E. Hazen, A. Johnson, D. Osborne, D. Orlov, J. Shank, D. Warner, S. Whitaker, R. Wilson

LNPI: V.T. Gratchev, A.G. Krivschich, O.E. Prokofiev, V.M. Samsonov, V.V. Sarantsev, N.K. Terentiev

ORNL: R. Todd, M. Bauer, C. Britton, A. Wintenberg

HU: K. Lau, B. Mayers, J. Pyrlik, R. Weinstein

JINR: G. Alekseev, Yu. Bonyushkin, N. Khovanski, Z. Krumstein, G. Shelkov

SSCL: G. Mitselmakher, F. Stocker, L. Villasenor

LNPI
St. Petersburg

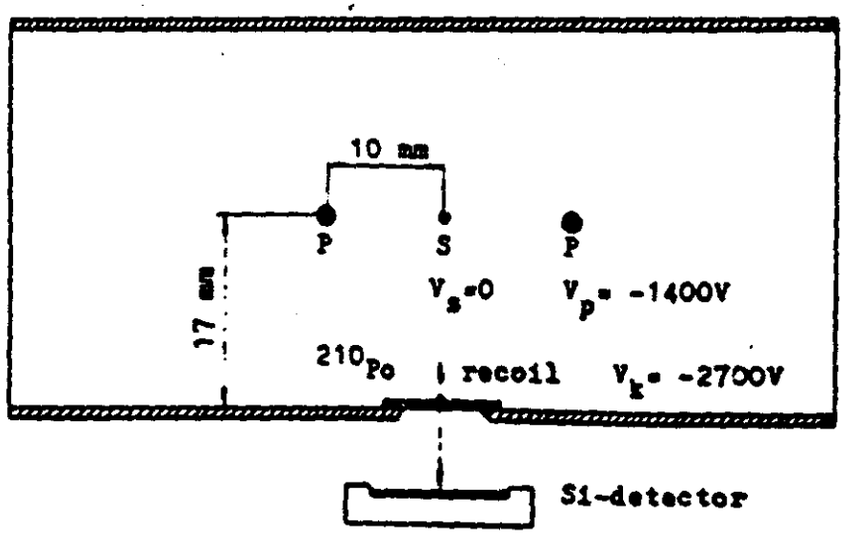
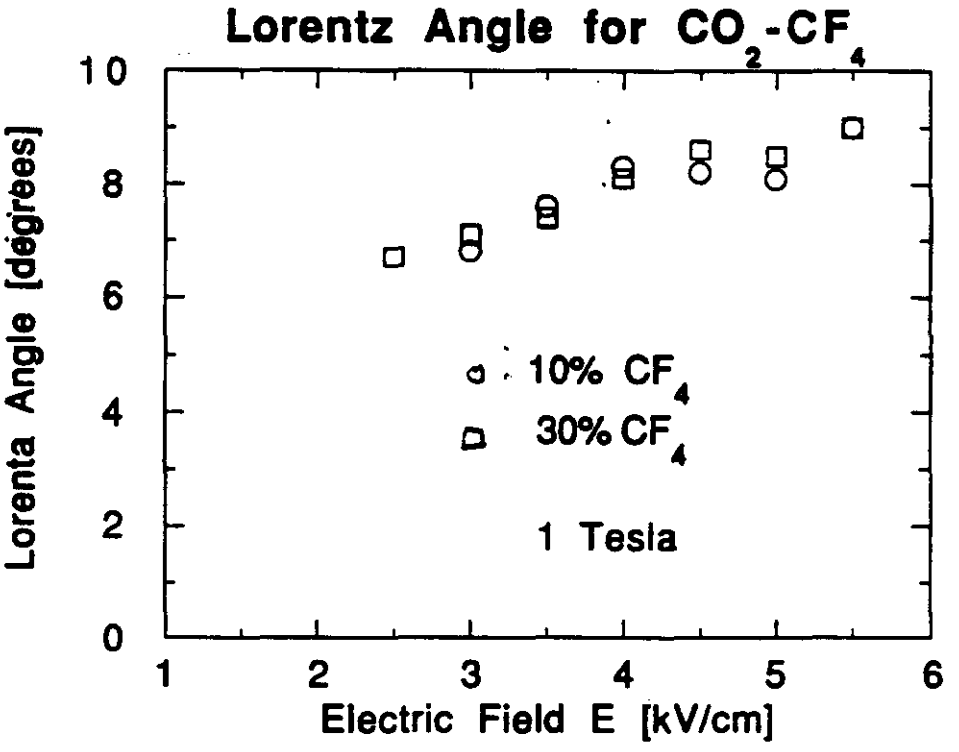


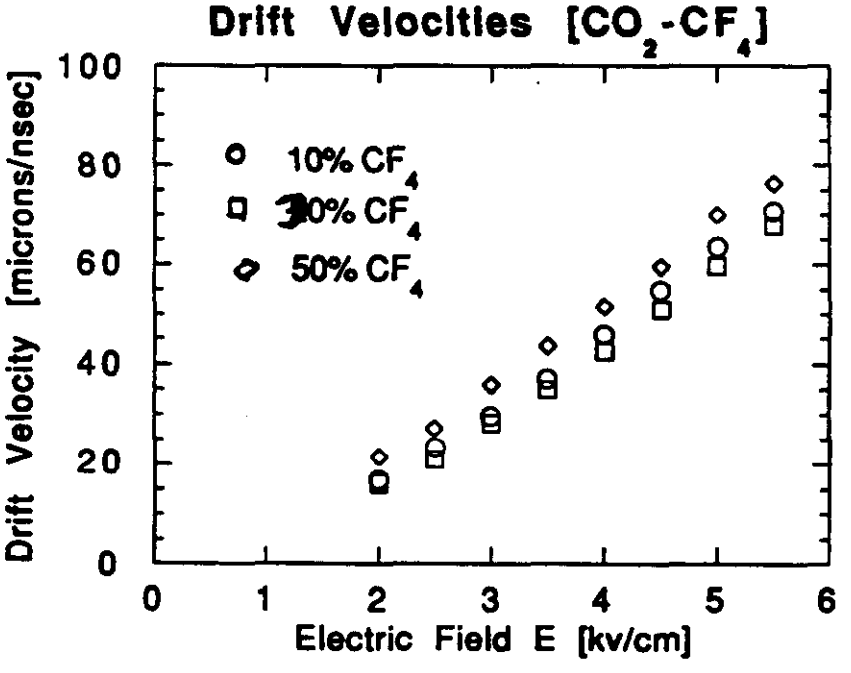
Fig. 1. Schematic layout of the drift chamber used in the electron drift velocity measurements. S – sense wire ⌀ 30 μm. P – potential wire ⌀ 75 μm.

Msrmnts of drift vel
and Lorentz angles.

PRELIMINARY

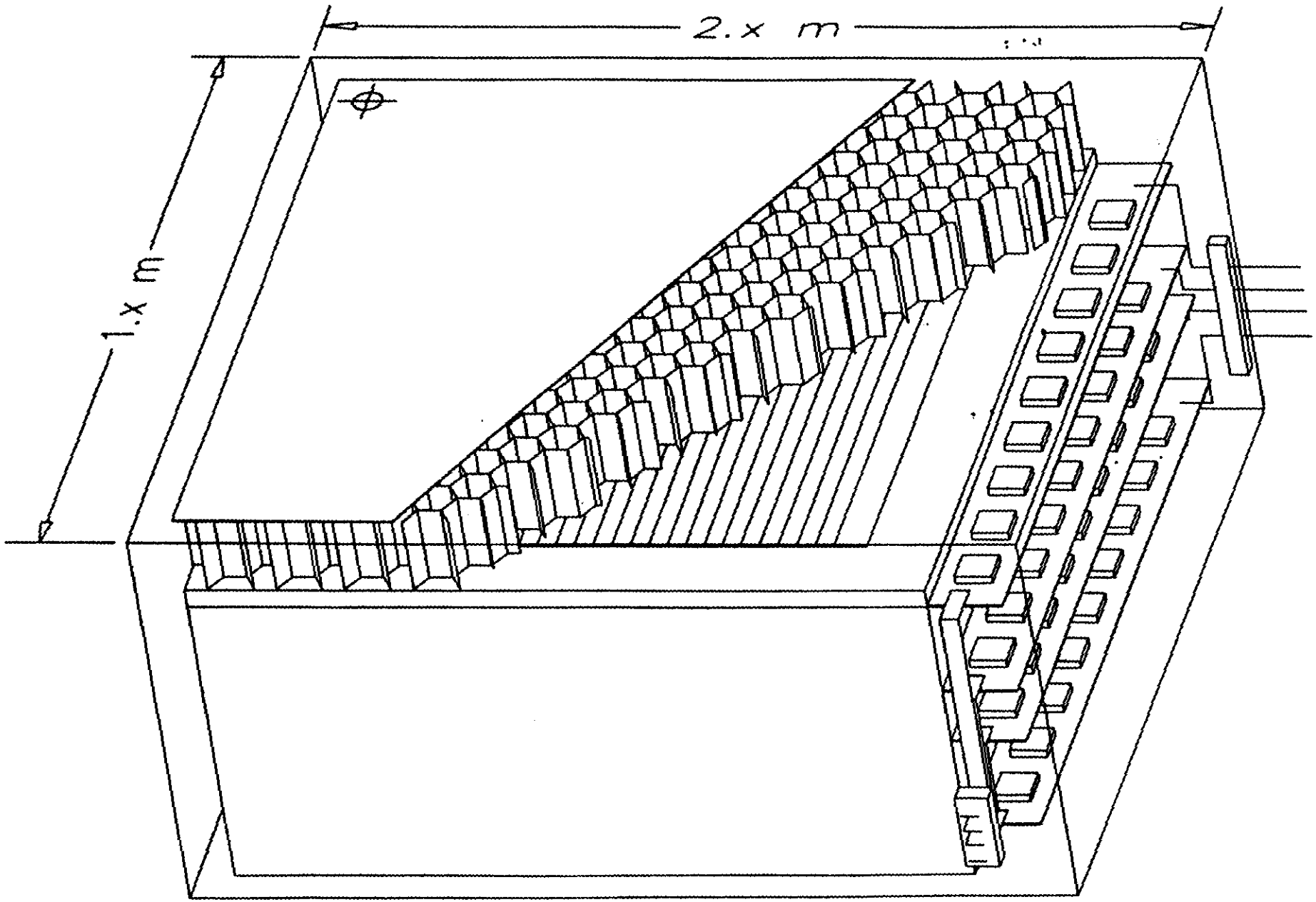
Oleg Prokoriev et al
LNPI





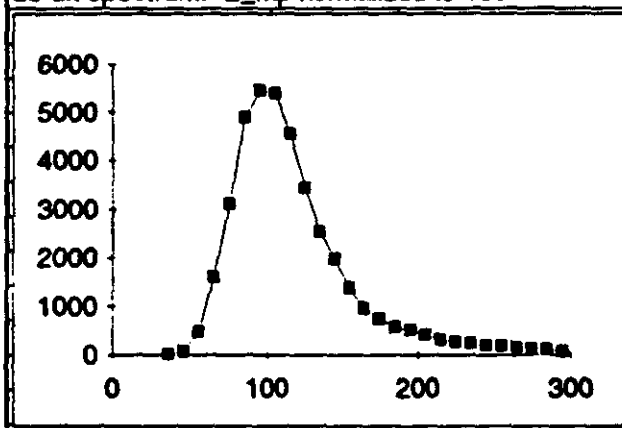
1.92 mm
.250 mm
1.9"

Interstrip Capacitance
σ < 0.5%
Number of strip pairs
0
5
10
15
20
25
24
25
26
Capacitance [pf]


2.x m
1.x m

ADC level settings (relative to E_mp) and resolution			
level 1	level 2	level 3	sigma/L*sqrt(12)
0.5	1	1.5	0.75
0.333	0.667	1	0.56
0.25	0.5	0.75	0.4
0.2	0.4	0.6	0.34
0.1667	0.3333	0.5	0.33
0.125	0.25	0.375	0.39
0.1	0.2	0.3	0.49
0.1	0.2	0.4	0.36
0.2	0.4	0.8	0.32
0.1	0.3	0.9	0.3
0.1	0.25	0.625	0.27
0.1	0.3	0.6	0.27
0.05	0.2	0.8	0.37
0.1	0.2	0.6	0.3

de-dx spectrum. E_mp normalized to 100



R&D Progress at Boston University
8 November 1991

Scott Whitaker

Gas Tests:

Pure CF4 and high-performance filter acquired --> good drift properties

Measurments of drift velocities and lorentz angles in CF4/CO2 mixtures
--> plots

Test chambers designed and in fab for gain studies

Readout electronics:

board for Amplex readout is designed, in layout

pc-driven readout conceived, being coded

Prototype chambers:

Medium-sized trapezoidal chamber designed

Cathode laid out -- drawing

Electrostatic modeling under way

Monte Carlo simulations

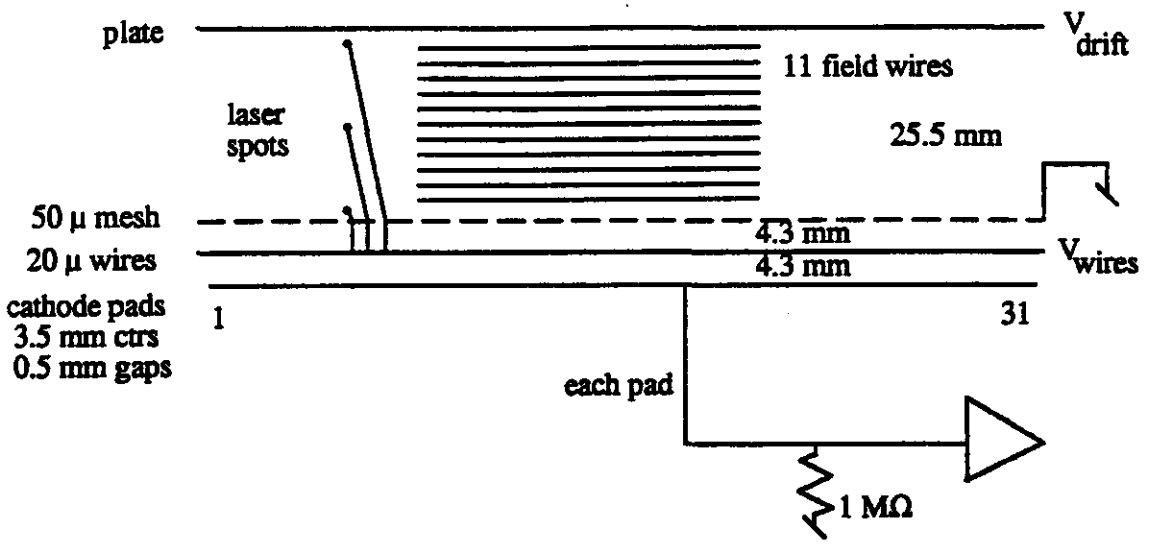
Geant up and running on SGI workstation

GEM MC being acquired from T. Bolton

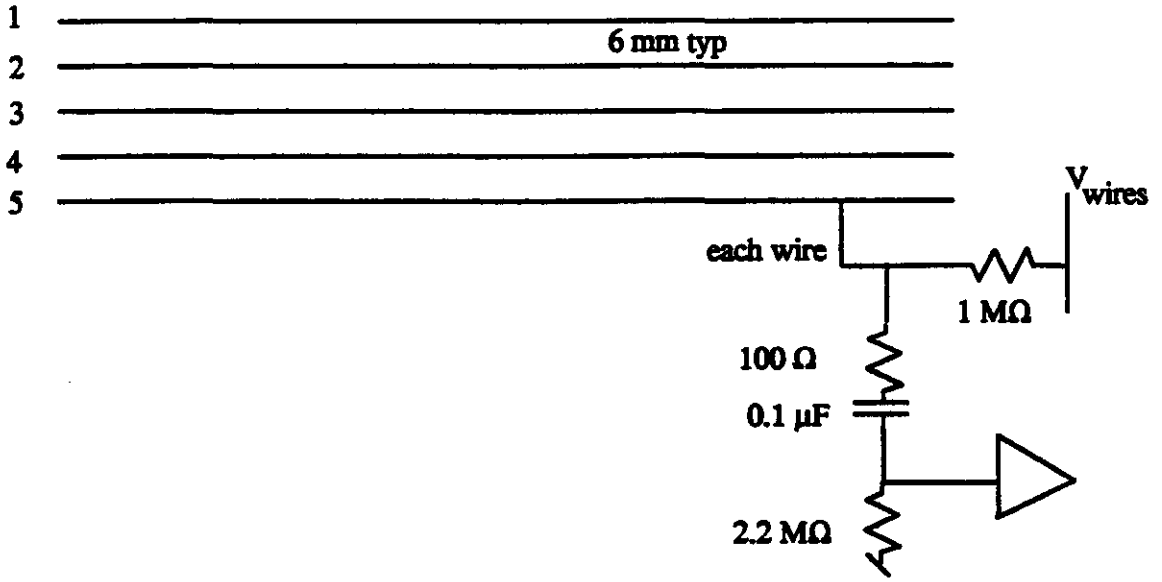
GAS TESTER

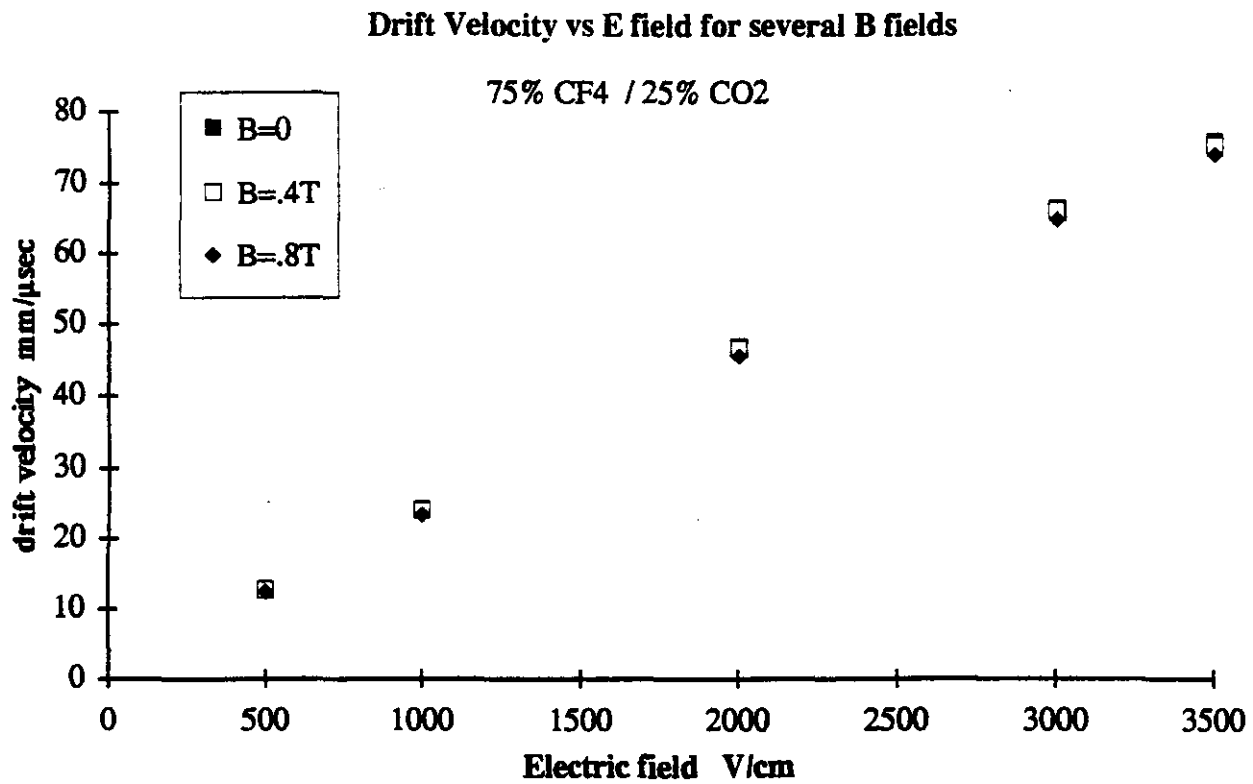
Bing Zhou
Alex Marin

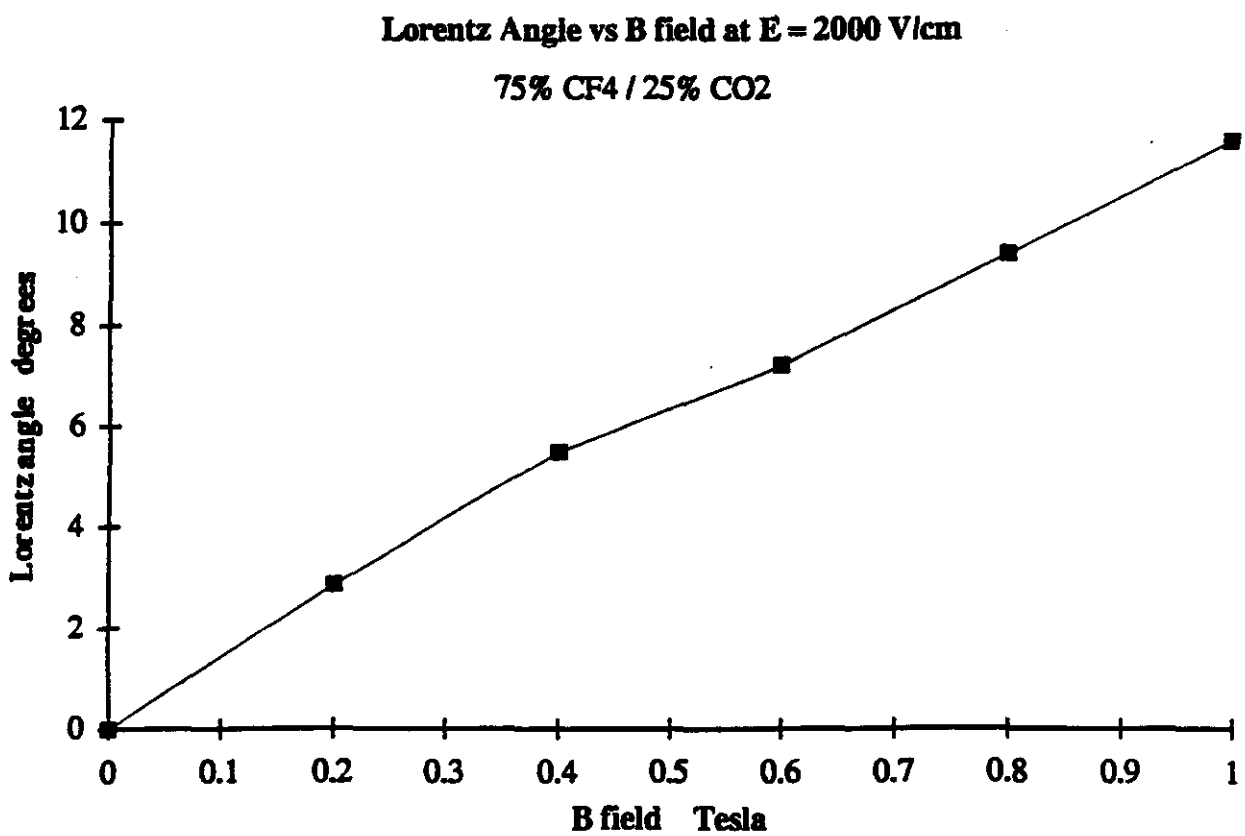
TOP VIEW



END VIEW

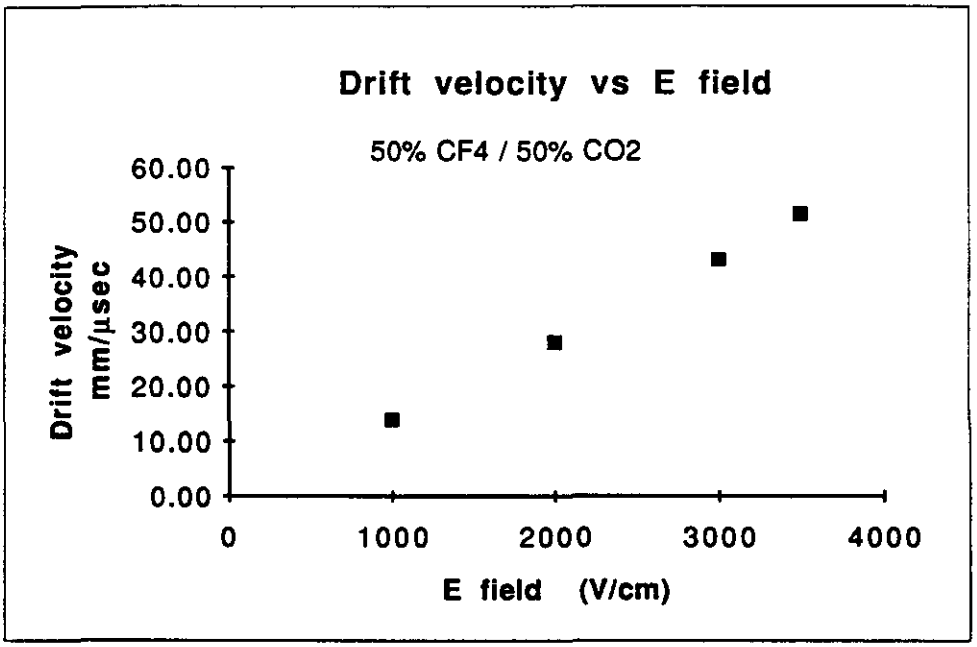


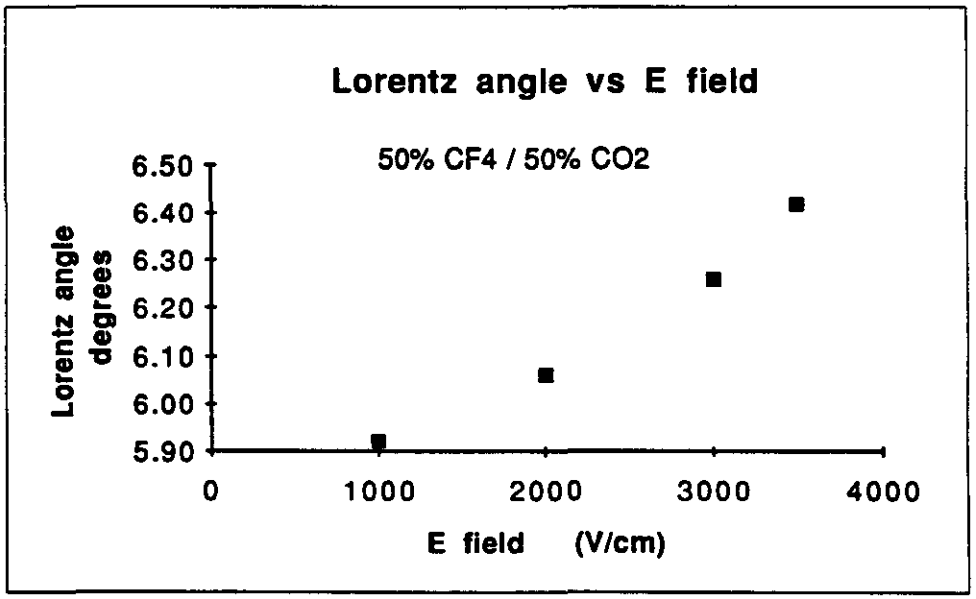

Drift Velocity vs E field for several B fields
75% CF4 / 25% CO2
B=0
B=.4T
B=.8T
drift velocity mm/µsec
0
10
20
30
40
50
60
70
80
0
500
1000
1500
2000
2500
3000
3500
Electric field V/cm


Lorentz Angle vs B field at E = 2000 V/cm
75% CF4 / 25% CO2
Lorentz angle degrees
0
2
4
6
8
10
12
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
B field Tesla

50% CF4 / 50% CO2

E field V/cm	B field Telsa	Drift vel mm/µsec	Theta L degrees
1000	0.8	13.98	5.92
2000	0.8	28.00	6.06
3000	0.8	43.13	6.26
3500	0.8	51.36	6.42

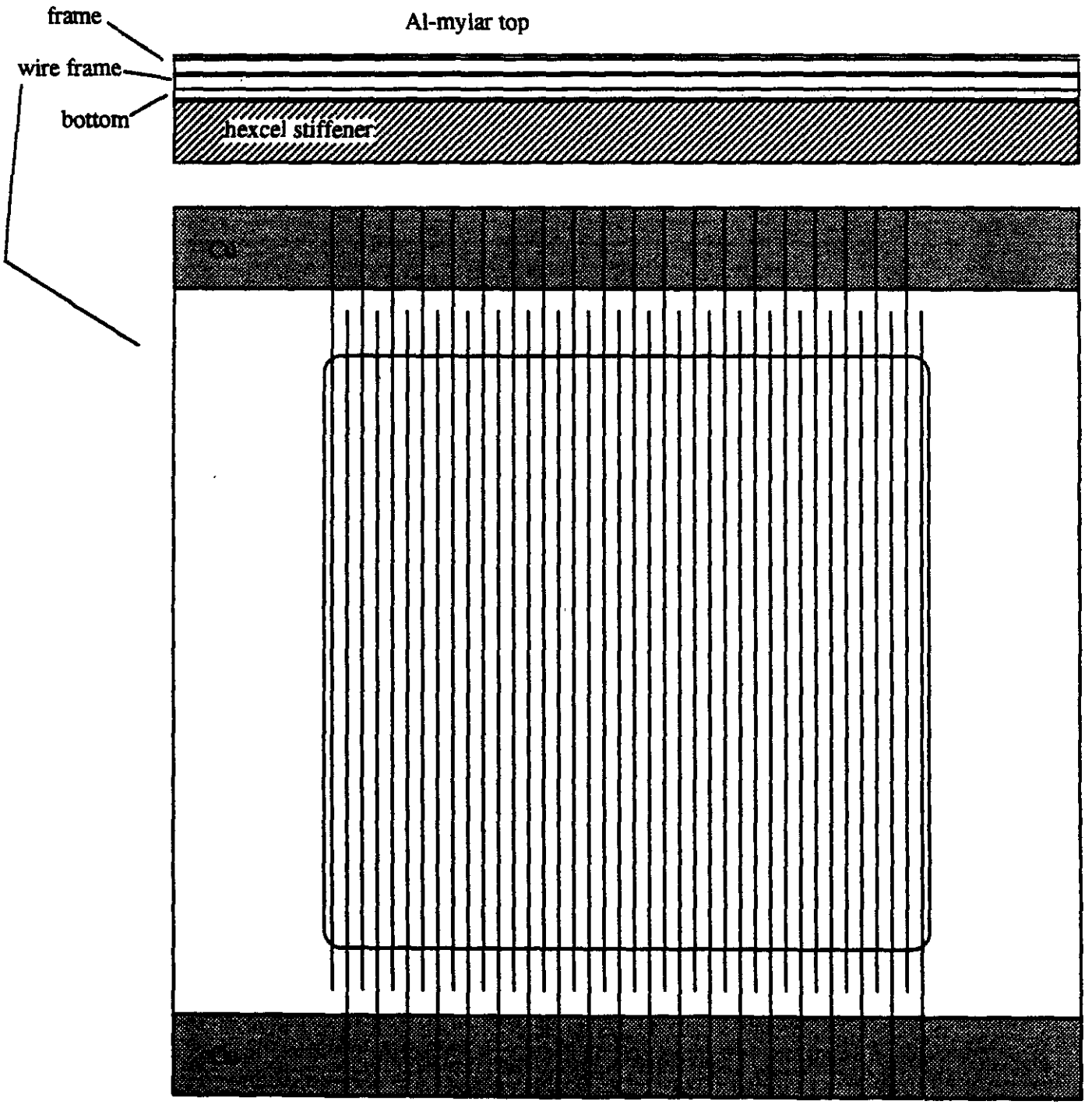




Scott Whitaker

Test Chambers -- assembly

scale -- full



MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LABORATORY FOR NUCLEAR SCIENCE
CAMBRIDGE, MASSACHUSETTS 02139

MEMORANDUM(91.10.20)

TO: Brown University
M. Widgoff

Indiana University
E. D. Alyea

MIT
Y. H. Chang
E. S. Hafen
P. Haridas
I. A. Pless

LLNL
E. Ables
K. van Bibber
R. Bionta
O. Fackler
D. Makowieki
C. Wuest

University of Tennessee
S. Berridge
W. Bugg
P. Y. C. Du

FROM: Irwin A. Pless

SUBJECT: Rough draft of the RPC part of the GEM LOI

DATE: 20 October 1991

Dear Colleagues:

We have been requested to submit a chapter on the RPCs to Frank Taylor. I am not certain how long this document should be, but as we know, all of the muon system has been allotted three pages.

RESISTIVE PLATE COUNTERS

1. RPC Characteristics

The original Resistive Plate Counters, developed in Rome ten years ago, work at a uniform electric field of about 40 kV/cm between parallel electrode plates of plastic phenolic (bakelite) with a resistivity about 10^{11} ohm-cm. The 2 mm thick plates are separated by 2 mm using PVC spacers. Sensitive volume is filled with a gas mixture of 60% argon, 38% isobutane, and 2 % freon. The field electrodes are a graphite varnish (about 500 kohms per square) coating the outer surfaces of the bakelite. RPCs have a measured time resolution of about 1 nanosecond. Spatial readout is made via pick up strips insulated from the field electrodes by a 0.3 mm thick polyethylene film. The voltage induced on these pickup strips is about 0.5 volts into 50 ohms.

RPCs have been used in many experiments with the largest having dimensions 0.5 x 6.0 meters. It is planned that the GEM RPCs will have dimensions of up to 3.3 x 4.0 meters.

2. RPC Geometry in the Muon Sub-system

The RPC subsystem will be deployed in three concentric cylinders in the barrel. The inner, central and outer cylinders will have radii of 3.70, 6.00, and 8.30 meters and lengths of 13.28, 20.96, and 29.00 meters, respectively. Each cylinder will consist of sections subtending 22.5 degrees.

The RPC system will completely shadow the precision muon measuring components as seen from the interaction point. RPCs will furnish three-dimensional space points for particles passing through the system. Short RPC strips running perpendicular to the magnetic field lines will give the X-coordinate while long RPC strips running parallel to the magnetic field lines will give the Y-coordinate.

3. Functions of the RPC Subsystem

The RPCs will perform the following functions for the GEM detector:

1. Furnish the first level muon trigger.
2. Furnish the event beam crossing tag.
3. Furnish the Z-coordinate for the muon tracks.
4. Furnish the muon tracking "roads" for the precision tracking elements.
5. Furnish an anti-coincidence trigger to veto cosmic rays.
6. Furnish a cosmic ray coincidence trigger to test GEM subsystems.

The logic for the trigger has four components:

1. Three-fold coincidence timing in the non-bend plane.
2. Straight-line space fit to three points in the non-bend plane.
3. Three-fold timing in the bend plane.
4. Three-point sagitta measurement in the bend plane.

eliminated in the off-line analysis by a cut on the total energy deposited in the calorimeters. 5000 muon events and 15000 pion events of 70 Gev/c momentum were collected.

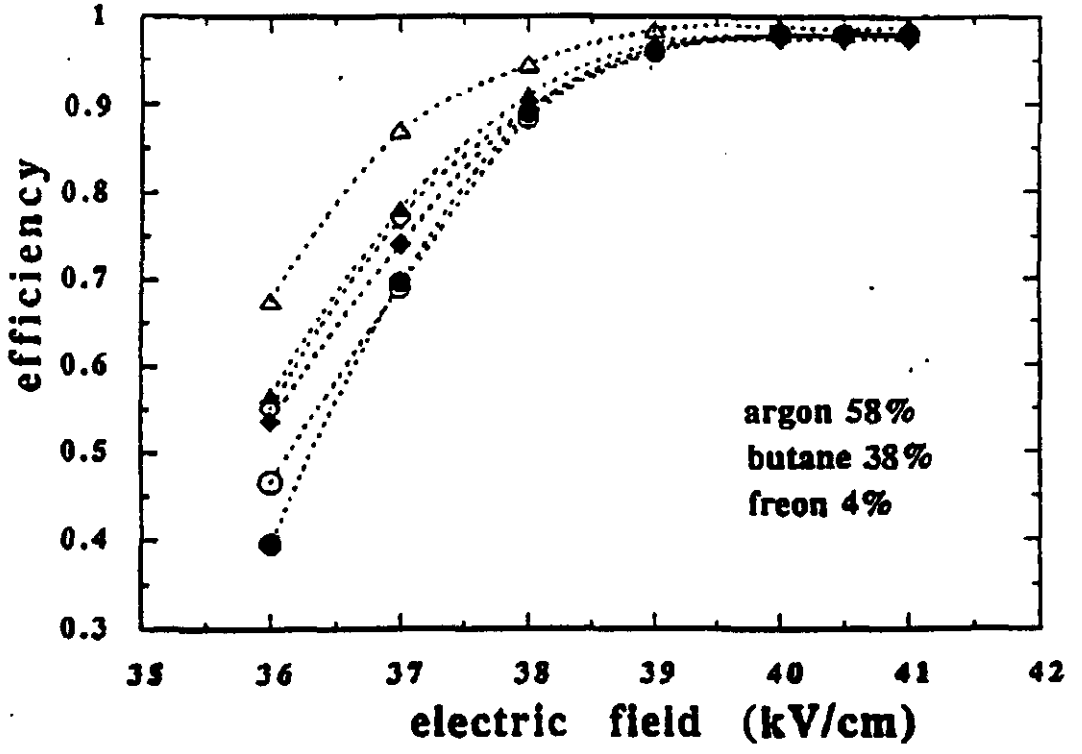


Fig.4 RPCs efficiency versus the applied electric field measured with 70 GeV/c muon events.

5. Chamber efficiency

Fig. 4 shows the efficiency of the RPC chambers in the X1 beam as a function of the applied electric field, measured for 70 GeV/c muons. The gas mixture was 58% argon, 38% n-butane and 4% freon. The efficiency for a given chamber was defined as the ratio between the number of times in which a hit was seen in the expected region of the counter and the total number of incident muons. All chambers show an efficiency around 97% for electric fields over 40 KV/cm under a muon flux of about 15 Hz/cm^2. Operation up to fluxes of 40 Hz/cm^2, concentrated over a surface of about 5 cm^2, showed no appreciable degradation of the efficiency.

The out-of-spill rate of the fast-OR was about 10 KHz giving about 0.5% probability of spurious hits per chamber within the 500 ns shaping time. This 'noise' is originated by discharges due to inhomogeneities of the electric field close to the spacers.

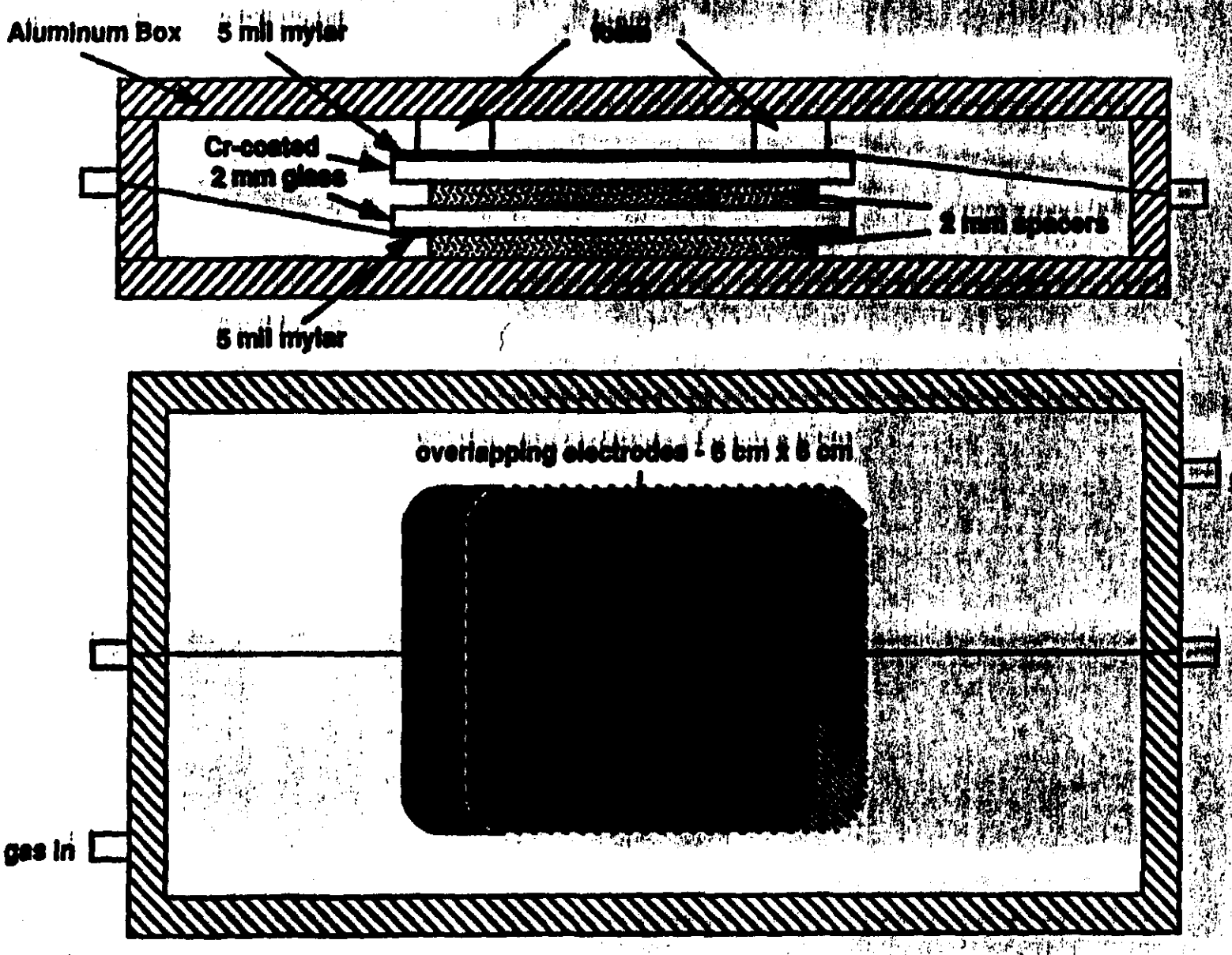
6. Tracking with RPCs

Tests have been done to study the tracking capability of RPCs with high energy muons.An algorithm has been developped to track the muons in both X1 and H2 set-up.

Resistive Plate Counter R&D at LLNL -
Craig Wuest, Elden Ables, Richard Bionta, Dan Makowelcki

- I. Piess visit to LLNL on 10/10/91.
- F. Taylor visit to LLNL on 10/21/91.
- Prototype RPC construction has begun:
  1. Conductive electrode version for testing of timing, rates, effects of bulk resistivity.
  2. Resistive electrode version for testing effects of surface resistivity and bulk resistivity on timing, rates, dead time and dead area.
  3. Resisitive electrode version with 1 cm pickup strips for position sensing measurements.
- Procurement:
  1. Bertan Model 225 10 kV current limiting power supply with GPIB.
  2. 2 milliCurie Ruthenium-106 (3.5 MeV beta endpoint) for position measurements.
  3. 60% Ar, 38% Butane, 2% freon to start with. Other gases available.

RPC Prototype



determines which momentum activates the trigger.

The non-bend plane trigger logic is illustrated in Figure 2.

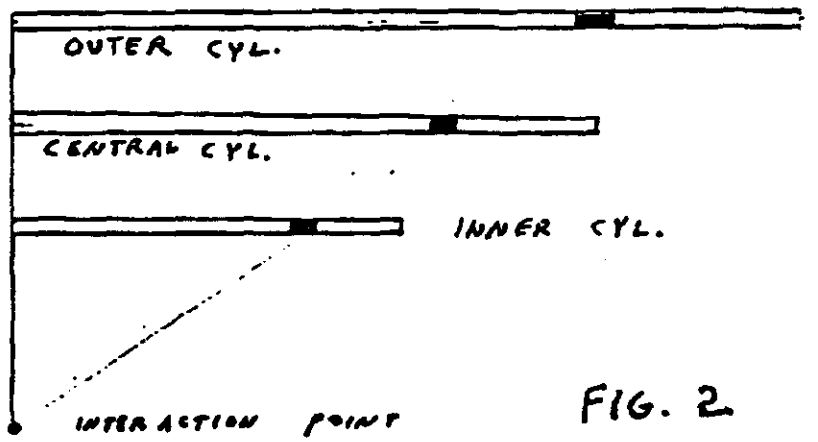


FIG. 2

The strip widths of the inner and outer cylinders "project" back to the intersection region. This not only makes the straight line fit logic simpler, but also reduces the total electronic channel count. Four of the 1.2 centimeter strips on the central cylinder will be logically joined to create a strip of 4.8 centimeters to conform to the strip projection geometry.

The 3 centimeter strip width for the inner cylinder was chosen to account for the multiple scattering of a 10 GeV/c muon passing through the 12 radiation lengths of calorimeter.

The trigger requirement in the non-bend plane is that three strips in a "tower" be in time coincidence. At the end of this section we will discuss a possible technique for electronically creating this non-bend plane trigger.

The trigger logic in the bend plane will obviously be more complicated than in the non-bend plane. This logic is illustrated in Figure 3.

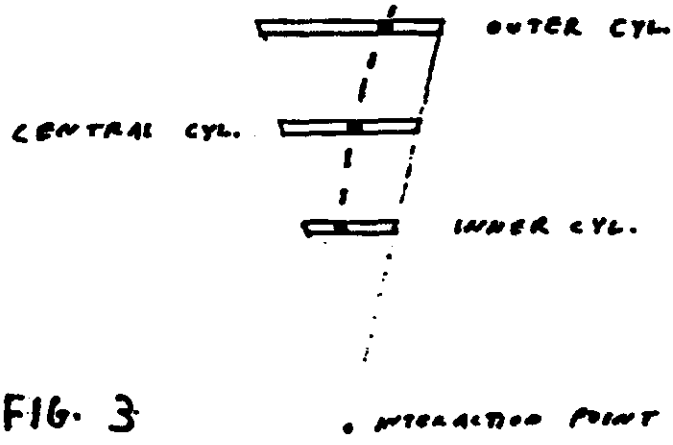
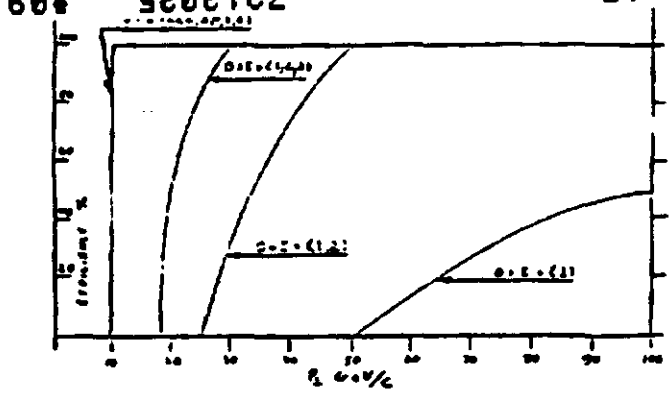


FIG. 3

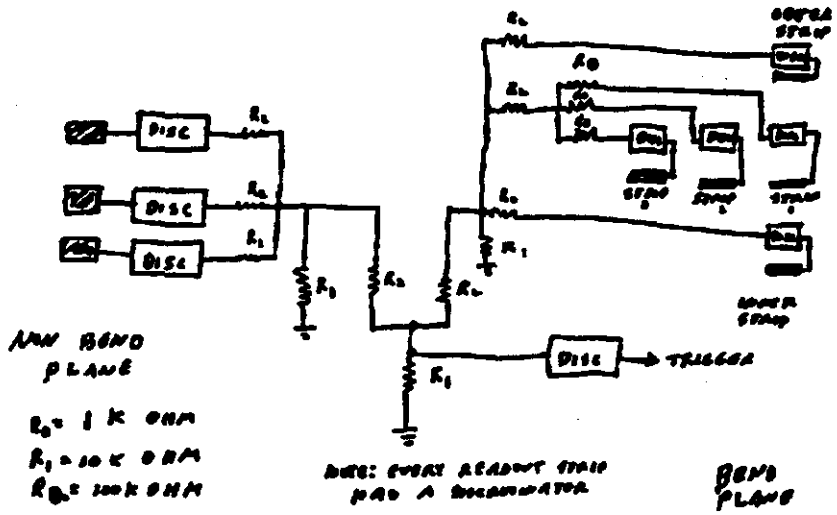
FIG. 5



This type of trigger is very flexible and simple. It should be emphasized that the final trigger is formed by a coincidence between the non-bend plane trigger and the bend plane trigger.

The triggers described above can be implemented with a passive resistor network which has a decision time of about 10 nanoseconds. As an example of such a passive resistor network, we show in Figure 6 a trigger that selects muons with $P_{\perp}$ greater than 30 GeV/c.

FIG. 6



Such circuits can easily be implemented either on a single chip or a hybrid circuit.

C. Furnish the Z-coordinate for the muon tracks.

We have used 1.2 cm widths for the X-strips of the central cylinder so as to furnish the X-coordinate of the muon tracks. As noted in Section B, a strip width of 4.8 cm is adequate for the trigger, but for the Z-coordinate of the muon track we require a precision of ± 0.6 cm which leads to the 1.2 cm X-strip width.

V. CHANNEL COUNT

The channel count is as follows:

Non-bend plane	21,392
Bend plane	8,832
Total	30,224

VI. BUDGET

We estimate the complete cost of an RPC system to be about $2,600 per square meter. We note that the barrel will require about 2,300 square meters of RPCs which implies a total cost of about $6 x 10^6. The detailed estimate follows:

	ITEM	COST ($/m^2)
1.	Glass (e.g. Schott B270 float glass)	66.1
2.	Resistive Electrode (e.g. carbon doped Aquadag)	2.2
3.	Foam (e.g. polyurethane sheet)	36.5
4.	Pick-up electrodes (e.g. metal tape)	9.8
5.	Insulators (e.g. G10 sheet)	41.3
6.	Aluminum box (1/16" sheet)	30.2
7.	Spacers (e.g. SS304 disks on 30 cm centers)	0.05
	Total Materials	186.15
	Total Materials (x2 for machining and waste)	372.3
8.	Fabrication cost estimate: $60/hr @ 1m^2/hr	60.0
9.	Gas fittings (e.g. 1 brass fitting every 30 cm on edge x 2 for gas manifold)	2.03
10.	Tygon tubing (1/8" diameter, 1 km long)	0.33
11.	RG-174 coaxial cabling (1 km)	0.12
12.	LEMO connectors (2 x 30,224 channels)	180.3
13.	Electronics (30,224 discriminators, 10,074 3-fold coinc., 9,650 QADC, 32 2-fold coinc.)	648.5
14.	Gas (Recirculator or throw away over 10 years)	150.0
	Total Miscellaneous	1,041.3

SUBTOTAL:

Materials, Fab., Gas System, Elect. System	**1,413.6**

This implies a total cost of $3.3 M for a 2,300 m^2 system. Since the RPC system will require some structural support and stiffeners, which have not been engineered at this time, it is difficult to know how to estimate this cost. Also, the RPCs will presumably be mounted onto the overall muon drift tube system structure. We will conservatively estimate the cost of any RPC specific structural support to be $600/$m^2$ and contingency for all of the above to be 30% or $600/$m^2$ giving:

RPC Materials, Fab., Gas System, Electr. System	1413.6
Structural supports and integration with drift tubes	600.0
Contingency (30%)	600.0
Total	**2613.6**

Thus for a 2,300 m^2 system, the total cost would be about $6M. The largest uncertainty is in the structural support and integration cost estimate.

The coincidence timing and space-point fitting in the non-bend plane eliminates most punch-throughs, low energy tracks, and random pick-up noise. The coincidence timing in the bend plane placed in coincidence with the coincidence in the non-bend plane further reduces the random pick-up noise problem. The sagitta measurement in the bend plane determines which momentum activates the trigger.

The proposed trigger will be able to select four ranges: 10, 30, 50 and 100 GeV/c transverse momentum, under computer control. The trigger decision time can be made less than 100 nanoseconds and, by use of resistor networks, can possibly be made less than 10 nanoseconds. Figure 1 is a plot of the efficiency of the triggers as a function of transverse momentum.

The logic for furnishing the event beam crossing tag must be fast enough to cope with the 16 nanosecond beam crossing time. We have designed for a 10 nanosecond decision time. We note the X-strip on the inner RPC cylinder has a length of 1.5 meters. The propagation time down this strip is less than 8 nanoseconds. If the RPC jitter time is less than 2 nanoseconds, we can use the pulse from these strips as a simple and inexpensive beam crossing tag.

4. Research and Development Issues

The following are the R&D issues that we believe have to be resolved before RPCs can be a technique of choice for the GEM Detector:

1. Can one build a large RPC (up to 3.3 x 4 meters) that is 99% efficient?
2. Can RPCs be built that depends on surface resistance and not bulk resistance?
3. Can an industrial type manufacturing technique be developed?
4. Can a large RPC have a trigger jitter of less than 2 nanoseconds?
5. Can a non-flammable gas be developed for use in RPCs?
6. How will RPCs work in a magnetic field?
7. What is the maximum counting rate of a large RPC?
8. What is the lifetime of a large RPC?

We have submitted a detailed R&D proposal that will answer the above questions in a timely manner.

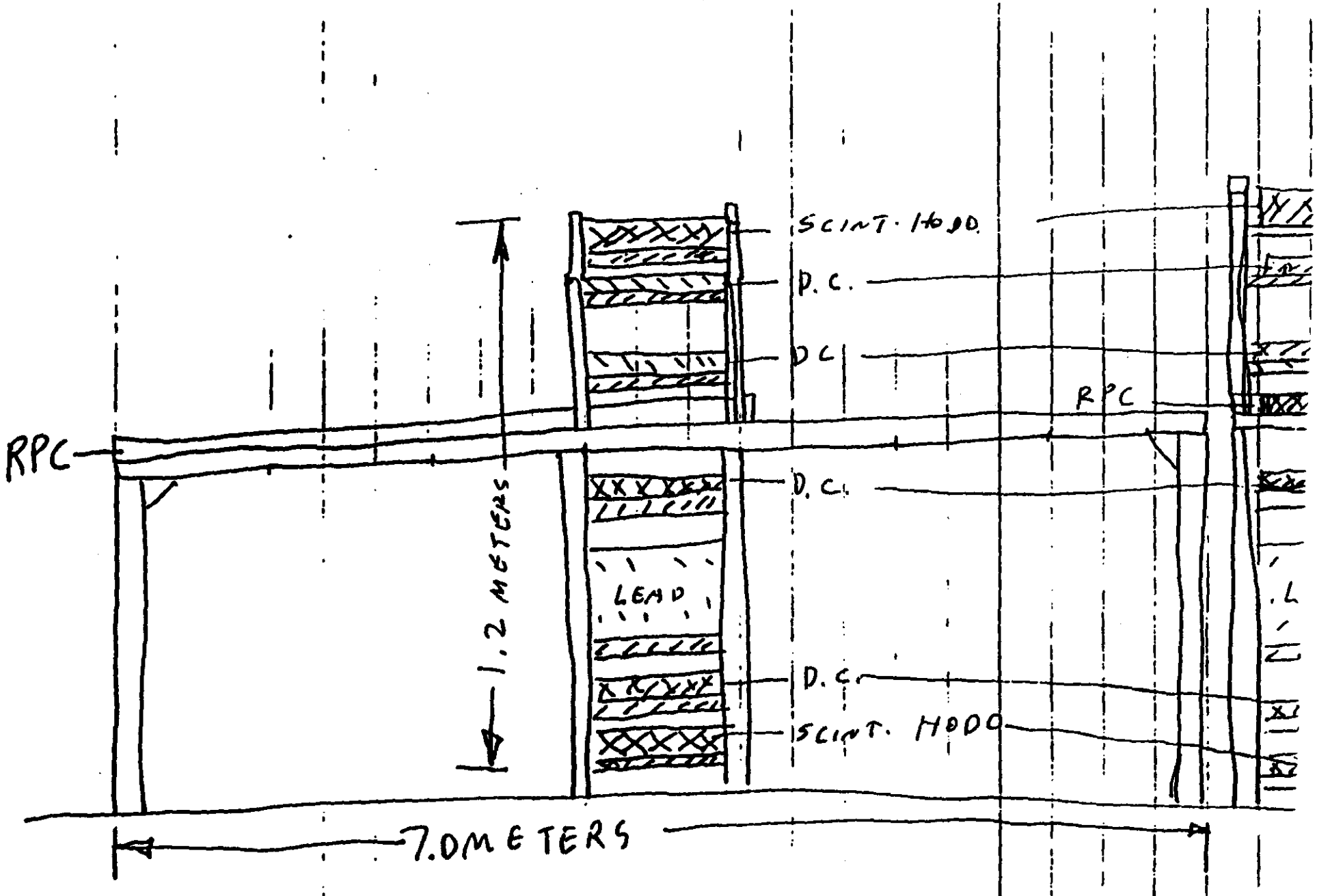
5. Channel Count

Non-Bend plane	20,920
Bend plane	17,632
Total	**38,552**

6. External Services

The following services will be required for the RPC subsystem:

1. High Voltage Power Supply: 10 kilovolts
2. RPC gas: 100 liters per hour


SCINT. HODO
D. C.
D C
RPC
RPC
D. C.
LEAD
1.2 METERS
D. C.
SCINT. HODO
7.0 METERS

TRIGGER / DAQ LOI Overview

- Three Level Trigger

GEM Trigger/DAQ Design Goals				
Level	Rate In	Rate Out	Latency	Comments
1	62 MHz	10 kHz	3 μs	Synchronous, Pipelined
2	100 kHz	300 Hz	100 μs	Asynchronous, Monotonic
3	3 kHz	10 Hz	—	CPU Ranch

Table 7.1 Design goals for the GEM Trigger/DAQ System. Output rates are for operation at $\mathcal{L} = 10^{33}$ cm^{-2}s^{-1}.

- Level 1

  Calorimetry — Supertowers $\Delta\eta \times \Delta\phi = .2 \times .2$
  - γ/e — HAC Veto
  - Jets — Local Sums
  - $\not{E}_T$ — Global Sums

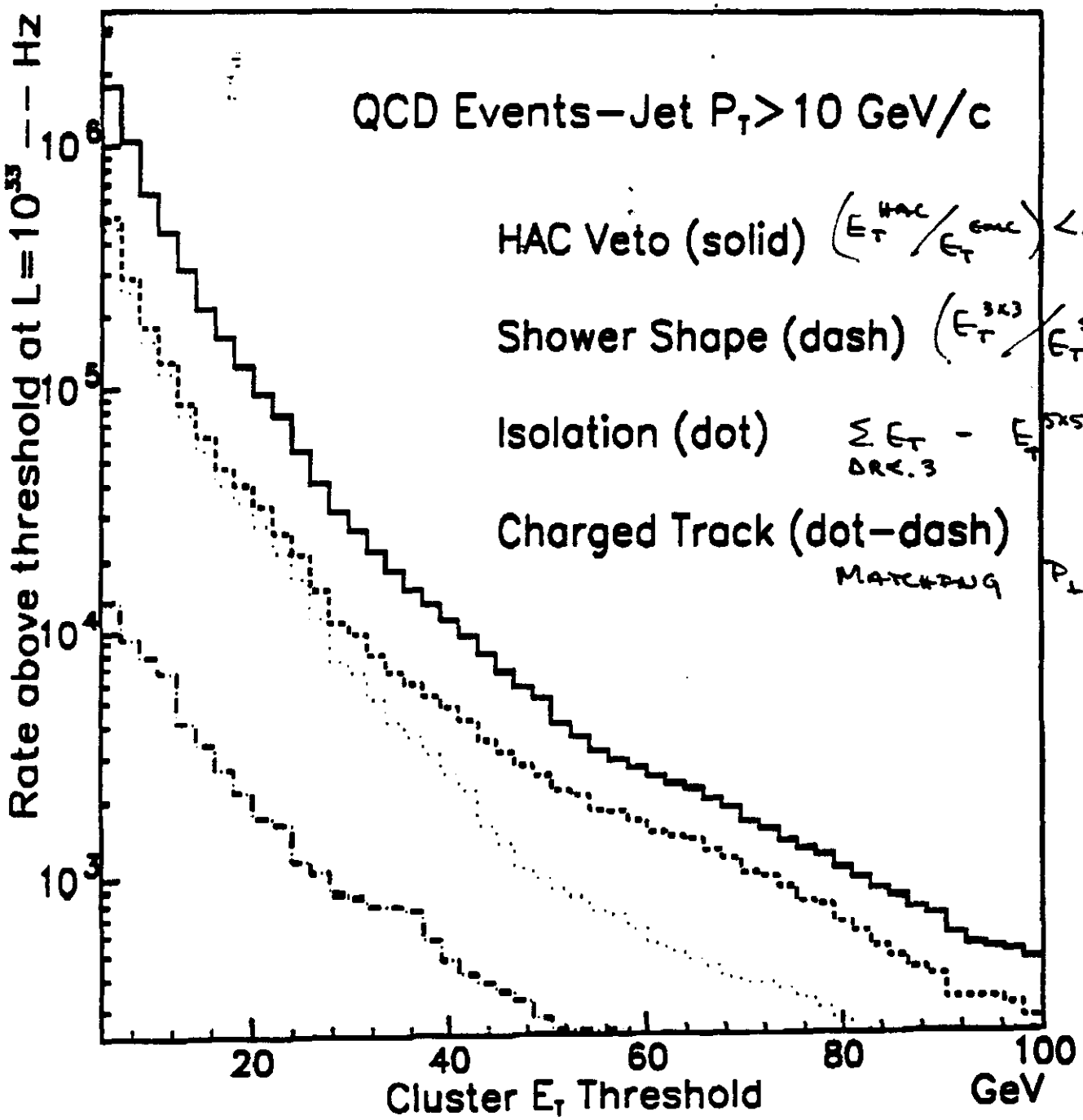
  Muons — Hit Patterns in 3rd and/or 2nd Layer
  $\Rightarrow P_\perp$ / Pointing Cut

- Level 2

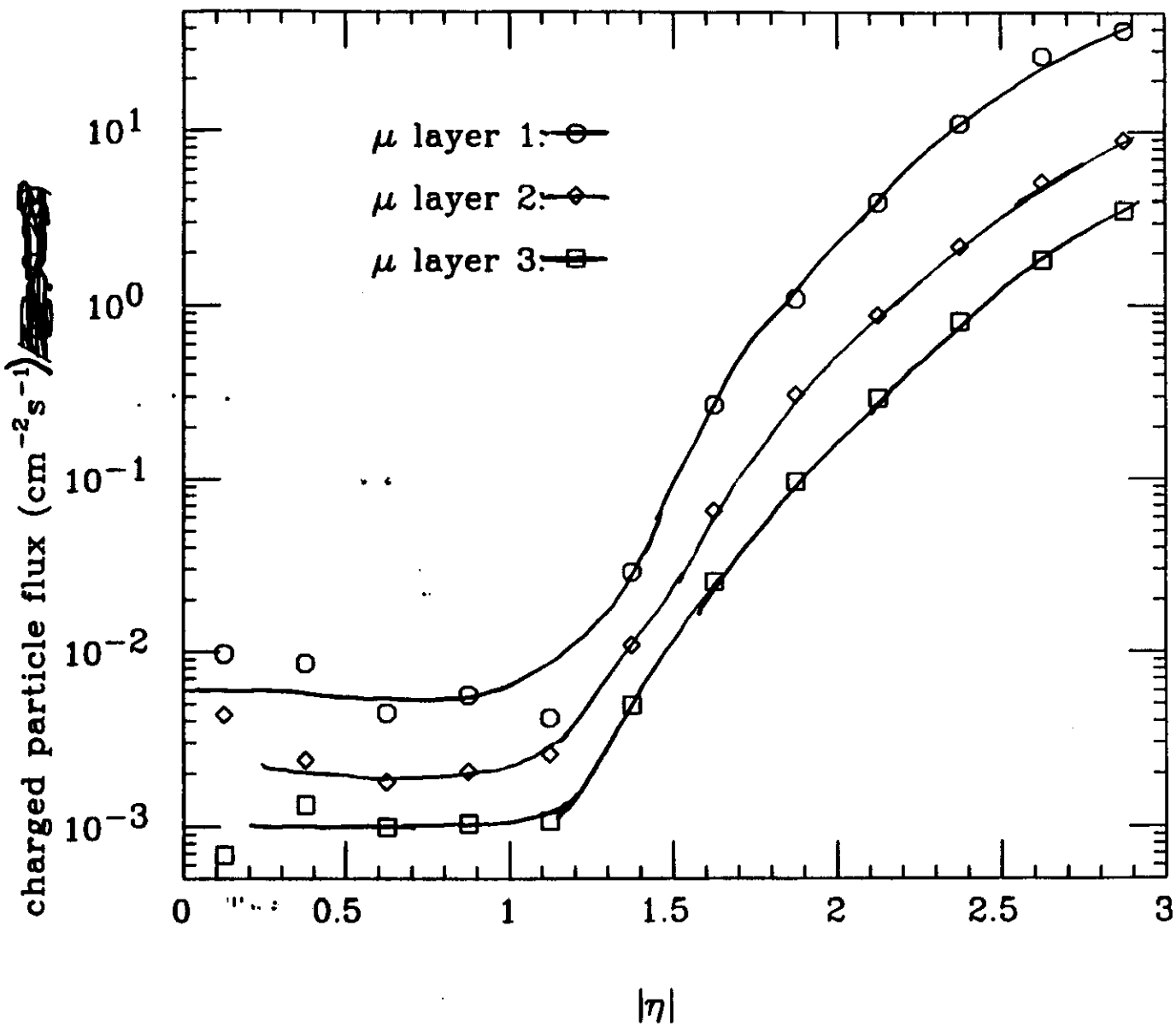
  Calorimetry — Full Detector Granularity
  - Shower Shape
  - Isolation
  - Associated Electron Track (Central Tracker)

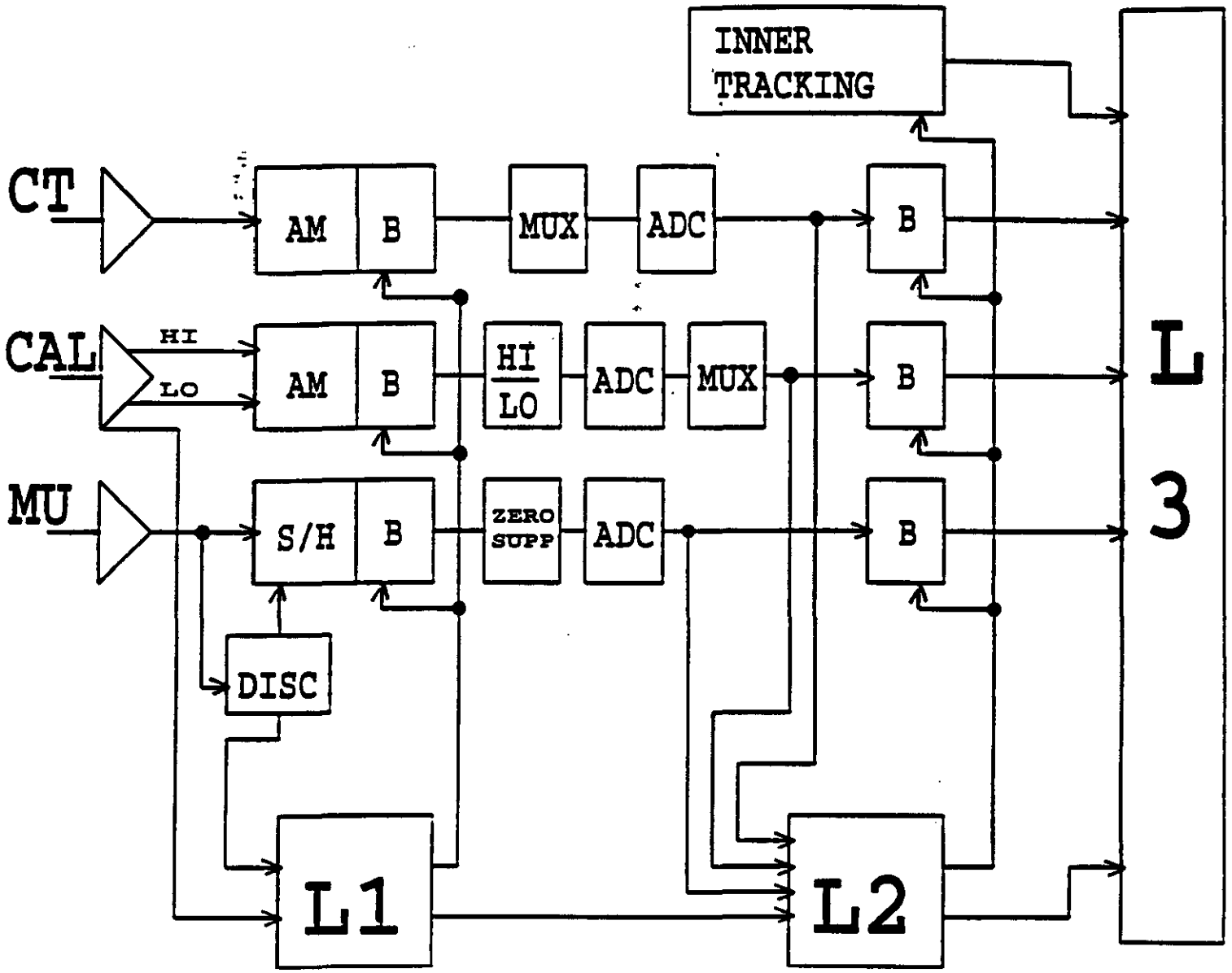
  Muons — Full $P_\perp$ Measurement

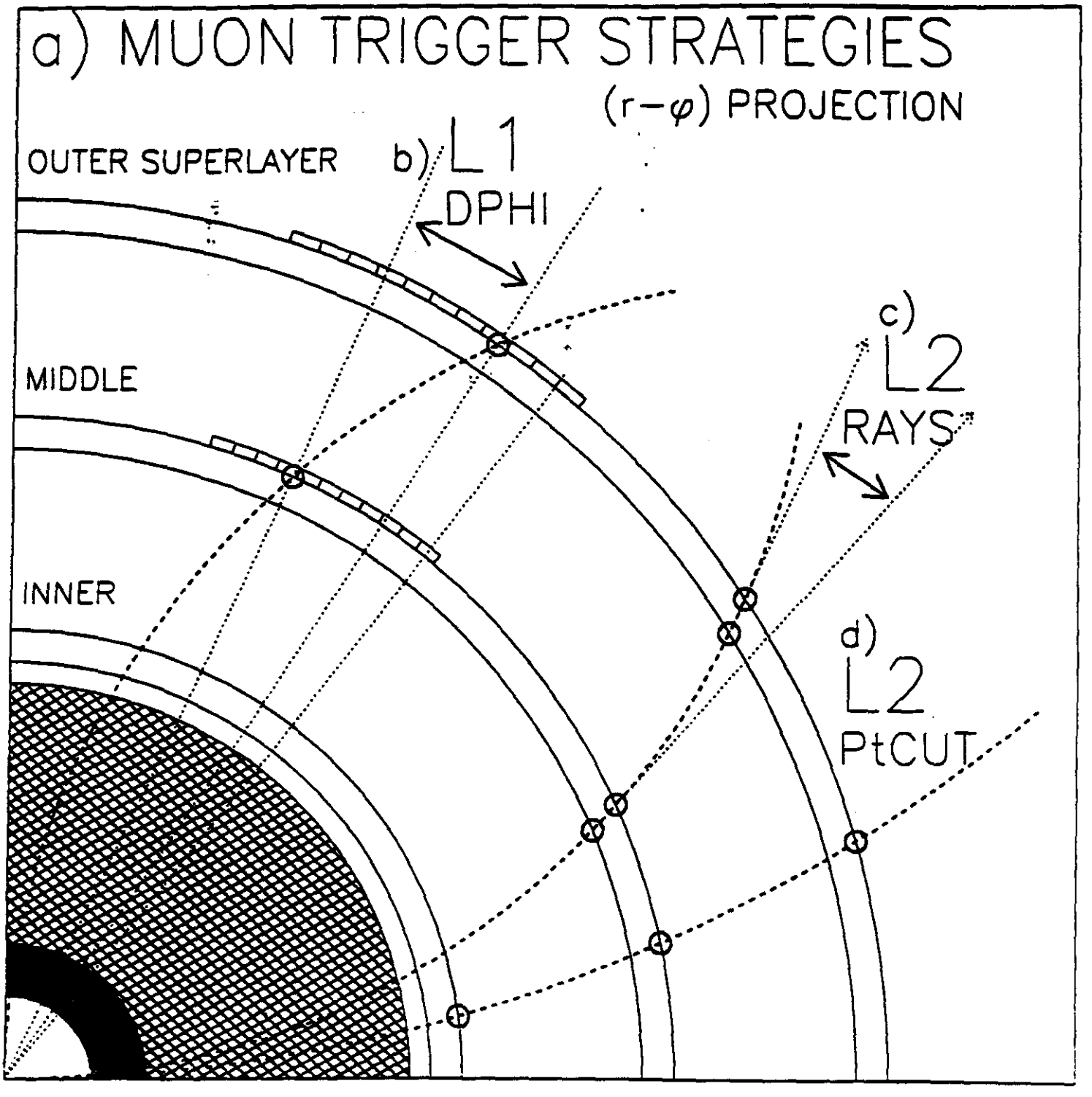
Electron/Photon Trigger Strategy/Rates



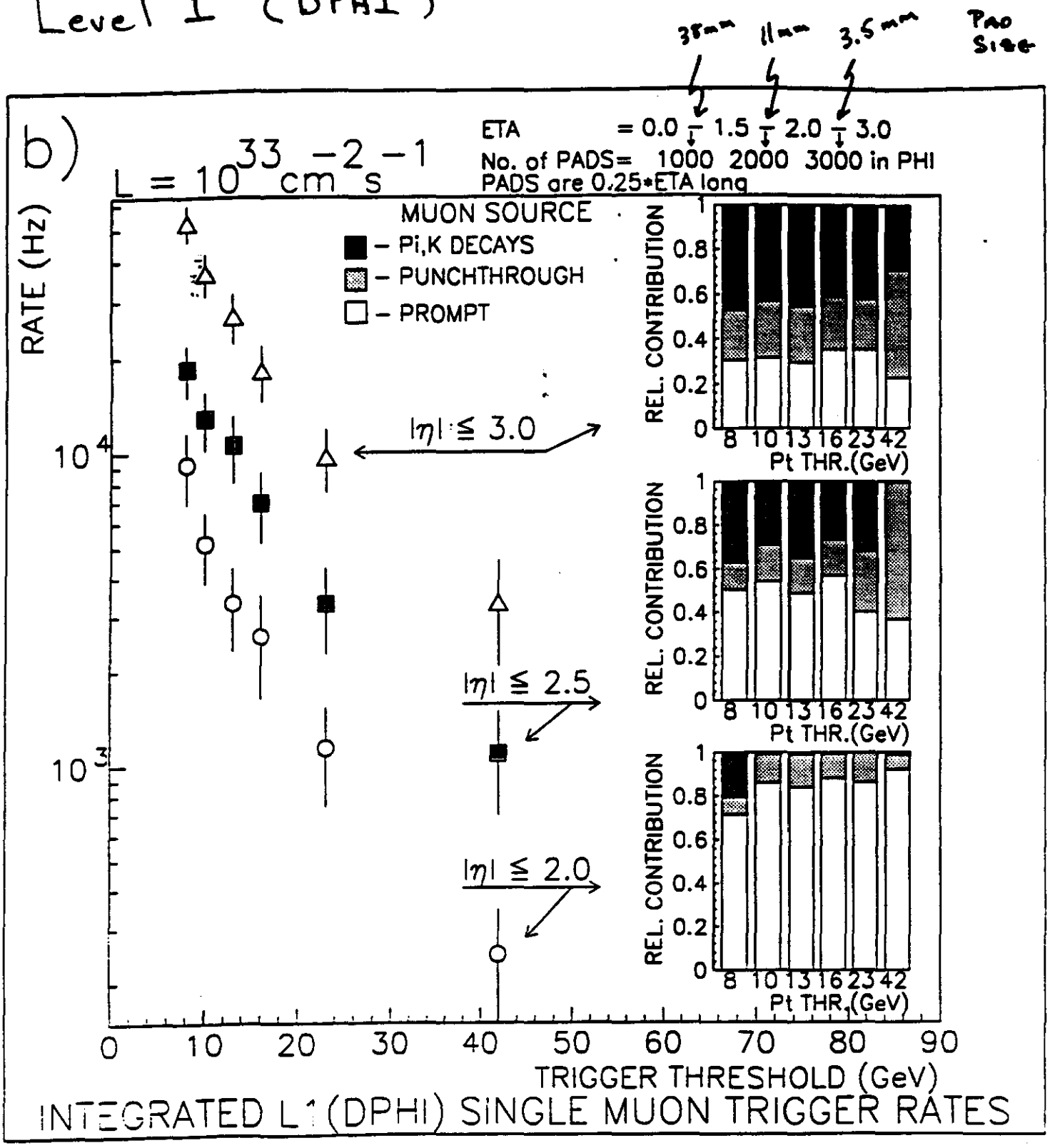
Hit Rate (#/cm²) in Muon Chambers



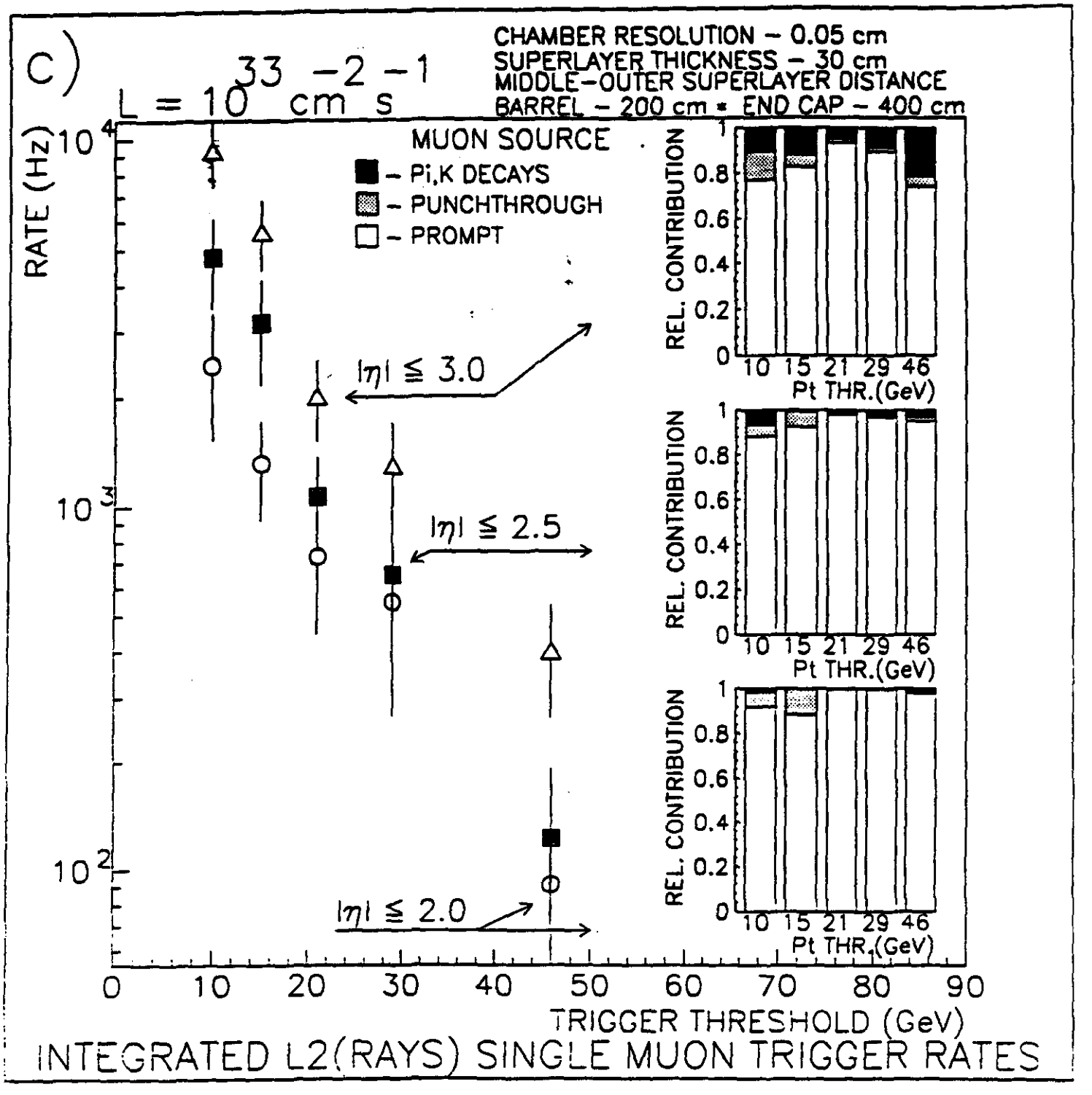

INNER
TRACKING
CT
AM
B
MUX
ADC
B
CAL
HI
LO
AM
B
HI
LO
ADC
MUX
B
L
3
MU
S/H
B
ZERO
SUPP
ADC
B
DISC
L1
L2


a) MUON TRIGGER STRATEGIES
(r−φ) PROJECTION
OUTER SUPERLAYER
b) L1
DPHI
MIDDLE
c)
L2
RAYS
INNER
d)
L2
PtCUT

Level 1 (DPHI)

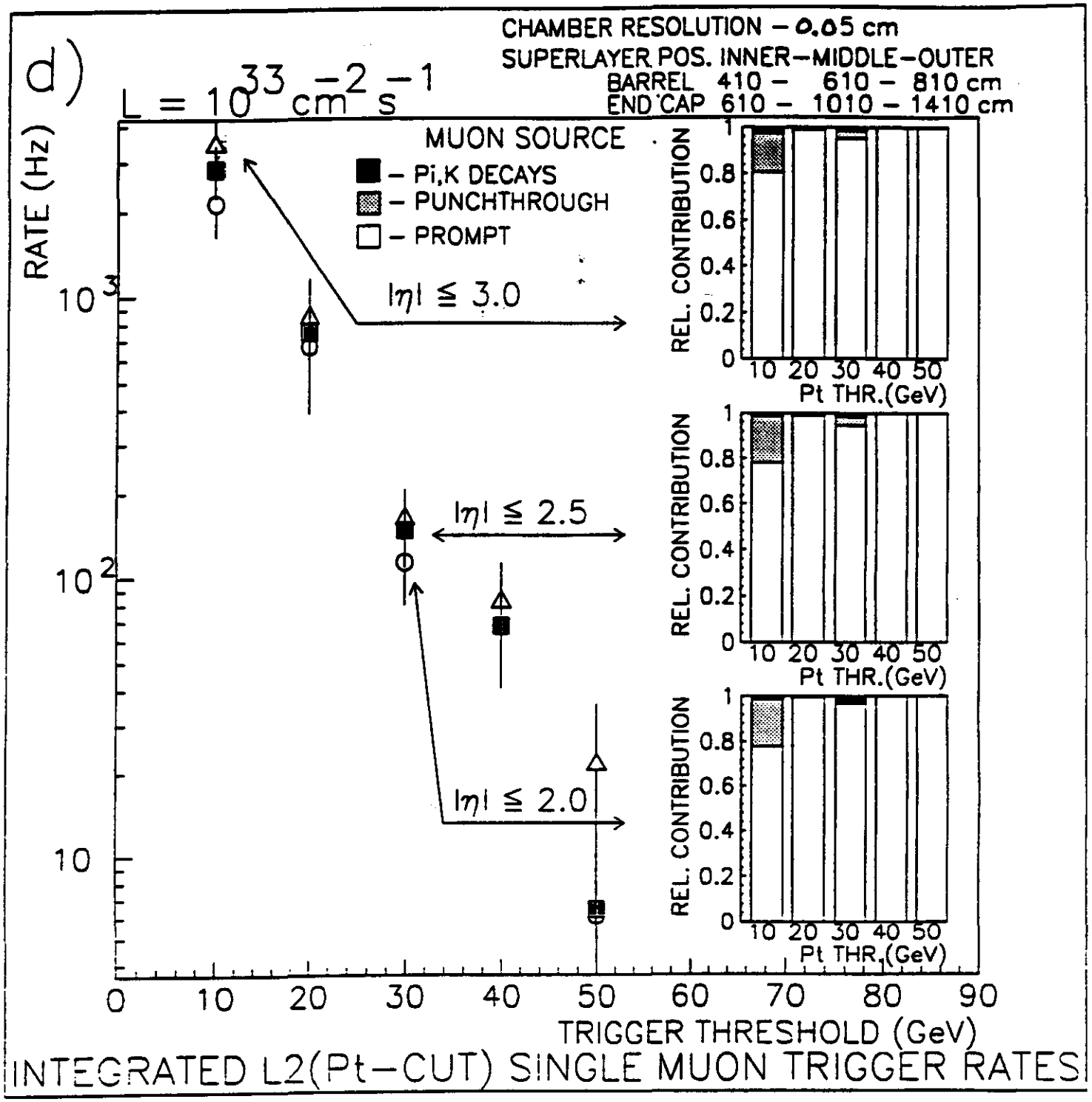

38mm
11mm
3.5mm
Pad Size
b)
$L = 10^{33} cm^{-2} s^{-1}$
ETA = 0.0 1.5 2.0 3.0
No. of PADS= 1000 2000 3000 in PHI
PADS are 0.25*ETA long
MUON SOURCE
– Pi,K DECAYS
– PUNCHTHROUGH
– PROMPT
RATE (Hz)
10^4
10^3
$|\eta| \leq 3.0$
$|\eta| \leq 2.5$
$|\eta| \leq 2.0$
REL. CONTRIBUTION
Pt THR.(GeV)
8 10 13 16 23 42
0 10 20 30 40 50 60 70 80 90
TRIGGER THRESHOLD (GeV)
INTEGRATED L1 (DPHI) SINGLE MUON TRIGGER RATES

Level 2 (Rays)

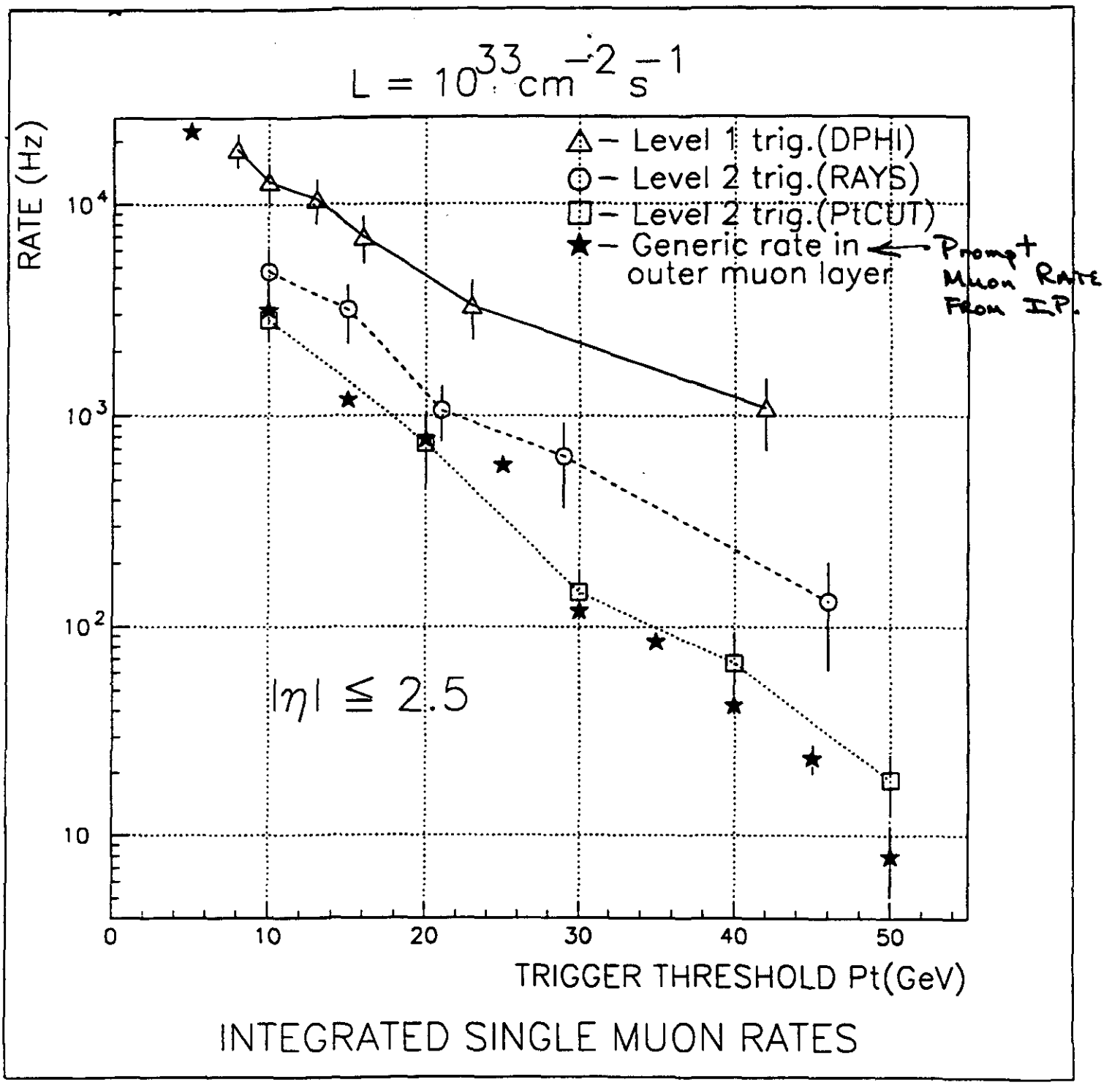


INTEGRATED L2(RAYS) SINGLE MUON TRIGGER RATES

Level 2 ($P_{T\,cut}$)



INTEGRATED L2(Pt–CUT) SINGLE MUON TRIGGER RATES



INTEGRATED SINGLE MUON RATES

R. [illegible]
Nov 8, 1991

Simulation of Energetic Muons in GEM Muon System with LSTs

Issue Considered:

Is there sufficient redundancy of position measurements in descoped GEM Muon System?

- How often are 8 layers ≠ 8 good x measurements?
- How often are 4 layers ≠ 4 good x measurements?

At this point only consider muon measurements "compromised" by extra hits in <u>same</u> cell with the muon

Good Hit ≡ Muon passes nearest to the wire

GEOMETRY: 3 Superlayer in barrel region

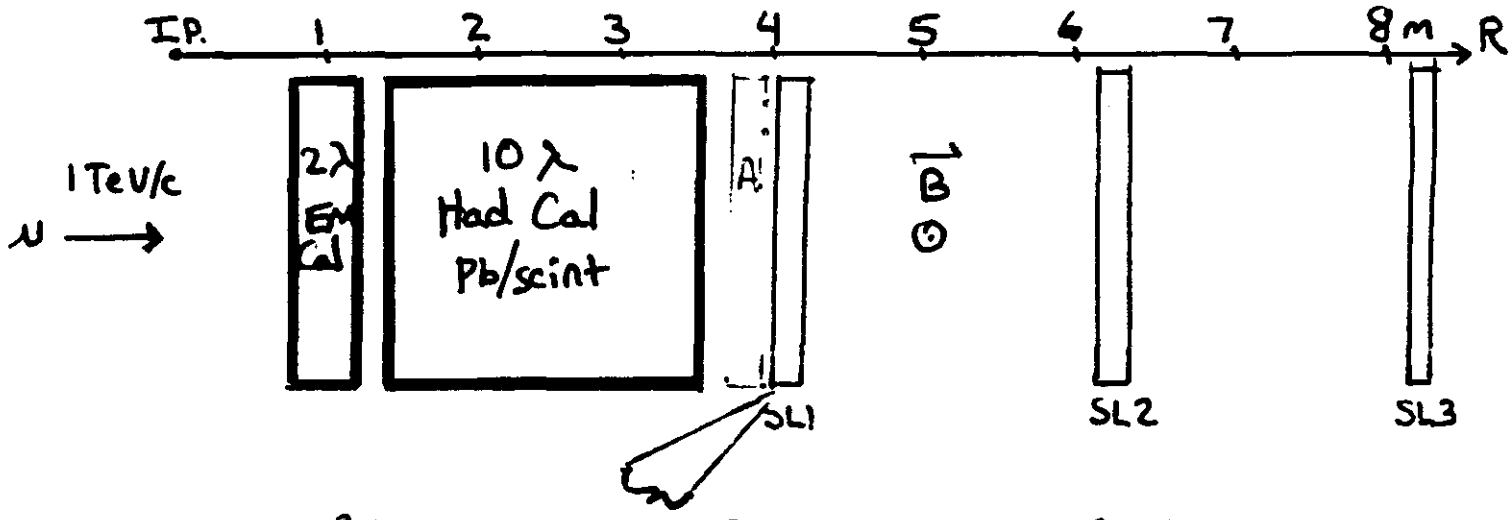
SL1 :	8 layers	4.0-4.2m	radially out
SL2 :	8 layers	6.1-6.3m	radially out
SL3 :	4 layers	8.2-8.3m	radially out

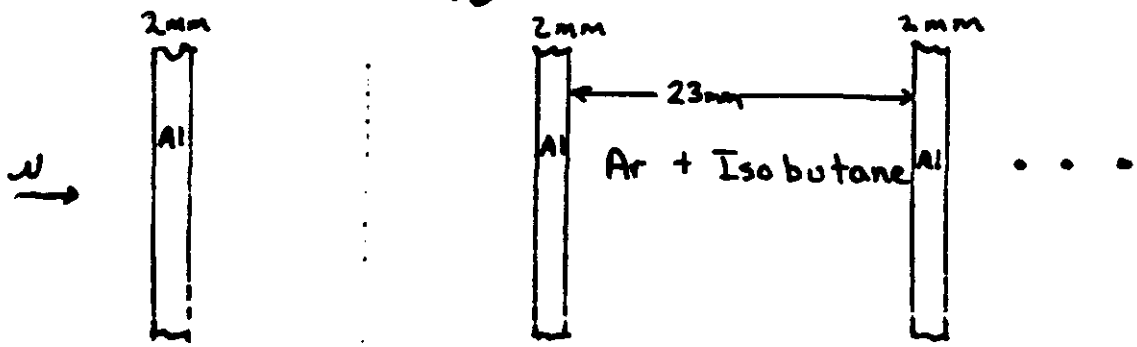
Field : 0.8T Calorimeter : 12 λ Pb/scint.

GEANT Simulation: All processes enabled

E cutoffs: 1 MeV γ, e except in Gas cell & Al walls of chambers – 10 keV

GEANT Detector: Only 90° considered so far.

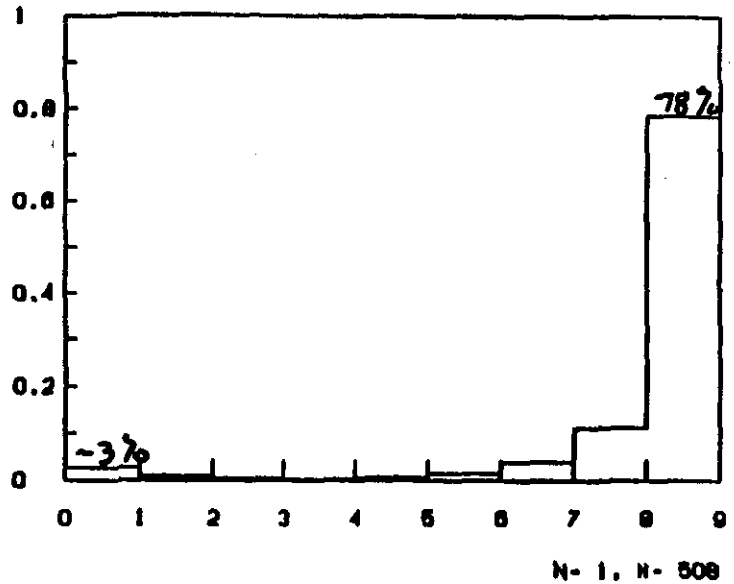




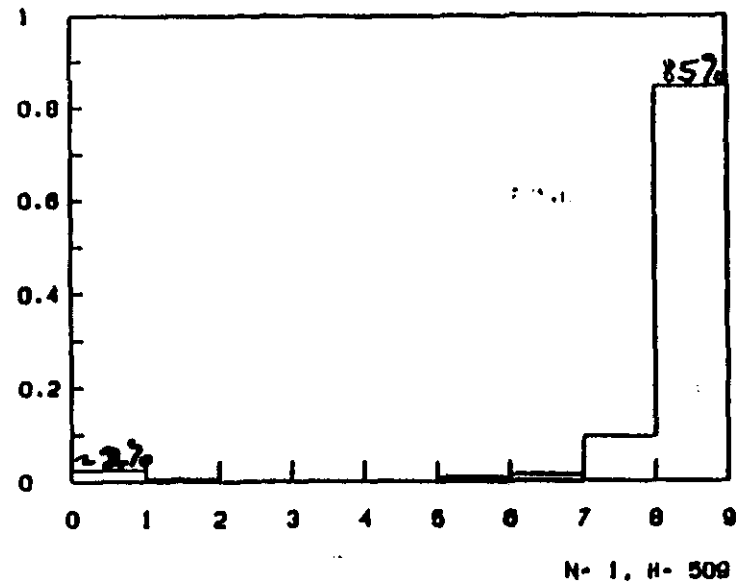
"Cell" Geometry reconstructed off line to GEANT Sim. The Cells in every other layer offset by ½ cell width. "wire" spaced every 2.5 cm (cell size) and oriented along field. – Cell – "walls" – are massless.

↖ No Geometric ineffic.

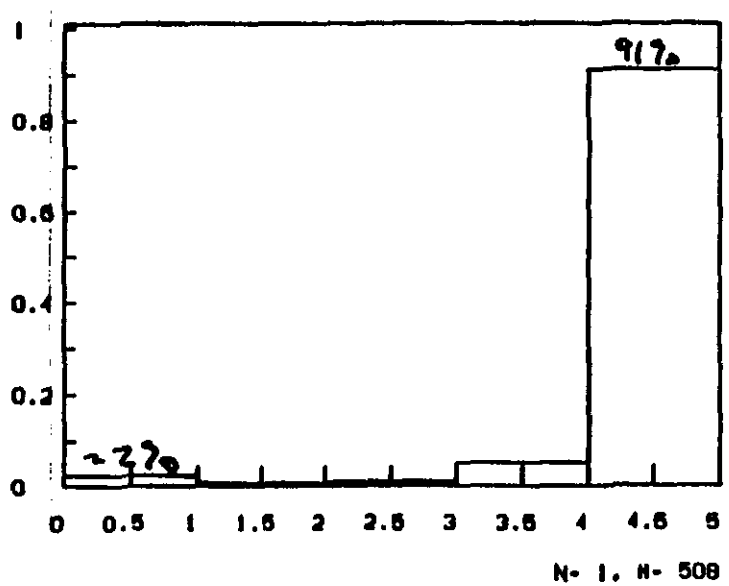
1TeV/c Muons at 90degrees (GEANT Simulation) Through GEM Baseline detector



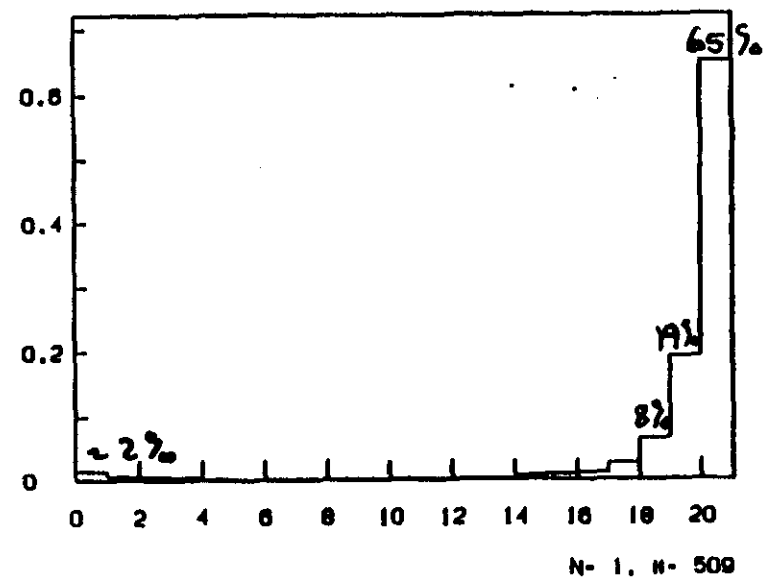
SL1



SL2



SL3

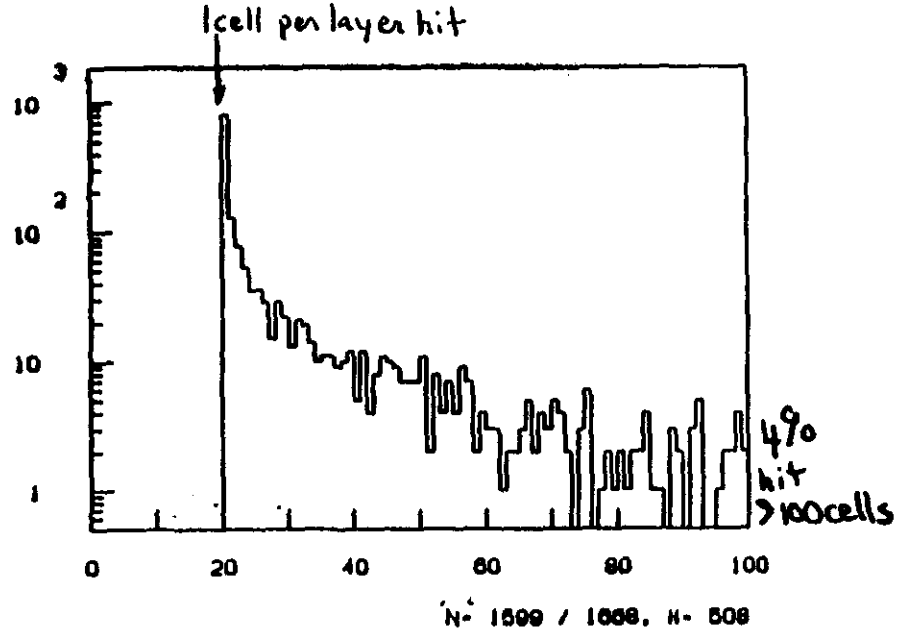


SL1+SL2+SL3

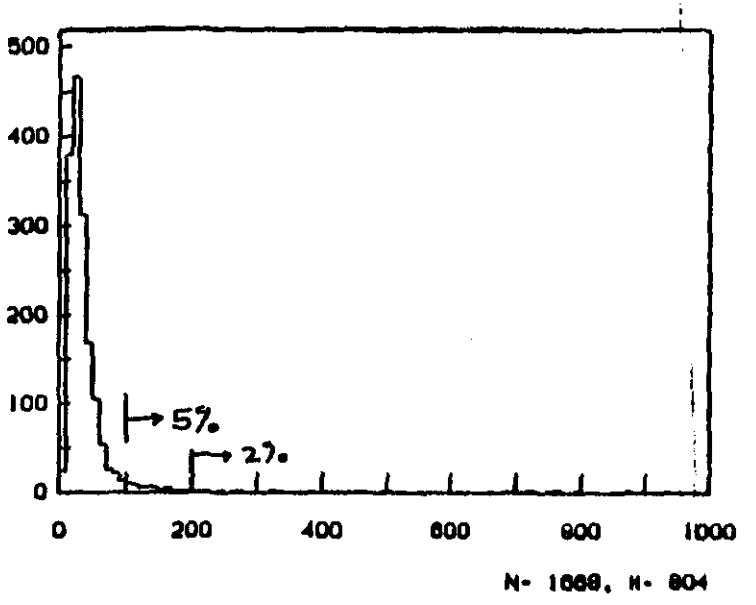
Probability for N good hits out of superlayer

1TeV/c Muons at 90degrees (GEANT Simulation)

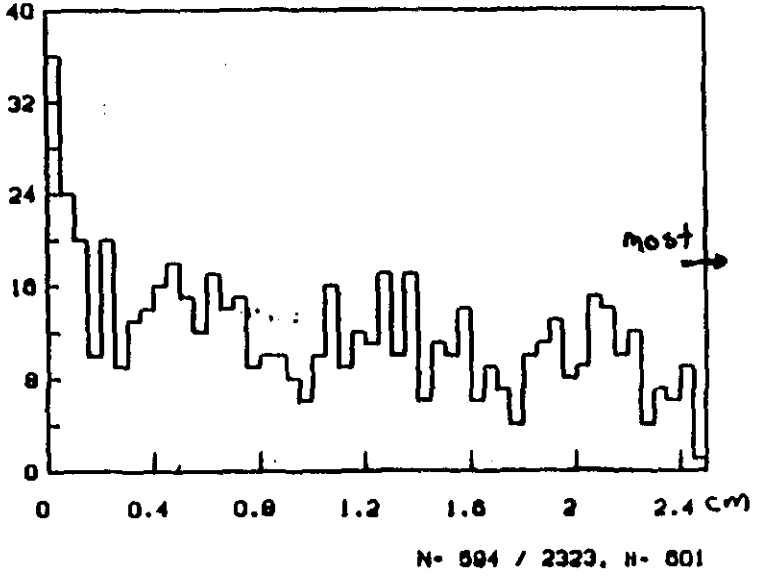
Through GEM Baseline detector



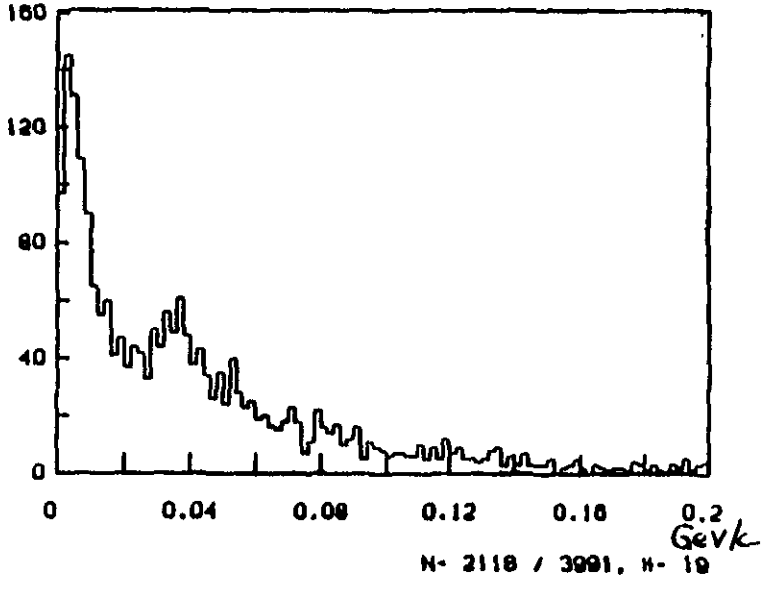
Number of different cells hit



Energy Loss in GeV

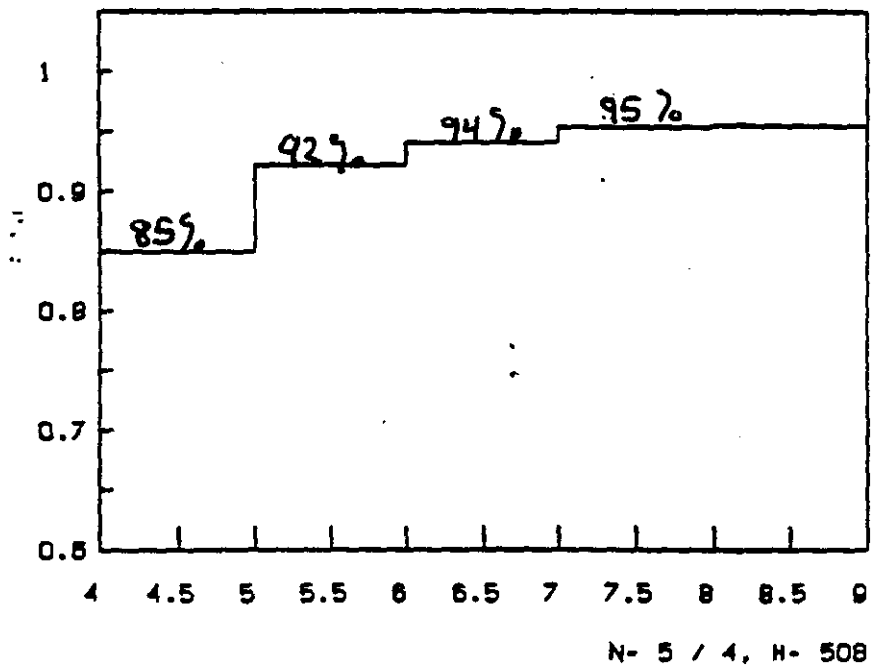


Sep Mu-elec in Bend-plane (cm)

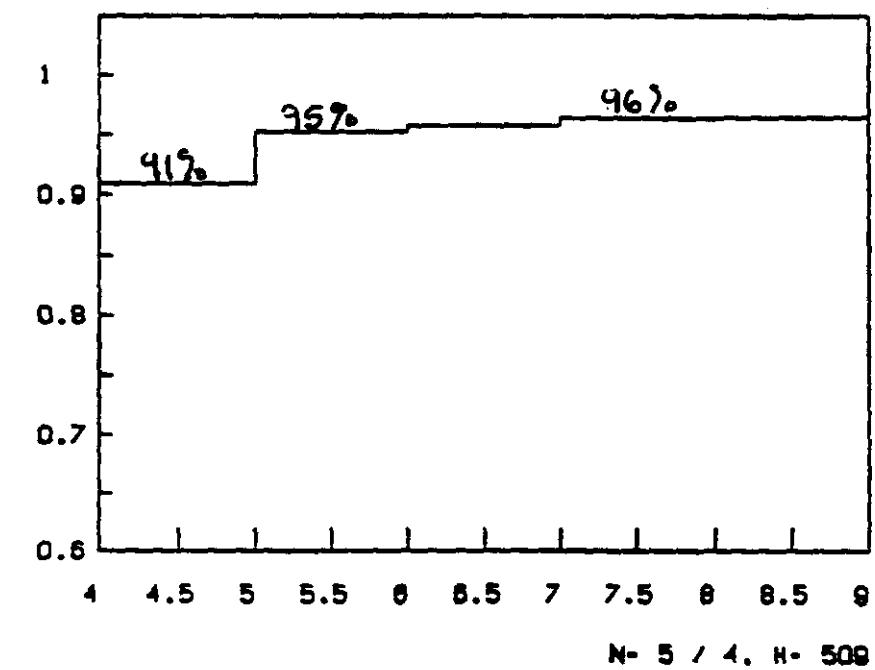


Momentum of extra particles

1TeV/c Muons at 90degrees (GEANT Simulation)



First N layers in SL1



First N layers in SL2

Probability for at least 4 good hits in SL

Some Preliminary Conclusions

For 1TeV/c μ incident at 90° in 0.8T field

- Encouraging in that only ~2% of muons completely obscurred

- 8 layers of cells produce 8 good μ measurements 78% after Al to 85% after large air gap ~10% of μ is SL1 or SL2 produce 7 good μ hit

- 4 Layers of cells after Large air gap produce 4 good μ hits 91% of the time

- Out of 20 layers, 20 good μ hits occur only 65% of the time but > 18 good hits occur 92% of the time

- To get ≥4 good hits in SL1 with ≥ 95% probability requires 7 layers

Note: The above numbers are to be reduced by geometric inefficiencies.
In forward region advantage of $\vec{B}$ reduced.

R. McNeil
Nov 8, 1991

Particle Rates in GEM Muon System
(How thick to make Calorimeter)

From a muon point of view - Calorimeter
ABSORBs Hadrons $\Leftrightarrow$ Suppresses Punchthrough

To evaluate Calorimeter thickness, must consider different contributions to particles in Muon system

1. Prompt μs produced from c, b, t quark decays

2. Decay in-flight of π/K before Calorimeter

3. Hadron Punchthrough including decays in Calor.

[illegible]

Possible Thickness Evaluation Philosophy:

1) The overall rate from hadron punchthrough should be much less than that from prompt μ and π/K decay in tracking region

2) Rate of particles above P_T threshold (trigger) from Punchthrough should much less than from Prompt μ + π/K decay in tracking region

3) Pattern Recognition? $\rightarrow$ Need to Develop this criterion

Towards a Fast Subroutine for Hadron Punchthrough

Punchthrough Shower Profiles include:

Full GEANT simul.

- Probability for ≥ 1 Punchthrough Particle
- Momentum Spectrum of Particles exiting Absorber
- Multiplicity Spectrum of punchthrough Particles
- Lateral Spread of Punchthrough (w.r.t. parent track projection)
- Outgoing angle of Punchthrough (w.r.t. parent track direction)
- ⋮

$\Downarrow$

Fast Subroutine (P_{INC}, Thickness) called from ISAJET analysis program, etc.

$\Downarrow$

Punchthrough Background Rates

$\boxed{\text{4-vectors of outgoing particles}}$

Update to PCHTHR subroutine

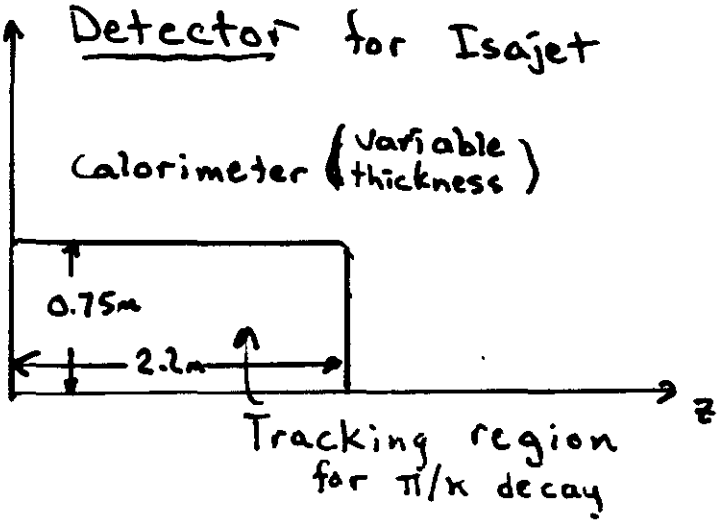
V 2.0 features

1) Probability, momentum, multiplicity tables now exist for the Thickness range 6 - 30 λ

2) Multiplicity range extended to 50

3) Particle Type now in output data

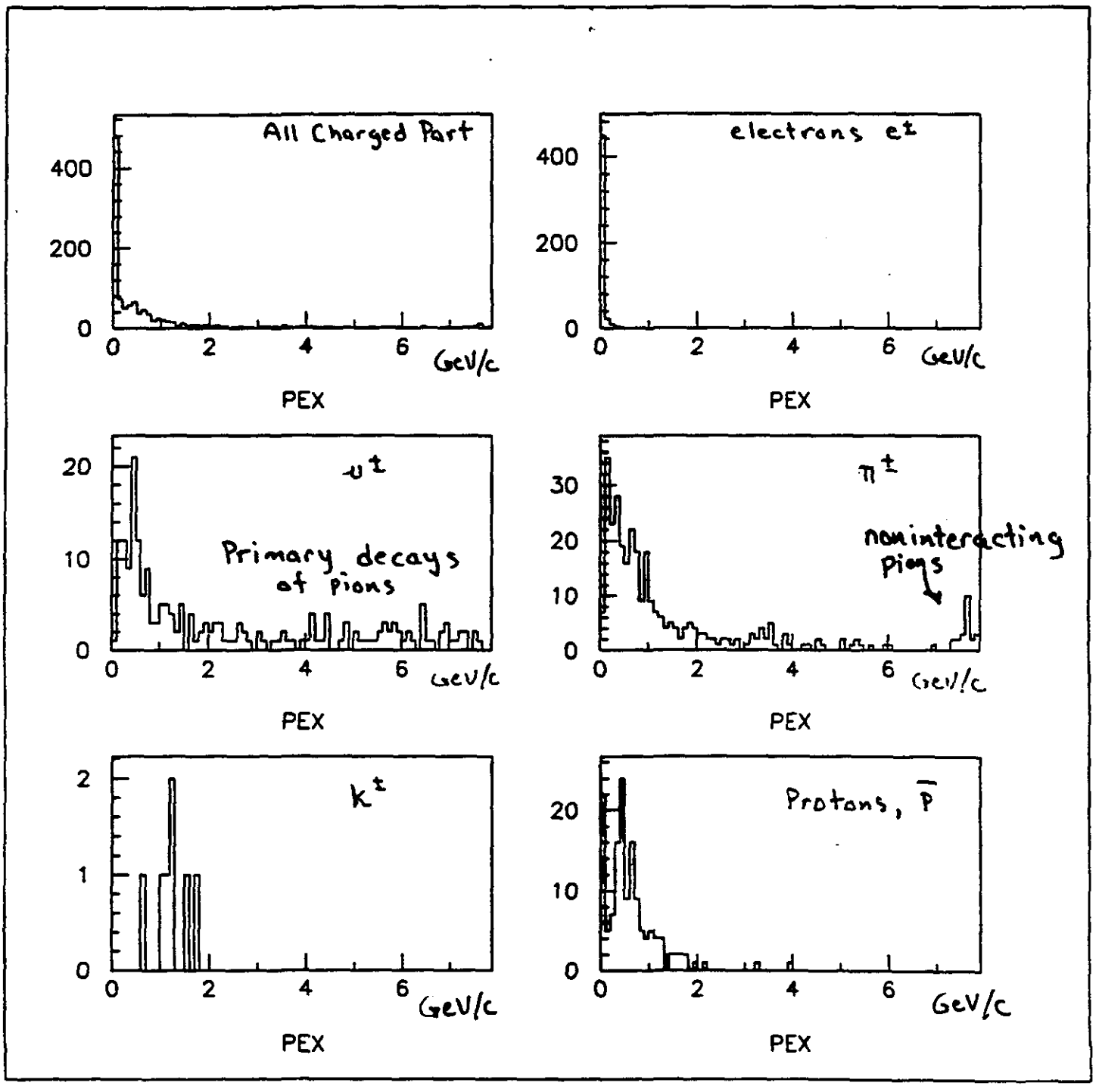
4) Probability for non interacting pion and primary decay for muon now in.



1ST ν Chamber in barrel at R = 3.7m
1ST ν Chamber in forward region at z = 5.5m

Simulate Rates using Isajet Twojet events through Calorimeter of CONSTANT Thickness
Integrate Rate in bins of η.

- Momentum Distribution of exiting particles by type
- 10 GeV/c Incident Pions
- After 10λ

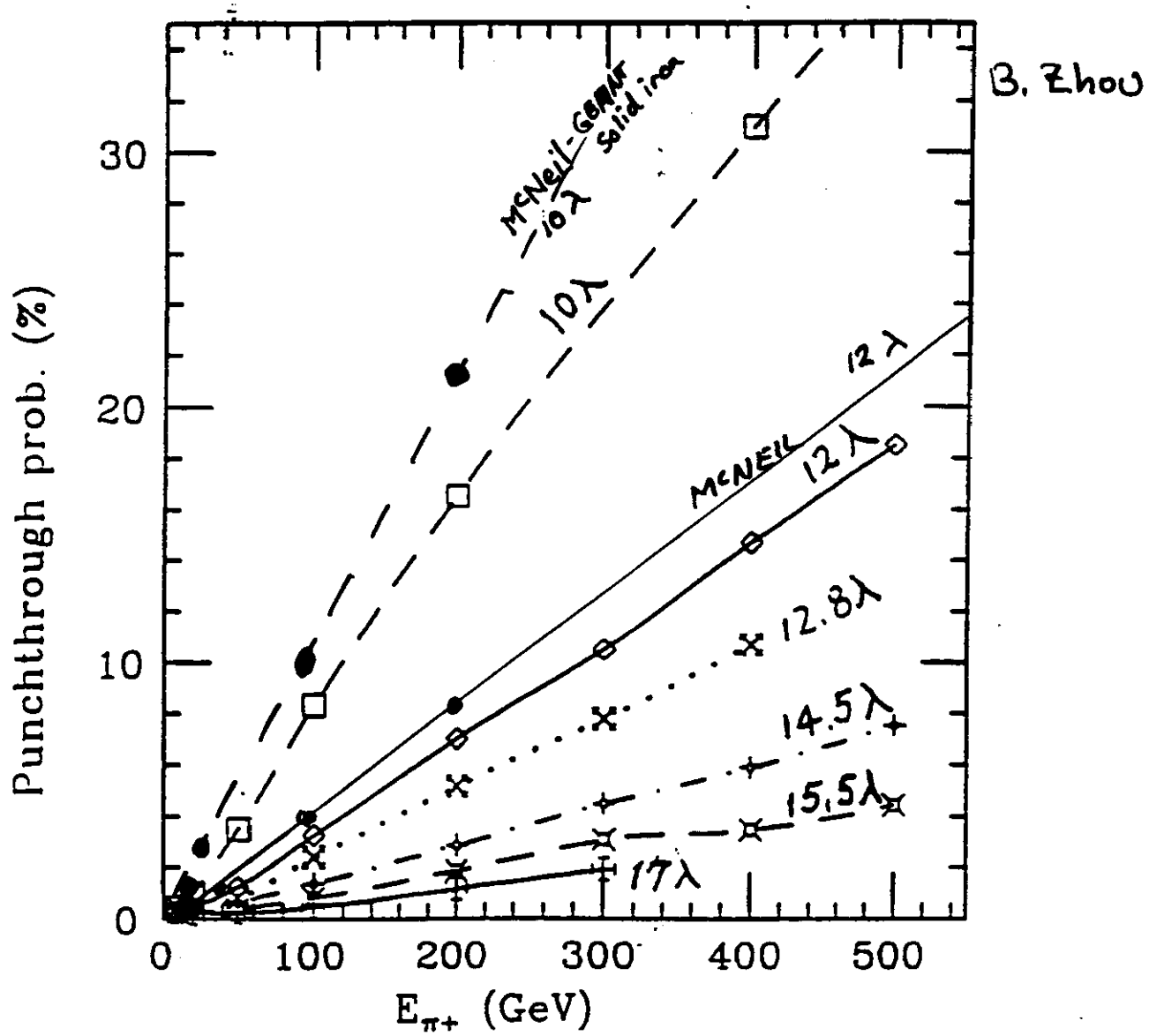


Rates of Particles exiting absorber which is 'constant' thickness in radial direction.

From ISAJET Twojet events and V2.0 of PCHTHR

Rate (kHz)		0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5
	Prompt	151	166	357	2694	5626
8λ	Decay	1212	4249	8820	13694	13211
	Punch	980	2362	6325	19101	64443
	Total	2344	6778	15501	35488	83279
	Prompt	120	78	188	1332	5460
10λ	Decay	470	2063	5260	9742	12112
	Punch	164	437	1381	4054	13 598
	Total	761	2578	6829	15 128	3470
	Prompt	96	59	151	823	4736
12λ	Decay	244	1054	3257	7115	10798
	Punch	62	171	525	1394	4063
	Total	402	1280	3933	9332	19596
	Prompt	93	49	97	556	4004
14λ	Decay	125	591	2067	5167	9336
	Punch	34	98	332	851	1895
	Total	251	738	2495	6574	15235

Comparison of PCHTHR (McNEIL) with B. Zhou result

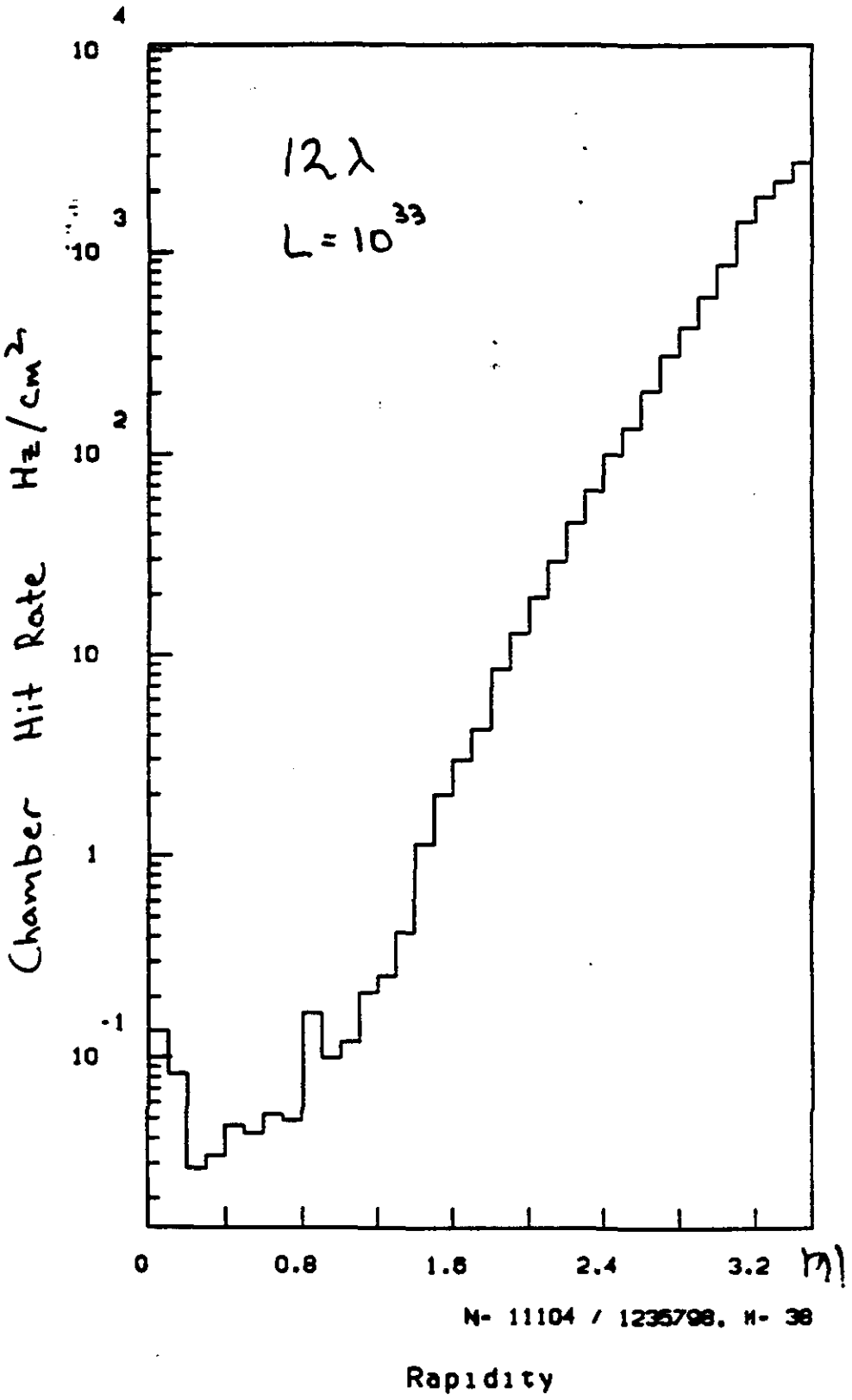


Both from GEANT Simulation

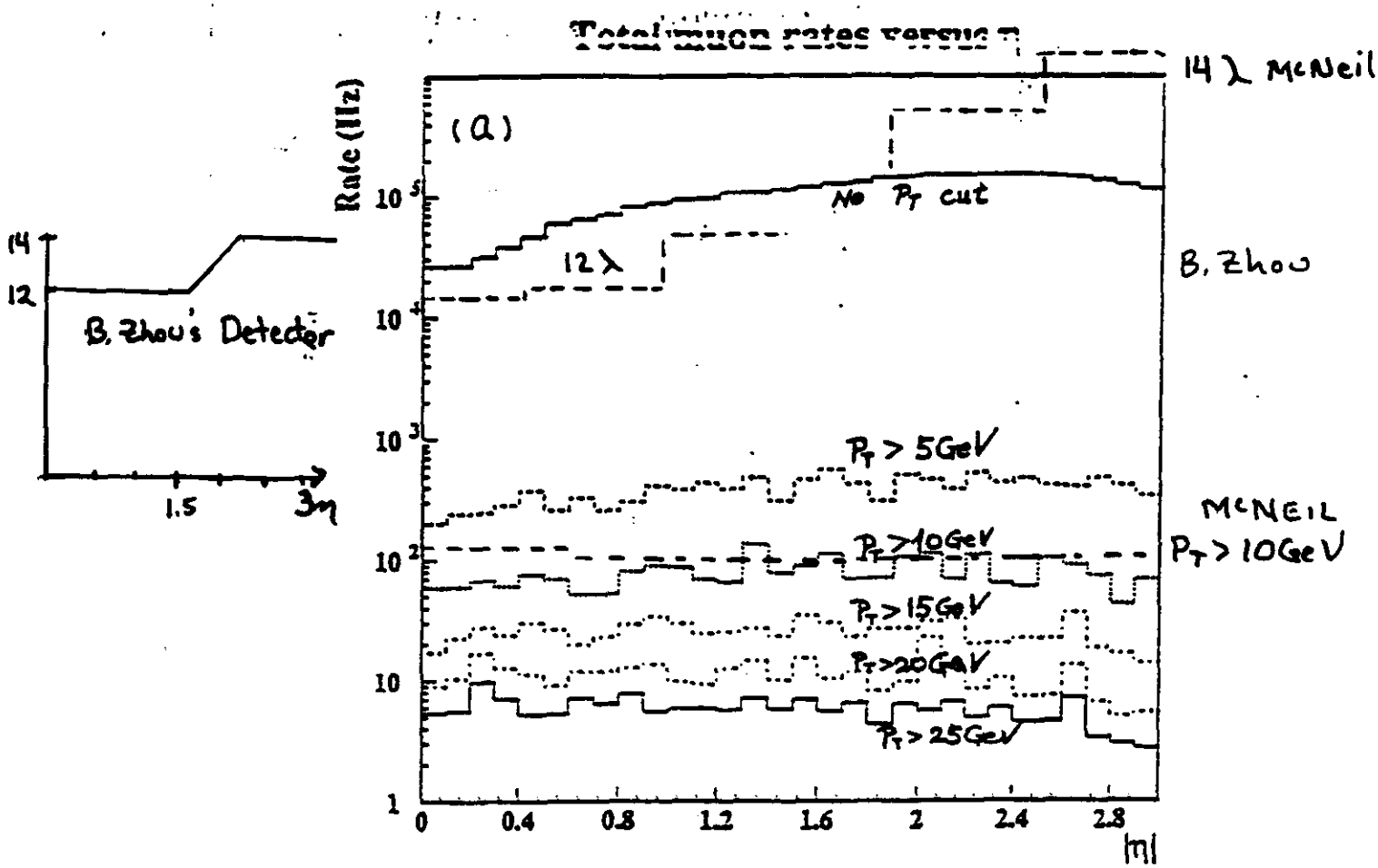
B. Zhou uses higher Energy cutoffs 1GeV e γ, .5GeV had

Figure 2 Singel π^+ punchthrough probabilities as functions of energy of the incident π^+ and the absorber thickness.

Twojet Events PtJET>4GeC/c STD LUM



Hit Rate for First chamber after CAL


Total muon rates versus η
(a)
Rate (Hz)
14 λ McNeil
No P_T cut
12 λ
B. Zhou
P_T > 5GeV
McNEIL
P_T > 10GeV
P_T > 10GeV
P_T > 15GeV
P_T > 20GeV
P_T > 25GeV
|η|
14
12
B. Zhou's Detector
1.5
3η

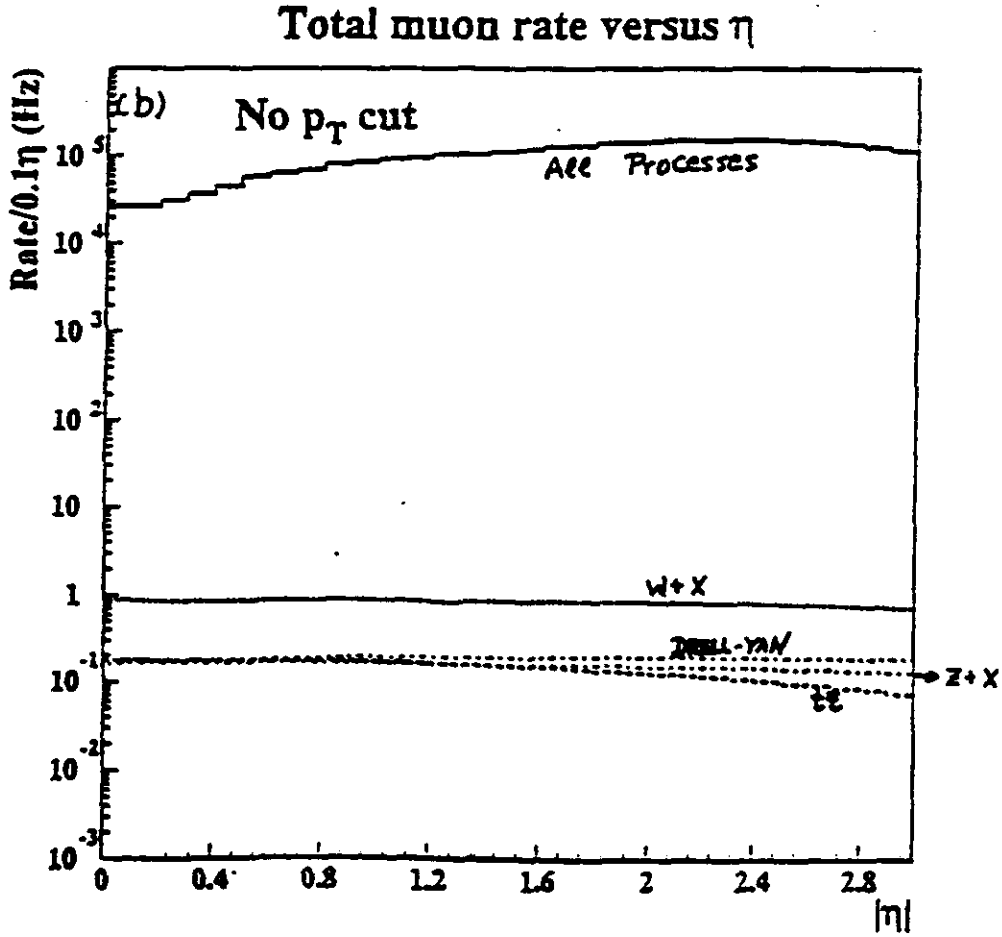

Total muon rate versus η
(b)
No p_T cut
Rate/0.1η (Hz)
All Processes
W+X
DRELL-YAN
Z+X
$\tau\tau$
|η|

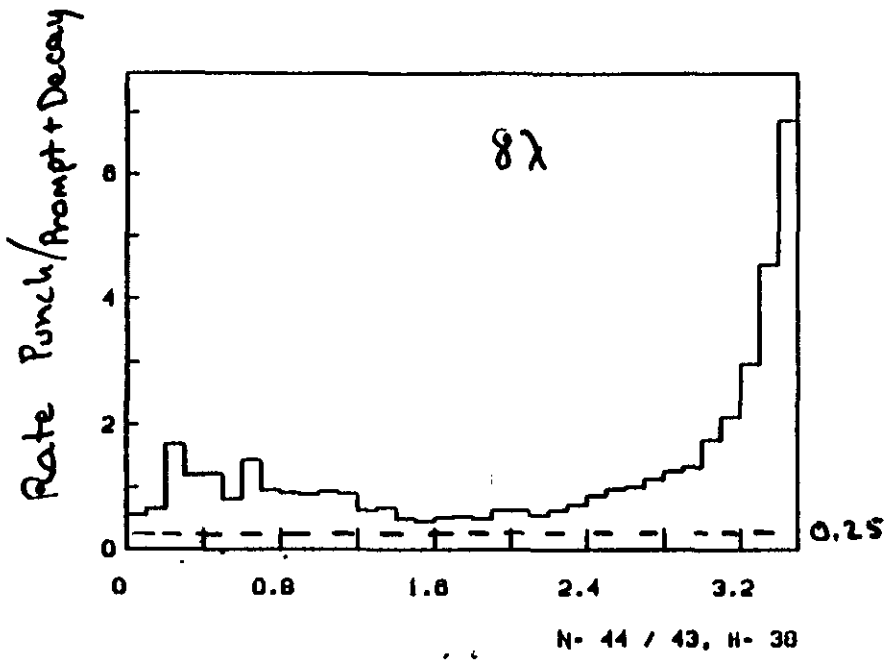
Figure 3

Dan Green & Dave Hedin

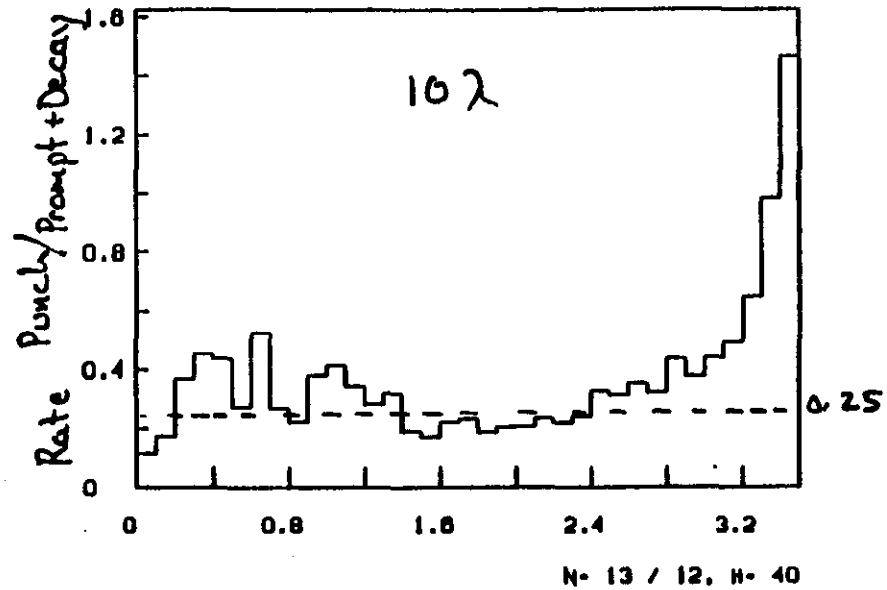
Table 2: Muon Rates versus Absorber Thickness

	$0 < \|\eta\| < 3$	$0 < \|\eta\| < 1$	$1 < \|\eta\| < 2$	$2 < \|\eta\| < 3$	
All	28,000	400	4100	23,000	
punch	4,900	70	420	4,400	9 λ
prompt	400	16	130	250	
All	18,000	250	2700	15,000	
punch	430	5	30	400	12 λ
prompt	400	16	130	250	
All	11,000	130	1500	9600	
punch	40	0.4	3	40	15 λ
prompt	380	13	120	250	
All	6800	80	700	6000	
punch	5	-	0.4	5	18 λ
prompt	270	13	70	190	
All	4400	50	460	3900	
punch	0.7	-	-	0.7	
prompt	270	10	70	190	
All	2700	30	270	2400	
punch	-	-	-	-	
prompt	270	10	70	190	
All	900	12	70	800	
punch	-	-	-	-	
prompt	150	7	10	135	
All	400	2	24	340	
punch	-	-	-	-	
prompt	140	0.6	7	130	

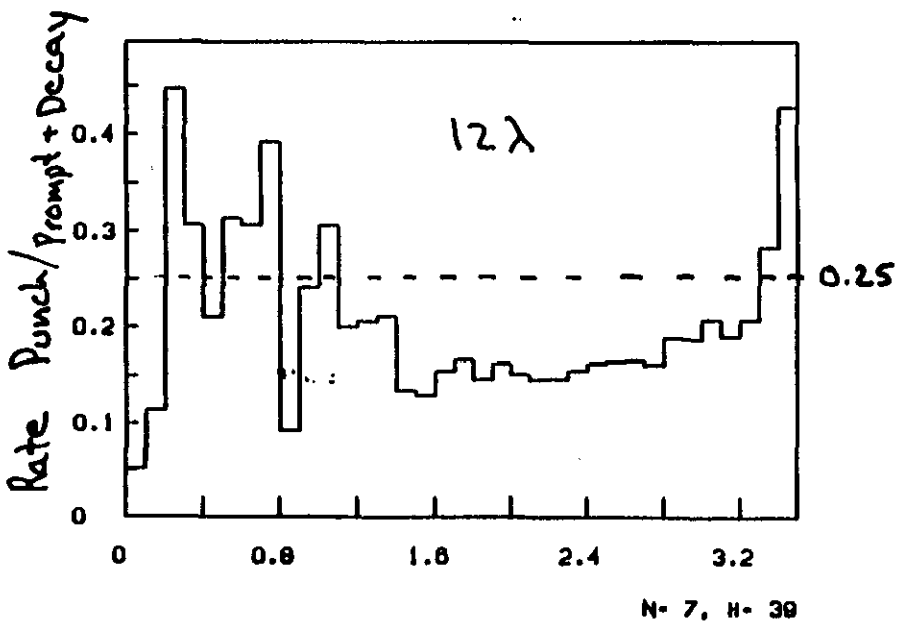
) summed over p_t Rate (kHz)



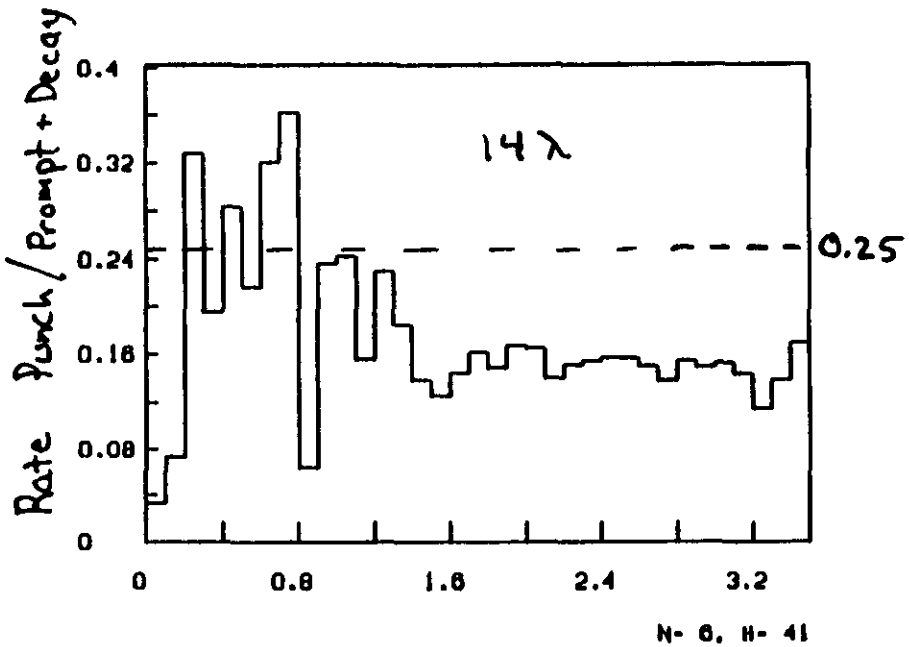
eta 81



eta 101



eta 121



eta 141

- Both Zhou & McNeil's Rates rely on GEANT
  Need to continue to validate GEANT (Tune)

- PCHTHR has been updated to consider
  Absorber thickness $< 12\lambda$, Can be used to produce particles (Type, position, 4-momentum) after Cal.

- Overall rates of punchthrough vs Prompt $\nu + \pi)K$ decay after calorimeter can be used to develop criteria for evaluation of calorimeter thickness, I will pursue this.

BUT,

This does not consider pattern recognition and fake triggers. This needs to be worked on.

TRIGGER/DAQ LOI Overview

- Three Level Trigger

GEM Trigger/DAQ Design Goals				
Level	Rate In	Rate Out	Latency	Comments
1	62 MHz	10 kHz	3 μs	Synchronous, Pipelined
2	100 kHz	300 Hz	100 μs	Asynchronous, Monotonic
3	3 kHz	10 Hz	—	CPU Ranch

Table 7.1 Design goals for the GEM Trigger/DAQ System. Output rates are for operation at $\mathcal{L} = 10^{33}$ cm^{-2}s^{-1}.

- Level 1

  Calorimetry — Super-towers $\Delta\eta \times \Delta\phi = .2 \times .2$
  - γ/e — HAC Veto
  - Jets — Local Sums
  - $\not{E}_T$ — Global Sums

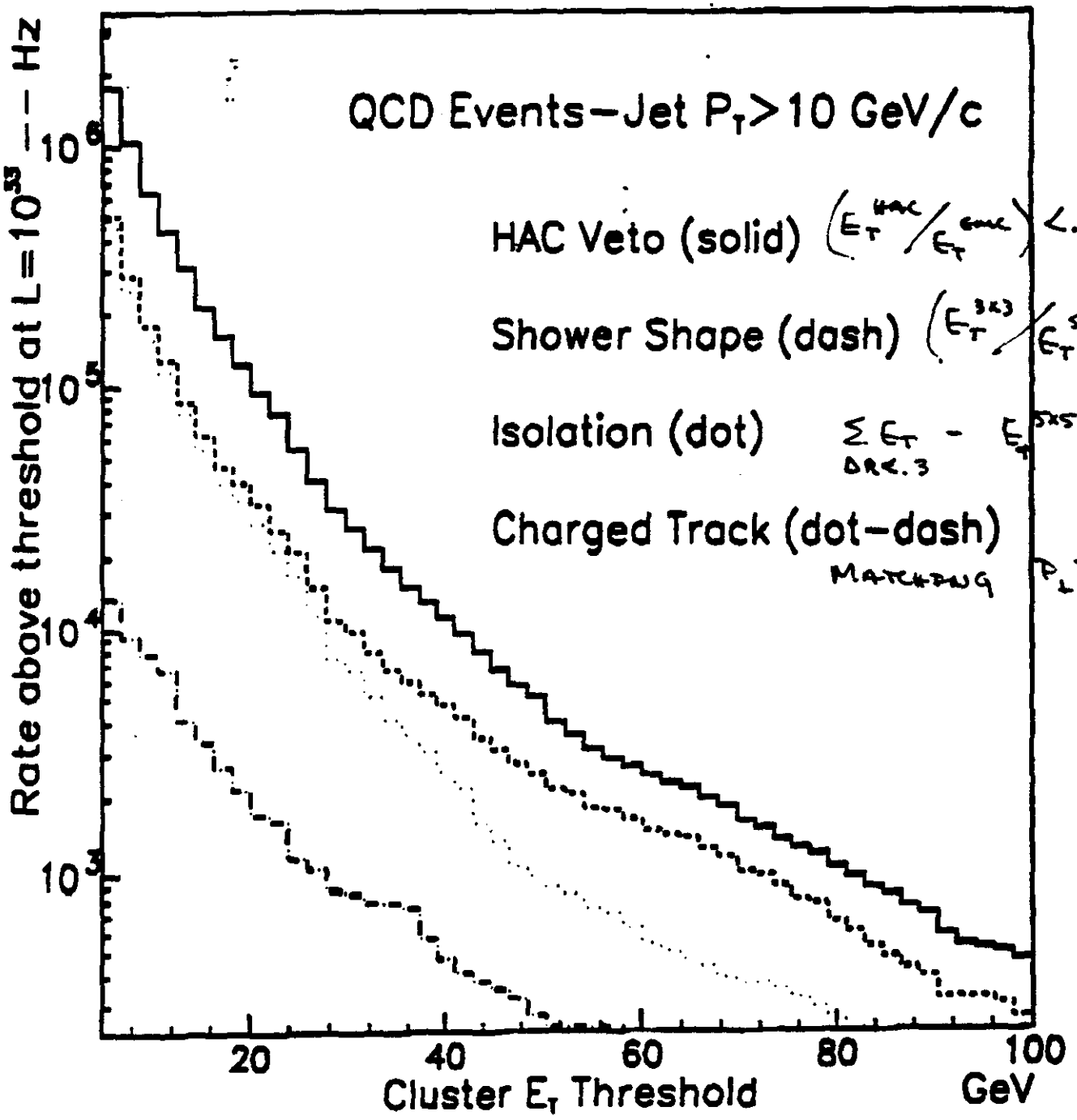
  Muons — Hit Patterns in 3rd and/or 2nd Lay
  $\Rightarrow P_\perp$ / Pointing Cut

- Level 2

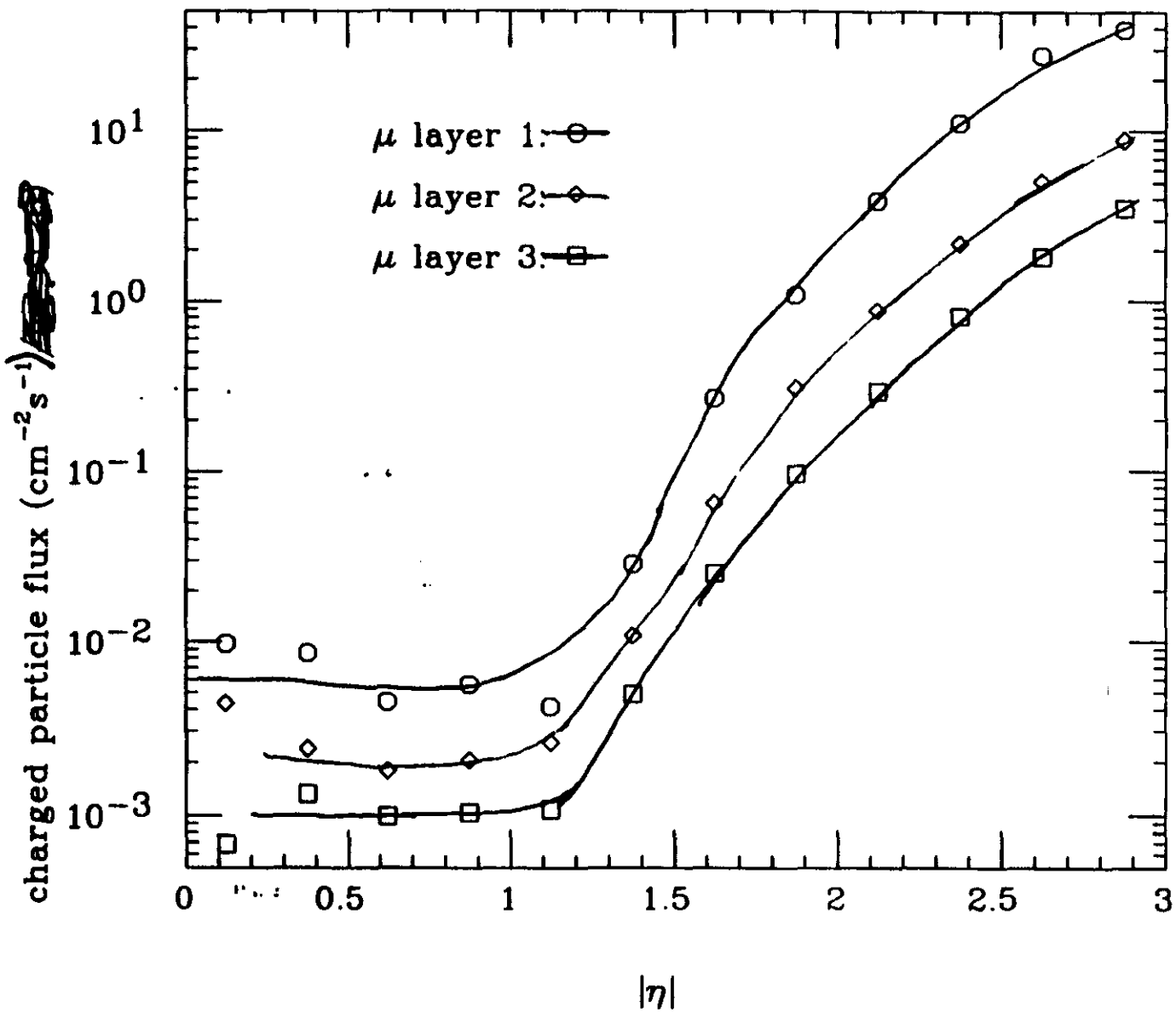
  Calorimetry — Full Detector Granularity
  - Shower Shape
  - Isolation
  - Associated Electron Track (Central Tracker)

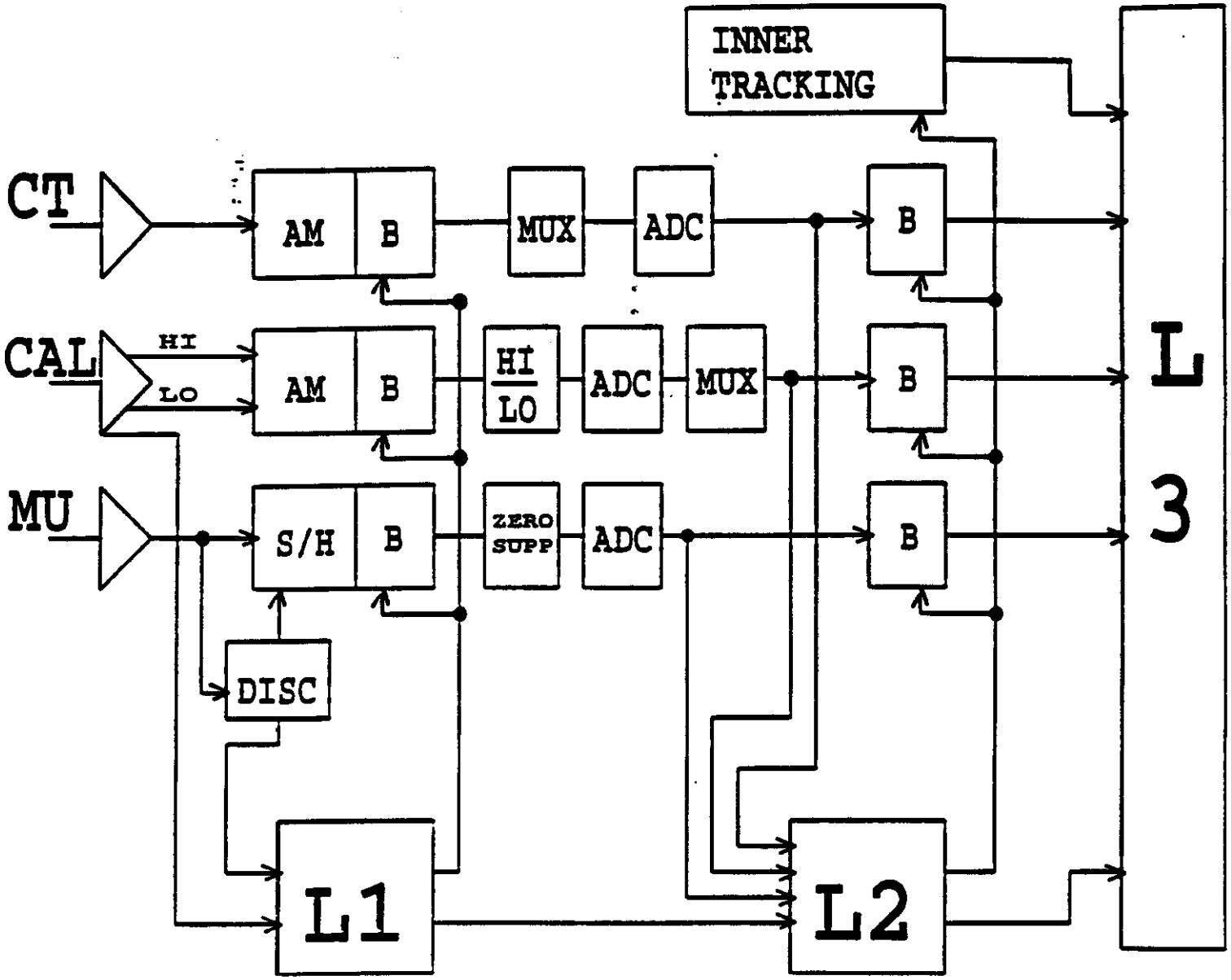
  Muons — Full $P_\perp$ Measurement

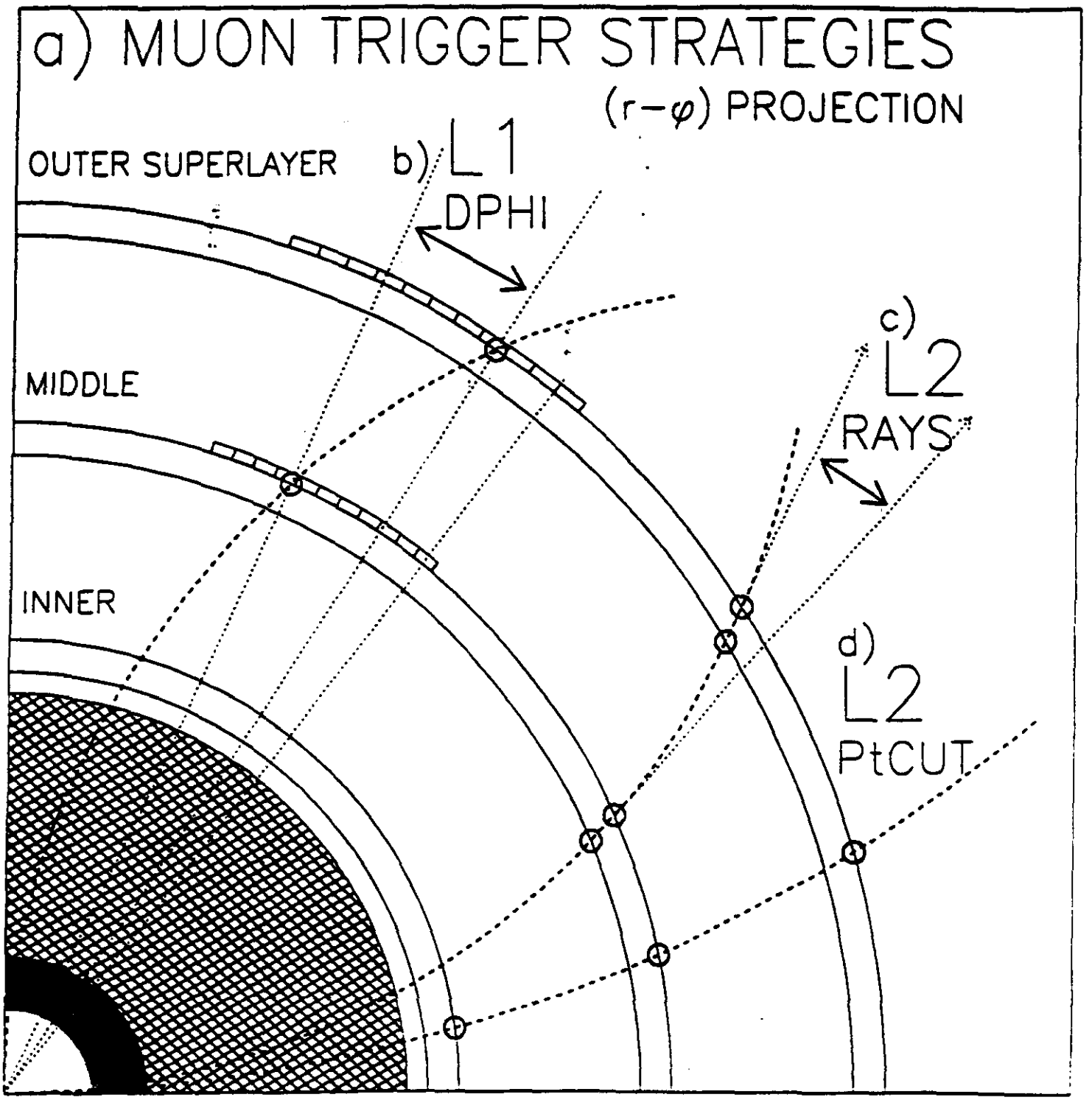
Electron/Photon Trigger Strategy/Rates



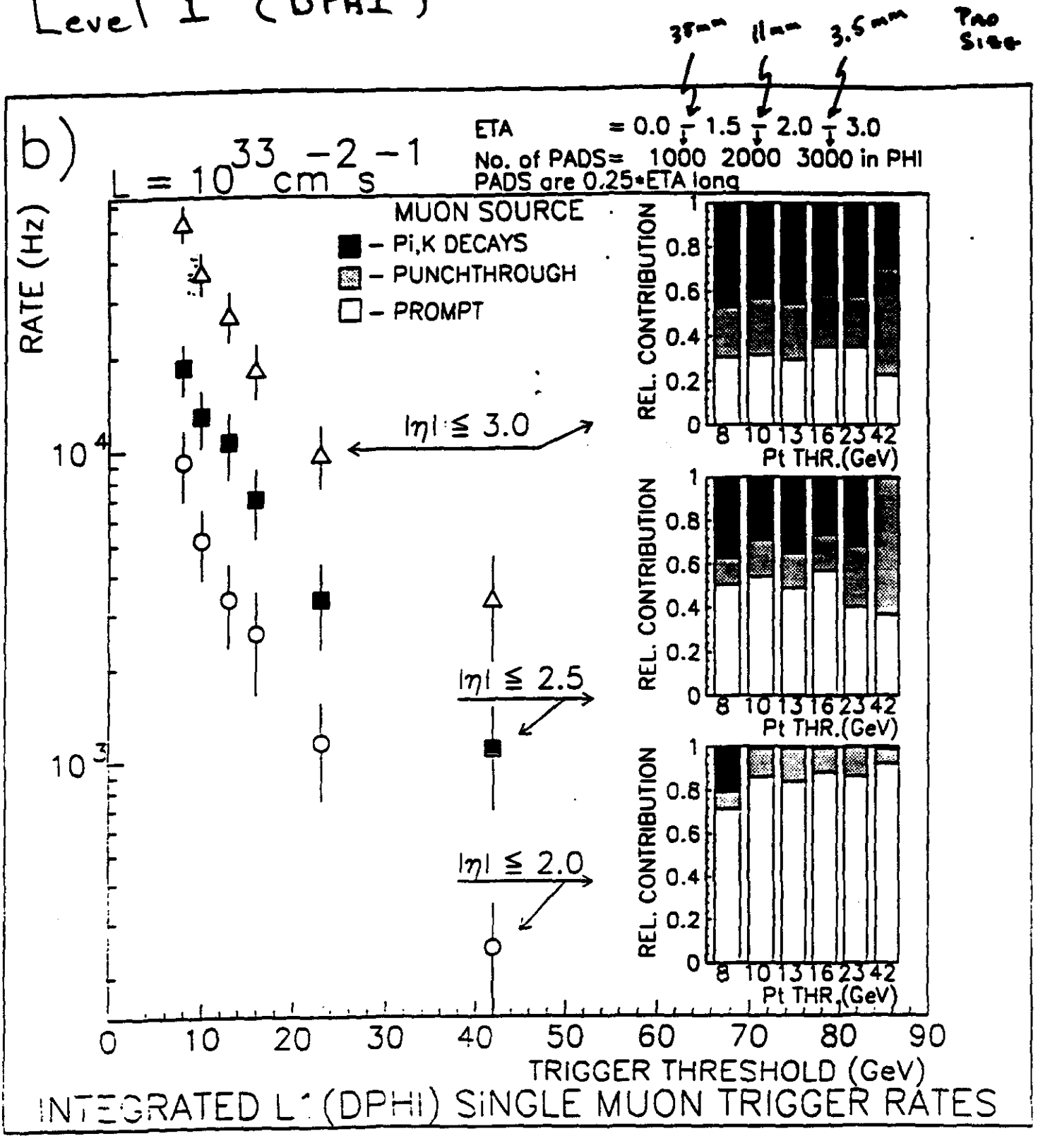
Hit Rate (#/cm²) in Muon Chambers



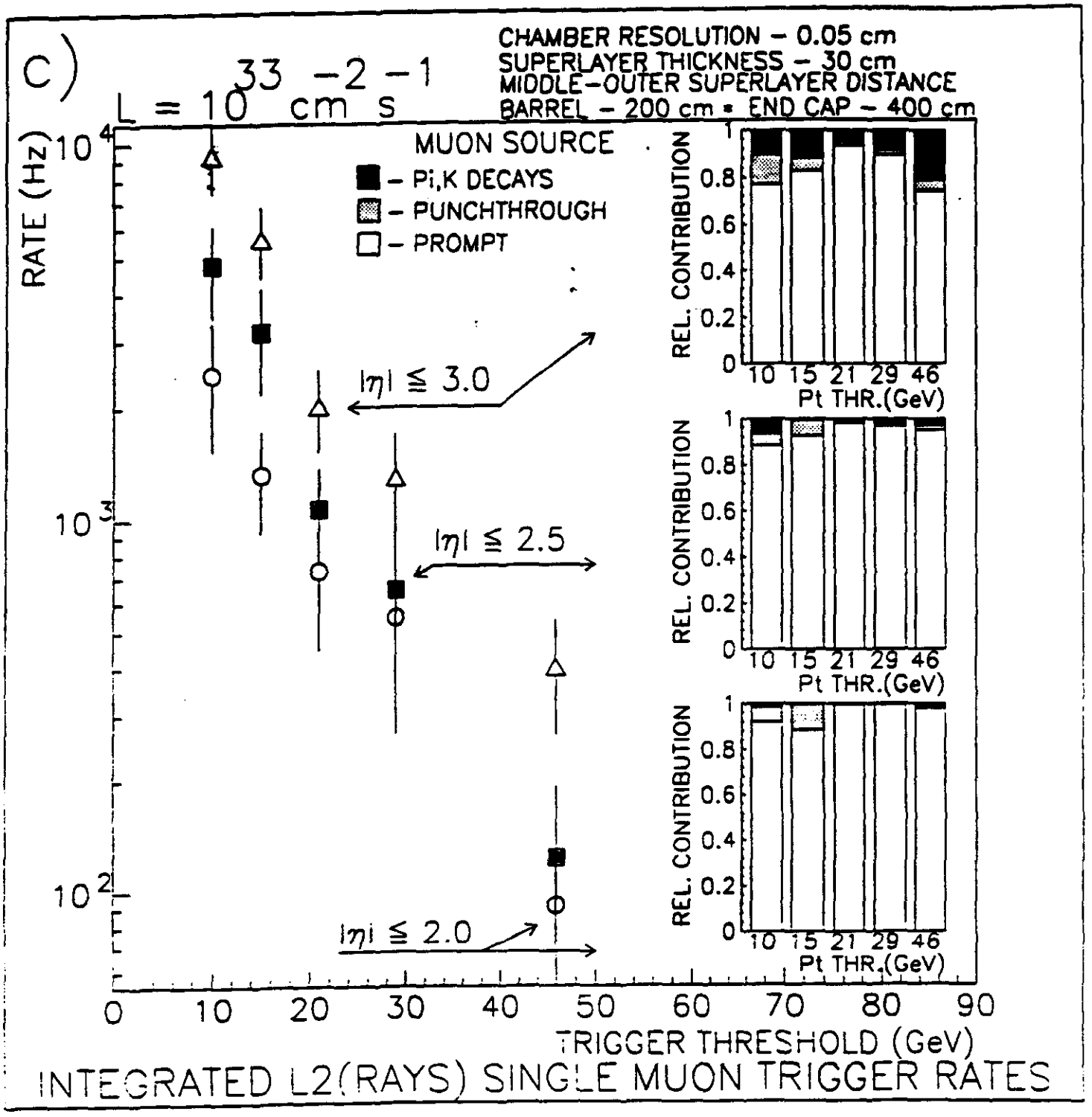

INNER
TRACKING
CT
AM
B
MUX
ADC
B
CAL
HI
LO
AM
B
HI
LO
ADC
MUX
B
L
3
MU
S/H
B
ZERO
SUPP
ADC
B
DISC
L1
L2


a) MUON TRIGGER STRATEGIES
(r−φ) PROJECTION
OUTER SUPERLAYER
b) L1
DPHI
MIDDLE
c)
L2
RAYS
INNER
d)
L2
PtCUT

Level 1 (DPHI)

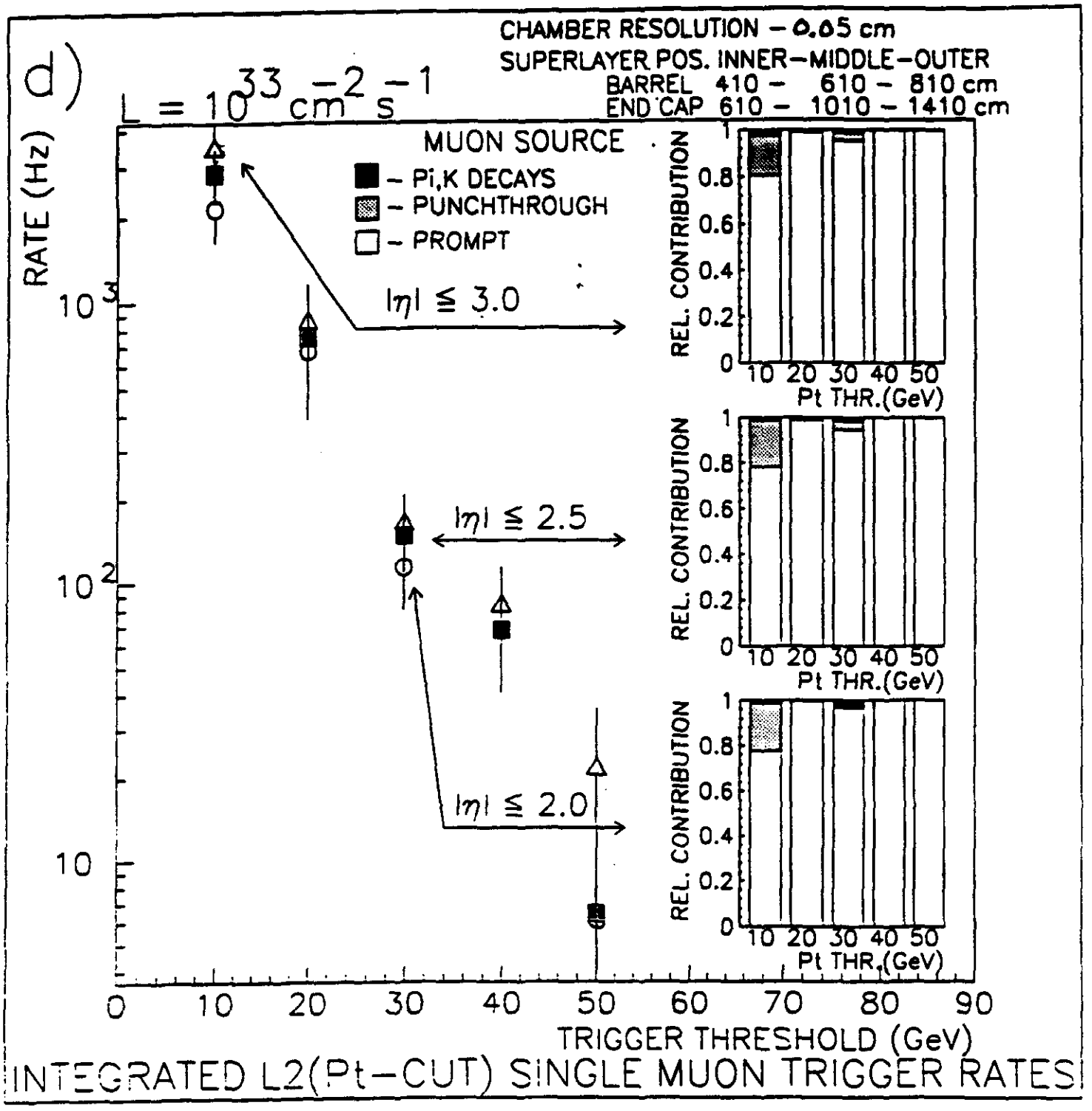

38mm
11mm
3.5mm
Pad Size
b)
$L = 10^{33} cm^{-2} s^{-1}$
ETA = 0.0 1.5 2.0 3.0
No. of PADS= 1000 2000 3000 in PHI
PADS are 0.25*ETA long
MUON SOURCE
– Pi,K DECAYS
– PUNCHTHROUGH
– PROMPT
RATE (Hz)
10^4
10^3
$|\eta| \leq 3.0$
$|\eta| \leq 2.5$
$|\eta| \leq 2.0$
REL. CONTRIBUTION
Pt THR.(GeV)
0 10 20 30 40 50 60 70 80 90
TRIGGER THRESHOLD (GeV)
INTEGRATED L1 (DPHI) SINGLE MUON TRIGGER RATES

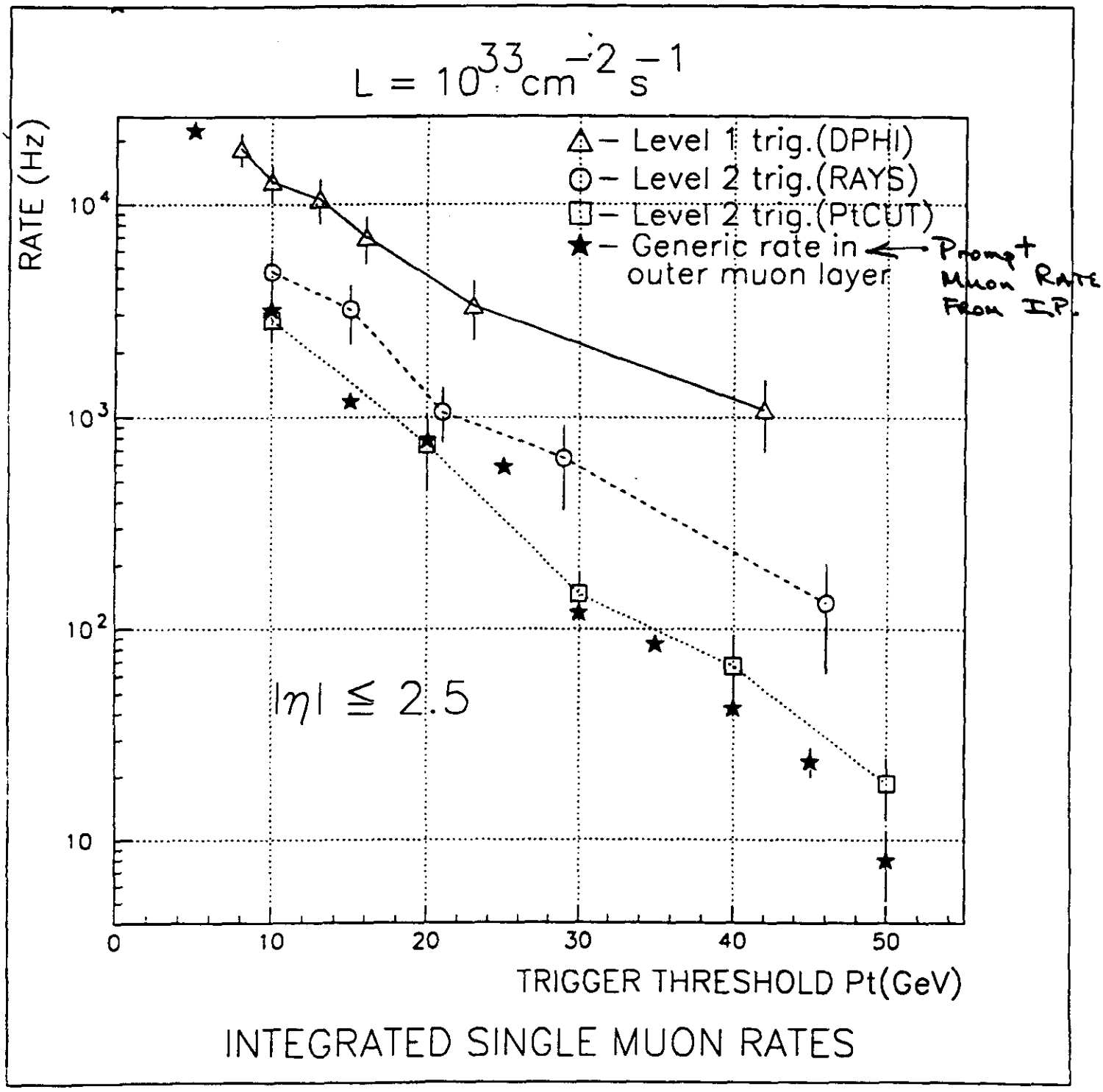
Level 2 (Rays)



INTEGRATED L2(RAYS) SINGLE MUON TRIGGER RATES

Level 2 ($P_{T\,CUT}$)





INTEGRATED SINGLE MUON RATES

Weinstein: 10/1/91

K. Lau, B. Mayes, L. Pinsky, J. Pyrlik, R. Weinstein
Univ. of Houston and SCARF

1. Houston Advocates SC/DC chambers

2. There are at present a significant number of important variables which have been set (temporarily?) without broad discussion or testing.

3. The next transparency shows what we consider to be necessary work on SC/DC chambers.

SC/DC Aluminum Option

I "Arbitrary" Parameters

- 1" cell
- Al cathode
- 8 cell extrusion
- Design of Support Box
- Gas

A.
- 1 cm cell. Electronics cost?
- Changes in Al weight?
- 0.4 cm cell for small angles?

- Use of 4 cell extrustion to decrease Al mass.
- Use of folds, trusses, hexcell,.....
- Optimize reference wall structure.

C. Test each gas for:
- Plateau Length
- Dead t at SSC rates
- N_2 sensitivity
- Double Pulsing

Test final choices for:
- life time
- feasibility of N_2 removal

D.
- Effect of Al, Ni, C on stability.
- Cost of Ni coating.

II. "Basic" Questions

- Lorentz Angle

B.
- Measure Lorentz Angle

III. Needed Development

- Wire machine
- Cheap, reliable, mass produced holddown

E.
- Must have < 1 error/6 miles. Try for < 1 error/ 10 miles.

F.
- Cut assembly cost.
- Cut Parts cost.
- Increase holddown reliability

Notes

A. Cell Size

Note that, pushed by electronics, we developed a 16" DC for MAC detector at PEP.

Then, because of gas vol., total dimension, and total drift time, we switched to 4" tubes.

For the GEM SC/DC detectors, do we KNOW Electronics problem is dominant?

Consider the following variables:

1. Lifetimes

At small angles, lifetime may be measured in months. 1cm chamber increases T_{life} by 2.5. Cell size of 0.4cm increases T_{life} by 6.3.

2. Drift Time

If drift time for 1" is, for example, 200 ns, drift t for 1cm is 78ns, and 0.4cm is 31ns.

3. Dead Time

Dead time, as far as I know, is not measured for the proposed gases. Slide 4 shows dead time effect in "standard gas" in an ongoing CERN test.

Cell size reduces dead time by 2.5 for 1cm cells and 6 for 0.4cm cells.

4. Gas Volume

With 1" cell, total chamber volume may be of magnitude 1,000 $m^3 \approx 10^6 l$.

Leakage (+) O_2 removal causes N_2 accumulation. N_2 accumulation causes a shift in the operating characteristics (Slide 5). The situation worsens for nonflammable gases we have tested, due to a shortened plateau.

A blow-off,e.g., every 10 days would cost $500k/yr. with standard gas.

This is reduced by 2.5 for 1cm cells and 6 for 0.4cm cells.

5. Electronics, Revisited

Problem for small cell is increased electronics. The increased cost of ganging, e.g., (3) 1cm chambers on one TDC, with 3 flags, needs to be seriously considered. This cost can then be rationally weighted against items 1-4.

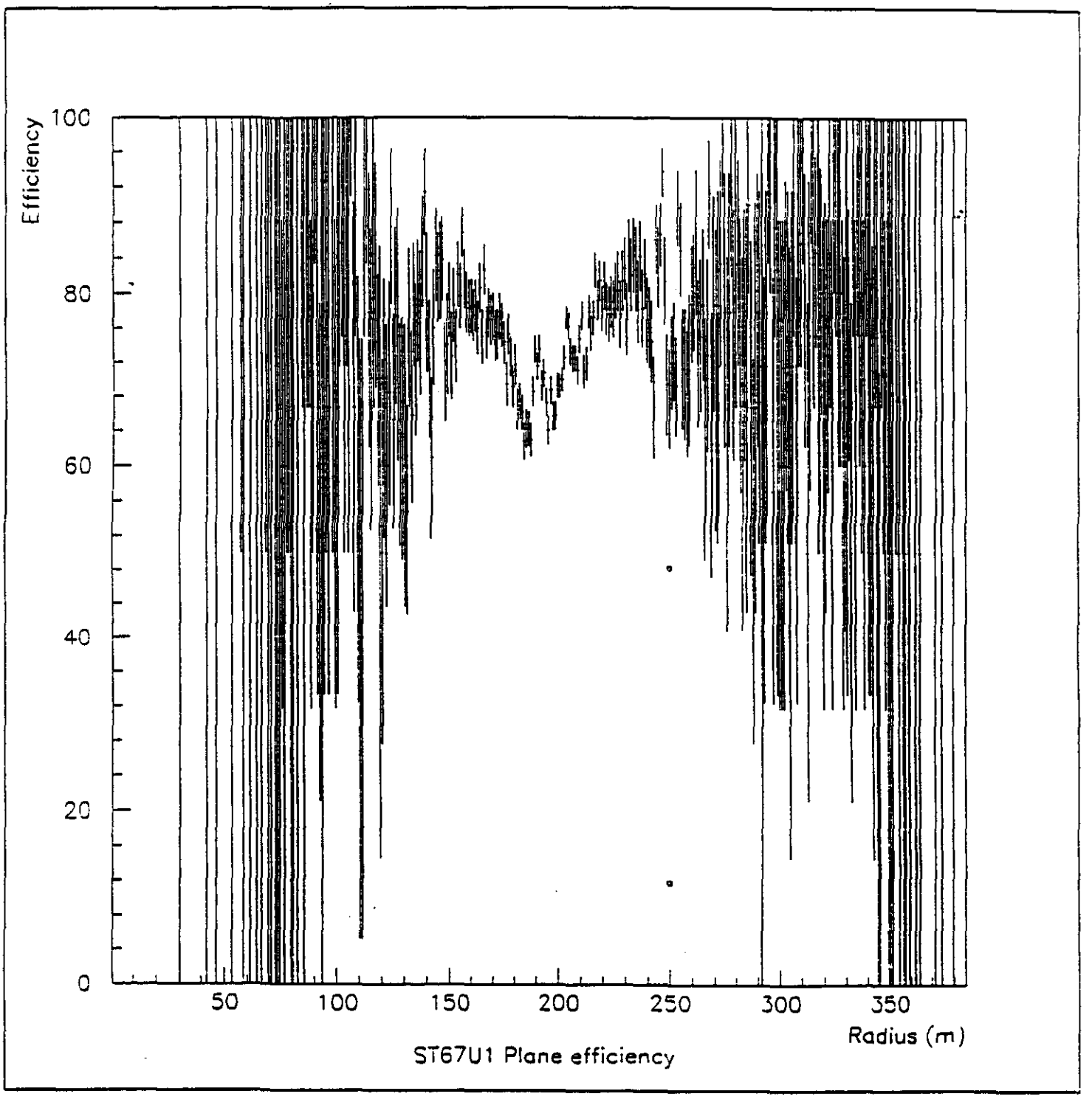

Efficiency
100
80
60
40
20
0
50
100
150
200
250
300
350
Radius (m)
ST67U1 Plane efficiency

Fig 3

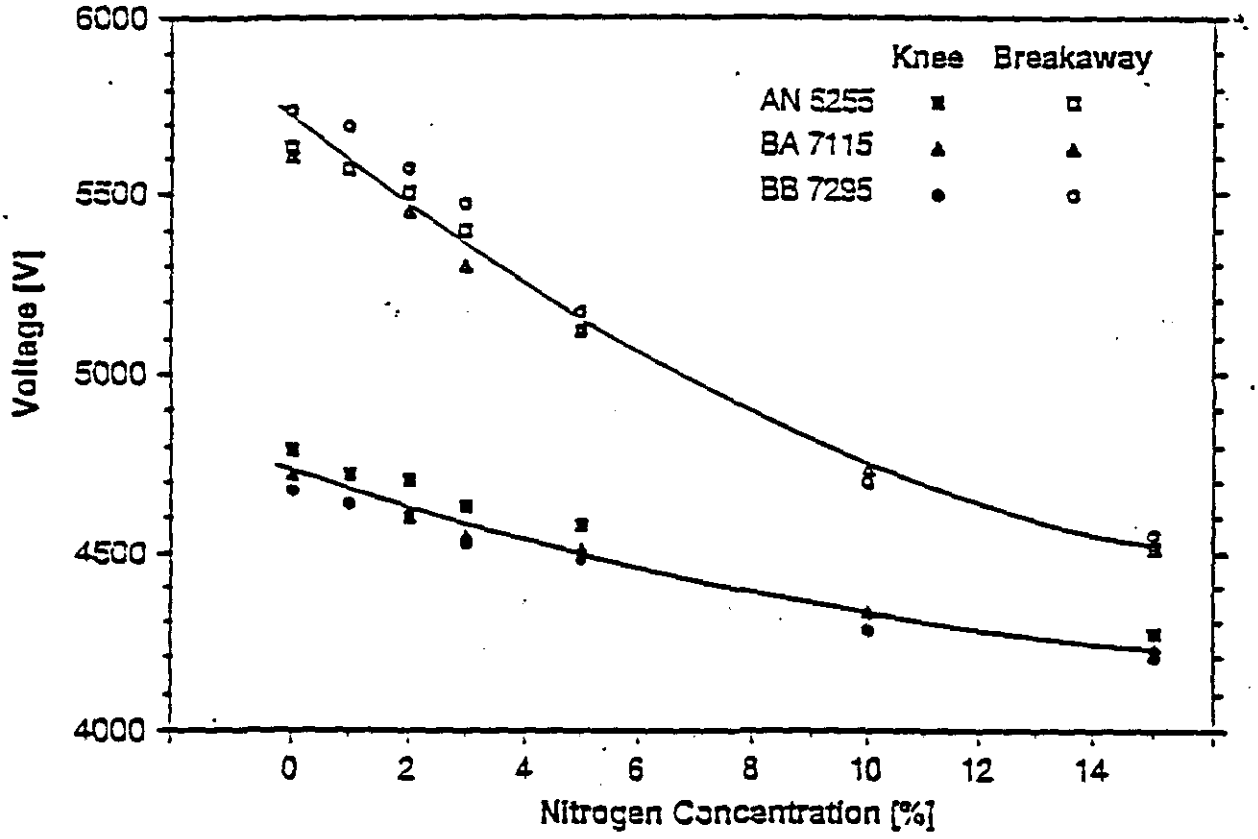
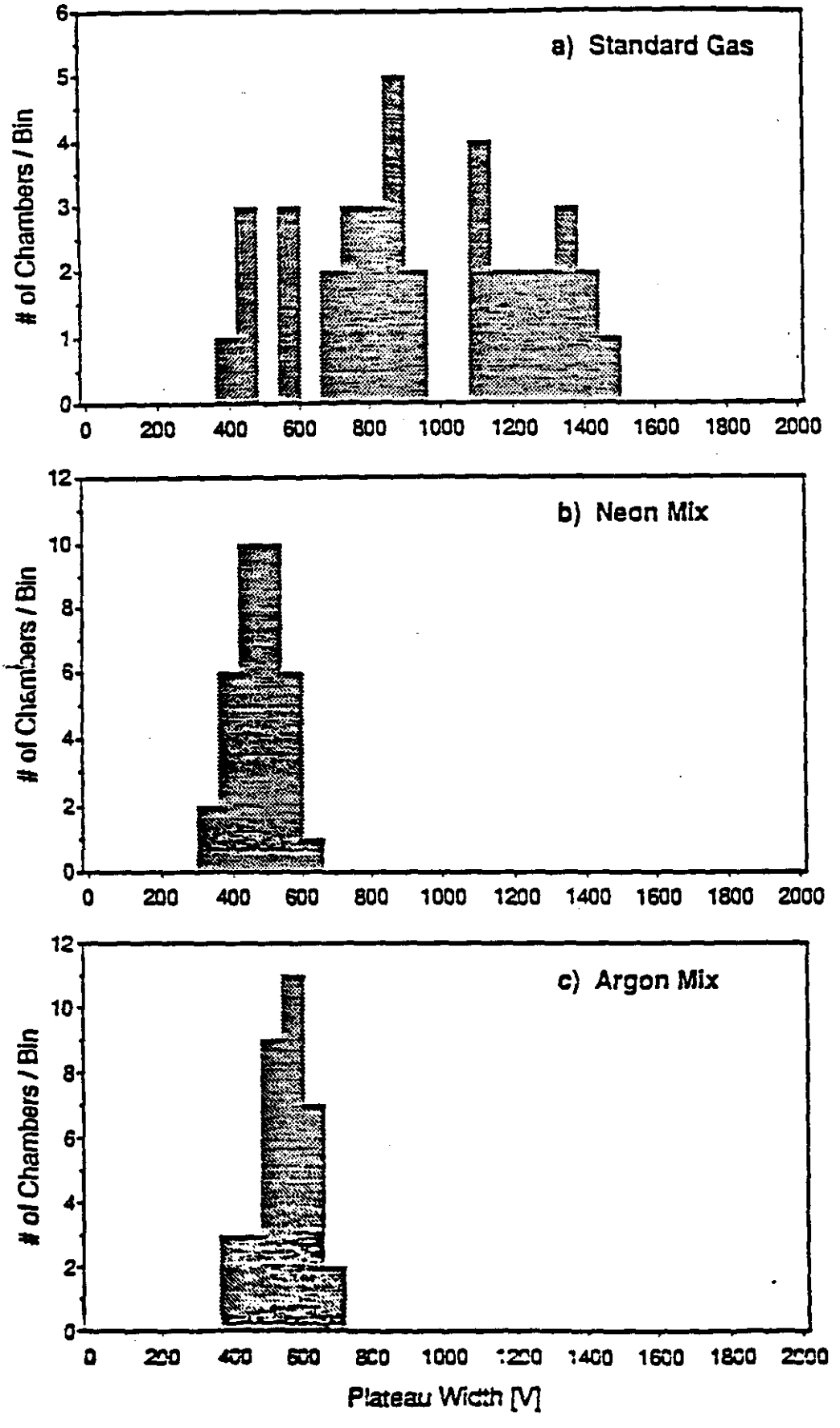


Fig. 4 Effect of Nitrogen Contamination. Plateau at any % Nitrogen is top (open) point minus bottom (filled) point. Plateau not only narrows, but moves to lower HV.


a) Standard Gas
b) Neon Mix
c) Argon Mix
# of Chambers / Bin
Plateau Width [V]
0
200
400
600
800
1000
1200
1400
1600
1800
2000