Tracking Studies for the ILC

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INFN Napoli

M. Thomson – 11 July 2005

The ILC

★ILC baseline parameters currently being discussed
- main features "known"

- **Center-of-Mass Energy : ~ 90 – 1000 GeV**
- **Baseline Luminosity : 2×10^{34} $cm^{-2}s^{-1}$ (>1000xLEP)**
- **Time Structure : 5 (10?) Bunch-trains/s**
  - Time between collisions: ~ 300 (150) ns

e.g. TESLA TDR

- **"Physics" Event Rate (fairly modest):**

  $e^+e^-\rightarrow qq$ ~100/hr $e^+e^-\rightarrow W^+W^-$ ~1000/hr

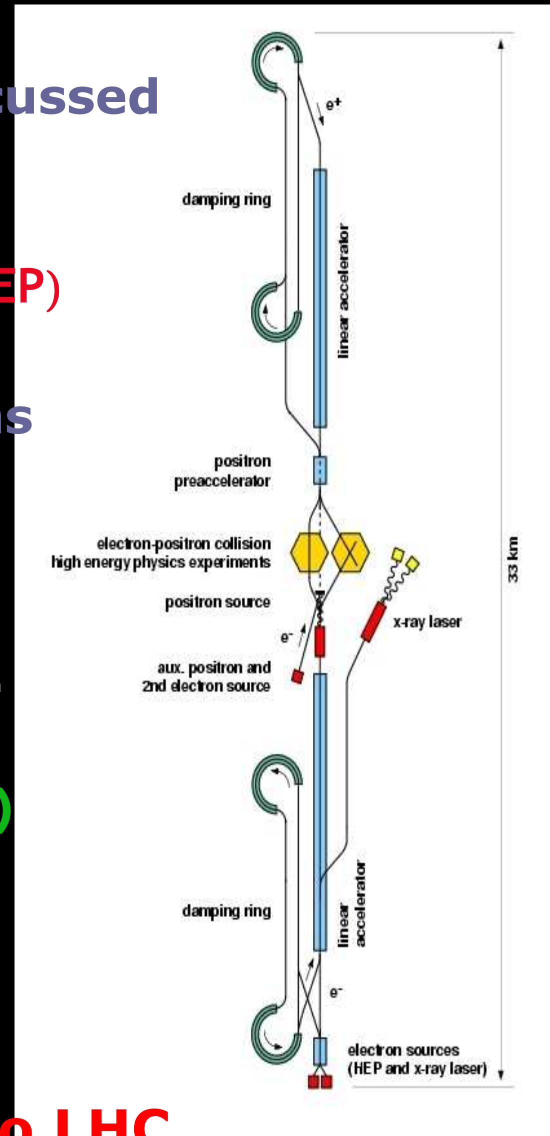
  $e^+e^-\rightarrow tt$ ~50/hr $e^+e^-\rightarrow HX$ ~10/hr
- **\`Backgrounds\` (depends on ILC parameters)**

  $e^+e^-\rightarrow qq$ ~0.1 /Bunch Train

  $e^+e^-\rightarrow\gamma\gamma\rightarrow X$ ~200 /Bunch Train

  ~500 hits/BX in Vertex det.

  ~5 tracks/BX in TPC

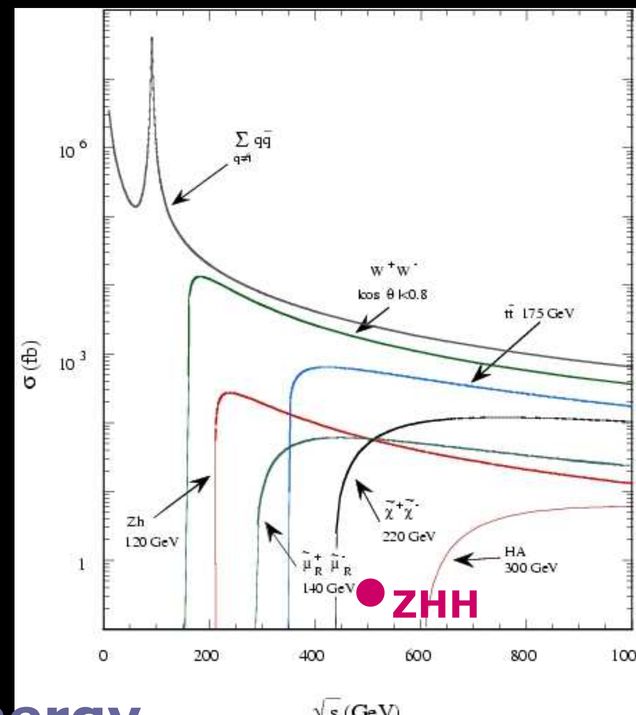


★ **Event rates modest – small compared to LHC**

Physics / Detector Requirements

Precision Studies/Measurements

★ **Higgs** sector
★ **SUSY** particle spectrum
★ **SM particles** (e.g. W-boson, top)
★ and much more...



Difficult Environment:

★ **High Multiplicity final states**
often **6/8 jets**

★ **Small cross-sections**
e.g. $\sigma(e^+e^- \rightarrow ZHH) = 0.3$ fb

★ **Many final states have "missing" energy**
neutrinos + neutralinos(?)/gravitinos(?) + ????

The Tracking Paradigm at ILC

- $\Delta pt/pt^2 \leq 5 \times 10^{-5}$ GeV^{-1} resolution
- 99% tracking efficiency in multi-jets environnemnt
- Very good forward tracking (because of $1+\cos^2\theta$ factor in production)

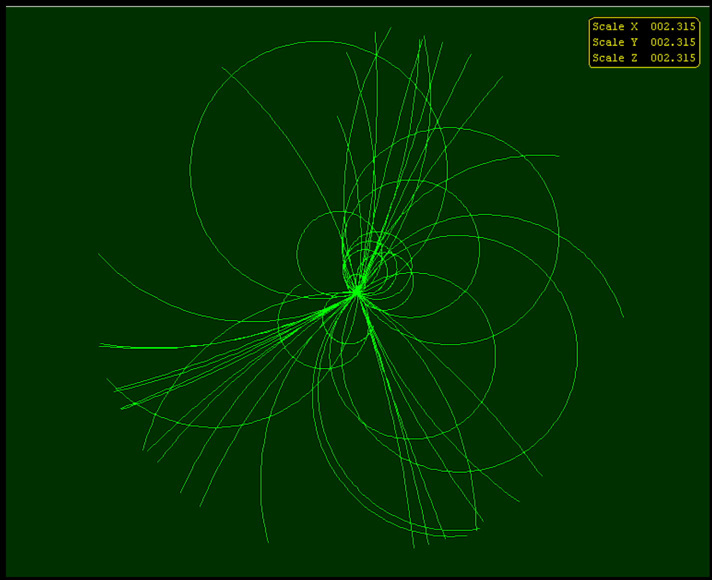
Summary of Concept Design

	GLD	LDC	SiD	4-th
Tracker	TPC + Si-strip	TPC + Si-strip	Si-strip	TPC/DC (+ Si-strip)
Calorimeter	PFA Rin=2.1m	PFA Rin=1.6m	PFA Rin=1.27m	Compensating Rin=1.5m
B	3T	4T	5T	3.5T No return yoke
BR^2	13.2 Tm^2	10.2 Tm^2	8.1 Tm^2	(non-PFA)
E_{store}	1.6 GJ	1.7 GJ	1.4 GJ	2.7 GJ
Size	R=7.2m |Z|=7.5m	R=6.0m |Z|=5.6m	R=6.45m |Z|=6.45m	R=5.5m |Z|=6.4m

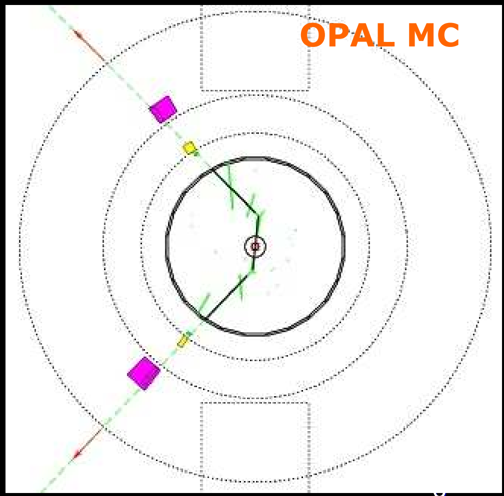
Slide from LDC/GLD

Motivation for a TPC

Advantages of a TPC:



- ★ Large number of 3D space points
  - good pattern recognition in dense track environment
- ★ Good 2 hit resolution
- ★ Minimal material
  - little multiple scattering
  - little impact on ECAL
  - conversions from background γ
- ★ dE/dx gives particle identification
- ★ Identification of non-pointing tracks
  - aid energy flow reconstruction of V^0
  - signals for new physics
    - e.g. Reconstruction of kinks
    - GMSB SUSY: $\tilde{\mu} \rightarrow \mu + \tilde{G}$



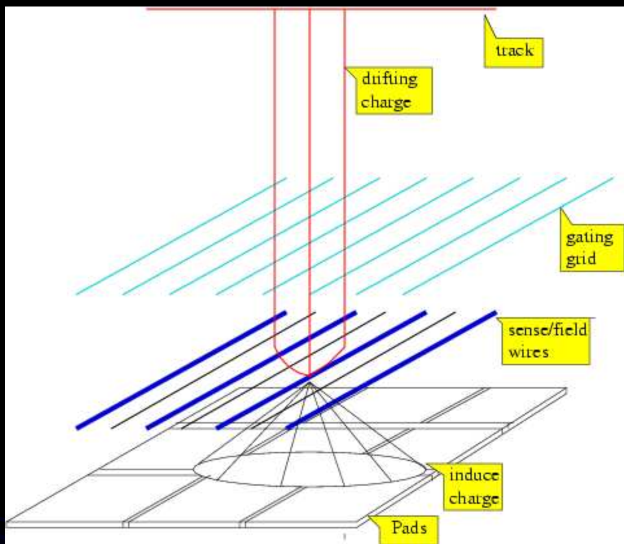
+ Large WORLDWIDE R&D effort suggests that a TPC for an ILC detector is viable

+ Size helps : $\sigma_{1/p} \sim \frac{1}{BR^2}$

Slide from LDC/GLD

Gas Amplification: MWPC vs MPGD

MWPC : Multi-wire proportional chambers
MPGD : Micro-pattern gas detectors



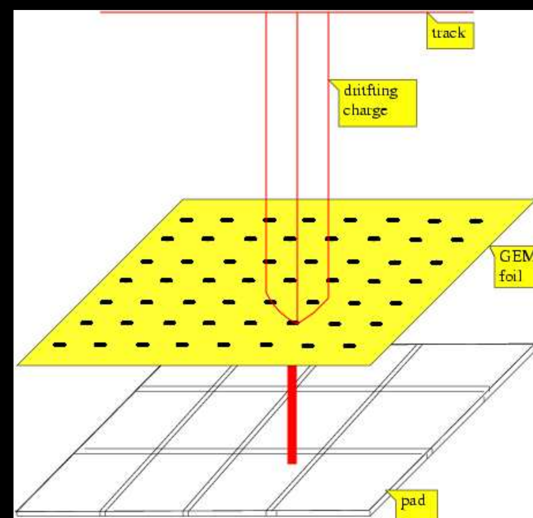
Previous TPCs used multiwire chambers not ideal for ILC.

resolution limited by:

- **ExB effects**
  angle between sense wires and tracks
- **Strong ion feedback – requires gating**
- **Thick endplanes – wire tension**

Gas Electron Multipliers or MicroMEGAS

- **2 dimensional readout**
- **Small hole separation ⇨**
  reduced ExB effects ⇨
  improved point resolution
- **Natural supression of ion feedback**
- **No wire tension ⇨ thin endplates**



SiD starting point/motivation (2)

H.Weerts

- Robustness of silicon against unexpected beam conditions/loss
- Silicon is expensive, so limit area by limiting radius of EMCAL
- Get back BR^2 by pushing B up (~5T)
- Maintain tracking resolution by using silicon strips in tracker
- Make full use of 5 VXD space points for pattern recognition
- Buy safety margin for VXD with the 5T B-field (limit radial extent of pair background; smaller radius for VXD.)

M. Breidenbach – 26 September 2005

SiD Concept Design Study Goals

- Design a comprehensive LC detector, aggressive in performance but constrained in cost.
- Optimize the *integrated* physics performance of its subsystems.
- Evolve the present starting point of SiD towards a more complete and optimized design.
- Interest the international HEP community in the experimental challenges of a LC.

Standard Physics requirements

- a) Two-jet mass resolution comparable to the natural widths of W and Z for an unambiguous identification of the final states.
- b) Excellent flavor-tagging efficiency and purity (for both b- and c-quarks, and hopefully also for s-quarks).
- c) Momentum resolution capable of reconstructing the recoil-mass to di-muons in Higgs-strahlung with resolution better than beam-energy spread .
- d) Hermeticity (both crack-less and coverage to very forward angles) to precisely determine the missing momentum.
- e) Timing resolution capable of tagging bunch-crossings to suppr tracker.
- f) Very forward calorimetry that resolves each bunc

Particle Flow Calorimetry

Pixellated Vertex Detector

Si Strips in high B

Si-W EMCal

Fast detectors w timing electronics

Rad hard pixel calorimetry

Motivations for a DCH with Cluster Counter Readout

A drift chamber à la KLOE with cluster counting (≥ 1GHz, ≥ 2Gsa/s, 8bit)

- uniform sampling throughout >90% of the active volume
- 60000 hexagonal drift cells in 20 stereo superlayers (72 to 180 mrad)
- cell radius 0.6 ÷ 0.7 cm (max drift time < 300 ns)
- 60000 sense wires (20 μm W), 120000 field wires (80 μm Al)
- high efficiency for kinks and vees
- spatial resolution on cell impact par. σ_b = 50 μm (σ_z = 300 ÷ 700 μm)
- particle identification $\sigma(dN_{cl}/dx)/(dN_{cl}/dx) = 2.0\%$
- transverse momentum resolution $\Delta p_\perp / p_\perp = 2 \cdot 10^{-5}\, p_\perp \oplus 5 \cdot 10^{-4}$
- gas contribution to m.s. 0.15% X_0, wires contribution 0.40% X_0
- high transparency (barrel 2.8% X_0, end plates 5.4%/cosθ X_0+electronics)
- poweful 3D reconstruction algorithm
- easy to construct and very low cost

is realistic, provided:

- cluster counting techique is at reach (front end VLSI chip)
- fast and efficient counting of single electrons to form clusters is possible
- 50 μm spatial resolution has been demonstrated

CLUster COUnting

For a given set up, and a digitized pulse (t_{last} is constant with a spread < 20 ns)

$t_0 = t_{last} - t_{max}$ gives the trigger time

$b_f = \int_{t_0}^{t_{first}} v(t)\, dt$ first approx. of impact parameter b

$(c/2)^2 = r^2 - b_f^2$ length of chord

$N_{cl} = c / (\lambda(\beta\gamma) \times \sin\theta)$ expected number of cluster

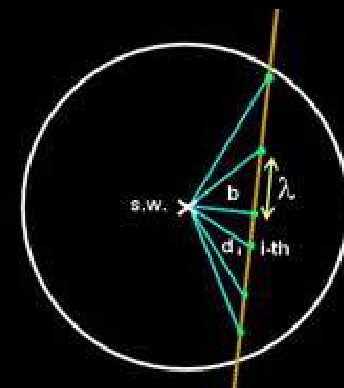
$N_{ele} = 1.6 \times N_{cl}$ expected number of electrons (to be compared with counted one)

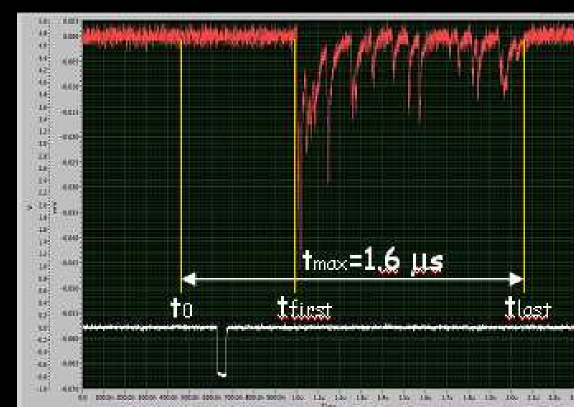
$\{t_i\}$ and $\{A_i\}$, $i=1,N_{ele}$ ordered sequence of ele.drift times and their amplitudes

$P(i,j)$, $i=1,N_{ele}$, $j=1,N_{cl}$ probability i-th ele. $\in$ to j-th cl.

$$D_i^{N_{cl}}(x) = \frac{N_{cl}!}{(N_{cl}-i)!\,(i-1)!}(1-x)^{N_{cl}-i}\,x^{i-1}$$

probability density function of ionization along track





How had Physics driven the Central Tracker choices for the four ILC concepts?

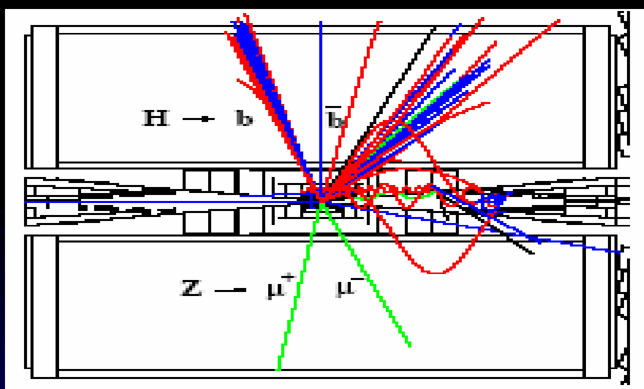
Original Snowmass Results

Goal: $\Delta p_t/p_t^2 \le 5 \times 10^{-5}$ GeV^{-1} 10X LEP, and 3X CMS

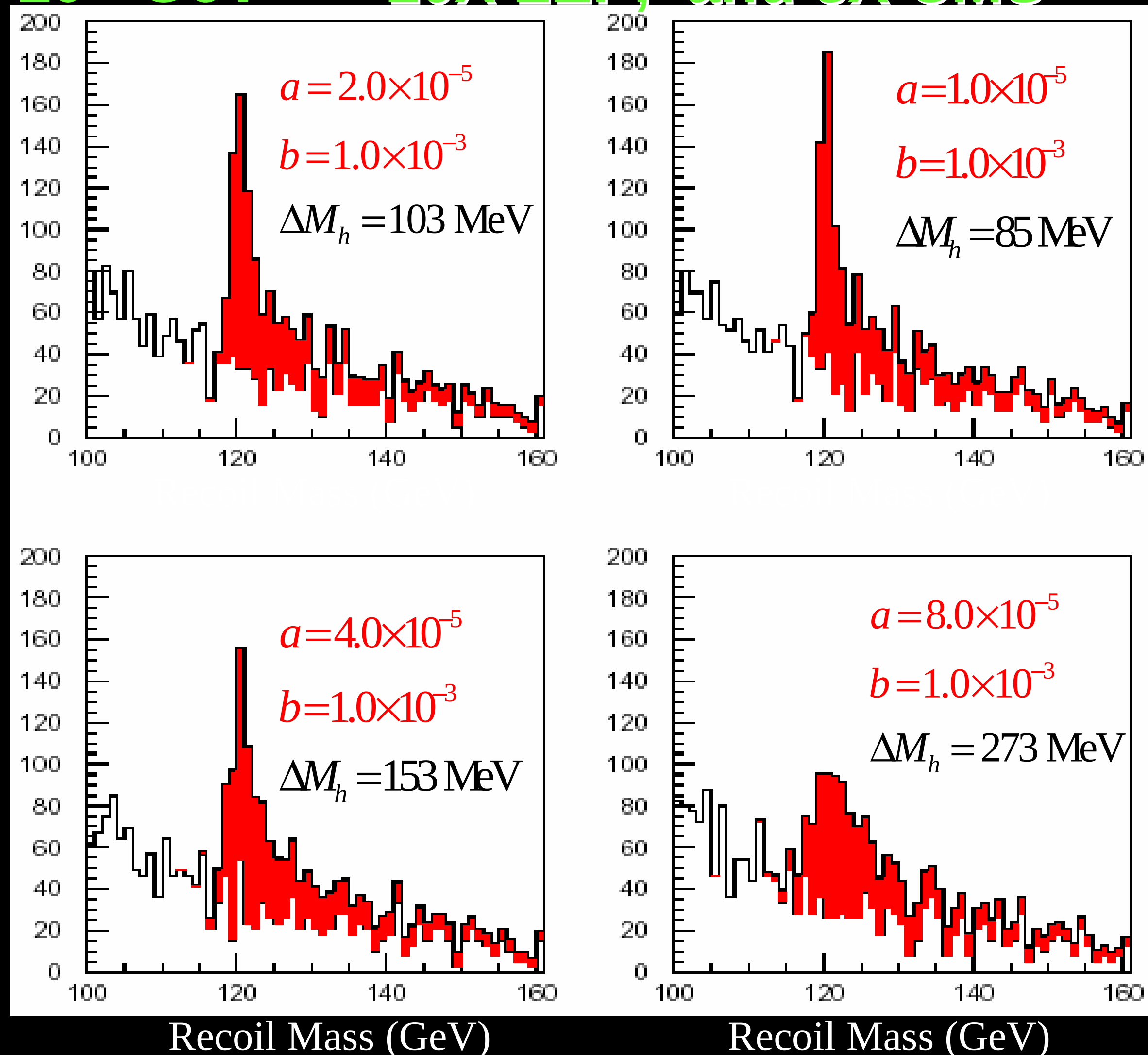
$e^+e^- \to Z^oH^o \to \mu^+\mu^- X$

Recoil Mass Measurement

$$\frac{\delta p_t}{p_t^2} = a \oplus \frac{b}{p_t \sin\theta}$$

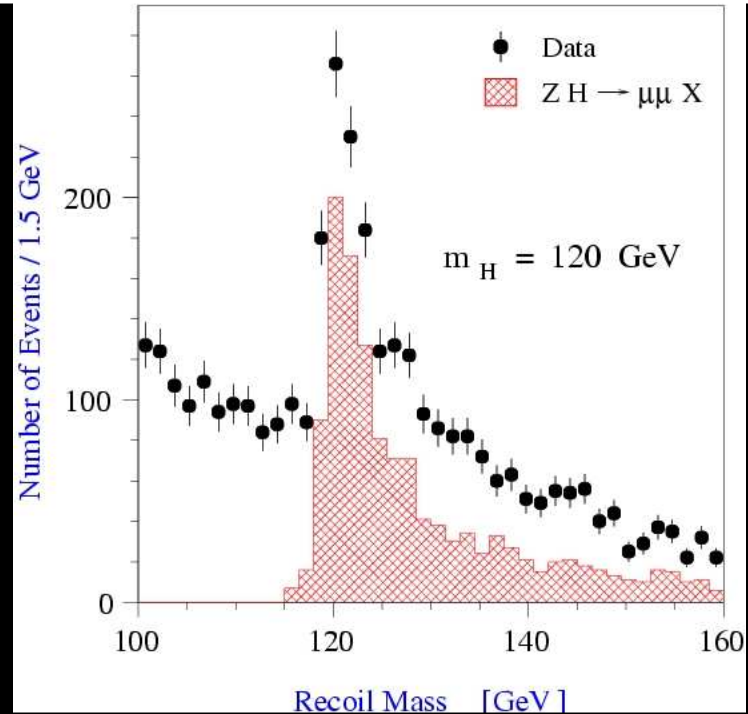


- **Boost Effective Luminosity**
- **Improve Tag**



Slide from SiD

LDC Studies



★ **momentum: d(1/p) ~ 10^{-4}/GeV(TPC only)**
~ 0.4x10^{-4}/GeV(w/vertex)
(1/10xLEP)

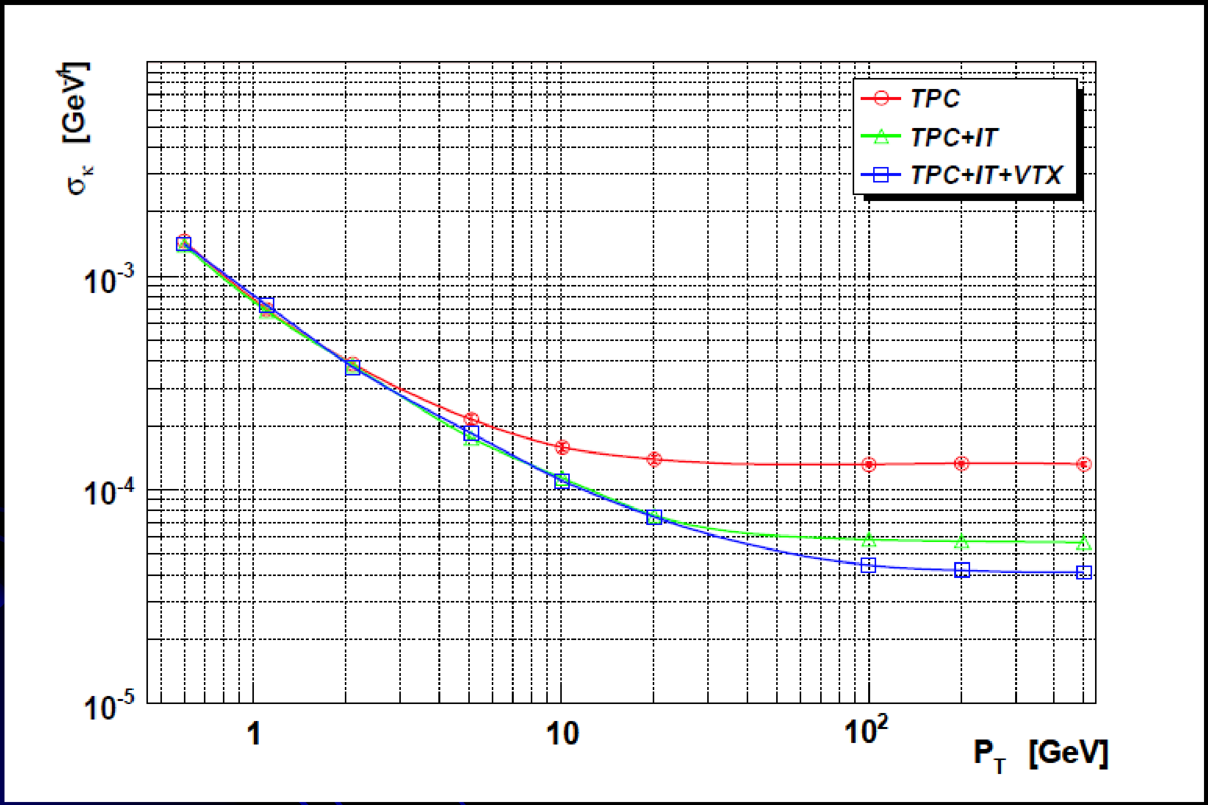
$e^+e^- \rightarrow ZH \rightarrow ll\ X \rightarrow \delta\sigma_H$ dominated by beam-beam, effects, backgrounds.
Better momentum resolution not needed?

★ **tracking efficiency: ~99% (overall)**

excellent and robust tracking efficiency by combining vertex detector and TPC, each with excellent tracking efficiency

Slide from LDC

LDC/GLD Single Particle Studies



LDC/GLD Conclusion

The performance goal can be achieved with GLD detector with TPC of 150μm point resolution and 200 measurements

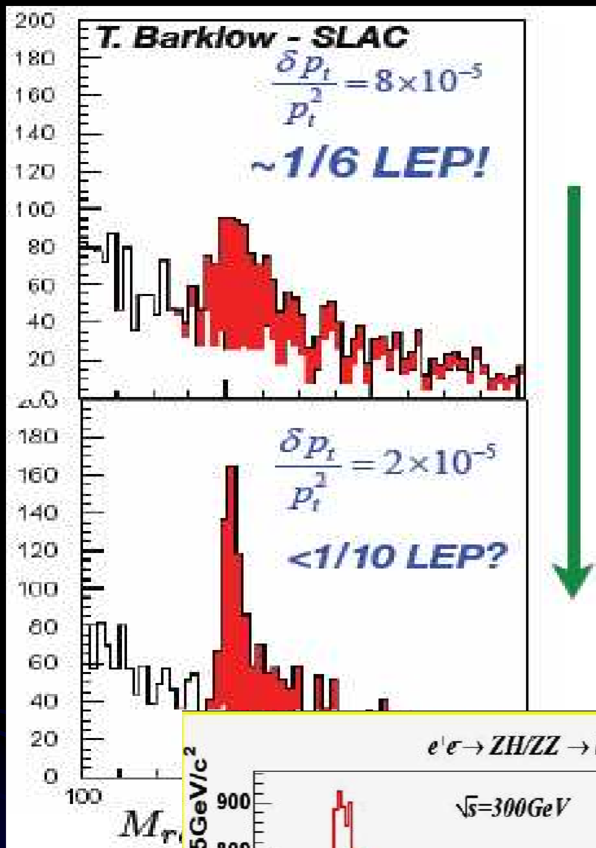
Slide from GLD

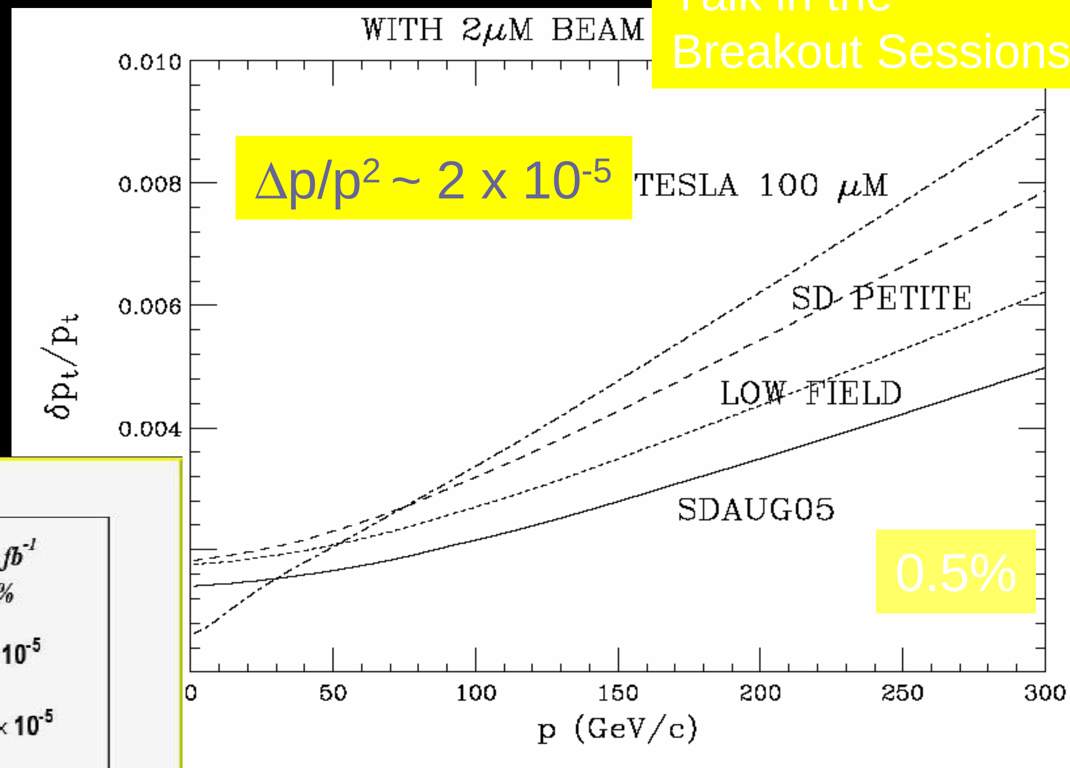
$$e^+e^- \rightarrow Z^0H^0 \rightarrow \mu^+\mu^- + X$$

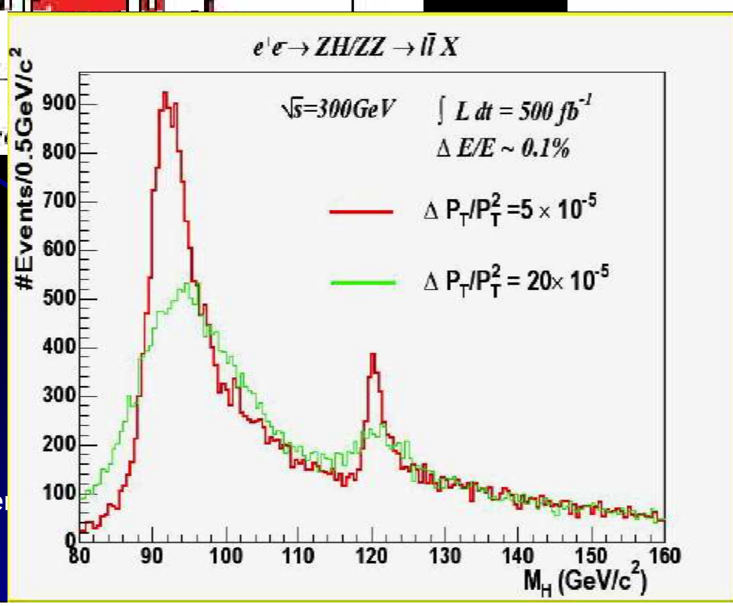
SiD tracking studies

- Physics Premium on Superb Momentum Resolution
- Challenges
  Low Material Budget
  Robust Pattern Recognition

See Tim Nelson's Talk in the Breakout Sessions





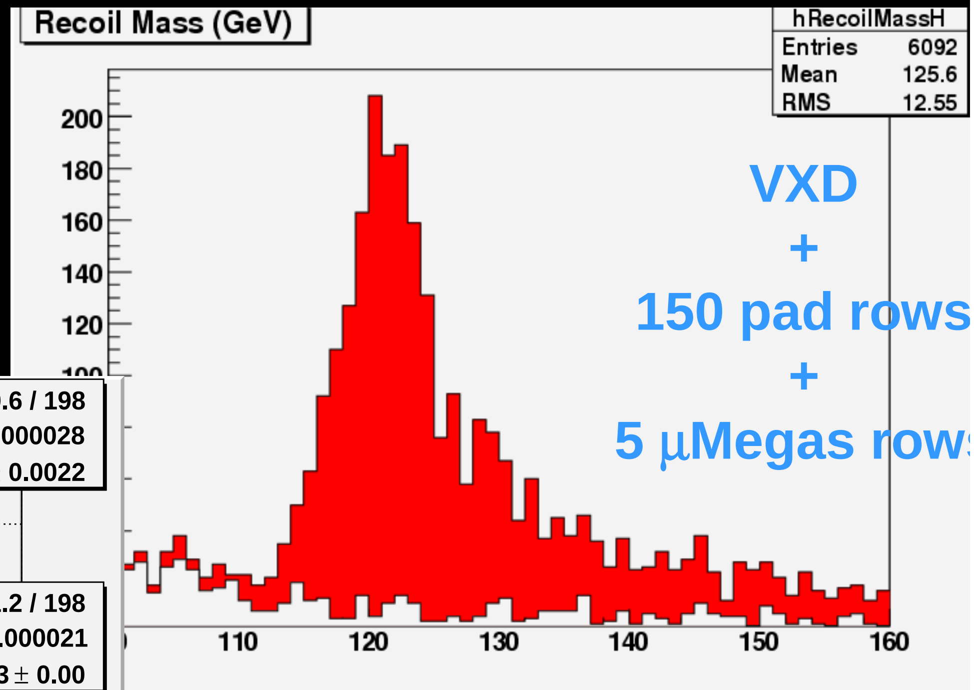


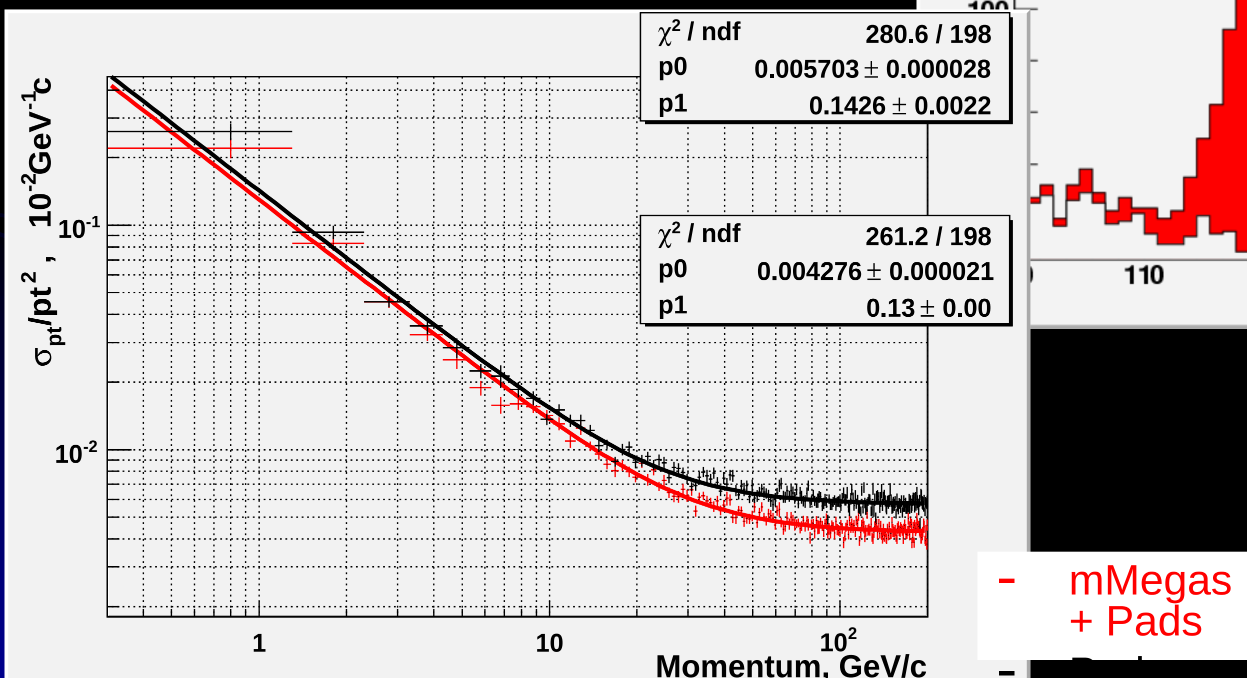
Slide from SiD

4th Concept TPC Studies

$e^+e^- \rightarrow Z^oH^o \rightarrow \mu^+\mu^-X$ + ZZ -> $\mu^+\mu^-X$ background (500 fb @ Ecm=350 GeV)

VXD + TPC with Hybrid Readout





Slide from 4th Concept

Observations:

- Entire ILC Tracking decisions based on one single Physics channel:

  $e^+e^- \to Z_o H_o \to \mu^+\mu^- X$

- Jet reconstruction:
  - Disregard resolution issues
  - Only care that ε_{rec} >99%

The Whole Picture

- e^+e^- -> Z_oH_o -> $\mu^+\mu^-X$ foundamentally important at ILC for M_{Higgs} measurements
- Low statistics channel (> 2yrs data taking unless run at Ecm = 230 GeV)
- Jets reconstruction in Dual Readout Calorimetry uses heavily the central tracker (60% charged components in jets)
- PFA is going the same direction
- Other semi-exclusive channel are appearing in the Physics scenario
- Cannot disregard V_o's (about 2(evt in multijets)

Simulation Frameworks

- Current studies are not using the same 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

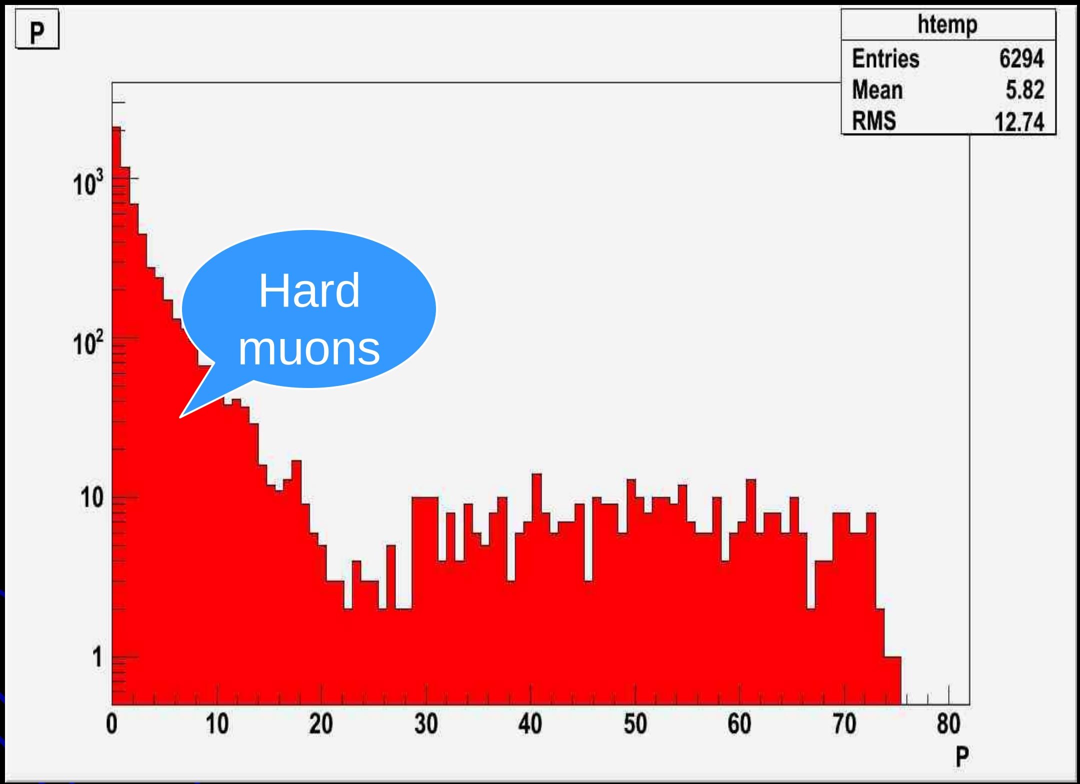
Introducing A New Study

- Define few Physics channel of interest for the tracking
- Compare SiD tracker, TPC and 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
  - Put a basis for detector optimization
- FNAL – INFN Lecce joint study

Benchmark Channels

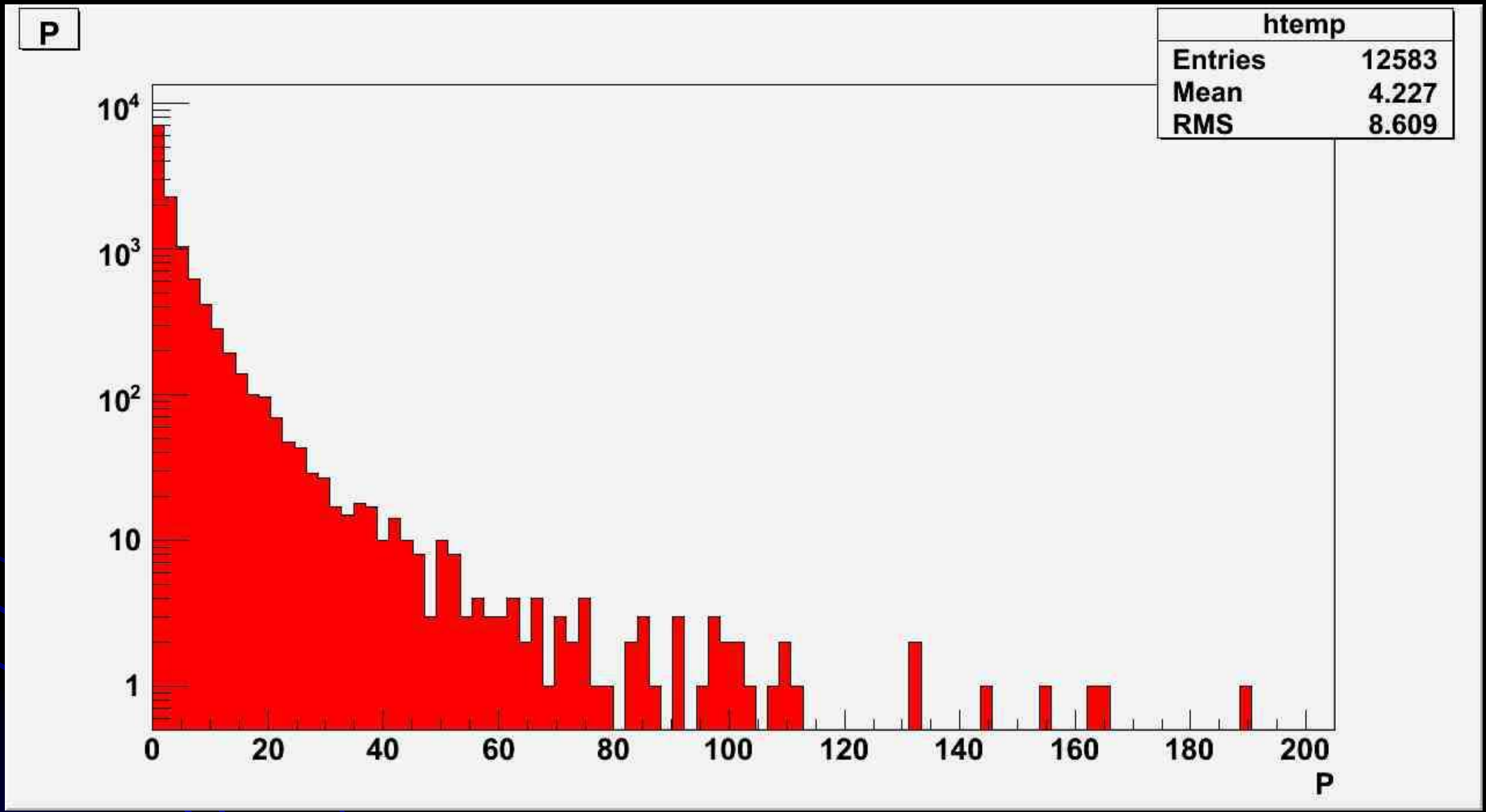
- e^+e^- -> Z_oH_o -> $\mu^+\mu^-X$ with e^+e^- -> Z_oZ_o -> $\mu^+\mu^-X$ background [E_{cm}=230]
- e^+e^- -> ttbar->6jets
- e^+e^- -> W^+W^- ->4jets
- τ Polarization Study (also important for EM calorimetry)
- Beam background studies

$e^+e^- \to Z_o H_o \to \mu^+\mu^- X$ + $e^+e^- \to Z_o Z_o \to \mu^+\mu^- X$ background [E_{cm}=230]



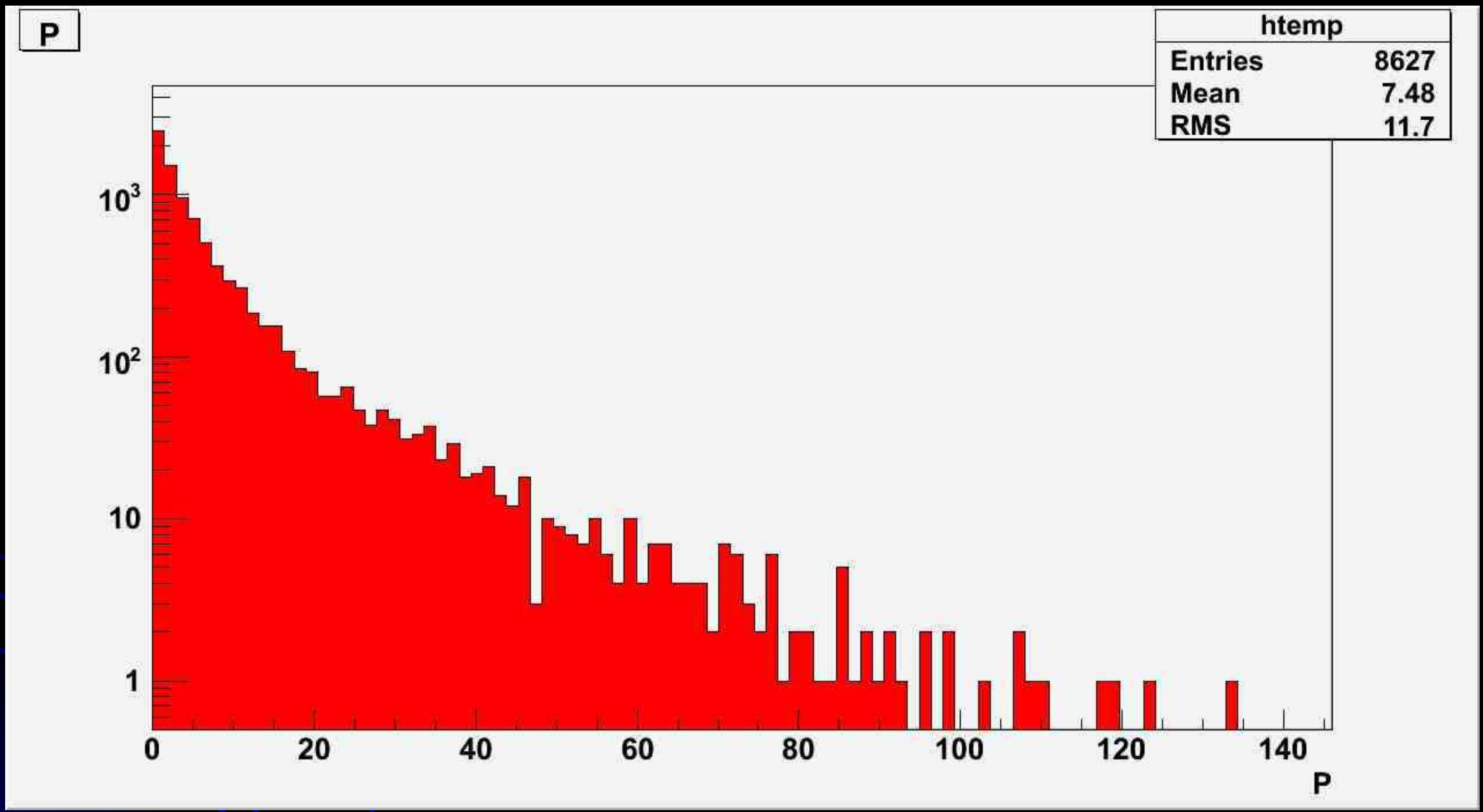
- Momentum spectrum for generated tracks entering the central tracker region
- Standard benchmarck channel
- Used as reference with existing analyses

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 -> $\tau\,\nu$ -> $\rho\,\nu$ -> $\pi^+\,\pi^0$

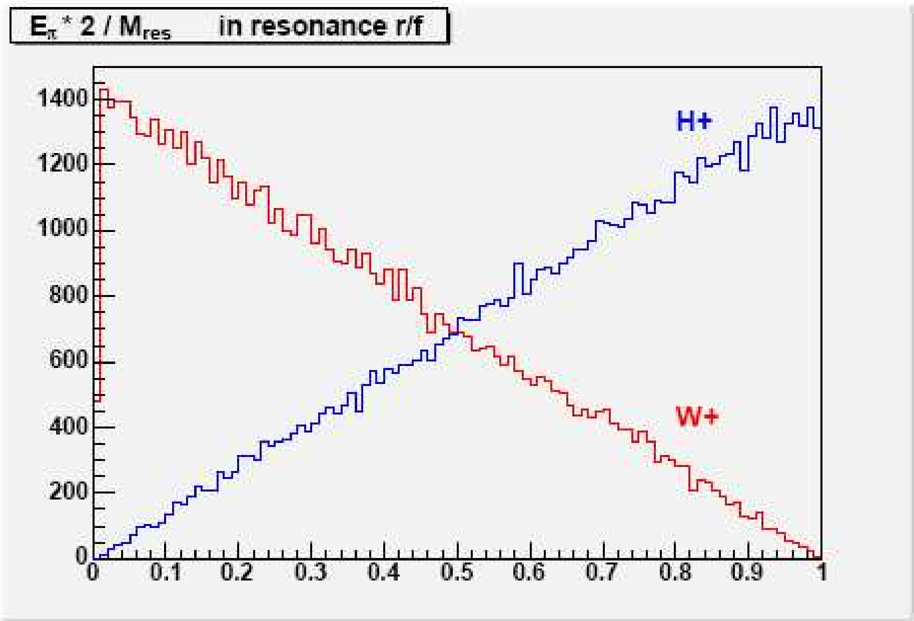


Figure 1: $\pi^{\pm}$ meson energy spectrum in the resonance rest frame.

- 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)

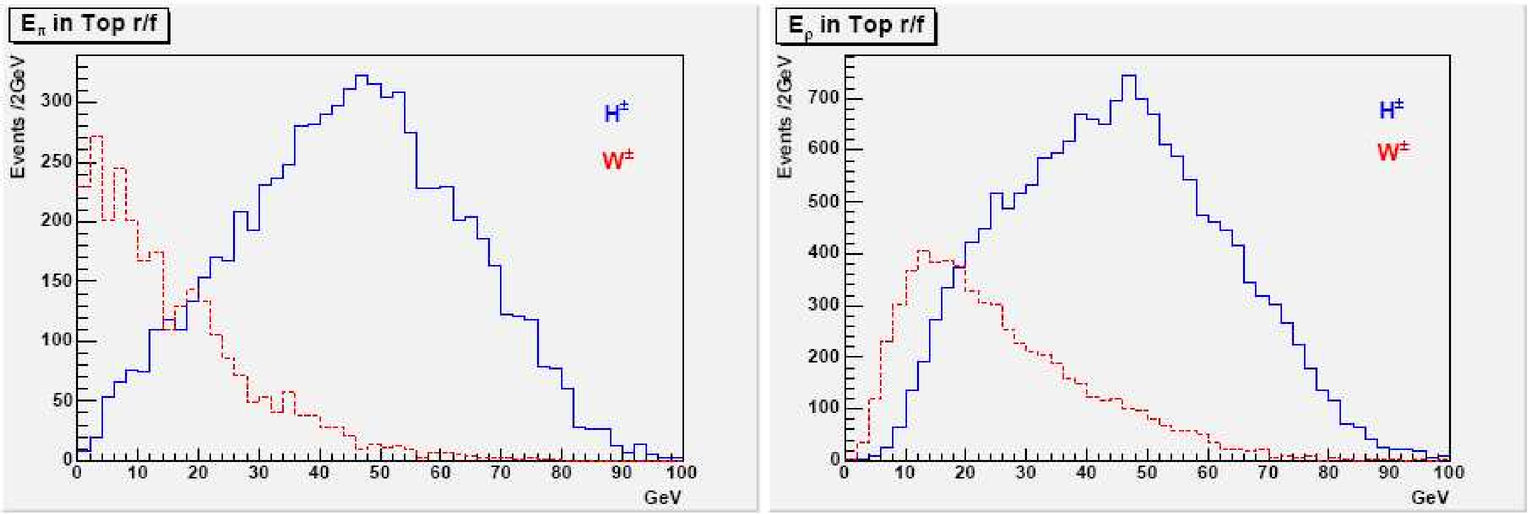


Figure 2: The energy spectrum of the $\pi^{\pm}$ meson (left) and $\rho^{\pm}$ meson (right). The dotted line corresponds to the background, and the solid one to signal.

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

Gluckstern Rules Here

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

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

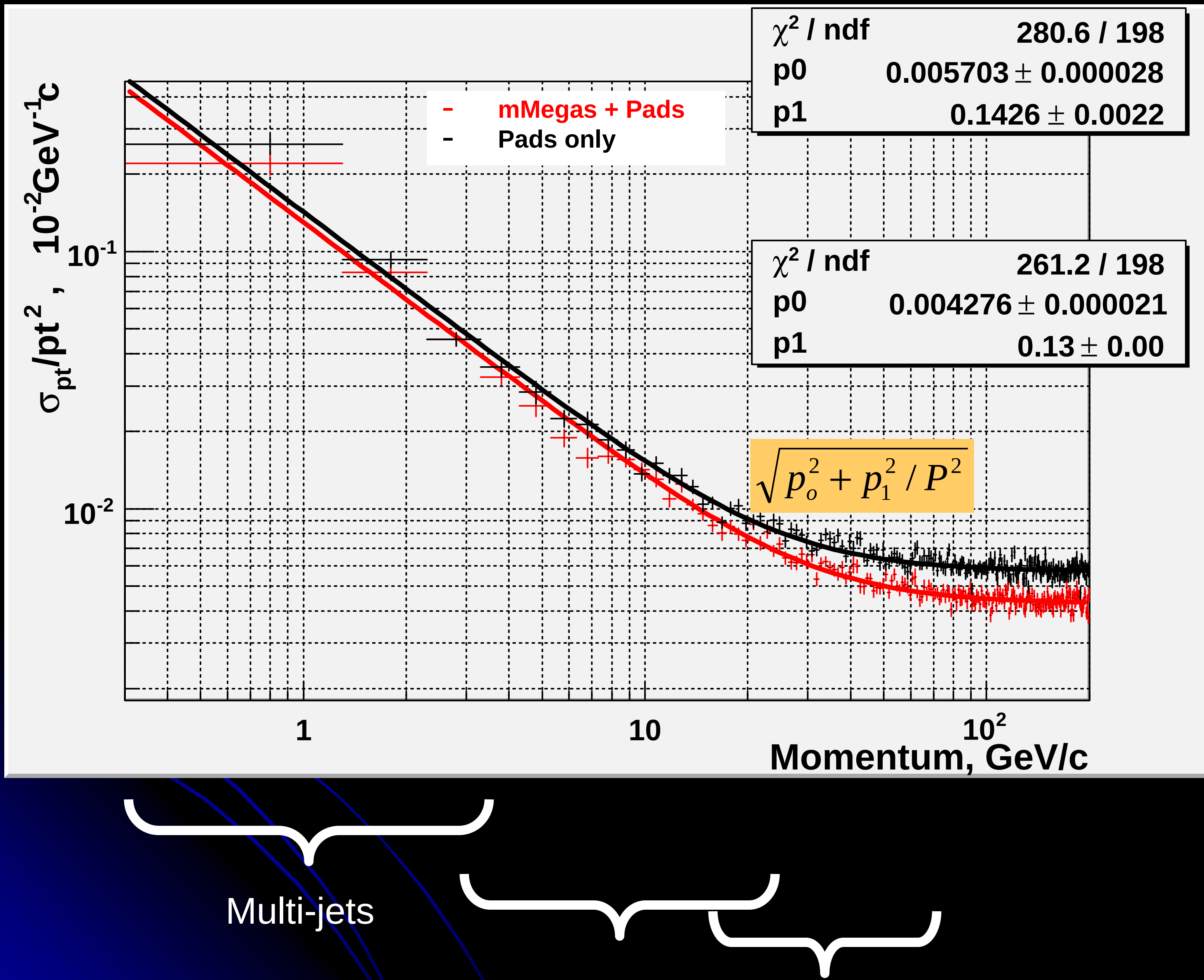
@ ILC, for B = 5 T, $L_\perp$ = 1.5 m

$$\frac{\delta p_\perp}{p_\perp^{\ 2}} = 5.3\frac{\varepsilon_\perp}{\sqrt{N+4}} \oplus \frac{7.2\times10^{-3}}{p_\perp \sin\theta}\sqrt{\frac{L}{X_0}} \Rightarrow$$

N = 150 , L ~ 2m
(1 cm^2 hex. cells)
60.000 sense wires
120.000 field wires

$$\frac{\varepsilon_\perp}{\sqrt{N+4}} = 4\times10^{-6} \qquad \frac{L}{X_0} = 2\times10^{-2}$$

$$\varepsilon_\perp \cong 50\mu m! \quad X_0 \geq 100m!$$



χ^2 / ndf 280.6 / 198
p0 0.005703 ± 0.000028
p1 0.1426 ± 0.0022
χ^2 / ndf 261.2 / 198
p0 0.004276 ± 0.000021
p1 0.13 ± 0.00
mMegas + Pads
Pads only
$\sqrt{p_o^2 + p_1^2 / P^2}$
σ_{pt}/pt^2 , 10^{-2}GeV^{-1}c
10^{-1}
10^{-2}
1
10
10^2
Momentum, GeV/c
Multi-jets
$H^+ \to \pi\nu$
HoZo

- VXD + TPC

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)

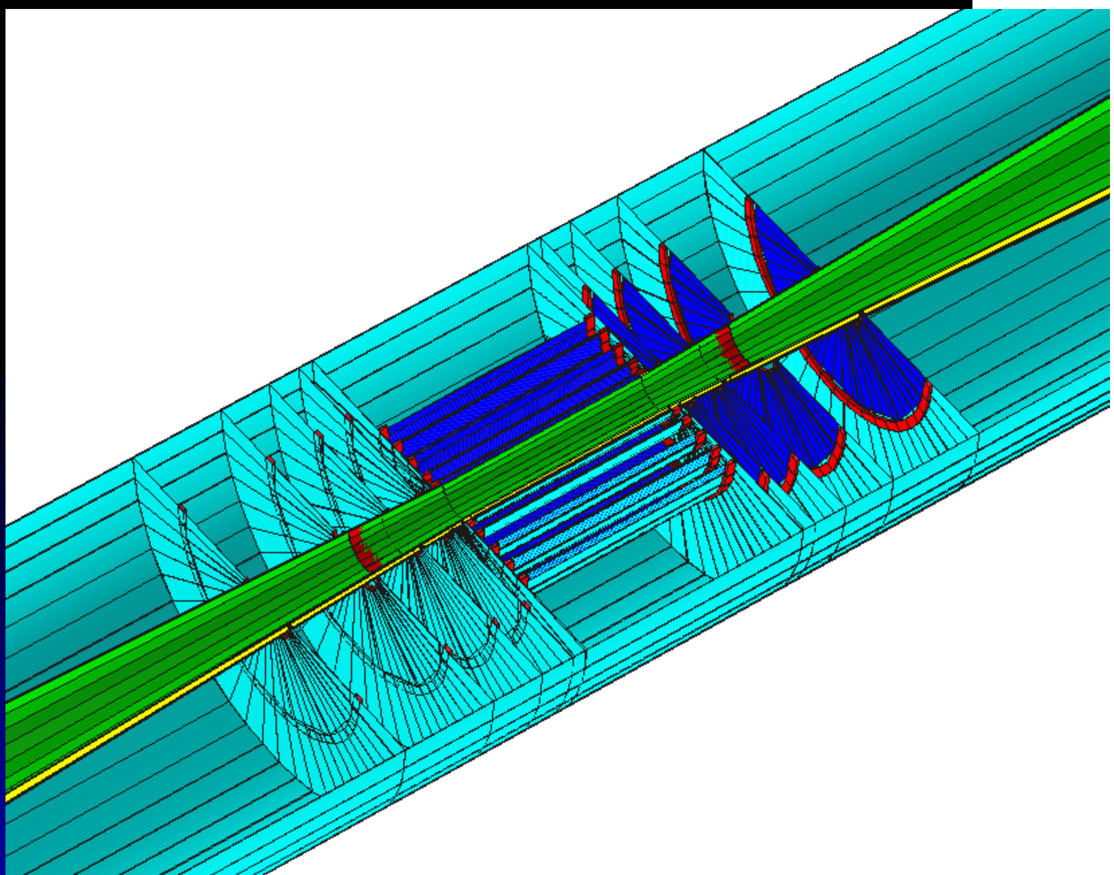
- **Several versions of the same detector are possible (choose at run time)**

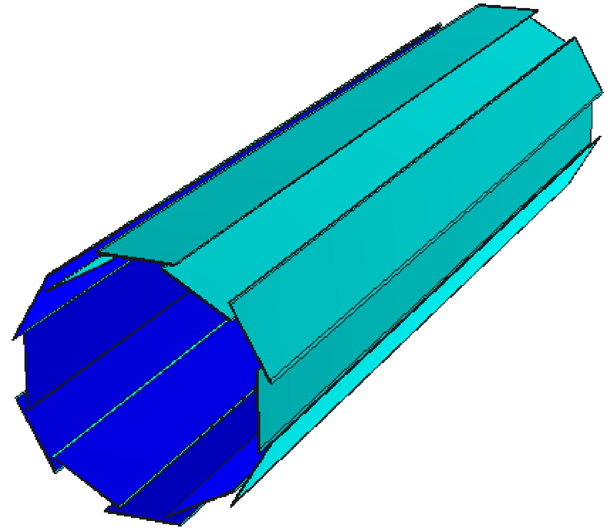
The Event Generators

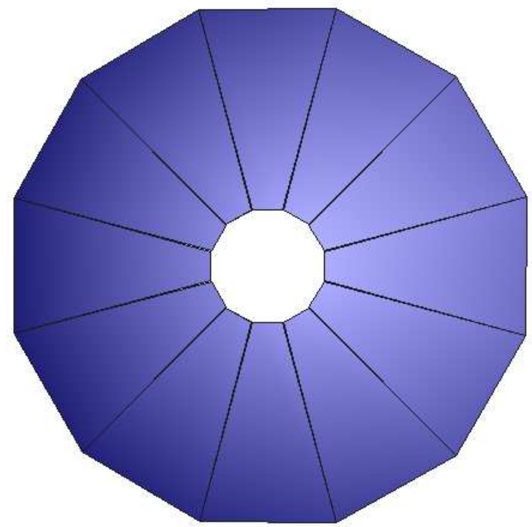
- The event generators (for tracking studies) used:
  - Pandora-Pythia/Sherpa/Whizard /CompHep for Physics Channels
  - Guinea-Pig for Beam Background
  - A variety of phase space generators and cocktails of them for detector performance

The Sub-Detectors Involved

SiD/4th VXD



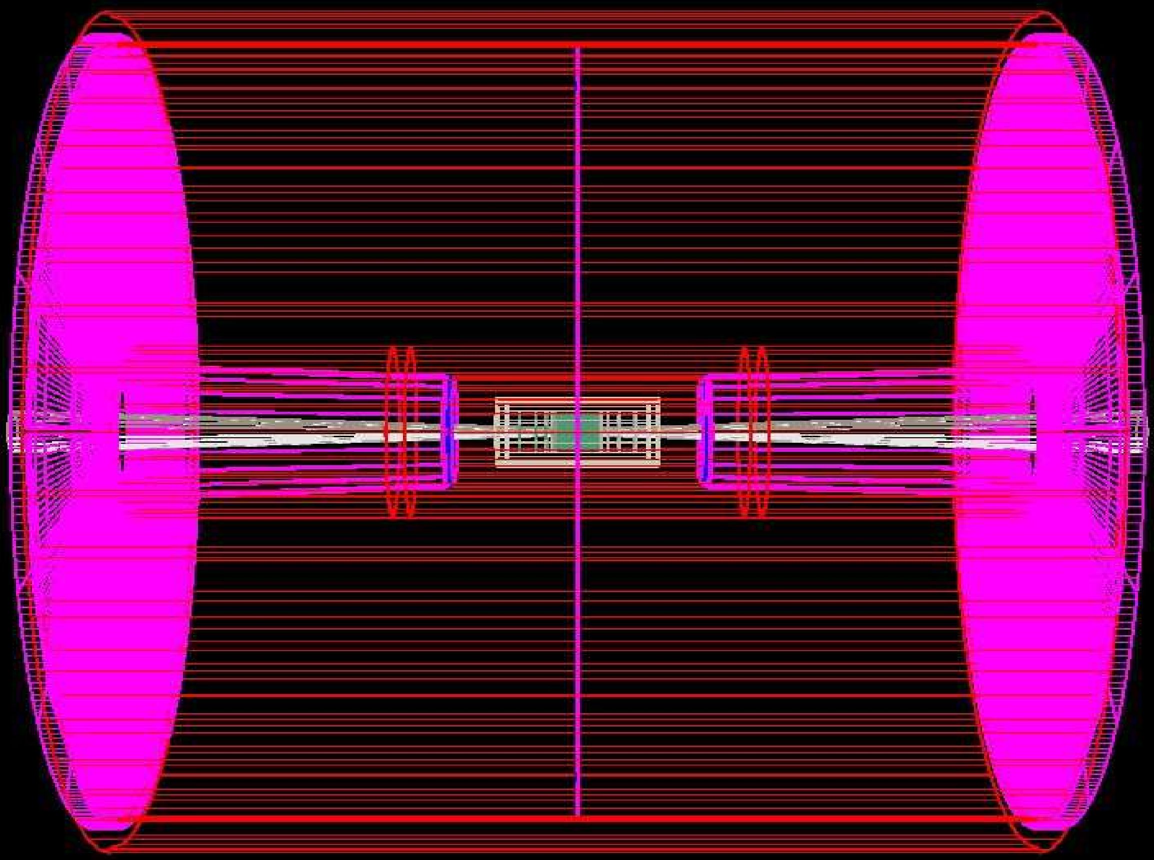




Beam Pipe and VXD layout

- Beam Pipe:
  - 400 μm Be
  - 25 μm Ti
- VXD:
  - 5 barrel layers x 4 endcaps
  - 20 μm 20 μm pixel size
  - Detector support: 100 μm CarbonFiber
  - Si modules: 100 μm Si
  - Outer shield: 430 μm CarbonFiber

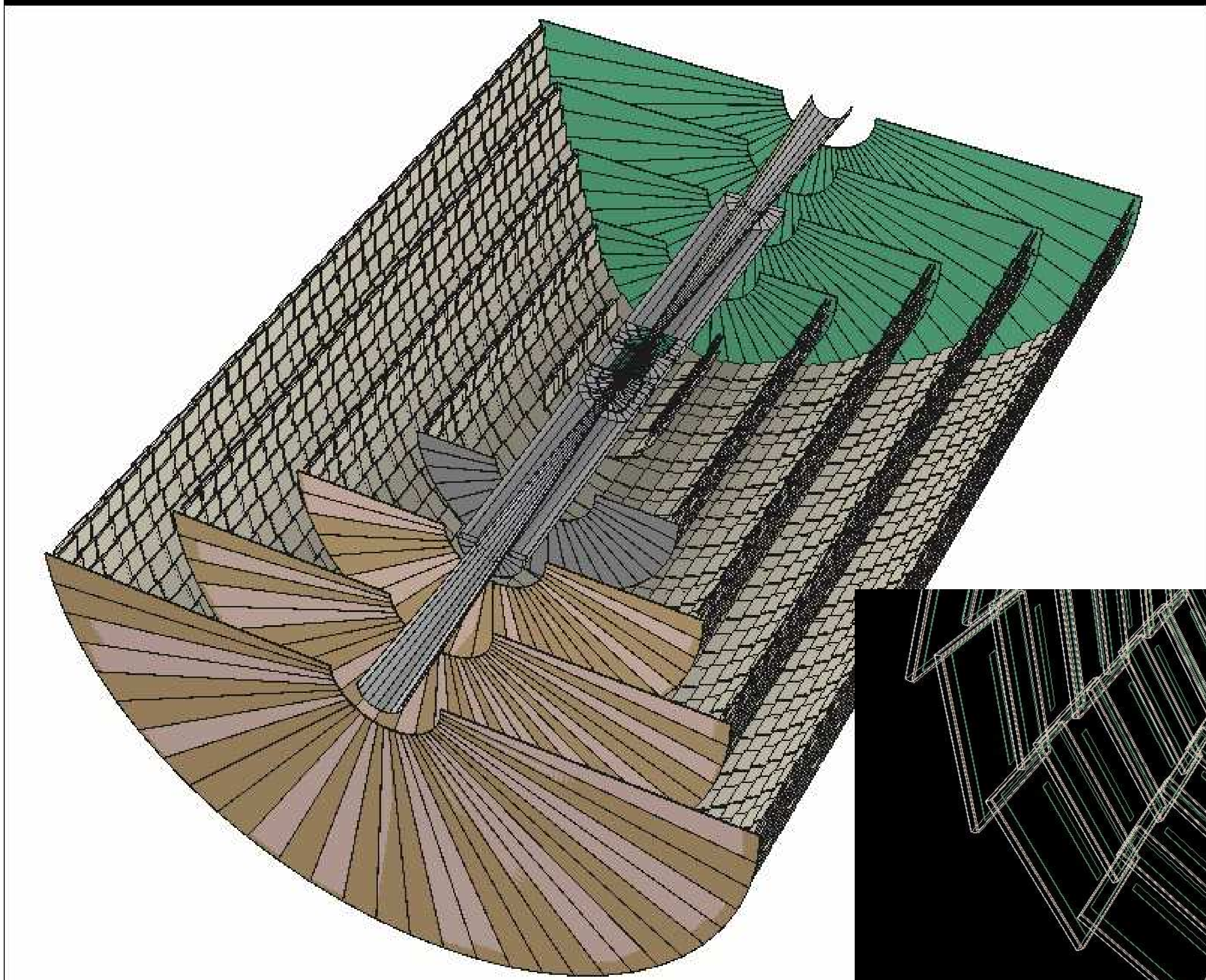
TPC

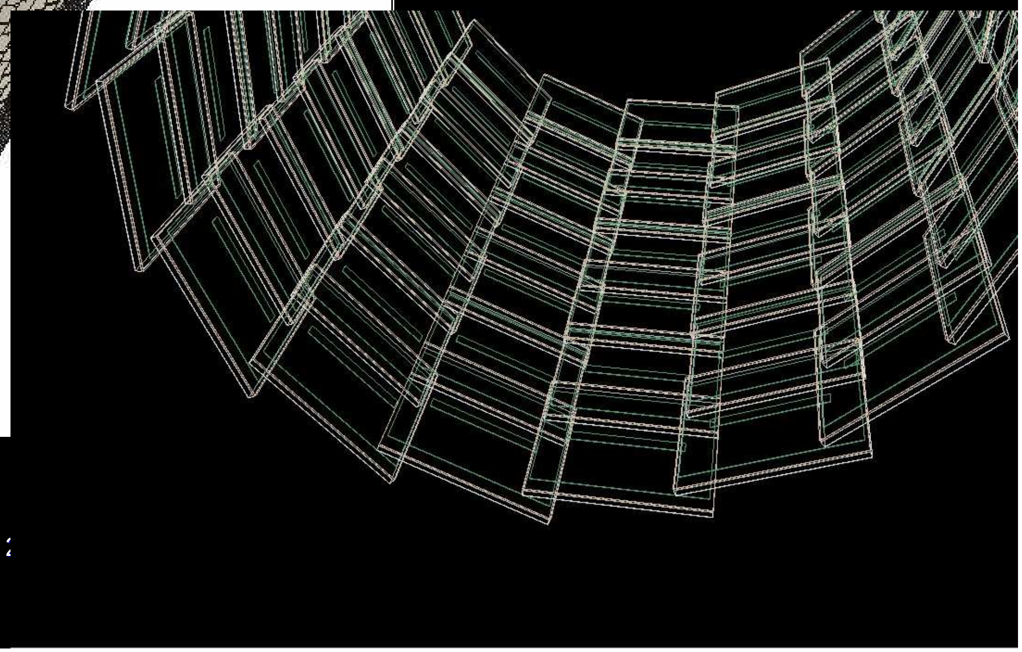


TPC Layout

- 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 – 137cm (145 cm for DCR)
- 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

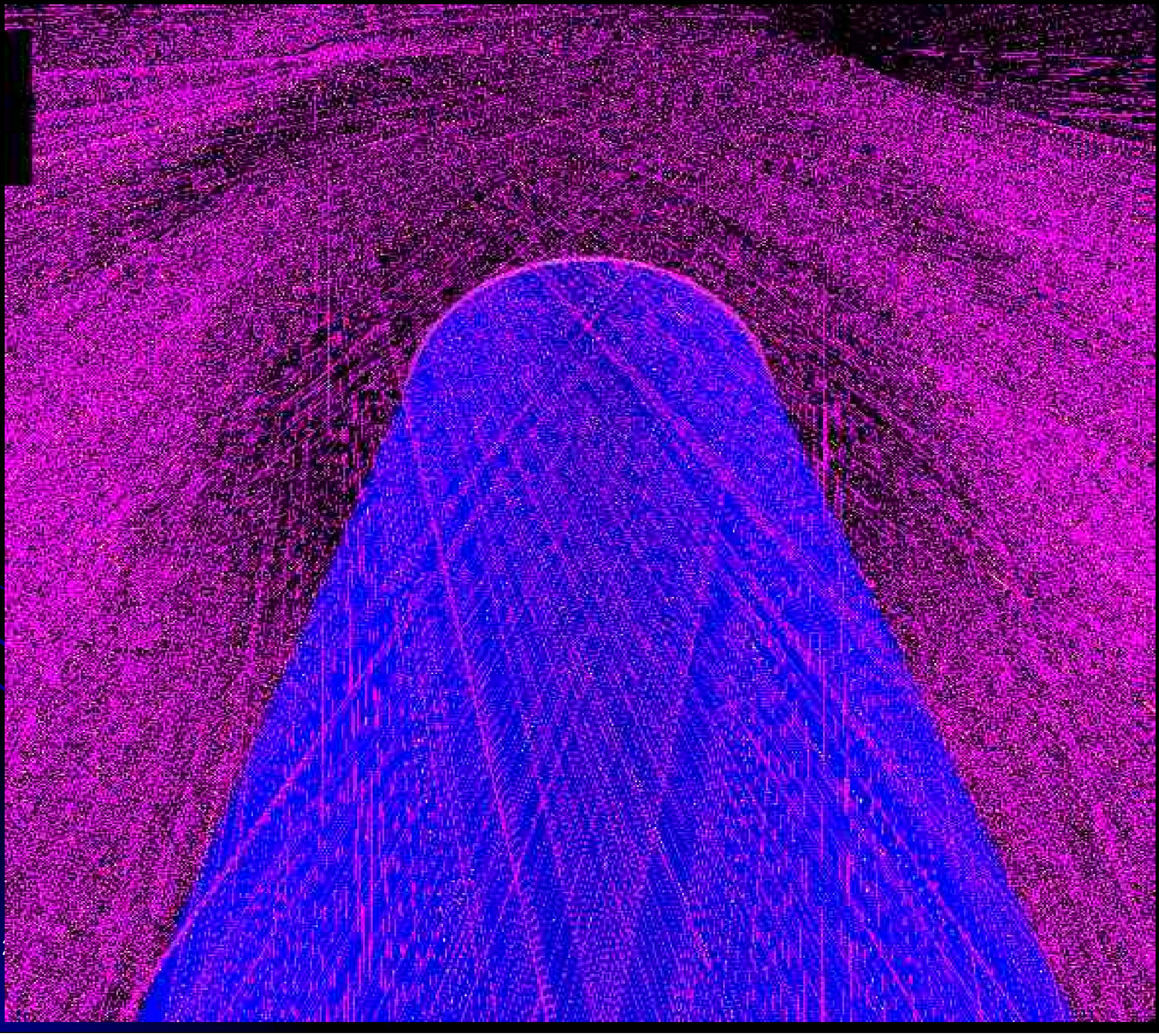




SiD Tracker Layout (Barrel)

- Version 1.0 (SiD01-Polyhedra)
- Guard ring: mm 0.07
- Barrel Layers: 5
- Total Tiles Barrel 7312
-
- **Tile 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

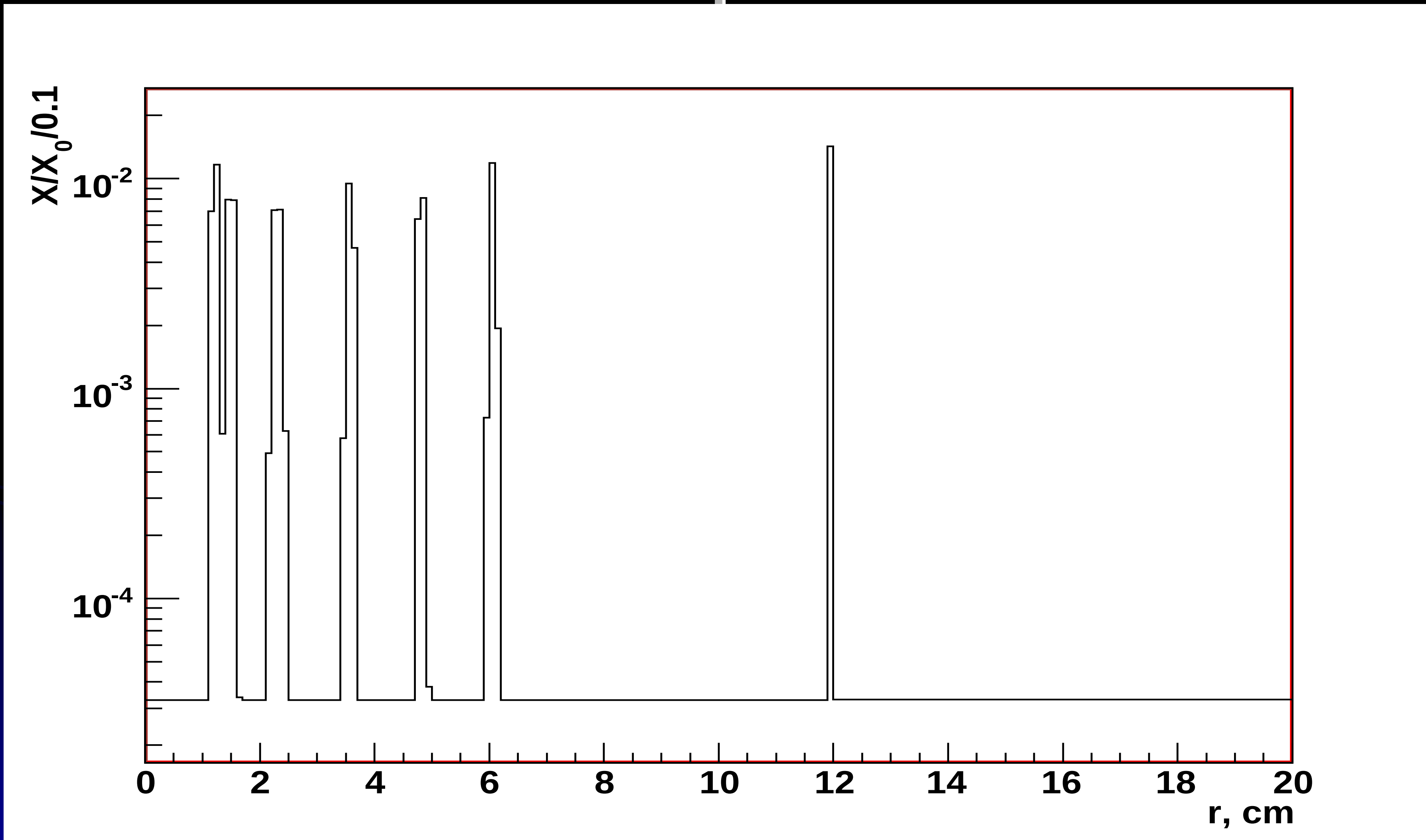
ClouCou Drift Chamber



DCH Layout

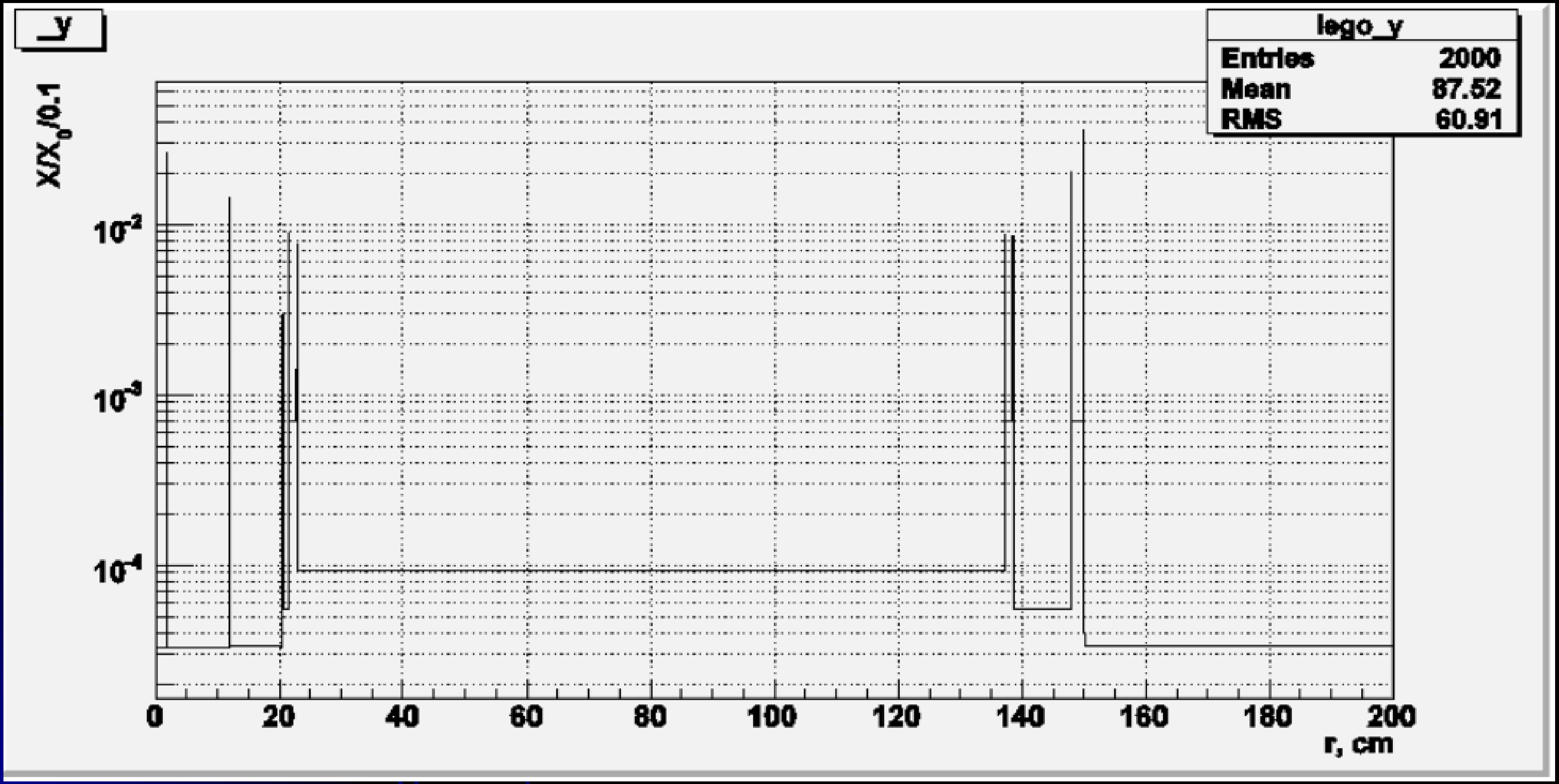
- Vessel: 23-150 cm (Active volume: 37-145 cm)
- Individual wires simulated
  - 60000 20 μm W sense wires
  - 120.000 80 μm Al field wires
- Gas: 90% He + 10% iC4H10
- Layers: 152
- Cells size and shape:
  - 6.35 mm x 6.35 mm axial square for reconstruction studies
  - Exagonal all-stereo superlayers,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

Material Budget in 1mm step: Beam Pipe + VXD



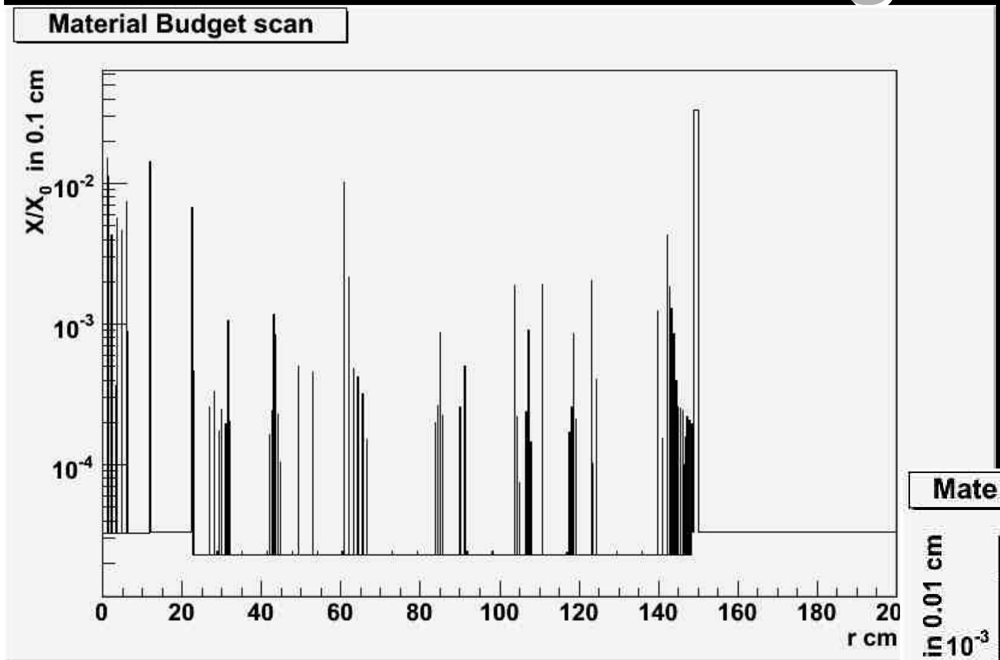
Intregrated over φ

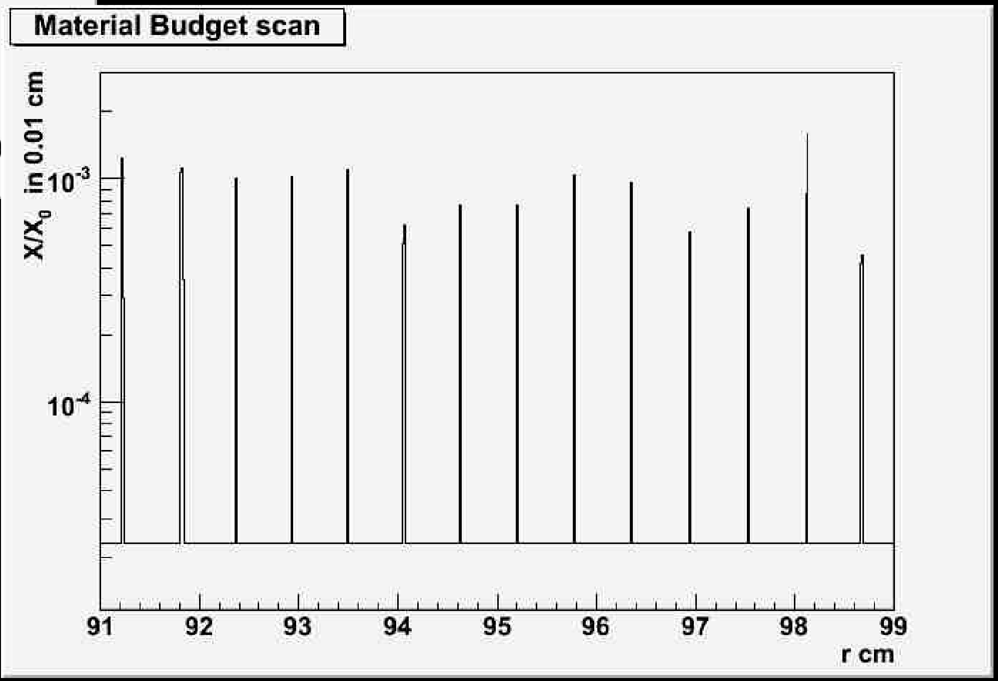
Material Budget inn 1mm step: TPC



Intregrated over φ

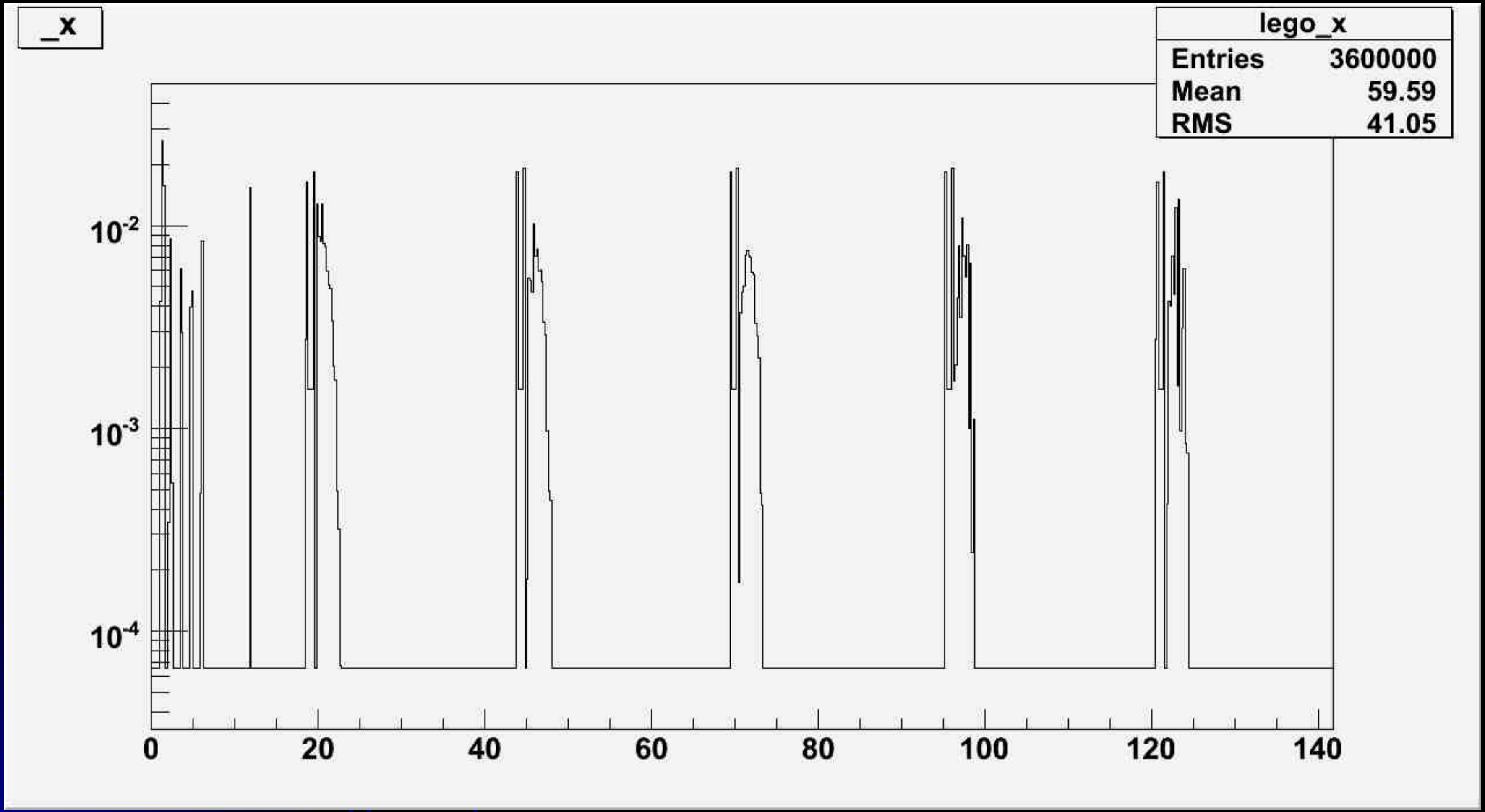
Material Budget inn 1mm step: DCH





Intregrated over φ

Material Budget in 1mm step: Si-Barrel



Intregrated over φ

Material Budget at θ= 90º

- Beam Pipe: 0.18% X/X_o
- VXD:
  - Detector & support: 0.8% X/X_o
  - Outer shield: 0.16% 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 :7.56% (Si= 5.33% + Support=2.23%)
- **Endcap Inner Disks: 2.93 % X/Xo**
- **Endcap Outer Disks: 4-39-5.39 % X/Xo**

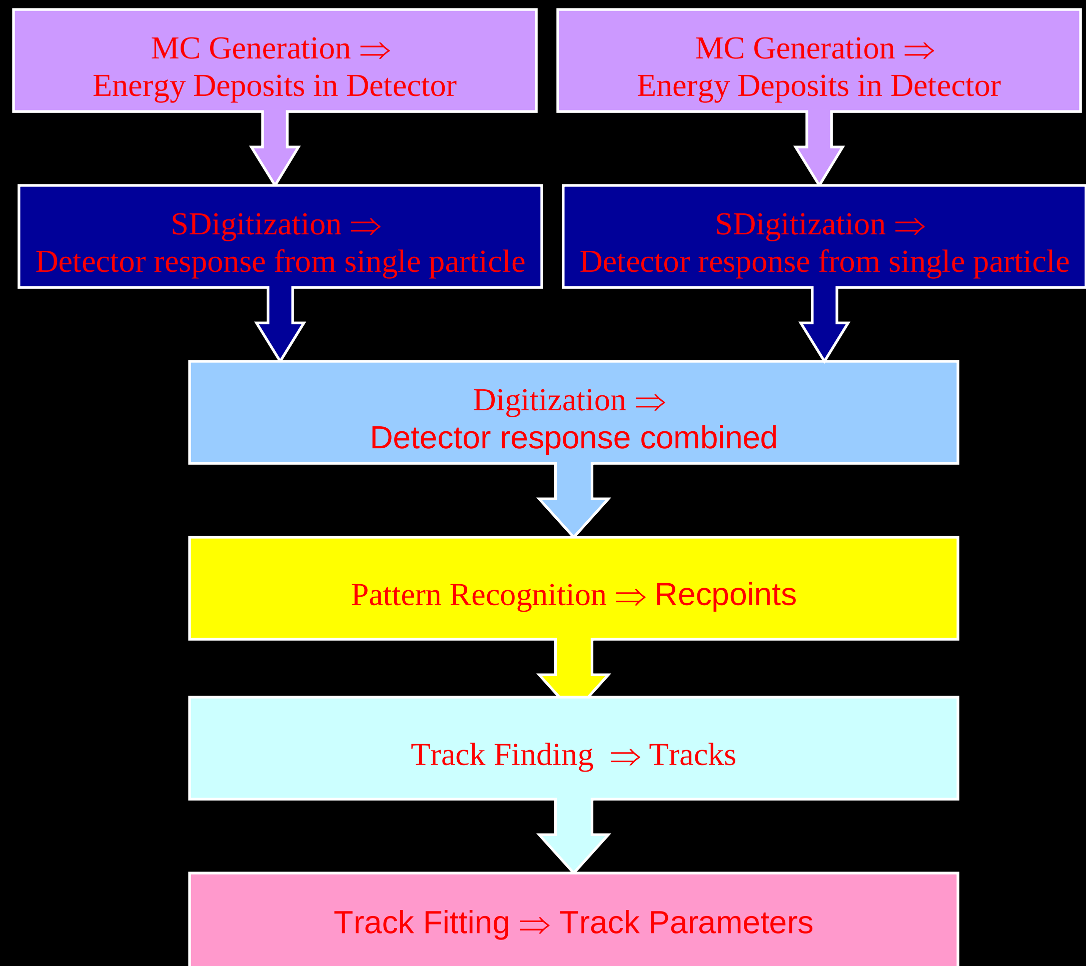
- **Drift Chamber**
- Gas [He-C4H10/90-10]: 0.15%
- Wires: 0.4%
- Vessel:
  - Inner wall: 0.1% X/Xo
  - Outer wall: 2% X/Xo
  - Endcaps (wires, pads,electronics & services included): 8% X/Xo

Simulation and Reconstruction Algorithms

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 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

- Add coupling effect between nearby strips
  - different contribution from left and right neighbours
  - Proportional to nearby signals (B-field effect)

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):

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

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

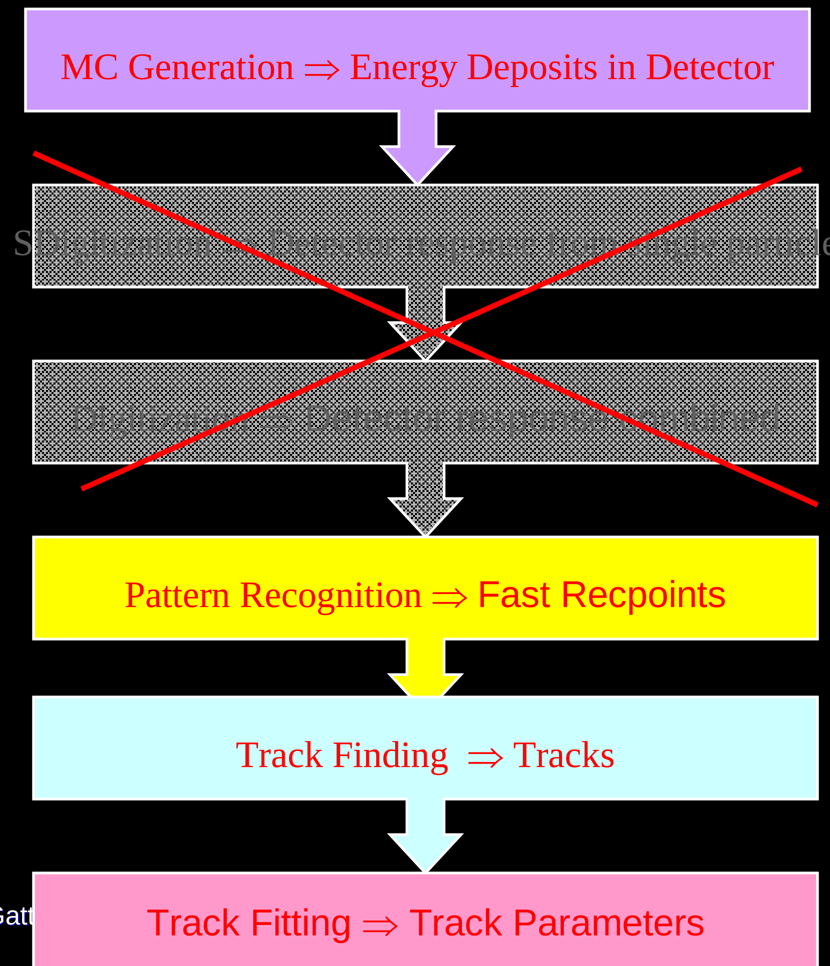
$$\sigma_{pCOG} = \sqrt{\frac{\sigma_T^2(z_{max}-z)}{N_{ch}}G_g + \frac{tan(\beta)^2 l_{pad}^2 G_{Landau}(N_{prim})}{12N_{chprim}} + \sigma_{noise}^2} \quad (8)$$

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

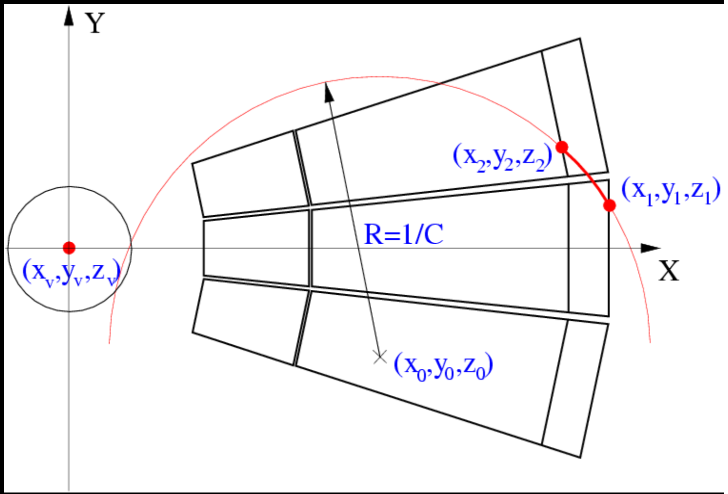
DCH SDigitization (in progress)

- 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)



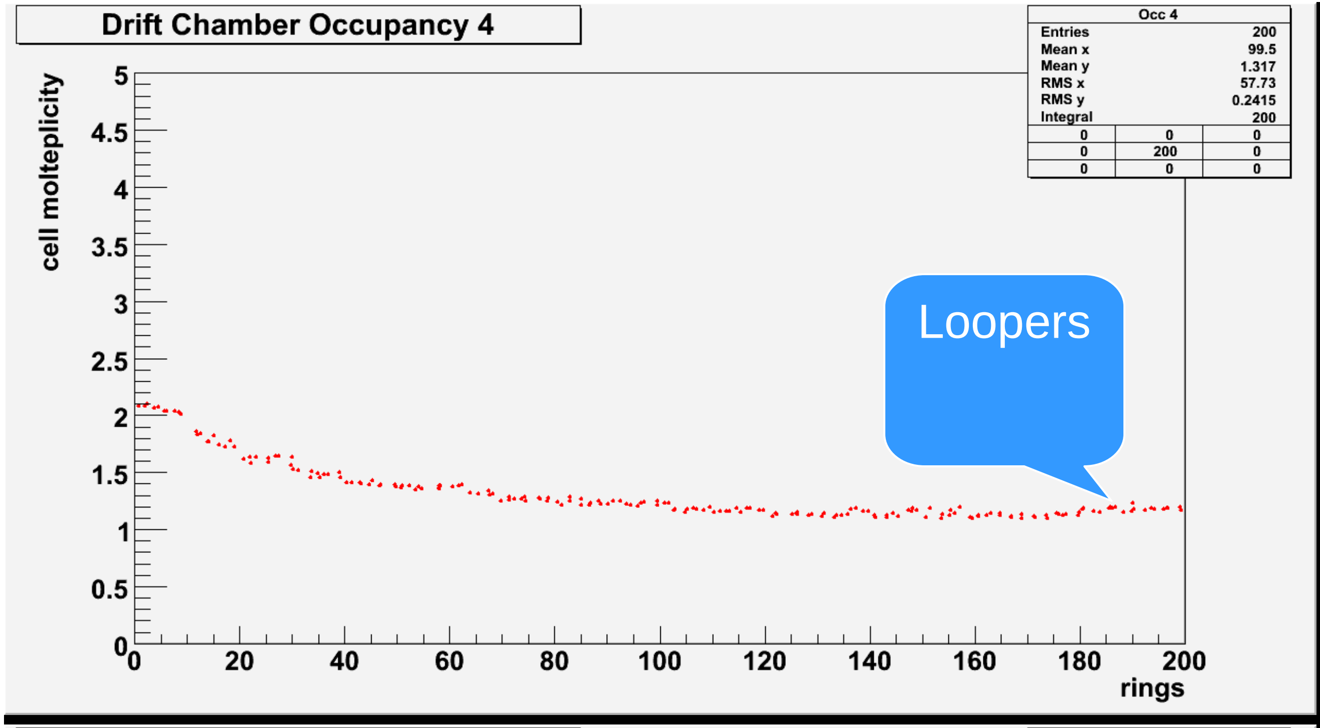
- Primary TPC/DCH seeding: looks for tracks with 20 hits (pads and/or μmegas) apart + beam constraint
- Secondary TPC/DCH seeding: looks for tracks with hits in layer 1, 4 and 7 (no beam constraint)
- **Parallel Kalman Filter** then initiated:
  - 1st step: start from TPC/DCH fit + prolongation to VXD (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

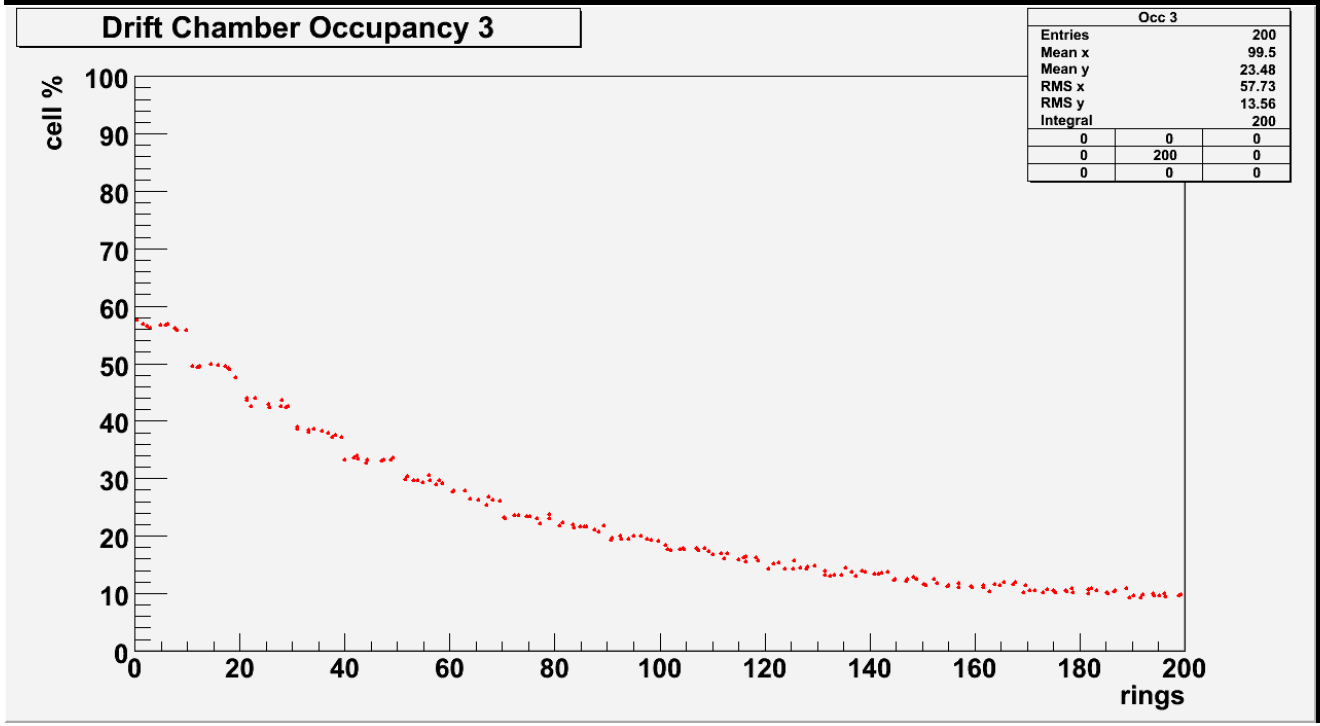
*not yet implemented

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

Single Particle Studies





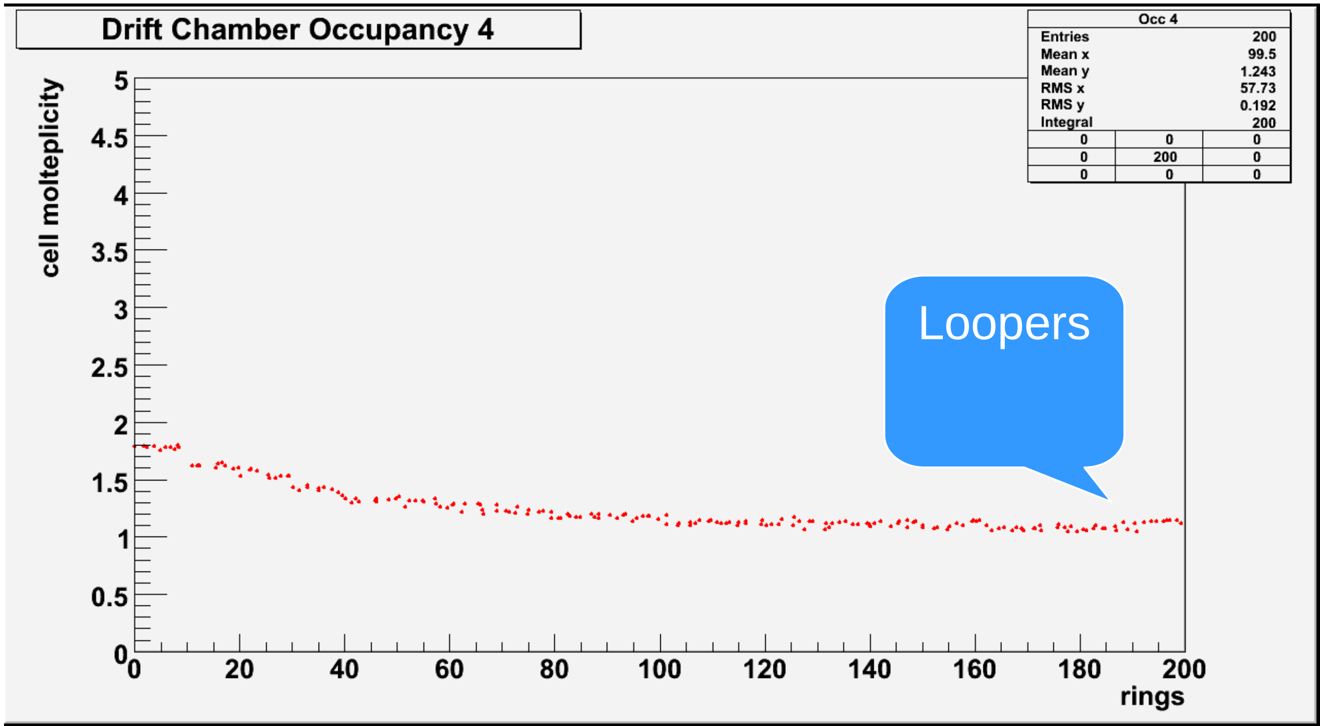
DCH

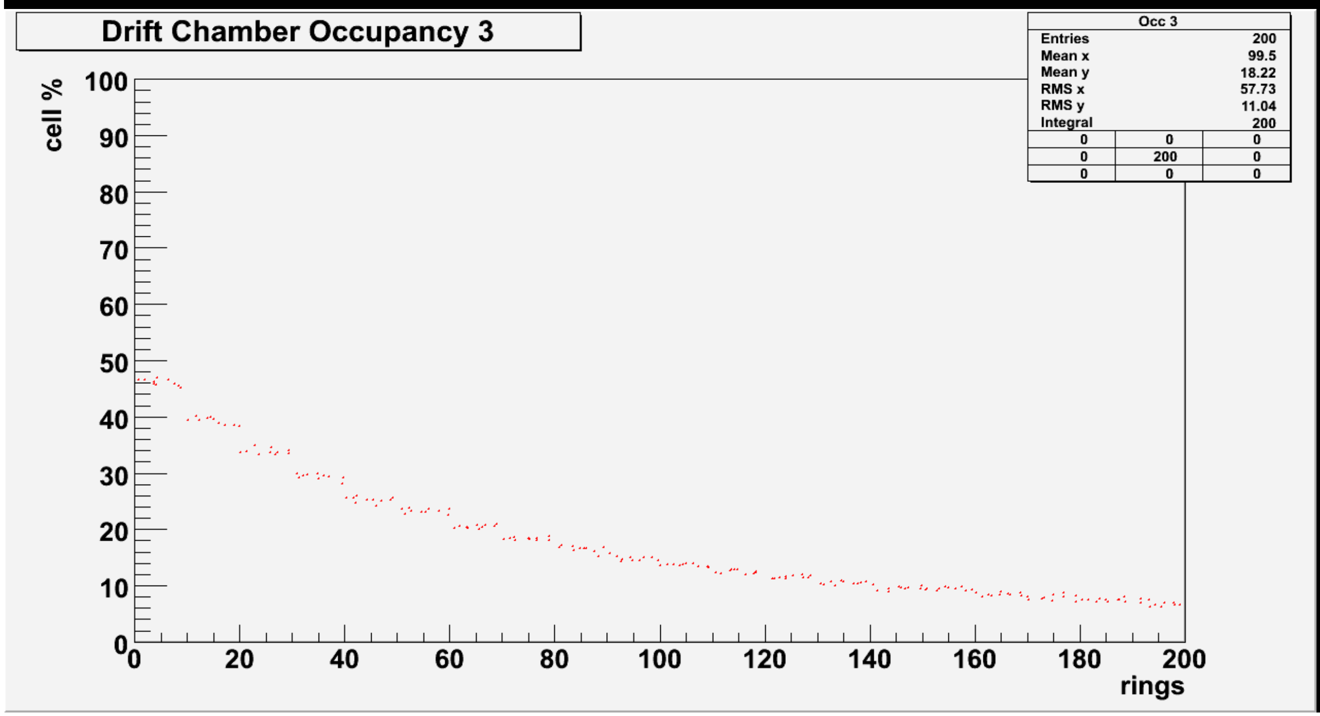
$e^+e^- \to t\underline{t} \to 6$ jets with DCH

E_{CM}=500 GeV

- Hits per cell vs layer
- Occupancy vs layer

DCH





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

E_{CM}=500 GeV

- Hits per cell vs layer

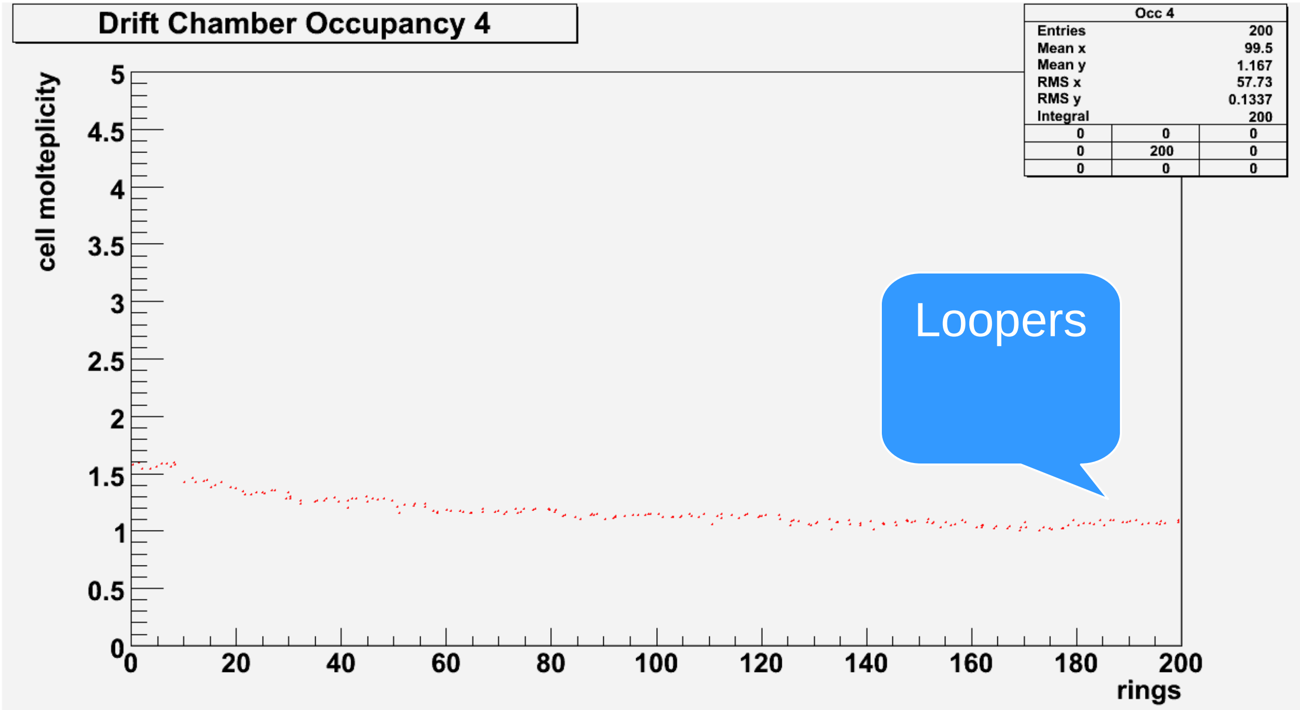
- Occupancy vs layer

DCH

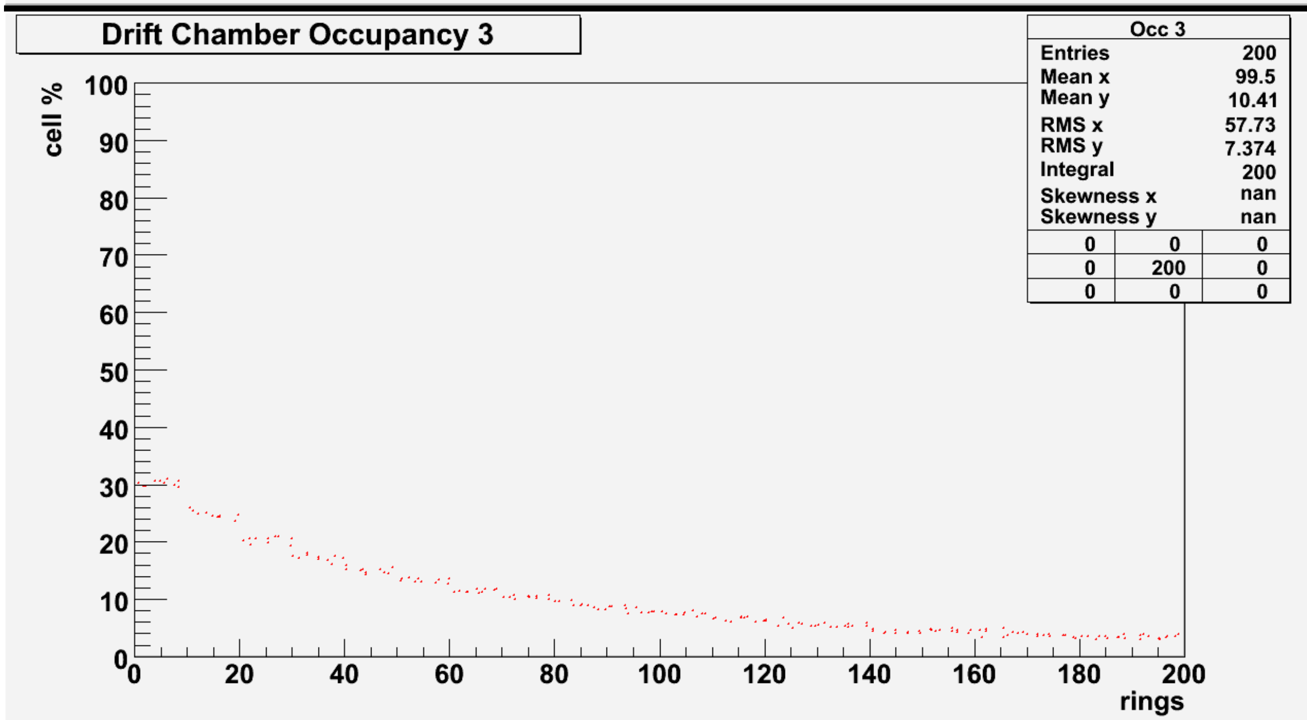
$e^+e^- \rightarrow H^oZ^o \rightarrow$ 2 jets+2muons with DCH

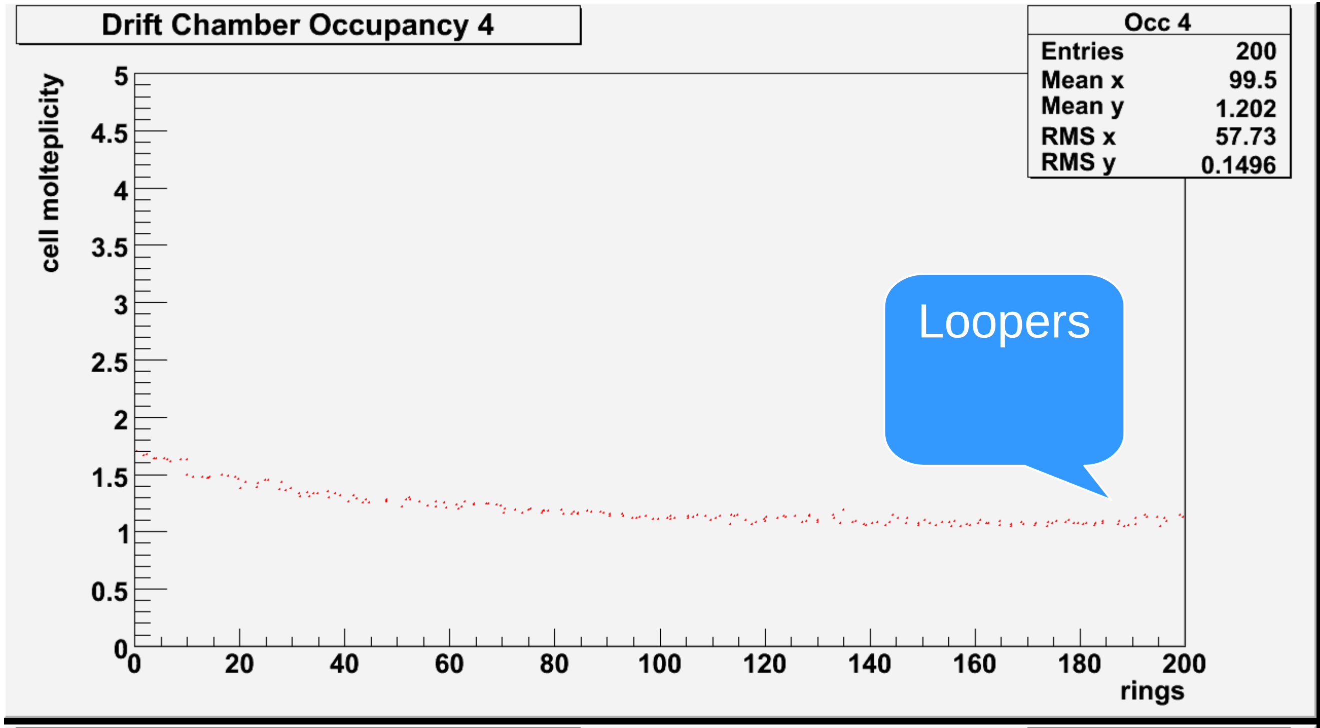
E_{CM}=230 GeV

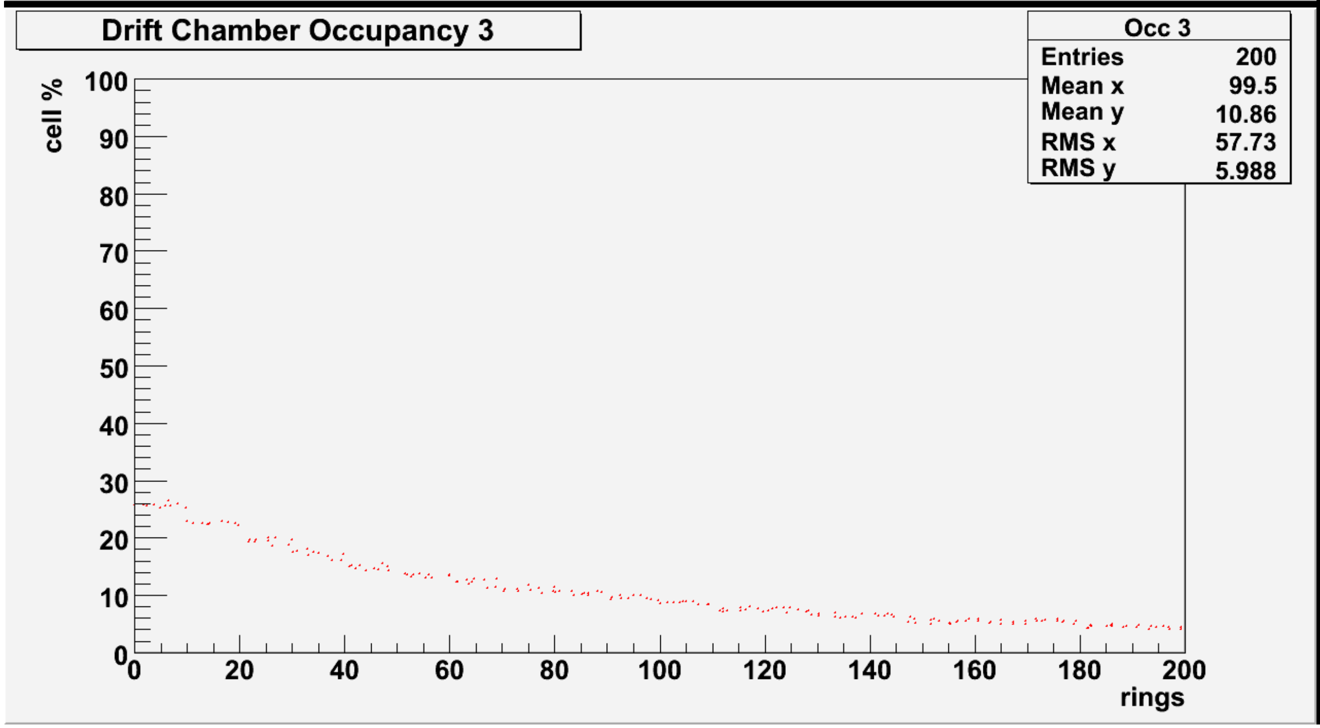
- Hits per cell vs layer



- Occupancy vs layer





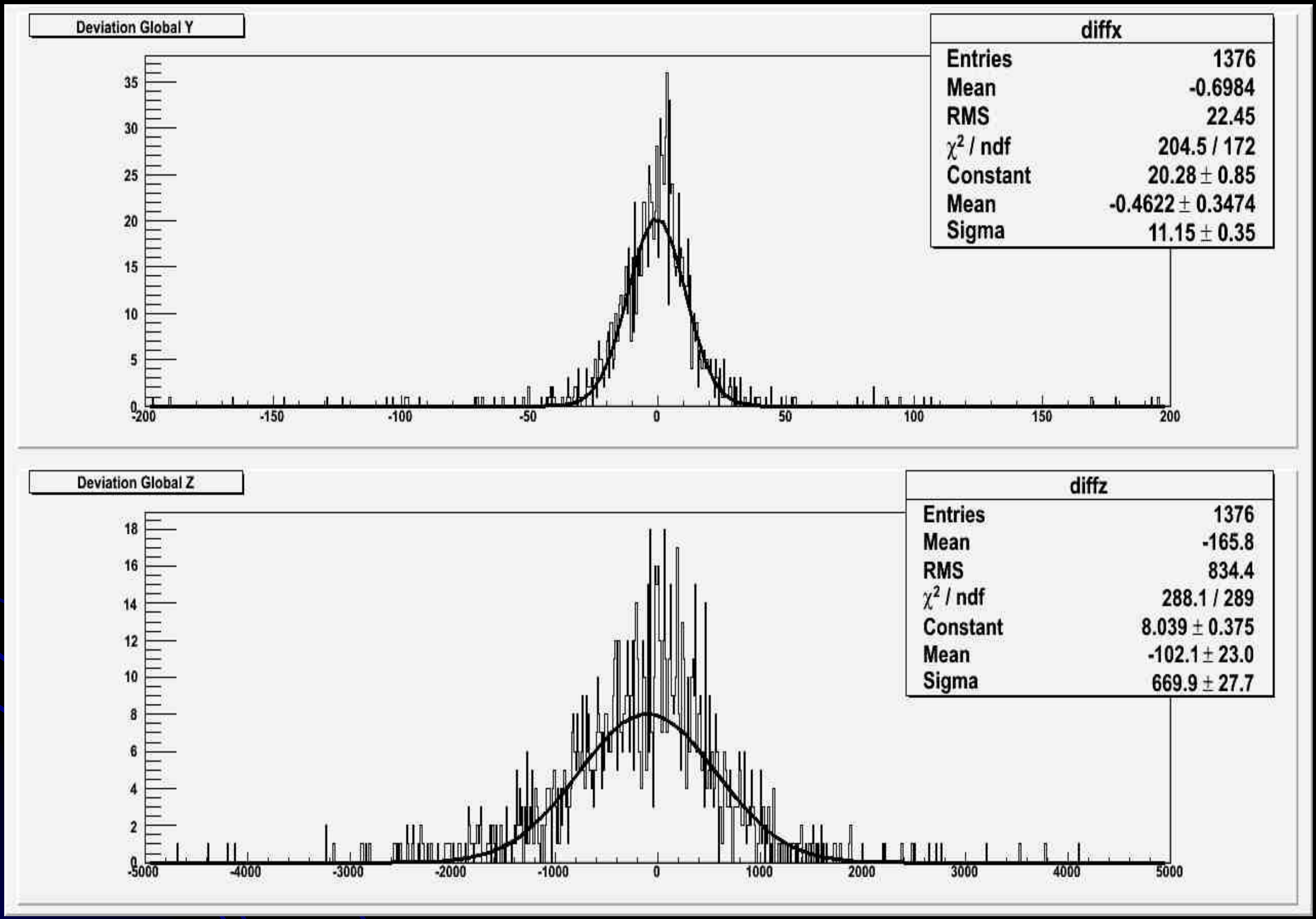


DCH

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

- Hits per cell vs layer
- Occupancy vs layer

SiD Single Cluster Resolution



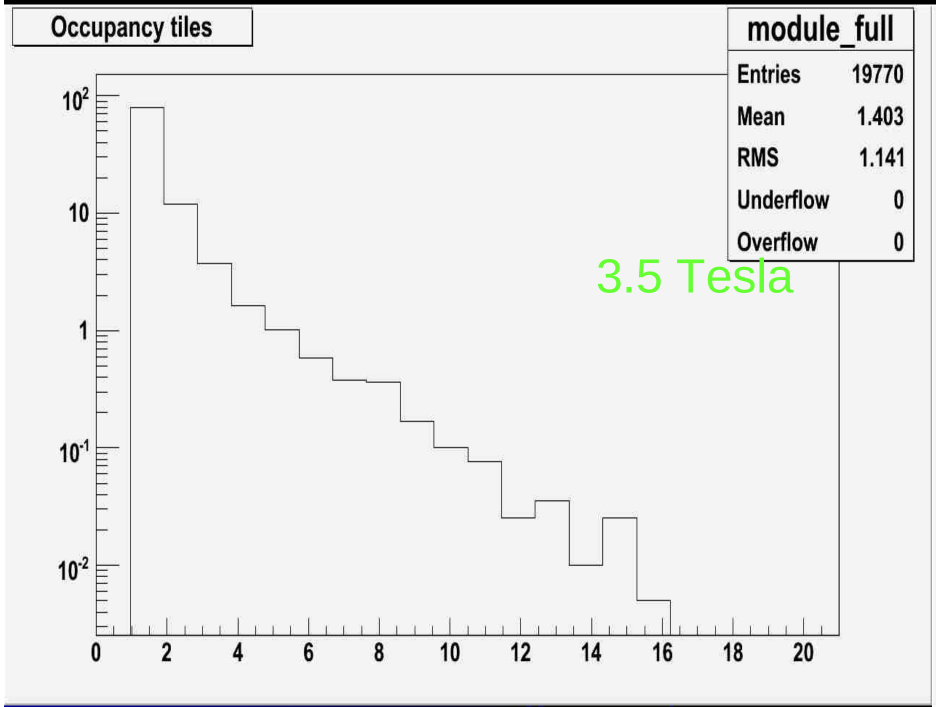
Noise =100 e

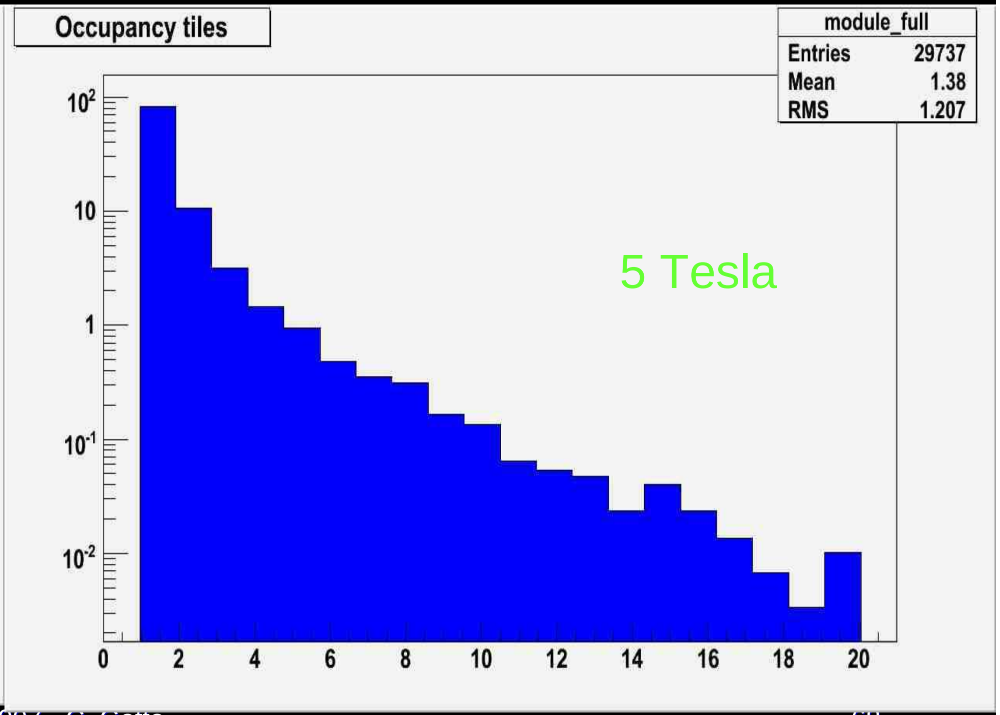
SiT

SiD Tile Occupancy Studies (Barrel)

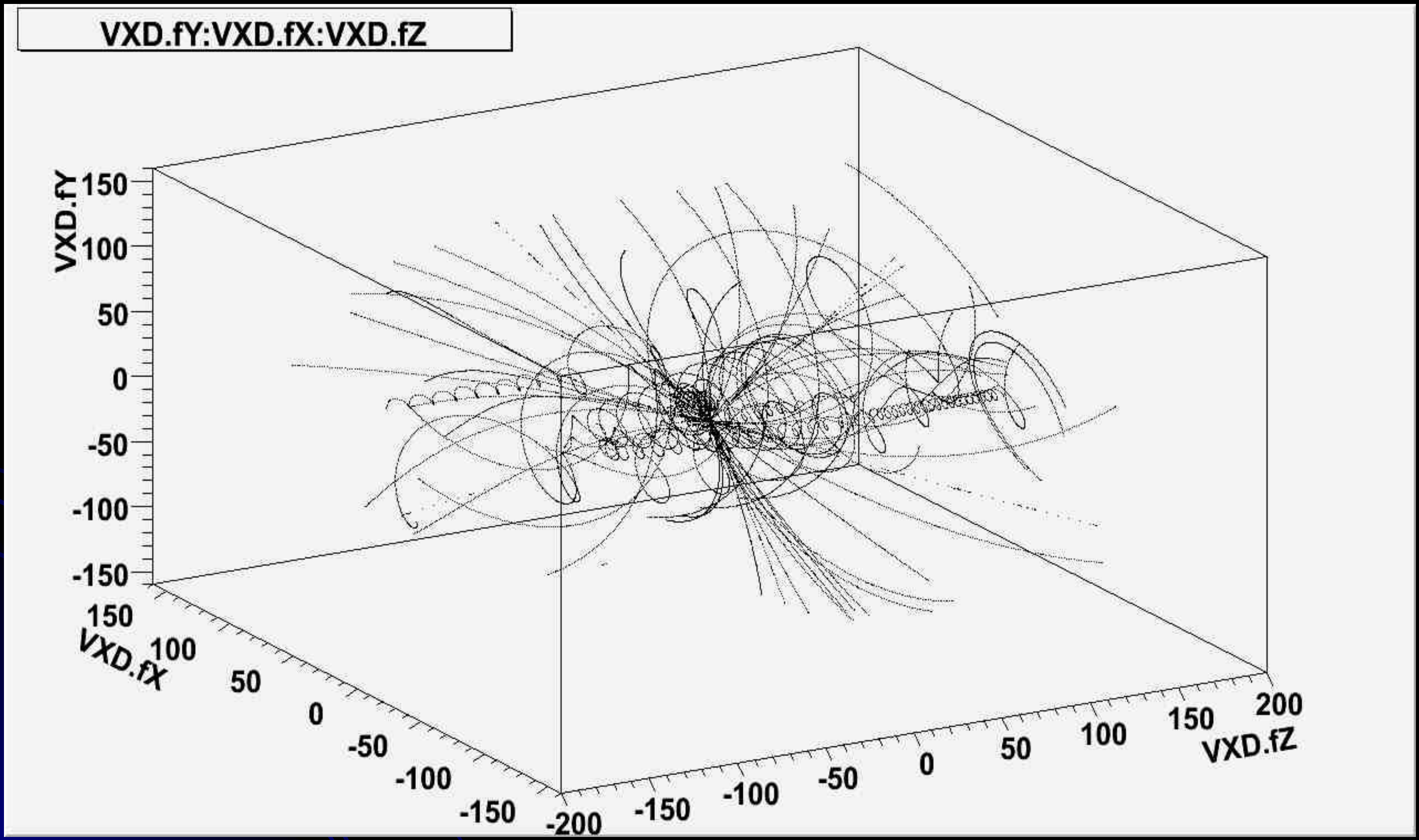
E+e- -> ZHH

50% More Hits at 5 Tesla





e+e- -> ZHH at 5 Tesla

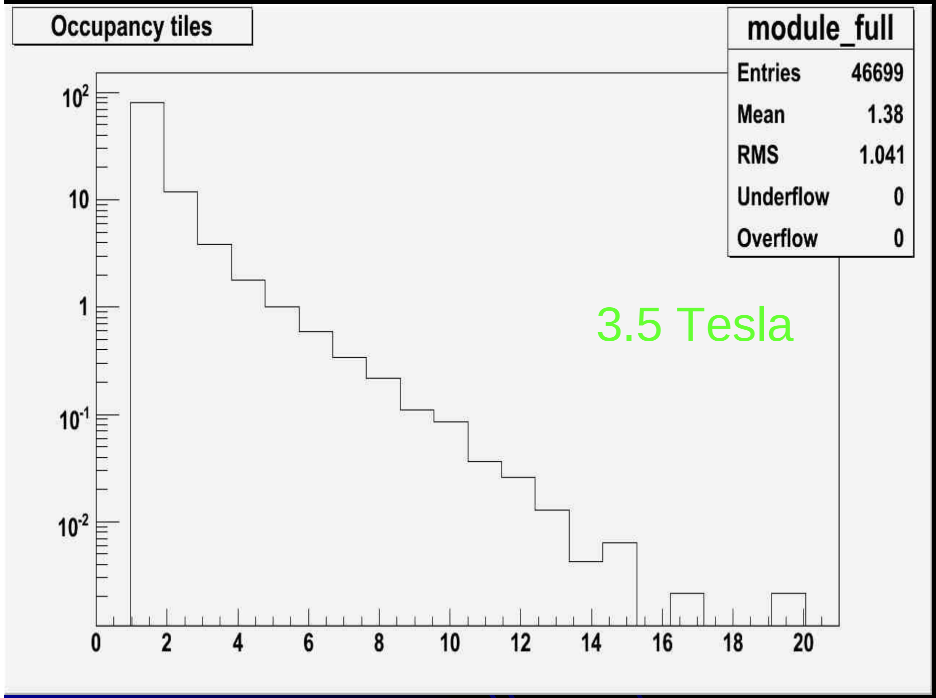


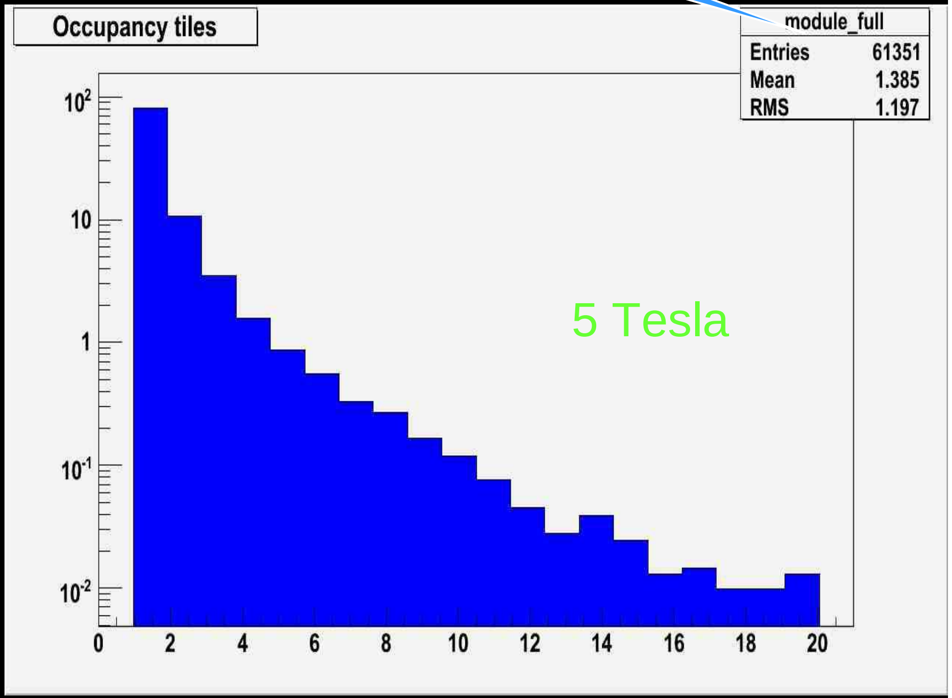
SiT

SiD Tile Occupancy Studies (Barrel)

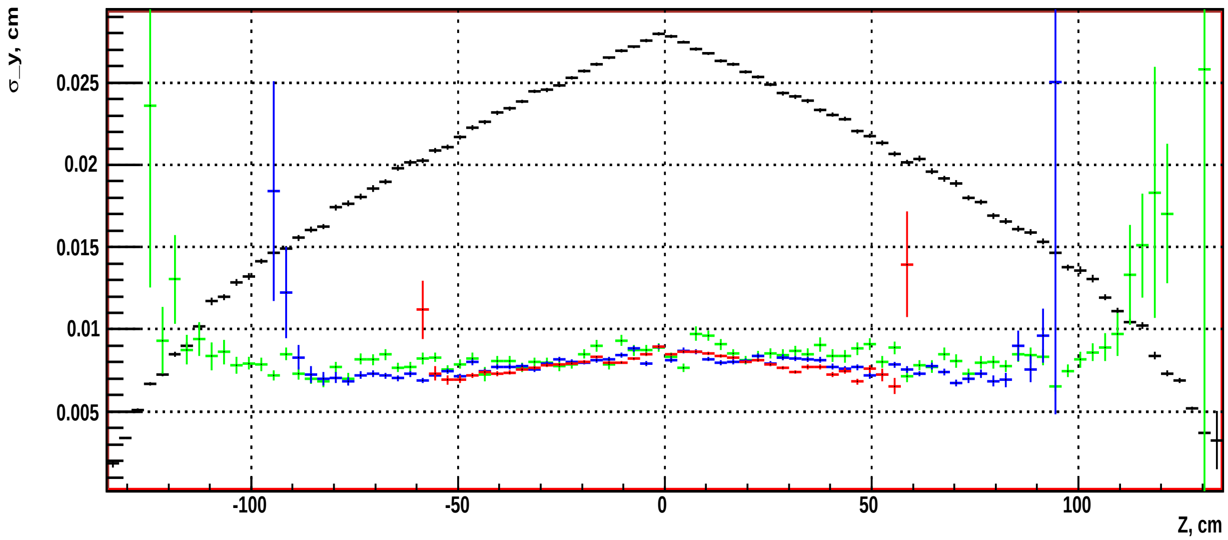
E+e- -> ttbar

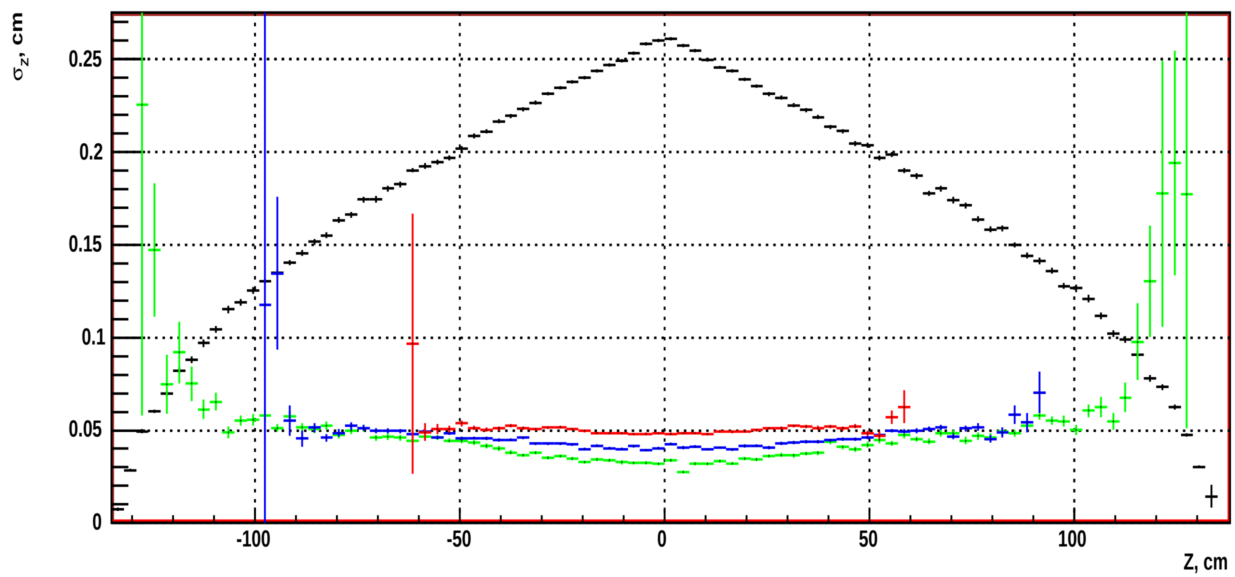
40% More Hits at 5 Tesla





TPC Total Resolution





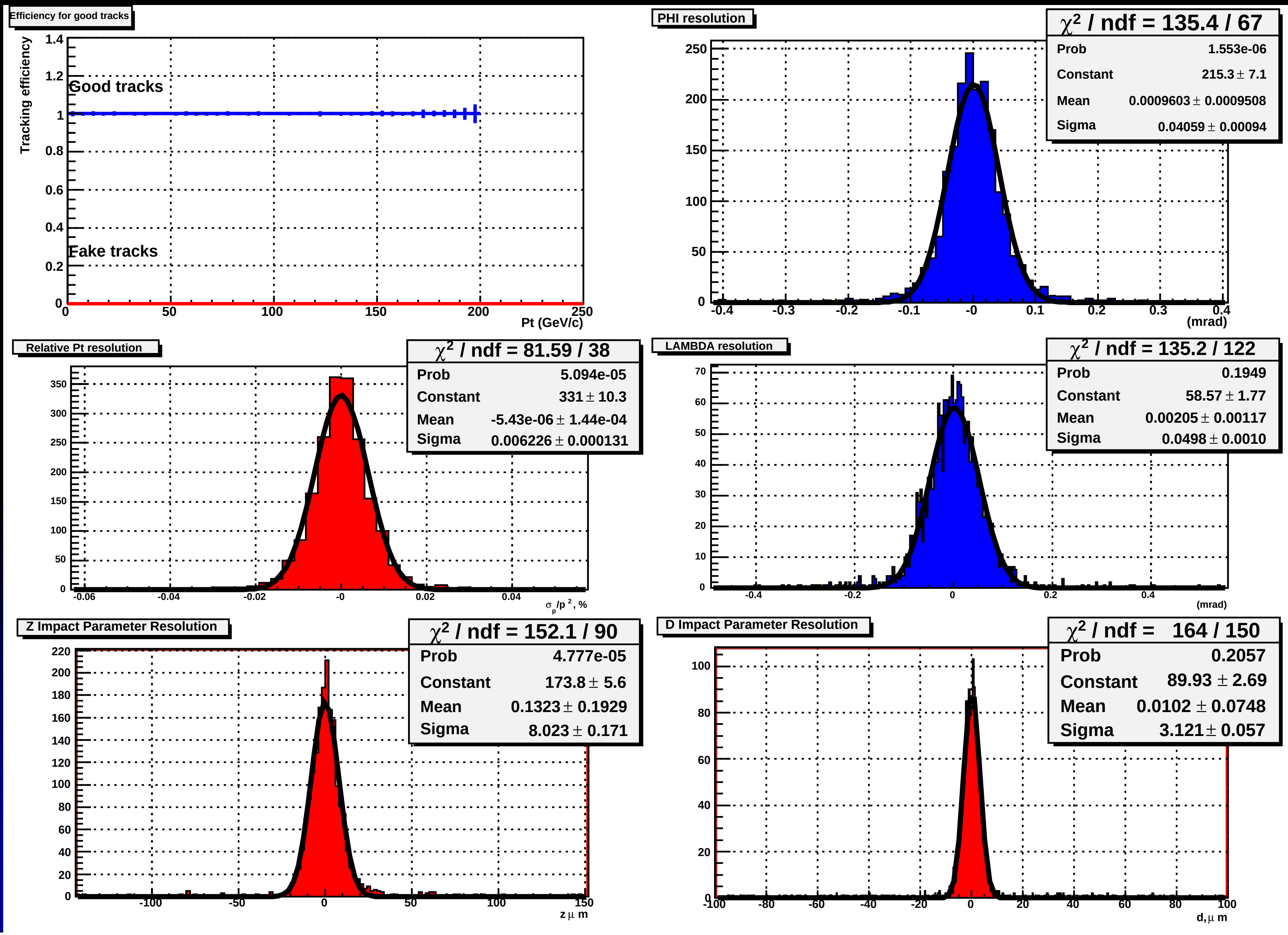
- outer pads
- intermediate pads
- inner pads

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

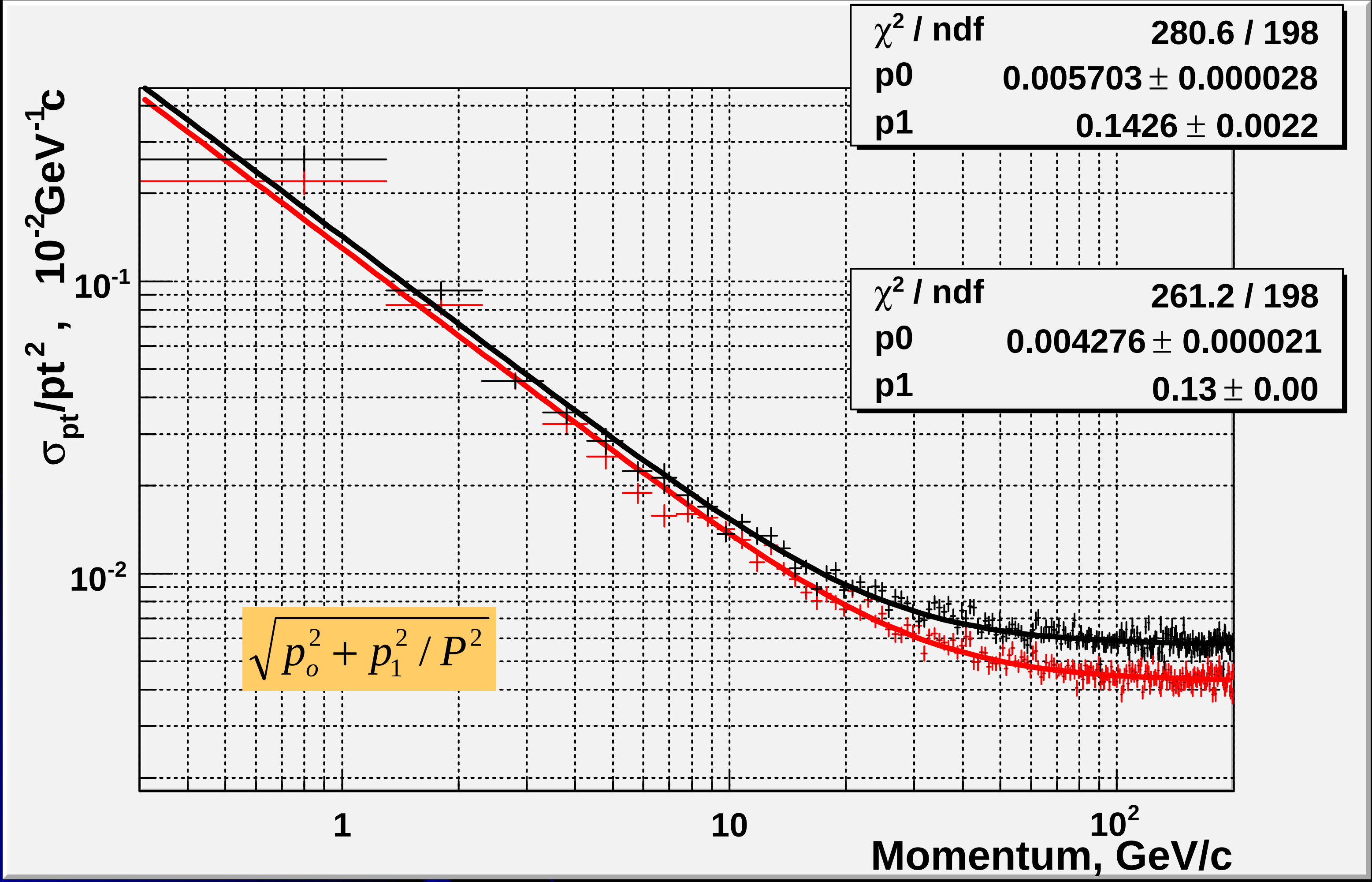
Includes 50μm constant term (pds only)

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

TPC Tracking Resolution (μ 0.5-200 GeV)



TPC Momentum Resolution



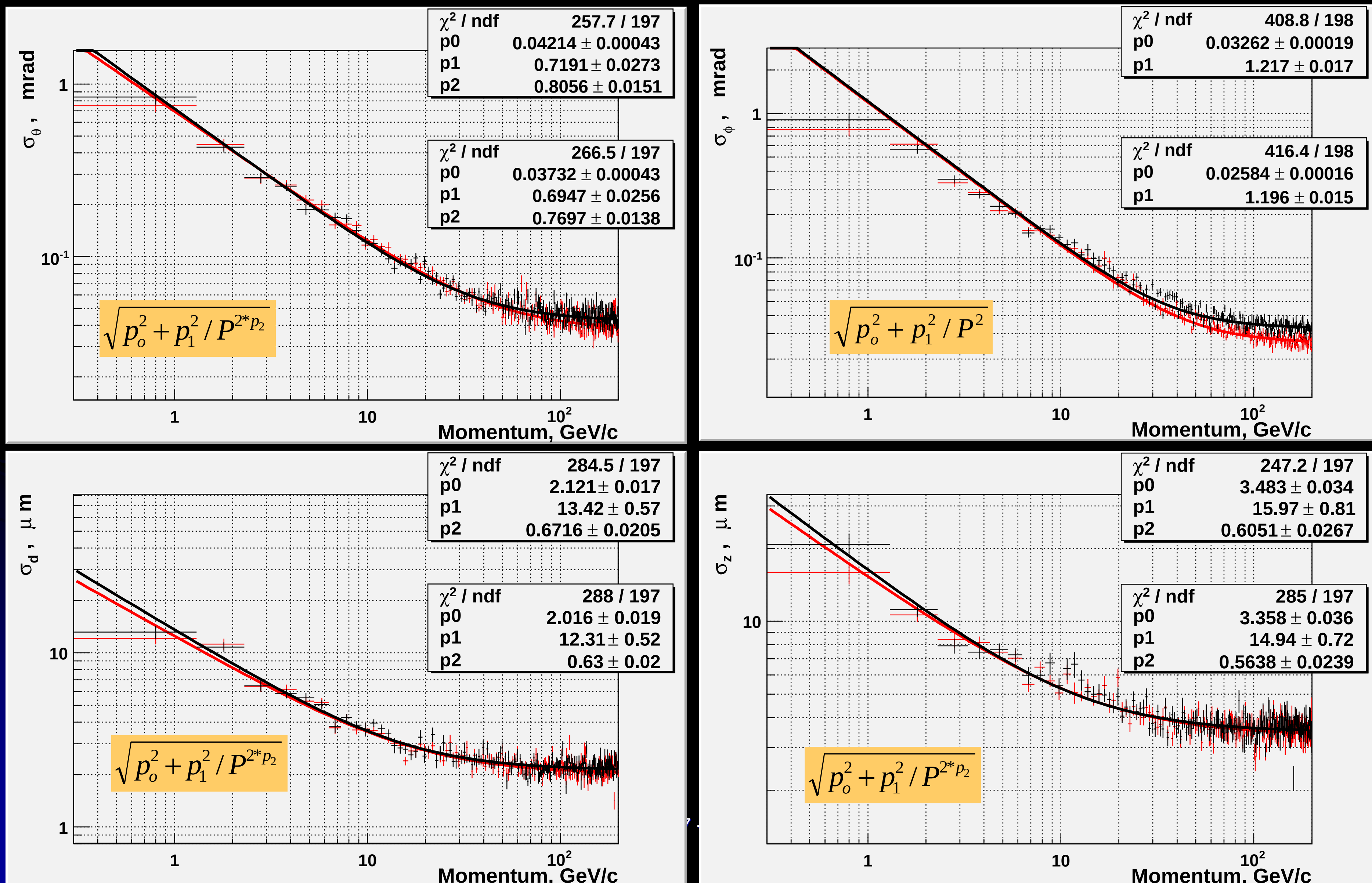
$$\sqrt{p_o^2 + p_1^2 / P^2}$$

- VXD + TPC
- 10 muons
- P = 0.5-200 GeV

- mMegas + Pads
- Pads only

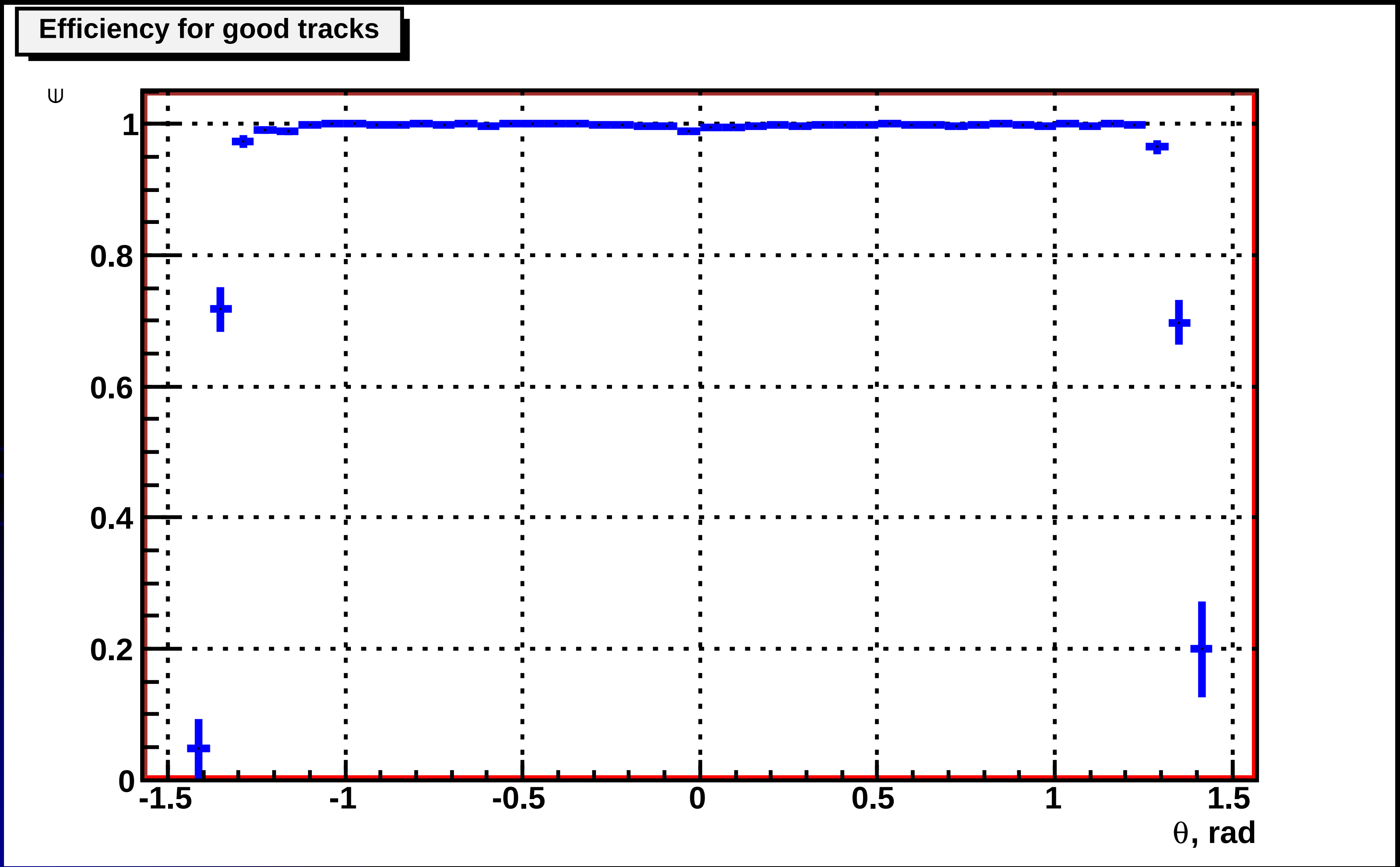
Other Resolutions

- mMegas + Pads
- Pads only

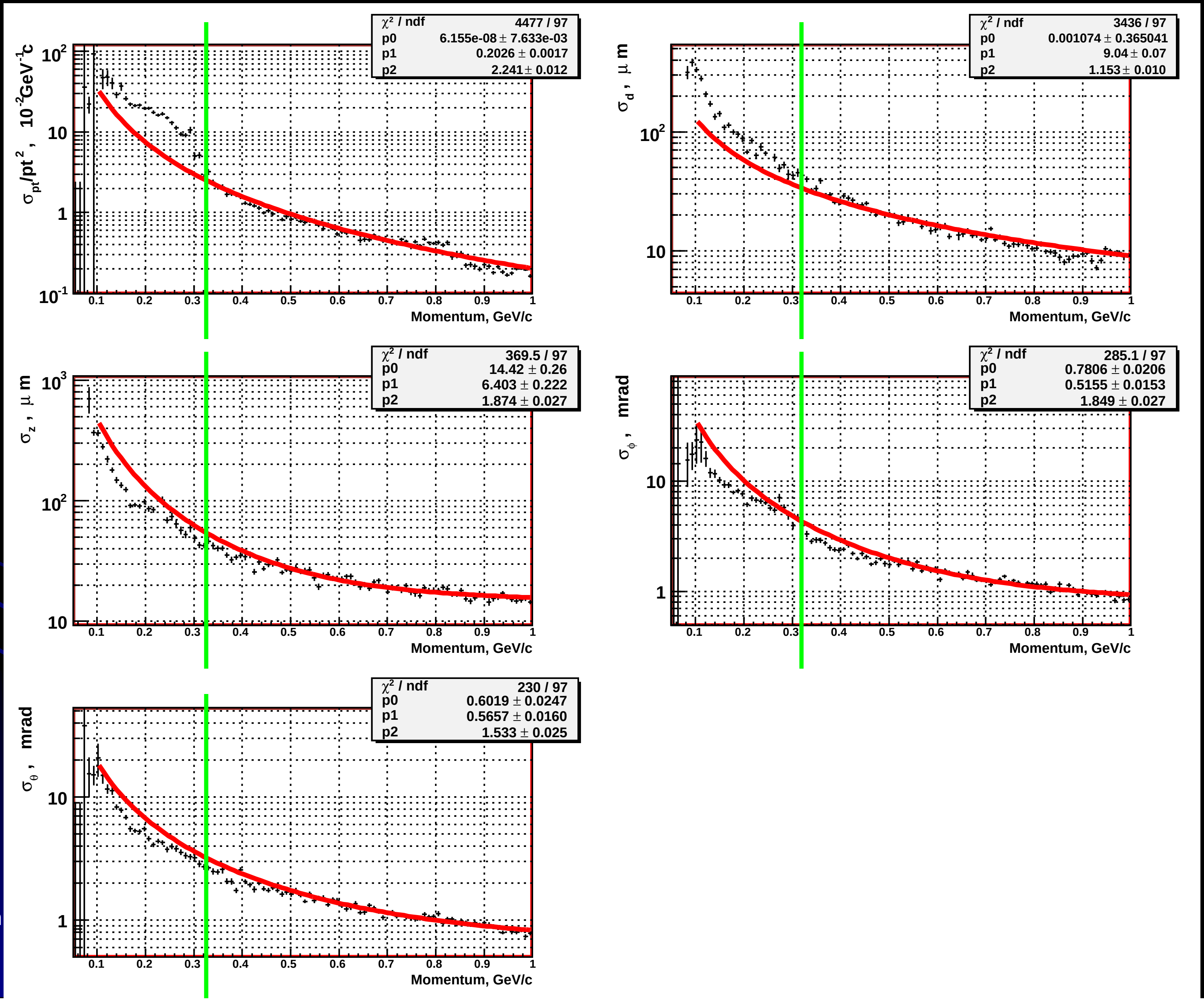


TPC

Reconstruction Efficiency (P>0.5 GeV)

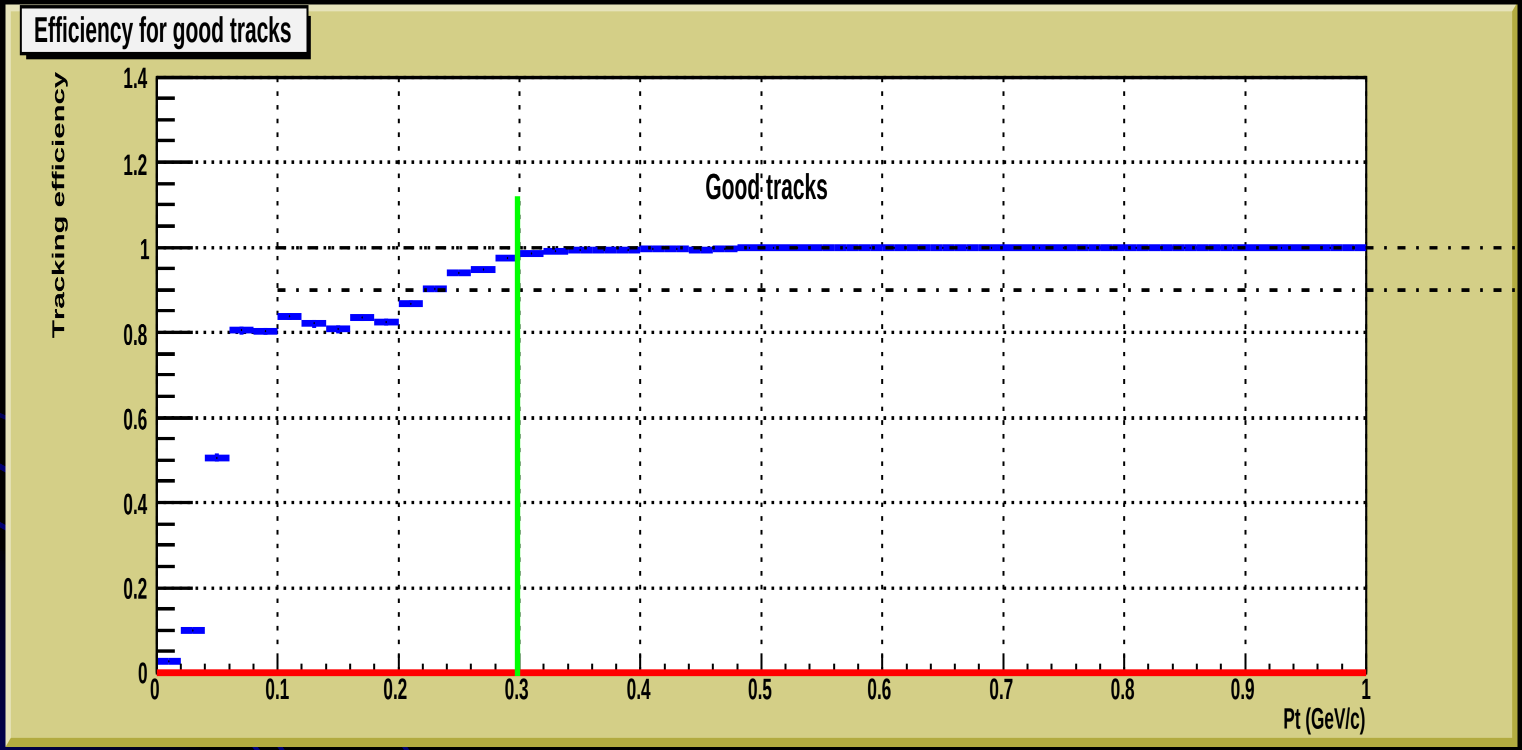


Low Momentum Performance (<1 GeV) TPC



Low Momentum Efficiency

- 10 muons/evt (P_t range 20-1000 MeV)
- $|\tan(\lambda)|<2.57$

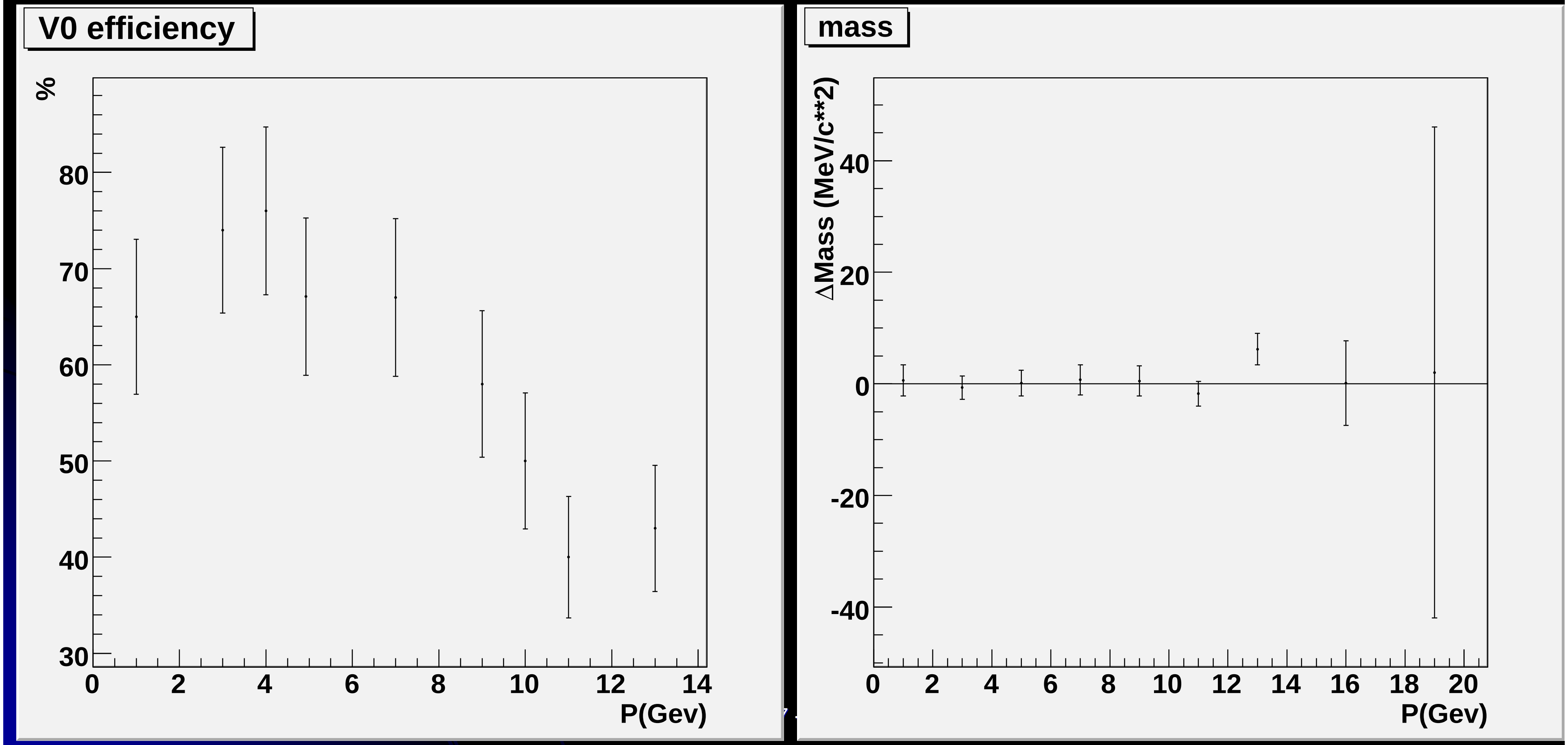


Tracking Performance for Single Tracks (P>500 MeV)

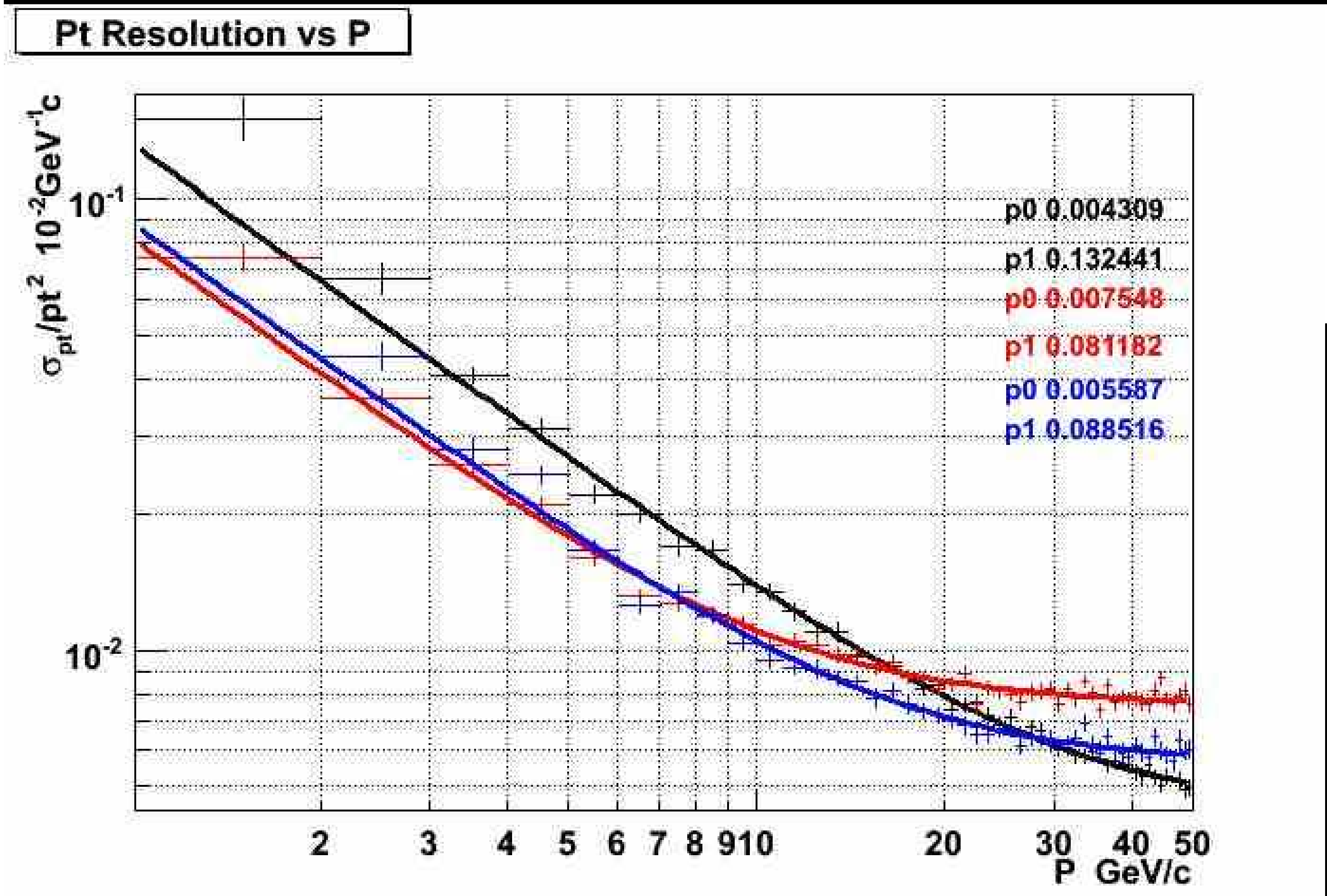
- Tracking is working for:
  - P_t > 20 MeV
  - $|\theta| > 12^o$
- High momentum tracks:
  - $\sigma(1/p_t) = 0.4 \times 10^{-4}$
  - $\sigma(d) = 3.1\ \mu m$
  - $\sigma(z) = 8.0\ \mu m$
- Efficiency (P_t>300MeV) = 99.8%

TPC

Performance with V0's



DCH vs TPC (gaussian smearing)

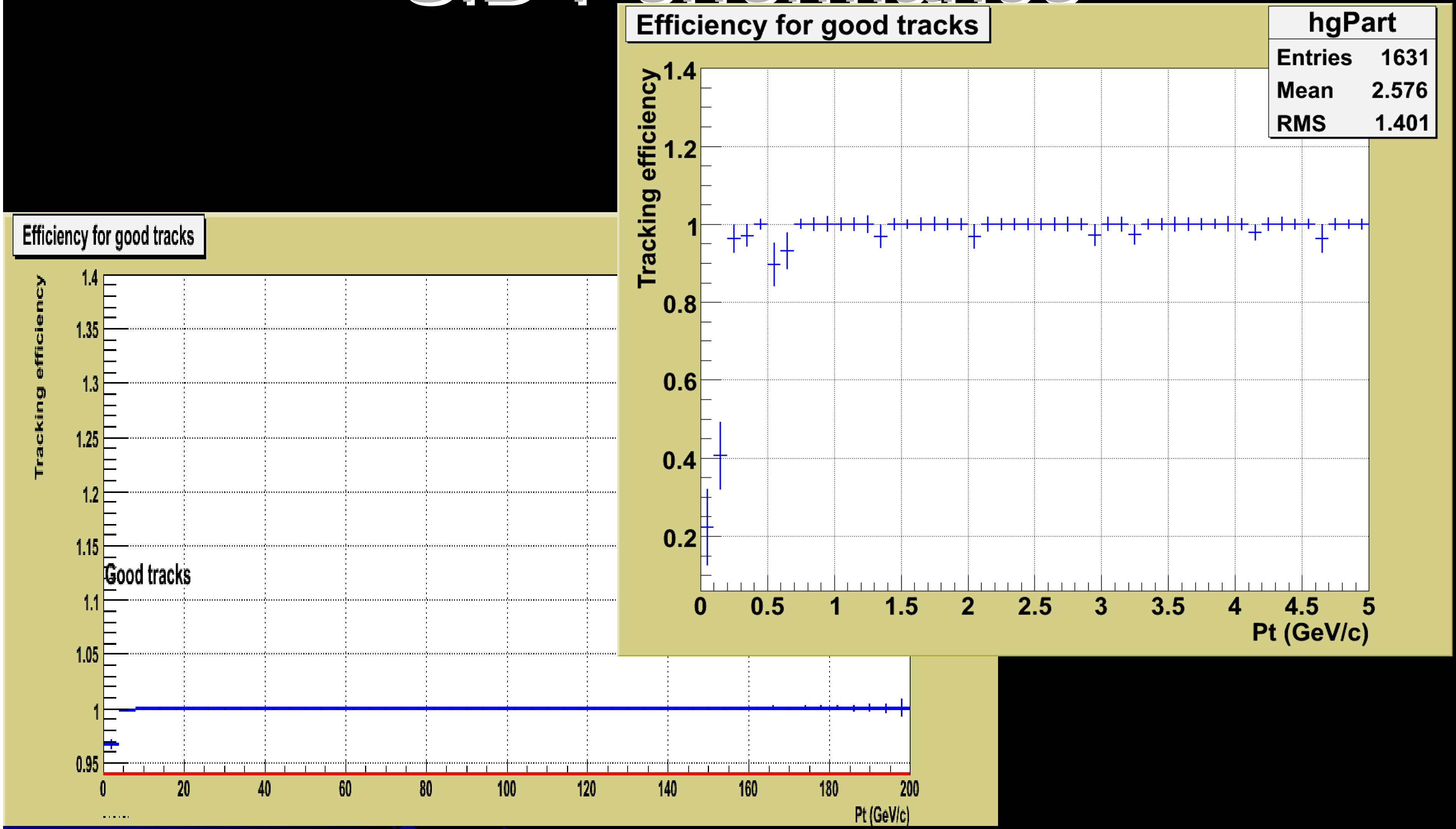


- - TPC
- - Kloe
- - ClouCou

Very preliminary – Gaussian smearing - 3.5 Tesla

SiD

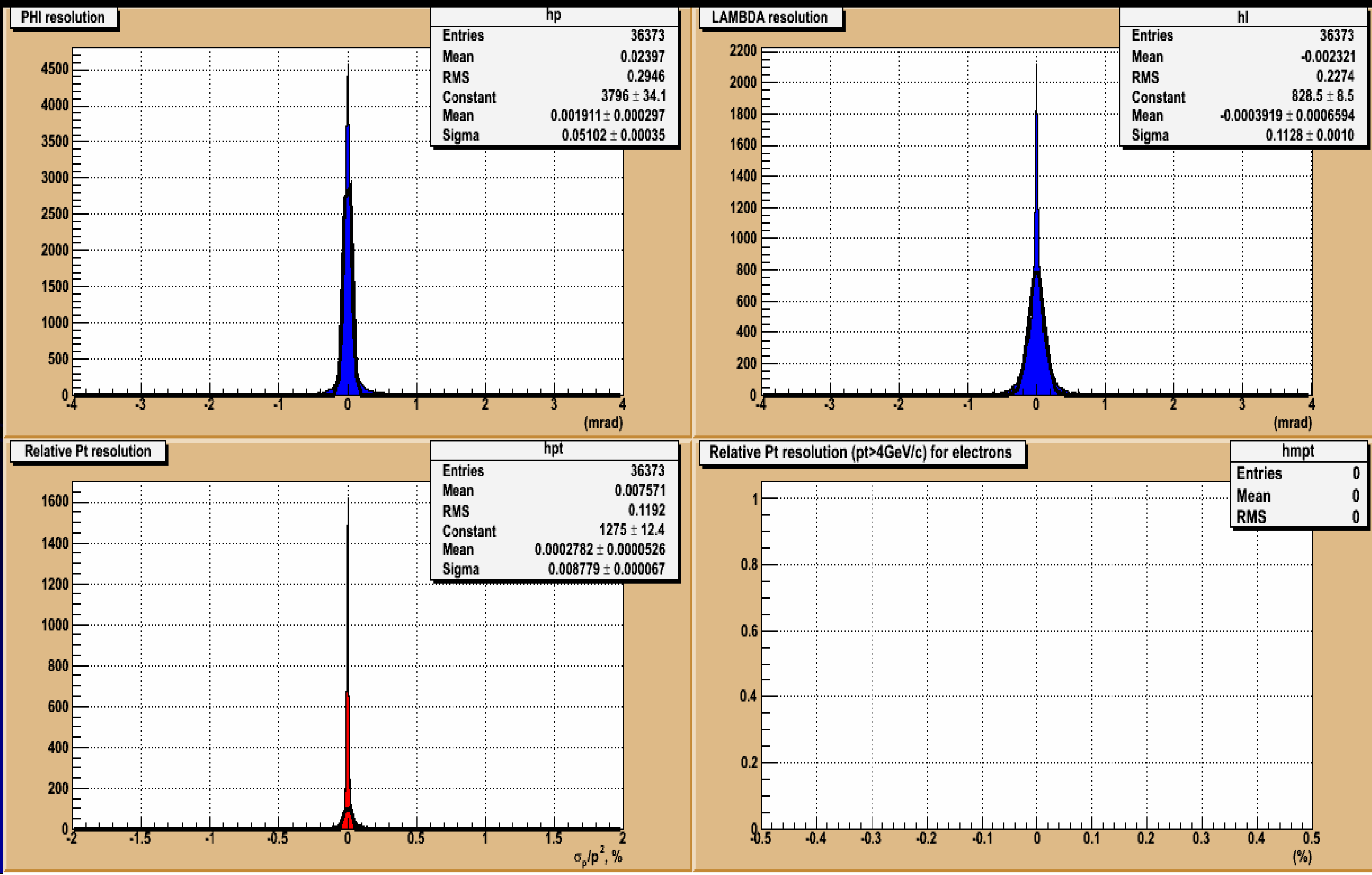
SiD Performance



Very preliminary – Gaussian smearing - 3.5 Tesla

SiD

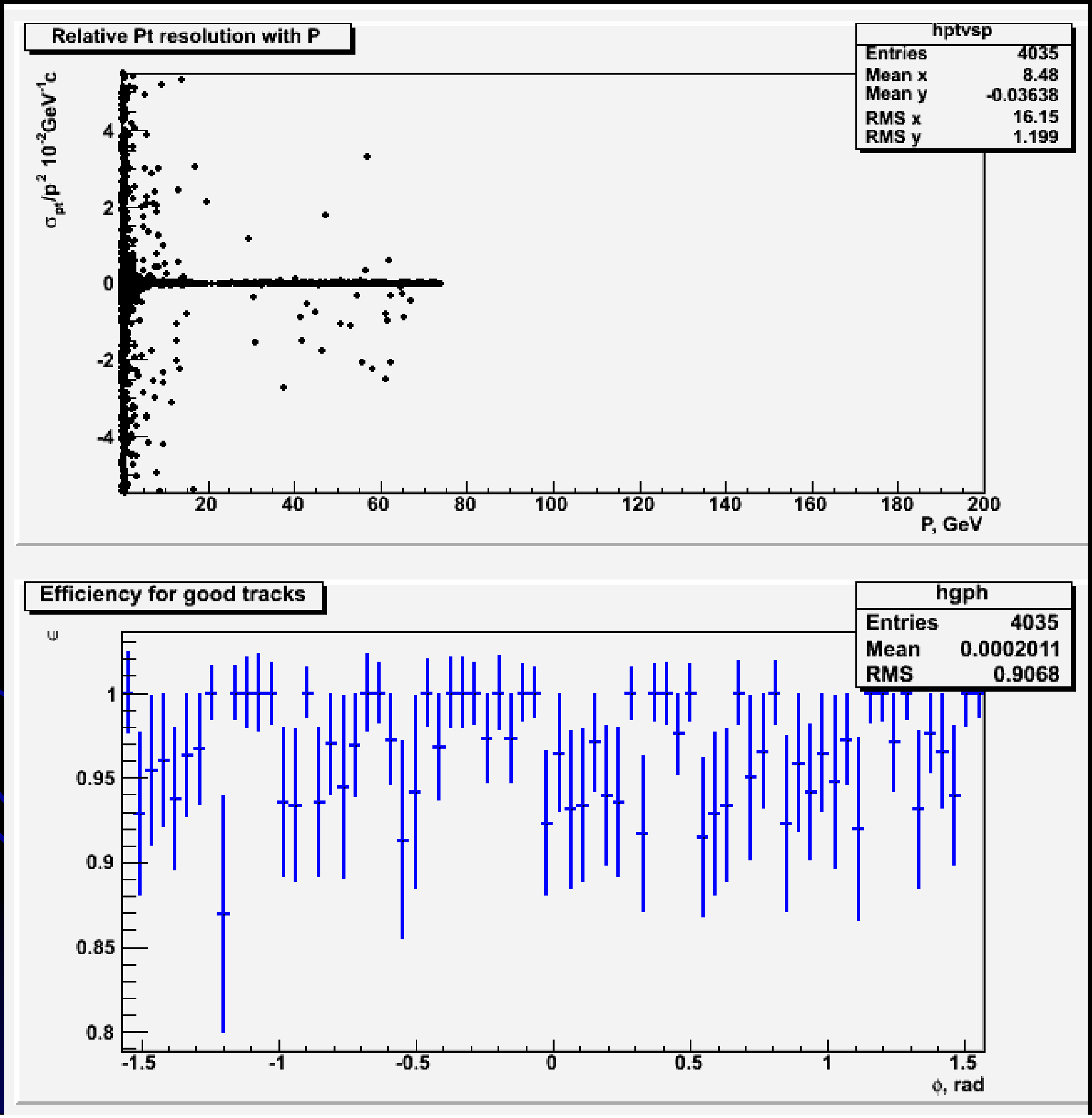
SiD Performance



Very preliminary – Gaussian smearing - 3.5 Tesla

SiD

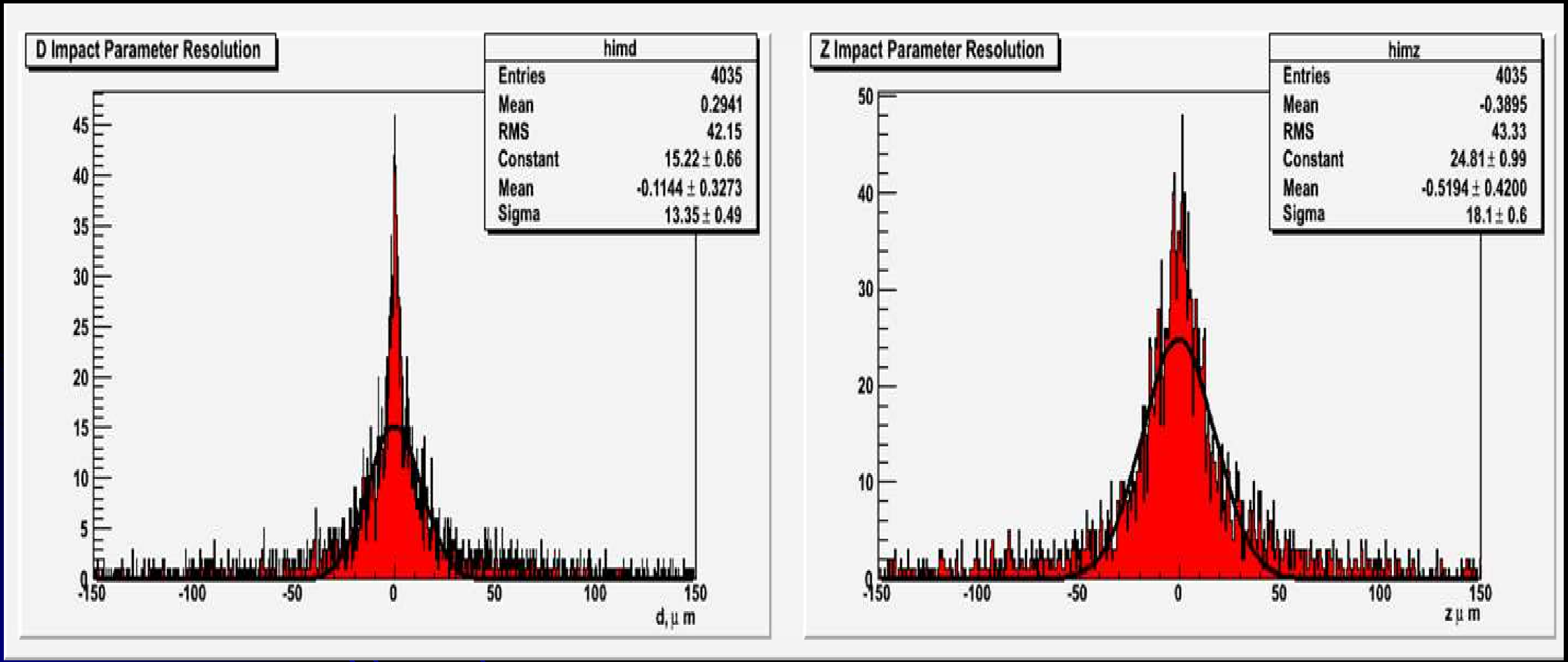
SiD Performance



Very preliminary – Gaussian smearing - 3.5 Tesla

SiD

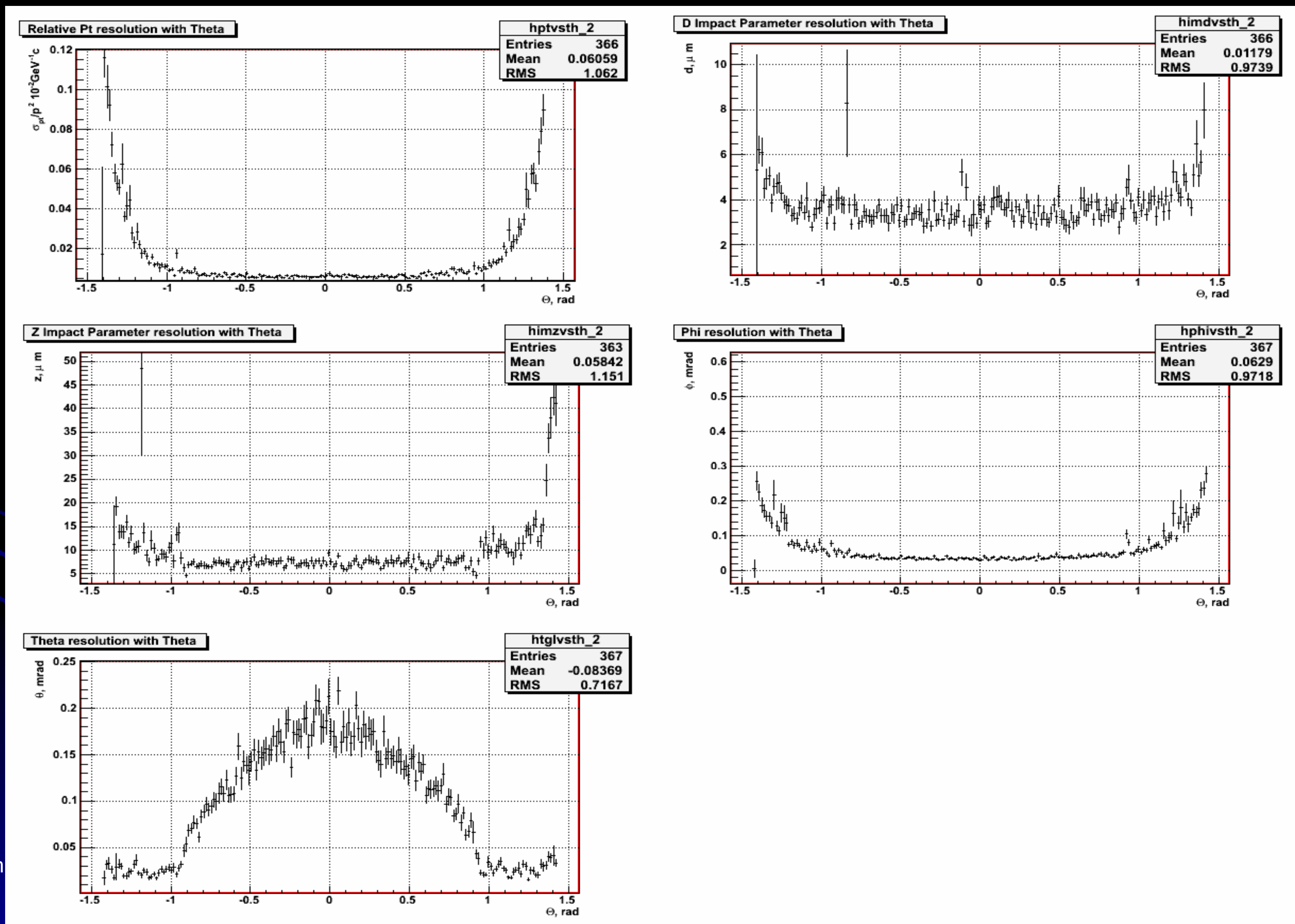
SiD Performance



Very preliminary – Gaussian smearing - 3.5 Tesla

SiD

SiD Performance

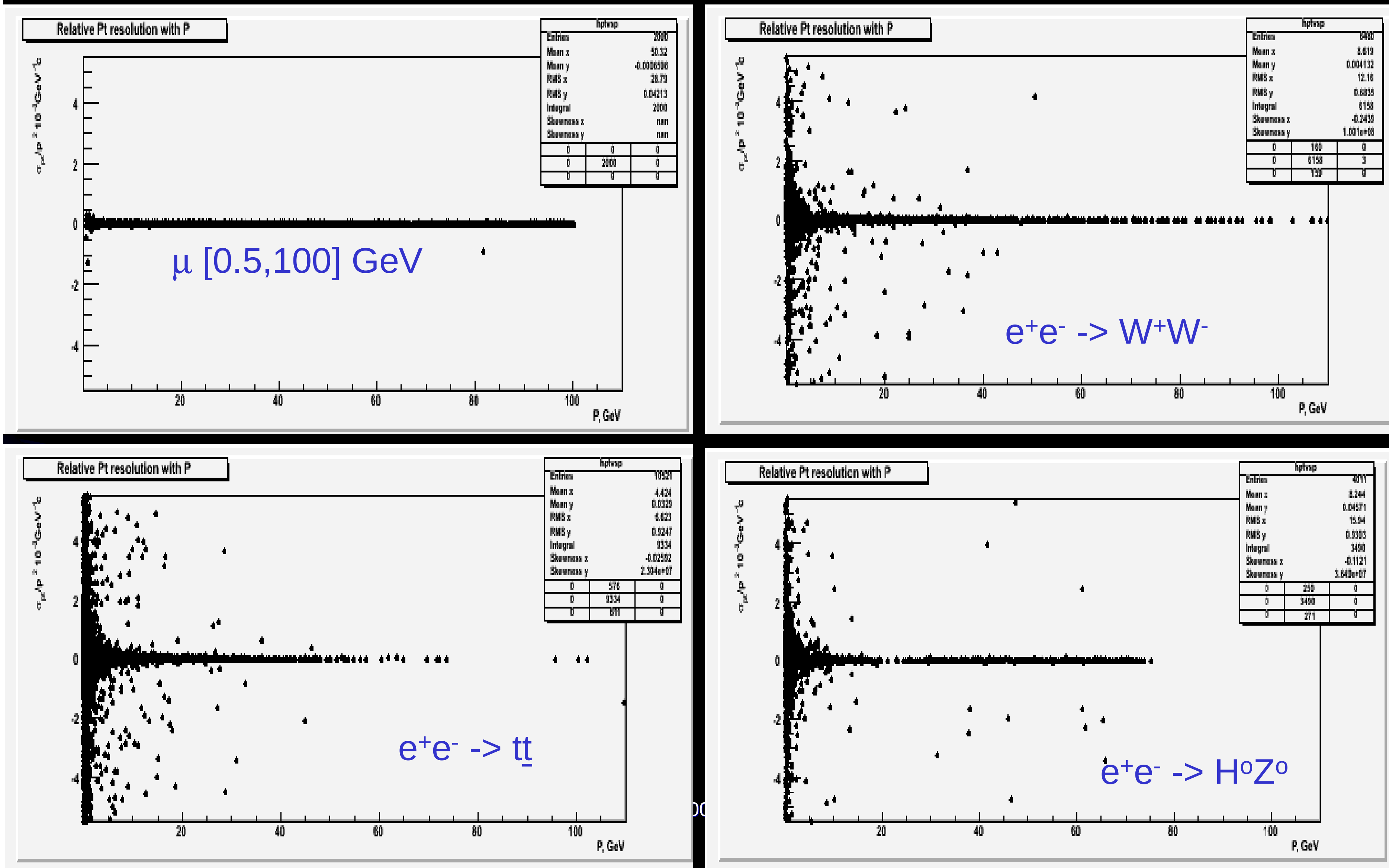


Detector Performance with Physics

- Only VXD + TPC and VXD + DCH at present

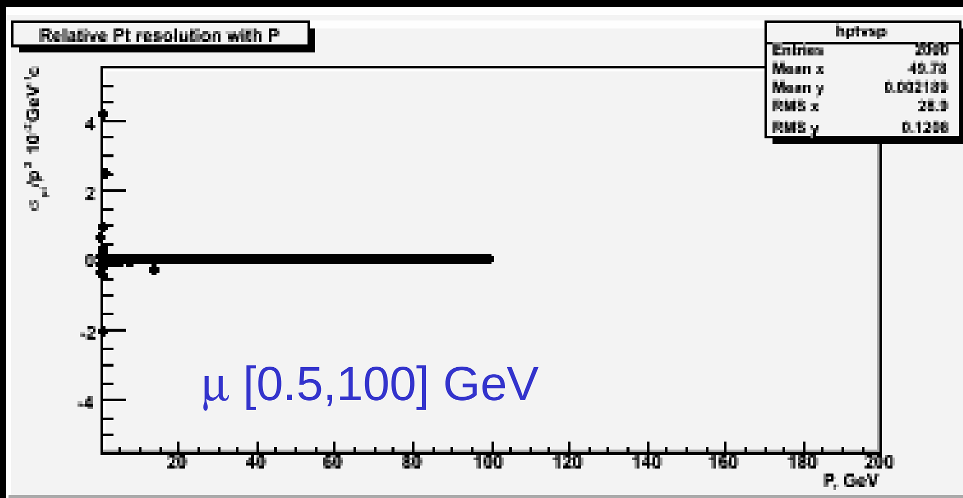
TPC

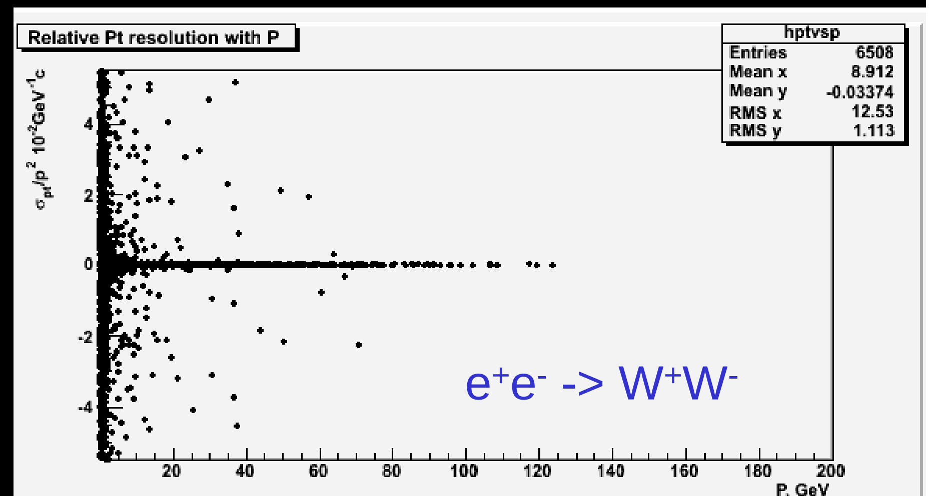
$\Delta(1/p_t)$ vs P



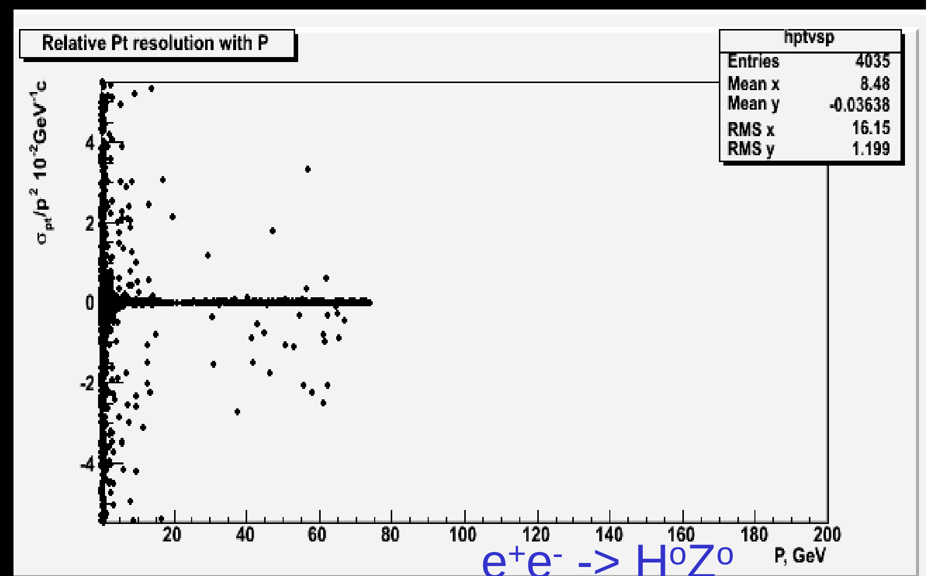
DCH

$\Delta(1/p_t)$ vs P



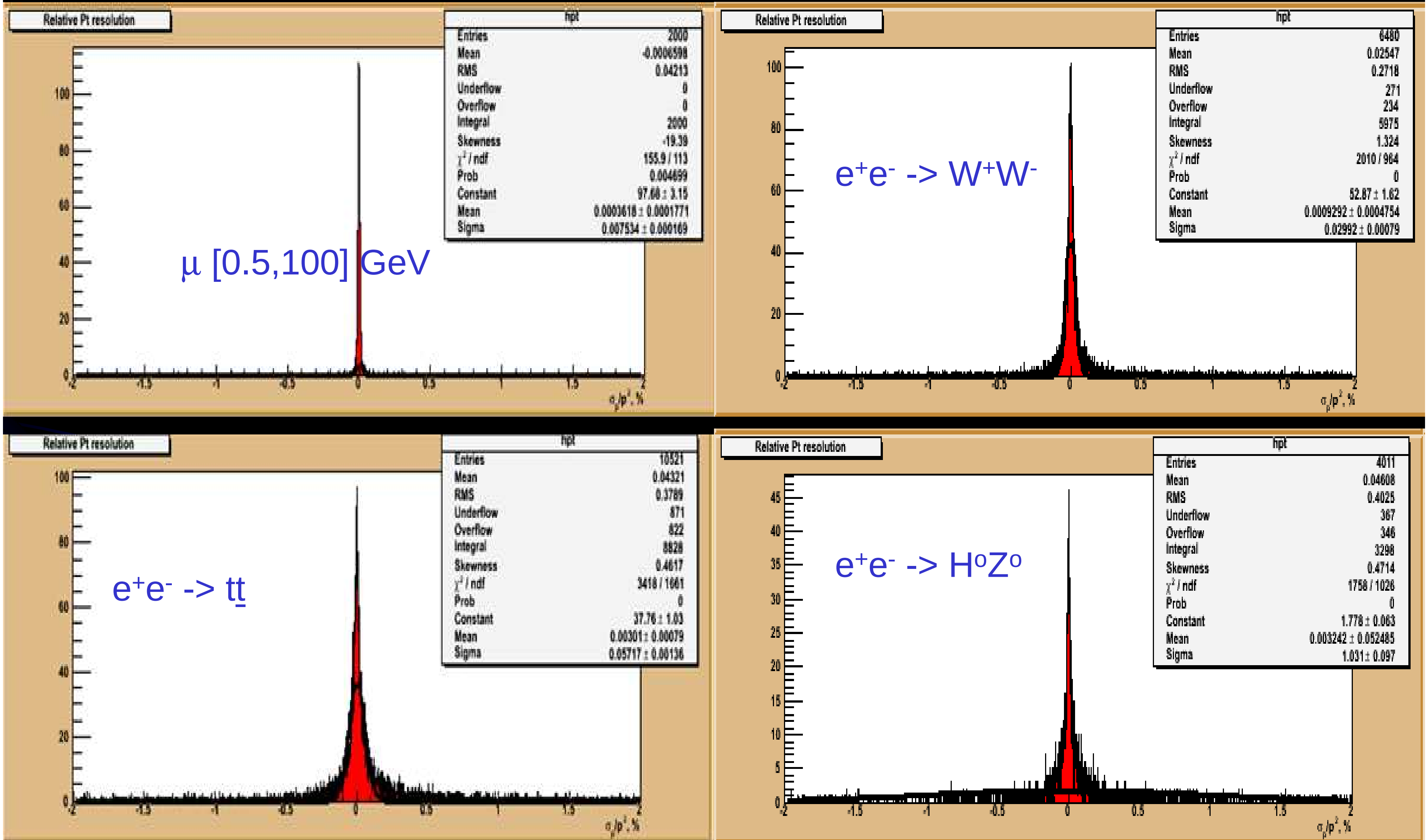


e+e- -> tt̄



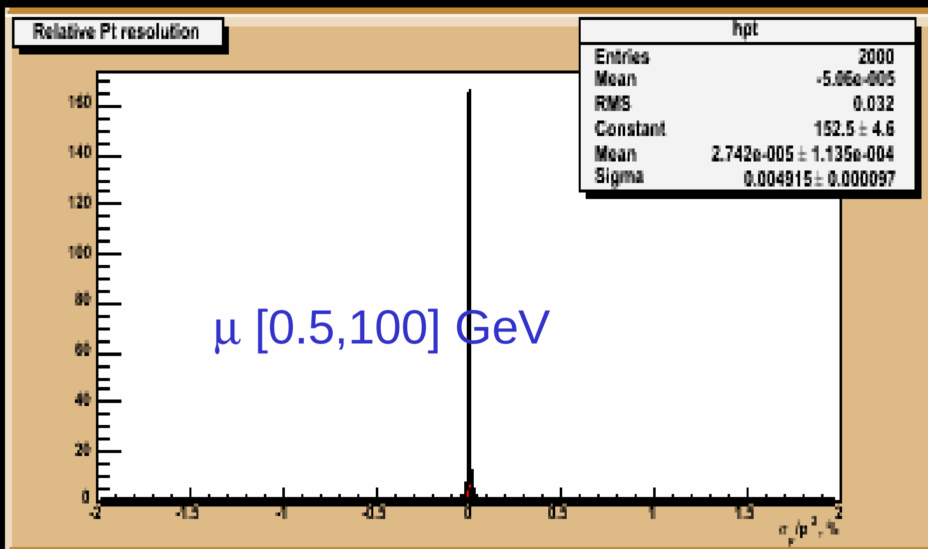
TPC

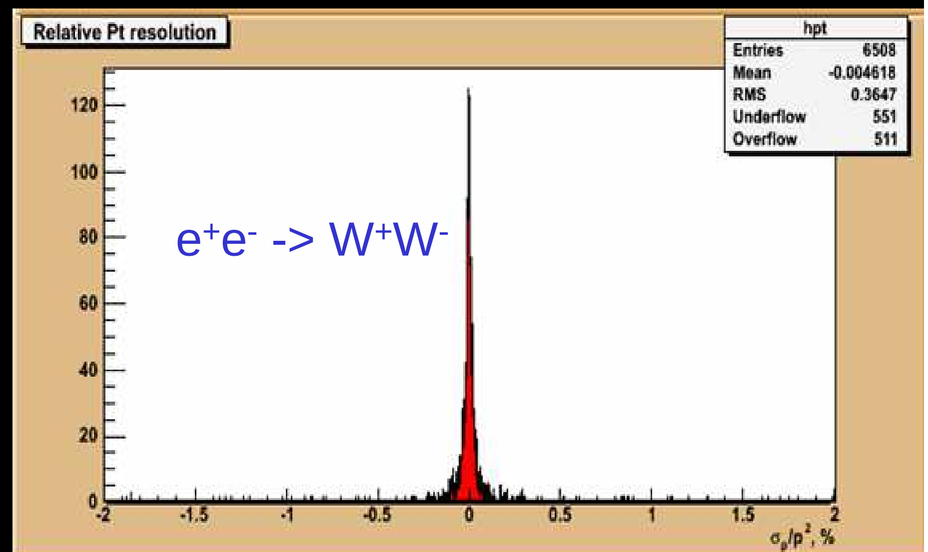
$\Delta(1/p_t)$



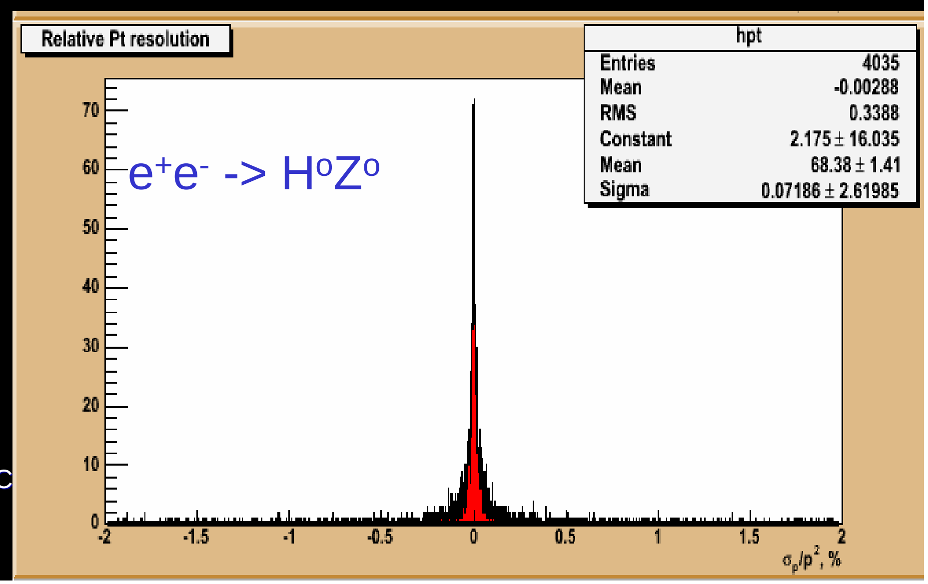
DCH

$\Delta(1/p_t)$



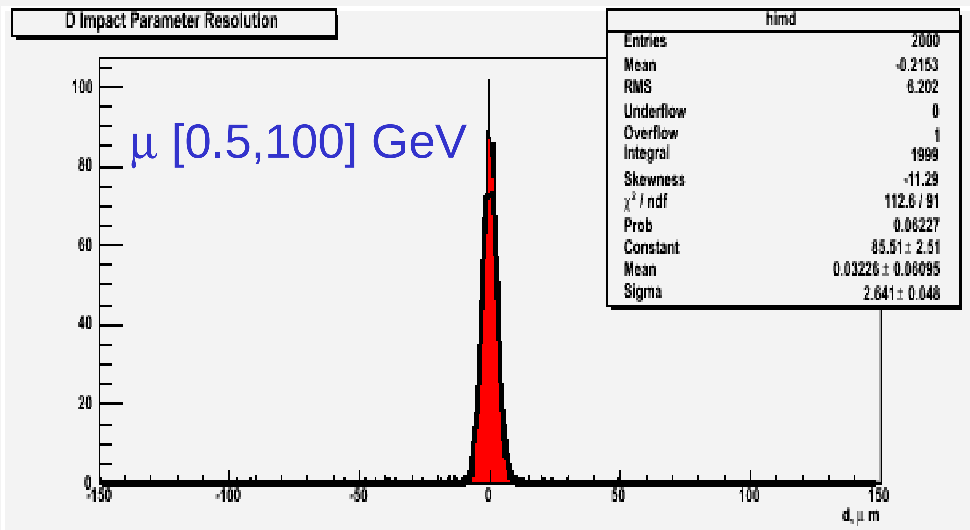


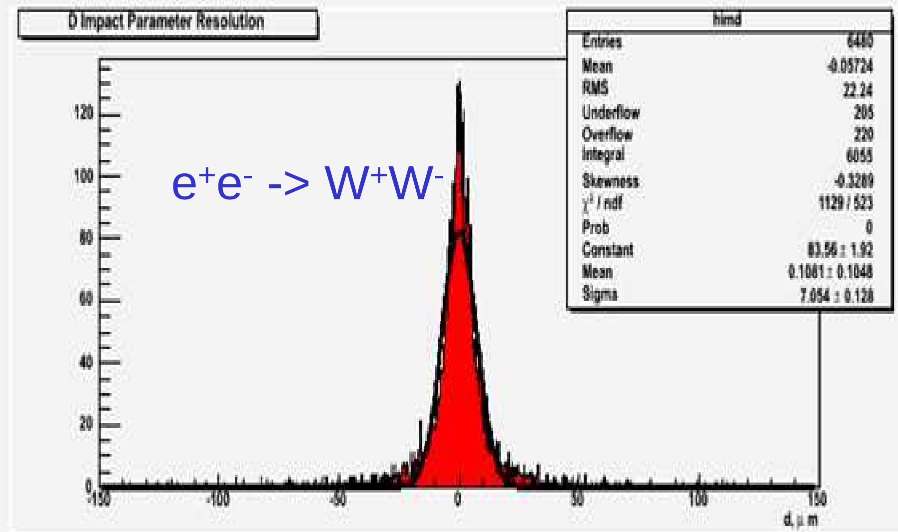
$e^+e^- \to t\bar{t}$

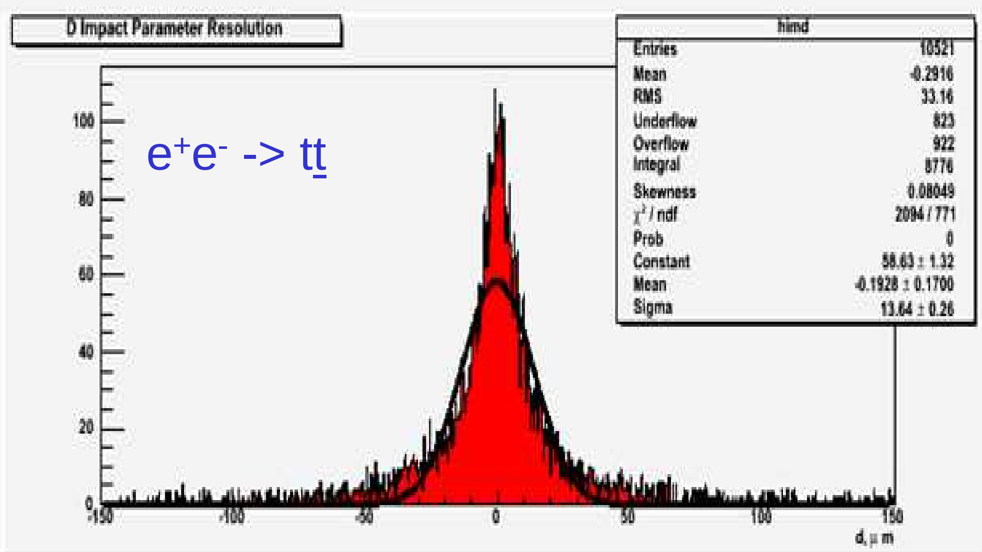


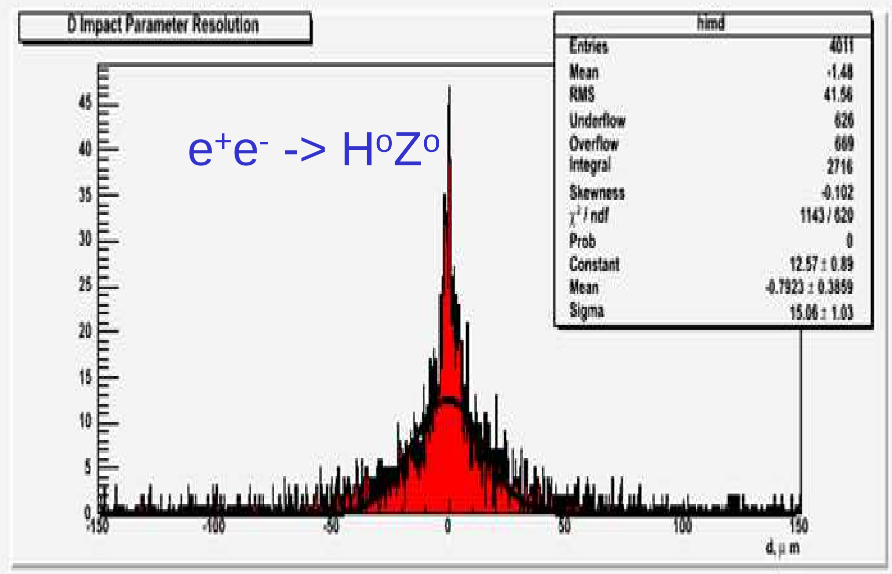
ΔD_o

TPC

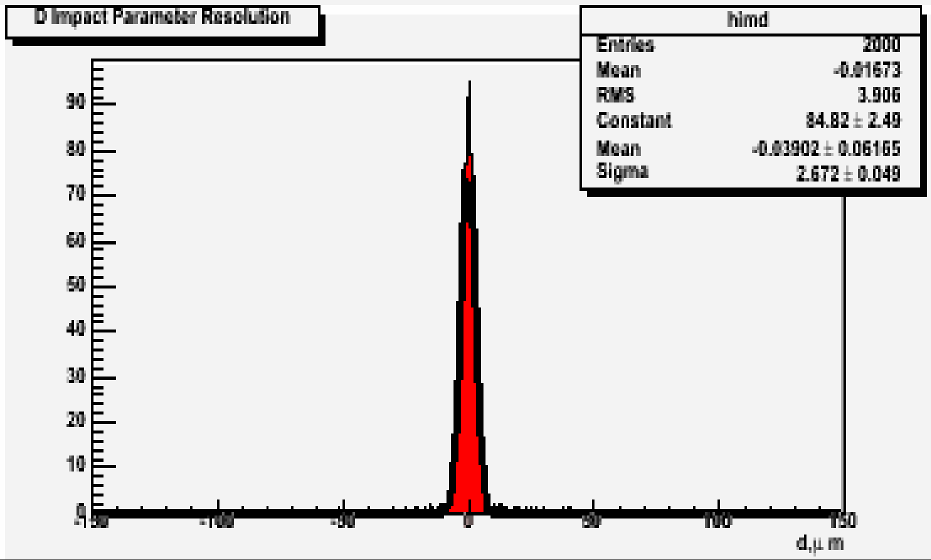

D Impact Parameter Resolution
himd
Entries 2000
Mean -0.2153
RMS 6.202
Underflow 0
Overflow 1
Integral 1999
Skewness -11.29
χ² / ndf 112.6 / 91
Prob 0.06227
Constant 85.51 ± 2.51
Mean 0.03226 ± 0.06095
Sigma 2.641 ± 0.048
μ [0.5,100] GeV
d, μ m

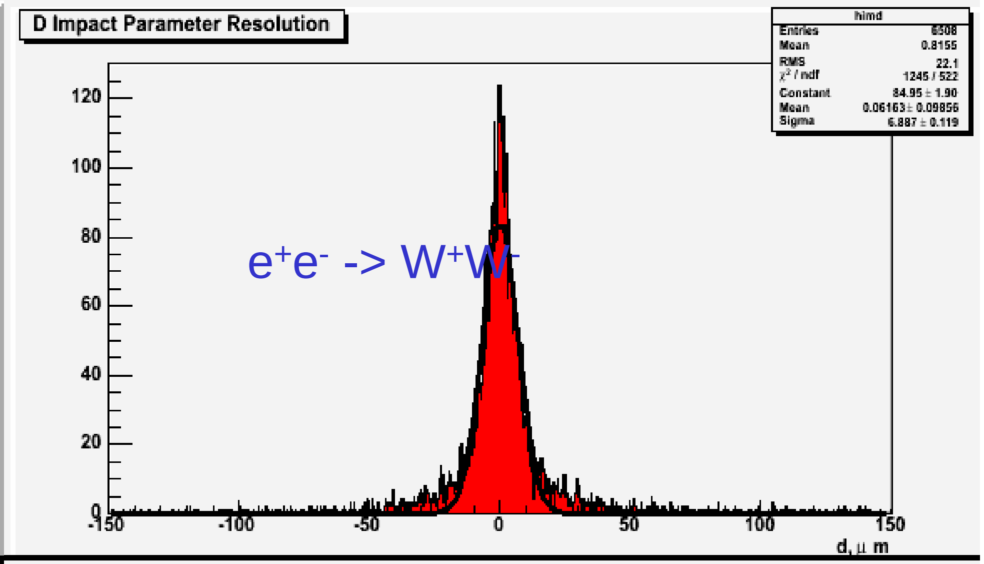

D Impact Parameter Resolution
himd
Entries 6480
Mean -0.05724
RMS 22.24
Underflow 205
Overflow 220
Integral 6055
Skewness -0.3289
χ² / ndf 1129 / 523
Prob 0
Constant 83.56 ± 1.92
Mean 0.1081 ± 0.1048
Sigma 7.054 ± 0.128
e⁺e⁻ -> W⁺W⁻
d, μ m


D Impact Parameter Resolution
himd
Entries 10521
Mean -0.2916
RMS 33.16
Underflow 823
Overflow 922
Integral 8776
Skewness 0.08049
χ² / ndf 2094 / 771
Prob 0
Constant 58.63 ± 1.32
Mean -0.1928 ± 0.1700
Sigma 13.64 ± 0.26
e⁺e⁻ -> tt
d, μ m

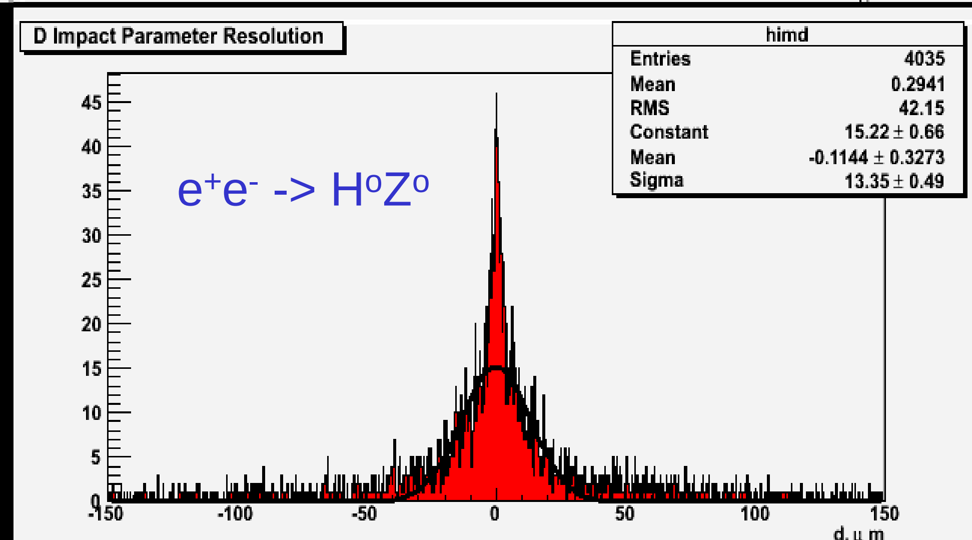

D Impact Parameter Resolution
himd
Entries 4011
Mean -1.48
RMS 41.56
Underflow 626
Overflow 669
Integral 2716
Skewness -0.102
χ² / ndf 1143 / 620
Prob 0
Constant 12.57 ± 0.89
Mean -0.7923 ± 0.3859
Sigma 15.06 ± 1.03
e⁺e⁻ -> H°Z°
d, μ m

ΔD_0



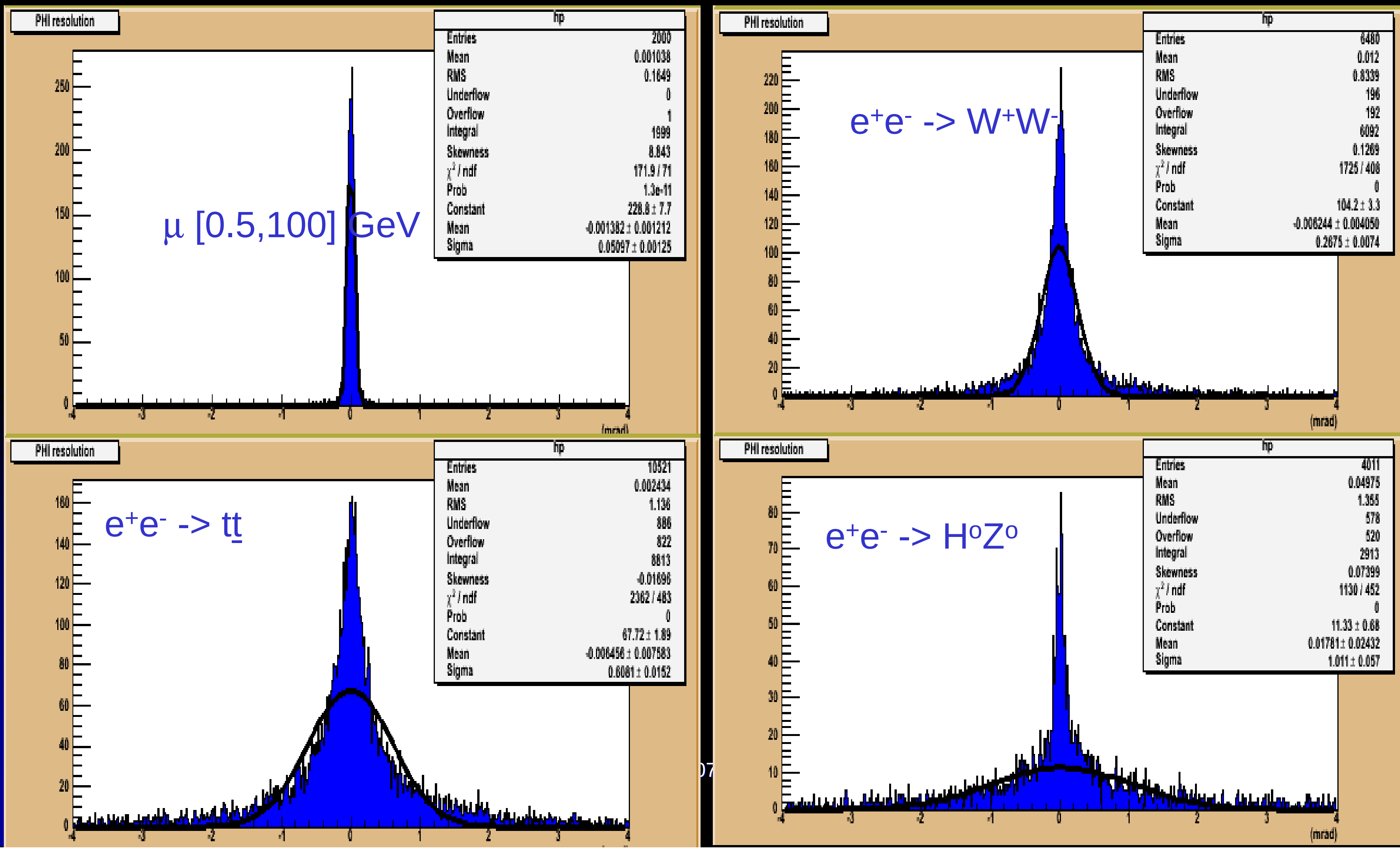


$e^+e^- \to t\bar{t}$

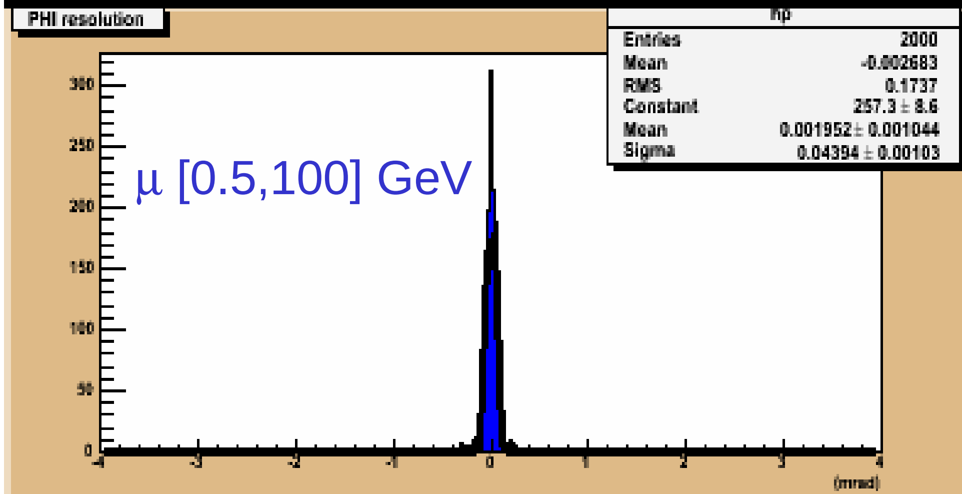


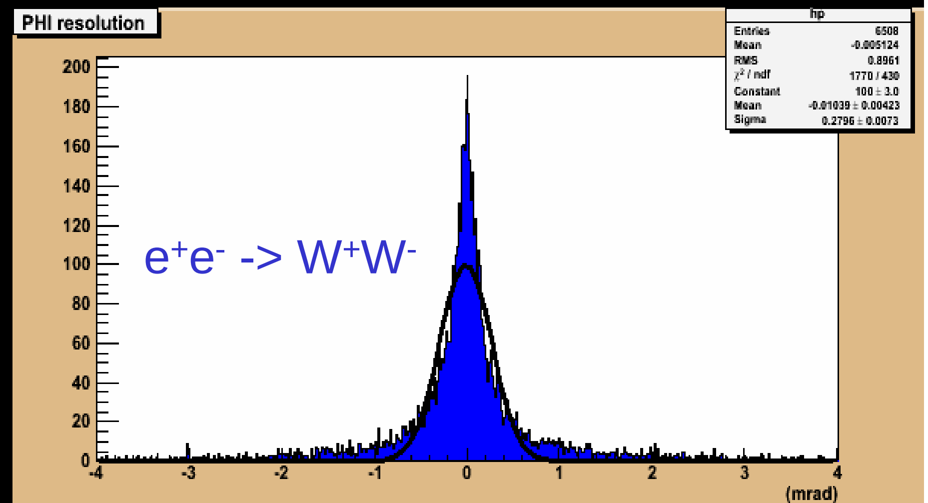
TPC

Δφ

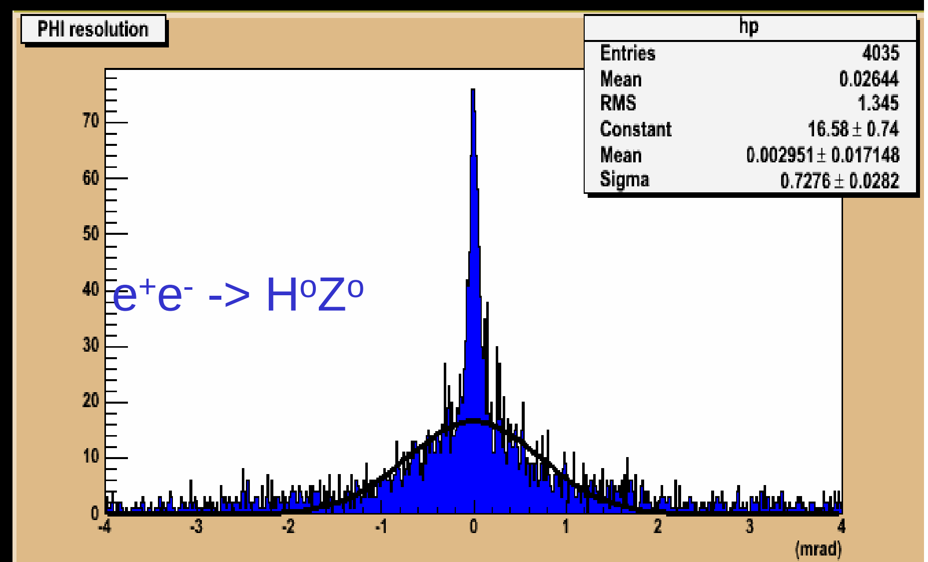

PHI resolution
hp
Entries 2000
Mean 0.001038
RMS 0.1649
Underflow 0
Overflow 1
Integral 1999
Skewness 8.843
χ² / ndf 171.9 / 71
Prob 1.3e-11
Constant 228.8 ± 7.7
Mean -0.001382 ± 0.001212
Sigma 0.05097 ± 0.00125
μ [0.5,100] GeV
(mrad)
PHI resolution
hp
Entries 6480
Mean 0.012
RMS 0.8339
Underflow 196
Overflow 192
Integral 6092
Skewness 0.1269
χ² / ndf 1725 / 408
Prob 0
Constant 104.2 ± 3.3
Mean -0.006244 ± 0.004050
Sigma 0.2675 ± 0.0074
e+e- -> W+W-
(mrad)
PHI resolution
hp
Entries 10521
Mean 0.002434
RMS 1.136
Underflow 886
Overflow 822
Integral 8813
Skewness -0.01696
χ² / ndf 2362 / 483
Prob 0
Constant 67.72 ± 1.89
Mean -0.006456 ± 0.007583
Sigma 0.6081 ± 0.0152
e+e- -> tt
PHI resolution
hp
Entries 4011
Mean 0.04975
RMS 1.355
Underflow 578
Overflow 520
Integral 2913
Skewness 0.07399
χ² / ndf 1130 / 452
Prob 0
Constant 11.33 ± 0.68
Mean 0.01781 ± 0.02432
Sigma 1.011 ± 0.057
e+e- -> HoZo
(mrad)

$\Delta\varphi$

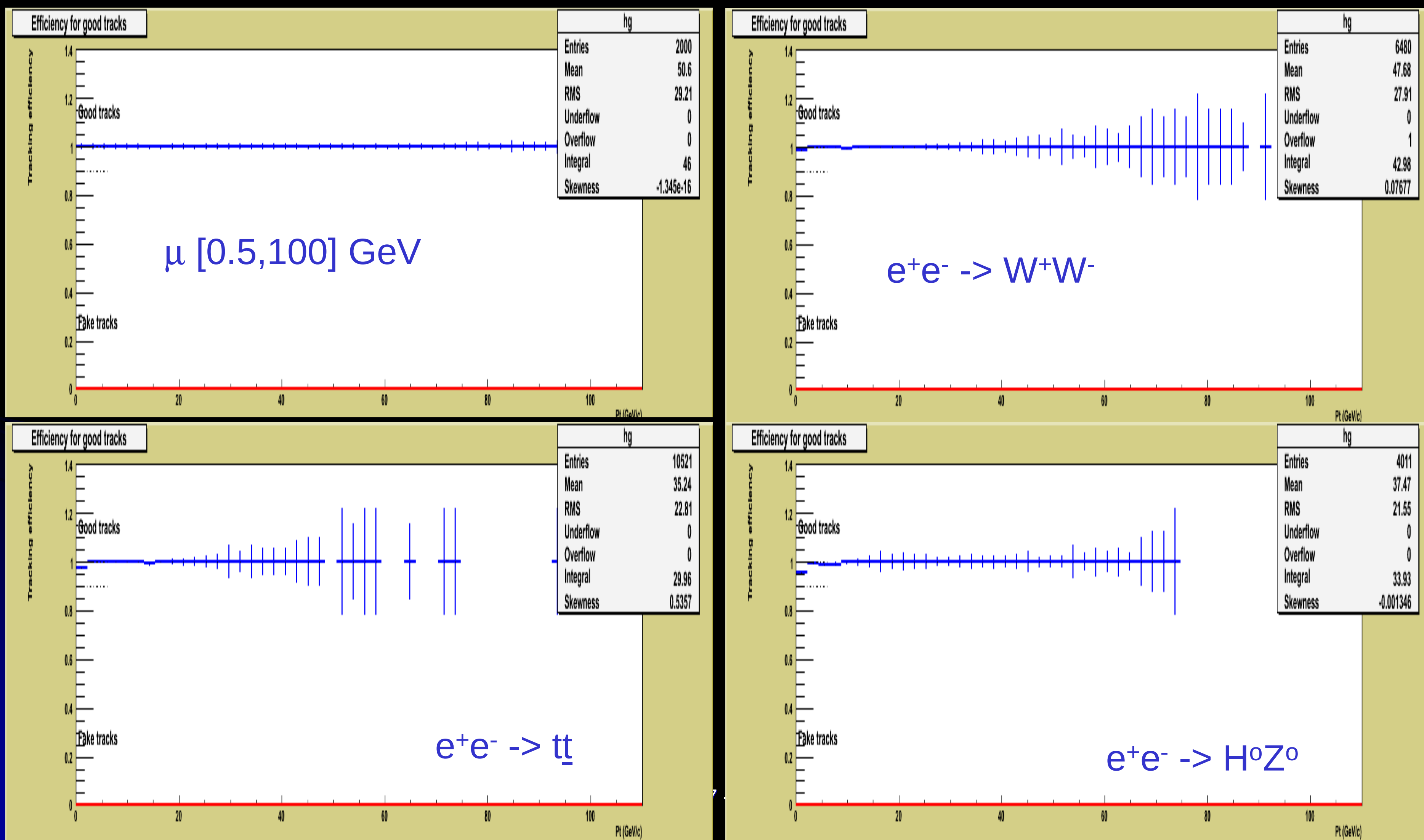




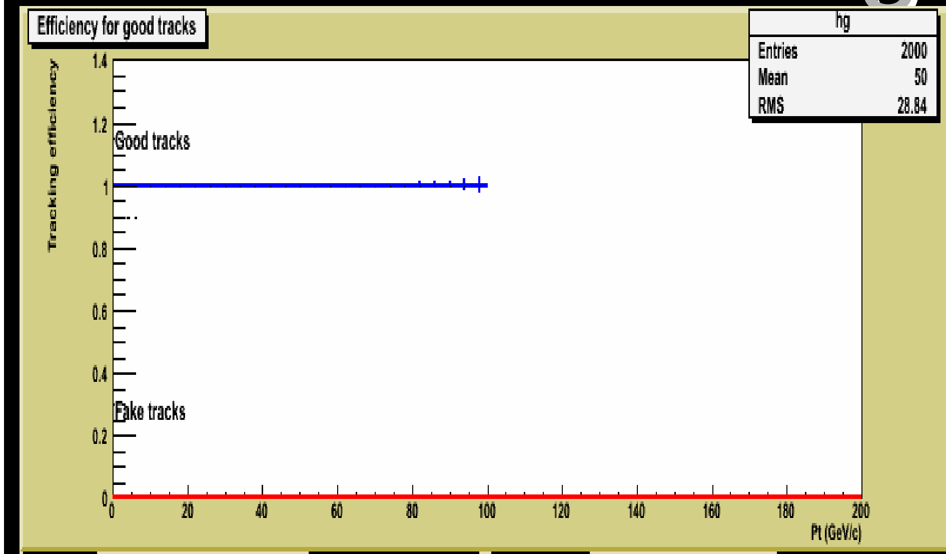
$e^+e^- \to t\bar{t}$

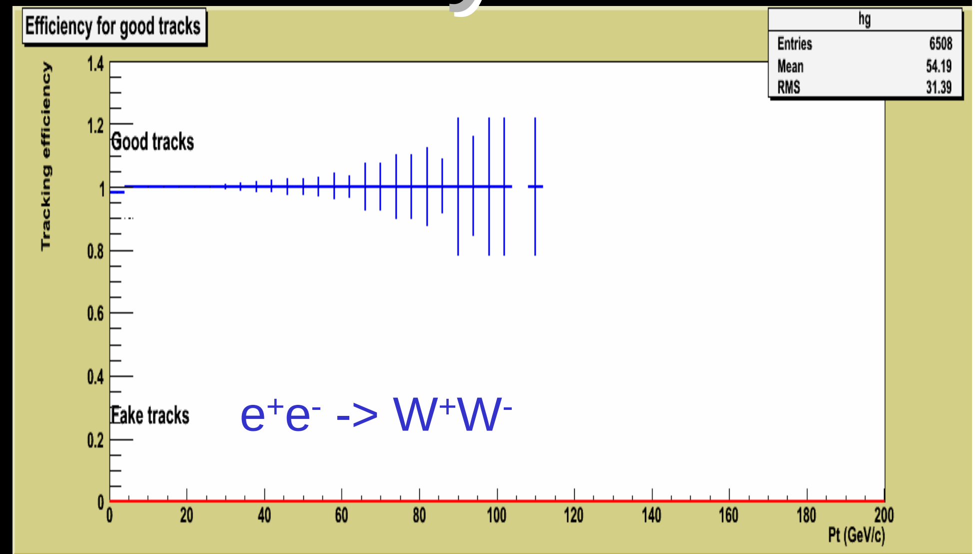


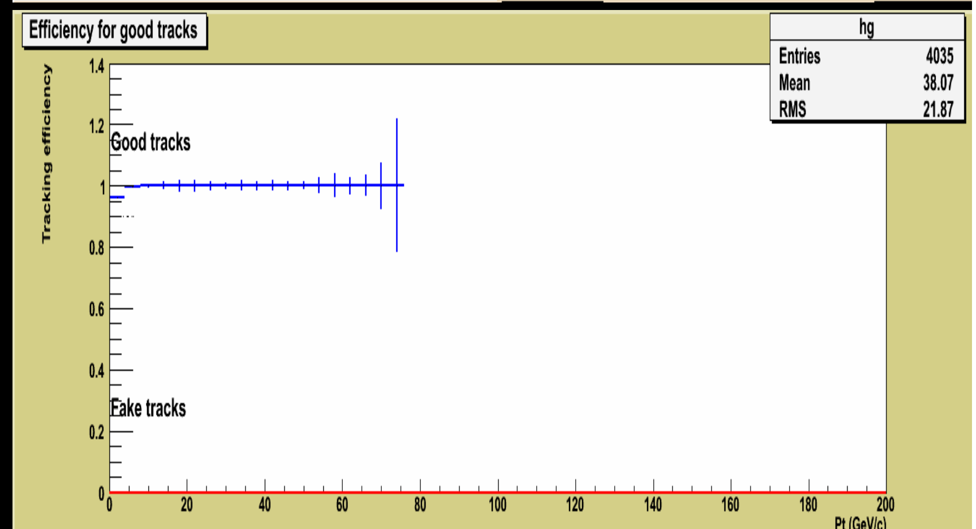
Tracking Efficiency



Tracking Efficiency

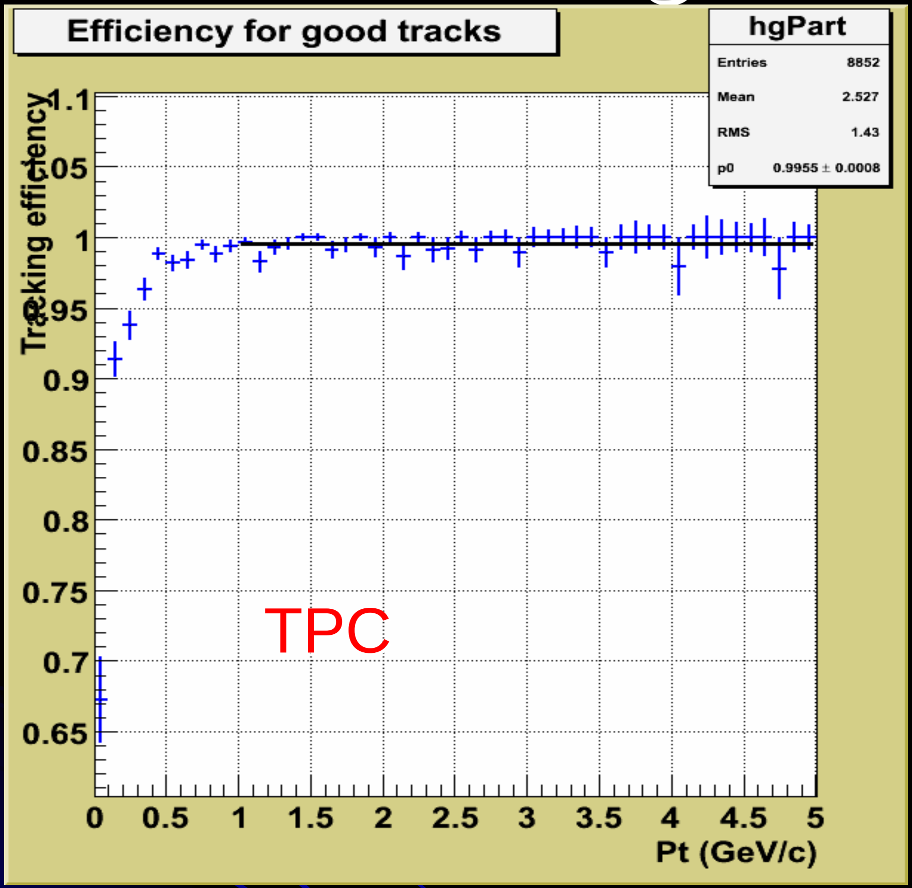






$e^+e^- \to t\bar{t}$

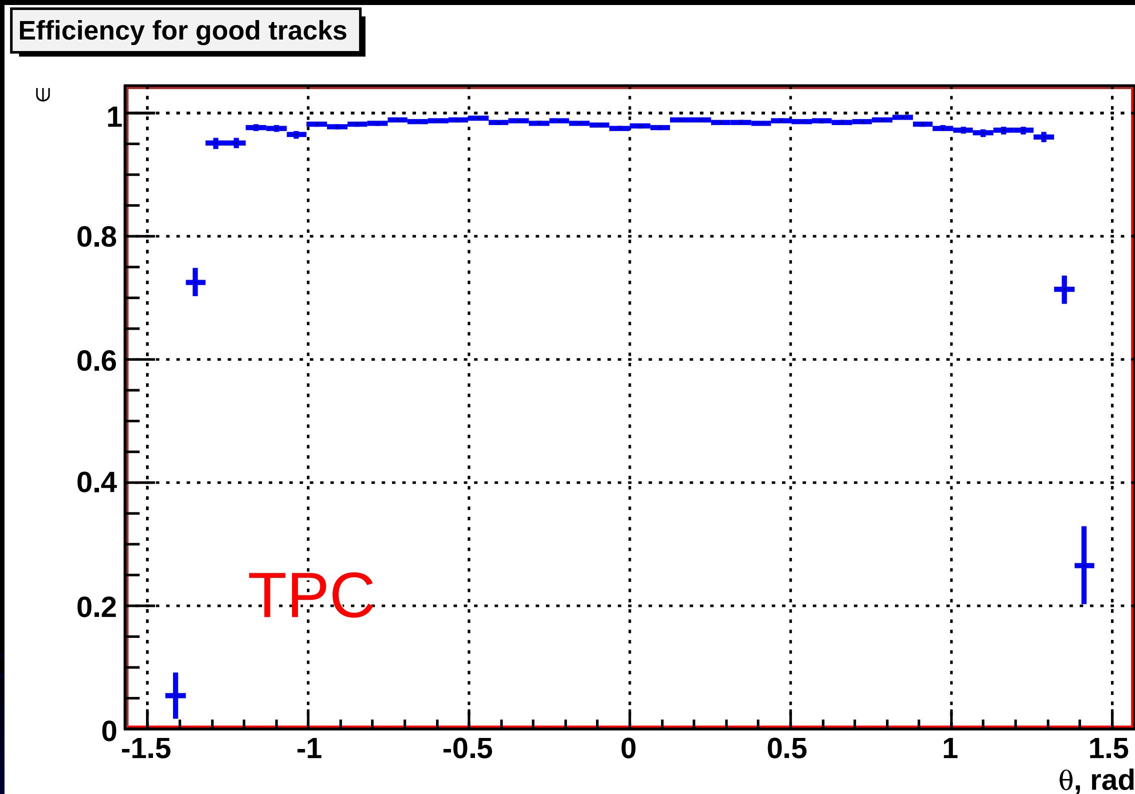
Tracking Efficiency low P



e+e- -> tt̲ -> 6 jets

DCH

Tracking Efficiency vs θ

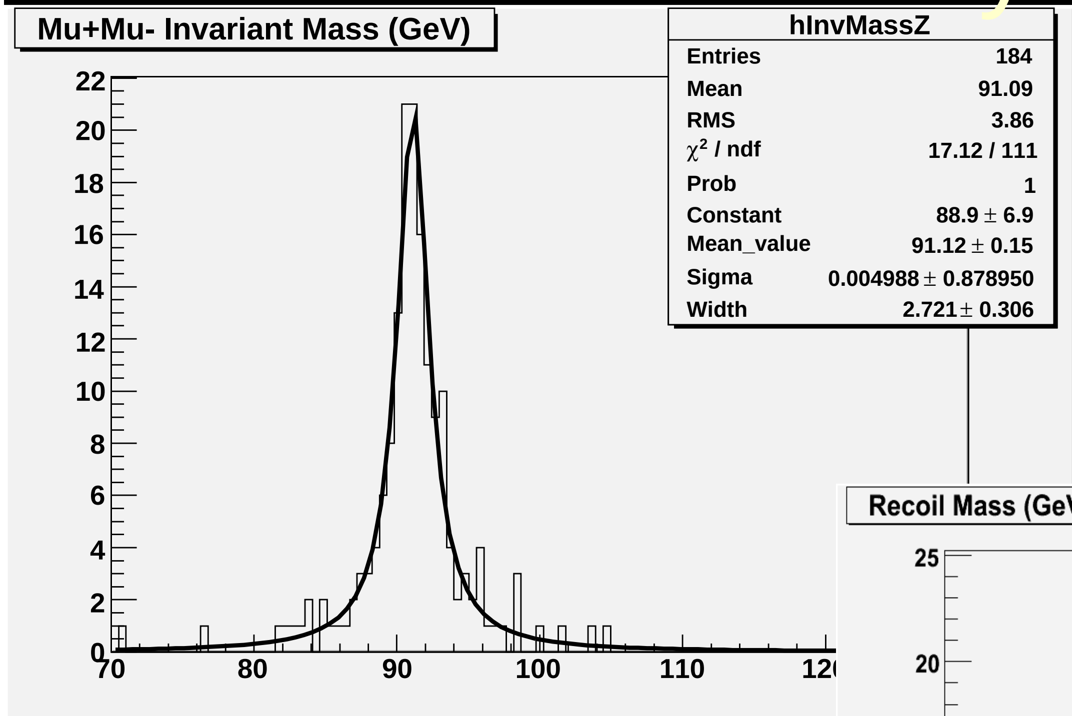


e+e- -> tt -> 6 jets

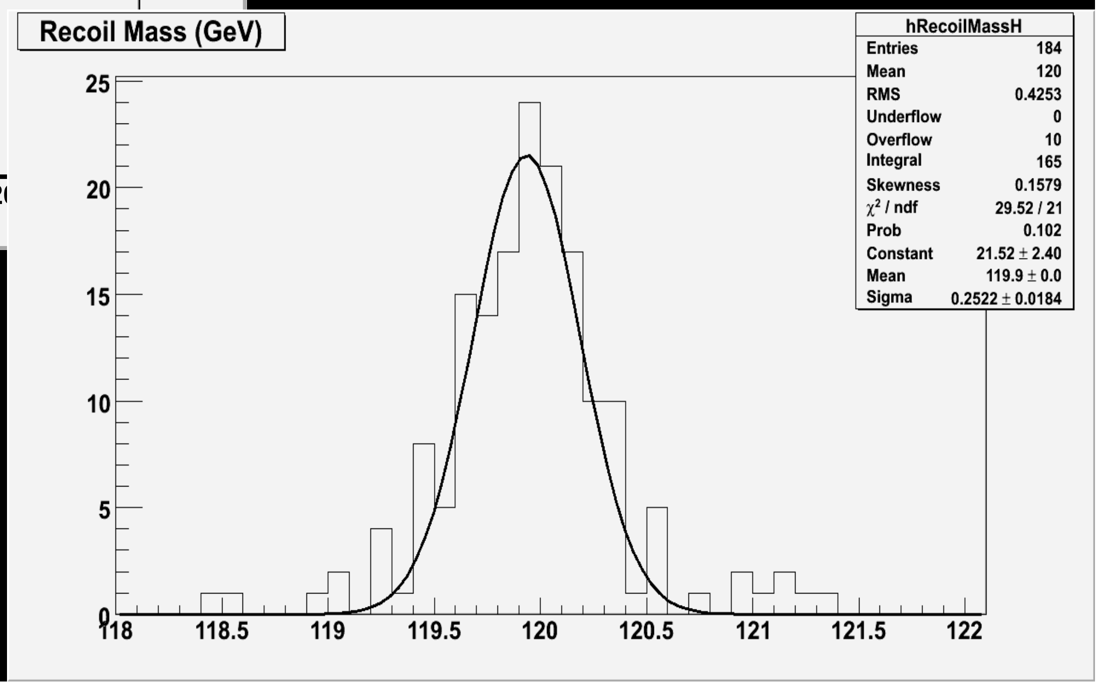
DCH

$e^+e^- \rightarrow H^oZ^o$ @ E_{cm} = 230 GeV Analysis

TPC



- ΔM_{recoil} = 380 MeV (90% RMS)
- ΔM_{recoil} = 250 MeV (gauss fit)



Summary of Performance

- Tracking efficiency:

  ε_{reco} > 90 % above 100 MeV

  ε_{reco} = 99.7 % above 1.5 Gev

- TPC or DCH + VXD resolution:
  - $\sigma(1/p_t) = 6\ x10^{-5}$ up to $8\ x10^{-4}$
  - $\sigma(\varphi) = 0.05$ up to 1 mrad
  - $\sigma(d) = 2.6\ \mu m$ up to $15\ \mu m$
  - $\sigma(z) = 3.9\ \mu m$ up to $18\ \mu m$

- Totally dominated by MS
- e^+e^- -> H^oZ^o @ E_{cm} = 230 GeV is the worse case

Status of the Project

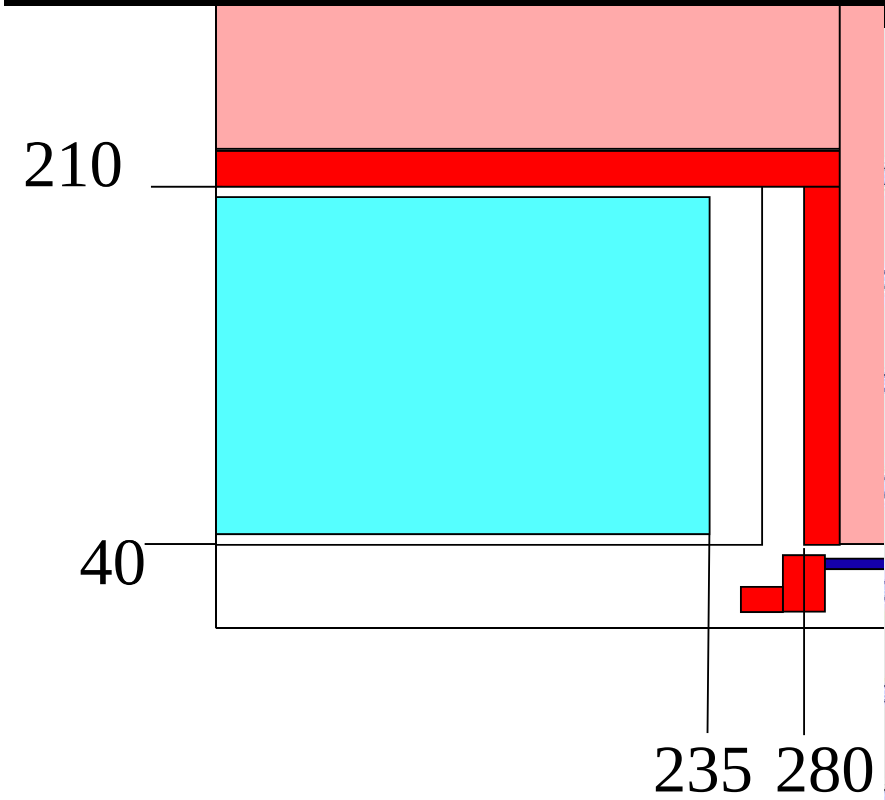
- VXD and TPC: simulation and reconstruction finalized
- Si Tracker:
  - SDigitization-Digitization-Clusterization completed (single and double side detector configuration)
  - Need to define the segmentation in tiles of Endcaps
  - Need to adapt Kalman Filter (F. Ignatov)
- DCH
  - Simplified digitization completed (no waveform, only timing of first 2 clusters
  - More than enough for current studies
  - Reconstruction OK
- Physics Studies alresy started

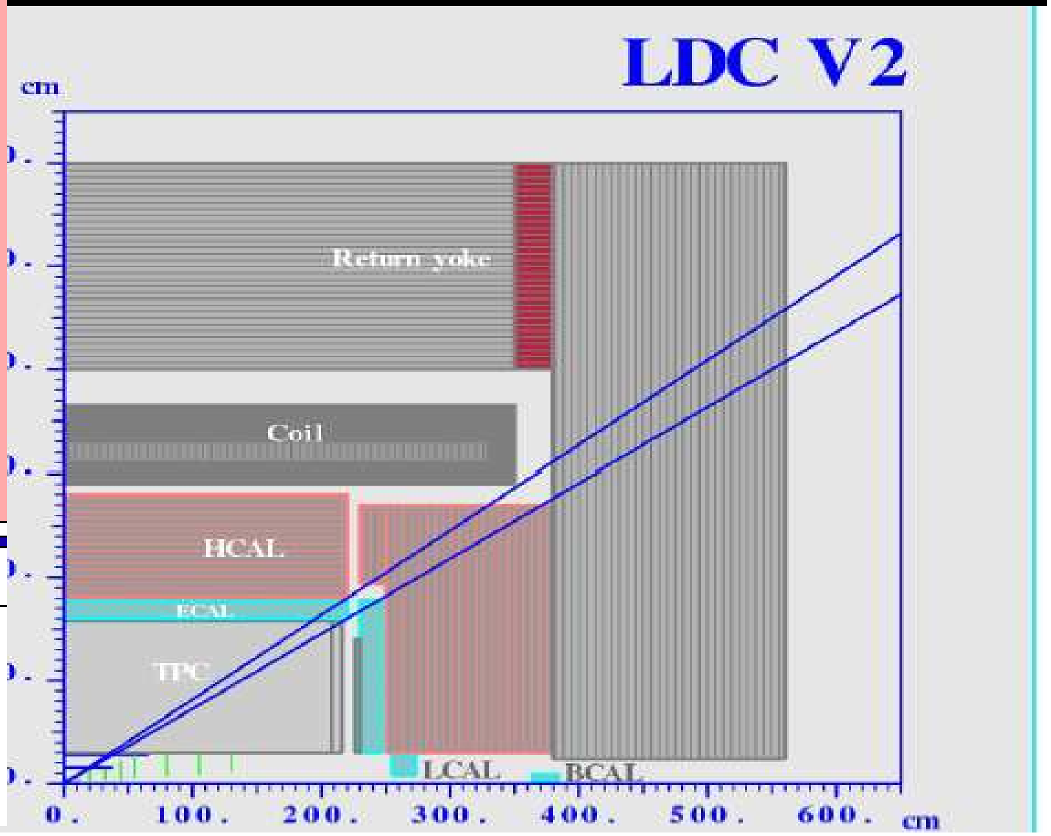
Conclusions

- A cross-concept detector study has recently started
- Goal is to get further insight on three Detector technologies for a Central Tracker at ILC
- FNAL and INFN-Lecce collaboration
- Full machinery will be in place shortly
- Preliminary studies already out
- It can be used with other Physics channels of interest

Backup slides

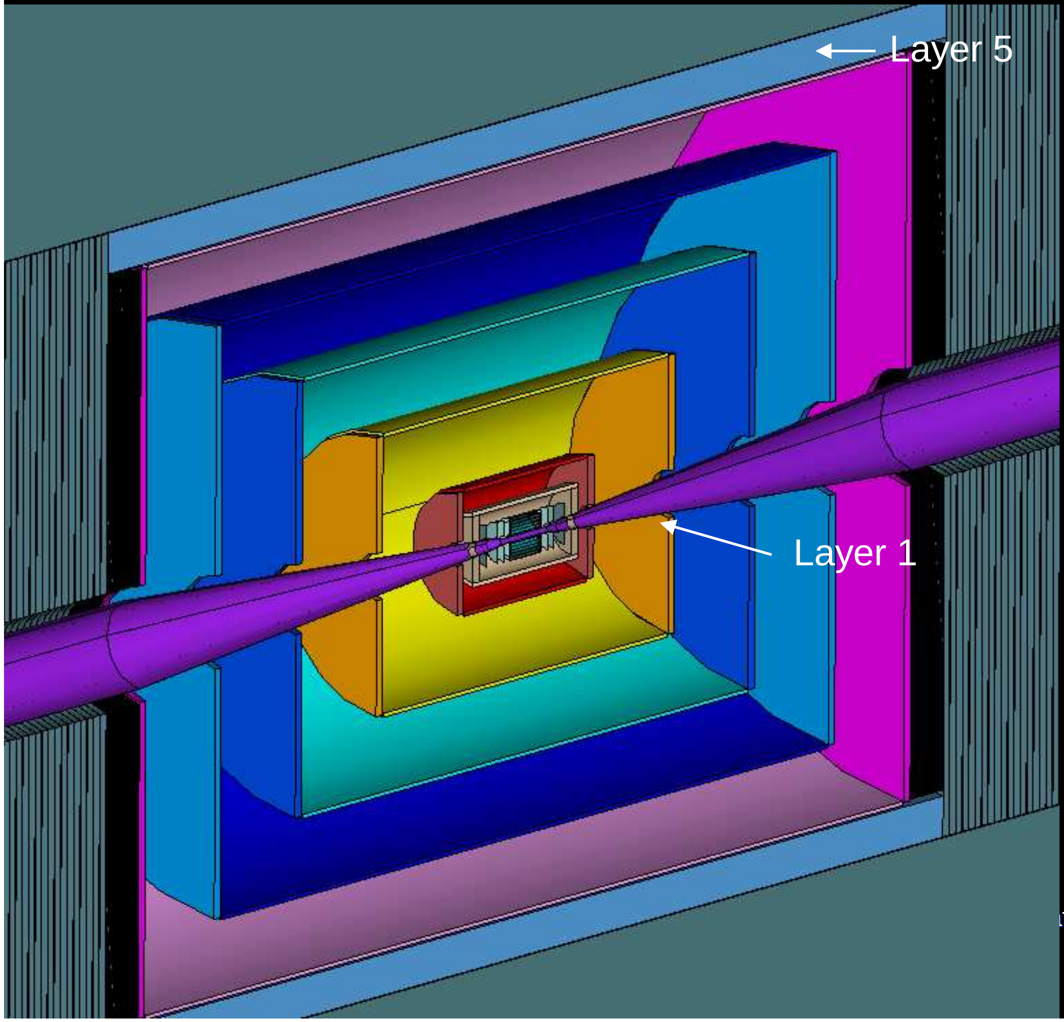
GLD/LDC


210
40
235 280


LDC V2
cm
Return yoke
Coil
HCAL
ECAL
TPC
LCAL
BCAL
0.
100.
200.
300.
400.
500.
600.
cm

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

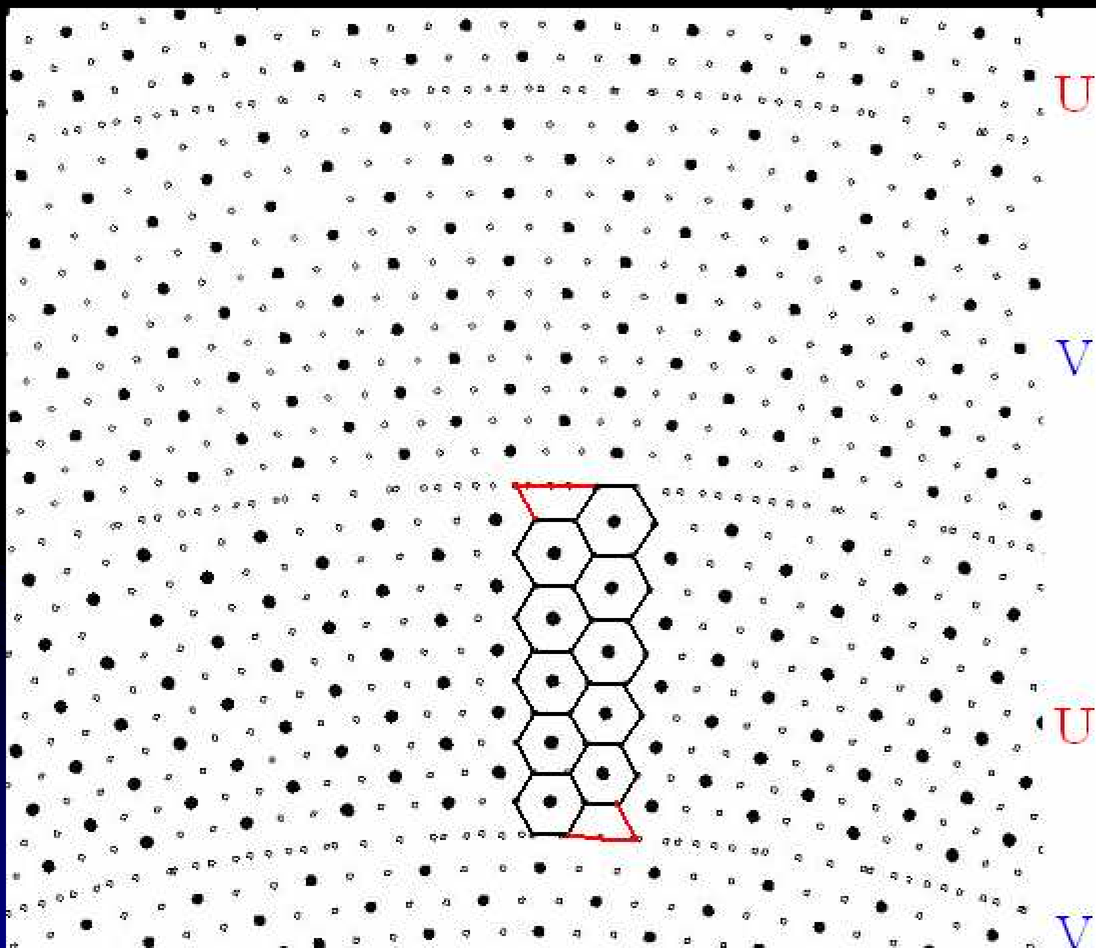


tto

- 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

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 !)

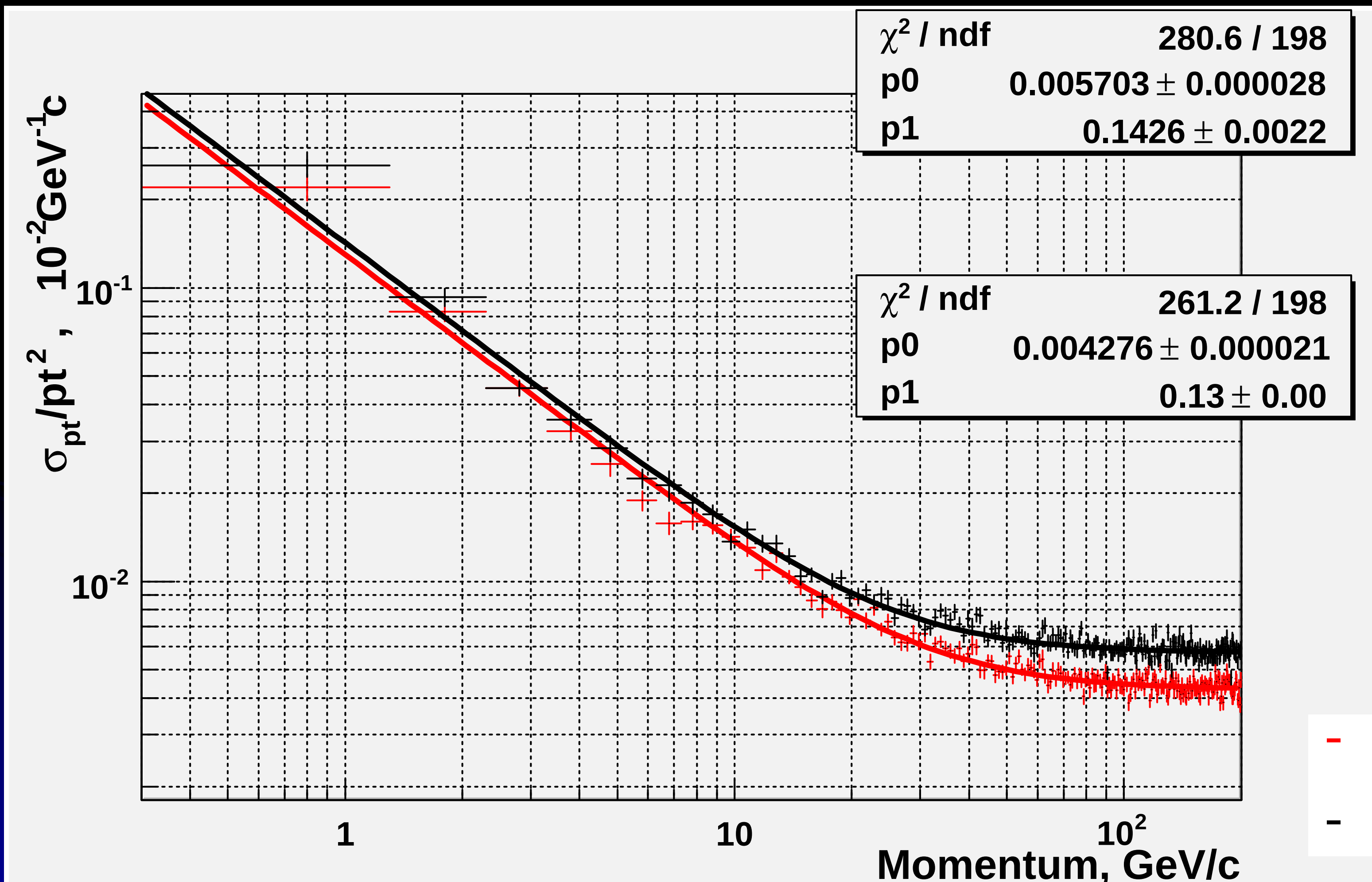
20 superlayers, in 200 rings
10 cells each (7.5 in average)
at alternating stereo angles
±72 ÷ ±180 mrad
(constant stereo drop = 2 cm)

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

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

>90% sampled volume

4th Concept Momentum Resolution with TPC



- VXD + TPC
- 10 muons
- P = 0.5-200 GeV

- mMegas + Pads

- Pads only

Slide from 4th Concept

Proposed Central Trackers

- GLD/LDC
  - Argon based TPC with MPGD readout
- SiD
  - Si-strips detector
- 4th Concept: under discussion
  - TPC with hybrid readout
  - He base Drift Chamber with Cluster Counting
  - SiD detector
- SiLC
  - Gas base central tracker sandwiched between Si detector

Sub-detector	GLD	LDC
Vertex det.	FP CCD	CPCCD/CMOS/DEPFET/ISIS/SOI/ ...
Si inner tracker	Si strip (4-layers)	Si strip (2-layers)
Si forward trk.	Si strip/pixel (?)	Si strip/pixel (?)
Main trk.	TPC	TPC
Additional trk.	Si endcap/outer trk. (option)	Si endcap/external trk.
EM CAL	W-Scintillator	W-Si
HCAL	Fe(Pb)-Scintillator	Fe-Sci./RPC*/GEM*
Solenoid	3T	4T
Muon det.	Scintillator strip	Sci strip/PST/RPC

Existing Studies

- Single particle studies
- Physics studies

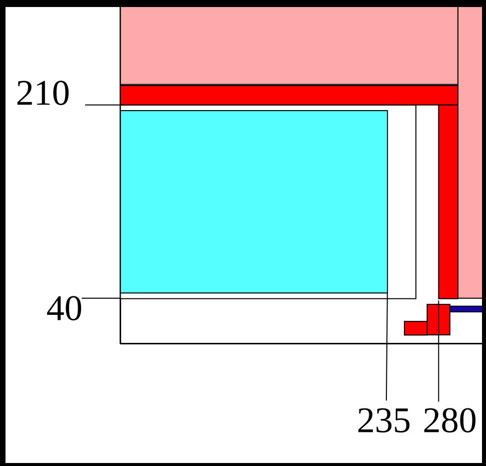
Motivation for a TPC

- continuous 3-D tracking, easy pattern recognition throughout large volume, well suited for large magnetic field
- ~99% tracking efficiency in presence of backgrounds
- time stamping to 2 ns together with inner silicon
- minimum of X_0 inside Ecal (<3% barrel, <30% endcaps)
- σ_{pt} ~ 100μm (rφ) and ~ 500μm (rz) @ 4T
- 2-track resolution <2mm (rφ) and <5-10mm (rz)
- dE/dx resolution <5% -> e/pi separation, for example
- easily maintainable if designed properly, in case of beam accidents, for example
- design for full precision/efficiency at 20 x estimated backgrounds

tracker requirements

- Small cross sections < 100 fb, low rates, no fast trigger.
- Higgs measurements & SUSY searches require:
  - High granularity continuous tracking for good pattern recognition.
  - Good energy flow measurement in tight high multiplicity jets.
  - Excellent primary and secondary b, c, τ decay vertex reconstruction.
- TPC is an ideal tracker for ILC.
  - Momentum resolution goal $\Delta(1/p_T) \sim 5.10^{-5}$ (GeV^{-1}) achievable with vertex + Si inner tracker + TPC with $\Delta(1/p_T) \sim 2 \times 10^{-4}$ (GeV^{-1})
- ILC TPC tracker goals:
  - 200 track points with $\sigma(r, \varphi) = 100$ µm, $\sigma(r, z) = 500$ µm
  - 2 track resolution < 2mm in (r, φ) and < 5 mm in (r, z)
  - dE/dx resolution < 5%

GLD TPC Conceptual Design



- ★ Inner radius: **40 cm**
- ★ Outer radius: **200 cm**
- ★ Half-length : **235 cm**
- ★ Readout : **200 radial rings**

- Drift velocity **~5cm μs^{-1}** (depends on gas)
- Total Drift time ~ 50μs
  - i.e. **integrate over ~100 BX**

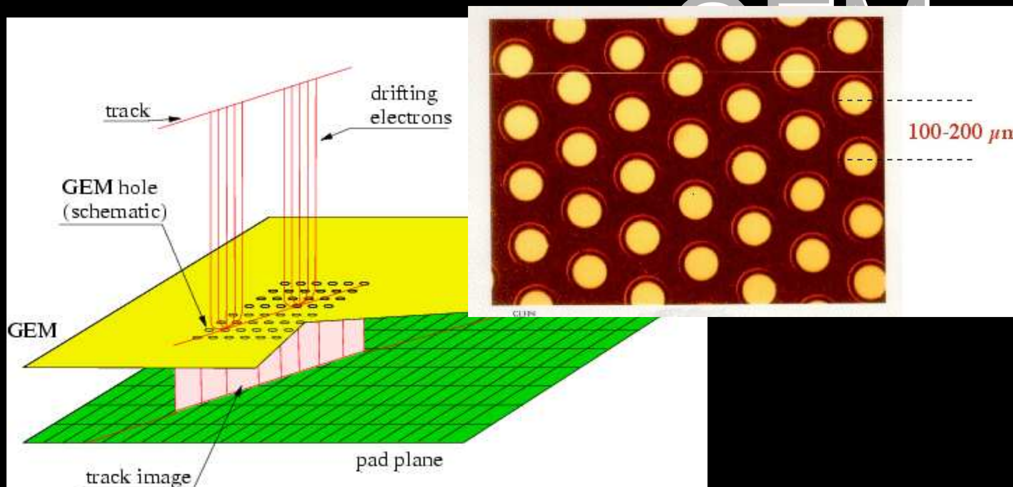
★**Background** ⇨ ~10^5 hits in TPC (depends on gas/machine)

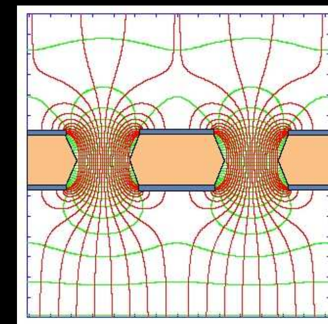
★**~10^9** 3D readout voxels (1.2 MPads+20MHz sampling)

⇨**0.1% occupancy**

★No problem for pattern recognition/track reconstruction even when taking into account background !

★ One Major Question (?) : **Readout technology**





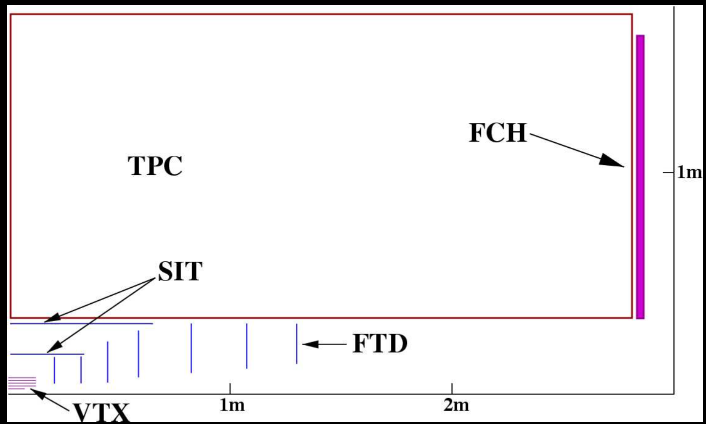
- ★ High electric field strength in GEM holes ~ 40-80 kV/cm
- ★ Amplification occurs between GEM foils (50 μm)
- ★ Ion feedback is suppressed : achieved 0.1-1 %
- ★ Limited amplification (<100) - use stack of 2/3 GEMs

- ✸ Ultimate viability of MPGDs subject of active worldwide R&D (of which KEK test beam studies play importart role)
- ✸ MWPCs considered fallback option

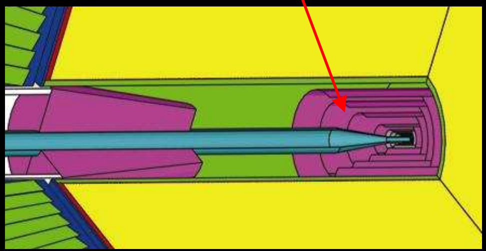
Tracking = VTX + SIT + TPC +……

- ★To achieve good momentum resolution need to augment VTX/TPC particularly in the ENDCAP/far forward region

e.g. TESLA TDR



IT



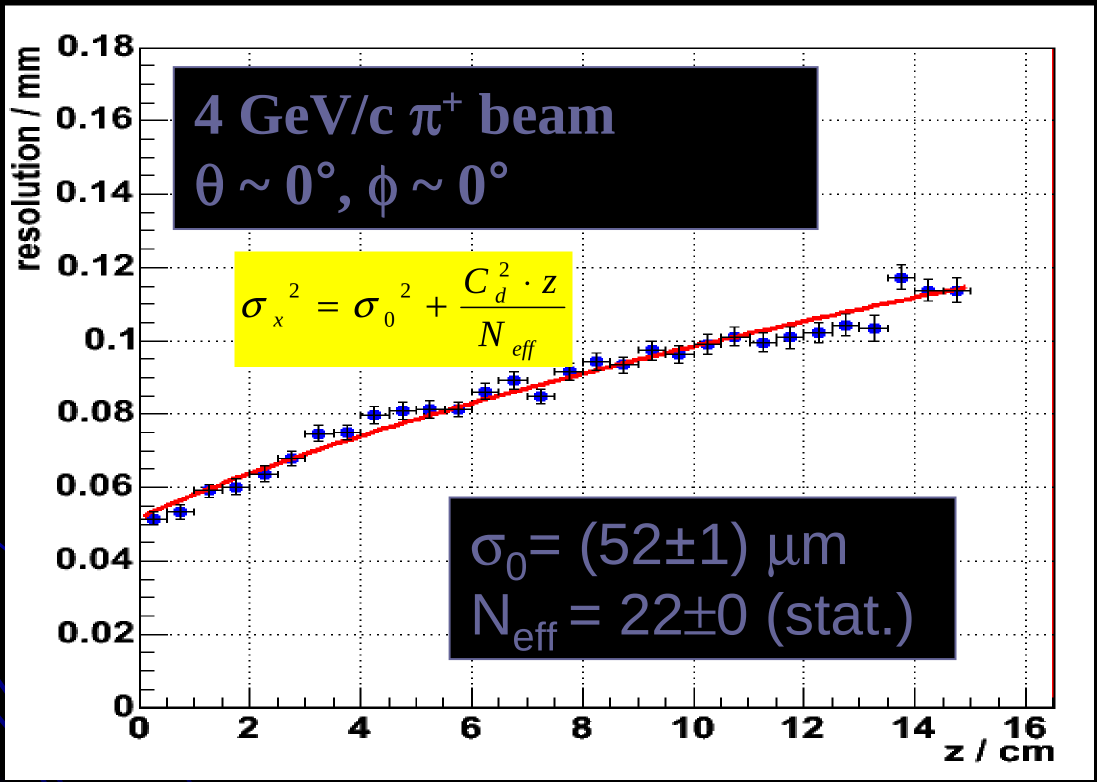
GLD Concept:

- ★ **Intermediate tracker (IT) :** 4 layers of Si
  - ★ 9cm – 30cm
  - ★ 20 μm Si strips
- ★ **Forward Si disks :** coverage down to 150 mrad

★Forward tracking is IMPORTANT
- needs carefully evaluation in GLD studies !
- including tracking behind TPC endplane…

TPC Performance

- Resolution by *Position sensing from charge dispersion in MPGDs with a resistive anode*



LDC/GLD Summary

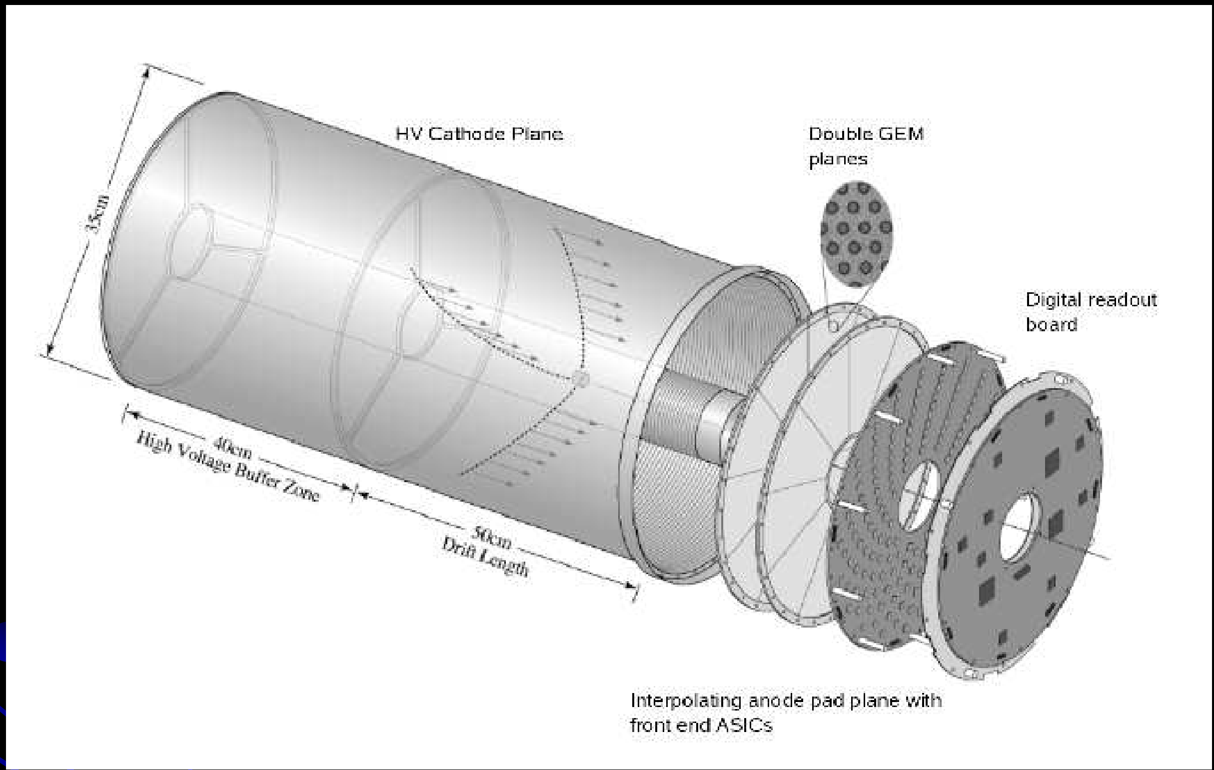
Table 1: Performance goals and design parameters for a TPC with standard electronics at the ILC detector.

Size (LDC–GLD average)	$\phi = 3.6$m, L = 4.3m outside dimensions
Momentum resolution (B=4T)	$\delta(1/p_t) \sim 10 \times 10^{-5}$/GeV/c TPC only; $\times$ 0.4 incl. IP
Momentum resolution (B=4T)	$\delta(1/p_t) \sim 3 \times 10^{-5}$/GeV/c (TPC+IT+VTX+IP).
Solid angle coverage	Up to at least $\cos\theta \sim 0.98$
TPC material budget	$< 0.03X_0$ to outer fieldcage in r
	$< 0.30X_0$ for readout endcaps in z
Number of pads	$> 1\times10^6$ per endcap
Pad size/no.padrows	$\sim$ 1mm$\times$4–6mm/$\sim$200 (standard readout)
$\sigma_{singlepoint}$ in $r\phi$	$\sim 100\mu$m (for radial tracks, averaged over driftlength)
$\sigma_{singlepoint}$ in rz	$\sim$ 0.5 mm
2-hit resolution in $r\phi$	$<$ 2 mm
2-hit resolution in rz	$<$ 5 mm
dE/dx resolution	$<$ 5 %
Performance robustness	$>$ 95% tracking efficiency for all tracks–TPC only)
(for comparison)	($>$ 95% tracking efficiency for all tracks–VTX only)
	$>$ 99% all tracking[13]
Background robustness	Full precision/efficiency in backgrounds of 1% occupancy
	(simulations estimate $<$ 0.5% for nominal backgrounds)
Background safety factor	Chamber will be prepared for 10 $\times$ worse backgrounds
	at the ILC start-up.

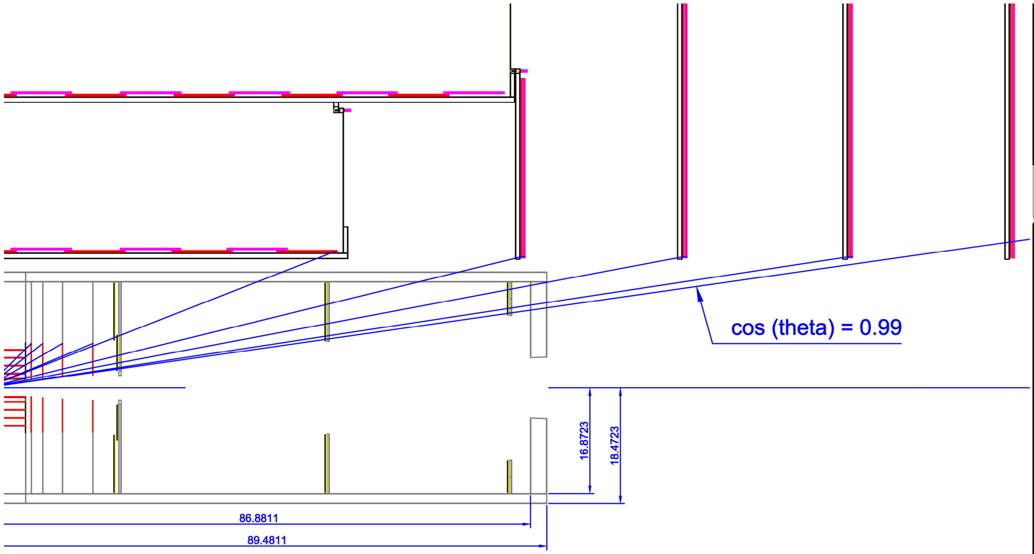
TPC Related Issues

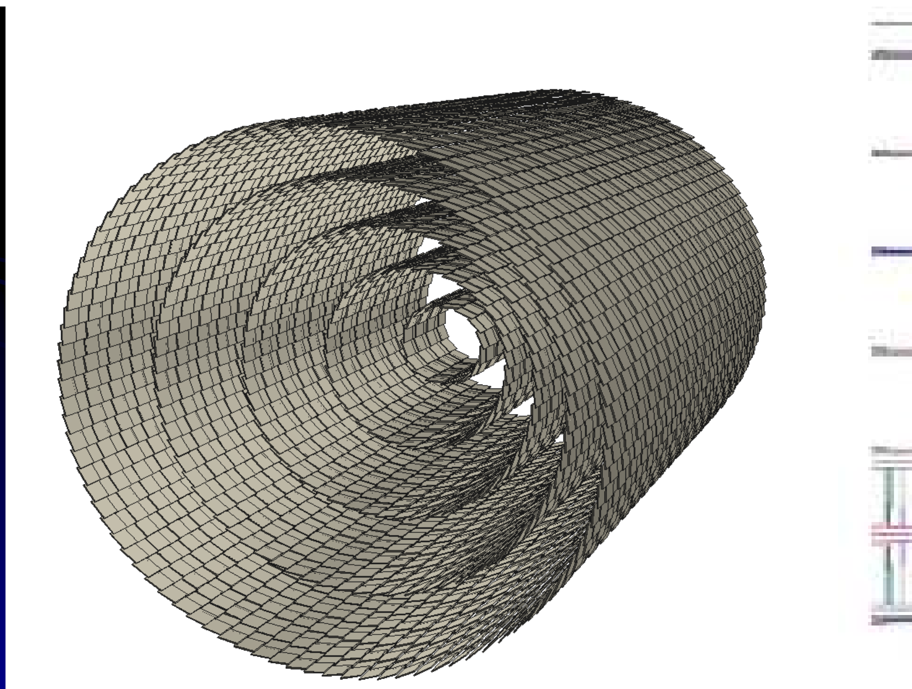
- High point resolution (<150μm) after long drift (>2m)
- MWPC readout → MPGD readout
- Gas choice
- Large scale (R~2m) structure
- MPGD reliability: GEM and MicroMEGAS
- Positive ion feedback
- High density and low material electronics

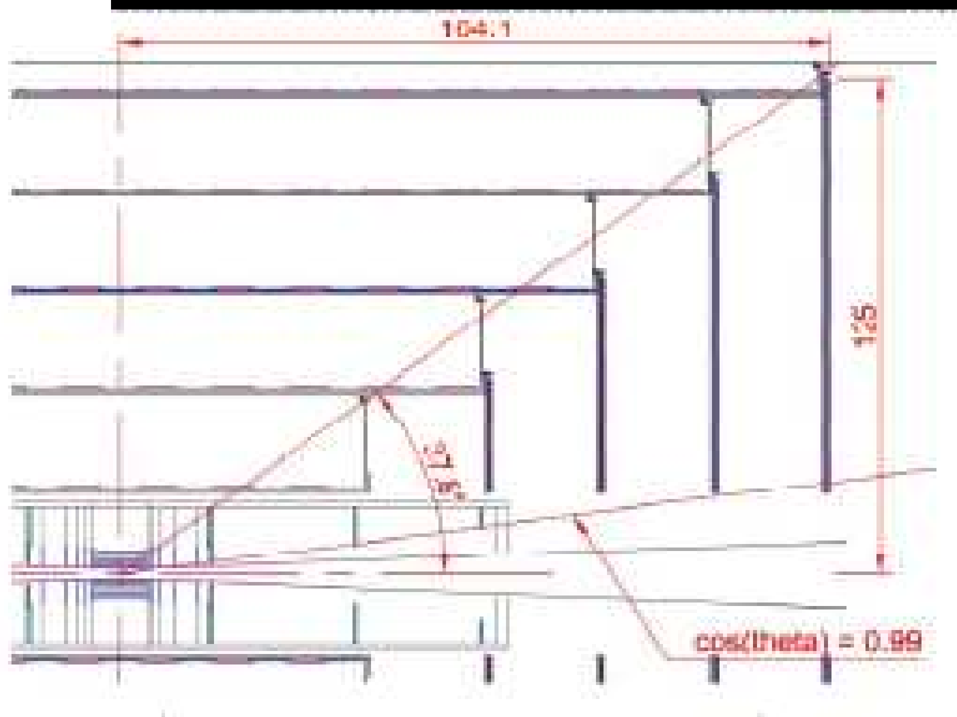
The endcp issue



acker


cos (theta) = 0.99
16.8723
18.4723
86.8811
89.4811




104.1
125
cos(theta) = 0.99

Architecture arguments

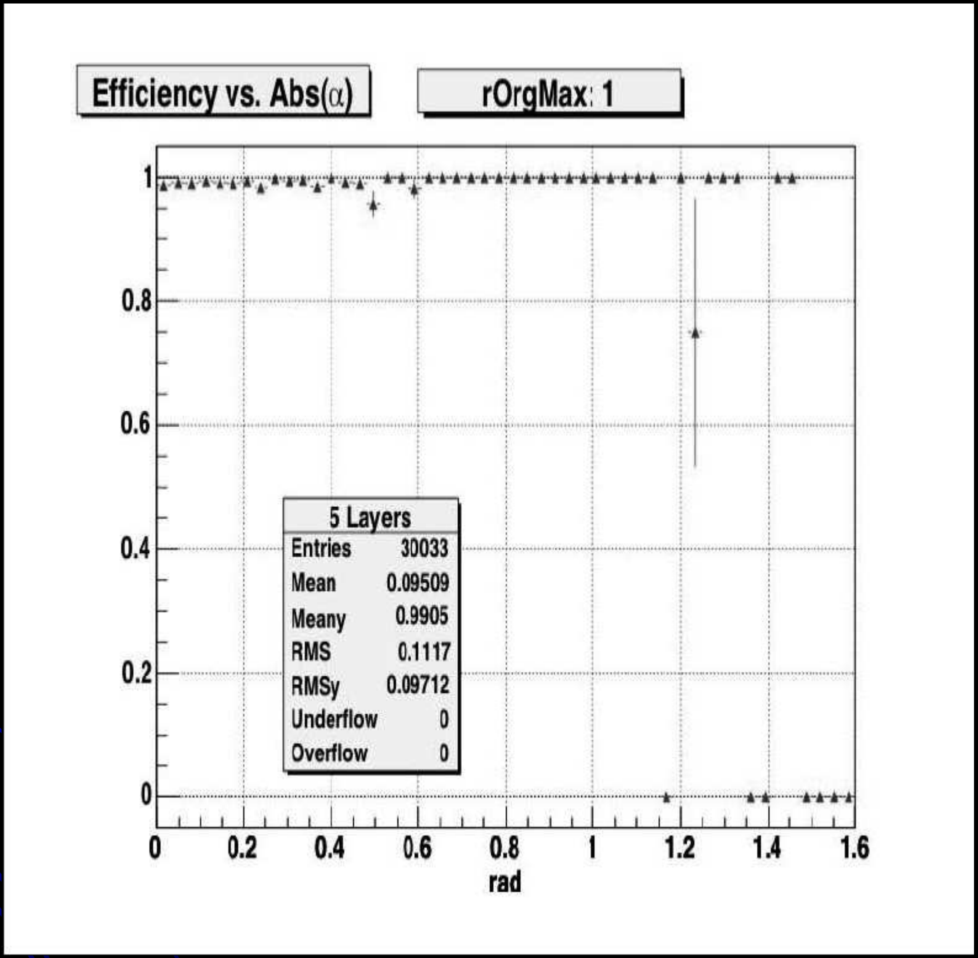
Detector outline considerations

- *Accept* the notion that excellent energy flow calorimetry is required, use W-Si for EMCAL and the implications for the detector architecture…

This is the **monster** assumption of SiD

- Calorimeter (and tracker) Silicon is expensive, so limit area by limiting radius (and length)
- Maintain BR^2 by pushing B (~5T)
- Excellent tracking resolution by using silicon strips
- 5T field allows minimum VXD radius.
- Do track finding by using 5 VXD space points to determine track – tracker measures sagitta. Exploit tracking capability of EMCAL for V's. Explore track finding with the Si strips.

SiD Tracking Efficiency

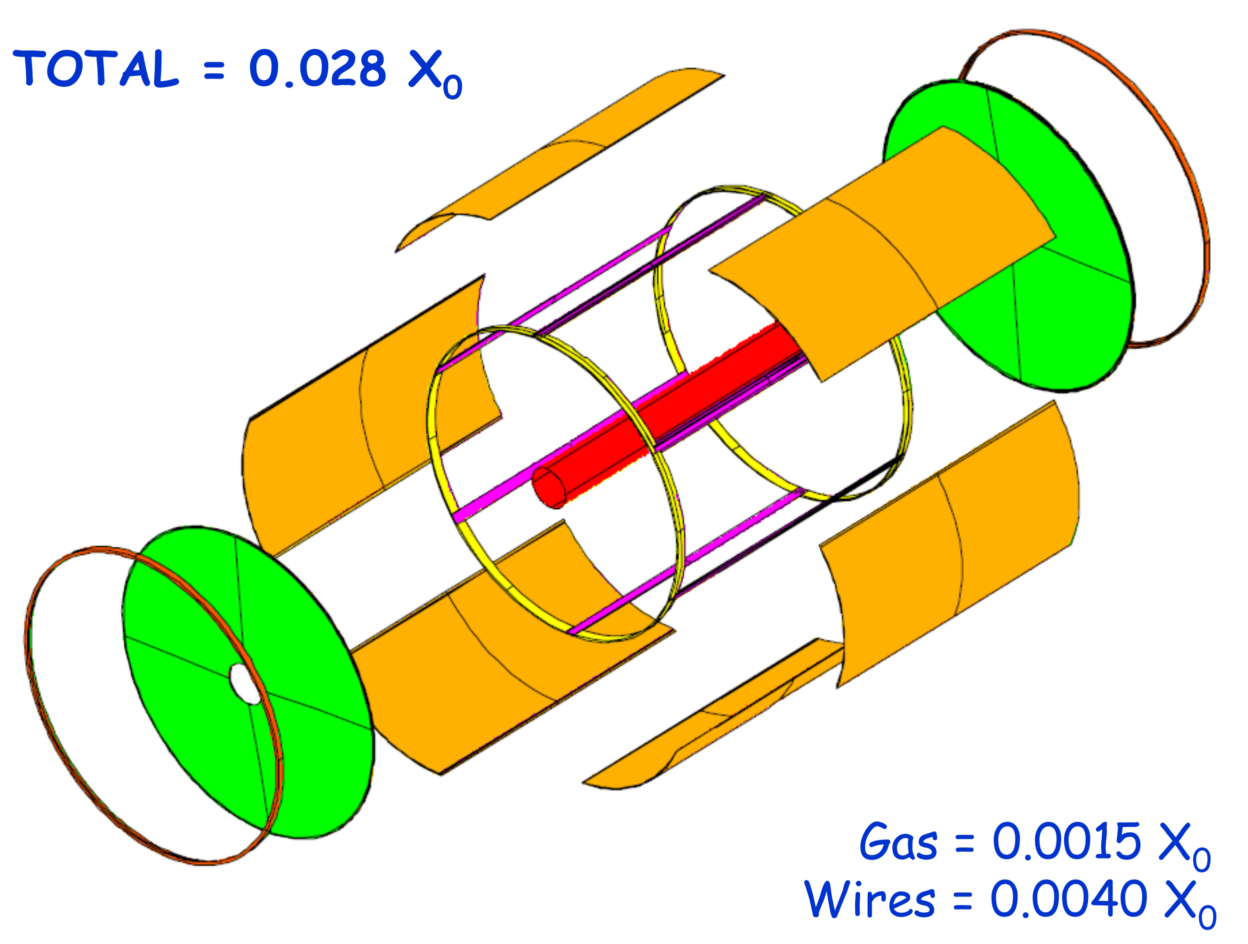


SiD Tracker Issues

- About 14 x 10^6 strips for the barrel
- Endcaps channel count depend on segmentation

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)

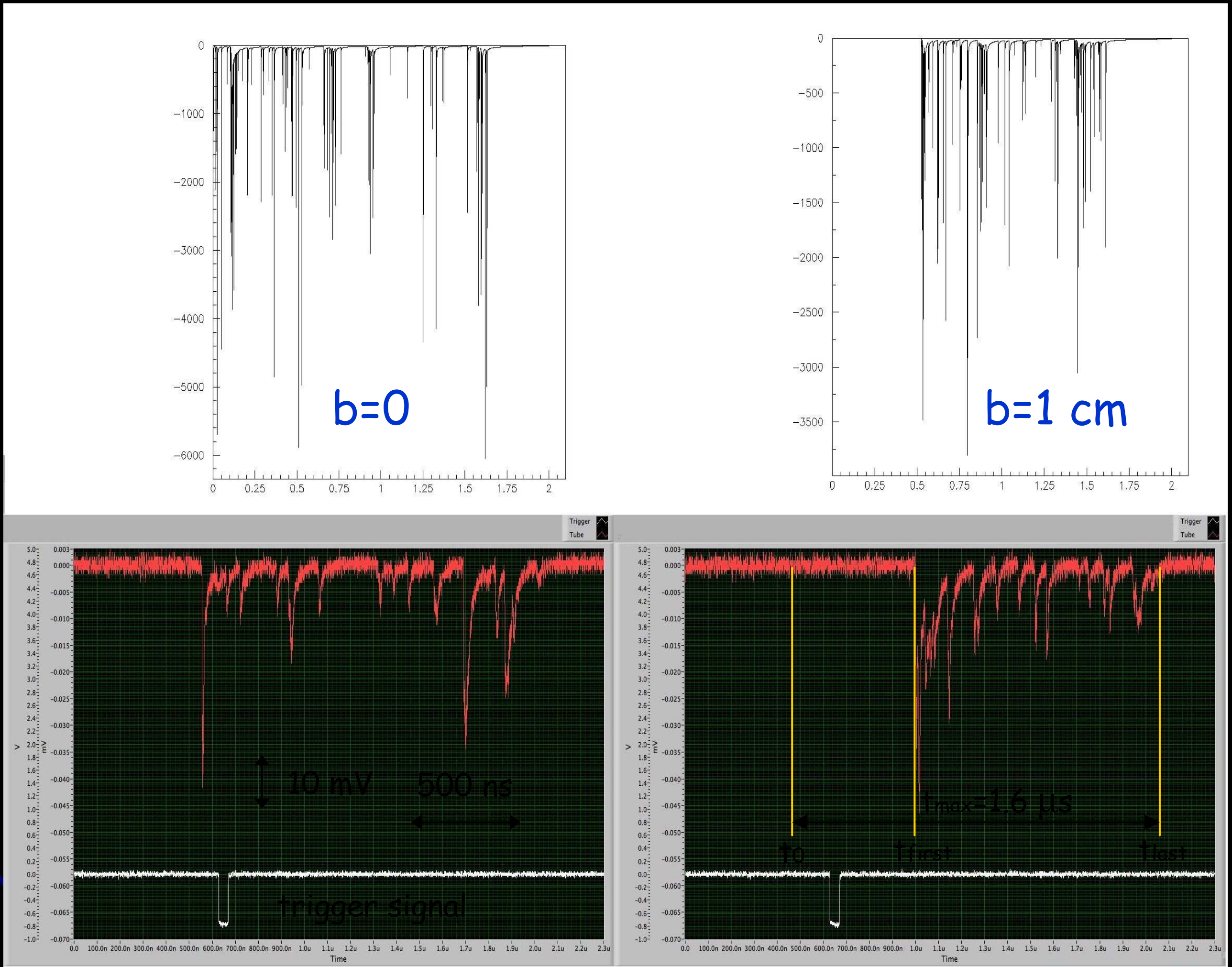
Outer cylindrical wall:
C-f./hex.cell. sandwich
held by 6 unidir. struts
0.020 X_0)

Retaining ring

Stiffening ring

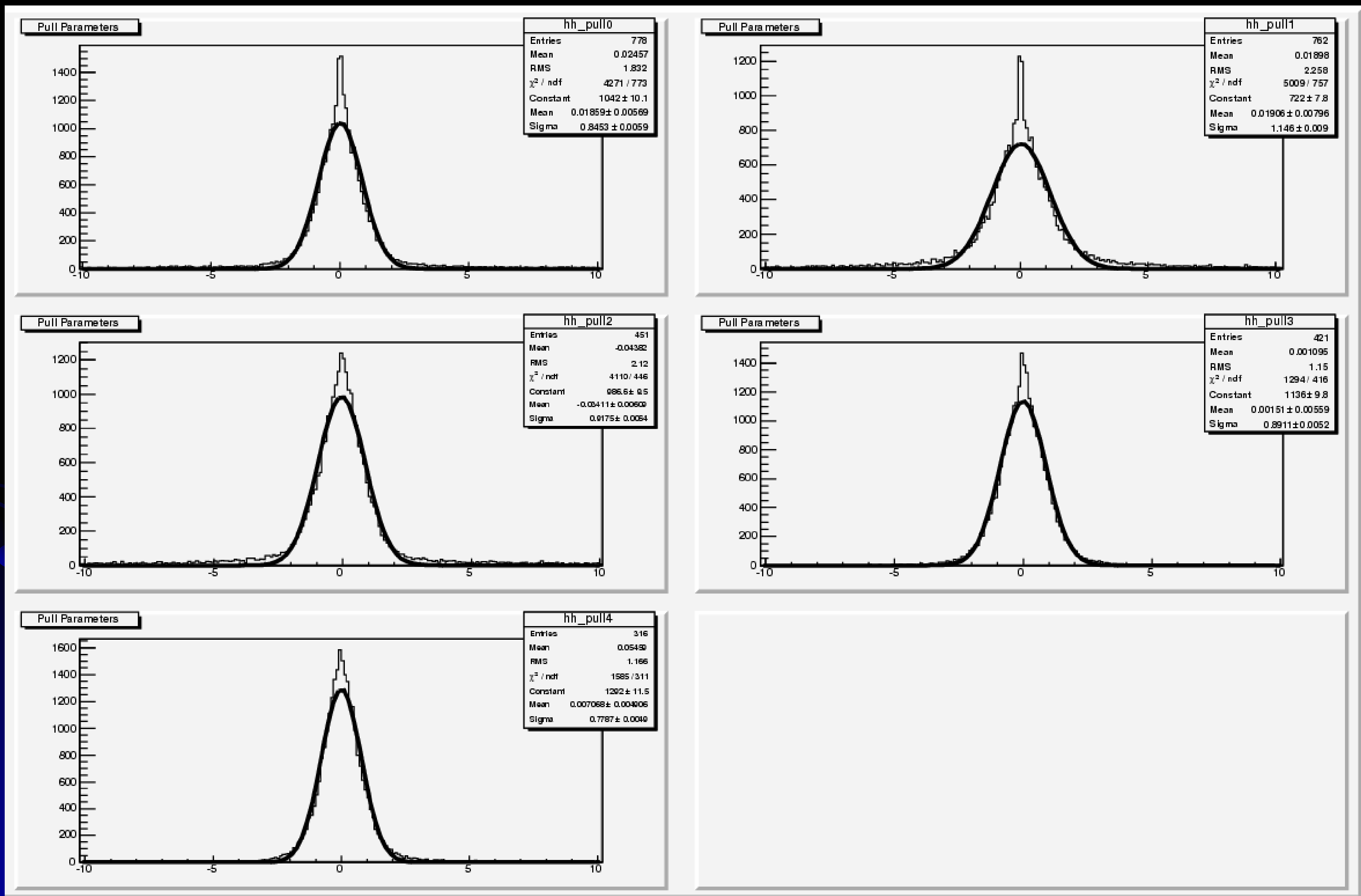
CLUster COUnting

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



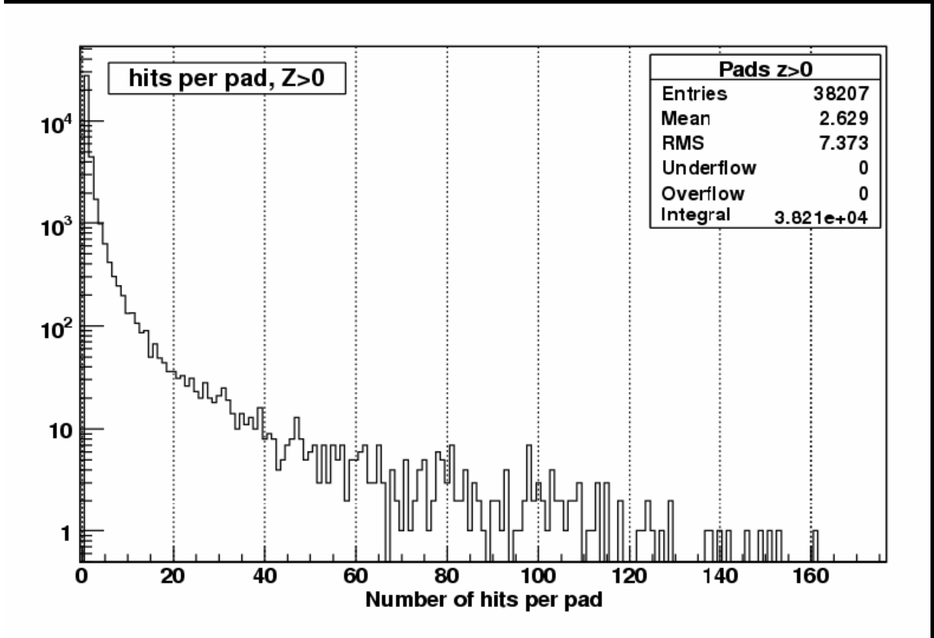
cosmic rays triggered
by scintillator telescope
and readout by:
8 bit, 4 GHz, 2.5 Gsa/s
digital sampling scope
through a 1.8 GHz, x10
preamplifier

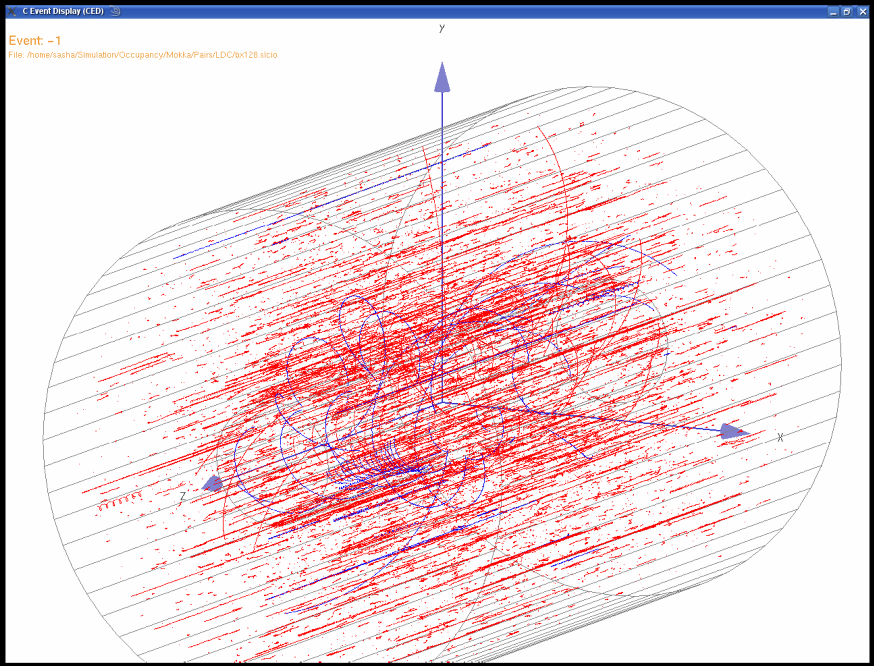
Pulls (full digitization)



Pair Background with GuineaPig

- 128 Bunch Crossing





6mm x1 mm pads in LDC TPC

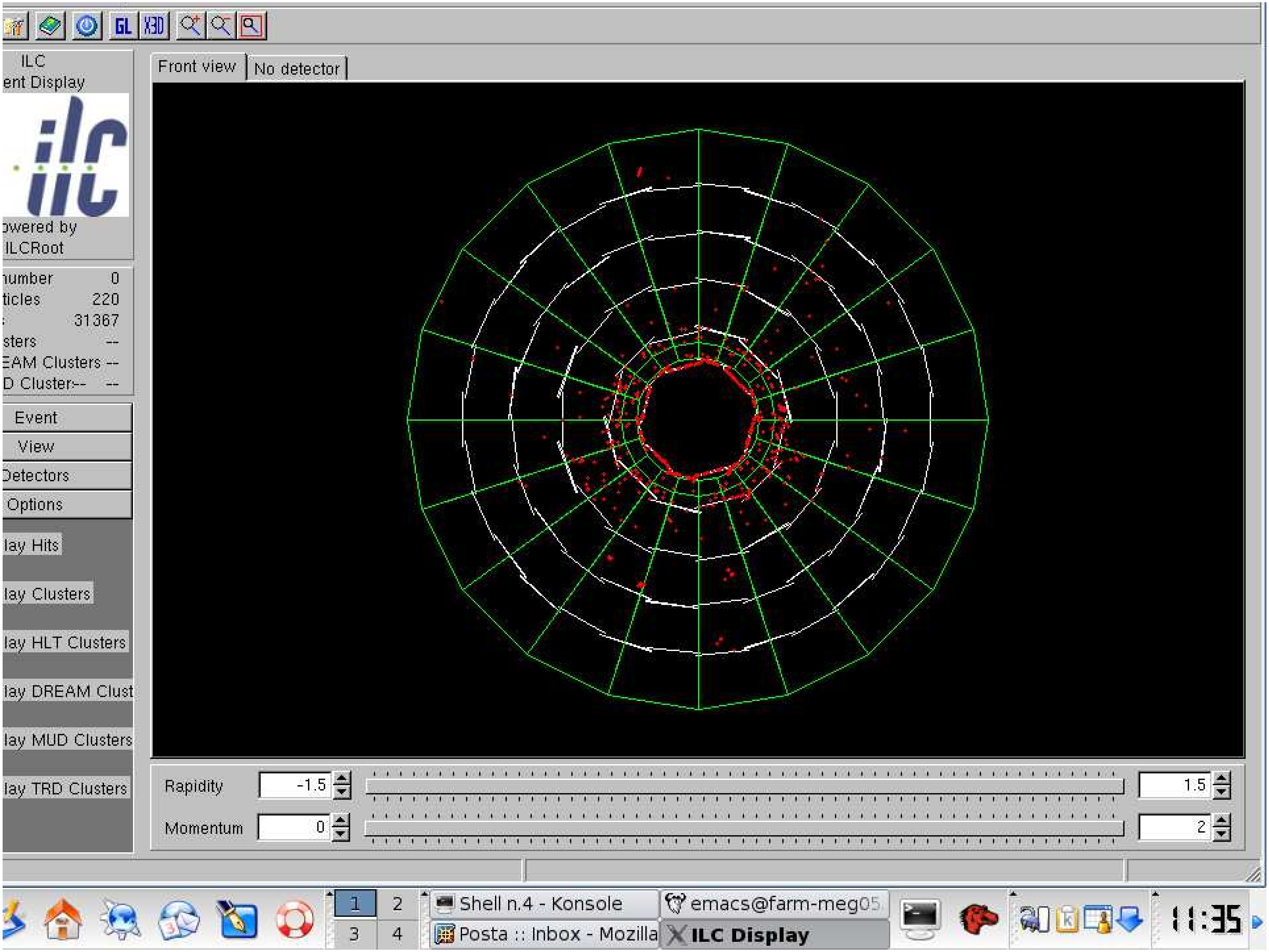
160 * 64 = 10240 hits

Beam Pair Background Study (preliminary)

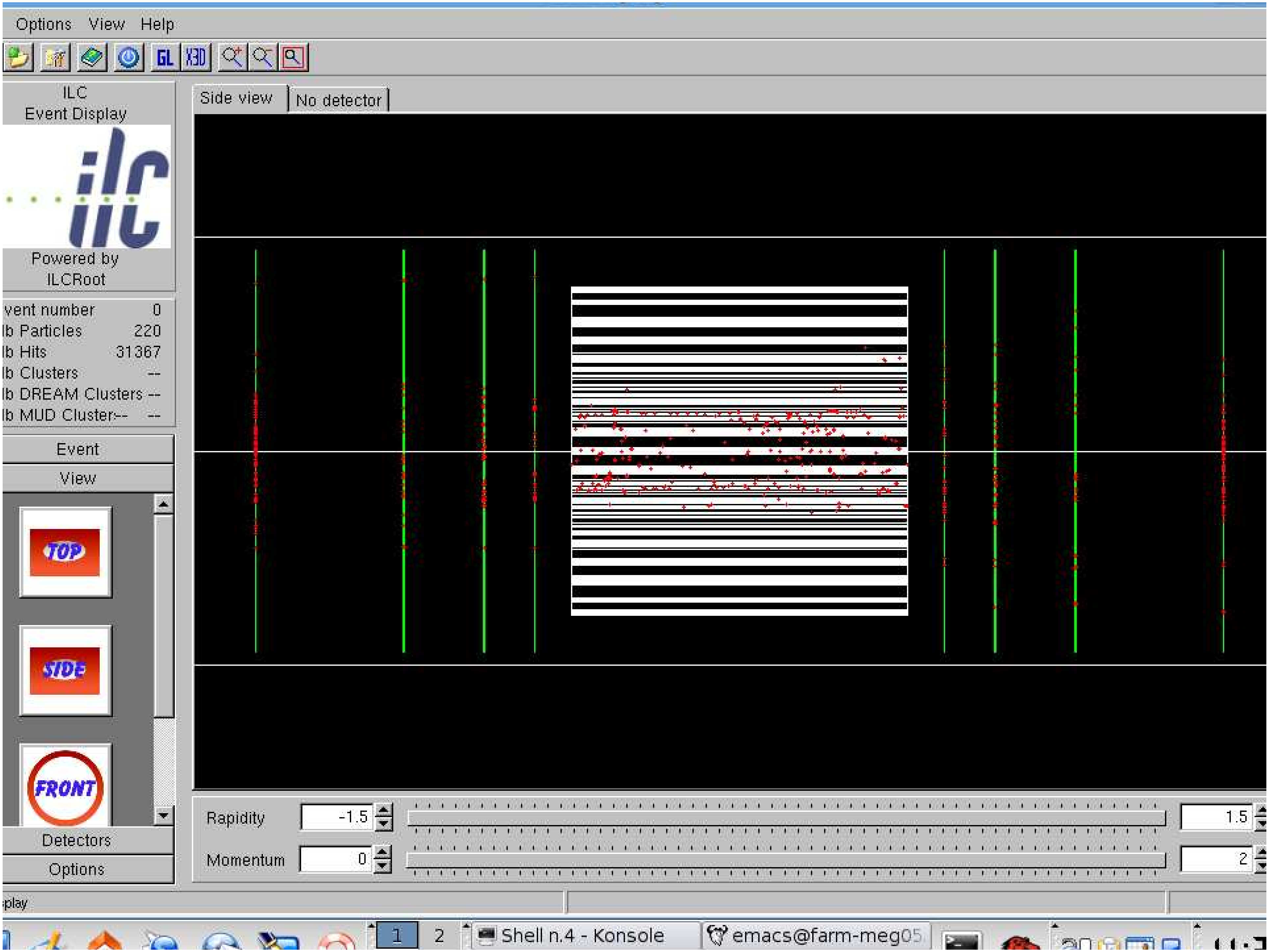
- Study coordinated by Rob Kutsckhe
- Interface to Guinea-Pig output added to ILCroot
- Tested with current SA VXD tracker and generic accelerator parameters
- Full VXD Digitization

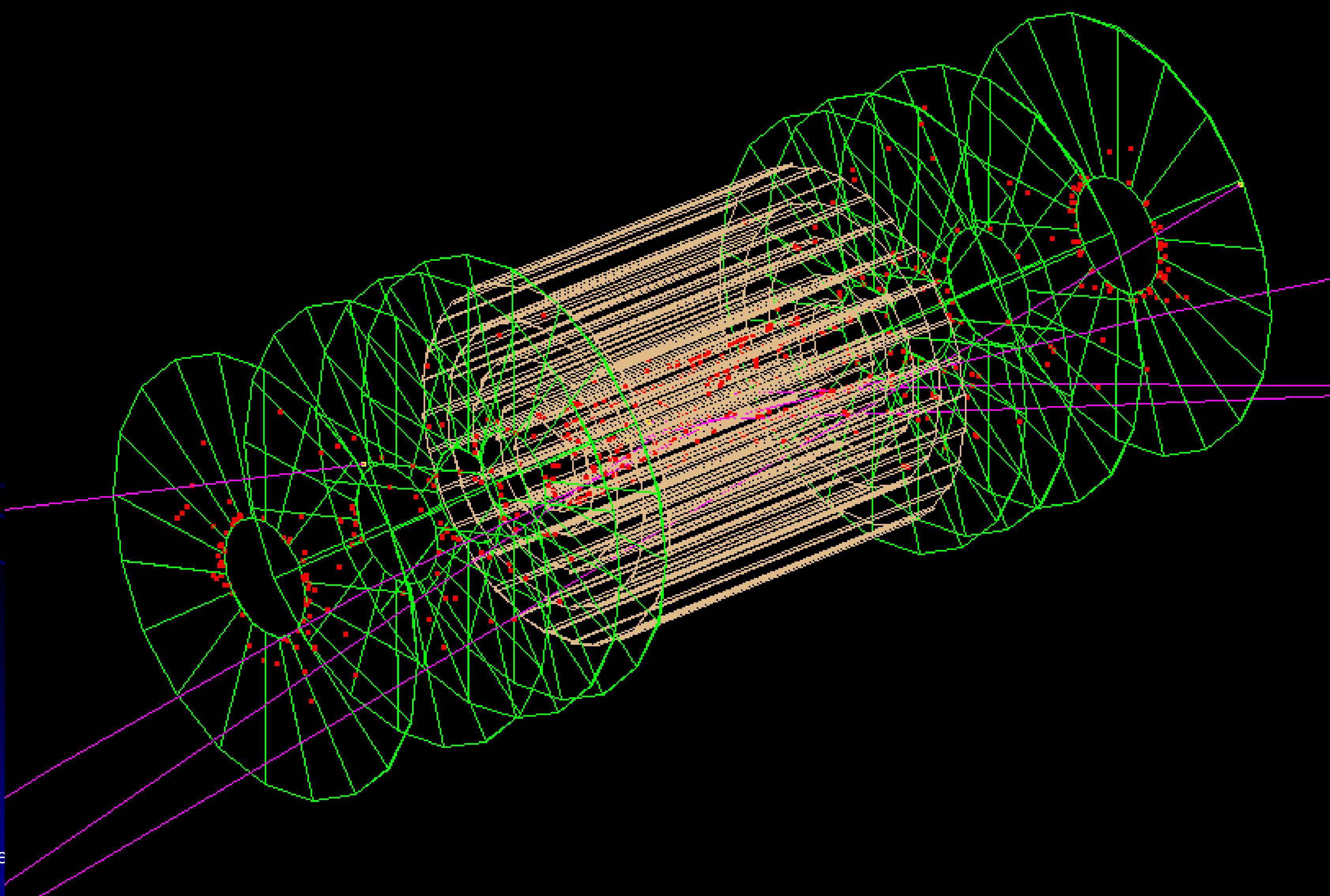
Acc.dat

- $ACCELERATOR:: NLC-B-500
- { energy = 245. ;
- particles = 0.95 ;
- emitt_x = 4.5 ;
- emitt_y = 0.1 ;
- beta_x = 12. ;
- beta_y = 0.12 ;
- sigma_z = 120. ;
- dist_z = 0 ;
- espread = 0.003 ;
- which_espread = 0;
- offset_x = 0 ;
- offset_y = 0. ;
- waist_x = 0 ;
- waist_y = 0 ;
- angle_x = 0 ;
- angle_y = 0 ;
- angle_phi = 0 ;
- trav_focus = 0 ;
- charge_sign = -1;
- }



ILC
ent Display
owered by
ILCRoot
umber 0
ticles 220
31367
sters --
EAM Clusters --
D Cluster-- --
Event
View
Detectors
Options
lay Hits
lay Clusters
lay HLT Clusters
lay DREAM Clust
lay MUD Clusters
lay TRD Clusters
Front view
No detector
Rapidity
-1.5
1.5
Momentum
0
2
Shell n.4 - Konsole
emacs@farm-meg05
Posta :: Inbox - Mozilla
ILC Display
11:35


Options View Help
GL X3D
ILC
Event Display
Powered by
ILCRoot
vent number 0
lb Particles 220
lb Hits 31367
lb Clusters --
lb DREAM Clusters --
lb MUD Cluster-- --
Event
View
TOP
SIDE
FRONT
Detectors
Options
Side view
No detector
Rapidity -1.5 1.5
Momentum 0 2
Shell n.4 - Konsole
emacs@farm-meg05

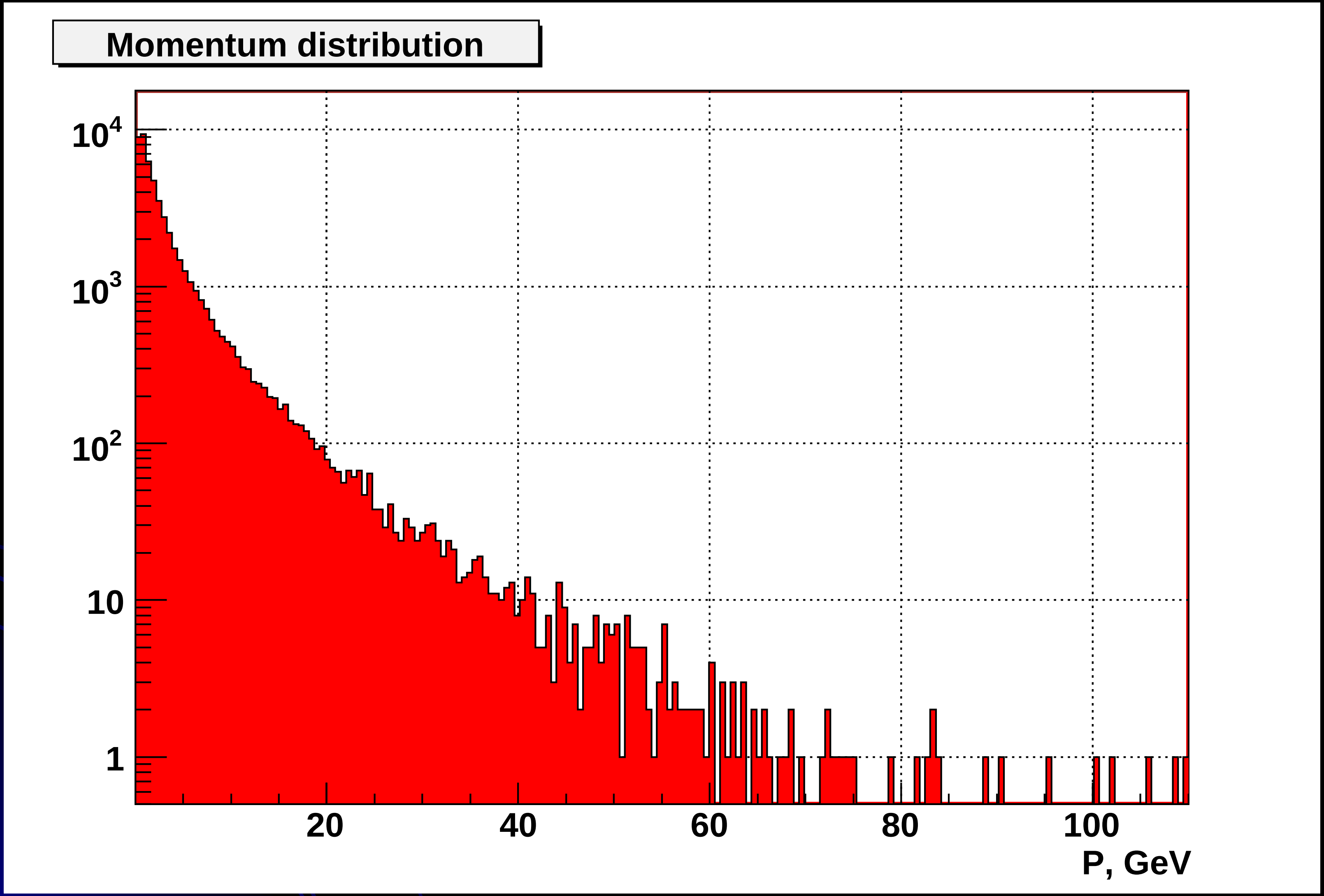


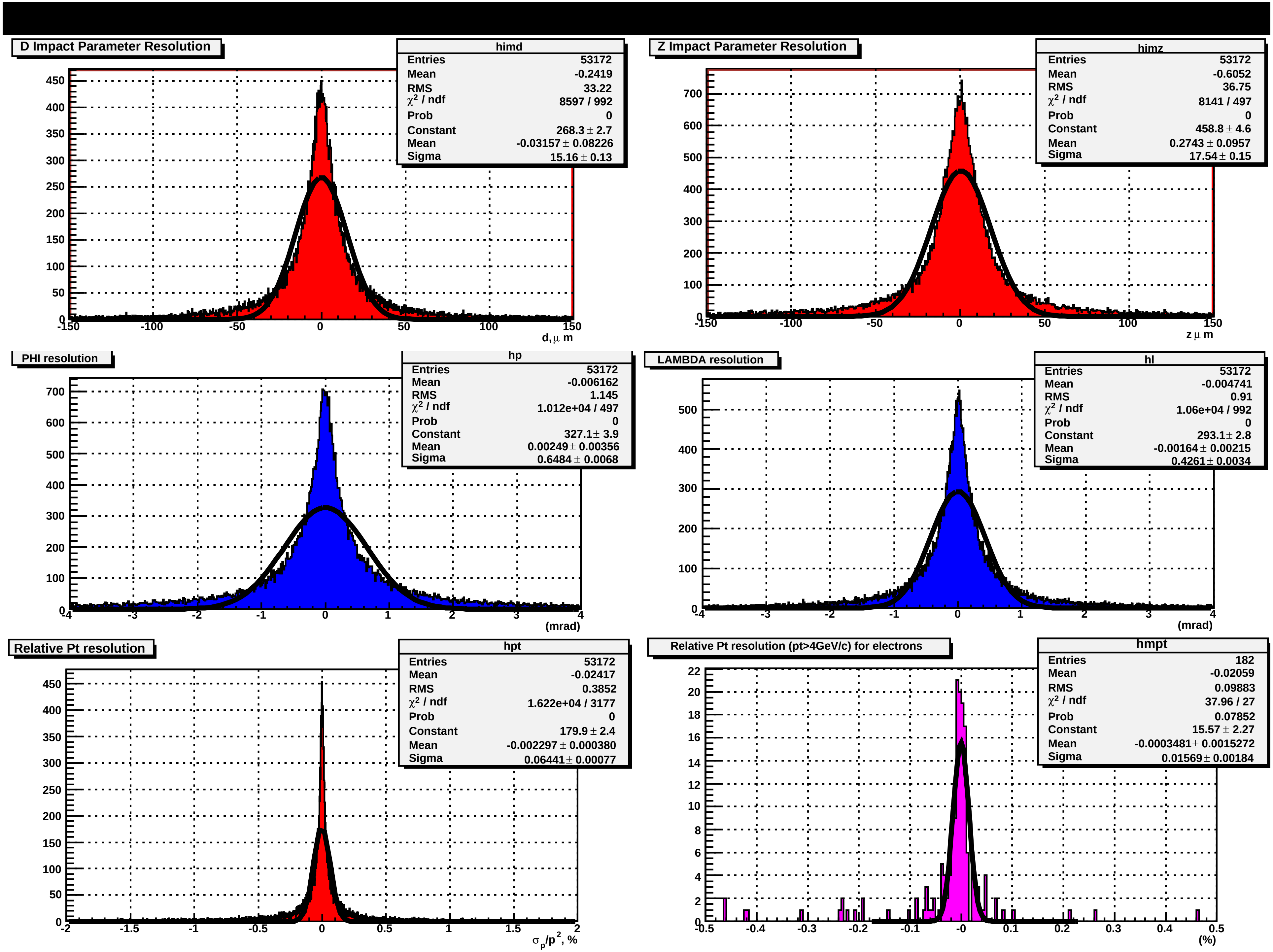
Se

Should we worry?

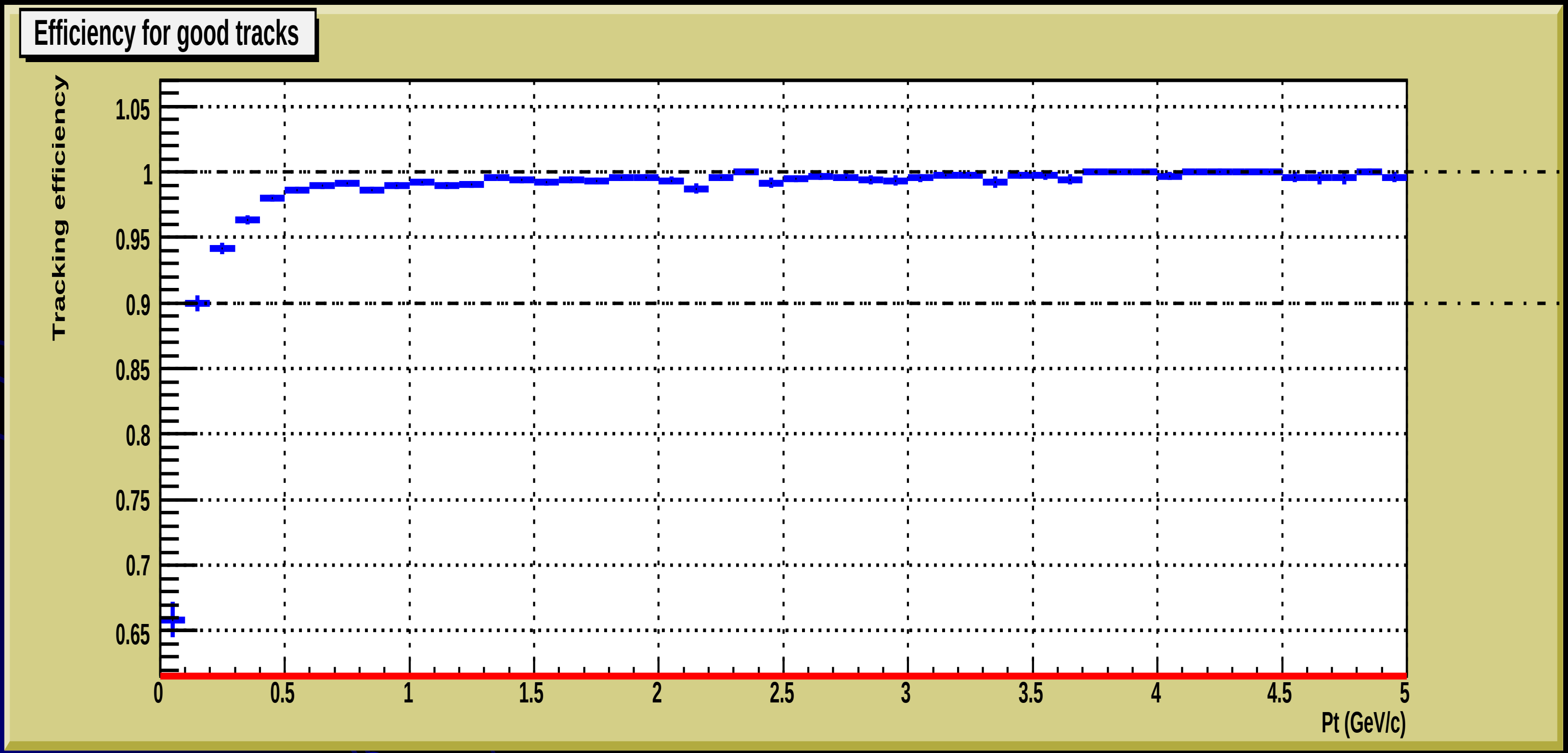
- 31367 hits
- 20 reconstructed particles (8 in TPC)
- Better not to overlook this background
- Will merge SDigit from Signal and Background to evaluate the overall effect

$e^+e^- \rightarrow t\bar{t} \rightarrow 6$ jets



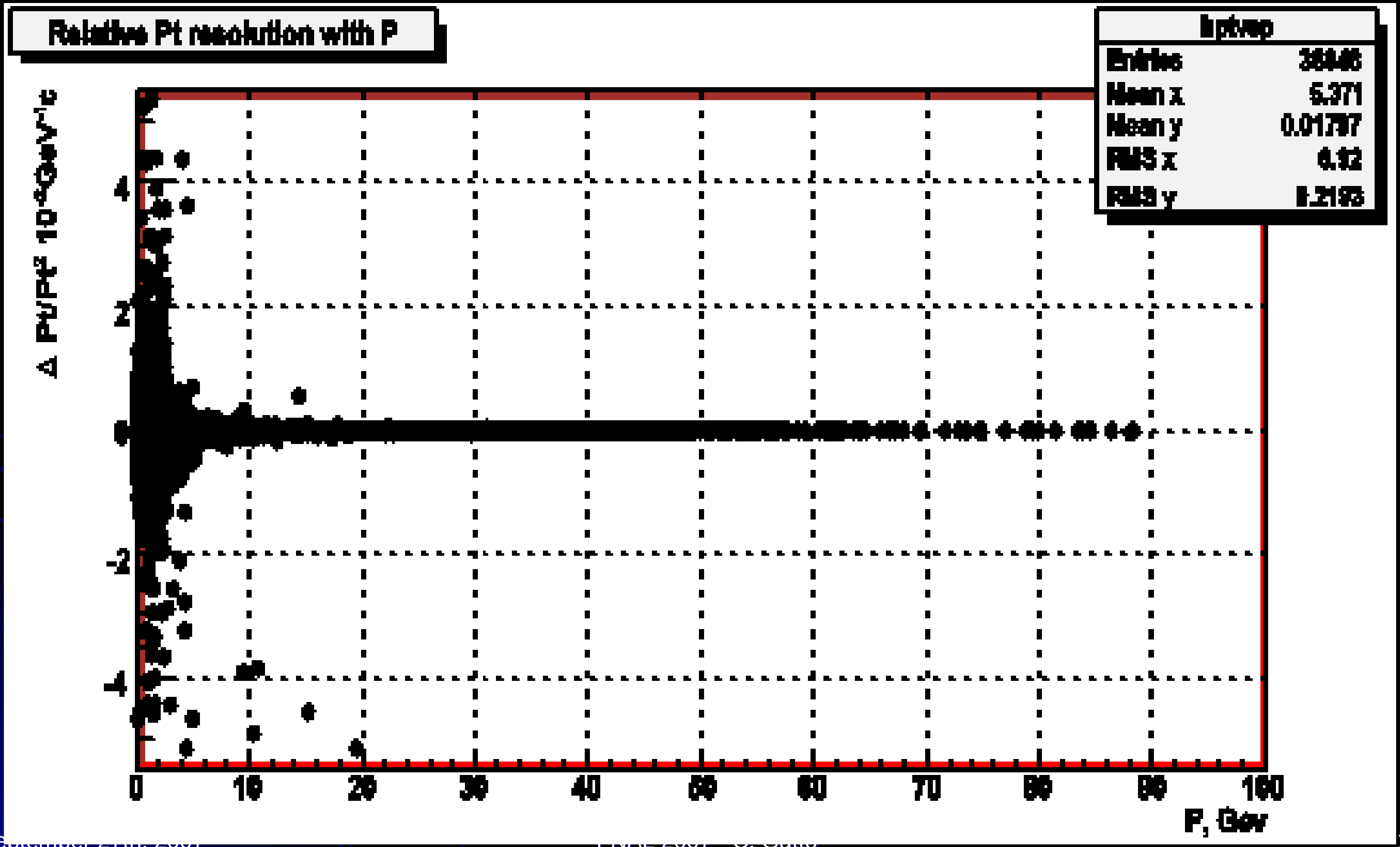

D Impact Parameter Resolution
himd
Entries 53172
Mean -0.2419
RMS 33.22
χ2 / ndf 8597 / 992
Prob 0
Constant 268.3 ± 2.7
Mean -0.03157 ± 0.08226
Sigma 15.16 ± 0.13
d,μ m
Z Impact Parameter Resolution
himz
Entries 53172
Mean -0.6052
RMS 36.75
χ2 / ndf 8141 / 497
Prob 0
Constant 458.8 ± 4.6
Mean 0.2743 ± 0.0957
Sigma 17.54 ± 0.15
z μ m
PHI resolution
hp
Entries 53172
Mean -0.006162
RMS 1.145
χ2 / ndf 1.012e+04 / 497
Prob 0
Constant 327.1 ± 3.9
Mean 0.00249 ± 0.00356
Sigma 0.6484 ± 0.0068
(mrad)
LAMBDA resolution
hl
Entries 53172
Mean -0.004741
RMS 0.91
χ2 / ndf 1.06e+04 / 992
Prob 0
Constant 293.1 ± 2.8
Mean -0.00164 ± 0.00215
Sigma 0.4261 ± 0.0034
(mrad)
Relative Pt resolution
hpt
Entries 53172
Mean -0.02417
RMS 0.3852
χ2 / ndf 1.622e+04 / 3177
Prob 0
Constant 179.9 ± 2.4
Mean -0.002297 ± 0.000380
Sigma 0.06441 ± 0.00077
σp/p2, %
Relative Pt resolution (pt>4GeV/c) for electrons
hmpt
Entries 182
Mean -0.02059
RMS 0.09883
χ2 / ndf 37.96 / 27
Prob 0.07852
Constant 15.57 ± 2.27
Mean -0.0003481 ± 0.0015272
Sigma 0.01569 ± 0.00184
(%)

e^+e^- -> $t\bar{t}$ -> 6 jets

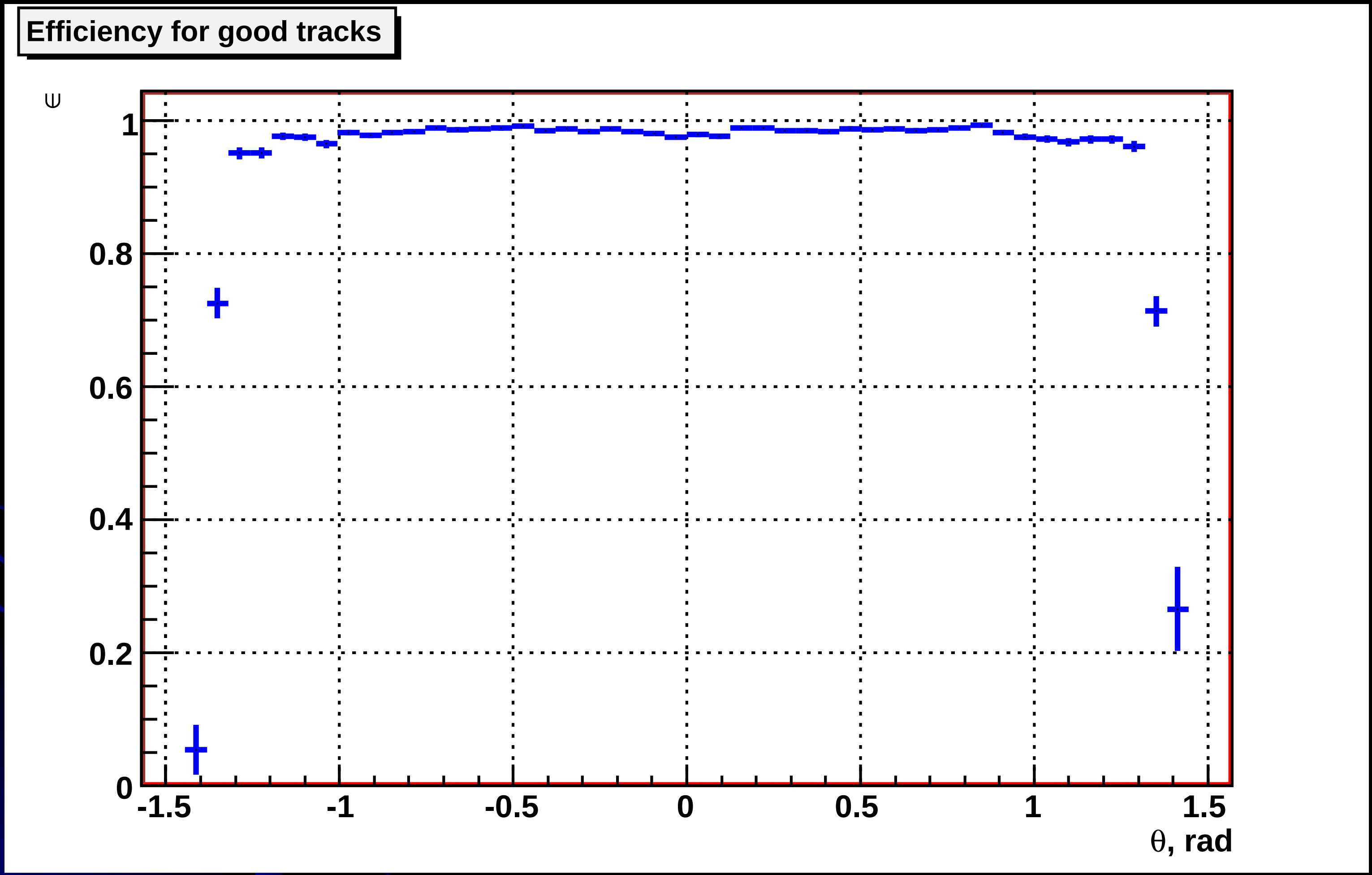


$e^+e^- \rightarrow t\bar{t} \rightarrow 6$ jets

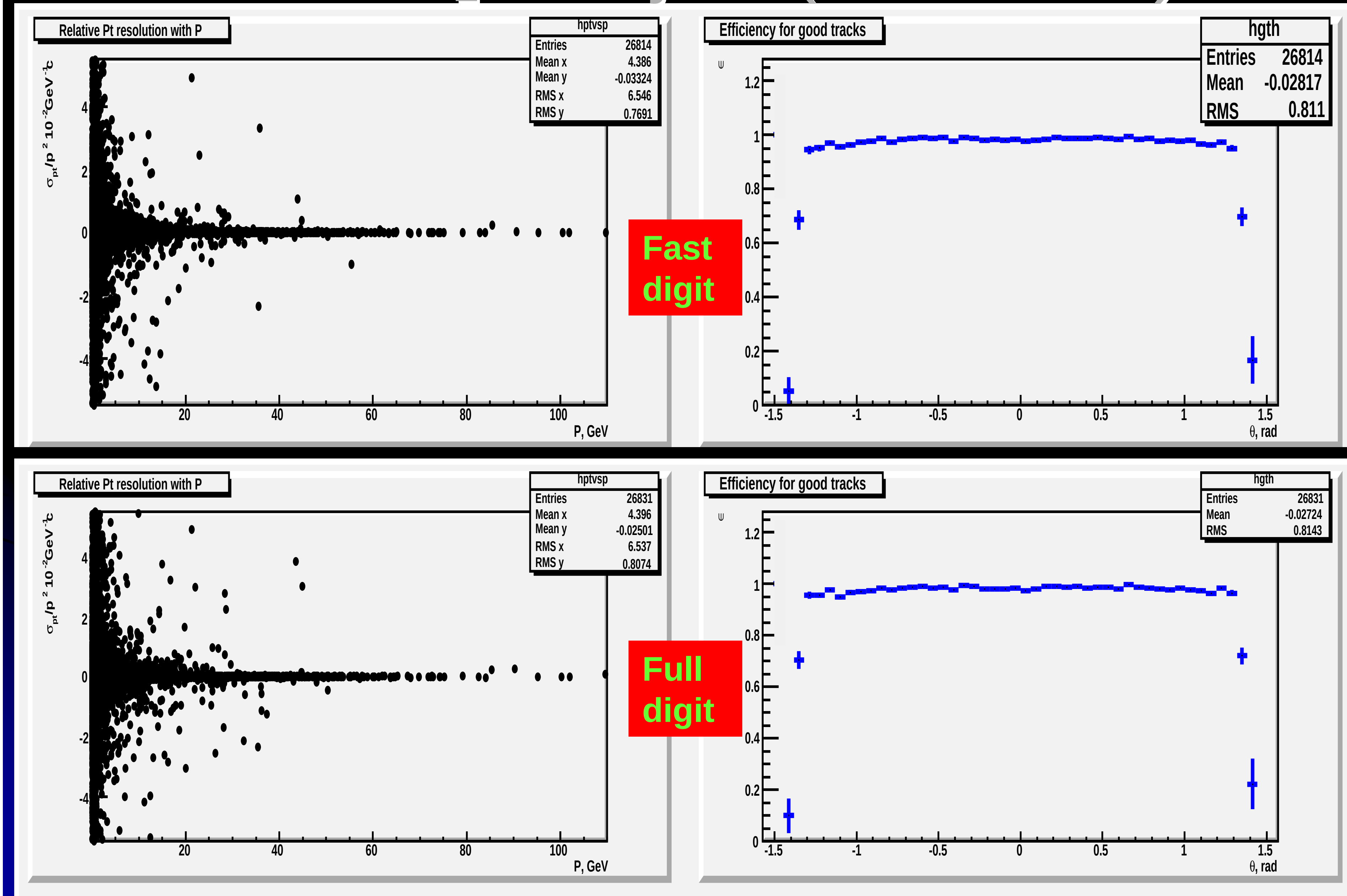
- Relative Pt resolution with P

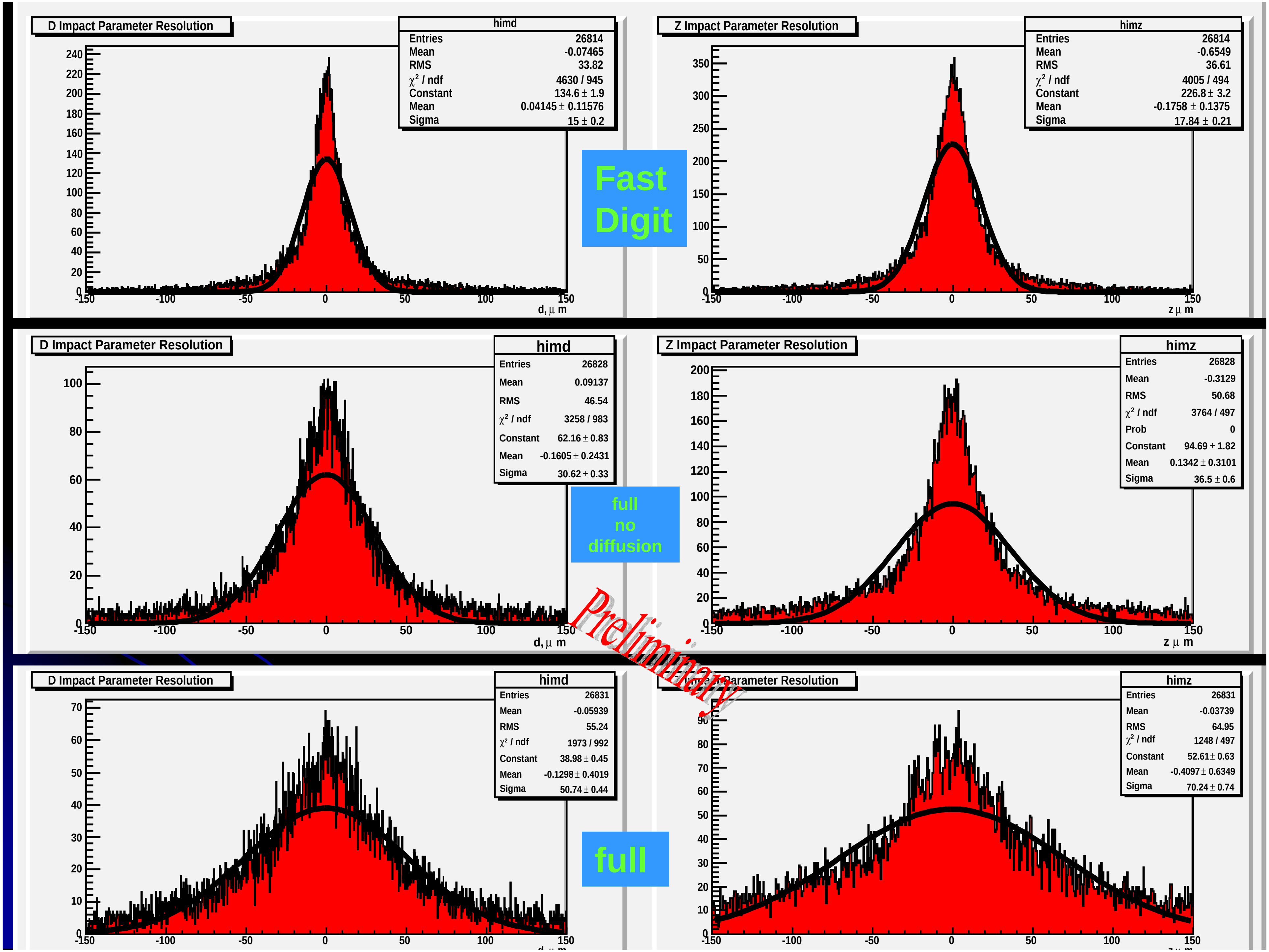


e^+e^- -> $t\bar{t}$ -> 6 jets



$e^+e^- \to t\bar{t} \to$ 6 jets (fast vs full)





D Impact Parameter Resolution
himd
Entries 26814
Mean -0.07465
RMS 33.82
χ² / ndf 4630 / 945
Constant 134.6 ± 1.9
Mean 0.04145 ± 0.11576
Sigma 15 ± 0.2
d, μ m
Z Impact Parameter Resolution
himz
Entries 26814
Mean -0.6549
RMS 36.61
χ² / ndf 4005 / 494
Constant 226.8 ± 3.2
Mean -0.1758 ± 0.1375
Sigma 17.84 ± 0.21
z μ m
Fast Digit
D Impact Parameter Resolution
himd
Entries 26828
Mean 0.09137
RMS 46.54
χ² / ndf 3258 / 983
Constant 62.16 ± 0.83
Mean -0.1605 ± 0.2431
Sigma 30.62 ± 0.33
d, μ m
Z Impact Parameter Resolution
himz
Entries 26828
Mean -0.3129
RMS 50.68
χ² / ndf 3764 / 497
Prob 0
Constant 94.69 ± 1.82
Mean 0.1342 ± 0.3101
Sigma 36.5 ± 0.6
z μ m
full no diffusion
Preliminary
D Impact Parameter Resolution
himd
Entries 26831
Mean -0.05939
RMS 55.24
χ² / ndf 1973 / 992
Constant 38.98 ± 0.45
Mean -0.1298 ± 0.4019
Sigma 50.74 ± 0.44
himz
Entries 26831
Mean -0.03739
RMS 64.95
χ² / ndf 1248 / 497
Constant 52.61 ± 0.63
Mean -0.4097 ± 0.6349
Sigma 70.24 ± 0.74
full

e^+e^- -> $t\underline{t}$ -> 6 jets
Summary of Performance

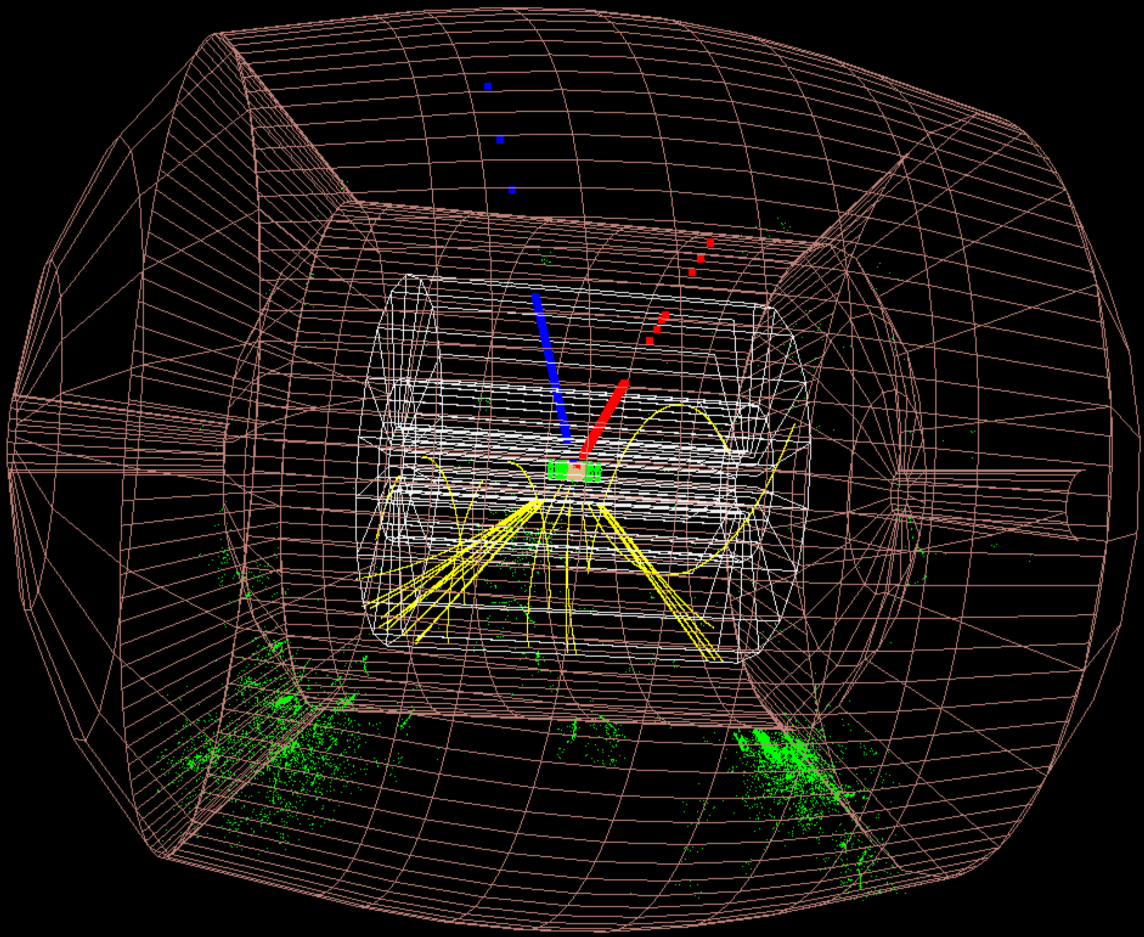
- Tracking efficiency:

  ε_{reco} > 90 % above 100 MeV

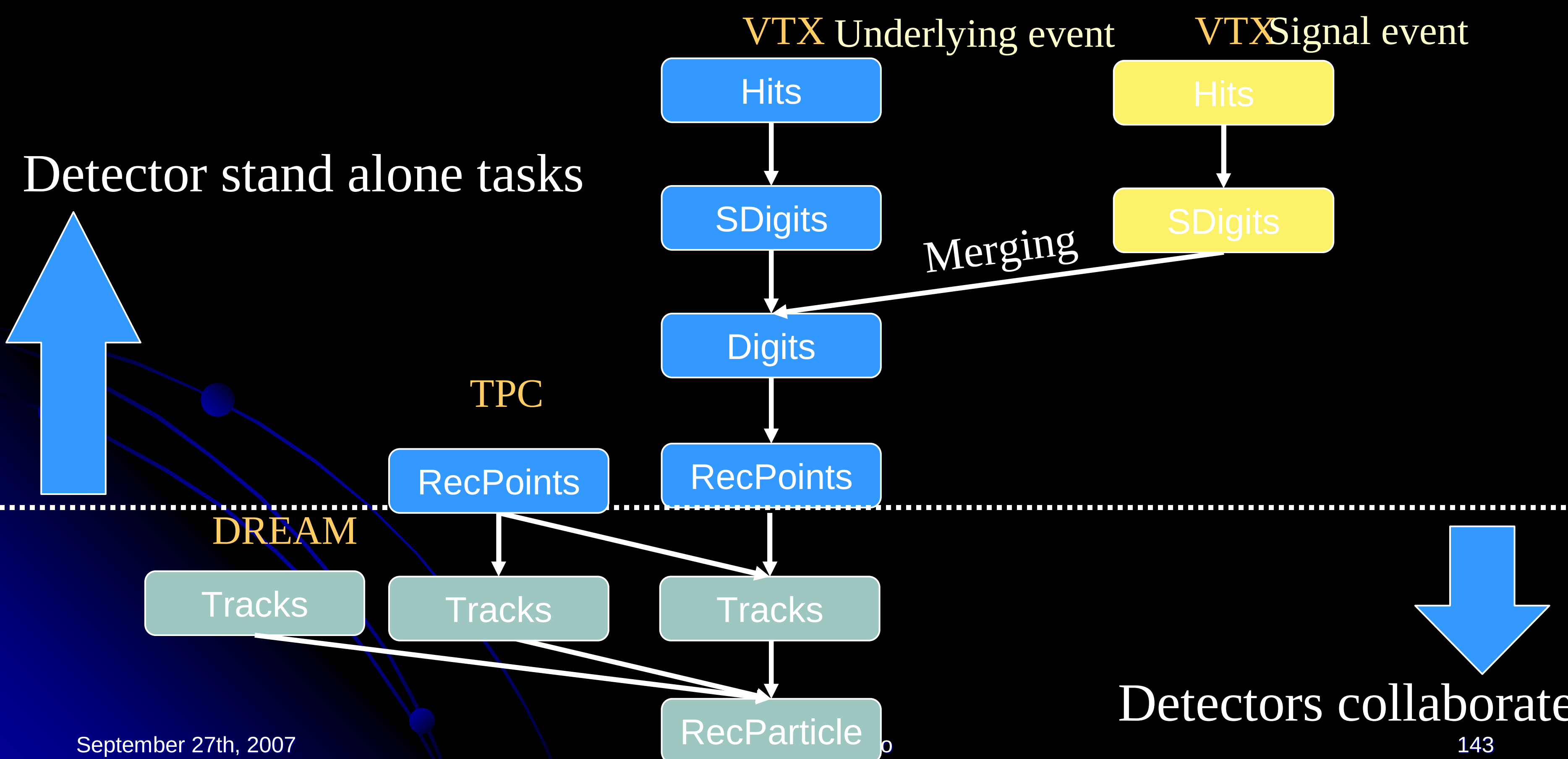
  ε_{reco} = 99.7 % above 1.5 Gev

- TPC + VXD resolution (gaussian smearing):
  - $\sigma(1/p_t) = 6.4\ 10^{-4}$
  - $\sigma(d) = 15\ \mu m$ (> 30 μm with full VXD Digitization)
  - $\sigma(z) = 18\ \mu m$ (> 35 μm with full VXD Digitization)
- Totally dominated by MS

$e^+e^- \rightarrow Z^oH^o \rightarrow \mu^+\mu^-X$



Processing Flow

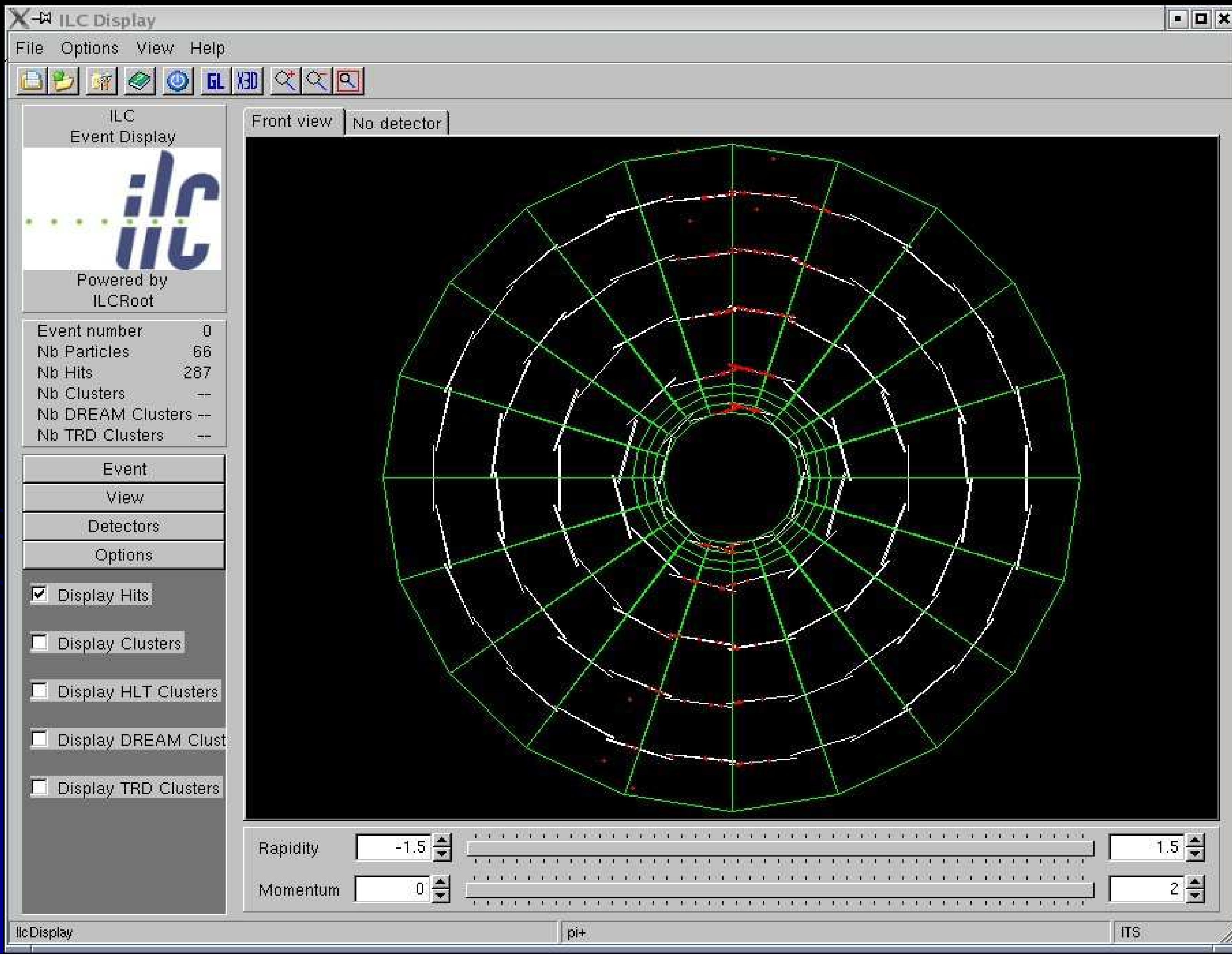


M. Thomson – 11 July 2005

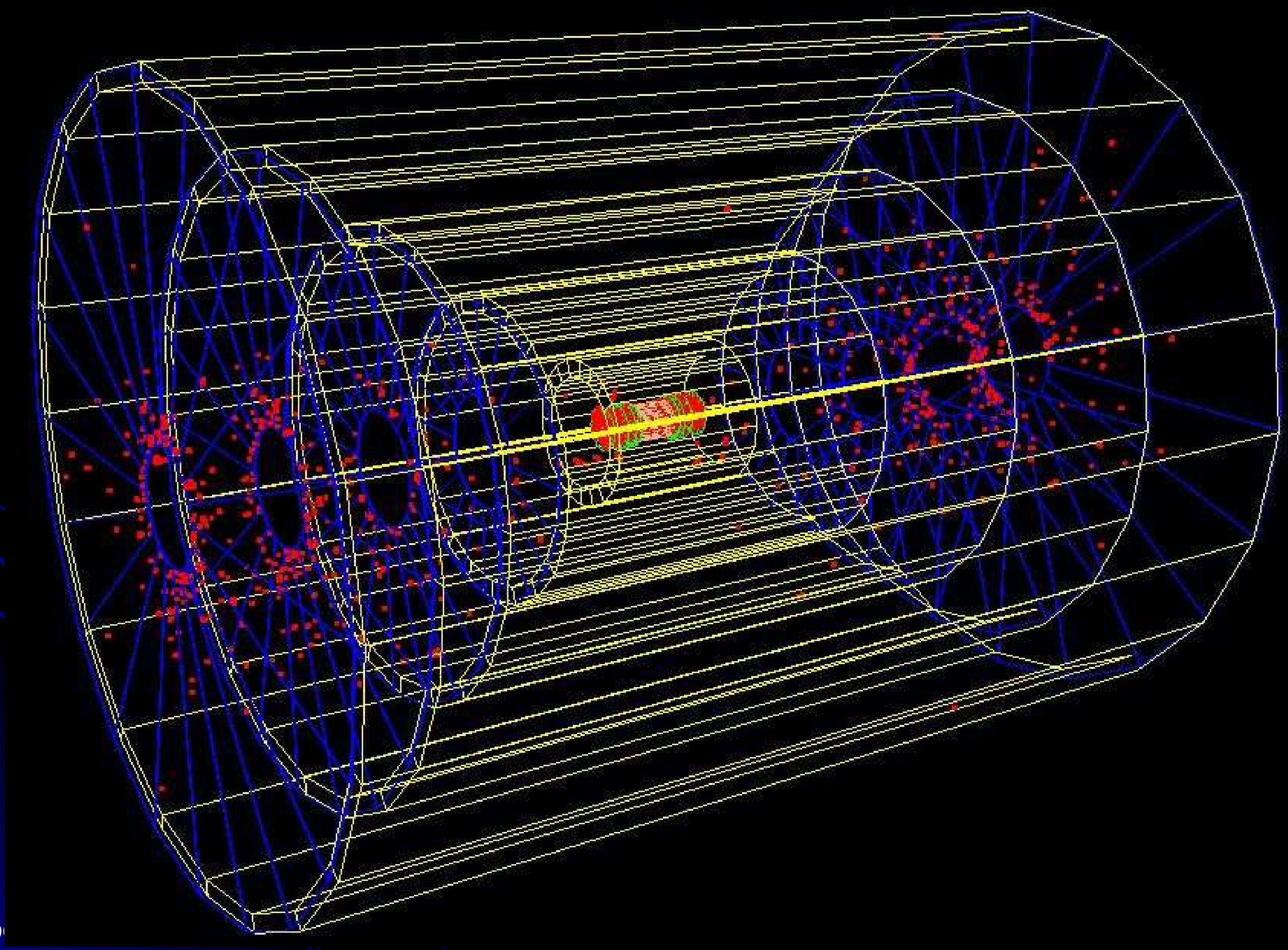
Impact on Detector Design

- **Radiation Hardness does not dictate detector design**
- **Modest timing requirements**
- **Must be able to cope with modest gamma-gamma bgd**
-

VXD Event Display



GuineaPig Event Display



DCH Event Display