EMC in Fast Simulation

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SuperB baseline design

Backward Calorimeter
Geometry in the fastsim

- 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.

![Diagram showing geometry of the fastsim setup]

- Bkwd extension (not in current version)
- Bkwd EMC 14 cm thick
- 75 cm
- 120 cm
- 31 cm
- CsI 30 cm thick
- 112.7 cm
- 180.9 cm
- Fwd L(Y)SO
- 20 cm thick
- Room for PID
- 91 cm
- 140.8°
- 26.9°
- 15.8°
Display
Proposed backward calorimeter

Behind DCH I propose to place Pb-scintillator sampling calorimeter

- 2.8 mm thick Pb plates $\Rightarrow 1/2 X_0$
- 3.0 mm thick scintillator tiles
- Sizes vary from $3.8 \text{ cm} \times 3.8 \text{ cm} \rightarrow 7.8 \text{ cm} \times 7.8 \text{ cm}$ ($R_M \sim 6.0 \text{ cm}$)
- Cylindrical geometry, $r_i=0.31 \text{ m}$, $r_a=0.75 \text{ m}$
  - Coverage $\sim 300 \text{ mr}$
- 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

Gerald Eigen, SuperB meeting Elba, 31/05/2008

8 ring, 60 tiles/ring
New materials in MaterialsList.data

- Forward LSO: Lu$_2$SiO$_5$; LYSO: add ~5% Yttrium
  - $d = 7.4 \text{ g/cm}^3$; $X_0^* = 1.14 \text{ cm}$; $\lambda_1^* = 21 \text{ cm}$. ($R_M = 2.07 \text{ cm}$)

- Backward Pb-scintillator plates: (2.8mm Pb + 3.0mm scintillator tiles)$\times 24$
  - Treated as a homogeneous material, rather than sampling plates.
  - 2.8mm Pb = 0.5 $X_0$; 3mm Polystyrene $\sim 0.007 X_0$.

<table>
<thead>
<tr>
<th></th>
<th>Z</th>
<th>A</th>
<th>X0</th>
<th>d</th>
<th>$X_0^*$ (cm)</th>
<th>$\lambda_1^*$ (cm)</th>
<th>$R_M$ (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pb</td>
<td>82</td>
<td>207.2</td>
<td>6.37</td>
<td>11.35</td>
<td>0.56</td>
<td>17.6</td>
<td>1.6</td>
</tr>
<tr>
<td>Polystyrene</td>
<td>3.5</td>
<td>6.5</td>
<td>43.8</td>
<td>1.06</td>
<td>41.3</td>
<td>77.1</td>
<td>6.8</td>
</tr>
</tbody>
</table>

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

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

$\langle X_0^* \rangle = \frac{L_1 + L_2}{L_1/X_0^*_1 + L_2/X_0^*_2} = 1.14 \quad \langle X_0 \rangle = 6.87$

$\langle A \rangle = 69.3 \quad \langle Z \rangle = 28.1$
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.

\[
\langle R_M \rangle \simeq R^\text{Pb}_M \frac{L_1 + L_2}{L_1} = 3.3 \text{cm}
\]
• 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.
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 $\theta/\varphi$, no rotation).
Performance

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

- **π⁰ 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

- 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 straightforward, 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 \( \alpha \):

\[
 w^{(\alpha)}_j = \frac{E^{(\alpha)} e^{-2.5|\vec{r}^{(\alpha)} - \vec{r}_j|}}{\sum_{\alpha} E^{(\alpha)} e^{-2.5|\vec{r}^{(\alpha)} - \vec{r}_j|}} \\
 E^{(\alpha)} = \sum_j w^{(\alpha)}_j E_j \\
 \sum_{\alpha} w^{(\alpha)}_j = 1
\]

- 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 $\leftrightarrow$ n clusters (split); n GTracks $\leftrightarrow$ 1 cluster (merge)
- Validation; QA; parameter tuning.
- Energy calibration.
- Hadronic shower.
- Background frame mixing.