PFlow Review

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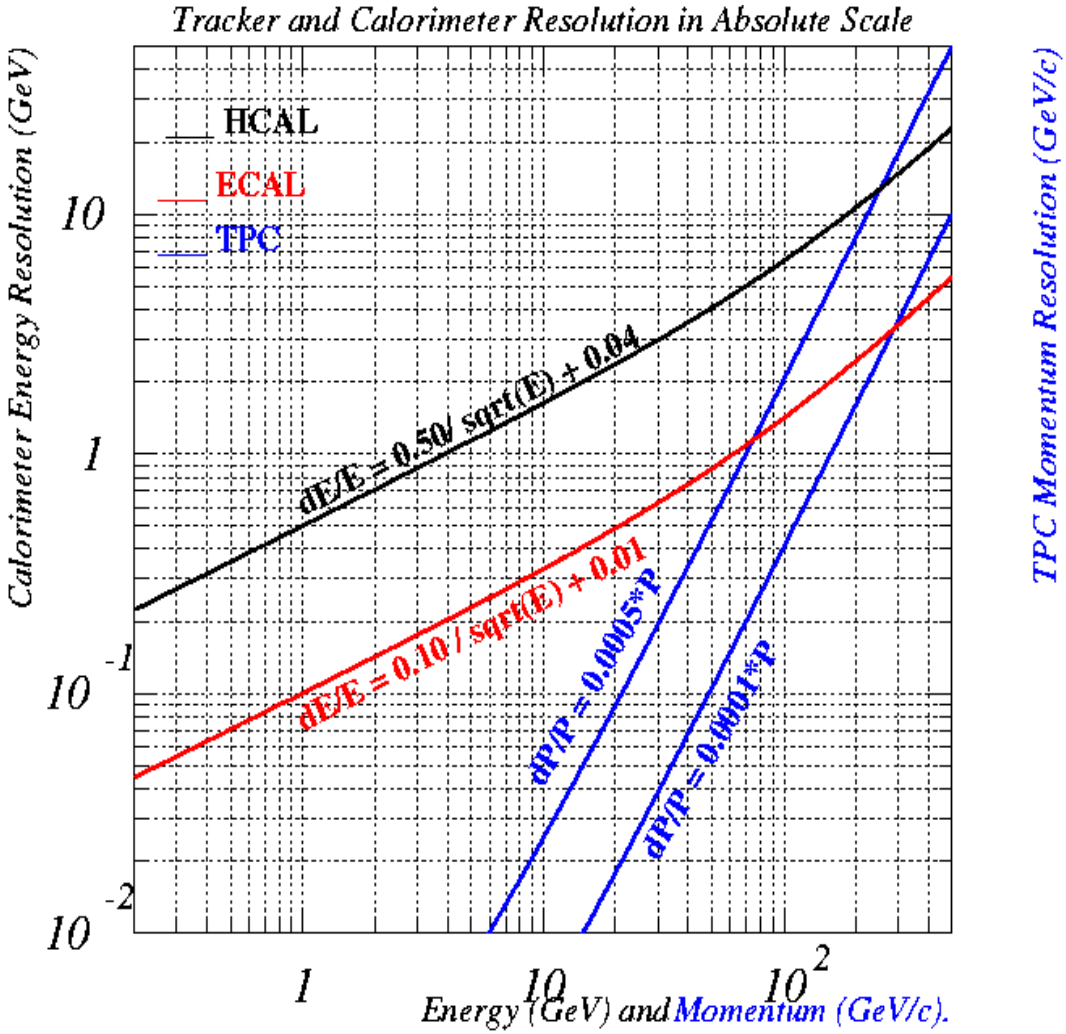
Introduction

- PFlow concept has found wide acceptance as an optimal approach for event reconstruction in the LC experiment
  - PFA performance is one of the main factors, driving detector design
- ILC collaboration enters the phase of detector optimization
  - we desperately need tools to perform detector optimization studies (realistic PFA is one of these tools)
- At the stage of detector optimization, flexibility of reconstruction software is favored over performance
  - PFA should have minimal dependence on detector geometry to enable detector optimization
  - PFA can be further optimized once the detector configuration is chosen and fixed

Particle Flow Concept

- Basic idea : optimal reconstruction of every measurable particle in an event
- Tracker is superior w.r.t. calorimeter
  - use tracker to estimate 4-momenta of charged objects
  - use calorimeter for reconstruction of neutral objects
- Implications for detector
  - good pattern recognition in tracking device to facilitate efficient track reconstruction in jets with high local particle densities
  - imaging capabilities of calorimeters are favored over compensation/resolution



Perfect PFA : What theory predicts

- Jet energy resolution
  $\sigma^2(E_{jet}) = \sigma^2(ch.) + \sigma^2(\gamma) + \sigma^2(h^0) + \sigma^2(conf.)$
- Excellent tracker :
  $\sigma^2(ch.) << \sigma^2(\gamma) + \sigma^2(h^0) + \sigma^2(conf.)$
- Perfect PFA : $\sigma^2(conf.) = 0$
- $\sigma^2(E_{jet}) = A^2_\gamma E_\gamma + A^2_h E_{h0} = w_\gamma A^2_\gamma E_{jet} + w_{h0} A^2_h E_{jet}$
  $\sigma(E_{\gamma,h})/E_{\gamma,h} = A_{\gamma,h}/\sqrt{E_{\gamma,h}}$

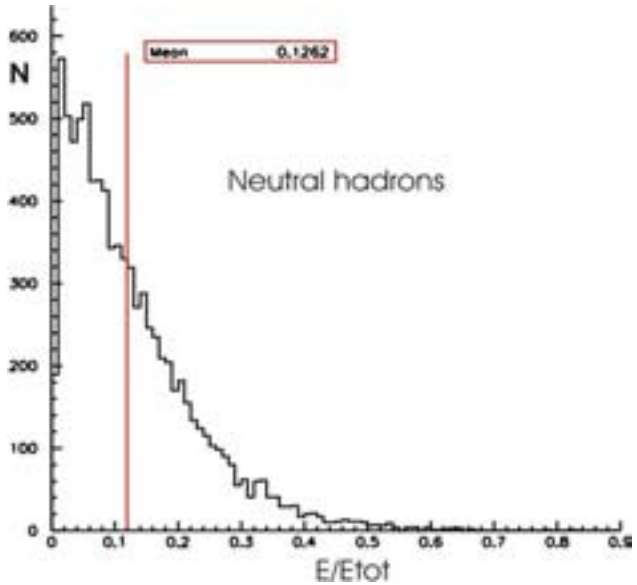
Typically $w_\gamma = 25\%$; $w_{h0} = 13\%$

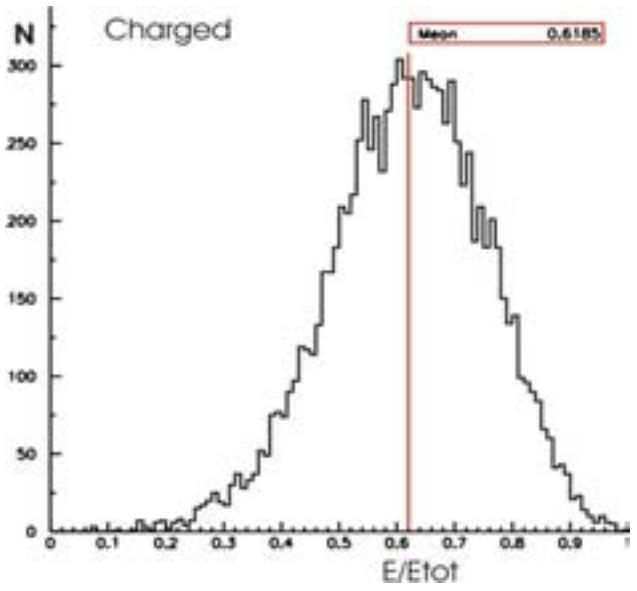
$A_\gamma = 11\%$; $A_{h0} = 34\%$

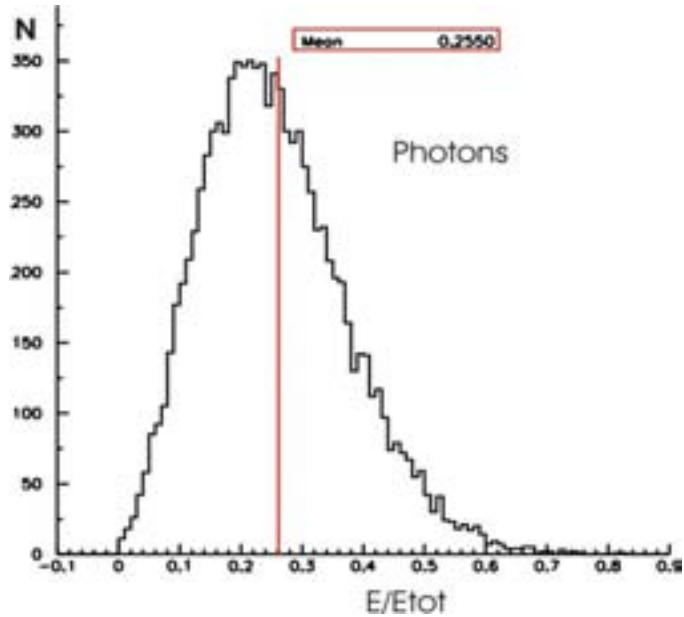
$\Rightarrow \sigma(E_{jet})/E_{jet} = 12\%/\sqrt{E_{jet}}$

$A_\gamma = 11\%$; $A_{h0} = 50\%$

$\Rightarrow \sigma(E_{jet})/E_{jet} = 17\%/\sqrt{E_{jet}}$

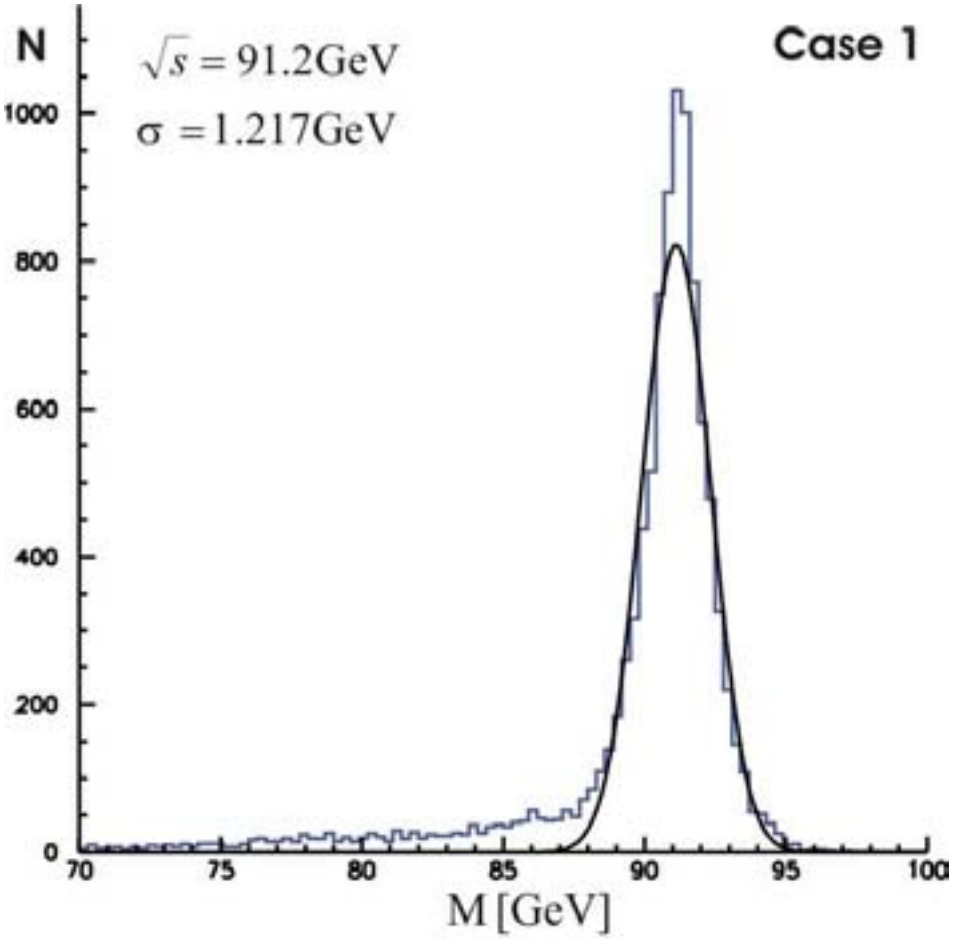






Toy MC Experiment

- Smear particle momenta and energies according to the resolution anticipated for a given particle type
  - photons : $\sigma E_\gamma / E_\gamma = 11\%/\sqrt{E_\gamma}$
  - h0 : $\sigma E_{h0} / E_{h0} = 34\%/\sqrt{E_{h0}}$
  - charged : $dp/p = 10^{-5}\, p$
- Toy experiment performed on hadronic decays at Z pole confirms theoretical predictions



Studies by P.Krstonosic

Factors Contributing to Resolution

$e^+ e^- \rightarrow Z^0 \rightarrow q\bar{q}$ at 91.2GeV

Studies by P.Krstonosic

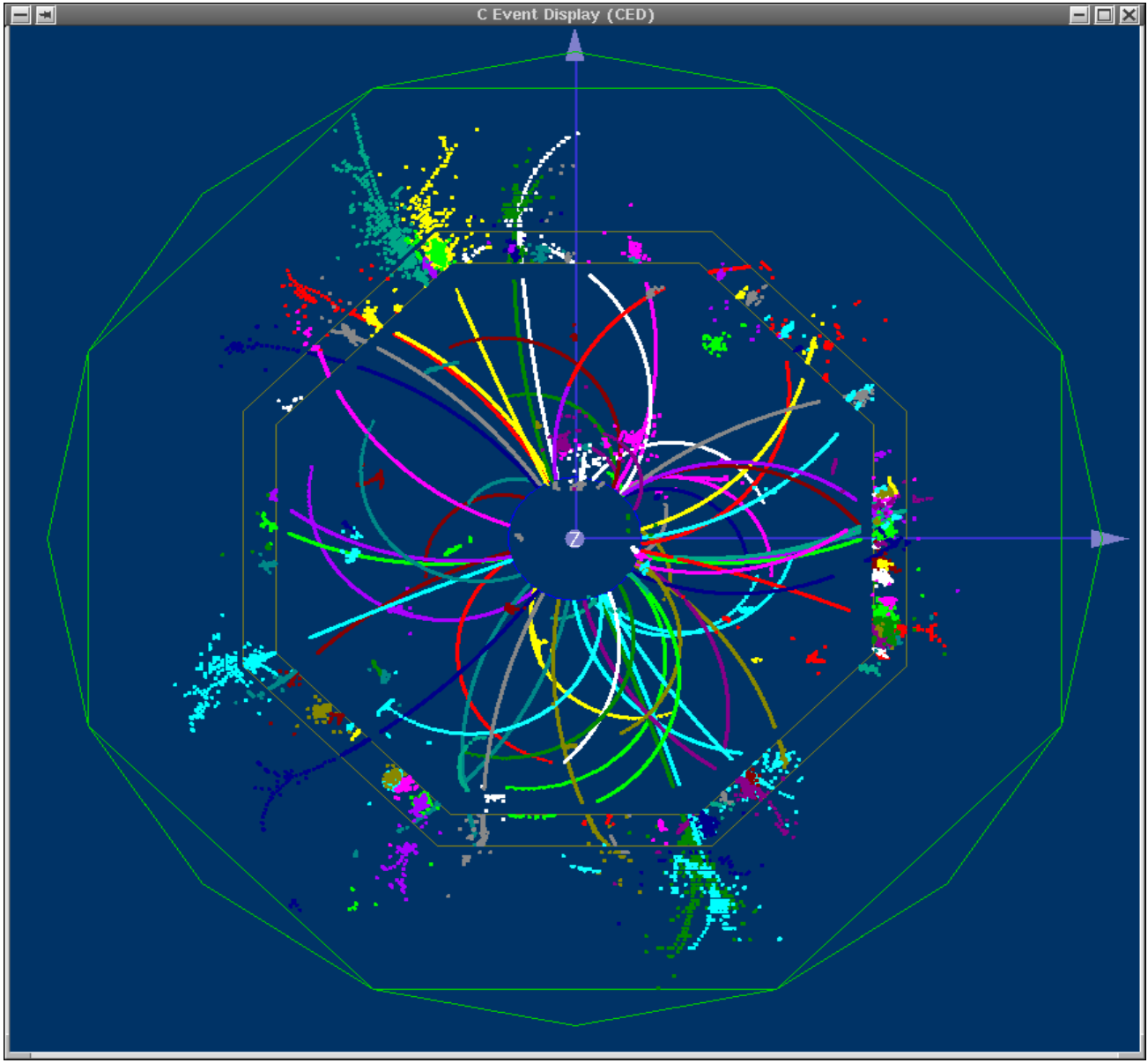
Effect	σ [GeV] separate	σ [GeV] not joined	σ [GeV] total ($\%/\sqrt{E}$)	σ to total
$E_v > 0$	0.84	0.84	0.84 (8.80%)	12.28
$Cone < 5^o$	0.73	1.11	1.11(11.65%)	9.28
$P_t < 0.36$	1.36	1.76	1.76(18.40%)	32.20
σ_{HCAL}	1.40	1.40	2.25(23.53%)	34.12
σ_{ECAL}	0.57	1.51	2.32(24.27%)	5.66
M_{neutral}	0.53	1.60	2.38(24.90%)	4.89
M_{charged}	0.30	1.63	2.40(25.10%)	1.57

Reconstruction Tools

- Complete PFA implemented in a modular way within the framework of MARLIN (F.Gaede)
- Components :
  - Tracking in TPC based on LEP code adopted to LC detector (Steve Aplin)
  - Dedicated pattern recognition designed for Si tracker (still under development, but first results are available)
  - Calorimeter clustering exploiting imaging capabilities of calorimeters
- PFA : track – cluster matching ; particle ID; estimation of particle 4-momenta at PCA to IP
- Event shapes; jet clustering (P.Krstonosic, J.Samson, T.Kraemer, O.Wendt)

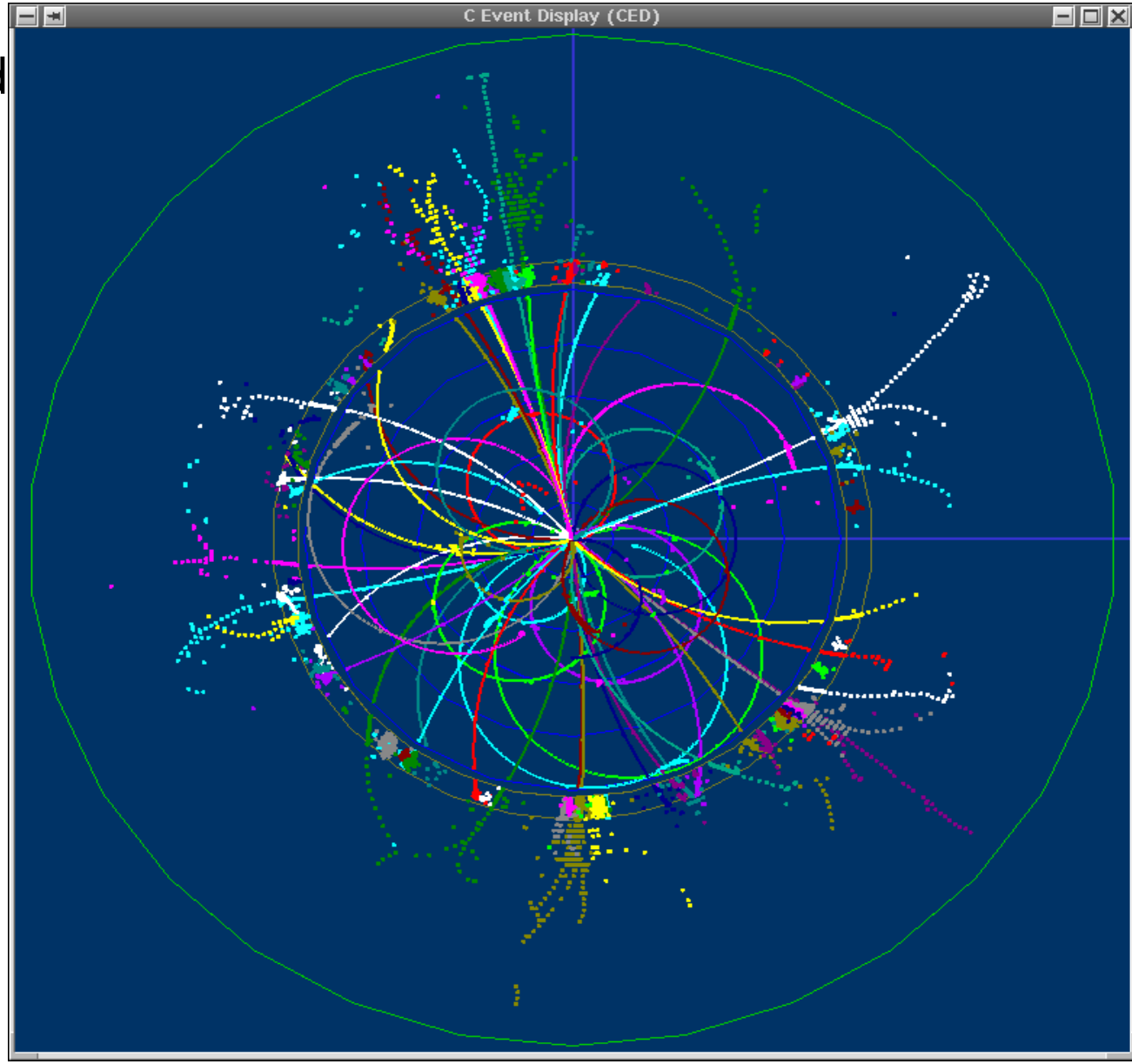
ttbar => 6jet with Large Detector

- Detector response simulated with Mokka for TESLA TDR geometry with tile HCAL (tile size 3x3 cm^2)
- Reconstruction :
  - Pattern recognition in TPC
  - Track fitting using helix model with specific ionisation energy loss
  - Pattern recognition and cluster finding in ECAL & HCAL
  - PFA



ttbar => 6jet with SiD

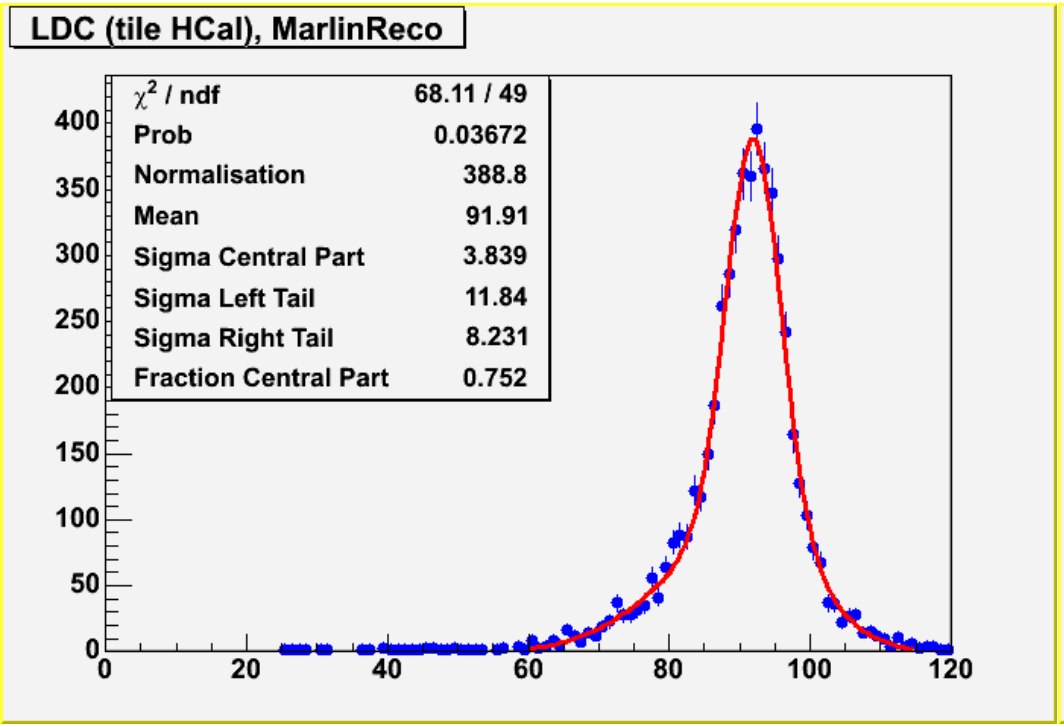
- Detector response simulated with SLIC (with RPC HCAL). LCIO file provided by N.Graf
- Reconstruction :
  - Dedicated pattern recognition in Si Tracker
  - Track fitting using helix model
  - Pattern recognition and cluster finding in ECAL & HCAL
  - PFA



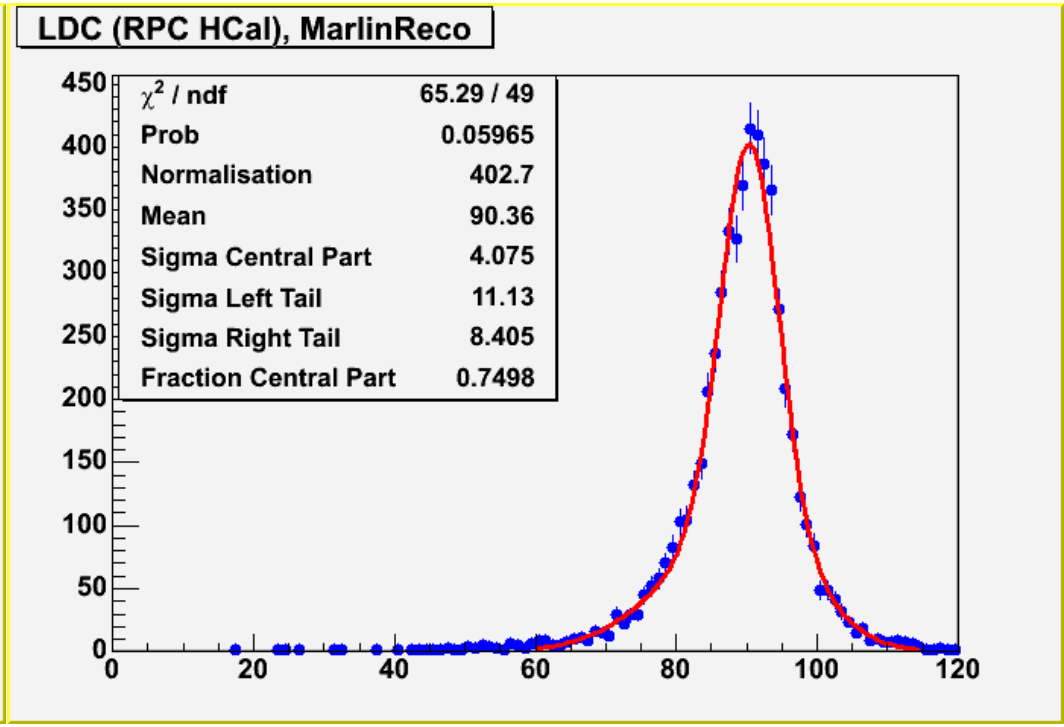
First Results : What we achieved

Z0-> u,d,s jets at 91.2 GeV, no ISR, no beamstrahlung

Analogue Tile HCal (3x3 cm^2 tile size)



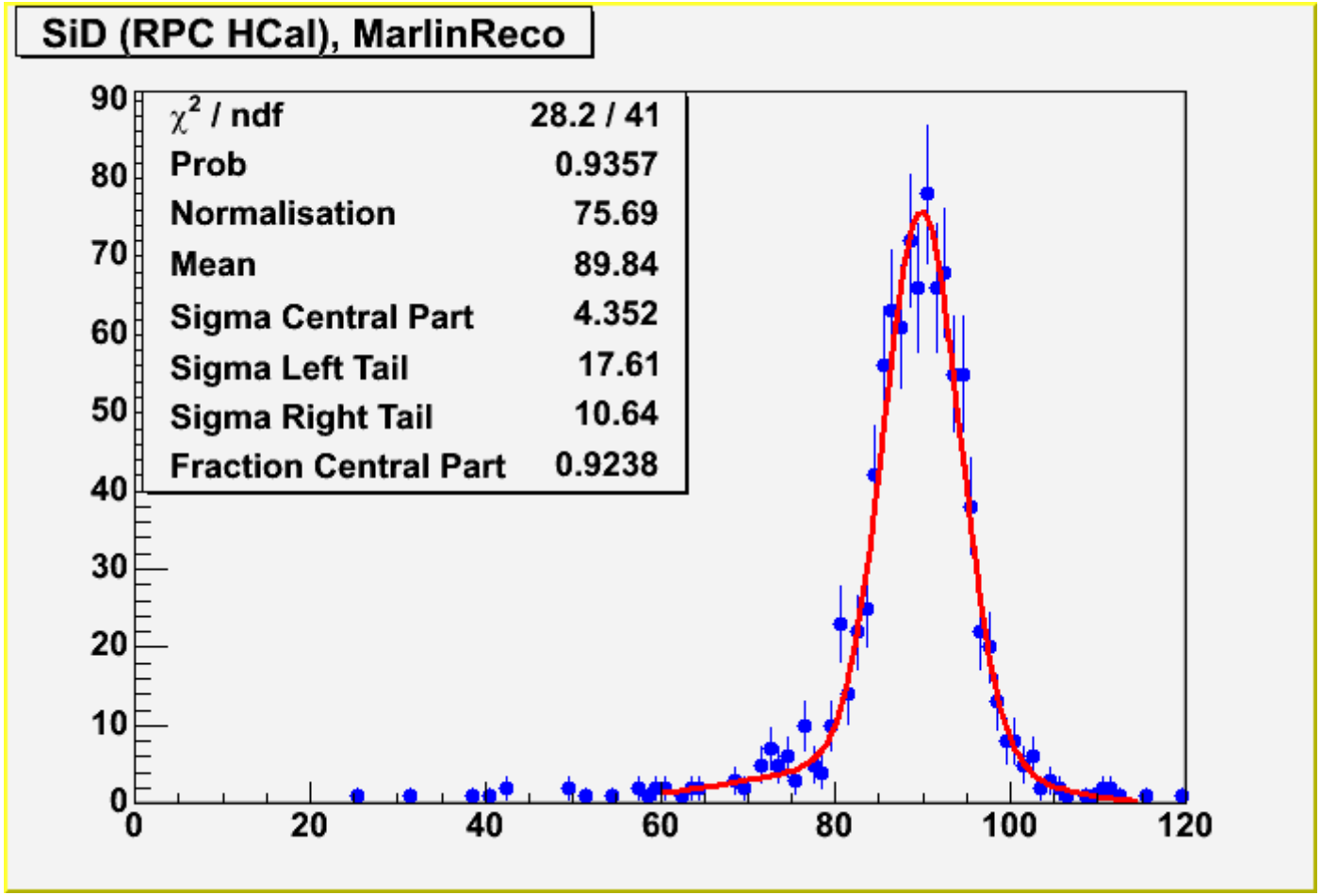
Digital RPC HCal (1x1 cm^2 pad size)



Simple gaussian fit gives 4.6(4.7) GeV resolution for tile(RPC) Hcal, but fit has very poor χ^2

Results for SiD

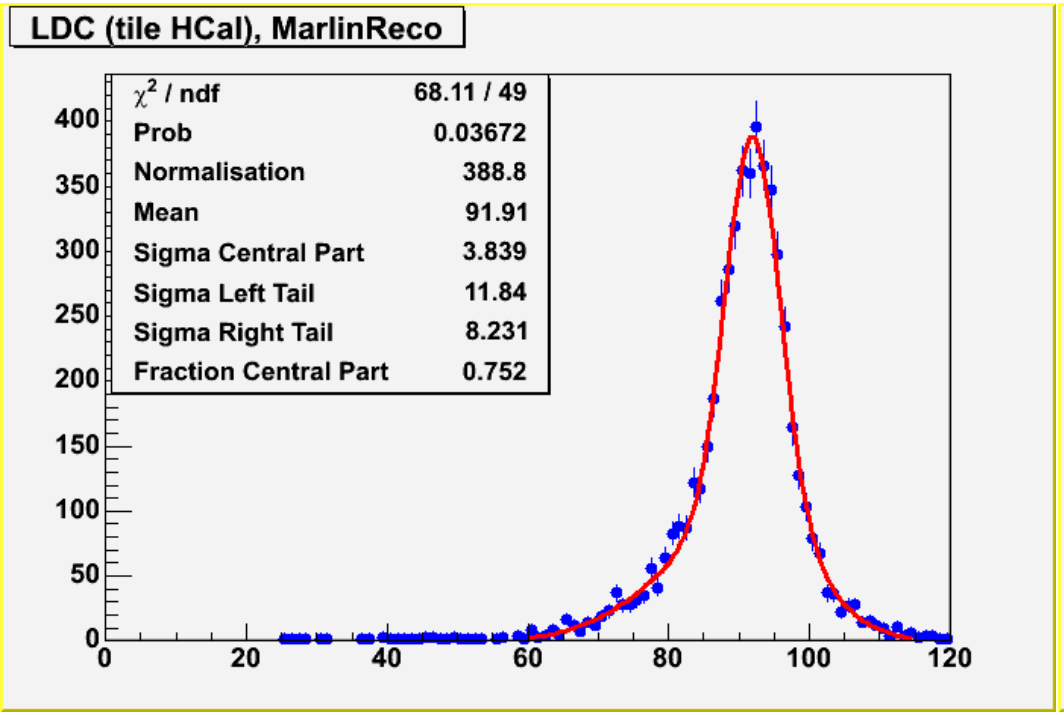
Z0 -> u,d,s jets @ 91.2 GeV. Detector simulation with SLIC program. Files provided by N.Graf. Dedicated pattern recognition in Si tracker

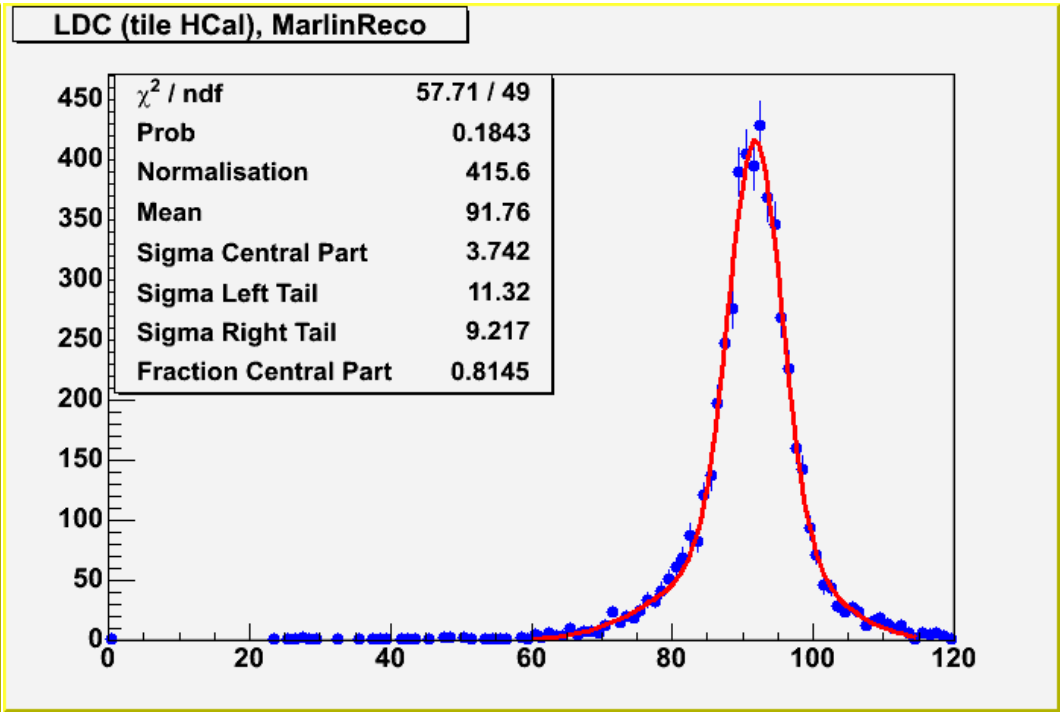


Performance of Tracking

Realistic tracking
(TPC only)

True tracks + realistic track fitting
(VTX+SIT+TPC+FTD)

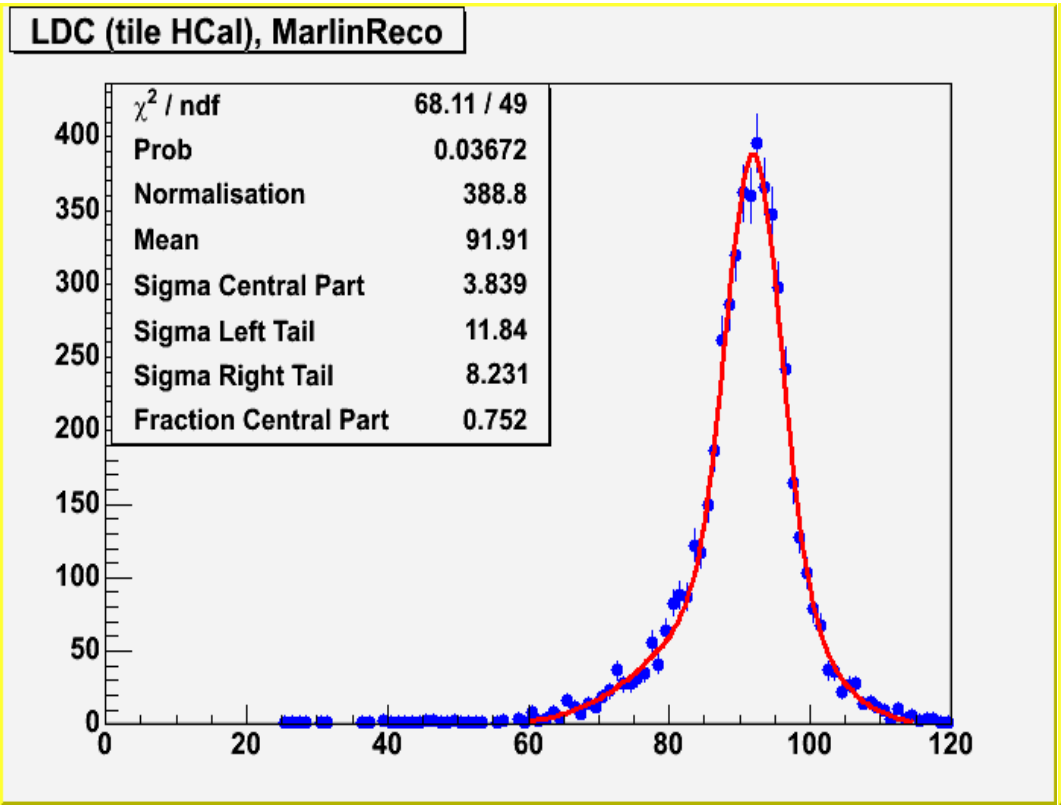




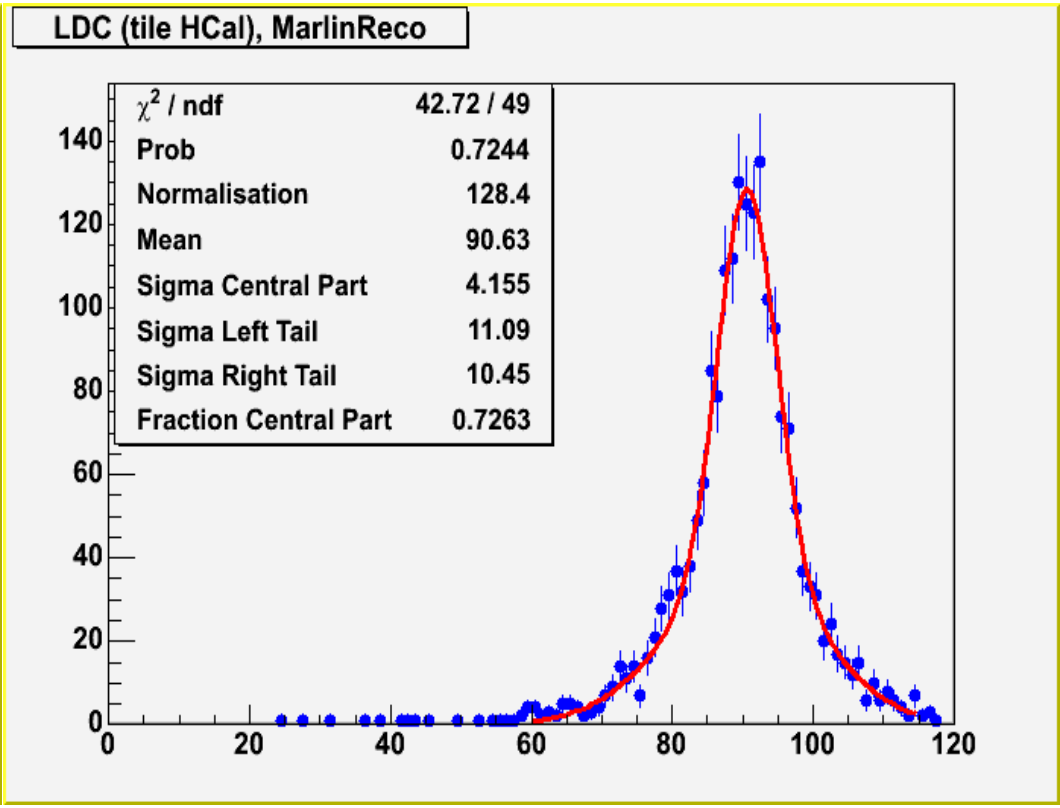
Realistic tracking does good job (almost as performant as **perfect** tracking using VTX+SIT+TPC+FTD). Thanks to Steve!

PFA Performance vs. HCAL Granularity

tile Hcal (3x3 cm^2 tile size)



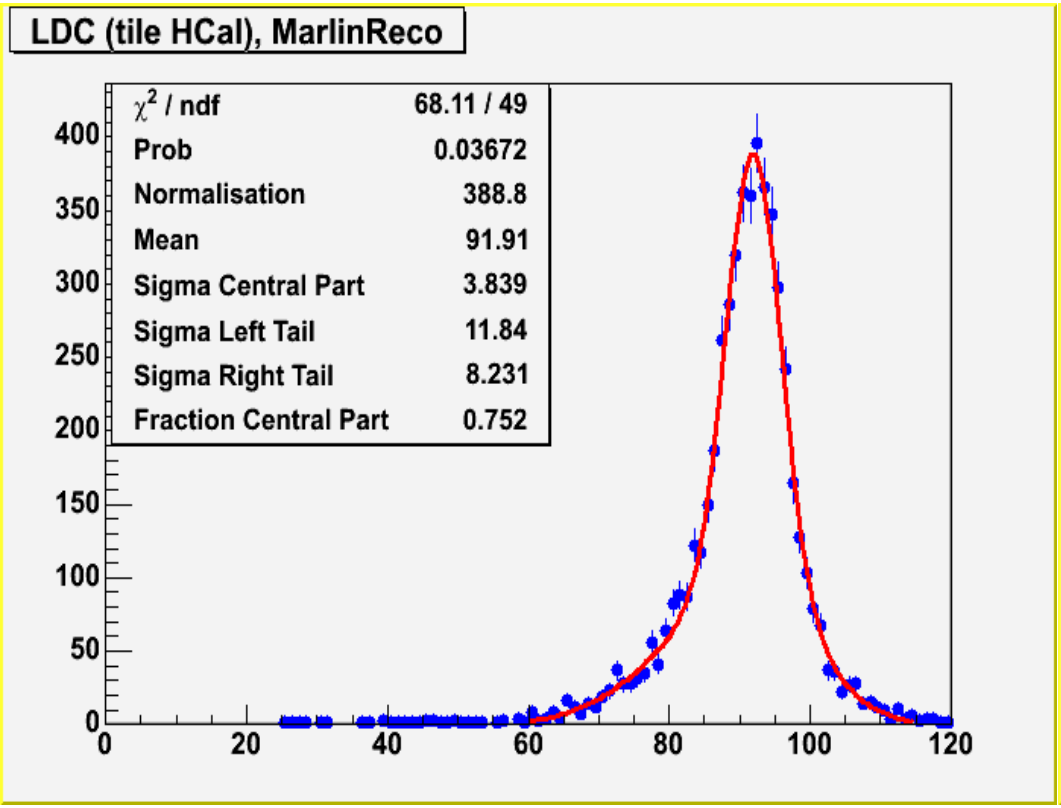
tile Hcal (6x6 cm^2 tile size)



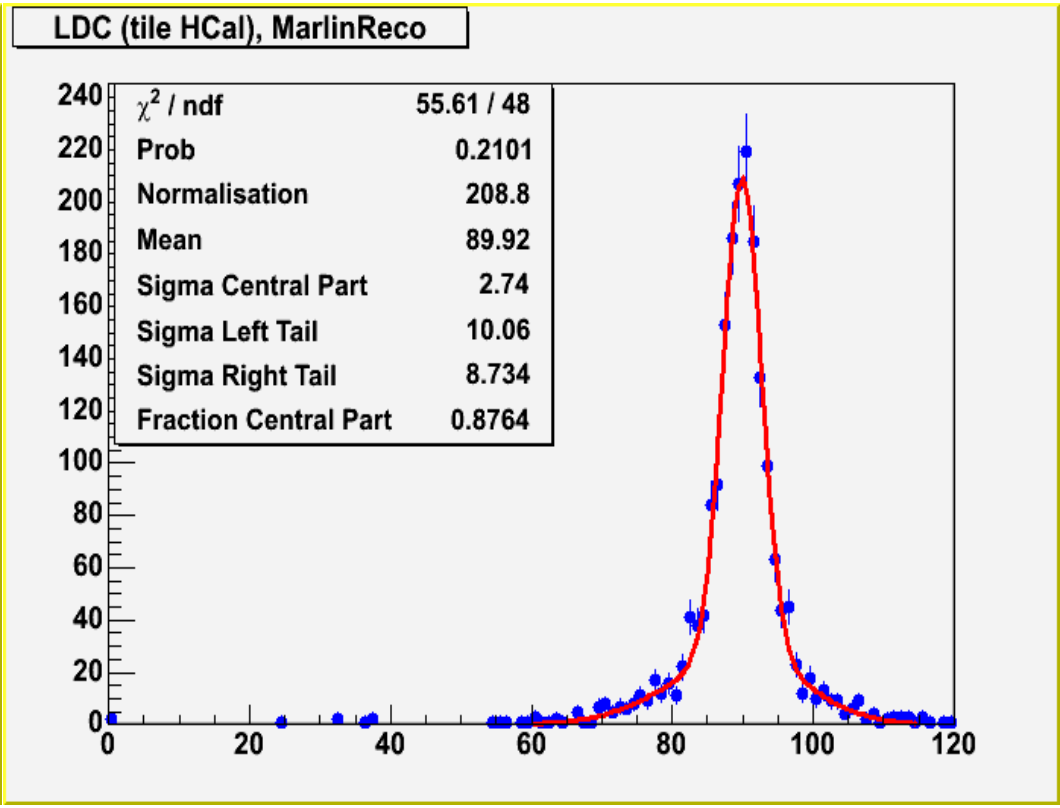
PFA with TrueTracks & TrueClusters

tile Hcal (3x3 cm^2 tile size)

Realistic PFA



PFA with TrueTracks and TrueClusters



Summary

- PFA with dedicated pattern recognition in tracking device and calorimeter clustering algorithm is implemented within modular package MARLIN
- Reconstruction software is characterised by minimal dependence on detector geometry and can be used for detector optimization studies
- Desired performance is not yet achieved but there is still room for improvements
  - inclusion of V0 and kink finding procedure
  - inclusion of tracking in the forward region
  - refining clustering procedure
- PFA will be discussed in detail in dedicated presentation on Monday 22/08/05