4th Concept Detector Performance

Tracking
Calorimetry
Physics Studies

On behalf of 4th Software Group
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4th Concept Software Framework: ILCroot

- Unique 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

Detector Simulation

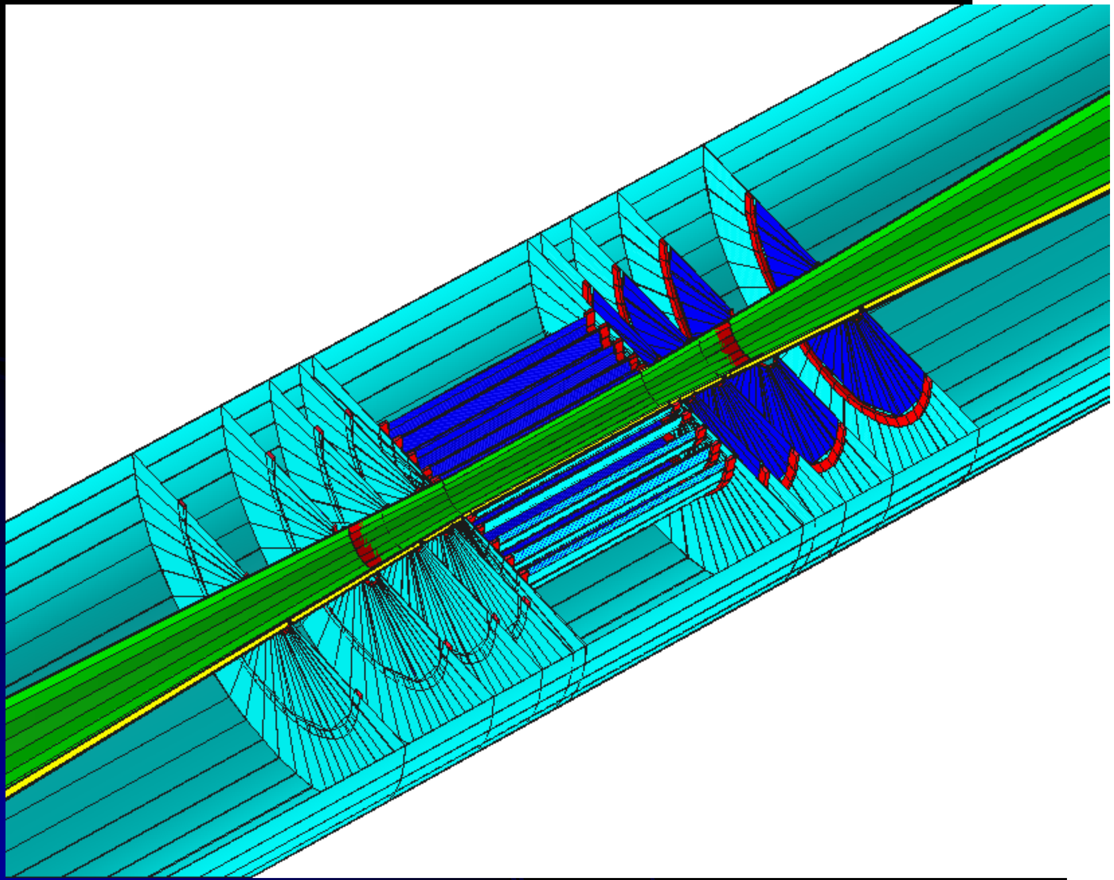
- Full simulation will be in place for the DCR final results
- VXD, TPC and DREAM implemented in the simuation
- Hits using G3, G4 or Fluka (depends on the study)
- SDigits + Digits + Pattern Recognition
- Full Parallel Kalman Filter for track reconstruction (includes kinks and V0)
- PID (no muons)

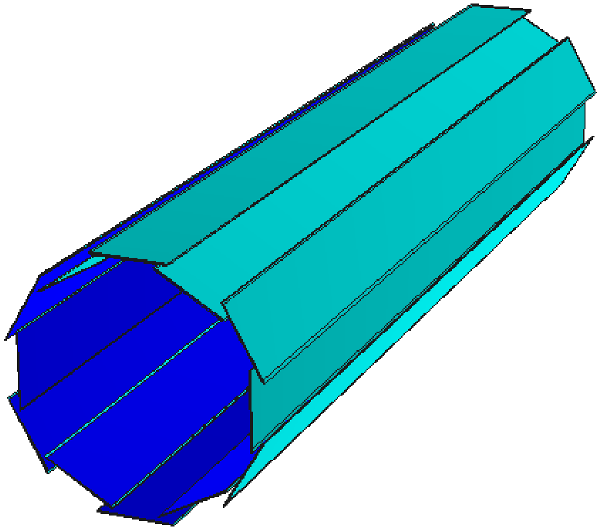
Detector Simulation (2)

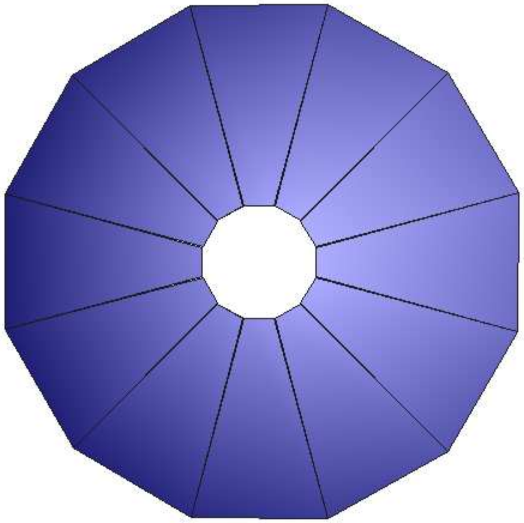
- Studies for Valencia have:
  - SDigits + Digits + Pattern Recognition or DREAM
  - Gaussian smearing for VXD and TPC

Tracking Studies

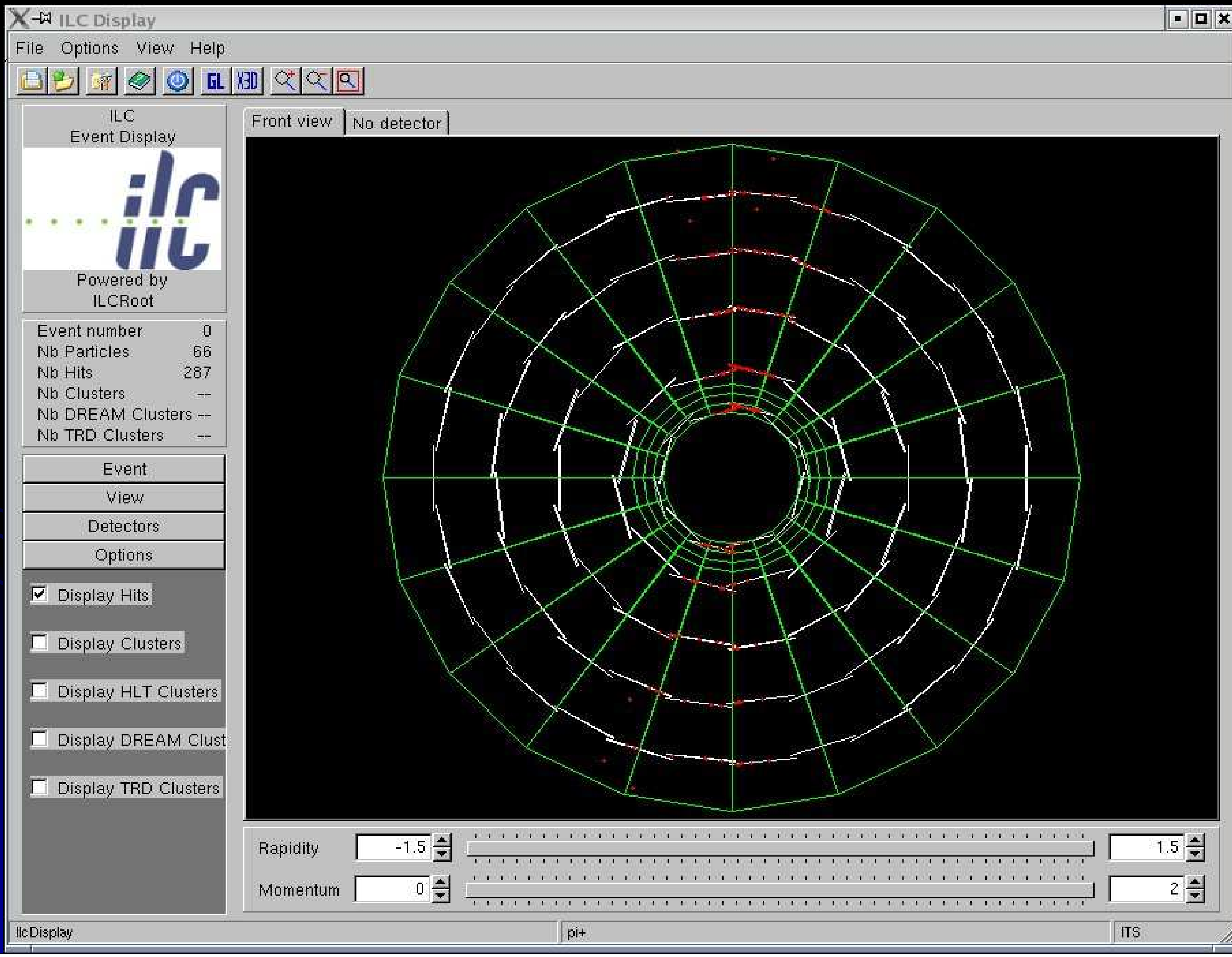
SiD/4th VXD







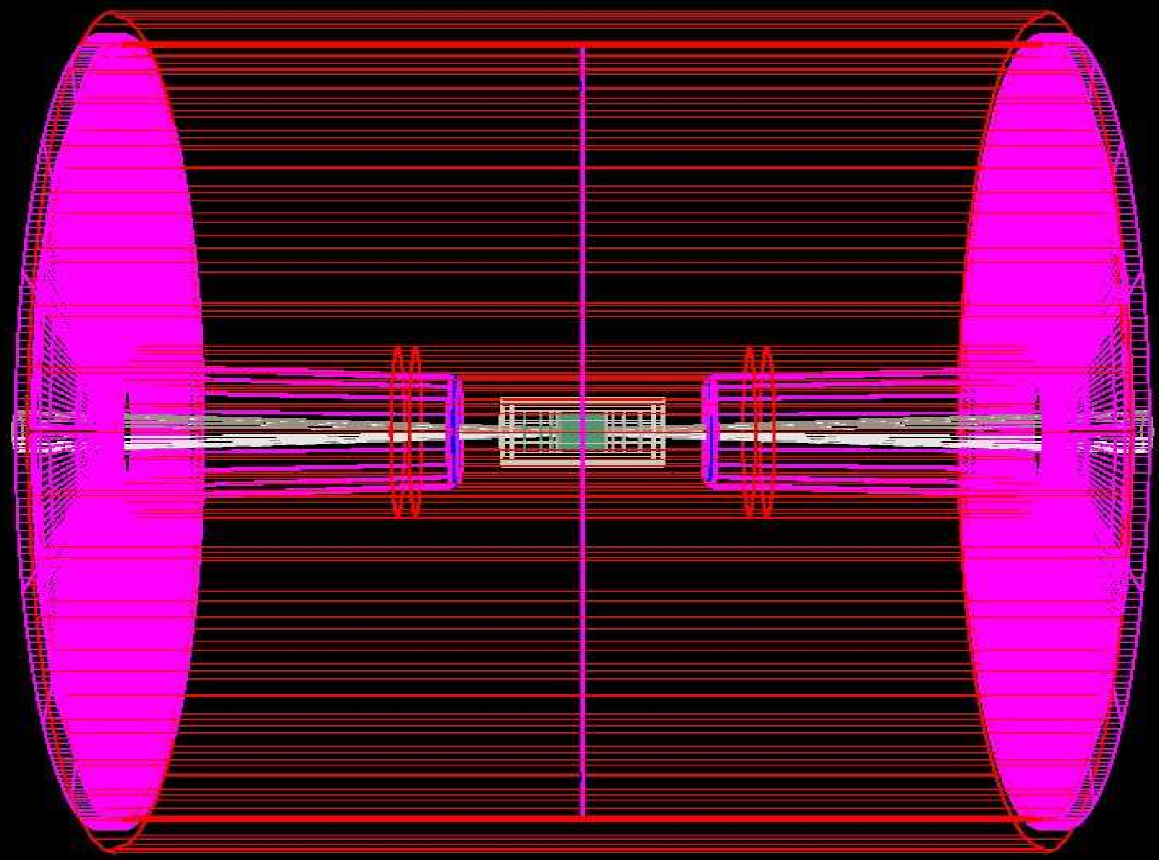
VXD Event Display



VXD Simulation

- Gaussian smearing of hits (5μm x 6 μm)
- Barrel only
- Pattern recognition through Parallel Kalman Filter

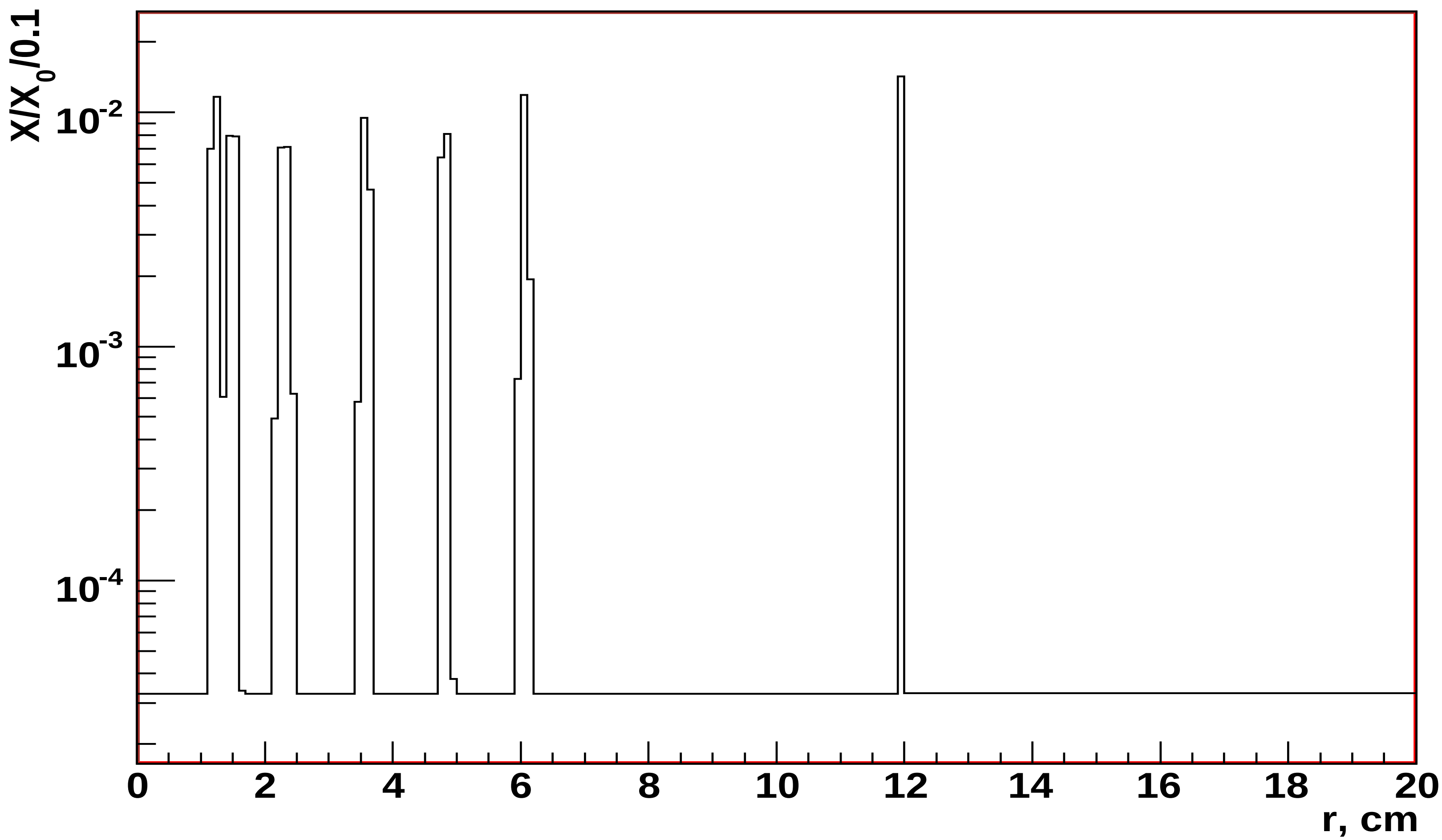
4th Concept TPC



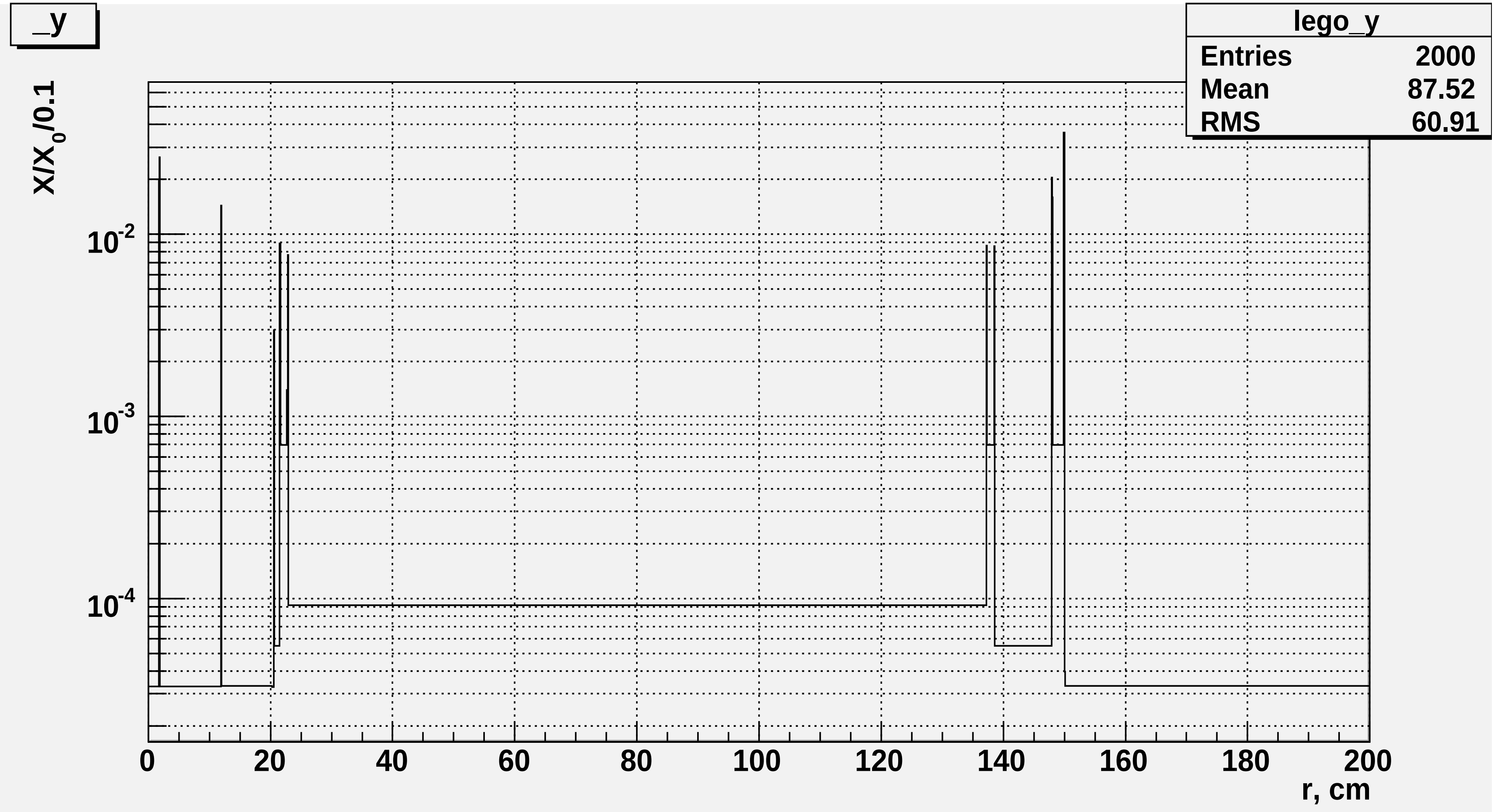
TPC Simulation

- 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

Material Budget (small radii)



Material Budget (overall)



Material Budget (η=0)

- Beam Pipe: 0.18% X/X_o
- VXD:
  - Detector & support: 0.8% X/X_o
  - Outer shield: 0.16% X/X_o
- TPC
  - Gas: 1.3% (along 1.2 m)
  - Vessel:
    - Inner wall + cage: 0.29% X/X_o
    - Outer wall: 1.2% X/X_o
    - Endcaps (wires, pads,electronics & services included): 54% X/X_o

Tracking Resolution (perfect read-out)

- Full Kalman Filter with 150 measurements
- TPC alone: $\sigma(1/p_t) = 1 \times 10^{-4}$
- TPC + VXD: $\sigma(1/p_t) = 0.5 \times 10^{-4}$
- Beam constraint makes no further improvements

TPC Pads Simulation (fast)

Sigma of cluster COG position determination

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

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

50 µm

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

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

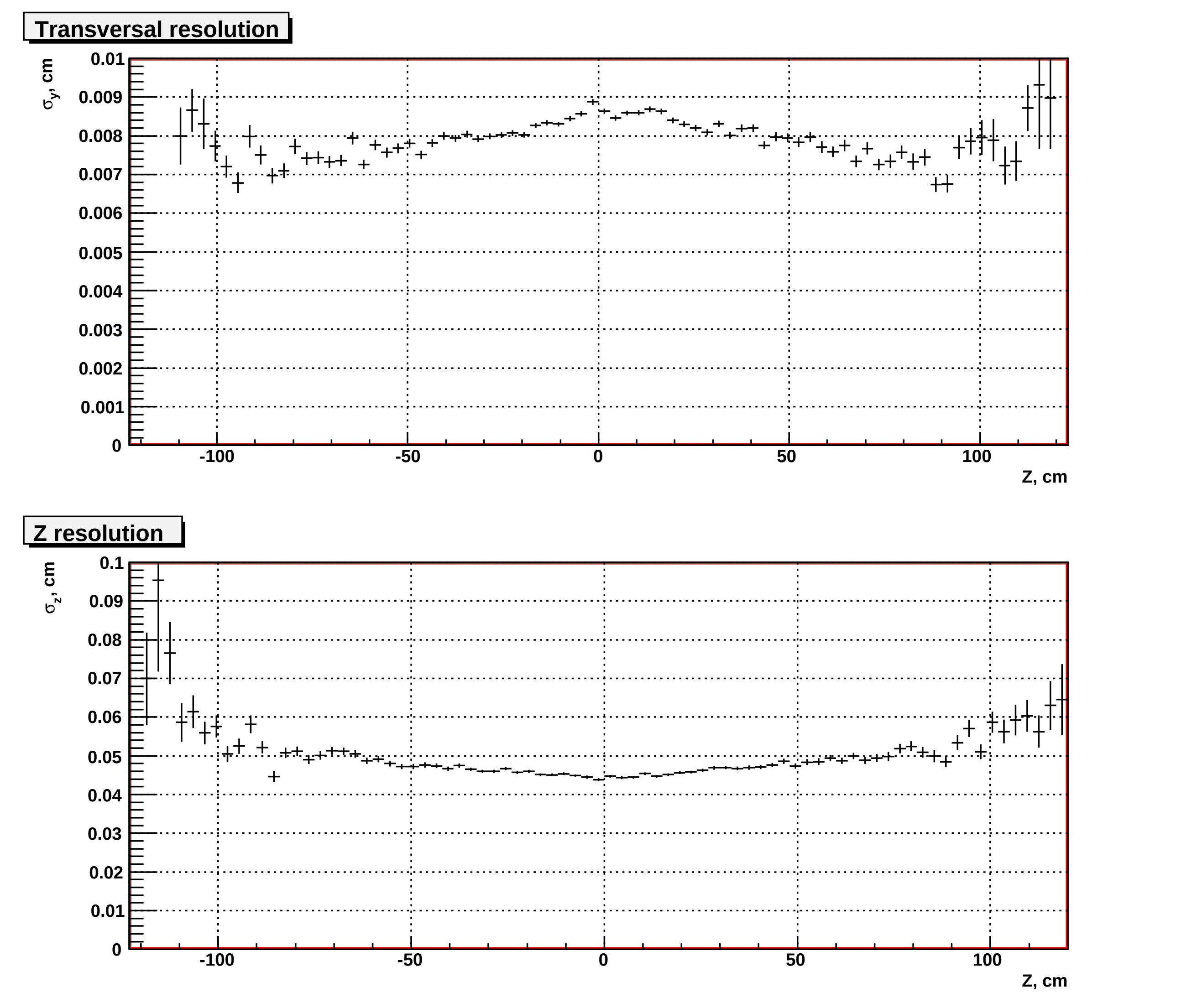
N_{ch} - total number of electrons in cluster
N_{chprim} - number of primary electrons in cluster
G_g - gas gain fluctuation factor
G_{Landau} - secondary ionization fluctuation factor

Gas Related Uncertainties

- In Ar-CF4 with 4th Concept Geometry:
- σ = 200-250 μm/electron
- Integrating over 1 cm corresponds to: σ =36-45 μm

- Useless to read out with an uncertainty much less than that
- MuMegas in the 4th Concept correspond to about 3 μm in 1 cm (average 27 points/cm@55 μm /$\sqrt{12}$)

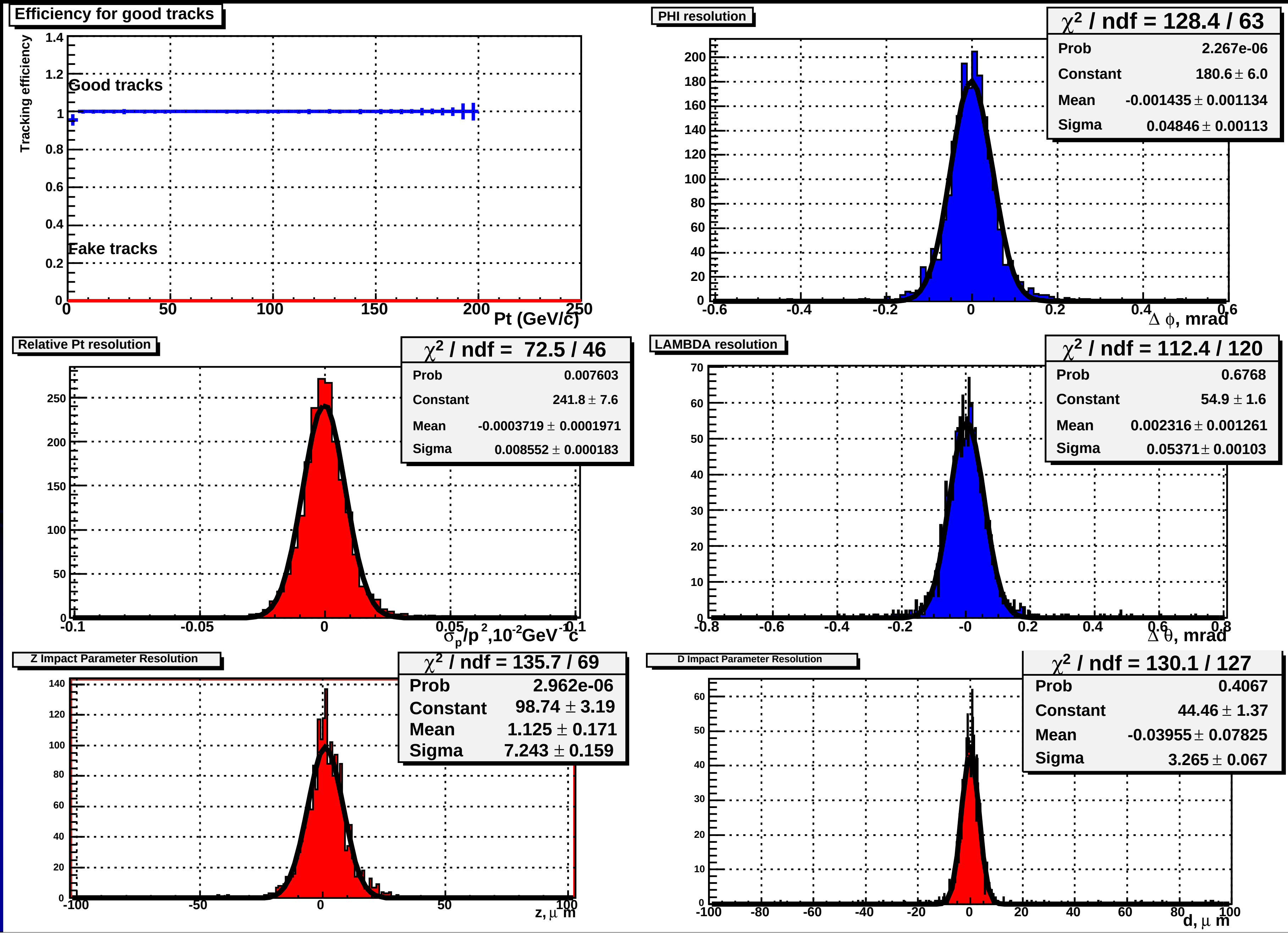
TPC space resolution (pads readout)



Includes 50μm constant term

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

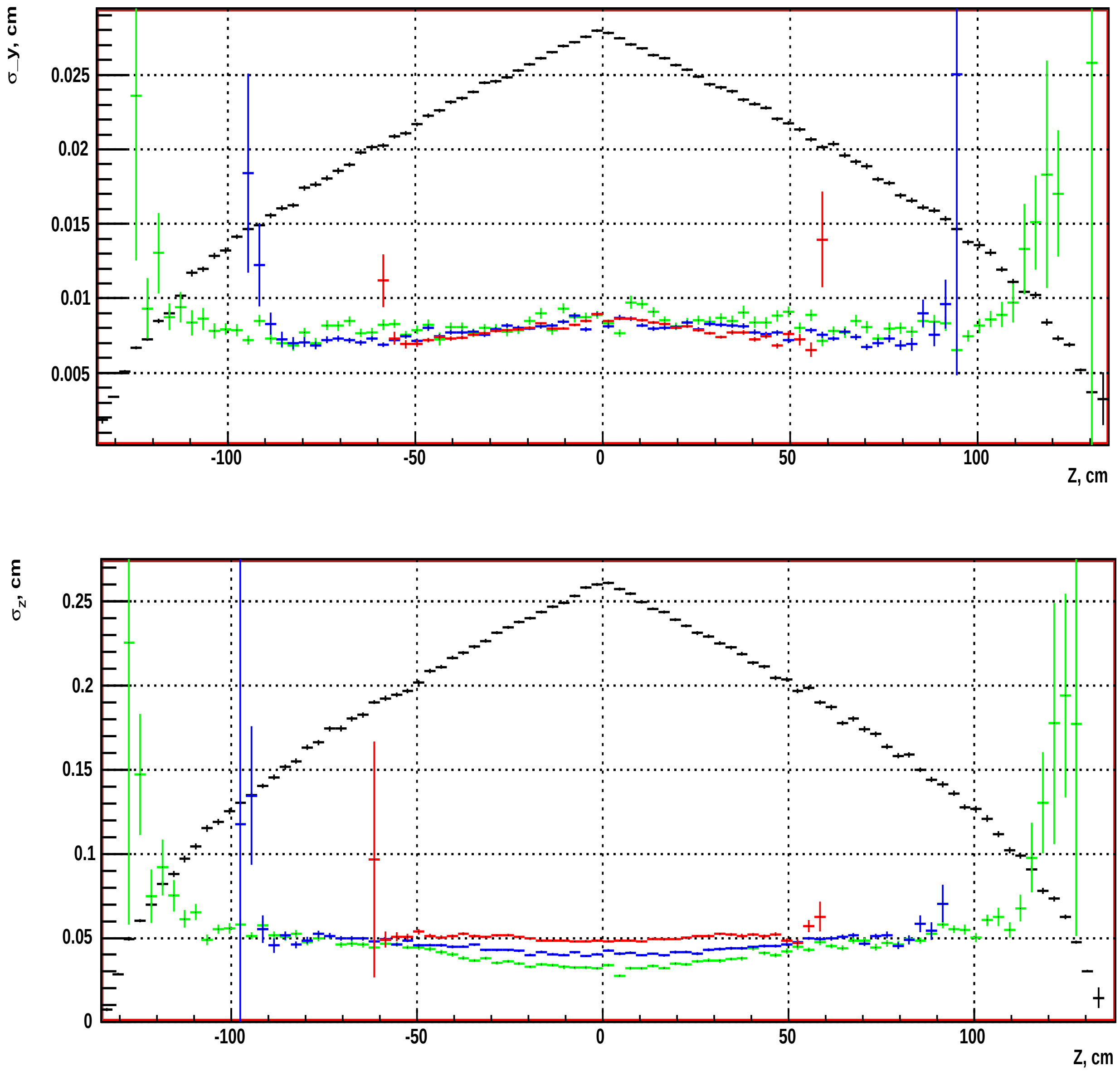
Tracking Resolution (TPC pads read-out)



Tracking Resolution (pads read-out)

- **Using 10 muons 0.5-200 GeV and $|\tan(\theta)|<0.9$**
- Average pads resolution: 40-70 μm $\oplus$ 50 μm (gas statistis $\oplus$ pad resolution $\oplus$ const. term)
- Full Kalman Filter with 150 measurements
- TPC alone: $\sigma(1/p_t) = 2 \times 10^{-4}$
- TPC + VXD:
  - $\sigma(1/p_t) = 0.9 \times 10^{-4}$
  - $\sigma(d) = 3.3\ \mu m$
  - $\sigma(z) = 7.2\ \mu m$
- Efficiency refers to tracks with at least 30 hits in the TPC (r_{min} ~ 40 cm or ~0.38 Gev)

TPC Total Resolution



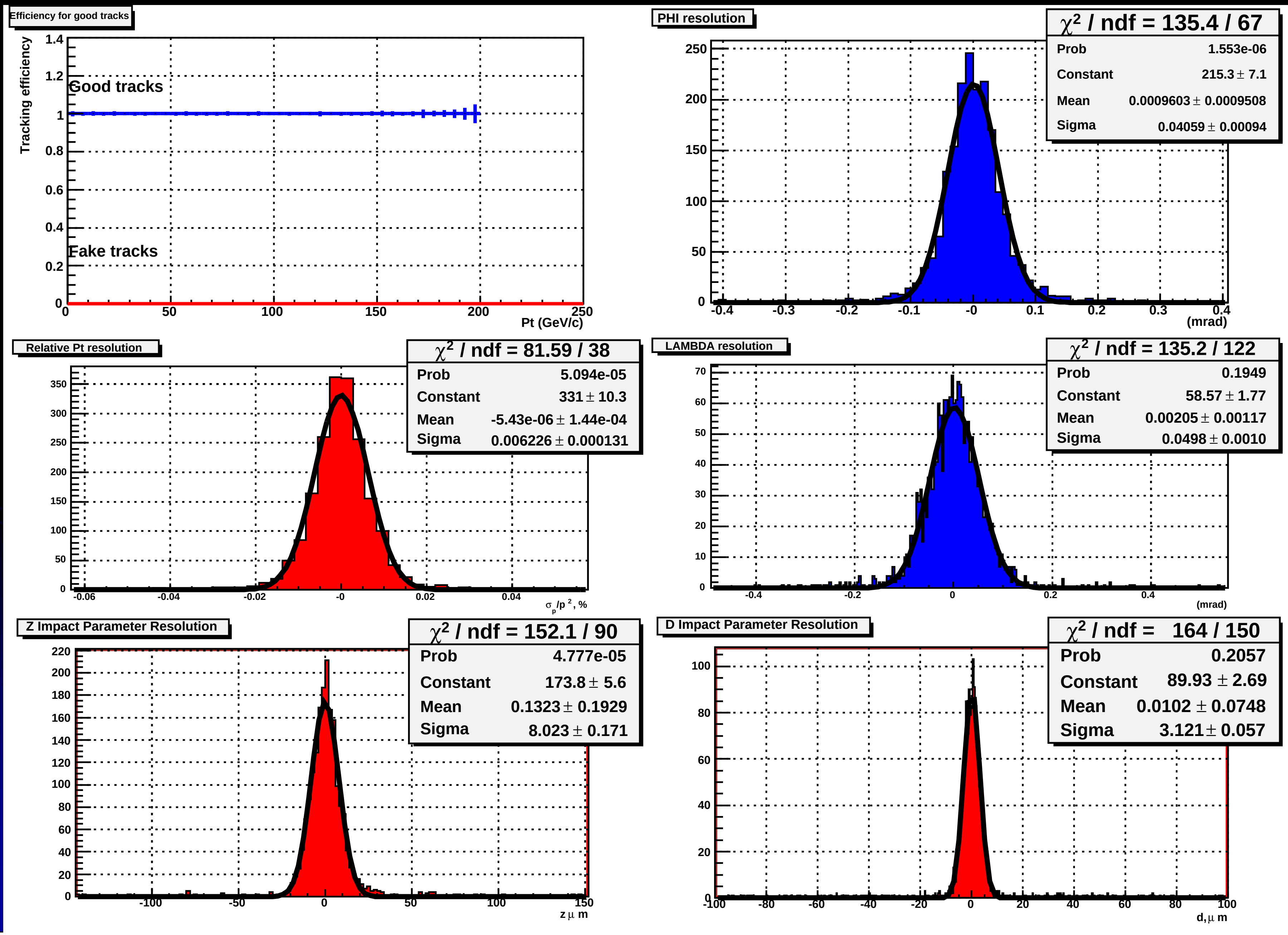
- outer pads
- intermediate pads
- inner pads

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

Tracking Resolution (TPC pads + MuMegas)

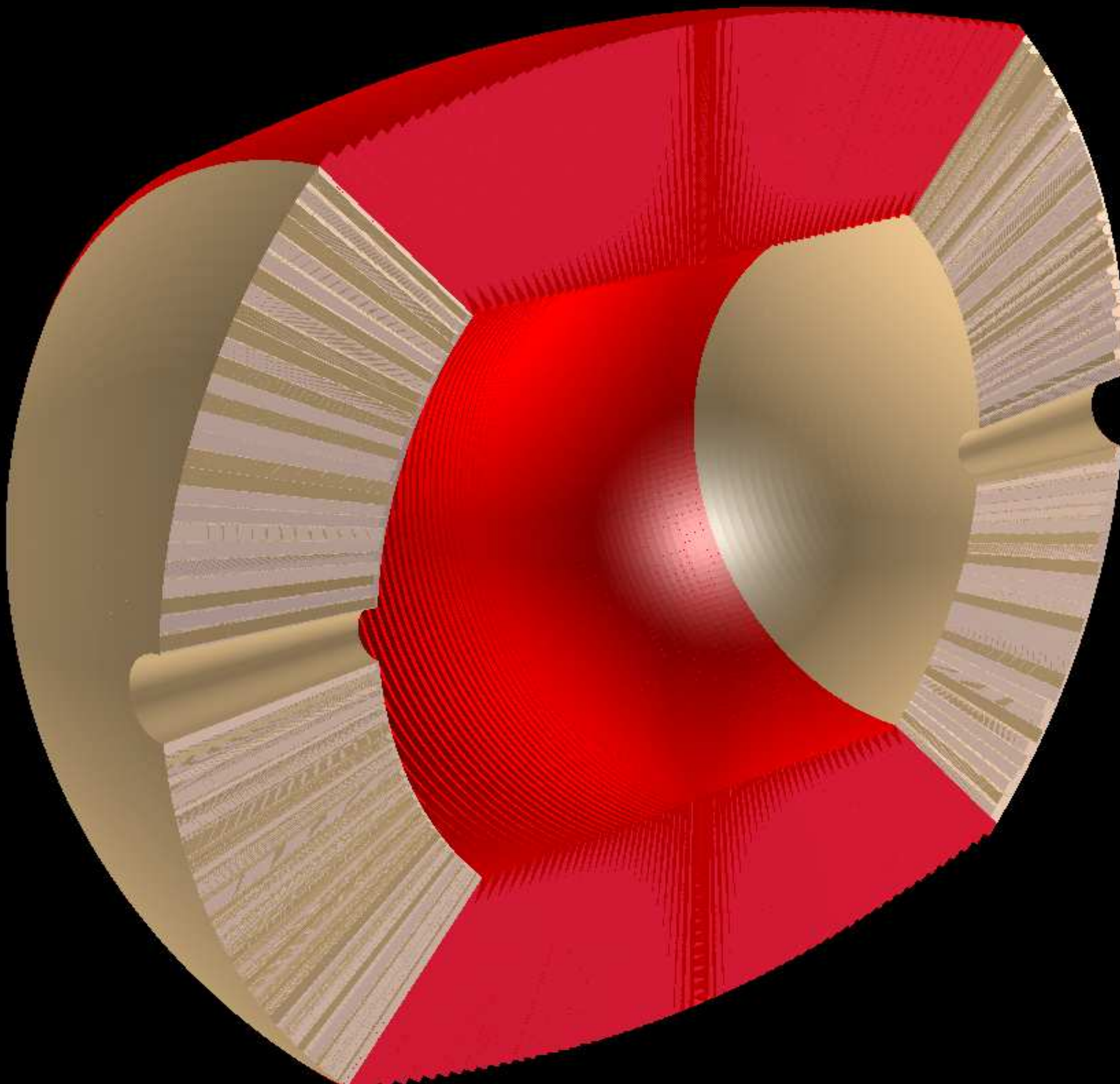


Tracking Resolution (pads + MuMegas read-out)

- Using 10 muons/evt 0.5-200 GeV and $|\tan(\theta)|<0.9$
- Full Kalman Filter with 150 + 5 x ~90 measurements
- TPC + VXD:
  - $\sigma(1/p_t) = 0.6 \times 10^{-4}$
  - $\sigma(d) = 3.1\ \mu m$
  - $\sigma(z) = 8.0\ \mu m$
- Efficiency refers to tracks with at least 30 hits in the TPC (r_{min} ~ 40 cm or ~ 0.38 Gev)
- Efficiency for low Pt tracks improves noticebly

Calorimetry Studies

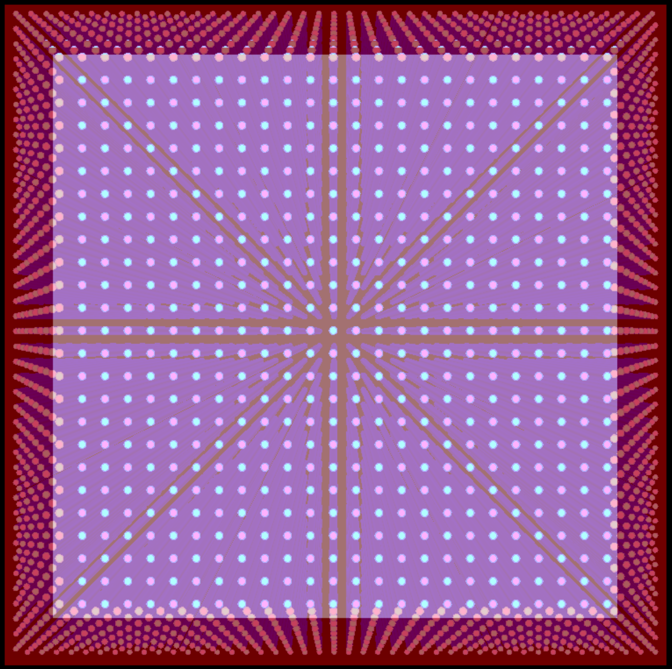
DREAM



DREAM Simulation

- 1.5m Cu + scintillating fibers + Cerenkov fibers
- ~ 10 λ
- Fully projective geometry
- ~1.5° aperture angle
- Azimuth coverage down to 3.4°
- Barrel: 13924 cells (236 slices containing 59 cells)
- Endcaps: 3164 cells arranged in 27 rings

DREAM Cells



Bottom view of
single cell

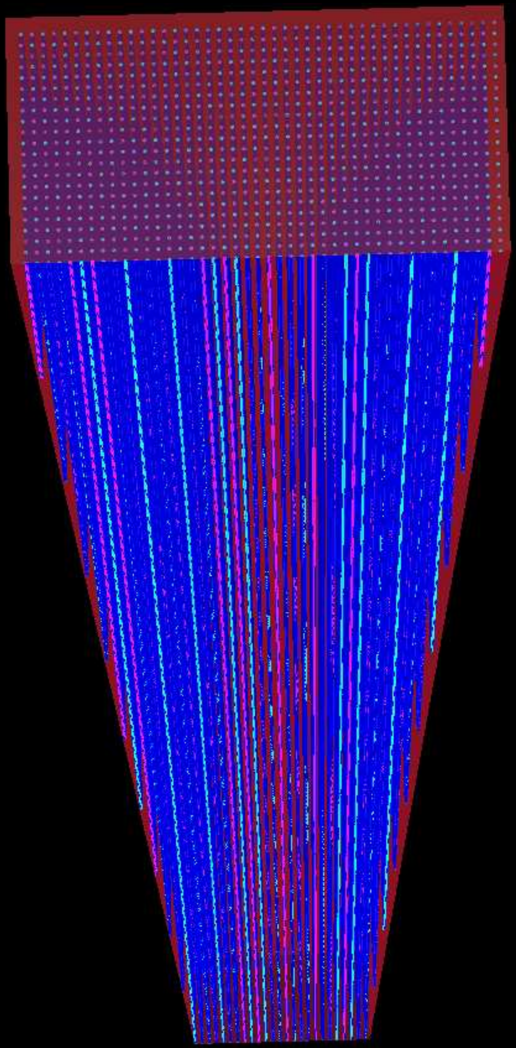
Bottom cell size:
~2 cm

Top cell
size: ~ 4 cm

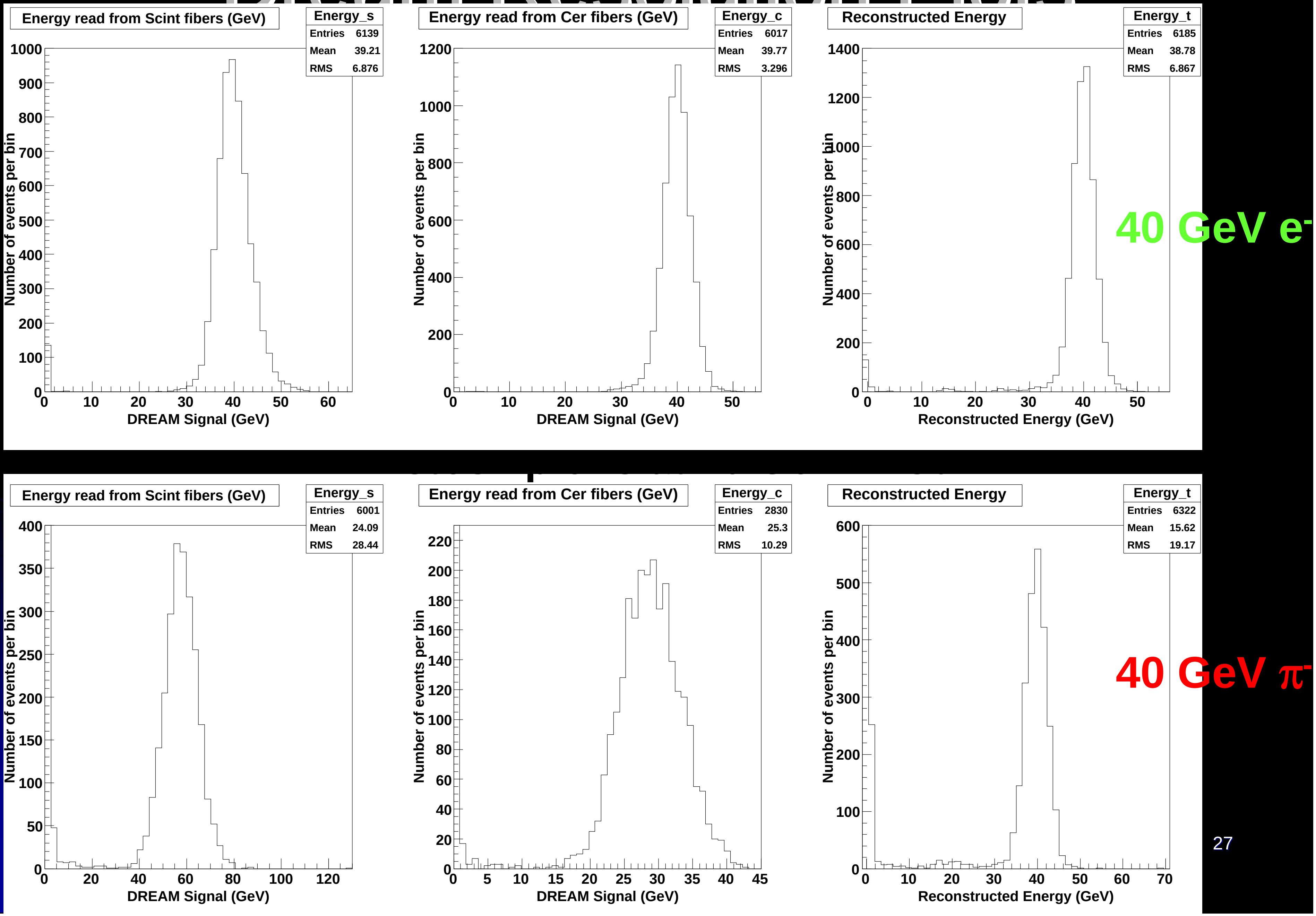
- Number of fibers inside each cell: 1980
equally subdivided between Scintillating and Cerenkov
Fiber stepping ~2 mm

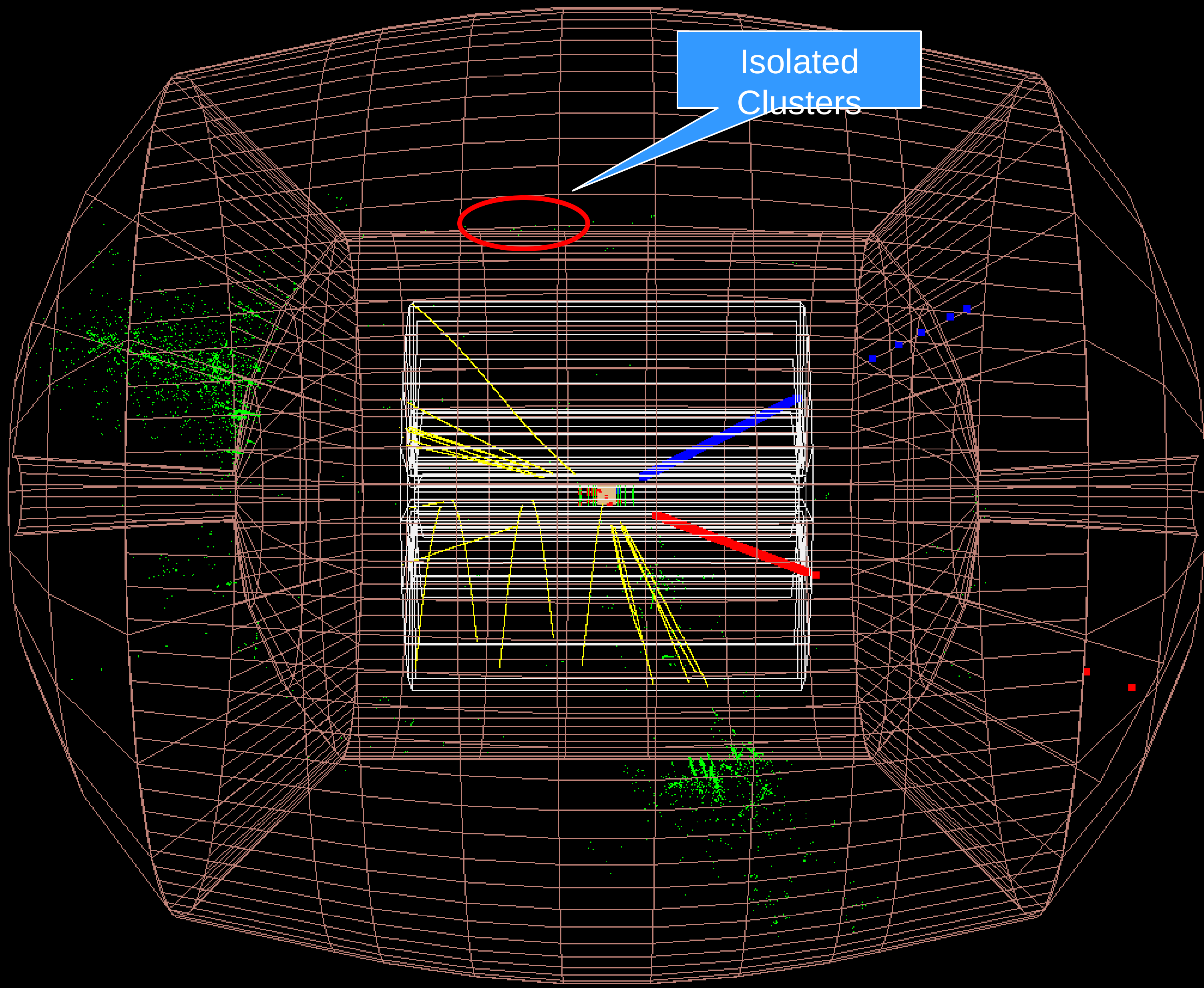
Prospective view of
clipped cell

Cell length:
150 cm (but DoD
has 100cm)



Dream Resolution Plots

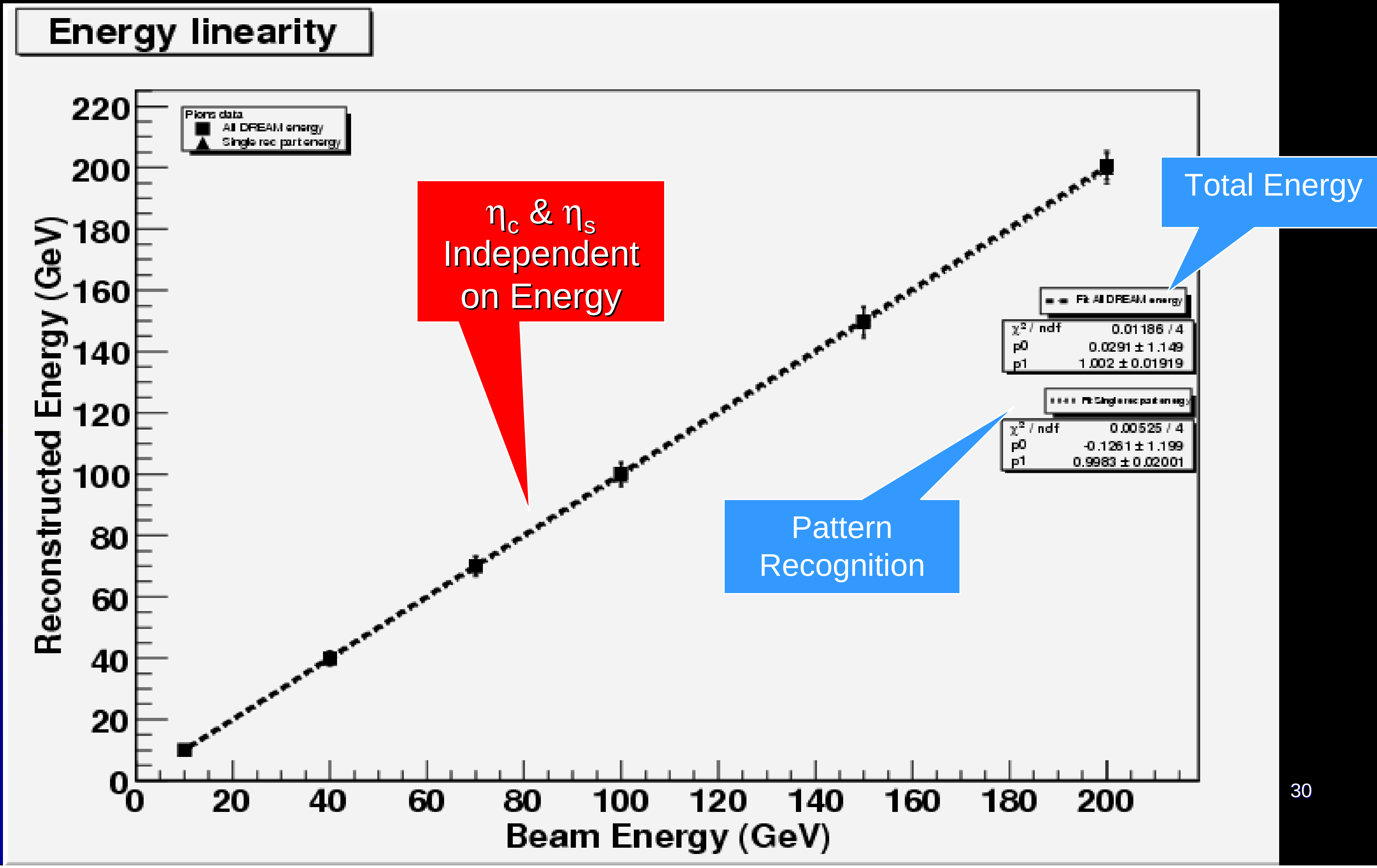



Isolated
Clusters

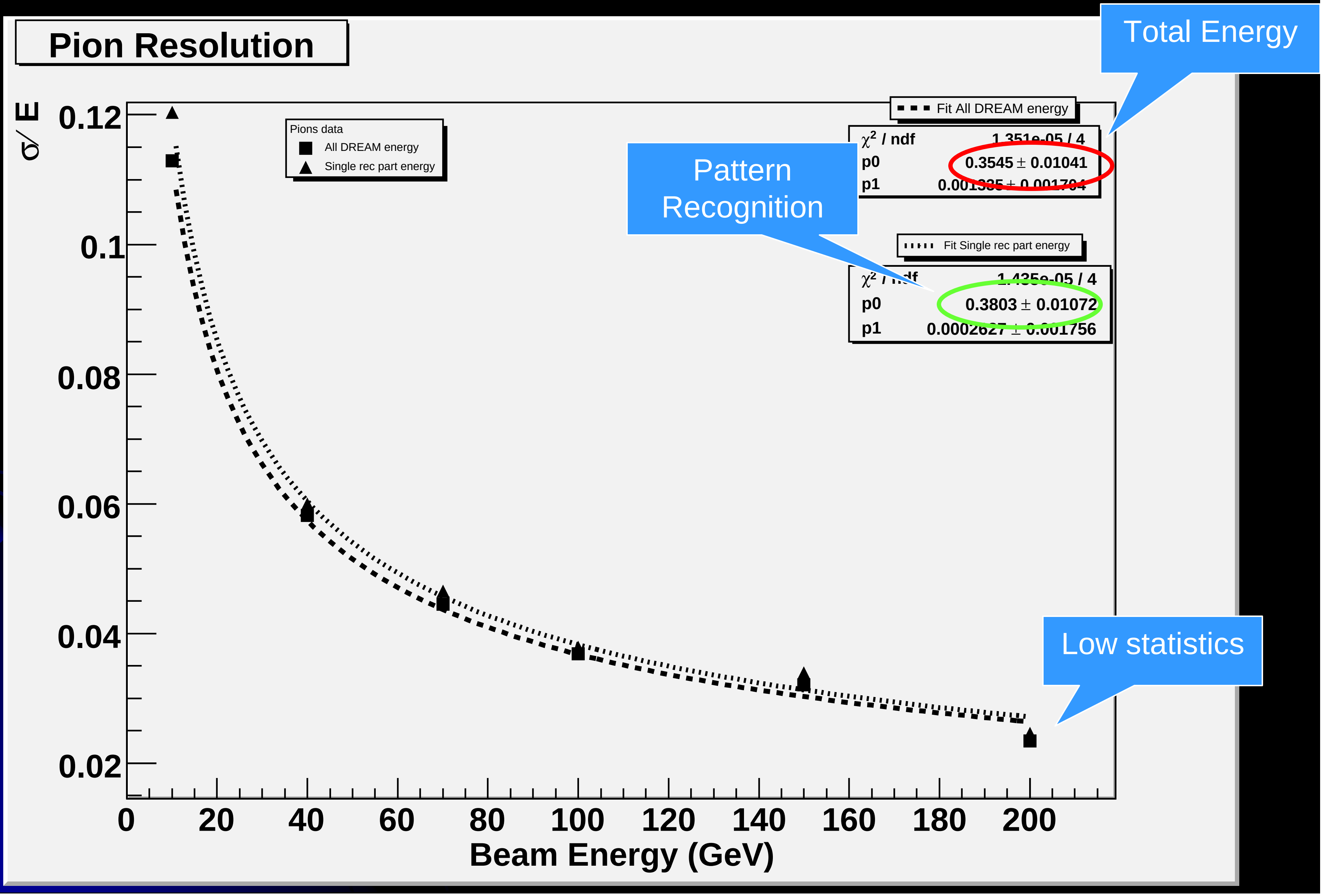
Calibration Algorithm

- $$E = \frac{\eta_s * S(\eta_c - 1) - \eta_c * C(\eta_s - 1)}{\eta_c - \eta_s}$$

Reconstructed vs Beam Energy

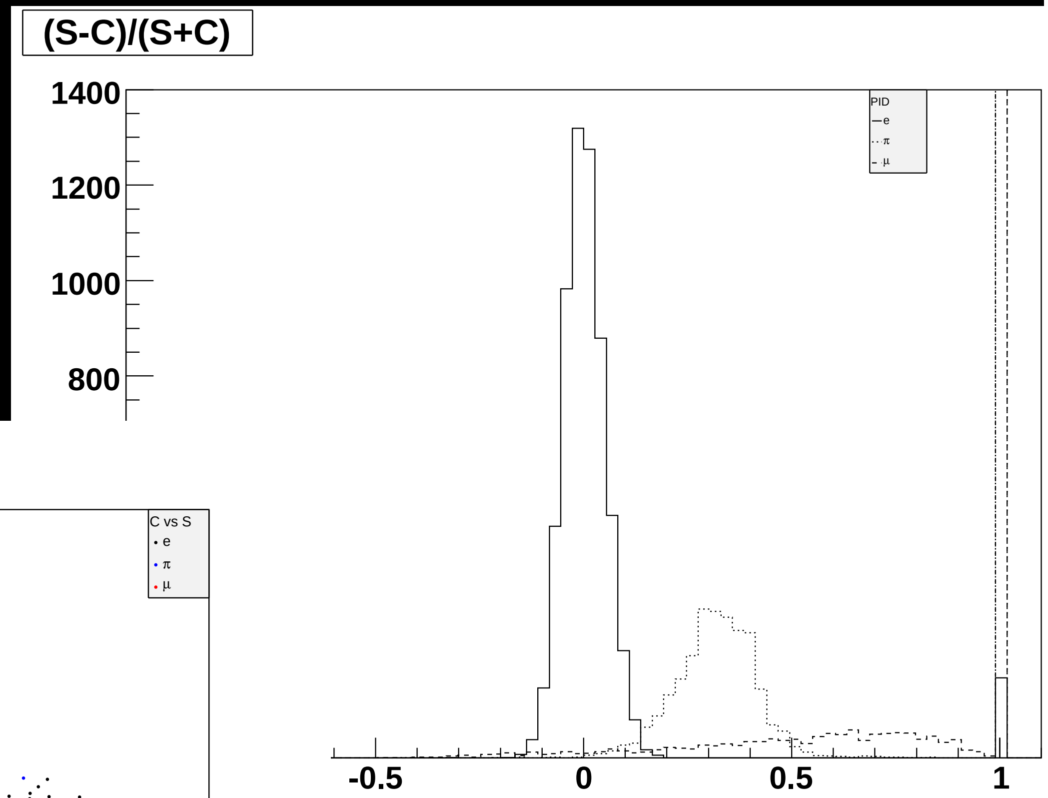


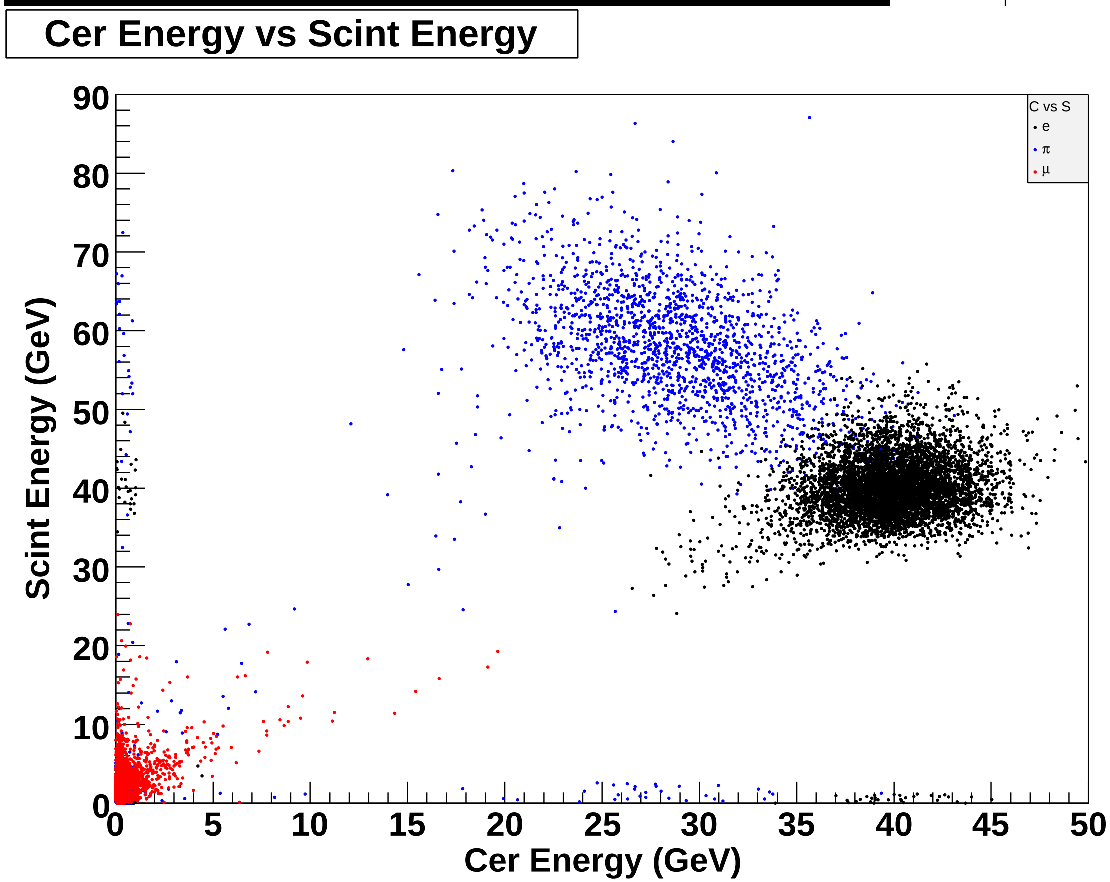
Resolution for hadrons



PID from DREAM

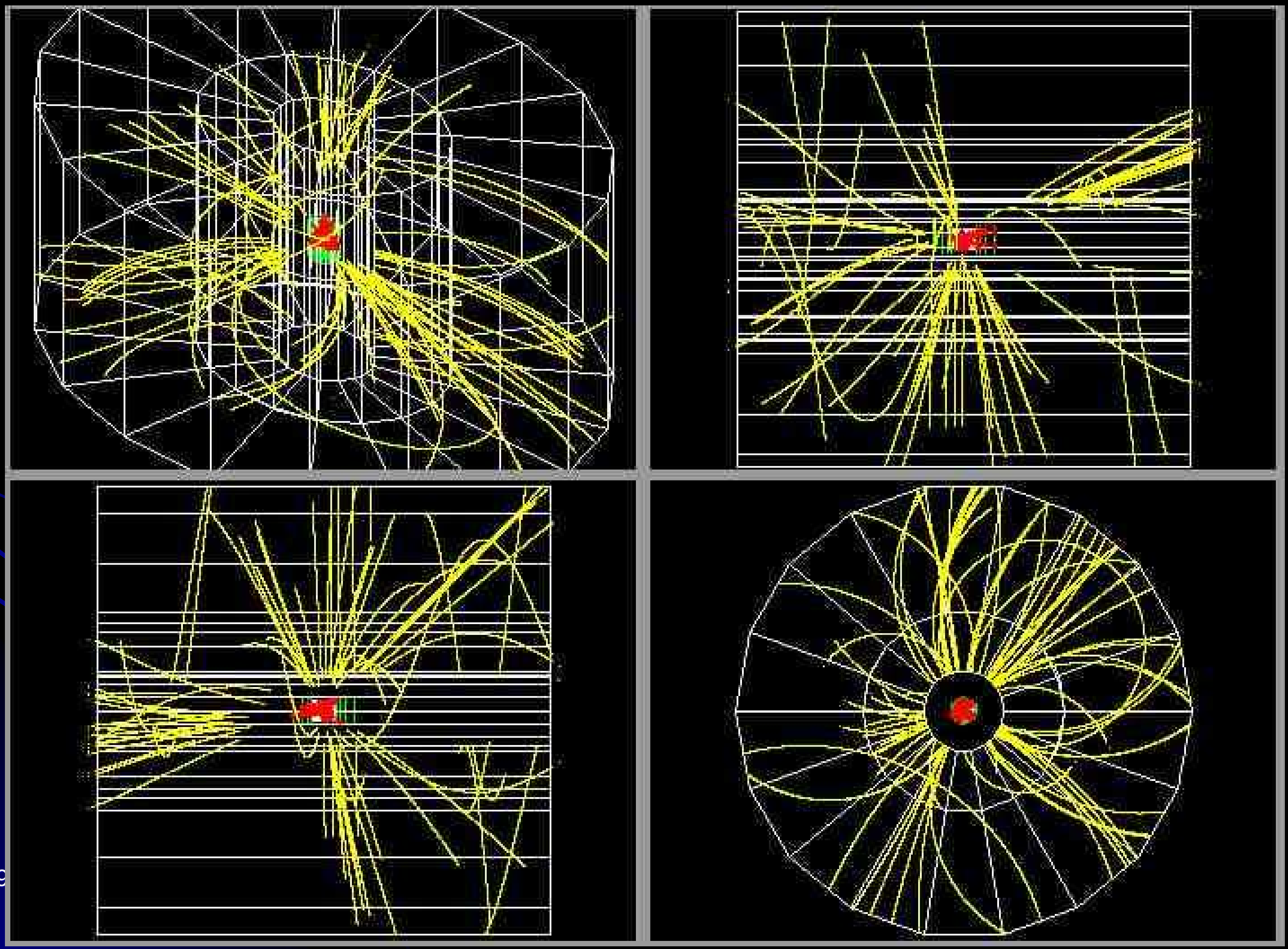
- 40 GeV particles



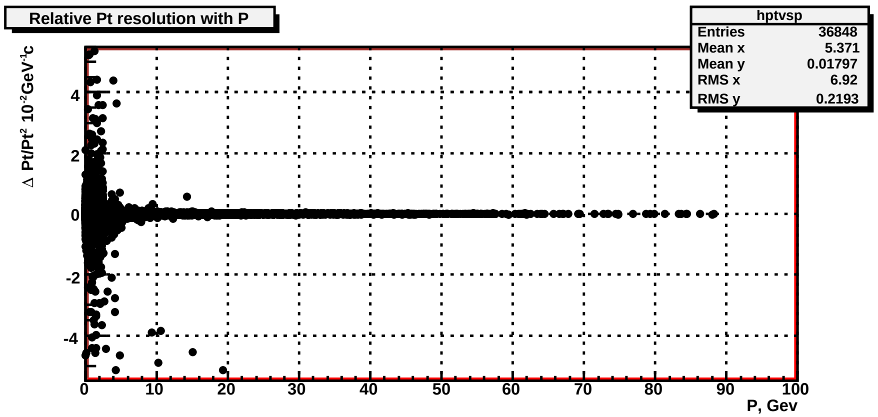


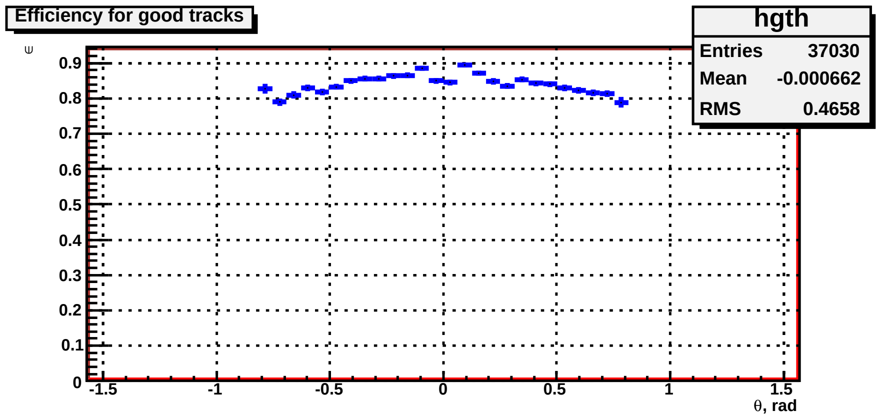
Physics Studies

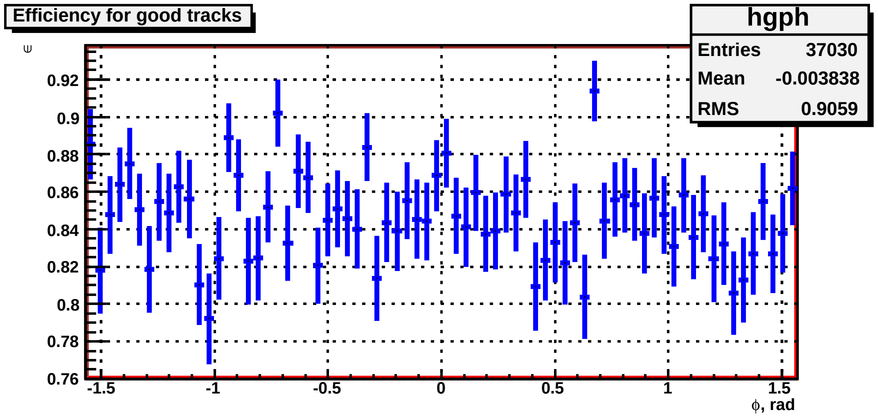
e^+e^- -> $t\underline{t}$ -> 6 jets

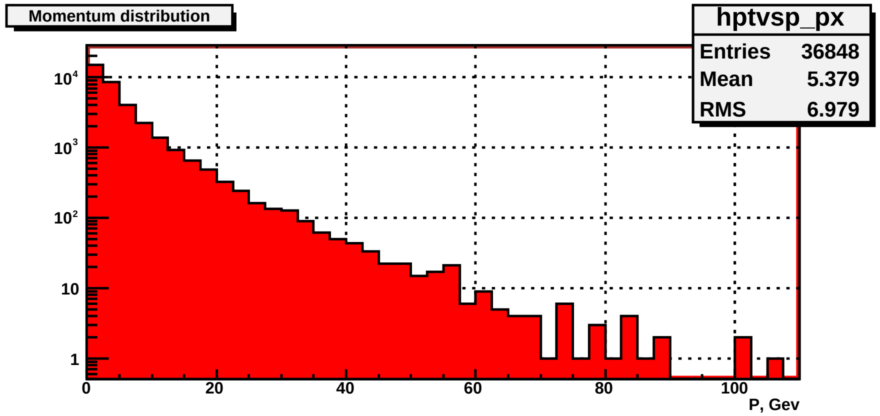


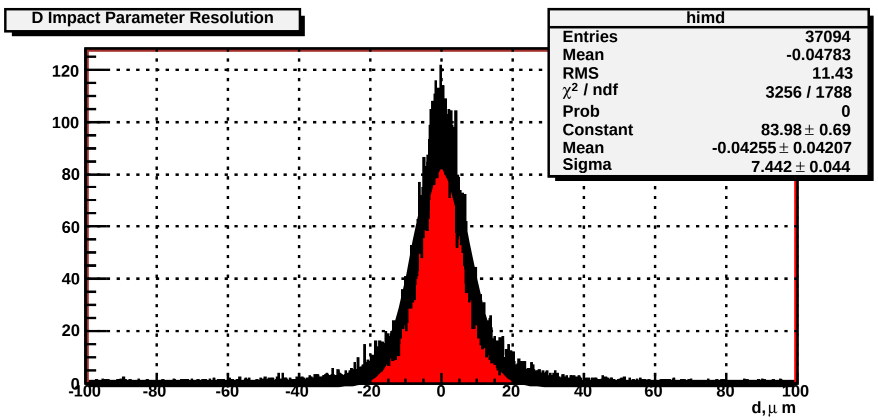
e^+e^- -> tt -> 6 jets (pads only)

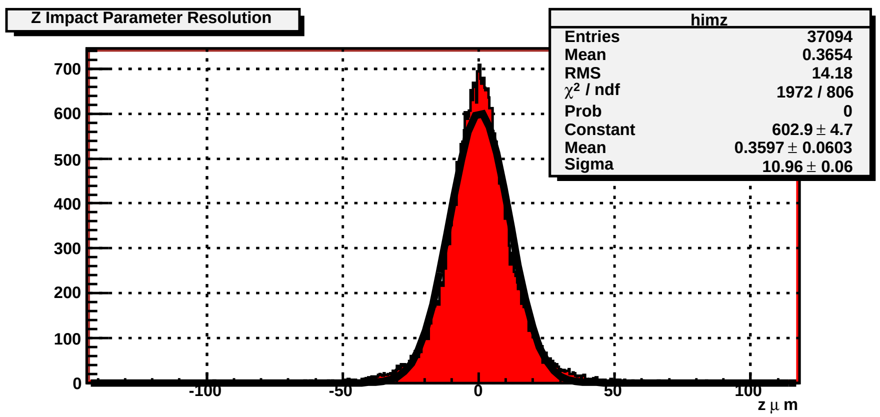




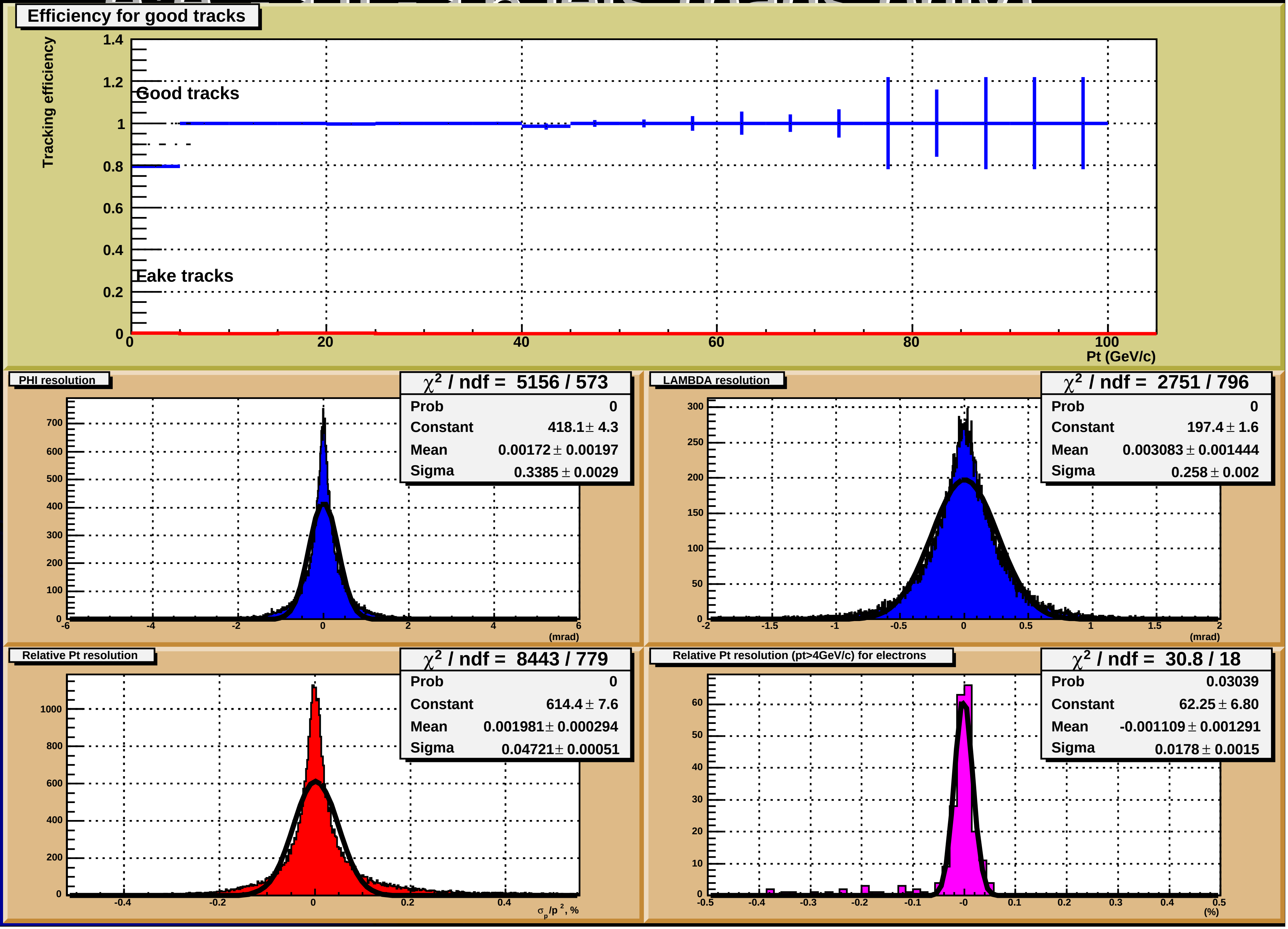




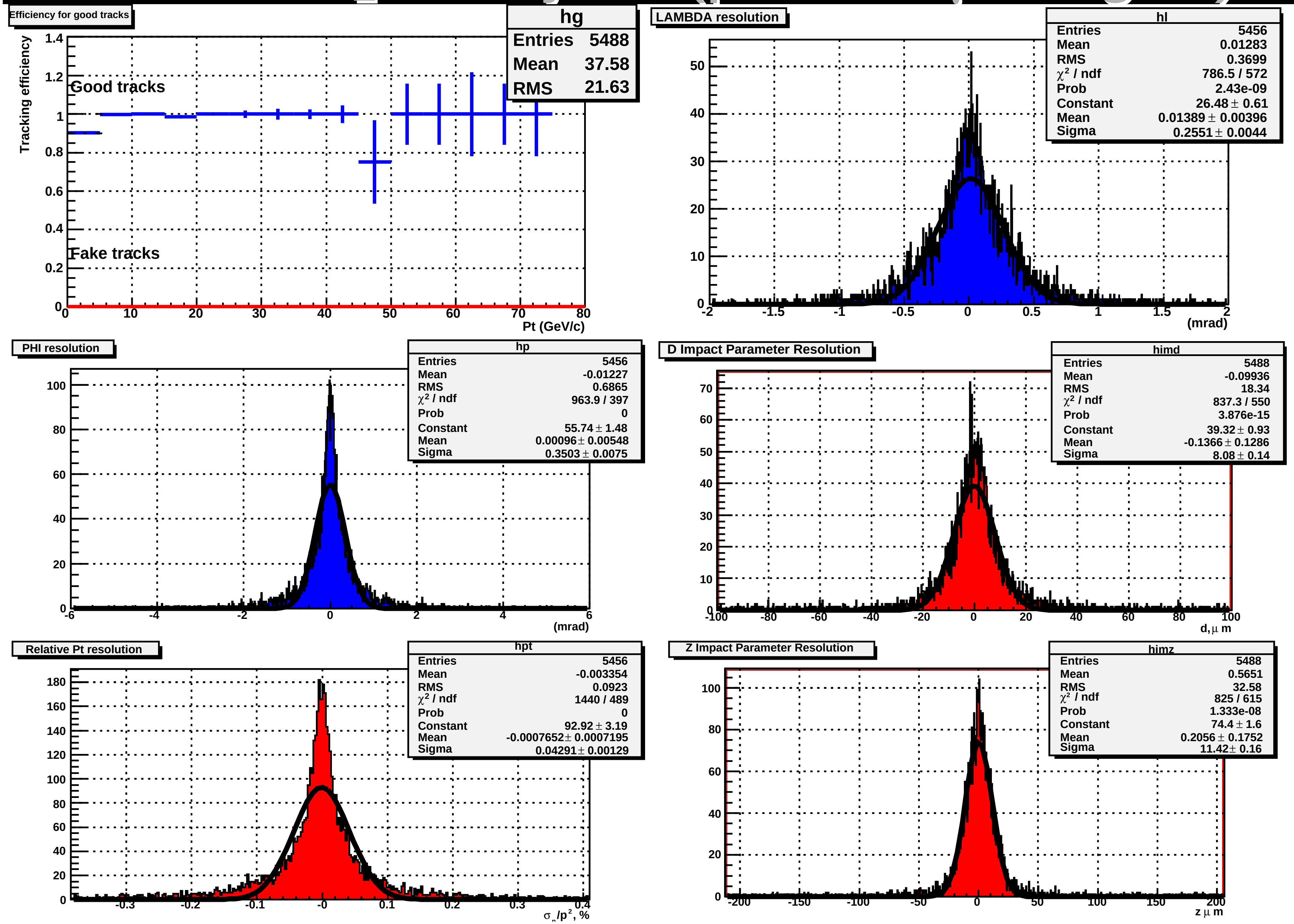




e+e- -> tt -> 6 jets (pads only)



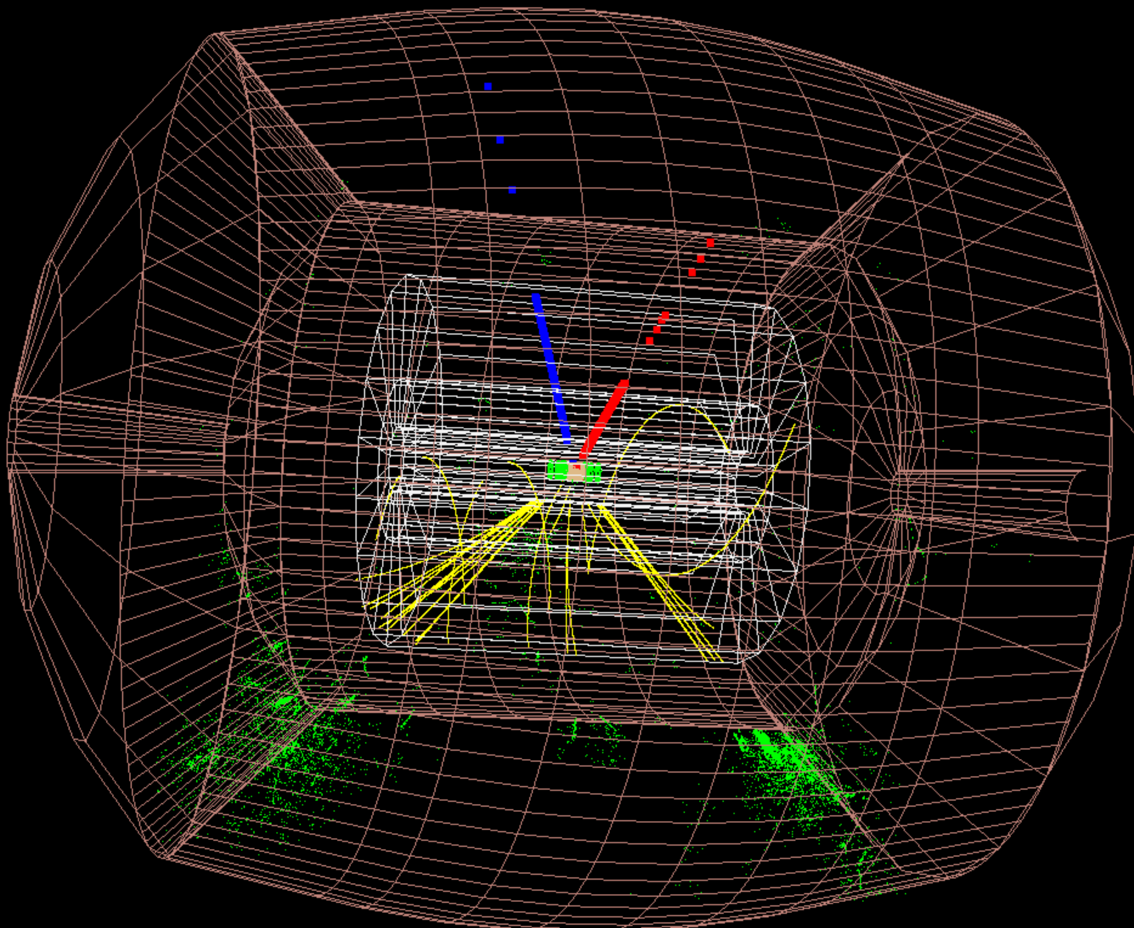
e+e- -> tt -> 6 jets (pads + μMegas)



e^+e^- -> $t\bar{t}$ -> 6 jets
Pads only vs Pads + μMegas

- Tracking efficiency: 85% -> 90%
- Momentum & space resolution barely affected
- TPC + VXD resolution:
  - $\sigma(1/p_t)$ Totally dominated by MS
  - $\sigma(d) = 8\ \mu m$
  - $\sigma(z) = 11.0\ \mu m$

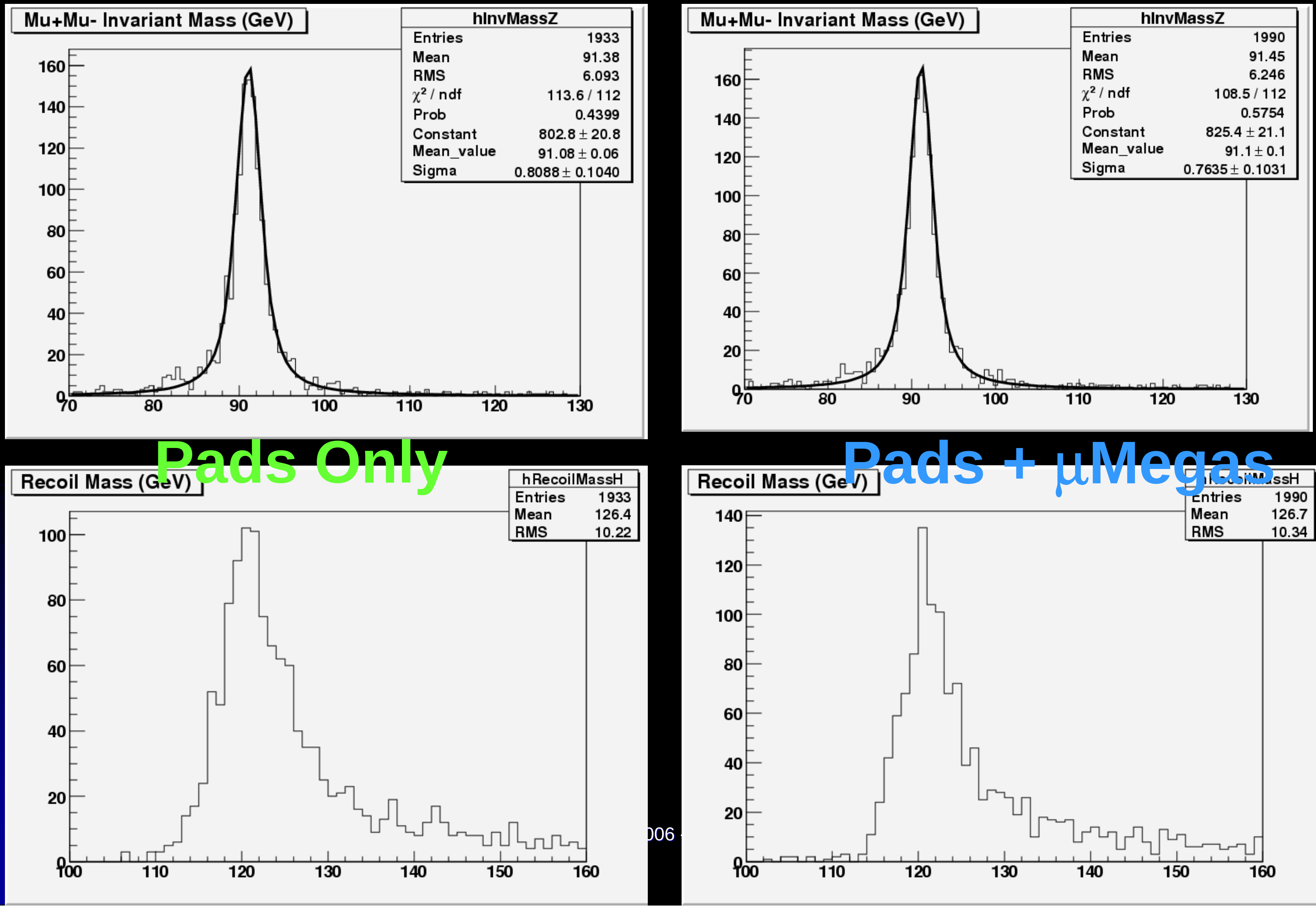
e^+e^- -> Z^oH^o -> $\mu^+\mu^-X$



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

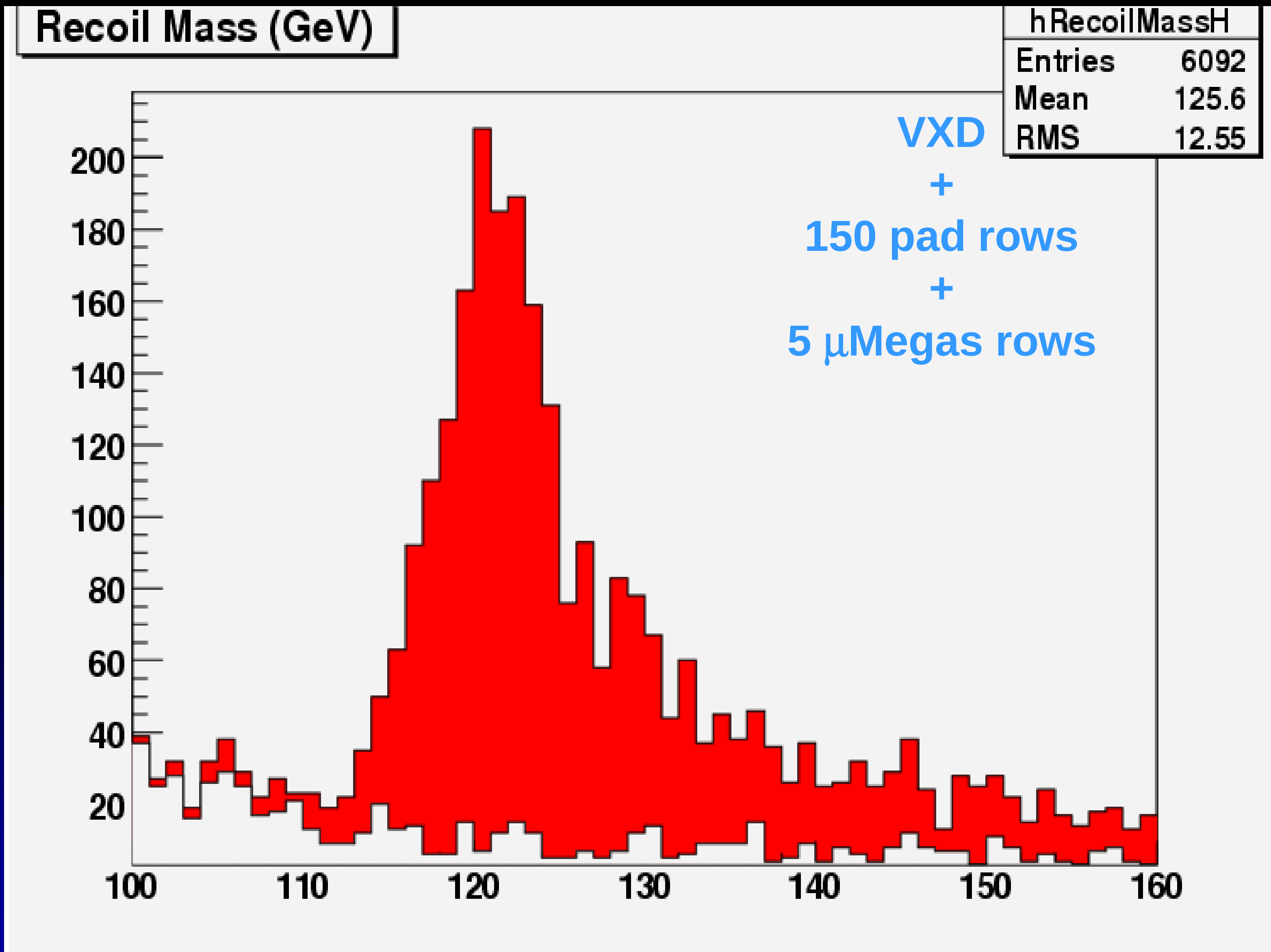
- Pads only vs Pads+MuMegas
- Simple analysis
- Perfect muon-ID (no MUD at present)
- Cut $|P| > 20$ GeV
- Loose DCA cuts:
  - $\eta < 50\ \mu m$
  - $\xi < 40\ \mu m$
- Requires no kink in track reconstruction
- Multiple entries per event

Mass Plots



Mu+Mu- Invariant Mass (GeV)
hInvMassZ
Entries 1933
Mean 91.38
RMS 6.093
χ² / ndf 113.6 / 112
Prob 0.4399
Constant 802.8 ± 20.8
Mean_value 91.08 ± 0.06
Sigma 0.8088 ± 0.1040
Mu+Mu- Invariant Mass (GeV)
hInvMassZ
Entries 1990
Mean 91.45
RMS 6.246
χ² / ndf 108.5 / 112
Prob 0.5754
Constant 825.4 ± 21.1
Mean_value 91.1 ± 0.1
Sigma 0.7635 ± 0.1031
Pads Only
Pads + μMegas
Recoil Mass (GeV)
hRecoilMassH
Entries 1933
Mean 126.4
RMS 10.22
Recoil Mass (GeV)
Entries 1990
Mean 126.7
RMS 10.34

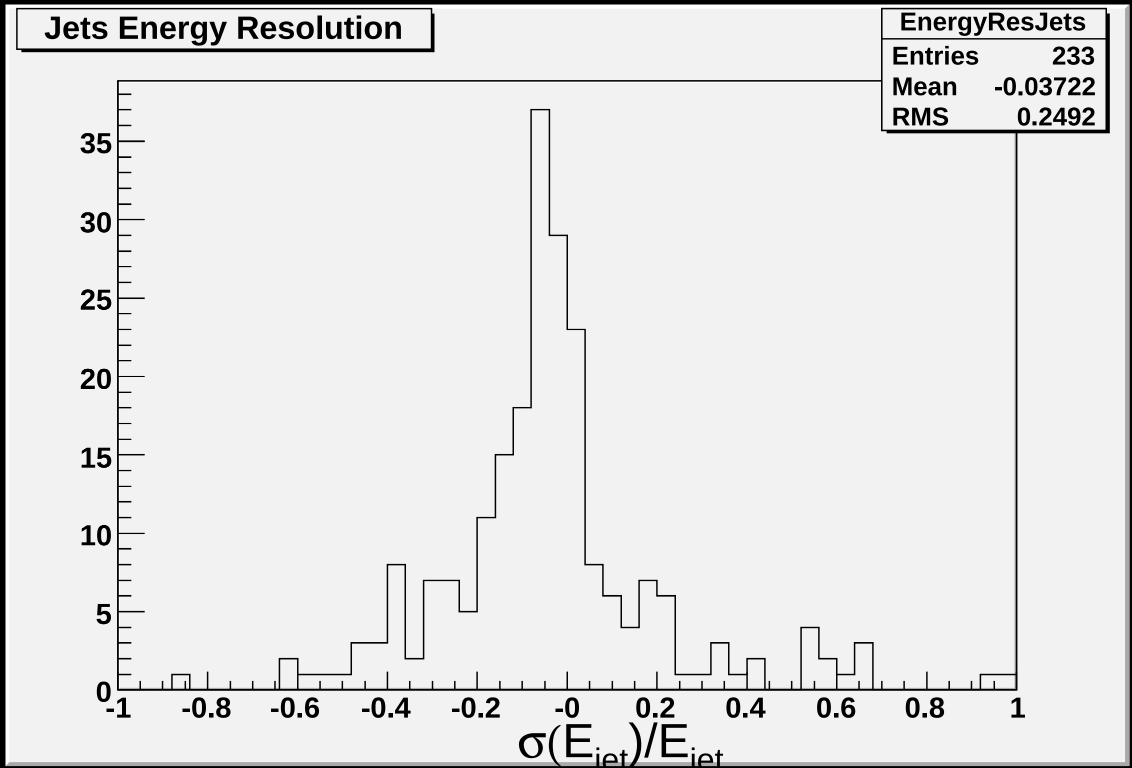
Recoil Mass (500 fb)



Signal
+
ZZ->$\mu^+\mu^-$X
background

$e^+e^- \to Z^oH^o \to l^+l^- b\underline{b}$

- Very preliminary results
- No Jet finder
- Only pattern recognition in the DREAM



Conclusions

- 4th Concept baseline detector implemented in ILCroot
- Full simulation almost in place for DCR (about another month)
- Performance is good:

  Calorimetry: $\sigma_E/E = 36\%/\sqrt{E}$

  Tracking:

  $\sigma(1/P_t) = 0.6 \times 10^{-4}$

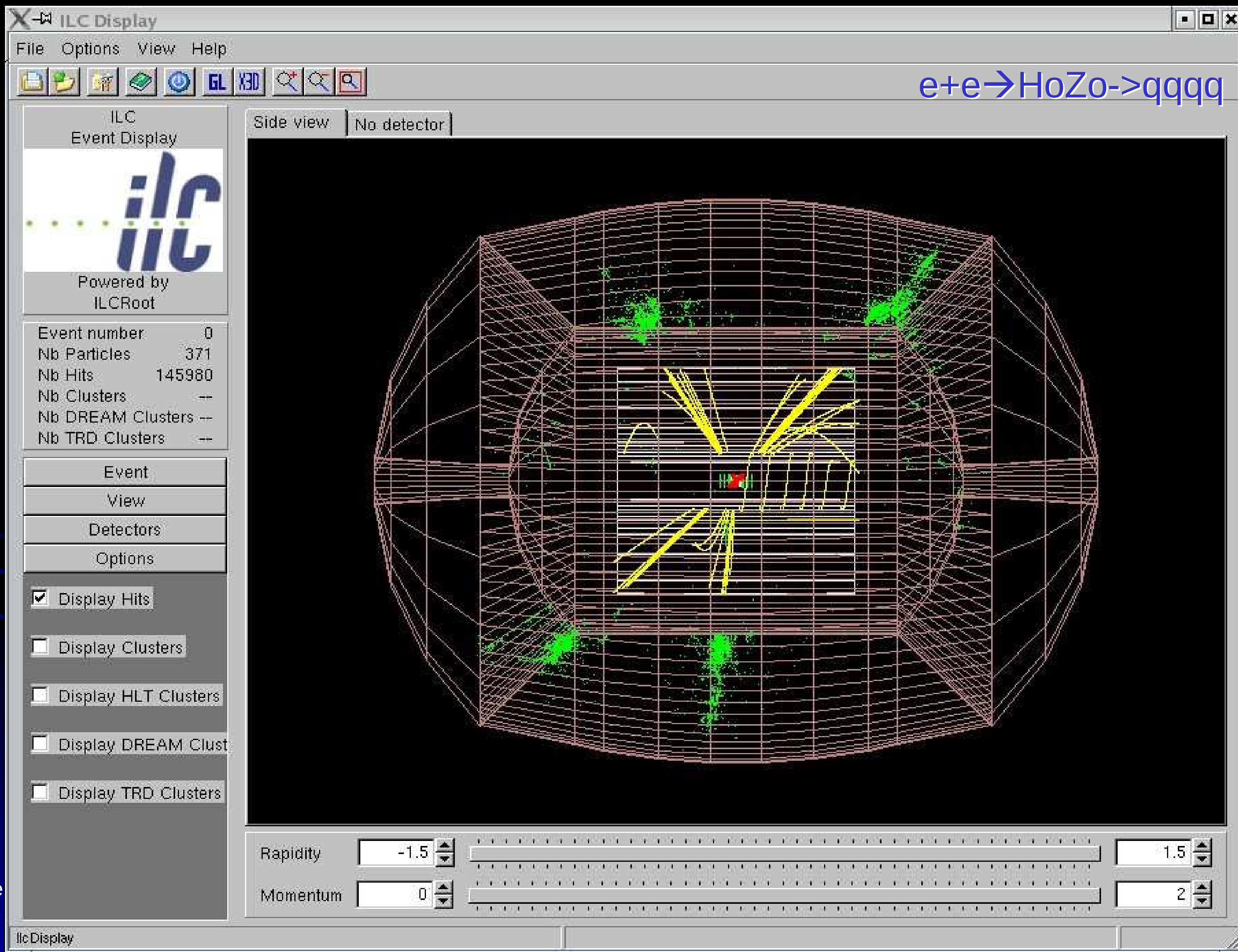
  $\sigma(d) = 3\ \mu m$ (8 μm for tt->6jets)

  $\sigma(z) = 8\ \mu m$ (11 μm for tt->6jets)

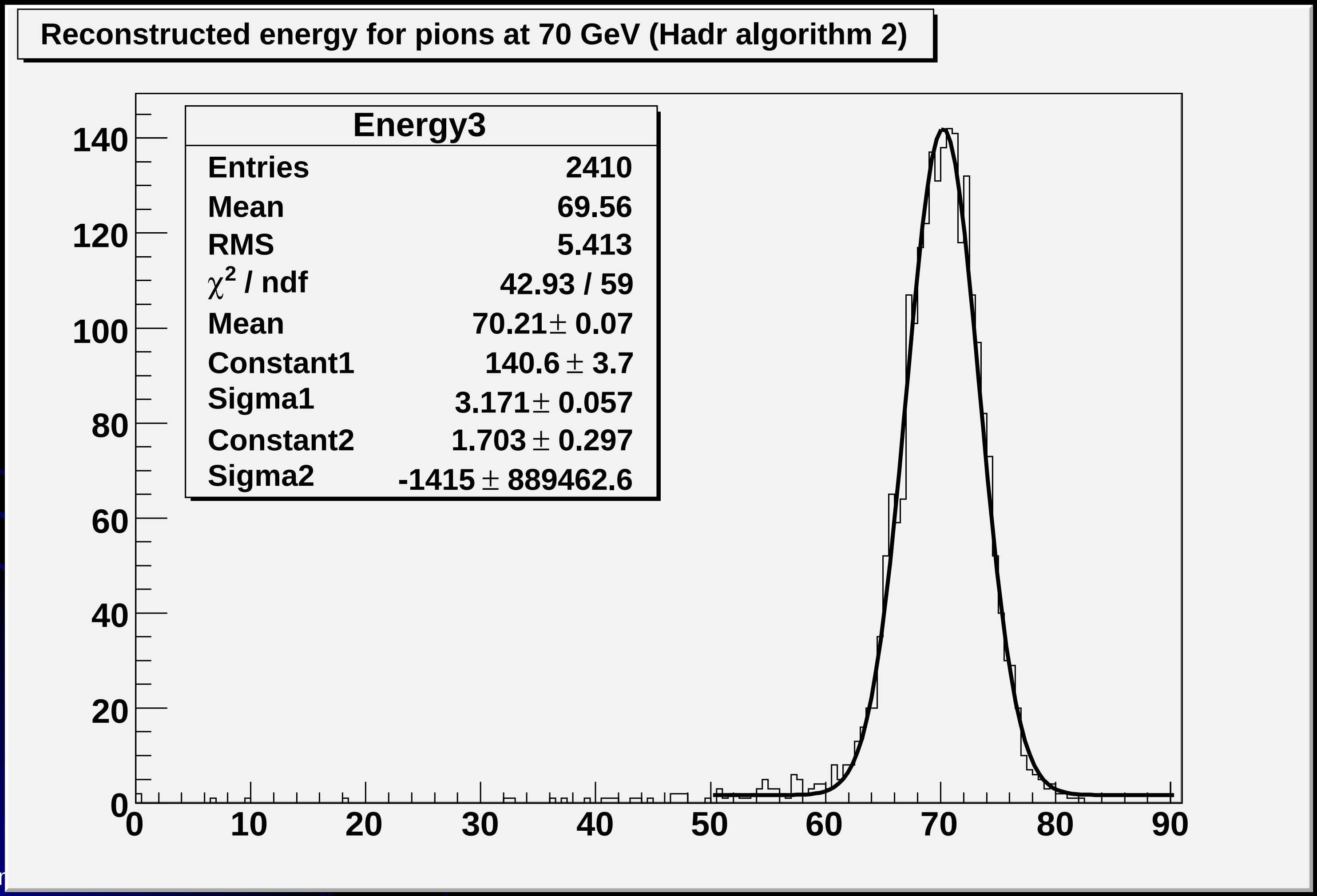
- Event production (generation + reconstruction) in progress
- Very slow with Fluka: ~1-3 hr/evt
- Parametric implementation of the code
- Detector optimization will start next year
- EMCAL and Muon Spectrometer simulation delayed

Backup slides

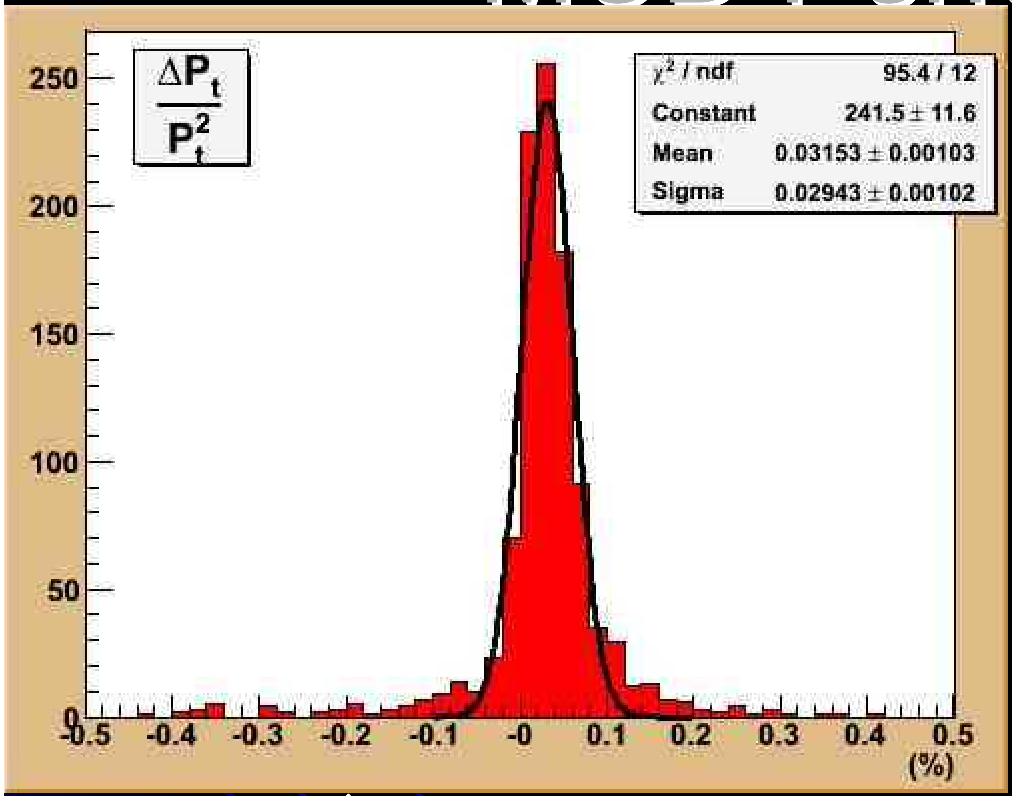
Present Status: VXD+TPC+DREAM



Dream Performance (pions)



MUD Performance



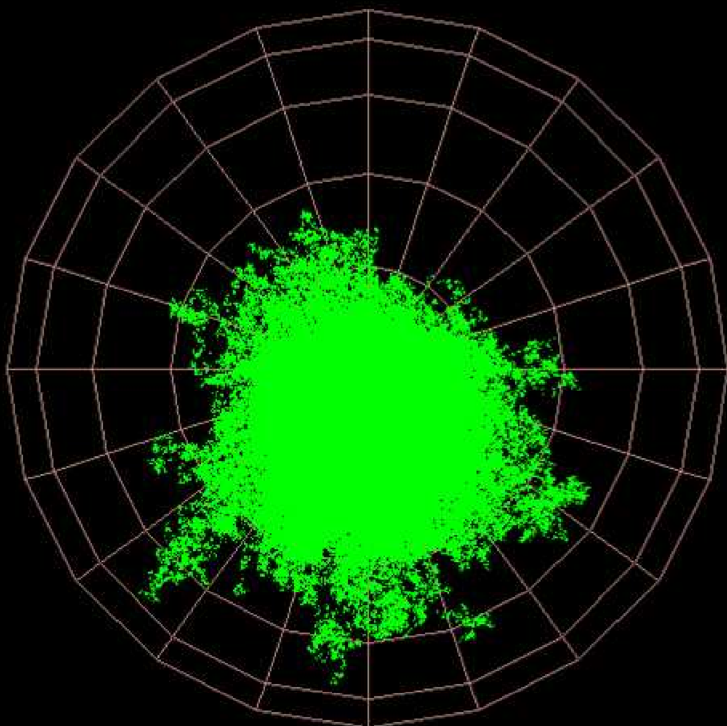
From LCWS06

- TPC for pattern recognition + seeds finding
- Kalman filter for trach fit
- Compare momentum reconstructed in the MUD to that generated at the origin

Results from DREAM simulation (V. Di Benedetto)

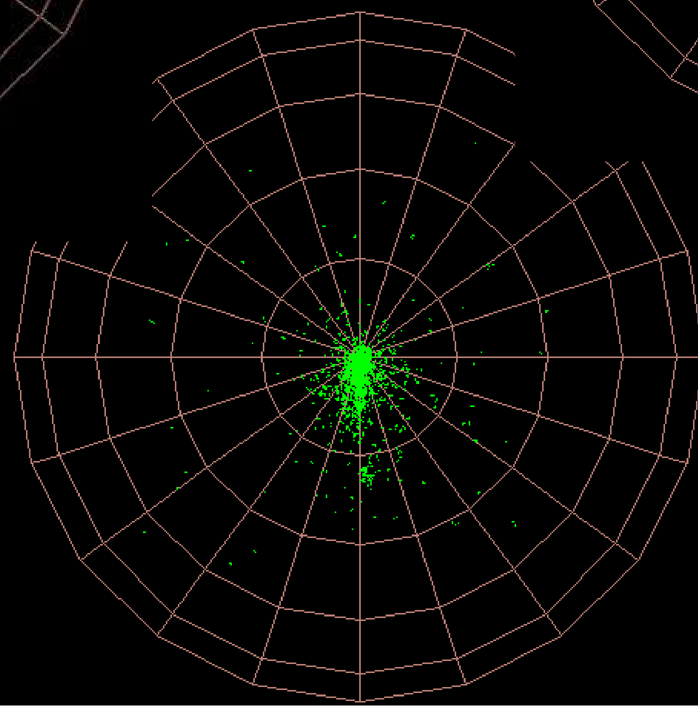
- Scintillation and Cerenkov processes well simulated
- Easily switch from Cu to W (however, need to change calibration values of η_S and η_C)
- Pattern recognition in place (nearby cells).
- Hadronic showers appear to reproduce the compensation effect seen in the test module (Fluka)
- PiD ($e/\pi/\mu$) results are very promising

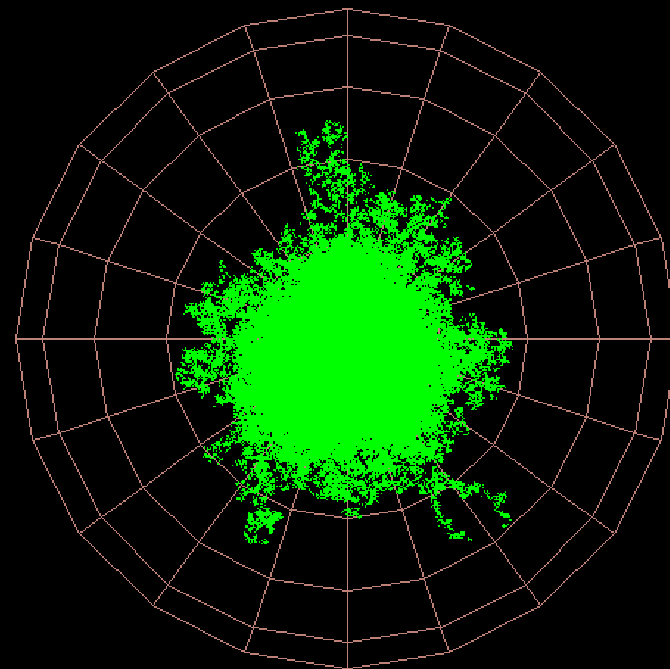
Fluka vs G3/G4



Fluka

Geant3

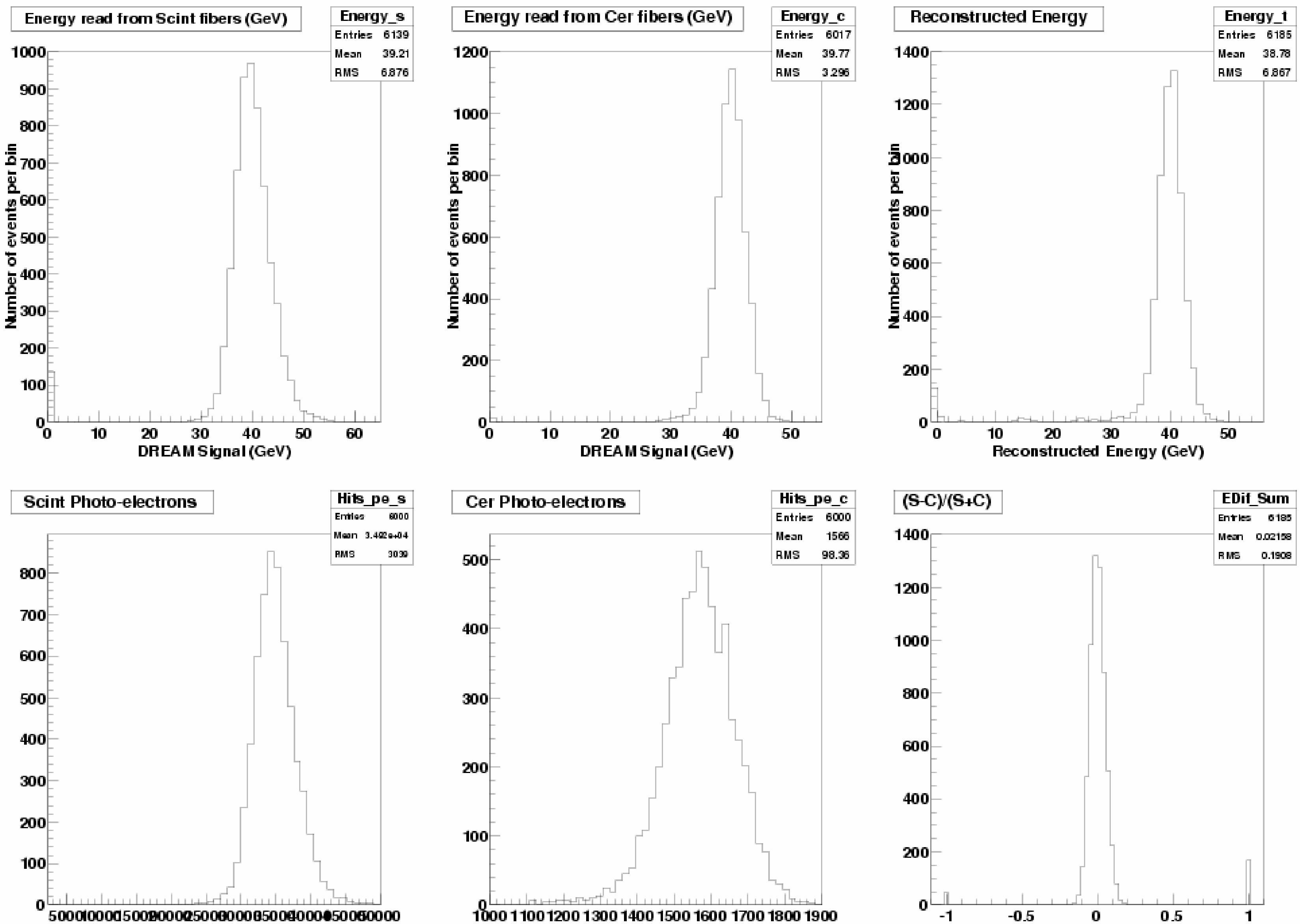




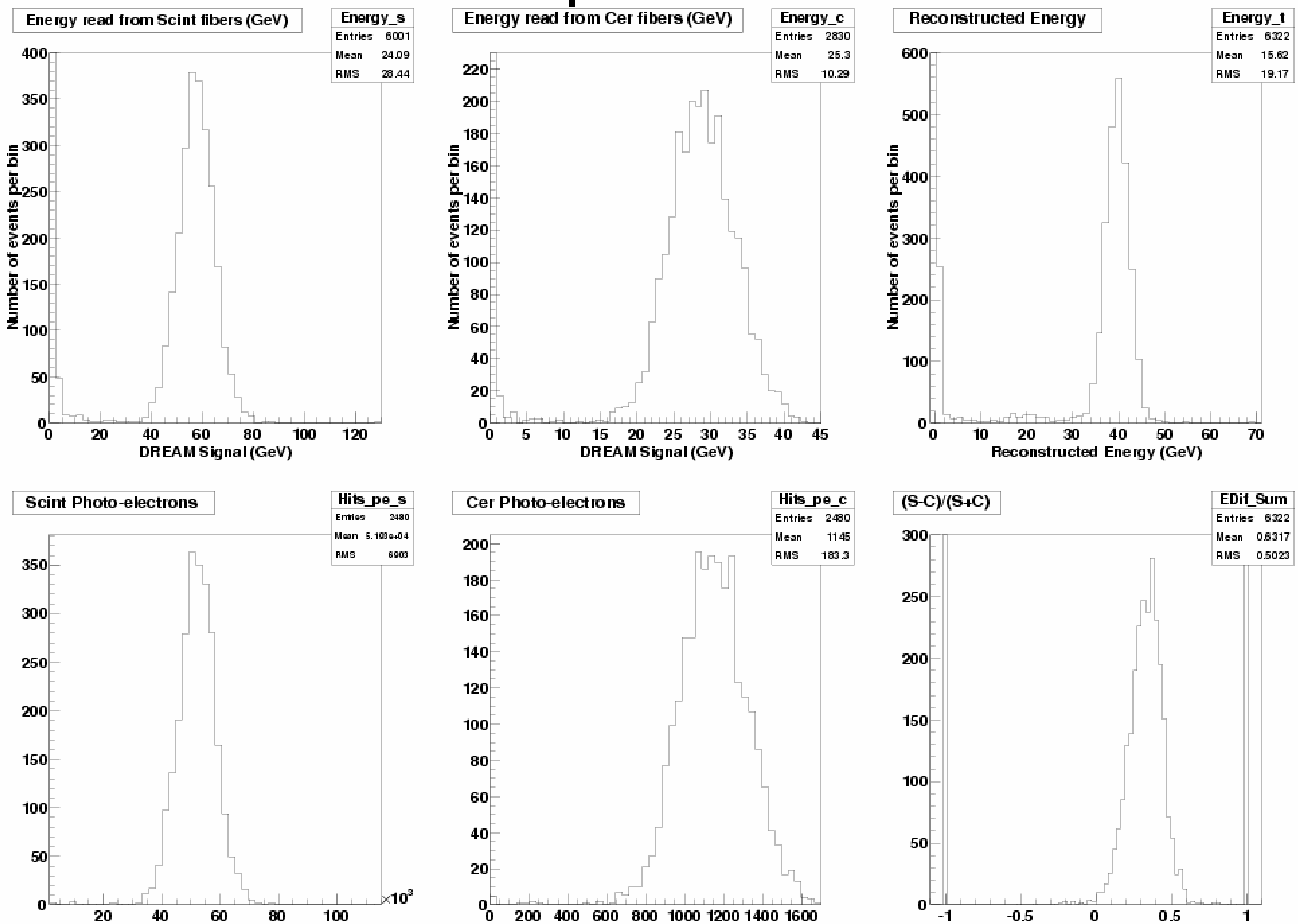
Geant4

π^- at 50 GeV in Pb Sphere of 500 cm Radius

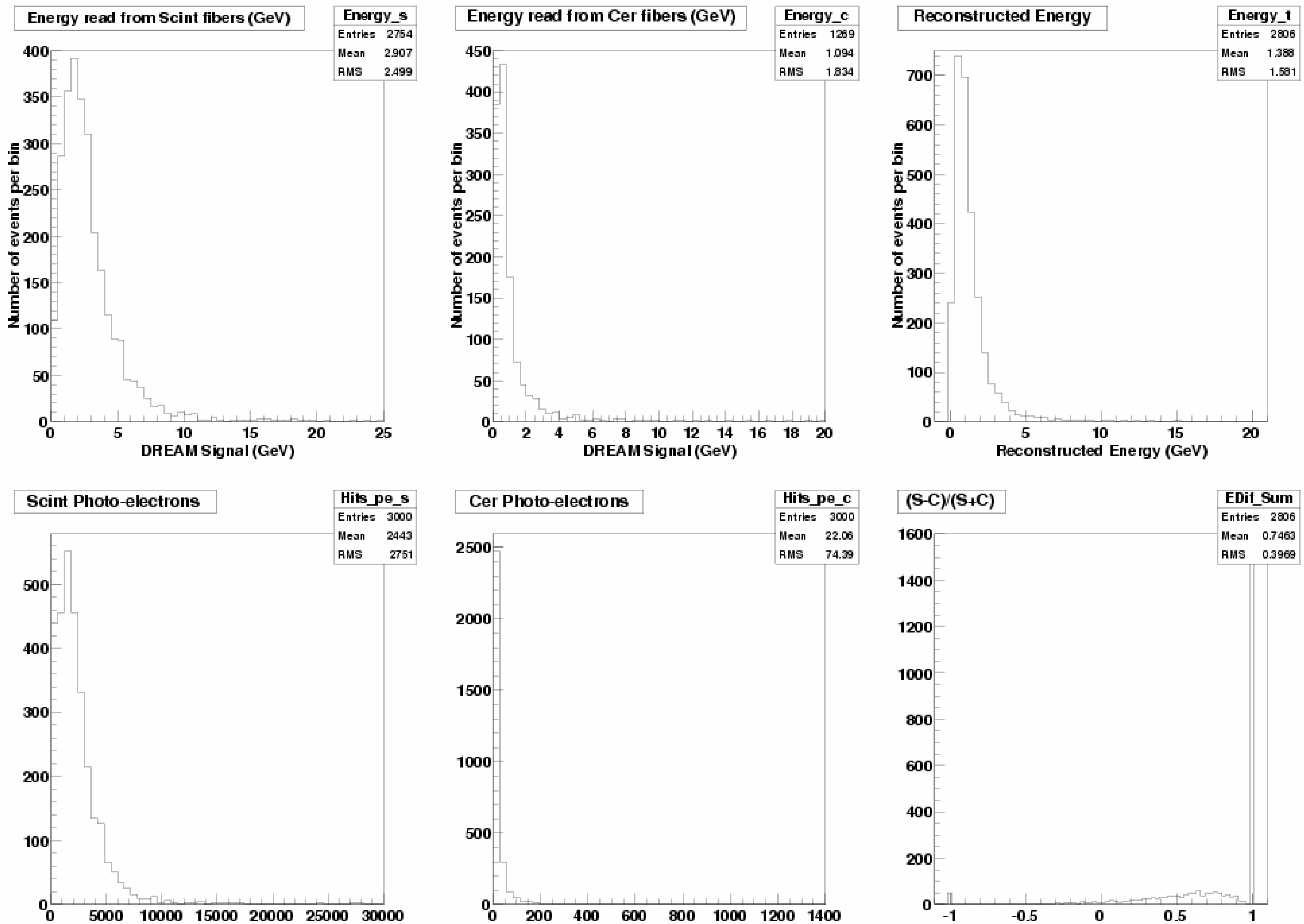
Histos electrons at 40 GeV in Cu



Histos   pions at 40 GeV in Cu



Histos muons at 100 GeV in Cu



LCIO vs MONARC

MC Generation ⇒ Energy Deposits in Detector

Digitization ⇒ Tracker Hits

Track Finding ⇒ Tracks

Track Fitting ⇒ Track Parameters

MC Generation ⇒ Energy Deposits in Detector

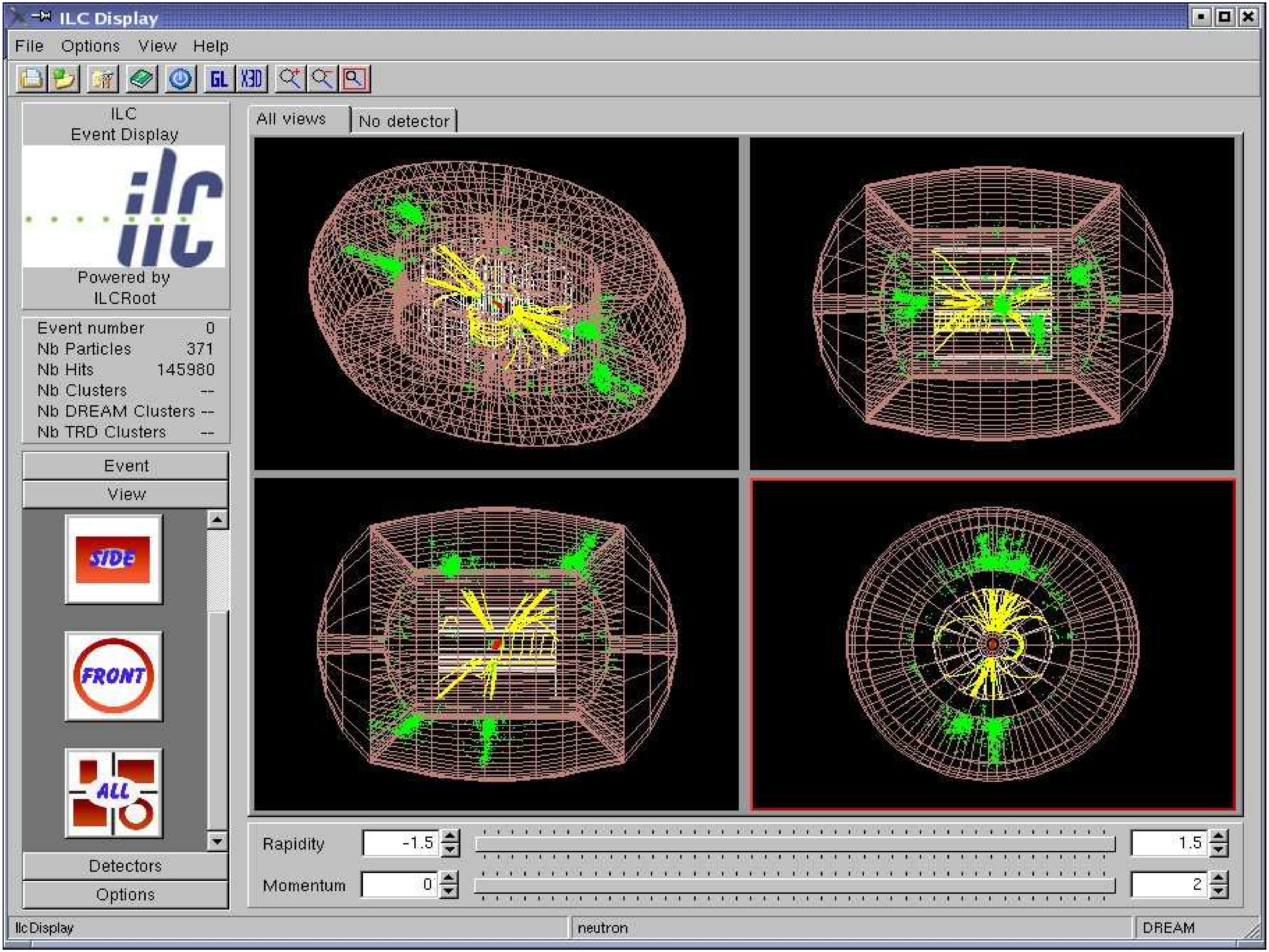
SDigitization ⇒ Detector response from single particle

Digitization ⇒ Detector response combined

Pattern Recognition ⇒ Recpoints

Track Finding ⇒ Tracks

Track Fitting ⇒ Track Parameters



ILC Display
File Options View Help
GL X3D
ILC
Event Display
Powered by
ILCRoot
Event number 0
Nb Particles 371
Nb Hits 145980
Nb Clusters --
Nb DREAM Clusters --
Nb TRD Clusters --
Event
View
SIDE
FRONT
ALL
Detectors
Options
All views
No detector
Rapidity -1.5 1.5
Momentum 0 2
IlcDisplay
neutron
DREAM

Present Status: VXD+TPC+DREAM