GEM TN-92-60

GEM Muon Group Meeting - SSCL

January 24, 1992

Abstract:

Transparencies and agenda for the GEM Muon Group Meeting on January 24, 1992 held at the SSCL.

1/24/92

GEM Muon Hardware meeting

General Remarks / R&D $ — Frank Taylor

Engineering / Integration & Cost Review — Frank Nimblett

TTR up date — Gena Mitselmakher

PDT R&D — Carl Bromberg, Georgui Chelkov

LSDT R&D — Louis Osborne

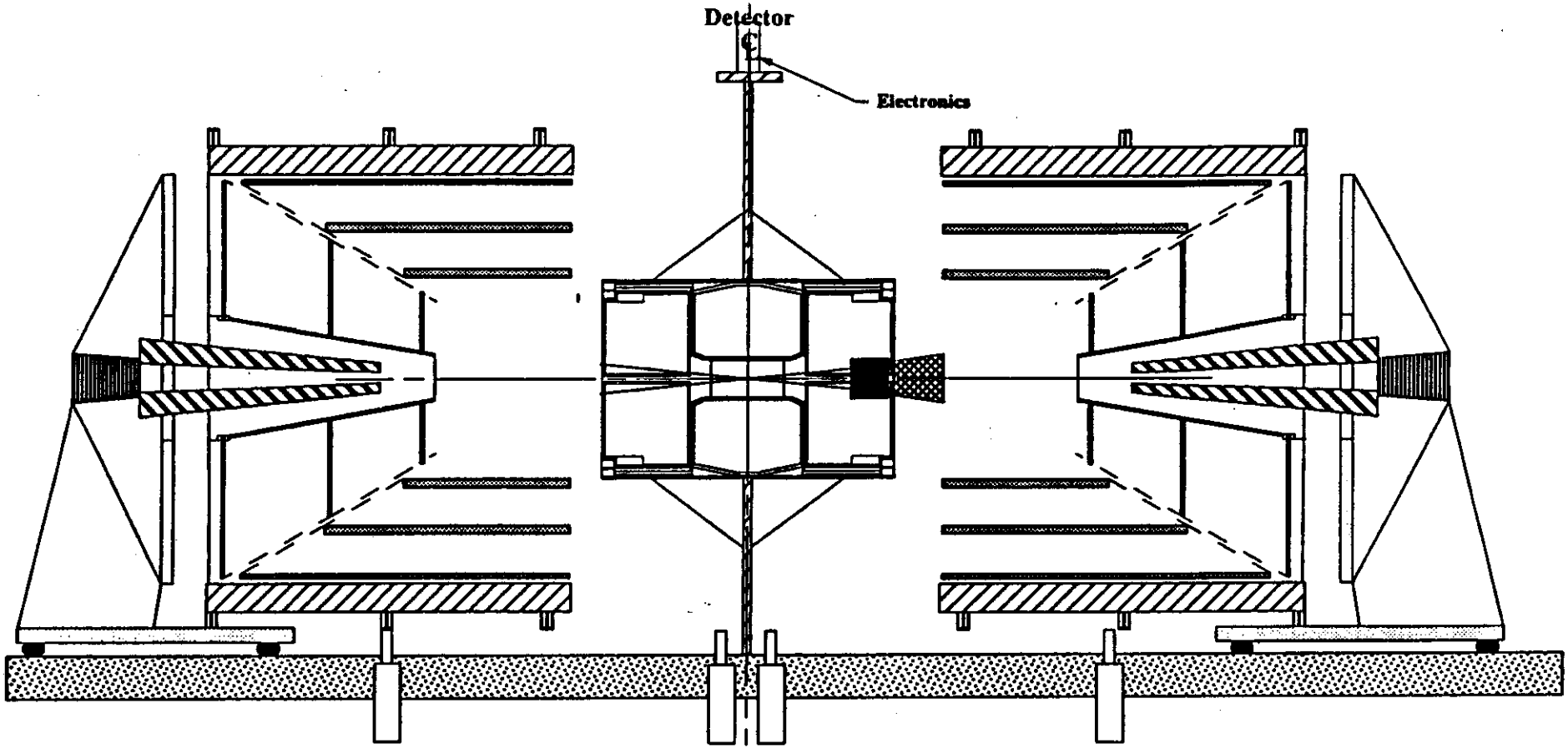
RPC R&D — Craig Wuest, Irwin Pless

CSC R&D — Scott Whitaker

Future Plans / Milestones — Group

M-meeting 1/24/92

Name	Phone	E-mail
Louis S. Osborne	617-253-2396	Osborne@MITLNS
Scott Whitaker	(617) 353-8916	SCOTT@BUPHYC
Dick Todd (ORNL)	(615) 574-5650	toddra@vlsi01.ic.ornl.gov
IRWIN A. PLESS (MIT)	617-253-2367	MITLNS:: PLESS
Phil Leibold	214 708 5011	LEIBOLD SSCVX1
Frank Stocker	(214) 708-6025	Stocker@SSCVX1
Chiaki Yanagisawa	(516) 632-8285	SBHEP::CHIAKI
Craig R. Wuest	(510) 423-2909	EDSEQ1::WUEST, WUEST@LLNL.GOV
Brian Smith	(505) 665-2666	BSMITH@CAEVAX.MEEDIV.LANL.GOV
Frank Nimblett	(617) 258-1393	NIMBLETT@DRAPER.COM
MOHAMMAD MOHAMMADI	516-632-8107	SBHEP:: MOHAMMADI
Jim SHANK	617 353 6028	SHANK@BUPHYC
Gena Mitselmakher	214-708-6001	SSCVX1::MITSELMAKHER
Maged Atiya	516 282 3067	atiya@BNLDAG
Roy Weinstein	713 749 4385	Univ. of Houston
Vinnie Polychronakos	516-282-3982	POLYCHRON@BNLDAG
Leogii Chelkov	7.95 - 923-9237	CHELKOV@VXCERN
Karl van Bibber	510-423-8949	PEGASYS@SLACESA
Carl Bromberg	517-353-1809	MSUHEP::BROMBERG
Ewald Zimmer-Nixdorf	(214) 708 6205	SSCVX1::ZNX



GEM Configuration Option Study
Liquid Argon Calorimeter
Integral Calorimeter Version

G.03.AS.0003

EBERLE/RENNICH

Features:

- integral muon chamber support structure
- gap at $\eta \approx 0$ acceptance loss?

  resolution loss?
- flux concentrator

What's needed for baseline Specification 3/8/92

+ local support

- Size, weight, channel count of chambers
  drawings to Draper by 2/7/92 F.N.
- Location of chambers in magnet

  R_1, R_2, R_3 F.N.

  Z_1, Z_2, Z_3 Draper by 2/18/92
  present to E/I meeting
- Conceptual design of chamber supports
  F.N./Draper by 2/18/92
- alignment concept ($\sigma_{ext} \lesssim 25\mu$, $\sigma_{int} \lesssim 50\mu$)
  F.N./Draper by 2/18/92
- analysis of $\delta p_\perp / p_\perp$ ($\delta P/P$)
  - with B-field shape
  - realistic chamber location & X_0

  L.R./J.D.S./FET Simulations 3/2/92
- hadron punch through λ cal (Pb, Ur, Fe, W?)
  R.McN. M.A. Simulations 3/2/92
- analysis of Lorentz angle effects
  CSC - V.P./S.N., PDT - S.A., LSDT - F.E.T.
- B-field mapping J.D.S./P.M./L3 person/LR
- Cost estimate F.N./Draper by 3/2/92
- Trigger concept I.P./M.A. Simulations group 3/2/92
- GEM μ-System Baseline Packet 3/6/92
  FET will compile

  10 to 20 pages (specs, resol'n, drawings ...)

R & D Budget:

GEM \$14 m = \$12 m | + \$2 m |
DOE Texas

	Old ('91)	New (1/24/92)	fraction
CSC	\$500 k	\$470 k	94 %
PDT	400	378	94.5 %
LSDT	480	442	92 %
RPC	300	260	87 %
SCARF	80	64	80 %
Drapen	700	616	88 %
TTR	240	200	83.3 %
	\$2.7 m	\$2.430 m	

EFFECT OF GEM MAGNET ASSEMBLY OPTIONS ON GEM MUON SYSTEM

F. Nimblett 20 Jan 92

ORIGINAL MAGNET CONCEPT: TWO MAGNET HALVES ASSEMBLED WITH CENTRAL WEB PRIOR TO INSTALLATION OF LIQUID ARGON CALORIMETER

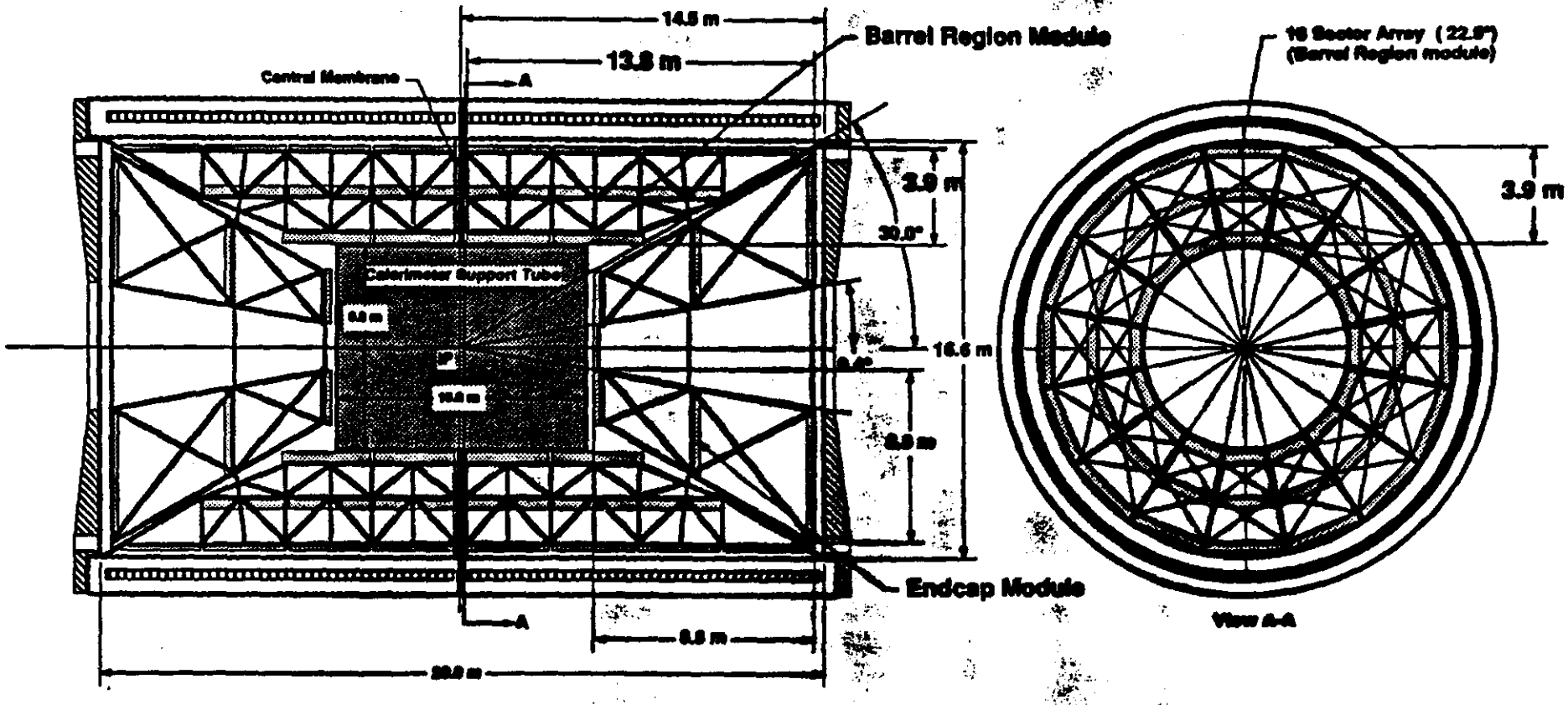
- Muon System installation can occur only after calorimeter is installed and SHORT LINE RR is removed.

- Calorimeter Cabling and Cryo Pipe Concerns
  - If they exit the central web, affects magnet assy
  - Exit at 30° Muon split line causes serial assy. with central muon, services and endcap muon syst.

- Access Requirements after installation
  - Removal of Quad or possibly a cantilevered Quad.
  - Retraction of Pole
  - Removal of at least one endcap muon sector module unless there is adequate access space at the 30° split line plus gymnastic ability for the technicians.

- Global Alignment of modules (approx. 1mm) is most likely to be maintained in this system !!!

- Central tracker access requires significant disassembly on both ends of the muon system, services, service support structures plus the addition of fixturing to remove the endcap calorimeters and finally the central tracker; THE WORST OPTION TO ADDRESS THIS CONCERN !!



GEM MUON SYSTEM

SPLIT CALORIMETER CONCEPT: BARREL CALORIMETER STAYS WITH SELF-STANDING CENTRAL WEB; ENDCAP CALORIMETER IS MOUNTED IN THE MAGNET HALF WITH WEB SYSTEM BETWEEN MUON MODULES.

- Muon System and calorimeter installations will be serial operations; Endcap calorimeter and services along 30° split line, followed by Barrel Region muon system.

- Web system to support 900 ton endcap calorimeter will detract from the muon system Phi acceptance! Deflections of such large horizontal plates (1 inch thick) will be on the order of 1 to 2 inches. This translates into additional Phi acceptance loss.

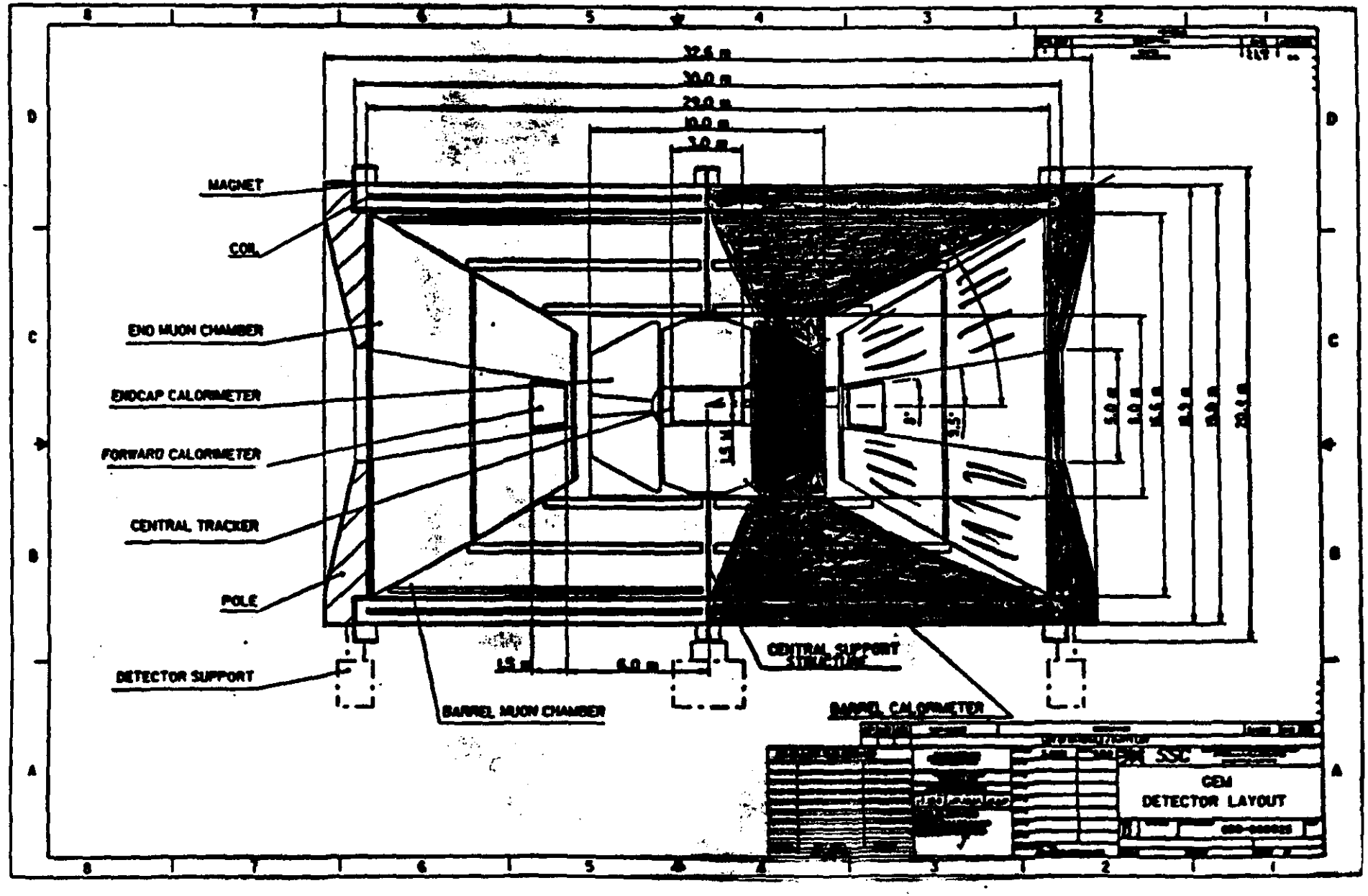
- This same 900 ton calorimeter weight also has the potential to add significant cost and complexity to the magnet structure which would have to support it.

- Since we are still in the cartoon phase of design, buckling of lower vertical plates hasn't been considered. Commitment to this design is a commitment to permit the web structure necessary to assure a safe stable structure! MORE POTENTIAL LOSS OF PHI ACCEPTANCE !!

- Calorimeter services, cables and cryo-pipes coming out the 30° split line, detract from muon system Theta coverage. Again commitment to this design is a commitment to permit the space necessary for undefined services and safety vents even if they increase in size in the future !!

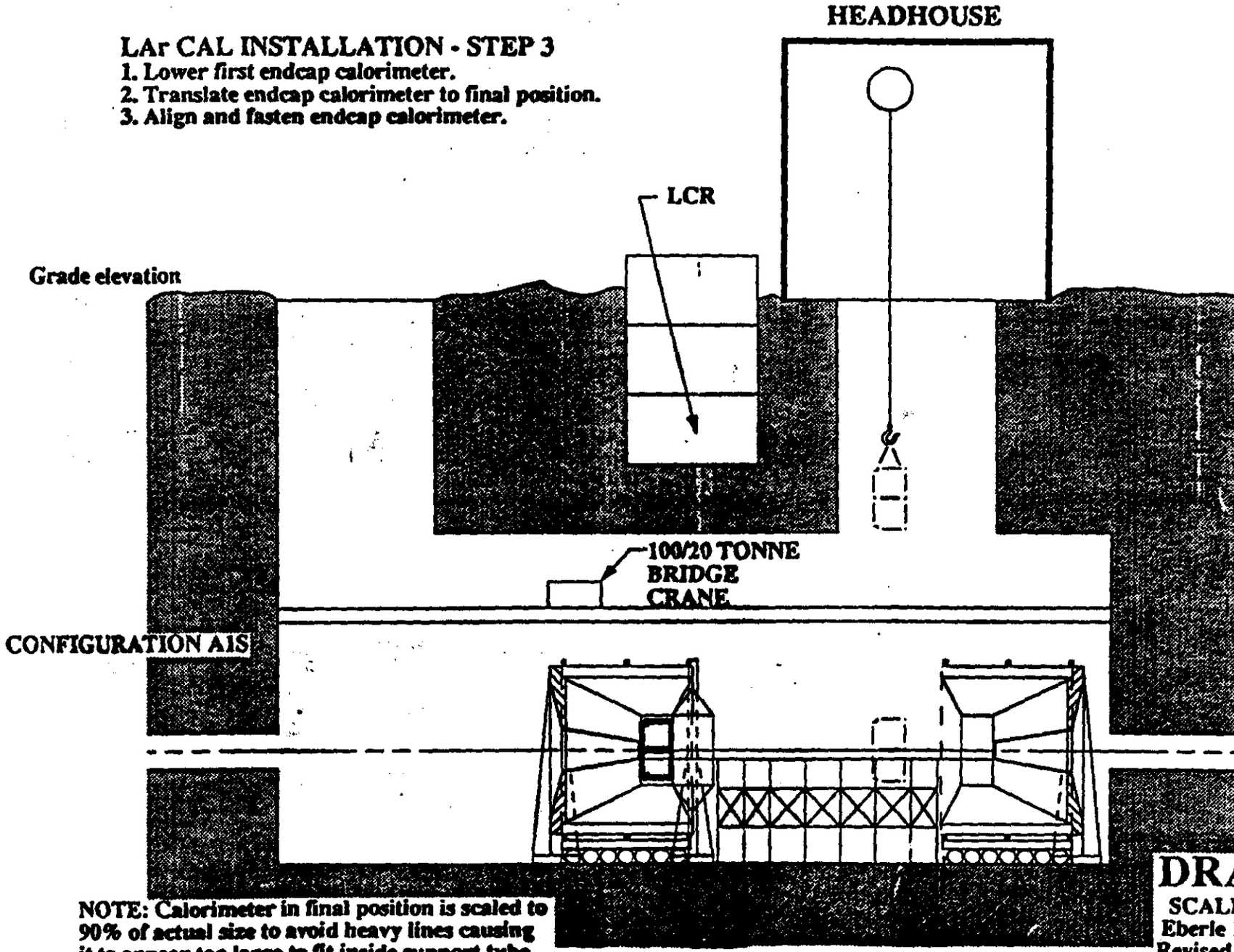
- CENTRAL TRACKER ACCESS BEST IN THIS OPTION !!

- Maintenance of global muon system alignment in the process of moving the magnet is more difficult and may require considerable effort to reevaluate the muon system alignment characteristics after reassembly. An active alignment transfer system to monitor position and orientation of muon system relative to Tracker/Quad fiduciary marks would be a helpful addition to such a mobile system. A system which could determine the relative positions of the muon system elements to an accuracy of tens of microns over a range of 5mm may be adequate. Hopefully this system could also be capable of referencing to the overall system reference (Quads?). Sensor technology certainly exists to easily accomplish such a task. What is needed is someone to conceive and implement such a system. In addition, an accurate indicator system to aid in the accurate relocation of the magnet halves is recommended to minimize the need for correction factors.


MAGNET
COIL
END MUON CHAMBER
ENDCAP CALORIMETER
FORWARD CALORIMETER
CENTRAL TRACKER
POLE
DETECTOR SUPPORT
BARREL MUON CHAMBER
CENTRAL SUPPORT STRUCTURE
BARREL CALORIMETER
32.6 m
30.0 m
23.0 m
10.0 m
3.0 m
1.5 m
6.0 m
SSC
CEM
DETECTOR LAYOUT

LAr CAL INSTALLATION - STEP 3

1. Lower first endcap calorimeter.
2. Translate endcap calorimeter to final position.
3. Align and fasten endcap calorimeter.



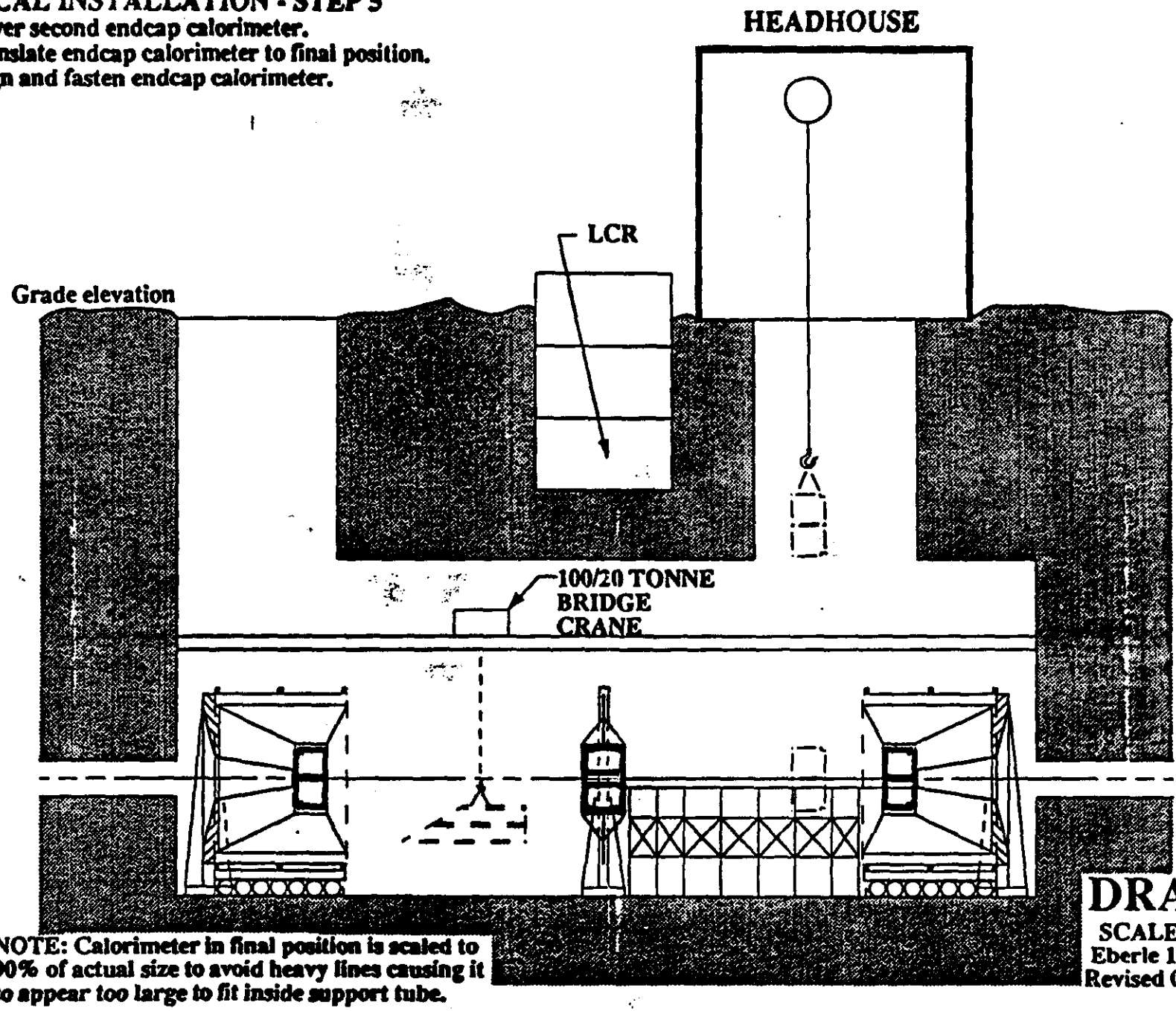
NOTE: Calorimeter in final position is scaled to 90% of actual size to avoid heavy lines causing it to appear too large to fit inside support tube.

DRAFT

SCALE 625:1
Eberle 12/17/91
Revised 01/06/92

LAr CAL INSTALLATION - STEP 5

1. Lower second endcap calorimeter.
2. Translate endcap calorimeter to final position.
3. Align and fasten endcap calorimeter.



NOTE: Calorimeter in final position is scaled to 90% of actual size to avoid heavy lines causing it to appear too large to fit inside support tube.

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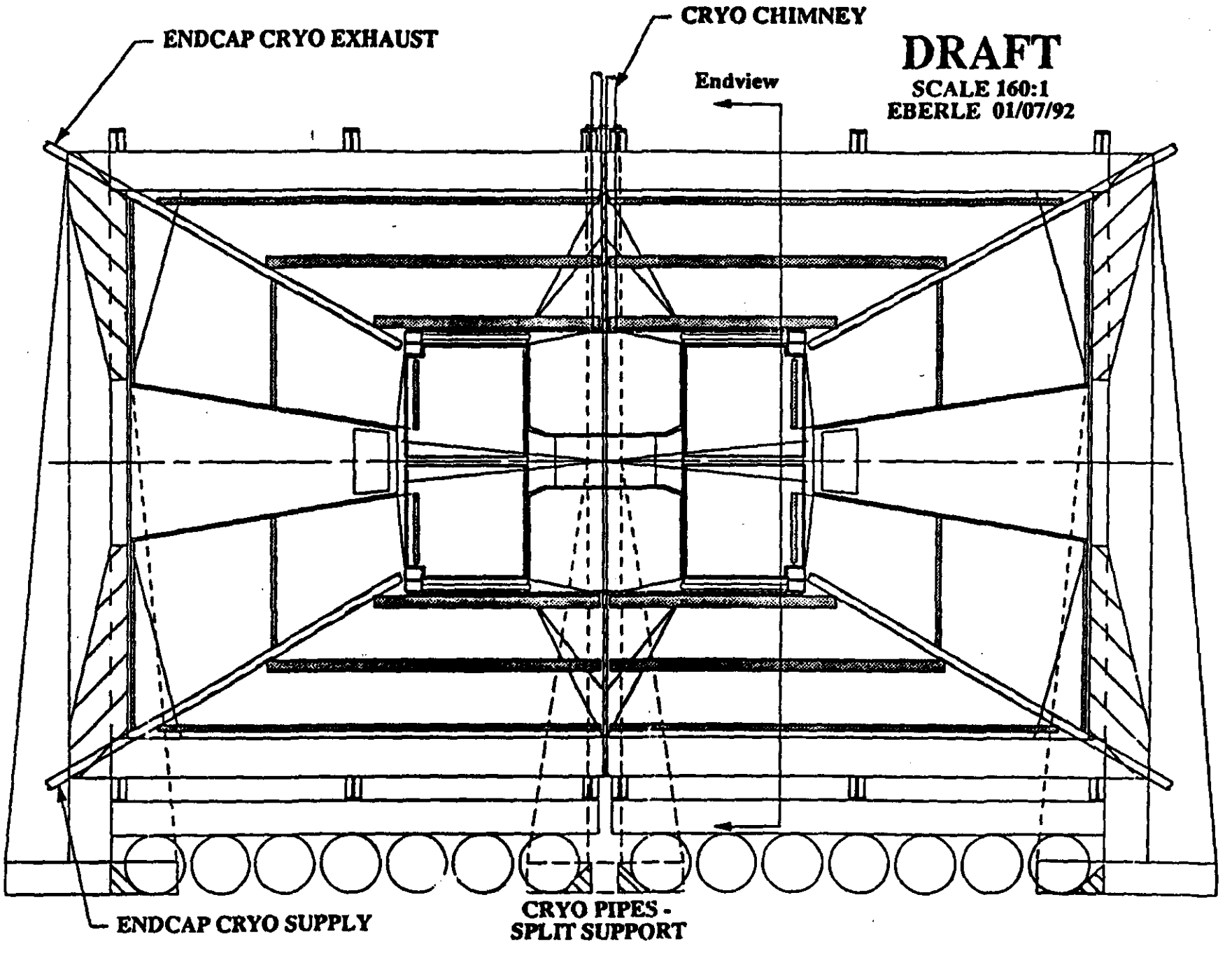
SCALE 625:1
Eberle 12/17/91
Revised 01/06/92


ENDCAP CRYO EXHAUST
CRYO CHIMNEY
DRAFT
SCALE 160:1
EBERLE 01/07/92
Endview
ENDCAP CRYO SUPPLY
CRYO PIPES -
SPLIT SUPPORT

INTEGRATED CALORIMETER CONCEPT: THE ENTIRE CALORIMETER ASSEMBLY IS CONTAINED WITHIN A SELF-STANDING CENTRAL WEB. ALL SERVICES FOR THE CALORIMETER EXIT IN THE VICINITY OF THE CENTRAL WEB.

- Muon System, calorimeter installations and cabling can now be essentially parallel operations.

- Calorimeter services exiting at central web means loss of coverage in Theta in an area least affecting physics goals!!

- Webs to provide some support tube rotational stability and stiffen the tube have always been in the baseline and have been demonstrated to be stable in short lengths. They do however cause potential problems if they get large radially and eliminate the possibility of having an adequate integrated muon space-frame structure!

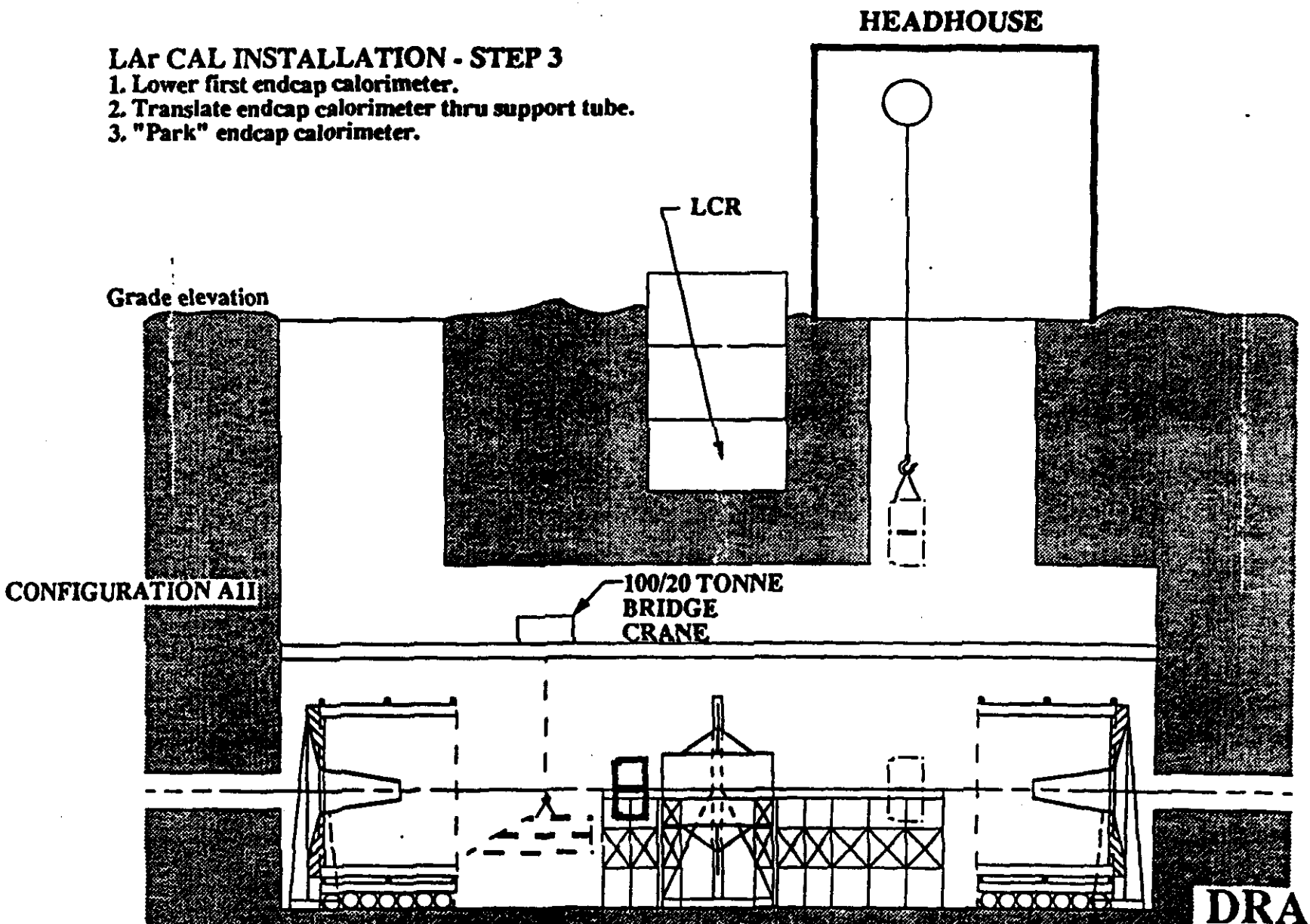
- Maintenance of global muon system alignment in the process of moving the magnet is more difficult and may require considerable effort to reevaluate the muon system alignment characteristics after reassembly. An active alignment transfer system to monitor position and orientation of muon system relative to Tracker/Quad fiduciary marks would be a helpful addition to such a mobile system. A system which could determine the relative positions of the muon system elements to an accuracy of tens of microns over a range of 5mm may be adequate. Hopefully this system could also be capable of referencing to the overall system reference (Quads?). Sensor technology certainly exists to easily accomplish such a task. What is needed is someone to conceive and implement such a system. In addition, an accurate indicator system to aid in the accurate relocation of the magnet halves is recommended to minimize the need for correction factors.

- With the Lower Electronics Control Room now being housed in a vertical shaft beside the main hall, freeing the space above the hall, this option could be further improved by specifying, if possible from a design standpoint, that the two main hall access shafts be placed closer to the hall center (13 to 14 meters between the inside walls of the two shafts). This would further decrease the distance the endcap calorimeter would have to travel on a rail system for at least the initial installation.

- With the introduction of the flux-sucker to the pole assembly, all non-critical components, with the possible exception of the forward calorimeter which remains undefined, can be placed on this pole assembly where alignment requirements will be less stringent.

LAr CAL INSTALLATION - STEP 3

1. Lower first endcap calorimeter.
2. Translate endcap calorimeter thru support tube.
3. "Park" endcap calorimeter.



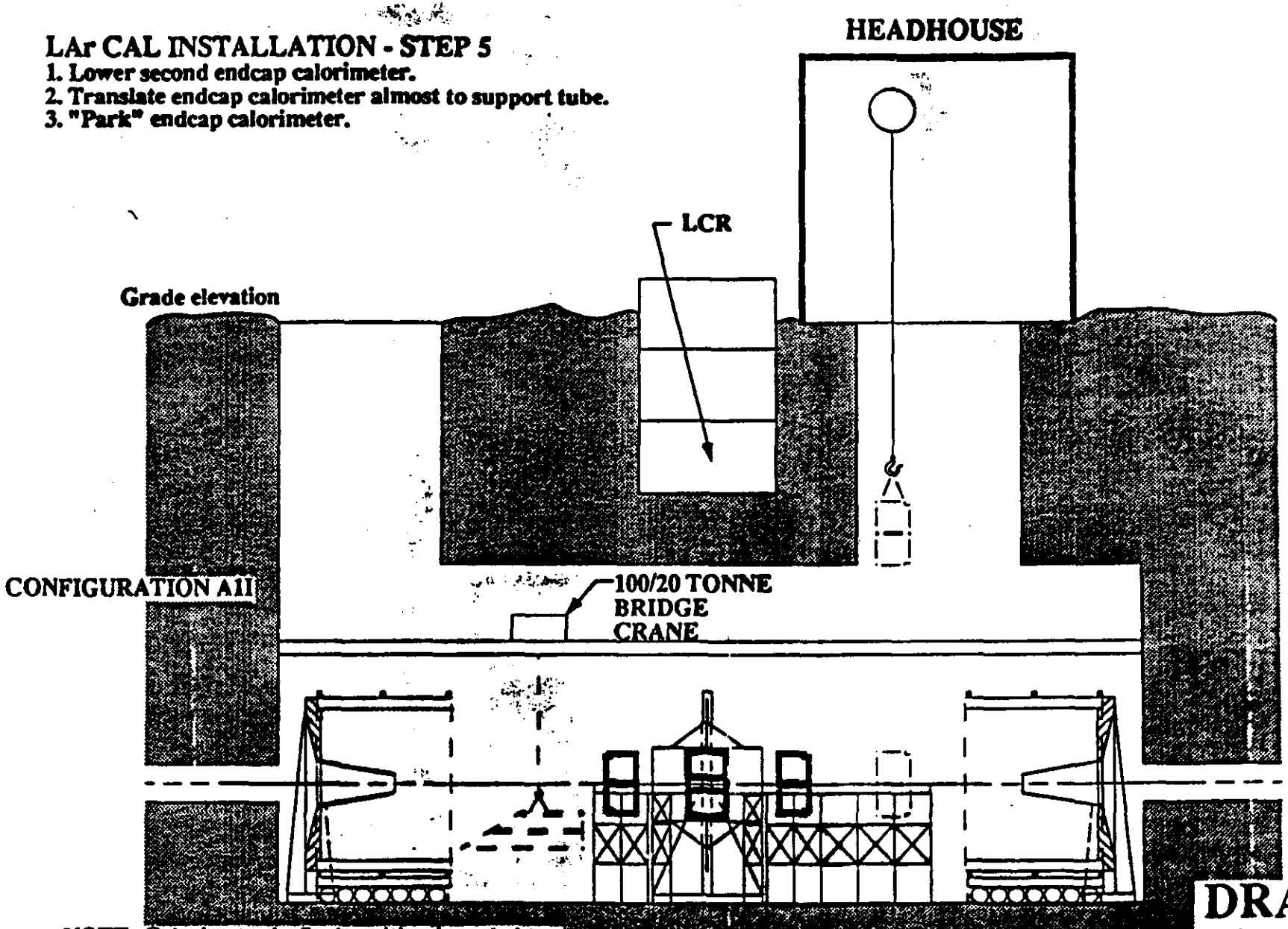
NOTE: Calorimeter in final position is scaled to 90% of actual size to avoid heavy lines causing it to appear too large to fit inside support tube.

DRAFT

SCALE 625:1
Eberle 12/10/91
Revised 01/03/92

LAr CAL INSTALLATION - STEP 5

1. Lower second endcap calorimeter.
2. Translate endcap calorimeter almost to support tube.
3. "Park" endcap calorimeter.



NOTE: Calorimeter in final position is scaled to 90% of actual size to avoid heavy lines causing it to appear too large to fit inside support tube.

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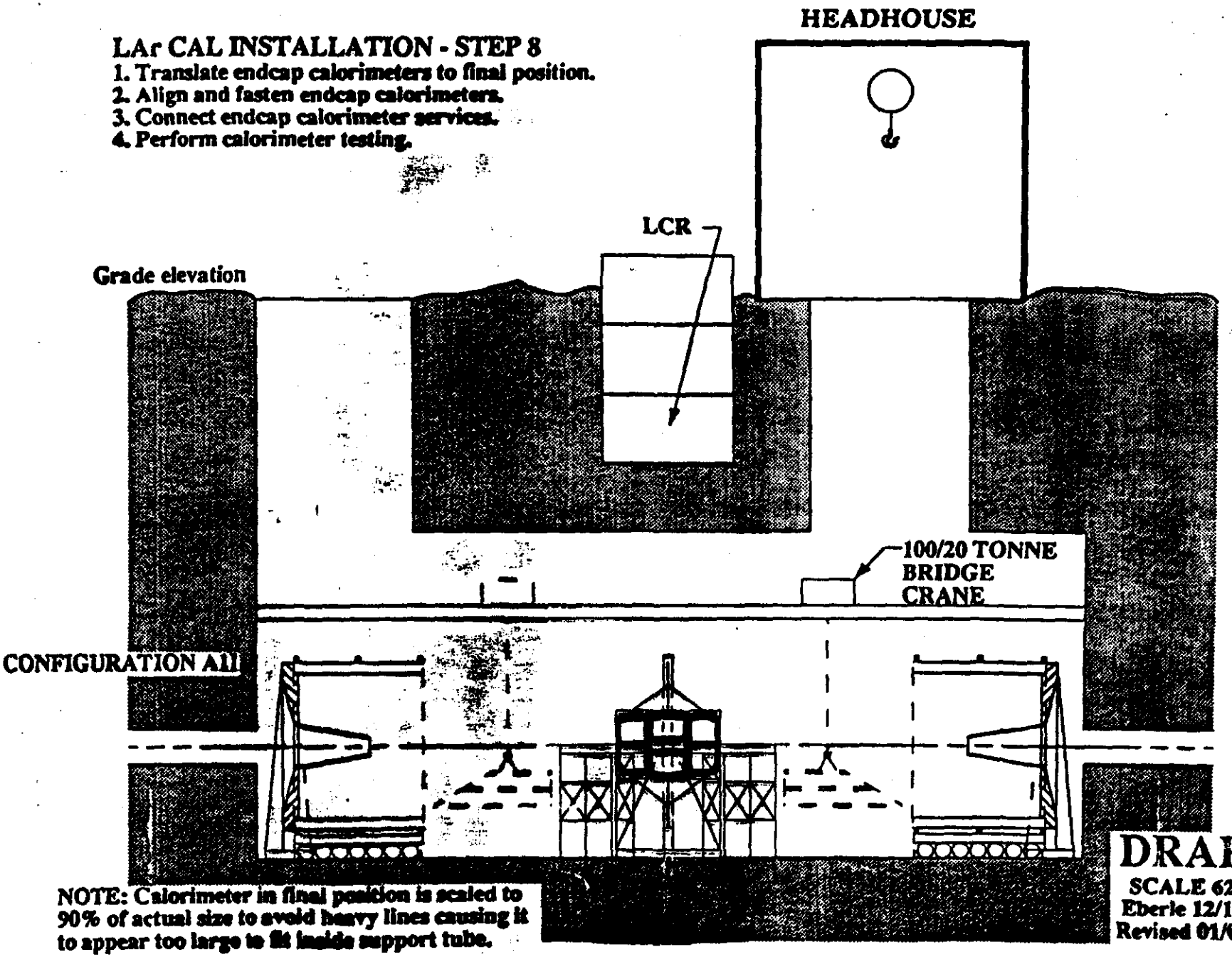
SCALE 625:1
Eberle 12/16/91
Revised 01/03/92

LAr CAL INSTALLATION - STEP 8

1. Translate endcap calorimeters to final position.
2. Align and fasten endcap calorimeters.
3. Connect endcap calorimeter services.
4. Perform calorimeter testing.



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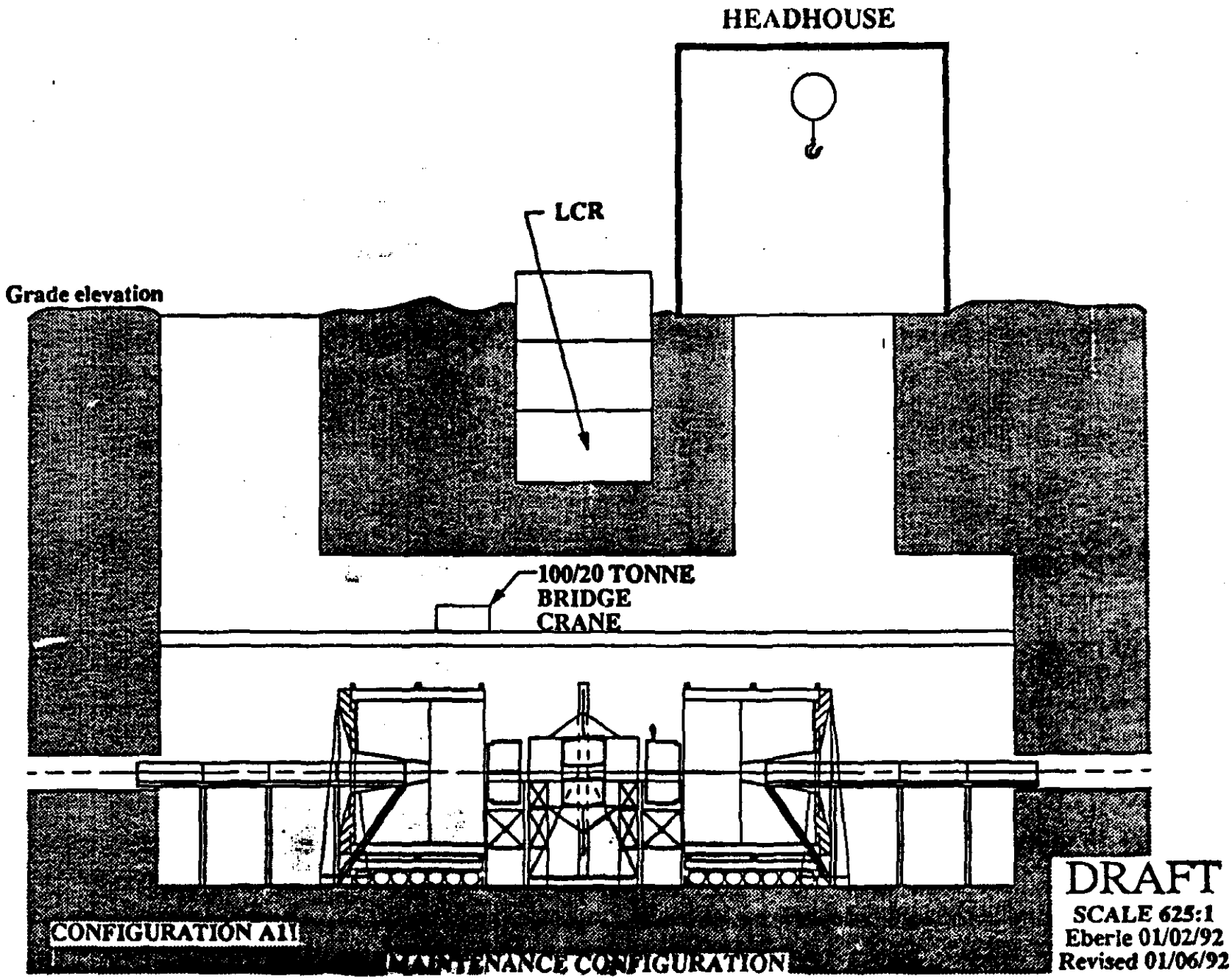
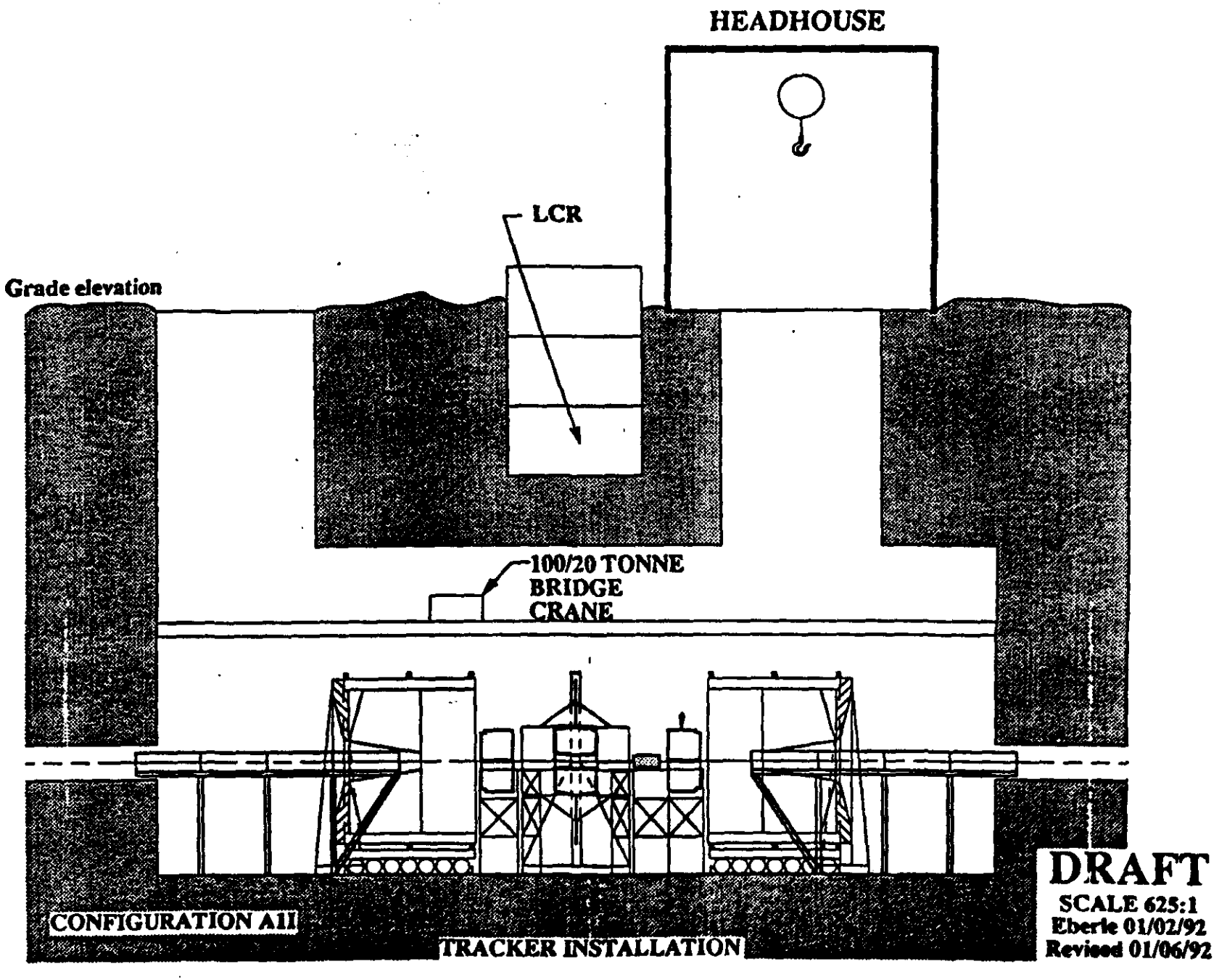
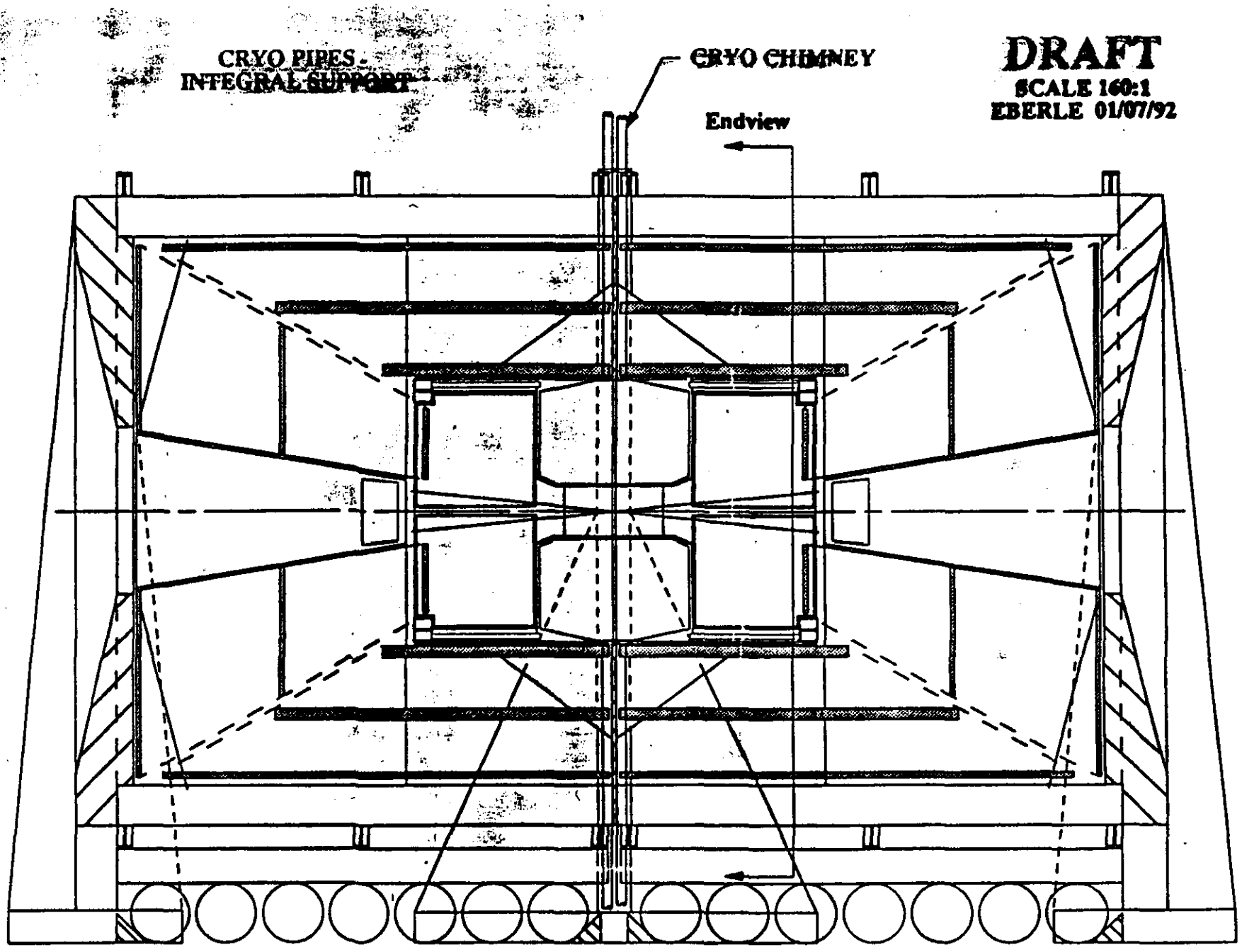
SCALE 625:1
Eberle 12/16/91
Revised 01/03/92


HEADHOUSE
LCR
Grade elevation
100/20 TONNE
BRIDGE
CRANE
CONFIGURATION A11
MAINTENANCE CONFIGURATION
DRAFT
SCALE 625:1
Eberle 01/02/92
Revised 01/06/92


HEADHOUSE
LCR
Grade elevation
100/20 TONNE
BRIDGE
CRANE
CONFIGURATION A11
TRACKER INSTALLATION
DRAFT
SCALE 625:1
Eberle 01/02/92
Revised 01/06/92



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SCALE 160:1
EBERLE 01/07/92

SPLIT CALORIMETER WITH FLUX SUCKER : ENDCAP MUON SYSTEM ATTACHED TO THE POLE PIECE: ENDCAP CALORIMETER IS CANTELEVERED OFF THE POLE PIECE, HELD UP BY CONICAL STRUCTURE OR A COMBINATION OF FLUX-SUCKER AND RADIAL WEBS.

- Endcap Muon System mounted to the pole has been rejected on the basis of difficulty in isolating from the pole piece motion due to magnetic forces. Attachment to the Barrel Region muon structure appears more stable (NOT ANALYZED).

- Conical support structure option limits options at the 30° split line and cuts into Theta coverage.

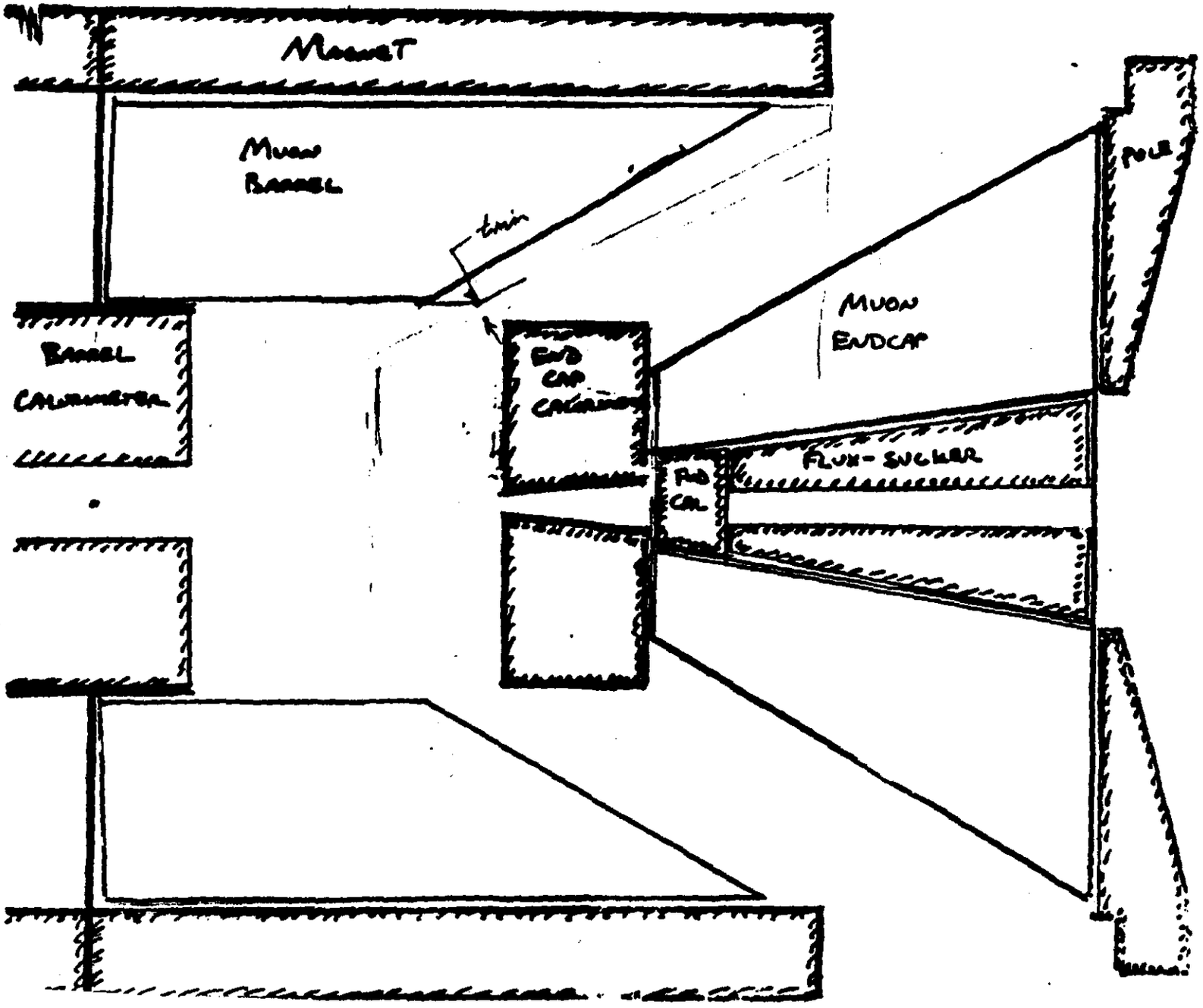
- Calorimeter services would take additional space along the 30° split line, further detracting from the Theta muon acceptance.

- Flux-sucker/radial webs option introduces the same problems discussed in the other split options. Probable large horizontal web deformations or possible buckling of the lower vertical webs remain an issue. Commitment to this design is again a commitment to permit the web structure necessary to assure a safe stable structure! MORE POTENTIAL LOSS OF PHI ACCEPTANCE in the endcap region!!

- This option creates another separate problem of moving a very large mass along with a relatively delicate assembly (similar to the barrel region) with care and accuracy in a less desirable cantilevered configuration.

- Alignment problems on reassembly of the pole assembly will be similar to the problems associated with any of these options except the original non-separable option. They should be slightly less since they are in principle limited to the endcap region, but there are no guarantees on that.

- This system, while better for Central Tracker access, still leaves the problem of inserting a 9 meter long bridge over the exposed barrel region muon chambers in order to get to the tracker to work on it or to remove it.

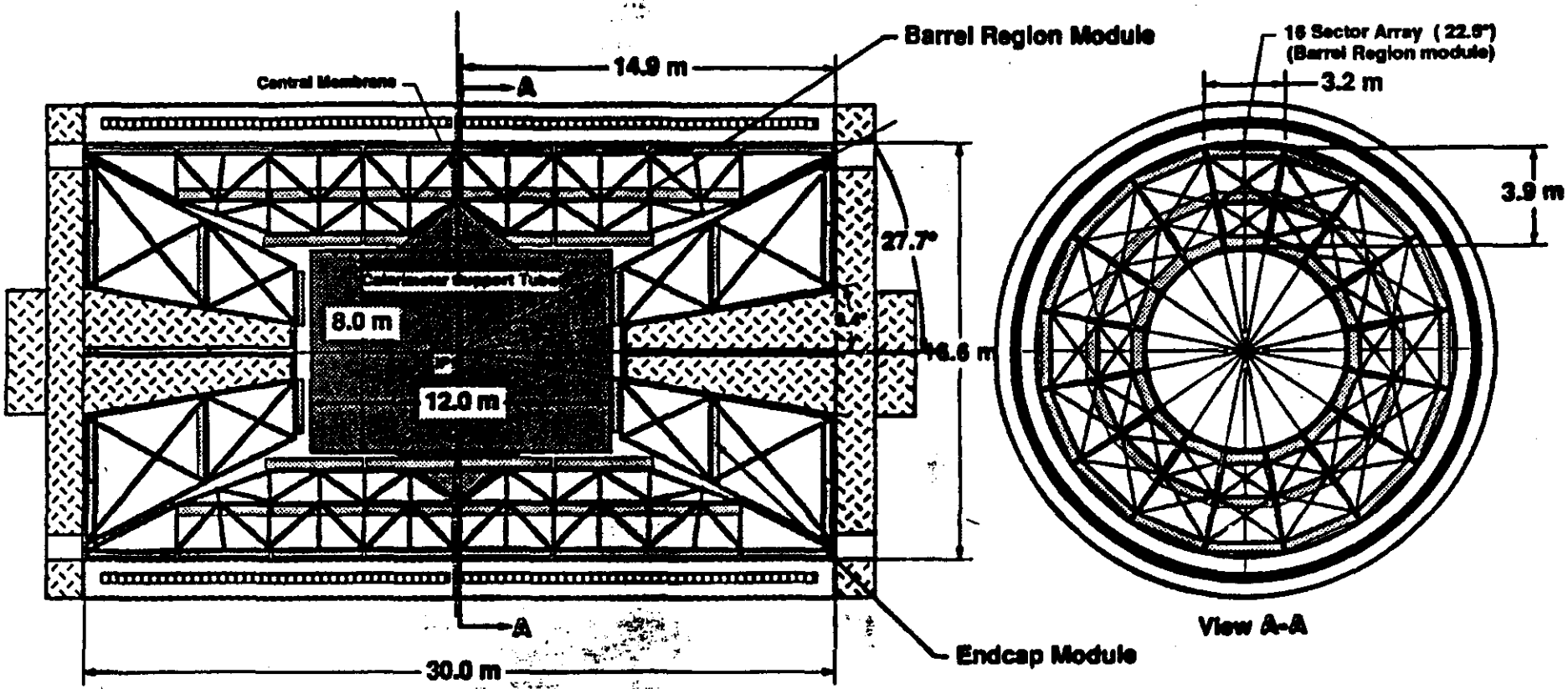

MAGNET
MUON BARREL
BARREL CALORIMETER
END CAP CALORIMETER
END CAP
MUON ENDCAP
POLE
FLUX-SUCKER

CONCLUSION

From the Muon System standpoint, the best GEM magnet assembly option of those currently under consideration is

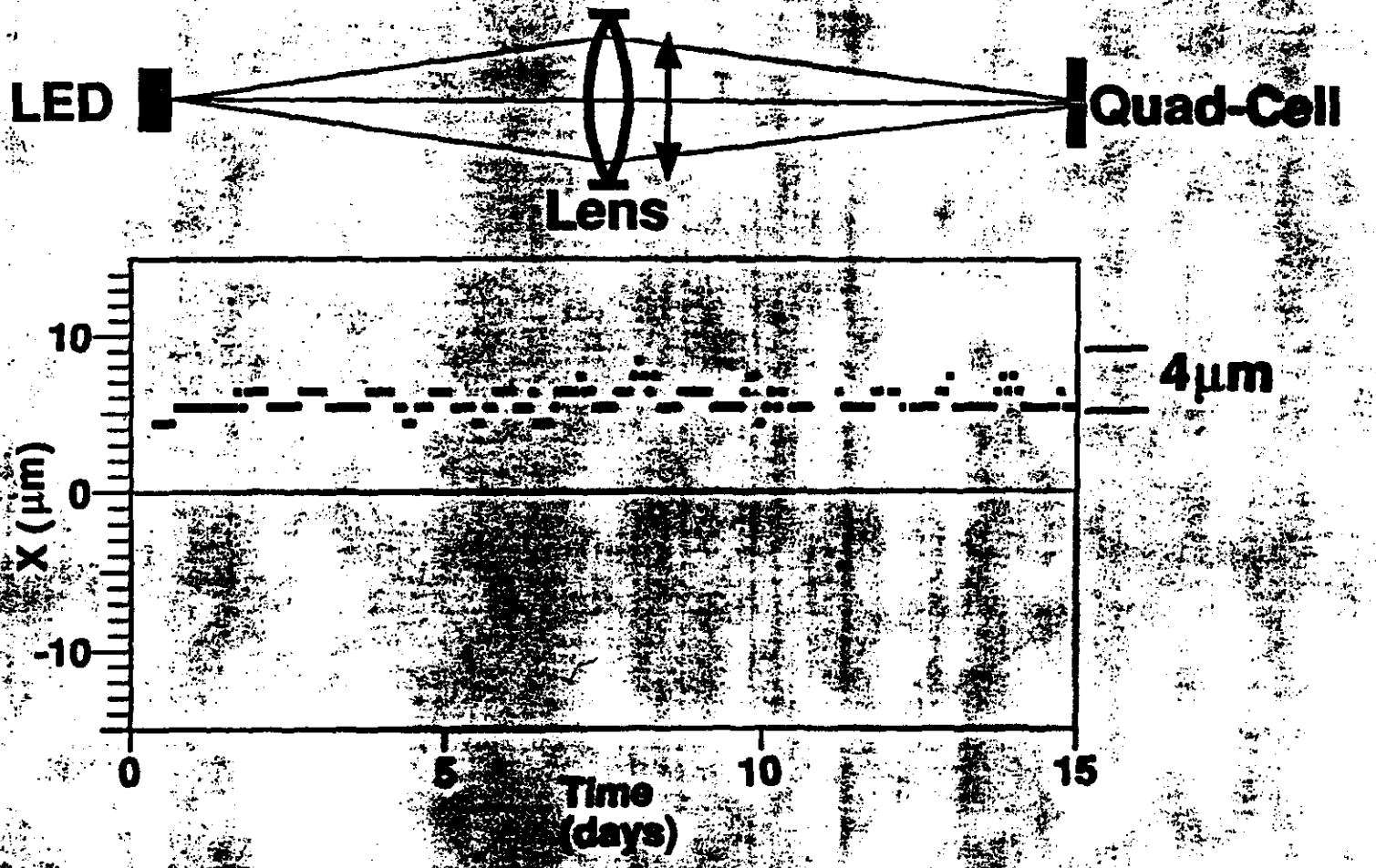
THE INTEGRATED CALORIMETER OPTION

- BEST MUON SYSTEM STABILITY POTENTIAL
- MAXIMIZES PARALLEL ASSEMBLY OPTIONS
- MINIMIZES SERIAL ASSEMBLY OPERATIONS BETWEEN SUBSYSTEMS
- LEAST LOSS OF MUON SYSTEM COVERAGE
- REASONABLE CENTRAL TRACKER ACCESS
- MAGNET COMPLEXITY HIGHER
- CALORIMETER ACCESS IS GOOD
- FORWARD CALORIMETER OPTIONS LOOK PROMISING
- INTRODUCTION OF FLUX-SUCKER/ POLE/COIL OPTIONS APPEAR REASONABLE



GEM MUON SYSTEM
Integrated Calorimeter Option

F. Nimblett
21 January 1992



Fifteen -day stability of the L3 Muon Chambers within an octant

MUON SYSTEM COSTS

- COST REVIEW ON 16 DEC. CLEARLY POINTED OUT NEED TO IMPROVE COST ESTIMATES

- SYSTEM TOTAL COSTS AT COST REVIEW
  - LSDT BASED SYSTEM ---- $117M
  - PDT BASED SYSTEM ---- $128M

- CURRENT SNAPSHOT IN TIME COSTS
  - LSDT BASED SYSTEM ---- $108M
  - PDT BASED SYSTEM ---- $112M

- DIFFERENCE BETWEEN THE TWO RESULT FROM TWO MAJOR SOURCES.
  - SOME DOUBLE COUNTING OF PDT COSTS
  - STRUCTURE COSTS MORE BELIEVABLE !!
    (LoI USED EXTRAPOLATED L* COSTS)

- CAREFUL REVIEW OF WBS COST ENTRIES BY SUBSYSTEM IS VITAL IN THE FUTURE (STARTING TODAY)

- IN THE FUTURE, <u>MUCH BETTER BACKUP INFORMATION</u> IN A <u>UNIFORM FORMAT</u> WILL GREATLY AID IN IMPROVING THE ACCURACY AND ABILITY TO UNDERSTAND THE MUON COST ESTIMATE !!

- ALL FUTURE SUBSYSTEM INPUT TO THE COST BOOK SHOULD BE ON THE STANDARD FORMS TO BE DISTRIBUTED TODAY.
  - HARDCOPY OF WBSs, BACKUP SHEETS, SCHEDULE (FASTRACK),GEM COST PLAN
  - DISCS WITH ALL INFORMATION (MAC) (EXCEL 3, MS WORD 4, FASTRACK APPL.)

- THESE FORMS REPRESENT A MINIMUM INPUT. ADDITIONAL CONCISE INFORMATION WILL IMPROVE THE UNDERSTANDING OF COST BASIS IN THE FUTURE.

<u>CURRENTLY IT IS NEARLY IMPOSSIBLE TO FOLLOW!</u>

<u>THIS MUST IMPROVE BY THE APRIL 6 COST REVIEW.</u>

MUON SYSTEM
COST ESTIMATION WORKSHEET

WBS Element Title: Sector Support Stucture; Off-Site; Machining/Inspection

WBS Element No: 3.2.1.2.5.1.5 **Date:** 6 Dec 91 **Rev:** 0 **Estimator:** Hamilton/Kondoleon

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Scope: This element covers the labor and labor costs for the machining and inspection of structure components. Also, oversight for purchasing stock and material for machining.

Engineering/Design **PY:** **Comp. Rate($K/PY):** **PoP:**
N/A

M&S: Engineering/Design and Inspection/Administration **($K): 60**
Misc. office supplies for Administration: $21K
Travel: 1 person, 4 trips to machine shop, inspection shop @$2K/trip $8K
PC/Mac/workstation charges: $31K

Inspection/Administration **PY: 1.64** **Comp. Rate($K/PY): 54** **PoP: 1/94-3/96**

Assumes Engineering (nat. avg.) oversight of purchasing activity: 1/4-time for 24 months = .5 PY
Assumes Engineering (SSCL) oversight of machining and inspection activity: 1/4-time for 2.25 yrs = .56 PY

Assumes Sr. and Jr. Tech (job shop) for oversight and performance of following:
Weld inspection, 10 min per weld, total welds=4448 sections * 2=8,896*1/6=1,482 hrs (structure)
Weld inspection, 10 min per weld, total welds=576 sections *2=1,152*1/6=192 hrs (chamber support)
Section inspection (saw & end machined) 10 min. per section= 5024 total sections *1/6= 838 hrs
End plug inspection (machine) 5 min per plug *2per section*5024=838 hrs
TOTAL HOURS 3,350 hrs = 1.60 PY

Assumes labor costs for components (truss joint elements, etc.): 6 PY, total tech of 7.60 PY

Procurement/Fabrication Material **($K) 1469**
Material
Support tubes [illegible]
Material cost 4.50 $/foot (K$)
47 elements require 14 sections of 24 foot long tubes for each side 336 ft *2*16*2 = 21,504 ft
45 elements require 20 sections of 24 foot long tubes for cross connect 480 ft *16*2=15,360 ft
18 elements require 7 sections of 24 foot long tubes for chamber support 168 ft*16*2= 5,376 ft
TOTAL LENGTH 42,240 ft
@ 4.50 $/ft material cost $190K

End plugs
2 end plug per tube. 5024 tubes= 11,000 end plug required
Material cost 4.00$ per piece (3.0 Dia x 6.00 in long 6061-T651) =$44K

Assumes material costs for other components (truss joint elements, etc.): $1000K

Fabrication Equipment
3 strap on machines for chamfer and c.b. machinning $15K
1 cross hole machine $200K

Inspection Equipment
tube end inspection $5K
tube length inpection $5K
weld inspection $10K

Machining
tubes cut to length 157 saw cuts per section * 16*2= 5,024 cuts @ 6per hour= 838 hours
machining of tube ends(chamfer &c.h.) 5024 tubes machines*2 ends@15min per tube=1,256 hrs
total hrs = 2094 hrs = 1 PY

end plugs: 1hour per piece *11000 pieces = 11000 hrs = 5.3 PY

Assumes machining costs for other components (truss joint elements, etc.): 20 PY

Material: Installation/Assembly **($K) 32**
Misc. office supplies for Installation/Assembly = $32K

Contingency **Total: 38**

Technical:	0	Basis:	none
Cost:	30	Basis:	engineering judgement, material and labor rate concern
Schedule:	8	Basis:	delays completion of critical path item

Comments
Material cost based on quotes from Ryerson 12-5&6 91
Engineering estiimate used to size the number and lengths of the structural elements needed.
Machine cost based on interface with E. McCormack (Draper shop group leader 12-6-91)

ESTIMATION WORKSHEET BACK-UP

WBS ELEMENT DESCRIPTION: Sector Support Structures; Off-Site; Machining/Inspection

WBS ELEMENT NUMBER: 3.2.1.2.5.1.5

DATE: 6 Dec 91 **REV:** 0 **ESTIMATOR:** Kondoleon/Hamilton

ENGINEERING/DESIGN

Organization: none

LABOR	PY	Rate ($K/PY)	$K
engineer, nat'l lab	0.00	154	0
designer, nat'l lab	0.00	93	0
drafteman, nat'l lab	0.00	77	0
engineer, nat'l avg	0.00	133	0
designer, nat'l avg	0.00	107	0
drafteman, nat'l avg	0.00	82	0
Total, w/ Comp Rate	0.00	0	0

M&S: ENG/DESIGN and INSPECT/ADMIN	$K
office supplies ($2.4K/PY)	21
PC/Mac/workstation operating charges ($3.6K/PY)	31
travel	8
office/engineering service equipment	0
	0
	0
ww	0
xx	0
yy	0
zz	0
Total	60

INSPECTION/ADMINISTRATION

Organization: SSCL, job shop

LABOR	PY	Rate ($K/PY)	$K
engineer, nat'l lab	0.00	154	0
sr. tech, nat'l lab	0.00	103	0
jr. tech, nat'l lab	0.00	77	0
engineer, nat'l avg	0.00	133	0
sr. tech nat'l avg	0.00	107	0
jr. tech nat'l avg	0.00	82	0
engineer, SSCL	0.56	78	44
sr. tech, SSCL	0.00	60	0
sr. tech, job shop	3.80	54	205
jr tech, job shop	3.80	39	148
Total, w/ Comp Rate	8.66	84	464

CONTINGENCY

	Factor	Percentage	Total
technical	0	0	0%
cost	15	2	30%
schedule	6	1	6%
Total Contingency			36%

INSTALLATION/ASSEMBLY

Organization: job shop/machine shop

LABOR	PY	Rate ($K/PY)	$K
engineer, nat'l lab	0.00	154	0
sr. tech, nat'l lab	0.00	103	0
jr. tech, nat'l lab	0.00	77	0
engineer, nat'l avg	0.00	133	0
sr. tech, nat'l avg	0.00	107	0
jr. tech, nat'l avg	0.00	82	0
engineer, SSCL	0.00	78	0
sr. tech, SSCL	0.00	60	0
machinist, job shop	26.30	74.8	1966
sr. tech, job shop	0.00	54	0
jr tech, job shop	0.00	39	0
rigger, welder	0.00	52	0
pipefitter, electrician	0.00	47	0
Total, w/ Comp Rate	26.30	75	1966

PROCUREMENT and FABRICATION MATERIAL	$K
support, lifting [illegible]	190
end plugs	42
other (to be identified)	1000
materials and supplies (nuts, bolts, etc)	[illegible]
inspection equipment	[illegible]
3 strap-on machines for chamfer, C/S machining	15
1 cross hole machine	200
tube end inspection equip	5
tube length inspection equip	5
weld inspection equip	10
ww	0
xx	0
yy	0
zz	0
Total	1469

MATERIAL: INSTALLATION/ASSEMBLY	$K
office supplies ($1.2K/PY)	32
travel	0
office/engineering service equipment	0
equipment operating charges	0
ww	0
xx	0
yy	0
zz	0
Total	32

COMMENTS

ENGINEERING COORDINATION

- COMMUNICATION OF ENGINEERING DESIGN PROGRESS IN SUBSYSTEMS MUST IMPROVE

- IN ORDER TO SUPPORT THE MUON SYSTEM, IT IS NECESSARY TO KNOW WHAT IT LOOKS LIKE!!

- I NEED REASONABLE SKETCHES OF ANTICIPATED MUON CHAMBER STRUCTURAL DESIGNS.

- MOST IMPORTANTLY, I NEED DETAIL ON THE STRUCTURE NEAR THE ENDS OF THE CHAMBERS WHERE ATTACHMENTS TO SUPPORT STRUCTURE WILL BE MADE.

- SYSTEM BLOCK DIAGRAMS OF CHAMBERS WHICH RELATE TO THE WBS WOULD AID GREATLY IN UNDERSTANDING THE SYSTEM AS WELL AS COSTING OF THE SYSTEM.

- AS I INDICATED AT THE LAST MUON MEETING, I NEED UP-TO-DATE INFORMATION ON THE CHAMBER SUBSYSTEMS IN ORDER TO REACT TO THE DESIGNS.

- AGAIN, I WOULD LIKE TO REQUEST A MONTHLY REPORT, DUE TO ME ON THE LAST WORKING DAY OF EACH MONTH, FROM EITHER A SUBGROUP ENGINEER OR PHYSICIST. SINCE I WILL BE THE MUON INTEGRATION COORDINATOR, REPORTING OF THIS PROGRESS EARLY EACH MONTH WILL BE PART OF MY RESPONSIBILTIES. I WILL NEED INPUT FOR THESE REPORTS TO GEM PROGRAM MANAGEMENT!
  (THE REPORTS SHOULD START THIS MONTH)

- SEND TO:
  FRANK NIMBLETT
  DRAPER LABORATORY
  555 TECHNOLOGY SQ.
  MS #23
  CAMBRIDGE, MASS. 02139
  EMAIL NIMBLETT@DRAPER.COM
  TEL- (617) 258-1393 FAX - (617) 258-1131

L. SKOTTBERG
1/24/92

Pressurized Drift Tubes (PDT)

BU
IHEP

Electronics
Gas Choices
What Pressure?

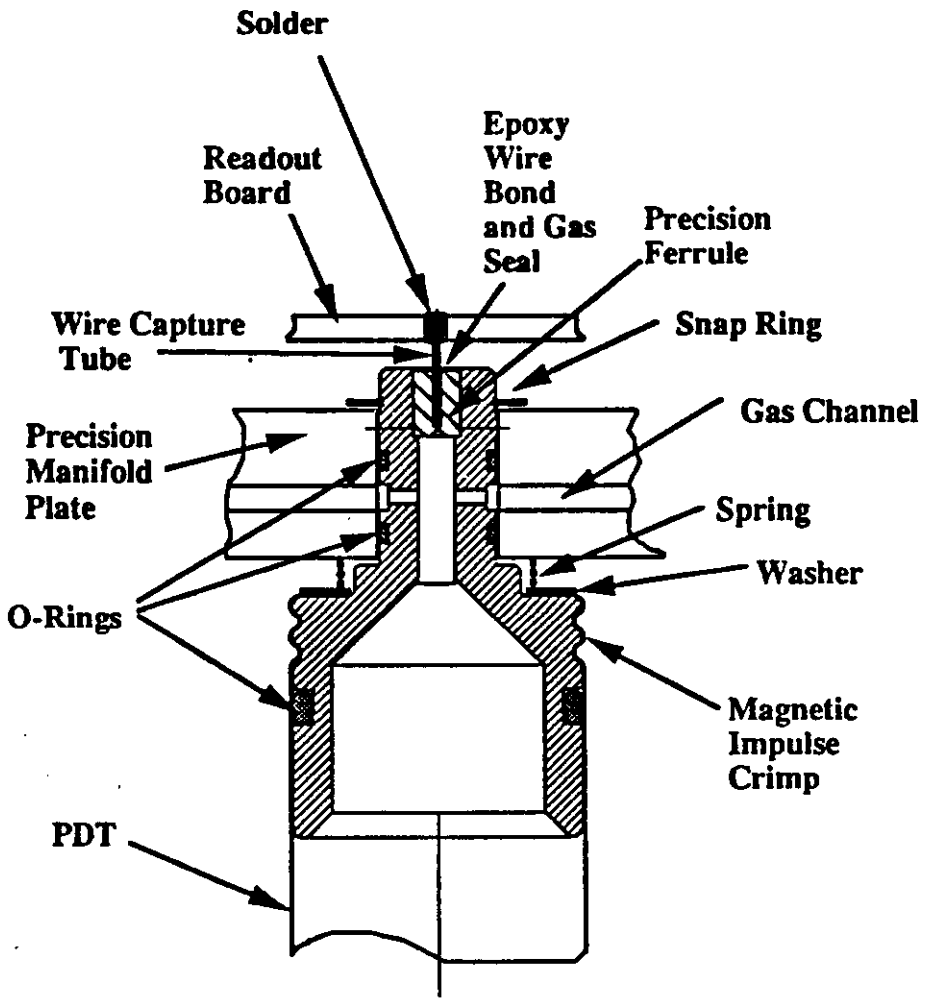
MSU
LANL
SSC

Precision Mechanical
Gas Manifolds/Mixe
HV Distribution
Signal Collection
Mounting/Alignment

1/24/92
C. BROMBERG

Assembly Sequence- Captured Plug Version

1. Cut tubes to length, clean
2. Attach seals to plugs, insert into tubes
3. Crimp tubes onto plugs
4. Pressure test each tube
5. Feed wire thru tubes, insert ferrules and crimp tubes.
6. Position ferrules and crimp wire into tubes.
7. Seal ferrules with adhesive and fill crimp tubes with solder
8. Pressure test each tube.
9. Attach 0-rings, washers and springs to one end of tubes
10. Assemble tubes into precision plates and secure with clips
11. Asemble other ends of tubes into precision plate
12. Pressure test tube asembly.
13. Epoxy tubes together at several points along their length



1/24/92
C. BROMBERG

ordered

1) 100 Aluminum Tubes @ 22 each.

1.5" diam.
300μ wall
3.8 m long.

Investigating compatible Carbon Fiber / Plastic Tubes

2) Plugs + Manifold Plates

In house parts

Georgi Chelkov

GEM MUON DETECTOR R&D PROGRAM ON 1992 at LNP JINR DUBNA

DETECTOR STUDIES

- DRIFT TUBE CHAMBER

  * design and tests of the small prototypes based on high pressure drift tubes
  * intrinsic resolution vs pressure (up to 10 atm)
  * drift tube parameters optimization (gaz mixture, wire-tube diameters, ...)

- PROFILED CATHODE DETECTORS

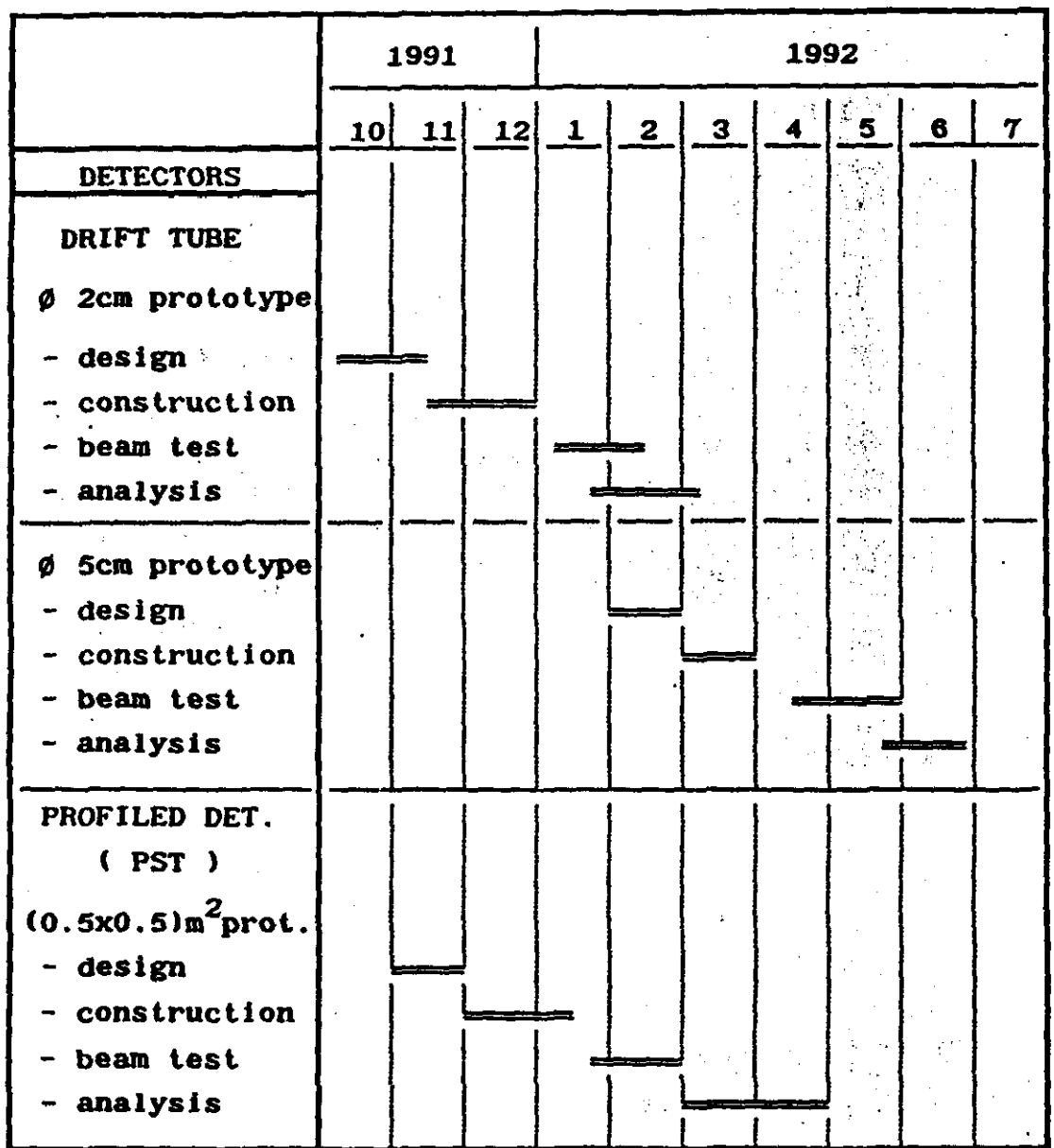
  * gas mixture (fast for trigger)
  * design and tests of the prototypes
  * drift and strip read-out resolution

- MODULE DESIGN AND ALIGNMENT STUDIES

- FRONT-END ELECTRONICS STUDY

MC SIMULATION OF A MUON SYSTEM PERFORMANCE

DUBNA LNP R&D PROGRAM ON 1991-1992



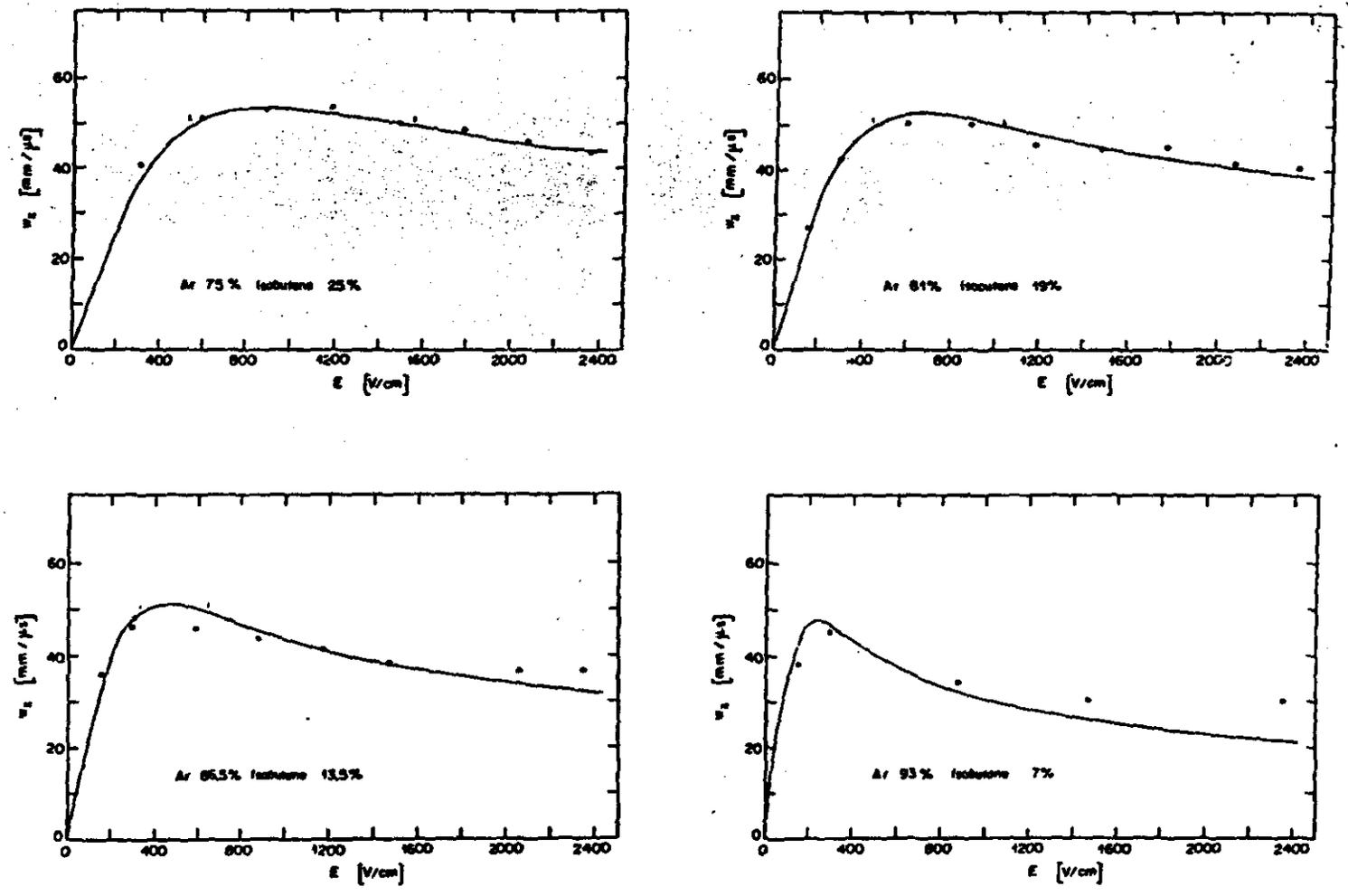
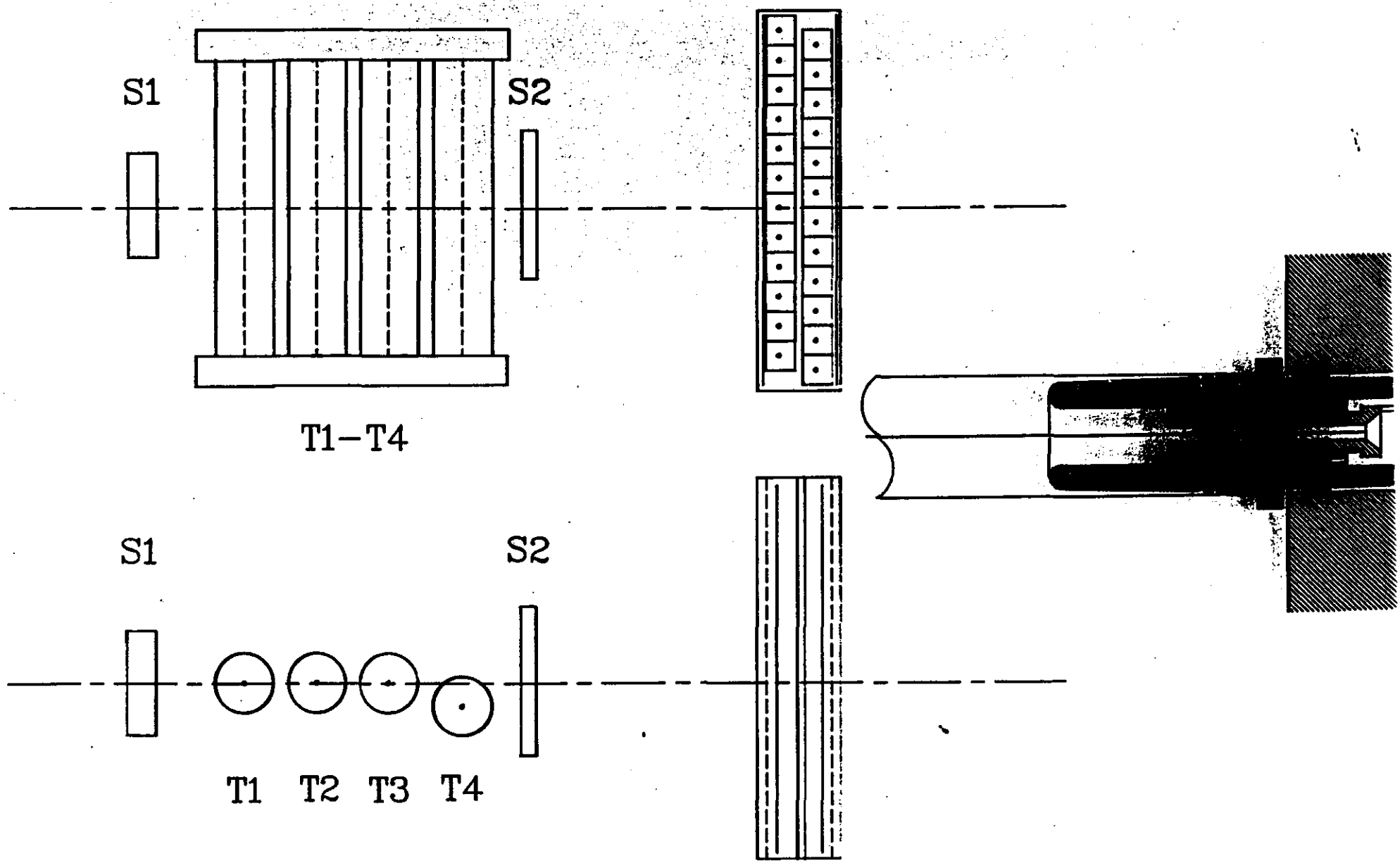
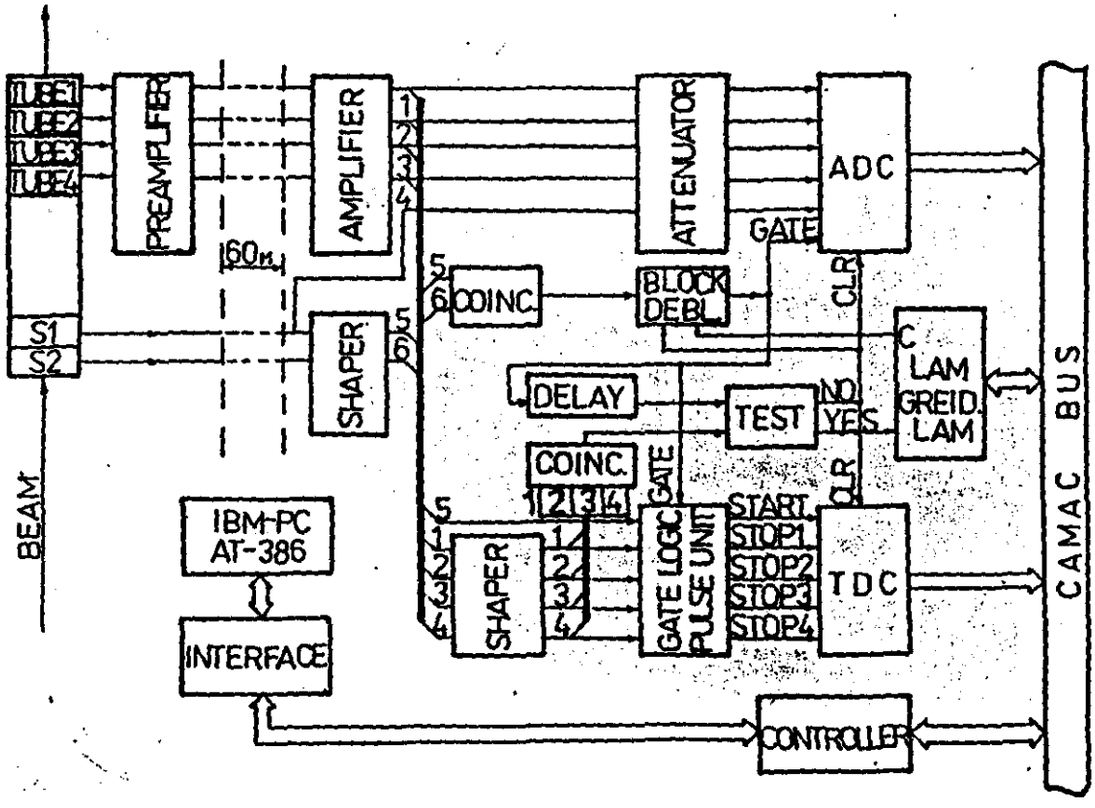
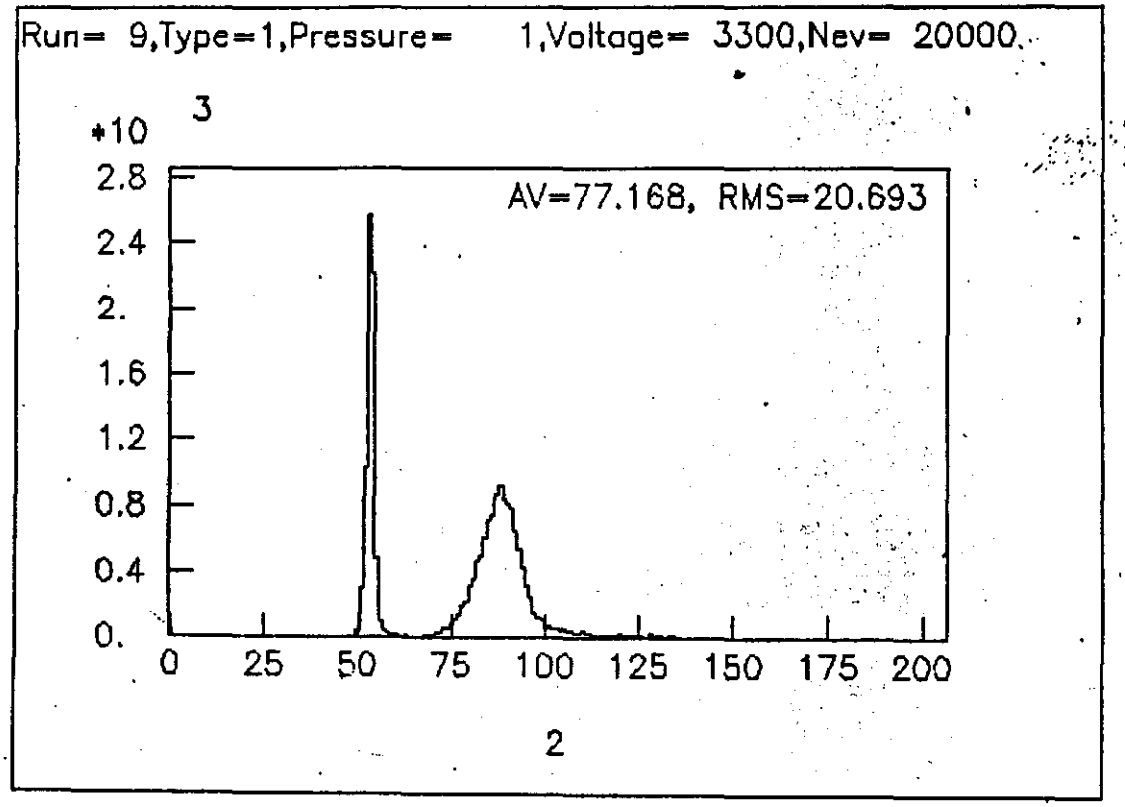
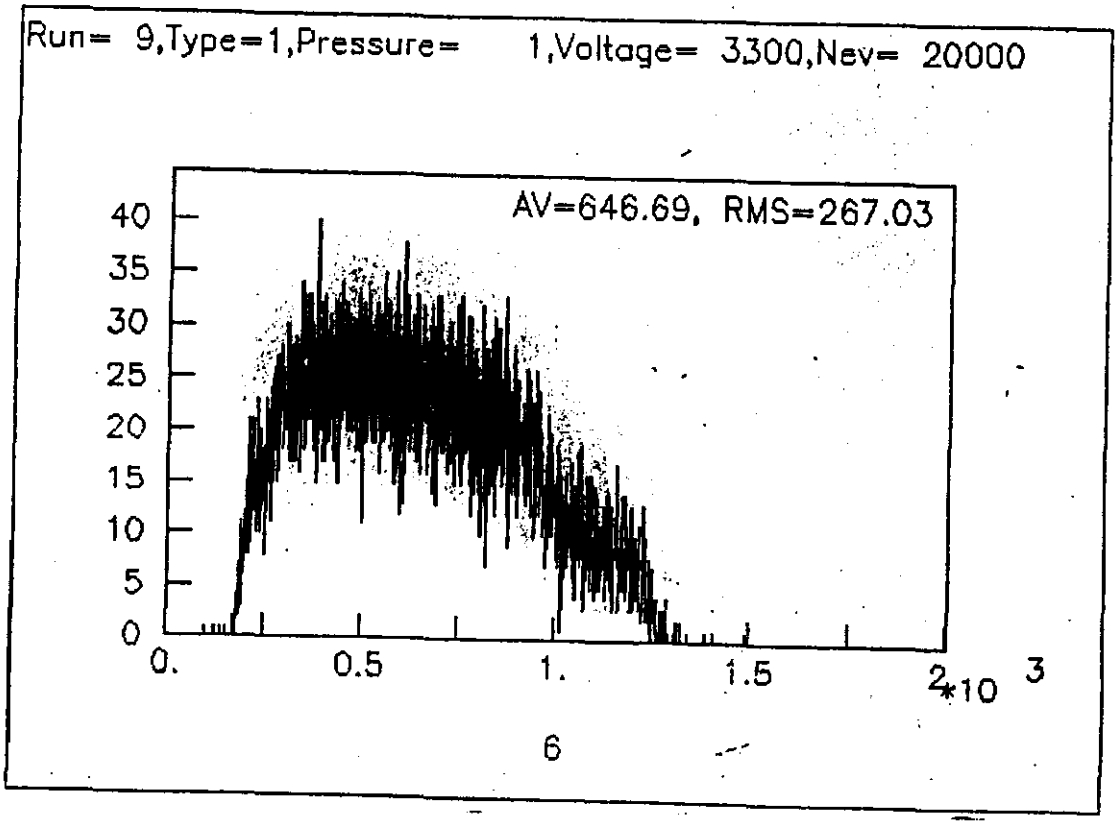


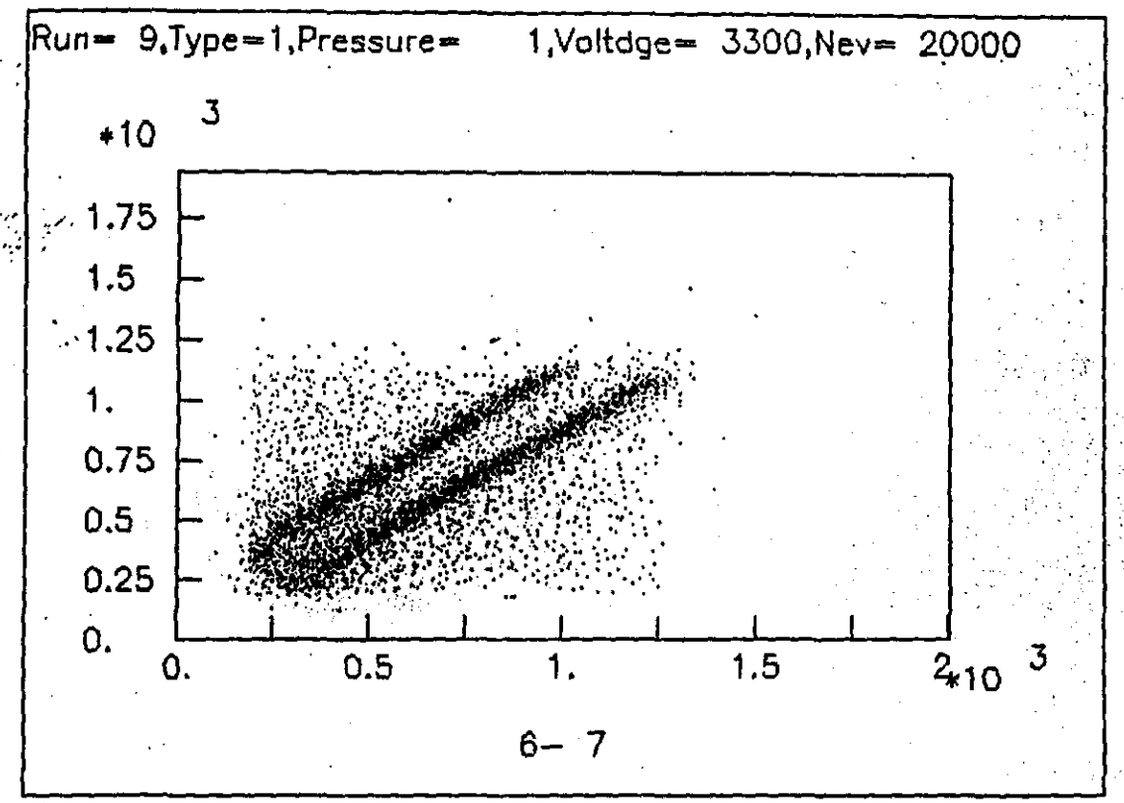
Fig. 116 Schultz (1976)


S1
S2
T1–T4
S1
S2
T1
T2
T3
T4

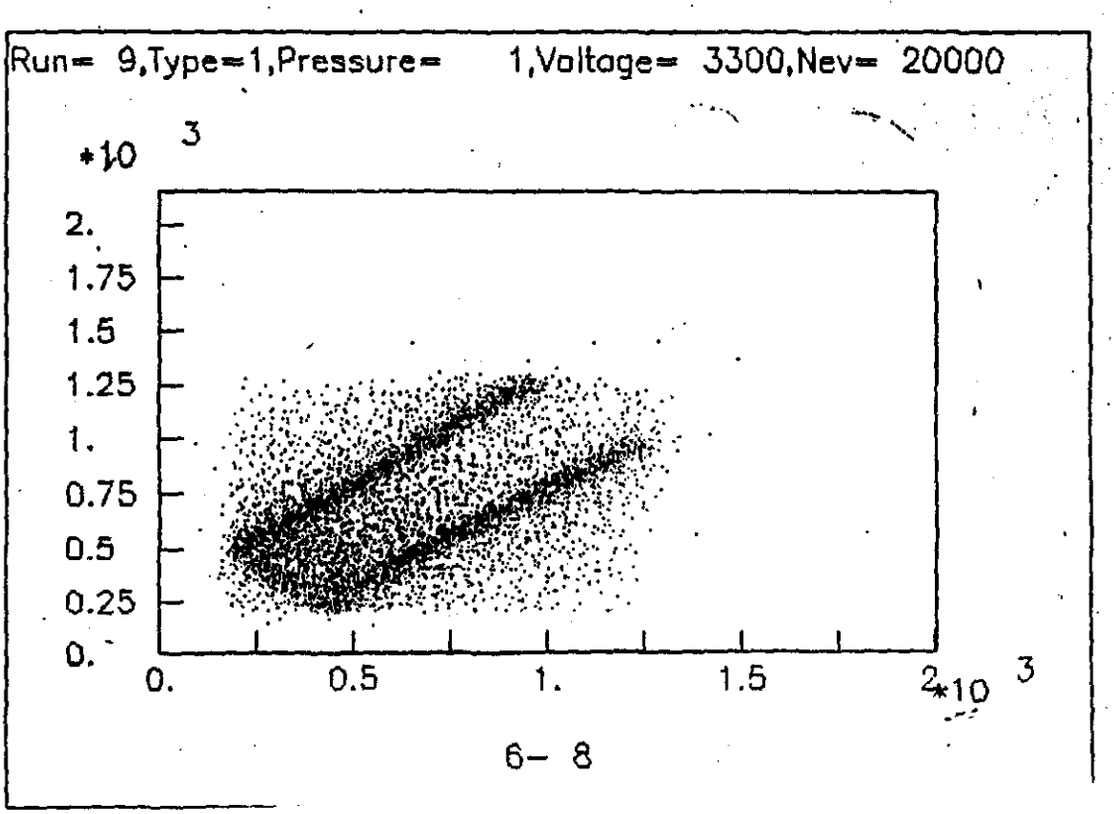

TUBE1
TUBE2
TUBE3
TUBE4
S1
S2
BEAM
PREAMPLIFIER
60м
AMPLIFIER
SHAPER
COINC.
DELAY
COINC.
1 2 3 4
SHAPER
IBM-PC
AT-386
INTERFACE
ATTENUATOR
BLOCK
DEBL.
TEST
NO
YES
GATE
CLR
GATE LOGIC
PULSE UNIT
START
STOP1
STOP2
STOP3
STOP4
ADC
TDC
LAM
GREID.
LAM
CONTROLLER
CAMAC BUS


Run= 9,Type=1,Pressure= 1,Voltage= 3300,Nev= 20000.
3
*10
2.8
2.4
2.
1.6
1.2
0.8
0.4
0.
AV=77.168, RMS=20.693
0
25
50
75
100
125
150
175
200
2

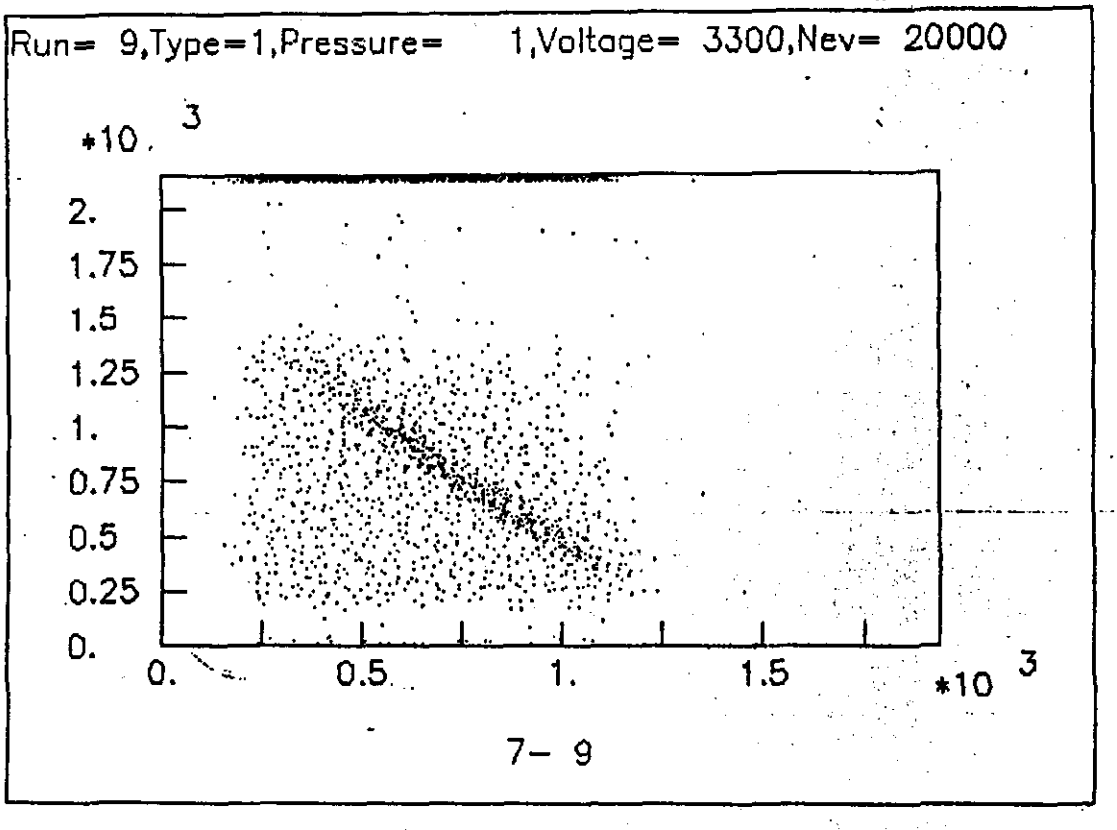

Run= 9,Type=1,Pressure= 1,Voltage= 3300,Nev= 20000
AV=646.69, RMS=267.03
40
35
30
25
20
15
10
5
0
0.
0.5
1.
1.5
2
*10
3
6

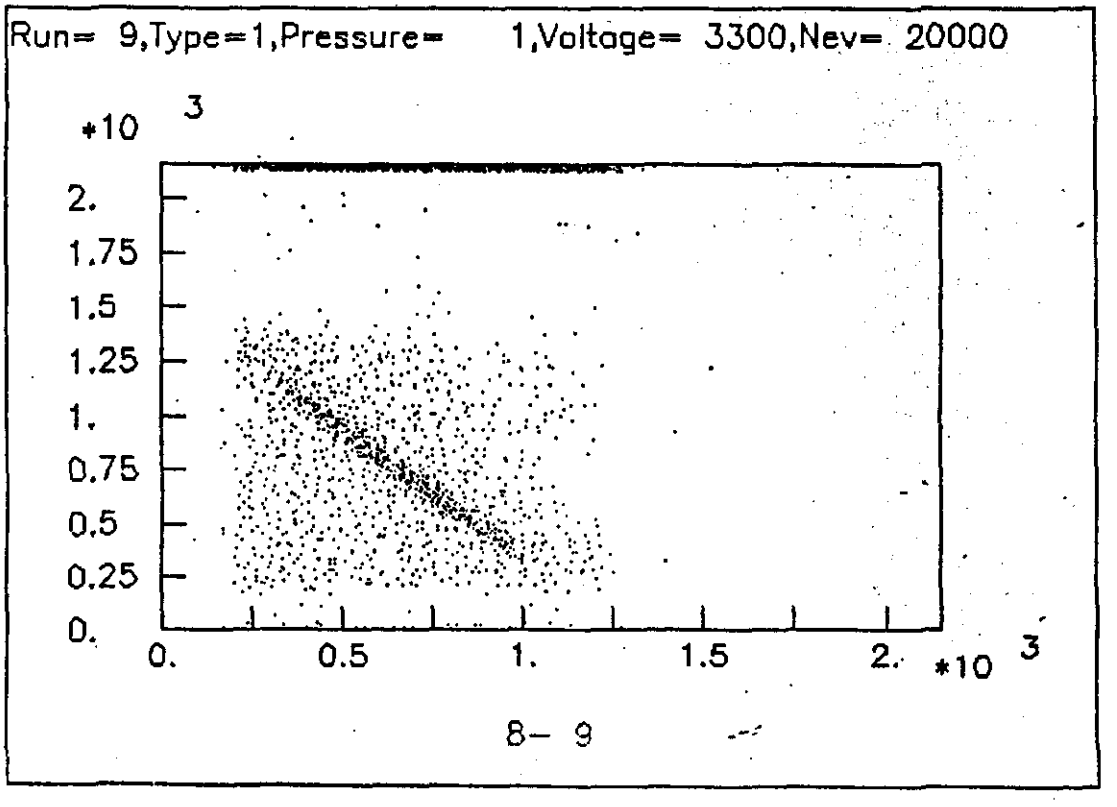

Run= 9,Type=1,Pressure= 1,Voltdge= 3300,Nev= 20000
*10 3
1.75
1.5
1.25
1.
0.75
0.5
0.25
0.
0.
0.5
1.
1.5
2*10 3

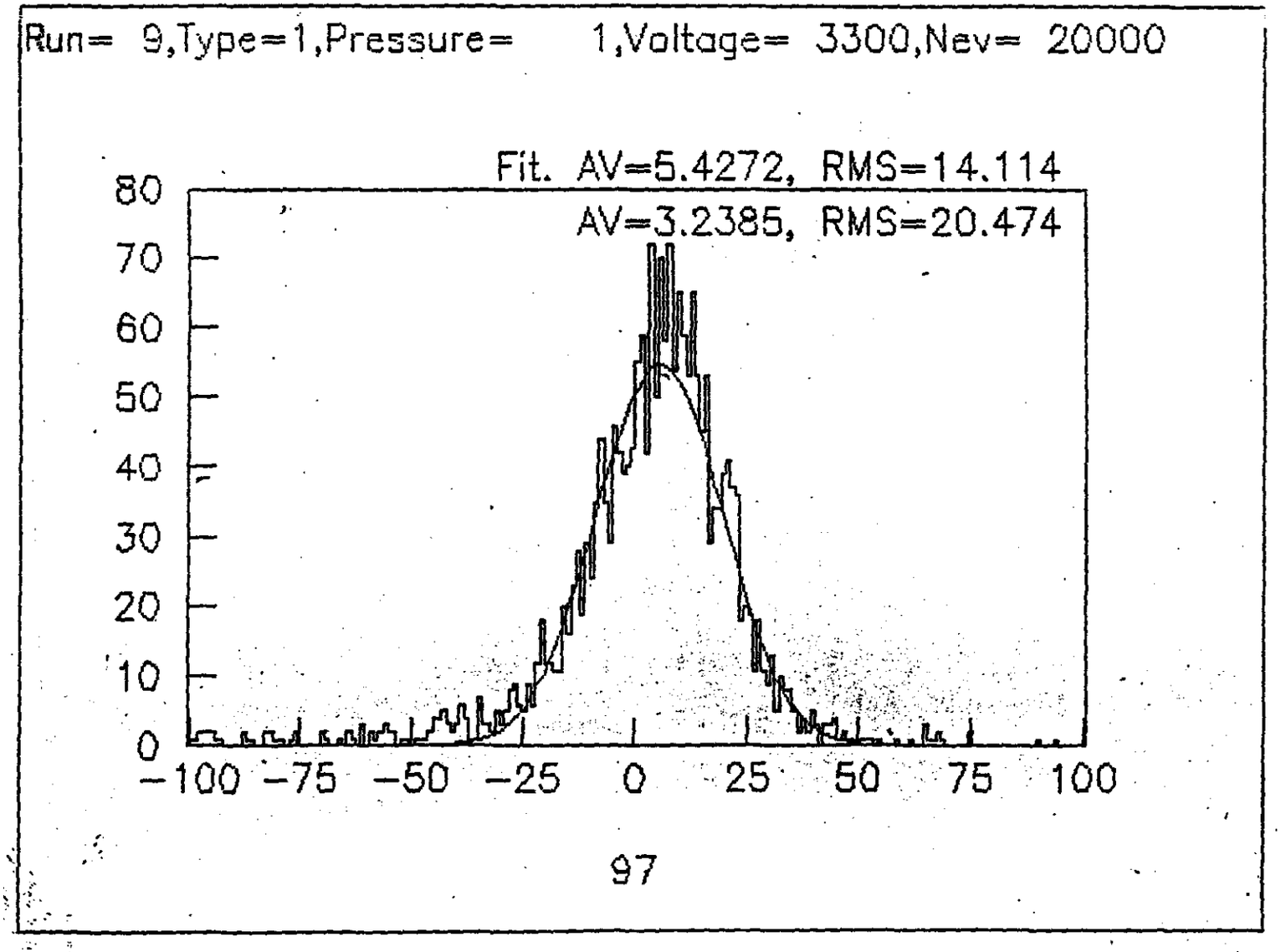
6- 7


Run= 9,Type=1,Pressure= 1,Voltage= 3300,Nev= 20000
*10 3
2.
1.75
1.5
1.25
1.
0.75
0.5
0.25
0.
0.
0.5
1.
1.5
2*10 3

6- 8

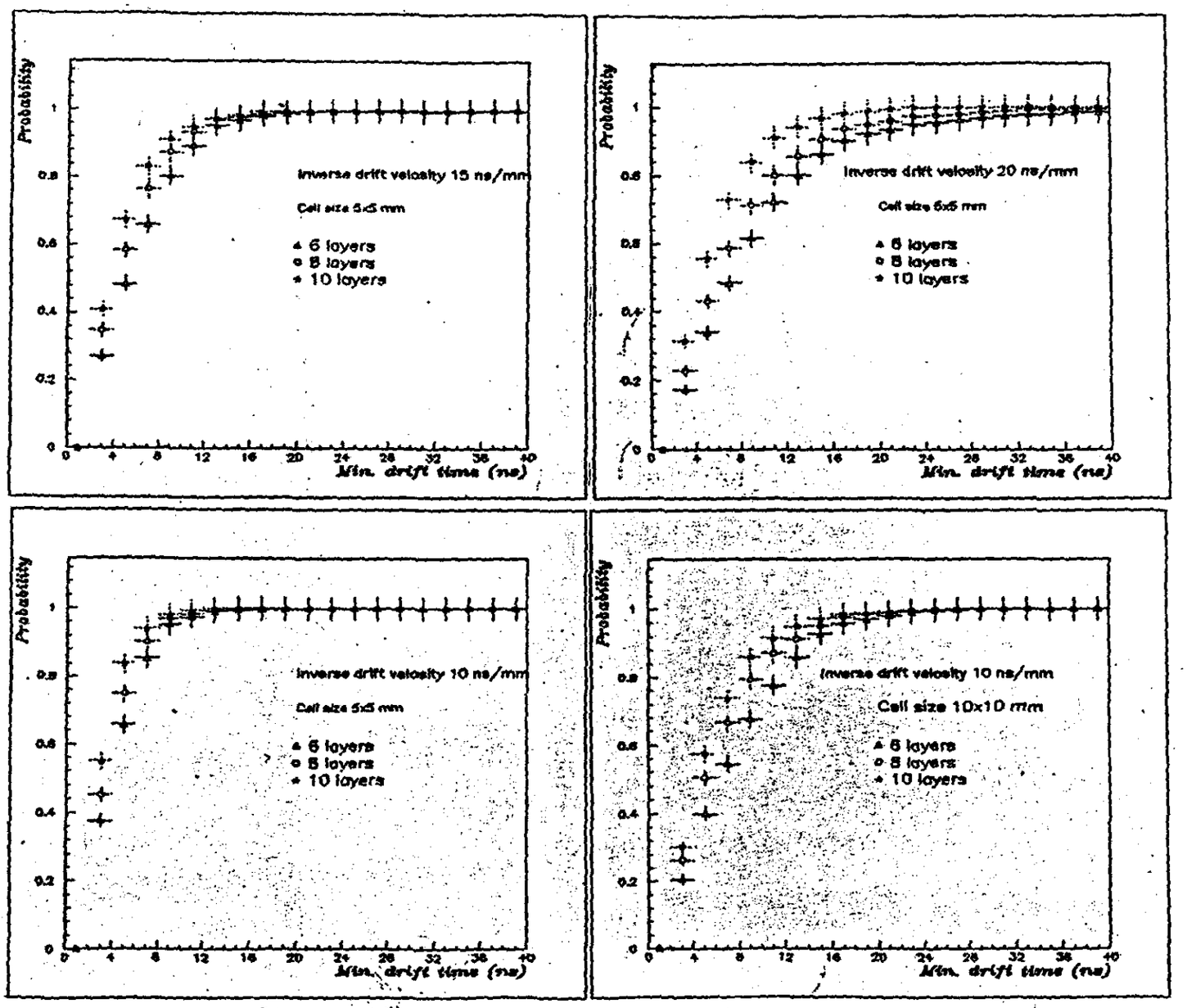

Run= 9,Type=1,Pressure= 1,Voltage= 3300,Nev= 20000
*10 3
2.
1.75
1.5
1.25
1.
0.75
0.5
0.25
0.
0.
0.5
1.
1.5
*10 3
7- 9


Run= 9,Type=1,Pressure= 1,Voltage= 3300,Nev= 20000
*10 3
2.
1.75
1.5
1.25
1.
0.75
0.5
0.25
0.
0.
0.5
1.
1.5
2.
*10 3
8- 9


Run= 9,Type=1,Pressure= 1,Voltage= 3300,Nev= 20000
Fit. AV=5.4272, RMS=14.114
AV=3.2385, RMS=20.474
80
70
60
50
40
30
20
10
0
−100 −75 −50 −25 0 25 50 75 100

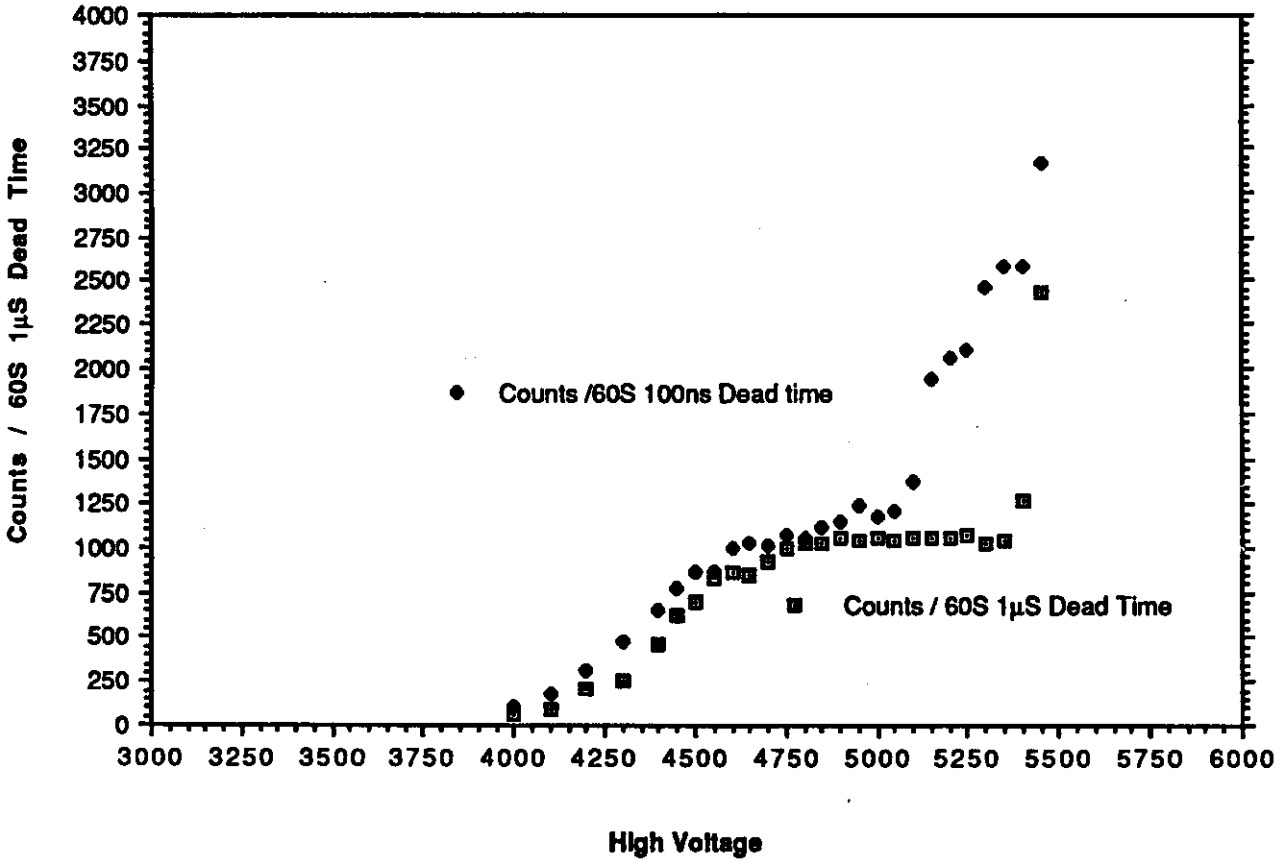
FAST LOW-NOISE CURRENT PREAMPLIFIER

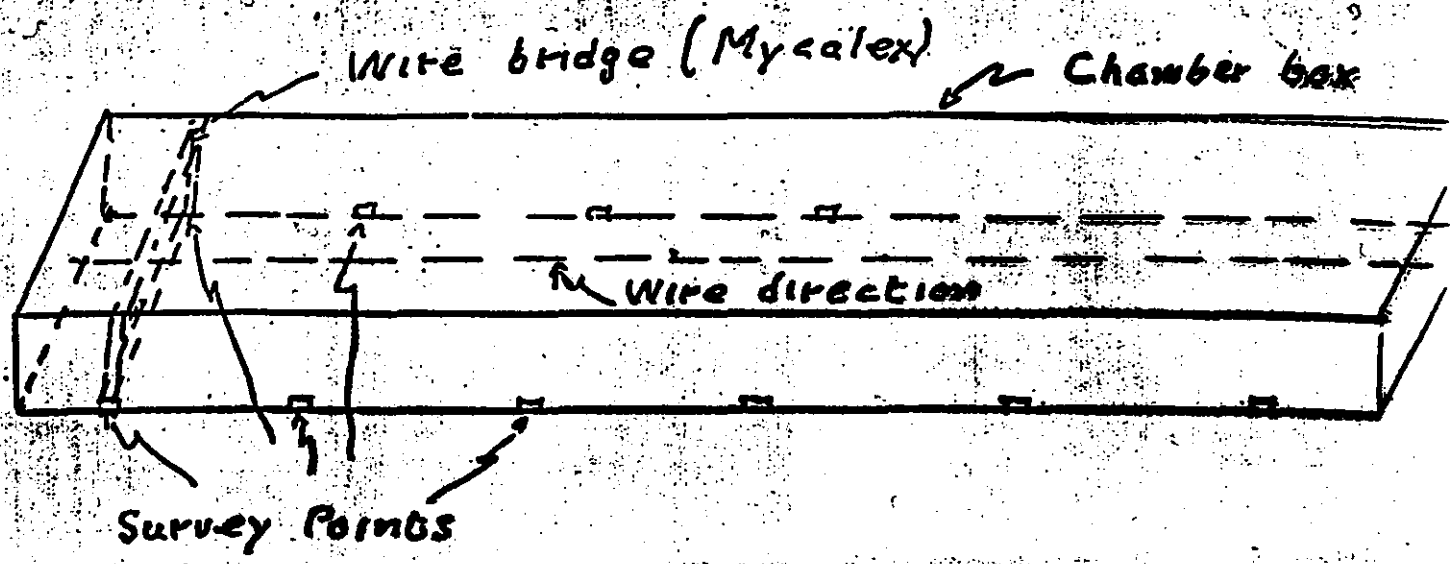
GAIN COEFFICIENT	10-80
THE EQUIVALENT NOISE CHARGE (ENC $_{C_D=0}$)	- 2000 e^- R.M.S.
INPUT DYNAMICS RANGE	- 32000
OUTPUT	- BIPOLAR FOR TWISTED PAIRES (ρ - 110 Ω)
INPUT PROTECTION	EXSISTS
POWER SUPPLY	∓ 12 V


Probability
Min. drift time (ns)
Inverse drift velocity 15 ns/mm
Cell size 5x5 mm
6 layers
8 layers
10 layers
Inverse drift velocity 20 ns/mm
Cell size 5x5 mm
6 layers
8 layers
10 layers
Inverse drift velocity 10 ns/mm
Cell size 5x5 mm
6 layers
8 layers
10 layers
Inverse drift velocity 10 ns/mm
Cell size 10x10 mm
6 layers
8 layers
10 layers

Kay Weinstein

SSC-1 Plateau 1μs & 100ns Dead Times





Philosophy

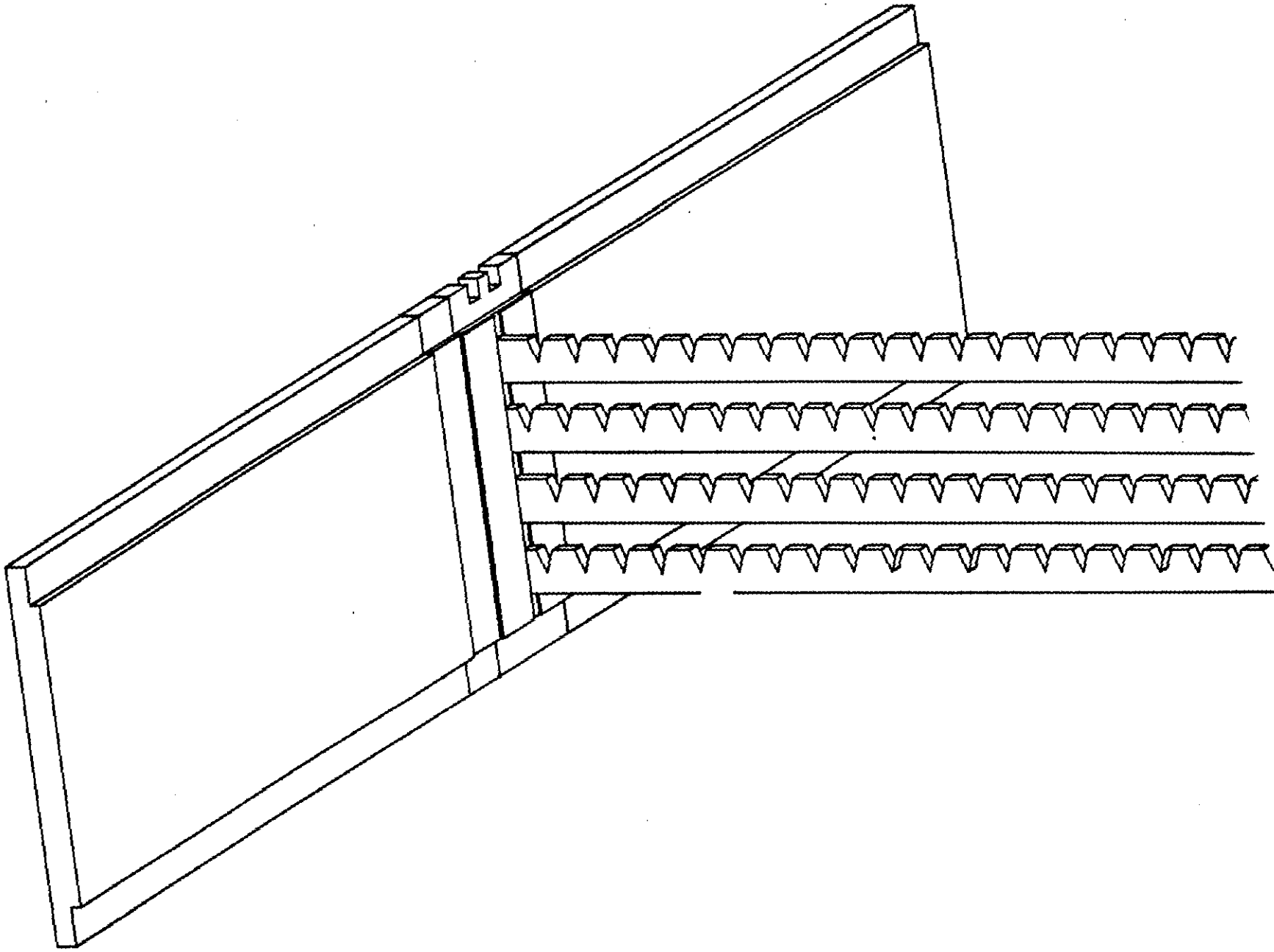
Wires placed to $\pm 12.5 \mu m.$ with respect to survey points,

1) indenpendent of gravity
2) " temperature
3) " warp and sag of the chamber.

Survey points known to $\pm 12.5 \mu m.$,

1)by surveying
2)by placement (unlikely)
3)by monitoring.

L.S.Osborne



II. R & D Program.

A, The Tasks

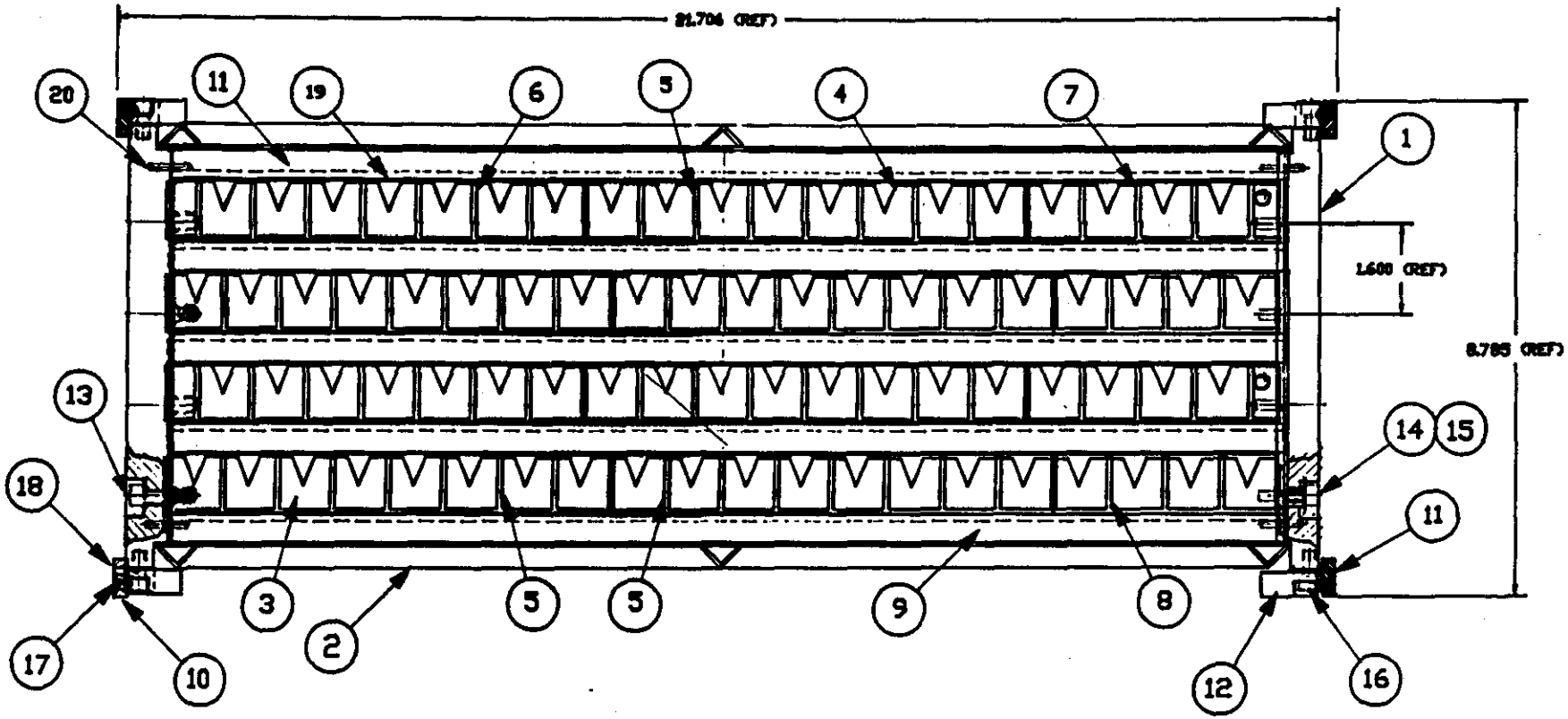
We list the tasks we expect to complete adding in parenthesis the institution(s) bearing the responsibility:

1) Finish assembly and test of 2, 0.5 m. wide chambers.(MIT)
2) Measure chamber tube performance in magnetic fields.(MIT)
3) Design and build (D & B) 2, 1 meter wide chambers.(MIT)
4) D & B pick-up strip plane.(MIT)
5) Investigate and make thinner cathodes.(MIT & UNY-SB)
6) D & B optical window system.(MIT)
7) D & B tiltable chamber stand as a cosmic ray muon telescope.(MIT)
8) Adjoin prototype optical alignment system to the chambers.(MIT, with the help of Draper Lab.)
9) Design of apparatus for mass production of chambers; estimate production costs.(U. of Houston)
10) Investigate various materials for use as cathodes.(MIT)
11) Analyse the data from both; 1) runs taken at Fermilab on a small prototype, and 2) data with cosmic rays on the 0.5 m. and 1.0 m. chambers.(MIT, UNY-SB, & LSU)
12) Simulation studies of the muon system directed toward optimization of the subsystem and integration with the rest of the detector.(MIT)
13) 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.(LeCroy,MIT)

LSDT R&D Work

Milestones(all in '92): (from proposal to TNRLC)

Delivery of LeCroy electronics for 0.5 m. chamber	Jan. 1 ready
Design of thin cathodes	Jan. We are hoping "Solar Kinetics" succeeds
Design of 1.0 m. chamber	Jan. So far on schedule
Assembly of 0.5 m. chambers	Feb. Parts are in, Except!
Assembly of 1.0 m. chambers	March
Delivery of 1.0 m. chamber to SSCL	May
Set final specs. on chambers	Aug.
Assemble cost figures for EDR	Sept.



[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	4	CATHODE SHEET, [illegible] ALUMINUM SHEET
	1/8 x 1/2 LG	24	PIN, [illegible]
	[illegible] x 3/8 LG	6	SCREW, FLT HD, [illegible]
	[illegible]	[illegible]	SCREW, [illegible] HD, [illegible]
	1/4 IN	40	WASHER, FLAT, [illegible]
[illegible]		24	SUPPORT SCREW
	[illegible]	24	SCREW, [illegible] HD, [illegible]
[illegible]		[illegible]	CLAMP, COVER SHEET
	[illegible]	6	CATHODE SHEET [illegible] CHANNEL
[illegible]		24	[illegible], PRECISION
[illegible]		24	CATHODE SUPPORT CHANNEL
[illegible]		2	CATHODE, TYPE B
[illegible]		2	CATHODE, TYPE C
[illegible]		2	CATHODE, TYPE D
[illegible]		6	CATHODE, TYPE A
[illegible]		[illegible]	WIRE [illegible], TYPE B
[illegible]		[illegible]	WIRE [illegible], TYPE A
[illegible]		2	COVER SHEET, STIFFENED
[illegible]		1	FRAME ASSEMBLY, MACHINED
[illegible] NO.	STOCK ITEMS	[illegible]	NAME

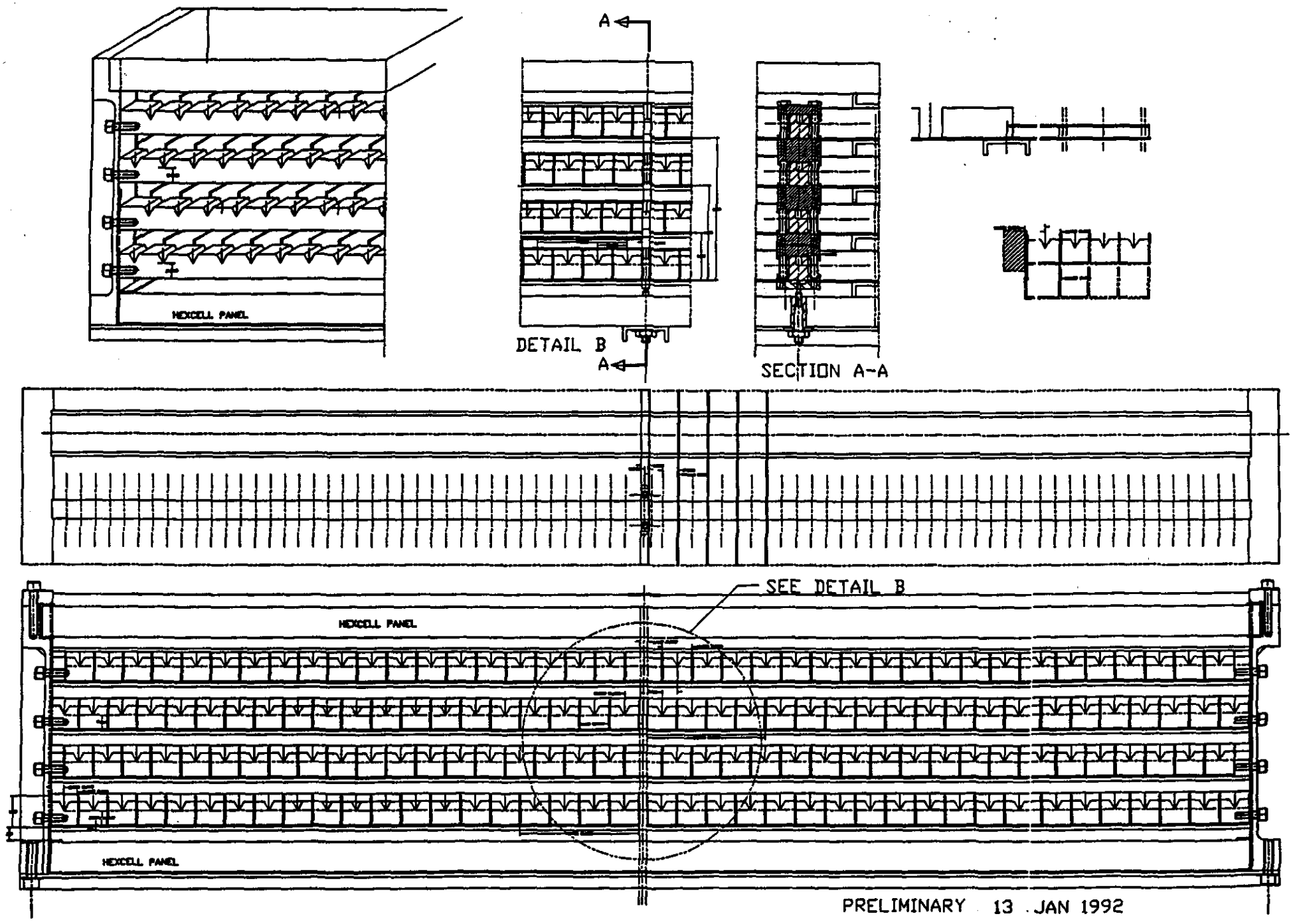
REV	PER	DWN BY	DATE	REVISION DESCRIPTION
C	LO	[illegible]	[illegible]	ADDED CATHODE SHEETS; INCREASED OVERALL H
B	LO	[illegible]	[illegible]	CATHODES REDRAWN .1640-IN HIGHER TO CENTE
A		BB	[illegible]	GEN. CORRECTIONS. ADDED CATHODE SUPPORT C

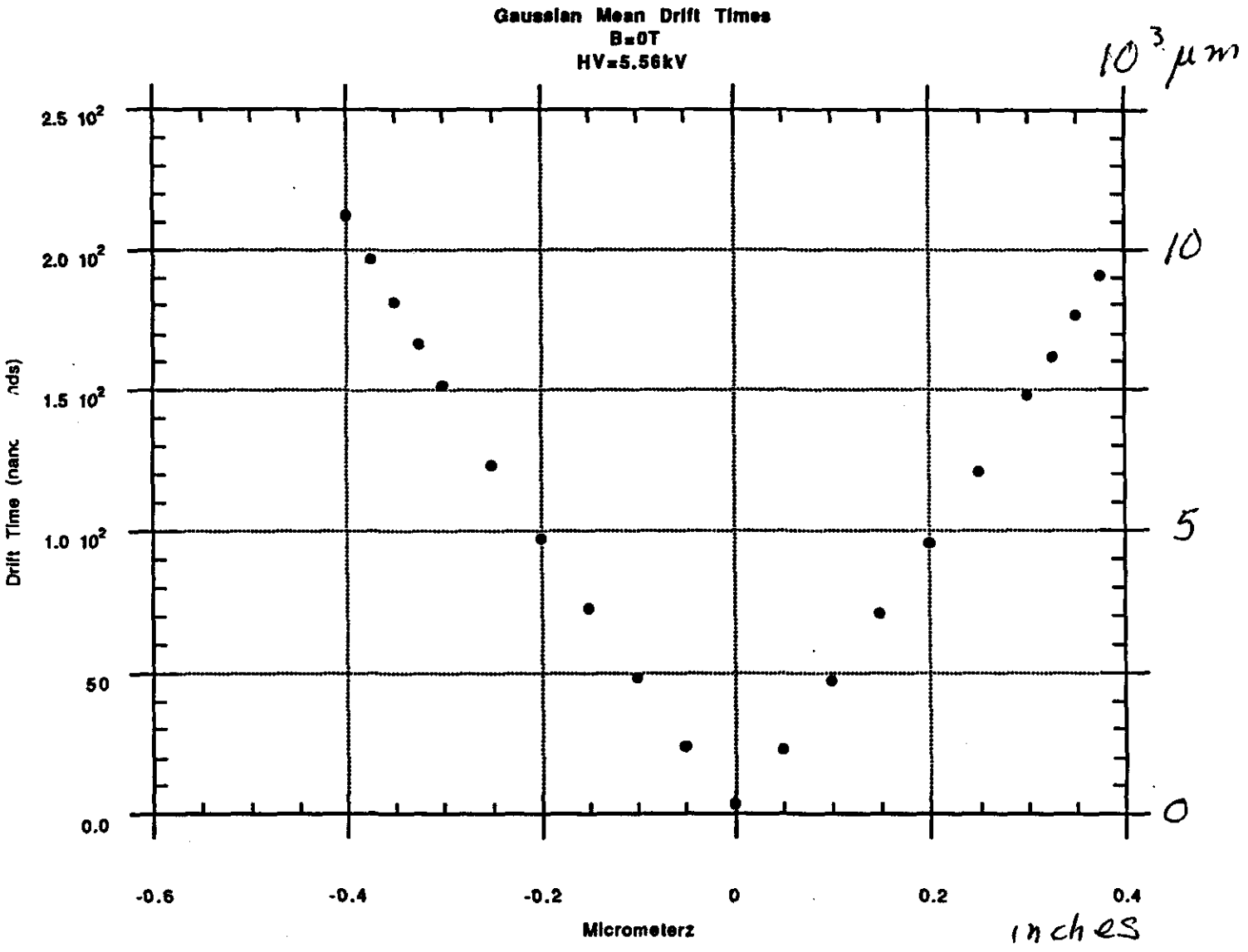
USED ON	
NEXT ASSEMBLY	
SCALE 1:1	WEIGHT
DRAWN BY L S OSBORNE	DATE
DRAWN BY B M BAILEY	4/29/91
CHECKED BY	
APPROVED BY	

LABORATORY FOR NUCLEAR SCIEN
MASSACHUSETTS INSTITUTE OF TECHN
CAMBRIDGE, MA 02139

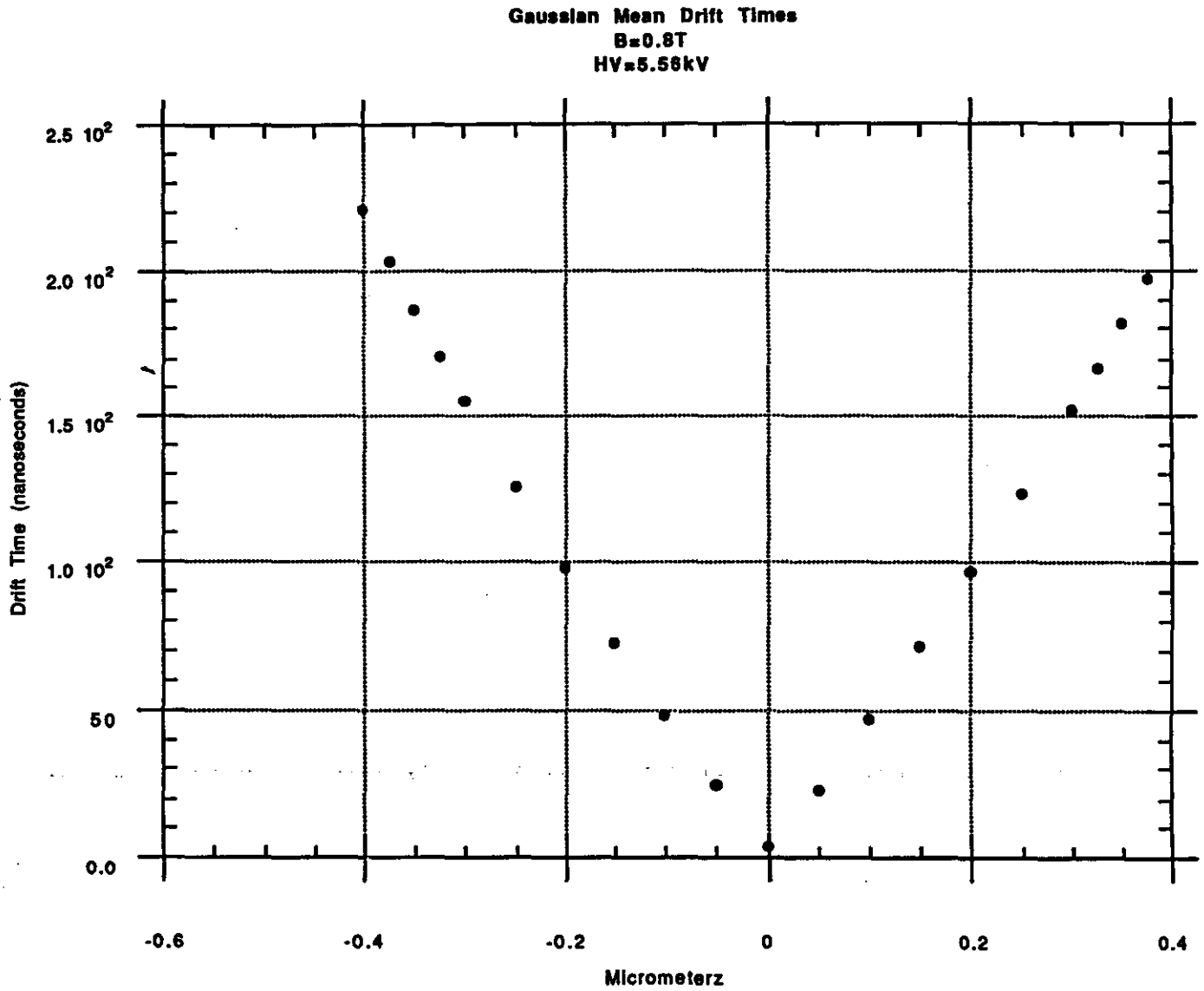
PROTOTYPE MUON CHAMBE
PARTIAL SECTION
END VIEW

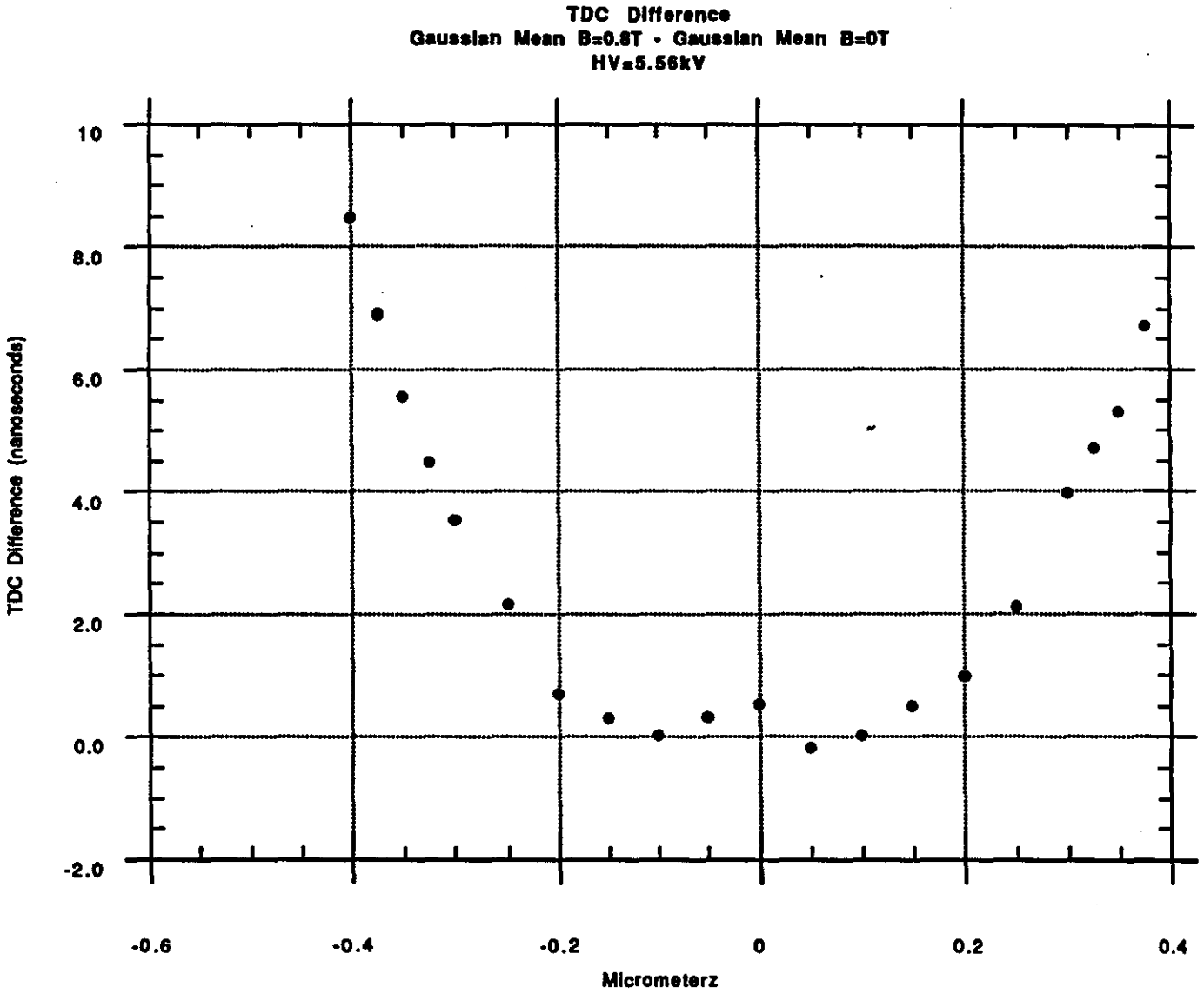
PROJECT NO.	SIZE	DRAWING NO.
	D	CSC91-04

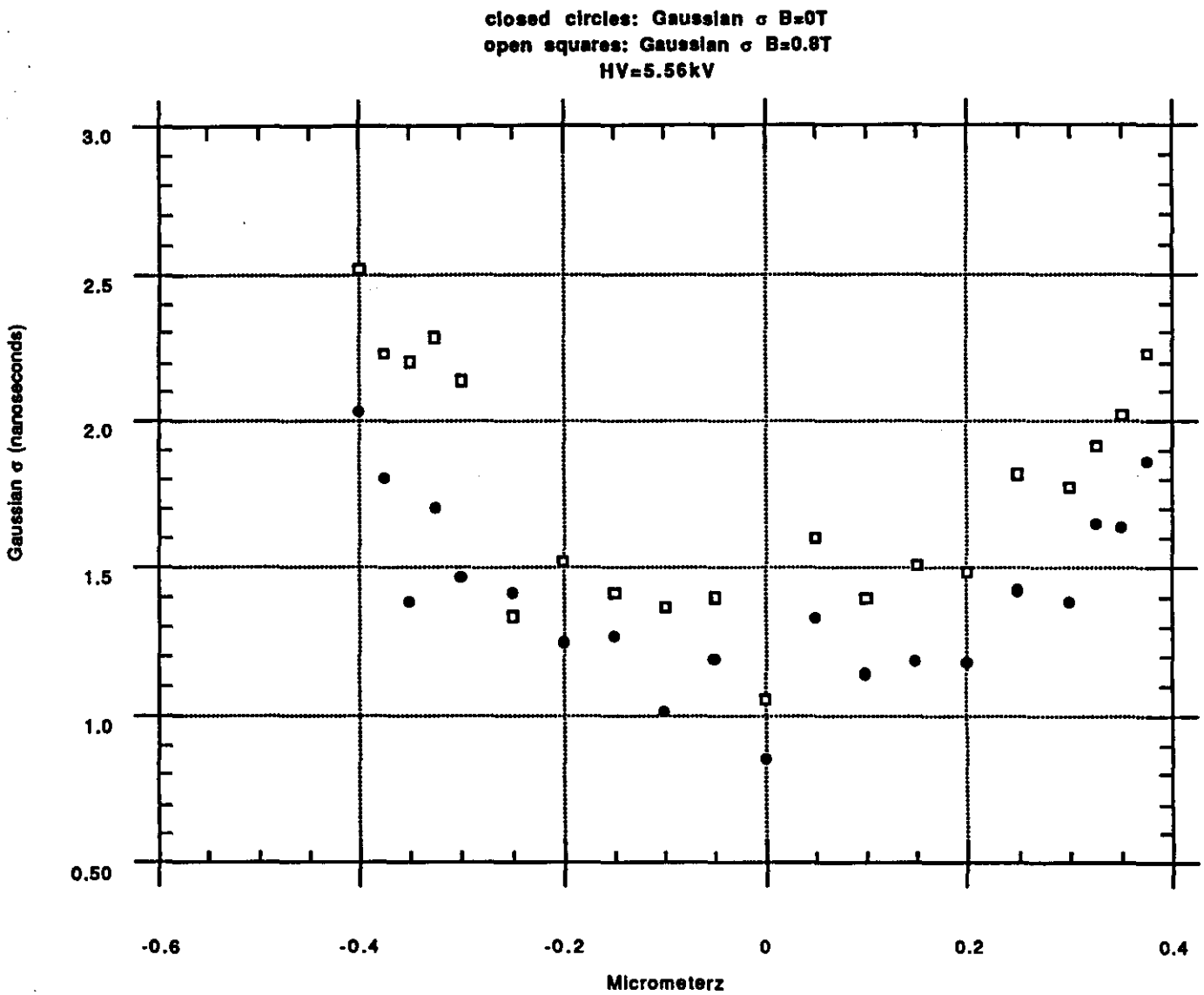

HEXCELL PANEL
A
DETAIL B
A
SECTION A-A
SEE DETAIL B
HEXCELL PANEL
HEXCELL PANEL
PRELIMINARY 13 JAN 1992

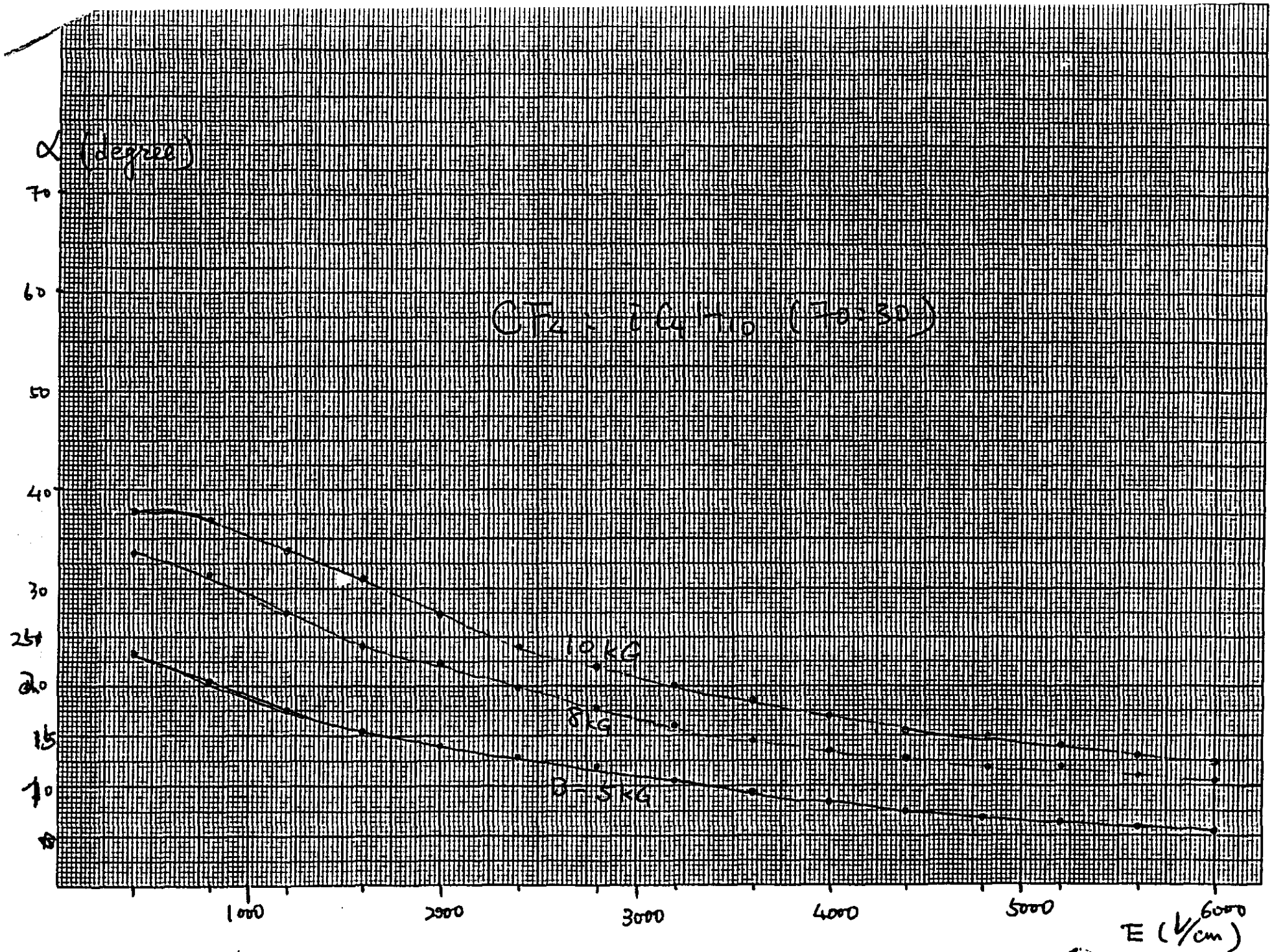

Gaussian Mean Drift Times
B=0T
HV=5.56kV
Drift Time (nanc nds)
2.5 10^2
2.0 10^2
1.5 10^2
1.0 10^2
50
0.0
-0.6
-0.4
-0.2
0
0.2
0.4
Micrometerz
10^3 μm
10
5
0
inches

$v = 50 \mu m./sec.$

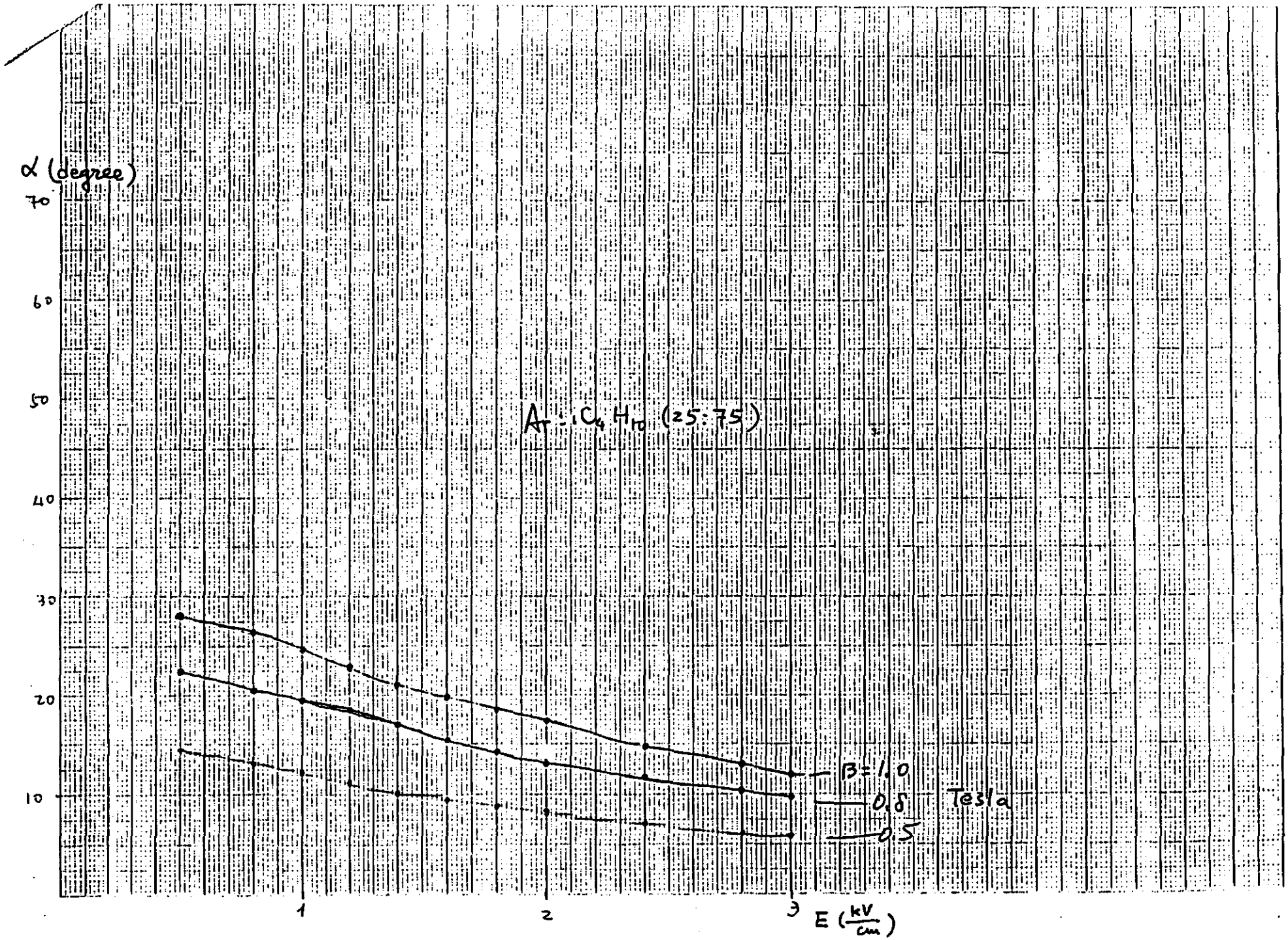

Gaussian Mean Drift Times
B=0.8T
HV=5.56kV
2.5 10²
2.0 10²
1.5 10²
1.0 10²
50
0.0
Drift Time (nanoseconds)
-0.6
-0.4
-0.2
0
0.2
0.4
Micrometerz


TDC Difference
Gaussian Mean B=0.8T - Gaussian Mean B=0T
HV=5.56kV
TDC Difference (nanoseconds)
10
8.0
6.0
4.0
2.0
0.0
-2.0
-0.6
-0.4
-0.2
0
0.2
0.4
Micrometerz


closed circles: Gaussian σ B=0T
open squares: Gaussian σ B=0.8T
HV=5.56kV
Gaussian σ (nanoseconds)
3.0
2.5
2.0
1.5
1.0
0.50
-0.6
-0.4
-0.2
0
0.2
0.4
Micrometerz



SQUARE 10 X 10 TO THE CENTIMETER
AS-8014-11
GRAPH PAPER GRAPHIC CONTROLS CORPORATION Buffalo, New York Printed in U.S.A.


α (degree)
70
60
50
40
30
20
10
Ar : iC4H10 (25:75)
B = 1.0
0.8
0.5
Tesla
1
2
3
E (kV/cm)

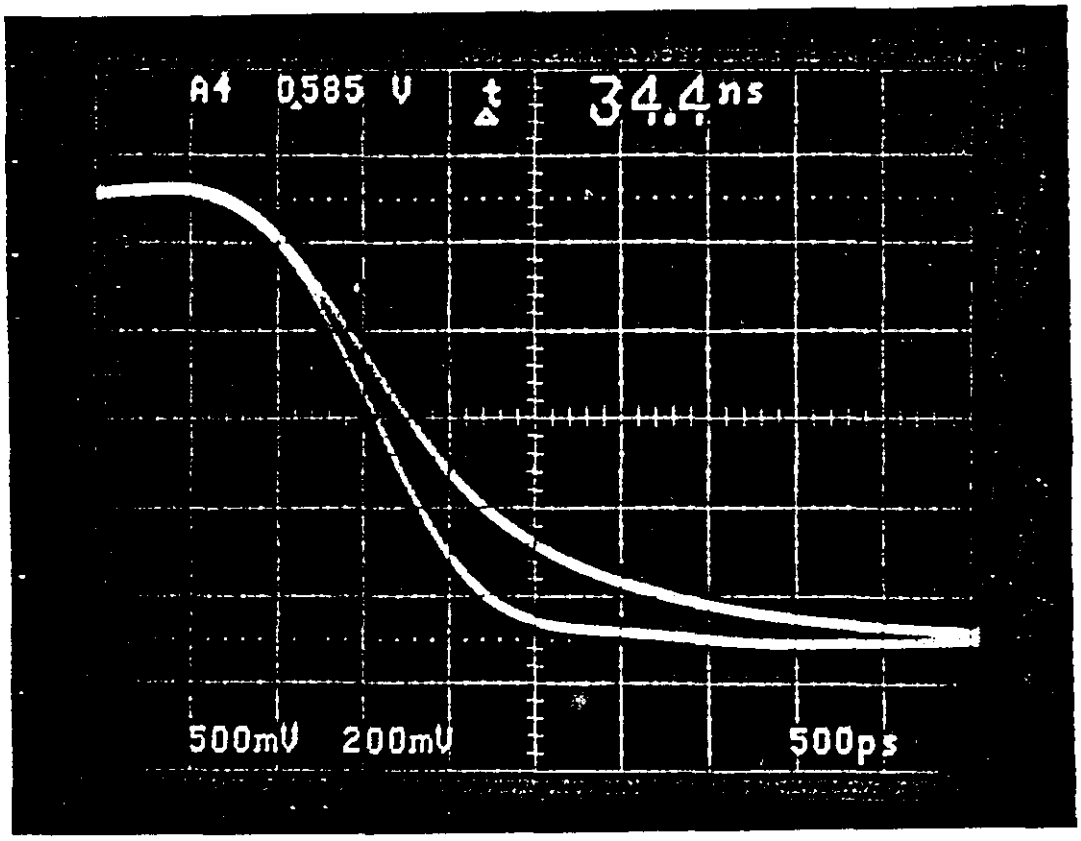
Electronics

MIT producing 50 preamp boards

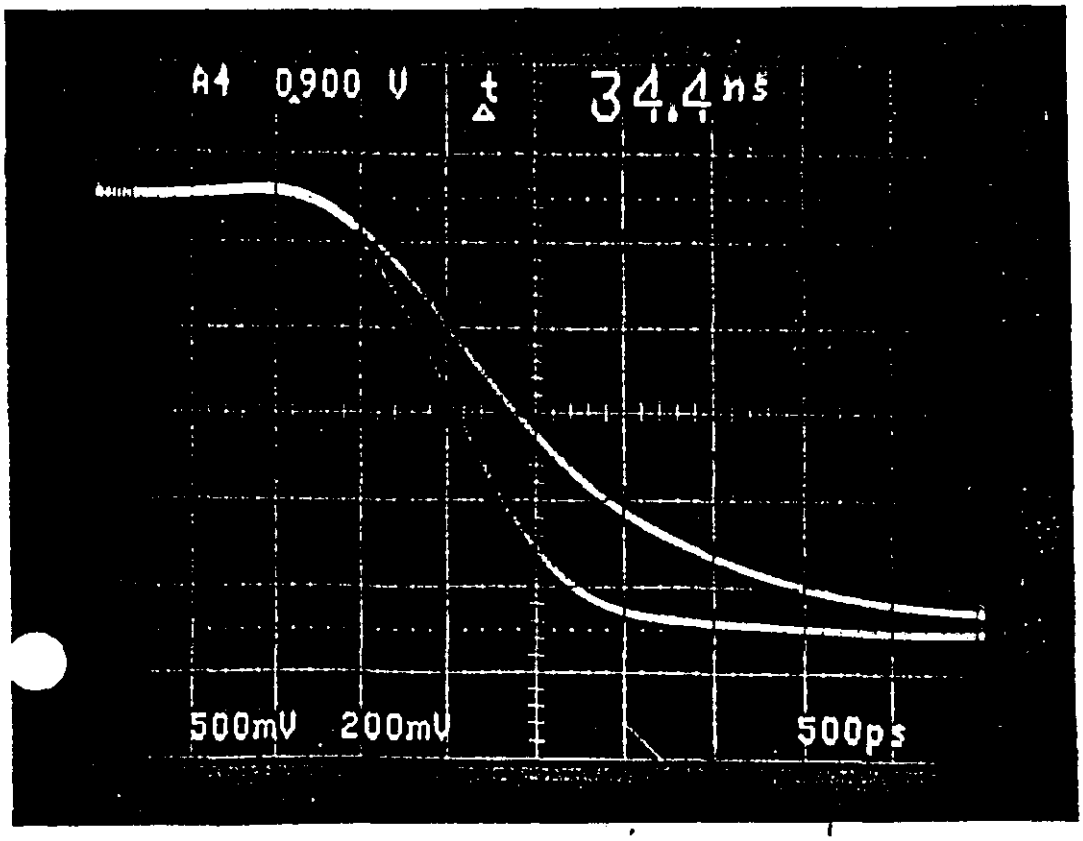
LeCroy has TDC's ready

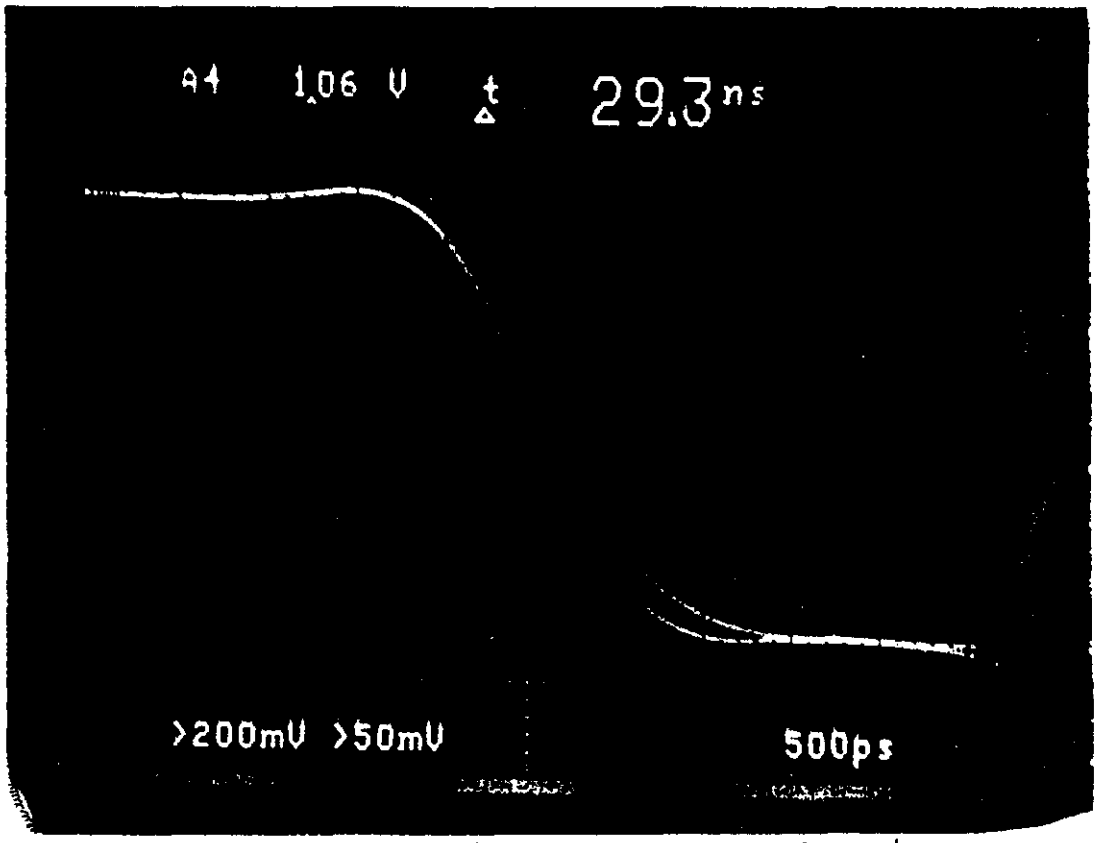
LeCroy working on trigger system.

IN vs OUT (after 7 meters)
4 mil Cu Be wire



Same – Cathode cut in 6 places





Au-plated W intact

Solar Kinetics

Present: from folding machine

limited in width

Squeeze

<u>New idea</u>

all 10 mil material

Adaptable to precision placement and mass production

Cathode Material

Houston and MIT

Al vs

Nickel vs

Copper vs

?

GEM: LIMITED STREAMER DRIFT TUBE GROUP

(Proposal to TNRLC-Dec. 9, 1991)

III. The Budget (Revised Jan. 21, 1992)

Institution	Item	Time in man-months	Cost in k$	Sub-total
Univ. of Houston	Mech.Eng.	9	80	80
LeCroy Corp.	Elec.Eng & Electronics		20	20
Louisiana State Univ.	Student	4	5	5
Mass. Inst. of Tech.				381
	Mech. Eng	6	36	
	Draftsman	5	30	
	Elec. Eng.	4	30	
	Mech. Tech.	12	45	
	Mach.Shop(MIT)		30	
	Elec. Tech.	12	80	
	Student help	15	25	
	Chamber parts & outside work		50	
	Alignment Tools		35	
	Optical Alig.		20	
U. of N. Y. at Stonybrook	Student	3	5	5
Total				491

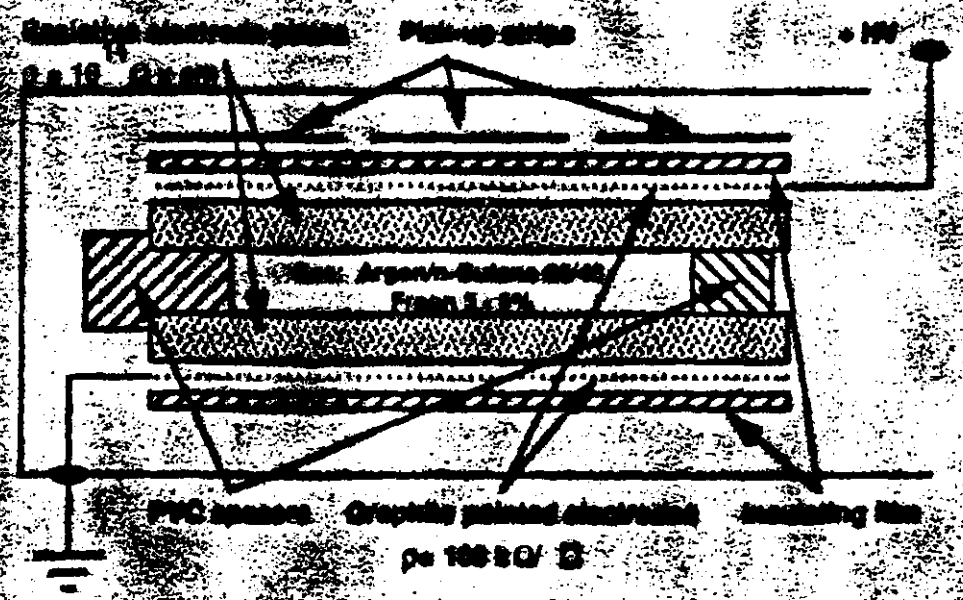
Resistive Plate Counter R&D Plans and Progress

- LLNL is fabricating chromium and cermet coated glass and thin film RPC prototypes and performing similar measurements as outlined previously.
- LLNL will fabricate a 1 m x 2 m or larger RPC using new materials based the experience gained with the prototype and assemble it at MIT for testing with the RPC test stand.
- MIT and LLNL are jointly studying the choices for fast trigger electronics for the barrel RPC subsystem:
  - Momentum selectable trigger based on fast CMOS "and/or" chips.
  - Momentum selectable trigger using hit patterns programmed into an associative memory by computer (also being considered for the forward muon subsystem trigger).
  - A choice of 10, 20, 30/40, or 50 GeV/c momentum trigger is available using RPC pickup strip hit information in non-bend plane (beam-crossing tag) and bend plane (momentum tag).
- Meetings to discuss software and hardware implementations of the trigger will place on December 17, 1991 and January 6, 1992.
  - Analysis codes will be written to study particle rate, trigger acceptance for each trigger out, and trigger rates for each trigger out as a function of transverse momentum.
  - Also among the issues to be studied are triggers due to random hits, the effect of a second trigger on pattern recognition strategies, and second trigger rate as a function of live time.

Resistive Plate Counter (RPC) Program

Brown, Indiana, LLNL, MIT, Tennessee

Sketch of a Resistive Plate Chamber



Muon barrel RPC functions:

1. Beam crossing tag
2. Muon trigger
3. Z coordinate of muon
4. Pattern recognition road

Among the R&D goals are studies of:

1. Rise time jitter
2. Efficiency
3. Gas (non-flammable)
4. Noise and aging
5. Maximum counting rate
6. Materials
7. Manufacturing techniques

V. CHANNEL COUNT

The channel count is as follows:

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

VI. BUDGET

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

	ITEM	COST ($/m^2)
1.	Glass (e.g. Schott B270 float glass)	68.1
2.	Resistive Electrode (e.g. carbon doped Aquadag)	2.2
3.	Foam (e.g. polyurethane sheet)	36.5
4.	Pick-up electrodes (e.g. metal tape)	9.8
5.	Insulators (e.g. G10 sheet)	41.3
6.	Aluminum box (1/16" sheet)	30.2
7.	Spacers (e.g. SS304 disks on 30 cm centers)	9.05
	Total Materials	186.15
	Total Materials (x2 for machining and waste)	372.3
8.	Fabrication cost estimate: $60/hr @ 1m^2/hr	60.0
9.	Gas fittings (e.g. 1 brass fitting every 30 cm on edge x 2 for gas manifold)	2.03
10.	Tygon tubing (1/8" diameter, 1 km long)	0.33
11.	RG-174 coaxial cabling (1 km)	0.12
12.	LEMO connectors (2 x 30,224 channels)	180.3
13.	Electronics (30,224 discriminators, 10,074 3-fold coinc., 9,650 QADC, 32 2-fold coinc.)	648.5
14.	Gas (Recirculator or throw away over 10 years)	150.0
	Total Miscellaneous	1,041.3

SUBTOTAL:

Materials, Fab., Gas System, Elect. System	**1413.6**

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

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

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

E. A. PLESS

R AND D – RPC

1. RISE TIME JITTER
   (1–2 NANOSECONDS ?)
2. EFFICIENCY
   (96% ?)
3. GAS – NON FLAMMABLE
4. NOISE AND AGING
   (NOISE ~ 10X COSMIC RAY ?
   AGING ?)
5. MAXIMUM COUNTING RATE
   (~ 100 HERTZ / CM^2 ?)
6. MATERIALS
7. MANUFACTURING TECHNIQUES
8. EFFECT OF LONG PICK UP STRIPS

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

M. Mohammadi

EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH

CERN/DRDC/91-53
RD-5 / Status Report
January 13th, 1992

Status report of the RD5 Experiment

A. Böhrer, H. Faissner, T. Moers, R. Priem, H. Reithler, R. Schleichert, H. Schwarthoff, H. Tuchscherer and H. Wagner.
III. Physikalisches Institut A, RWTH Aachen, Germany

Gy.L. Bencze[2], M. Della Negra[1], K. Eggert, A. Hervé, H. Plothow - Besch, E. Radermacher[1] and C. Seez[3]
CERN, Geneva, Switzerland

M. Aalste, R. Brenner, A. Hentinen, I. Hietanen, V. Karimäki, R. Kinnunen, J. Lindgren, K. Österberg, M. Pimiä, C. Rönnqvist, J. Tuominiemi, T. Tuuva and M. Voutilainen
Research Institute for High Energy Physics, SEFT, University of Helsinki and Åbo Akademi, Finland

A. Ferrando, L. Martinez-Laso, E.Torrente Lujan
CIEMAT, Madrid, Spain

H. van der Graaf, G.A.A. Witteman, R. Bergman, C. Brouwer, A. König, C. L. A. Pols and T. Wijnen
NIKHEF-H and University of Nijmegen, The Netherlands

A. Bettini, P. Casoli, S. Centro, R. Martinelli, A. Meneguzzo and P. Zotto,
Dipartimento di Fisica, Università di Padova, Italy

C. Bacci, F. Ceradini, G. Ciapetti, F. Lacava, A. Nisati, E. Petrolo, L. Pontecorvo, S. Veneziano and L. Zanello
Dipartimento di Fisica, Università di Roma "La Sapienza" and INFN, Italy

R. Cardarelli, A. Di Ciaccio and R. Santonico
Dipartimento di Fisica, Università di Roma "Tor Vergata" and INFN, Italy

D. Cline, S. Lazic and S. Otwinowski
U.C.L.A., Los Angeles, USA

W. Gorn, J. Layter and B. C. Shen
U.C., Riverside, USA

M. Andlinger, A. Kluge, F. Szoncso, G. Walzel and C.- E. Wulz
HEPHY, Österreichische Akademie der Wissenschaften, Vienna, Austria

W. Dominik, K. Doroba, M. Gorski, J. Krolikowski, L. Ropelewski, R. Szwed and G. Wrochna
Institute of Experimental Physics, Warsaw University, Poland

1) Joint spokesmen
2) Visitor from Central Research Inst. for Physics, KFKI, Budapest, Hungary
3) Visitor from Imperial College, London, U.K.

field shaping cathodes (-5kV and -7kV) at the edges of the tube guarantees a drift velocity of 52 μm/ns constant within 3% over the whole width of the tube. The maximum drift time is 1.5 μs. The single point resolution is on average 400 μm for tracks with the angular distribution of beam particles at RD5 (all muons were used without cuts on track quality). The detection efficiency of each tube is about 99% over the whole width of the tube.

In January 1991 the modules together with the original readout, trigger electronics and cabling were moved from the UA1 experiment to the RD5 area and were installed in the H2 beam. In order to test and operate the chambers independently online programs (one based on the OS9, the other based on the MacUA1 system) were developed to test the multiple time digitizers (MTD). Another important tool was a program to give test pulses to each of the 585 wires and read back the response. This implied a check of the whole chain starting from the wires and ending at the wire patterns for each chamber. In the middle of June '91 systematic tests were started. Only four dead wires were found. This number was reduced to two, corresponding to 0.35 % of all wires. At the end of July a local monitoring program including hit, wire and time distributions as well as an event display was ready. The chambers were filled with gas mixture and were tested with high voltage. During the run the high voltage was controlled by program. Both the low voltage for the signal preamplifierlifiers as well as the high voltage were monitored by program. There were no problems with the high voltage or low voltage during the run.

After having the chambers, the read out and the control programs ready we triggered locally on cosmic and parasitic muons in the beam. From the beginning we saw at the event display clean muon tracks in all three modules. In addition the hit, wire and time distributions showed the expected shapes. This situation was monitored over the whole run period and stayed stable.

The resistive plate chambers

Sixteen planes of Resistive Plate Chambers (RPCs) were installed in 1991. Each plane measures $2 \cdot 2$ m^2 and has 64 read out strips of 31 mm pitch. The planes are coupled in pairs providing one measurement in the horizontal projection, z, and one in the vertical projection, y. Station 1 (see Fig. 1) has four pairs with two y-z measurements before and after the muon drift chambers. There is one y-z pair in each of the two slots in the iron toroid. Station 2 has two y-z pairs with one measurement on either side of the drift chambers.

Each plane is made of two RPCs of dimensions 1 x 2 m^2 assembled as shown in Fig. 16. The RPCs [10] are made from two bakelite plates of 1 x 2 m^2 surface and 2 mm thickness. The plates have a volume resistivity of about 10^{11} Ω cm. The sensitive gas volume is a 2 mm gap between the two plates. In order to separate the plates by a fixed distance over the whole surface, PVC disks of 12 mm diameter are glued on the plates. The gas gap is closed at the edges with a PVC frame.

The outer surface of the resistive plates are coated with a graphite solution with a surface resistivity of ≈ 100 kΩ. The two graphite electrodes, transparent to the fast component of the discharge pulse, are connected to the high voltage power supply to produce the electric field. A thin foil of PVC is glued on the graphite surface to provide isolation of the high voltage electrodes.

The read out electrode is segmented into thin aluminum strips of 29 mm width and 31 mm pitch. The strip plane is separated from the outer ground shield with a foam plate 10 mm thick. Each strip is terminated on 50 Ω on either end and one side is connected to the frontend electronics. The propagation time of the transmission line is about 5 ns/m and there is no attenuation of pulses from the induction point to the end. A section of the chamber is shown in Fig. 17.

The frontend electronics is shown in Fig. 18. Each plane provides a fast trigger signal made with the wired OR from the discriminator outputs of the 64 strips. The digital signals from the individual strips are 100 ns long and are read out with VME registers strobed by the scintillator hodoscope trigger. When the experiment trigger arrives to the input register in the VME crate, the data are sent to the data acquisition system via optical fiber.

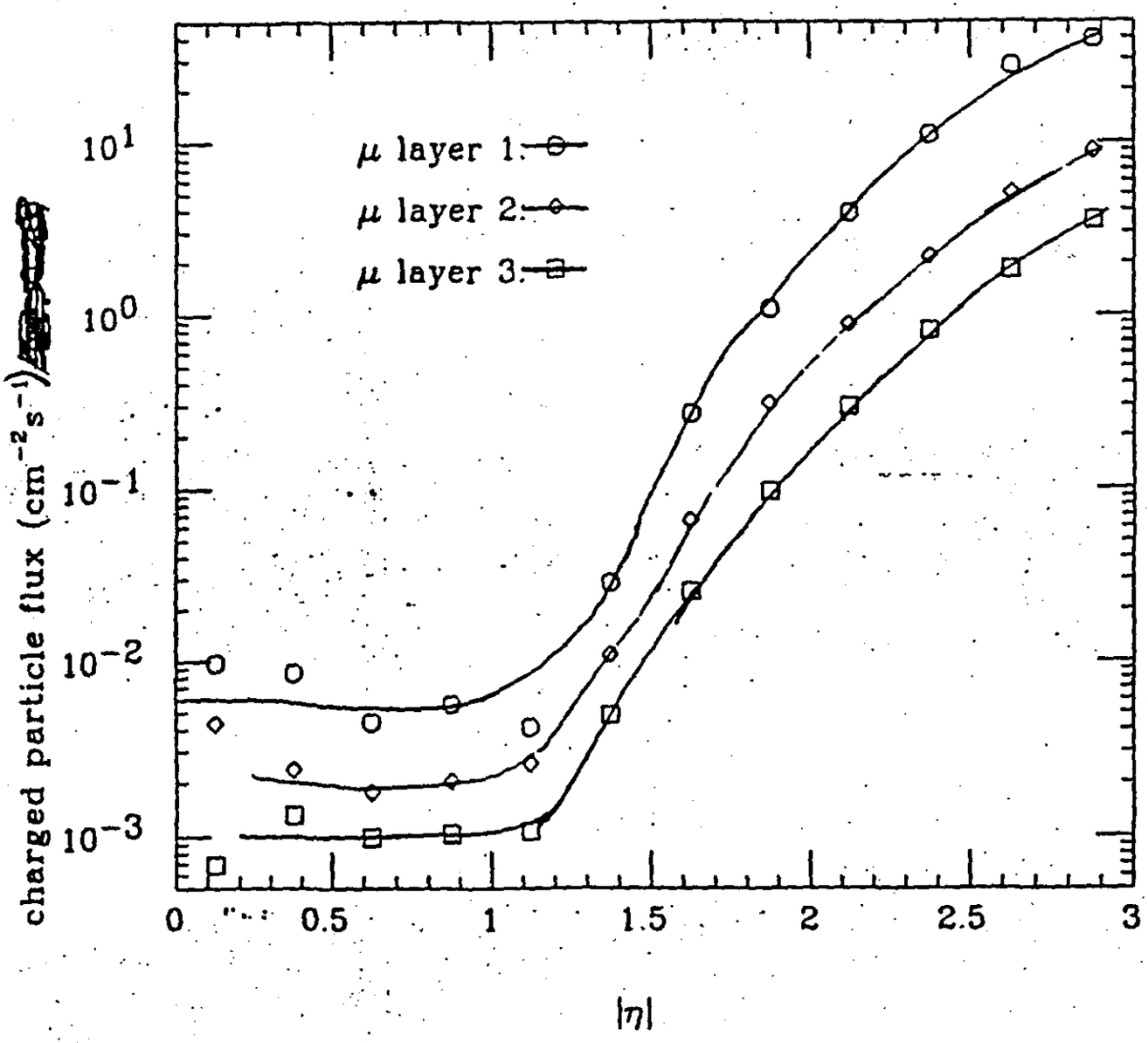
The chambers have been operated with a gas mixture of 58% argon, 38% n-butane and 4% of freon. The supply voltage was 7.1 kV. In these conditions, the single rate measured with the fast OR signals was on average 10 kHz per plane depending on the resistivity of the electrode plates. The probabilty of accidental hits, measured with a random trigger, was between 10^{-4} and 10^{-3} per plane.

The efficiency, averaged over the whole surface of the chambers, measured with the fast OR signals with muons of the beam halo, was on average 96%.

The measurement of the single chamber efficiency as a function of the particle flux was done by tracking high momentum muons (100-300 GeV/c) through the different planes of RPC chambers. Signals from adjacent strips were grouped in clusters, then tracks were defined with a least square fit to a straight line in both projections. Fig. 19 shows the distribution of the residuals from the fitted tracks. The average r.m.s space resolution is about 8 mm. The single plane efficiency was measured by requiring that a hit is found within four strips centred on the expected beam position. At low beam intensity, smaller than 10 Hz/cm^2, the efficiency for the different chambers varies between 96% and 99%.

Chambers with two different resistivities for the electrode plates were tested. The resistivity of the electrodes is an important parameter that defines the recovery time of the electric field after a local discharge. Low resistivity chambers were placed in station 1 while the chambers in the slots of the iron magnet and in station 2 have resistivity a factor 5 larger. Fig. 20 shows the efficiency as a function of the muon flux in different chambers. A significant degradation in efficiency is observed in the chambers with high resistivity electrodes for particle fluxes larger than 50 Hz/cm^2. In the low resistivity RPCs the efficiencies degrade only at fluxes larger than 100 Hz/cm^2 [11,12]. It should be noted that the drop in efficiency at high rates does not affect the hadron punchthrough measurements, since,

Hit Rate (#/cm²) in Muon Chambers



II-2

RATES

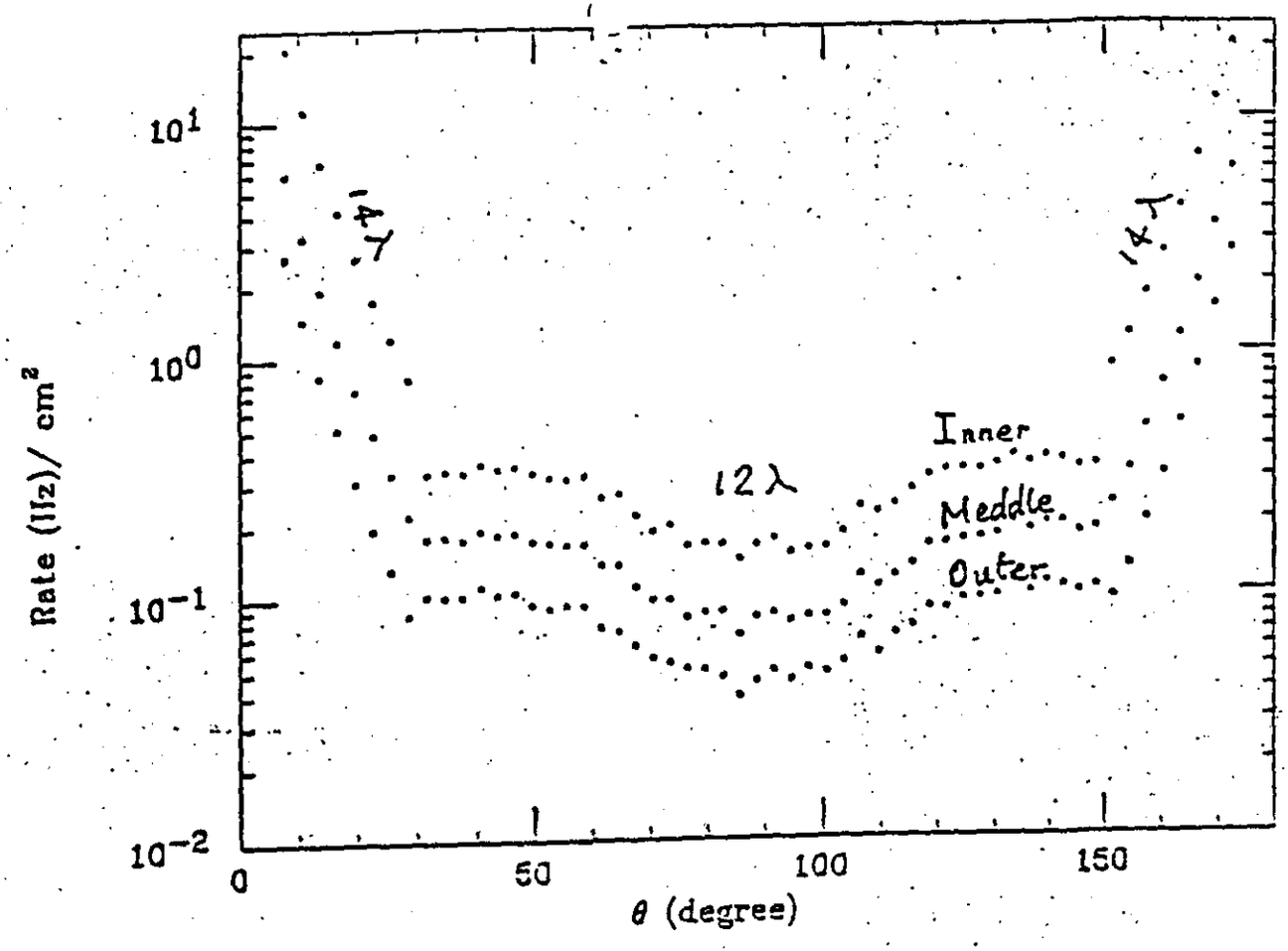


Figure 5

RATES

CALCULATED HIT RATE IN THE BARREL ~ 5×10^{-1} HERTZ/CM^2

THIS IS SMALL COMPARED TO 50-100 HERTZ/CM^2

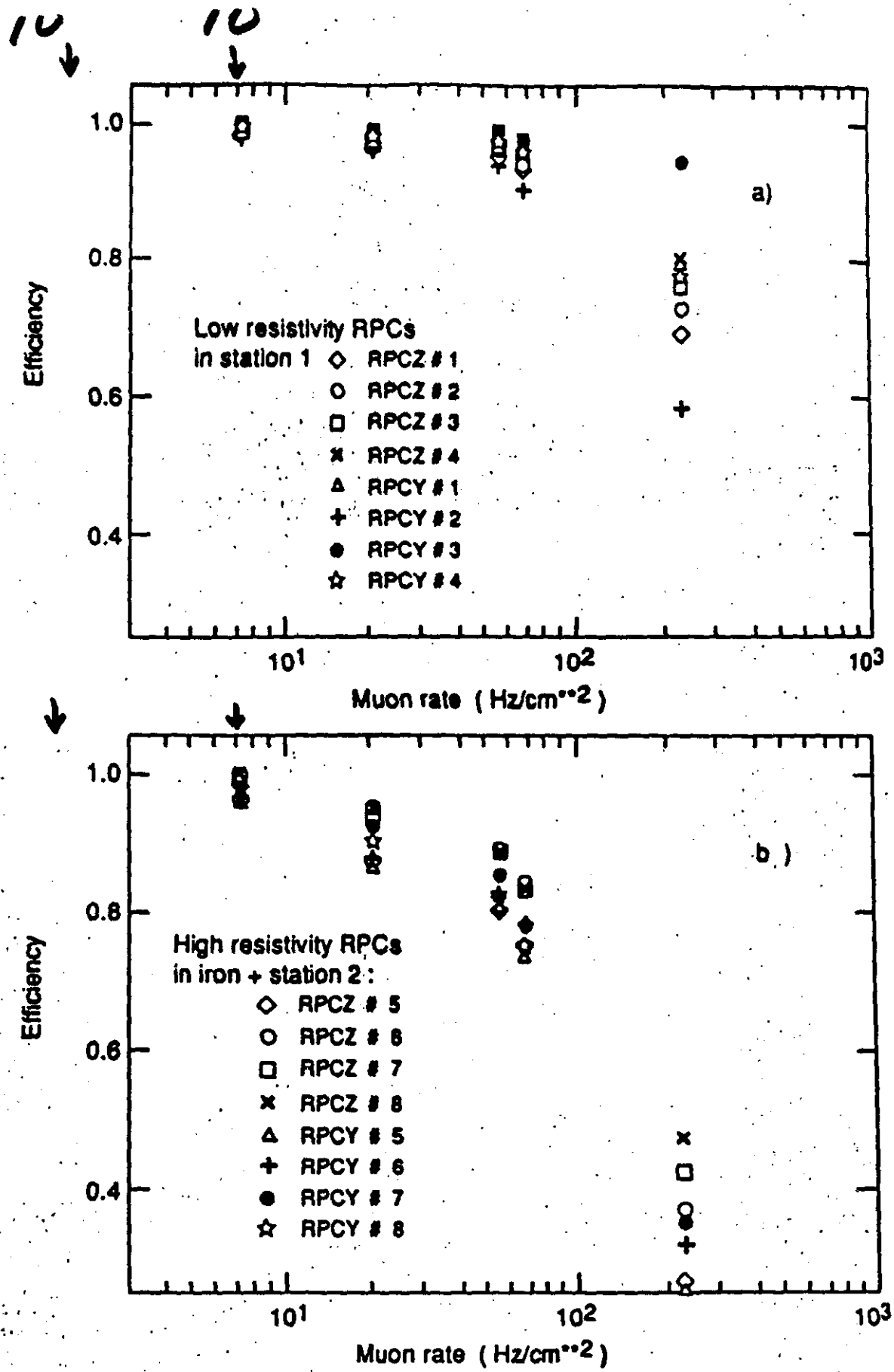
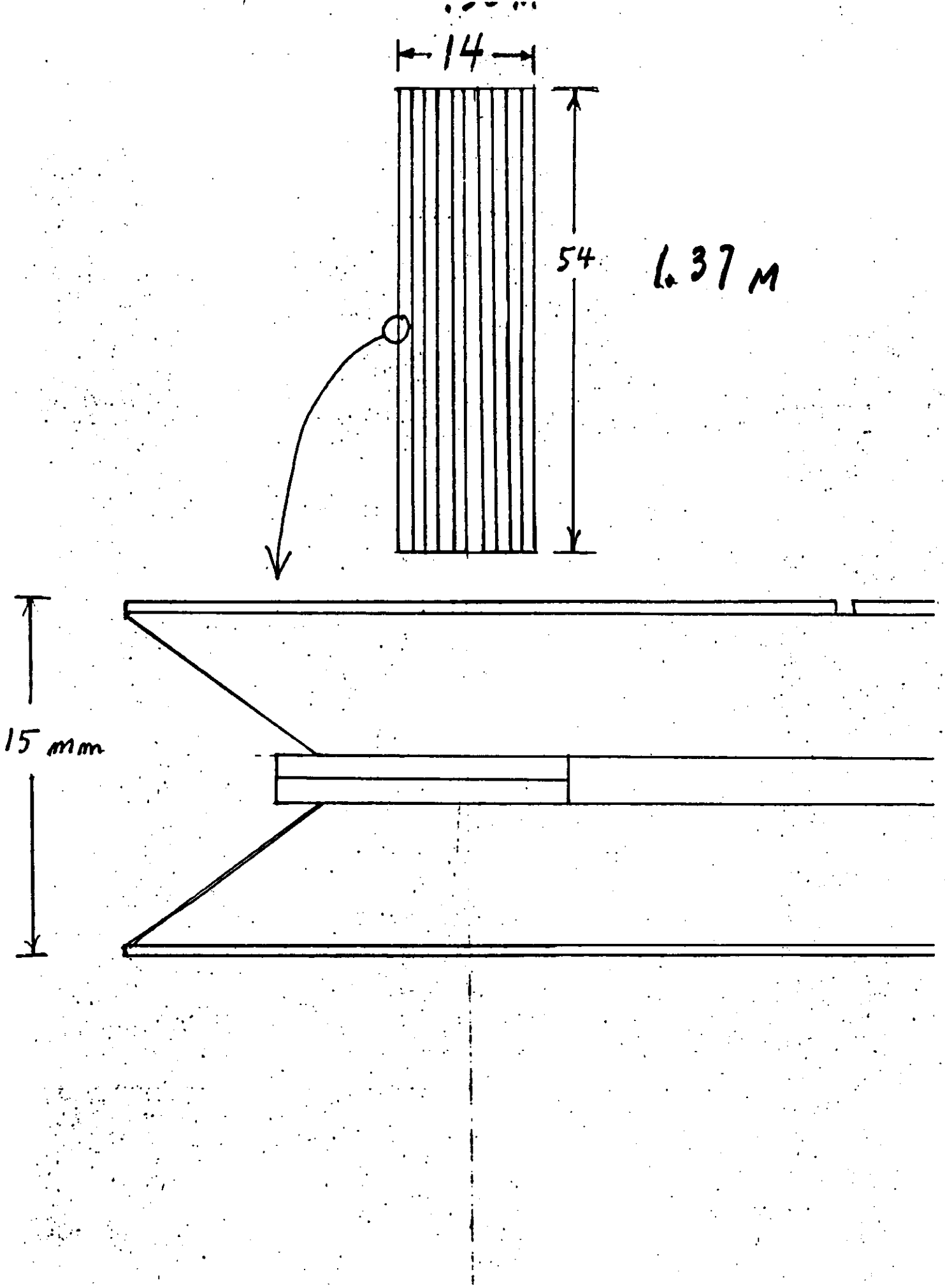
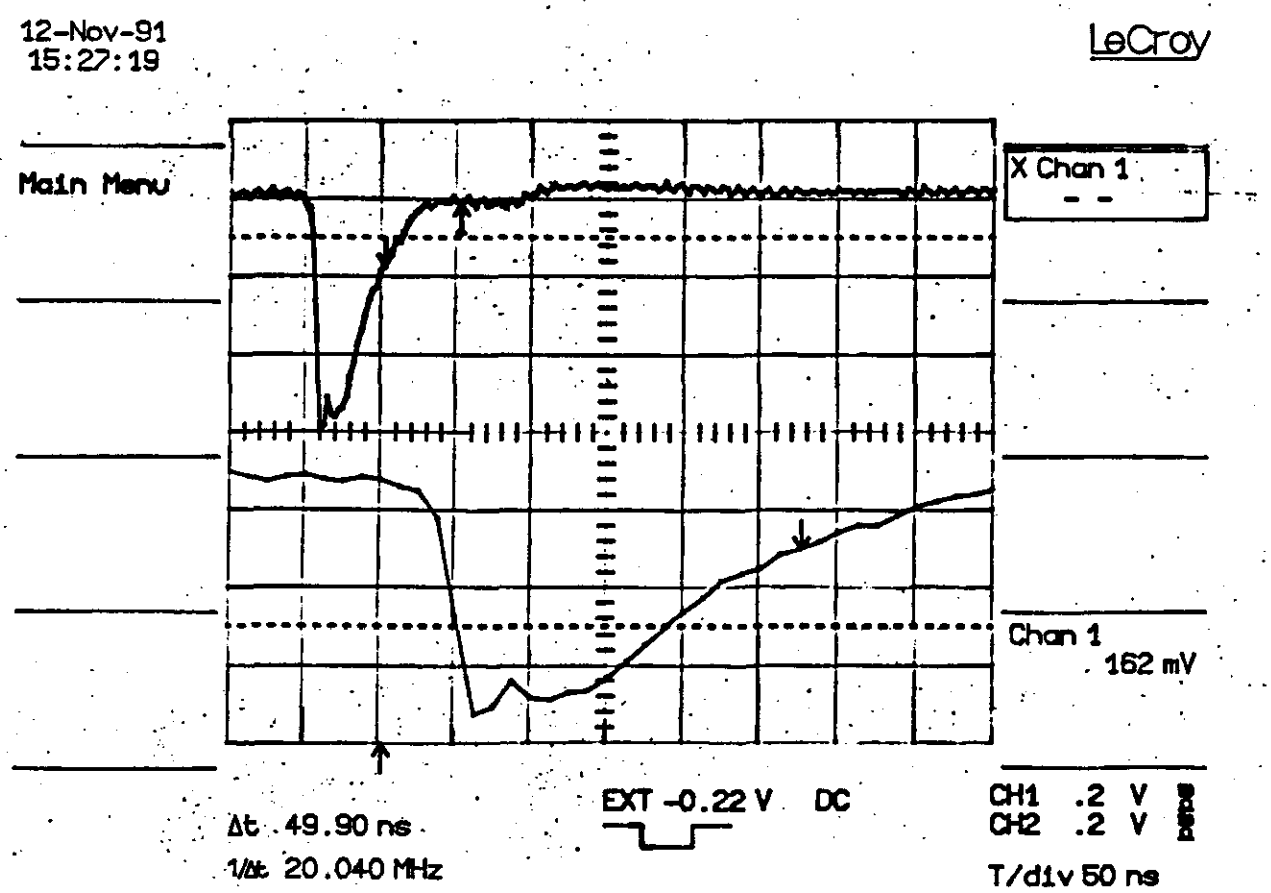

10
10
1.0
0.8
0.6
0.4
Efficiency
a)
Low resistivity RPCs
in station 1
RPCZ # 1
RPCZ # 2
RPCZ # 3
RPCZ # 4
RPCY # 1
RPCY # 2
RPCY # 3
RPCY # 4
10^1
10^2
10^3
Muon rate (Hz/cm**2)
1.0
0.8
0.6
0.4
Efficiency
b)
High resistivity RPCs
in iron + station 2 :
RPCZ # 5
RPCZ # 6
RPCZ # 7
RPCZ # 8
RPCY # 5
RPCY # 6
RPCY # 7
RPCY # 8
10^1
10^2
10^3
Muon rate (Hz/cm**2)

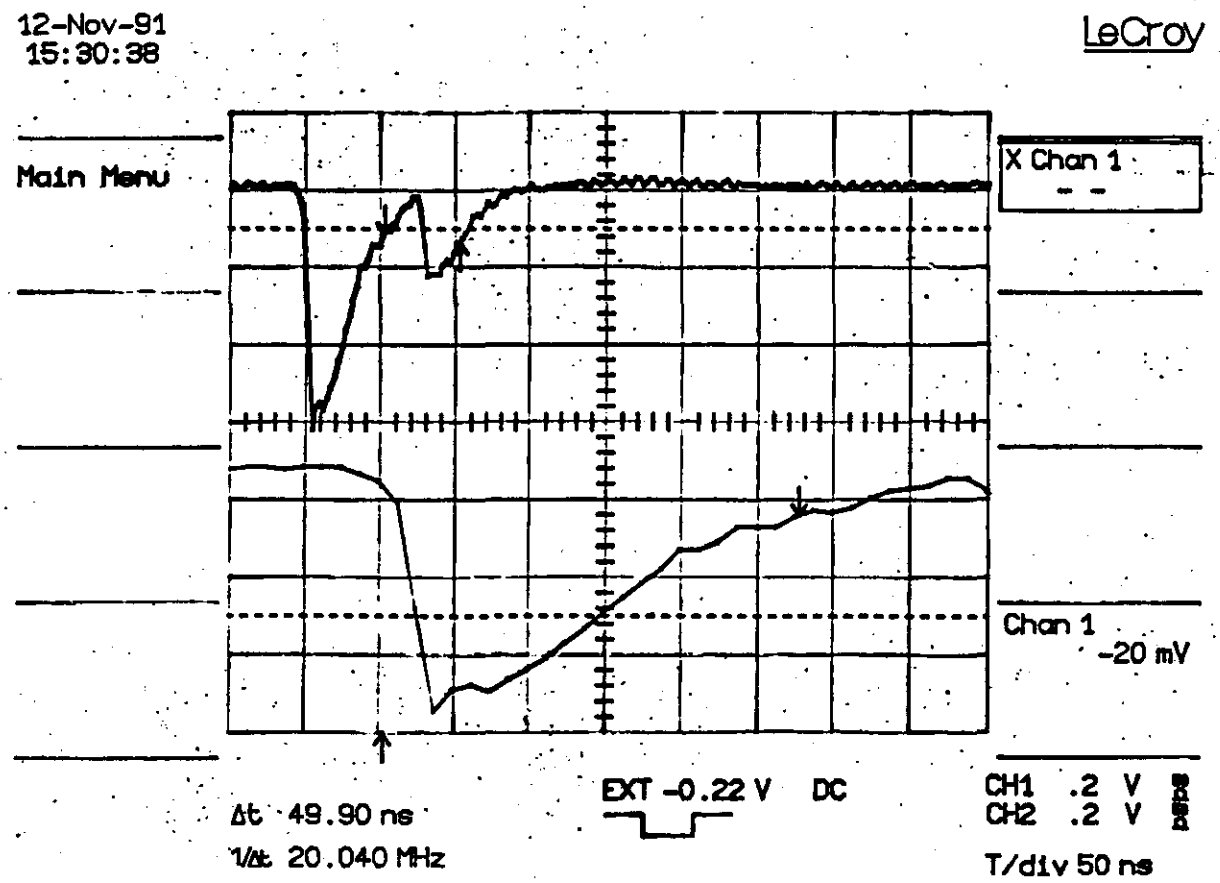
FIG. 20


14
54
1.37 M
15 mm

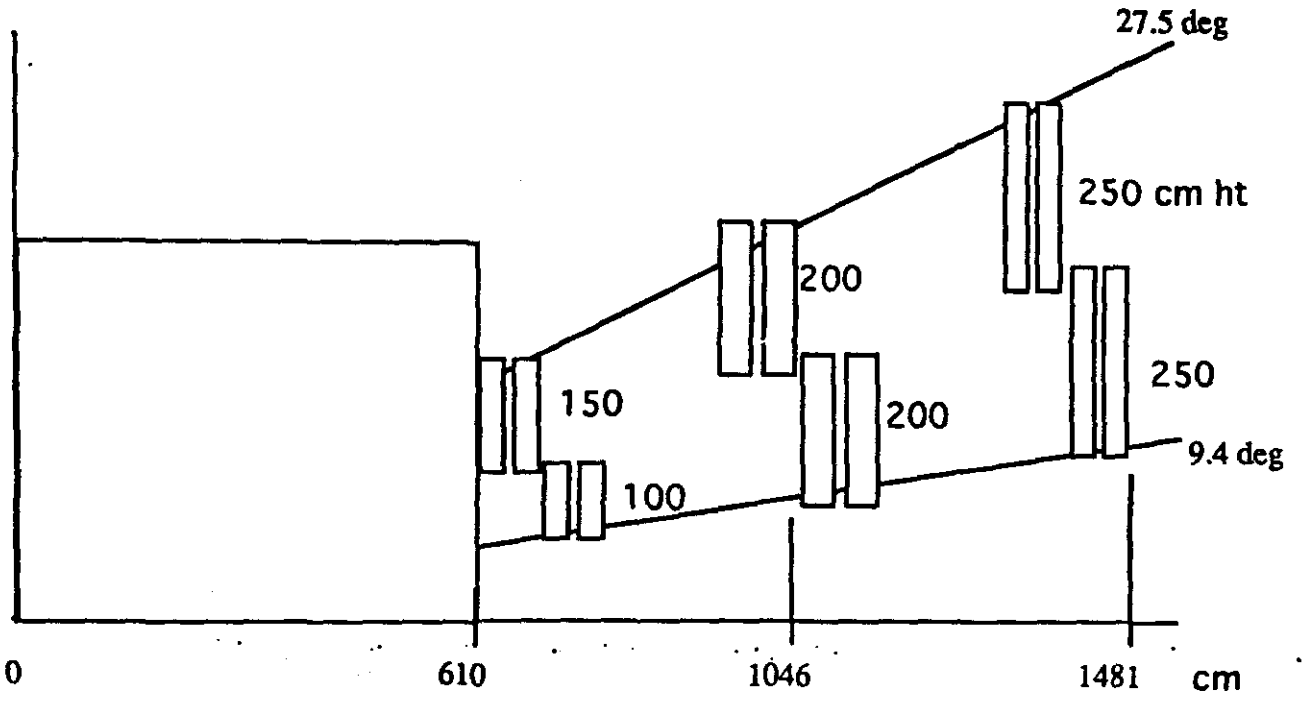
4000 V, readout end



9000 V Far end



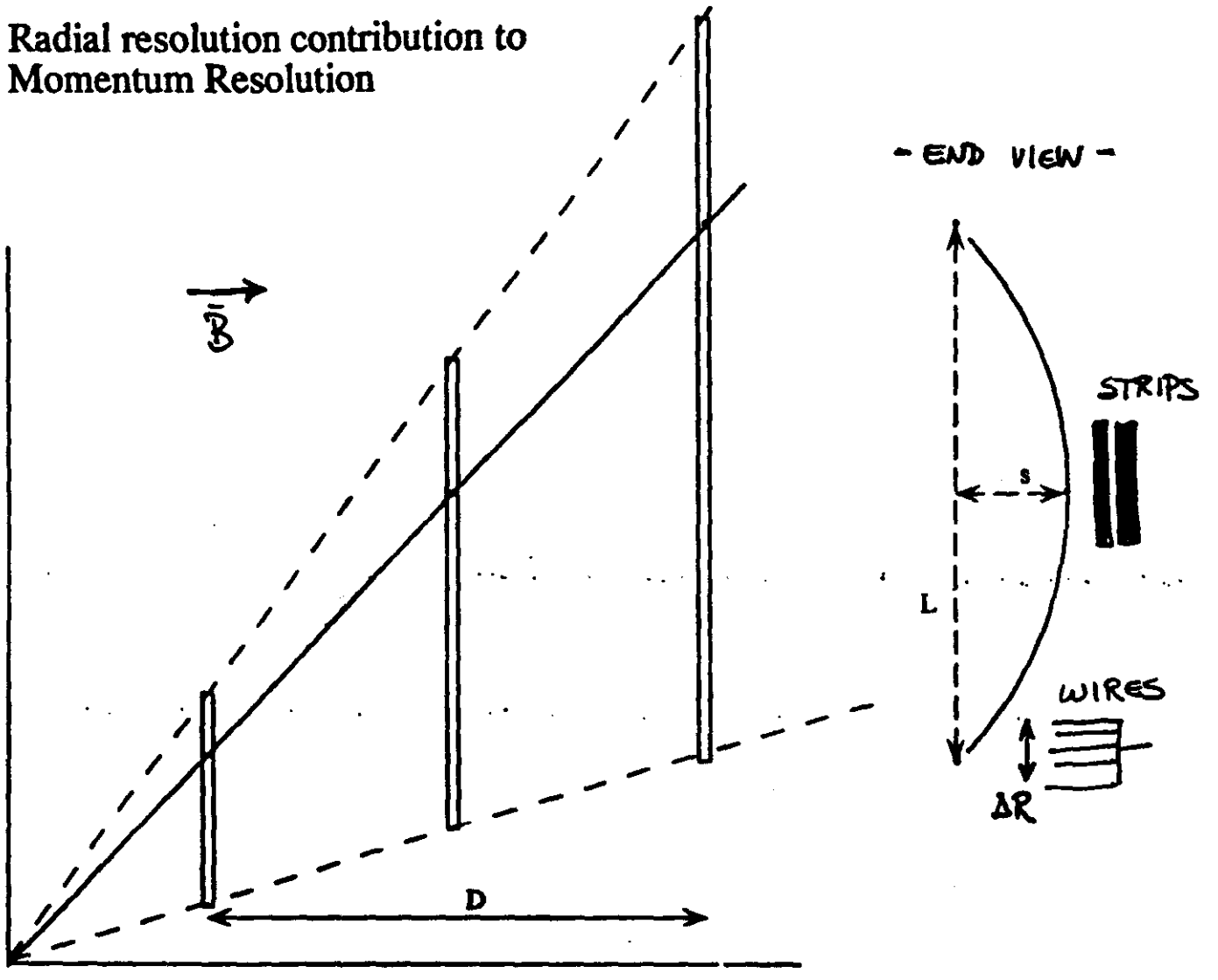
CSC Layout



Info needed for specification of the CSC layout:

B field
max module dimensions

Radial resolution contribution to Momentum Resolution



$$p = \frac{\alpha D L}{8 s} \qquad \alpha = .8 \frac{GeV}{Tm} \cdot B$$

$$\frac{\delta p}{p} = \frac{\delta L}{L} \oplus \frac{\delta s}{s} = \left\{ \left(\frac{\delta L}{D \tan\theta} \right)^2 + \left(\frac{8 p \, \delta s}{\alpha D^2 \tan\theta} \right)^2 \right\}^{1/2}$$

$$\delta L = \sqrt{2} \cdot \frac{\Delta R}{\sqrt{12}} \cdot \frac{1}{2}$$

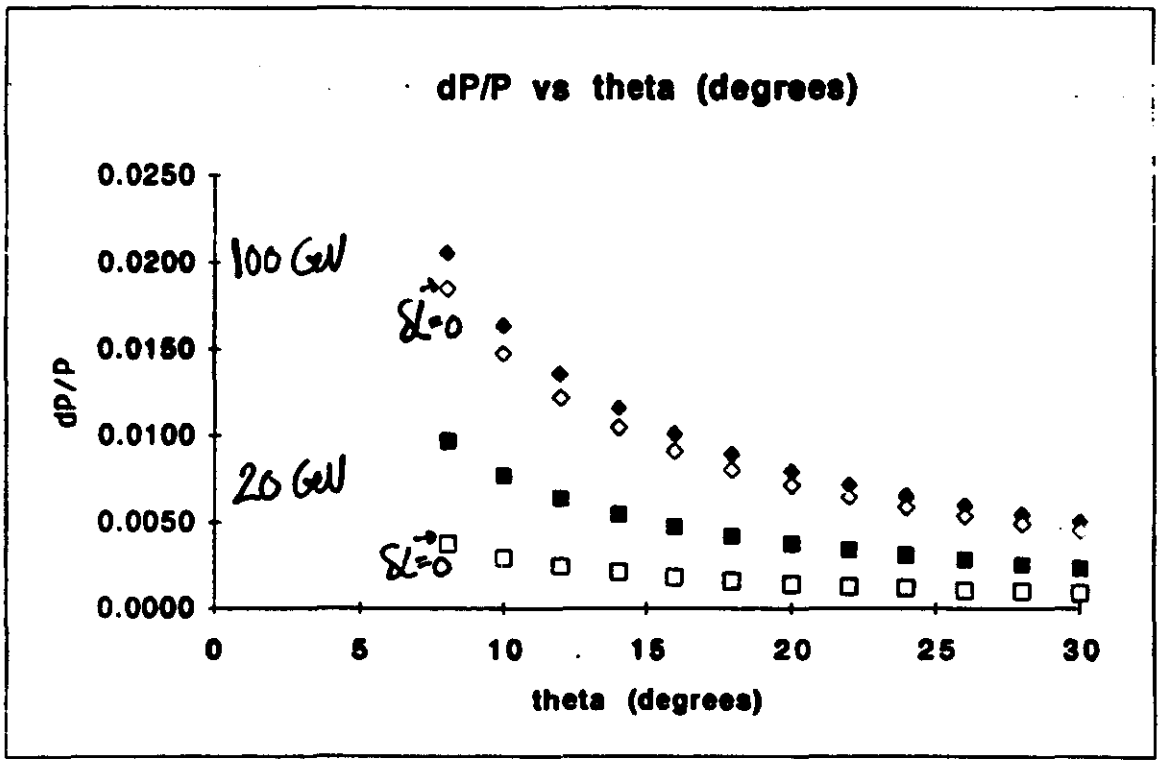
stagger

Momentum resolution in the GEM endcaps, including radial resolution

Scott Whitaker
23-Jan-92

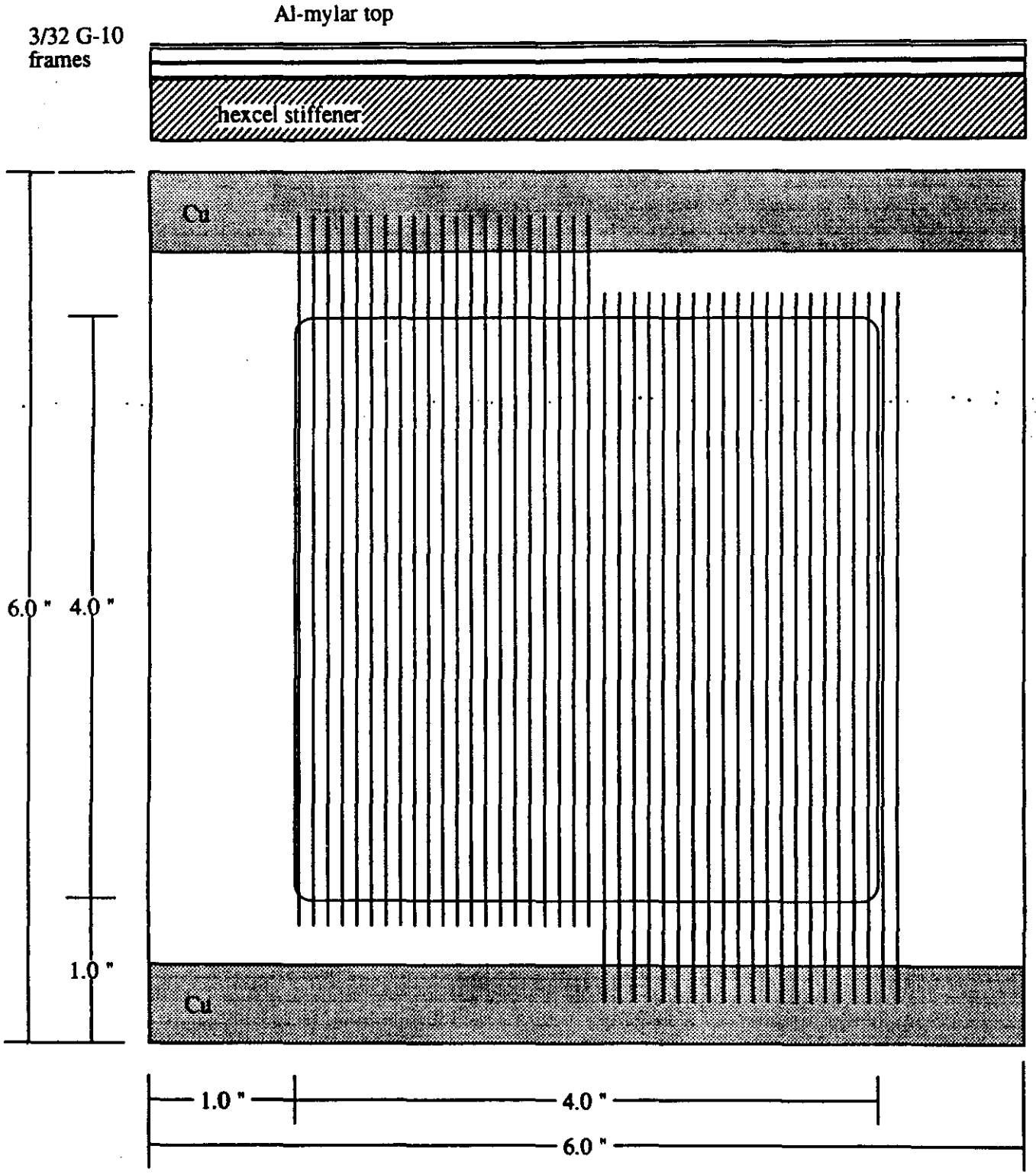
dL=		0.01		
ds=		5.00E-05		
D=		8		
pL=		20	PH=	100

theta (deg)	dpL/pL w. dl	dl=0	dpH/pH w. dl	dl=0
8	0.0096	0.0037	0.0206	0.0185
10	0.0077	0.0030	0.0164	0.0148
12	0.0064	0.0025	0.0136	0.0123
14	0.0054	0.0021	0.0116	0.0104
16	0.0047	0.0018	0.0101	0.0091
18	0.0042	0.0016	0.0089	0.0080
20	0.0037	0.0014	0.0079	0.0072
22	0.0034	0.0013	0.0071	0.0064
24	0.0030	0.0012	0.0065	0.0058
26	0.0028	0.0011	0.0059	0.0053
28	0.0025	0.0010	0.0054	0.0049
30	0.0023	0.0009	0.0050	0.0045

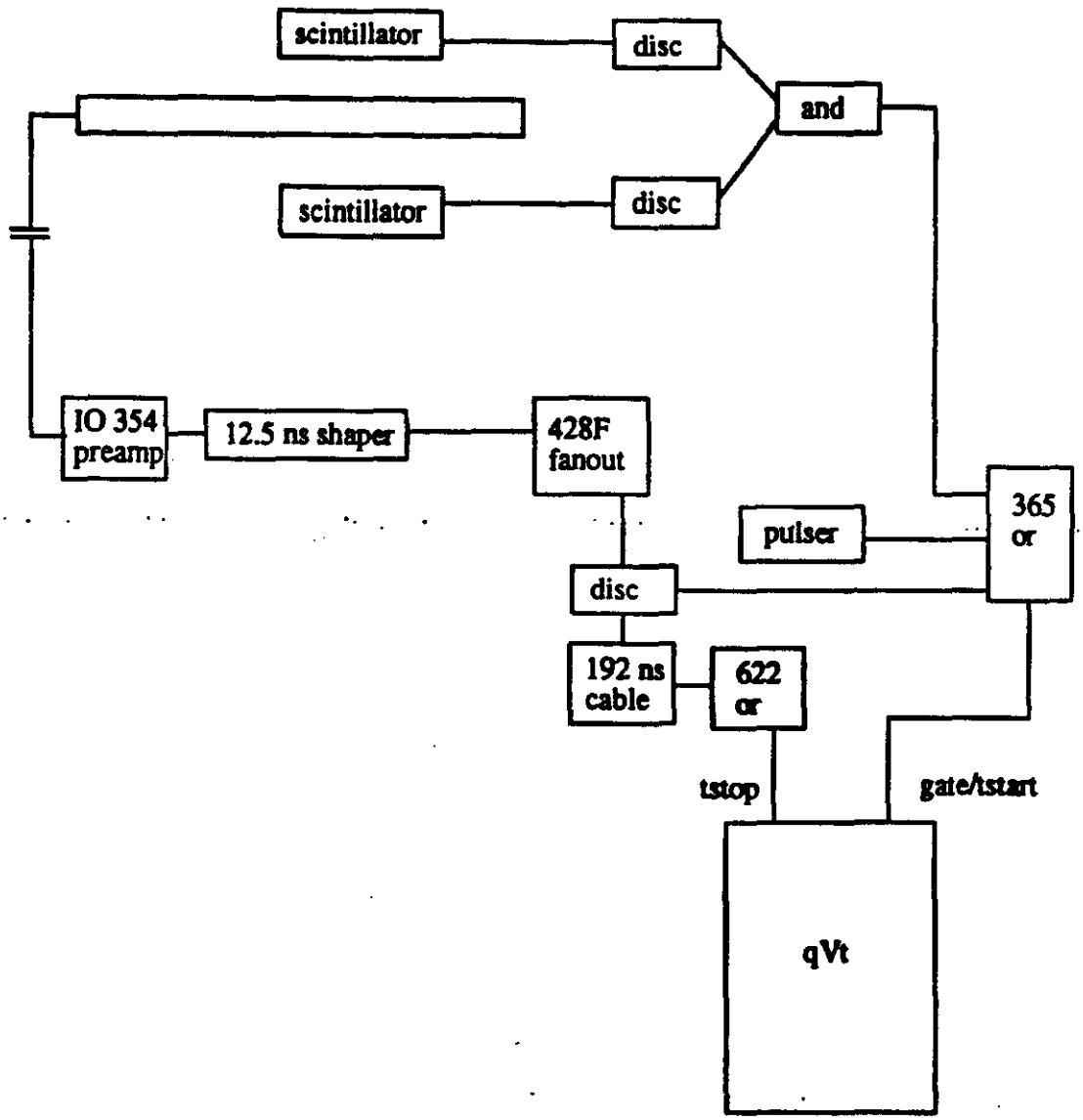


Test Chambers

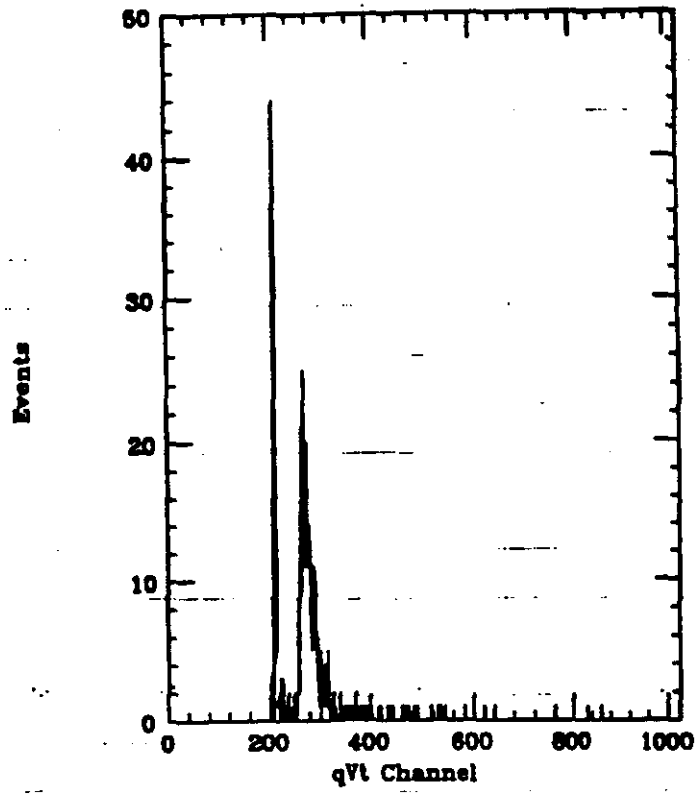
scale -- full



Setup for CSC gain and timing tests



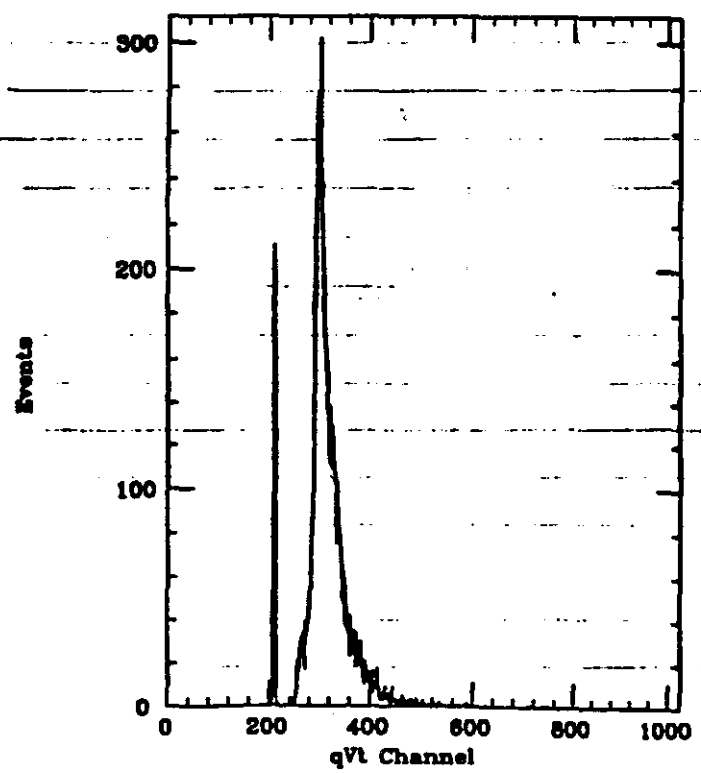
Cosmic Ray Spectrum 25% CF4 2900 V

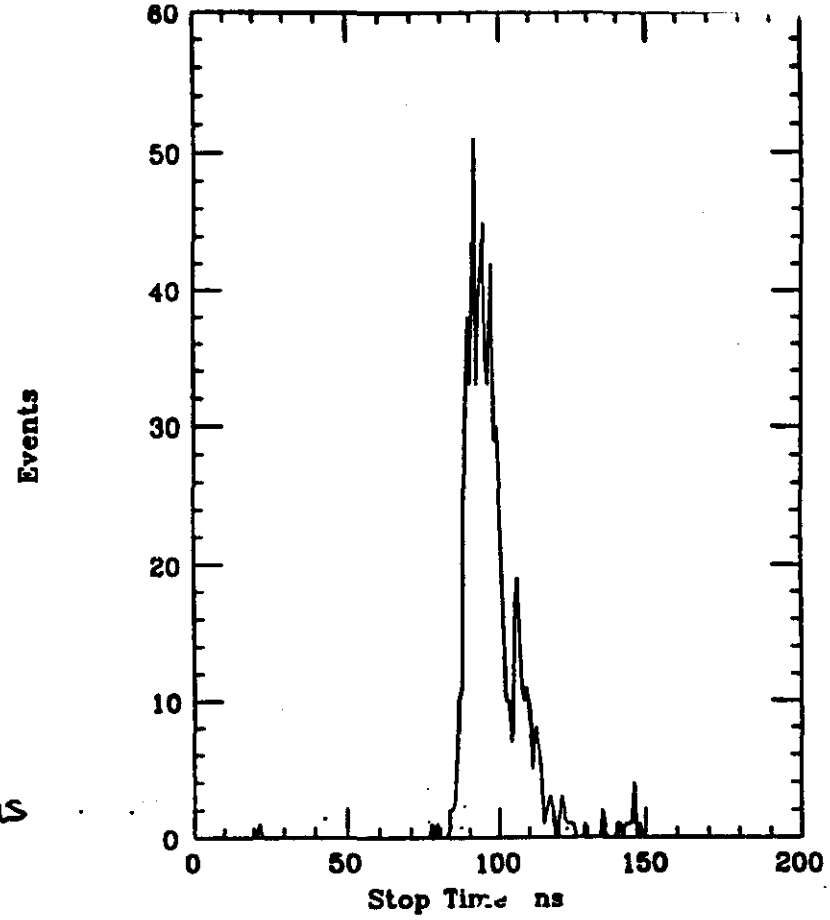


gas gain ~ 5×10^4

1. needs proper measurement

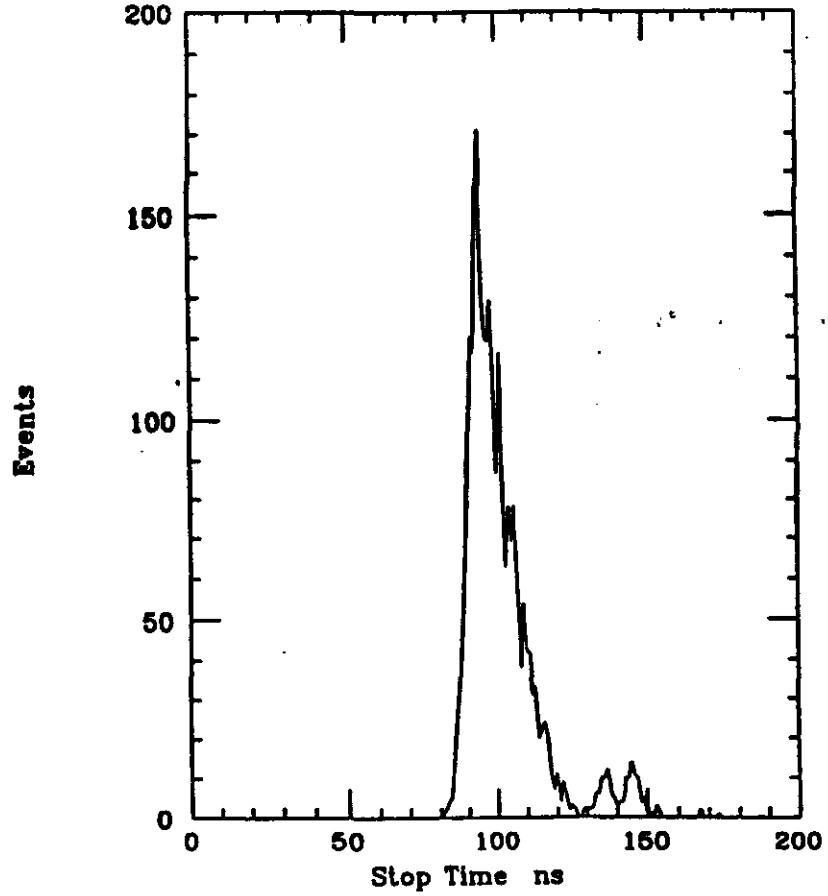
Fe-55 Spectrum 25% CF4 2900 V





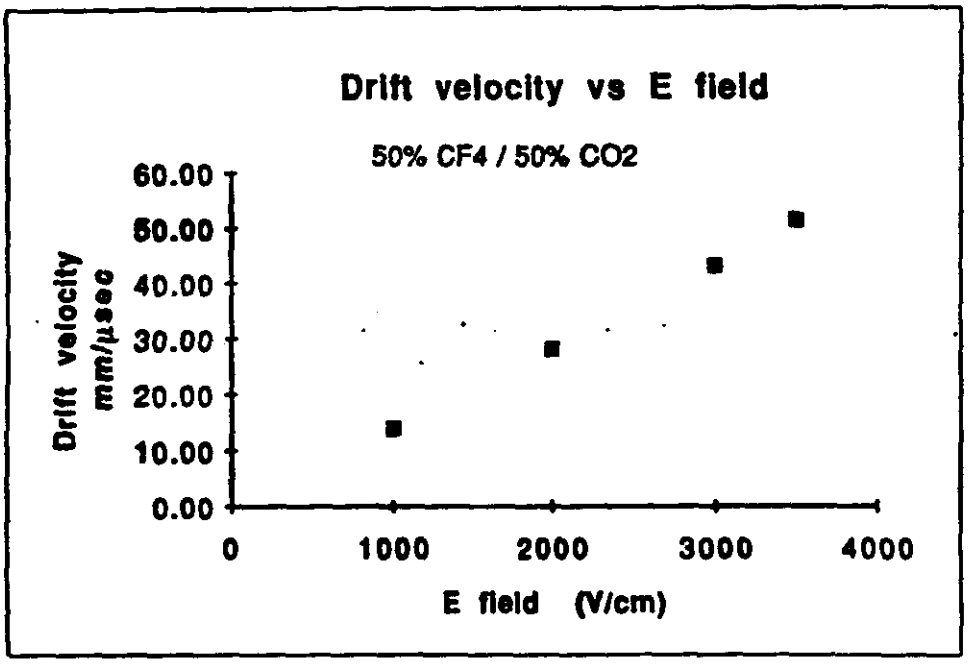
$\Delta t \leq 30$ ns

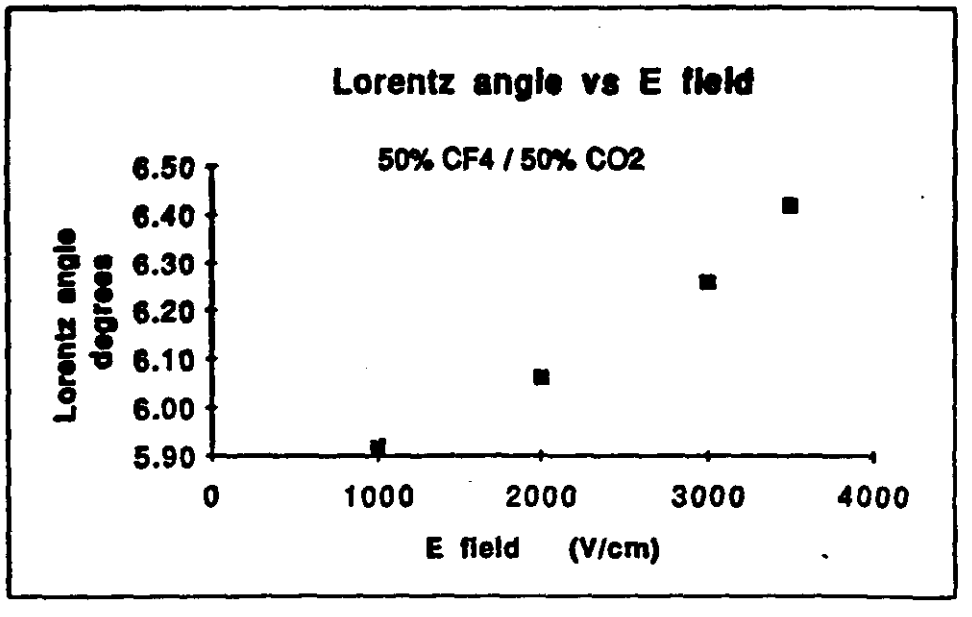
Time Distribution 25% CF4 2900 V

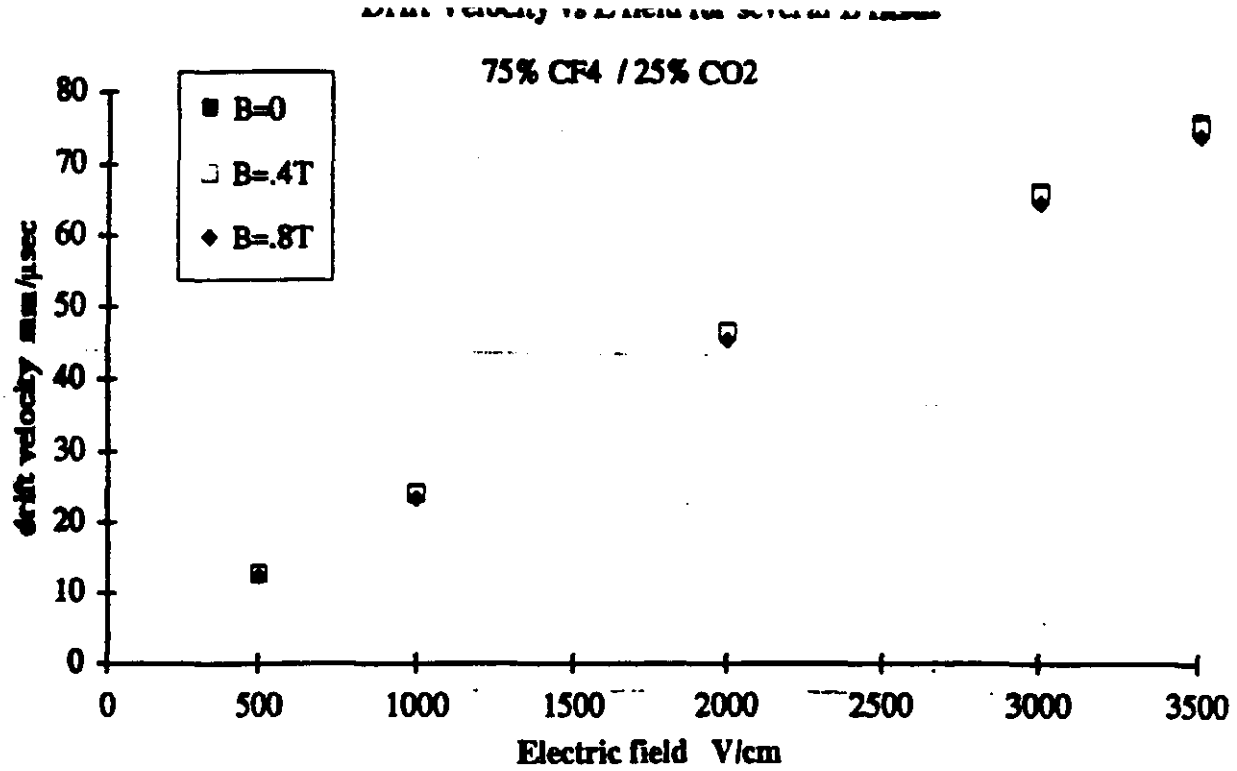


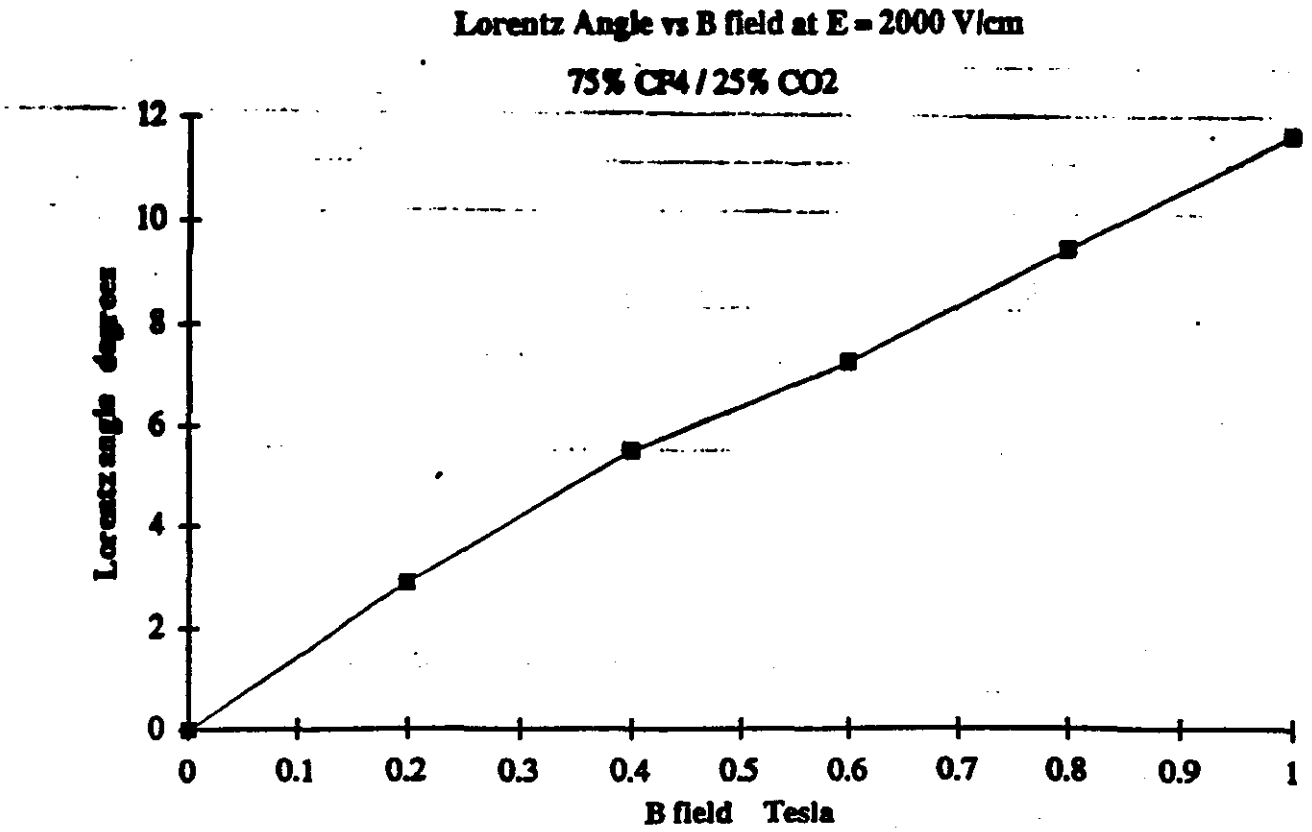
50% CF4 / 50% CO2

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






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


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