Performance of EMC and physics related studies

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Aim of this study

- Quantify impact of different EMC resolutions on physics using FastSim
- Possible figures of merit:

FOM	sample	notes
S/sqrt(S+B)	$B \to K^* \nu\nu$ (signal + BB bkg)	@ intermediate stage of selection, not enough BB stat to check this after all cuts
E_{extra} shape		
γ reco. eff.	$B \to K^* \nu\nu$ (signal + BB bkg), single part.	
π^0 reco. eff.		
π^0 mass resol.		

in this talk

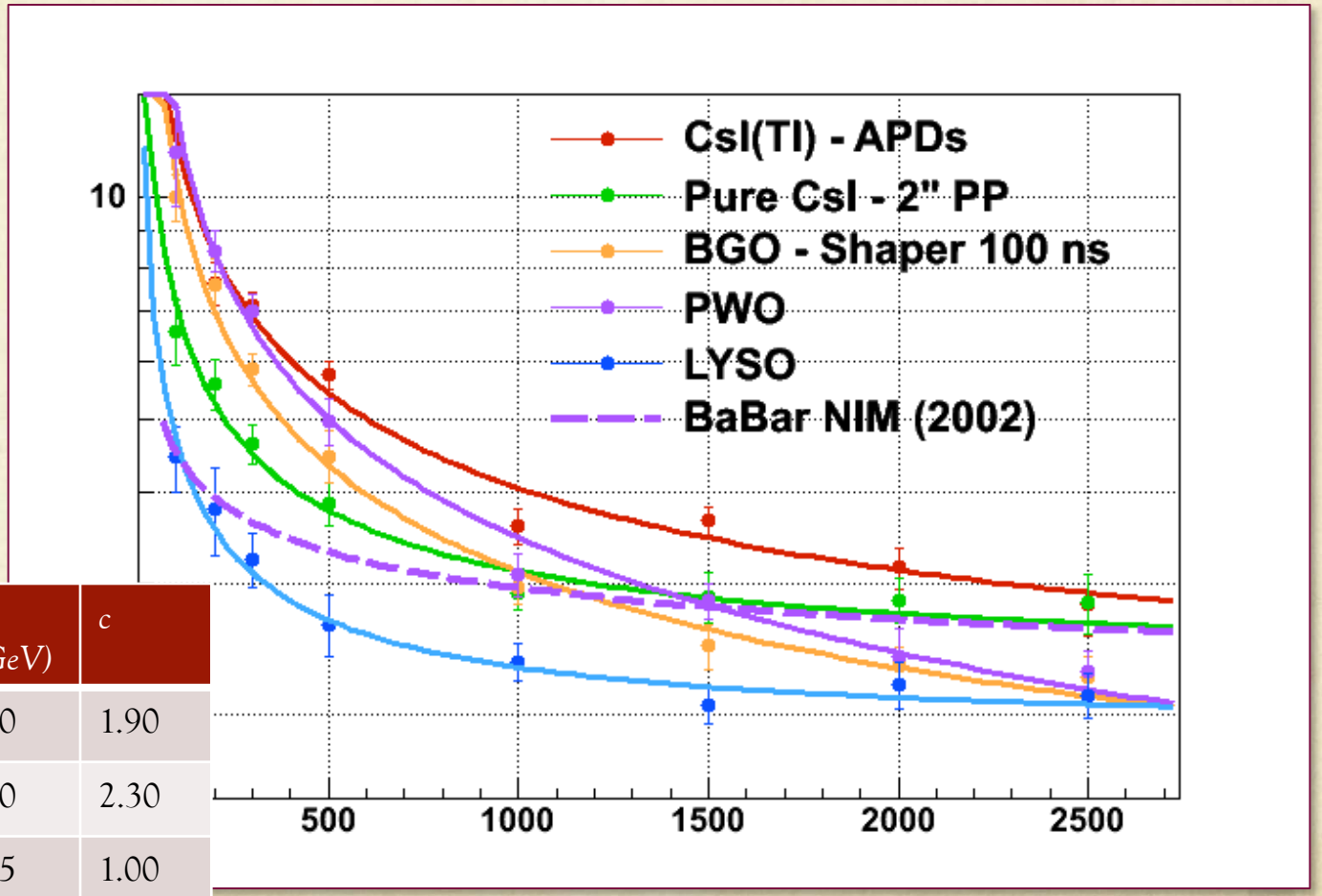
FastSim algorithm

Strategy (I)

- The usual resolution function: $$\frac{\sigma(E)}{E} = \frac{a}{\sqrt{E}} \oplus \frac{b}{E} \oplus c$$
- From FullSim, extract *a*, *b*, and *c* + params for Crystal-Ball describing energy deposit
- Implement smearing and calibration algorithm in FastSim
- Validate on single-γ samples
- Evaluate figures of merit in different scenarios
  - LYSO FWD (+ CsI(Tl) Barrel)
  - CsI FWD (+ CsI(Tl) Barrel)
  - BGO FWD (+ CsI(Tl) Barrel)

Strategy (II)

- Resolutions from Stefano's FullSim studies



crys/pars(%)	*a* ($GeV^{1/2}$)	*b* (*GeV*)	*c*
LYSO	1.35	0.0	1.90
CsI	2.12	0.0	2.30
BGO	2.90	0.5	1.00

Samples

- Single γ beams
  - EMC region: FWD ($\cos\theta \in [0.90,0.96]$), Barrel+FWD ($\cos\theta \in [-0.85,0.89]$)
  - Energies: (30,50,80,100,250,300,350,400,500,600,700,800) MeV , (1,2,2.5) GeV
  - Usage: Method validation, γ reconstruction efficiency

- Single π^0 beams
  - EMC region: FWD ($\cos\theta \in [0.90,0.96]$), Barrel+FWD ($\cos\theta \in [-0.85,0.89]$)
  - Energies: [0.1,2] GeV
  - Usage: π^0 reconstruction efficiency, π^0 mass resolution

NB: in this FastSim study, events from machine bkg not mixed with physical π^0 and γ (incorporated in FullSim resolution)

Cluster reconstruction in FastSim

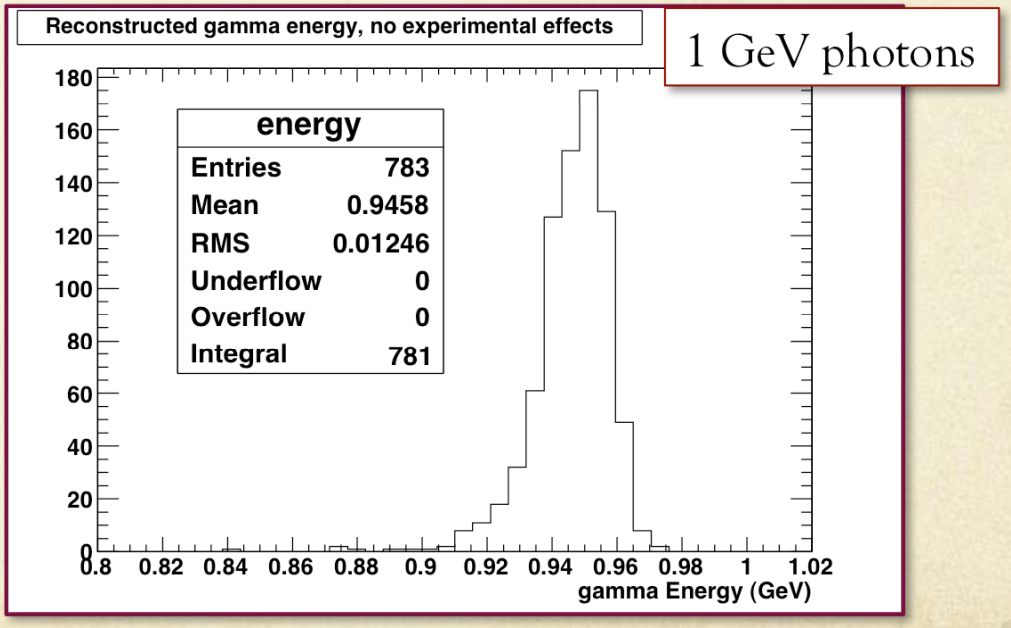
- 3 experimental effects incorporated:
  1. energy smearing due to finite energy resolution
  2. electric noise, i.e. randomly switch on crystals around the reconstructed cluster
  3. global calibration

- modifying smearing parameters allows to change emc resolution

- official FastSim smearing alghoritm: calibration compensate smearing effects
  → different resolutions need different calibration constants
  → try to implement simplified smearing algorithm with calibration independent from resolution

Simplified smearing algorithm: starting point

- Energy distribution after clustering: no smearing, electronic noise nor calibration included
- Distribution asymmetric and peak shifted wrt generated value due to reconstruction effects
- Need calibration factor to shift the peak to the right position
- Smearing algorithm should take "intrinsic" width distribution into account

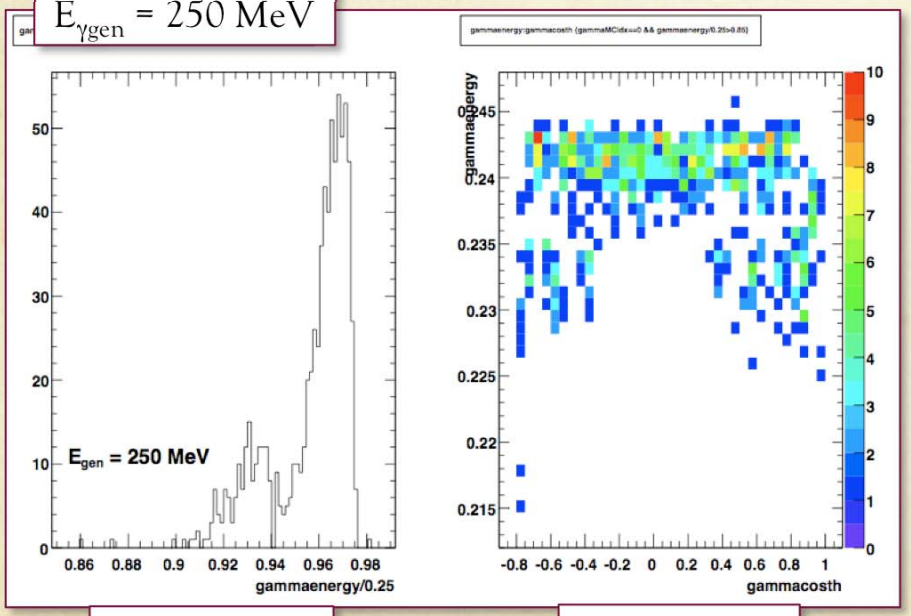


Energy distribution: no exp effects

- Double peak in the [250-400] MeV region
- (Feature disappears when adding exp effects)

Single γ beams
Barrel + FWD

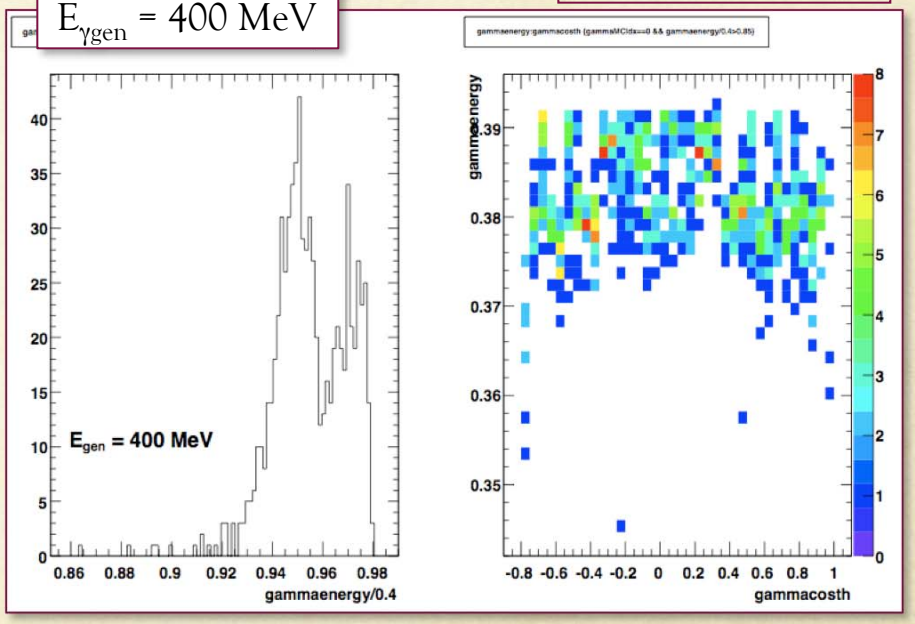
$E_{\gamma gen}$ = 250 MeV



$E_{\gamma reco}/E_{\gamma gen}$

E_γ vs $\cos\theta_\gamma$

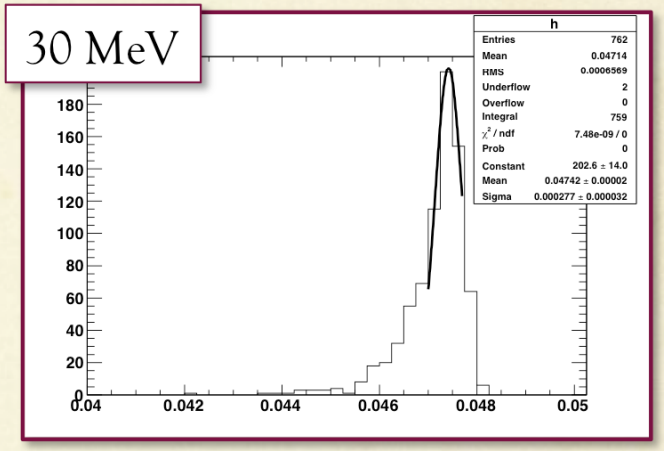
$E_{\gamma gen}$ = 400 MeV



1. Calibration: Gaussian fits

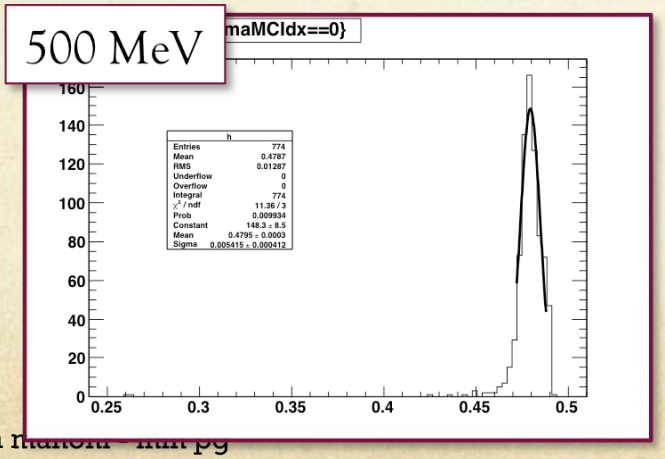
- mono-energetic single γ beams in barrel + fwd, reconstructed without applying calibration, electronic noise, smearing (just clustering)
- Reco energy distributions:

30 MeV

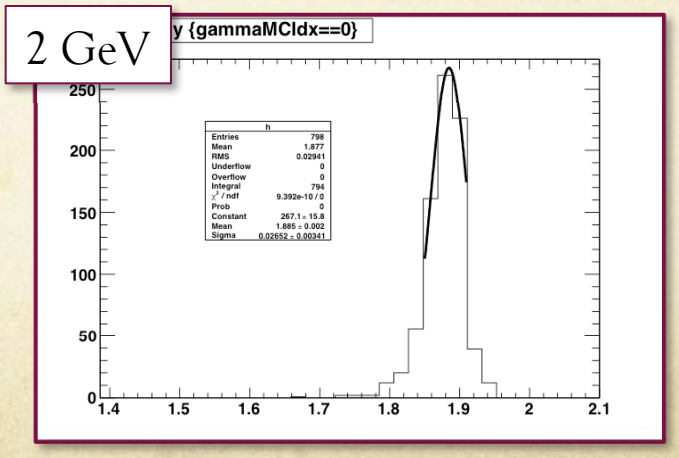


Single γ beams
Barrel + FWD

500 MeV



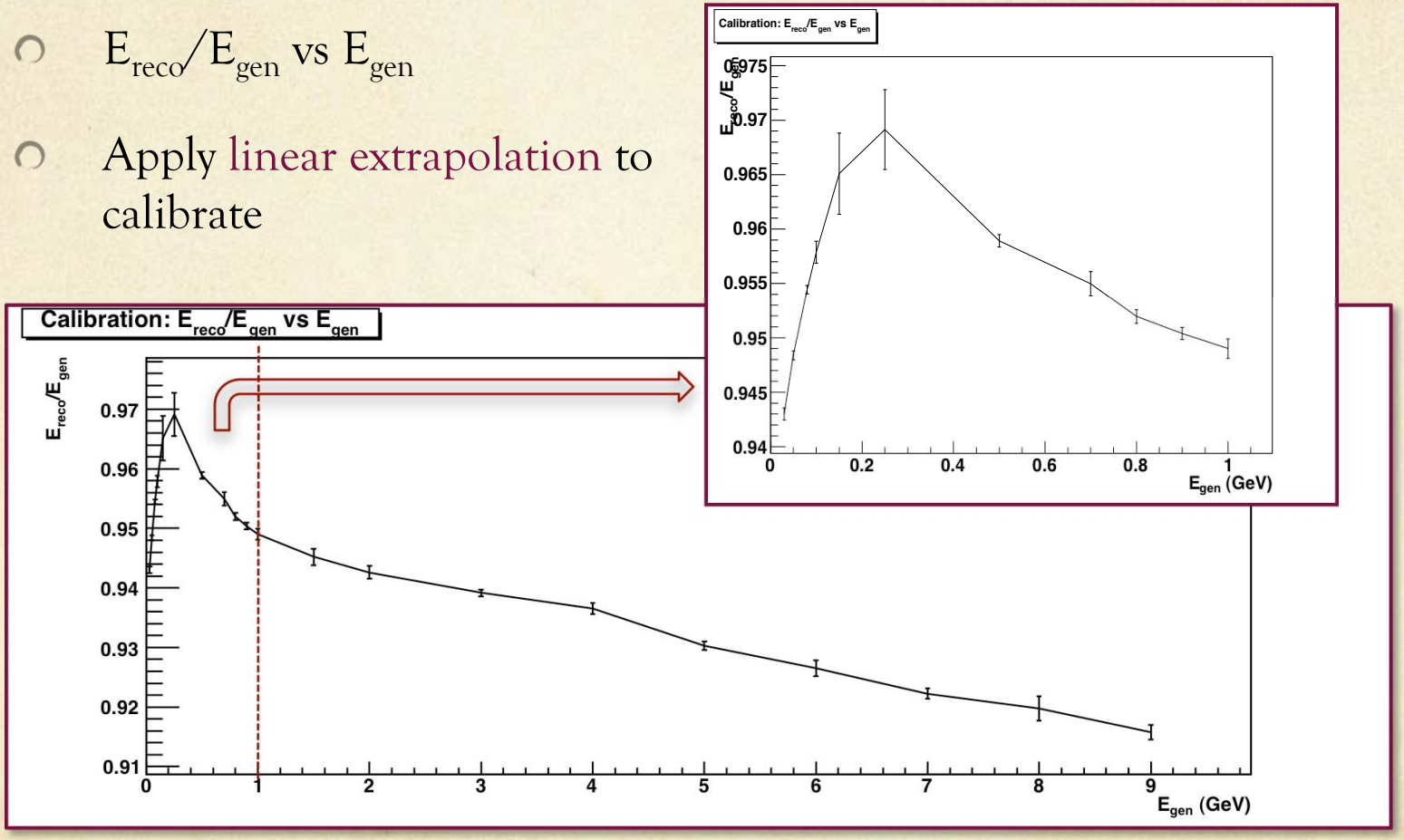
2 GeV



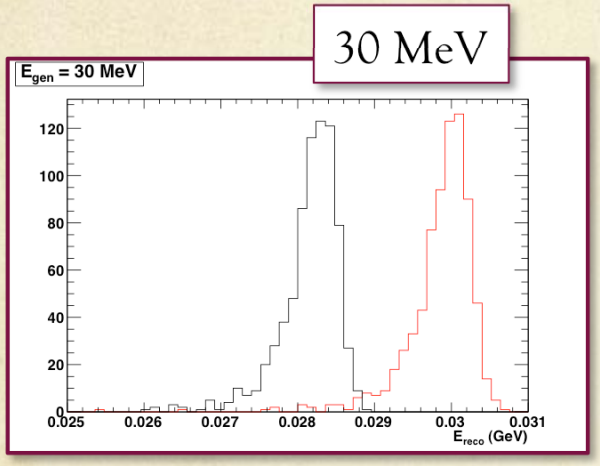
1. Calibration: Barrel (I)

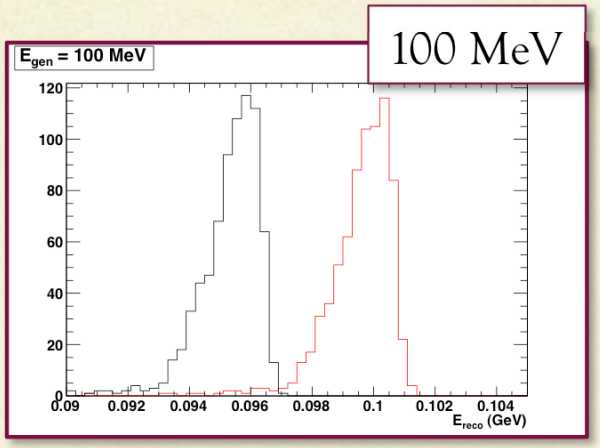
Single γ beams
Barrel + FWD

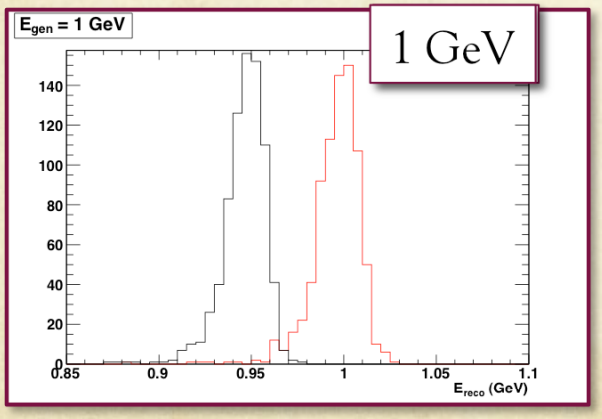
- E_{reco}/E_{gen} vs E_{gen}
- Apply linear extrapolation to calibrate

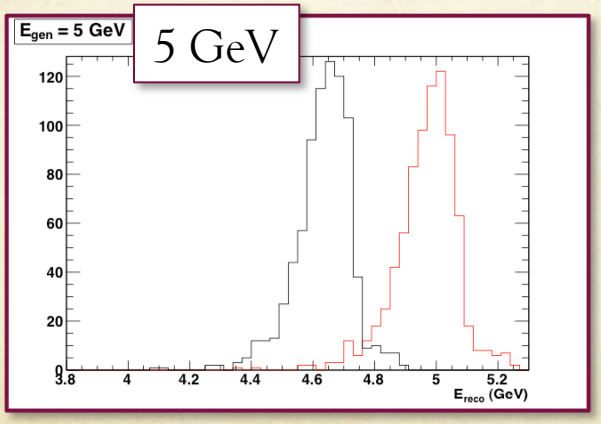


1. Calibration : Barrel (II)









before calibration
after calibration

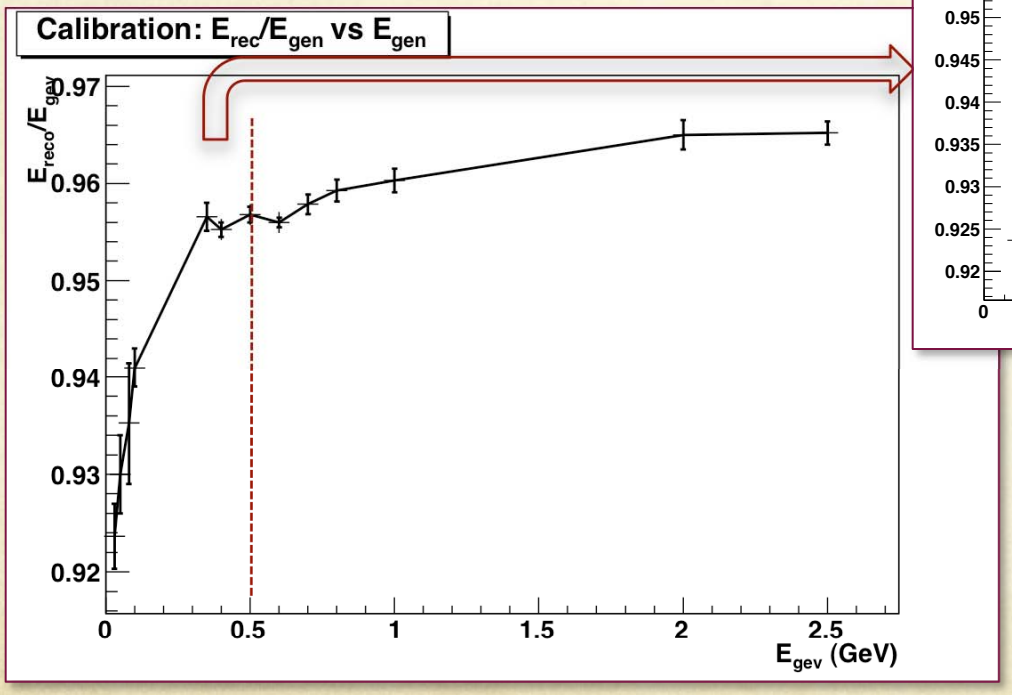
(smearing and electronic noise not incorporated)

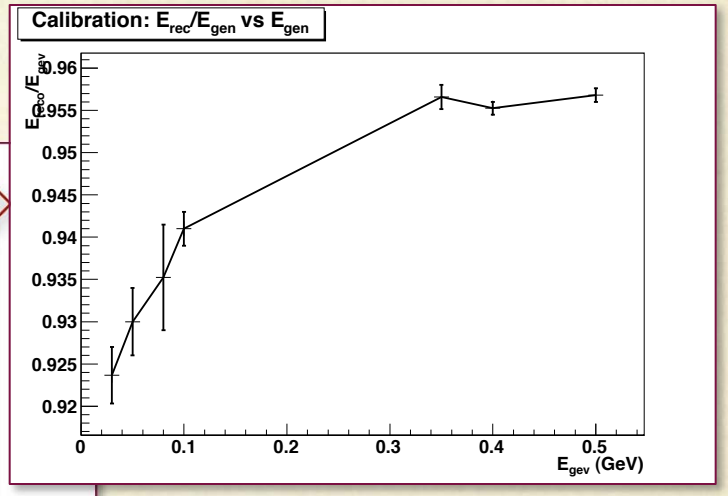
Single γ beams
Barrel + FWD

1. Calibration: FWD

Single γ beams
FWD

- E_{reco}/E_{gen} vs E_{gen}
- Apply linear extrapolation to calibrate



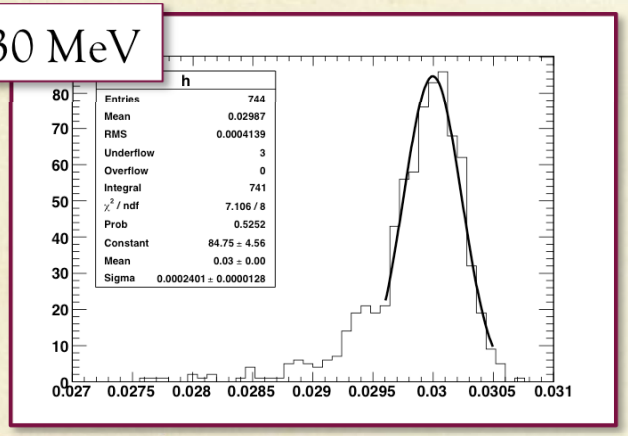


2. “Intrinsic” width: Gaussian fits

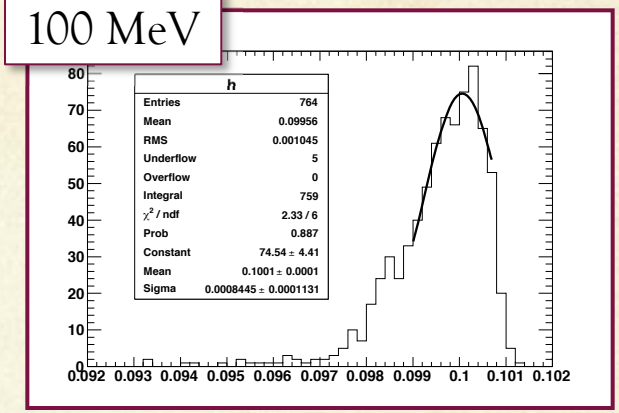
- Gaussian fit to calibrated reconstructed energy, to determine intrinsic distribution width

Single γ beams
Barrel + FWD

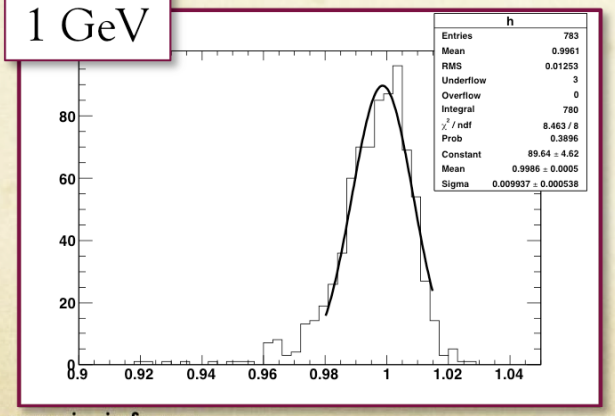
30 MeV



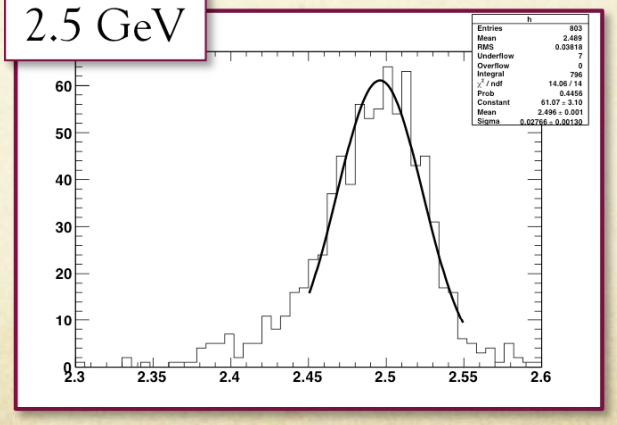
100 MeV



1 GeV

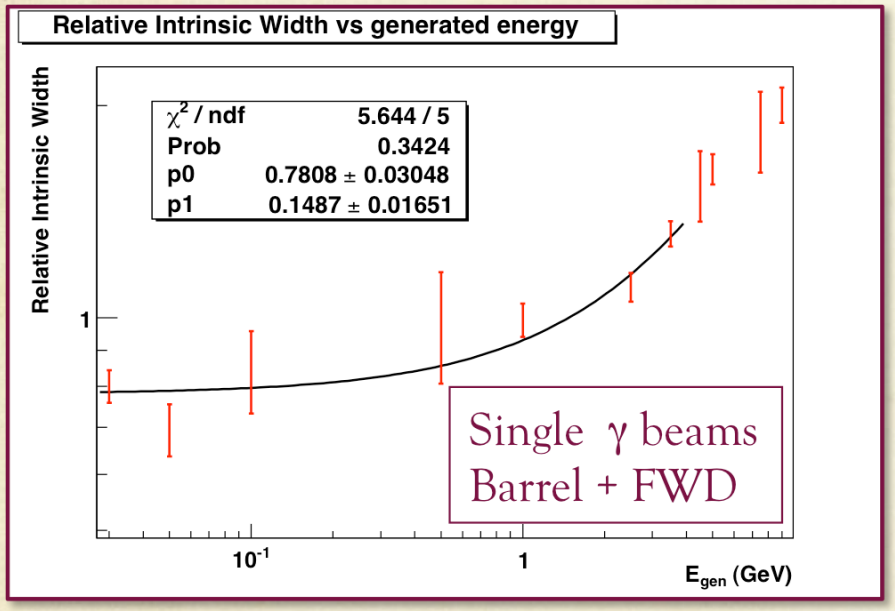


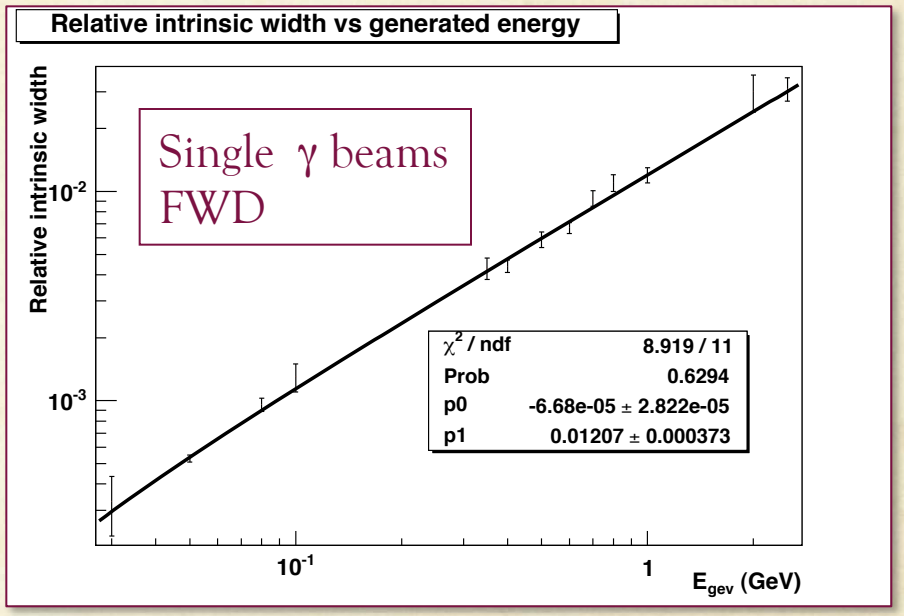
2.5 GeV



2. “Intrinsic” width

Fit function: $\sigma_{int}(E) = p_0 + p_1 E$





3. Smearing : method

- compute expected resolution $\frac{\sigma(E)}{E} = \frac{a}{\sqrt{E}} \oplus \frac{b}{E} \oplus c$
- compare expected resolution with intrinsic width (σ_{intr}) and compute smearing coefficient
  - if (σ_{exp}>σ_{intr}) {

    σ=sqrt(σ_{exp}^2-σ_{intr}^2);

    generate a random number (δE) with CB distribution

    CB parameters: m=0; σ; α, n= from CB shape of simulations

    }

  else: do not apply smearing
- scale energy: E_{reco} = E x (1+δE)

Validation

Validation method

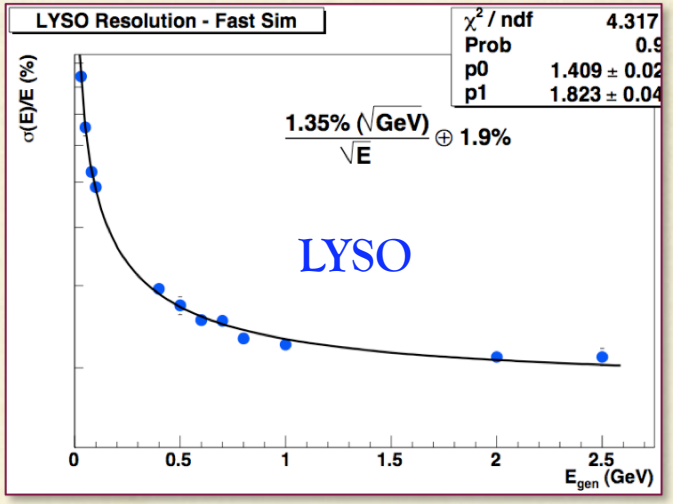
- Modify FastSim configuration file PacEmc/PacEmcGeom_SuperB.xml for different FWD options

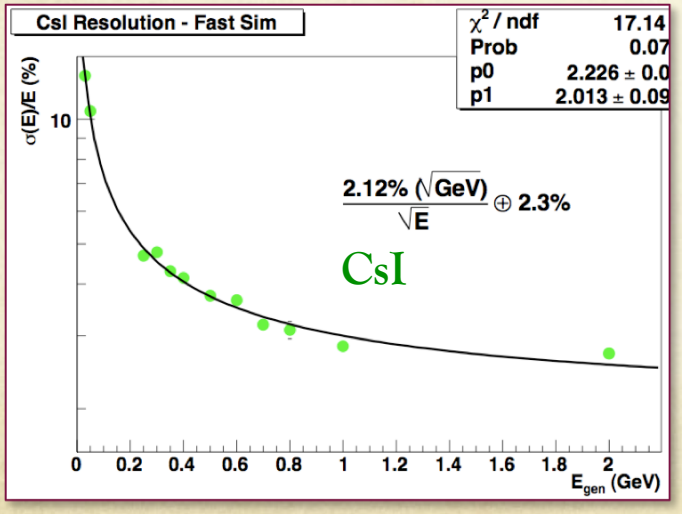
	FWD_LYSO	FWD_BGO	FWD_CsI	Barrel
NRings	20	20	9	40
NPhi	according to geometry			120
rMoliere	2.7	2.23	3.67	3.7
EnergyResFa	0.0135	0.029	0.0212	0.0138
EnergyResFb	0.0	0.005	0.0	0.0
EnergyResFc	0.019	0.01	0.023	0.023
thetaResolution	2.0e-3	5.0e-3	2.0e-3	5.0e-3
phiResolution	2.0e-3	5.0e-3	2.0e-3	5.0e-3
sigLifeF1	1	1	0.75	0.65
sigTau1 (ns)	41	300	30	680
sigTau2 (ns)	41	300	6	3340

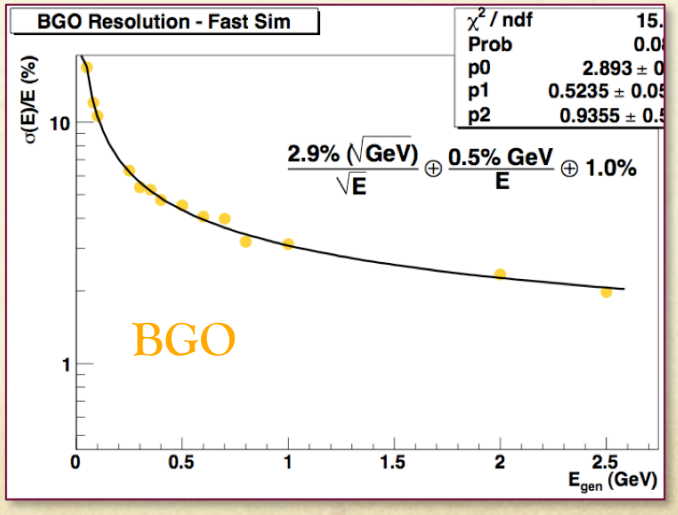
(From FullSim studies)

Validation results: FWD (I)

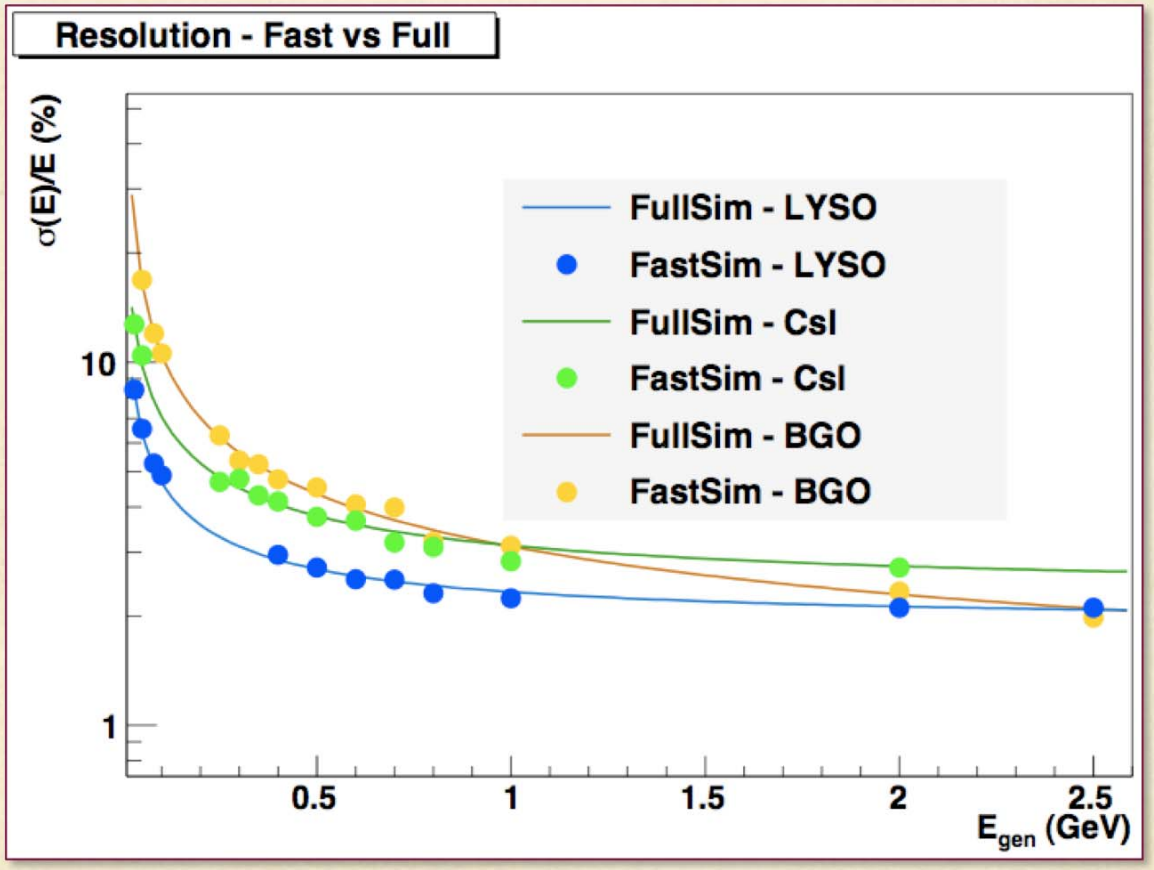
Single γ beams
FWD







Validation results: FWD (II)

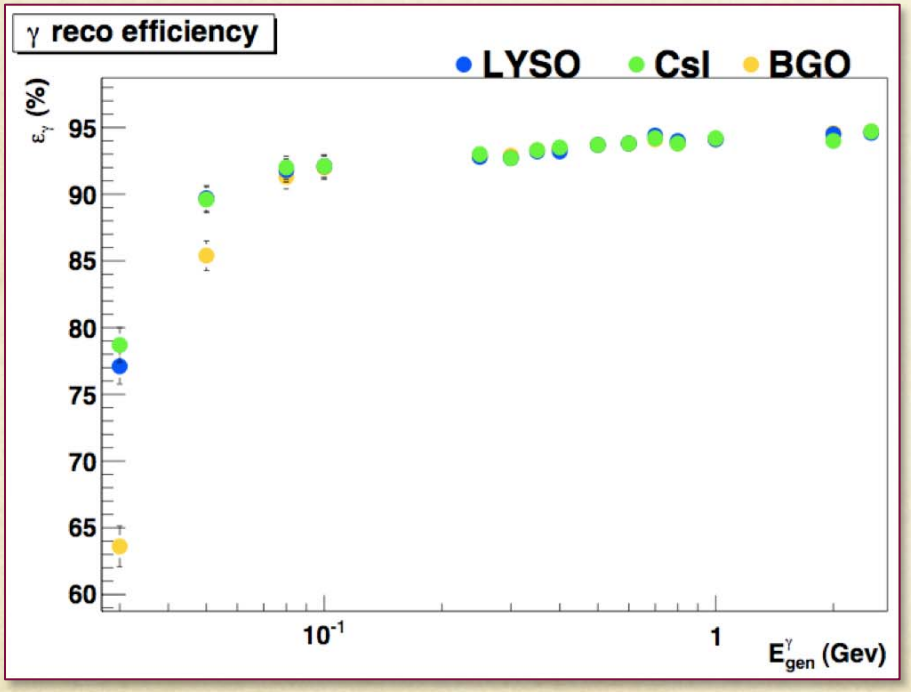


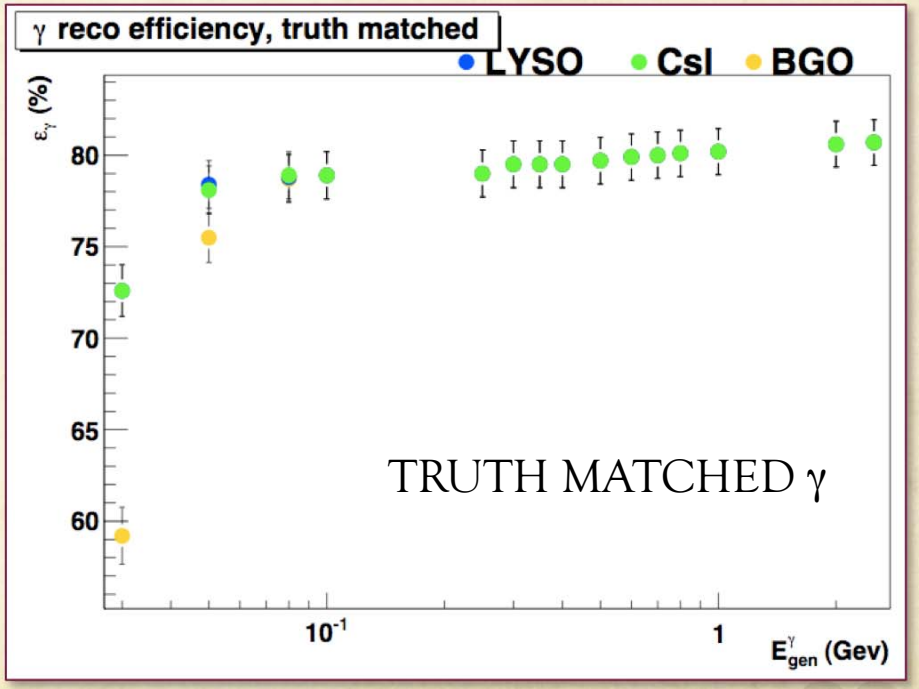
Single γ beams
FWD

- Similar check performed for the Barrel

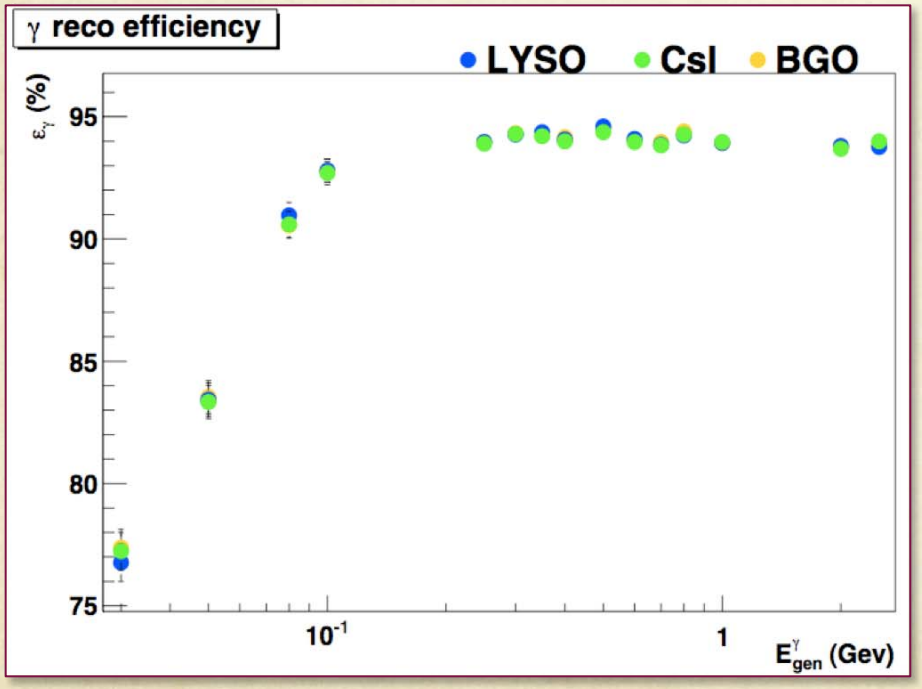
Results on γ/π^0

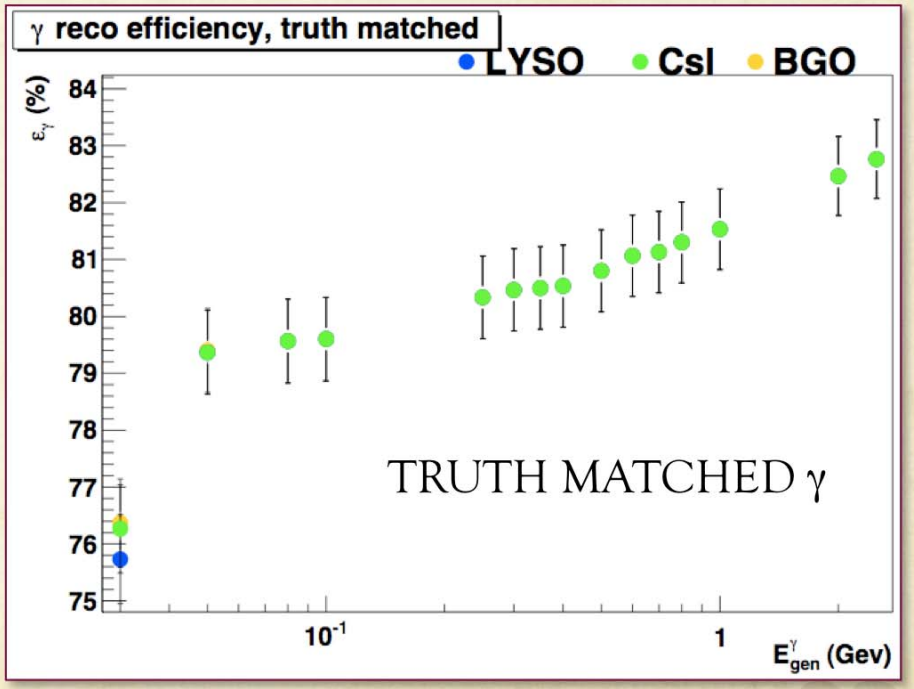
γ reco efficiency: FWD



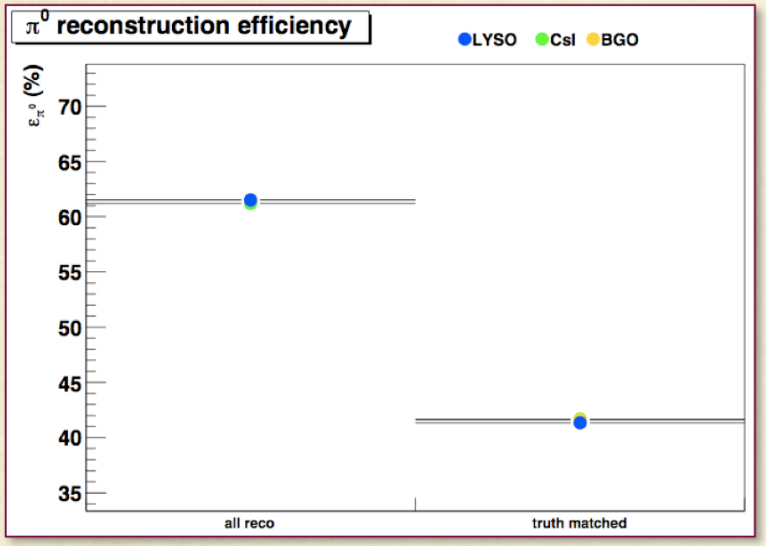


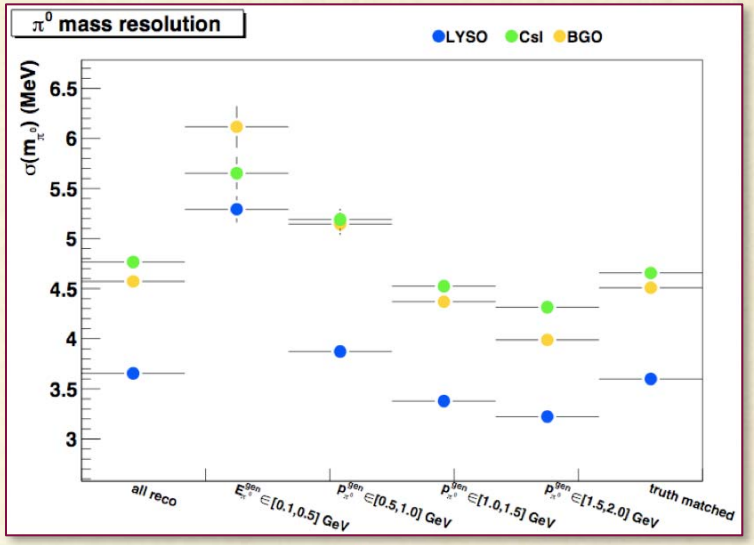
γ reco efficiency: Barrel+Fwd

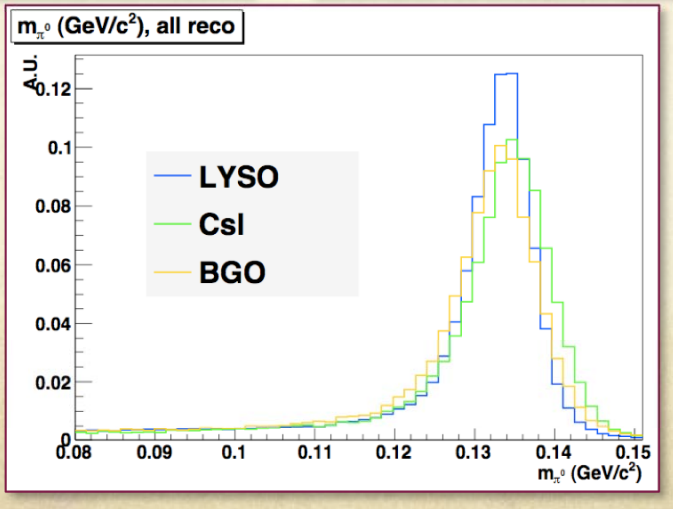




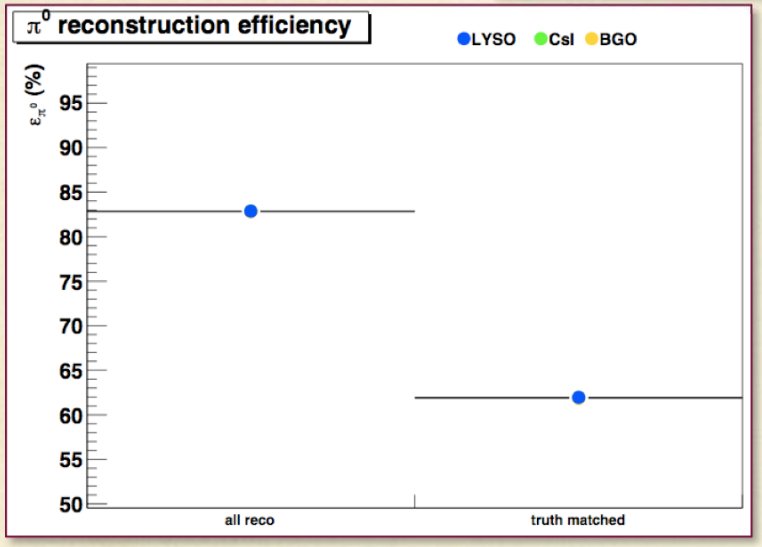
π^0 reco eff and mass resolution: FWD

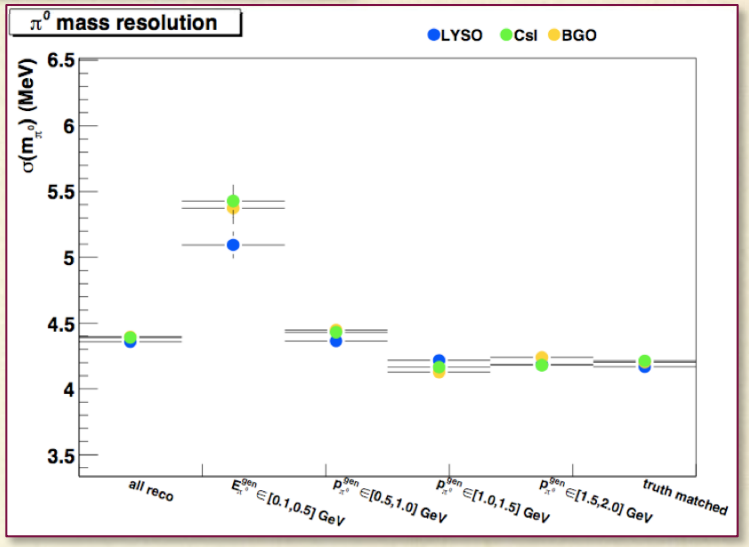


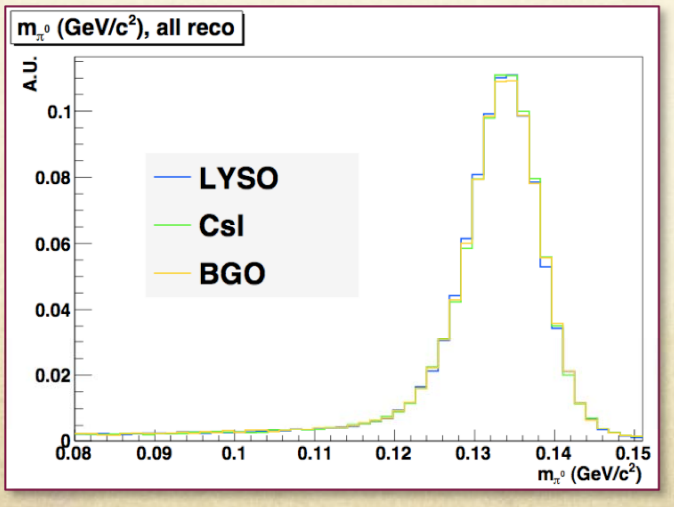




π^0 reco eff and mass resolution: Barrel + FWD







Conclusions

- Aim of the study presented today: modify FastSim EMC code to vary calorimeter resolution and evaluate impact of different EMC technologies on physics
- Experimental effects incorporated: electronic noise (OK as it is in official FastSim), calibration (new method with calib parameters independent from resolution), smearing (new)
- Satisfactory results from validation on single γ beams
- Single π^0/γ beam sample studied to compare different crystals:
  - FWD-only samples: LYSO has the best performances, as expected
  - FWD + BARREL: barrel performances dominate
- Next step: run on $B \rightarrow K^* \nu\nu$ and generic BB events, including machine bkg

Extra Slides

Smearing in FastSim

- Resolution parameterization: gaussian component + exponential tail

$$\text{gfluct} = \sqrt{\left(\frac{f_a}{E^{ep}}\right)^2 + f_b^2}$$

$$\text{efluct} = \sqrt{\left(\frac{c_{exp}}{E^{p_{exp}}}\right)^2 + d_{exp}^2}$$

par	fwd	brr	bwd
f_a	0.0102	0.0102	0.14
f_b	0.0	0.0	0.03
ep	0.264	0.264	0.5
c_{exp}	0.0165	0.0165	0.0
d_{exp}	0.0284	0.0284	0.0
p_{exp}	0.50	0.50	0.0

- determine parameters from BaBar data, corresponding to BaBar resolution:

$$\frac{\sigma(\mathrm{E})}{\mathrm{E}} = \frac{2.35\%}{\sqrt[4]{\mathrm{E}}} \oplus 1.35\%$$

- Not trivial to find a set of (6) parameters corresponding to a given resolution without data

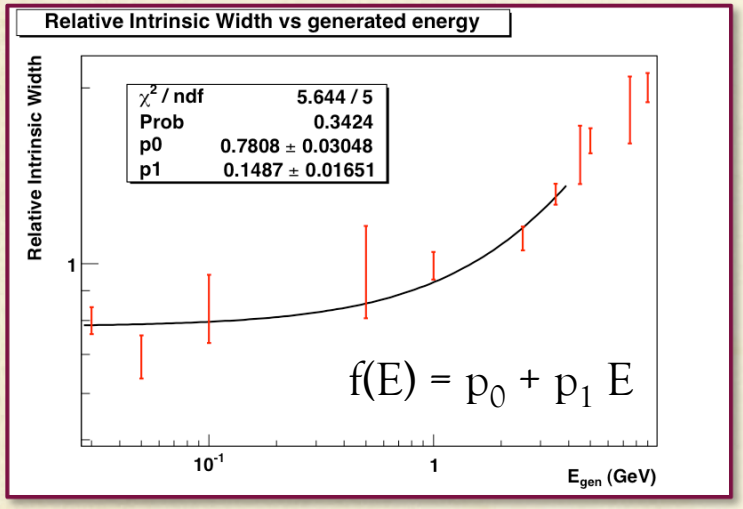
Calibration: Gaussian fits, Barrel + FWD

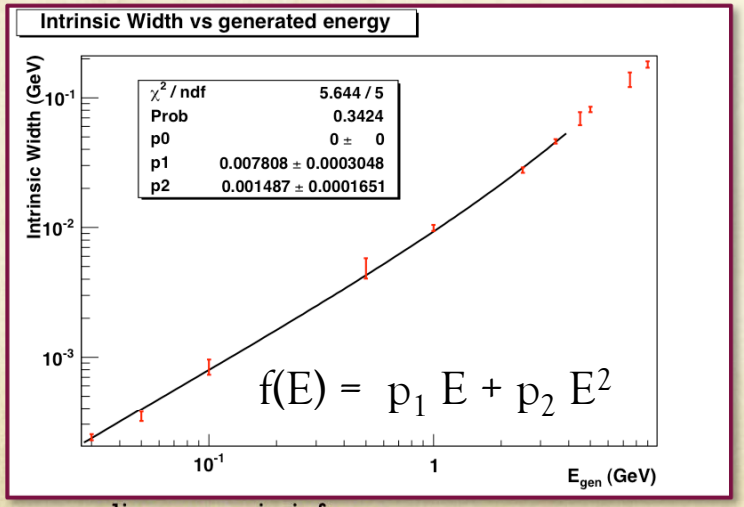
- Generate mono-energetic single gamma beams in barrel + fwd region, reconstruct without applying calibration, electronic noise algorithm, smearing (just clustering)
- Gaussian fit to reconstructed energy to determine peak position

E_{gen} (GeV)	E_{peak} (GeV)
0.03	0.0283 ± 0.0002
0.05	0.04742 ± 0.00002
0.08	0.07636 ± 0.00003
0.1	0.0958 ± 0.0001
0.15	0.1448 ± 0.0006
0.25	0.2423 ± 0.0009
0.5	0.4795 ± 0.0003
0.7	0.6685 ± 0.0008
0.8	0.7616 ± 0.0005
0.9	0.8553 ± 0.0005

E_{gen} (GeV)	E_{peak} (GeV)
1.0	0.9490 ± 0.0009
1.5	1.4178 ± 0.0021
2.0	1.8852 ± 0.0023
3.0	2.8175 ± 0.0017
4.0	3.746 ± 0.004
5.0	4.651 ± 0.003
6.0	5.559 ± 0.08
7.0	6.456 ± 0.006
8.0	7.358 ± 0.017
9.0	8.242 ± 0.011

2. “Intrinsic” width: Barrel





Single γ beams
Barrel + FWD

E_{gen} (MeV)	σ(E) (MeV)	σ(E)/E
30	0.240 ± 0.013	0.8%
50	0.347 ± 0.029	0.7%
100	0.844 ± 0.113	0.8%
500	4.92 ± 0.09	1.0%
1000	9.94 ± 0.05	1.0%
2500	27.67 ± 0.13	1.1%
3500	46.10 ± 0.19	1.3%

FullSim : Barrel + FWD