Energy Resolution with $\pi^0$

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Outline

0. Motivation
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2. Investigation: BaBar vs. Belle
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Motivation

• $\pi^0$: Best candidate to study EMC energy resolution since (1) at low energy scale, the mass resolution of $\pi^0$ mostly comes from the energy resolution of the detector; (2) they are copiously available.

• Is the energy resolution uniform in the whole detector or only a part of the system is contributing to the poor energy resolution we observe at low energy?

• Can we identify other first order effects that deteriorates the energy resolution at low energy?

• Does second order effect such as movement of the BeamSpot at IR have an important contribution to improve on the energy resolution?
Analysis using Micros

- “AllEvents” from early RUN-II data with three or more tracks per event and $R^2 < 0.9$ (about 25 million Events).
- Energy of each $\pi^0$ (form veryLoosePi0 list) is less than 0.5 GeV.
- Energy of each of the two $\gamma$ is more than 0.125 GeV.
- For comparison, SP4 MC ($uds$ and $B^+B^- / B^0\bar{B}^0$ Generic) is used.
Mass Resolution in every TWO $\phi$ rings along barrel for Monte Carlo and data.
\[ \theta \text{ dependency on } \pi^0 \text{ mass/resolution} \]

- Mass Resolution in every THREE \( \phi \) rings along barrel for Monte Carlo and data.
Mass Resolution for each FIVE θ rows for data.
Symmetric $\pi^0$ s with both $\gamma$ of equal energy.

- $\pi^0$ mass resolution vs. gamma energy for Monte Carlo and data.
How much fitting systematics gone to this measurement?

1: fit range: 0.06-0.21 GeV
2: fit range: 0.08-0.18 GeV

0.1 < E_{\gamma_1} < 0.2 GeV
0.1 < E_{\gamma_2} < 0.2 GeV;

<table>
<thead>
<tr>
<th>N_{trk}</th>
<th>\sigma_{\pi^0}</th>
<th>\sigma_{\pi^0}^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 2</td>
<td>5.99 MeV</td>
<td>6.73 MeV</td>
</tr>
<tr>
<td>&lt;= 2</td>
<td>6.00 MeV</td>
<td>6.88 MeV</td>
</tr>
<tr>
<td>&gt; 8</td>
<td>6.47 MeV</td>
<td>6.66 MeV</td>
</tr>
</tbody>
</table>

At low energy the result has about 10% systematic error coming mainly from the background tail. Statistical error is negligible.
Impact of BeamSpot movement on $\sigma_{\pi^0}$

- With a large movement of the BeamSpot, the peak position is shifted by 1 MeV from the nominal $\pi^0$ mass.
- If you have a lot of runs with bad BeamSpot, the resolution will be affected.
Consider a run with BeamSpot @ (0.034, 0.351, 0.359)

Recalculate $\pi^0$ mass using the BeamSpot position.

Peak position : $0.1339 \text{ GeV}$ (before correction) $\rightarrow 0.1342 \text{ GeV}$ (after correction)

This is a second order effect to affect $\pi^0$ mass resolution.

Some more studies will be done soon.
Some Investigations: BaBar vs. Belle

- \( E_\gamma > 0.05 \text{GeV} \); Hadronic type events.

### BaBar

<table>
<thead>
<tr>
<th>ID</th>
<th>Entries</th>
<th>Mean ( M_{\gamma\gamma} ) (GeV/c^2)</th>
<th>RMS ( M_{\gamma\gamma} ) (GeV/c^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>0.1093E+07 ± 3586.</td>
<td>0.1311</td>
<td></td>
</tr>
<tr>
<td>P2</td>
<td>0.1351 ± 0.2352E-04</td>
<td>0.2679E-01</td>
<td></td>
</tr>
<tr>
<td>P3</td>
<td>0.1661 ± 0.1891E-04</td>
<td>0.1027E+05/41</td>
<td></td>
</tr>
<tr>
<td>P4</td>
<td>0.1741 ± 0.3667E-02</td>
<td>0.0814E+05</td>
<td></td>
</tr>
<tr>
<td>P5</td>
<td>0.365E+05</td>
<td>0.357E+05</td>
<td></td>
</tr>
<tr>
<td>P6</td>
<td>0.509E+07 ± 4094</td>
<td>0.435E+07 ± 0.3593E+07</td>
<td></td>
</tr>
<tr>
<td>P7</td>
<td>0.509E+07 ± 4094</td>
<td>0.435E+07 ± 0.3593E+07</td>
<td></td>
</tr>
<tr>
<td>P8</td>
<td>0.509E+07 ± 4094</td>
<td>0.435E+07 ± 0.3593E+07</td>
<td></td>
</tr>
<tr>
<td>P9</td>
<td>0.297E+09 ± 0.1583E+07</td>
<td>0.297E+09 ± 0.1583E+07</td>
<td></td>
</tr>
</tbody>
</table>

### Belle

<table>
<thead>
<tr>
<th>ID</th>
<th>Entries</th>
<th>Mean ( M_{\gamma\gamma} ) (GeV/c^2)</th>
<th>RMS ( M_{\gamma\gamma} ) (GeV/c^2)</th>
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</thead>
<tbody>
<tr>
<td>P1</td>
<td>0.1027E+07 ± 41</td>
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<tr>
<td>P2</td>
<td>0.7289E+07</td>
<td>0.1346</td>
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<tr>
<td>P3</td>
<td>0.5261E+02</td>
<td>0.1412</td>
<td></td>
</tr>
<tr>
<td>P4</td>
<td>0.1346</td>
<td>0.1412</td>
<td></td>
</tr>
<tr>
<td>P5</td>
<td>0.1790E+07</td>
<td>0.1412</td>
<td></td>
</tr>
<tr>
<td>P6</td>
<td>0.4728E+08</td>
<td>0.1790E+07</td>
<td></td>
</tr>
<tr>
<td>P7</td>
<td>0.1076E+08</td>
<td>0.4728E+08</td>
<td></td>
</tr>
<tr>
<td>P8</td>
<td>0.1918E+10</td>
<td>0.1076E+08</td>
<td></td>
</tr>
<tr>
<td>P9</td>
<td>0.5976E+10</td>
<td>0.1918E+10</td>
<td></td>
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</tbody>
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Asish Satpathy: Energy Resolution with \( \pi^0 \)

EMC Calibration Meeting, 26th March 2003 (page 11)
Assume that the background shape is same for both the plots.

- The difference between BaBar and Belle is prominent.
- Larger low energy tail (in blue curve) may be caused due to energy resolution or background shape. Hard to identify background shape only.
Photon Quality : BaBar vs. Belle

**BaBar**

- We adopt software sparcification: Crystal with more than 1.0 MeV are used to make clusters.
- We start from a seed crystal with 10 MeV energy and again have a threshold of 5 MeV to allow adding the neighbouring crystal to make clusters.
- Our typical intrinsic noise is about 400 keV. In barrel it is about 500-600 keV.
- Clearly we are limited by noise at low energy.

**Belle**

- Belle adopts hardware sparcification: Crystals with more than 0.5 MeV are used to make clusters.
- Belle starts from a seed crystal with 10 MeV energy and add all neighbouring crystals with more than 0.5 MeV to make clusters.
- For beam data, intrinsic electronics noise level is 200-250 keV. In Barrel region, even affected by pile-up due to beam background, it is 300-350KeV.
- This somehow explains why Belle is about 25% better than us in $\pi^0$ resolution.
Comments

- There are regions in our detector where the $\pi^0$ mass resolution is higher than the average value.
- BeamSpot correction will have negligible impact on improving the $\pi^0$ mass resolution. But it is certainly nice to have a list with this correction. Work in progress to produce this list with a default BeamSpot correction switch (tcl parameter).
- At low energy we are affected by electronics noise and that explains why Belle is doing slightly better.
- At high energy, $\pi^0$ is not a tool to test and compare anything.
- Things that still need to be understood at low energy region: why MC is not consistent with data?

Acknowledgment
H. Sagawa, and K. Miyabayashi for sharing some Belle Info.