Shower Simulation

DESY ATLAS Meeting

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DESY - Hamburg

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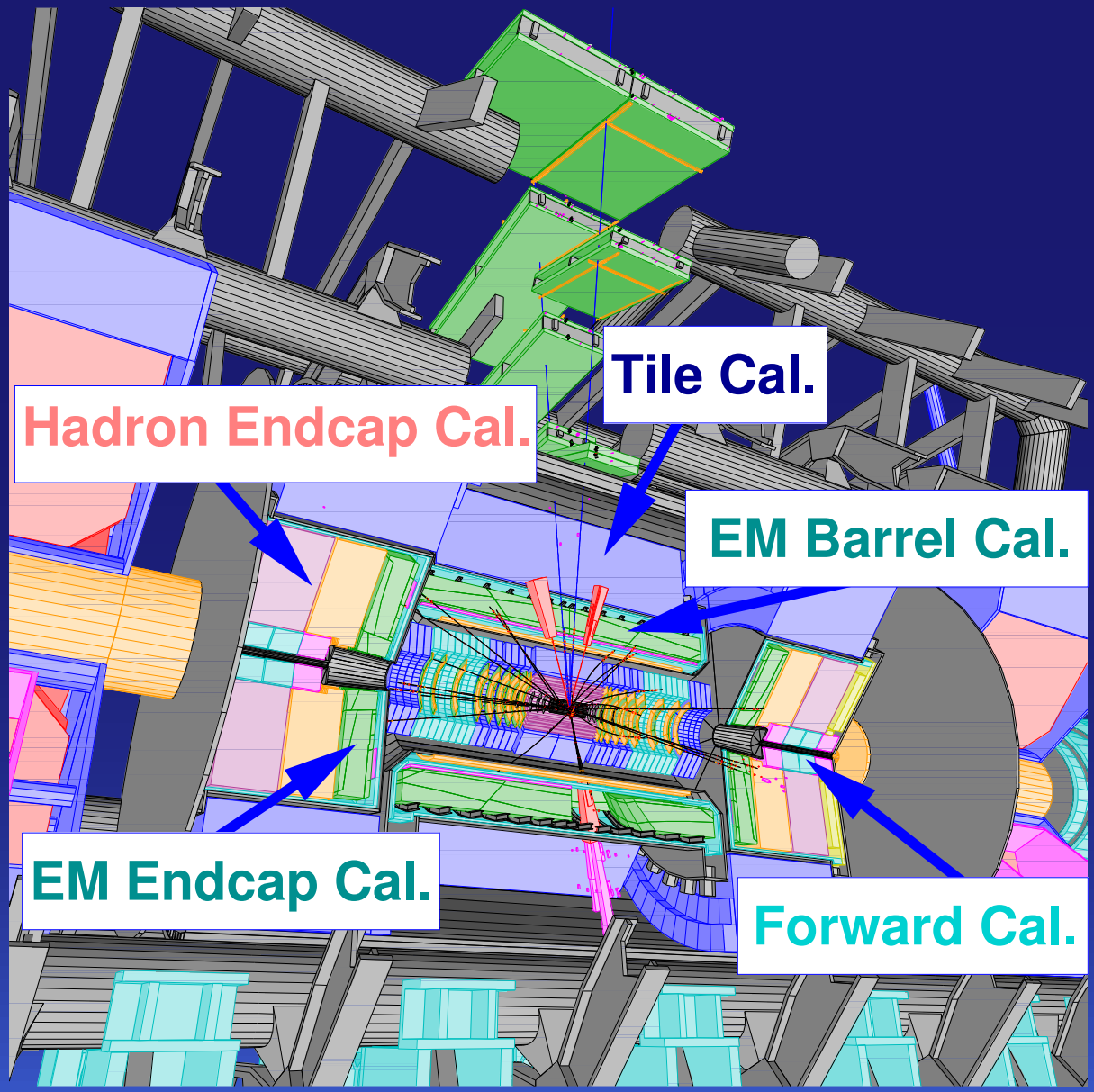
- **Calorimeter**
- **Fast Simulation**
- **Timing**
- **Cluster Reconstruciton**
- **Moments**

Our Mission: Fast Detector Simulation

- **the full Geant4 based ATLAS detector simulation is too slow**
  - → $Z \rightarrow e^+e^-$: **15 min**
  - → $H \rightarrow ZZ$: **35 min**
  - → **main time is spent in calorimeters**
- **parametrisation of electron showers as a first step**
  - → **handles high energy photons as well**
  - → **maybe other particles as well**
- **parametrisation done by Anthony Waught and Elisabetta Barberio**
  - → **EMB, EMEC, FCAL**
- **things to do (for us)**
  - → **get started with software**
  - → **validation (concentrate on reconstruction level)**
  - → **optimisation**
  - → **better parametrisation**

ATLAS Calorimeters

- Layout of the ATLAS Calorimeters
- EM LAr-Pb accordion calorimeter
  - Barrel (EMB): $|\eta| < 1.4$
  - End-cap (EMEC): $1.375 < |\eta| < 3.2$
- Hadron calorimeters
  - Barrel (Tile): Scint.-Steel $|\eta| < 1.7$
  - End-cap (HEC): LAr-Cu $1.5 < |\eta| < 3.2$
- Forward calorimeter (FCal) $3.2 < |\eta| < 4.9$
  - FCal1: LAr-Cu
  - FCal2&3: LAr-W



Fast Shower Simulation

Using FastSimModel class from G4FastSimulation for implementing fast simulation in full G4 simulation

- **test energy of particle**
  - → $0.0 < E < 0.1\,\mathrm{GeV}$: **kill electrons and photons (buggy)**
  - → $0.1 < E < 0.5\,\mathrm{GeV}$: **full simulation (e, γ)**
  - → $0.5 < E < 100\,\mathrm{GeV}$: **full simulation ($\gamma$), parametrisation (e)**
- **test if shower is fully contained in calorimeter**
  - → **longitudinal Z(95%), radial R(95%)**
- **apply parametrisation:**
  - → **kill particle**
  - → **generate fake steps along initial trajectory**
  - → **parametrised energy deposition including fluctuations**
  - → **longitudinal:** $\frac{1}{E}\frac{dE(t)}{dt}$
  - → **radial:** $\frac{1}{E(t)}\frac{dE(t,r)}{dr}$

Fast Shower Parametrisation

- **Following hep-ex/0001020:**

"The Parameterized simulation of electromagnetic showers in homogeneous and sampling calorimeters." G. Grindhammer, S. Peters (1993)

- **Use full simulation to derive parametrisations for given functional form:**

$$\rightarrow < \frac{1}{E}\frac{dE(t)}{dt} >= \frac{(\beta t)^{\alpha-1}\beta \exp -\beta t}{\Gamma(\alpha)}$$

t: longitudinal shower depth
α: shape parameters
β: scaling prameter

$$\rightarrow < \frac{1}{E(t)}\frac{dE(t,r)}{dr} >= p\frac{2rR_C^2}{(r^2+R_c^2)^2} + (1-p)\frac{2rR_T^2}{(r^2+R_T^2)^2}$$

r: shower radius
$R_C(t)$: median of energy distribution of the shower core
$R_T(t)$: median of energy distribution of the shower tail
p: weighting

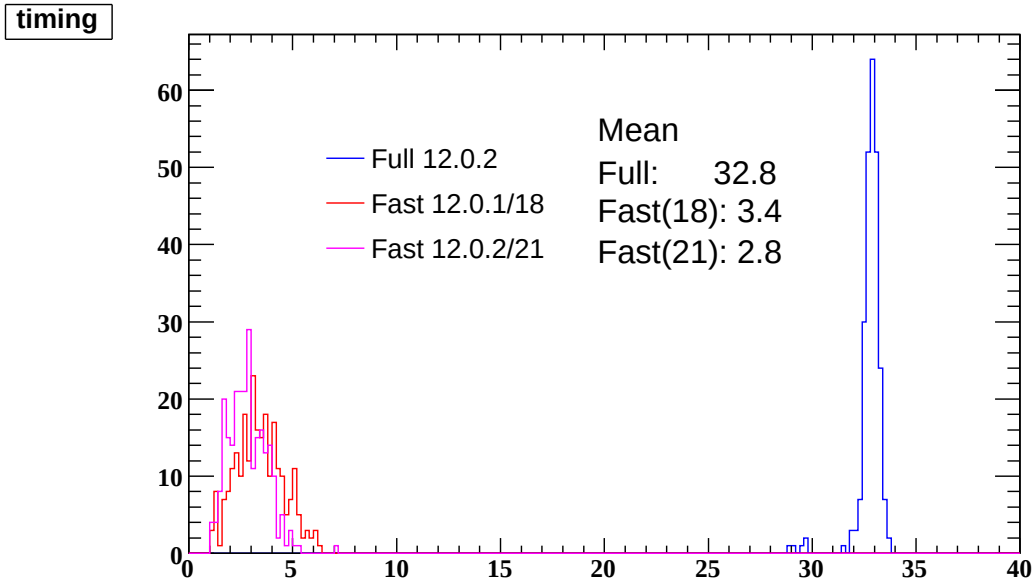
Our Setup

- using AtlasOffline 12.0.2 with LArG4FastSimulation package
  - → Calo only (DetFlags.Calo_setOn())
  - → full simulation
  - → fast simulation (LArG4FastSimulation-00-00-18)
  - → fast simulation bugfix (LArG4FastSimulation-00-00-21)
  - → fast simulation bugfix (set GEneToKill to 0)
- single electron, fixed position and energy
  - → energy: 100 GeV
  - → position: in front of LAr / center of detector
- looking at reconstruction level
- looking at cluster quantities (energy, moments, ...)

Timing of simulation

Time per event for 250 events (CERN/ELO_2800):

- → **full simulation**
- → **fast simulation 00-00-18**
- → **fast simulation 00-00-21**



our bug fix: set GEneToKill to 0 instead of 0.1 (0.1 is in official 12.0.1 release).

default bug fix: set GEneToKill to 0 and set GFlagToKill to false

Timing of Simulation

Timing comparison for 100 GeV electrons injected at the calorimeter surface or at the center of the detector.

Parameterization (00-00-18), at Calorimeter	0.32 ± 0.01 sec
Parameterization (00-00-18), at (0,0)	3.44 ± 0.28 sec
Parameterisation (00-00-21), at (0,0)	2.95 ± 0.21 sec
Parameterization (00-00-18), at (0,0), full for low energy γ	9.3 ± 0.8 sec
Full GEANT, at Calorimeter	33.10 ± 0.10 sec
Full GEANT, at (0,0)	35.96 ± 0.14 sec

- timing information at reco level from G4SimTimer
- new tag event better than old one
- work on parametrisation decision

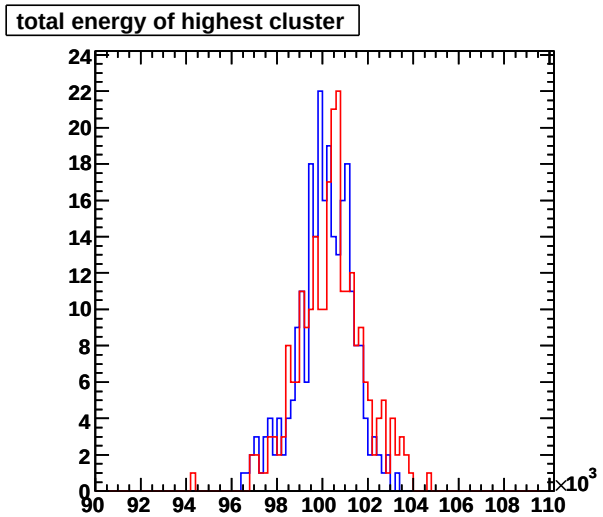
Cluster Reconstruction

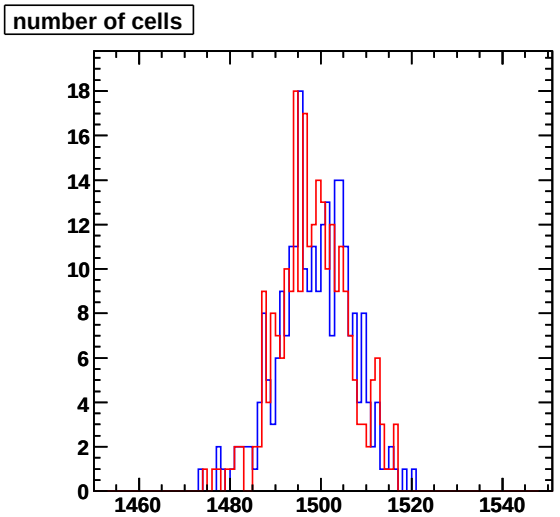
Different clustering algorithms:

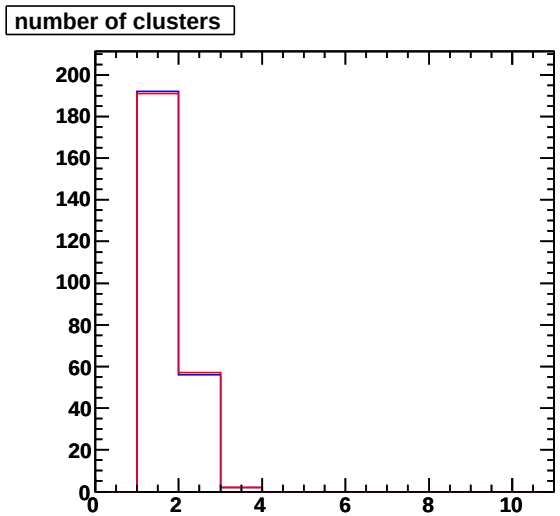
- **sliding window clustering:** LArClusterEM, LArClusterEM35, LArClusterEM37, CombinedCluster
  - → https://twiki.cern.ch/twiki/bin/view /Atlas /Slidi ngWind owClus tering
  - → precluster in 5x5 window (η, ϕ)
  - → cone around barycenter of precluster in XxY window (3x5,3x7, 5x5)
  - → sampling variables in ESD

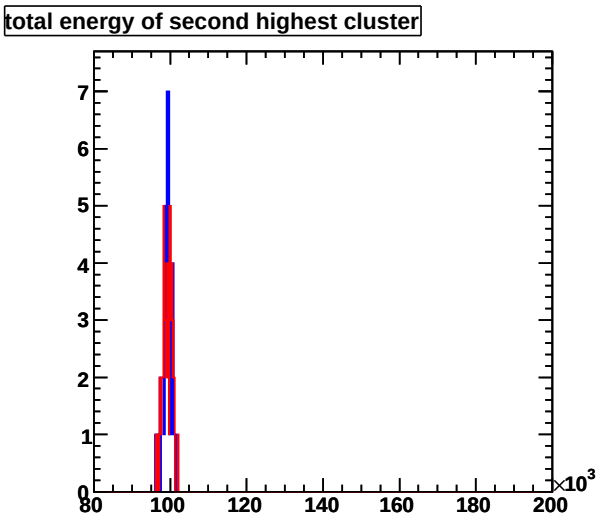
- **topological clustering:** EMTopoCluster, CaloCalTopoCluster
  - → https://twiki.cern.ch/twiki/bin/view /Atlas /Topol ogical Cluste ring
  - → group cells in clusters based on their neighbor relations and on the significance of their energy contents
  - → sampling variables in ESD
  - → cluster moments in ESD

Cluster Reconstruction: Plots









- CombinedClusters
- full simulation
- fast simulation

→ looks good!

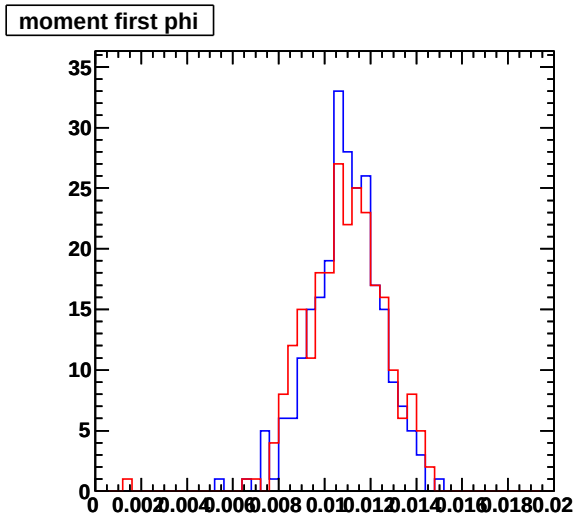
→ maybe some bias in total energy!

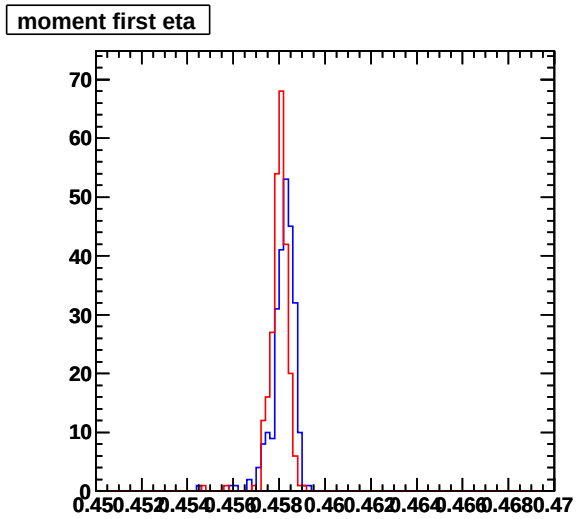
Cluster Moments

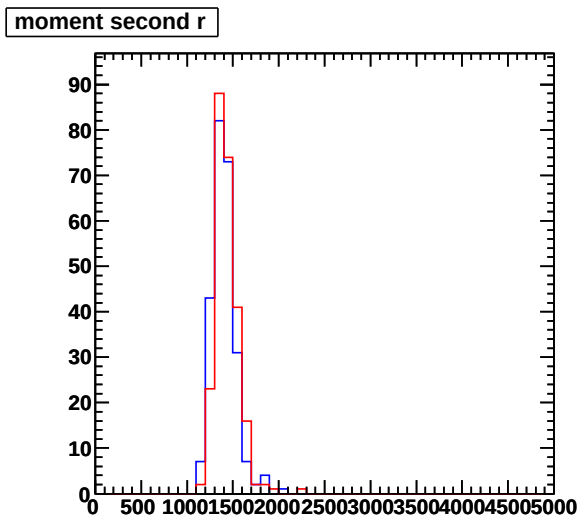
Default list of cluster moments are stored on ESD level for combined topo clusters (threshold 420) and EM topo cluster (threshold 630):

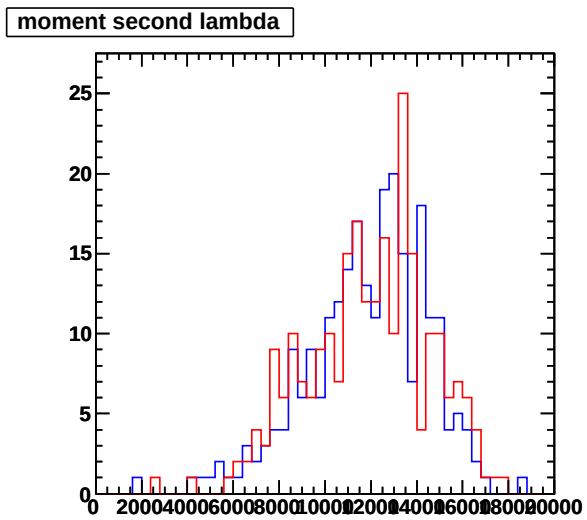
- → https://twiki.cern.ch/twiki/bin/view/At las/Cl usterM oments
- → η, ϕ
- → ρ: energy density
- → cluster axis is calculated from the energy weighted spacial correlation
- → angular cluster deviation from IP-to-Center (ϕ, θ, α)
- → r: radius to shower axis
- → λ: distance from cluster center along cluster axis
- → λ_{center}: distance from front face to cluster center along cluster axis
- → first moment in ϕ, η, ρ, x, y, z
- → second moment in r, λ, ρ
- → normalised second lateral and longitudinal moment
- → energy fraction in EM calo, most energetic cell

Cluster Moments Plots I







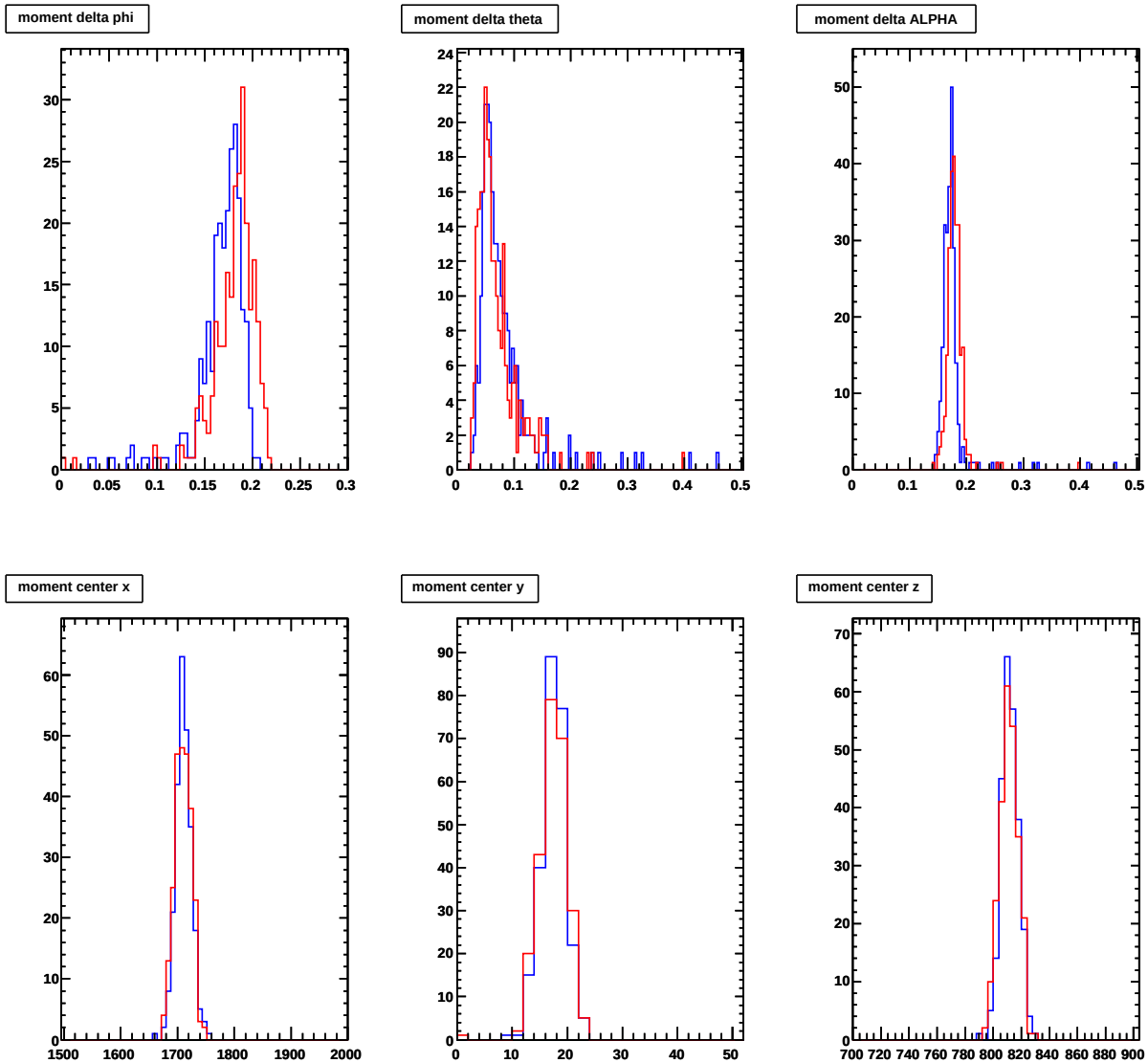


- EMTopoClusters
- full simulation
- fast simulation

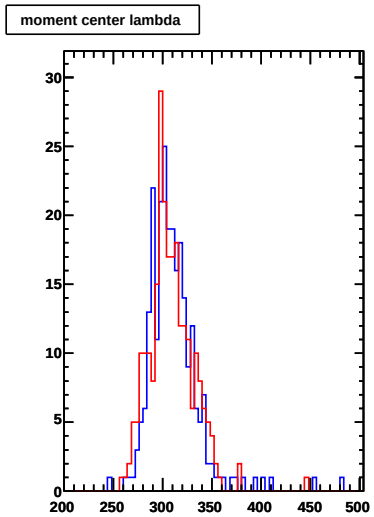
→ looks okay!

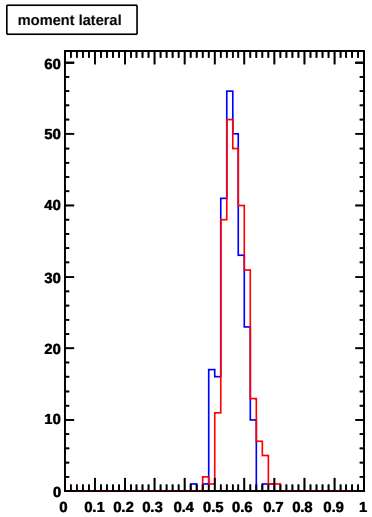
→ some differences visible

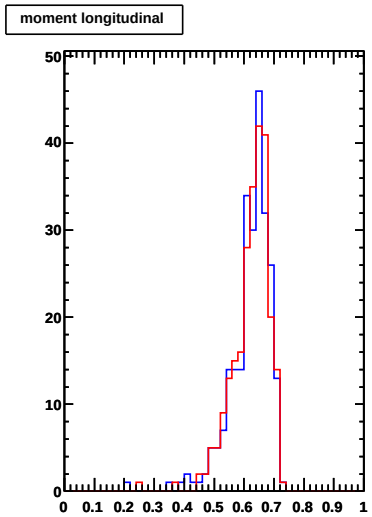
Cluster Moments Plots II

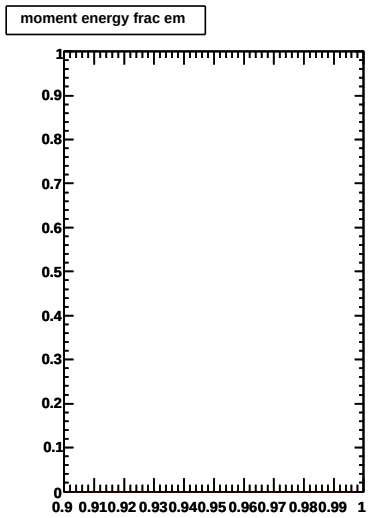


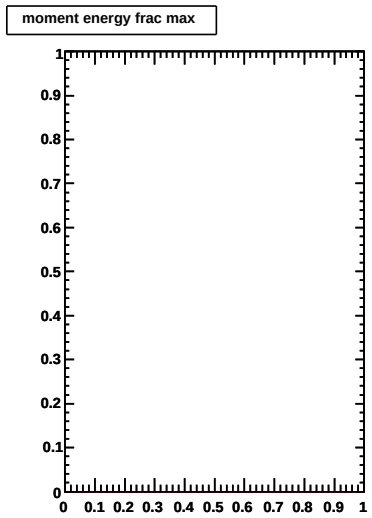
Cluster Moments Plots III

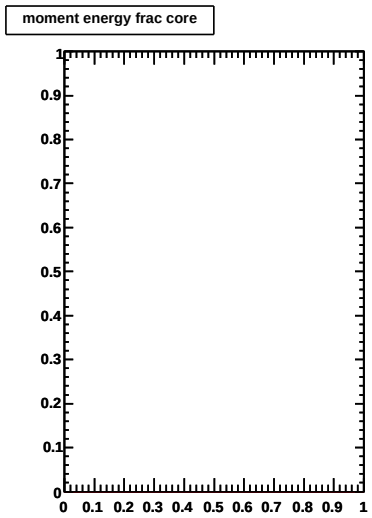




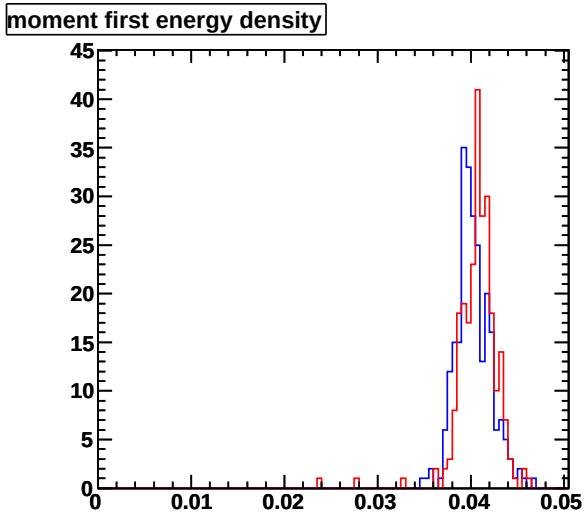


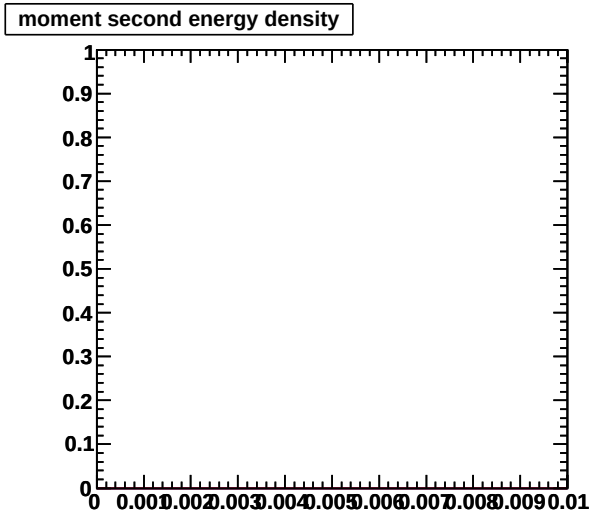






Cluster Moments Plots IV





- CombinedClusters
- full simulation
- fast simulation

→ bias in energy!

→ 2^{nd} moment not available in ESD!

Summary

- **real work is going on!**
  - → found bug in energy deposition
- **know how to run athena framework at CERN:**
  - → simulation, digitization, ESD/AOD, histograms
  - → access to cluster moments
  - → work on sampling variables
  - → work on scanning (energy, η, ϕ, particles)
- **concentrate on reconstruction level! What is used at later stage?**
  - → e/γ or e ID
  - → e/π or π^0/γ seperation
- **define contribution besides validation**
  - → optimisation of parametrisation decision
  - → ...