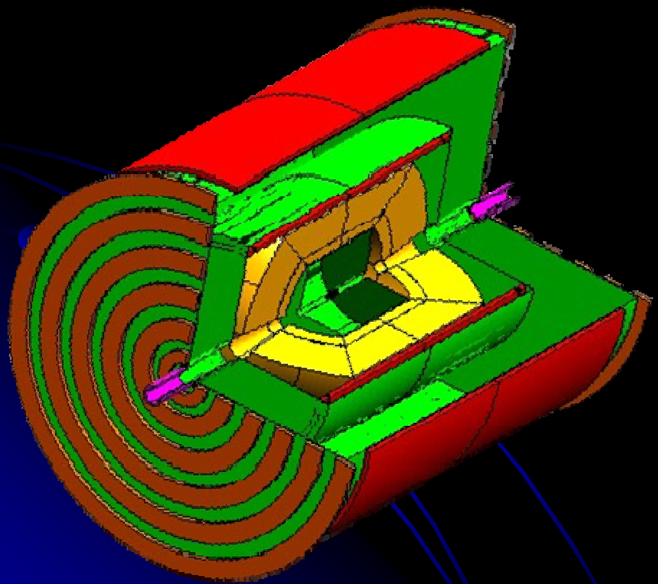
Calorimetry Studies in the 4th Concept



On behalf of 4th Concept Software Group

D. Barbareschi
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G. Terracciano

Outlines

- New resolution plots for HCAL with increased statistics
- New Dual Readout ECAL
- More studies involving calorimetry and Muon Spectrometer

Simulation Details

- Full simulation is in place HCAL and ECAL (no gaussian smearing nor perfect pattern recognition)
- Hits using Fluka (for calorimeter studies)
- Cerenkov and Scintillation photon production and propagation in the fibers fully simulated
- Full SDigits + Digits + Pattern Recognition chain implemented
- PID implemented

Reconstruction Details (ECAL and HCAL)

- Build Clusters from cells distant no more than two towers away
- Unfold overlapping clusters through a Minuit fit to cluster shape (in progress)
- Get η_s and η_c with a calibration run at 40 GeV
- Compute E_{tot} from E_C and E_S with:

$$E_{tot} = \frac{\eta_s * E_S(\eta_c - 1) - \eta_c * E_C(\eta_s - 1)}{\eta_c - \eta_s}$$

- PID

The 4th Concept Hadron Calorimeter

Cu + scintillating fibers + Ĉerenkov fibers

3° aperture angle

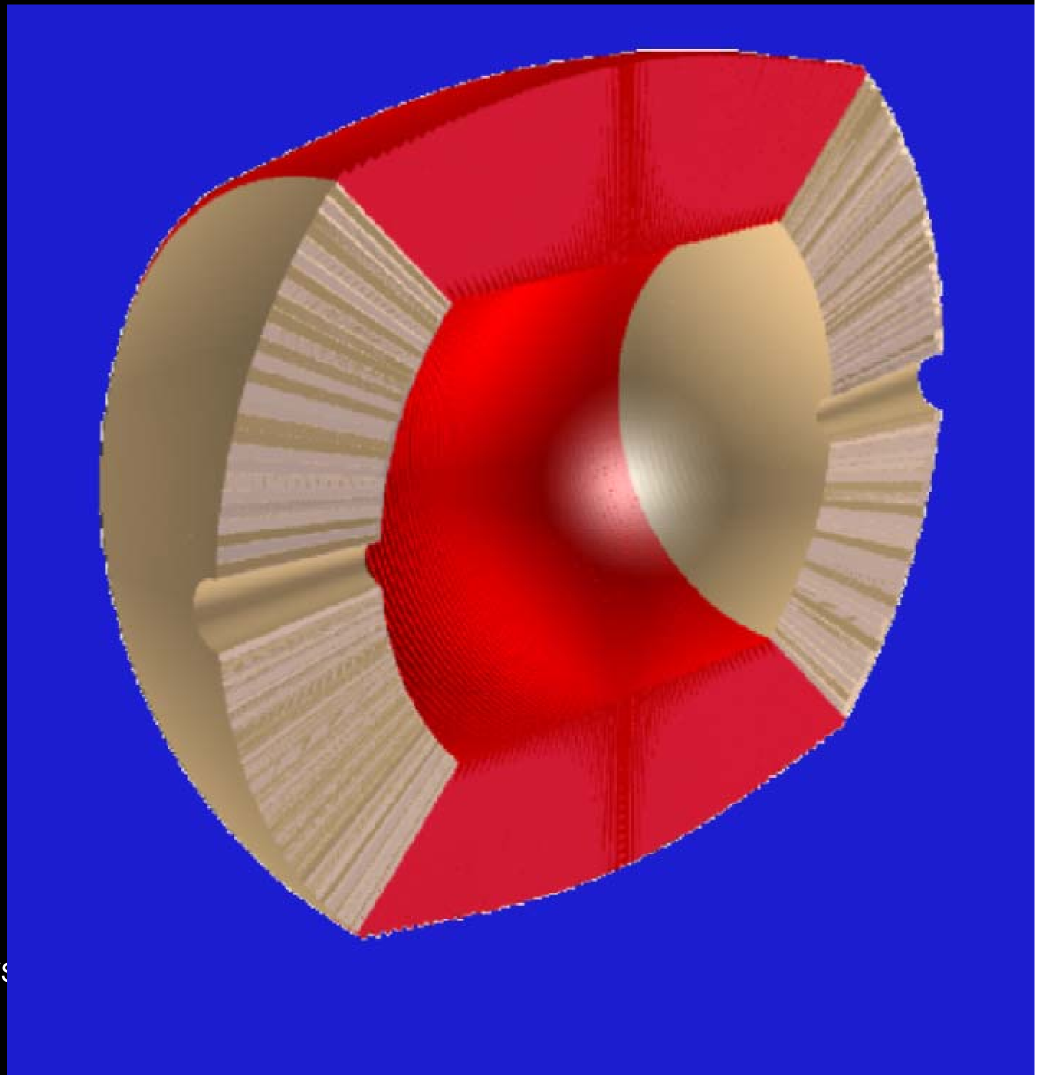
~ 10 λ_{int} depth

Fully projective geometry

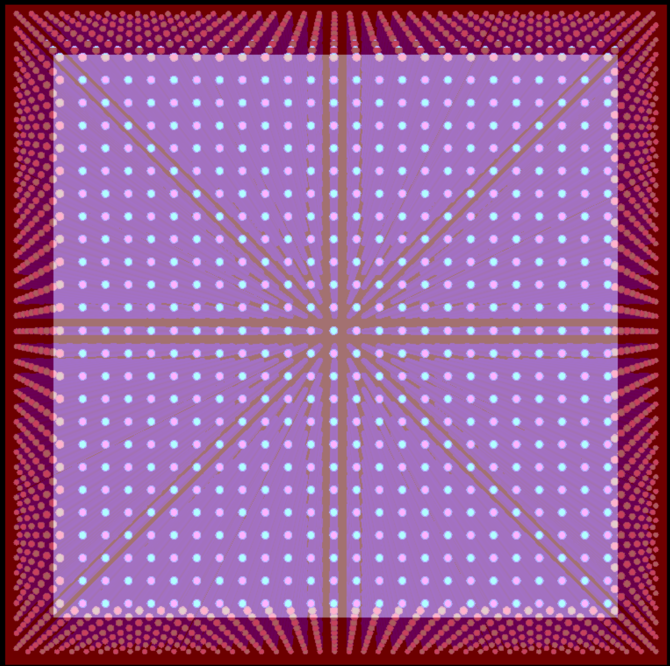
Azimuth coverage

down to 3.8°

- Barrel: 13924 cells
- Endcaps: 3164 cells



HCAL Cells



Bottom view of
single cell

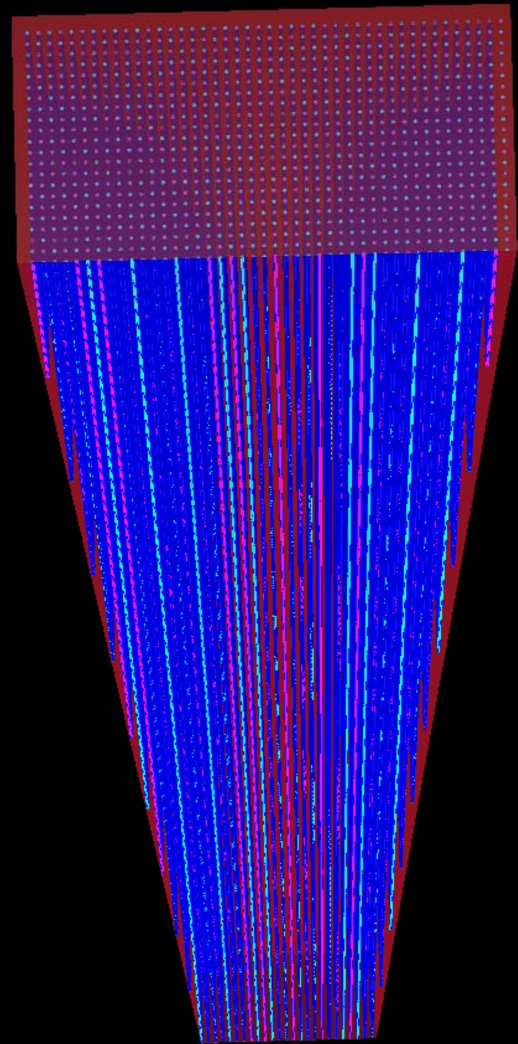
Bottom cell size:
~4.8 cm

Top cell
size: ~ 8.8 cm

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

Prospective view of
clipped cell

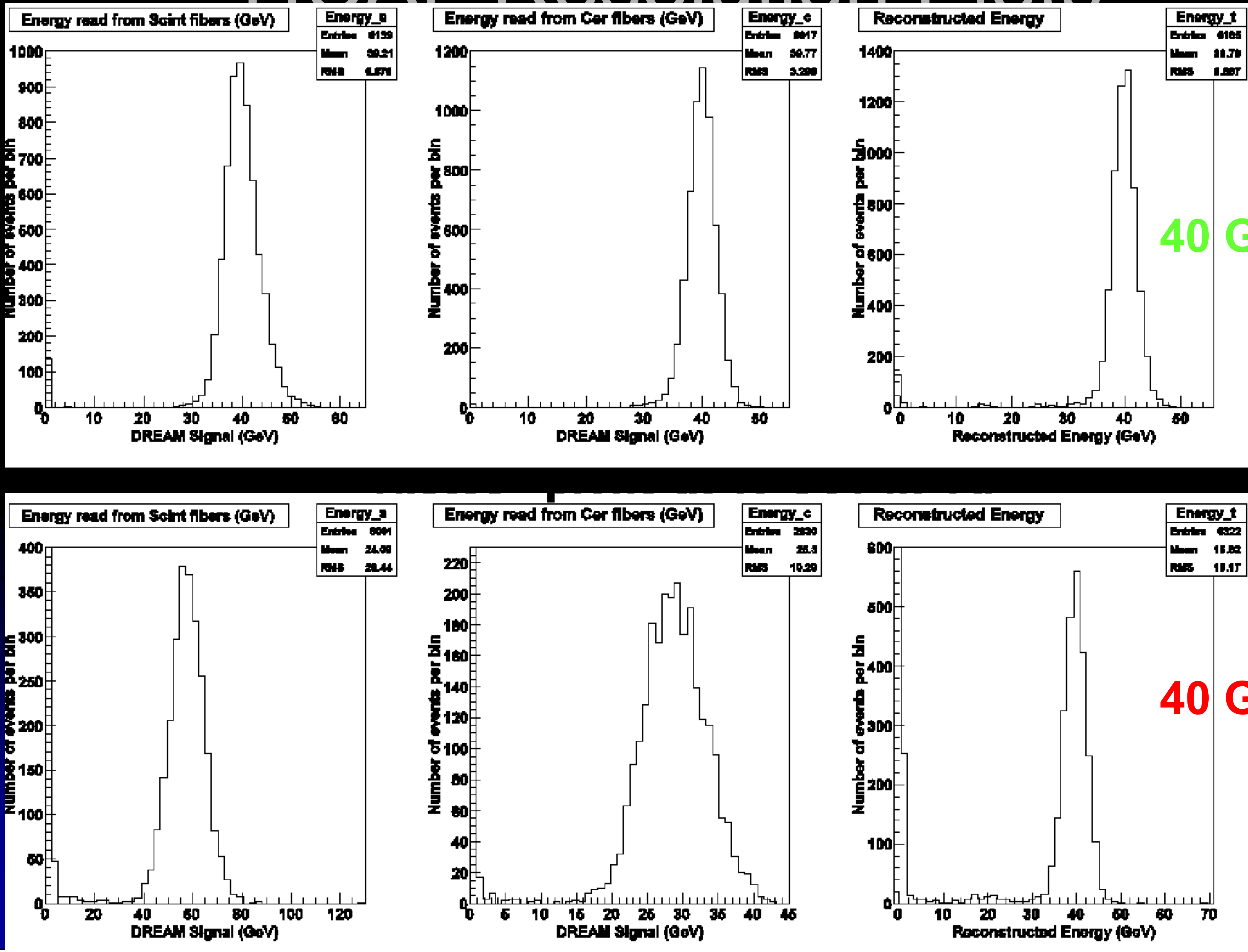
Cell length:
150 cm



HCAL Performance Studies

- Studies redone with larger statistics
- Single particle and jet performance (see A. Mazzacane's talk on jet finding)
- Improved pattern recognition has negligeable effect

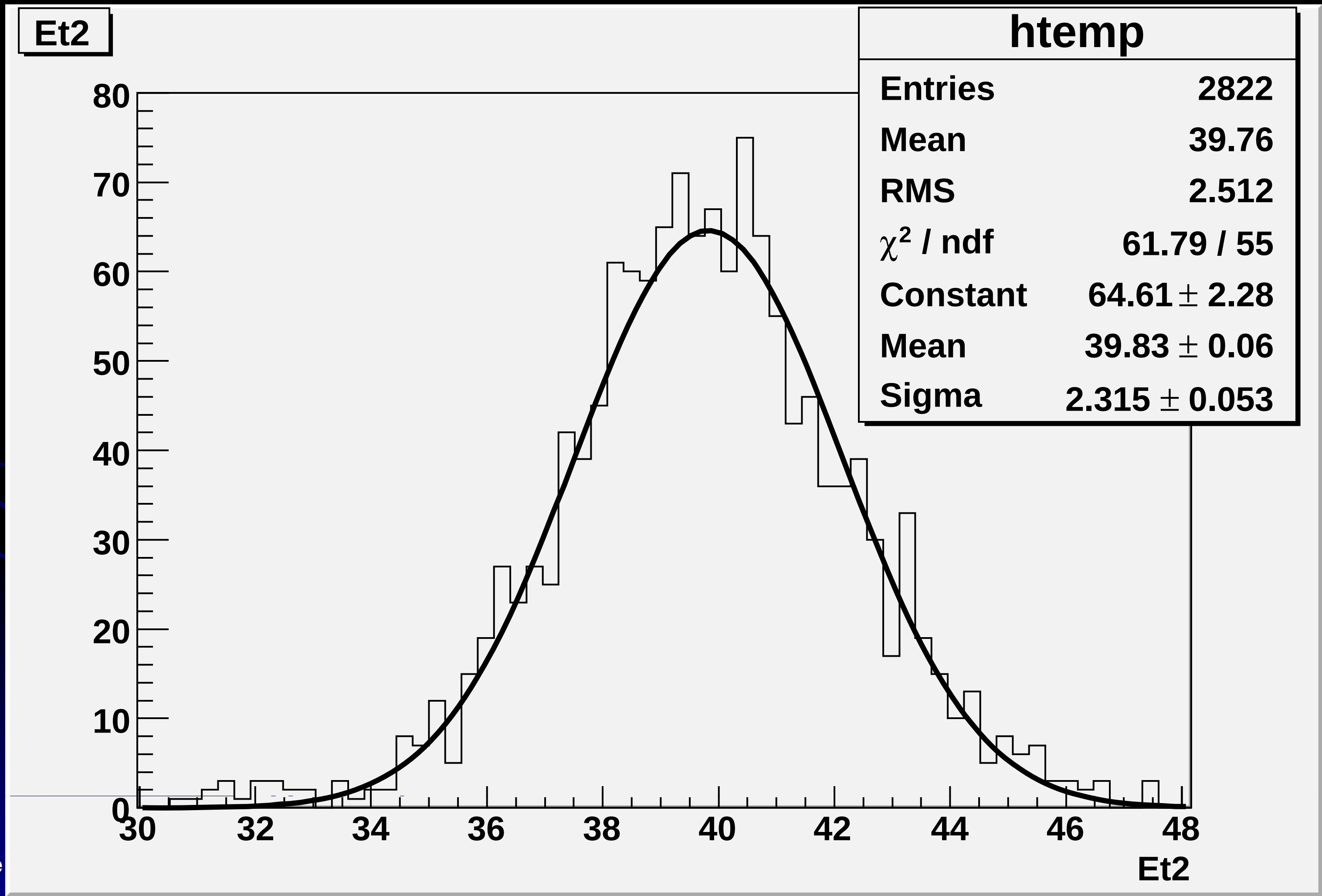
HCAL Resolution Plots



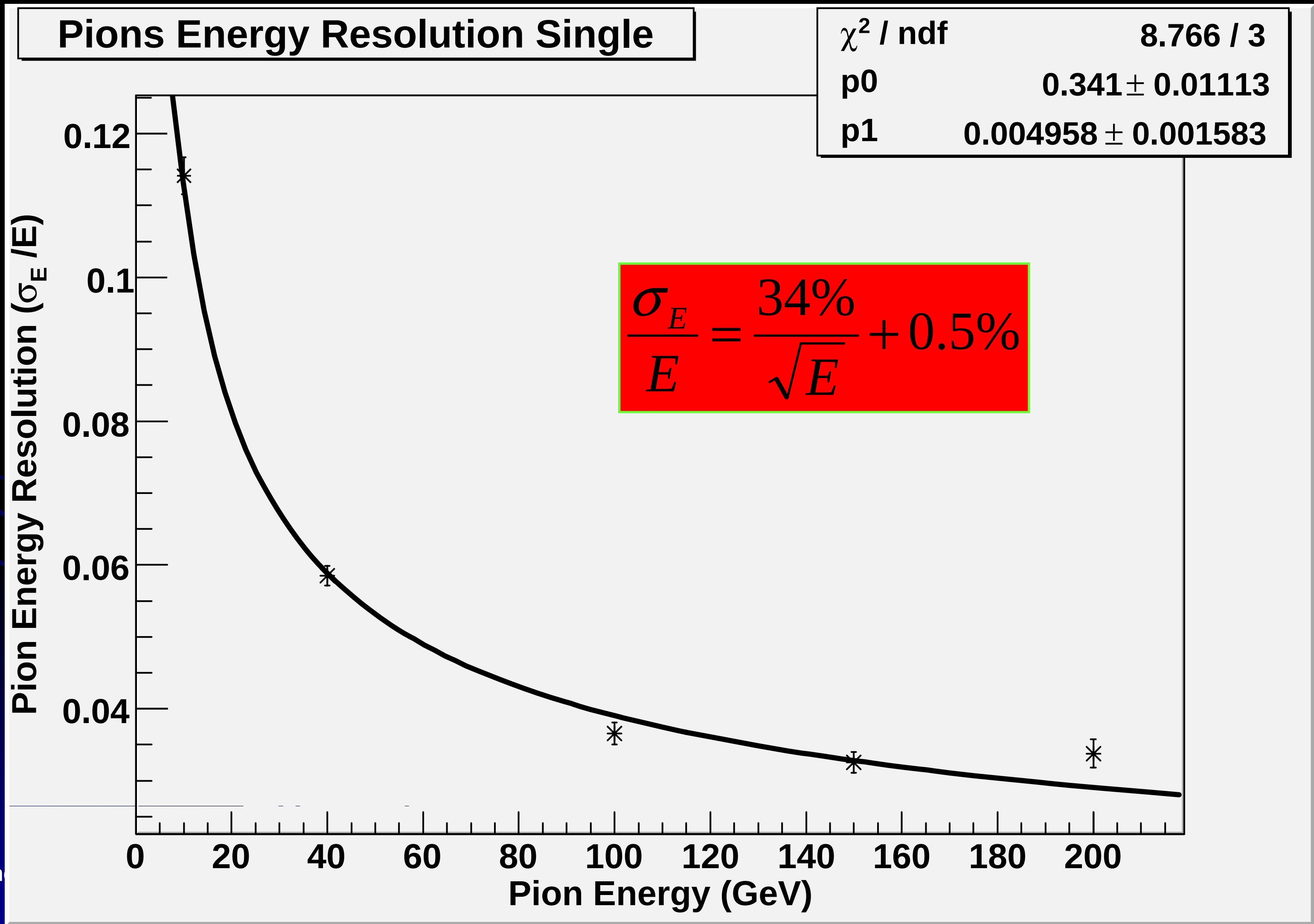
40 GeV e⁻

40 GeV π^-

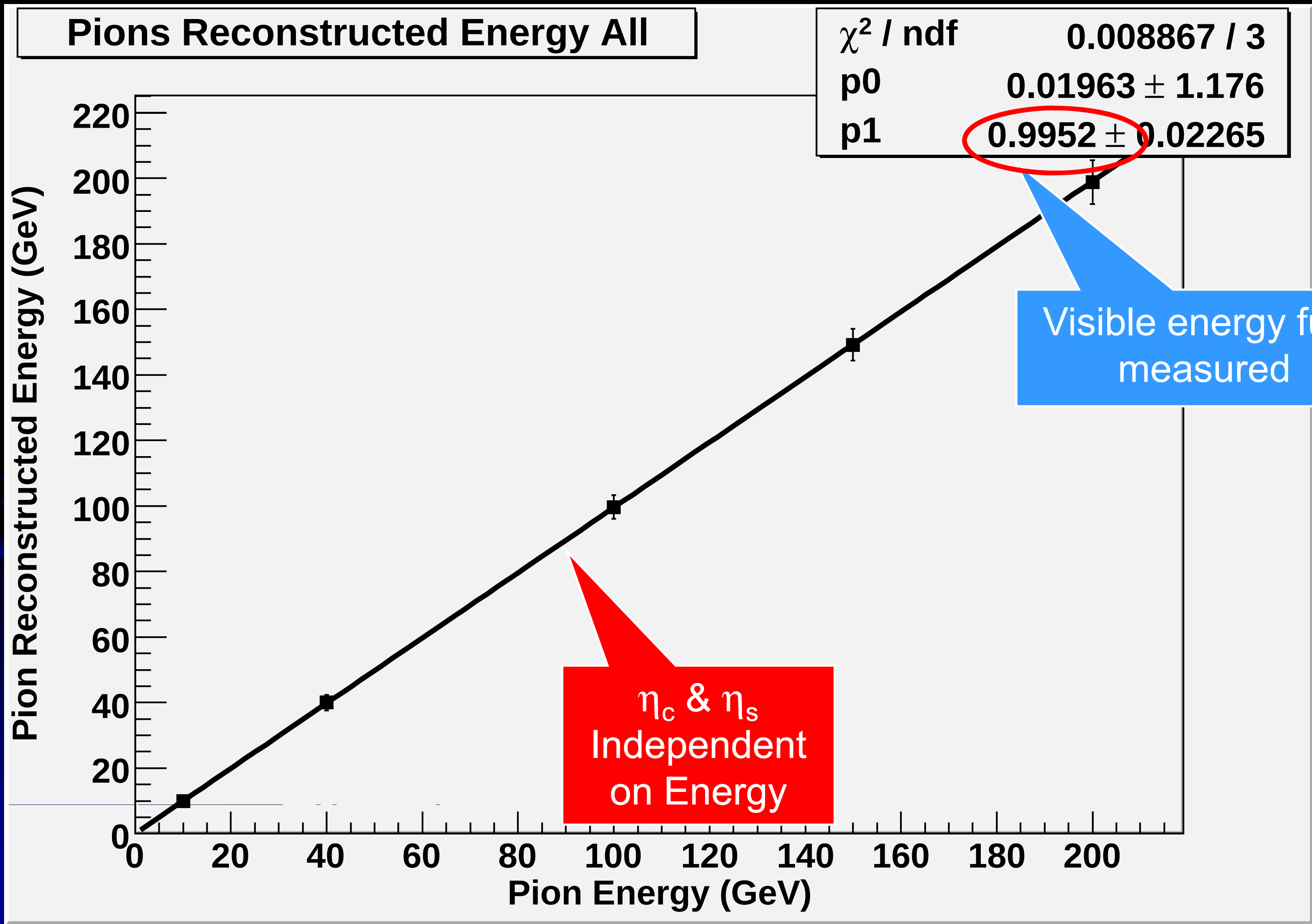
40 GeV Reconstructed Pion



HCAL resolution with single π

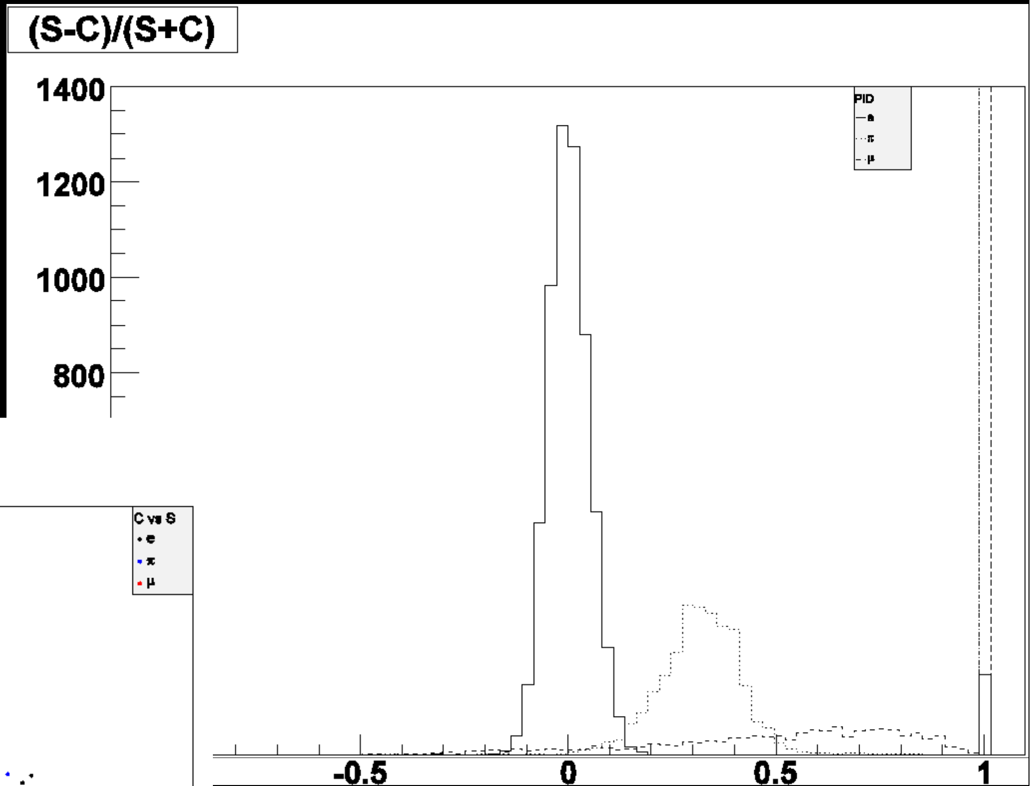


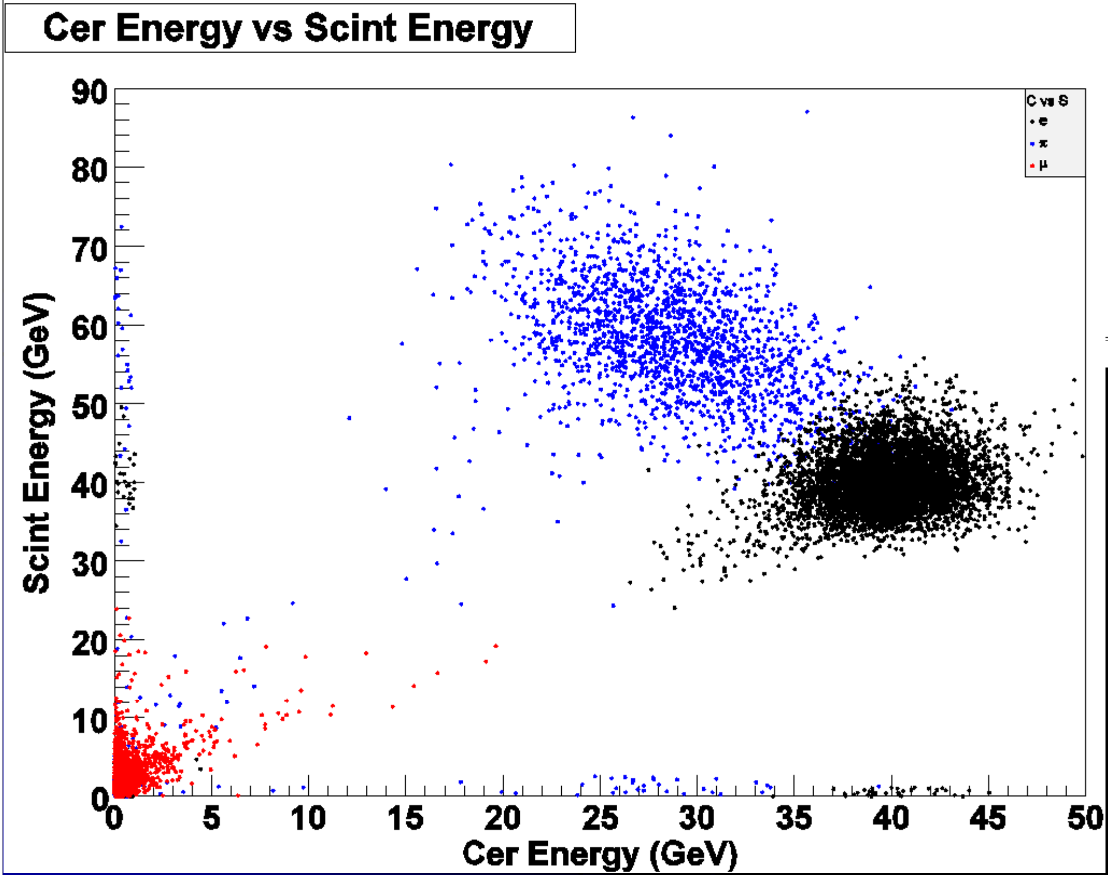
HCAL response with single π



PID from HCAL

- 40 GeV particles

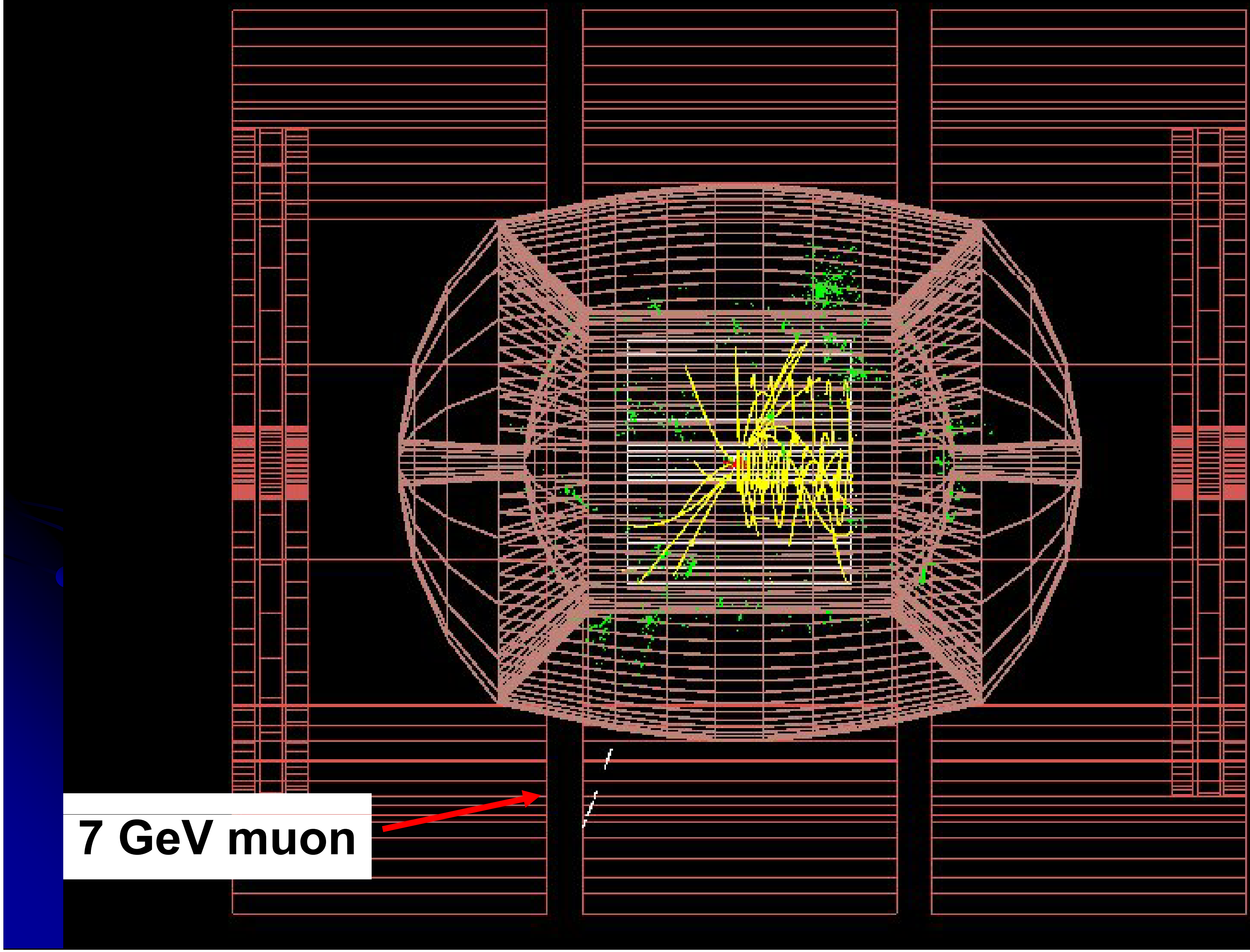




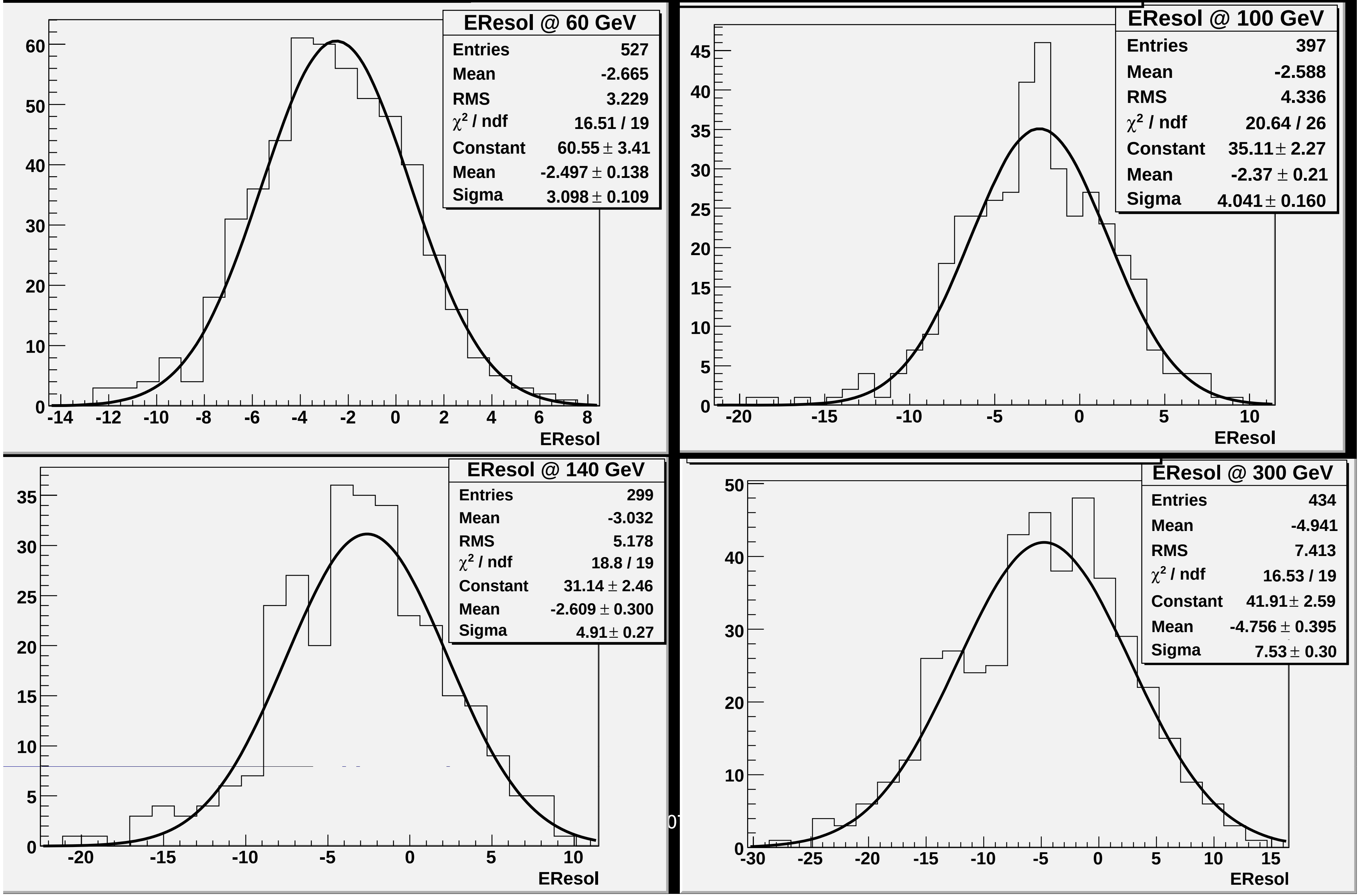
Jets Performance Studies

- e^+e^- –> qq generated in E_{cm} = [60, 500] GeV range
- Only **total reconstructed energy** considered
- No attempt to reconstruct the jet or to correct for escaping muon
- See A. Mazzacane's talk for jet finding

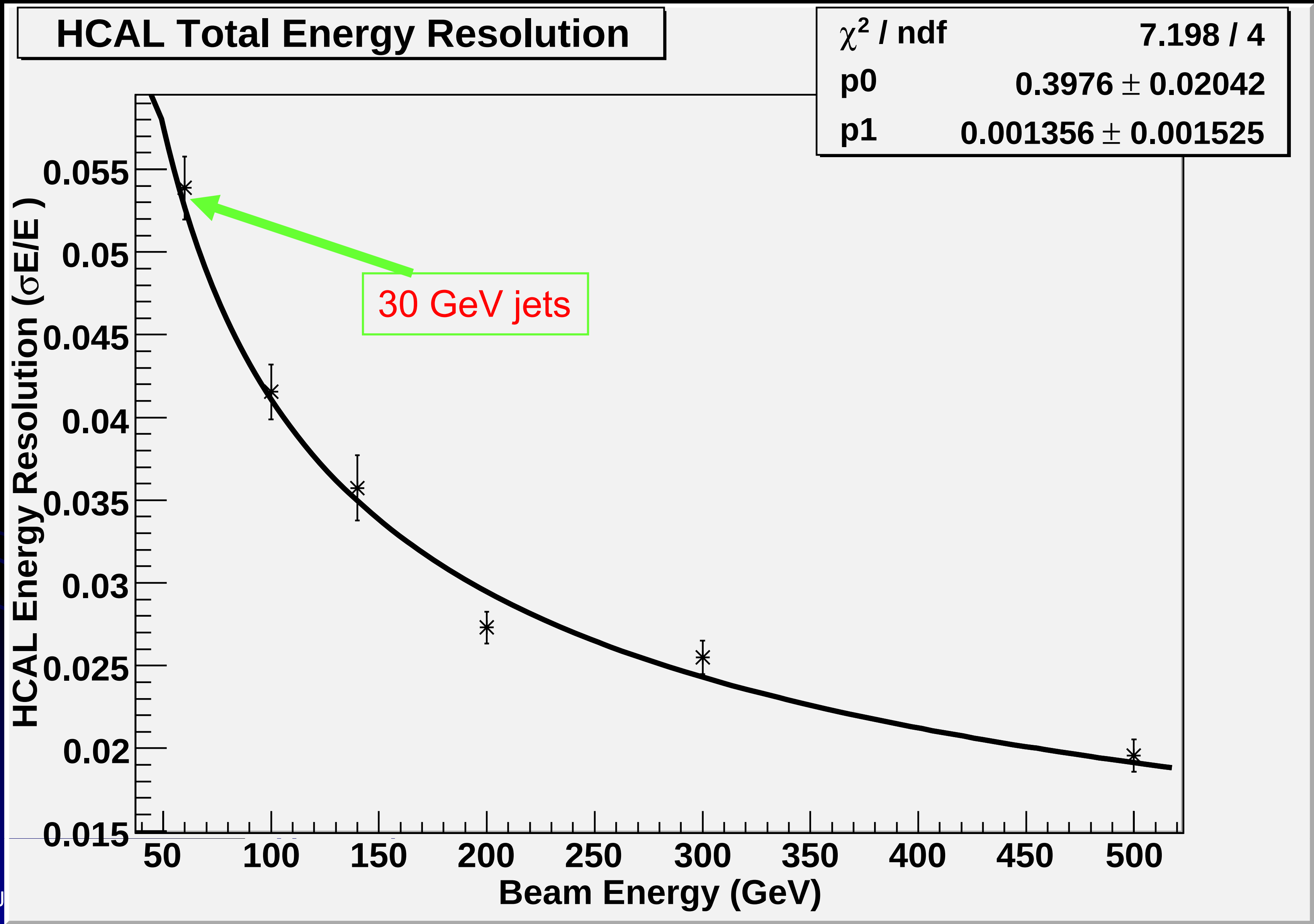
60 GeV dijets events



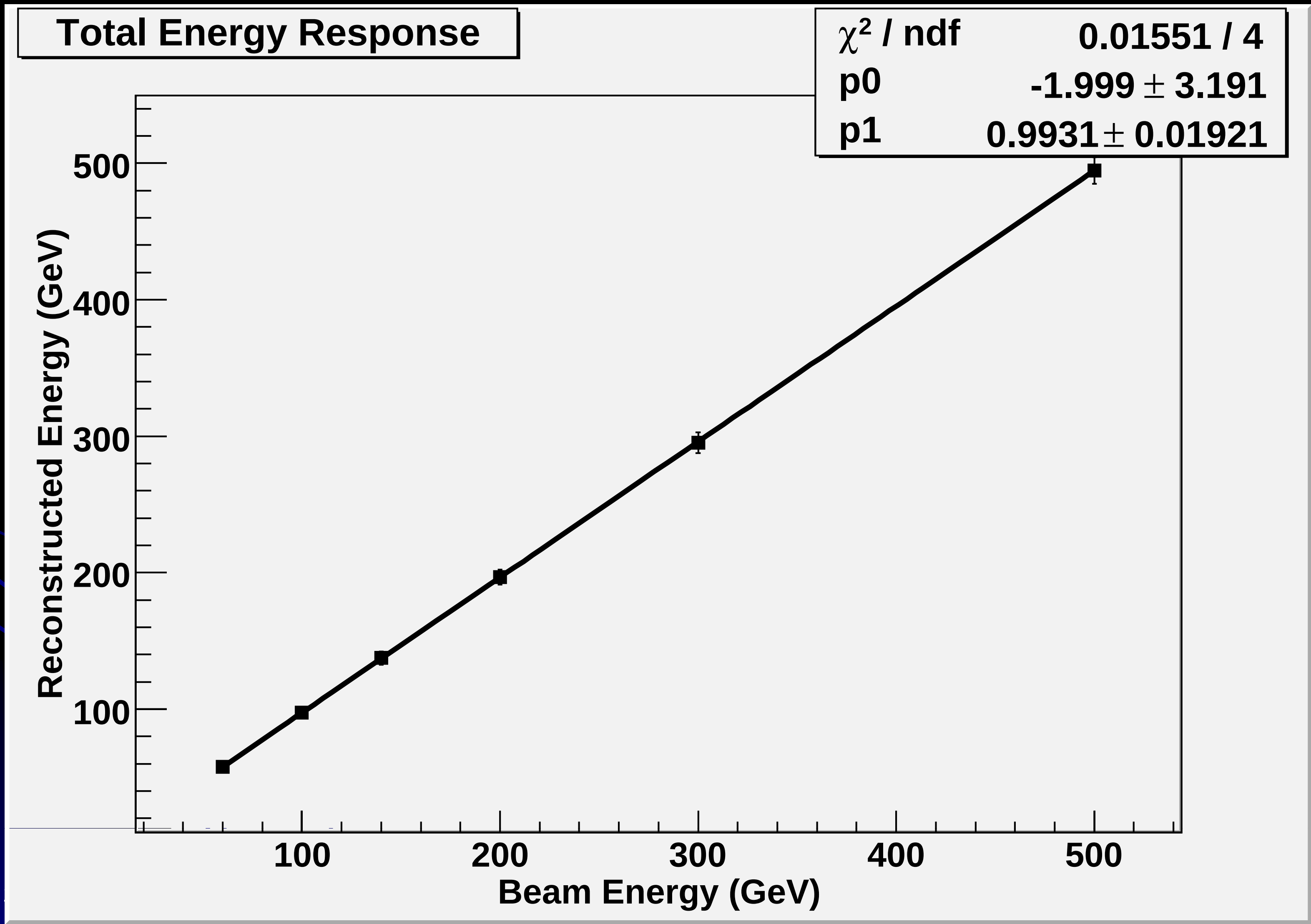
Di-jets Energy Resolution

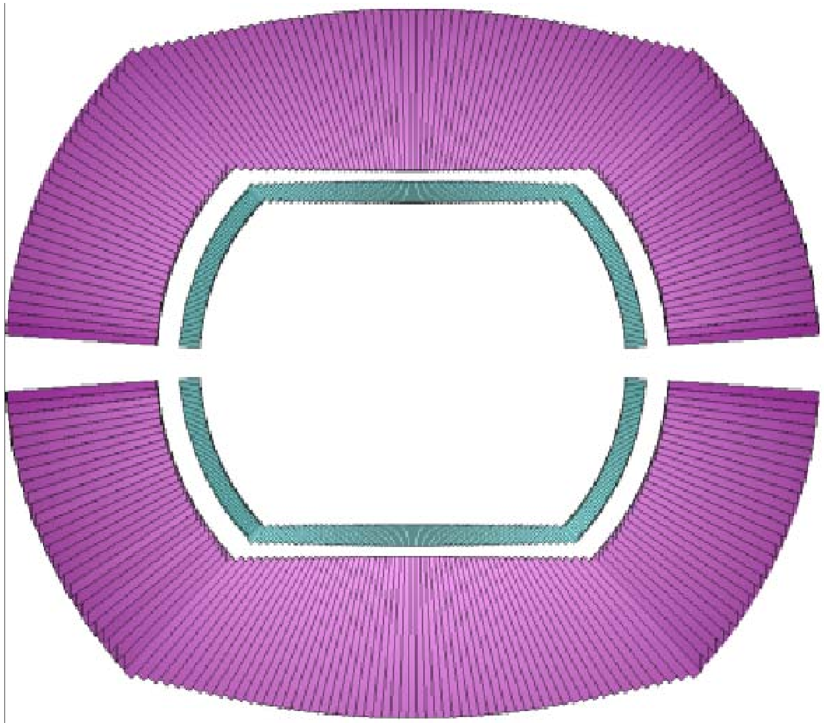


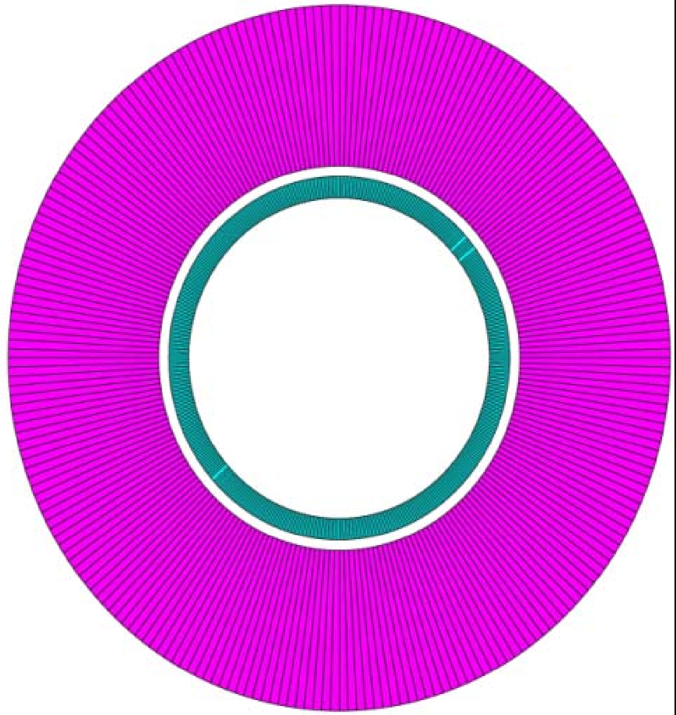
HCAL resolution with di-jets



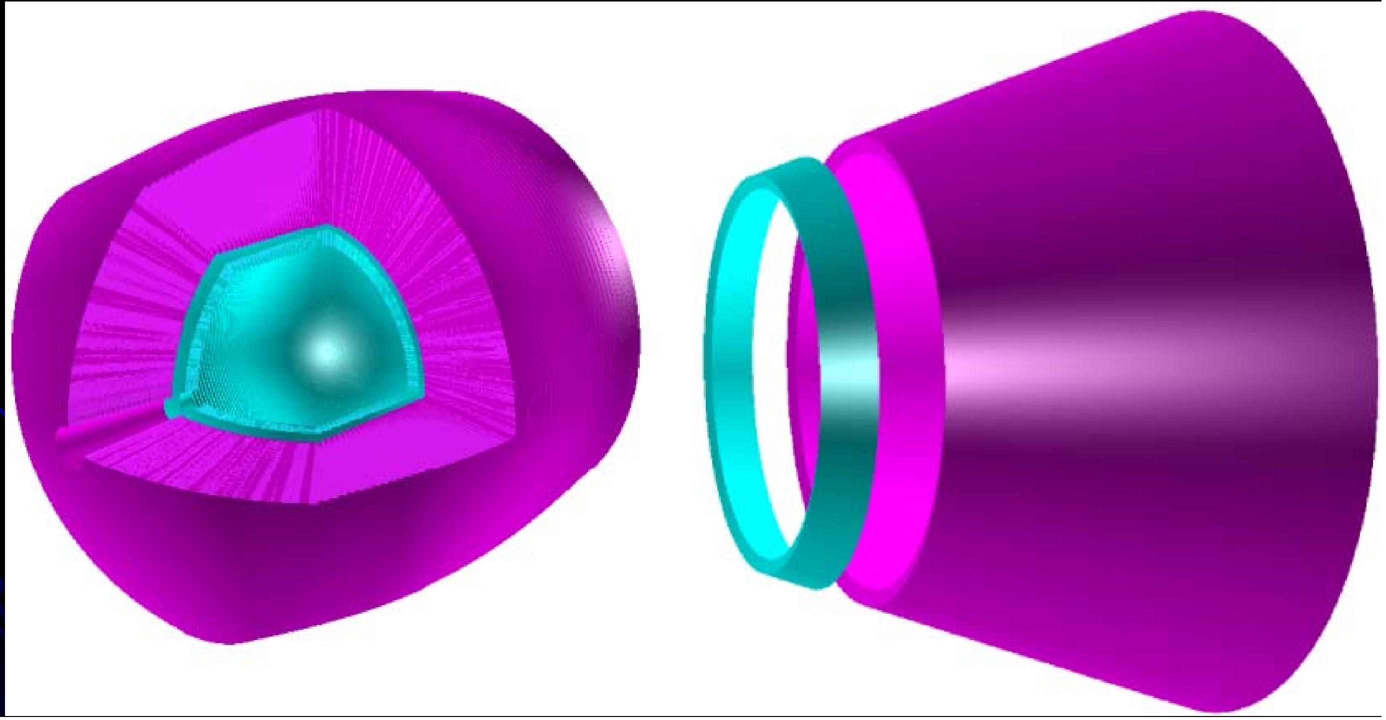
HCAL response with di-jets







ECAL + HCAL



June 2nd, 2007

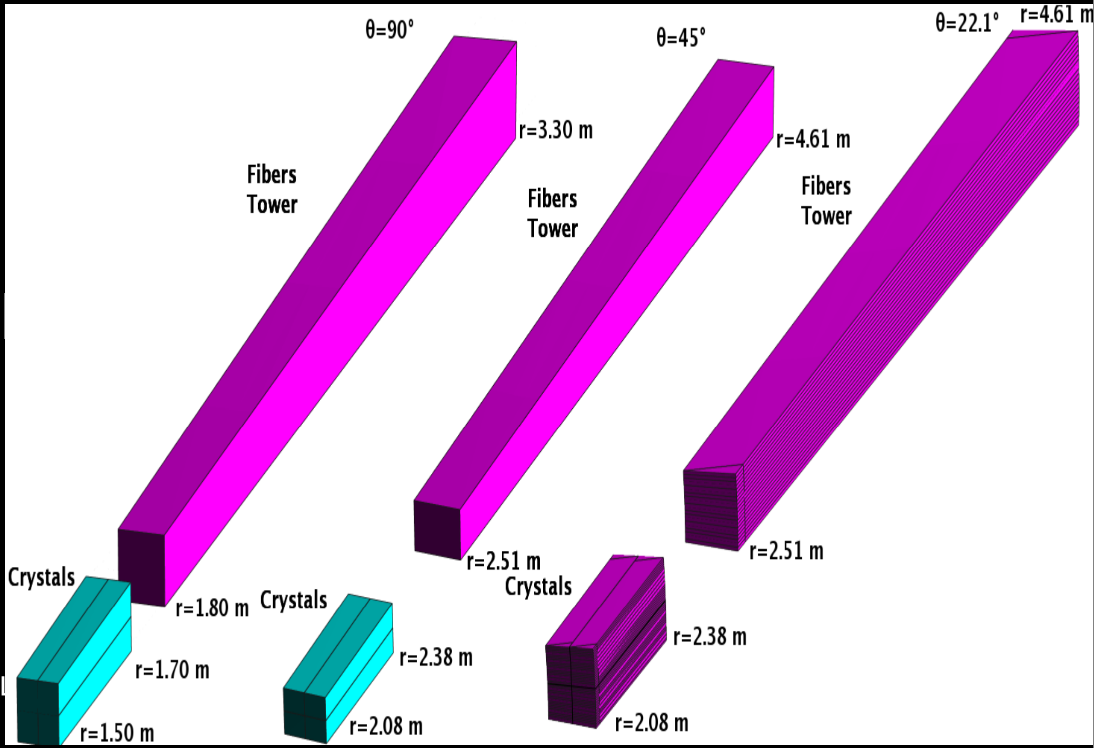
The 4th Concept Crystal Calorimeter

- 25 cm PbF_2 with 0.15% Gd doping
- ~ 1.25 λ
- ~ 27.7 X/X_o
- Fully projective geometry
- ~1.5° aperture angle
- Azimuth coverage

down to 3.4°
- Barrel: 55696 cells

(944slices containing 236 ce
- Endcaps: 12656 cells

arranged in 108 rings

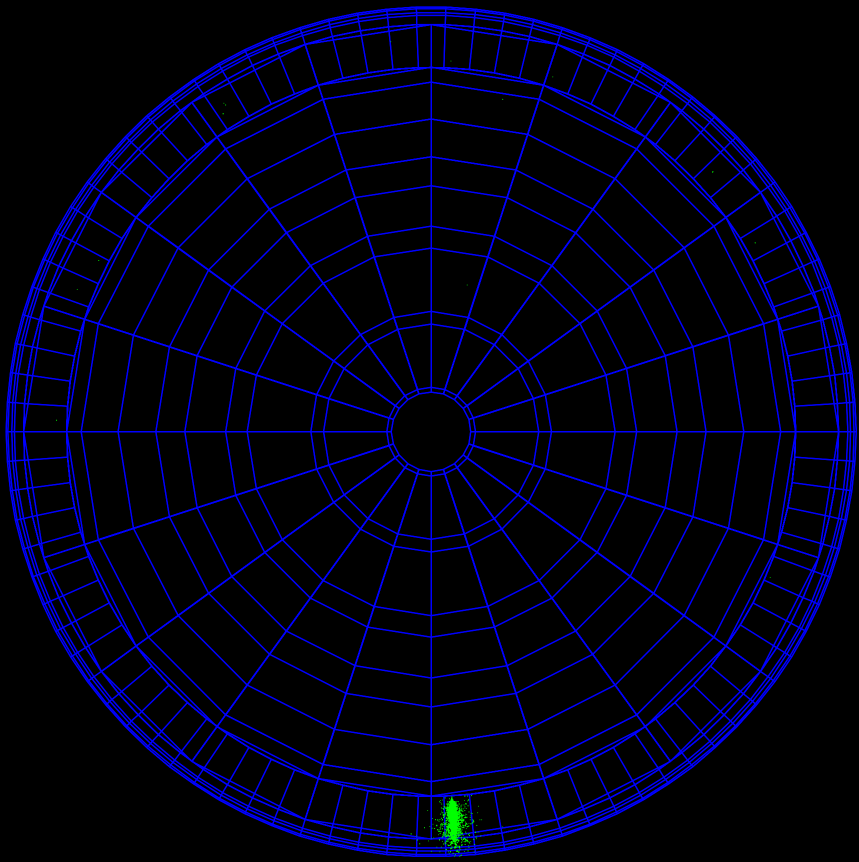


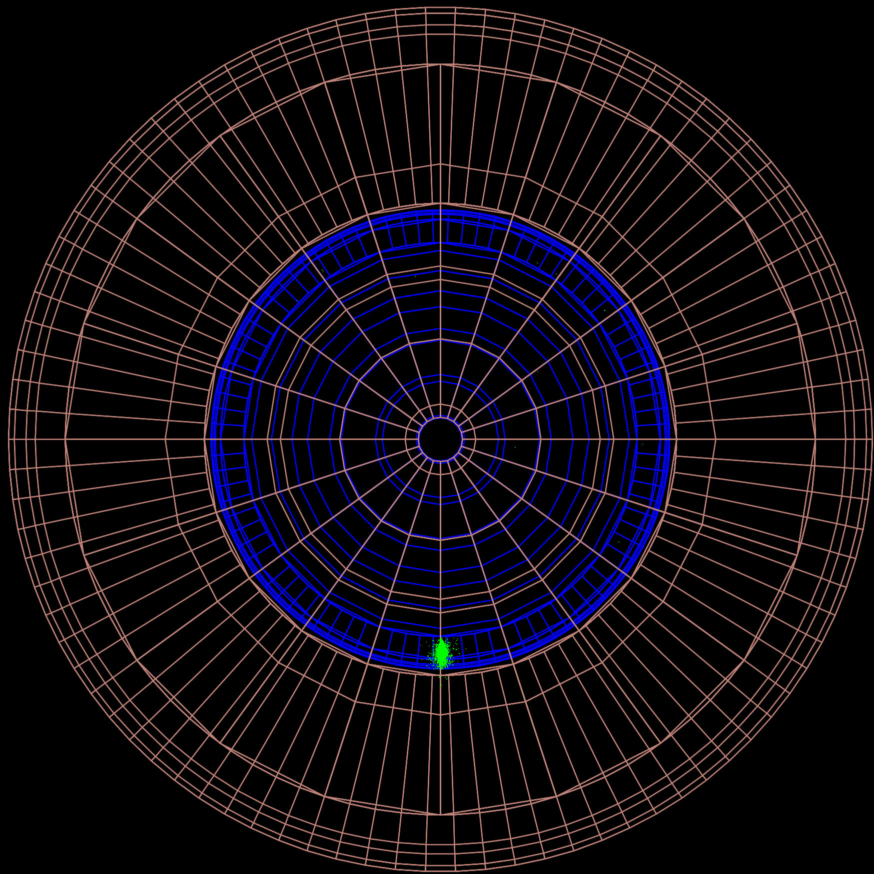
ECAL Performance Studies

- Assume 10% QE and PbF2 doped with 0.15% Gd
  - Scintillation pe yield: 4.5 pe/MeV
  - Cerenkov pe yield: 1.5 pe/MeV

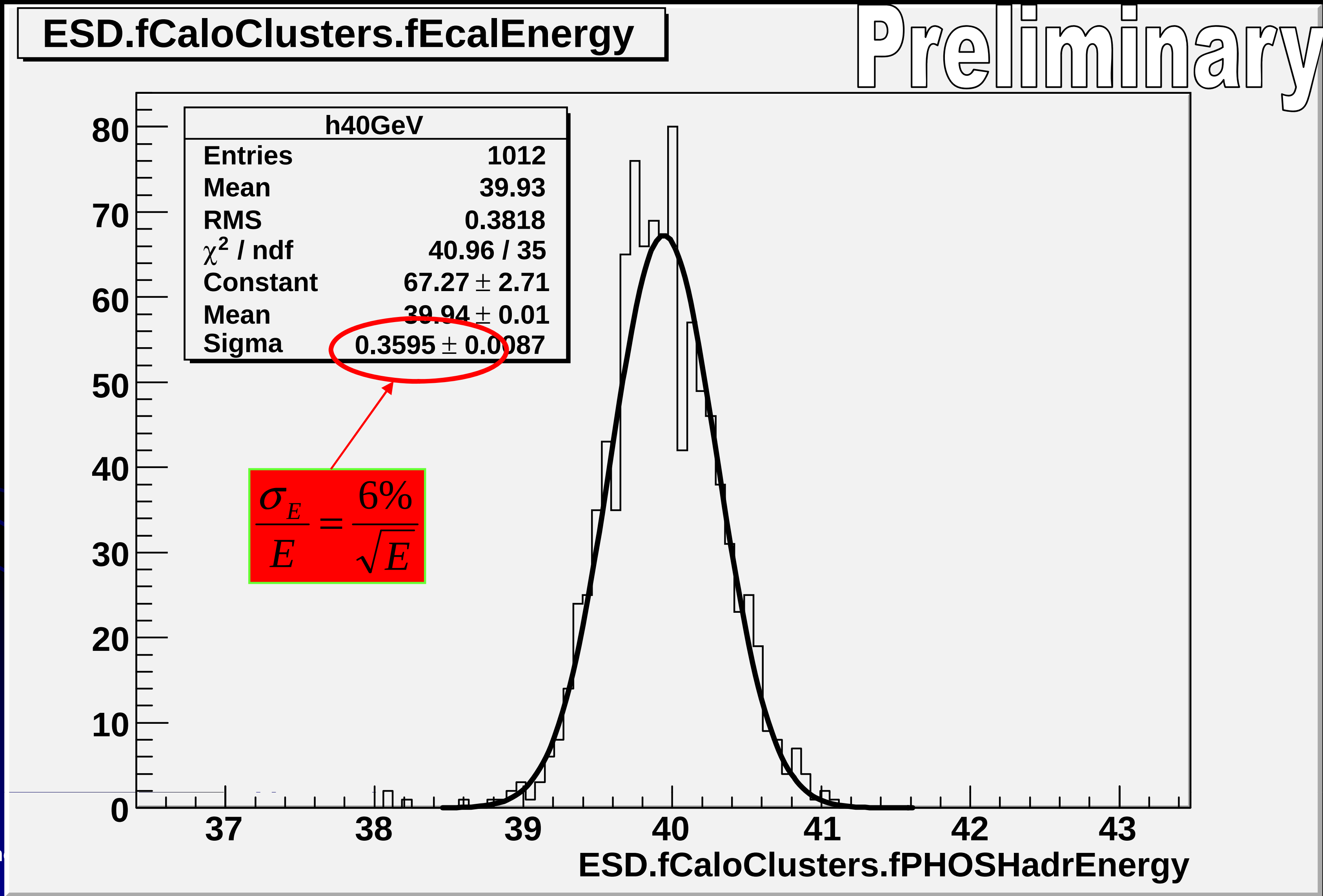
- Preliminary resolution results with π^{o} in 10-200 GeV range
- $\tau \rightarrow \nu\pi\gamma\gamma$ studies in progress

70 GeV π^o in ECAL+HCAL

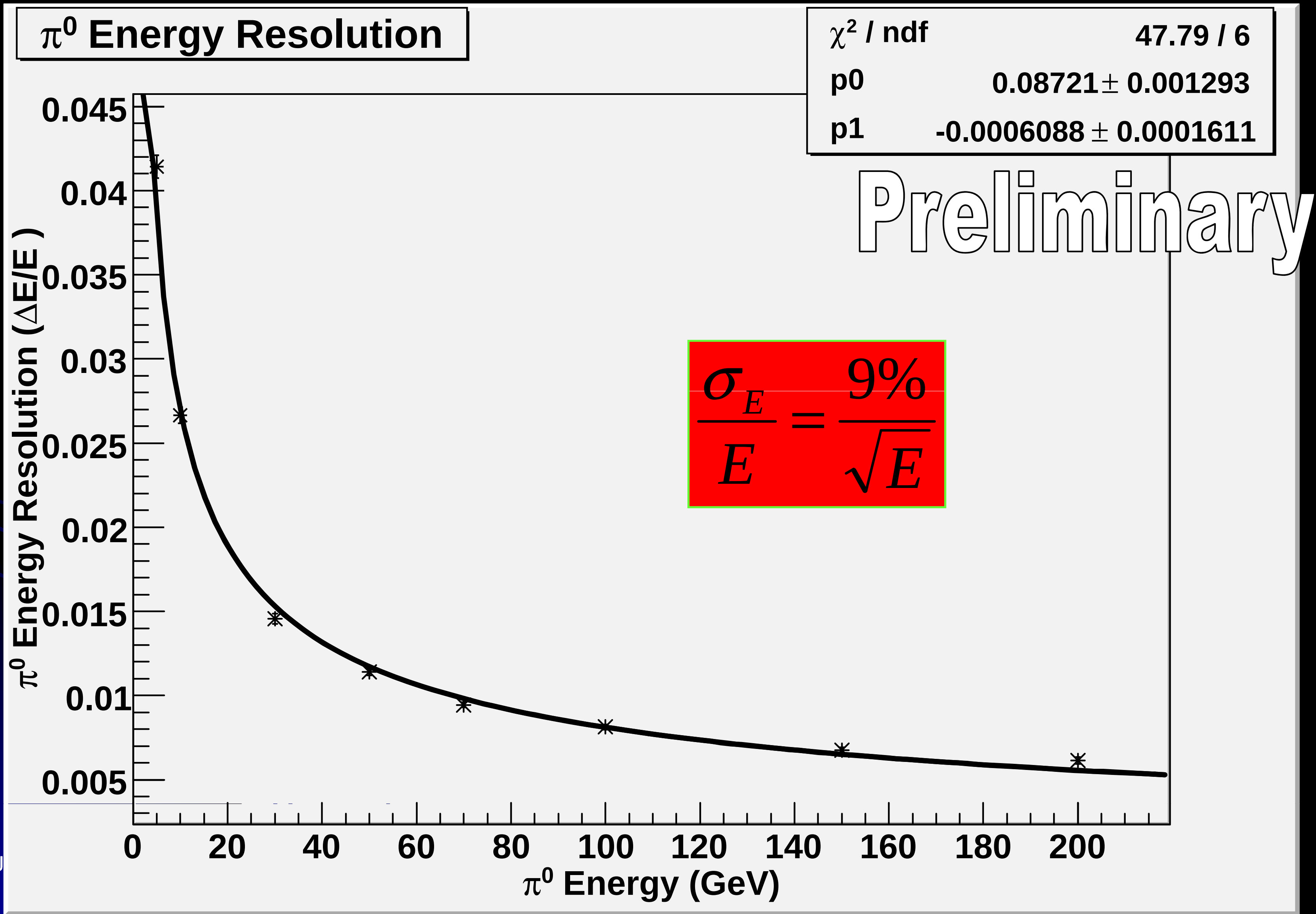




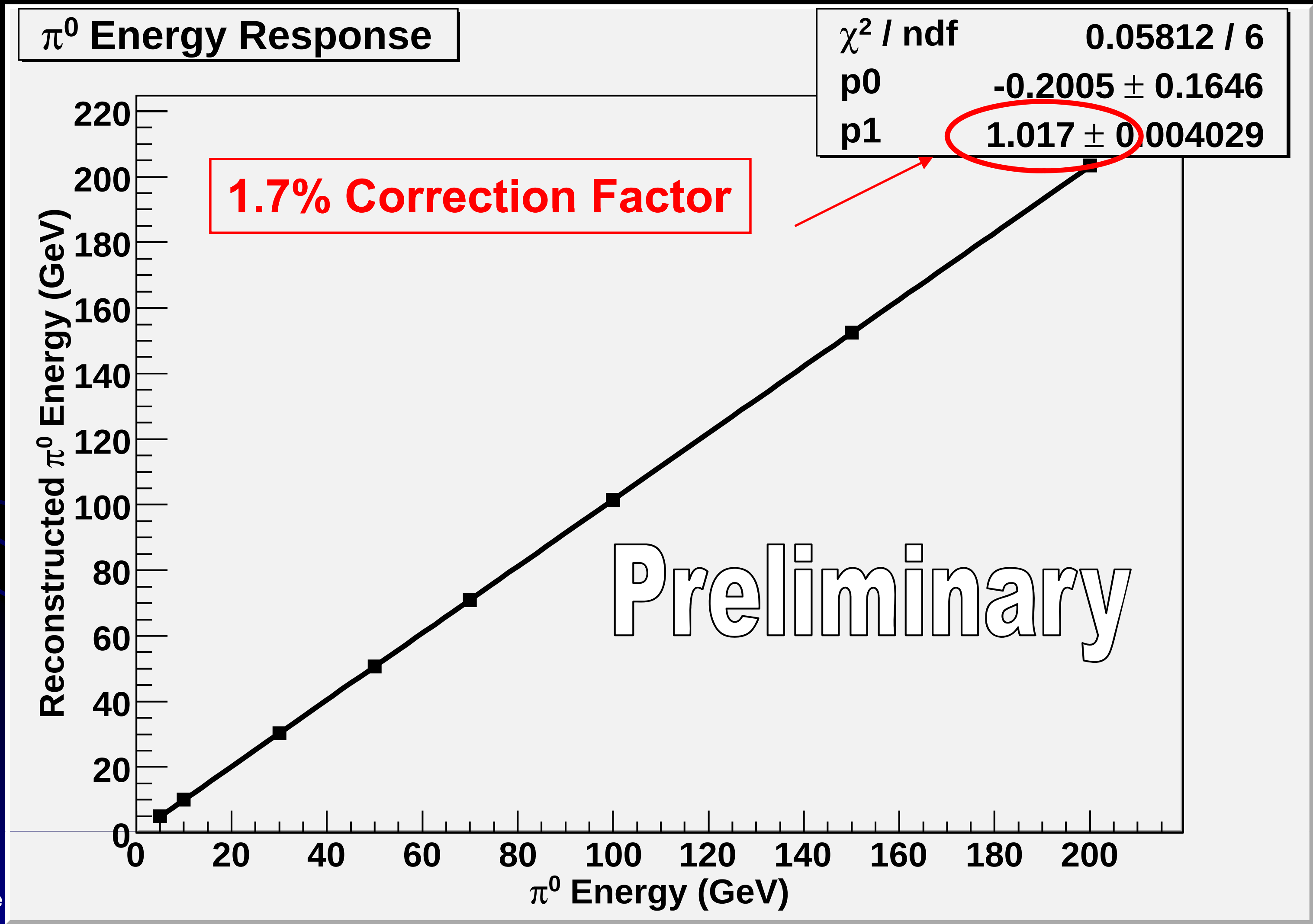
Resolution for 40 GeV e⁻



Resolution for π°'s ECAL+HCAL



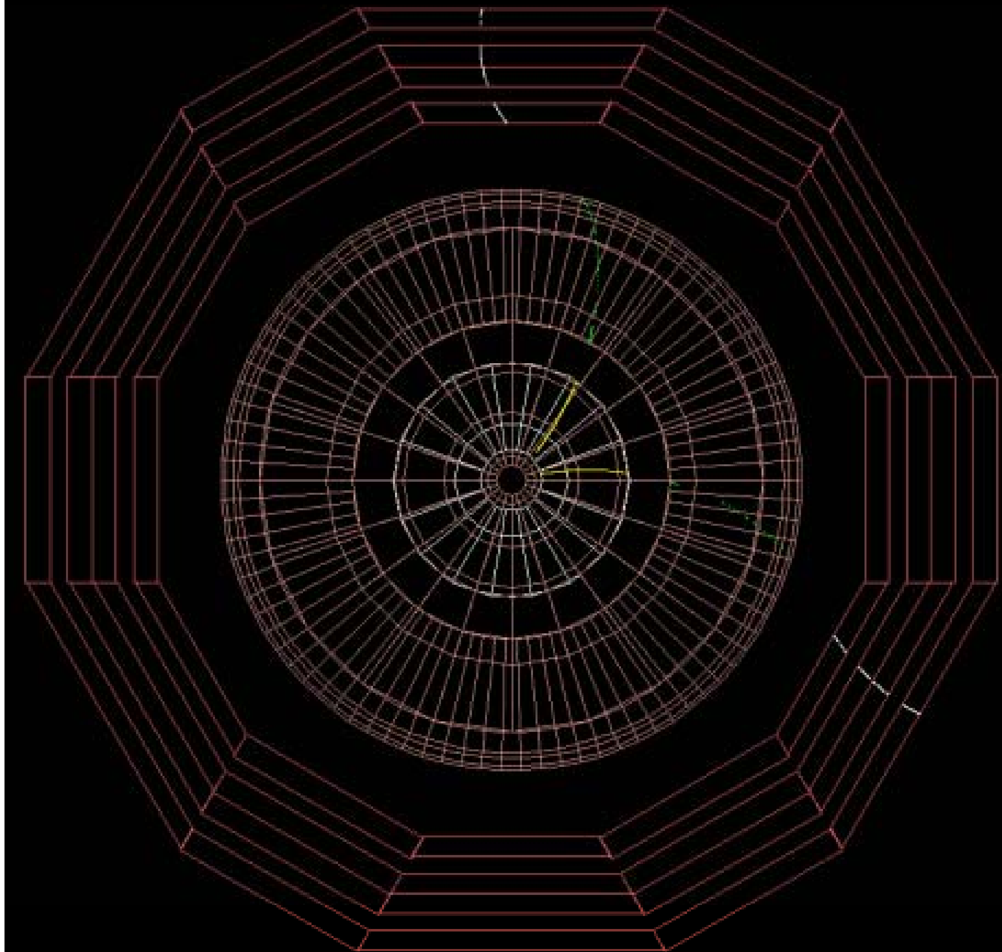
Energy Response for π^o's
ECAL+HCAL



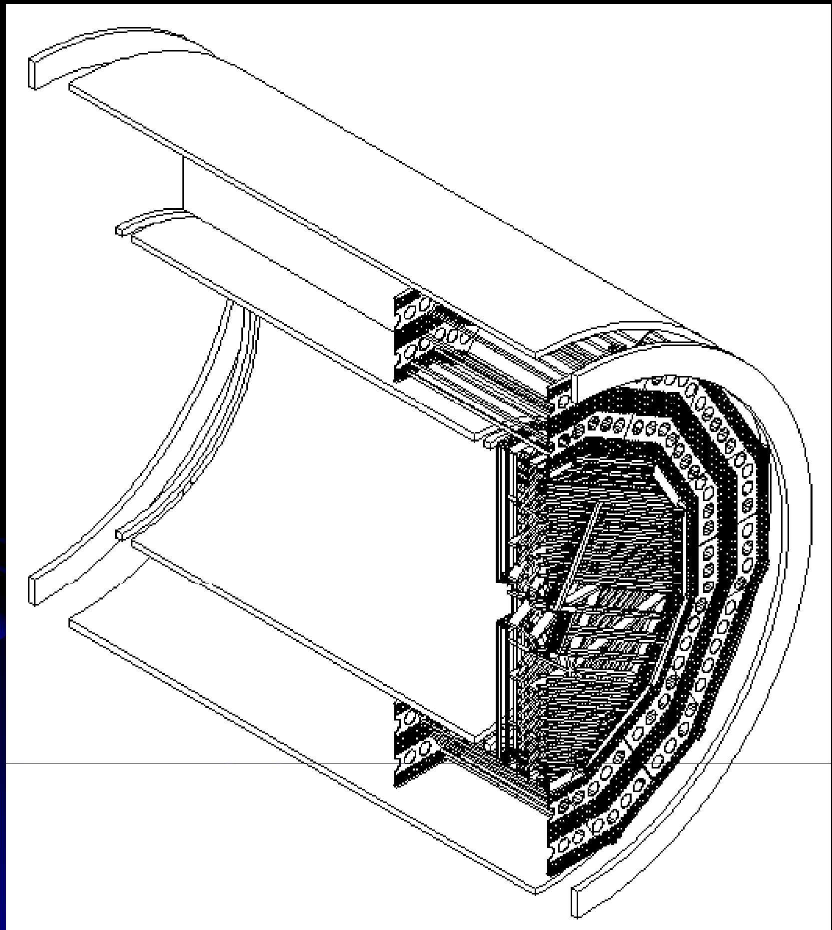
MUD and Calorimetry

- Essential for jet reconstruction
  - Measure the momentum of hard particles escaping the calorimeter
  - Tail catcher for HCAL
- Provides continuous calibration via muon brehemstralung

$\mu^+ \mu^-$ at 3.5 GeV/c



Muon Spectrometer with Dual Solenoid (MUD)

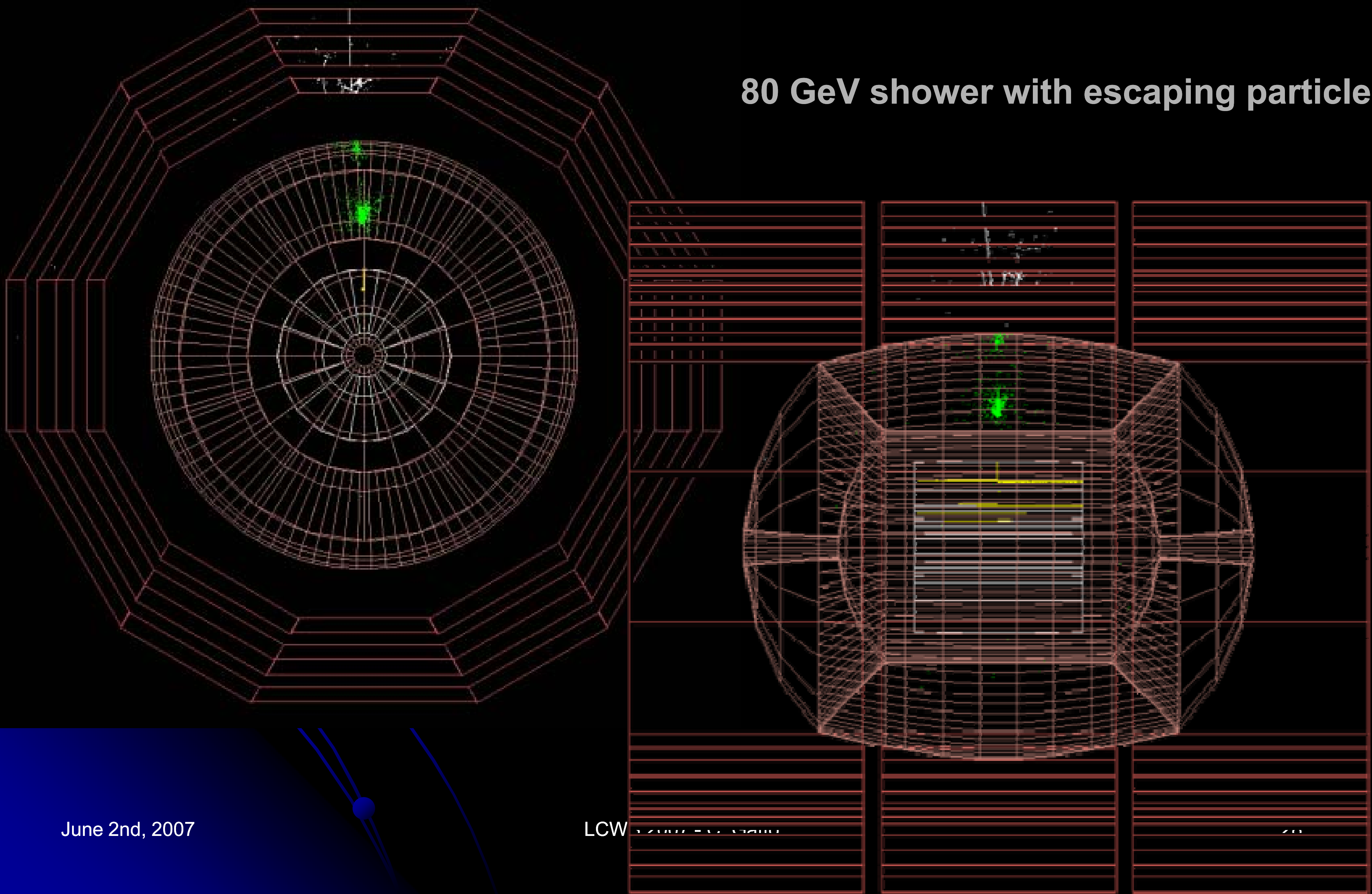


Barrel:
- 31500 tubes
- 21000 channels
- 840 cards

End caps:
- 8640 tubes
- 9792 channels
- 456 cards

Total:
- 40140 tubes
- 30792 channels
- 1296 cards

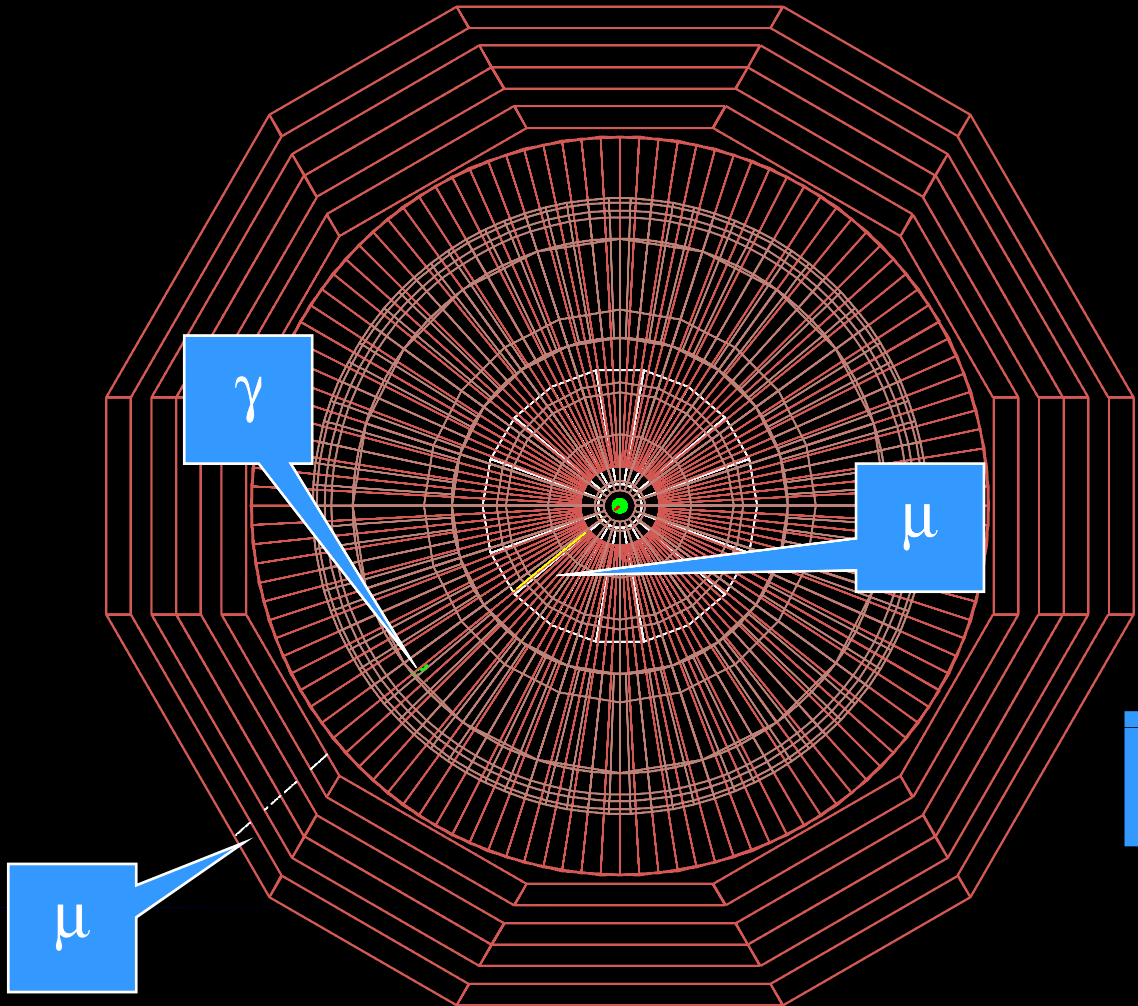
MUD for jet finding and tail catching



80 GeV shower with escaping particles

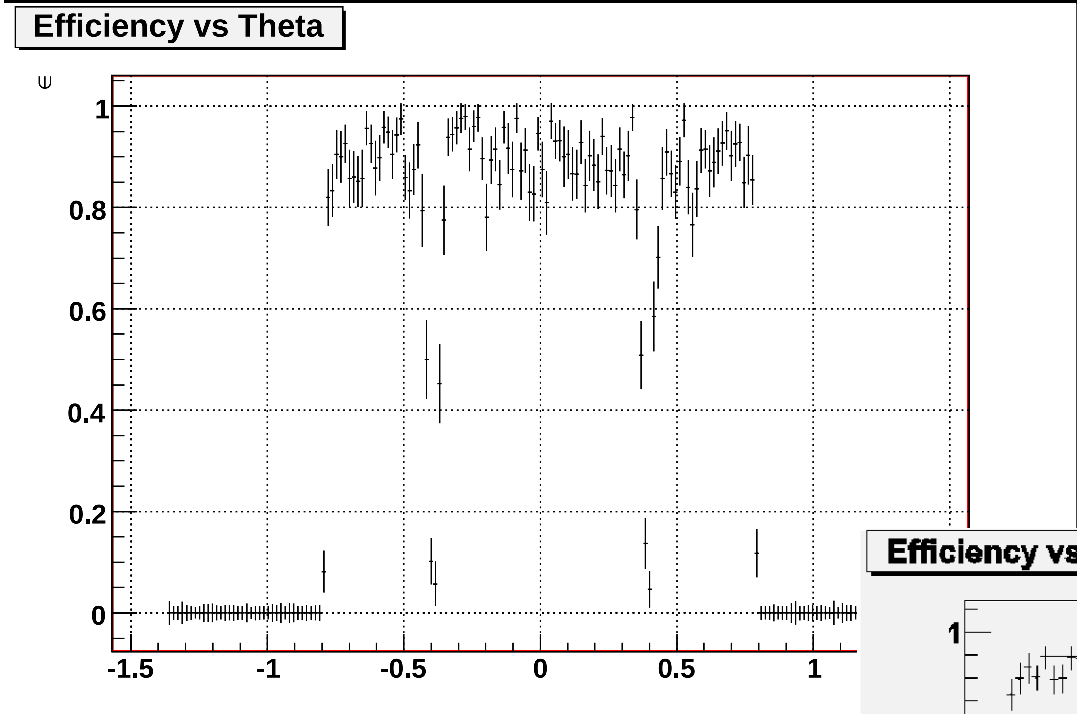
MUD for Calorimeter Calibration

- P_{CT}=44.5 GeV
- P_{MUD}=38.0 GeV
- E_{γ}(truth)=8.0 GeV

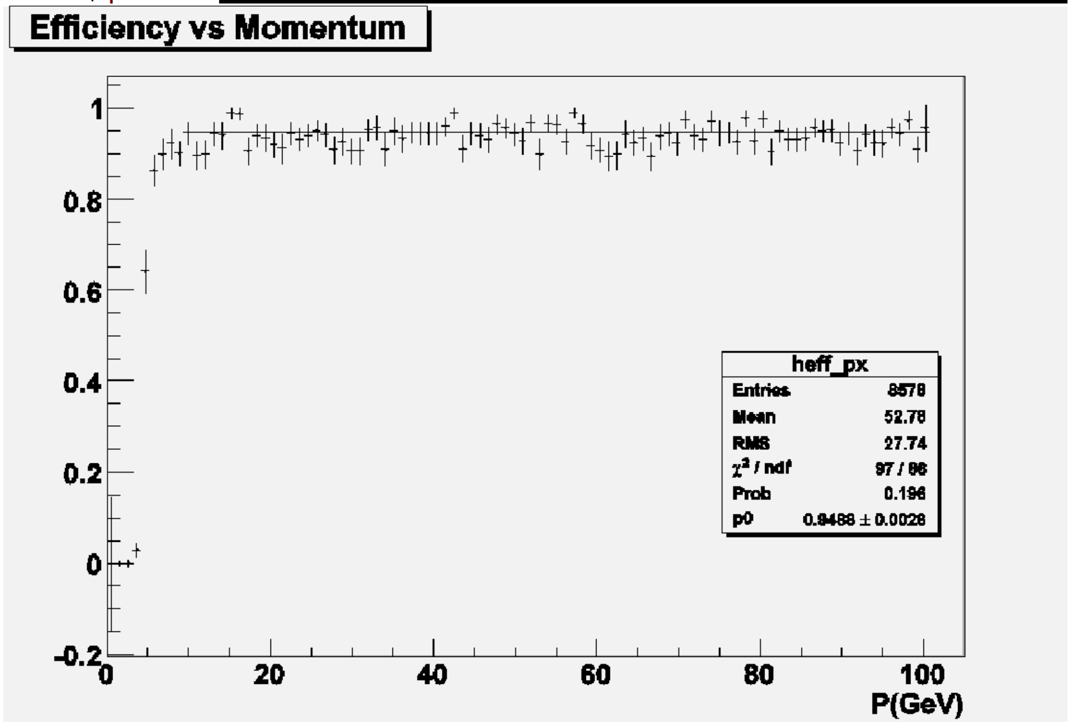


μ –>μγ

Efficiency (Barrel Only)



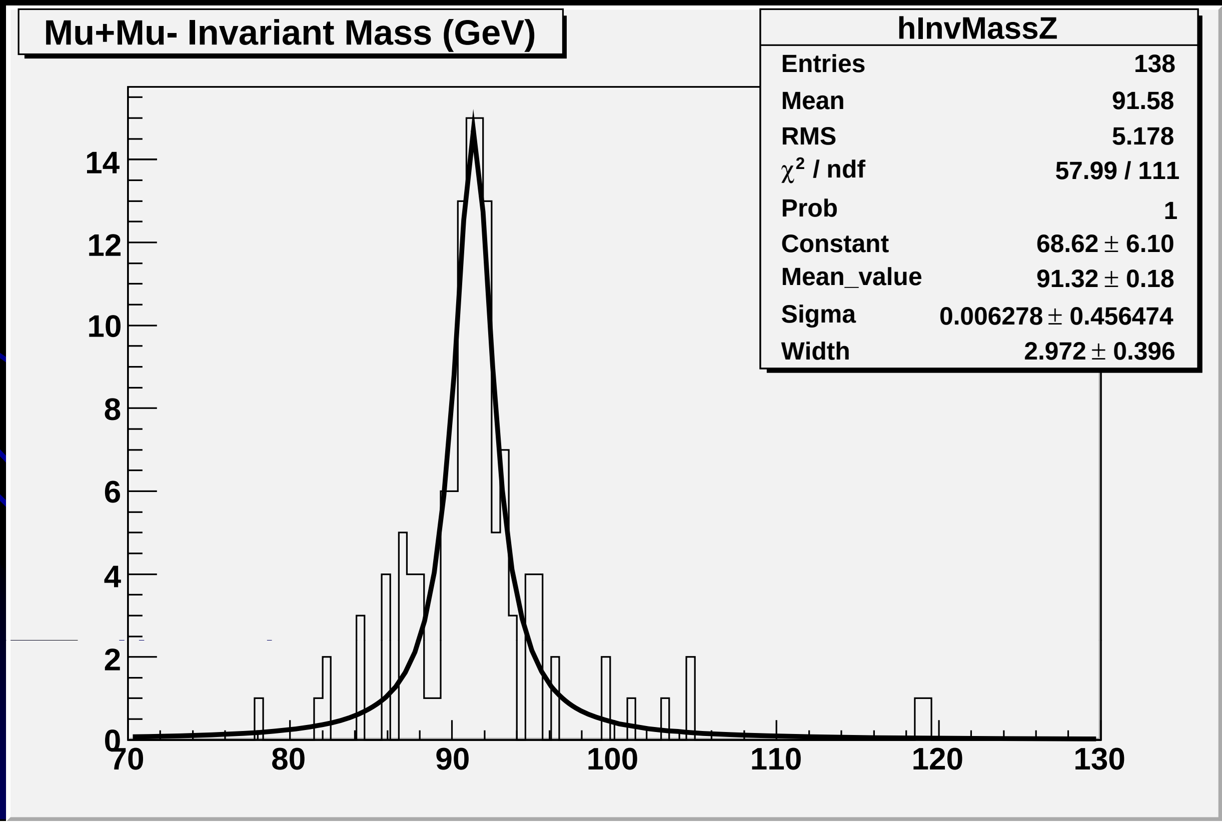
- P>20 GeV
- Tracks already reconstructed in TPC



- P>4 GeV
- Cracks excluded
- Tracks already reconstructed in TPC

e^+e^- -> $H^oH^oZ^o$ -> 4 jets 2 muons

- E_{cm} = 500 GeV
- Efficiency (total) = 92% (no SA tracker)



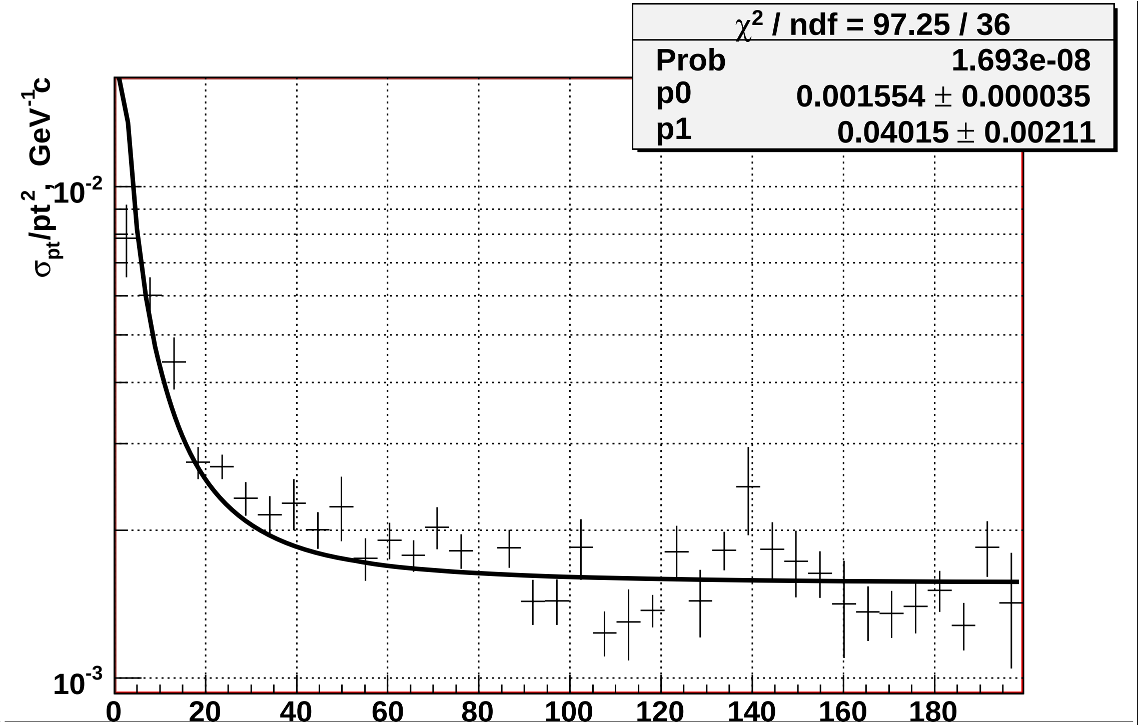
MUD Performance

- Tracking is working for:
  - P_t > 400 MeV
  - $|\theta| > 45^{\circ}$ (barrel only)
- High momentum tracks resolution:
  - $\sigma(1/p_t) = 1.6 \times 10^{-3}$

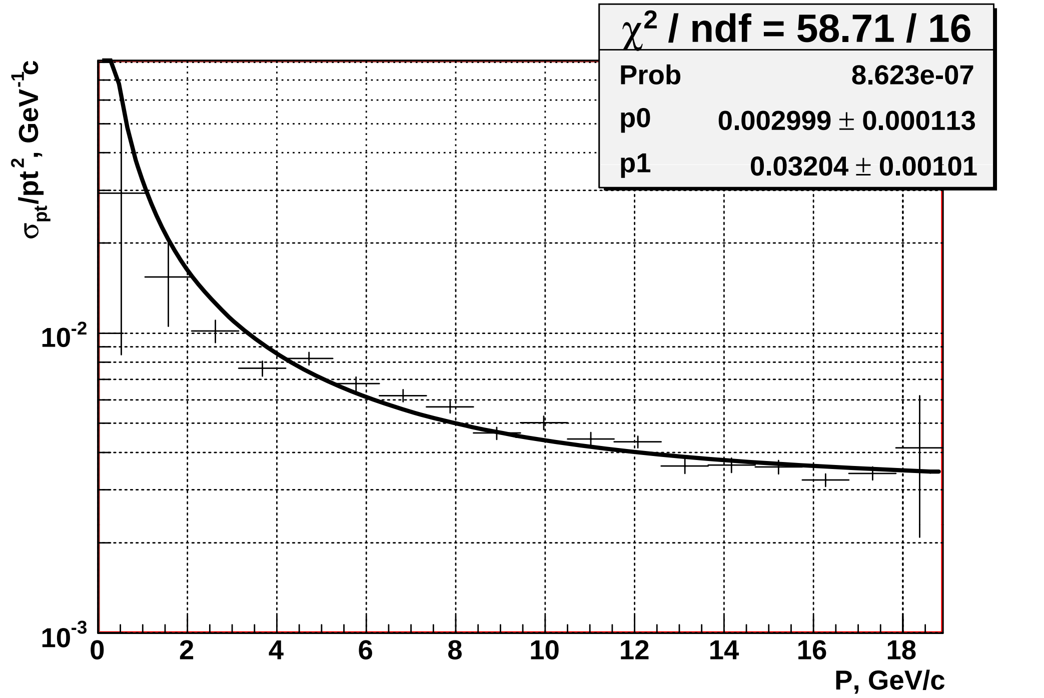
Very conservative 200 μm single point resolution used

- Efficiency (P_t>6 GeV) = 95%

P_t Resolution



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



Conclusions

- Performance of Hadron Calorimeter is good (including pattern recognition) and **INDEPENDENT OF ENERGY**:

$\sigma_E/E = 34\%/\sqrt{E}$ (single hadrons)

$\sigma_E/E = 40\%/\sqrt{E}$ (jets – total energy – no corrections)

- Expected to improve with jet finding (recovery of soft tracks and lost muons)
- Detector optimization not yet started (Cu vs Pb, fibers fraction)
- New Dual Readout EMCAL implemented

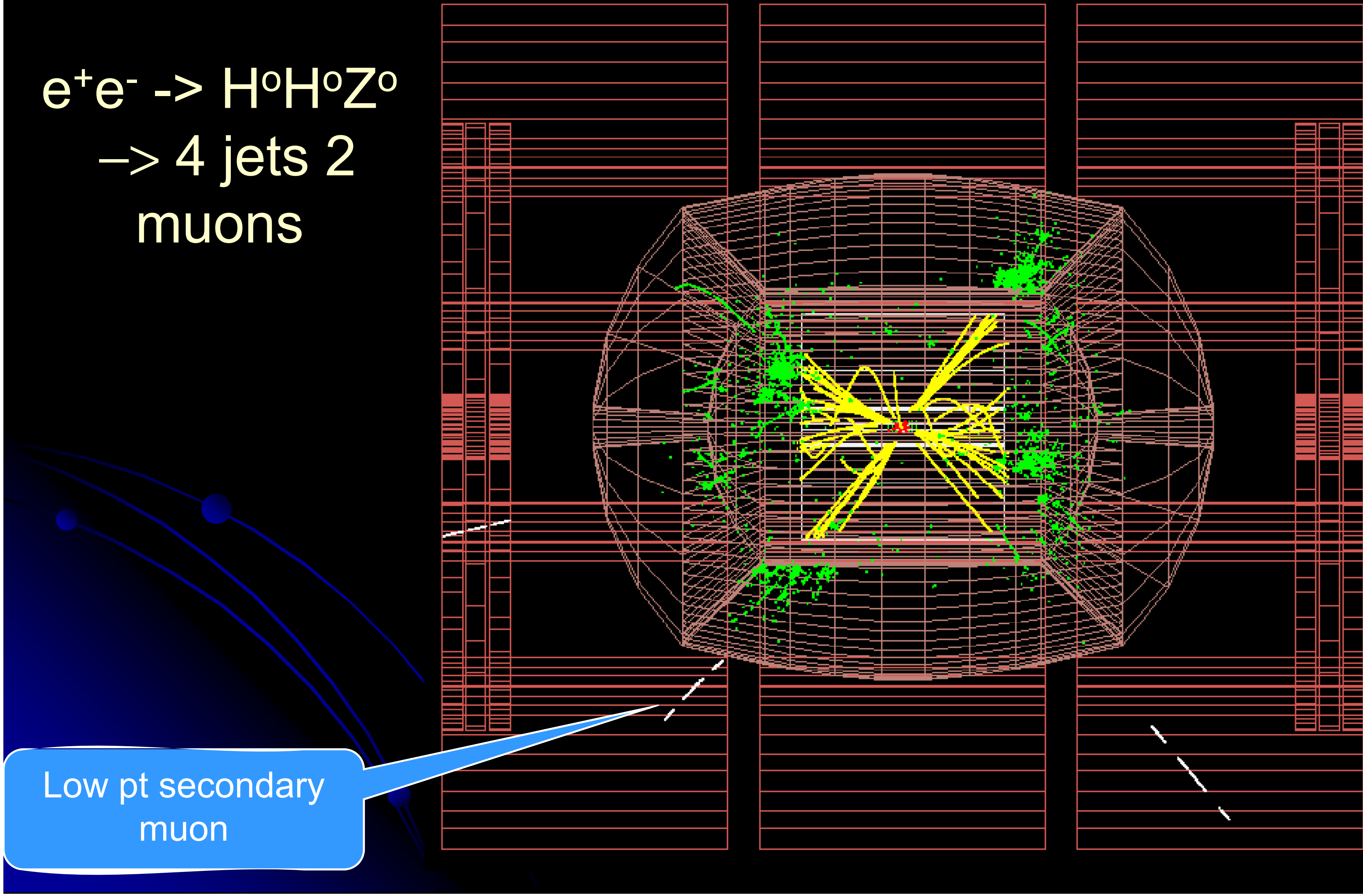
$\sigma_E/E = 6\%/\sqrt{E}$ ECAL (very preliminary)

$\sigma_E/E = 9\%/\sqrt{E}$ ECAL+HCAL (very preliminary)

- $\pi^0 \rightarrow \gamma\gamma$ separation from τ decay is under study
- Very high efficiency of muon finding in the midst of 4 jets (Muon Spectrometer)

Finding muons in the midst of jets

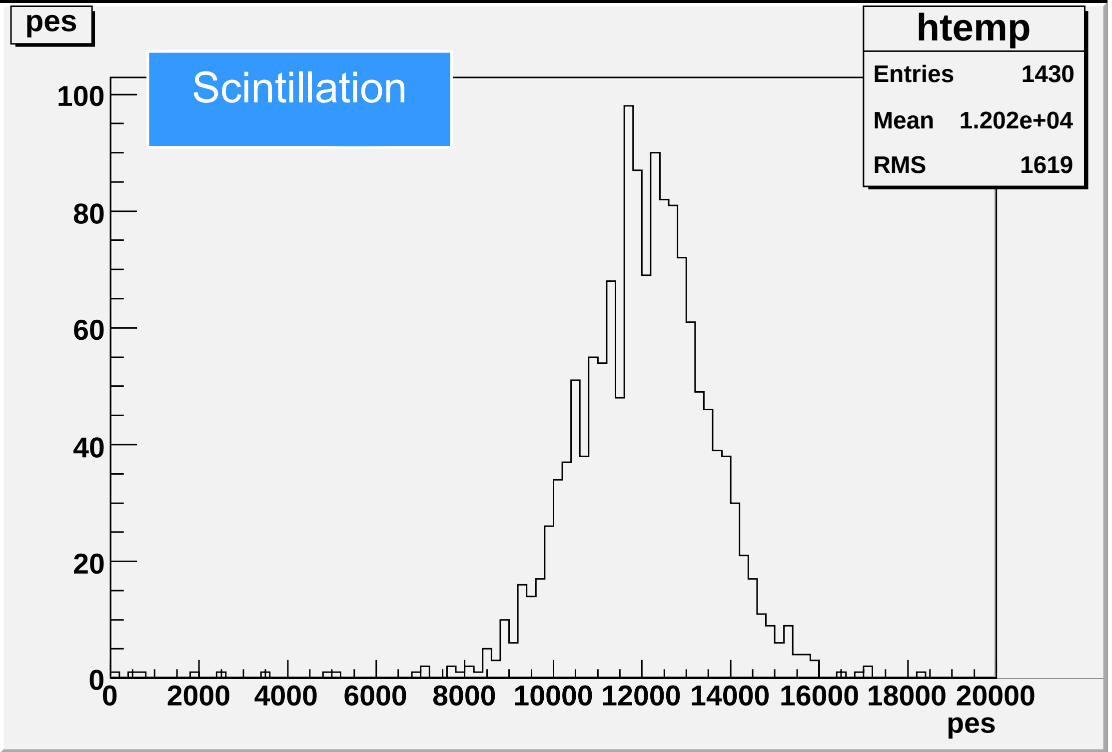
$e^+e^- \to H^oH^oZ^o$
$\to$ 4 jets 2 muons

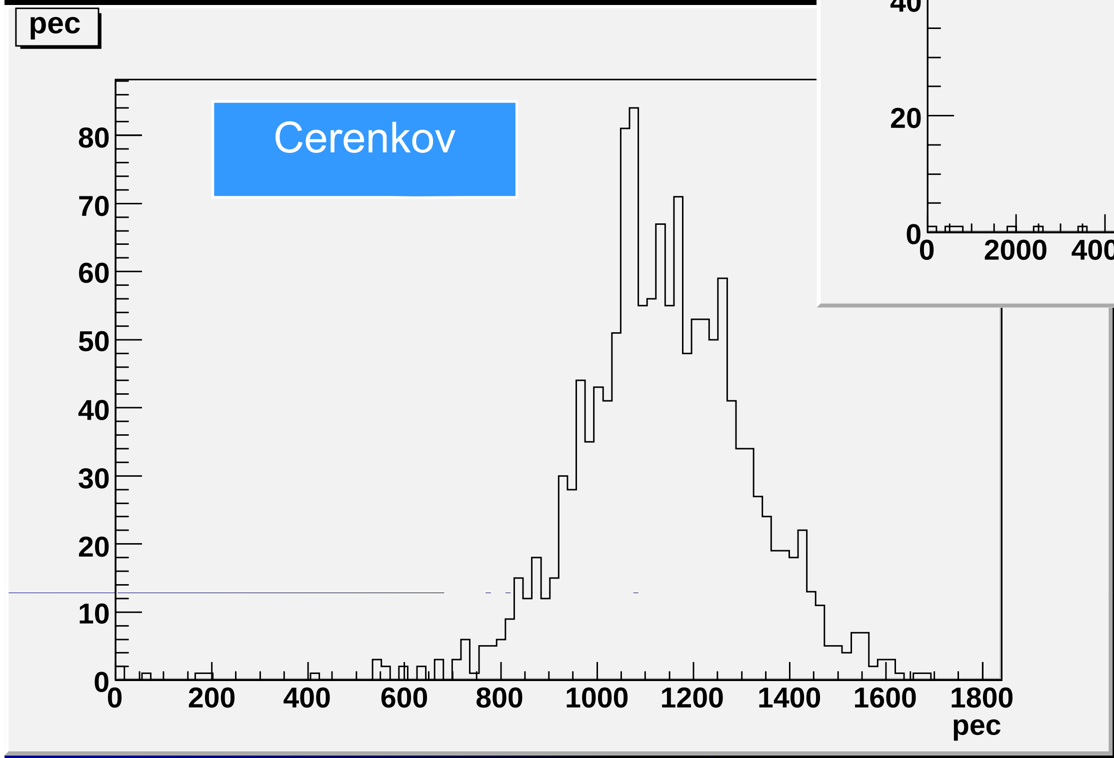


Backup slides

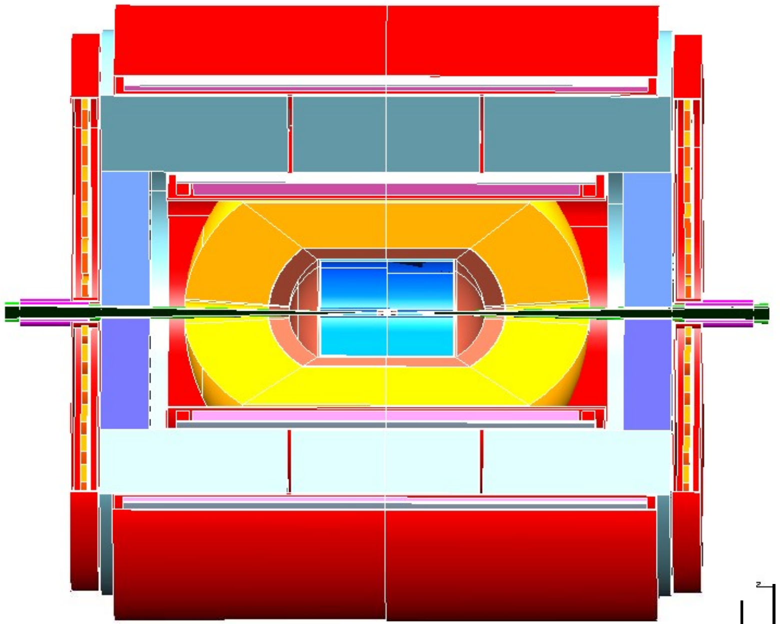
PE Distribution

- 40 GeV π^-





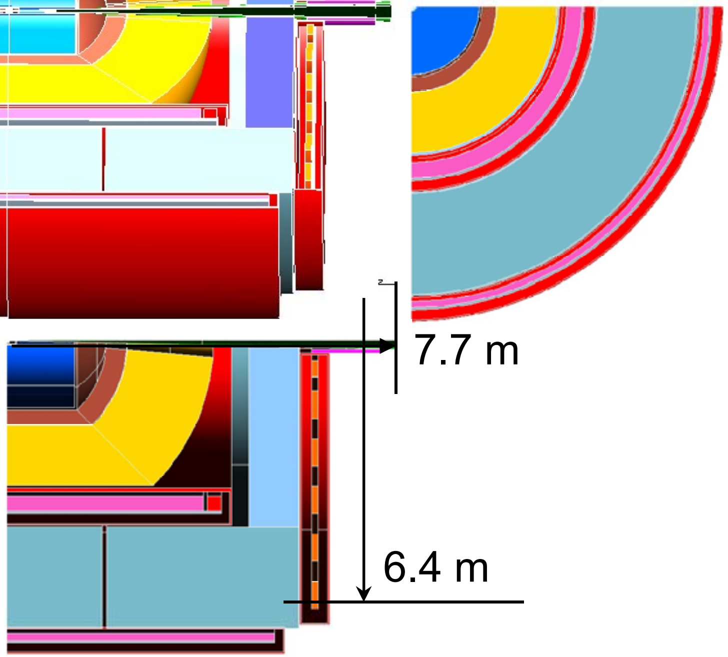
4th Concept Detector Layout

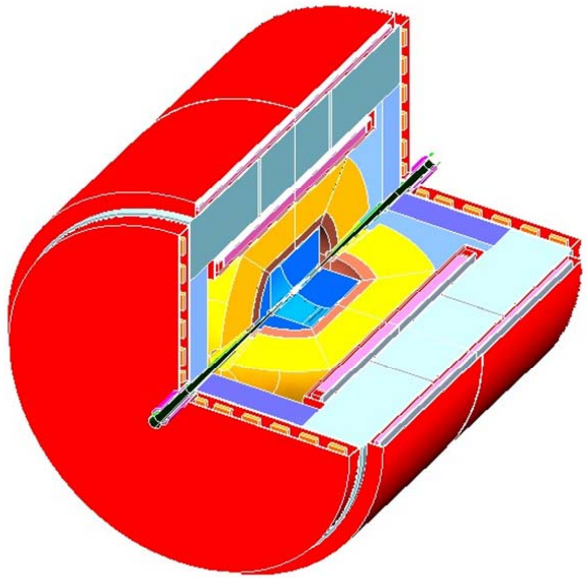


NOVEL FEATURES:

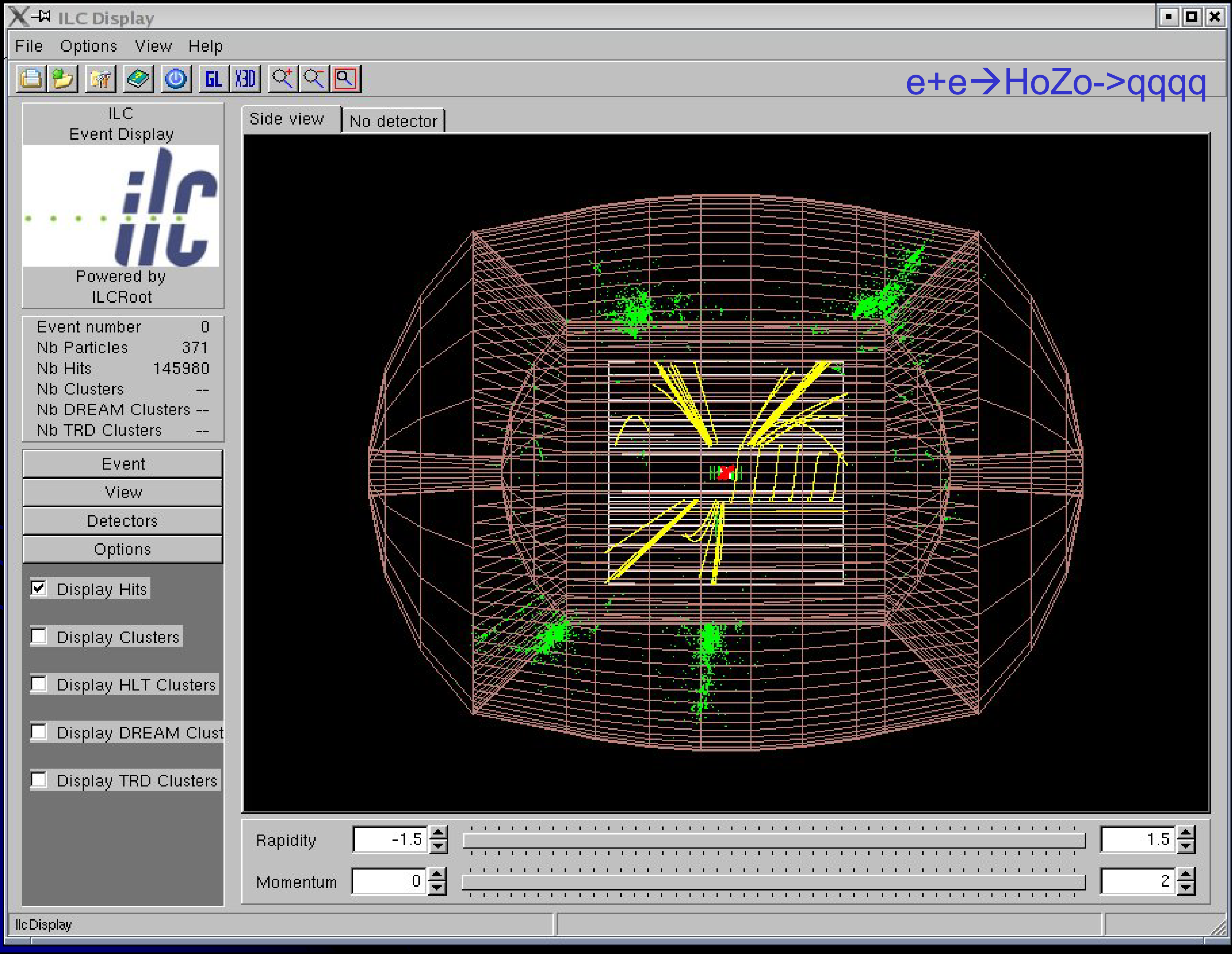
Triple-readout fiber calorimeter: scintillation/Cerenkov/neutron

Muon dual-solenoid iron-free geometry

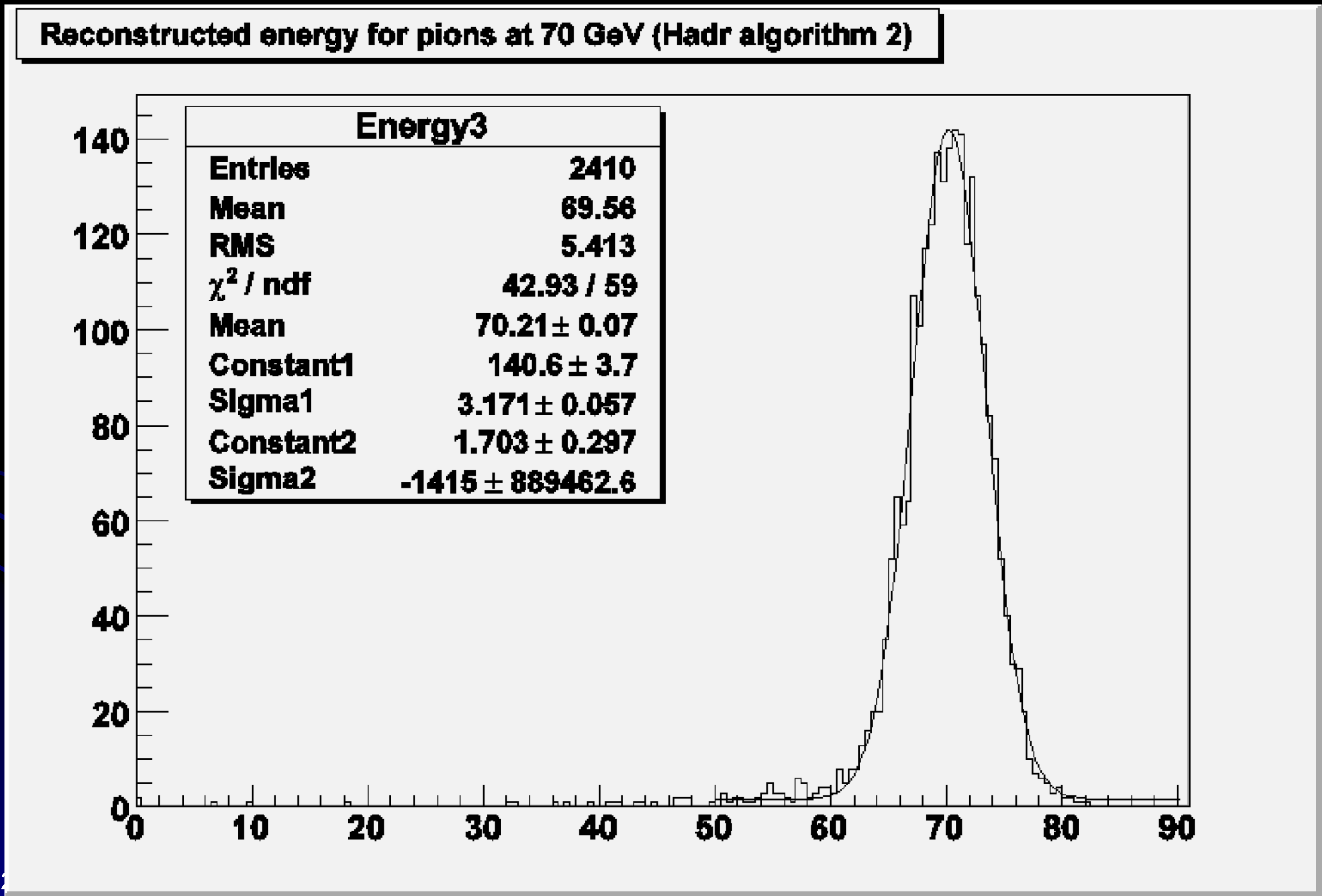




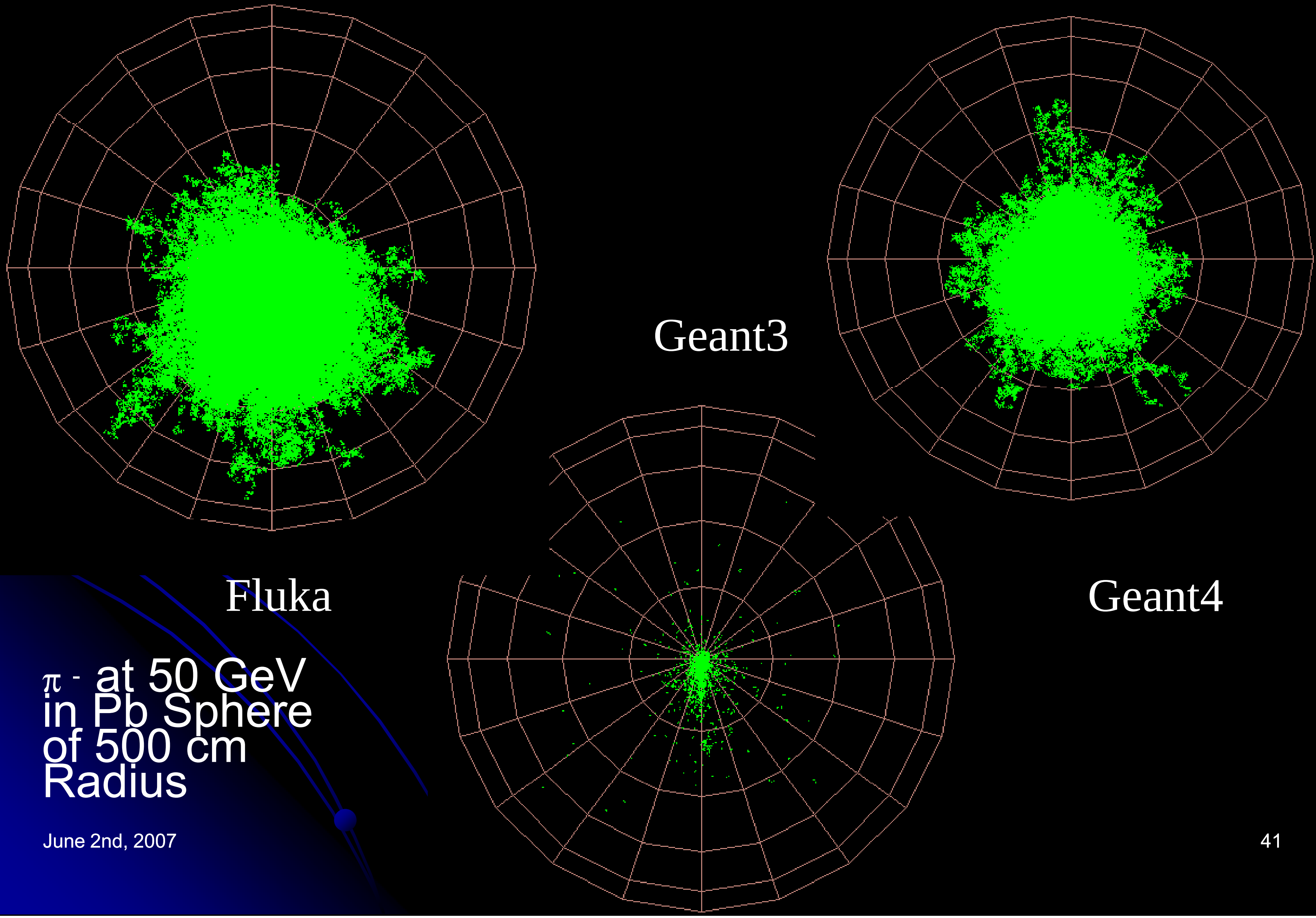
Present Status: VXD+TPC+DREAM



Dream Performance (pions)



Fluka vs G3/G4



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

F. Grancagnolo talk, ILC Workshop Valencia 2006

m-System basic element: drift tube

radius 2.3 cm
filled with 90% He – 10% iC_4H_{10} @ NTP
gas gain few × 10^5
total drift time 2 μs
primary ionization 13 cluster/cm ⇒ ≈ 20 electrons/cm total
both ends instrumented with:

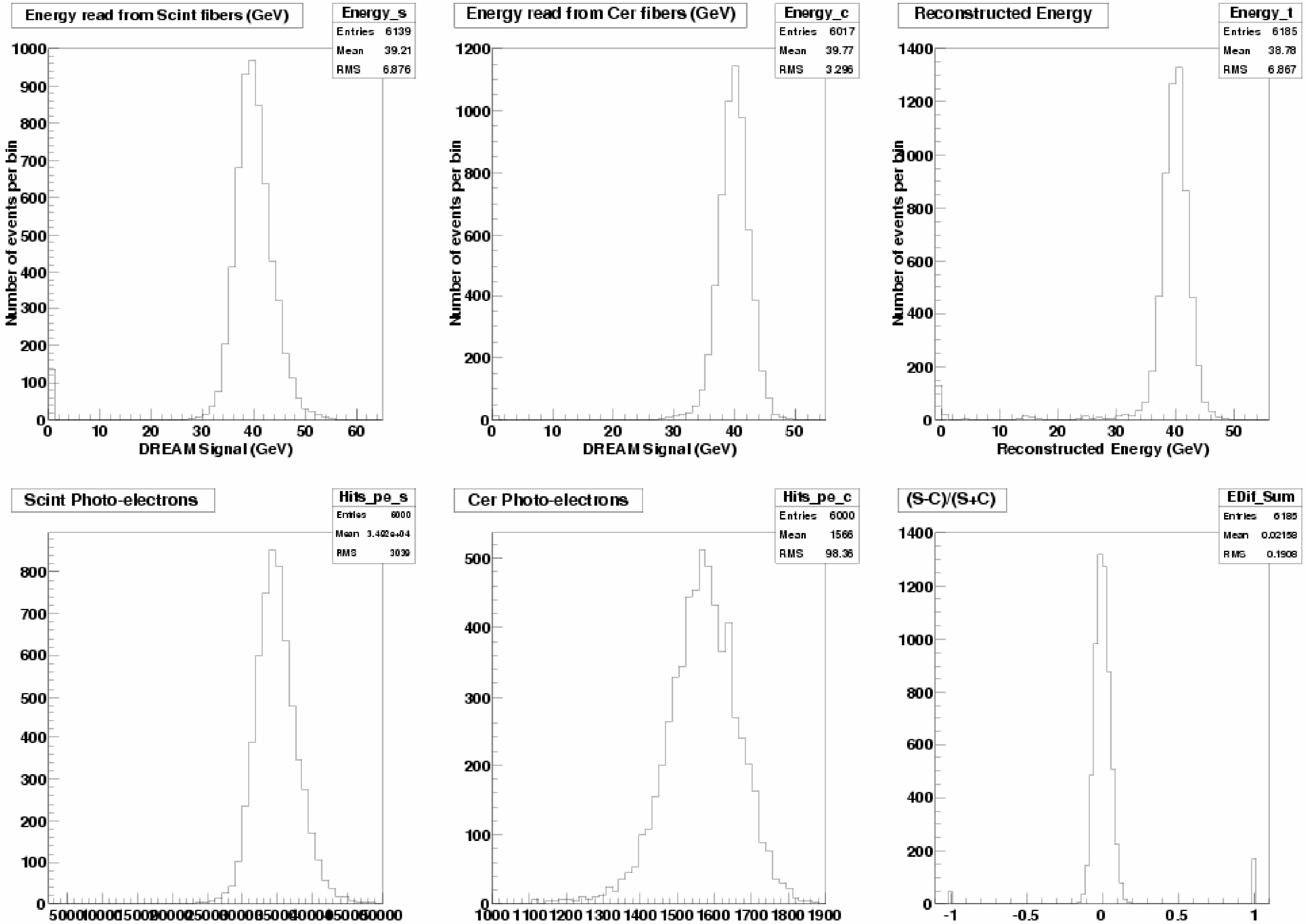
- > 1.5 GHz bandwith
- 8 bit fADC
- > 2 Gsa/s sampling rate
- free running memory

ASIC chip under development at INFN-LE

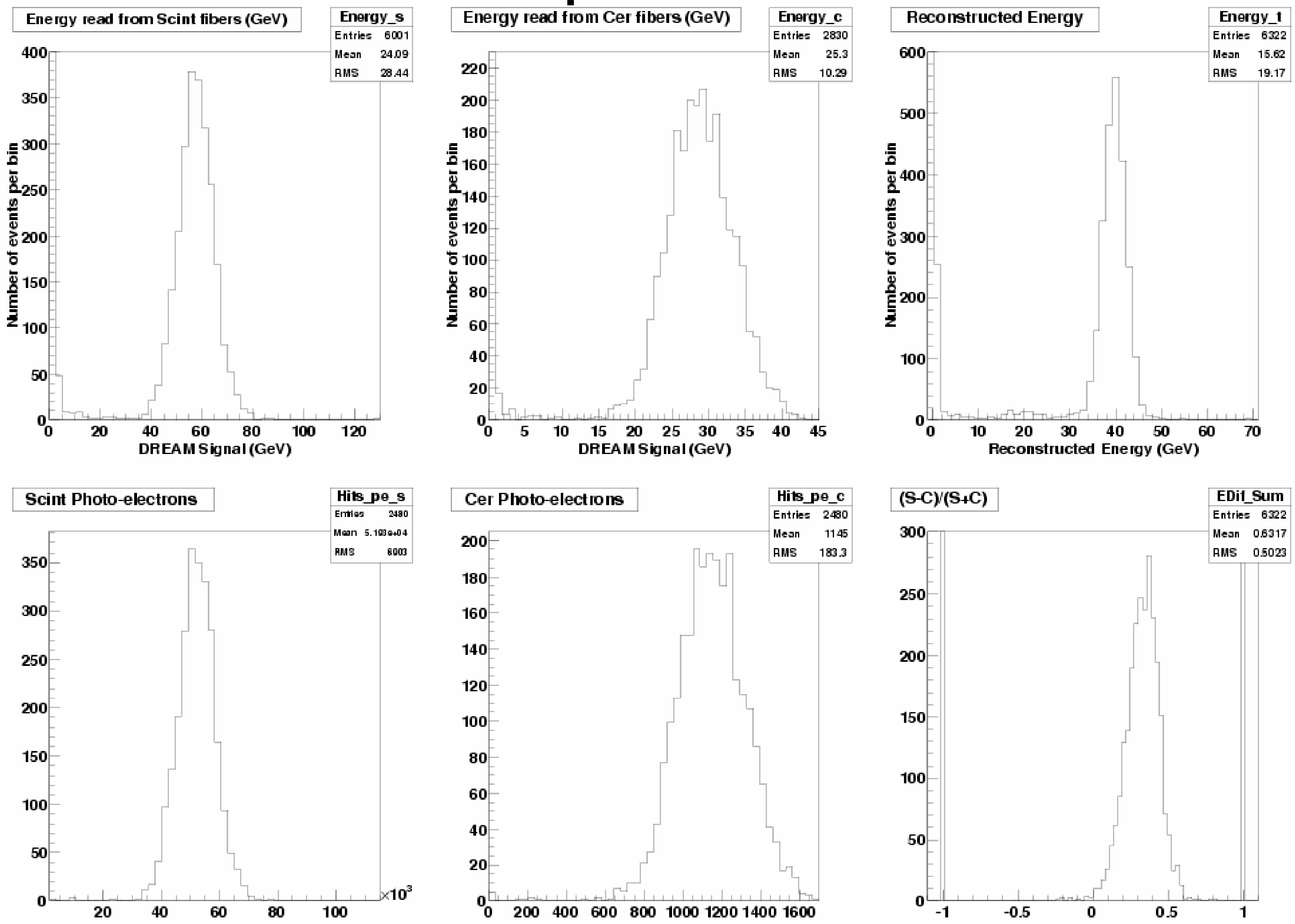
for a

- fully efficient timing of primary ionization: **cluster counting**
- accurate measurement of longitudinal position with **charge division**
- particle identification with **dN_{cl}/dx**

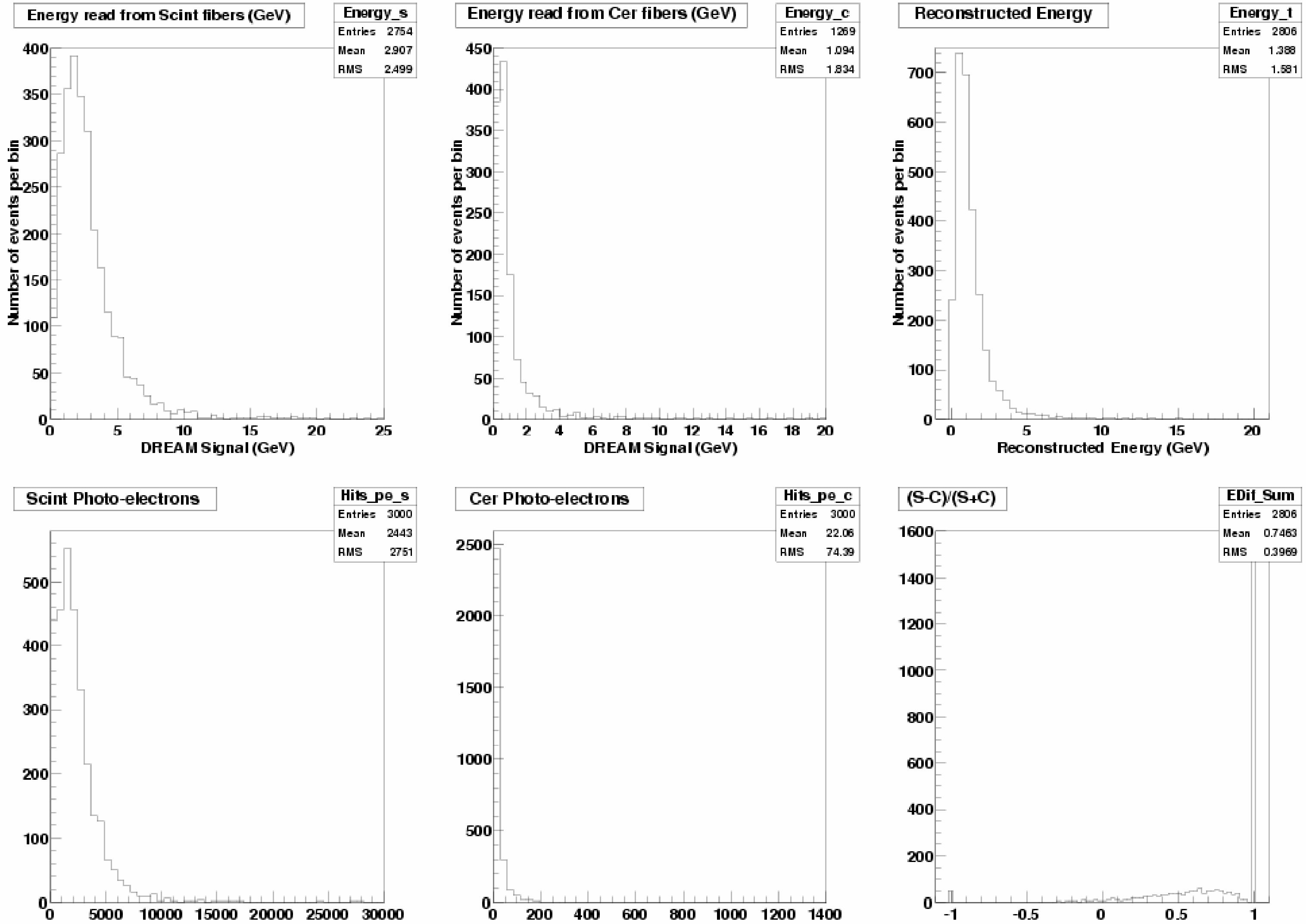
Histos electrons at 40 GeV in Cu

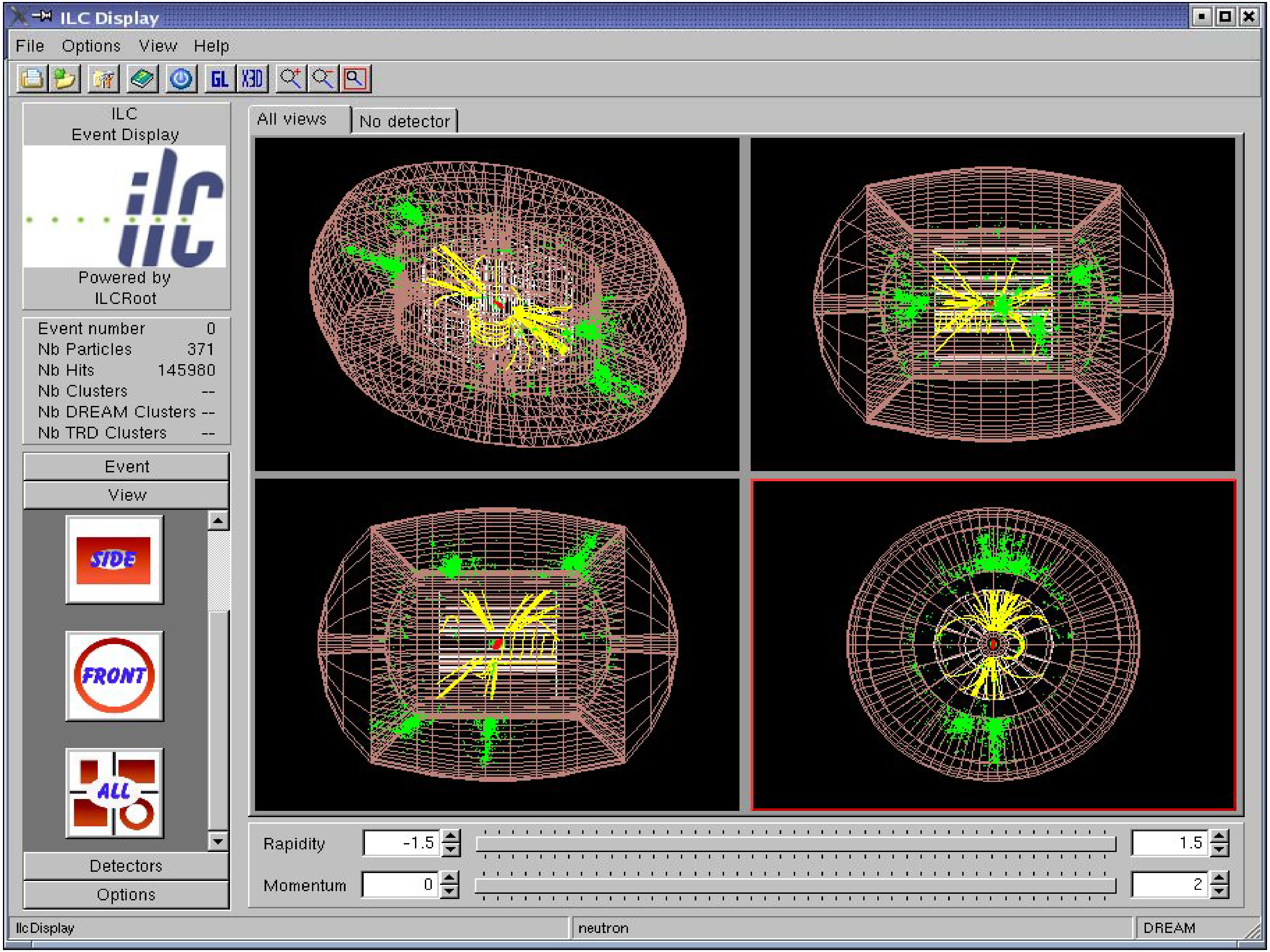


Histos pions at 40 GeV in Cu



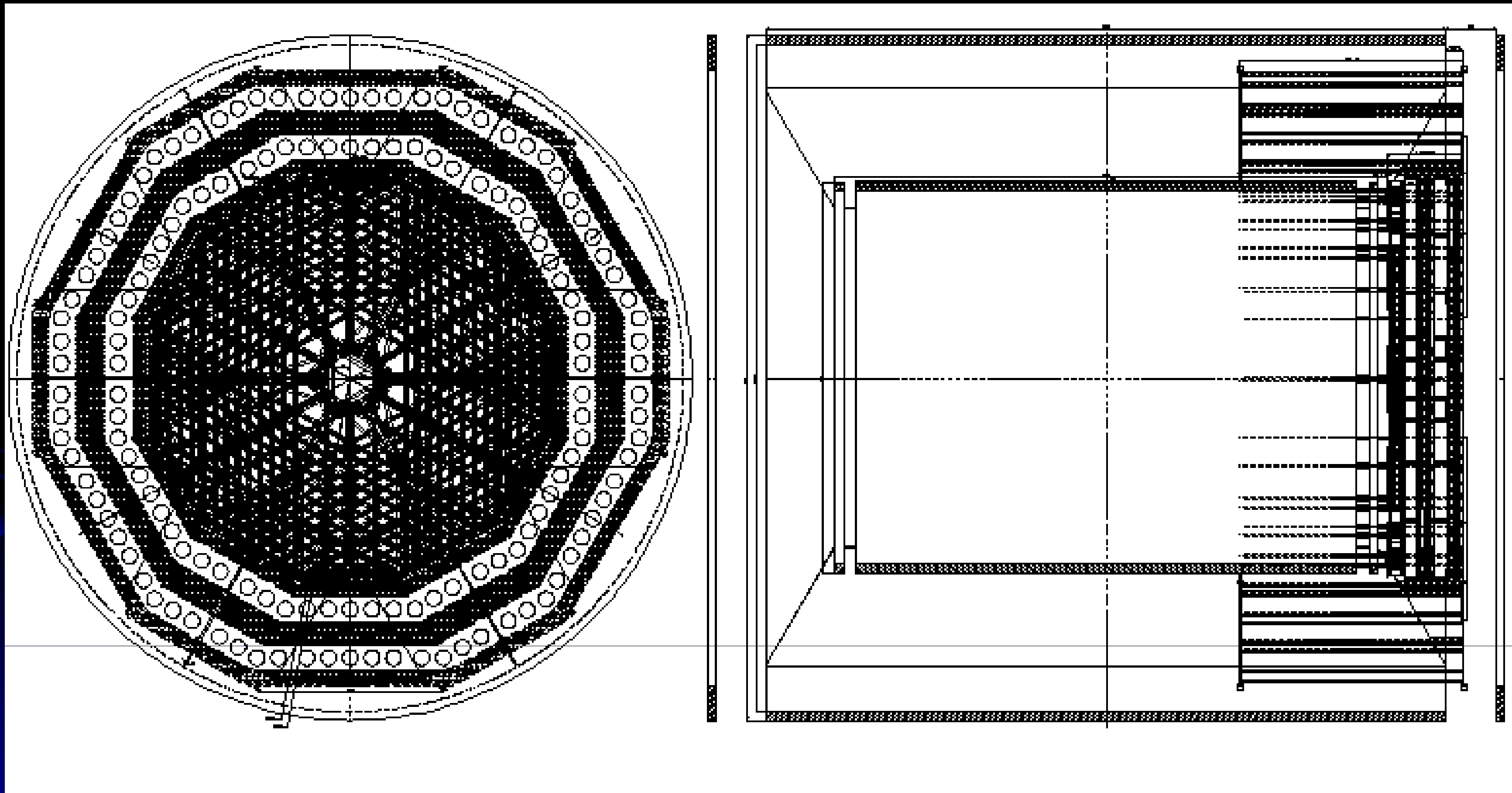
Histos muons at 100 GeV in Cu



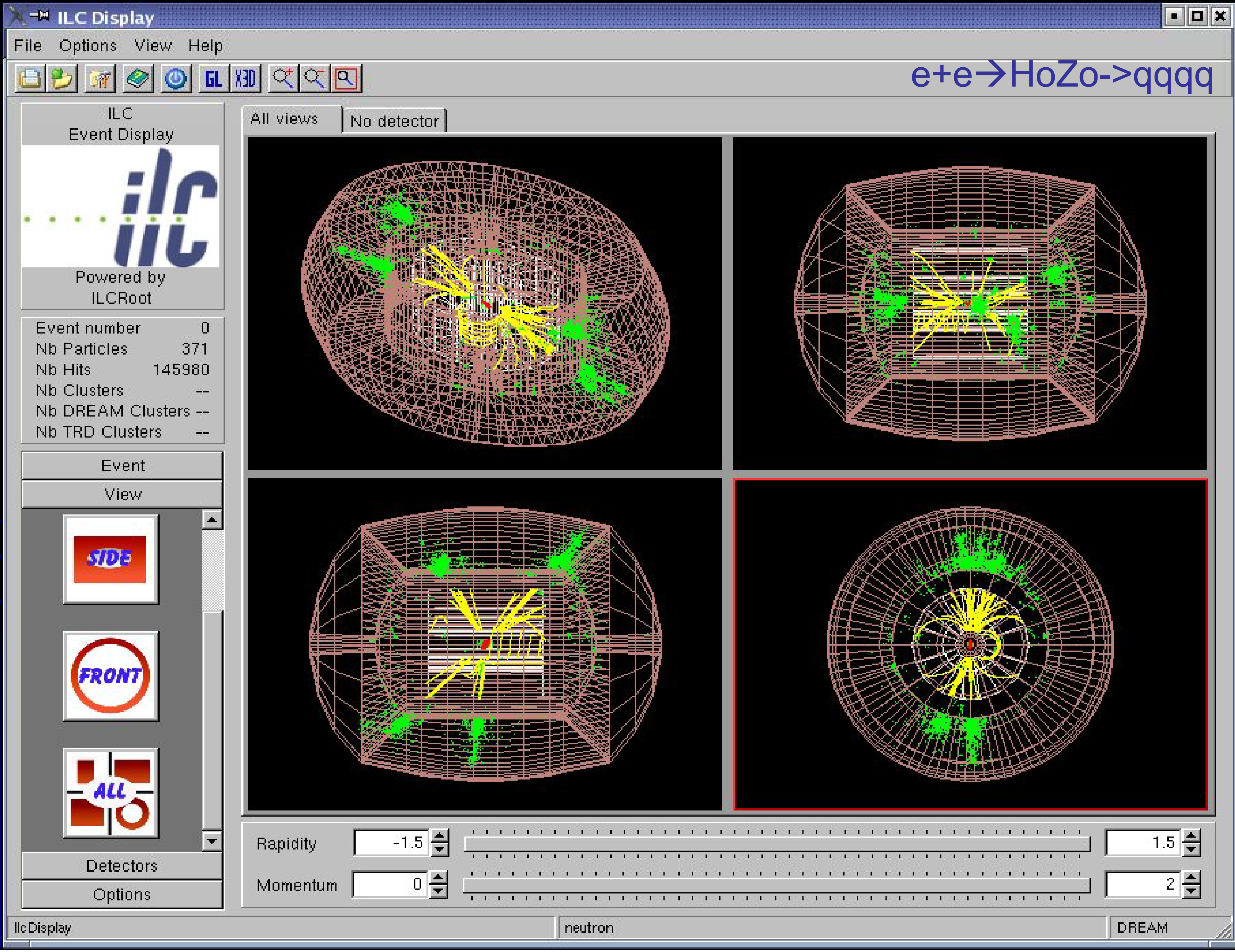


ILC Display
File Options View Help
GL X3D
ILC
Event Display
ilc
Powered by
ILCRoot
Event number 0
Nb Particles 371
Nb Hits 145980
Nb Clusters --
Nb DREAM Clusters --
Nb TRD Clusters --
Event
View
SIDE
FRONT
ALL
Detectors
Options
All views
No detector
Rapidity -1.5 1.5
Momentum 0 2
IlcDisplay
neutron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

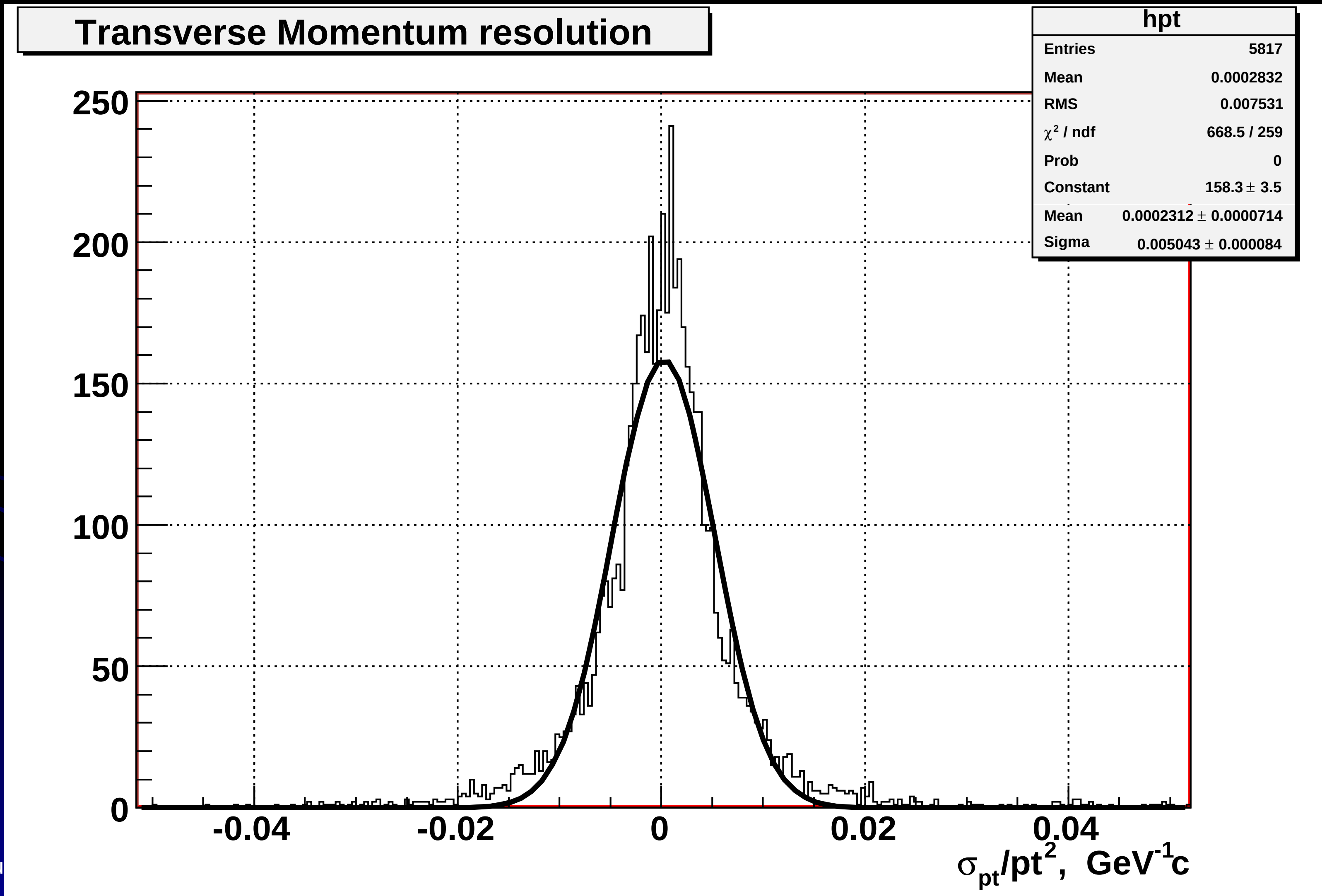
Full Spectrometer



Present Status: VXD+TPC+DREAM



P_t Resolution (0.3-20 GeV)



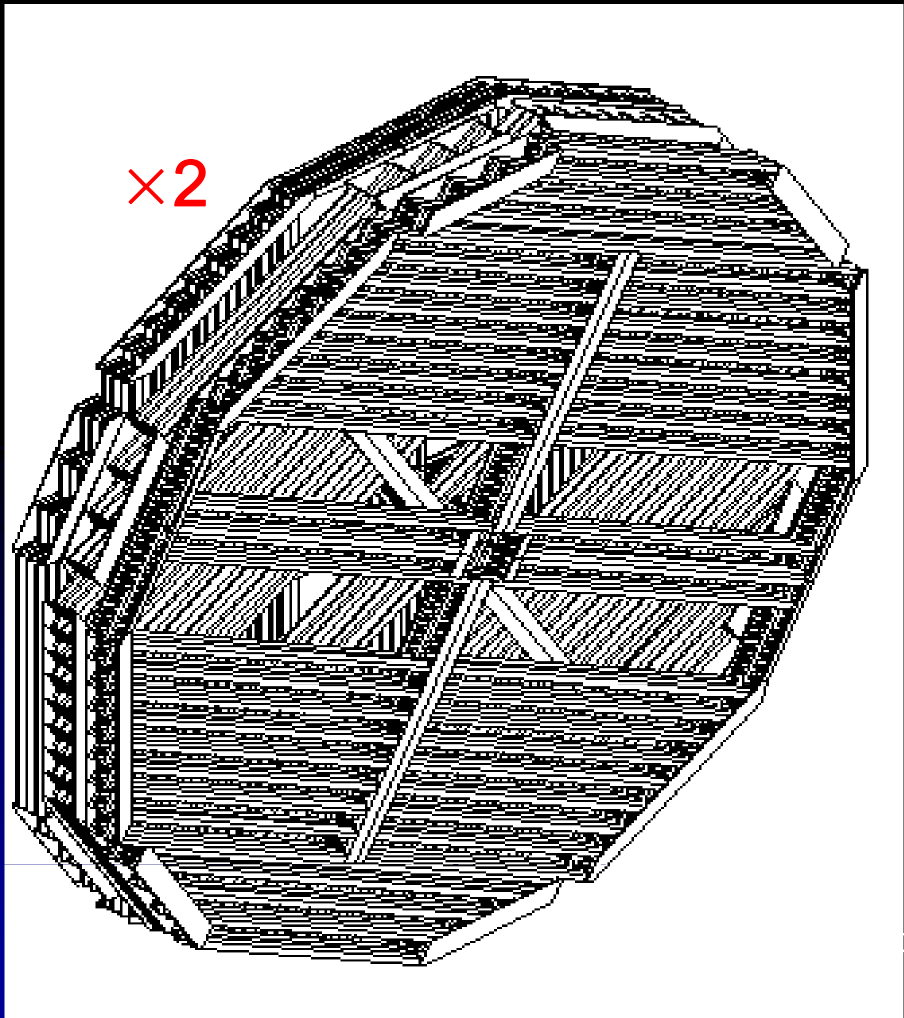
Tracking Algorithm

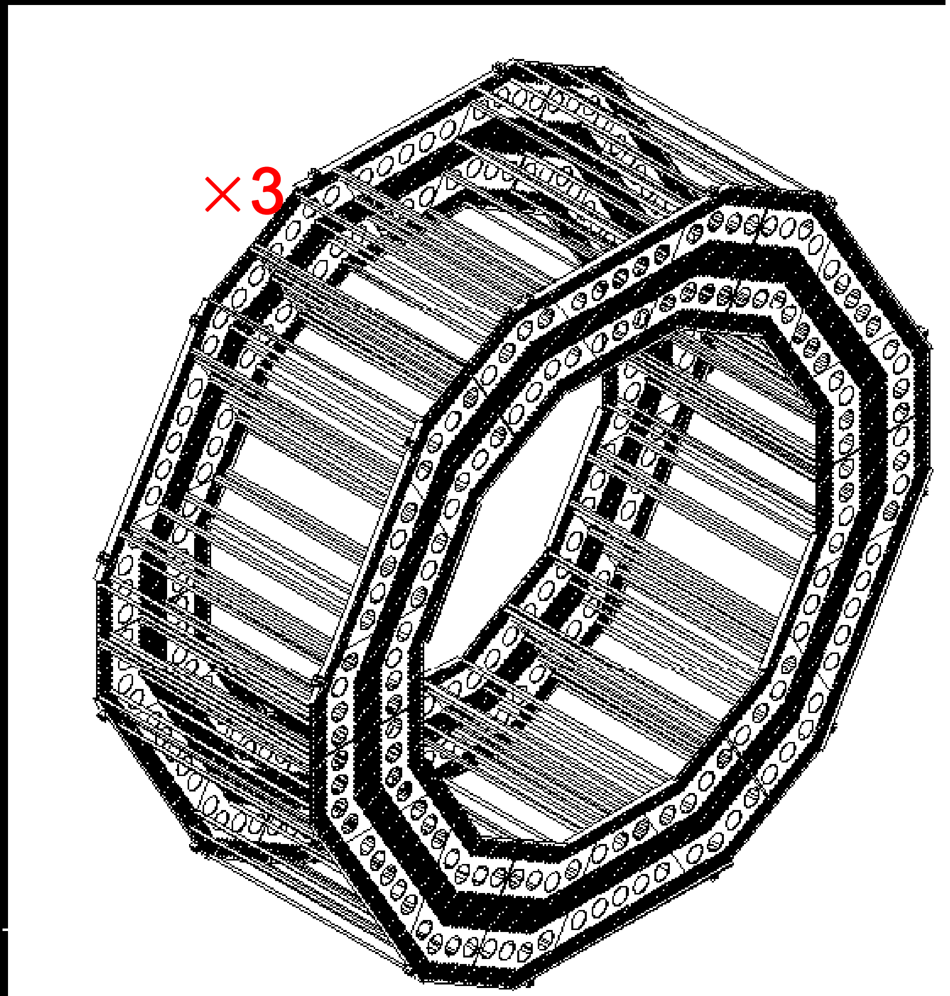
- Primary TPC seeding: looks for tracks with 20 hits (pads and/or μmegas) apart + beam constraint
- Secondary TPC seeding: looks for tracks with hits in layer 1, 4 and 7 (no beam constraint)
- **Parallel Kalman Filter** then initiated:
  - 1st step: start from TPC fit + prolongation to VXD (add clusters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

MUD Simulation

- Individual Drift Tubes, no support, electronics, services
- Gaussian smearing of hits (200μm x 4mm) to make Fastrecpoints (no Cluster Counting yet)
- Pattern recognition through Parallel Kalman Filter
- Standalone Tracker not yet implemented

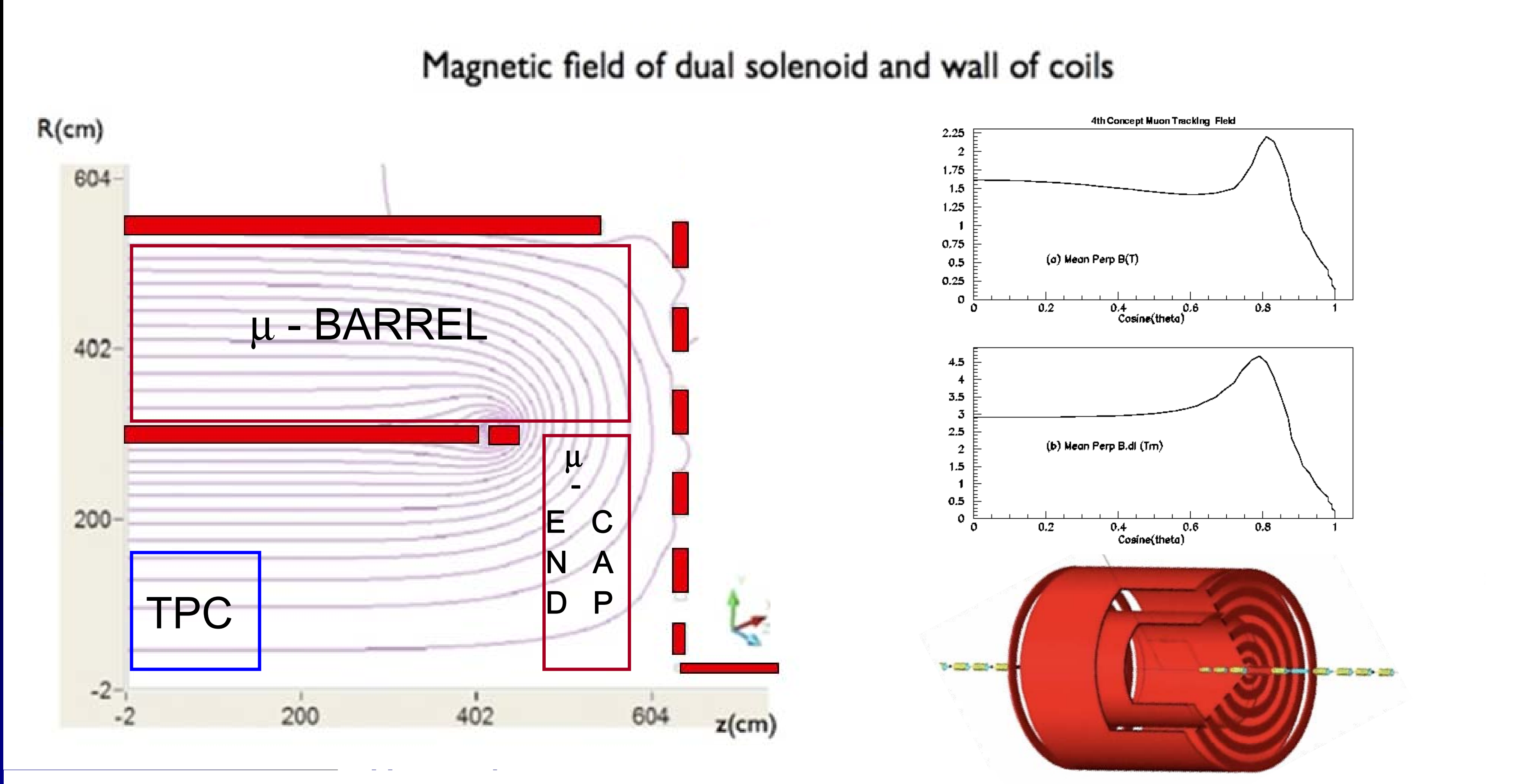
Muon Spectrometer





A. Mikailicenko talk, ILC Workshop Valencia 2006

Dual Solenoid B-field



Simulation Steps

- Hits: produced by MC (Fluka)
- SDigits:
  - simulate detector response for each hit (Cerenkov and Scintillation fibers)
  - Simulate electronics
  - Add random noise
- Digits:
  - merge digit from several files of SDigits (example Signal + Beam Bkgnd)
  - Apply threshold
- Recpoints:
  - Clusterize nearby Digits
  - Unfold overlapping showers