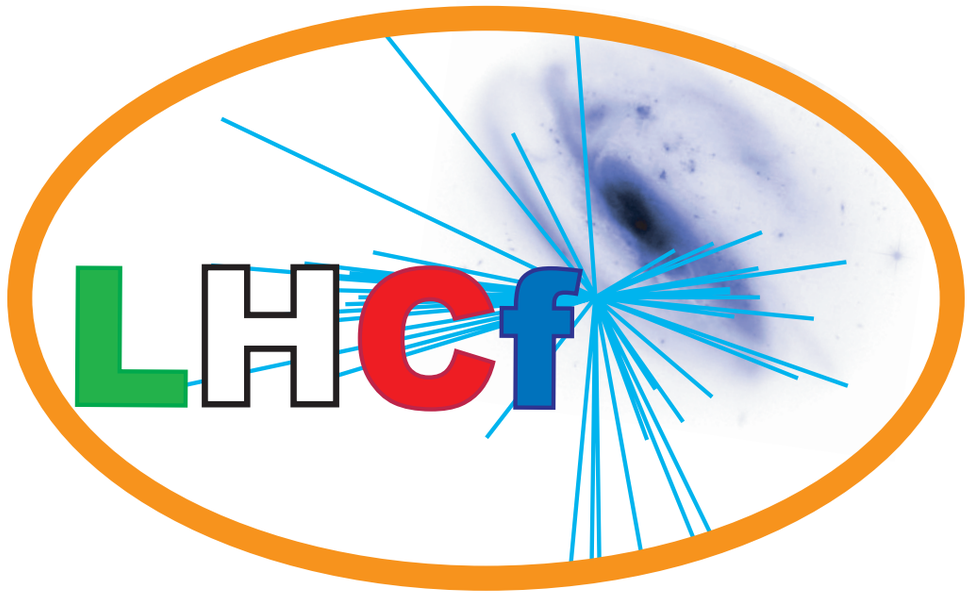
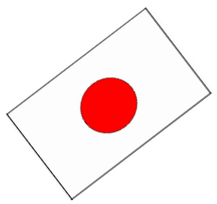


Performance of LHCf in Run II

Hiroaki MENJO Nagoya University, Japan
on behalf of the LHCf collaboration

LHCP2015, St. Petersburg, 31 Aug.-5 Sep.

The LHCf collaboration



***,**Y.Itow, *Y.Makino, *K.Masuda, *Y.Matsubara, *E.Matsubayashi,**
*****H.Menjo, *Y.Muraki, *Y.Okuno, *,**T.Sako, *M.Ueno, *Q.D.Zhou**

**Solar-Terrestrial Environment Laboratory, Nagoya University, Japan*
***Kobayashi-Maskawa Institute, Nagoya University, Japan*
****Graduate School of Science, Nagoya University, Japan*

K.Yoshida *Shibaura Institute of Technology, Japan*

T.Iwata, K.Kasahara, T.Suzuki, S.Torii

Waseda University, Japan

Y.Shimizu, T.Tamura *Kanagawa University, Japan*

N.Sakurai *Tokushima University, Japan*

M.Haguenauer *Ecole Polytechnique, France*

W.C.Turner *LBNL, Berkeley, USA*

O.Adriani, E.Berti, L.Bonechi, M.Bongi, G.Castellini, R.D'Alessandro, M.Delprete, M.Grandi, G.Mitsuka, P.Papini, S.Ricciarini, A.Tiberio

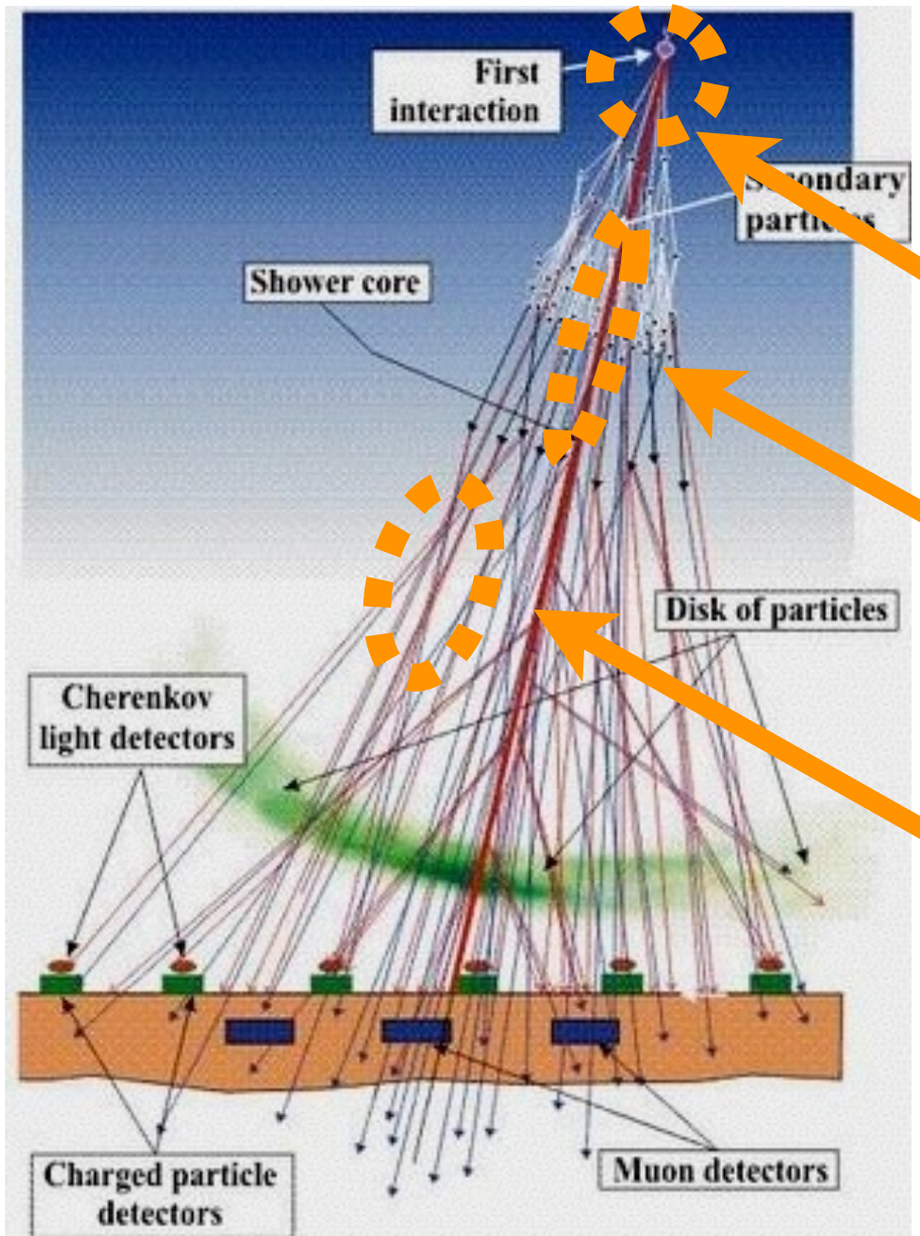
INFN, Univ. di Firenze, Italy

A.Tricomi *INFN, Univ. di Catania, Italy*

A-L.Perrot *CERN, Switzerland*

LHCf - LHC forward -

LHCf is one of the LHCf forward experiments,
motivated for testing the hadronic interaction models
used in the air shower simulations for Ultra-High Energy Cosmic Rays
UHECRs (~ 10^{20}eV) at LHC

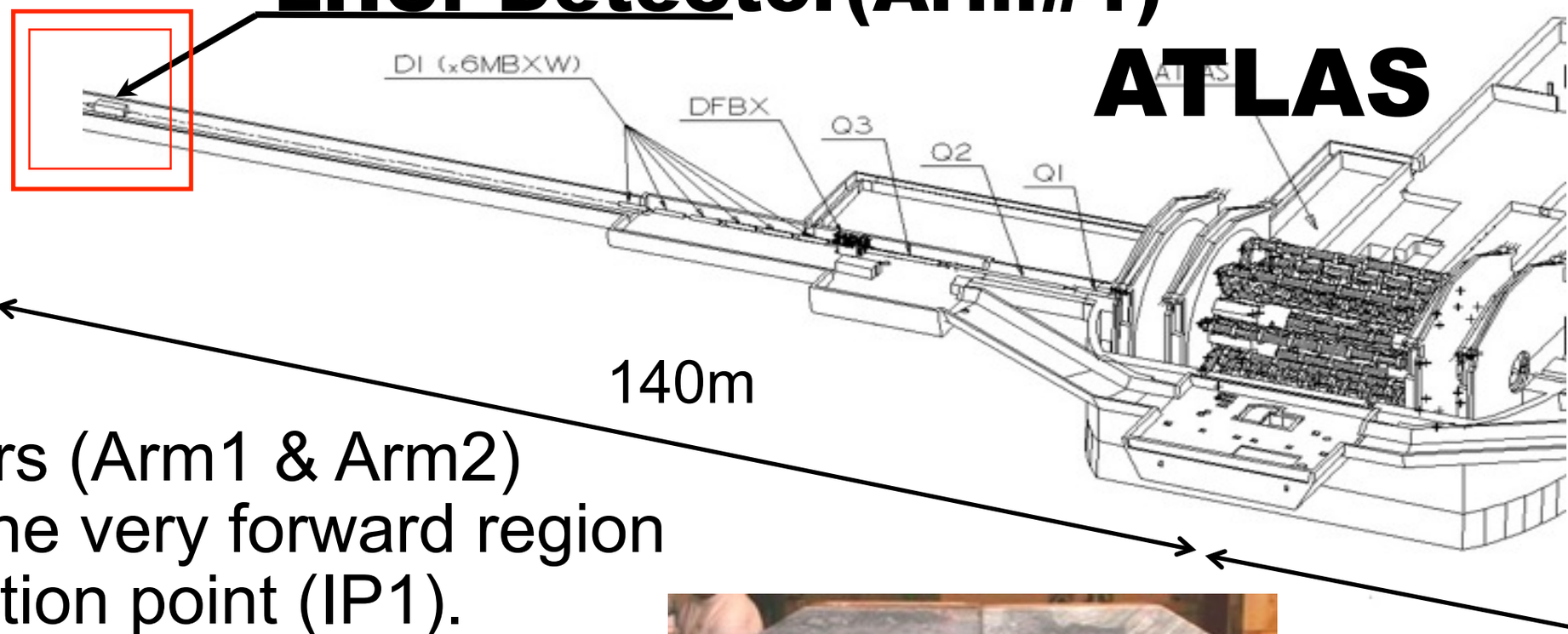


Key Parameters

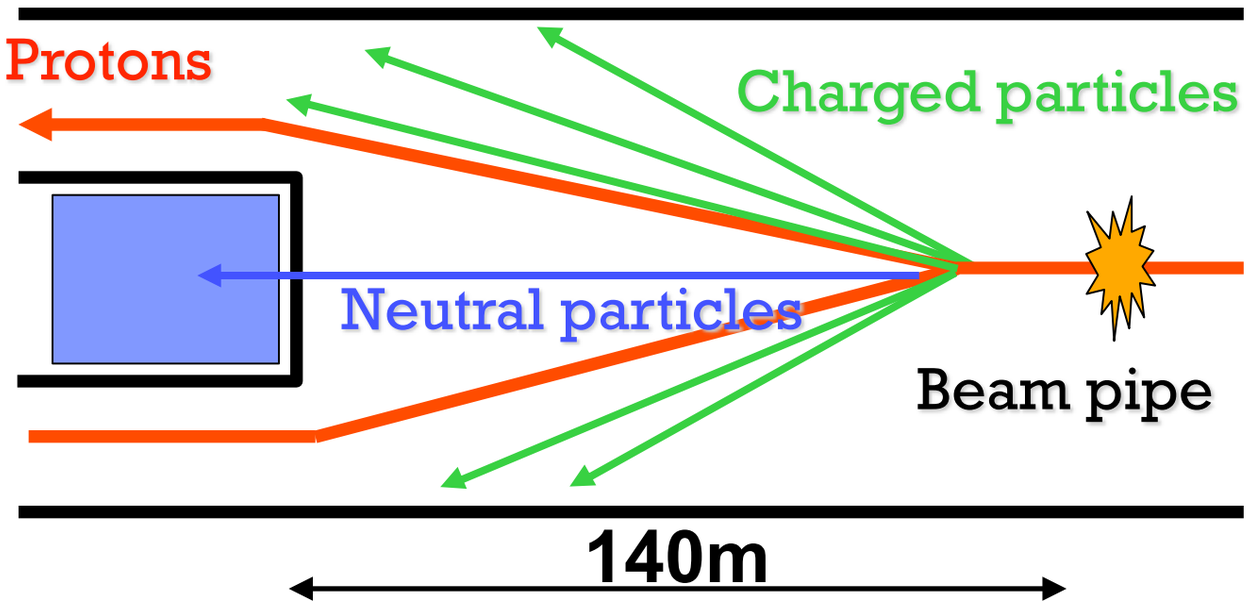
- Inelastic Cross Section
  →TOTEM, ATLAS, CMS,ALICE
- Forward Energy Spectrum
  →**LHCf**, ZDC and etc.
- Inelasticity k= 1-p_{lead}/p_{beam}
  →**LHCf**, ZDC and etc.
- Multiplicity
  →Central detectors

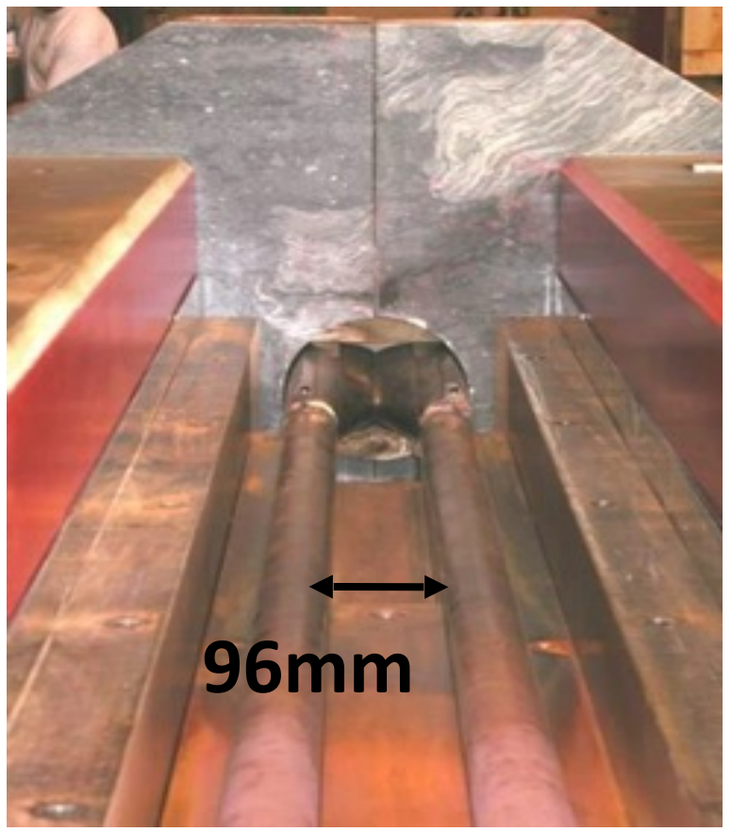
+Nuclear Effect @ CR-Air

Experimental Setup



Two LHCf detectors (Arm1 & Arm2) are installed into the very forward region of the LHC interaction point (IP1). LHCf can measure neutral particles (γ, n) at the rapidity range **η > 8.4.**





The LHCf detectors

Sampling and Positioning Calorimeters

- W (44 r.l , 1.7λ_I) and Scintillator x 16 Layers
- Four positioning sensitive layers
  XY-Scintillator bars (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

40% for Neutrons

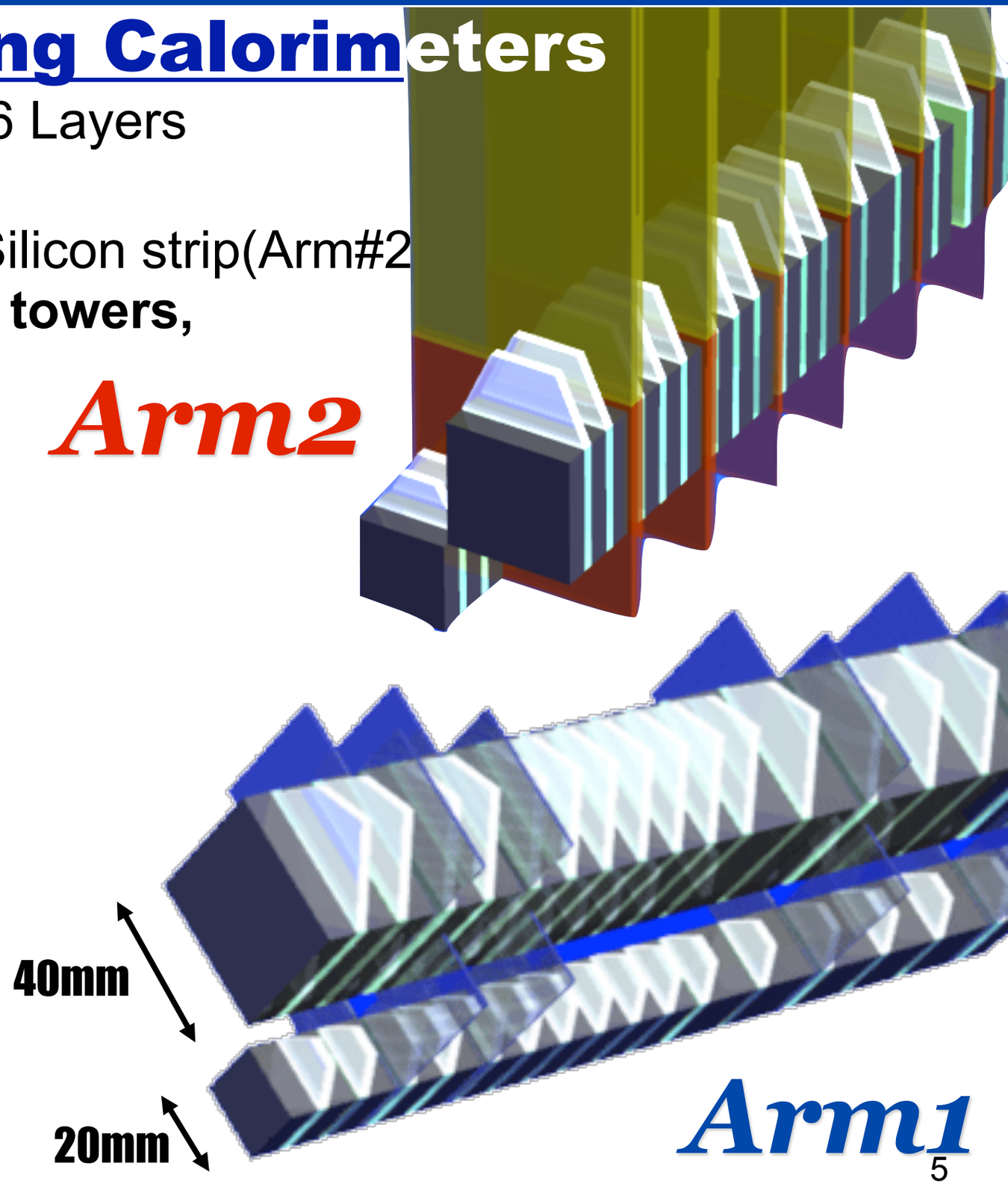
Position resolution

< 200μm for Photons

a few mm for Neutrons

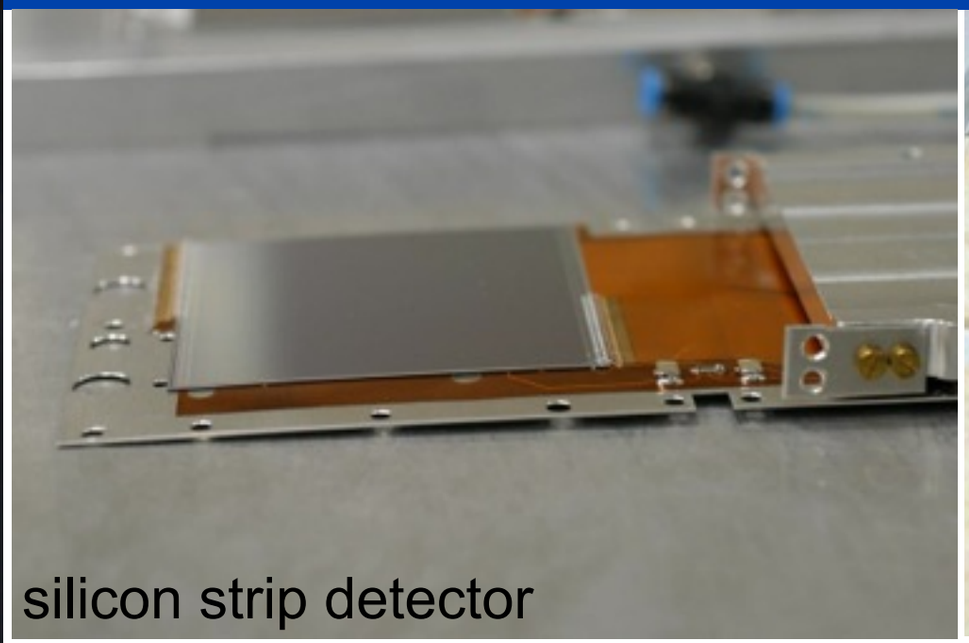
Front Counter

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

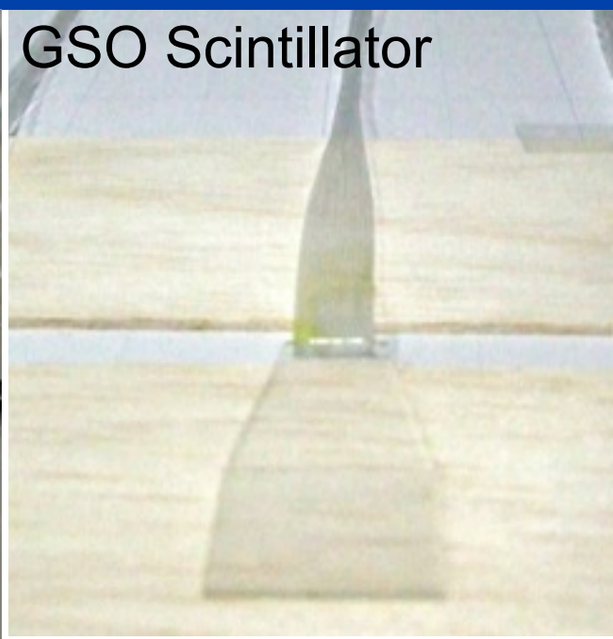


The LHCf detectors

Arm1 Detector

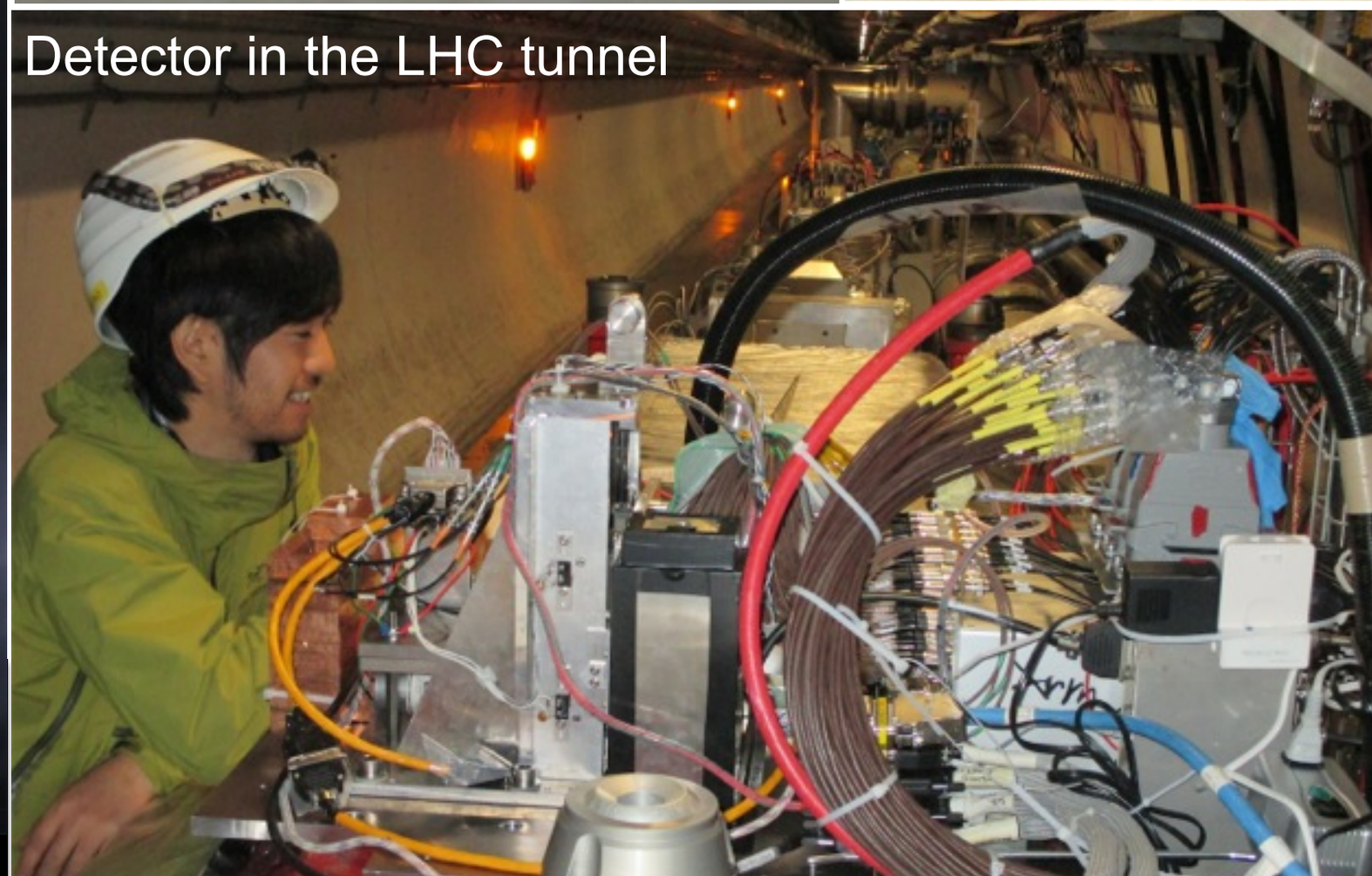


silicon strip detector



GSO Scintillator

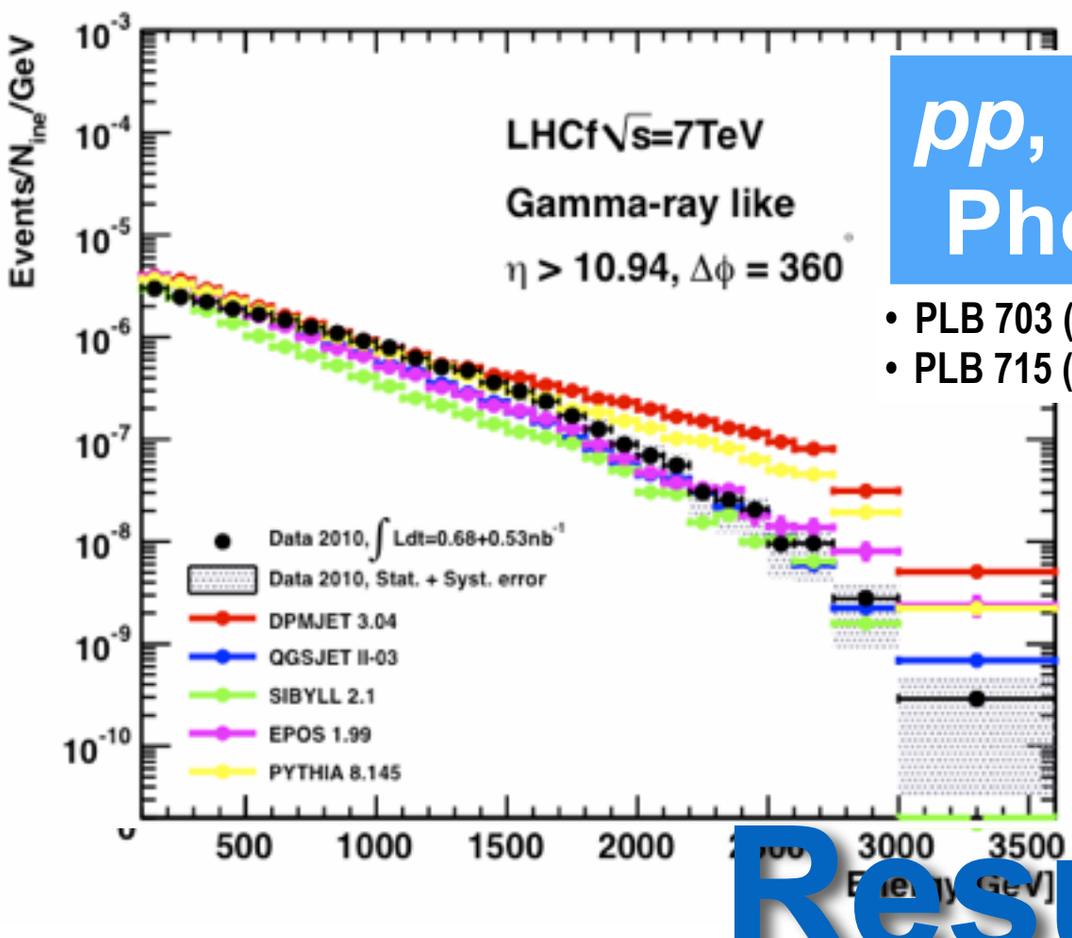
Detector in the LHC tunnel



Results in Run I

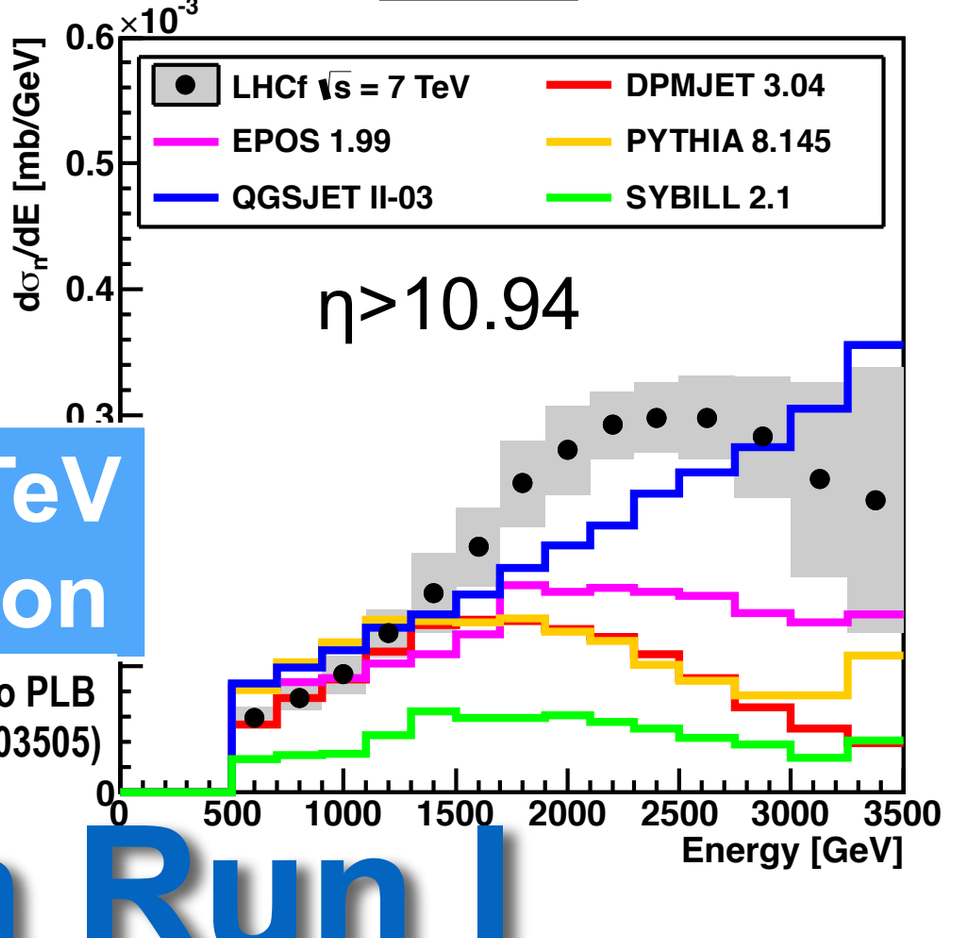
pp, 7TeV Photon

- PLB 703 (2011) 128-134
- PLB 715 (2012) 298-303



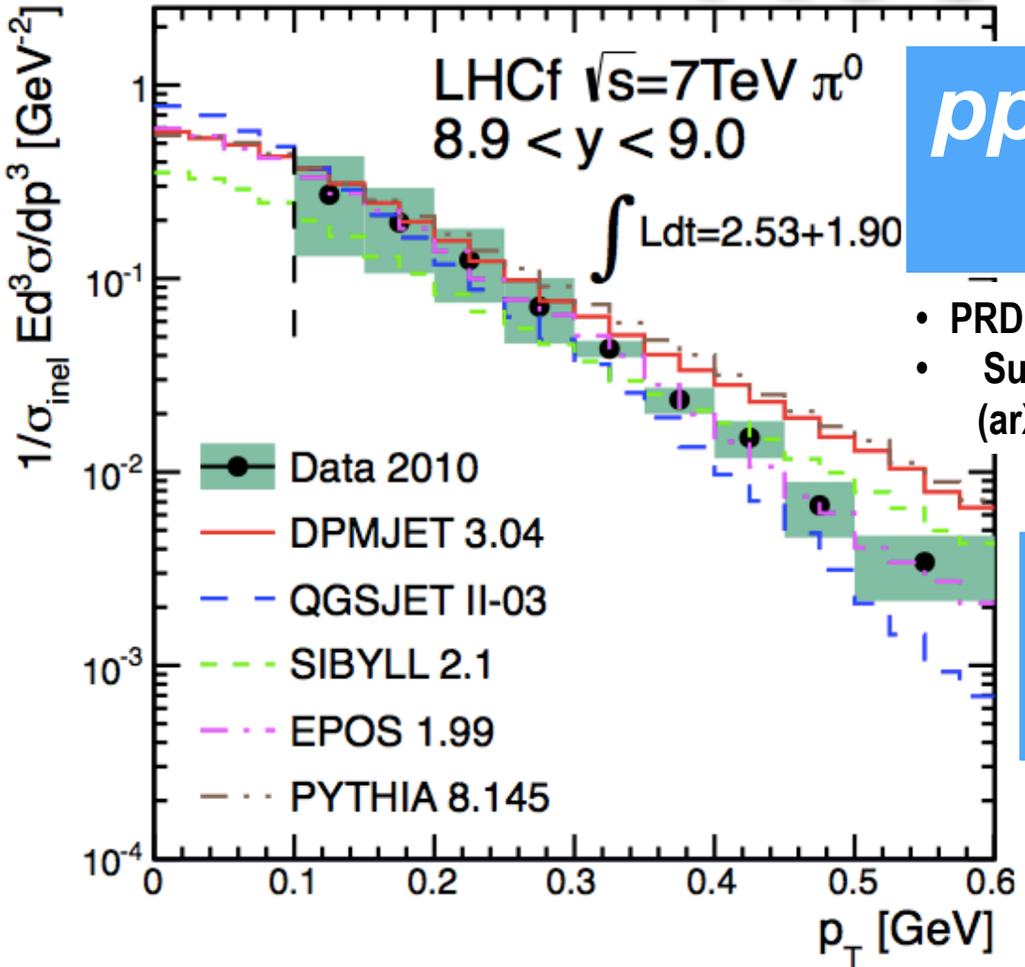
pp, 7TeV Neutron

- Submitted to PLB (arXiv:1503.03505)



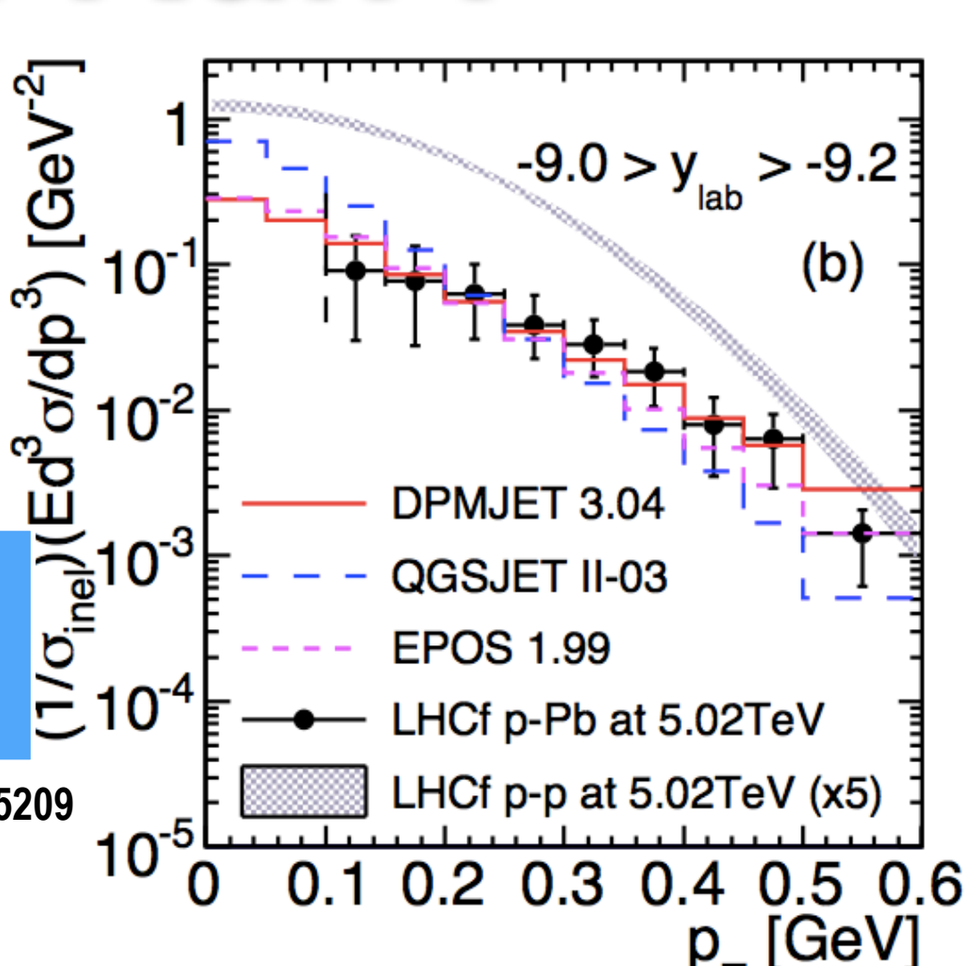
pp, 7TeV π^0

- PRD 86 (2012) 092001
- Submitted to PLB (arXiv:1507.08764)



pPb, 5TeV π^0

PRC 89 (2014) 065209



Operation in 2015

- LHCf physics operation with pp $\sqrt{s}$=13TeV has been completed !!
  - LHCf detectors were installed in Nov. 2014
  - Special physics operation with low pile-up in 9 - 13 June 2015.
  - After the operation, LHCf detectors were removed on 15 June during TS1.

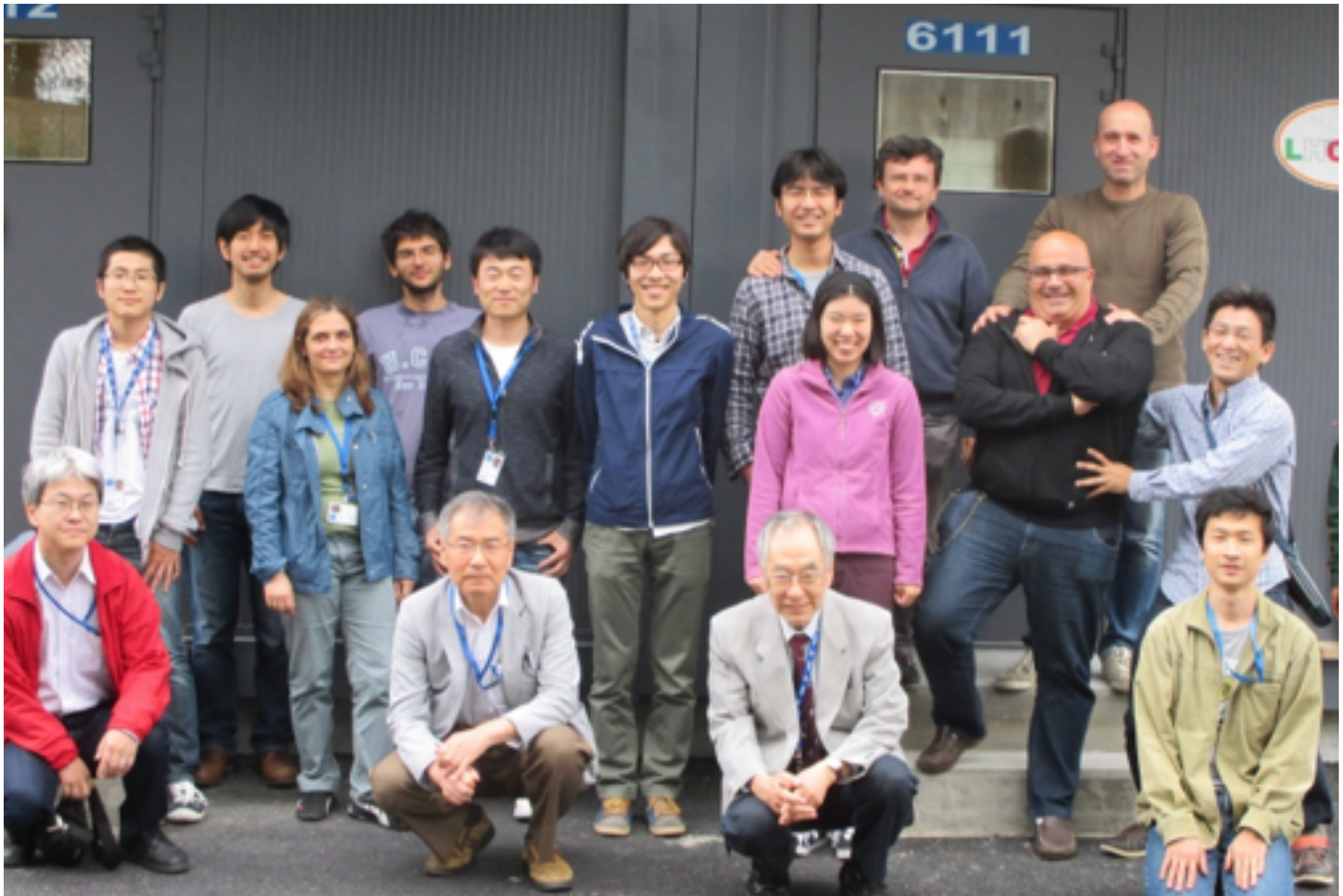
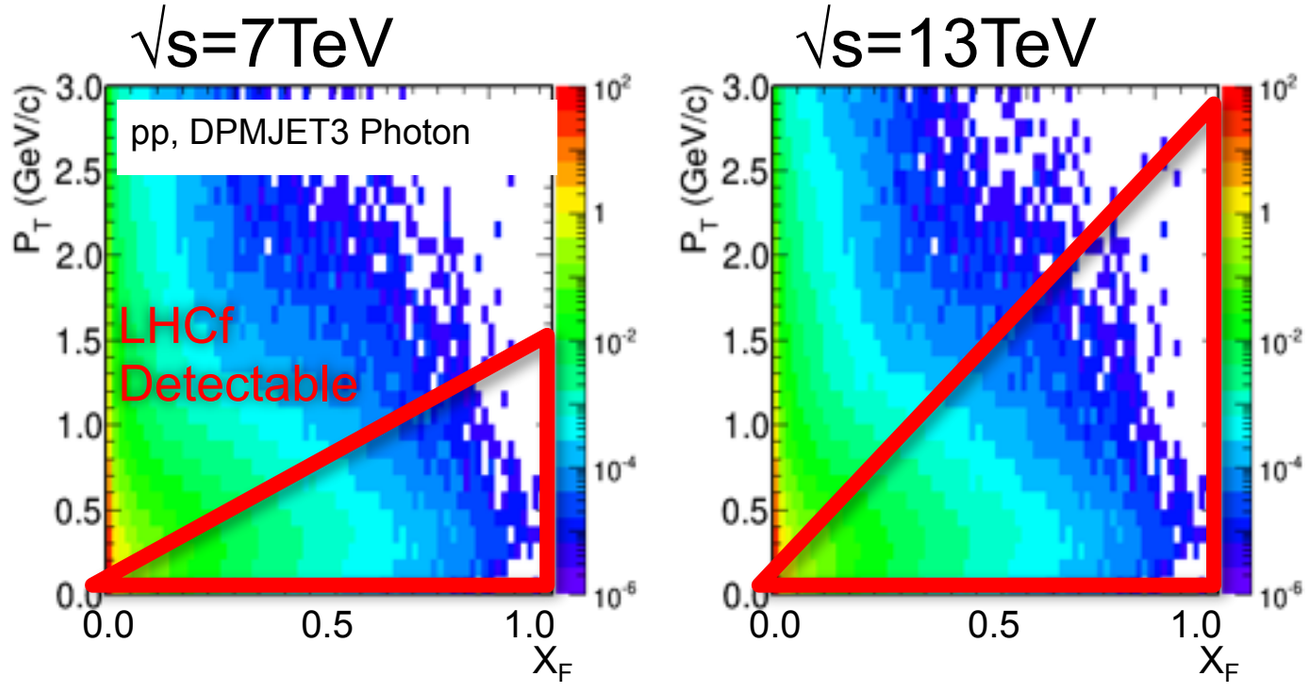


Photo @ CERN
Most of collaborators were in the front of the LHCf control room.

LHCf in Run II

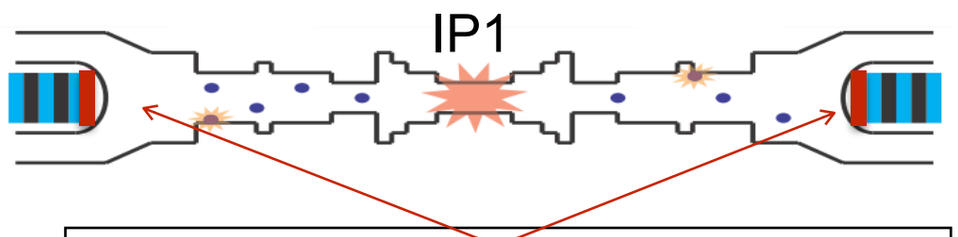
- Physics Motivation
  - Test the hadronic interaction models at the highest collision energy. $E_{Lab}=0.9\times10^{17}$eV
  - Energy Scaling
  - Enlarge the p_T acceptance.



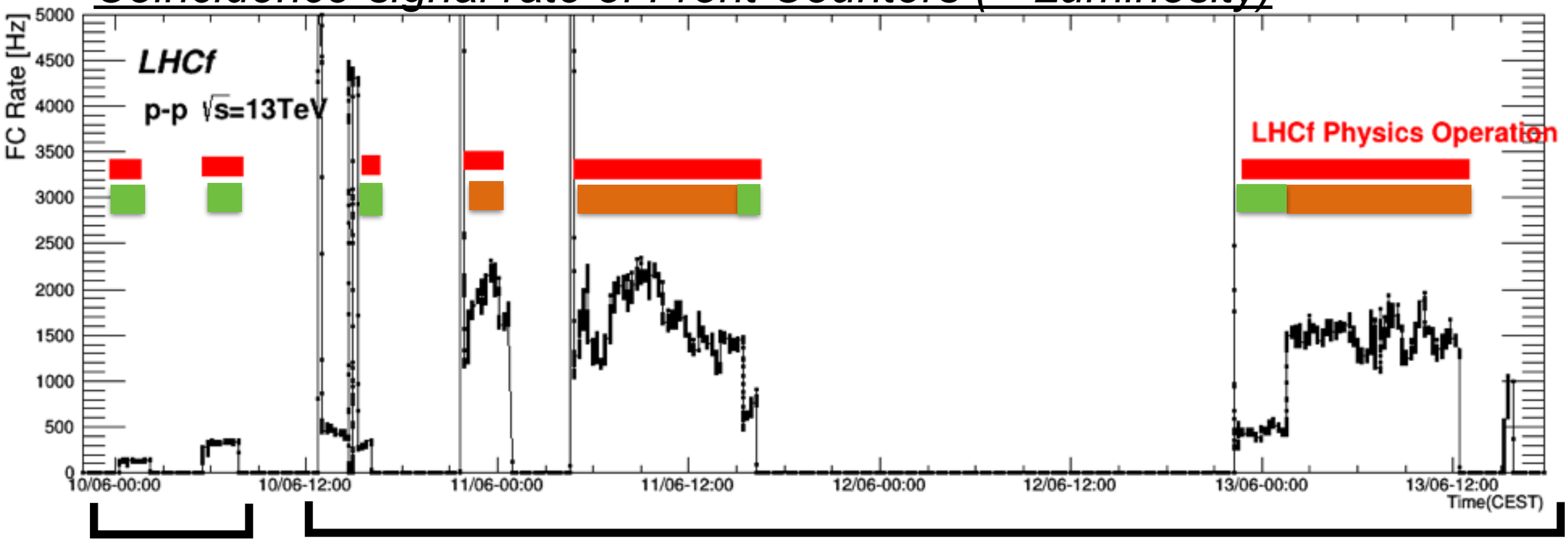
- Detector/DAQ upgrades for Run II
  - Improved the radiation hardness with replacing Plastic scintillators → GSO scintillators
  - Modified the silicon strip detectors to improve the dynamic range.
  - Optimized the layer depths of silicon strip detector in Arm2.
  - Upgraded the trigger system with new logic board.
  - Installed a new layer system as a calibration source for PMTs

Special run in June 2015

- The LHCf dedicated run.
  - 6 physics fills
  - Low Pileup : μ = 0.01-0.03
    - μ=0.01 for photon, neutron analysis
    - μ=0.03 for π^0 analysis



Coincidence-signal rate of Front Counters (∝ Luminosity)



β*=19m, I_b=2x10^{10}

β*=19m, I_b=10^{11}, separation collisions

Operation in Run II

- 26.6 hours of operation with DAQ rate of 200 - 500 Hz
- 39 M shower events and 0.53 M π^0 events were obtained.
- The final triggers of LHCf were sent to ATLAS for common operation.

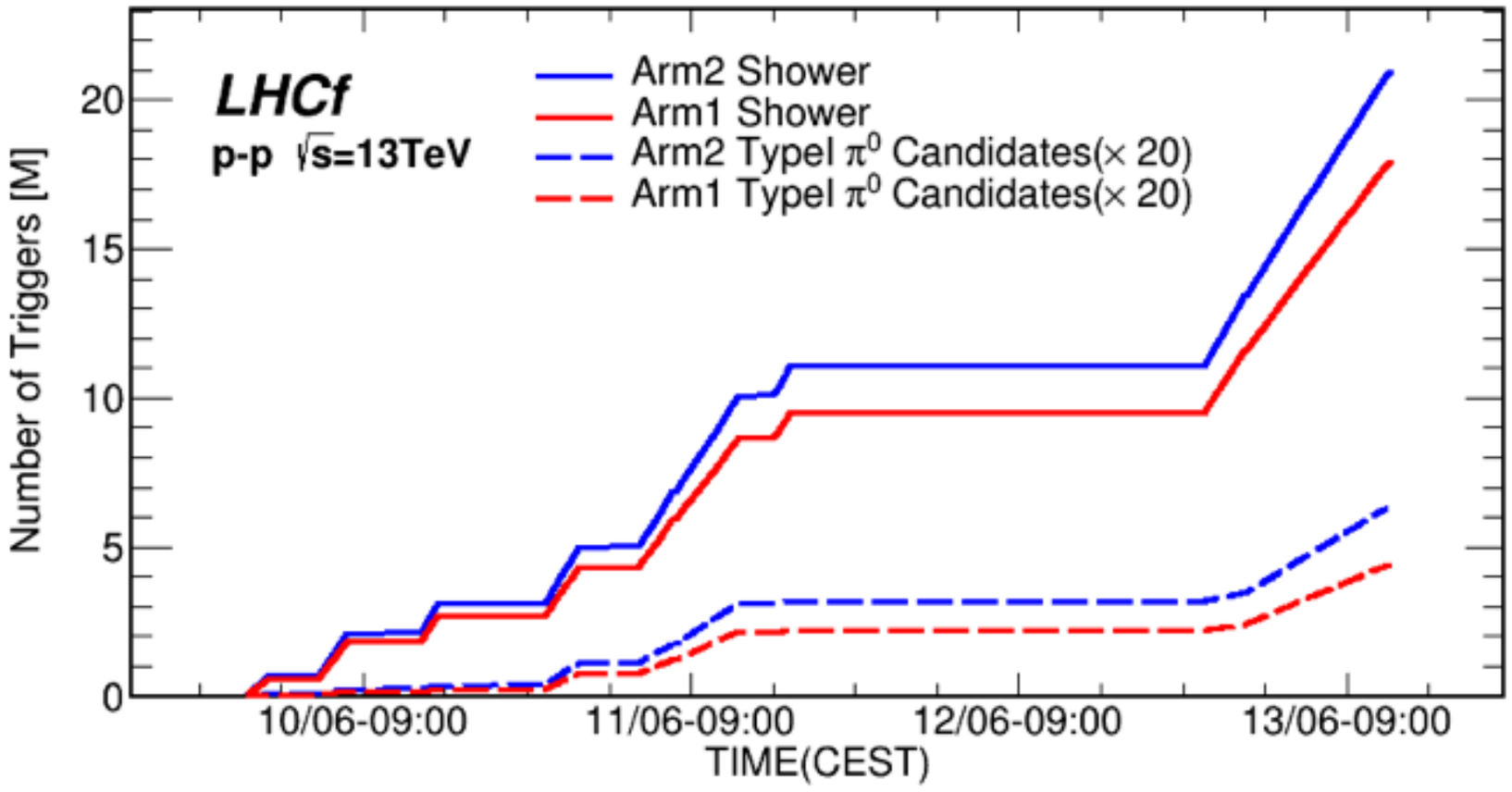


Table of Statistics

	Arm1	Arm2
Shower Events	18 M	21 M
π^0 Events	0.22 M	0.31 M

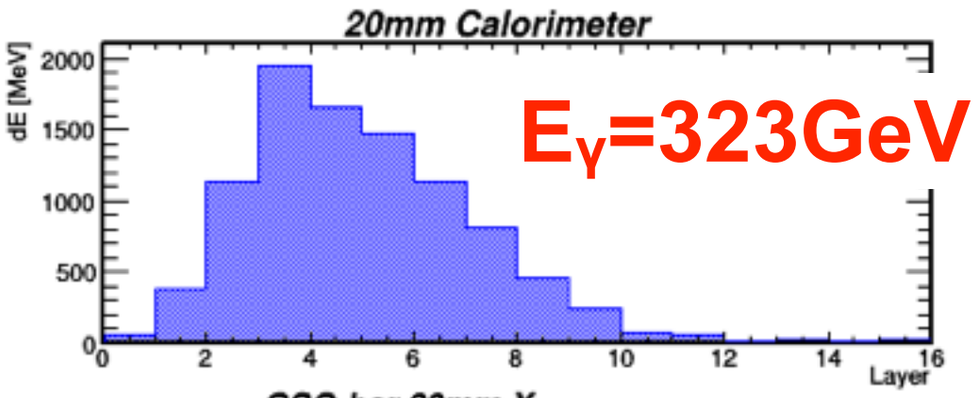
Arm1 Event Display

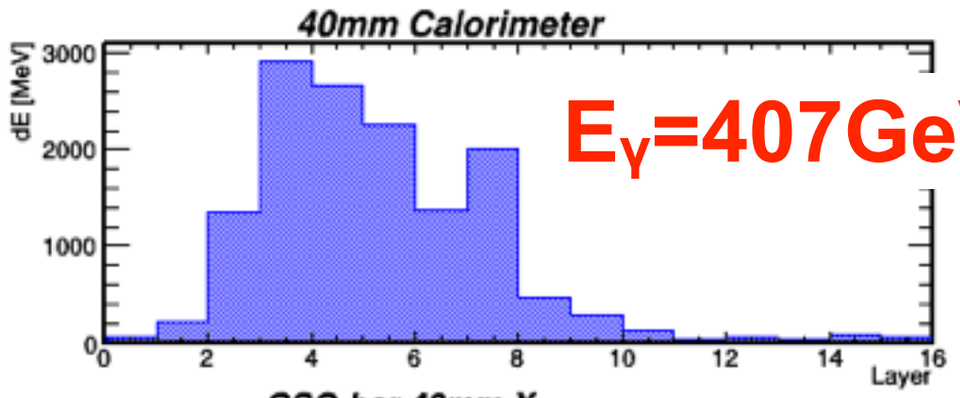
LHCf Arm1 Detector

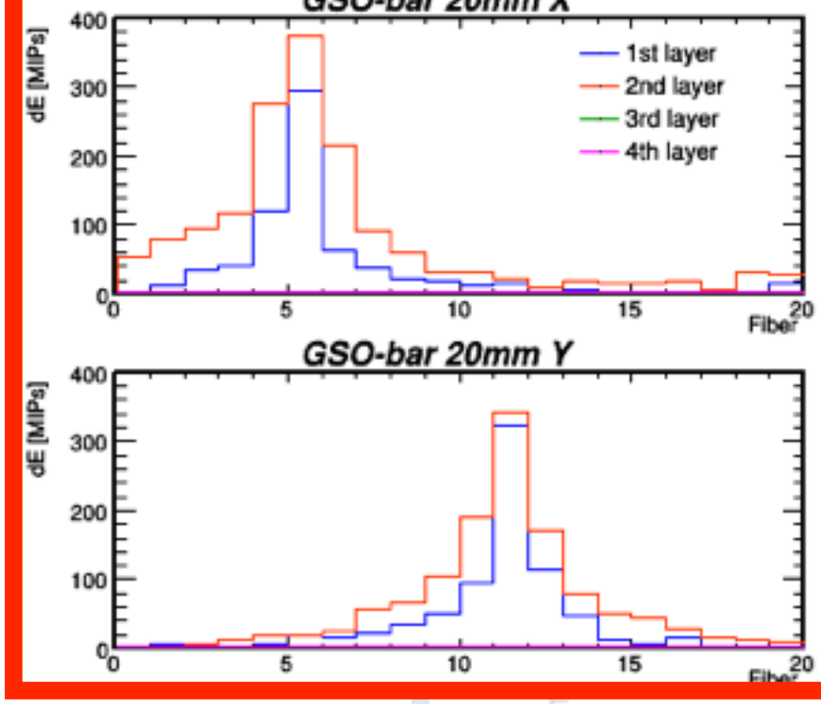
π^0 Candidate Event

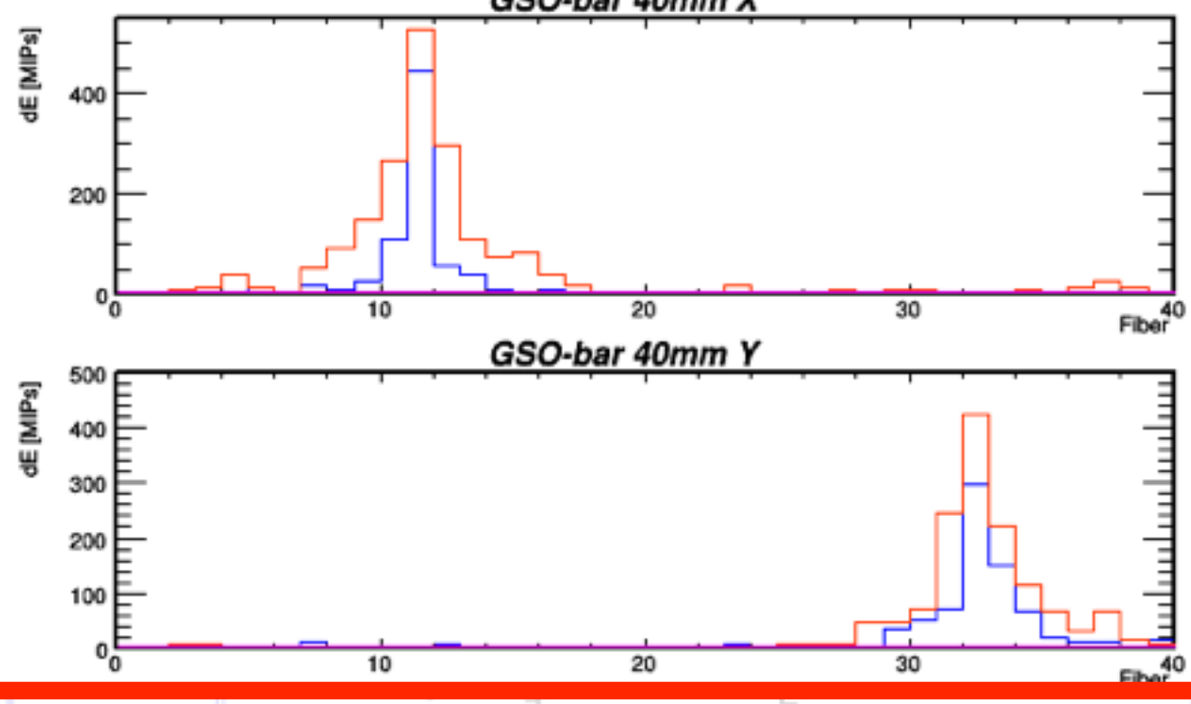
LHC p-p, $\sqrt{s}$ = 13 TeV Collisions

RUN:	44299
NUMBER:	4990
TIME:	1434141164
FILL:	3855
E_{20mm} :	323 GeV
E_{40mm} :	407 GeV
$M_{\gamma\gamma}$:	138 MeV









Arm1 Event Display

LHCf Arm1 Detector

RUN: 44299
NUMBER: 4990
TIME: 1434141164

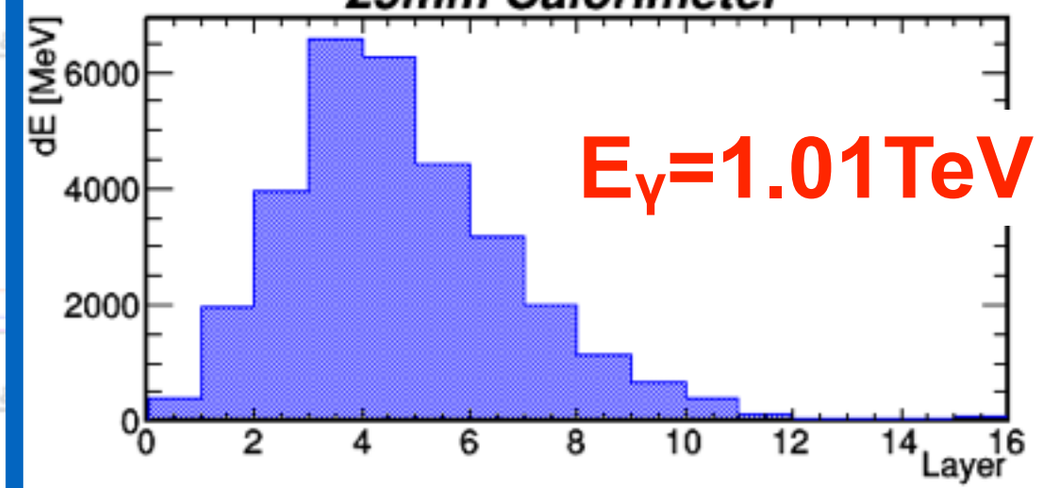
Arm2 Event Display

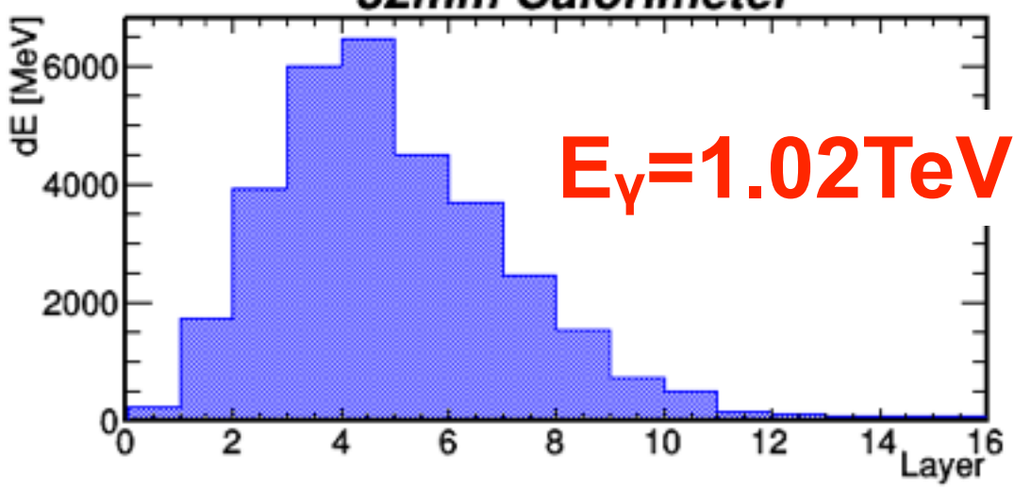
LHCf Arm2 Detector

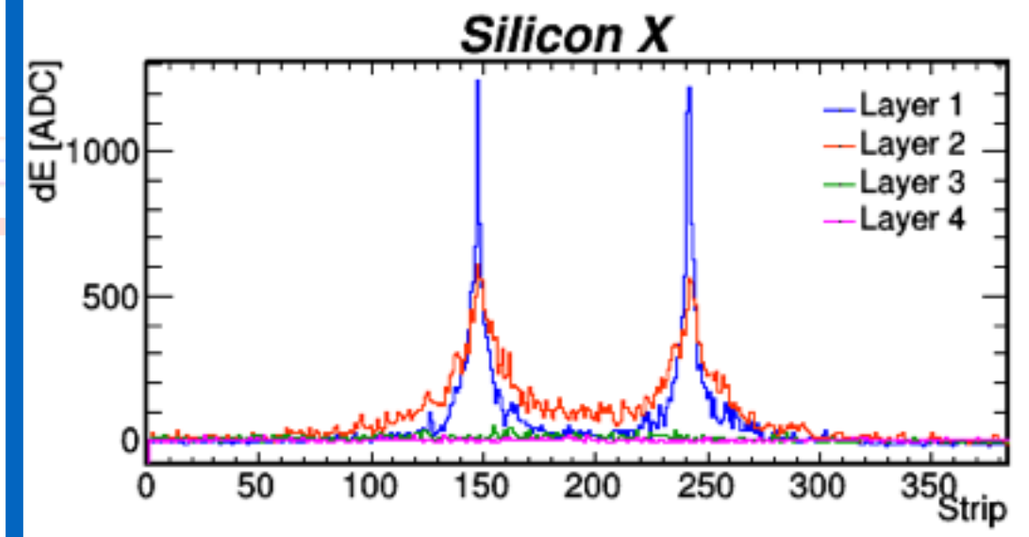
π^0 Candidate Event

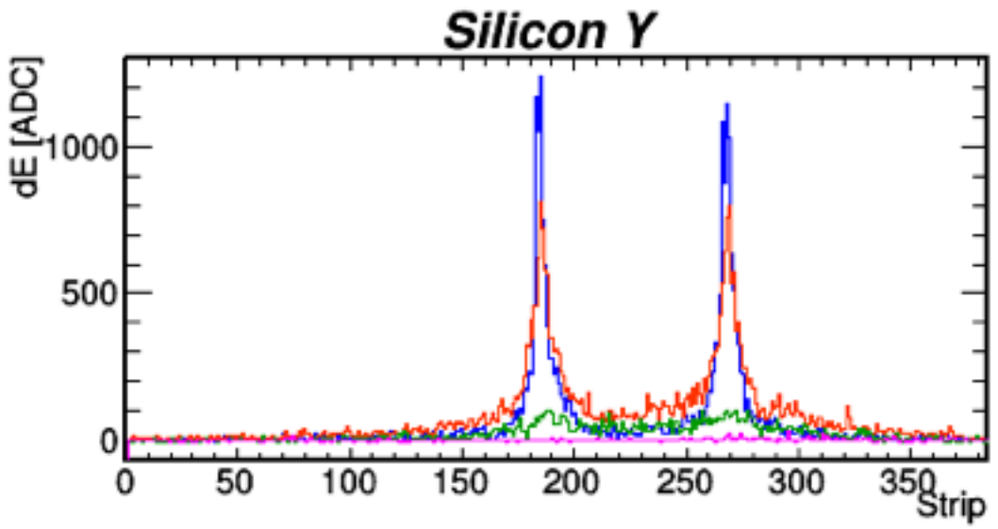
LHC p-p, $\sqrt{s}$ = 13 TeV Collisions

RUN: 44484
NUMBER: 3010
TIME: 1434152507
FILL: 3855
E_{25mm}: 1014 GeV
E_{32mm}: 1021 GeV
$M_{\gamma\gamma}$: 147 MeV





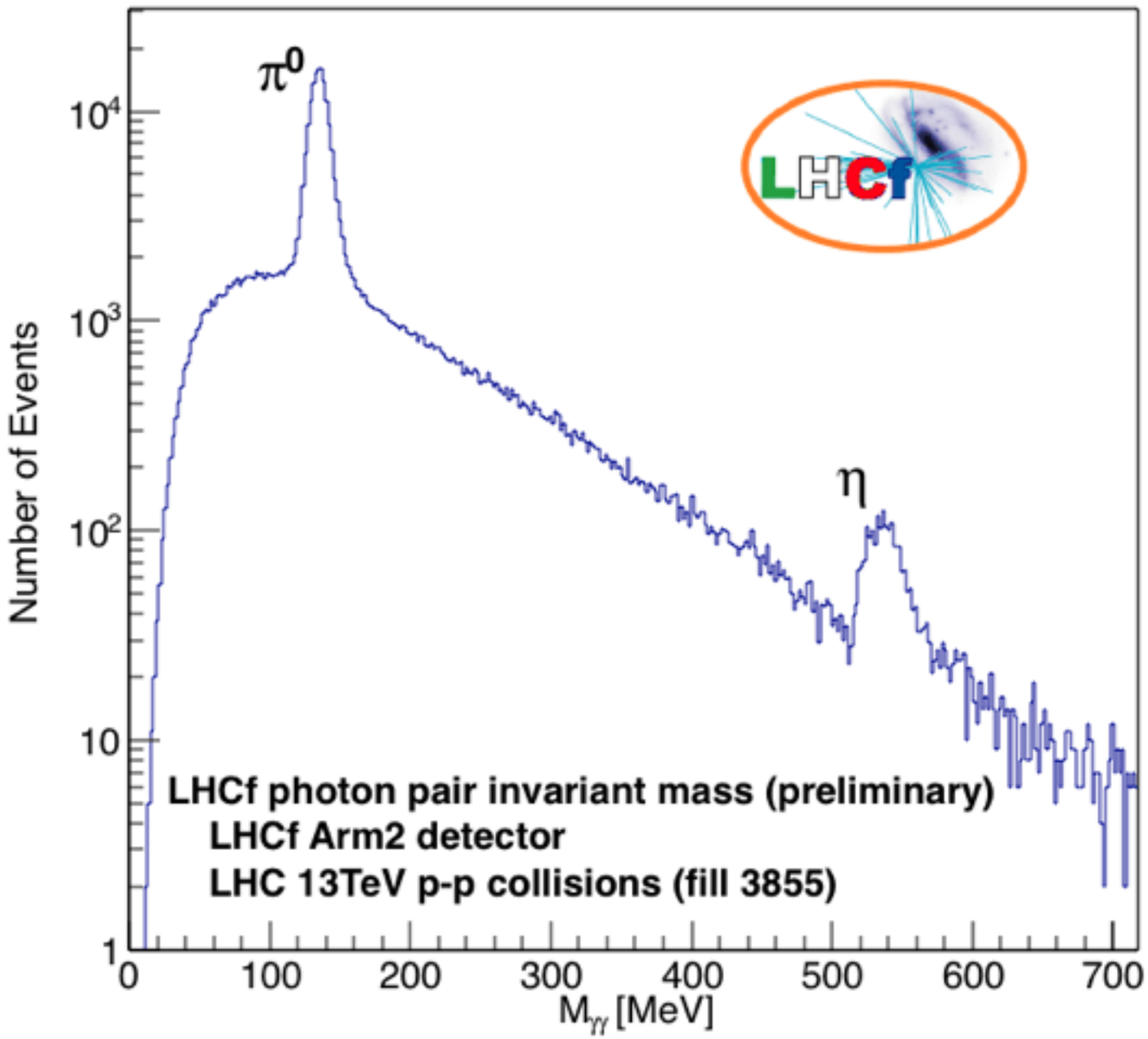


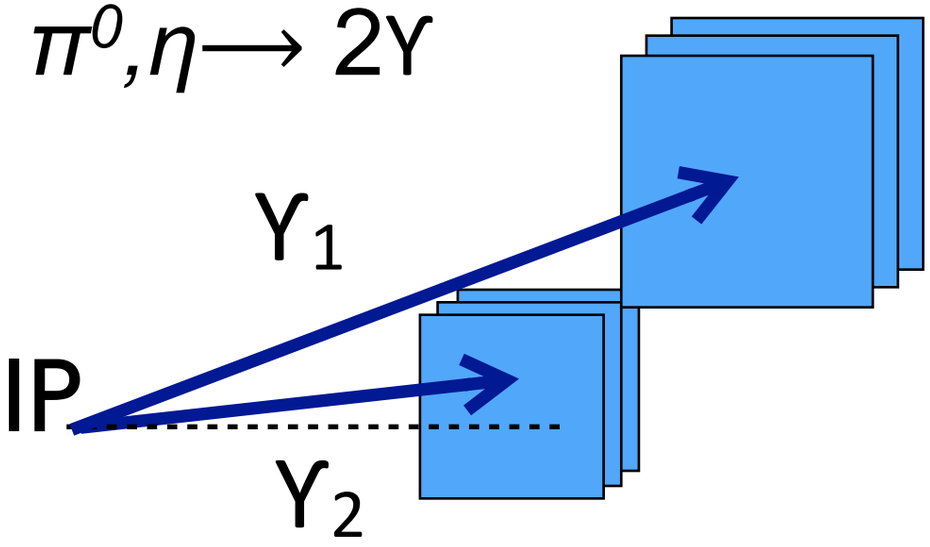


$M_{\gamma\gamma}$ distribution

Peaks corresponding to π^0, η

- Event sample for measurement of π^0,η inclusive spectra
- Evaluate the energy scale of calorimeters.





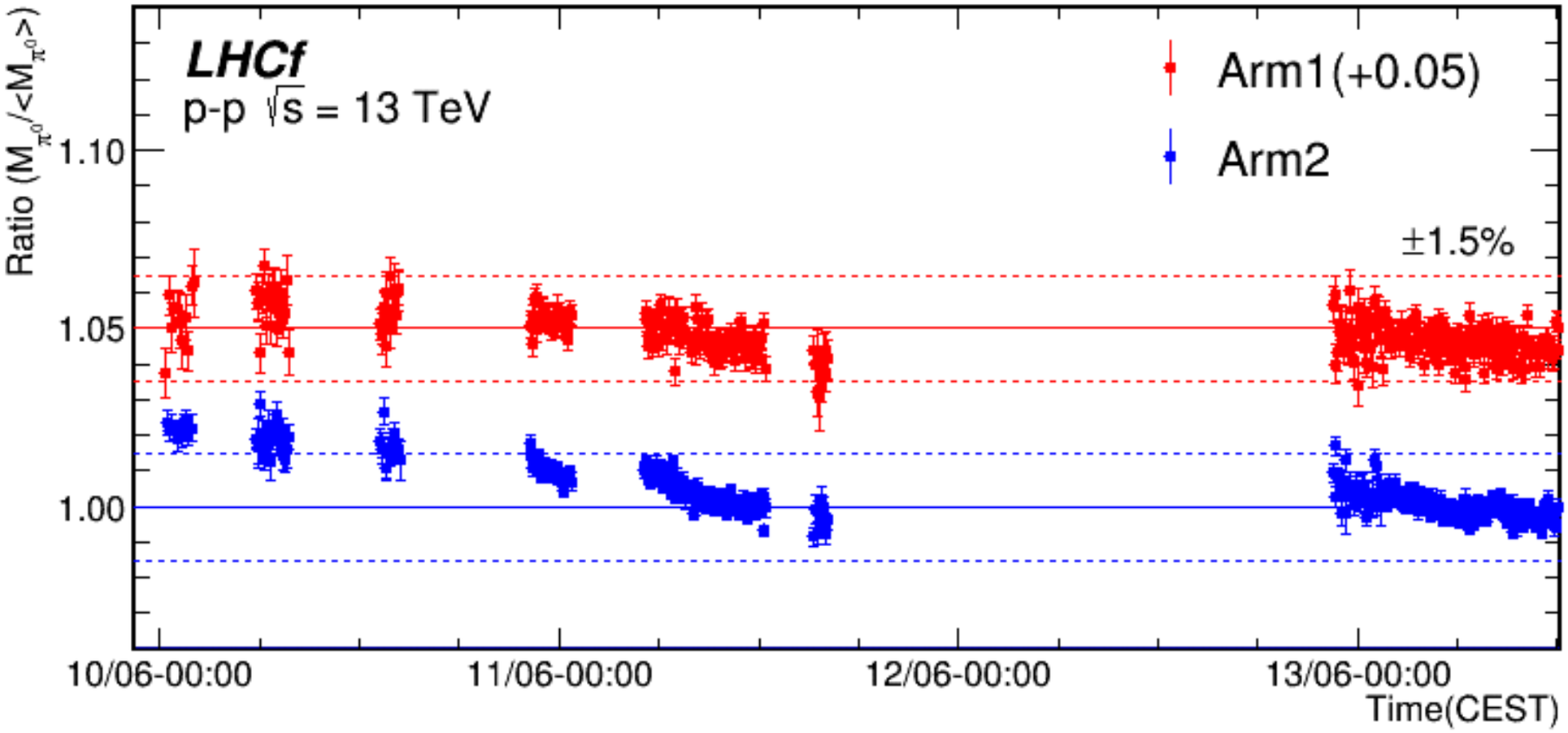
Energy thresholds
for π^0 and η detections

For π^0 : $E_{\pi 0} > 600$GeV

For η : $E_\eta > 2.2$ TeV

Stability of Energy Scale

- The energy scales of detectors could be monitored by peak mass position of π^0
- They were stable within a few %.



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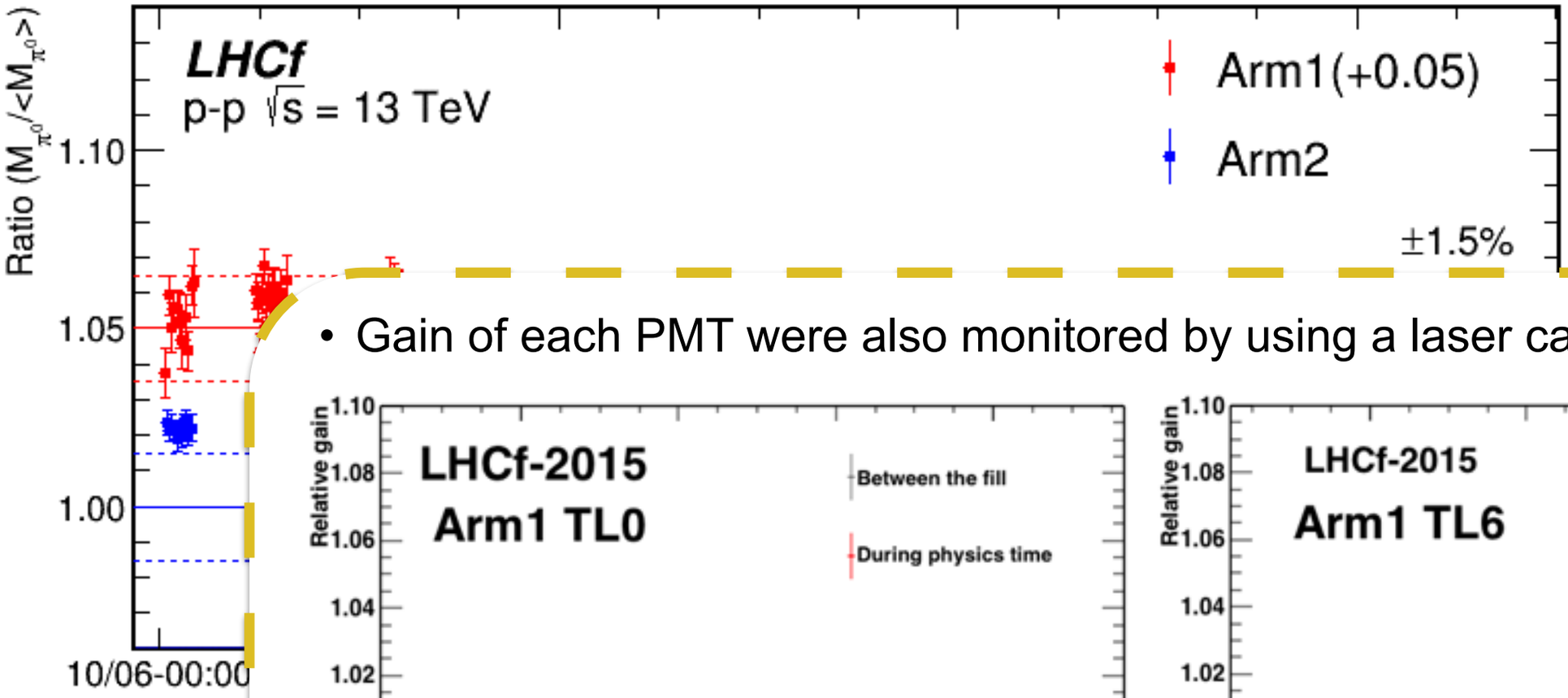
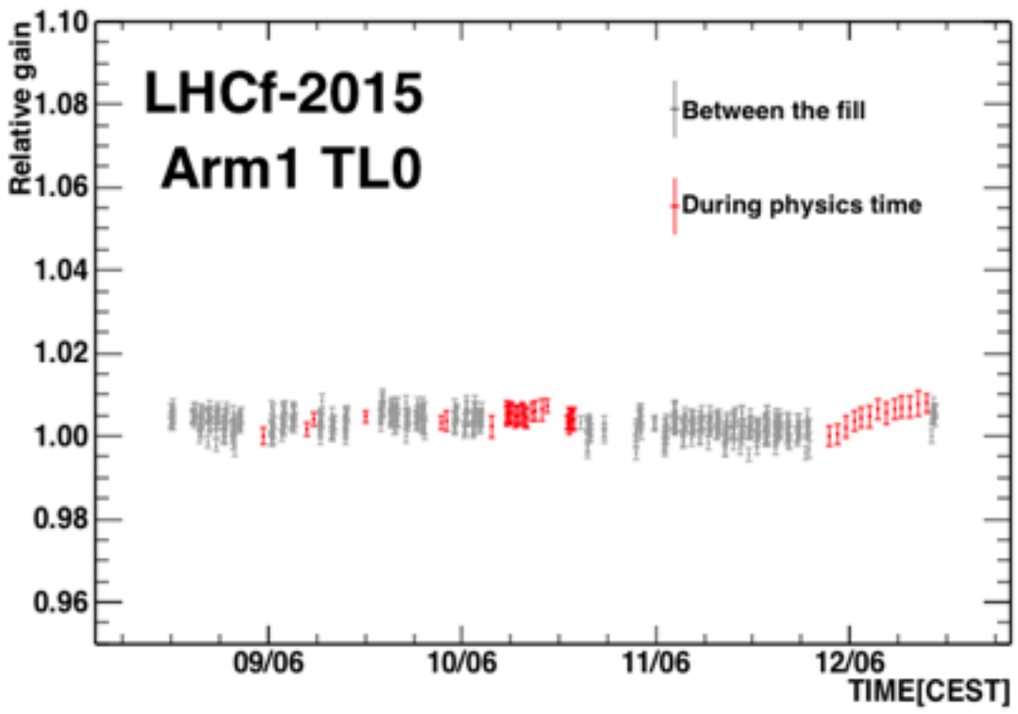
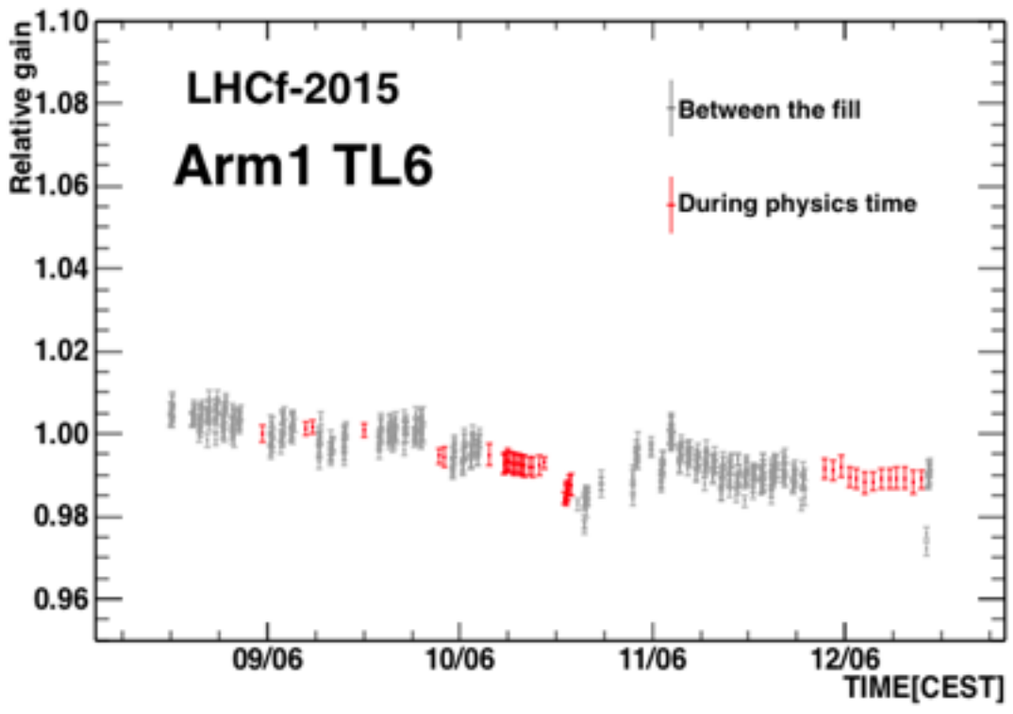


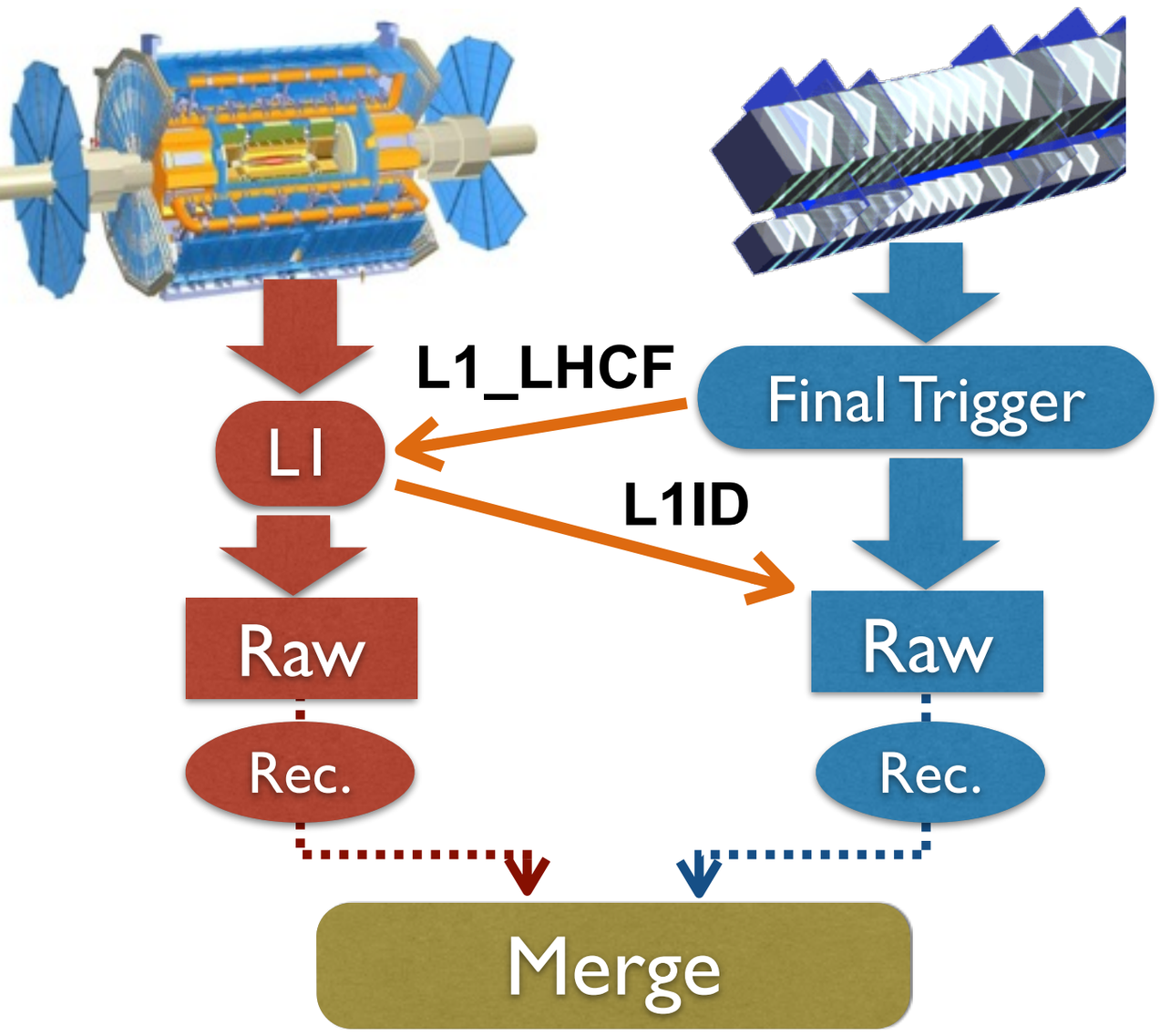
- Gain of each PMT were also monitored by using a laser calibration system





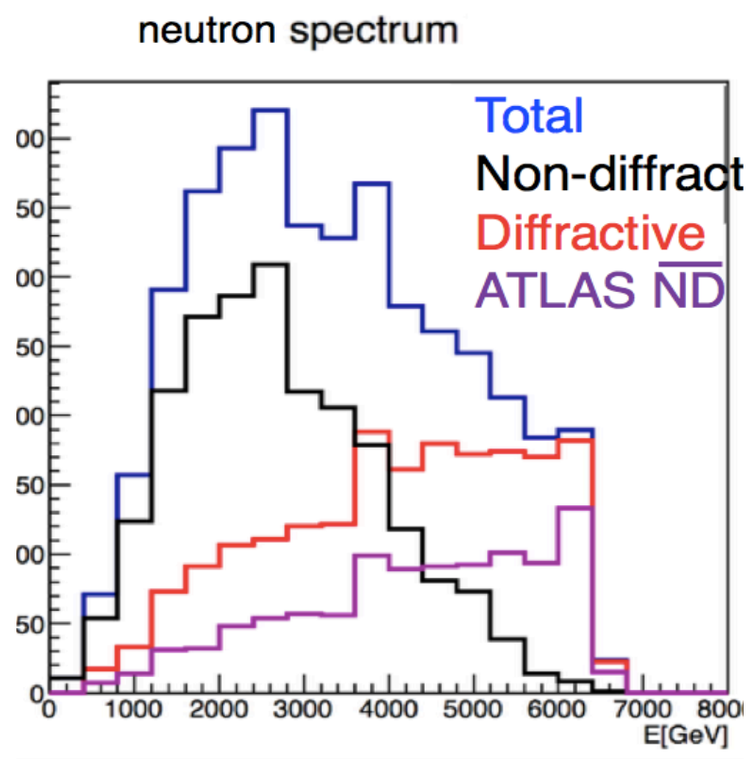
Common Operation with ATLAS

- Signals of LHCf final trigger were send to the ATLAS DAQ system to trigger the ATLAS



Physics Items
of the common operation

- Diffractive Physics
  Study of forward particle production with event category of diffractive/non-diffractive



a MC study by PYTHIA

- Measurement of p-π interaction

Summary

The LHCf experiment has successfully completed the operation with *pp*, $\sqrt{s}$=13TeV collisions in Run II.

- LHCf had a operation in 9-13 June, 2015 with low-pileup collisions. In 26.6 hours operation, 39 M showers and 0.5 M π^0 events were obtained.
- During the operation, the detectors and the DAQ worked without any problems. The energy scale of calorimeters were stable within a few %.
- Common operation with ATLAS has been performed with sending the LHCf trigger to ATLAS.
- Analysis for physics are on-going now.