Photon Energy Resolution of the BaBar EMC using a μμγ Sample

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Outline

- Measure the BaBar EMC photon energy resolution, using a $e^+e^-\rightarrow \mu\mu\gamma$ sample
  - What I was trying to do
  - What I did
  - Where it’s going
- Apologies to those who have seen this all before! However, thought it would be good for those not familiar to see this since I haven’t given a talk since September 2005
- No significant work has been done since; Sudan will take over this task, with assistance from me
The Task

- Study of photon energy resolution at high energies, using a sample of $e^+e^-\rightarrow\mu^+\mu^-\gamma$ events
- Would like to compare measured photon energy with ‘true’ photon energy
- Photon energy as determined by a 1C kinematic fit provides an estimator of the true photon energy
- The fit assumes that energy and momentum missing after subtracting muons’ energy from beam energy is that of the photon... Photon measurements are **not** used, except perhaps as a start (best guess) value for the fitter
- However, kinematic fit is not perfect, and this must be taken into account
Sample Selection

- Data sample from ~184 fb\(^{-1}\) of BaBar data
- Plot shows photon energy spectrum from $\mu \mu \gamma$ events
- Main cuts applied to the sample:
  - Two ‘good’ measured tracks
  - One ‘good’ measured photon
  - One of the charged particles identified as a muon (using a loose muon selector)
  - Convergent kinematic fit
  - $\chi^2$ probability > 0.05
- Cuts leave around 1.2 million events from data
Obtaining The ‘True’ Resolution

- I have the kinematically-fitted photon energy $E_{\gamma}^{\text{fit}}$, which is an estimator for the true photon energy $E_{\gamma}^{\text{true}}$

- I can define:

$$x = \frac{E_{\gamma}^{\text{meas}}}{E_{\gamma}^{\text{fit}}}, \quad y = \frac{E_{\gamma}^{\text{meas}}}{E_{\gamma}^{\text{true}}}$$

- For the probability density of $y$ write $g(y; \theta)$, where $\theta$ in this case is a vector of the input parameters for a crystal ball function

- Distribution of $x$ is $f(x)$

- Finite width of $E_{\gamma}^{\text{fit}}/E_{\gamma}^{\text{true}}$ means that $g(y) = f(x)$

- Can discretise distributions as histograms with $N$ bins, which gives the expected number of entries in bin $i$ of the respective distribution:

$$\nu_i = \nu_{\text{tot}} \int_{\text{bin}i} f(x) \, dx \quad \mu_i(\tilde{\theta}) = \mu_{\text{tot}} \int_{\text{bin}i} g(y; \tilde{\theta}) \, dy$$

- Actual number of entries observed in bin $i$ of data is $n_i$
Response matrix

- Expectation values $\mathbf{\mu} = (\mu_1, ..., \mu_N)$ and $\mathbf{\nu} = (\nu_1, ..., \nu_N)$ are related by the response matrix $R_{ij}$:

$$\nu_i = \sum_{j=1}^{N} R_{ij} \mu_j$$

- Where $R_{ij}$ is defined as:

$$R_{ij} = P(x \text{ found in bin } i \mid \text{ value of } y \text{ in bin } j) = \frac{\text{Number found in cell } i,j}{\text{number in column } j, \text{ including the underflow & overflow}}$$

- The response matrix should be independent of the properties of the detector.
- It is instead a measure of the properties of the fitter
- If the inputs for the muon measurements are the same in data and MC, there should be no problem...
Estimation of the Parameters of $y$

- Minimise the $\chi^2$, taking $n_i$ to be Poisson distributed, so $\sigma^2 \approx n_i$

\[
\nu_i = \sum_{i=1}^{N} \frac{(n_i - \nu_i(\vec{\theta}))^2}{\sigma^2} = \sum_{i=1}^{N} \frac{(n_i - \sum_{j=1}^{N} R_{ij} \mu_i(\vec{\theta}))^2}{\sigma^2}
\]

All plots from MC: $E^{\text{meas}}_Y / E^{\text{true}}_Y$; $E^{\text{meas}}_Y / E^{\text{fit}}_Y$; function is from minimising $\chi^2$
FWHM from MC

Essentially want to see that I get back out what I put in, which seems to be the case
FWHM from Data

Is it important that the response function $E_{\gamma}^{\text{meas}}/E_{\gamma}^{\text{fit}}$ is not the same in data and MC?
Unfolding seems to improve matters, but still off by ~0.5% in the lower energy regions.
Data Peak Position

What’s going on in the lower energy range? Is it a feature of the method, or a true effect?
Fits to FWHM and Peak Plots

- FWHM plots were parameterised as: \( \frac{\sigma_E}{E} = \frac{a}{\sqrt[4]{E}} \oplus b \)
- Should try fitting FWHM plots using a power of \(-1/\alpha\) rather than \(-1/4\)
- Peaks were simply fitted by a constant \(c\)
- Error evaluation still needs checking over
- I get:

<table>
<thead>
<tr>
<th></th>
<th>(a) (FWHM)</th>
<th>(b) (FWHM)</th>
<th>(c) (Peak)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MC</strong></td>
<td>1.73 e–2</td>
<td>1.06 e–2</td>
<td>1.000</td>
</tr>
<tr>
<td><strong>Data</strong></td>
<td>1.81 e–2</td>
<td>1.57 e–2</td>
<td>1.002</td>
</tr>
</tbody>
</table>
Conclusions

- To a some approximation, have managed to extract the energy resolution of the BaBar detector using the $\mu\mu\gamma$ sample.
- However, still some open questions and things to do...
  - Is the response matrix sensitive to the different energy response shapes of data and MC, and if so, how sensitive?
  - Need to find out how well MC and data compare for muon tracking
  - Still need to work on the error calculations
- Would like to update this with Neutrals group control samples

To be continued...
Supplemental slides