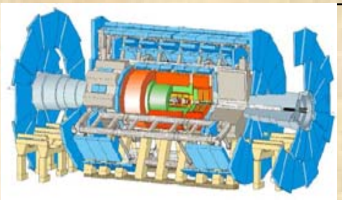
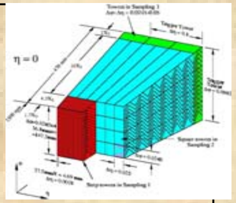
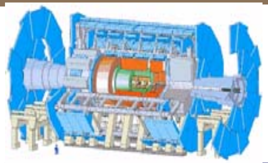


Electrons/Photons Reconstruction with the ATLAS Detector

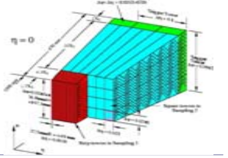


Kamal Benslama
Columbia University

On Behalf of the ATLAS Collaboration
June 08, 2006
Calorimetry in High Energy Physics



Physics Motivations



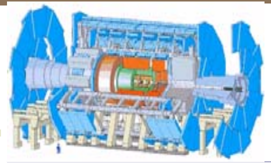
- ☐ **Higgs search**

$$H \to \gamma\gamma$$

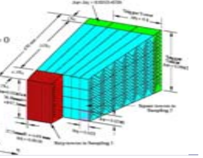
$$H \to ZZ^{*} \to 4e$$

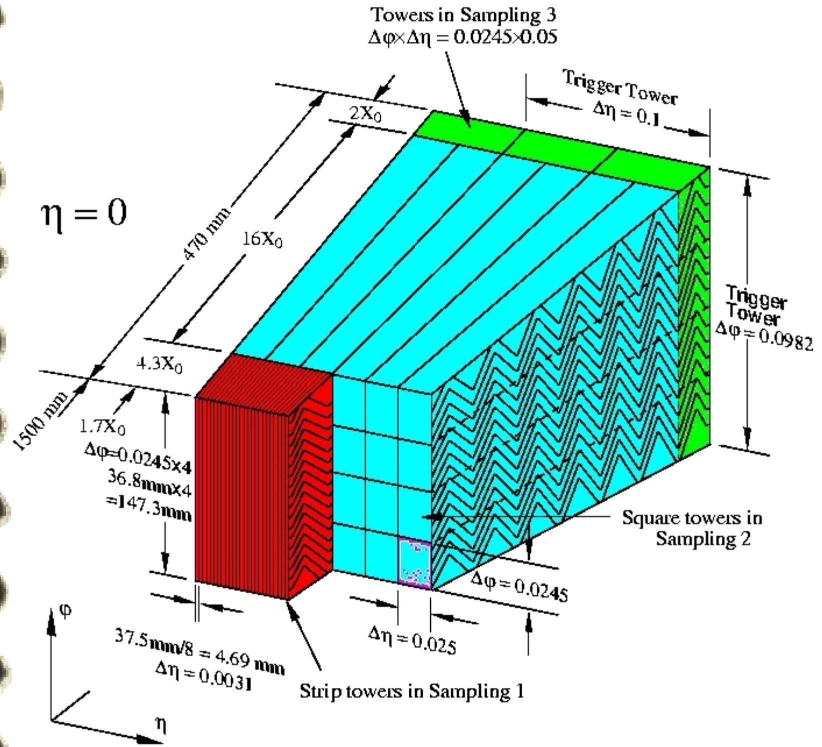
- ☐ **BSM**
  - TeV resonances
  - SUSY

- ☐ **Many SM processes, top, Z to ee, W to eν**
  - Backgrounds to new physics
  - Calibration processes



ATLAS LAr EM Calorimeter





Layer	**Granularity** (Δη×Δφ)
Pre-sampler	0.025 x 0.1
Front	0.003 x 0.1
Middle	0.025 x 0.025
Back	0.05 x 0.025

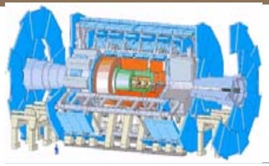
good energy resolution

$$\sigma(E)/E \sim 10\%/\sqrt{E} \oplus 0.7\%$$

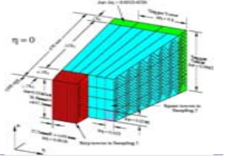
excellent angular/position resolution and particle identification capability

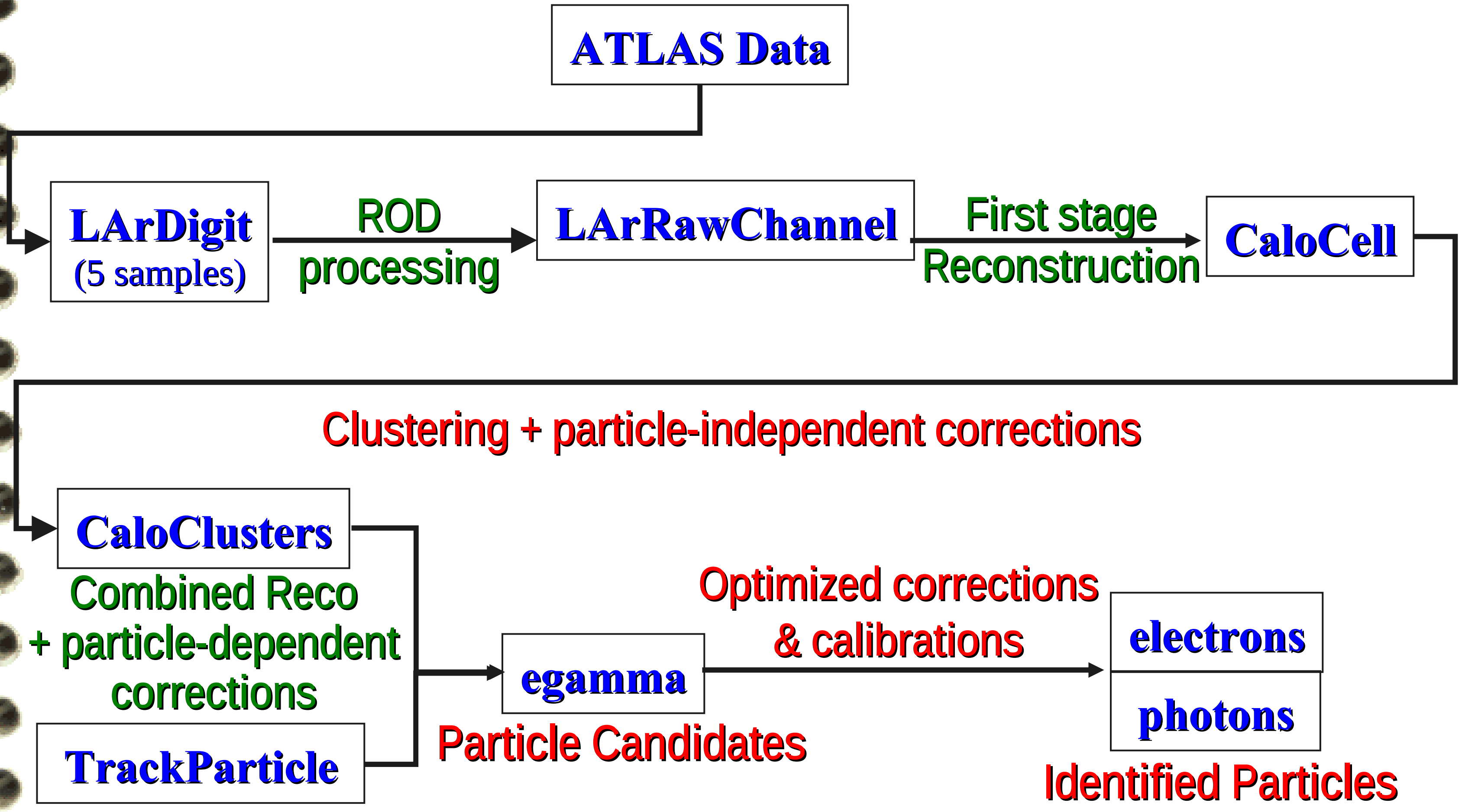
$$\sigma(R\varphi) \sim 9mm/\sqrt{E} \qquad \sigma(R\eta) \sim 3mm/\sqrt{E}$$

Presampler detector in front of EM: $\Delta\eta \times \Delta\varphi \sim 0.025 \times 0.1$



Reconstruction Data Flow





ATLAS Data

LArDigit (5 samples)

ROD processing

LArRawChannel

First stage Reconstruction

CaloCell

Clustering + particle-independent corrections

CaloClusters

Combined Reco + particle-dependent corrections

TrackParticle

egamma

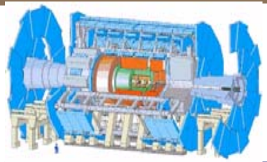
Particle Candidates

Optimized corrections & calibrations

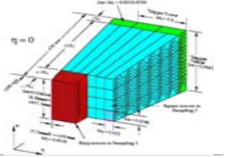
electrons

photons

Identified Particles

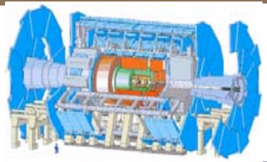


Clustering and Corrections

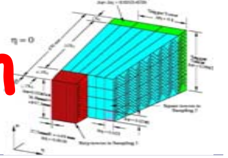


- ☐ Sliding window clustering
  - build an eta-phi grid of towers and search for local maxima
- ☐ Corrections at the cluster level
  - eta position
  - phi position
  - phi energy modulation
  - eta energy modulation
  - gap correction
  - layer weights correction

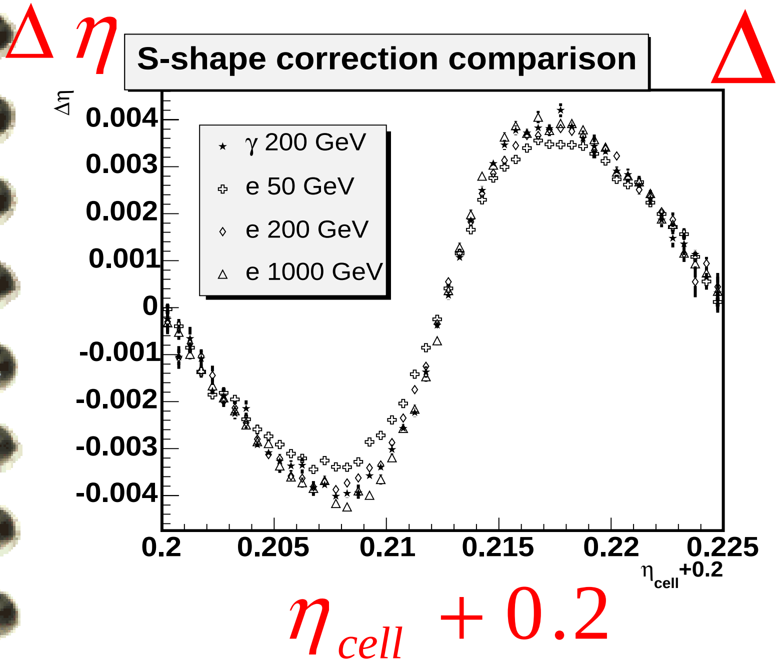
  these corrections are derived using single electrons
- ☐ Refinement of corrections depending on the particle (e/γ) type
- ☐ Inter-calibrate region with Zee

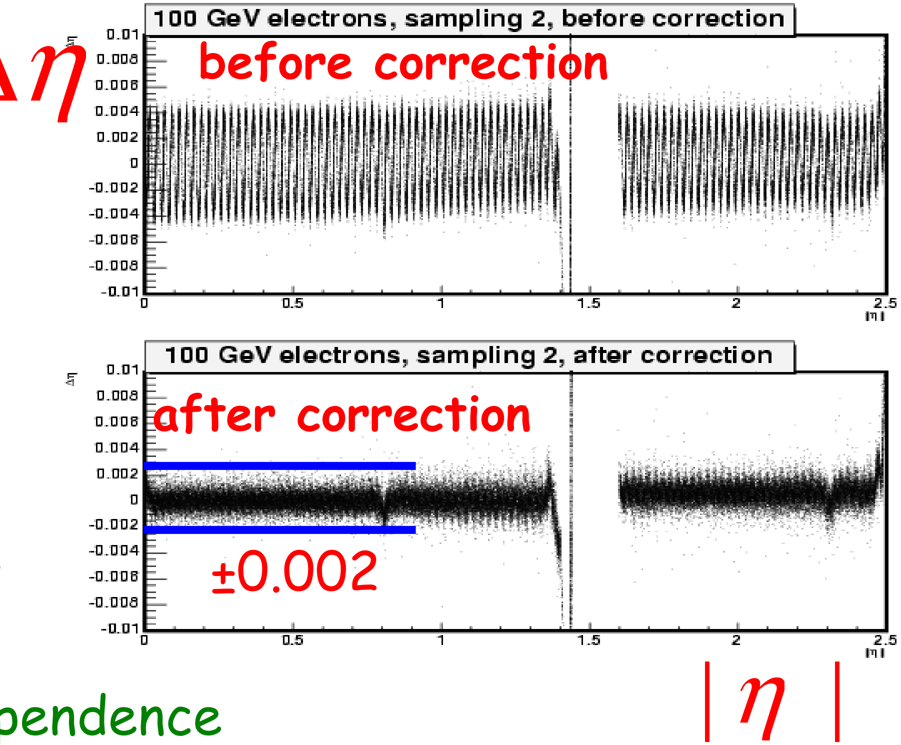


Cluster Correction: eta position



- ❑ Clustering with fixed size
  - Correct position S-shape in eta
  - Essentially to account for fine granularities of LAr Calorimeter

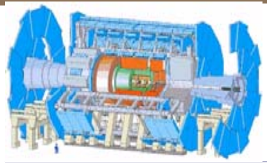




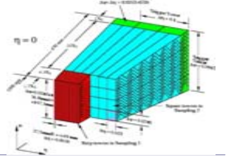
Small energy and particle dependence

Currently same correction for e and γ

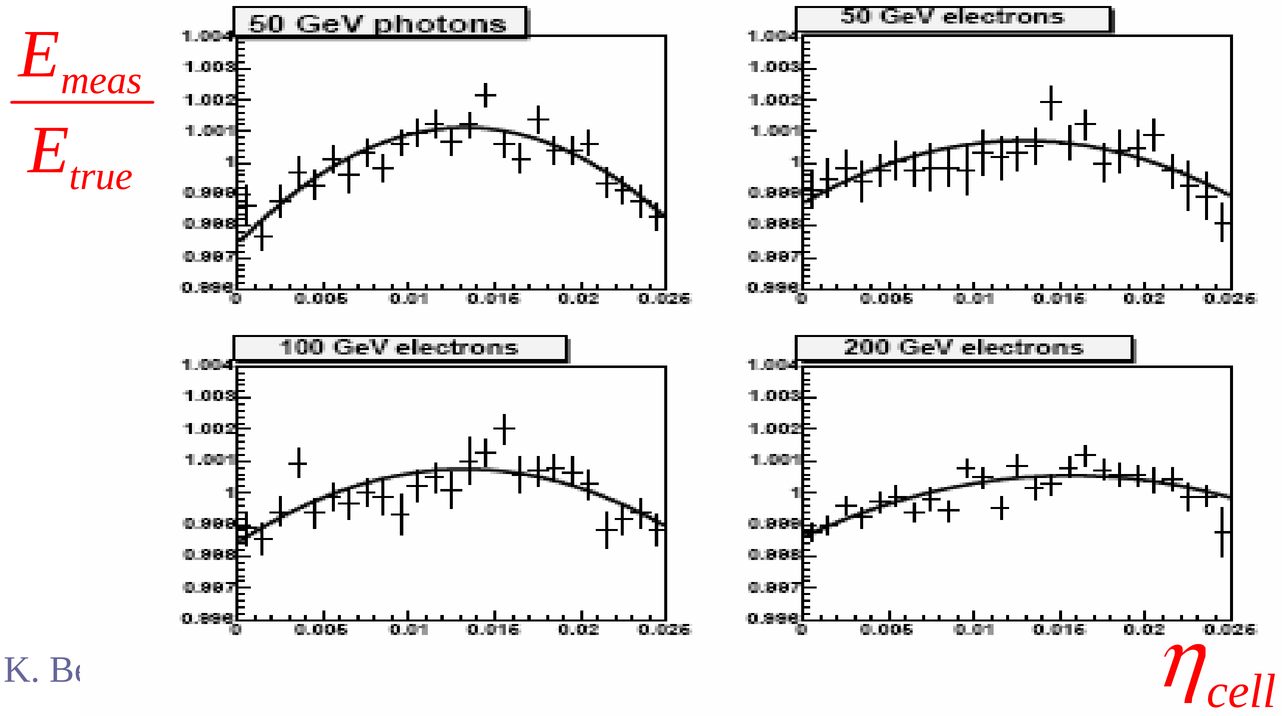
100 GeV electrons

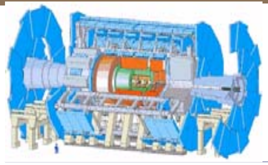


Cluster Correction: Eta Modulation

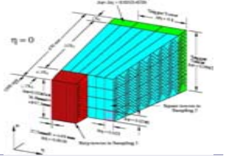


- Eta modulation of energy response
- Fixed calorimeter size with steps of 0.025, therefore shower containment is a function of eta
- Quadratic polynomial sufficient to correct for effect of about **0.1-0.2%**





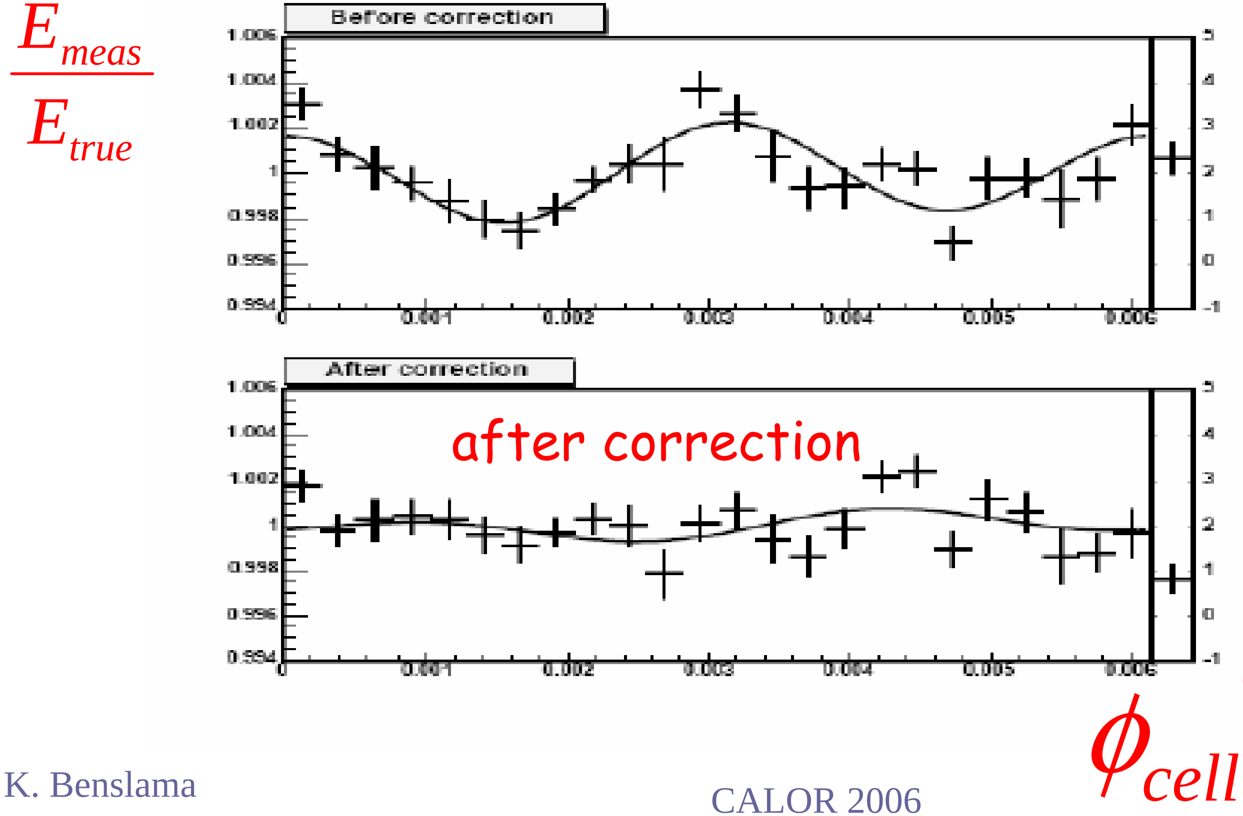
Cluster Correction: Phi Modulation



- ❖ **Containment effect the same as for eta**
- ❖ **Additional component parameterized as sin/cos sums**
- ❖ 0.1-0.2% effect

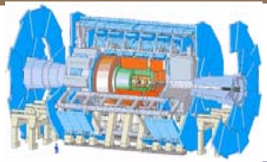
before correction

200 GeV electrons

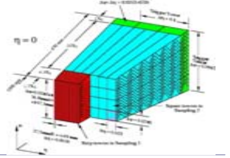


Corrections are function of eta

Residual effect < 0.03% after correction

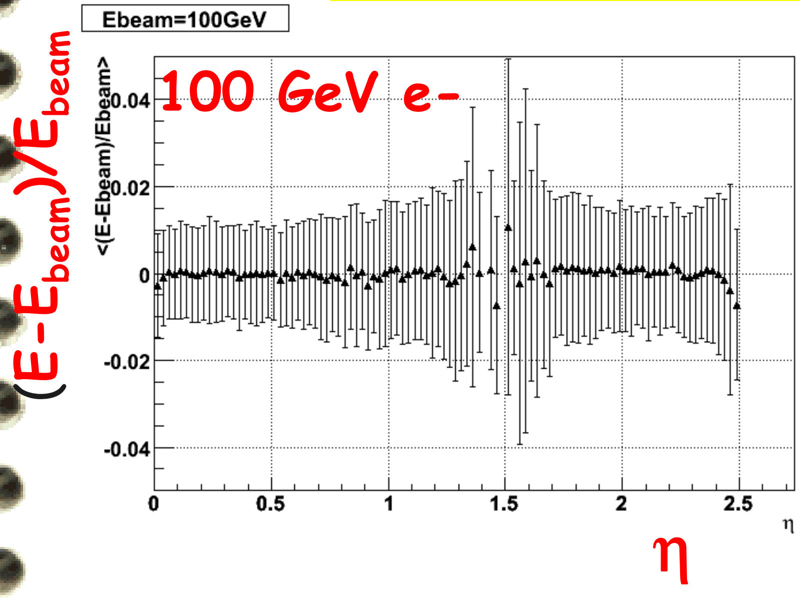


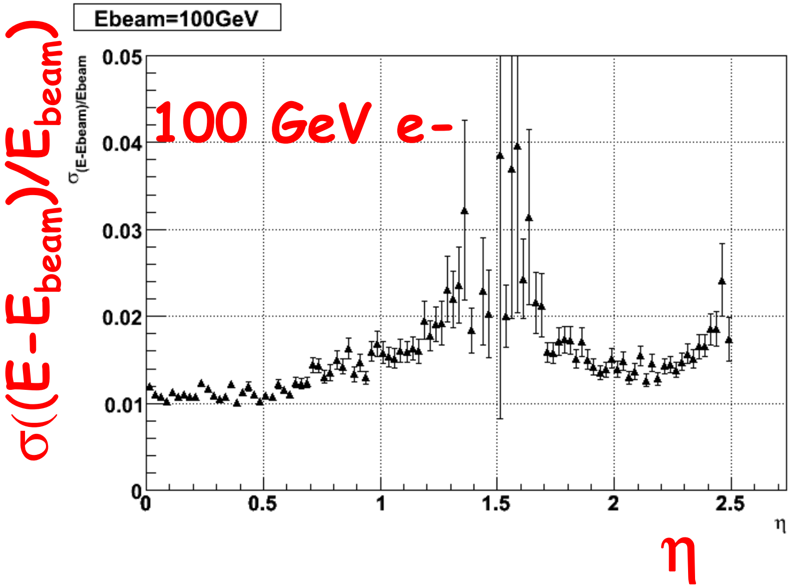
Cluster Correction: Layer Weights



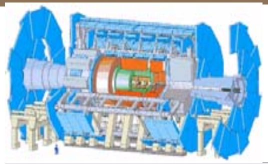
- **Layer Weights Correction:**
  - ATLAS Layer Weights (essentially only eta dependent) calculated using single electrons and following parameterization:

$$E_{rec} = \lambda\left(b + W_0 E_{pres} + E_1 + E_2 + W_3 E_3\right)$$

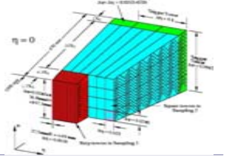




Optimize simultaneously energy resolution and linearity



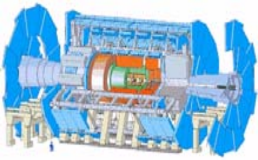
High pT Algorithm



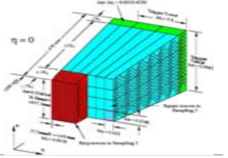
- e-gamma reconstruction uses both calorimeter and track particle information as inputs. Properties of the shower are then computed:

  For example:
  - **Leakage in Had. Cal** **ET(had-layer1)/ET(3X7)**
  - **Shower shape** **E2(3X7)/E2(7X7)**
  - **Energy weighted width in sampling 2**
  - **Energy fraction, energy weighted shower width in the first sampling**

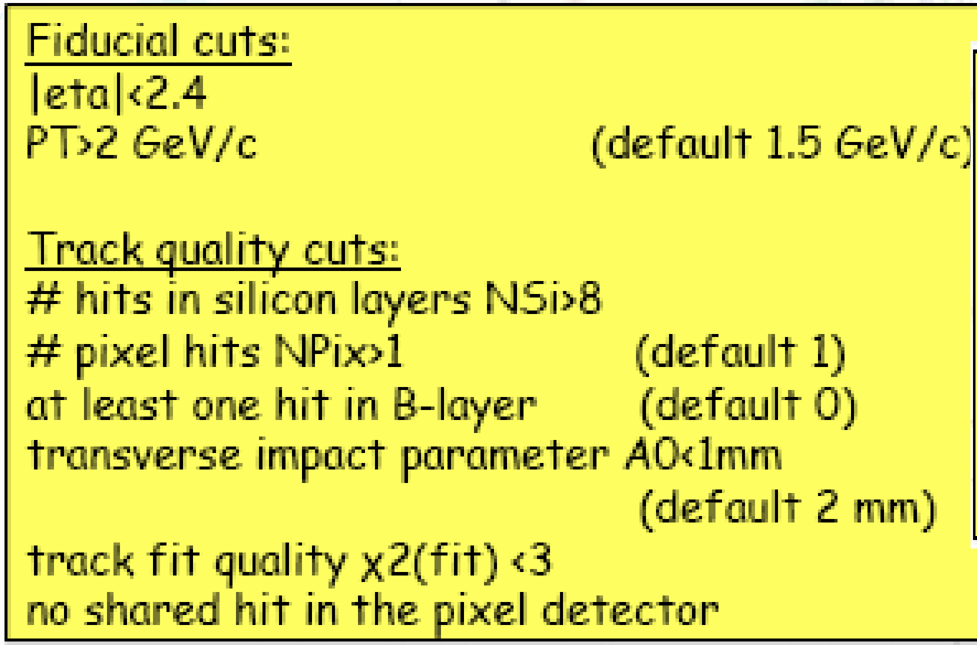
- The track match is searched for with the following criteria: E/P cut and matching in eta and phi (extrapolated to calo)



Low pT Algorithm

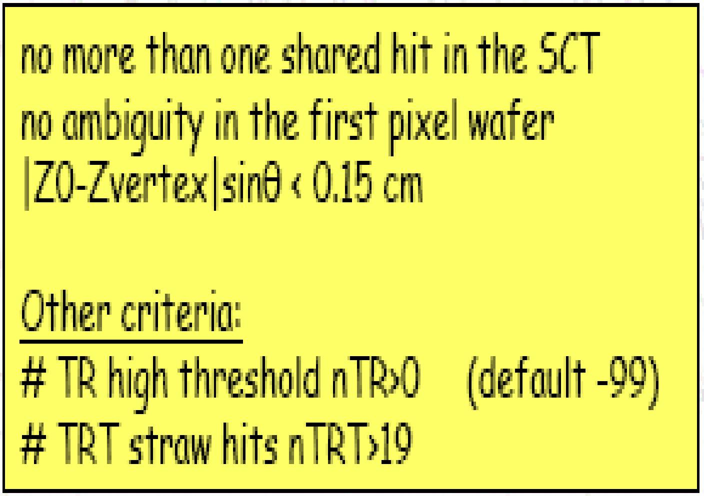


- For each track
  - apply track quality cuts
  - extrapolate to particular sampling of EM Calo
- In each sampling look for the cell with max E deposit
- Create cluster around that cell
- **Estimate discriminating variables**



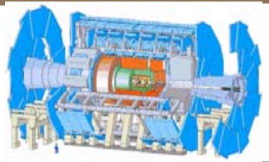
Fiducial cuts:
|eta|<2.4
PT>2 GeV/c (default 1.5 GeV/c)

Track quality cuts:
hits in silicon layers NSi>8
pixel hits NPix>1 (default 1)
at least one hit in B-layer (default 0)
transverse impact parameter A0<1mm (default 2 mm)
track fit quality χ2(fit) <3
no shared hit in the pixel detector

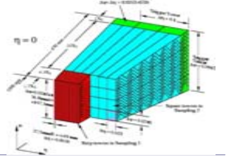


no more than one shared hit in the SCT
no ambiguity in the first pixel wafer
|Z0-Zvertex|sinθ < 0.15 cm

Other criteria:
TR high threshold nTR>0 (default -99)
TRT straw hits nTRT>19



Identification Description



Identification of electromagnetic object (same for e/γ):

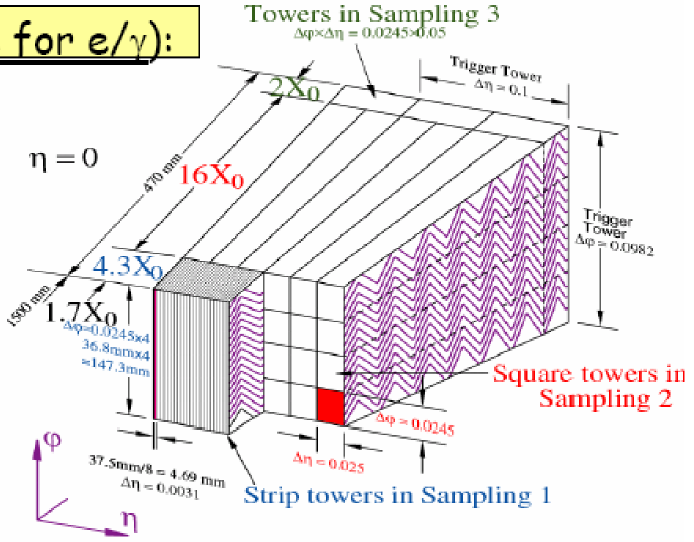
Leakage in Hadronic calorimeter

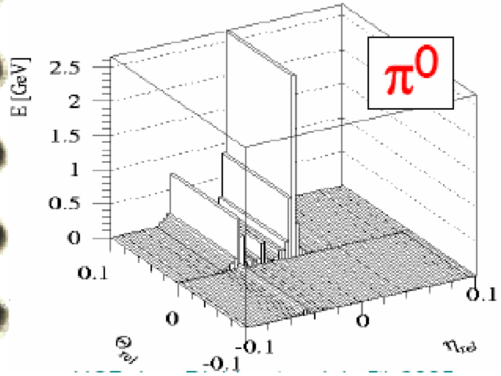
EM sampling 2 : different transverse development of electromagnetic and hadronic showers.

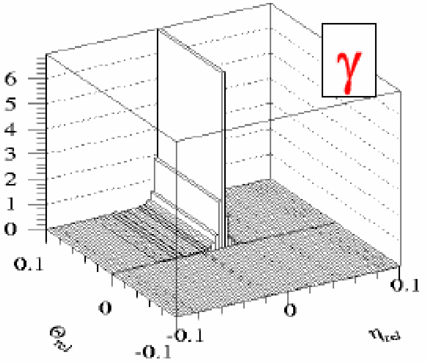
- shower shapes in η and φ
- shower width in η direction

EM sampling 1 : only jets with a little hadronic activity survive. Fine segmentation of the strips :

- look for substructures in strips
- shower width in η



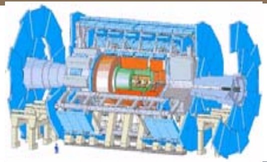




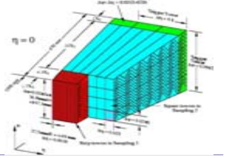
Use of the Inner Detector:

Electron identification :

- track matching ($\Delta\eta$, $\Delta\phi$), E/p
- use of transition radiation
- identification of conversions



eID/jet Rejection



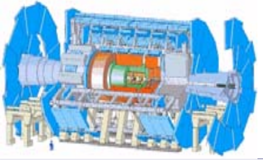
Dijet cross section ~ 1mb
Z to ee 1.5×10^{-6} mb
W to eν 1.5×10^{-5} mb

Need a rejection factor of 10^5 for electrons

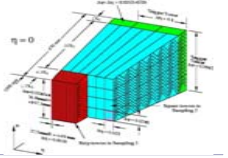
Identification methods:

Cuts
Neural net
likelihood

Cuts are binned so far in eta (pT coming)



eID/jet Rejection



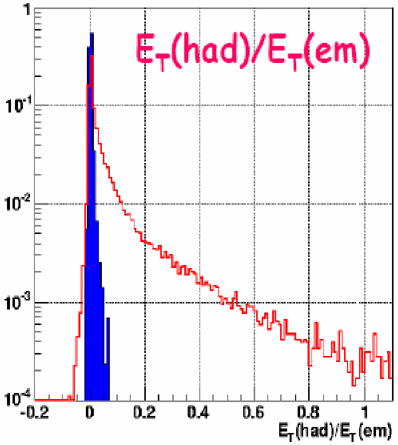
Use the shower shapes in the calorimeter

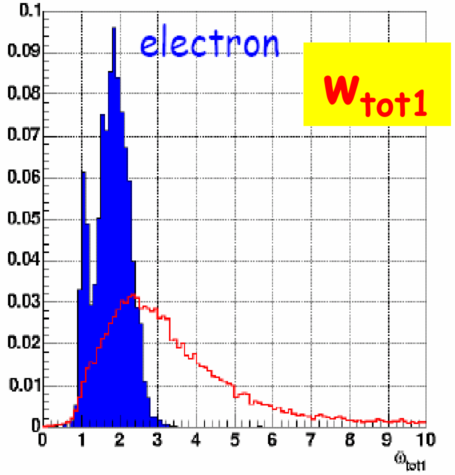
- **hadronic leakage**
- **width in the second sampling**
- **ratio in the middle of 3x7/7x7**
- **width in 40 strips**

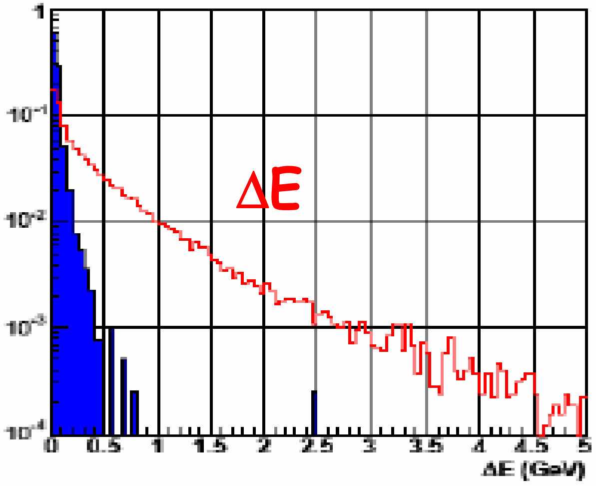
Search for secondary maxima in the strips:

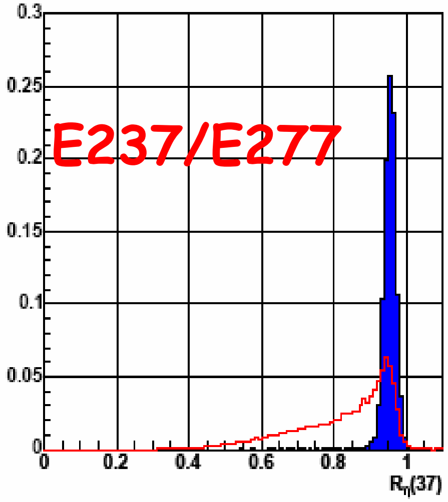
- **ΔE=Emax2-Emin**
- **ShowerCore**

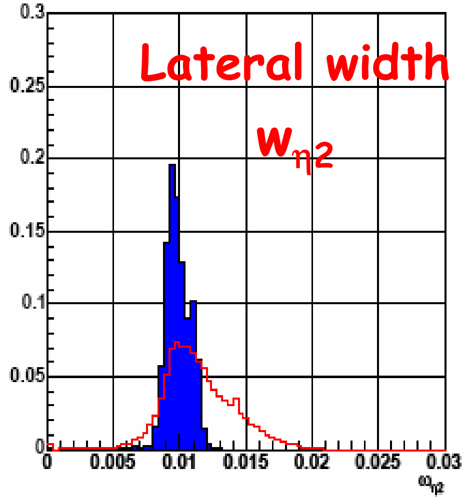
Fside= (E7strips-E3strips)/E3strips

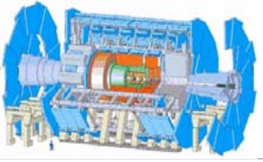




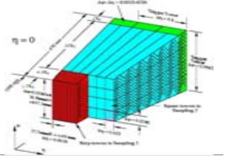








eID/jet Rejection: Results



e-id efficiency

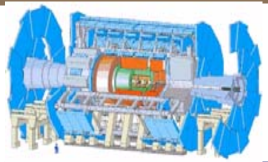
	e (low lumi)	e(high lumi)
LVL1	95.8+-0.3	94.6+-0.2
Calo	91.5+-0.4	90.5+-0.3
ID	87.4+-0.5	85.3+-0.5
ID-Calo	82.2+-0.6	79.2+-0.4
TRT	79.0+-0.6	77.3+-0.5

rejection

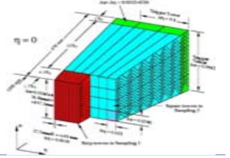
	R (pT>17 GeV) *1000	R (pT>25 GeV) *1000
Had Calo	1.00+-0.01	0.48+-0.01
Calo 2nd	1.65+-0.02	0.85+-0.01
Calo 1st	3.01+-0.06	1.71+-0.04
ID	35.9+-2.5	20.5+-1.8
ID-Calo	103+-12	43+-6
TRT	222+-38	71+-12

For a 75-80% e-id efficiency, a rejection ~10^5 is achieved

Rejection can be improved using multivariate techniques

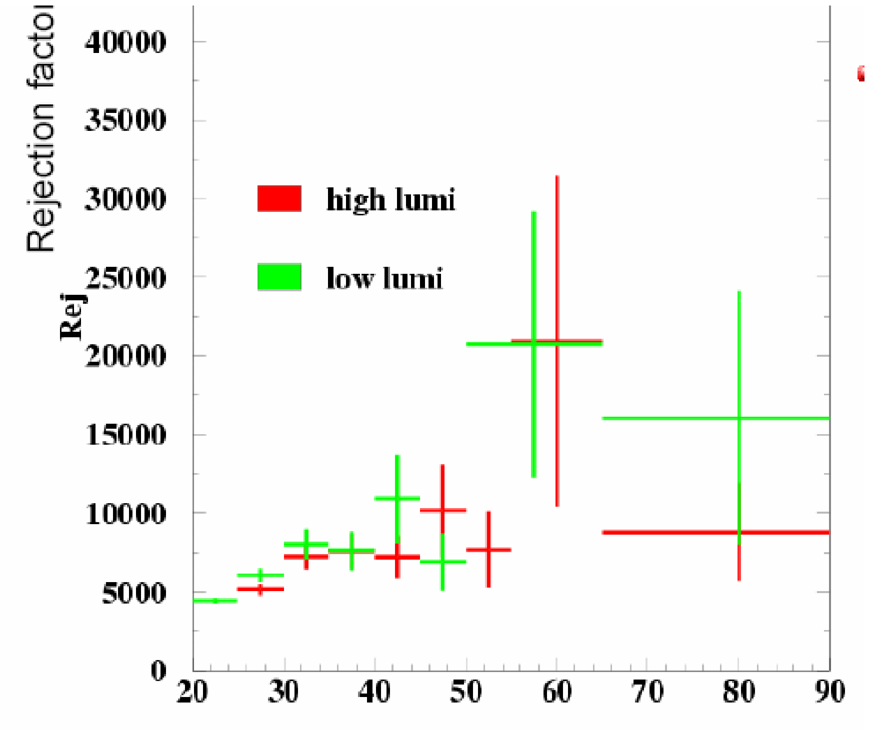


γ/jet Separation

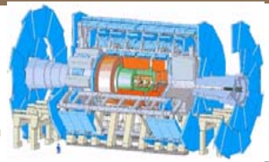


☐ Data Used:

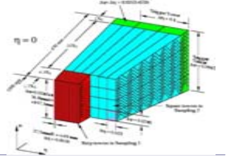
- single γ or γ from H to $\gamma\gamma$
- QCD dijets with $p_T > 17$ GeV (low lumi) and 25 GeV (high lumi)



- For ε ~ 80% R ~ 7000
- Rejection of quark jets ~ 3000
- Rejection of gluon jets ~21000



Low pT Electron Identification



# of TR hits

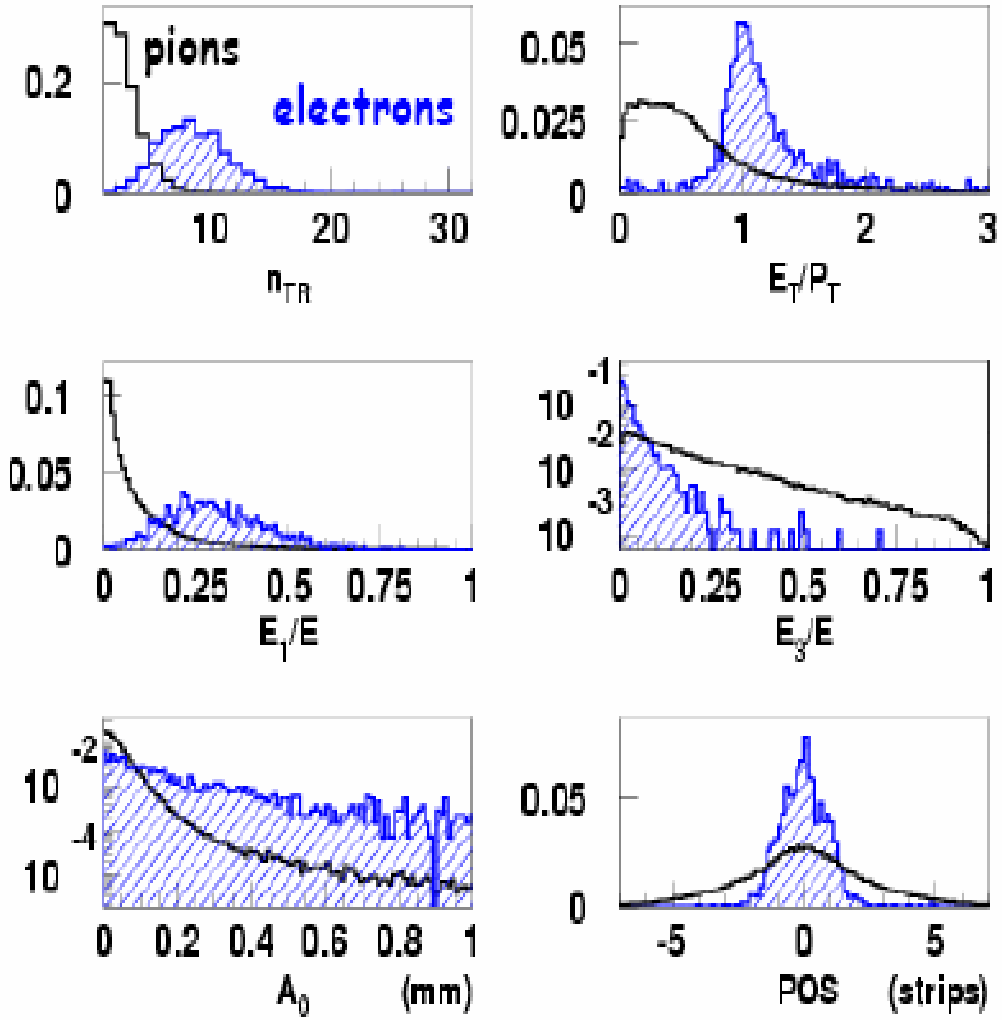
Et(calo)/pt

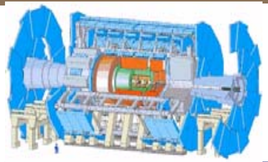
fraction of E in 1st sampling

fraction of E in 3rd sampling

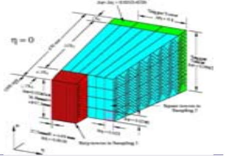
transverse impact parameter

diff between shower and impact position



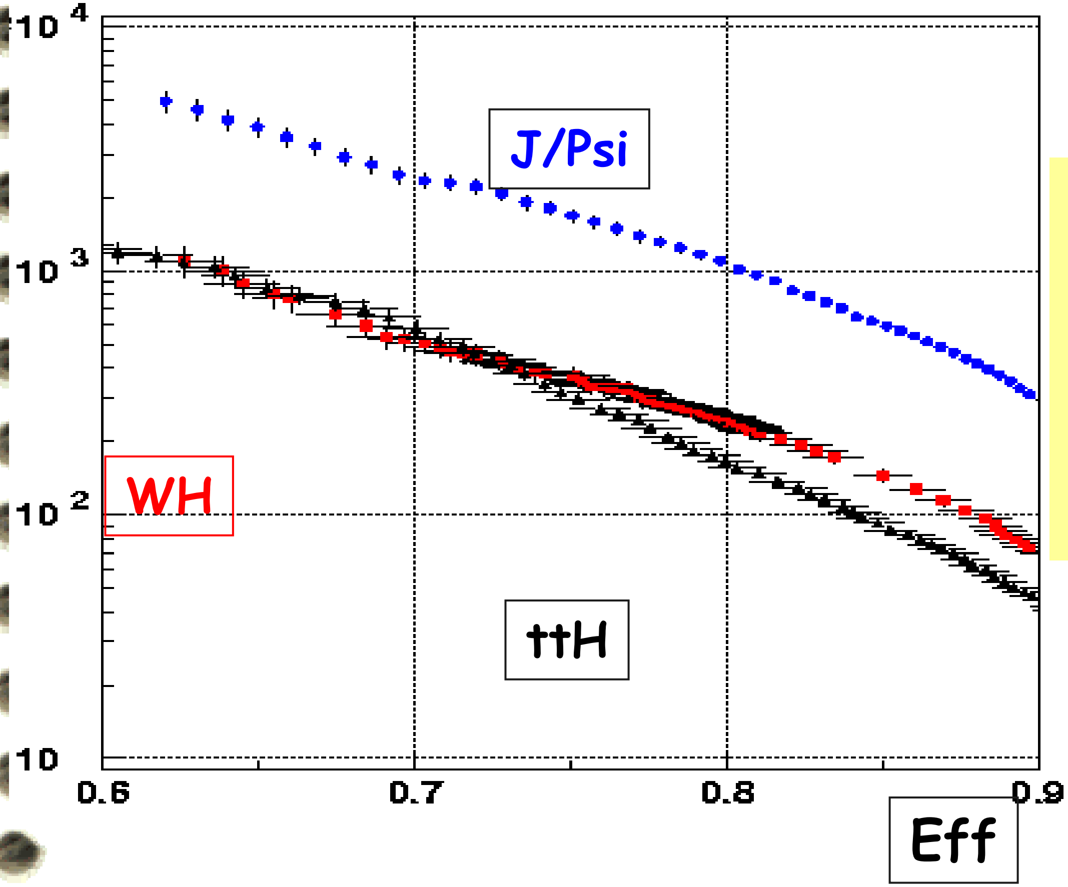


Low pT eID: Results



PDF and neural net for ID: analysis dependant

Rejection



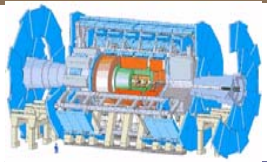
e-id efficiency = 80%

Pion rejection in:

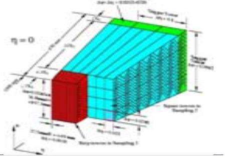
J/Psi : 1050±50

WH(bb) : 245±17

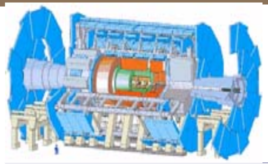
ttH : 166 ±6

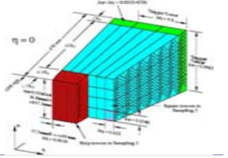


Conclusion

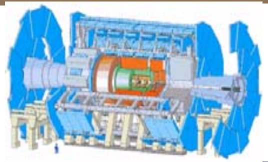


- Electrons and photons ID are essential ingredients for new physics at the LHC
- Procedures and methods for calibration are established and tested in test beam
- Different algorithms for eID/γID have been developed
- Dedicated algorithms needed for e^- from b's have been developed

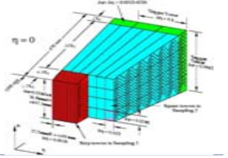




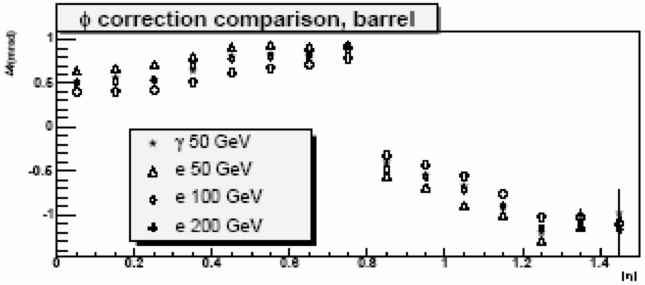
Backup Slides

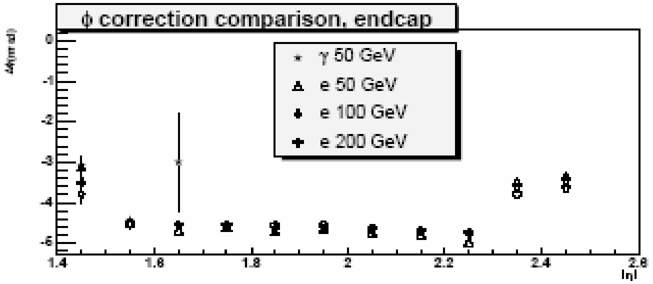


Phi Position Correction



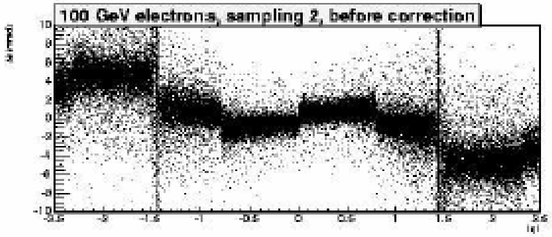
- Correct ϕ bias in sampling 2.
- $\Delta\phi = \phi_{\text{true}} - \phi_{\text{meas}}$.

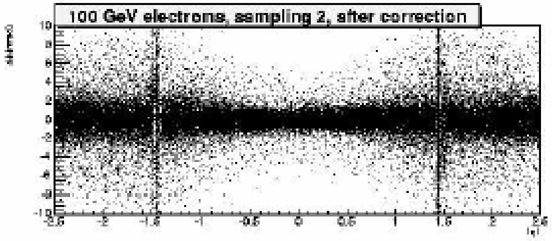




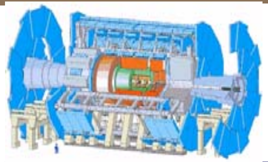
- A small energy dependence is seen.
- 50 GeV photons look most like 100 GeV electrons.

- Interpolate in $|\eta|$ and energy.

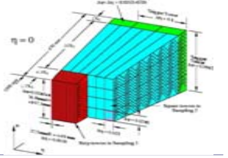




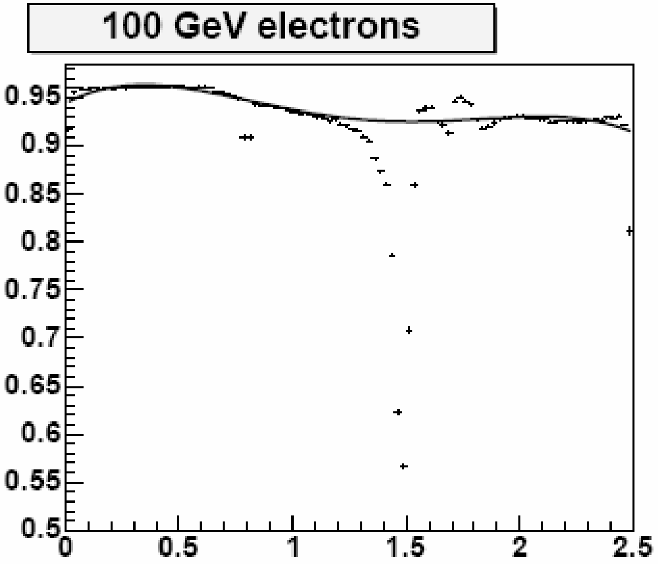
- Note: sign difference for $\pm\eta$; different from G3.



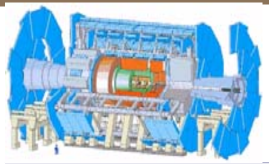
Gap Correction



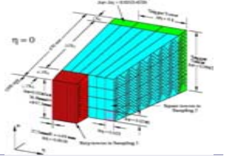
- Attempt to correct for the energy lost in the gap between the cryostats.
- Use the tile calorimeter scintillator to recover some of the energy.
- Correction: $E' = A(E_c + \alpha E_s)$, where E_s is the scintillator energy.
- Weights A and α defined as a function of $|\eta|$.
- Plot $E_{\mathrm{meas}}/E_{\mathrm{true}}$. Fit a function to the points outside the gap; interpolate across the gap.
  - (Don't use detailed MC information about energy deposition in dead material both for simplicity and so that the same procedure may be used for real data.)
- Example for 100 GeV electrons:



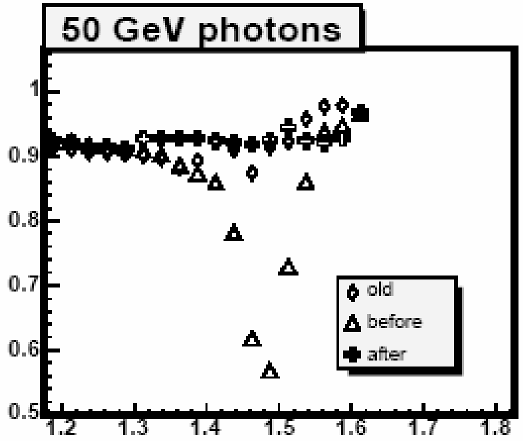
- Choose α to minimize $\sigma(E')$.
- Choose A to get the $\langle E' \rangle$ to match the interpolating polynomial.

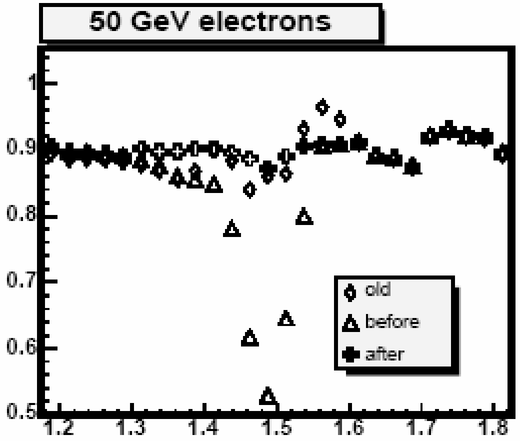


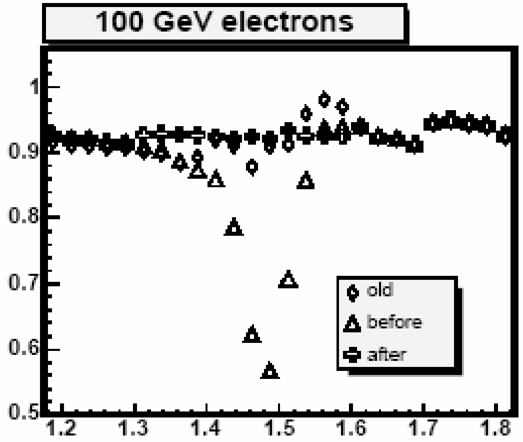
Gap Correction

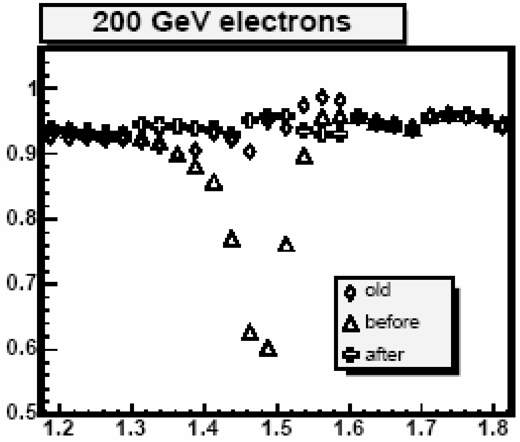


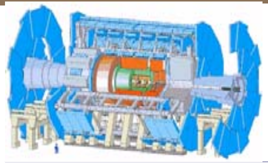
- $E_{\rm meas}/E_{\rm true}$ vs. $|\eta|$ before and after correction.



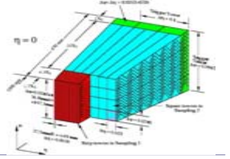


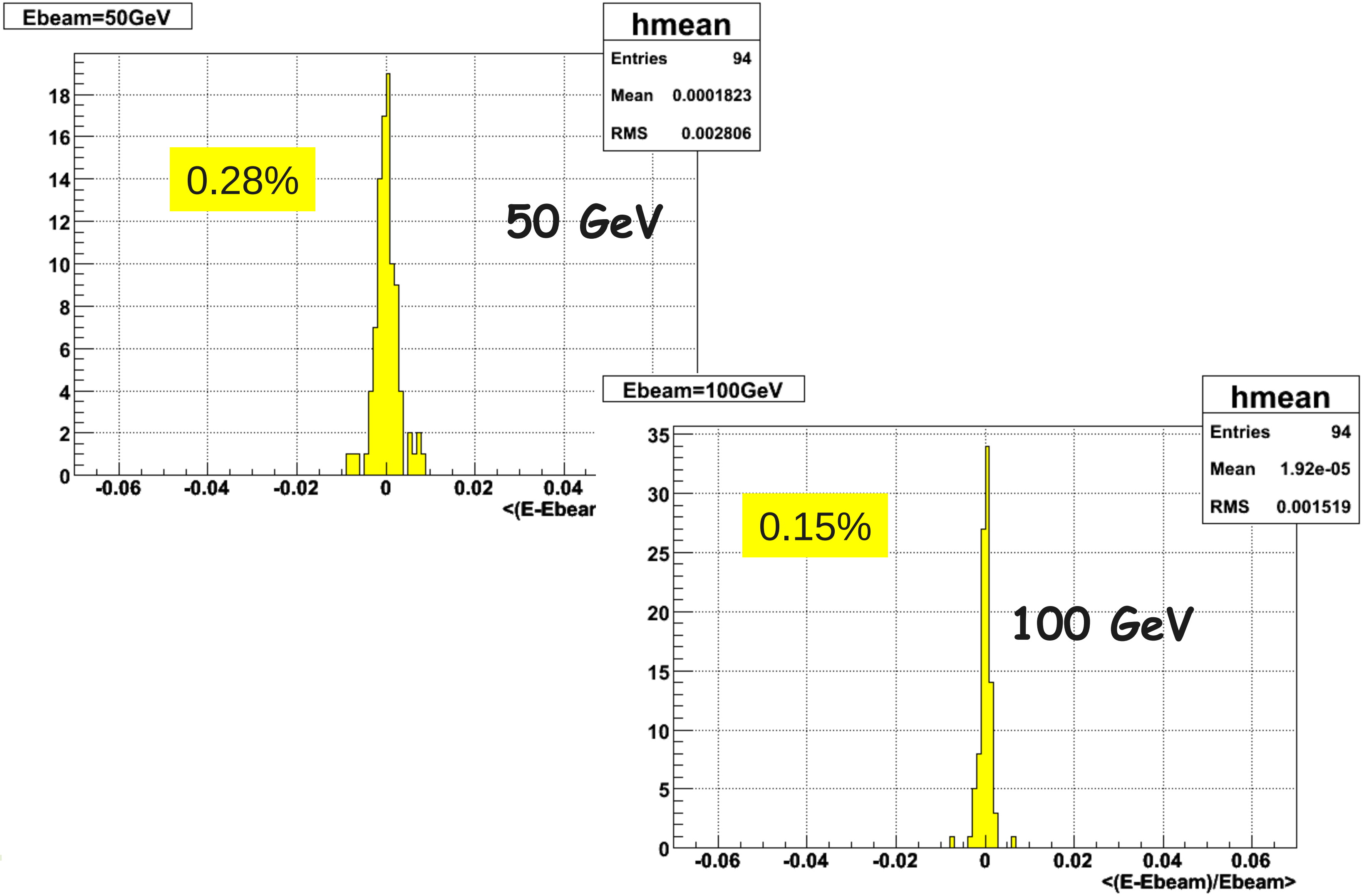






Layer Weights



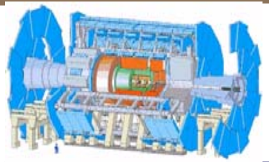


0.28%

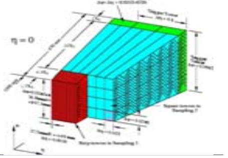
50 GeV

0.15%

100 GeV



Uniformity and Z→ee



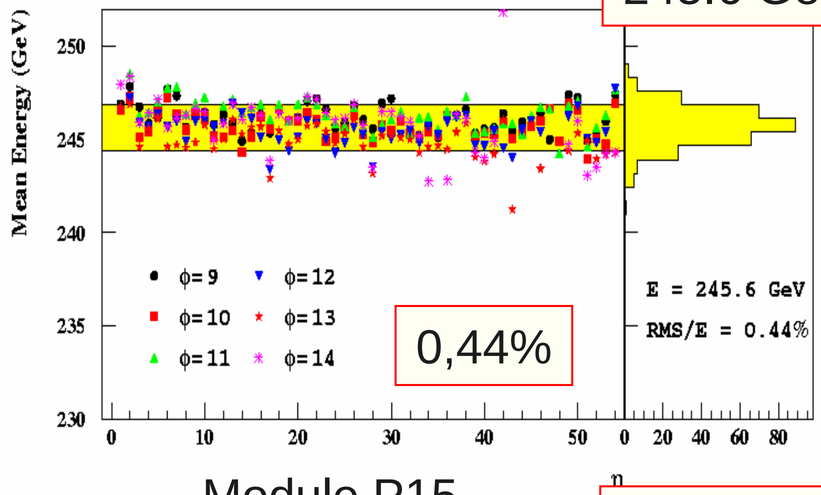
- uniformity 0.2x0.4 ok in testbeam:
  - 1% quasi online
  - 0.5% difficult
  - energy scale stable to 0.13%
- description of testbeam data by Monte Carlo satisfactory
- make use of Z→ee Monte Carlo and Data in ATLAS for intercalibration of regions
- 448 regions in ATLAS (denoted by i)
- mass of Z know precisely
- $E_i^{reco} = E_i^{true}(1+\alpha_i)$
- $M_{ij}^{reco} = M_{ij}^{true}(1+(\alpha_i+\alpha_j)/2)$
- fit to reference distribution

At low (but nominal) luminosity, 0.3% of intercalibration can be achieved in a week (plus E/P later on)! Global constant term of 0.7% achievable!

Testbeam 0.62% and 0.56% global constant term already achieved
Module to module variation 0.05%

Module P13

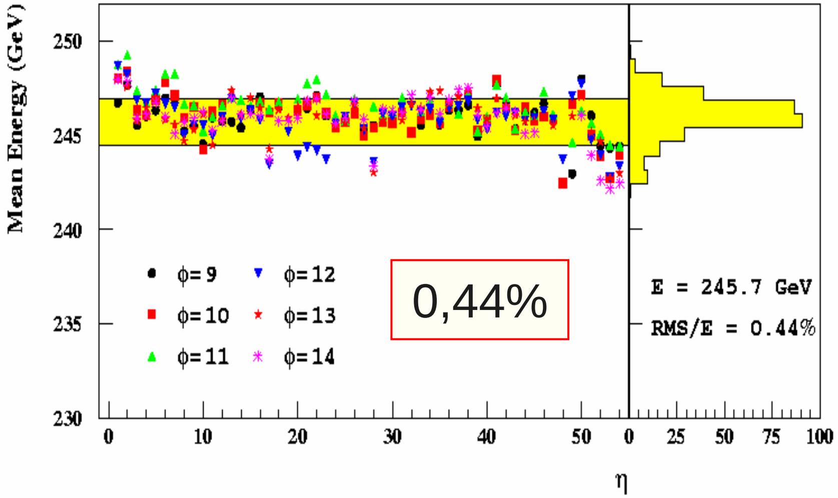
245.6 GeV



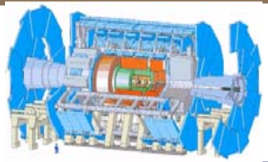
0,44%

Module P15

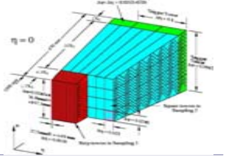
245.7 GeV



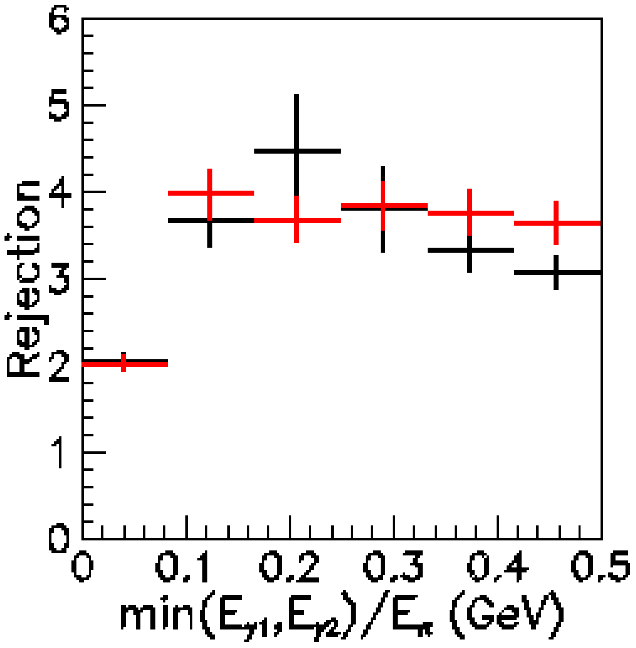
0,44%



γ/π^0 Separation

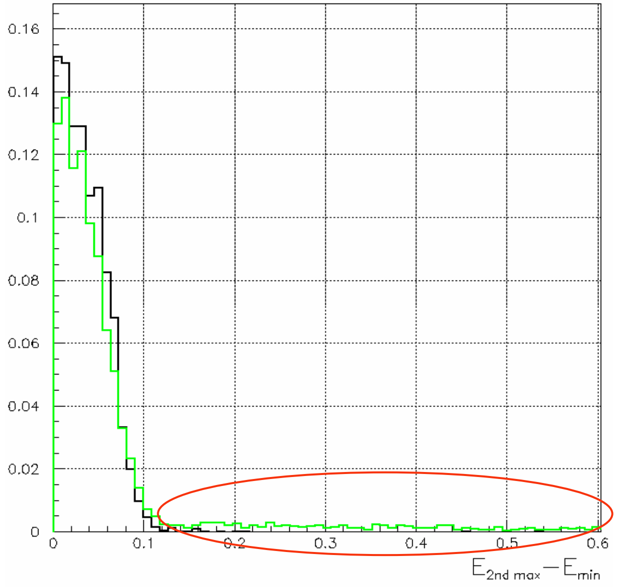


- **use finely segmented first CALO compartment and search for secondary maxima, shower width etc**
- **need a separation factor of at least 3**



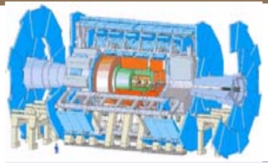
R (data) = 3.18 ± 0.12 (stat)

R (MC) = 3.29 ± 0.10 (stat)

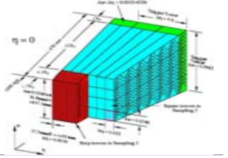


$E_{2nd\ max}$ - E_{min}

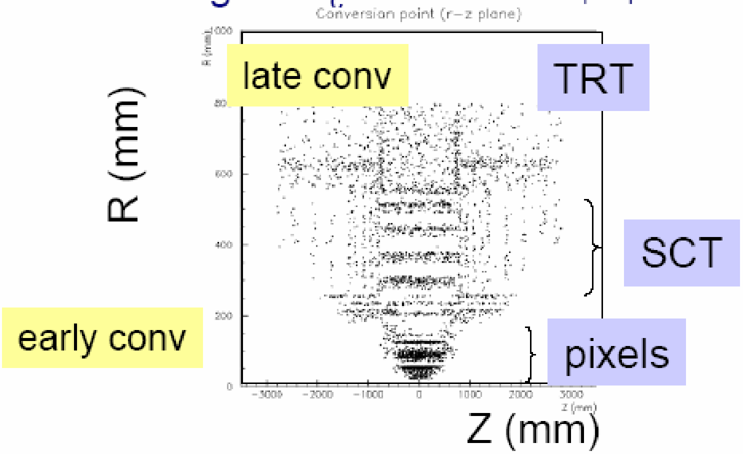
Results obtained with Full simulation G3/DC1 or G4/DC2 are in agreement

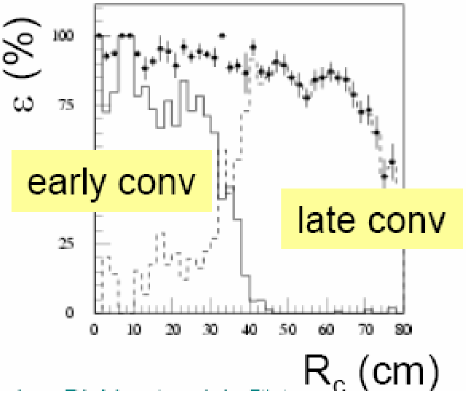


γ Conversions and its Effects on γ/π^0



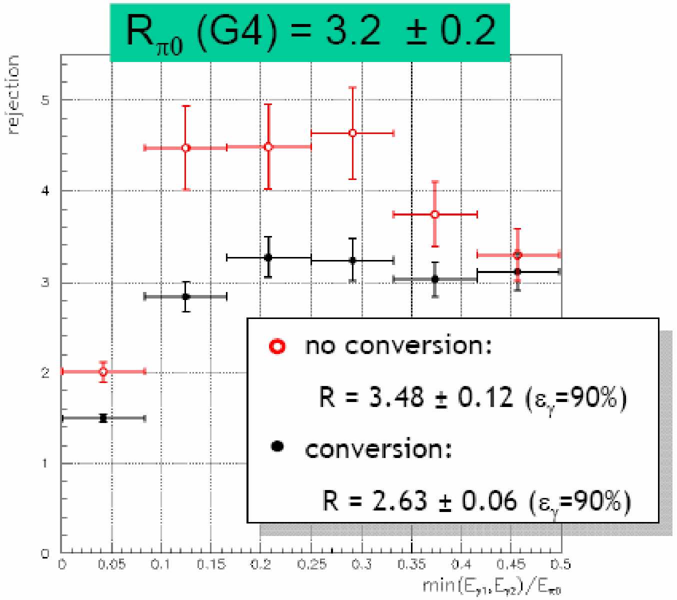
- ~30% (depending on η) probability for photon conversion in the ID cavity
- ID will identify and reconstruct with a ~80% efficiency photon conversions in the region R_c<80 cm and $|z|$ < 280 cm – where ~80% of conversions occur



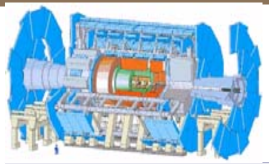


Results from G4 full simulation

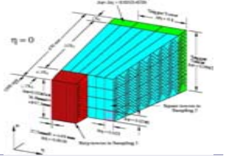
$R_{\pi 0}$ (G4) = 3.2 ± 0.2



Small effect on $R_{\pi 0}$ due to different start of showering
Identification of conversions ⇒retuning of cuts

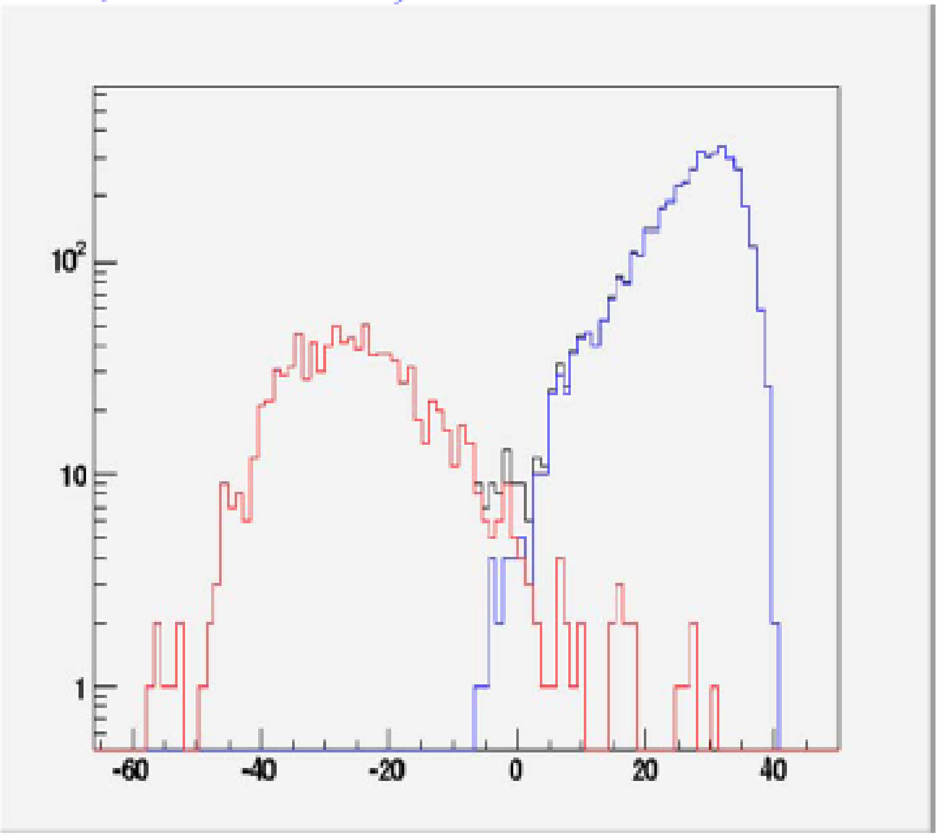


e/jet Separation: Results



NO ID Variables USed

$$\log\left(\frac{\prod_{1}^{n} pdf_{signal}}{\prod_{1}^{n} pdf_{background}}\right)$$



Cut1:
ε ~ 95
R ~ 3.6 x 10^4

Cut2:
ε ~ 90
R ~ 4.1 x 10^4

Cut3:
ε ~ 83
R ~ 1.2 x 10^5

ε ~ 82.1
R ~ 1.4x 10^5

DC1

ε ~ 84
R ~ 1.2x 10^5

Tuned IsEM