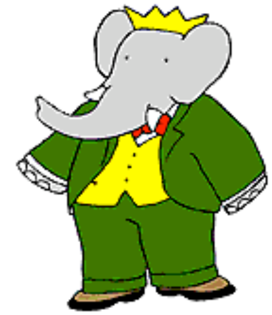
Studies of photon energy response of the BaBar Electromagnetic Calorimeter



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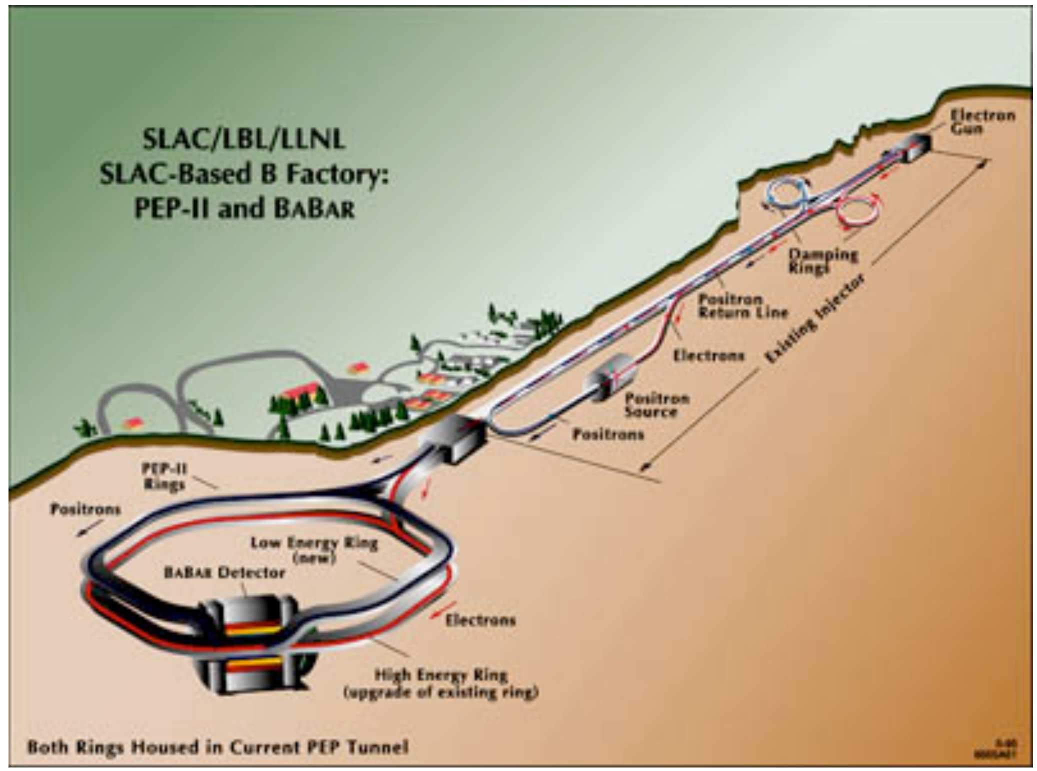
Outline

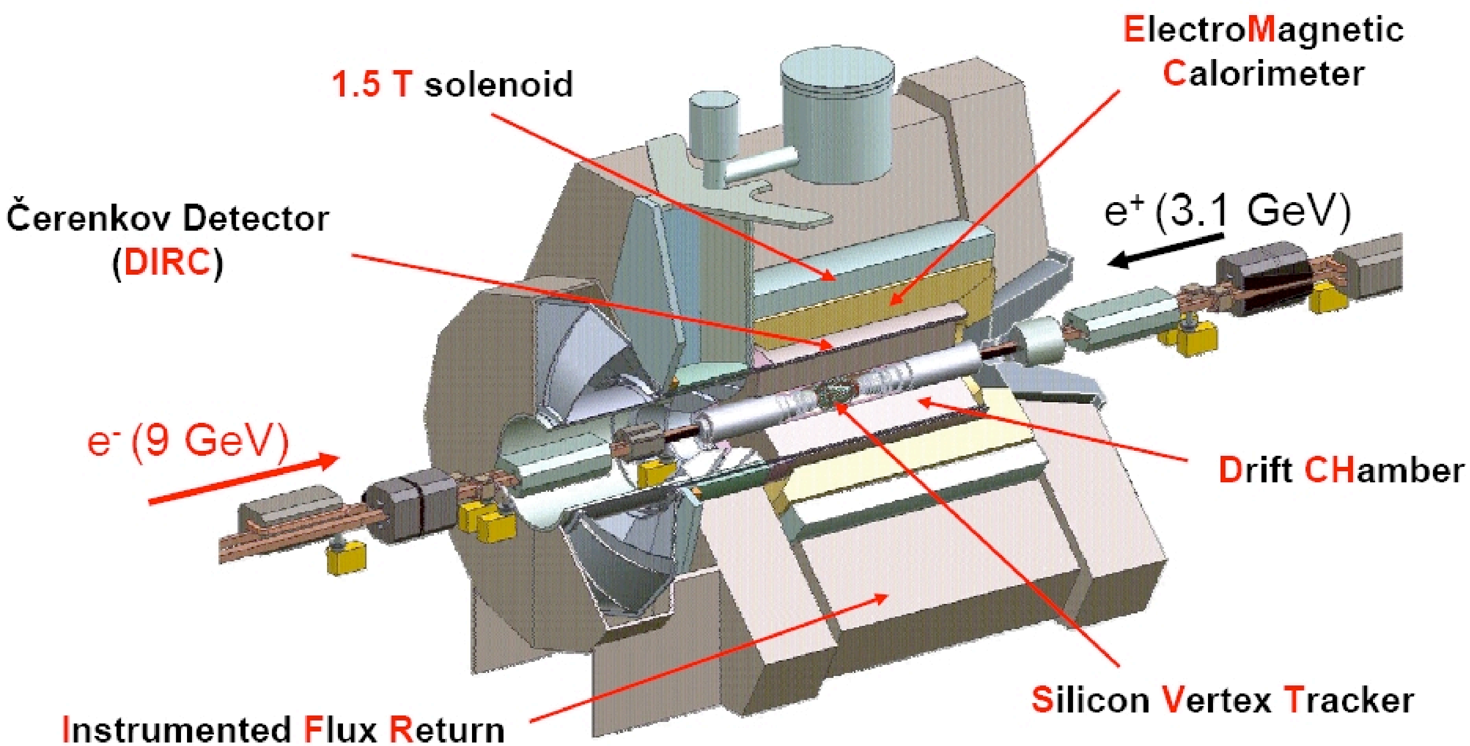
- Introduce BaBar experiment and Calorimeter
- Motivation to improve the calorimeter's Monte Carlo simulation
- Methodology
- Results
- Uses in analyses
- Conclusion

The PEP-II accelerator & BaBar Experiment

- Located at SLAC, California
- 9.1 GeV electrons and 3 GeV positrons colliding to form $\Upsilon(4S)$ which decays to B mesons.
- So far has accumulated ~529fb^{-1} of data

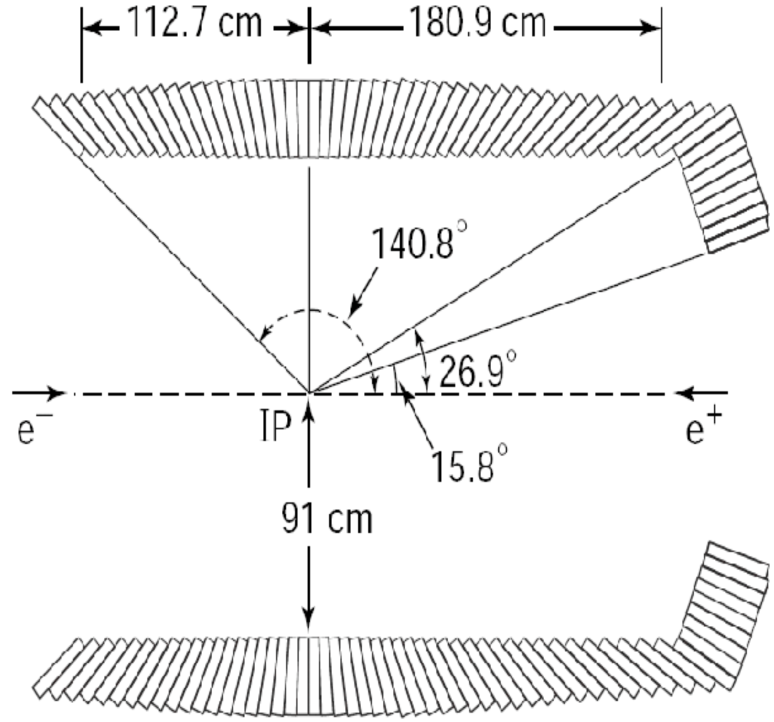


The BaBar Detector



The BaBar EMC

- Accurately measures showers produced by electrons and photons
- 6580 thallium-doped CsI crystals in rings
- Divided into barrel and endcap, arranged asymmetrically

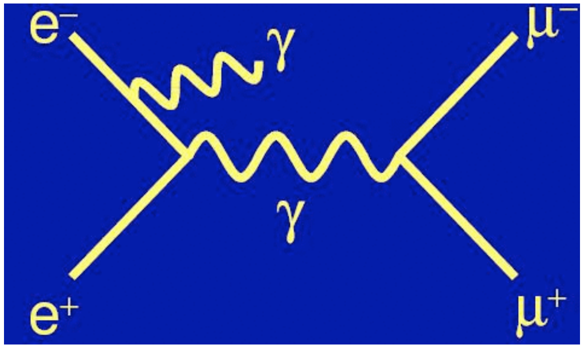


Introduction

- Wanted to perform a resolution study -> need to be able to compare energy of photon as measured by the calorimeter (E_{meas}), with the energy determined without using the calorimeter(E_{fit}).

- Need to choose a suitable sample of events.
- $e^+e^- \longrightarrow \mu^+ \mu^- \gamma$ was chosen,

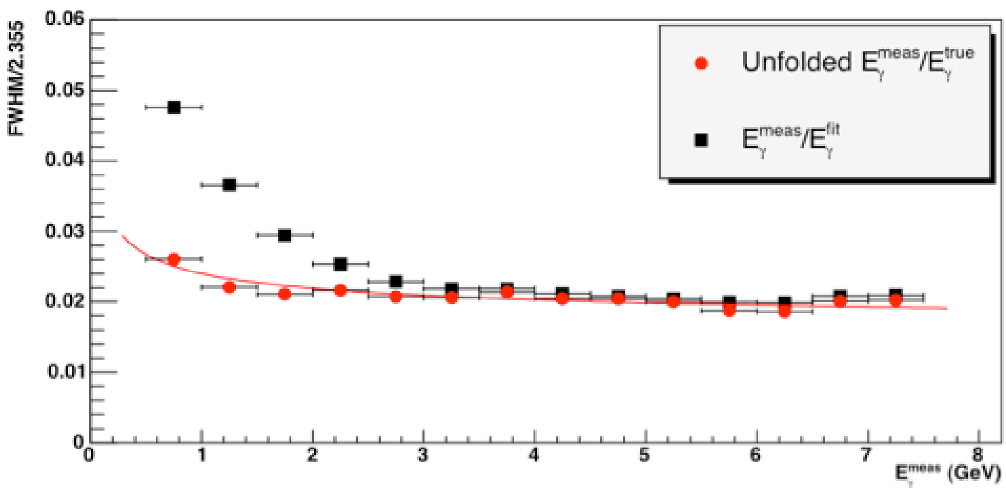
  as the energy can be calculated using momentum and energy conservation, there is also low background due to an isolated photon, high number of events.



- Distributions of E_{meas}/E_{fit} can then be compared in MC and Data

Calorimeter resolution

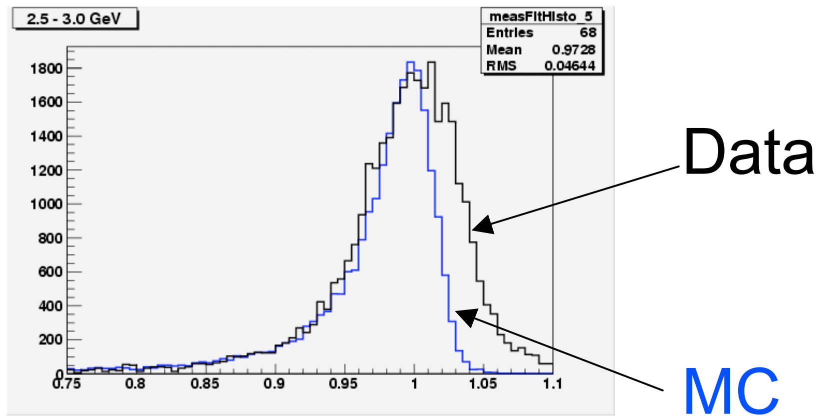
- Technique used energy as measured by Calorimeter (E_{meas}) and energy as obtained by a kinematic fit (E_{fit}).
- In MC we also had the true energy of the photon(E_{true}), in Data we used an unfolding procedure to obtain the 'true' distribution(E_{unfold}).
- This distribution of E_{meas}/E_{unfold} was then plotted over varying energy bins to ascertain the resolution



~2%

Motivation I

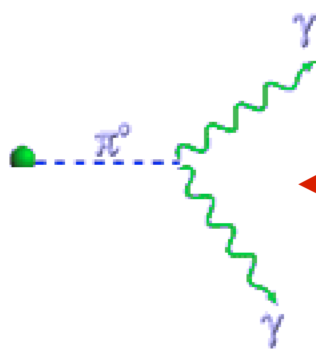
- While investigating energy resolution of photons detected in EMC, we noticed that MC and Data didn't agree



- Material between crystals in the EMC was not modelled correctly, or crystal non-uniformity in MC, miscalibration of crystals…none could be shown to be a significant problem
- Led us to believe MC simulation package did not model EM showers correctly
- Not easy to fix simulation of showers in simulation-so try to smear the MC to improve agreement

Motivation II

- An analysis which I am currently working on is hadronic mass spectra of $\tau^- \longrightarrow K^0_s\pi^-\nu$, but planning to work simultaneously on the above decay mode, but adding a neutral pion to the final state



98.8% decays into photons, having improved MC and Data agreement in my reconstruction will yield lower systematic errors

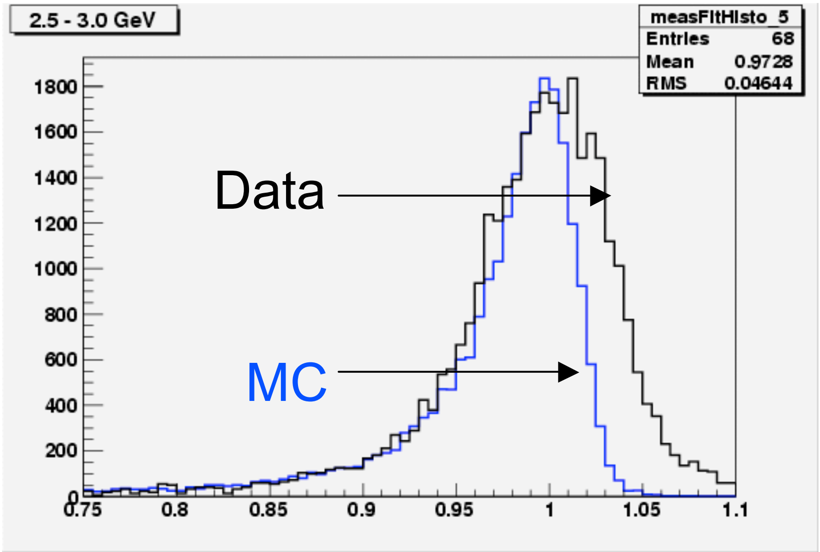
Methodology

- $X = E_{meas}/E_{fit}$ - data
- $Y = E_{meas}/E_{fit}$ -MC
- The problem lies in the fact that the pdf's of the above distributions have different shapes
- Define new variable z, with pdf $\mathbf{s}(z)$ such that $x' = y + z$ has same pdf as X.
- Represent these variables as histograms:

$$\boldsymbol{n} = (n_1.....,n_N) \text{ - } data$$

$$\boldsymbol{\mu} = (\mu_1....., \mu_N) \text{ - } MC$$

$$\boldsymbol{\nu} = (\nu_1..., \nu_N) \text{ - } Smeared$$



Methodology

- Now because $x' = y + z$, its distribution is given by the Fourier convolution of y and z:

$$f(x') = \int s(x'-y)g(y)dy \quad \rightarrow \quad f(x') = \int s(x'|y)g(y)dy$$

- To express this in terms of histograms, we define the conditional probability to have x in bin i given that y is in bin j :

$$S_{ij} = P(x\ in\ bin\ i\ |\ y\ in\ bin\ j)$$

- We can thus relate the histograms of x' and y by:

$$\nu_i = \sum_{j=1}^{N} S_{ij}(\vec{\theta})\mu_j$$

[θ Is a vector representing a set of parameters which characterise the pdf $s(z)$]

Smearing distributions

- Need to discover a smearing function which can accommodate differences between MC and Data
- Started off with a few, narrowed down to two possibilities:

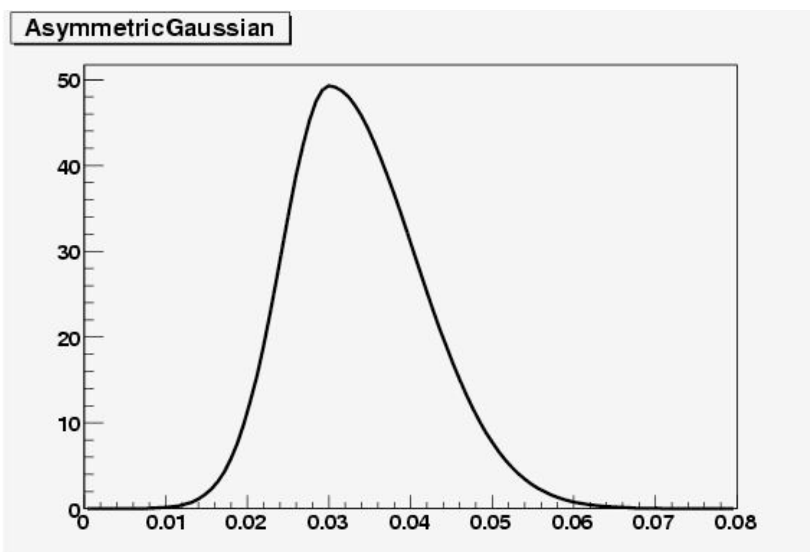
$$s(z;\varepsilon,\sigma) = \frac{1}{\sqrt{2\pi}\sigma} e^{-(z-\varepsilon)^2/2\sigma^2}$$

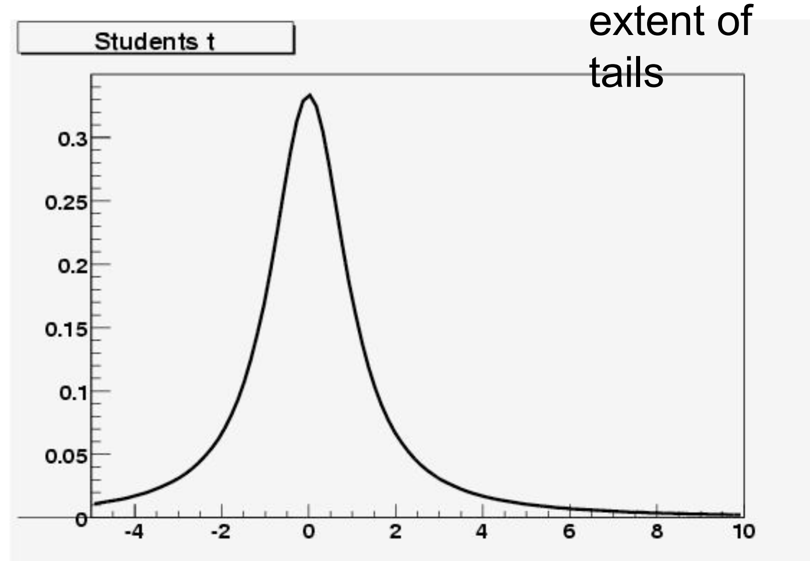
Gaussian

$$s(z;\varepsilon,\lambda,\nu) = \frac{1}{\lambda}\frac{\Gamma((\nu+1)/2)}{\sqrt{\nu\pi}\,\Gamma(\nu/2)}\left(1+\frac{t^2}{\nu}\right)^{-(\nu+1)/2} \quad t = \frac{z-\varepsilon}{\lambda}$$

Students *t*

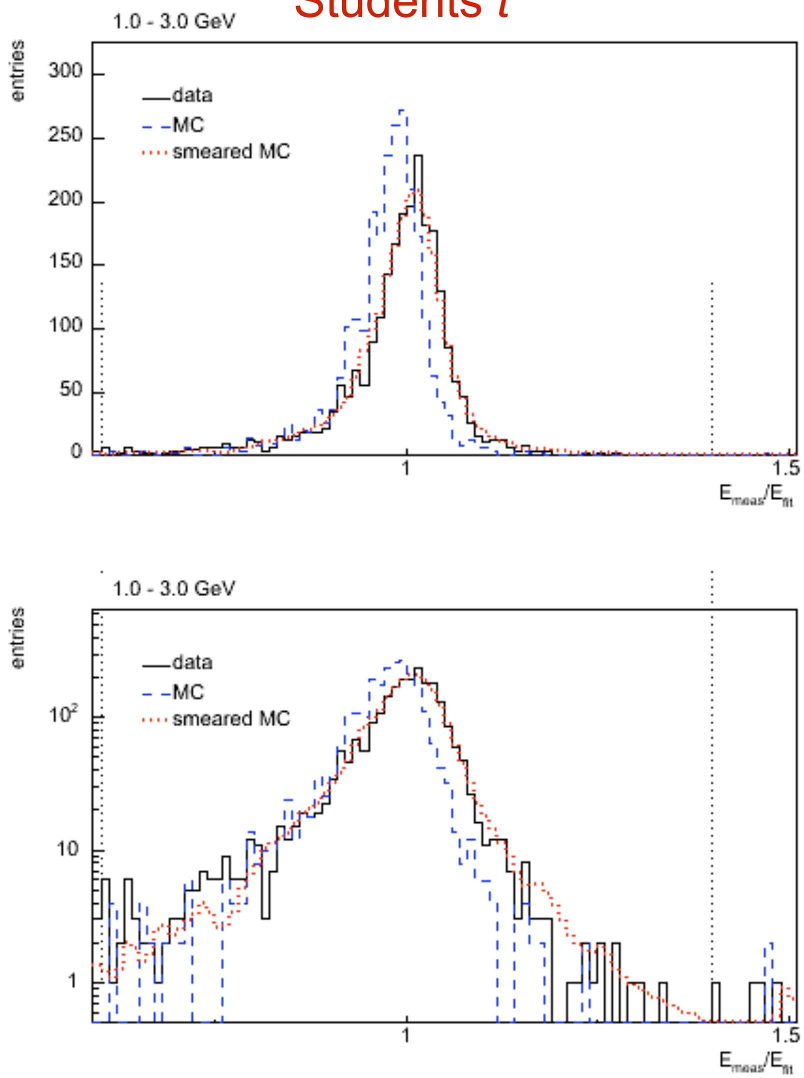
Controls extent of tails



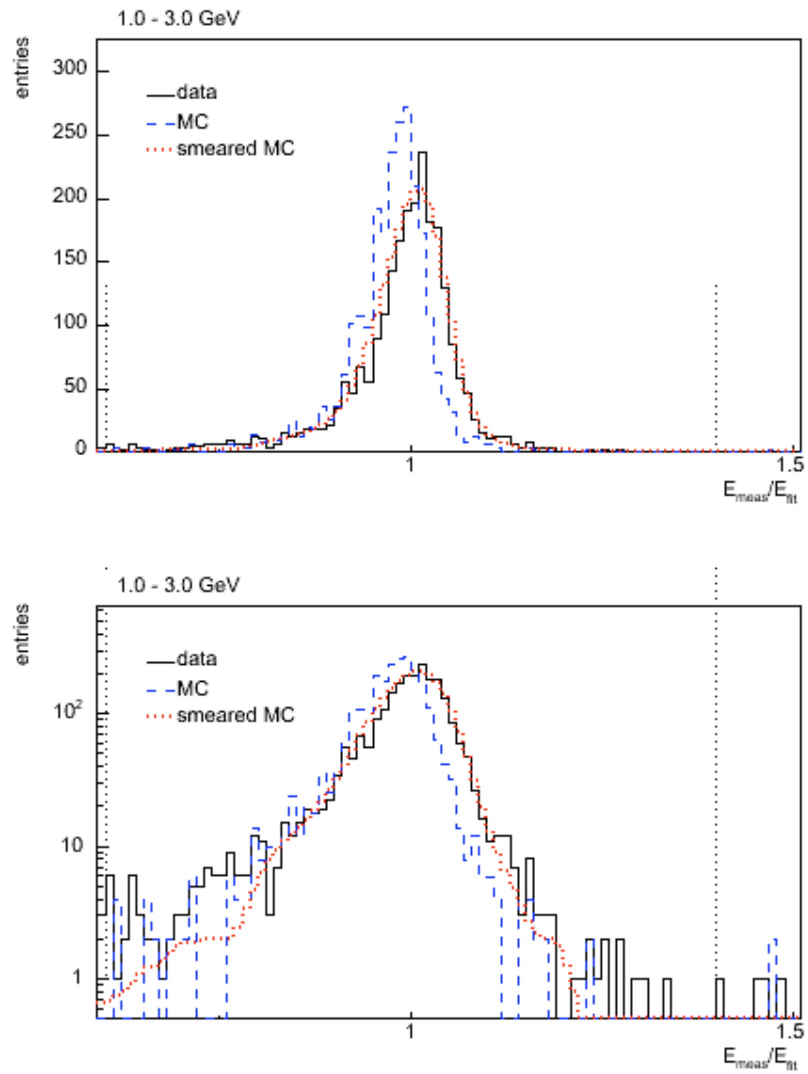


Comparing smearing functions

Students *t*

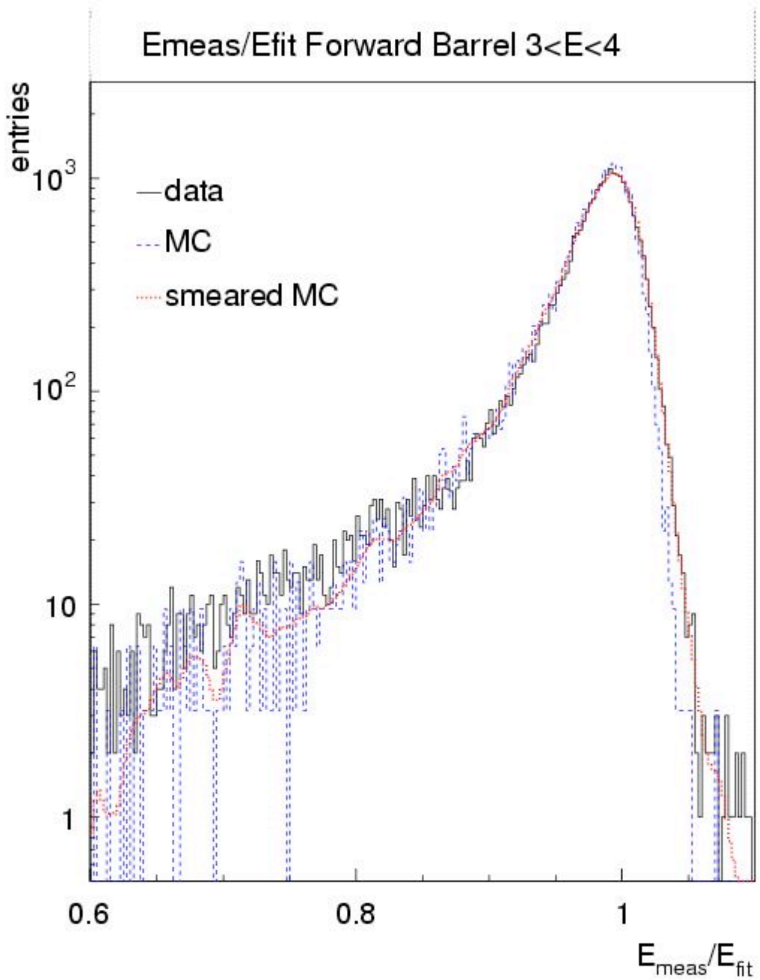


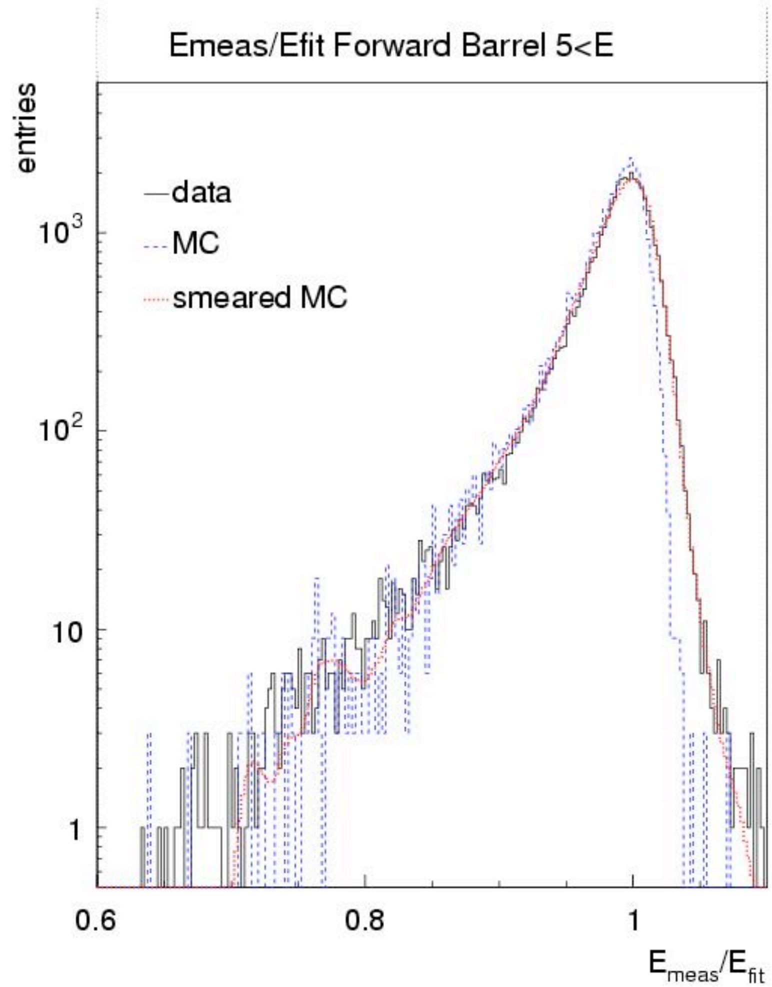
Asymmetric Gaussian



Results

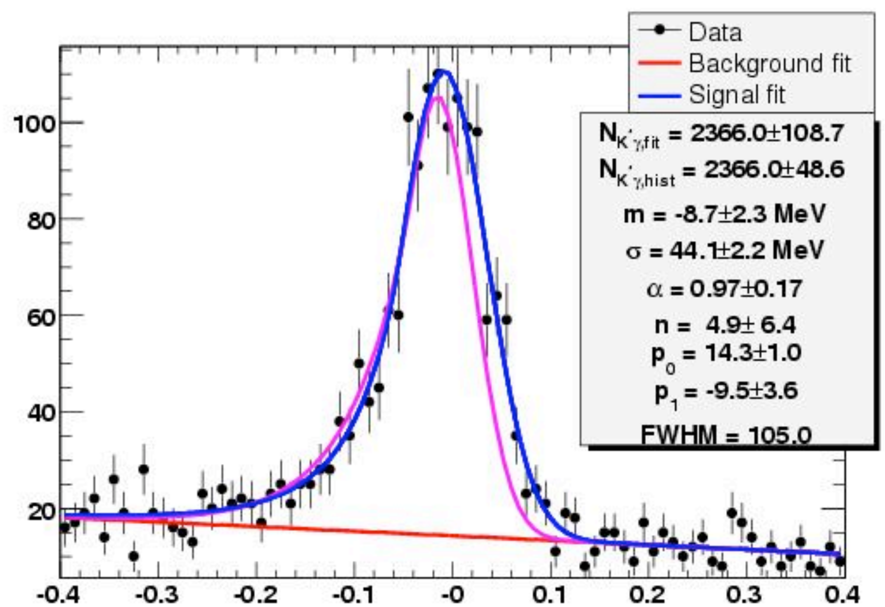
using Students *t*

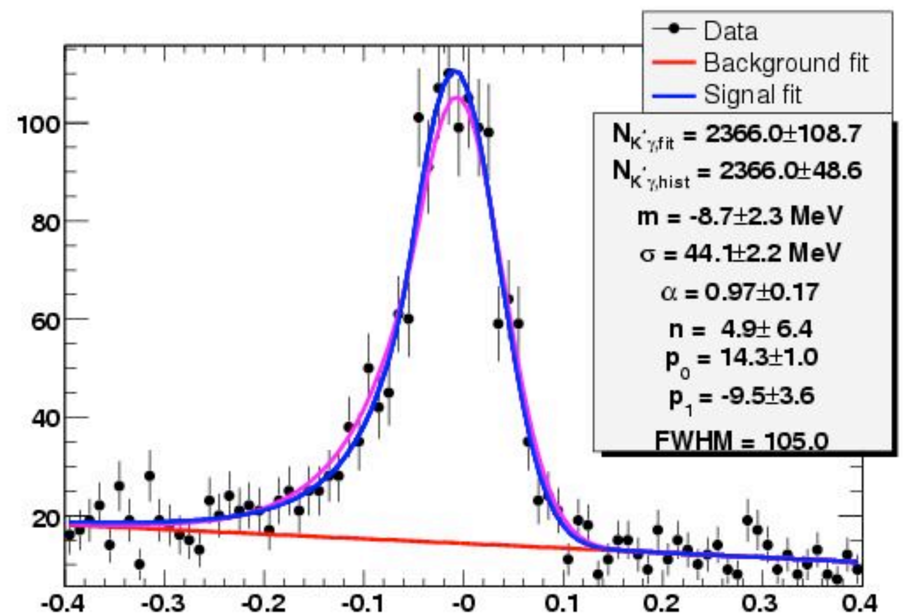




Validation of Smearing

- The smearing was tested on an analysis of the decay mode $B \longrightarrow K^*\gamma$
- Red curves are MC, Blue are Data





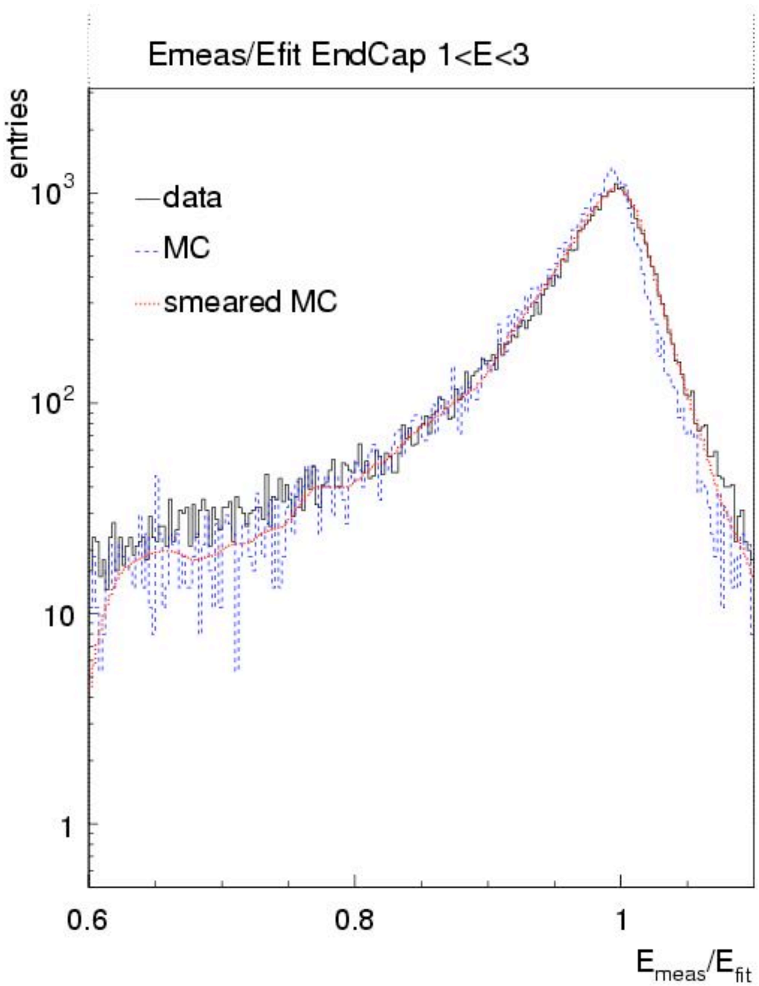
Conclusions

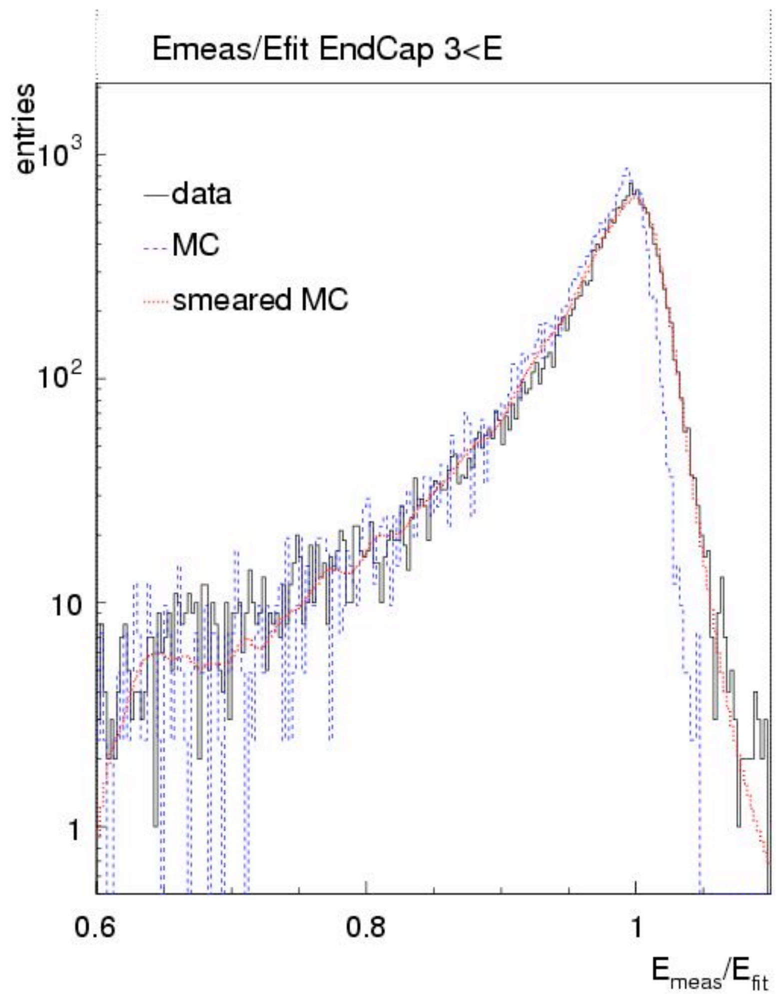
- Smearing using Students *t* conclusively improved MC and Data agreement
- With this improvement, systematic studies in analyses that include a photon, will strongly improve uncertainties on selection efficiencies between MC and Data, and evaluation of fits to variables like delta-E.
- Smearing can now be used as a correction as part of BaBar event simulation

Backup Slides

Results of smearing MC

- using Students *t* distribution





Results continued…