Results from LHCf

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On behalf of the LHCf collaboration

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Results from LHCf

(1) Forward photon energy spectra
in the psudo-rapidity ranges of η>10.94 and 8.81<η<8.9

O. Adriani, et al. arXiv:1104.5294v2, CERN-PH-EP-2011-061

(2) Ongoing analyses,

- P_T distribution of forward photons,
- Neutrons, π^0, η, K^0

(Short reminder about the LHCf experiment)

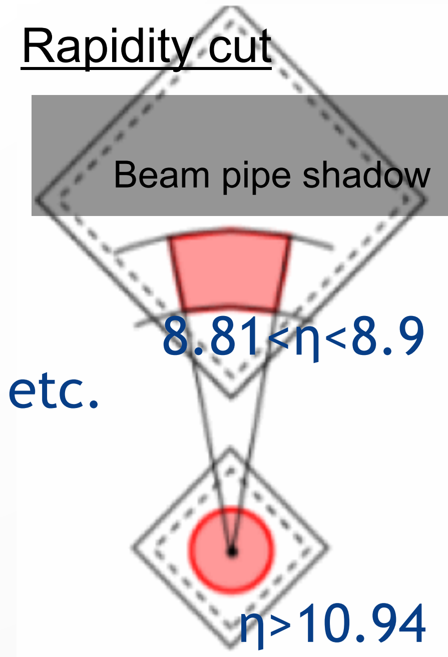
LHCf is a forward experiment, which covers the rapidity region of > 8.4 as ZDC's. The LHCf detectors have two small sampling and positioning calorimeter towers to measure the energy and the impact position of energetic secondary individually. LHCf had operations at 900GeV and 7TeV p-p collisions in 2009 and 2010

(1) Forward photon energy spectra

- DATA
  - 15 May 2010 17:45-21:23, at Low Luminosity $6x10^{28}cm^{-2}s^{-1}$
  - 0.68 nb-1 for Arm1, 0.53nb-1 for Arm2
- Analysis Procedure
  1. Energy Reconstruction from total energy deposition in a tower with some corrections, shower leakage out etc.
  2. Particle Identification by shape of longitudinal shower development.
  3. Cut multi-particle events.
  4. Two Psudo-rapidity selections, η>10.94 and 8.81<η<8.9.
  5. Combine spectra between the two detectors.

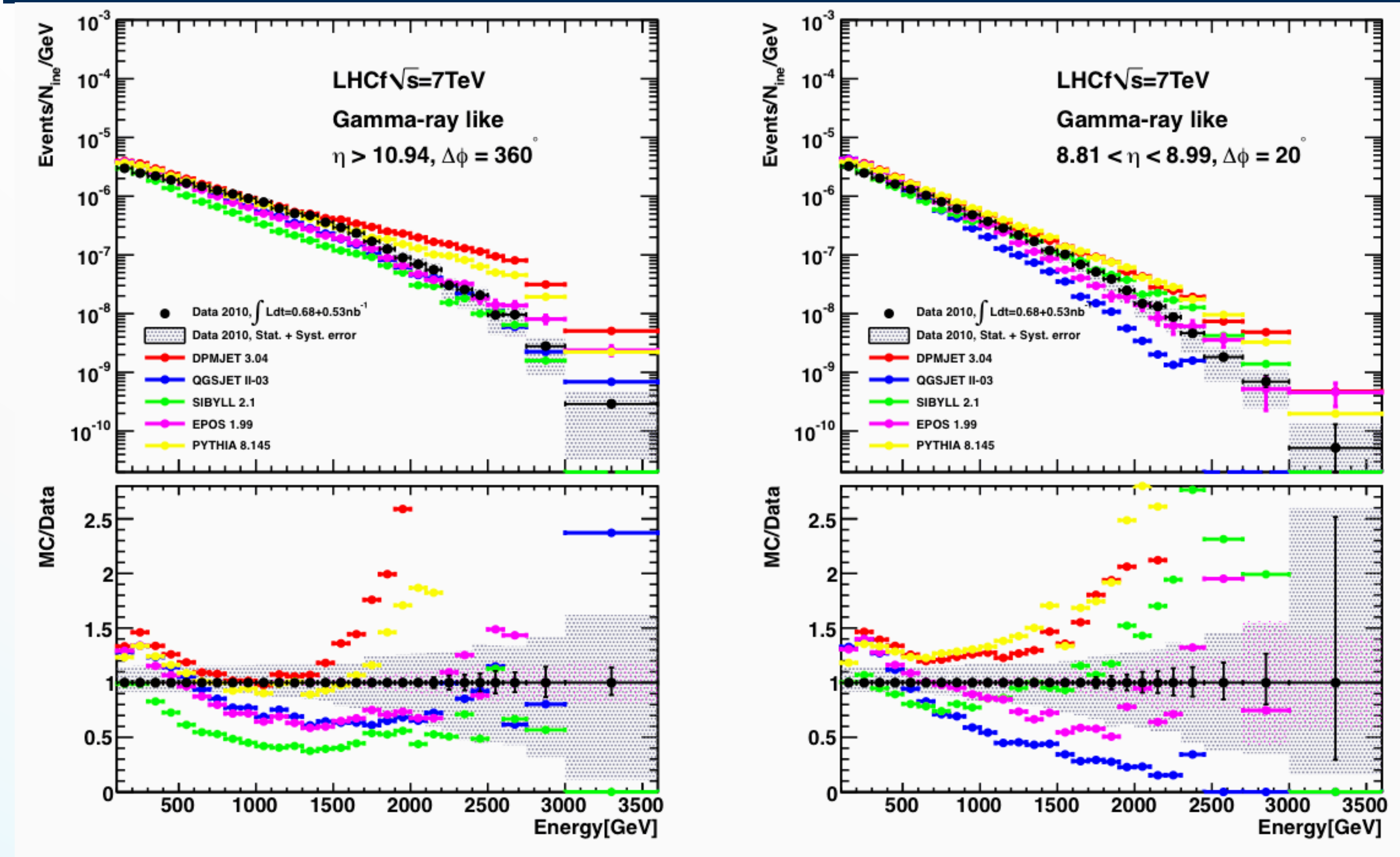
  ➔Measured spectrum ≅ Inclusive photon spectrum because of the bias of multi-hit cut. (±10%)
- Comparison with 5 MC's (next slide)

  DPMJET3.04, QGSJETII-03, SYBILL2.1, EPOS1.99 and PYTHIA 8.145 (with the default parameters)



(1) Forward photon energy spectra

DPMJET 3.04 QGSJETII-03 SIBYLL 2.1 EPOS 1.99 PYTHIA8.145

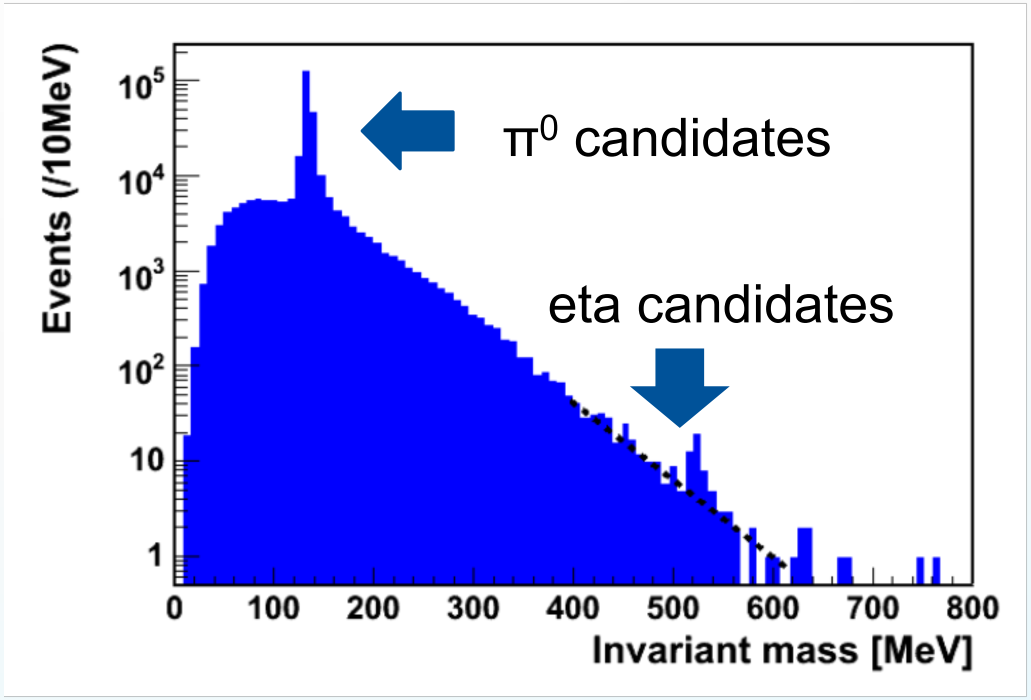


Gray hatch : Systematic Errors

Violet hatch: Statistics errors of a MC

(2) Ongoing analyses

- $\sqrt{s}$=900GeV p-p
  - Energy spectra for photons and neutrons
- $\sqrt{s}$=7eV p-p
  - Energy spectra for photons with wider rapidity range. (➔η>8.5)
  - P_T distribution of γ's (<0.9GeV/c @ 2TeV γ)
  - Neutrons (ΔE~30%)
  - π^0 ($E_{\pi 0}$>600GeV)
  - Eta (E_{eta}>2TeV),
  - K^0

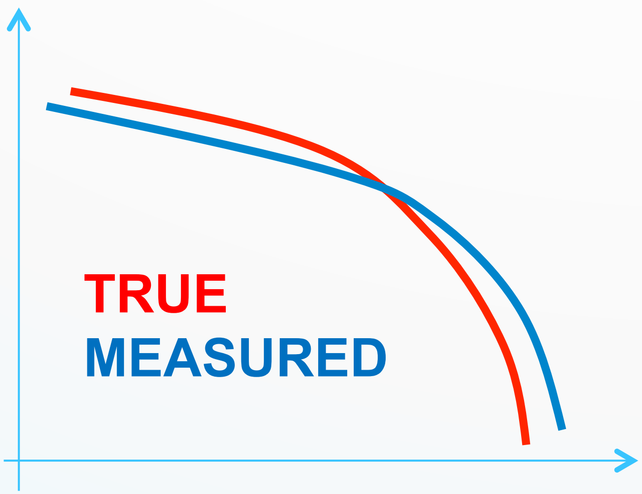


Backup slides

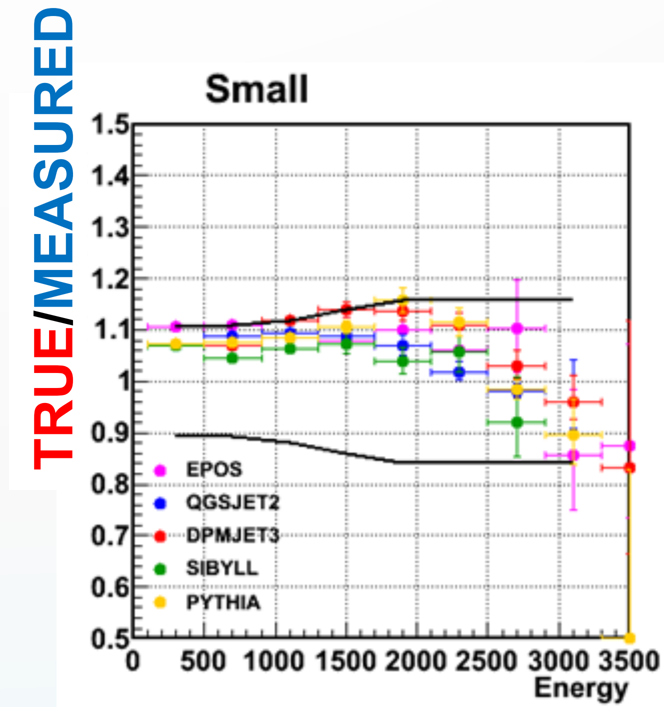
Analysis 3. -Multi-hit identification-

Effect of Multi-hit cut on spectra

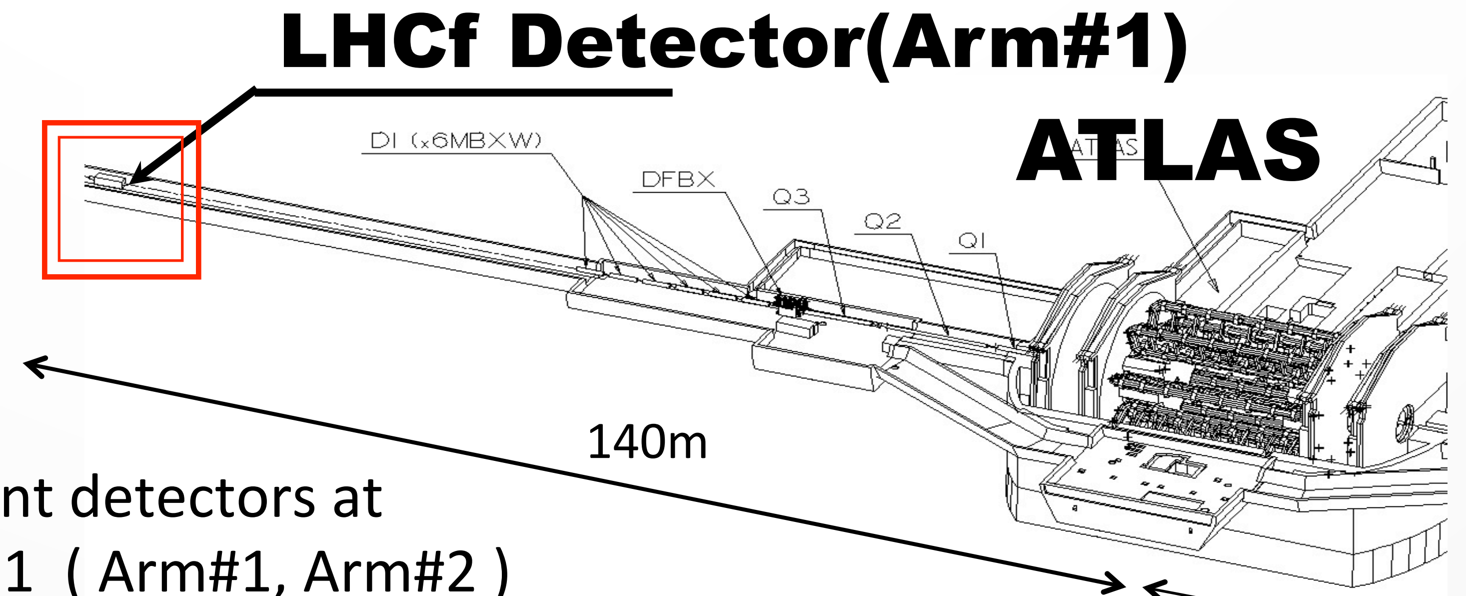
- ✓ Suppression due to multi-hit cut at medium energy
- ✓ Overestimate due to multi-hit detection inefficiency at high energy (mis-identify multi photons as single)
- ✓ No correction applied, but same bias included in MC to be compared



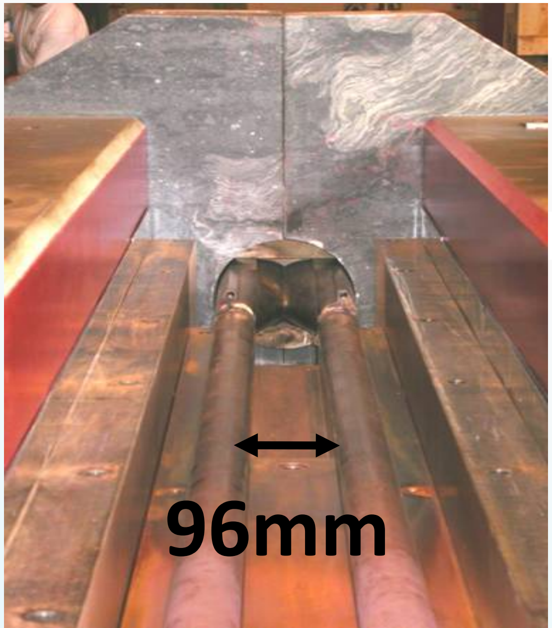
True: photon energy spectrum at the entrance of calorimeter

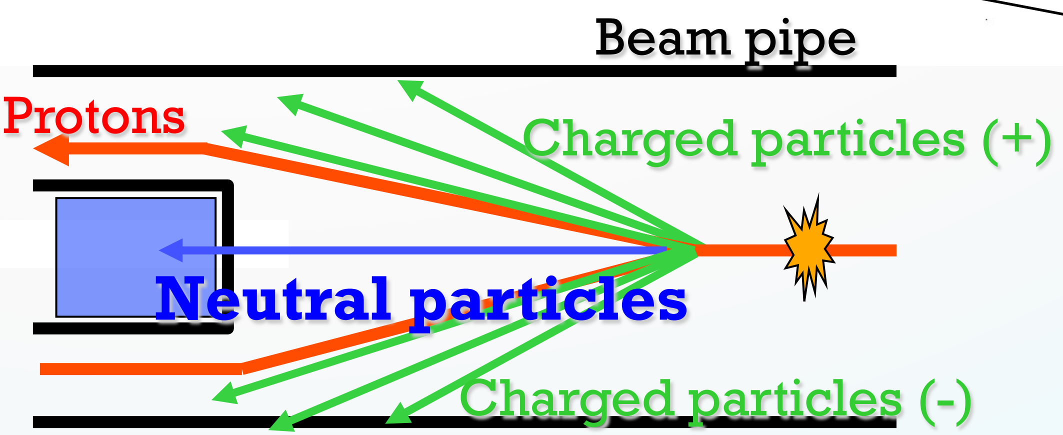


Detector Location



Two independent detectors at either side of IP1 (Arm#1, Arm#2)





TAN -Neutral Particle Absorber-

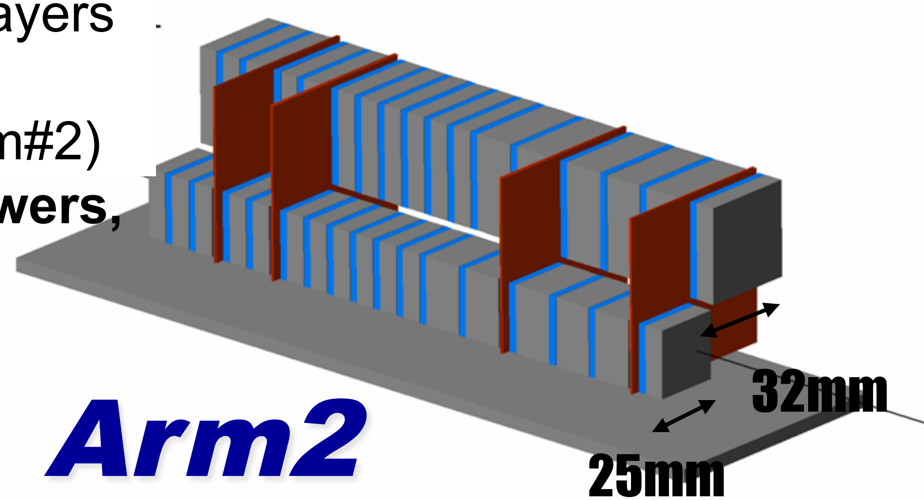
transition from one common beam pipe to two pipes

Slot : 100mm(w) x 607mm(H) x 1000mm(T)

The LHCf Detectors

Sampling and Positioning Calorimeters

- W (44 r.l , $1.7\lambda_I$) and Scintillator x 16 Layers
- 4 positioning layers
  XY-SciFi(Arm1) and XY-Silicon strip(Arm#2)
- **Each detector has two calorimeter towers, which allow to reconstruct π^0**



Expected Performance

Energy resolution (> 100GeV)

< 5% for photons

30% for neutrons

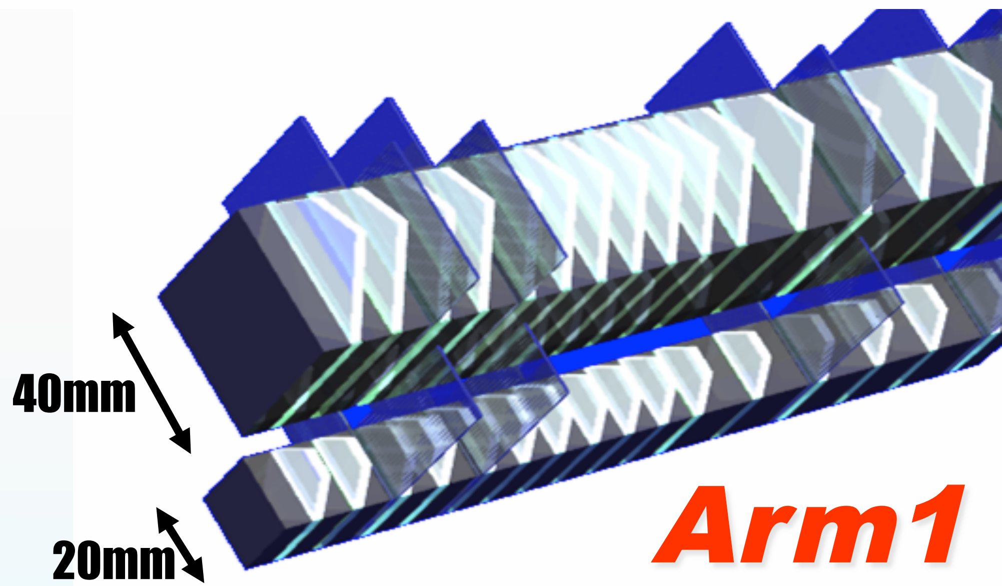
Position resolution

< 200μm (Arm#1)

40μm (Arm#2)

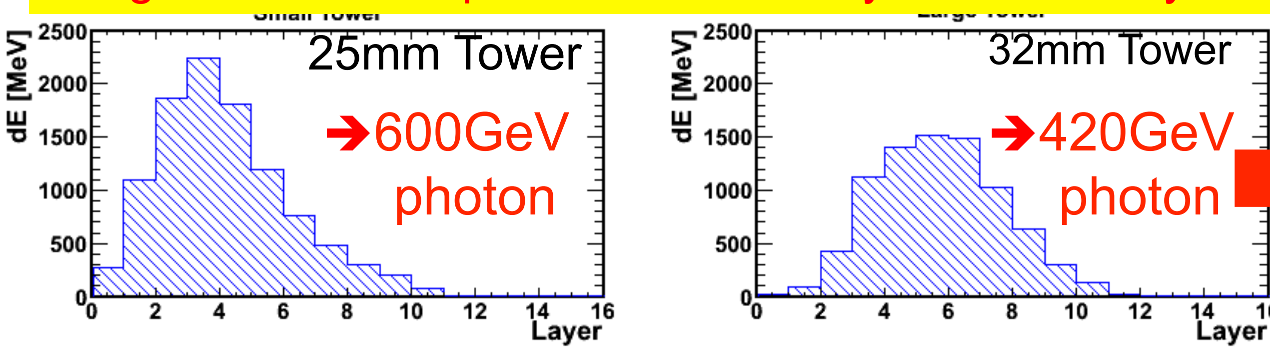
Front Counter

- thin scintillators with 80x80mm^2
- **To monitor beam condition.**
- **For background rejection of beam-residual gas collisions by coincidence analysis**



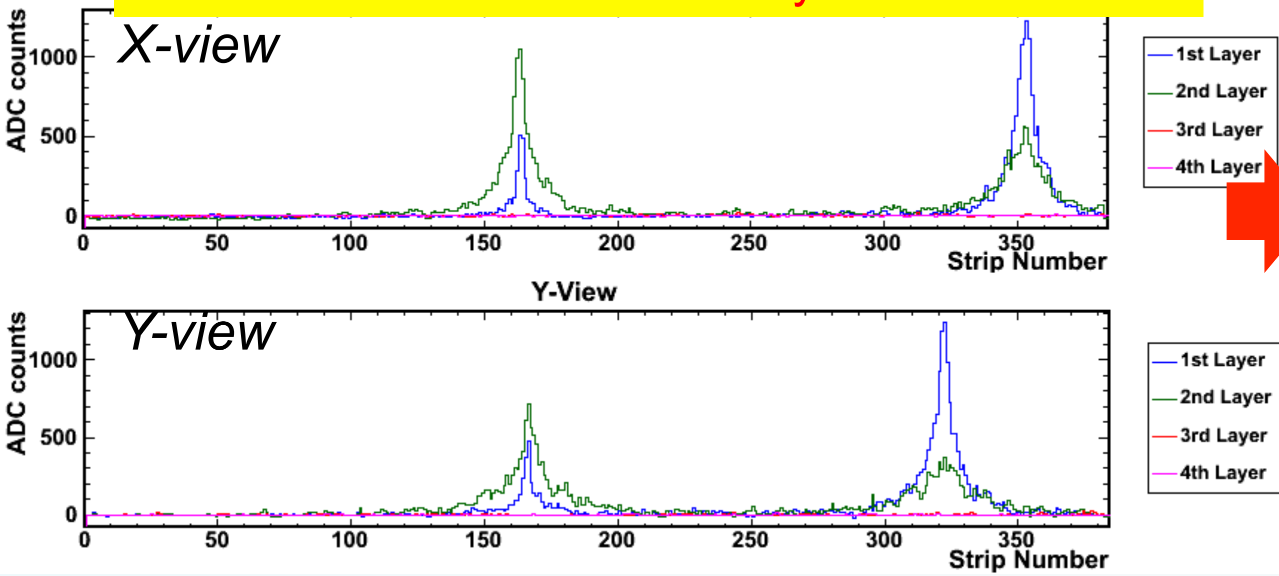
Event sample

Longitudinal development measured by scintillator layers



Total Energy deposit
➔Energy
Shape
➔PID

Lateral distribution measured by silicon detectors

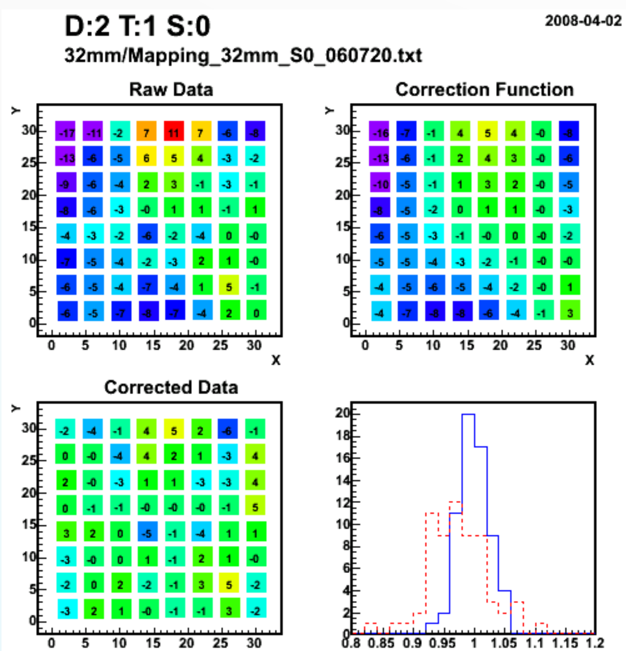


Hit position,
Multi-hit search.

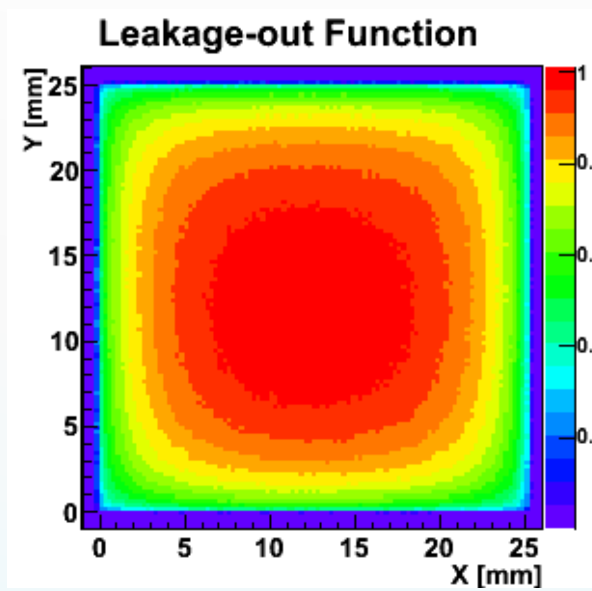
Analysis 1. - Energy reconstruction -

- Energy reconstruction : $E_{photon} = f(\Sigma(dE_i))$ (i=2,3,…,13)

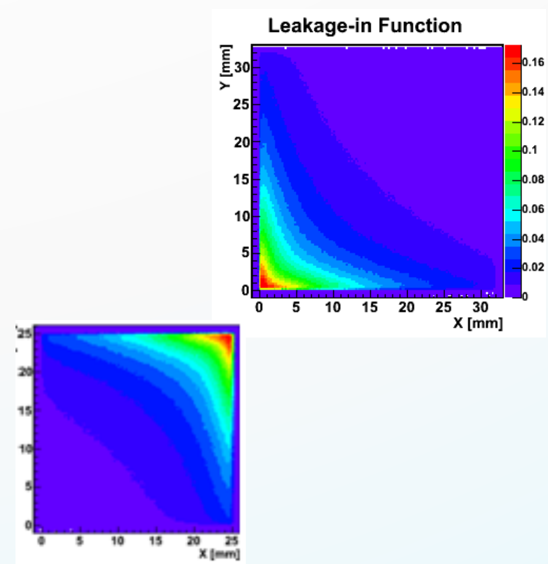
  ($dE_i = AQ_i$ determined at SPS. f() determined by MC.
  E : EM equivalent energy)
- Impact position from lateral distribution
- Position dependent corrections
  - Light collection non-uniformity
  - Shower leakage-out
  - Shower leakage-in (in case of two calorimeter event)



Light collection nonuniformity



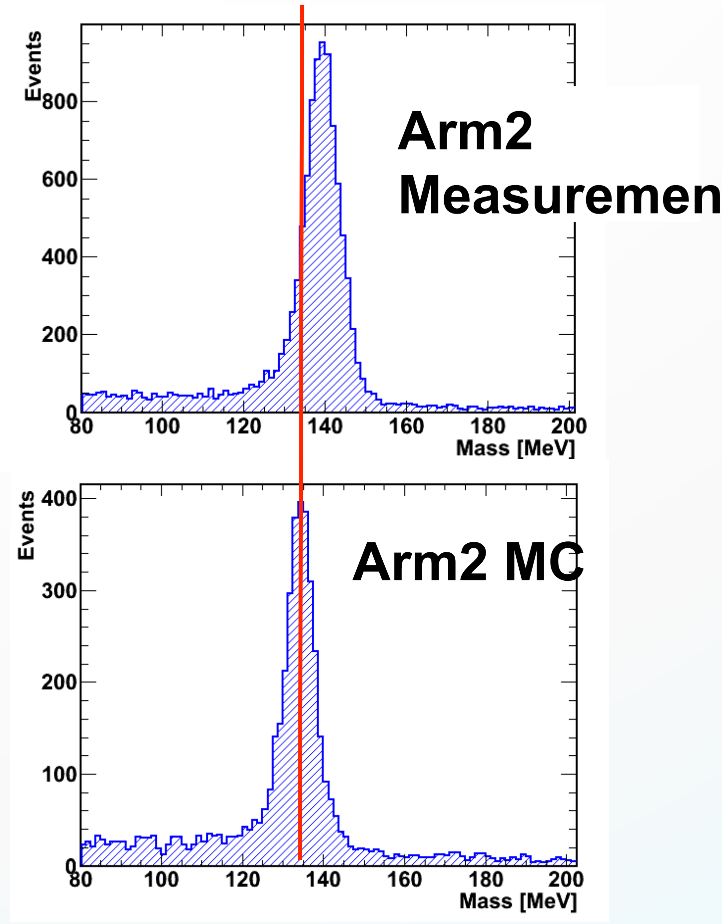
Shower leakage-out

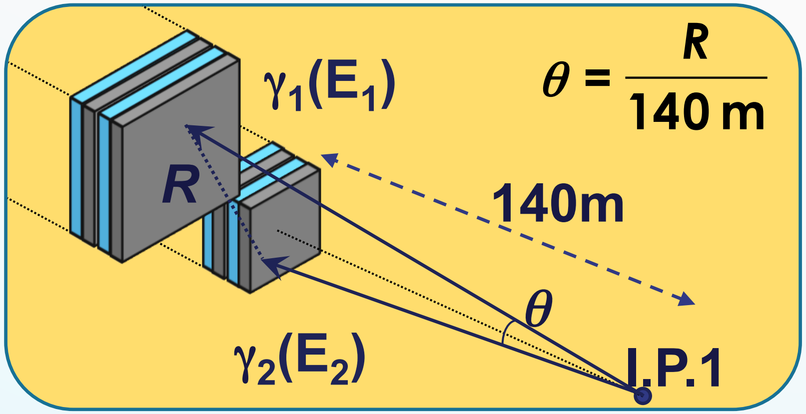


Shower leakage-in

Analysis 1. - Energy reconstruction -

- Energy scale can be checked by π^0 identification from two tower events.
- Mass shift observed both in Arm1 (+7.8%) and Arm2 (+3.7%)
- No energy scaling applied, but assigned the shifts in the systematic error in energy





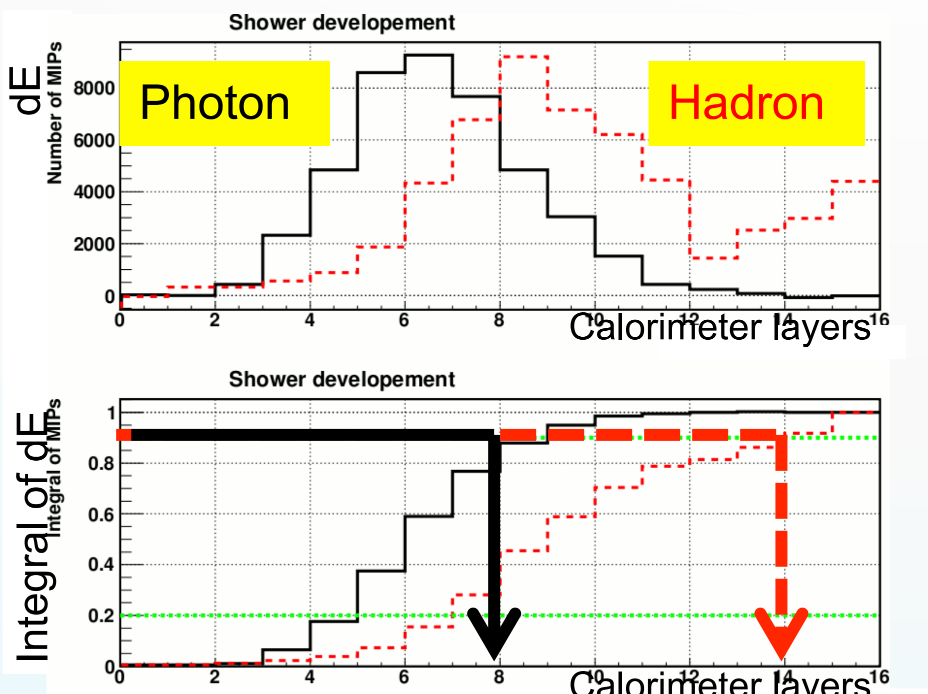
$$M = \theta\sqrt{(E_1 x E_2)}$$

Analysis 2. – Particle Identification -

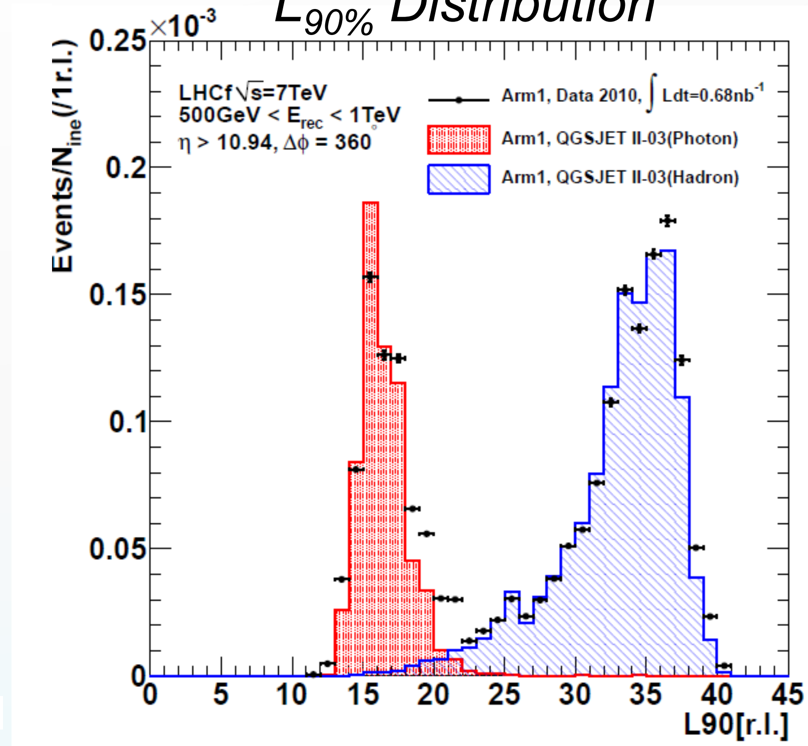
- Event selection and correction
  - Select events $<L_{90\%}$ threshold and multiply P/ε
    ε (photon detection efficiency) and P (photon purity)
  - By normalizing MC template $L_{90\%}$ to data, ε and P for certain $L_{90\%}$ threshold are determined.

Calorimeter Depth

Elemag: 44r.l.
Hedonic: 1.7λ



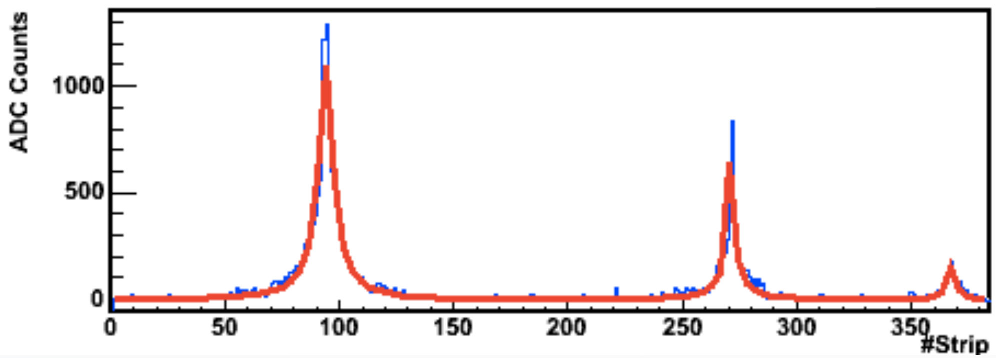
$L_{90\%}$ Distribution

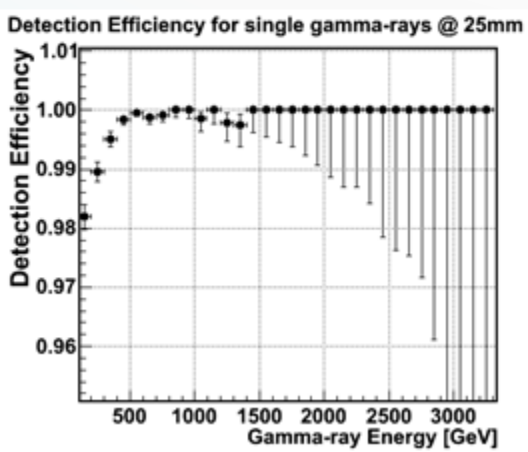


Analysis 3. -Multi-hit identification-

- Event cut of multi-peak events,
  - Identify multi-peaks in one tower by position sensitive layers.
  - Select only the single peak events for spectra.

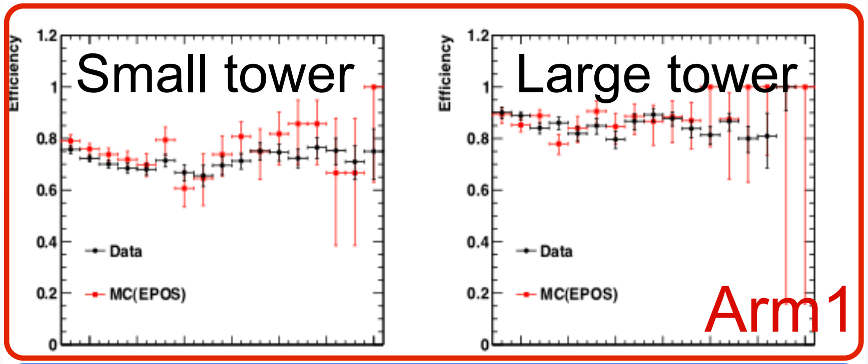
An example of multi peak event

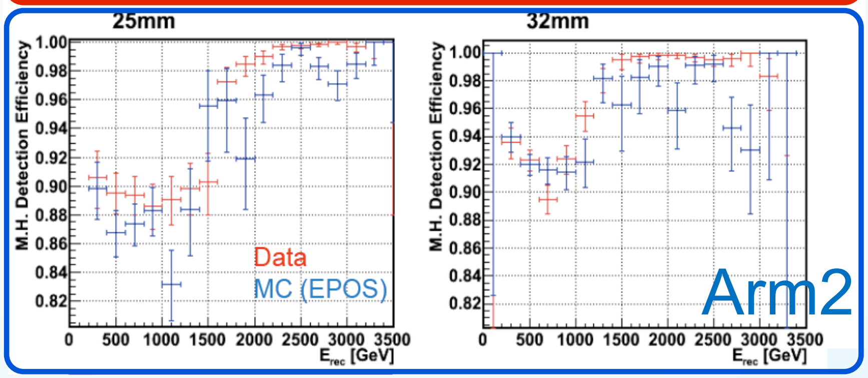




Single hit detection efficiency

Double hit detection efficiency

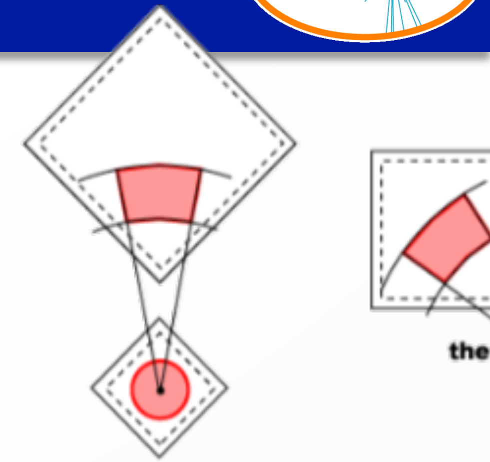


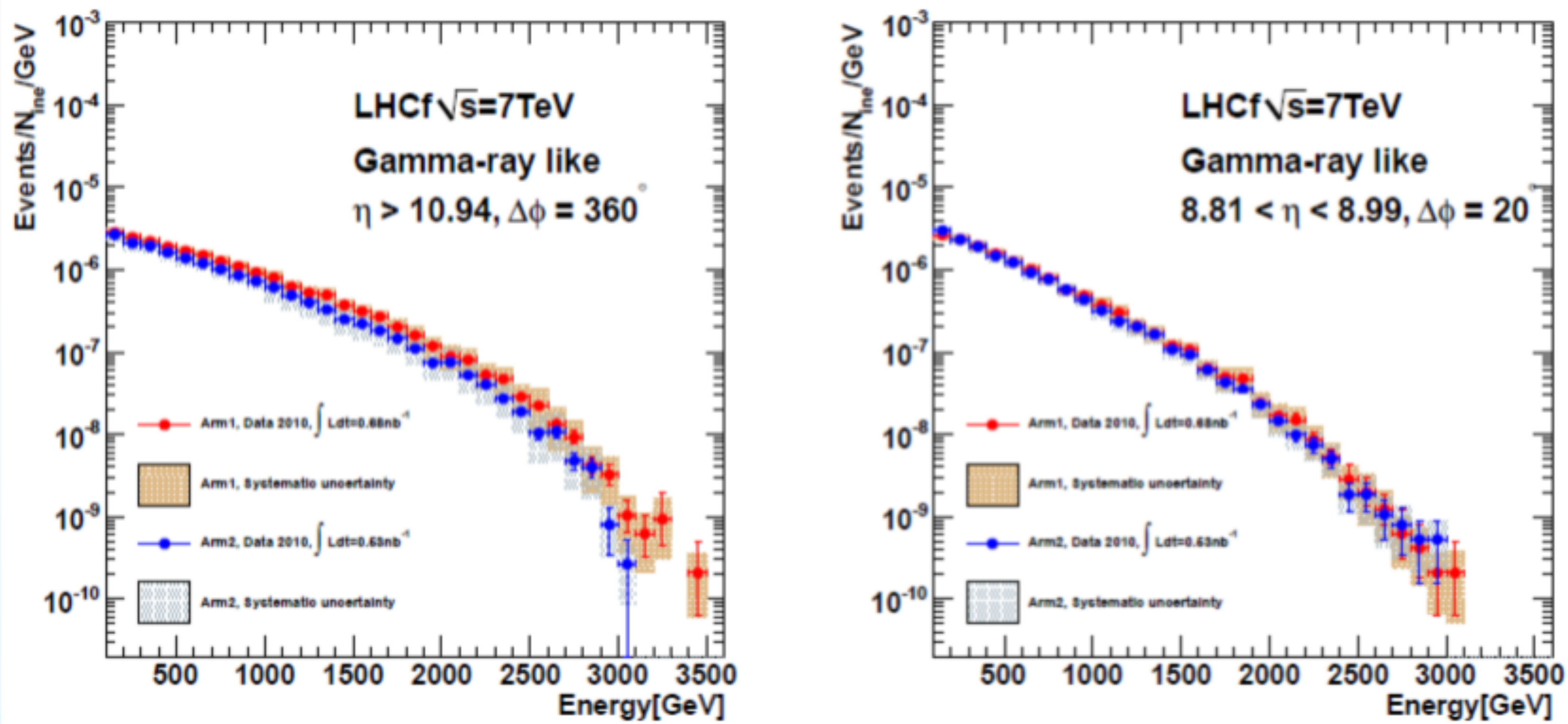


Analysis 4 and 5. –Rapidity cut and combine-

- Psudo-rapidity selection, η>10.94 and 8.81<η<8.9
- Normalized by number of inelastic collisions with assumption as inelastic cross section of 71.5mb
- Spectra in the two detectors are consistent within errors.

➔ Combined between spectra of Arm1 and Arm2



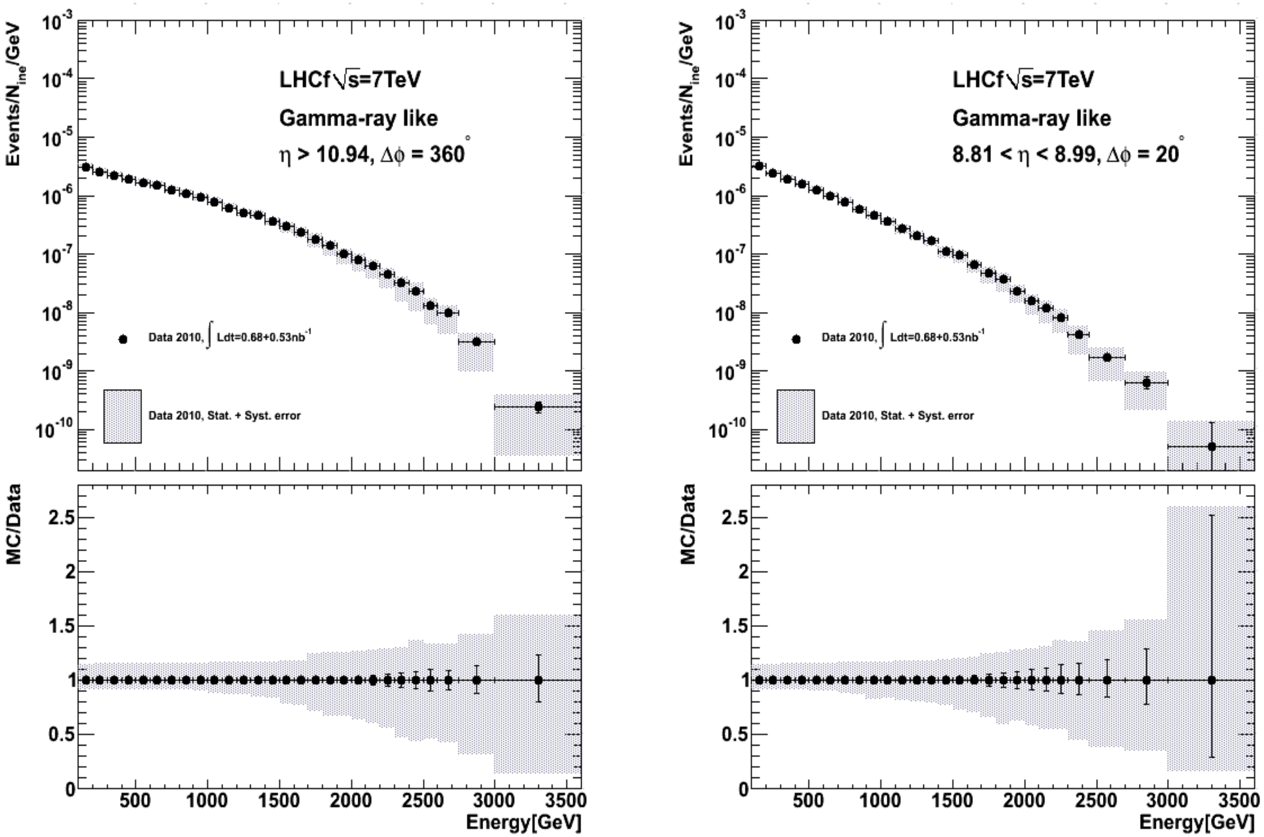


Arm1 detector **Arm2 detector** Filled area : uncorrelated systematic error

Results - Combined spectra-

Error bars : statistical Error

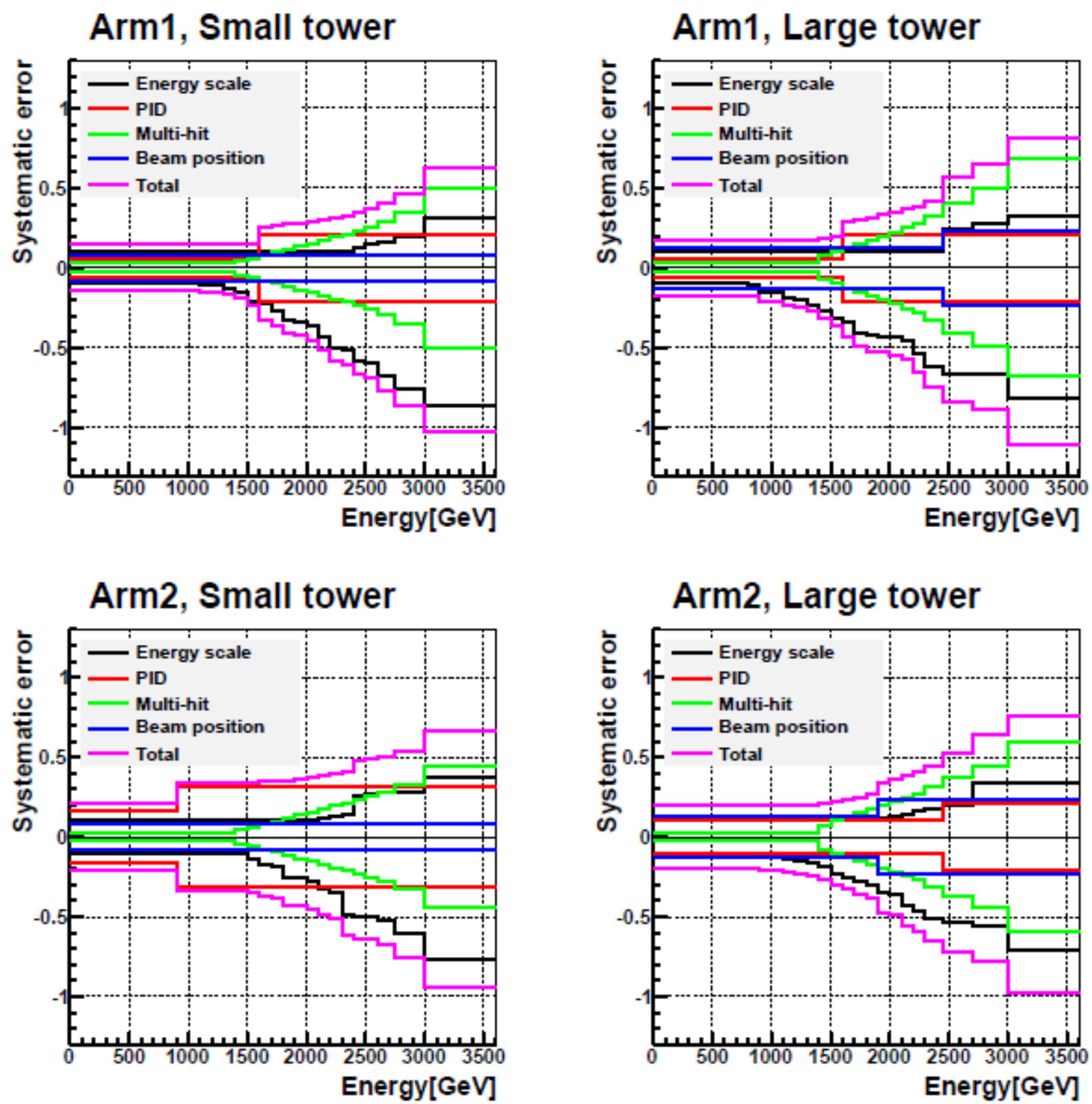
Gray hatch : Systematic Errors



Sources of Systematic errors

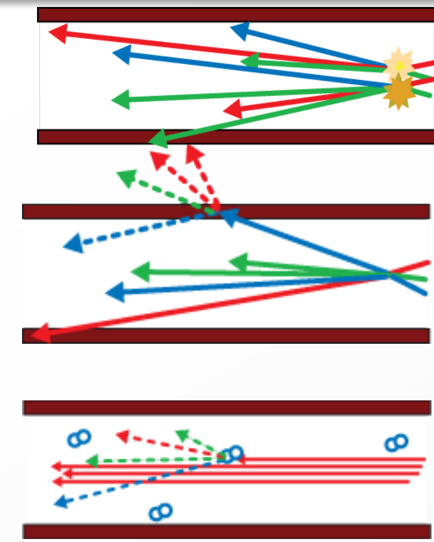
- Energy Scale
- Beam Center
- Multi-Hit cut performance
- PID
- Number of inelastic collisions

Summary of systematic errors

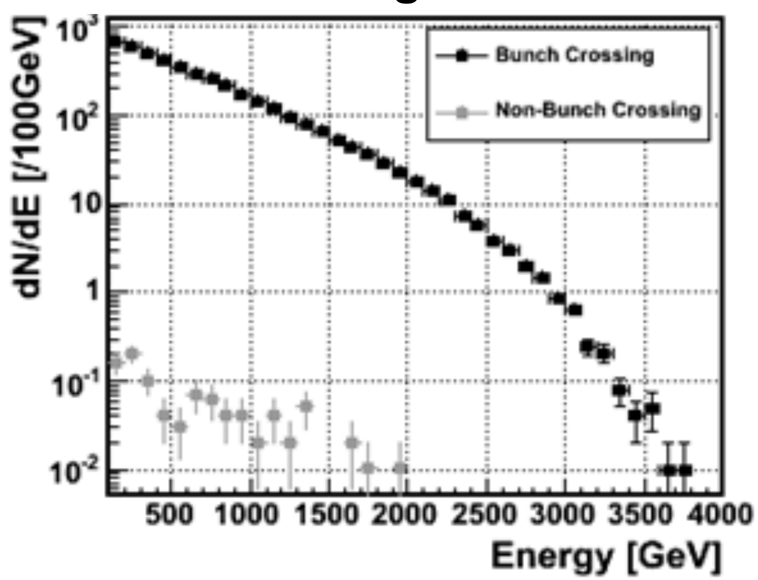


- Backgrounds -

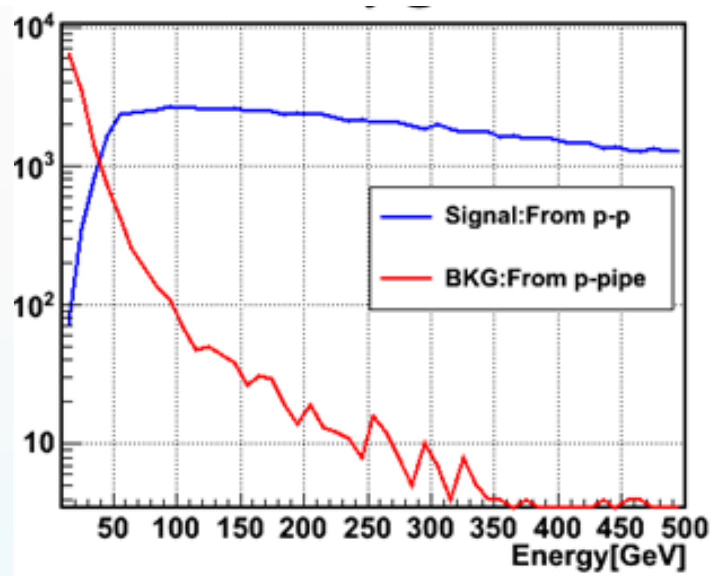
- Pileup of collisions in one beam crossing
  - Low Luminosity $6 \times 10^{28} cm^{-2} s^{-1}$
    - ➔ 7% pileup at collisions, 0.2% at the detectors.
- Collisions between secondary's and beam pipes
  - Very low energy particles. A few % at 100GeV
- Collisions between beams and residual ga
  - It can be estimated by data with non-crossing bunches.
    - ➔ <0.1%



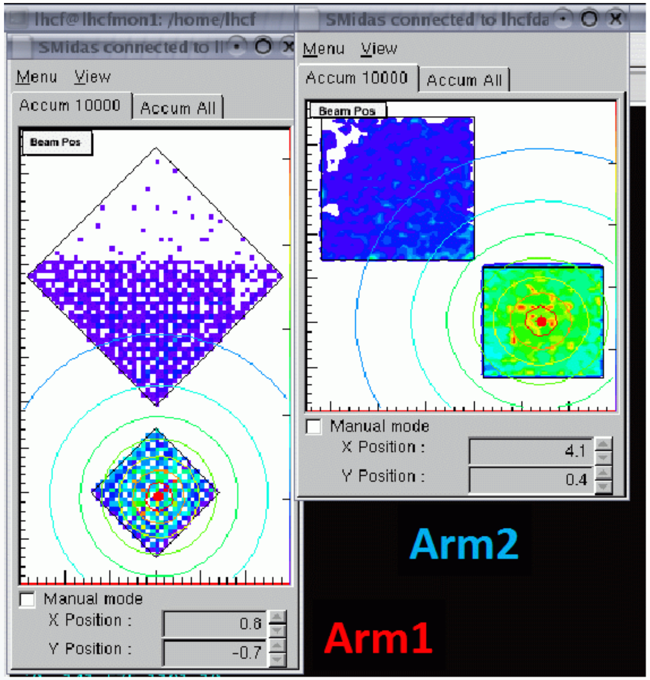
Beam-Gas backgrounds



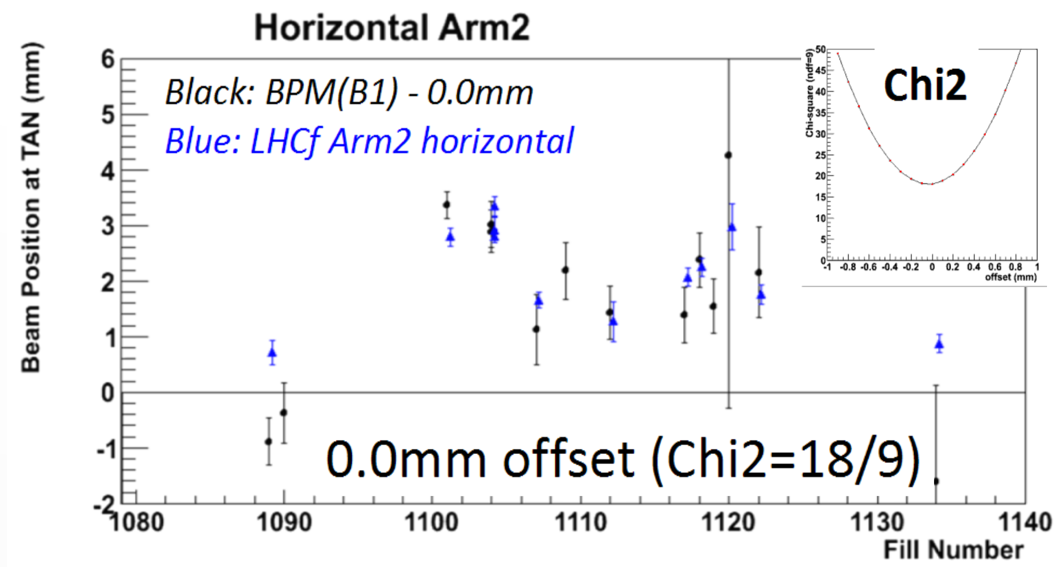
Secondary-beam pipe backgrounds



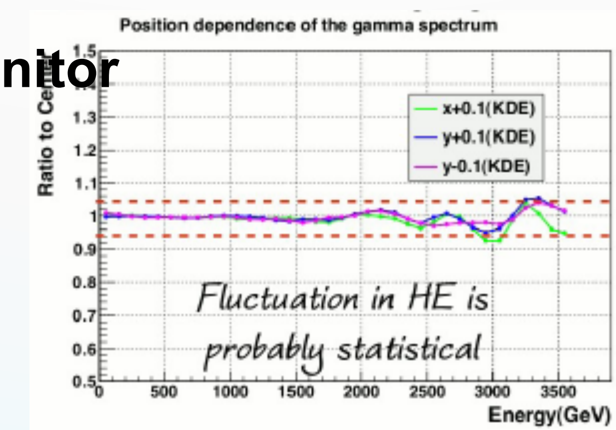
Beam center measurement

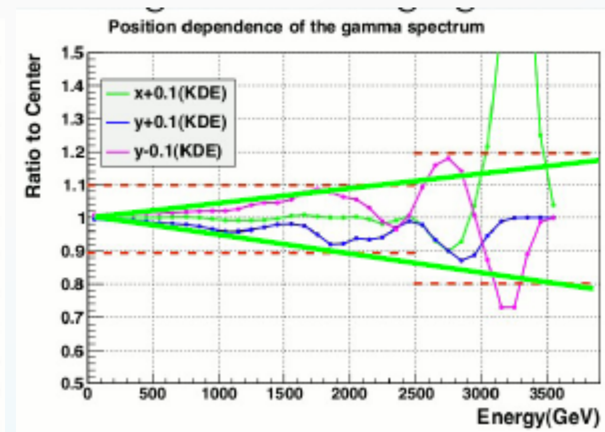


LHCf online hit-map monitor



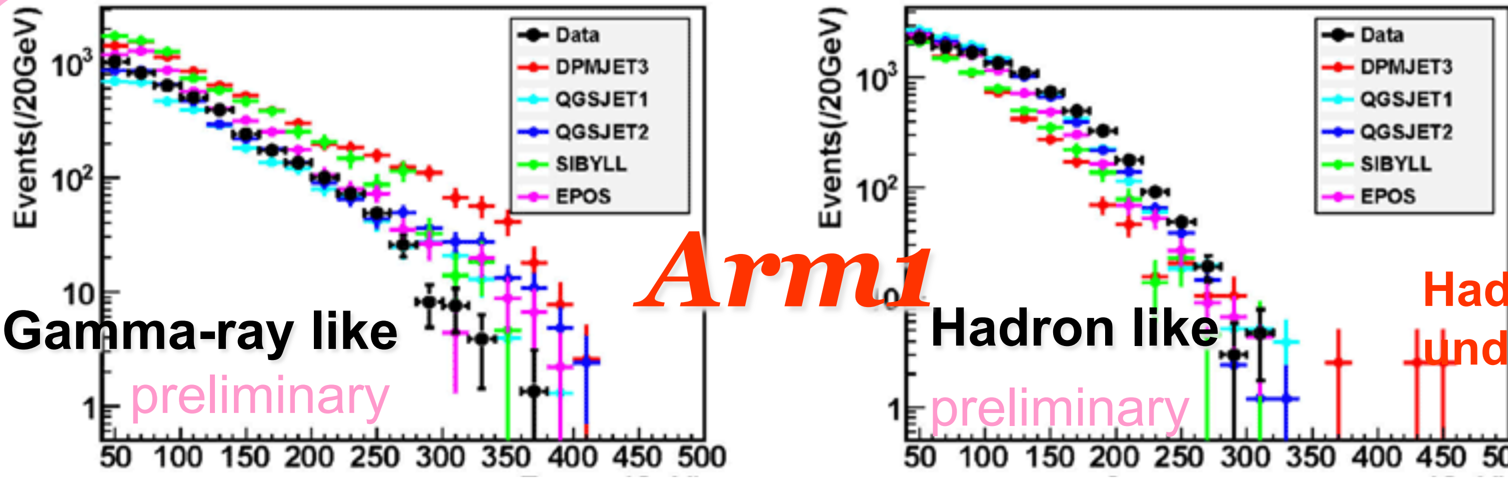
Beam center LHCf vs BPMSW





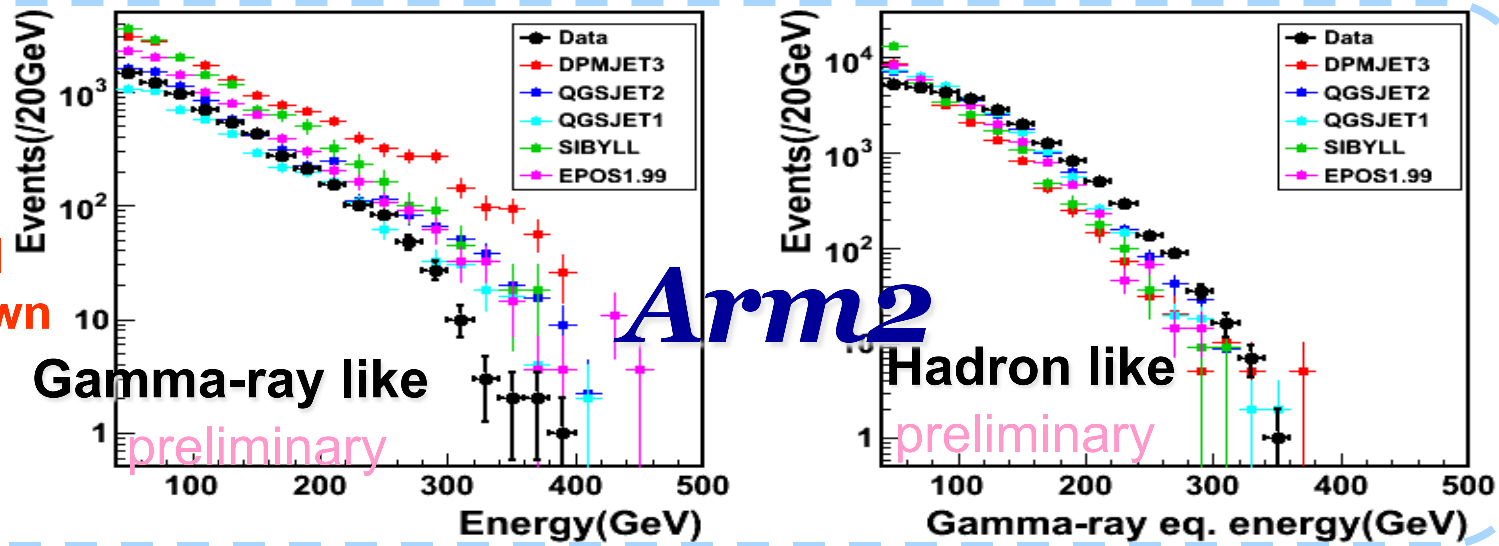
Effect of 1mm shift in the final spectrum

Energy Spectra at 900GeV



Hadron response under study

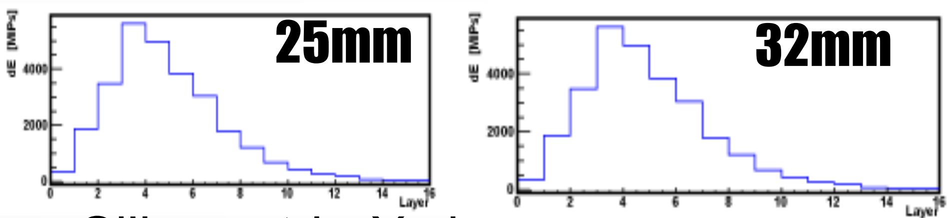
Only statistical errors are shown



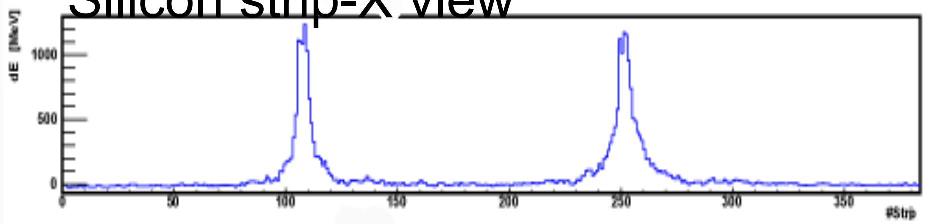
The spectra are normalized by number of gamma-ray and hadron like events
The detector response for hadrons and the systematic error are under study.

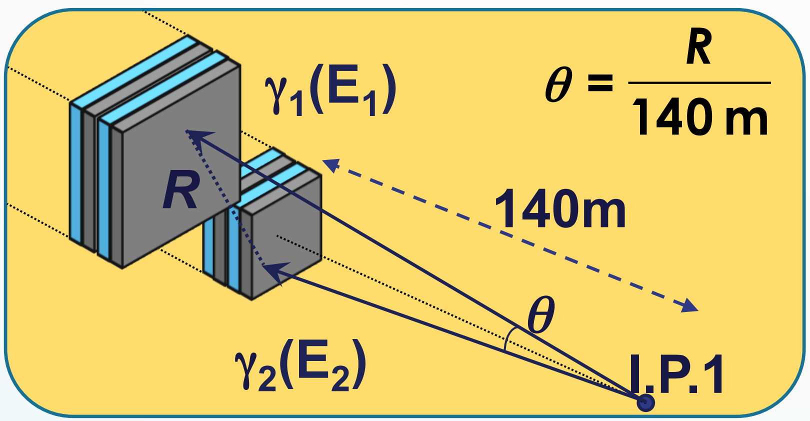
π^0 reconstruction

An example of π^0 events



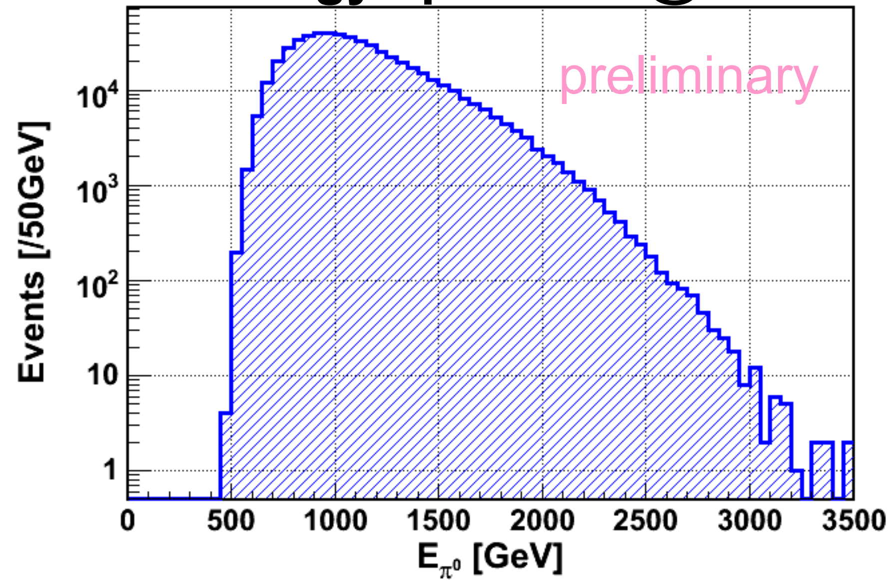
Silicon strip-X view



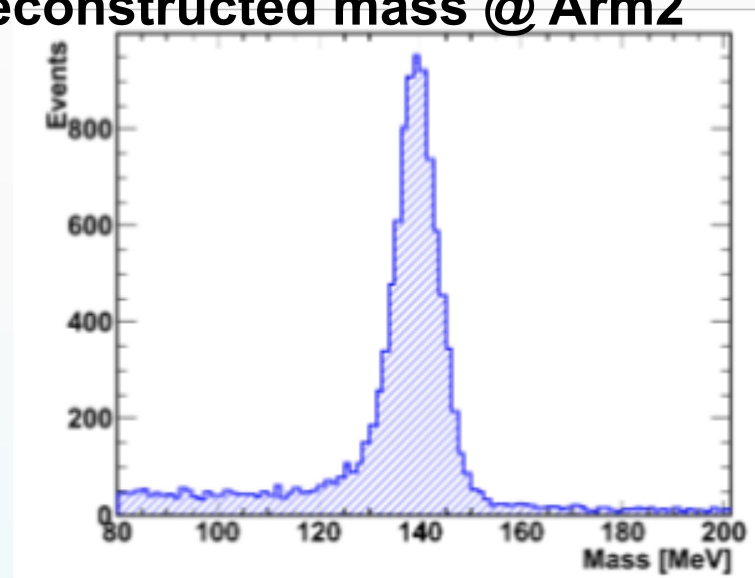


- Pi0's are a main source of electromagnetic secondaries in high energy collisions.
- The mass peak is very useful to confirm the detector performances and to estimate the systematic error of energy scale.

measured energy spectrum @ Arm2

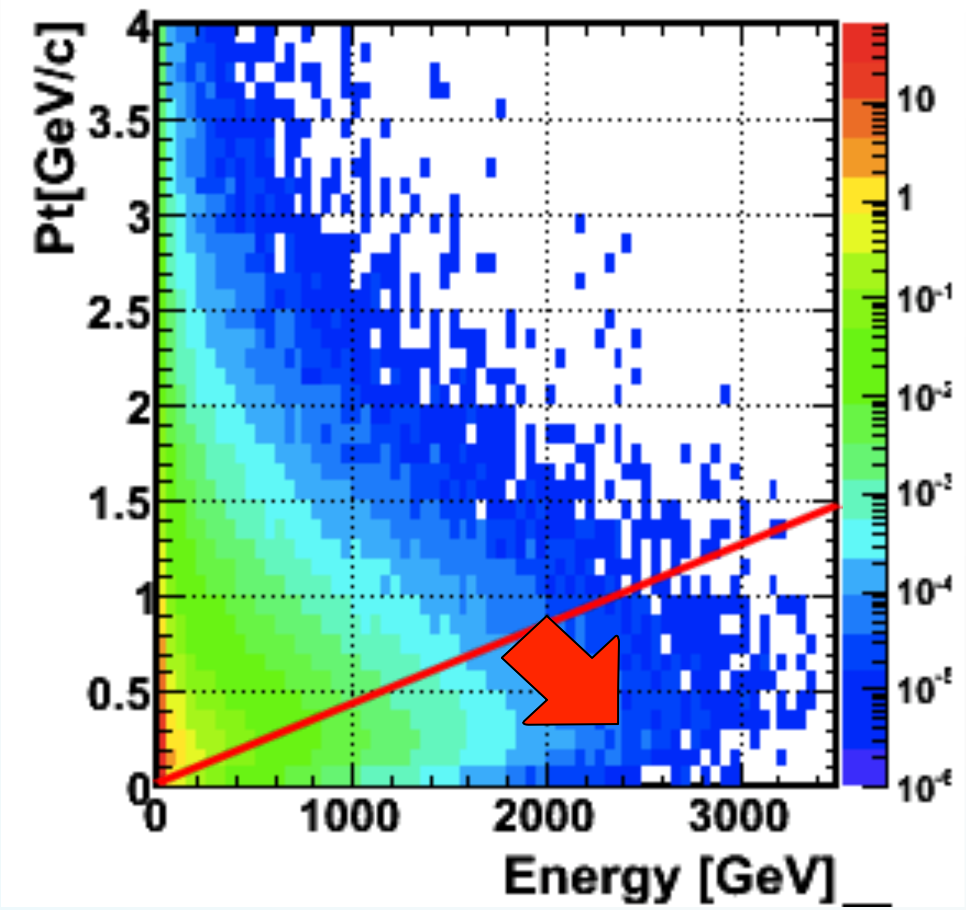


Reconstructed mass @ Arm2



P_T distribution for photons

pp 7TeV, EPOS



Front Counter

- ✓ Fixed scintillation counter
- ✓ $L = C \times R_{FC}$; conversion coefficient calibrated during VdM scans