EMC in Fast Simulation

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Caltech
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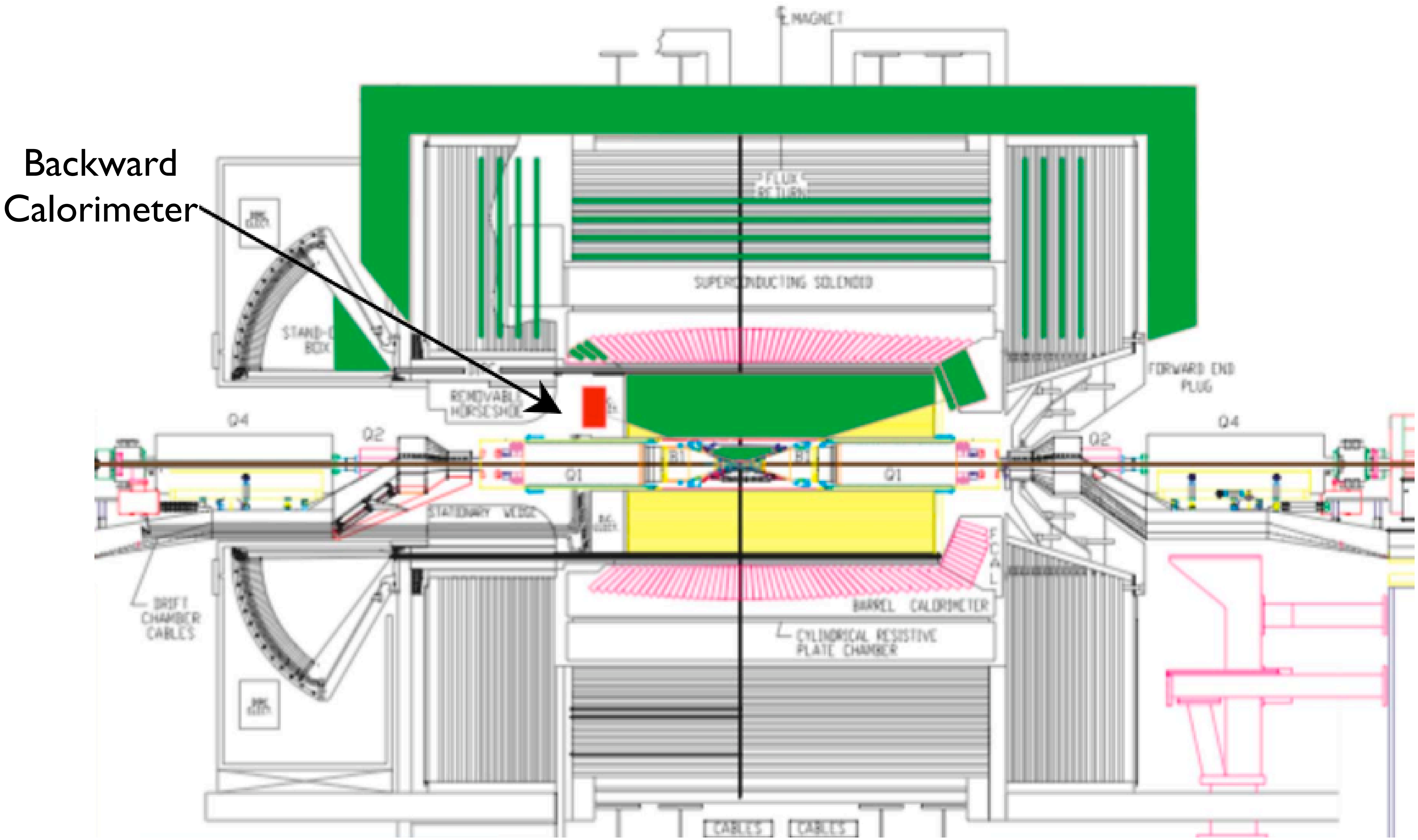
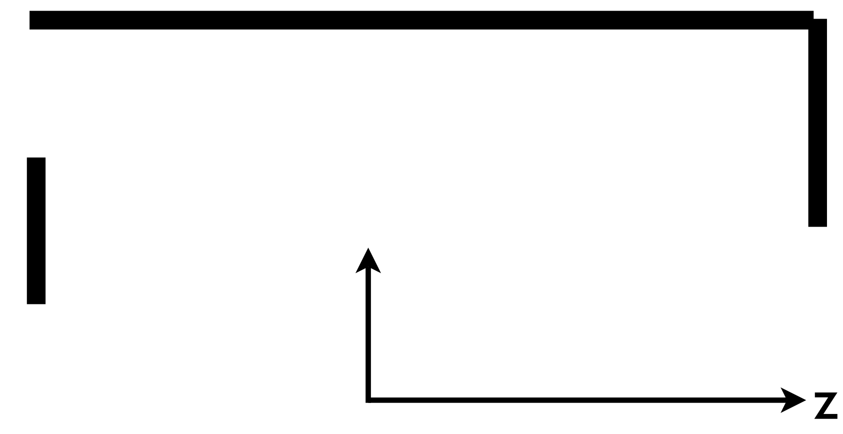
SuperB Computing workshop, Frascati, Italy

SuperB baseline design



Geometry in the fastsim

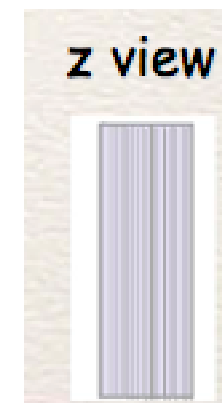
- Barrel: cylinder. Endcaps: disks
- 2D representation, with thickness used to calculate interaction probability and energy loss.
  - If real detector elements are not projective, edge effect is not modeled.
- Uniform $\Delta\varphi$; uniform $\Delta\theta$ in endcaps; uniform $r\Delta\theta$ in barrel (or equivalently, uniform in pseudo-rapidity $\eta=-\ln(\tan(\theta/2))$).



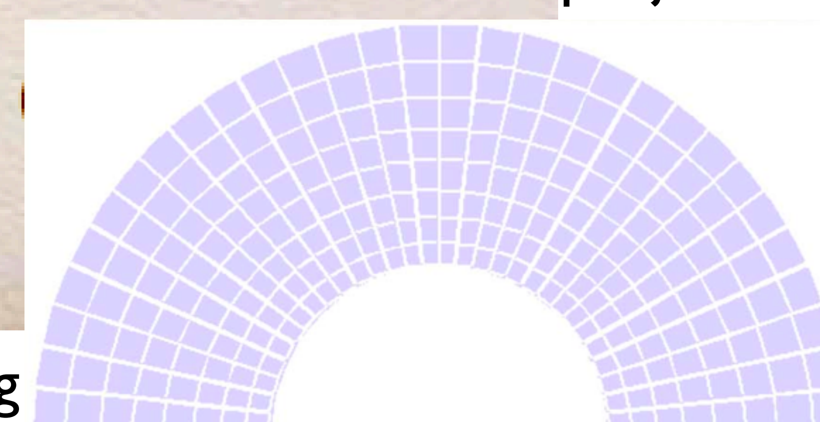
Proposed backward calorimeter

- Behind DCH I propose to place Pb-scintillator <u>sampling calorimeter</u>
  - 2.8 mm thick Pb plates ➔ 1/2 X_0
  - 3.0 mm thick scintillator tiles
  - Sizes vary from 3.8 cm × 3.8cm → 7.8 cm × 7.8 cm (R_M ~6.0 cm)
  - cylindrical geometry, r_i=0.31 m, r_a=0.75 m   Pb: R_M=1.5 cm
    ➔ coverage~ 300mr
  - 24 planes with thickness of $12X_0$
  - scintillator is segmented into tiles, size increasing outwards
    ➔ total: 11,520 channels
  - Scintillator tiles are read out with WLS fibers
    coupled to a SIPM

G. Eigen, SuperB meeting Elba, 31/05/2008



Not projective



Gerald Eigen

8 ring, 60 tiles/ring

EMC clusters

- An EMC cluster is represented by the class `PacEmcCluster` (inherit from `AbsRecoCalo`), which contains a list of `PacEmcDigi`. The latter represents the energy deposition in a single crystal.
- Both classes mimic the respective classes in BaBar, but no calibration, timing, and data flow information is represented.

Shower library abandoned

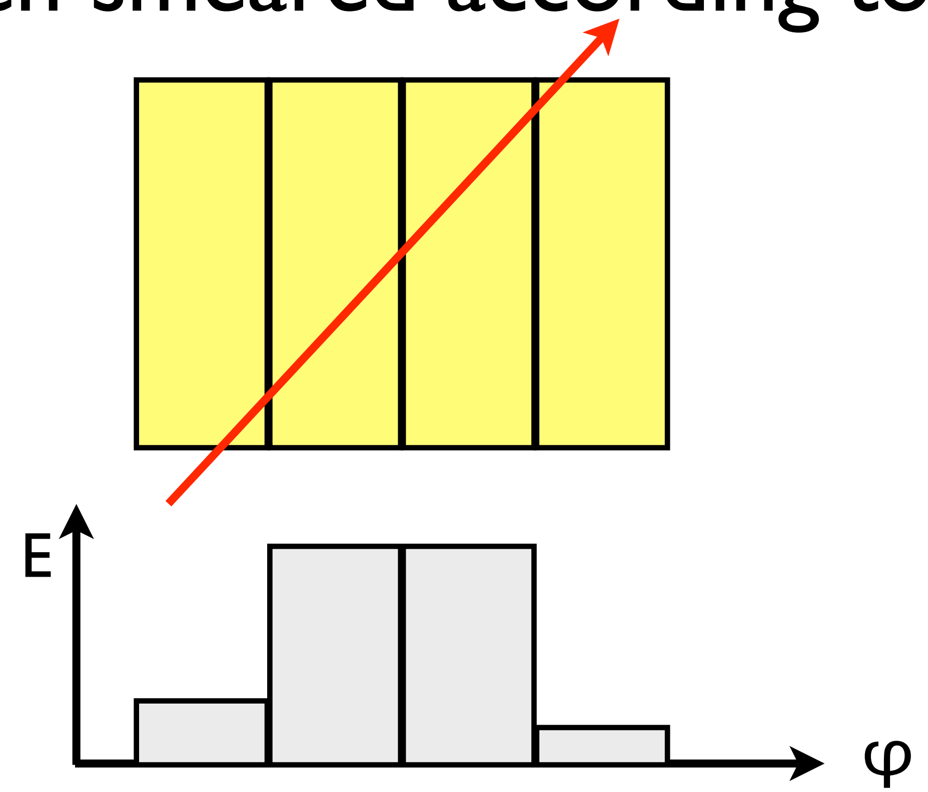
- At Elba we proposed using a shower library generated from full simulation, from which we sample an appropriate cluster to simulate detector response, in order to faithfully reproduce the correlation between crystals, especially for hadron shower.
- We later realized that the shower library is not easy to implement. A complete implementation requires large space, non-trivial look-up scheme, and running full simulation each time when geometry or material is changed.
- We have basically abandoned the shower library idea, and try to also parametrize hadronic shower. (see later).

Ionization

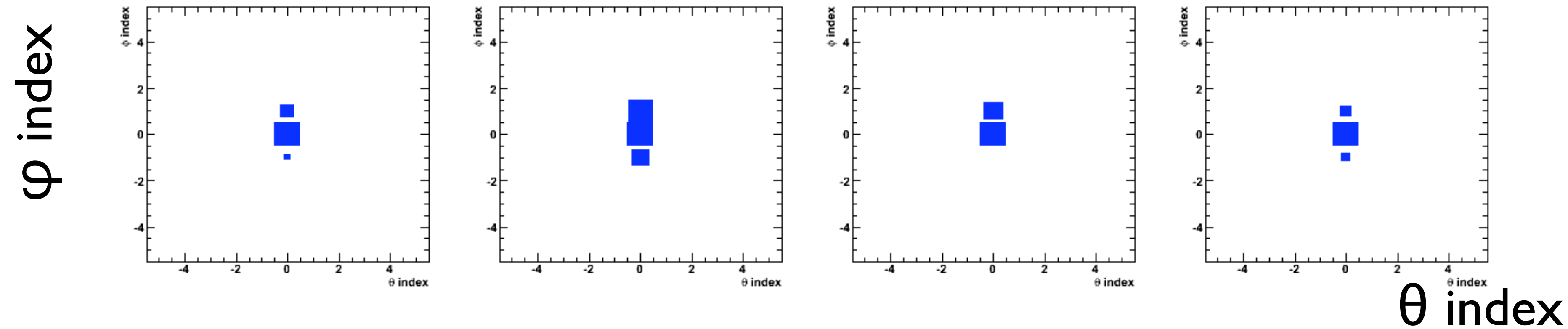
- If a particle does not shower in the EMC (effects: `normal`, `stop`, `interact`, `brems`, `compton`, `convert`), we simply distribute the energy loss to the crystals it passes through. Energy is proportional to the path length in each crystal.
- Curving inside the EMC is ignored.
- Energy in each crystal is then smeared according to

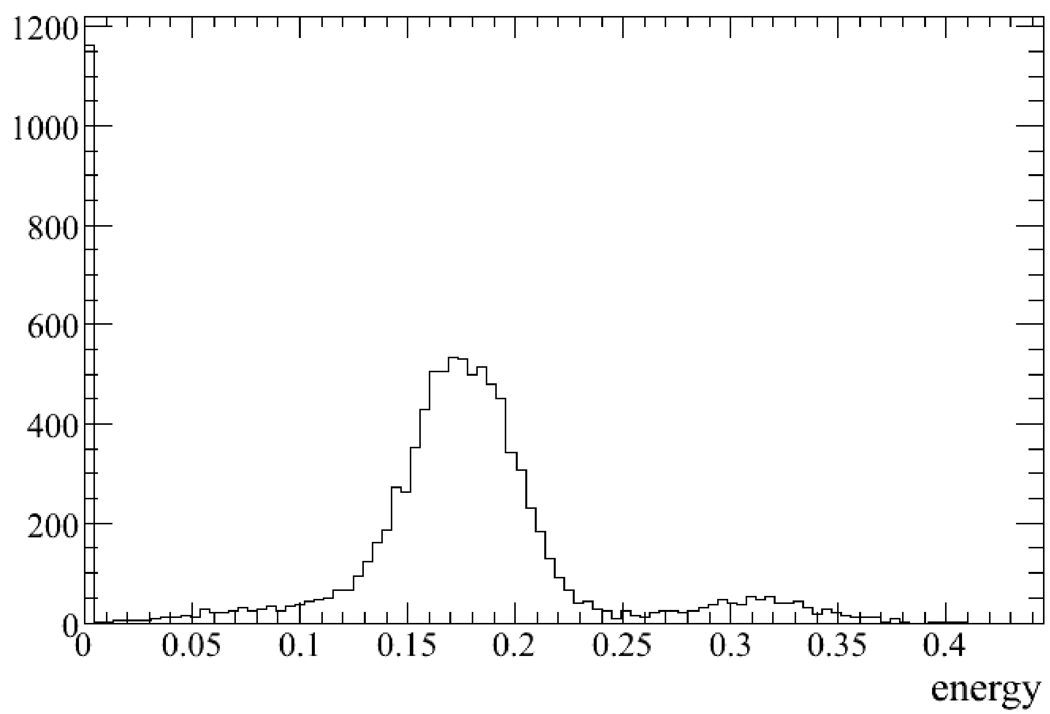
$$\frac{\sigma_E}{E} = \frac{a}{E^d} \oplus b$$

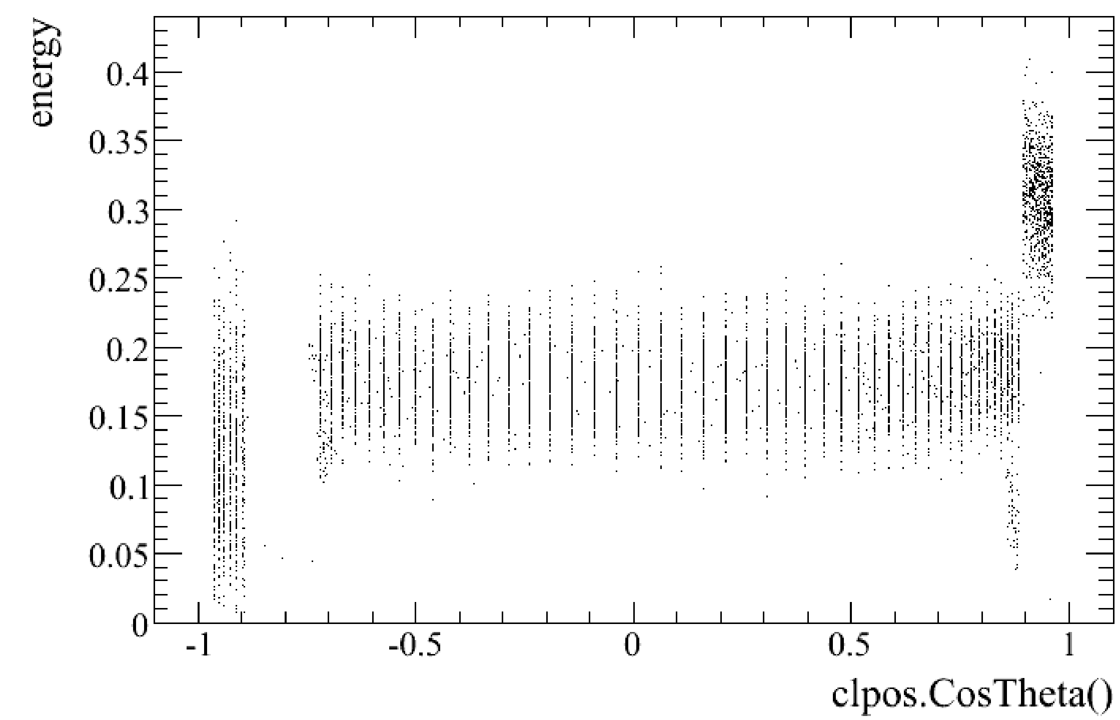
a, b, d are configuration parameters



One-GeV/c muons







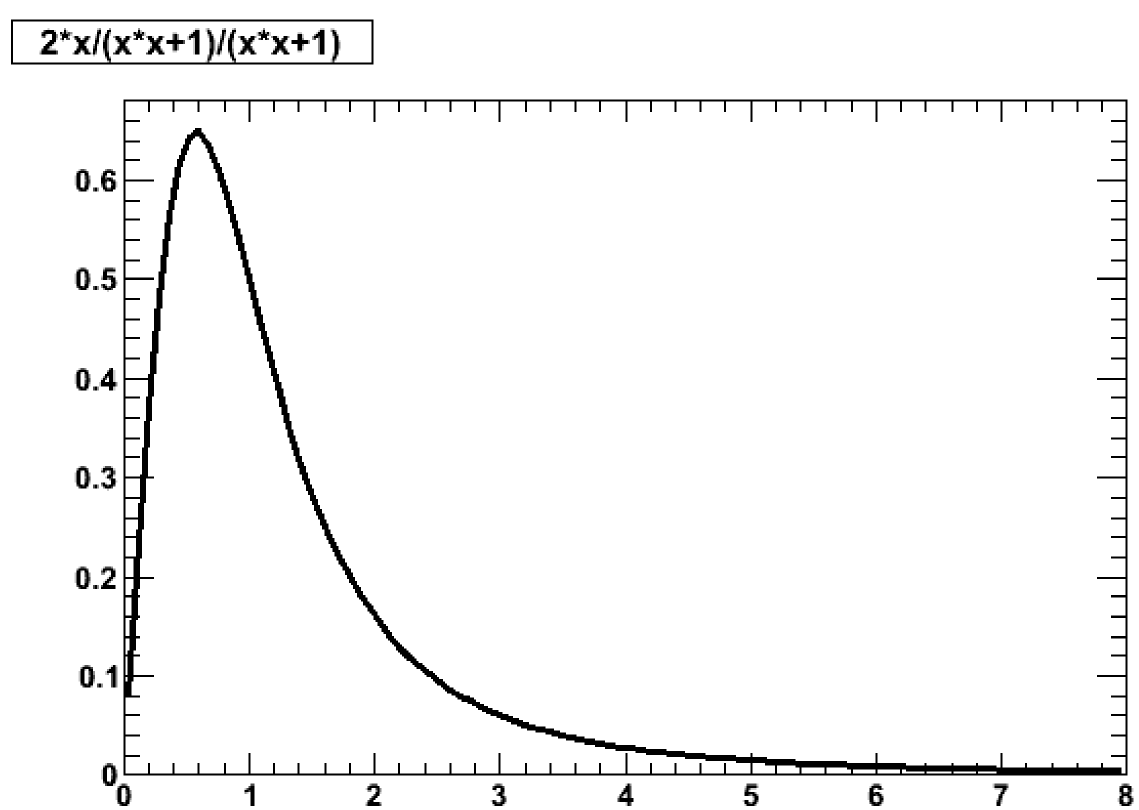
- Forward: 30cm LSO: $26X_0$; Barrel: 30cm CsI: $16X_0$: Backward: 14cm Pb+scintillator: $12X_0$.

EM shower

- The lateral shower development is assumed to be symmetric
- On average 10% of the deposited energy lies outside R_M, and about 1% outside 3.5 R_M.
- The radial distribution can be modeled phenomenologically with

$$f(r) = \frac{2rR^2}{(r^2+R^2)^2}$$

[PDG2008 Sec. 27.5, or NIM A290, 469]

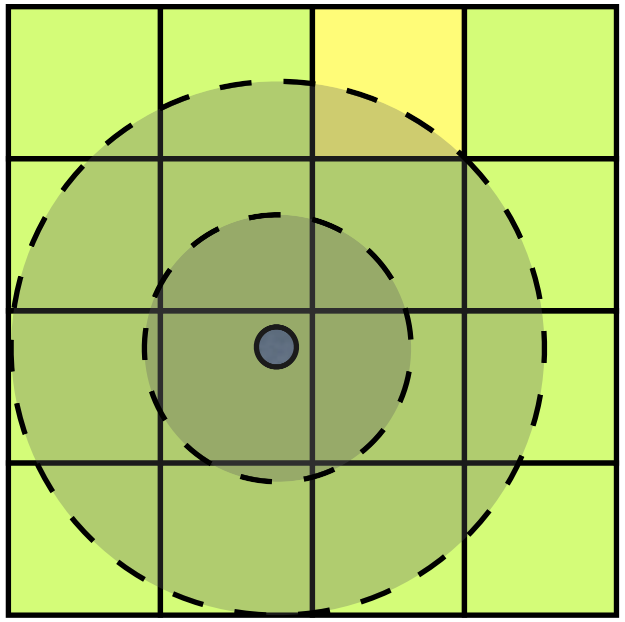


$$\int_r^\infty f(r')dr' = \frac{R^2}{r^2+R^2}$$

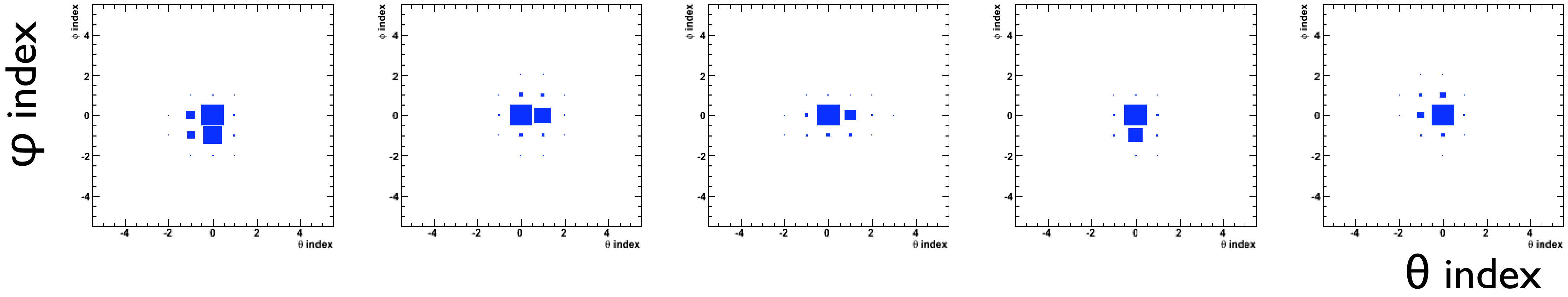
$R_M = 3R$

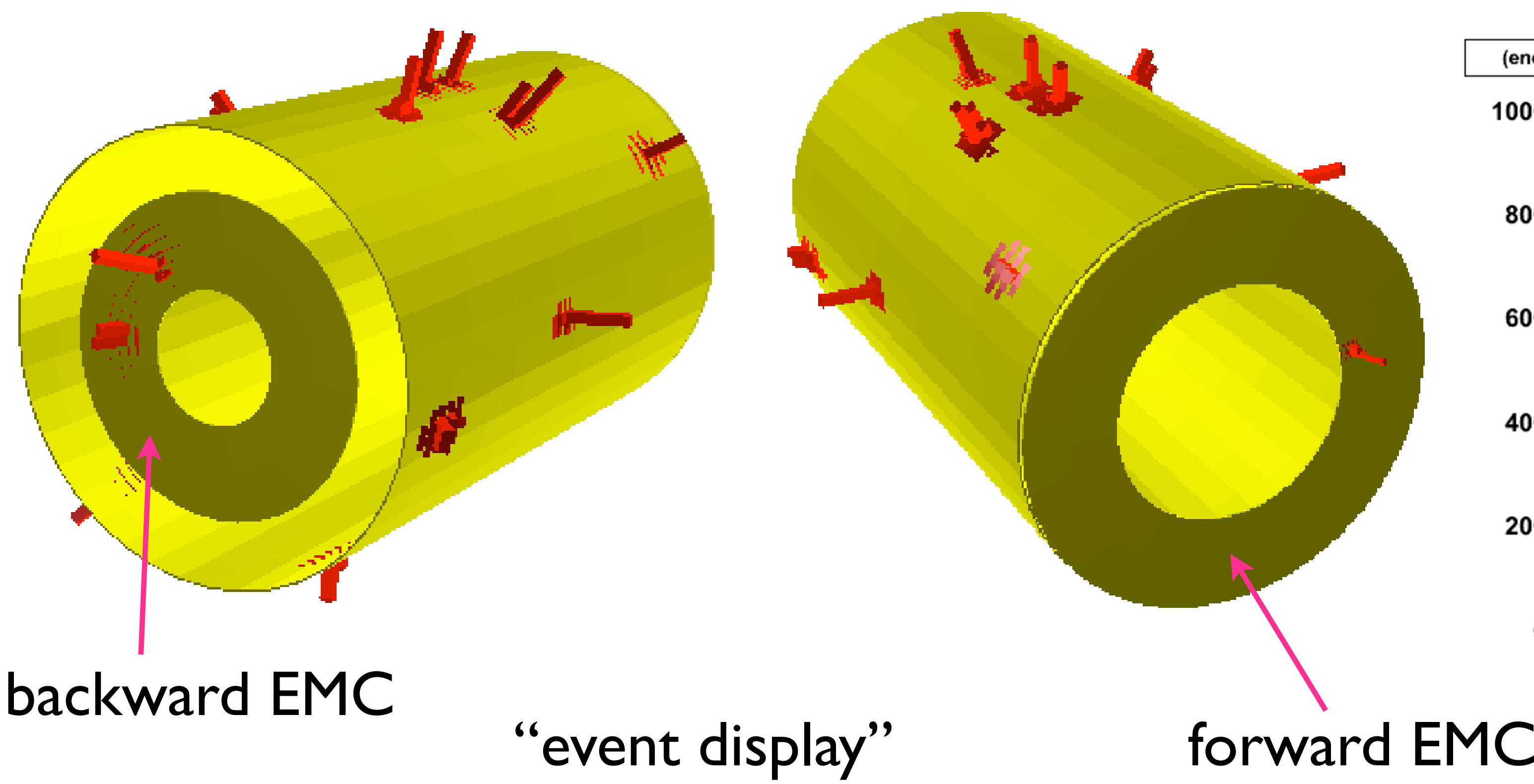
EM shower (II)

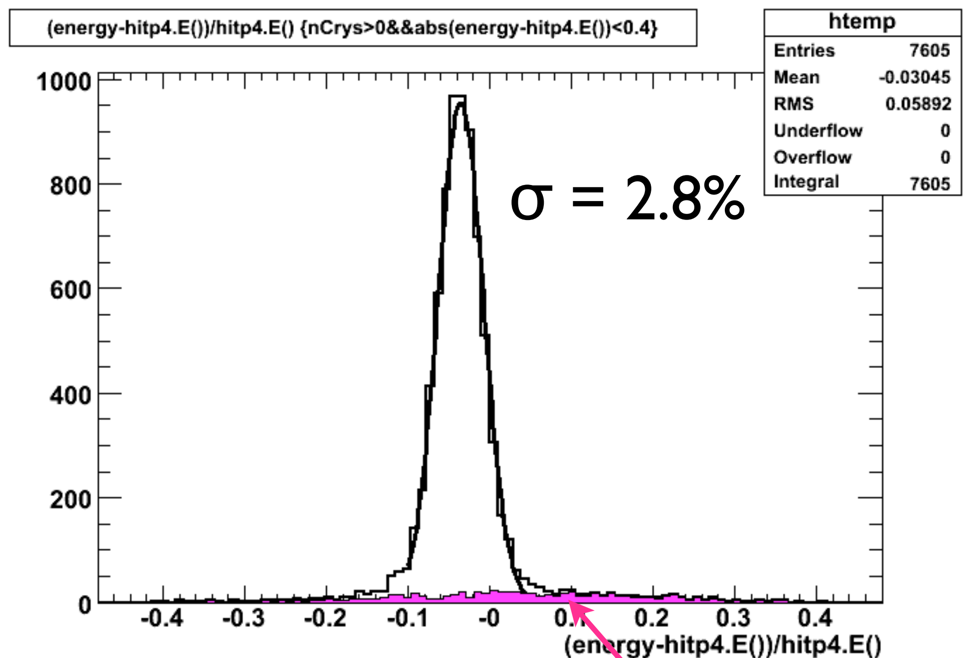
- Probability and energy loss of a shower are determined by radiation length and path length.
- Starting with the crystal where a particle hits, calculate the integral of f(r) (numerically) on nearby crystals.
- Energy loss is distributed over crystals according to the integral.
- R_M is allowed to fluctuate, so do energy in each crystal and eccentricity (axes along θ/φ, no rotation).



One-GeV photons

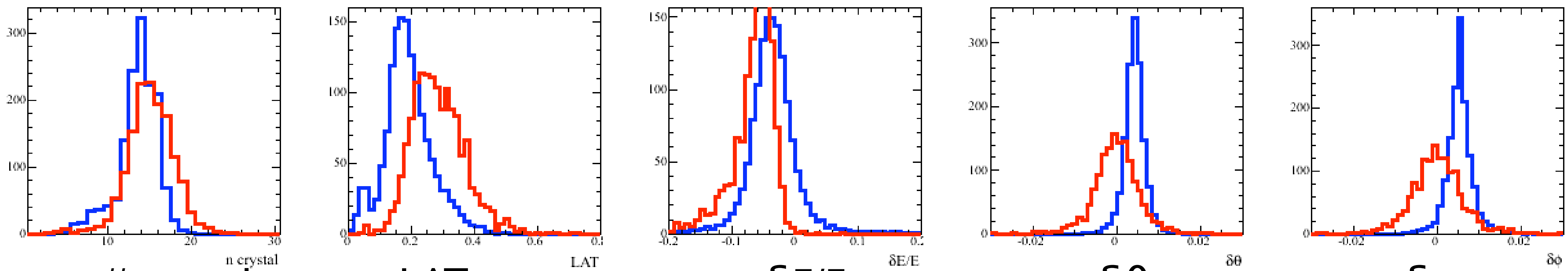






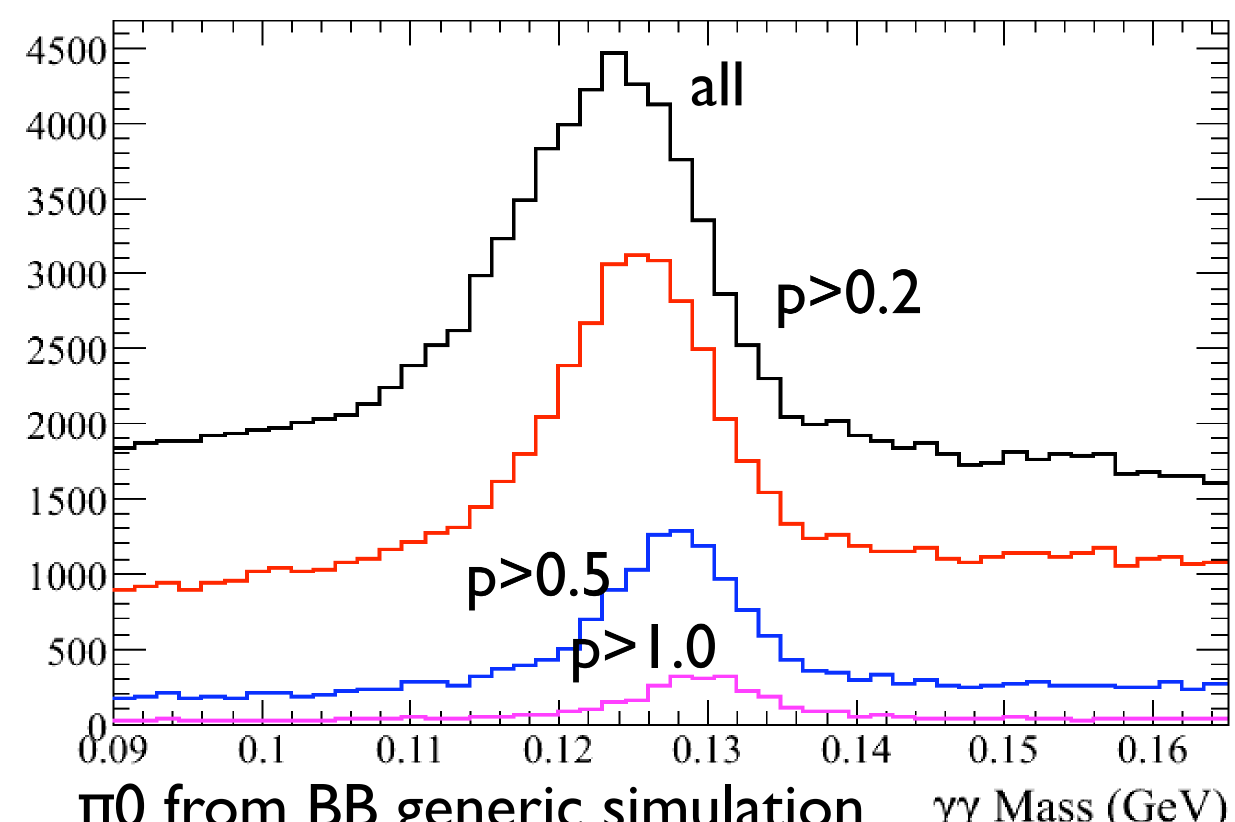
Performance

- One-GeV photons: Blue= FastSim; Red= BaBar full Sim



\# crystal LAT moment δE/E δθ δφ

- Angles are biased.
- Energy is not calibrated; large bias in pi0 mass.
- pi0 resolution is better than the full simulation.



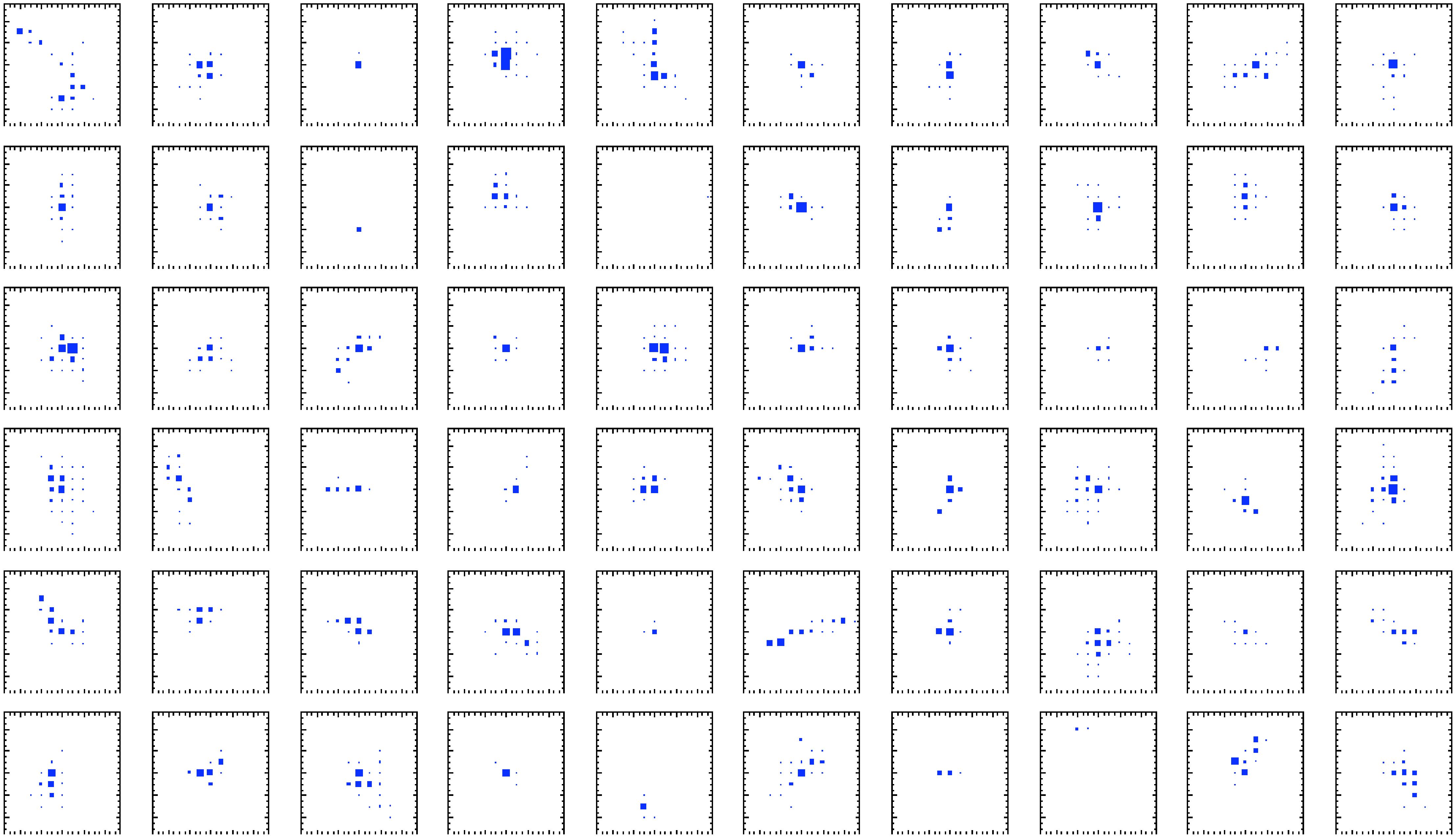
π0 from BB generic simulation

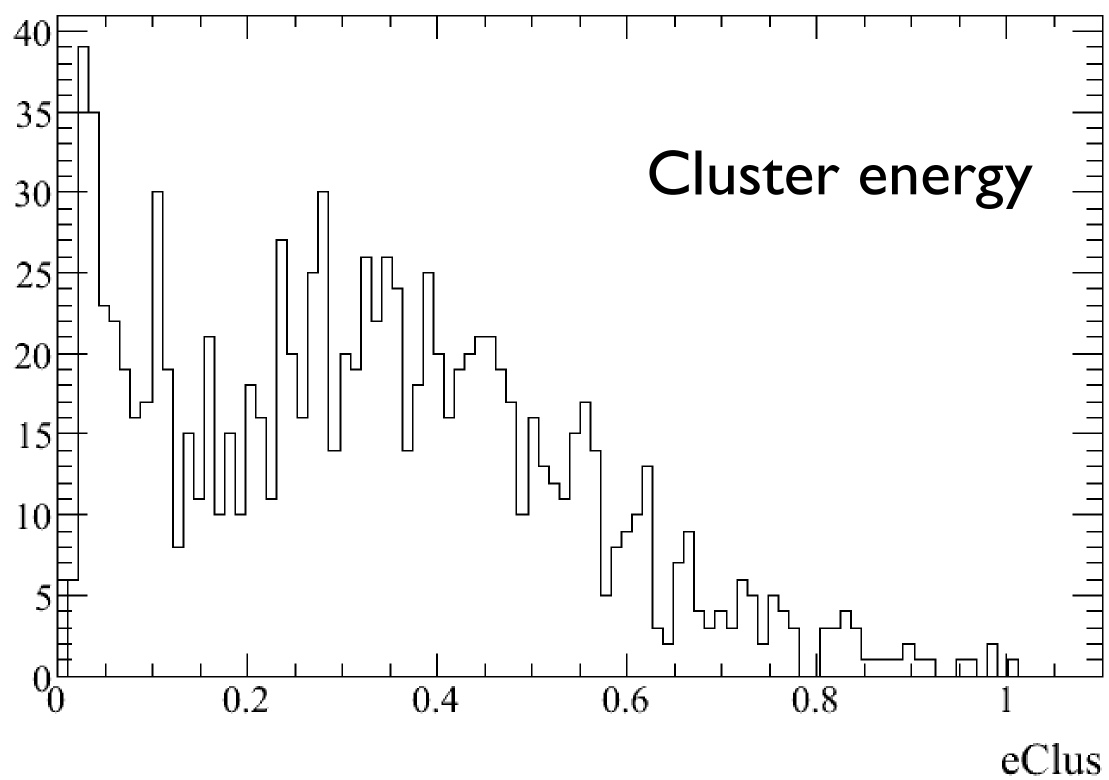
Hadronic shower

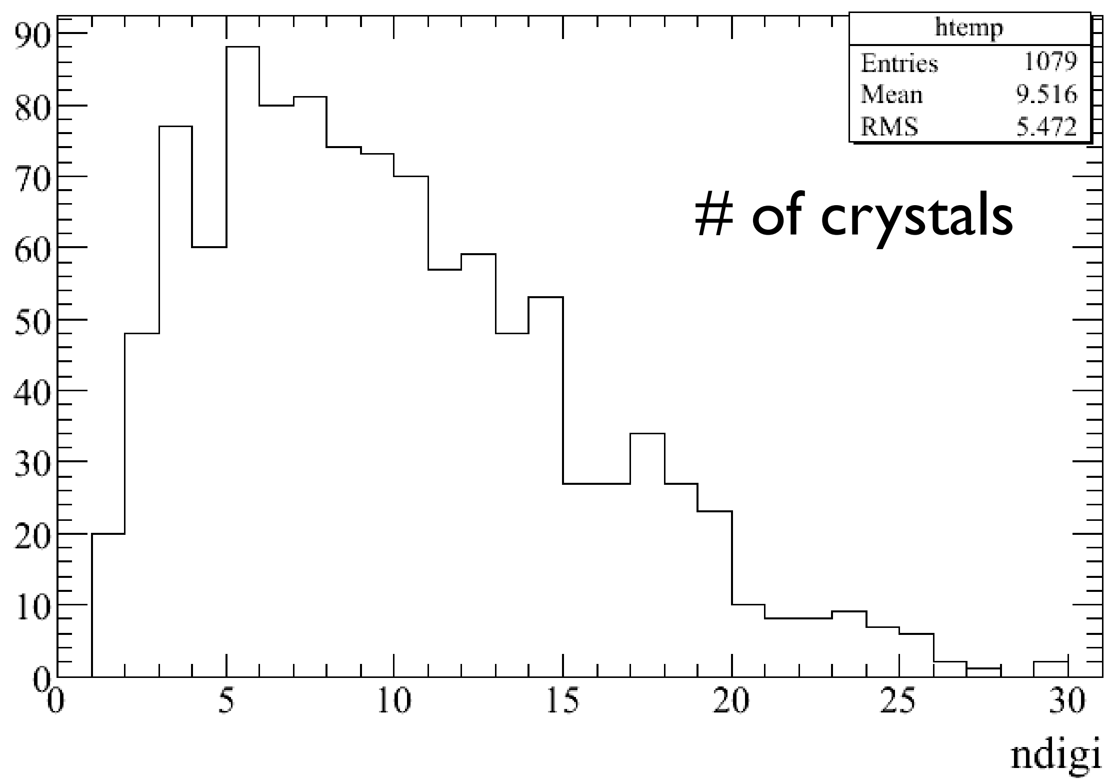
- Hadronic showers are irregular and difficult to model with a simple parametrization.
- New idea: use random walk to navigate through crystals and create large fluctuation to create irregular patterns.

What hadronic showers look like

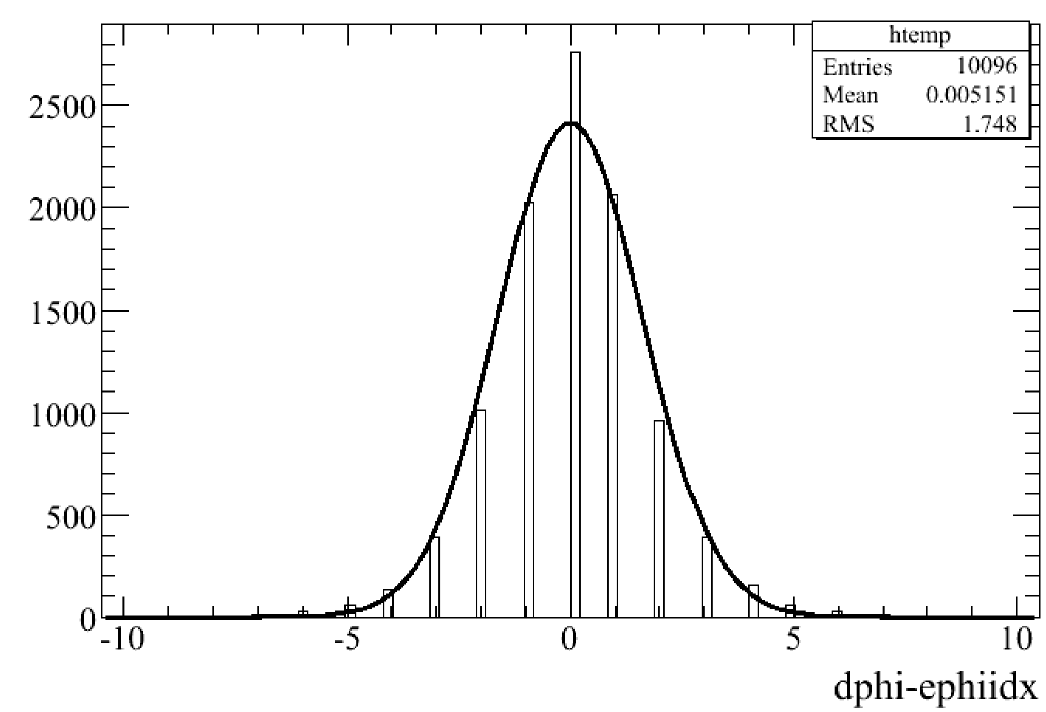
- Samples of 1GeV/c KL shower shapes from Babar full simulation (only about 1/2 of all KL leave a cluster in Babar EMC)







- Energy distributed in a wide range.
- Average shower shape is very close to a Gaussian.



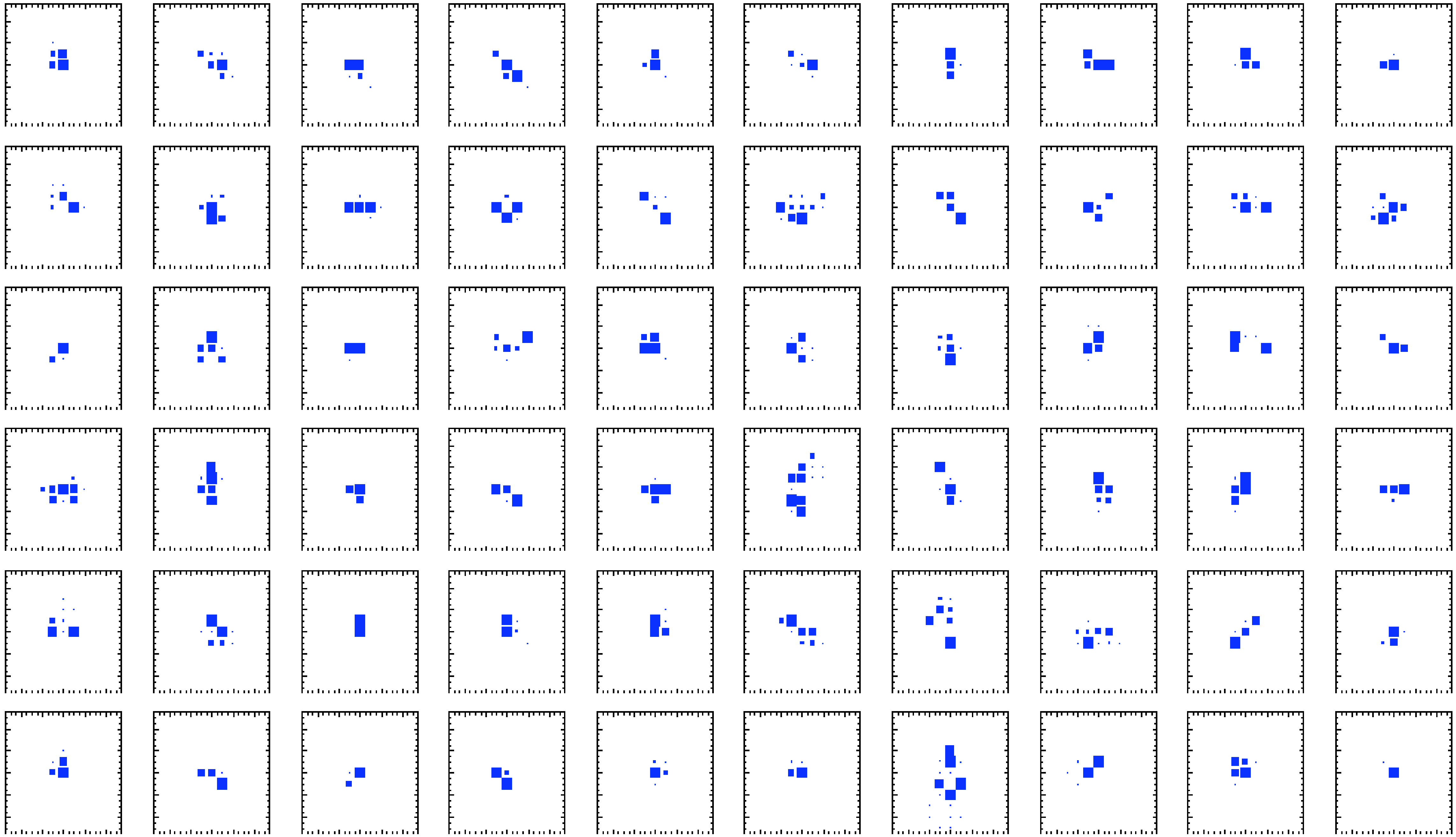
Hadronic shower modeling procedure

1. Determine the total deposited energy E from longitudinal shower profile plus smearing.
2. Start from the crystal (i,j) where a hadron enters.
3. Determine the average energy Eij in that crystal (a fraction of E) based on an integral of a 2D Gaussian.
4. Fluctuate Eij using a Poisson with a large quanta.
   - Eij = TRandom::Poisson(Eij/quanta) * quanta
   - and then smear it : Eij = Eij + TRandom::Gaus(0,σ_E)
5. Fill that crystal with Eij, and reduce E by Eij.
6. Random walk to a nearby crystal (i', j') with probabilities proportional to the 2D Gaussian profile.
7. Repeat step 3 until E <= 0 or has walked too far.

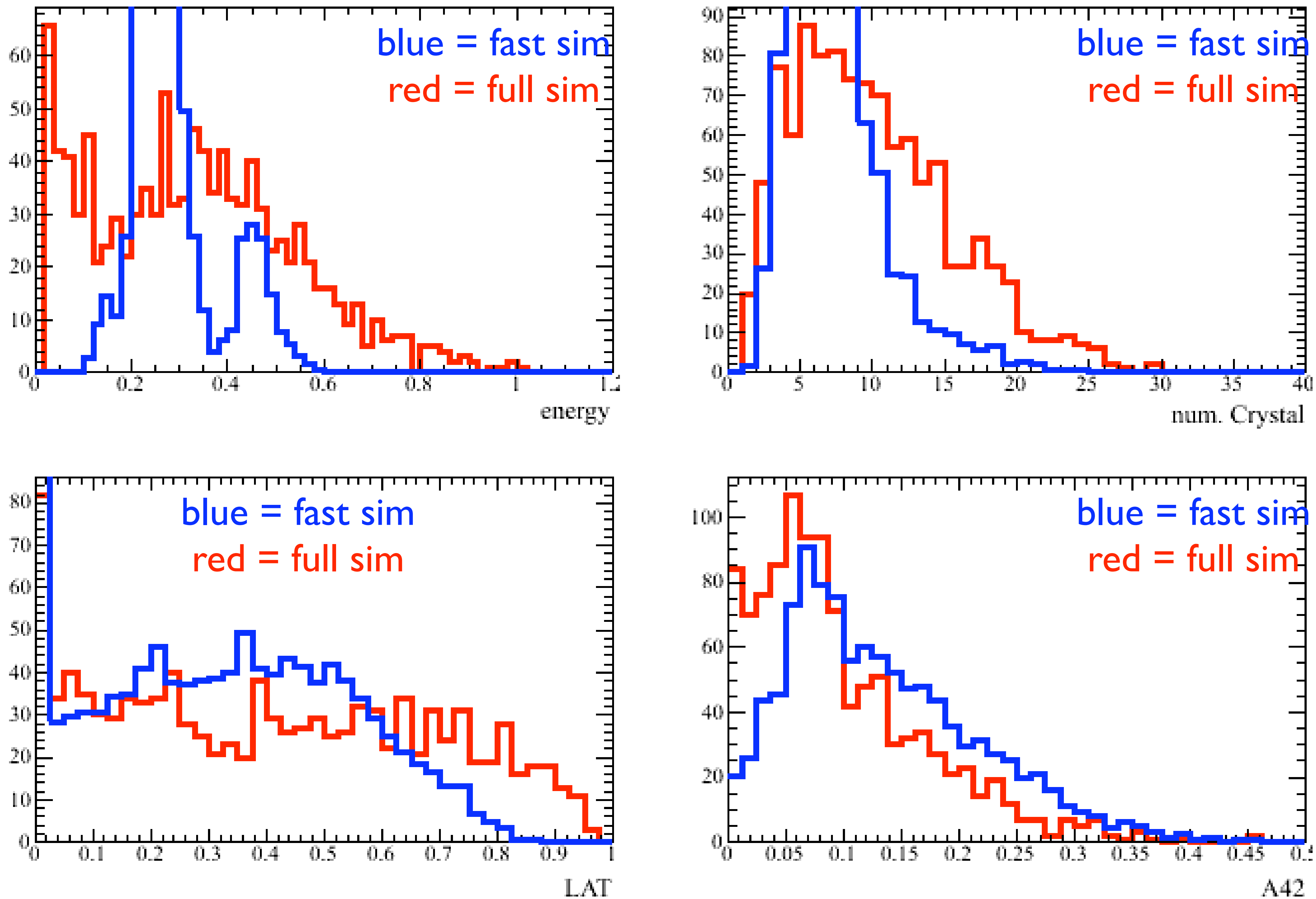
Test with 1 GeV/c K_L^0

- Parameters:
  - Overall profile σ= 7.5 cm
  - Maximum distance: 30 cm
  - Energy "quanta" = 50 MeV
  - Extra fluctuation σ_E = 50 MeV
  - Minimum energy = 1 MeV
- Caveat: currently in fastSim when KL interacts, its energy loss is calculated based on the material's interaction length. Due to the difficulty in modeling the longitudinal profile, we know this energy loss is not yet modeled properly.

Test examples



Compare with full simulation



Conclusions

- EMC is able to simulate MIPs, EM showers and hadronic showers.
- Shower library is abandoned.
- It is possible to generate very irregular shower shape with random walk.
- We haven't spent any time tuning parameters. Performance does not match full simulation well yet.
- Many still need to be done:
  - longitudinal shower profile, track-cluster matching, cluster merging/splitting, validation plots macros, etc...