GEM TN-92-237

Central Tracker Meeting - Brookhaven National Laboratory

November 5, 1992

Abstract:

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

Agenda for Tracker Meeting

V. Thomas

Scott Nutter	IPC Cathodes	9:00 – 9:20
Tim Thompson	IPC Composites	9:20 – 9:40
George B.	Silicon Detectors	9:40 – 9:55
Jim Musser	IPC Electronics	9:55 – 10:25
C. Baltay	General Comments	10:30 – 11:30
Shawn McKee	Simulation Status	11:30 – 12:00
Irwin Sheer	$H \to \gamma\gamma$ Vertex Find.	12:00 – 12:30
Jenny Thomas	IPC Two track Res.	12:30 – 1:00
LUNCH		
A Sumarokov	Work in Taiwan	2:00 – 2:45
G. Hills/J. Brau	Si Strip Length	2:45 – 3:45
Tracker Steering Committee		4:00 – 6:00

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Presentation by:

J. Thomas

What should go into the next version of Tracker Progress Report / TDR?

1. Increased Outer Radius?
   - When can we get firm decision?
   - this will affect
     - IPC Design
     - Simulations
     - Performance
   - If we do increase radius, how soon can we write report?
2. Silicon Strip Length
   - Same questions as above

Some Short-term Deadlines

1. We <u>have a</u> budget (M$ 48 + 7 + 1) and we <u>have</u> Draft 1 of Tech. Design Report

   We will use these to satisfy GEM deadlines & requests until we have something better

2. Polish Existing Budget — Nov 15, 92

   H. Pretty will coordinate

3. Next version of Central Tracker Progress report (No Page limit) — ~~Nov 15~~ Jan 1, 92

   Brenda will assemble this

4. Draft 2 of Tech. Design Report — ~~Dec 1~~ Jan 15, 92

   Readers Digest version of Progress Report, ≤ 100 Pages

   Brenda will assemble this

5. Next cut at Budget — Dec 15, 92 Jan 30

   H. Pretty will coordinate

How much can we delay these deadlines if GEM TDR slips beyond Jan 31, 92?

Collaboration with Taiwan

ACADEMIA SINICA

Research group of S.C. Lee et al

ITRI Industrial & Technical Research Institute
5500 Employees, ~300M$ Annual Budget
Has 11 Labs or Institutes

ERSO - Electronics Research Service Org.
MRL - Material Science Research Lab
MIRL - Precision Machining etc.
⋮

NSC National Science Council (Funding Agency)

TAIWANESE UNIVERSITIES

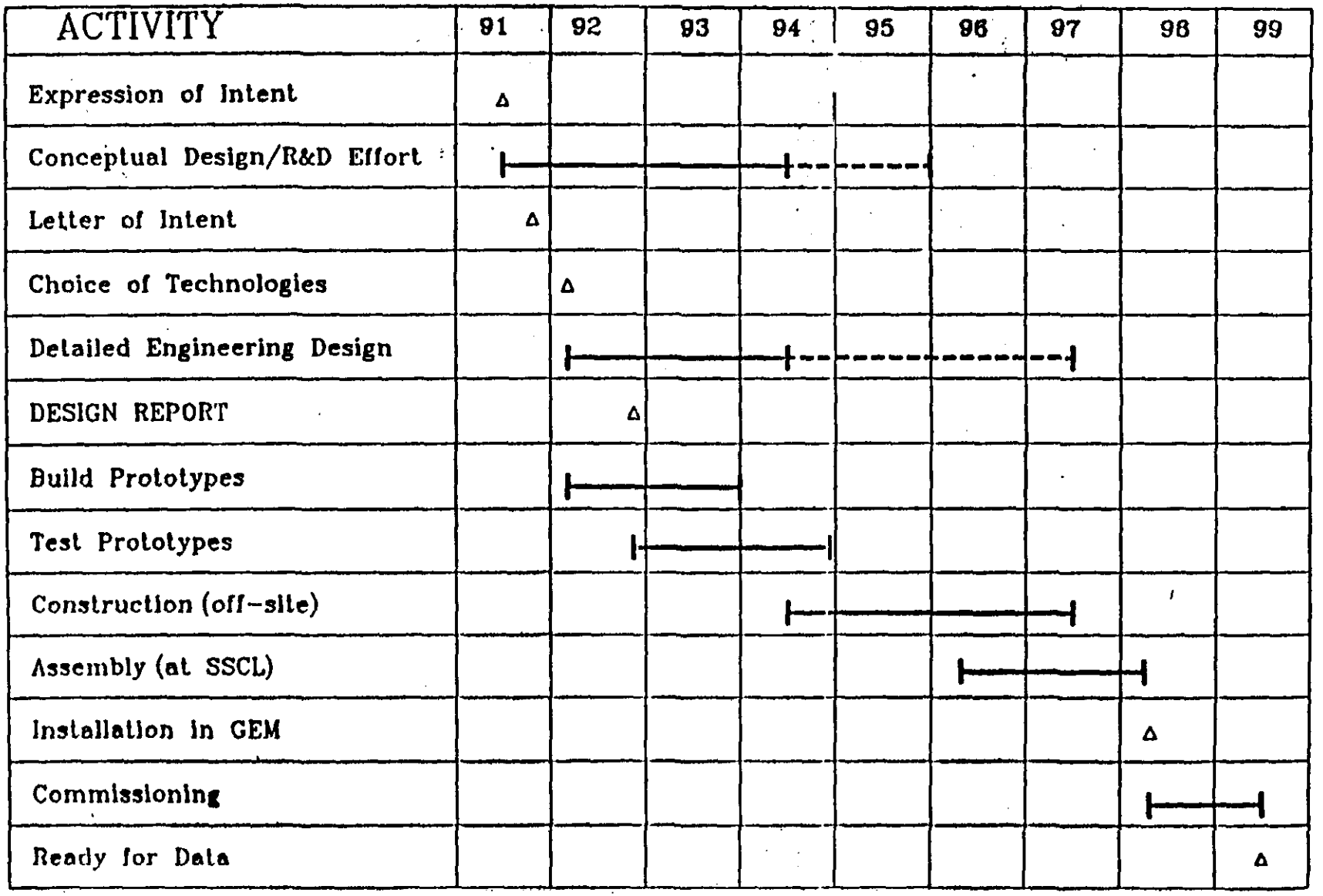
Students, research groups

SCOPE - We are proposing ~50M U.S.$ collaboration

HELP from T.D. Lee Foundation [illegible]

REV. 1 (2/13/1992)

GEM CENTRAL TRACKER SCHEDULE



GEM Central Tracker
Proposed Plan for Collaboration on R&D and Engineering Design

Approximately two-year period - 1993 & 1994

1. **Sign Agreement to formalize Phase I collaboration on R&D effort and engineering design.**

2. **Consolidate project-oriented working groups to start collaboration**

   a) Identify U.S. and Chinese group leaders
   b) Group members

3. **Each working group (in coordination with overall Central Tracker Management) should start in November 1992 to**

   a) Set up schedule of short and long visits back and forth
   b) Develop work plan of activities
   c) Propose a schedule for the work plan
   d) Define milestones for "Deliverables" i.e. measureable signs of progress such as specific designs, prototypes, test results, etc.

4. Define Subsystem Prototype program

   a) Identify person in charge
   b) Institutional responsibilities
   c) Develop schedules & milestones

5. Sign Phase II of the Agreement

6. Develop Fabrication Plan for the Central Tracker

   a) Define subsystems or tasks
   b) Identify persons in charge of each subsystem
   c) Propose institutional responsibility for each subsystem
   d) Develop fabrication schedule for each subsystem
   e) Define milestones to measure progress

GEM Central Tracker R&D and Design Working Groups

Mechanical--Group A

Overall Coordination: R. Barber/C. Hsu (CMS)
?

TASK	U.S.A.	TAIWAN	
		ITRI Engineers	Physicists
1) Silicon Tracker	R. Barber ?	C.L. Wu	A. Chen
a) Support & cooling rings, ladders, etc.	T. Thomson, R. Barber	Chung-Lin Wu, Larry C.C. Tang	P.K. Teng
b) Support frame	T. Thomson	Y.C. Chen	P.K. Teng
c) Cooling & gas flow	R. Barber	Chung-Lin Wu, Larry Tang, Ping-Ho Sam Shih	P.K. Teng
d) Alignment & monitoring	~~R. Barber~~ J. Haulon	Li-Shing Lee	M.T. Cheng
e) Cabling	R. Barber, B. Cooke	Jong-Ming Liu	M.T. Cheng
2) IPC Tracker	W. Emmet	L.S. Lee	A. Sumarokov
a) Chamber modules	W. Emmet	Chung-Lin Wu, Jau-Liang Chen, Larry Tang	A. Sumarokov
b) Support structure	W. Emmet, T. Thomson	Chung-Lin Wu	A. Sumarokov
c) Cooling and gas flow	D. Neeper	Ping-Ho Sam Shih	A. Sumarokov
d) Alignment & monitoring	~~R. Barber~~ J. Haulon	Li-Shing Lee	M.T. Cheng
e) Cabling	W. Emmet	Jong-Ming Liu	M.T. Cheng

GEM Central Tracker R&D and Design Working Groups

Electronics--Group B

Overall Coordination: Jim Musser/Julia Fu-Su

TASK	U.S.A.	TAIWAN	
		ITRI Engineers	Physicists
1) Silicon Detector	Dave Lee, S. Hahn	Julia Fu-Su	A. Chen
a) Detectors	R.T. Kollipara J. Brau	W.C. Tsai	M.J. Wang
b) Front end amplifiers	S. Hahn	S.W. Chang, Sebastian Liau	S.Y. Chao
c) Digital pipeline (CMOS1)	B. Cooke	Steven Yang, Peter Chou	M.T. Cheng
d) Readout controller (CMOS2)	D. Strom ~~J. Brau~~ ?		M.T. Cheng
e) Multichip module (MCM)	B. Cooke	Fang-Lin Chao, H.C. Chang, Mei-Ling Chou	M.T. Cheng
f) Fiber optics / Power Dist.	~~J. Mills~~ B. Cooke	W.S. Chan	P.K. Teng
2) IPC Electronics	Jim Musser, C. Bender	S.K. Peter Chou	J. Antos
a) Front end amplifiers	P. O'Connor	S.W. Chang, Sebastian Liau	S.Y. Chao
b) Switched capacitor array	C. Britton	Peter Chou	M.T. Cheng
c) ADC, Multiplexer	J. Musser J. Haun		M.J. Wang
d) A to D pipeline	G. Haller	Steven Yang	M.T. Cheng
e) Readout controller	C. Bender		M.T. Cheng
f) Fiber optics / Power Dist.	C. Bender	W.S. Chan	P.K. Teng

Silicon Microstrip Detectors

R&D Schedule and Milestones

Oct 26, 92

Proposed ERSO GEM Silicon Microstrip R&D Plan

Fabricate 1st Microstrips based on 7.93 x 4.01 cm2 design (minimize strip resitance)	8/92-12/92
Develop back-to-back 2 chip bonding with 5 micron precision	12/92-3/93
Develop rad-hard poly resitance of 500kOhm	1/93-4/93
Study effects of edge defects on wafer yield and strip reliability	1/93-4/93
Fabricate 1st GEM specific microstrip prototype	3/93-5/93
Study microstrip characteristics (leak current, depletion voltage, breakdown voltage, poly resist, etc) vs. radiation exposure and develop hardening procedures	4/93-9-93
Fabricate 2nd GEM specific microstrip prototype	9/93-11/93
Study microstrip characteristics (leak current, depletion voltage, breakdown voltage, poly resist, etc) vs. radiation exposure and develop hardening procedures	11/93-4-94
Fabricate Final GEM specific microstrip prototype	4/94- 6/94

MILESTONES

Deliver 7.93 x 4.01 cm2 microstrip detector to Oregon (goal: strip res: 10 ohm/cm)	Jan 15, 1993
Define GEM silicon detector design	Feb 31, 1993
Deliver 1st GEM specific prototype	May 1, 1993
Define revised GEM detector design	Oct 15, 1993
Deliver 2nd GEM microstrip prototype	Jan 1, 1994
Define Final GEM detector design	June 15, 1994
Deliver Final GEM Prototypes	Aug 1, 1994

R&D Prototype Program

1. Silicon Tracker

    a) 18 cm Barrel Ladder
    b) Forward Disc

2. IPC Tracker

    a) Barrel Chamber
    b) Endcap Chamber

3. Test Beam Setups

    a) Silicon Ladders
    b) IPC Chambers

GEM Central Tracker Subsystems for Fabrication

1. Silicon Detector Mechanical

   a) Barrel Detector

      i) Ladder Assemblies

      ii) Support and Cooling Rings

      iii) Barrel Assembly

   b) Forward Detector

      i) Detector Discs

      ii) Support and Cooling Rings

      iii) Two Forward Assemblies

   c) Support Structure Space Frame

   d) Cooling and Gas Flow Systems

   e) Alignment and Monitoring System

2. IPC Tracker Mechanical

a) Barrel Region

i) Chamber Modules

ii) Support Structure

b) Forward Detectors

i) Chamber Modules

ii) Support Structure

c) Overall Support Structure and Kinematic Mounts

d) Cooling and Gasflow Systems

e) Alignment and Monitoring System

3. Silicon Tracker Electronics

   a) Silicon Detectors

   b) Front End Preamplifiers

   c) Digital Pipeline Buffer

   d) Readout Controller

   e) Multichip Module

   f) Fiber Optics

4. IPC Electronics

   a) Front End Amplifier

   b) Pipeline Buffer

   c) Analog to Digital Converter

   d) Readout Controller

   e) Fiber Optics

October 26, 1992

Response to Proposed Action Items

From Oct. 5-8, 1992

GEM Central Tracker Meeting in Taiwan

Group A - Mechanical

1. Specify detailed working items and arrange persons in charge

   C. Baltay/D. Hsing — Oct. 28-30, 1992

2. Deliver information to ITRI such as specifications, drawings, reports, etc.

   ~~R. Barber~~, W. Emmet/Chung-Liu Wu — Nov. 1992
   T. Thompson

3. Arrange a visit to the facilities and labs in USA

   ~~All engineers involved~~ — Nov. 1992
   RD Group leader.

4. Provide current R&D status to ITRI

   ~~R. Barber~~, W. Emmet/Chung-Liu Wu — Nov. 1992
   T. Thompson

5. Provide vendors information to ITRI

   ~~R. Barber~~, W. Emmet/Chung-Liu Wu — Nov. 1992
   T. Thomson

Group B - Electronic

1. ITRI Designers/Processors to join U.S. Vendor Design Review Meetings

   J. Musser/ Julia Fu-Su Appropriate times

2. Provide Specifications to ERSO

   J. Musser, D. Lee/ Julia Nov. 1992

3. Provide SPICE Parameters to ERSO

   J. Musser, D. Lee/ Julia Nov. 1992

4. Provide Vendor Information to ERSO

   J. Musser, D. Lee/ Julia Nov. 1992

5. Provide Current R&D Information to ERSO

   J. Musser, D. Lee/ Julia Nov. 1992

✓ 6. **Provide ERSO's BiCMOS SPICE Parameters to U.S.**

Talia /J. Musser, D. Lee Nov. 1992
Paul O'Conner

7. **Fabricate Preamp, SCA in ERSO's BiCMOS Process**

8. **Identify ITRI Engineers to Visit/Work in LANL, ORNL, BNL, IU, ~~AND~~, SLAC & Oregon.**

D. Hsing/C. Baltay Oct. 28-30, 1992

9. **Provide TI's MCM Spec to ERSO**

D. Lee/ F. L. Chao (ERSO) Nov. 1992

10. **Fabricate prototype MCM at ERSO**

R & D Requests for FY93

GEM Central Tracker

October 6, 1992

GEM Central Tracking - FY93 R & D Request
(in thousands of dollars)

	Contact	Engineering Design	R&D M&S	Total
1. Central Tracker (Not including Electronics)				
a) Silicon Tracker				
Los Alamos	D. Lee	476	417	893
Univ. of Oregon	J. Brau	85	115	200
Moscow State Univ.	G. Bashind-zhagyan.	0	20	20
b) Pad Chambers				
Los Alamos	R. Barber	140	0	140
Yale University	C. Baltay	94	104	198
Univ. of Michigan	G. Tarle	55	55	110
SUNY Albany	M.S. Alam	0	40	40
c) Test Beam Work				
SSC	K. Morgan	0	155	155
SUNY Albany	M.S. Alam	0	40	40
		850	946	1,796
2. Central Tracking Electronics				
a) Silicon Tracker				
Los Alamos	S. Hahn	560	570	1,130
Univ. of Oregon	J. Brau	50	50	100
b) Pad Chambers				
Brookhaven	P. O'Connor	120	25	145
Indiana Univ.	J. Musser	85	110	195
Oak Ridge	C. Britton	120	105	225
SLAC	G. Haller	120	30	150
Univ. of Michigan	G. Tarle	84	20	104
		1,139	910	2,049

Presentation by:

G. Bashindzhagyan

Nov. 5, 92

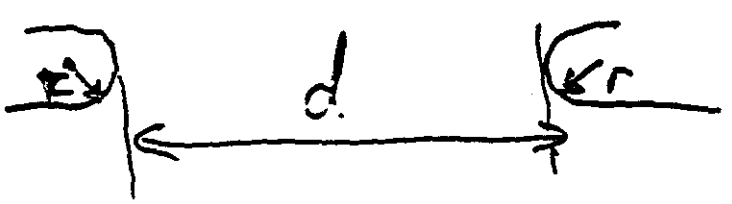
G. Bashindzhagyan

<u>The problem of the strip resistivity is very important</u>

The detector designed at Moscow State Univ. has Al lines 15 μm width and 1 μm thickness. Calculated resistivity is about 17 Ohm/cm but it could be more because of not pure metal.

Our plan for next few months:

* To measure the real strip resistivity
* To increase the thickness of aluminum layer by 2 μm.
* To try to increase the width of Al from 15 to 30 μm.
  Interstrip capacitance should increase only ~ 6 %



$$C = \frac{\pi \varepsilon_0 \varepsilon l}{\ln \frac{d-r}{r}}$$

for Si $\varepsilon \simeq 12$
for SiO_2 $\varepsilon \simeq 4$
for Al lines $\varepsilon \simeq 2$

<u>but</u> there is information that breakdown voltage is going down due to wider metallization. We will check it.

We plan to do with Jim Brau's group.

* To make test structure with 6, 12 and 18 cm strips

* To measure interstrip capacitance and capacitance to backside expesim.

* To readout simultaneously 5 strips using low noise and fast hybrid electronic channels to test experimentall the charge sharing between neighbour strips, the shape of the signals with lazer source of charging.

* To measure real noise distribution, noise influence from neighbouring strips, noise dependance on the strip lengh

?

We hope to get results before the GGM meeting in the beginning of March 93.

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Presentation by:

D. A. Neeper

D. A. NEEPER LANL

GEM Outer Tracker

Cooling of electronics for IPCs

Total barrel heat load 13.6 kW

	Temp Rise (°C)	
	1	5
Water flow g.p.m.	51.5	10.3

IPC powers: 250

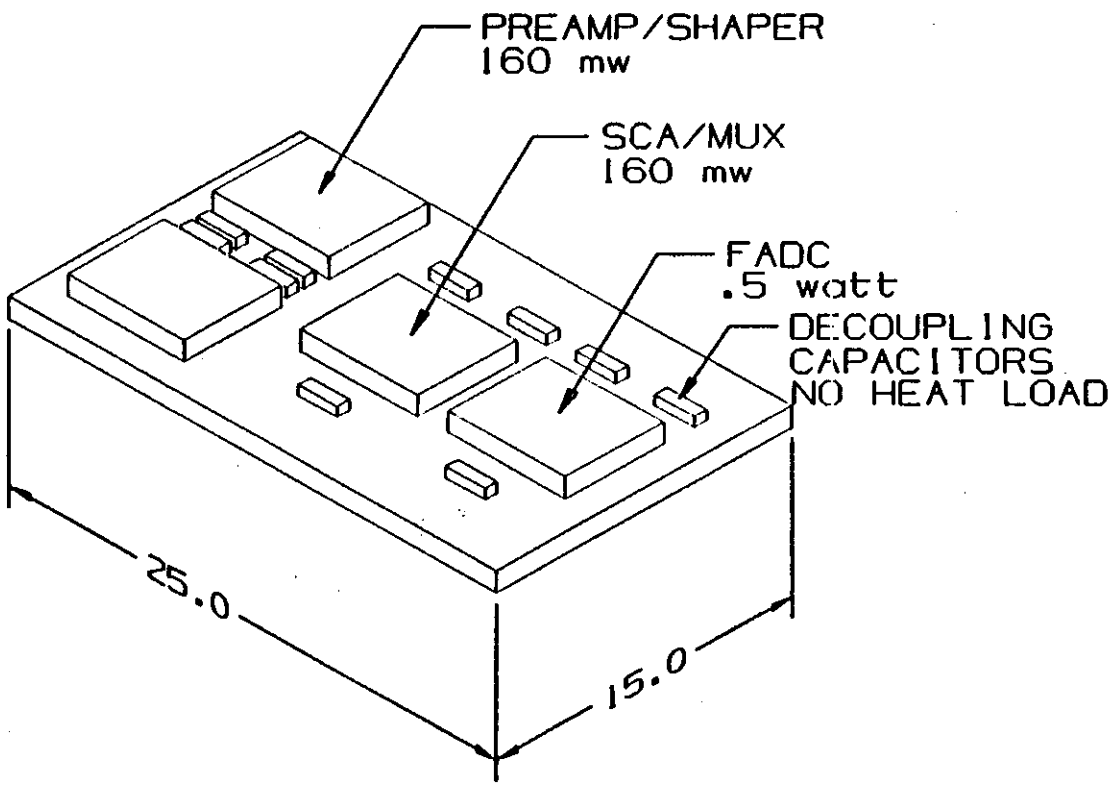
~170

~140

Flow to/from any IPC must enter and exit at the same end.

Laminar flow preferred.

GEM IPC TRACKER



IPC MULTI-CHIP MODULE
1 MCM/HYBRID PER 16 IPC CHANNELS

ALL DIMENSIONS ARE IN mm

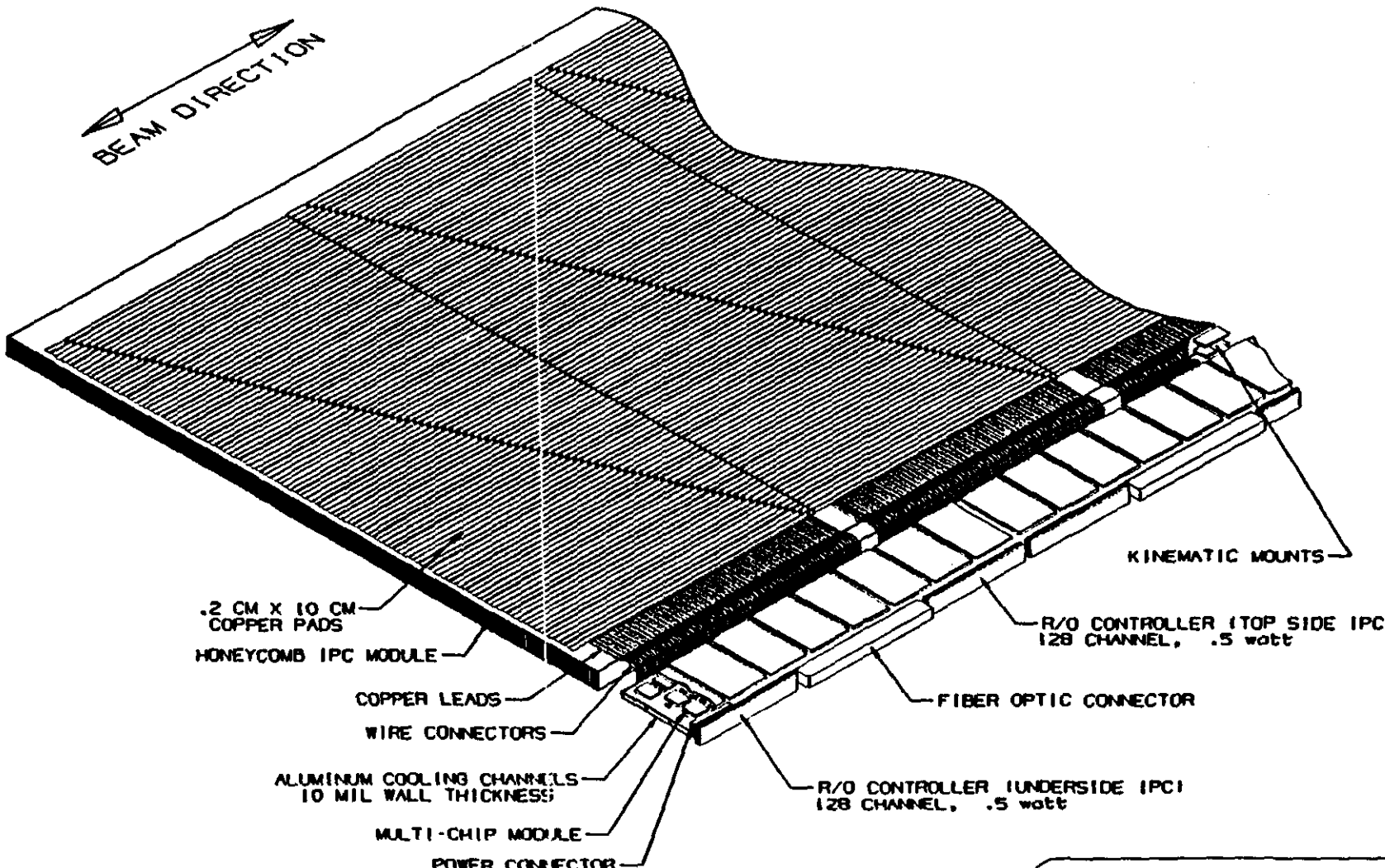
LOS ALAMOS

MEE-12
MECHANICAL AND ELECTRONIC
ENGINEERING DIVISION

JRVCOLASSY LAYER 2 8-31-92

GEM IPC TRACKER

IPC MODULE ASSEMBLY

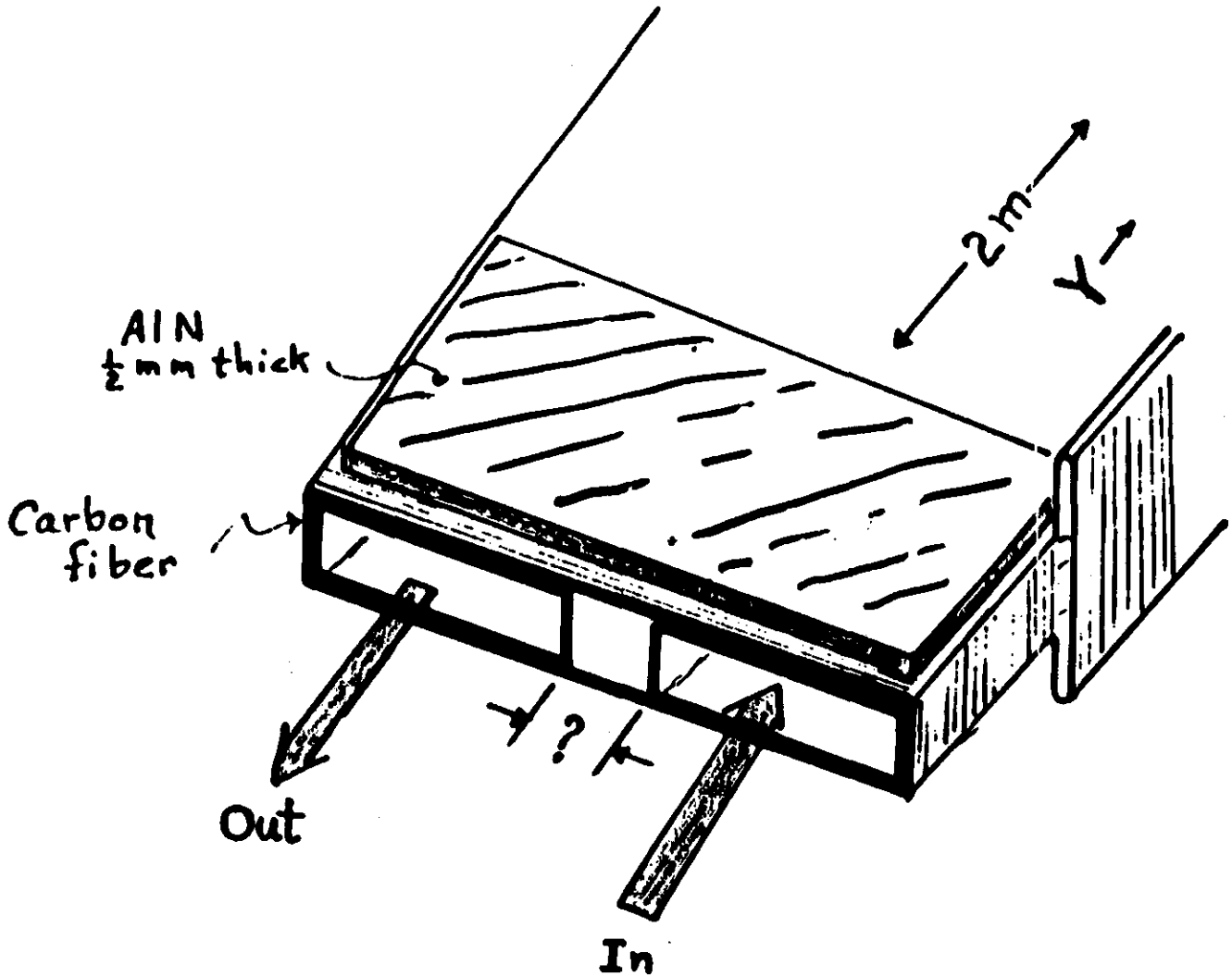


ALL DIMENSIONS ARE IN mm

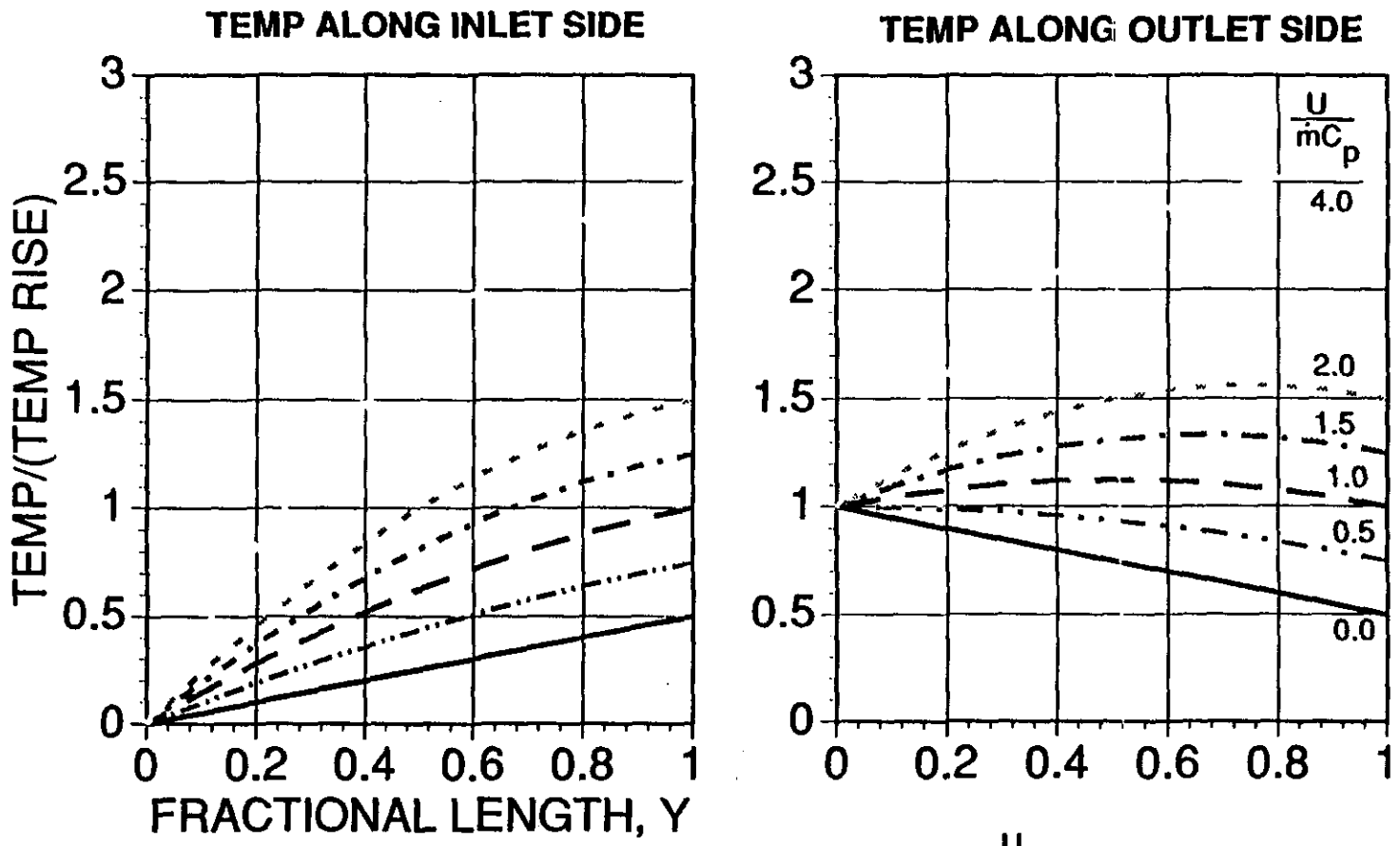
LOS ALAMOS

MEE-12
MECHANICAL AND ELECTRONIC
ENGINEERING DIVISION

JRVCOOLASSY 8-31-92

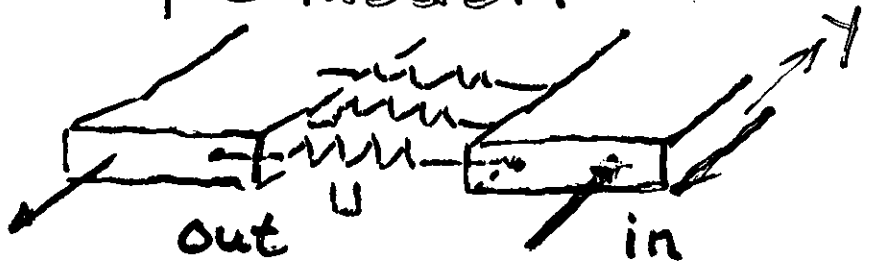


IPC Cooling Channel



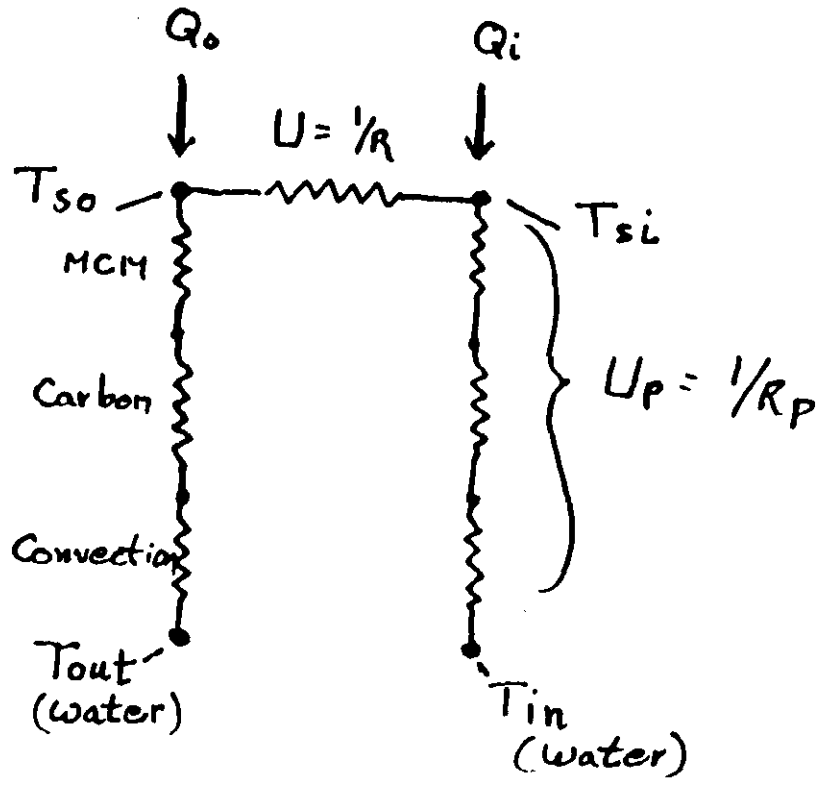
$\frac{U}{\dot{m}C_p}$		L(mm)
0.0	———	inf.
0.5	— · · ·	4.82
1.0	— —	2.41
1.5	— · —	1.61
2.0	· · · ·	1.21
4.0		0.60

Simple model:

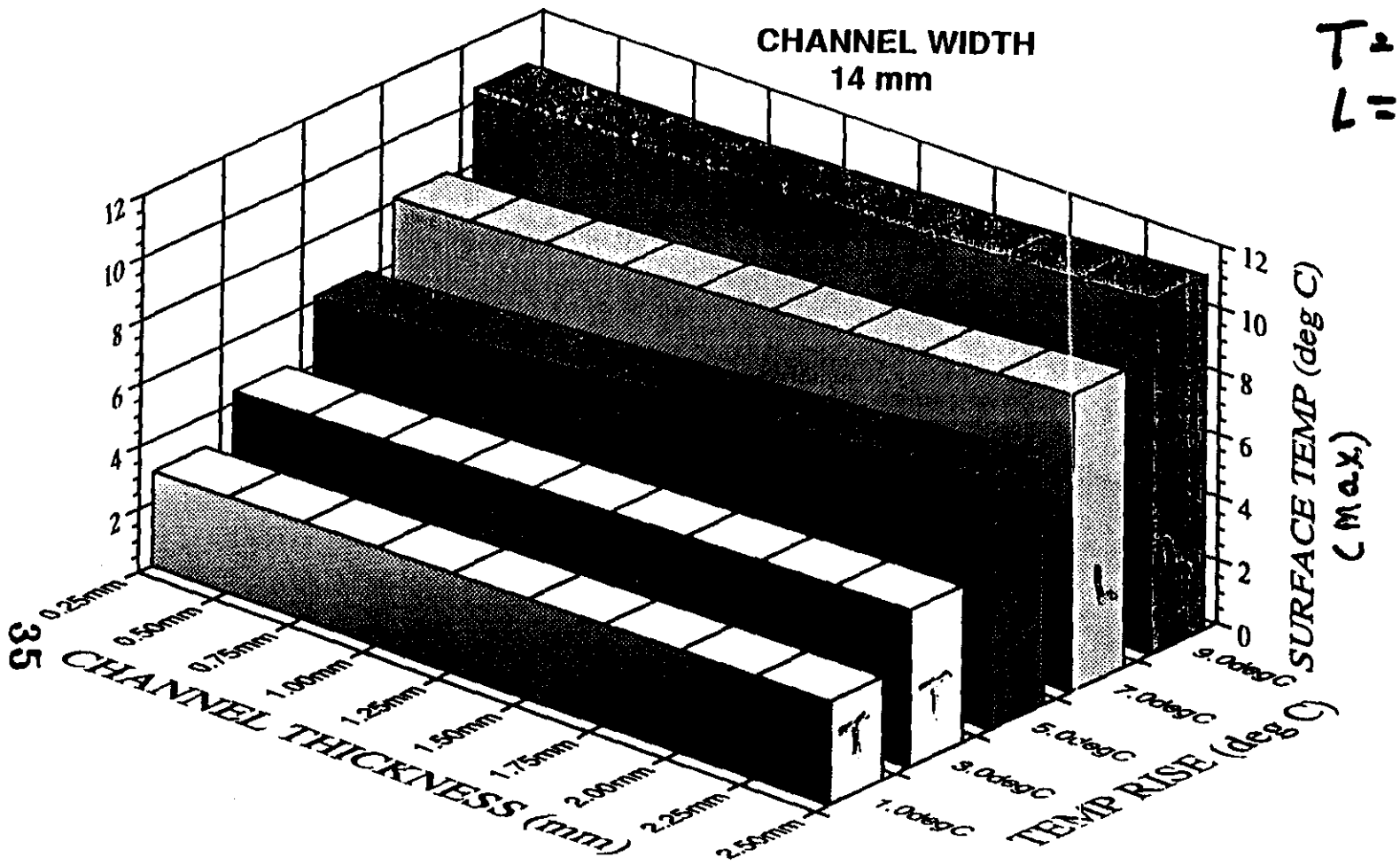


Water-to-water conductance increases water temperature

More realistic model



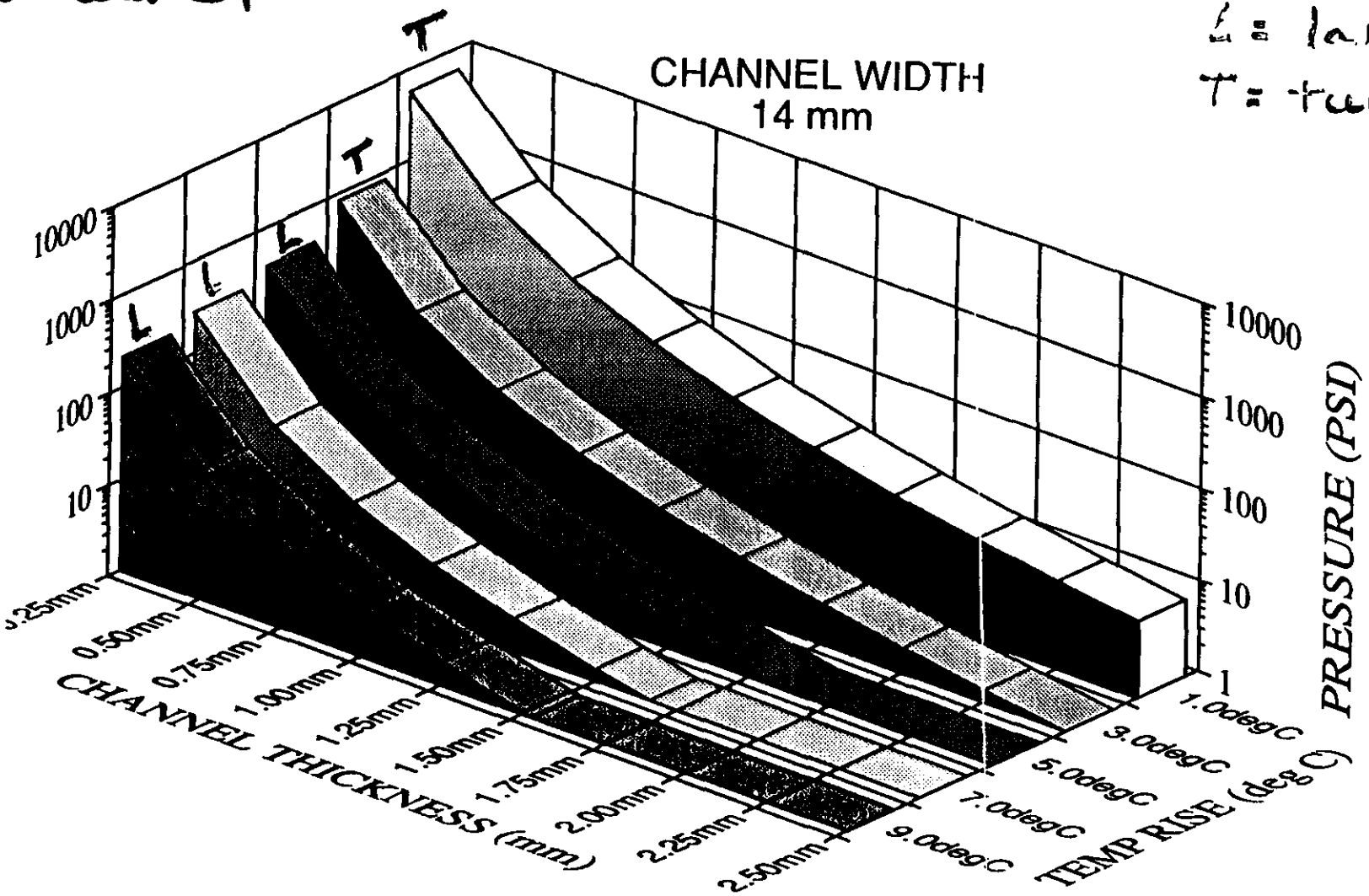
Thermal model at any position, y, along the length of the channel.



"Surface temperature" is the maximum, at any location, on inlet or outlet channel, measured above water temperature at the inlet [illegible]

250 watt IPC

L = laminar
T = turbulent



Conclusions

With flow set for 5°C temperature rise of the water; and inlet at 20°C

- Temperature of AlN surface = 28°C max
- Chip temperature 1.5°C > surface (Most powerful chip)
- Optimal distribution is
  - ~60% of power on inlet side
  - ~60% of area on outlet side
- Maintaining water pressure < 1 atm should prevent bubbles.
- Pressure drop across IPC with largest flow (250 W) will be < 1 PSI (plus return bend).
- Flow will be laminar.

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Presentation by:

Shawn McKee

Shawn McKee

Central Tracking Simulations

I) Introduction and Status
Shawn McKee

II) $H_0 \rightarrow \gamma\gamma$ Vertex Finding
Irwin Sheer (30 minutes)

III) IPC Two Track Resolution
Jenny Thomas (30 minutes)

IV) Simulation Work in Taiwan
Alexei Sumarokov (45 minutes)

- At 3:30 we are scheduled to meet with part of the GEM-wide simulations group to discuss work-plan for GEMFAST.

- From 4:00 on we will have informal discussions about GEANT modifications, IU workshop and other simulation issues.

Simulation Group Deadlines

November 8: ?	Turn in outline → completed simulation results for CT TDR simulations section
November 15: ?	Chapter 7 sent to TDR co-ordinator
November 18:	Changes to GEANT geometry and materials completed. Larger radius and longer silicon ladders?
November 16 - 20:	IU Workshop (GEANT and TDR focus)
November 30:	GEMFAST parameterizations due.

TDR date should slip ~1 month?

TDR Work

Simulations are required to demonstrate LOI claims for the central tracker

① ID the primary vertex of an event of interest
The main event of interest for vertex finding is $H_0 \to \gamma\gamma$. Those listed as working on this are Yuri Fisyak, Shawn McKee and Irwin Sheer. Two methods are being examined: multiplicity of the vertex and high P_t recoil tracks.

② Separate electrons and gammas using the presence or absence of a charged track pointing to an electromagnetic shower
Answering this claim requires carefull bookkeeping. Low P_t tracks are a source of potential problems. Pattern recognition (at some level) should be use. Melynda Brooks, Stuart Mufson and Jenny Thomas are listed as working on this

③ Provide track information for $e^{\pm}$, $\mu^{\pm}$ or gamma isolation cuts, and to help with rejection of conversion and Dalitz pairs.
Requires forcing conversions and determining tagging efficiency. General questions about particle ID must be answered. Stuart Mufson

I DR Work

(cont)

④ Aid in electron-hadron separation by providing momentum measurements that can be compared with the energy deposition in the calorimeter.

The GEMFAST calorimeter can be used t optimize the momentum-energy comparison cut. Electrons and hadrons should be run through GEANT to accurately simulate the effects of material and pattern recognition

Jaroslav Antos and Melynda Brooks

⑤ Help with the rejection of background by matching the muon momentum measured in the CT with the momentum measured in the muon system.

This requires a fairly detailed model of both the central tracker and the muon system to accurately represent th expected backgrounds and momenta measurements. Yuri Fisyak (SIGEM)

⑥ Determine the electron sign up to 400 (800?) GeV

A realistic model should be used to accurately represent tails in the measure momentum distributions for electrons.

Melynda Brooks and Stuart Mufson.

GEANT

All future simulations work depends upon an accurate, up to date CT model. We are implementing a number of improvements

1. New geometry; accurate representations of supports, cooling, cabling and electronics. Larger radius (.70 → .95). Change silicon ladder length (12 → 18)? Melynda Brooks, Shawn McKee

2. Improvements to pattern recognition code. Bug fixes and parameter updates. Melynda Brook, Jenny Thomas

3. Interface to GEMGEN Irwin Sheer, Shawn McKee

4. Adding pattern recognition to IPCs Stuart Mufson, Jenny Thomas

5. Utilizing RTP files for run control Irwin Sheer

GEMFAST

The physics simulations for GEM will all be based upon the GEMFAST code. Each subsystem is responsible for providing accurate, debugged parameterizations of their subsystems. The parameterizations should be defendable as a good representation of the subsystem in question. We will provide:

- Momentum resolution as a function of η and momentum for electrons and muons (This may use sampling from histograms)
- Impact parameter in R and Z as a function of η and momentum.
- Isolation determination for a given track
- Radiation and interaction lengths versus ϕ and η for each superlayer
- Routine returning hits expected versus ϕ, η and momentum
- Routine returning conversion probability versus ϕ and η (Also output spectrum of created particles

Summary

- Everyone is working hard to complete software for GEMFAST

- There are workers assigned to the 6 primary goals of the central tracker

- Strongly recommend moving back the TDR date for the central at least 1 month to allow us time to utilize newest design.

- Write ups for the progress report have been recieved from: Irwin Sheer
  Jenny Thomas

- The IU workshop will allow us to focus on outstanding issues.

Multi-Track Resolution of Interpolating Pad Chambers

MULTI-TRACK RESOLUTION OF INTERPOLATING PAD CHAMBERS.

- MOTIVATION FOR MULTI-TRACK RECONSTRUCTION
- DESCRIPTION OF SIMULATION PROGRAM
- PROCEDURE USED FOR 1 TRACK, 1 CO-ORDINATE RECONSTRUCTION
- TWO TRACK RESOLUTION
- THREE TRACK IDENTIFICATION
- IMPLICATIONS ON PHYSICS ABILITY

TWO TRACK RESOLUTION OF IPCs

1 • WHY IS 2 TRACK RESOLUTION IMPORTANT?

- DEGREDATION OF RESOLUTION OF ISOLATED TRACKS WHEN MIN-BIAS TRACK NEARBY

- CAN WE IDENTIFY FOR $e^{\pm}$ IN HEAVY JETS
  - CHARGE — b- PHYSICS, t- PHYSICS
  - MOMENTUM — b- JETS SOMETIMES VERY COLLIMATED – HARD TO DISENTANGLE IN THE EMCAL

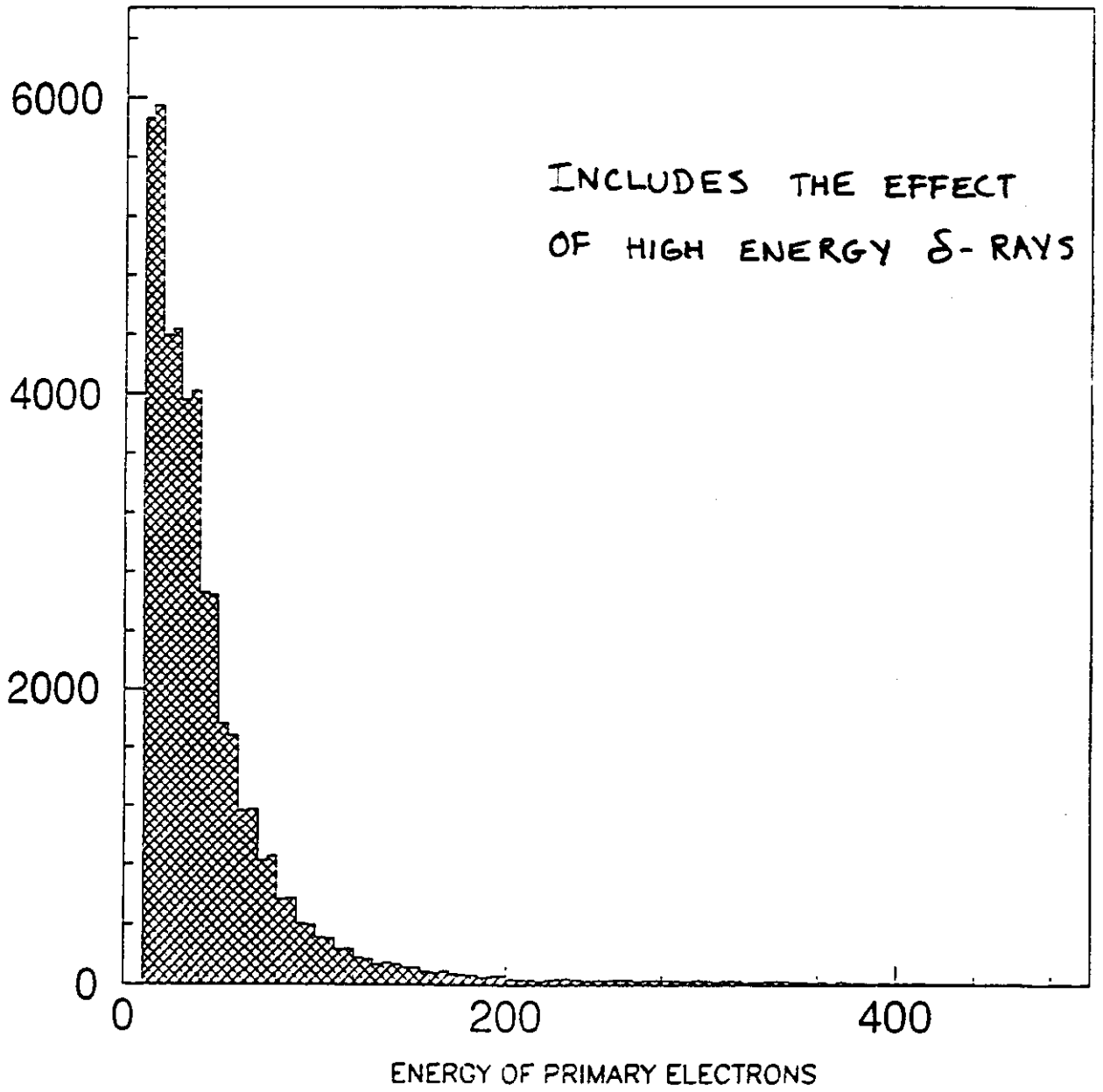
2. • IN SILICON, 10μm RESOLUTION, 50μm PITCH

- TRACKS CLOSER THAN 50μm NOT RESOLVED

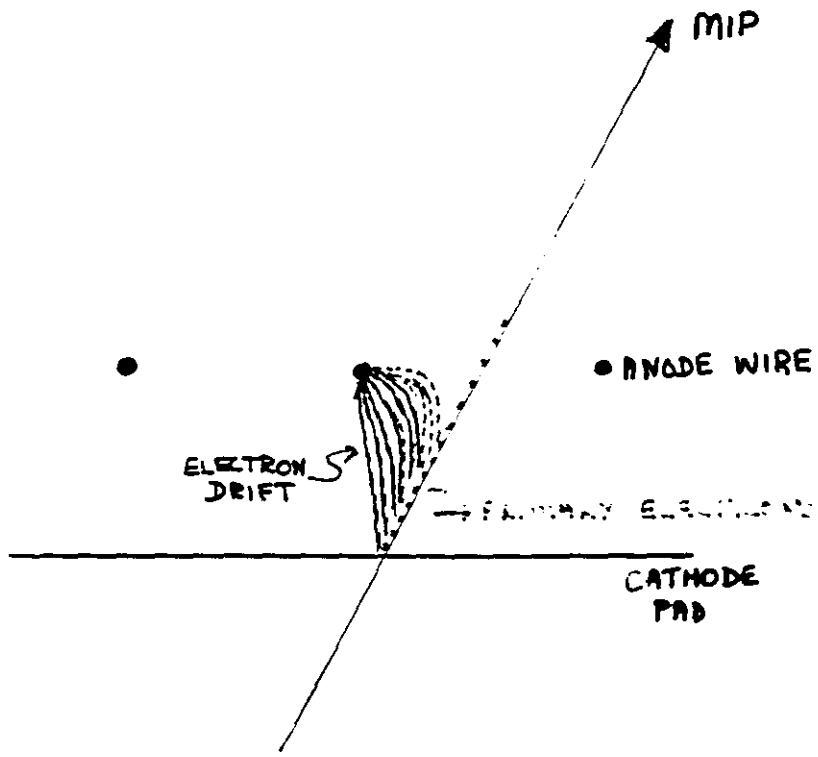
- OTHERWISE, VERY GOOD 2 TRACK RESOLUTION

(GEM CSC μ- CHAMBERS) HAVE WRITTEN A PROGRAM TO SIMULATE CSC IN CO_2CF_4 (50:50)

- PRIMARY ELECTRONS PRODUCED ALONG TRACK (15/mm) ACCORDING TO A MEASURED DISTRIBUTION (RUSSIA)



- ELECTRONS STEP ACCORDING TO THEIR MFP (55μm) INCLUDING DIFFUSION (51μm/mm DRIFT) ALONG THE FIELD LINES INCLUDING E×B OF 8KG FIELD.

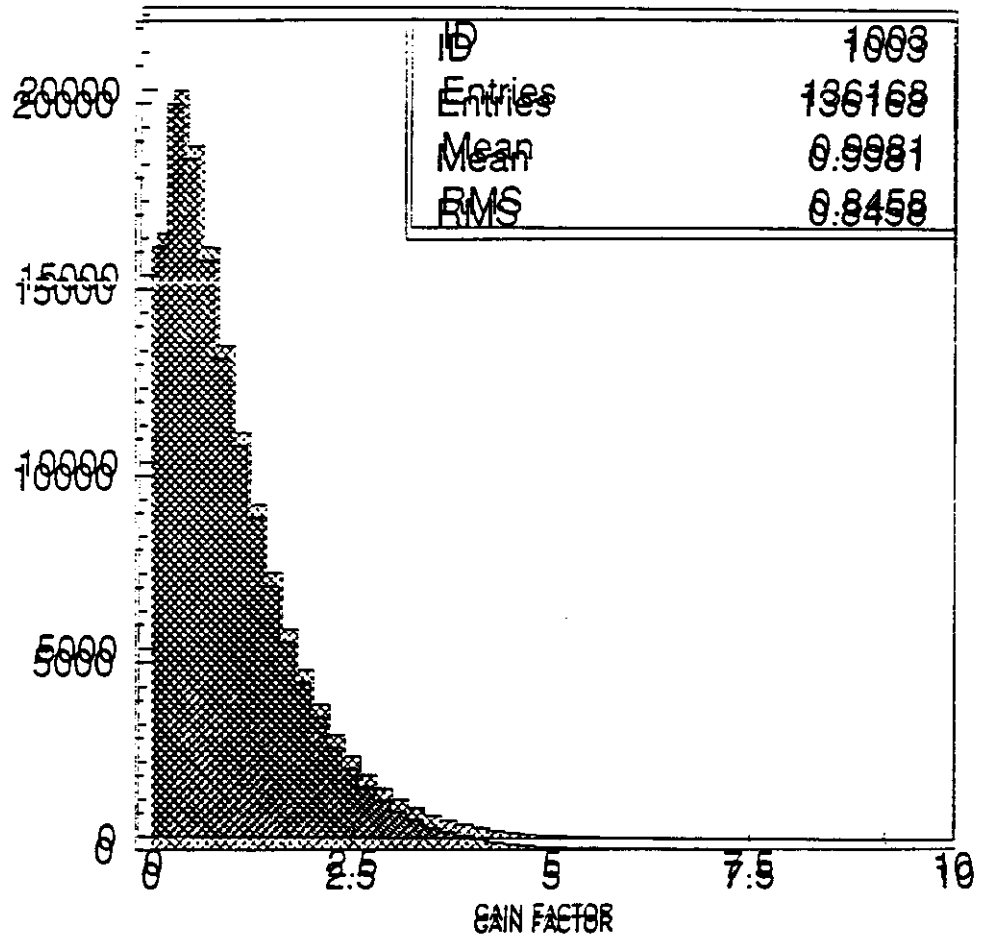


- ANODE GAIN IS FOLDED WITH A POLYA DISTRIBUTIO

$$\ln M = 2CV_a B \left\{ \ln(r_o/r_a) - 1 + r_a/r_o \right\}$$

$r_o = 2CV_a/pS_o$ B, S_o – GAS CONSTANT P – PRESSURE (TOR

r_o IS RADIUS



IS GAIN OF 2×10^4 * POLYA CORRECT ?

- CHARGE SIGNAL INDUCED ON THE PADS ACCORDING TO ~~[illegible]~~ MATHIESON'S RECIPIE.

- NOISE OF 1500 e^- RMS IS ADDED TO EACH PAD

- NOISE CONTRIBUTION OF 1% OF SIGNAL THEN ADDED FOR CALIBRATION.

HOPEFULLY THE NOISE IS CONSERVATIVE

- GEM TRACKER GEOMETRY

  2.5 mm PAD WIDTH

  2.0 mm ANODE-CATHODE SPACING

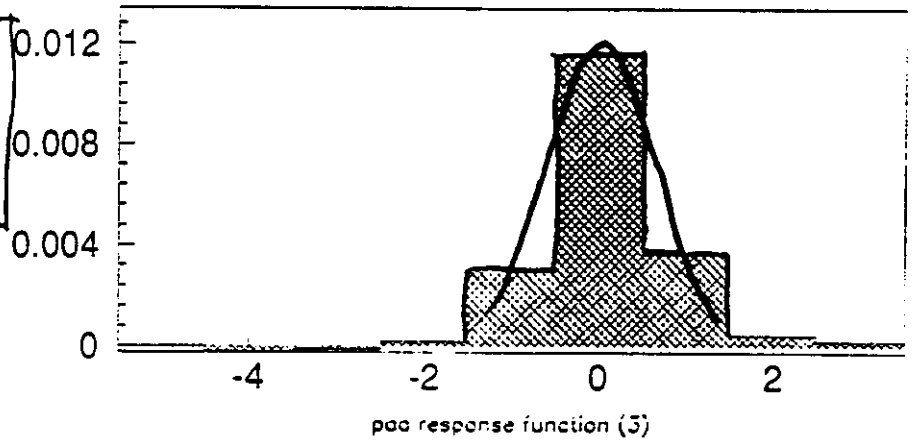
  2.0 mm ANODE PITCH

- 20% OF SIGNAL ACCEPTED DUE TO 20 nsec COLLECTION TIME

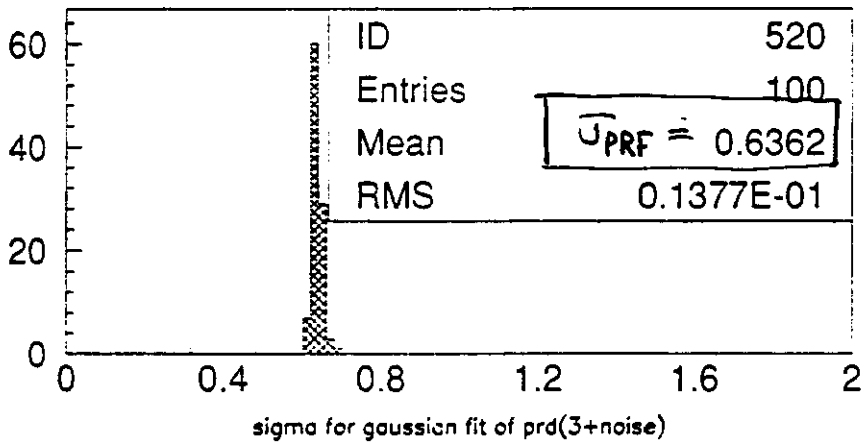
4. ONE TRACK PROCEDURE (GAUSSIAN APPROACH)

♦ MEASURE "PAD RESPONSE FUNCTION" FOR 1 TRACK

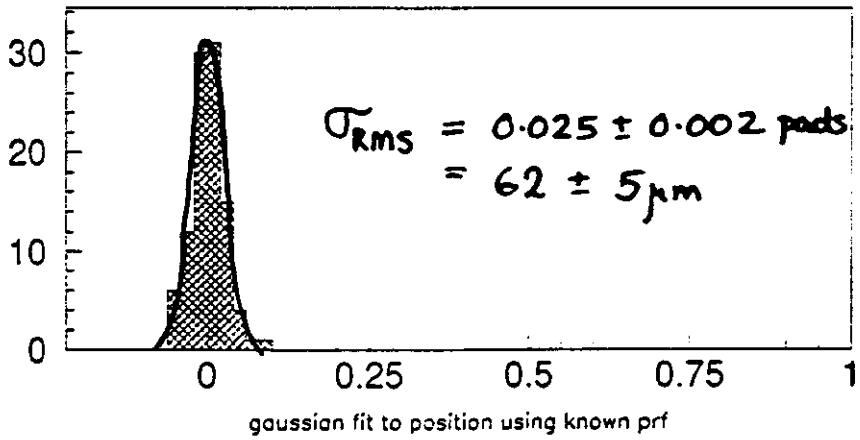
USE ONLY 3 PADS
NOISE HURTS MOST
IN THE TAILS



PLOT FITTED VALUE
OF σ_{PRF} FOR
MANY TRACKS



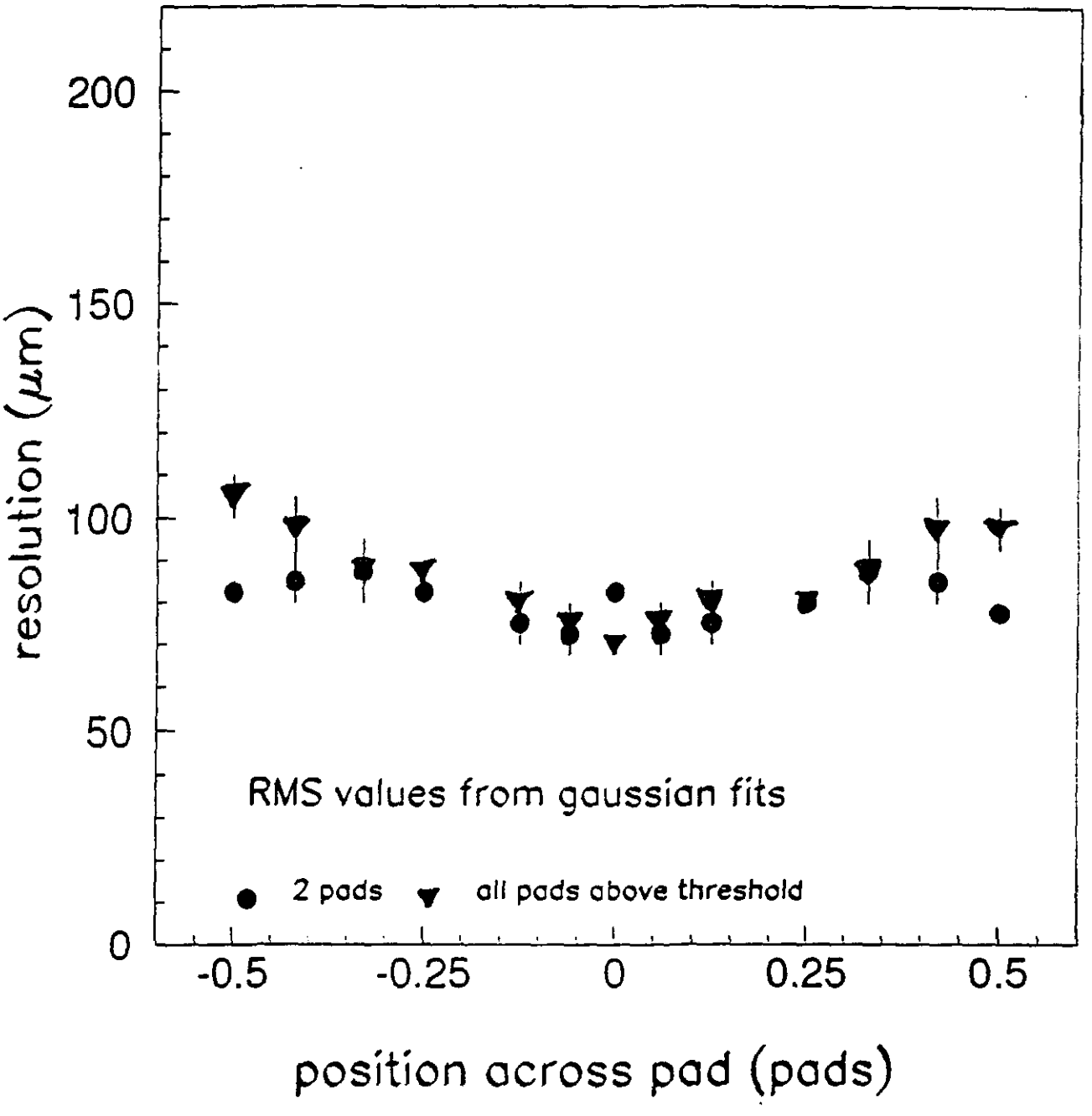
USE KNOWN σ_{PRF}
AND FIT FOR
POSITION

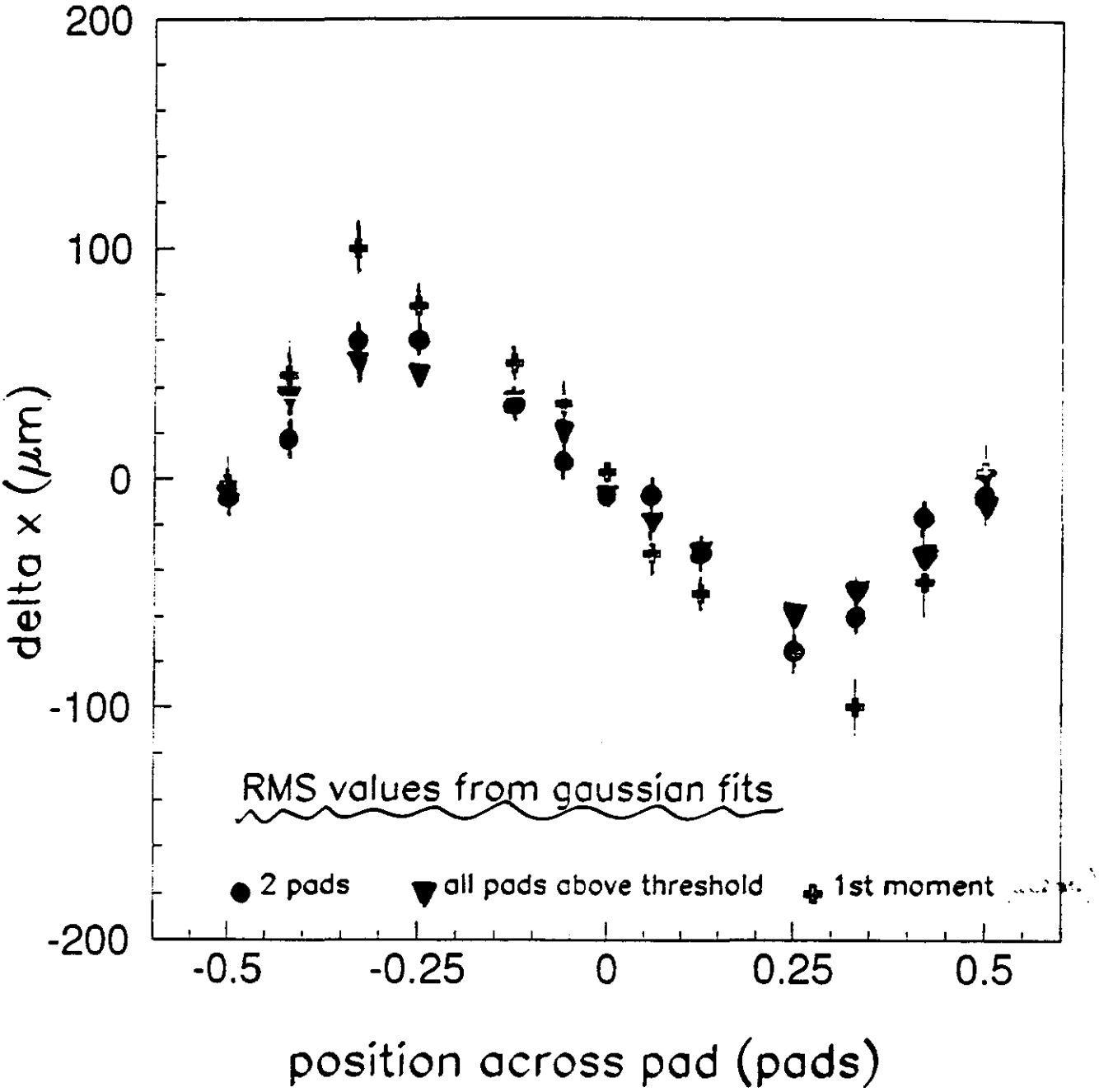


♦ ASSUME PRF IS THE SAME FOR ALL TRACKS
IRRESPECTIVE OF ANGLE

• EITHER, LOOK AT ALL PADS ABOVE THRESHOLD

OR, 2 LARGEST PADS

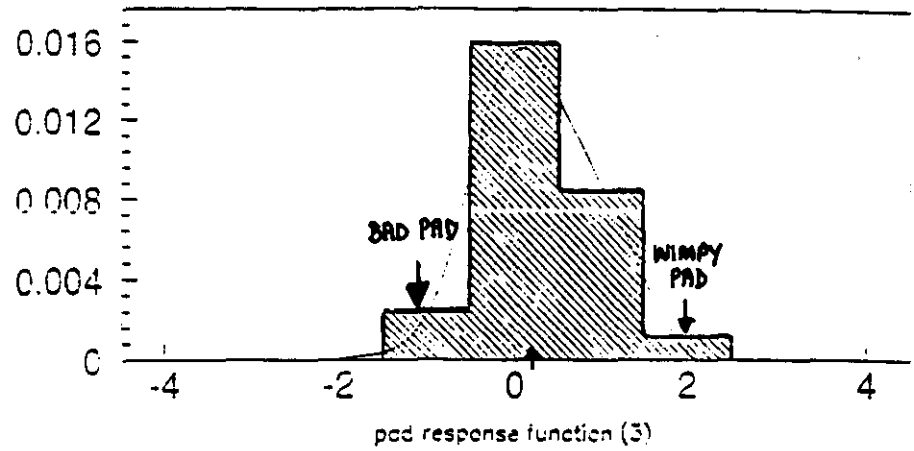




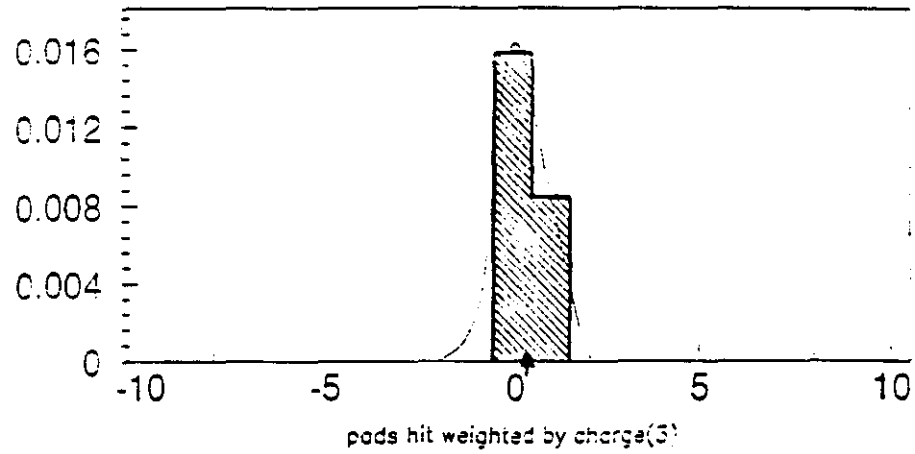
- SHIFTS ARE SMALLER FOR GAUSSIAN FITS EXCEPT AT CENTRE & EDGES

- FOR SINGLE TRACKS, SYSTEMATIC OFFSETS CAN EASILY BE UNDERSTOOD, & REDUCED (NOT ELIMINATED)

→ CONSPIRACY OF END PADS CAUSES SHIFT TO LEFT IN THIS CASE — LESS SEVERE IF WIMPY PAD IS USED



IN SOME CASES, 2 PADS ARE → BETTER, BUT MOSTLY WHEN TRACK IS BETWEEN PADS.



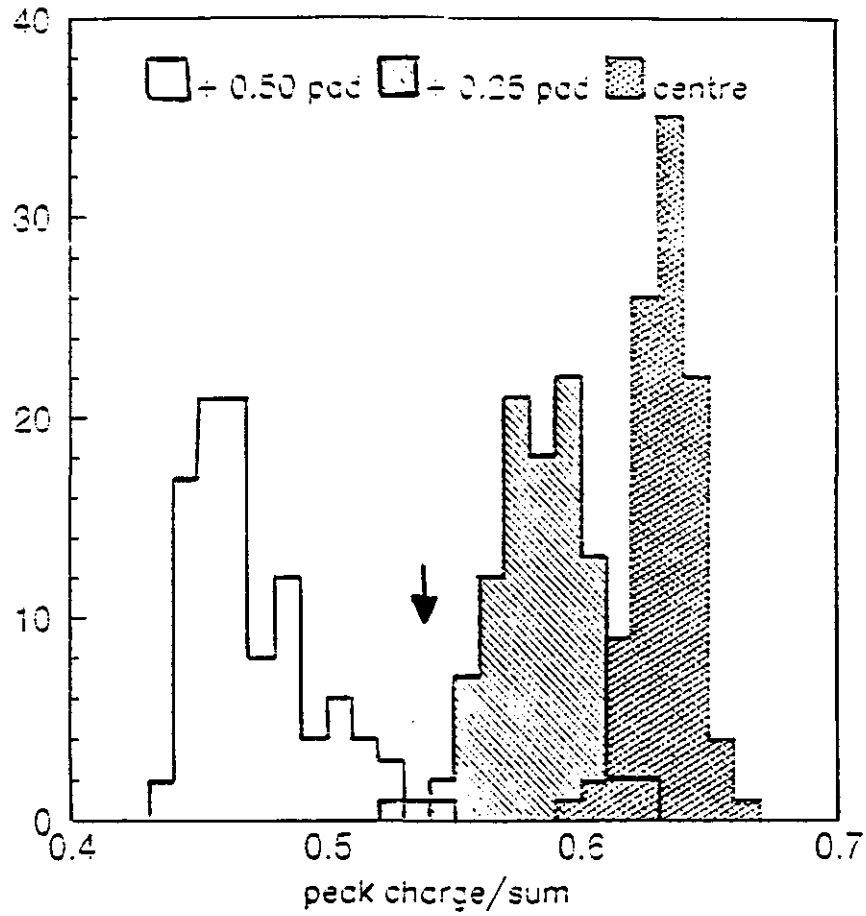
- A GOOD INDICATOR IS RATIO OF

$$\frac{\text{PEAK CHARGE}}{\text{SUM CHARGE}}$$

FOR ALL PADS ABOVE THRESHOLD

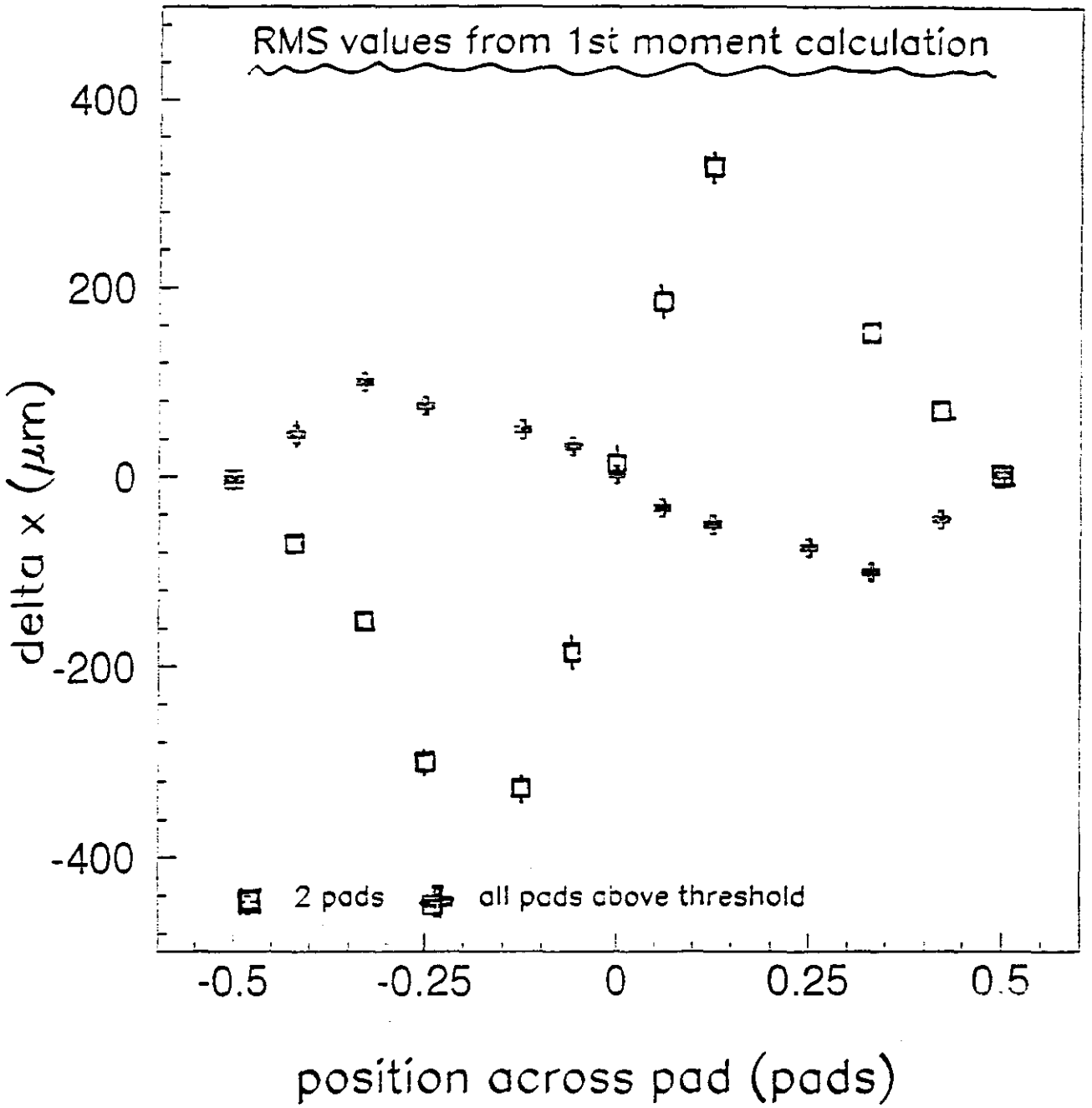
(I USED 0.001 pC, 4 × NOISE)

- BIGGEST IMPROVEMENT IS FOUND AT +0-5 (TRACK GOES BETWEEN PADS) USING 2 PADS ONLY

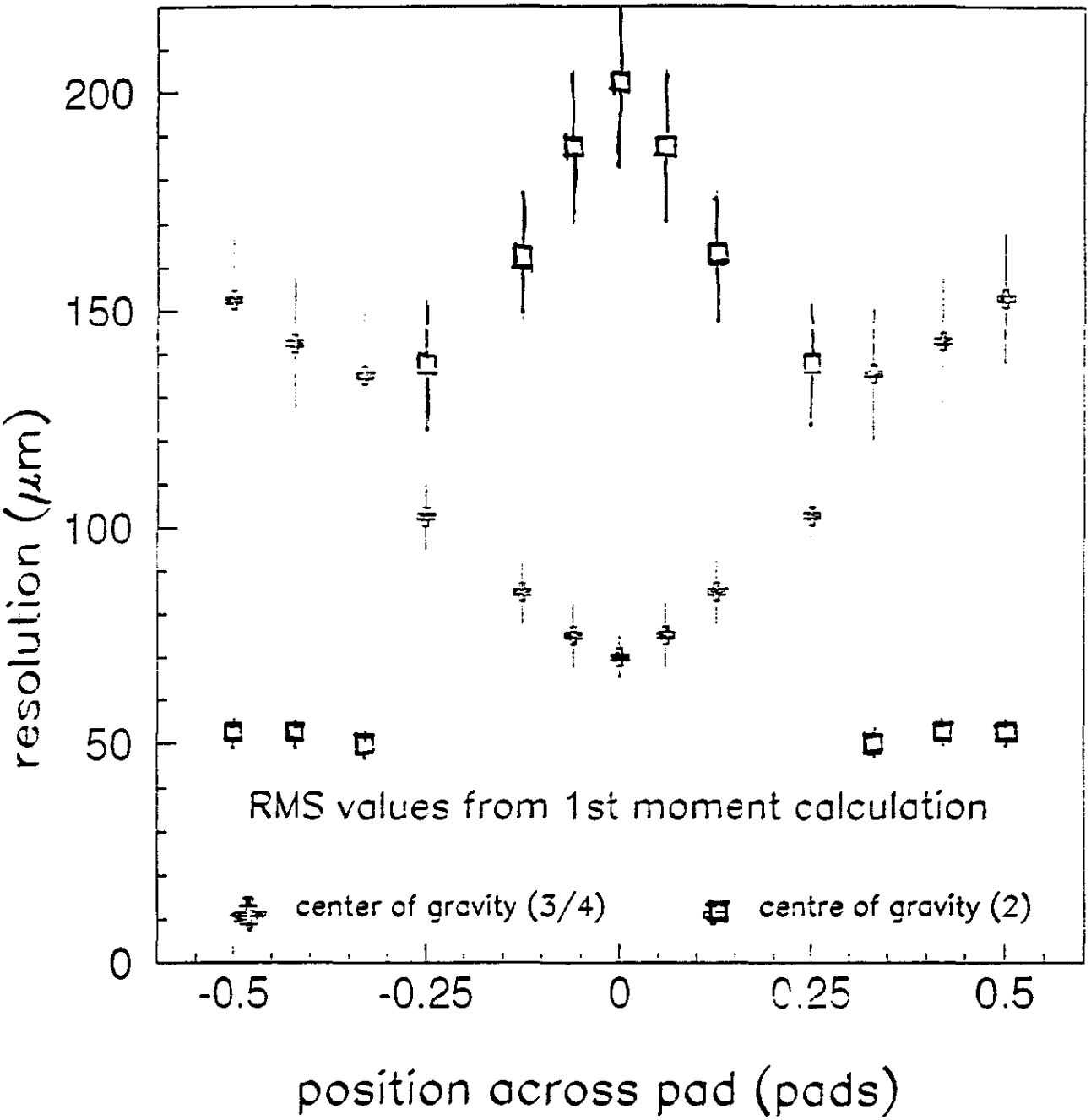


- A DIFFERENT APPROACH IS TO FIT THE CENTER OF GRAVITY, RATHER THAN GAUSSIAN, TO SAME PADS:

$$M_1 = m_1 / m_0 \quad : \quad m_0 = \sum q_i \qquad m_1 = \sum x_i q_i$$



- USING ALL PADS, EXCURSIONS ARE HORRIFIC!
- USING 2 PADS, MUCH EASIER TO CORRECT.



- CONTRIBUTION TO RESOLUTION OF SYSTEMATIC SHIFT UNCERTAINTY MUST BE ADDED IN

	0	1/4 pad	1/2 pad
GAUSSIAN (ALL PADS)			
WIDTH	70μ	80μ	80μm
DISPLACEMENT	15μ	5μ	15μ
GAUSSIAN (2 PADS)			
WIDTH	70μ	80μ	80μ
DISPLACEMENT	15μ	5μ	15μ
MOMENTS (2 PADS)			
WIDTH	200μ	150μ	50μ
DISPLACEMENT	50μ	10μ	50μ
MOMENTS (ALL PADS)			
WIDTH	70μ	100μ	150μ
DISPLACEMENT	25μ	10μ	15μ

5. TWO TRACK RESOLUTION

- FIRST PROBLEM IS TO IDENTIFY THAT THERE ARE 2 TRACKS

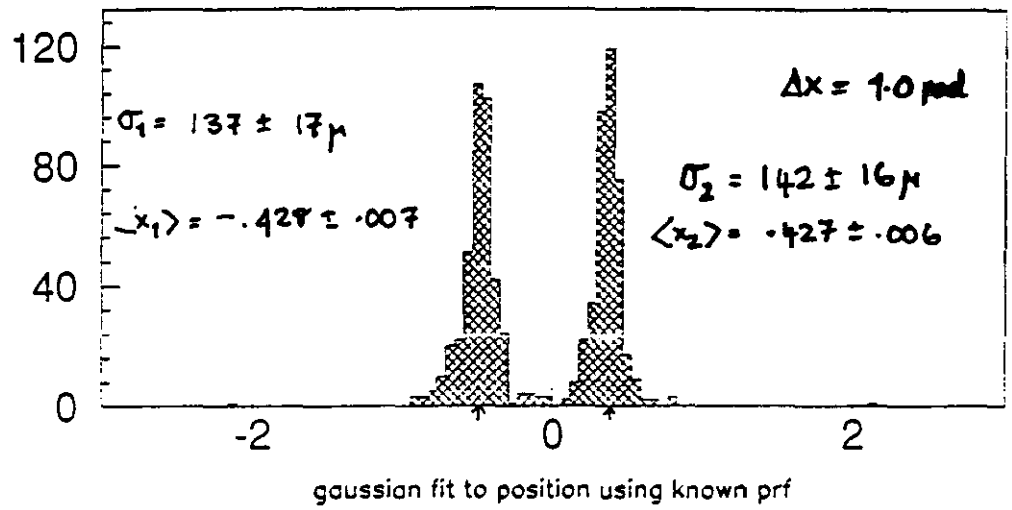
- WHEN TRACKS ARE SEPARATED BY $> 1/2$ PAD, SHAPE DIFFERENCE IS APPARENT + $\frac{dE}{dx}$: χ^2 TEST ALSO

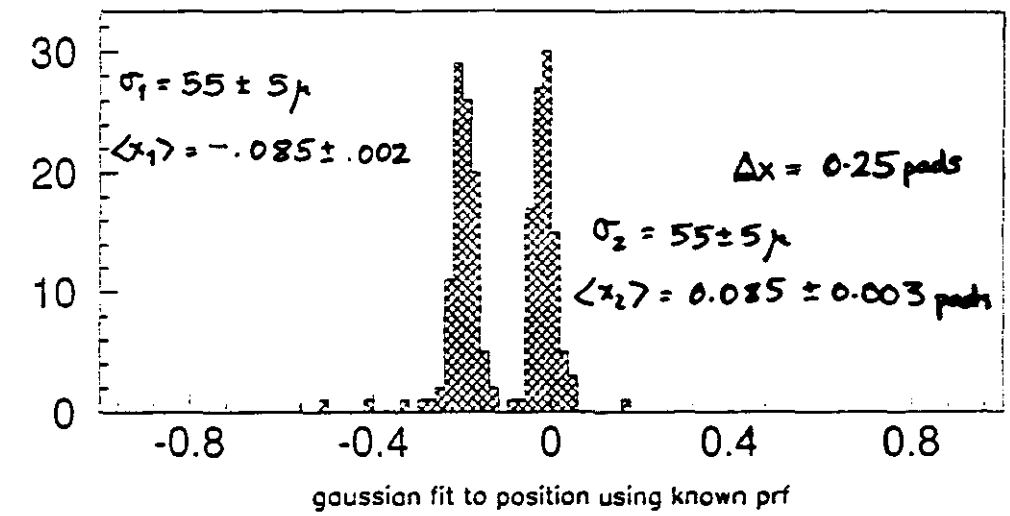
- $< 1/2$ PAD SEPARATION, ONLY $\frac{dE}{dx}$ IS AVAILABLE

- FIT TO TWO GAUSSIANS OF WIDTH σ_{PRF} :

$$A e^{-\left(\frac{x-\bar{x}_1}{2\sigma_{PRF}}\right)^2} + B e^{-\left(\frac{x-\bar{x}_2}{2\sigma_{PRF}}\right)^2}$$

- RESULT OF FITTING TWO GAUSSIANS WITH KNOWN σ_{PRF} YIELDS TWO POSITIONS

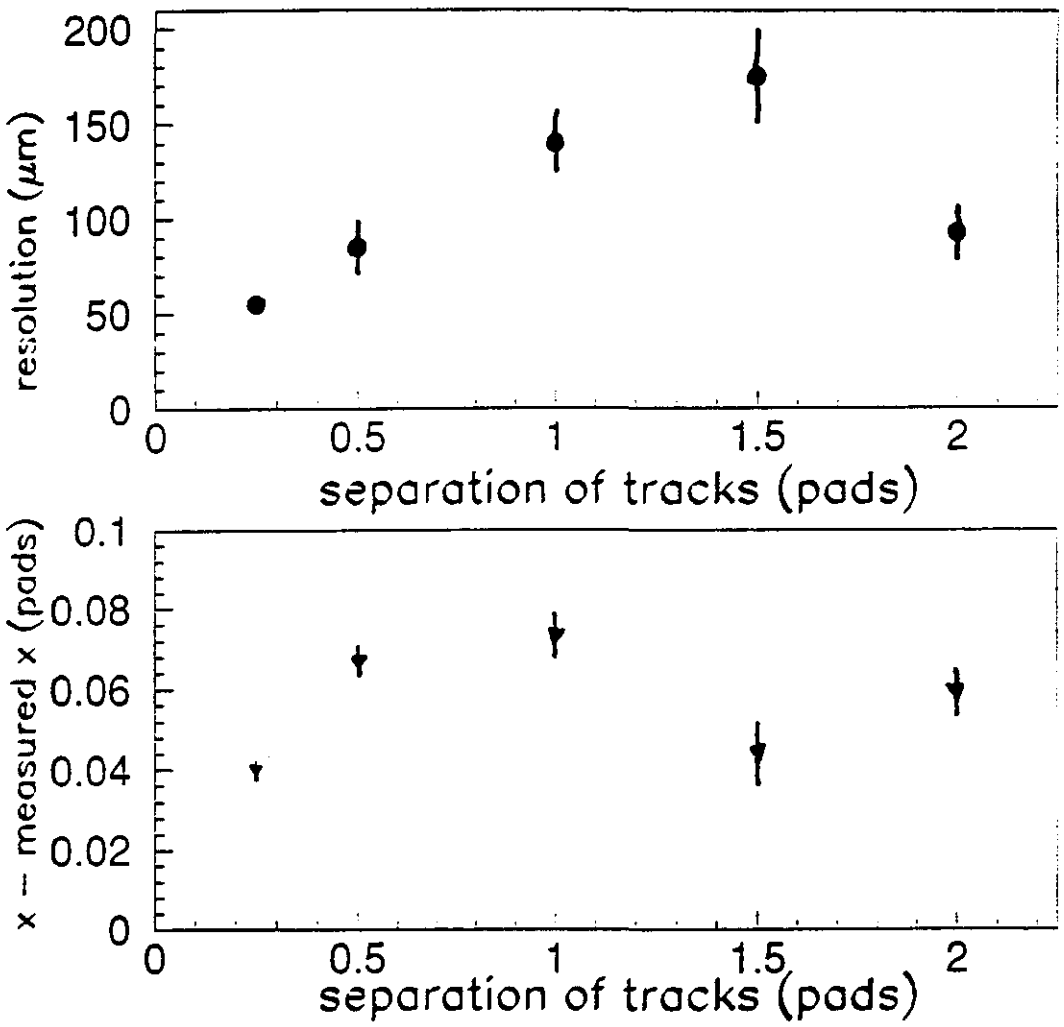




- A SYSTEMATIC OFFSET IS APPARENT

  CAN PROBABLY BE CORRECTED FOR

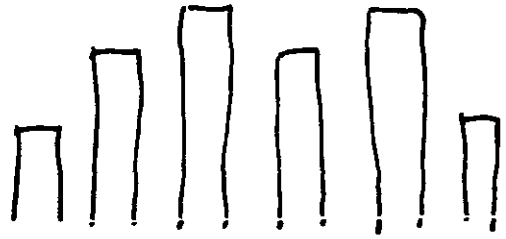
- SUMMARY OF TRACK SEPARATION VS RESOLUTION & SYSTEMATIC OFFSET



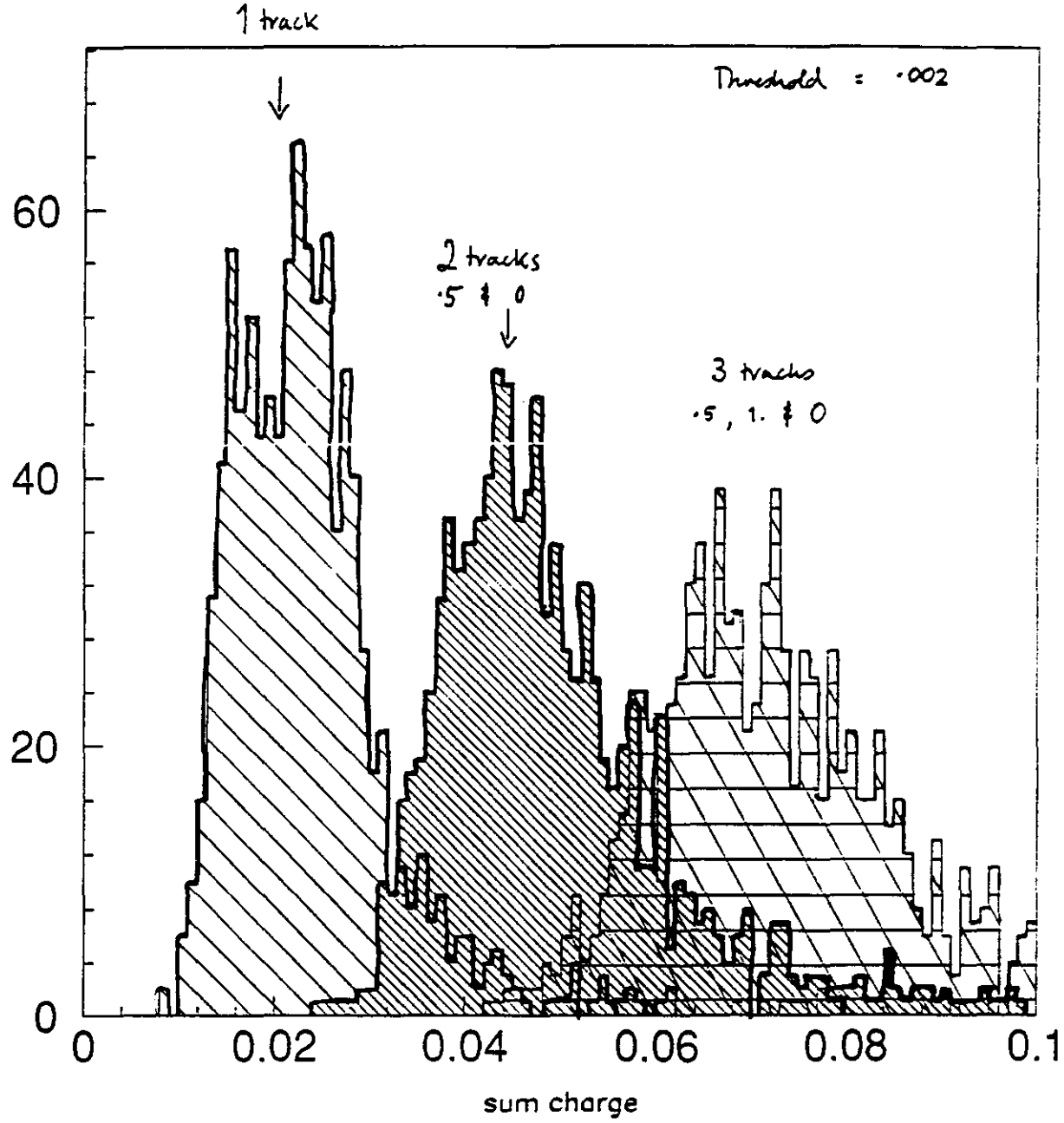
- OFFSET NEEDS TO BE UNDERSTOOD

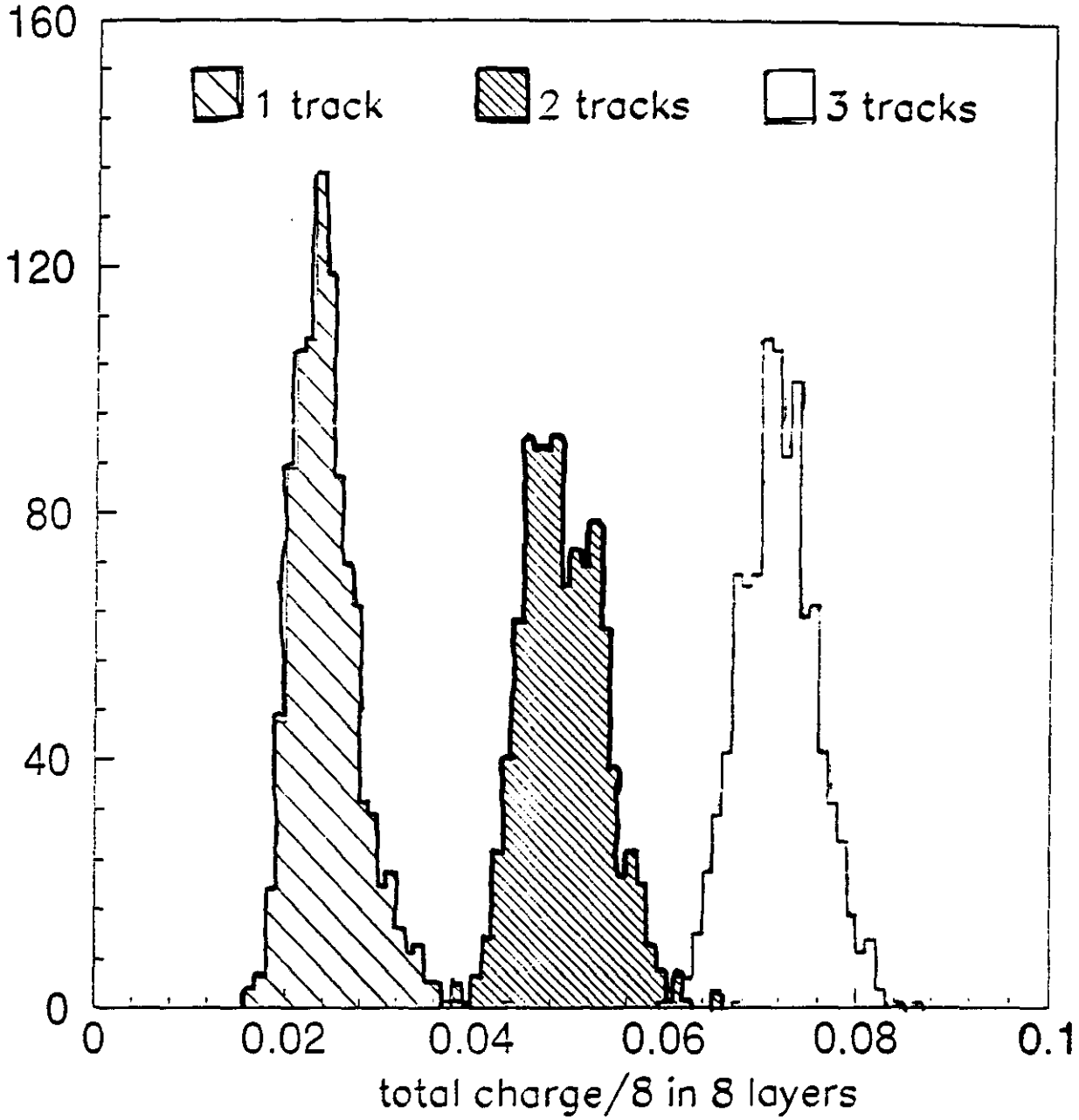
5 TRACK RESOLUTION

- WHEN TRACKS ARE SEPARATED BY MORE THAN ONE PAD, EASY TO RECOGNISE

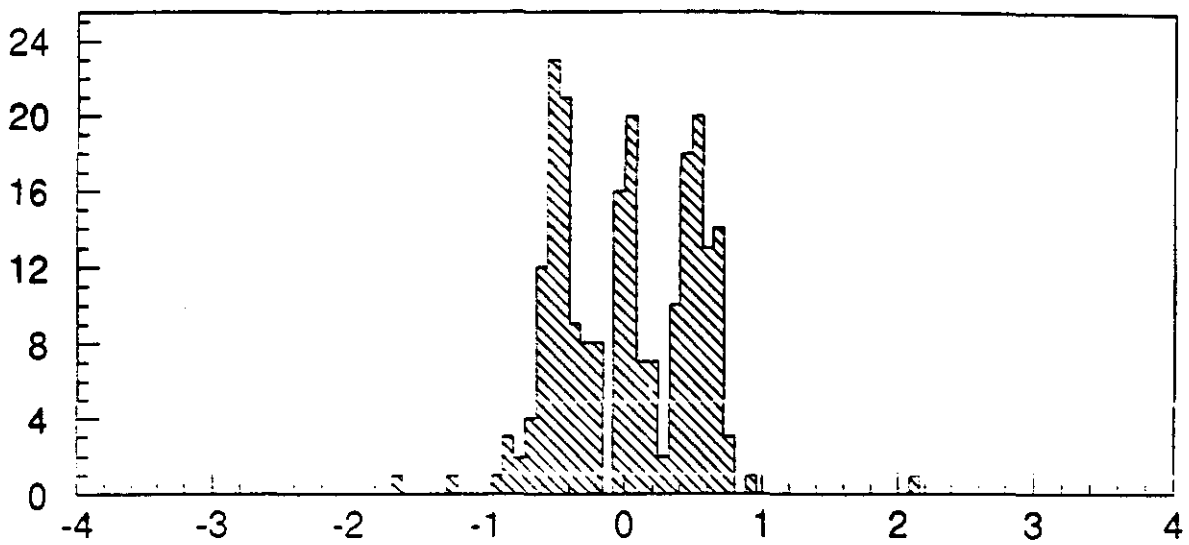


- WHEN TRACKS ARE CLOSE TOGETHER NOT SO OBVIOUS - LOOK AT TOTAL CHARGE ON ALL PADS ABOVE THRESHOLD


1 track
Threshold = ·002
2 tracks
·5 & 0
3 tracks
·5 , 1. & 0
60
40
20
0
0
0.02
0.04
0.06
0.08
0.1
sum charge



TOTAL_CHARGES.PS



gaussian fit to x1,x2,x3 using known prf

- THIS LOOKS LIKE THE LIMIT OF MULTI-TRACK RESOLUTION

- $\frac{dE}{dx}$ IS A VERY POWERFUL TOOL FOR 3-PRONG τ DECAYS

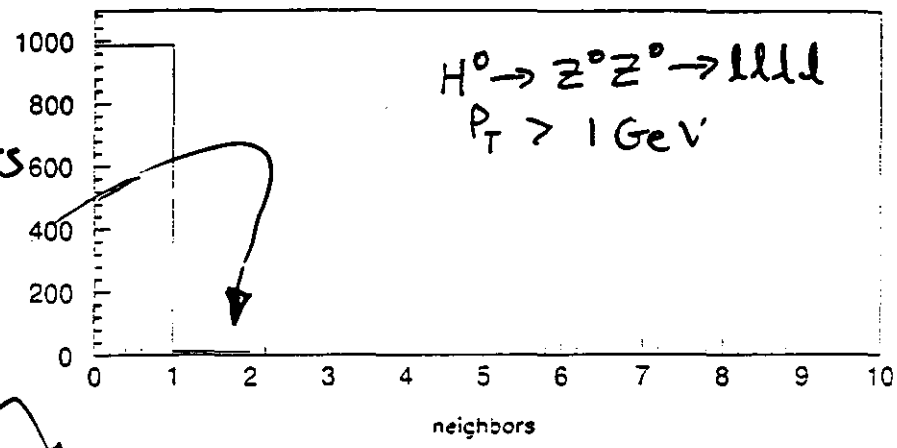
- MAKE SURE ELECTRONICS' DYNAMIC RANGE IS UP TO THE TASK

- ~~TO ACHIEVE THIS $\frac{dE}{dx}$, CS MUST SPREAD OUT OVER 3 ANODE WIRES, TO AVOID SATURATION. CHECK TOO~~

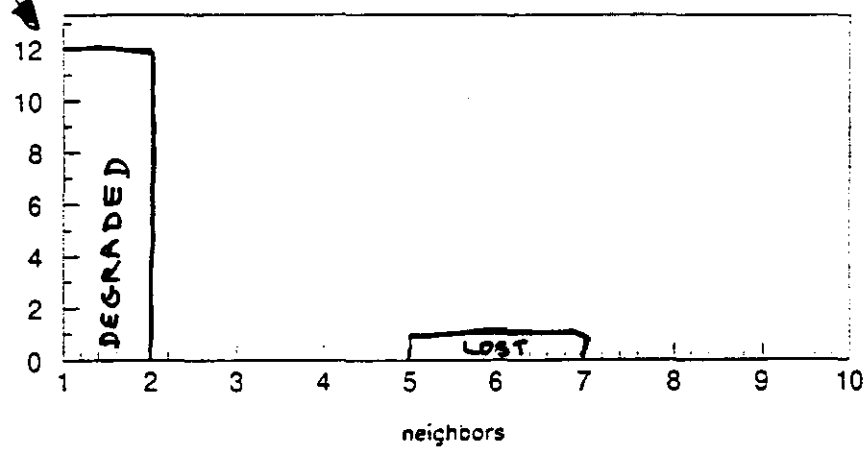
6. PHYSICS IMPLICATIONS

- SIGNAL TRACKS ARE AFFECTED BY A NEARBY* MIN-BIAS OR SIGNAL EVENT TRACKS.

~1% OF TRACKS ARE DEGRADED



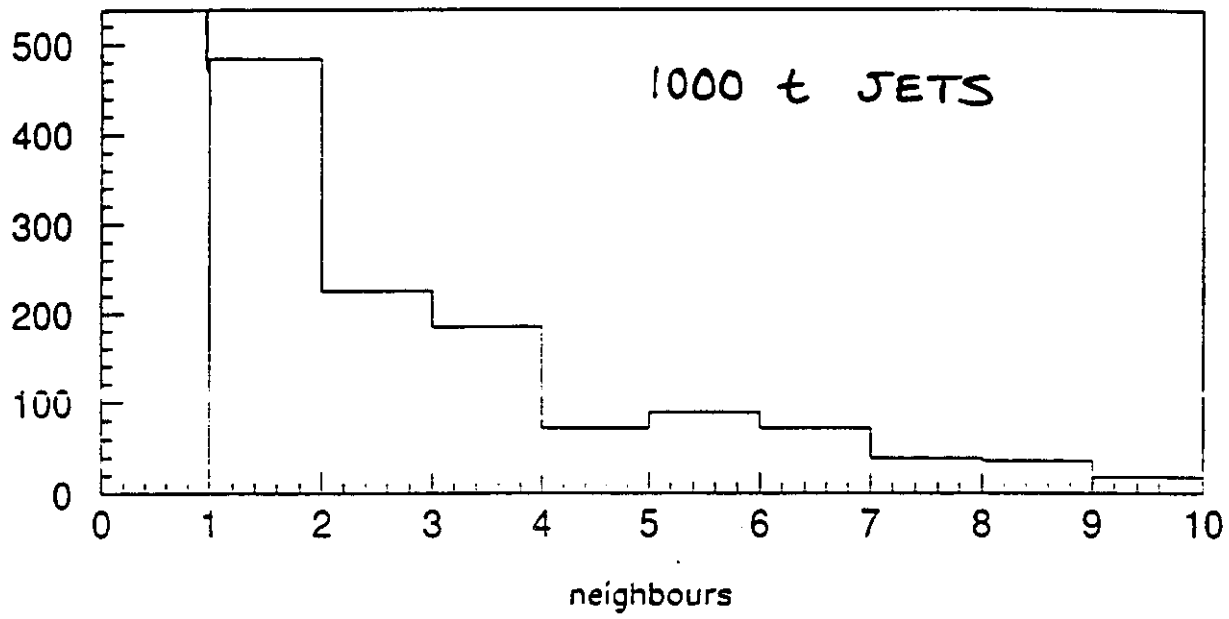
~1‰ ARE LOST



- * NEARBY MEANS INSIDE 3 PADS

- FOR b OR t JETS . . .

LOOK AT ALL TRACKS ABOVE 1 GeV



ESTIMATE!!

- ~ 2/3 OF T JETS SHOULD BE COMPLETELY RECONSTRUCTABLE

- $\frac{dE}{dX}$ IS IMPORTANT TO RECOGNISE & MEASURE # TRACKS IN A JET.

7. CONCLUSIONS

- 2 TRACK RECONSTRUCTION IS DOABLE:

  RESOLUTION IS DEGRADED AT WORST BY FACTOR 2 OR 3, AT BEST NOT AT ALL

- 3 TRACKS VERY CLOSE TOGETHER CAN BE RECOGNIZED BY $\frac{dE}{dx}$, AT LEAST A LARGE FRACTION OF THE TIME

- IT IS BETTER TO FIT TO REAL FUNCTION RATHER THAN GAUSSION – CAN ONLY IMPROVE MATTERS!

gem

γeμ

Presentation by:

G. Mills

G. MILLS

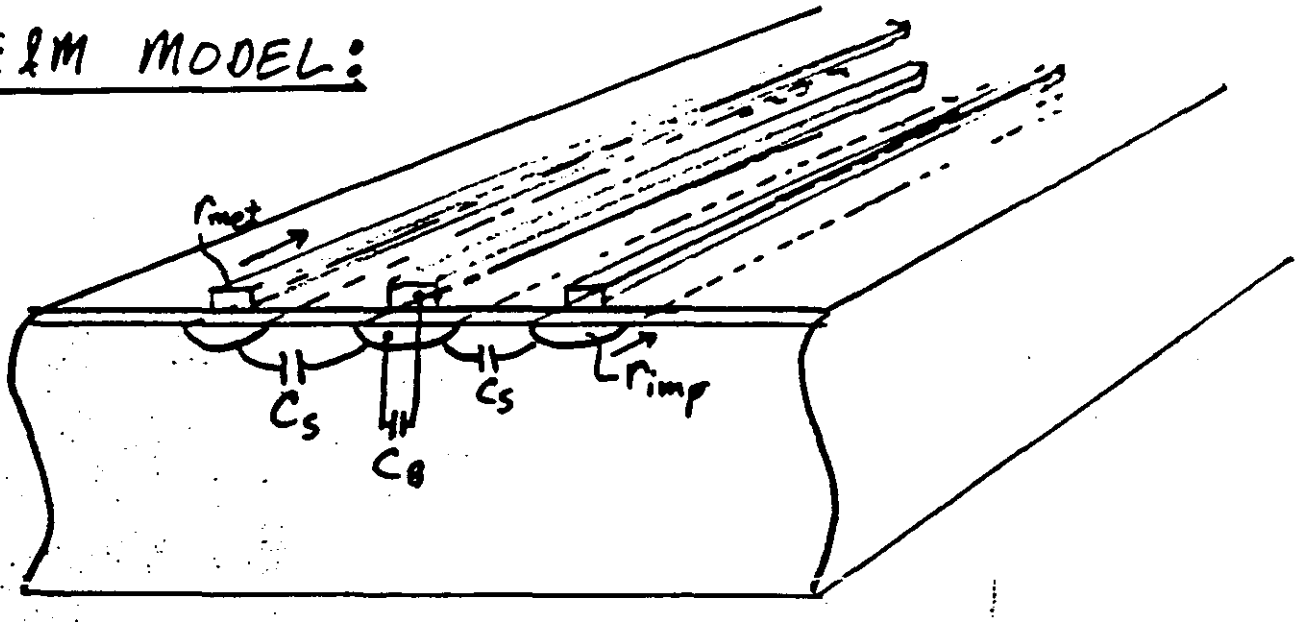
12 vs. 18 cm

CONTINUED ....

- REVIEW
- EQUIVALENT NOISE CHARGE
  + CHARGE SHARING
- SIGNAL LOSS
- EFFICIENCIES
- CONCLUSIONS

PULSE PROPAGATION

E&M MODEL:



$r_{met} \sim 50\,\Omega/cm$

$r_{imp} \sim 100\,K\Omega/cm$

$C_s \sim .6\,pF/cm$

$C_B \sim 15\,pF/cm$

MEASUREMENT OF OPAL/MICRON STRIP DET:

$r_{met} = 81\,\Omega/cm$ (for strip .8μm X 10μm)

FOR 2μ X 15μ strip ⇒ ~ 22 Ω/cm

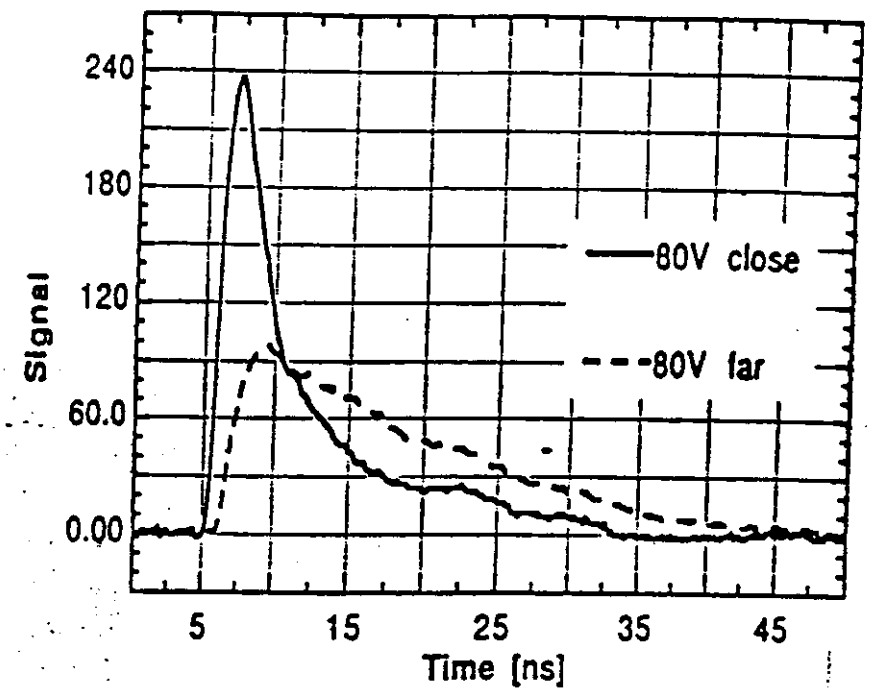


Fig. 2. Pulse shapes from an IR laser close / far observed with the Hamamatsu detector.

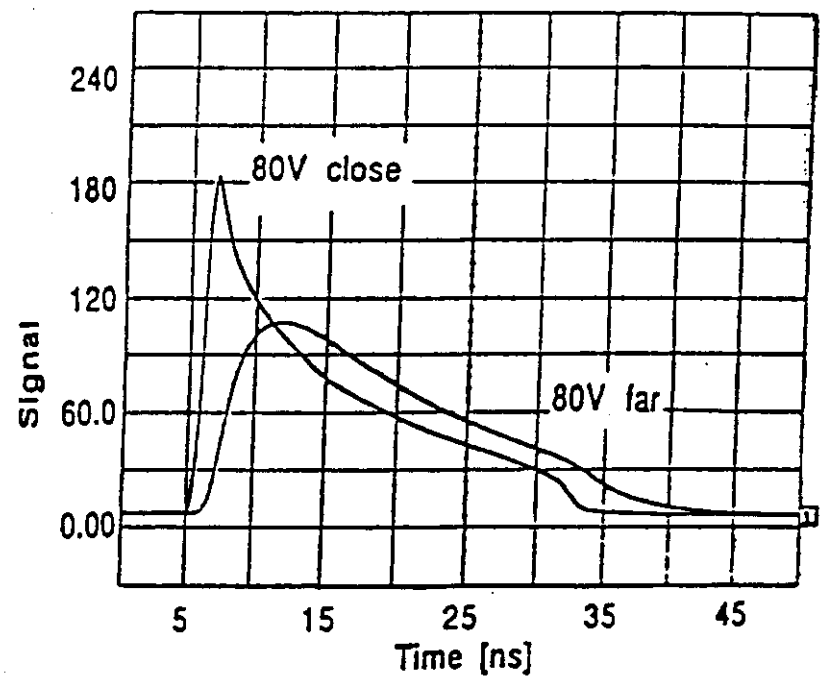
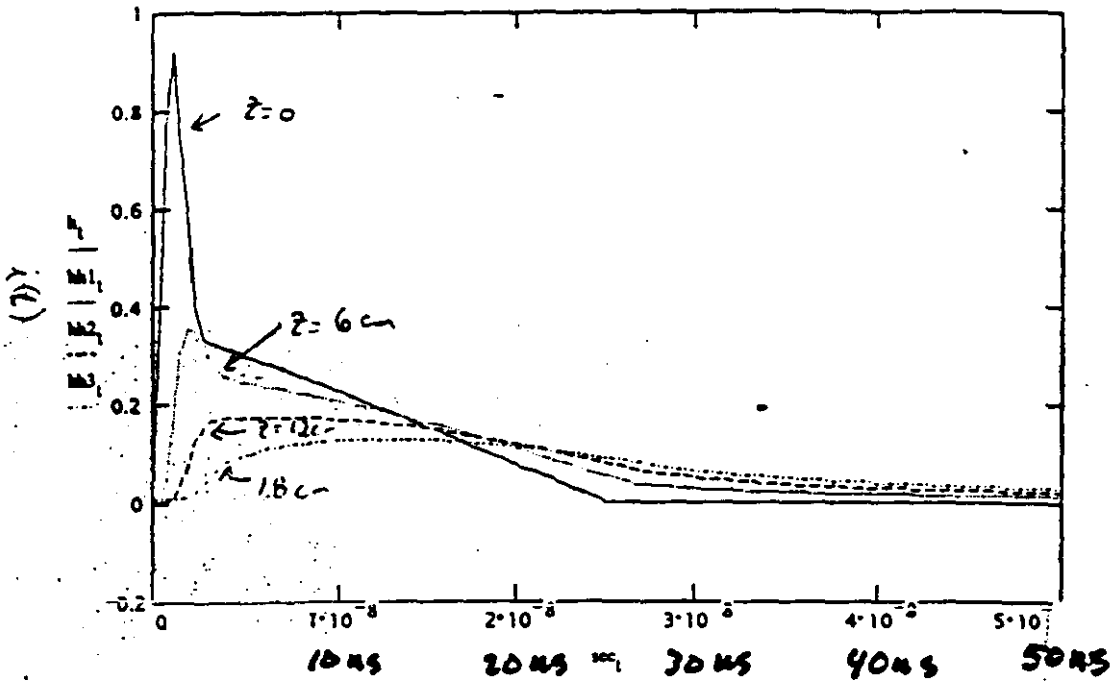


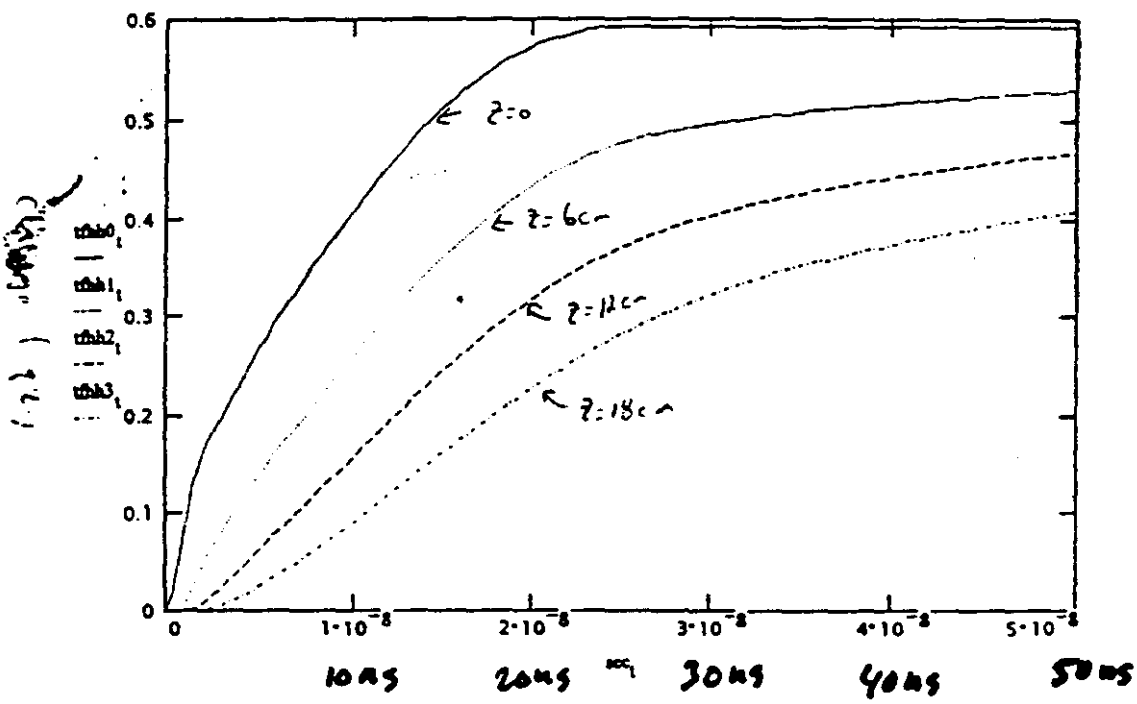
Fig. 3. Simulated pulse shape of the Hamamatsu detector with pulse close to and far from the amplifier with $R_s = 100\ \Omega/\mathrm{cm}$.

(SANTA CRUZ ...)

PULSE SHAPES AT AMPLIFIER INPUT



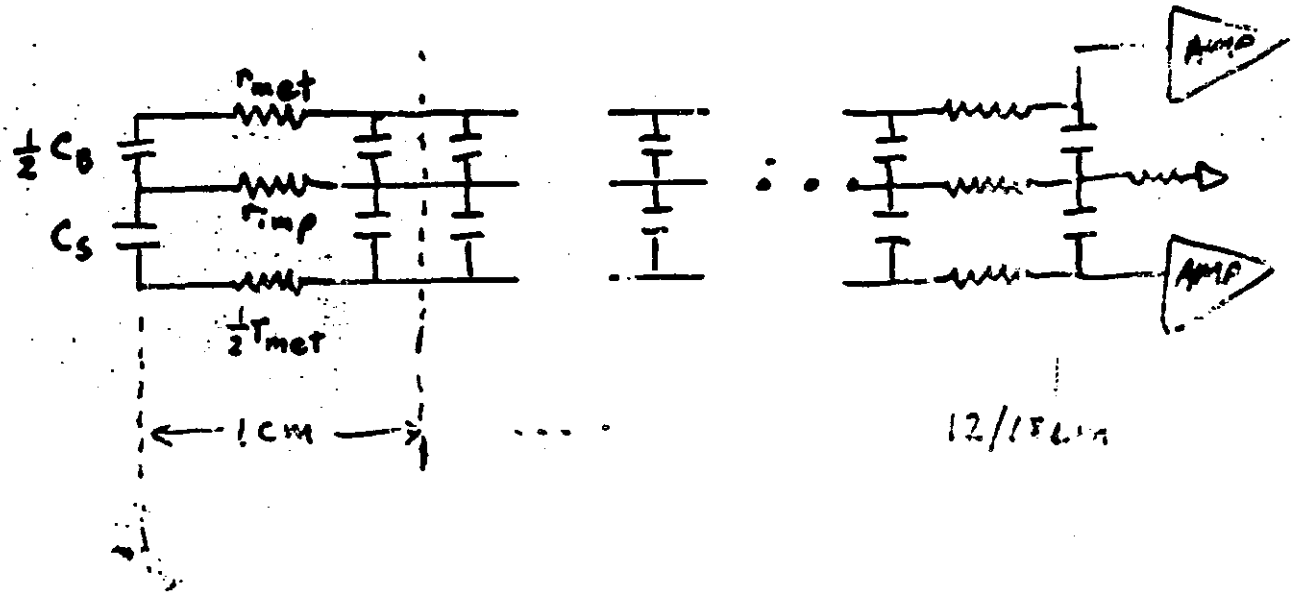
INTEGRATED PULSE SHAPE



(B. COOKE)

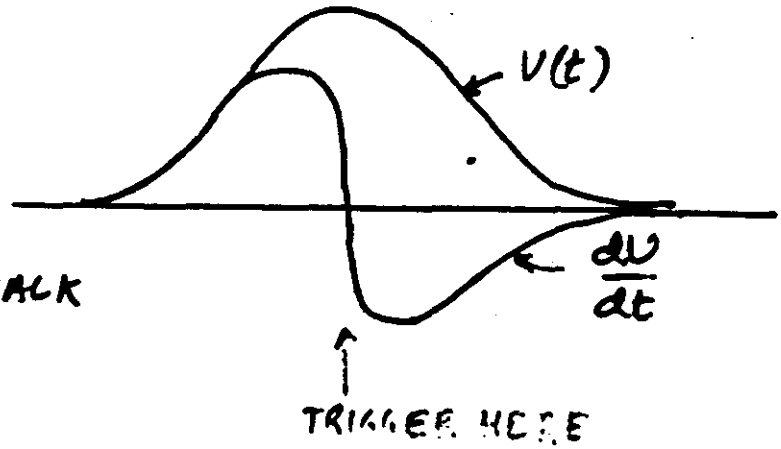
CIRCUIT SIMULATION

DETECTOR:



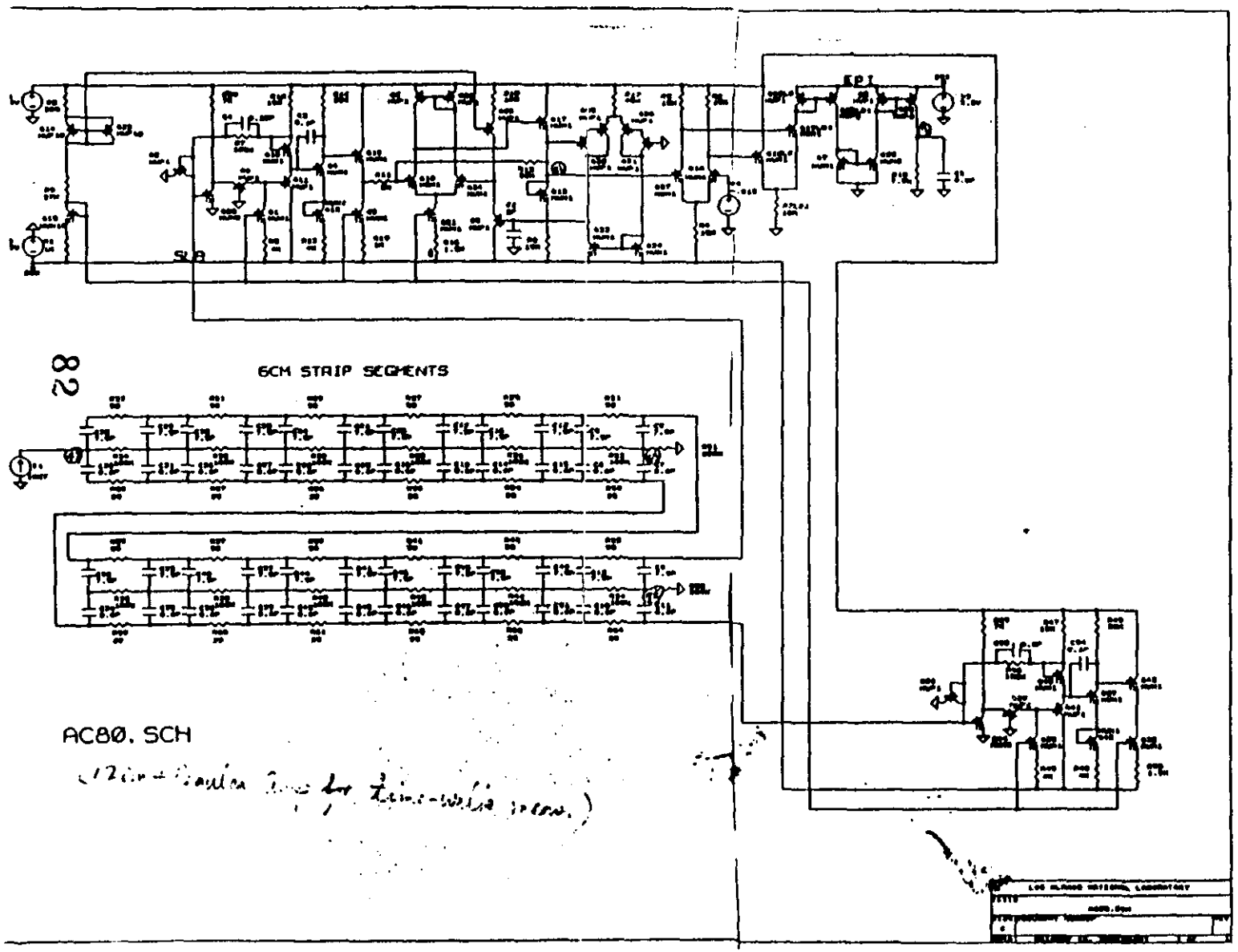
AMPLIFIER/COMPARATOR:

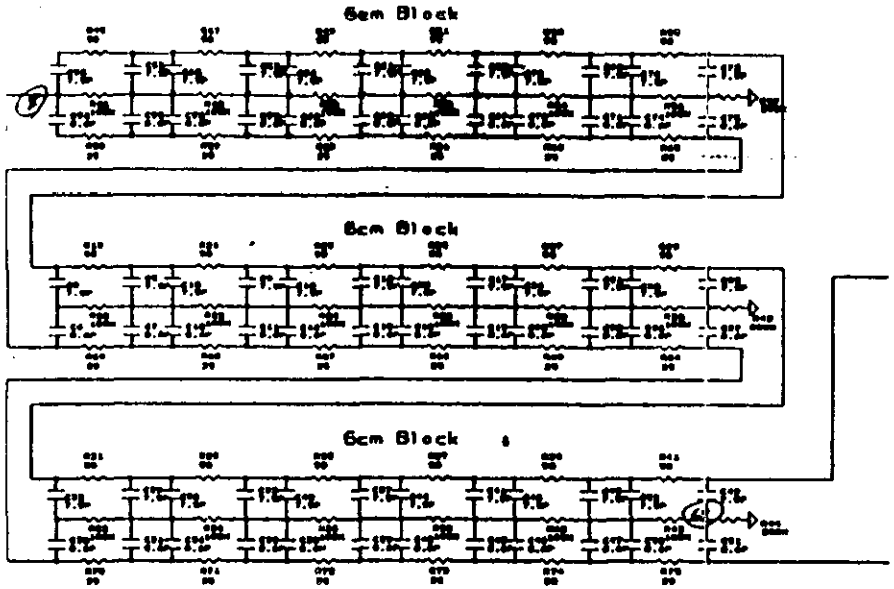
ZERO CROSSING TIME.

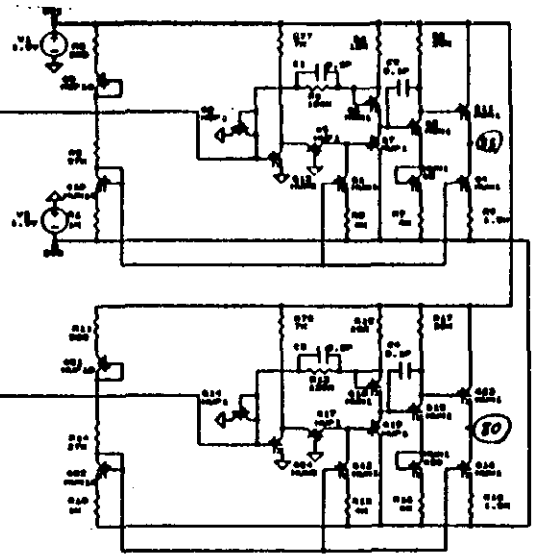


- ELIMINATES TIME WALK PROBLEM!

FULL CIRCUIT FOR ZERO CROSSING SIMULATION







83

AC83 (Similar to AC75)
For AC noise test
Used realistic Id input waveform
for simulation

OTES:
1. There is no connection between p+ strips of the two 6cm detectors rs.

CIRCUIT FOR NOISE SIMULATION

Sangkoo Hahn/10-15-92

Summary of Simulations, 12cm vs. 18cm

1. For a lumped detector capacitance, single-channel strip, with 16ns square input current pulse (This has been the traditional setup to define amplifier performance);

Det. Capacitance	Noise Equiv. Charge	Time-Walk (6k - 48k electrons)
15pF	1620 electrons RMS	5ns
22.5	2070	8

2. For 3-channel distributed R-C strips with amplifiers, and with 16ns square input pulse (This is the noise that we expect at the amplifer output, and should be the base of determining the threshold levels);

Det. Length	Noise Equiv. Charge	Time-Walk
12cm	2150	not measured
18cm	2605	not measured

3. For 3-channel distributed R-C strips with amplifiers, and with realistic input pulse waveform (resulting in charge sharing among adjacent channels and with amplifier noise feedback as in case 2, see note 3);

Det. Length	Noise Equiv. Charge (Far/Near-ends)	Time-Walk (Far/Near-ends)
12cm	2540/2210	13.7ns(no 6k trigger)/10.2ns(no 6k trigger) *Threshold = 5000 electrons (3x1620)*
18	3550/2710	9.1ns(no 6k, 9k, 12k trigger)/9.0ns (no 6k, 9k trigger) *Threshold = 6250 electrons (3x2070)*

Notes:

1. The thresholds used for the time-walk measurements were based on the equivalent noise of a lumped, single-channel arrangement, which is a lot more optimistic than the distributed case. I used the lower numbers because I felt that the simulation results may not be very interesting, with only a few input charge pulses triggering the LD, if the more realistic numbers (based on the noise of the distributed case) were used.

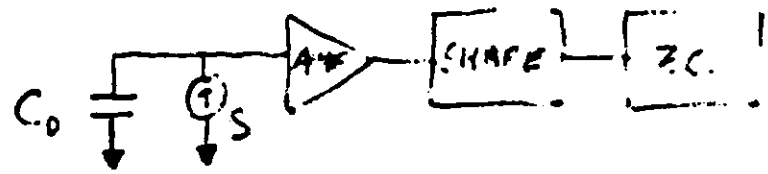
2. This simulation is solely based on nominal transistor gains as an expected beginning-of-life performance. Both noise and time-walk figures would certainly degrade with doses over the life time. It is not simple to show how much degradation we should expect since there is no accepted radiation damage curve on these new series of transistors except that some transistors lose the current gain by more than a factor of two at 100uA of collector current at or around 1MRad.

3. The termination of neighboring strips with amplifier inputs contributes additional noise through (what Berkely people call) noise feedback; essentially, the noise voltage at the amplifer output node injects noise currents into adjacent channels through feedback capacitances.

EQUIVALENT NOISE

SIMPLE MODEL:

	ENC
12cm	1620e
18cm	2070e

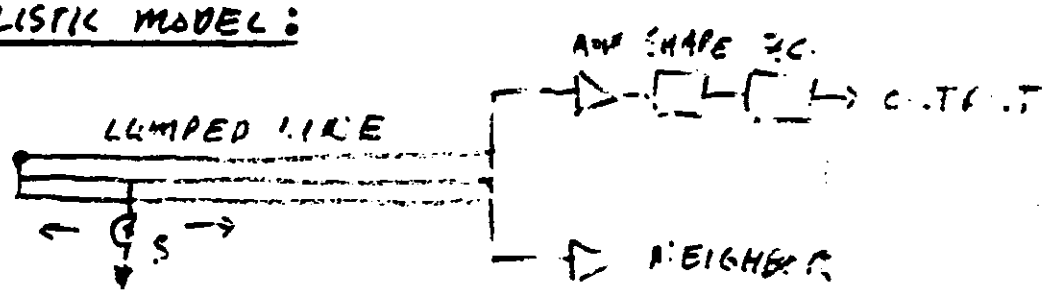


- ALL INPUT PULSES HAVE THE SAME SHAPE AND GAIN

⇒ ① CONSTANT EQUIVALENT NOISE
② AMPLIFIER SEES FULL SIGNAL

MORE REALISTIC MODEL:

	ENC NEAR	ENC FAR
2	2210e	2540e
8	2750e	3550e



- PULSE SHAPE DEPENDS ON POSITION

⇒ ① ENC DEPENDS ON POSITION

② PARASITIC LOSS OF SIGNAL TO NEIGHBORING STRIP.

IE.
'CHARGE SHARING'

(E.N.C. DEFINITION:
① MEASURE RMS VOLTAGE AFTER SHAPER v_{rms}
② INJECT KNOWN CHARGE AT INPUT POINT, Q_0, MEASURE V_0 AFTER SHAPER
③ $ENC \equiv v_{rms} \times \frac{Q_0}{V_0}$)

SIGNAL LOSS

- CHARGE SHARING ALREADY ACCOUNTED FOR IN ENC (~ .75)
- ATTENUATION ALONG STRIP (NEAR OR FAR)

  USE AVERAGE : (50-70% strip)

  12 cm ~ .93

  18 cm ~ .88
- RADIATION DAMAGE :

  10-15% FROM TRAPPING

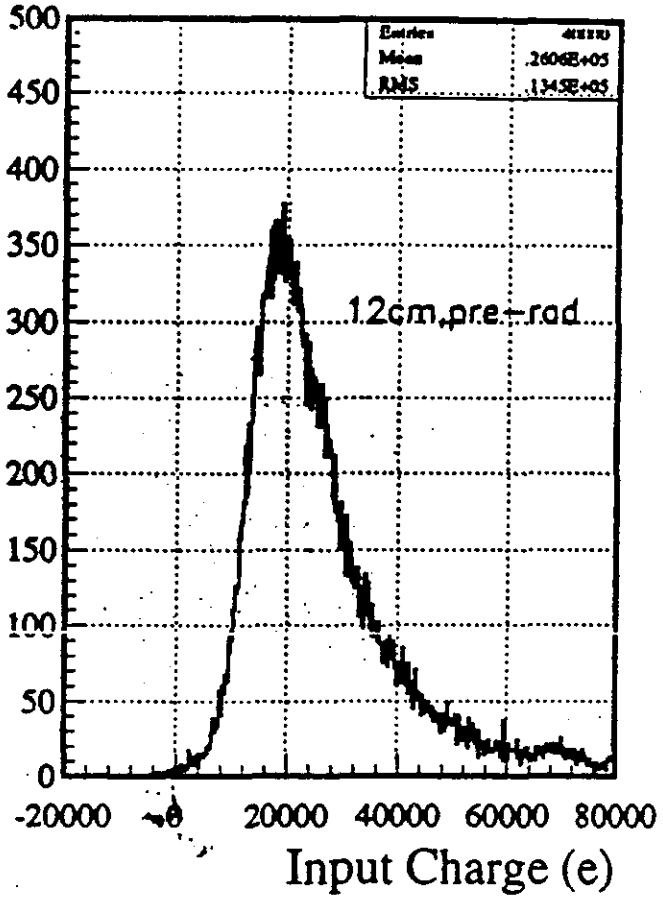
  5% FROM INCREASED CHARGE SHARING

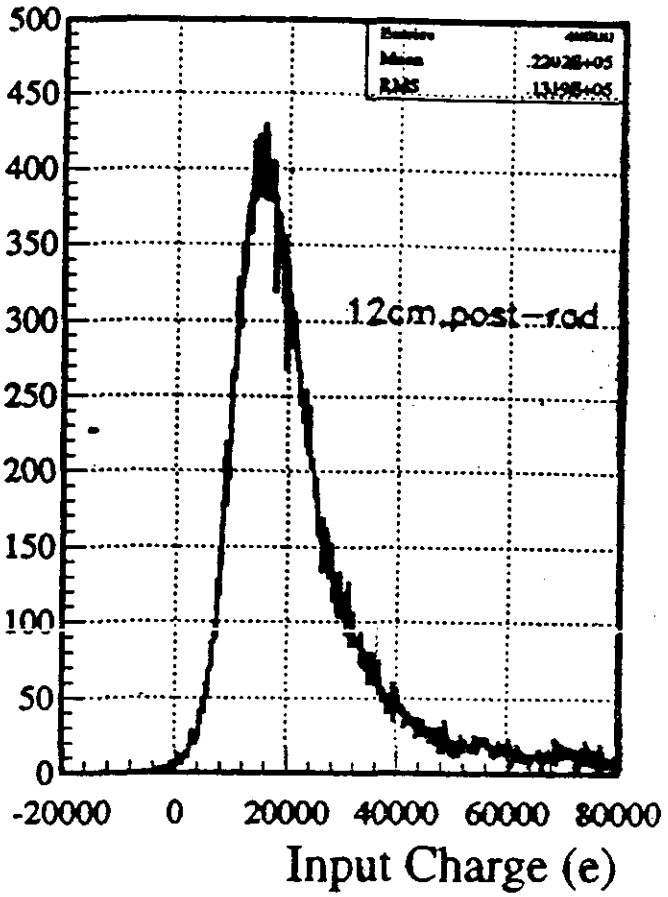
  20%

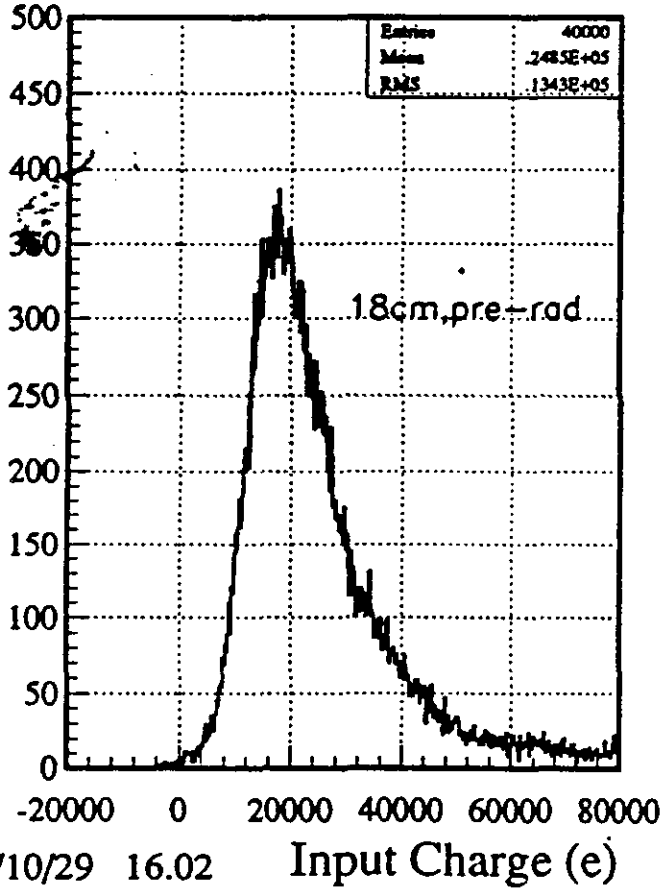
TOTAL : (NOT INCLUDING CHARGE SHARING)

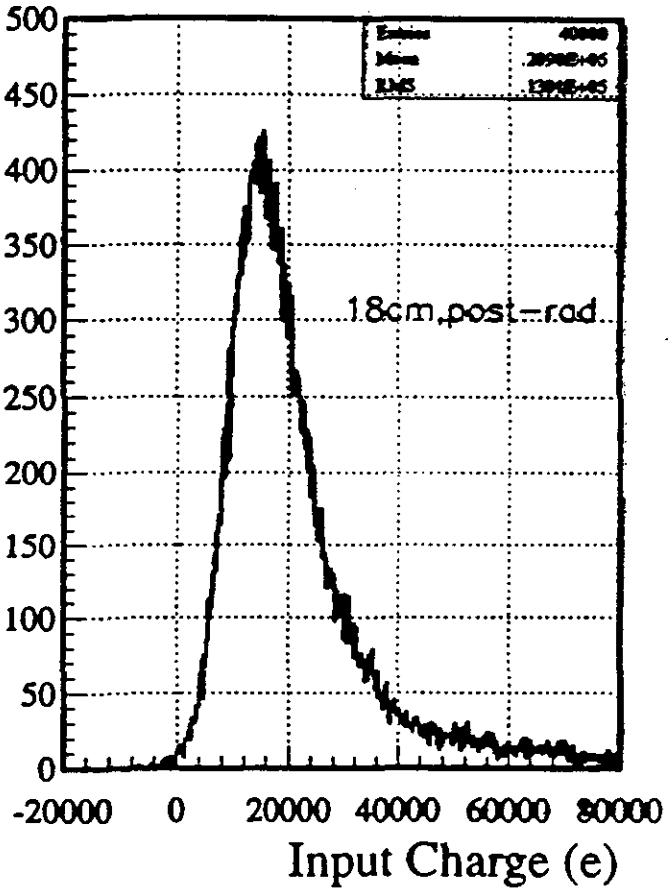
	PRE-IRRADIATION	POST-IRRADIATION
12 cm	.93	.74
18 cm	.88	.70

18cm BARREL



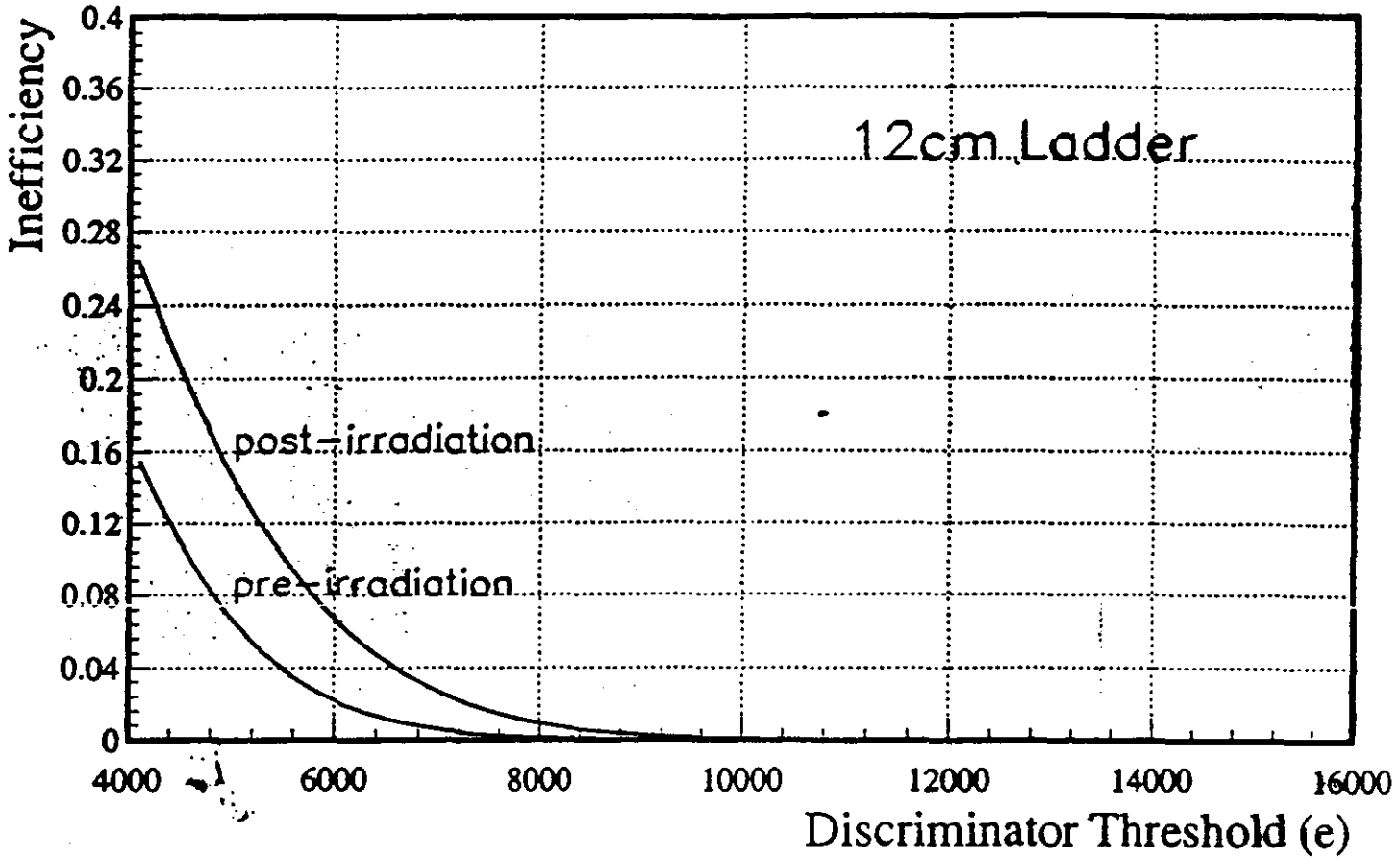


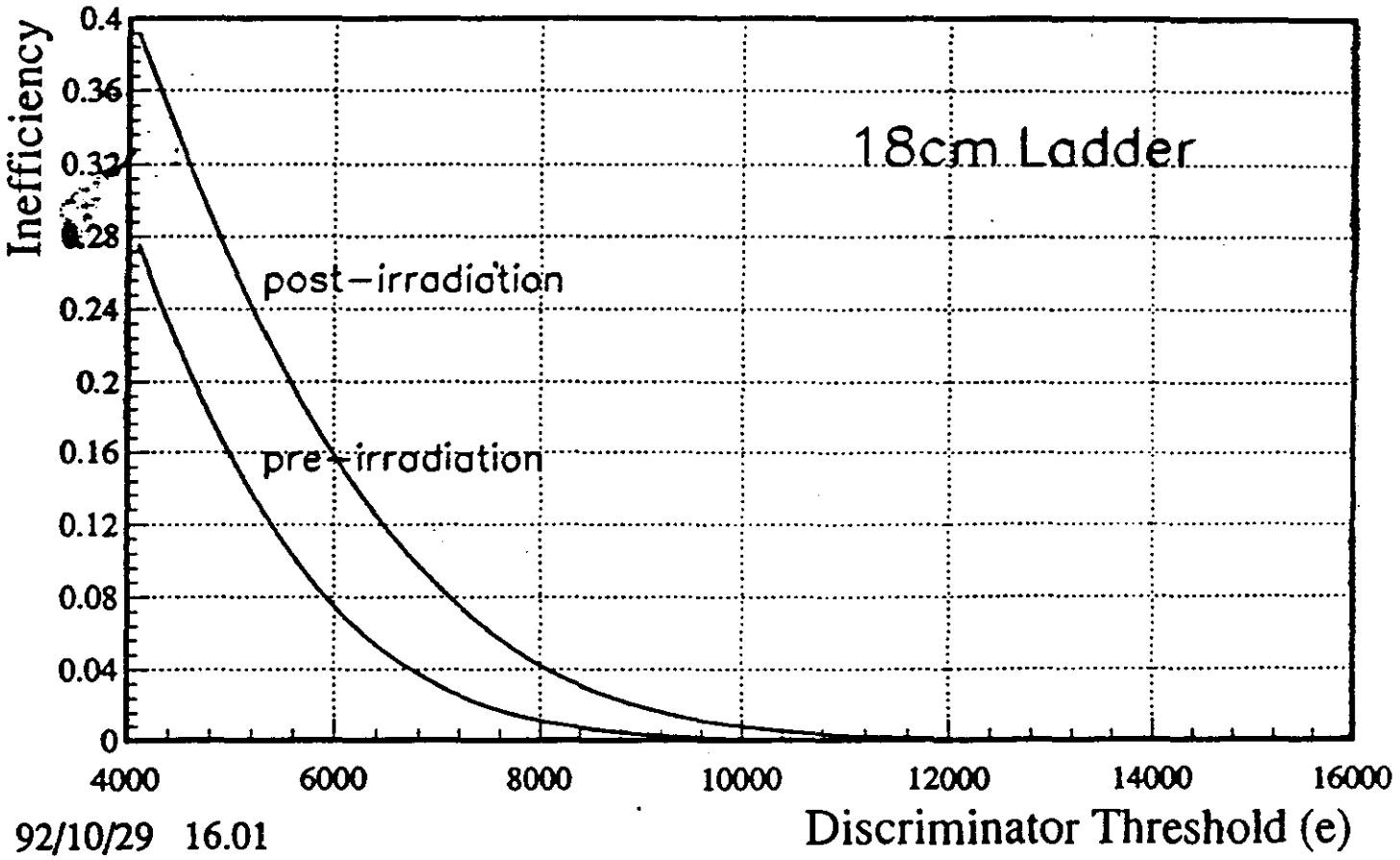




92/10/29 16.02

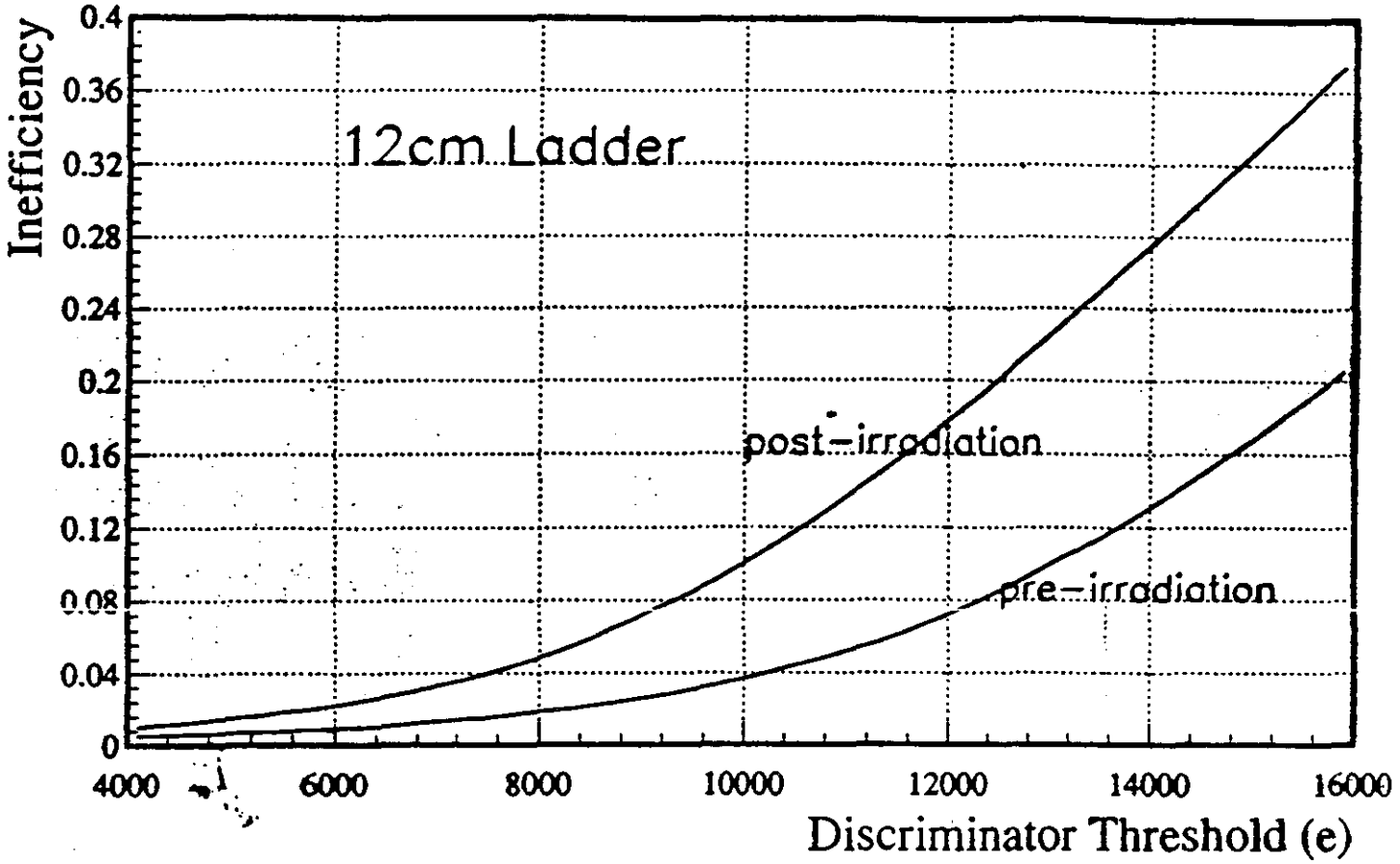
18cm BARREL

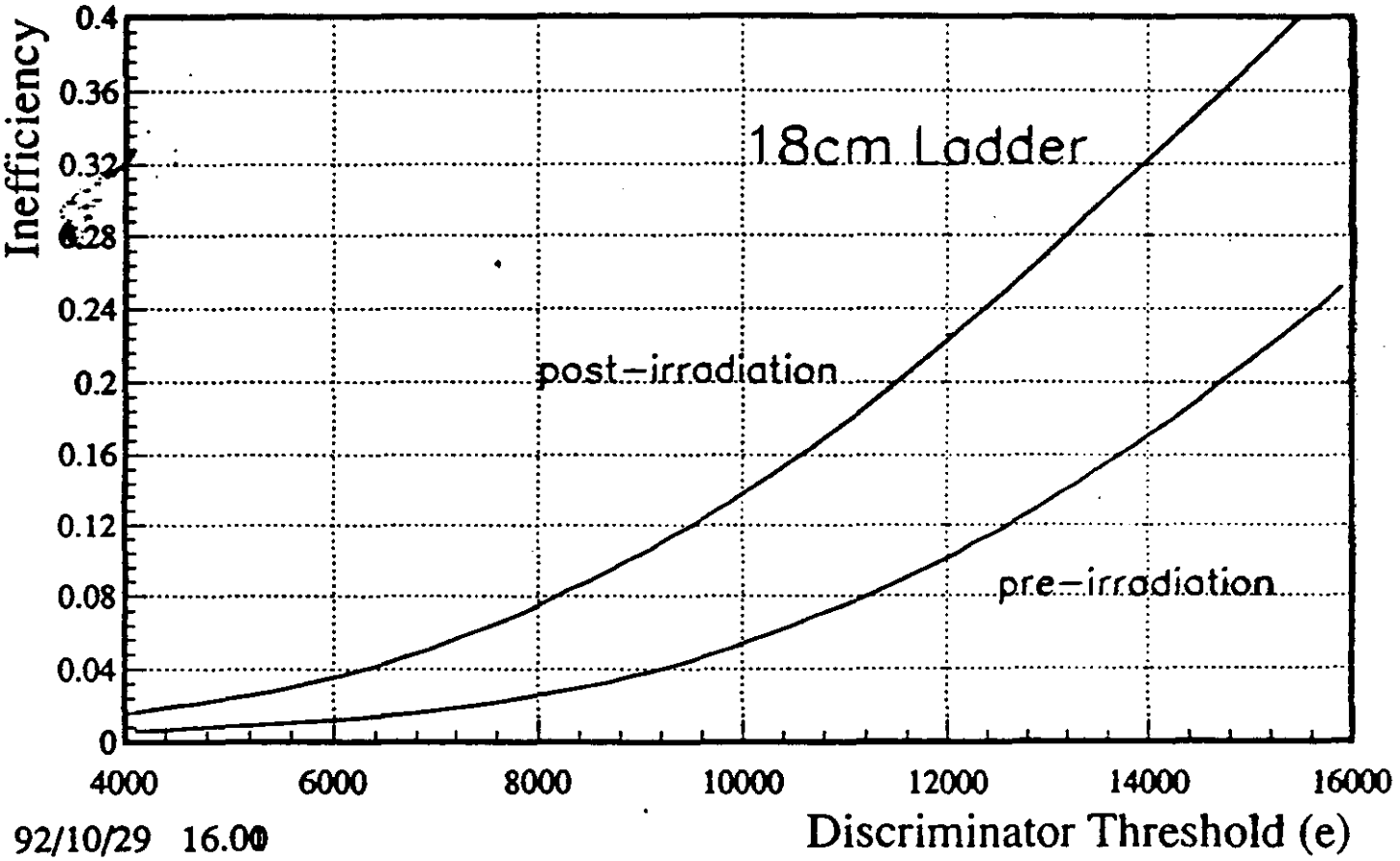




92/10/29 16.01

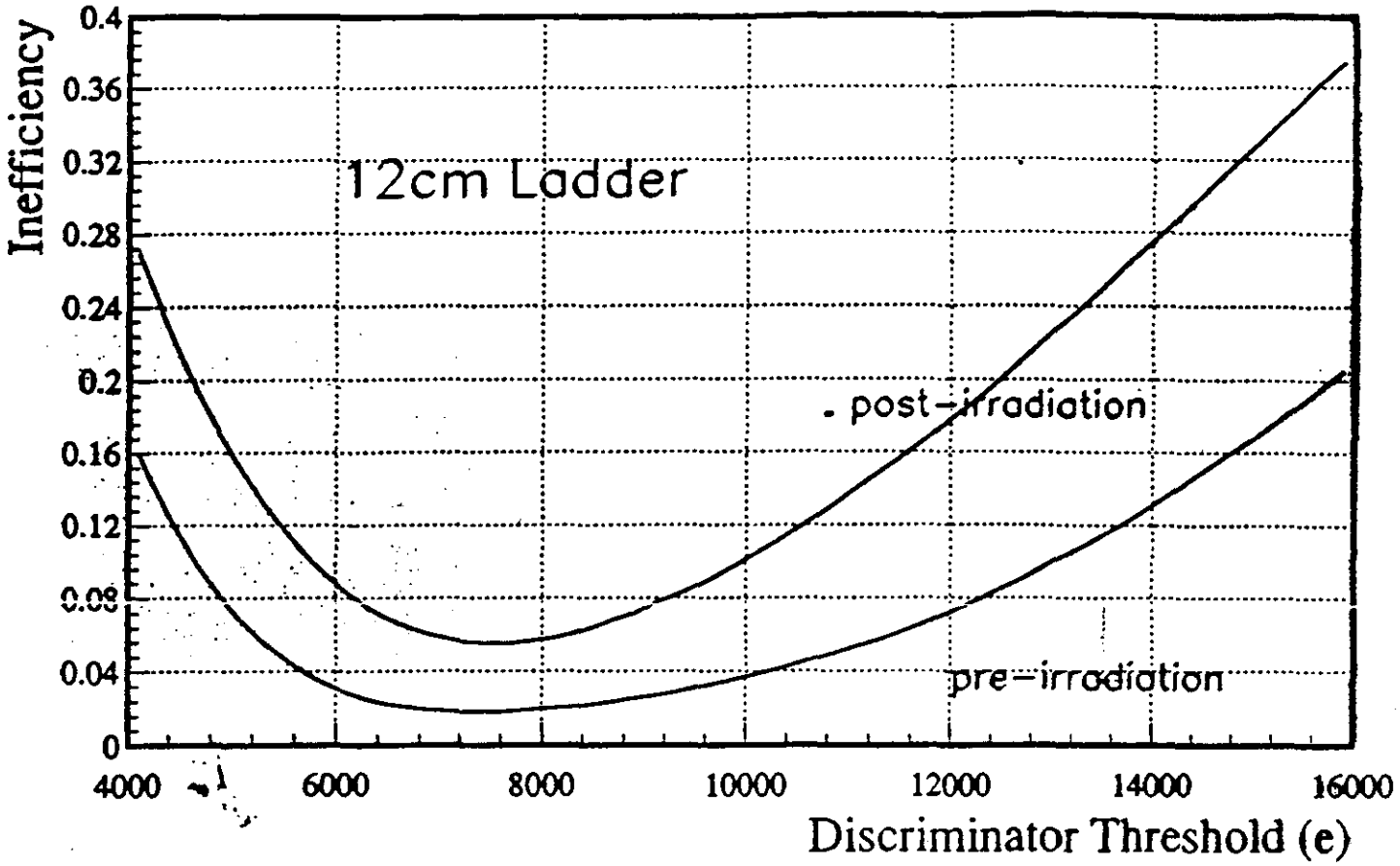
18cm BARREL

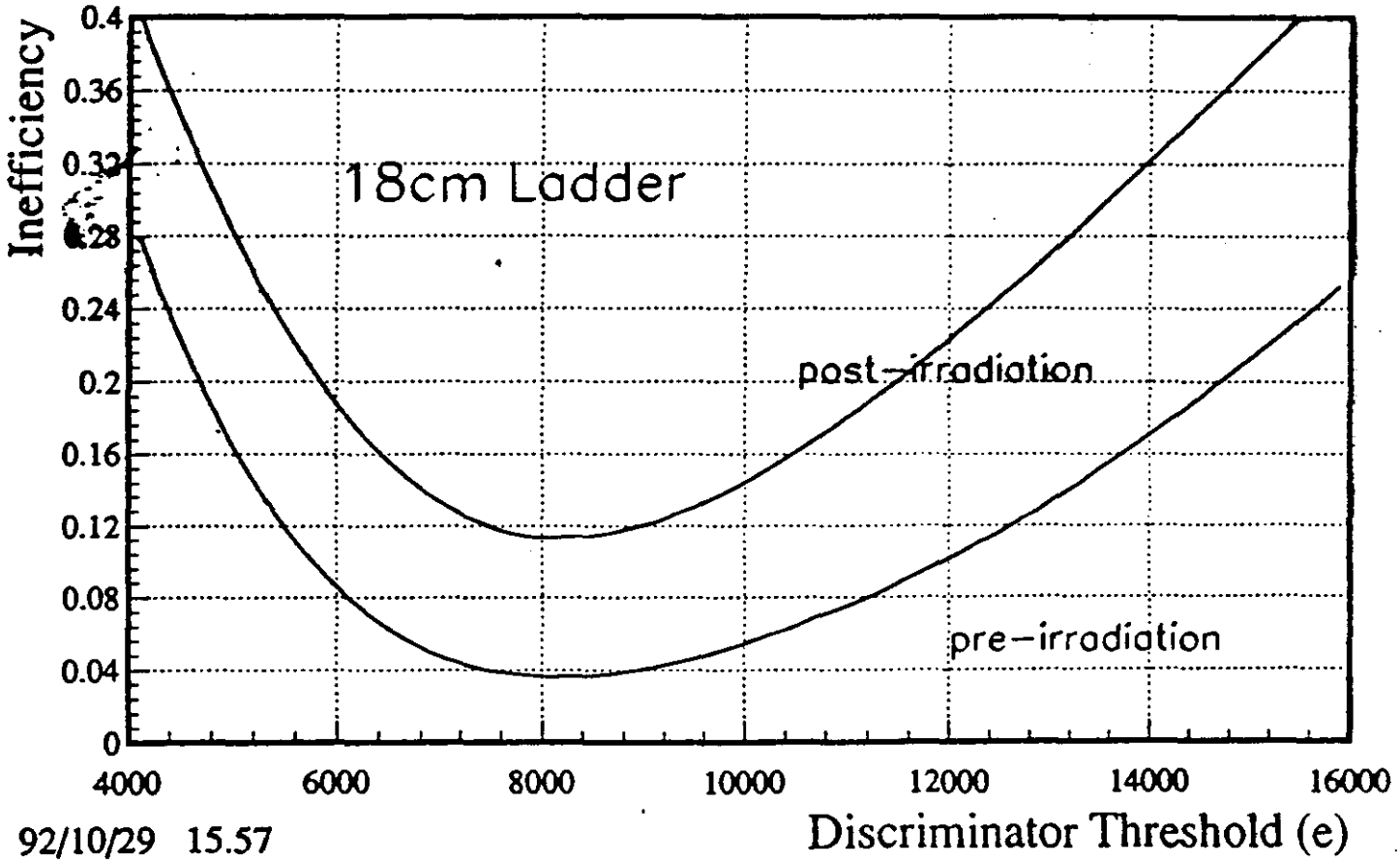




92/10/29 16.00

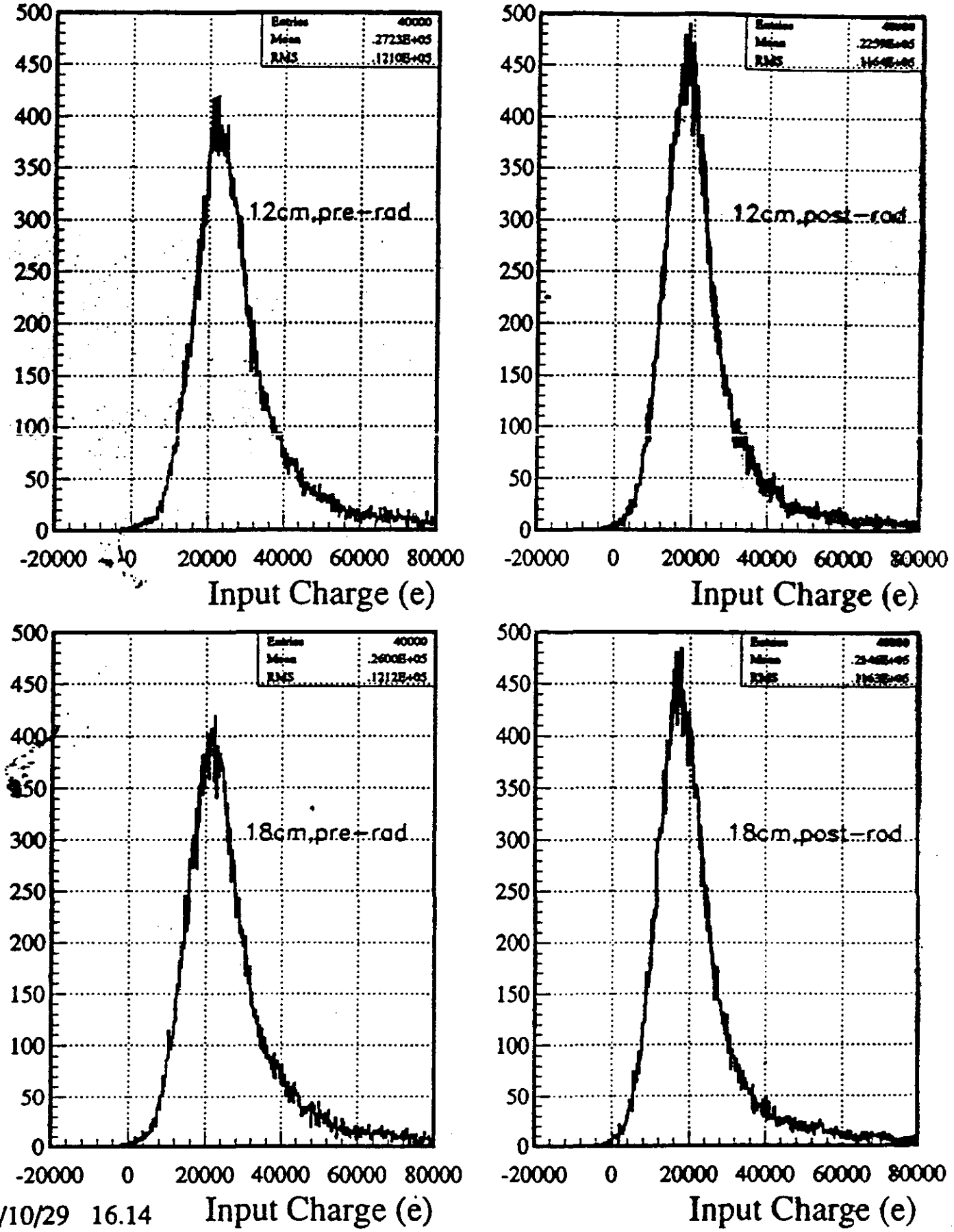
18cm BARREL





92/10/29 15.57

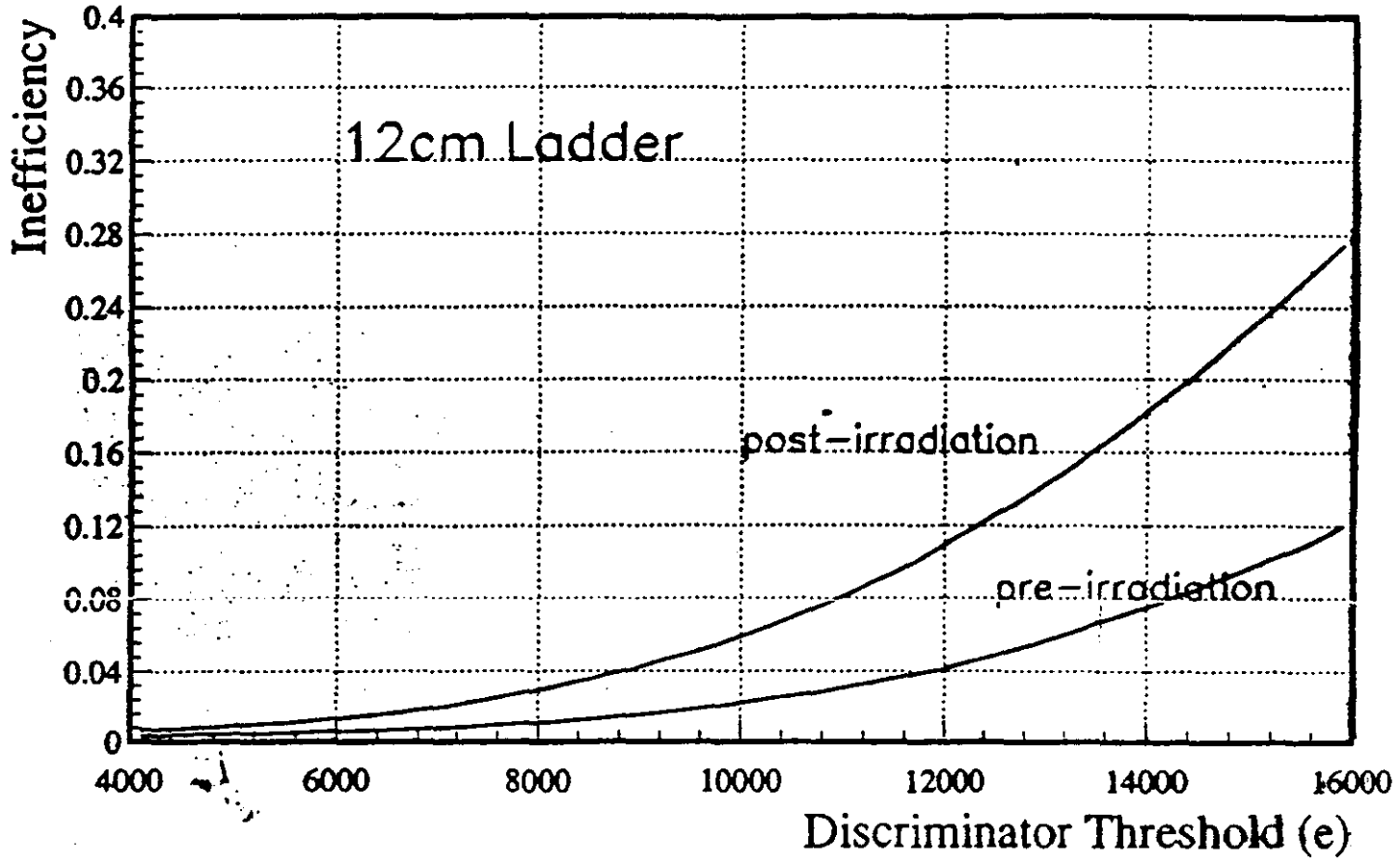
18cm BARREL + FORWARD

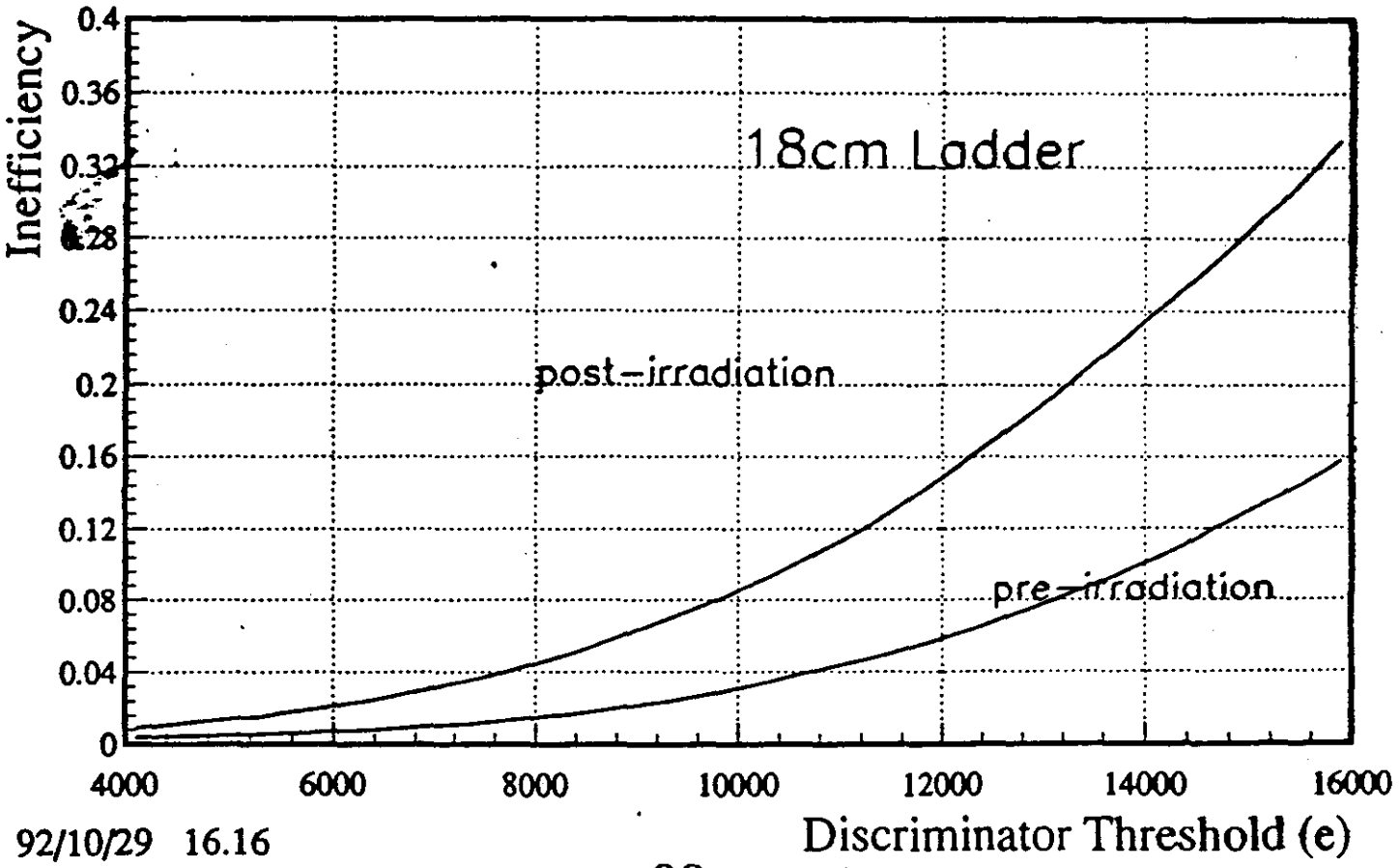


92/10/29 16.14

Signal Ineff. for Higgs+MB (1GeV P_t cut)

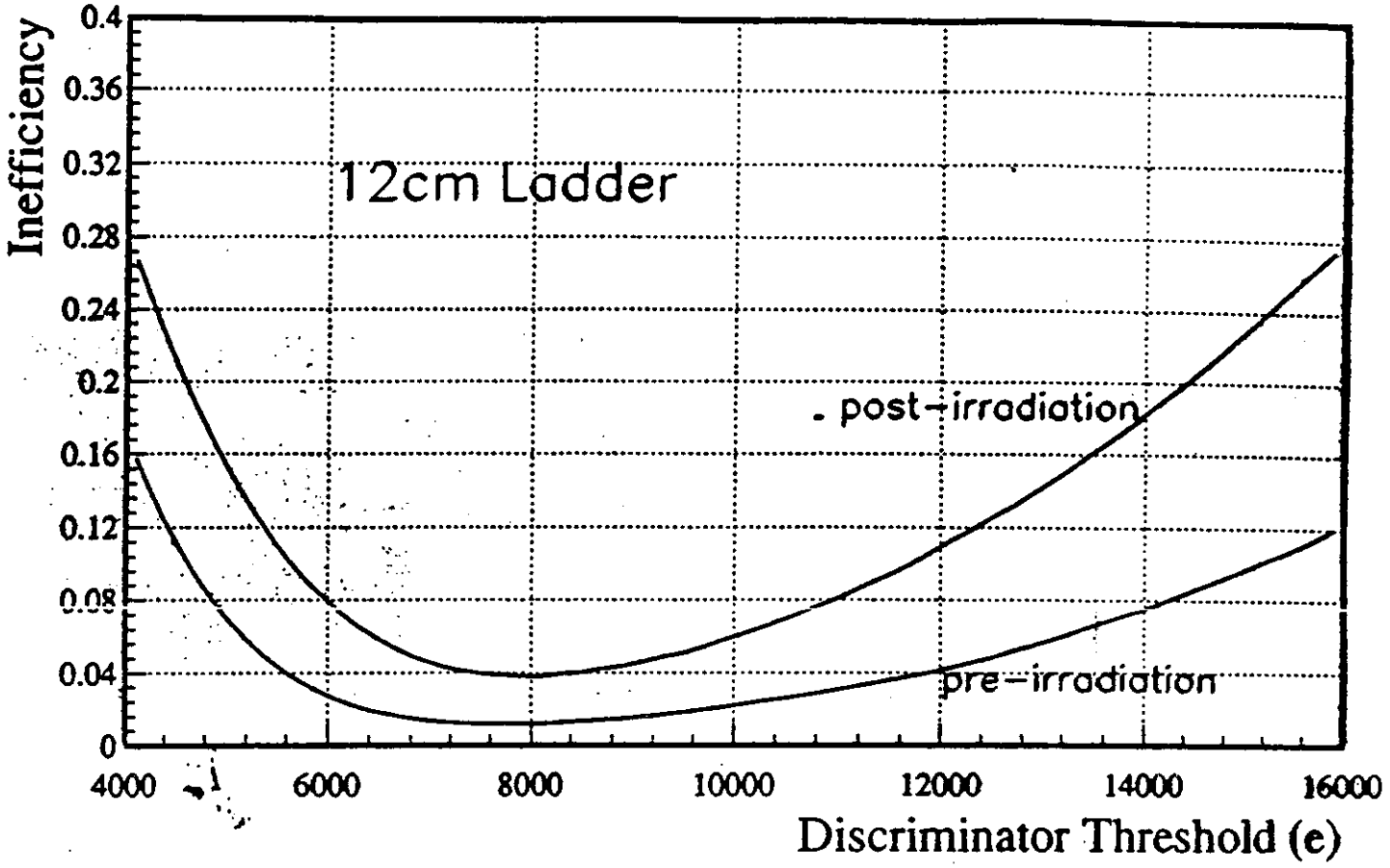
18cm BARREL + FORWARD

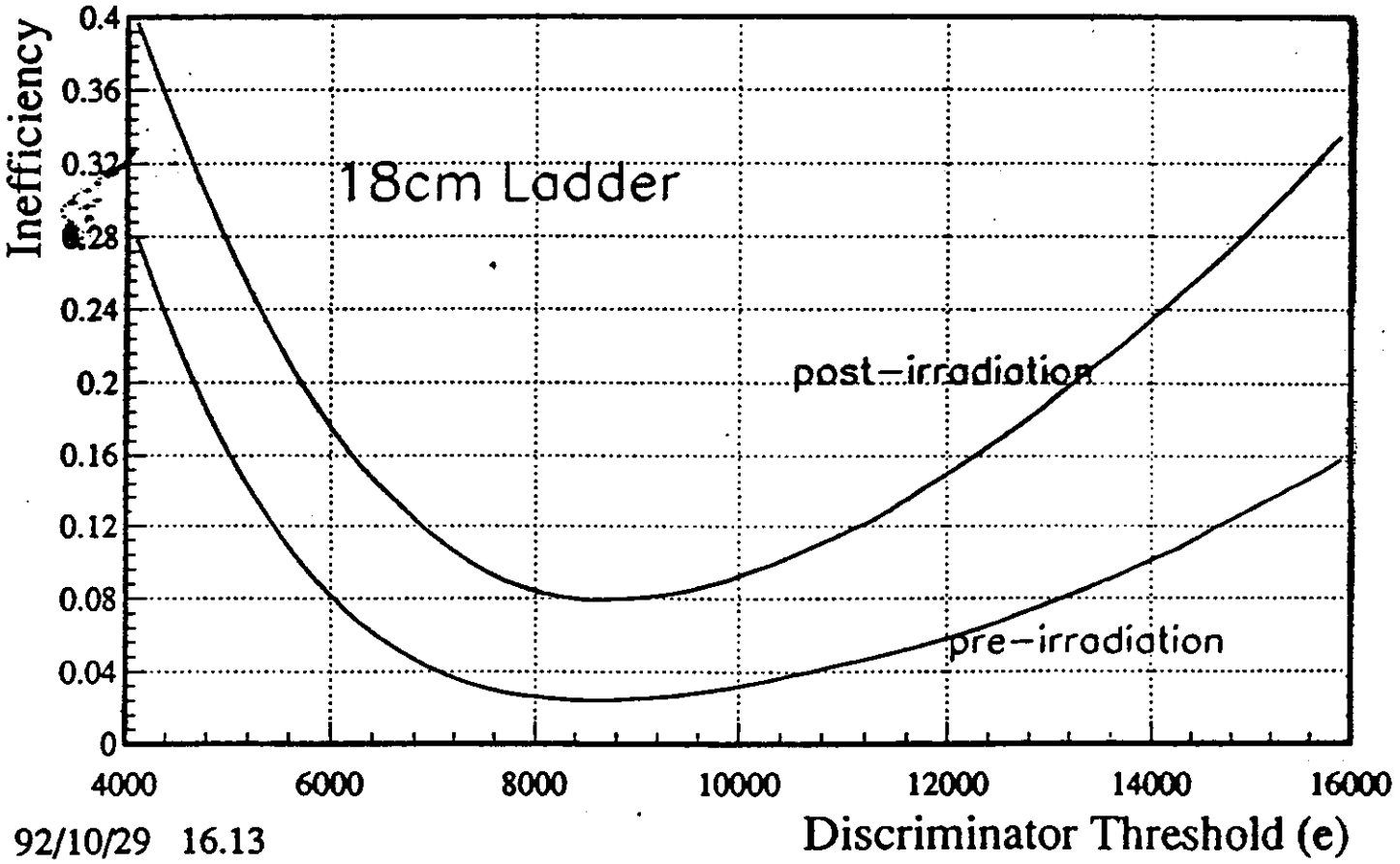




92/10/29 16.16

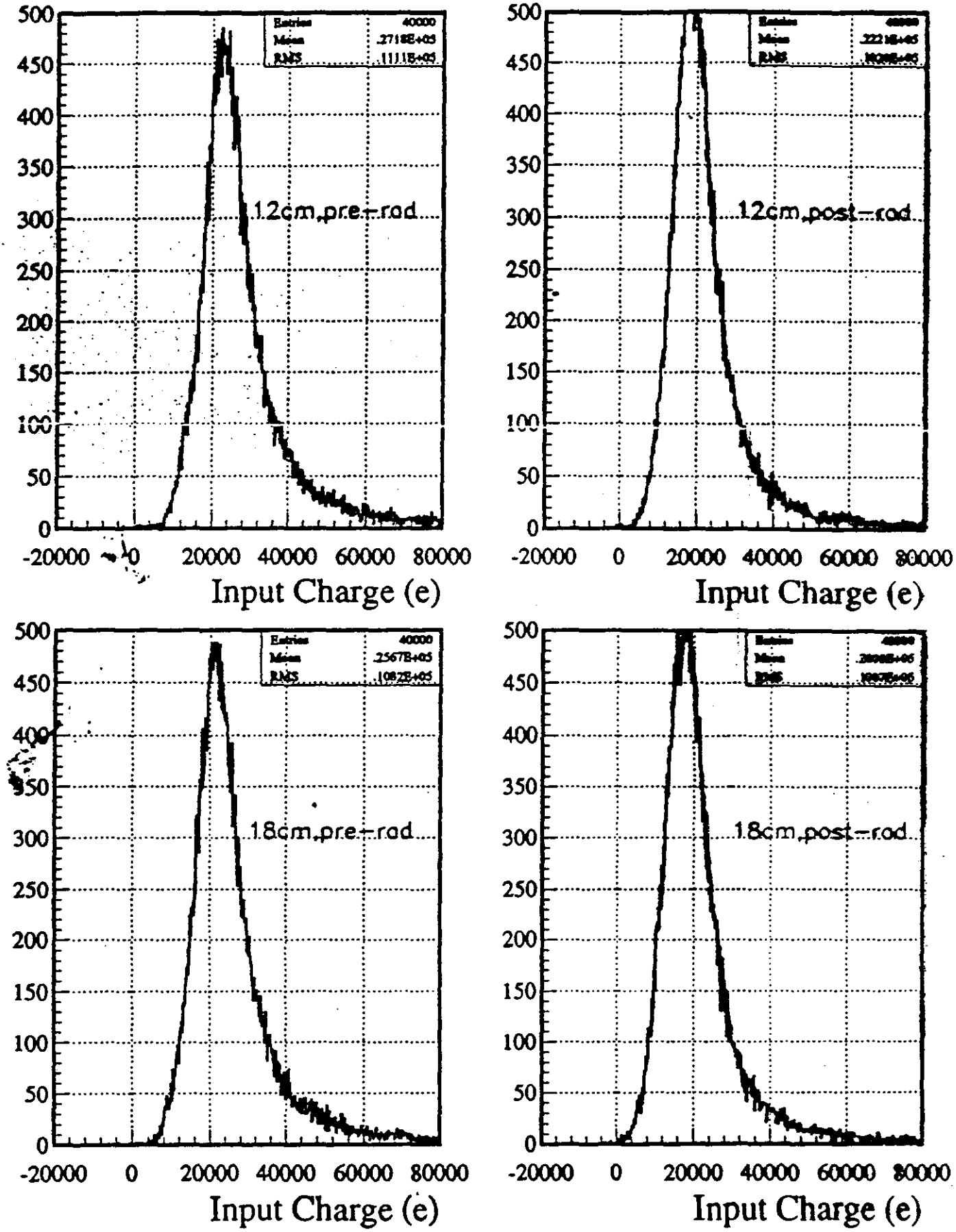
18cm BARREL + FORWARD



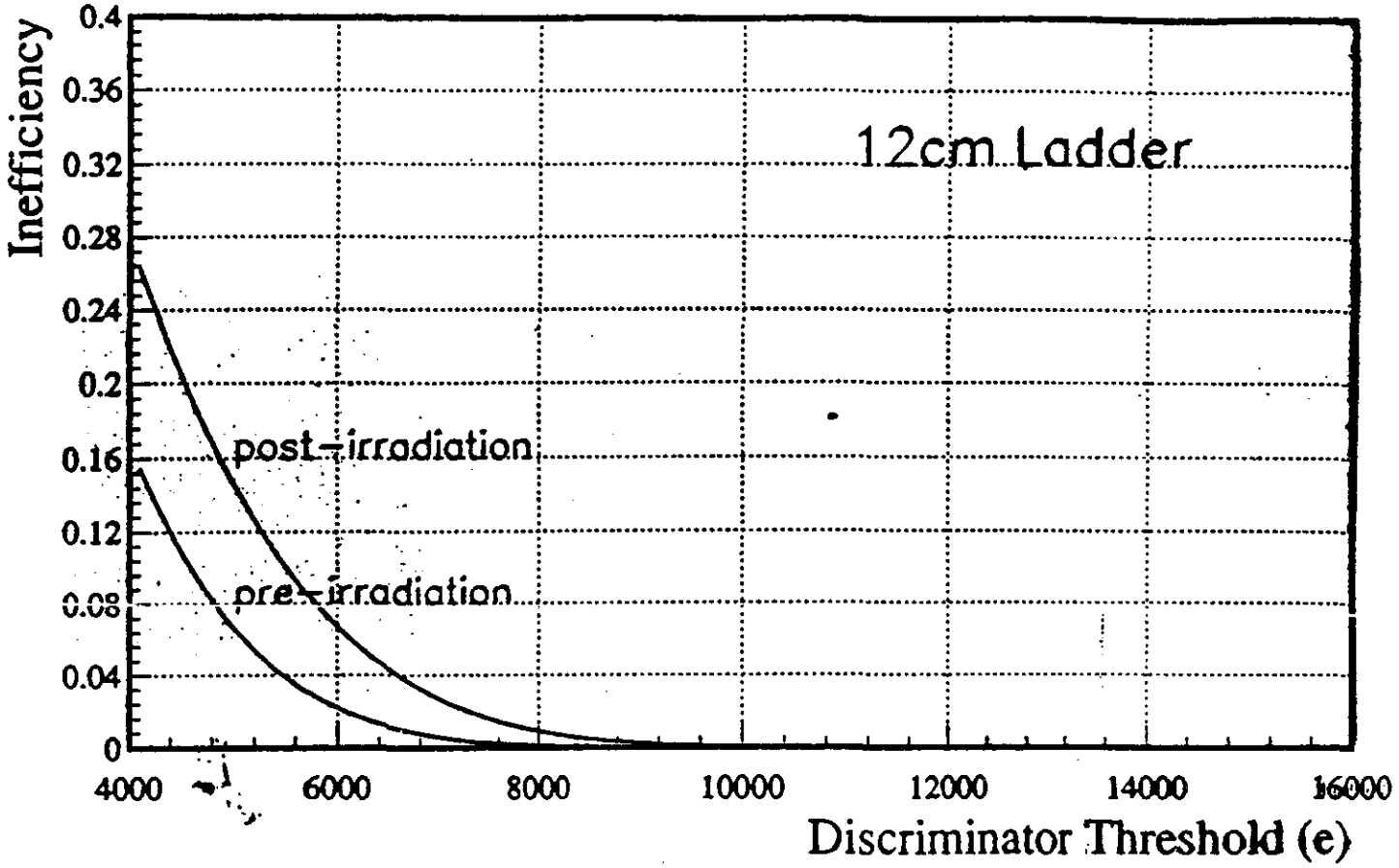


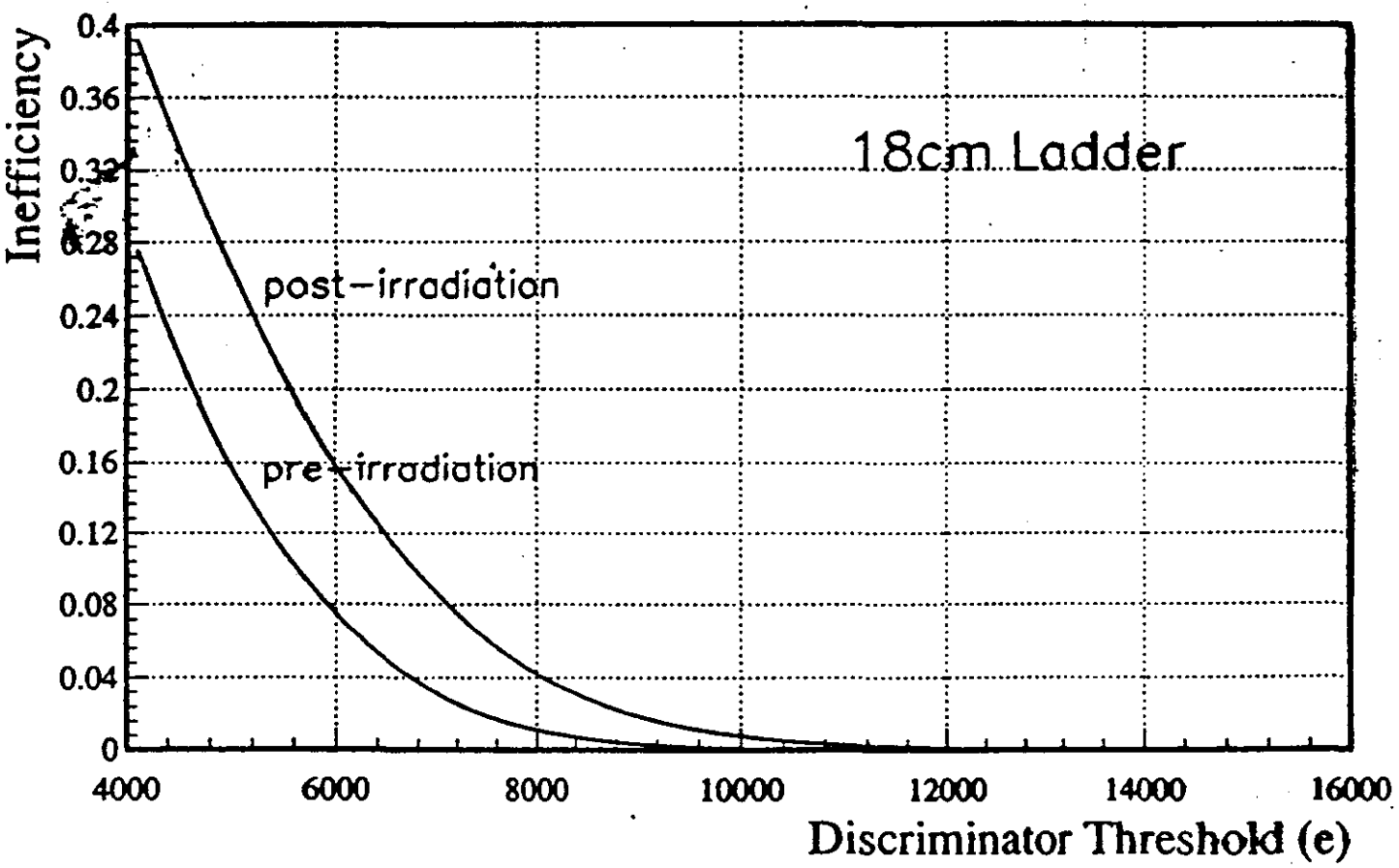
92/10/29 16.13

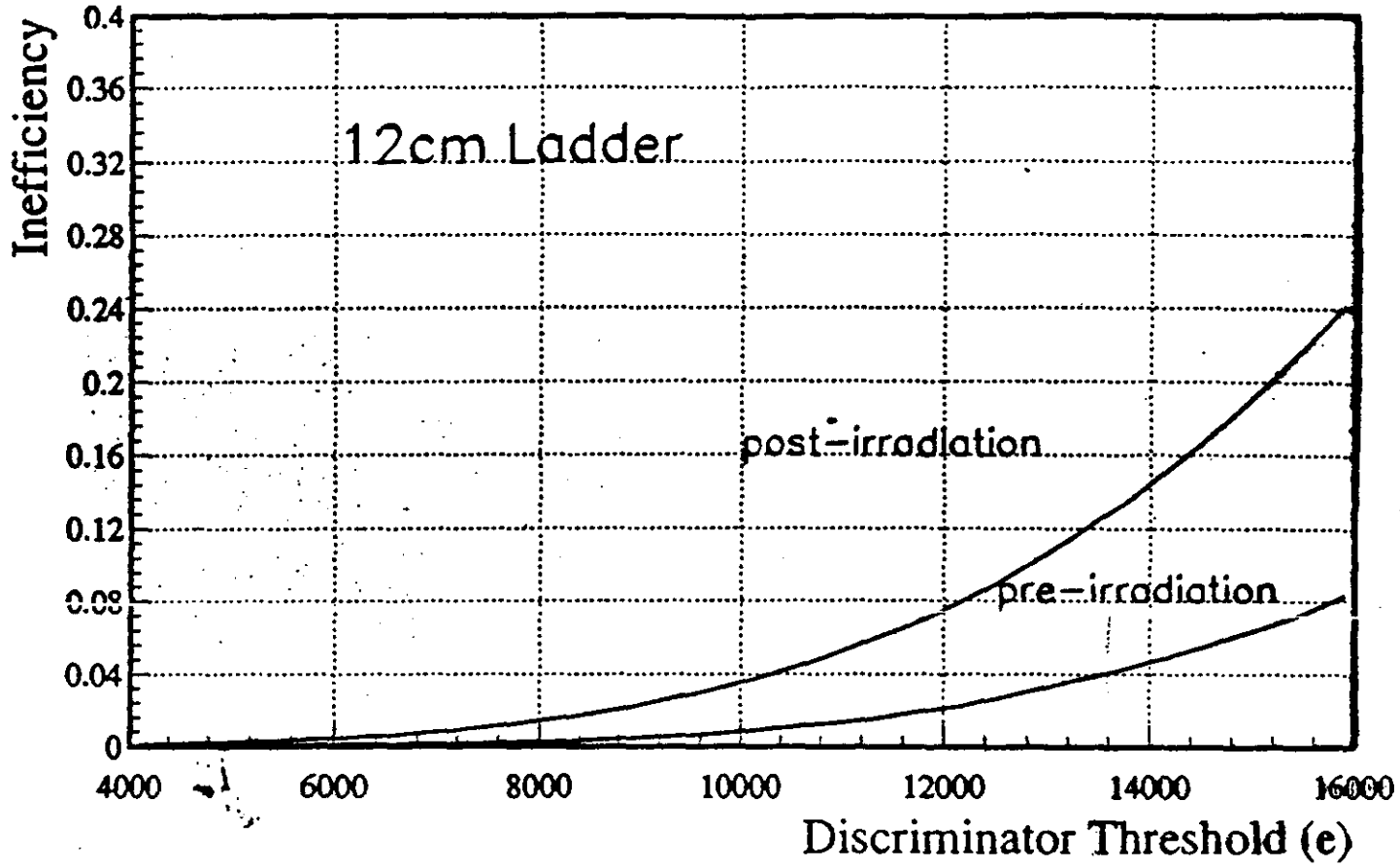
12cm BARREL + FORWARD

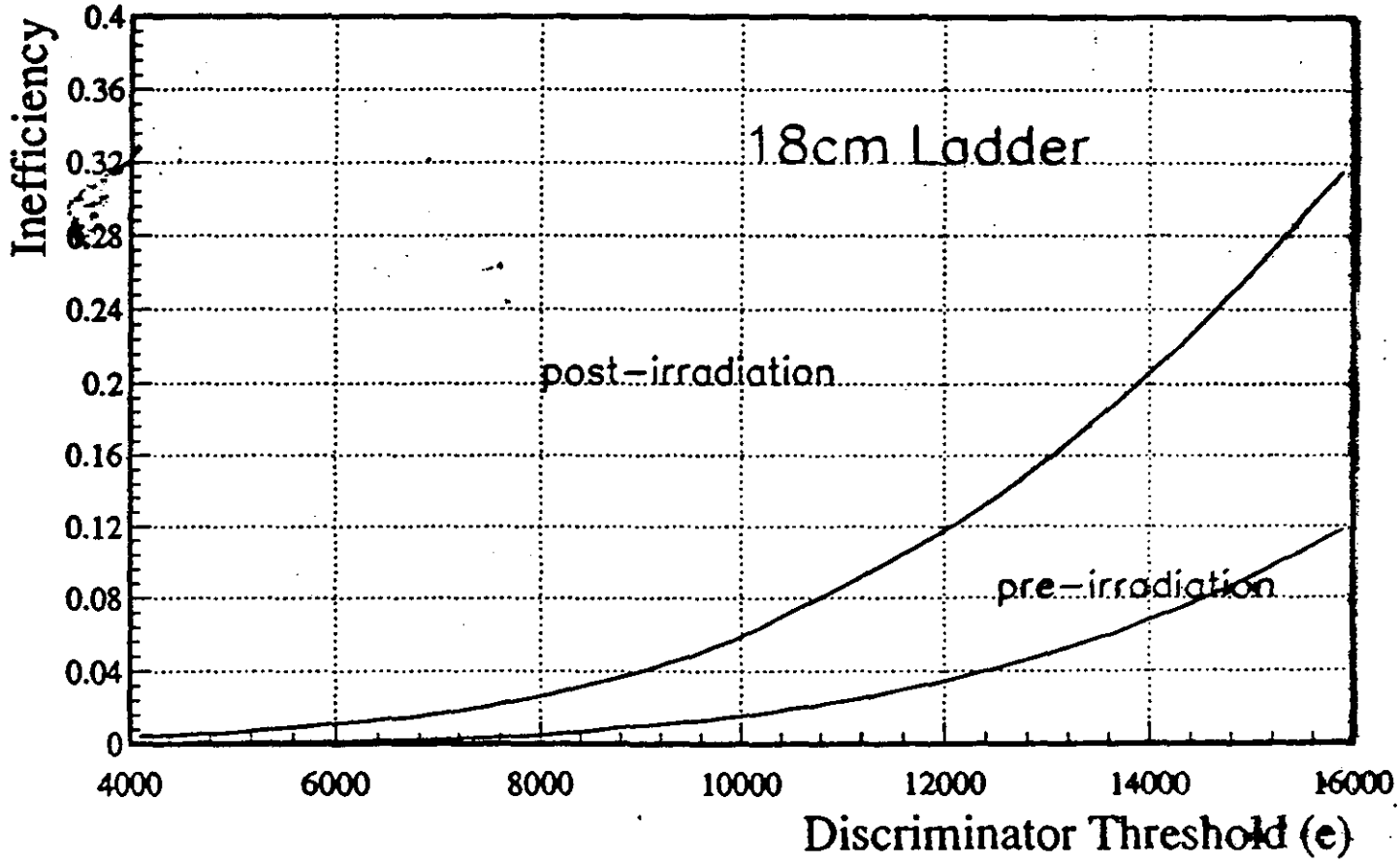


12cm BARREL + FORWARD

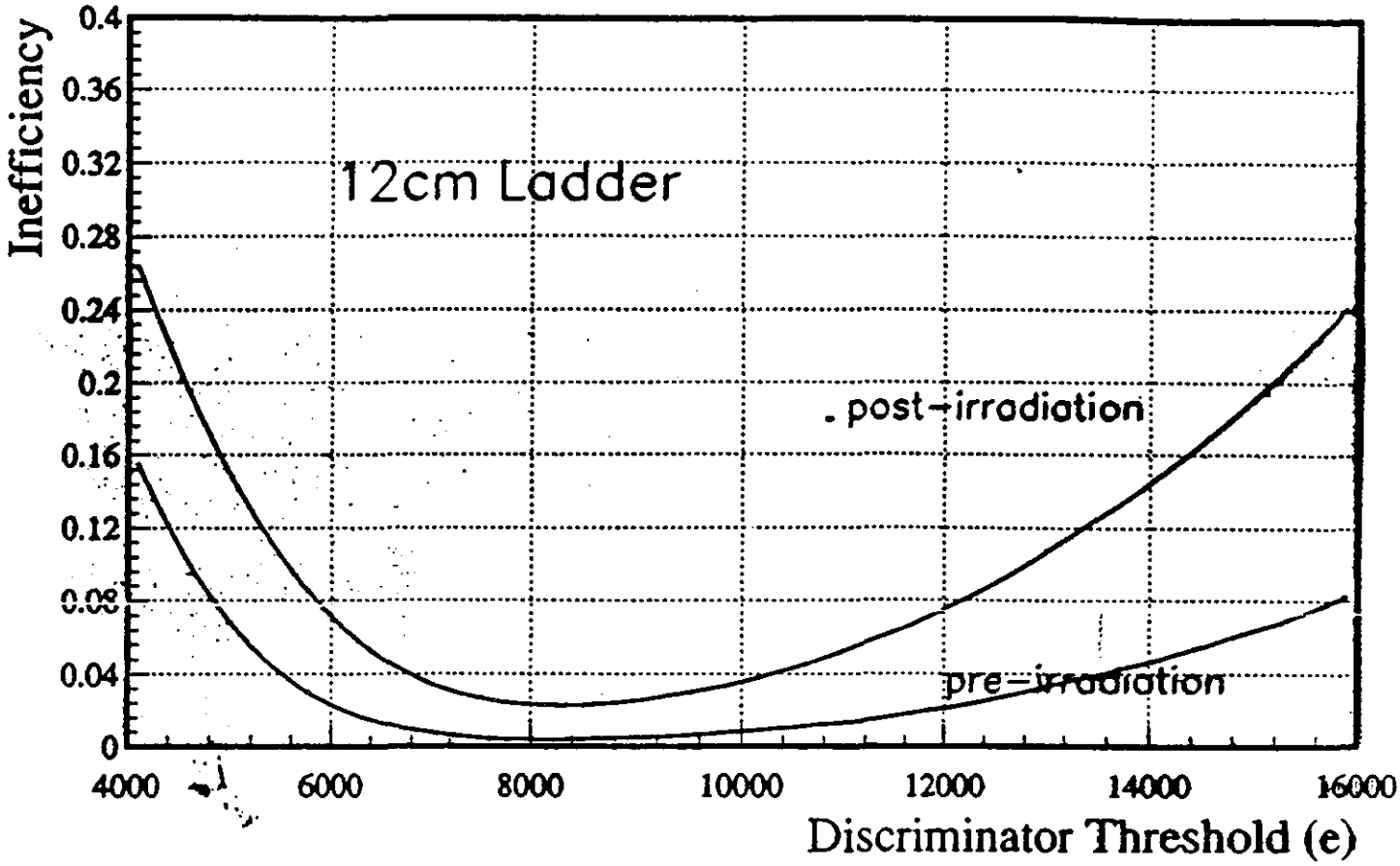


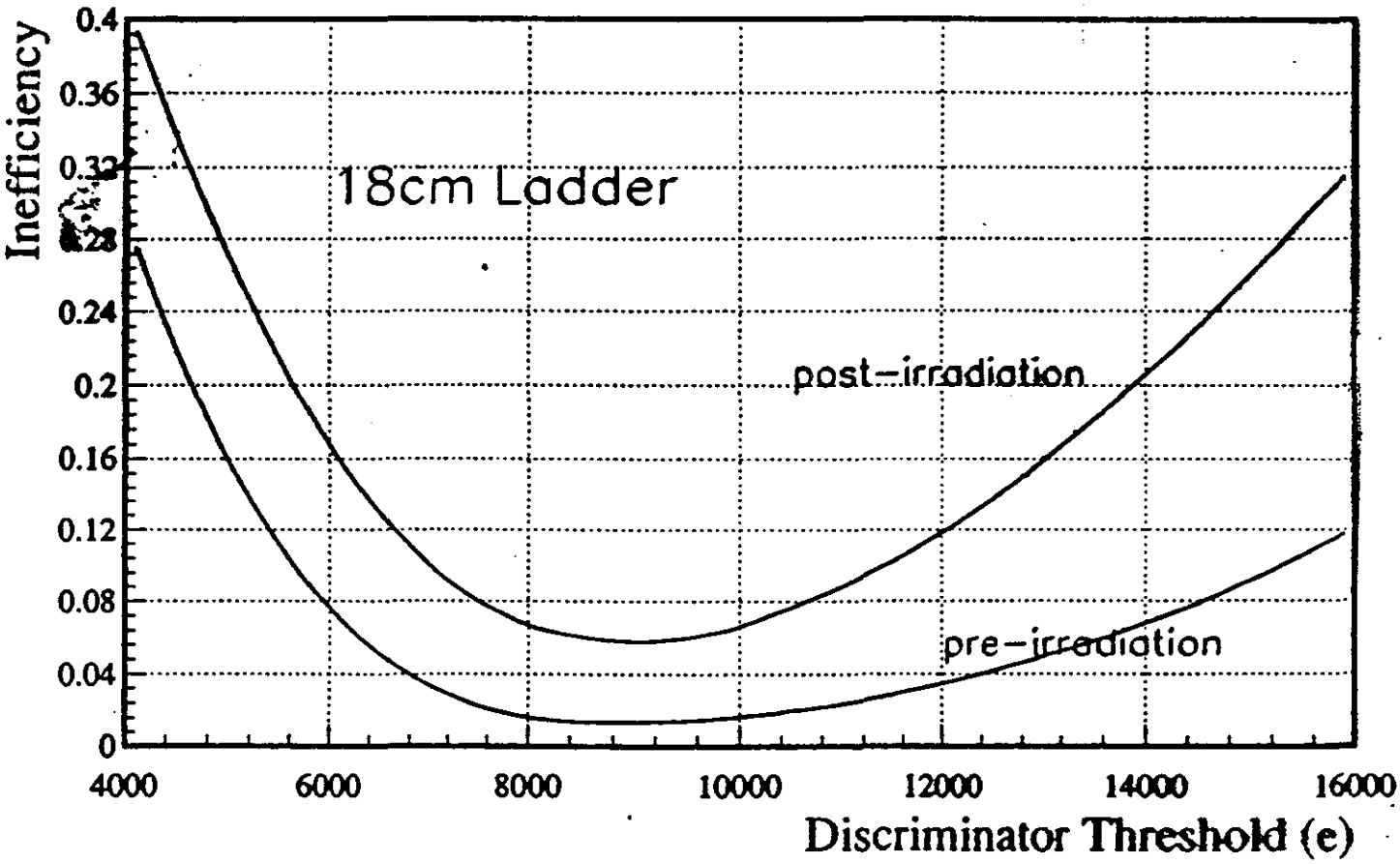


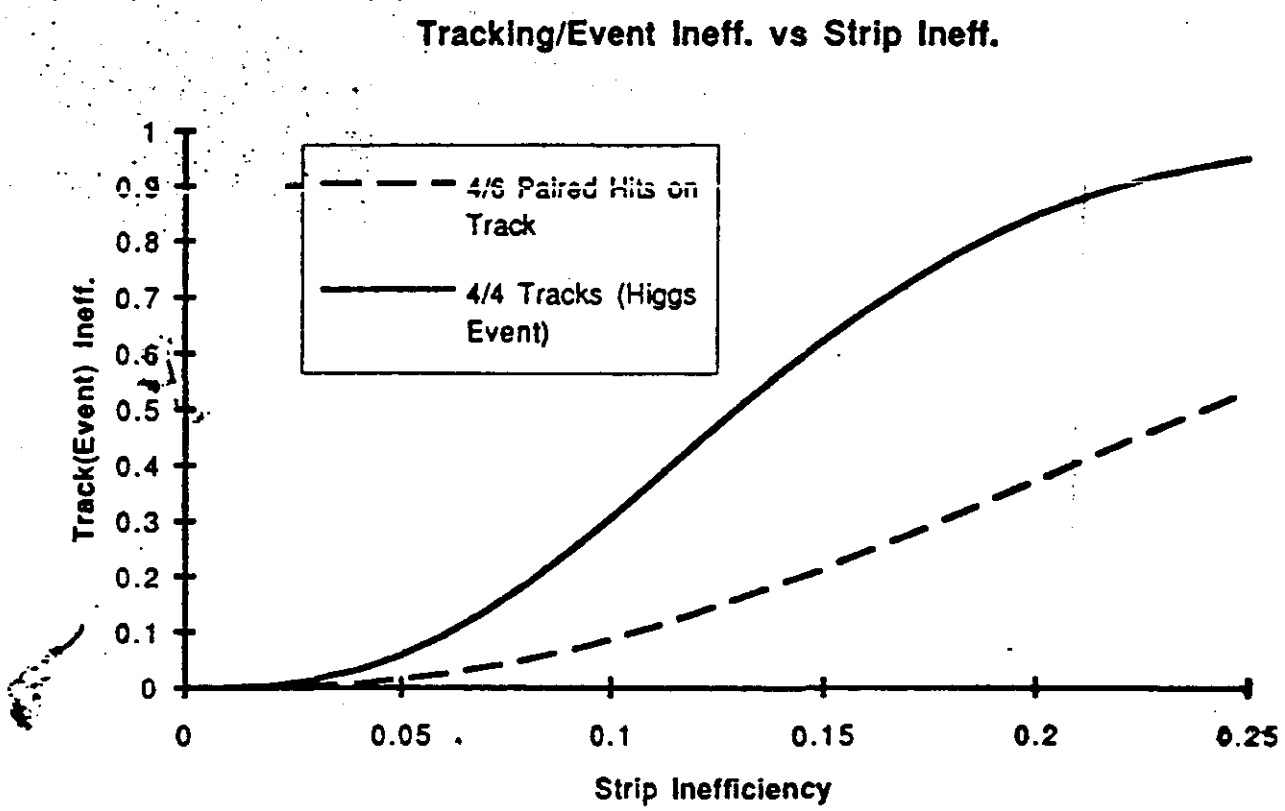

12cm Ladder
Inefficiency
0.4
0.36
0.32
0.28
0.24
0.2
0.16
0.12
0.08
0.04
0
post-irradiation
pre-irradiation
4000
6000
8000
10000
12000
14000
16000
Discriminator Threshold (e)


18cm Ladder
Inefficiency
0.4
0.36
0.32
0.28
0.24
0.2
0.16
0.12
0.08
0.04
0
post-irradiation
pre-irradiation
4000
6000
8000
10000
12000
14000
16000
Discriminator Threshold (e)

12cm BARREL + FORWARD






Tracking/Event Ineff. vs Strip Ineff.
4/6 Paired Hits on Track
4/4 Tracks (Higgs Event)
Track(Event) Ineff.
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.05
0.1
0.15
0.2
0.25
Strip Inefficiency

gem

γeμ

Presentation by:

S. Hahn

11-4-92
S. Hahn

Si-Tracker Electronics

MCM

GE/TI - High Density Interconnect
Sample layout started

CMOS

UTMC, Harris: device library installed
Architecture being settled
Subcircuits being simulated
LANL/SNLA/LSI Logic CRADA being w[illegible]ed on

Bipolar

Presentation at Yellowstone
Poster session at IEEE-NSS '92
AT&T contract to be signed (tile-array)
12 cm vs. 18 cm

12 cm vs. 18 cm

Cost

Less number of channels

Noise

Capacitance

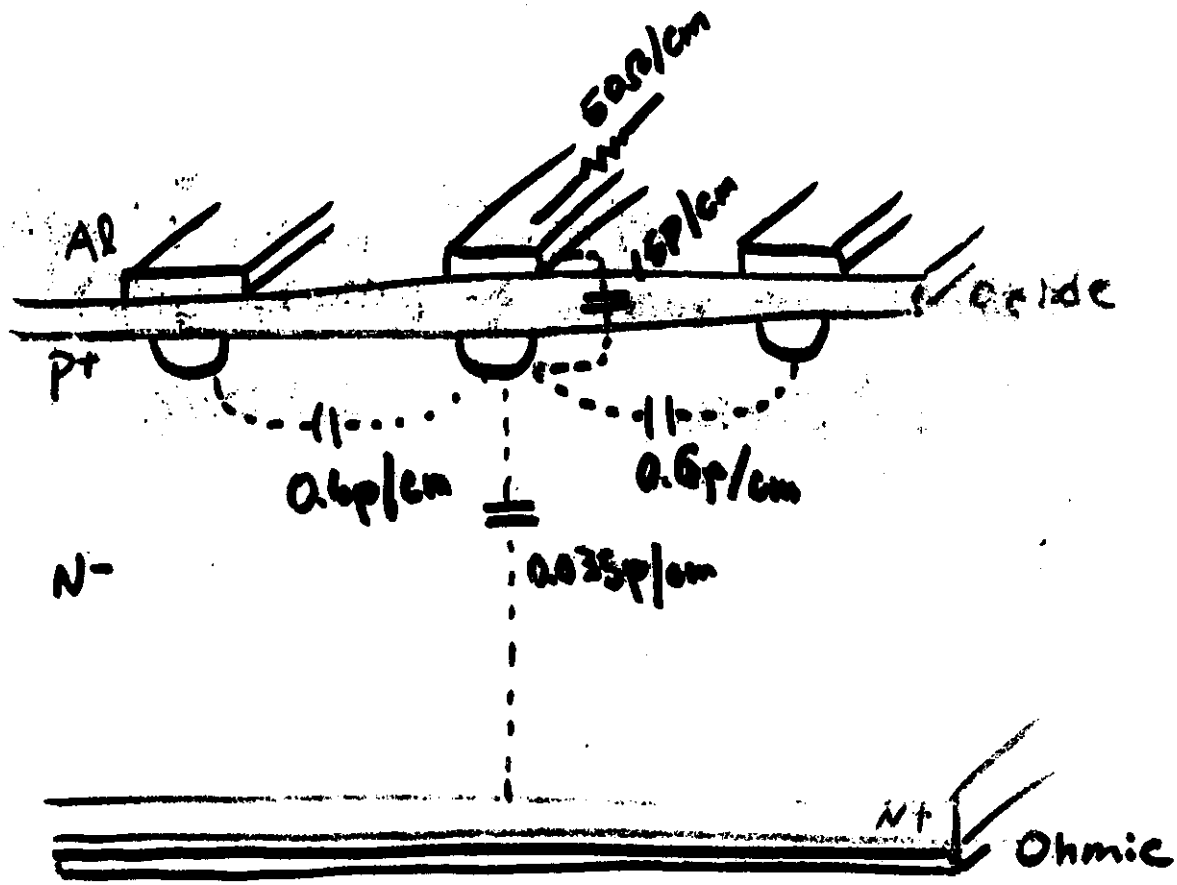
Metal strip resistance
(transmission-line effect)

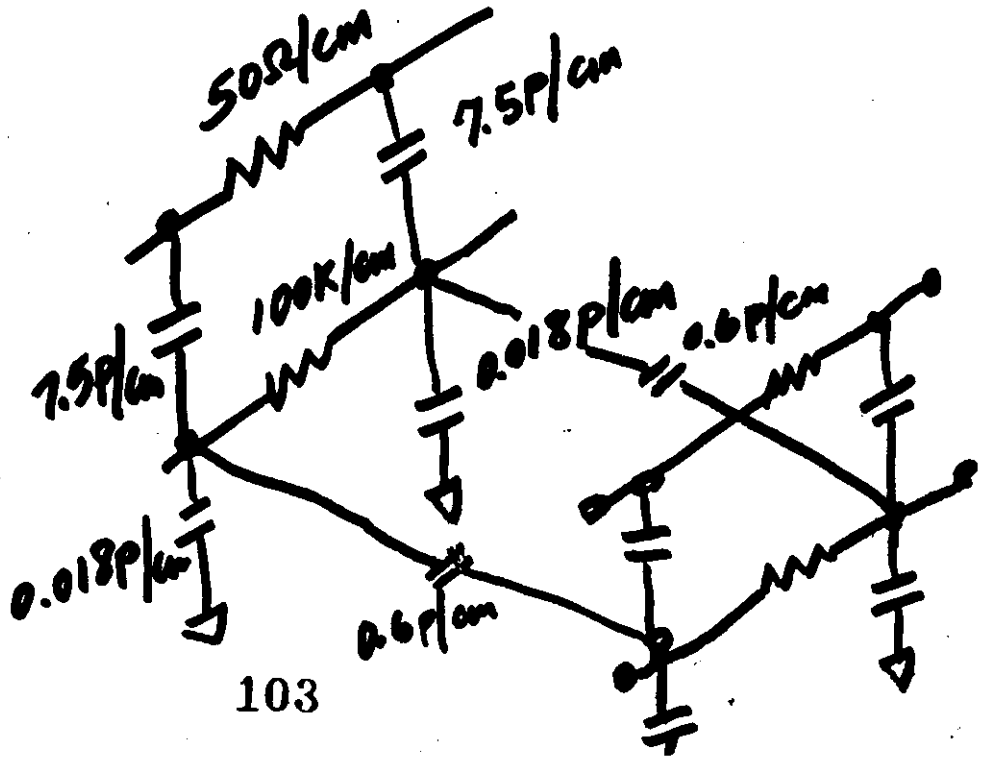
Charge-coupling

Realistic charge waveform

Time-walk

Pseudo Zero-crossing detection


50Ω/cm
Al
1pF/cm
oxide
P+
0.6pF/cm
0.6pF/cm
N-
0.035pF/cm
N+
Ohmic


50Ω/cm
7.5pF/cm
100K/cm
7.5pF/cm
0.018pF/cm
0.6pF/cm
0.018pF/cm
0.6pF/cm

"Equiv." Noise Charege (e^- RMS)*
(Degradation of signal amplitude)

	50Ω/cm	20Ω/cm
12cm	2184	1864
18cm	3378	2761

* Far-end injection

✓ $0.8\mu^T \times 10\mu^W \rightarrow 80\Omega/cm$

Custom Bipolar Integrated Circuit Designs for the Front-End Electronics of the Silicon Tracker Subsystem for SSC-GEM Detector

Sangkoo F. Hahn and Maureen M. Cafferty
Los Alamos National Laboratory, Los Alamos, NM 87545

Abstract

Extremely high radiation background (up to 5 MRad over a 10 year lifetime), a large number of channels (3.2 M), high speed, low noise requirements (1250 electrons RMS), and low power consumption (1 mW/channel), present a formidable challenge for front-end electronics of the Silicon Tracker subsystem for the SSC-GEM (Gamma, Electron, Muon) Detector. Simulation results from the bipolar designs for an analog integrated circuit to process charge inputs from silicon strip detectors are presented using AT&T and Harris transistor models.

I. Introduction

The decision was made earlier that a bipolar IC technology was to be used for the processing of the charge signals from the Si-strip detectors to meet the noise, speed and power requirements. The main function of the bipolar IC is to make an unambiguous logic decision of either hit or no-hit per every beam-crossing (with a period of 16 ns) for every channel based on the amount of charge collected from the strip detectors. Due to the low occupancy of less than 1%, the dead-time of the circuit operation between events can be as much as 150 ns. The design features and the major simulation results are described.

II. Design Features

The preamp uses the familiar cascode configuration with an input transistor geometry of three times the area of the minimum geometry transistors to reduce the noise from the base spread resistance. The feedback resistor and capacitor set the shaping time of 30 ns. The feedback resistor is made as large as possible for minimum noise contribution while remaining small enough to maintain reasonably constant bias conditions, which are sensitive to transistor gain changes, over the lifetime of the system.

The intermediate amplifier is a minimum component stage which is very sensitive to the bias level at the base of Q22. The resistors, R5 and R6 are adjusted for maximum possible gain without pushing Q22 into saturation. This maximizes the signal to noise ratio from this stage (Figure 1).

The shaper/baseline restorer stage has a closed loop gain of about eight, for the signal, with a signal swing of about 40 mV for a 6000 electron input charge. The baseline restoration circuit causes some noise degradation but has a crucial role of stabilizing the DC bias level of the input node to the comparator. Without the restoration, the drift of the DC level would present a serious control problem to the circuit operation (Figure 2). The comparator design is straightforward with a differential-pair input stage followed by current-mirror amplifiers for current output (Figure 3).

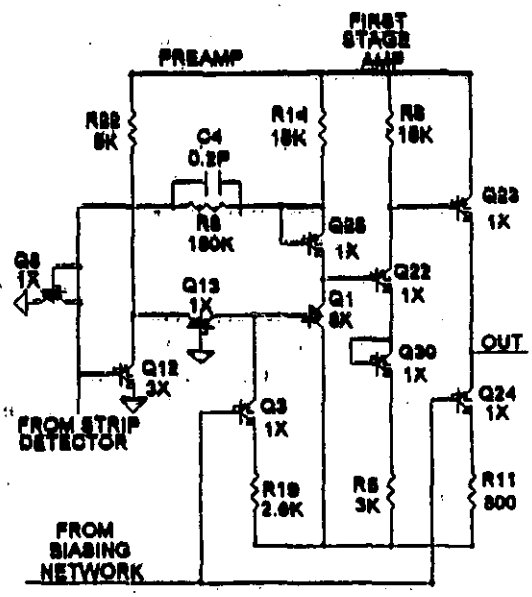


Fig. 1 Preamp & Intermediate-stage amplifier

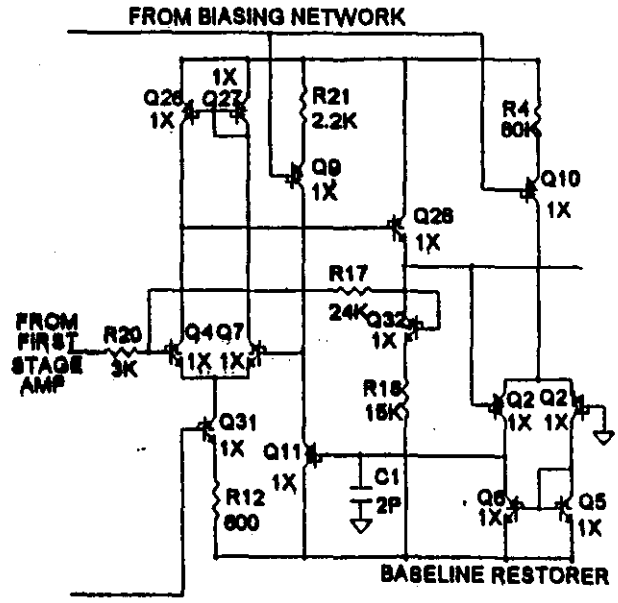


Fig. 2 Shaper\Amplifier

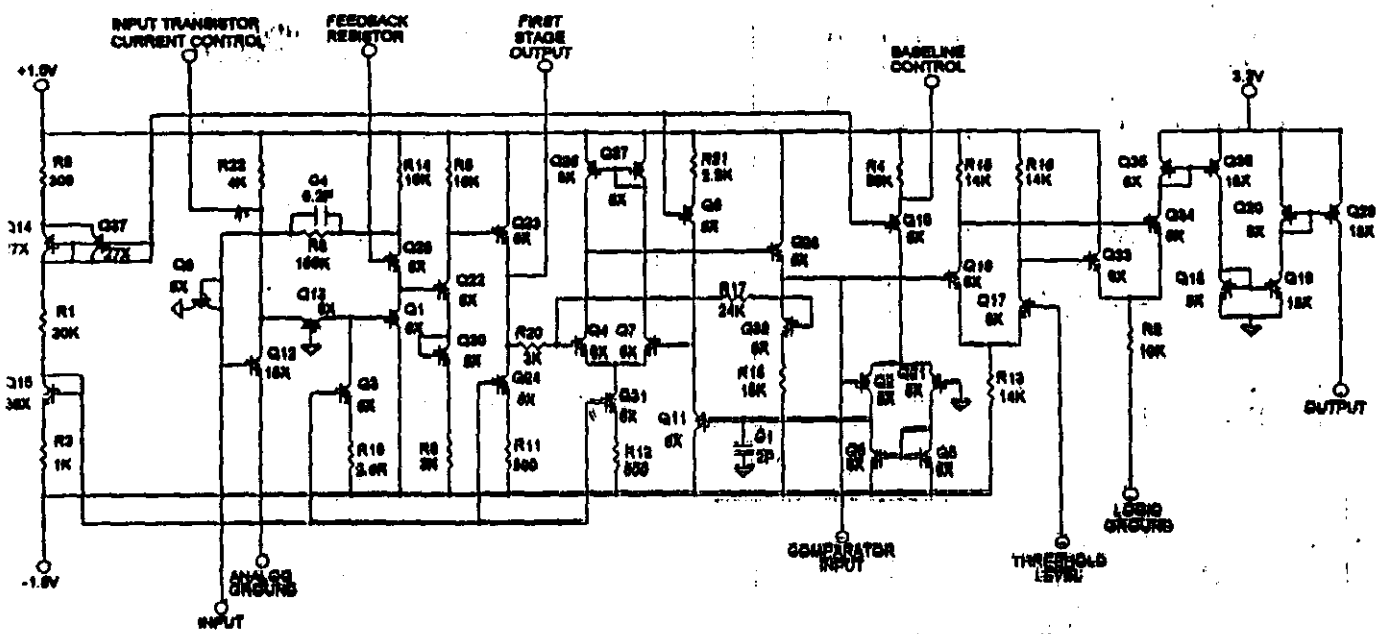


Fig. 3 Schematic for semi-custom layout utilizing the AT&T ALA110 tile array

III. Simulation Results

A. AT&T Tile Array ALA110

Simulations were performed using models from the AT&T CBIC-V process. A design based on the ALA110 tile array models will be submitted to AT&T for semi-custom fabrication, and the chip will be tested when available. The schematic and the pinouts are shown in Figure 3. The tile array is for small-scale applications and contains minimum area geometry transistors of 32.5 x 47.5 μm which are too large for the final design. The final design will be based on smaller geometry transistors.

Simulation results using MicroSim's PSPICE were obtained for charge inputs from 6000 electrons to 48000 electrons. The current source simulating the waveform out of a 300 μm thick PIN diode [1] is shown in Figure 4.

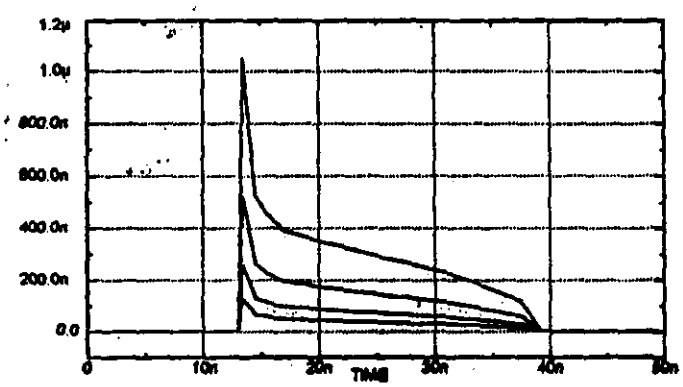


Figure 4

Simulations were run for strip lengths of 6 cm, 12 cm, and 18 cm with nominal transistor current gains for beginning of life and low current gains for assumed end of life performances. The strip detector was simulated using lumped elements with three strips and three amplifiers in parallel as shown in Figure 5 [2] to reflect coupling effects between adjacent channels.

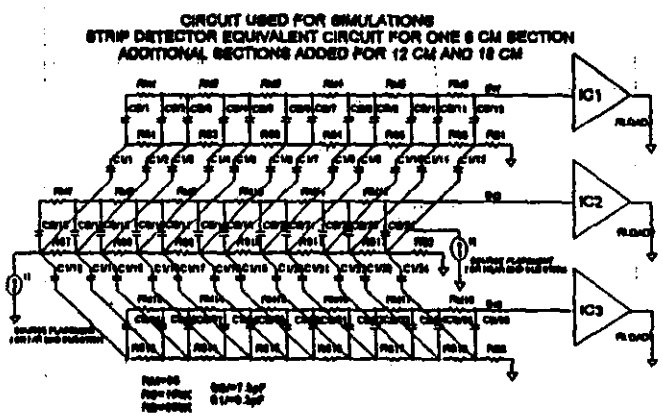


Figure 5

Simulation results between using AT&T subcircuit models for the resistors and capacitors and using ideal resistors and capacitors were virtually identical, but the noise performance was about 8% worse for the subcircuit resistors and capacitors. The simulation times for three amplifiers utilizing all subcircuit models were much longer than practical, therefore, ideal resistors and capacitors were used in all subsequent results.

Typical signals at the input of the comparator for 12 cm strip length, near end injection are shown in Figure 6 while the comparator outputs are shown in Figure 7. Note that the time-walk is measured at the falling edge of the comparator output waveform to take advantage of the pseudo zero-crossing time pick-off effect.

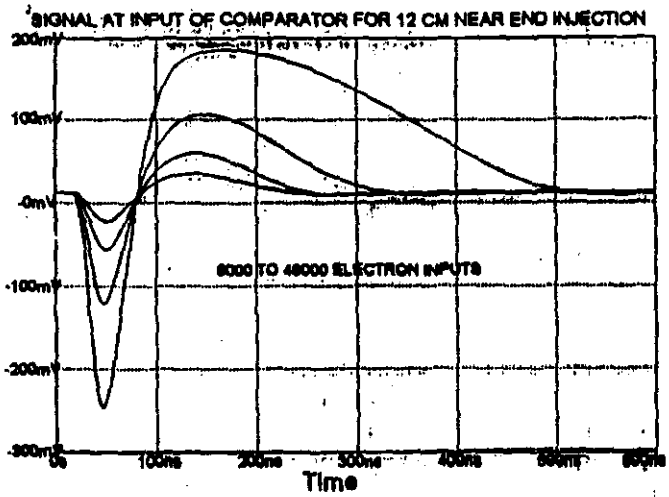


Figure 6

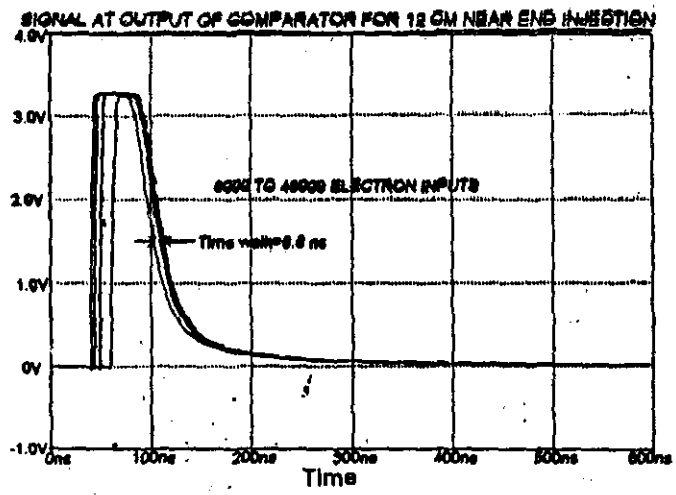


Figure 7

The simulation results are summed up in Table 1 for beginning of lifetime and end of lifetime. Small signal amplitude, time walk, and noise results are shown for 6 cm, 12 cm, and 18 cm detector strip lengths. The amplitude was measured for the 6000 electron input. Time walk was measured for 6000 to 48000 electron inputs with a comparator threshold level set to 60% of the small signal swing for each detector strip length. The noise was calculated at the input to the comparator.

B. Harris UHF

Simulations were also performed using models for Harris UHF small geometry transistors for 12 cm and 18 cm detector strip lengths.

The noise for the 12 cm far-end was 2540 electrons and 2210 electrons for the near-end. The time walk was 13.7 ns for the far-end and 10.2 ns for the near-end with the threshold level equal to 5000 electrons (no 6000 electron trigger).

The noise for the 18 cm far-end was 3550 electrons and 2710 electrons for the near-end. The time walk was 9.1 ns for the far-end (no 6000 or 12000 electron trigger) and 9.0 ns (no 6000 electron trigger) with the threshold level equal to 6250 electrons.

BEGINNING OF LIFETIME

(transistor current gain approx. 110, baseline=13.7 mV)

	FAR END INJECTION				
	AMPLITUDE (mV)	TIME WALK (ns)	THRESHOLD LEVEL (mV)	INTEGRATED NOISE (mV)	NOISE (electrons RMS)
6 CM	26.5	7.5	-9.4	7.8	1216
12 CM	31.6	12.8	-9.8	11.8	2184
18 CM	35.4	21.0	-9.5	14.5	3379
	NEAR END INJECTION				
	AMPLITUDE (mV)	TIME WALK (ns)	THRESHOLD LEVEL (mV)	INTEGRATED NOISE (mV)	NOISE (electrons RMS)
6 CM	26.5	6.6	-9.4	7.8	1212
12 CM	34.3	9.6	-9.8	11.8	2012
18 CM	31.8	11.8	-9.5	14.3	2890

END OF LIFETIME

(transistor current gain approx. 45, baseline=28.8 mV)

	FAR END INJECTION				
	AMPLITUDE (mV)	TIME WALK (ns)	THRESHOLD LEVEL (mV)	INTEGRATED NOISE (mV)	NOISE (electrons RMS)
6 CM	20.3	7.3	11.6	8.4	1367
12 CM	22.4	11.3	14.2	8.3	2223
18 CM	19.2	19.6	16.4	9.8	3231
	NEAR END INJECTION				
	AMPLITUDE (mV)	TIME WALK (ns)	THRESHOLD LEVEL (mV)	INTEGRATED NOISE (mV)	NOISE (electrons RMS)
6 CM	26.4	7.1	11.6	8.4	1362
12 CM	24.1	9.6	14.2	8.3	2066
18 CM	22.0	11.4	16.4	9.8	2873

Table 1

IV. CONCLUSION

A preliminary design for the front-end electronics for the Silicon Tracker subsystem for the SSC-GEM (Gamma, Electron, Muon) Detector has been simulated and will be submitted to AT&T for semi-custom fabrication.

The results show excellent beginning-of-life performance and acceptable end-of life performance (10 year lifetime, 5 MRad total dose) for required time walk (<16 ns), with the given power (1 mW) for a 12 cm detector strip length, but clearly degraded performance at 18 cm lengths.

V. REFERENCES

[1] W.C. Sailor, H.-J. Ziock, W.W. Kinnison, K. Holzcheiter, "A Model for the Performance of Silicon Microstrip Detectors", *Nuclear Instruments and Methods in Physics Research*, A303 (1991) pp. 285-297

[2] Issy Kipnis "Analog Front-End Electronics for the SDC Silicon Tracker", Workshop on Front-End Electronics for Silicon Detectors at Future High Luminosity Colliders, Yellowstone National Park, Wyoming, 17 September 1992

Study of Pad Chamber Performance

Study of Pad Chamber Perforance

Yen-Chu Chen[1,2], *Melin Huang*[1], *Alexei Sumarokov*[1]

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[2] *Department of Physics, National Cheng-Kung University, Tainan, Taiwan 70101, R.O.C.*

Abstract

A simplified pad chamber geometry with a width 2.5 mm along the anode wire direction is used to study the pad chamber performance. From this study it is found that 40 μm hit position resolution and 1.8 c/TeV momentum resolution are achievable when signal over noise ratio is 200 and with $10^{34} cm^{-2} sec^{-1}$ luminosity.

Appendix 3.1

Study of Pad Chamber Performance

Alexei Sumarokov[1], Yen-Chu Chen[1,2], Melin Huang[1]

[1] *Institude of Physics, Academia Sinica, Taipei, Taiwan, 11529, R.O.C.*
[2] *Department of Physics, National Cheng Kung University, Tainan, Taiwan, 70101, R.O.C.*

We employ a simple geometry to study the pad chamber performance so as to investigate the dependence of hit position resolution on Signal/Noise ratio and the two-track resolution. After simulating, we found that the hit position resolution can reach 50 μm when Signal/Noise ratio is about 300 and the two-track resolution can be as good as about 0.5 cm , the size of one pad.

Considering two tracks passing through the pad chamber, we use two ways to obtaine hit positions. The first one is the center of gravity with SIN correction and the second one is non-linear fit. The center of gravity is a very efficient way to obtain hit position. However, there is a systematic error one need to take care, that is, the hit position calculated by the center of gravity is different from the real hit position systematicaly. If the track hits at the edge or at the center of one pad, the difference is close to zero; but when the track hits at the 1/4 of 3/4 of one pad width, the difference is largest. The shap of this difference versus hit position looks like a sine wave. In using the center of gravity, one thus should calculate the SIN correction first and use these data to correct the value calculated by the center of gravity. The 50 μm accuracy was achieved at Signal/Noise about 300. Here, we used Gaussian distribution to simulate the noise. Fig.(1a) and Fig.(1b) are the resolutions of two tracks calculated from the center of gravity with SIN correction. The second one, non-linear fit, is the fit of four parameters, 2 x0 and 2 qt, where x0 and qt are the hit position and the total induced charge of one track respectively. After non-linear fit, the resolutions are shown in Fig.(2a) and Fig.(2b) respectivly. As shown in these plots, the track resolution is greatly improved from about 130 μm to 60 μm after non-linear fit is applied.

With the fit, we next calculate the R.M.S. and FWHM of the track resolution in several delta x bins. Each bin is the same size as half pad. The result is shown in Fig.3, where star sign(*) and circle sign(o) represent R.M.S. and FWHM respectively. When the two-track distance(dx) is greater than 1.25 cm, the resolution is as good as about 50 um. However, it is getting worse when dx is below 1.25 cm and is higher than 200 um when dx is less than 0.5 cm.

We finally turn into the study of efficiency. Ten thousand events were thrown uniformly with respect to two-track distance as shown in Fig.(4a). After reconstruction, about eight thousand events survived and the distribution with respect to dx is shown in Fig.(4b). From Fig.(4b), one can see that the efficiency is close to 100 % when dx is greater than about 1.5 cm and the efficiency is down to 50 % when dx is about 0.5 cm.

From the current study, we would say that the track resolution can be 50 μm at Signal/Noise ratio about 300 and the two-track resolution is about 0.5 cm with 50 % efficiency. We still try to develop another algorithm to improve the two-track resolution.

0.1. A simple geometry

- 4 cylinders each with radius 38.988, 48.401, 56.960 and 66.378 cm respectively.

  Each cylinder is a superlayer of two pad chambers seperated by 2 cm.

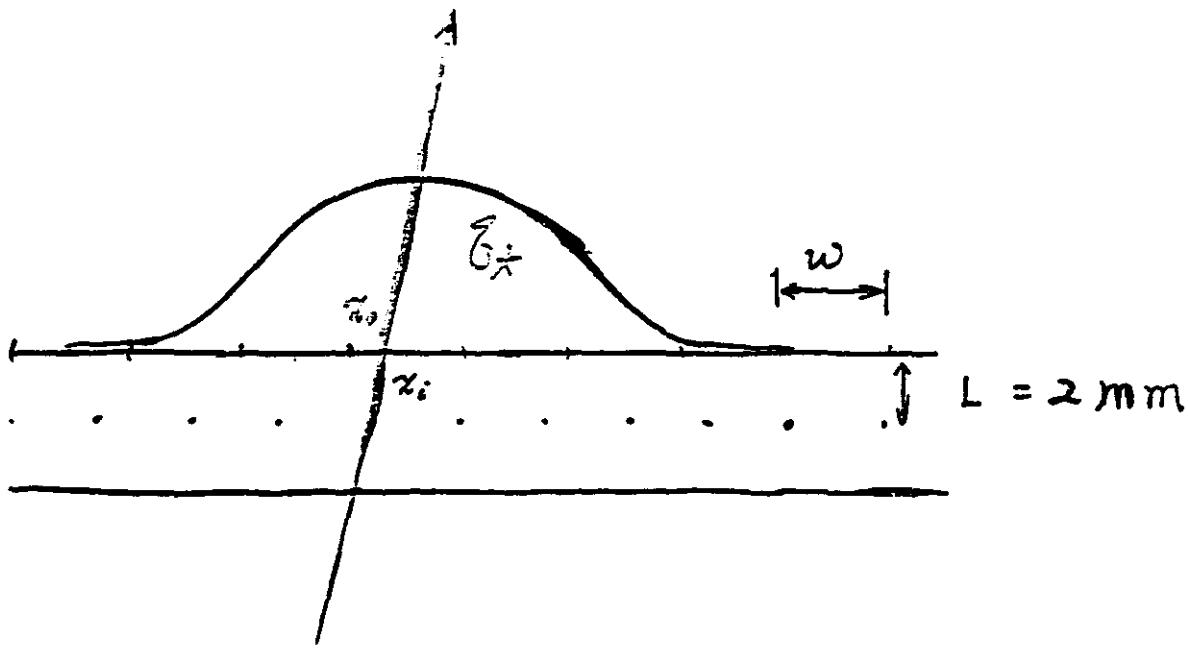
  $\Rightarrow$ 8 cylinders in total.

- $\Delta\phi \Delta\eta = 7 \times 10^{-4}$

  $W_\phi \approx 2.5$ mm $\Rightarrow$ W_η is calculated in each cylinder

0.2. Simulation of charge distribution on pads

$$q_i(x_i) = \frac{2 q_t}{\pi} \cdot \tan^{-1}\left[\frac{\sinh \frac{\pi w}{4L}}{\cosh \frac{\pi (x_i - x_0)}{2L}}\right]$$



q_t : can be given as a fixed no. or given according to $\frac{dE}{dx}$ distribution.

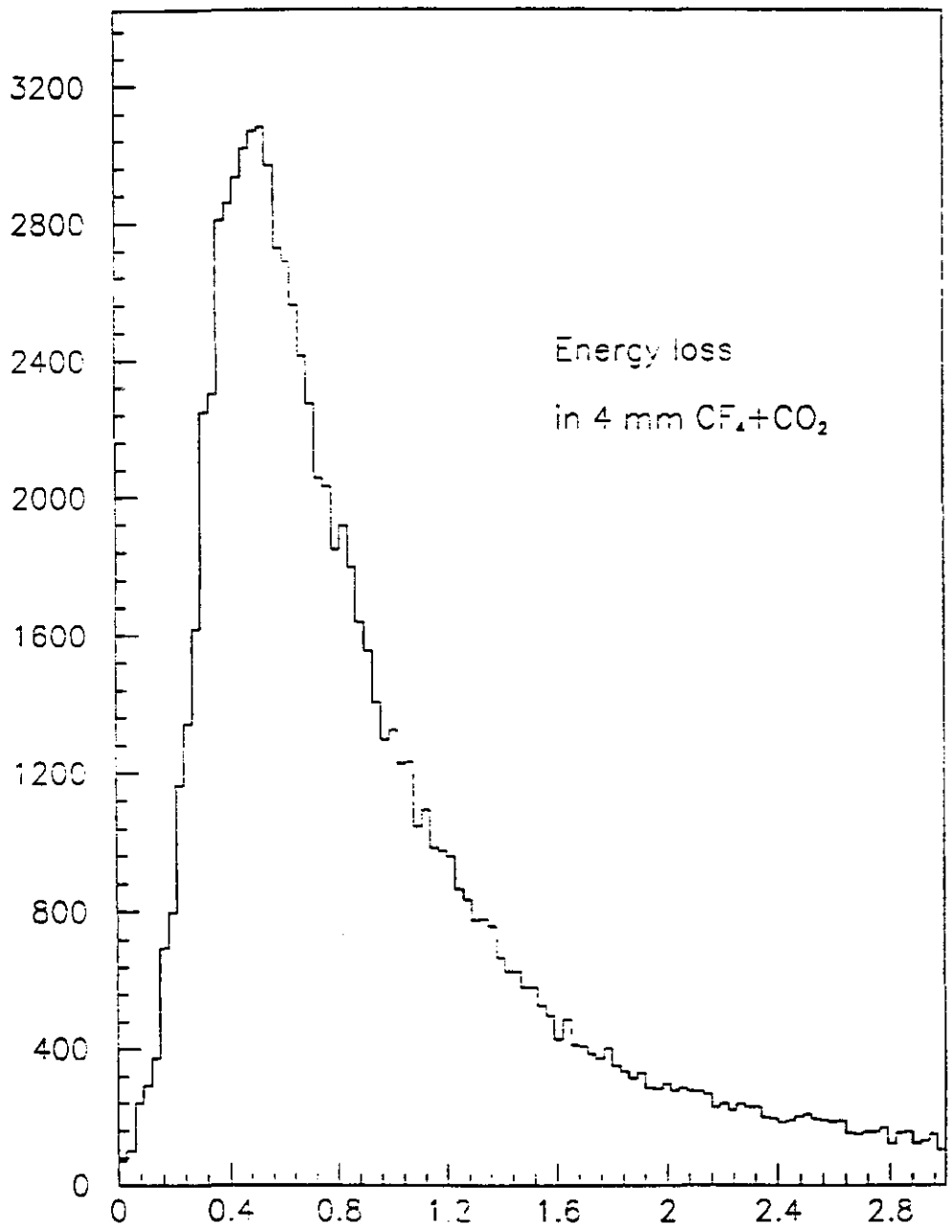


Fig 1. dE/dx (arb. scale)

1.1. Calculation of hit position

- Center of Gravity (C.G.)

$$\langle x \rangle = \frac{\sum_k x_k q_k}{\sum_k q_k}$$

→ need correction

- Non-Linear Fit (N.L.F.)

Use the result from CG together with cluster analysis to obtain the conjecture values for Non-Linear Fit

$\Rightarrow x_0, q_t$

1.2. Adding Gaussian noise

$$q_k = q_k + q_{k,noise}$$

$$q_k = 0 \quad . \text{ if } q_k < 3\,\sigma_{noise}$$

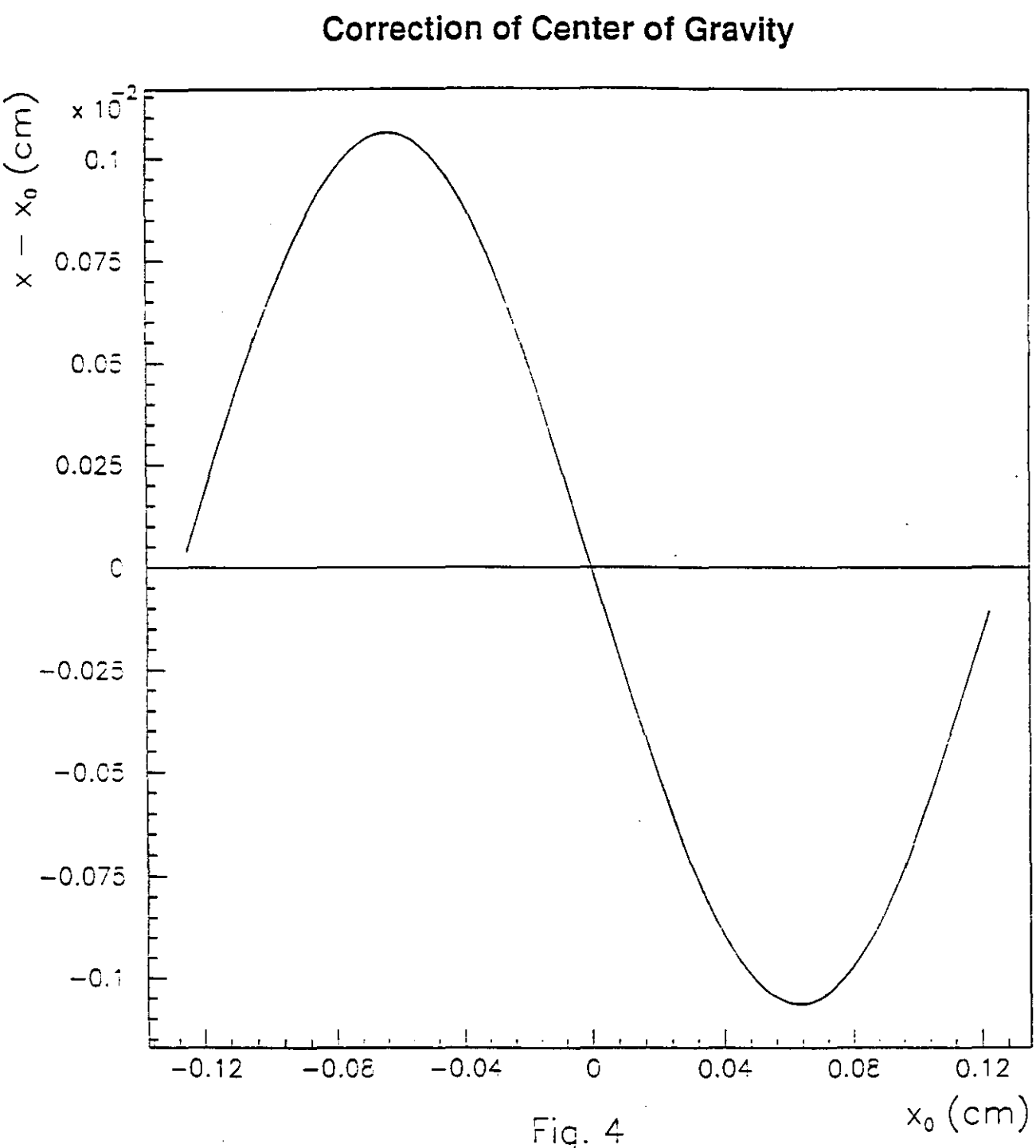

Correction of Center of Gravity
x − x₀ (cm)
x 10⁻²
0.1
0.075
0.05
0.025
0
−0.025
−0.05
−0.075
−0.1
−0.12
−0.08
−0.04
0
0.04
0.08
0.12
x₀ (cm)

Fig. 4

Track and Momentum resolution

S/N ~ 200

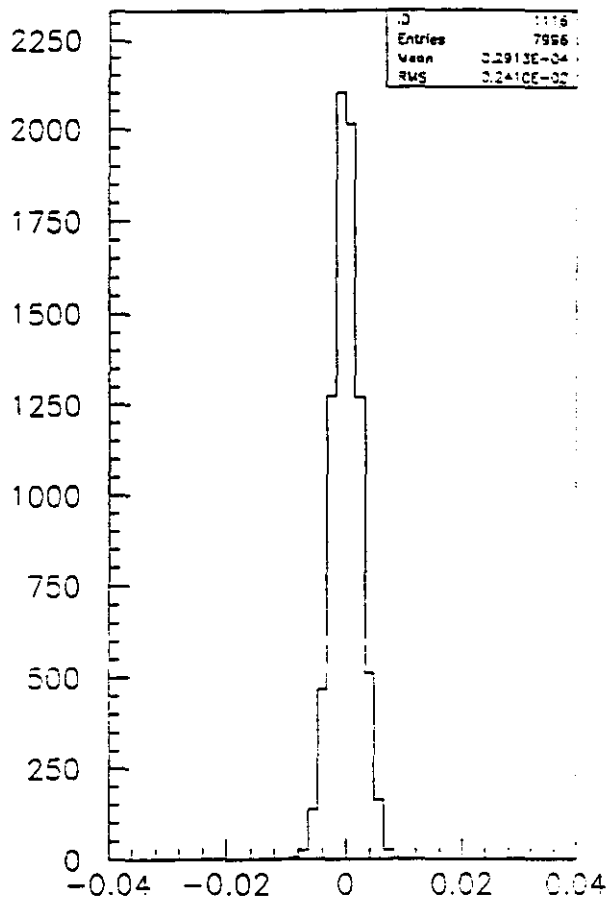


Fig. 2c, delta(x) for fixed energy loss

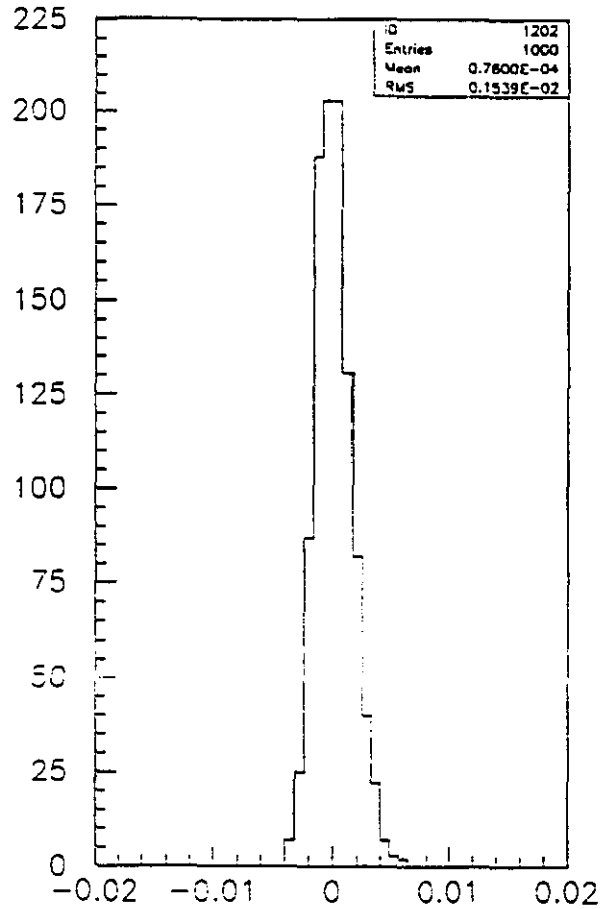


Fig. 2b, $\Delta P_T/P_T^2$ for fixed energy loss

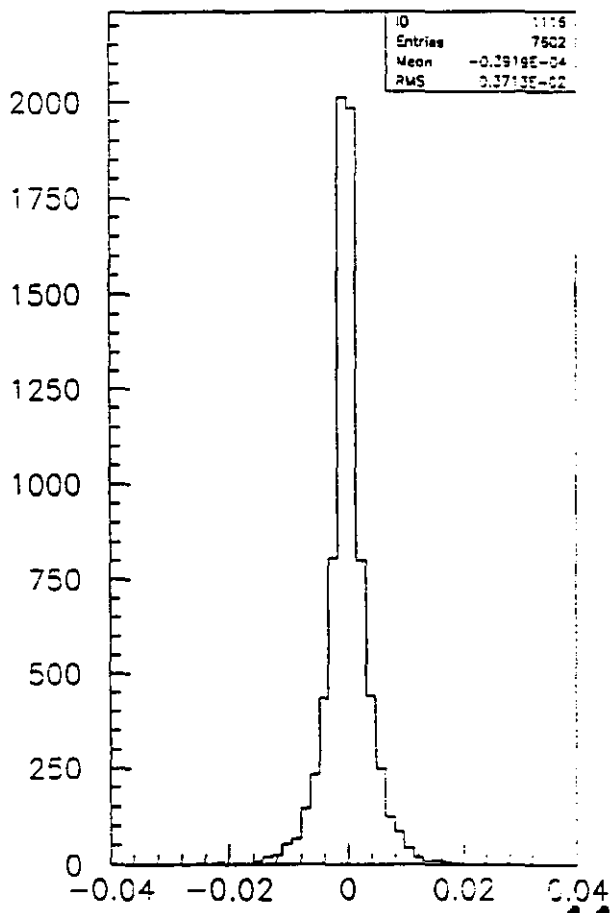


Fig. 3c, delta(x) for dE/dx distribution

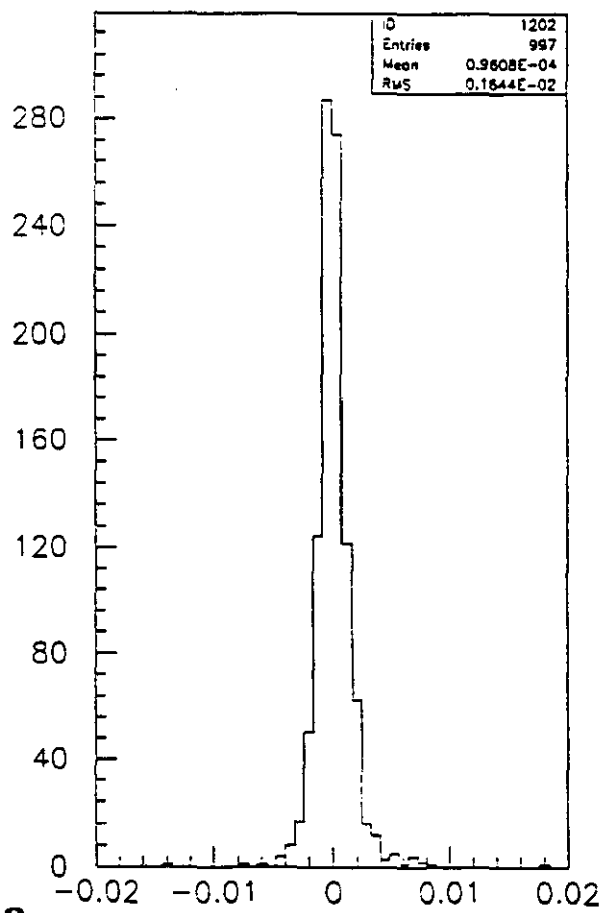


Fig. 3b, $\Delta P_T/P_T^2$ for dE/dx distribution

Track and Momentum resolution

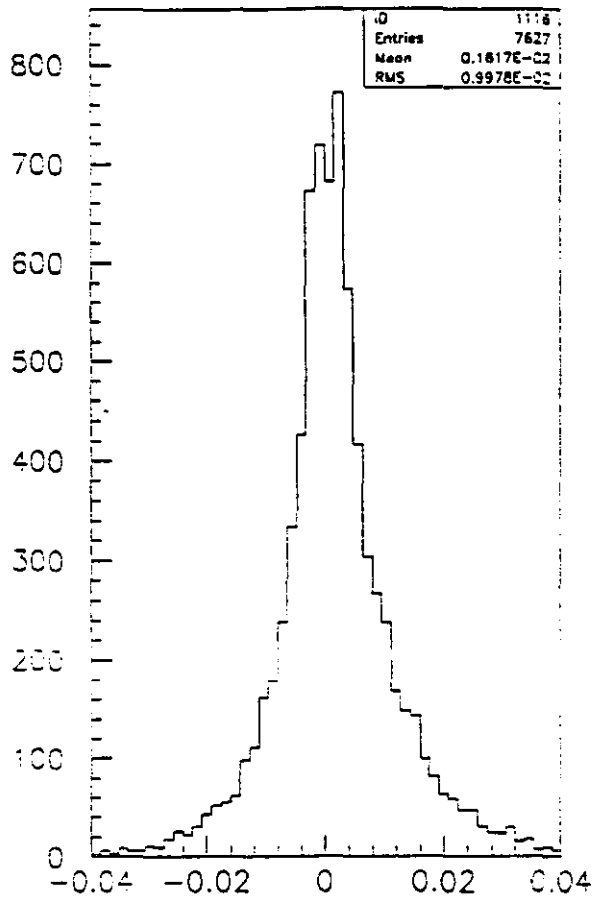


Fig. 5a, deltc(x) (cm) Centr−Gravity

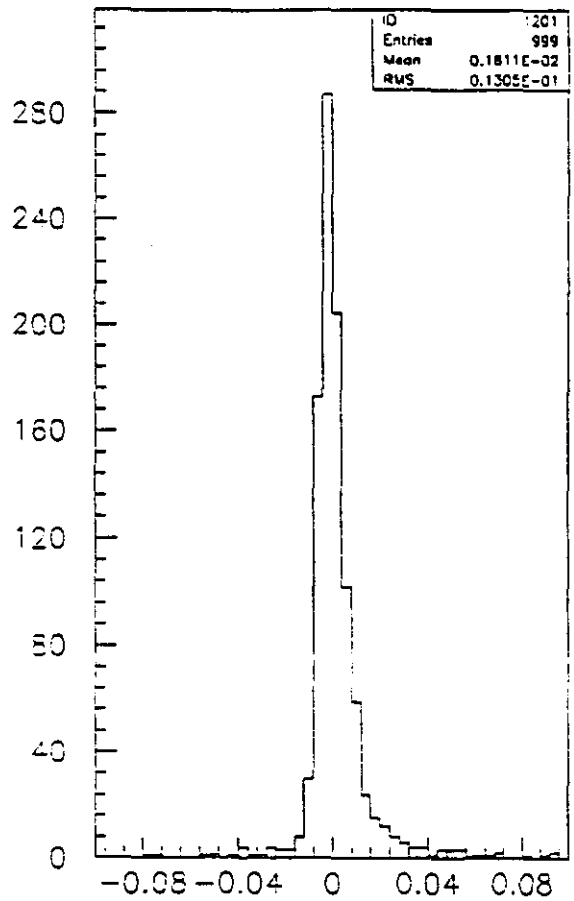


Fig. 5b, $\Delta P_T/P_T^2$ (c/GeV), no vertex

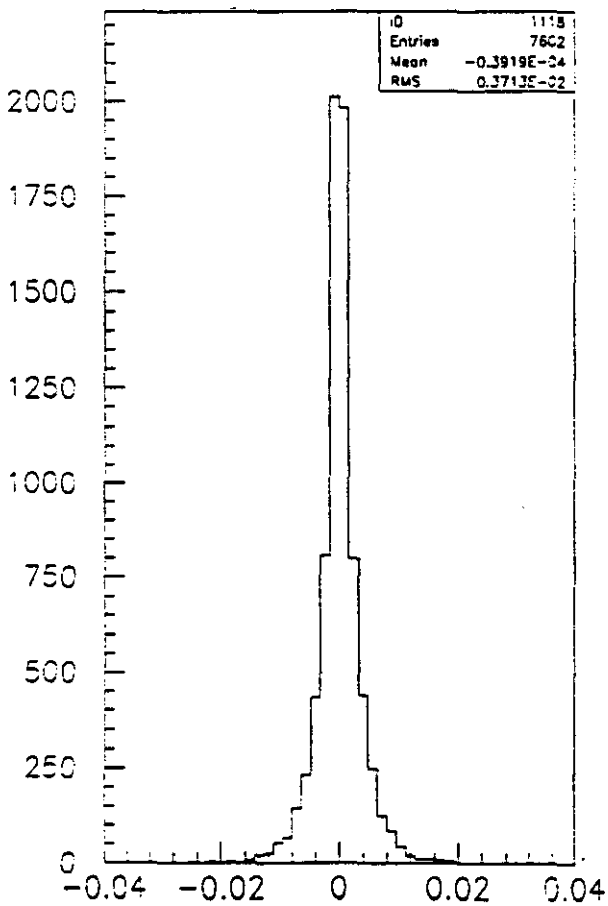


Fig. 6a, deltc'(x) (cm) non linear fit

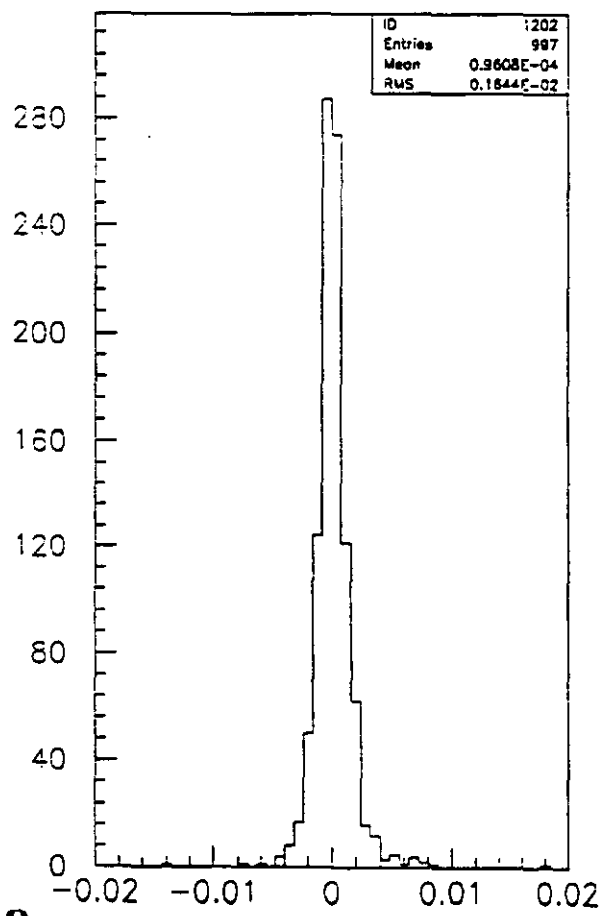


Fig. 6b, $\Delta P_T/P_T^2$ (c/GeV), with vertex

2.1. Calculation of Momemtum

- $y = a_1 + a_2 \cdot x + a_3 \cdot x^2$

$$\left(a_3 = \frac{1}{2R} \right)$$

$$\Rightarrow P_T = \frac{0.15B}{a_3}$$

Track and Momentum resolution vs Signal/noise

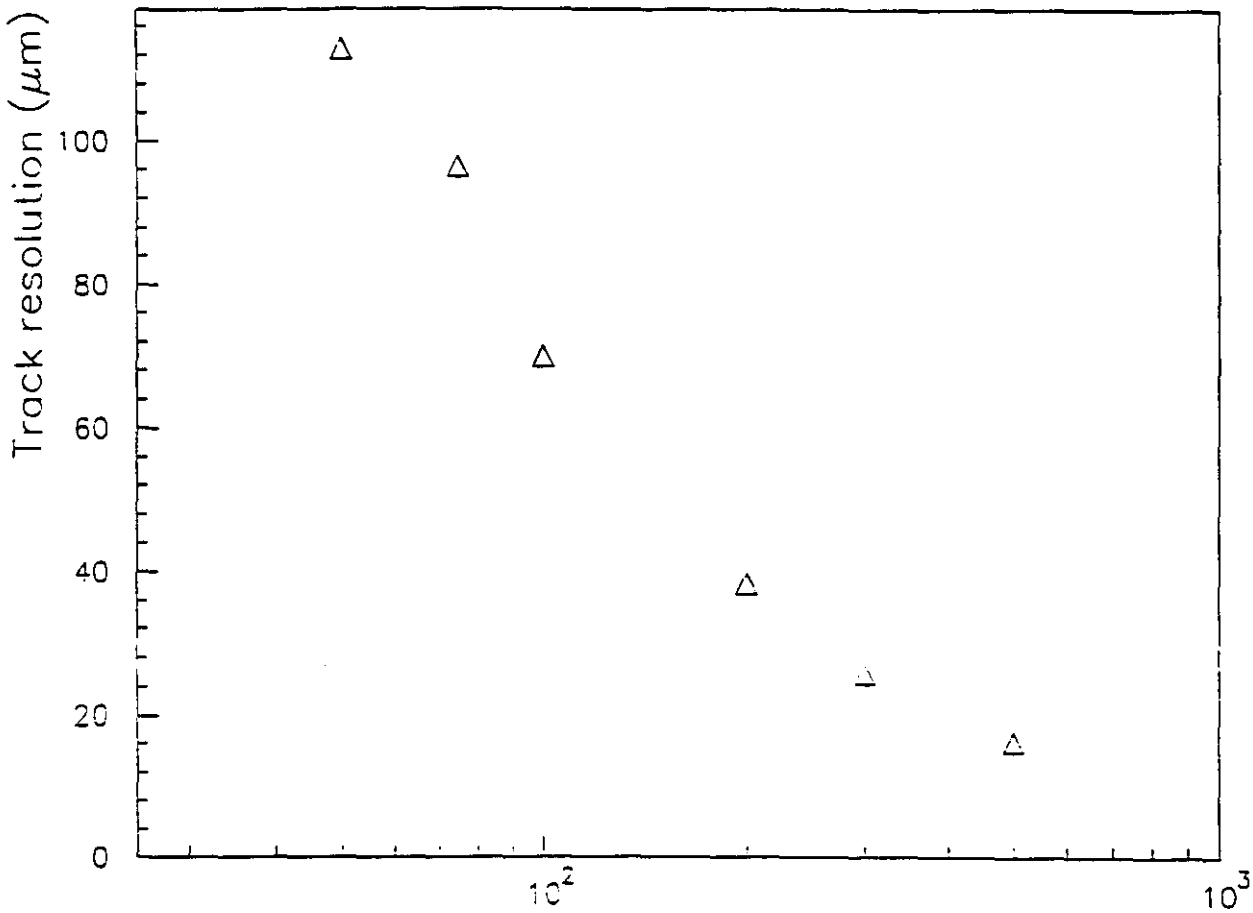
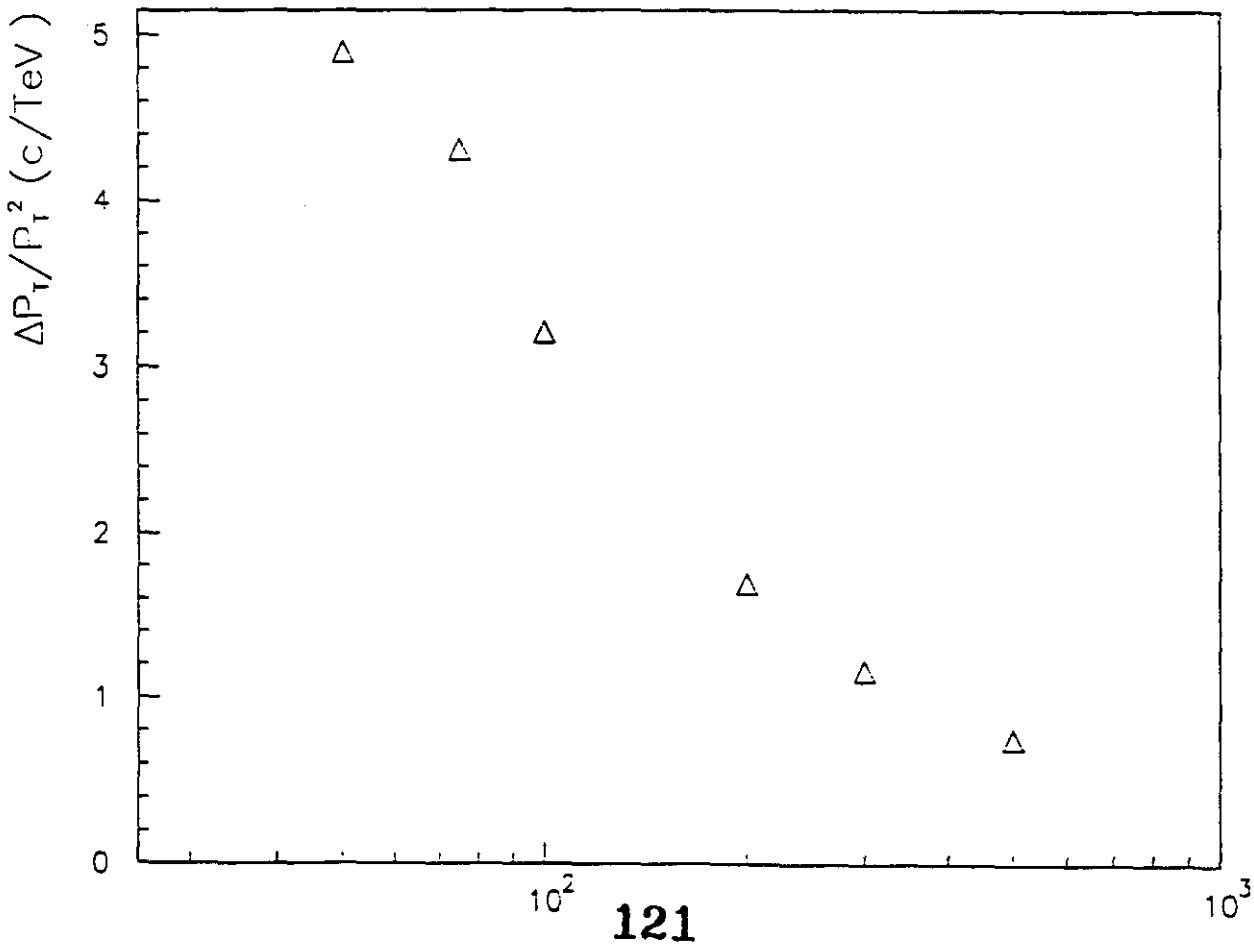


Fig. 7 Signal/noise



3.1. Track and momentum resolution vs. Luminosity

- Occupancy and Luminosity

2 %	10^{33}
12 %	10^{34}

- Throw back ground tracks according to occupancy.

⇒ Calculate the hit positions and then the momentum.

3.2. Efficiency of Track identification

cuts :

① $\chi^2 < 3$

② $n_{point} \geqslant 6$. (no overlaping of two induced charge)

$\langle L \rangle \simeq 2$ mm. $\Rightarrow$ $L < 2.2$ mm

width of charge distribution

Momentum resolution vs Luminosity

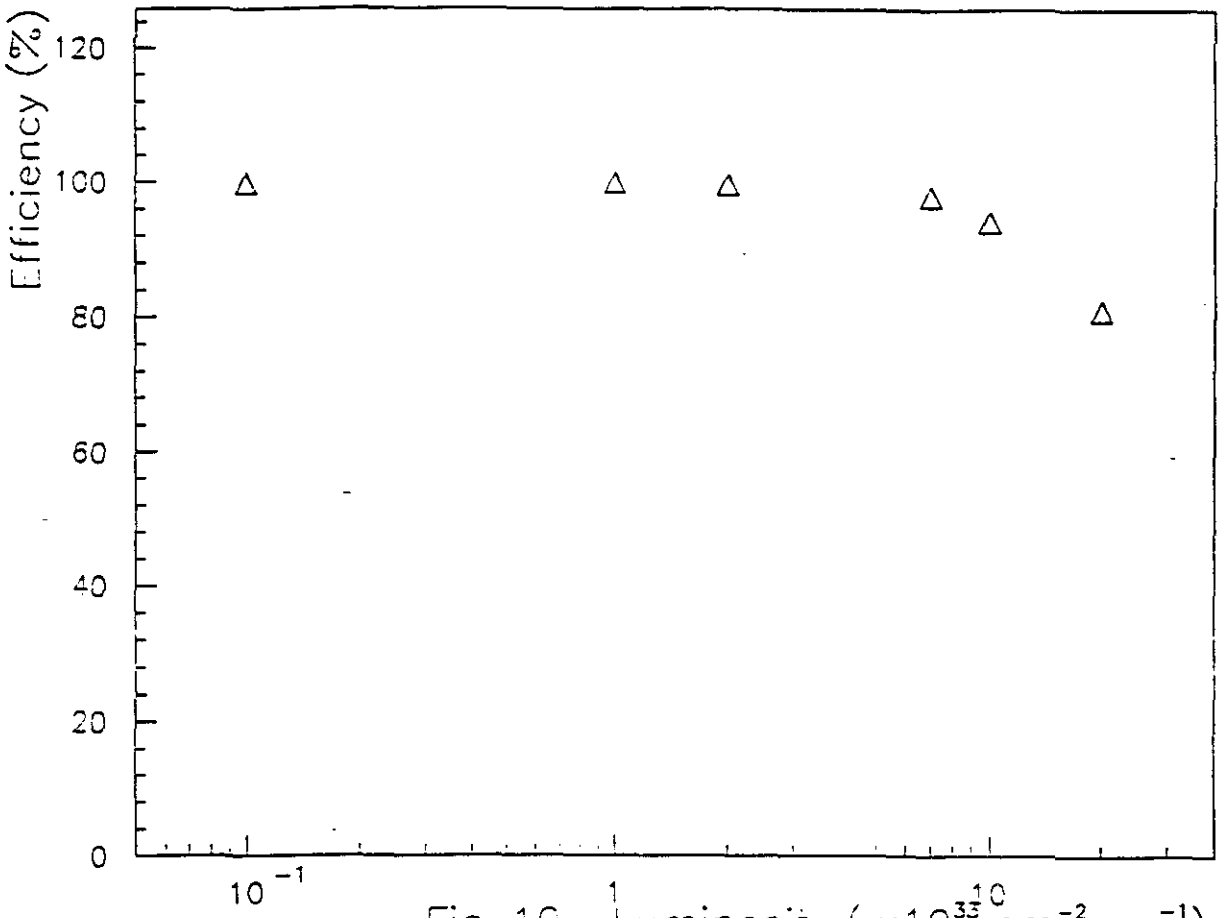


Fig. 10 Luminosity ($\times 10^{33}$ $cm^{-2}sec^{-1}$)

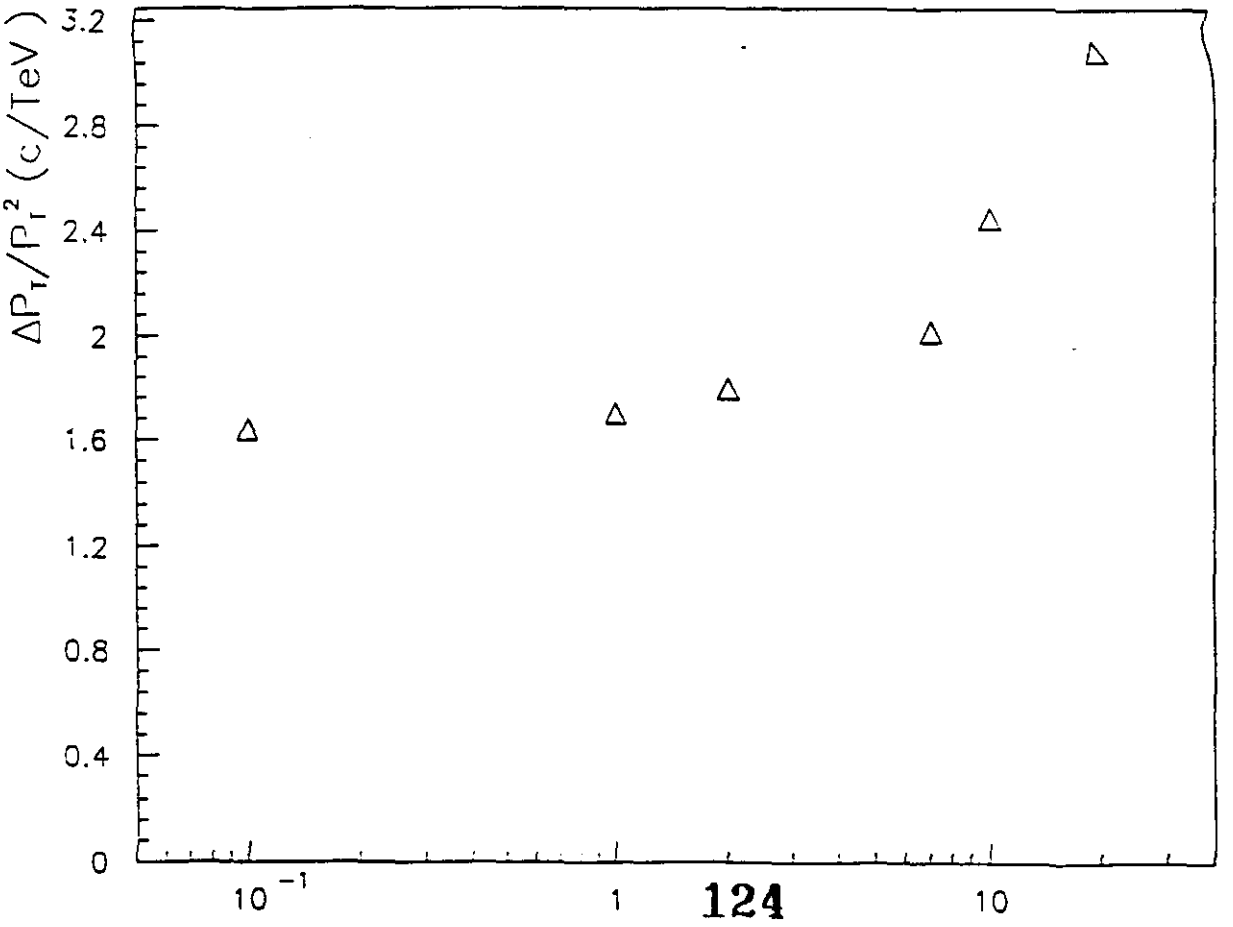


Fig. 11 Luminosity ($\times 10^{33}$ $cm^{-2}sec^{-1}$)

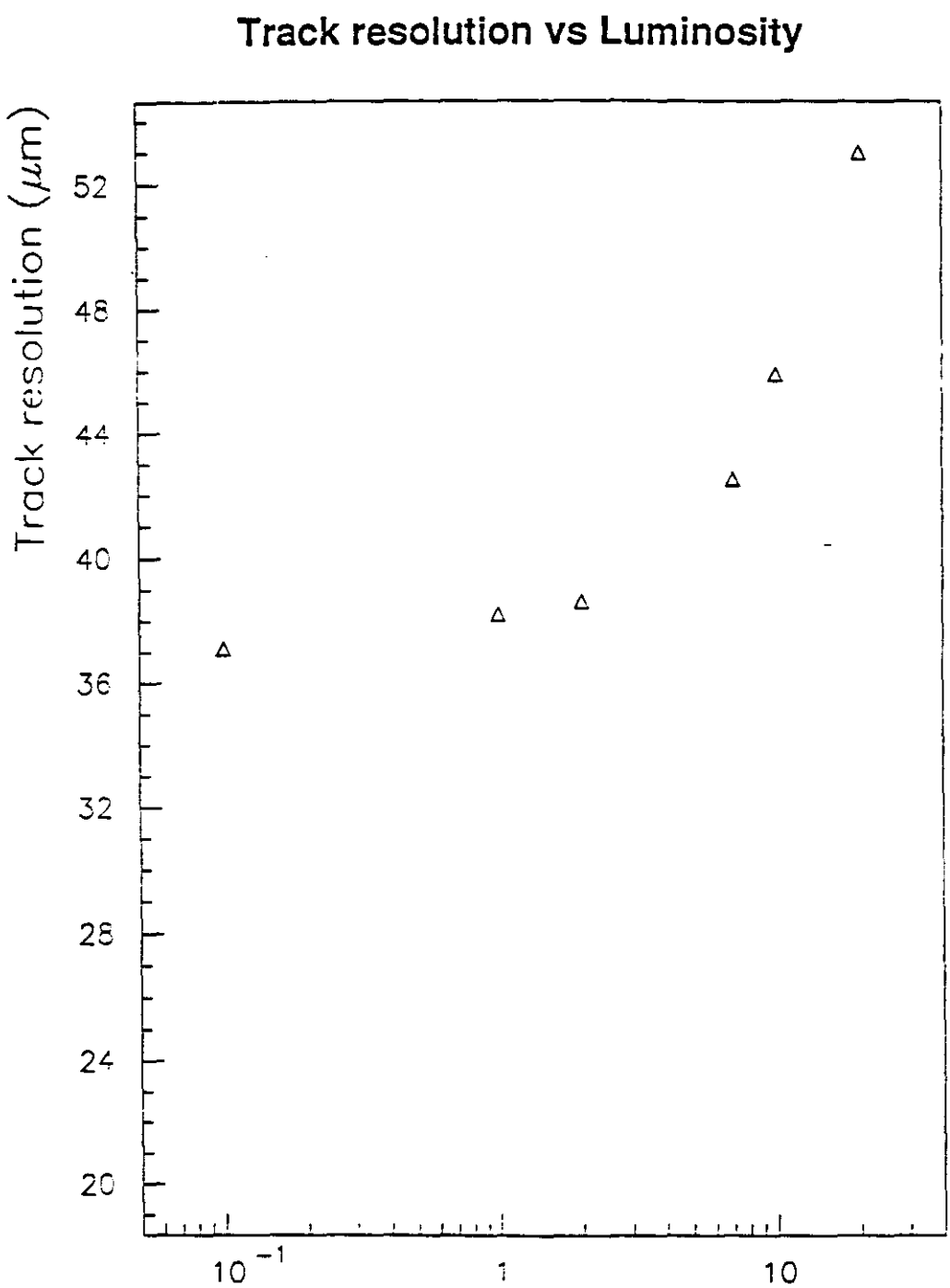


Fig. 9 Luminosity ($\times 10^{33}$ $cm^{-2}sec^{-1}$)

Conclution :

1. hit position resolution = 40 μm
   momentum resolution = 0.0018 c/GeV
   are achievable with (pad width = 2.5 mm
   S/N = 200

2. Efficiency of track identification — Luminorsity

~100 %	?	10^{33}
~95 %	?	10^{34}

Presentation by:

A. Sumarokov

Academia Sinica
Taiwan

GEM CT Simulation

- Physics goals of the central tracker
- Geant CT Simulation program
- Pad chambers study (plane geometry, efficiency, momentum resolution)
- CT Geometry (SMD, Pad chambers)
- Calorimeter, muon system - interface to FAST1
- Hits, Digitizations, Pattern recognition
- Single particle, pile up, Higgs event (momentum resolution)
- Material budget: SMD, PAD chambers, electronics, cables, cooling system, gas enclosure
- Higgs study, efficiency of electron reconstruction
- Higgs to $\gamma\gamma$

2 Physics Goals, Design Parameters, and Detector Performance

2.1 Physics Goals of the Central Tracker

The physics goals for the central tracking in GEM can be divided into two categories. The first are those features that are required to support the primary objectives of GEM, namely the detection of gammas, electrons and muons at high p_t. Some examples of these are:

- Identify the primary vertex of an event of interest, so that it can be separated from other pileup events in the memory time of the detector.

- Separate electrons and gammas using the presence or absence of a charged track pointing to an electromagnetic shower in the calorimeter.

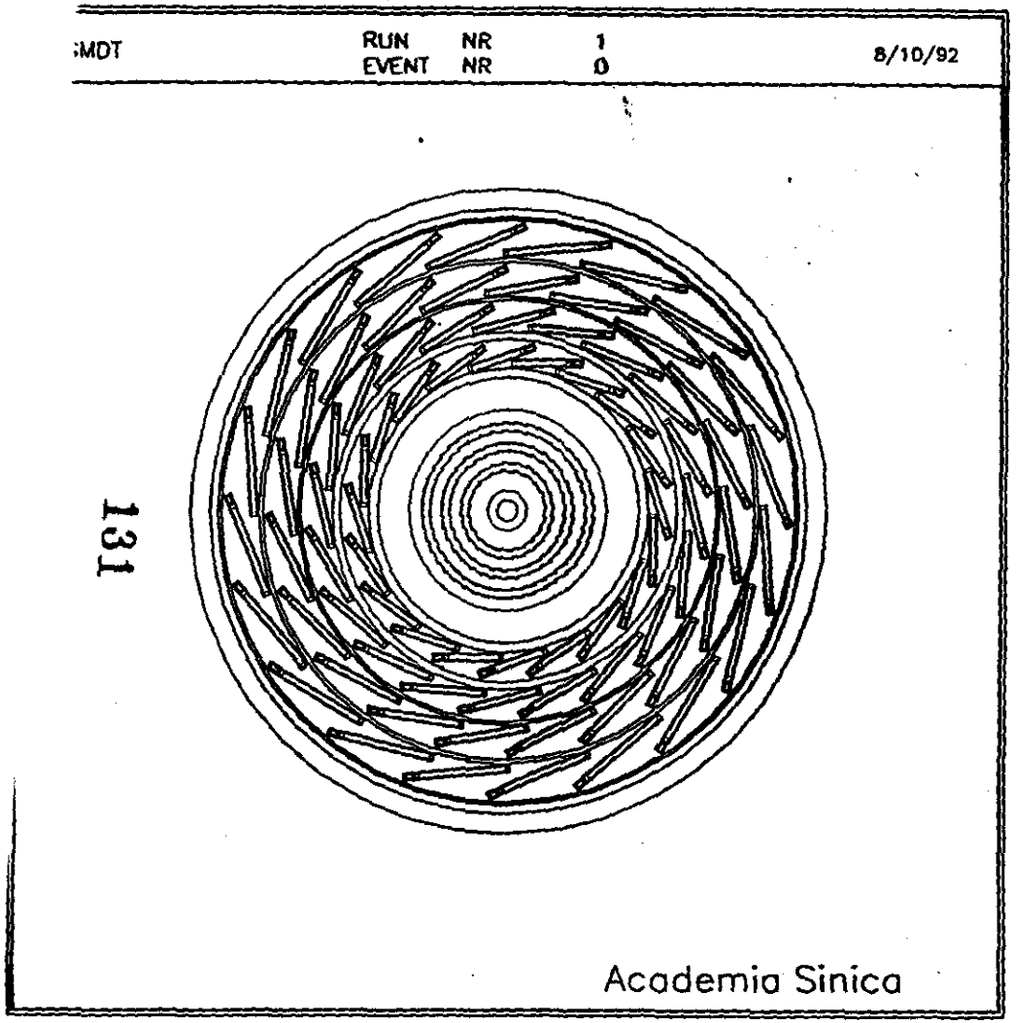
- Provide track information for e, μ or γ isolation cuts, and to help with rejection of conversions and Dalitz pairs.

- Help with electron-hadron separation by providing a momentum measurement that can be compared with the energy deposition in the calorimeter.

- Help with rejection of background by matching the muon momentum measured in the central tracker with the momentum measured in the muon chambers.

- Determine the electron sign up to 400 GeV/c.

The tracker should be able to fulfull these goals well at the design luminosity of $10^{33}cm^{-2}s^{-1}$. These capabilities should also survive to luminosities up to $10^{34}cm^{-2}s^{-1}$. These minumum goals do not require full pattern recognition, but can be met by looking for hits in the tracker in a specific road extrapolated from the calorimeter or the muon system.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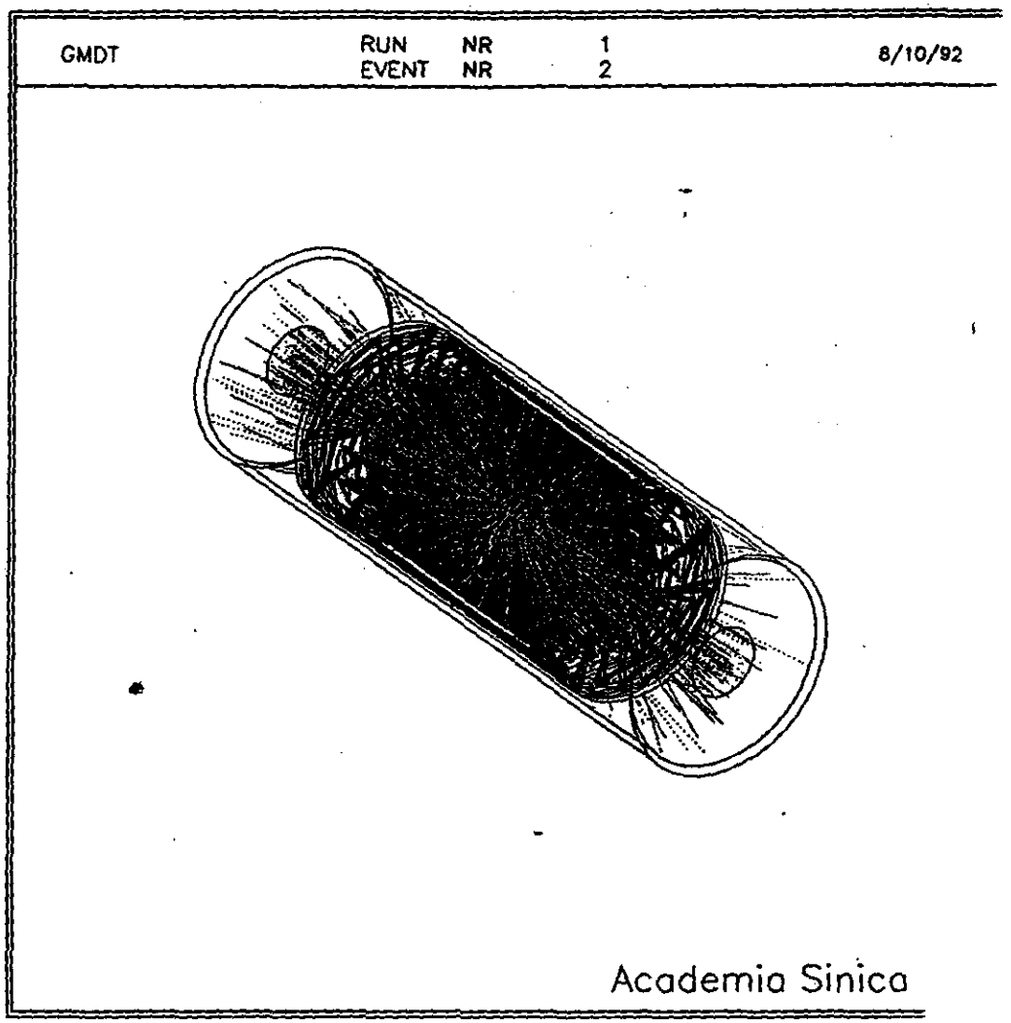
EVENT NR 0
8/10/92
Academia Sinica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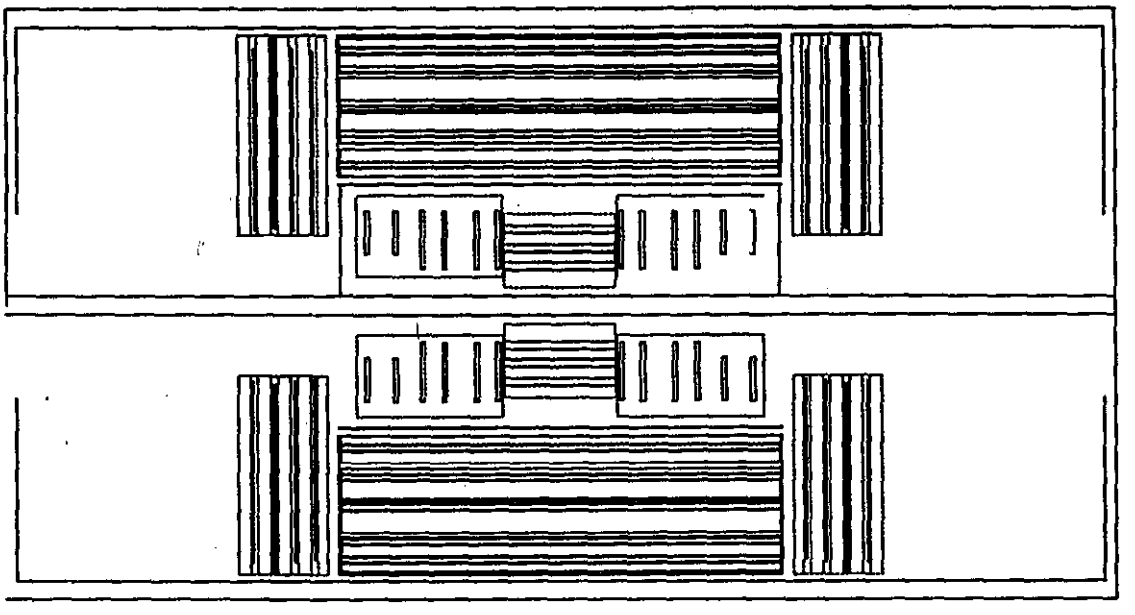
EVENT NR 2
8/10/92
Academia Sinica



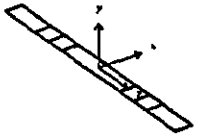
T

LDRM specifications

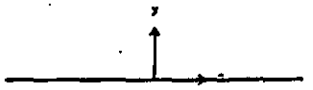
8/10/92

Box

DX = cm 1.66
DY = cm .14
DZ = cm 24.1



10 cm



GMDT

SMD specifications

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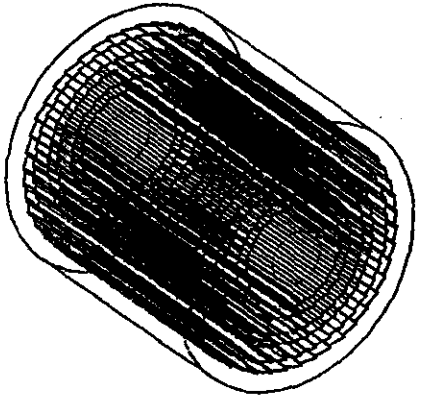
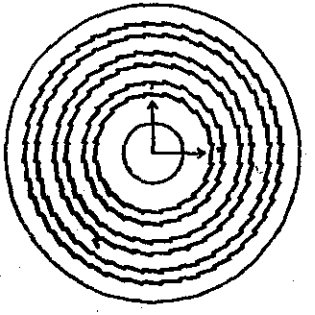
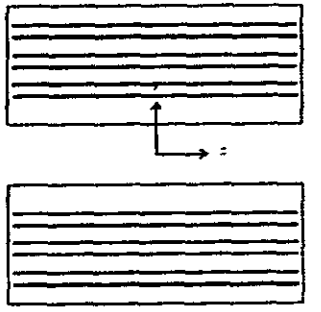
Tube

RMIN = cm 5
RMAX = cm 25
DZ = cm 25



10 cm





MDT

SFD1 specifications

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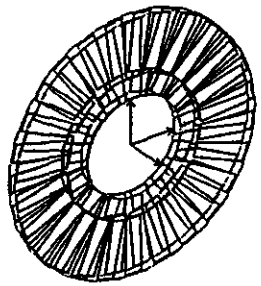
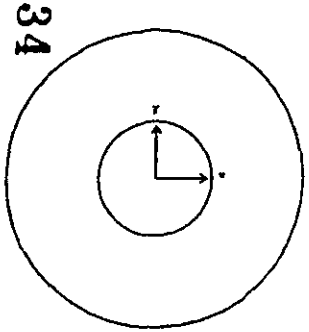
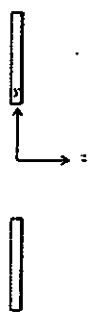
Tube

RMIN = cm 10
RMAX = cm 26
DZ = cm 1



10 cm





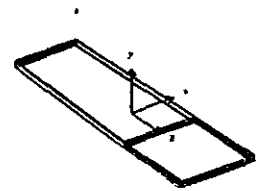
GMDT

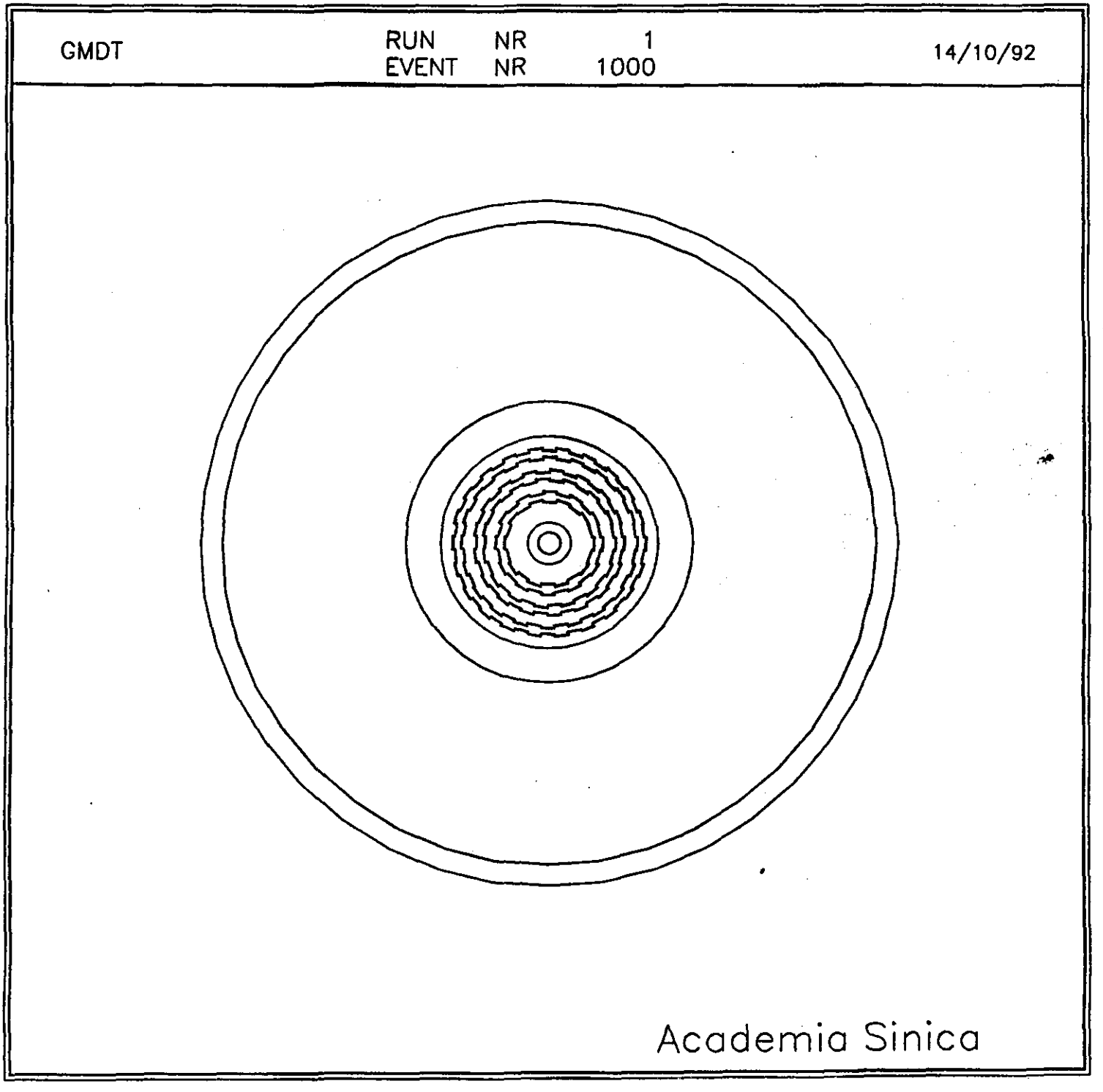
SFWM specifications

8/10/92

Trd1

DX1 = cm 1.428
DX2 = cm 1.778
DY = cm .14
DZ = cm 5.66




GMDT
RUN NR 1
EVENT NR 1000
14/10/92
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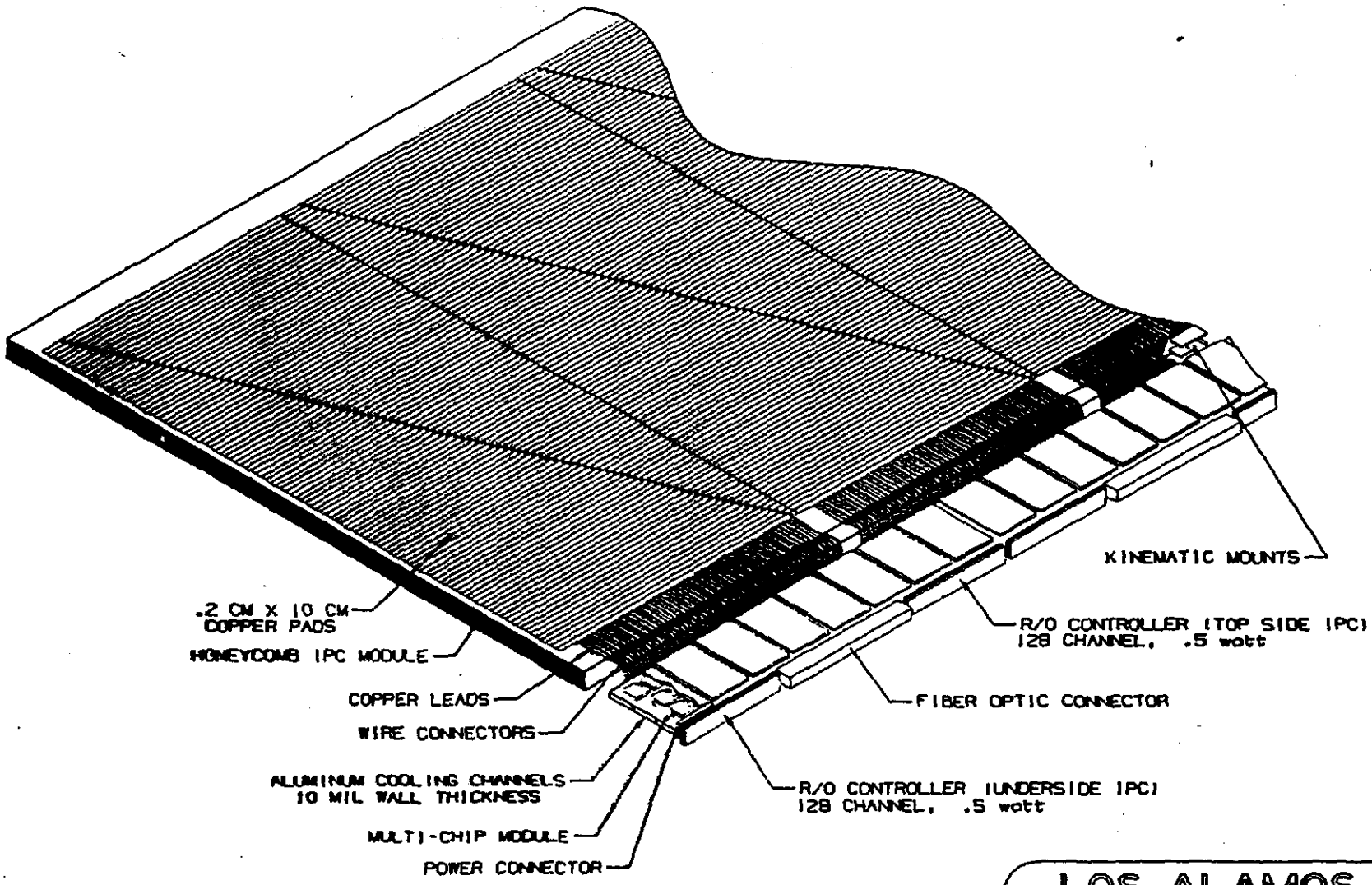
GEM SILICON TRACKER

IPC MODULE ASSEMBLY



ALL DIMENSIONS ARE IN mm

LOS ALAMOS

MEE-12
MECHANICAL AND ELECTRONIC
ENGINEERING DIVISION

JRVCOOLASSY 8-31-92

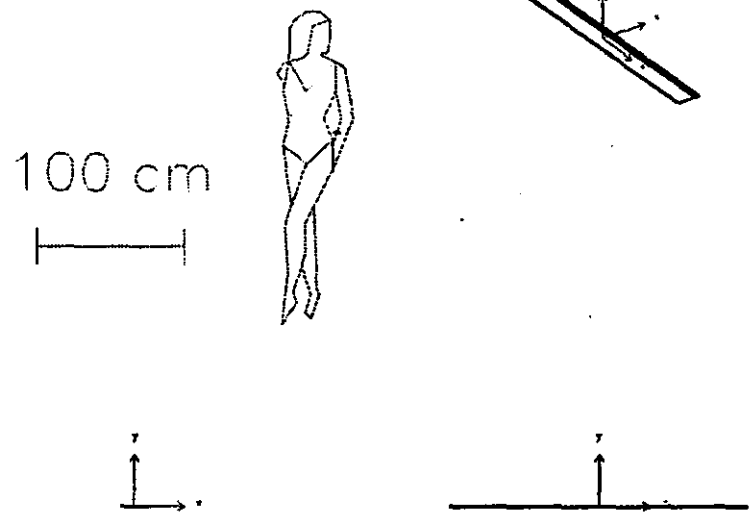
GMDT

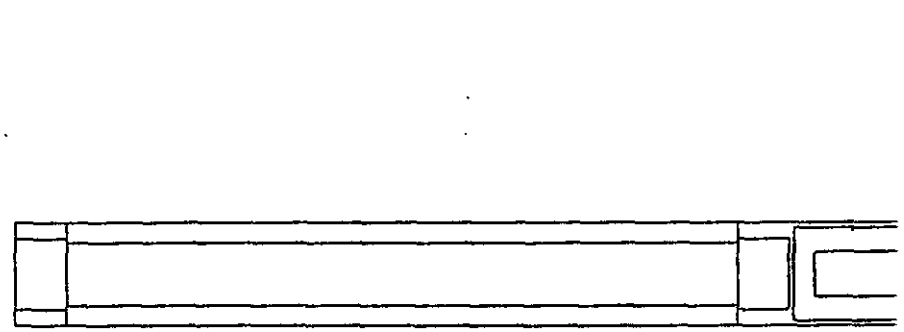
TKB1 specifications

8/10/92

Box

DX = cm 9.05
DY = cm 1
DZ = cm 99

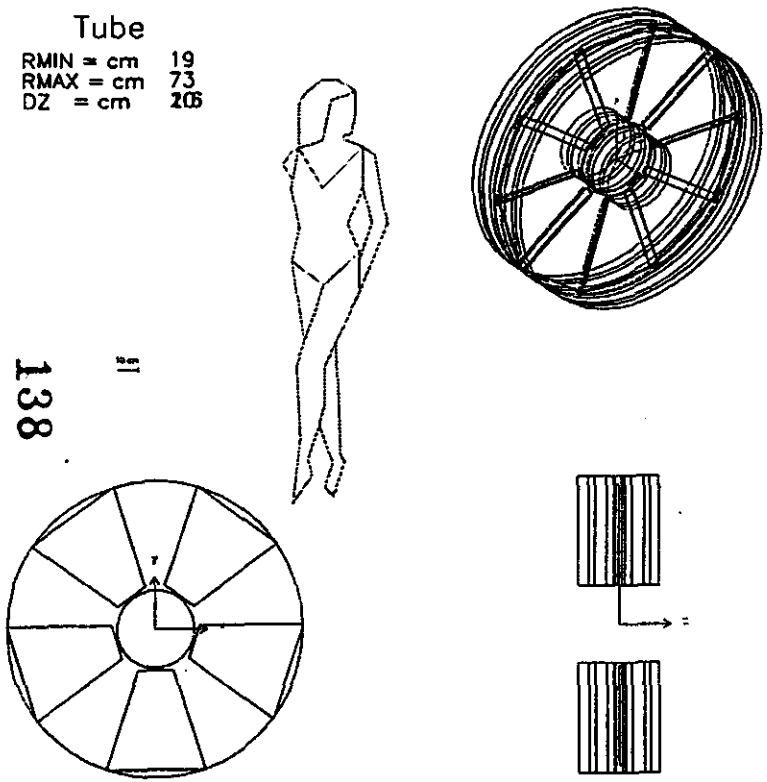




MDT D&DL specifications 8/10/92

Tube

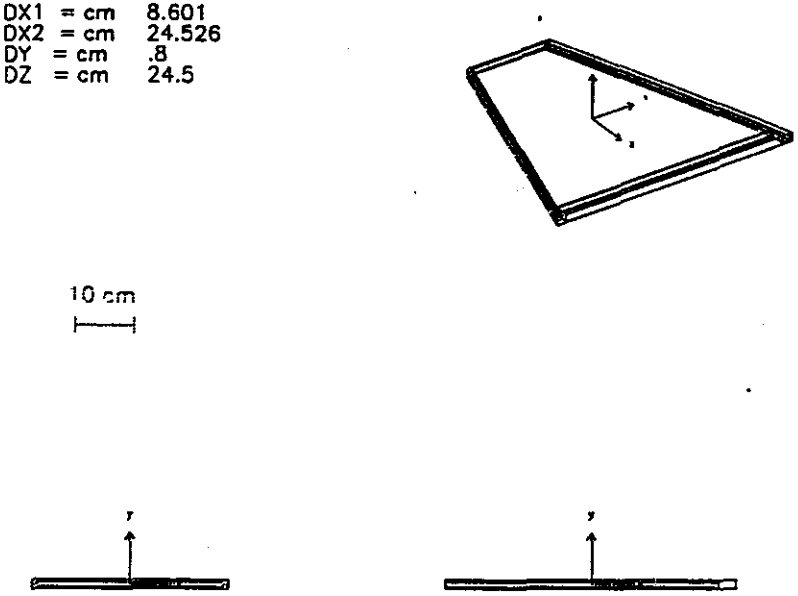
RMIN = cm 19
RMAX = cm 73
DZ = cm 206



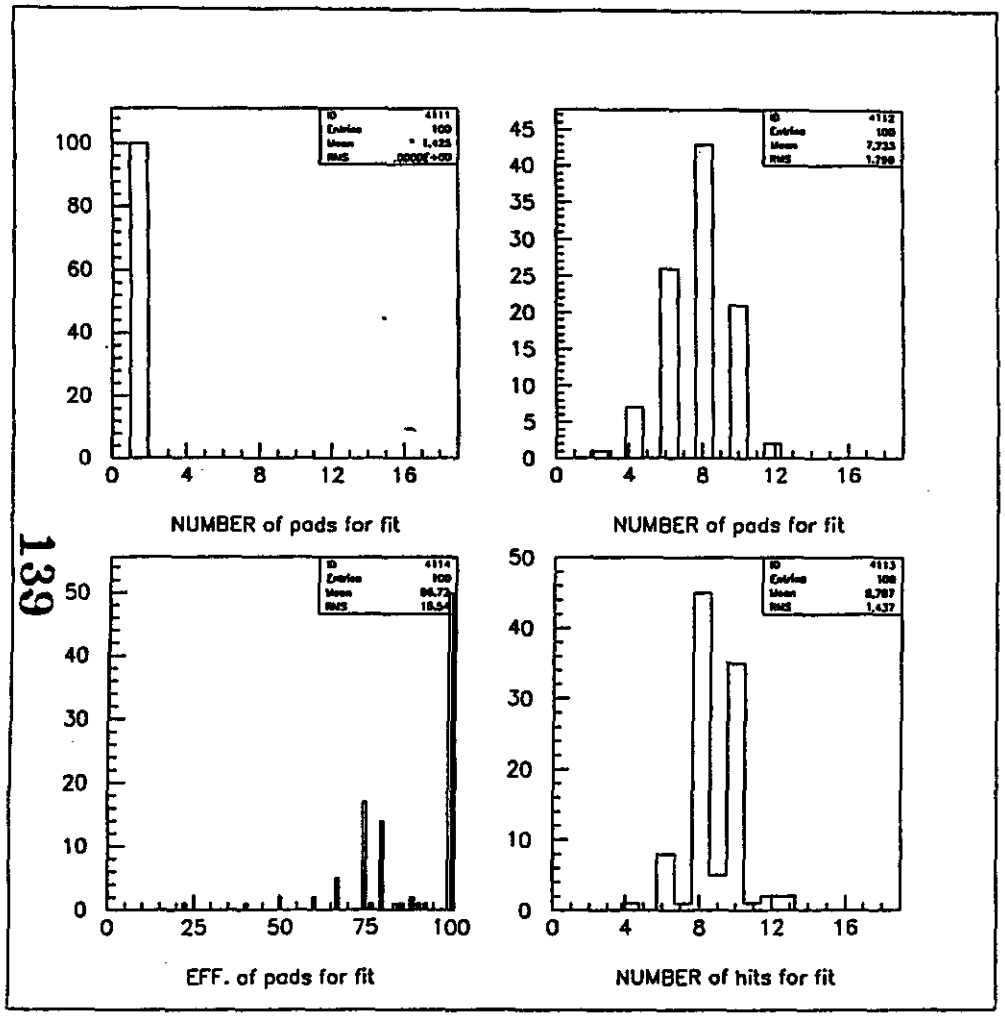
GMDT PDSR specifications 8/10/92

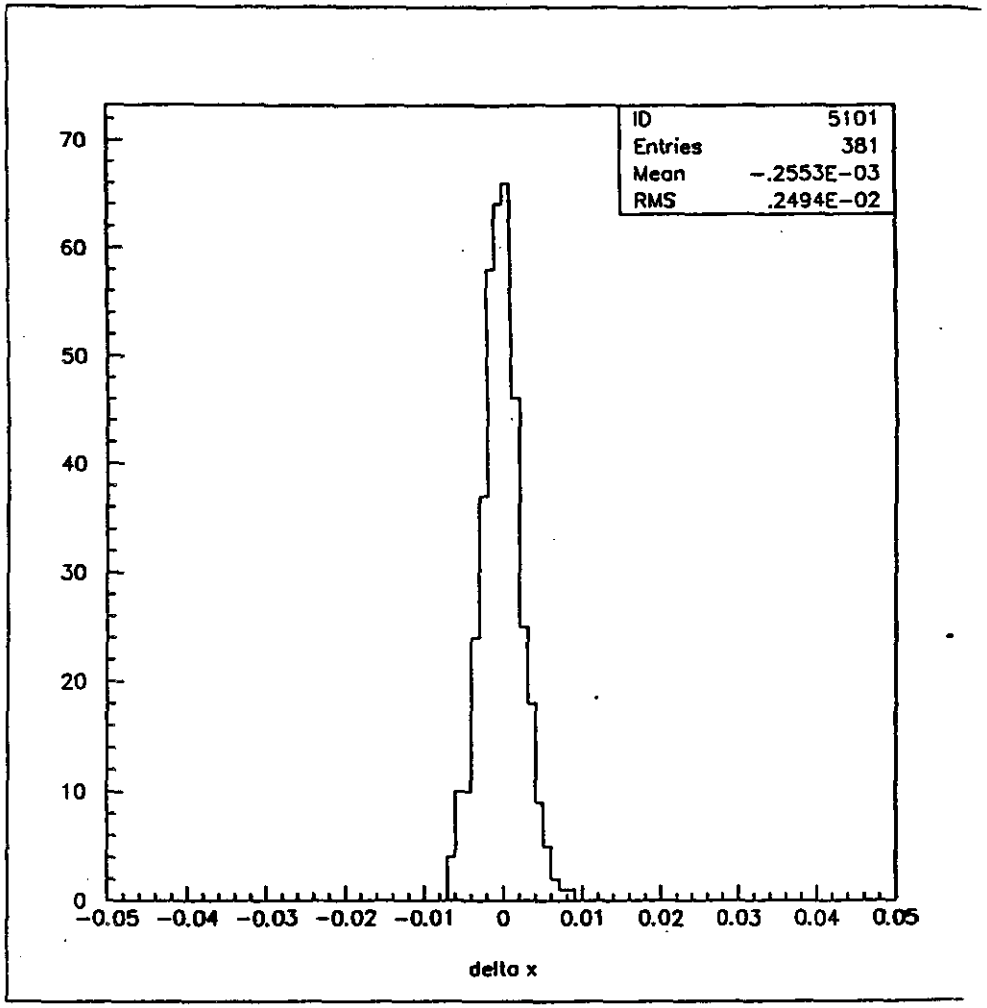
Trd1

DX1 = cm 8.601
DX2 = cm 24.526
DY = cm .8
DZ = cm 24.5

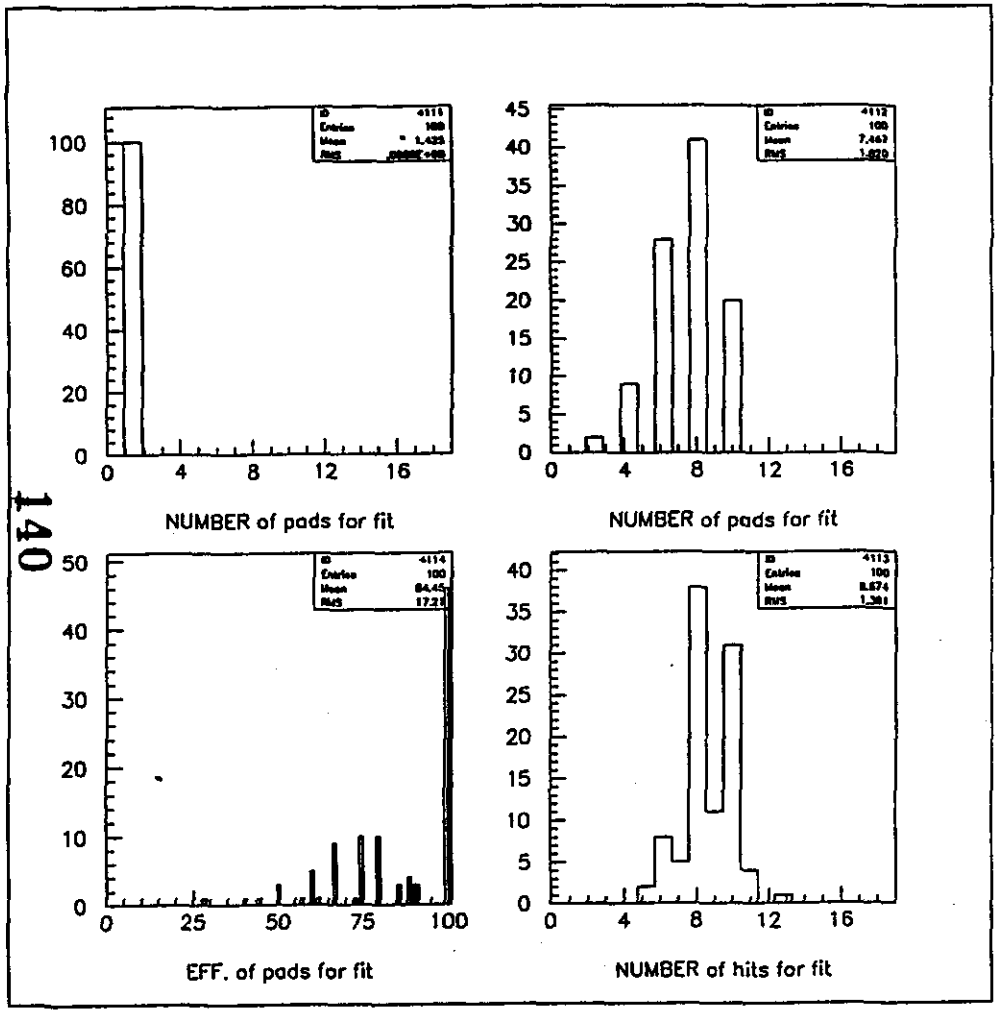


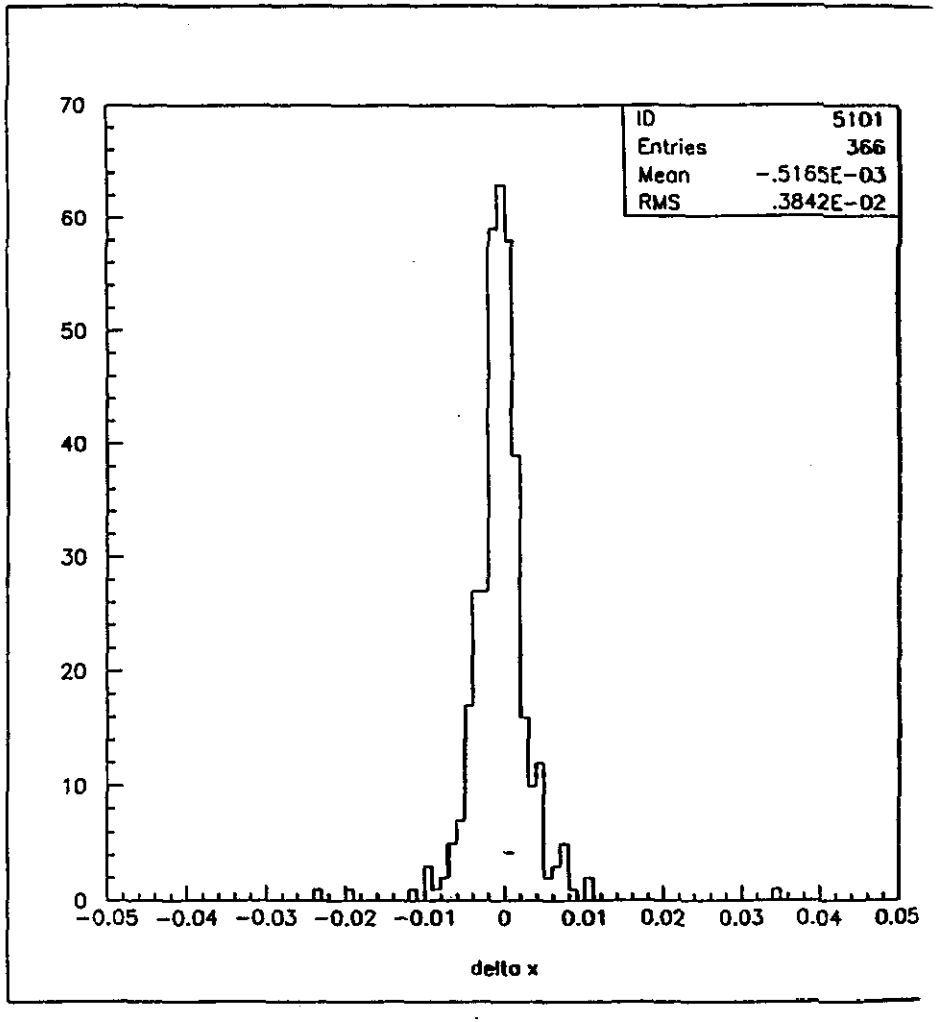
Нет тормозного излучения и δ-электронов.





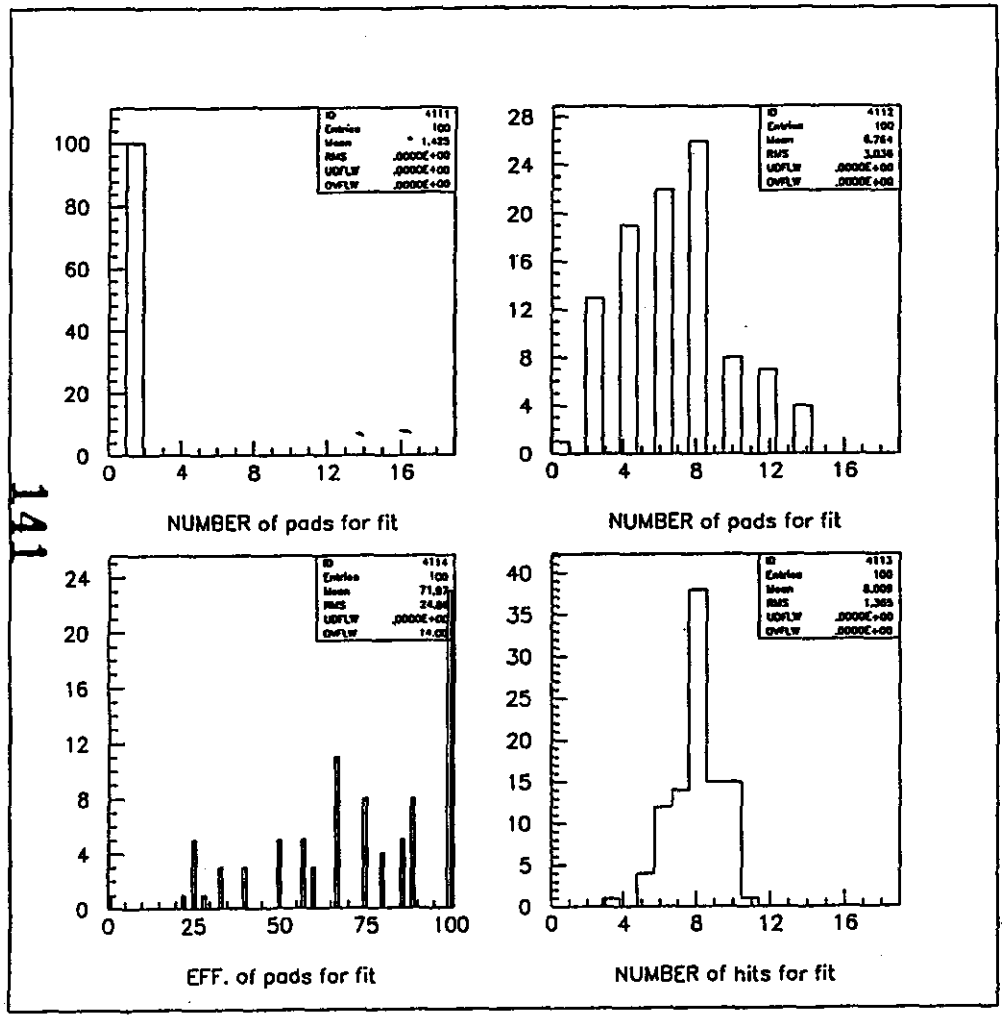
Вихоревич Тамбов Г. - Алексеевич

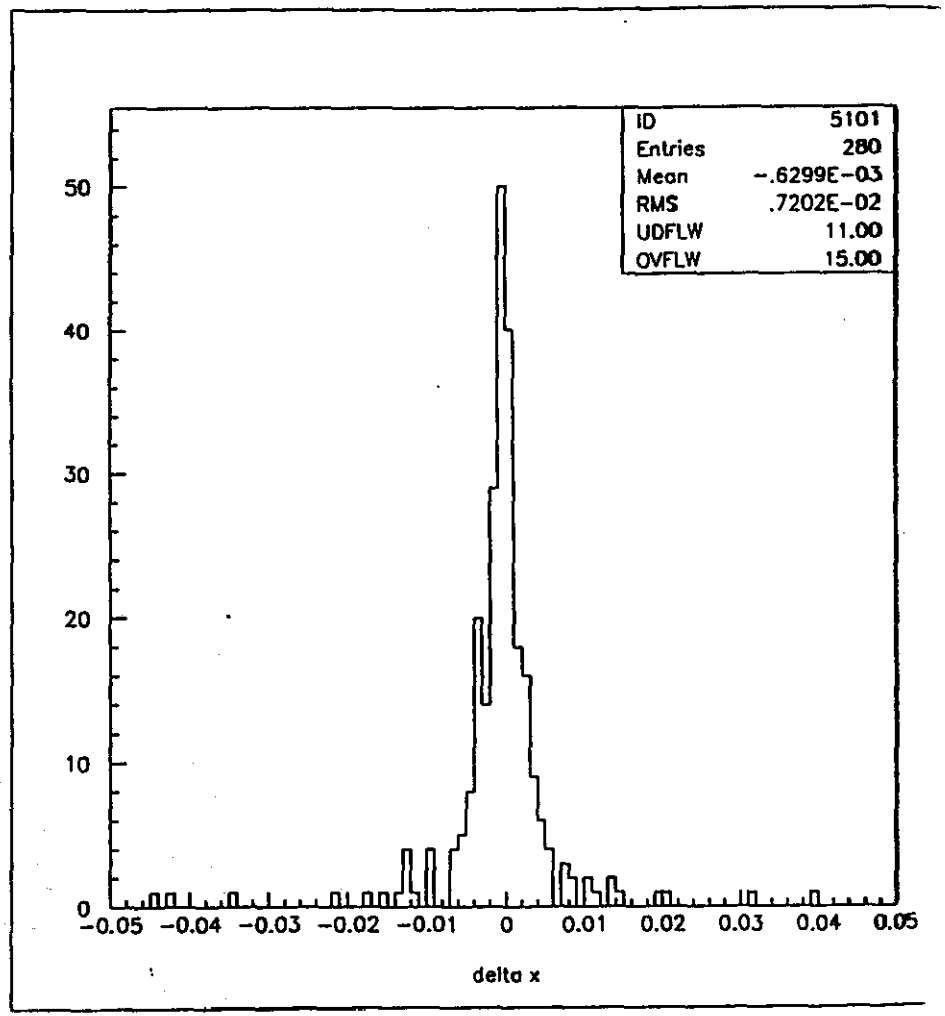




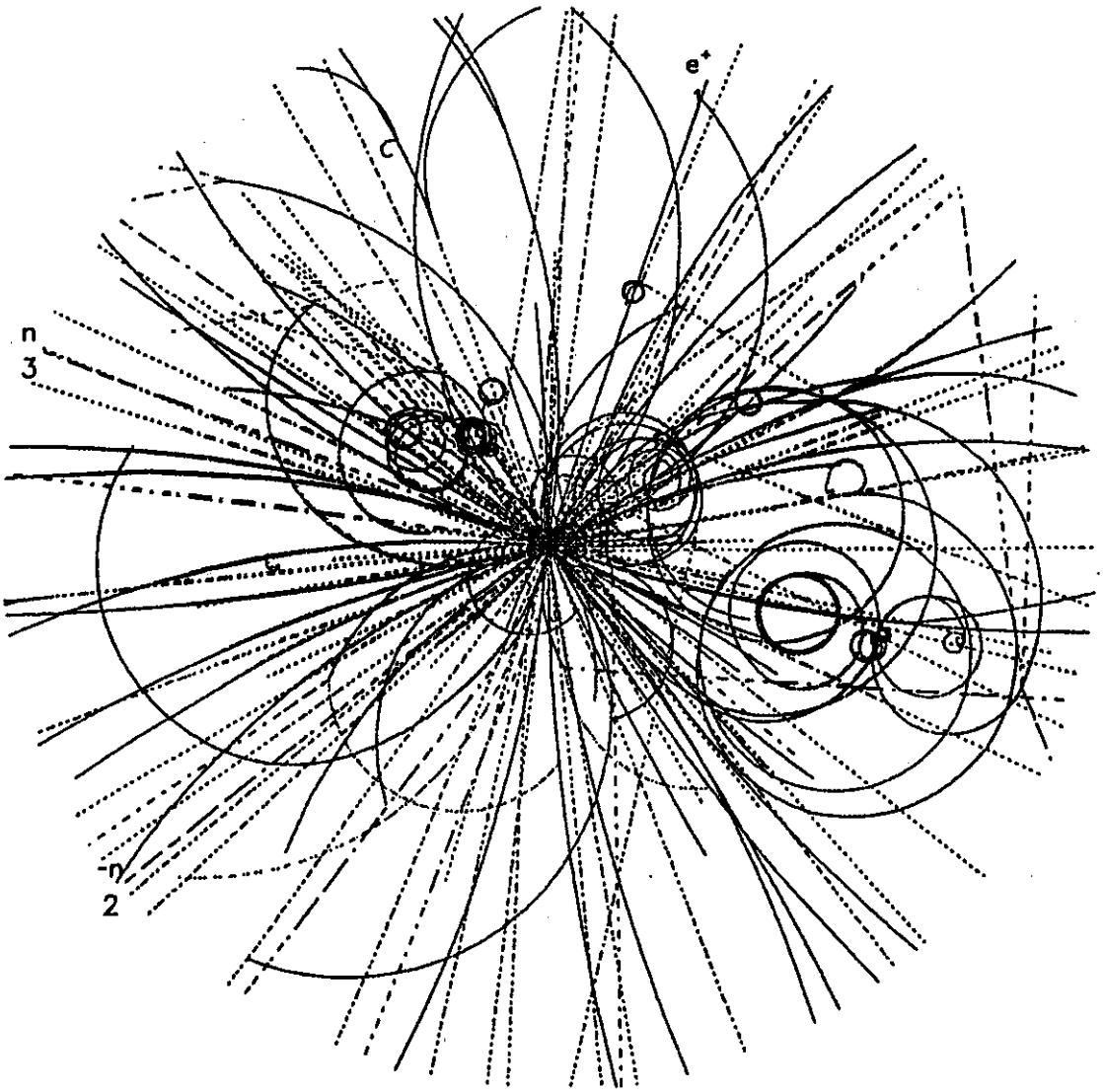
Δ bounce c |Δx| > 6 mm

(1)



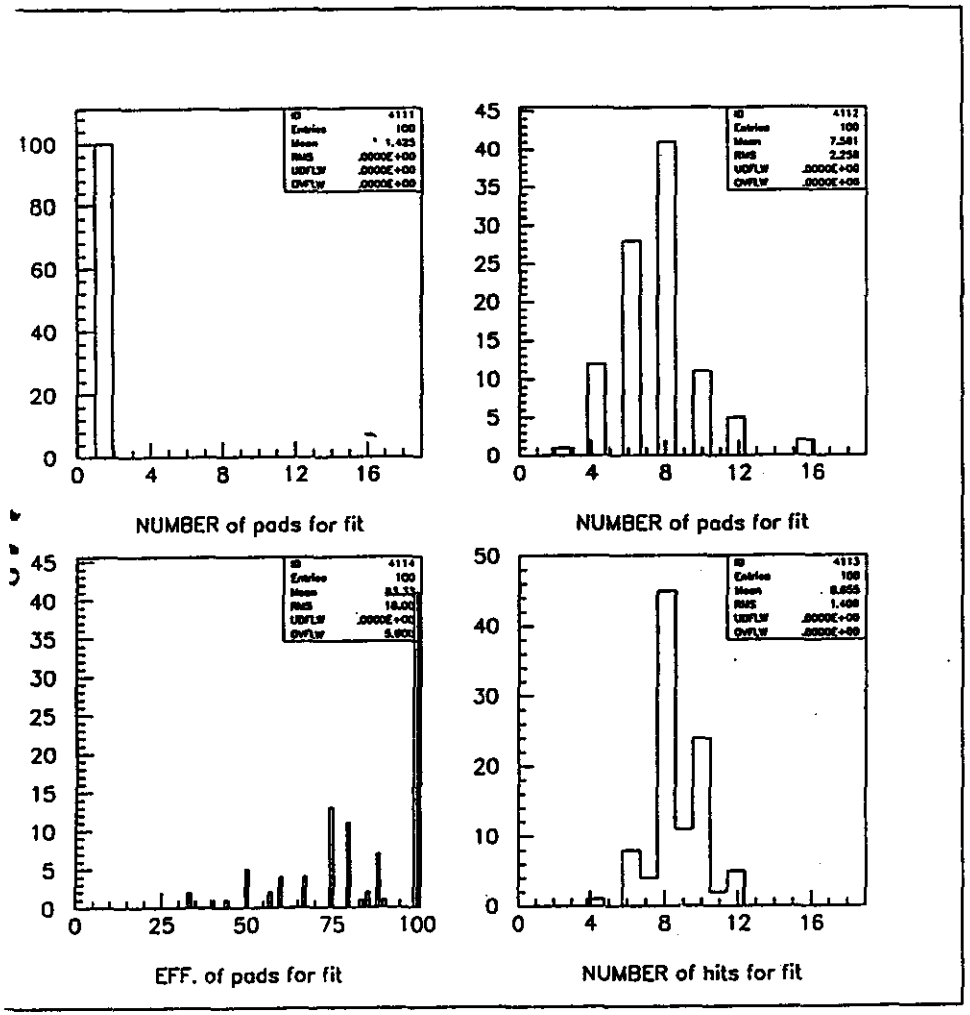


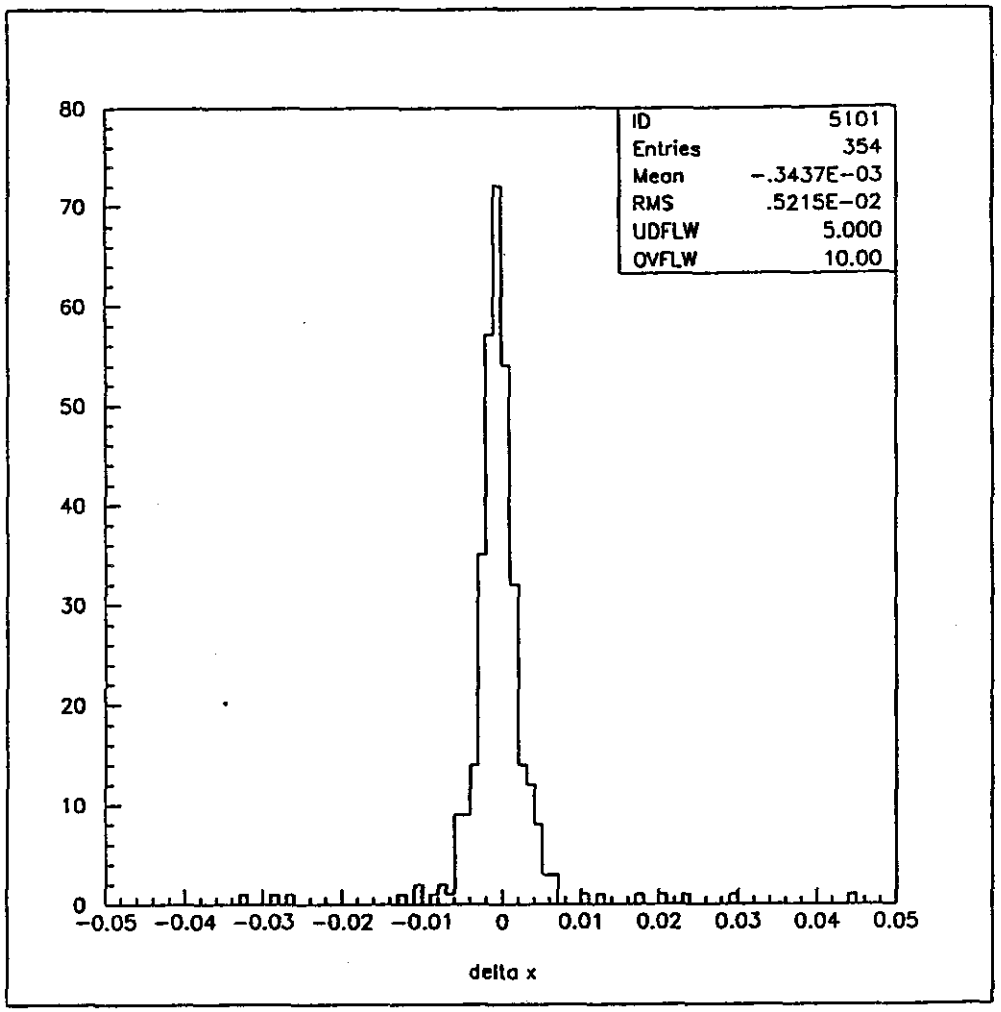
e^+ + pile-up (@ 10^{33})



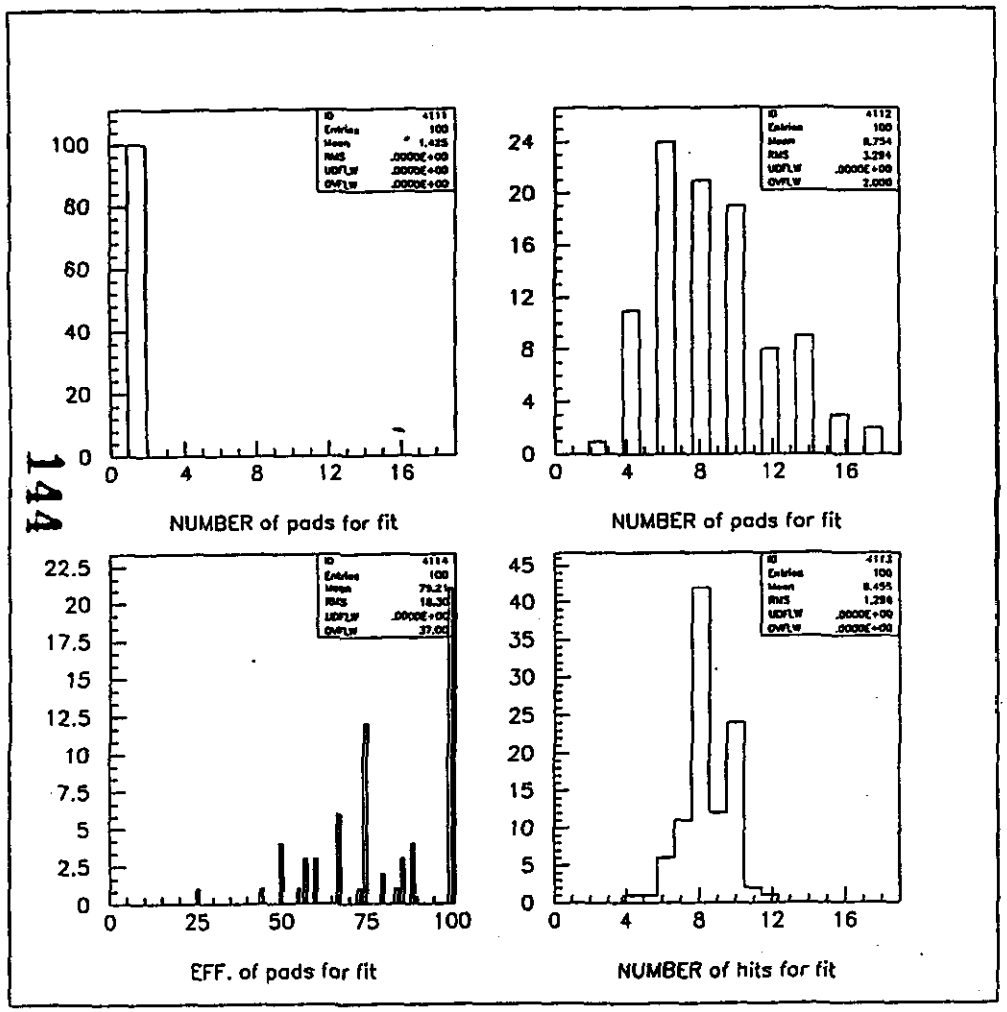
[illegible] $|\Delta y| > 5$ [illegible], [illegible] + [illegible]

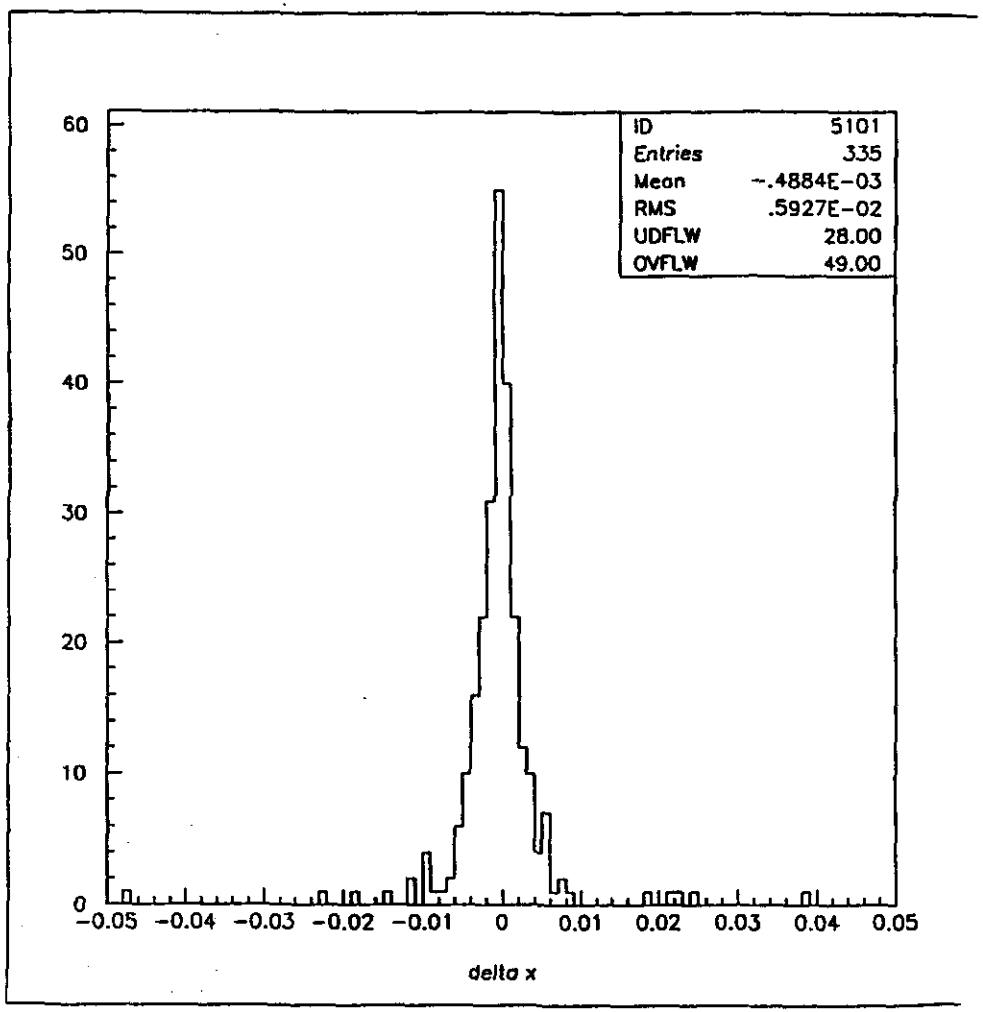
pile-up = 10^{33}. Корректировано кол-во вещества

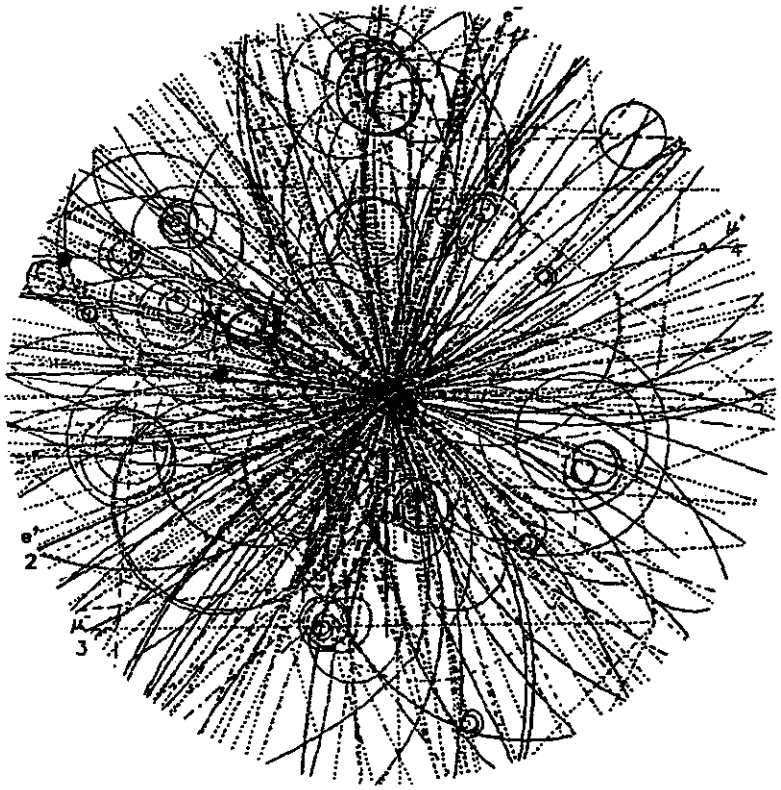


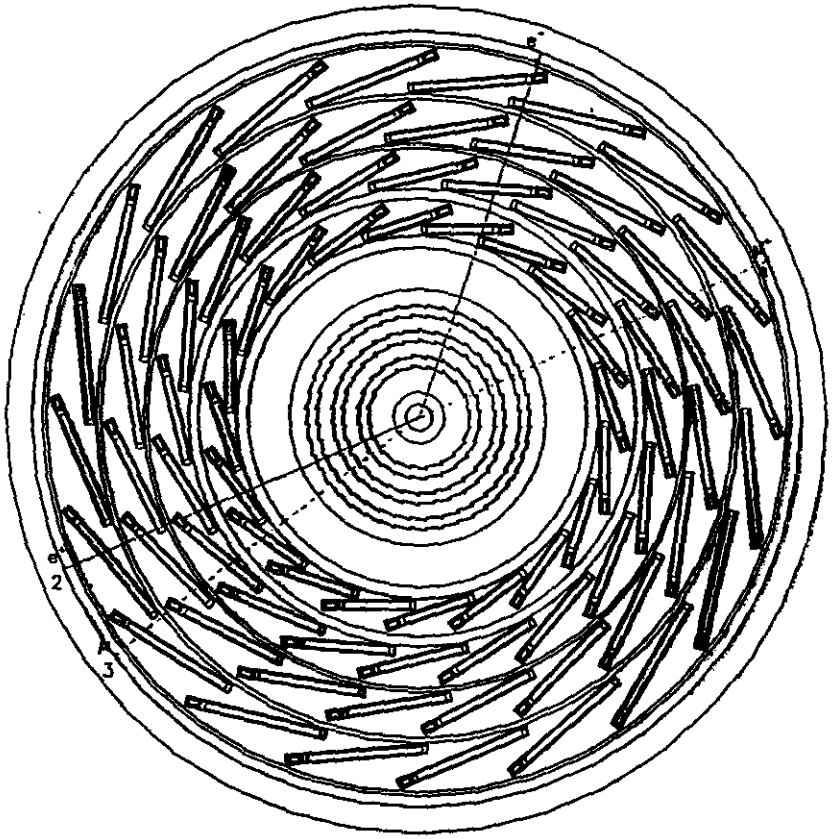


e^- + pile up (10^{34})



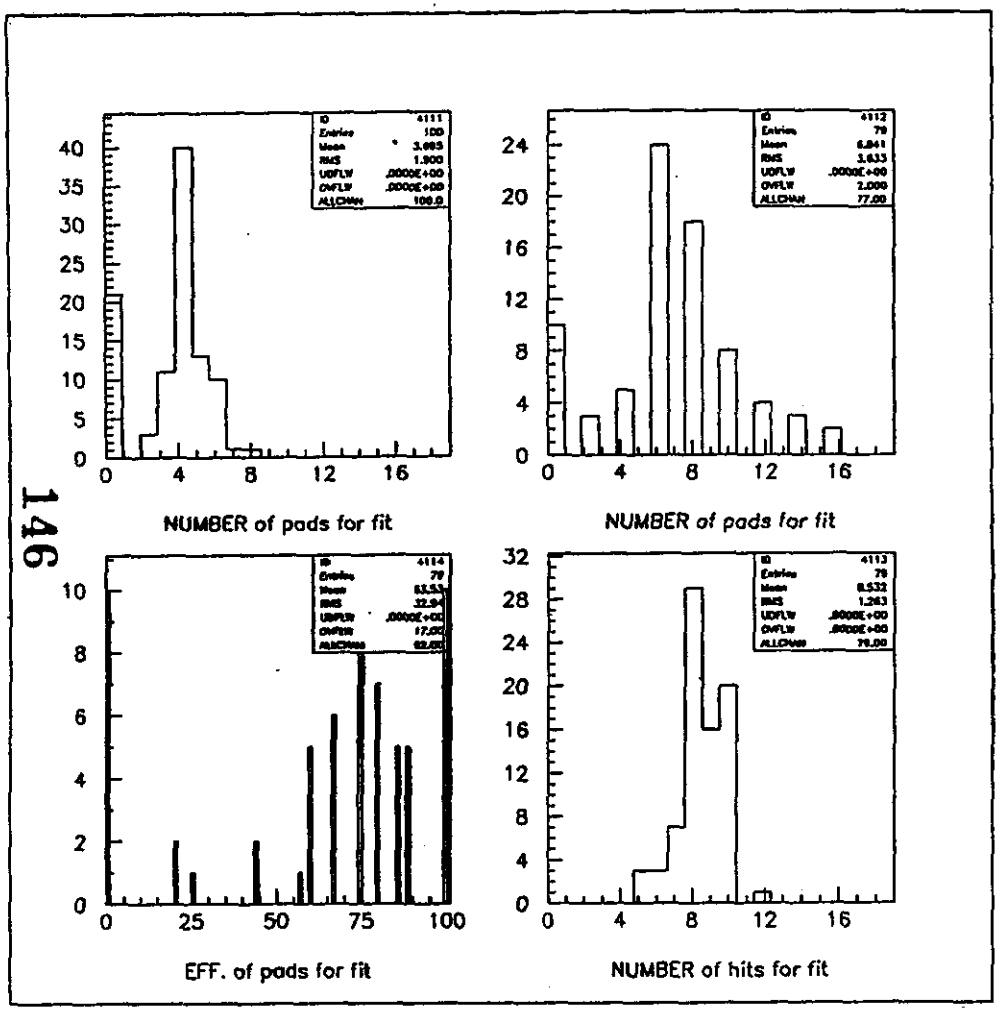


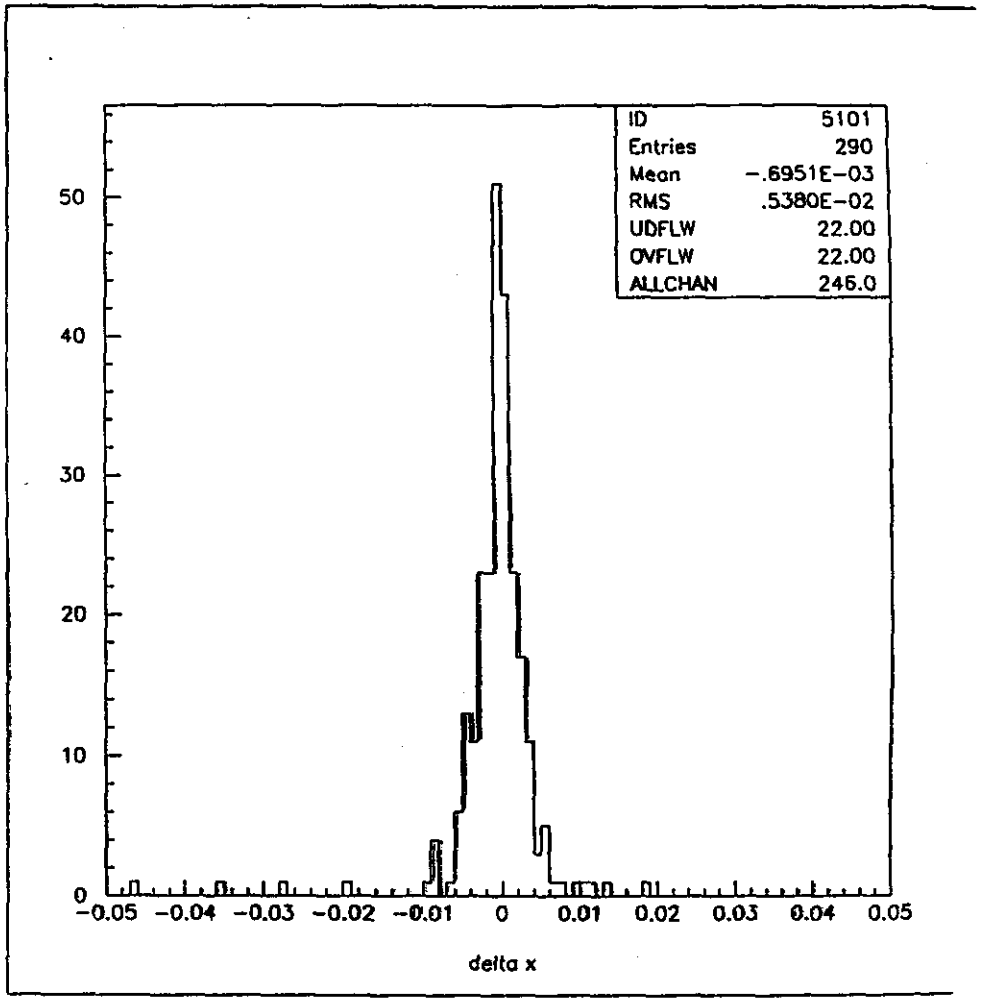




Higgs (150 GeV) + pile up

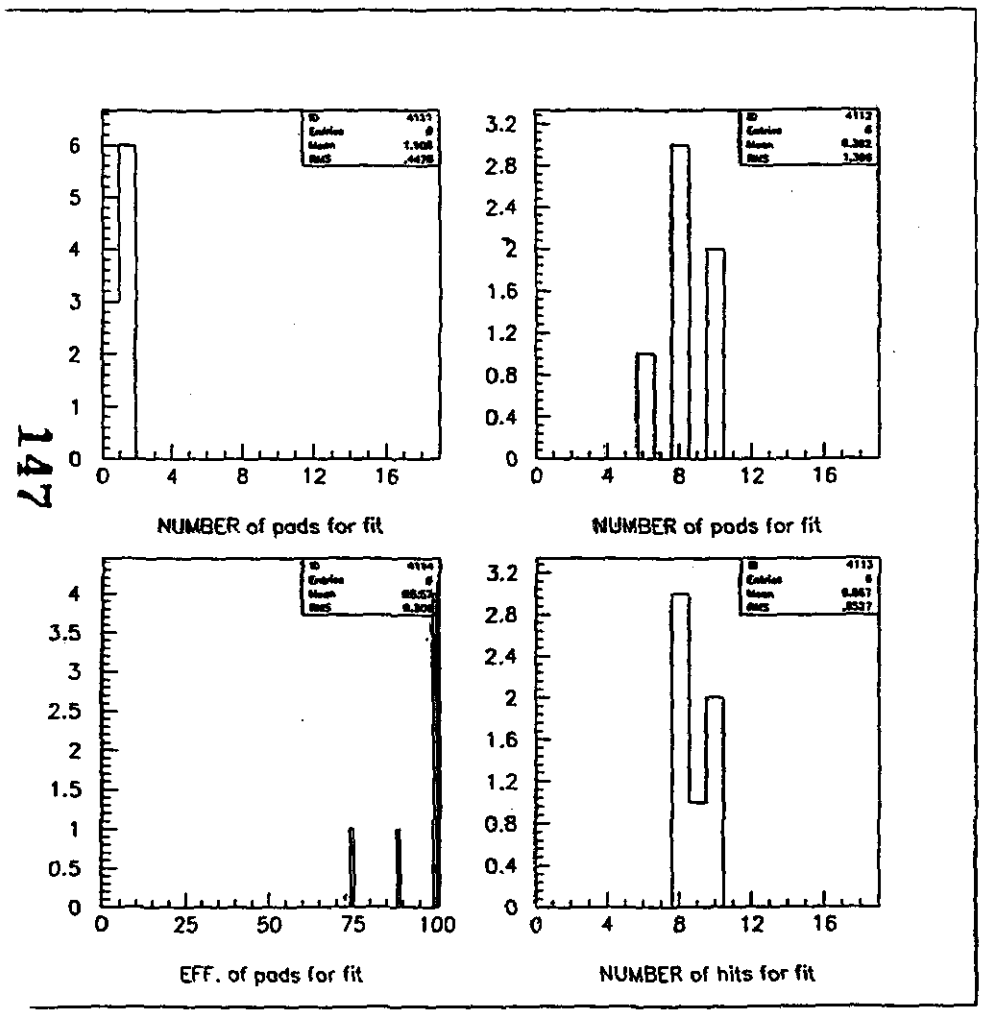
Higgs (150 GeV) + pile up E_t cut = 10 GeV

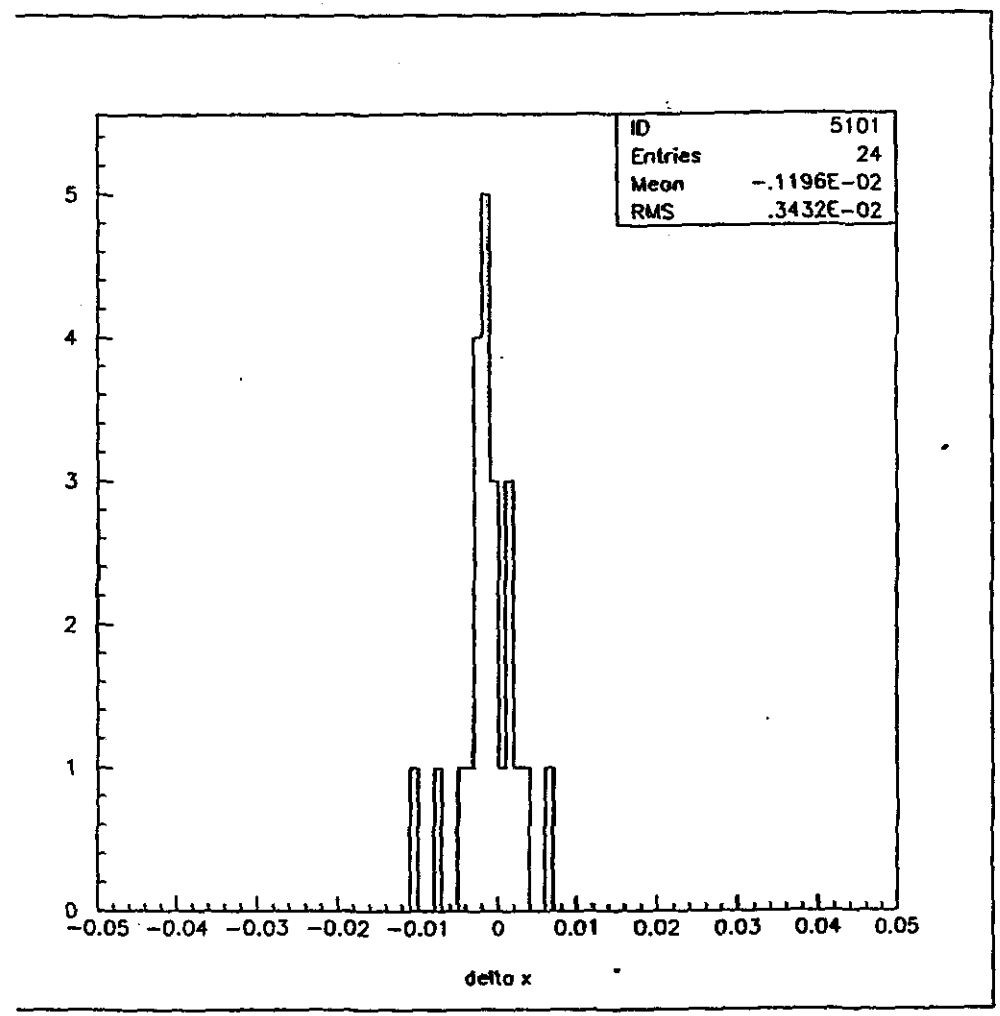




Higgs (150 Gev) + pile up

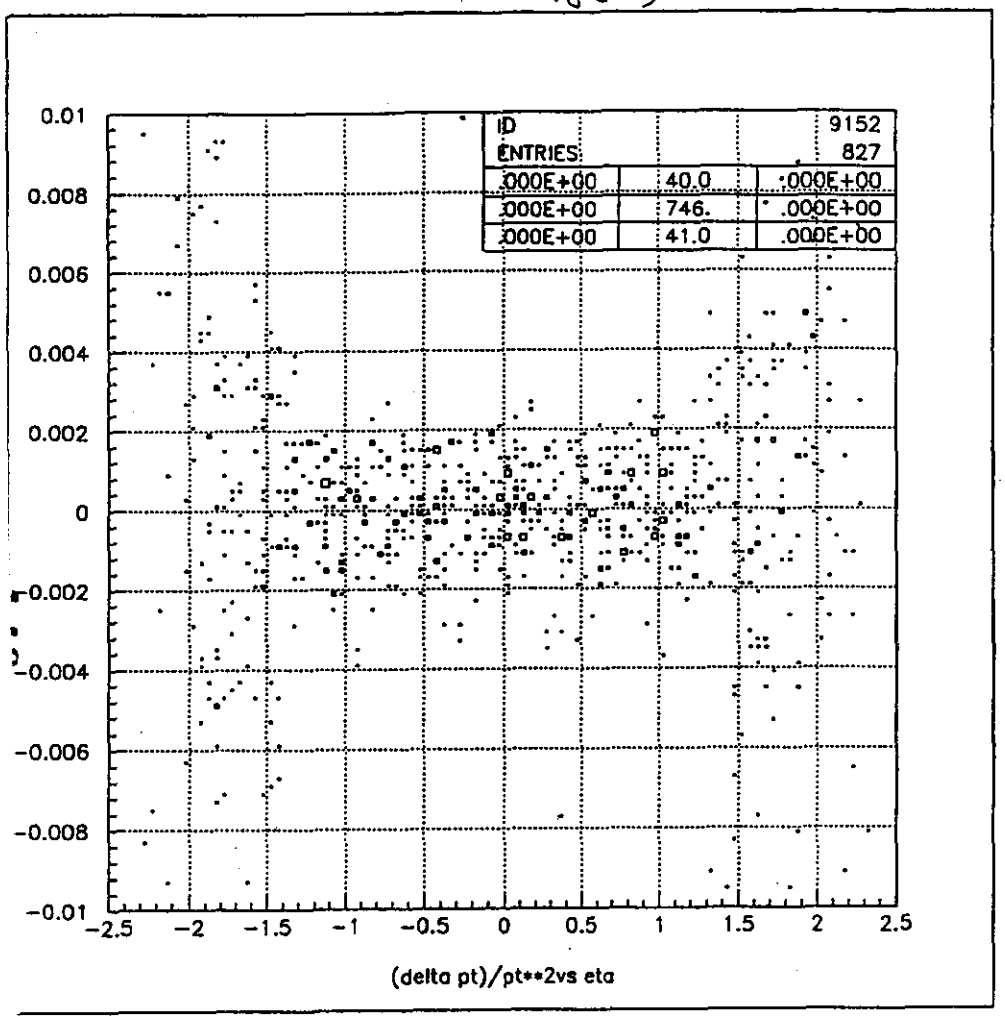
E_t cut = 100 Gev

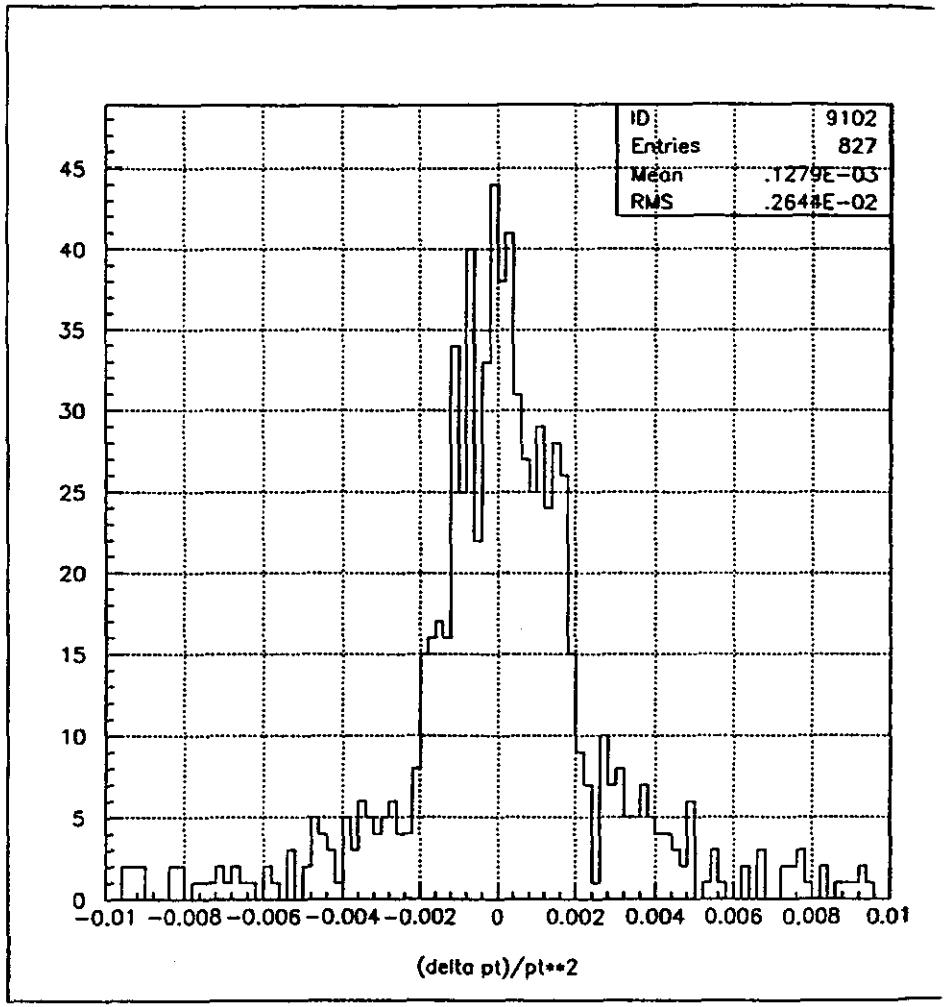




Моделирование оптимального угла для forward Pad

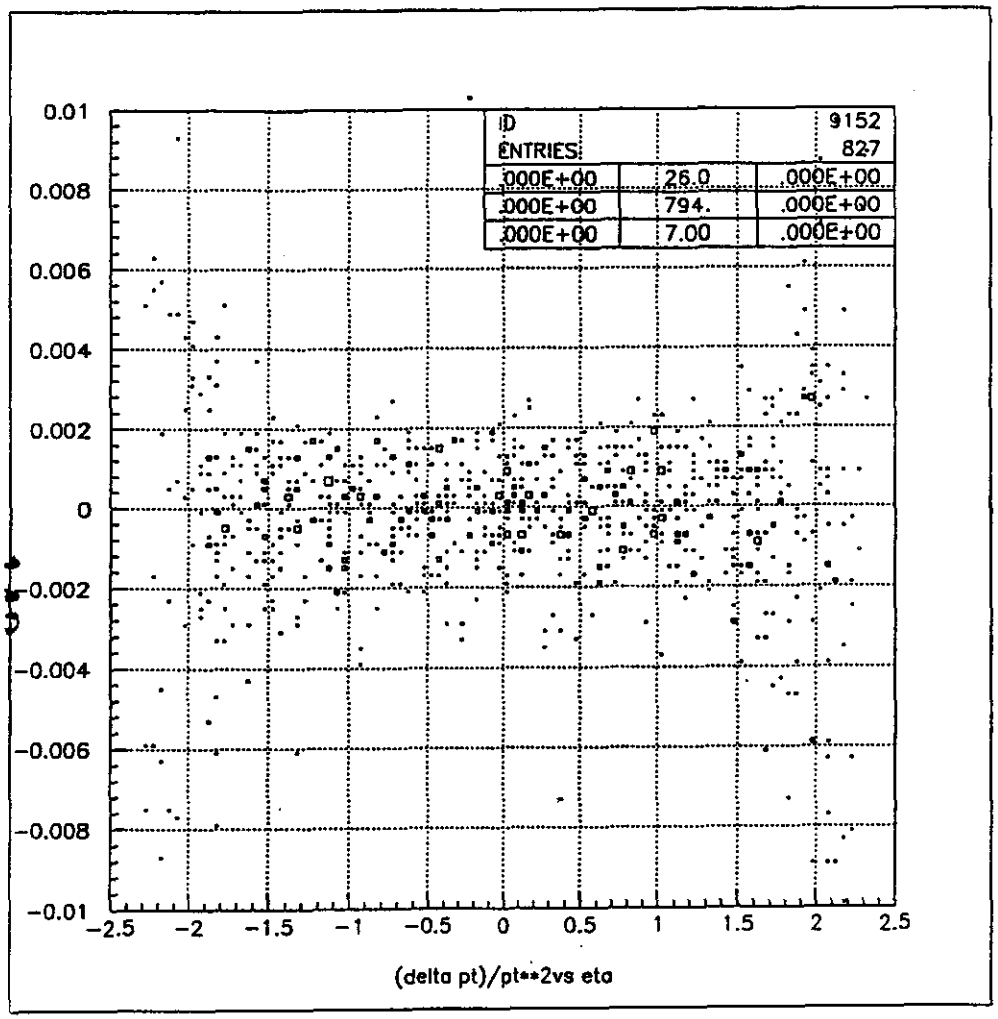
$tg(\alpha)$

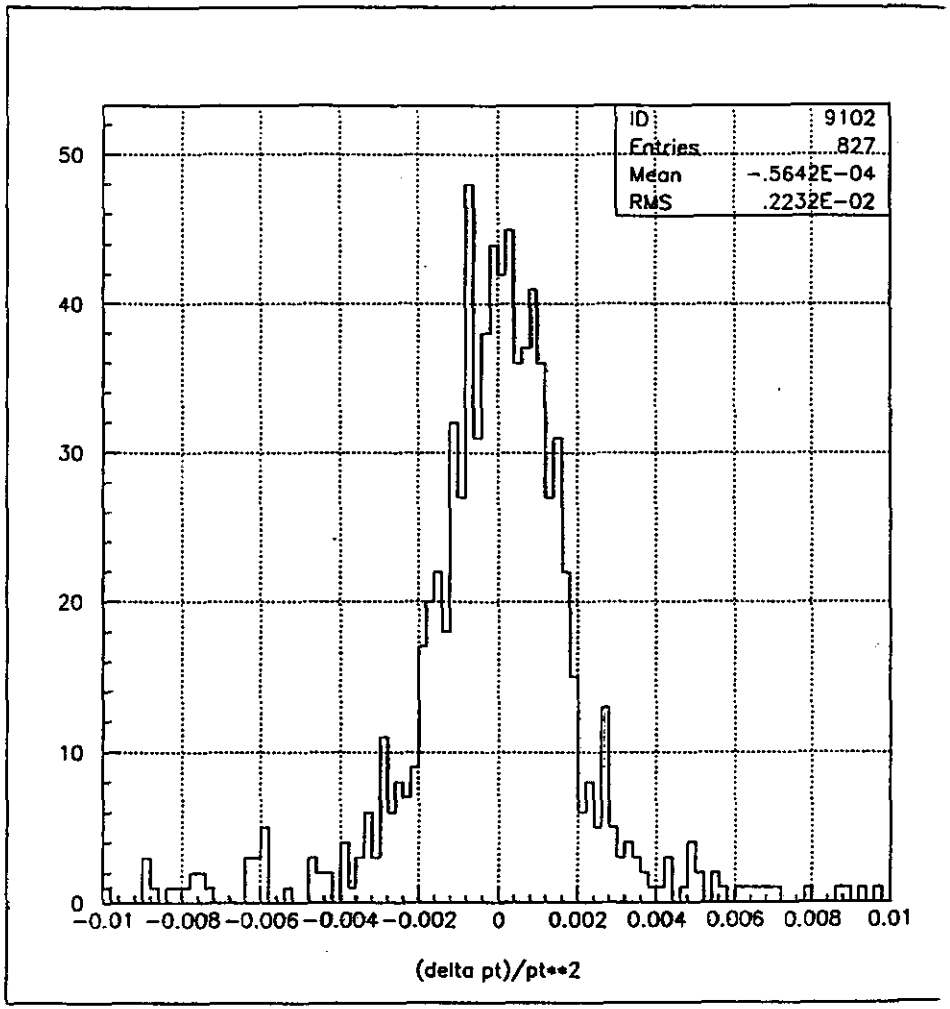




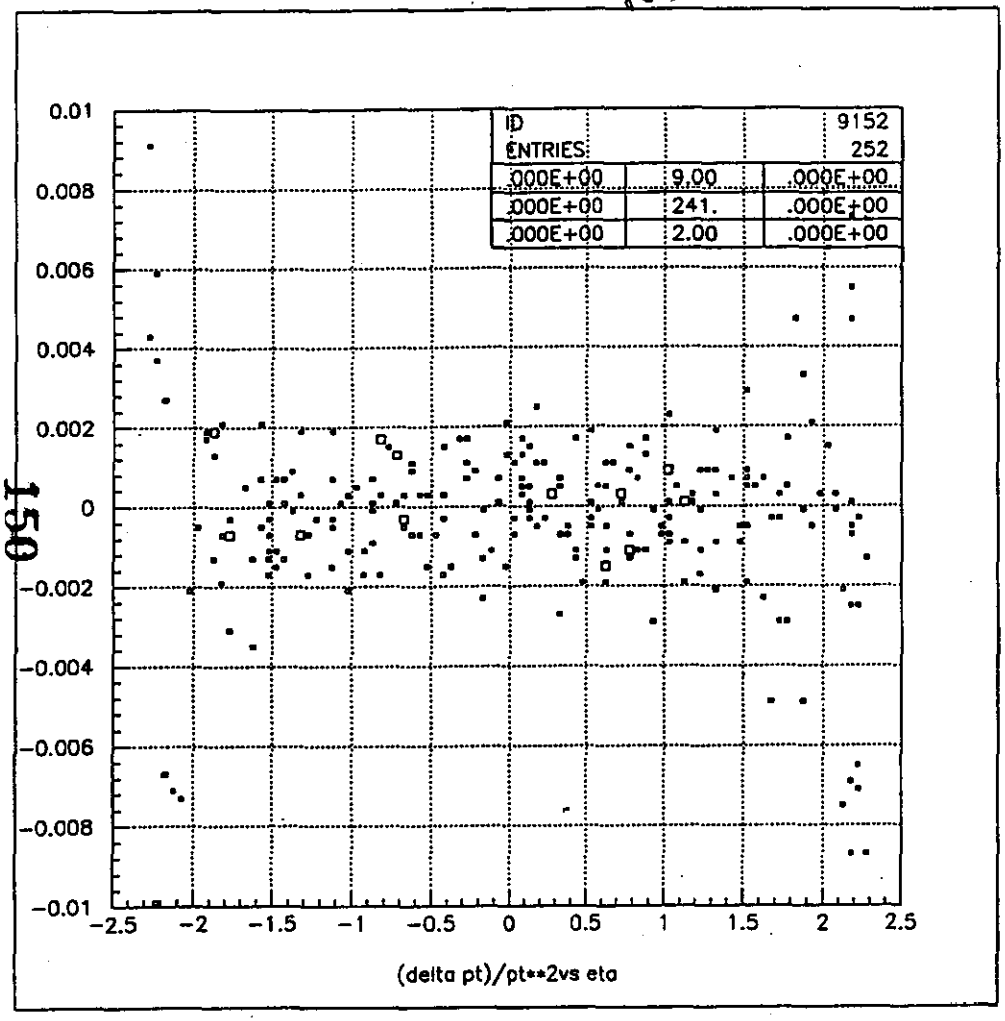
Выбор оптимального угла (stereo)

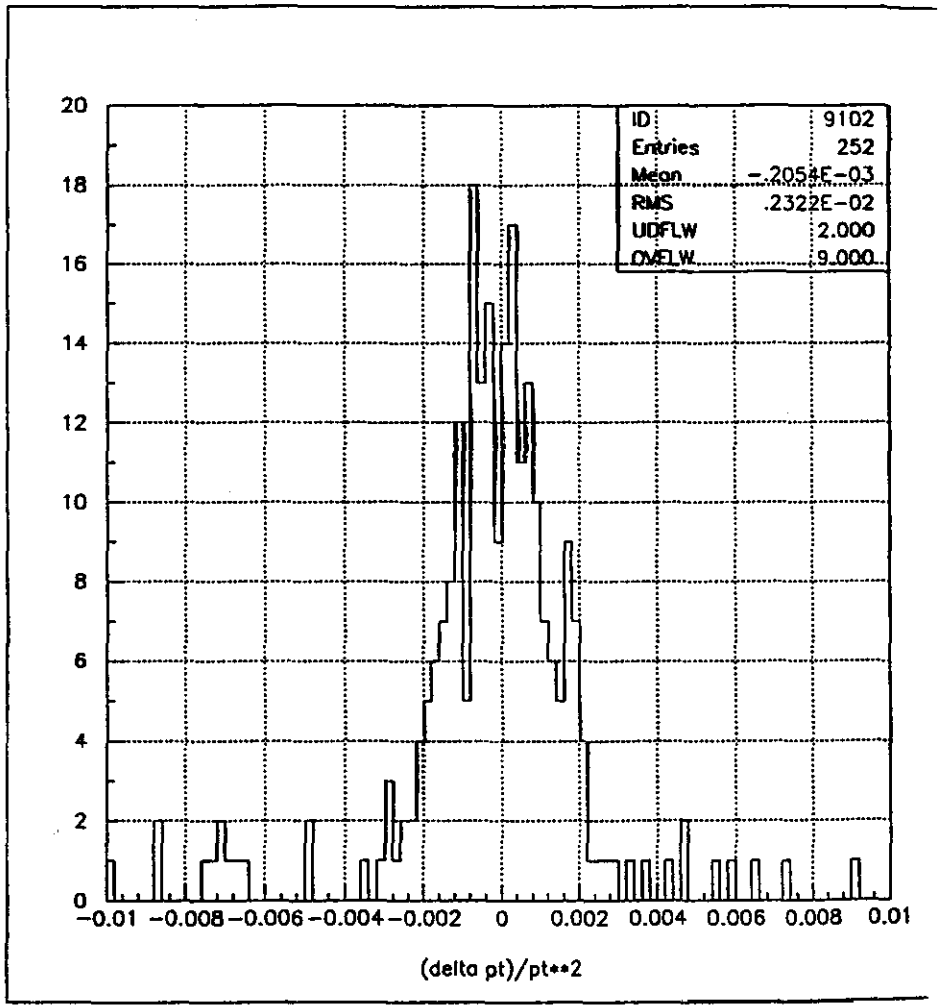
3½ (1)





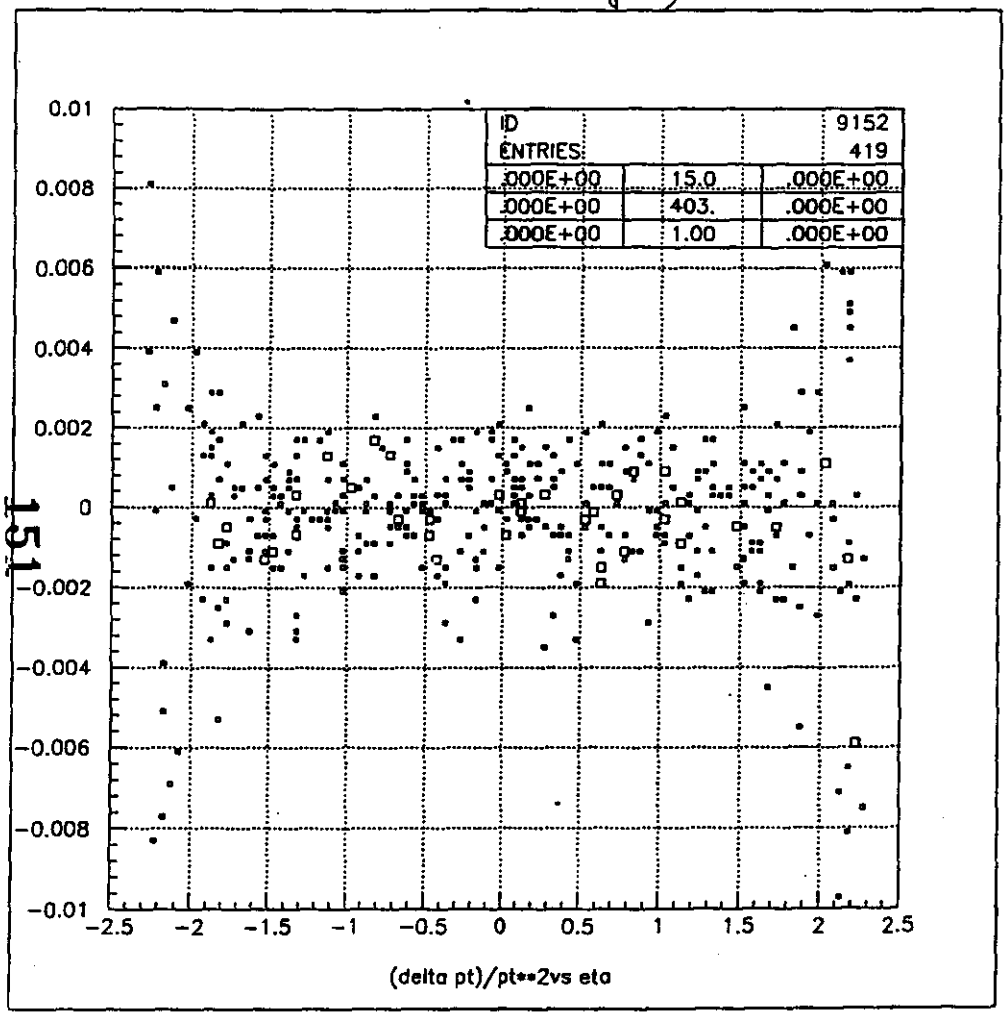
Моделирование оптимального
Stereoyzia forw. Pad.
Sty(2)

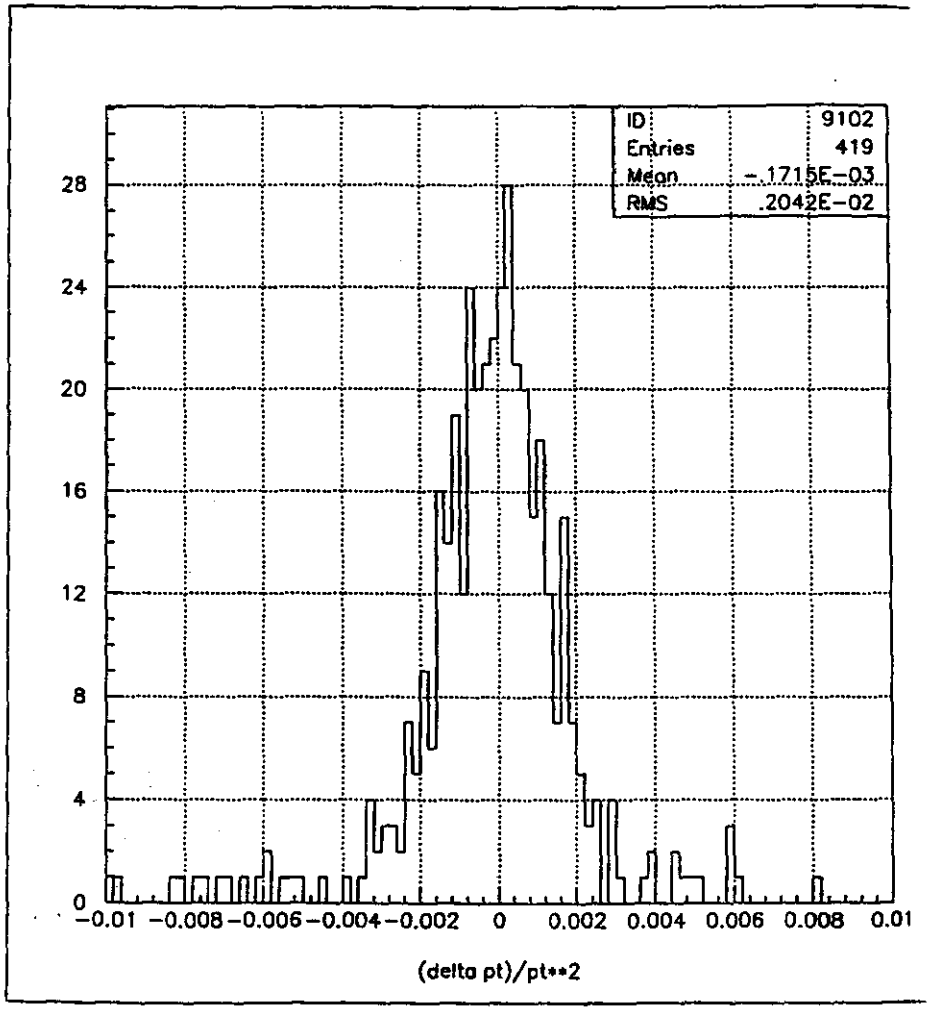




Моделирование оптимального угла form. Pad

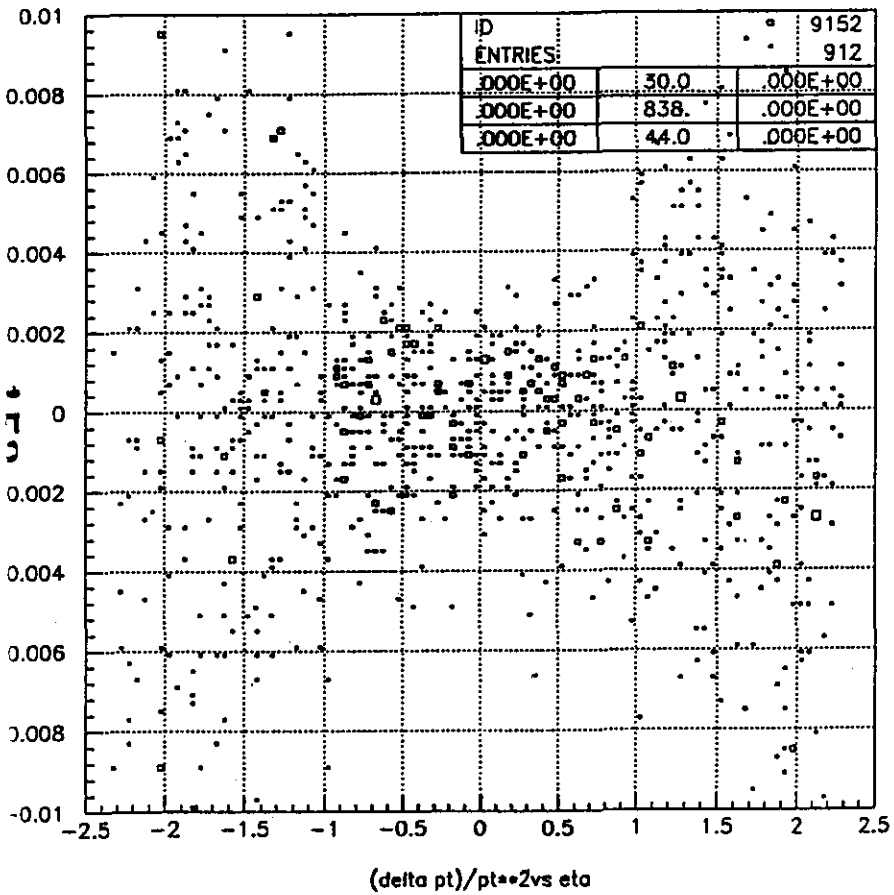
10 tg(α)

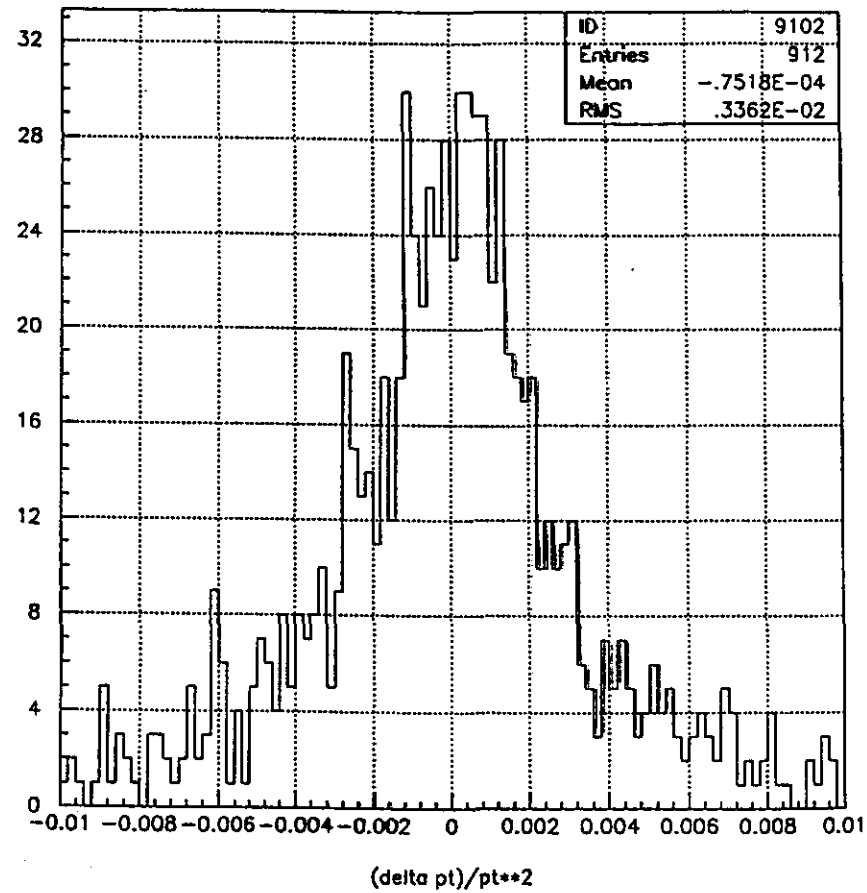




SMD Выбор оптимального Stereo_ang

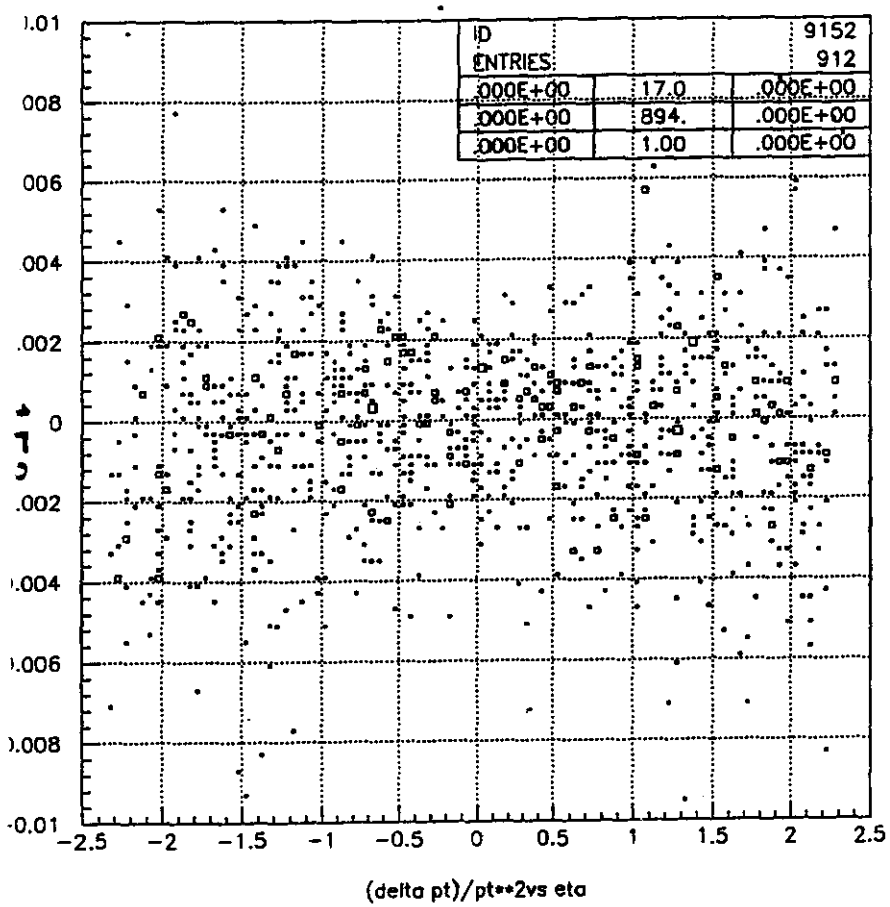
$tg(\alpha)$

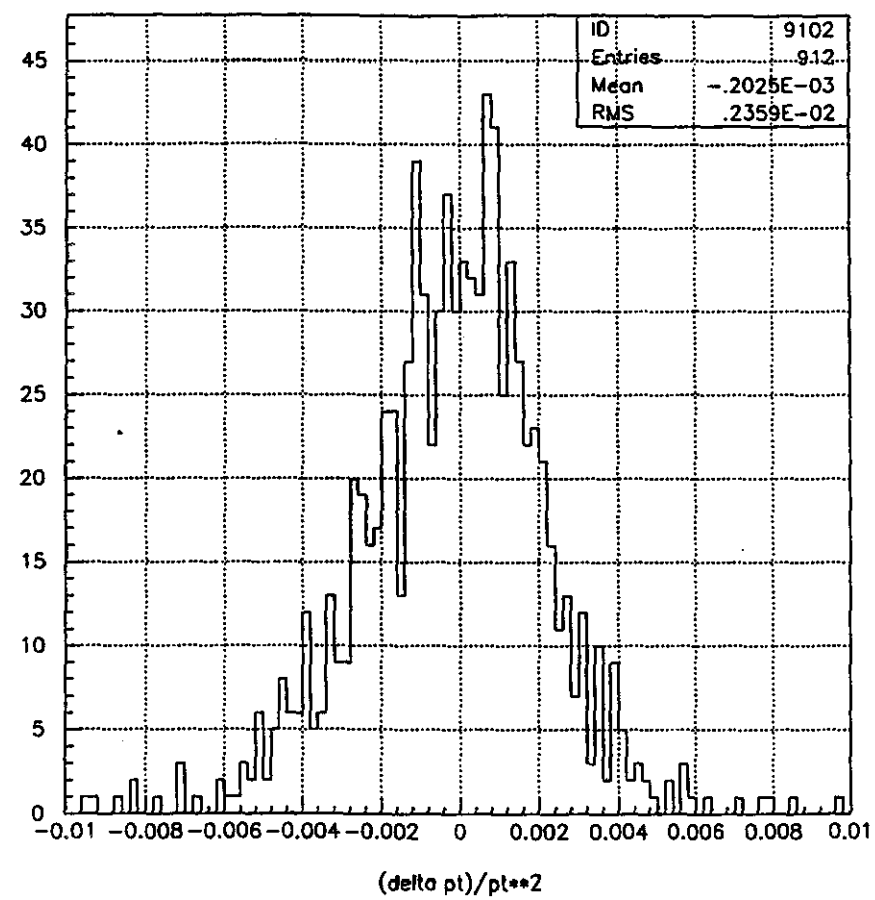




SMD Выбор оптимального Stereo-angl.

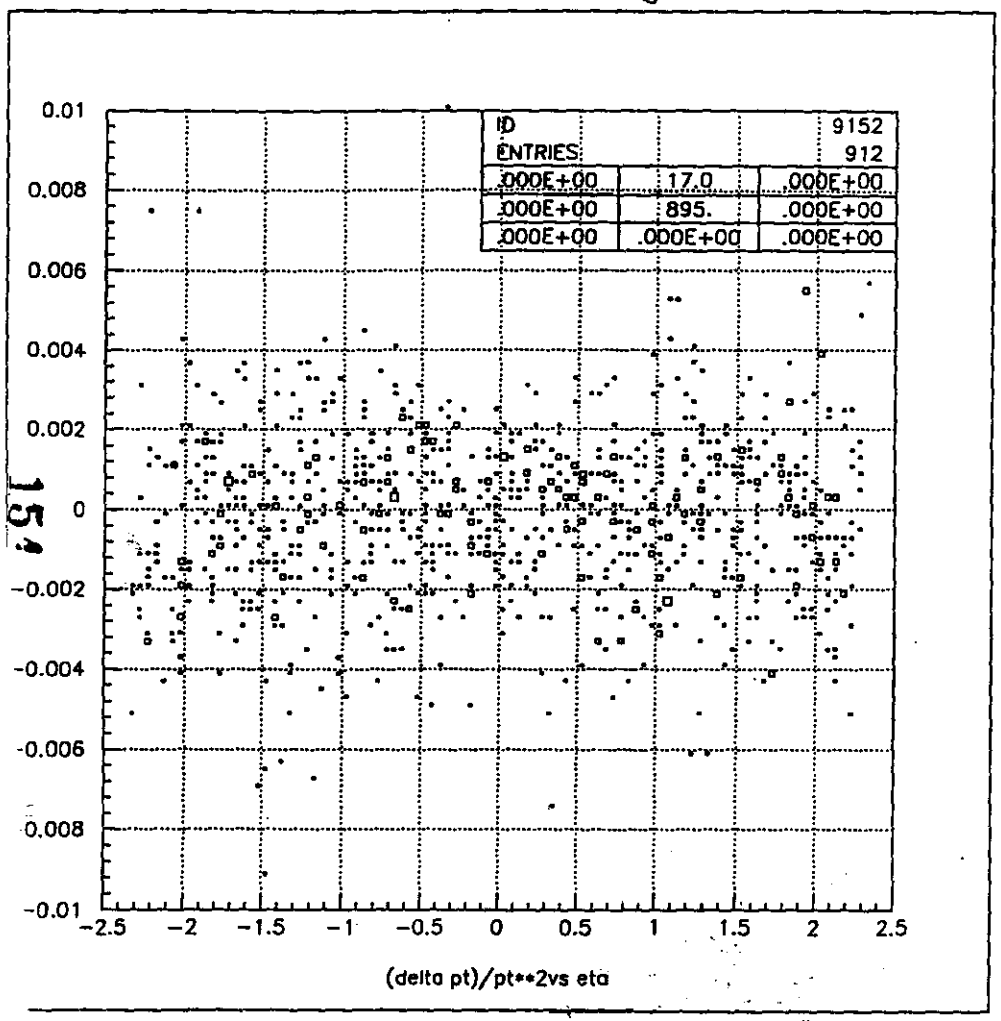
$3\,tg(\alpha)$

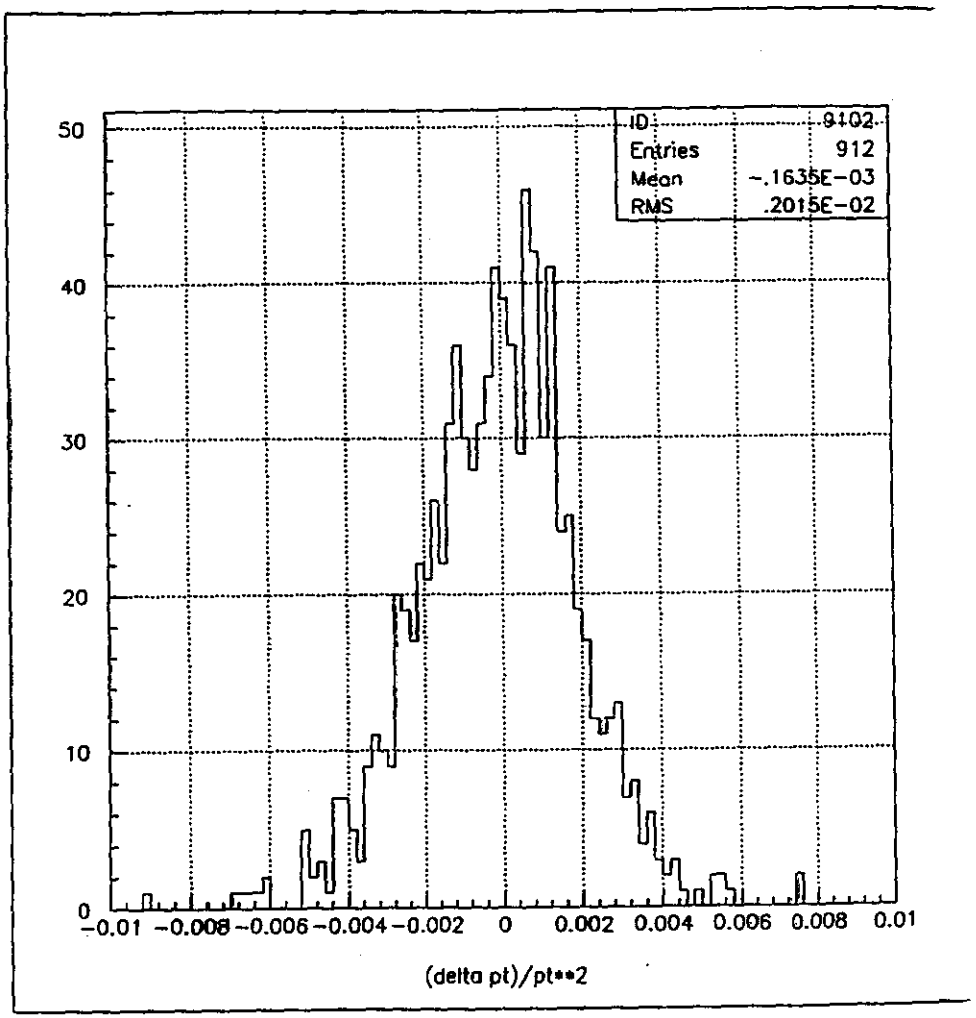




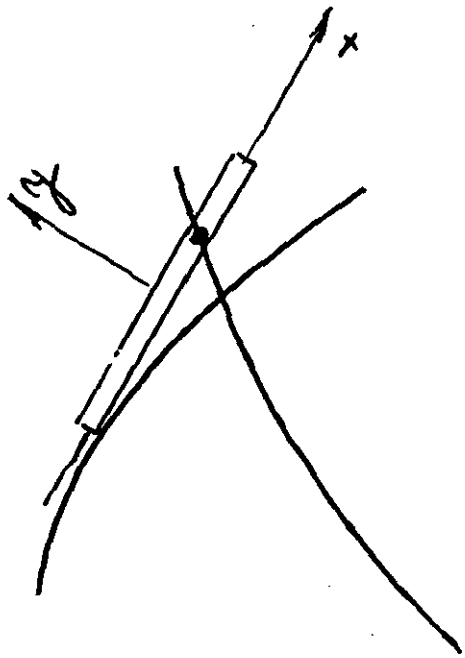
SMD Выбор оптимального Stereo_angl

5 tg(α)



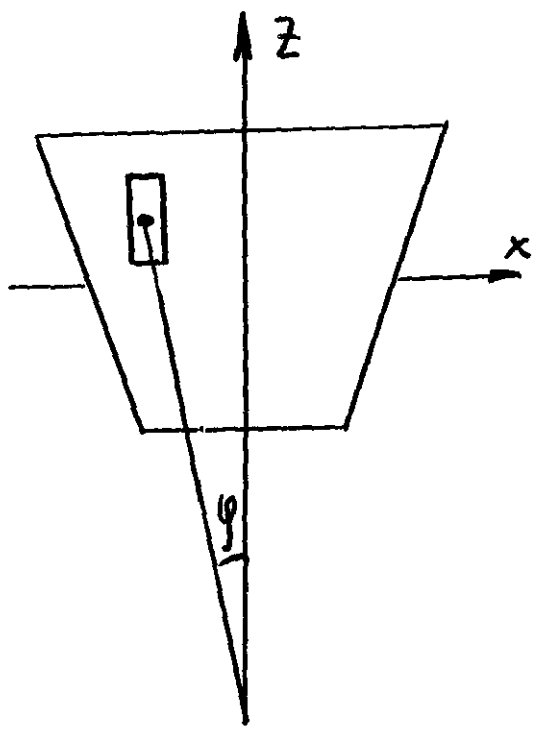


154



$$\varphi = f(x, y)$$

$$\sigma_\varphi \sim \sigma_x$$



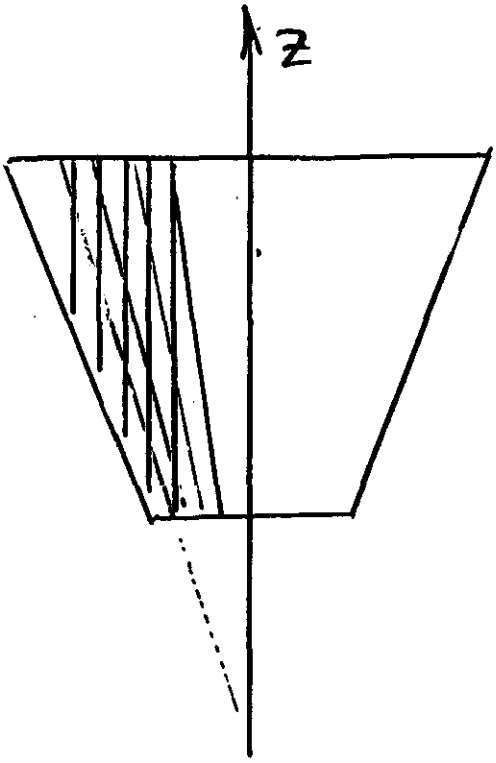
$$\varphi = f(x, z)$$

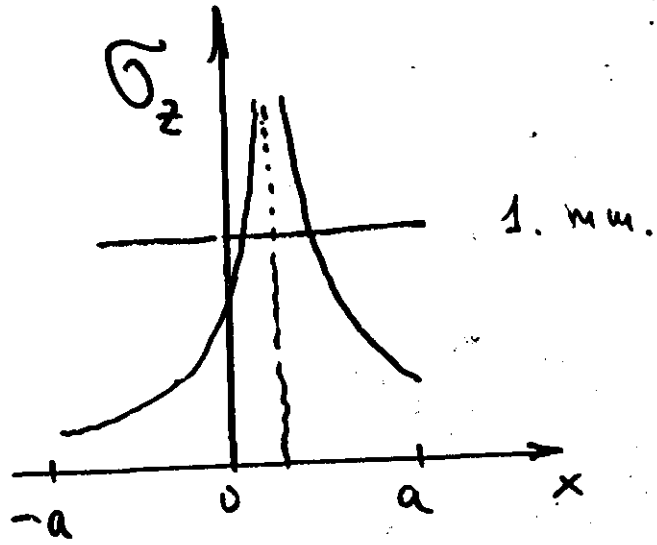
$$\sigma_\varphi \cdot r = \sigma_z \sin\varphi \oplus \sigma_x \cos\varphi$$

$$\mathrm{tg}\,\varphi > 2\,\mathrm{tg}\,(\text{stereo}) \sim \frac{\sigma_x}{\sigma_z}$$

1) $\sigma_z \downarrow \qquad \sigma_\varphi \sim \frac{\sigma_x}{r}$

2) $f(x)$



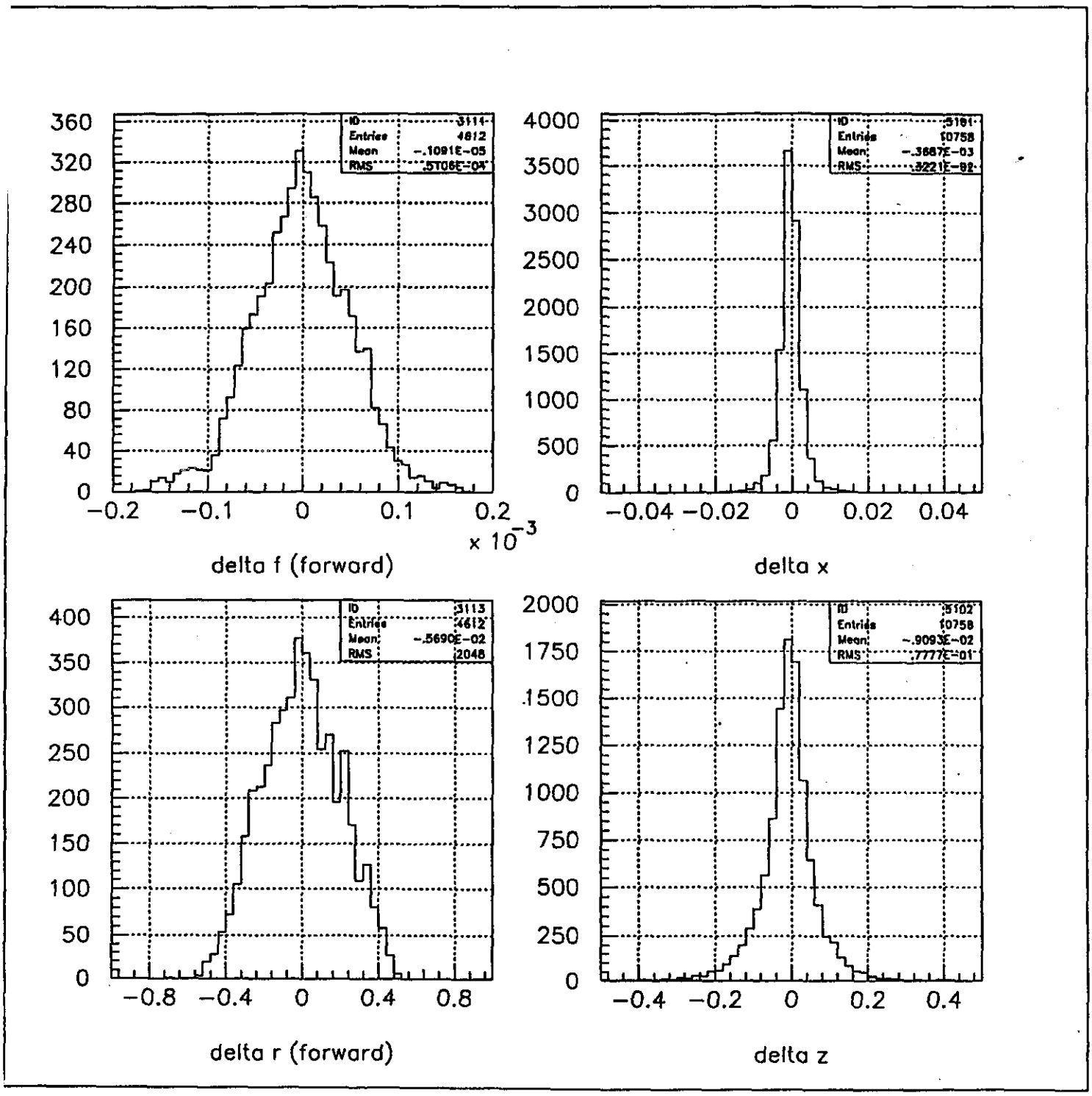


$\varphi = f_j(\text{Stereo})$

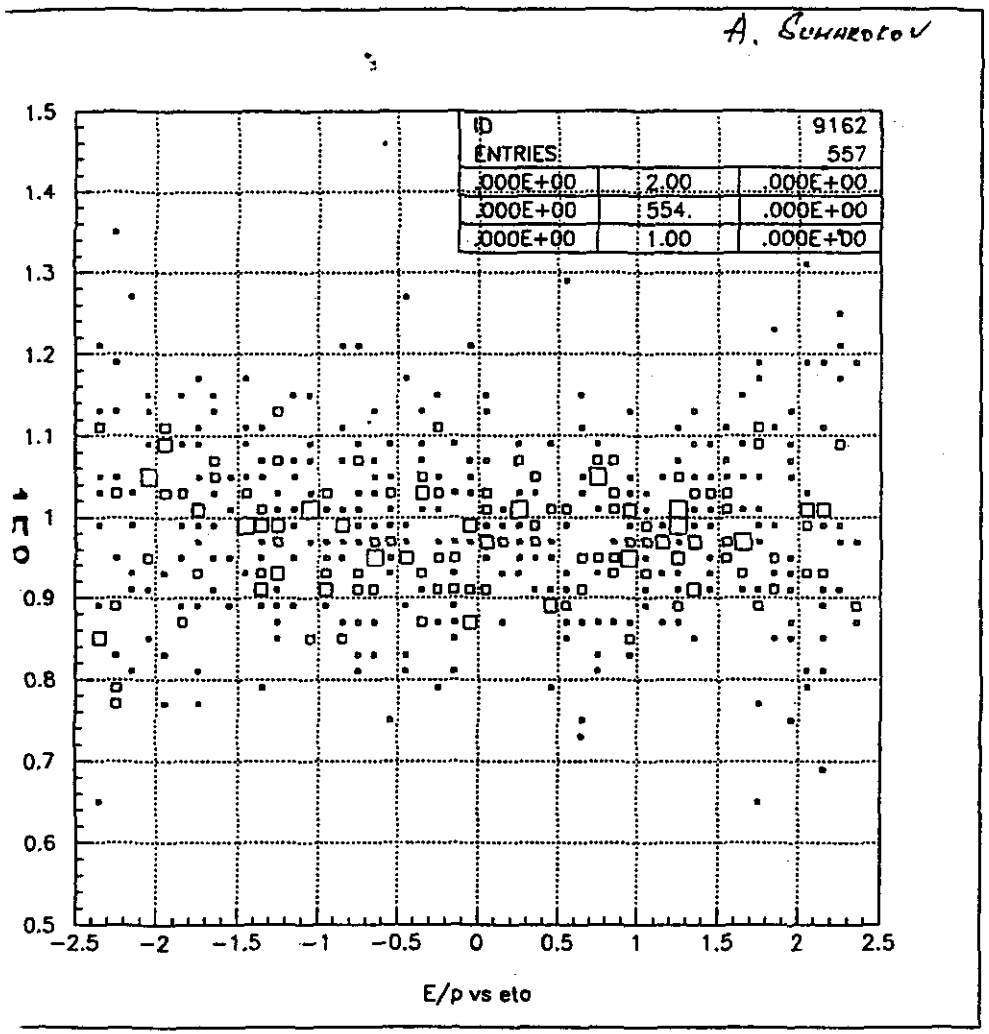
3. Stereo(φ)

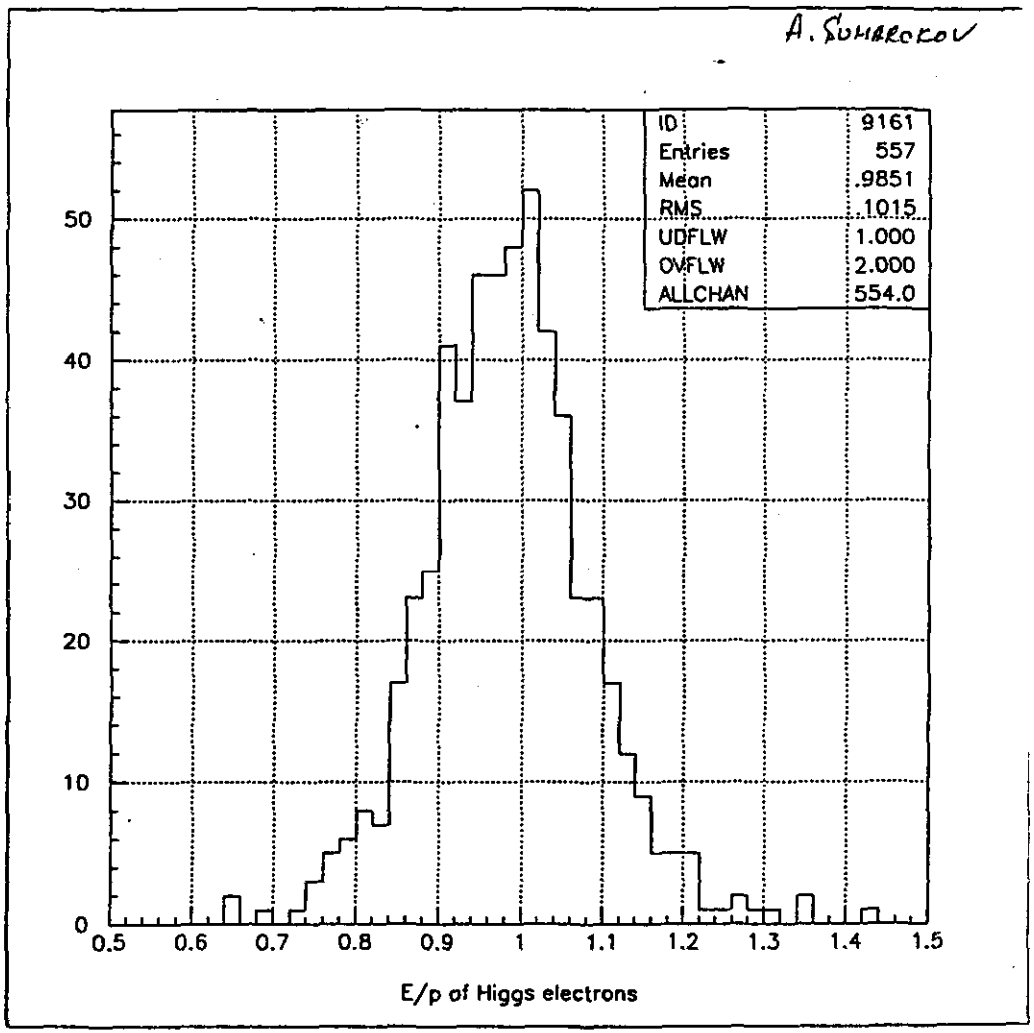
$\sigma_\varphi \sim \sigma_x$ – exellent

Single track

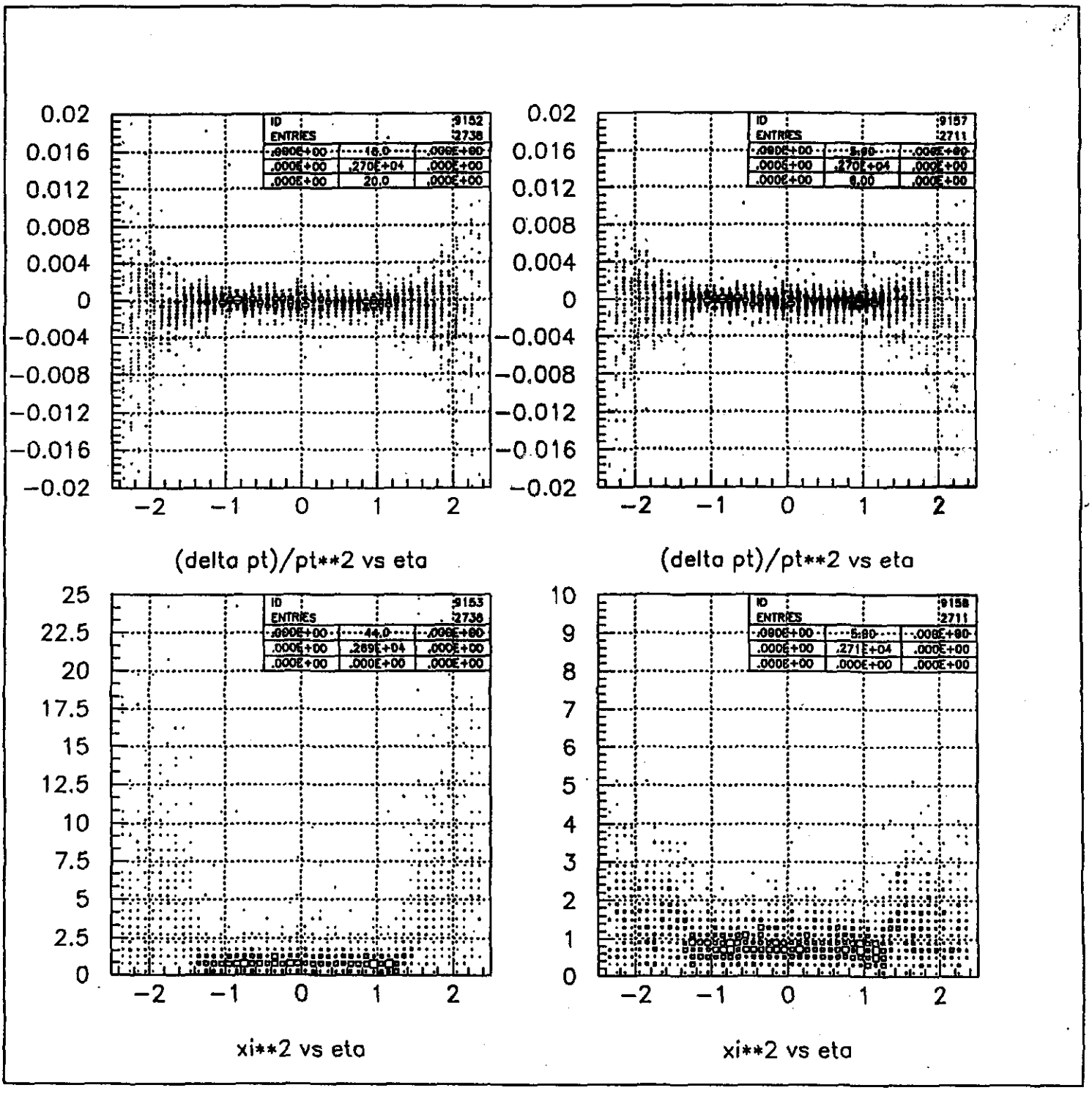


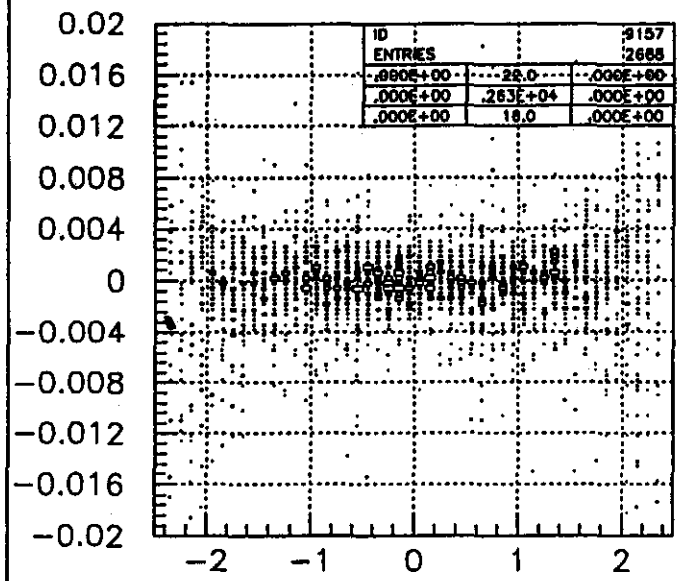
Single Track (p = 100 GeV, η - random).



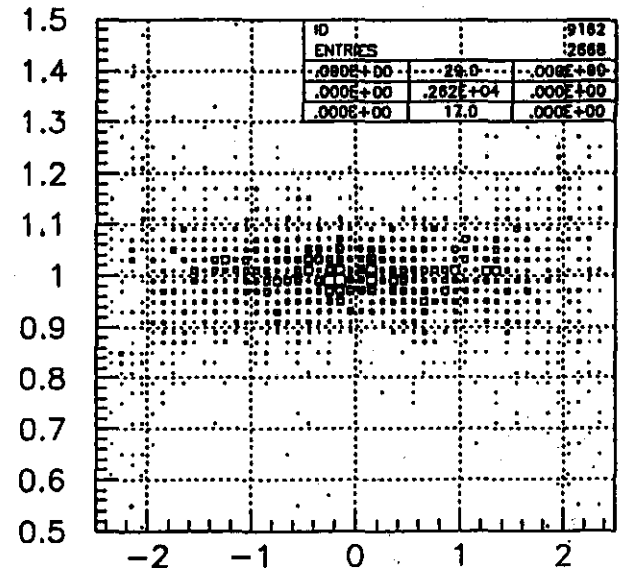


Single track

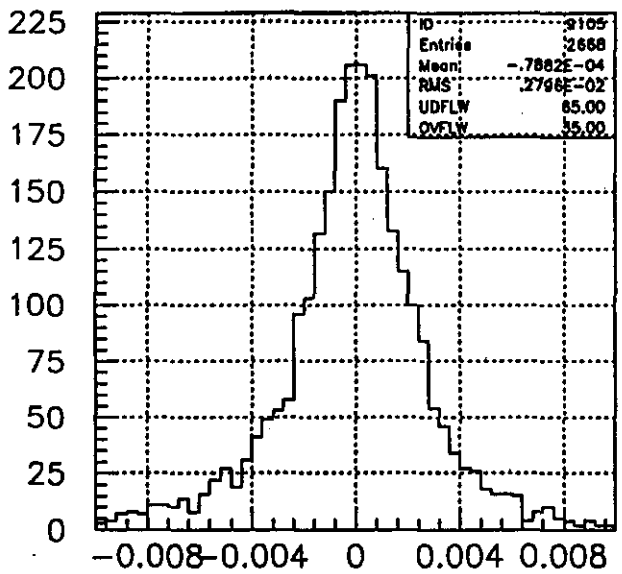




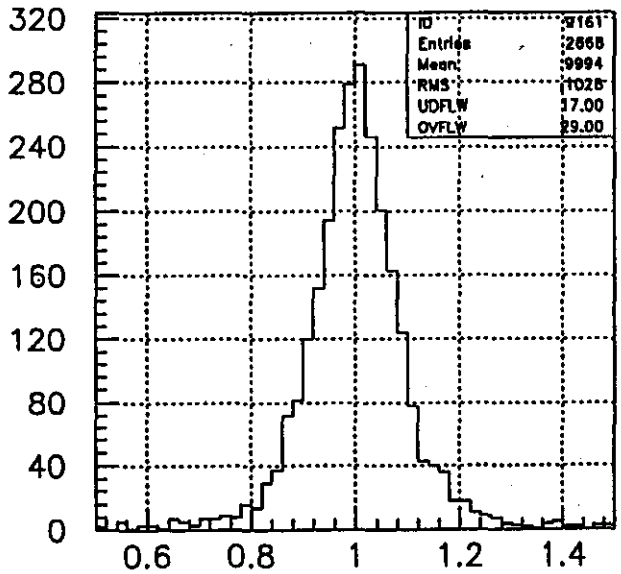
d(pt)/pt**2 vs eta



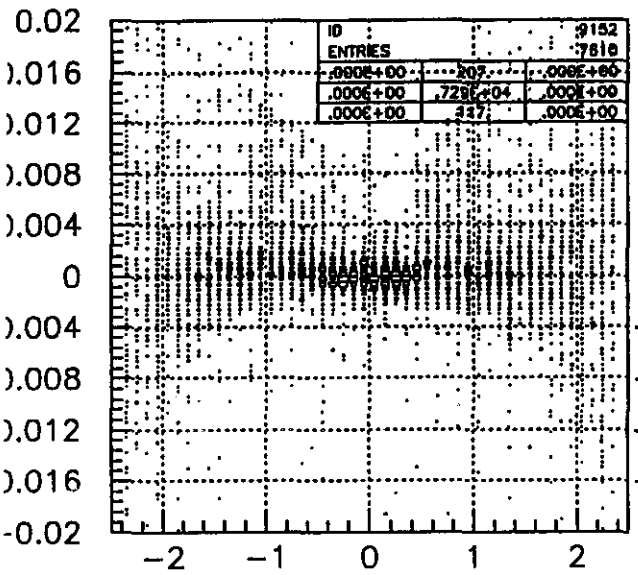
E/p vs eta



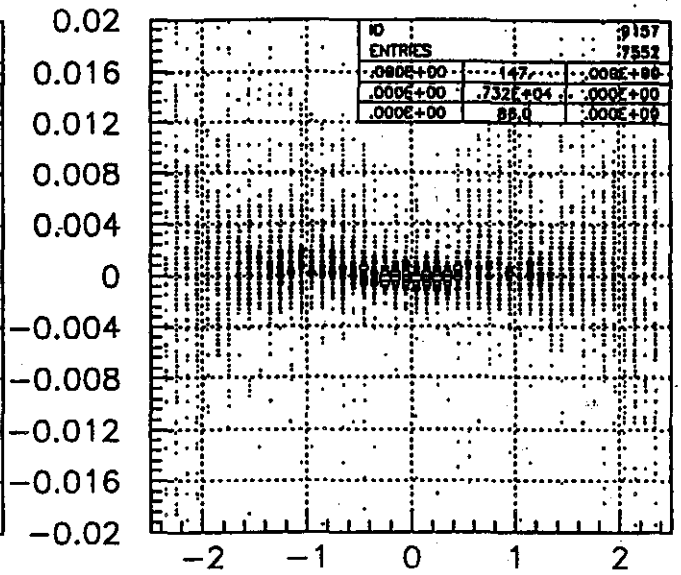
(delta pt)/pt**2



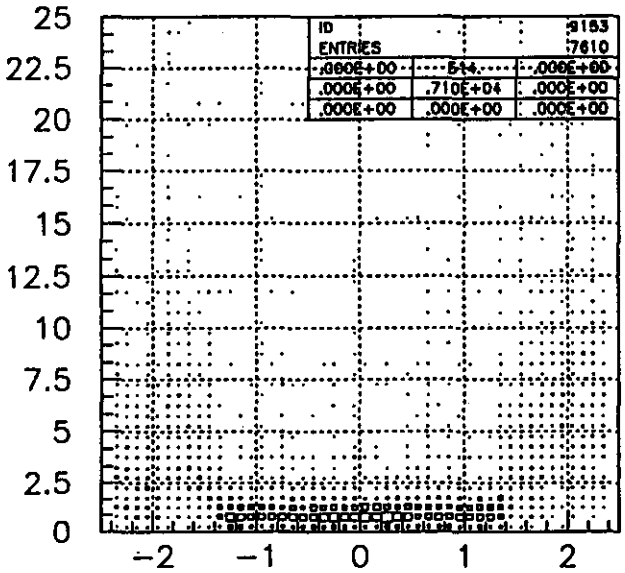
E/p of Higgs electrons



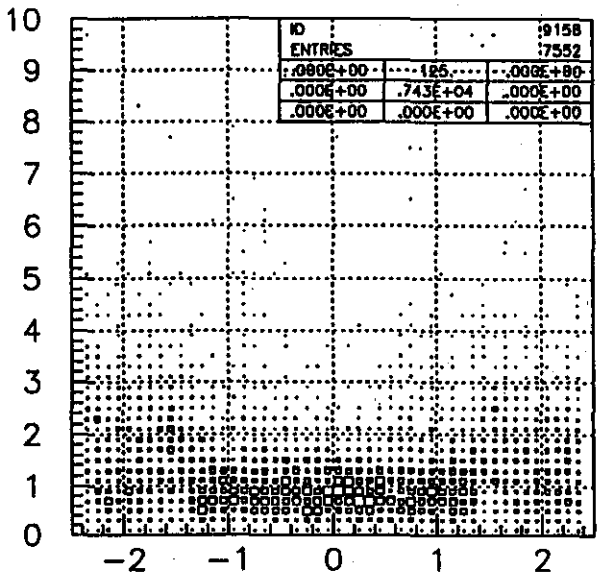
d(pt)/pt**2 vs eta



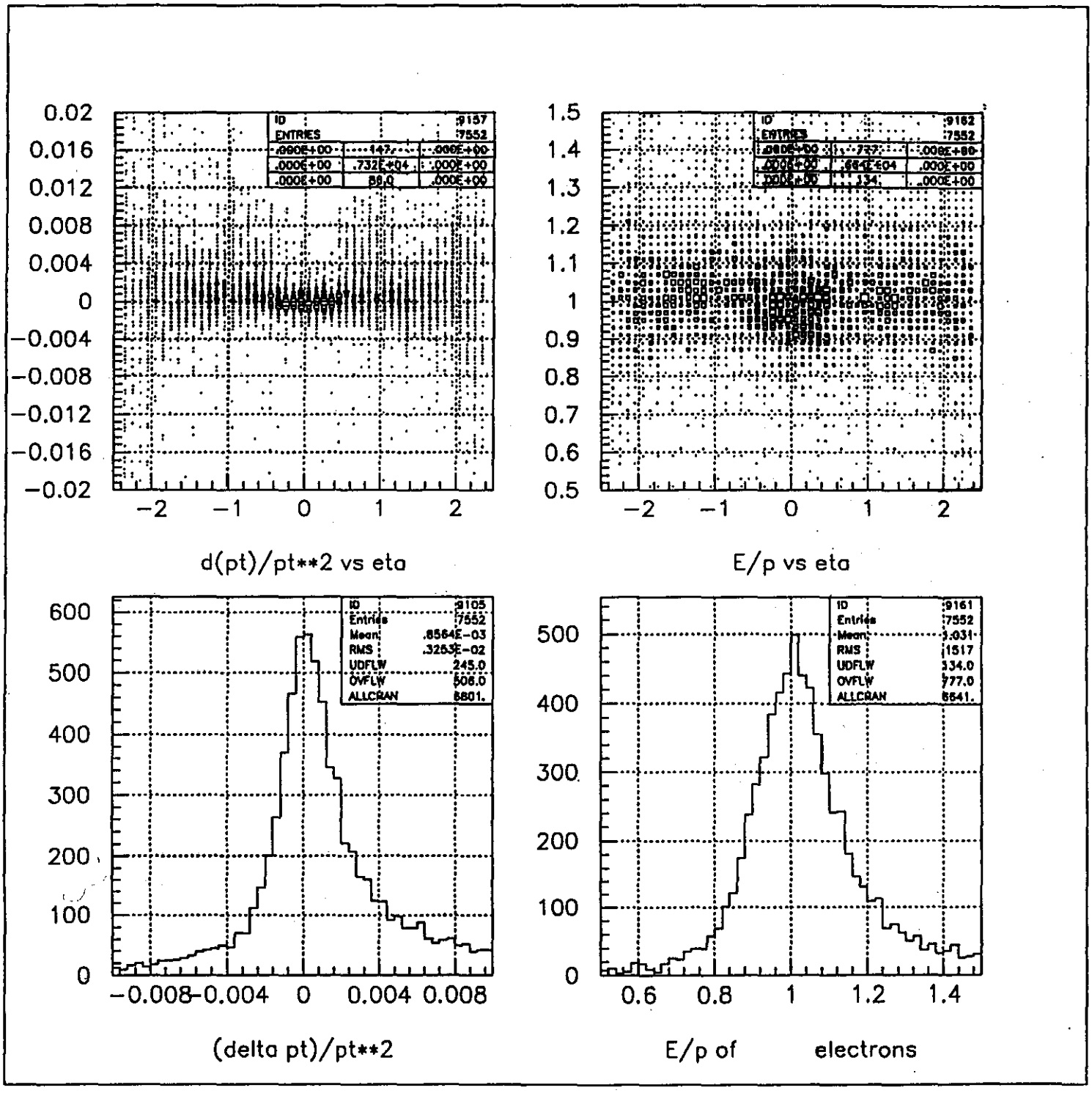
d(pt)/pt**2 vs eta

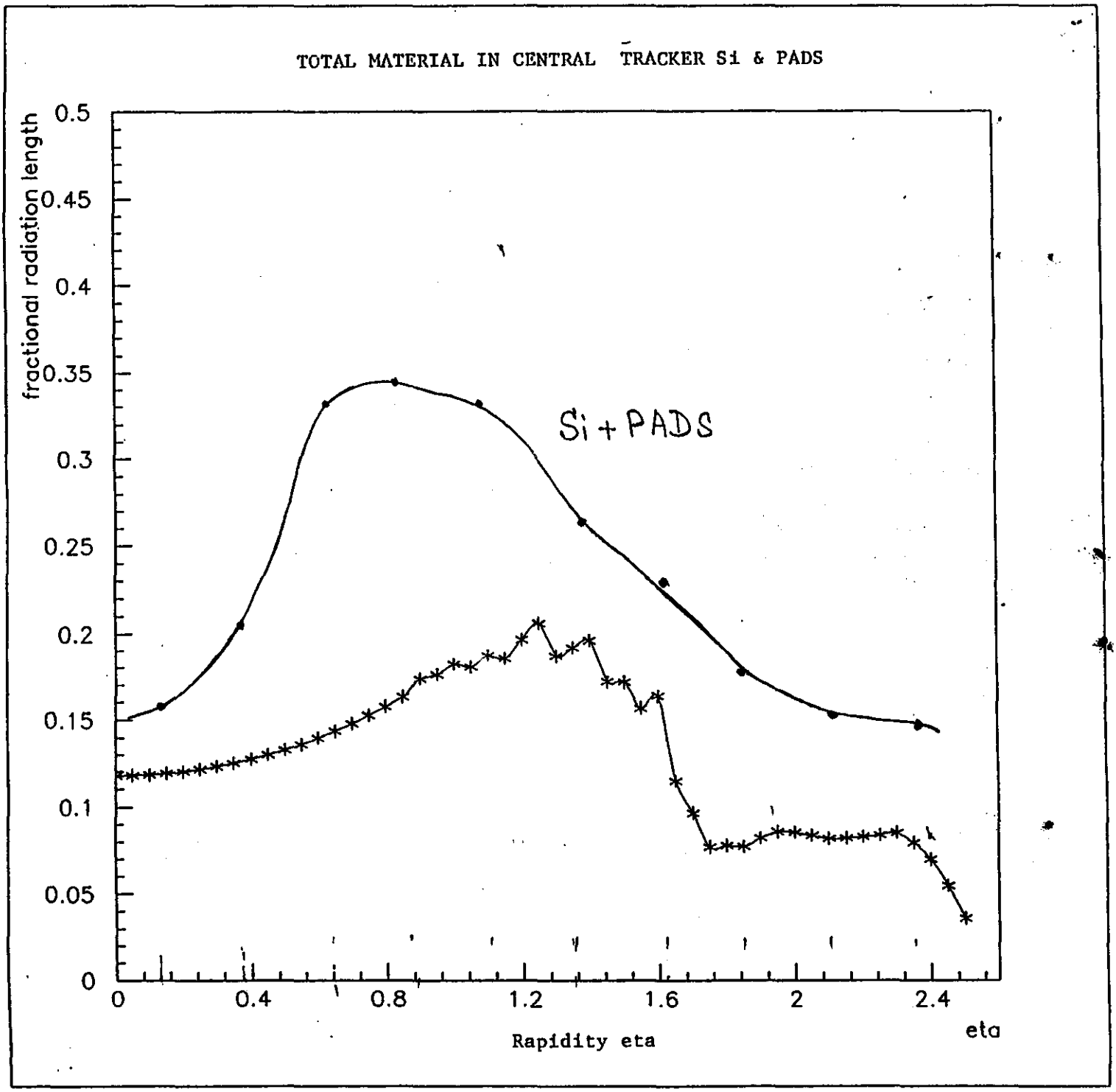


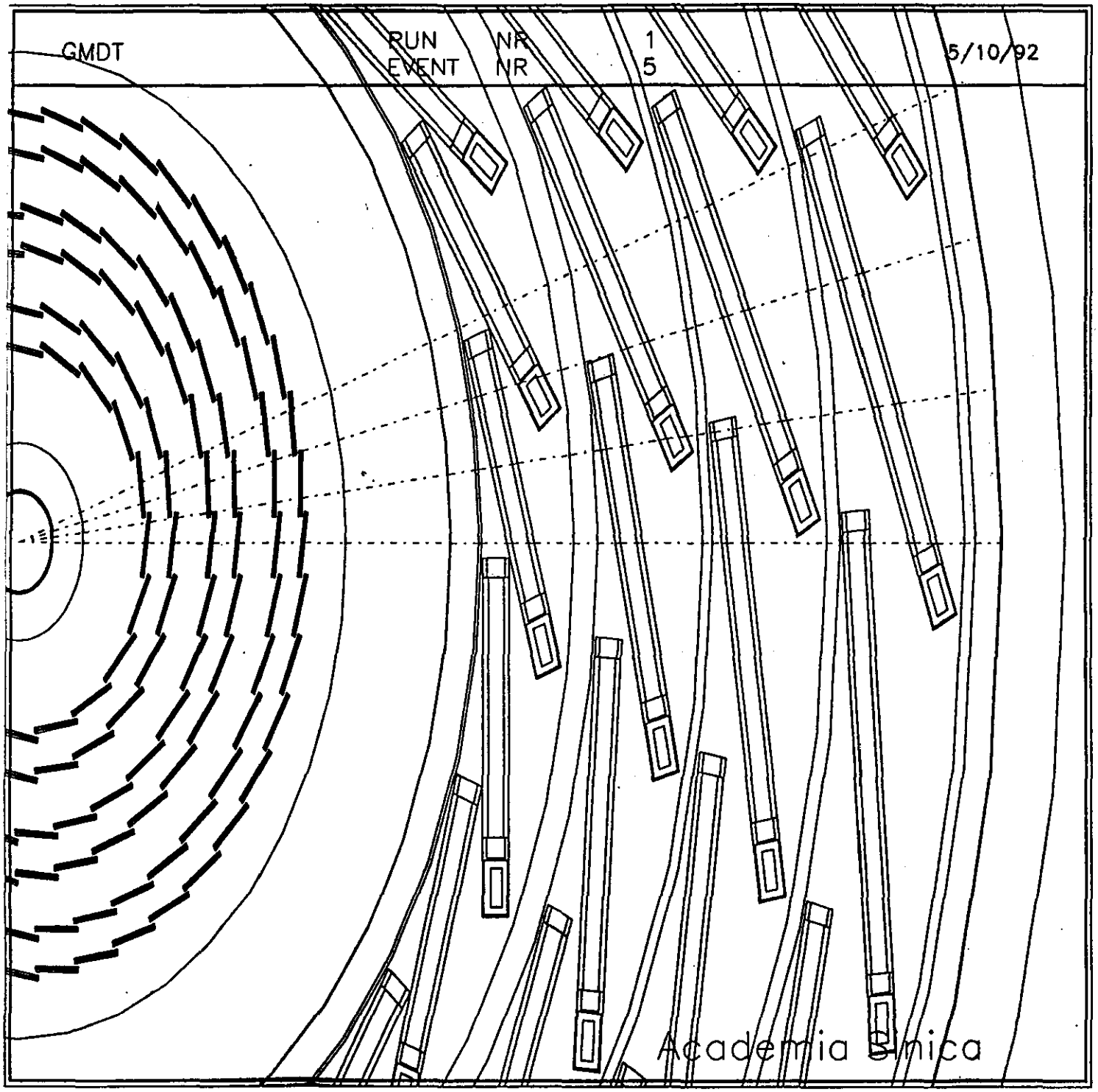
xi**2 vs eta

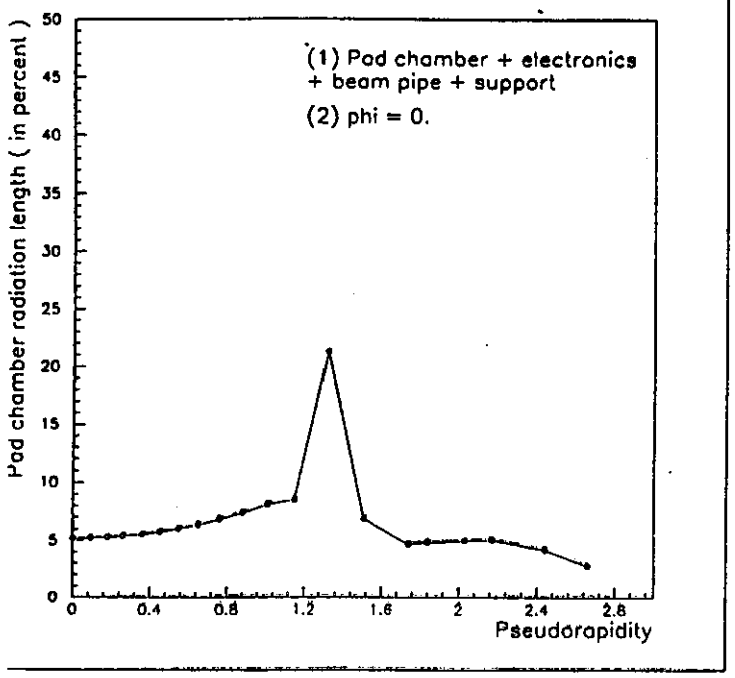


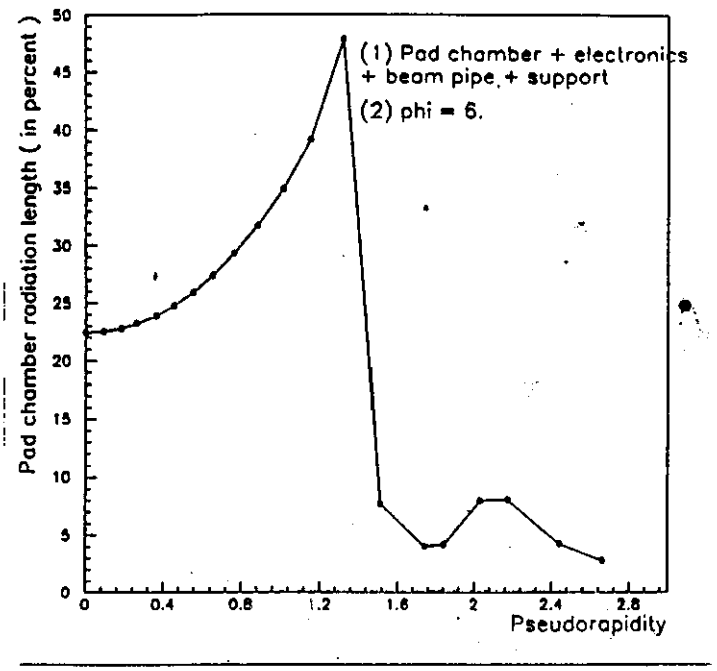
xi**2 vs eta

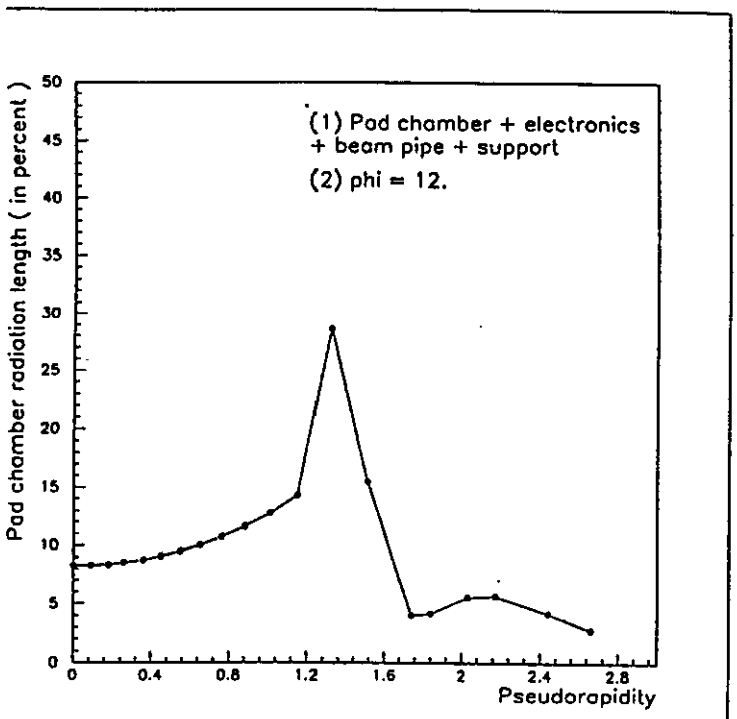

d(pt)/pt**2 vs eta
E/p vs eta
(delta pt)/pt**2
E/p of electrons

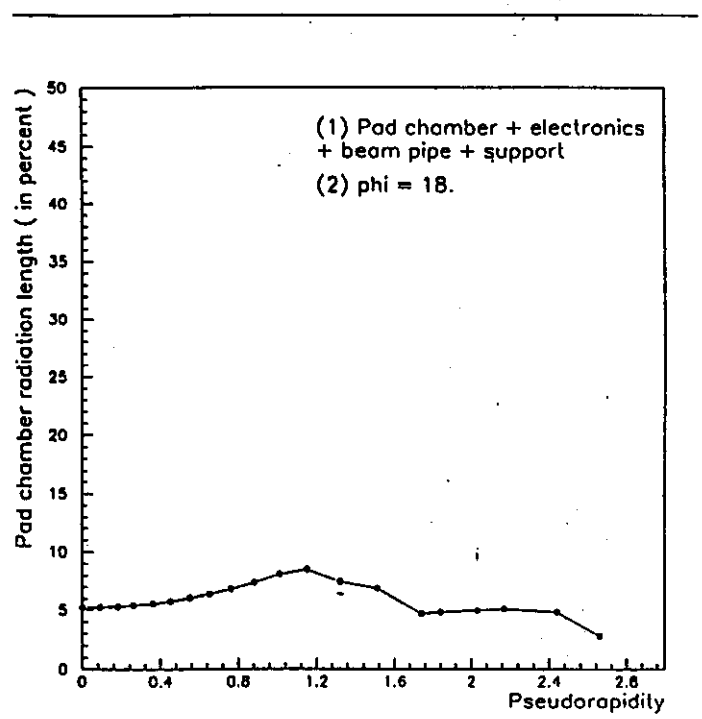

TOTAL MATERIAL IN CENTRAL TRACKER Si & PADS
fractional radiation length
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Si + PADS
0
0.4
0.8
1.2
1.6
2
2.4
eta
Rapidity eta

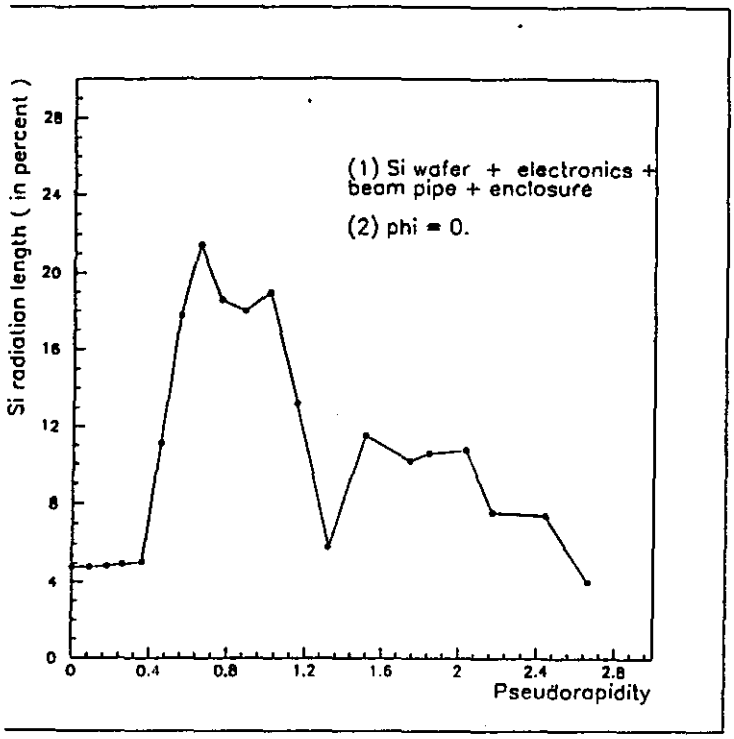

GMDT
RUN NR 1
EVENT NR 5
5/10/92
Academia Sinica

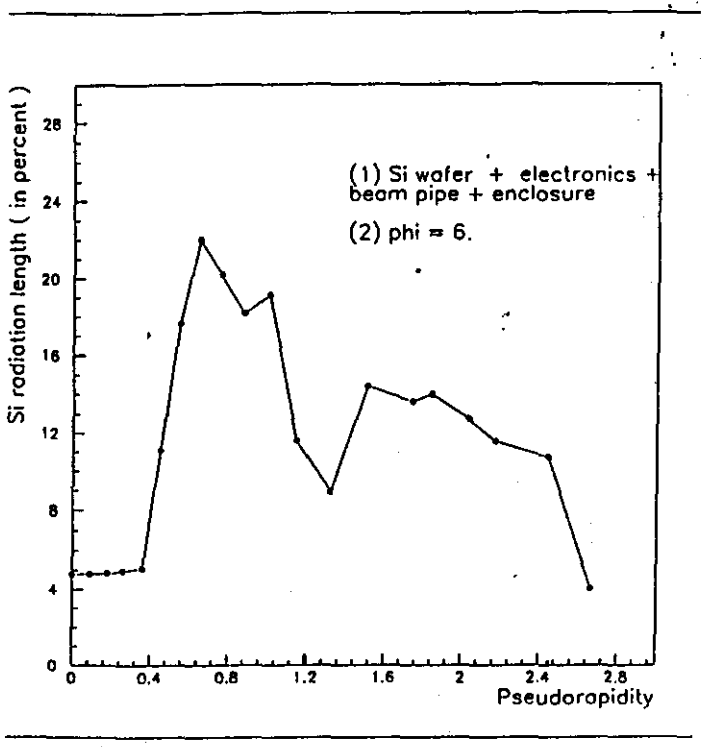

(1) Pad chamber + electronics
+ beam pipe + support
(2) phi = 0.
Pad chamber radiation length (in percent)
Pseudorapidity

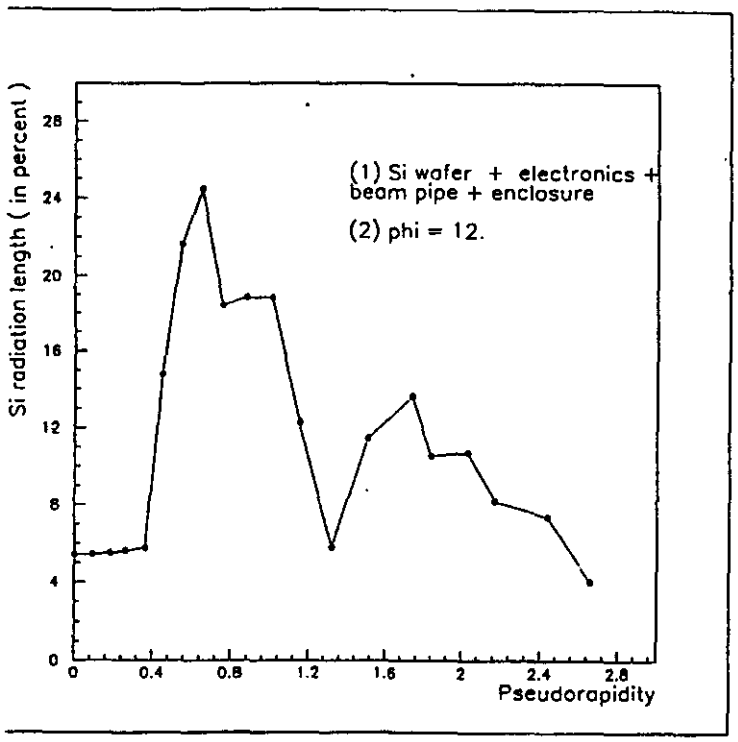

(1) Pad chamber + electronics
+ beam pipe + support
(2) phi = 6.
Pad chamber radiation length (in percent)
Pseudorapidity

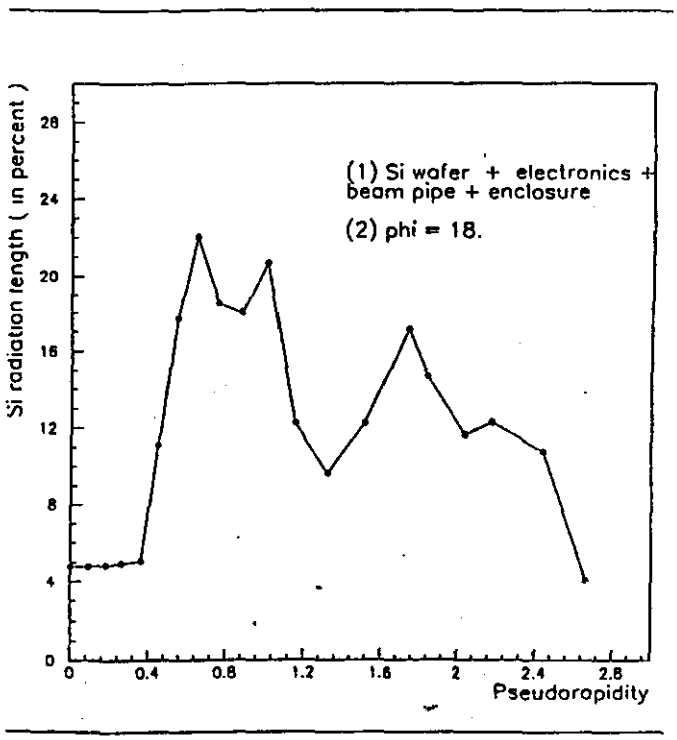

(1) Pad chamber + electronics
+ beam pipe + support
(2) phi = 12.
Pad chamber radiation length (in percent)
Pseudorapidity

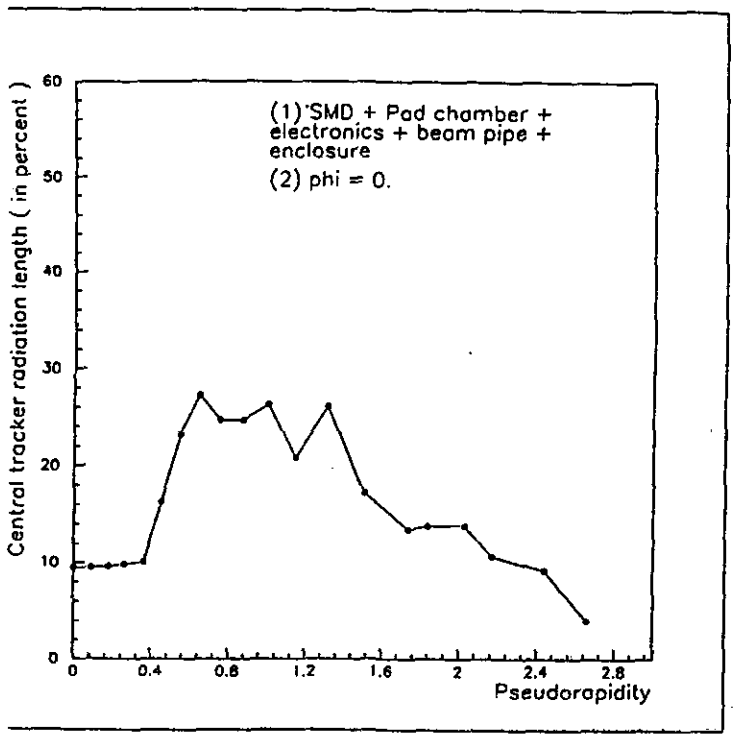

(1) Pad chamber + electronics
+ beam pipe + support
(2) phi = 18.
Pad chamber radiation length (in percent)
Pseudorapidity

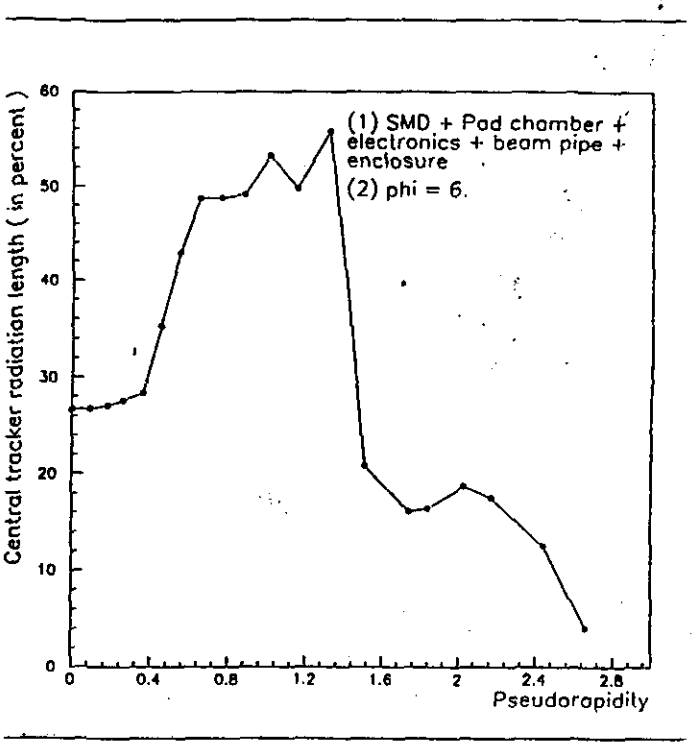

(1) Si wafer + electronics + beam pipe + enclosure
(2) phi = 0.
Si radiation length (in percent)
Pseudorapidity

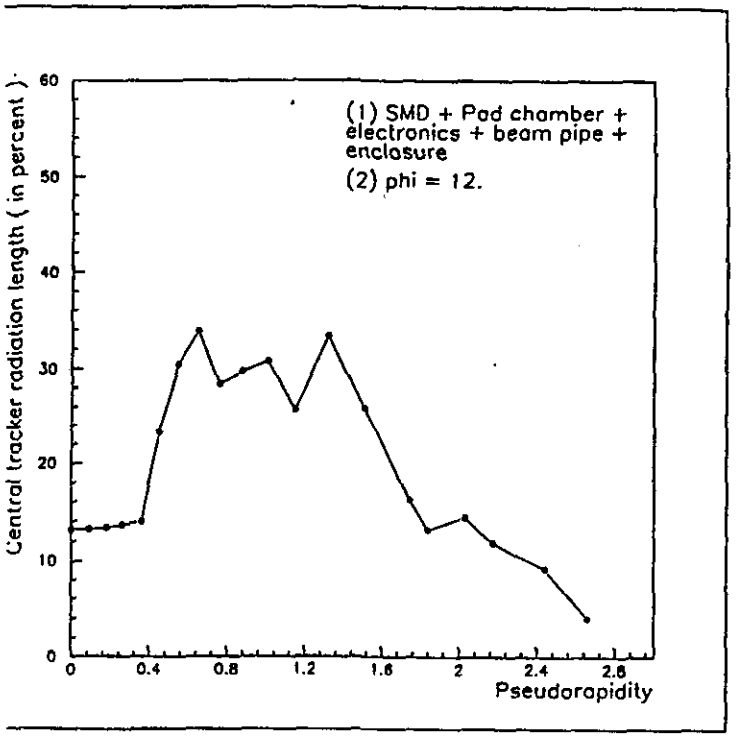

(1) Si wafer + electronics + beam pipe + enclosure
(2) phi = 6.
Si radiation length (in percent)
Pseudorapidity

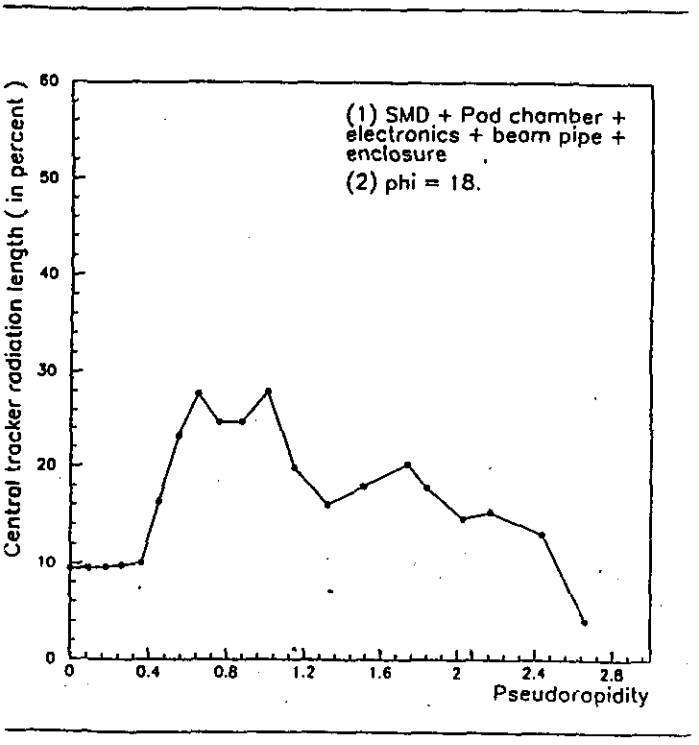

(1) Si wafer + electronics + beam pipe + enclosure
(2) phi = 12.
Si radiation length (in percent)
Pseudorapidity


(1) Si wafer + electronics + beam pipe + enclosure
(2) phi = 18.
Si radiation length (in percent)
Pseudorapidity

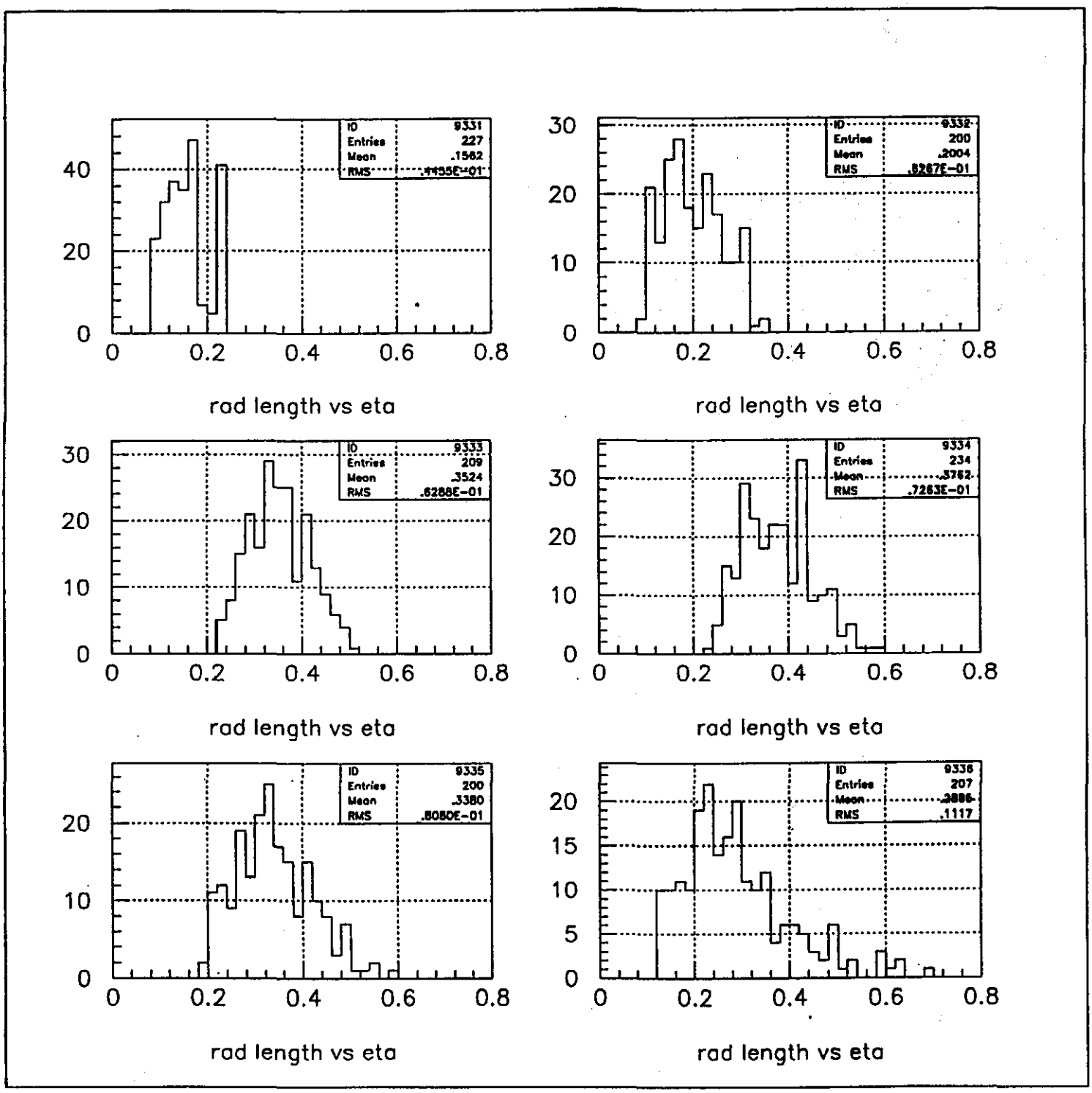

(1) SMD + Pad chamber + electronics + beam pipe + enclosure
(2) phi = 0.
Central tracker radiation length (in percent)
Pseudorapidity

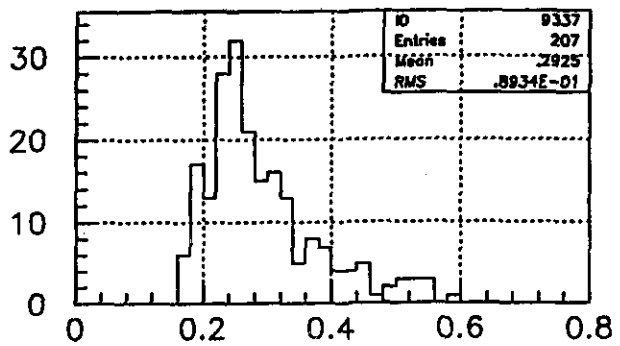

(1) SMD + Pad chamber + electronics + beam pipe + enclosure
(2) phi = 6.
Central tracker radiation length (in percent)
Pseudorapidity


(1) SMD + Pad chamber + electronics + beam pipe + enclosure
(2) phi = 12.
Central tracker radiation length (in percent)
Pseudorapidity

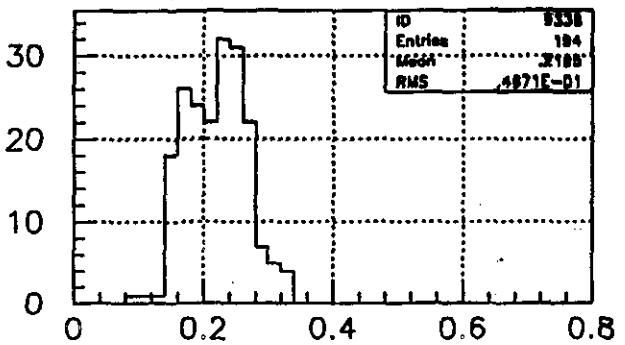

(1) SMD + Pad chamber + electronics + beam pipe + enclosure
(2) phi = 18.
Central tracker radiation length (in percent)
Pseudorapidity

Распределение вещества в СТ
$\Delta y = .25$

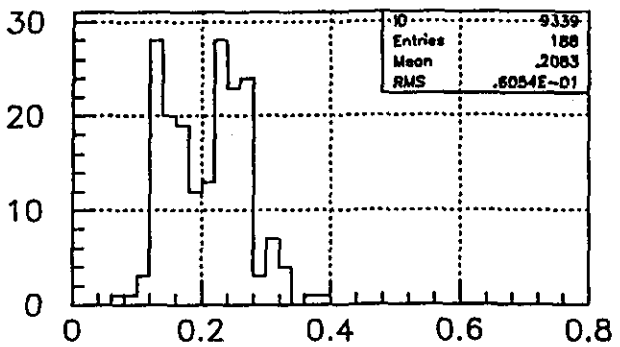




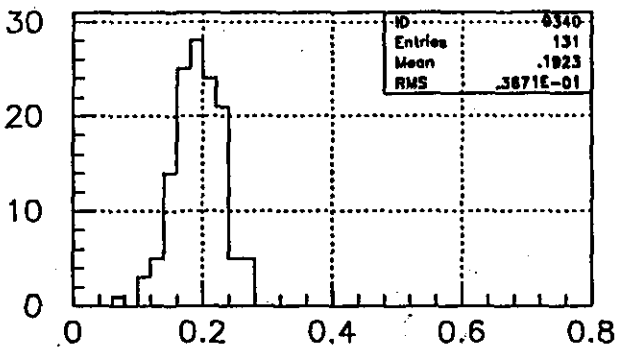
rad length vs eta



rad length vs eta

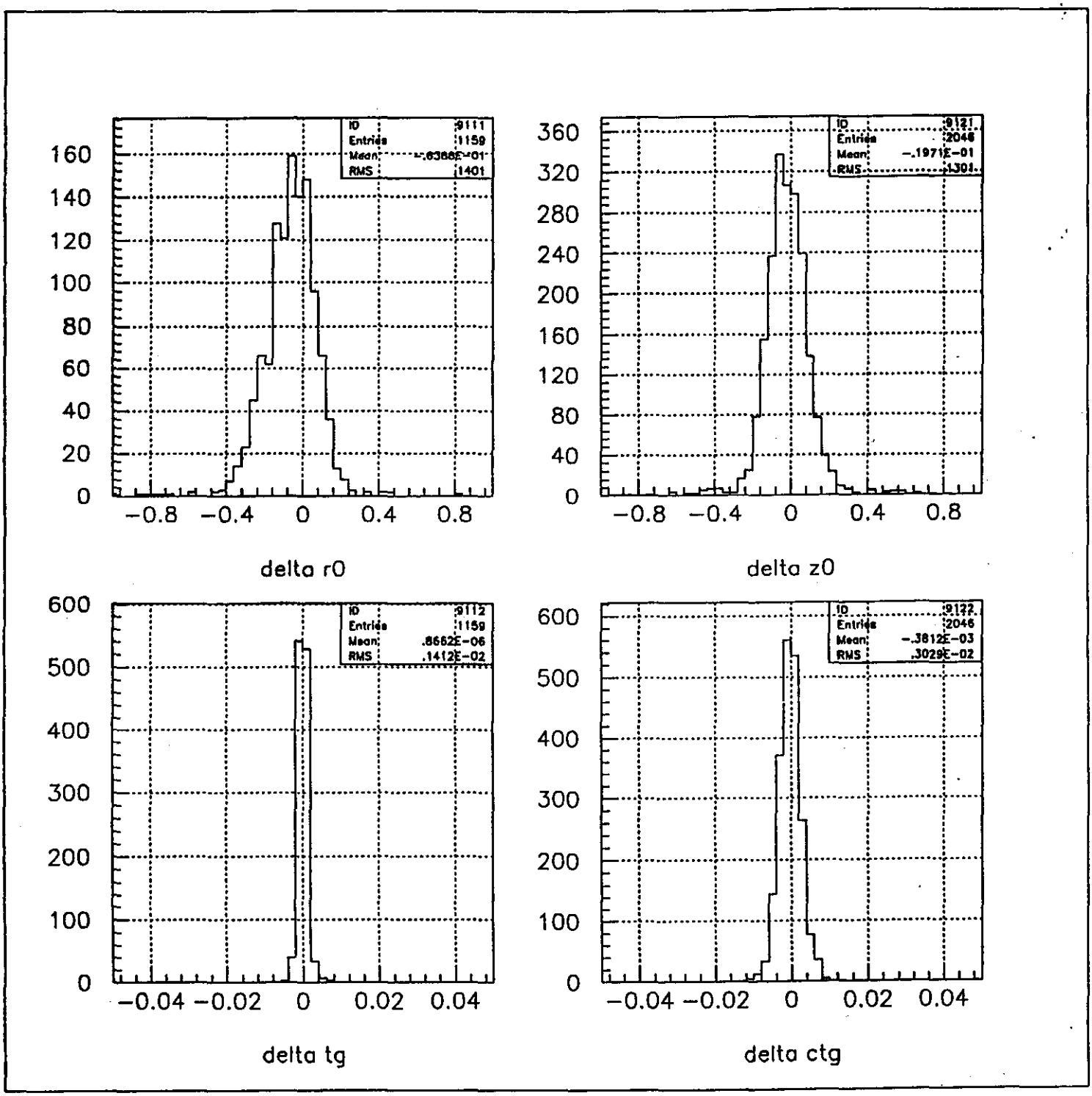


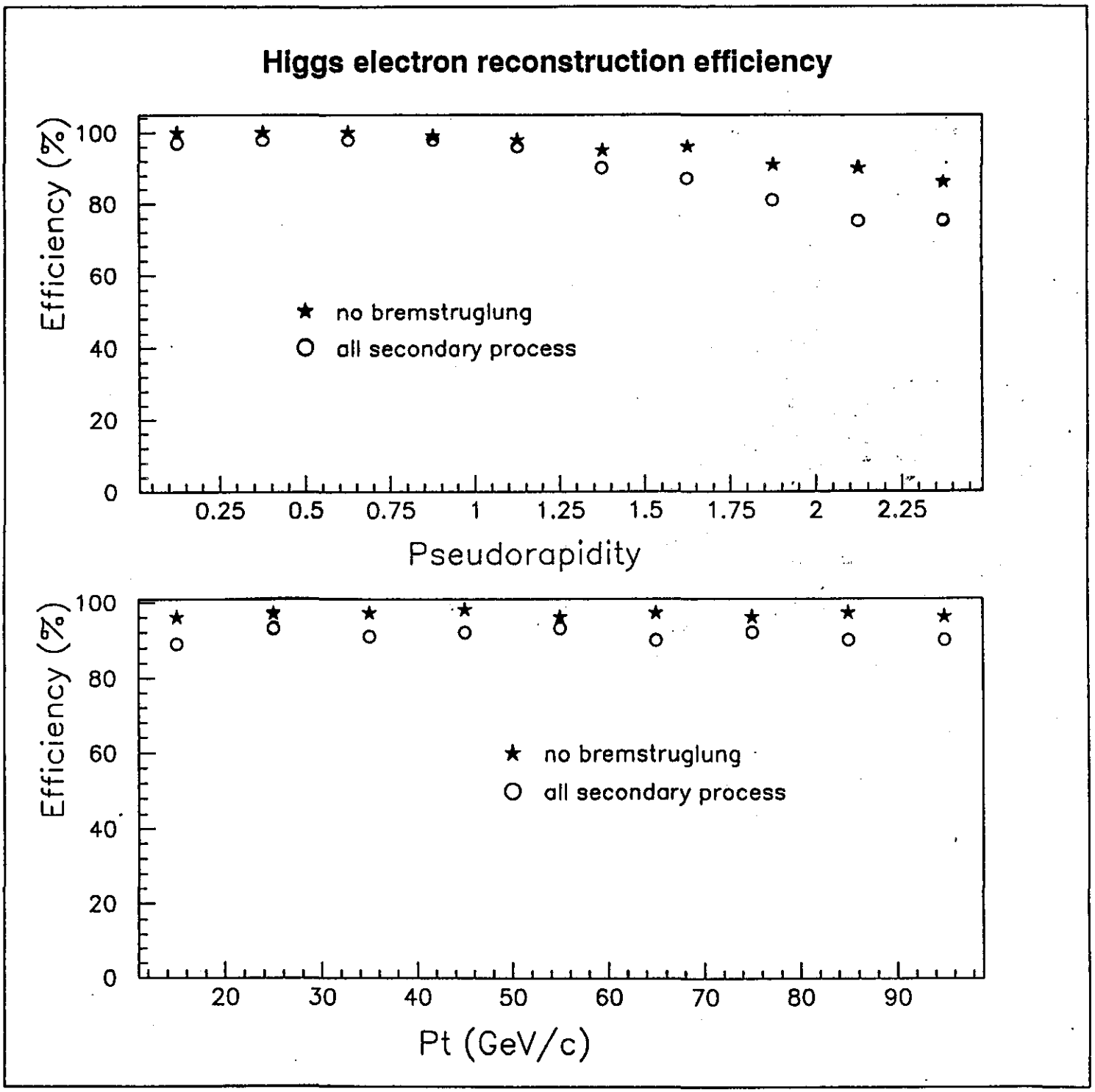
rad length vs eta



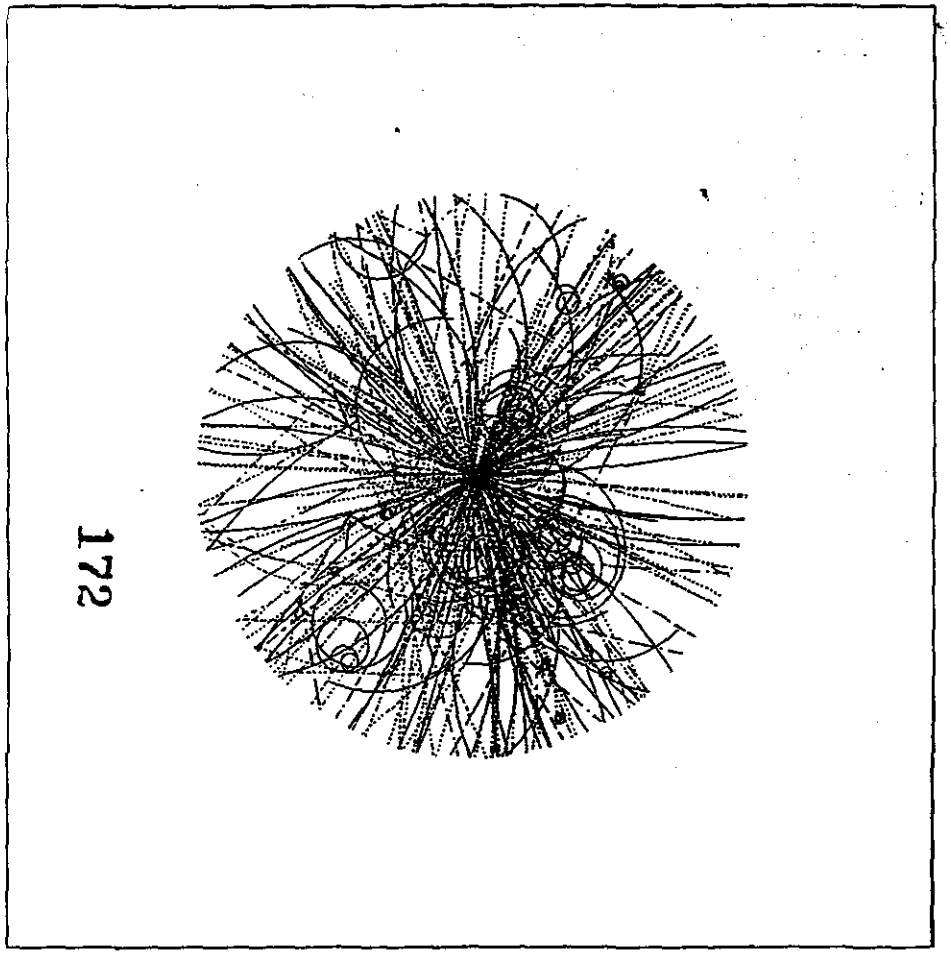
rad length vs eta

Vertex resolution for fitted electron (Higgs → lll l)
no bremstrahlung.

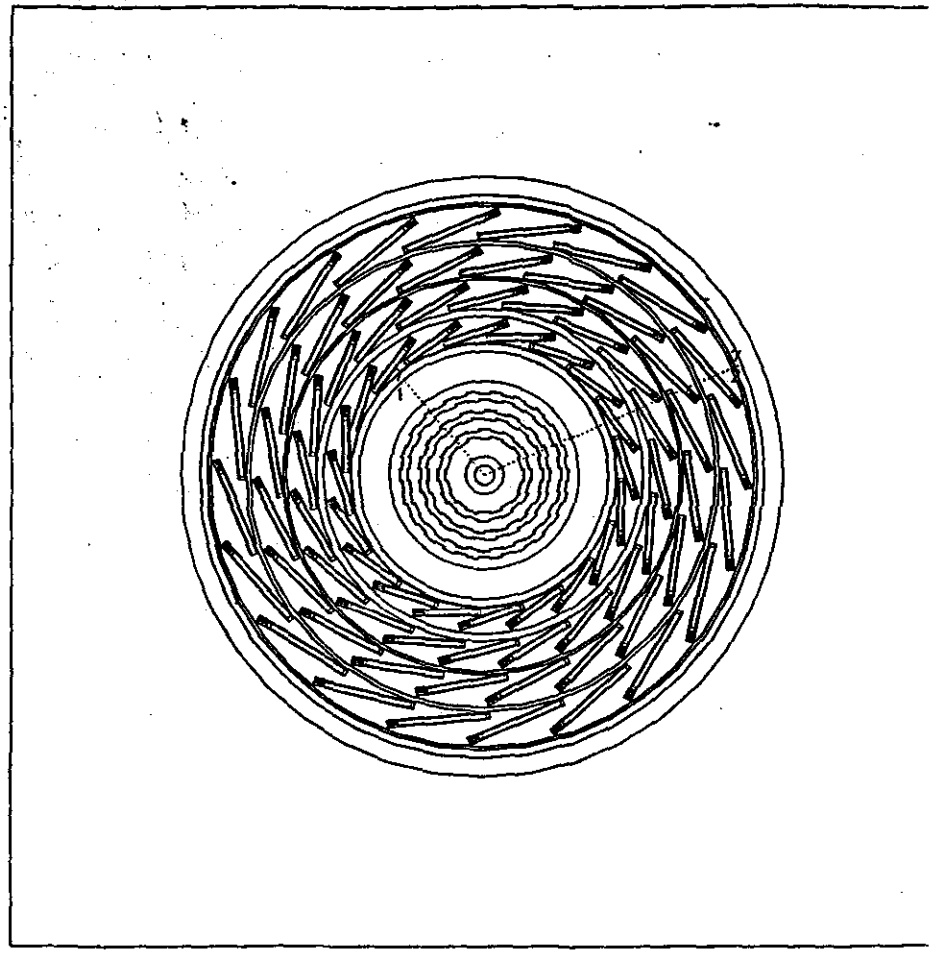



Higgs electron reconstruction efficiency
Efficiency (%)
100
80
60
40
20
0
no bremstruglung
all secondary process
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
Pseudorapidity
Efficiency (%)
100
80
60
40
20
0
no bremstruglung
all secondary process
20
30
40
50
60
70
80
90
Pt (GeV/c)

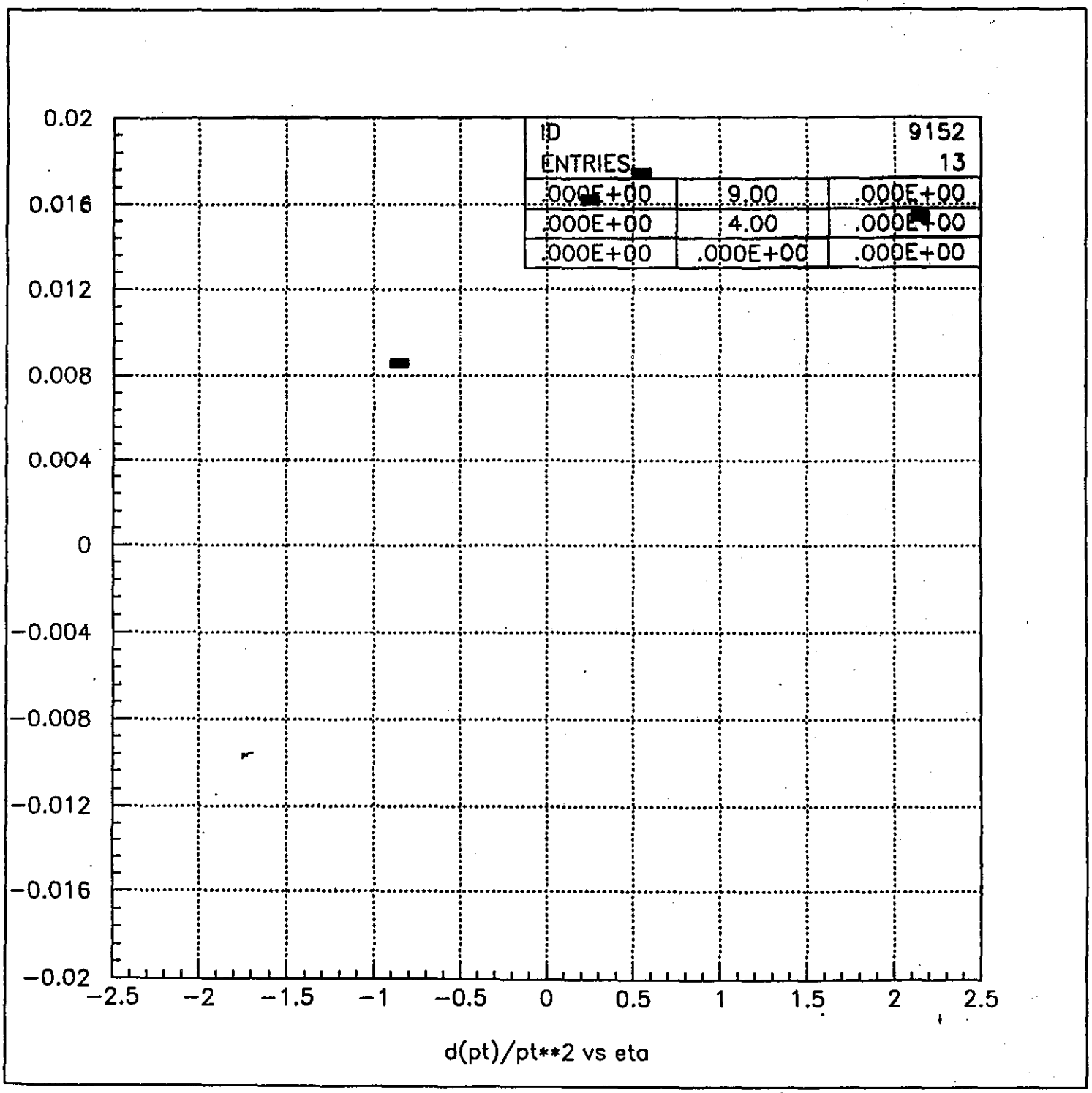
Higgs → γγ (80 GeV)



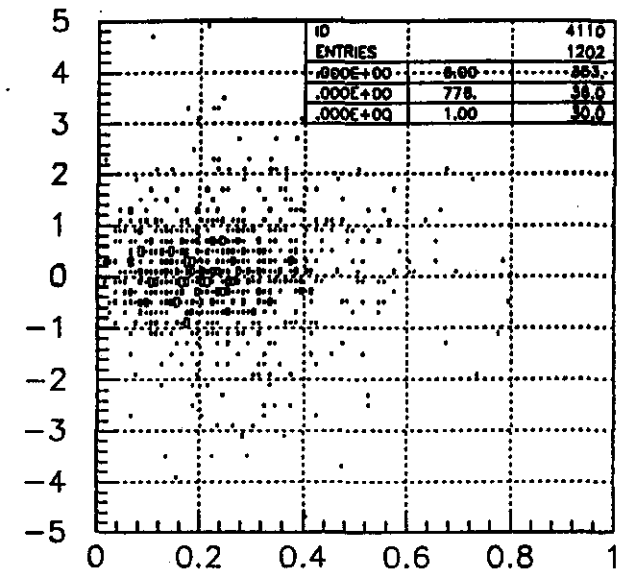
Higgs → γγ (80 GeV)



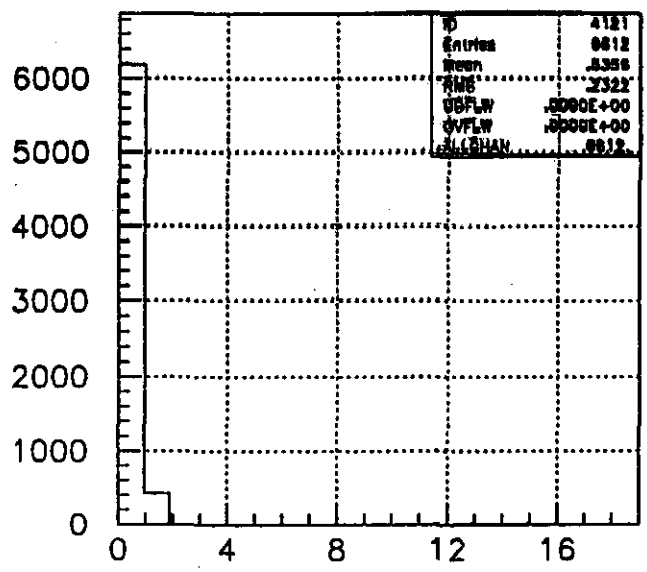
1 Higgs → γγ


ID 9152
ENTRIES 13
.000E+00 9.00 .000E+00
.000E+00 4.00 .000E+00
.000E+00 .000E+00 .000E+00
0.02
0.016
0.012
0.008
0.004
0
−0.004
−0.008
−0.012
−0.016
−0.02
−2.5 −2 −1.5 −1 −0.5 0 0.5 1 1.5 2 2.5
d(pt)/pt**2 vs eta

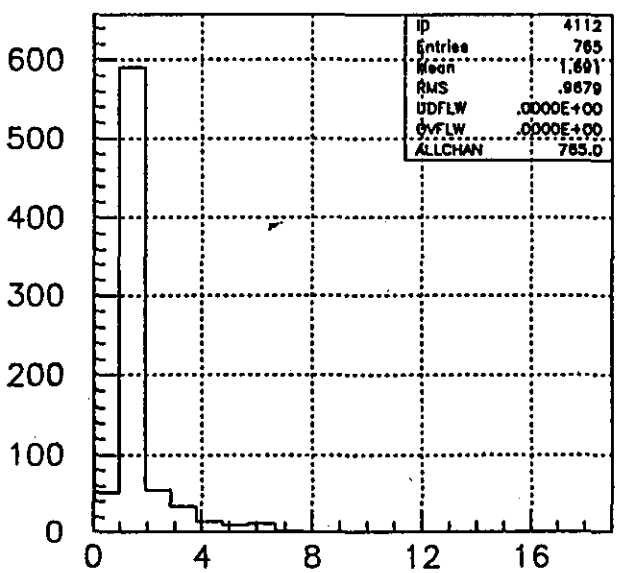
Higgs → γγ



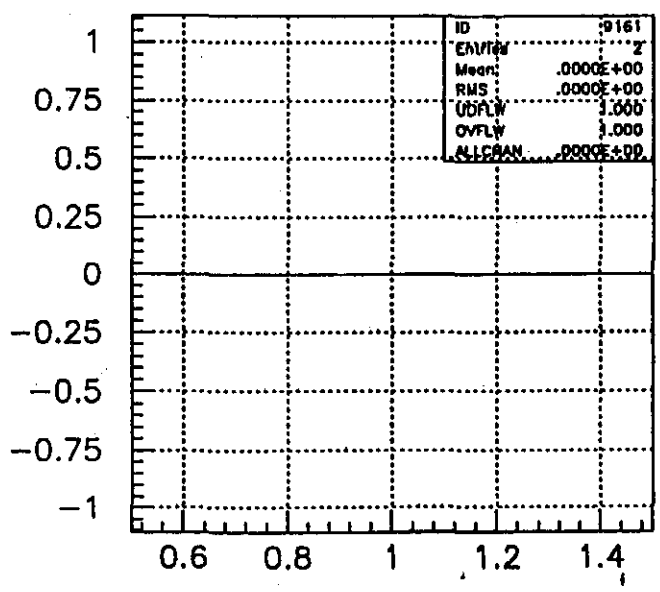
dE vs SHOWER–HIT position



NUMBER of hit candidates



NUMBER of pads for fit



E/p of Higgs electrons