EMC in Fast Simulation

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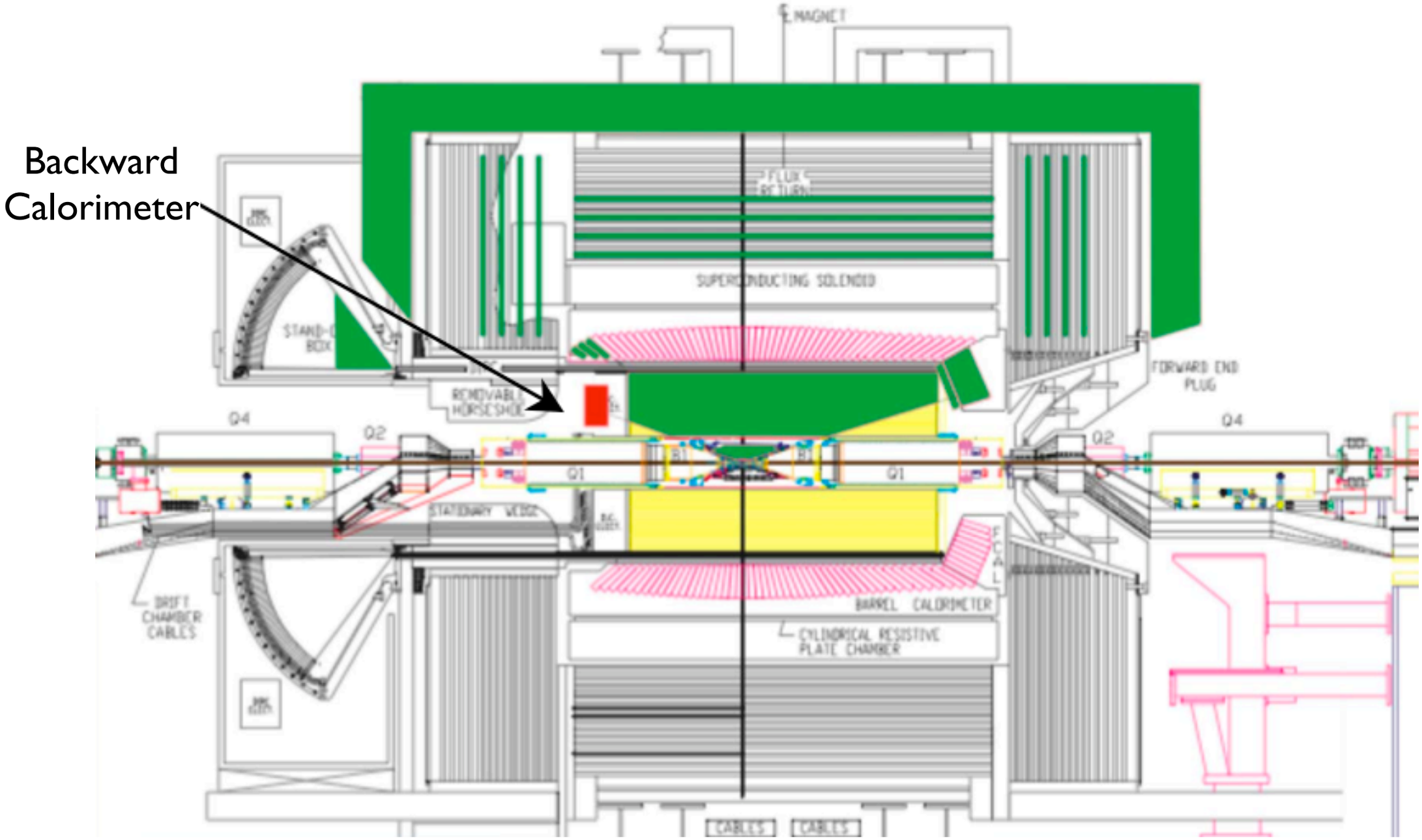
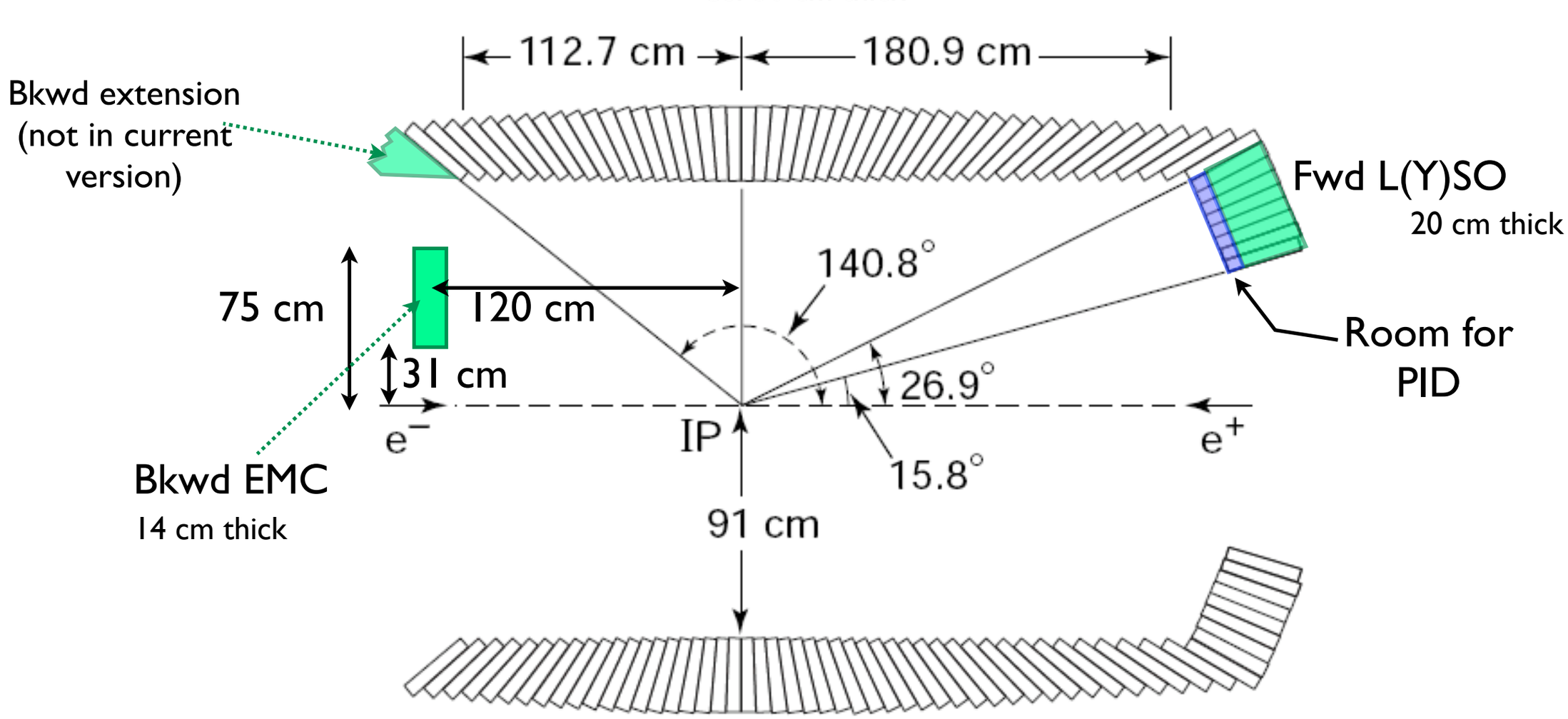
SuperB baseline design

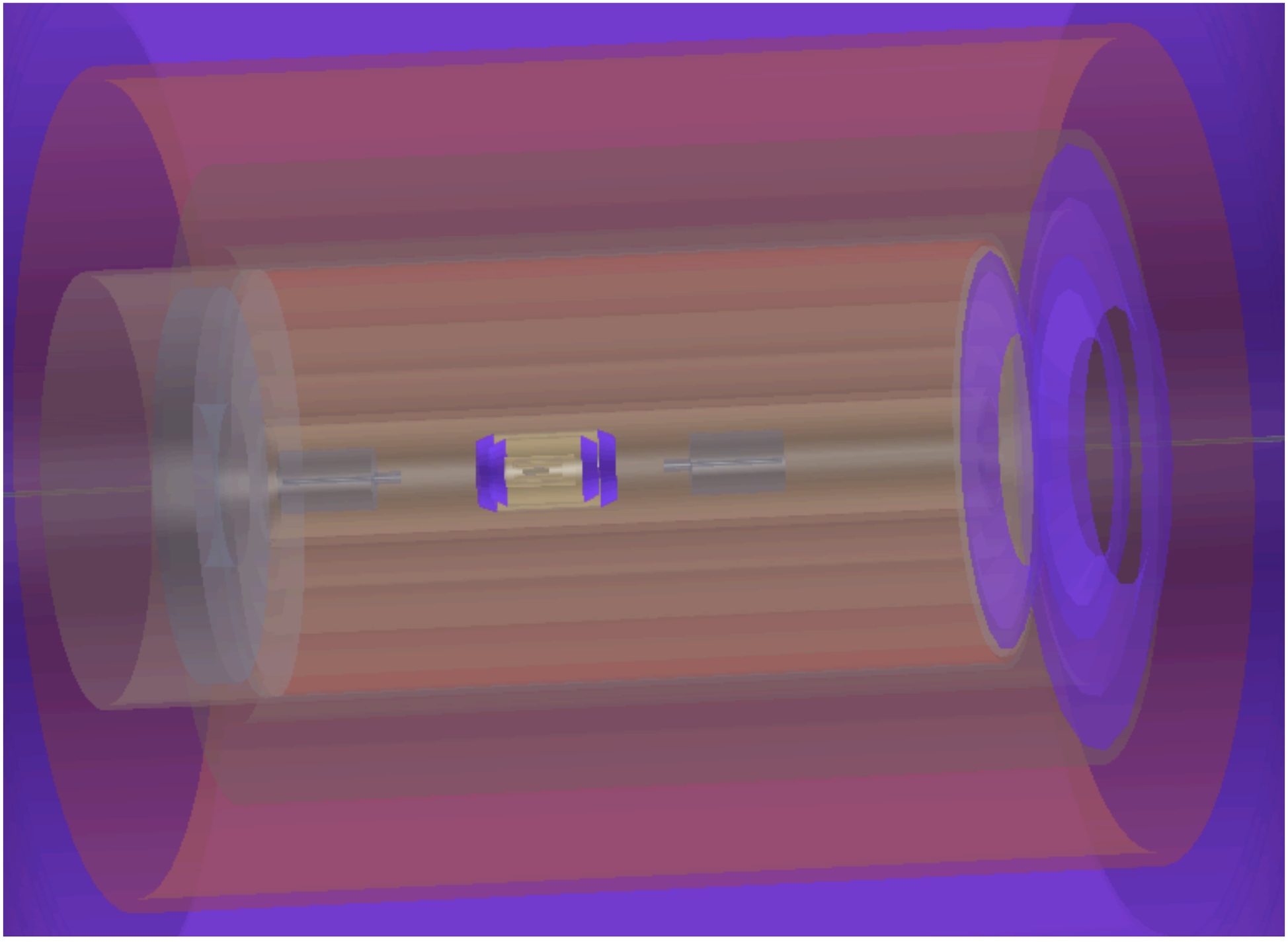


Geometry in the fastsim

- Barrel: cylinder. Fwd endcap: cone. Bkwd endcap: disk.
- 2D representation, with thickness used to calculate interaction probability and energy loss.
- Uniform $\Delta\varphi$; uniform $\Delta\theta$ in endcaps; uniform $r\Delta\theta$ in barrel.



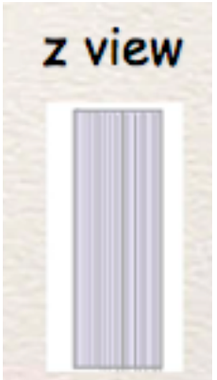
Display



Proposed backward calorimeter

- Behind DCH I propose to place Pb-scintillator sampling calorimeter
  - 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
    ➔ 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

Pb: R_M=1.5 cm



Not projective

8 ring, 60 tiles/ring

Gerald Eigen

New materials in MaterialsList.data

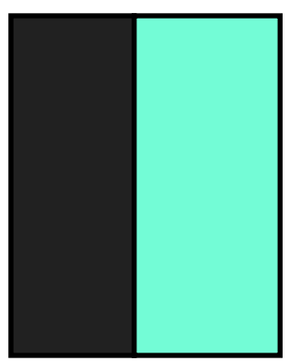
- Forward LSO: Lu_2SiO_5; LYSO: add ~5% Yttrium
  - d= 7.4 g/cm^3; X_0^*= 1.14 cm; λ_I^*= 21 cm. (R_M= 2.07 cm)
- Backward Pb-scintillator plates: (2.8mm Pb + 3.0mm scintillator tiles)x24
  - Treated as a homogeneous material, rather than sampling plates.
  - 2.8mm Pb = 0.5 X_0; 3mm Polystyrene ~ 0.007 X_0.

	Z	A	X0	d	X_0^* (cm)	λ_I^*(cm)	R_M(cm)
Pb	82	207.2	6.37	11.35	0.56	17.6	1.6
Polystyrene	3.5	6.5	43.8	1.06	41.3	77.1	6.8

$$\langle d \rangle = (d_1 L_1 + d_2 L_2)/(L_1 + L_2) = 6.03$$

$$\langle A \rangle = 69.3 \qquad \langle Z \rangle = 28.1$$

$$\langle X_0^* \rangle = \frac{L_1 + L_2}{L_1/X_{0;1}^* + L_2/X_{0;2}^*} = 1.14 \qquad \langle X_0 \rangle = 6.87$$



New materials continued

- Moliere radius: Since the scintillator only contributes to a small amount of radiation length, only Pb contributes to creating shower particles. The spacing between Pb makes the shower profile larger, simply from geometric effect.

$$\langle R_M \rangle \simeq R_M^{\mathrm{Pb}} \frac{L_1 + L_2}{L_1} = 3.3\mathrm{cm}$$

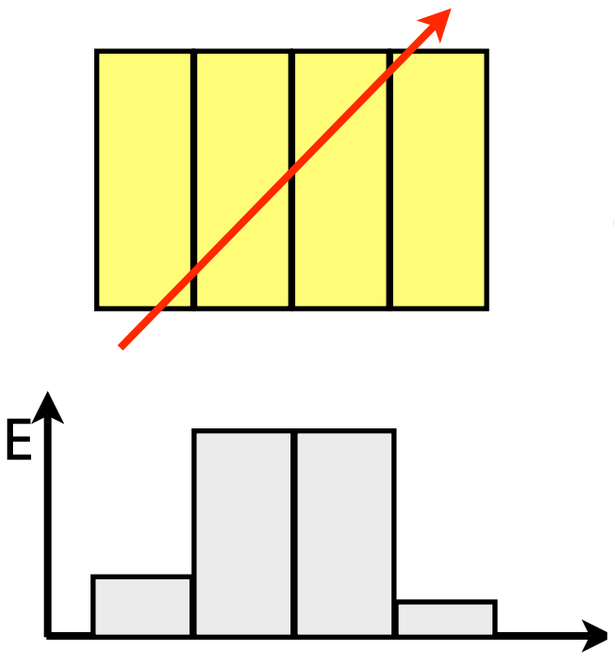
EMC clusters

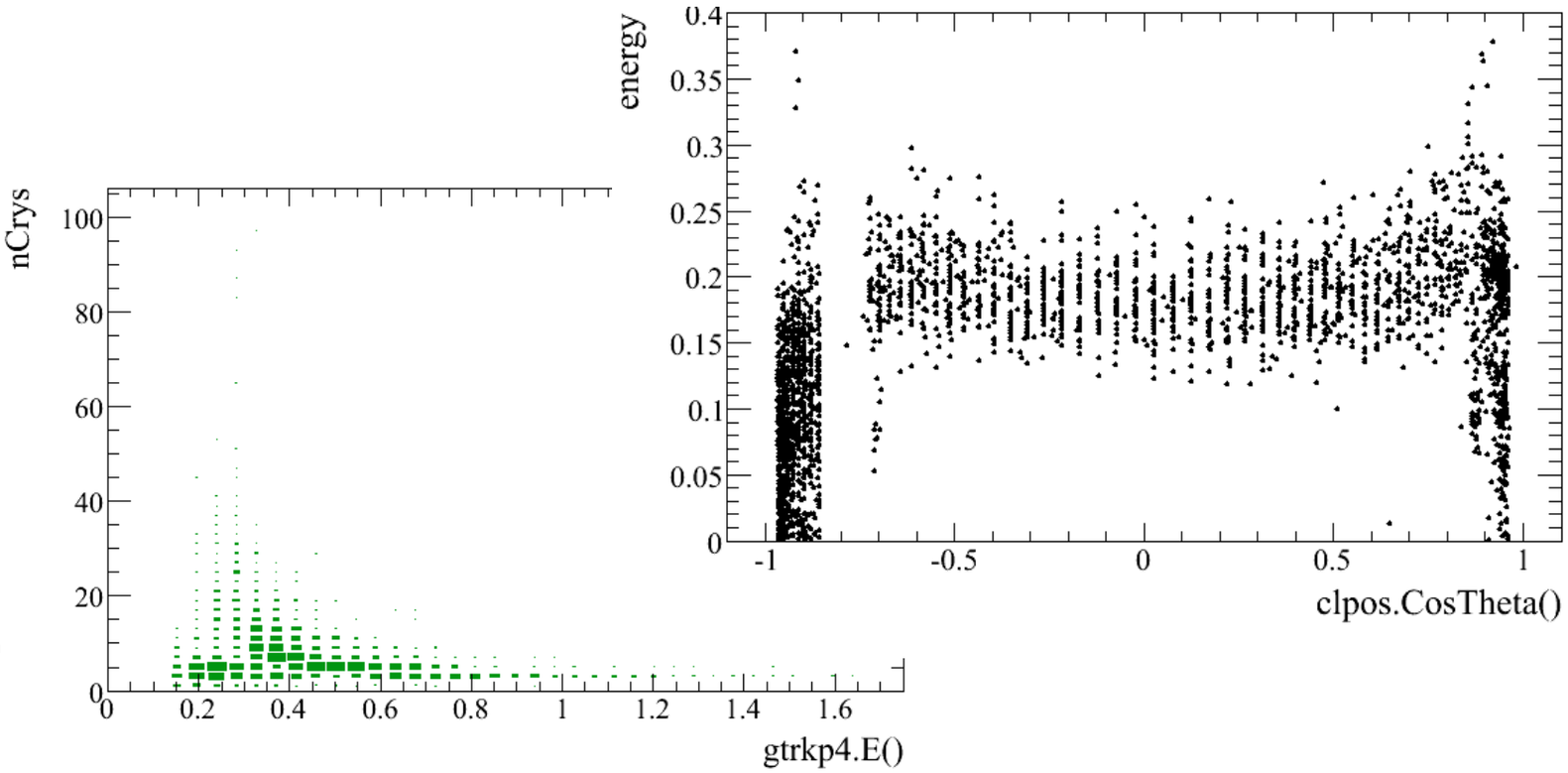
- An EMC cluster is represented by the class `PacEmcCluster` (inherit from `AbsRecoCalo`), which contains a list of `PacEmcDigi`. The latter represents the energy deposition in a single crystal.
- Both classes mimic the respective classes in BaBar, but no calibration, timing, and data flow information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

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





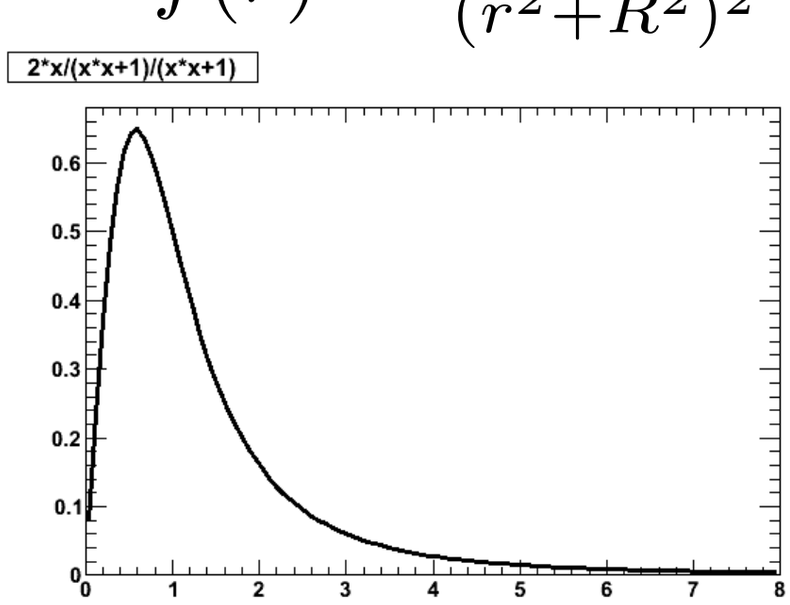
EM shower

- 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

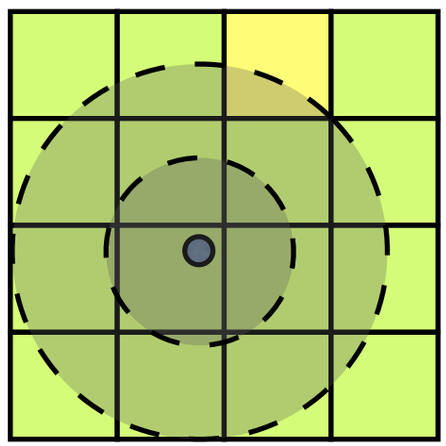
$$f(r) = \frac{2rR^2}{(r^2+R^2)^2}$$

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

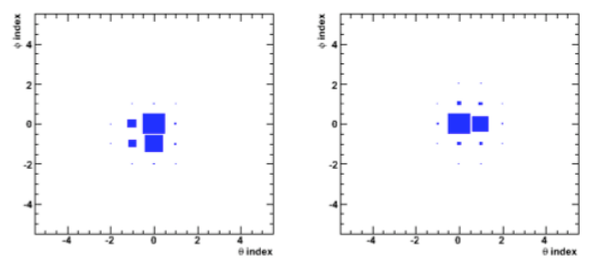
$$\int_r^\infty f(r')dr' = \frac{R^2}{r^2+R^2}$$



$R_M = 3R$

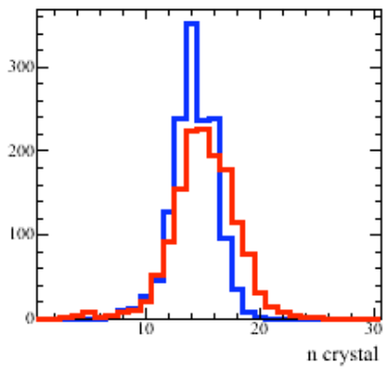


- R_M is allowed to fluctuate, so do energy in each crystal and eccentricity (axes along θ/φ, no rotation).

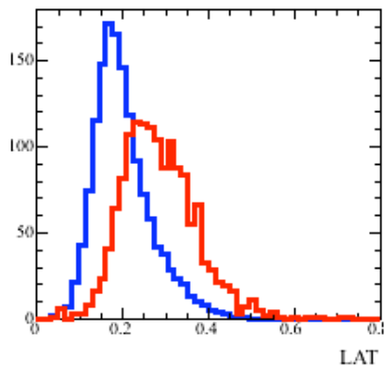


Performance

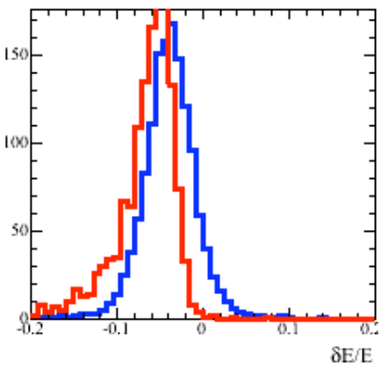
- One-GeV photons: Blue= FastSim (BaBar config); Red= BaBar full Sim



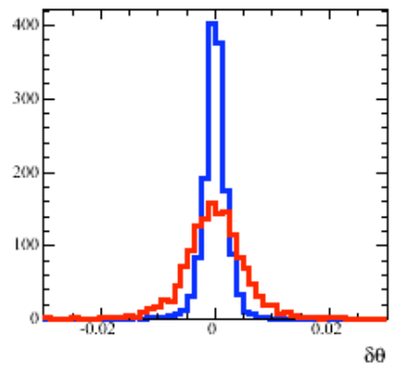
crystal



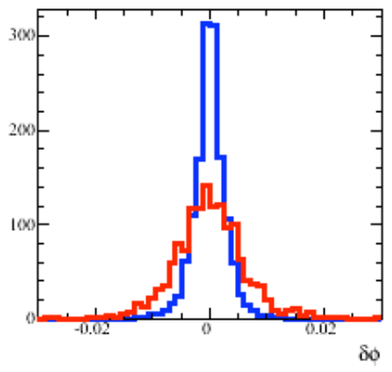
LAT moment



δEraw/Eraw

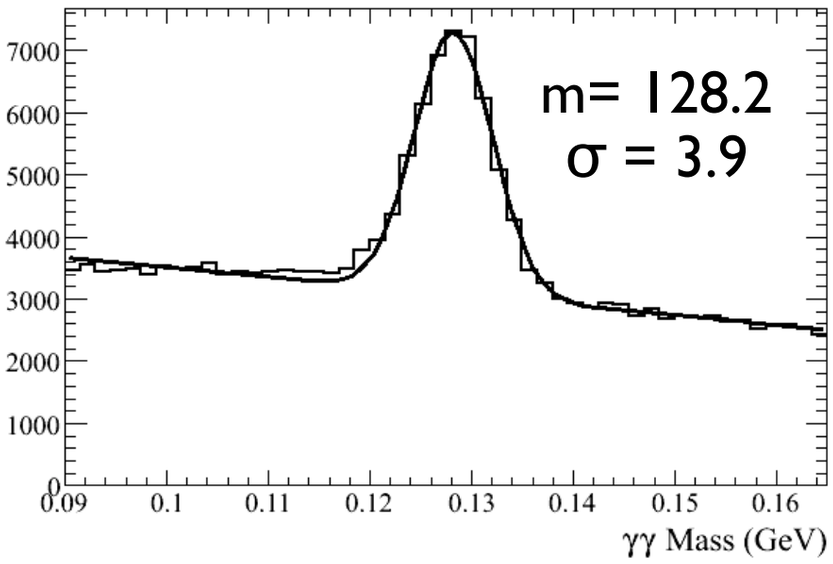


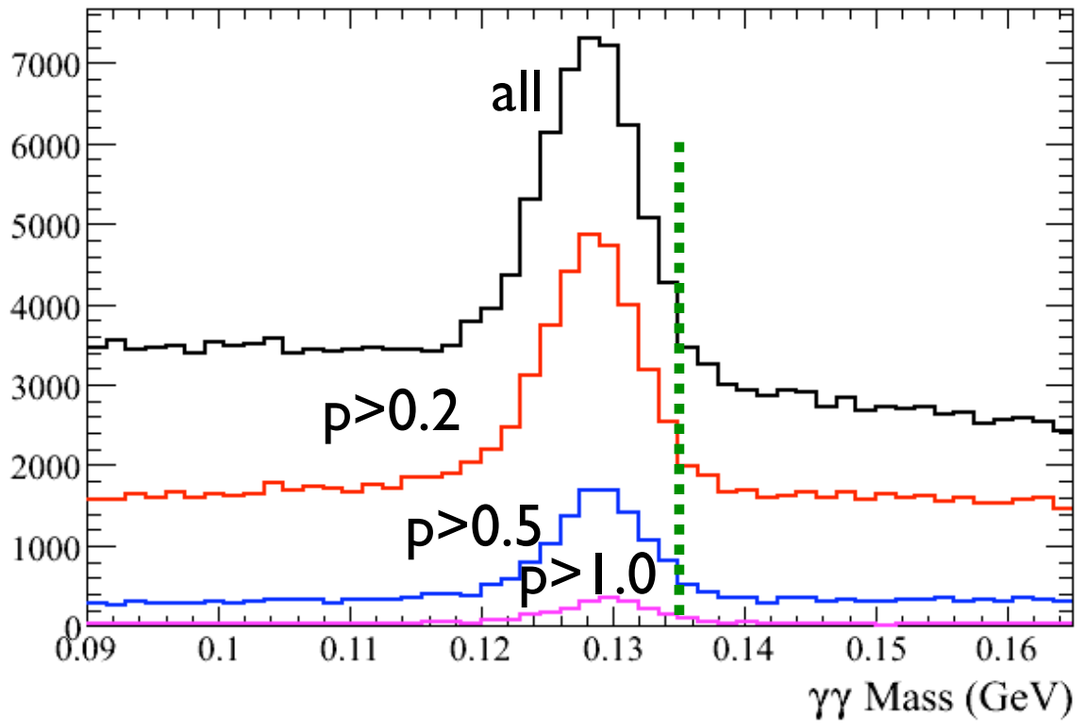
δθ



δφ

- π^0 from BB generic simulation

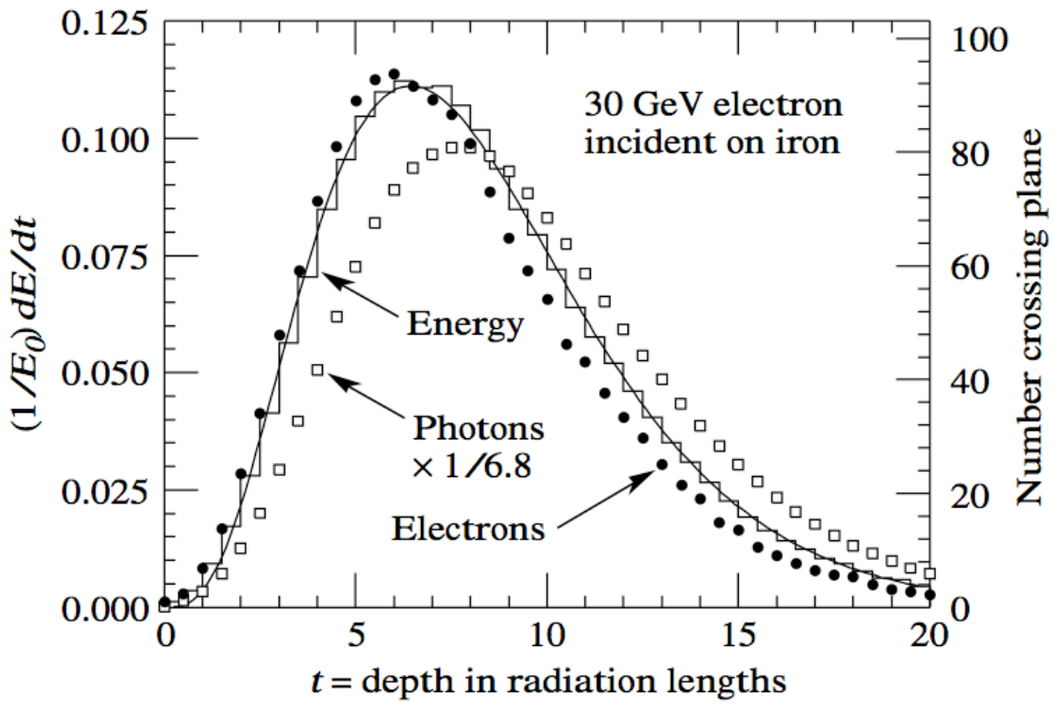




Need calibration. Resolution too high.

Longitudinal shower profile

- Need to know how much energy should be deposited on average, given the particle energy and the radiation lengths in and in front of the EMC, before creating clusters.
  - Not in PacEmc, but calculated in PacSim (D. Brown)
- Profile depends on the material atomic number Z.
- Tricky to model when shower transits from one material to another. But important for detector study.

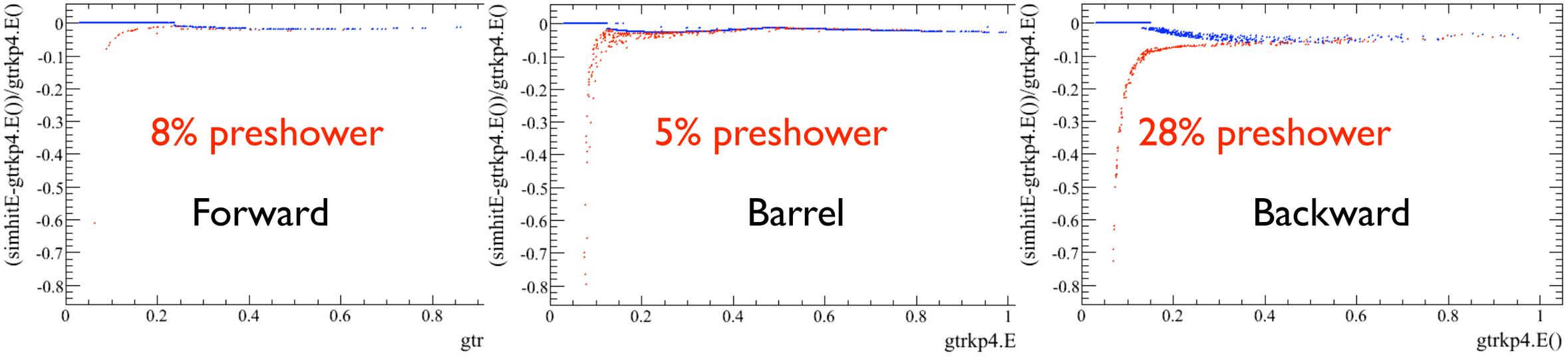


$$\frac{dE}{dt} = E_0\, b\, \frac{(bt)^{a-1} e^{-bt}}{\Gamma(a)}$$

The integral has no closed-form solution.
We use numerical integration.

Expected energy deposition

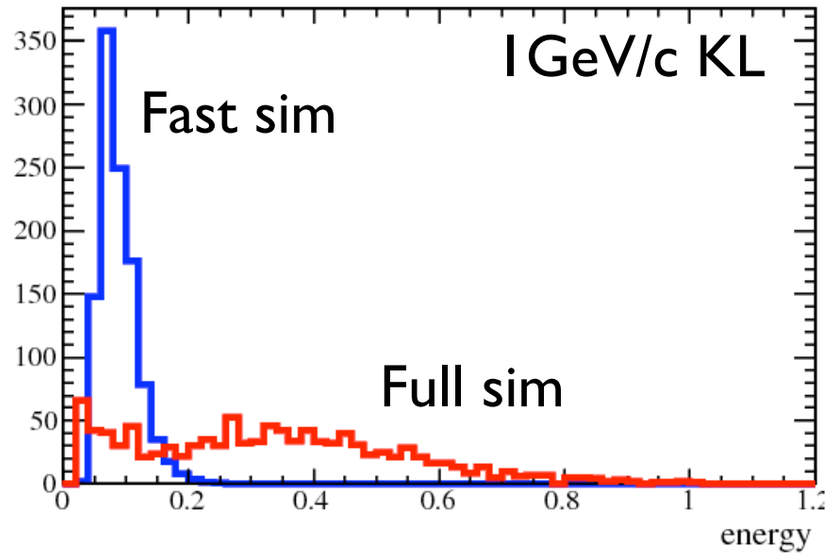
Blue: shower starts at EMC; Red: shower starts before EMC



- Except for very low energy, up to several percent energy leaks out of the back side.
- See energy loss due to preshower for low energy photons.
- Need to check against the full simulation.

Hadronic shower

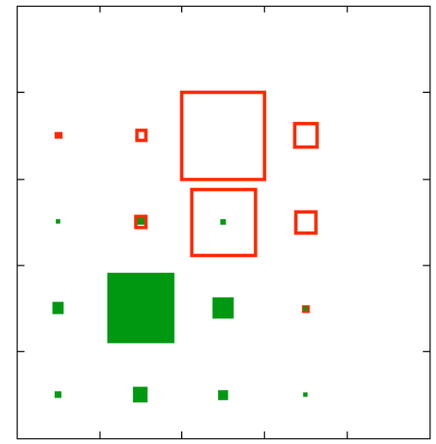
- Similar way to calculate the longitudinal integral, replacing radiation length with interaction length. However, it grossly underestimates the energy deposition.

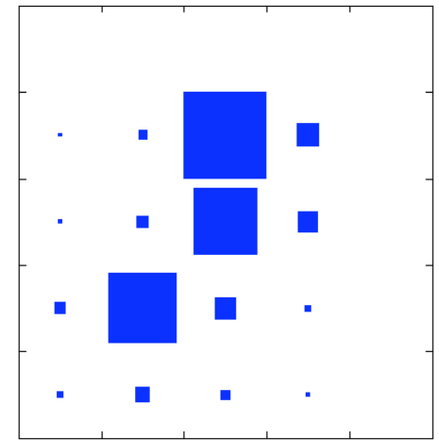


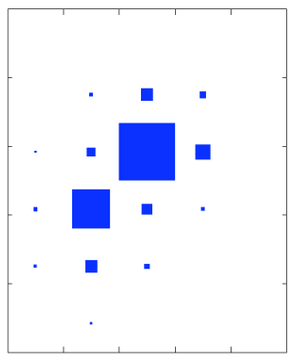
- Hadronic showers are irregular and difficult to model with simple parametrizations.
- Use random walk to navigate through crystals and create large fluctuation to create irregular patterns in a cluster.

Cluster merging

- Merging is straight forward, simply adding energies in each crystal.
- There is no cluster reconstruction process. We know which crystals belong to the same cluster to begin with.
- We only merge clusters that are close enough to produce a single bump cluster.
  - #bumps = #local maxima
  - local maxima ≡ crystal energy higher than its neighboring eight.
  - This function hasn't been turned on in V0.0.2.







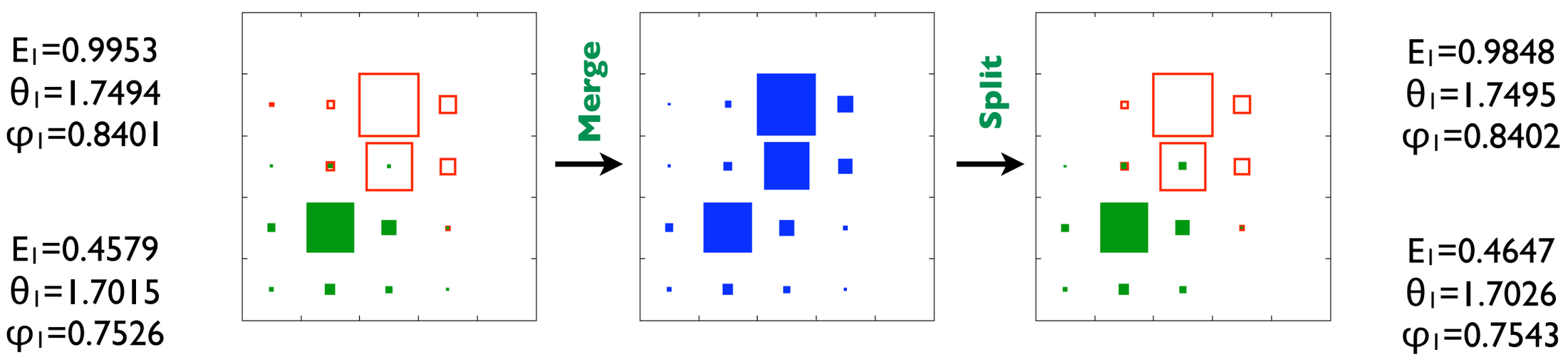
Is this one- or two-bump?

Cluster splitting

- Need to split clusters to simulate hadronic shower split-offs.
- Split clusters that have more than one local maximum.
  - Assign a weight to each crystal j for each new one-bump clusters α:

$$w_j^{(\alpha)} = \frac{E^{(\alpha)} e^{-2.5|\vec{r}_{(\alpha)} - \vec{r}_j|}}{\sum_\alpha E^{(\alpha)} e^{-2.5|\vec{r}_{(\alpha)} - \vec{r}_j|}} \qquad E^{(\alpha)} = \sum_j w_j^{(\alpha)} E_j \qquad \sum_\alpha w_j^{(\alpha)} = 1$$

  - Calculate weights and then new $E^{(\alpha)}$ and $r_{(\alpha)}$ iteratively until converge.



This function hasn't been turned on in V0.0.2.

More to do

- Ability to divide forward endcap into two regions (CsI, and LYSO).
- Track-cluster matching information.
- Truth association:
  - 1 GTrack ↔ n clusters (split); n GTracks ↔ 1 cluster (merge)
- Validation; QA; parameter tuning.
- Energy calibration.
- Hadronic shower.
- Background frame mixing.