GEM TN-91-43

GEM MUON SUBGROUP MEETING

December 12, 1991

Abstract:

Agenda, list of participants and transparencies contributed to the GEM Muon Subgroup Meeting held on December 12, 1991..

Agenda: Muon Subgroup Meeting 12/6/91

(1) Status of the LoI, R&D proposal, and Management Issues -
9:00-9:30 - Frank Taylor

(2) System Integration and Engineering -
9:30-10:00 - Frank Nimblett

(3) Updates from the individual R&D tasks: (about 20 minutes each)

- CSC - Vinnie Polychronakos and Scott Whitaker
- RPC - Irwin Pless
- PDT - Carl Bromberg and Brian Smith
- LSDT - Frank Taylor
- SCARF - Kwong Lau

LUNCH - 12:00-13:00

(4) Simulation of muon system performance - Roger McNeil et al.
13:00-14:00

(5) Items requiring attention:

- (a) How well do we need to know the B-field (L-angle and Integral(Bdl) - Jim Sullivan 14:00-14:20
- (b) Trigggering - Irwin Pless 14:20-14:40

BREAK - 14:40-15:00

(6) TTR Working meeting: 15:00-17:00 - Gena Mitselmakher and muon group.

Discussion of needs of technologies for the TTR including channel count, DAQ system, etc.
DAQ - Ken McFarlane
Engineering - Tom Prosapio
How to measure chamber resolution - Frank Taylor

NOTE to Tecnology Proponents: Please compile information about your specific needs for the TTR for this segment of meeting.

12/6/91 μ-meeting

Name	phone	E-mail
Frank Taylor	617-253-7249	FET @ MITLNS
Orrin Fackler	(510) 423-1766	FACKLER@NEU.LLNL.GOV
MOHAMMAD MOHAMMADI	(516) 632-8107	SBHEP::MOHAMMADI
CHIAKI YANAGISAWA	(516) 632-8295	SBHEP::CHIAKI
Frank Stocker	(214) 708-6025	STOCKER@SSCVX1
Luis Villasenor	(214) 708-6209	VILLASENOR @SSCVX1
LARRY ROSENSON	617-253-7595	ROSENSON@MITLNS
IRWIN A. PLESS	617-253-2367	PLESS @ MIT LNS
RICHARD A. TODD	(615) 574-5650	toddra@icsun1.ic.ornl.gov
Brian Smith	(505) 665-2666	BSMITH@CAEVAX.MEEDW.LANL.GOV
Michael Marx	214 708 6188	SSCVX1::MARX
Dmitri Denisov	(708) - 840 - 3590	FNAL::DENISOVD
KWONGT LAU	(713) 749-4385	LAU@UHOU
Sergei Mitselmakher	(214) 708-6001	SSCVX1::MITSELMAKHER
FRANK NIMBLETT	(617) 258-1393	NIMBLETT@DRAPER.COM
Ken McFarlane	214-708-6120	MCFARLAN@SSCVX1
KARL VAN BIBBER	510-423-8949	PEGASYS@SLACESA
James D. Sullivan	617-253-7537	SULLIVAN@MITPFC

FET

GEM Muon Group R&D

SUBGROUP	DESCRIPTION	
CSC	Cathode Strip Chamber Subgroup; coordinated by V. Polychronakos, Brookhaven National Lab.	$500k
LSDT	Limited Streamer Drift Tube Subgroup; coordinated bu L. Osborne, MIT	$480k
PDT	Pressurized Drift Tube Subgroup; coordinated by S. Ahlen, Boston Univ.	$400k
RPC	Resistive Plate Chamber Subgroup; coordinated by I. Pless, MIT, and C. Wuest, Lawrence Livermore National Lab.	$300k
ENG	Engineering Subgroup; coordinated by F. Nimblett, Draper Lab.	$700k
TTR	Texas Test Rig Subgroup; coordinated by G. Mitselmakher, SSC Lab.	$240k
SCARF	Streamer Chamber Assembly and Research Facility Subgroup; coordinated by R. Weinstein, Univ. of Houston	$80k
		$2,700k

132 people
21 Institutions
4 countries

SEM μ-system:

Draft organization / 12-5-91 B. Barish

Ahlen / Taylor: coordinators

Steering Committee:

M. Atilya, R. McNeil, G. Mitselmakher,
L. S. Osborne, V. Polychronakos,
C. Wuest, F. Nimblett

GEM COST REVIEW

1. Scheduled December 10-11 at SSCL. or 11-12

2. Subsystem physicists required.

3. Lead design engineers required.

4. Integration team members invited.

5. Cost estimate engineers required.

6. Electronics and mechanical technologies required. Mechanical engineers and physicists should not present electronics cost estimates.

COST REVIEW FORMAT

1. Each subsystem to be reviewed.

2. Liquid argon will be emphasized, but brief reviews of BaF/fiber system and preradiator and forward calorimeters will be covered.

3. LeCroy will make first presentation of electronics estimates. Other lead electronics engineers should be present.

4. For each subsystem we will need efficient presentations of:

a. Physics performance parameters and requirements
b. Basic design parameters, dimensions, channel counts,...
c. Status of design.
d. Design team members and effort put into design to date.
e. Cost estimate with emphasis on basis, fraction of estimate with various bases.
f. Plan for next 2 months and descope options.

Management Issues:

Need:

- electronics coordinator
  Works with Marlow/Shaevitz
  Communicates to μ group
  electronics decisions, ...
- trigger system coordinator
  Works with simulations group
  and electronics group. Develops
  trigger scheme ...
- alignment coordinator
  Works with individual technologies
  for local alignment requirements
  Considers how the global alignment
  is to be applied.
- simulation coordinator
  Simulates μ system performance.
  Provides guidance on design.
- engineering coordinator
  overview of all engineering
- magnet

GEM MUON SYSTEM R&D/ENGINEERING PLAN

(1) Introduction

The GEM muon system has the following specifications:

Pseudorapidity coverage:	
Barrel:	$0 < \eta < 1.3$
Endcap:	$1.3 < \eta < 2.5$
Momentum resolution at small momentum:	
Barrel (avg. over rapidity):	1.0%
Endcap (avg. over rapidity):	1.2%
Momentum resolution at large momentum:	
Barrel (avg. over rapidity):	7% p/TeV
Endcap (avg. over rapidity):	7% p/TeV
Radiation lengths in middle module:	
Barrel:	< 10%
Endcap:	< 8%
Systematic sagitta error:	50 μm
Time resolution:	< 5 ns
Level 1 trigger latency time:	< 3 μs
Level 2 trigger latency time:	< 100 μs
Total muon system cost:	< $130M

To achieve these goals the GEM Collaboration has selected the following design for the muon system:

BARREL

Metallic drift tubes to be used for momentum determination and level 2 trigger.

Resistive Plate Chambers (RPC's) to be used for level 1 trigger, bunch crossing tag, and z determination.

ENDCAP

Cathode Strip Chambers (CSC's) to be used for momentum determination, bunch crossing tag, level 1 and 2 triggers, and r determination.

It will be necessary for the barrel drift tubes to achieve a single wire resolution of 100 μm and the CSC's to achieve a single plane resolution of 75 μm to satisfy the above specifications. Two types of drift tubes are under consideration for the barrel: Pressurized Drift Tubes (PDT's), and open profile Limited Streamer Drift Tubes (LSDT's).

The GEM Muon Group consists of 132 physicists and engineers from 21 institutions and 4 countries (USA, China, USSR, Romania). This Group has organized itself into 7 Subgroups to carry out the engineering and R&D activities necessary to bring the current muon system concept to a fully developed design for the GEM Technical Proposal (TP) to be submitted in November 1992. The Subgroups are:

SUBGROUP	DESCRIPTION
CSC	Cathode Strip Chamber Subgroup; coordinated by V. Polychronakos, Brookhaven National Lab.
LSDT	Limited Streamer Drift Tube Subgroup; coordinated bu L. Osborne, MIT
PDT	Pressurized Drift Tube Subgroup; coordinated by S. Ahlen, Boston Univ.
RPC	Resistive Plate Chamber Subgroup; coordinated by I. Pless, MIT, and C. Wuest, Lawrence Livermore National Lab.
ENG	Engineering Subgroup; coordinated by F. Nimblett, Draper Lab.
TTR	Texas Test Rig Subgroup; coordinated by G. Mitselmakher, SSC Lab.
SCARF	Streamer Chamber Assembly and Research Facility Subgroup; coordinated by R. Weinstein, Univ. of Houston

The membership, tasks, and budgets for the Subgroups will be described in subsequent sections. In the next section we give a brief and general overview.

(2) Major Goals for FY92 and the Budget Breakdown Between Subgroups

For the time from December 1991 to September 1992 it will be necessary to complete the following jobs:

i) Decide between PDT's and LSDT's for the barrel. This will be based on tests of modules to be installed in the Texas Test Rig (TTR) which will be built at the SSC Lab. Tests will be done with a hardened cosmic ray spectrum and the decision will be based on cost and performance. Critical issues are alignability, resolution per wire, material thickness, operation stability and safety, and cost and difficulty of assembly.

ii) Build and test a prototype CSC to substantiate preliminary conclusions that this device will perform up to specifications for the endcaps. Critical issues are performance in magnetic fields, channel to channel uniformity and calibratibility, material thickness, and electronics cost.

iii) Develop a base of experience with the use of RPC's to substantiate preliminary conclusions that this device will perform up to specifications for the barrel. Critical issues are time resolution, noise rate, stability of noise rate, RF noise induced in neigboring drift tube detectors, charged particle rate capabilities, and material thickness. A two prong approach will be followed: evaluation of Italian made RPC's, and the construction and evaluation of small prototypes produced with new plate materials.

iv) Carry out engineering design and cost evaluation for the TP. Critical issues are: (a) alignment at the module level (a module being a set of adjacent tracking layers), the sector level (a sector is a set of 3 modules used to make a sagitta measurement), and globally (knowledge of the interaction point and other detectors relative to the muon system sectors); (b) design of system to monitor alignment; (c) thickness of support materials; (d) geometrical efficiency for muon acceptance; (e) formulation of plans for installing, servicing, and operating muon system over life of experiment; and (f) bottoms up cost determination of muon system.

The requested budget for the muon system engineering and R&D for FY92 is $2.7M. It will be divided as follows among the 7 Subgroups:

SUBGROUP	FY92 BUDGET
CSC	$500k
LSDT	$480k
PDT	$400k
RPC	$300k
ENG	$700k
TTR	$240k
SCARF	$80k
TOTAL	$2,700k

Details of the Subgroup R&D/Engineering plans are in the following sections. They are each broken down into a participant list, an overall plan, a descussion of electronics R&D (beyond the amplifier and shaper level), and a discussion of the plan for integration into the TTR in Spring 1992. The Subgroup budgets are collected in the final section.

(3) CSC Subgroup

Participants: 28 people from 4 institutions.

INSTITUTION	PARTICIPANTS
Brookhaven National Lab. (BNL)	Polychronakos, Radeka, Stephani, Yu, Smith, Rogers, O'Connor, Harder, Rescia, Paffrath
Boston Univ. (BU)	Whitaker, Shank, Johnson, Osborne, Warner, Wilson, Hazen, Orlov, Earle
Oak Ridge National Lab. (ORNL)	Todd, Bauer, Britton, Wintenberg
Leningrad Nuclear Physics Institute (LNPI)	Vorobyov, Prokovief, Terentief, Smirnoff, Gratshef

R&D/ENGINEERING PLAN

For FY92 the CSC R&D plan will emphasize the construction and testing of a full scale prototype similar to a complete, 4-layer module of the final endcap detector. Several other activities will be pursued in parallel. These will address specific questions relating to the CSC technology through Monte Carlo studies and the construction and evaluation of small chambers.

The primary goals of the study of the full scale prototype are:

i) Evaluation of construction techniques;

ii) Determination of resolution performance parameters;

iii) Demonstration of feasibility of monolithic multiplexed readout;

iv) Demonstration of trigger capabilities;

v) Determination of precision of bunch crossing assignment using anode wires;

vi) Evaluation of degradation of resolution as a function of angle of incidence.

The module will consist of four independent chambers of size 2 m x 1.28 m, which corresponds roughly to the largest module for the final design. Each chamber will have 256 readout strips, with a pitch of 5 mm, for a total of 1024 channels. Each channel will be equipped with a hybrid preamplifier matched to the strip capacitance. The signals will be shaped and multiplexed in the AMPLEX monolithic chips. All 1024 channels will be read out by a single custom built CAMAC module. To study the various level 1 trigger algorithms under consideration, 32 channels from each of the 4 planes will be equipped with a second, faster shaper (40 ns FWHM), followed by a discriminator. This corresponds to an area of 2 m x 0.16 m which will be instrumented for trigger studies. The 800 anode wires per plane (with a wire spacing of 2.5 mm) will be grouped into 40 channels per plane providing 5 cm wide elements for the determination of the orthogonal coordinate and assignment of the bunch crossing. These channels will be equipped with hybrid amplifiers and shapers followed by discriminators and 4-wide OR circuits. The 40 OR outputs will be read out with commercial TDC units. Note that these earliest-time-of-arrival measurements using the TDC's are done only to study the bunch crossing assignment ability of the device. TDC's would not be used in the final detector.

The full scale prototype will be built at BNL with participation of all groups. The mechanical design will be done jointly by engineering teams from BU and BNL. Construction of parts for the prototype will be done at BU. The design will be completed by January 1992. The strip readout electronics (including a calibration system) will be built at BNL. Anode readout will be the responsibility of ORNL. The electronics for the 128 channels for the trigger implementation will be done by BU and BNL.

Parallel activities will include:

i) Measurements on various gases to find the optimal mixture with regard to drift velocity and Lorentz angle (BU, LNPI).

ii) Detailed simulations of detector performance (BU, LNPI, BNL).

iii) Construction of several small chambers to study cathode optimization and performance in a magnetic field (BU, LNPI).

ELECTRONICS R&D

Some effort will be devoted to fine tune the parameters of the AMPLEX chip as well as the determination of additional functionality necessary for the chip to provide the level 1 trigger signals. Work will also be required to define an additional digital monolithic circuit for control of the AMPLEX chip (supply of local HOLD, RESET, etc.). Nearly half of BNL's electronic engineering budget, as well as some of the ORNL electronic engineering budget, will be devoted to this activity.

TTR PLAN

The CSC prototype is nearly self sufficient with only one CAMAC slot needed to read out all 1024 cathode strip channels. The additional equipment required (40 TDC channels, 128 latching discriminators, 40 OR circuits) will be borrowed from the BNL High Energy Electronics Pool. Jim Shank (BU) will be the CSC liason person with the TTR for data acquisition. He will be assisted in hardware questions by Vinnie Polychronakos. Thorough testing of the prototype will be done at the place of construction. When moved to the TTR in Spring 1992, Shank, Polychronakos, and other members of the CSC Subgroup will spend whatever time is required at the SSC for completion of the tests.

(4) LSDT Subgroup

Participants: 23 people from 7 institutions.

INSTITUTION	PARTICIPANTS
MIT	Osborne, Kendall, Rosenson, Ross, Taylor, Verdier, Wadsworth
Lawrence Livermore National Lab. (LLNL)	Fackler, Capell, Weanus
LeCroy Corporation (LRS)	Sumner, Hoftiezer
Lousiana State University (LSU)	McNeil, Metcalf
State University of New York at Stony Brook (SUNYSB)	Mohammadi
Vanderbilt University (VU)	Venuti, Panvini
Joint Institute for Nuclear Research, Dubna (JINR)	Korytov, Bonyushkin, Khovansky, Malyshev, Sedykh, Tokmenin

R&D/ENGINEERING PLAN

The LSDT chambers are rectangular boxes containing 4 layers of wires, with each wire located in a covered U-profile cathode 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 the 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. 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 on or distort the wire support. At present, we have chosen Mycalex for the bridge material, as it is stable and machinable.

The alignability of the LSDT's is based on the bridge design, which capitalizes on the fact that 12.5 μm machining precision over spans of 1 m are readily achievable with the use of computer controlled machine tools. The cost effectiveness of the LSDT design follows from the development of inexpensive manufacturing methods of similar chambers by the SLD, Aleph, and SCARF groups. The LSDT design has the flexibility of being made to any length desired, with wire supports at any points of choice to control wire sag. The wires can be laid down multiply (as with Iarocci tubes), inspected, and tested for positioning and tension before being covered. Chamber parts can be manufactured in most modern machine shops.

The wires will be operated in limited streamer mode. We have found that the large, fast pulses achieved in this manner provide excellent drift time measurements.[1] Our tests utilized laser beams, cosmic rays, and the 500 GeV test beam at Fermilab. The use of aluminum cathodes makes the tubes themselves good transmission lines that preserve pulse rise time and enable coarse spatial measurements along the wire length by using instrumentation at both ends of the wires. Because the wires lie in cathodes open at the top it is also possible to determine position orthogonal to the drift time direction with instrumented strips placed over the open side. Strip signals correlated with wire signals enable x-y determinations for each track in a single chamber.

The electronics system for the drift time and z measurements is being developed by LRS.[2] They base their design on the LRS MVL407 discriminator chip and the LRS MTD132 TDC chip, the latter achieving sub-ns time resolution. These will be used for prototype measurements. However, it is expected that even faster electronics will be available for the final system.

Below we list the tasks we expect to complete in FY92, adding in parenthesis the institution(s) bearing the corresponding responsibility.

i) Finish assembly and test of 2, 0.5 m wide chambers (MIT);

ii) Measure tube performance in magnetic fields (MIT);

iii) Design and build (D & B) 2, 1 meter wide chambers (MIT & LLNL);

iv) D & B pick-up strip plane (MIT);

v) Investigate and make thinner cathodes (MIT & SUNYSB);

vi) D & B optical window system (MIT);

vii) D & B tiltable chamber stand as a cosmic ray muon telescope (MIT);

vii) Adjoin prototype optical alignment system to the chambers (MIT, Draper Lab.);

viii) Bottoms up cost analysis of the total system (LLNL);

ix) Investigate various materials for use as cathodes (VU);

x) Analyse the data from runs taken at Fermilab on a small prototype, and runs with cosmic rays on the 0.5 m and 1.0 m chambers (MIT, SUNYSB, & LSU);

xi) Simulation studies of the muon system directed toward optimization of the subsystem and integration with the rest of the detector (MIT);

xii) Provide chamber electronics, investigate state of the art electronics for TDC's, and examine scenarios for the use of chambers in a level 1 trigger system (LRS, MIT).

The schedule for completion of the above tasks has the aim of proving the feasibility, quality, and costs of the LSDT system so that it may be compared with other technologies in time for the TP at the end of the year. Milestones are listed below:

MILESTONE	DATE
Delivery of LeCroy electronics for 0.5 m. chmber:	January 1992
Design of thin cathodes:	January 1992
Assembly of 0.5 m chambers:	February 1992
Assembly of 1.0 m chambers:	March 1992
Delivery of 1.0 m. chamber to SSC Lab.:	May 1992
Set final specs. on chambers:	August 1992
Assemble cost figures for EDR:	September 1992

ELECTRONICS R&D

The R&D in electronics breaks up into several categories:

i) Discriminator and shaping on each wire; this is devloped and built by MIT;

ii) TDC units for chamber prototypes-to be available in January 1992 (LRS);

iii) Trigger electronics which will take signals from the TDC units; this might be considered as a first prototype of a more sophisticated version in the final system; this will also be available in January 1992 (LRS);

iv) Begining R&D into faster versions of the TDC's (LRS);

v) Cost estimates for the electronics of the muon system, including cabling and HV system (LRS).

The units for item ii) are essentially the LeCroy 2277 CAMAC modules which use the MTD132 chip, a pipelined TDC with a capacity of 16 hits per channel and a least count of 0.75 nsec. The trigger unit, item iii), will be a custom built CAMAC unit with 32 inputs from 2, 2277 units. The 32 inputs are combined in a pre-defined logic matrix to produce 16 trigger signals. These 16 signals are then used to address a 65,536 bit memory, which contains the trigger decision. The above will be provided for both the 0.5 m chambers and the 1.0 m chambers.

Eventually, a new chip will be designed for any drift time muon system and optimized for that system. Expected improvements in IC processing in the SSC time frame will certainly allow cost, performance, and power dissipation to be enhanced compared to the current circuit. In any event, design concepts can be used to do cost estimates for the final system (item iv). A costing for the total system, similar to the one for EMPACT/TEXAS[2] will be done (item v).

TTR PLAN

We expect to be able to deliver a 1 m x 4 m chamber to the TTR at the SSC Lab in May 1992; the chamber would have been previously tested as a particle detector. The chamber would have 4 layers of wires (the layers being staggered); each layer has 40 wires. However, we would fully instrument only a subset of wires - 8 wires on each layer at a given time. We would include the

necessary CAMAC modules and crate for read-out. Someone, probably Dr. A. Korytov, would accompany the apparatus to put it into operating condition. His stay would be limited to setup time due to restrictions in travel funding and the local demands on his time. We would also bring down the necessary programs for reading data out.

We will retain the second 1 m chamber at MIT to continue tests with variants on mechanical structure, chamber gasses, wire materials, cathode materials, etc.

(5) PDT Subgroup

Participants: 53 people from 7 institutions.

INSTITUTION	PARTICIPANTS
Boston Univ. (BU)	Ahlen, Marin, Zhou, Hazen, Earle, Varner
Michigan State Univ. (MSU)	Bromberg, Miller, Joy, Richards, Yosuf
Los Alamos National Lab. (LANL)	Sanders, Hanlon
SSC Lab. (SSCL)	Smith, Mitselmakher, Stocker, Villasenor, Yost, Vanyashin, Zimmer-Nixdorf, Prosapio
Joint Institute for Nuclear Research, Dubna (JINR)	Alexeev, Bonyushkin, Fialovszky, Gornushkin, Malyshev, Tokmenin, Vertogradov
Institute of High Energy Physics, Beijing (IHEP)	Xu + 10 others
Institute of Atomic Physics, Bucharest (IAP)	Pascovici, Aculai, Blaj, Bozdoc, Butacu, Ciobanu, Dorobantu, Ighicianu, Popa, Radulescu, Spanu, Stan-Sion, Valeanu, Zimmer

R&D/ENGINEERING PLAN

Round, metal tubes of the sort being considered for the PDT option have been used successfully at colliders in large solenoidal magnetic fields as precision tracking devices: (a) 3 m long stainless steel tubes (2.54 cm diameter, 200 μm wall thickness) are being used in the 1.5 T field at CDF;[3] and (b) 3.7 m long stainless tubes (2.54 cm diameter, 150 μm thickness) were used in the 1.6 T field at HRS.[4] The HRS tubes achieved a diffusion limited spatial resolution of 160 microns using a safe gas ((90% Ar, 9% CO_2, and 1% CH_4). The CDF tubes were operated in limited streamer mode to optimize charge division performance, achieving 200 μm resolution transverse to the wire, and 2.5 mm resolution along the wire.

The symmetry of round, cylindrical tubes operated with axes parallel to magnetic fields enables reliable and precise tracking due to the simple electric field configuration and the independence of the time to space function on angle of incidence. In addition to the CDF and HRS tubes, there have been numerous other examples of the use of round tubes at colliders (mostly as vertex detectors), in magnetic fields as high as 3 T (AMY),[5] with resolutions as good as 45 μm (the MAC drift tubes, with aluminum cathodes, which were operated with a 49.5:49.5:1 Ar-CO_2-CH_4 gas at 60 psia[6]). Furthermore, the cylindrical geometry of tubes enables improvement of resolution through pressurization. The AMY straw drift tubes (25 μm wall thickness), were in fact pressurized iindividually at 21 psia.[5] And tests done on a spare octant of HRS drift tubes at 30 psia[7] have shown that resolution does improve as expected with increasing pressure, implying that a resolution of 100 μm can be achieved with the safe HRS gas at 30 psia.

The current preferances for the tube type for the GEM PDT option are aluminum tubes with 300 micron wall thickness, and about 3 cm diameter. The inner and middle modules would each consist of 8 layers of staggered tubes, and the outer modules would have 4 staggered layers. The number of radiation lengths in the central modules would be X = 8.5%. To keep X small, we favor aluminum over stainless steel material. The main advantage of the latter is reduced reactivity and fewer problems with spurious electrical discharges. However, the PDT's would be operated in saturated proportional, and not limited streamer mode, so that this is probably not a major concern.

The PDT alignment philosophy is based on accurate placement of wire ends relative to end plate fiducials. This 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 muon group members which have demonstrated that wire position can be predicted correctly within a few μm (for 4 m long wire tensioned at 80% of the yield strength, sag will be about 230 μm, with an electrostatic component in a 3 cm diameter tube of about 5 μm).

The primary goal of the FY92 R&D program for the PDT Subgroup is the demonstration of the suitability of the PDT design for GEM. In particular it must be shown that a cost effective design and assembly procedure can be developed; these must be appropriate for the reliable construction, assembly, testing, and operation of approximately 100,000 drift tubes having gas tight seals for operation at 15 psig, and having wires held stably so that positions can be predicted correctly to within several μm. A two prong program is planned to acvhieve this goal:

(i) TTR PROTOTYPE

A large scale prototype drift tube module will be designed and constructed to be installed into the TTR for the Spring 1992 tests. This will be approximately 4 m long, 1 m wide, with 4 layers of close packed tubes, each layer having 40 tubes. The mechanical design will emphasize quality with regard to (a) reliable, gas tight seals (utilizing o-rings and gaskets, with minimal or no reliance on glue seals); (b) precise placement of wires (to within 20 μm) relative to a precision fiducial end plate; (c) straightness of tubes (to 1/2 mm); (d) derivation of module rigidity through bonding of the tubes (as a kind of honeycomb structure); and (e) reliable assembly procedure which does not require a great deal of technical skill.

To conserve costs only 24 tubes per layer will be outfitted with commercially available electronics. Each tube end will be connected (through a custom built connector) to a coaxial cable which will deliver high voltage to the tube, and will carry the signal from the tube to a high voltage divider/signal router box, from which the signal will be directed to a fast commercial current amplifier (gain of about 200), then to a commercial discriminator (10 mV minimum threshold), and then to a commercial CAMAC based TDC (1 μs full scale, 0.25 ns least count). This electronic configuration has been tested under adverse conditions of a balloon borne experiment,[8] and has been found to have excellent noise suppression characteristics, primarily because the signal is propagated along coaxial cables continuously from the source to the amplifier input.

MSU, LANL, and the SSCL will be responsible for the mechanical design and construction of the prototype, which will be located at the TTR facility at the SSC Lab. BU will be responsible for the electronics for the prototype. This includes selection and procurement of the commercial equipment, design and construction of the HiV dividing boxes, construction of the cables required, and software for the data acquisition. BU will also be responsible for the pressurized gas system, which will be computer controlled and will employ precise pressure monitors, temperature monitors, and input and output electronic flow meters/controllers.

LANL will provide silicon strip detectors to be used to determine alignment capabilities of the prototype. LANL and SSCL will provide alignment equipment to enable comparison of absolute track coordinates determined by both the silicon and PDT arrays. The number of tracking layers (4) in the PDT prototype is sufficient to determine internally the single wire resolution independent of alignment errors.

(ii) SPARE HRS OCTANT

A spare octant of the HRS outer drift ube system has been loaned to the BU group by the Indiana University group (led by Harold Ogren) which built these detectors. This octant will be moved to Boston where a number of tests will be carried out:

(a) Wire tension will be measured 14 years after construction; a comparison with the known initial tension will provide valuable information on long term tension stability with this type of tube design (for HRS the wires were crimped and soldered).

(b) Resolution measurements will be made with various gases and pressures to help select a gas suitable for the TTR test. Detailed measurements of gas drift properties in magnetic fields will be made on selected gases at various pressures and fields at the MIT cyclotron magnet with the BU gas test chamber setup. Such measurements will determine the time-space function required for track reconstruction.

(c) The electronics and acquisition system for the TTR tests will be developed and debugged in Boston on the HRS octant prior to being shipped to the SSCL

ELECTRONICS R&D

There will be no electronics R&D for the PDT's in FY92. The electronics requirements are satisfied by existing commercially available systems. While it is likely that some cost savings could be anticipated with refined systems, it is felt that such work has low priority for 1992. No hardware work is planned on the development of a PDT level 2 trigger.

TTR PLAN

The PDT prototype will be constructed at the SSCL in early Spring 1992, based on the MSU/LANL/SSCL design. The electronics procured and built at BU will be moved to the SSCL in May 1992, and testing of the module will occur during June 1992. Alex Marin and Gary Varner will spend the time required in Dallas to get the acquisition system and electronics for the PDT prototype up and running. All PDT institutions will participate in the data analysis.

(6) RPC Subgroup

Participants: 15 people from 5 institutions.

INSTITUTION	PARTICIPANTS
MIT	Pless, Chang, Hafen, Haridas
Lawrence Limore National Lab. (LLNL)	Wuest, Ables, van Bibber, Bionta, Fackler, Makowiecki
Brown Univ. (BrU)	Widgoff
Indiana Univ. (IU)	Alyea
Univ. of Tennessee (UT)	Bugg, Berridge, Du

R&D/ENGINEERING PLAN

RPC's, developed in Rome ten years ago, are essentially narrow gap spark counters. They operate at a uniform electric field of about 40 kV/cm between parallel electrodes of resistive material. Typically, 2mm thick plates are separated by 2 mm gaps with the use of spacers. The sensitive volume is filled with a gas mixture of 60% argon, 38% isobutane, and 2 % freon. Spatial readout is made via pick up strips insulated from the field electrodes by a polyethylene film. The voltage induced on these pickup strips is about 0.5 V into 50 Ω, with a measured time resolution of about 1 ns. RPCs have been used in many experiments with the largest having dimensions 0.5 m x 6.0 m. It is planned that the GEM RPCs will have dimensions of up to 3.3 m x 4.0 m.

RPC's have been tested and found to work at rates up to 40 Hz/cm^2, well above those expected in the barrel region of GEM, even at a luminosity of 10^{34} cm^{-2}s^{-1}. They have also been found to work well in close proximity to drift chambers, for which a 25 μm aluminum cover around the RPC's is used as an RF shield.

The RPC R&D program for FY92 will consist of two major areas:

i) Measure the properties of a 1 m x 2 m RPC furnished to MIT by R. Santonico of the Rome 2 University. These properties include:

a) Pulse rise time jitter;
b) Maximum counting rate per unit area;

c) Efficiency;
d) Lifetime.

ii) Measure the properties of a large size RPC produced by the RPC Subgroup.

An RPC test bed will be designed, fabricated, and installed at MIT, under the direction of the MIT group. MIT will also be responsible for the design and implementation of the RPC electronics. Equipment for the test bed will be provided and commissioned by other groups:

i) BrU will provide two scintillation hodoscopes; each hodoscope has two planes, one for x and one for y; each plane consists of 12 scintillators, each being 11 cm wide x 1.27 cm thick x 120 cm long; these will be used to provide timing information which will be used to determine RPC time resolution;

ii) IU will provide a multi-component gas system for the test bed; special emphasis will be placed on non-flammable mixtures for the tests (e.g. 86% CO_2, 10% isobutane, 2% Ar, and 2% freon);

iii) UT will provide 9 drift chambers, each having an area 1 m x 1 m; these will provide tracking information as an aid in understanding RPC performance.

MIT will be responsible for the installation of all RPC's, whether from Italy, or built by LLNL, into the test bed, and for the operation, data acquisition, and maintenance of this facility.

The GEM muon system will require thousands of square meters of reliable RPC's. Activities at LLNL will be focussed on optimizing chamber design and chamber materials with this fact in mind. Thus the emphasis at LLNL will be on the fabrication of large scale prototype RPC's using new materials and manufacturing methods. The FY92 R&D program at LLNL will include the following tasks:

i) Determination of the best plate material (plastic or glass), and coating technique for the large scale prototype RPC and characterization of the resistivity and surface uniformity of the materials. This will be performed by a physicist and the Chemistry and Materials Science (CMS) coatings group, requiring 0.125 FTE of a CMS engineer, and 0.25 FTE of a CMS technician.

ii) Construction of a large scale prototype RPC with dimensions to be determined by funding constraints, but probably 1 m wide and 1 to 4 m long. Construction techniques consistent with large scale production will be tested in the fabrication of this prototype. This effort will require 0.125 FTE of a CMS engineer, 0.25 FTE of a mechanical engineer, o.25 FTE of an electronics engineer and 1 full time physicist.

iii) Characterization of the large scale prototype RPC for noise, operating efficiency (plateau), time resolution and spatial resolution. This includes characterizing the size and temporal duration of the localized dead region after an electron avalanche is generated. Spatial resolution along the long pickup strips can also be studied, with particular attention being paid to uniformity and linearity of the position measurement near the edges of the chamber. Also, chamber lifetime and aging effects will be studied. Tracks will be generated using tagged cosmic rays, radioactive sources, and electrons from the LLNL 140 MeV Linac. This work will be carried out by a 0.25 FTE electronics engineer and 1/4 of a physicist.

ELECTRONICS R&D

None will be done in FY92.

TTR PLAN

An RPC prototype will be moved to the TTR in Spring 1992. It will be necessary to demonstrate that operation of the drift tube prototypes are not degraded by RF interference from the RPC.

(7) ENG Subgroup

Participants: 10 people from 3 institutions.

INSTITUTION	PARTICIPANTS
Draper Lab.	Nimblett, Hamilton + 3 others
Los Alamos National Lab. (LANL)	Sanders, Hanlon + 1 other
SSC Lab. (SSCL)	Smith + 1 other

R&D/ENGINEERING PLAN

The plan described here characterizes the staffing required to implement those engineering tasks necessary to proceed from the current, rather primitive, state of the design of the GEM muon system to the TP in November 1992. This effort requires covering all aspects of the muon system to some level through both a conceptual design phase and the preliminary design phase which will provide the basis for the design, costing and scheduling of the muon system for the TP. The scope of this effort is fixed by the nature of the TP and by the SSC schedule, but the level of detail and the accuracy to which these tasks will be accomplished will be limited by the funds available in FY92.

FY92 activities will consist two basic tasks:

(i) TASK 1 - complete conceptual design of entire muon system for 2 barrel technologies, exclusive of the chamber designs themselves.

This effort will include:

a) Conceptual layouts of proposed chambers (not detailed drawing);

b) Electronic racks and mounting concepts;

c) Cable routing and support concepts;

d) Conceptual design of interfaces to structures, interfaces to magnet support points or other attachment options;

e) Structural support concepts for chambers along with structural analysis and assembly procedures and schedules;

f) Muon system alignment concepts (local and global);

g) Consideration of allotment of space and attachments for muon system (and other systems) service requirements;

h) Consideration of safety air venting, temperature control and air routing through the muon system;

i) Conceptual design for chamber gas systems, including plumbing and surface facility requirements;

j) Initial cost book entries for all of the above.

The costing and overall design concepts will serve as elements in the decision to select one of the two barrel region options by early July 1992. Routine engineering program management and associated travel expenses are also included in this task description and will require a portion of the allotted funding.

To maintain a critical mass on this task will require that the majority of the conceptual design work be done at Draper. However, the global alignment of both the muon system and the overall detector will necessitate interactions among Draper (F. Nimblett), the SSCL (D. Veal), LANL (J. Hanlon) and LLNL (G. Deis). The alignment concept is an area of critical concern which can affect the entire detector architecture and must be addressed very soon in the conceptual design activity.

Expenditures for this task, other than salaries and travel, include computer usage costs, and materials and supplies costs to purchase PC software to improve compatibility within the engineering team and the SSCL and also to provide additional PC based analytical tools to improve group productivity.

(ii) TASK 2 - Preparation for the GEM muon system portion of the Technical Proposal.

Following the selection of the barrel chamber options for the GEM muon system in early July, this task will combine TASK 1 with the chosen chamber options for the barrel and endcaps from the detector subgroup R&D activities to formulate a preliminary design for the GEM muon system.

This effort will provide the design, costing and scheduling basis for the TP.

As with the conceptual design task, the overall scope of this task must include all aspects of the muon system design to some level. It is anticipated that the conceptual design activities will provide the basis for prioritizing the various design elements of the preliminary design in a manner that will permit us to place the limited engineering resources onto the most critical items, whether this criticality be due to technical, cost or schedule risk factors. An additional component of this effort is the need to spend engineering funds on the selected chamber technologies to develop the chamber design detail sufficiently to provide accurate cost estimates based on vendor quotes and to properly integrate the chambers and their alignment structures into the respective support structures. As with the conceptual design, routine engineering program management and associated travel expenses are also included in this task description.

As with TASK 1, most of the efforts of this task will be concentrated at Draper to maintain critical mass. Exceptions to this will involve the alignment task (as described for TASK 1) and those tasks associated with detailed chamber design, which will draw support from LANL, LLNL, BNL, and Draper.

(8) TTR Subgroup

Participants: 8 people from 1 institution.

INSTITUTION	PARTICIPANTS
SSC Lab. (SSCL)	Mitselmakher, Stocker, Villasenor, Yost, Vanyashin, Zimmer-Nixdorf, Prosapio, Smith

R&D/ENGINEERING PLAN

The GEM Collaboration has decided to construct a test facility at the SSCL to evaluate different muon-chamber prototypes during June and July 1992. This evaluation will serve to select the detector technologies that are best suited for the GEM muon system. For this purpose, we will construct the Texas Test Rig (TTR) that will accomodate large scale muon chamber prototypes that will be tested under identical conditions using cosmic muons. The muon technologies to be tested include the PDT's, LSDT's, CSC's and RPC's.

The TTR will consists of an iron toroid magnet, two planes of scintillation counters (one above and the other below the TTR), two layers of Iarocci tubes above and two layers below the magnet, and five compartments to place the muon chambers under test. The dimensions of the largest of the muon-chamber prototypes will be 4 m x 1 m x 0.2 m. Each of the TTR compartments will be about 5 m long, 2.1 m wide and 0.25 m high, so that it can accomodate larger prototypes in the future.

The 1 m thick iron of the magnet will harden the cosmic ray spectrum to muon momenta greater than 1.4 GeV. The muon spectrum can be further hardened (muon momenta greater than 5 to 10 GeV) by imposing offline cuts on the deflection of the muon track before and after it traverses the 1.4 T magnet; this will be done in order to to keep the systematic error introduced by multiple scattering small compared to the expected resolution of the chamber prototypes. We will determine the muon direction above and below the magnetized iron by means of four planes of Iarocci chambers. We are studying two aproaches towards the construction of the magnet: the first is to use the iron from the recently decommissioned D0 Cosmic Ray Telescope from Fermilab; the second is to make our own magnet in a way that is more optimized for our application. We will select one of these options based on several criteria such as cost, performance, viability and schedule. The decision as to which type of magnet we will build will be taken by the end of November 1991. The SSCL group will be responsible for the construction of the magnet. The magnet will be ready by April 1992.

The scintillation counters will provide both the trigger and the the start signal for the TDC's. We expect to have the scintillation counters manufactured for us at Fermilab or LANL. The scintillation counters will be 2.7 m long, 20 cm wide and 2.5 cm thick. We will have two layers of area 5 m x 1.2 m each, which will require 24 counters and 48 phototubes. The scintillation counters will be ready by April 1992.

The coincidence of the signals from the scintillation counters and the four Iarocci chambers will be the trigger for the data acquisition system (DAQ). The SSCL group will provide the trigger electronics, DAQ computer, mass storage, interface cards computer to CAMAC, and crate controllers. The proponents of the technologies will provide the CAMAC crates, the TDC and/or ADC modules, power supplies and the interconnecting cables that are required. The proponents will be responsible for making their prototypes operational at SSCL. The SSCL group will develop the basic data acquisition software in coordination with the DAQ liason person of each of the proponent institutions.

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.

The Iarocci chambers will provide both the trigger and a measurement of the incoming and outgoing directions of the muons. Each of the four planes of Iarocci chambers will provide x-y position measurement with a cell size of 1 cm for each coordinate. The Institute for Beam Particle Dynamics at the University of Houston will provide the Iarocci chambers with strip boards, front end electronics, CAMAC read out system, gas system, high voltage supply, gas, and monitor/alarm system. The Iarocci tubes will be ready by April 1992.

The prototypes use different gases (mixtures consisting of up to 4 gases). The proponents of each technology will provide their own gas mixers. We will ensure they are being built according to the applicable SSCL safety regulations. The SSCL will provide a complete gas system as a backup system for any of the technologies. The SSCL will also provide exhaust and alarm systems as well as the racks for the gas bottles.

The GEM Muon Group plans to take data for approximately one month in June 1992 to allow enough time for analysis and comparision of the performance of the different prototypes before the due date for the TP. All components being provided by SSCL will be ready by April 1992 to allow installation of the individual technologies by their proponents in May 1992. We will start taking data on June 1, 1992.

(9) SCARF Subgroup

Participants: 7 people from 1 institution.

INSTITUTION	PARTICIPANTS
Univ. of Houston (UH)	R. Weinstein, K. Lau, B. Mayes, J. Pyrlik and 3 others

R&D/ENGINEERING PLAN

The Streamer Chamber Assembly and Research Facility (SCARF) of the Univ. of Houston has developed state of the art facilities for assembling, with outstanding reliability, large quantities of large area limited streamer tubes. The expertise and experience of the SCARF Subgroup is an exceedingly valuable asset to the GEM muon system. An example of the value of this group was indicated in the preceeding section in the description of the tracking chambers to be provided for the TTR. Additional tasks to be taken on by the SCARF Subgroup in support of the GEM muon system during FY92 are indicated in this section.

i) Optimization of cathode surface material is a critical aspect of the development of the CSC concept. The SCARF Subgroup will work on this problem by measuring plateau lengths of U-profile chambers made of extruded Al, extruded Al coated with C, and extruded Al coated with Ni in both streamer and proportional modes. Extruded Al U-channels with 8 or more channels will be obtained from local suppliers. C coating will be done at SCARF. Ni coating will be done by local industry. Plateaus with 100 micron (for streamer mode) and 50 micron (for proportional mode) silver-plated Be-Cu wires and Ar-Isobutane (1:3) gas mixture will be measured. The knees and breakaways will be determined. Afterpusling will be studied. It is expected that most of this task will be completed by June 1992.

ii) As a corollary of the activity listed above, the SCARF Subgroup will provide cost etimates for Ni coated Al, in both U-profiles (LSDT) and tubes (PDT). This information can be made available by April 1992.

iii) An important issue for the CSC task is whether there is any benefit of housing the anode wires in open profile tubes, as opposed to the baseline design of having the wires housed in open chambers. Various opinions on this subject have been espoused throughout the evolution of the GEM muon system design phase. The SCARF Subgroup will work on this problem by constructing a small prototype chamber (1 m x 0.5 m) with strip readouts. The wires for the chamber will be placed in U-profiles with 1 cm cell size. The strips will have 5 mm pitch. The SCARF Subgroup will investigate strip signal size, multiplicity, and cross talk in both the proportional and streamer modes. It is expected that construction will be completed in June 1992 and that the tests will be completed by September 1992.

iv) The properties of a large gas volume of the barrel drift system will be studied. Air leaks and their effects on the system will be studied. This will be done by August 1992.

If time permits, the SCARF Subgroup will explore the possible use of nitrogen-based gas mixtures (e.g. nitrogen-CF_4) as candidates for inexpensive and nonflammable gases.

(10) References

(1) Toroidal Spectrometer Group Progress Report, SSC Progress Report No.218 (Sept.15, 1991).

(2) EMPACT/TEXAS Tech. Note \# 338, from LeCroy Corp. Nov.26, 1990 (Revised Feb.26, 1991).

(3) S. Bhadra et al., Nucl. Instr. Meth. **A268**, 92 (1988); also see Nucl. Instr. Meth. **A269**, 33 (1988).

(4) G. Baranko, Ph.D. Thesis, Indiana University (1983).

(5) H. Kagan, private communication (1990).

(6) W.W. Ash et al., Nucl. Instr. Meth. **A261**, 399 (1987).

(7) S. Ahlen, unpublished HRS report (1983).

(8) S. Ahlen et al. Phys. Rev. Lett. **61**, 145 (1988).

(11) Budget

The budgets for the different muon system Subgroups for FY92 are given on the following pages. Indirect costs have been added as appropriate in each line. The following notation has been used:

ME = Mechanical Engineer;
D = Designer/Draftsman;
MT = Mechanical Technician;
EE = Electronics Engineer;
ET = Electronics Technician;
CMSE = Chemical, Materials Science Engineer;
CMST = Chemical, Materials Science Technician.

	A	B	C	D	E
1	CSC SUBGROUP			LSDT SUBGROUP	
2					
3	BNL Prototype Equipment:	$87,000		LSDT Prototype Equipment (MIT):	$75,000
4	BU Prototype Equipment:	$44,000		Prototype Equipment (VU):	$5,000
5	ORNL Prototype Equipment:	$14,000		Alignment Expenses (MIT):	$55,000
6	BNL ME:	$20,000		6 mo. of LLNL ME:	$70,000
7	BNL MT:	$50,000		8 mo. of MIT ME:	$55,000
8	BU ME:	$30,000		12 mo. of MIT MT:	$45,000
9	BU MT:	$30,420		2 mo. of MIT D:	$10,000
10	BNL EE:	$50,000		LRS EE/Equipment:	$20,000
11	BNL ET:	$50,000		4 mo. of MIT EE:	$30,000
12	BU EE:	$20,000		12 mo. of MIT ET:	$80,000
13	BU ET:	$20,000		15 mo. of MIT Students:	$25,000
14	ORNL EE:	$30,000		LSU Student:	$5,000
15	ORNL ET:	$23,000		SUNYSB Student:	$5,000
16	BNL Supplies/Services:	$15,000			
17	BU Supplies/Services:	$10,500		TOTAL:	$480,000
18	ORNL Supplies/Services:	$6,080			
19				PDT SUBGROUP	
20	TOTAL:	$500,000			
21				PDT Prototype Equipment (BU):	$162,000
22				6 mo. of LANL ME:	$60,000
23				4 mo. of LANL D:	$32,000
24				4 mo. of LANL D:	$32,000
25				6 mo. of Joy (MSU MT):	$30,000
26				6 mo. of Richards (MSU ME):	$36,000
27				1 mo. of Hazen (BU EE):	$6,000
28				7 mo. of Varner (BU ET/EE):	$42,000
29					
30				TOTAL:	$400,000
31					

	A	B	C	D	E
32	RPC SUBGROUP			ENG SUBGROUP	
33					
34	MIT Prototype Equipment:	$37,000		Conceptual Design	
35	LLNL Prototype Equipment:	$18,000		6 mo of Draper ME:	$90,000
36	BrU Prototype Equipment:	$31,000		5 mo. of Draper ME:	$75,000
37	IU Prototype Equipment:	$12,000		5 mo. of LANL ME:	$50,000
38	UT Prototype Equipment:	$20,000		7 mo. of Draper D:	$61,600
39	12 mo. MIT MT:	$100,000			
40	2.5 mo.LLNL MT:	$18,900		TP Preparation	
41	2.5 mo. LLNL EE:	$29,500		5 mo. of Draper ME:	$75,000
42	1.3 mo. LLNL CMSE:	$14,700		4 mo. of Draper ME:	$60,000
43	2.5 mo. LLNL CMST:	$18,900		4 mo. of Draper ME:	$60,000
44				4 mo. of LANL ME:	$40,000
45	TOTAL:	$300,000		4 mo. of LANL ME:	$40,000
46				4 mo. of Draper D:	$35,200
47	TTR SUBGROUP:			5 mo. of Draper D:	$44,000
48					
49	TTR Magnet:	$80,000		Materials/Supplies/Other:	$40,000
50	TTR DAQ:	$65,000		Travel:	$29,200
51	TTR Iarocci Tubes:	$50,000			
52	MT:	$30,000		TOTAL:	$700,000
53	Supplies:	$15,000			
54				SCARF SUBGROUP	
55	TOTAL:	$240,000			
56				Prototype Equipment:	$17,000
57				MT:	$26,900
58				ET:	$26,900
59				Supplies/Services:	$9,200
60					
61				TOTAL:	$80,000
62	GRAND TOTAL:	$2,700,000			

GEM Muon System Status (Engineering)

06 December 1991

Frank Nimblett
Draper Laboratory

Engineering Overview

- R&D and Engineering SOW and Budget completed.

  ($700K Engineering budget still considered inadequate to properly complete Conceptual Design and get far enough into the Preliminary Design of Muon Subsystem to produce a competent Technical Proposal for the Muon Subsystem)

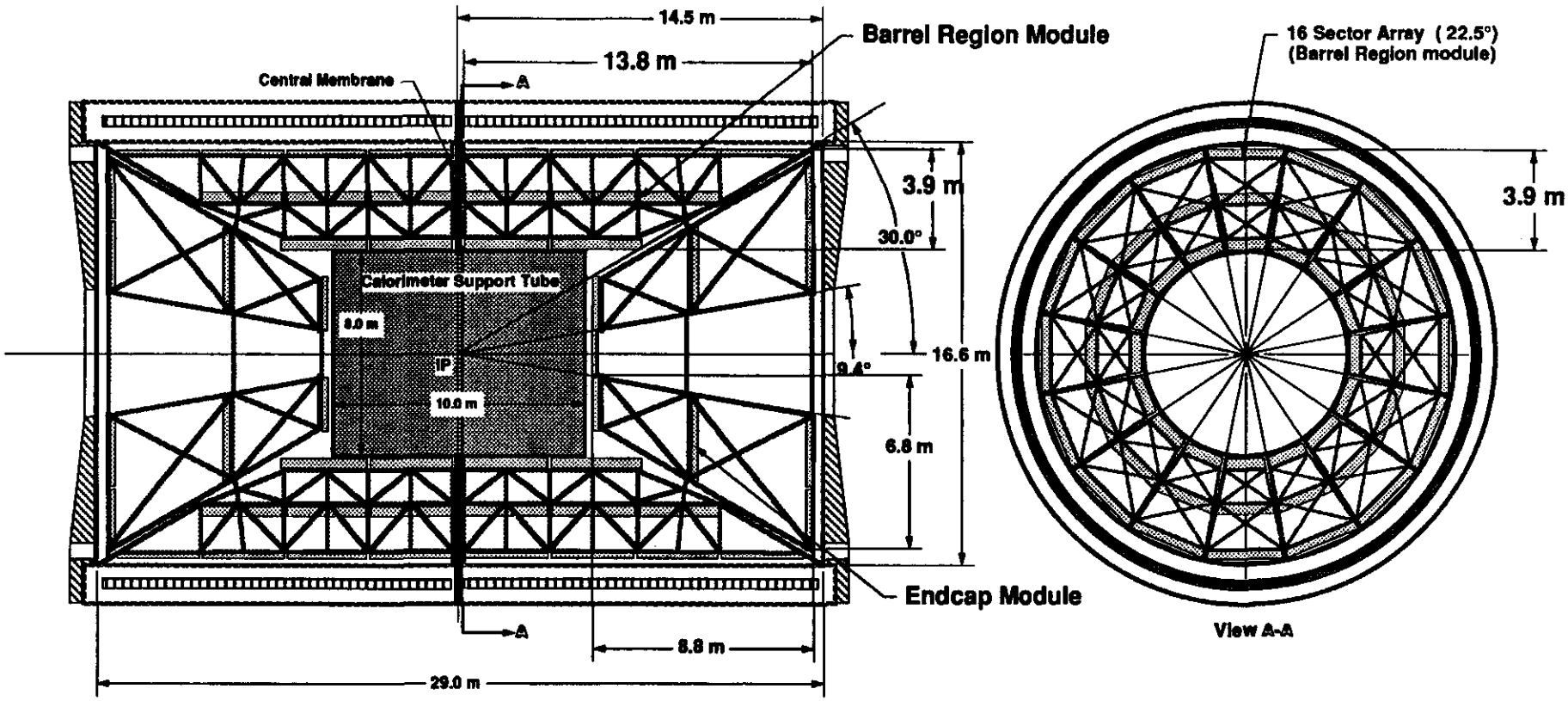
- Engineering Budget allows NO money for development and evaluation of actual support and alignment hardware such as structure elements, interface hardware or the straight-line monitors which will likely be the backbone of muon system alignment.

- LoI Muon Subsystem Costing complete (Lower Contingency of 40% (60% previously) reflects an increase in estimated engineering design dollars)

  The Muon System Still Needs a lot of work !!

Muon System Engineering Near Term Effort (Costing Refinement)

- T. Kondoleon has initiated the muon support structure design and costing activity. M. DePiero has just start working the Muon/Magnet Interface hardware problem.
- Chamber costing could also benefit from backup on the supplied costs (better definition of assembly processes and some sketches of chamber concepts would be a helpful) !
- Electronics cost estimates will hopefully benefit from LeCroy's effort at unified costing. (Must Identify which electronics costs in the muon system costing will or will not be covered by this effort)



GEM MUON SYSTEM

Engineering Issues

- Interface of Muon System to Magnet remains a serious issue to be settled.

  (Currently examining support/isolation concept of large right-angle flexural plates, one per sector. One leg of the right angle would bolt to end plates of magnet halves and the other leg would support an integrated muon structure made up of 16 serially-integrated modules per end)

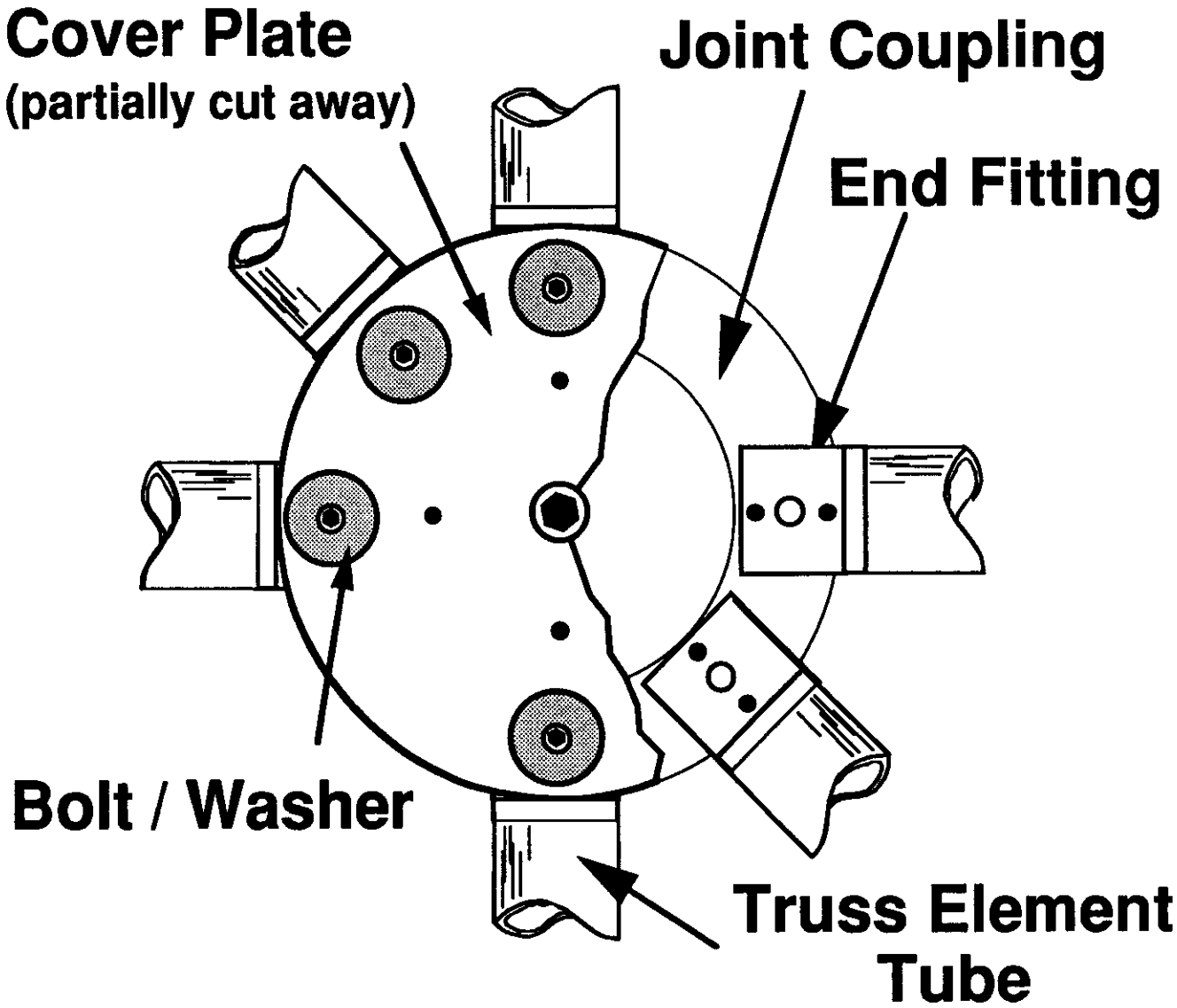
  Need to negotiate mounting space options on the magnet end plates (initial reaction on 20 Nov. from G. Deis and C. Johnson was quite positive; design effort at Draper has just started).

- Global alignment and monitoring of the Muon system with respect to the IP and Quadrapole Fiduciary marks remains an issue to be settled. This is a major collaboration issue between SSCL, Muons and Magnet at a minimum.

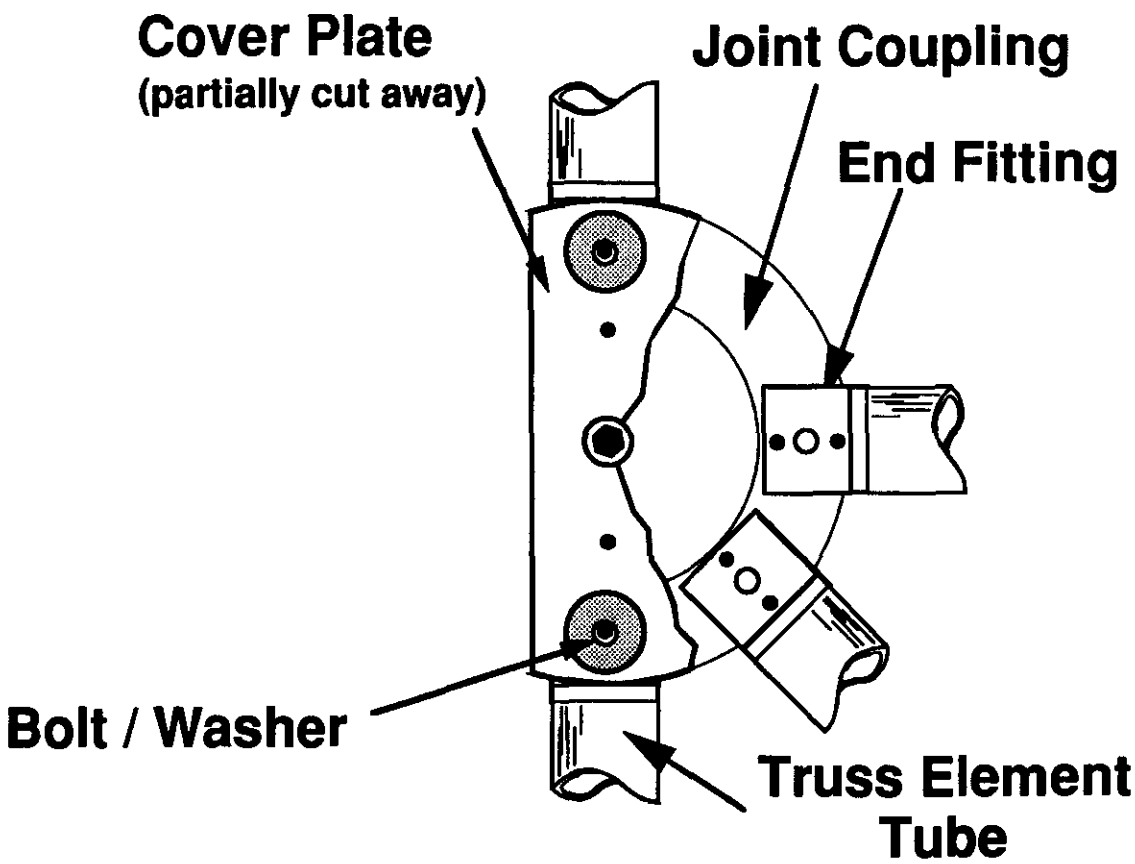
  (G. Sanders has recommended an aggressive attack of problem, with a compact but diverse group of interested engineers and physicists).

  I concur, but who manages the task and where does the funding come from??

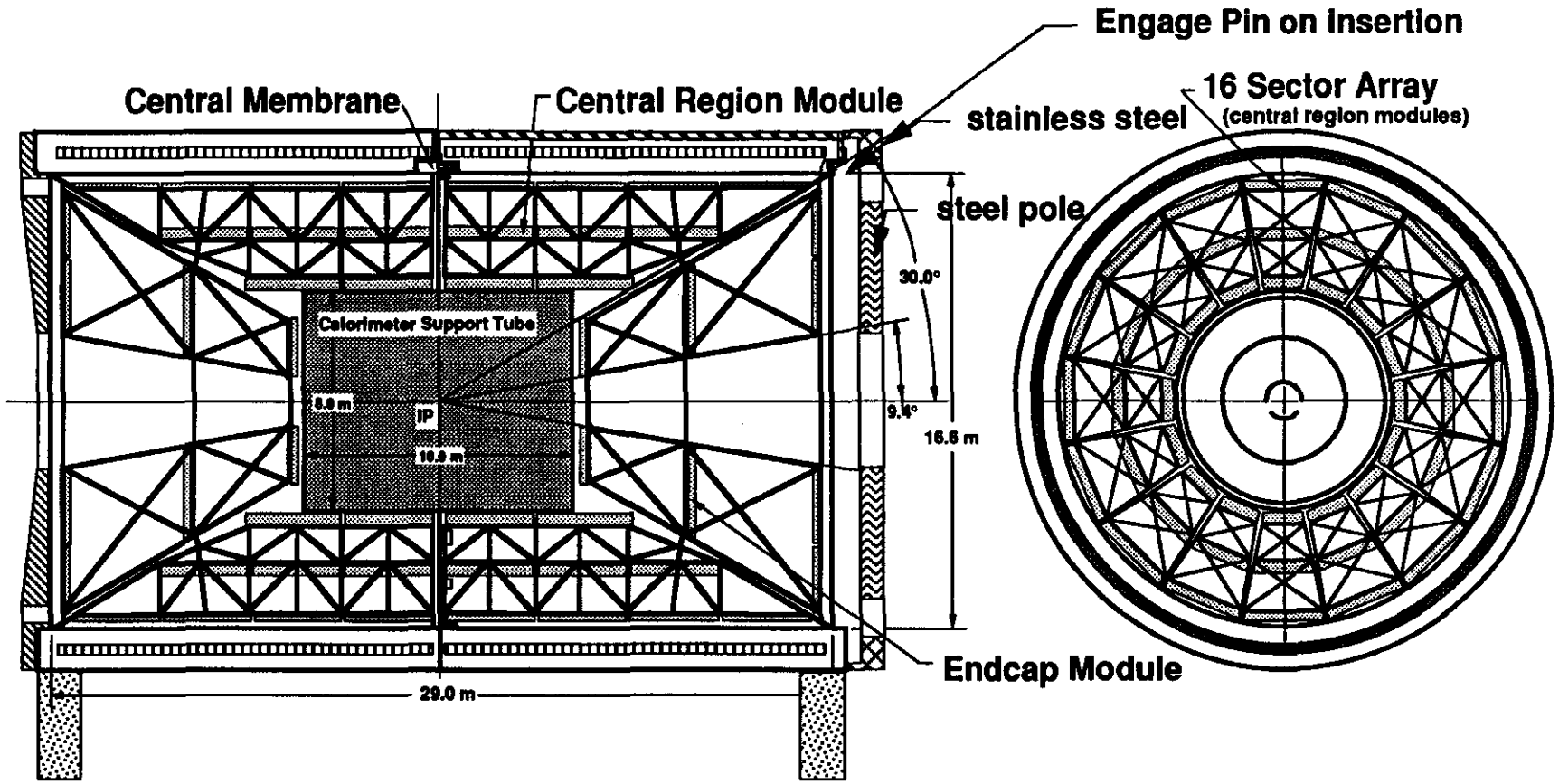
GEM MUON SUPPORT STRUCTURE (CLEVIS JOINT ASSEMBLY)



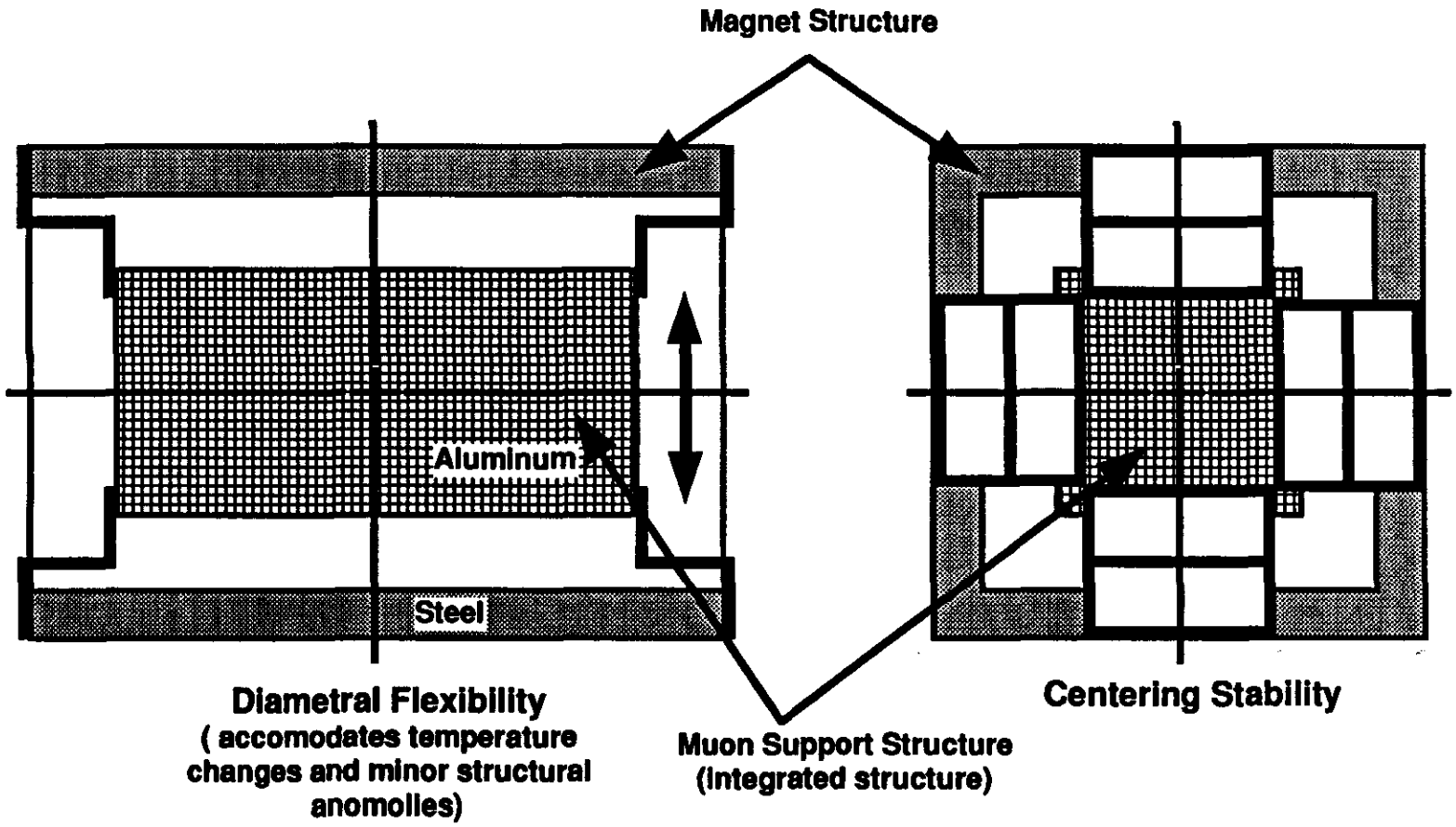
GEM MUON SUPPORT STRUCTURE
(CLEVIS JOINT ASSEMBLY)



(End Joint Illustrated)



GEM MUON SYSTEM



GEM Muon System Support Concept

F. Nimblett
Draper Lab
06 December 1991

- There is a new option of an East Campus hall. It features multiple shafts and an assembly scenario which separates the magnet halves from the central detector assembly. This Central detector assembly would be a self-supporting assembly which would permit relatively quick access to the central tracker. Barrel region muon system assembly into the magnet halves would be done from the central membrane end. Endcap muon chamber installation would still be done from the pole ends.

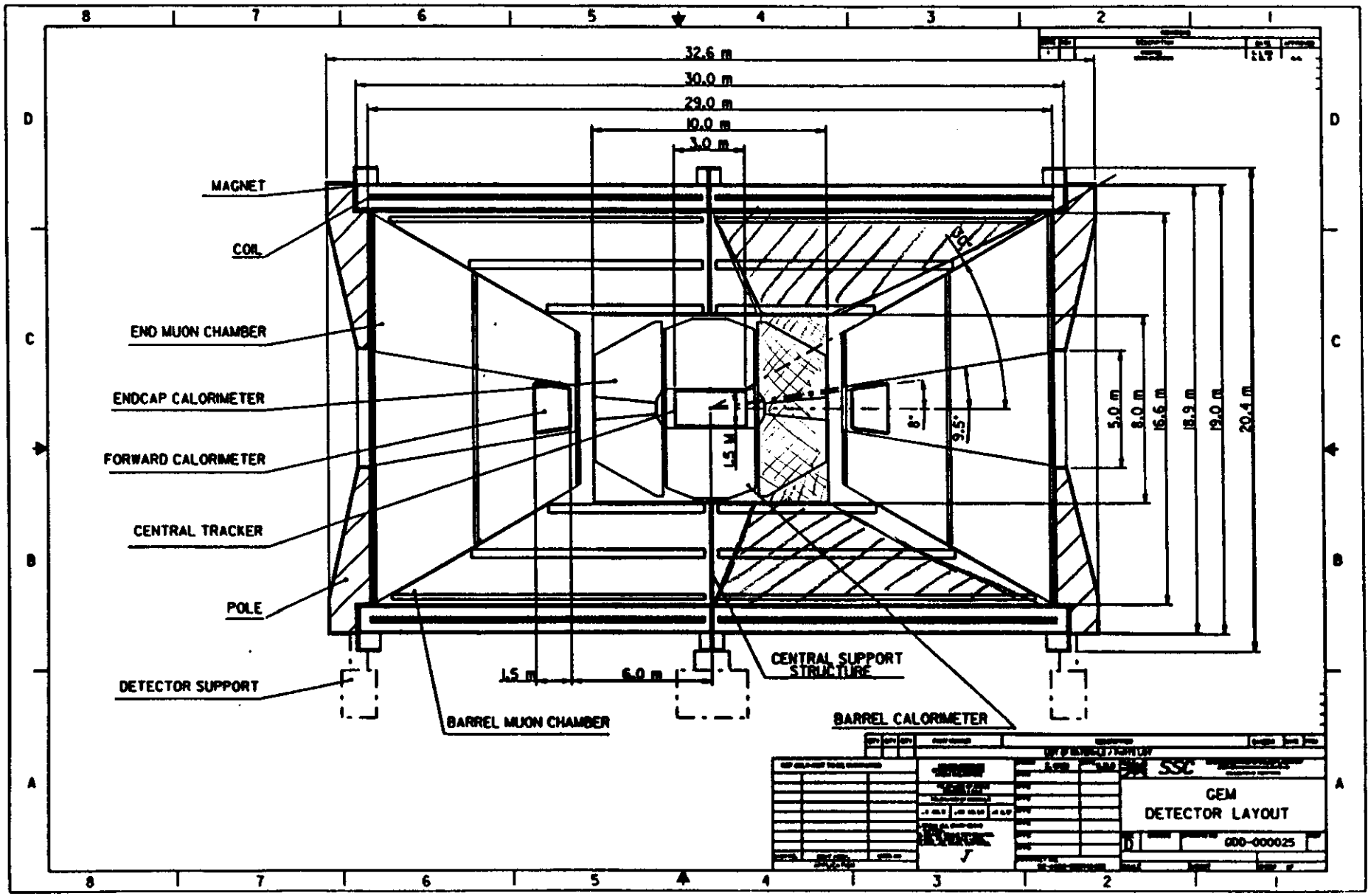
  In principle, this looks like a very good approach.

  It is important to have an understanding of magnet deflections and the resulting interaction with the muon system as a function of movement along an imperfect rail system!!

  Can the muon system maintain alignment?

  <u>Can</u> and <u>should</u> the magnet and muon system accomodate the web-suspended 600t LAr Endcap Calorimeter concept suggested by Lyle Mason ?? New potential interface with calorimeter system must be resolved soon!

  Recommend a meeting of lead engineers with some muon physics representation to try a work out a viable tracker access scheme that pleases the magnet, muon, calorimeter (both options) and tracker subgroups. This scheme should address services and assembly and cabling options for all systems!!


32.6 m
30.0 m
29.0 m
10.0 m
3.0 m
MAGNET
COIL
END MUON CHAMBER
ENDCAP CALORIMETER
FORWARD CALORIMETER
CENTRAL TRACKER
POLE
DETECTOR SUPPORT
BARREL MUON CHAMBER
CENTRAL SUPPORT STRUCTURE
BARREL CALORIMETER
1.5 m
6.0 m
1.5 M
8°
9.5°
5.0 m
8.0 m
16.6 m
18.9 m
19.0 m
20.4 m
SSC
GEM
DETECTOR LAYOUT
000-000025

- Creating a GOOD Muon System conceptual design, with correspondingly lower contingency cost estimates, in the next 2 to 3 months will be a major undertaking and something of a "budget bruiser". Utilization of these resources up front will in turn put a strain on the already very limited $$ resources to be used later in GFY92 for preparation of the Technical Proposal.

- On the Up-Side, Draper has committed two additional designers and a draftsman to this effort. The staff available for GEM Muon work as of 25 November will consist of F. Nimbett, T. Kondoleon, M. DiPierro, T. Hamilton, B. Antkowiack and G. Robb.

Engineering coordination:

Current funding permits only a minimal effort in this area.

R&D Engineering:

Monthly reports from the specific subgroup lead engineers sent to F. Nimblett by EMail, FAX, or Fast Carrier Pigeon, preferably on the last day working day of each month, will be the vehicle to track design progress and problems. There is no need to wait if a serious problem arises !!

This information should provide the chamber engineering design information necessary to proceed with chamber layout studies, support structure design and alignment system design. Initial input should be as complete as possible to serve as the design baseline. Subsequent reports should address ONLY changes to this baseline. If no change, then a simple "no change" will do.

As structural support and detail alignment schemes mature, similar information will go out to the chamber subgroups for comment on the same schedule.

Subgroup engineering is essentially on its own! Comments from me on individual chamber design details will be limited to items affecting overall system design or something I interpret as a serious problem (correctly or incorrectly).

Today, I would like to get a list of reporting engineers or physicists from each subgroup along with telephone no., FAX no., EMail address and regular mail address.

Muon System Engineering Design:

This effort involves both the design of the support structures, interface hardware, alignment hardware and all service considerations through the conceptual design of the system and into the preparation for the Technical Proposal. It also reserves money to fund a portion of the effort necessary to help design the selected chambers to a sufficient level of detail for vendor estimates on at least the big-ticket items.

Total of 1.5 FTE /M , after chamber selections are made, for all chamber subsystems will go to designated subgroup engineering staff, assuming they want to do the preliminary design

Similar effort will be applied at Draper to integrate these selected technology preliminary designs into the overall muon system which will be defined in the Technical Proposal.

V. Polychronakos
12/6/91

CSC Progress Report

- BU has built small chamber for gas, gain studies etc
  - 10×10 cm^2 active area
  - 20 and 50 μm anode wires
- Mass flow controller system for full prototype
- Trapezoidal cathode and AMPLEX board ready for fabrication.
- Started design work for full prototype.
  - Design of cathode strip prototype
  - Investigation of hexcell sandwitching techniques
- Working with P. Jarron on AMPLEX modifications
- Calibration of test chamber at LNPI now completed and more gas studies (drift vel. Lorentz angle) underway.
- Gearing up for full size prototype.

RPC Irwin Pless

DESCOPED ~~SSC R & D~~ PROPOSAL FOR THE GEM MUON BEAM TAGGING TRIGGER AND Z-COORDINATE MEASURING SYSTEM USING RESISTIVE PLATE COUNTERS

(COMPLETE VERSION)

14 November 1991

I. COLLABORATION

The collaboration proposing this R & D program consists of the following groups:

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. Makowiecki
C. Wuest*

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

*co-spokespersons

II. R & D PROPOSAL

The descoped Resistive Plate Counter (RPC) R & D Proposal consists of two major areas:

A. Measure the properties of the 1 meter by 2 meter R & D furnished by R. Santonico of the Rome 2 University.
B. Measure the properties of a large size, collaboration constructed, RPC.

A. Properties of the Italian RPC to be measured.

1. Pulse rise time jitter.
   In order to measure the pulse time jitter of the Italian RPC we will need a test facility. It is proposed that the test facility use a cosmic ray telescope to select muons for testing the RPCs. The telescope should furnish a zero time pulse that has a jitter of less than two nanoseconds. Scintillation hodoscopes provided by Brown University will provide this timing. The telescope should also furnish the point of intersection of a cosmic ray muon with the RPC under test with an accuracy of less than 3 cm. In order to achieve this, one needs at least three tracking planes with this resolution. Since the two scintillation hodoscopes available from Brown cannot furnish this resolution, our solution is to use four drift chamber planes that are available from the University of Tennessee. These drift chambers will furnish the intersection of the muon track with the RPC with a spatial resolution of about 200 microns.

2. Maximum Counting Rate
   We propose to make a rough test of the maximum counting rate of the RPCs by using a radioactive source. An accelerator test would be much preferable but, given the time available, using a source is the only practical technique.

3. Efficiency
   The scintillator hodoscope will be used to measure the efficiency of the Italian RPC.

4. Life Time
   We will make a crude measurement of the lifetime of the RPCs by using a radioactive source.

B. Measure the Properties of a Large Size, Collaboration Constructed, RPC

1. Size of Prototype
Given the financial constraints, it may be very difficult to construct a 1 meter by 4 meter RPC prototype. We can certainly construct a 1 meter by 1 meter prototype and we will aim to construct as large a prototype as possible.

2. Prototype Materials
We would like to construct prototypes of as many types of material as possible. Phenolic, lucite, glass, lexan, and polyethylene are candidate materials that immediately come to mind. However, again given the financial constraints, we will make an educated guess as to the best material to chose and construct our prototype out of the chosen material.

3. Measuring the Properties of the Prototype RPC
After preliminary testing of the prototype RPC at LLNL, the prototype will be sent to MIT. At MIT the prototype will use the test facility to measure pulse rise time jitter, maximum counting rate, efficiency and lifetime.

III. R&D PROGRAMS OF THE COLLABORATING INSTITUTIONS

A. Brown Experimental Program

Brown has two scintillation hodoscopes which have been used in previous experiments at FNAL. Each hodoscope has two planes, one for the x-coordinate and one for the y-coordinate. Each plane contains 12 scintillator paddles and photomultipliers. Each paddle is 11 cm wide, 1.27 cm thick and 120 cm long. Brown will set up a trigger system with an overall time zero resolution of about one nanosecond. This system will be shipped to MIT and assembled as part of the RPC test bed. The time zero furnished by these hodoscopes will be used to evaluate the RPC time resolution.

The complete testing of the scintillation system at MIT will be the responsibility of Brown University. Prof. M. Widgoff will be responsible for this work.

B. Indiana Research Program

Indiana has designed and built several multi-component gas systems. The four-component system envisaged for the RPC effort would utilize four mass flow meters scaled for the currently expected gas ratios. For example, we are considering a nonflammable mixture consisting of 86% CO_2, 10% isobutane, 2% argon, and 2% freon. However, it will be simple to accommodate essentially any gas ratios. In addition, the gas system will have the required filters, flow meters, high pressure and low pressure gauges, and flow control valves.

Indiana will ship the gas system to MIT and commission it at MIT. Prof. E. D. Alyea will be responsible for this work.

C. LLNL Experimental Program

To develop a suitable RPC trigger counter for the GEM detector, keeping in mind that thousands of square meters of reliable RPCs will be needed, we propose to concentrate our R&D effort at LLNL on the fabrication of large scale prototype RPCs using alternative materials and manufacturing methods.

We have identified candidate materials such as resistive plates of glass or plastic, and various coatings that could be easily adapted to mass production of RPCs. In addition to the application of standard resistive coatings based on paints, we are also equipped to sputter a number of different materials on large area plates and could, for example, provide cermet thin film coatings (chrome/silicon monoxide) with resistivities controllable from a few tens of kohms/square to a few Mohms/square. We are interested in cermet coatings because we have experience in producing these coatings for other position sensitive avalanche counters under development at LLNL, and because we feel that the surface resistivity and uniformity of these coatings can be more readily controlled than for resistive paints. Many resistive coating technologies and plate materials should be suitable for RPCs, however, because of R&D funding limitations, we would concentrate on the application of one or two material choices such as glass or plastic plates with cermet thin film coatings or silk-screened resistive paints.

Particular attention will be paid to the effect of the choice of RPC materials on pulse rise times and pick-up electrode transmission line characteristics.

We have available general purpose electronics and gas handling systems available from previous research projects carried out in FY 1991 L* and GEM R&D programs in muon chamber design and liquid scintillator hadron calorimetry. This includes high voltage power supplies, amplifiers, discriminators, TDC and ADC modules, and scalers and data acquisition systems.

The LLNL program for R&D is the following:

1. Determine the best plate material (plastic or glass), and coating technique for the large scale prototype RPC and characterize them for resistivity and surface uniformity. This will be performed by a physicist (not included in the R&D cost) and the Chemistry and Materials Science (CMS) coatings group, consisting of a 0.125 FTE engineer, and 0.25 FTE technician.

2. Build a large scale prototype RPC with dimensions to be determined by funding constraints - 1 meter wide and 1 to 4 meters long-keeping in mind the goal of large scale production of RPCs. This effort will utilize the 0.125 FTE CMS engineer, the 0.25 FTE mechanical technician, the 0.25 FTE electronics engineer and 1 FTE of physicists (not included in the R&D budget).

3. Characterize the large scale prototype RPC for noise, operating efficiency (plateau), time resolution and spatial resolution. This includes characterizing the size and temporal duration of the localized dead region after an electron avalanche is generated. Spatial resolution along the long pickup strips can also be studied, with particular attention being paid to uniformity and linearity of the position measurement near the edges of the chamber. Also, chamber lifetime and aging effects can be studied with accelerated tests using high rate localized pulsing. Tracks can be generated using tagged cosmic rays, and radioactive sources. In addition, the LLNL 140 MeV Electron Linear Accelerator could be utilized as a source. This work will be performed by a 0.25 FTE electronics engineer and a 0.25 FTE physicist (physicist not included in the R&D cost)

D. MIT Research Program

It will be the responsibility of MIT to design, fabricate, and install the mechanical parts of the RPC test bed at MIT. It is intended that this test bed be at least 7 meters long so that an RPC can have all its sensitive area scanned by the 1 meter by 1 meter cosmic ray telescope. This will be accomplished by having the ability to slide any part of the RPC under the telescope. All cables and gas connections must be designed to allow for this movement.

MIT will be responsible for the design and implementation of the RPC electronics. It will be the responsibility of MIT to assemble the scintillation hodoscope system from Brown, the gas system from Indiana, and the drift chamber system from Tennessee into a single operating system. It will also be the responsibility of MIT to connect all RPCs either from Italy or LLNL into the RPC test bed and collect all relevant data.

MIT will be responsible for the DAQ system for the RPC test bed. The choice of the DAQ computer will be made in consultation with the other members of the RPC subsystem. It would be desirable, but not a requirement, that all members use the same DAQ computer so as to facilitate program sharing.

The construction, maintenance, operation, and data acquisition function of the RPC test bed will be the responsibility of MIT. In order to carry out this responsibility, we have budgeted the services of a full-time electromechanical technician.

Y. H. Chang, E. S. Hafen, P. Haridas, I. A. Pless and a fulltime Mechanical Technician will be responsible for this work.

E. Tennessee Research Program

Tennessee has nine drift chambers, each of an area 1 meter x 1 meter. These chambers have been used in previous experiments at Fermilab National Laboratory. They each have a measured spatial resolution of 200 microns.

Tennessee proposes to rehabilitate these chambers and install them into the test bed at MIT. While the chambers come complete with amplifiers, all other electronics will have to be purchased or

borrowed.

The certification of the complete drift chamber installation at MIT will be the responsibility of the University of Tennessee.

S. Berridge, W. Bugg and P. Y. C. Du will be responsible for this work.

IV. BUDGET

The budget summary is as follows:

Brown	31.0 K
Indiana	12.0 K
LLNL	100.0 K
MIT	137.0 K
Tennessee	20.0 K
TOTAL	300.0 K

The detailed budgets follow.

BROWN

Brown will furnish four planes of scintillator hodoscopes with tubes. Each plane consists of twelve 11 cm wide by 1.27 cm thick by 120 cm long scintillator slats. These planes form two units, each with X and Y geometry.

R & D needs of Brown:

4 each	4413	Discriminators	@$ 1650	$ 6,600
1 each	4564	Logic Module	@$ 1871	$ 1,871
7 each	2229	TDC	@ $ 2160	$ 15,120
1 each	8025	Camac Crate		$ 4,995
Cables and Connectors				$ 2,000
Shipping, Brown - MIT				$ 500
TOTAL				$ 31,086

In addition to the above, Brown will need:

1 each	1440 High Voltage System		
	1449M Main Frame	@$ 7,176	$ 7,176
	1445A Controller	@$ 2,490	$ 2,490
4 each	1443 Modules	@$ 1,901	$ 7,604
TOTAL			$17,270

These components will be borrowed from another institution.

INDIANA

Indiana will manufacture the gas system for the resistive plate counters.

R & D needs for Indiana:

1 each Gas System - 4 Component	$ 11,000
Shipping, Indiana - MIT	$ 1,000
TOTAL	$ 12,000

In addition to the above, Indiana will need approximately $14,000 in mass flow meters and flow control valves. These will be borrowed from another institution.

LLNL

In the spirit of the GEM Detector goal, we have devised an R&D program designed to the level of funding allocated for LLNL, agreed upon by the members of the RPC collaboration. LLNL's allocation is $100K and the R&D program tasks are broken down as follows:

R & D needs for LLNL:

EQUIPMENT:

RPC materials (glass, coating targets, spacers, masks, etc.) based on estimates of $2300/m2 for 4 m2 of prototype RPC. See memo to F. Nimblett (10-15-91) by Wuest/Pless.	$13.8K

LeCroy 4413 Discriminators: 2 each @ $1,650	$3.3K
Shipping LLNL to MIT	$1.0K

RPC gas system and other RPC electronics (computer, data acquisition, muon telescope, etc.) supplied by LLNL

SALARIES:

0.125 FTE Chemistry and Materials Science Engineer: D. Makoweicki	$10.5K
0.25 FTE Chemistry and Materials Science Technician: P. Ramsey	$13.5K
0.25 FTE Mechanical Technician: M. Haro	$13.5K
0.25 FTE Electronics Engineer: E. Ables	$21.0K
Overhead on engineer and tech salaries	$23.4K
TOTAL	$100K

M.I.T.

MIT will furnish laboratory space for the resistive plate counter test bed. It will manufacture the resistive plate counter test bed and organize and supervise all tests of prototype resistive plate counters.

R & D needs of MIT:

6 each	4413	Discriminators	@$ 1,650	$ 9,900
8 each	2229	TDC	@$ 2,160	$ 17,280
1 each	8025	Camac Crate	@$ 4,995	$ 4,995
RPC Gas (3-4 components)				$ 5,000
Full time Technician (including overhead)				$ 100,000
TOTAL				$ 137,175

Note: This budget does not allow for any tests of an RPC in a magnetic field.

In addition, MIT will need a DAQ computer, a CAMAC crate controller, scalers, pulsers, a digital scope and mechanical construction. MIT will borrow these items from another institution.

TENNESSEE

Tennessee will furnish 4 planes of drift chambers each 1 meter x 1 meter in size. Each chamber has 25 sense wires, complete with amplifiers.

R & D needs of Tennessee:

4 each	Bertran 5 kv Positive H. Voltage	@ $ 1,000	$ 4,000
4 each	Bertran 5 kv Negative H. Voltage	@ $ 1,000	$ 4,000
1 each	8025 CAMAC Crate		$ 4,995
25 each	Bottles of HRS Gas	@$ 210	$ 5,250
Cables			$ 1,000
Shipping, Tenn. - MIT			$ 1,000
TOTAL			$ 20,245

In addtion to the above, Tennessee will need the following items:

5 each	4291	B TDC	@$ 1,814	$ 9,070
1 each	4298	TDC Controller	@$ 6,962	$ 6,962
1 each	4299	Camac Interface & Buffer	@$ 4,752	$ 4,752
TOTAL				$ 20,784

These will be borrowed from another institution.

V. INTERACTION WITH THE TEXAS TEST RIG

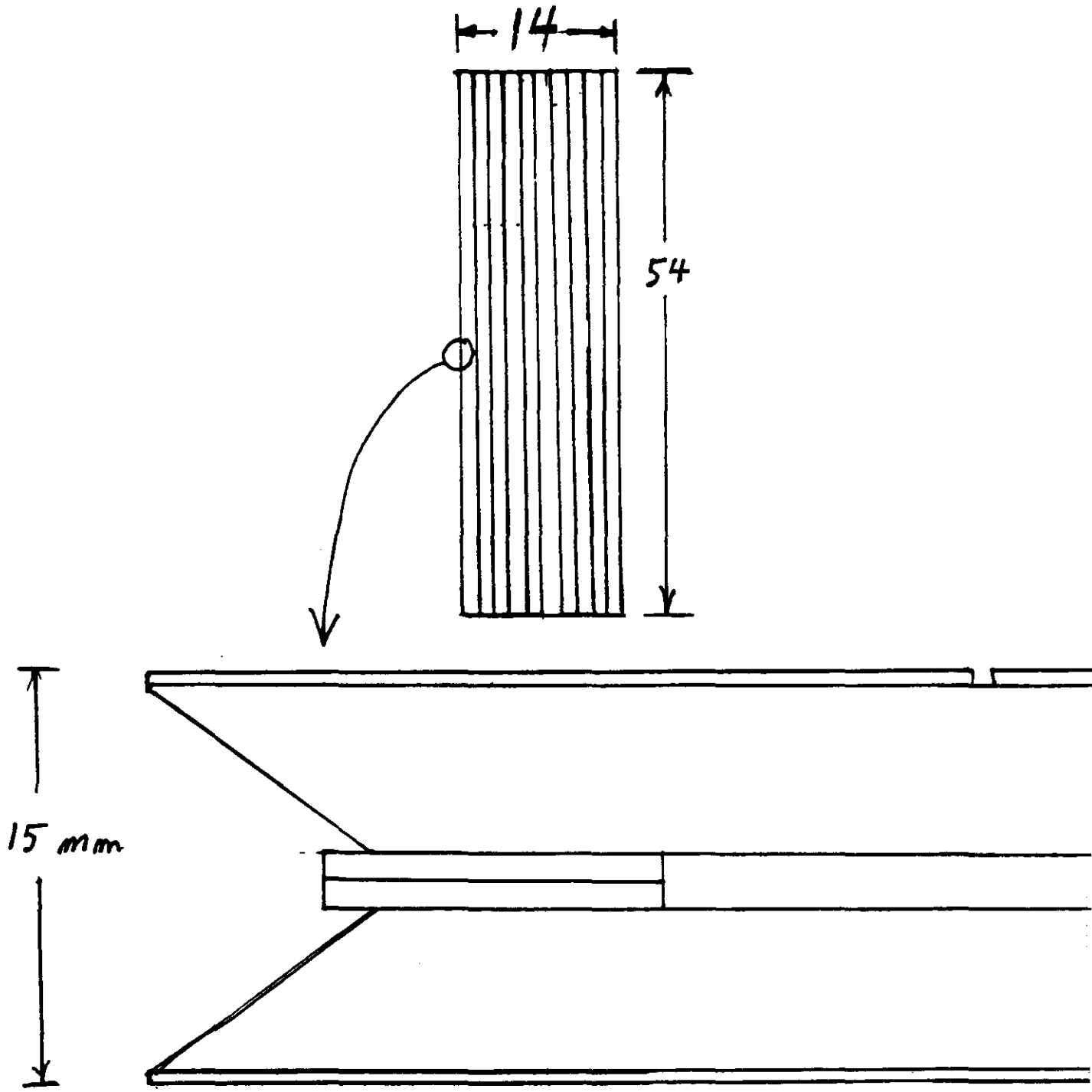
The RPC system is envisioned as a fast trigger system coupled to the slower drift chamber technology to be chosen. In order to study RPC operation alone, a fast trigger is needed and can be provided by scintillator paddles arranged in a hodoscope array. Because of the somewhat specialized nature of the RPC system in the overall muon chamber system, it seems to us that there is no immediate advantage or need to install the RPC prototypes in the Texas Test Rig (TTR). Of course, at some point in the future, when the muon tracking technology is implemented in the TTR, a layer of RPCs above and below the tracking chambers could be utilized to provide the cosmic ray trigger, if it is requested.

Even after the final results of the current R & D work is completed,

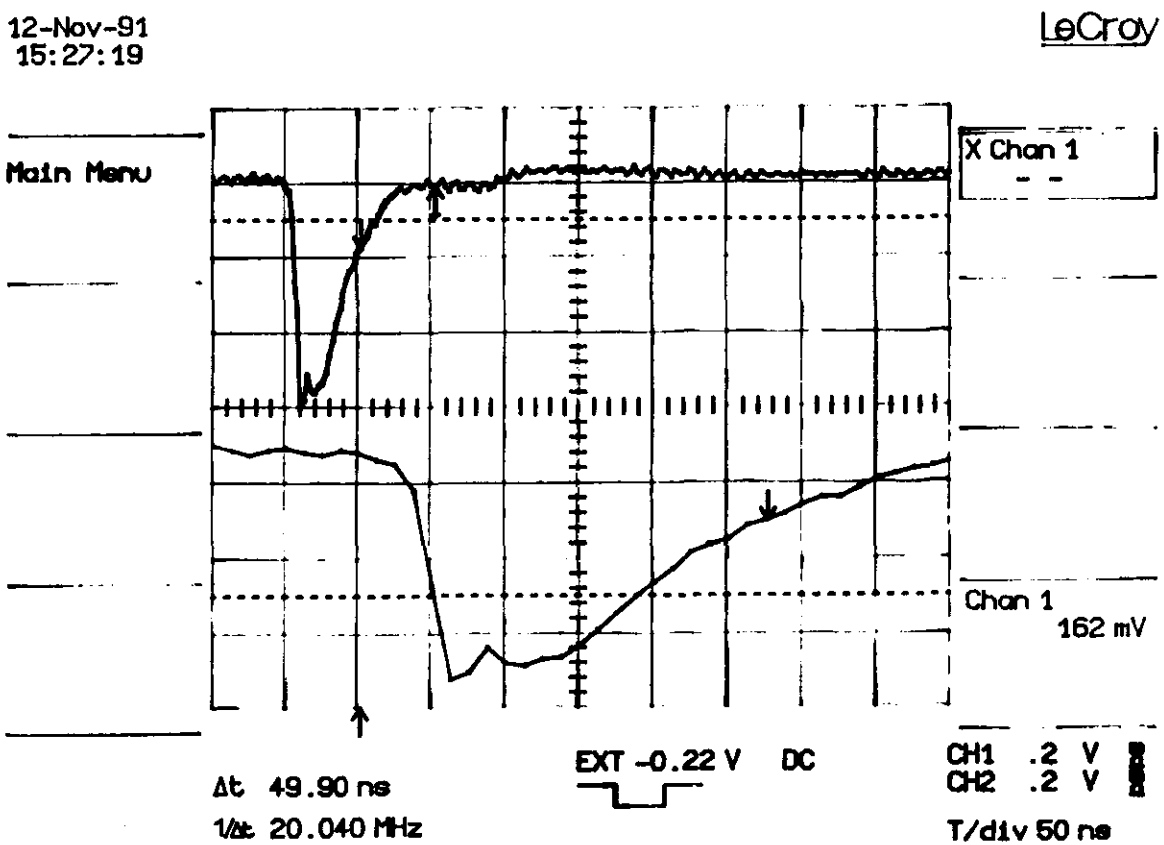
we envision a program of R&D utilizing scintillator tagging of cosmic rays and high energy betas (Ru-106) as a means of verifying the proper operation of the RPC for pulse rise time, noise and aging. Position resolution measurements can be made using scintillator tagging coupled with University of Tennessee's high resolution drift chambers. Once these issues are resolved, the large scale RPC prototypes could be moved to the TTR.

The interfacing to the TTR is yet to be determined but is somewhat simpler than the interfacing for tracking chambers since one RPC layer will be the top-most part of the muon tracking system in order to tag the downward directed cosmic ray muons. The second RPC can be place between tracking chambers midway down through the TTR or on the bottom-most layer.

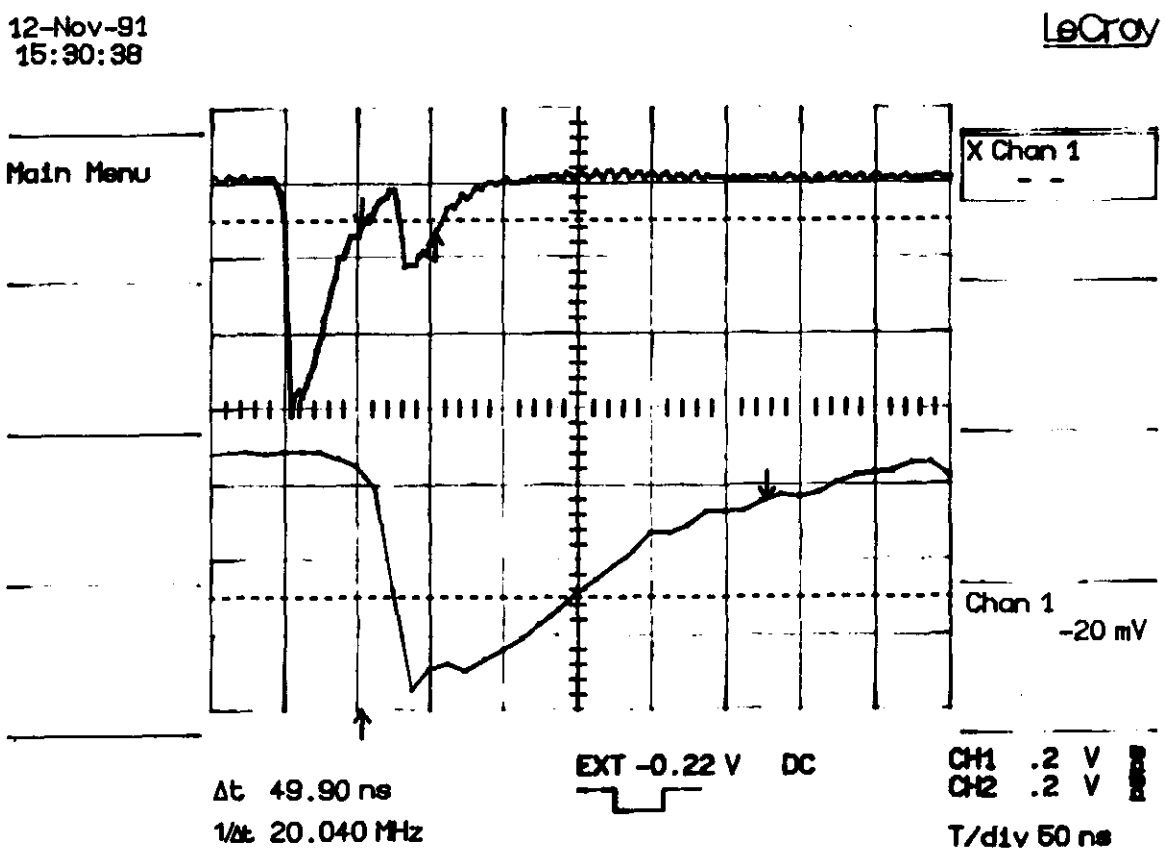
The electronics/DAQ liason person for the LLNL RPC group is E. Ables. The electronics/DAQ liason person for the MIT RPC group is P. Haridas.


14
54
15 mm

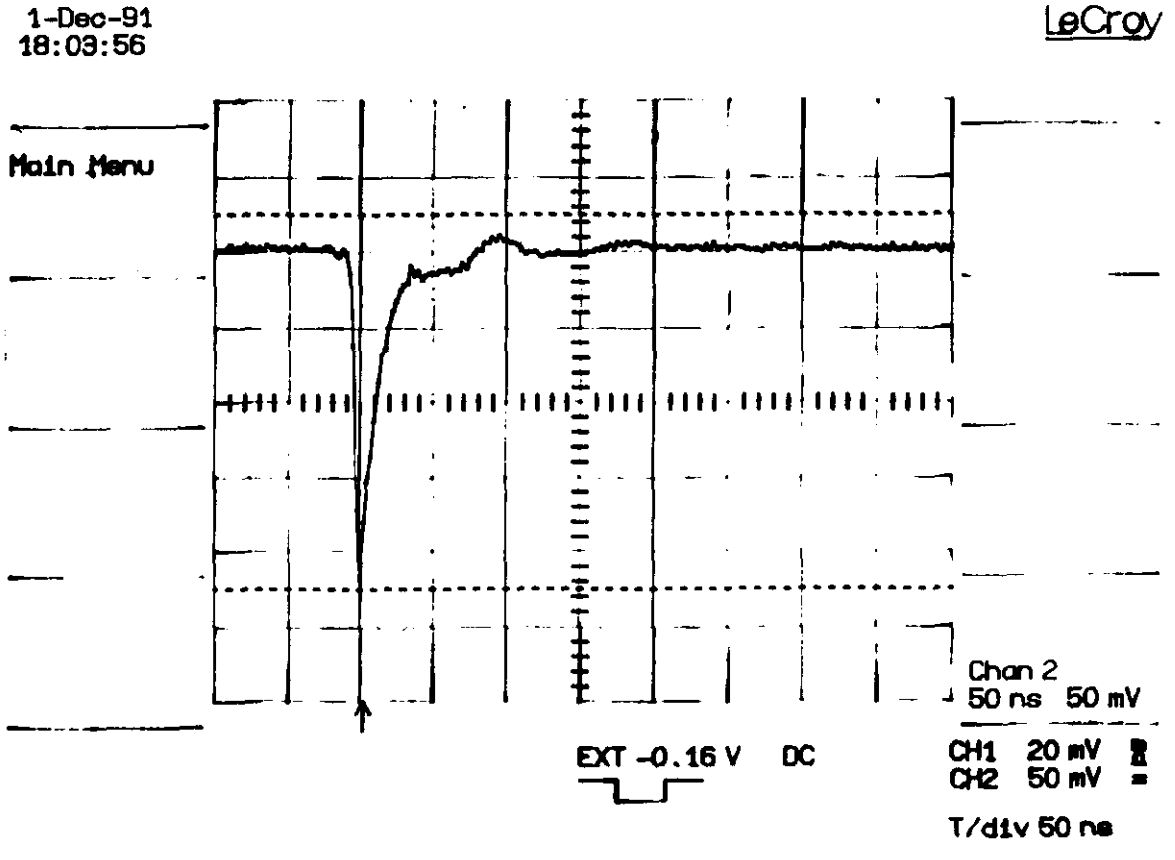
9000 V, readout end



9000 V Far end



Laser


1-Dec-91
18:03:56
LeCroy
Main Menu
Chan 2
50 ns 50 mV
EXT -0.16 V DC
CH1 20 mV
CH2 50 mV
T/div 50 ns

FET 12/6/9

LSDT Progress

Activity:

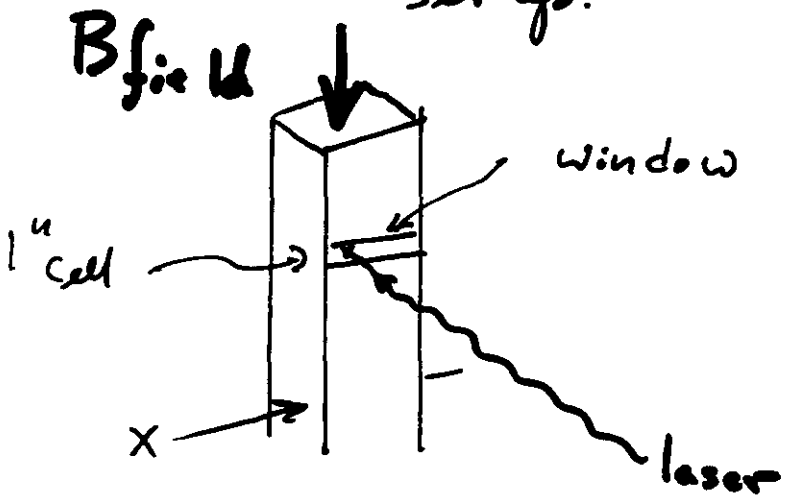
1) Constructing $0.5 \times 6\ m^2$ chamber

- mylar bridges (0.5m) at MIT
- Al sidewalls machined
- Parts delivered for top & bottom.
- cathodes on order (60mil Al)

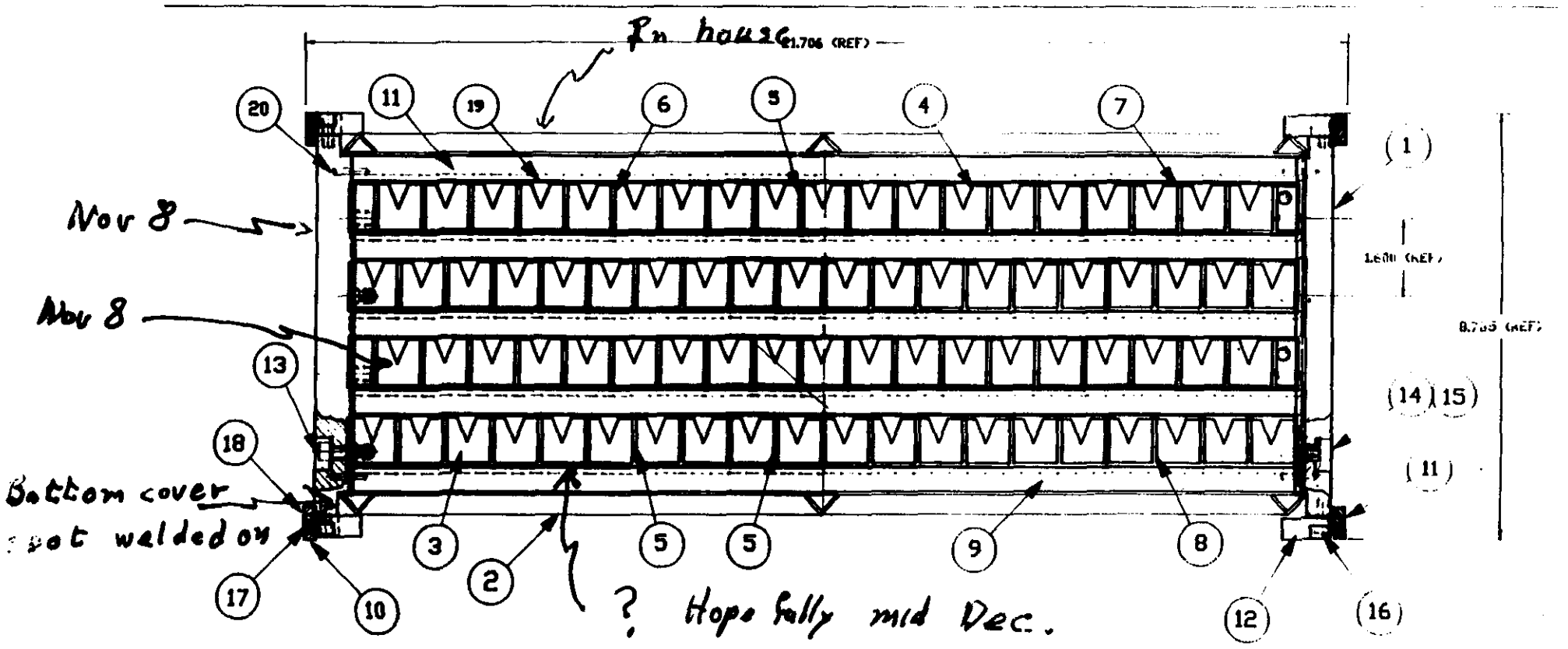
2) Design of $1m \times 4m$ chamber underway

Have to support wire bridge in middle.

3) Lorentz angle measurements being set up.



Study resol'n vs x, B,
measure d vs time
check with direct mea
of L-angle.



Electronics;
MIT Dec. 1
LeCroy Jan 1

C	LD	30	ADDED CATHODE SHEETS, INCREASED OVERALL HEI
B	LD	30	CATHODES REDRAWN .3448-IN HIGHER TO CENTER
A		30	REV. CORRECTING ADDED CATHODE SUPPORT CHA

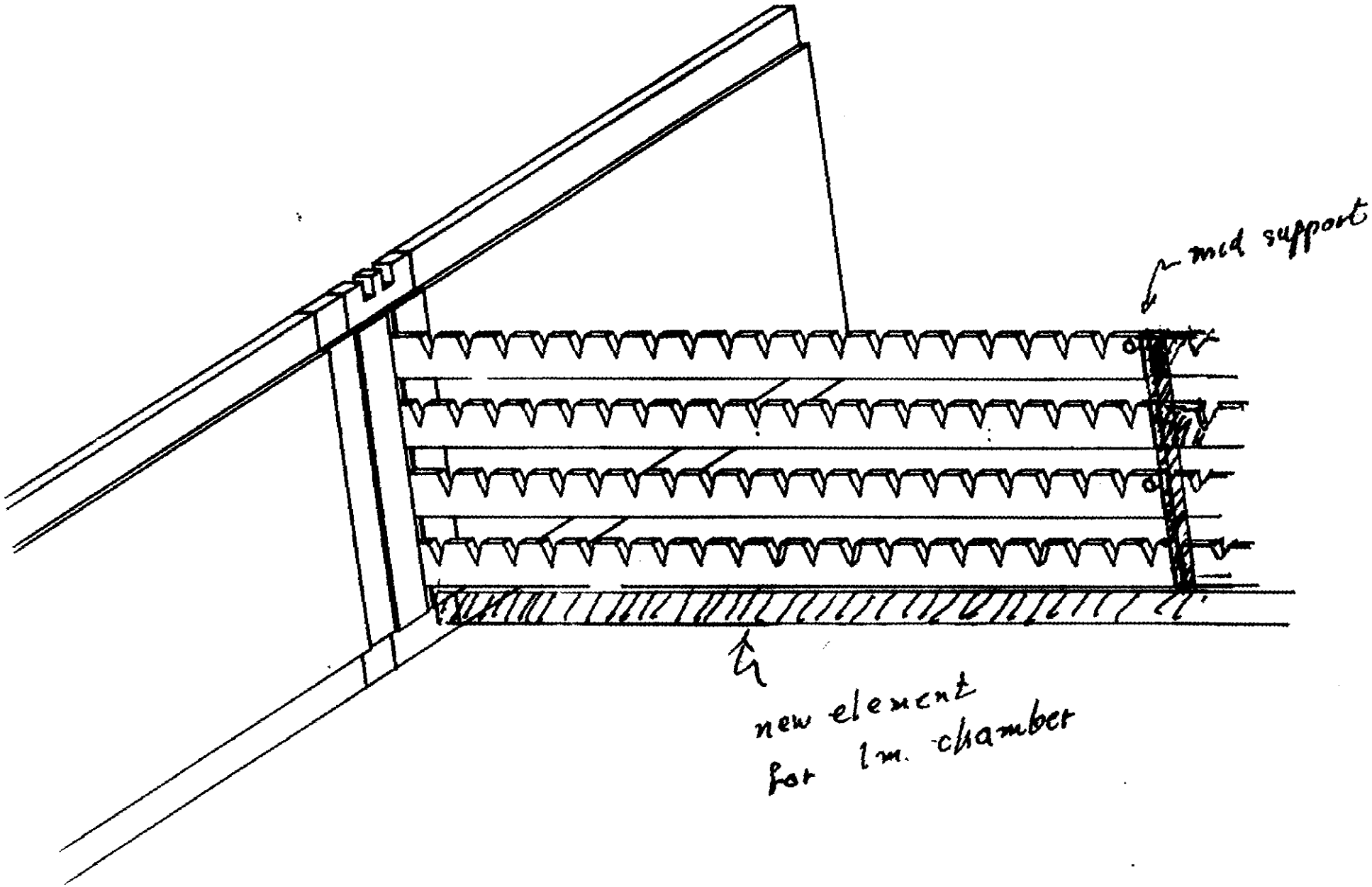
		4	
		4	
		04	
		4	
		04	
		40	
		04	
		04	
		04	
		4	
		04	
		04	
		8	
		8	
		8	
		4	
		10	
		10	
		2	
		1	
		1	
NO.	STOCK FIGHT	NO. REQD	NAME

LABORATORY FOR NUCLEAR SCIENC
MASSACHUSETTS INSTITUTE OF TECHNOL
CAMBRIDGE, MA 02139

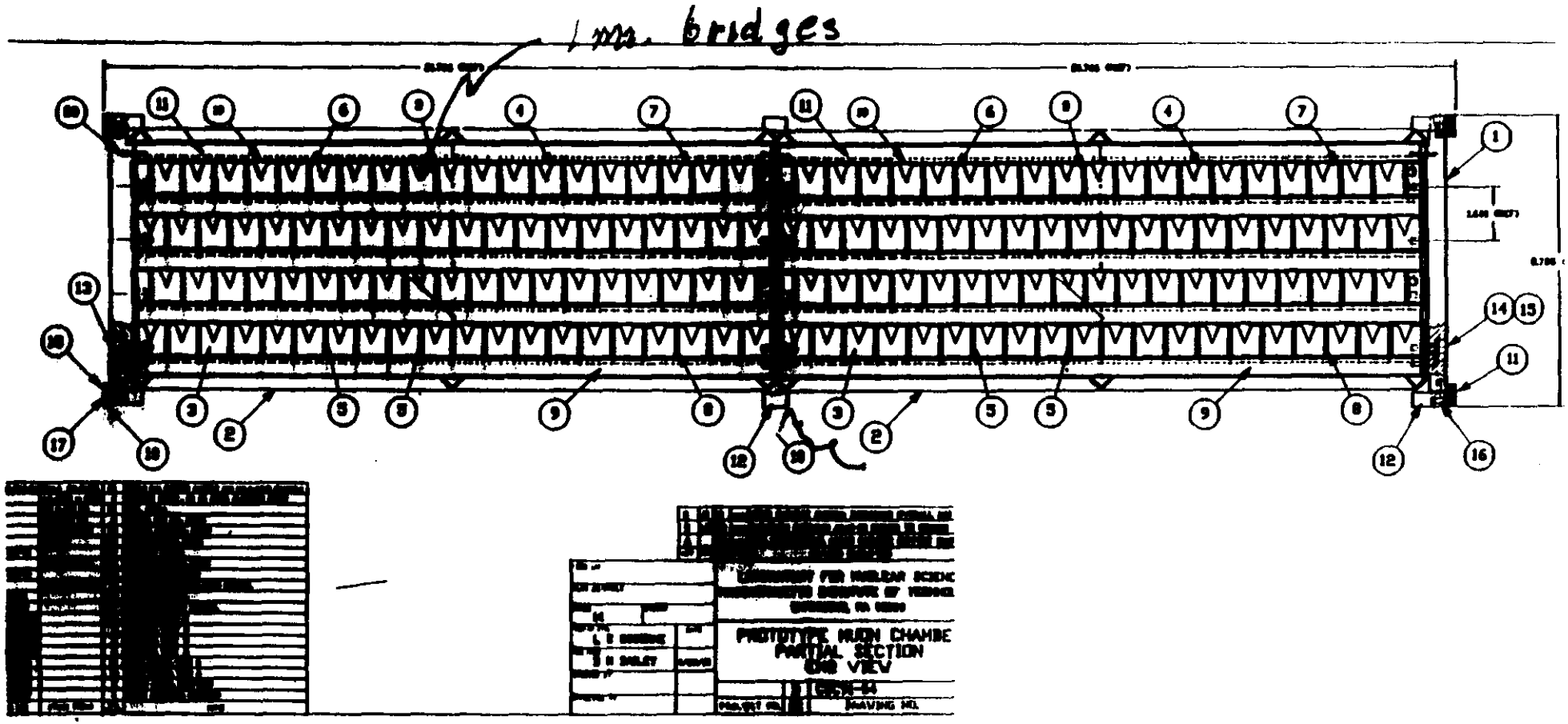
PROTOTYPE MUON CHAMBE
PARTIAL SECTION
END VIEW

1d		
L S OSBORNE		
D M BAILEY	4/29/91	

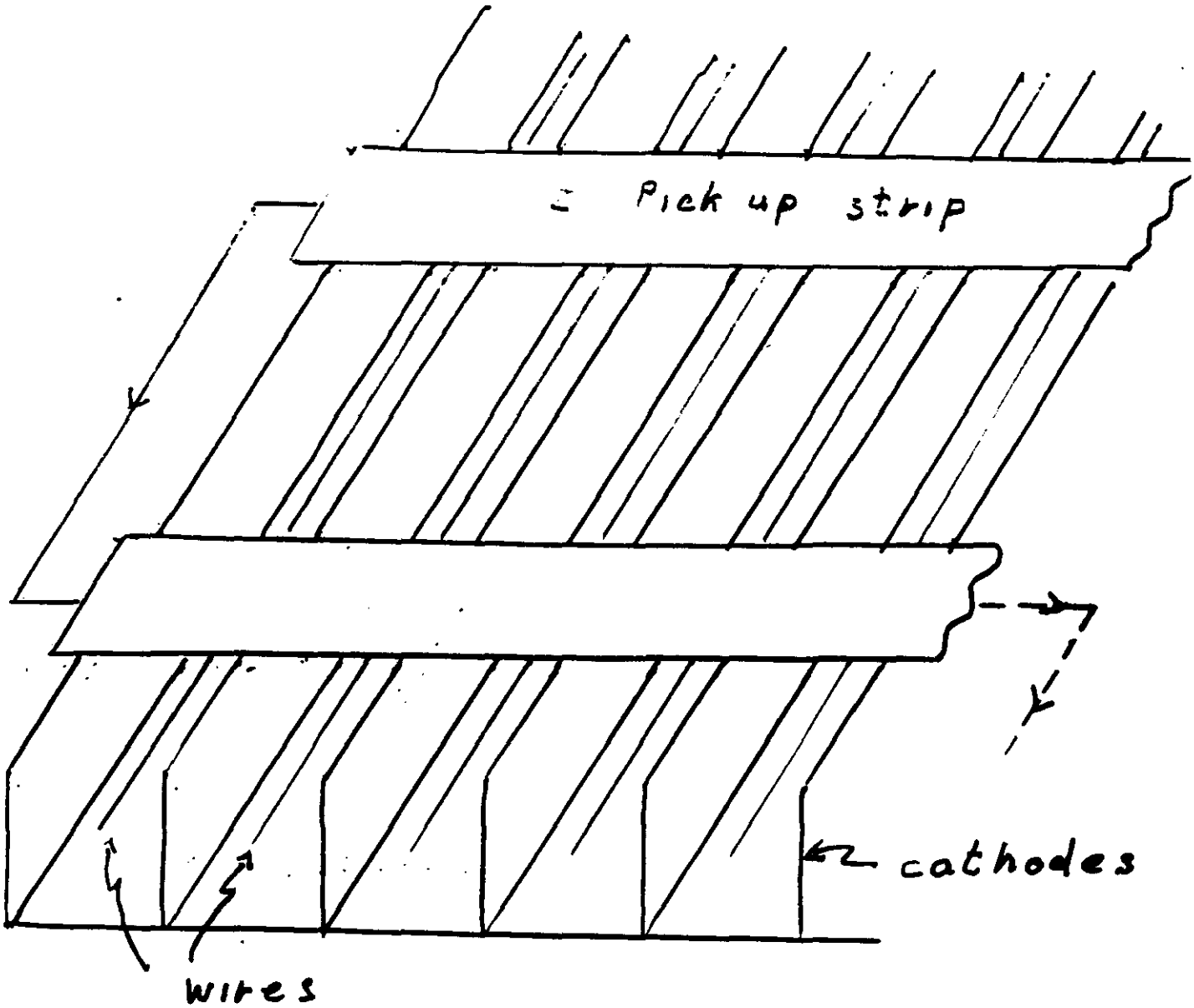
D CSC91-04


mid support
new element
for 1m. chamber

1 meter chamber

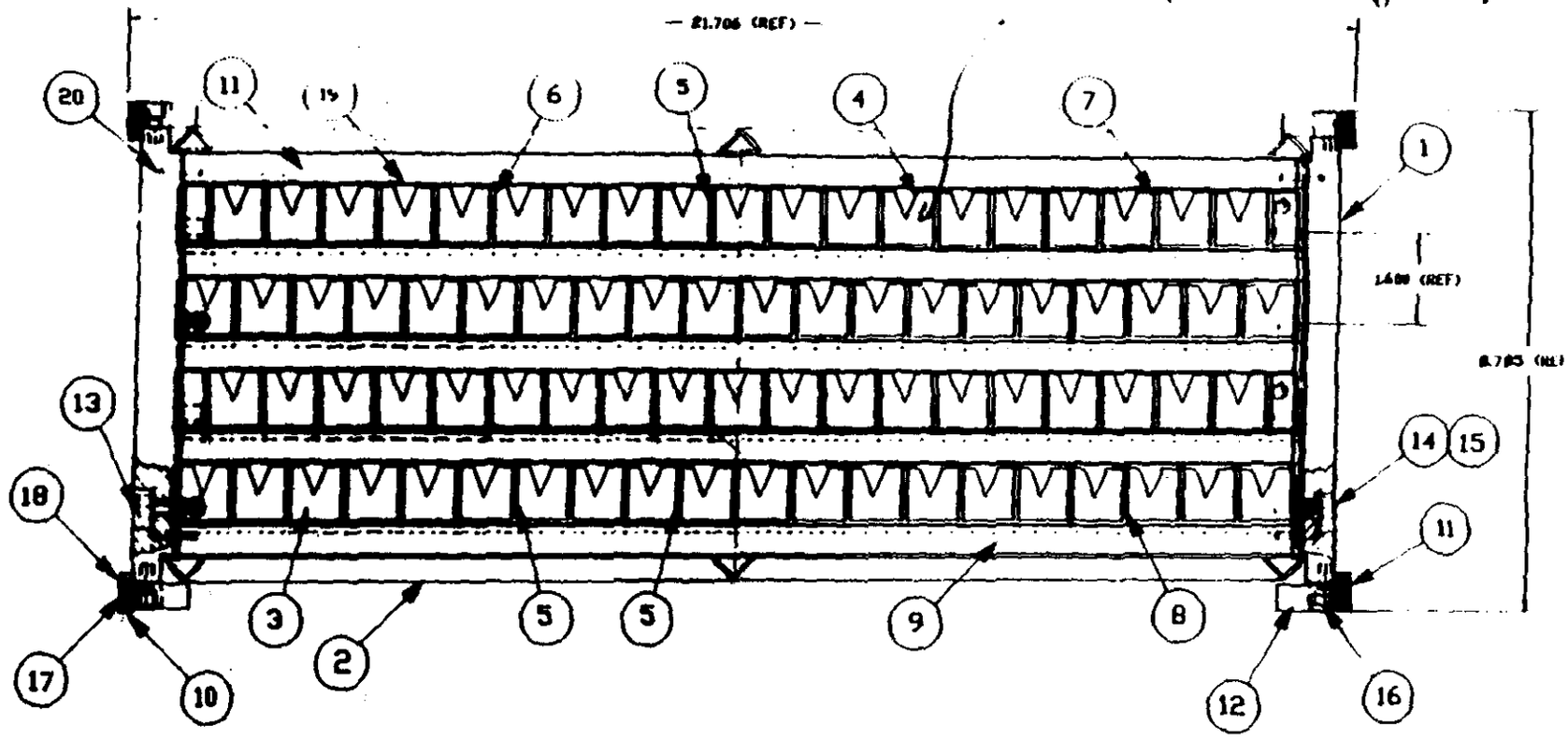


Z Measurement with Pickup Strips



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.

Wires supported by bridge

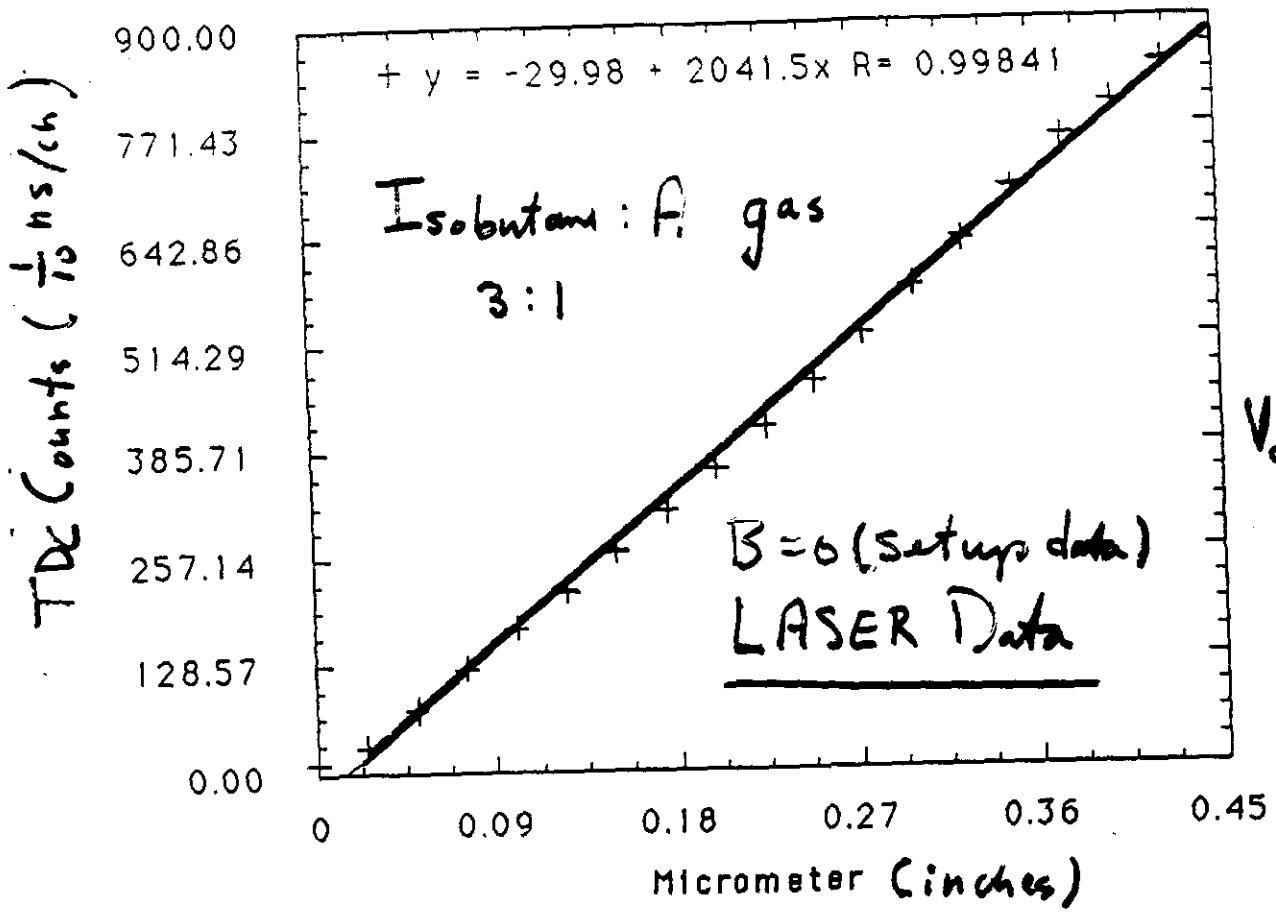


LABORATORY FOR NUCLEAR SCIENC
MASSACHUSETTS INSTITUTE OF TECHNOL
CAMBRIDGE, MA 02139

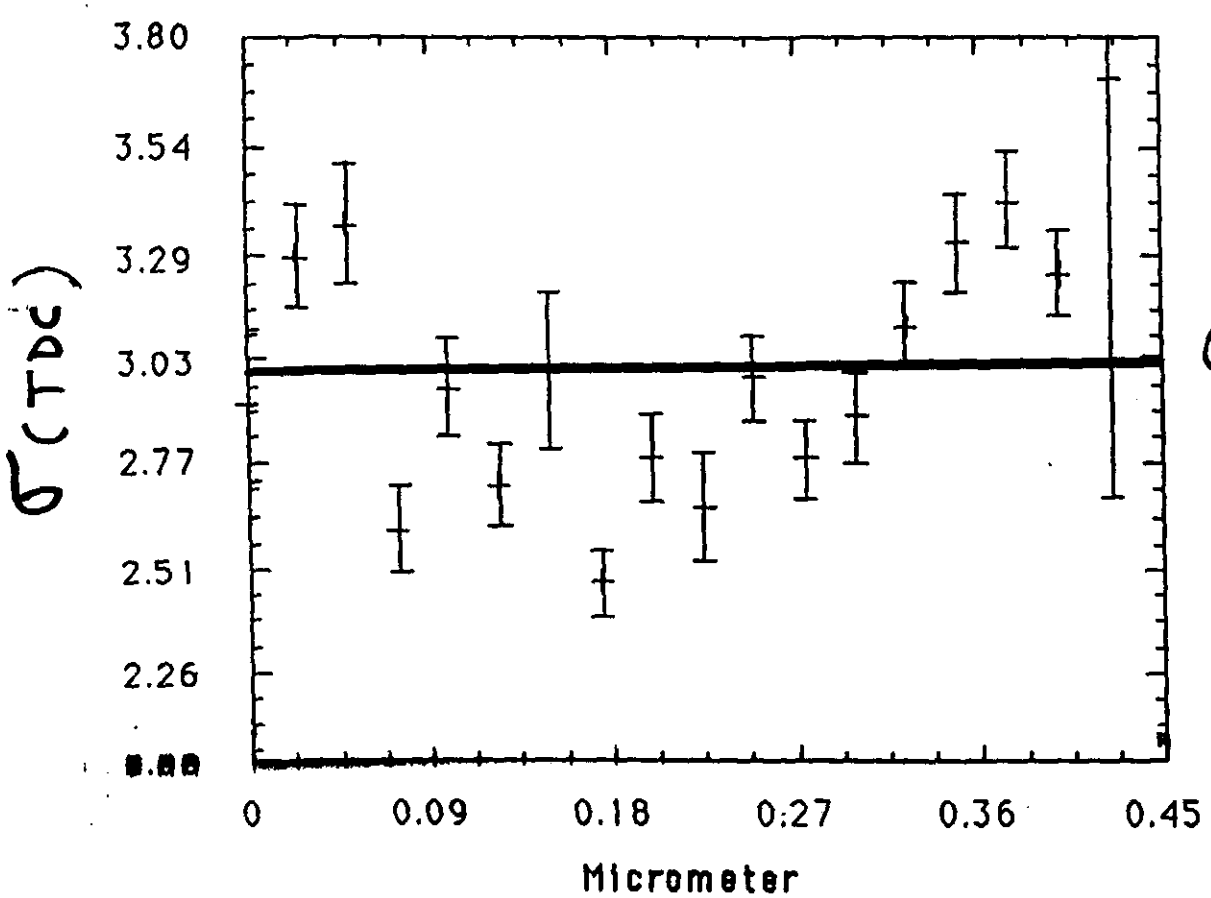
L S OSBORNE
D H BAILEY

PROTOTYPE MUON CHAMB
PARTIAL SECTION
END VIEW

D CSC91-04

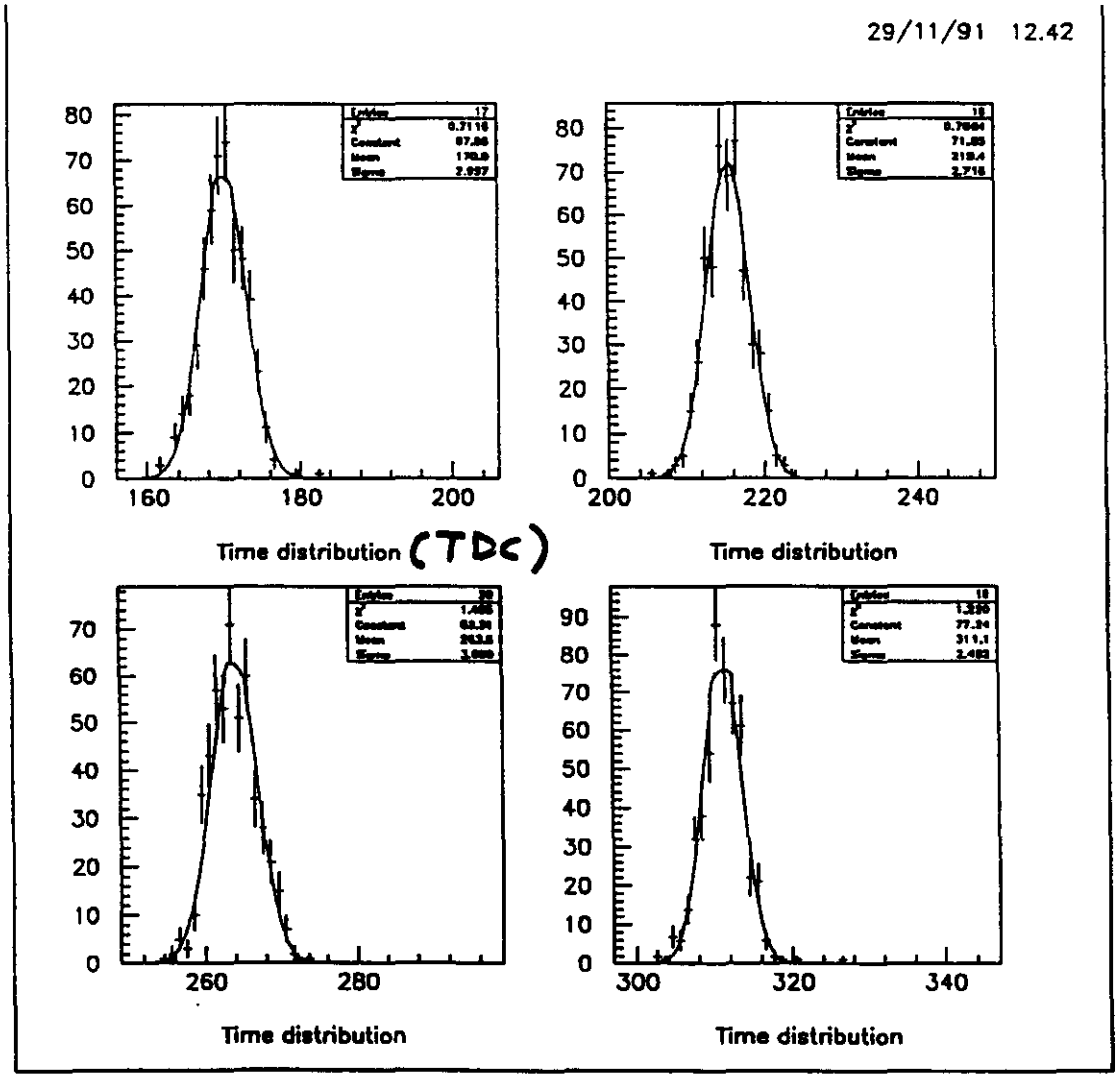


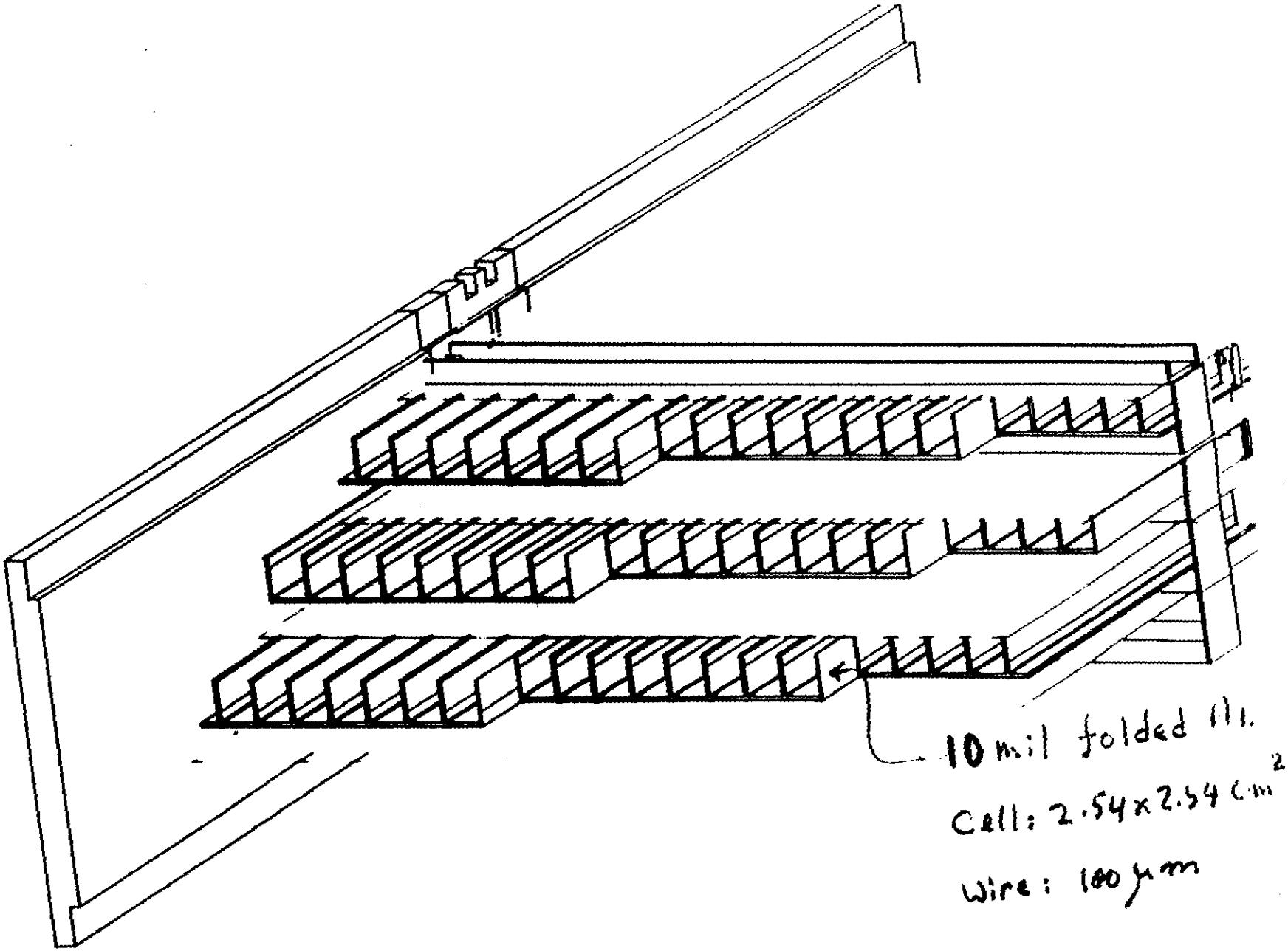
$V_d = 0.0124 \frac{c}{n}$



$\sigma_d \approx 37 \mu m$

Typical Data : 3 to 1 gas

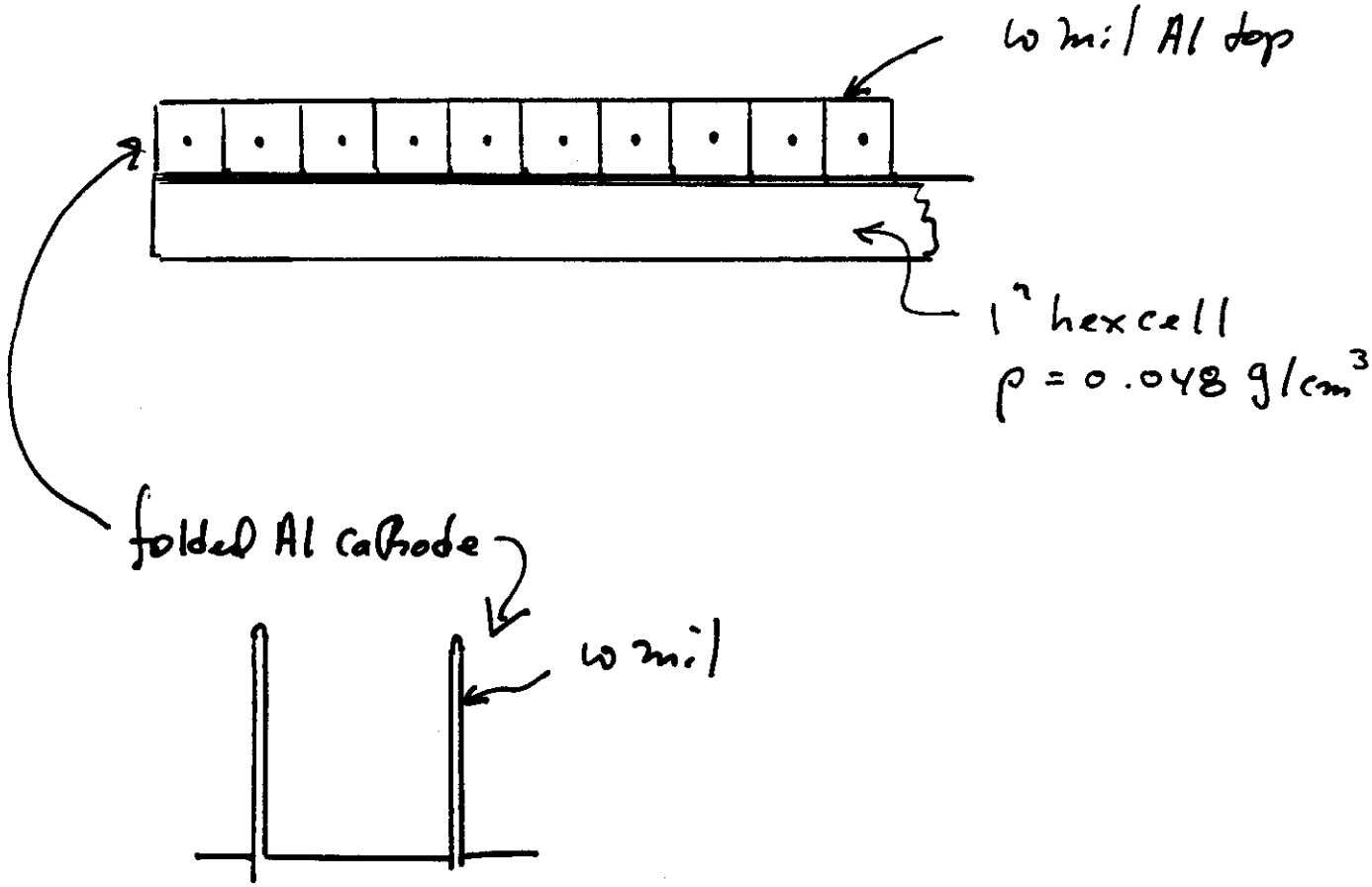



10 mil folded Ill.
Cell: 2.54 x 2.54 cm²
Wire: 100 μm

4) Studying way to reduce cathode material

8 layers $1 \times 4\,m^2$ $W = 100.6$ kg, $\underline{nX_0 = 10.5\%}$

⋮

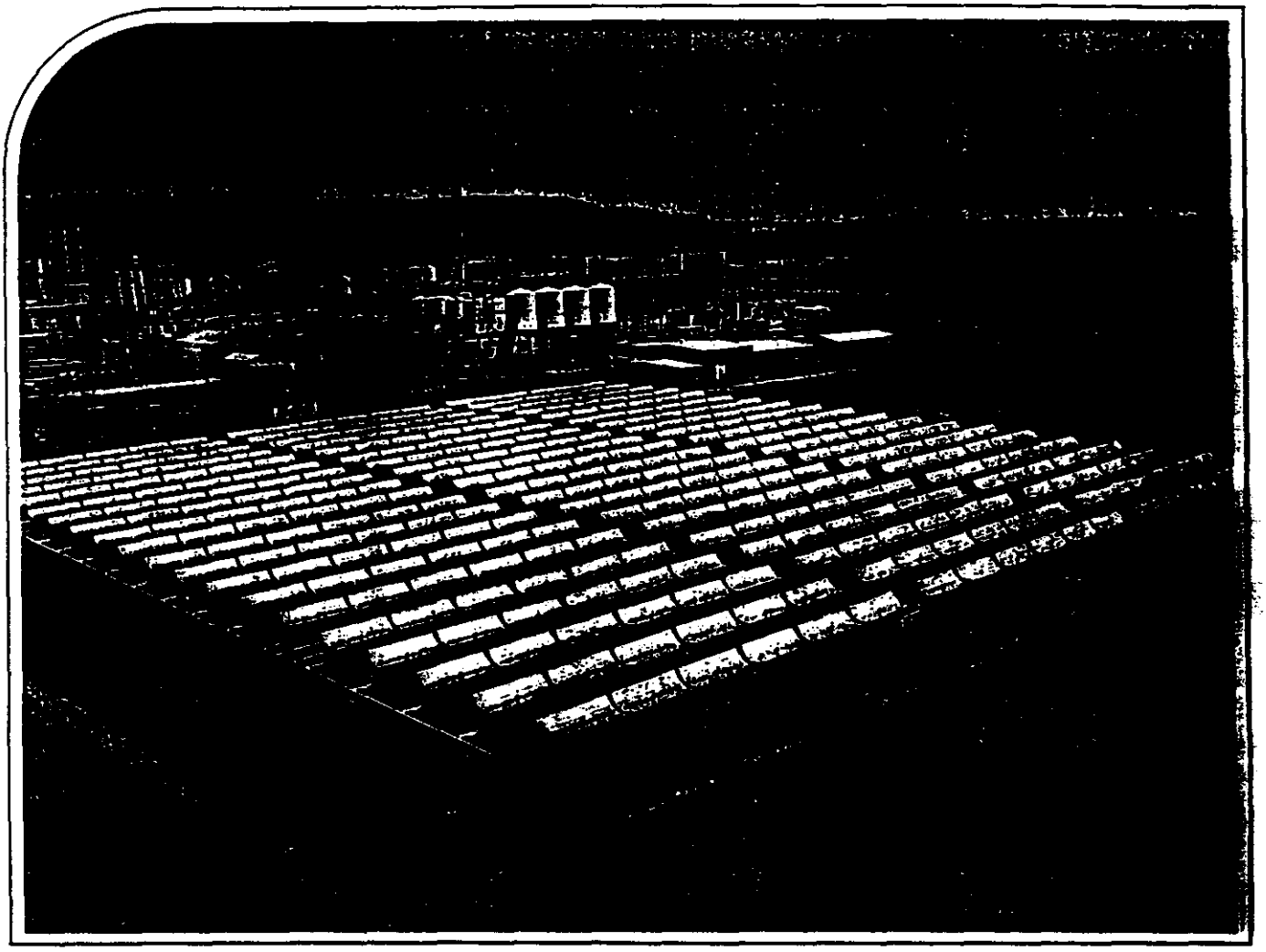


- Can cathodes be made straight enough
- is further internal support needed?
- how to implement y-strips?

5) Meeting at LLNL Dec. 16(?)

- review mechanical design
- " cost estimate
- new ideas / cathode construction ...

SOLAR GENERATED PROCESS STEAM AND HOT WATER FOR INDUSTRY



SOLAR KINETICS INC.

Solar Kinetics, Inc.
10635 King William Drive
Dallas, Texas 75220
(214) 556-2376

quote: 12" x 96" x 0.01" wall $11.88

Compare extrusion 80 mil wall $30.00

Dec 6. 1991
Kwong Lau
GEM-μ Group

SCARF/UH R&D PROGRAMS

I. COMPARATIVE STUDIES OF CATHODE MATERIAL FOR LSDT

- Candidates :
  1. Untreated Aluminum Extrusions (Al Ex)
  2. Nickel-coated Al Ex
  3. Carbon (Graphite)-coated Al Ex
  4. Others
- Variables :
  1. Plateau Length
  2. Afterpulsing
  3. Dark Current

II. SMALL (0.5 m x 1.0 m) STRIP READOUT PROTOTYPE

- 1 cm x 1 cm cell size (U-channel) Chambers
- Proportional and Streamer Modes
- Precision (1 %) Charge Readout Electronics
- Precision (1 % ?) 5mm Pitch Strips
- Measure Pulse Heights, Cross Talk, Resolution etc.

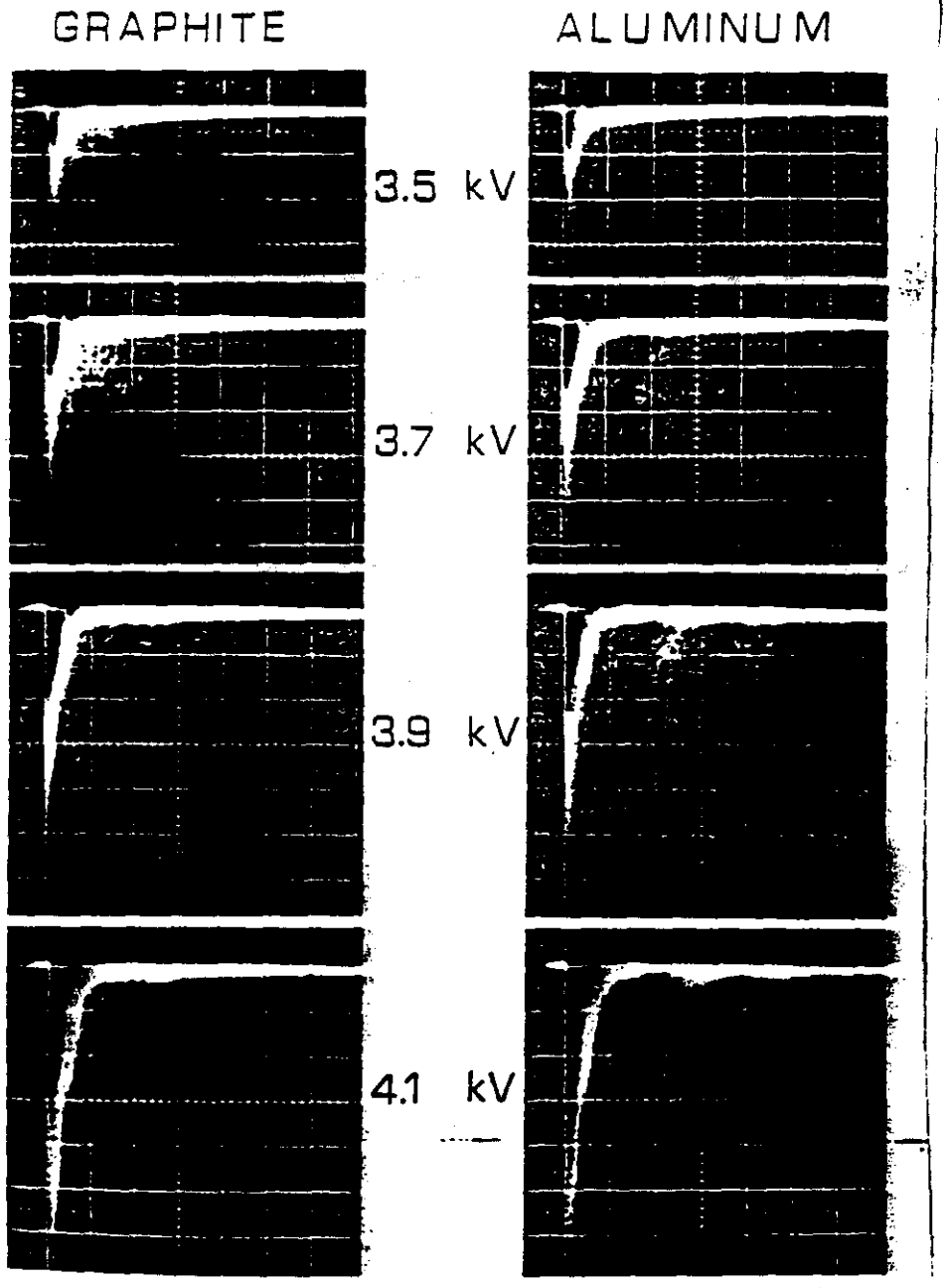
III. GAS STUDIES

- Nitrogen Contamination Effects
- Nitrogen-based Nonflammable Gas Mixtures

Taken from:

G. Battistoni et al.,

NIM 217 (1983) 433



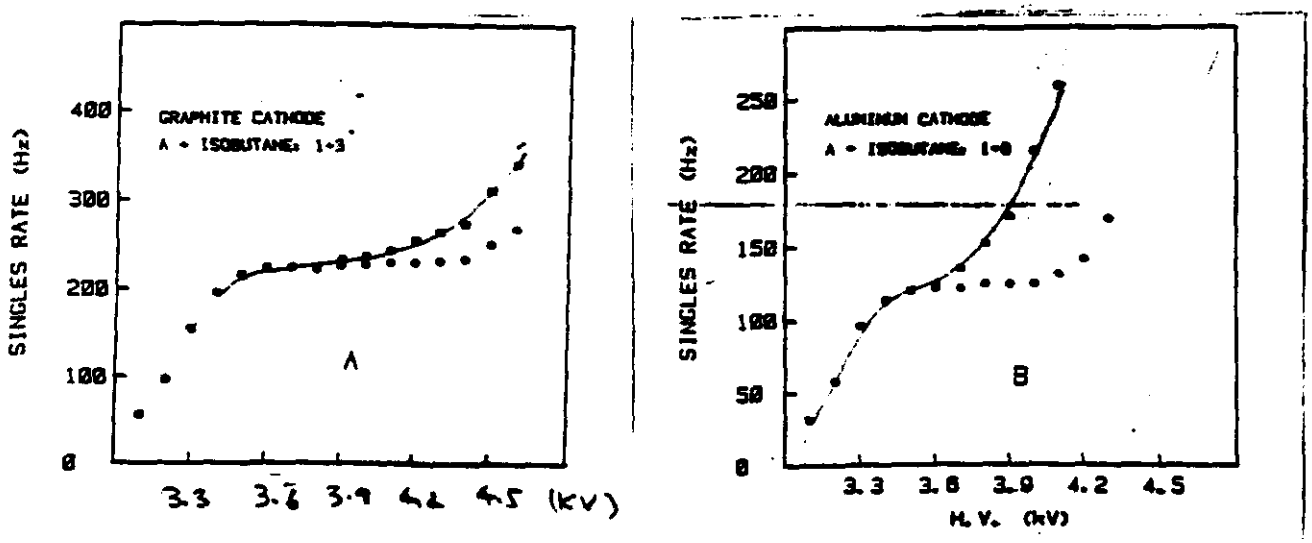


Fig. 1. Singles rate plateaus for graphite (a) and aluminum (b) cathodes; 6×6 mm² tube size, 40 μm wire. *Data*: 1 μs time shaping; *equipment*: 200 ns shaping plus recovery time.

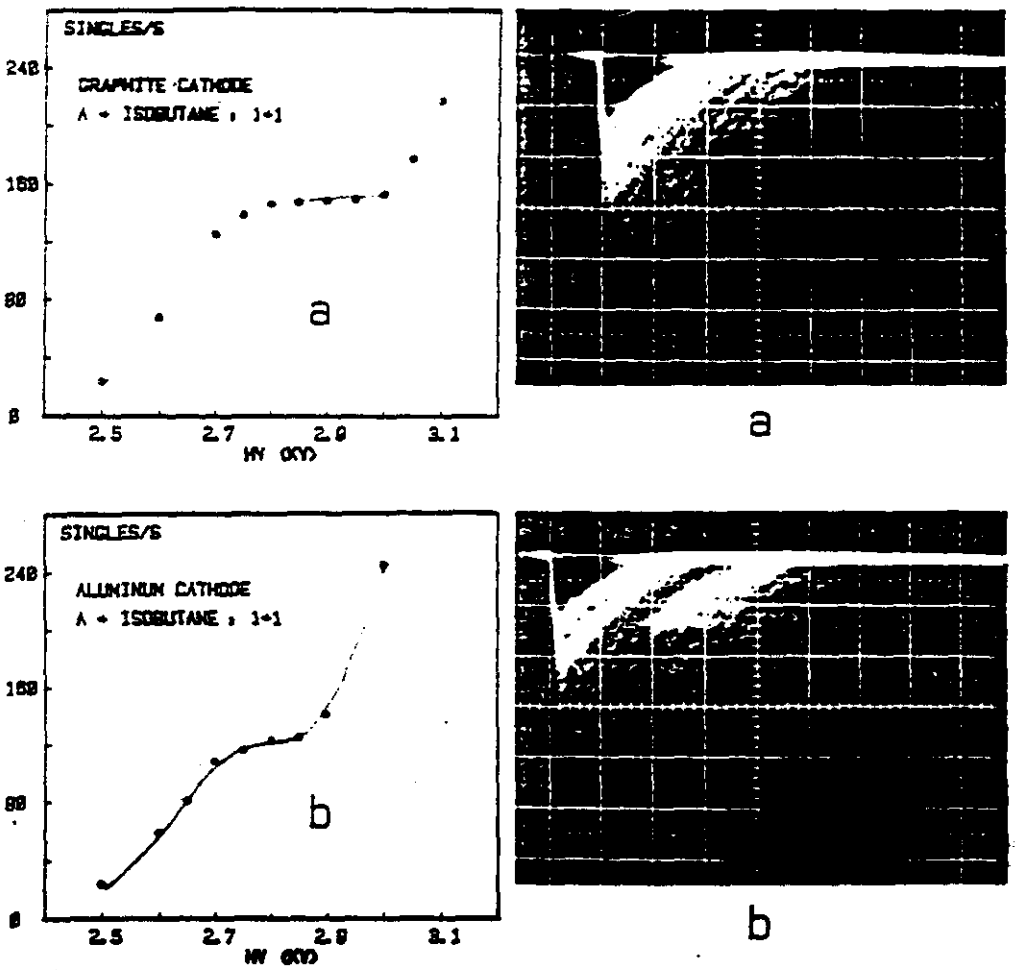


Fig. 4. Singles rate plateaux and wire pulses (at 2.9 kV), for graphite (a) and aluminum (b) cathode; 8×8 mm² tube, 40 μm wire; gas mixture: Ar+isobutane: 1+1. Vertical scale: 50 mV/div; horizontal scale: 50 ns/div.

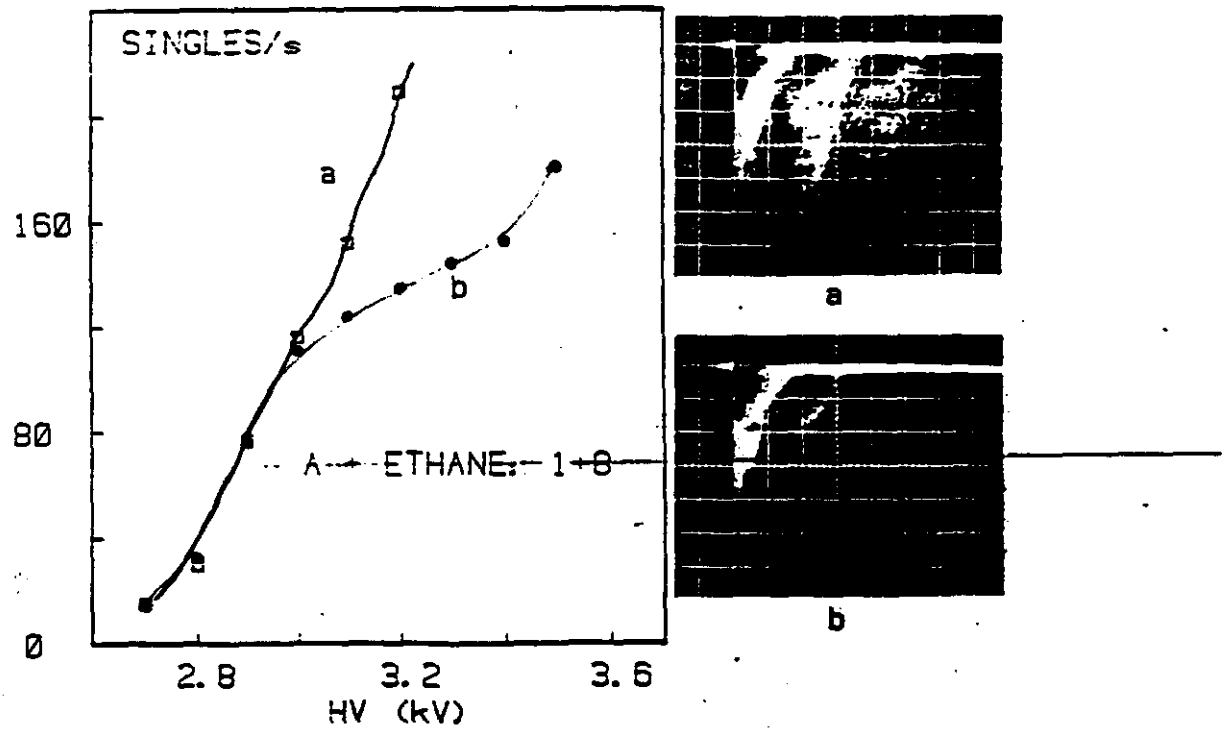
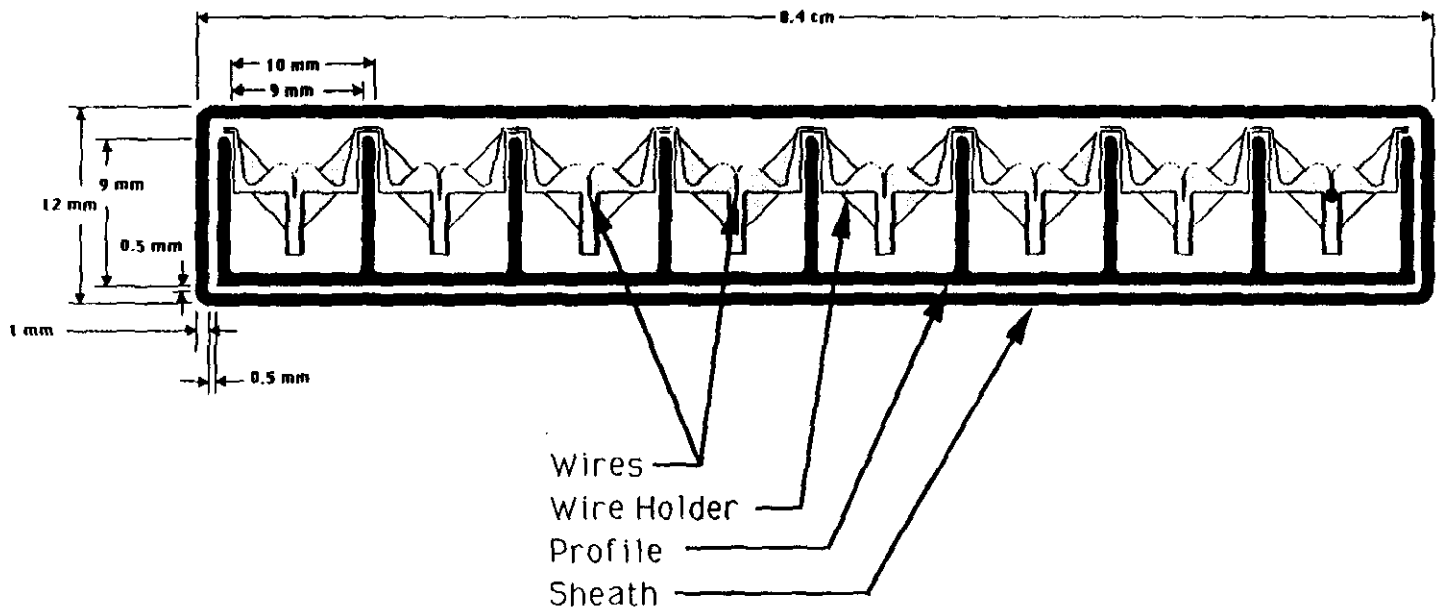
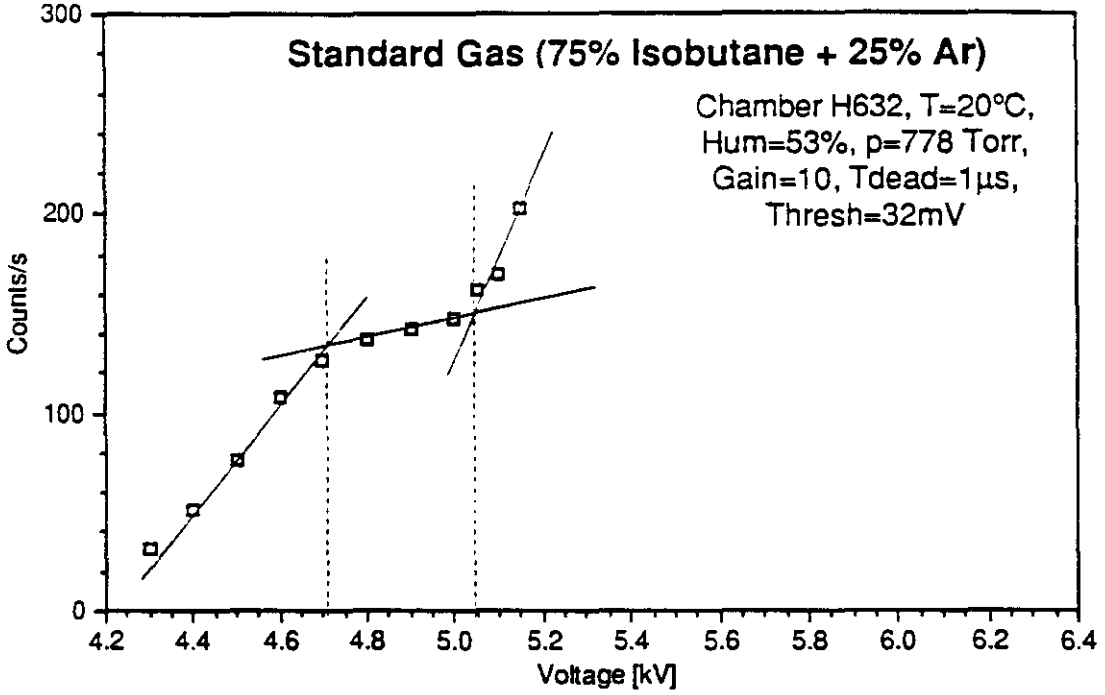
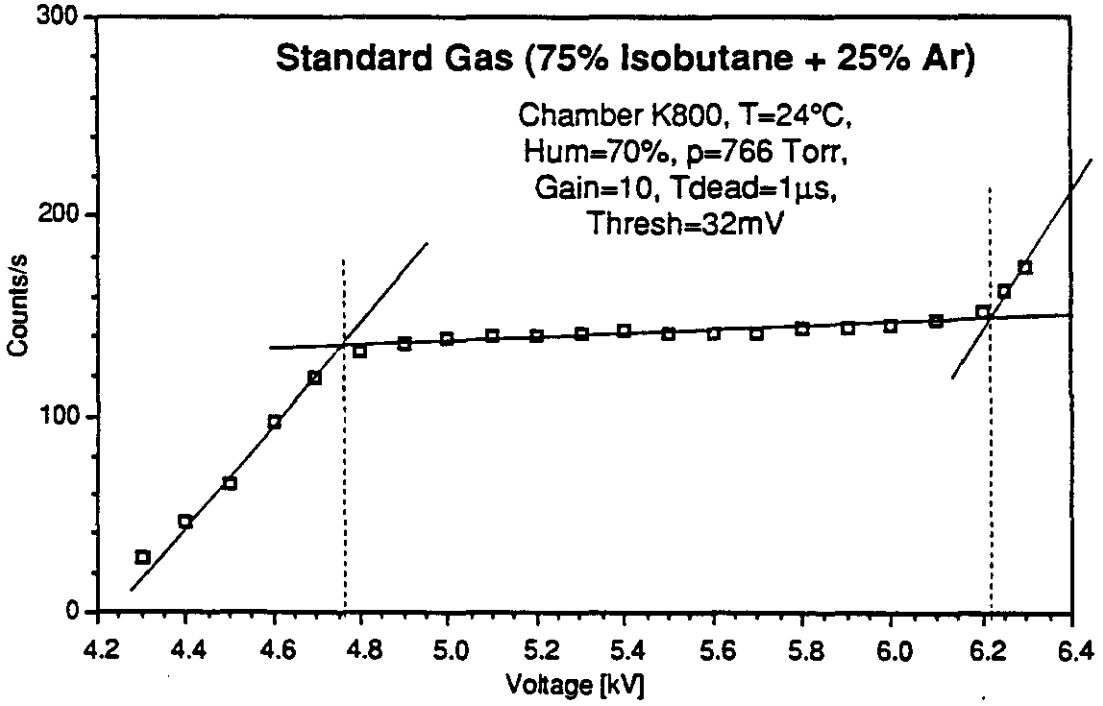
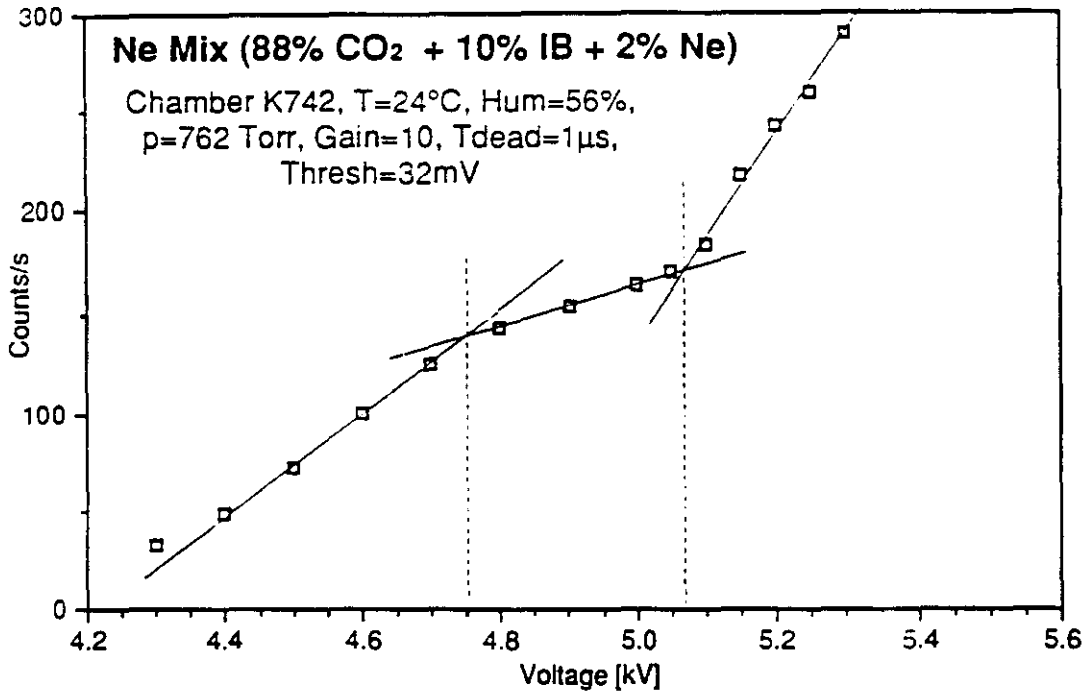


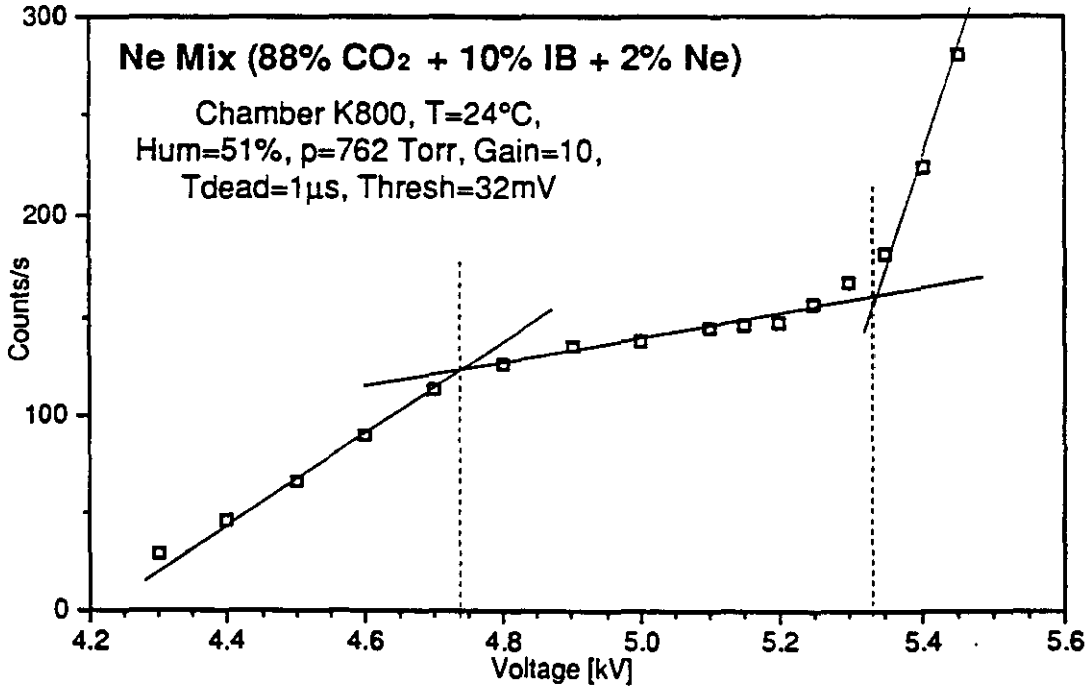
Fig. 7. Singles rate plateaux and wire pulses (at 3.2 kV) for aluminum (a) and graphite (b) cathodes; 8×8 mm² tube, 40 μm wire; gas mixture: Ar+ethane: 1+8. Vertical scale: 50 mV/div; horizontal scale: 50 ns/div.

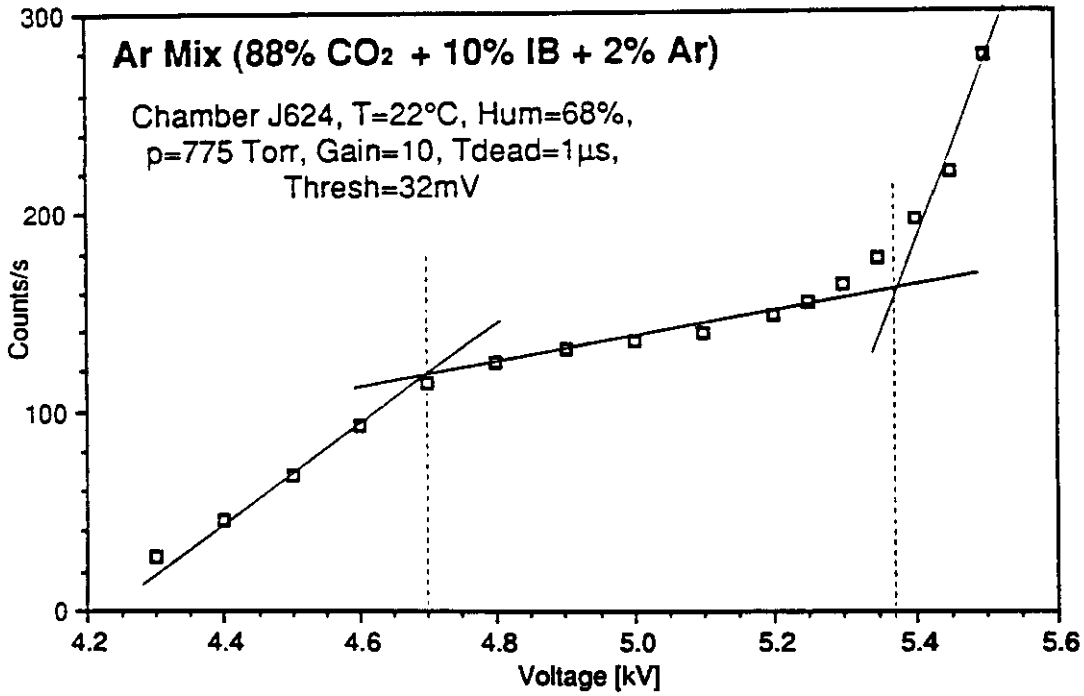

8.4 cm
10 mm
9 mm
9 mm
12 mm
0.5 mm
1 mm
0.5 mm
Wires
Wire Holder
Profile
Sheath

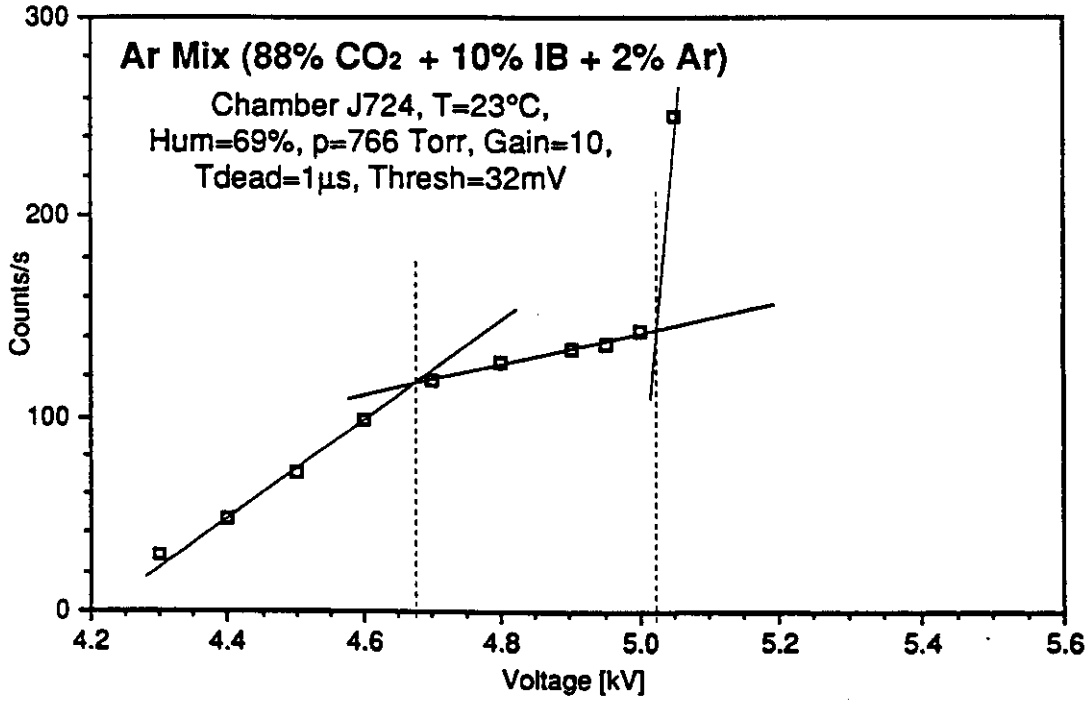

Standard Gas (75% Isobutane + 25% Ar)
Chamber H632, T=20°C,
Hum=53%, p=778 Torr,
Gain=10, Tdead=1µs,
Thresh=32mV
Counts/s
Voltage [kV]
0
100
200
300
4.2
4.4
4.6
4.8
5.0
5.2
5.4
5.6
5.8
6.0
6.2
6.4

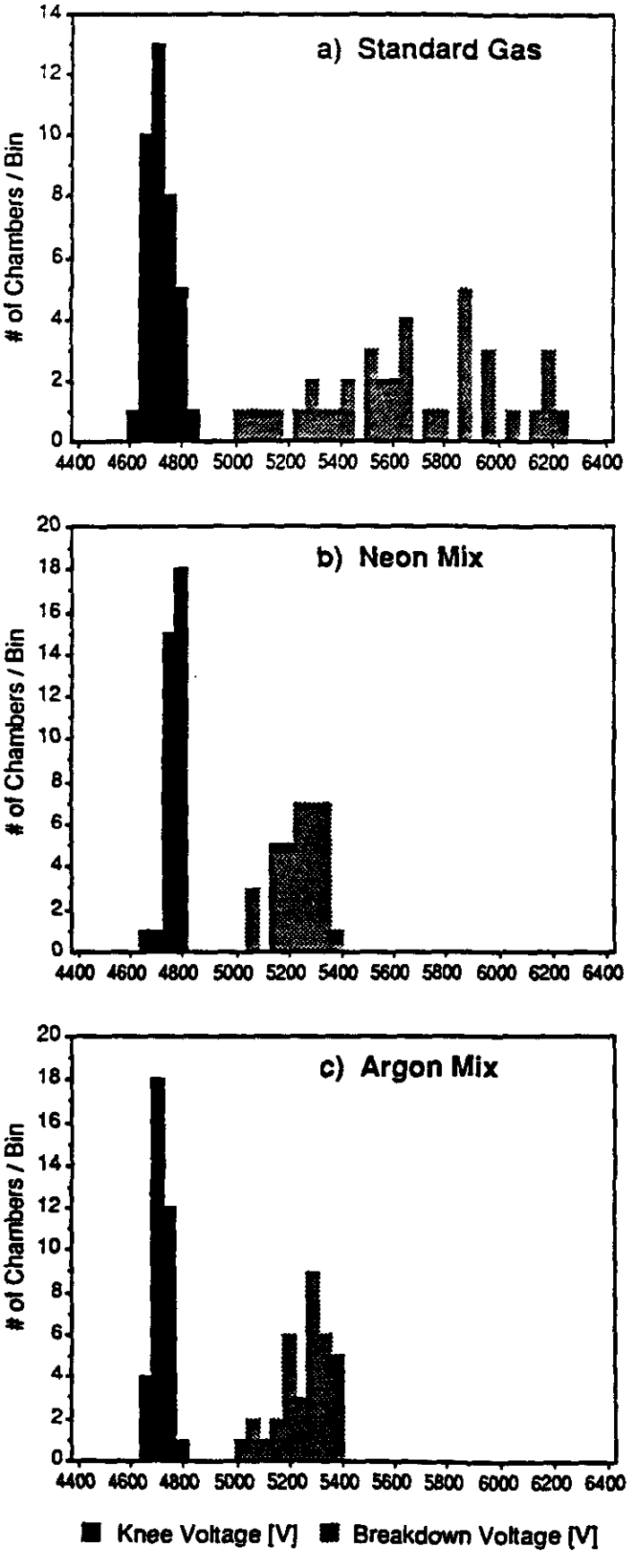

Standard Gas (75% Isobutane + 25% Ar)
Chamber K800, T=24°C,
Hum=70%, p=766 Torr,
Gain=10, Tdead=1µs,
Thresh=32mV
Counts/s
Voltage [kV]
0
100
200
300
4.2
4.4
4.6
4.8
5.0
5.2
5.4
5.6
5.8
6.0
6.2
6.4

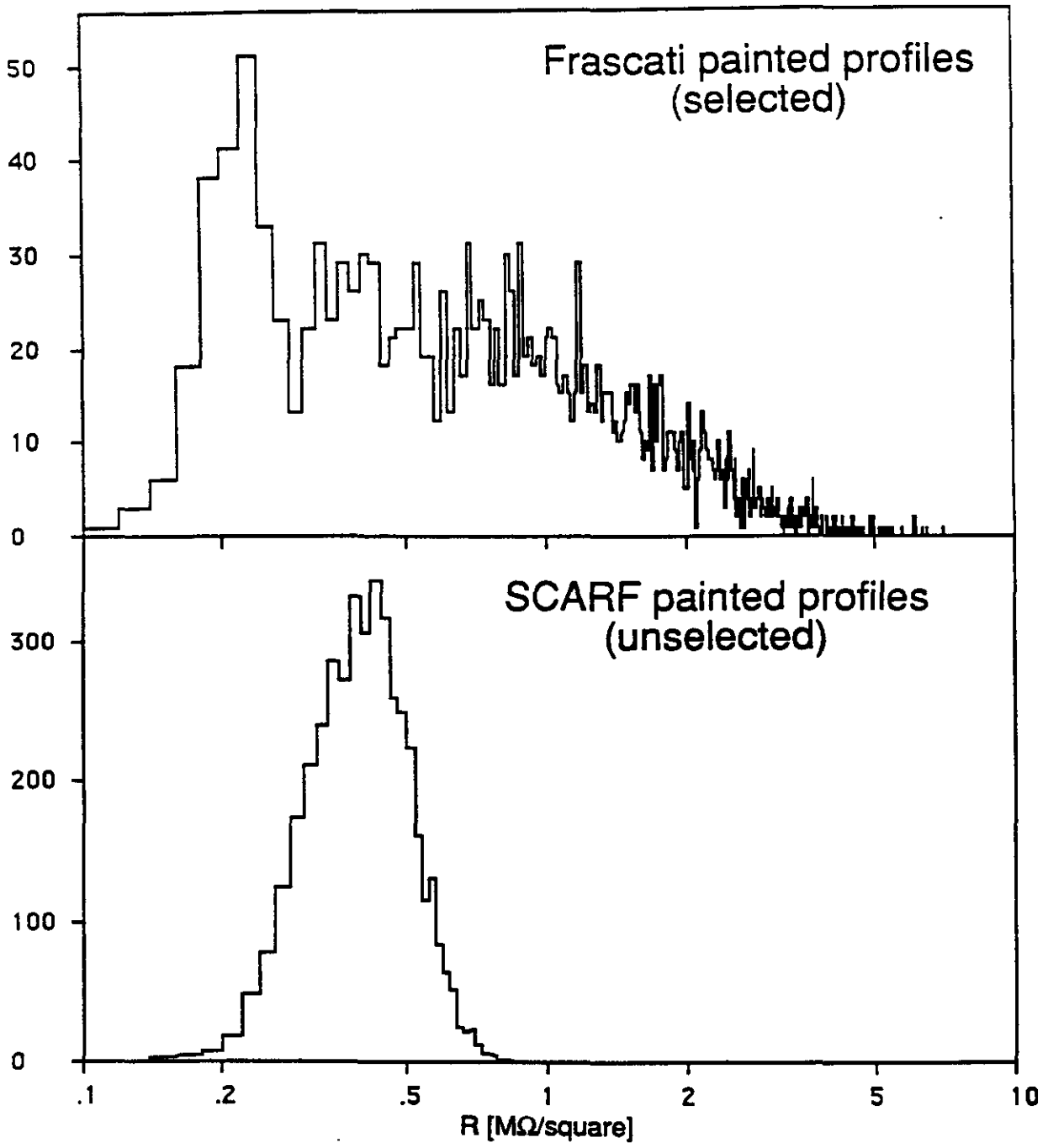

Ne Mix (88% CO2 + 10% IB + 2% Ne)
Chamber K742, T=24°C, Hum=56%,
p=762 Torr, Gain=10, Tdead=1µs,
Thresh=32mV
Counts/s
Voltage [kV]
0
100
200
300
4.2
4.4
4.6
4.8
5.0
5.2
5.4
5.6

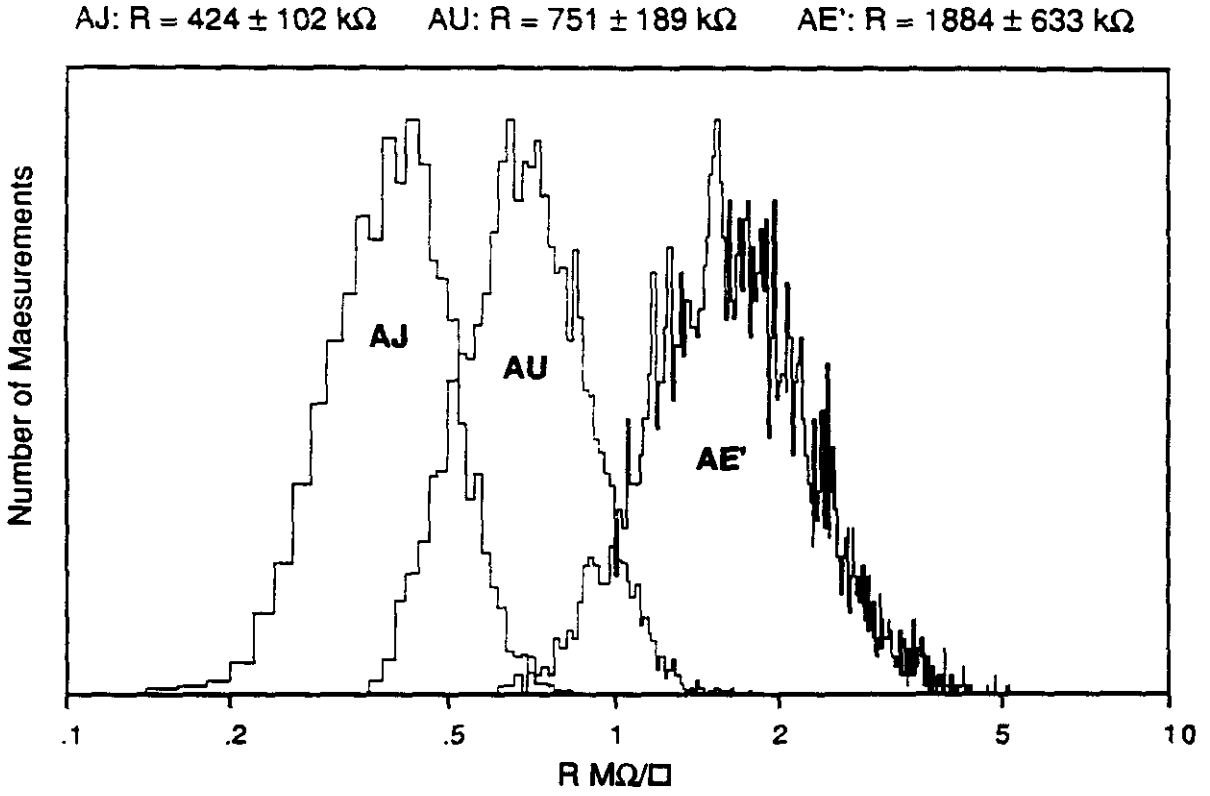

Ne Mix (88% CO2 + 10% IB + 2% Ne)
Chamber K800, T=24°C,
Hum=51%, p=762 Torr, Gain=10,
Tdead=1µs, Thresh=32mV
Counts/s
Voltage [kV]
0
100
200
300
4.2
4.4
4.6
4.8
5.0
5.2
5.4
5.6

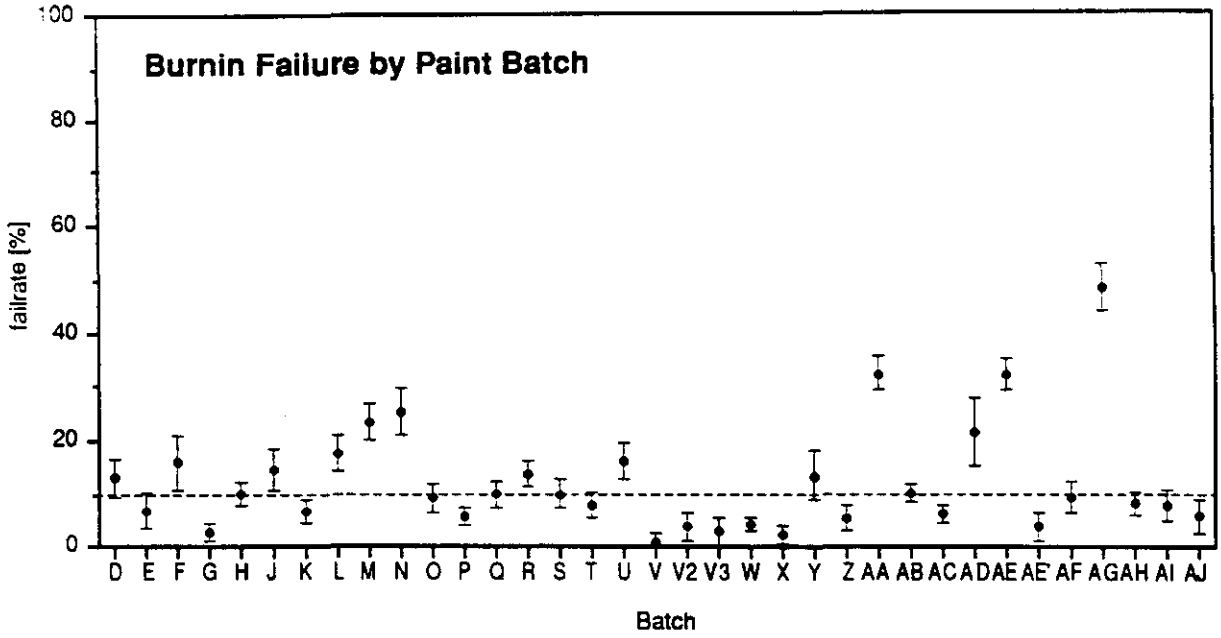

Ar Mix (88% CO2 + 10% IB + 2% Ar)
Chamber J624, T=22°C, Hum=68%,
p=775 Torr, Gain=10, Tdead=1µs,
Thresh=32mV
Counts/s
Voltage [kV]
0
100
200
300
4.2
4.4
4.6
4.8
5.0
5.2
5.4
5.6

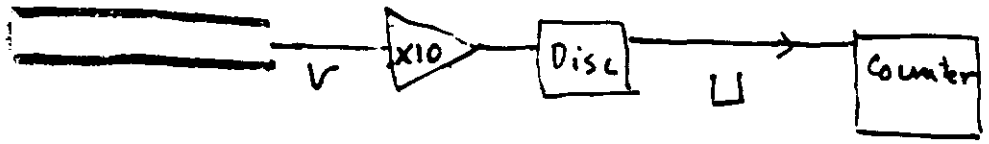

Ar Mix (88% CO2 + 10% IB + 2% Ar)
Chamber J724, T=23°C,
Hum=69%, p=766 Torr, Gain=10,
Tdead=1µs, Thresh=32mV
Counts/s
Voltage [kV]
0
100
200
300
4.2
4.4
4.6
4.8
5.0
5.2
5.4
5.6


a) Standard Gas
b) Neon Mix
c) Argon Mix
# of Chambers / Bin
0
2
4
6
8
10
12
14
16
18
20
4400 4600 4800 5000 5200 5400 5600 5800 6000 6200 6400
Knee Voltage [V]
Breakdown Voltage [V]


Frascati painted profiles
(selected)
SCARF painted profiles
(unselected)
50
40
30
20
10
0
300
200
100
0
.1
.2
.5
1
2
5
10
R [MΩ/square]


AJ: R = 424 ± 102 kΩ
AU: R = 751 ± 189 kΩ
AE': R = 1884 ± 633 kΩ
Number of Maesurements
AJ
AU
AE'
.1
.2
.5
1
2
5
10
R MΩ/□


Burnin Failure by Paint Batch
failrate [%]
100
80
60
40
20
0
D E F G H J K L M N O P Q R S T U V V2 V3 W X Y Z AA AB AC AD AE AE AF AG AH AI AJ
Batch


x10
Disc
Counter

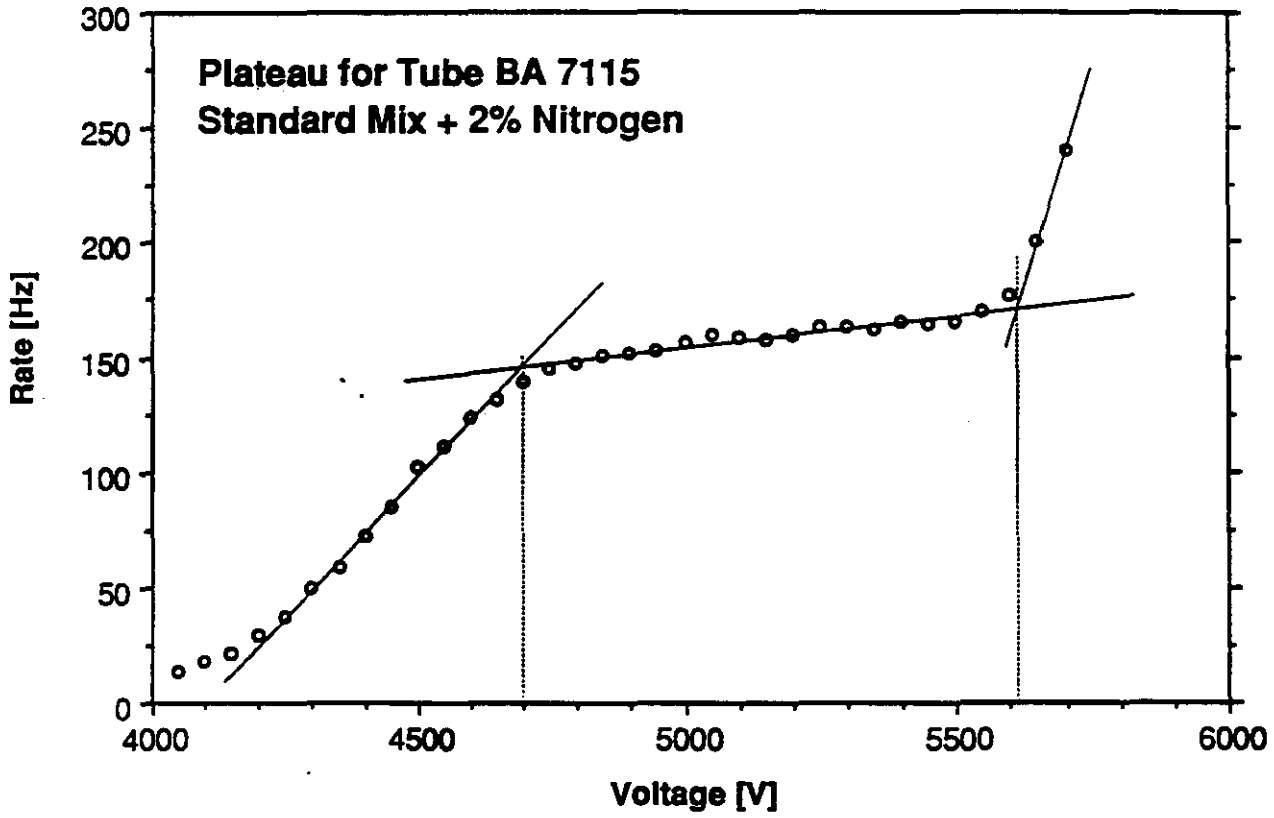
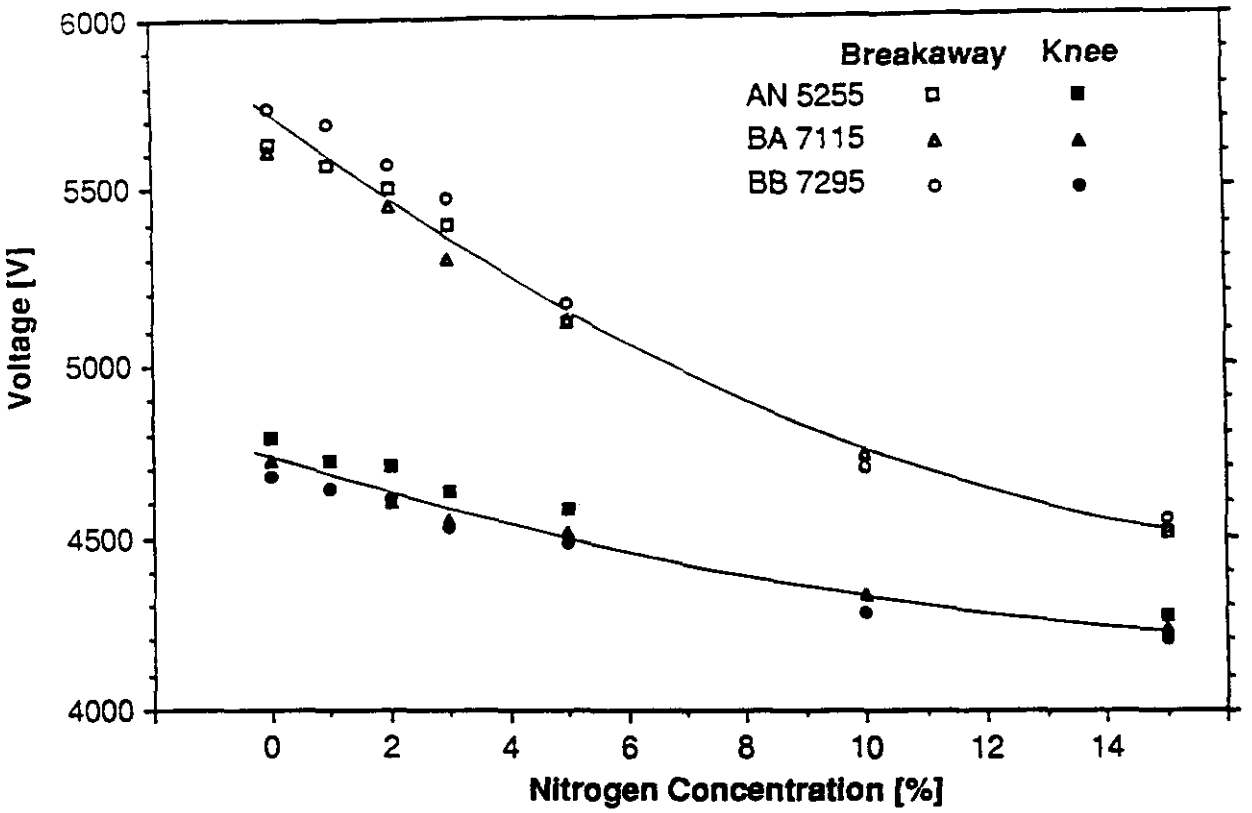

Plateau for Tube BA 7115
Standard Mix + 2% Nitrogen
Rate [Hz]
Voltage [V]
0
50
100
150
200
250
300
4000
4500
5000
5500
6000

Fig 1


Breakaway
Knee
AN 5255
BA 7115
BB 7295
Voltage [V]
6000
5500
5000
4500
4000
0
2
4
6
8
10
12
14
Nitrogen Concentration [%]

R. McNeil

Muon Simulations for GEM
(The Speaker's Prejudices)

The GEM Muon Simulation Group is forming.
Some participants will meet today.

Four kinds of Muon Simulations:

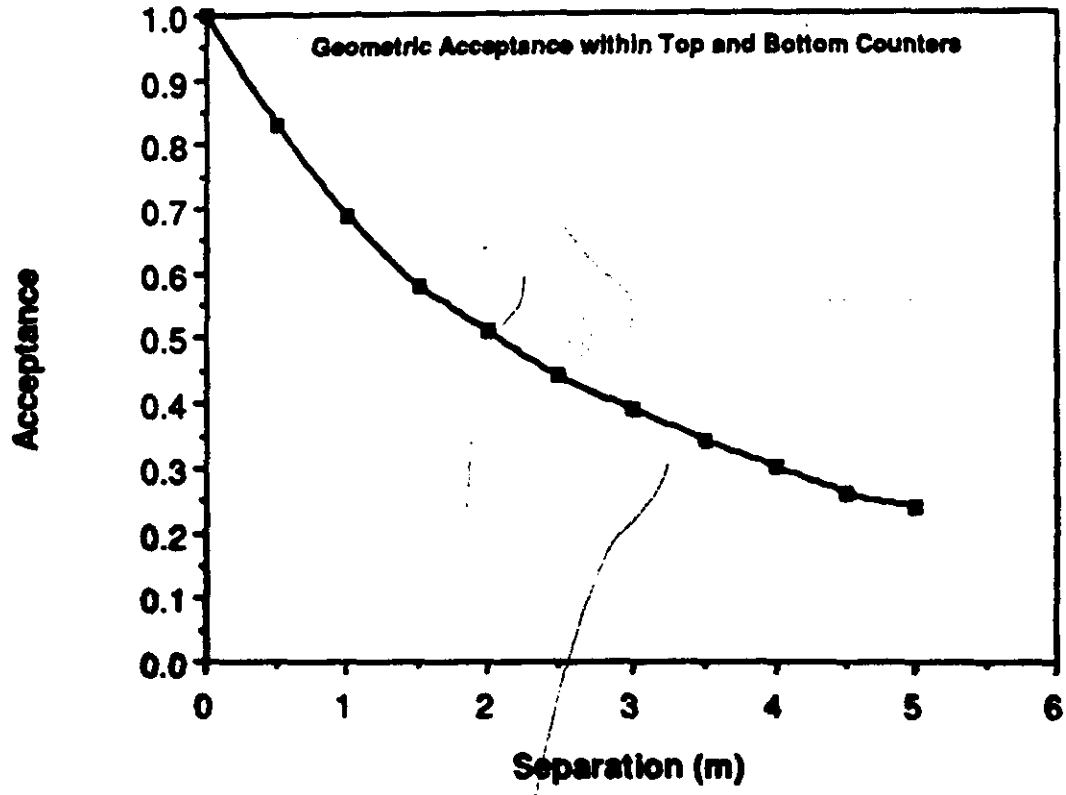
1. Muon Background Simulations
   - Hadron-induced backgrounds - Punchthrough/decay
   - Muon-induced backgrounds - δrays, showers from μ rad
   - Beam Pipe Sprays

2. Muon Measuring System Performance Simulations
   - dP/P Studies - Alligument, μ Eloss, mult. scat.
   - Acceptance studies: η coverage, effic., cracks,
   - Signal readout linkage - reduction of channels
   - Pattern Recognition studies - Tracking, cellsize, chaml placem

3. Trigger System Performance Simulations
   - Trigger Rate Simulations - Thresholds; $P_\perp$, η
   - Trigger device parameters - RPC & Pad Chamber:
   - Fake triggers in high Multiplicity events - Pattern Rec

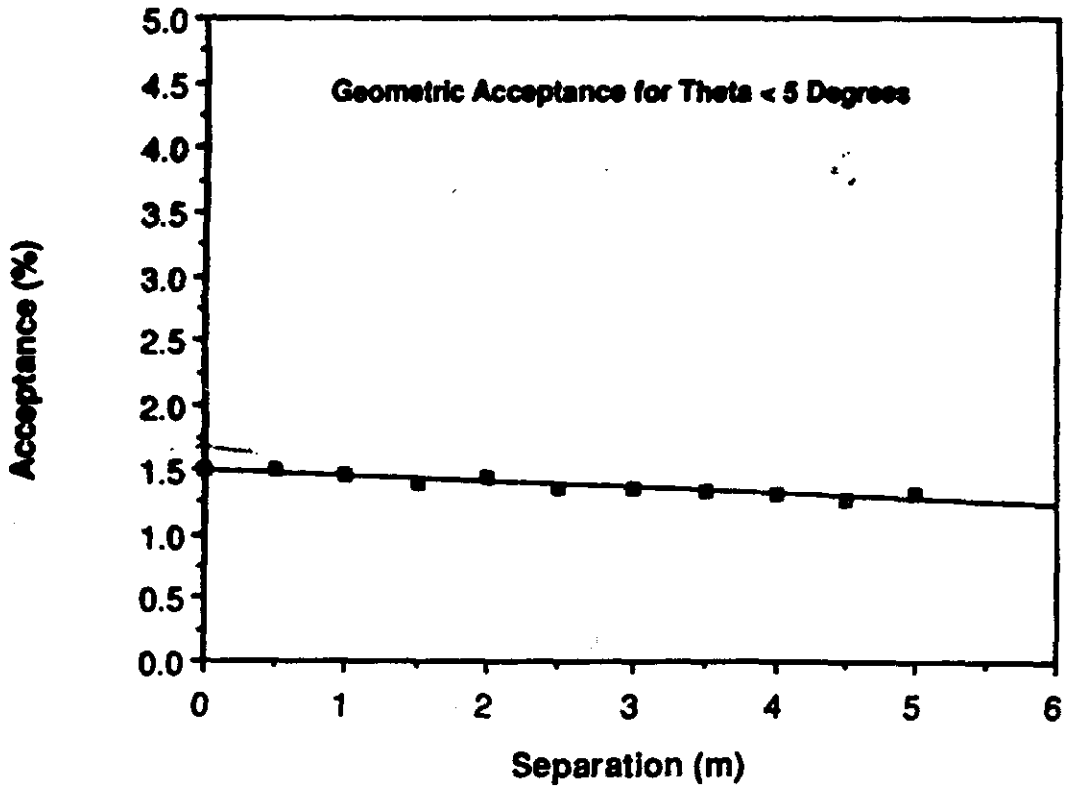
4. "Muon Physics" Simulations
   - Requirements Set by Physics Benchmarks - H, Z', Top, $\tilde{g}$, ... on acceptance, dP/P, ± sign determ,
   - Impact of Muon backgrounds

Assuming $J(\theta,\varphi) = J_0 \cos^2\theta$



$\therefore R \sim 20 \mu s/m^2$

$P_\mu > 1.4$ GeV



$R \sim 0.8 \mu s/m$

$P_\mu > 1.4$ GeV

Some critical issues/goals to address in the near future

1. Validation of GEANT - what are the limitations?
   Fine tuning of GEANT Energy Cutoffs (Standardize)
   Compare with Experimental Data - CERN, FNAL, BNL, ...

Participants : Stony Brook, LSU,

2. How thick to make Calorimeter (hadron absorber)
   << Sets Scale for entire detector >>
   Cracks in Calorimeter for Cables?, fibers nearly projective

Participants : LSU, BU,

3. Shielding Beam Pipe Sprays
   How much shielding needed to protect muon detector

Participants : ?

4. Criteria for Muon Chamber Design
   How many layers, configuration, acceptance, efficiencies $\frac{dp}{p}$
   cell size (need to consider each technology low/hi Lum)

Participants : BU, LSU, MIT

5. Criteria for Trigger System Design
   Configuration, effic., fake triggers, Pattern Recognition

Participants : BU, Stony Brook, BNL, MIT, LSU, Colombia

6. Initiate Pattern Recognition Studies for μ chamber
   Event reconstruction of benchmark processes
   Feedback results to Chamber design. Linkage of signa
   Is full GEANT simulation necessary?

Participants : [illegible]

Needs

1. More Participants - recruiting

2. Coordination of existing/planned efforts

3. Standardize Simulation Efforts
   Baseline Simulation Parameters/configuration

   GEM Simulation Software Package
   Generators + Detector Simulation Software + Geometry

ISAJET Pythia ⋮	GEANT fast Punchthrough Subrout.	Tracking Cal Muons

4. Computing ?

Irwin Pless

(1)

GEM MUON TRIGGER

M. MOHAMMADI

R. McNEIL

V. POLYCHRONAKOS

L. ROSENSON

M. SEMAN (ADVICE)

T. BOLTON (ADVICE)

E. S. HAFEN

K. VON BIBBER

M. WIDGOFF

C. YANAGISAWA

M. ATIYA

S. VANYASHA

O. FACKLER

TASKS

1. SIMULATION

2. CONCEPTUAL DESIGN

3. HARDWARE

GOALS:

1. BEAM CROSSING TAG $\cong$ 10 NANOSEC

2. $P_\perp$ TRIGGER $\cong$ 10 NANOSEC

   a. RANGE

      GREATER THAN:

      10 GEV

      20 GEV

      30 GEV

      50 GEV

   b. BARREL + FORWARD

THE RESISTIVE PLATE COUNTER RPC BARREL SUBSYSTEM OF GEM

20 October 1991

I. INTRODUCTION

RPCs will be used in the barrel component of the GEM muon subsystem to perform the following functions:

A. Furnish the beam crossing tag.
B. Furnish the first level muon trigger.
C. Furnish the Z-coordinate for the muon tracks.
D. Furnish the muon tracking "roads" for the precision tracking elements.
E. Furnish an anti-coincidence trigger to veto cosmic rays.
F. Furnish a cosmic ray coincidence trigger to test GEM subsystems.

These items will be discussed in Section IV. In Section II we will present the characteristics of an RPC. In Section III we will describe the RPC geometry inside the muon subsystem. As stated above, in Section IV we will discuss the functions that the RPC subsystem will perform as part of GEM. In Section V we will enumerate the channel count and in Section VI we will estimate the budget for the RPC subsystem.

II. RPC CHARACTERISTICS

The original Resistive Plate Chambers, developed in Rome ten years ago, work at an uniform electric field of ~ 40 kV/cm between parallel electrode plates of a plastic phenolic material (bakelite) with a resistivity $\rho \cong 10^{11}\ \Omega$ cm. The plates, 2 mm thick, are kept separated at a distance of 2 mm by spacers of polyvinyl chloride. Gas tightness is insured by a frame of the same material. The sensitive volume is filled with a gas mixture of argon/butane plus a small percentage of freon 13B1 at normal pressure. The generating field electrodes are layers of a graphite varnish coating the outer surface of the plates. They are isolated from the read-out electrodes by a 300 μm thick film. A section of the chamber is shown in Fig. 1.

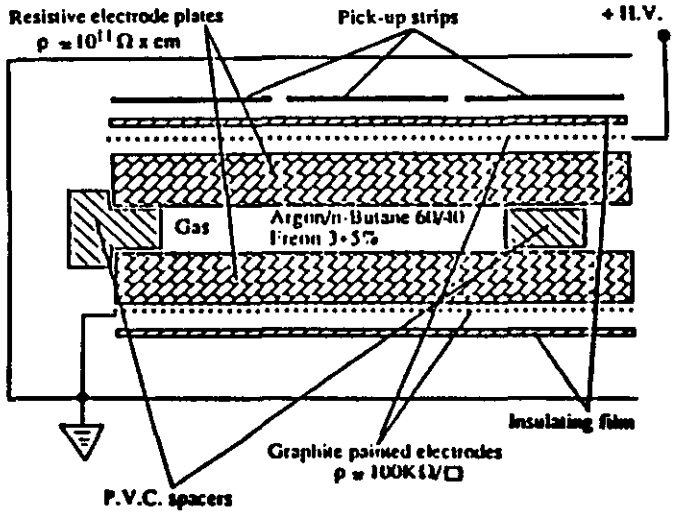


Fig. 1

It is quite possible that the RPCs used in GEM will use quite a different insulating material than the bakelite used in the original resistive plate detectors.

The characteristics of an RPC are displayed in Table I.

Table 1 - Characteristics of RPCs

plate bulk resistivity	$10^{11} \pm \Omega$ cm
electric field	~ 40 kV/cm
pulse charge	10^2 pC
pulse rise time	~ 3 ns
pulse duration	~ 10 ns
discharge area	0.1 cm^2
recovery time	10^{-2} s
time resolution	~ 1 ns

The efficiency of an RPC has been measured and is consistent with 100%. For most RPCs the active area is only 97% of the geometric area due to the dead regions caused by the spacers. The RPCs used in GEM will have the dead region caused by spacers reduced to less than 1%.

III. THE RPC GEOMETRY INSIDE THE MUON SUBSYSTEM

The RPC subsystem will be deployed in three concentric cylinders in the barrel. The inner cylinder will have a radius of 3.70 meters and a length of 6.64 meters. The central cylinder will have a radius of 6.00

meters and a length of 10.48 meters. The outer cylinder will have a radius of 8.30 meters and a length of 14.50 meters. Each cylinder will be formed by sections subtending 22.5 degrees. The RPC system will completely shadow the precision muon measuring components.

Each layer of RPCs in a section will have X-strips (perpendicular to the magnetic field) and Y-strips (parallel to the magnetic field). The X-strips measure the muon trajectories in the non-bend plane and the Y-strips measure the muon trajectories in the bend plane.

The X-strips on the inner cylinder will be 3 centimeters wide; on the central cylinder they will be 1.2 centimeter wide; on the outer cylinder they will be 6 centimeter wide. All Y-strips will be 1.3 centimeters wide. The choice of these widths will be explained in Section IV.

IV. FUNCTIONS OF THE RPC SUBSYSTEM

A. Furnish the beam crossing tag.

Since the time between beam crossings is 16 nanoseconds, the maximum error allowed in measuring this crossing time cannot exceed 10 nanoseconds. The X-strip on the inner RPC cylinder has a length of 1.5 meters. Therefore the maximum transit time down this strip is about 8 nanoseconds. If the RPC jitter time is less than two nanoseconds, we can use the pulse from the short RPC strips as our beam crossing tag. This is a simple and inexpensive beam crossing tag.

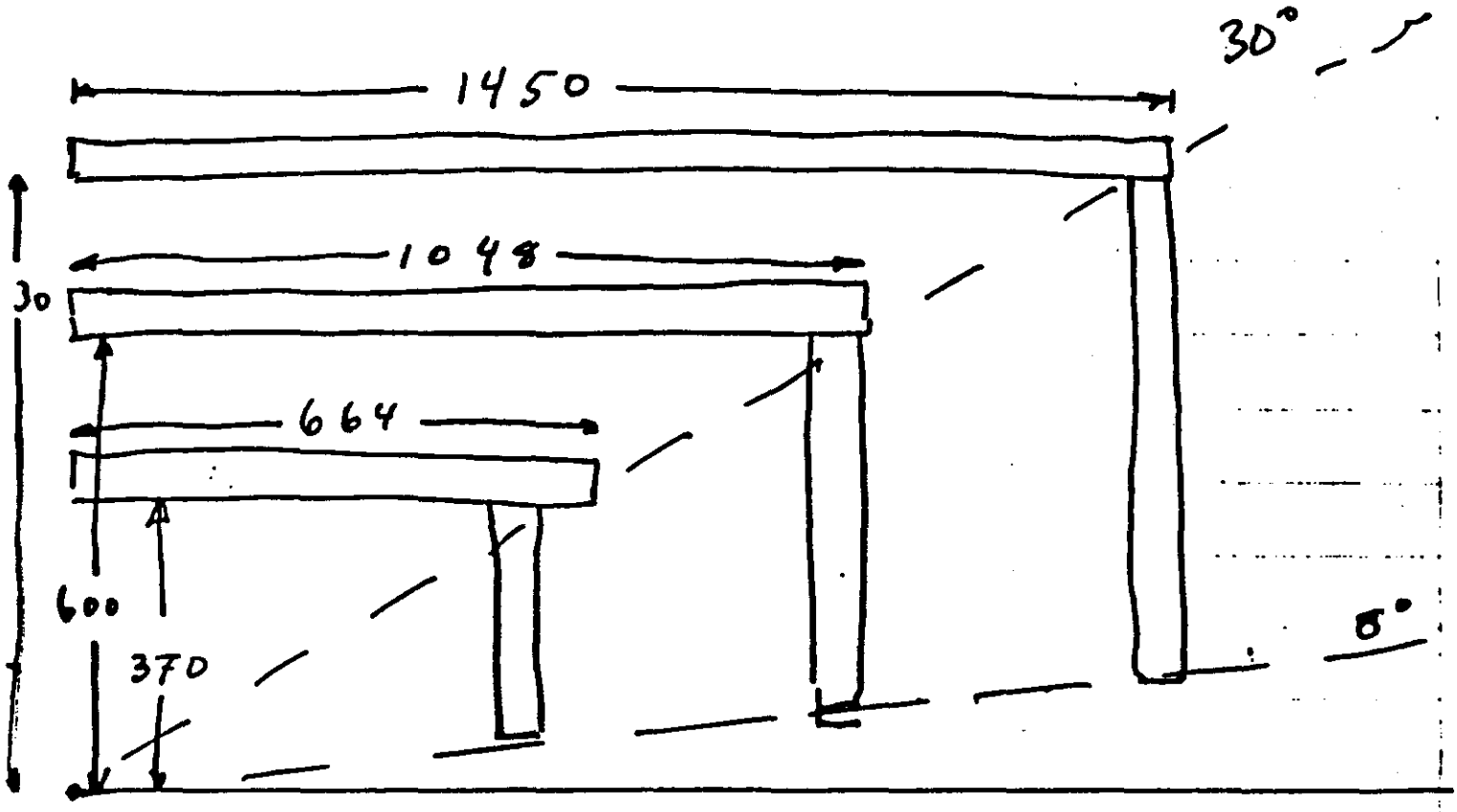
B. Furnish the first level trigger.

The first level trigger will have four components:

NO CHANGE → 1. Three fold coincidence timing in the non-bend plane
NO CHANGE 2. Straight line space fit to three points in the non-bend plane.
NO CHANGE 3. Three fold coincidence timing in bend plane.
CHANGE → 4. A three point space arc fit in the bend plane. The sagitta of the arc will measure the muon momentum.

The coincidence timing and space point fitting in the non-bend plane eliminates all low energy tracks and random noise from the trigger. The coincidence timing in the bend plane placed in coincidence timing with the non-bend plane further reduces the random noise problem. The arc fitting in the bend plane

PROPOSED GEM
MUON TRIGGER



~~BARREL - BEND PLANE - 3 CM STRIPS~~
~~BARREL - NON BEND PLANE~~
~~OUTER - 3 CM STRIPS~~
~~INNER - 3 CM STRIPS~~
~~MIDDLE - 1 CM STRIPS~~

BASE LINE DESIGN

determines which momentum activates the trigger.

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

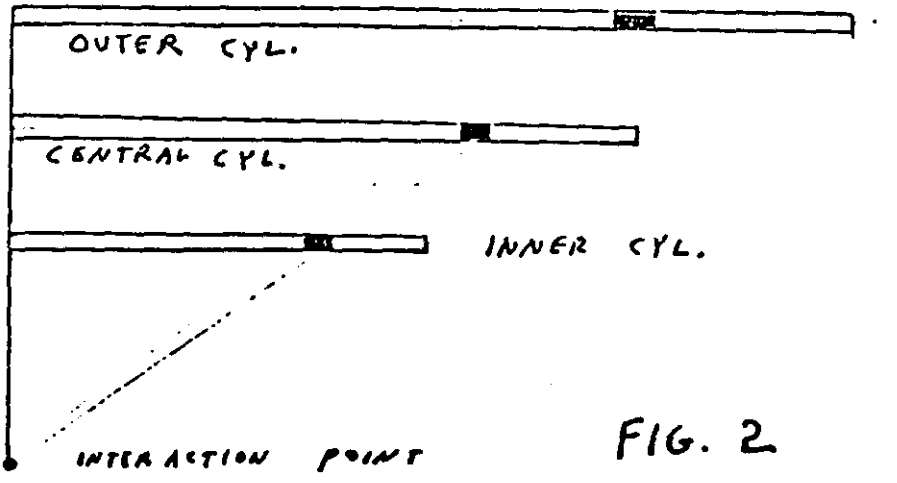


FIG. 2

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.

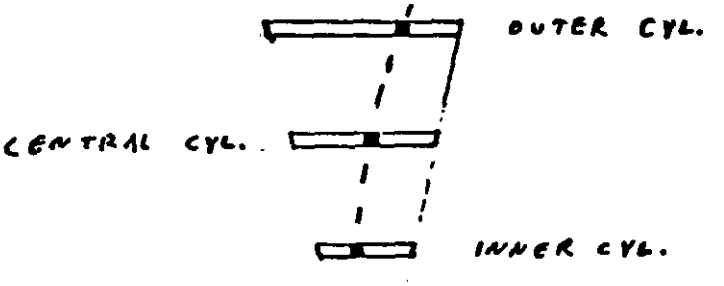


FIG. 3

INTERACTION POINT

In the bend plane all the strips are of equal width of 1.3 centimeters, and hence there is no projection back to the interaction point. A basic assumption in the trigger logic is that any muon trajectory is contained in a single sector. We ignore, in the trigger, any muon that crosses from one sector to a neighboring sector. A sector is 22.5 degrees wide, which means that the central segment is 240 centimeters wide. For a 50 GeV/c $P_\perp$ track, the sagitta between the inner segment and outer segment is 1.3 centimeters. Since we want to trigger with good efficiency on 50 GeV/c $P_\perp$ track, we have chosen our Y-strip width to be 1.3 cm.

The trigger logic consists of measuring the sagitta of the struck strip in the central segment with respect to the struck strips on the inner and outer segments. Figure 4 illustrates this logic.

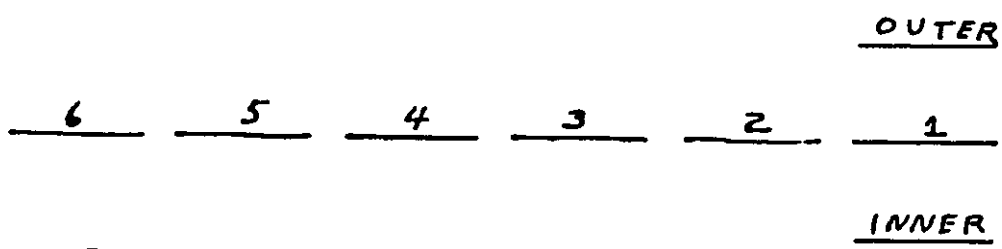
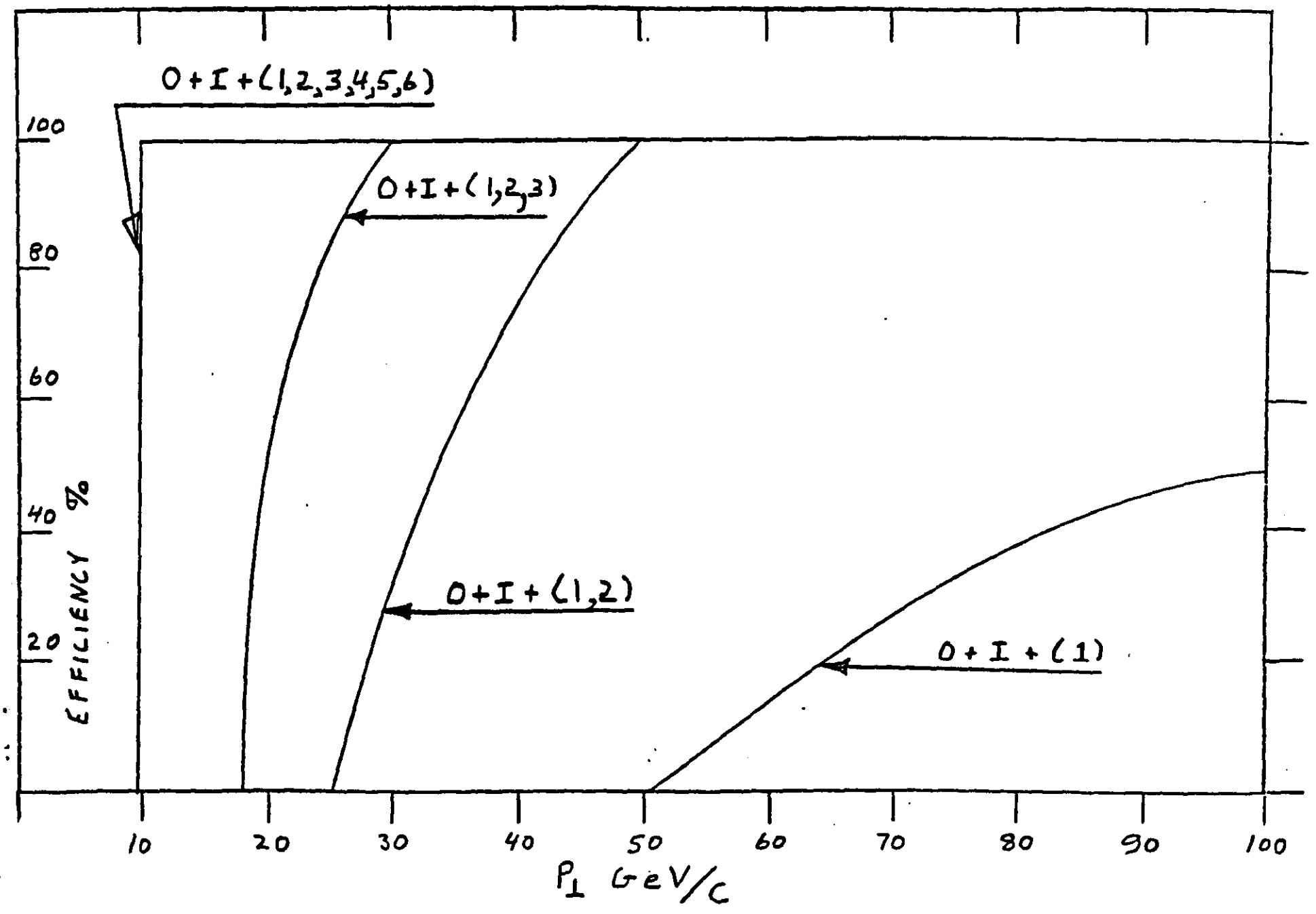


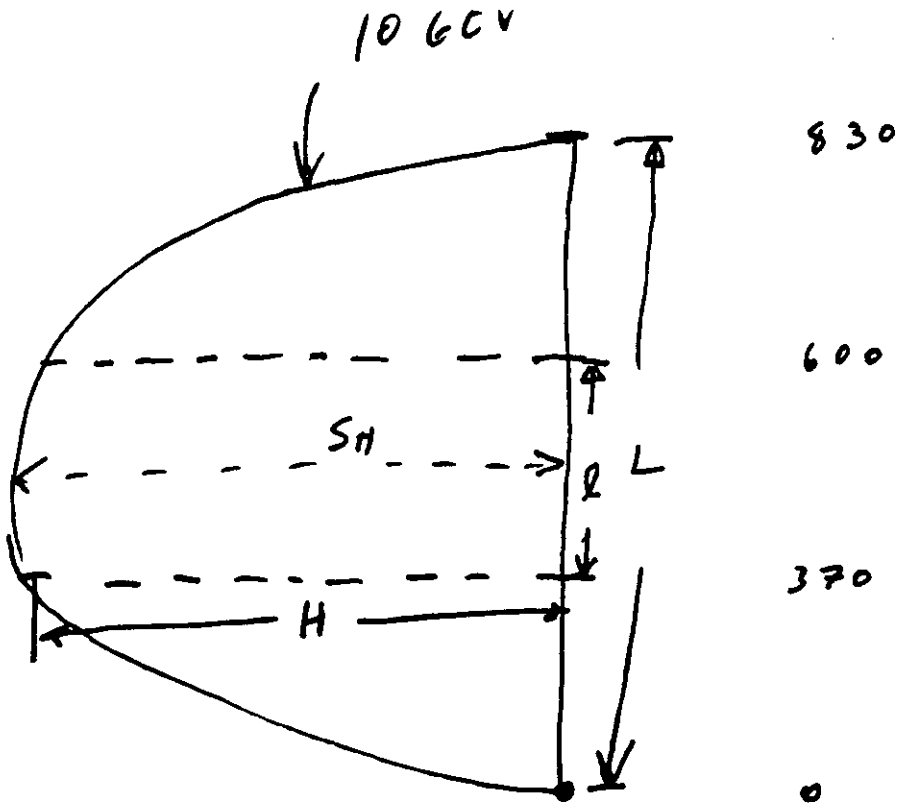
FIG. 4

O represents the struck outer strip and I represents the struck inner strip. A coincidence of O, I and the or of 1 and 2 selects all tracks with a $P_\perp$ greater than 50 GeV/c.

If we want to trigger on all tracks with $P_\perp$ greater than 50 GeV/c, we set up a triple coincidence between O, I, and the or of 1, 2.
If we want to trigger on all tracks with $P_\perp$ greater than 30 GeV/c, we set up a triple coincidence between O, I and the or of 1, 2, 3.

Figure 5 plots the efficiency of various trigger combinations as a function of $P_\perp$.


O + I + (1,2,3,4,5,6)
O + I + (1,2,3)
O + I + (1,2)
O + I + (1)
100
80
60
40
20
EFFICIENCY %
10
20
30
40
50
60
70
80
90
100
$P_\perp$ GeV/c



$$H = S_H \left(1 - \left(\frac{\ell}{L}\right)^2\right)$$

APPROXIMATELY

$S_H = 21.2$ CM
$L = 830$ CM
$\ell \cong 230$ CM

$H = 19.5$ CM

ERROR ON H DUE TO MULTIPLE SCATTERING IS ABOUT 1.1 CM - ABOUT THE SAME AS THE 1.5 CM STRIP WIDTH

SAGITTA USING THE THREE RPC PLANES IS 6.5 CM

THE ERROR ON THIS SAGITTA DUE TO MULTIPLE SCATTERING IS SMALL COMPARED TO THE 1.3 CM STRIP WIDTH.

HENCE FOR EACH MOMENTUM RANGE, WE HAVE TWO WAYS TO MEASURE THE $P_\perp$.

THE CURRENT LOGIC IS TO USE BOTH TECHNIQUES IN COINCIDENCE.

CONCEPTUAL DESIGN

FOR EACH STRIP ON THE OUTER BARREL AND FOR EACH MOMENTUM RANGE ONE HAS A SET OF HARD WIRED LOGIC.

1. ALL STRAIGHT LINE TRIPLE COINCIDENCES IN THE NON BEND PLANE ARE FANNED IN TO GIVE A NON BEND TRIGGER (THERE ARE 3 X 221 = 663 SUCH TRIGGER CIRCUITS TO ACCOUNT FOR MULTIPLE SCATTERING IN THE CALORIMETER)

2. A TRIPLE COINCIDENCE IS FORMED WITH THE OR OF SEVERAL STRIPS IN THE CENTRAL CYLINDER AND A STRIP ON THE INNER CYLINDER (THERE IS AN AVERAGE OF TWO SUCH CIRCUITS, DEPENDING ON THE MOMENTUM RANGE)

THE TOTAL NUMBER OF CIRCUITS FOR A SECTOR IS:

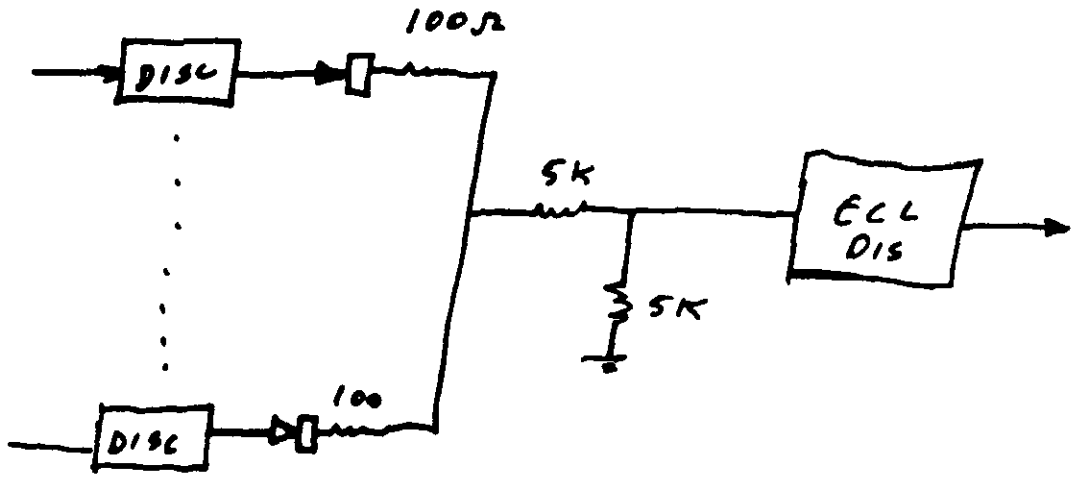
1. NON BEND PLANE 3X221 = 663
2. BEND PLANE 2 X 254 = 508

IF ONE HAS 4 MOMENTUM RANGES THEN THE NUMBER OF CIRCUITS IS

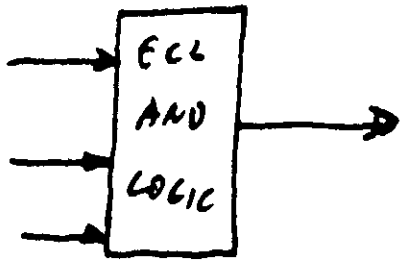
1. NON BEND PLANE		663
2. BEND PLANE	4 x 508	= 2 032
	TOTAL	2,695

AS AN EXAMPLE OF THE KIND OF CIRCUITS ONE IS TALKING ABOUT, THE FOLLOWING CAN BE BUILT OUT OF 100K SERIES SIGNETICS ECL CHIPS, FOR EXAMPLE THE SIGNETICS 100101 5 INPUT OR/NOR CHIP.

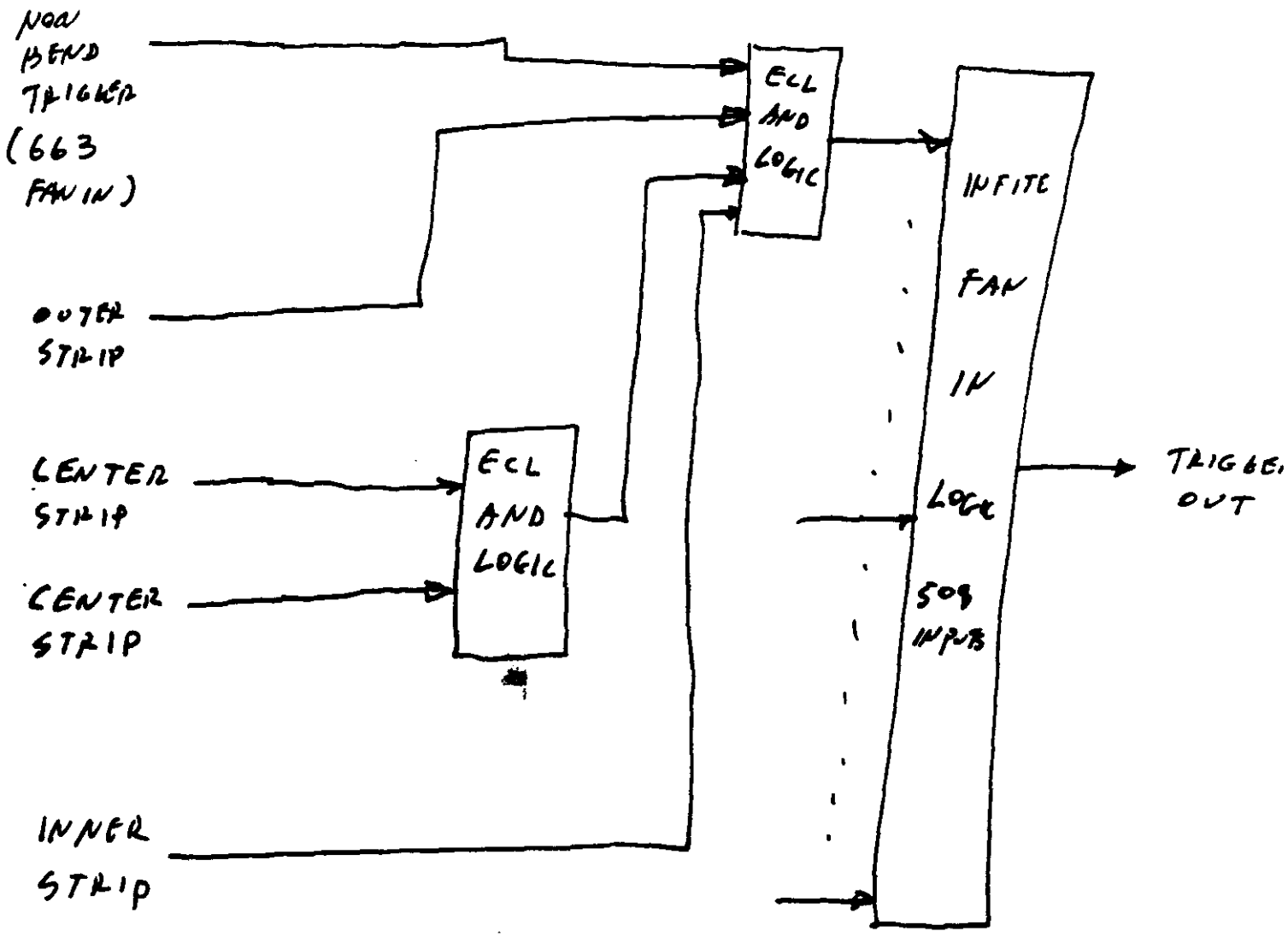
INFINITE FAN IN



3 FOLD COINCINENCE



SAMPLE LOGIC FOR 50 GEV TRIGGER



IN PRINCIPLE, THIS LOGIC CAN BE USED IN THE FORWARD DIRECTION. HOWEVER THE FORWARD DIRECTION HAS A MUCH HARSHER ENVIRONMENT.

THE BEAM CROSSING LOGIC CAN BE VERY SIMILAR.

THE TIMING TRIGGER, ESPECIALLY NEAR 10 DEGREES, WILL OBVIOUSLY BE A CHALLANGE. THE P_t TRIGGER NEAR 10 DEGREES WILL BE EVEN A GREATER CHALLANGE.

SINCE THE FORWARD CHAMBERS MIGHT HAVE PRECISION MEASUREMENTS FROM THE OUTER SUPER LAYERS AVAILABLE, IT IS QUITE POSSIBLE THAT A POINT-LIKE DETERMINATION OF THE MOMENTUM MIGHT BE POSSIBLE.

ONE OF THE CRUCIAL QUESTIONS THAT MUST BE INVESTIGATED IS WHAT IS THE PHYSICS LOST IF WE DO NOT TRIGGER ON MUONS WITH LARGE η.

FOR EXAMPLE, IF WE COULD RESTRICT OUR TRIGGER TO MUONS WITH RAPIDITY LESS THAN 1.5, LIFE WOULD BE SIMPLE. IF WE HAVE TO TRIGGER ON RAPIDITIES

UP TO 2.5 – LIFE IS VERY HARD, INDEED

CONCLUSION

WE HAVE THE NUCLEUS OF A MUON TRIGGER GROUP – LOTS OF PROBLEMS – SOME IDEAS.

PLEASE JOIN THIS EXCITING EFFORT

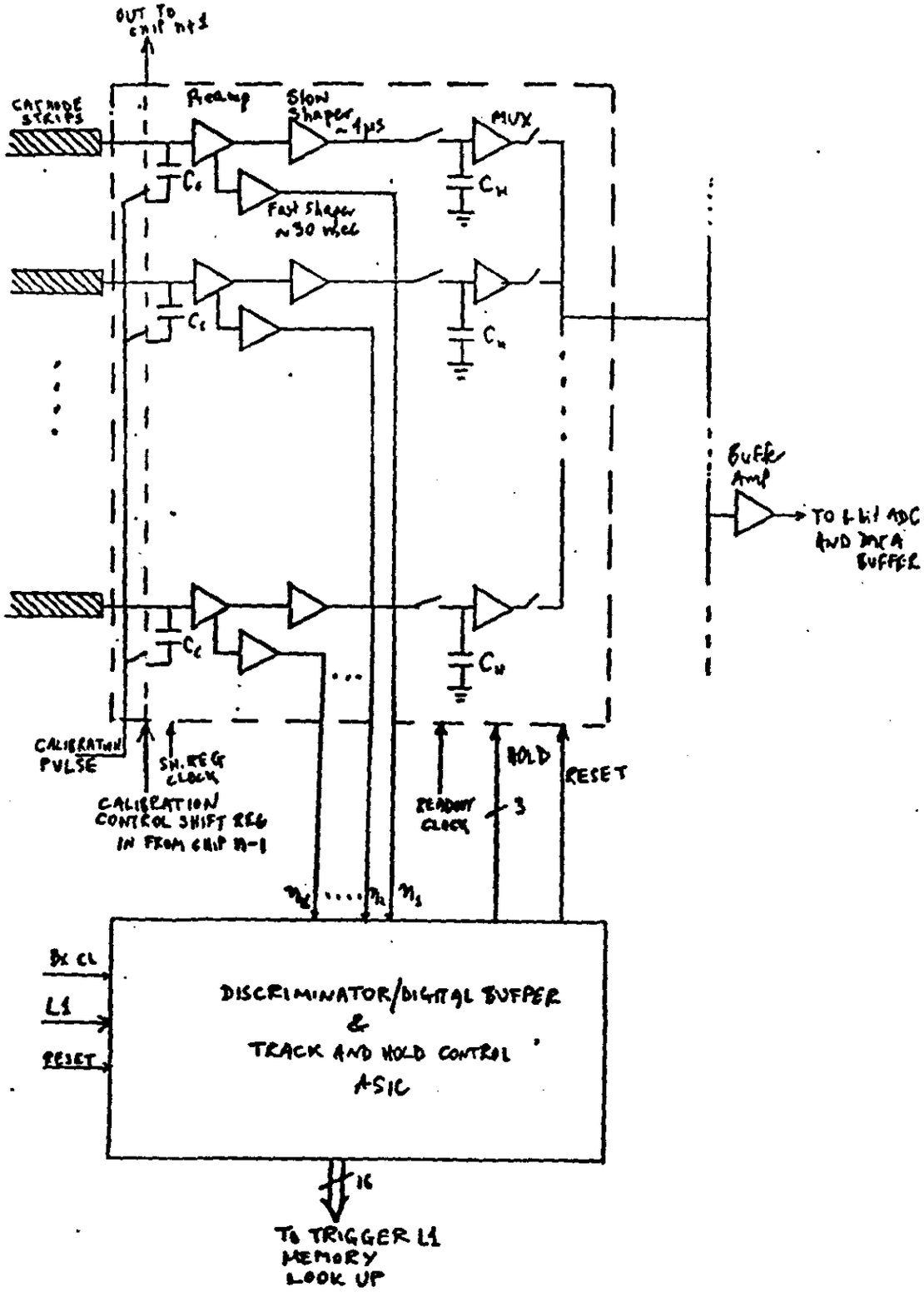
Triggering in and cope V. Polychronakos

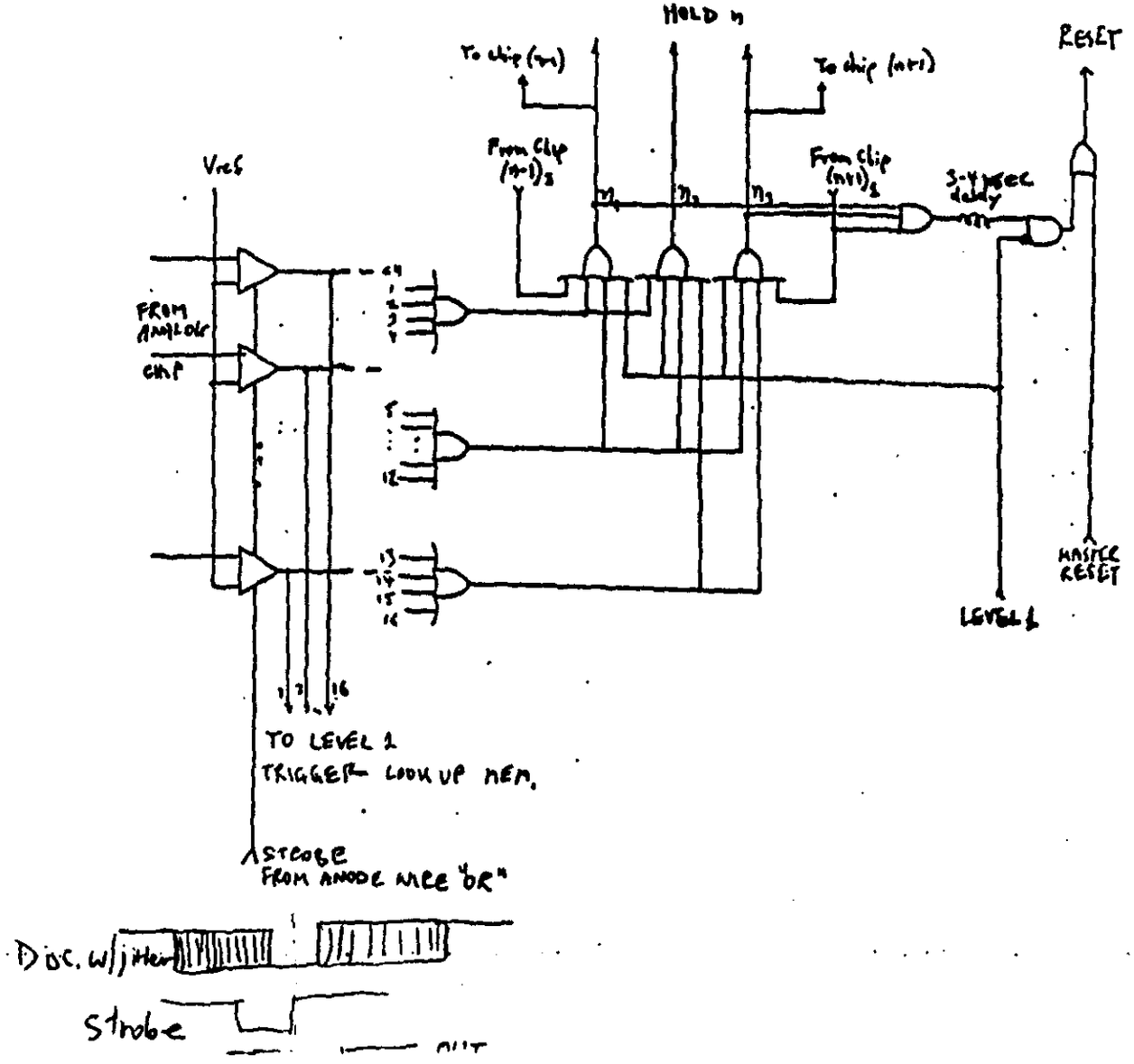
- Readout has to be simple, affordable, highly integrated
- Interconnections kept to a minimum
- Long term reliable operation

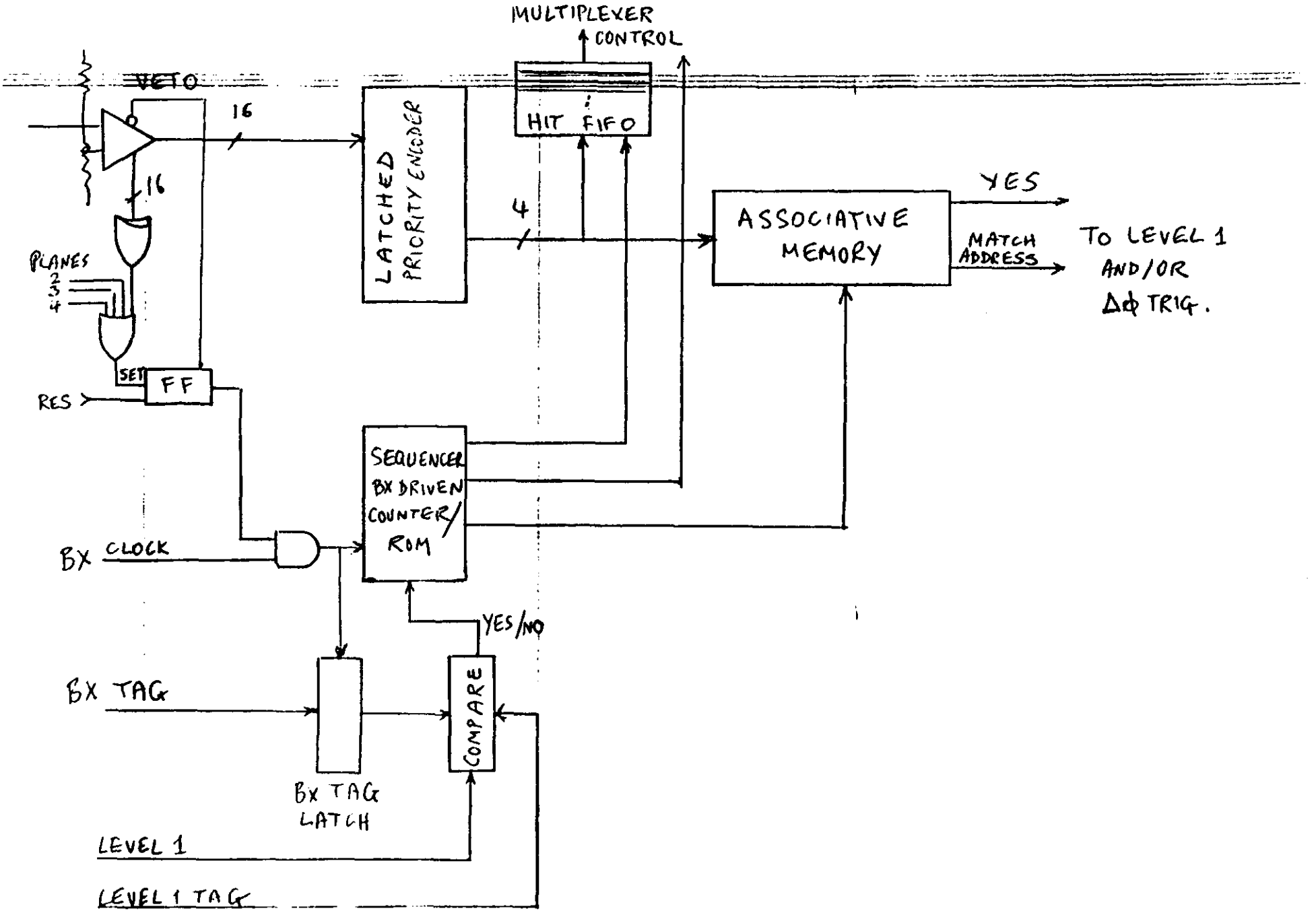
Take advantage of very low occupancy rates

- Long Integration time ⇒ easier, cheaper electronics
- Self-triggered (data driven) readout possible
- Tolerate local dead time even at level 1

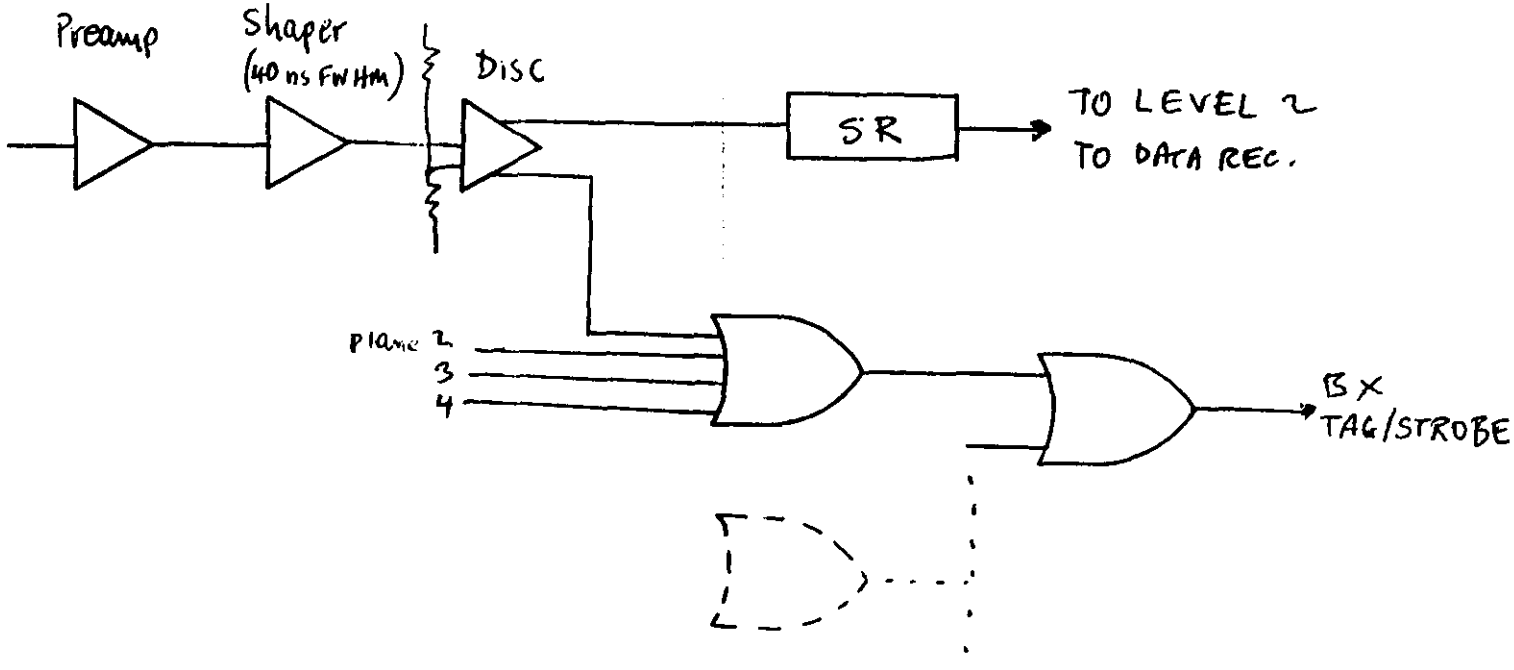
3 x .5
m x .1


OUT TO chip n+1
CATHODE STRIPS
Preamp
Slow Shaper ~1μs
MUX
C_c
C_H
Fast Shaper ~30 nsec
Buffer Amp
TO L1 ADC AND DPCA BUFFER
CALIBRATION PULSE
SH. REG CLOCK
CALIBRATION CONTROL SHIFT REG IN FROM CHIP n-1
HOLD
RESET
READOUT CLOCK
3
n_k .... n_2 n_1
BX CL
L1
RESET
DISCRIMINATOR/DIGITAL BUFFER & TRACK AND HOLD CONTROL ASIC
16
To TRIGGER L1 MEMORY LOOK UP


HOLD n
RESET
To chip (n-1)
To chip (n+1)
From Clip (n-1)
From Clip (n+1)
3-4 nsec delay
Vref
FROM ANALOG CHIP
MASTER RESET
LEVEL 1
TO LEVEL 1
TRIGGER LOOK UP MEM.
STROBE
FROM ANODE MCP "OR"
Disc. w/jitter
Strobe


MULTIPLEXER CONTROL
VETO
16
16
PLANES
2
3
4
SET
FF
RES
LATCHED PRIORITY ENCODER
HIT FIFO
4
ASSOCIATIVE MEMORY
YES
MATCH ADDRESS
TO LEVEL 1 AND/OR Δφ TRIG.
SEQUENCER BX DRIVEN COUNTER/ ROM
BX CLOCK
YES/NO
BX TAG
COMPARE
BX TAG LATCH
LEVEL 1
LEVEL 1 TAG

ANODE READOUT BLOCK DIAGRAM



The AMchip: a full-custom CMOS VLSI associative memory for pattern recognition.

S.R.Amendolia+*, S.Galeotti*, F.Morsani*, D.Passuello*, L.Ristori#, G.Sciacca#, N.Turini^x
*INFN-Pisa, #Univ. and INFN of Catania, +Univ. of Sassari, ^xUniv. and INFN of Bologna
ITALY.

Abstract.

An Associative Memory full-custom CMOS VLSI chip (AMchip), to be used in fast Trigger Systems for pattern recognition, has been designed and is being successfully tested at INFN in Pisa. The AMchip is the first full-custom associative memory IC developed for high energy physics until today. It contains about 140000 mos transistors, has been realized in 1.5 micron, double metal, silicon gate CMOS technology, and is housed in a 120 pins package. The AMchip has been designed to be used with any kind of detector which provides in output the hits coordinates, such as, for example, a silicon microstrips detector. We plan to realize a new AMchip version using sub-micron technology (available in the 1992) and new circuital solutions, improving the patterns capacity of a factor 4, and improving significantly the speed. These versions will be developed to match new high energy physics experiments' specific requirements (see, for example, the CDF Silicon Vertex Tracker).

AMCHIP OVERVIEW.

A list follows of the most relevant characteristics of the AMchip:

- full-custom core of about 121000 MOS transistors, 1 cm^2 die;
- 20 different tiles designed containing 1136 transistors;
- storage capacity of 7680 bits, organized in 60-bit rows;
- 80 pins of signals, 40 of power and ground; the prototype is in a 120-pin PGA case;
- 60-bit bidirectional Data Bus, 7-bit bidirectional Address Bus;
- 4 bits of Operational Code (each AMchip operation has its own Operational Code);
- non overlapping two phase clock inputs (each elementary operation is executed synchronously with the clock in one cycle);
- parallelizable architecture to increase AMsystem memory size;
- one AMchip can accept data from 5 planes of detector, each plane having the hits coordinates coded on 12 bits.

THE AMCHIP FUNCTIONALITY.

A description of the working principle of the Associative Memory and of how it can be used to solve pattern recognition problems in high energy physics experiments can be found in references [1], [2] and [3]. The AMchip contains an array of static Content Addressable Memory (CAM) WORDs. Each WORD is 12 bit wide. The array consists of 128 rows and 5 columns for a total of 640 WORDs. Each row is called a PATTERN and each column is called a PLANE (see fig.1). The data bus is 60 bit wide so that one PATTERN is read or written in a single clock cycle. Each CAM WORD is equipped with a comparator and a flip-flop called HIT-BIT. There are five HIT-BITs per PATTERN: they form the HIT REGISTER.

While functioning in INPUT mode, the content of each WORD is compared to the content of the data bus and, in case of match, the corresponding HIT-BIT is set.

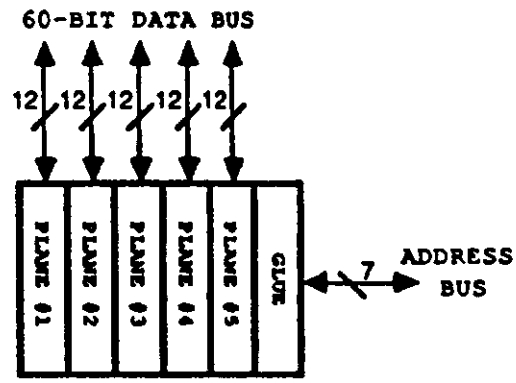


Fig.1: AMchip core block diagram

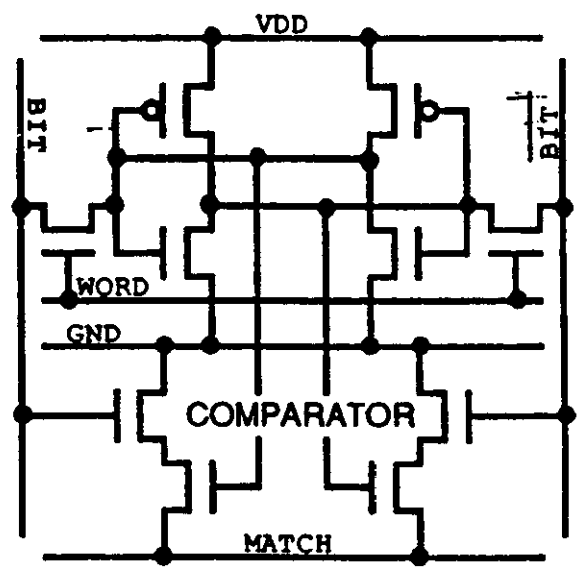


Fig.2: CAM cell schematic diagram

G. Mitselmakher

SSCL GEM muon group meeting

11/22/91

1. Meetings – every week but not more than 1 hour each time on fridays?
2. Purpose: news, schedule, responsibilities.

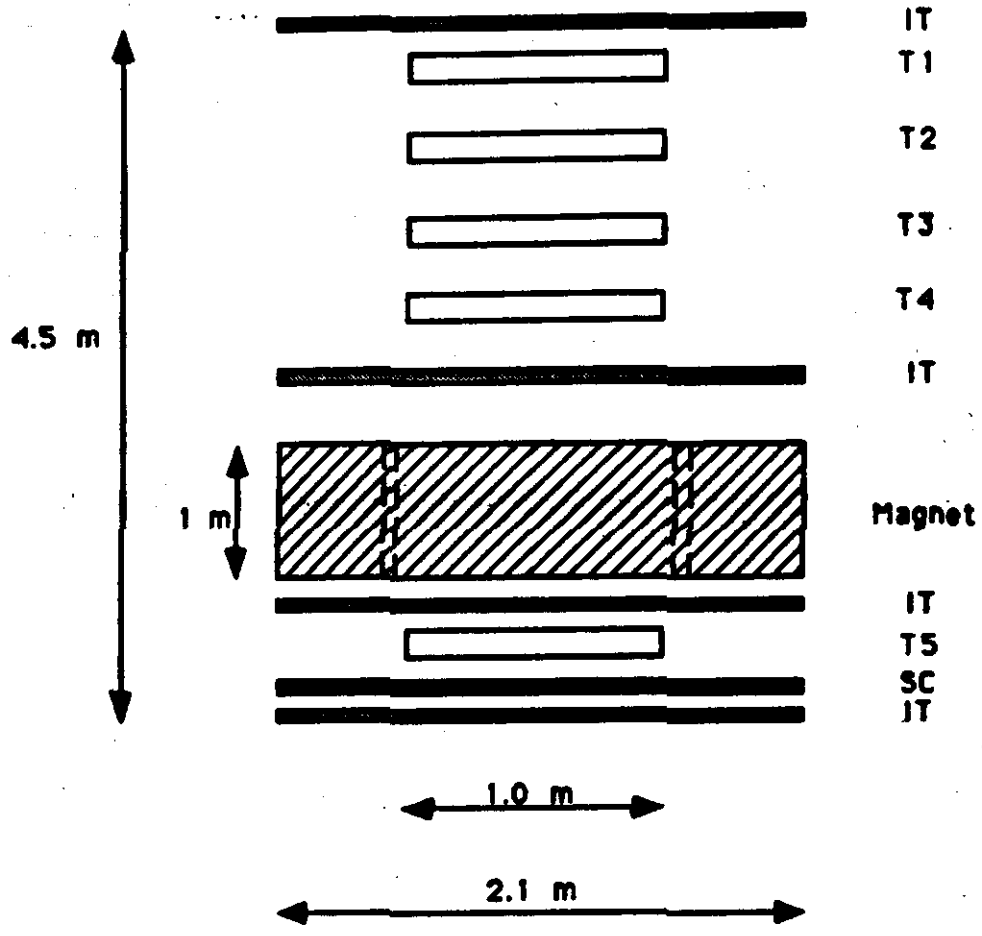
today:

1. G. Mitselmakher – meeting with F. Gilman, J. Siegrist, M. Marx

conclusions: 1. TTR supported by SSCL
2. Can start purchasing NOW – need a list ASAP.
3. Gilman will call Fermilab about iron for magnet
4. Start to hire technicians
5. Support visitors from USSR. (and Mexico).

TTR TEXAS TEST RIG

GEM MUON CHAMBERS EVALUATION TEST STAND



Legend:

T1-T5 Technologies to be Evaluated
- T1 Pressurized Drift Tubes
- T2 Limitied Streamer Drift Tubes
- T3 Cathode Strip Chambers, Multiwire Geometry
- T4 Cathode Strip Chambers, Open Profile
- T5 Resistive Plate Chambers

SC Scintillator Counters

IT Iarocci-Tube Chambers for Trigger

18 November 1991

PROPOSAL FOR CONSTRUCTION OF A MUON TEST FACILITY AT THE SSCL

M.Botlo, M. Hecht, K. McFarlane, M.Marx, C. Milner, G. Mitselmakher(*), T.Prosapio, F. Stocker, A. Vanyashin, L. Villasenor, G. Yost, E. Zimmer-Nixdorf (SSCL)

K. Lau, B. Mayes, J. Pyrlik, R. Weinstein (UH, Houston)

A.Gonzalez (IFUG,Leon)

A.Golutvin, V.Tchistilin, I.Tichomirov (ITEP,Moscow)

L. Barabash, Yu. Bonushkin, Z. Krumstein (JINR, Dubna)

Yu.Fisyak, V.Zhukov (MSU,Moscow)

V.Sarantsev (SNPI,Gatchina)

(*)-contact person

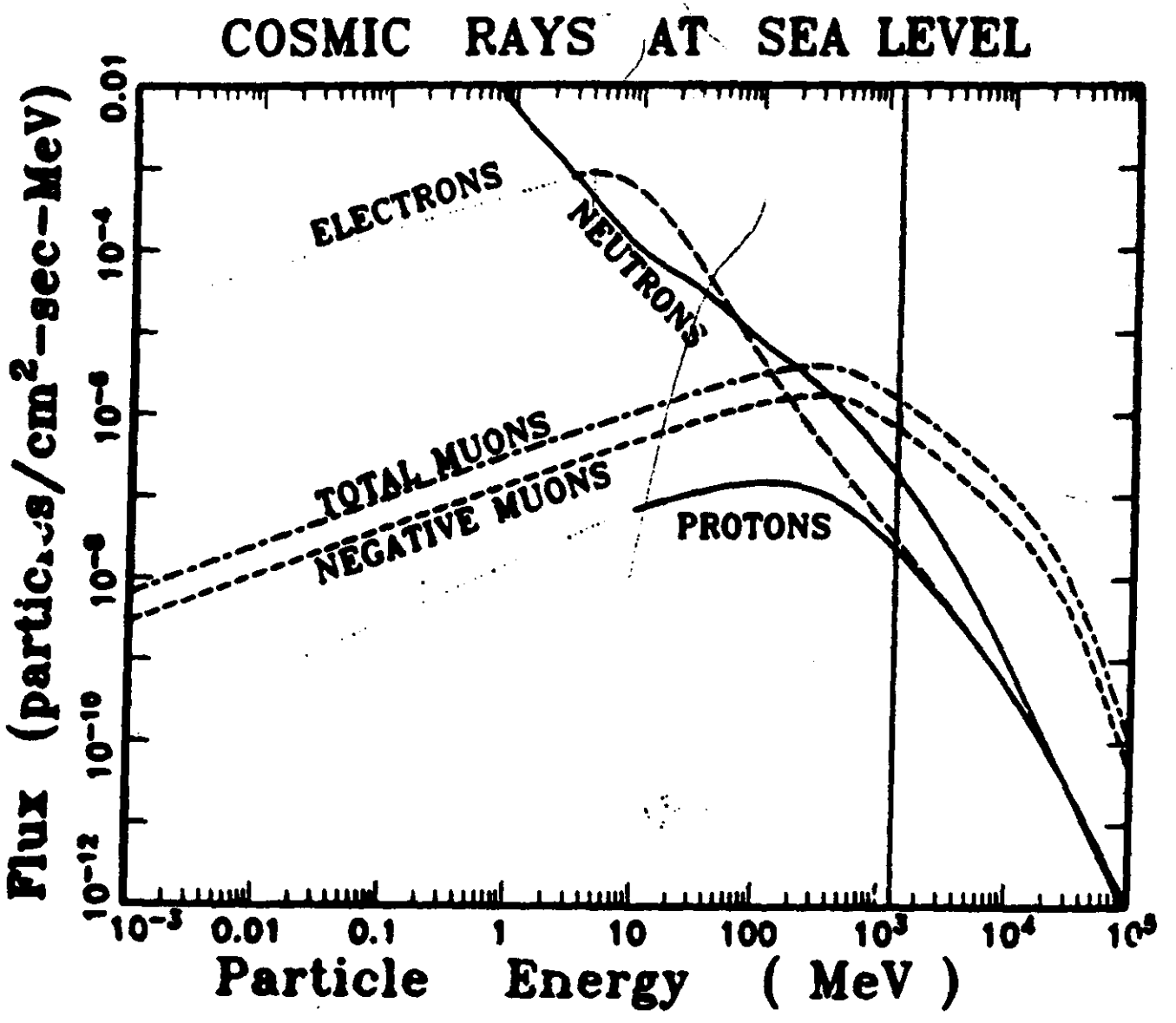
Participating Institutions:

Brookhaven National Laboratory
Boston University
Draper Laboratory
Joint Institute for Nuclear Research
Houston University
Institute of Theoretical and Experimental Physics
Los Alamos National Laboratory
Louisiana State University
Lawrence National Laboratory
Massachusetts Institute of Technology
Michigan State University
Moscow State University
Oak Ridge National Laboratory
St.Petersburg Nuclear Physics Institute
State University of New-York at Stony Brook
Superconducting Super Collider Laboratory
Texas A&M University
University of Guanajuato

REQUEST OF SSCL FOR FY 1992: $493,000
2.0 FTE engineers
3.5 FTE technicians

TTR L. Villasenor

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.)



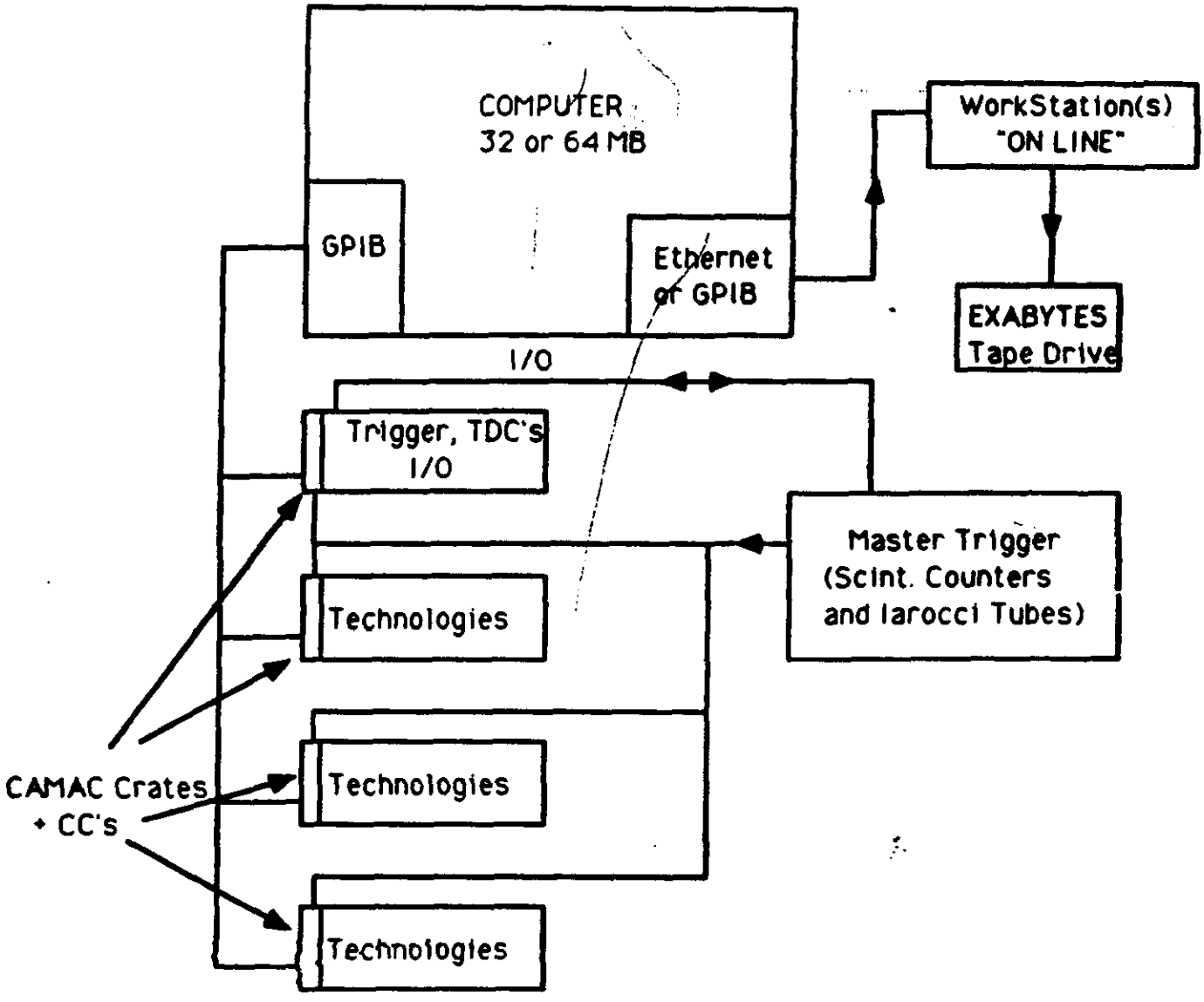
1 m of Fe ⇒ $P_{muon} \geq 1.4$ GeV

or ~ 60 μ's / m² s

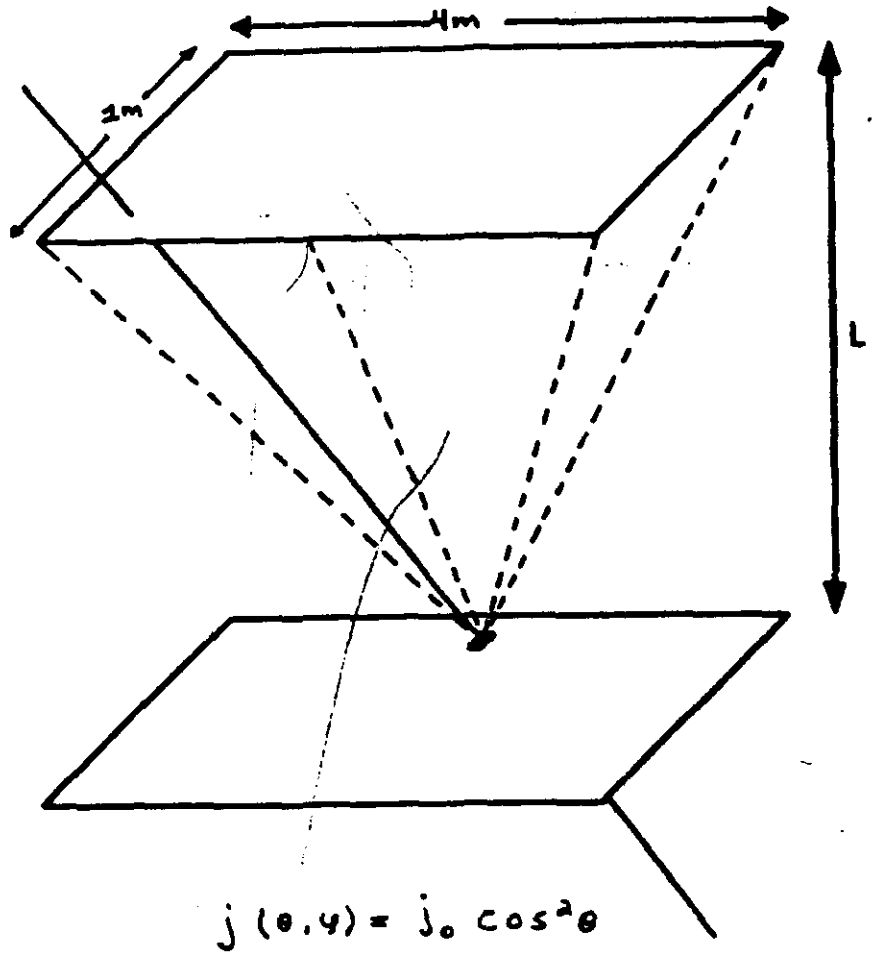
for A = 4 m² ⇒ R ~ 240 Hz

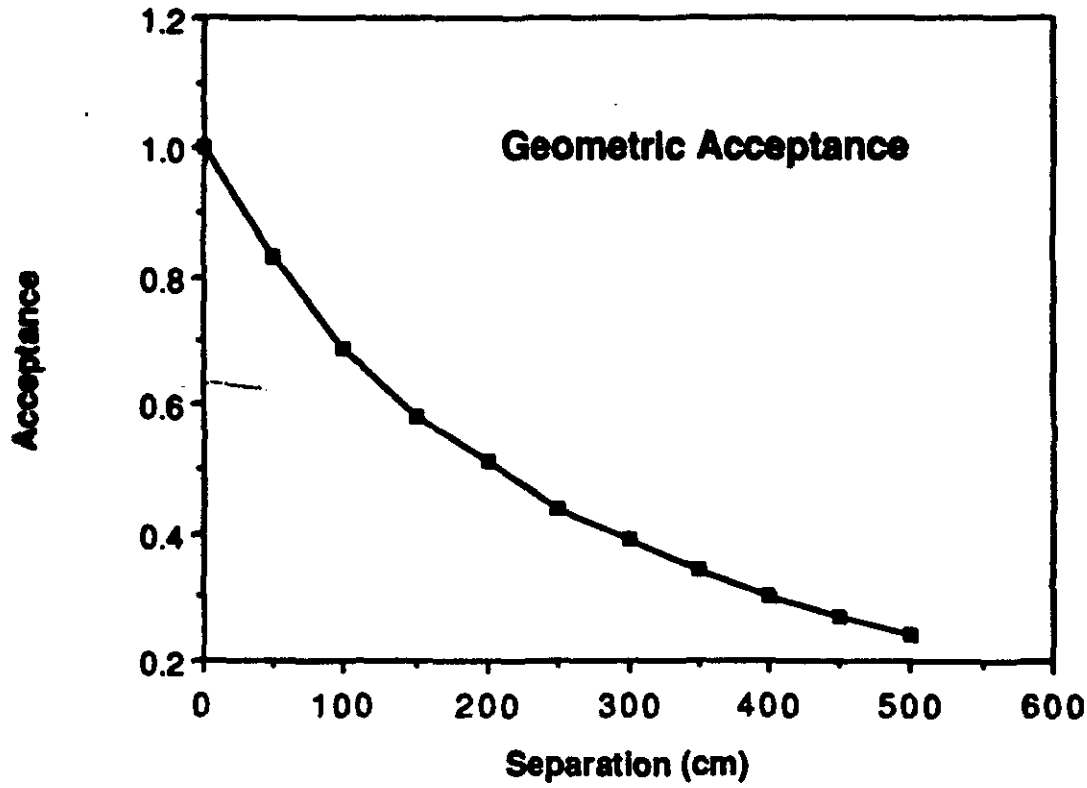
Geometric Acceptance ⇒ Rates O(10-100)

Possible DAQ System

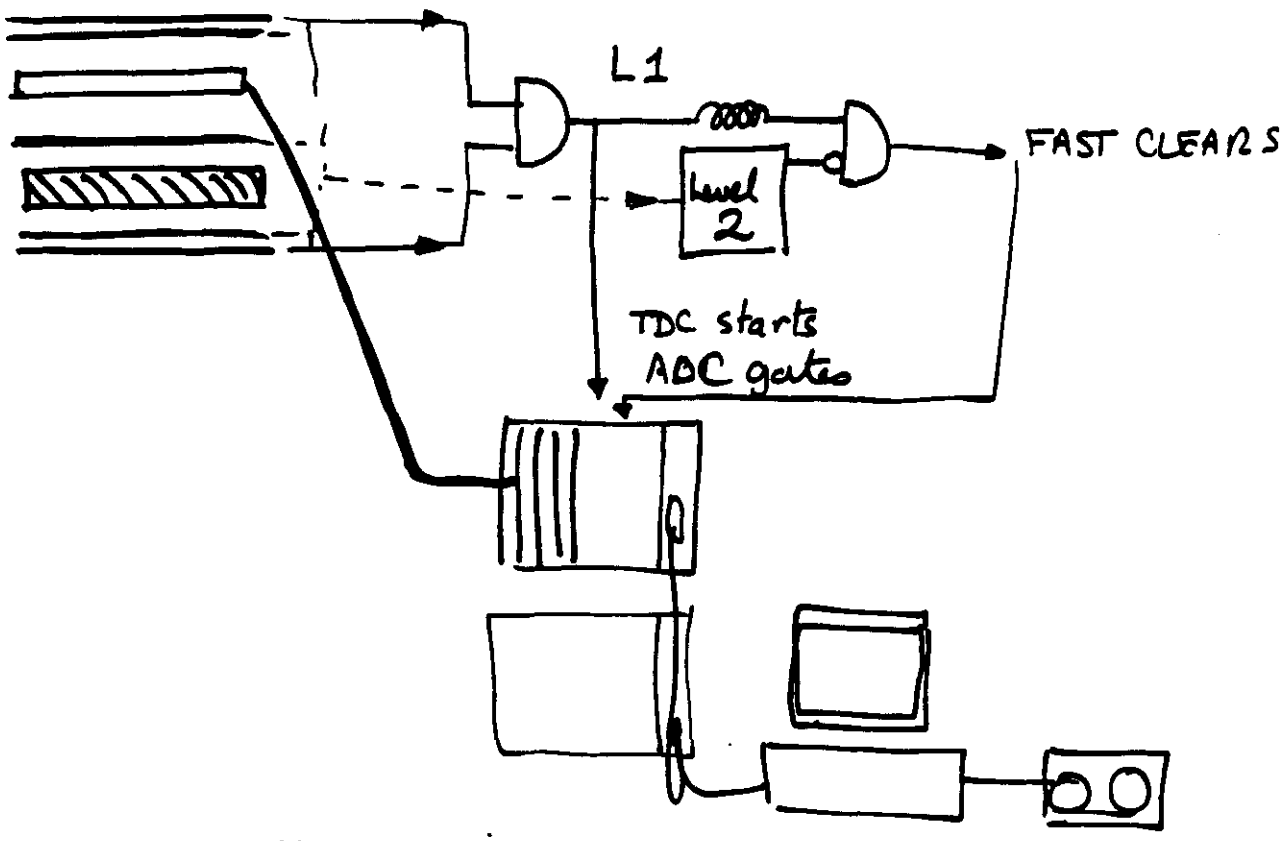


About 1200 Channels
2.4 kB/Event
24 kB/sec at 10 Hz
About 1 Tape/Day


4m
1m
L
j (θ,φ) = j₀ cos²θ


Geometric Acceptance
Acceptance
Separation (cm)
1.2
1.0
0.8
0.6
0.4
0.2
0
100
200
300
400
500
600

TTR Trigger/DAQ block diagram



SSCL Provides

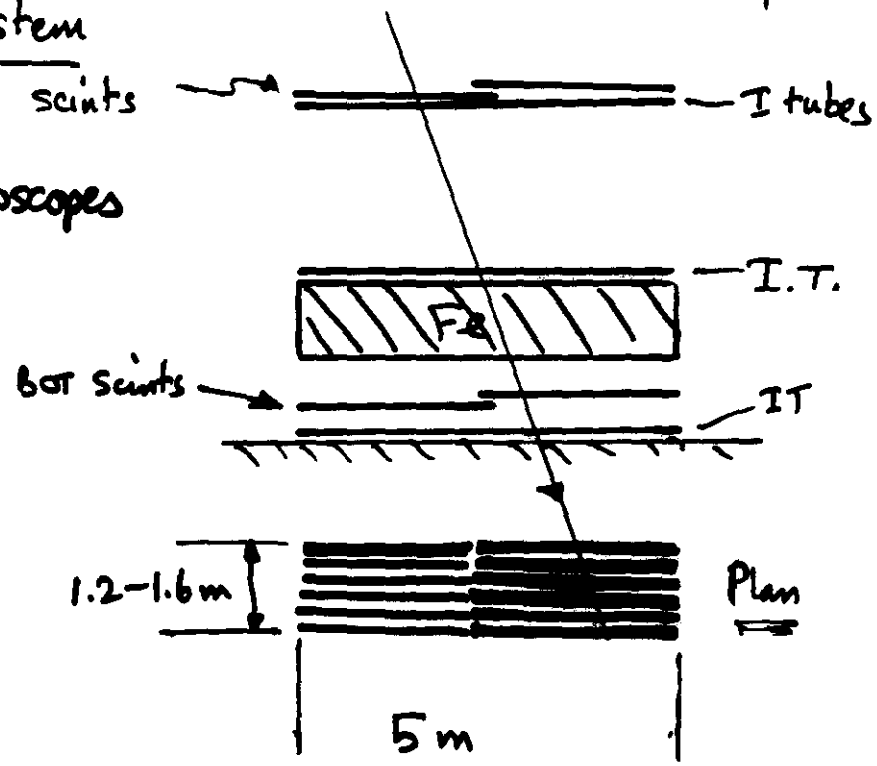
- CAMAC crates & controllers, DAQ computer, recording
- L1 signals (ECL, NIM) up to 16 starts + 16 gates
- Fast clear up to 32
- Level 2 capability given suitable signals

'User' provides

- Detector
- DAQ modules (ADC, TDC, special); manuals
- Cables to match L1 delay. (or other signal buffer)
- input sockets (BNC, lemo, or 0.1" space ECL)
- Any dead time signals if needed.

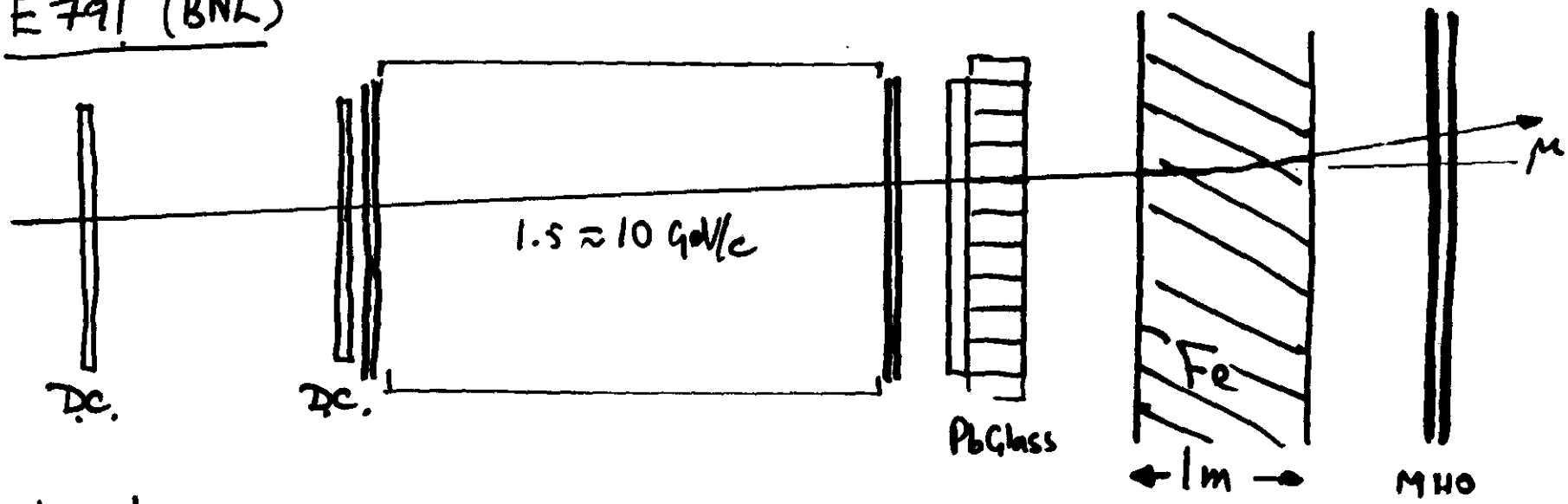
Muon Trigger System

- Top & bottom hodoscopes
- Iarocci tubes



Hodoscopes consist of 12-16 double-ended scintillation counters in two panels top & bottom. Total of 24-32 slats, 48-64 PMT's. Slats are 2.6 m × 0.2 m × 25 mm thick.

E791 (BNL)



Muon hodoscope

Vertical Counters

2.6 m active length

19 cm. wide

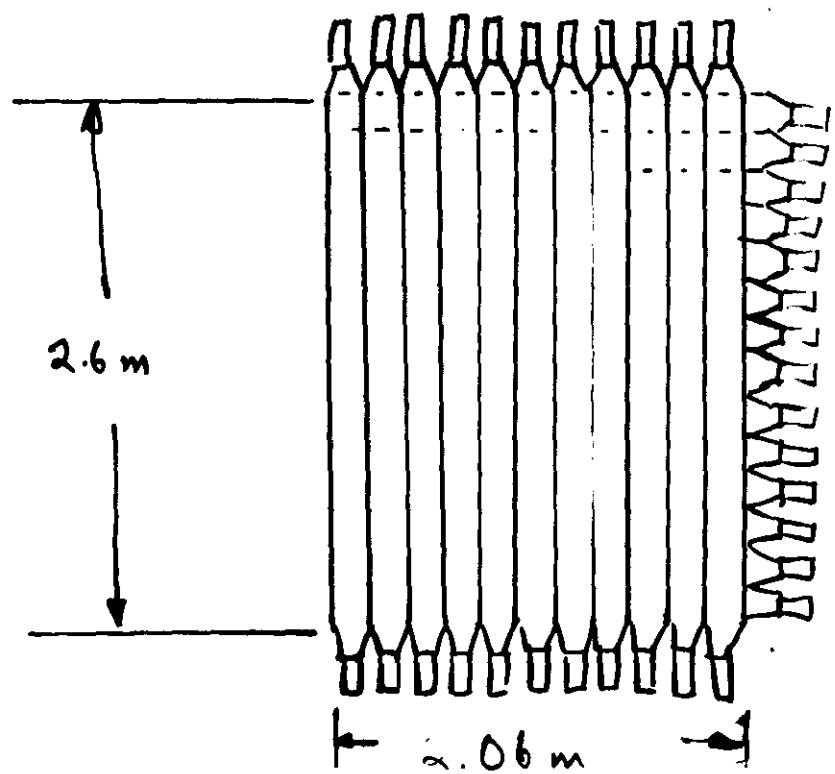
26 mm thick

double ended.

Horizontal

2.06 m active length

single-ended (blackened)



(w)

Performance and capabilities

Particle passage to Level 1 : 200 ns ± 20 ns

Accidentals $\ll$ 0.1 Hz

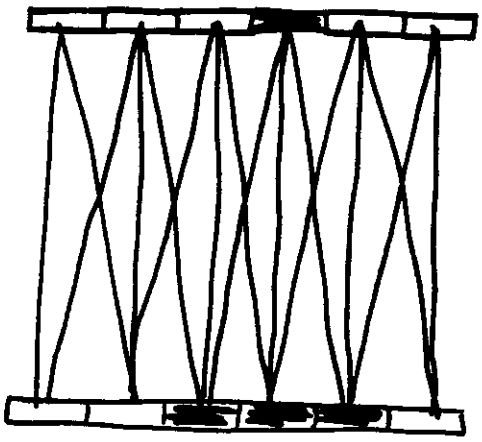
Timing accuracy (Level 1) : 10 ns jitter (± 5 ns)

off line : $\leqslant$ 250 ps

Programmability: at Level 2, any combination of slats.

Iarocci tubes introduced at Level 2.

Sample Level 2



restrict angular range of triggers

L1 Delay (sample calculation)

Scintillator	18 ns	$(^{+0}_{-2})$
PMT	43 ns	(±5)
Signal Cable	75 ns	trimmed (min. 50ns)
Split	0 ns	
Cable	4ns	
disc	18ns	(±2ns)
cable	3ns	
OR/AND	12ns	(±2ns)
Cable	3ns	
ECL-NIM	6ns	(±1ns)
Cable	2ns	
AND	10ns	
	194	±10ns
Cable	2ns	
disc (shaper)	10ns	
cable	2ns	
Fan out	7ns	
	215 ns	

cable to detector DAQ ?

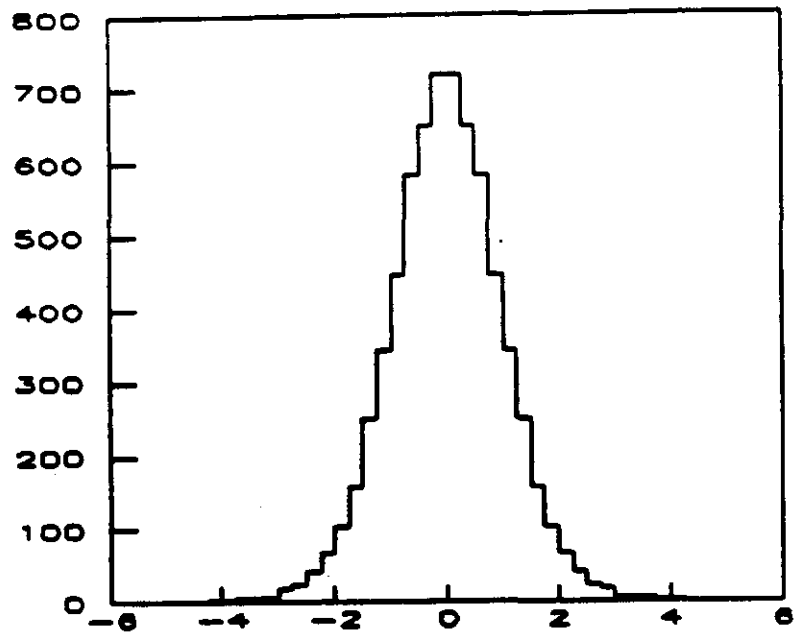


Figure 1: Sample MHO time distribution from muons. The horizontal scale is in nsec.

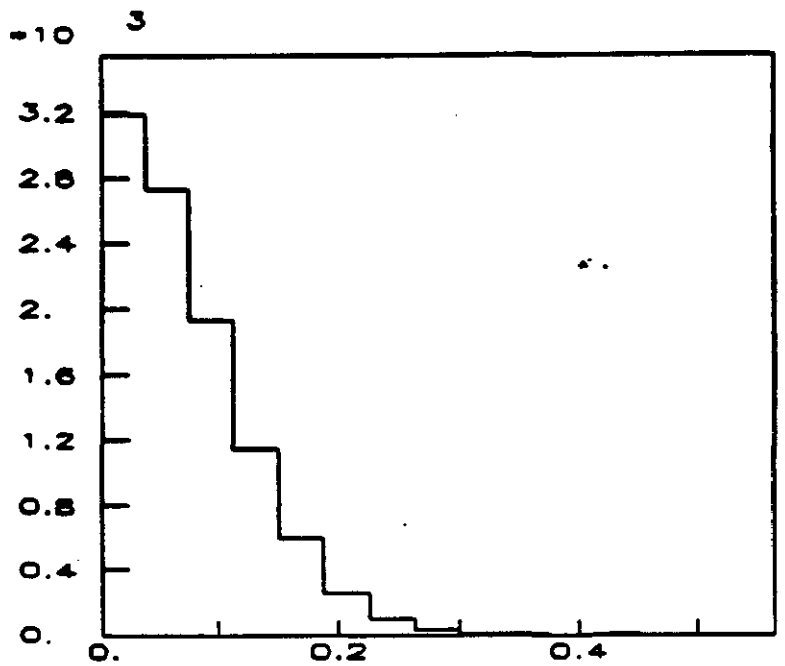
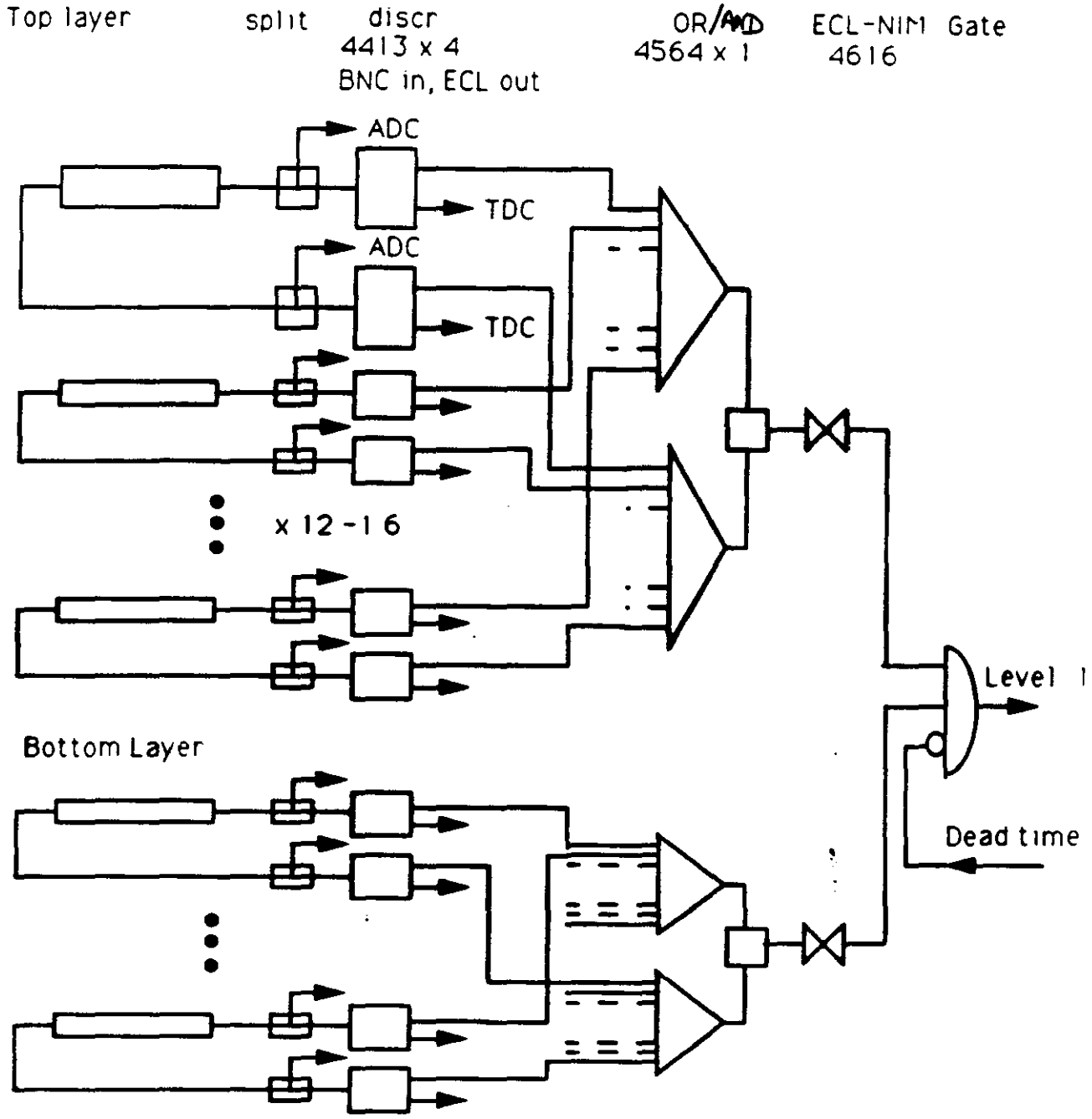


Figure 2: Sample MHO space difference distribution from muon tracks with momentum between 2.0 and 3.0 GeV. The horizontal scale is in meters.

Muon Trigger - Version 2



a time closest to the event time, since the event time seemed like a more objective comparator. Unfortunately, this didn't work because the average event time is not zero, and the resulting time distributions were asymmetric. So, we had to settle with using the vertical time that was closest to the horizontal time.

To summarize, the new time match quantities that we defined were

$$T_1 = t_{HOR} - \hat{t}_{VER}$$

and

$$T_2 = \frac{t_{HOR} + \hat{t}_{VER}}{2} - \text{TIMTSC}$$

where

$$\hat{t}_{VER} = \begin{cases} t_{BOT} & \text{if } |t_{BOT} - t_{HOR}| \leq |t_{TOP} - t_{HOR}| \\ t_{TOP} & \text{otherwise.} \end{cases}$$

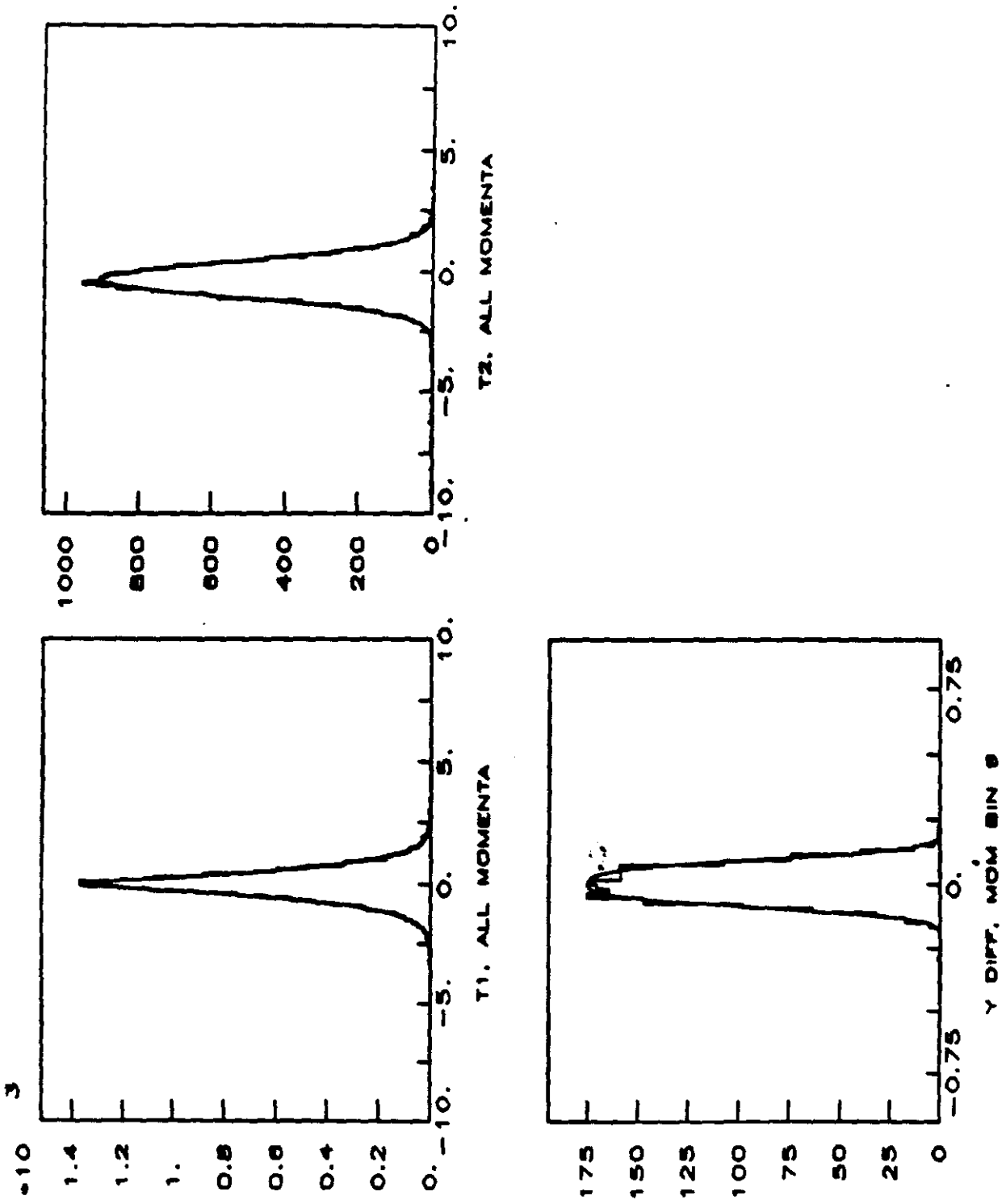


Figure 19: Distributions of T_1, T_2, and space difference from muons fit with the new functional forms described in the text. The times are in nsec, and the distances are in meters.

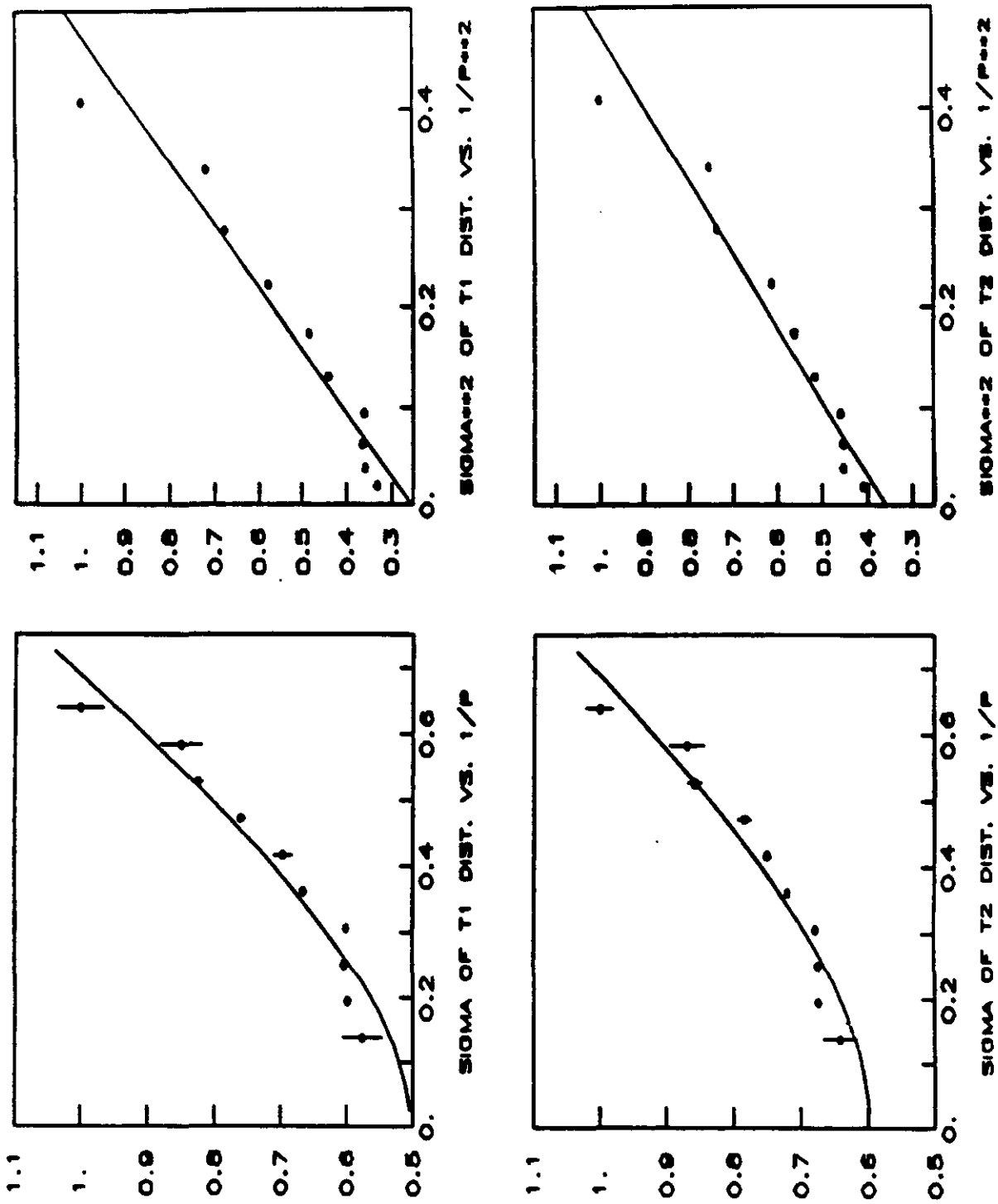


Figure 25: For the time distributions, σ versus $1/p$ and σ^2 versus $(1/p)^2$. The σ's are in nsec, and the momenta are in GeV.

dist. type	μ	C_1	C_2	σ-p relation
T_1	−0.0313 nsec	0.2543 nsec^2	1.5659 nsec^2-GeV^2	$\sigma = \sqrt{C_1 + C_2/p^2}$
T_2	−0.3076 nsec	0.3570 nsec^2	1.3534 nsec^2-GeV^2	
x_{diff}	−0.0039 m	−0.0095 m	0.2234 m-GeV	$\sigma = C_1 + C_2/p$
y_{diff}	0.0004 m	−0.0073 m	0.1982 m-GeV	

Table 3: Means and σ-p fit parameters for each type of distribution.

12/6/91 KL & RW

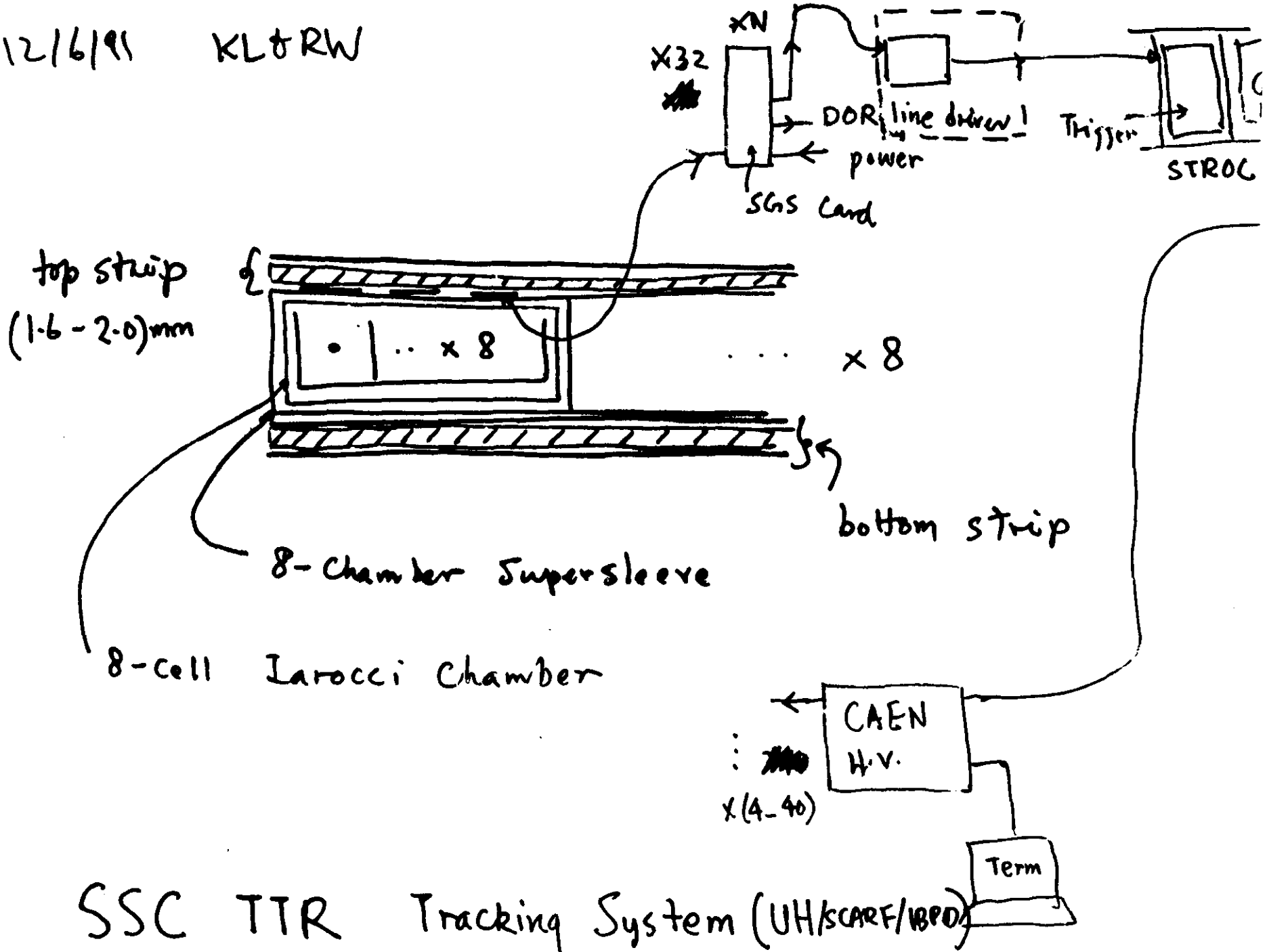
SSC TTR TS (1m x 4m)

- 4 layers of LST's each 1m x 4m
- Top and bottom readout per LST layer (1 cm pitch in both cases)

PARTS & AVAILABILITY

• Chambers :	55 4-m chambers	2 weeks
• Super-sleeve (optimal)		2 months
• Strips	32 m^2 = 8 x (1m x 4m)	2 months
• Electronics	SQS (63 cards)	March 1, 92
	Line driver (1 unit)	March 1, 92
	Controller (1 unit)	March 1, 92
• Gas	3 component, 1%	2 months
• HV	1 CAEN	2 months

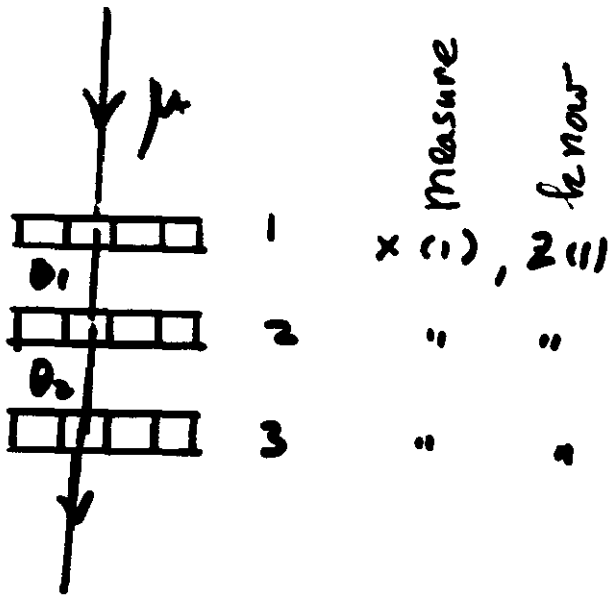
12/6/91 KL&RW



SSC TTR Tracking System (UH/SCARF/IBPD)

How to measure chamber resol'n

Compute: $\Delta\theta_{12} = \dfrac{X(2) - X(1)}{L_{21}} - \dfrac{X(3) - X(2)}{L_{32}}$



σ_0 = layer resol'n

σ_{ms} = ms effect.

$$\sigma^2(\Delta\theta_{12}) = \frac{6}{L^2}\sigma_0^2 + \boxed{\frac{1}{L^2}\sum_i \sigma_{ms}^2(i)}$$

correlated ? small

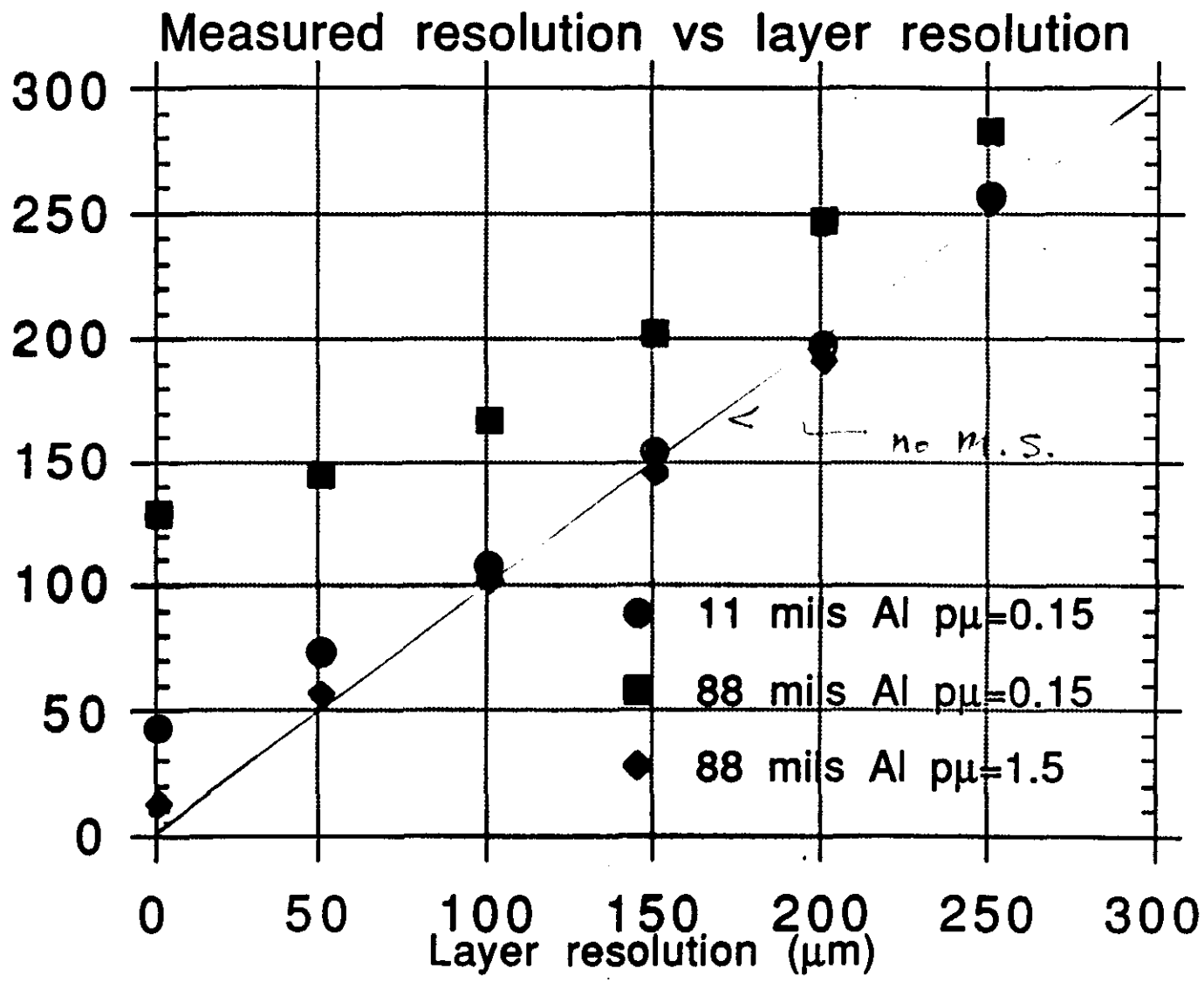
$$\approx \frac{6}{L^2}\sigma_0^2$$

M.C. to see how well σ_0 determined

Conclude: Ok for CSC $\sigma_0 \sim 50\mu m$

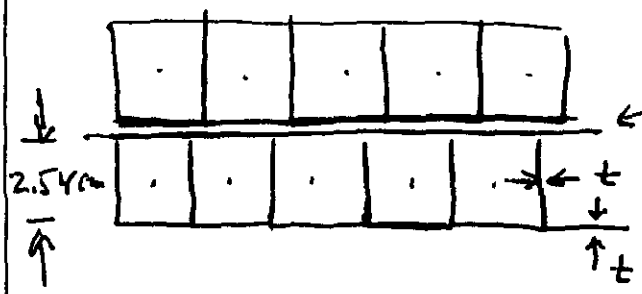
Ok for LSDT (PDT) $\sigma \sim 100\mu m$

if: $P_\mu > 1.5$ GeV/c $\Rightarrow \sim 1$ m of Fe required


Measured resolution vs layer resolution
300
250
200
150
100
50
0
0
50
100
150
200
250
300
Layer resolution (μm)
11 mils Al pμ=0.15
88 mils Al pμ=0.15
88 mils Al pμ=1.5
no m.s.

Simulation of LSDTO

① Extrusion version:



$\frac{1}{16}$" G-10 Cu clad

$= 1.64\% X_0$

$\Rightarrow$ 0.146 cm Al eq.

$t = 80$ mils Al $\Rightarrow$ 160 mils average Al

$n X_0 = 0.160 \times 2.54 \times 2.7 / 24 = 4.57\% X_0$

(not going through walls – known by selection ⇒)

$= 2.29\% X_0$

80 mils 0.203 cm think much thicker than real design.

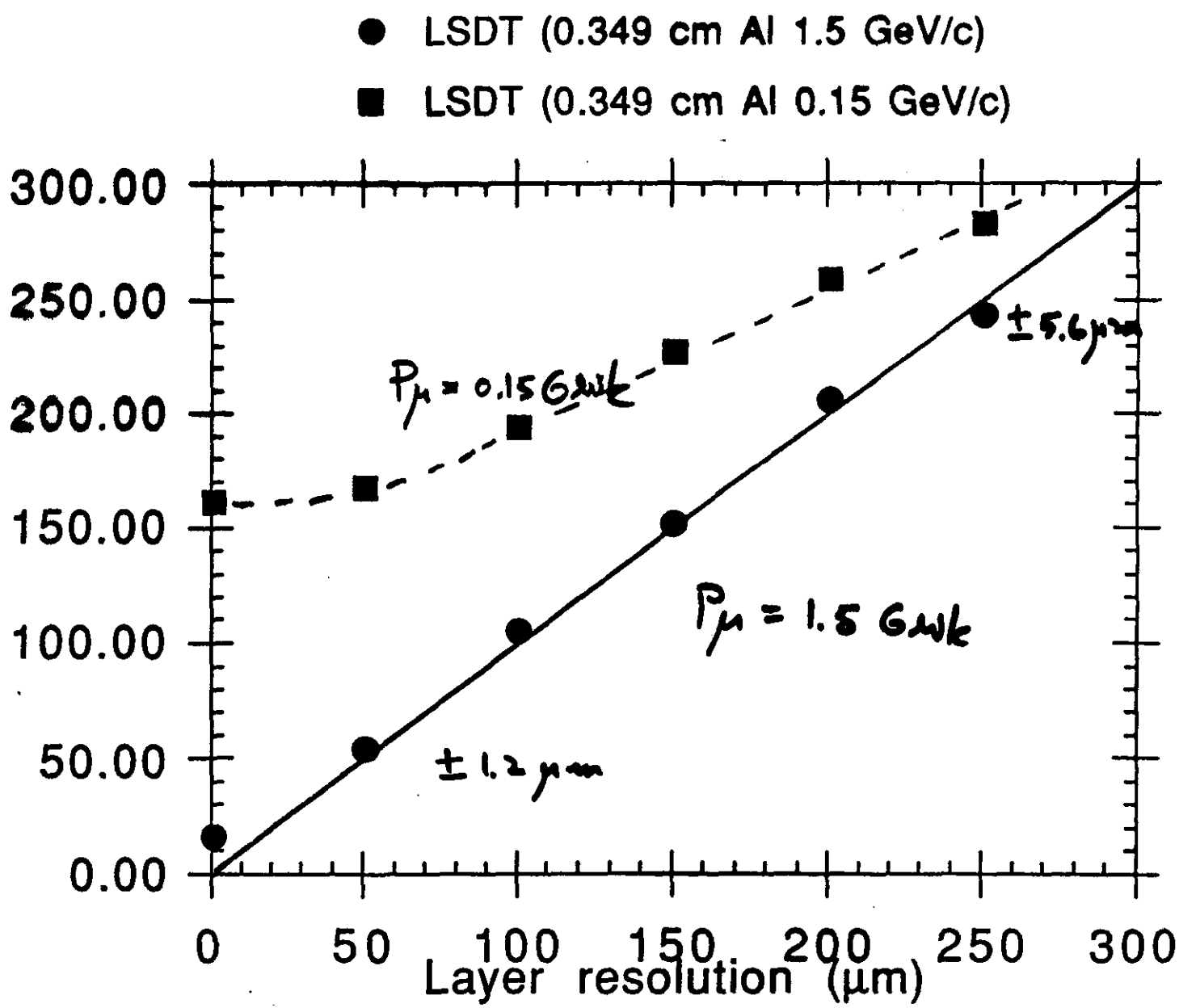
Total thickness = 0.203 L = 2.849
0.146
0.349 cm of Al. ← take this as worse case

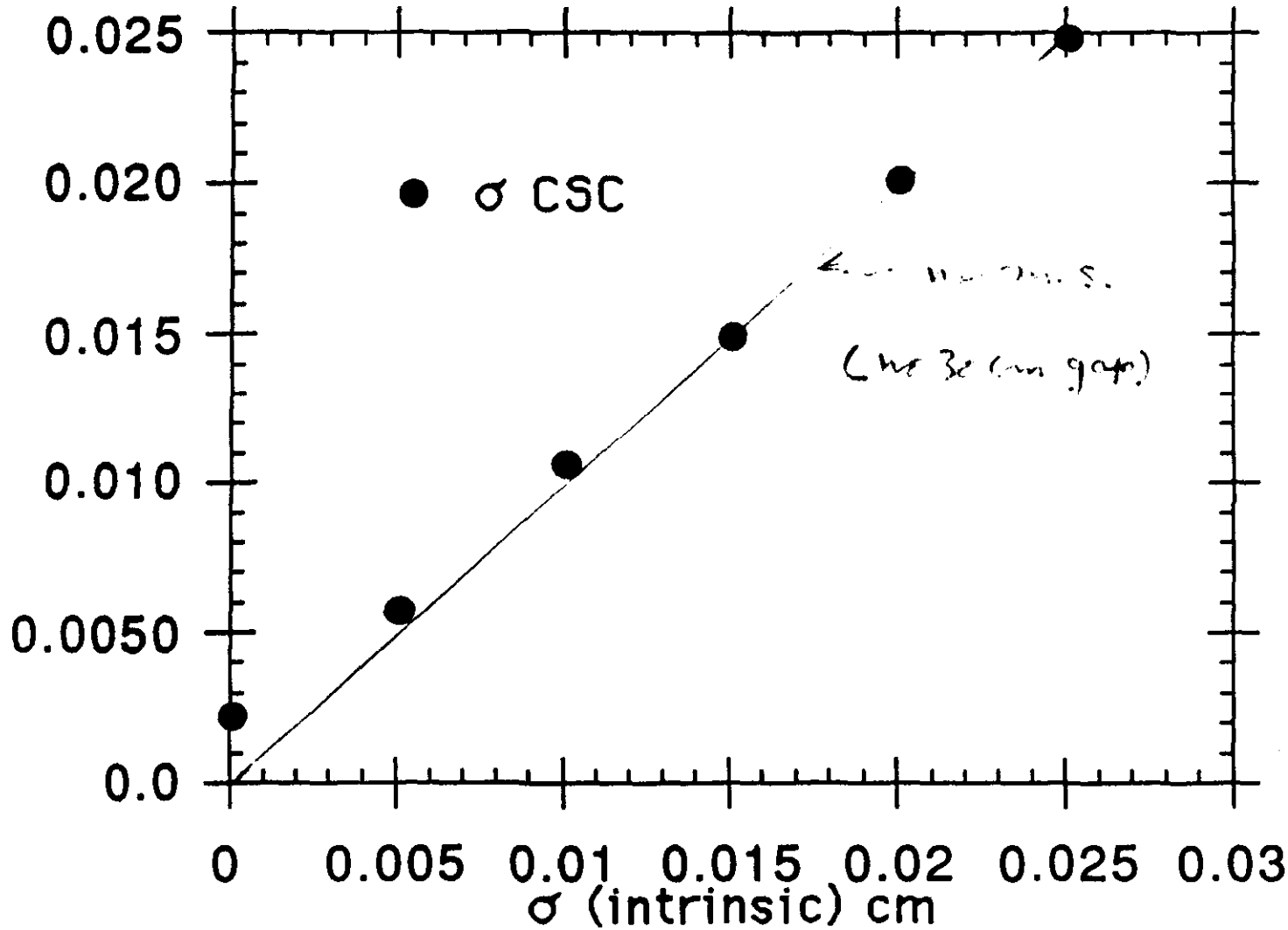
31% X_0 for 8 layers

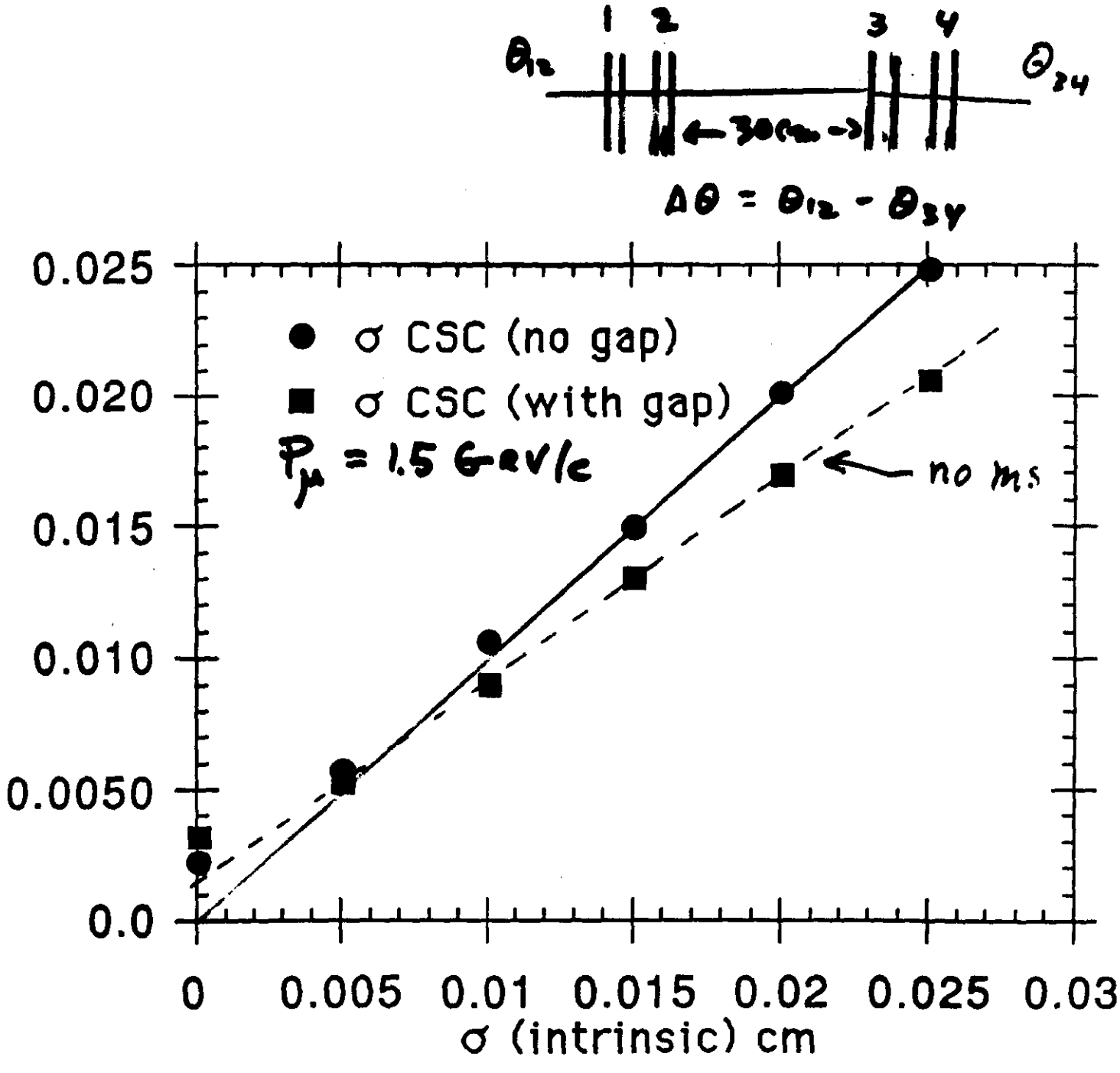
σ	$\sigma(\Delta\theta)$	"σ_0" $= \frac{L}{\sqrt{6}}\sigma(\Delta\theta)$
0.001	0.001381	0.0016
0.0051	0.004639	0.00539
0.0101	0.009075	0.0105
0.0151	0.01297	0.0151
0.0201	0.01771	0.02059
0.0251	0.02090	0.0243

PDT will be thinner than this. 8.5% X_0 for 8 layers

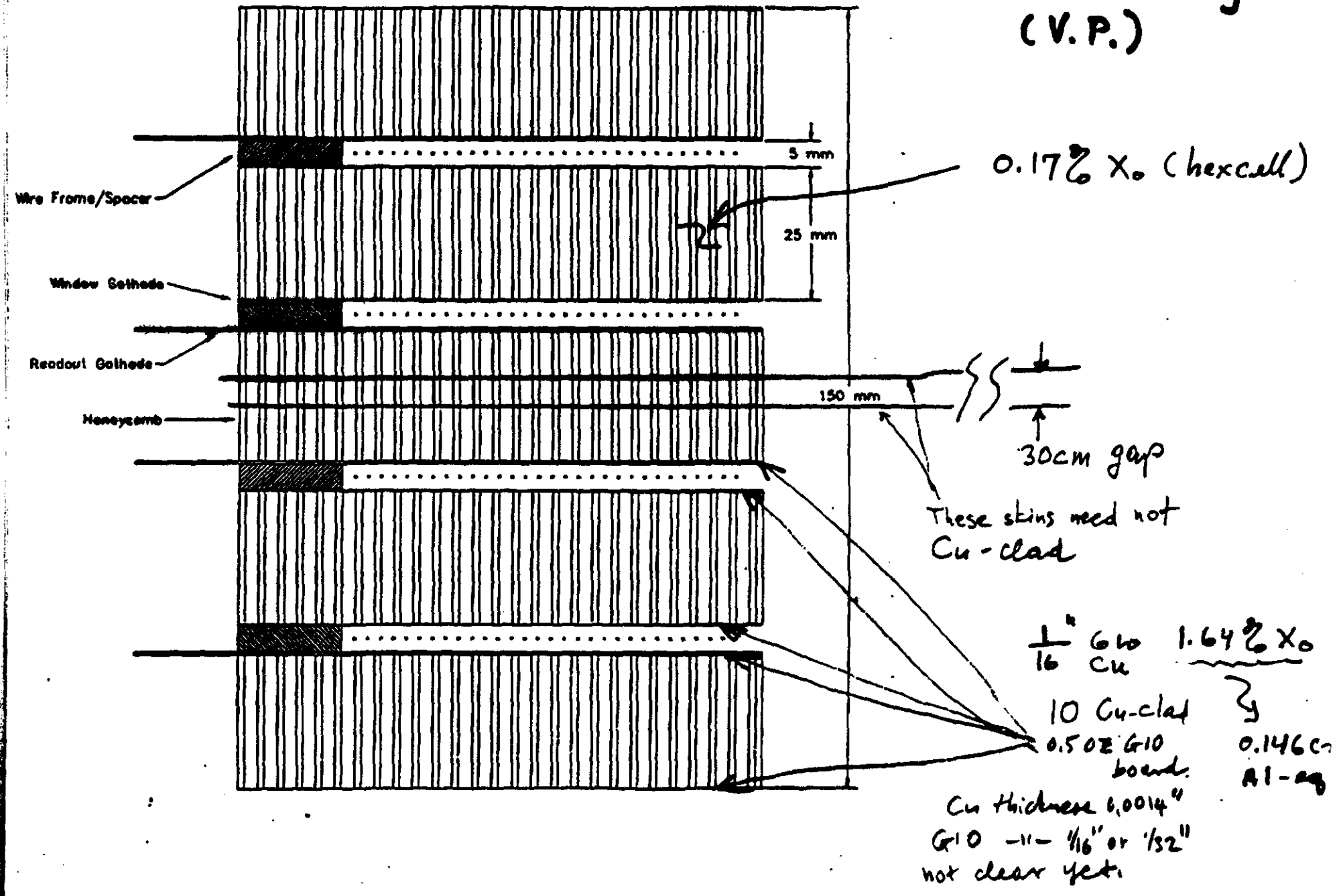
hence even for such a thick arrangement does ok.


LSDT (0.349 cm Al 1.5 GeV/c)
LSDT (0.349 cm Al 0.15 GeV/c)
300.00
250.00
200.00
150.00
100.00
50.00
0.00
0
50
100
150
200
250
300
Layer resolution (μm)
Pμ = 0.15 GeV/c
Pμ = 1.5 GeV/c
± 1.2 μm
± 5.6 μm


0.025
0.020
0.015
0.010
0.0050
0.0
σ CSC
0
0.005
0.01
0.015
0.02
0.025
0.03
σ (intrinsic) cm


1 2 3 4
θ_{12}
θ_{34}
30cm
$\Delta\theta = \theta_{12} - \theta_{34}$
σ CSC (no gap)
σ CSC (with gap)
P_μ = 1.5 GeV/c
no ms
0.025
0.020
0.015
0.010
0.0050
0.0
0
0.005
0.01
0.015
0.02
0.025
0.03
σ (intrinsic) cm

CSC Geometry (V.P.)



Further work:

1) δ-rays

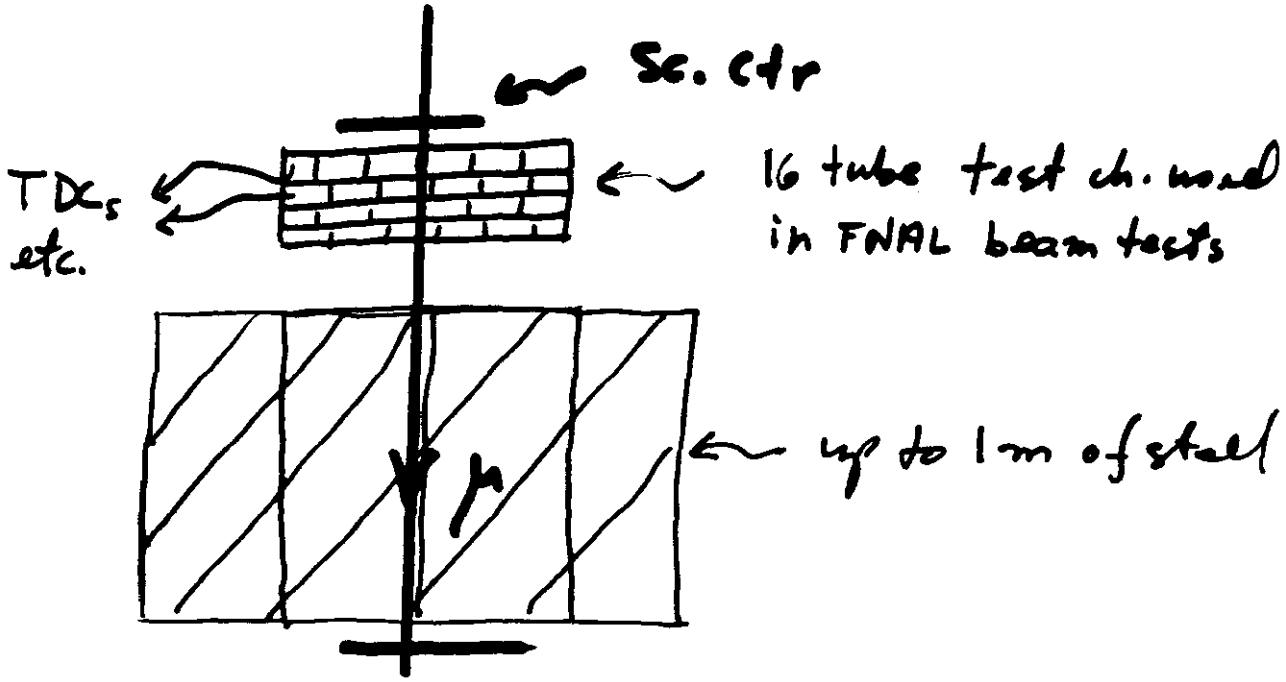
E-spectrum

θ-spectrum

details of technology simulation

goal: Try to simulate what measured.

2) Actual test of TTR:



test understanding of P_μ dependence & X_0 dependence