Comparison Study of Central Trackers for the ILC

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On behalf of Software Groups

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Status of Current Tracking Studies

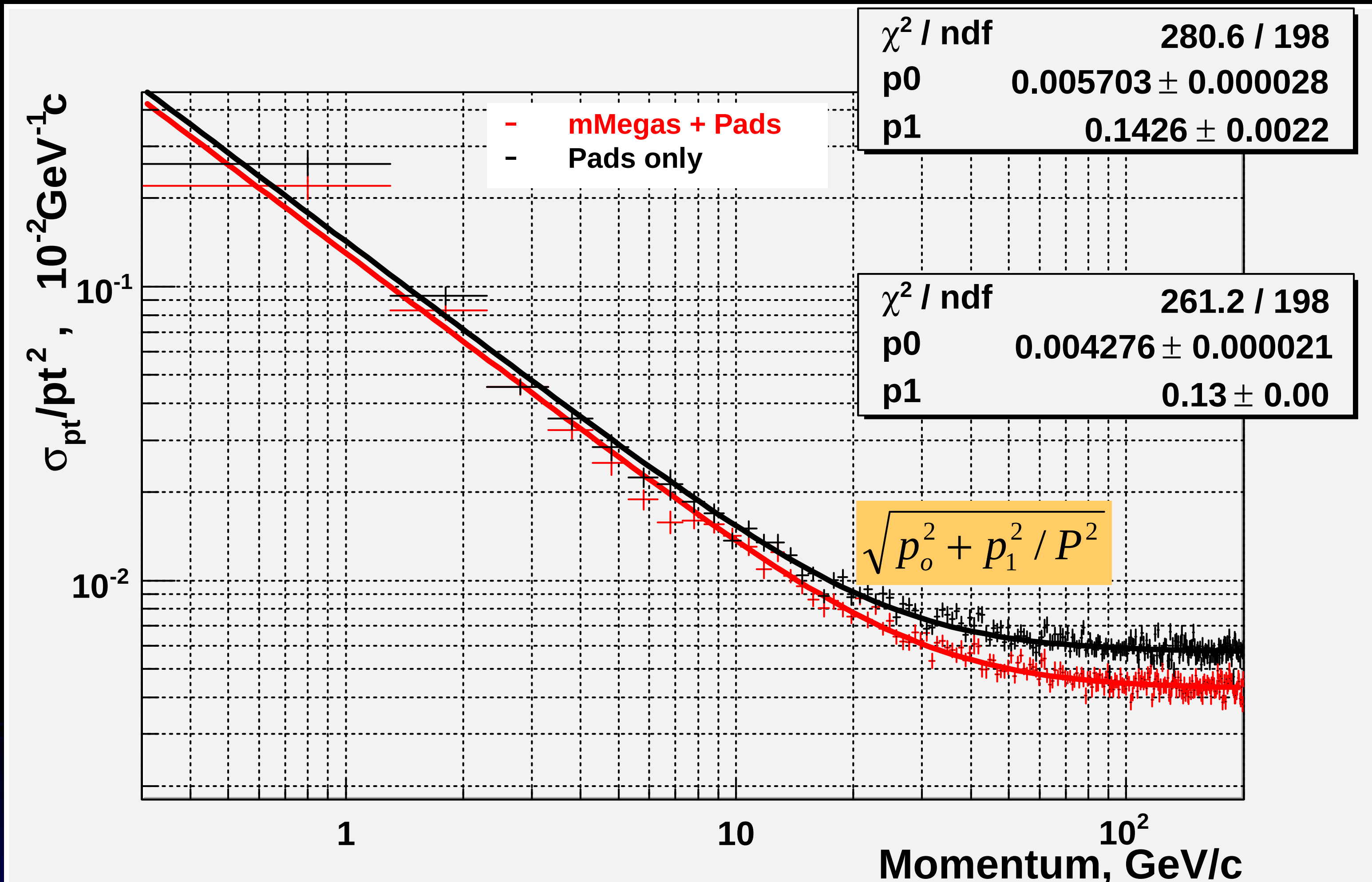
- Based on different simulation framework
- Different event generators
- Different level of detector simulation details (example: gaussian smearing vs full digitization)
- Different algorithms for pattern recognition and track fitting

Introducing A New Study

- Compare SiD tracker, former 4th Concept TPC and CluCou DCH on the same footing (as much as possible)
  - Use the same software framework
  - Use the same events
  - Use the same simulation details (wherever possible)
  - Use the same track fitter (but different pattern recognition algorithms)
- Goal:
  - Identify strenght and weakness of each technology
  - Give indications toward an optimal tracker for LC
  - Put a basis for detector optimization
- FNAL – INFN joint study

Benchmark Channels

- Single particle
- e^+e^- -> Z_oH_o -> $\mu^+\mu^-X$ with e^+e^- -> Z_oZ_o -> $\mu^+\mu^-X$ background [E_{cm}=230]
- e^+e^- -> ttbar->6jets
- e^+e^- -> W^+W^- ->4jets
- τ Polarization Study (also important for EM calorimetry)
- Beam background studies



- VXD + TPC

Expected

$$(\delta\kappa)^2 = \left(\frac{\varepsilon_\perp}{L_\perp^2}\sqrt{\frac{320}{N+4}}\right)^2 + \left(\frac{0.016\,(GeV/c)}{L\beta p_\perp \sin\theta}\sqrt{\frac{L}{X_0}}\right)^2$$

$$\kappa = 1/\rho \qquad \rho = p_\perp/0.3B$$

Multi-jets

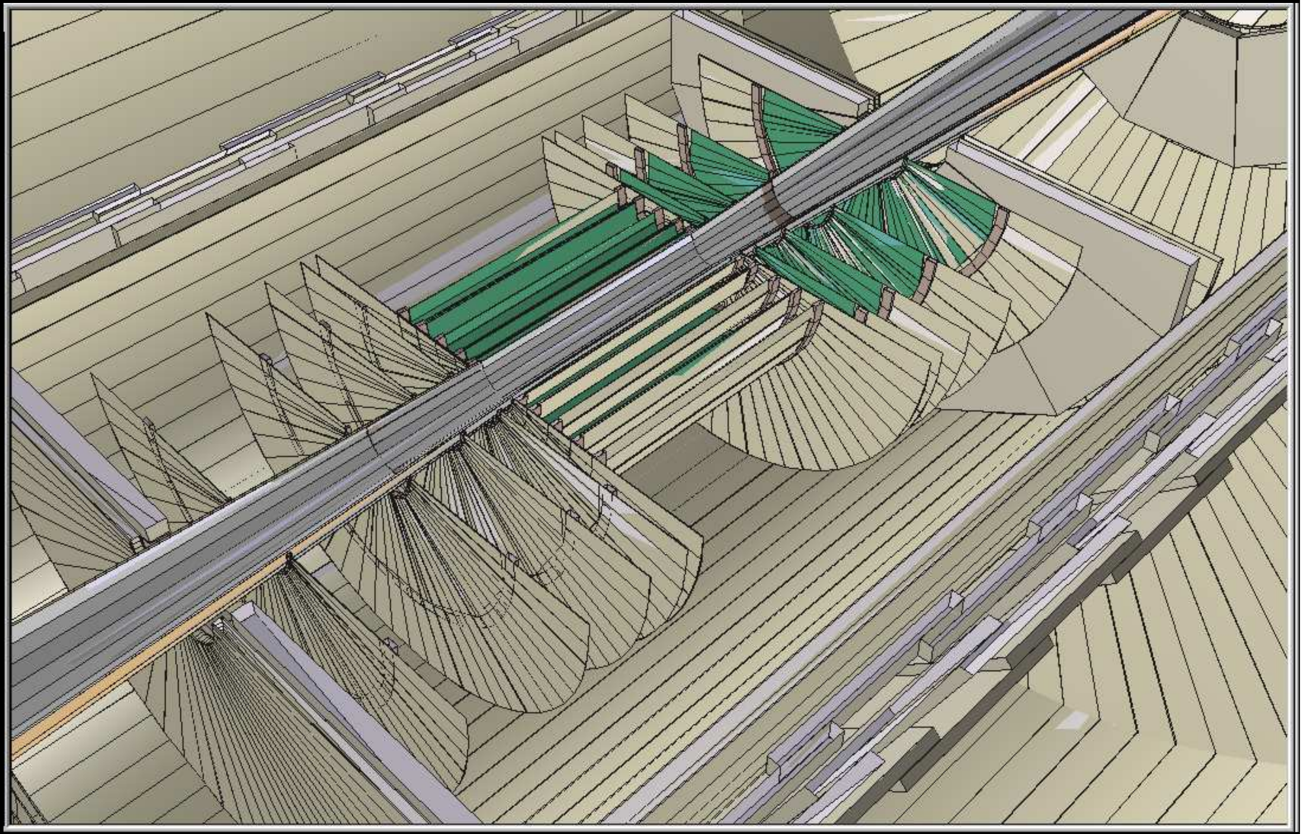
$H^+ \to \tau\nu \to \pi\nu$

HoZo

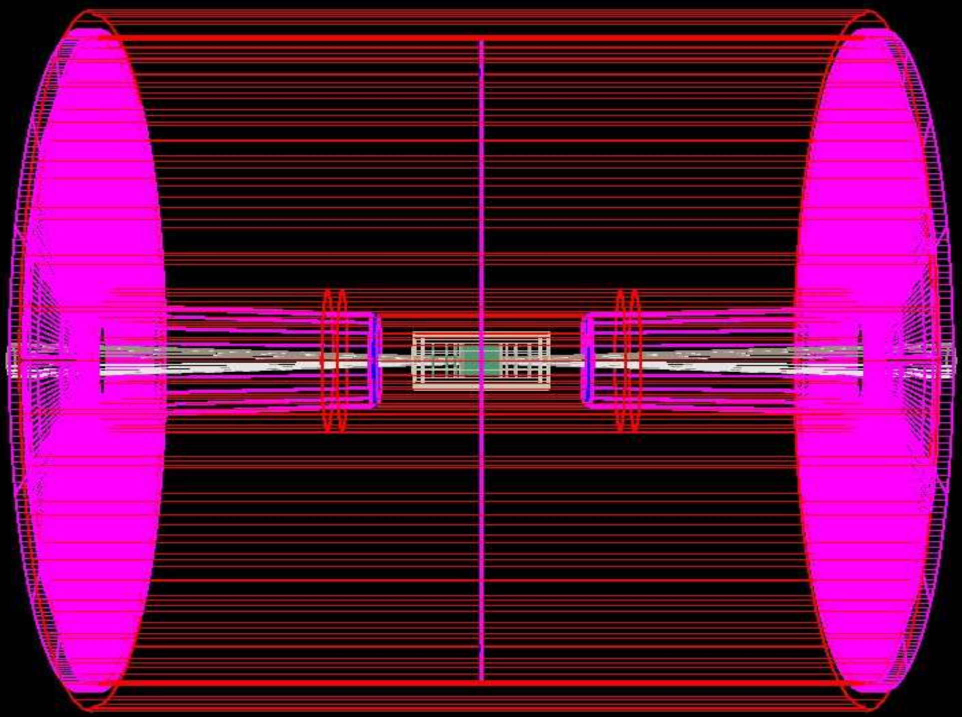
The Sub-Detectors Involved

Beam Pipe and VXD layout

- Beam Pipe:
  - 400 μm Be
  - 25 μm Ti
- VXD: SiD/4th Concept
  - 5 barrel layers x 4 endcaps
  - 20 μm x 20 μm pixel size
  - Detector support: 100 μm CarbonFiber
  - Si modules: 100 μm Si

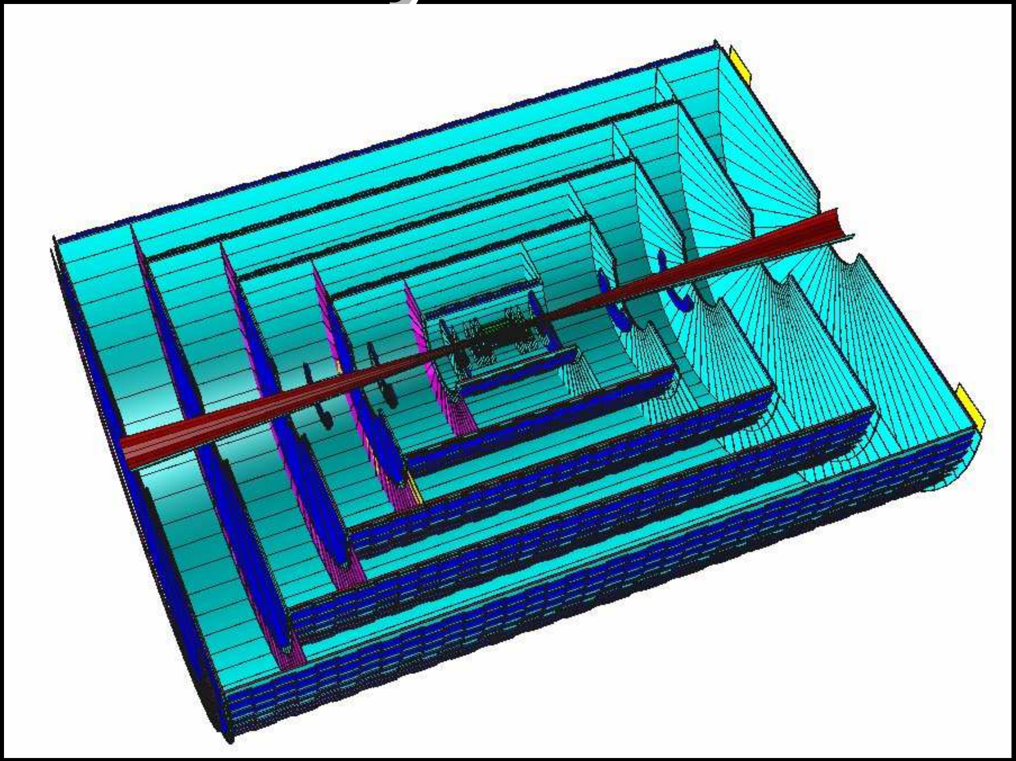


TPC Layout



- Gas: Ar-CF4: 97-3
- Alice's vessel scaled down
  - Inner Radius: 0.20 m
Outer Radius: 1.50 m
Half Length : 1.50 m
  - Active readout region: 25 cm – 45
- All passive material included in geometry
  - Cage
  - Endcaps
  - Electronics and cables
  - Services
  - Support
- Readout
  - Pad Inner: Width 0.23 cm Length 0.42 cm
Pad Outer1: Width 0.34 cm Length 0.57 cm
Pad Outer2: Width 0.34 cm Length 0.85 cm
  - 5 MuMega rows
  - 512 pixels with 55 μm x 55 μm
  - Cluster statistics included (30/cm)
  - ε = 90%/electron

SiD Tracker Layout



- Version SiD01-Polyhedra + SiD01
- Guard ring: mm 0.07
- Barrel Layers: 5
- Total Tiles Barrel 7312
-
- **Wafer layout**
- Strip pitch 50 µm
- Strip thickness (Si wafer) 300 µm
- Strip length 93.31 mm
- Tile width 93.531 mm
- Carbonfiber in 0.228 mm
- Rohacell tickness 3.175 mm
- Carbonfiber out 0.228 mm
- Si support 300 µm x 6.667 mm x 63.8 mm
- Kapton Layer 0.1 mm
-
- **Support layout**
- Carbon Fiber 500 µm
- Rohacell 8.075 mm
- Carbon Fiber 500 µm
-
- **Barrel Layer layout**
- Radial position (Barrel) cm 18.5-24.5; 44.1-50.1; 69.6-75.6; 95.2-101.2; 120.8-126.5
- Z-length cm 53.4; 121.6; 189.6; 257.8; 326

- **Endcap rmin rmax z position in cm**

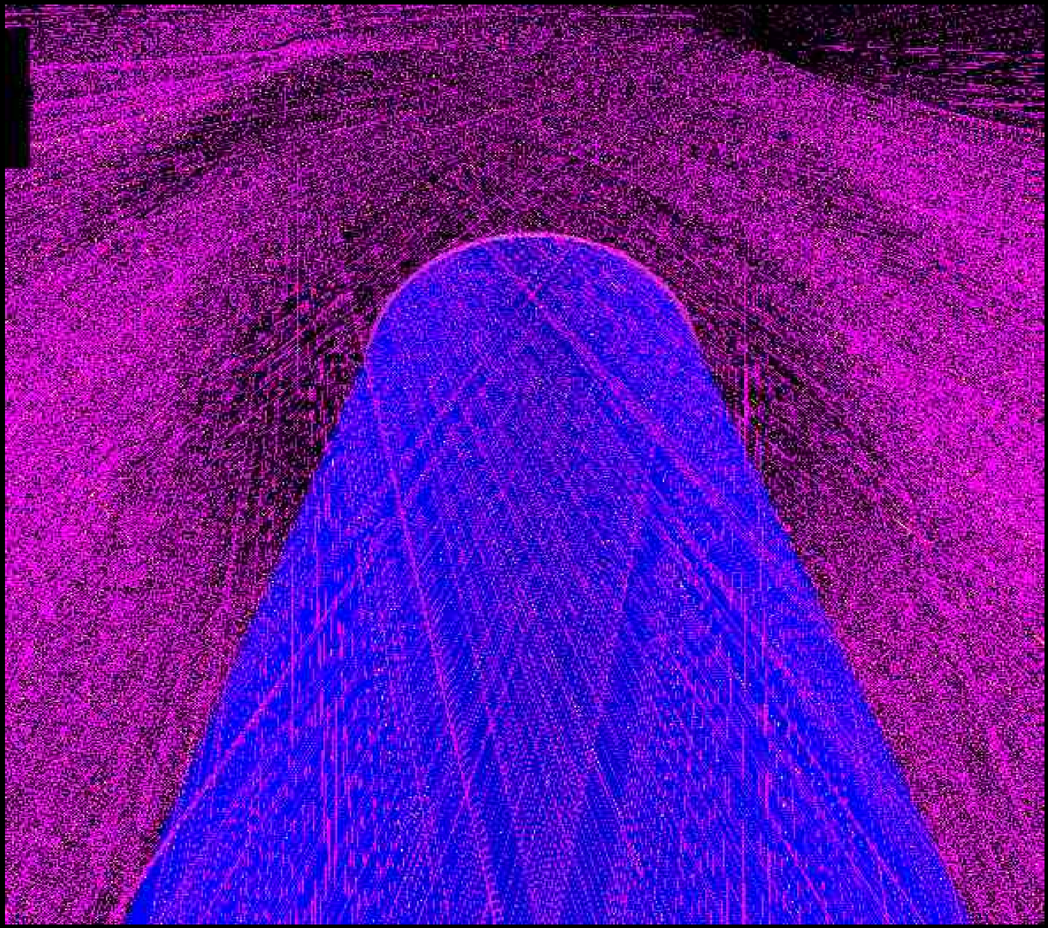
Endcap	rmin	rmax	z position in cm
1	18.5	48.6	62.9148
2	18.5	74.1	96.915515
3	18.5	99.7	131.016285
4	19.5	125.3	165.117005
5	2.78	16.67	20.59408
6	7.51	16.67	54.04408
7	11.65	16.67	83.14408

Barrel has single sensor strips

Endaps have double sensor strips with 17.5 mrad stereo angle

DCH Layout

- Vessel: 23-150 cm
- Active volume: 37-145 cm
- Individual wires simulated
  - 60000 20 μm W sense wires
  - 120.000 80 μm Al field wires
- Gas: 90% He + 10% iC4H10
- Layers: 152
- Cells size and shape:
  - 6.35 mm x 6.35 mm axial square for reconstruction studies
  - Exagonal all-stereo superlayers, r-dependent size, for occupancy studies



Material Budget at θ= 90°
(θ= 0° for endcaps/endplates)

- Beam Pipe: 0.18% X/X_o
- VXD:
  - Detector & support: 0.8% X/X_o

TPC

- Gas[Ar-CF4/97-3]: 1.3%
- Vessel:
  - Inner wall + cage: 0.29% X/X_o
  - Outer wall: 1.2% X/X_o
  - Endcaps (wires, pads,electronics & services included): 35-54% X/X_o

Si Tracker

- Barrel :6.21% (Si= 3.98% + Support=2.23%)
- **Endcap Inner Disks: 2.93 % X/Xo**
- **Endcap Outer Disks: 4.39-5.39% (with supports) X/Xo**

- **Drift Chamber**
- Gas [He-C4H10/90-10]: 0.15%
- Wires: 0.4%
- Vessel:
  - Inner wall: 0.1% X/Xo
  - Outer wall: 2% X/Xo
  - Endcaps (wires, pads,electronics & services included): 8% X/Xo

Caveat

- None of the layout have been optimized yet
  - CluCou group is redesigning the endcaps with spherical shape (+65 cm in z)
  - SiD has not segmented the endcaps yet

⬇

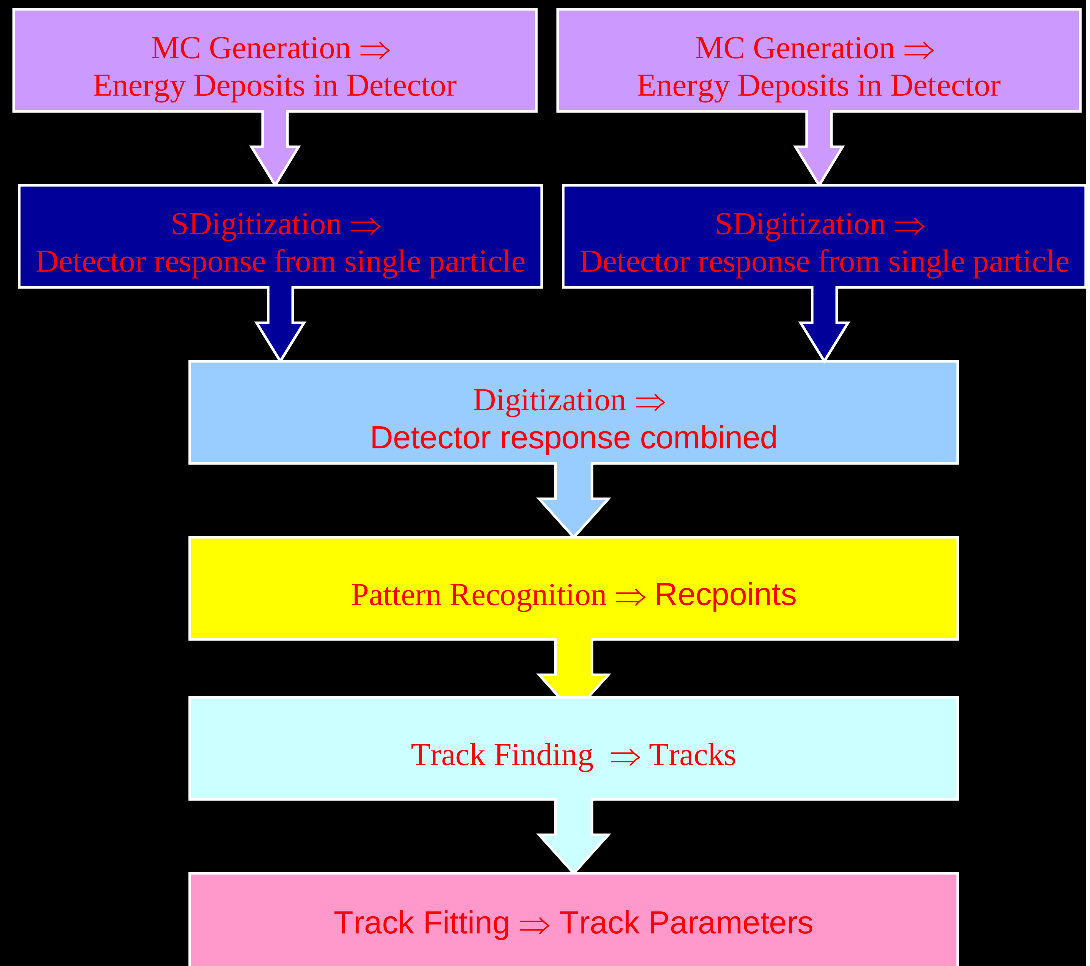
- Efficiency studies as function of momentum will not be presented

Simulation and Reconstruction Algorithms

- All studies performed with ILCroot

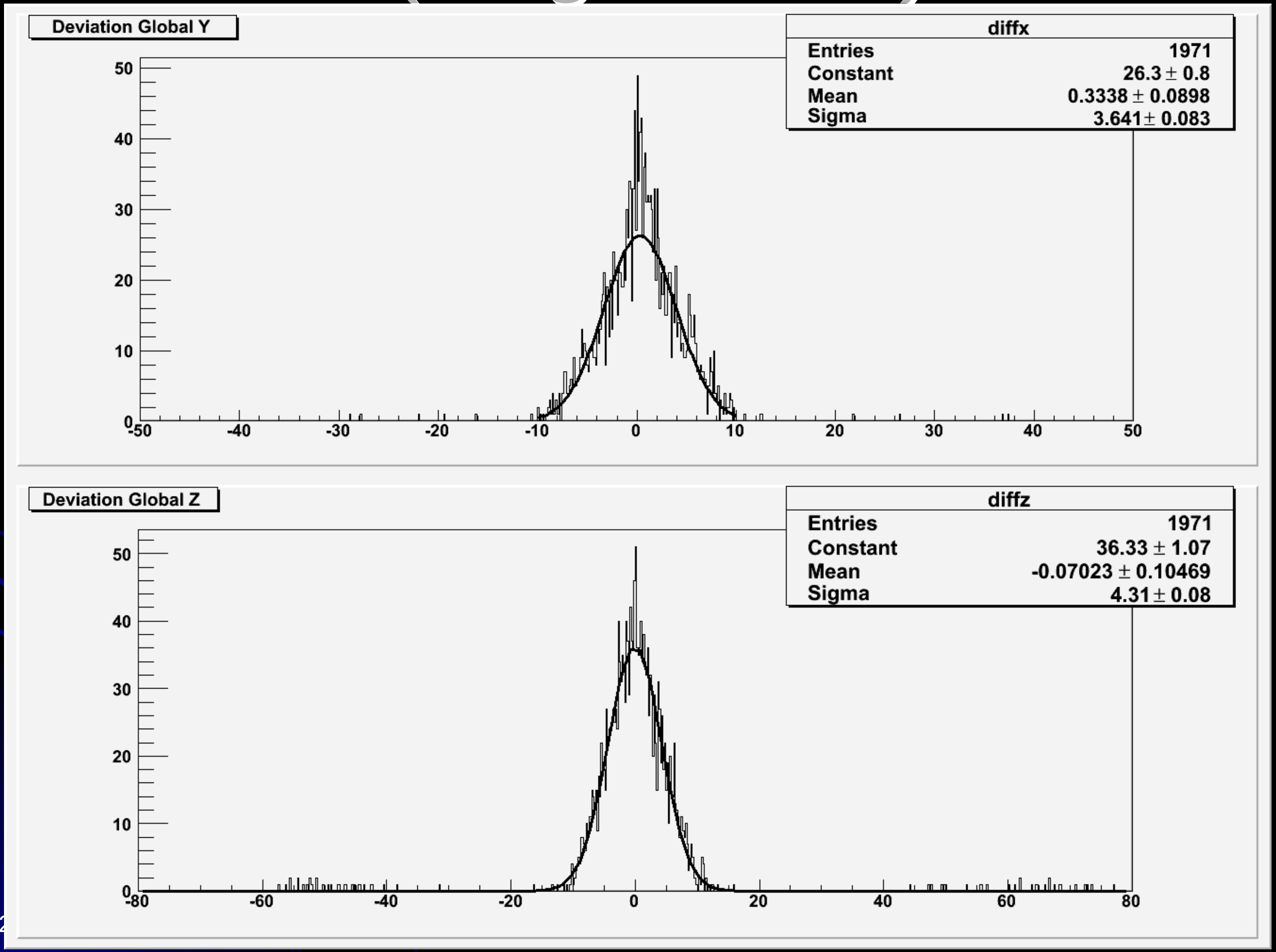
Simulation (Full Digitization)*

*except TPC



- Hits: produced by MC (G3,G4,Fluka)
- SDigits: simulate detector response for each hit
- Digits: merge digit from several files of SDigits (example Signal + Beam Bkgnd)
- Recpoints: Clusterize nearby Digits
- Pattern recognition through Parallel Kalman Filter

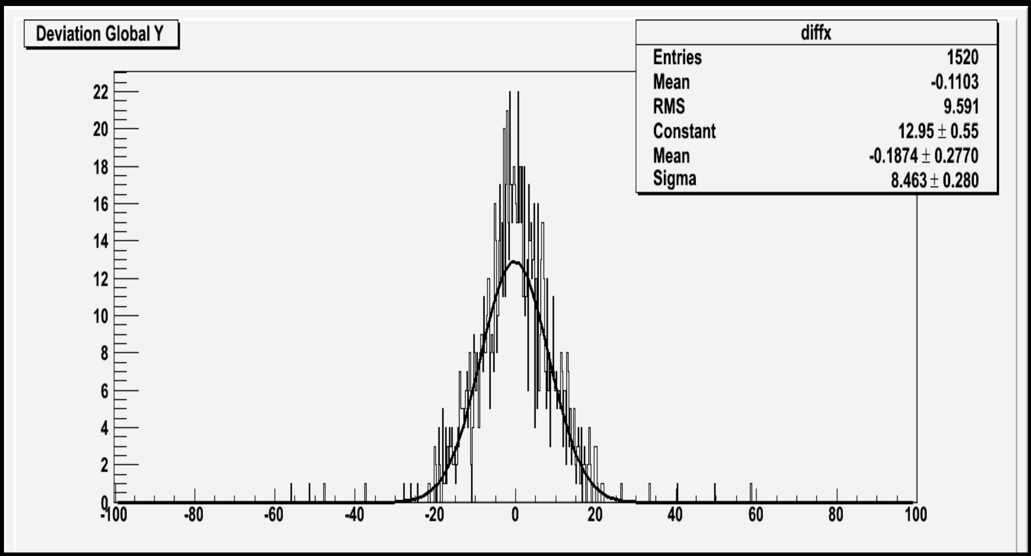
VXD Single Cluster Resolution (single track)

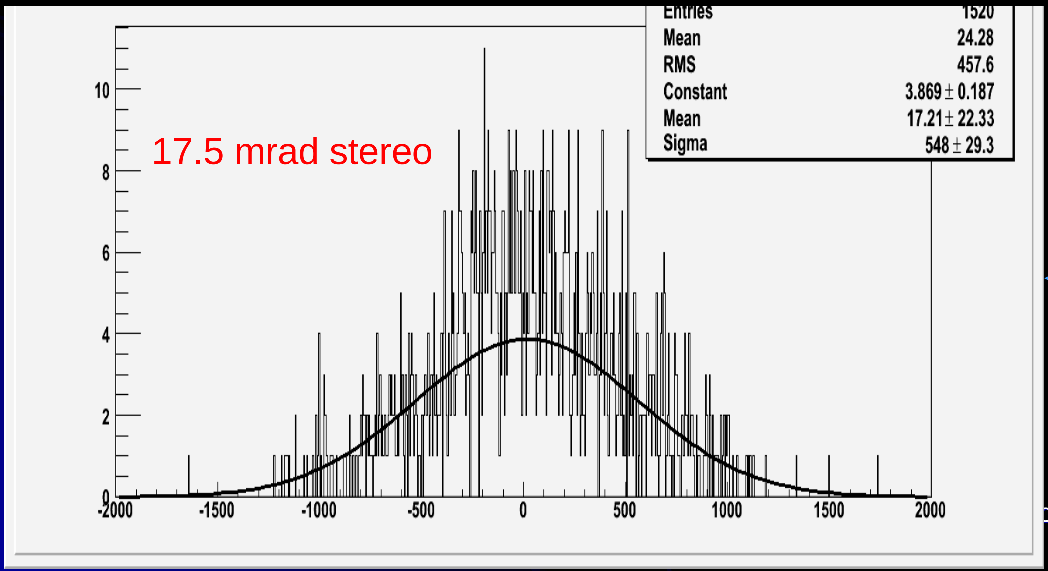


SiT Single Cluster Resolution (single track)

s/n = 20
Threshold = 3 x noise
Add extra fudge factor with σ=5µm

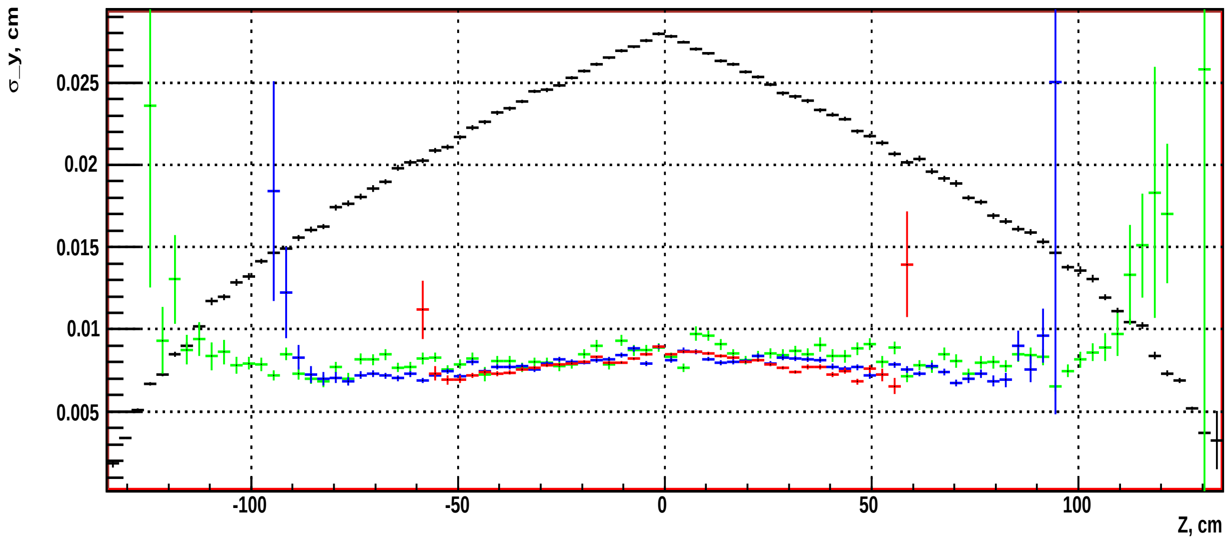
Barrel y coordinate
Endcap y coordinate

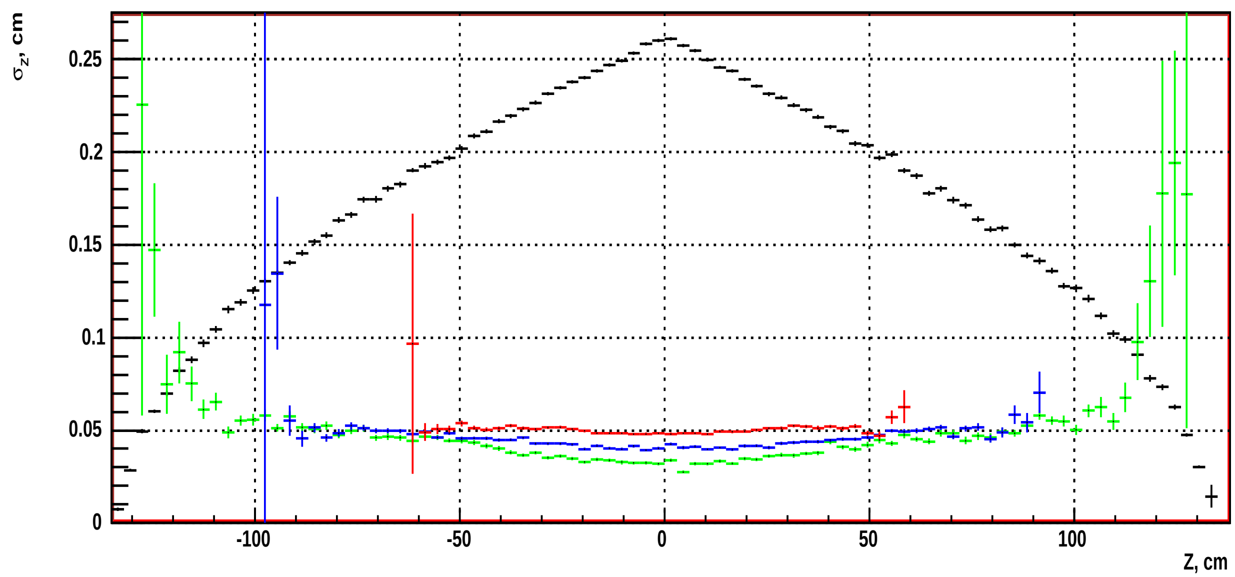




Endcap x coordinate

TPC Total Resolution





— outer pads
- intermediate pads
- inner pads

black - µMega 1 layer (just a diffusion for one electron)

Includes 50µm constant term (pads only)

Plots are for 10 muons 0.5-200 GeV and |tan(θ)|<0.9

Single Particle Studies

- 10,000 events: 10 muons
- P: [0.02,200] GeV
- θ: [0,180°]
- φ: [0,360°]
- B: 3.5 Tesla
- No background -> use gaussian smearing of hits for faster simulation

Defining "Good Tracks" (reconstructable)

I. DCA(true) < 3.5 cm

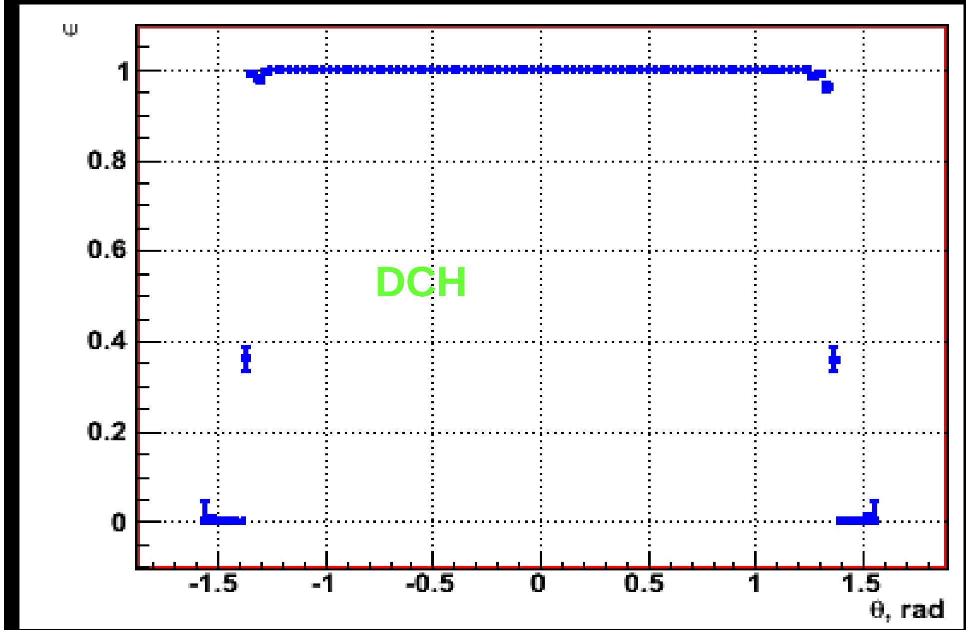
AND

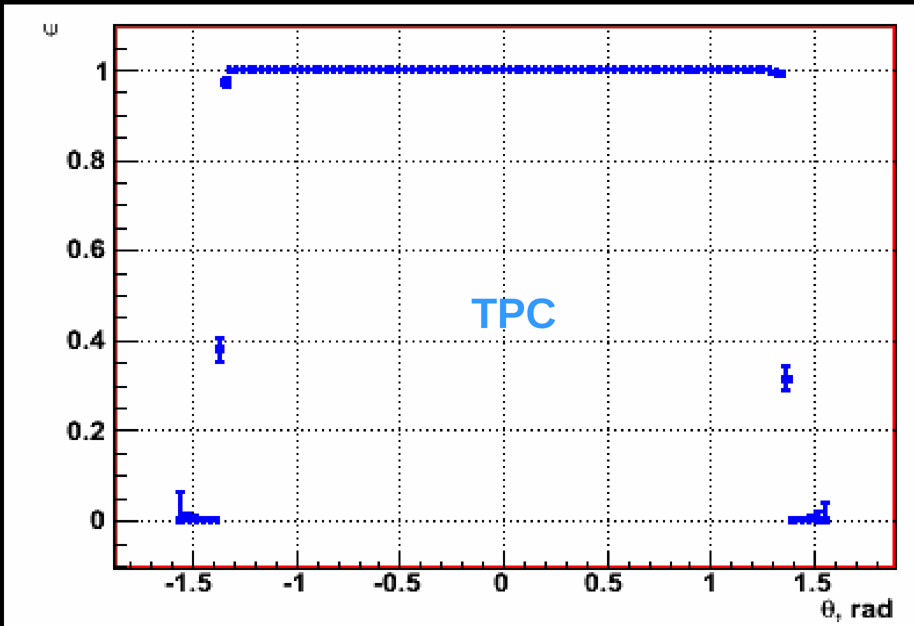
II. (At least 20 hits in TPC/DCH

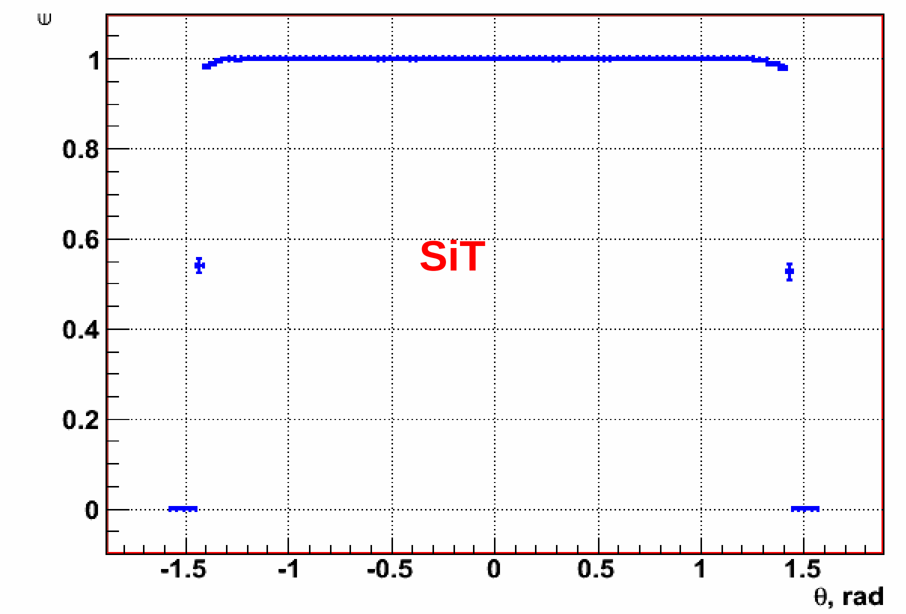
OR

III. At least 4 hits in SiT + VXD)

Good Tracks vs θ

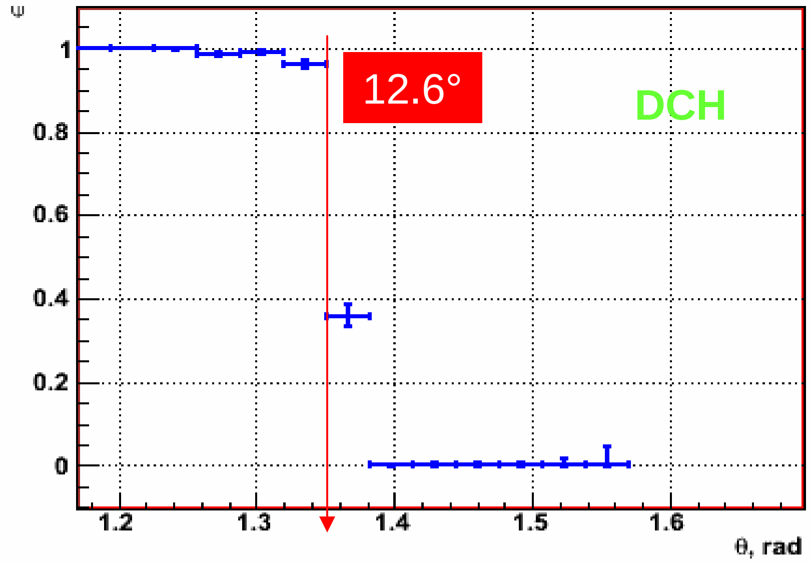


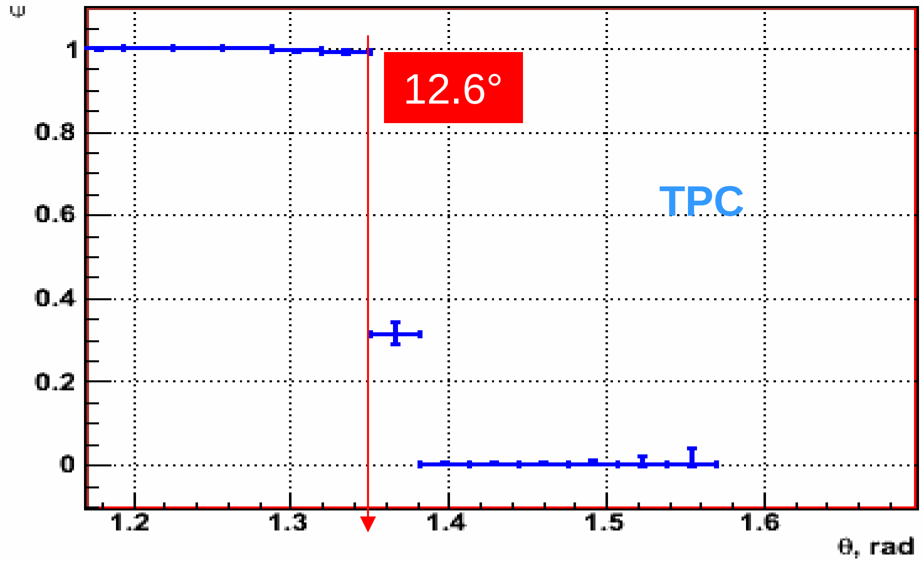


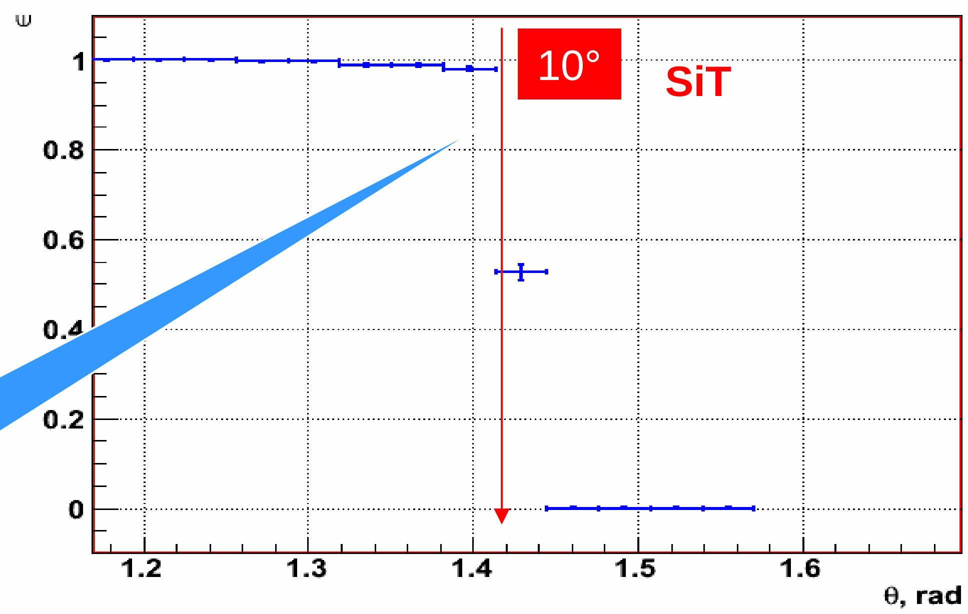


$$\varepsilon = \frac{Good\ Tracks}{Total\ Tracks\ Generated}$$

Good Tracks vs θ (zoom)





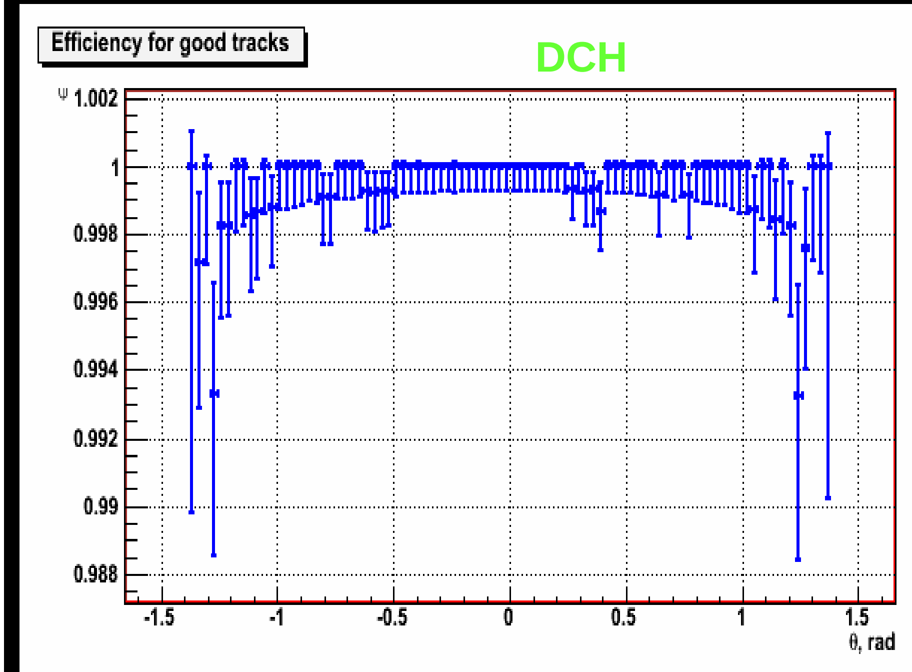


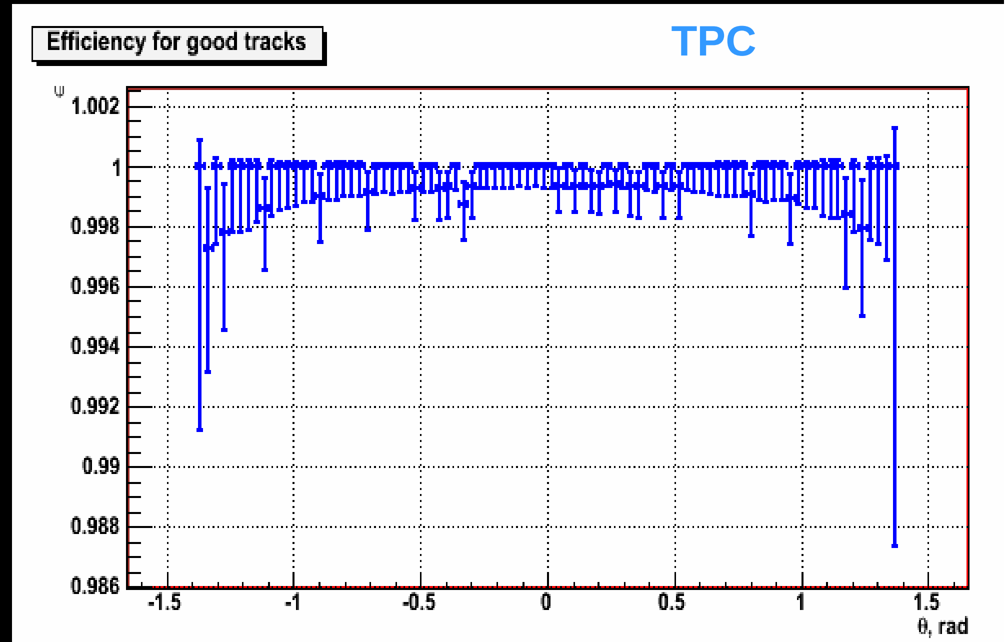
$$\varepsilon = \frac{Good\ Tracks}{Total\ Tracks\ Generated}$$

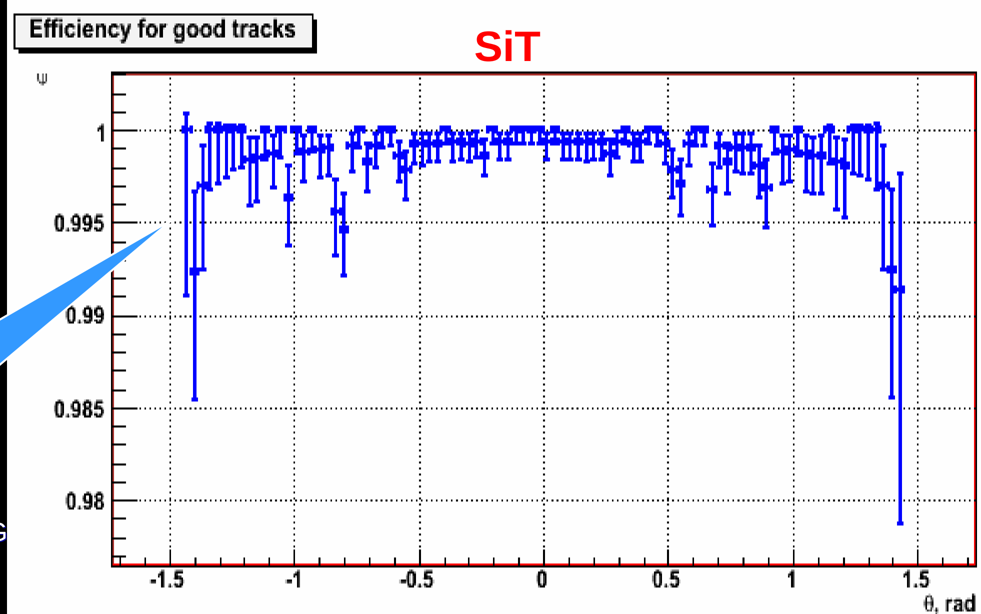
Extended coverage from Forward Tracker

Efficiency vs θ

10 muons





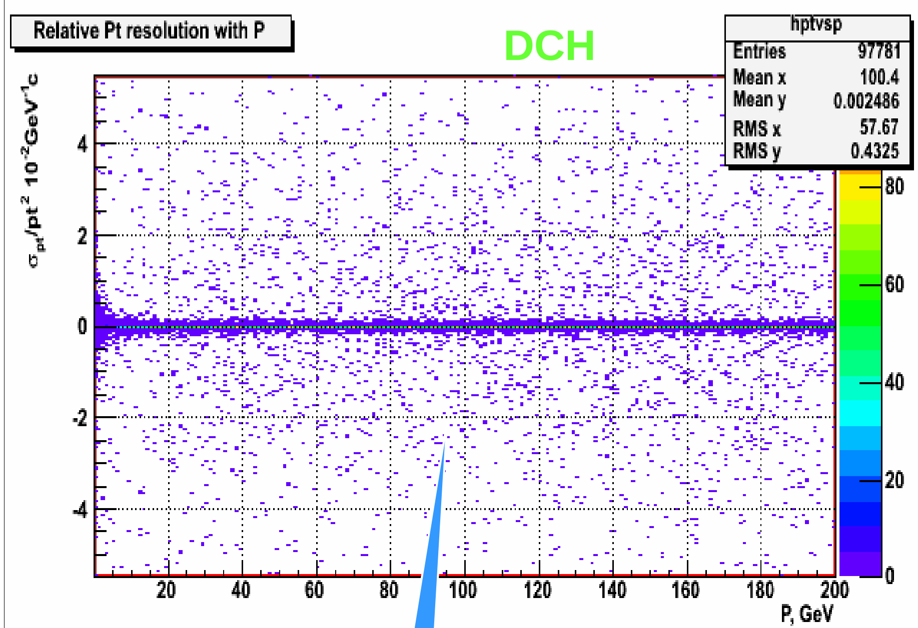


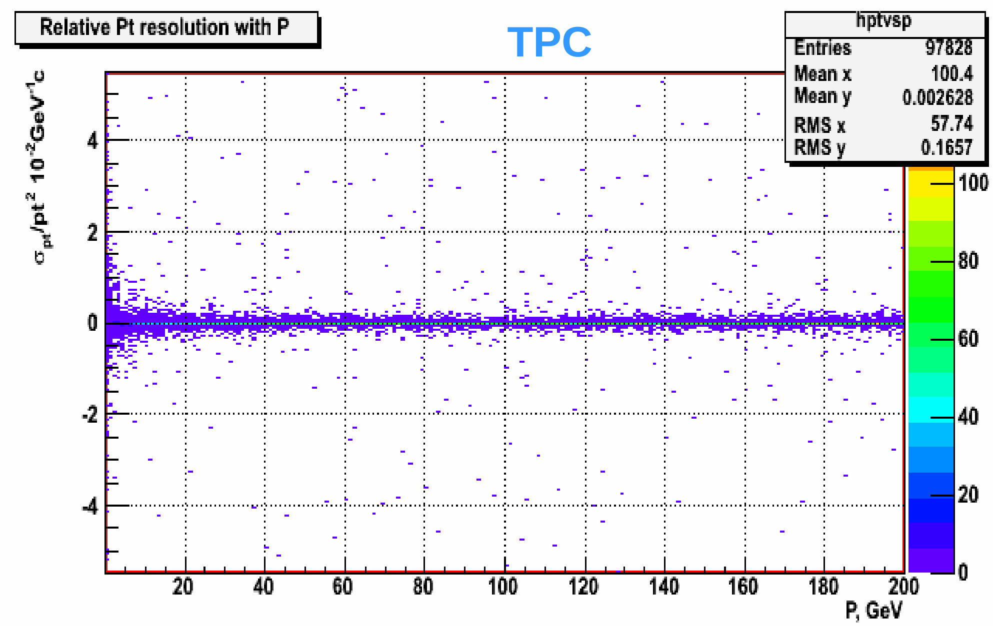
$$\varepsilon = \frac{reconstructed\ tracks}{good\ tracks}$$

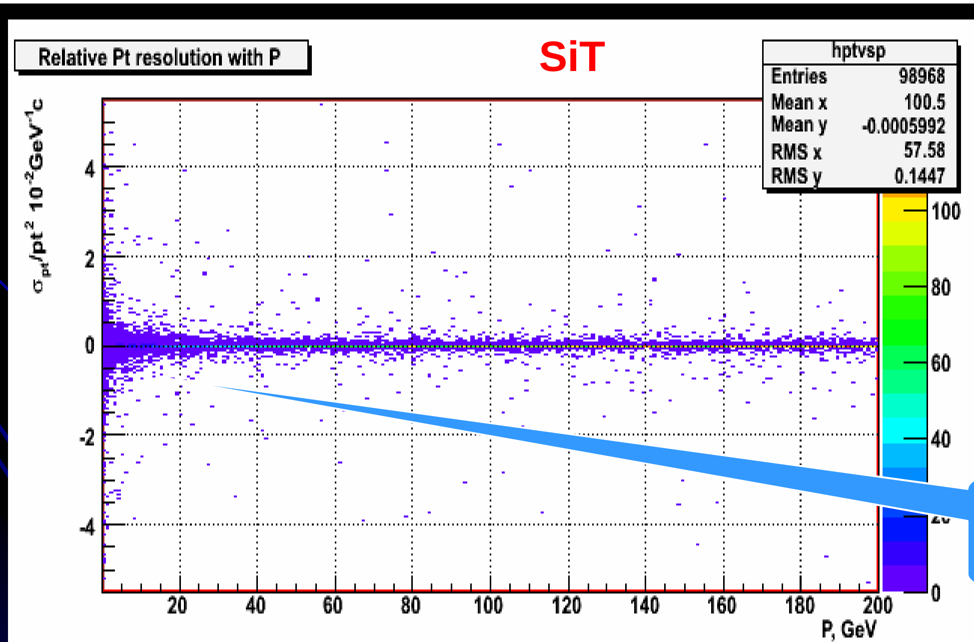
Extended coverage from Forward Tracker

Momentum Resolution vs P

10 muons







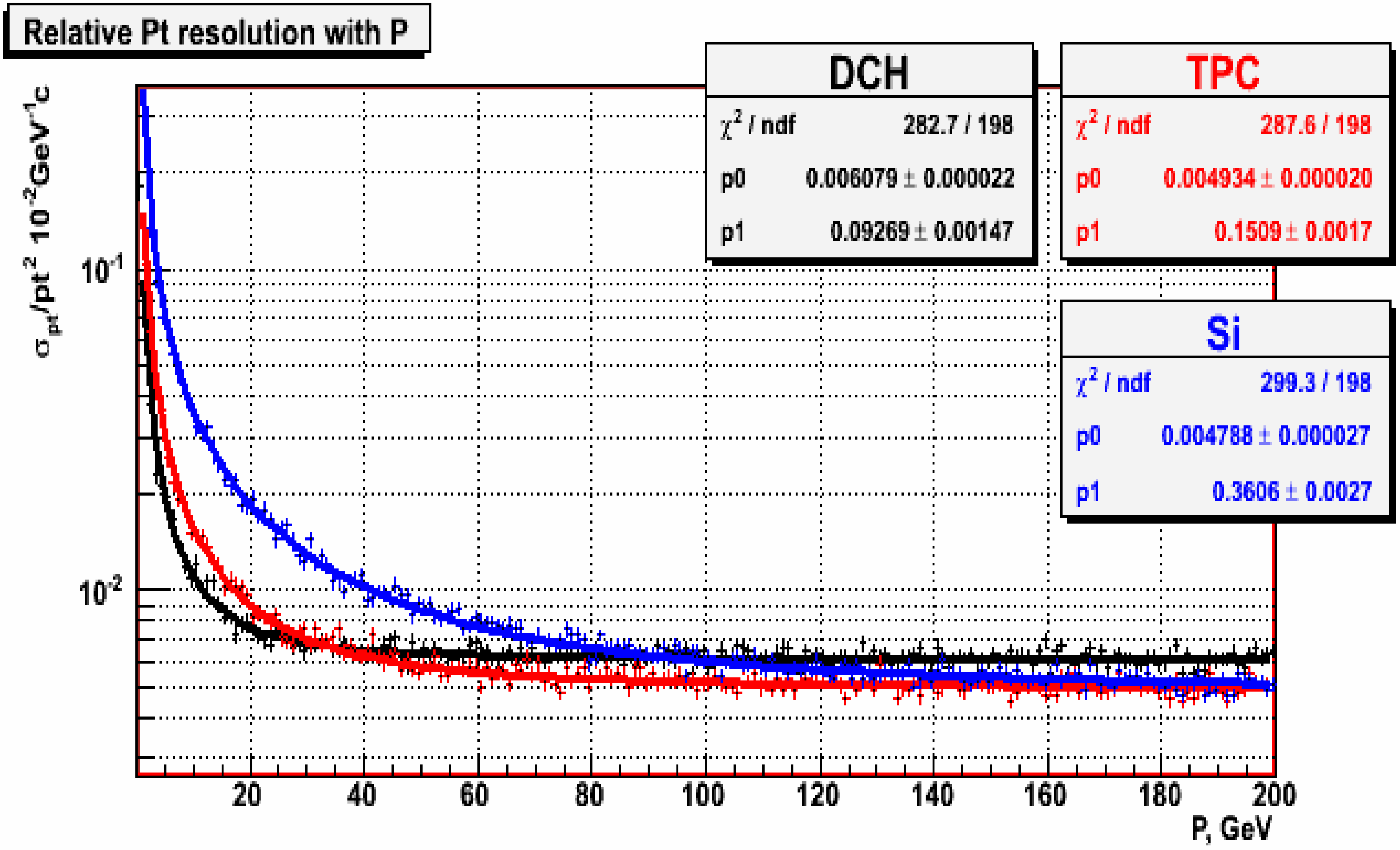
wires

Larger MS

October 22nd, 2007

$\sqrt{p_o^2 + p_1^2 / P^2}$ Momentum Resolution vs P

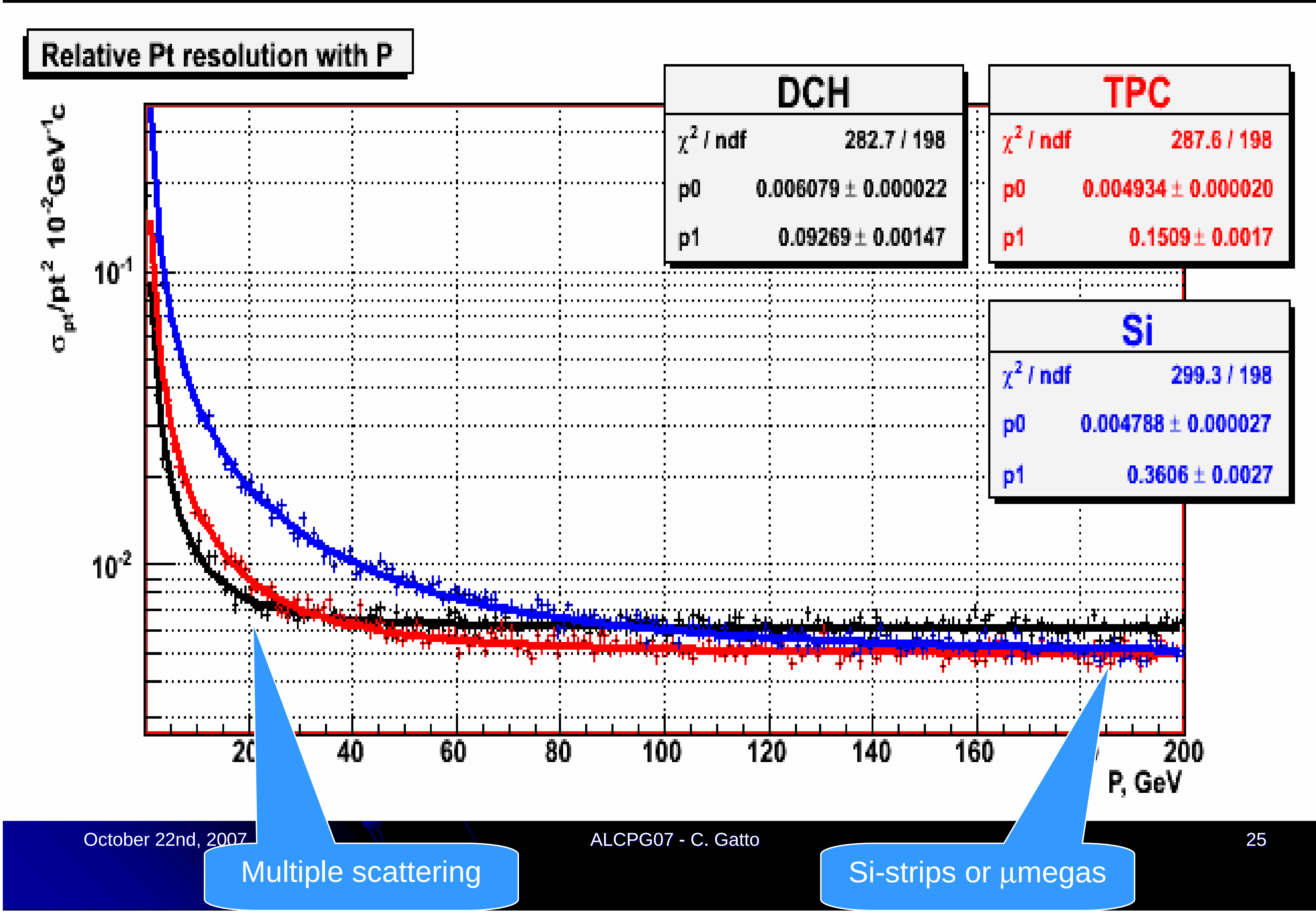
10 muons



Momentum Resolution vs P

$\sqrt{p_o^2 + p_1^2 / P^2}$

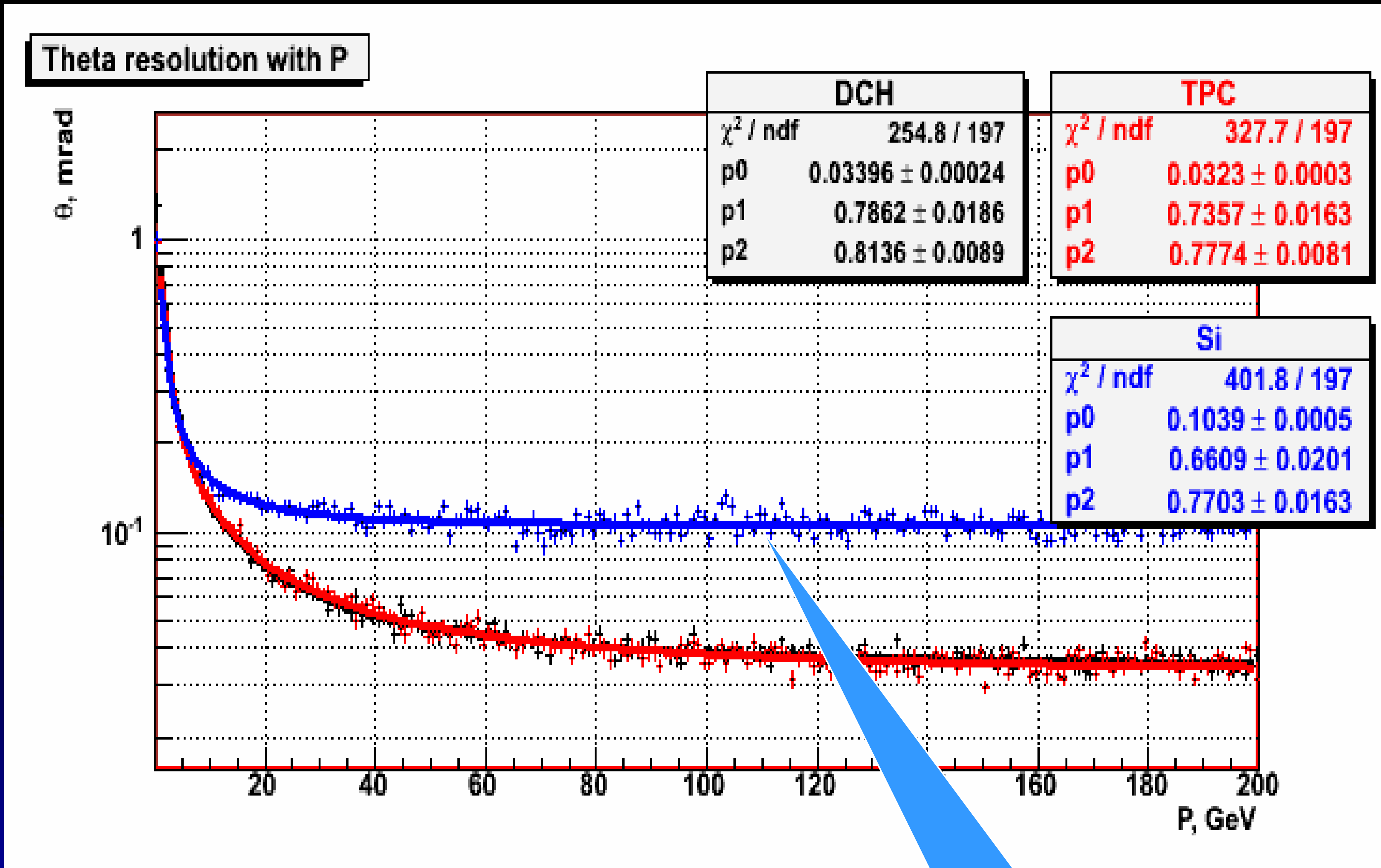
10 muons



$\sqrt{p_o^2 + p_1^2 / P^{2*p_2}}$

10 muons

θ Resolution vs P

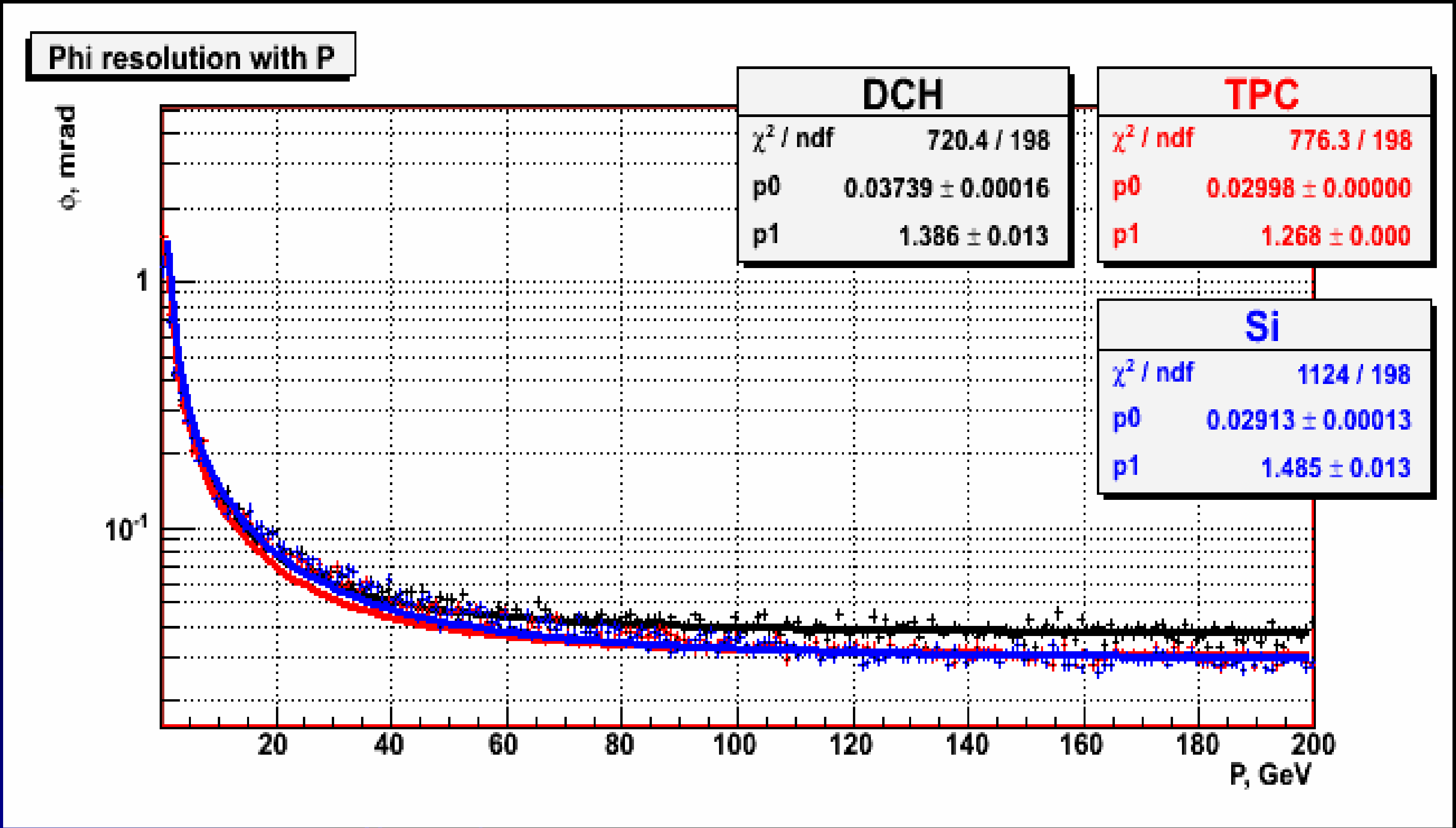


Single sensors in barrel

$\sqrt{p_o^2 + p_1^2 / P^2}$

10 muons

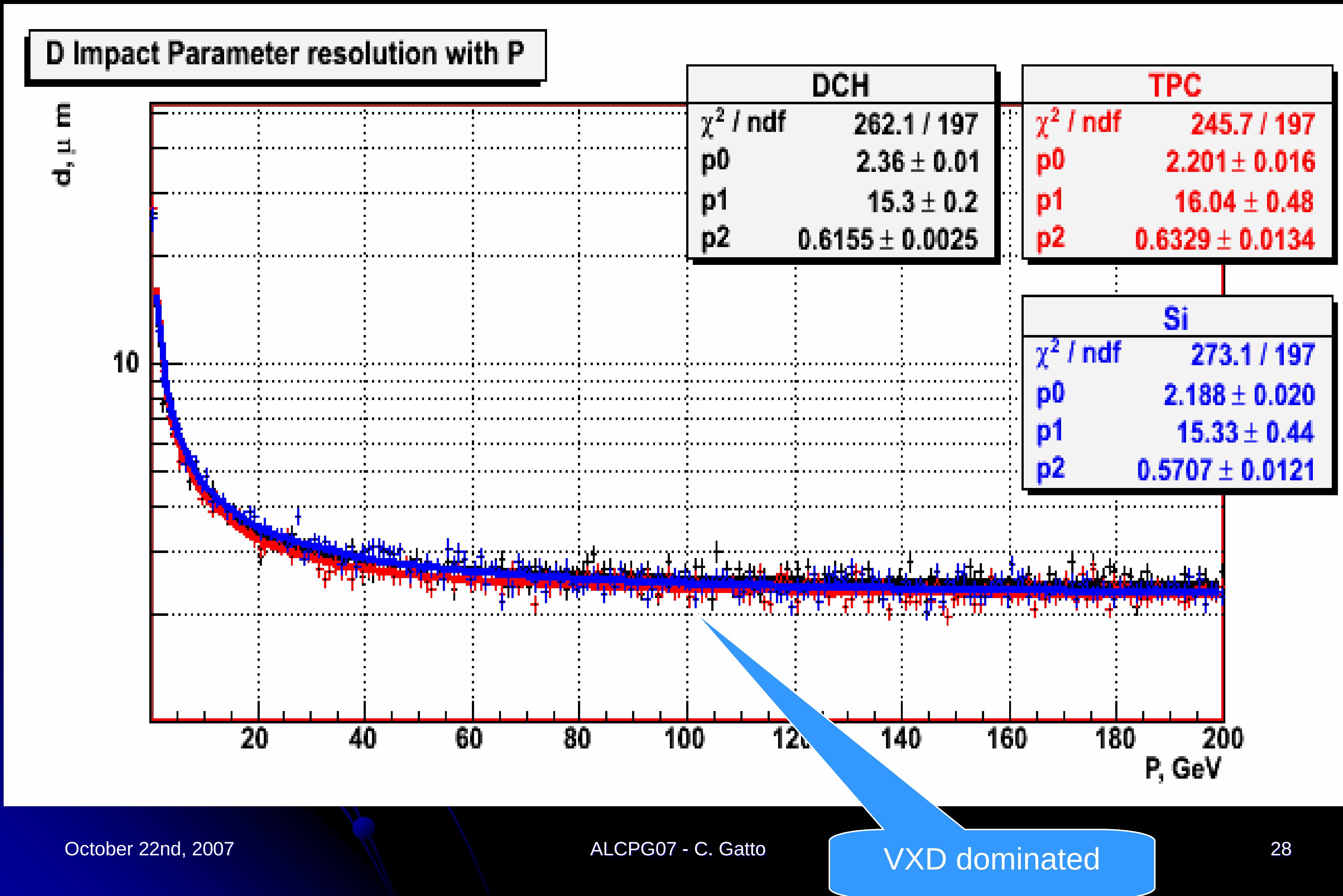
φ Resolution vs P



$\sqrt{p_o^2 + p_1^2 / P^{2*p_2}}$

D$_0$ Resolution vs P

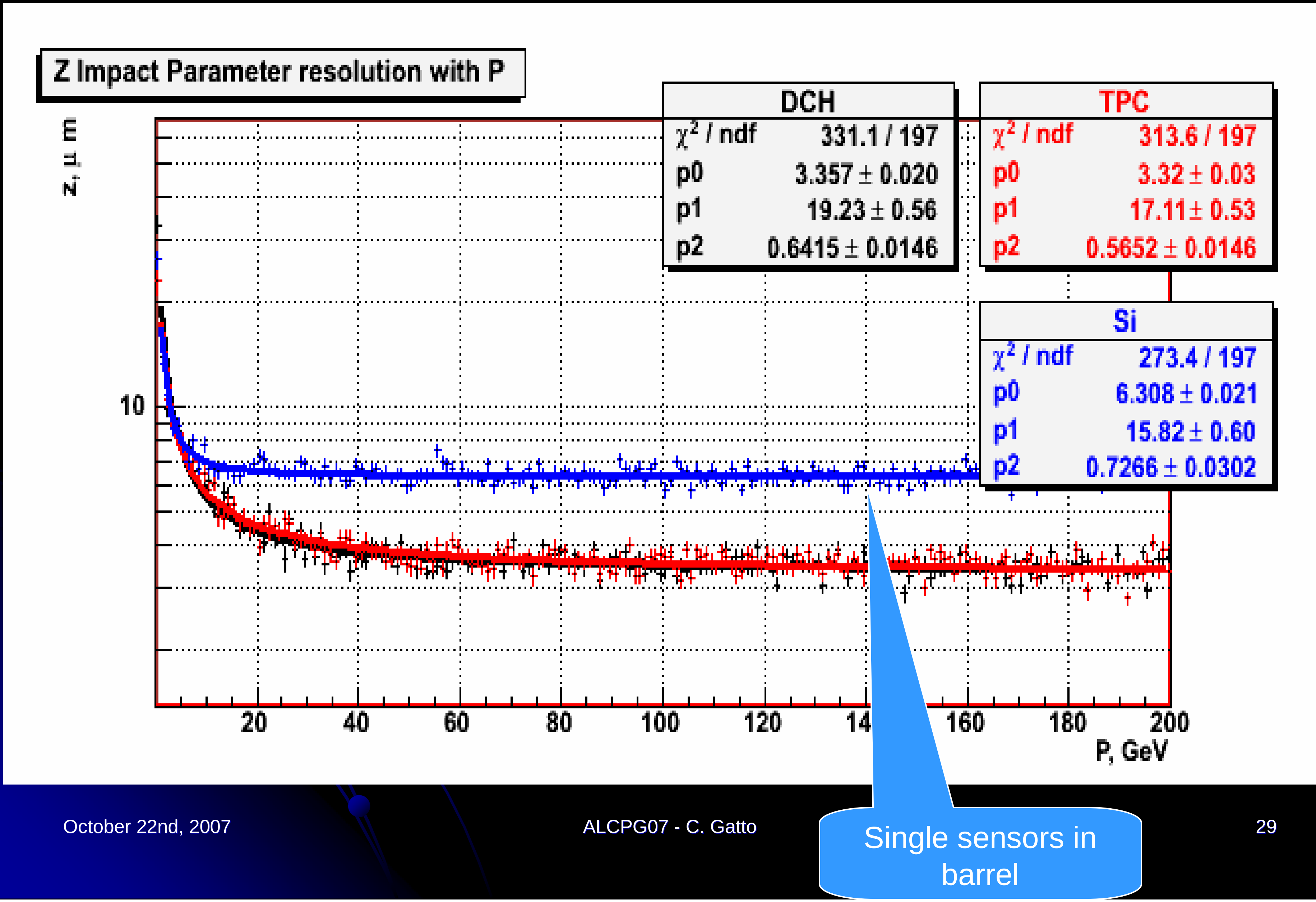
10 muons



$\sqrt{p_o^2 + p_1^2 / P^{2*p_2}}$

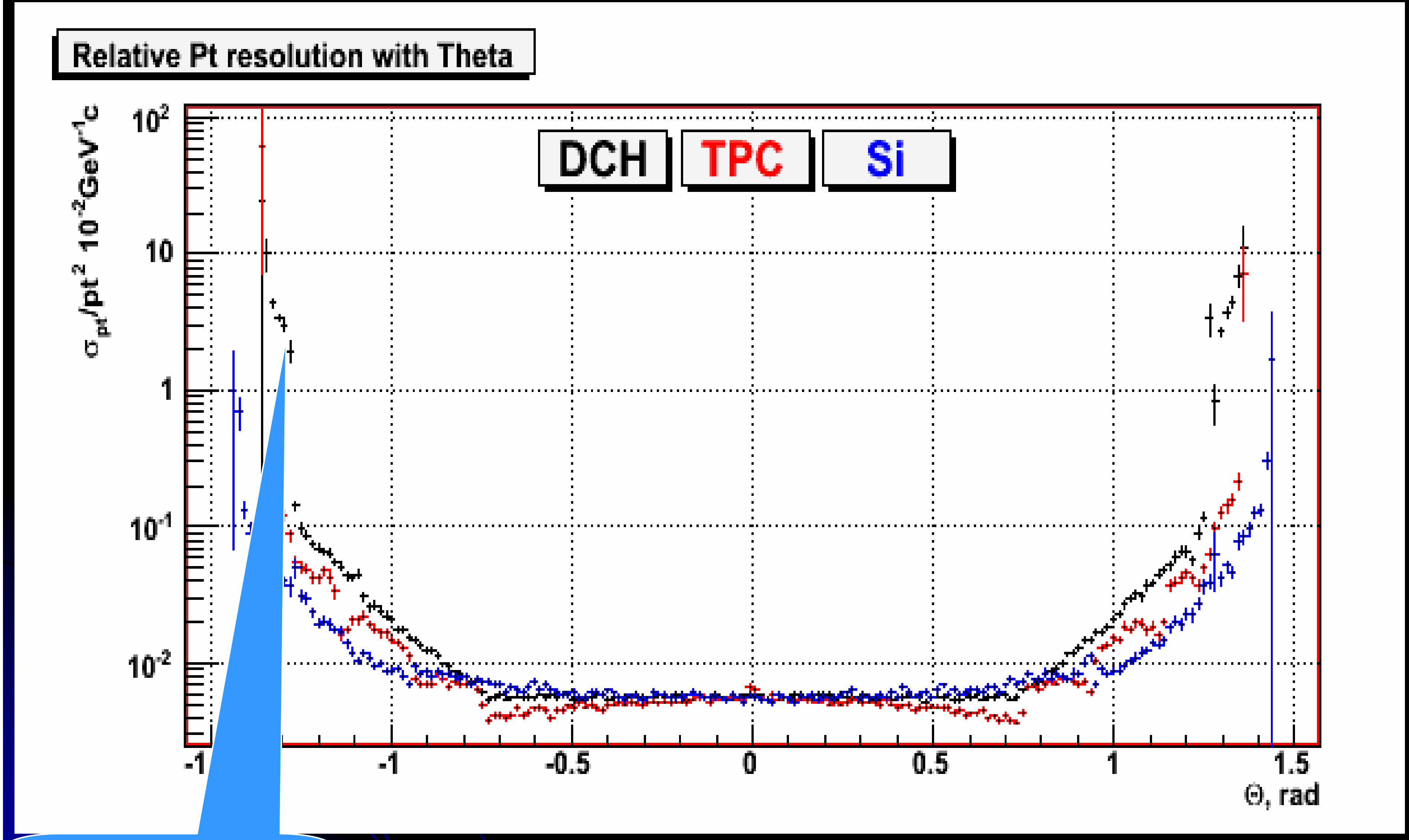
10 muons

Z_o Resolution vs P



Pt Resolution vs θ

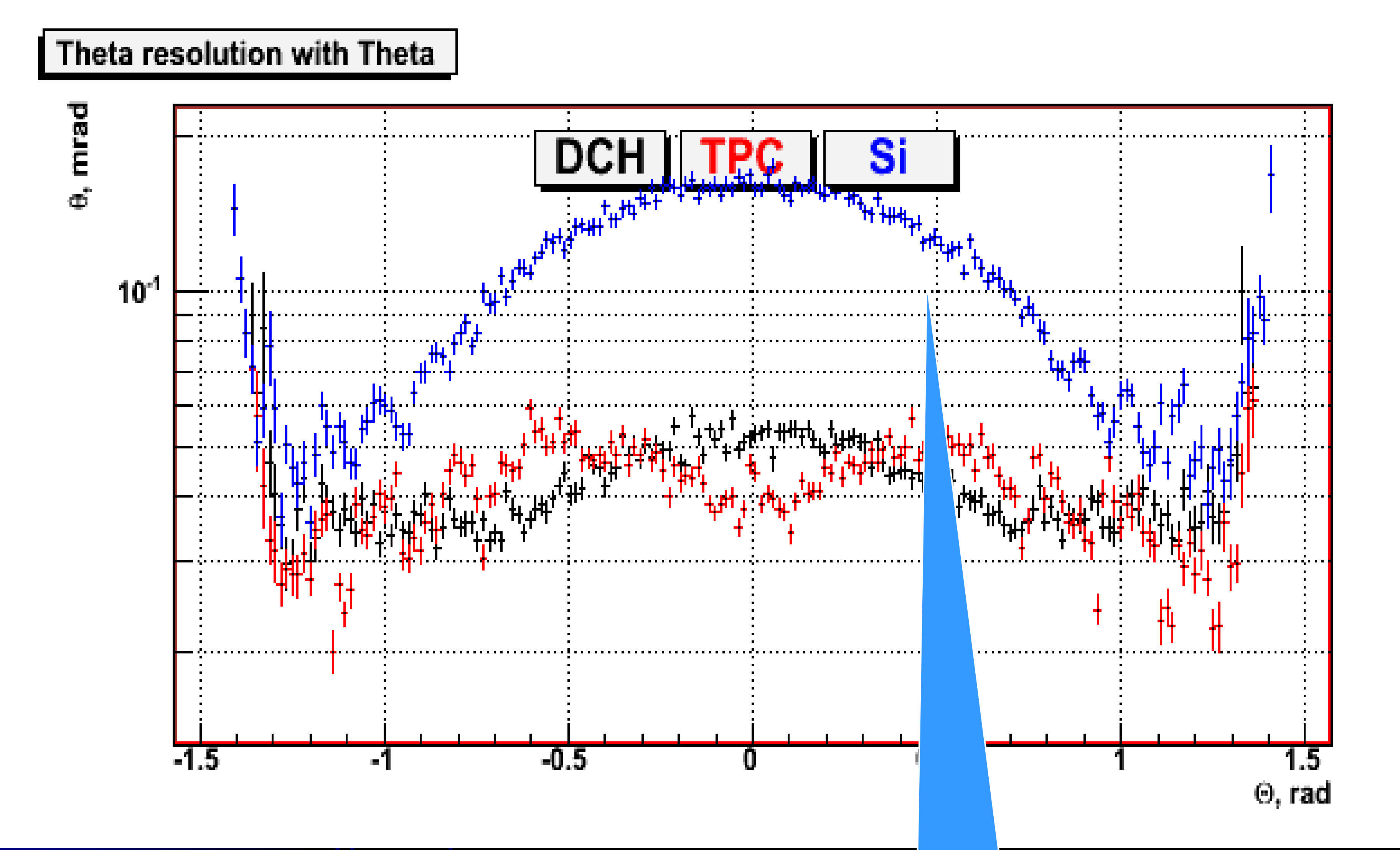
10 muons



No Forward Tracking

θ Resolution vs θ

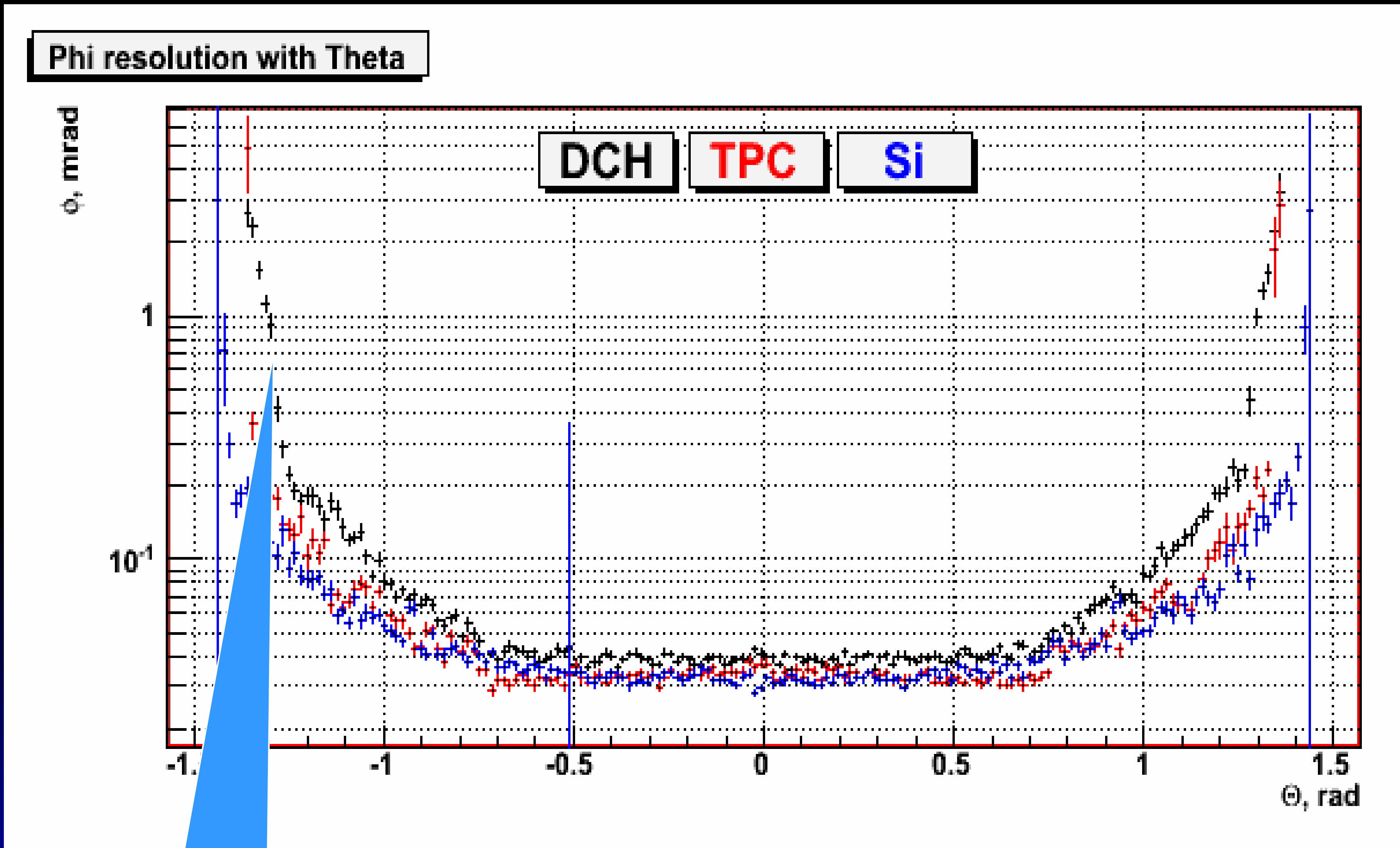
10 muons



Single sensors in barrel

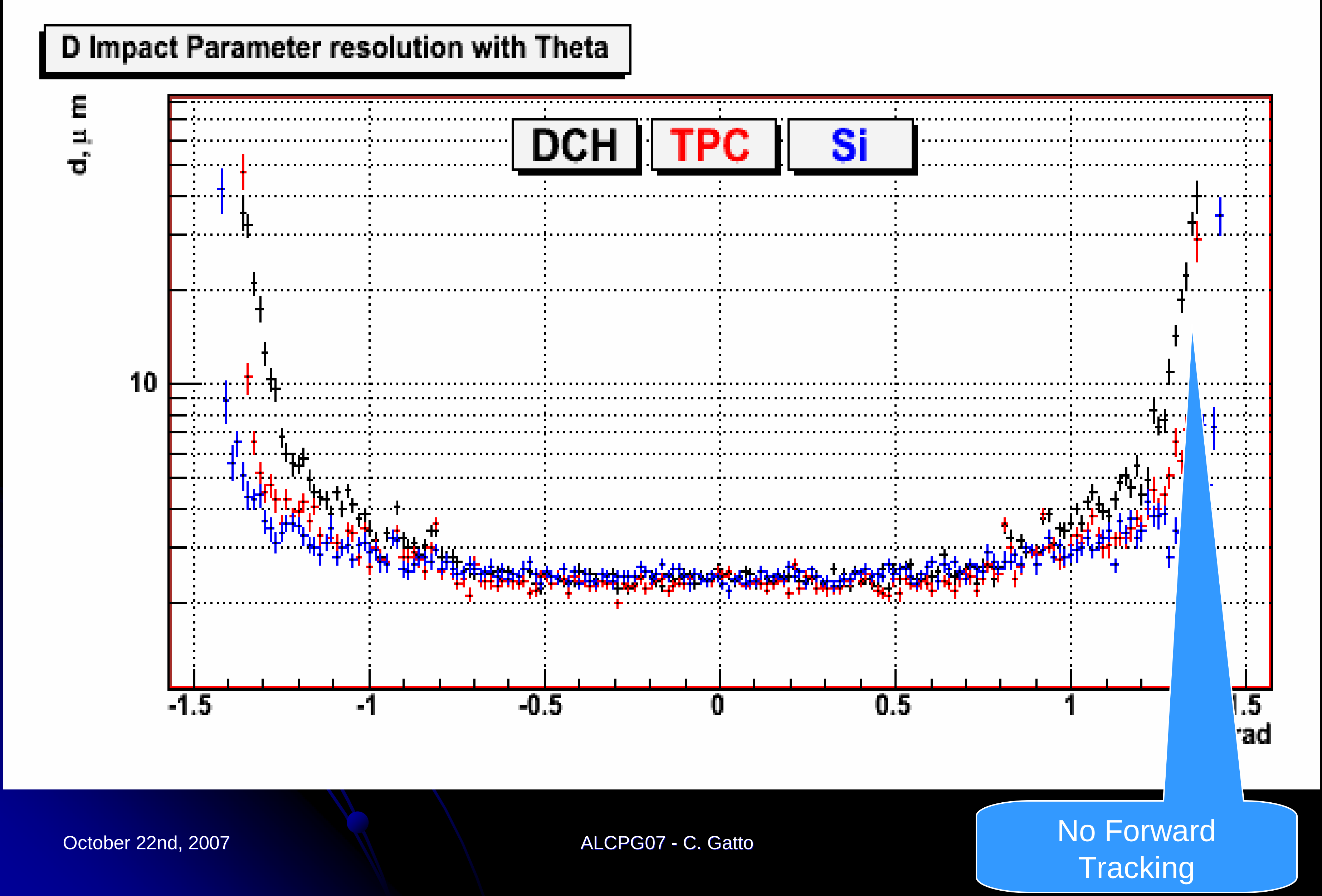
φ Resolution vs θ

10 muons

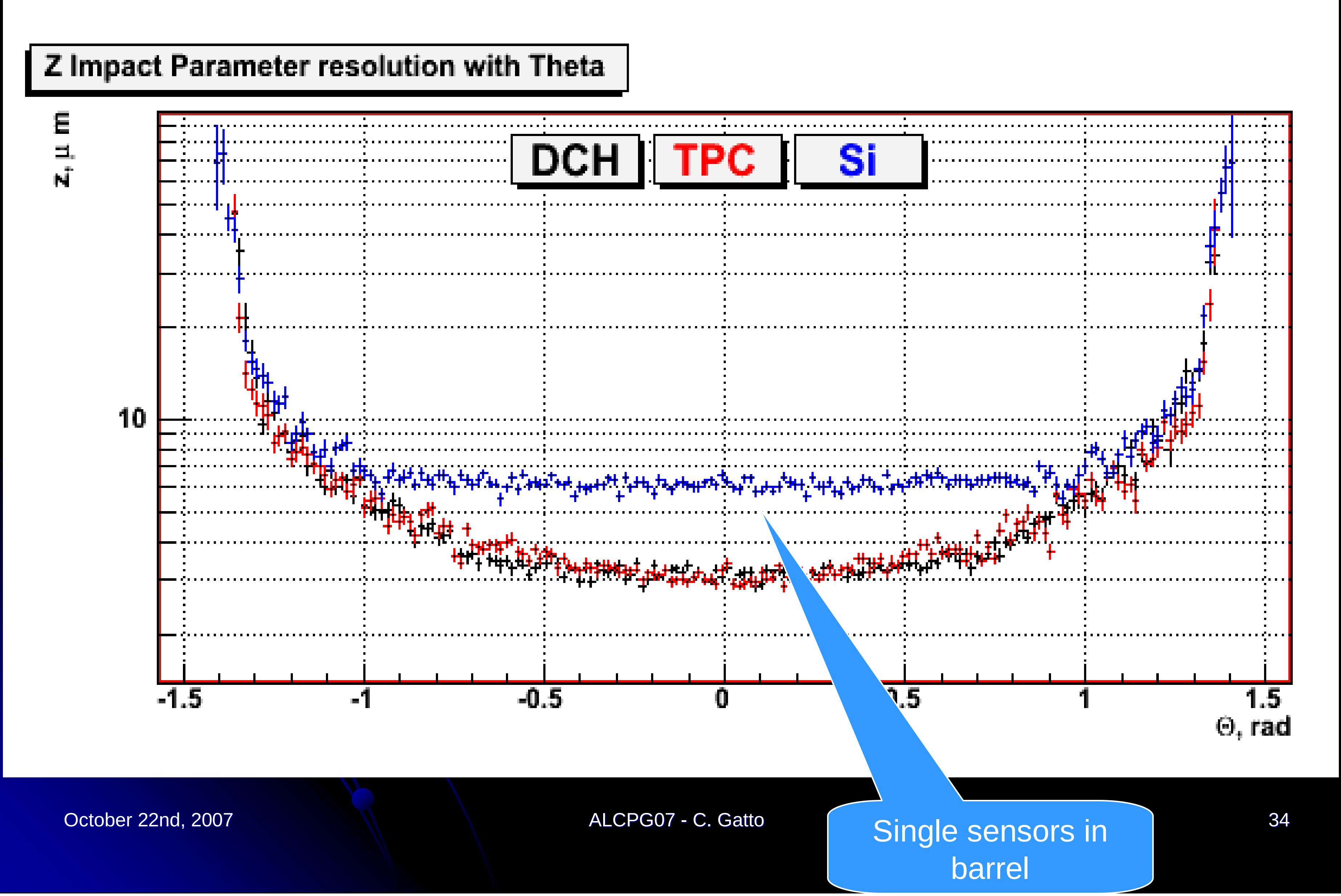


No Forward Tracking

Do Resolution vs θ

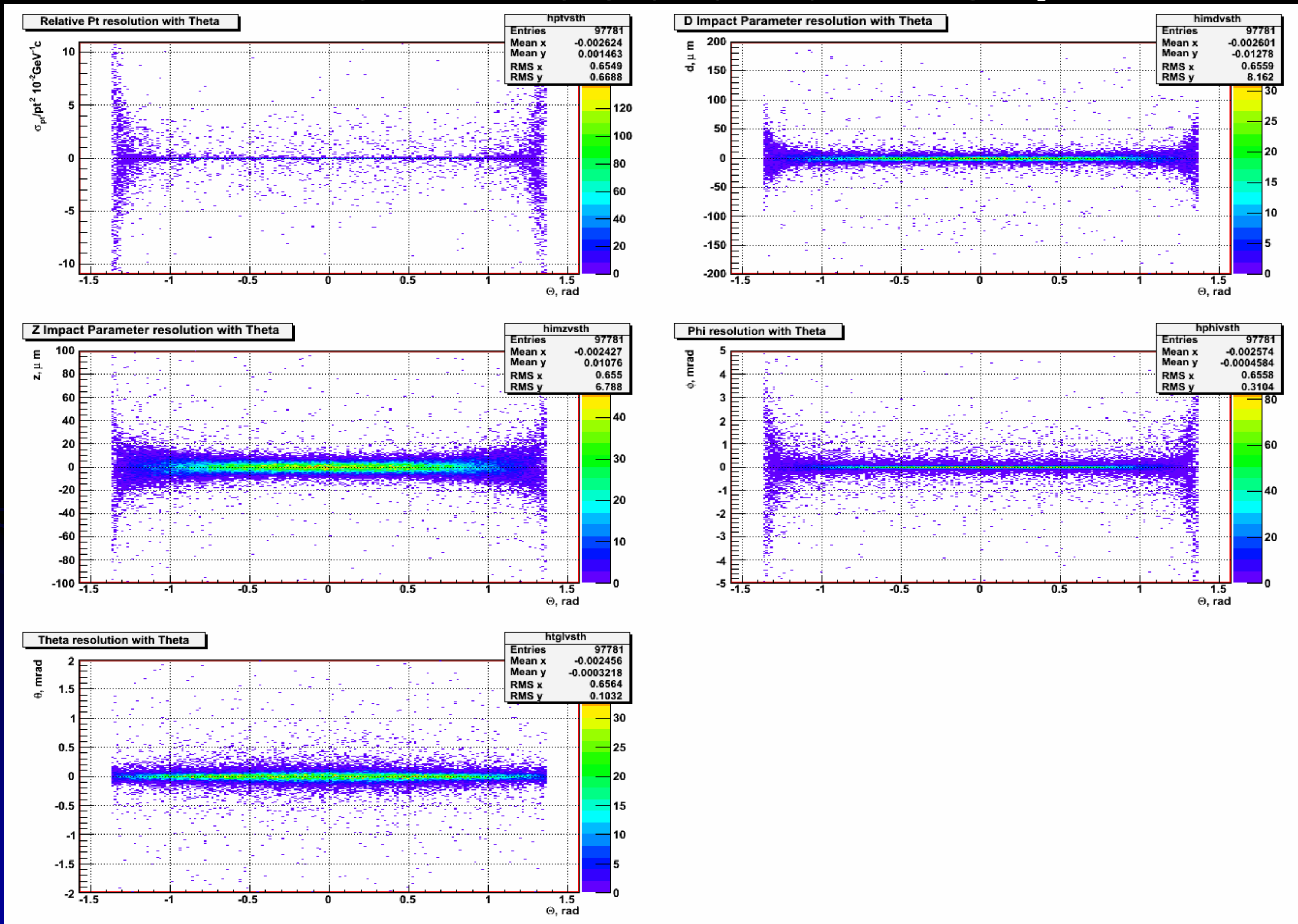


Zo Resolution vs θ



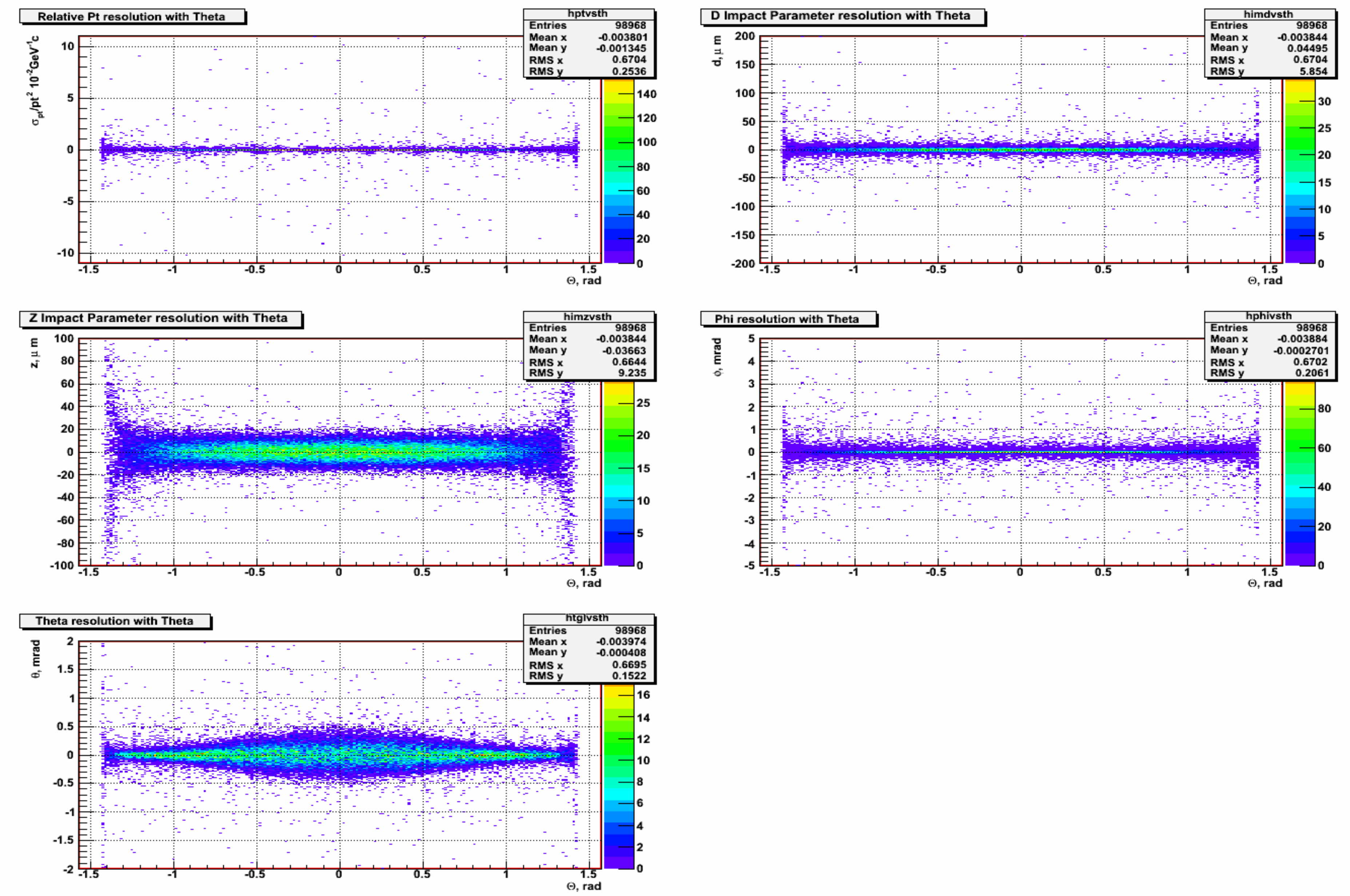
10 muons

DCH Resolution vs θ



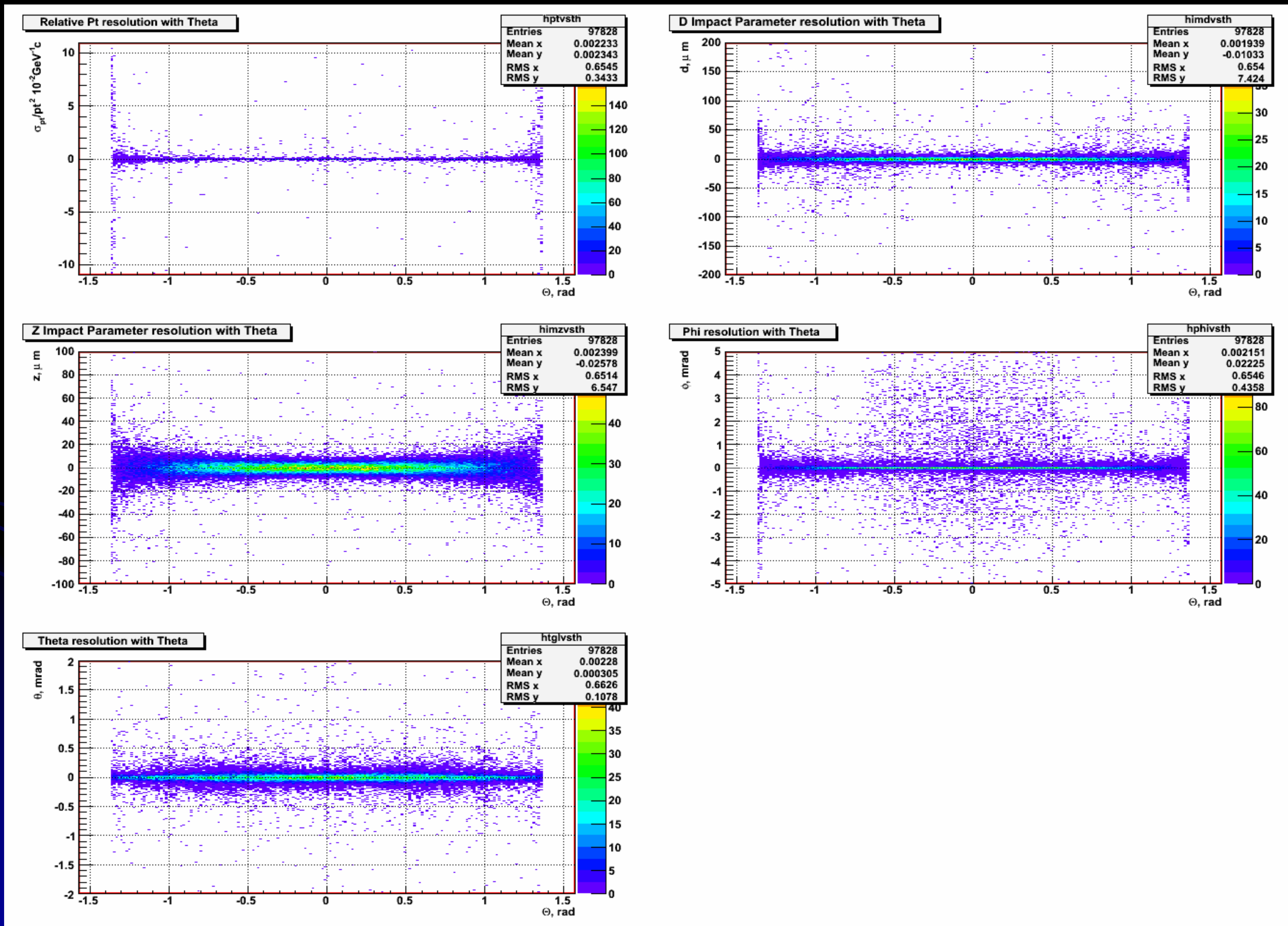
SiT Resolution vs θ

10 muons



10 muons

TPC Resolution vs θ



Tracking Performance for Single Tracks (P=[0.02,200] GeV)

DCH

$$\sigma(P_t^{-1}) = 9.3/P \oplus 0.61\times10^{-4}\,GeV^{-1}c$$
$$\sigma(\vartheta) = 0.79/P^{0.81} \oplus 0.034\ mrad$$
$$\sigma(\varphi) = 1.39/P \oplus 0.037\ mrad$$
$$\sigma(D_o) = 15.3/P^{0.62} \oplus 2.4\ \mu m$$
$$\sigma(Z_o) = 19.2/P^{0.64} \oplus 3.4\ \mu m$$

TPC

$$\sigma(P_t^{-1}) = 15.1/P \oplus 0.49\times10^{-4}\,GeV^{-1}c$$
$$\sigma(\vartheta) = 0.74/P^{0.78} \oplus 0.032\ mrad$$
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SiT

$$\sigma(P_t^{-1}) = 36.1/P \oplus 0.48\times10^{-4}\,GeV^{-1}c$$
$$\sigma(\vartheta) = 0.6/P^{0.77} \oplus 0.10\ mrad$$
$$\sigma(\varphi) = 1.5/P \oplus 0.029\ mrad$$
$$\sigma(D_o) = 15.3/P^{0.57} \oplus 2.2\ \mu m$$
$$\sigma(Z_o) = 15.8/P^{0.64} \oplus 6.3\ \mu m$$

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MS effect

Tracking Performance for Single Tracks (P=[0.02,200] GeV)

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$\sigma(P_t^{-1}) = 9.3/P \oplus 0.61\times10^{-4}\,GeV^{-1}c$

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$\sigma(Z_o) = 15.8/P^{0.64} \oplus 6.3\ \mu m$

MS effect

Single sensor effect

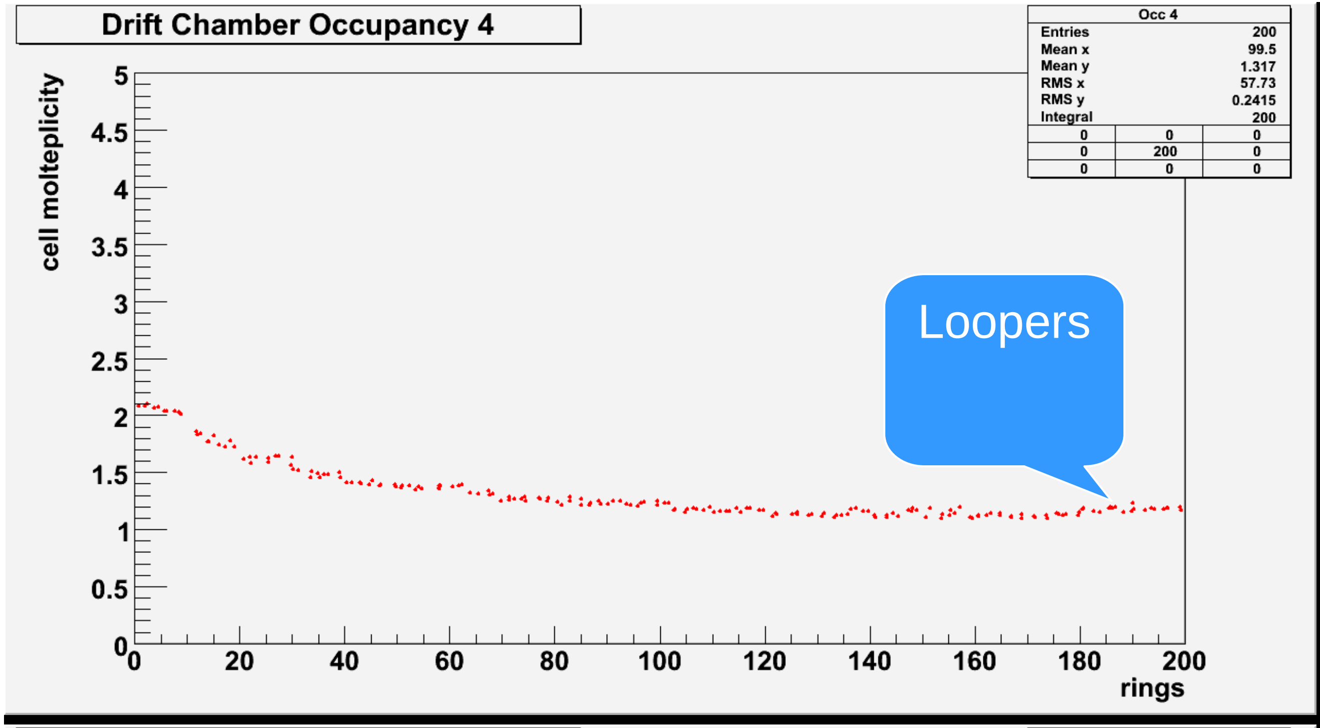
Detector Performance with Physics

- e^+e^- -> ttbar->6jets (1000 events)
- Full digitization (very important in multi-jet environnement)

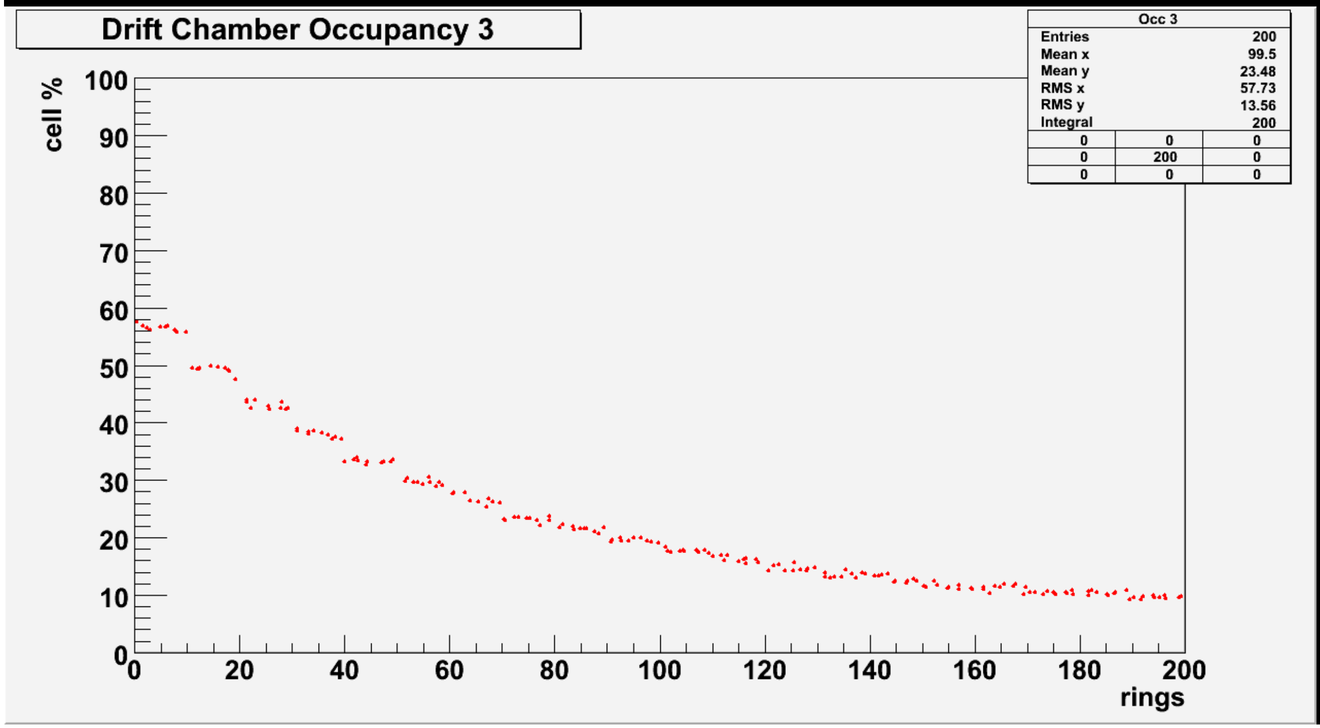
DCH

$e^+e^- \to t\bar{t} \to 6$ jets with DCH

E_{CM}=500 GeV



- Hits per cell vs layer



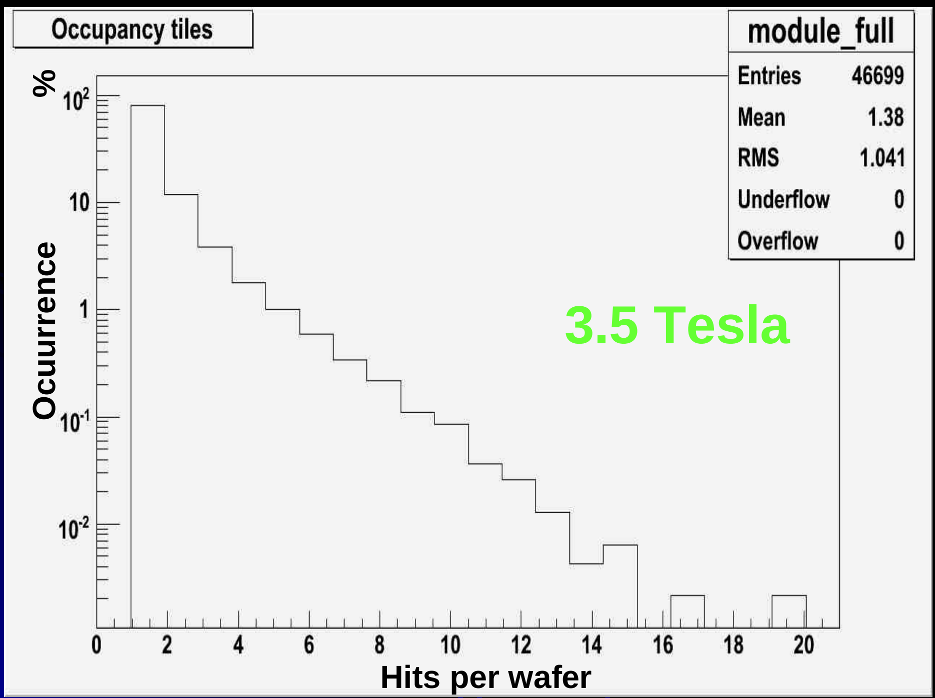
- Occupancy vs layer

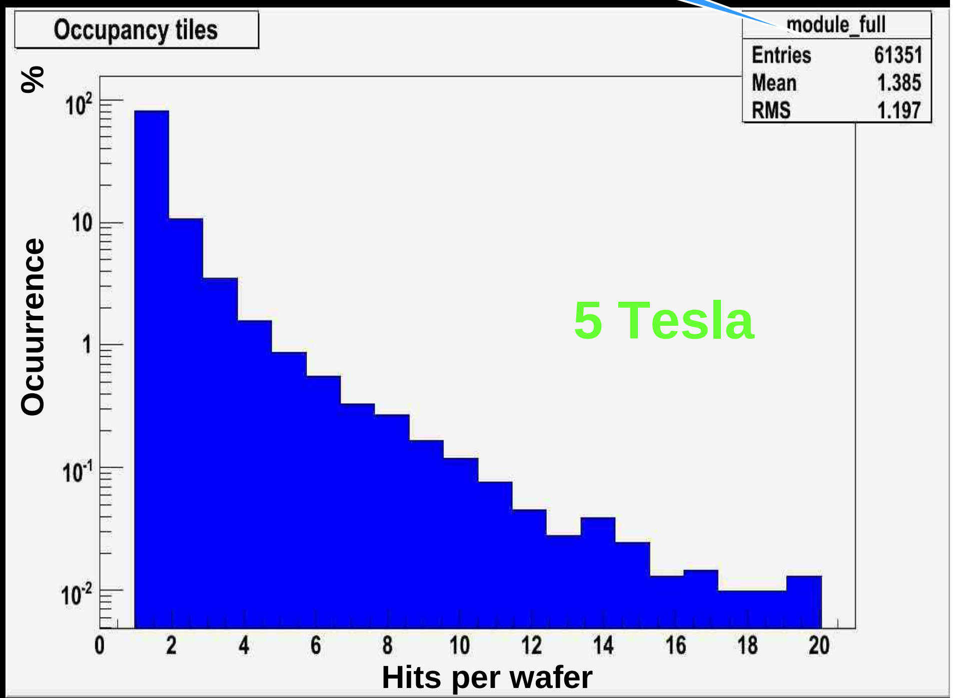
ttbar->6jets

SiT Wafer Occupancy Studies (Barrel)

200 events only

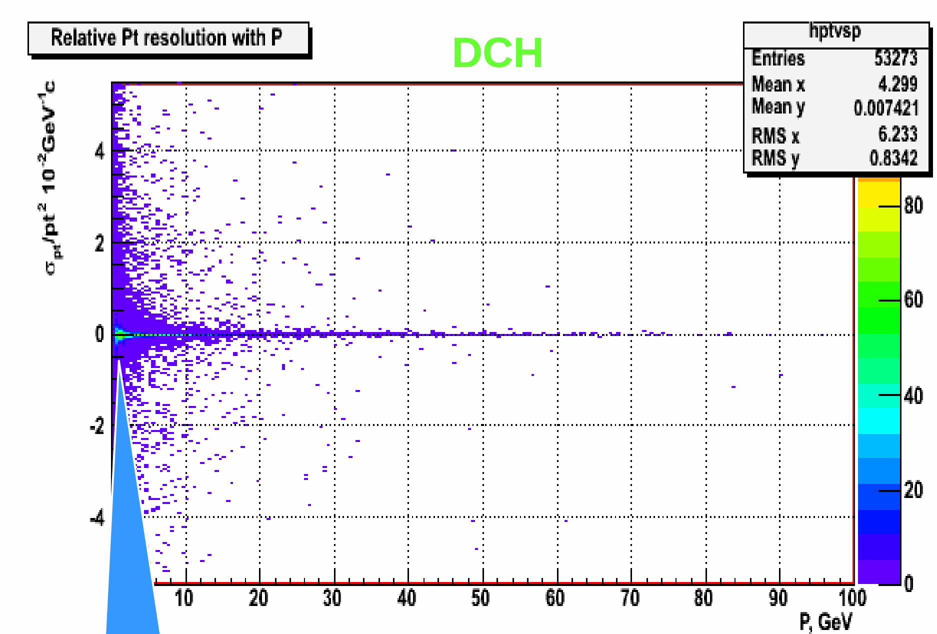
32% More Hits at 5 Tesla (loopers)

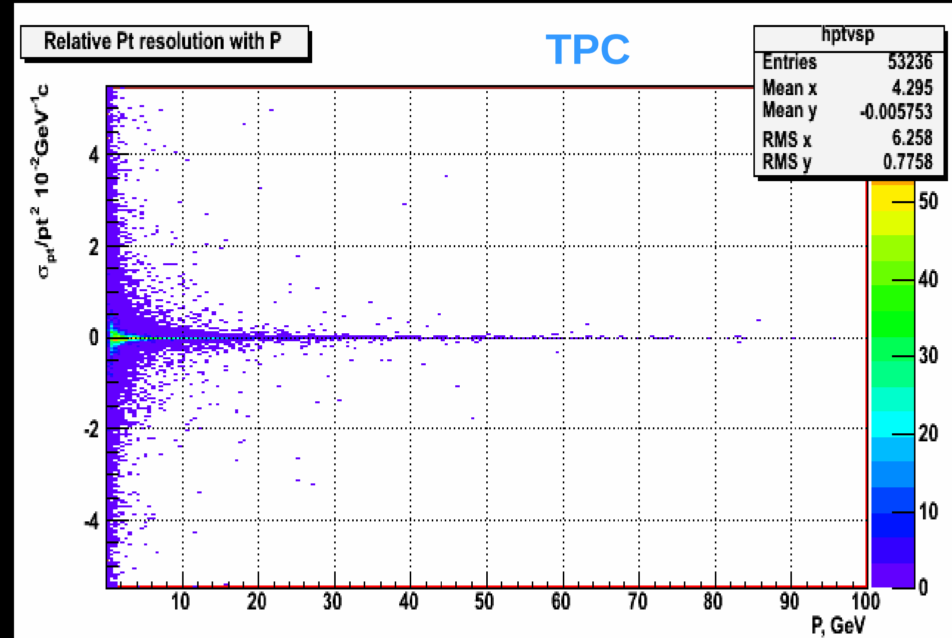


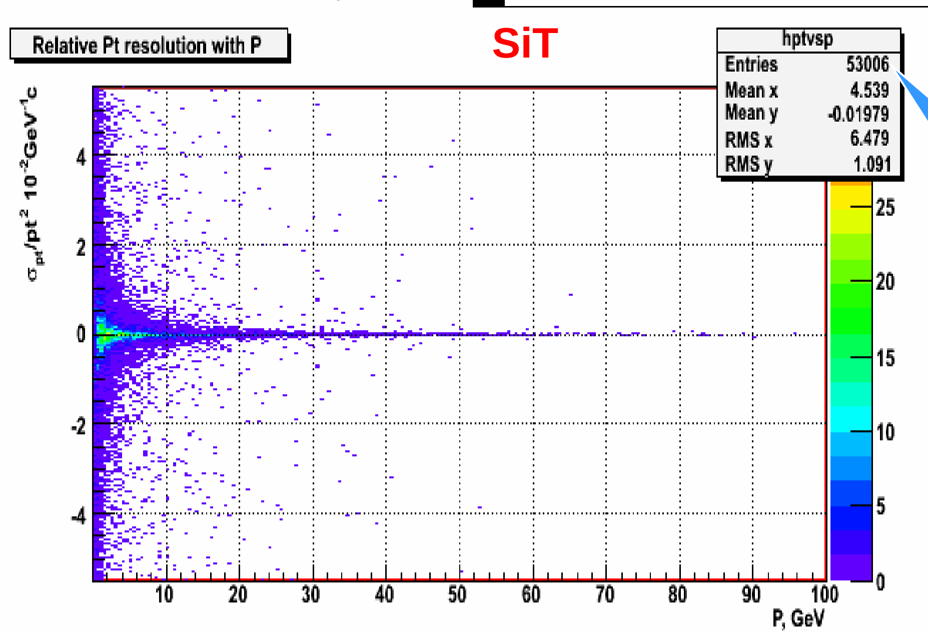


Momentum Resolution vs P

ttbar->6jets





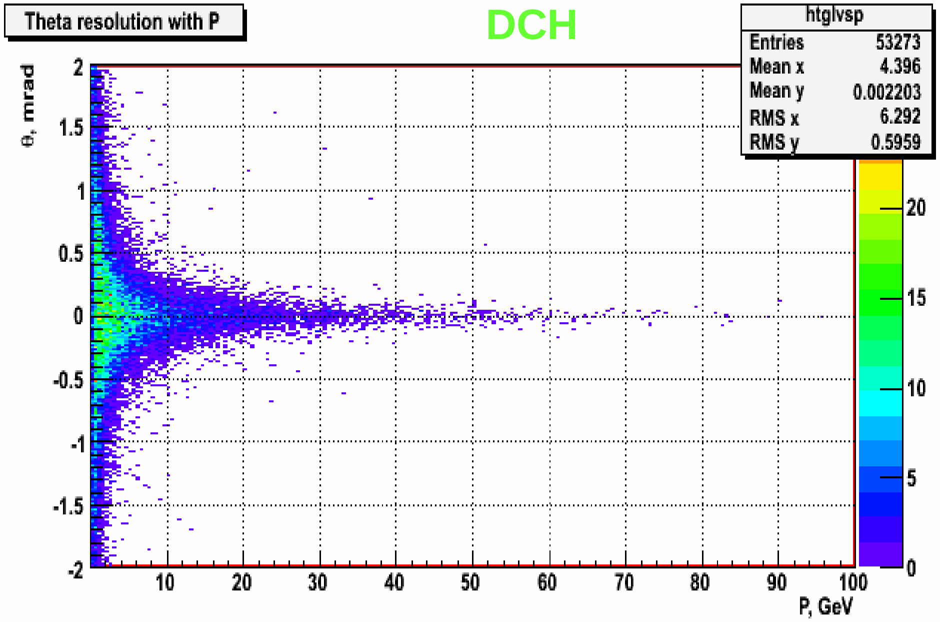


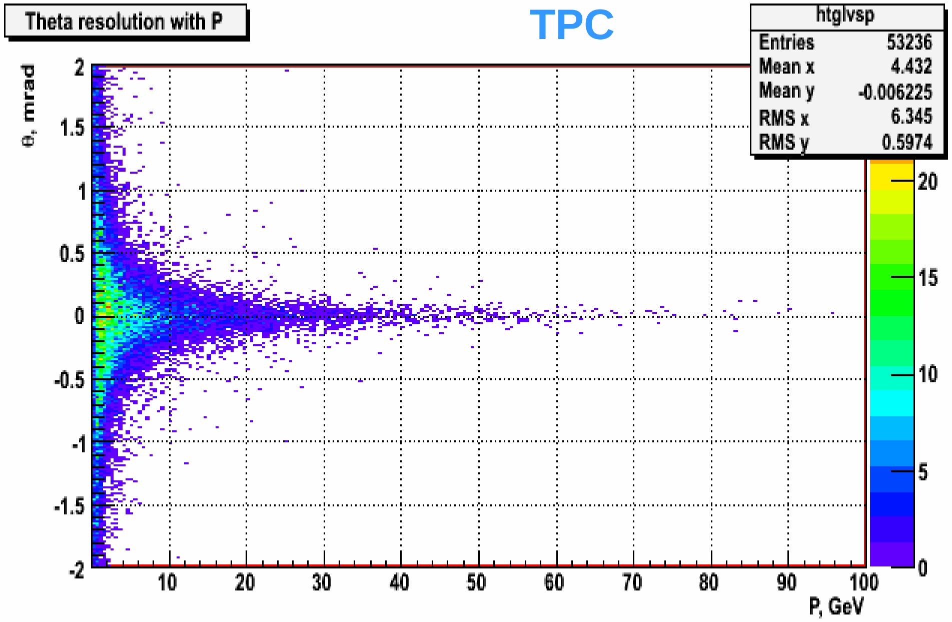
Lower multiple scattering

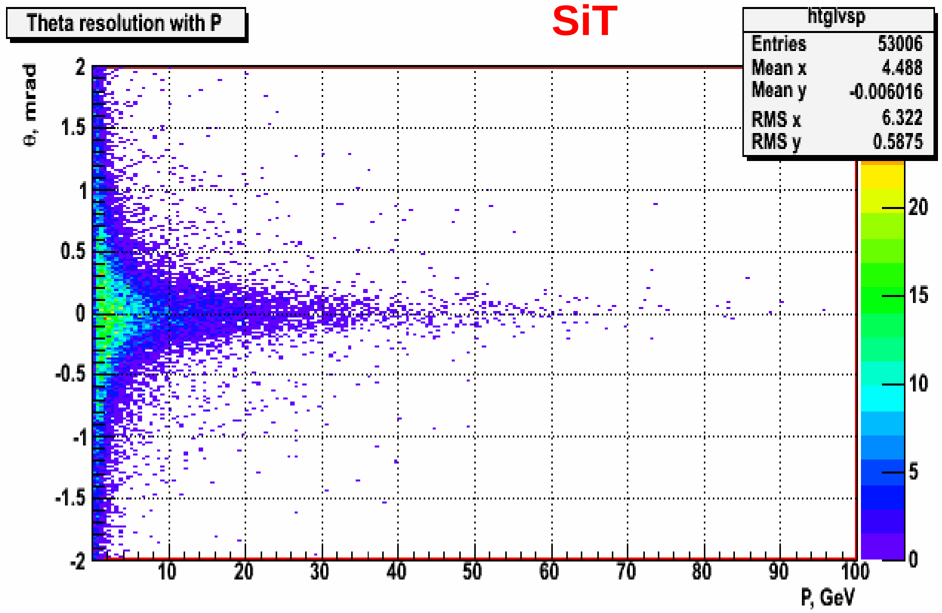
0.5% fewer tracks reconstructed

θ Resolution vs P

ttbar->6jets

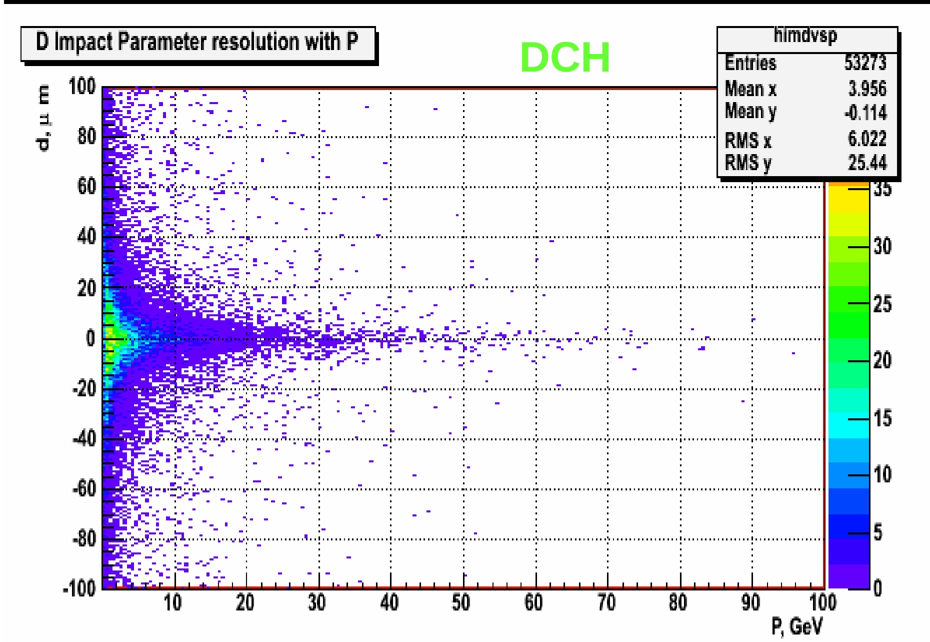


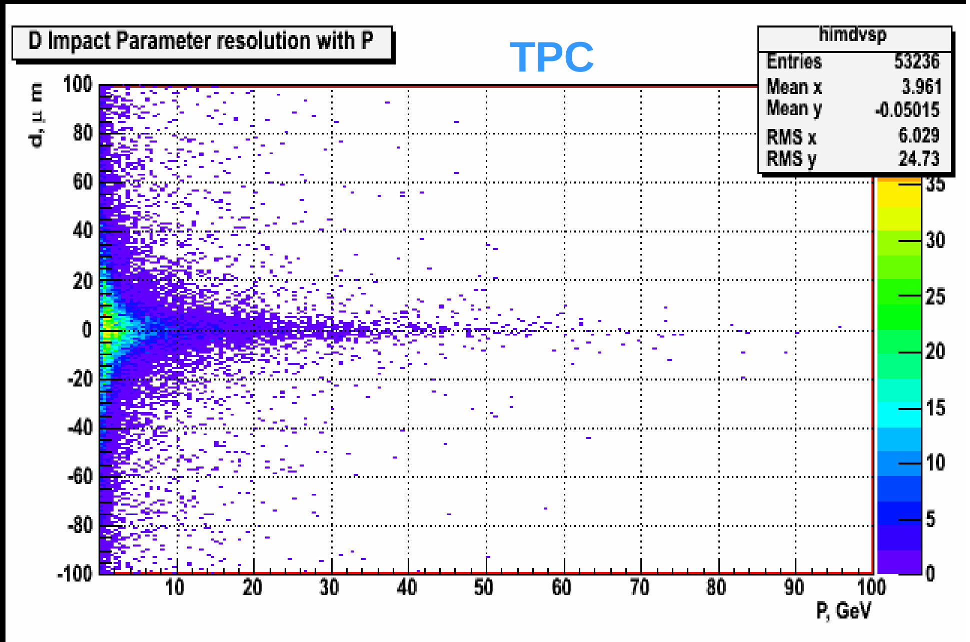


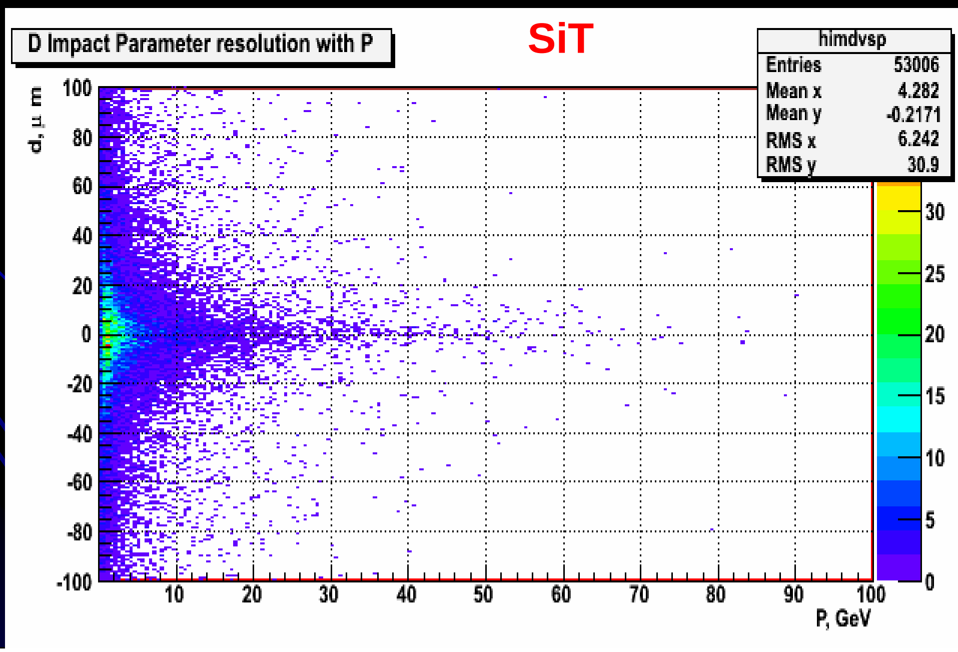


Do Resolution vs P

ttbar->6jets

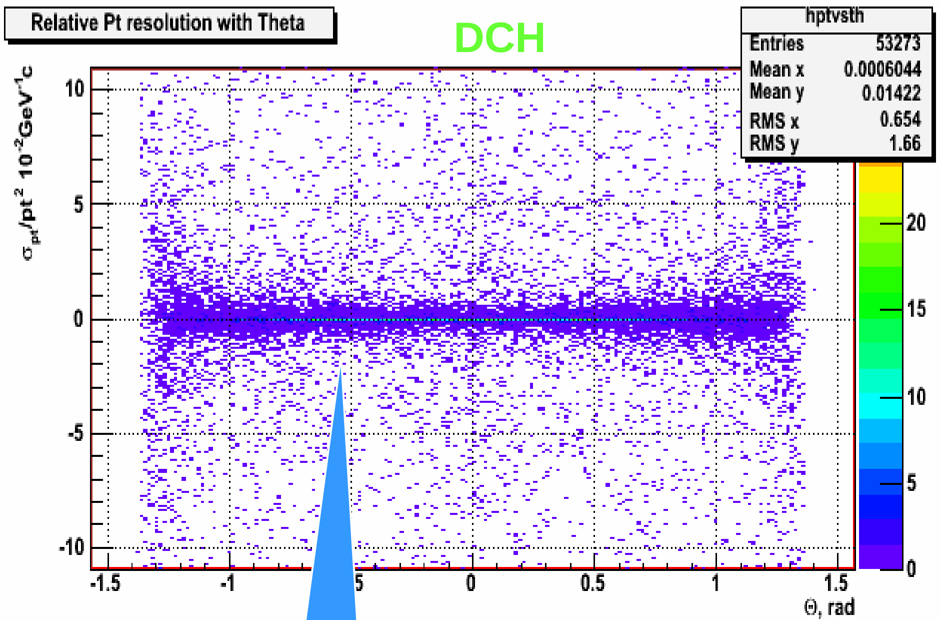


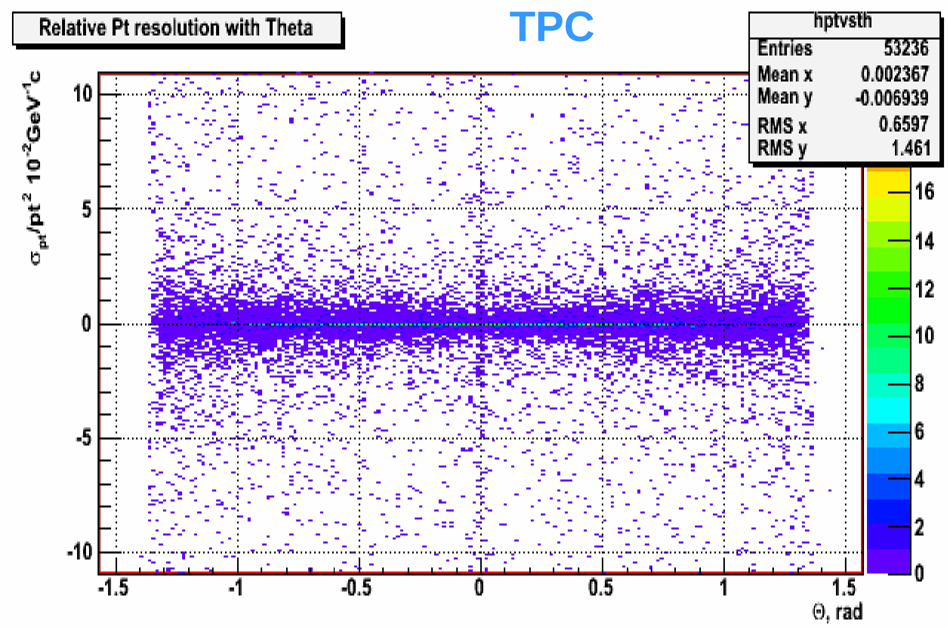


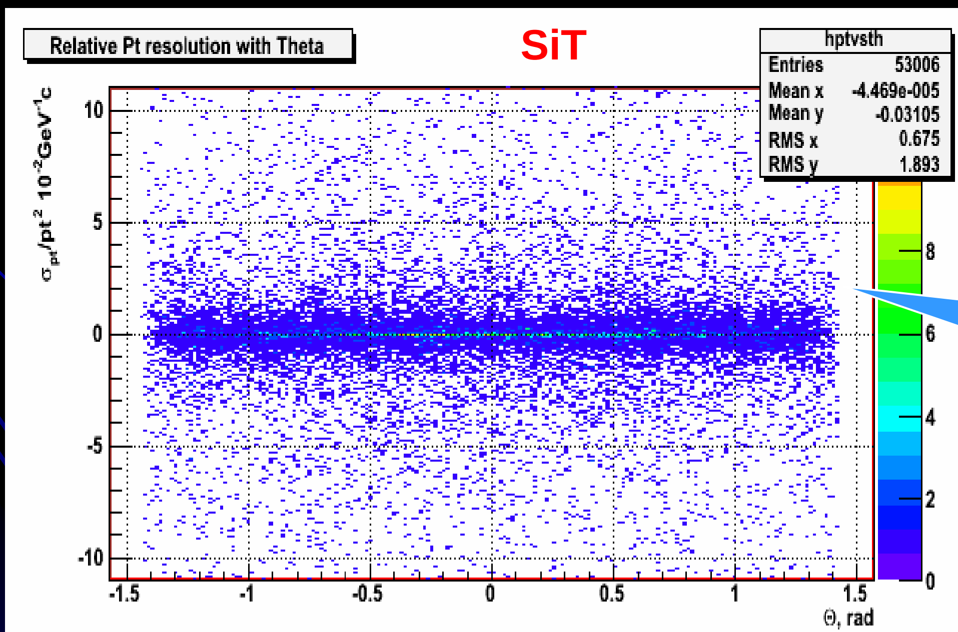


Pt Resolution vs θ

ttbar->6jets





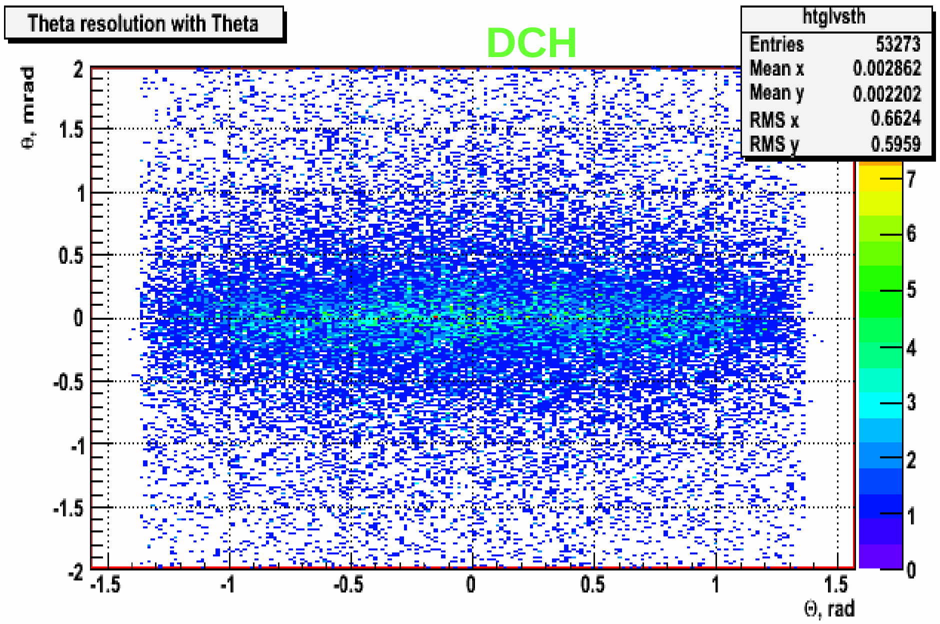


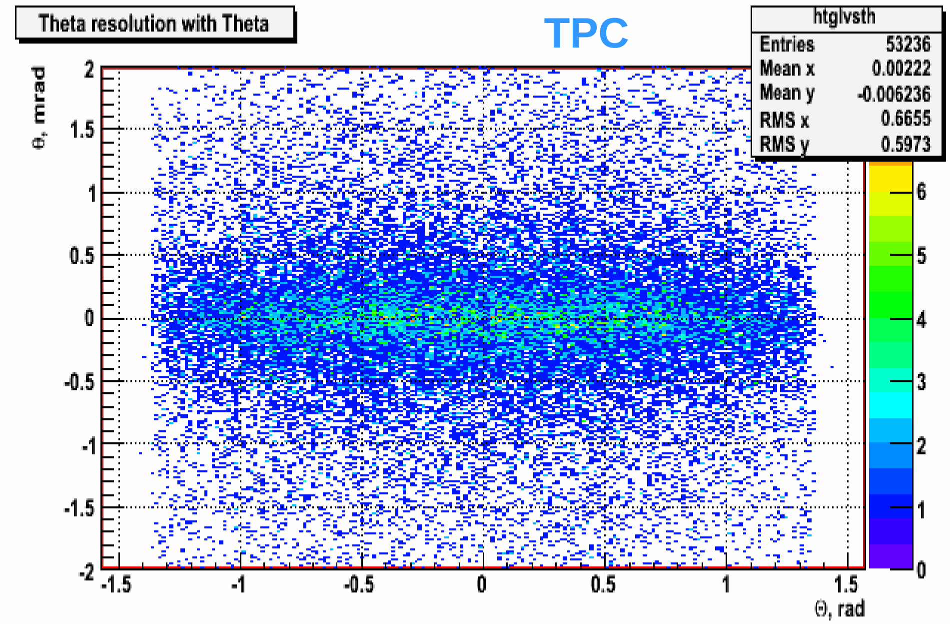
Lower multiple scattering

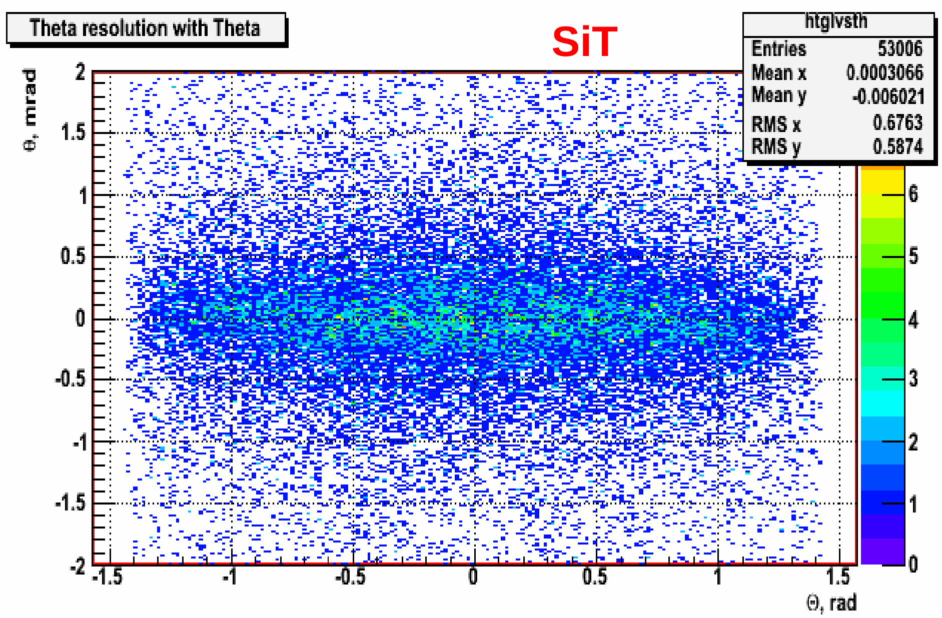
Extended coverage

θ Resolution vs θ

ttbar->6jets

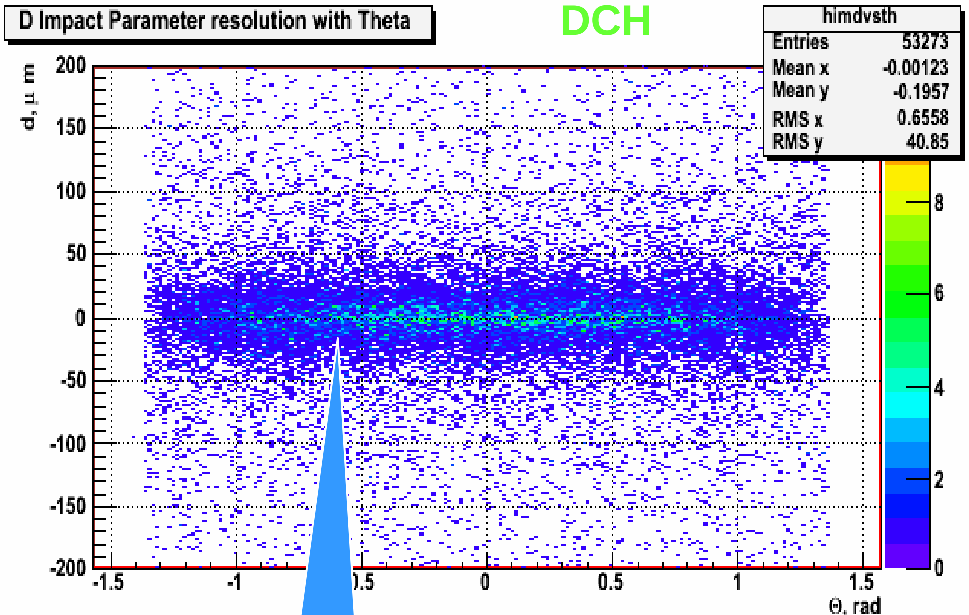


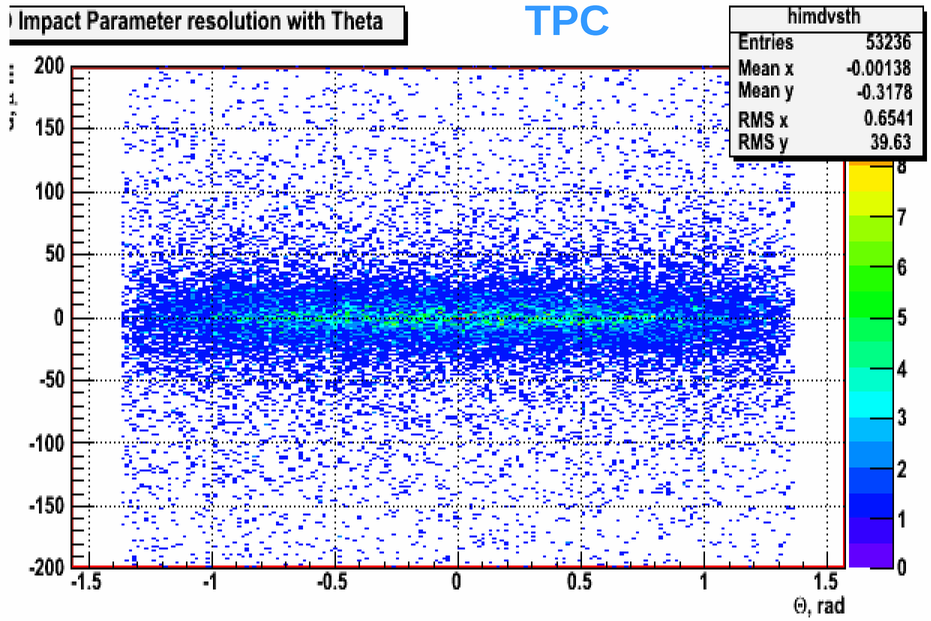


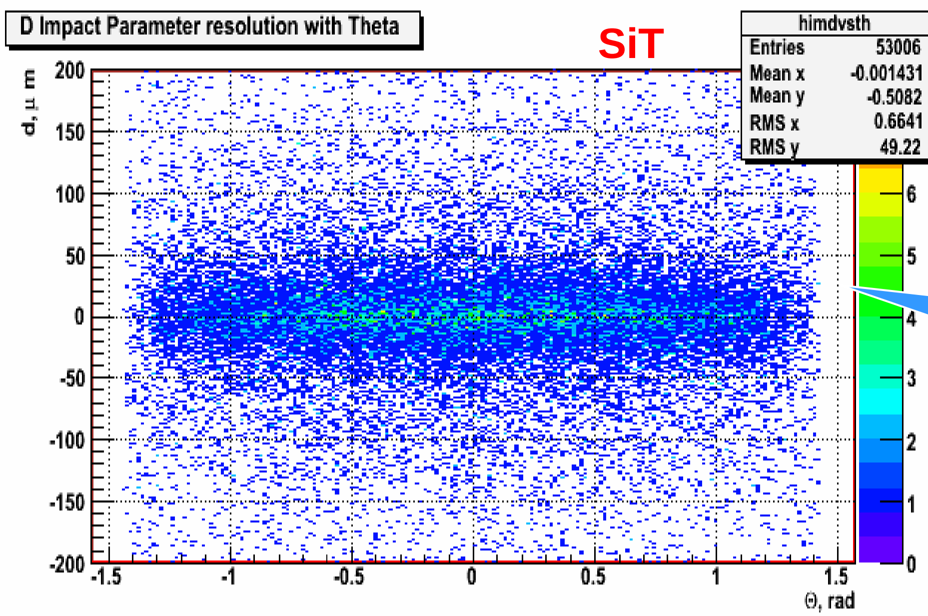


ttbar->6jets

Do Resolution vs θ







Lower multiple scattering

Extended coverage

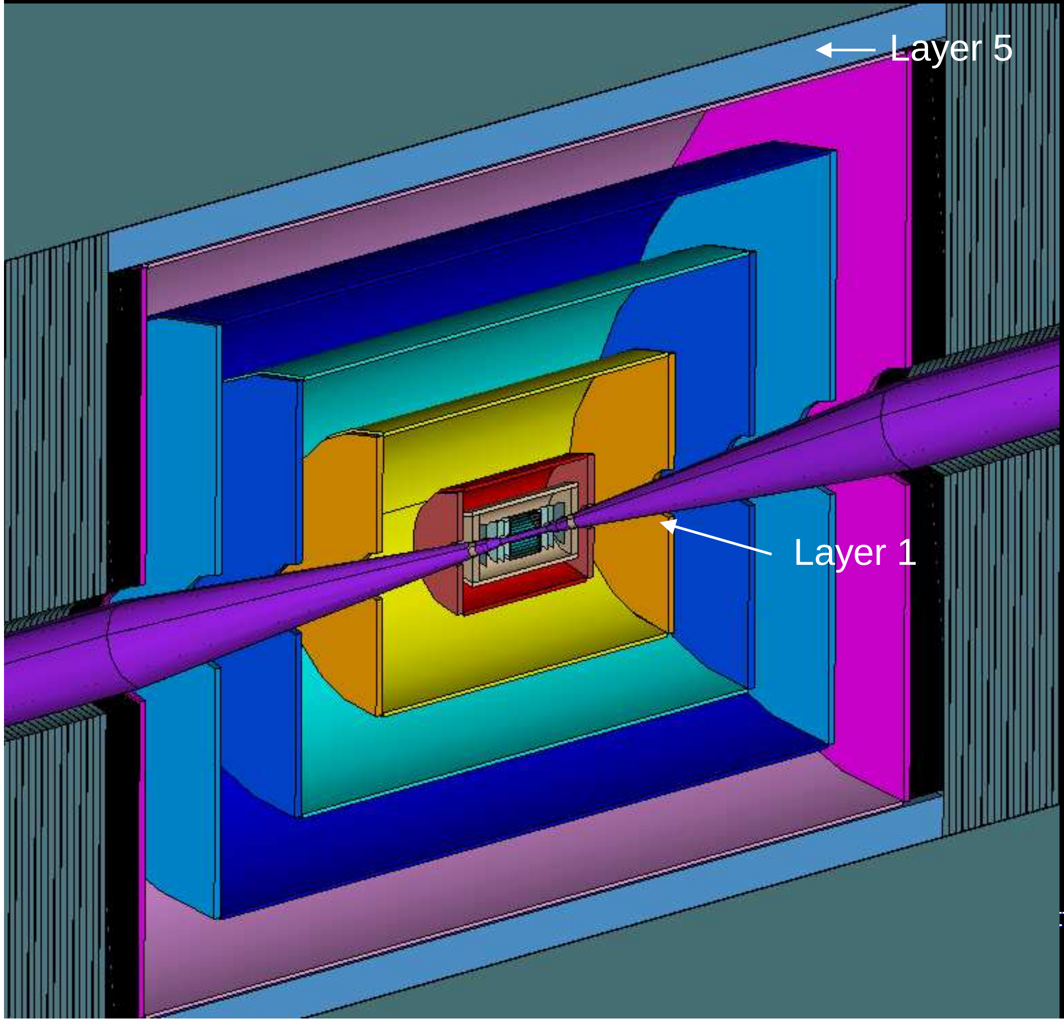
Conclusions

- A cross-concept detector study has recently (1.5 months) started, comparing **CluCou DCH, 4th TPC and SiD Tracker**
- Goal is to get further insight into three Detector technologies for a Central Tracker at ILC
- FNAL and INFN collaboration
- Full machinery is in place, including **digitization, pattern recognition and Kalman Fit** (V0 reconstruction missing in SiT)
- Several studies already in progress
- **Turn-key simulation**: usable with any Physics channels and/or background
- **Perfect environment for detector optimization**

Backup slides

SiD Tracker

- 5-Layer silicon strip outer tracker, covering R_{in} = 20 cm to R_{out} = 125 cm, to accurately measure the momentum of charged particles

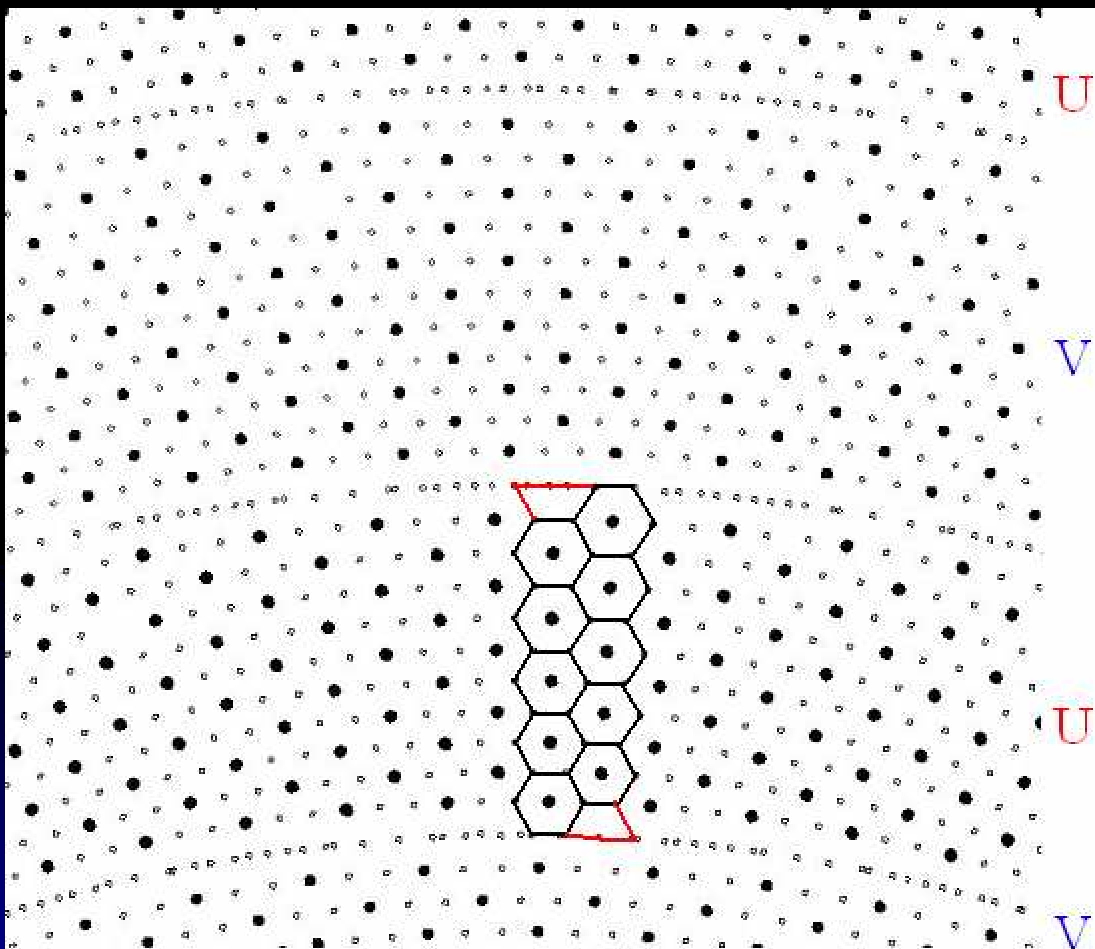


- Support
  - Double-walled CF cylinders
  - Allows full azimuthal and longitudinal coverage
- Barrels
  - Five barrels, measure Phi only
  - Eighty-fold phi segmentation
  - ~ 10 cm z segmentation
  - Barrel lengths increase with radius
- Disks
  - Four double-disks per end
  - Measure R and Phi
  - varying R segmentation
  - Disk radii increase with Z

:to

4thConcept ILC Drift Chamber

Layout



Hexagonal cells f.w./s.w.=2:1

cell height: 1.00 ÷ 1.20 cm
cell radius: 6.00 ÷ 7.00 mm

(max. drift time < 300 ns !)

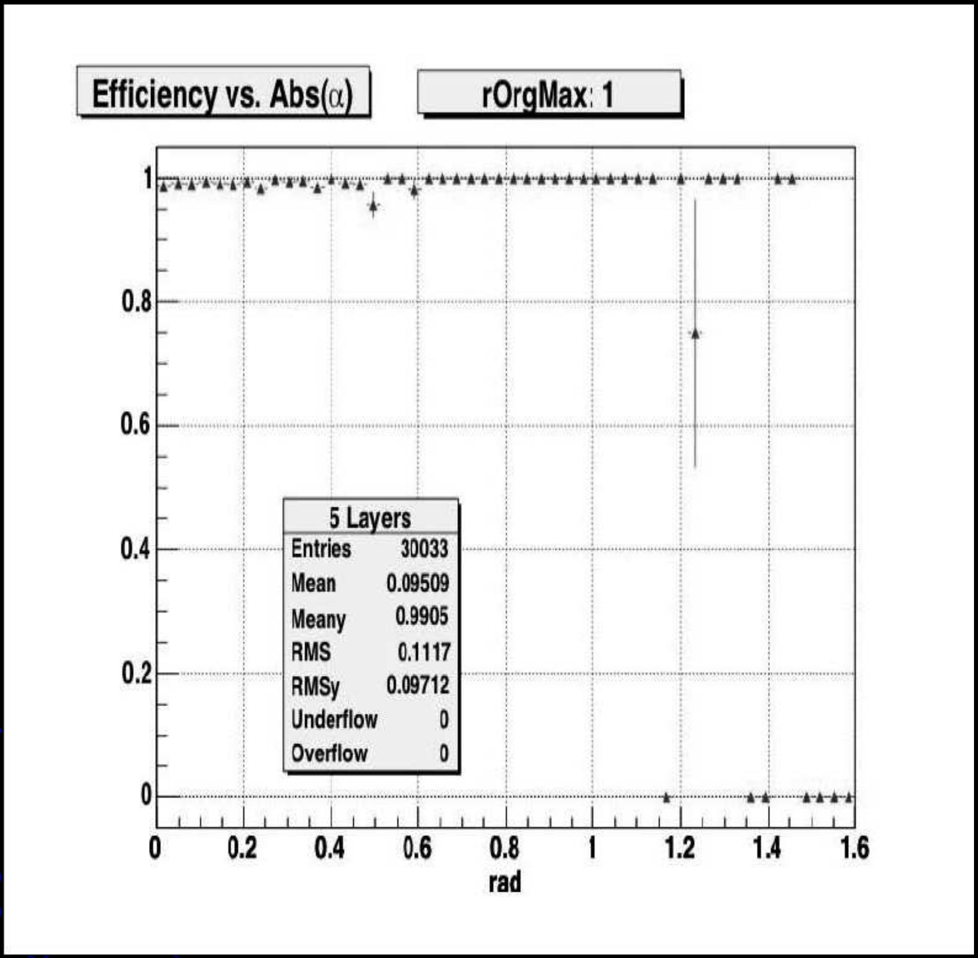
20 superlayers, in 200 rings
10 cells each (7.5 in average)
at alternating stereo angles
±72 ÷ ±180 mrad
(constant stereo drop = 2 cm)

60000 sense w. 20 μm W
120000 field w. 80 μm Al

"easy" t-to-d r(t) (few param.)

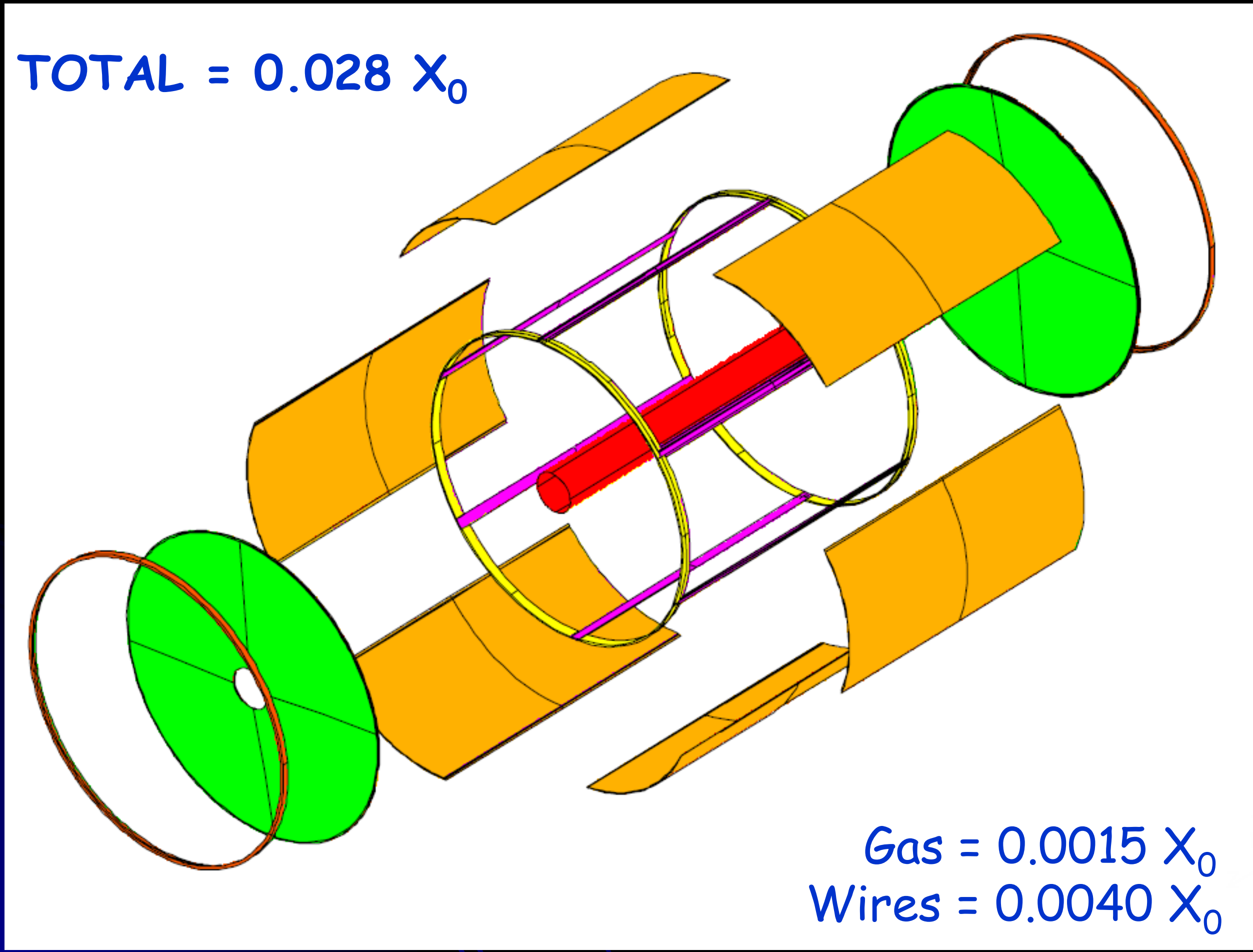
>90% sampled volume

SiD Tracking Efficiency



4thConcept ILC Drift Chamber

Layout and assembly technique



Length:
3.4 m at r = 22.5 cm
3.0 m at r = 147.0 cm

Spherical end plates:
C-f. 12 mm + 30 μm Cu
(0.047 X_0)

Inner cylindrical wall:
C-f. 0.2 mm + 30 μm Al
(0.001 X_0)

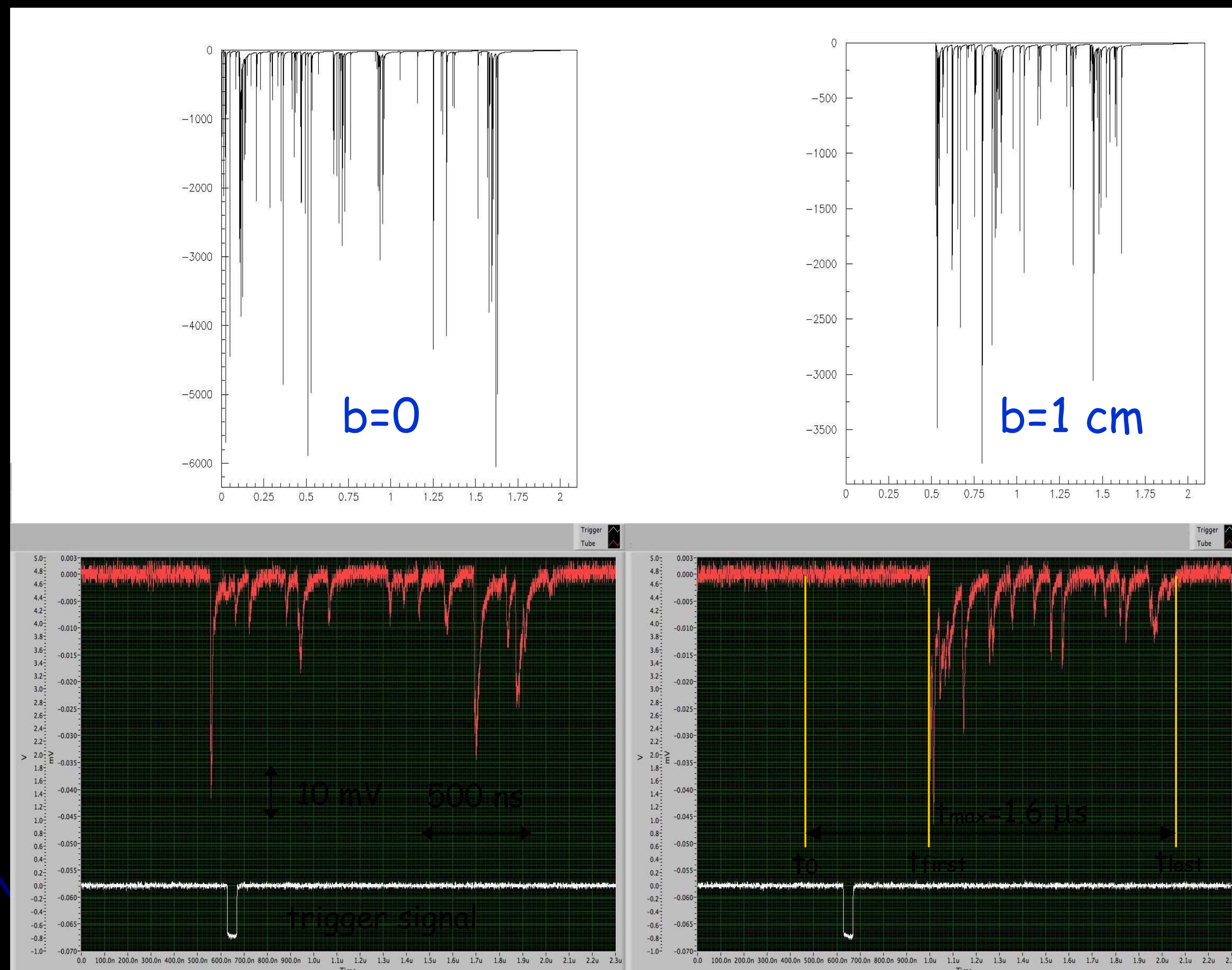
Outer cylindrical wall:
C-f./hex.cell. sandwich
held by 6 unidir. struts
0.020 X_0)

Retaining ring

Stiffening ring

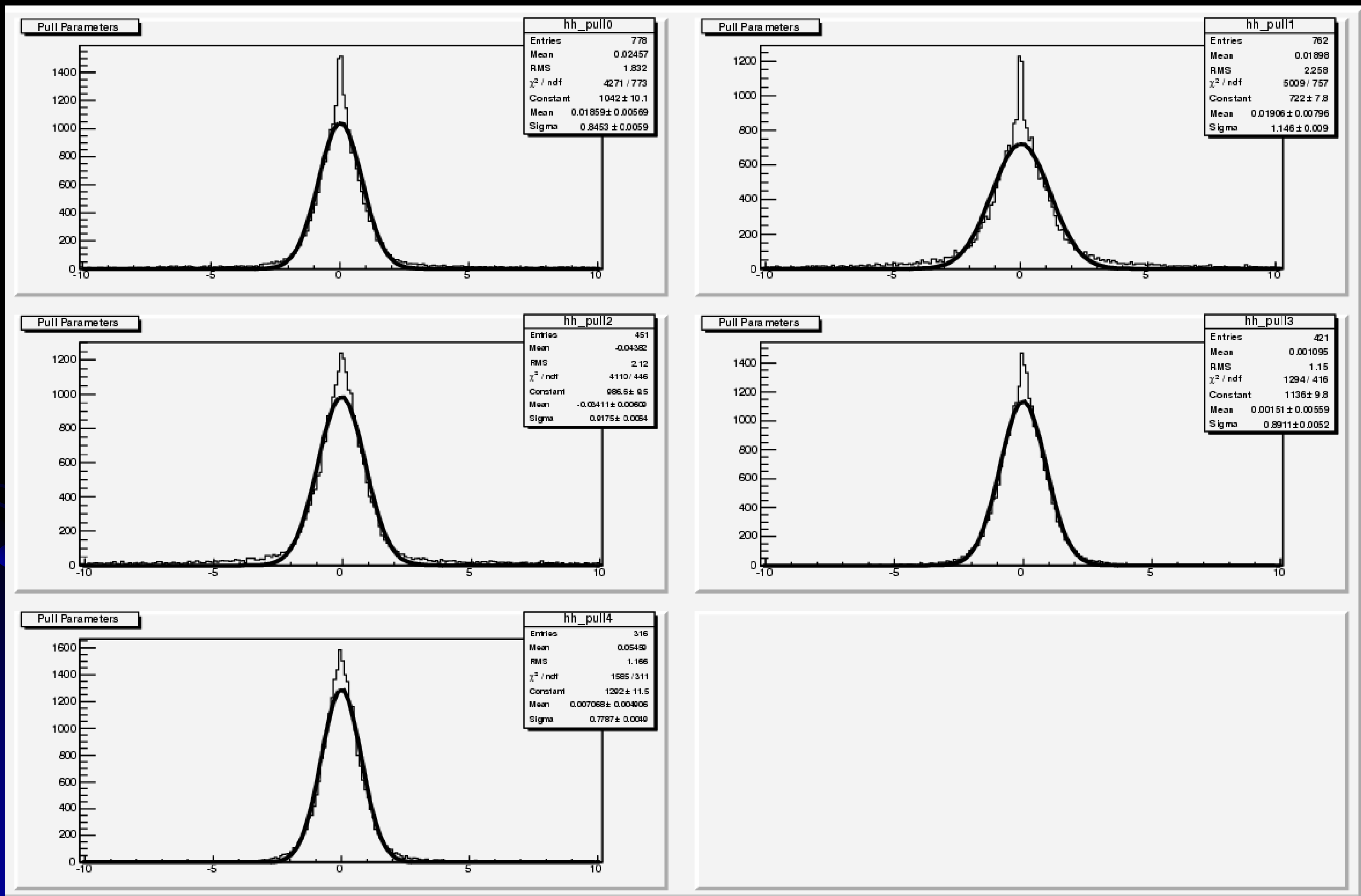
CLUster COUnting

MC generated events:
2cm diam. drift tube
gain = few x 10
gas: 90%He-10%iC_4H_{10}
no electronics simulated
vertical arbitrary units

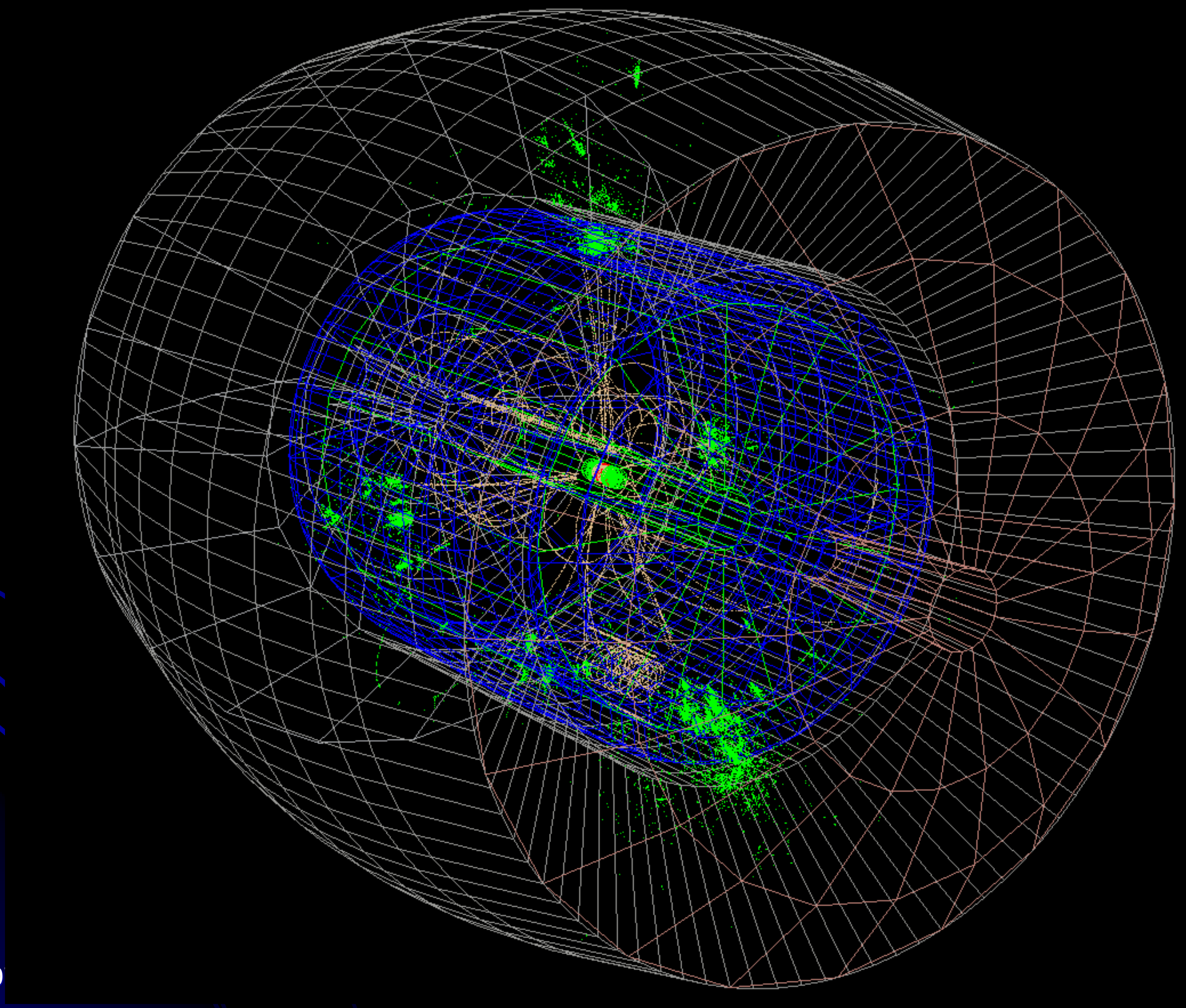


cosmic rays triggered
by scintillator telescope
and readout by:
8 bit, 4 GHz, 2.5 Gsa/s
digital sampling scope
through a 1.8 GHz, x10
preamplifier

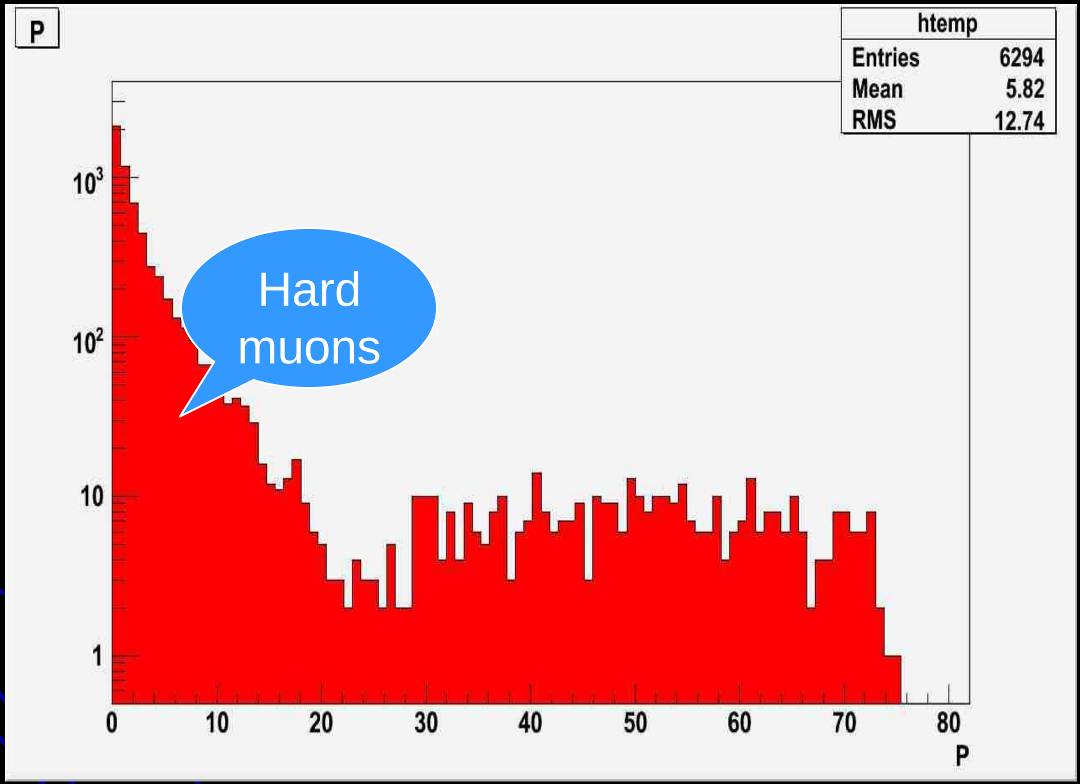
Pulls (full digitization)



DCH Event Display

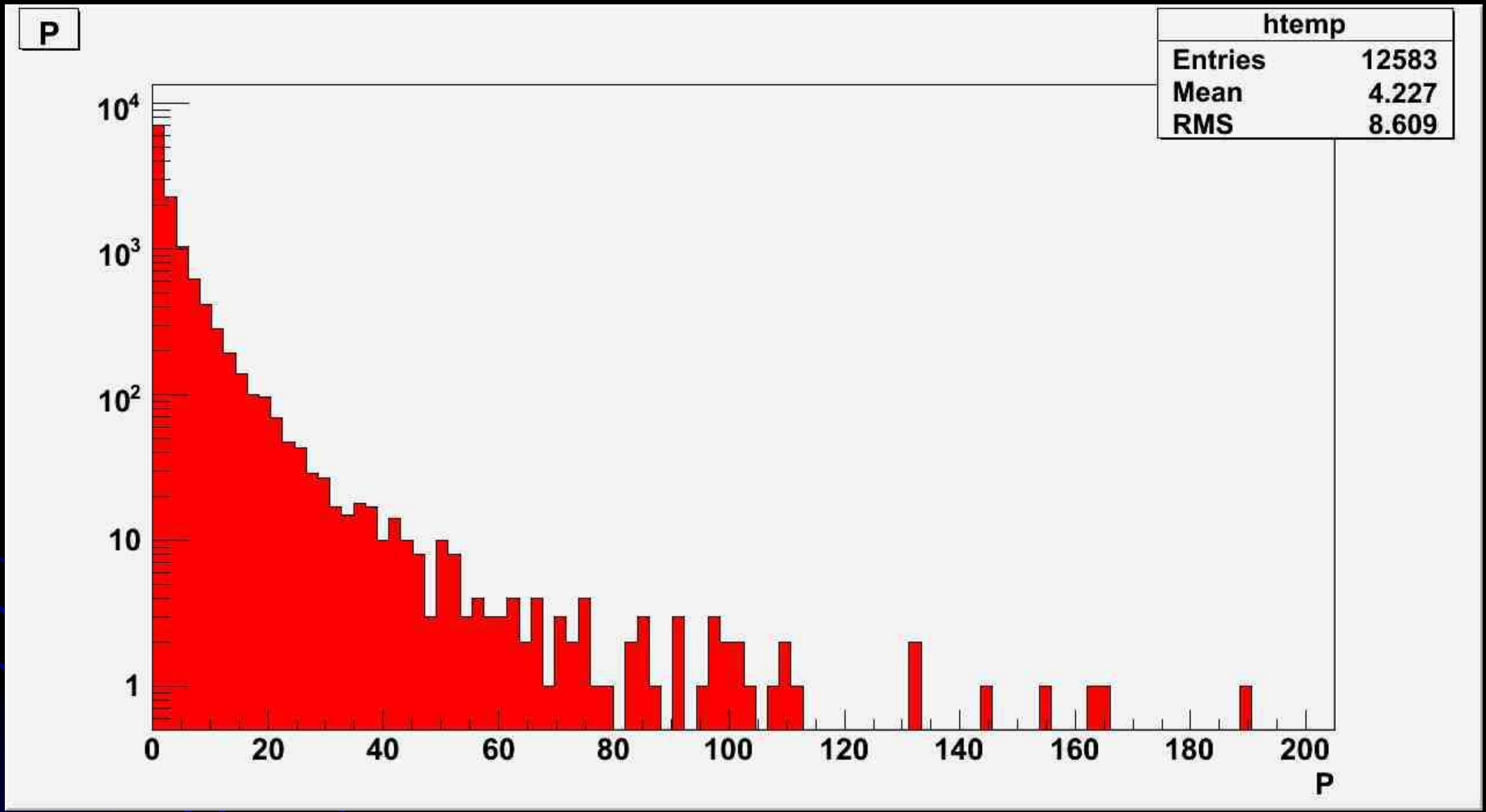


$e^+e^- \rightarrow Z_oH_o \rightarrow \mu^+\mu^-X$ + $e^+e^- \rightarrow Z_oZ_o \rightarrow \mu^+\mu^-X$ background [E_{cm}=230]



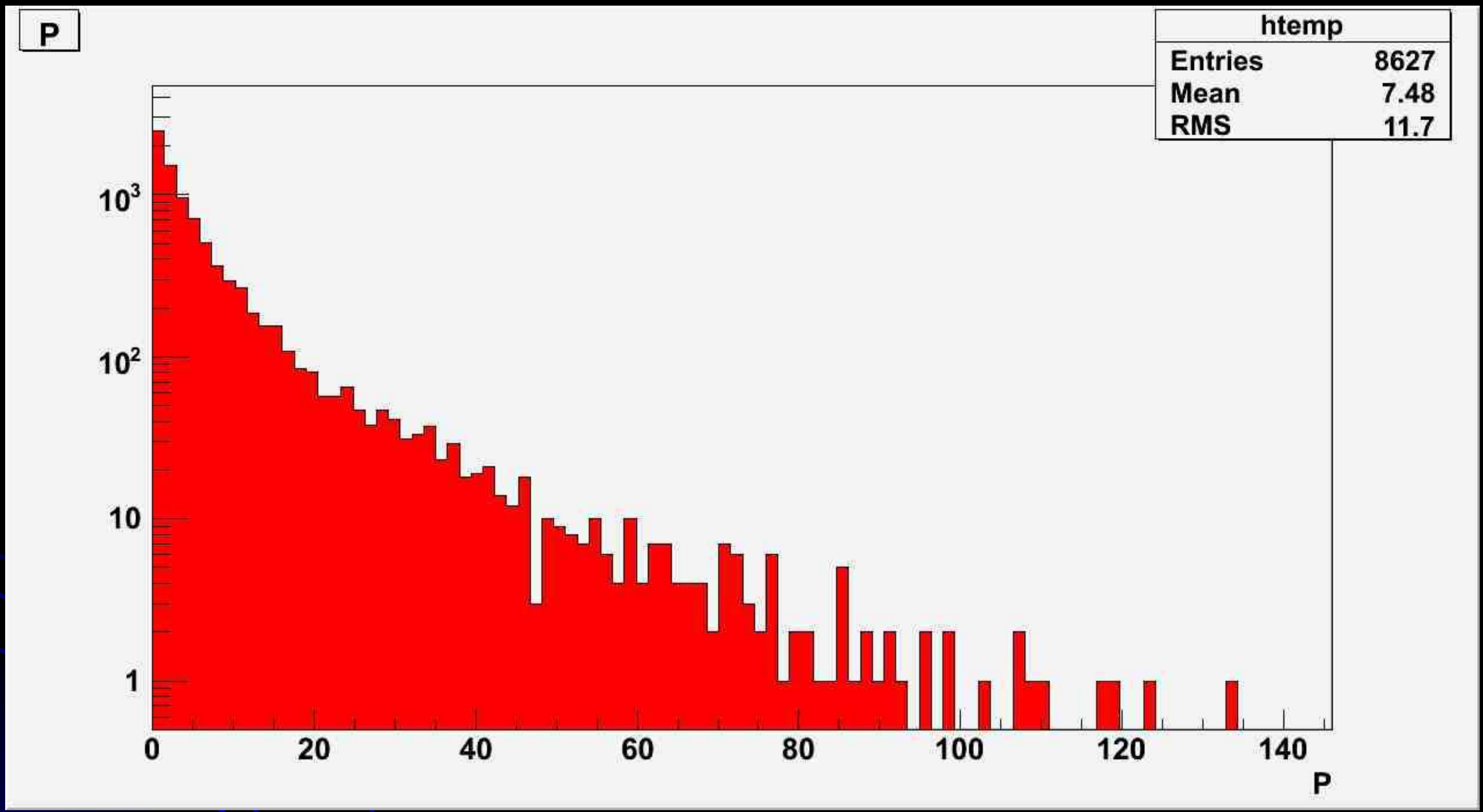
- Momentum spectrum for generated tracks entering the central tracker region
- Standard benchmarck channel
- Used as reference with existing analyses

e^+e^- -> ttbar->6jets E_{cm}=350



- Momentum spectrum for generated tracks entering the central tracker region
- One of channels with softest charged tracks

e^+e^- -> W^+W^- ->4jets Ecm=350



- W^+ and W^- generated mostly in the forwar/backward direction
- Channels with soft charged tracks emitted in the forward direction

τ Polarization Study in e^+e^- -> ttbar ->H^+H^- bbar -> $\tau\ \nu$ -> $\pi^+\ \nu$ e^+e^- -> ttbar ->H^+H^- bbar -> $\tau\ \nu$ -> $\rho\ \nu$ -> $\pi^+\ \pi^o$

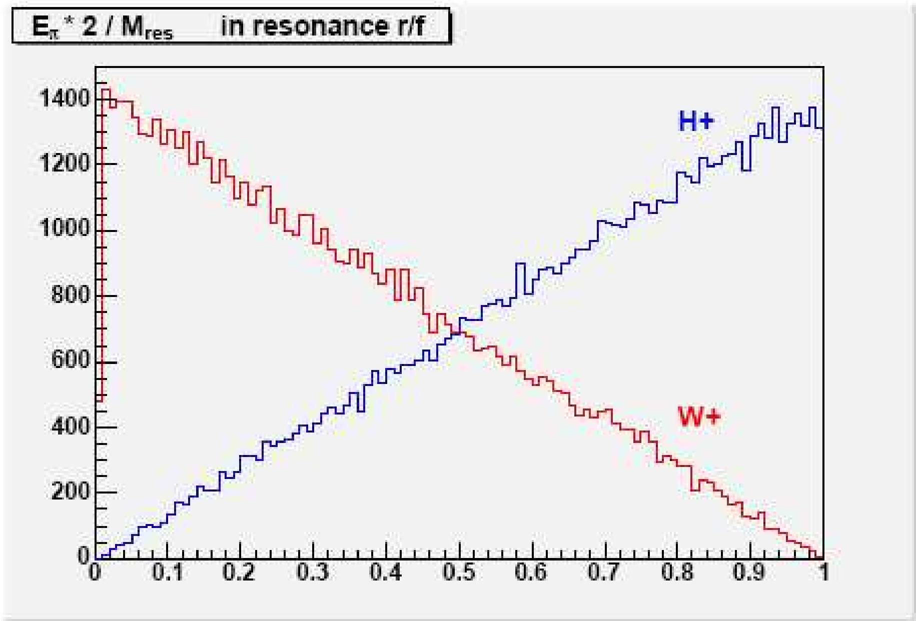


Figure 1: $\pi^{\pm}$ meson energy spectrum in the resonance rest frame.

- From: **Impact of tau polarization on the study of the MSSM charged Higgs bosons in top quark decays at the ILC**
- E. Boos and V. Bunichev, *Skobeltsyn Institute of Nuclear Physics, MSU, 119992 Moscow, Russia*
- M. Carena, *Fermi National Accelerator Laboratory, Batavia, IL 60510, USA*
- C.E.M. Wagner, *High Energy Physics Division, Argonne National Laboratory, Argonne, IL 60637, USA and*
- *Enrico Fermi Institute, Univ. of Chicago, 5640 S. Ellis Ave., Chicago, IL. 60637, USA*
- FERMILAB-CONF-05-265-T,

Charged pion spectra (E_{CM}=800 GeV)

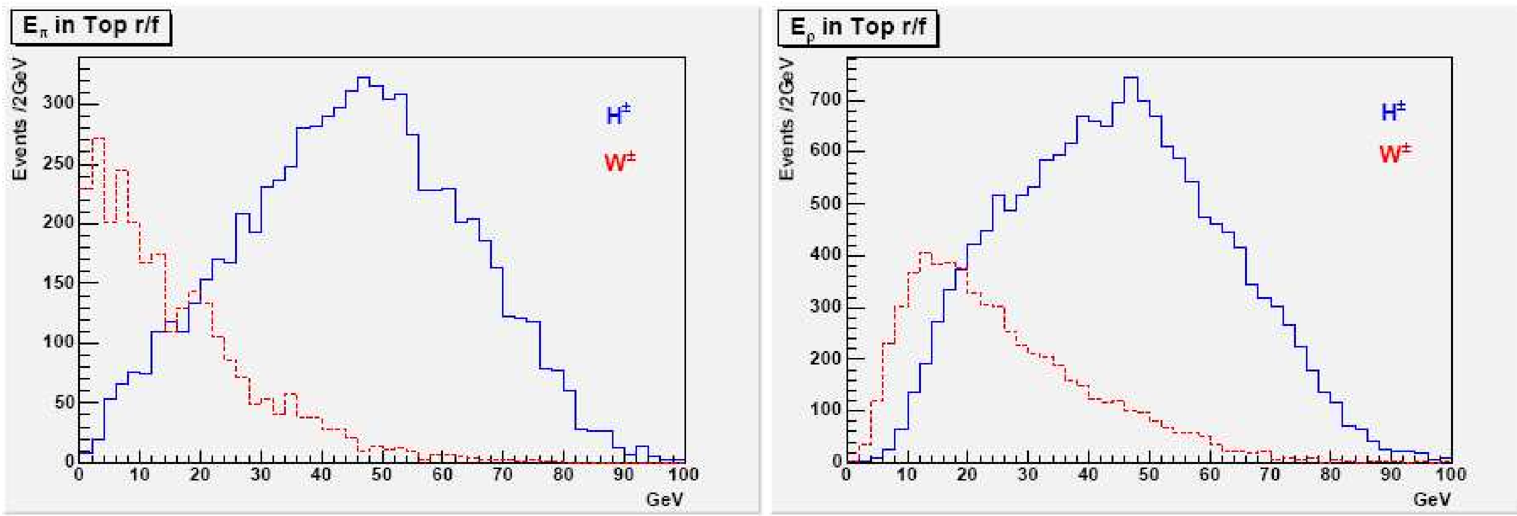


Figure 2: The energy spectrum of the $\pi^\pm$ meson (left) and $\rho^\pm$ meson (right). The dotted line corresponds to the background, and the solid one to signal.

- Semi-exclusive channel for charged Higgs study
- Gives several insight in the MSSM parameters

The Framework: ILCroot

- Integrated framework for generation, simulation, reconstruction and analysis
- CERN architecture (Aliroot)
- Uses ROOT as infrastructure
  - All ROOT tools are available (I/O, graphics, PROOF, data structure, etc)
  - Extremely large community of users/developers
- TGenerator for events generation
- Virtual Geometry Modeler (VGM) for geometry
- Virtual Montecarlo (VMC) for simulation
- Six MDC have proven robustness, reliability and portability
- Available via cvs repository at Fermilab:
  cvs -d :pserver:anonymous@cdcvs.fnal.gov:/cvs/ilcroot co
- For the installation, see:
  http://www.fisica.unile.it/~danieleb/IlcRoot

The Virtual Montecarlo Concept

- Virtual MC provides a virtual interface to Monte Carlo
- It decouples the dependence of a user code on a concrete MC
- It allows to run the same user application with all supported Monte Carlo programs
- The concrete Monte Carlo (Geant3, Geant4, Fluka) is selected and loaded at run time
- Choose the optimal Montecarlo for the study

A Modular Approach: The Detector Class

- **Both sensitive modules (detectors) and non-sensitive ones are described by this base class.**
- **This class must support:**
  - **Geometry description**
  - **Event display**
  - **Simulation by the MC**
  - **Digitization**
  - **Pattern recognition**
  - **Local reconstruction**
  - **Local PiD**
  - **Calibration**
  - **QA**
  - **Data from the above tasks**

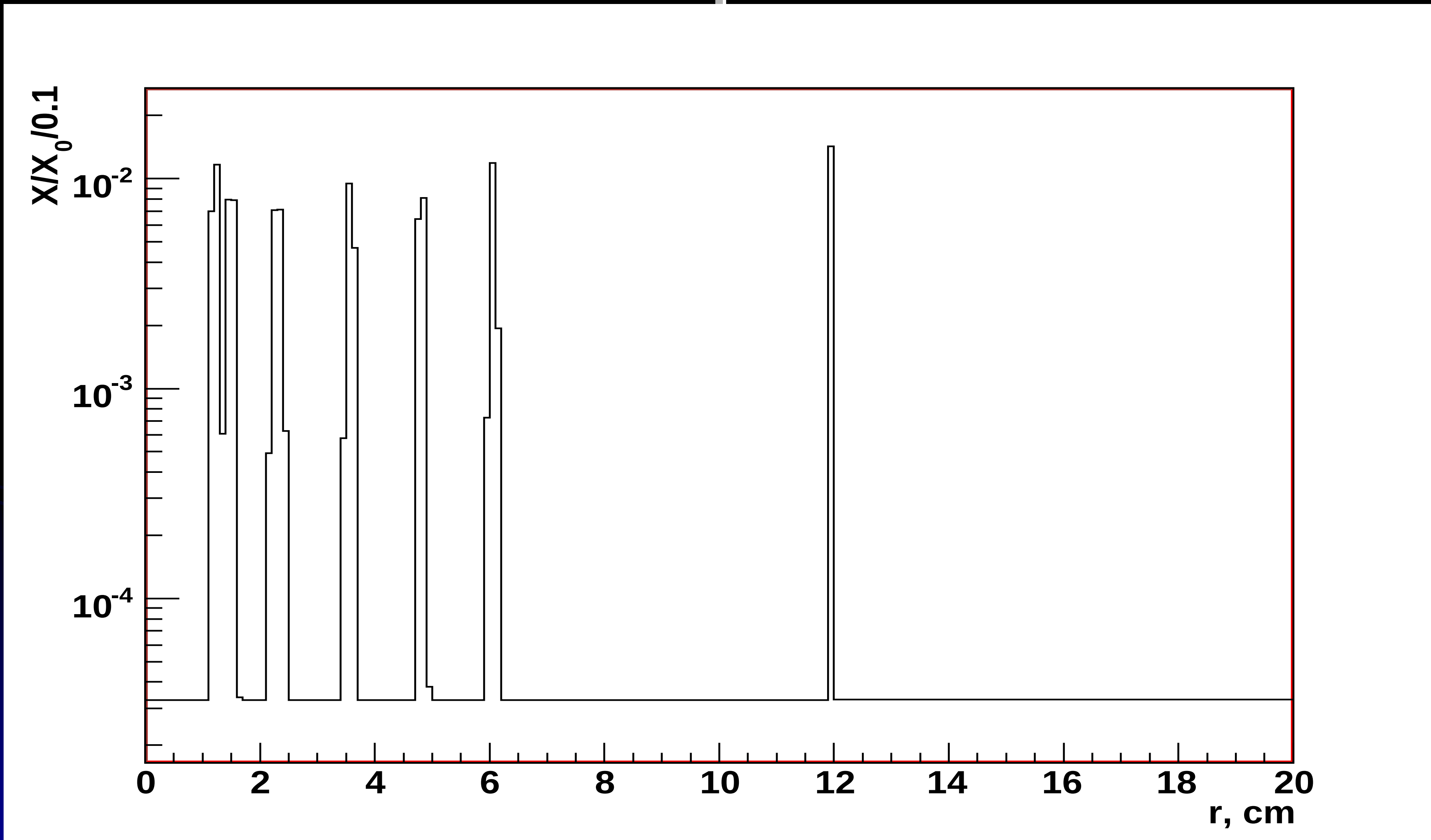
- The geometry can be specified using:
  - ***Root (TGeo)***
  - Geant3
  - Geant4
  - Fluka
  - GDML
  - XML
  - Oracle
  - CAD (semi-automatic)

- **Several versions of the same detector are possible (choose at run time)**

The Event Generators

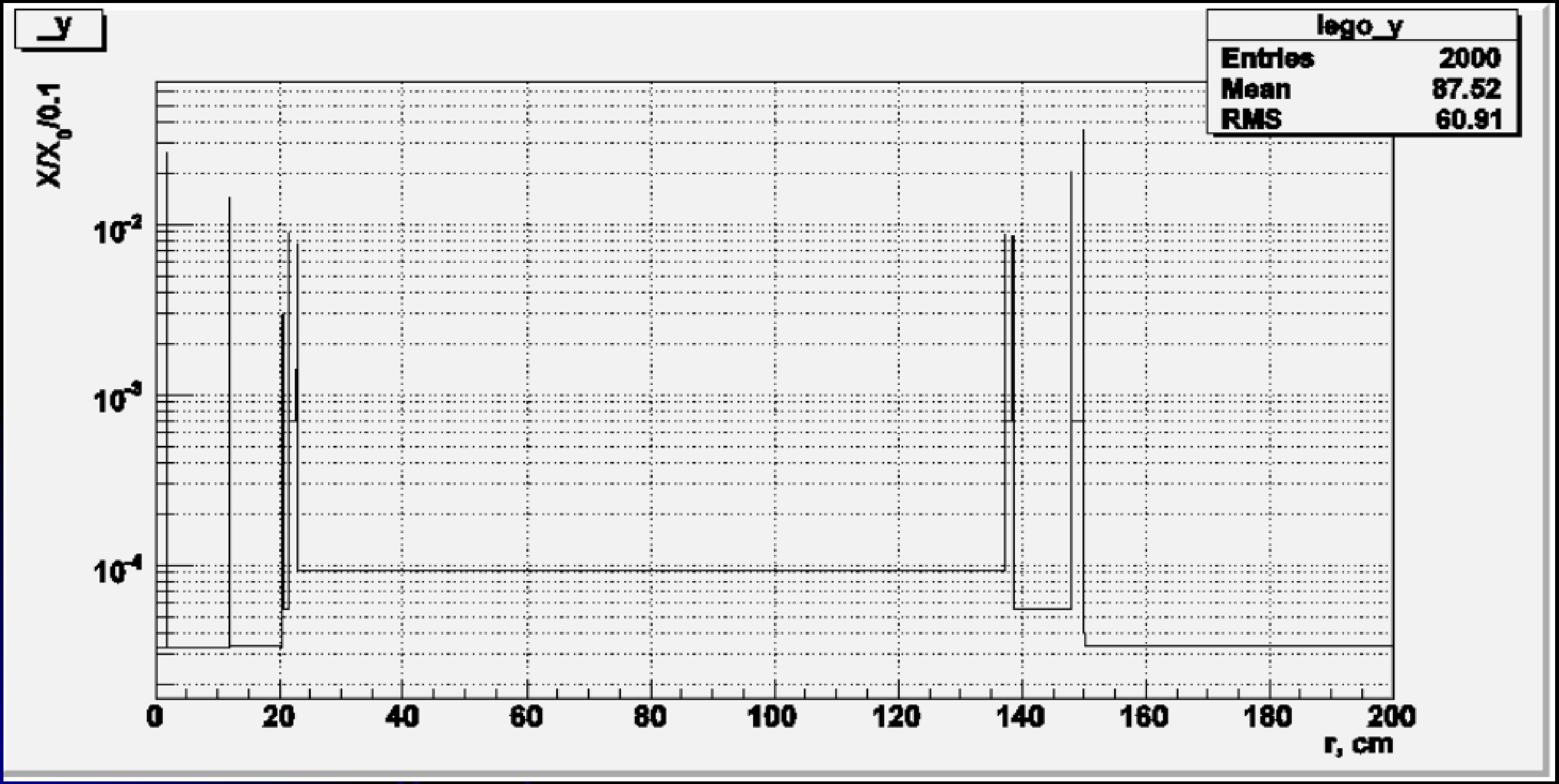
- The event generators (for tracking studies) used:
  - Pandora-Pythia/Sherpa/Whizard /CompHep for Physics Channels
  - Guinea-Pig for Beam Background
  - A variety of phase space generators and cocktails of them for detector performance

Material Budget in 1mm step: Beam Pipe + VXD



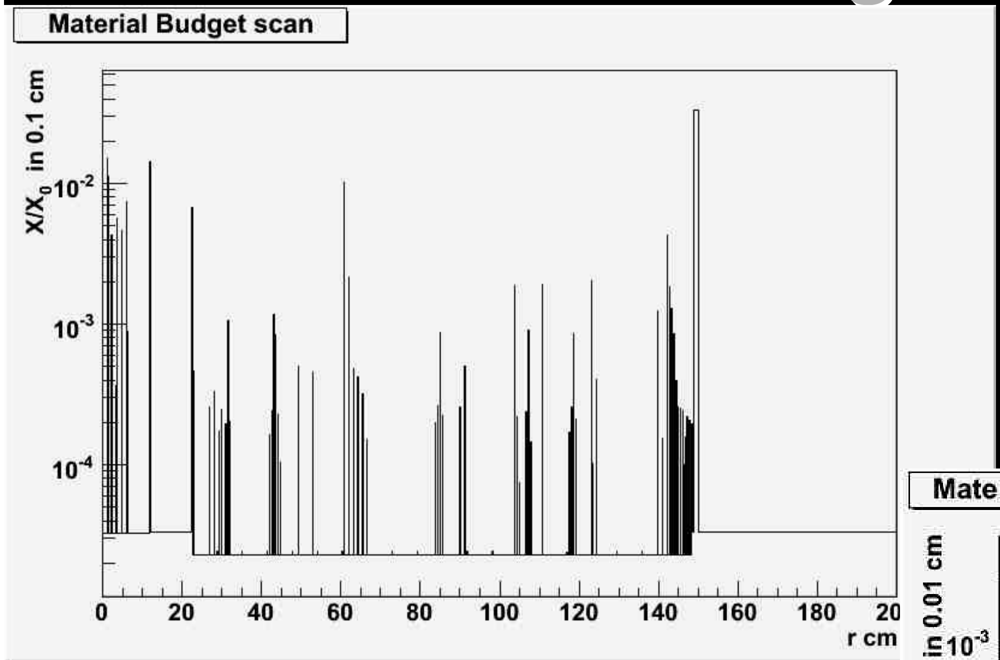
Intregrated over φ

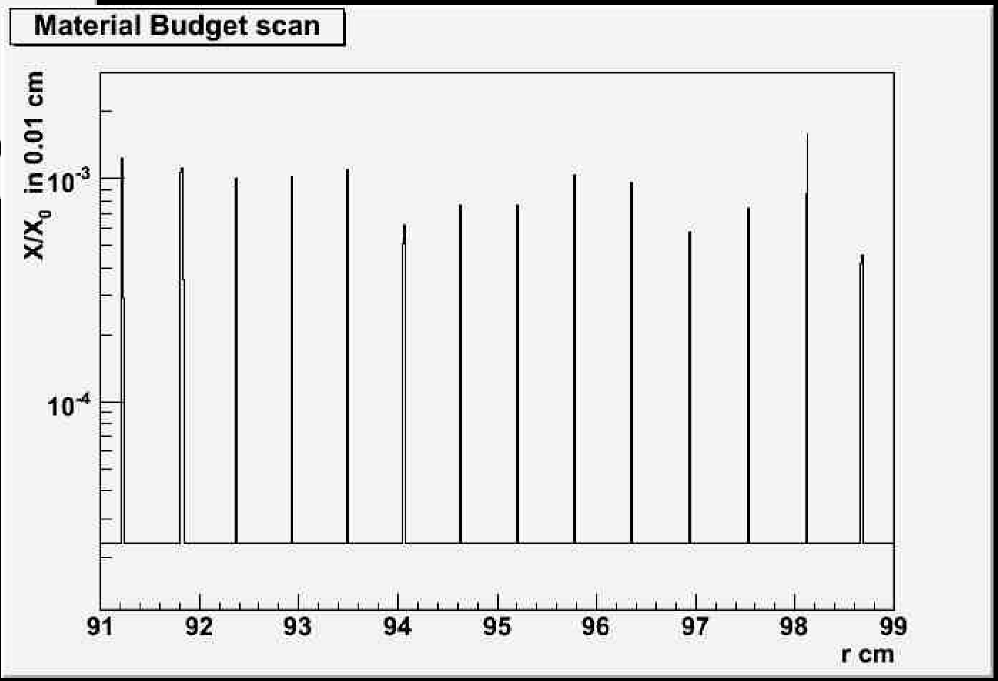
Material Budget inn 1mm step: TPC



Intregrated over φ

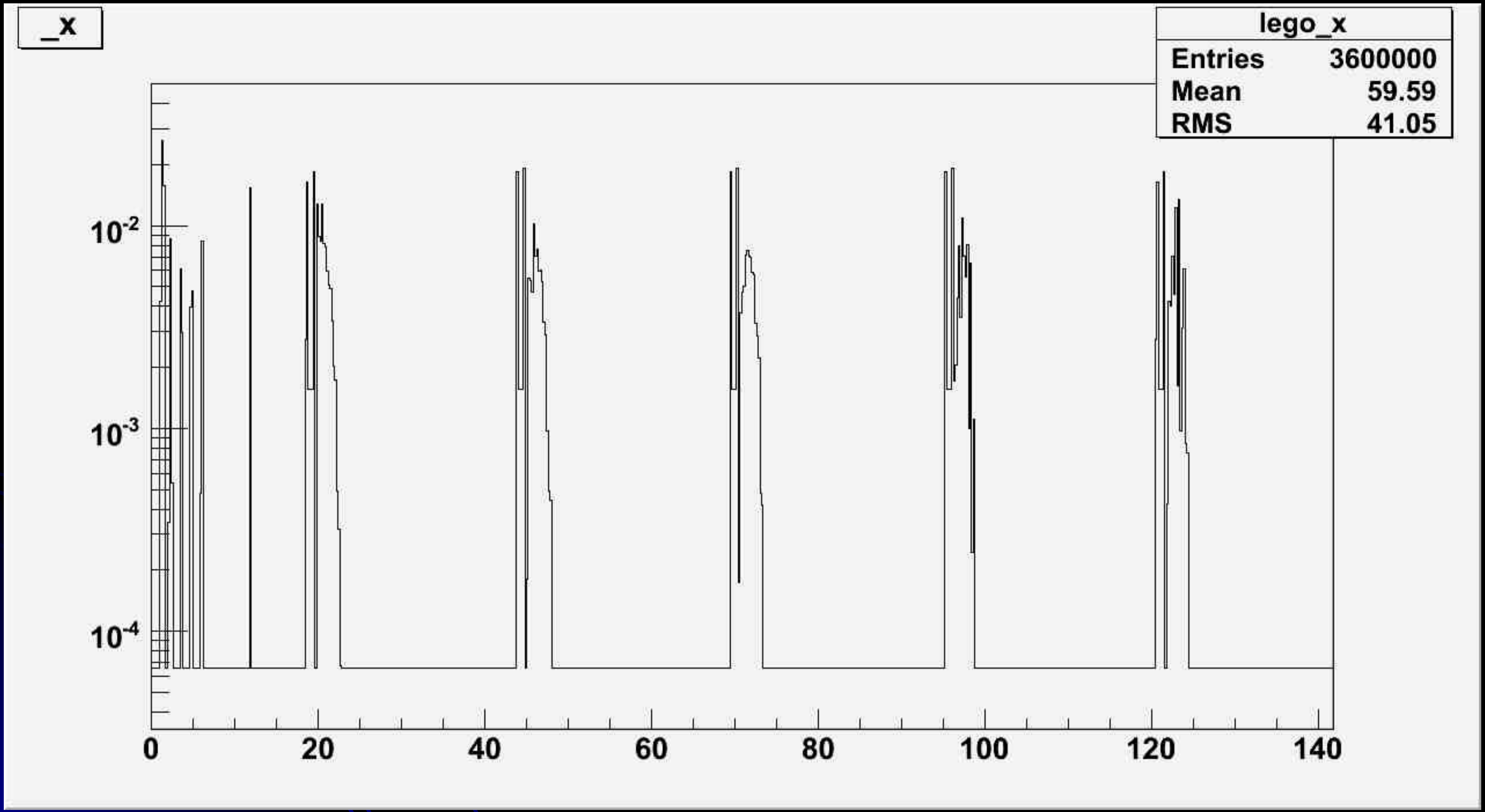
Material Budget inn 1mm step: DCH





Intregrated over φ

Material Budget in 1mm step: Si-Barrel

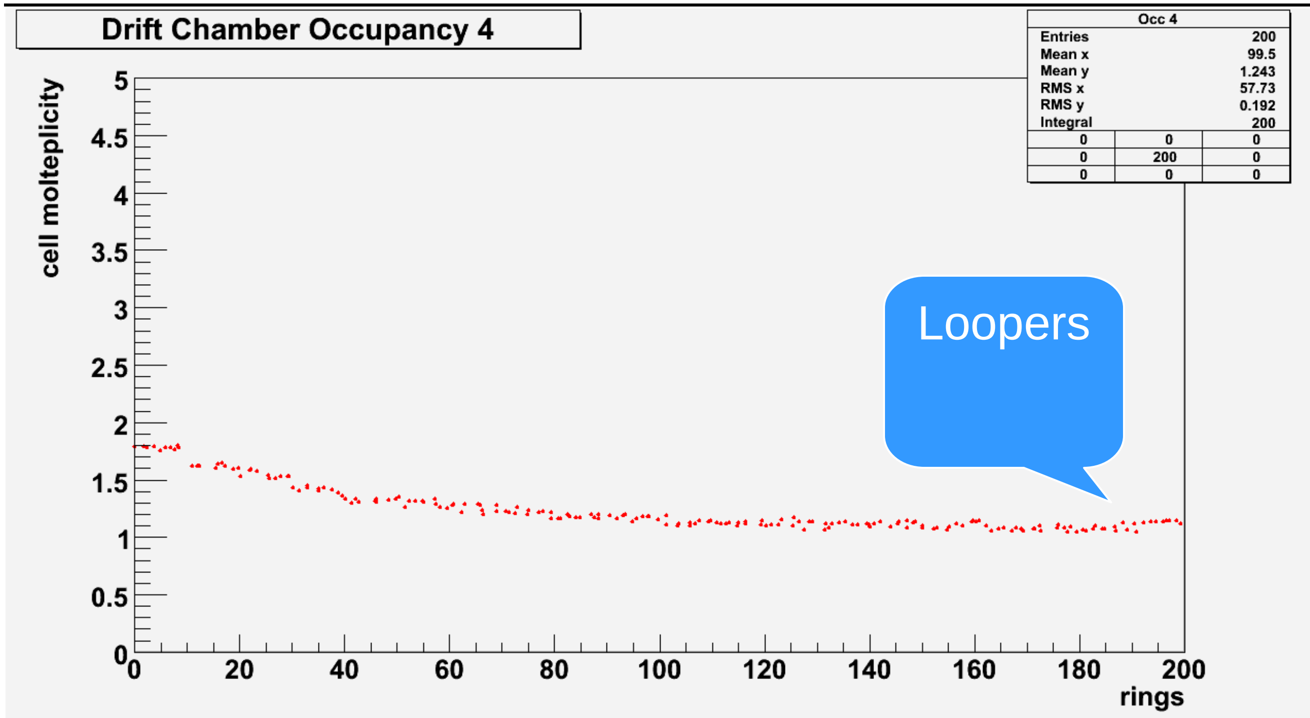


Intregrated over φ

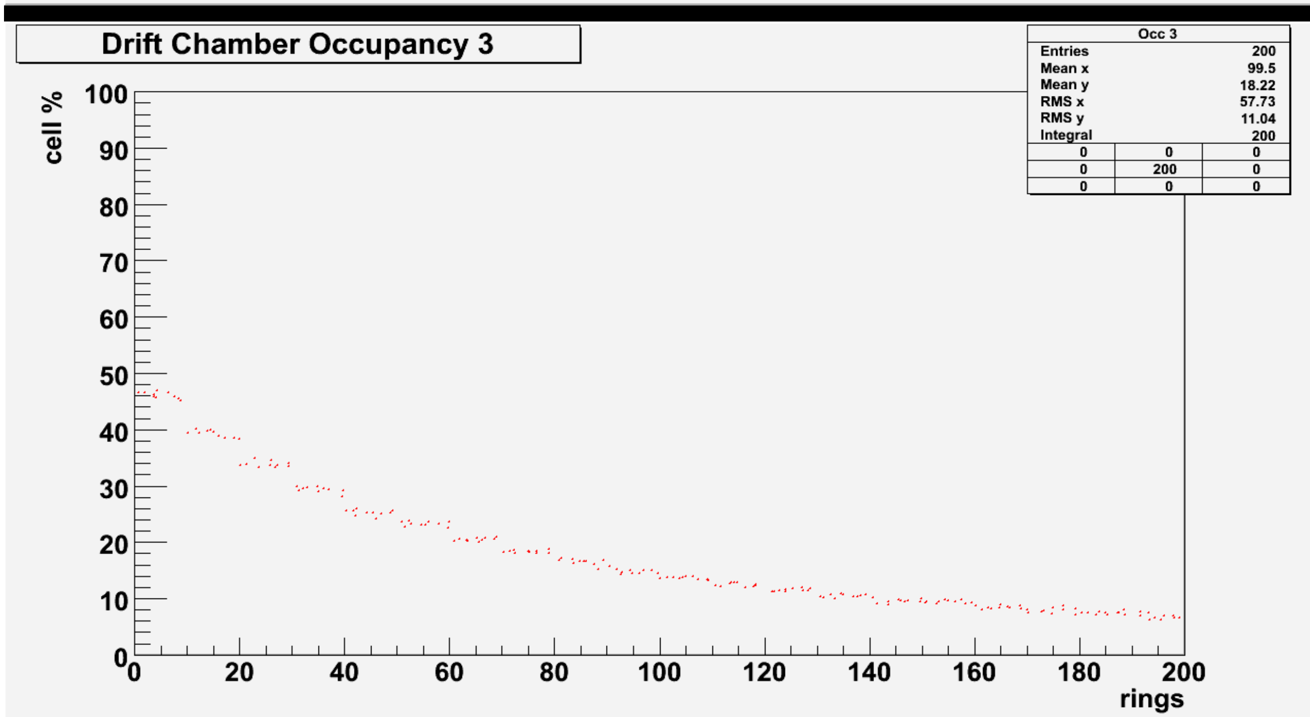
DCH

e^+e^- -> HHZ -> 4 jets+2muons with DCH

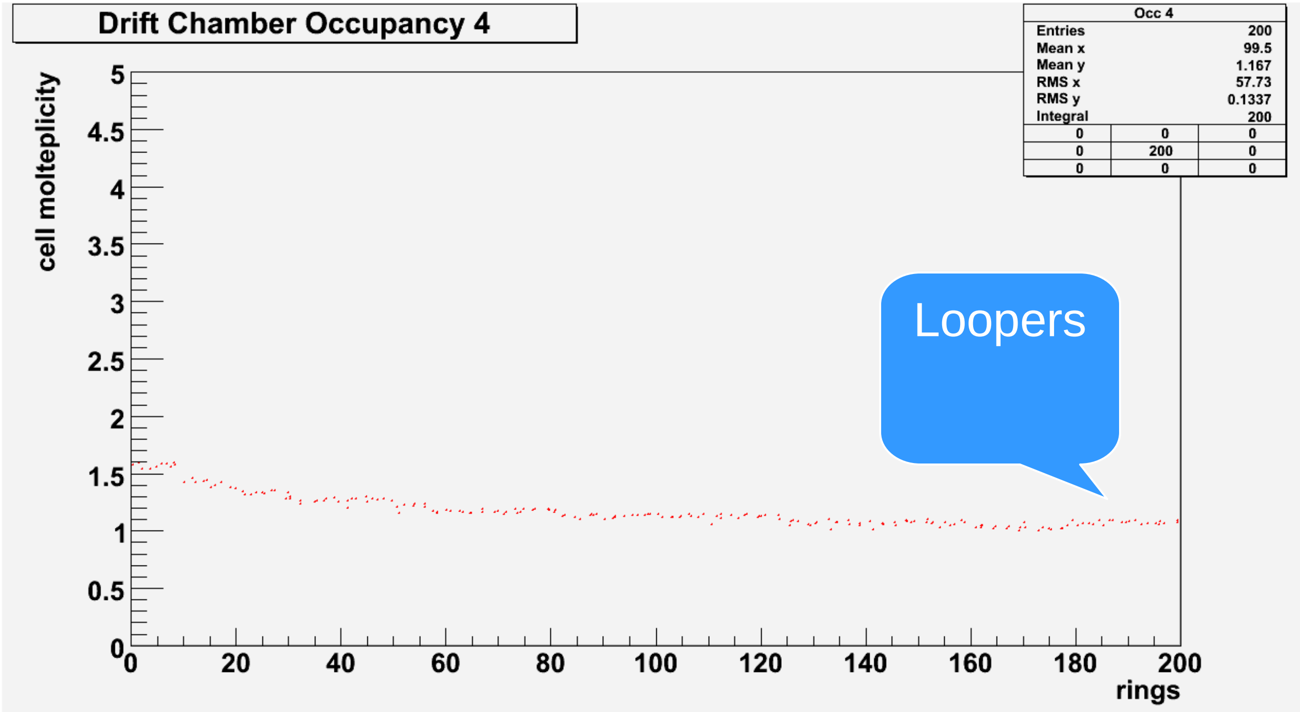
E_{CM}=500 GeV

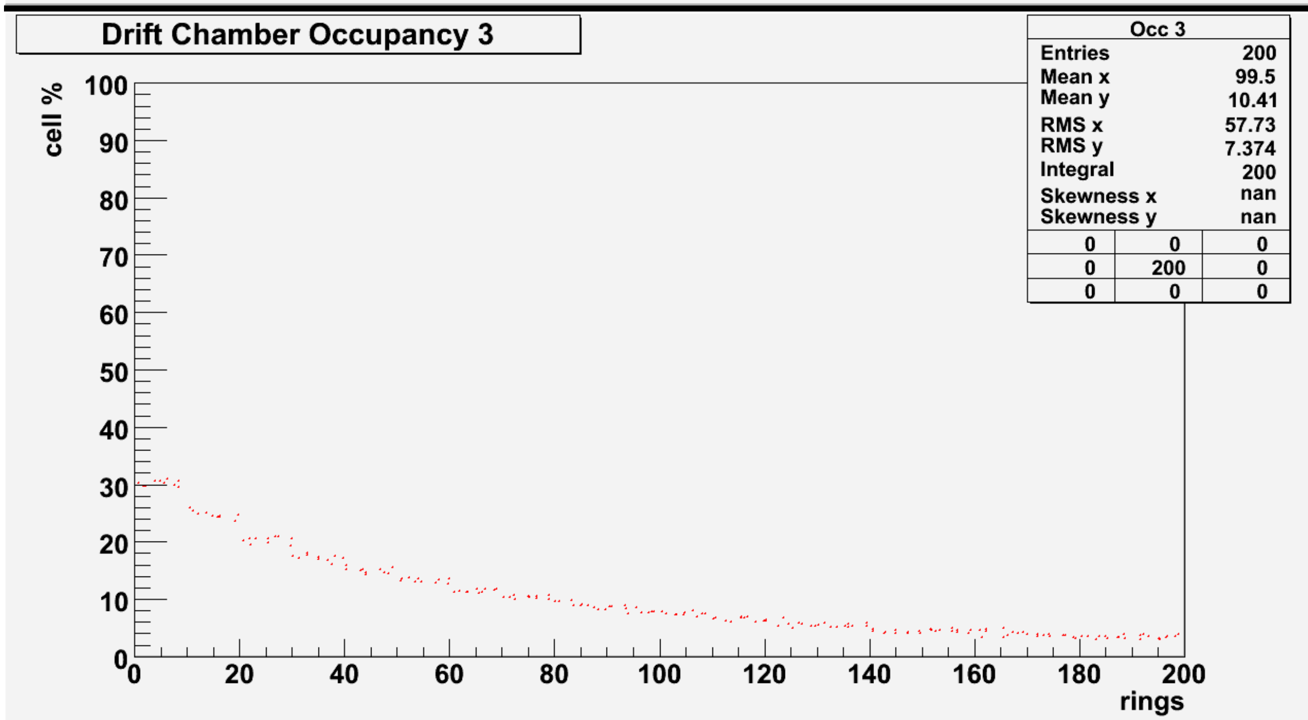


- Hits per cell vs layer



- Occupancy vs layer





DCH

$e^+e^- \rightarrow H^oZ^o \rightarrow$ 2 jets+2muons with DCH

E_{CM}=230 GeV

- Hits per cell vs layer

- Occupancy vs layer

VXD SDigitization

- Follow the path of the track inside the silicon in steps of 1 μm
- Per each step:
  - convert the energy deposited into charge
  - spreads the charge asymmetrically across several pixels:

$$f(x,z) = Errf(x_{step}, z_{step}, \sigma_x, \sigma_z)$$

$$\sigma_x = \sqrt{T \cdot k / e \cdot \Delta l / \Delta V \cdot step}$$

$$\Delta l = Si\,tickness, \quad \Delta V = bias\,voltage, \quad \sigma_x = \sigma_x \cdot fda$$

- Simulate capacitive pixel coupling by switching on nearby pixels
- Add random noise
- Simulate electronic threshold

Clusterization For VXD

- Create a initial cluster from adjacent pixels (sidewise only)
- subdivide the initial cluster in smaller NxN clusters (to be optimized)
- Kalman filter picks up the best clusters

SDigitization Parameters

- Size Pixel X = 20 μm
- Size Pixel Z = 20 μm
- Eccentricity = 0.85 (fda)
- Bias voltage = 18 V volts
- cr = 0% (coupling probability for row)
- cc = 4.7% (coupling probability for column)
- threshold = 3000 Electrons
- electronics = 0 (elettronic noise)

SDigitization in Strips Detector

- Get the Segmentation Model for each detector module (allows for different segmentations)
- Load background hits from file (if any)
- Loop on the hits and create a segment in Si in 3D
  - Step inside the Si in equal size increments
    - Compute Drift time to p-side and n-side:

      ```
      tdrift[0] = (y+(seg->Dy()*1.0E-4)/2)/GetDriftVelocity(0);
      tdrift[1] = ((seg->Dy()*1.0E-4)/2-y)/GetDriftVelocity(1);
      ```
    - Compute diffusion constant:

      ```
      sigma[k] = TMath::Sqrt(2*GetDiffConst(k)*tdrift[k]);
      ```
    - integrate the diffusion gaussian from -3σ to 3σ
  - Charge pile-up is automatically taken into account

SDigitization in Strips (cont'd)

- Add gaussian electronic noise per each side separately: s/n = 20
- Add coupling effect between nearby strips
  - different contribution from left and right neighbours
  - Proportional to nearby signals (B-field effect)
- Threshold = 3 x noise

Clusterization in Strip Detector

- Create an initial cluster from adjacent strips
- Separate into Overlapped Clusters
  - Look for through in the analog signal shape
  - Split signal of parent clusters among daugheter clusters
- Intersect stereo strips to get Recpoints from CoG of signals (and error matrix)
- Kalman filter picks up the best Recpoints

The Parameters fot the Strips

- Strip size (p, n): 50 mm
- Stereo angle (p-> 17.5 mrad, n->17.5 mrad)
- Ionization Energy in Si = 3.62E-09
- Hole diffusion constant (= 11 cm^2/sec)
- Electron diffusion constant (= 30 cm^2/sec)
- v^P_{drift}(=0.86E+06 cm/sec) , v^N_{drift}(=2.28E+06 cm/sec)
- Calibration constants
  - Gain
  - ADC conversion (1 ADC unit = 2.16 KeV)
- Coupling probabilities between strips (p and n)
- σ of gaussian noise (p AND n)
- threshold

TPC Simulation (fast digit)

TPC Pads Simulation (fast digit)

Sigma of cluster COG position determination

- σ_t of cluster center (not systematic (threshold)effect):

$$\sigma_{tCOG} = \sqrt{\frac{\sigma_L^2 (z_{max} - z)}{N_{ch}} G_g + \frac{tan(\alpha)^2 l_{pad}^2 G_{Landau}(N_{prim})}{12 N_{chprim}} + \sigma_{noise}^2} \quad (7)$$

- σ_p of cluster center (not systematic (threshold) effect):

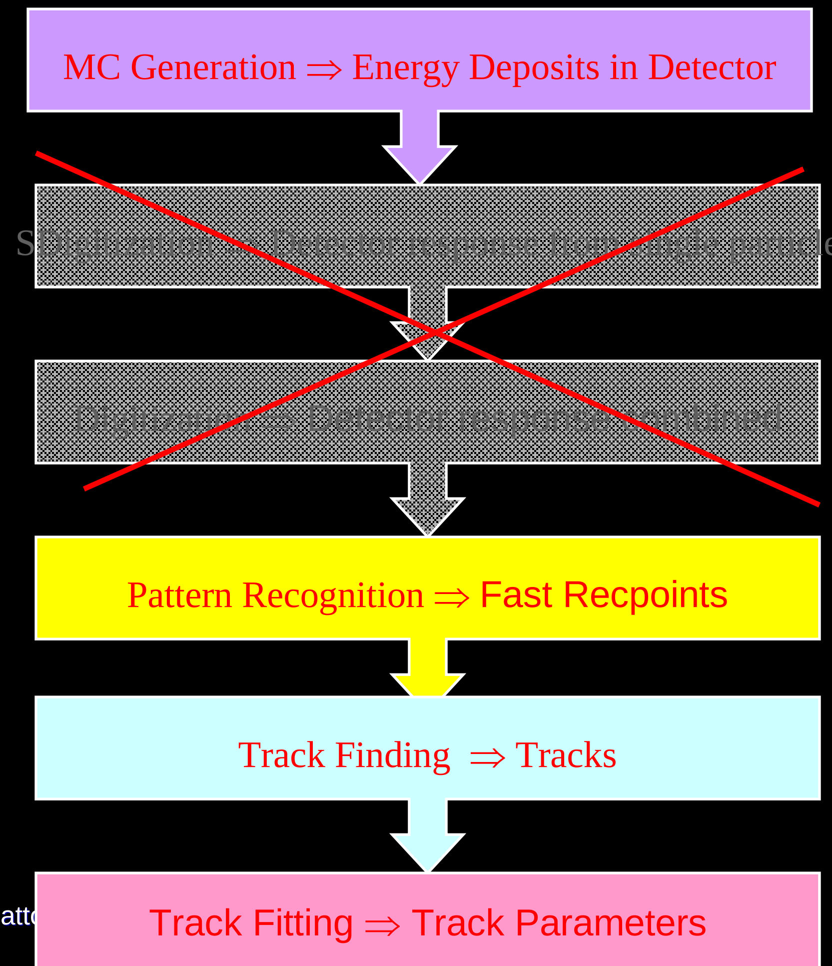
$$\sigma_{pCOG} = \sqrt{\frac{\sigma_T^2 (z_{max} - z)}{N_{ch}} G_g + \frac{tan(\beta)^2 l_{pad}^2 G_{Landau}(N_{prim})}{12 N_{chprim}} + \sigma_{noise}^2} \quad (8)$$

N_{ch} - total number of electrons in cluster
N_{chprim} - number of primary electrons in cluster
G_g - gas gain fluctuation factor
G_{Landau} - secondary ionization fluctuation factor

50 µm

From
P. Colas
V. Lepeltier
M. Ronan

Gaussian Smearing



TPC µmegas Simulation (fast digit)

- Gaussian smearing of hits (55µm / sqrt(12)) to make Fastrecpoints

DCH SDigitization (in progress)

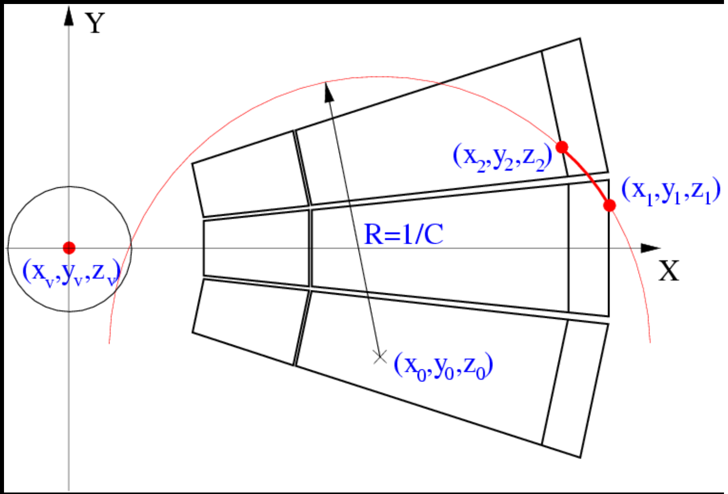
- Follow the path of the tracks inside the cell
- Per each deposited energy step:
  - convert the energy deposited into charge
  - Drift charge toward sense wire using Magboltz parameters
  - Add charge to FADC corresponding channel
- Add random noise
- Simulate electronic threshold

Clusterization For DCH (Cluster Counting)

- Clusterization is done per cell
- Shape analisys od FADC count
- Returns as many recpoints as the number of recognized clusters (max 2)

Tracking Algorithm (for TPC and DCH)

- Primary TPC/DCH seeding: looks for tracks with 20 hits (pads and/or µmegas) apart + <u>beam constraint</u>
- Secondary TPC/DCH seeding: looks for tracks with hits in layer 1, 4 and 7 (<u>no beam constraint</u>)
- **<u>Parallel Kalman Filter</u>** then initiated:
  - 1st step: start from TPC/DCH fit + prolongation to VXD (add clusters there)
  - 2st step: start from VXD, refit trough TPC/DCH + prolongation to MUD
  - 3st step: start from MUD and refit inword with TPC + VXD
- Final step: isolated tracks in VXD (see next slide) and in MUD*
- **Kinks and V0** fitted during the Kalman filtering
- All passive materials taken into account for MS and dEdx corrections



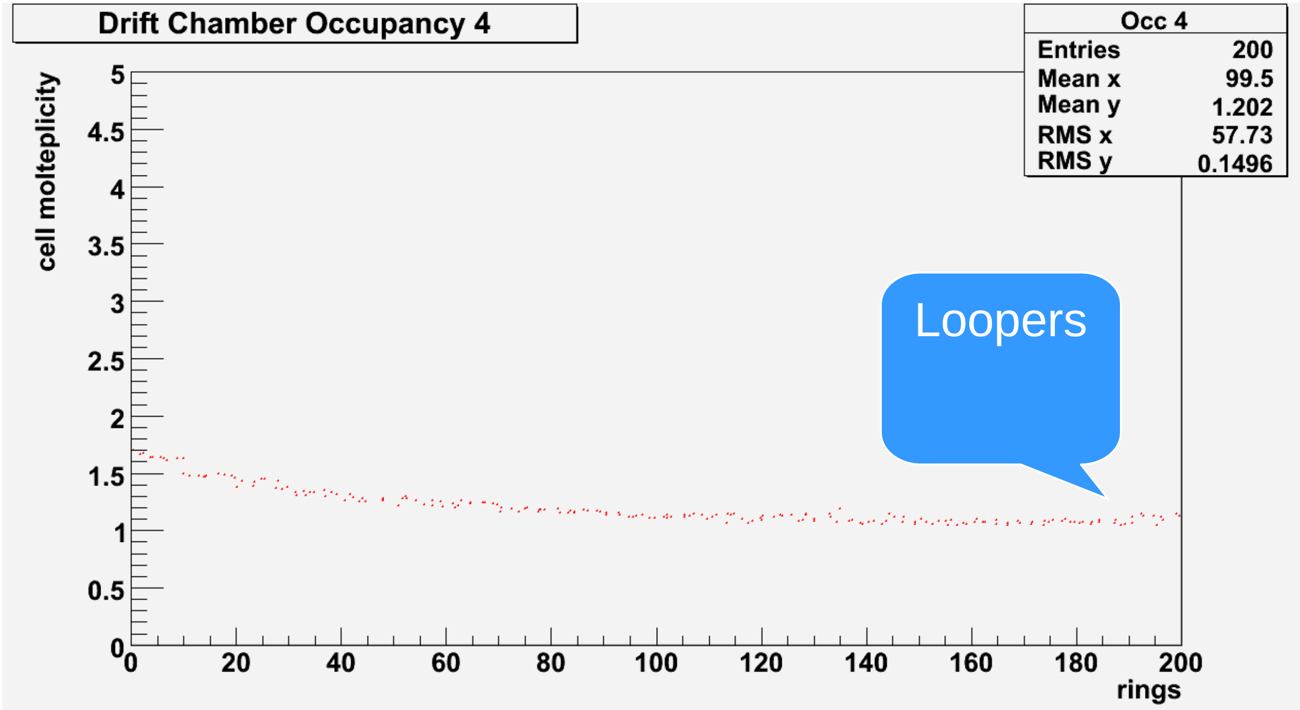
*not yet implemented

VXD Standalone Tracker

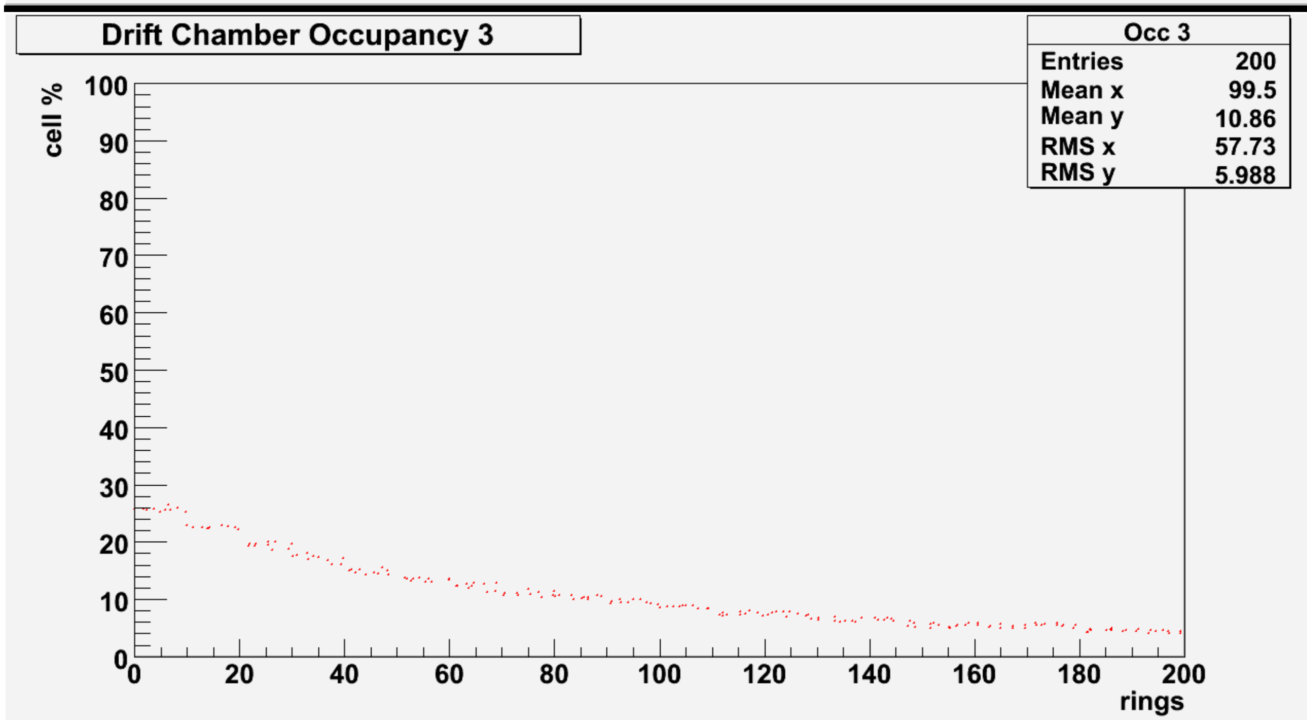
- Uses Clusters leftover from Parallel Kalman Filter
- **Requires at least 4 hits to build a track**
- Cluster finding in VXD in two steps
  - Step 1: look for 3 RecPoints in a narrow row or 2 + the beampoint.
  - Step 2: prolongate to next layers each helix constructed from a seed.
- After finding clusters, all different combination of clusters are refitted with the Kalman Filter and the tracks with lowest χ^2 are selected.
- Finally, the process is repeated attempting to find tracks on an enlarged road constructed looping on the first point on different layers and all the subsequent layers.
- In 3.5 Tesla B-field -> P_t > 20 MeV

DCH

$e^+e^- \to W^+W^-$
$\to$ 4 jets
with DCH
E_{CM}=500 GeV



- Hits per cell vs layer



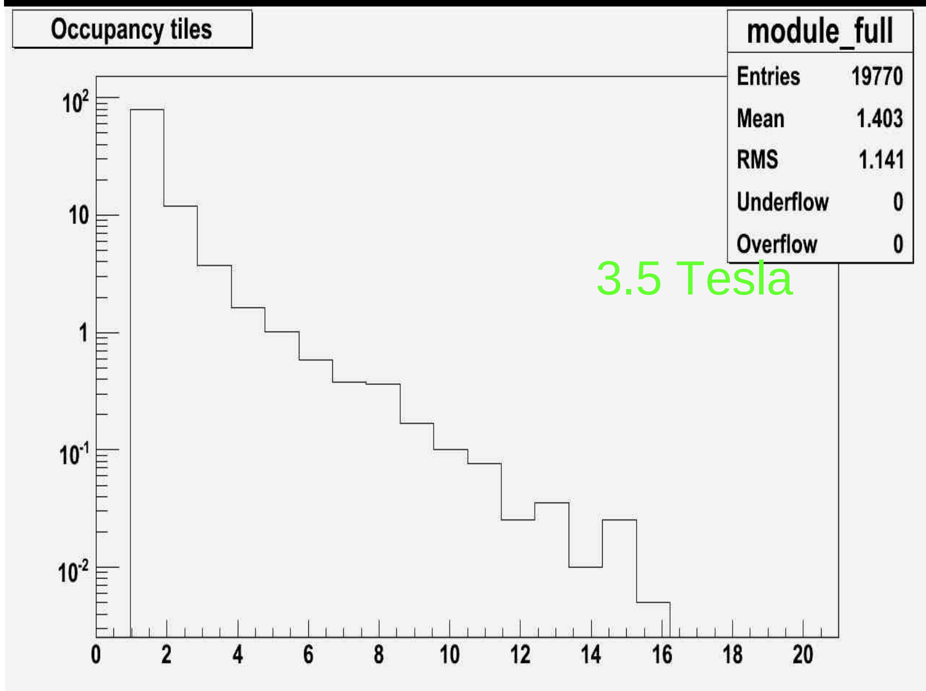
- Occupancy vs layer

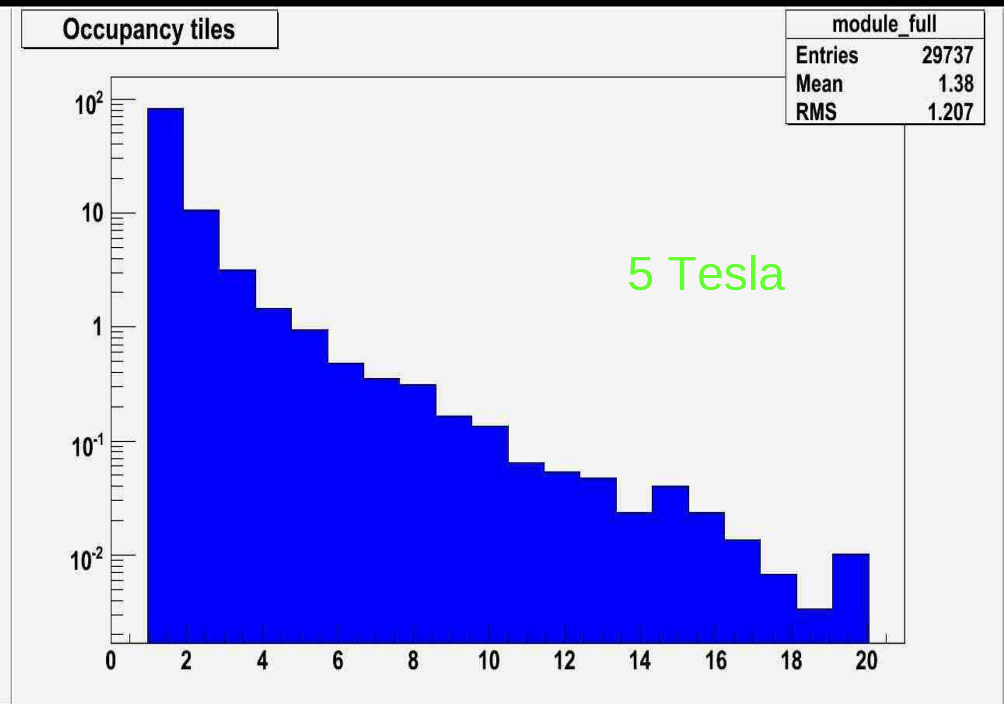
SiT

SiD Wafer Occupancy Studies (Barrel)

e+e- -> ZHH

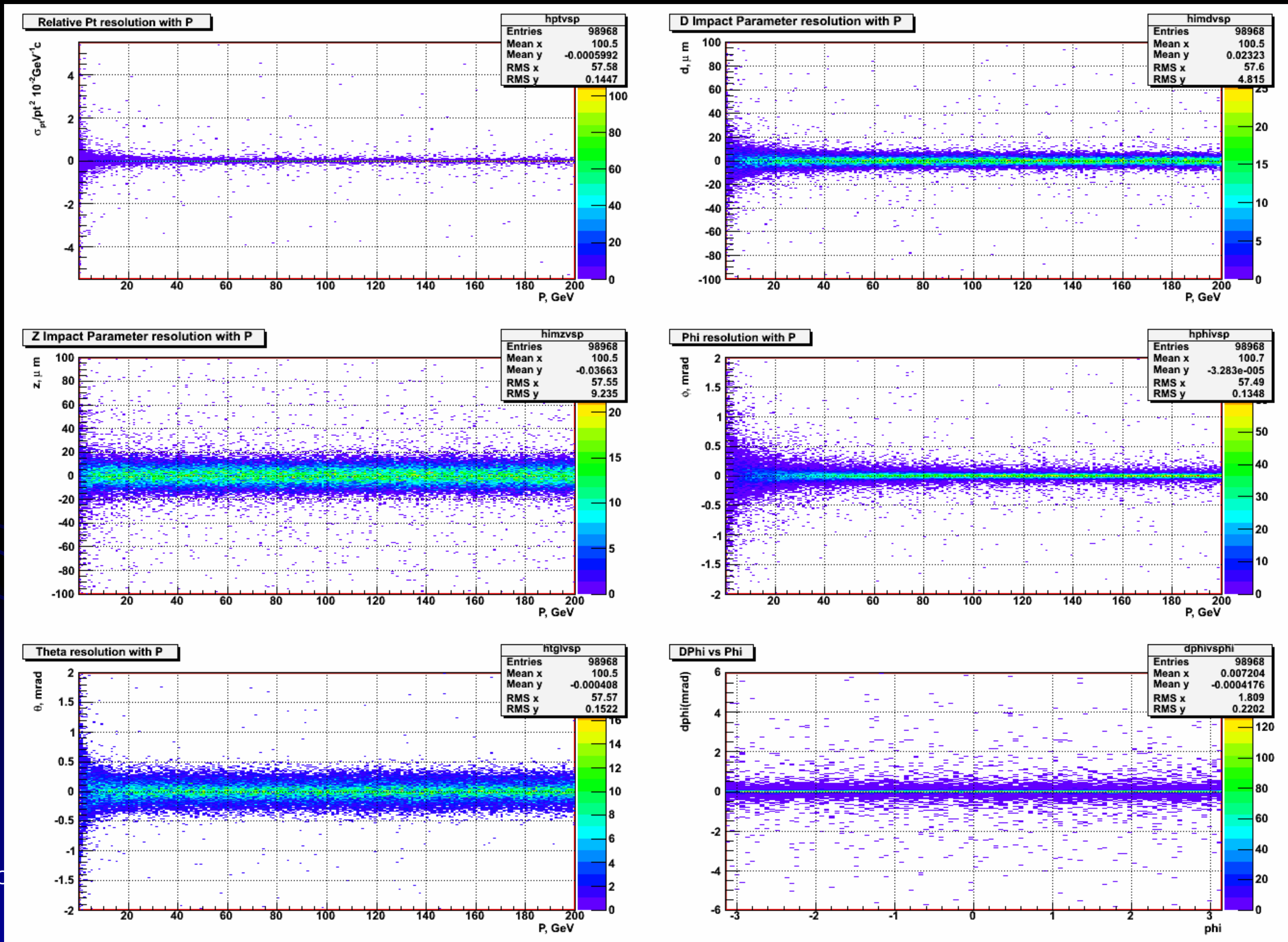
50% More Hits at 5 Tesla





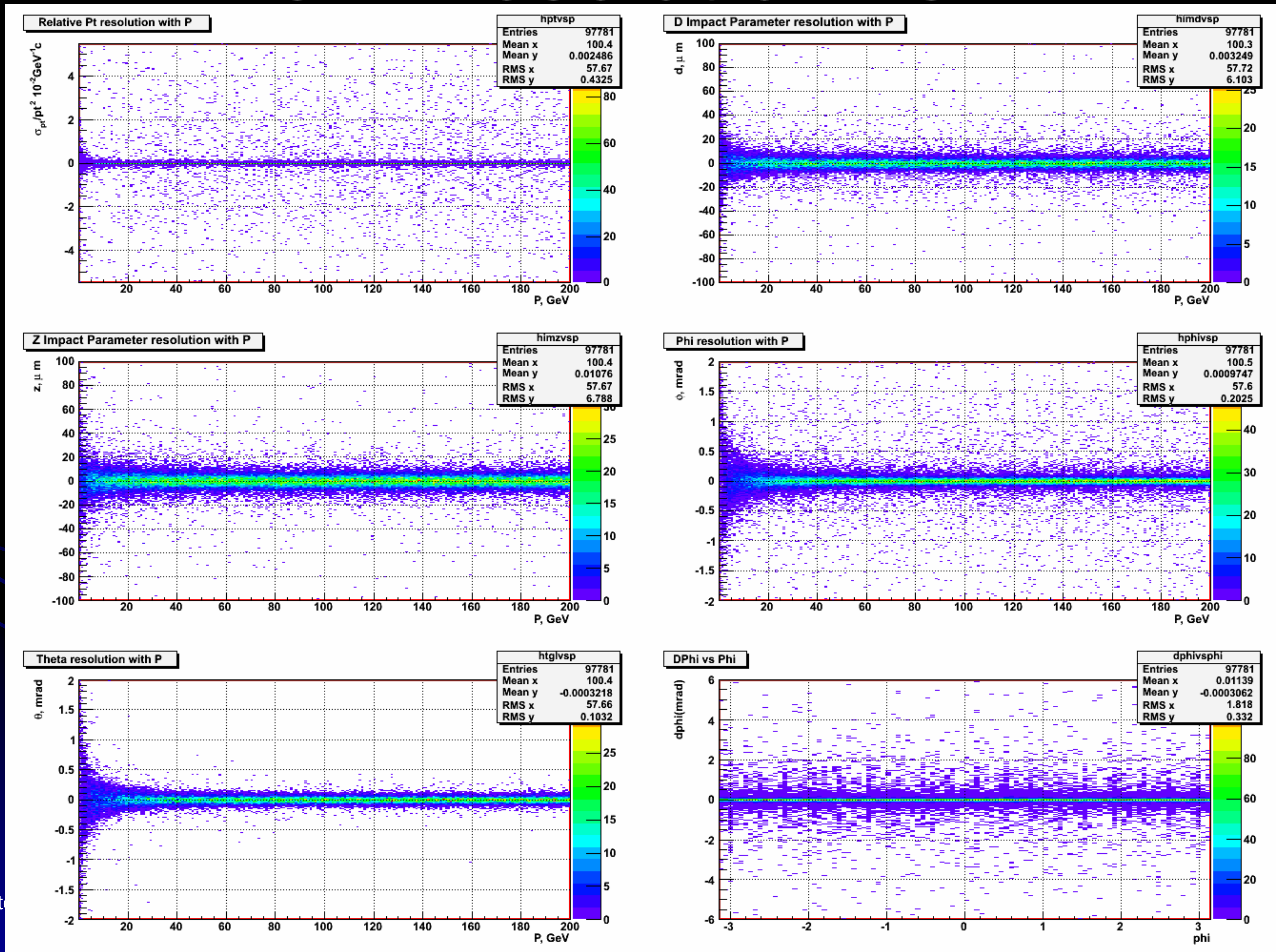
SiT Resolution vs P

10 muons



10 muons

DCH Resolution vs P



10 muons

TPC Resolution vs P