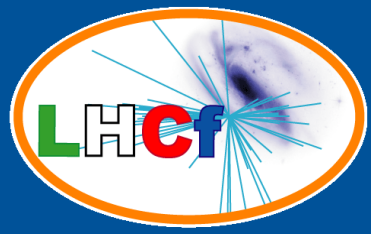
Forward photon energy spectrum at LHC 7TeV p-p collisions measured by LHCf

Hiroaki MENJO
(KMI, Nagoya University, Japan)
On the held of the LHCf collaboration



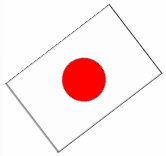
RICAP 2011, Roma, Italy, 25-27 May 2011

Contents

LHCf is a LHC forward experiment, which is dedicated for UHECR physics.

- Introduction
- Overview of the LHCf experiment
- Forward photon energy spectrum at $\sqrt{s}$ = 7eV proton-proton collisions
- Summary

The LHCf collaboration



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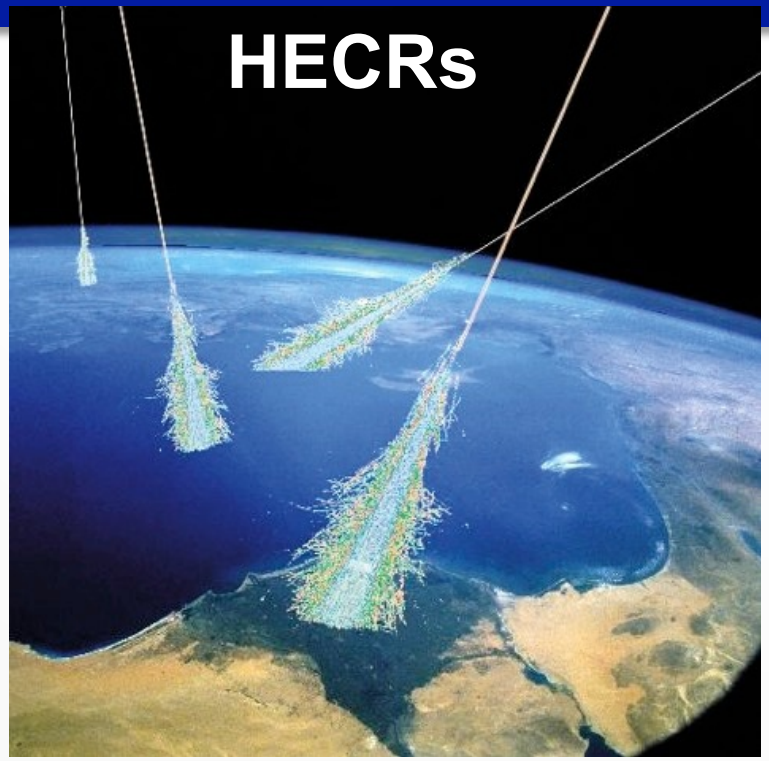
Introduction



Extensive air shower observation

- longitudinal distribution
- lateral distribution
- Arrival direction

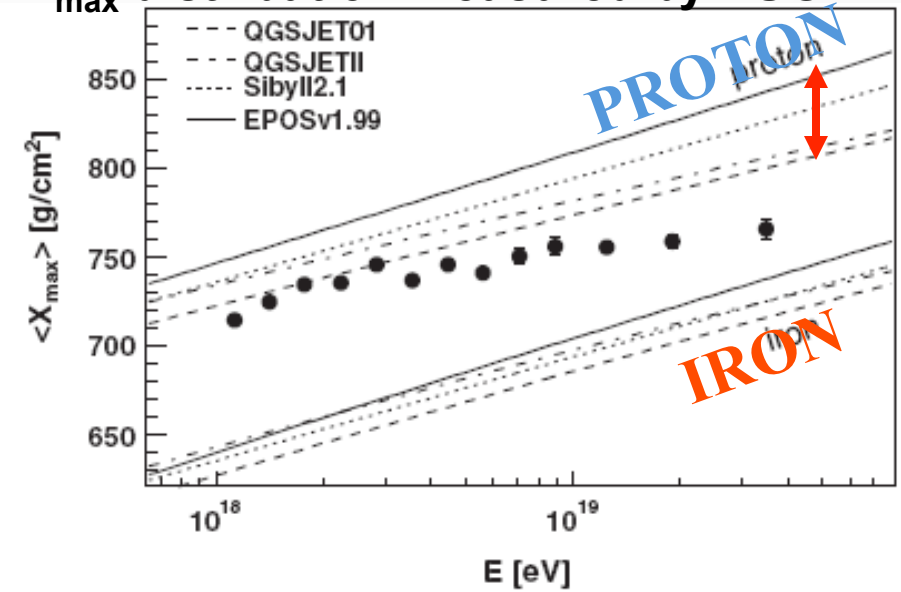
Air shower development

Astrophysical parameters

- Spectrum
- Composition
- Source distribution

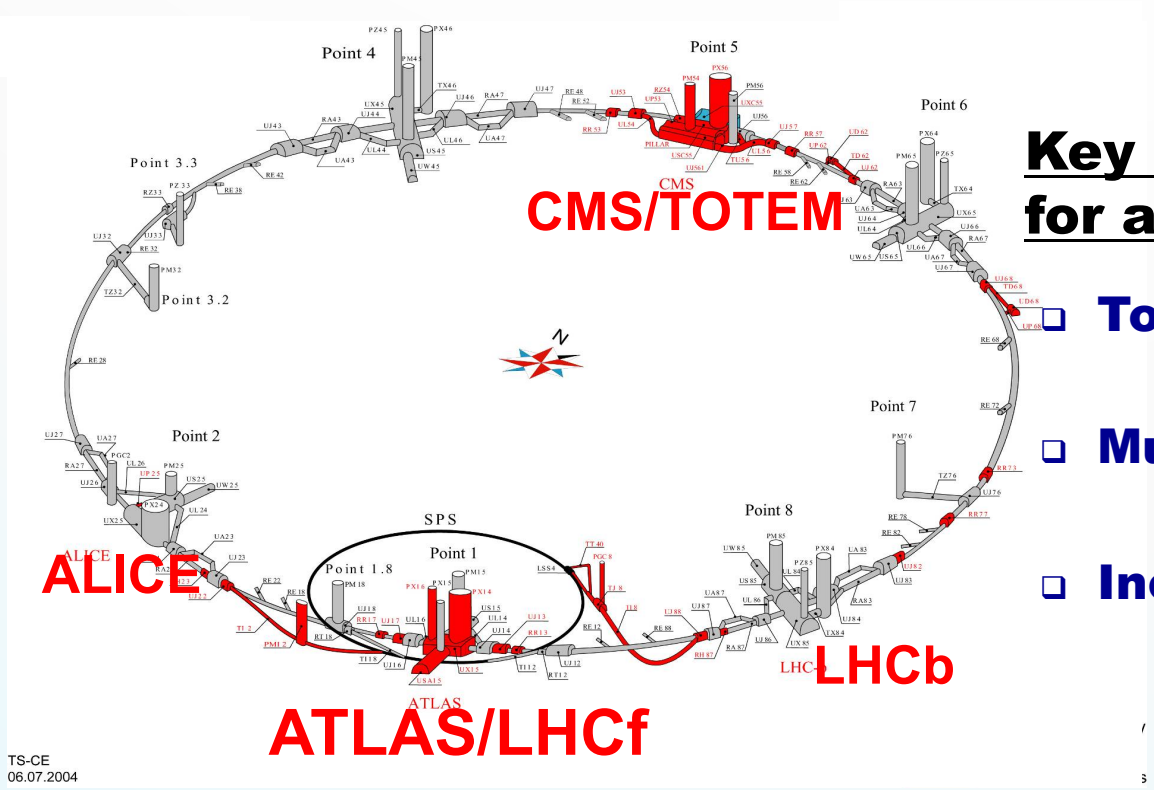
The hadron interaction models used in air shower simulations have an uncertainty due to the lack of experimental data
in the energy range over 10^{15}eV

X_{max} distribution measured by AUGER



The Large Hadron Collider (LHC)

pp 7TeV+7TeV → $E_{lab} = 10^{17}$eV 2014-
pp 3.5TeV+3.5TeV → $E_{lab} = 2.6 \times 10^{16}$eV
pp 450GeV+450GeV → $E_{lab} = 2 \times 10^{14}$eV

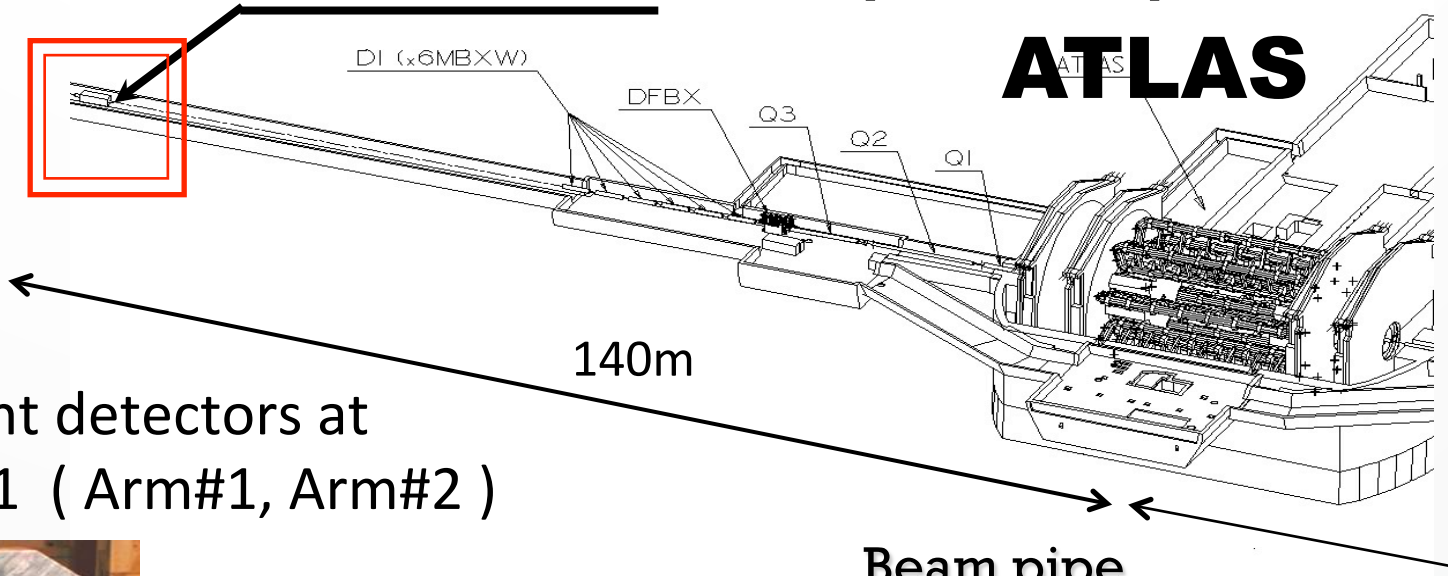


Key parameters for air shower developments

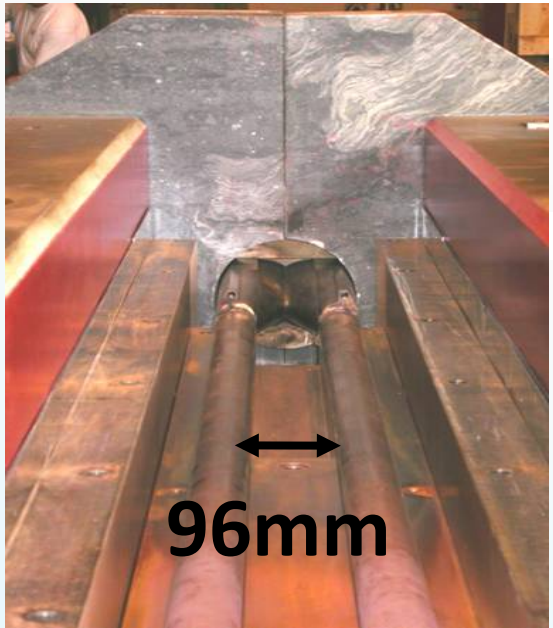
- Total cross section
  ↔ TOTEM, ATLAS(ALFA)
- Multiplicity
  ↔ Central detectors
- Inelasticity/Secondary spectra
  ↔ Forward calorimeters
  LHCf, ZDCs

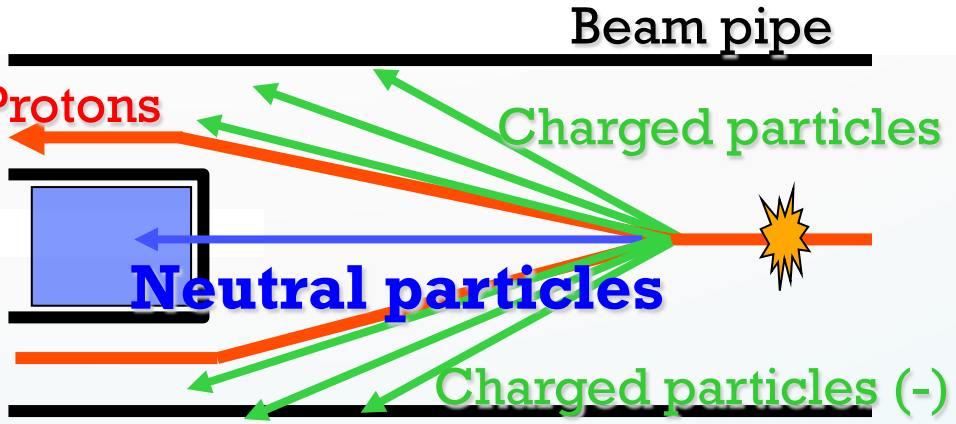
Detector Location

LHCf Detector(Arm#1)



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

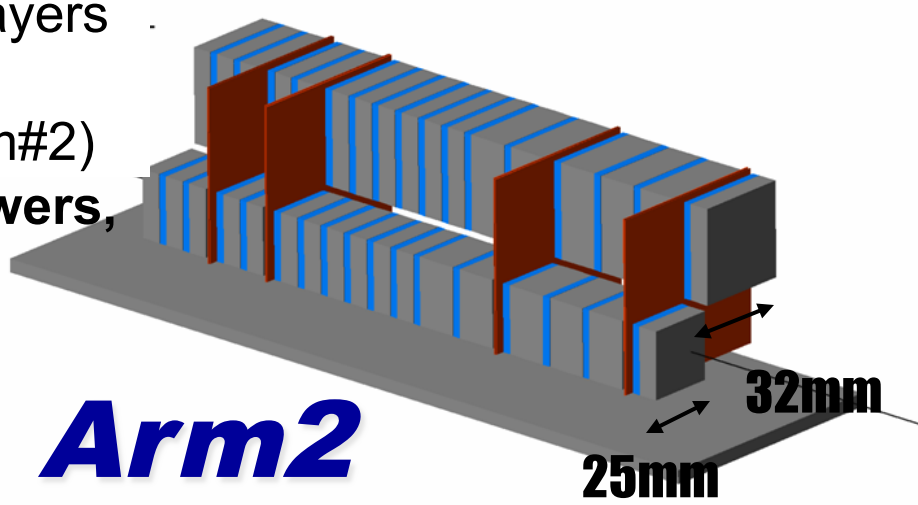
Slot : 100mm(w) x 607mm(H) x 1000mm(T)

The LHCf Detectors

Sampling and Positioning Calorimeters

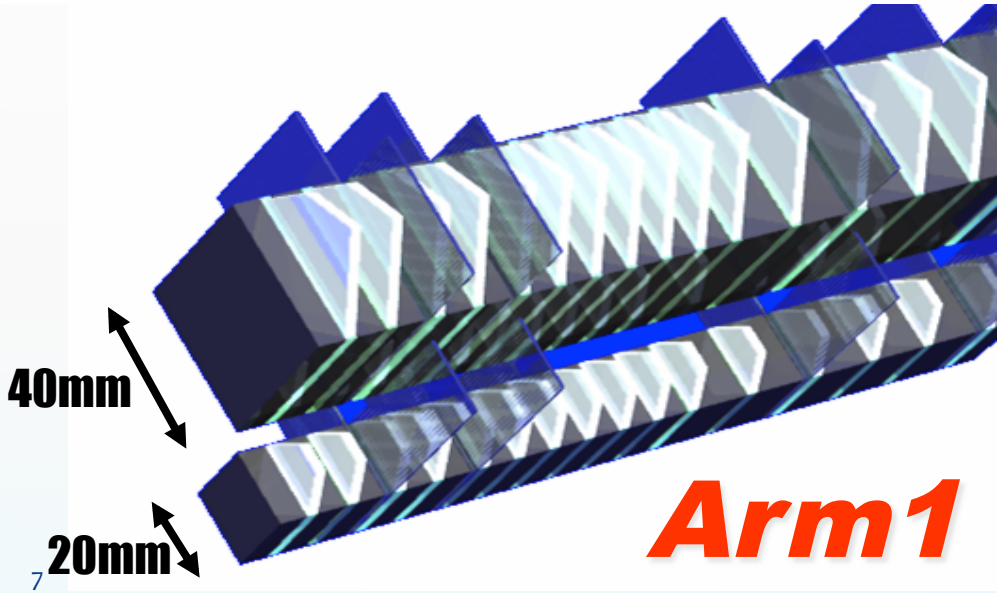
- W (44 r.l , 1.7λ_I) and Scintillator x 16 Layers
- 4 positioning layers
  XY-SciFi(Arm1) and XY-Silicon strip(Arm#2)
- **Each detector has two calorimeter towers, which allow to reconstruct π^0**

Expected Performance
Energy resolution (> 100GeV)
< 5% for photons
30% for neutrons
Position resolution
< 200μm (Arm#1)
40μm (Arm#2)



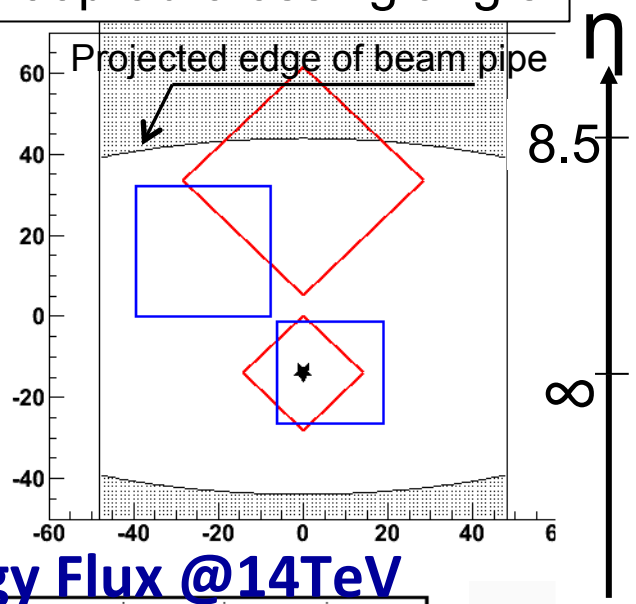
Front Counter

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



LHCf can measure

Front view of calorimeters
@ 100μrad crossing angle



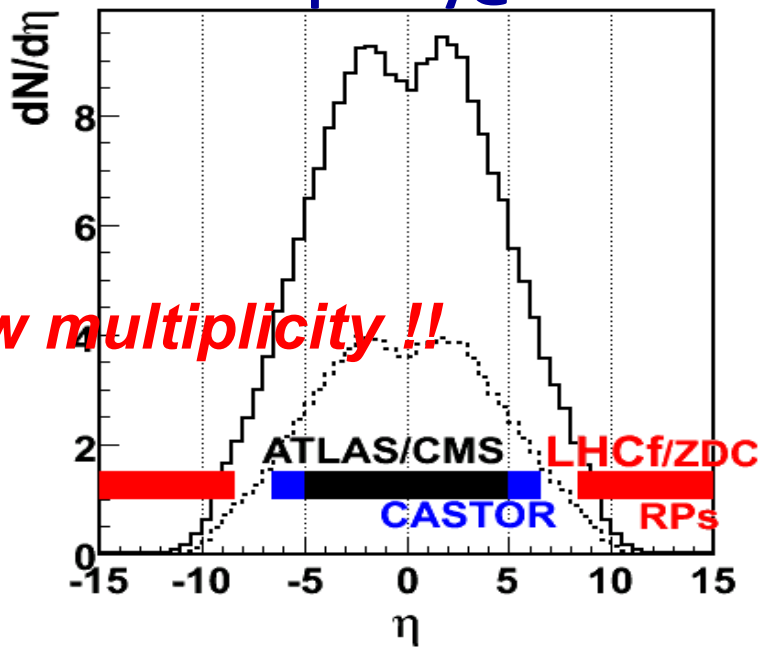
Energy spectra and
Transverse momentum distribution of

- **Gamma-rays (E>100GeV,dE/E<5%)**
- **Neutral Hadrons (E>a few 100 GeV, dE/E~30%)**
- **π^0 (E>600GeV, dE/E<3%)**

at psudo-rapidity range >8.4

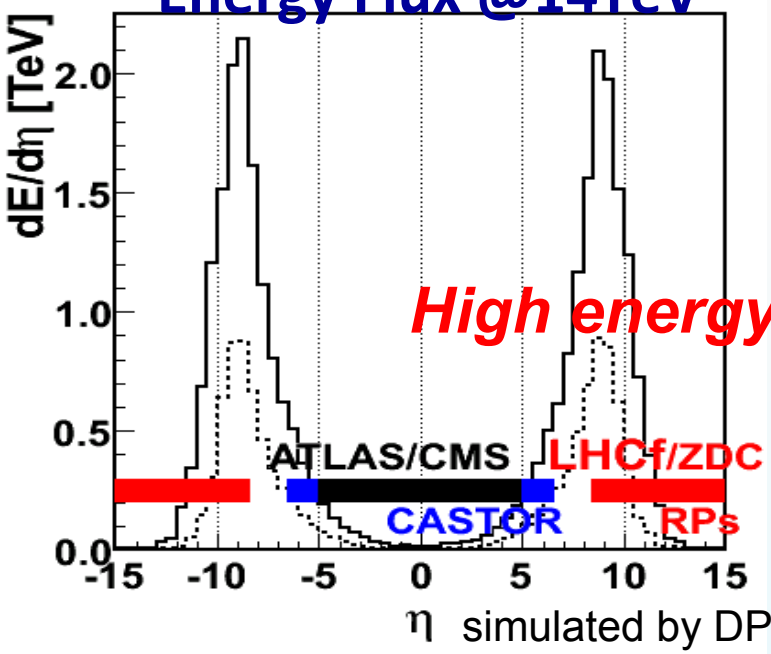
➔ **Forward region is very effective on air shower development.**

Multiplicity@14TeV



Low multiplicity !!

Energy Flux @14TeV



High energy flux !!

η simulated by DPMJET3

Operation in 2009-2010

At 450GeV+450GeV

- 06 Dec. –15 Dec. in 2009
  27.7 hours for physics, 2.6 hours for commissioning
  ~2,800 and ~3,700 shower events in Arm1 and Arm2
- 02 May – 27 May in 2010
  ~15 hours for physics
  ~44,000 and ~63,000 shower events in Arm1 and Arm2

At 3.5TeV+3.5TeV

- 30 Mar. – 19 July in 2010
  ~ 150 hours for physics with several setup
  With zero crossing angle and with 100μrad crossing angle.
  ~$2x10^8$ and ~$2x10^8$ shower events in Arm1 and Arm2

Operation at √s = 900GeV and 7TeV has been completed successfully.
The detectors has been removed from the LHC tunnels at July 2010,
and will be upgraded for the future operations.

Forward photon spectrum at $\sqrt{s}$ = 7eV p-p collisions

The paper has been submitted to PLB

" Measurement of zero degree single photon energy spectra for $\sqrt{s}$ = 7 TeV proton-proton collisions at LHC "

O. Adriani, et al.

arXiv:1104.5294

CERN-PH-EP-2011-061,

Seminar at CERN on 17-May by Prof. Sako is in the archive
http://indico.cern.ch/conferenceDisplay.py?confId=137111

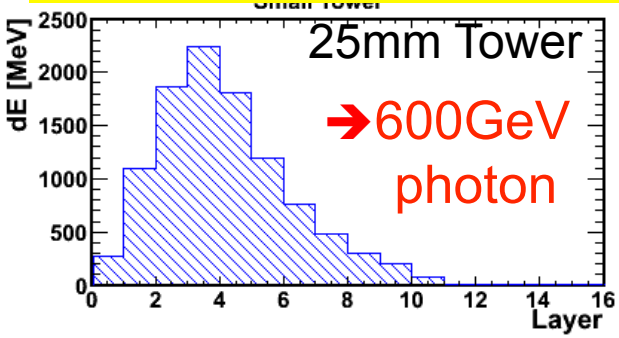
Analysis for the photon spectra

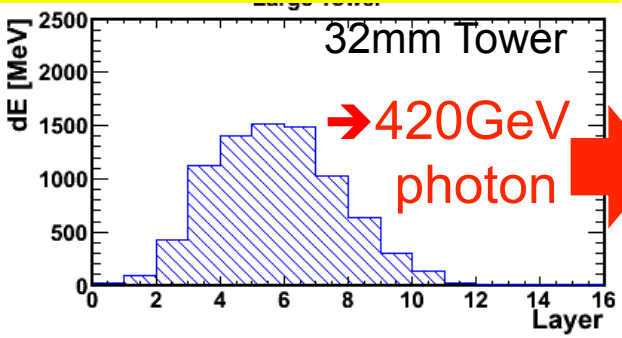
- DATA
  - 15 May 2010 17:45-21:23, at Low Luminosity $6 \times 10^{28} cm^{-2} s^{-1}$
  - 0.68 nb-1 for Arm1, 0.53nb-1 for Arm2

- Analysis Procedure
  - Energy Reconstruction from total energy deposition in a tower with some corrections, shower leakage out etc.
  - Particle Identification by shape of longitudinal shower development.
  - Cut multi-particle events.
  - Two Psudo-rapidity selections, $\eta > 10.94$ and $8.81 < \eta < 8.9$.
  - Combine spectra between the two detectors.

Event sample

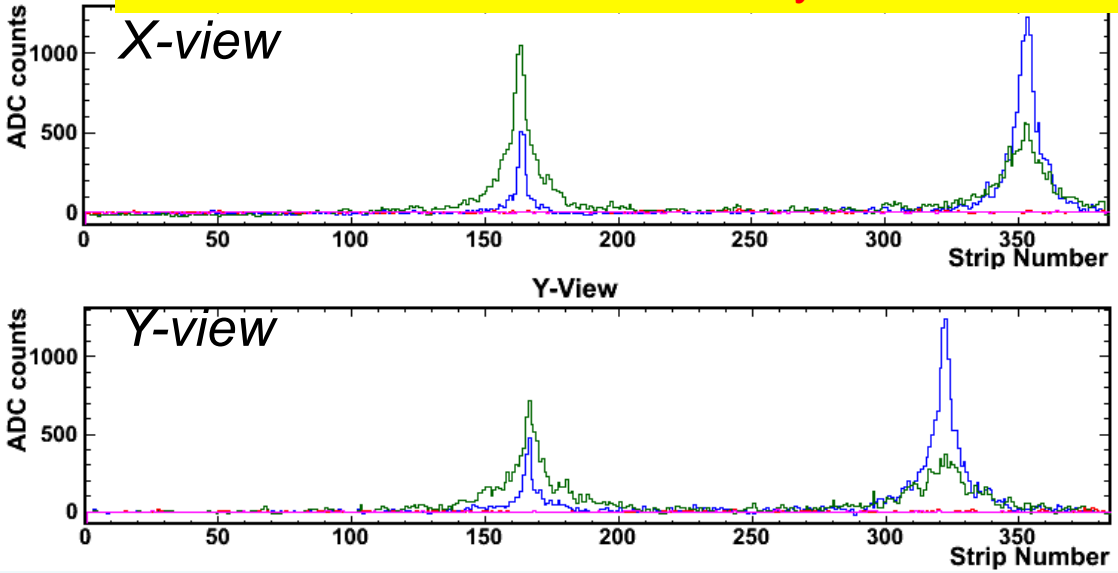
Longitudinal development measured by scintillator layers





Total Energy deposit
➔Energy
Shape
➔PID

Lateral distribution measured by silicon detectors



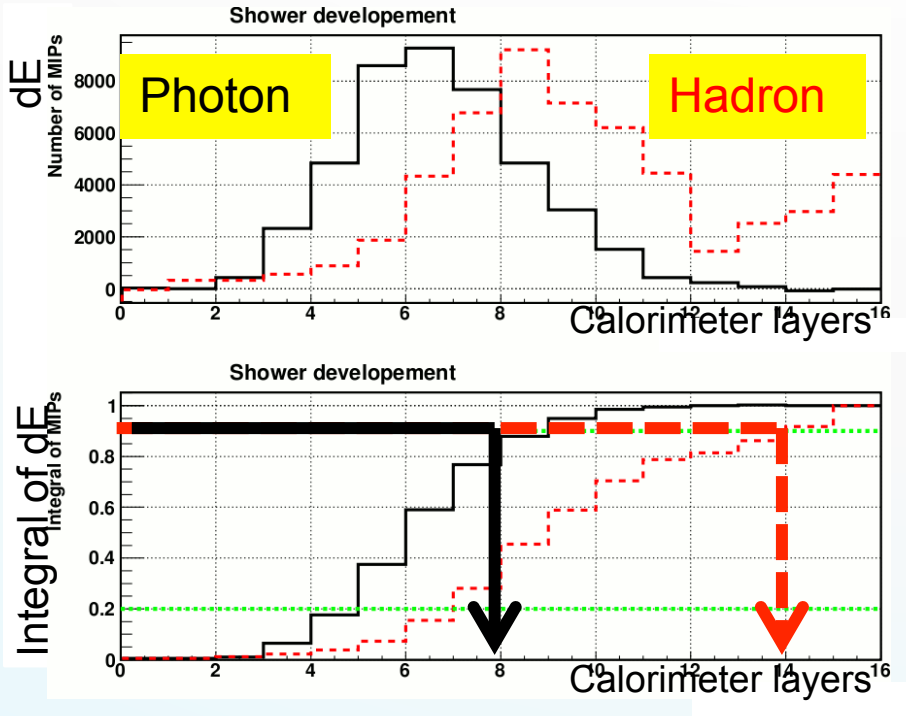
Hit position,
Multi-hit search.

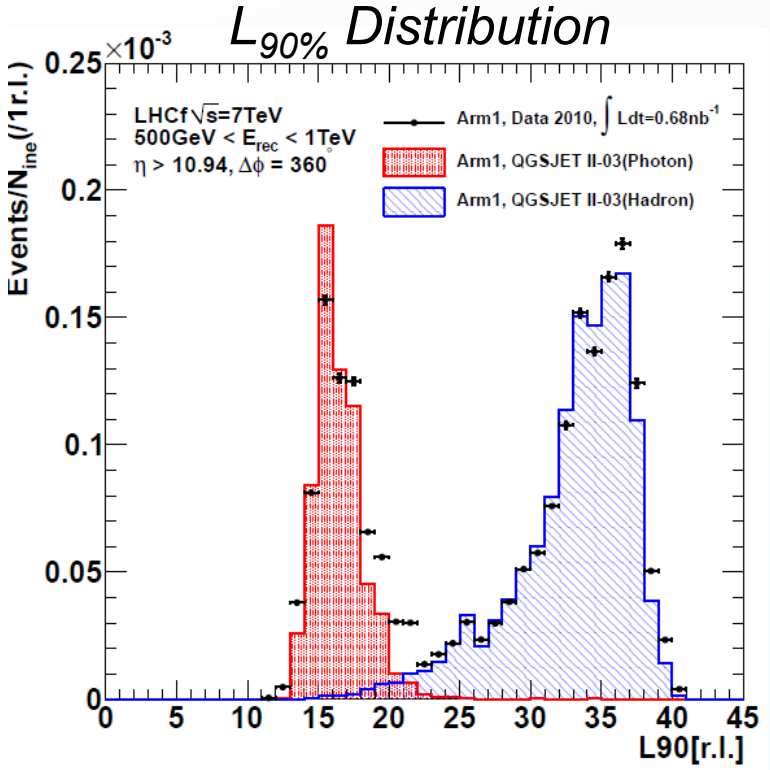
Particle Identification

- 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

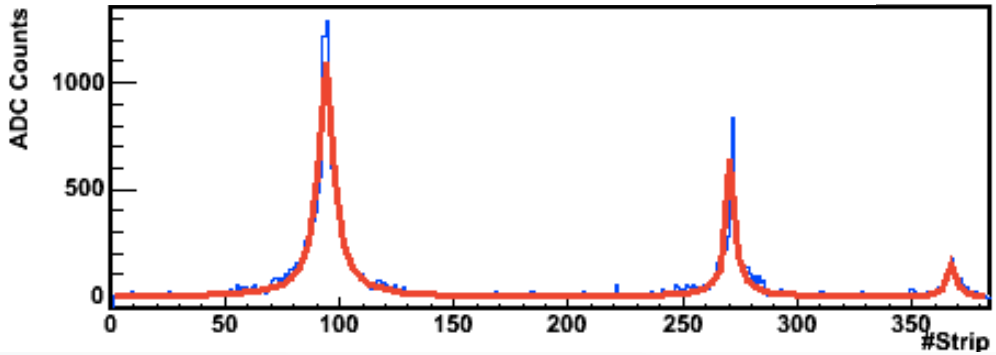




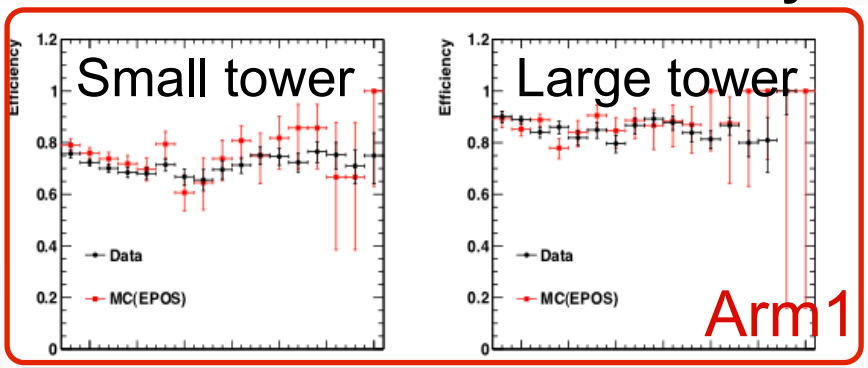
Multi-hit identification

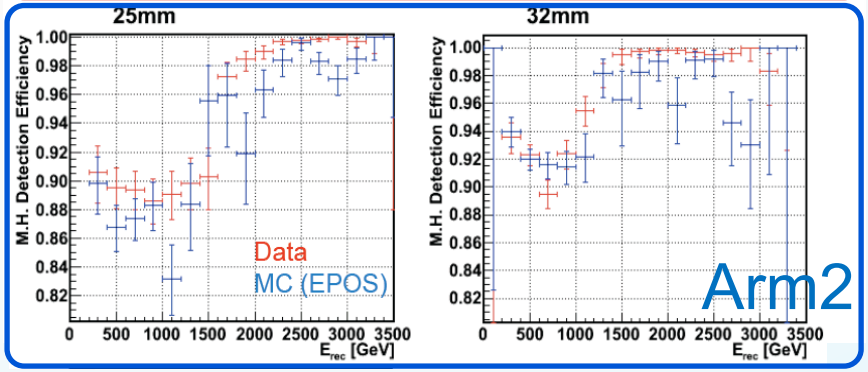
- Event cut of multi-peak events,
  - Identify multi-peaks in one tower by position sensitive layers.
  - Select only the single peak events for spectra.

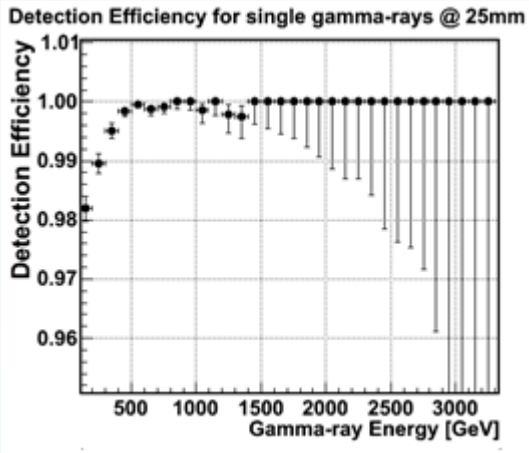
An example of multi peak event



Double hit detection efficiency





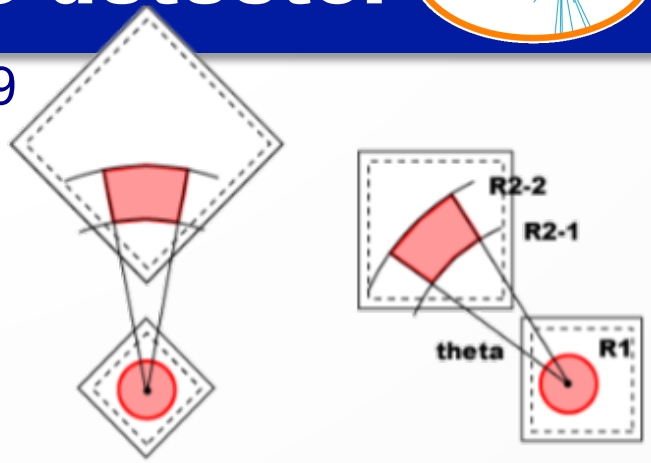


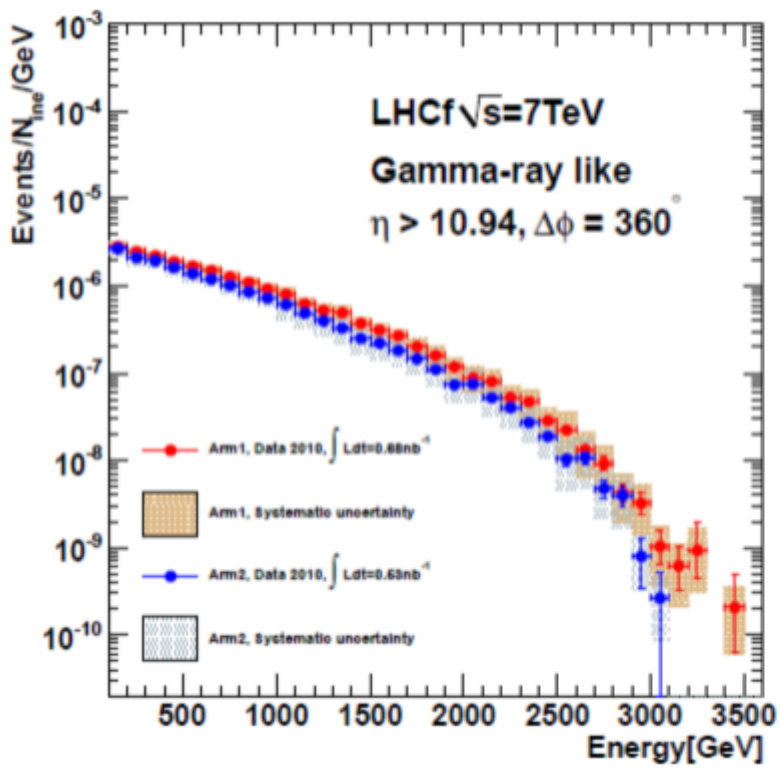
Single hit detection efficiency

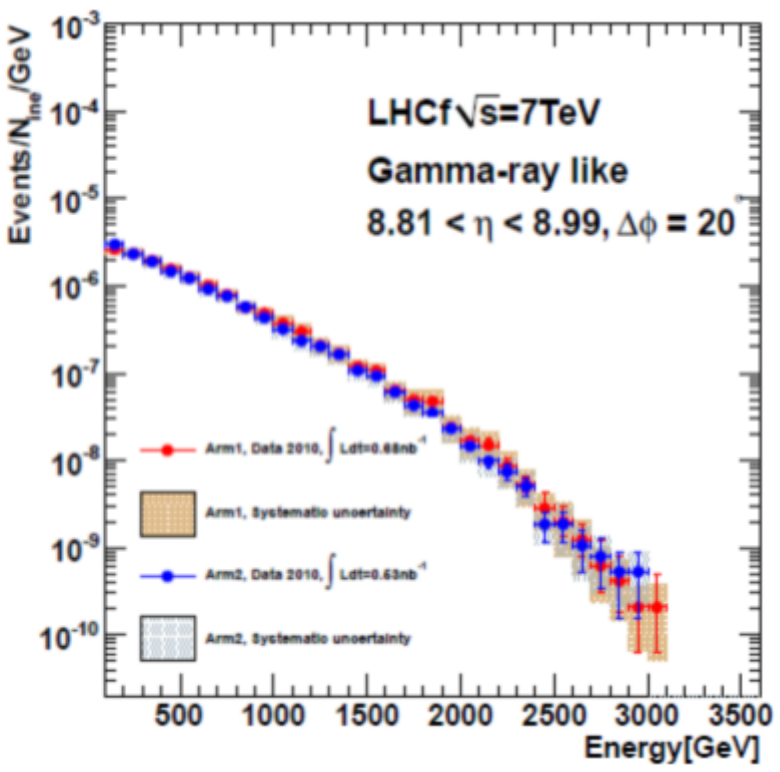
Comparison between the two detector

- Psudo-rapidity selection, $\eta>10.94$ and $8.81<\eta<8.9$
- 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





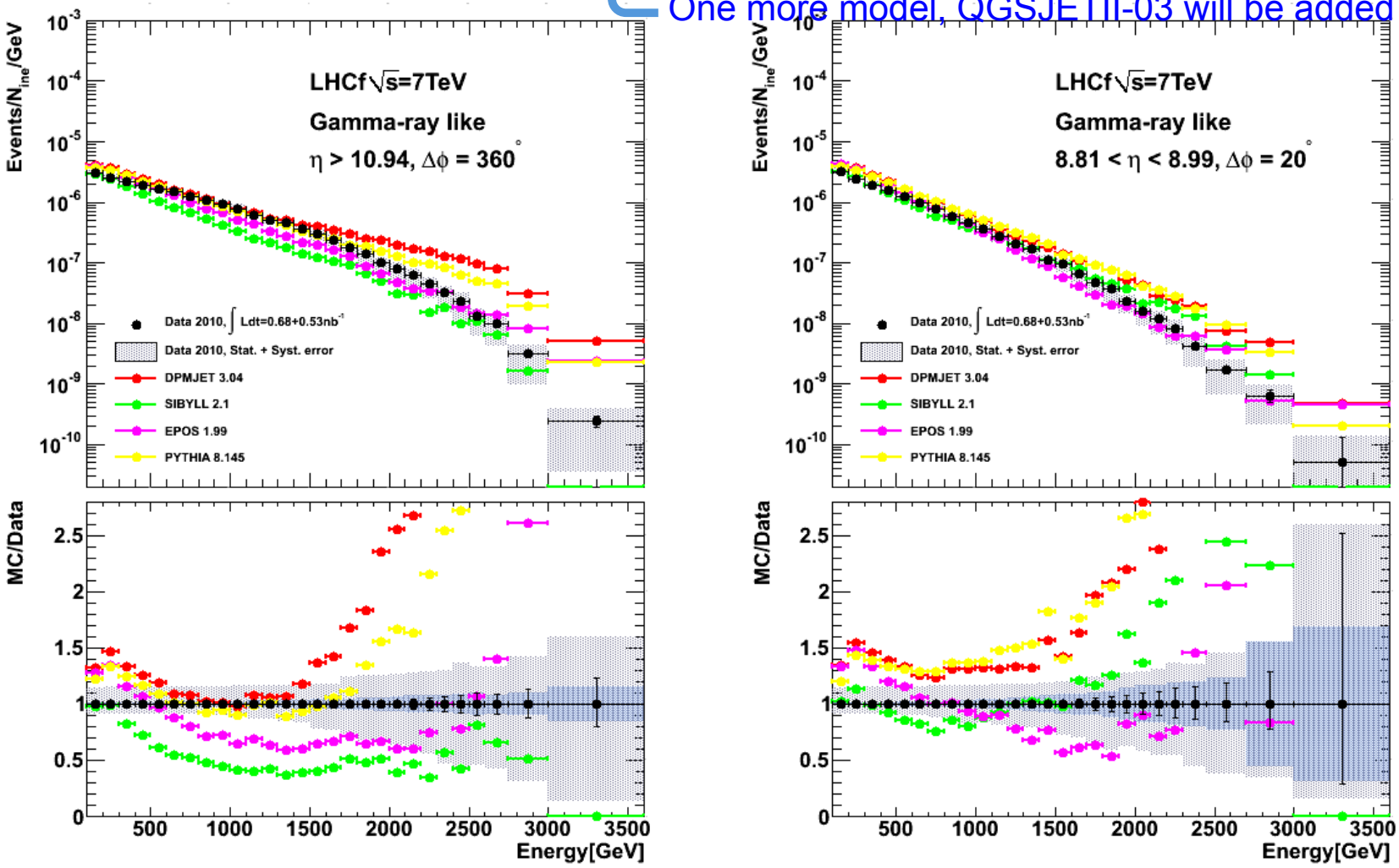


Arm1 detector **Arm2 detector** Filled area : uncorrelated systematic error

Comparison between MC's

DPMJET 3.04 SIBYLL 2.1 EPOS 1.99 PYTHIA 8.145

One more model, QGSJETII-03 will be added soon.



Gray hatch : Systematic Errors

Blue hatch: Statistics errors of MC

Next Plans

- Ongoing analysis
  - Energy spectrum of photons in the wider psudo-rapidity range.
  - P_T distribution
  - Hadron spectra
  - π^0 spectra
  - Photon and Hadron energy spectra at 900GeV.
- Future operations
  - p-p collisions at the LHC designed energy, $\sqrt{s}$ = 14TeV in 2014.
  - p-A , A-A collisions at LHC and operations at RICH (Only ideas)

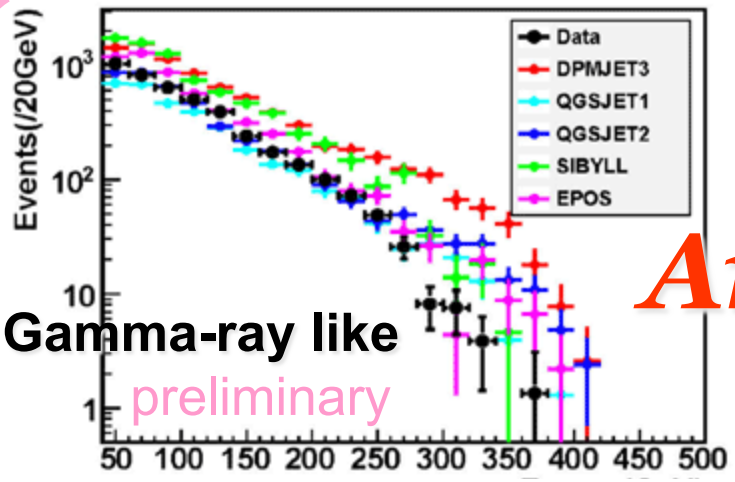
Summary

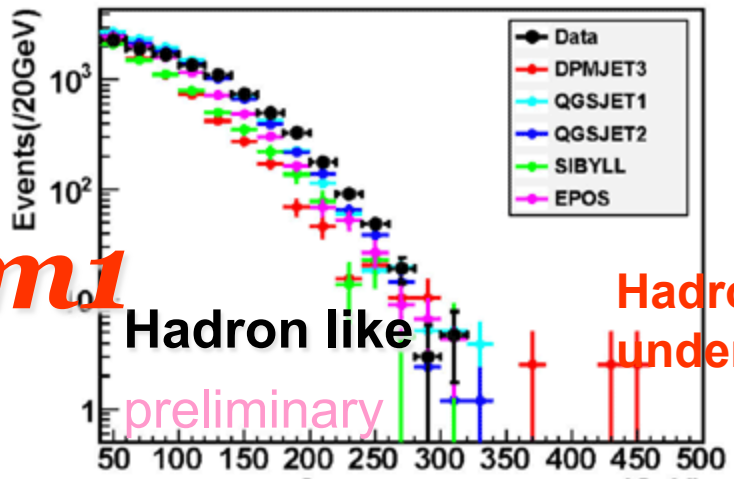
- LHCf is one LHC experiment dedicated for cosmic ray physics. The aim is to calibrate the hadron interaction models which are used in air shower simulations.
- LHCf measured photon forward energy spectra in the psudo-rapidity ranges, $\eta > 10.94$ and $8.81 < \eta < 8.9$ at $\sqrt{s}$ = 7TeV proton-proton collisions.
- We compared the spectra with several interaction models
  - None of the models perfectly agree with data
  - Large discrepancy especially in the high energy with all models.
- Analysis is ongoing. Results at $\sqrt{s}$ = 7TeV p-p collisions, energy spectra of photon, hadron, PT distributions and etc., will be provided soon and many results from future operations, p-p at 14TeV, p-A also.


!!!! Grazie !!!!
TEA ROOMS
Keats Shelley Museum

Backup slides

Energy Spectra at 900GeV

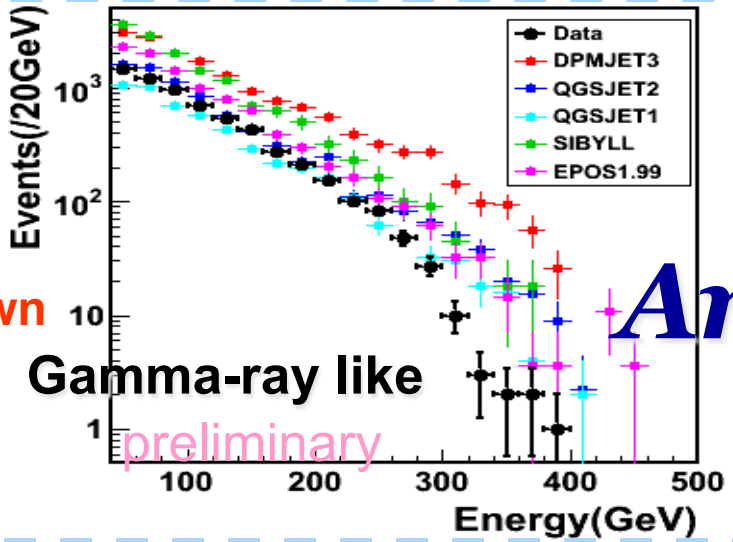




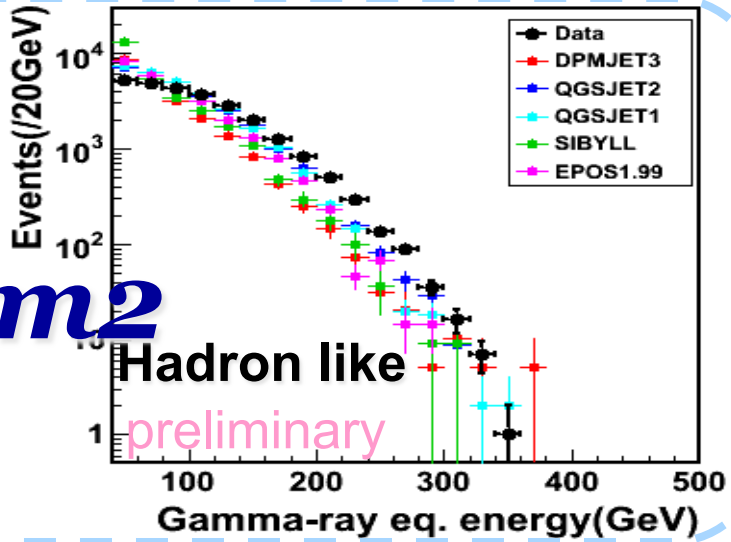
Arm1

Hadron response under study

Only statistical errors are shown



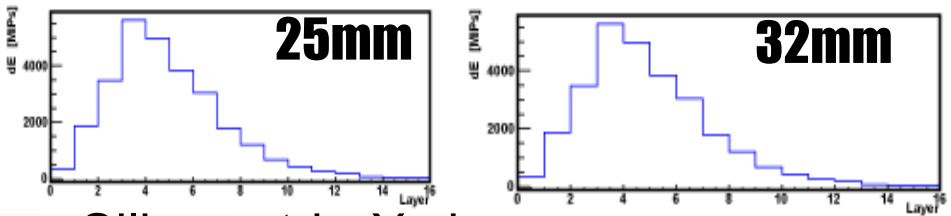
Arm2



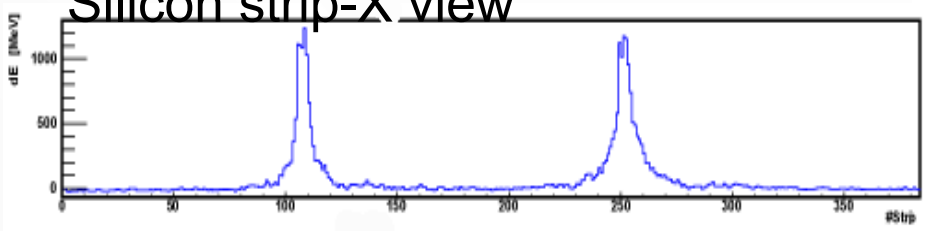
The spectra are normalized by number of gamma-ray and hadron like events
The detector response for hadrons and the systematic error are under study.

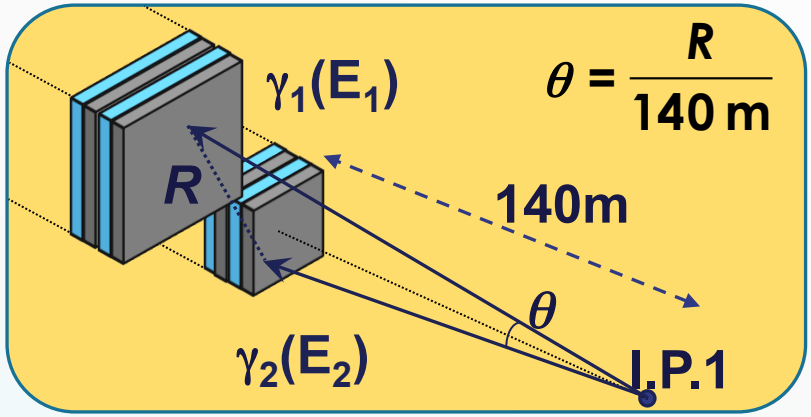
π^0 reconstruction

An example of π^0 events



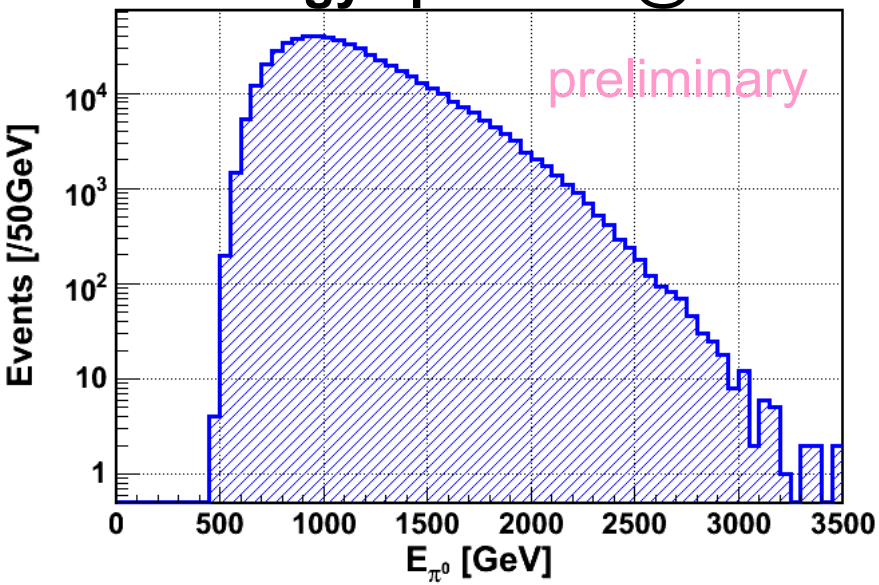
Silicon strip-X view



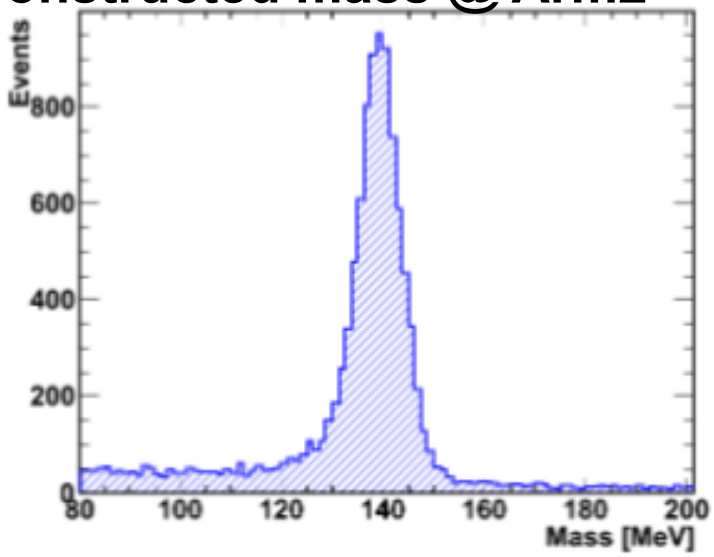


- Pi0's are a main source of electromagnetic secondaries in high energy collisions.
- The mass peak is very useful to confirm the detector performances and to estimate the systematic error of energy scale.

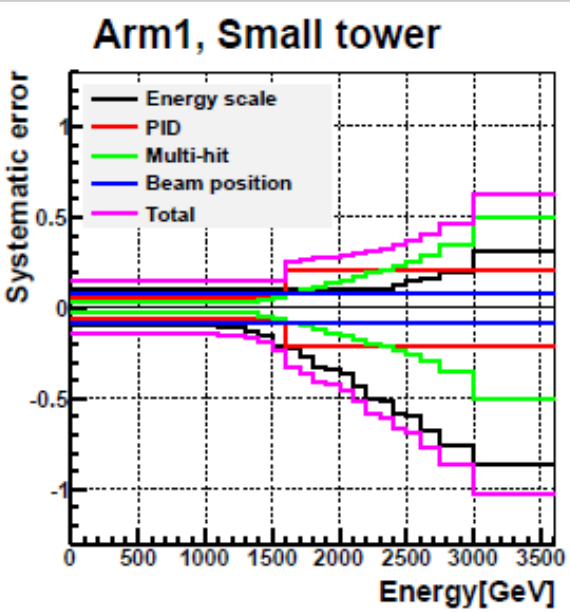
measured energy spectrum @ Arm2

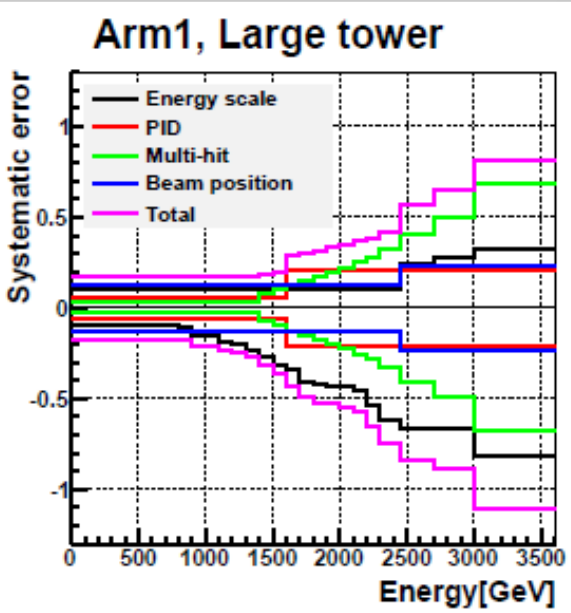


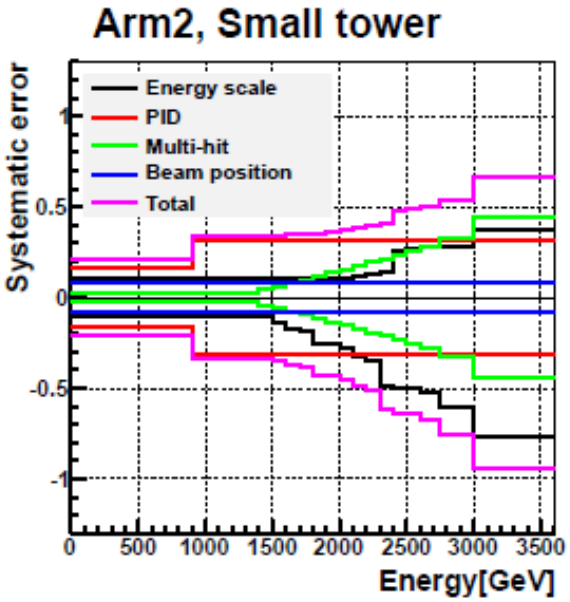
Reconstructed mass @ Arm2

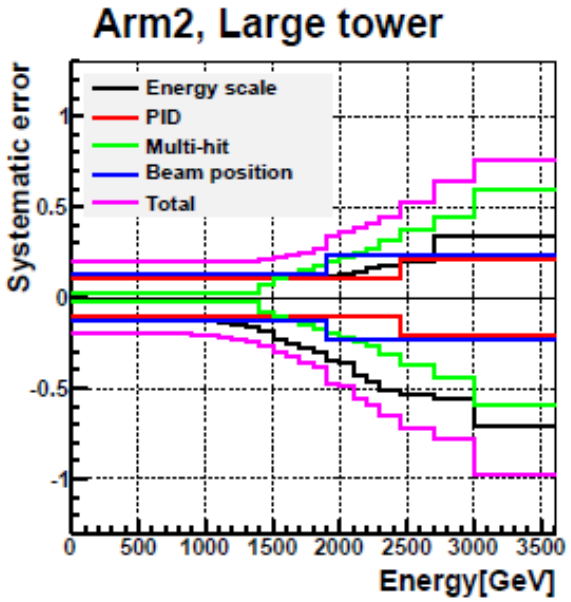


Summary of systematic errors



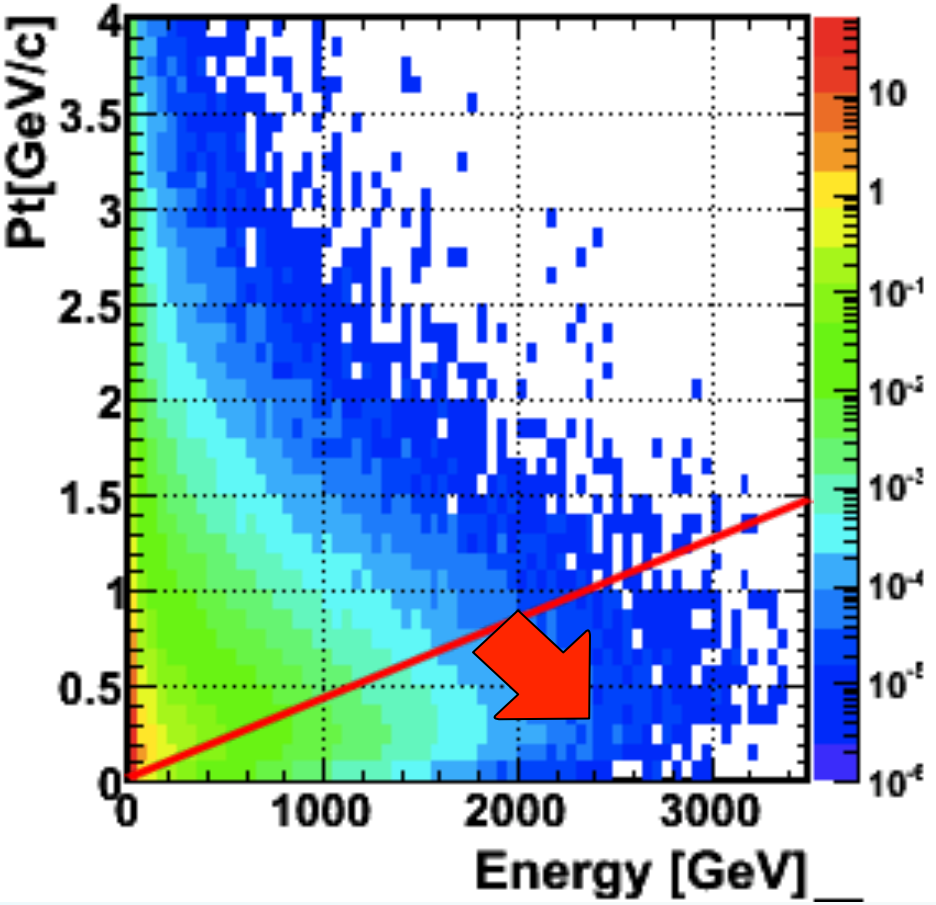






P_T distribution for photons

pp 7TeV, EPOS



Front Counter

- ✓ Fixed scintillation counter
- ✓ $L=CxR_{FC}$; conversion coefficient calibrated during VdM scans