GEM TN-92-241

Muon Meeting - Brookhaven National Laboratory

November 5, 1992

Abstract:

Agenda, attendees and presentations of the GEM Muon Meeting held at Brookhaven National Laboratory on November 5, 1992.

GEM Muon Meeting

BNL

November 5, 1992

muon meeting @ BNL
5 Nov '92

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Frank Taylor

General Remarks

Frank Taylor 11/4/92

Muon System Technology Choice

• R&D Program for FY92

R&D program for FY92 focused on building a number of prototypes of several technologies to determine properties and assess applicability for GEM Muon System.

Baseline 1:

	Barrel	Endcaps
L-1 Triggering:	RPC	CSC
Tracking:	PDT or LSDT	CSC

• Oct. 6-7 Technology Review Meeting:

Intended to define the TDR baseline (Baseline 2)

-proponent reports

-independent engineering assessment

-outside reviewers (Branson, Fabjan, Foley, (Nygren))

But at that time not all of the prototype chambers had been delivered to the TTR and there was little performance data.

Issues Listed for Oct. 6-7 Meeting

- Barrel Issues:

1. Which is the more attractive drift technology - PDT or LSDT ?
2. Will the RPCs perform in terms of jitter, background sensitivity, and longevity ?
3. In case RPCs are not accepted, is there an alternative trigger for the drift option ?
4. Will the CSCs perform in barrel in terms of resolution, alignment, and costs ?

- Endcap Issues:

1. Will the CSCs perform in terms of resolutions, background, and costs ?
2. Are there any alternatives to the CSCs in the Endcaps ?

Muon Chambers at the TTR

As of 11/3/92

Technology	Chamber size	TTR delivery date
PDT-JINR	1 m x 4 m x 8 layers	7/28/92 (delivered)
PDT-MSU	1.3 m x 3.8 m x 4 layers	9/29/92 (delivered)
LSDT	1 m x 4 m x 4 layers	9/22/92 (delivered)
LSDT	1 m x 4 m x 4 layers	10/23/92 (delivered) 10/28/92 (sent back)
RPC	1 m x 2 m x 2 layers	9/29/92 (delivered)
CSC-BU	0.5 m x 0.6 m x 3 x 2 layers	RD5-CERN (delivered)
CSC-BU	0.5 m x 0.6 m x 3 x 2 layers	
CSC-BNL	0.6 m x 0.6 m x 2x4 layers	10/20/92 (delivered)
CSC-BNL	1 m x 1.8 m x 4 layers	
CSC-UH	0.5 m x 1 m x 3 layers	9/92 (delivered)
CSC-JINR	1.1 m x 1.5 m x 2 layers	10/10/92 (delivered)

Result of Oct. 6-7 Meeting:

- Attempted to rate drift technologies in barrel:

  -LSDT with stand-alone trigger (without RPC) seemed attractive.

  =====however====

  -PDT (actually operated in limited streamer mode at 1 ATM.) would have essentially the same operation properties.

  -RPC low resistivity plastic looks attractive (high rate possible).

- CSC was not rated for barrel application (no performance data was available.)

- A number of questions were identified:

  -showering from material inside the chambers

  -acceptance coverage

  -location of alignment paths and affect on acceptance

  -comparative costs of chamber construction and electronics

• Present Situation:

- Examples of all chamber technologies have been delivered and tested at the TTR.

- Cost comparisons have been refined.

- Performance data available from all technologies.

- For today:

- summary of TTR results (Mitselmakher)

- description of each technology

    - CSC (Polychronakos)

    - LSDT (Osborne)

    - PDT (Bromberg)

    - Dubna Chambers
      PDT (A. Golutvin)
      CSC (Yu. Kiryushin)

    - RPC (Wuest)

- discussion of pros/cons of each technology (Marx - convener)

TO: Muon Group
FROM: F.E.Taylor
SUBJECT: Plans for BNL Meeting
DATE: 10/25/92 - Updated 11/3/92

We have been asked to give a presentation of status of the technologies at the plenary session on Nov. 4 and we are to get together as a muon group on Thursday Nov. 5.

(I) Nov. 4 afternoon Muon Group presentation in plenary session
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(1) General remarks - Taylor (10 min)

(2) Summary of results from the TTR - Mitselmakher (15 min)

(3) Technology Options:

- o CSC - Polychronakos (15 min)
- o LSDT - Osborne (15 min)
- o PDT - Bromberg (15 min)
- o PDT and CSC from Dubna - Golutvin (15 min)
- o RPC - Wuest (15 min)

(4) Open discussion - Marx moderator (30 min)

[Time for questions and discussion of pros/cons of technologies before the entire GEM Collaboration]

(II) Nov. 5 Muon Group Meeting (8:00 until 16:30)

At this meeting we should have in-depth answers to the questions raised at our Oct. 6-7 meeting, and review the engineering assessment report and the cost of the electronics. Our discussion should lead to what are the advantages, disadvantages, and risks of each technology solution. This should be summarized in a short document to be distributed to the Executive Committee on the afternoon of Nov. 6. Marx, Mitselmakher, Taylor, and Sawicki will be responsible for putting this document together. It should include charts comparing channel and chamber counts, alignment paths, costs of chambers, costs of electronics, test results to date, etc.

Draft Agenda: Muon Group Meeting 11/5/92

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(1) General Remarks: (Marx/Taylor) 8:00 - 8:15

(2) Results of TTR and RD5 tests: 8:15 - 10:15
(Mitselmakher-convener)

CSC-BNL/BU TTR and RD5 results (Polychronakos)
CSC-UH (Lau)
CSC-Dubna (Yu. Kiryushin)

PDT-Dubna (A. Golutvin)
PDT-MSU (Bromberg/Miller)

LSDT (Korytov)

RPC (Wuest/Pless)

(3) Joint meeting with Electronics Group: 10:30 - 12:00
(Marlow/Shaevitz - conveners)

Critique of muon trigger concept
Costing of electronics

Lunch

(4) Answers to Oct. 6-7 Questions:

Each Proponent is asked to list advantages of technology for submission to "master list" and answer Oct. 6-7 List of Questions.

- CSC (Polychronakos)	13:00 - 13:30
- PDT (Bromberg)	13:30 - 14:00
- LSDT (Osborne)	14:00 - 14:30
- RPC (Wuest)	14:30 - 15:00

Note:
Conveners are asked to organize presentations. Input expected from McNeil, Nimblett, Sawicki, et al., and other members of each technology team. See list of questions below.

Break

(5) Engineering Assessment Report (Sawicki)	15:15 -15:45
(6) Discussion of technologies (Group)	15:45 - 17:00

- Lists of Advantages/Disadvantages
- Results of straw poll

(III) Muon Group Steering Committee Meeting	17:15 - 19:30

We will try to make a recommendation of the TDR Baseline 2 technology.

Appendix:

List of the questions from Oct. 6-7 Meeting to be addressed during Joint Electronics/Muon session, or the Muon Afternoon session.

(I) Issues to be addressed by all technologies:

o Determine the costs of electronics and chamber construction in a uniform way - identifying those items constructed in the US versus those abroad.
[Electronics will be discussed at joint Electronics/Muon session.] [Sawicki to summarize chamber construction costs.]

o Assess by MC simulation the effect of material in the muon path. Bridge material for LSDTs, and side walls for CSCs.
[McNeil to summarize results.]

(II) LSDT:

o Update costs of chamber construction and electronics.
[Sawicki for chamber costs, Sumner for electronics during joint session.]

o Develop a layout of chambers in barrel region.
[Nimblett]

o Develop the integrated trigger concept.
[Shaevitz/Korytov during joint session.]

o Fully document muon resolution studies, including the effect of the angle of incidence.
[Korytov during TTR/Mitselmakher session.]
o Calculate chamber solid angle acceptance accounting for gaps associated with alignment paths.
[Osborne to document.]

o Decide whether carbon coating of cathodes is needed.
[Osborne.]

Added:
o Discuss alignment of wire in cathode.
[Osborne.]

(III) RPC:

o Build a 1 square meter chamber constructed of low resistivity plastic.
[Wuest and Pless.]

o Determine operation parameters (jitter, slewing, rate capability, neutron sensitivity).
[Wuest/Pless.]

(IV) CSC:

o Update costs of chamber construction and electronics.
[Sawicki for chamber costs. Electronics discussed in joint session.]

o Optimize channel count, especially for barrel application.
[Whitaker/Polychronakos.]

o Measure single layer resolution in RD5 and/or cosmics.
[Discussed during TTR/Mitselmakher session.]

o Develop conceptual design for T0 trigger.
[Discussed during joint session.]

o Perform stress analysis of chambers (endcaps with central rib and barrel). Will full-size chambers be planar?
[Polychronakos, et al.]

(V) PDT:

o Show layer resolution from TTR results.
[Bromberg/Miller and Dubna Group.]

o Discuss alignment of wire in cathodes.
[Bromberg.]

o Update operation parameters (LS-mode Vs Prop-mode).
[Bromberg.]

o Cost updates
[Bromberg/Sawicki]

Frank Taylor 11/6/92

Status of GEM Muon System

- Triggering and Tracking Technology:
  - o system performance
  - o complexity
  - o cost
  - o manufacturability

- Design of support structure:
  - o alignment to 25 μm and stable
  - o sector approach attractive for initial installation and alignment
  - o monolithic structure more stable
  - o coverage
  - o endcaps

Baseline 1 Resolutions

Cathode Strips:

Configuration (SL1:SL2:Sl3)	8:4:4 8:8:4 forward angles
Single layer resolution	75 μm RMS
Alignment (internal random)	50 μm RMS
Alignment (external SL-to-SL)	25 μm RMS

Drift:

Configuration (SL1:SL2:Sl3)	8:8:4
Single layer resolution	100 μm RMS
Alignment (internal random)	50 μm RMS
Alignment (external SL-to-SL)	25 μm RMS

- R&D Program for FY93:

  o Established 8 tasks with long-term focus

Some of the goals are:

  - perfect chamber design
  - establish prototype chamber factory
  - develop alignment of chambers
  - build prototype sector (s)
    - evaluate alignment scheme
    - study mechanical stability

- Organization and long-term planning

- TDR writing:

  o Muon Group concentrating on its problems and not writing

But:

  o Reports written on support structure and technologies are rough drafts for TDR chapters

Yuri Kiryushin

STATUS OF DUBNA CSC PROTOTYPE

PRESENTED BY Y. KIRYUSHIN

AT GEM MUON SUBSYSTEM MEETING

NOVEMBER 5 1992

JINR

BNL

PU

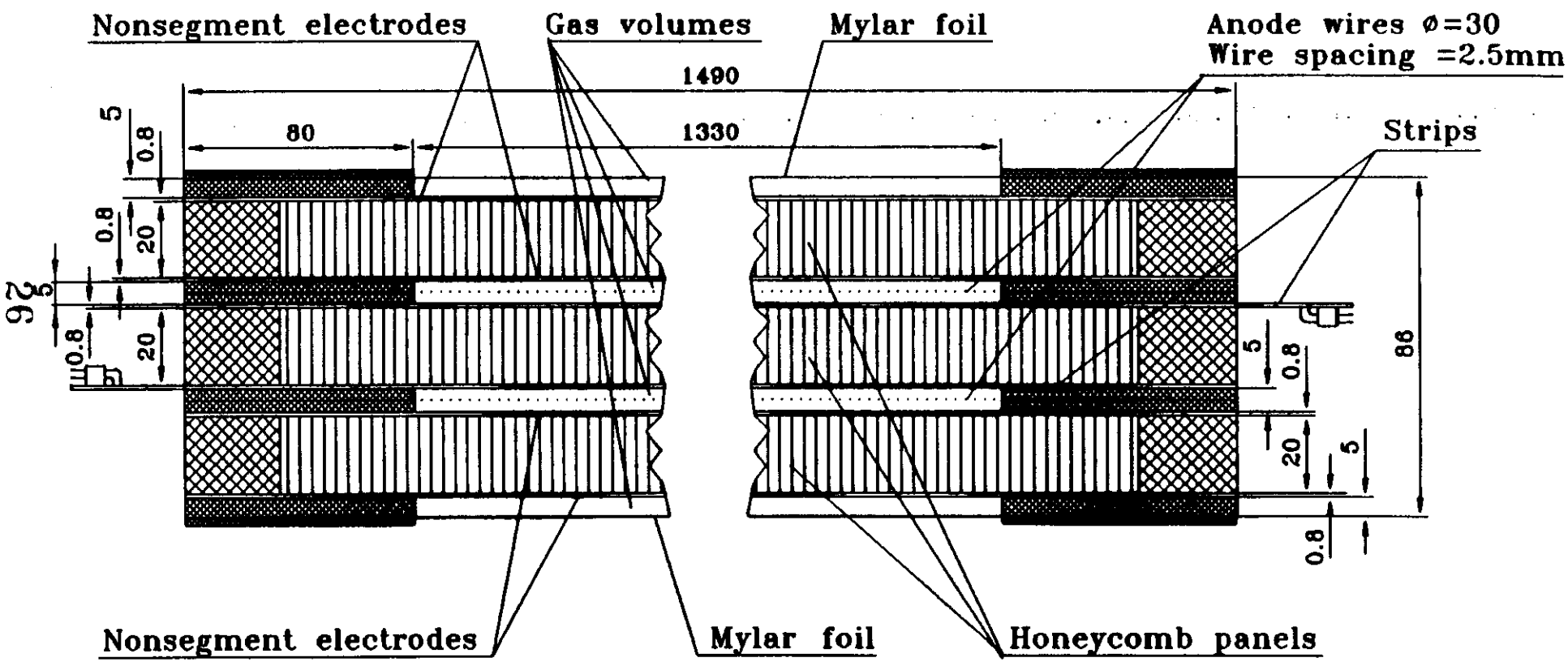
SSCL

ITEP

CSC PROTOTYPE DESIDN, CONSTRUCTION AND TEST SCHEDULE

- APRIL 92	DECISION TO DESIGN AND CONSTRUCT CSC PROTOTYPE AT DUBNA
- MAY 92	DESIGN HAS STARTED
- JULY 92	ELECTRONICS DESIGN COMPLETED
- JULY 92	CSC PROTOTYPE DESIGN COMPLETED
- SEPTEMBER 92	ELECTRONICS CONSTRUCTION COMPLETED
- 16 OCTOBER 92	CSC PROTOTYPE CONSTRUCTION COMPLETED
- 20 OCTOBER 92	CSC PROTOTYPE (1m x 1.5m) ARRIVED AT SSCL
- OCTOBER/ NOVEMBER 92	CSC PROTOTYPE TEST AT TTR

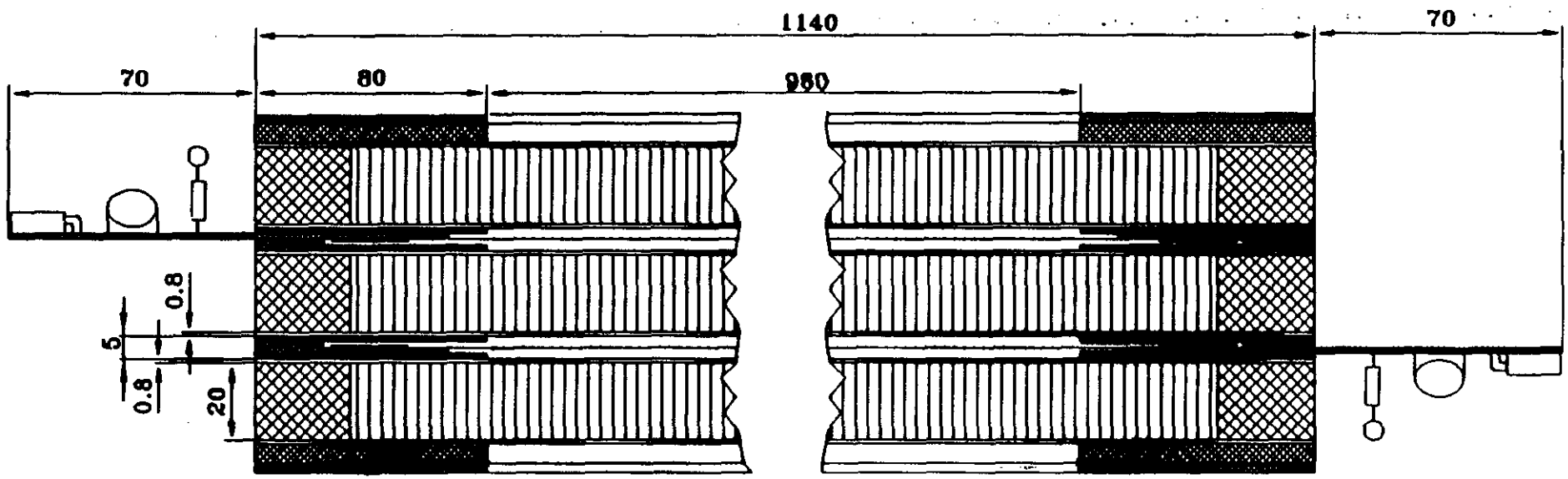
DUBNA CSC PROTOTYPE



Cross-section of MWPC perpendicular to the wires

(All dimensions in mm)

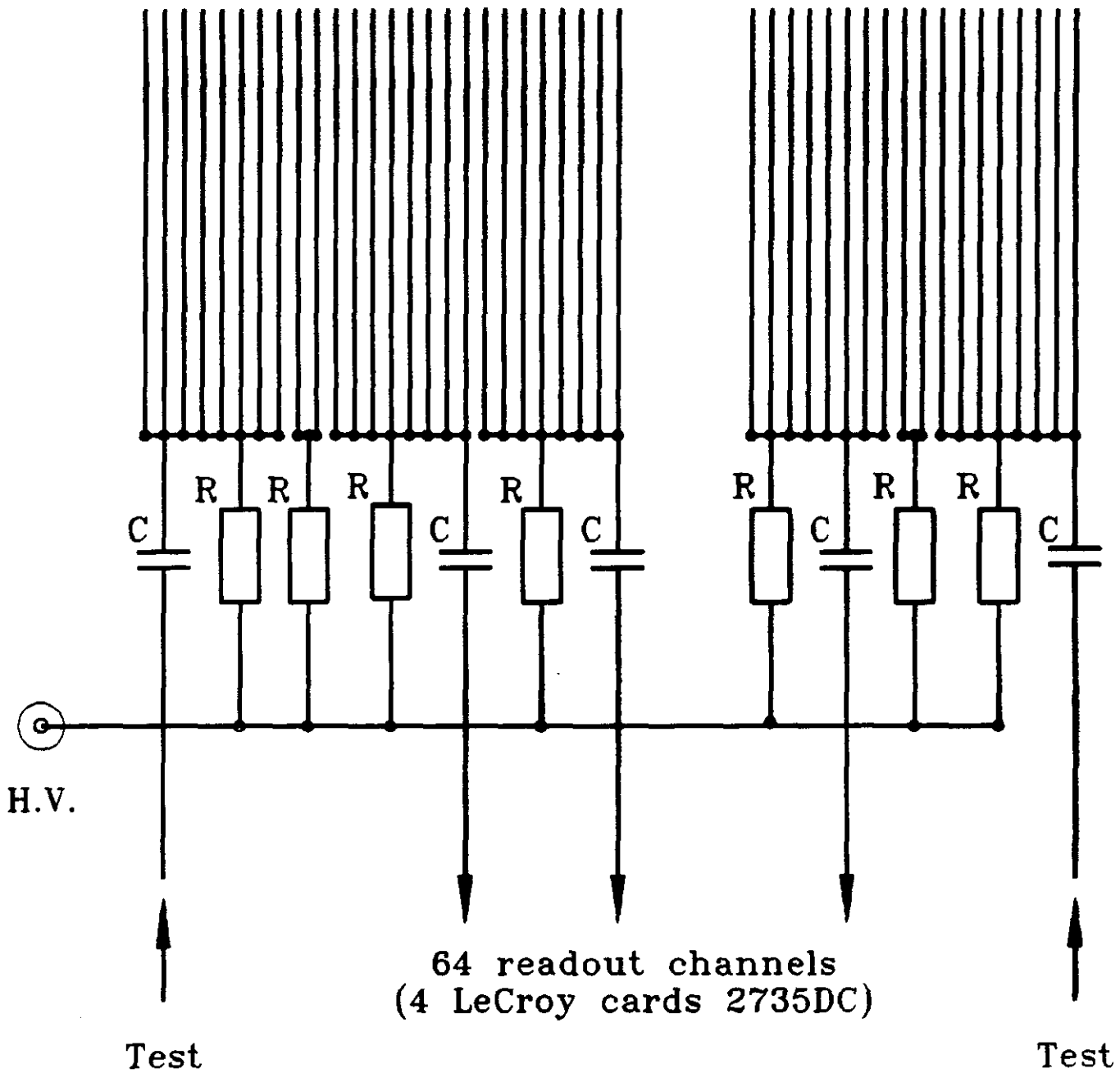
DUBNA CSC PROTOTYPE



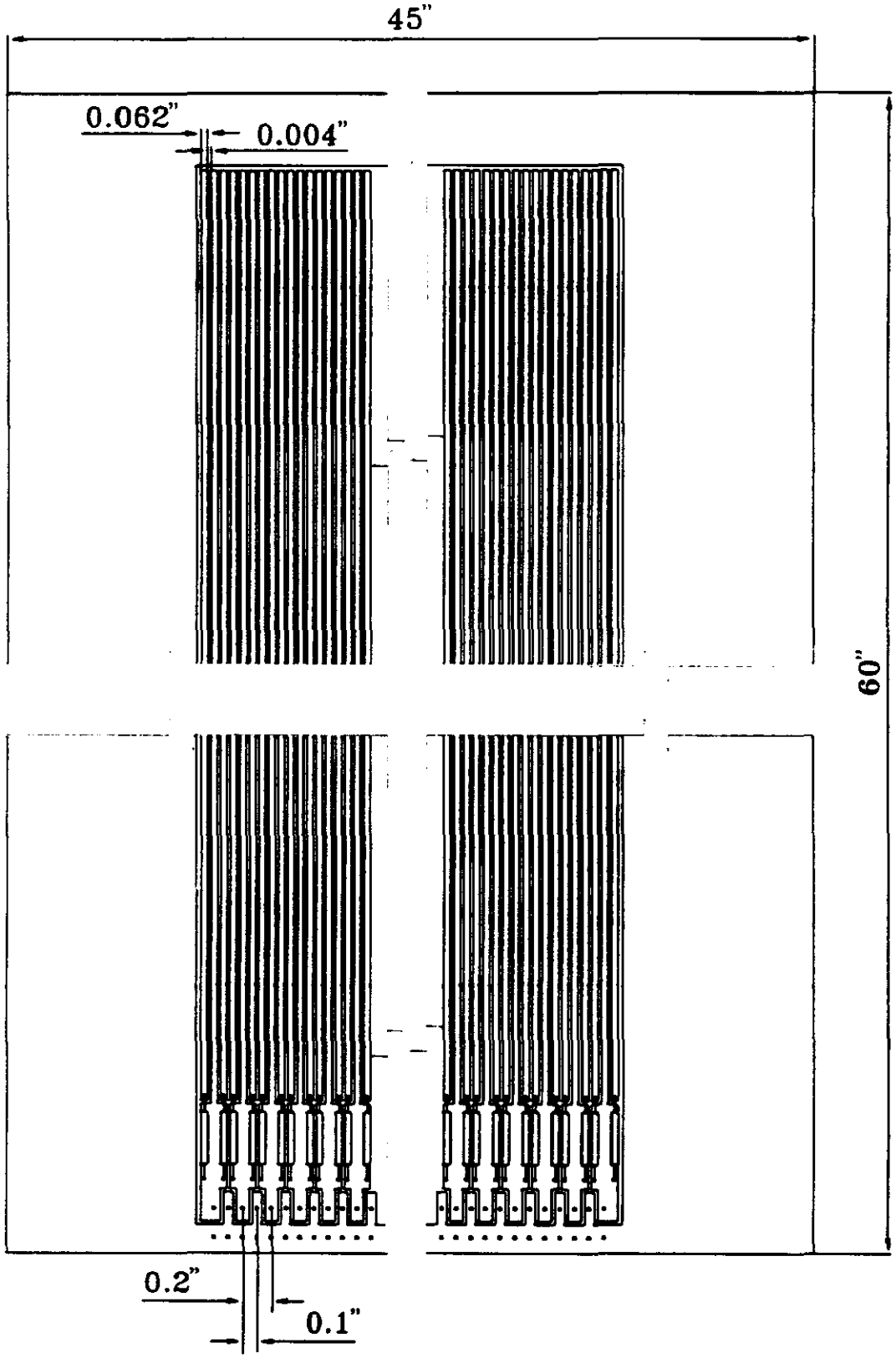
Cross-section of MWPC perpendicular to the strips

(All dimension in mm)

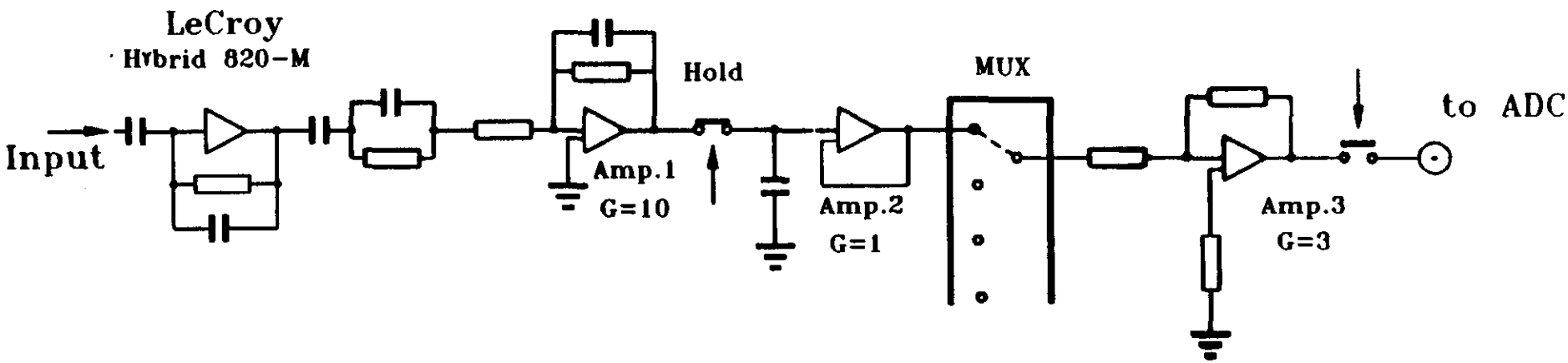
WIRE PLANE


R
R
R
R
R
R
R
C
C
C
C
C
H.V.
64 readout channels
(4 LeCroy cards 2735DC)
Test
Test

STRIP CATHODE



STRIP READOUT ELECTRONICS

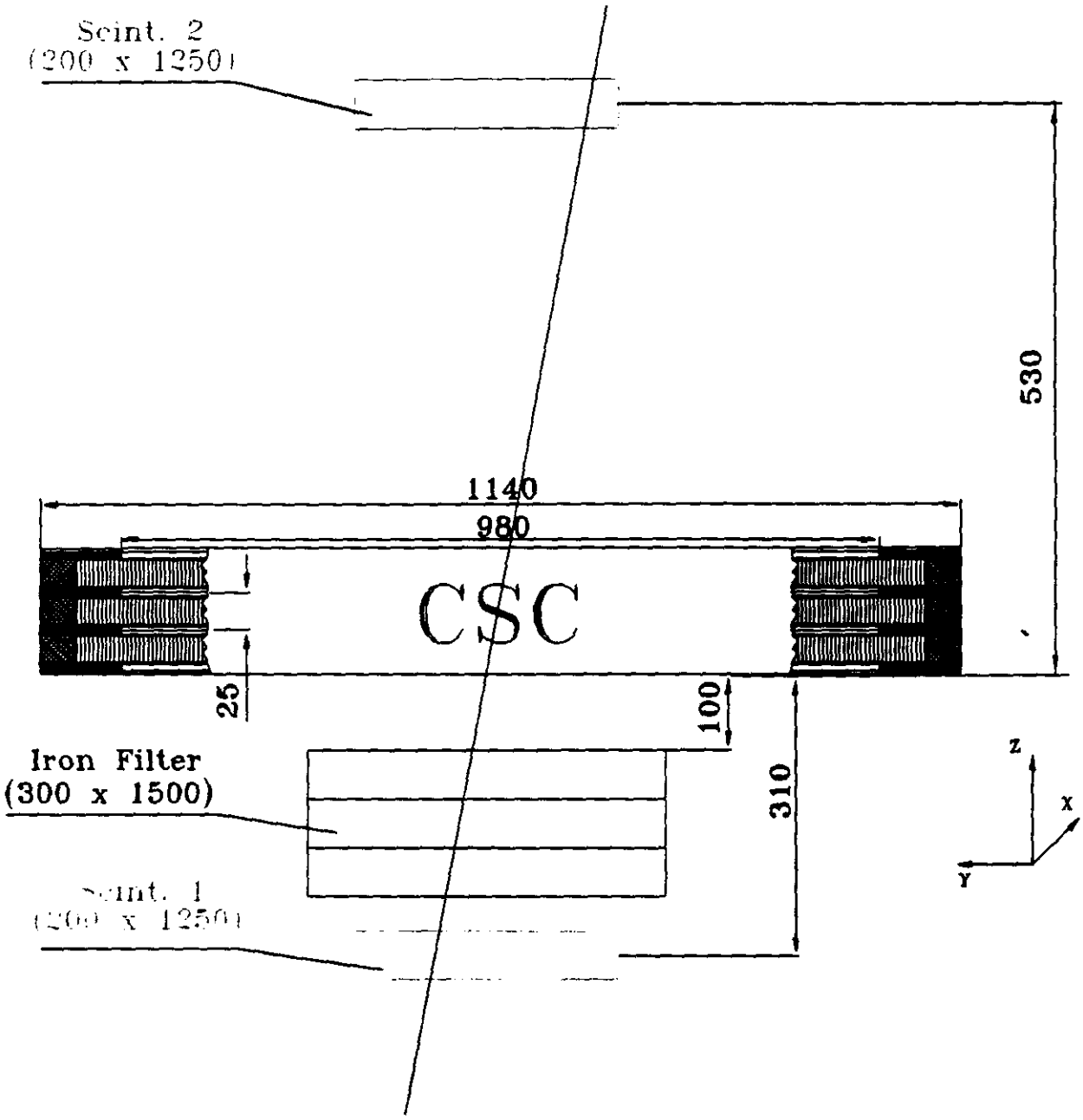


Noise – ENC 2500± 500 r.m.s. electrons for 100 pF

Peaking time – 2 μs

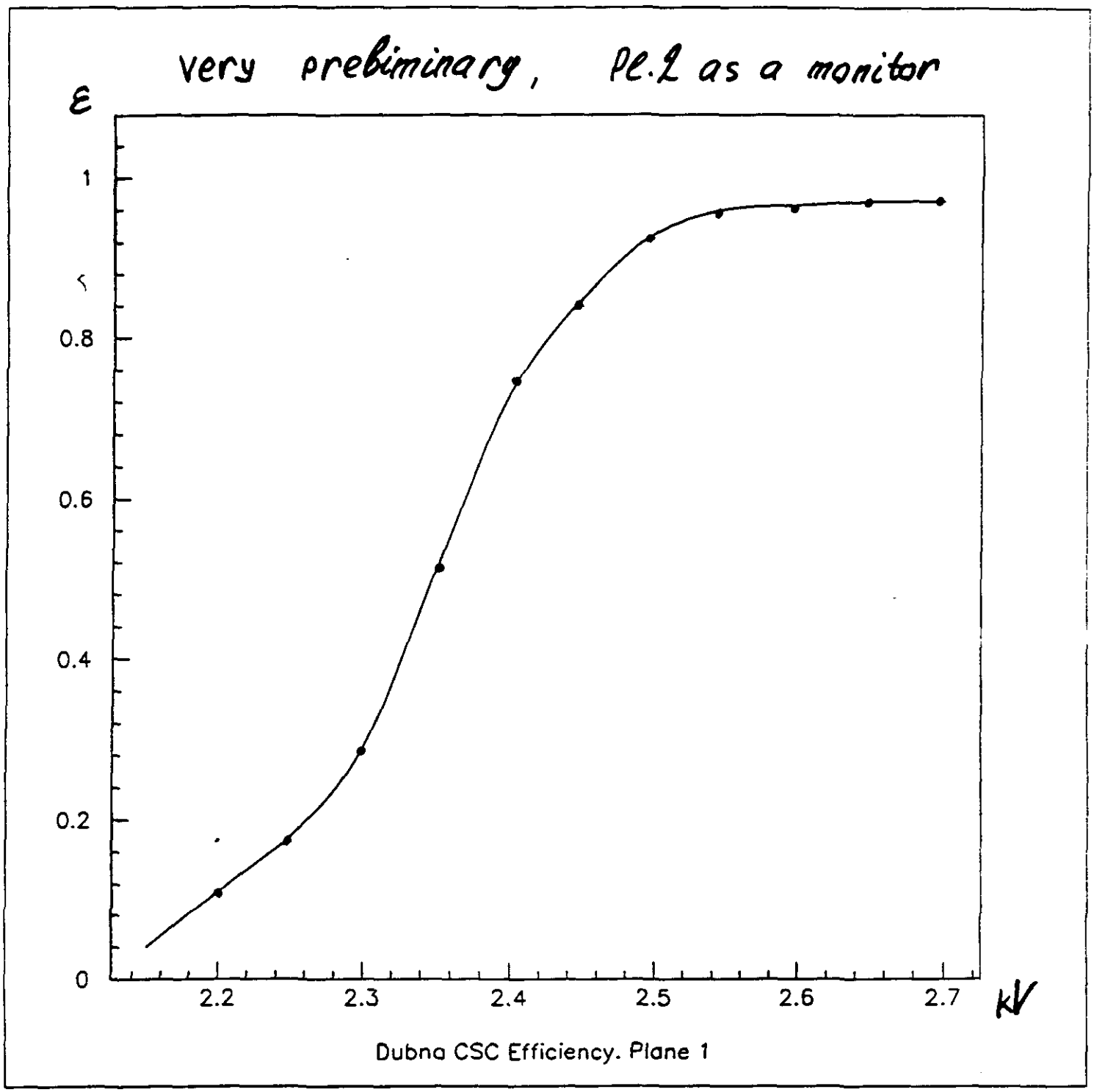
Readout time ~ 1.5 μs/channel

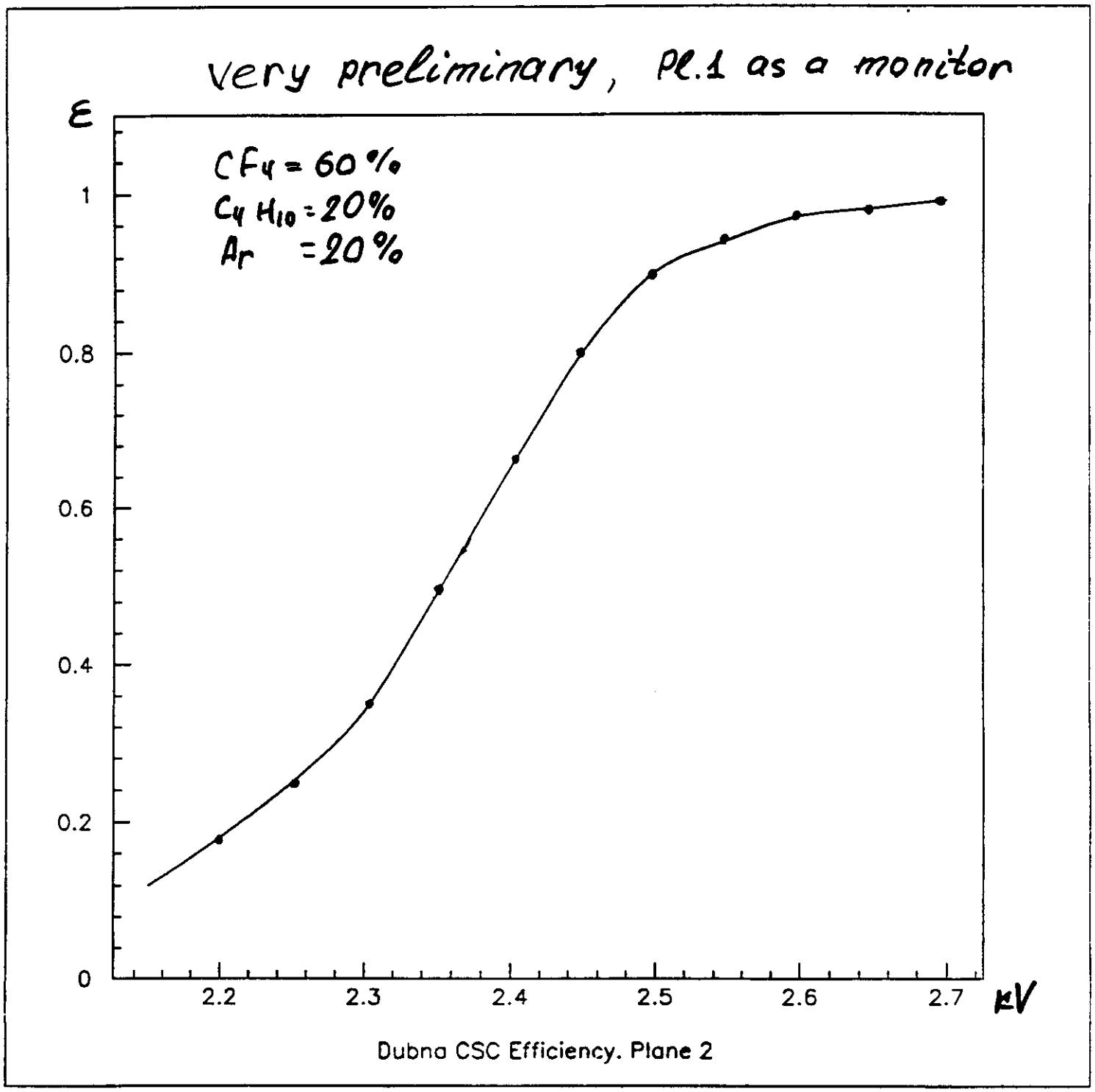
TEST SETUP 1

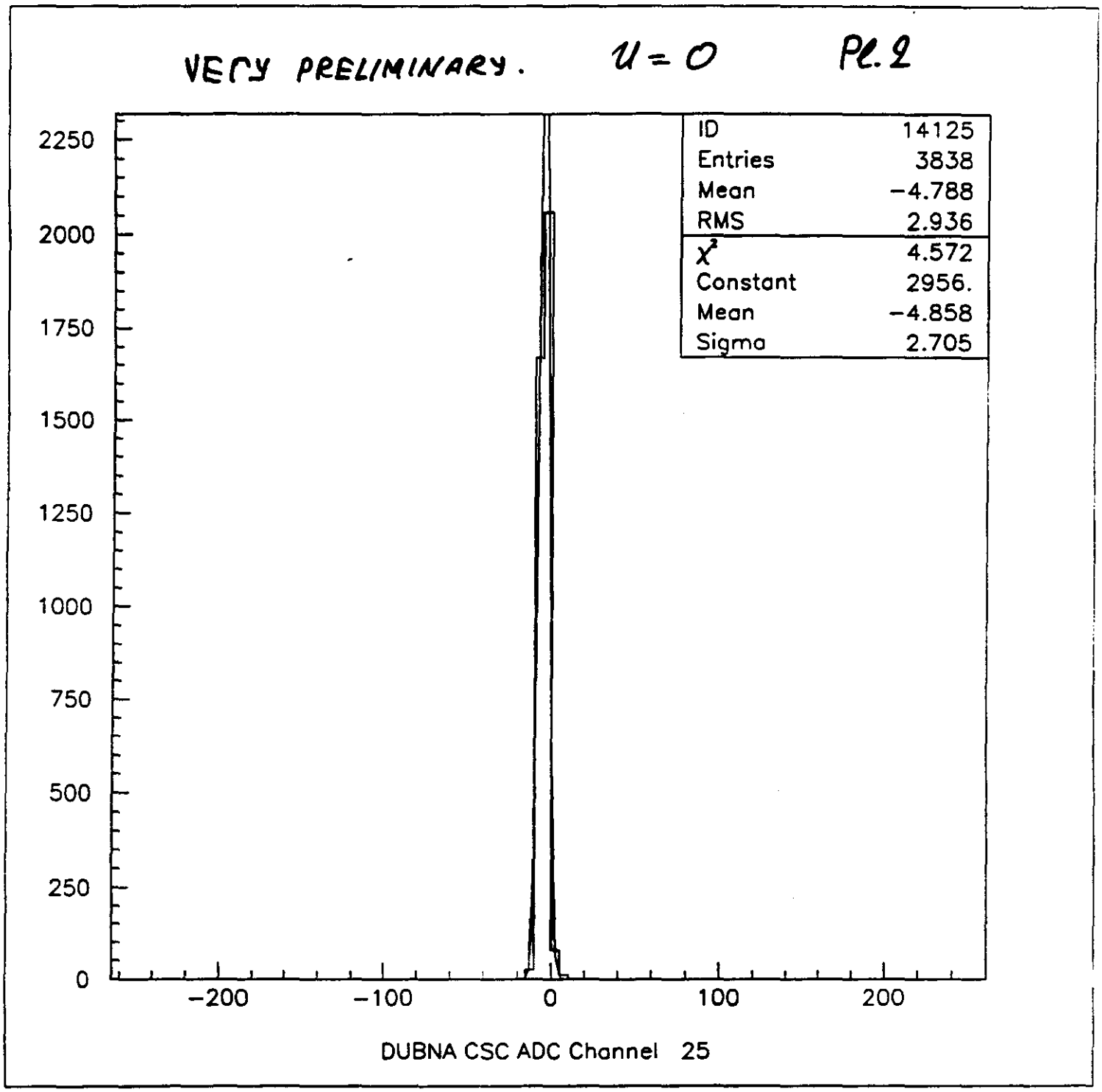


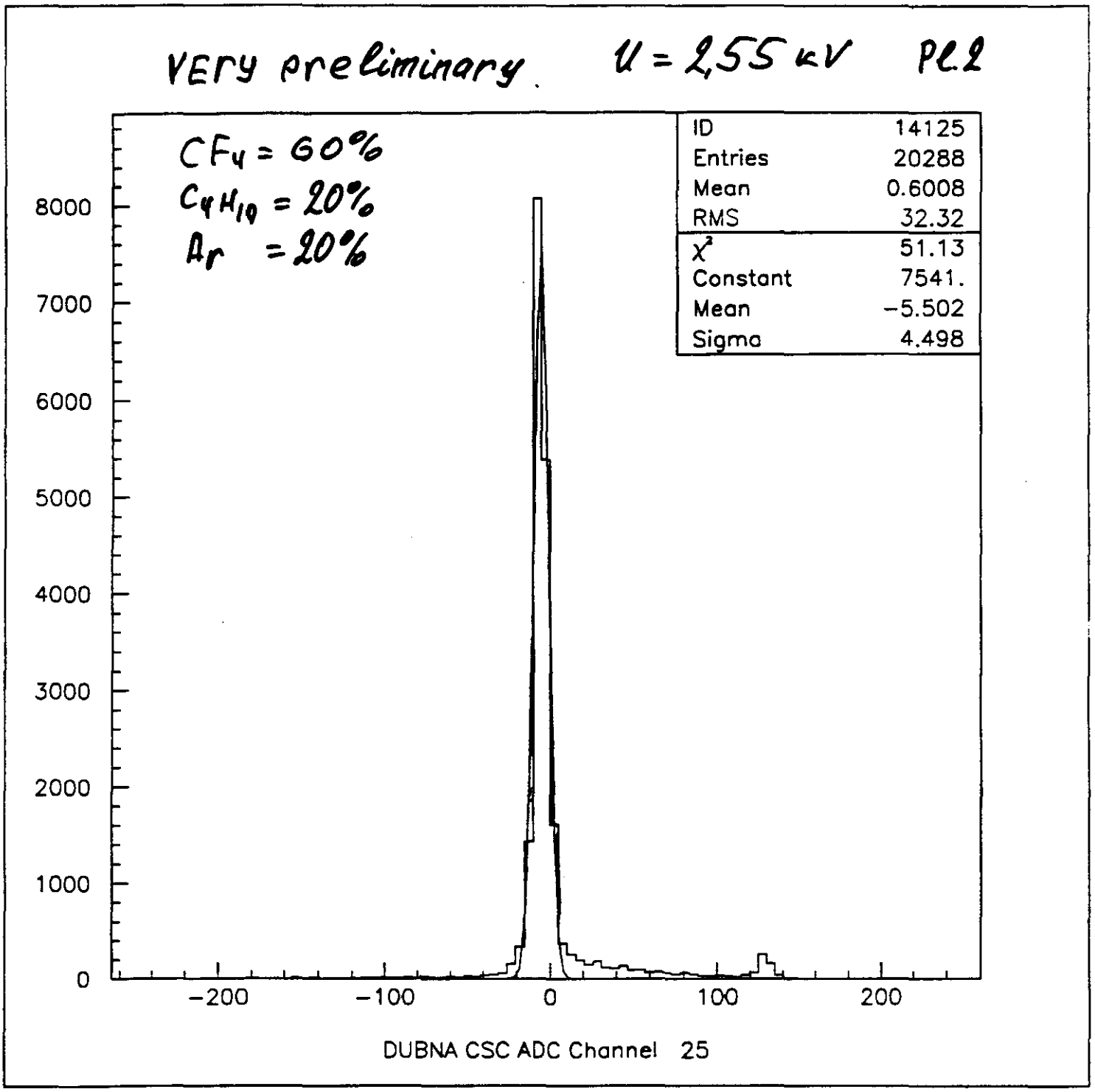
(All dimensions in mm)

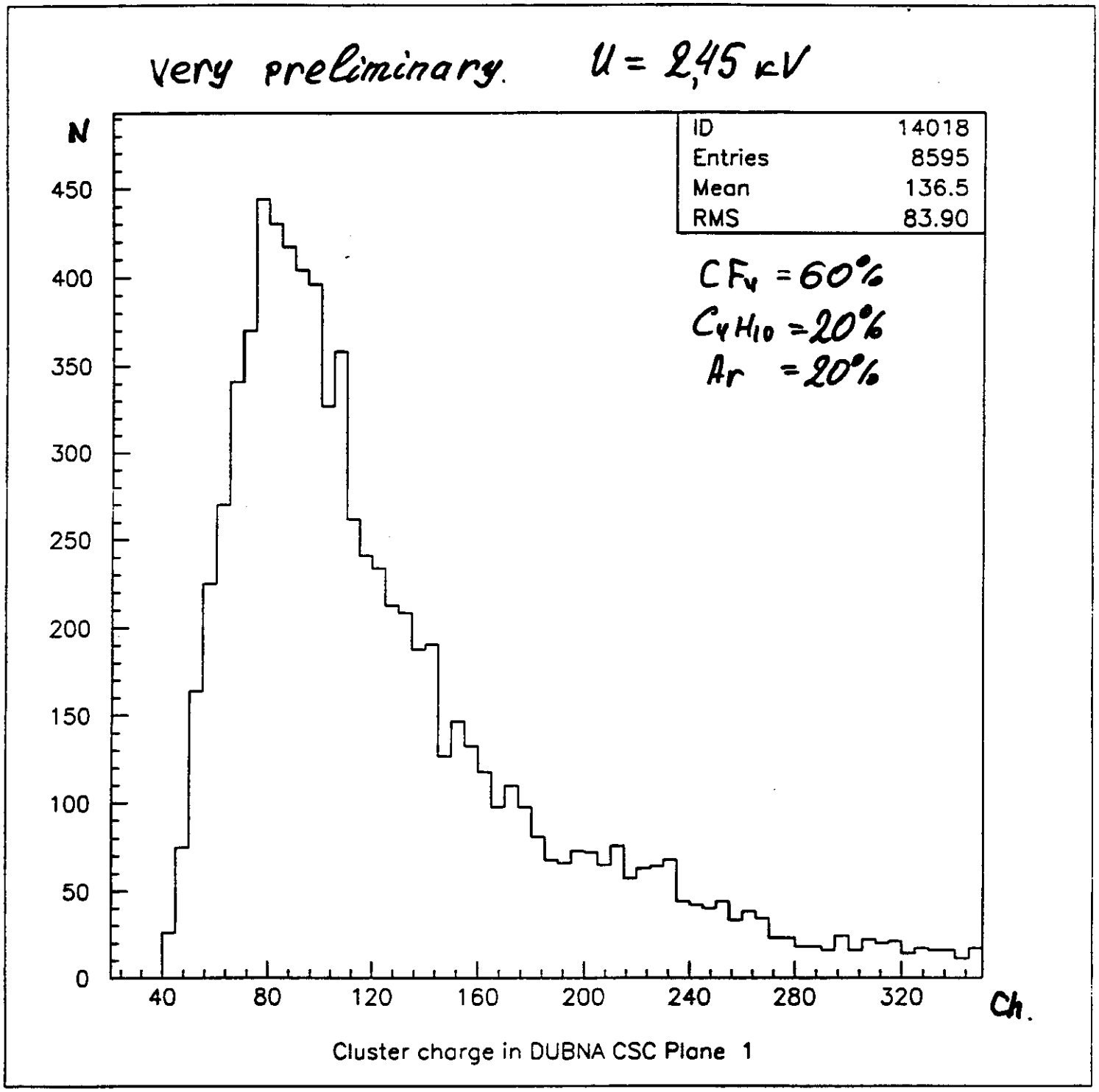
$CF_4 = 60\%$; Isob. = 20% ; Ar = 20%

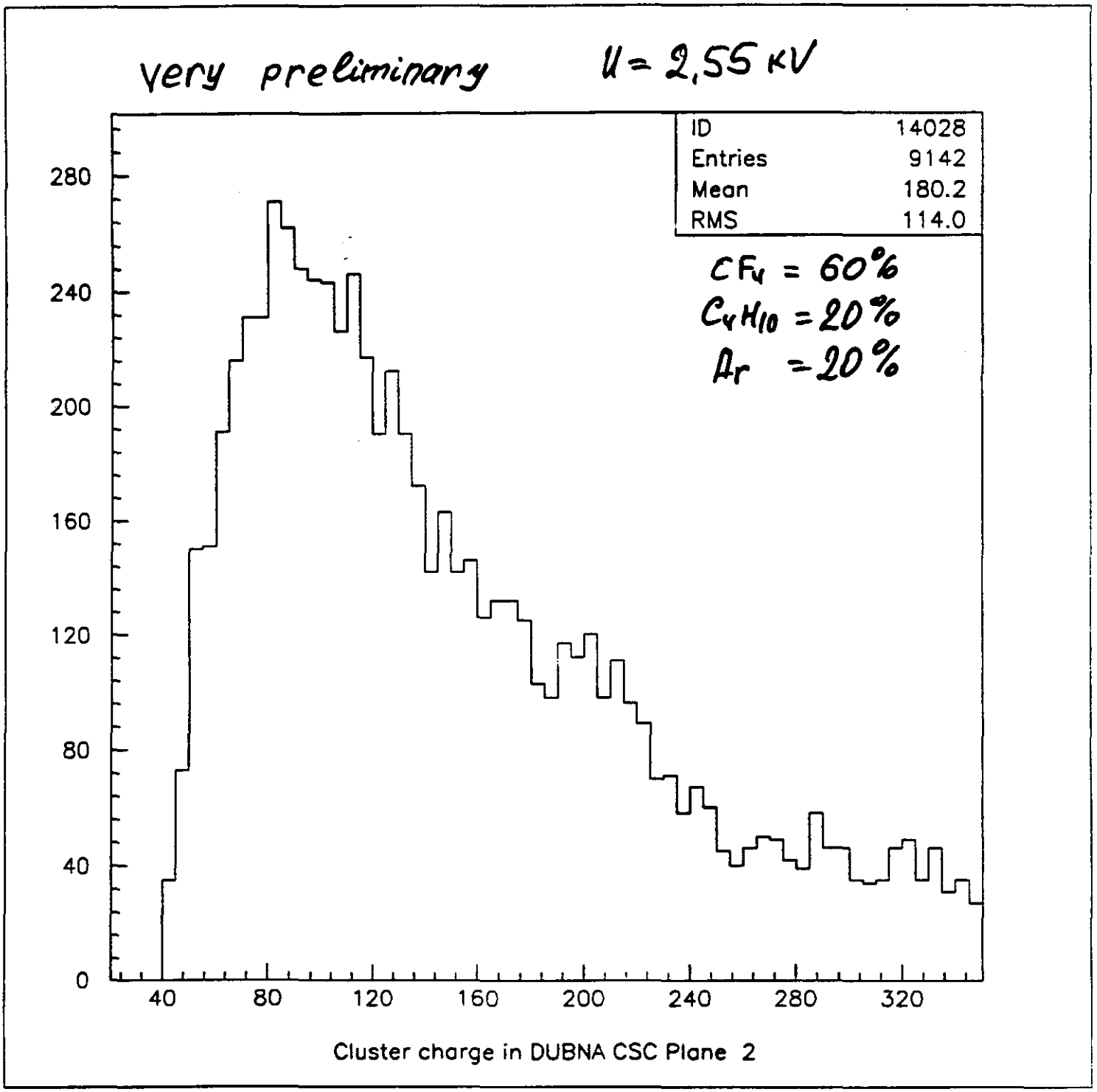


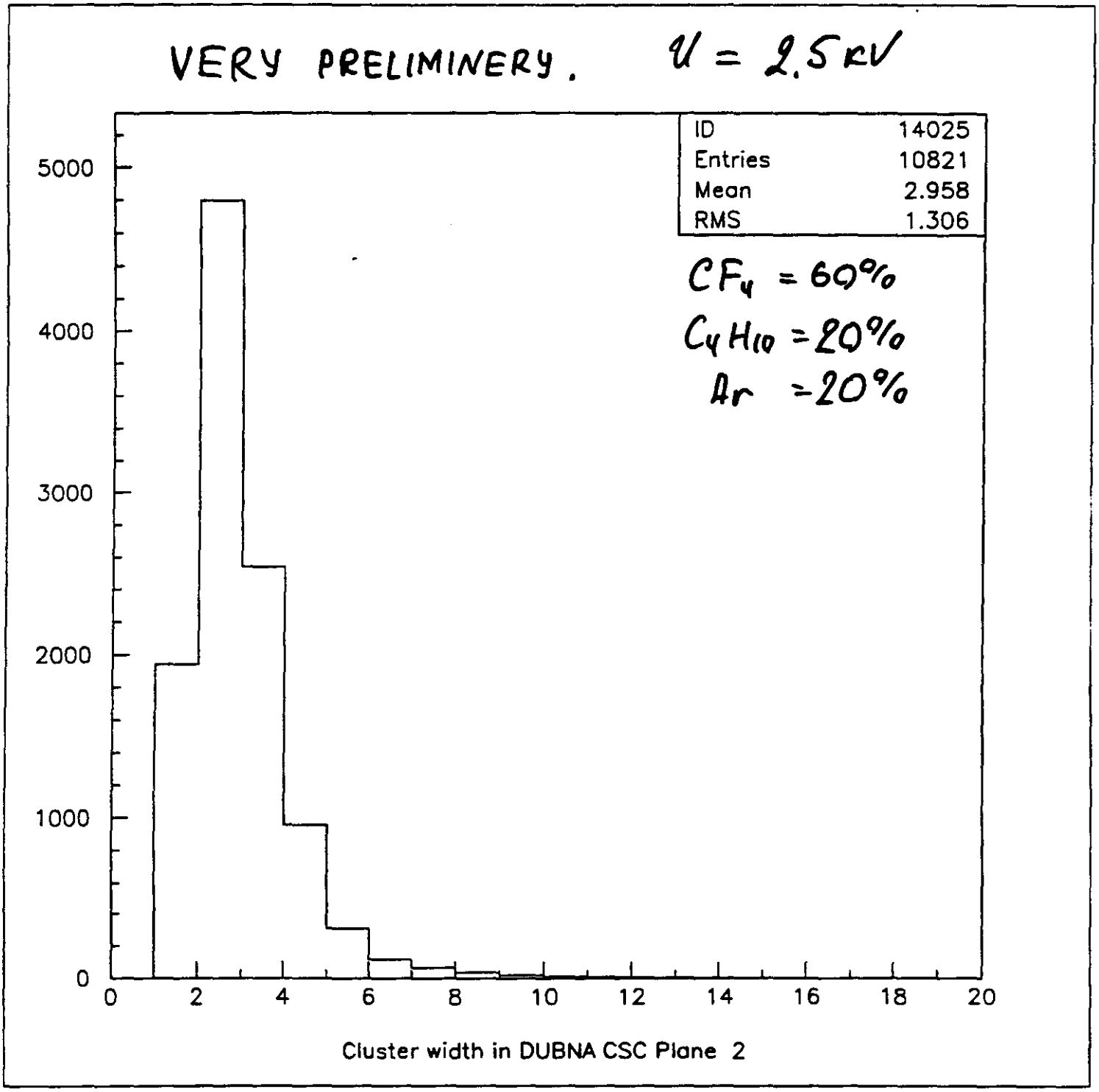

very preliminary, Pl.1 as a monitor
ε
CF4 = 60 %
C4 H10 = 20%
Ar = 20 %
1
0.8
0.6
0.4
0.2
0
2.2
2.3
2.4
2.5
2.6
2.7
kV
Dubna CSC Efficiency. Plane 2


VERY PRELIMINARY.
U = 0
Pl. 2
ID 14125
Entries 3838
Mean −4.788
RMS 2.936
χ² 4.572
Constant 2956.
Mean −4.858
Sigma 2.705
2250
2000
1750
1500
1250
1000
750
500
250
0
−200
−100
0
100
200
DUBNA CSC ADC Channel 25

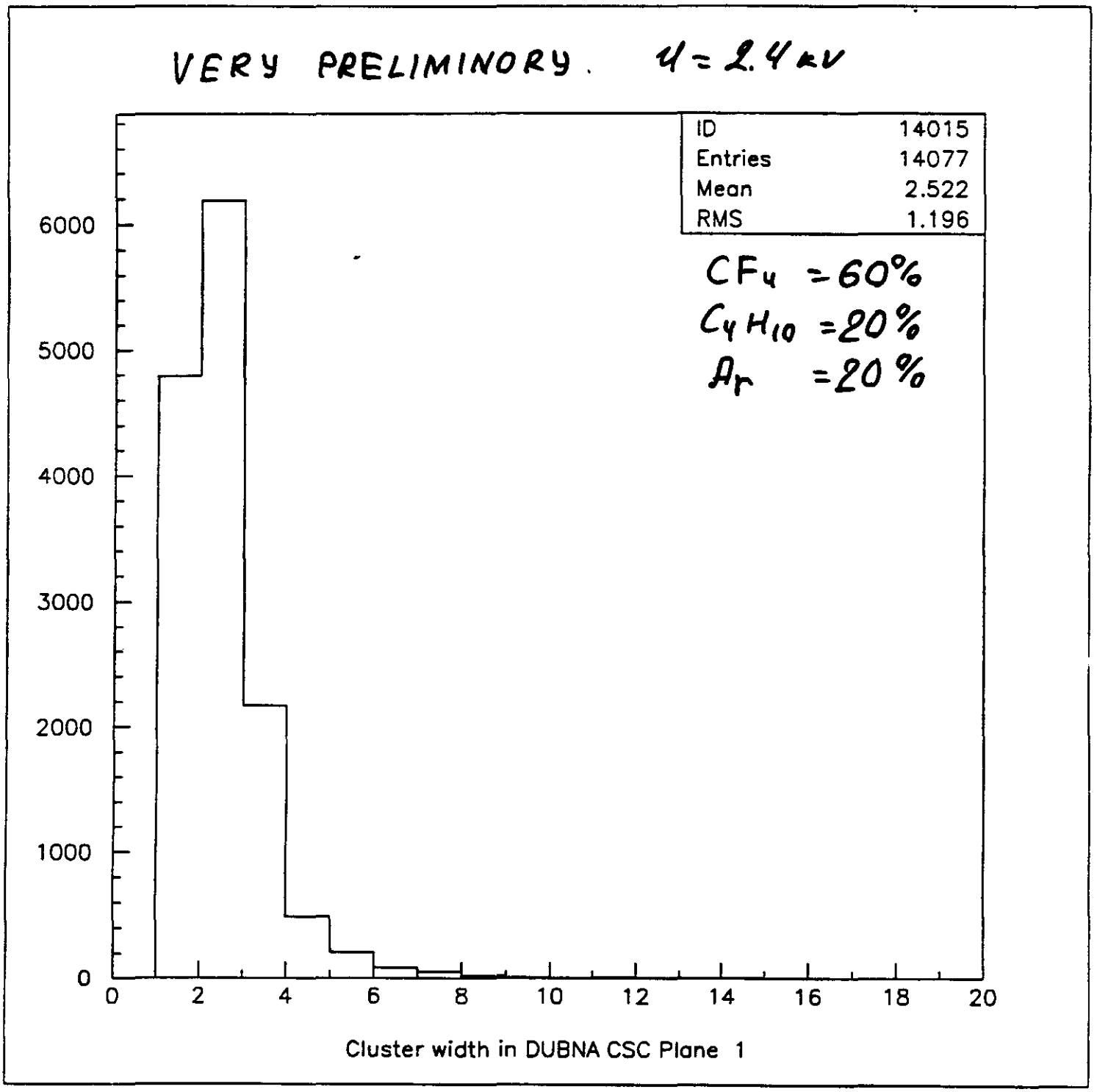

very preliminary
U = 2,55 kV
Pl.2
CF4 = 60%
C4H10 = 20%
Ar = 20%
ID 14125
Entries 20288
Mean 0.6008
RMS 32.32
χ² 51.13
Constant 7541.
Mean −5.502
Sigma 4.498
8000
7000
6000
5000
4000
3000
2000
1000
0
−200
−100
0
100
200
DUBNA CSC ADC Channel 25

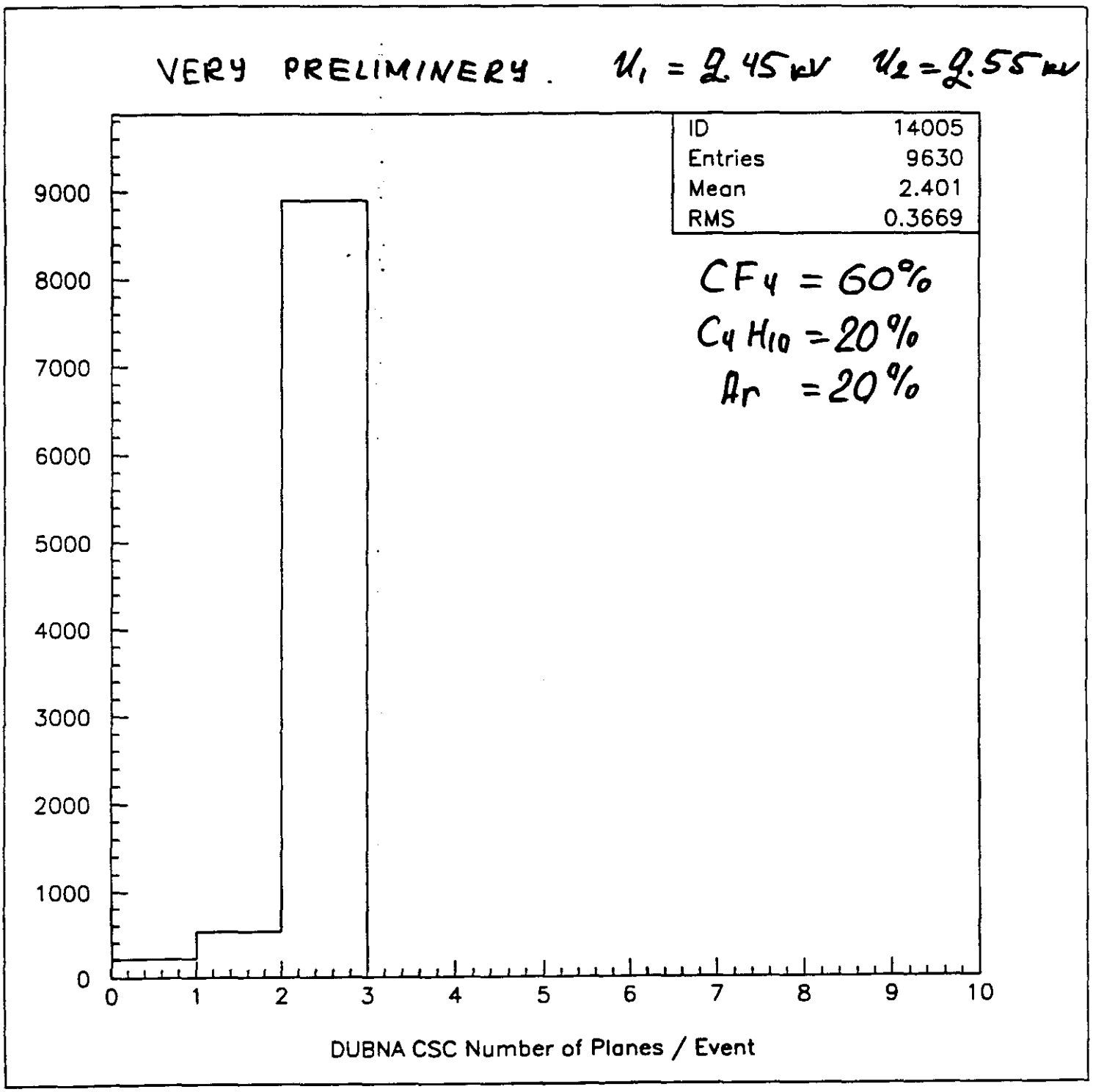

very preliminary. U = 2,45 kV
N
ID 14018
Entries 8595
Mean 136.5
RMS 83.90
CF4 = 60%
C4H10 = 20%
Ar = 20%
450
400
350
300
250
200
150
100
50
0
40
80
120
160
200
240
280
320
Ch.
Cluster charge in DUBNA CSC Plane 1


very preliminary
U = 2,55 kV
ID 14028
Entries 9142
Mean 180.2
RMS 114.0
CF4 = 60%
C4H10 = 20%
Ar = 20%
280
240
200
160
120
80
40
0
40
80
120
160
200
240
280
320
Cluster charge in DUBNA CSC Plane 2


VERY PRELIMINERY.
U = 2.5 kV
ID 14025
Entries 10821
Mean 2.958
RMS 1.306
CF4 = 60%
C4H10 = 20%
Ar = 20%
5000
4000
3000
2000
1000
0
0
2
4
6
8
10
12
14
16
18
20
Cluster width in DUBNA CSC Plane 2

37


VERY PRELIMINORY. U = 2.4 kV
ID 14015
Entries 14077
Mean 2.522
RMS 1.196
CF4 = 60%
C4H10 = 20%
Ar = 20%
6000
5000
4000
3000
2000
1000
0
0
2
4
6
8
10
12
14
16
18
20
Cluster width in DUBNA CSC Plane 1


VERY PRELIMINERY. $U_1 = 2.45$ kV $U_2 = 2.55$ kV
ID 14005
Entries 9630
Mean 2.401
RMS 0.3669
$CF_4 = 60\%$
$C_4H_{10} = 20\%$
$Ar = 20\%$
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0 1 2 3 4 5 6 7 8 9 10
DUBNA CSC Number of Planes / Event

Conclusions:

1. CSC prototype arrived from Dubna in a good condition, wires and electronics are O'K

2. We need to complete the electronics by LeCroy hybrids HQV 820-M, by TDC for wire readout and test the chamber in TTR. The accuracy of track localisation over the whole area is still to be demonstrated.

Serge Movchan

STATUS OF DUBNA PDT PROTOTYPE

PRESENTED BY S. MOVCHAN

AT GEM MUON GROUP MEETING (BNL)

NOVEMBER 4 - 6 1992

JINR /DUBNA/

ITEP /MOSCOW/

SSCL /DALLAS/

- INTRODUCTION
- TECNOLOGY CONCEPT
- 1 x 4 m PROTOTYPE
- RESULTS OF TTR TEST

  prop. mode

  streamer mode
- SUMMARY

PDT PROTOTYPE DESIGN, CONSTRUCTION AND TEST SCHEDULE

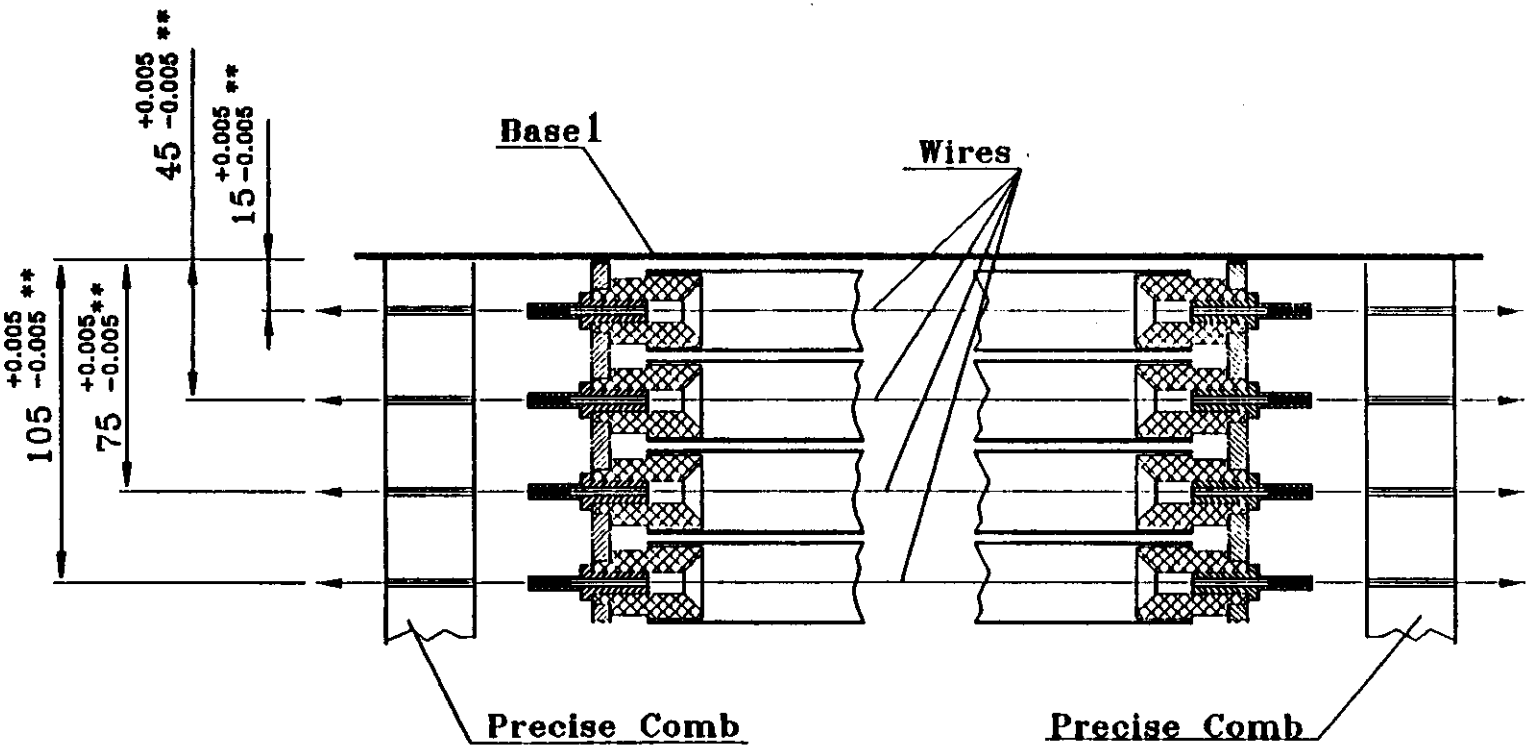
- JANUARY 92	DECISION TO DESIGN AND CONSTRUCT PDT PROTOTYPE AT DUBNA
- FEBRUARY 92	DESIGN HAS STARTED
- APRIL 92	"SMALL" PROTOTYPE CONSTRUCTED AND TESTED AT ITEP BEAM
- MAY 92	ELECTRONICS (PREAMP'S AND DISCRI'S) DESIGN COMPLETED
- JUNE 92	4m PROTOTYPE CONSTRUCTION COMPLETED
- JULY 92	4m PROTOPYPE FULLY INSTRUMENTED WITH ELECTRONICS
- 26 JULY 92	1m x 4m (2 x 0.5 x 4.0m) PROTOTYPE ARRIVED AT SSCL
- AUGUST 92	1m PROTOTYPE CONSTRUCTED
- SEPTEMBER 92	1m PROTOTYPE TESTED AT CERN MUON BEAM
-SEPTEMBER/ OCTOBER 92	4m PROTOTYPE TEST AT TTR (SSCL)

er/ki

TECNOLOGY CONCEPT

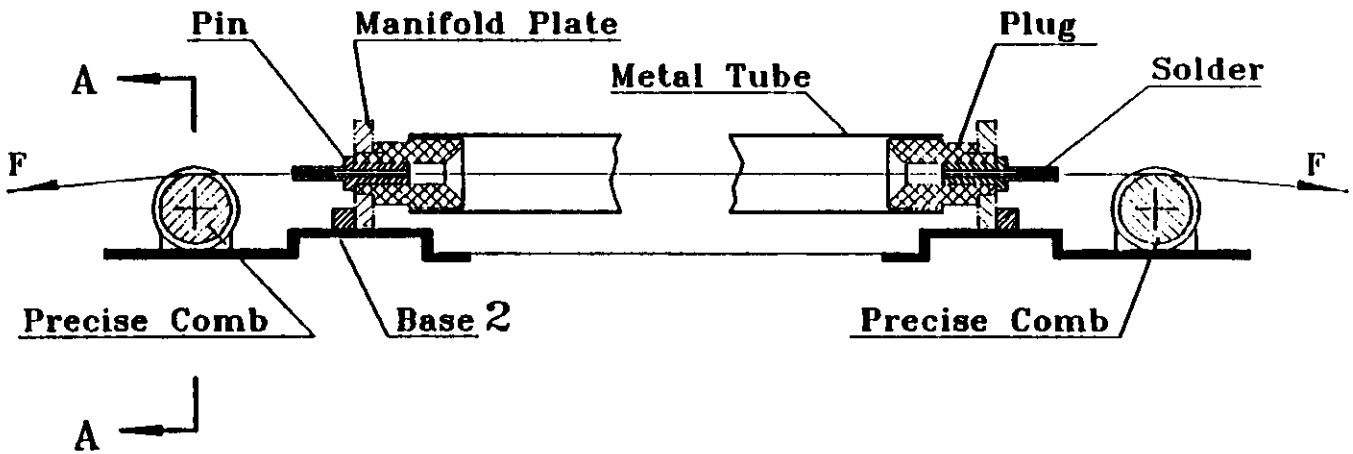
DUBNA PDT TECNOLOGY CONCEPT

(1)

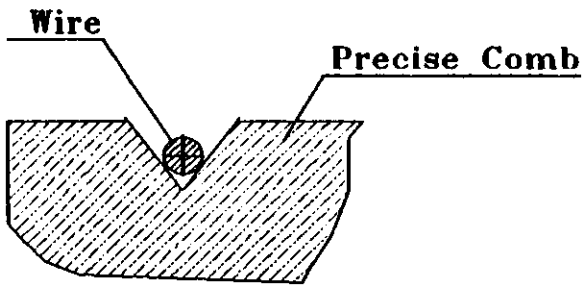


**–tolerances on grooves position

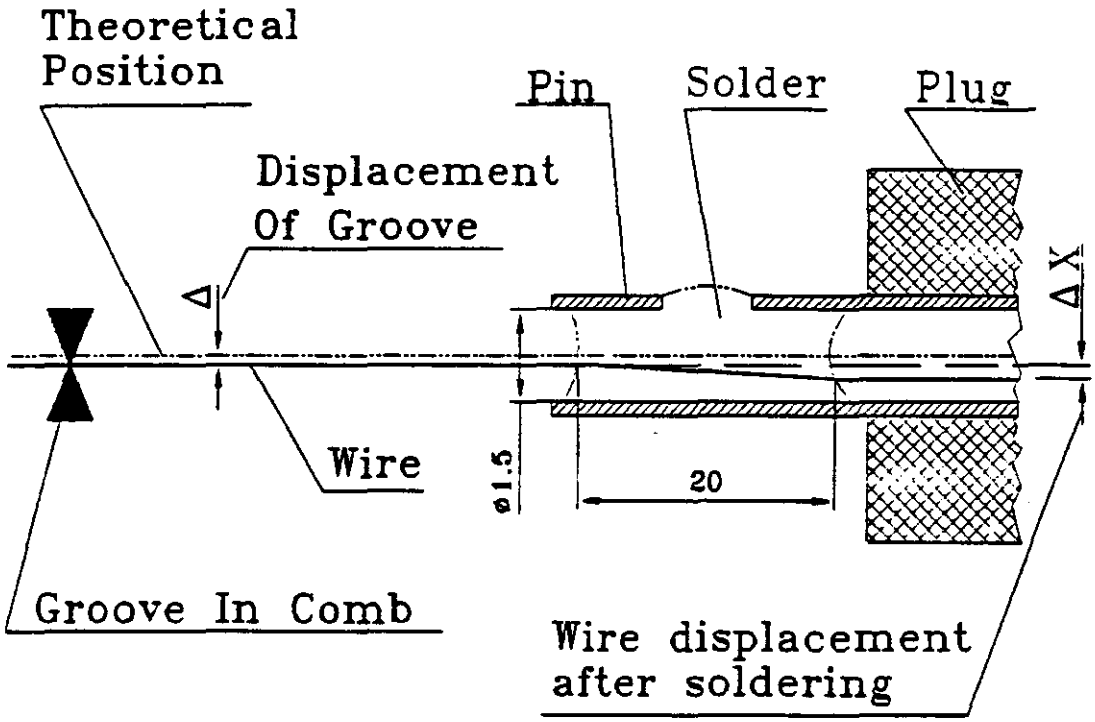
DUBNA PDT TECNOLOGY CONCEPT
(2)

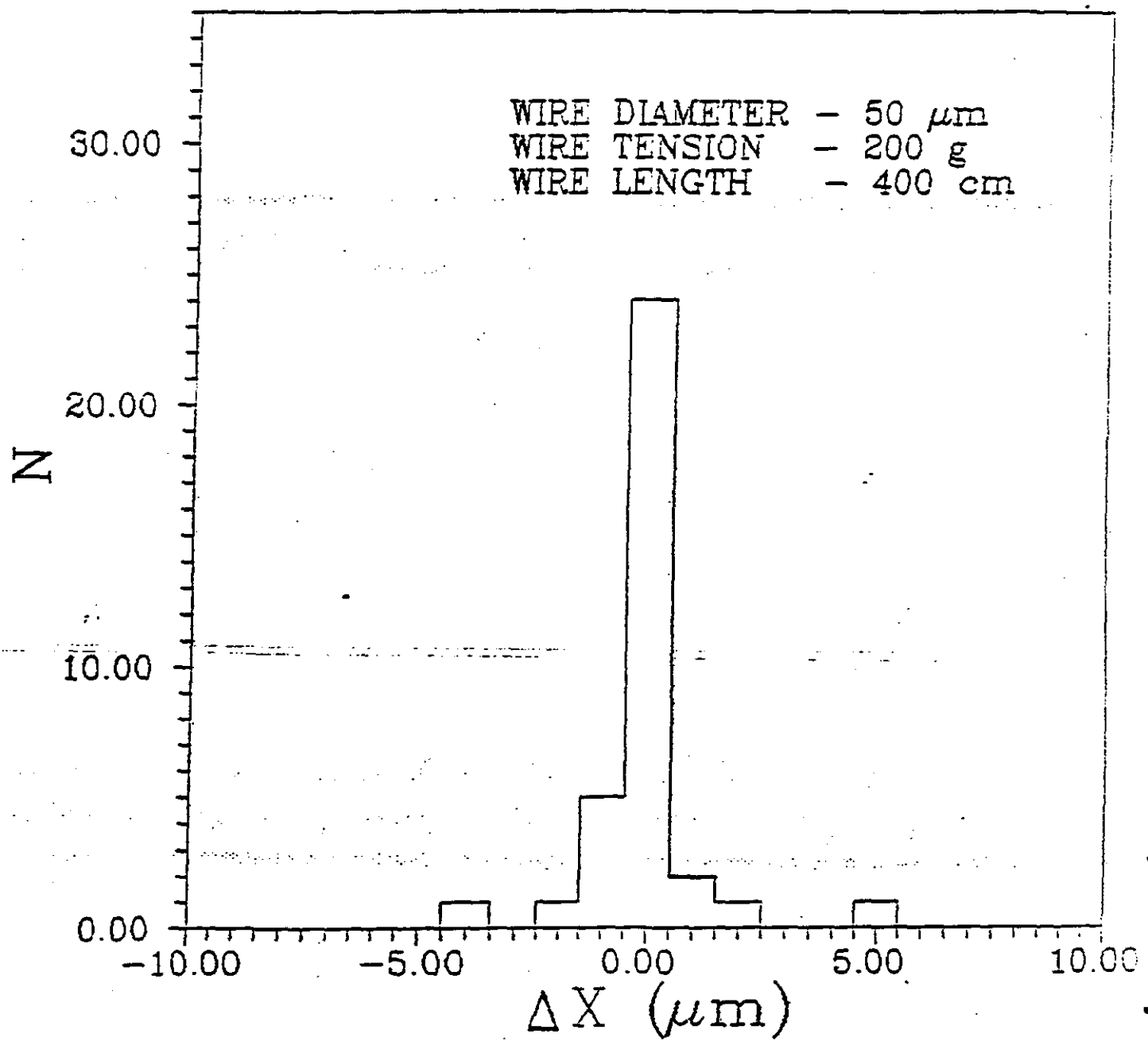


A–A

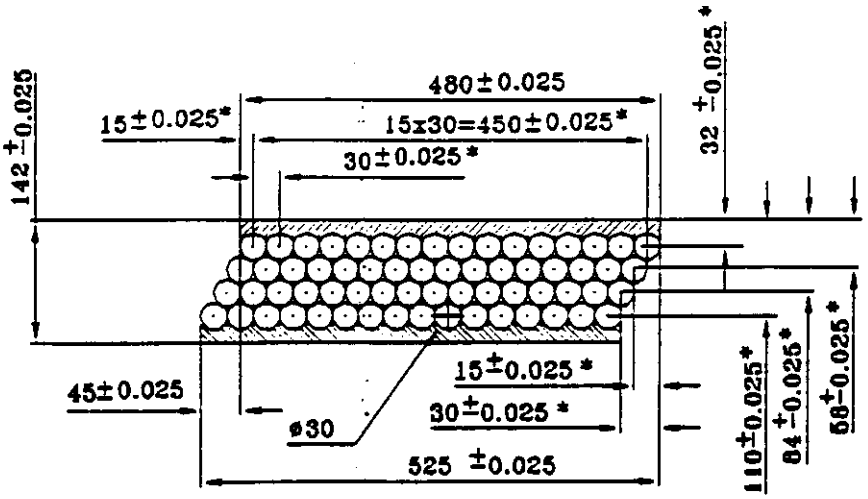


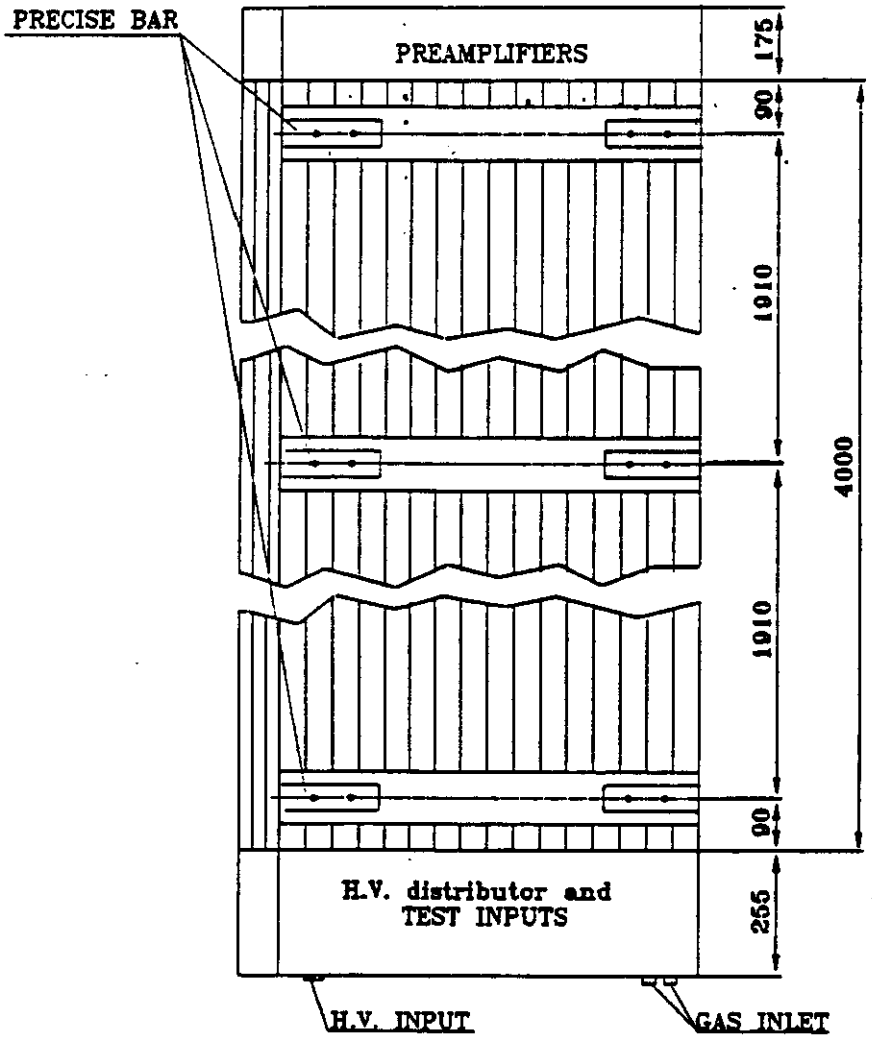
95/43


Theoretical Position
Pin
Solder
Plug
Displacement Of Groove
Δ
ΔX
Wire
ø1.5
20
Groove In Comb
Wire displacement after soldering

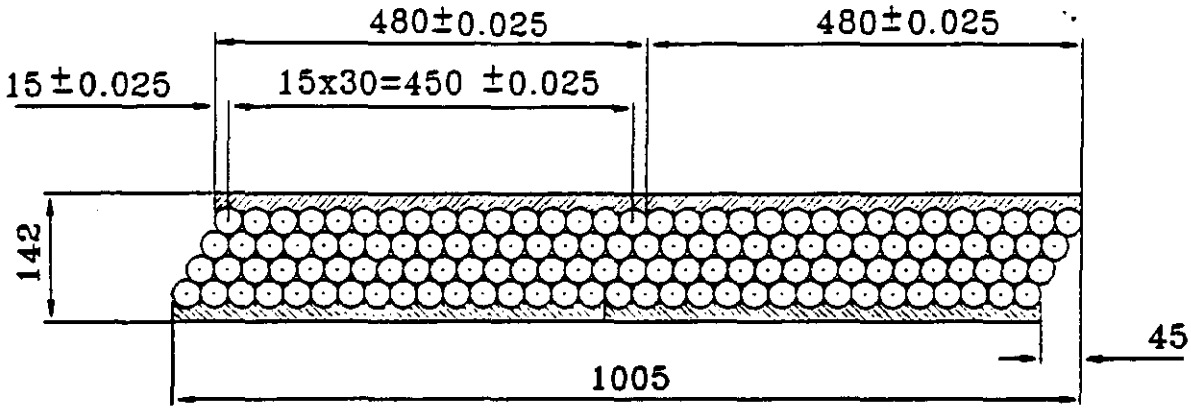

WIRE DIAMETER - 50 μm
WIRE TENSION - 200 g
WIRE LENGTH - 400 cm
30.00
20.00
10.00
0.00
N
-10.00
-5.00
0.00
5.00
10.00
ΔX (μm)

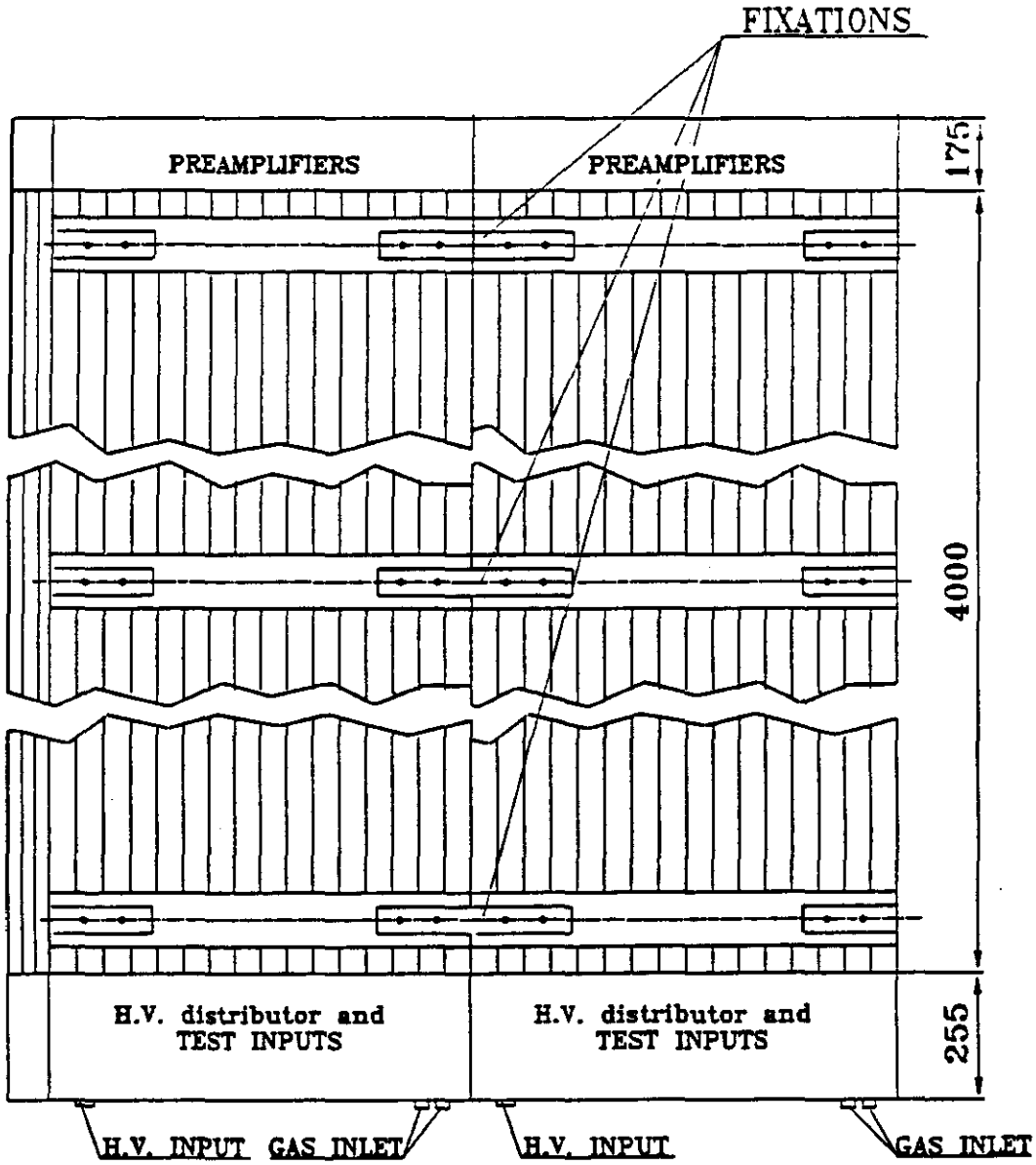
PROTOTYPE





* –tolerances on wires position

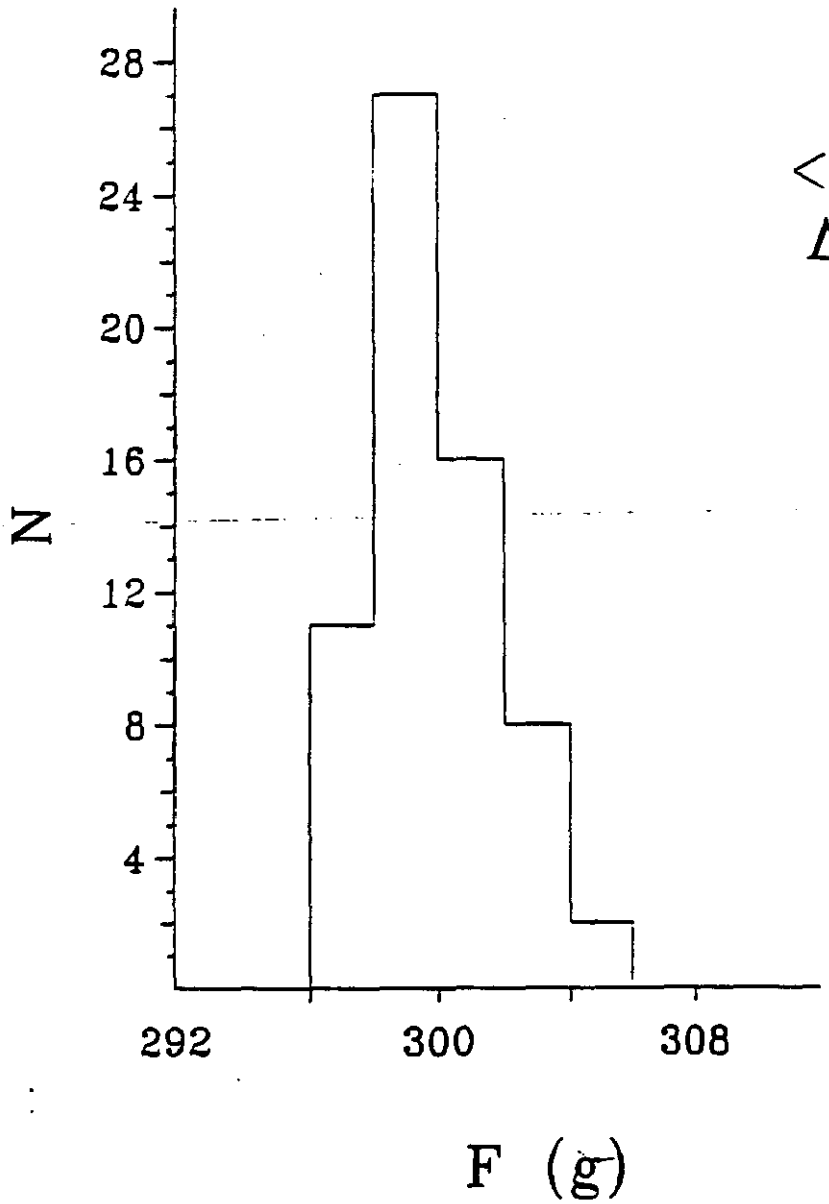

480±0.025
480±0.025
15±0.025
15x30=450 ±0.025
142
45
1005


FIXATIONS
PREAMPLIFIERS
PREAMPLIFIERS
175
4000
255
H.V. distributor and
TEST INPUTS
H.V. distributor and
TEST INPUTS
H.V. INPUT
GAS INLET
H.V. INPUT
GAS INLET

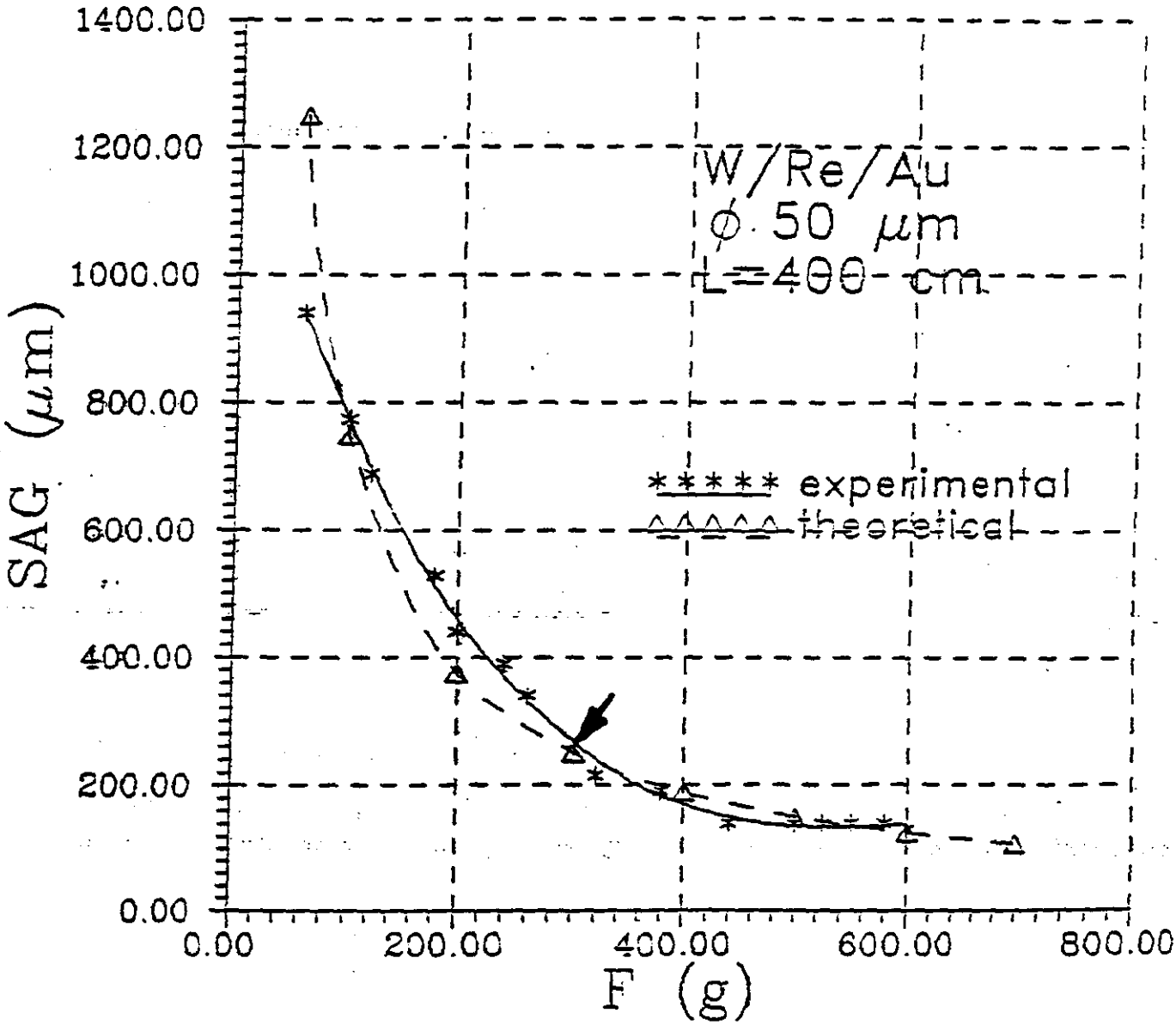
Es/5:

DUBNA PDT PROTOTYPE

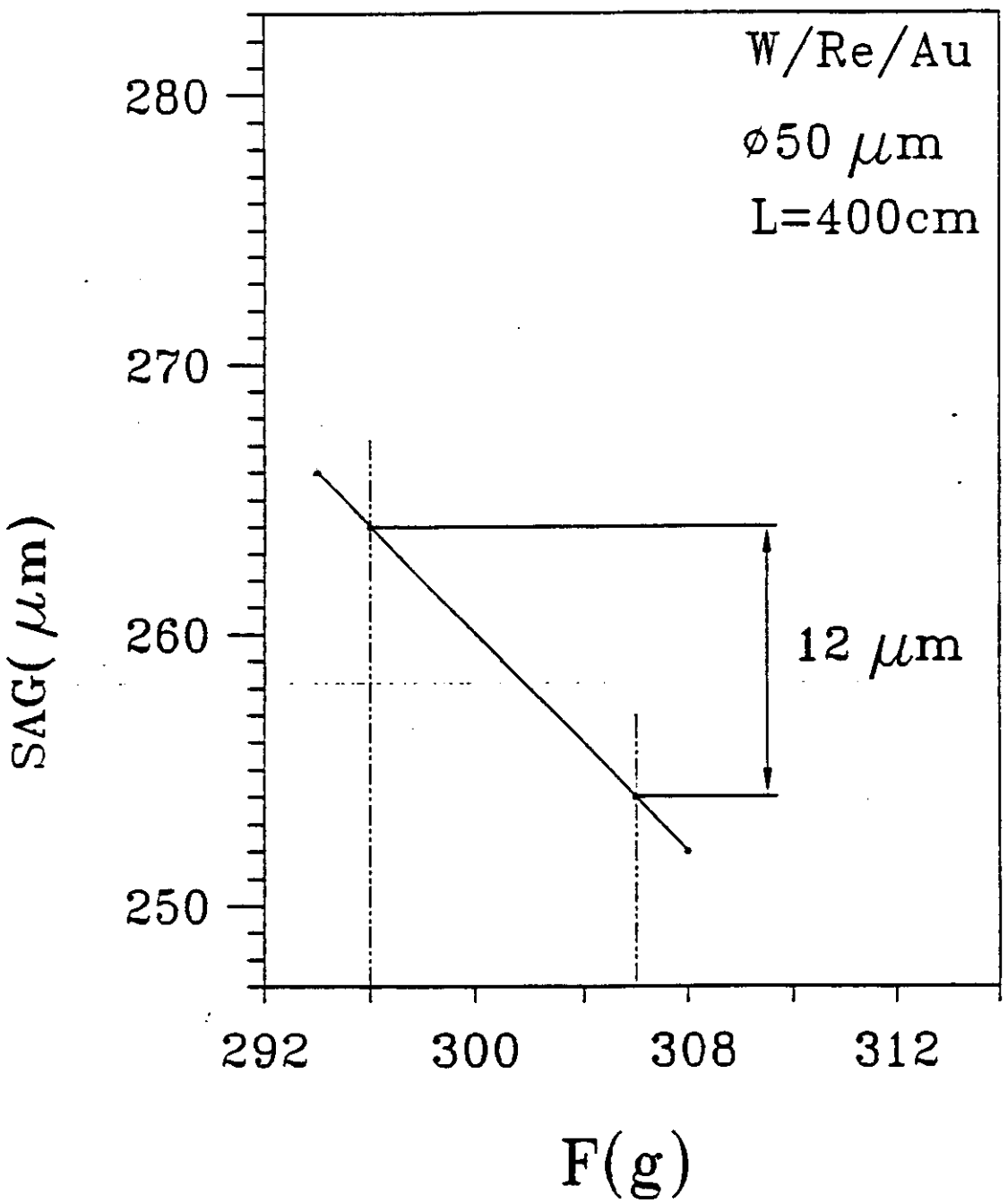
MODULE B
(64 tubes)



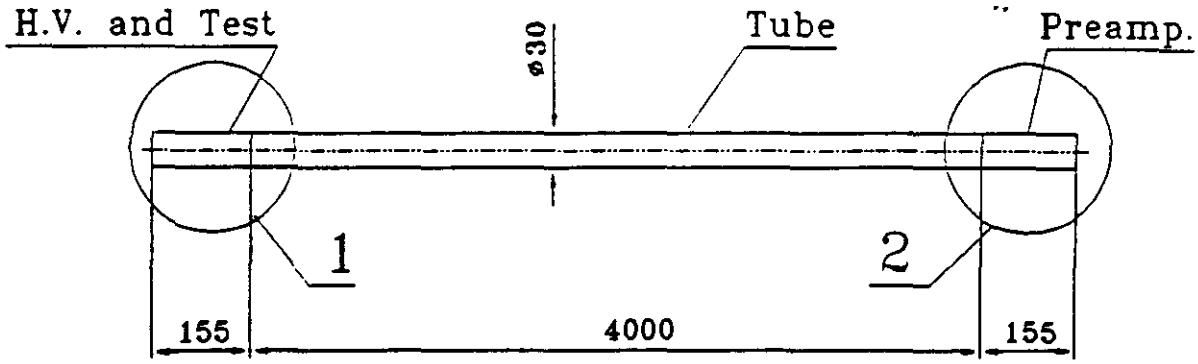
<F>=302,5
Δ = 3.3%


1400.00
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
SAG (μm)
0.00
200.00
400.00
600.00
800.00
F (g)
W/Re/Au
ϕ 50 μm
L=400 cm
***** experimental
^^^^^ theoretical

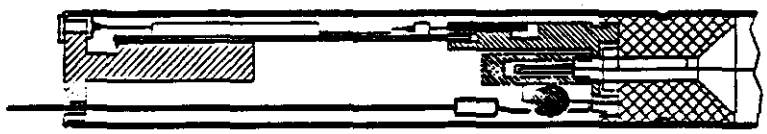
DUBNA PDT PROTOTYPE

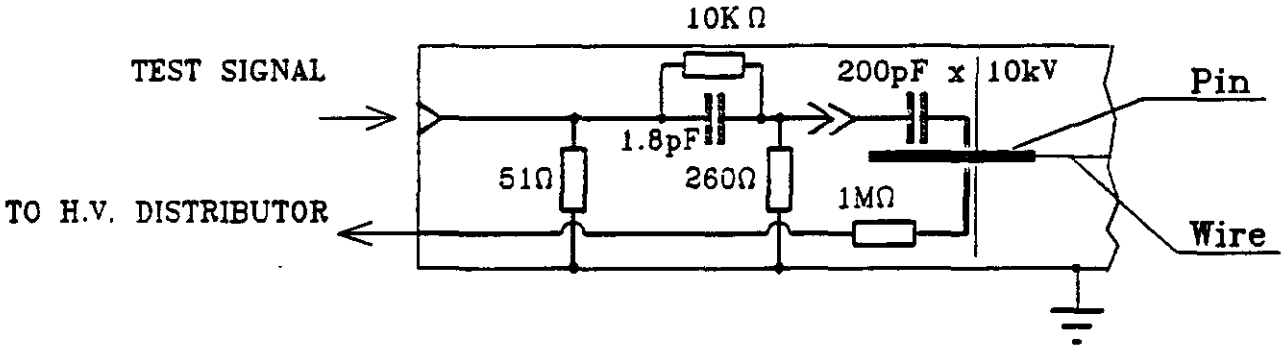


PDT. SCHEMATIC VIEW

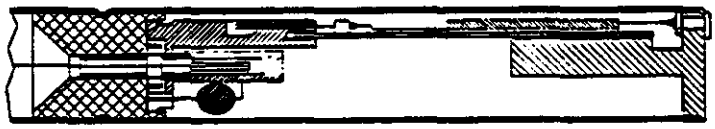


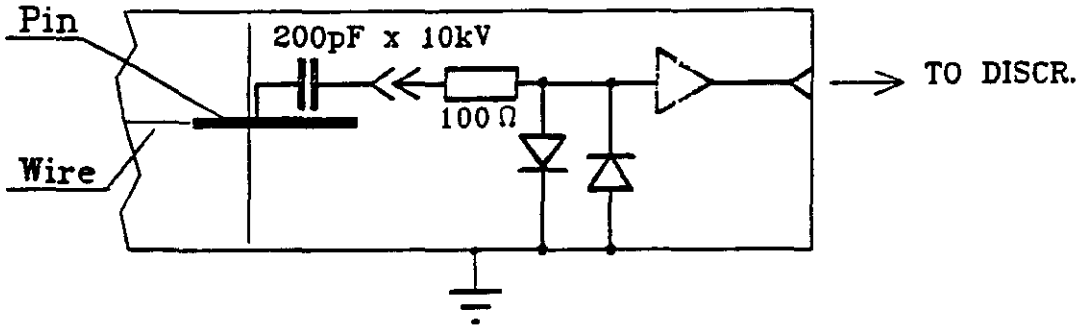
1



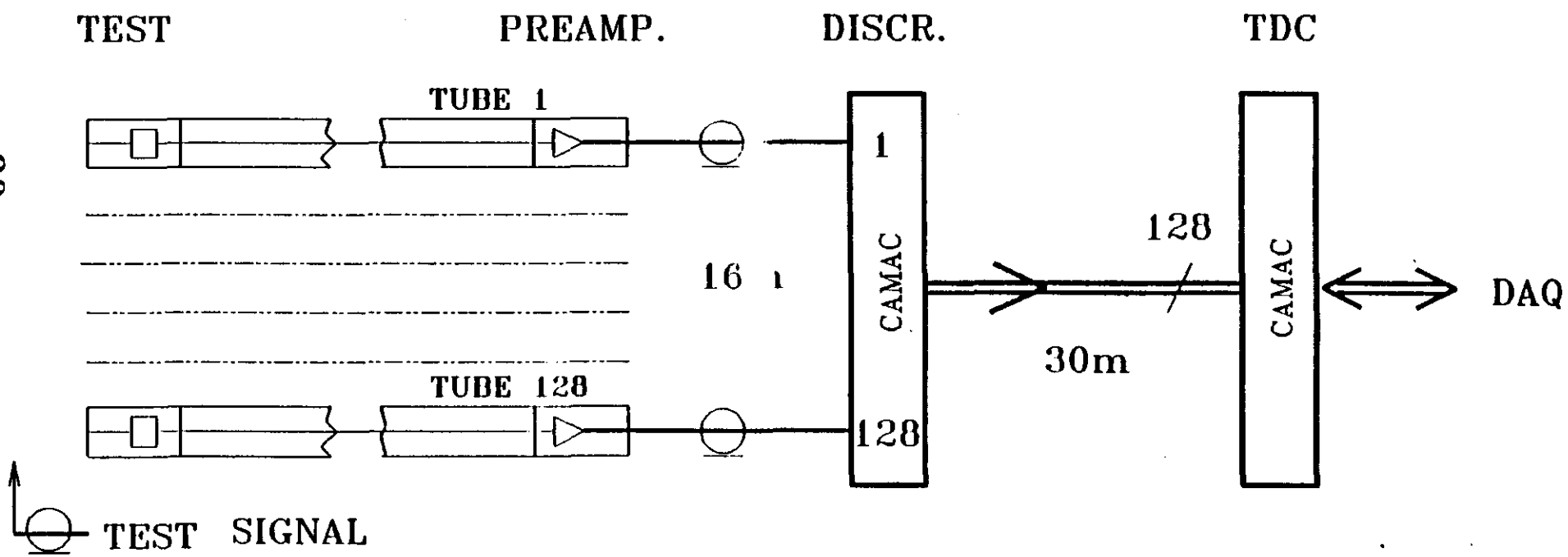


2





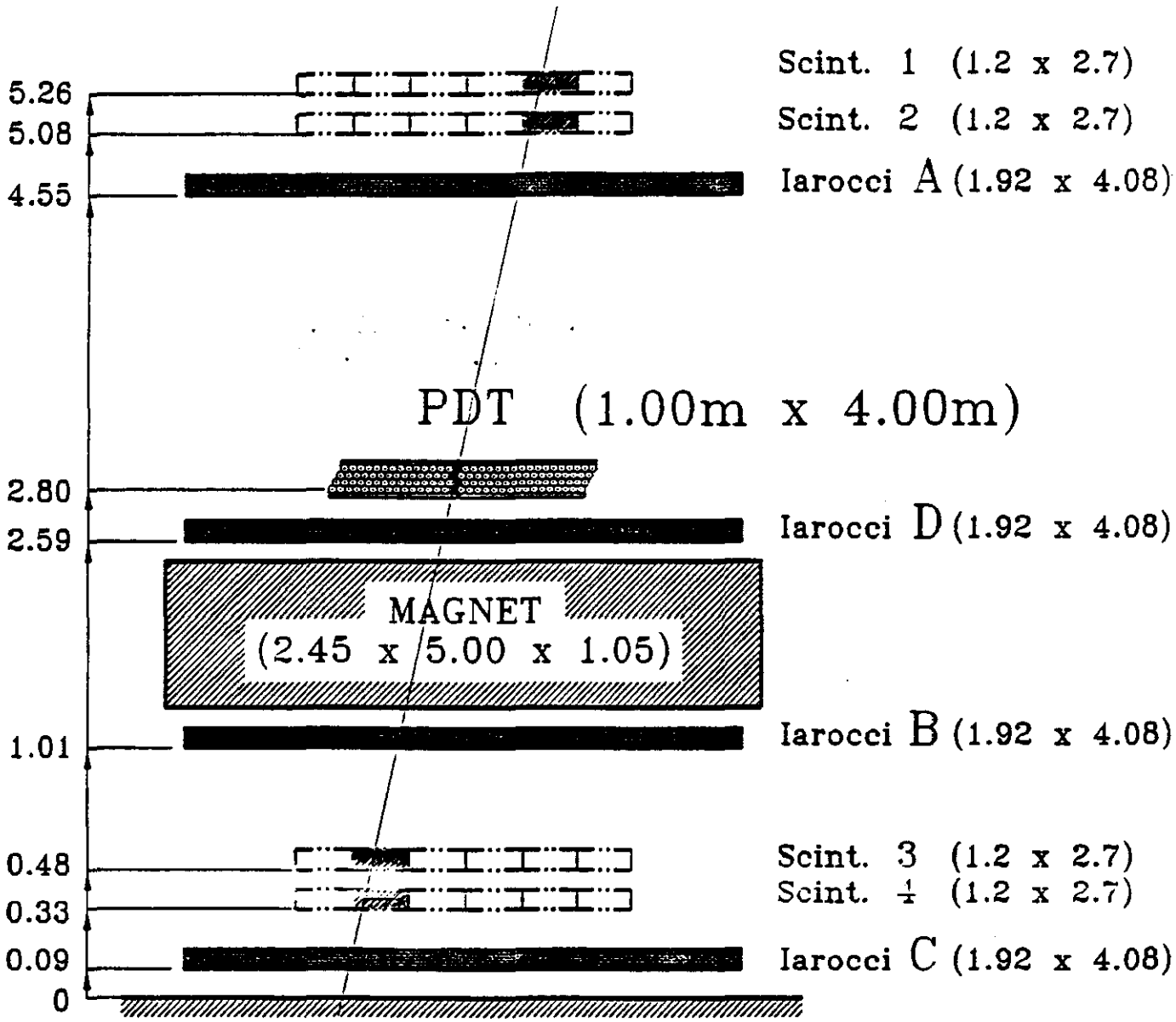
DUBNA PDT PROTOTYPE. ELECTRONICS



RESULTS OF TTR TEST

DUBNA PDT PROTOTYPE

TTR TEST SETUP

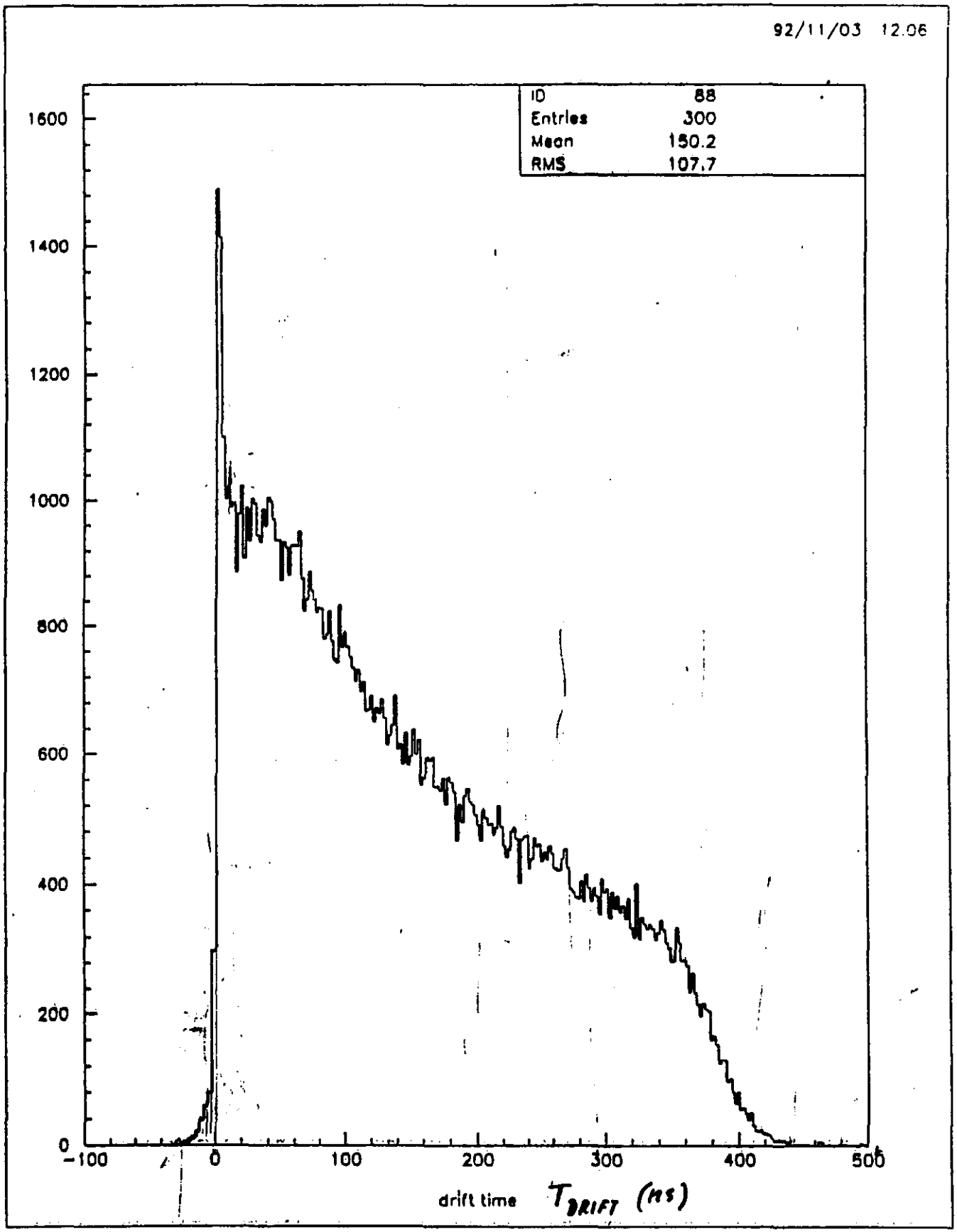


All dimensions in m

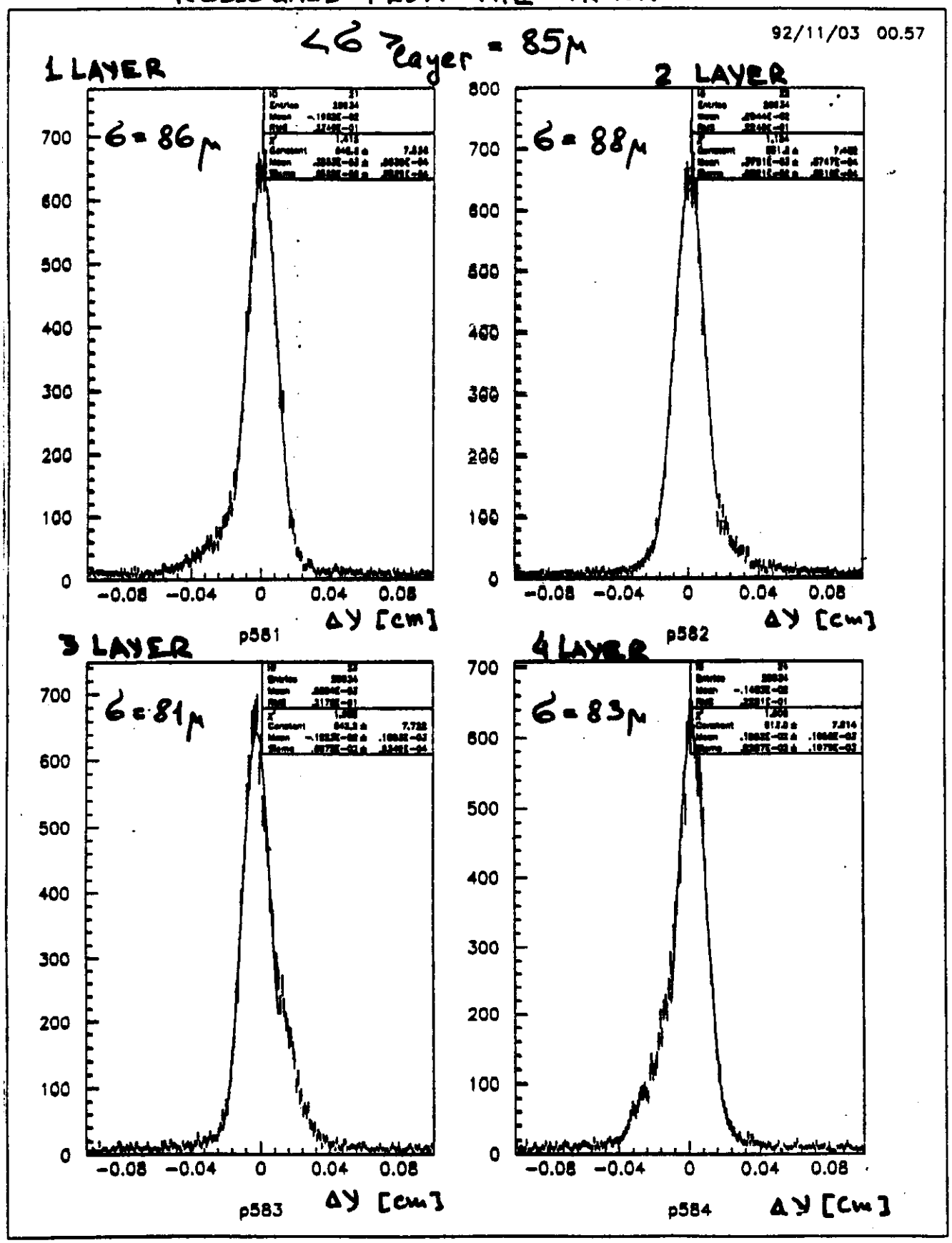
E2/515

$$Ar - isoC_4H_{10}(25/75)$$

$$P = 1 \text{ atm}$$

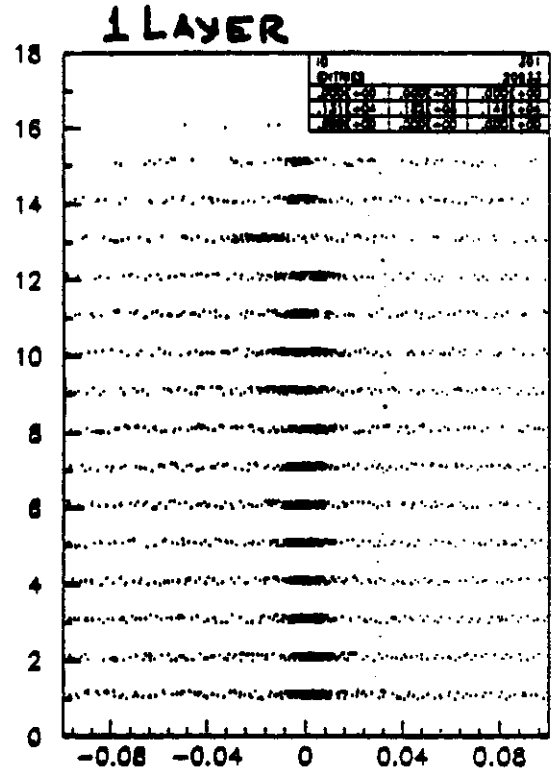

92/11/03 12.06
ID 88
Entries 300
Mean 150.2
RMS 107.7
1600
1400
1200
1000
800
600
400
200
0
-100
0
100
200
300
400
500
drift time T_{DRIFT} (ns)

RESIDUALS FROM THE TRACK

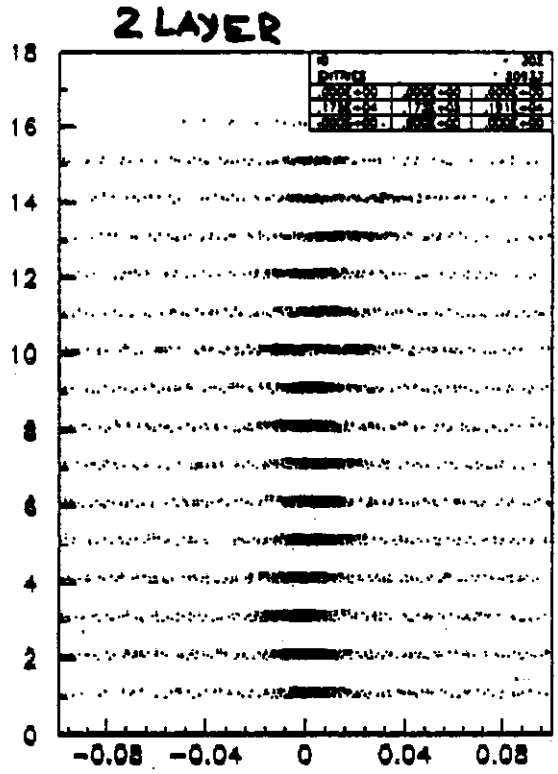


RESIDUALS vs TUBE NUMBER

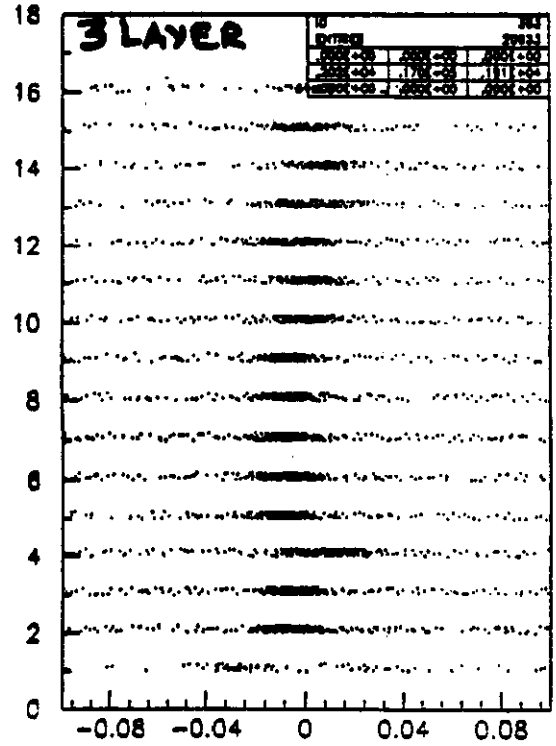
92/11/02 22.33



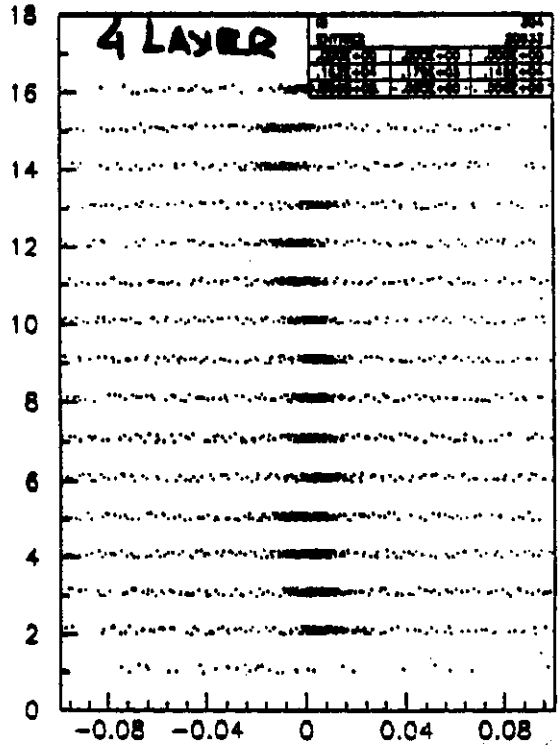
delta(Y) vs tube number for layer 1



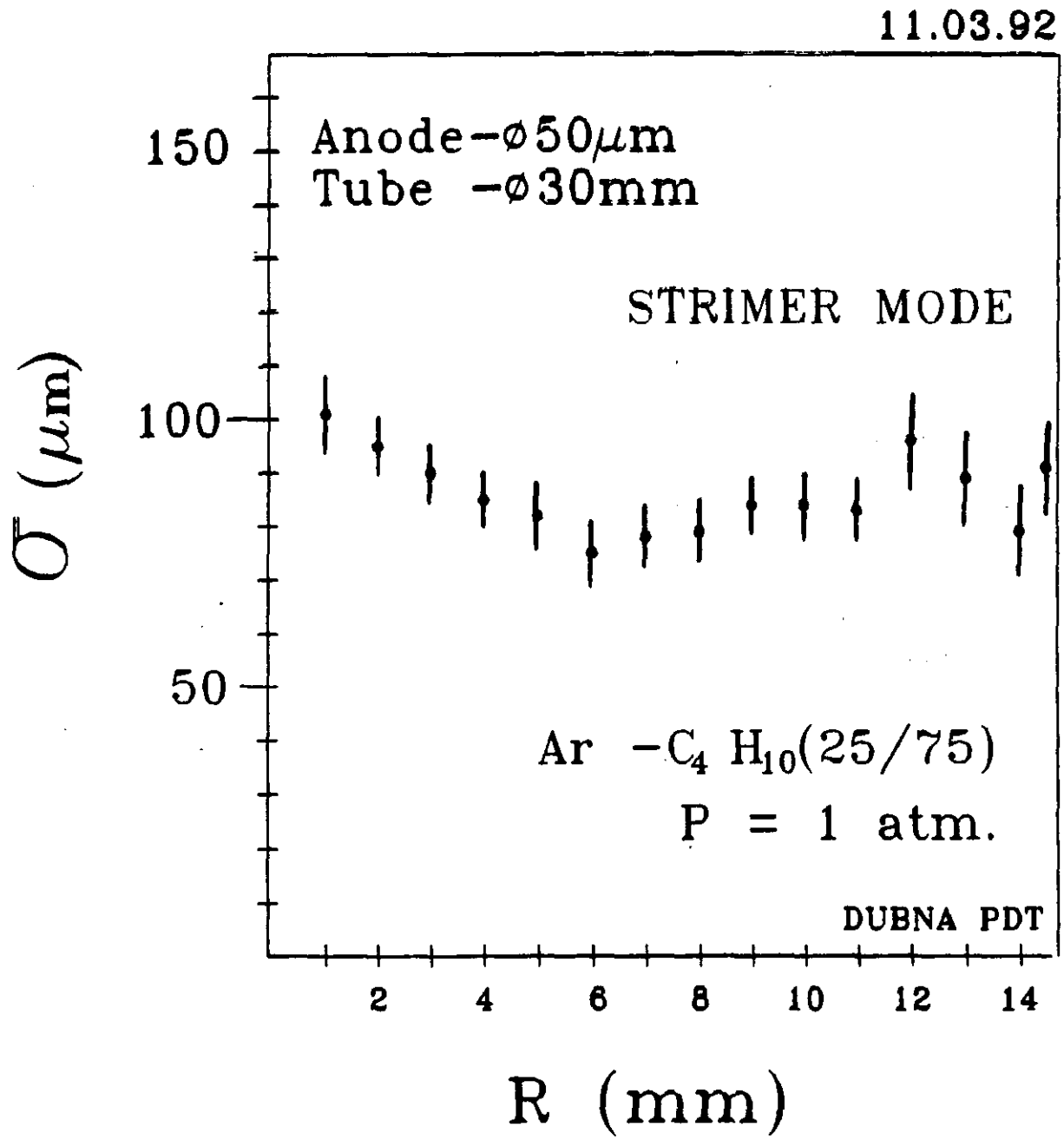
delta(Y) vs tube number for layer 2

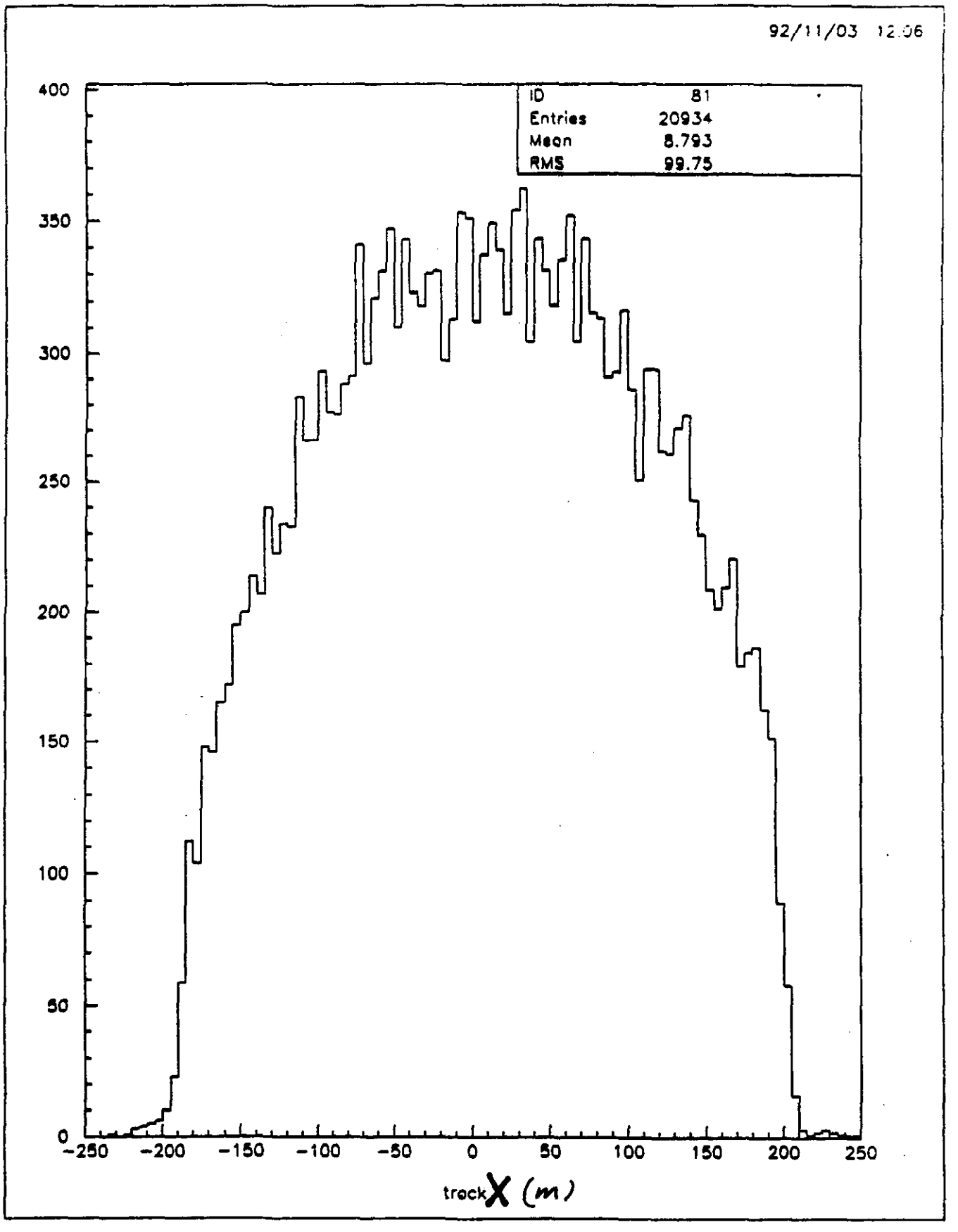


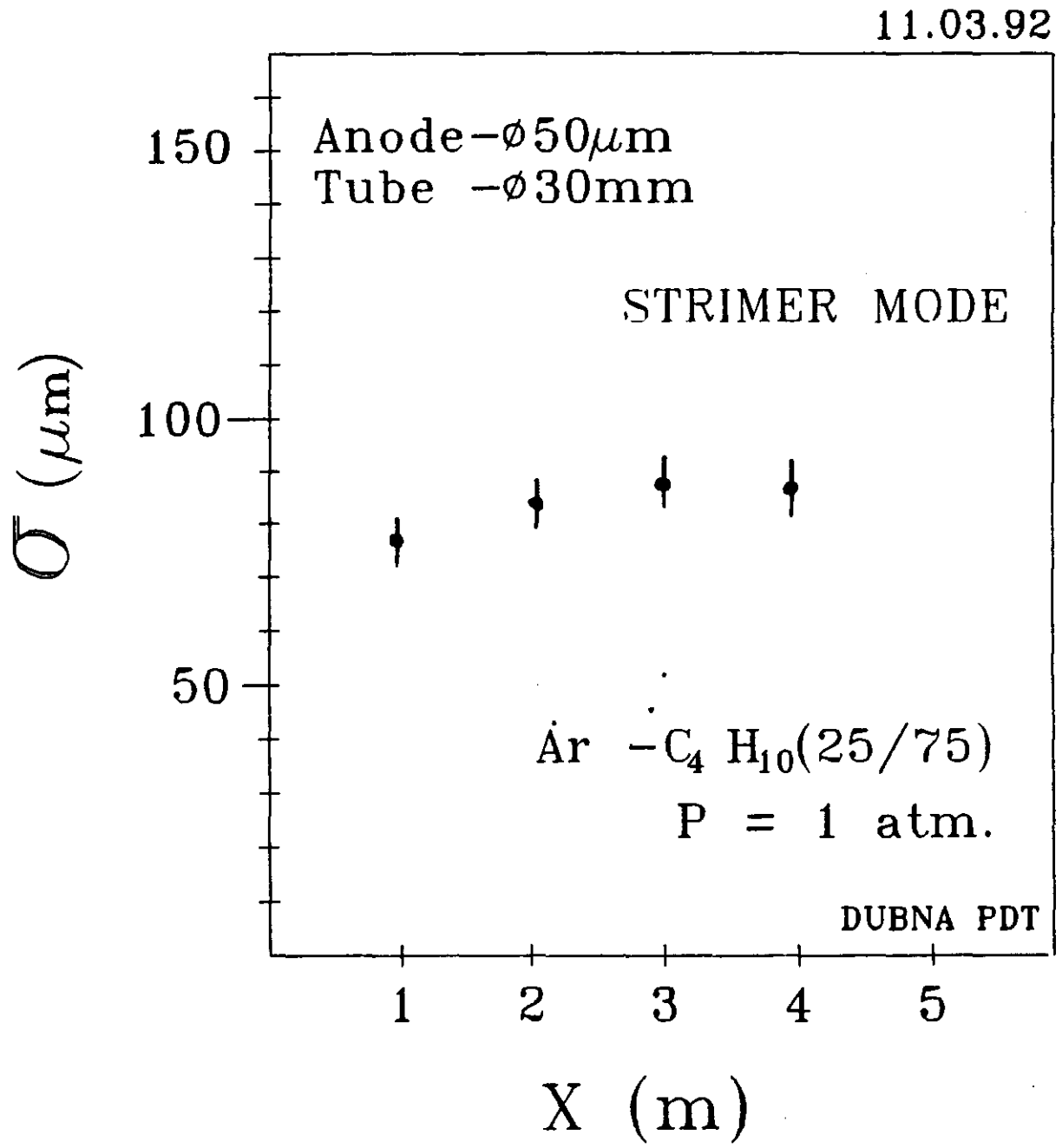
delta(Y) vs tube number for layer 3



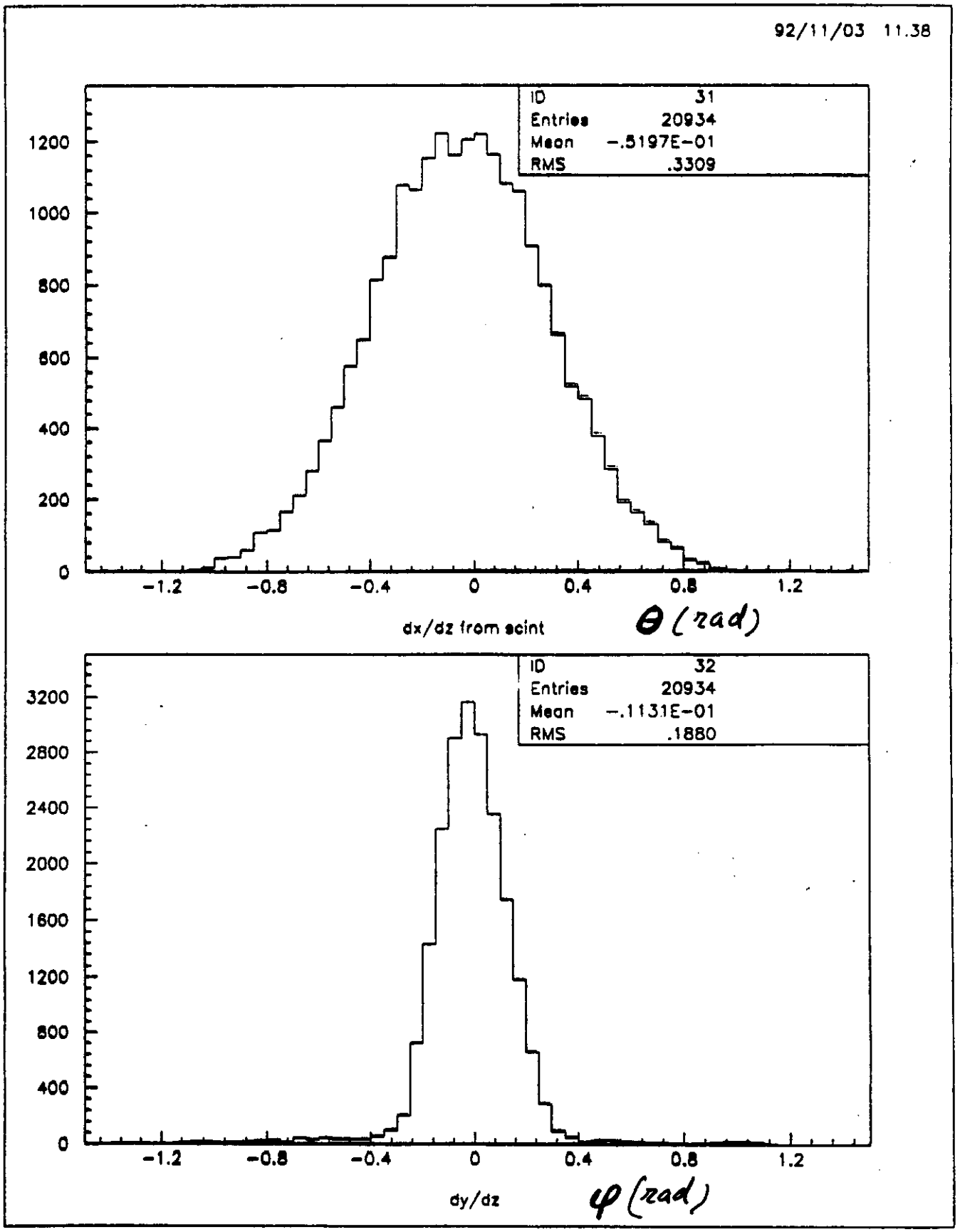
delta(Y) vs tube number for layer 4

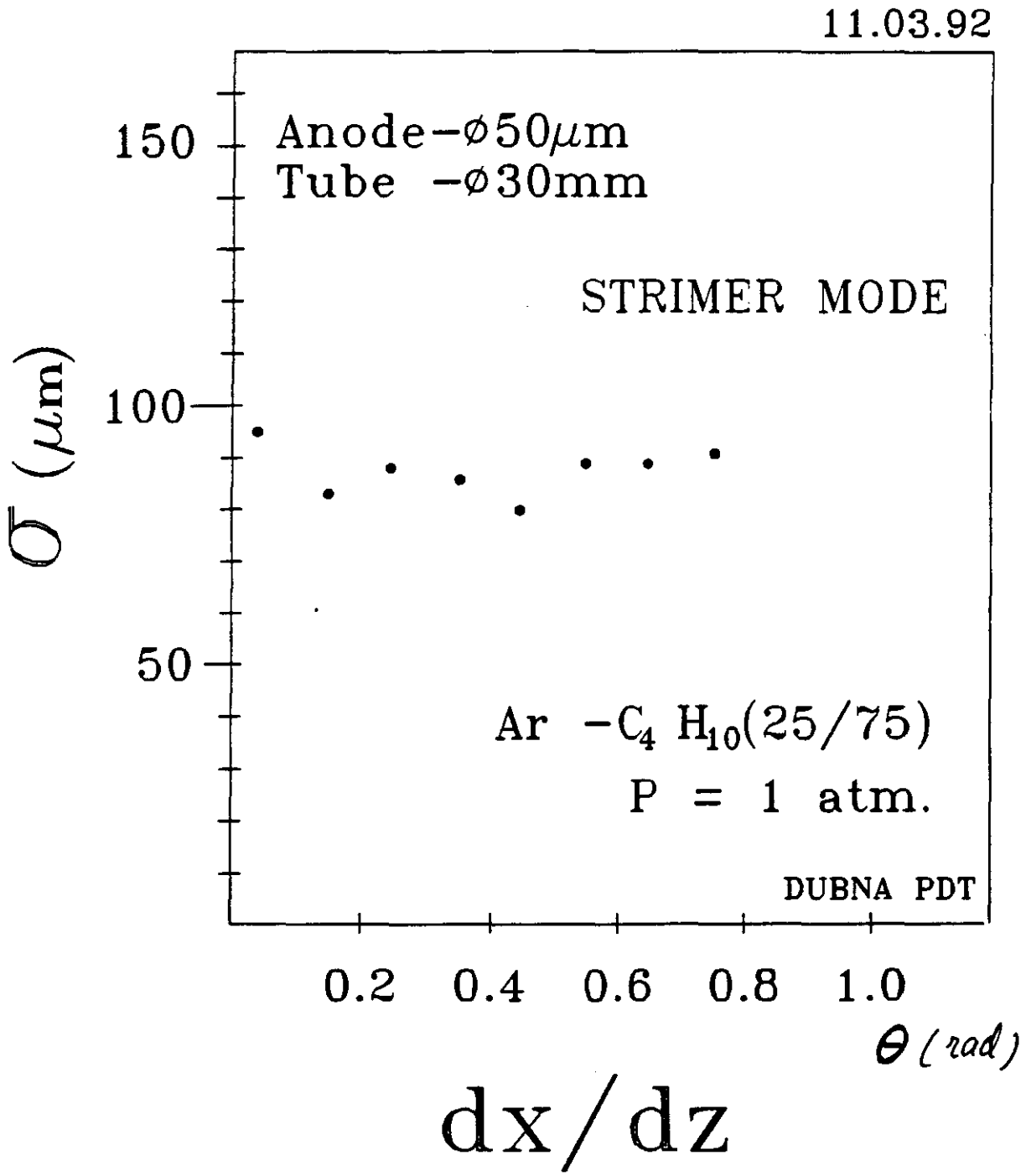

11.03.92
Anode-ø50μm
Tube -ø30mm
STRIMER MODE
Ar -C4 H10(25/75)
P = 1 atm.
DUBNA PDT
150
100
50
σ (μm)
2
4
6
8
10
12
14
R (mm)

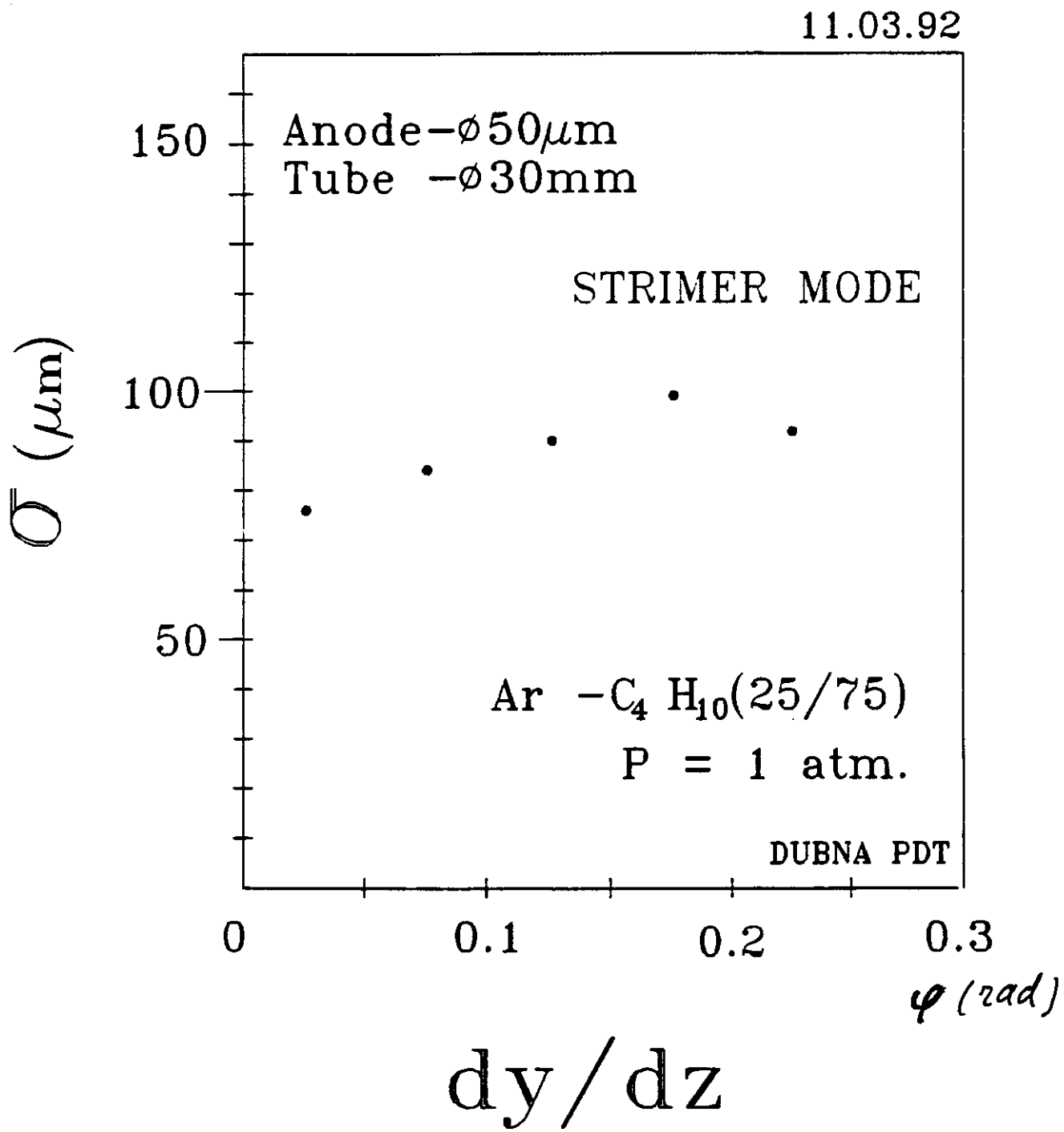

92/11/03 12:06
ID 81
Entries 20934
Mean 8.793
RMS 99.75
400
350
300
250
200
150
100
50
0
-250
-200
-150
-100
-50
0
50
100
150
200
250
track X (m)


11.03.92
Anode-ø50μm
Tube -ø30mm
STRIMER MODE
Ar -C4 H10(25/75)
P = 1 atm.
DUBNA PDT
150
100
50
σ (μm)
1
2
3
4
5
X (m)

74


92/11/03 11.38
ID 31
Entries 20934
Mean -.5197E-01
RMS .3309
1200
1000
800
600
400
200
0
-1.2
-0.8
-0.4
0
0.4
0.8
1.2
dx/dz from scint
θ (rad)
ID 32
Entries 20934
Mean -.1131E-01
RMS .1880
3200
2800
2400
2000
1600
1200
800
400
0
-1.2
-0.8
-0.4
0
0.4
0.8
1.2
dy/dz
φ (rad)


11.03.92
Anode-ø50μm
Tube -ø30mm
STRIMER MODE
Ar -C4 H10(25/75)
P = 1 atm.
DUBNA PDT
σ (μm)
150
100
50
0.2
0.4
0.6
0.8
1.0
θ (rad)
dx/dz


11.03.92
Anode-Ø50μm
Tube -Ø30mm
STRIMER MODE
Ar -C4 H10(25/75)
P = 1 atm.
DUBNA PDT
150
100
50
0
0.1
0.2
0.3
σ (μm)
φ (rad)
dy/dz

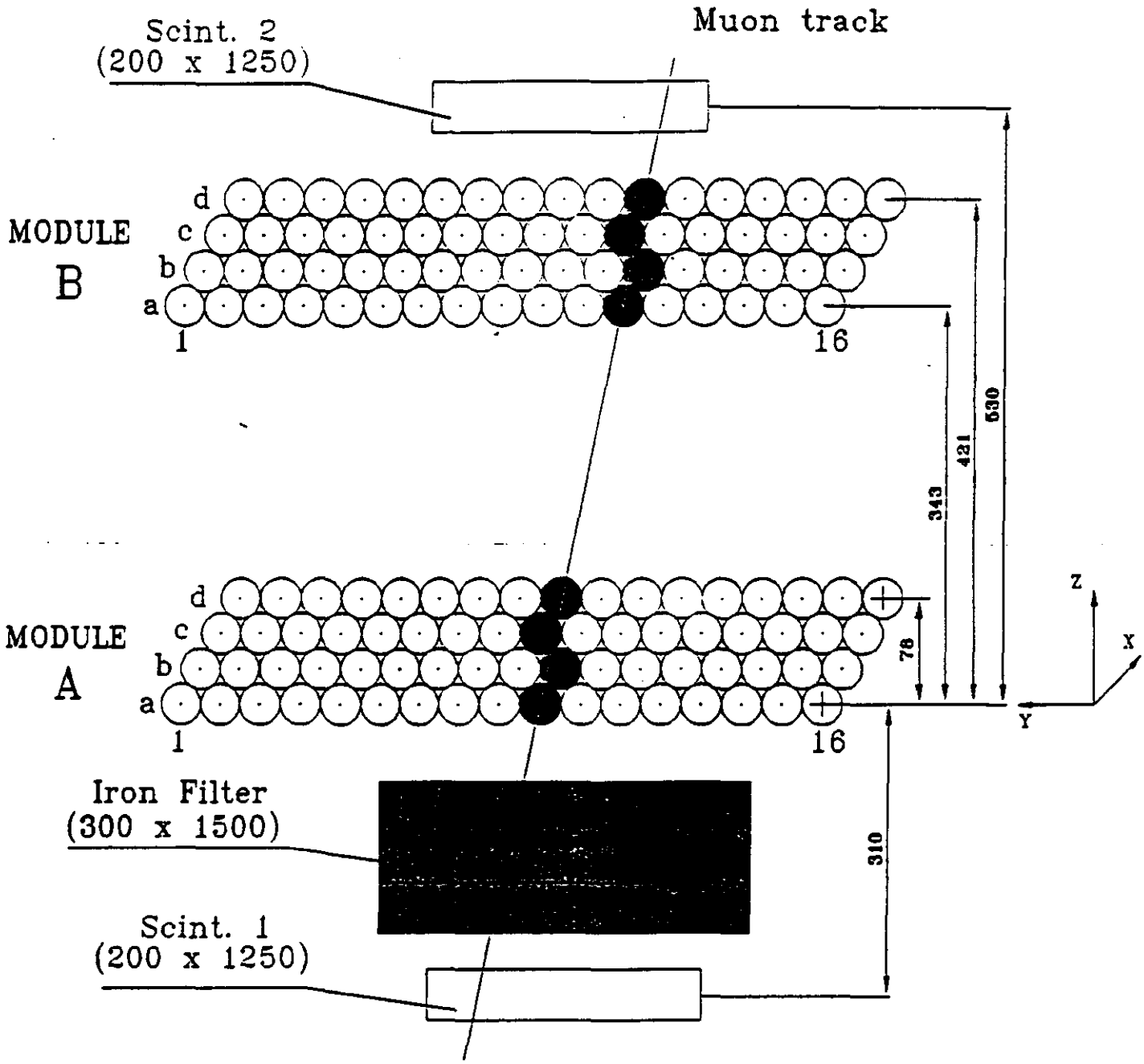
CONCLUTION:

STREAMER MODE:

- $\langle \sigma \rangle_{LAYER} = 85\ \mu$ (FOR ALL ANGLE)

- TECHNOLOGY – OK!

TEST SETUP



(All dimensions in mm)

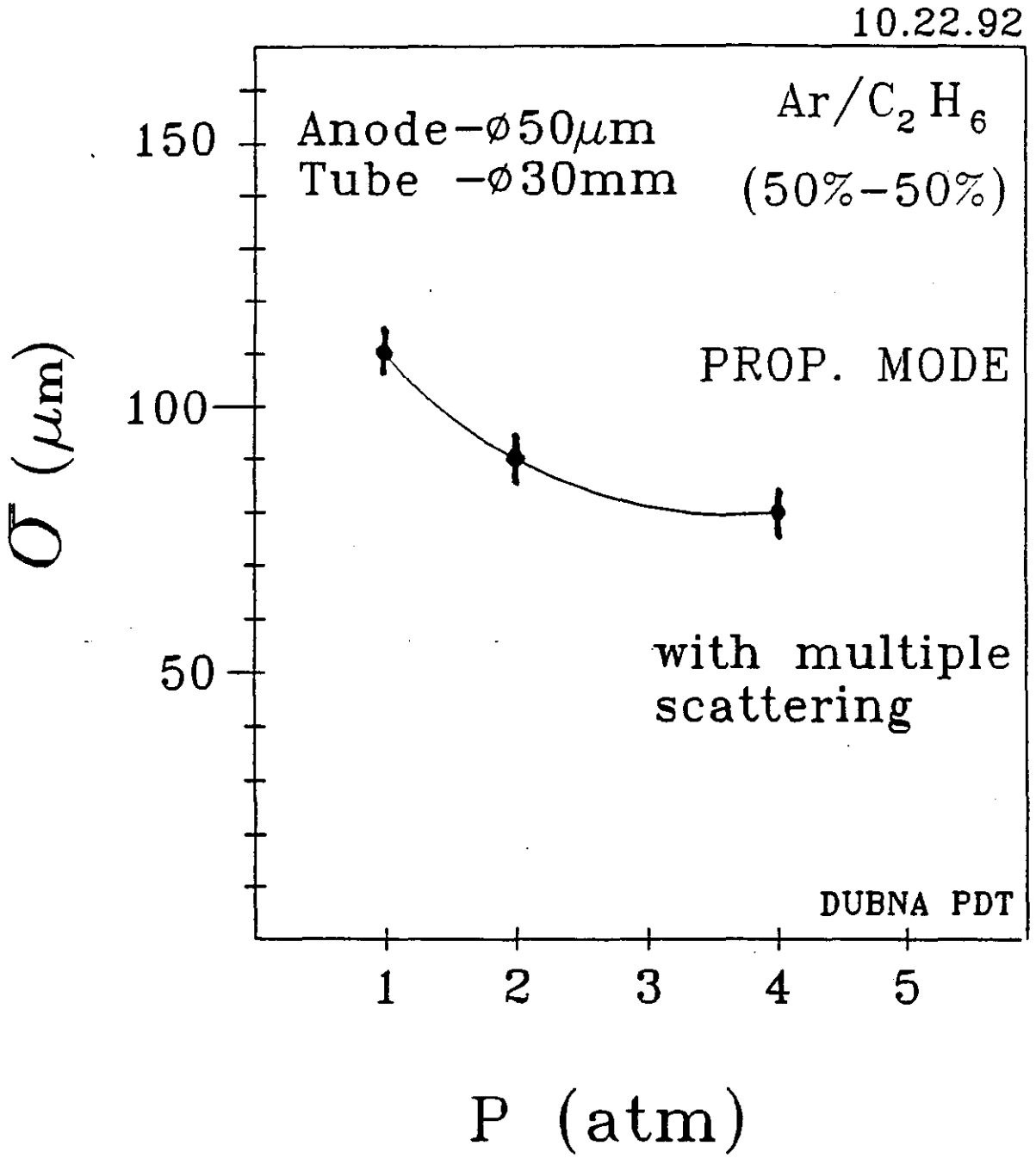
$Ar - C_2H_6(50/50)$

PROP. MODE

U_A kV	Layer / P_{atm}	1	2	3	4	1...4
		Δ	Δ	Δ	Δ	σ
3.1	1	(+28)	(−47)	(+8)	(+10)	110
4.3	2	(+32)	(−52)	(+10)	(+10)	92
5.9	4	(+36)	(−59)	(+8)	(+10)	76

σ −space resolution (μm)

Δ −systematic shift (μm)


10.22.92
Anode-ø50μm
Tube -ø30mm
Ar/C2H6
(50%-50%)
PROP. MODE
with multiple
scattering
DUBNA PDT
150
100
50
σ (μm)
1
2
3
4
5
P (atm)

81

Ar $-C_4H_{10}$(25/75)

P = 1 atm

U_A kV	Layer / Mode	1	2	3	4	1...4
		Δ	Δ	Δ	Δ	σ
4.1	prop.	(+34)	(−52)	(+12)	(+10)	95
4.5	strimer	(+34)	(−57)	(+10)	(+12)	82

σ −space resolution (μm)

Δ −systematic shift (μm)

SUMMARY

WE PROPOSE THE TECHNOLOGY FOR PDT MASS PRODUCTION. TTR TESTS HAVE DEMONSTRATED THAT THIS TECNOLOGY ALLOWS to ACHIEVE **RESOLUTION < 100 μ** FOR EACH LAYER OF 4 LAYERS μ-MODULE IN PROPORTIONAL AND STREAMER MODE.

BASIC PRINCIPLES:

- EXTERNAL SYSTEM OF MECHANICAL BASES;
- EXTERNAL COMB WITH PRECISE GROOVES POS.
- PRECISE FIXATION — SOLDERING OF WIRES;
- SELF-SUPPORT MECHANICAL CONSTRUCTION;
- PREAMP. — IN EACH TUBE
- SEQUENTIAL GAS FLOW

Craig Wuest

gem

$\gamma e \mu$

Muon System Technology Options

RPC—Craig Wuest

RESISTIVE PLATE CHAMBER TECHNOLOGY REVIEW

November 4, 1992

M. Widgoff
Brown University

E. D. Alyea
Indiana University

E. Ables, R. Bionta, M. Haro, D. Makowiecki, G. J. Mauger, M. McKernan, K. Miller, P. Ramsey, C. R. Wuest*
Lawrence Livermore National Laboratory

D. Chen, E. S. Hafen, P. Haridas, M. Lee, I. A. Pless*, S. Yunus
Massachusetts Institute of Technology

R. Santonico
University of Rome and Instituto Nazionale di Fisica Nucleare

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

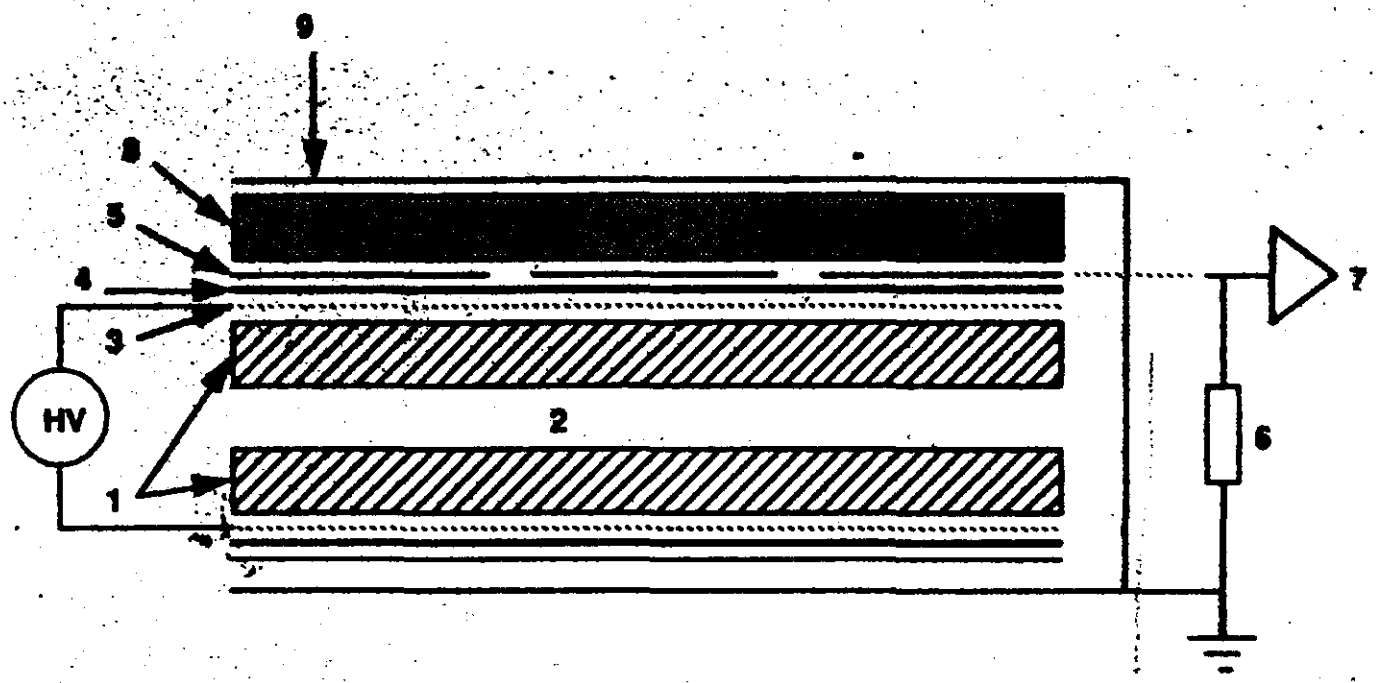
*Co-spokesmen

Resistive Plate Counter Design

- Resistive Plate Chambers (RPCs) have been in operation in experiments throughout the world since 1981.
- The current standard (Italian) design is two meters long by one meter wide with a sensitive gas gap of 2 millimeters.
- There are no wires or conductors anywhere in the sensitive region.
- The walls of the chamber - in contact with the gas of the sensitive volume - consists of a semi-conductor (Bakelite, for example) with a bulk resistance of about 10**11 ohm-centimeters.
- An ioniz ing particle passing through the sensitive volume (2 m x 1 m x 2 mm) breaks down the gap and creates an electrical discharge.
- This discharge is very fast (a few nanoseconds).
- The discharge is capacitively coupled to pick-up strips which are located outside the semiconductor walls of the gas cell.

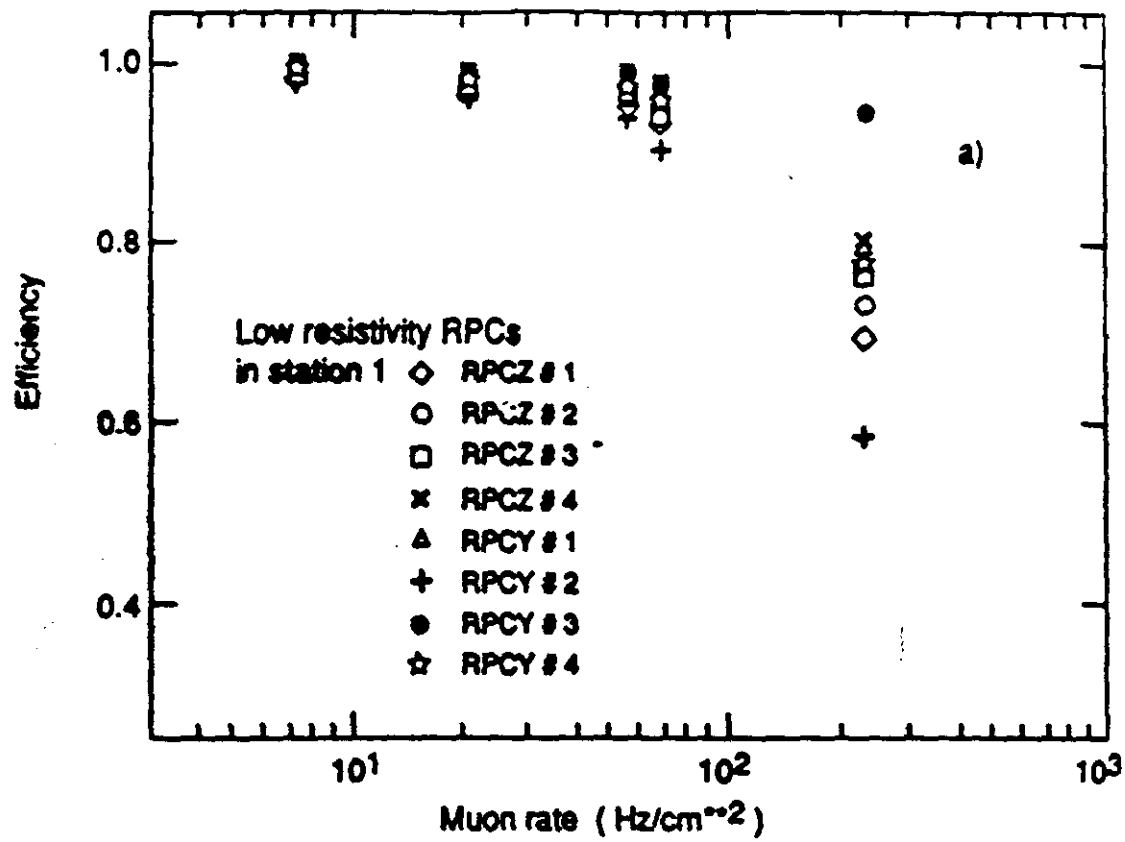
Resistive Plate Counter Design

- Hundreds of these chambers have been produced and are operating in experiments all over the world.
- A set of these chambers have operated at Frascati for 7 years.
- Such chambers are currently being used in E-771 at Fermilab.
- Recently L3 at CERN has ordered 400 of these chambers from General Technica, Colli, Italy, a company that is a commercial supplier of RPCs.
- Not a new technology, but rather a mature technology which is well understood and for which the manufacturing technology has already been transferred to industry.



1 Bakelite plate
2 gas
3 graphite coating
4 insulating foil
5 aluminum strips
6 line termination
7 discriminator
8 foam
9 aluminum ground plane

Figure 1


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)

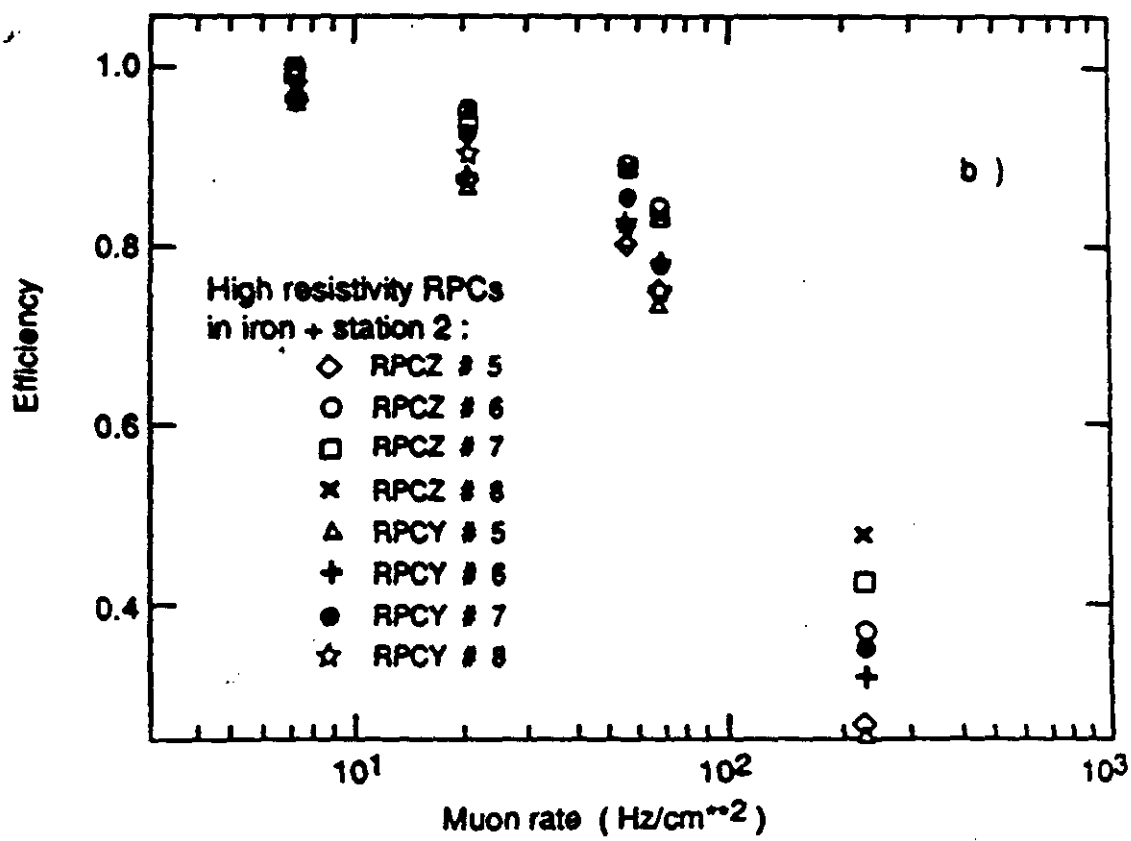

1.0
0.8
0.6
0.4
Efficiency
b)
High resistivity RPCs
in iron + station 2 :
RPCZ # 5
RPCZ # 6
RPCZ # 7
RPCZ # 8
RPCY # 5
RPCY # 6
RPCY # 7
RPCY # 8
10^1
10^2
10^3
Muon rate (Hz/cm**2)

FIG. 20

Resistive Plate Counter Technology Review

- In November 1991, the RPC Collaboration submitted its R&D program for the GEM Muon Beam Tagging Trigger and Z-coordinate Measuring System using Resistive Plate Counters.

- Properties of RPCs that have been measured include:

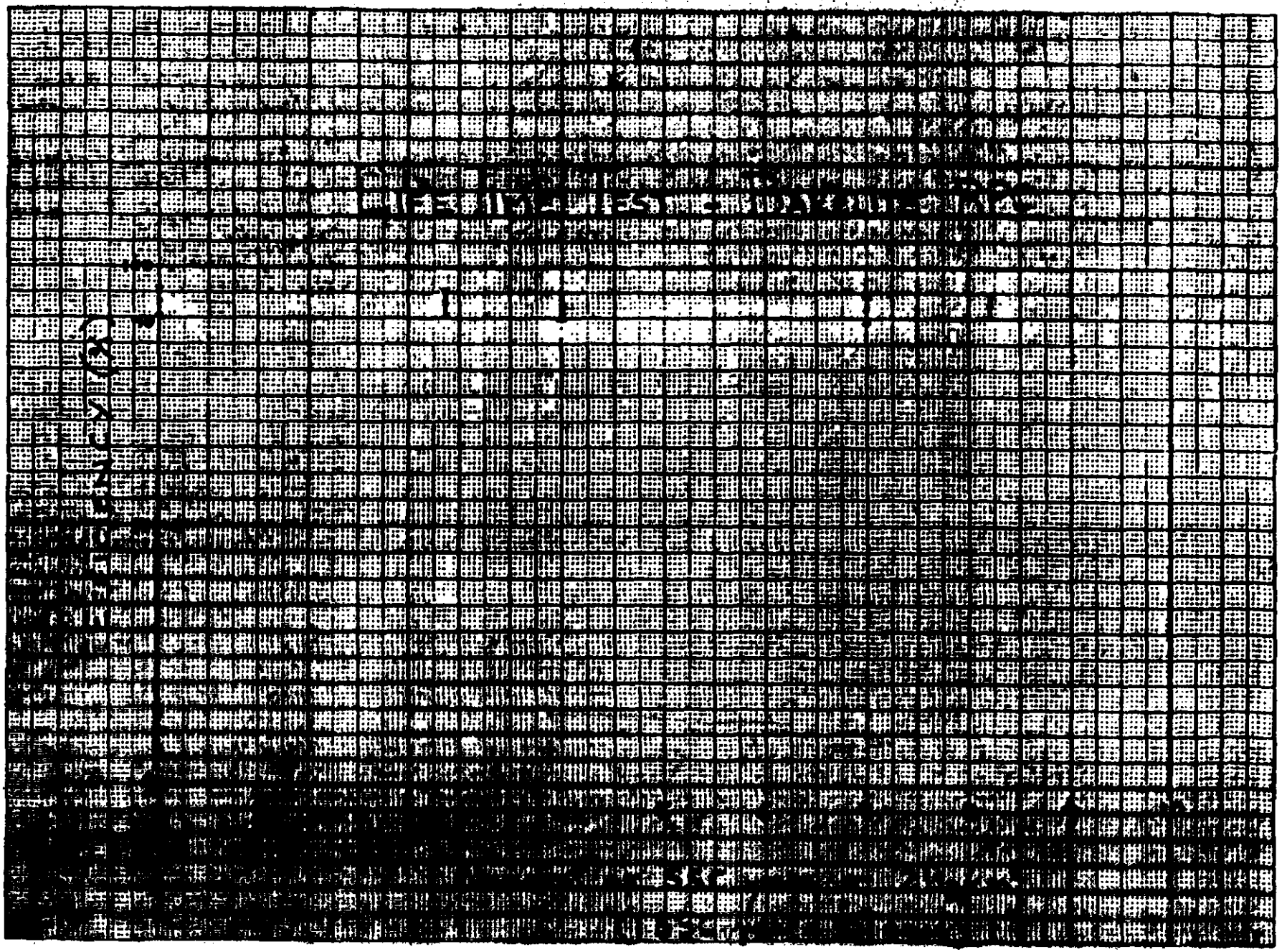
  - Pulse rise-time jitter
  - Maximum counting rate
  - Efficiency
  - Lifetime
  - Noise
  - Response to neutrons and gammas

- A number of RPC prototypes have been fabricated using new materials:

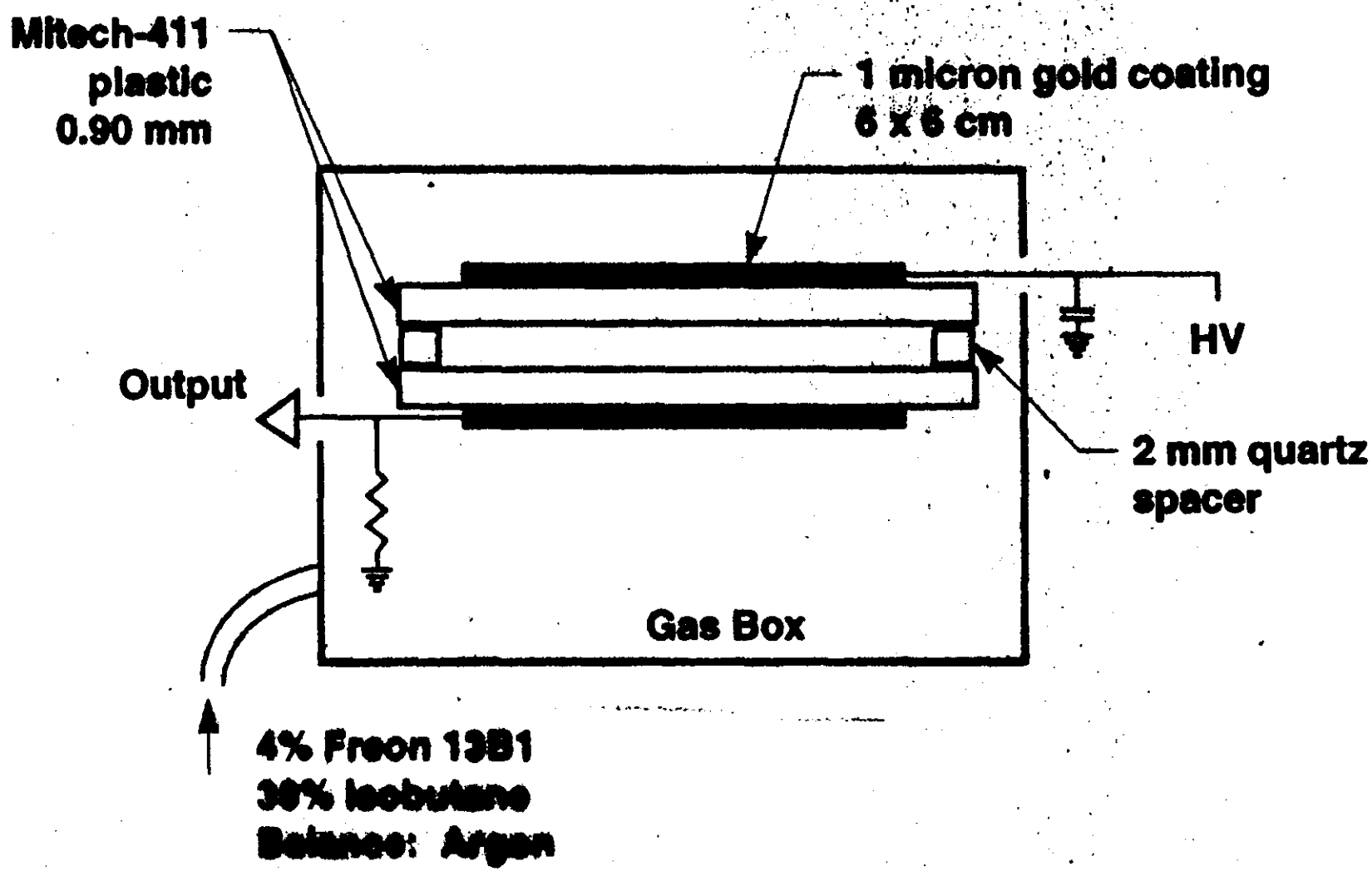
  - Glasses
  - Cermets
  - Plastics

- Results from the RPC R&D program:
  - Pulse rise-time jitter measured on 1m x 2 m Italian RPC - 1.4 ns
  - Pulse rise-time -2.5 ns
  - Pulse width - 50 ns
  - Pulse height - 200-500 mV into 50 ohms without amplification.
  - Saturated counting rate -
    - Glasses - 50-75 Hz/cm^2
    - Bakelite - 560 Hz/cm^2
    - Static-dispersive plastics - 15 KHz/cm^2
  - Efficiency – 95% using cosmic ray scintillator telescope.
  - Lifetime – 1% decrease in efficiency measured for 8.2 SSC years exposure.
  - Noise – 10 x cosmic rays.
  - Neutron sensitivity (1-10 MeV) – 4.8 x 10^-3, same as other technologies.
  - Photon sensitivity (1-10 MeV) – 6.6 x 10^-3.
- Conclusions:
  - The R&D program has successfully addressed the major concerns of RPC counting rate, aging/lifetime, neutron sensitivity, and noise.

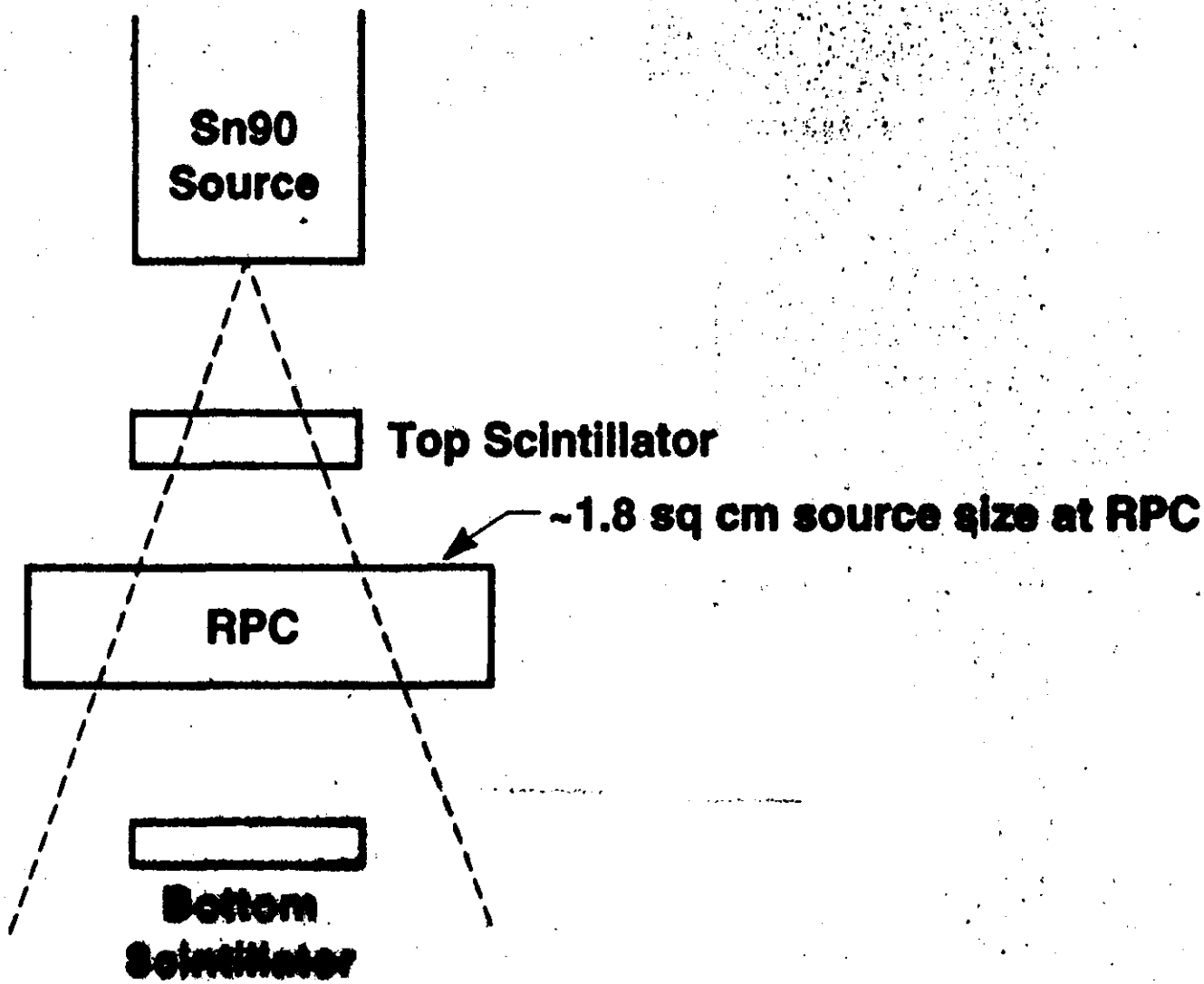
K-E Figure 16



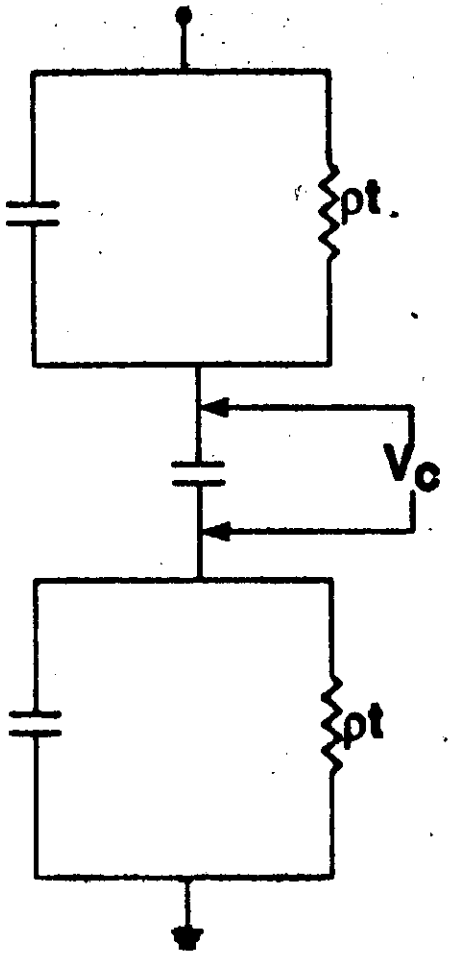
Materials Test Detector

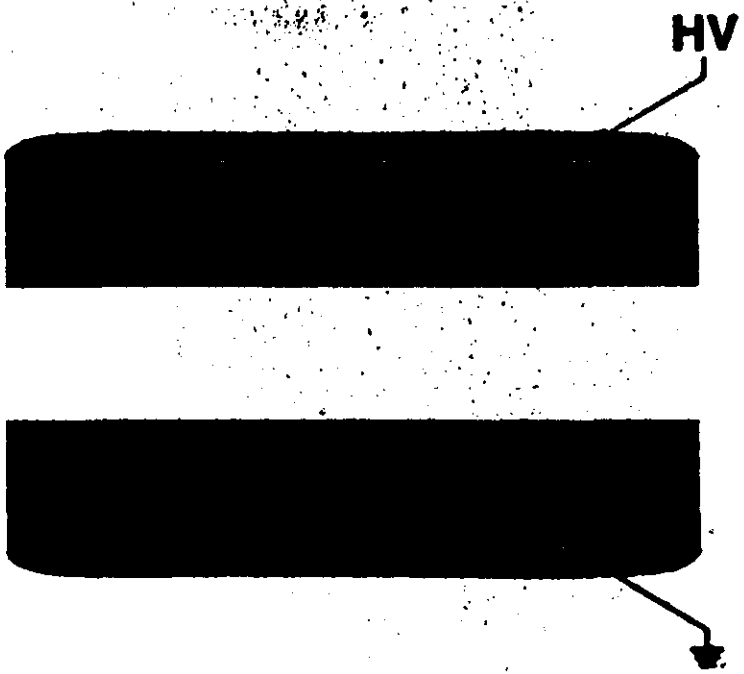


RPC Source Test

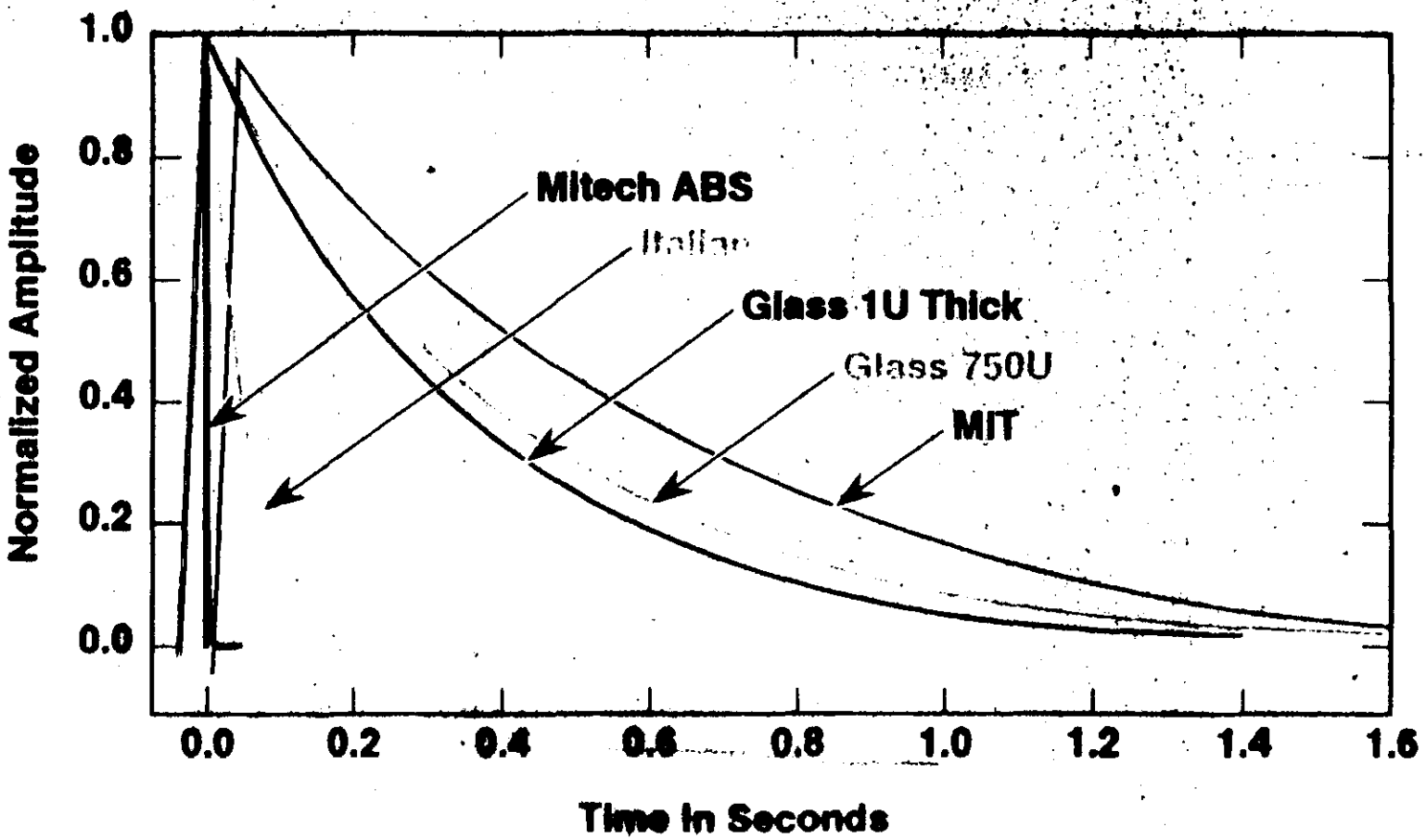


Spice RPC Model





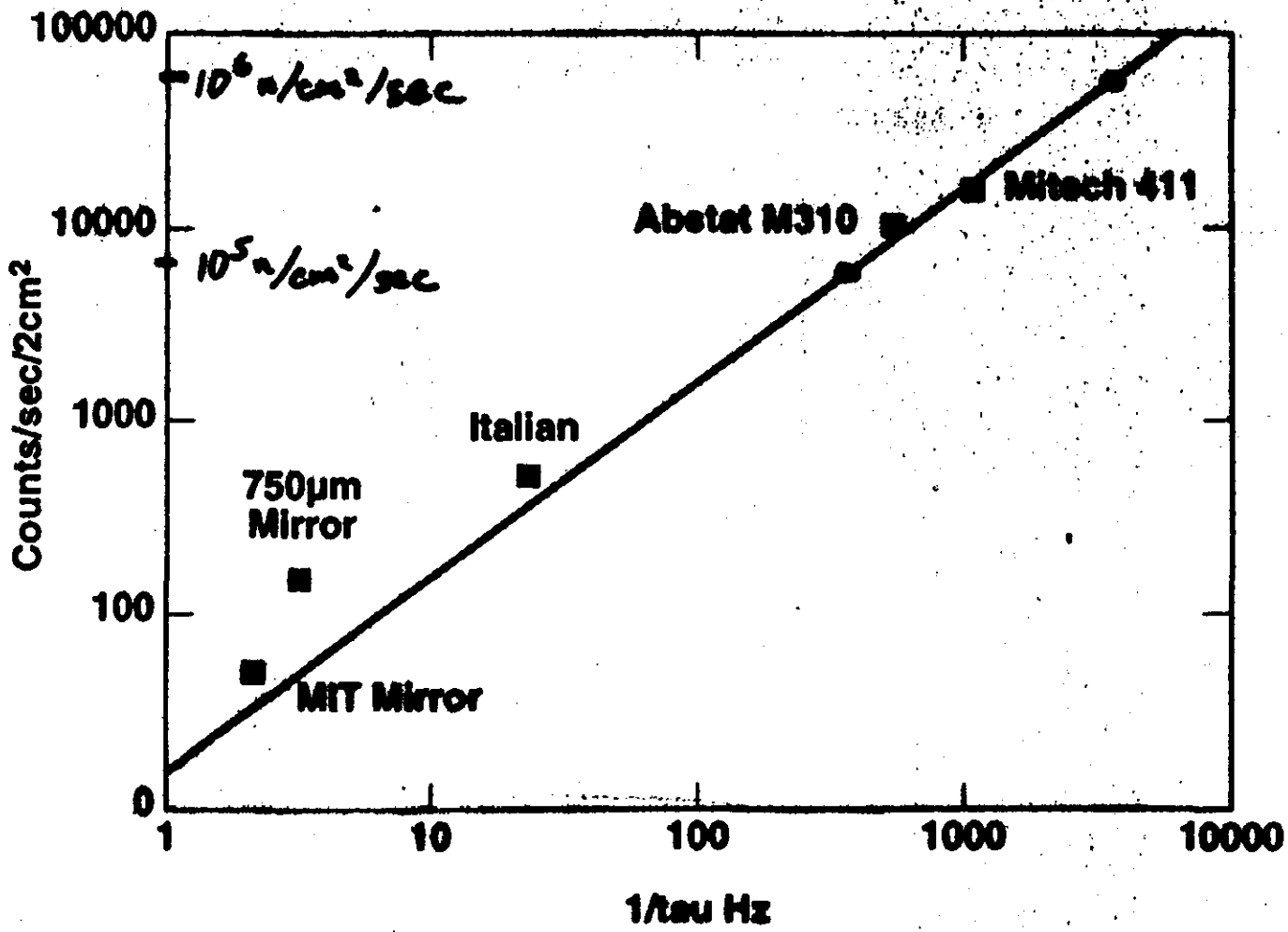
Spice Calculations of Recharge

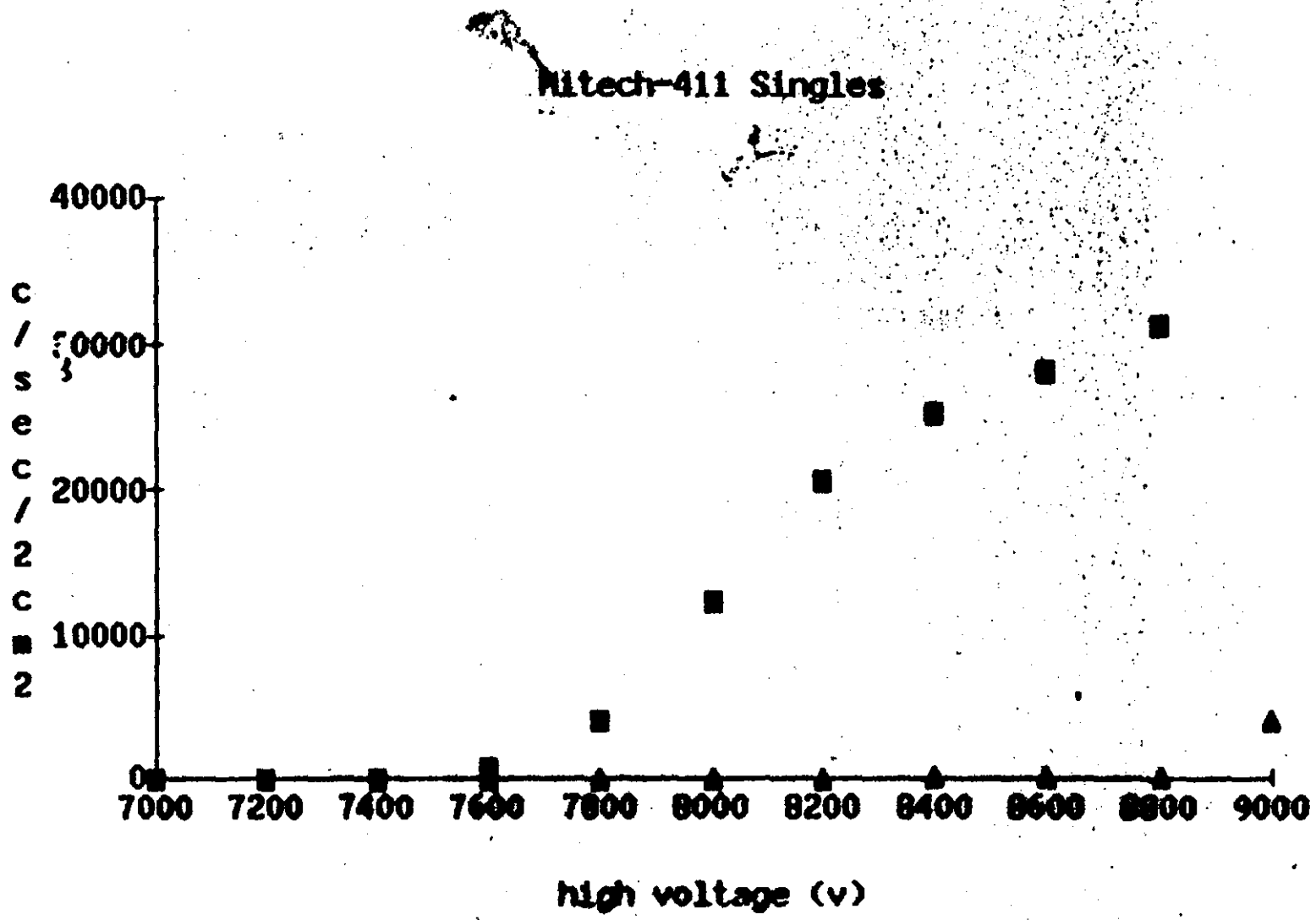


RPC Candidate Material

Material	Thickness (cm)	Bulk Resistivity (Ωcm)	Arc Resistivity (Ωcm^2)
MIT mirror	.300	5.0×10^{12}	1.5×10^{12}
750 micron mirror	.066	4.9×10^{12}	3.23×10^{11}
Kodak projector glass	.123	6.42×10^{11}	7.89×10^{10}
Italian RPC	.200	1.0×10^{11}	2×10^{10}
Bakelite	.161	4.5×10^{9}	7.24×10^{8}
ABSTAT–M310	.072	5.78×10^{9}	4.16×10^{8}
ABSTAT–M310	.060	5.78×10^{9}	3.47×10^{8}
Mitech–410	.090	2.03×10^{9}	1.83×10^{8}
Mitech–410	.030	2.03×10^{9}	6.19×10^{7}
Corning 0211 glass	.056	6.7×10^{7}	3.75×10^{6}
Boron	.0001	1×10^{6}	1×10^{2}

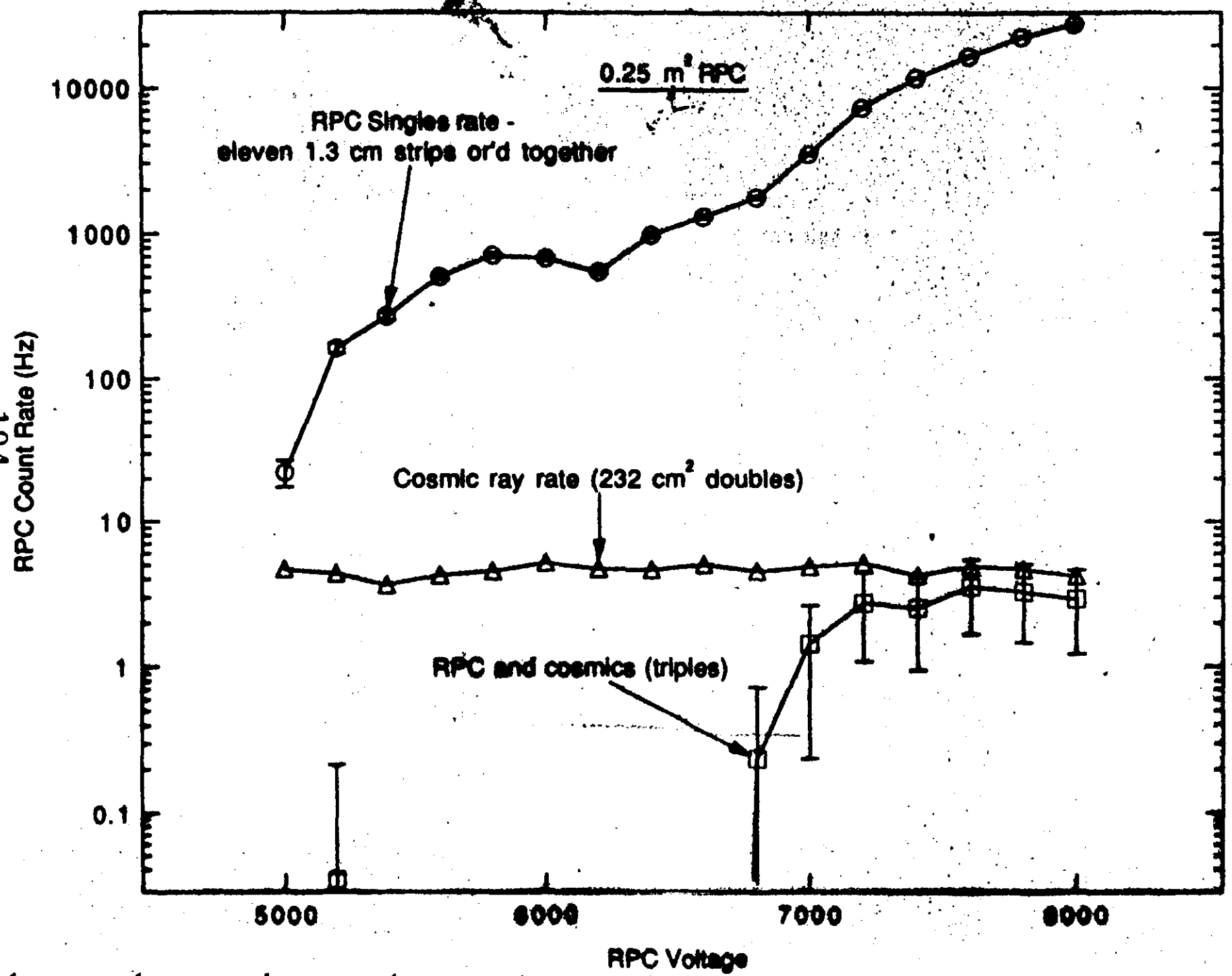
Saturated Singles Rate vs SPICE 1/tau

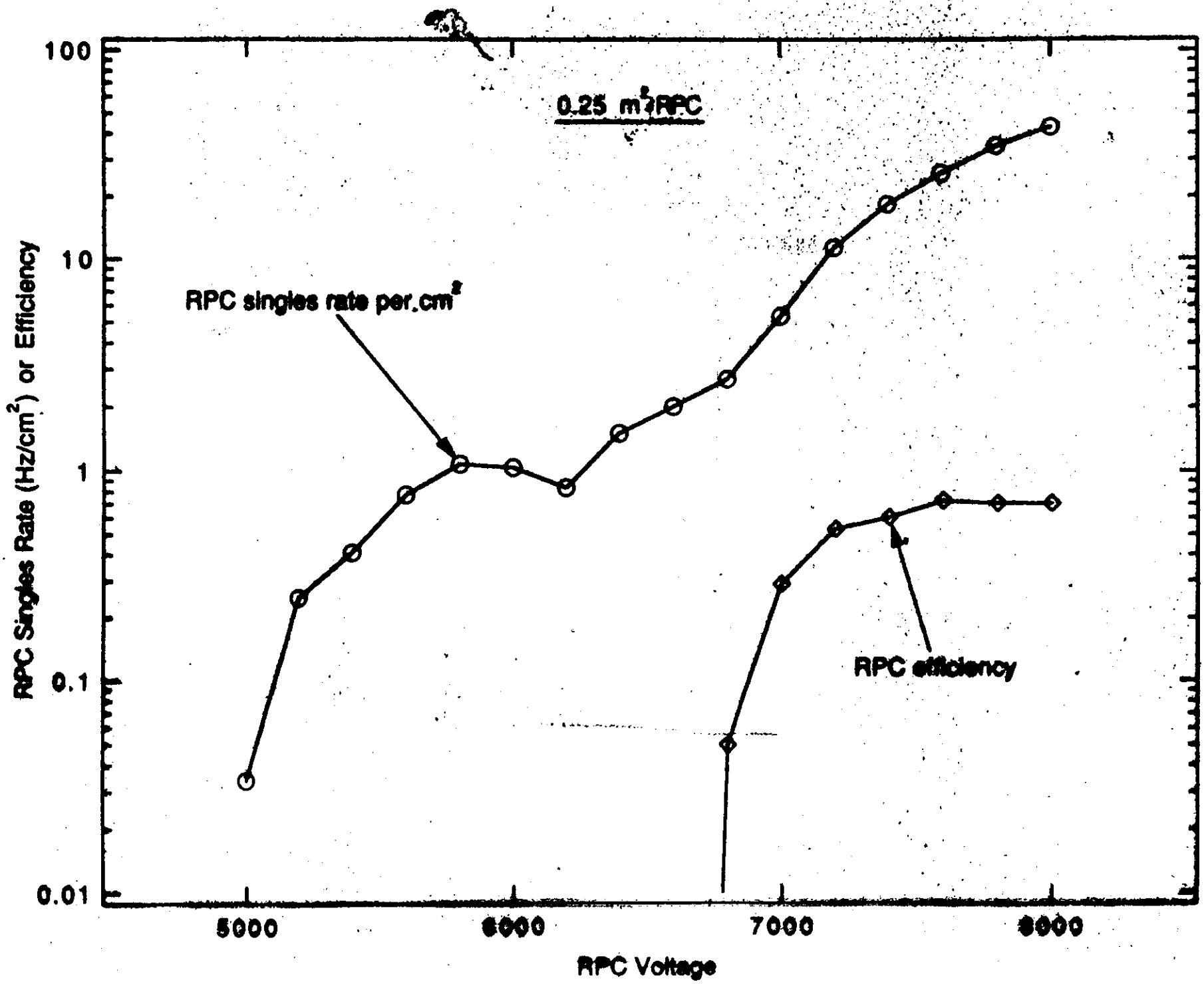



Hitech-411 Singles
c/sec/2cm2
40000
30000
20000
10000
0
7000
7200
7400
7600
7800
8000
8200
8400
8600
8800
9000
high voltage (v)

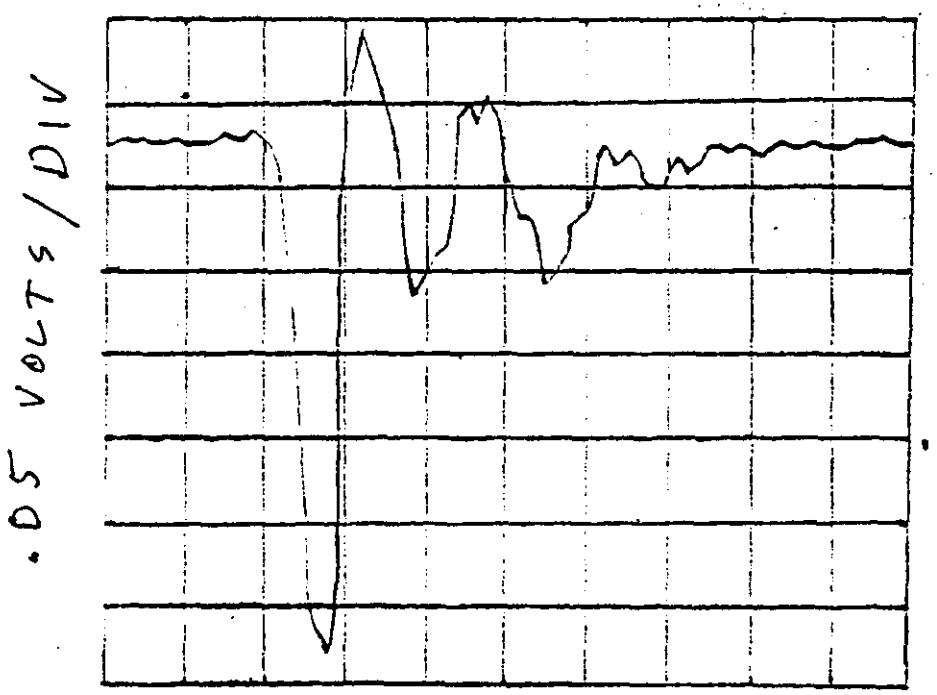
Resistive Plate Chamber Technology Review

- Results since October 6, 1992:
  - We have built 3 RPCs from low resistivity ABS plastics:
    - Two 51 cm x 51 cm (0.25 square meters each).
    - One 76 cm x 127 cm (0.96 square meters).
  - Measurements have been made on efficiency, noise rate, rate capability, jitter.
  - Noise - 20 Hz/cm**2
  - Pulse Height - 200-500 mV
  - Plateau > 800 Vwide (measured with two-fold cosmic ray coincidence)
  - Rate capability - 10-20 KHz/cm**2 (measured with 36 cm**2 RPC)
  - Jitter - less than 5 ns (measured with 36 cm**2 RPC)
- Single layer 1 m**2 RPC weighs 0.4 g/cm**2 (4.1 kg)
- Ar/CO2/isobutane/freon and CO2/CF4 gas mixes tested in RPCs.

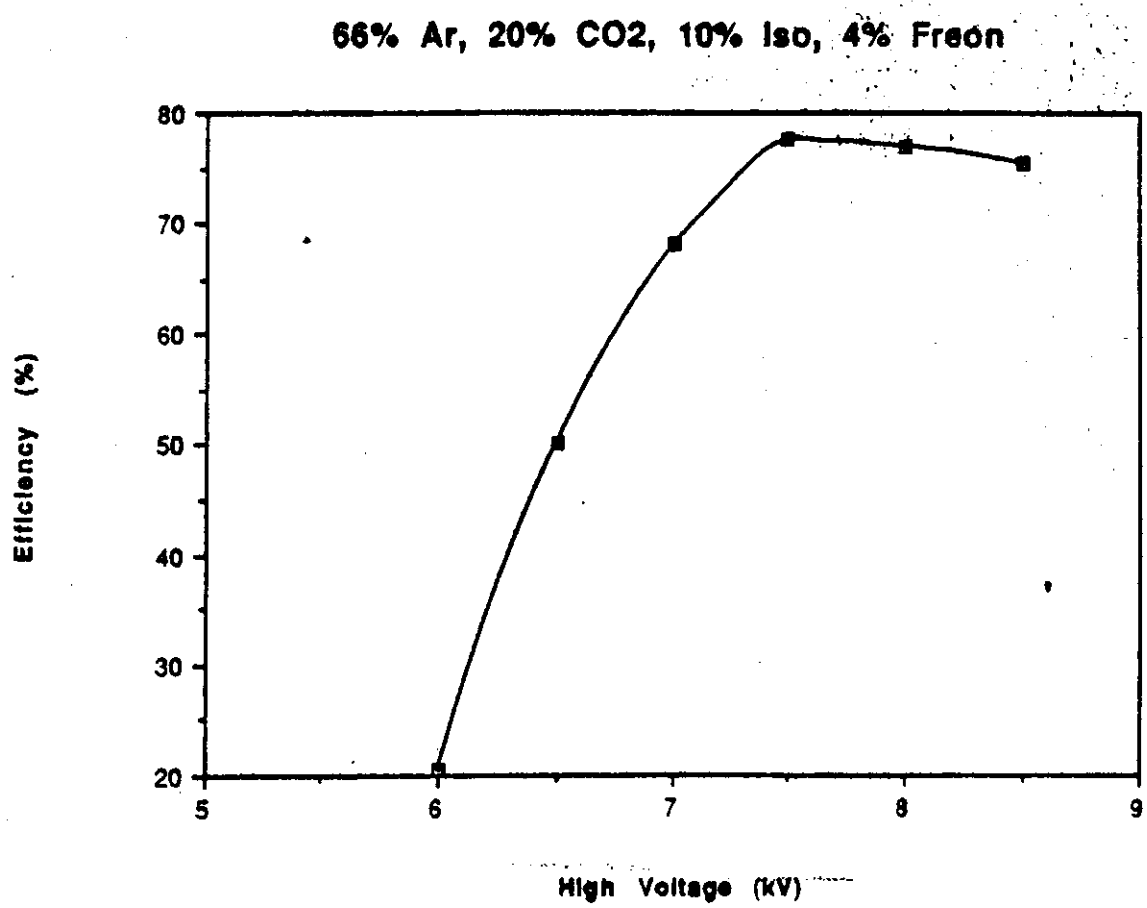

0.25 m² RPC
RPC Singles rate -
eleven 1.3 cm strips or'd together
Cosmic ray rate (232 cm² doubles)
RPC and cosmics (triples)
RPC Count Rate (Hz)
10000
1000
100
10
1
0.1
5000
6000
7000
8000
RPC Voltage


0.25 m²RPC
RPC singles rate per.cm²
RPC efficiency
RPC Singles Rate (Hz/cm²) or Efficiency
RPC Voltage
100
10
1
0.1
0.01
5000
6000
7000
8000

60% AR, 20% CO_2, 10% ISO,
4% FREON



20 NANOSECONDS/DIV


66% Ar, 20% CO2, 10% Iso, 4% Freon
Efficiency (%)
80
70
60
50
40
30
20
5
6
7
8
9
High Voltage (kV)

Scott Whitaker

FRANK TAYLOR

RATE CAPABILITY OF LSDTS

LSDT NOTE (TN-92-203) APPENDIX I

Performance - Temporal

"LOCAL WIRE LIMITATION" : ~ several msec

within 5 mm of previous hit

inefficiency? ⇒

$$1-\epsilon = R \cdot \Delta T \cdot 2\Delta L \cdot W$$

R = hit rate $cm^{-2} sec^{-1}$

$\Delta T = 2 \times 10^{-3}$ sec

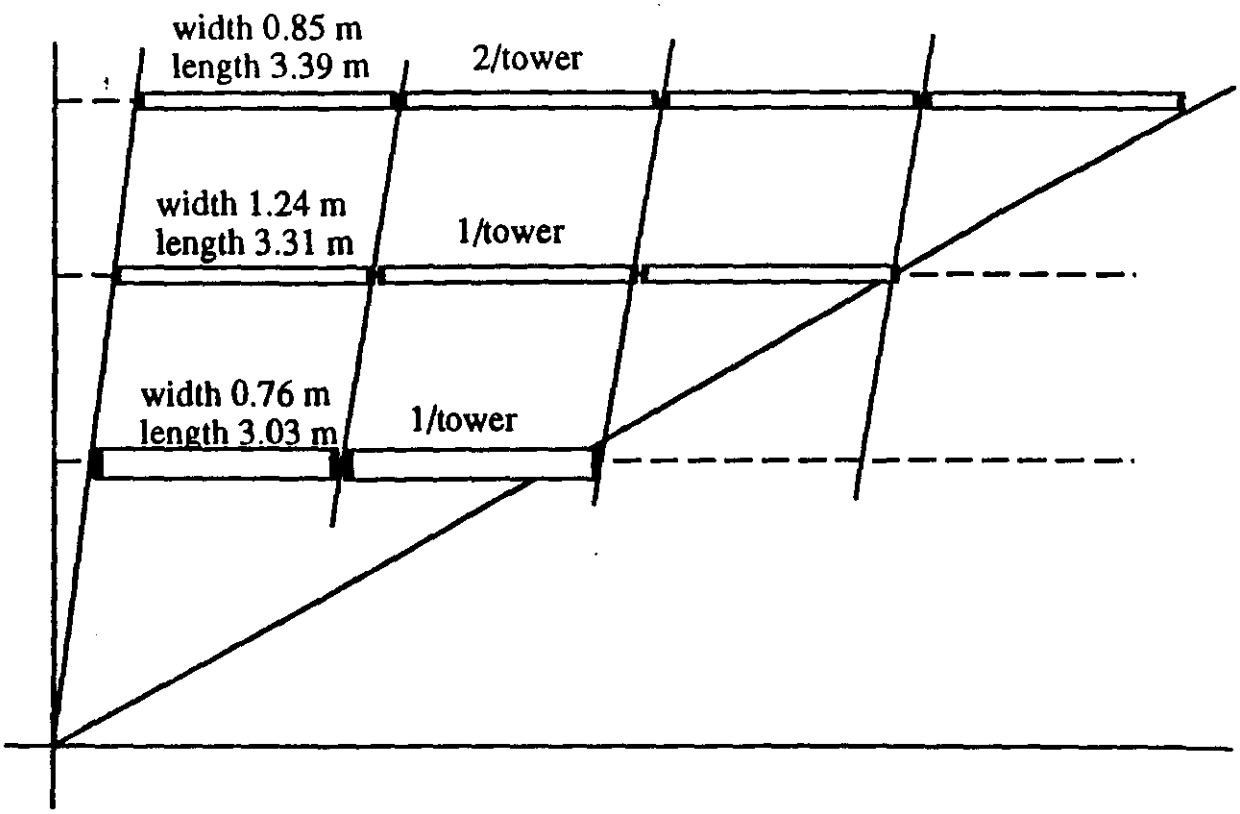
$\Delta L = 0.5$ cm

W = cell width 2.5 cm

$$1-\epsilon = 5 \times 10^{-3}\ cm^2 sec \times R$$

$1-\epsilon = 50\%$ for $R = 100 / cm^2 sec$

CSC Barrel Layout with Minimal Module Count



1. Combine layer 1 modules into 8-plane modules

2. IF alignment is manageable without projective towers, go to 3 modules per sector for layer 2

→ number of chambers = 2 x 32 x (4 x 2 + 3 + 2) = 832

Barrel CSC Layout

JSW 11-Oct-92

Nsct	32	frame width (m)	0.05
thmin (deg)	29.6	zclear (m)	0.05
thmax (deg)	83.71	ch modularity	1

Layer	1	2	3	
towers/sctr	2	4	4	
modules/tower	1	1	2	
radius (m)	3.854	6.282	8.588	
full width	0.859	1.337	0.946	
active width (m)	0.759	1.237	0.846	
phi ch pitch (m)	0.005	0.005	0.005	
ch/plane	152	247	169	
rnd to chmod	151	247	169	
full length	3.180	2.591	3.543	
active length	3.030	2.441	3.393	
z ch pitch (m)	0.095	0.103	0.105	
z ch / plane	32	24	32	
rnd to chmod	31	23	32	
planes/module	8	4	4	
phi ch / module	1208	988	676	
z ch / module	248	92	128	
				totals
Num. of modules	128	256	512	896
total phi ch	154624	252928	346112	753664
total zch	31744	23552	65536	120832

total ch	874496

dark borders mark settable parameters

Barrel CSC Layout

JSW 11-Oct-92

Nsct	32	frame width (m)	0.05
thmin (deg)	29.6	zclear (m)	0.05
thmax (deg)	83.71	ch modularity	**16**

Layer	1	2	3	
towers/sctr	2	3	4	
modules/tower	1	1	2	
radius (m)	3.854	6.282	8.588	
full width	0.859	1.337	0.946	
active width (m)	0.759	1.237	0.846	
phi ch pitch (m)	**0.007**	0.005	**0.007**	
ch/plane	108	247	121	
rnd to chmod	112	256	128	
full length	3.180	3.455	3.543	
active length	3.030	3.305	3.393	
z ch pitch (m)	0.095	0.103	0.105	
z ch / plane	32	32	32	
rnd to chmod	32	32	32	
planes/module	8	4	4	
phi ch / module	896	1024	512	
z ch / module	256	128	128	
				totals
Num. of modules	128	192	512	832
total phi ch	114688	196608	262144	573440
total zch	32768	24576	65536	122880

total ch	696320

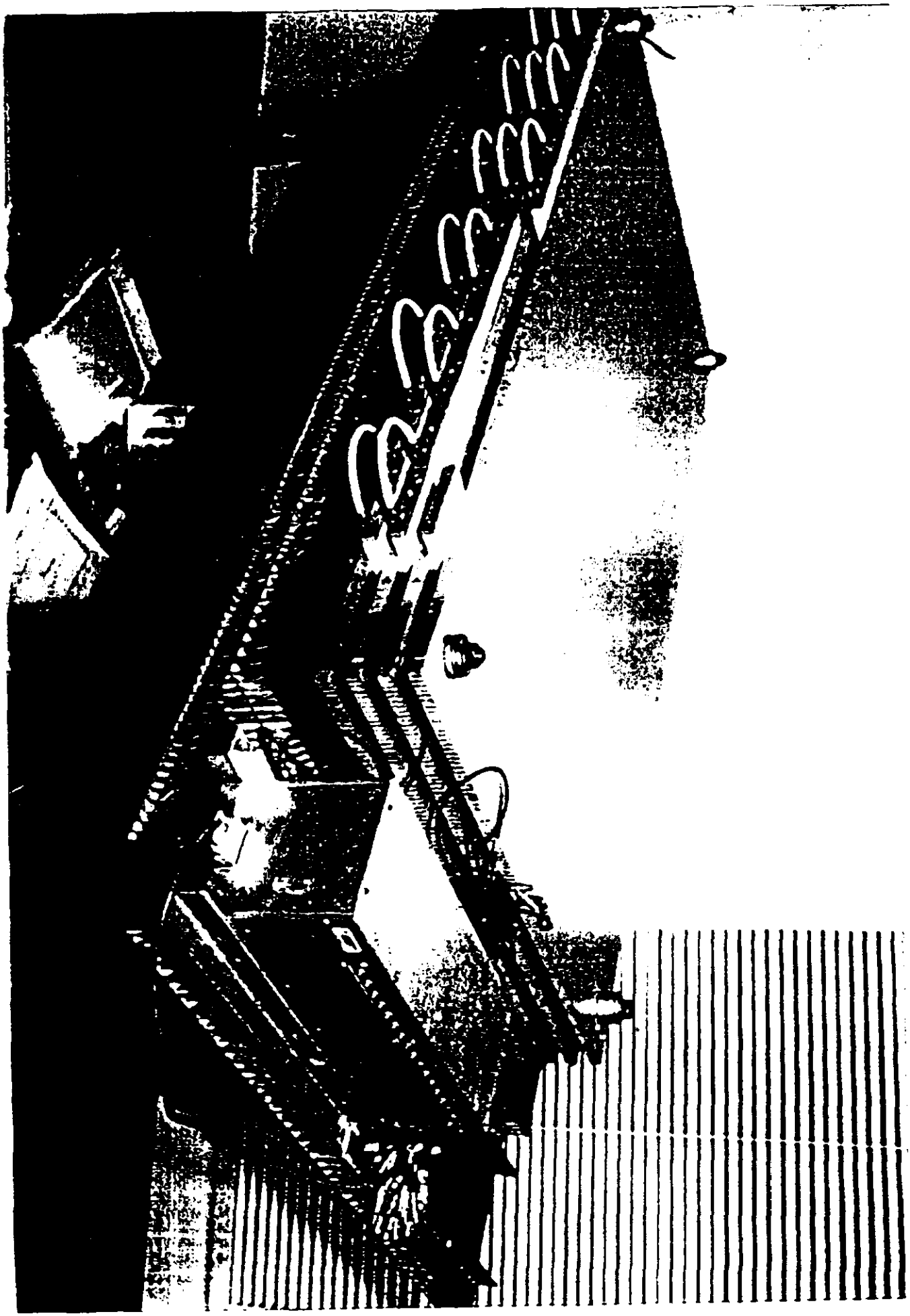
dark borders	mark settable parameters

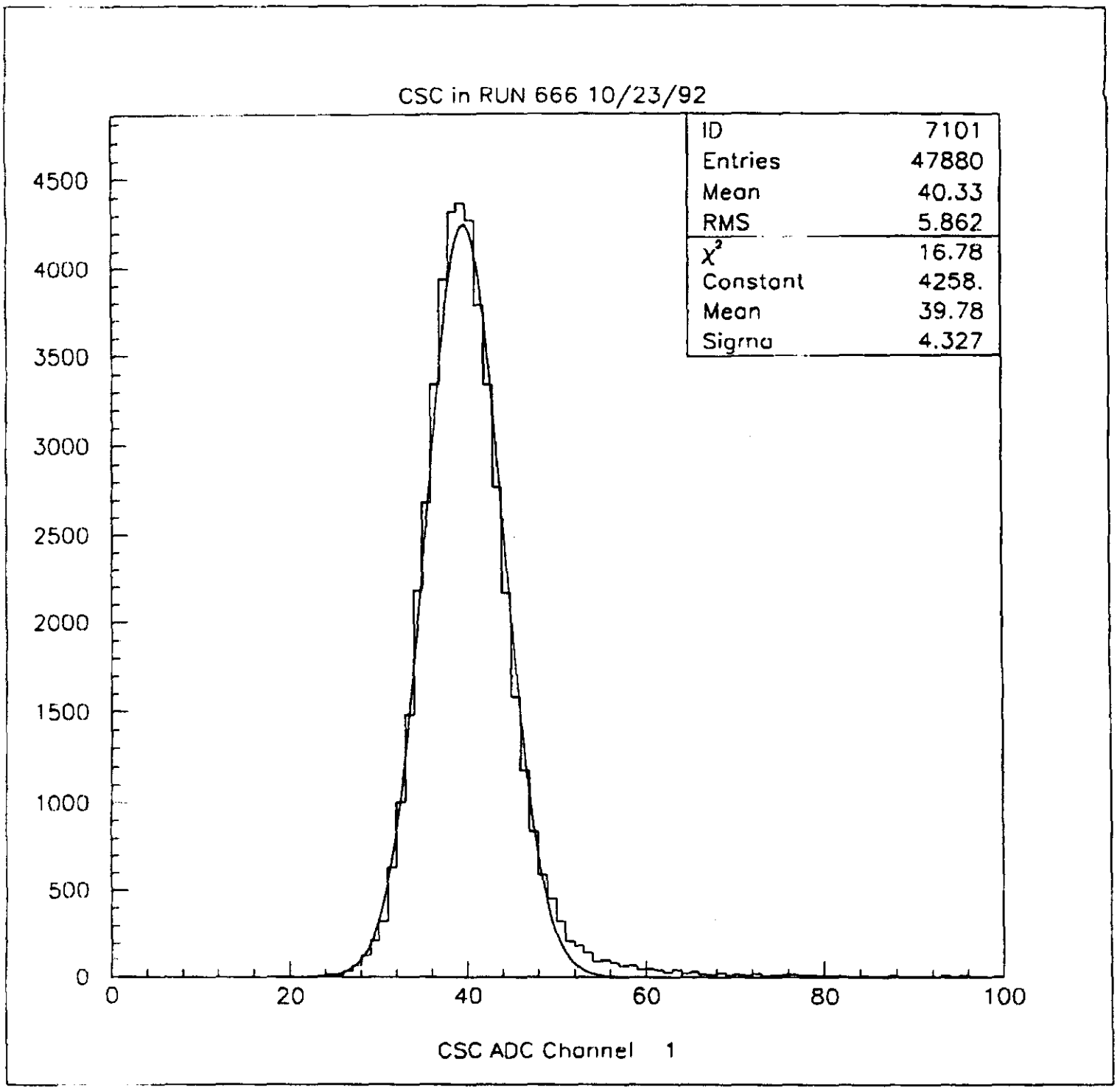
Kwong Lau

Preliminary Test Results of UH CSC Prototype at TTR

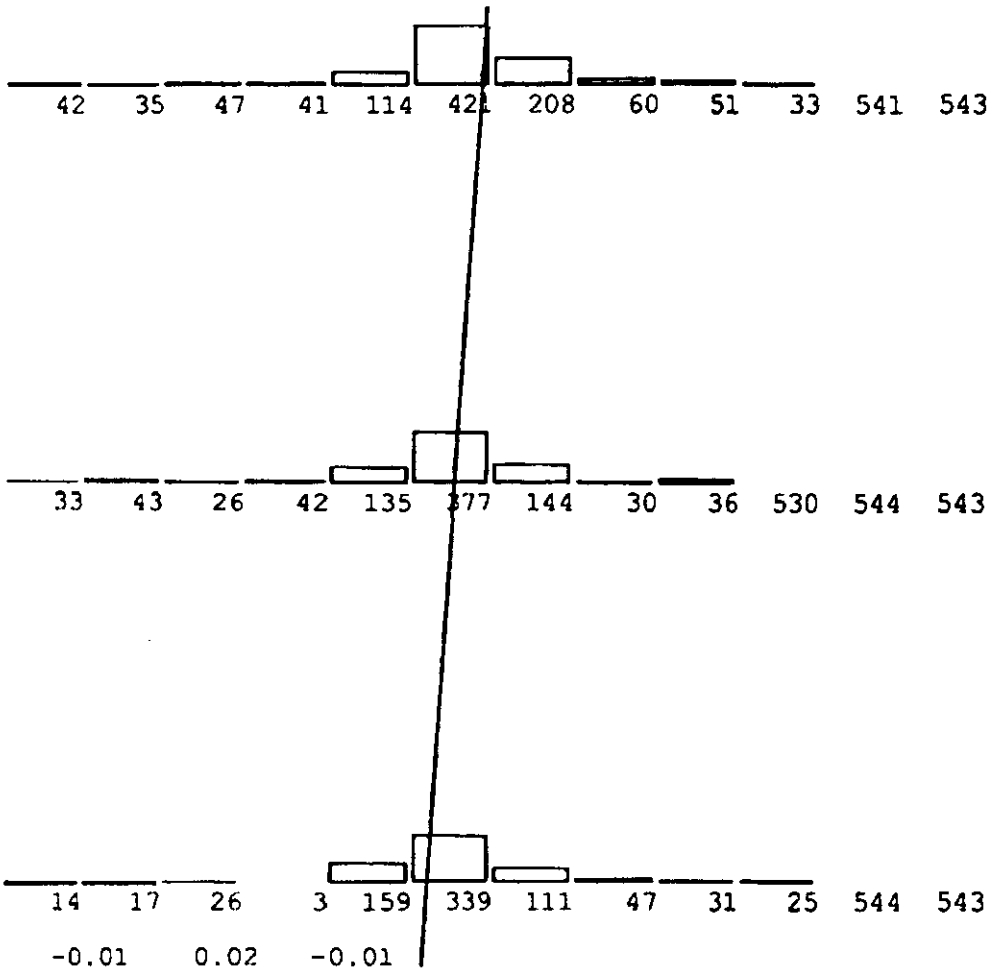
Kwong Lau

Nov 7, GEM μ Meeting

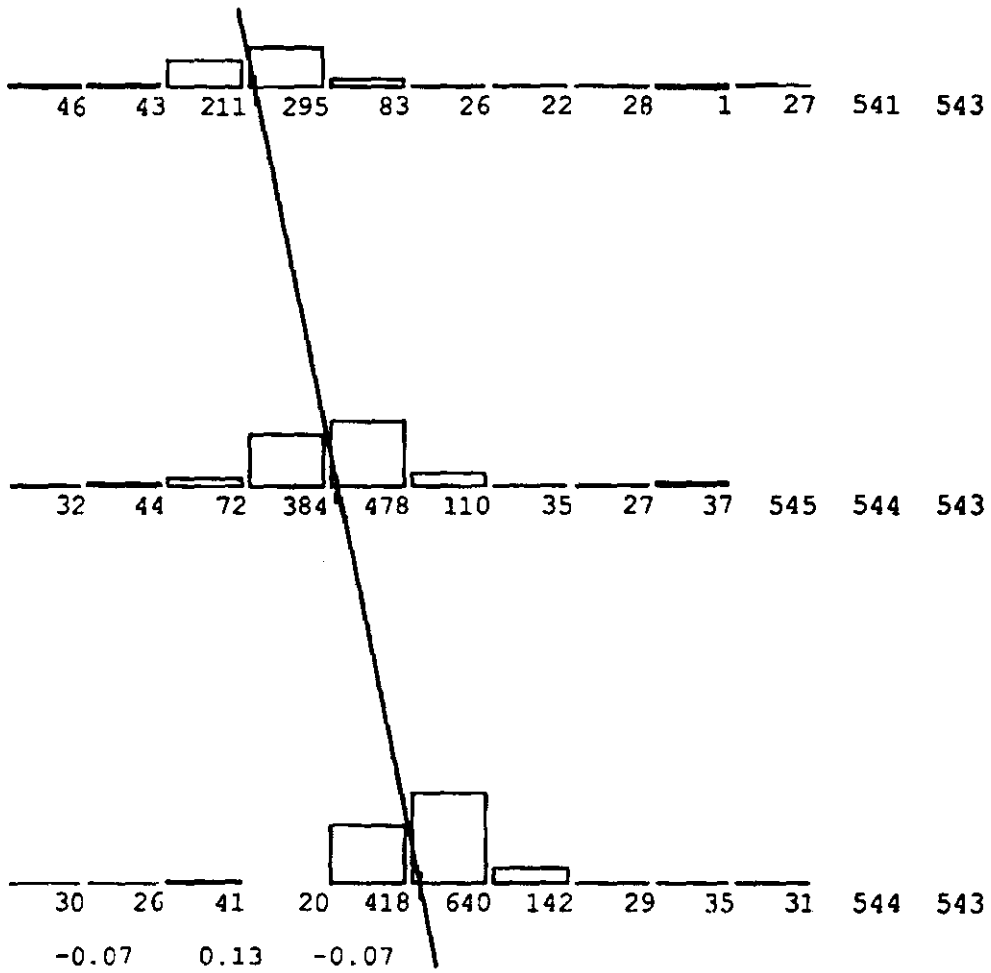



CSC in RUN 666 10/23/92
ID 7101
Entries 47880
Mean 40.33
RMS 5.862
χ² 16.78
Constant 4258.
Mean 39.78
Sigma 4.327
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
20
40
60
80
100
CSC ADC Channel 1

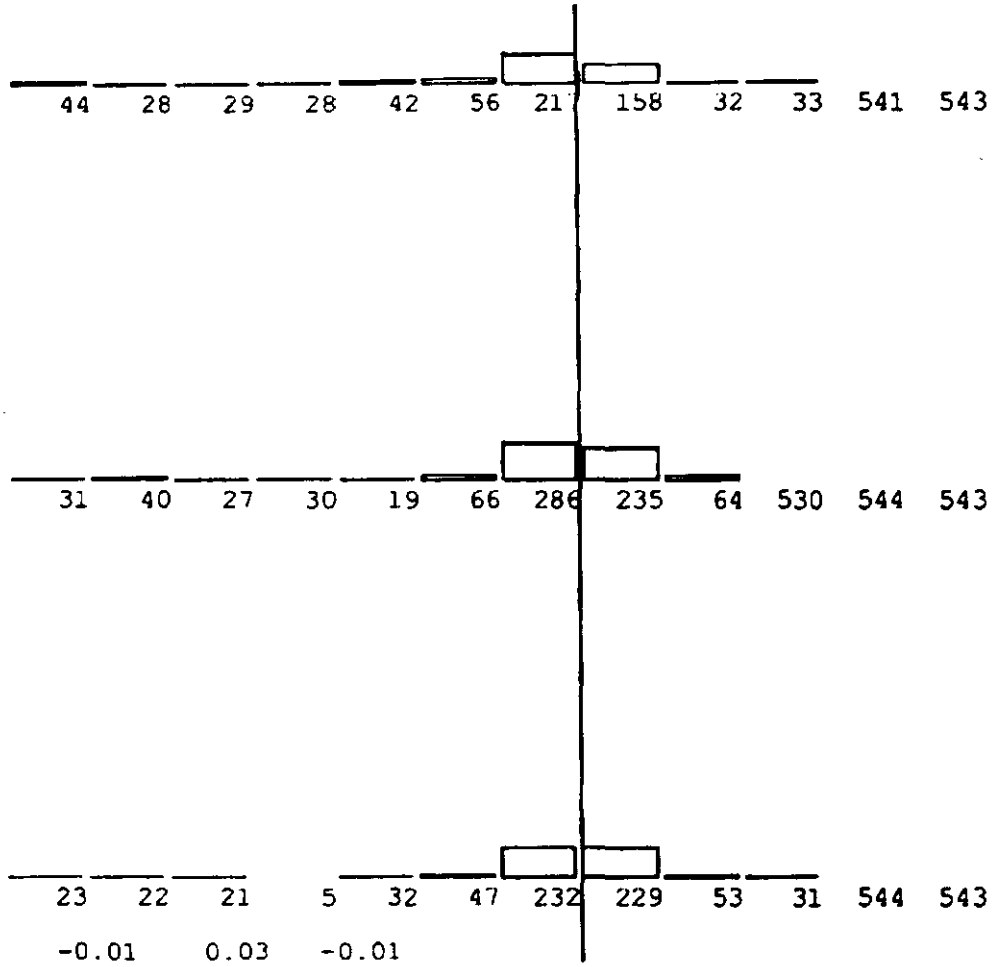
Run#: 666 Events on File: 45442 groups on file: 2
Event#: 4200 Fri, Oct 23, 1992 17:45

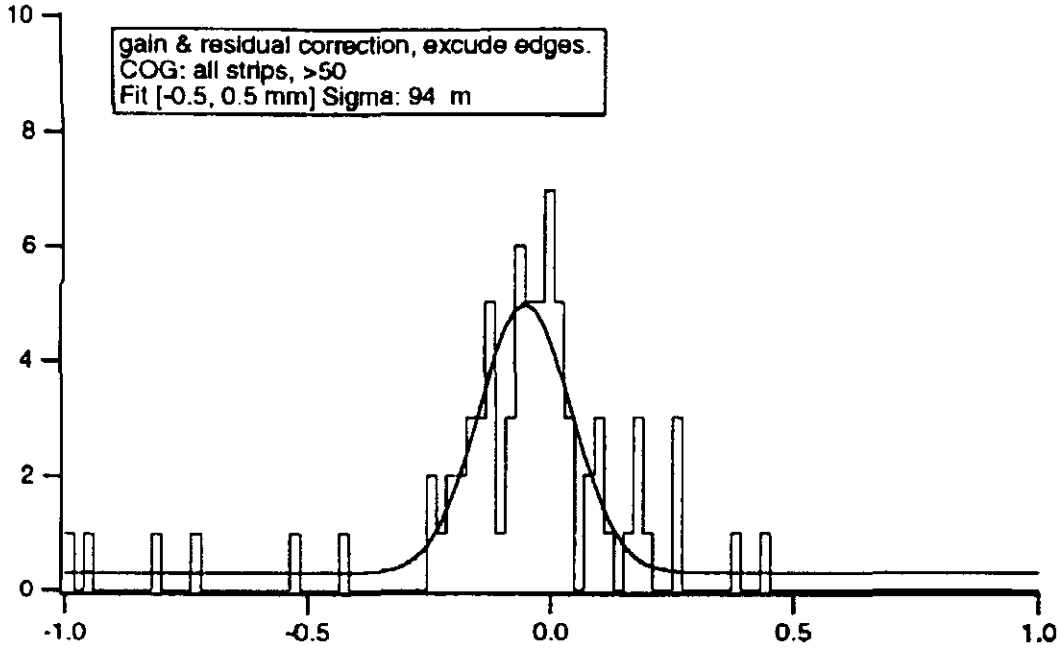


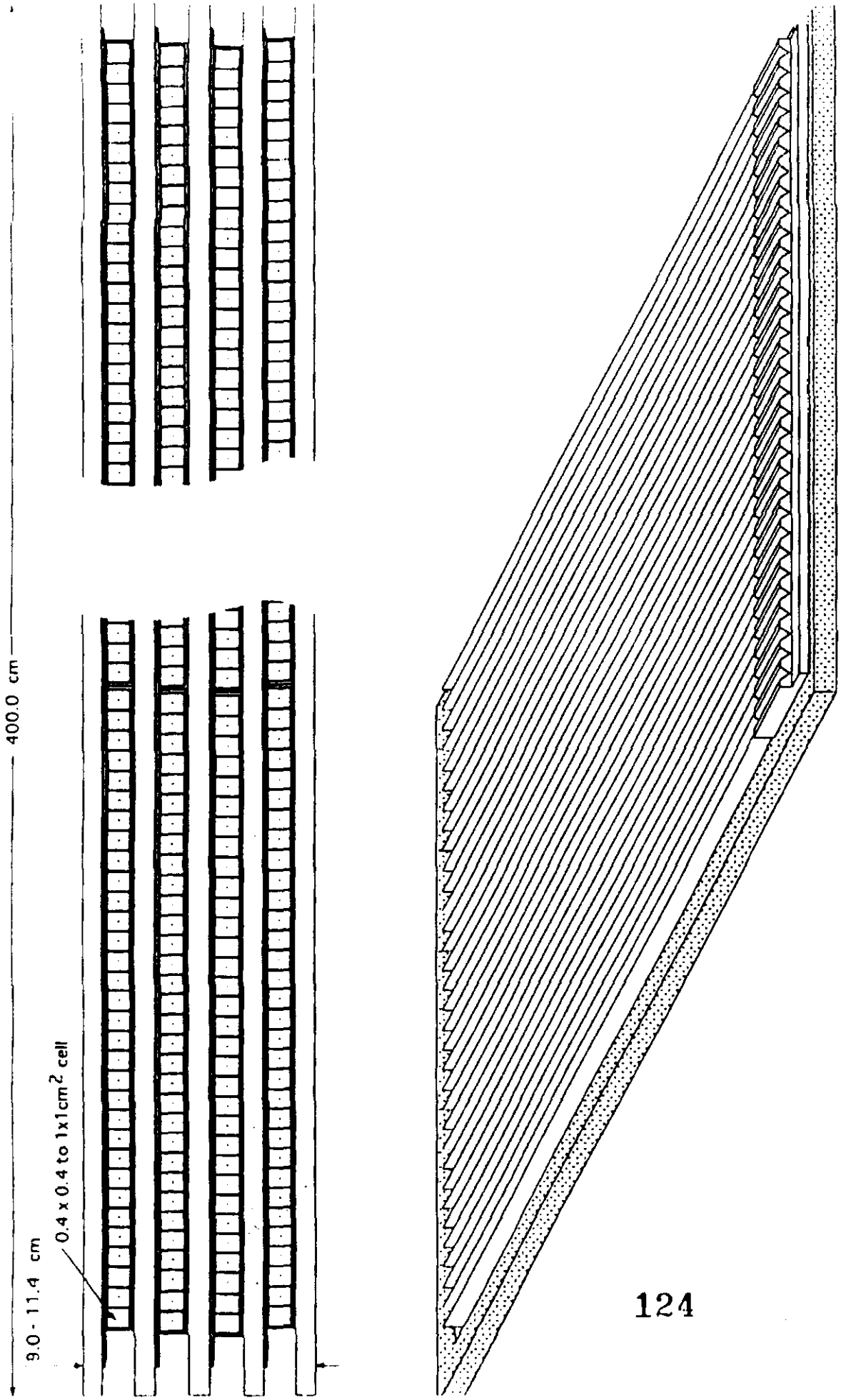
Run#: 666 Events on File: 46017 groups on file: 2
Event#: 1571 Fri, Oct 23, 1992 17:41



Run#: 666 Events on File: 46607 groups on file: 2
Event#: 2722 Fri, Oct 23, 1992 17:43




gain & residual correction, excude edges.
COG: all strips, >50
Fit [-0.5, 0.5 mm] Sigma: 94 m
10
8
6
4
2
0
-1.0
-0.5
0.0
0.5
1.0


400.0 cm
9.0 - 11.4 cm
0.4 x 0.4 to 1x1cm^2 cell

Mike Shaevitz

Subj: Assessment of the LSDT T0 Determination

Received: From NEVIS(SHAEVITZ) by MITLNS with Jnet id 3422
for FET@MITLNS; Tue, 3 Nov 1992 10:47 EST
Date: Tue, 3 Nov 92 10:44 EST
From: <SHAEVITZ@NEVIS>
Subject: Assessment of the LSDT T0 Determination
To: fet@mitlns
Original_To: JNET%"fet@mitlns", SHAEVITZ

Frank,

The following brief report comes basically from discussions at Nevis between myself, Bill Sippach, John Parsons, and Al Gara. Our bottom-line conclusion is that it should be possible to implement a T0 finding scheme in electronics but it will require that the alignment, time to distance function, and geometry be downloaded into the trigger electronics system with an accuracy of better than 150 microns. The cost is also non-negligible. I circulated the text to the following group: D.Marlow, M.Atiya, L.Osborne, D.Sumner, and B.Willis. I received comments back from Osborne and Atiya. Osborne reiterated that the four plane packages were in one chamber package and should allow alignments well within the 150 microns. Maged replied that he thought the number should be 100 rather than 150 microns and that the trigger TDC measurement error and muon deleta-rays will make the efficiency worse than quoted. He is doing some simulations and will prepare a writeup. I hope these thoughts will be of some use in the muon technology deliberations.

Mike

==========

Assessment of LSDT T0 Determination

Several members of the trigger group have been considering the Korytov triggering scheme where the bunch crossing is determined directly from the LSDT chamber drift times. The basic L1 trigger is formed using the cell hits alone in SL2 and SL3 to isolate tracks with Pt greater than 10 to 50 GeV. (The documents describe 4-fold coincidences in each of three stations SL2A, SL2B, and SL3 which is more than adequate to reduce the 10kHz/wire noise rate. In fact, 3- fold coincidences may be better in order to limit chamber efficiency effects while reducing the noise rate.) The cell hits are also used to make a crude measurement of the angle in SL2 (to about 5mr) for correcting the T0 measurement.

After the basic L1 trigger, the layers in SL2A and SL2B are taken in pairs to calculate T0 from the measured times using the Korytov scheme to correct for the drift time and track angle. Since all the discriminator hits are brought out to external racks, the signals are readily available for implementing these schemes in hardware. It is, therefore, believed that an electronics system could be developed that would identify the bunch crossing for each basic L1 trigger.

Many questions arise, though, concerning the exact implementation, cost, and efficiency. The implementation is not a trivial project and will probably double the electronics development effort needed. From the electronics scheme sketched by Sumner in the LSDT writeup and the one outlined by Marlow in his brief note, one would guess a cost of approximately $20/channel but this depends critically on the exact system design.

The major questions concerning the viability of these schemes are related to the estimates of T0 finding efficiency. While the redundancy due to having twelve pairs of layers seems very safe, this could degrade if many layers were rendered ineffective due to noise, chamber problems, or mis-alignment.

(The estimated efficiency is 99% for 12 pairs and reduces to 95% for 6 pairs.) For the Korytov scheme to work, the positions of the wires need to be known by the trigger system to about 150 microns and the relevant constants or patterns need to be downloaded to the trigger electronics. This would necessitate a reasonably good alignment available to the trigger electronics at the beginning and throughout the running. The trigger efficiency will depend on how accurately this alignment is known and maintained. Temperature and pressure drifts may need to be monitored leading to updated constants that need to be downloaded periodically. Since the chambers are in super-layer packages, some of the drifts due to temperature expansion and gas density changes will cancel when comparing adjacent layers and the packages may make the alignment tolerances easier to achieve.

While it appears that a scheme such as Korytov proposed can be implemented in hardware for determining T0 with the LSDT planes, the method is complicated and relies on a detailed parameterization of the muon system geometry in the trigger system. More straight forward techniques using faster detectors would seem to be a better choice.

Dan Marlow

CSC Readout Electronics
Design & Cost

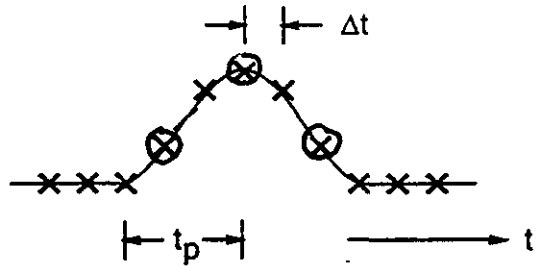
Presented at the

GEM Muon Technology
Selection Meeting
at BNL

Daniel R. Marlow
Princeton University

Nov. 5
~~October 6~~, 1992

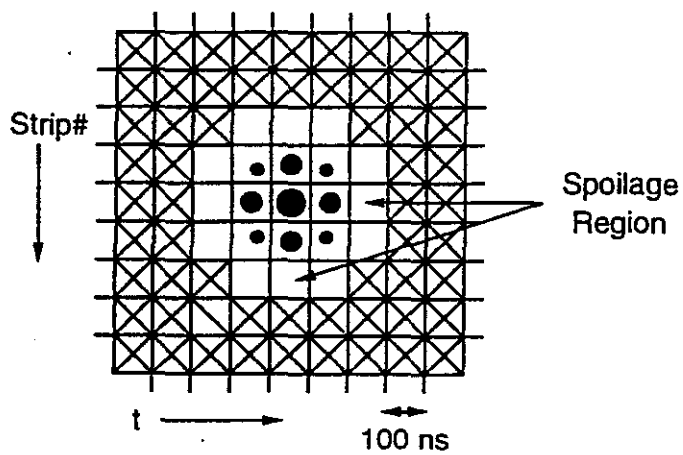
Analog Pipeline (SCA) Option



Assume

$$t_p = \text{pulse peaking time} = 300 \text{ ns}$$

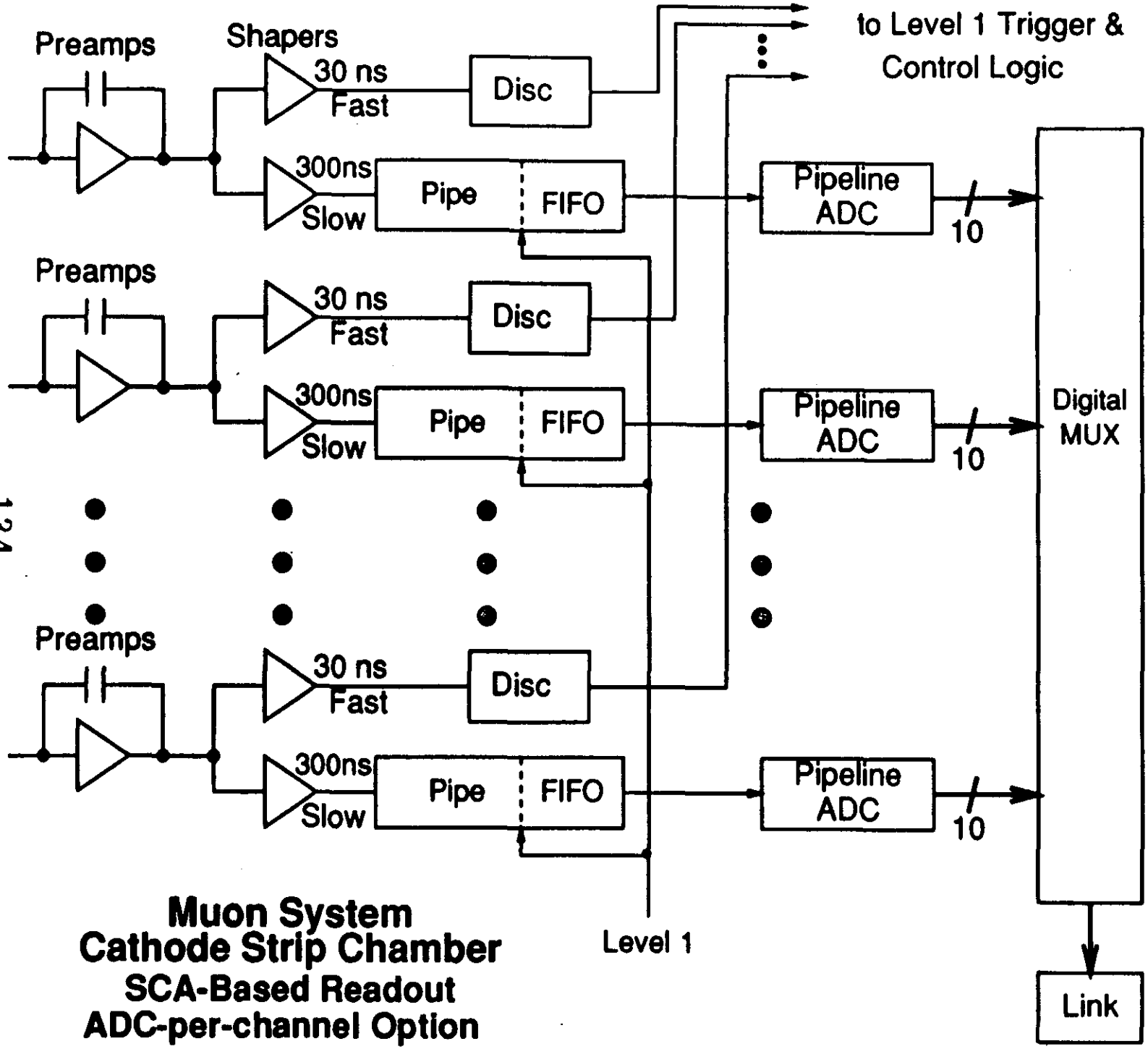
$$\Delta t = \text{sample clock period} = 100 \text{ ns}$$



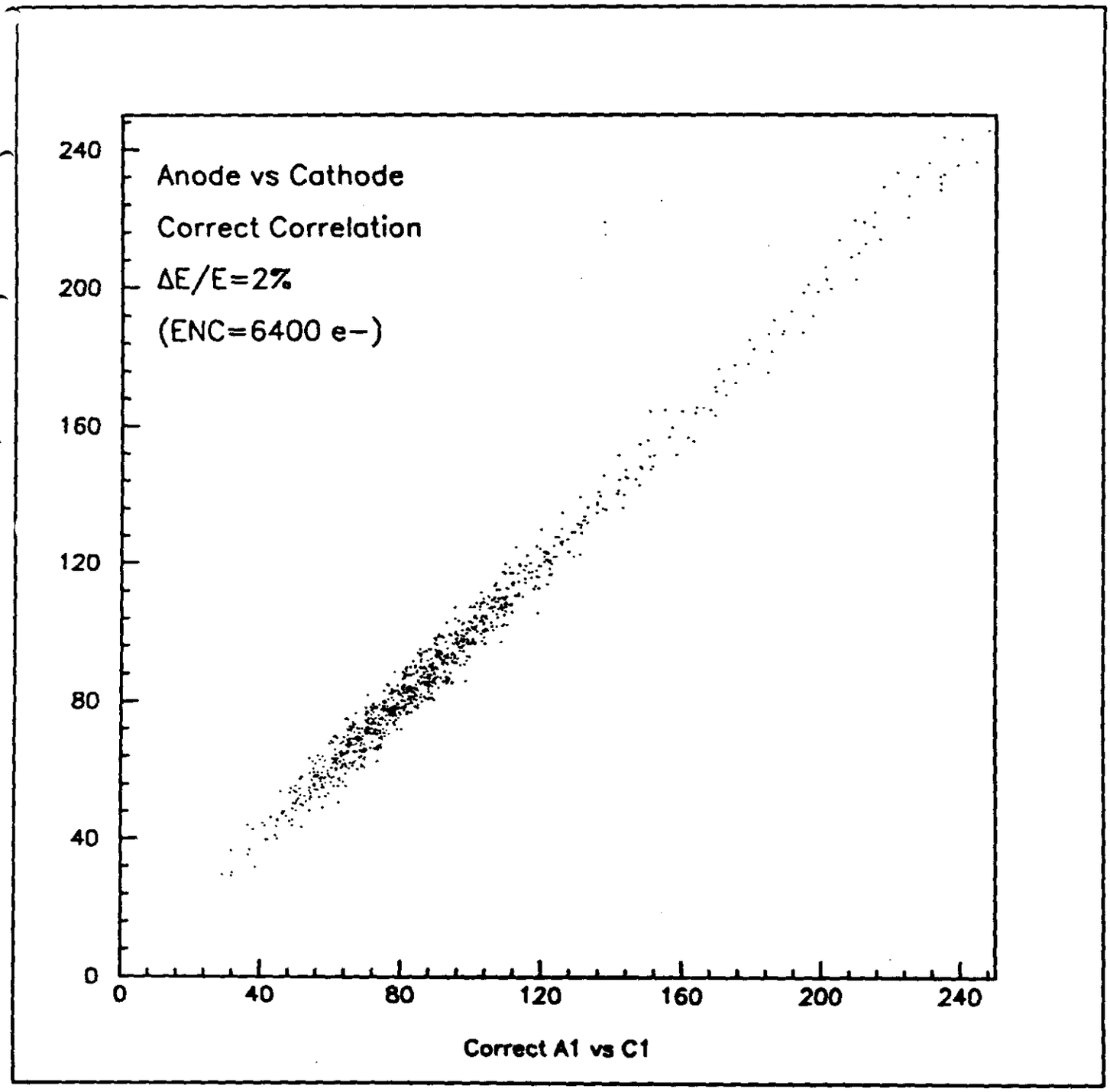
If accidental pulses falling within the indicated region in the space-time grid shown above are considered to spoil the signal pulse, the maximum unspoiled rate is given by

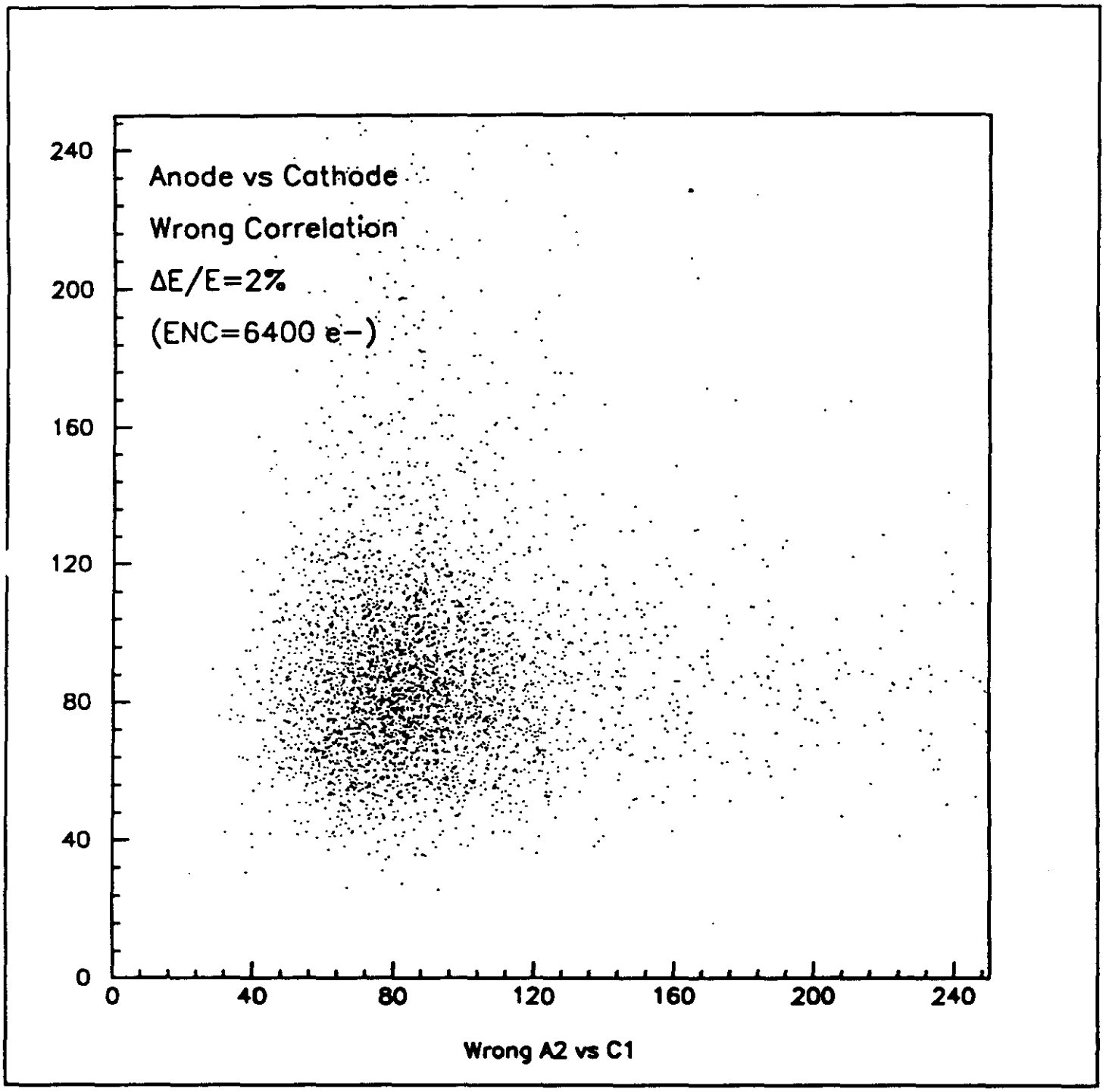
$$R_{\max} = \frac{p_{\max}}{21\Delta t} = \frac{0.1}{21 \times 10^{-7}} = 48 \text{ kHz}$$

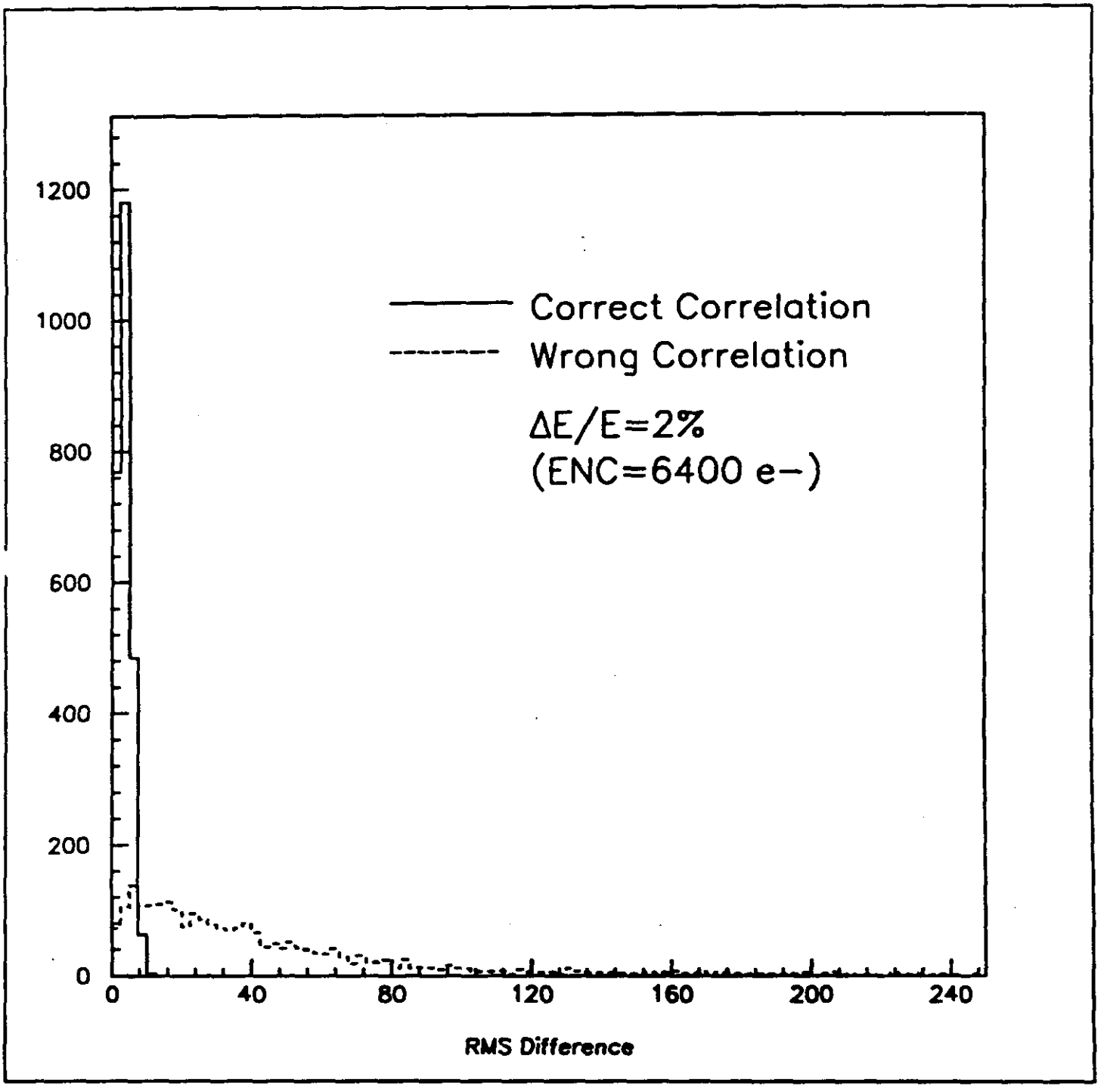
(corresponding to $r = 320 \text{ cm}^{-2}\text{s}^{-1}$)

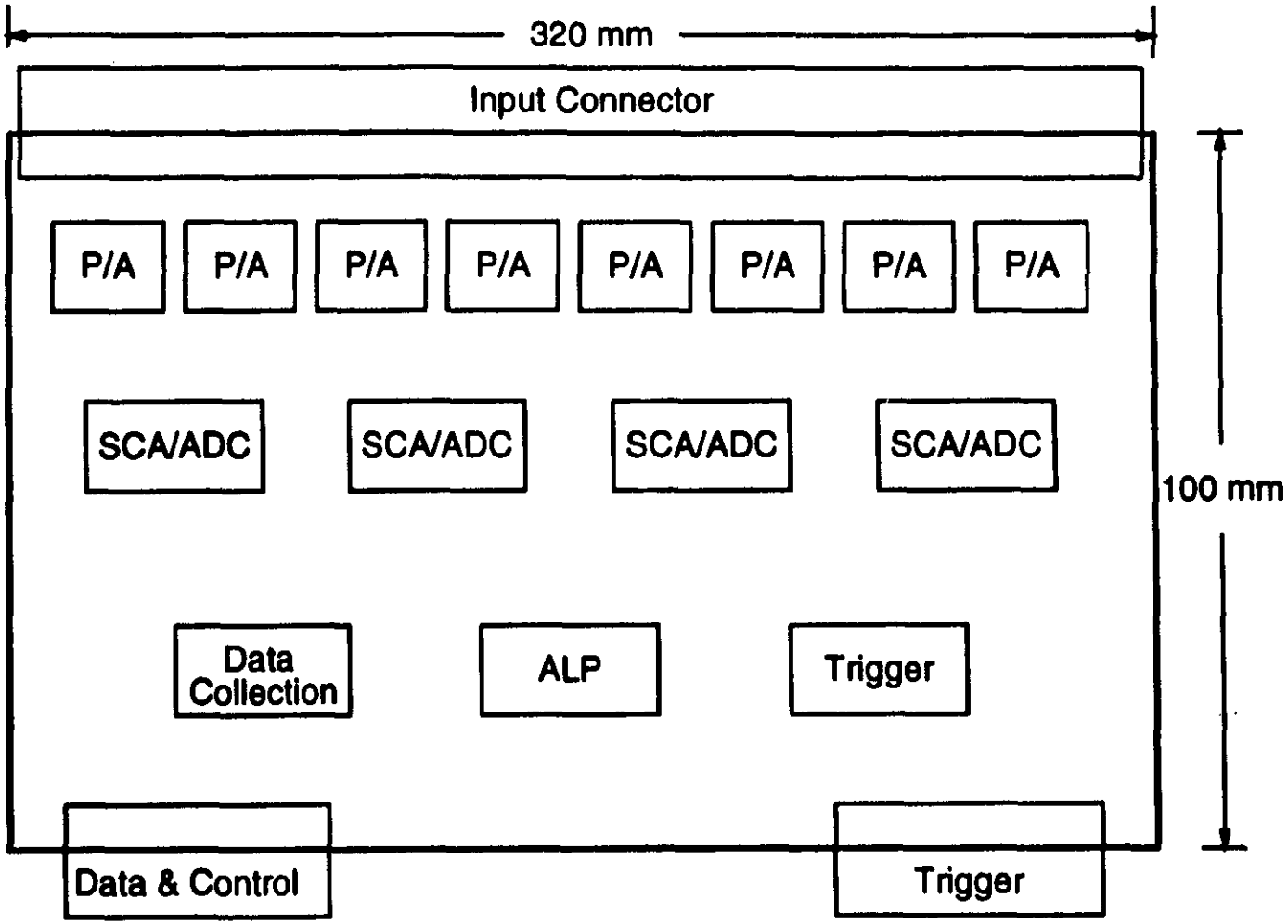


Muon System
Cathode Strip Chamber
SCA-Based Readout
ADC-per-channel Option


Anode vs Cathode
Correct Correlation
ΔE/E=2%
(ENC=6400 e−)
240
200
160
120
80
40
0
0
40
80
120
160
200
240
Correct A1 vs C1


Anode vs Cathode
Wrong Correlation
ΔE/E=2%
(ENC=6400 e−)
240
200
160
120
80
40
0
0
40
80
120
160
200
240
Wrong A2 vs C1


1200
1000
800
600
400
200
0
0
40
80
120
160
200
240
RMS Difference
Correct Correlation
Wrong Correlation
ΔE/E=2%
(ENC=6400 e−)



(Not to scale)

CSC Chamber Board Layout

64 Channels

Electronics Cost Estimate

Item	$/Board	$/Chan
IC's (see summary table)	$ 281	$ 4.39
PCB Fab. (0.15 $/cm^2)	$ 48	$ 0.75
Connectors (Male & Female)	$ 64	$ 1.00
Misc. Parts (W.A.G.)	$ 20	$ 0.32
Assy (1500 leads at $ 0.06/lead)	$ 90	$ 1.41
Q/A (20 min)	$ 10	$ 0.16
Test (1 man-hour)	$ 30	$ 0.47
Rework (20% at 2 hrs/ea)	$ 12	$ 0.19
LVPS (200 mW/chan at $ 5.00/W)	$ 64	$ 1.00
Mounting Hardware (W.A.G)	$ 20	$ 0.31
Packing & Shipping	$ 20	$ 0.31
Subtotal	$ 659	$ 10.30
Contingency (30%)	$ 198	$ 3.08
Grand Total	$ 857	$ 13.40

- Assumptions
  - 64 channel board of area 32 × 10 cm^2 (8 layers)
  - Includes P/A shaper, SCA/ADC, DCC, & 1st Level Trigger
  - SDC chip costing rules
  - PC costs based on discussions with U.S. & Canadian vendors
  - Assume SMT for automated assembly
  - Fixed costs of R&D, EDIA, & NRE not included

IC Cost Summary

SDC IC Costing Rules						
Size	Area	Yield	Fab.	Pkg	Test	Total
Tiny	6.8 mm^2	70%	$ 2.05	$ 1.00	$ 7.50	$ 10.55
Small	35 mm^2	65%	$ 11.17	$ 1.50	$ 8.00	$ 20.67
Medium	50 mm^2	60%	$ 17.65	$ 2.00	$ 8.50	$ 28.15

Non-recurring expenses (NRE):

— $ 25K per design for masks
— $ 5K per design for testing setup

CSC IC's			
Description	Type	Chans/Pkg	$/Chan
P/A Shaper	Tiny	8	$ 1.32
SCA/ADC	Medium	16	$ 1.75
ALP	Medium	64	$ 0.44
DCC	Medium	64	$ 0.44
Trig	Medium	64	$ 0.44
Total			$ 4.39

CSC System Cost Summary

- Additional Front End WBS Elements (added cost per 1000-channel-module)

— HVPS & Cable	\$ 200
— Fiber Data Links	\$ 370
— Trigger Cable	\$ 120
— Total add'l per chan. (incl. 30% cont.)	\$ 0.90

- Grand total per channel: \$13.40 + \$0.90 = \$14.30
- Channel Count
  - — 1050 K fine cathodes
  - — 160 K anodes (or coarse cathodes)
  - — 1210 K total
- Fixed cost of R&D, prototypes, etc. \$ 2760 K (from LRS report)
- Total Front End Cost (Includes contingency)

$$\boxed{\$2760\text{ K} + 1210\text{ K} \times \$14.30 = \$20.1\text{ M}}$$

- There is an additional \$ 6.6 M in the LRS report for the Level 1 trigger.

Daniel Marlow
Revised 10/7/92

Overall Cost Comparison for GEM Electronics

		Production				
System	Proto.	Cost/Chan	Cont	# Chan	Subtotal	Total
Si Vtx	$ 3,010 K	$ 2.13	30.6%	3200 K	$ 8,922 K	$ 11,933 K
IPC	$ 3,230 K	$ 16.11	36.4%	400 K	$ 8,791 K	$ 12,021 K
Calor.	$ 4,016 K	$ 141.80	30.5%	86 K	$ 15,290 K	$ 19,936 K
RPC	$ 560 K	$ 53.67	23.4%	33 K	$ 2,186 K	$ 2,745 K
DC Wire	$ 1,686 K	$ 37.40	35.6%	110 K	$ 5,578 K	$ 7,264 K
CSC Pad	$ 2,761 K	$ 19.48	40.8%	242 K	$ 6,642 K	$ 9,403 K
CSC Wire	$ 334 K	$ 34.35	25.0%	29 K	$ 1,245 K	$ 1,579 K
Hybrid Muon Front End Subtotal						$ 20,991 K
CSC Pad'	$ 2,761 K	$ 11.00	30.0%	1210 K	$ 17,303 K	$ 20,064 K

Comments

1.) As noted yesterday, the CSC wire development (prototype) costs in the hybrid muon approach have been overestimated due to a bookkeeping error. The correct number is approximately $ 334 K. The table above has been revised to reflect this correction.

2. A bottom-up (BU) cost estimate of the drift-wire readout has not been done. **Thus it is not possible to make a dependable systematic comparison on the time scale of a few hours.** In comparing costs one might be tempted to perform a simple "scaling", by the ratio of the bottom-up estimate to the LRS estimate for the CSC's—i.e. by scaling the production costs according to

$$F = \frac{\$11.00 \times 1.300}{\$19.48 \times 1.408} = 52\%$$

It is far from clear, however, that this is valid. In particular, the mix of integrated circuits versus cables and connectors is different for the two systems—the drift-wire schemes have on-chamber preamplifier/discriminators that drive cables to magnet-mounted rack electronics. The CSC electronics are almost entirely chamber-mounted.

Bearing in mind these caveats, the application of such a scaling exercise results in a reduction in the production costs for the hybrid scheme. This results in a revised total for the hybrid scheme of

$$\begin{aligned}\text{Cost}' &= \$20.99\ \text{M} - (1 - 0.52) \times (\$2,186\ \text{K} + \$5578\ \text{K} + \$6642\ \text{K} + \$1245\ \text{K}) \\ &= \$13.5\text{M}\end{aligned}$$

3. In the GEM WBS the first stage of the Level 1 trigger is by convention included as part of the front end electronics costs since the circuits will physically reside on the front-end boards. This has been done in both the LRS analysis and the bottom-up CSC cost analysis. In the hybrid (with RPC) scheme the inclusion of this circuitry is reflected in the higher per-channel cost of the RPC front ends.

   In addition there is, for all technologies, a separate system that performs the additional processing needed to condense the large number of trigger signals to a single trigger signal that can be fanned out system-wide. This is by convention included in a separate branch (the "Level 1 Trigger") of the WBS. All of the proposed trigger schemes start with a number of trigger elements that is driven by the required trigger segmentation, which is technology independent. Thus to a first approximation, the cost of these systems will be independent of technology and should be ignored when estimating possible cost Δ's.

Rick Sawicki

Muon Cost Estimating Status

BARREL ONLY

Richard Sawicki
Lawrence Livermore National Laboratory
November 4, 1992

Cost estimating contributors

- Cost coordinator
  - R. Gustavson, Draper
- Chamber material and assembly costs
  - CSC, C. Johnson, LLNL/SSCL
  - LSDT, J. Kelsey, MIT
  - PDT, C. Bromberg, MSU
- Assembly costs- foreign
  - I. Golutvin, Dubna
  - Y. Xie, IHEP
- Structural and cooling system costs
  - F. Nimblett, Draper
- Gas system costs
  - M. MacKernan, LLNL
- Electronic system
  - D. Marlow, Princeton
  - S. Calhoun, US Cost
- Alignment system costs
  - R. Sawicki, LLNL

Muon Technology Cost Summary

BARREL ONLY

	CSC	LSDT (w/trig)	PDT	(+) RPC	LSDT w/RPC	PDT w/RPC
Design	367	526	369	369	895	738
Material/Fabrication	13579	10179	6990	1995	12174	8985
Shipping	371	243	187	187	430	374
Facility Preparation	594	834	594	474	1308	1068
Assembly/Test	15157	8950	10785	1867	10817	12652
Support Structure	3267	3267	3120	0	3267	3120
Alignment	2309	2564	1063	15	2579	1078
Gas System	1467	1652	1496	242	1894	1738
Cooling System	1475	25	25	25	50	50
Electronics	9647	6771	5583	1687	7134	7270
SUBTOTAL	48233	35011	30212	6861	40548	37073
Contingency	16785	9377	8169	1778	11002	9946
TOTAL	65018	44388	38381	8639	51550	47019

17999 -26.1 -2432 0

173 9.

PDT with trigger:

Contingency assumptions

- Mechanical hardware
  - 30% contingency for PDT, LSDT and RPC technologies
  - 36% contingency for CSC technology

- Electrical hardware
  - 20% of PDT, LSDT and RPC technologies
    - -- although design is primitive it is conservative
  - 30% for CSC technology
    - -- design concept is agressive

	CSC	LSDT	PDT	RPC
Mechanical contingency	13891	8471	7389	1552
Electronic contingency	2894	905	780	226
Total contingency	16785	9376	8169	1778
Total if contingency = 30%	14469	10503	9064	2058
Difference	-2316	+1127	+895	+280

Material cost status

- Bottom-up mechanical system costs have been developed for all technologies

- LSDT and PDT costs, in general, are based on actual costs of prototype parts or vendor estimates for production parts

- CSC material costs now have supporting quotations for major structural components
  - cathode strips (CCT Marketing)
  - honeycomb panel with cathode plain attached (MC Gill)

CSC Material Costs

Chamber		A	B	C	D	TOTALS	
width (mm)		740	740	1320	960		32 sectors per barrel half
length (mm)		3152	3028	2515	3506		
panel area (m^2)		2.33	2.24	3.32	3.37		
ch/sector		2	2	4	8		
chambers/GEM		128	128	256	512	1024	
wire (m/panel)		903	867	1275	1308		2.5 mmpitch, full chamber width
wire (m/GEM)		231268	221872	652861	1339294	2,445,296	
		0.19366	0.19366	0.19366	0.19366		MC Gill "b"
		685.86	685.86	685.86	685.86		MC Gill "a"
COSTS:							
cath, plain	$/m^2	5	5	5	5		End cap quote
cath, strips	$/m^2	258	258	258	258		CCT marketing
manuf panel	$/panel	$1,386.01	$1,358.46	$1,682.37	$1,696.17		MC Gill (Cost=a+b*area(in**2))
wires	$/m	0.29	0.29	0.29	0.29		Quote from Luma
cir brds	$/m^2 of panel	50	50	50	50		estimate
cath, plain	$/GEM	$8,957.	$8,604.	$25,496.	$51,698.	$94,755.	
cath, strips	$/GEM	$308,111.	$295,990.	$877,065.	$1,778,414.	$3,259,580.	
manuf panel	$/GEM	$887,044.	$869,416.	$2,153,437.	$4,342,191.	$8,252,087.	
wires	$/GEM	$67,068.	$64,343.	$189,330.	$388,395.	$709,136.	
cir brds	$/GEM	$59,711.	$57,362.	$169,974.	$344,654.	$631,702.	
JINR spacers	$/GEM	$59,711.	$57,362.	$169,974.	$344,654.	$631,702.	estimated as same as cir brds
MATERIALS	$/GEM	$1,390,603.	$1,353,078.	$3,585,275.	$7,250,005.	$13,578,961.	

CSC MATERIAL COST PARAMETERIZATION (K$)

STRIPS ($/m^2)

Cost to Man Panels ($/m^2)	670	600	550	500	450	400	350	300	250	200	150
600	20008	19123	18492	17860	17228	16596	15965	15333	14701	14070	13438
550	19218	18334	17702	17070	16439	15807	15175	14543	13912	13280	12648
500	18428	17544	16912	16281	15649	15017	14385	13754	13122	12490	11859
450	17639	16754	16123	15491	14859	14228	13596	12964	12332	11701	11069
400	16849	15965	15333	14701	14070	13438	12806	12175	11543	10911	10279
350	16059	15175	14543	13912	13280	12648	12017	11385	10753	10121	9490
300	15270	14385	13754	13122	12490	11859	11227	10595	9964	9332	8700
250	14480	13596	12964	12332	11701	11069	10437	9806	9174	8542	7911
200	13691	12806	12175	11543	10911	10279	9648	9016	8384	7753	7121

MUON SYSTEM
COST ESTIMATION WORKSHEET

WBS Element Title: Central Region Sector Assembly; LSDTs; Off-Site; Machining/Inspection

WBS Element No: 03.2.1.2.3.1.5 **Date:** 28 Oct 92 **Rev:** 4 **Estimator:** Hamilton/Weinstein/Osborne/Kelsey

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

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

M&S: Engineering/Design and Inspection/Administration **($K):** 79

Misc. office supplies for Inspection/Administration:	$28K
PC/Mac/workstation charges:	$72K
Travel: 1 person, 4 trips to machine shop, inspection shop @$2K/trip	$8K

Inspection/Administration **PY:** 11.75 **Comp. Rate($K/PY):** 90 **PoP:** 1/94-3/96

Assumes Engrg. (natl. avg) oversight of stock/mat'l purchase activity: 7/8-time for 24 mos = 1.75 PY
Assumes Jr. Tech (natl.avg) performing inspection activity: 5 tech, full-time for 2 yrs = 10.00 PY

Procurement/Fabrication Material **($K)** 8967
from Weinstein/Osborne estimate:

aluminum for enclosures (extrusions):	$1174K
bridges:	$1808K
wire:	$356K
cathode planes:	$3011K
misc:	$80K
Hexcell (top & bottom)	$1517K
z-planes	$971K

Installation/Assembly **PY:** **Comp. Rate($K/PY):** **PoP:**
from Weinstein/Osborne estimate:

Material: Installation/Assembly **($K)** 0

Contingency **Total:** 30

Technical:	16	Basis:	new design, some R&D required
Cost:	6	Basis:	in-house estimate, minimal experience
Schedule:	8	Basis:	delays completion of critical path item

Comments

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MUON SYSTEM
COST ESTIMATION WORKSHEET

WBS Element Title: Central Region Sector Assembly; PDTs; Off-Site; Machining/Inspection

WBS Element No: 03.1.1.2.3.1.5 **Date:** 23 Oct. 92 **Rev:** 4 **Estimator:** Hamilton/Miller

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

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

M&S: Engineering/Design and Inspection/Administration **($K):** 42

Misc. office supplies for Inspection/Administration:	$14K
PC/Mac/workstation charges:	$20K
Travel: 1 person, 4 trips to machine shop, inspection shop @$2K/trip	$8K

Inspection/Administration **PY:** 5.63 **Comp. Rate($K/PY):** 68 **PoP:** 1/94-3/96

Assumes Engineering (nat. avg) oversight of stock/mat'l purchase activity: 1/4-time for 24 mos = .50 PY
Assumes Engineering (nat'l avg) oversight of machng & inspect activity: 1/2-time for 2.25 yrs = 1.13 PY
Assumes Sr. Tech (job shop) performing inspection activity: 1 tech, full-time for 2 yrs = 2.00 PY
Assumes Jr. Tech (job shop) performing inspection activity: 1 tech, full-time for 2 yrs = 2.00 PY

Procurement/Fabrication Material **($K)** 5959
from Miller estimate:

tubes	$3411K
plugs	$388K
wire	$114K
manifold plates	$1440K
Hexcell case	$86K
wire guides	$342K
R.O. Boards	$178K

Installation/Assembly **PY:** 6.34 **Comp. Rate($K/PY):** 95 **PoP:** 1/94-12/95
based upon Miller estimate:

assumes Sr.Tech, (nat'l avg) to fabricate tubes: 1.67 sr.tech. for 2 yrs = 3.34 PY
assumes Jr.Tech, (nat'l avg) to fabricate tubes: 1.50 jr.tech. for 2 yrs = 3.00 PY

Material: Installation/Assembly **($K)** 4
Misc. office supplies for Installation/Assembly = $4K

Contingency **Total:** 30

Technical:	16	Basis:	new design, some R&D required
Cost:	6	Basis:	in-house estimate, minimal experience
Schedule:	8	Basis:	delays completion of critical path item

Comments

DRAPER LABORATORY Nov 2.92 13:31 No.008 P.02

MUON SYSTEM
COST ESTIMATION WORKSHEET

WBS Element Title: Central Region Sector Assembly; RPCs; Off-Site; Machining/Inspection

WBS Element No: 03.1.1.2.4.1.5 **Date:** 16 June 92 **Rev:** 3 **Estimator:** T. Hamilton, C. Wuest

Scope: This element covers the labor and labor costs for the machining and inspection of the Bakelite RPC and assembly fixturing. Also, costs for oversight and purchasing of stock and material for machining.

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

M&S: Engineering/Design and Inspection/Administration **($K): 45**

Misc. office supplies for Inspection/Administration:	$15K
PC/Mac/workstation charges:	$22K
Travel: 1 person, 4 trips to machine shop, inspection shop @$2K/trip	$8K

Inspection/Administration **PY: 6.19** **Comp. Rate($K/PY): 68** **PoP: 1/94-3/96**

Assumes Engineering (nat'l avg) oversight of stock/material purchase activity: 1/4-time for 24 mos = .50 PY
Assumes Engineering (nat'l avg) oversight of machng & inspect activity: 1/2-time for 2.25 yrs = 1.13 PY
Assumes Engineering (SSCL) oversight of machng & inspect activity: 1/4-time for 2.25 yrs = 0.56 PY
Assumes Sr. Tech (job shop) performing inspection activity: 1 tech, full-time for 2 yrs = 2.00 PY
Assumes Jr. Tech (job shop) performing inspection activity: 1 tech, full-time for 2 yrs = 2.00 PY
- no inspection cost estimate provided from Wuest/Pless
- estimate of $100K (approx. 2 PY) for inspection from Weinstein/Osborne estimate approx doubled

Procurement/Fabrication Material **($K) 900**
from Wuest/Pless "Second Order" estimate:

aluminum U-channel:	$12K
Bakelite sheet (2mm):	$74K
Foam sheet (2mm):	$3.2K
Aquadag:	$46K
mylar (0.005"):	$42K
spacers, glue, etc.:	$1.0K
material for structural support:	$444K

- for structural support material: Wuest/Pless "first order" estimate of $600/m^2$ was prorated against materials, machining, and assembly based on percentages established on Page 3 of Wuest/Pless "First Order" estimate: $300/m^2 \times 2743\ m^2 \times 54\% = \$444K$

- general M&S (nuts, screws, gas fittings, elect. connectors):	$232K
- fixtures stock:	$46K

Installation/Assembly **PY: 10.8** **Comp. Rate($K/PY): 57** **PoP: 1/94-12/95**
from Wuest/Pless "First Order" estimate:

<u>RPCs Machining</u>

1.) $25/m^2 \times 2743\ m^2 = \$68.6K/\$57K/PY = 1.0\ PY$

2.) for structural support machining: Wuest/Pless estimate of $300/m^2$ was prorated against materials, machining, and assembly based on percentages established on Page 3 of Wuest/Pless "Second Order" estimate
$300/m^2 \times 2743\ m^2 \times 54\% = \$444K/\$57K/PY = 7.8\ PY$

Assumed assembly fixtures: 2 machinists, full-time for 1 year: 2 PY = 10.8 PY total

Material: Installation/Assembly **($K) 13**

Misc. office supplies for Installation/Assembly:	$13K

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Electronic cost evaluation

- A bottom-up estimate for CSC, LSDT and PDT electronic cost (barrel only) has been assembled
- CSC evaluation has evolved over the last few months and is documented in cost reports by D. Marlow
- LSDT and PDT electronic designs (which are assumed to be the same) were quickly assembled in the last two weeks and are consequently much less defensible
- RPC costs have not been evaluated and are assumed to be the same as the LSDT and PDT on a $/channel basis → Probably much better than this!
- CSC total cost is the greatest of any of the technologies because of the high channel count (877,000 in the barrel)
- Drift tube channel cost is higher than the CSC because five electronic boards are required for each module (only 1 for CSC)
  - further evaluation may evolve a more optimized design

GEM MUON ELECTRONICS COST ESTIMATE

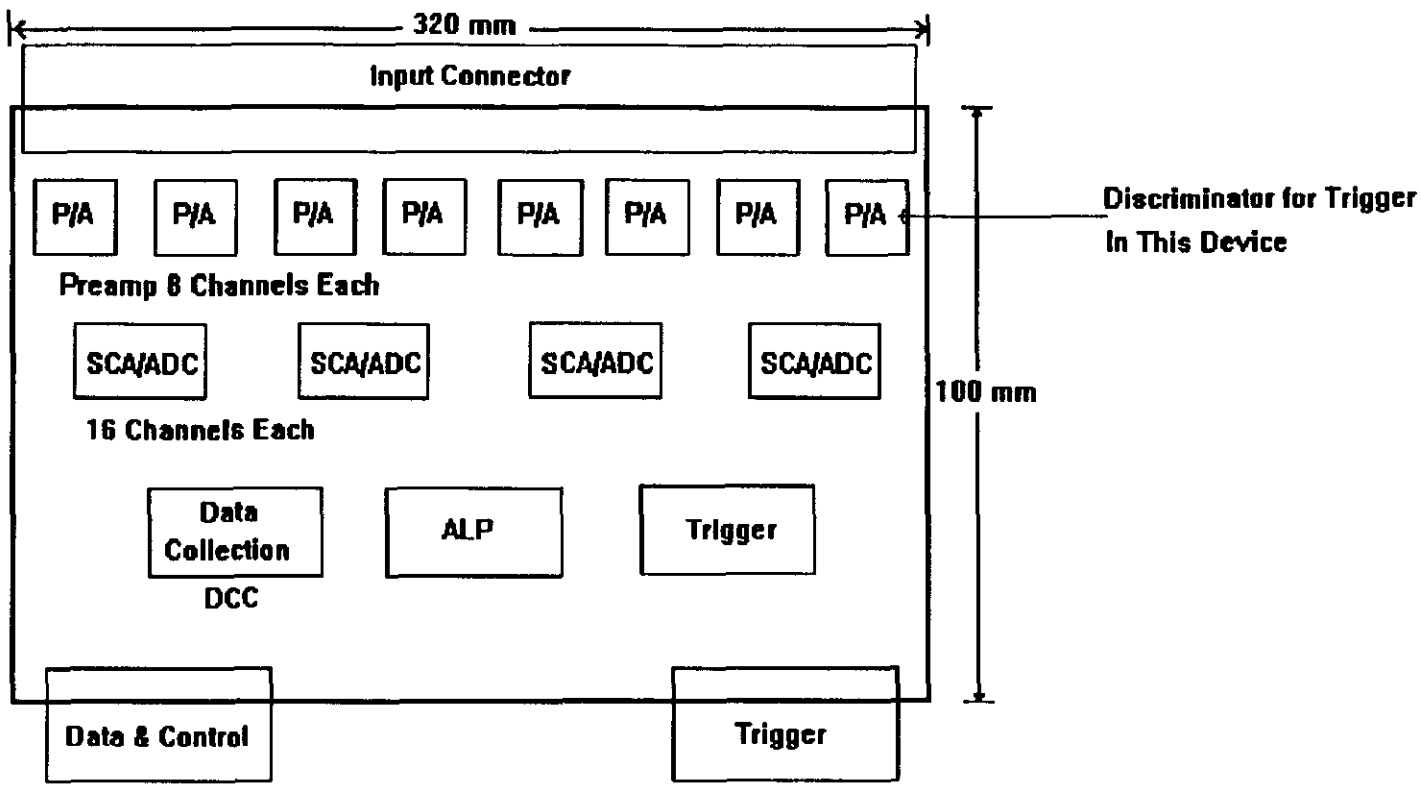
Item	CSC $/Chan	LSDT w/Trig $/Chan	LSDT w/RPC $/Chan	PDT $/Chan	PDT w/RPC $/Chan
IC's (see sumamry table)	$4.39	$12.32	$5.72	$5.72	$5.72
Capacitors	$0.00	$1.00	$1.00	$1.00	$1.00
PCB Fab. ($0.96/in^2)	$0.75	$5.42	$5.06	$5.06	$5.06
Connectors (Male & Female)	$1.00	$0.25	$0.25	$0.25	$0.25
Cables	$0.00	$6.25	$6.25	$6.25	$6.25
Misc. Parts (S.W.A.G.)	$0.32	$0.32	$0.32	$0.32	$0.32
Assembly (1500 leads @ $0.06/ea)	$1.41	$2.53	$2.53	$2.53	$2.53
Q/A @ 20 min/board	$0.16	$0.39	$0.39	$0.39	$0.39
Test @ 1 man-hour/board	$0.47	$1.17	$1.17	$1.17	$1.17
Rework 20% @ 2hrs/board	$0.19	$0.47	$0.47	$0.47	$0.47
LVPS (200 mW/chan @ $5.00/W)	$1.00	$1.00	$1.00	$1.00	$1.00
Mounting Hardware (S.W.A.G.)	$0.31	$0.31	$0.31	$0.31	$0.31
Packing & shipping	$0.31	$0.31	$0.31	$0.31	$0.31
Additional Front End Elements	$0.69	$9.40	$9.40	$9.40	$9.40
Subtotal Cost/Channel	$11.00	$41.14	$34.18	$34.18	$34.18
Channel Count	*877,000*	*110,000*	*143,000*	*114,000*	*147,000*
Subtotal Channel Cost	$9,647,000	4,525,400	4,887,740	3,896,520	5,024,460
Contingency (30% CSC; 20% others)	$3.30	$8.23	$6.84	$6.84	$6.84
Cost/Channel w/Contingency	$14.30	$49.37	$41.02	$41.02	$41.02
Channel Cost w/ Contingency	$12,541,100	$5,430,700	$5,865,860	$4,676,280	$6,029,940
Channels/ Board	*64*	*128*	*128*	*128*	*129*
Total Cost/Board	$915	$6,319	$5,251	$5,251	$5,292
			why?		
Fixed Cost (Prototype Development)	$0	$2,246,000	$2,246,000	$1,686,000	$2,246,000
Grand Total	$12,541,100	$7,676,700	$8,111,860	$6,362,280	$8,275,940

SDC IC Costing Rules						
Size	Area	Yield	Fab.	Pkg.	Test	Total
Tiny	6.8 mm^2	70%	$2.05	$1.00	$7.50	$10.55
Small	35 mm^2	65%	$11.17	$1.50	$8.00	$20.67
Medium	50 mm^2	60%	$17.65	$2.00	$8.50	$28.15

CSC IC's			
Description	Type	Chans/Pkg.	$/Chan.
P/A Shaper	Tiny	8	$1.32
SCA/ADC	Medium	16	$1.75
ALP	Medium	64	$0.44
DCC	Medium	64	$0.44
Trig	Medium	64	$0.44
Total			$4.39

IC COST TABLE
LSDT's/PDT'S

Description	Type	Chans/Pkg	$/Chan
Bipolar IC	Tiny	8	$1.32
Measurement TDC	Medium	8	$3.52
Clock 60MHz	Medium	128	$0.22
Data Collection Chips	Medium	64	$0.44
Trigger Chip	Medium	64	$0.44
Trigger - TDC	Medium	8	$3.52
Control Chips	Medium	21.3	$1.32
DRAM Chips	Medium	21.3	$1.32
FPCA	Medium	64	$0.44
TOTAL			$12.54

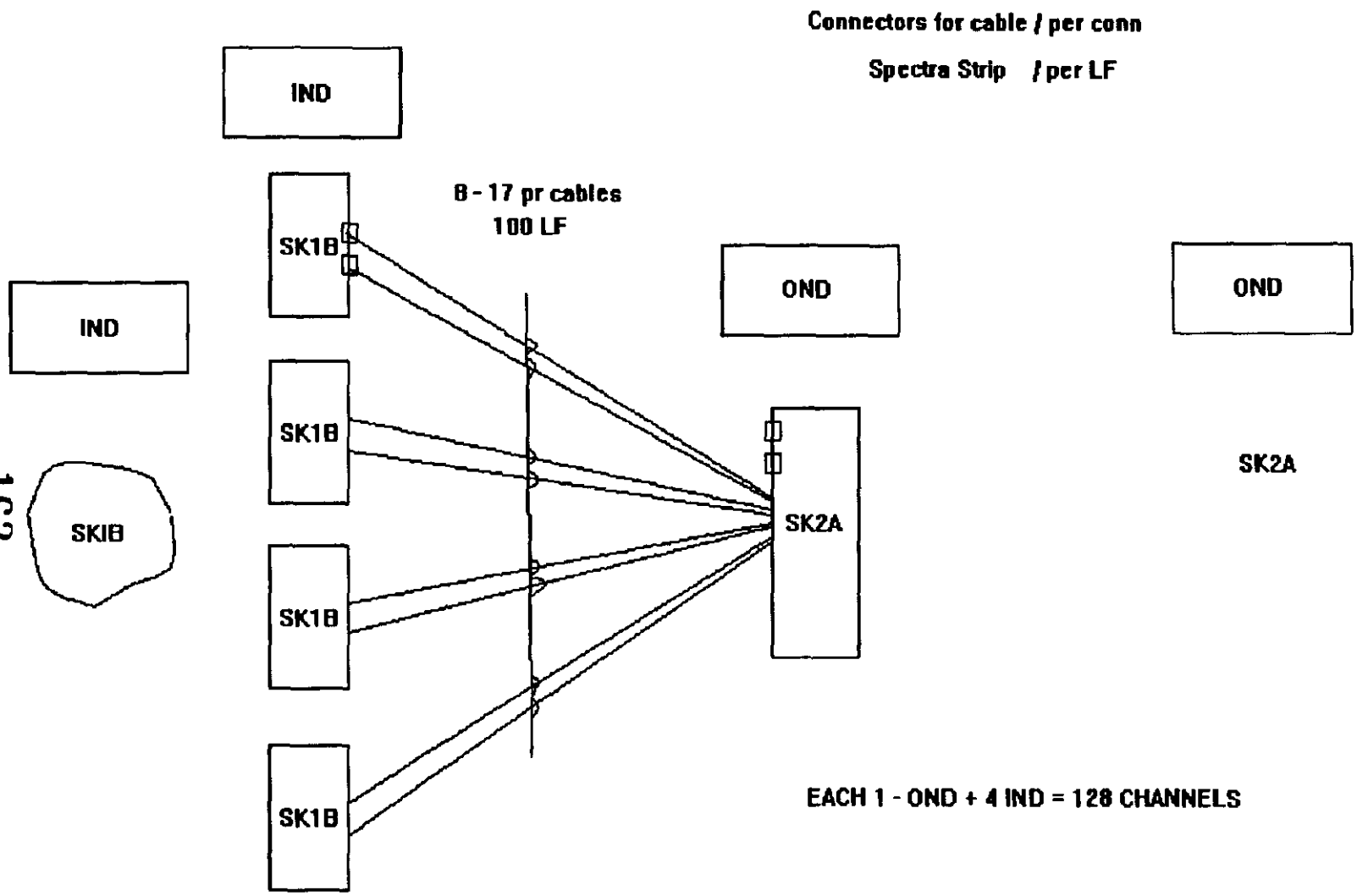


CSC CHAMBER BOARD LAYOUT

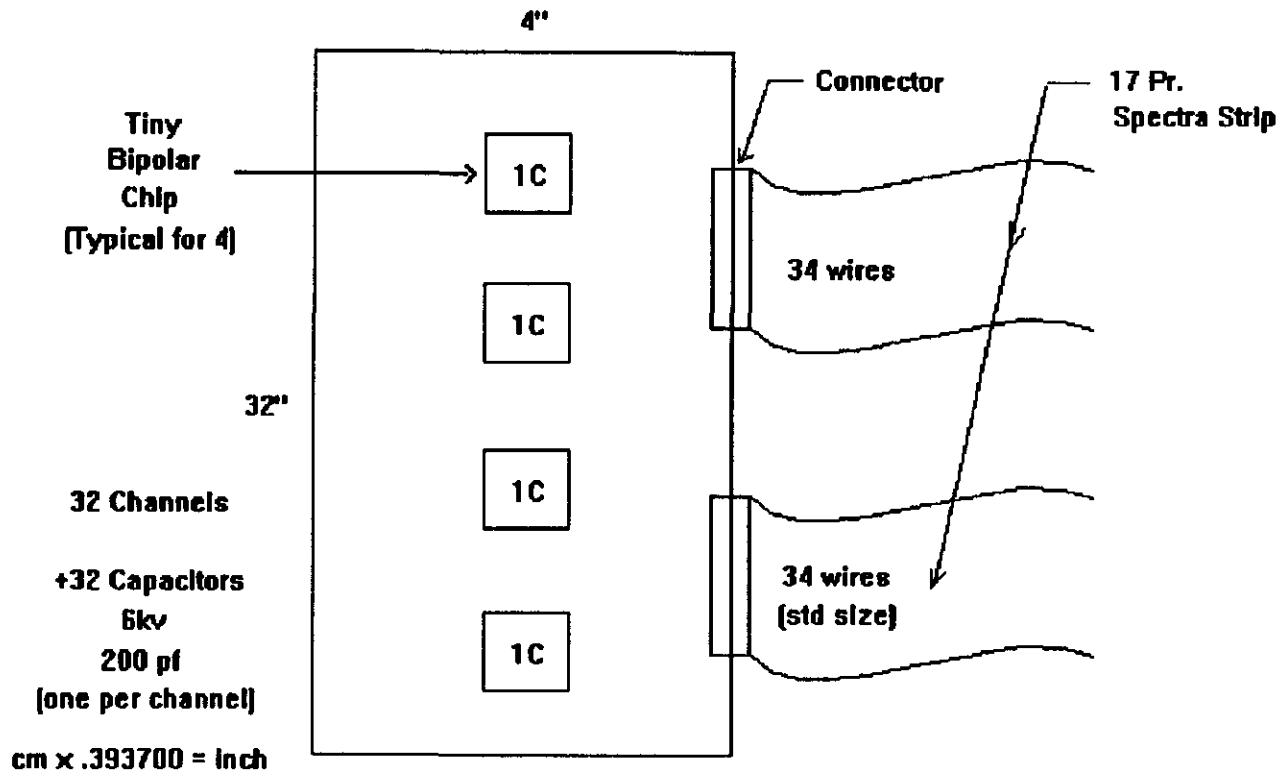
Not to Scale

16,000 Boards In Estimate
Multiplexing
Each channel = 5 mm
5 x 64 = 320 mm
64 Channels
Ea 1c is 16 Channels

320 mm = 12.5"
100 mm = 4"



LSOT BOARD LAYOUT

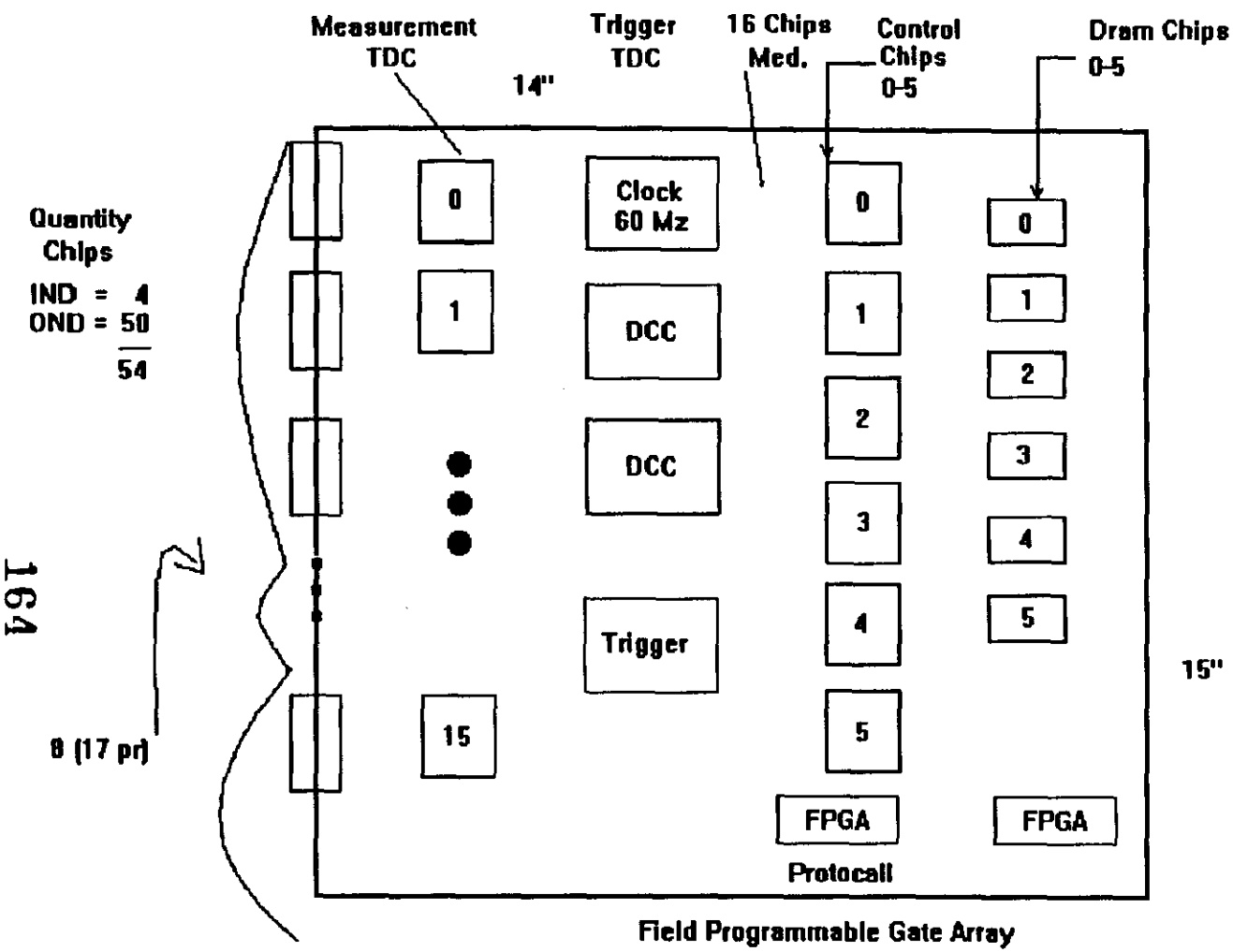


LSDT IND BOARD LAYOUT

32 Channels

4 IND To 1 OND

SK1B



128 Channels

Notes:

1. Control Chips are $60.00 Each
2. Board Is 8 layer
3. All Chips - Medium UNO

Integrated Trigger
SKI BTSK

Single Board

INTEGRATED TRIGGER / BOARD LAYOUT

SK2A

Assembly cost assumptions

- Assembly labor rates and task times are US estimates
  - labor rates based on GEM Cost Estimating Plan
  - task times estimated by US estimators

- Work force makeup

Discipline	K$/yr	Percent of workforce		
		CSC	LSDT	PDT
Engineer/physicist	133	13.4	10.6	12.8
Senior technician	107	46.3	44.7	55.3
Junior technician	82	40.3	44.7	31.9
Average rate K$/yr		100.4	98.6	102.4

- Does not include facility operation costs

- Costs based on number of hours to build an average size chamber

CSC Assembly Process

aggregate task	description	IHEP time	Dubna time	USA time
1	Incoming inspection	15 hr	16 hr	10 hr
2	Assemble precision positioning monitors on panel. (Fiducials)	12 hr	24 hr	10 hr
3	Drill holes in panels.	8 hr	32 hr	10 hr
4	Assemble gas outlets.	4 hr	8 hr	2 hr
5	Glue chamber frames to panels; glue PC boards to chamber frames; assemble spacers to panels.	38 hr	56 hr	10 hr
6	Assemble resistors to the stripped electrodes.	32 hr	48 hr	32 hr
7	Clean cathodes and chamber frames.	8 hr	8 hr	10 hr
8	Wind wire onto transfer frame.	48 hr	24 hr	4 hr
9	Establish wire tension.	9 hr	8 hr	8 hr
10	Clean wires.	2 hr	8 hr	4 hr
11	Install wires into chamber using transfer frame.	2 hr	64 hr	32 hr
12	Establish wire tension.	6 hr	8 hr	8 hr
13	Clean electrodes; perform electrode acceptance test; final clean electrodes; assemble and close the chamber.	38 hr	48 hr	40 hr
14	Assemble exterior mechanical parts.	10 hr	16 hr	4 hr
15	Assemble ground conductors, signal, HV connectors, etc.	10 hr	16 hr	4 hr
16	Flush chamber with gas; perform HV test; perform acceptance test; perform cosmic ray test.	34 hr	24 hr	8 hr
17	Package for shipping; move to storage; store; ship to SSC	6 hr	16 hr	4 hr
	Total	282 hr	424 hr	200 hr

21 Oct. 1992

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LSDT Assembly Process

task	aggregate task	description	IHEP time	Dubna time	MIT time
1	1	Incoming inspection	45 hr	16 hr	40 hr
2		*Mount connectors (HV, elect. & gas)*	*12 hr*	*8 hr*	*see 26*
3	2	Glue honeycomb bottom.	8 hr	32 hr	8 hr
4		Attach and glue bridge center supports.	24 hr		2 hr
5		Move to oven.	hr		1 hr
6		Oven cure.	24 hr*	hr	24 hr*
7		Move to assembly area.	hr		1 hr
8		Attach and check cross-bars.	hr		4 hr
9		Position cathode planes (4 layers).	32 hr		16 hr
10		Mount electronics cards (4 layers).	16 hr		8 hr
11		Prepare bridges for wiring (incmg. insp.?)	16 hr		hr
12		Fasten wire bridges to aluminum box (4 layers).	32 hr		4 hr
13		Solder wire to cards (4 layers).	16 hr		16 hr
14		Wire tension test (4 layers).	16 hr		8 hr
15		Glue wire to bridge (4 layers).	8 hr		2 hr
16		Move to wire alignment test area.	hr		4 hr
17		Check wire positions (4 layers).	24 hr		8 hr
18		Move to assembly area.	hr		4 hr
19		Attach isolation layer.	2 hr		2 hr
20		Make Z Strip connections	6 hr		8 hr
21	3	Install Z-strip plane.	4 hr	144 hr	
22		Position and glue top cover.	8 hr		12 hr
23		*Make HV connections*	*8 hr*		
24		*Attach electronics cards and Z stripe cabling*	*12 hr*		
25		*Install gas piping connectors*	*4 hr*		*see 28*
26		*Clean and check*	*4 hr*		

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27		*Perform connection check*	*10 hr*		
28		Attach gas and electronics.	*see 23-27*		20 hr
29		Transport to alignment area	hr		hr
30		Attach alignment fiducials.	8 hr		8 hr
31		Transport to final test area	4 hr		1 hr
32		Perform leak test.	8 hr		2 hr
33		Perform gas change.	8 hr (24 hr*)	hr*	24 hr*
34	4	Perform HV test; acceptance test.	2 hr	16 hr	2 hr
35	5	Perform life test (1 to 6 mo. duration).	8 hr	24 hr	4 hr
36	6	Package for shipping; move to storage; store; ship to SSC.	12 hr	16 hr	12 hr
		Total	357 hr	256 hr	197 hr
		number	704	704	512
		work year hours	1920	1920	1794
		Person Years	130.9	93.9	66.2

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* denotes cycle time, not labor hours

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PDT Assembly Process

task	aggregate task	description	IHEP time	Dubna time	MSU time
1		Prepare and test readout boards.	56 hr		18.6 hr
2	1	Assemble power busses.	16 hr	104 hr	8 hr
3		Assemble read-out boards.	20 hr		12.4 hr
4		Assemble high-voltage boards.	20 hr		12.4 hr
5	2	Inspect tubes.	24 hr	12 hr	15.8 hr
6	3	Cut tubes to length; deburr; clean; flare tube ends.	148 hr	64 hr	39.5 hr
7	4	Inspect plugs.	16 hr	4 hr	7.9 hr
8	5	Put O-rings onto plugs; crimp plugs into tubes.	72 hr	24 hr	39.6 hr
9	6	Pressure test tubes.	40 hr	8 hr	19.8 hr
10	7	Inspect and assemble manifold plates.	38 hr	16 hr	24 hr
11		Setup assembly table.	24 hr		16 hr
12	8	Assemble tubes into manifold.	44 hr	96 hr	15.8 hr
13		Insert wires into tubes	144 hr		79.2 hr
14		Seal plug ends.	24 hr		7.9 hr
15	9	Install gas fittings.	8 hr	16 hr	1 hr
16		Perform pressure test.	20 hr		16 hr
17	10	Perform HV test.	32 hr	16 hr	15.8 hr
18	11	Test wire tension.	24 hr	16 hr	15.8 hr
19	12	Assemble case.	36 hr	16 hr	20 hr
20	13	Final test.	30 hr	16 hr	16 hr
21	14	Package for shipping.	24 hr	16 hr	16 hr
		Total	858 hr	424 hr	418 hr

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Assembly time comparison

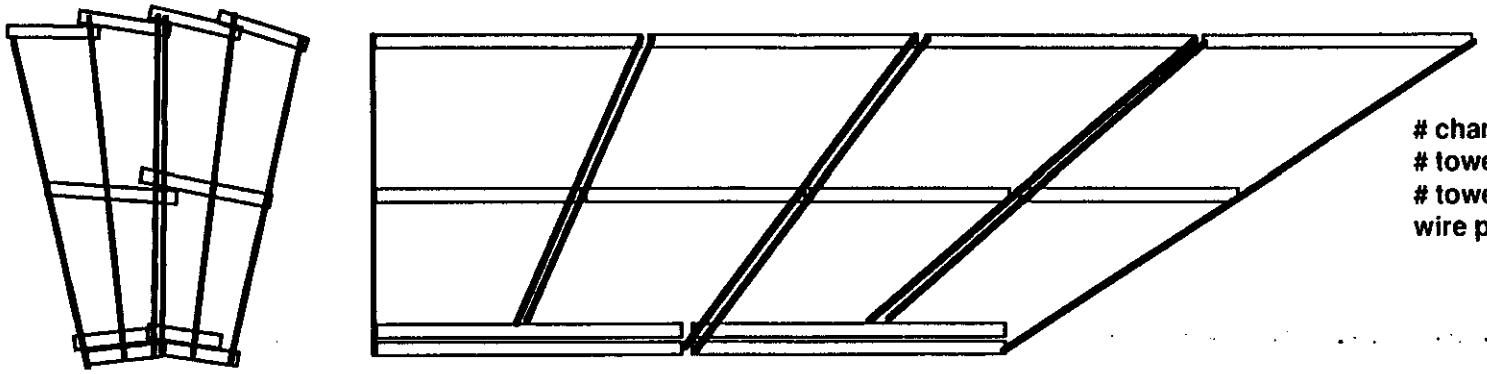
Time (hr) to fabricate average chamber

	USA	Dubna	IHEP	Average	Average/ USA	Cost delta (K$)**
CSC	200	424	282	302	1.51	6029
LSDT	197	256*	357	270	1.37	2375
PDT	418	424	858	567	1.36	2691

* time estimate that was provided contained some operations assumed to be performed in US. These times were subtracted out to provide for a fair comparison
**Cost delta equals increase in cost if USA cost times are increased to average times

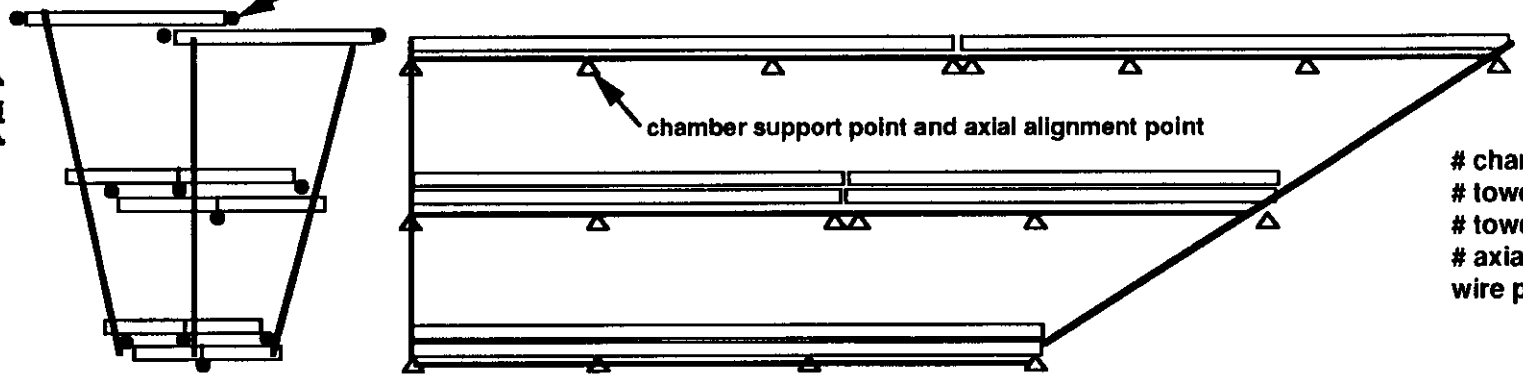
Alignment system comparison

CSC



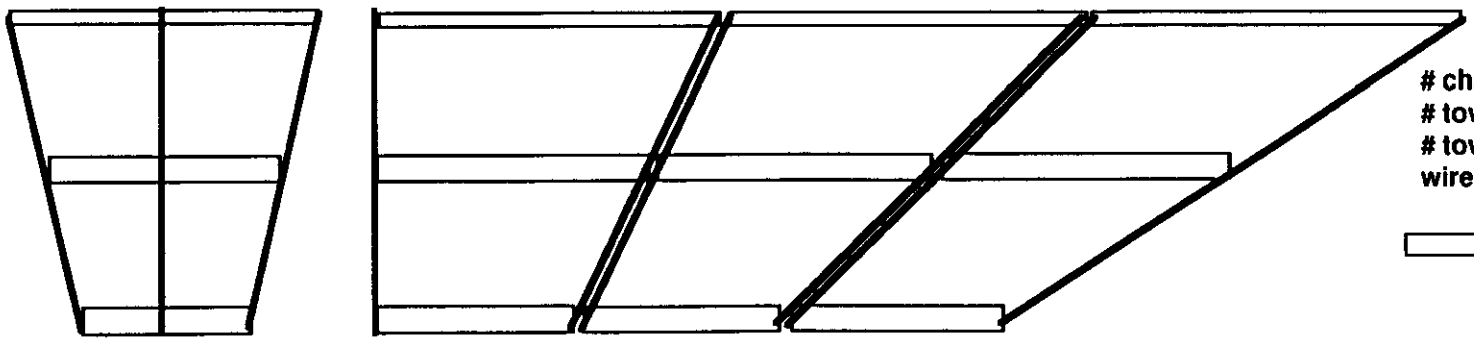
chambers = 32
towers = 8
tower alignment paths = 48 *
wire plane configuration = 8/4/4

LSDT



chambers = 16
towers = 1
tower alignment paths = 6
axial alignment paths =
wire plane configuration = 8/8/4

PDT

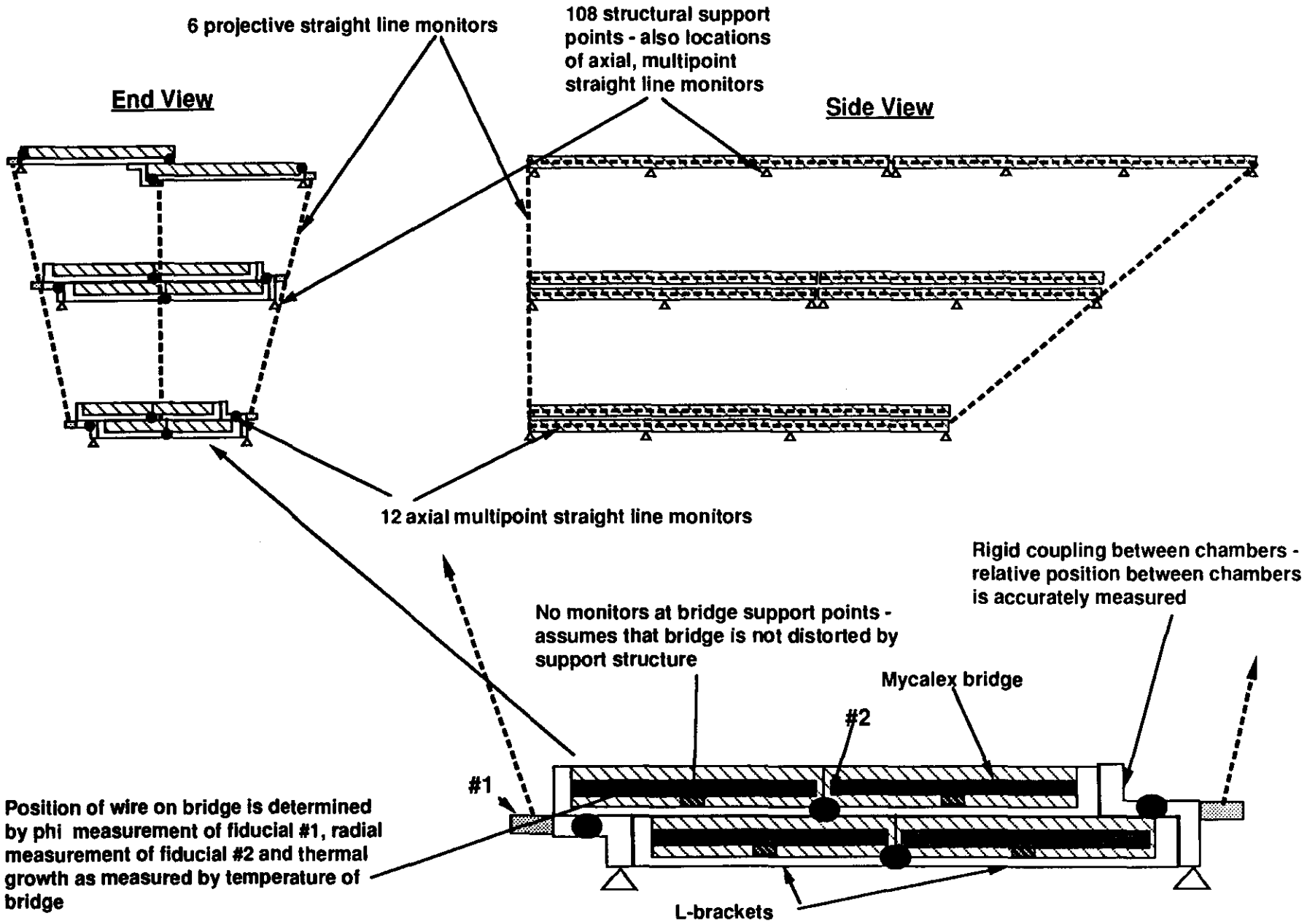


chambers = 9
towers = 3
tower alignment paths = 18
wire plane configuration = 8/8/4

= chamber

= alignment path

Proposed LSDT alignment configuration



Alignment system costs (K$)

	CSC	LSDT	PDT
Material costs			
(1) # projective alignment paths	48	6	18
(2) # axial alignment paths	0	12	0
(3) # axial alignment points	0	72	0
(4) # axial alignment sensors	0	48	0
(5) # temperature monitors	48	56	18
(6) # SLM = (1) + (4)	48	54	18
Total SLM cost = $750* (6) * 32	1152	1296	432
Total temp monitor cost = (5)*$70*32	108	125	40
Alignment test equipment	300	300	300
Total material cost	1560	1721	772
Installation and assembly labor costs			
(7) Fiducialization = (6) *32 * 8 hr/SLM * ~~$28.28~~ $25.57/hr	314	353	118
(8) Alignment = (6) *32 * 10 hr/SLM * ~~$28.28~~ $25.57/hr	393	442	147
Inspection and administration = .06((7)+(8))	42	48	16
Total installation and assembly labor costs	749	843	281
Total costs	2309	2564	1053
Labor rates assume following work group composition at SSCL job shop rates 10% engineer @ $49.97/hr 45% Jr. Tech @ $19.14/hr 45% Sr. tech @ $26.58/hr Average rate = $25.57/hr			

Gas system summary

- Estimates extrapolated from LLNL gas system designed and built for the the RPC development laboratory
  - design reviewed and approved by LLNL safety engineering
  - consistent with safe transport of flammable gas
  - one evaluator performed all estimates - results are consistent
- Design accounts for
  - required gas volume for each technology
  - 4 atm pressure for PDT system
  - resevoirs, compressors, SST tubing, manifolds, controls, gas monitors, gas analysis, scrubers
  - installation labor
- Evaluation was not integrated with gas system design currently being developed at SSCL
  - not possible in short time available
  - it should be anticipated that costs will increase as details of all component requirements emerge

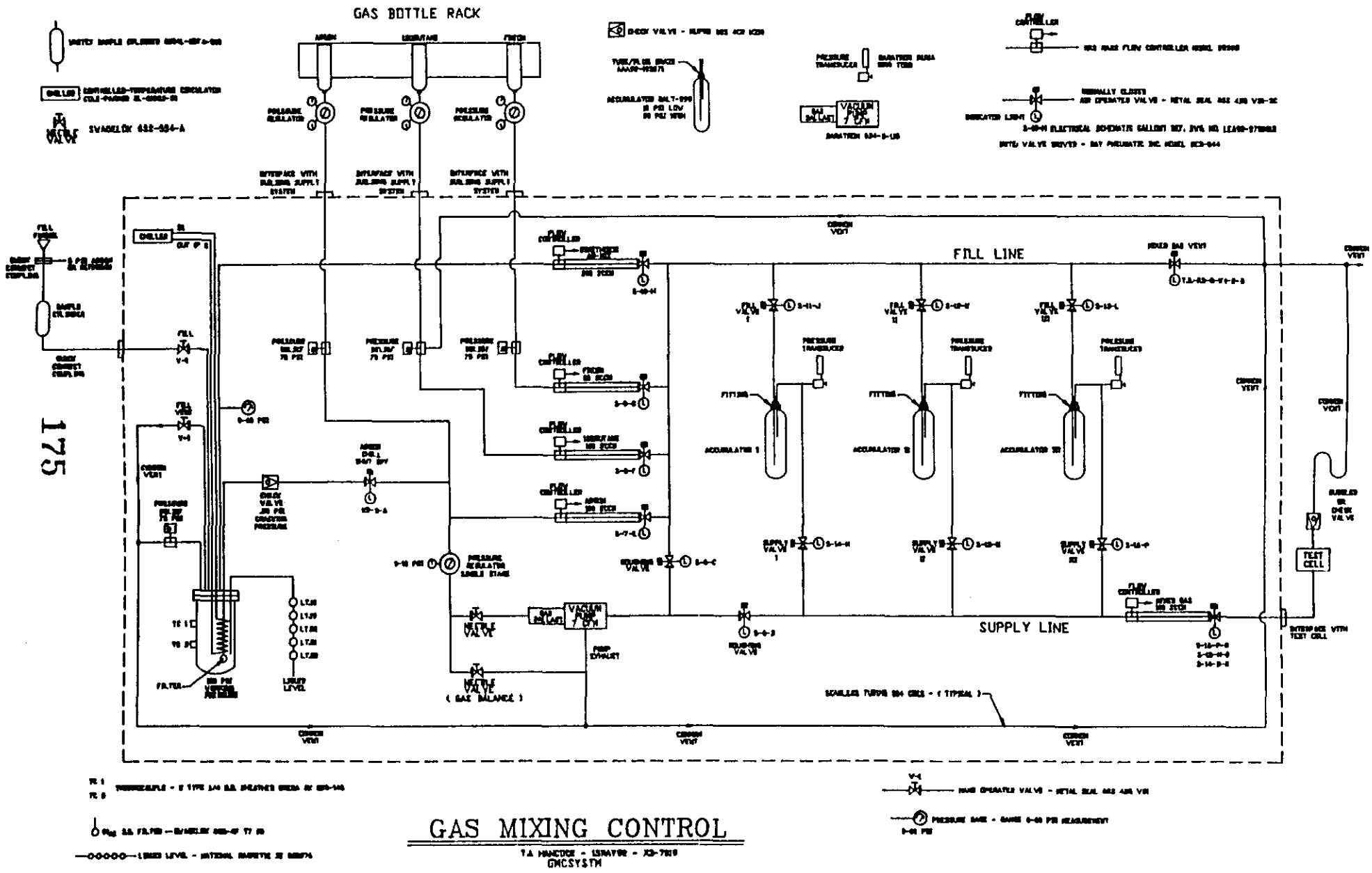

GAS BOTTLE RACK
FILL LINE
SUPPLY LINE
TEST CELL
GAS MIXING CONTROL

Figure 3

TO: CRAIG WUEST / RICK SAWICKI
FROM: MARK McKERNAN / FRED GRABNER
DATE: 10/28/92

SUBJECT: COST FOR FULL SIZE SSC GAS SYSTEM

PURCHASES COSTS

ITEM	COST EACH	QUANITY	COAST TOTAL CSC (CO2/CF4)	QUANITY	COST TOTAL LSDT (CO2/CF4/C4H10)
Lab View (System controler)	$30,000.00	1	$30,000.00	1	$30,000.00
Cabeling	$5,000.00	1	$5,000.00	1	$5,000.00
Sensors	$5,000.00	1	$5,000.00	1	$5,000.00
Electromechanical	$5,000.00	1	$5,000.00	1	$5,000.00
Flow controlers	$1,500.00	4	$6,000.00	5	$7,500.00
Flow Drivers	$800.00	4	$3,200.00	5	$4,000.00
Pressure transducers	$1,200.00	4	$4,800.00	5	$6,000.00
Pressure Driver card	$500.00	4	$2,000.00	5	$2,500.00
Transducer power supply	$500.00	2	$1,000.00	3	$1,500.00
Solonoid driver cards	$1,000.00	4	$4,000.00	4	$4,000.00
Neupro Valves 6BK	$208.00	64	$13,312.00	64	$13,312.00
Electric Values	$350.00	6	$2,100.00	6	$2,100.00
SST Tubing	$5.15	4000	$20,600.00	4000	$20,600.00
Swagelok fittings	$7.00	800	$5,600.00	800	$5,600.00
Gas Reservoir	$10,000.00	2	$20,000.00	2	$20,000.00
Vacuum pump oil free	$20,000.00	1	$20,000.00	1	$20,000.00
Pressure Regulators	$300.00	30	$9,000.00	30	$9,000.00
Press. sys. chassis	$10,000.00	1	$10,000.00	1	$10,000.00
Elect. Chassis	$5,000.00	2	$10,000.00	2	$10,000.00
Misc Hardware & material	$50,000.00	1	$50,000.00	1	$50,000.00
Supply Gases					
FREON 14 (CF4) 70lb.	$2,000.00	30	$60,000.00	30	$60,000.00
ISOBUTANE C4H10 116lb.	$600.00		$0.00	10	$6,000.00
CARBON DIOXIDE CO2 50 gal.	$100.00	30	$3,000.00	30	$3,000.00

Liquid gas supply Tanks	$20,000.00	1	$20,000.00	1	$20,000.00
Gas Manifoldes	$1,000.00	7	$7,000.00	9	$9,000.00
Gas Manifold racks	$1,800.00	3	$5,400.00	4	$7,200.00
Gas Manifold heaters	$1,000.00		$0.00	1	$1,000.00
Recovery tanks	$8,000.00	2	$16,000.00	4	$32,000.00
Scruber	$15,000.00	1	$15,000.00	1	$15,000.00
Transfer gas lines	$6.50	6000	$39,000.00	6000	$39,000.00
Refrigeration recovery unit	$20,000.00	1	$20,000.00	1	$20,000.00
Recovery transfer pump	$4,000.00	3	$12,000.00	3	$12,000.00
Recovery gas vessel	$1,200.00	16	$19,200.00	16	$19,200.00
Recovery gas manifold	$8,000.00	1	$8,000.00	1	$8,000.00
Pressure relief & check values	$8,000.00	1	$8,000.00	1	$8,000.00
Gas Chromatography (Thermal)	$30,000.00	1	$30,000.00	1	$30,000.00
Chamber pressure monitor	$7,000.00	1	$7,000.00	1	$7,000.00
Chamber pressure transducer	$9,600.00	1	$9,600.00	1	$9,600.00
Chamber relief mechanism	$30,000.00	1	$30,000.00	1	$30,000.00
Air compresor	$3,000.00	1	$3,000.00	1	$3,000.00
Oxygen moniter 6 ch.	$8,000.00	1	$8,000.00	1	$8,000.00
Iosbutane moniter 8 ch.	$6,500.00			1	$6,500.00
Relief Manifold & lines	$20,000.00			1	$20,000.00
TOTAL PURCHASE COST————————			$546,812.00		$604,612.00

MANPOWER CHARGES	FTE	For 6 Months			
Foreman	0.5		$33,930.00	0.5	$33,930.00
Electrical	2		$66,273.12	2	$66,273.12
Mechanical (Senior Tech.)	4		$102,687.84	6	$154,031.76
Crane op.	0.1		$2,956.61	0.3	$8,869.82
Riggers	0.5		$13,472.82	0.8	$21,556.51
Laborers	2		$29,357.28	2	$29,357.28
Welders	0.1		$2,694.56	0.3	$8,083.69
Pipefitters	0.3		$7,159.75	0.3	$7,159.75
Carpenters	2		$49,610.88	2	$49,610.88

Engineer site	0.5	$20,034.36	0.5	$20,034.36
Software Engineer	0.1	$5,216.87	0.2	$10,433.74
Draftsman	0.2	$5,794.20	0.3	$8,691.30
Painters	0.5	$8,498.16	0.5	$8,498.16
Coordinator Site	0.5	$11,953.80	0.5	$11,953.80
Clerks	0.3	$4,419.25	0.3	$4,419.25
Machinist	0.5	$16,604.82	0.5	$16,604.82
Coordinator LLNL	0.7	$41,290.20	0.7	$41,290.20
Chem. Eng. LLNL	0.5	$40,246.20	0.5	$40,246.20
Design and drafting LLNL	1	$58,986.00	1	$58,986.00
Design Eng. LLNL	1	$80,492.40	1	$80,492.40
Project leader LLNL	1	$67,860.00	1	$67,860.00
Industrial safety LLNL	0.7	$41,290.20	0.7	$41,290.20
Mechanical (Senior Tech)LLNL	1	$67,860.00	1.3	$88,218.00
Secretary LLNL	0.5	$17,246.88	0.5	$17,246.88
Software Eng. LLNL	0.3	$24,147.72	0.4	$32,196.96
TOTAL MANPOWER COST		$820,083.92		$927,335.09
MISCELLANEOUS FABRICATION COSTS (Brackets,fittings,tie downs,building materails,scaffolding,water lines electrical distribution etc...)		$100,000.00		$120,000.00
TOTAL COST		$1,466,895.92		$1,651,947.09

NOTE:
This estiment does not include the cost of shipping to the site location of individual components.

This estimate will require final review form a chemical and mechanical engineering.

TO: CRAIG WUEST / RICK SAWICKI
FROM: MARK McKERNAN / FRED GRABNER
DATE: 10/28/92

SUBJECT: COST FOR FULL SIZE SSC GAS SYSTEM

PURCHASES COSTS

ITEM	COST EACH	QUANITY	COAST TOTAL PDT (CO2/CF4)	QUANITY	COST TOTAL PDT & RPC (CO2/CF4/CBrF3)
Lab View (System controler)	$30,000.00	1	$30,000.00	1	$30,000.00
Cabeling	$5,000.00	1	$5,000.00	1	$5,000.00
Sensors	$5,000.00	1	$5,000.00	1	$5,000.00
Electromechanical	$5,000.00	1	$5,000.00	1	$5,000.00
Flow controlers	$1,500.00	4	$6,000.00	6	$9,000.00
Flow Drivers	$800.00	4	$3,200.00	6	$4,800.00
Pressure transducers	$1,200.00	4	$4,800.00	5	$6,000.00
Pressure Driver card	$500.00	4	$2,000.00	5	$2,500.00
Transducer power supply	$500.00	2	$1,000.00	3	$1,500.00
Solonoid driver cards	$1,000.00	4	$4,000.00	4	$4,000.00
Neupro Valves 6BK	$208.00	64	$13,312.00	64	$13,312.00
Electric Values	$350.00	6	$2,100.00	6	$2,100.00
SST Tubing	$5.15	4000	$20,600.00	4000	$20,600.00
Swagelok fittings	$7.00	800	$5,600.00	1000	$7,000.00
Gas Reservoir	$10,000.00	2	$20,000.00	4	$40,000.00
Vacuum pump oil free	$20,000.00	1	$20,000.00	1	$20,000.00
Pressure Regulators	$300.00	30	$9,000.00	30	$9,000.00
Press. sys. chassis	$10,000.00	1	$10,000.00	1	$10,000.00
Elect. Chassis	$5,000.00	2	$10,000.00	2	$10,000.00
Misc Hardware & material	$50,000.00	1	$50,000.00	1	$50,000.00
Supply Gases					
FREON 14 (CF4) 70lb.	$2,000.00	33	$66,000.00	33	$66,000.00
FREON 13B-1 CBrF3 150lb.	$2,200.00		$0.00	6	$13,200.00
CARBON DIOXIDE CO2 50 gal.	$100.00	30	$3,000.00	30	$3,000.00

Liquid gas supply Tanks	$20,000.00	1	$20,000.00	1	$20,000.00
Gas Manifoldes	$1,000.00	7	$7,000.00	11	$11,000.00
Gas Manifold racks	$1,800.00	3	$5,400.00	5	$9,000.00
Gas Manifold heaters	$1,000.00		$0.00	1	$1,000.00
Recovery tanks	$8,000.00	2	$16,000.00	4	$32,000.00
Recovery vessel	$1,200.00	16	$19,200.00	24	$28,800.00
Scruber	$15,000.00	1	$15,000.00	1	$15,000.00
Transfer gas lines	$6.50	6000	$39,000.00	6000	$39,000.00
Refrigeration recovery unit	$30,000.00	1	$30,000.00	1	$30,000.00
Recovery transfer pump	$4,000.00	3	$12,000.00	4	$16,000.00
Recovery gas manifold	$8,000.00	1	$8,000.00	2	$16,000.00
Pressure relief & check values	$11,000.00	1	$11,000.00	1	$11,000.00
Gas Chromatography (Thermal)	$30,000.00	1	$30,000.00	1	$30,000.00
Chamber pressure monitor	$7,000.00	1	$7,000.00	1	$7,000.00
Chamber pressure transducer	$9,600.00	1	$9,600.00	1	$9,600.00
Chamber relief mechanism	$30,000.00	1	$30,000.00	1	$30,000.00
Air compresor	$3,000.00	1	$3,000.00	1	$3,000.00
Chamber exhaust CTL	$10,000.00	1	$10,000.00	1	$10,000.00
Oxygen moniter 6 ch.	$8,000.00	1	$8,000.00	1	$8,000.00
Relief Manifold & lines	$20,000.00			1	$20,000.00
TOTAL PURCHASE COST————————			$575,812.00		$683,412.00

MANPOWER CHARGES	FTE	For 6 Months			
Foreman	0.5		$33,930.00	0.5	$33,930.00
Electrical	2		$66,273.12	2	$66,273.12
Mechanical (Senior Tech.)	4		$102,687.84	6	$154,031.76
Crane op.	0.1		$2,956.61	0.3	$8,869.82
Riggers	0.5		$13,472.82	0.8	$21,556.51
Laborers	2		$29,357.28	2	$29,357.28
Welders	0.1		$2,694.56	0.3	$8,083.69
Pipefitters	0.3		$7,159.75	0.3	$7,159.75
Carpenters	2		$49,610.88	2	$49,610.88

Engineer site	0.5	$20,034.36	0.5	$20,034.36
Software Engineer	0.1	$5,216.87	0.2	$10,433.74
Draftsman	0.2	$5,794.20	0.3	$8,691.30
Painters	0.5	$8,498.16	0.5	$8,498.16
Coordinator Site	0.5	$11,953.80	0.5	$11,953.80
Clerks	0.3	$4,419.25	0.3	$4,419.25
Machinist	0.5	$16,604.82	0.5	$16,604.82
Coordinator LLNL	0.7	$41,290.20	0.7	$41,290.20
Chem. Eng. LLNL	0.5	$40,246.20	0.5	$40,246.20
Design and drafting LLNL	1	$58,986.00	1	$58,986.00
Design Eng. LLNL	1	$80,492.40	1	$80,492.40
Project leader LLNL	1	$67,860.00	1	$67,860.00
Industrial safety LLNL	0.7	$41,290.20	0.7	$41,290.20
Mechanical (Senior Tech)LLNL	1	$67,860.00	1.3	$88,218.00
Secretary LLNL	0.5	$17,246.88	0.5	$17,246.88
Software Eng. LLNL	0.3	$24,147.72	0.4	$32,196.96
TOTAL MANPOWER COST		$820,083.92		$927,335.09
MISCELLANEOUS FABRICATION COSTS (Brackets,fittings,tie downs,building materails,scaffolding,water lines electrical distribution etc...)		$100,000.00		$130,000.00
TOTAL COST		$1,495,895.92		$1,740,747.09

NOTE:
This estiment does not include the cost of shipping to the site location of individual components.

This estimate will require final review form a chemical and mechanical engineering.

shipping costs

oversight PY	0.5	Y
rate (k$/yr)	133	R
truckload cost (k$)	3	c(t)
packaging cost / chamber (k$)	0.25	c(p)

	CSC	LSDT	PDT/BPC	
total chambers	1024	512	288	C
chambers/sector	32	16	9	
shipset	64	32	18	N
shipping cost	371	243	373	S
shipset chamber weight (lb)	18088	17600	10450	

$$S = Y * R + c(t) * C / N + c(p) * C$$

NOV- 2-92 MON 18:12 DRAPER LABORATORY INC FAX NO. 8172581108 P.03/07

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GEM MOUN COOLING COSTS

OCT 28, 1992

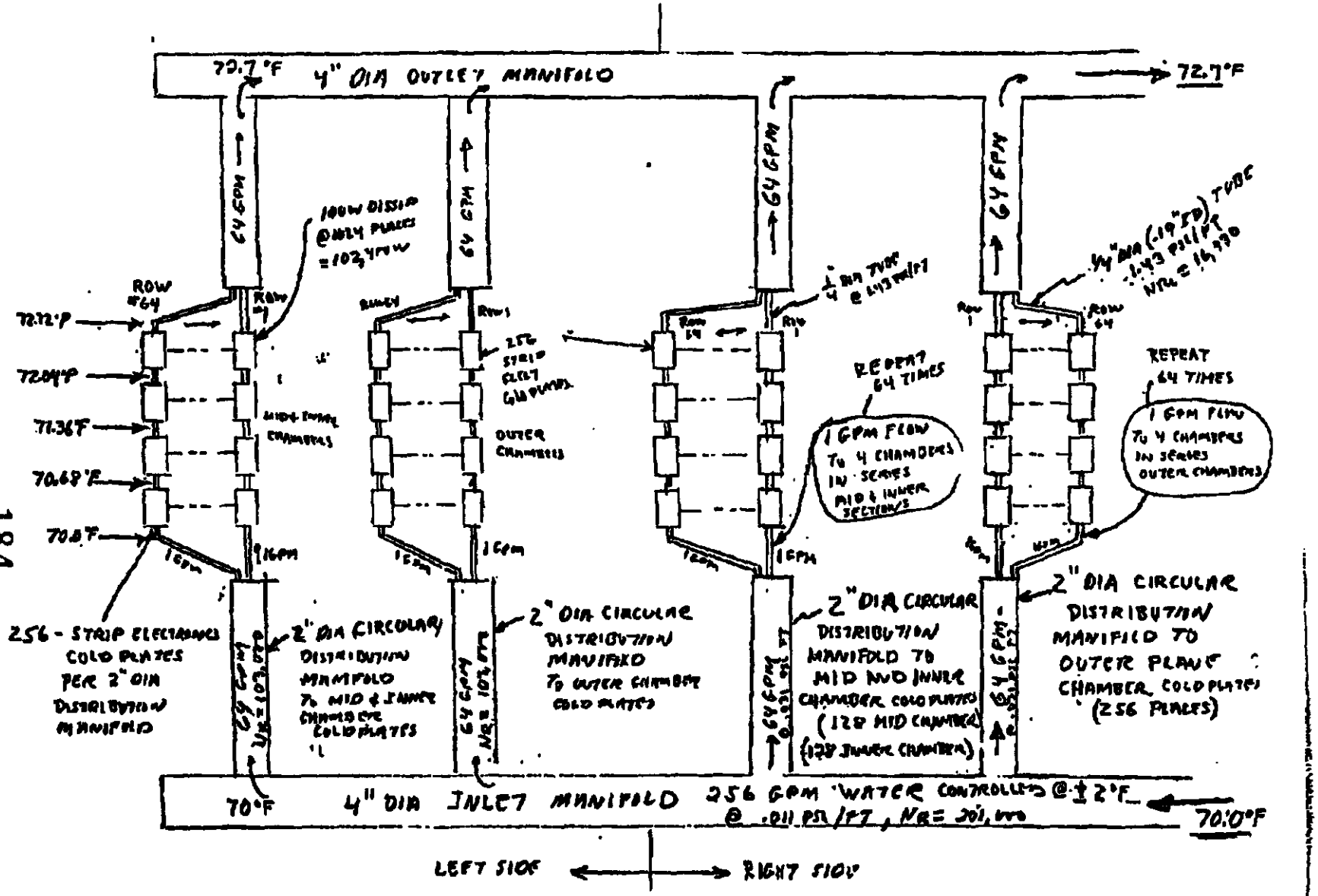
DESCRIPTION	PART #	VENDOR	UNIT COST ($) /1000	TOTAL REQ'd	TOTAL COST($)
Cold Plate,Strip Electronics	180-10-36C	EG&G Wakefield	100.00	1,024	102,400.00
Hardware					
Union,Flared	AN815-4J	AAA Aircraft Supply	2.40	1,024	2,457.60
Nut Coupler	AN 818-4J	AAA Aircraft Supply	0.91	4,096	3,727.36
Sleeve Coupler	AN819-4J	AAA Aircraft Supply	0.71	4,096	2,908.16
Copper Tubing	.25 "O.D.		$22.77 / 50 ft Roll	20	455.40
Temp Sensor	AD590 MH	Analog Devices	25.70	1,024	26,316.80
Heat Pipe Plate, Strip Electronics	.40"x 4.0"x46.0"	Thermacore Inc Lancaster ,PA Contact- Jerome Toth	700.00	1,024	716,800.00
(or)	.40"x4.0"x46.0"	Noren Products, Inc Menlo Park Ca Contact-Vern Chambers	1,400.00	1,024	1,433,600.00
Heat Pipe Tube, Wire Electronics	.375" Dia x 132" lg	Thermacore Inc Lancaster Pa Contact- Jerome Toth	200.00	1,024	204,800.00
(or)	.20"x.53"x132" lg (Flat Heat Pipe)	Noren Products, Inc Menlo Park, Ca Contact- Vern Chambers	280.00	1,024	286,720.00
Hardware					
Plate, Heat Pipe	.06x4.0x130" lg (Al)	-	14.00	1,024	14,336.00
U-Clamp,Heat Pipe	2.0" Wide (Alum)	-	0.28	1,024	286.00
Clamp, Cable	50N436	Newark Electrical	0.05	20,480	1,024.00
	Total Cost Without Heat Pipes For Strip & Wire Electronics				138,265.32
	Total Cost With Heat Pipes Made By Thermacore ,Inc.				1,075,513.30
	Total Cost With Heat Pipes Made By Noren Products, Inc				1,874,233.30

Facilities items

4" Main Coolant Inlet/Outlet Line & Associated Hardware- Total = 2

2" Circular Distribution Inlet/Outlet Headers & Associated Hardware- Total = 4

1/4" Dia Coldplate Inlet/outlet Lines to Dist. Headers & Associated Hardware - Total = 512 (Final # Req'd is Flow Arrangement Dependent



GEM MUON CHAMBER FLOW SCHEMATIC

Muon cost status summary

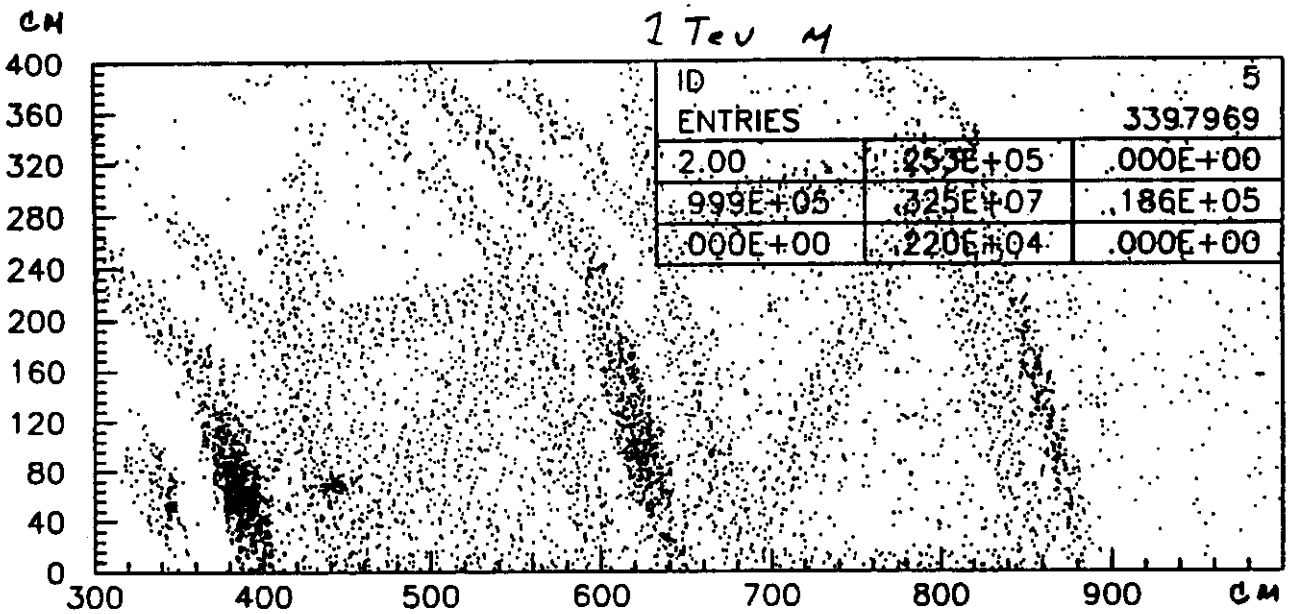
- CSC - 65018 K$
  - material cost is high
    - --honeycomb panel cost has potential for reduction
    - -- need to work more with vendors
  - assembly time (200 hr/chamber) is too high compared to other technologies
    - -- smaller chamber and simpler operations
  - 36% contingency should be lowered to reflect recent design progress
  - electronic cost design is very agressive with only 20% contingency
- LSDT w/internal trigger - 44388 K$
  - material costs have good backup
  - assembly costs must be scrutinized by a production engineering staff
  - electronic costs require additional engineering evaluation
  - alignment costs may be underestimated due to uncertainty in challenge of coupled axial and projective monitors
- PDT w/RPC - 47019 K$
  - material costs have good backup
  - discrepancy between USA and IHEP assembly times must be resolved
  - electronic costs require additional engineering evaluation
- Areas of common weakness
  - no design for chamber coupling or mounting hardware
  - no assembly facility operation costs
  - design costs need updating
  - gas and cooling system designs need engineering

Peter Dingus

Peter Dingus
SSCL 11/5/92

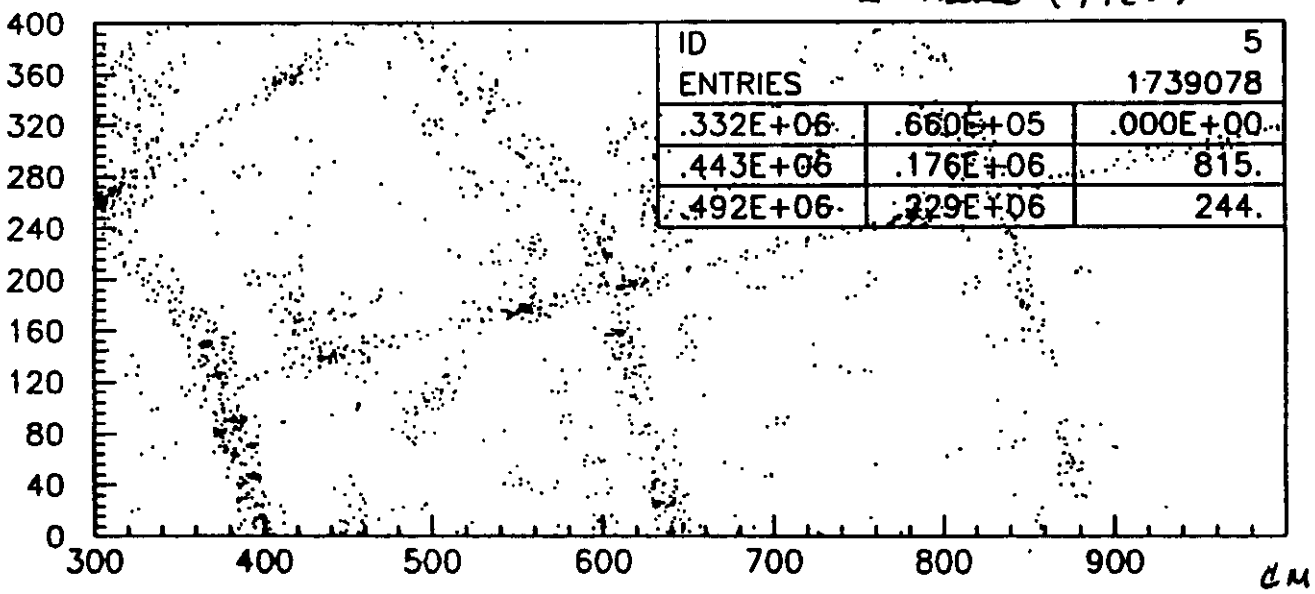
r-φ PLOT OF SECONDARY ORIGINS

1 TeV μ



YY VS XX

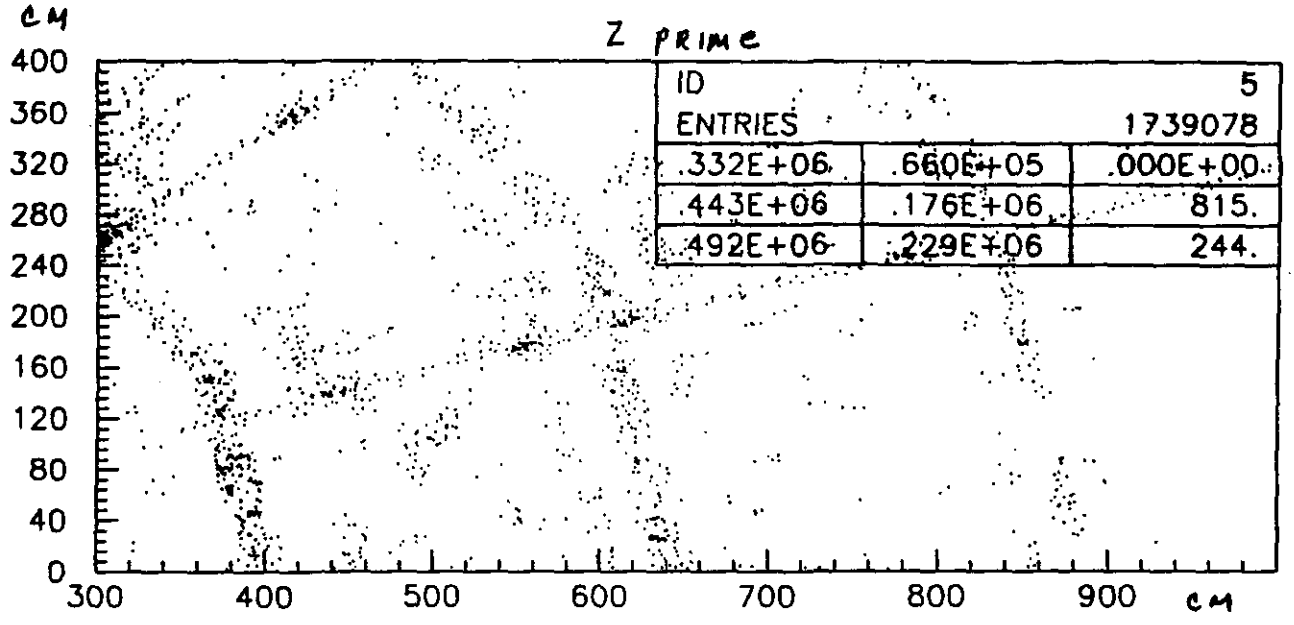
2′ Prime (4 TeV)



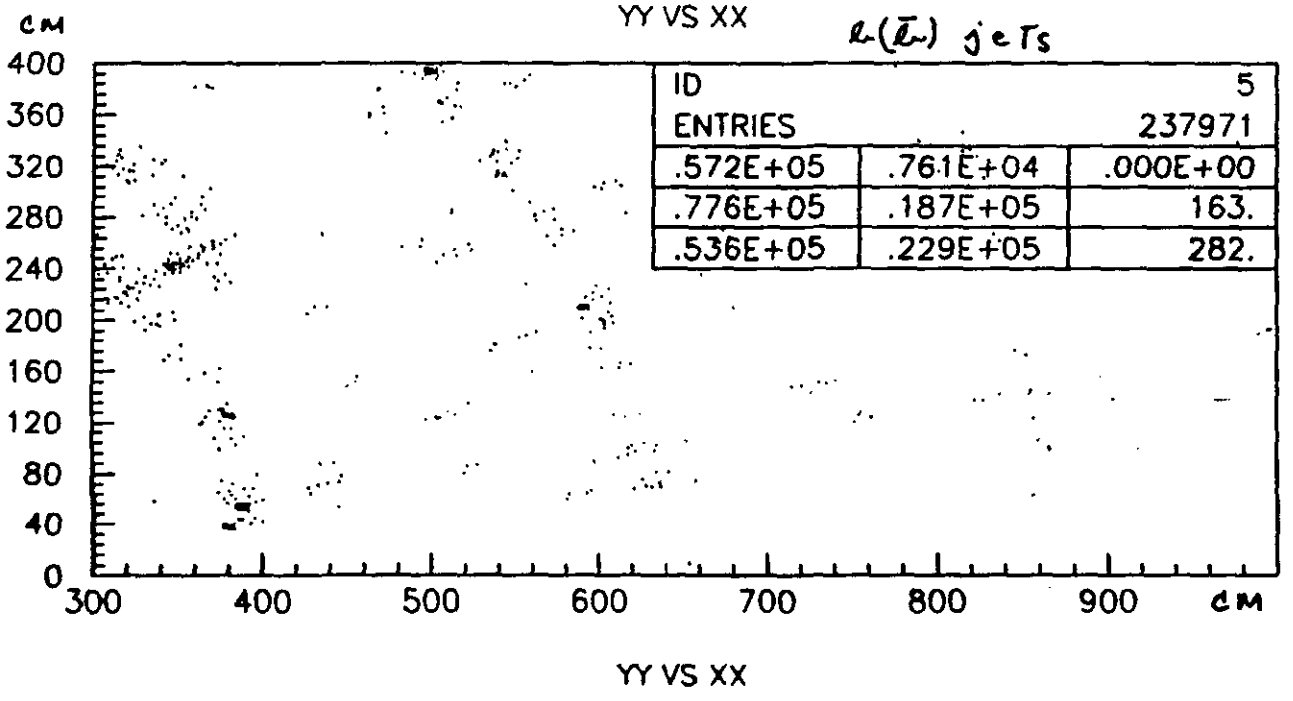
YY VS XX

r - φ PLOT

OF SECONDARY ORIGINS

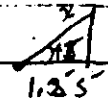


ID		5
ENTRIES		1739078
.332E+06	.660E+05	.000E+00
.443E+06	.176E+06	815.
.492E+06	.229E+06	244.



ID		5
ENTRIES		237971
.572E+05	.761E+04	.000E+00
.776E+05	.187E+05	163.
.536E+05	.229E+05	282.

6.25 NEUTRON CALCULATION



1st SL $\frac{Z}{2} = 632/2 = 316$ cm

2nd SL $Z/2 = 1043/2 = 521.5$

3rd SL $Z/2 = 1475/2 = 737.5$

For $2.5 \times 2.5 \Rightarrow$ 1st SL = 2.0×10^3

2nd SL = 3.3×10^3

3rd SL = 4.6×10^3

From $L = 10^{33}$, 10^{12} n/cm²/y, 5×10^{-3} hit/n/2.5 cm

$\sim 2 \times 10^2$ hit/cm²/sec

1st SL $\Rightarrow (2 \times 10^2) \times (2 \times 10^3) \times (16 \times 10^{-9}) = 6.4 \times 10^{-2}$ hit / 16 nsec-tube

2nd SL $\Rightarrow (2 \times 10^2) \times (3.3 \times 10^3) \times (16 \times 10^{-9}) = 1.05 \times 10^{-2}$ "

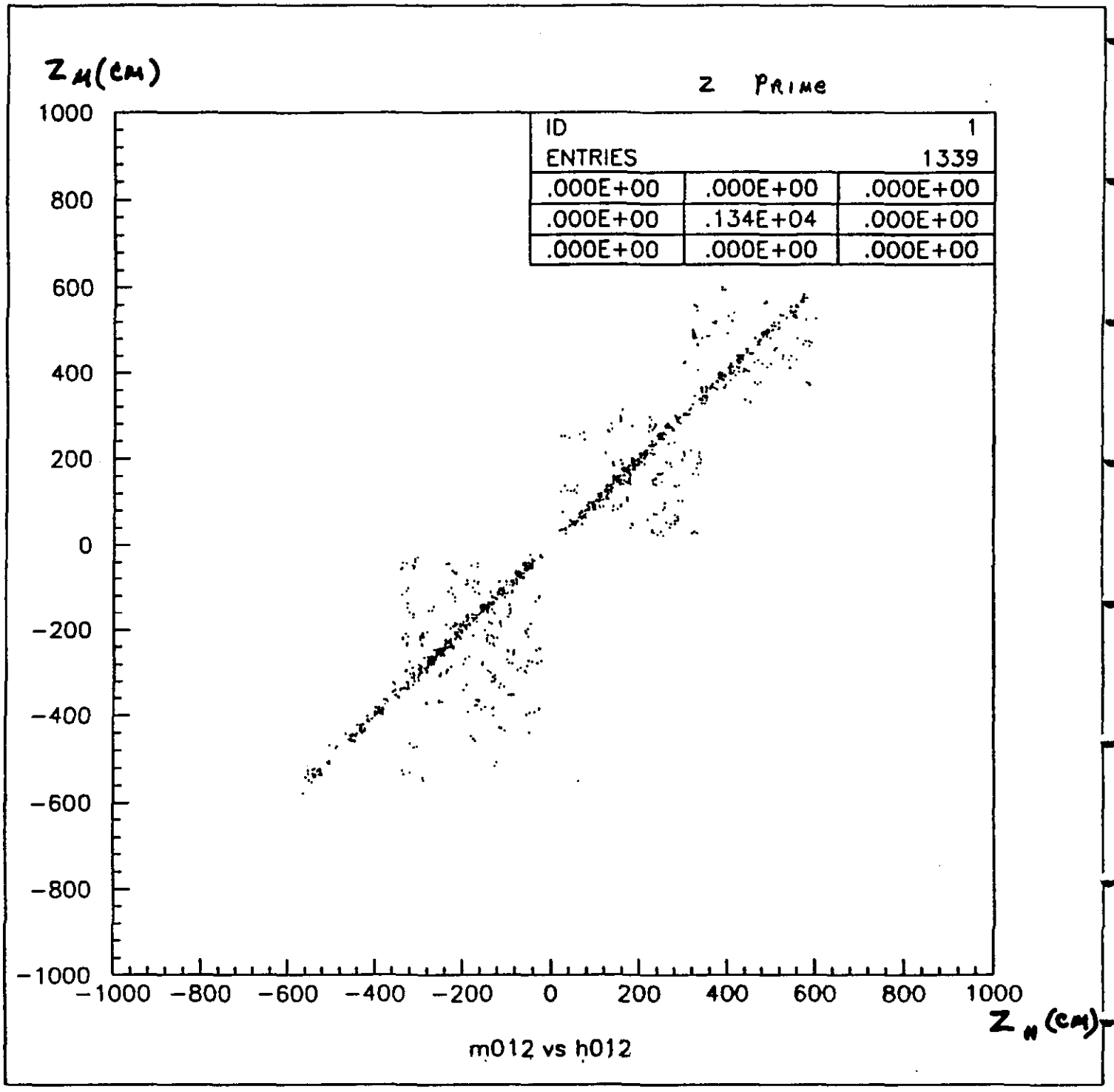
3rd SL $\Rightarrow (2 \times 10^2) \times (4.6 \times 10^3) \times (16 \times 10^{-9}) = 1.47 \times 10^{-2}$ "

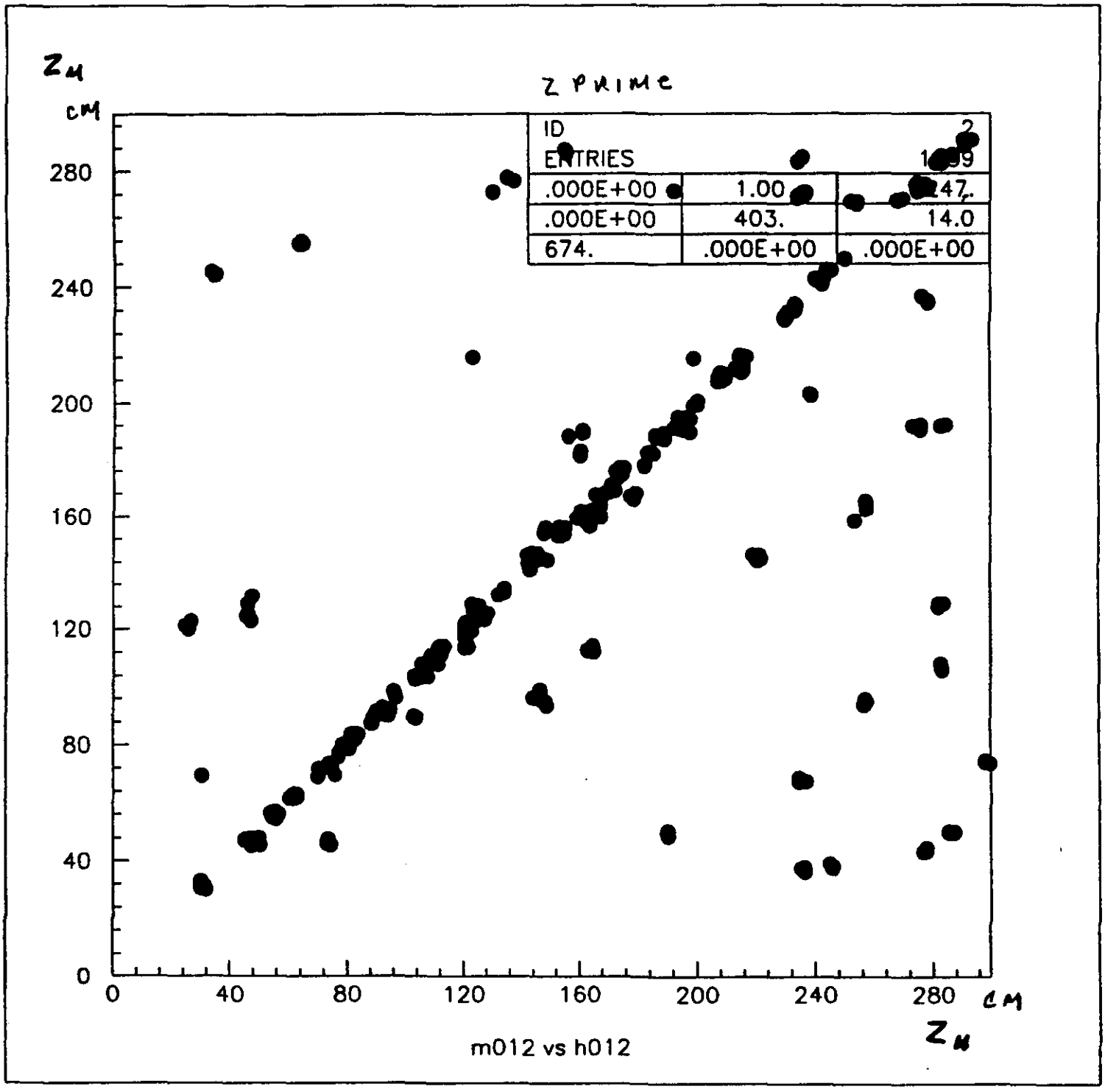
For 50 nm/m gas, 2.5 cm LSDT $\Rightarrow$ 400 ns drift from central point $\Rightarrow$ 2.5 beam crossings

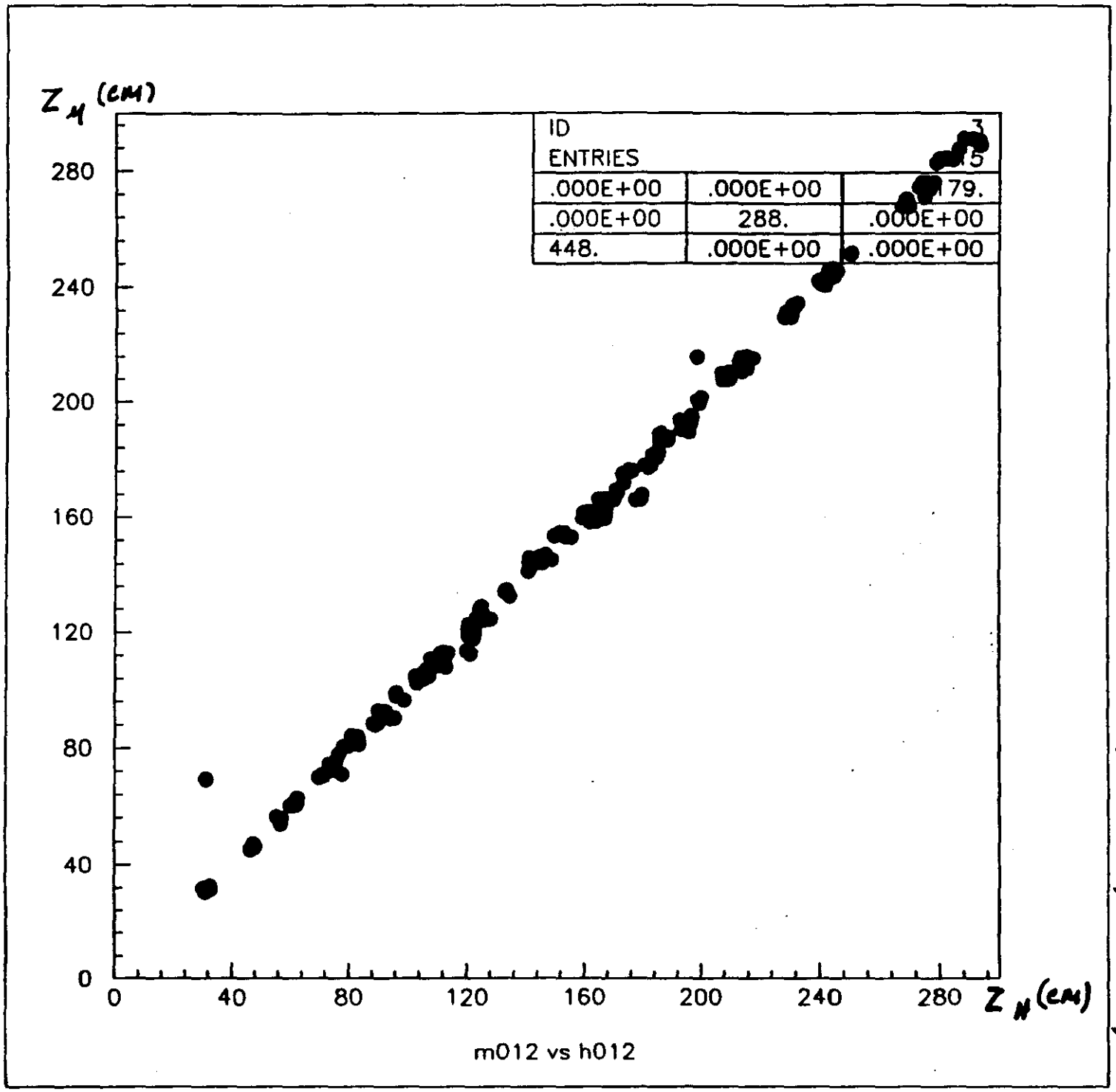
1st SL = 16 %

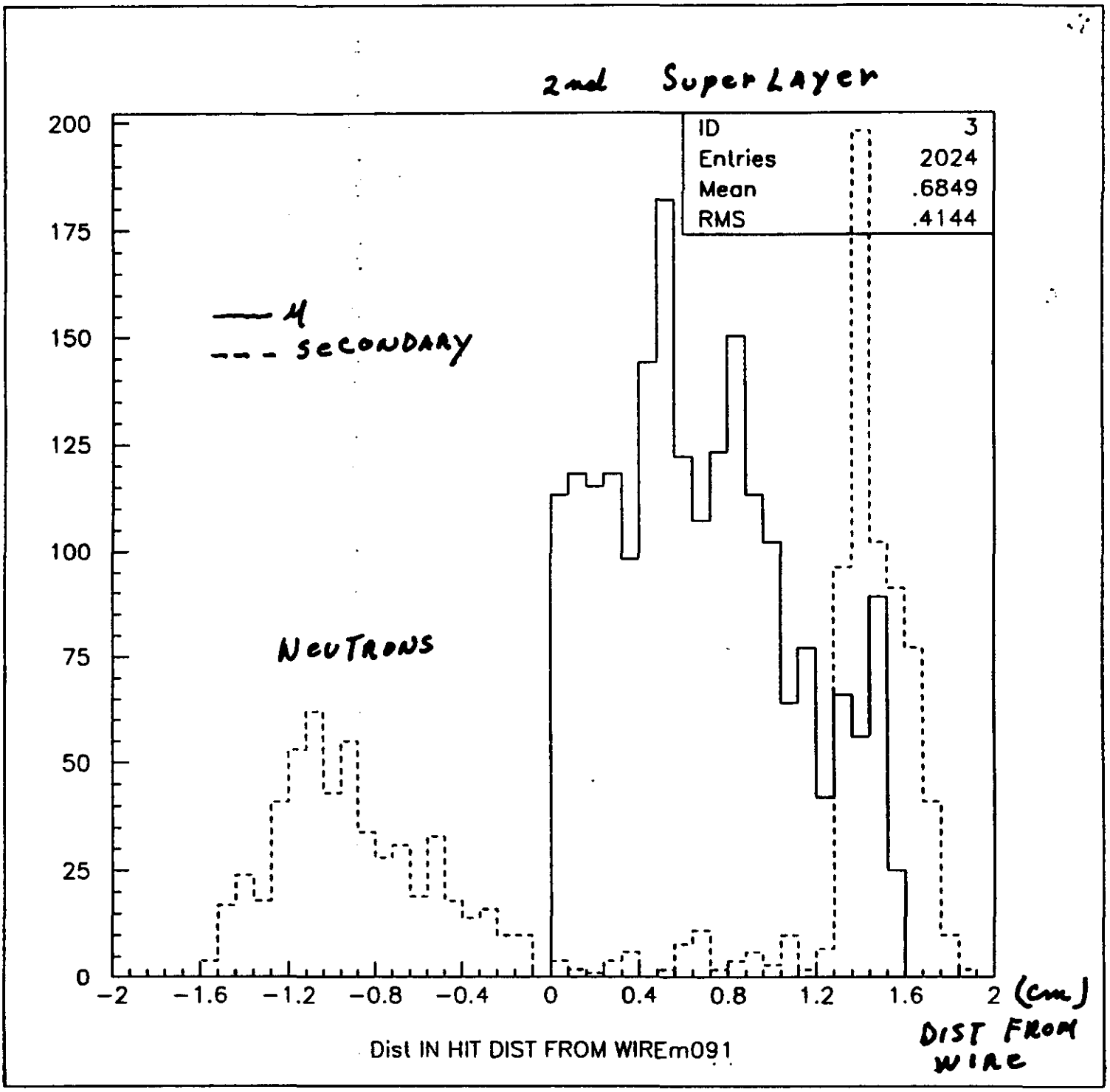
2nd SL = 26 %

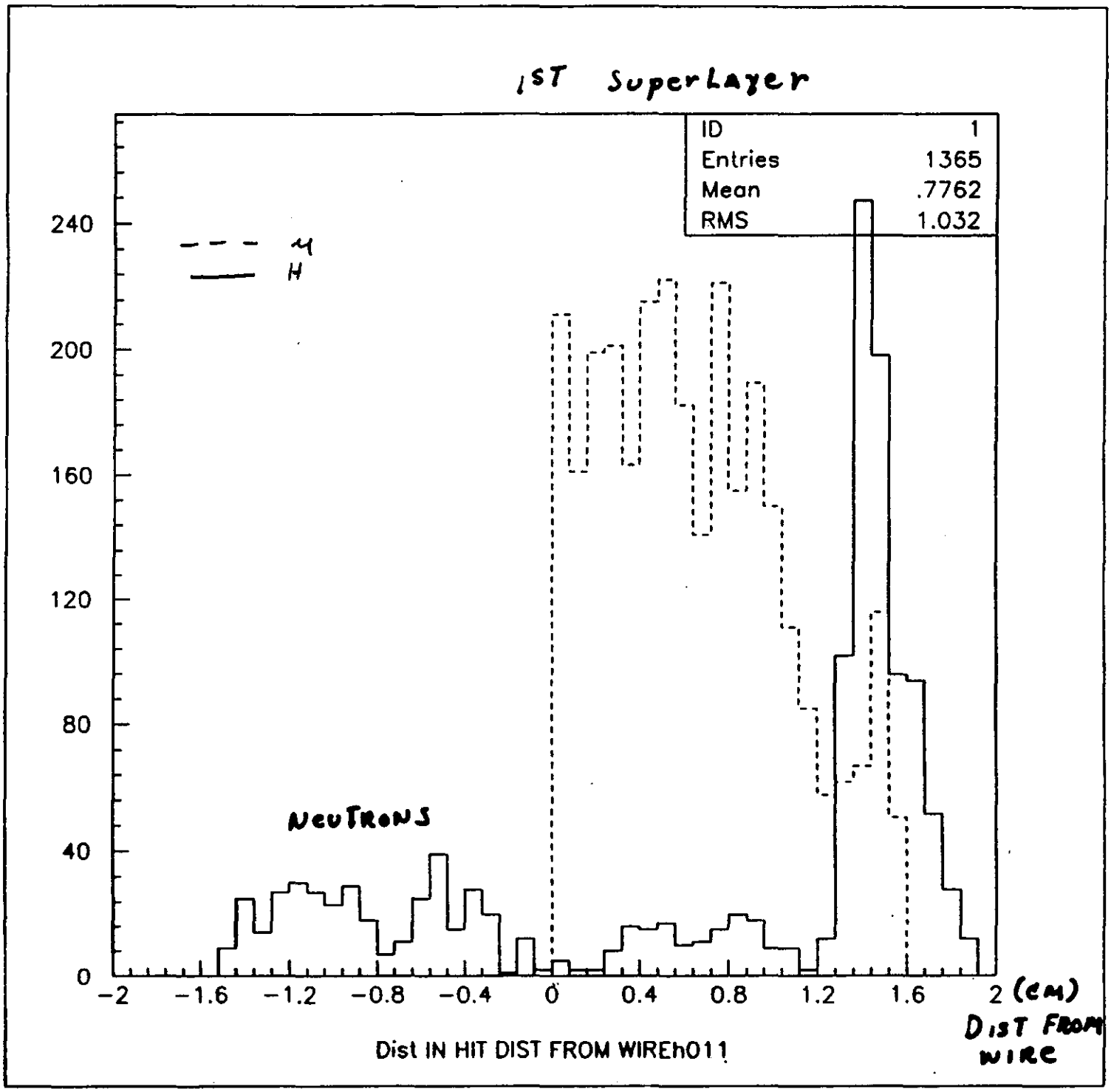
3rd SL = 38 %

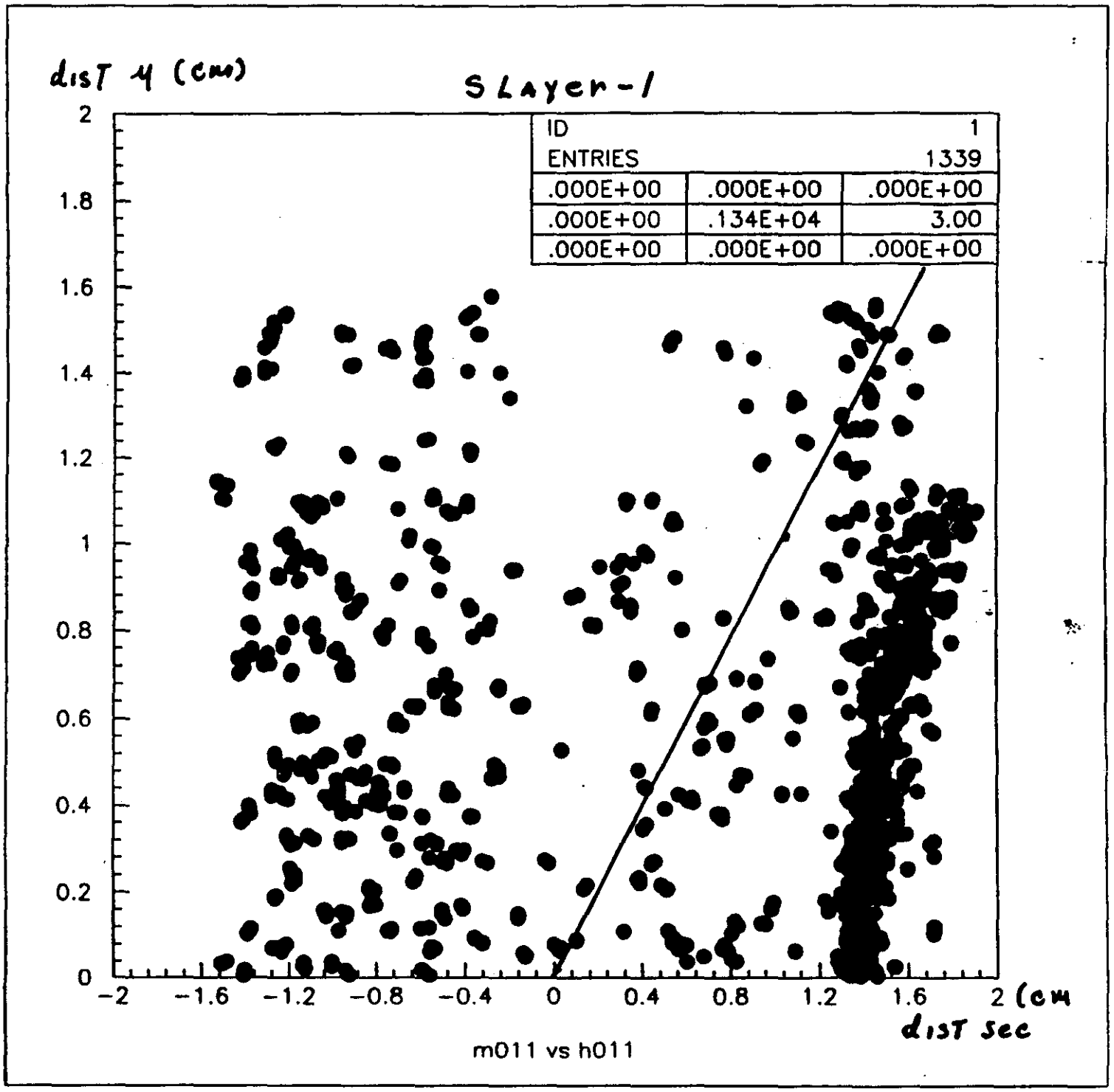

Z M (CM)
Z PRIME
ID 1
ENTRIES 1339
.000E+00 .000E+00 .000E+00
.000E+00 .134E+04 .000E+00
.000E+00 .000E+00 .000E+00
1000
800
600
400
200
0
-200
-400
-600
-800
-1000
-1000 -800 -600 -400 -200 0 200 400 600 800 1000
Z H (CM)
m012 vs h012

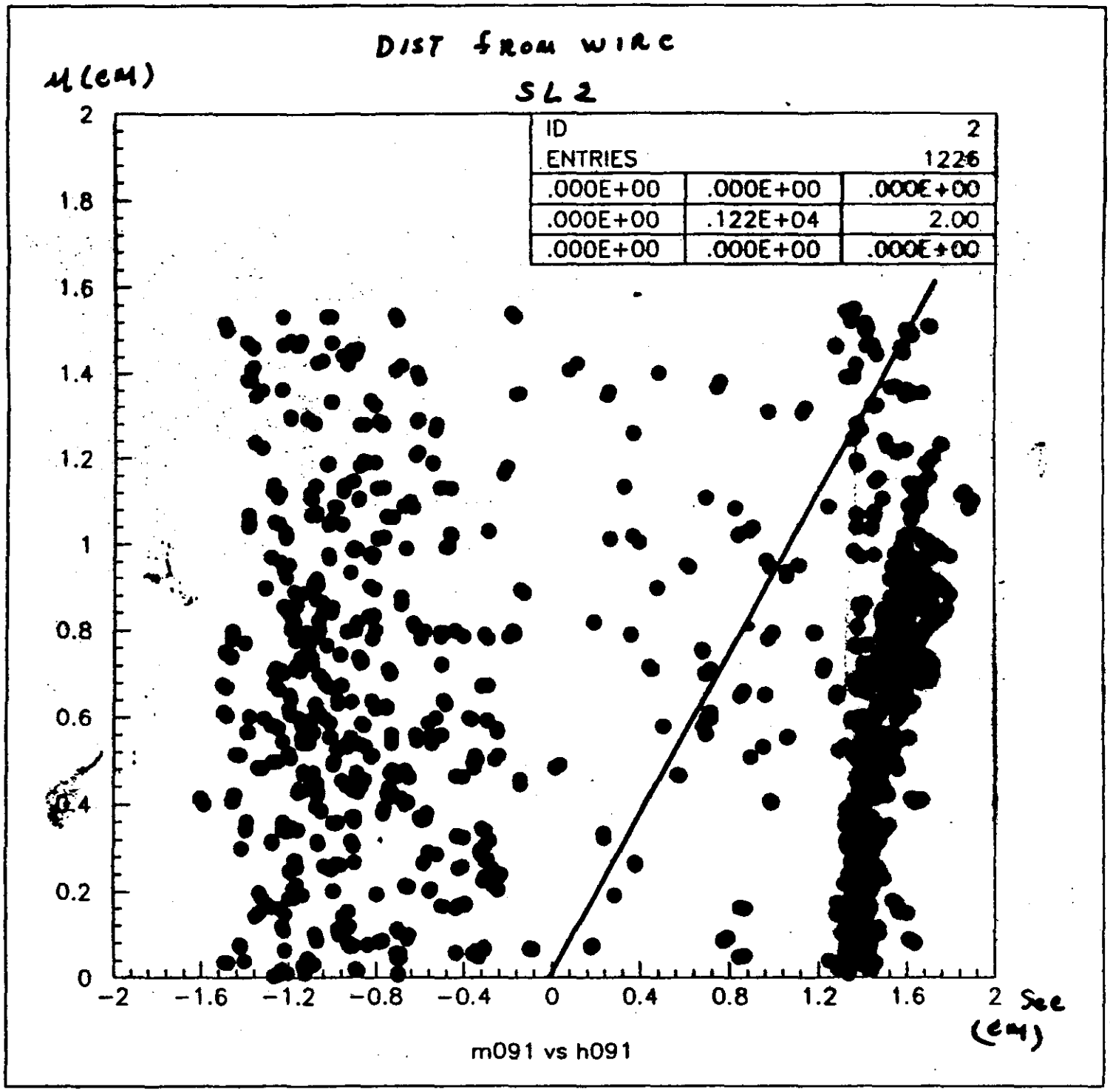

Z PRIME
ID 2
ENTRIES 1199
.000E+00 1.00 247.
.000E+00 403. 14.0
674. .000E+00 .000E+00
m012 vs h012
0
40
80
120
160
200
240
280
CM

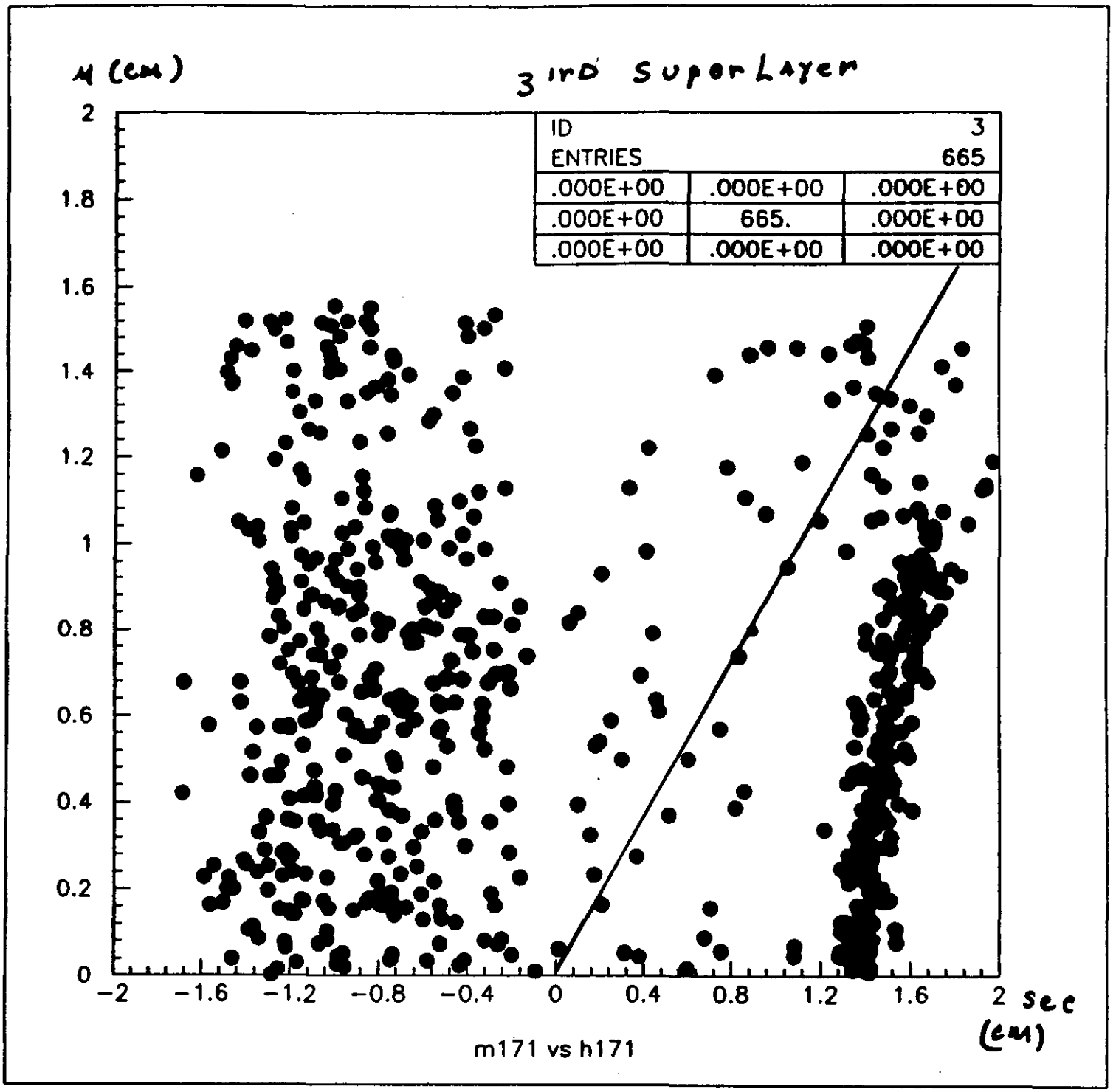

Z M (cm)
ID
ENTRIES
.000E+00
.000E+00
.000E+00
288.
.000E+00
448.
.000E+00
.000E+00
0
40
80
120
160
200
240
280
Z H (cm)
m012 vs h012

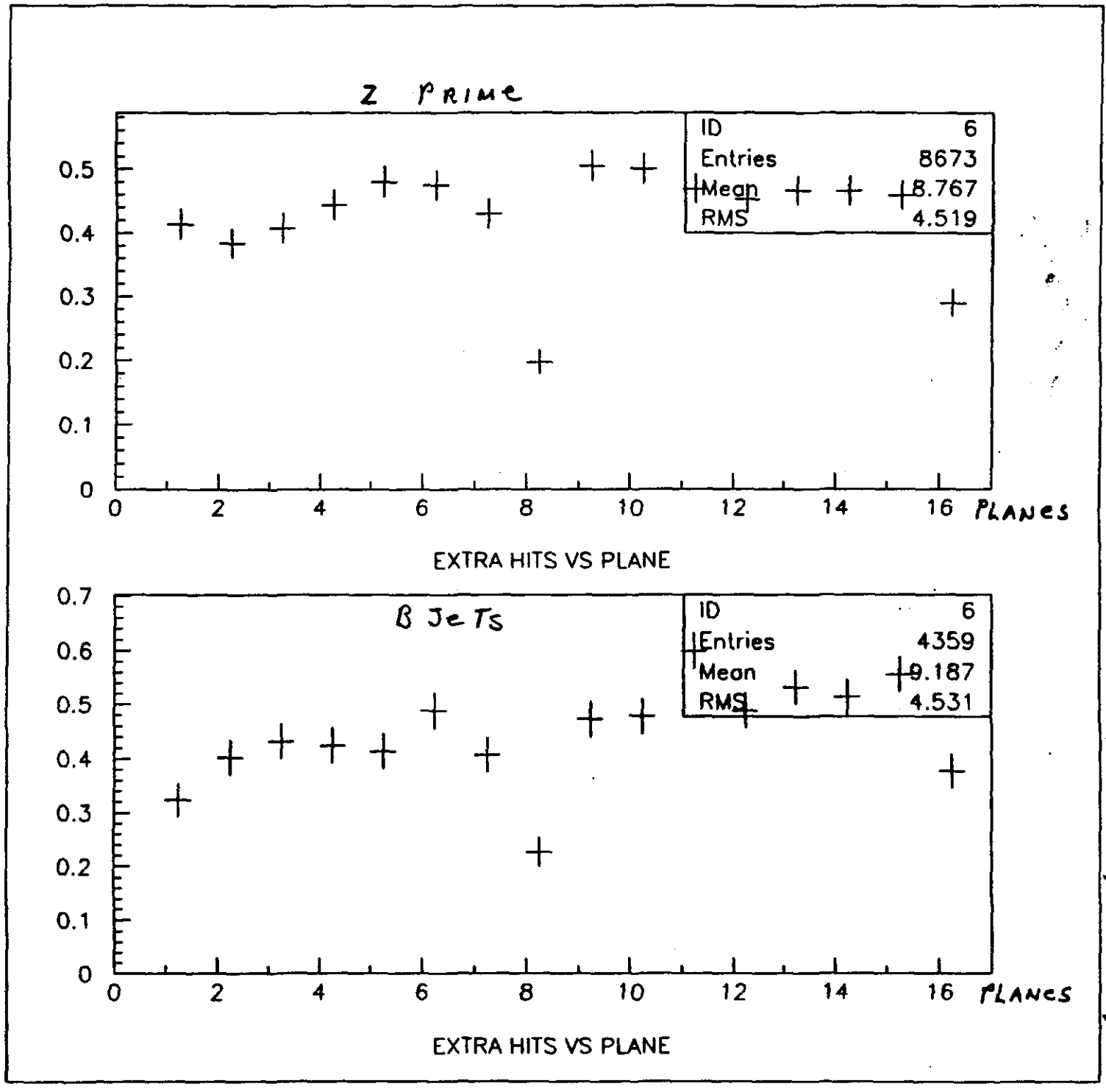

2nd SuperLayer
ID 3
Entries 2024
Mean .6849
RMS .4144
μ
SECONDARY
NEUTRONS
200
175
150
125
100
75
50
25
0
−2
−1.6
−1.2
−0.8
−0.4
0
0.4
0.8
1.2
1.6
2
(cm)
DIST FROM WIRE
Dist IN HIT DIST FROM WIREm091

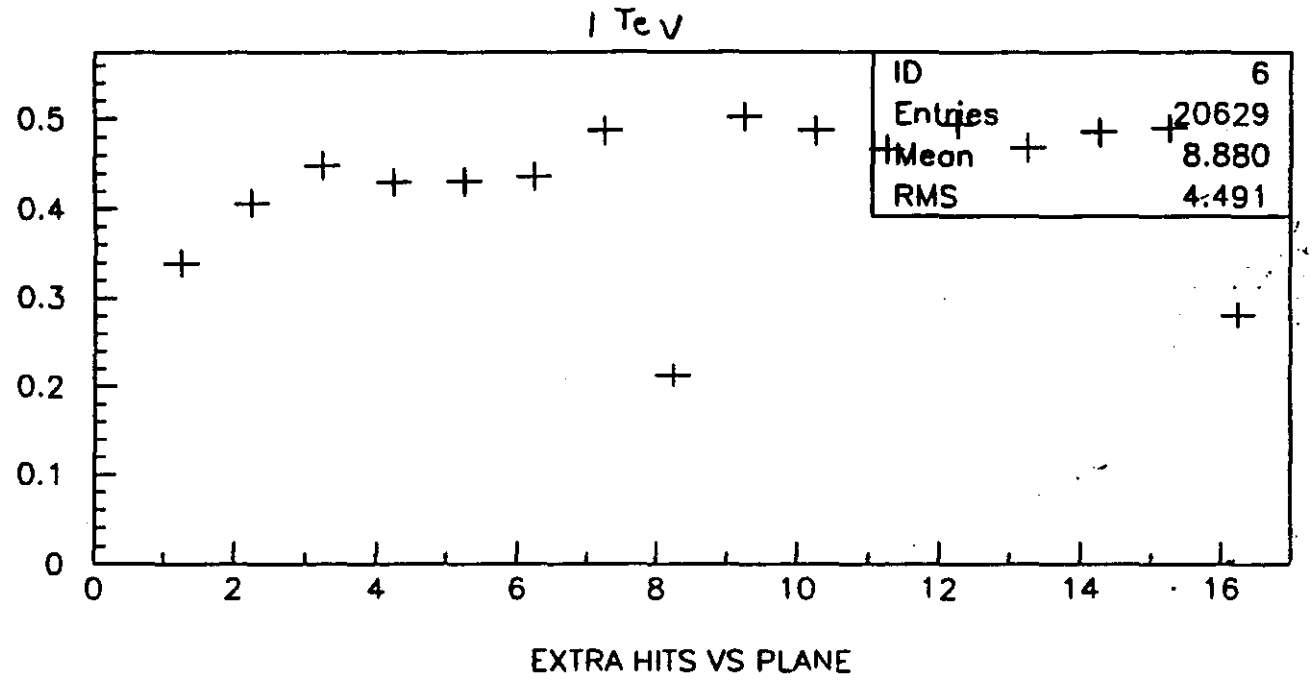

1ST SuperLayer
ID 1
Entries 1365
Mean .7762
RMS 1.032
μ
H
NEUTRONS
240
200
160
120
80
40
0
−2
−1.6
−1.2
−0.8
−0.4
0
0.4
0.8
1.2
1.6
2 (CM)
DIST FROM WIRE
Dist IN HIT DIST FROM WIREh011

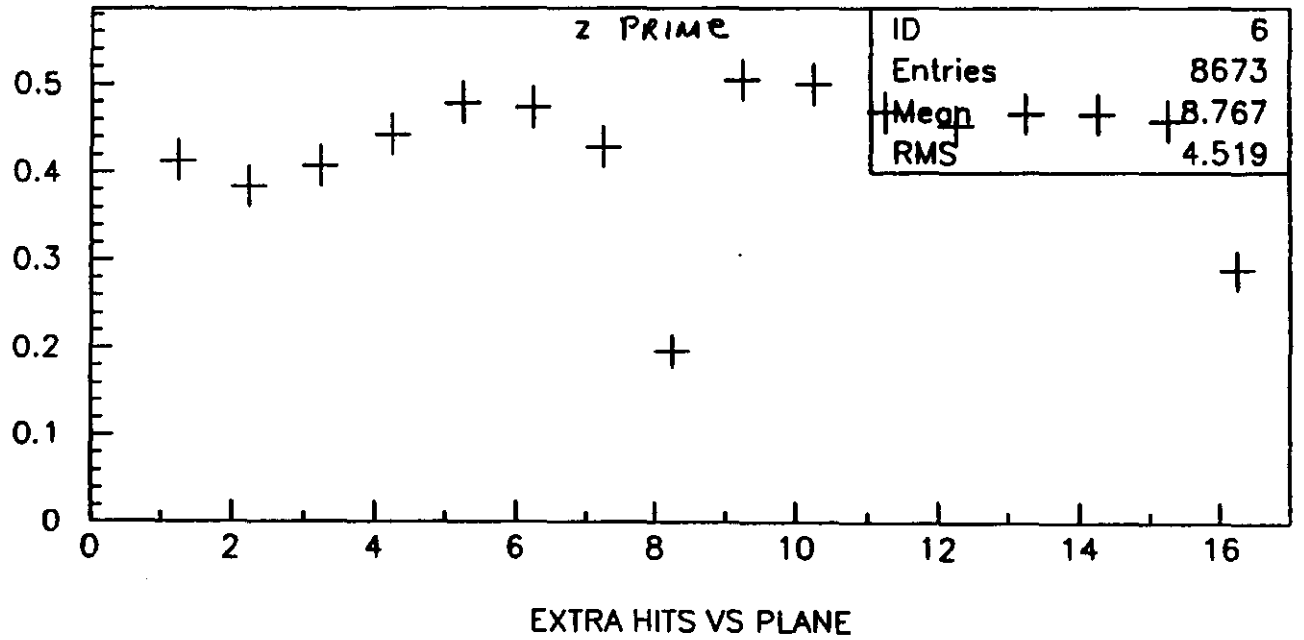

dist y (cm)
S Layer-1
ID 1
ENTRIES 1339
.000E+00 .000E+00 .000E+00
.000E+00 .134E+04 3.00
.000E+00 .000E+00 .000E+00
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
−2 −1.6 −1.2 −0.8 −0.4 0 0.4 0.8 1.2 1.6 2 (cm
dist sec
m011 vs h011

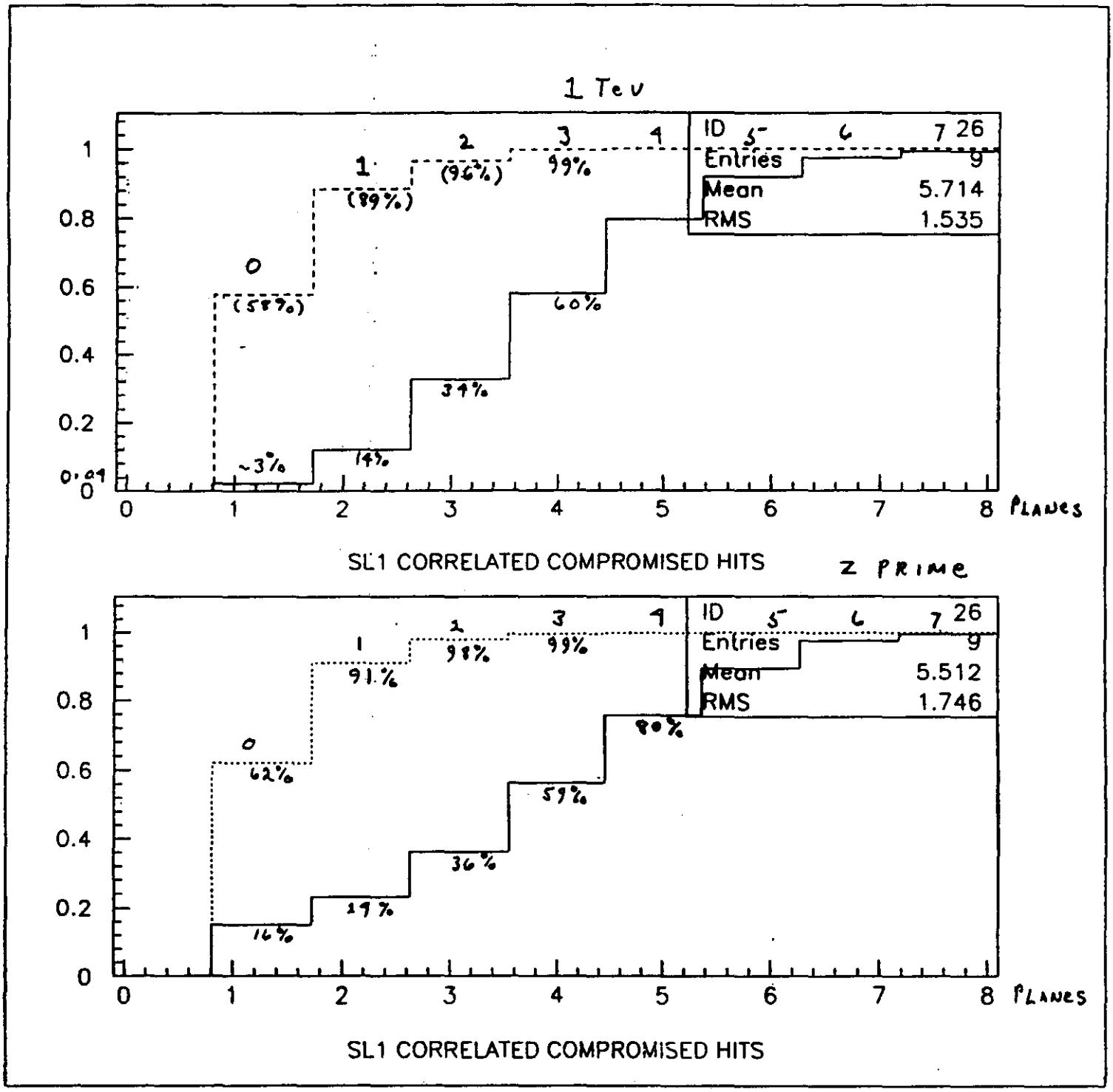

DIST FROM WIRE
SL 2
u (cm)
ID 2
ENTRIES 1226
.000E+00 .000E+00 .000E+00
.000E+00 .122E+04 2.00
.000E+00 .000E+00 .000E+00
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
−2 −1.6 −1.2 −0.8 −0.4 0 0.4 0.8 1.2 1.6 2
Sec (cm)
m091 vs h091

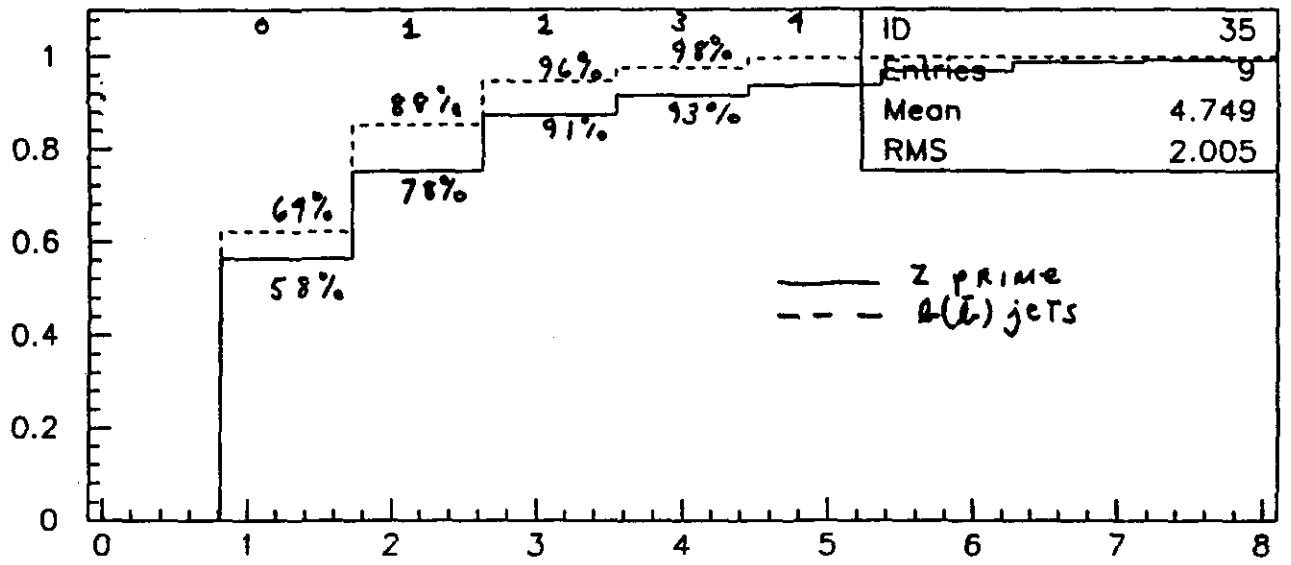

M (cm)
3 ird SuperLayer
ID 3
ENTRIES 665
.000E+00 .000E+00 .000E+00
.000E+00 665. .000E+00
.000E+00 .000E+00 .000E+00
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
−2 −1.6 −1.2 −0.8 −0.4 0 0.4 0.8 1.2 1.6 2
sec
(cm)
m171 vs h171


Z PRIME
ID 6
Entries 8673
Mean 8.767
RMS 4.519
0.5
0.4
0.3
0.2
0.1
0
0 2 4 6 8 10 12 14 16 PLANES
EXTRA HITS VS PLANE
B JETS
ID 6
Entries 4359
Mean 9.187
RMS 4.531
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 2 4 6 8 10 12 14 16 PLANES
EXTRA HITS VS PLANE

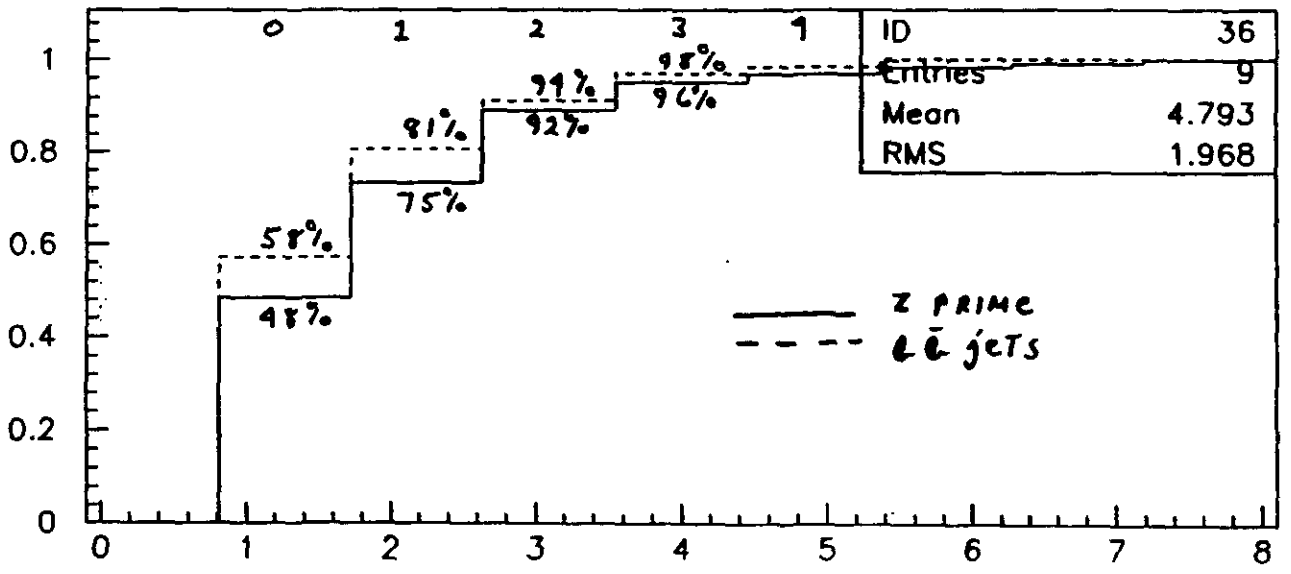

1 TeV
ID 6
Entries 20629
Mean 8.880
RMS 4.491
0.5
0.4
0.3
0.2
0.1
0
0 2 4 6 8 10 12 14 16
EXTRA HITS VS PLANE


z PRIME
ID 6
Entries 8673
Mean 8.767
RMS 4.519
0.5
0.4
0.3
0.2
0.1
0
0 2 4 6 8 10 12 14 16
EXTRA HITS VS PLANE


1 Tev
ID 26
Entries 9
Mean 5.714
RMS 1.535
PLANES
SL1 CORRELATED COMPROMISED HITS
Z PRIME
ID 26
Entries 9
Mean 5.512
RMS 1.746
PLANES
SL1 CORRELATED COMPROMISED HITS



SL1 CORRELATED AJACENT HITS



SL2 CORRELATED AJACENT HITS

% of μ cells/layer (plane) compromised

SLayer-1

Planes	1 Tev	Z prime	$B\bar{B}$ Jets
0	58%	62%	69%
1	89%	91%	92%
2	96%	98%	98.5%
3	99%	99%	99%
4	100%	100%	100%
5	"	"	"

SLayer-2

0	49%	59%	61%
1	84%	86%	85%
2	96%	97%	97%
3	99%	99%	99%
4	100%	100%	100%
5	"	"	"

SL-3 (75/75)

0	59% (89.5)	78%	72%
1	88% (95)	90%	91%
2	93% (96.5)	95%	95%
3	93.5%	95.5%	95.5%

SL-3 (62/75) (50/75)

0	61%	(90)	2%	69%	69%	93.5%	1%
1	90%	(95.5)	91%	91%	92%	94%	14%
2	96%	(97)	96%	96%	96%	96%	97%
3	96.5%			97%		97%	

SL-3 (50/75)

Chiaki Yanagisawa

Nov. 5, 1992
@ BNL.

Overlap effects of CSC

Chiaki Yanagisawa
Stony Brook

MC data used: (by Hai Yamadita)

- 1 TeV/c muons
- GEANT with 10 keV threshold
- CSC 8-4-4 configuration, End cap.
  → uniformly distributed: worst case scenario
- With/without extra material in front of superlayers - 0.78 X_0 to account for the support material.
- Overlap of chambers between sectors included.

Quantities used:

- Probability that N planes/layers have extra hits near the muon hits within distance r
- Probability to have extra hits within distance r.

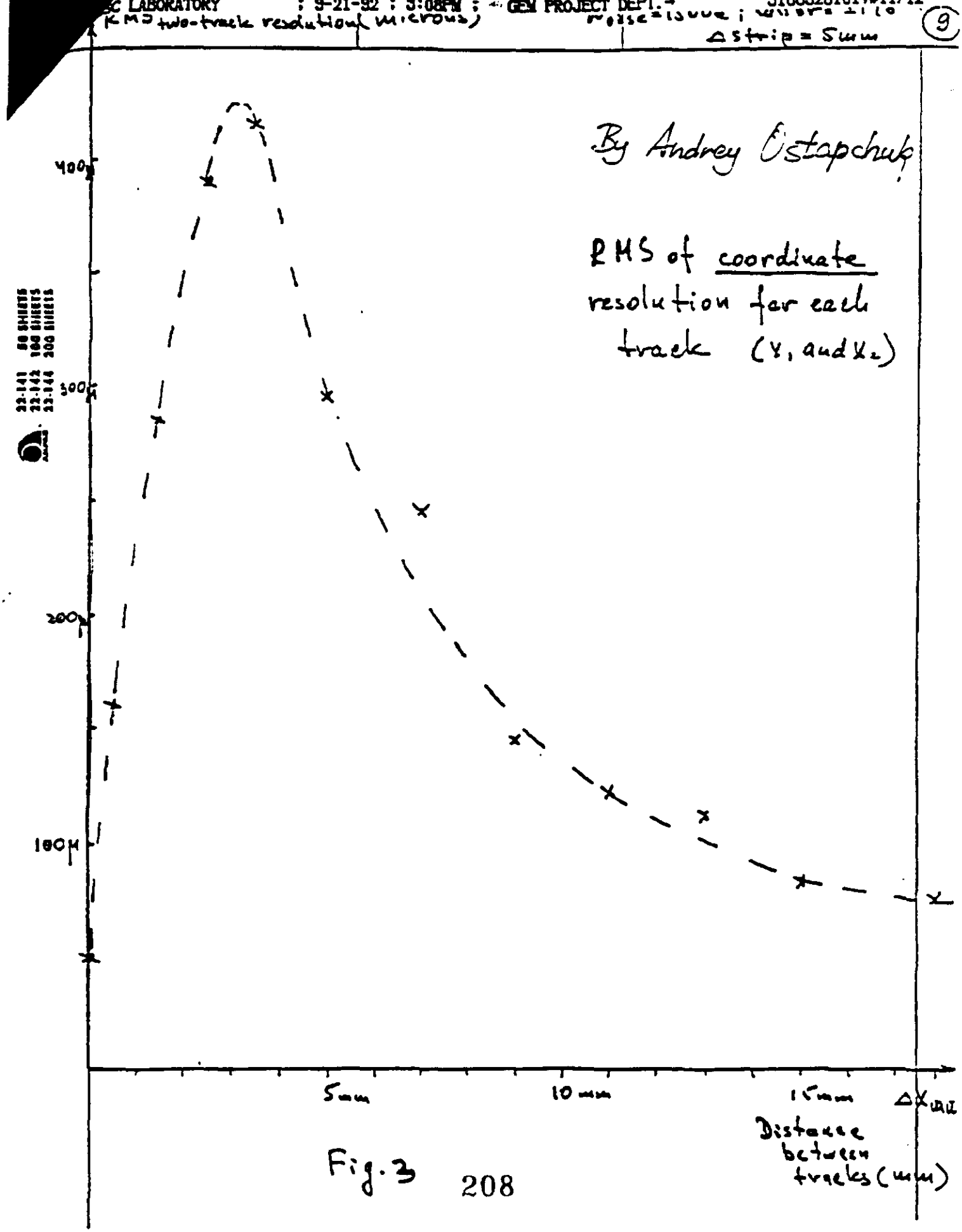
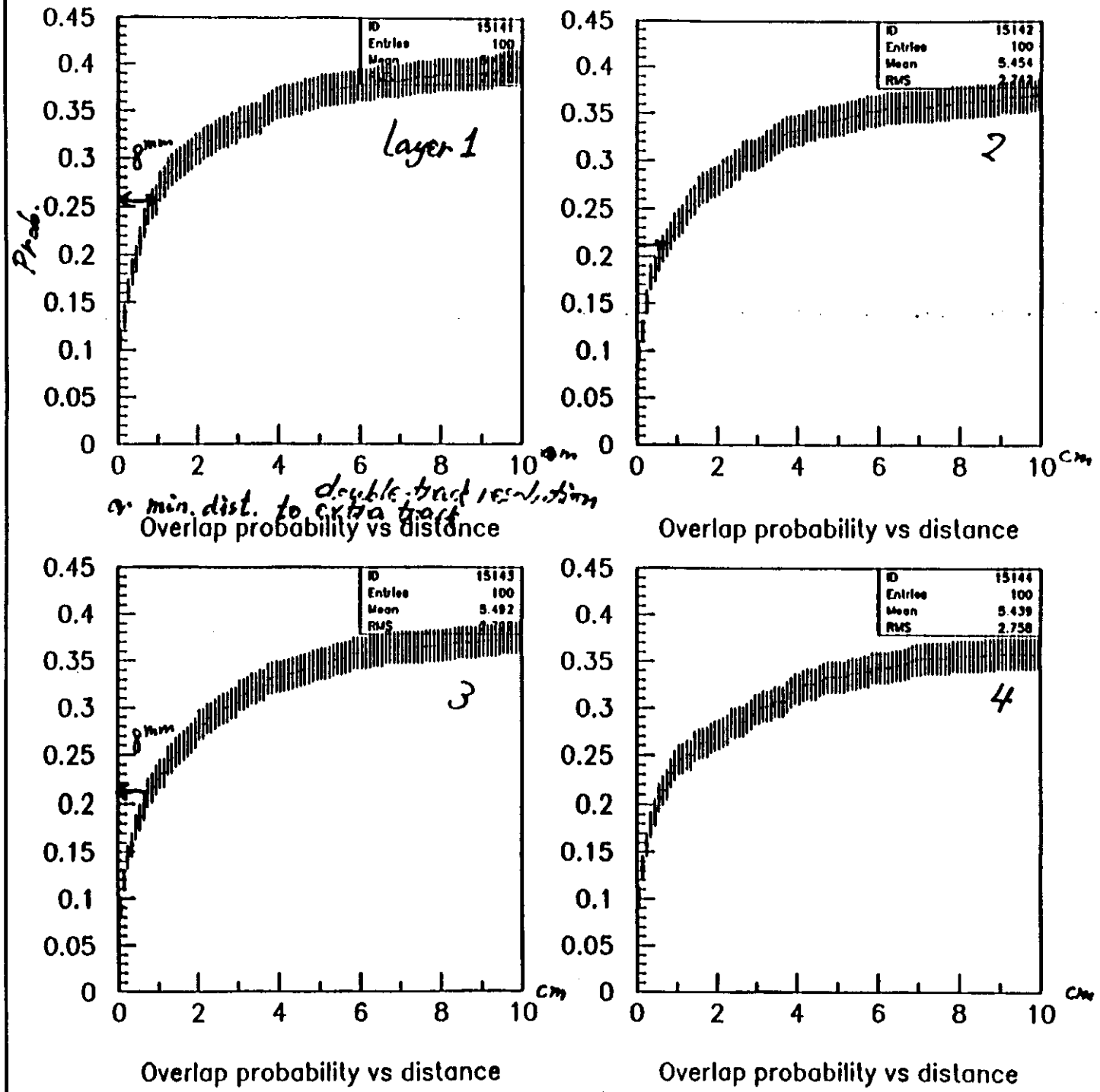

KMS two-track resolution (microns)
Noise = 1500e ; Width = 1.10
Δstrip = 5mm
9
By Andrey Ostapchuk
RMS of coordinate resolution for each track (x_1 and x_2)
400μ
300μ
200μ
100μ
5mm
10 mm
15mm
Δx_{DIL}
Distance between tracks (mm)

Fig. 3

SL1

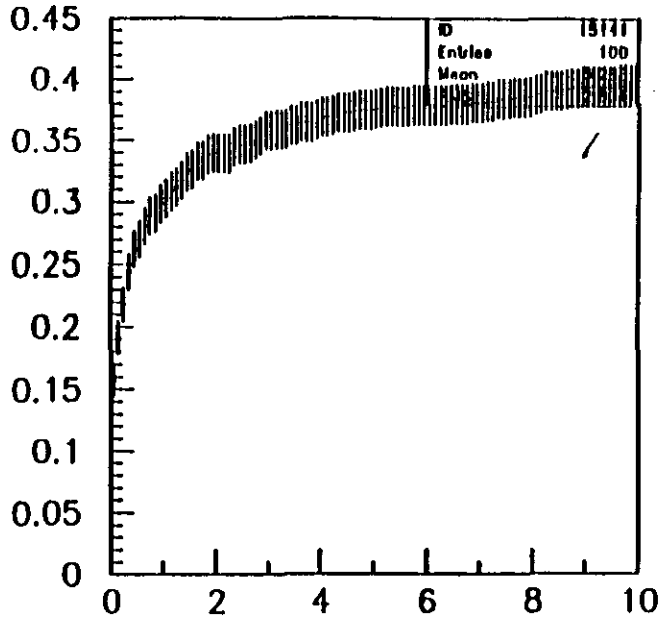
Probability to have extra hits as a function of double-track resolution

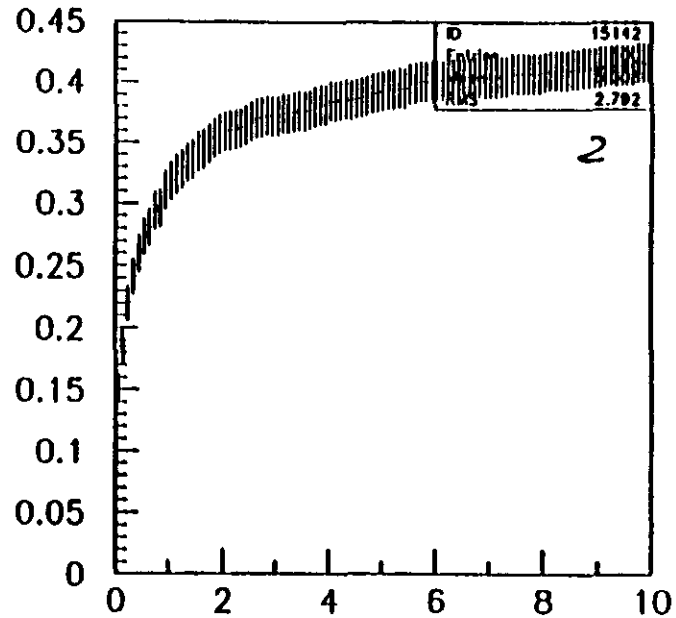


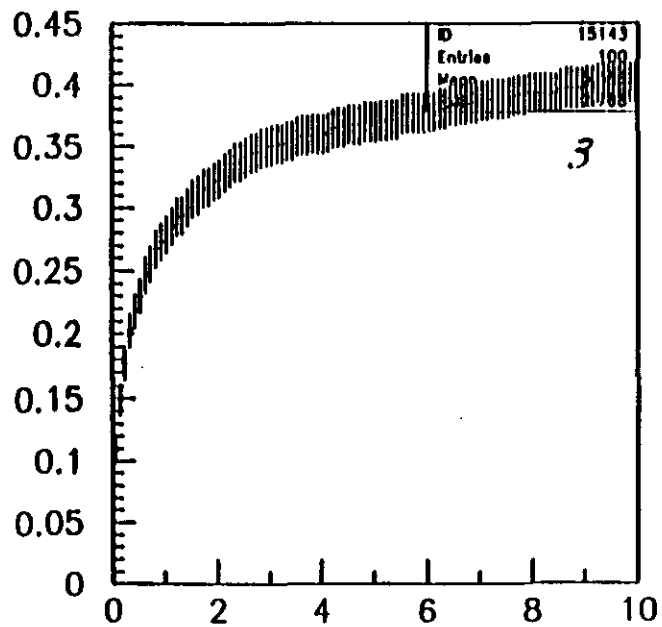
a min. dist. to extra hit double-track resolution

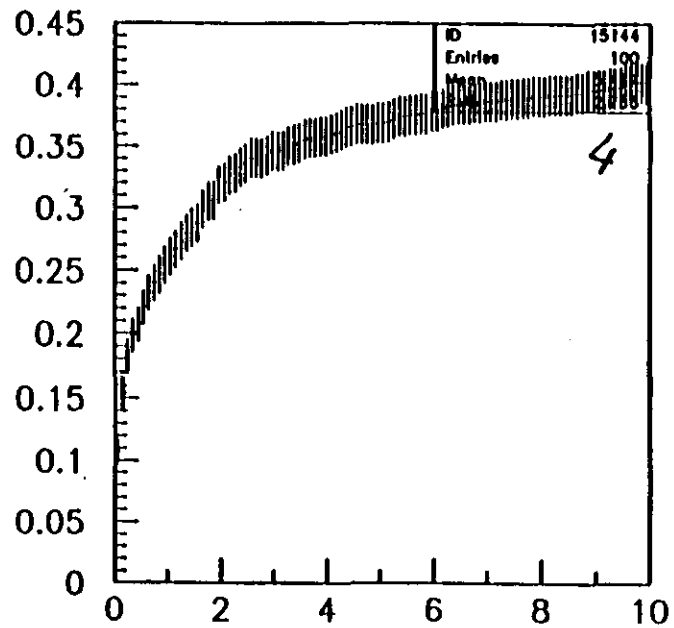
SL1

0.78 X_0


ID 15141
Entries 100
1
Overlap probability vs distance

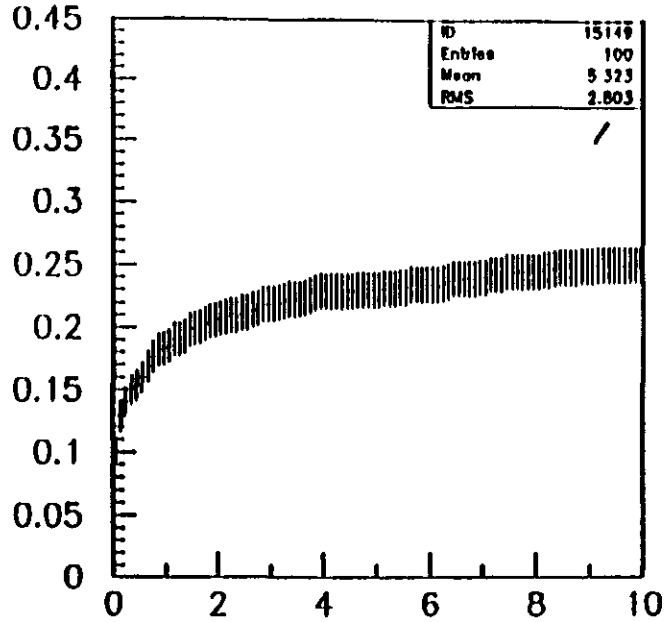

ID 15142
2.792
2
Overlap probability vs distance

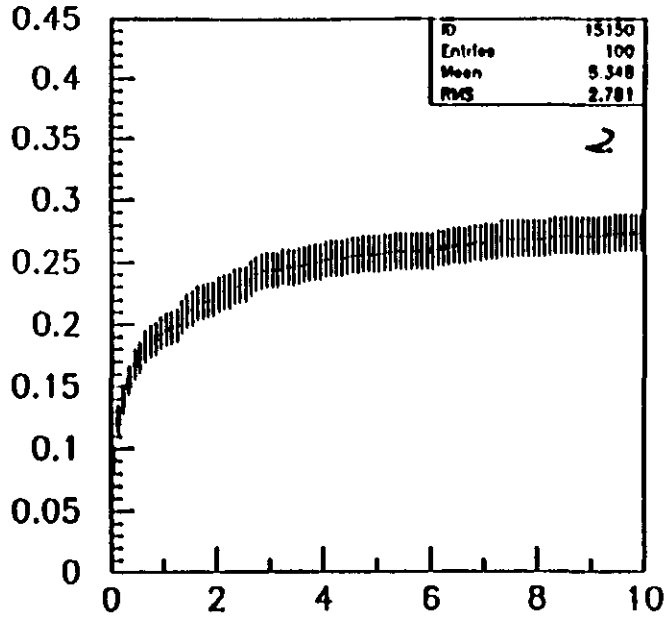

ID 15143
Entries 100
3
Overlap probability vs distance

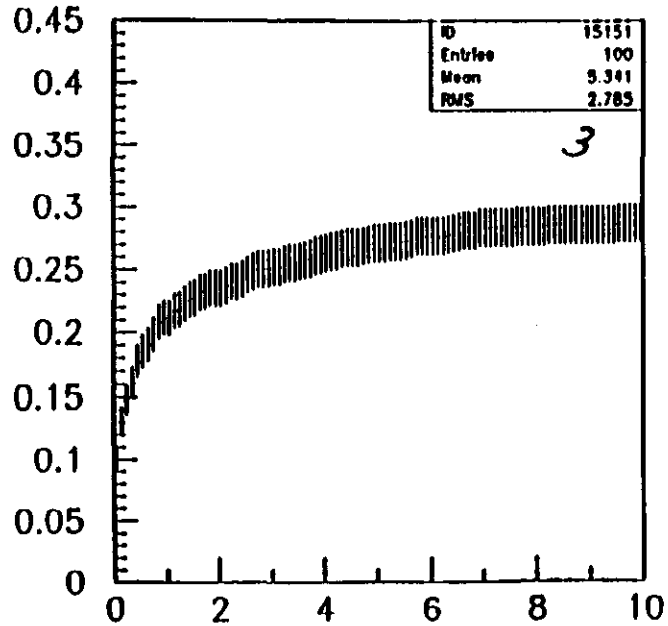

ID 15144
Entries 100
4
Overlap probability vs distance

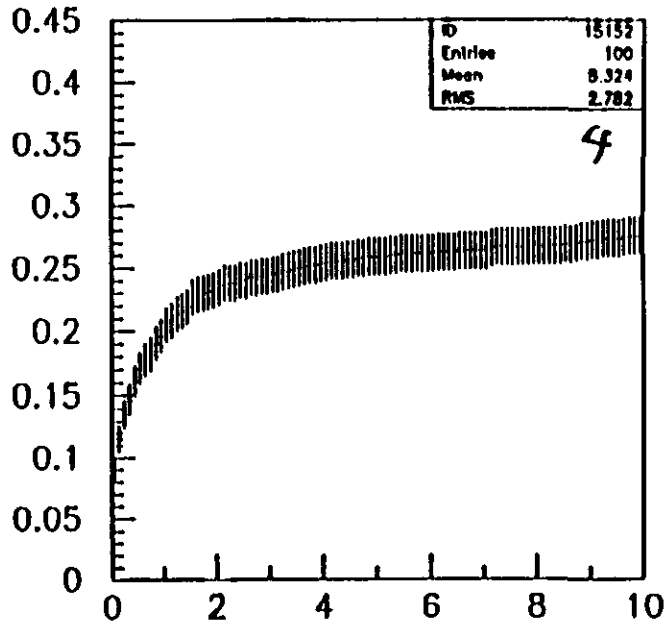
SL2

0.78X_0


ID 15149
Entries 100
Mean 5.323
RMS 2.803
1
Overlap probability vs distance

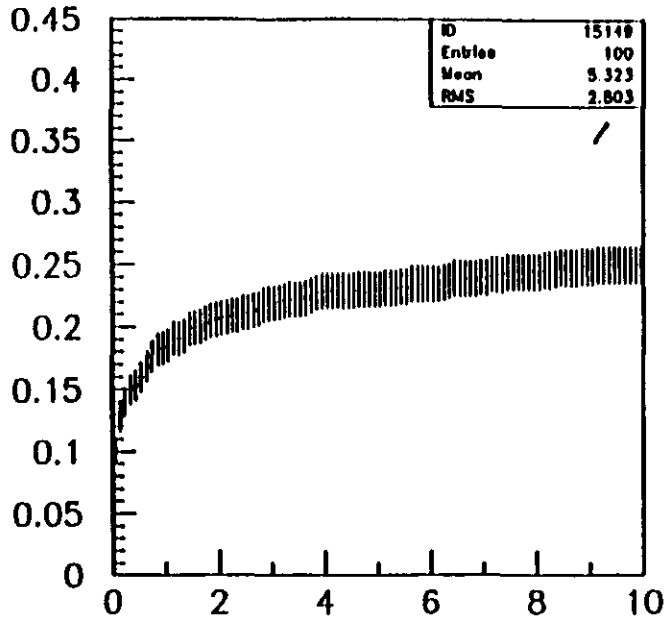

ID 15150
Entries 100
Mean 5.348
RMS 2.781
2
Overlap probability vs distance

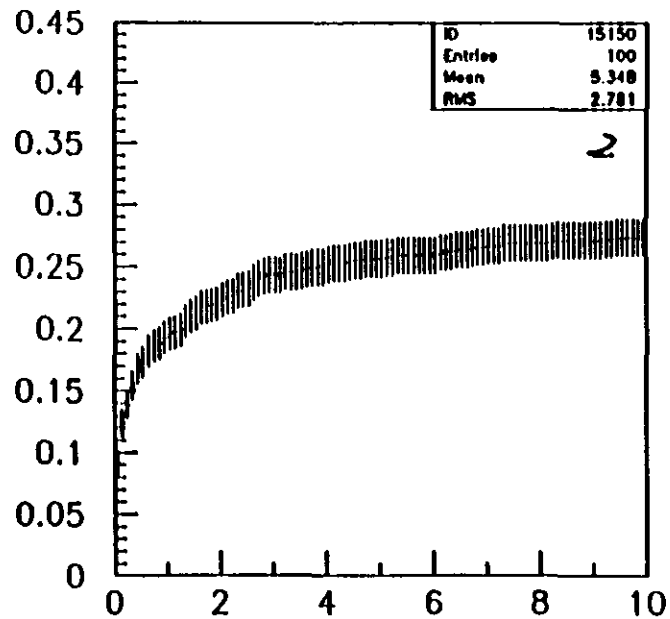

ID 15151
Entries 100
Mean 5.341
RMS 2.785
3
Overlap probability vs distance

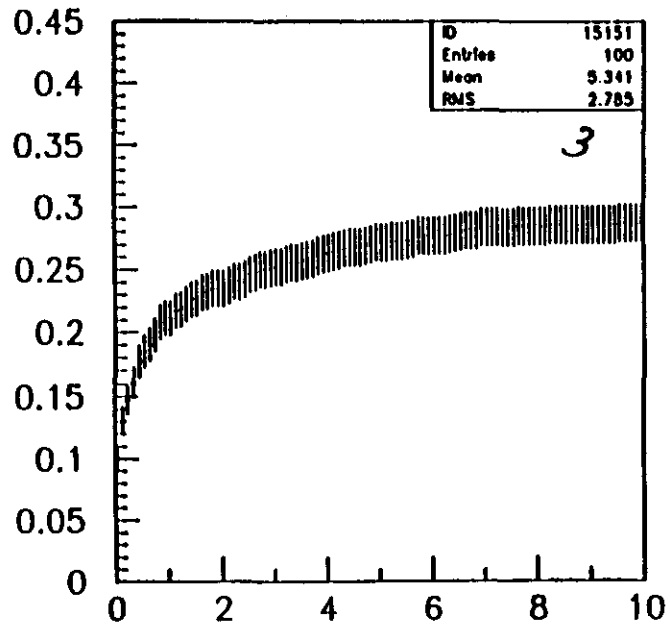

ID 15152
Entries 100
Mean 5.324
RMS 2.782
4
Overlap probability vs distance

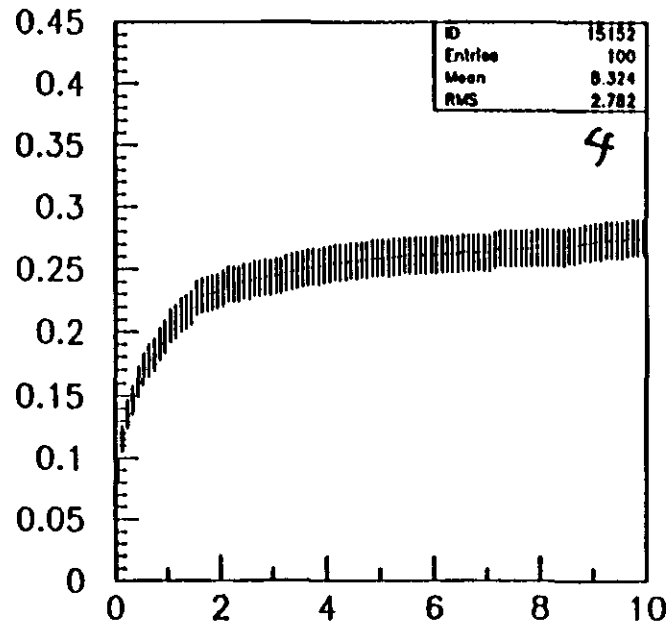
SL2

0.78X_0

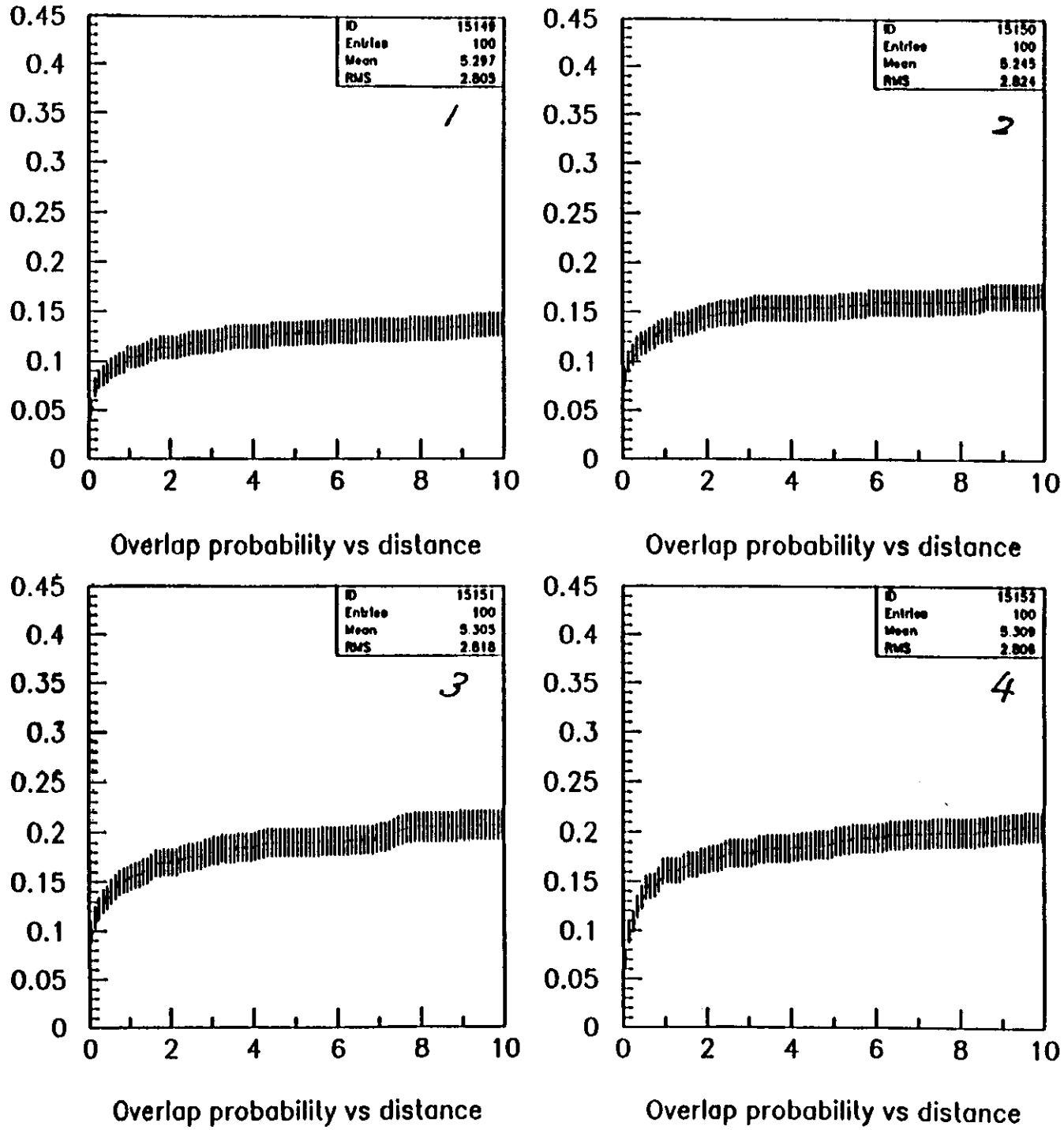

ID 15149
Entries 100
Mean 5.323
RMS 2.803
1
Overlap probability vs distance


ID 15150
Entries 100
Mean 5.348
RMS 2.781
2
Overlap probability vs distance


ID 15151
Entries 100
Mean 5.341
RMS 2.785
3
Overlap probability vs distance

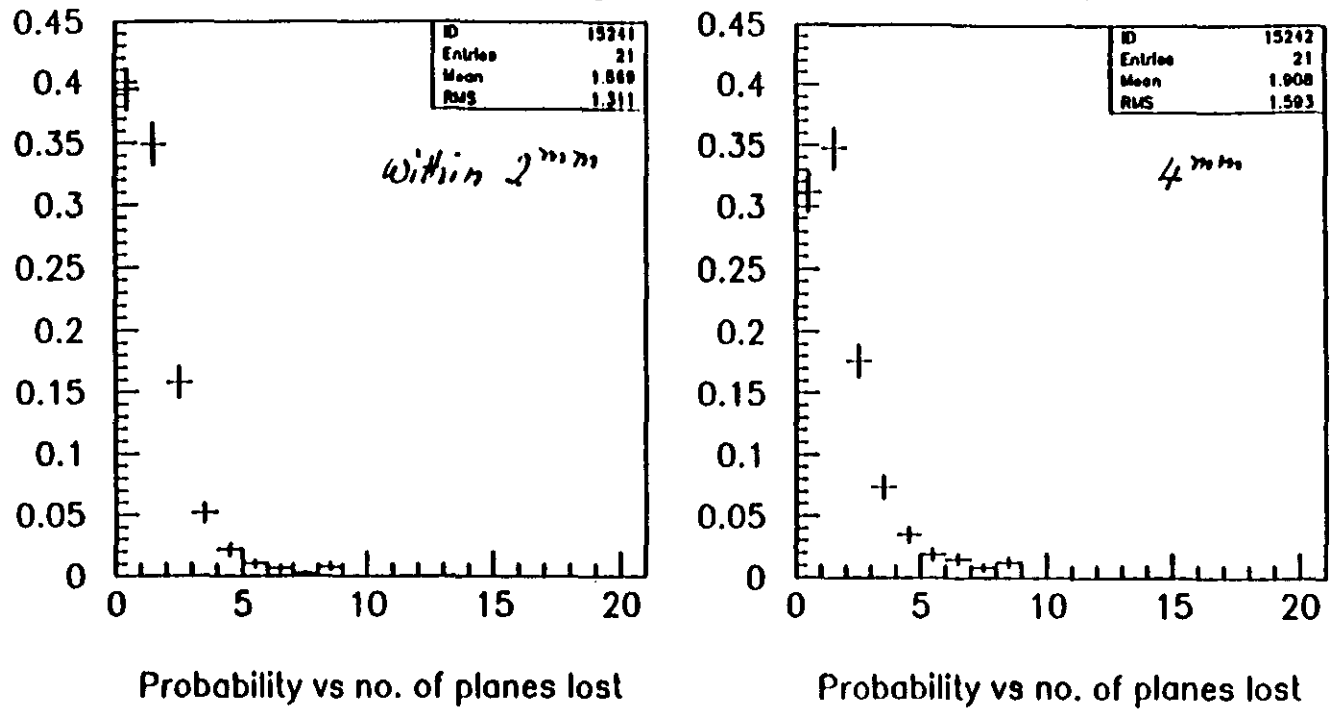

ID 15152
Entries 100
Mean 5.324
RMS 2.782
4
Overlap probability vs distance

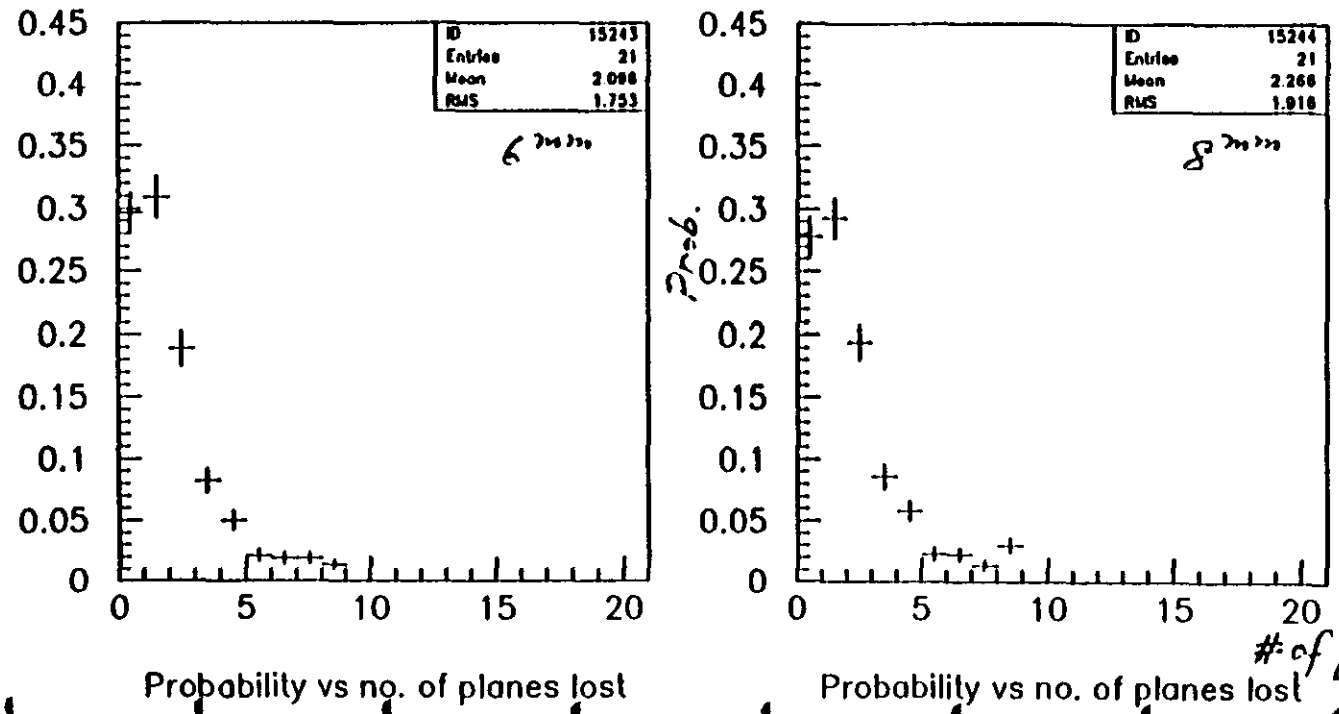
SL2


ID 15149
Entries 100
Mean 5.297
RMS 2.805
1
Overlap probability vs distance
ID 15150
Entries 100
Mean 5.245
RMS 2.824
2
Overlap probability vs distance
ID 15151
Entries 100
Mean 5.303
RMS 2.818
3
Overlap probability vs distance
ID 15152
Entries 100
Mean 5.309
RMS 2.808
4
Overlap probability vs distance

SL1

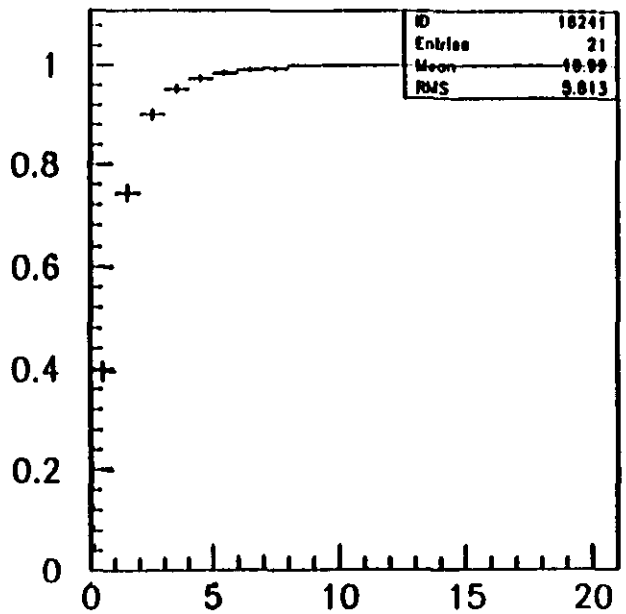
Probability that there are N layers with extra hits

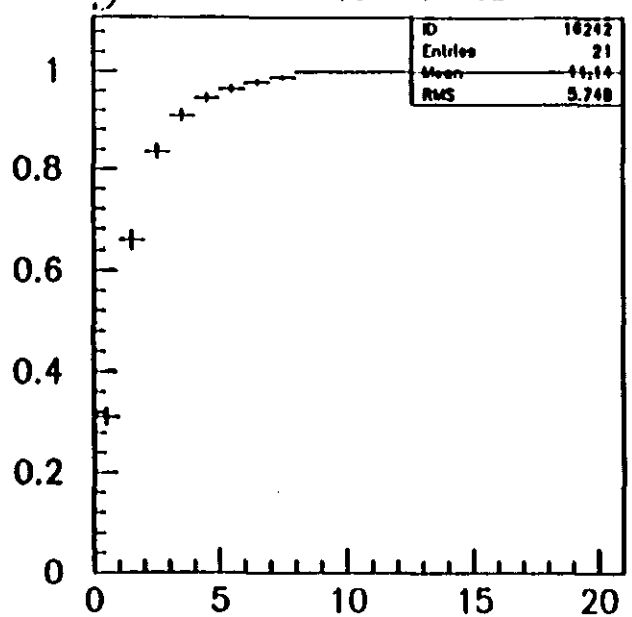


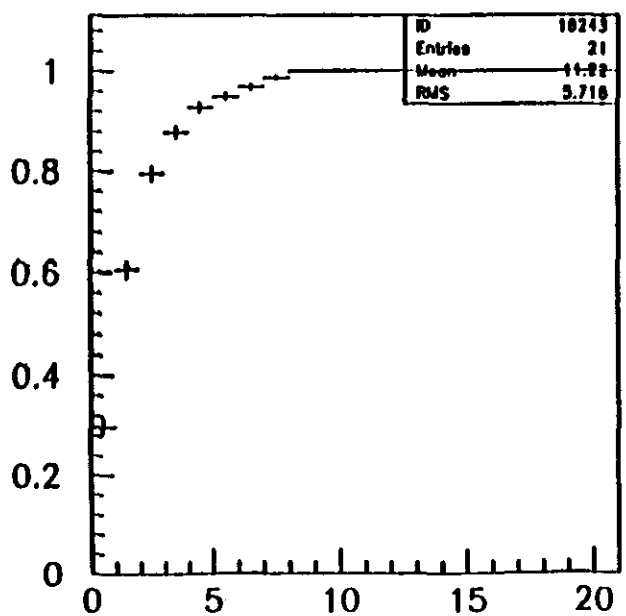


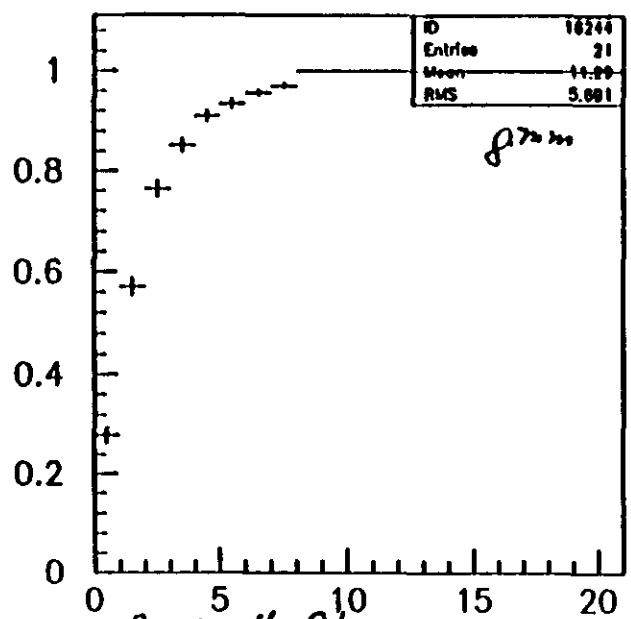
SL1

Prob. that there are N or less layers with extra hits



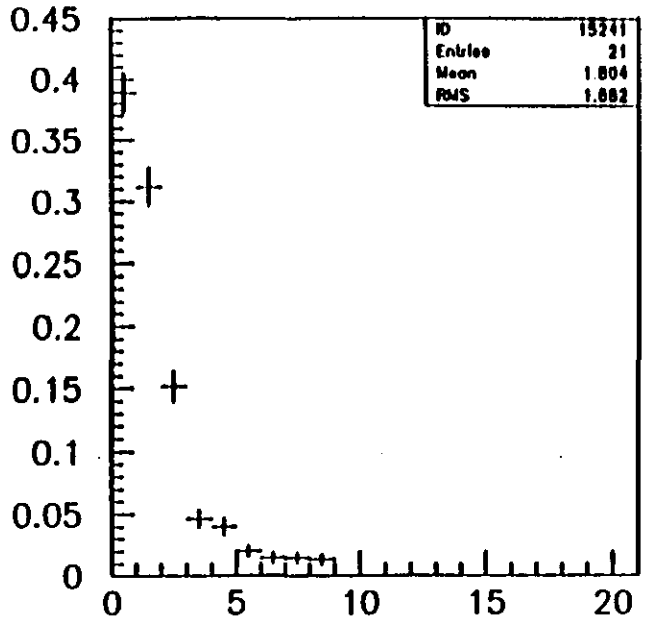




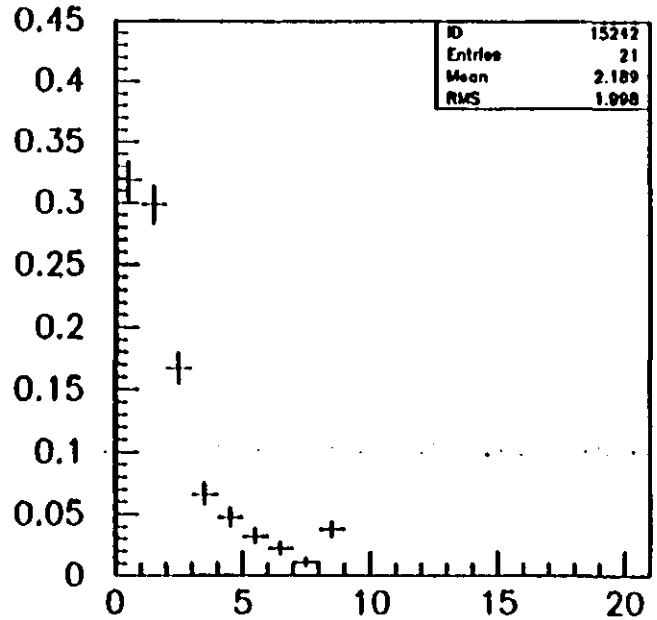


max. # of layers with extra hits

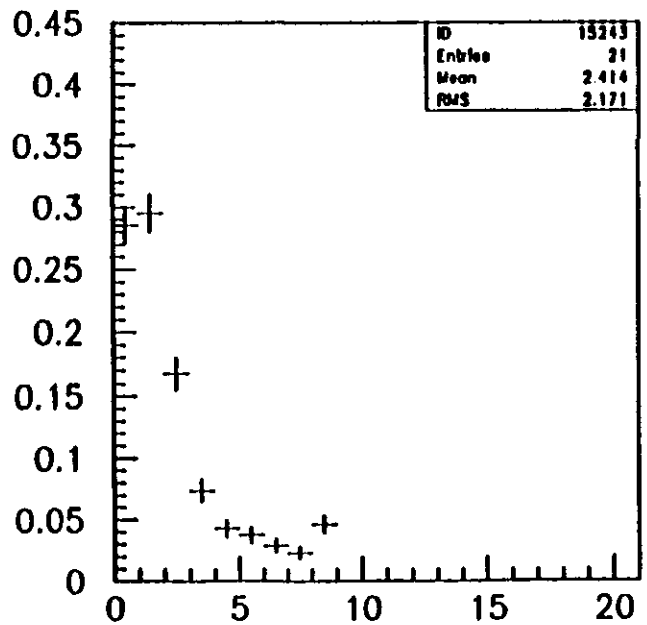
0.78X₀



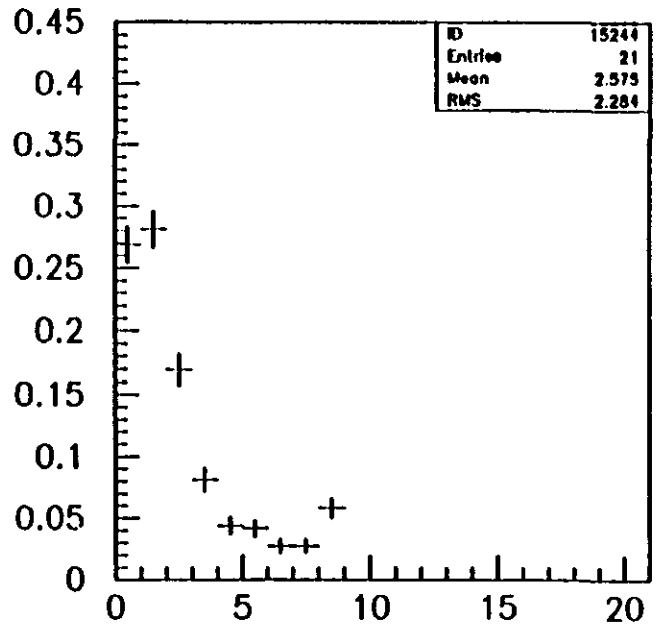
Probability vs no. of planes lost



Probability vs no. of planes lost

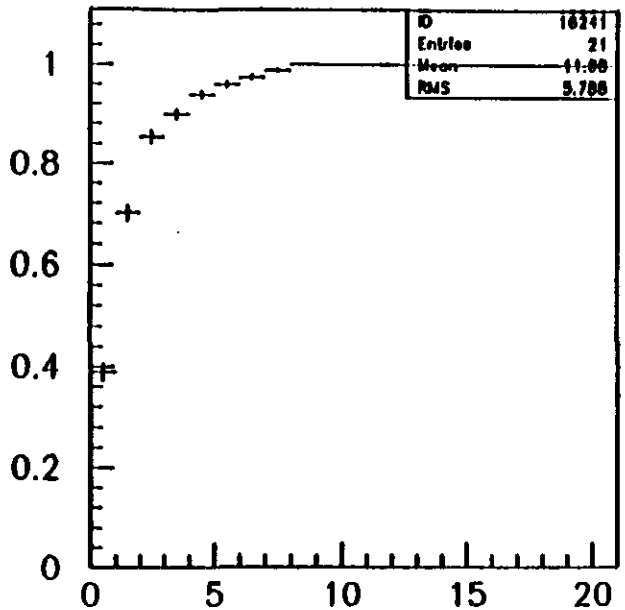


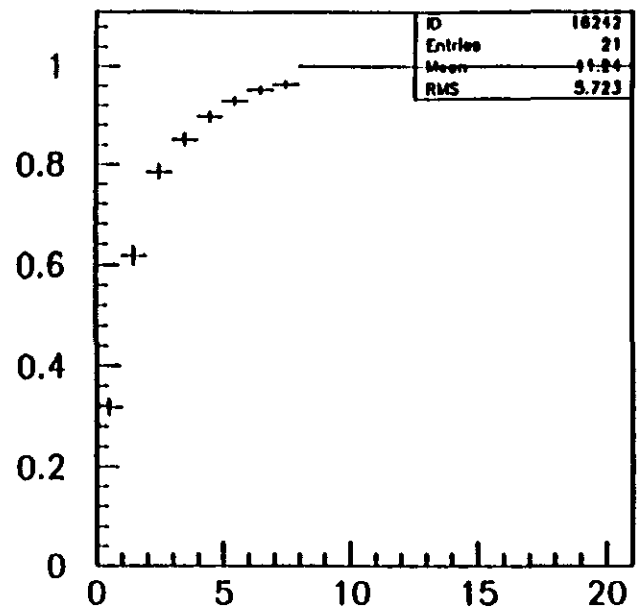
Probability vs no. of planes lost

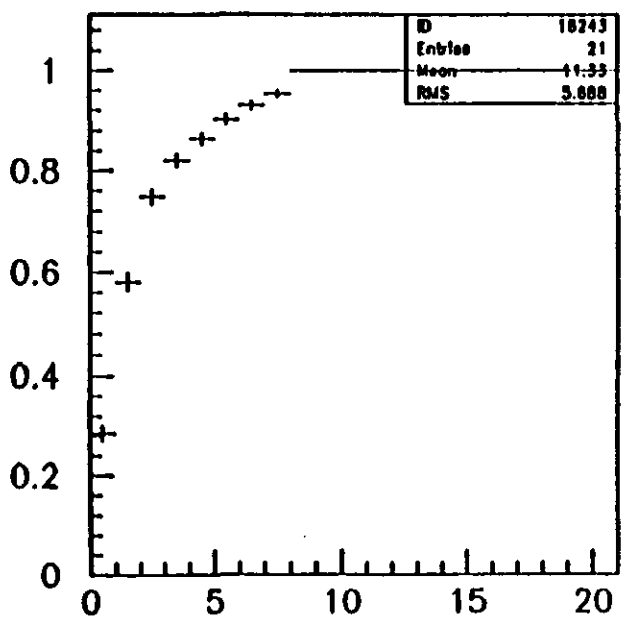


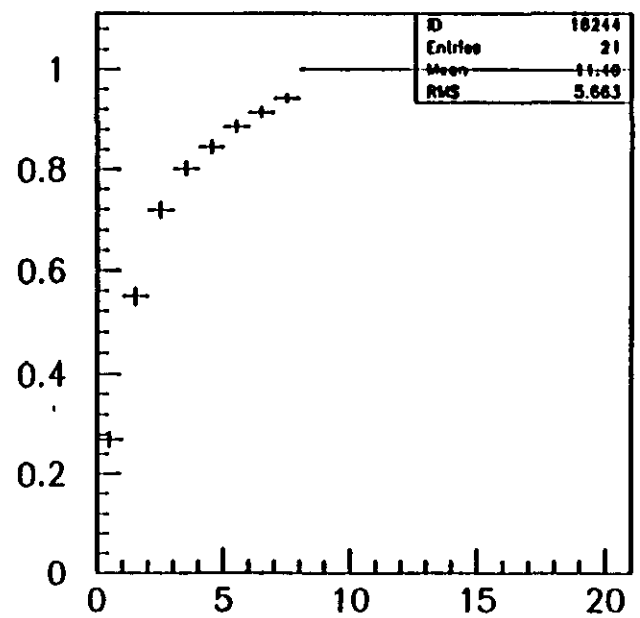
Probability vs no. of planes lost

0.78X_0

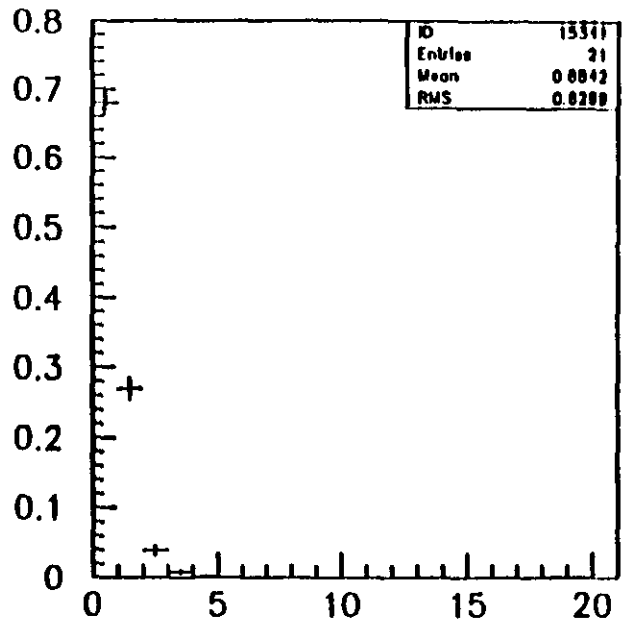

ID 18241
Entries 21
Mean 11.00
RMS 5.788
Probability vs no. of planes lost

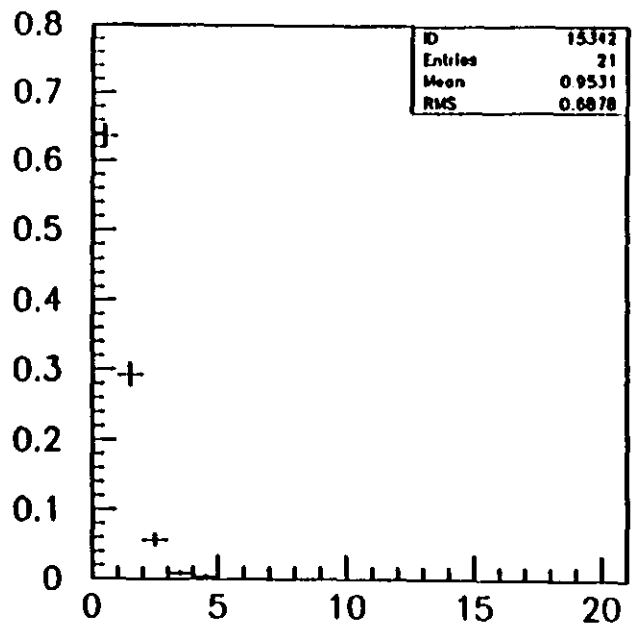

ID 18242
Entries 21
Mean 11.24
RMS 5.723
Probability vs no. of planes lost

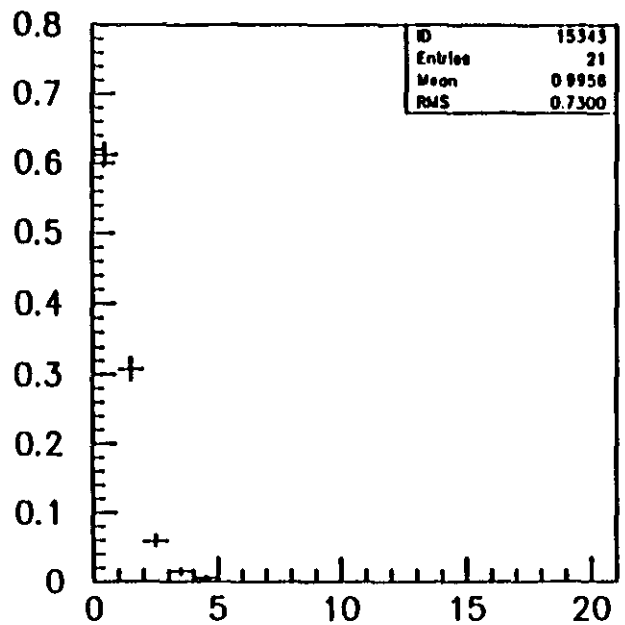

ID 18243
Entries 21
Mean 11.33
RMS 5.688
Probability vs no. of planes lost

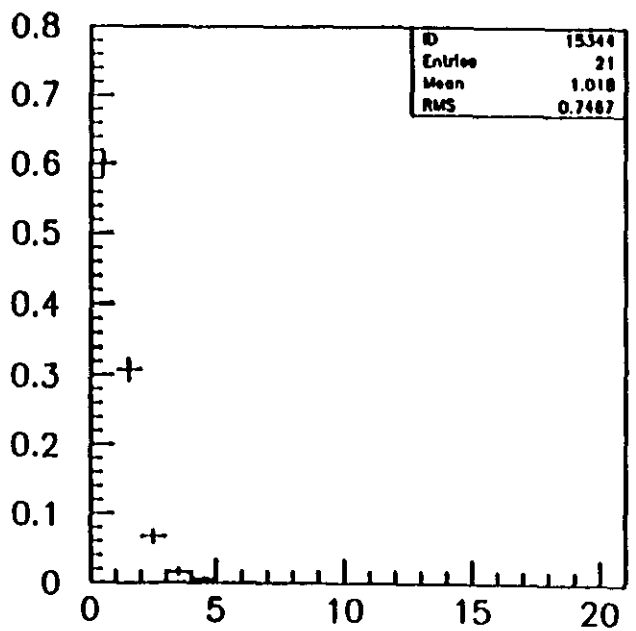

ID 18244
Entries 21
Mean 11.40
RMS 5.663
Probability vs no. of planes lost

SL2


ID 15341
Entries 21
Mean 0.8842
RMS 0.8289
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
5
10
15
20
Probability vs no. of planes lost

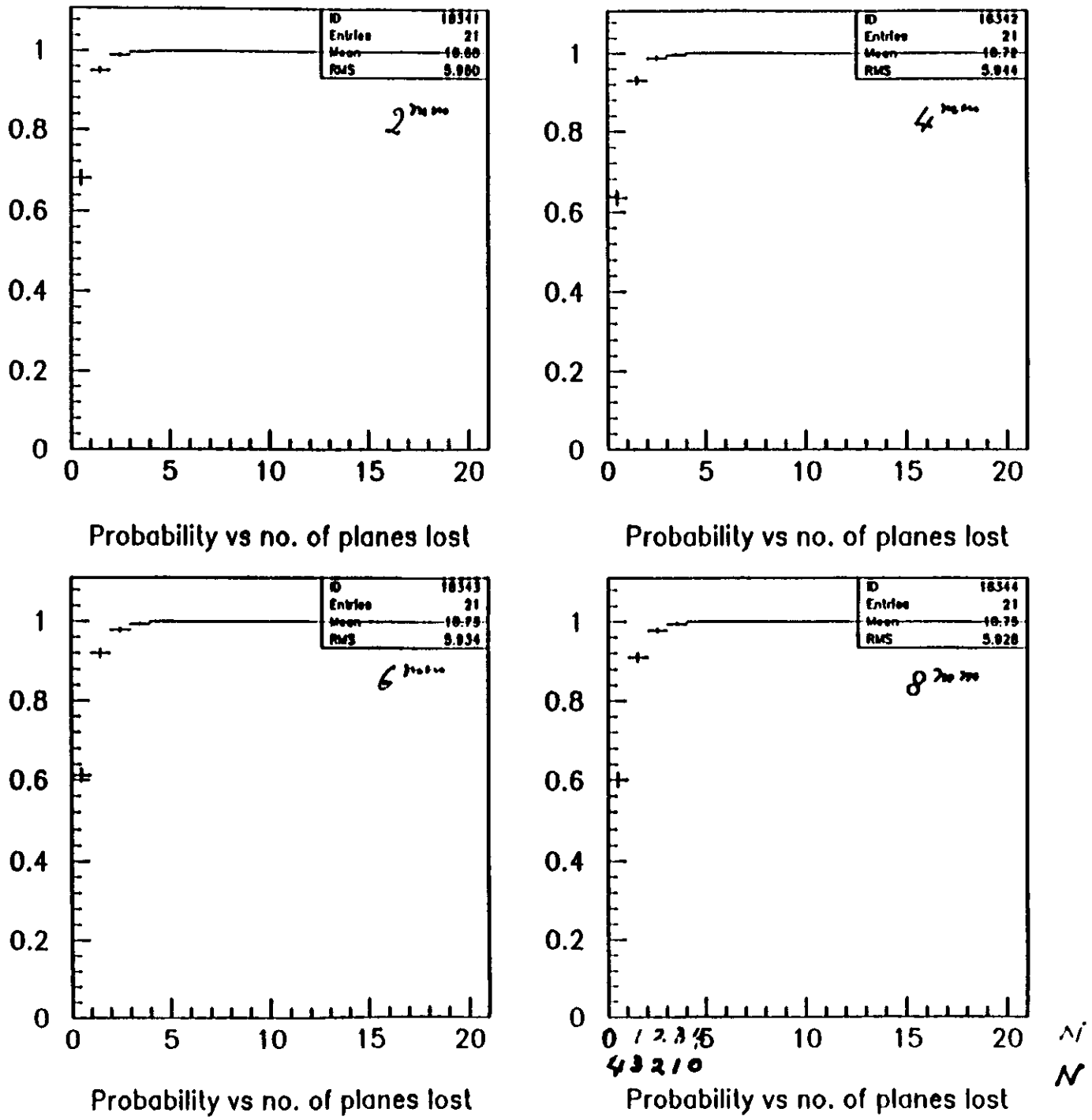

ID 15342
Entries 21
Mean 0.9531
RMS 0.6878
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
5
10
15
20
Probability vs no. of planes lost


ID 15343
Entries 21
Mean 0.9956
RMS 0.7300
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
5
10
15
20
Probability vs no. of planes lost

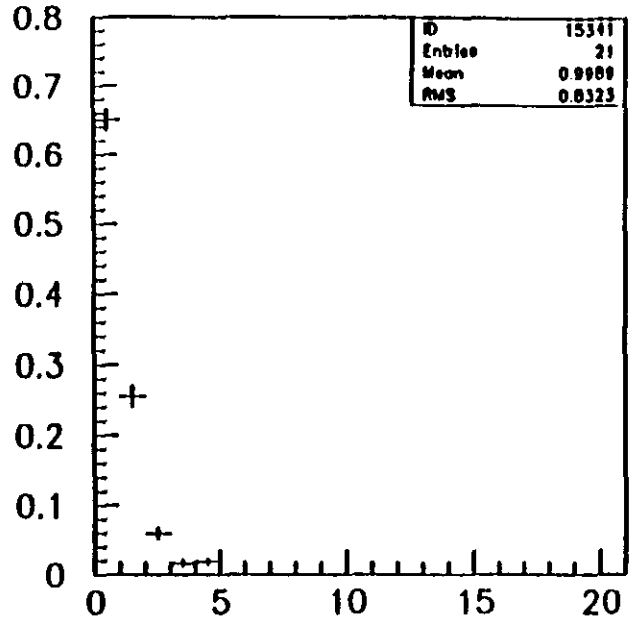

ID 15344
Entries 21
Mean 1.018
RMS 0.7487
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
5
10
15
20
Probability vs no. of planes lost

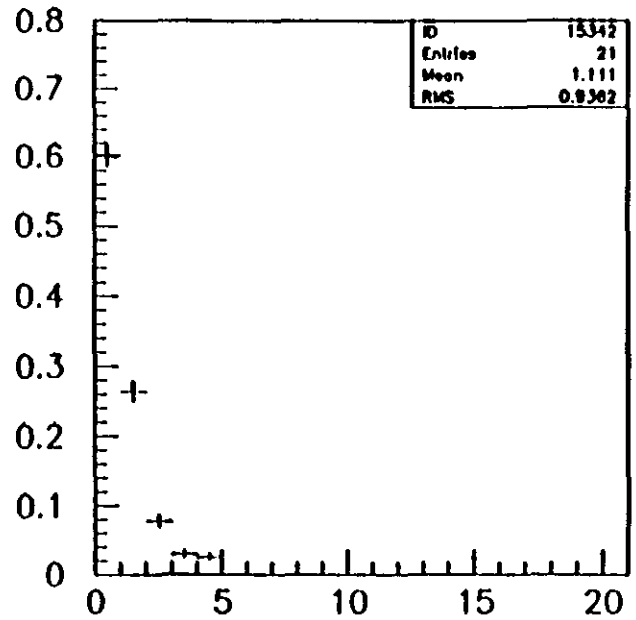
Probability that ≤ N layers have extra hits within 2, 4, 6, 8 mm of the main hit.

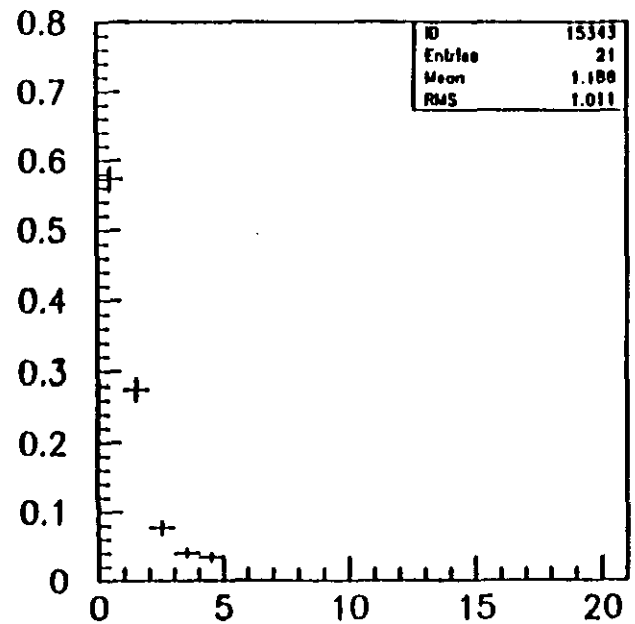
ZN SL2 don't have

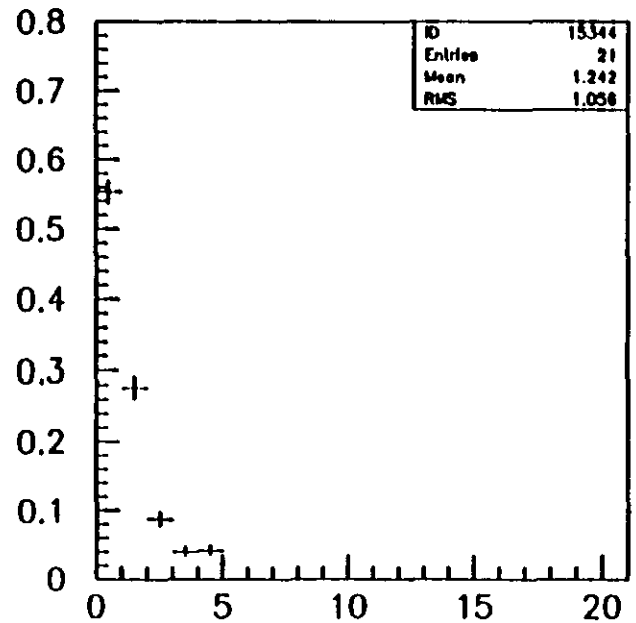


$0.78X_0$

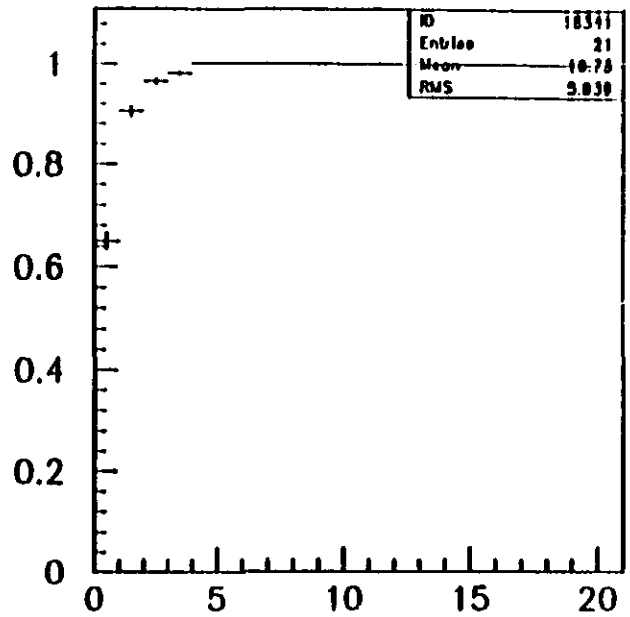

ID 15341
Entries 21
Mean 0.9989
RMS 0.8323
Probability vs no. of planes lost

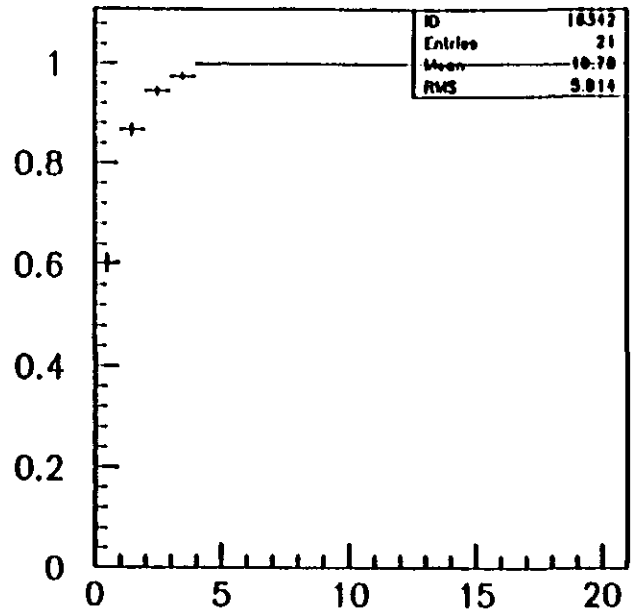

ID 15342
Entries 21
Mean 1.111
RMS 0.9362
Probability vs no. of planes lost

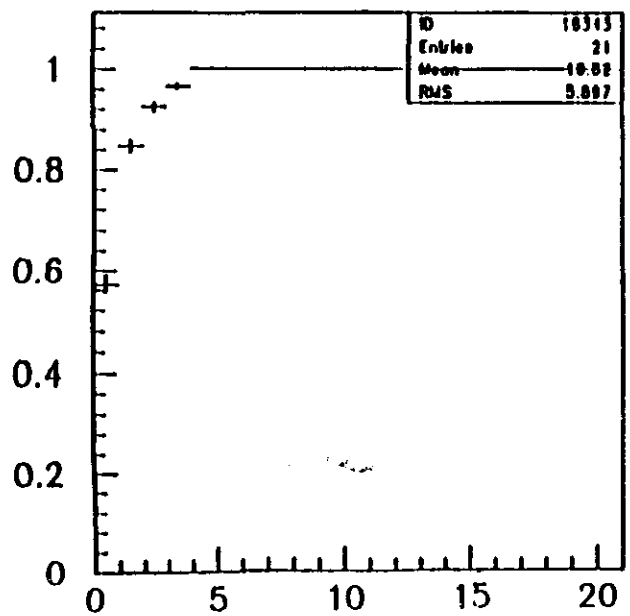

ID 15343
Entries 21
Mean 1.188
RMS 1.011
Probability vs no. of planes lost

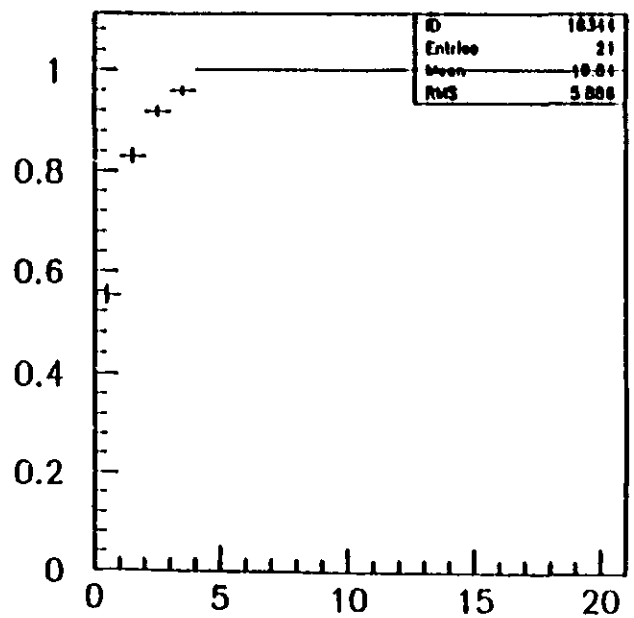

ID 15344
Entries 21
Mean 1.242
RMS 1.056
Probability vs no. of planes lost

0.78 X_0


ID 18341
Entries 21
Mean 10.78
RMS 5.030
Probability vs no. of planes lost


ID 18342
Entries 21
Mean 10.78
RMS 5.014
Probability vs no. of planes lost


ID 18343
Entries 21
Mean 10.82
RMS 5.007
Probability vs no. of planes lost


ID 18344
Entries 21
Mean 10.84
RMS 5.006
Probability vs no. of planes lost

Discussion of questions for each technology

CSC

1) Demonstration of full scale proto.
2) Correlation of pad/wire trigger in multihit
3) Working electronics
4) Take chamber to working collider → noisy environment.
5) Engineering design ready for mat's
6) Test in humid environment – cycle
7) Full cost estimate
8) η efficiency
9) Measure operation in $\vec{B}$
10) Support design
11) Optimization channel/chamber. – Vorobyov
12) 75 μm from existing chamber.
13) Test of endcap bent wire.
14) Measure double track
15) Produce full size cathode/panel
16) Calibration scheme proof
17) Broken wire mitigation.

CSC cont

18) Timing resl/rate (bunch)

19) Measure rate capability @ 10 kHz

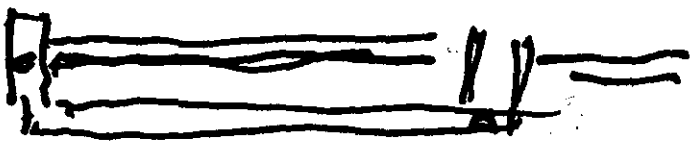
20) Fix operating params barrel ends

21) Resolution f(rate)

22) Alignment transfer/scheme.

LSDT

1) Wire pos'n ?
2) Alignment transfer/design design & build
3) Design for manuf/robustness
4) Stand alone trigger design, code done manufacture ~ suggested R&D
5) End cap geometry design & build (?)
6) After Pulsing - more R&D + present GEM note
7) Coating/signal prop/ σ will do
8) Operation of Full Scale Prototype done at MCT
   ↳ align
9) Non flammable gas will do
10) η efficiency will do
11) Rate capability incl σ, eff will do
12) Lifetime doing
13) ~~Distortion~~ Stability on design support/align
14) Occupancy/pattern recognition
15) Operation w/RPC will do
16) Acceptance



RDT

1) Wire sag — $\delta T \sim 1\%$ — Lifetime

2) Trigger?

3) End cap Geometry → Trigger

4) Pattern Recognition – n hits
no 2nd coord.

5) Diameter / DT / Trigger / Costs / tolerance sag wire

6) Alignment transfer / thermal / support

7) Tube to wire tolerance

8) Afterpulsing rate

9) Non flammable gas

10) n efficiency – vs P, gas

11) Monitoring scheme

12) Optimization mode / wire ϕ

13) σ vs P

14) Acceptance

15) Optimization / limitation of the width.

16) Resolution vs Rate

RPC (✓) done

✓ 1) Demonstrate rate capability at n $10^5/cm^2/s$

2) Noise below 10 Hz/(cm)^2 and stable

3) Working ~~large~~ full scale prototype in conjunction with DT at high rate

4) Specification for end cap

5) Lifetime measurement.

6) Rad hardness

7) n efficiency

✓ 8) Non flammable gas.

9) Time Res'l at high rate. slewing, efficiency, pos disp.

10) Design of mech. liner