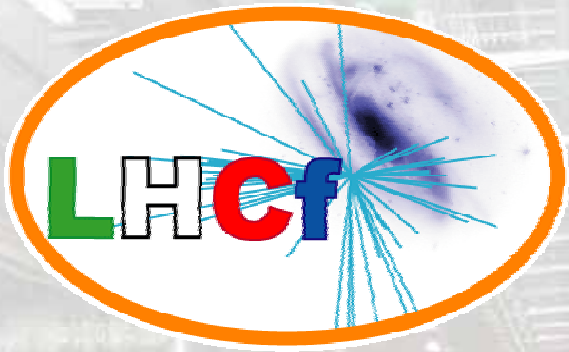
LHCf status report



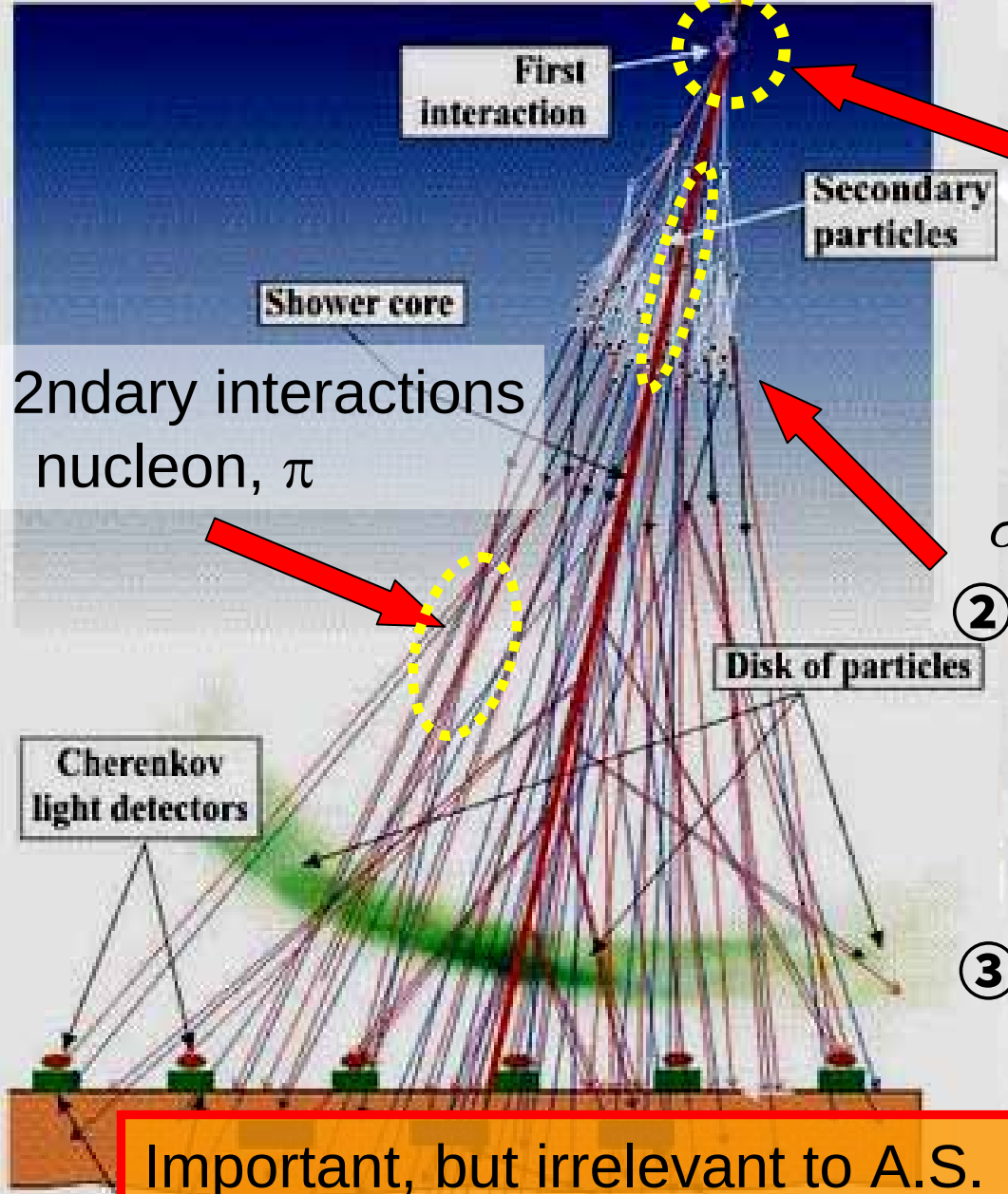
Yoshitaka Itow
for the LHCf collaboration
STE Lab / Kobayashi-Maskawa Inst.
Nagoya University

LHCC Open session
21Mar 2012 CERN

Kobayashi-Maskawa Institute
for the Origin of Particles and the Universe

LHCf activities 2011 - 2012

- Recent new results
  - 900GeV single photon spectra
  - 7TeV pi0 pT spectra
- Preparation for p-Pb run
- Status of detector upgrade



① Inelastic cross section

If large σ
rapid development
If small σ
deep penetrating

$\sigma_{inel} = 73.5 \pm 0.6^{+1.8}_{-1.3} mb(TOTEM)$

② Forward energy spectrum

If softer
shallow development
If harder
deep penetrating

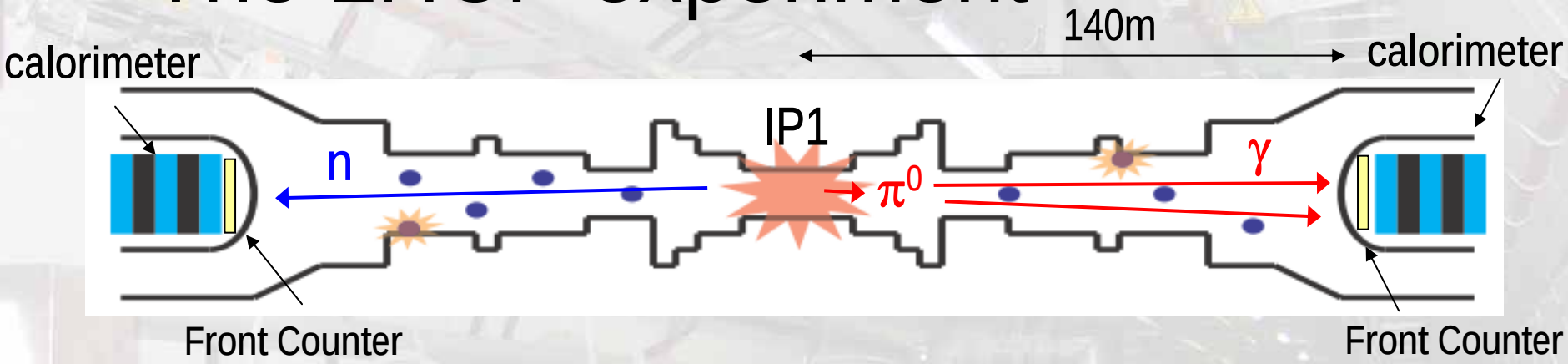
③ Inelasticity k= 1-p_{lead}/p_{beam}

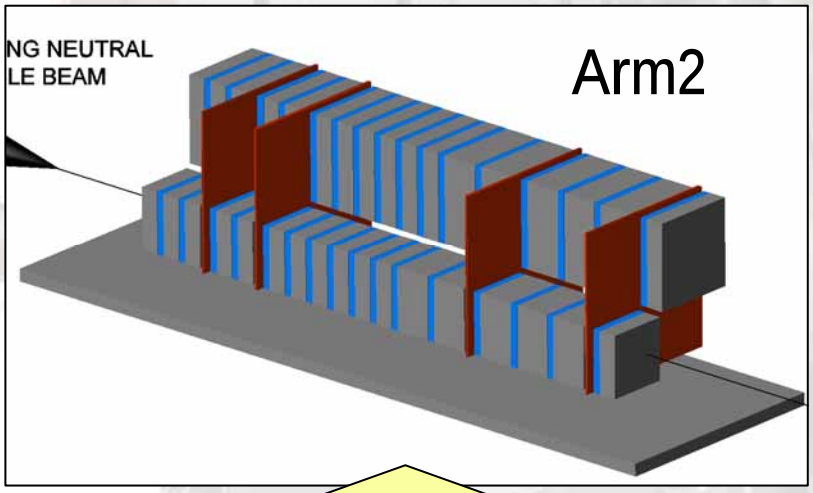
If large k
rapid development
If small k
deep penetrating

④ 2ndary interactions
nucleon, π

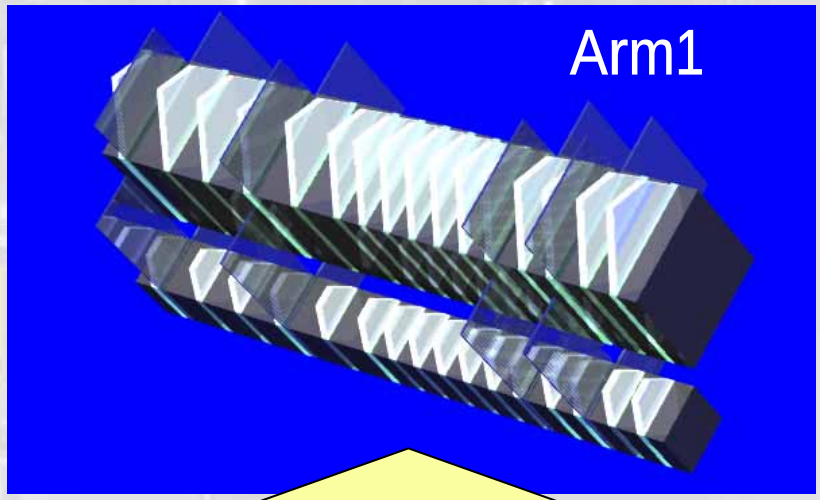
Important, but irrelevant to A.S.
⑤P_T
⑥multiplicity (relevant to N_μ)

The LHCf experiment





$44X_0$,
$1.6\ \lambda_{int}$



16 tungsten + pl.scinti. layers
25mmx25mm+32mmx32mm
4 Silicon strip tracking layers

16 tungsten + pl.scinti. layers
20mmx20mm+40mmx40mm
4 SciFi tracking layers

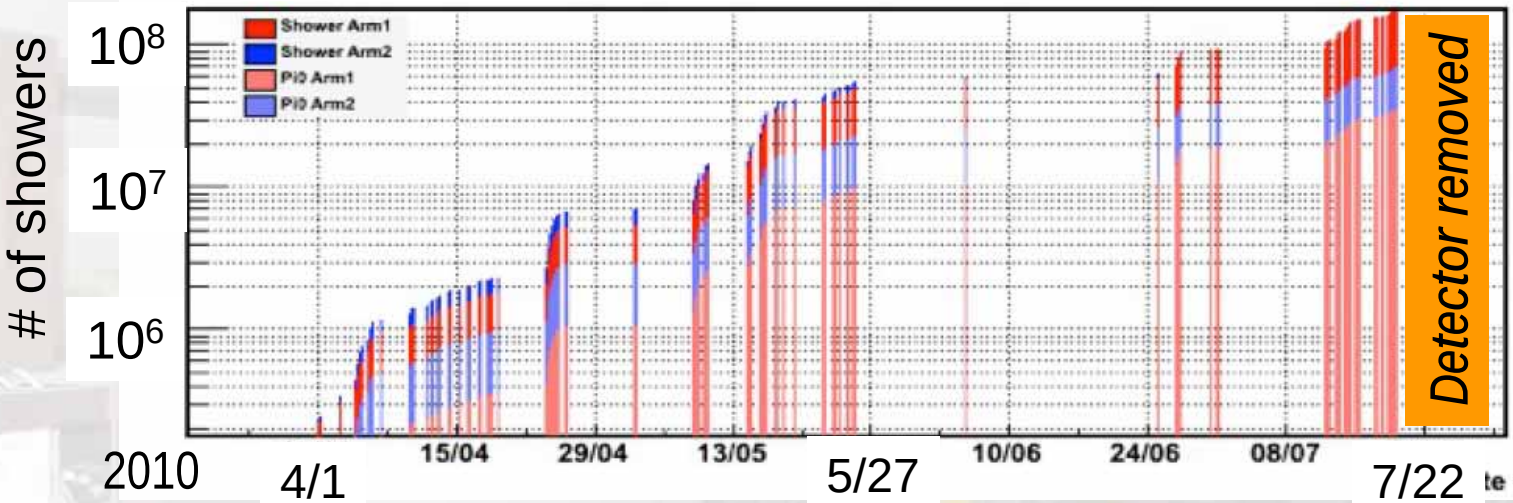
Summary of 2009-2010 run

Low luminosity (L=2~10e28cm^{2}s^{-1})
(1~2.5e10ppb, β*=2m,N_b=1~4)
No crossing angle

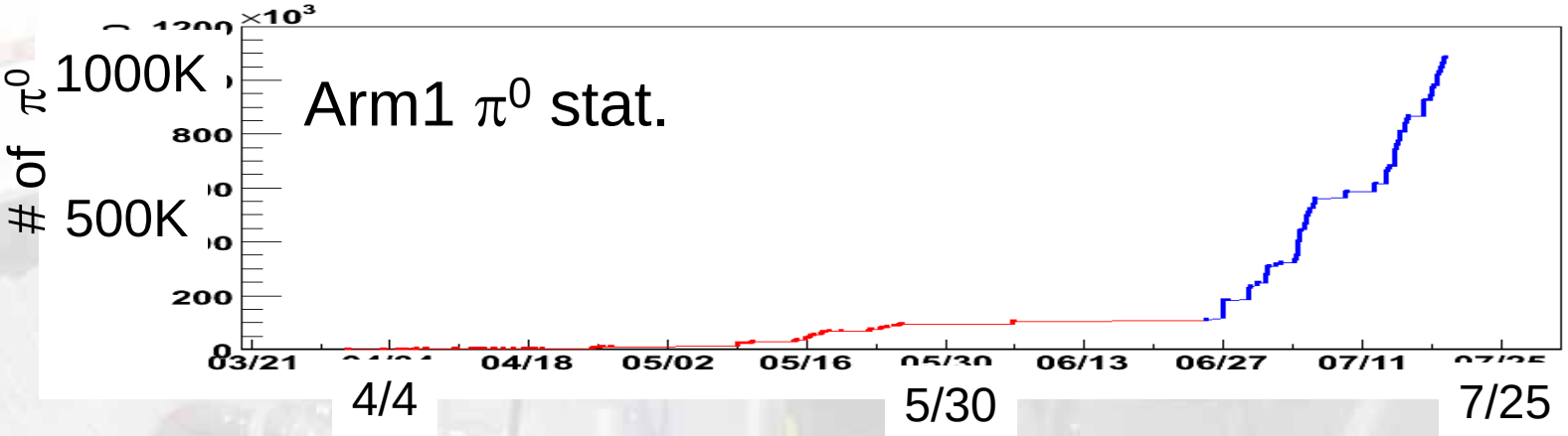
High luminosity (L=3~20e29cm^{2}s^{-1})
(1e11ppb, b*=3.5m,Nb=1~8)
100μrad crossing

900GeV

Integrated showers at 7TeV



~350nb^{-1} collected



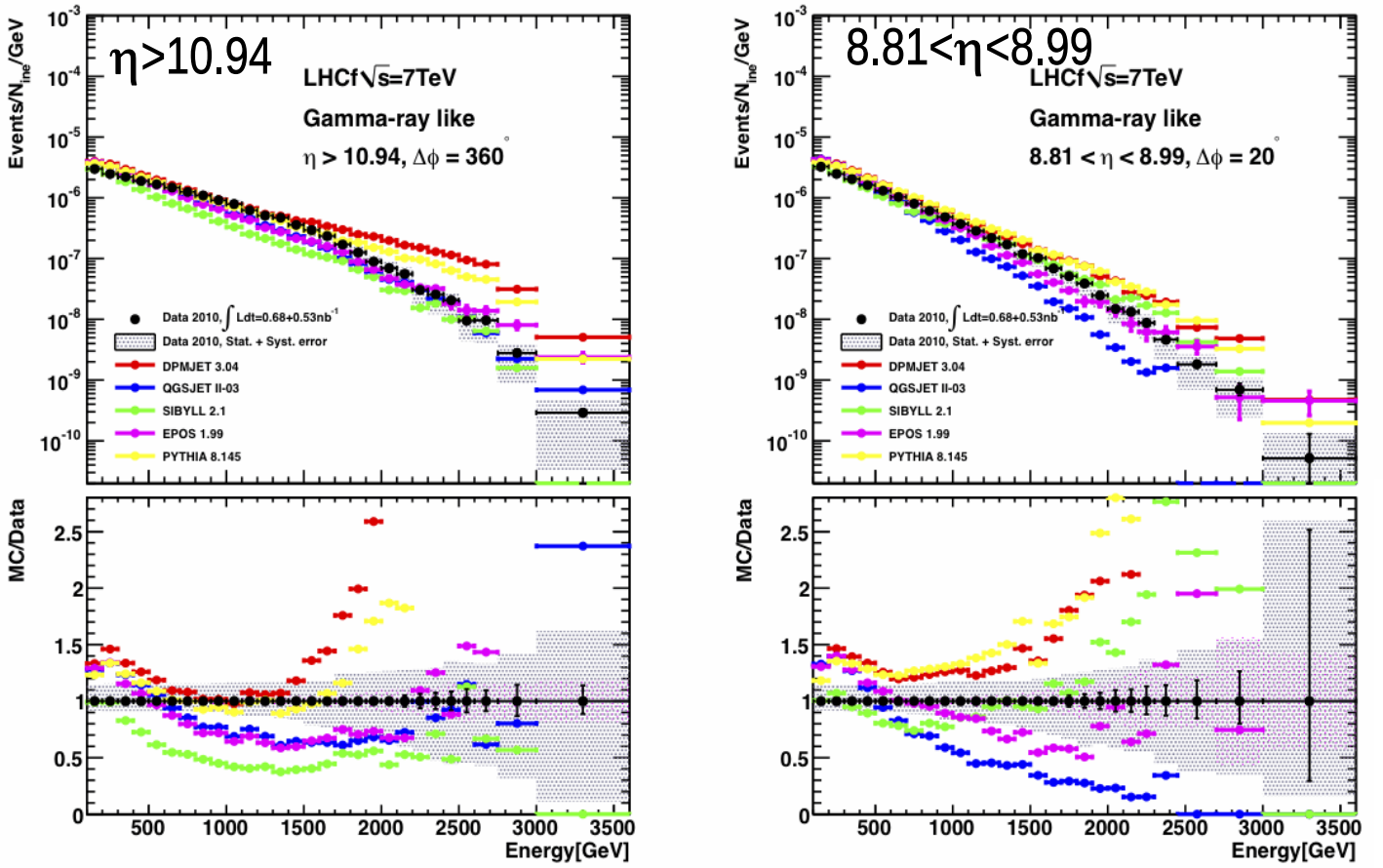
LHCf single γ spectra at 7TeV

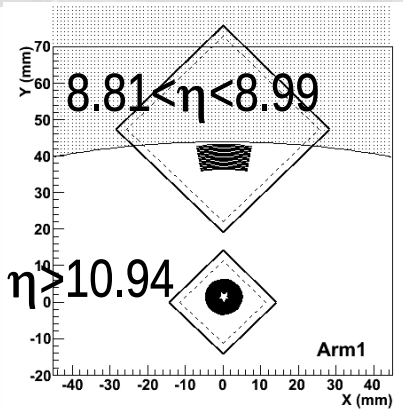
0.68 (0.53)nb^{-1} on 15May2010

DPMJET 3.04 QGSJETII-03 SIBYLL 2.1 EPOS 1.99 PYTHIA 8.145

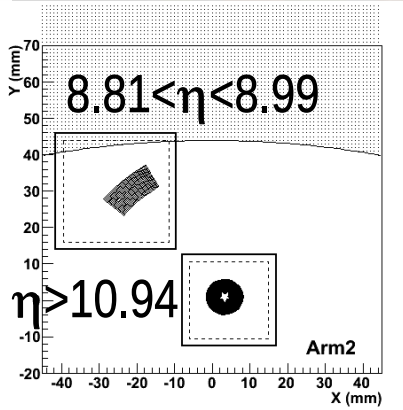
Gray hatch : Sys+stat errors

Magenta hatch: Stat errors of MC





Arm1



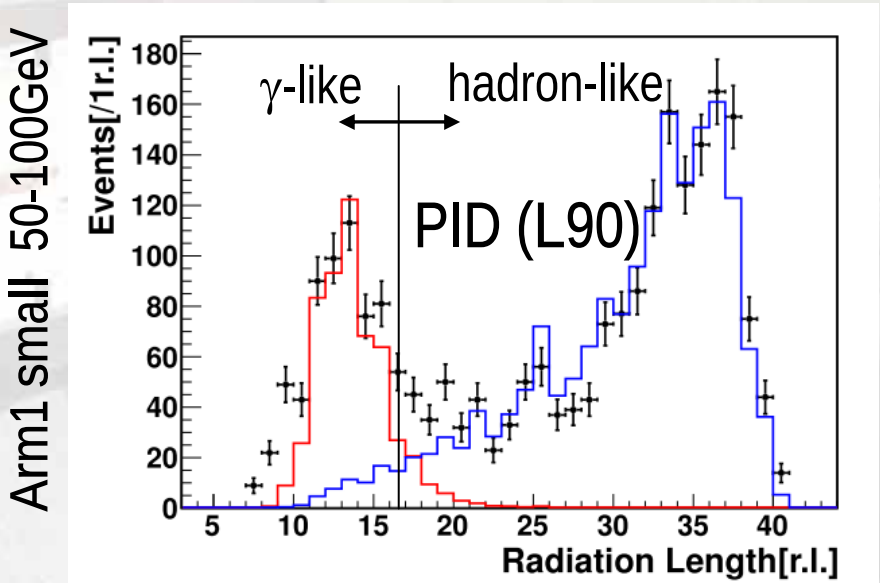
Arm2

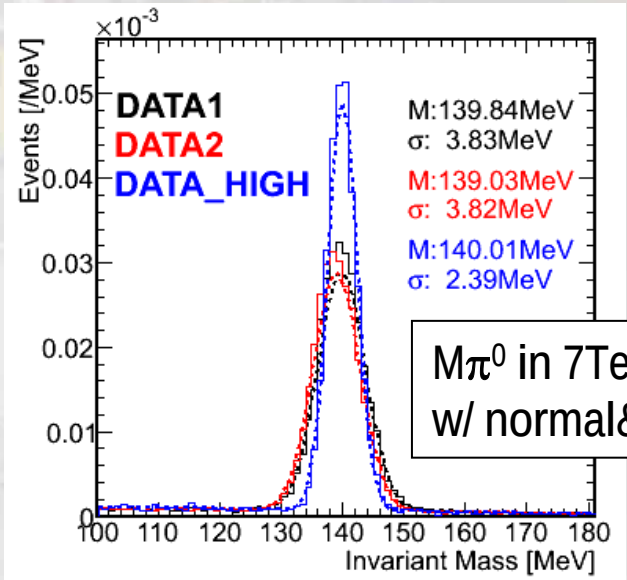
Phys.Lett. B703 (2011) 128-134

- None of the models agree with data
- Data within the range of model spread

New 900 GeV single γ analysis

- 0.3nb^{-1} data (44k Arm1 and 63k Arm2 events) taken at 2,3 and 27 May, 2010
- Low luminosity (L~10^{28} typical,1 or 4 xing), negligible pile up (0.05 int./xing).
- Relatively less η-dependence in the acceptance. Negligible multi-incidents at a calorimeter (~ 0.1 γ (>50GeV) /int.)
- Higher gain operation for PMTs. Energy scale calibration by SPS beam, checked with π^0 in 7TeV data.

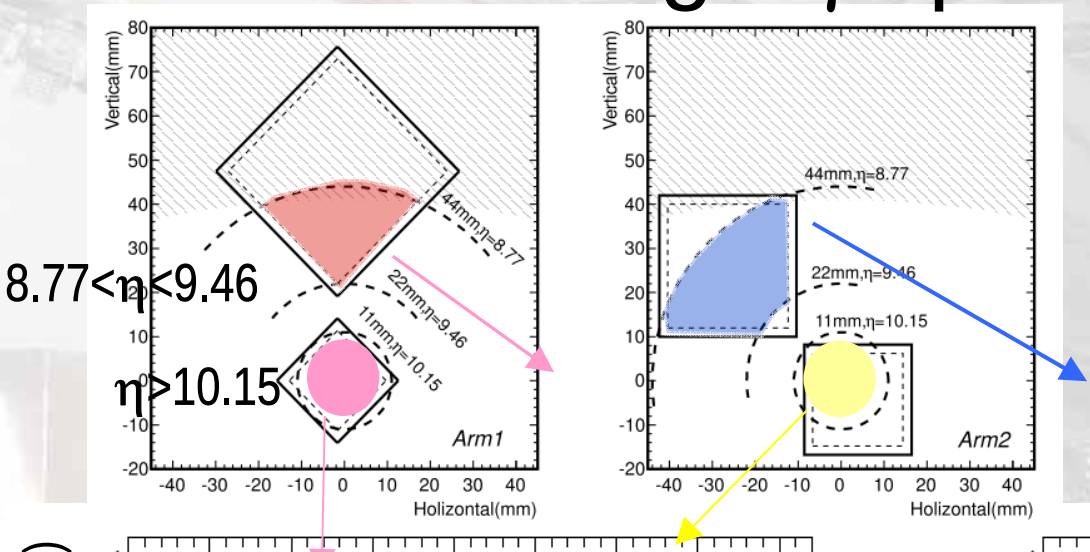




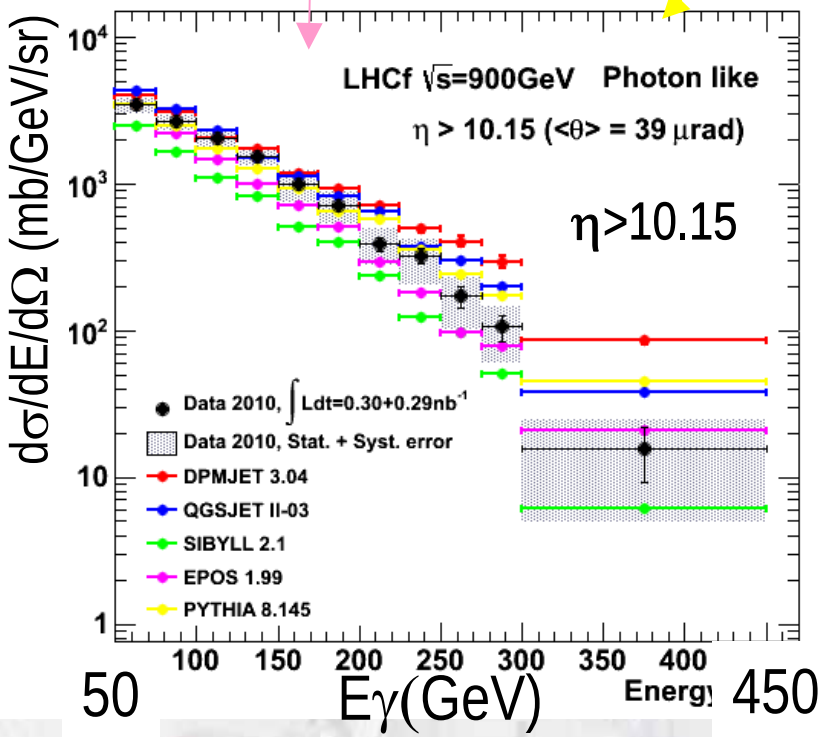
New LHCf single γ spectra at 900 GeV

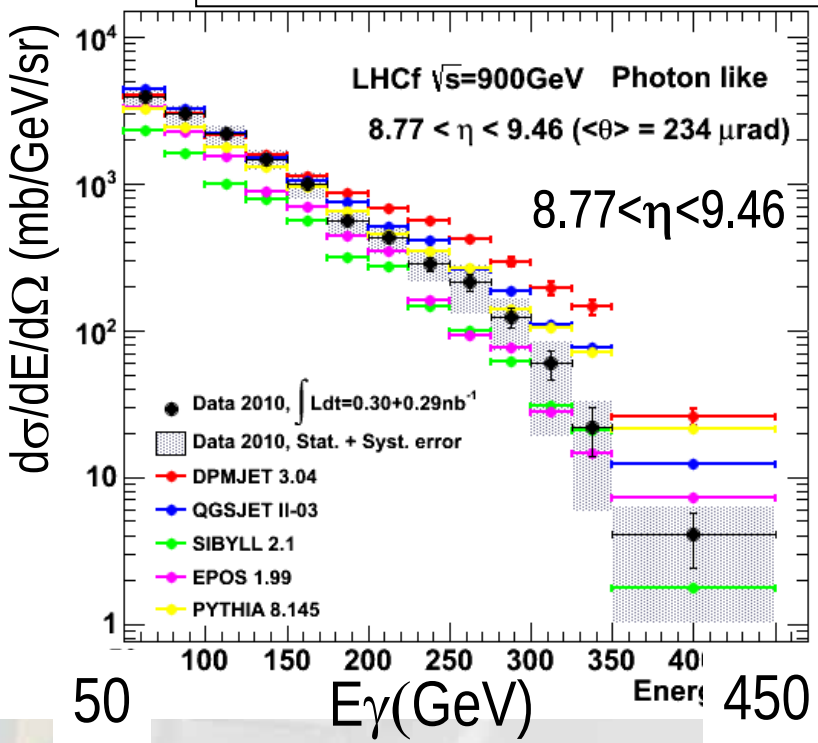
(submitted PLB)

DPMJET 3.04 QGSJETII-03
SIBYLL 2.1 EPOS 1.99
PYTHIA 8.145 Data

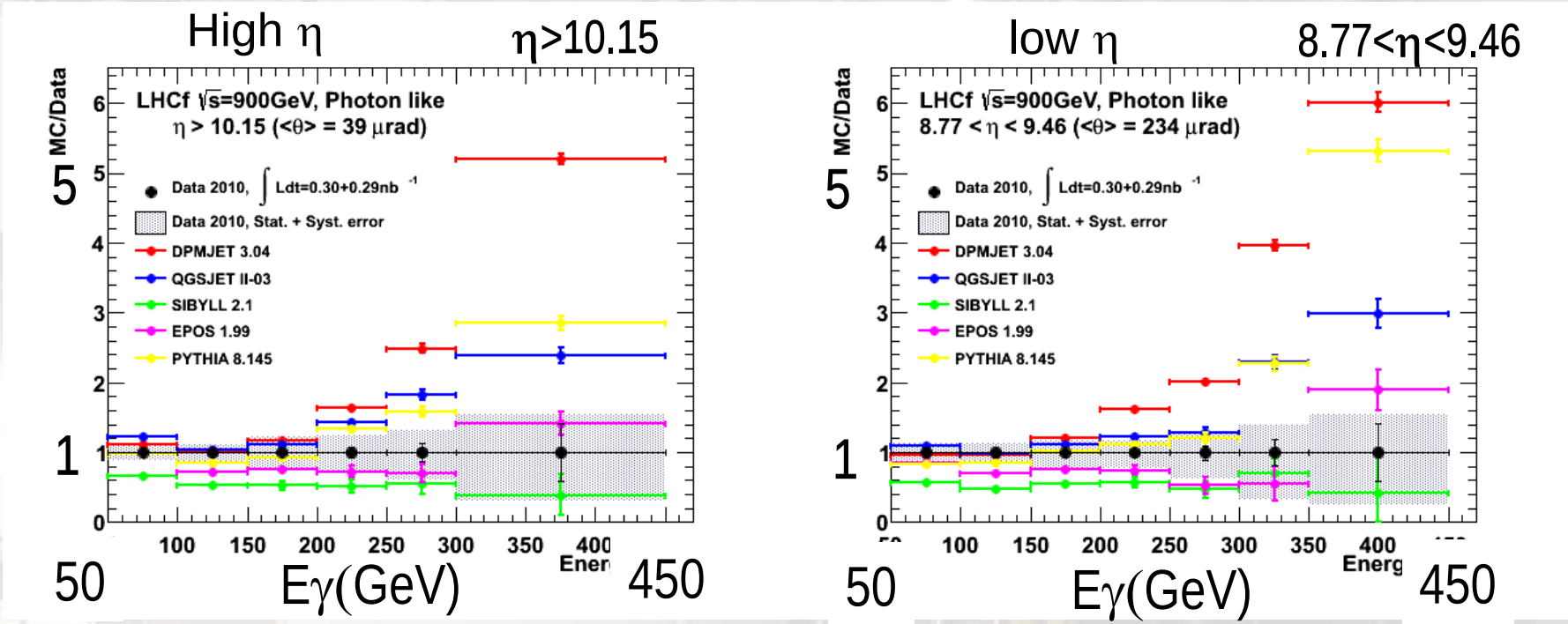


Arm1 + Arm2 combined
MC stat err only shown for DPMJET3
+-21% lumi err is not shown





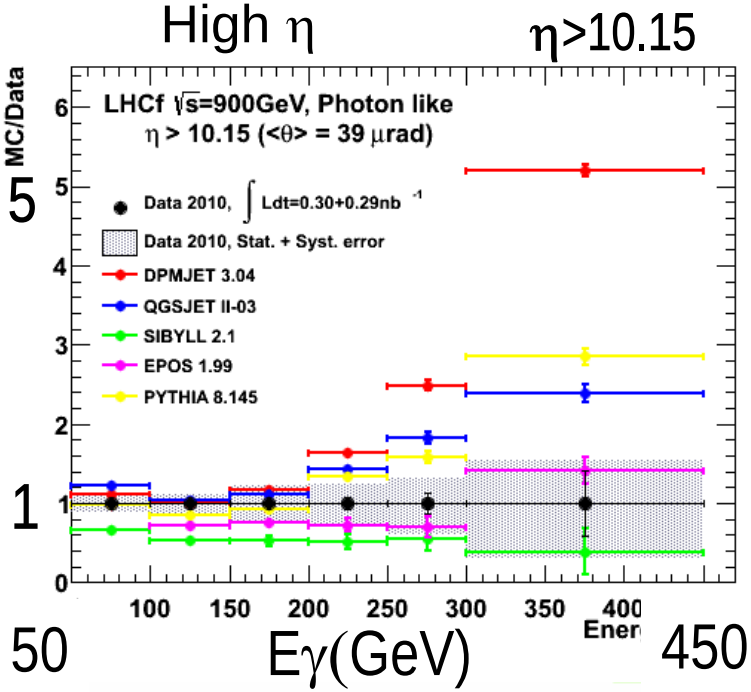
LHCf 900GeV single γ spectra: MC/Data

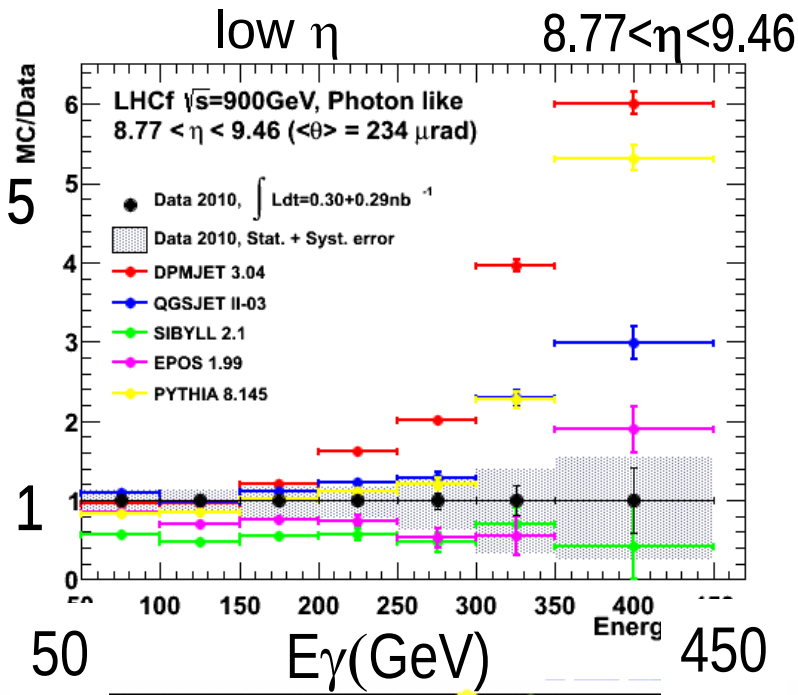


Error bars show stat errs for the samples.
Hatched areas show data stat+sys errs.

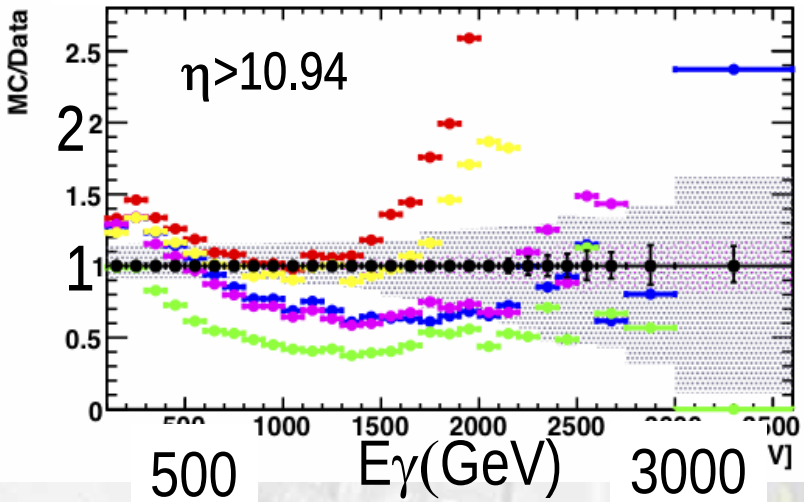
LHCf 900GeV single γ spectra: MC/Data

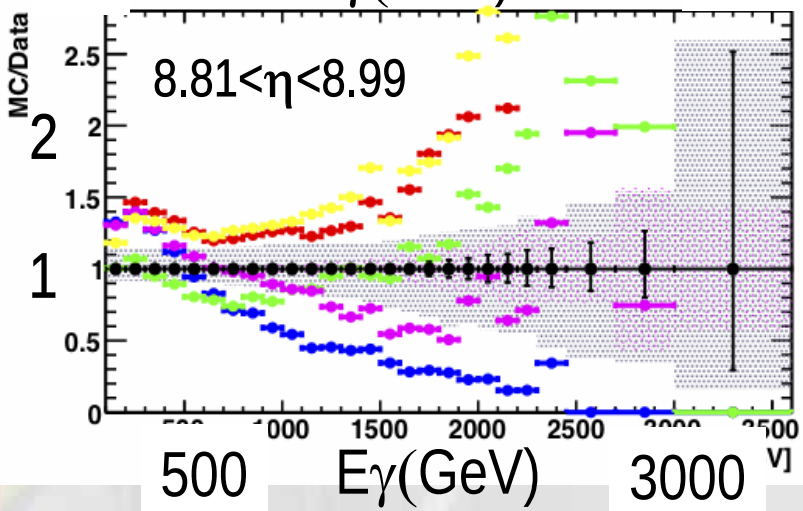
900GeV



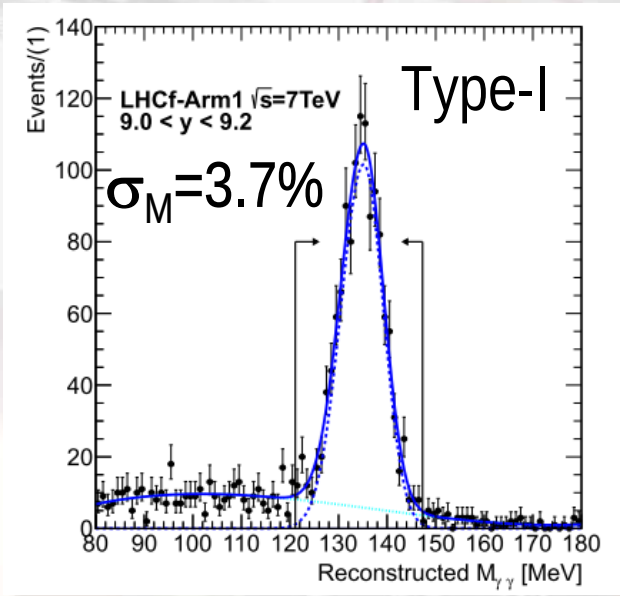


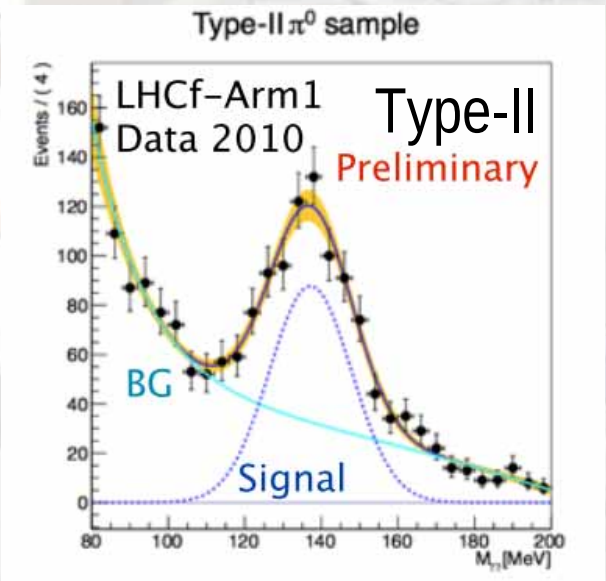
7TeV





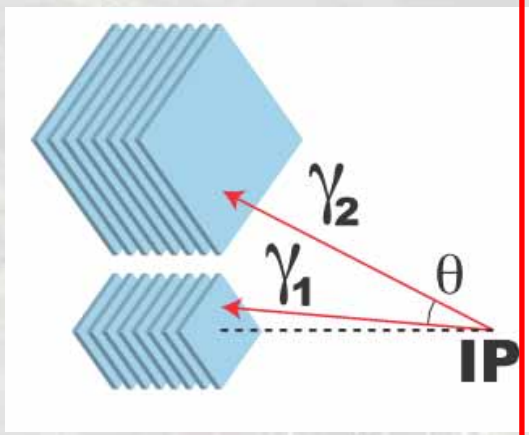
LHCf 7TeV π^0 analysis

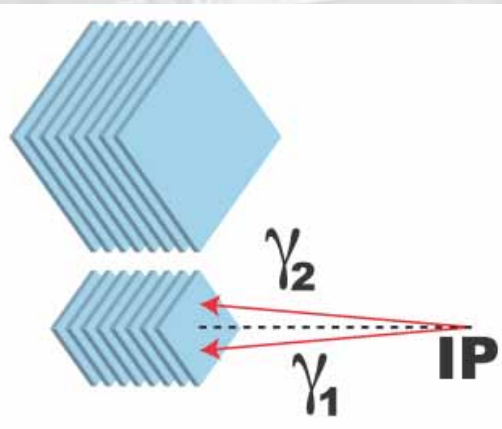


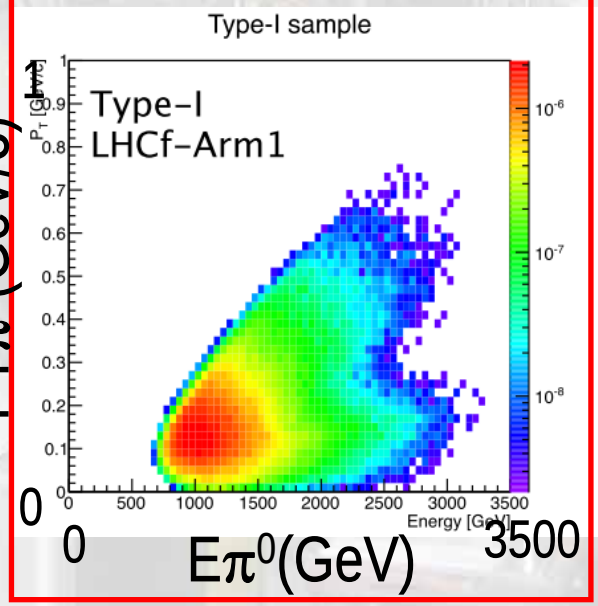


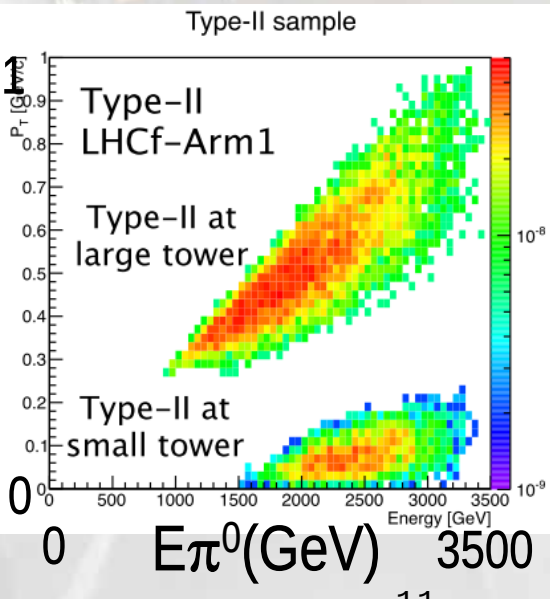
Type-I

Type-II



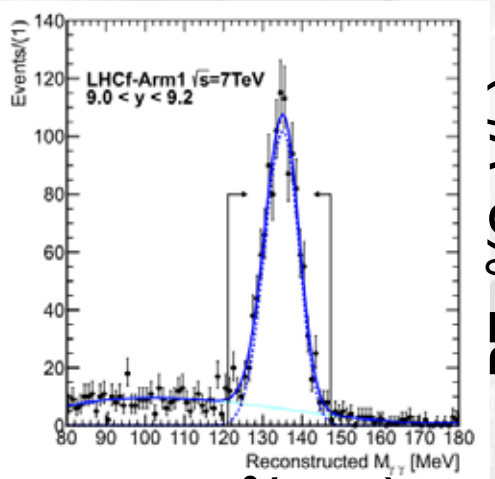




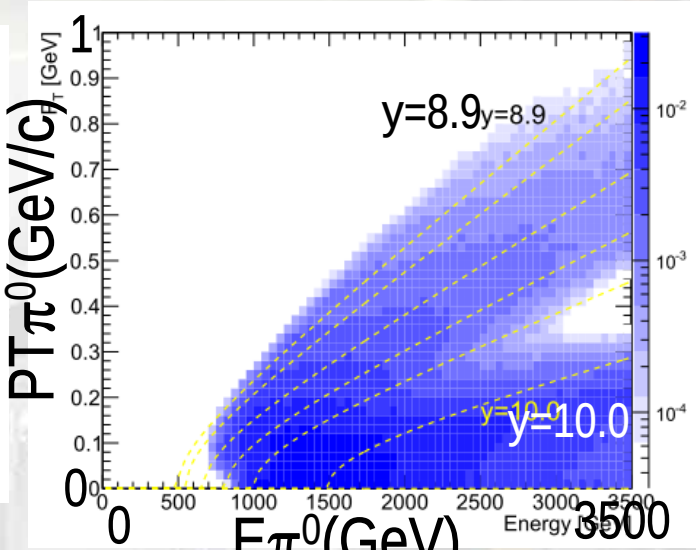


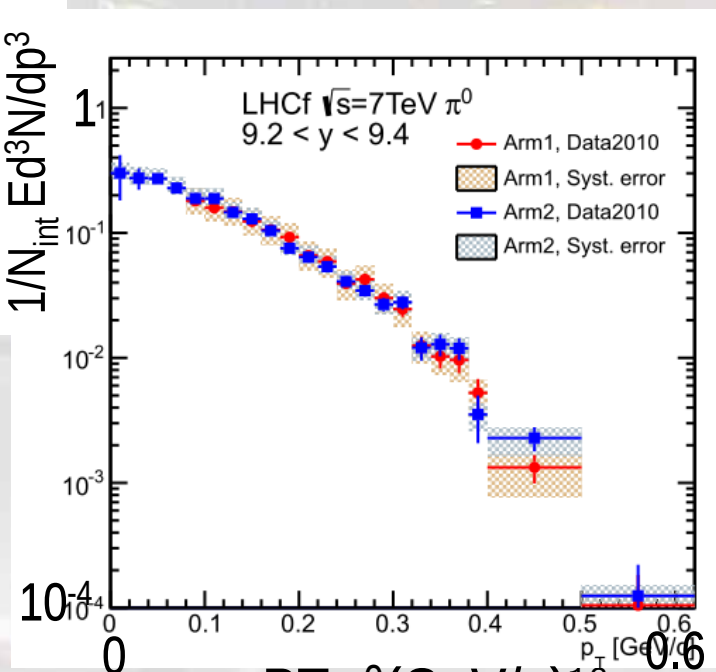
LHCf type-I π^0 analysis

- Low lumi (L~5e28) on 15-16May, 2.53(1.91) nb^{-1} at Arm1 (Arm2). About 22K (39K) π^0 for Arm1(Arm2) w/ 5%BG.
- For Eγ>100GeV, PID (γ selection), shower leakage correction, energy rescaling (-8.1% and -3.8% for Arm1&2).
- (E, P_T) spectra in +-3σ π^0 mass cut w/ side band subtracted.
- Unfolding spectra by toy π^0 MC to correct acceptance and resolution



Mπ⁰(MeV)



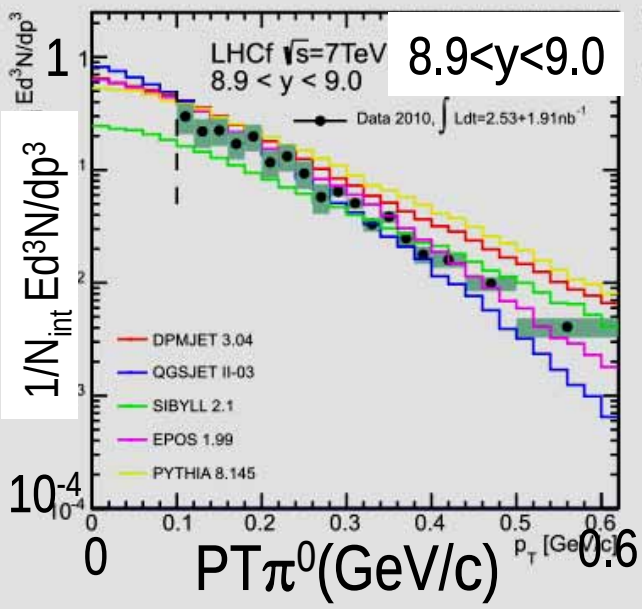


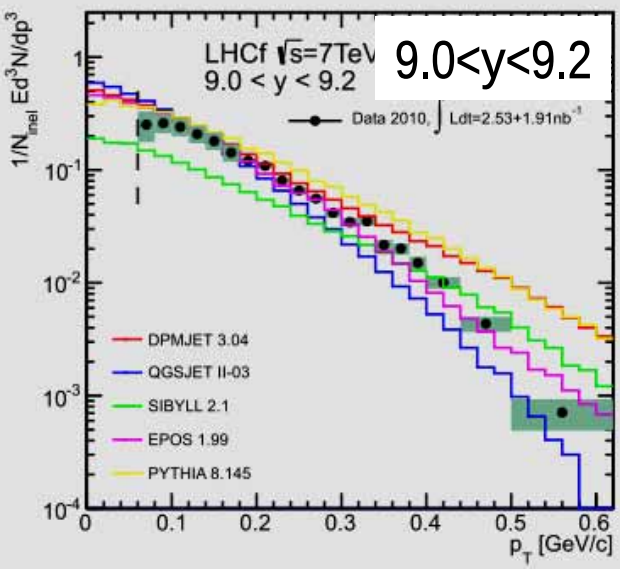
PTπ⁰(GeV/c)

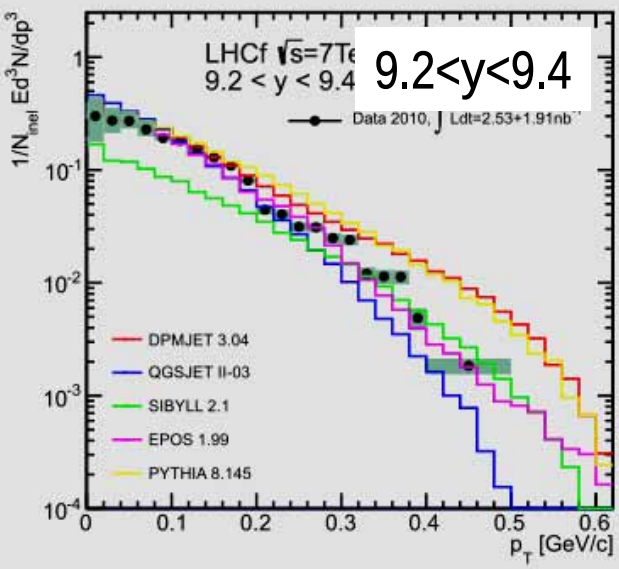
Combined type-I π^0 p_T spectra

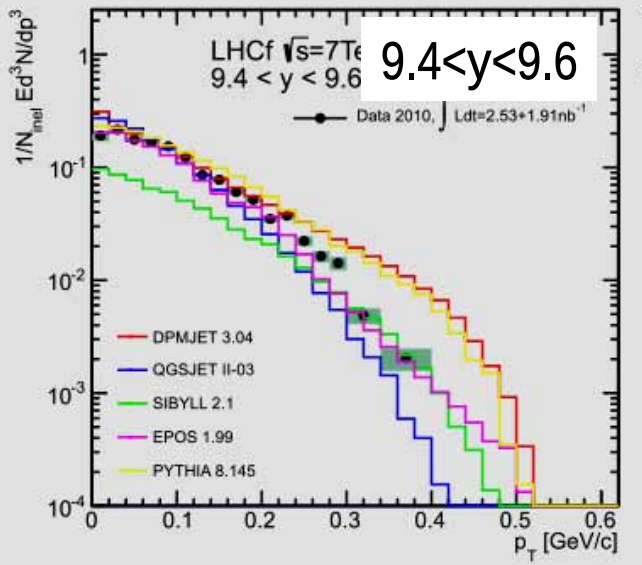
DPMJET 3.04 **QGSJETII-03** **SIBYLL 2.1** **EPOS 1.99** **PYTHIA 8.145**

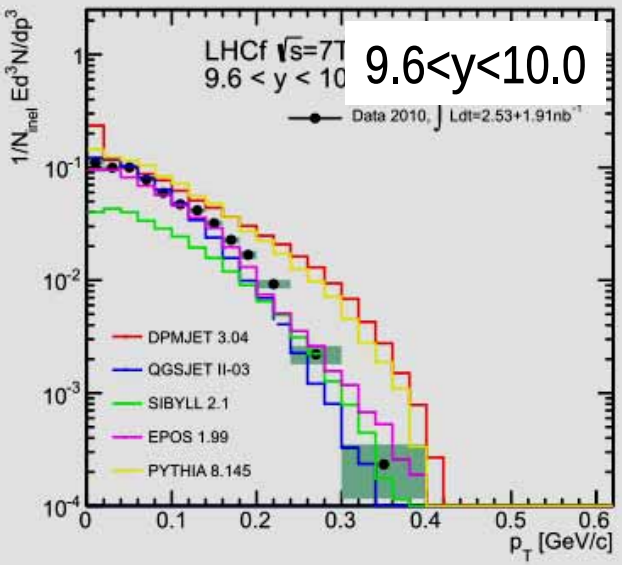
Sys+stat

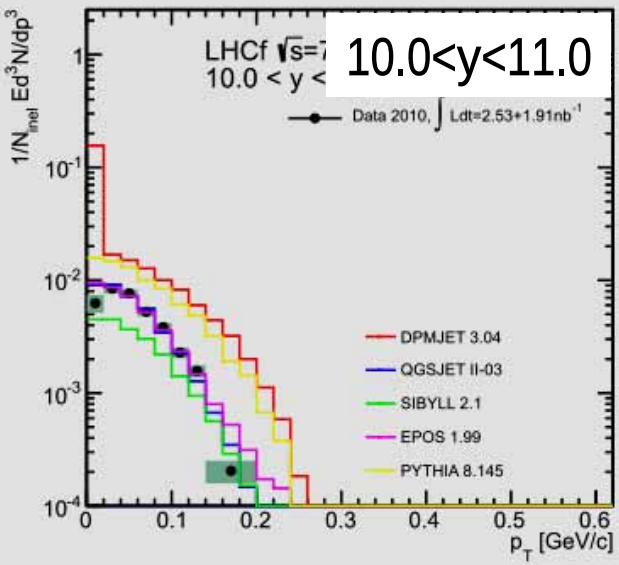










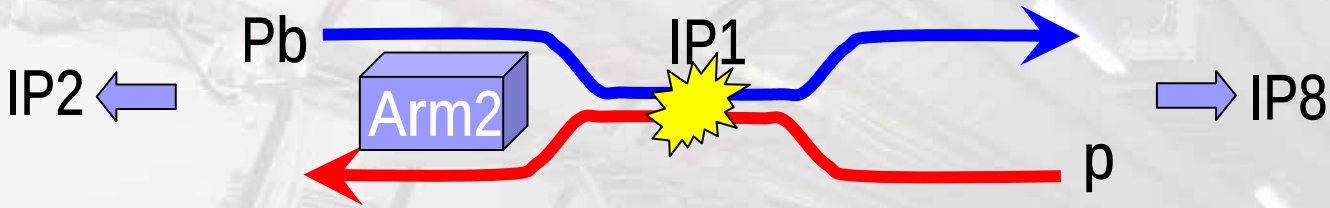


On-going analysis activity and plan

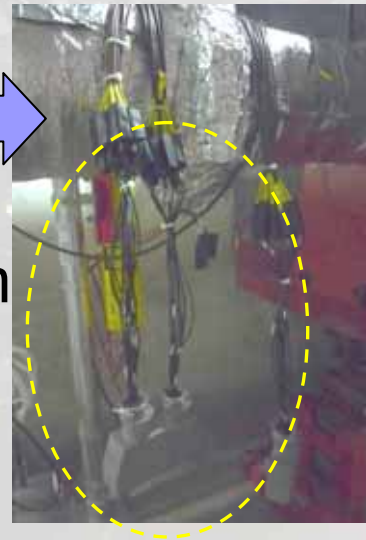
- On going activity
  - 7TeV hadron energy spectra → Inelasticity
  - Full analysis of single γ (larger η, p_T)
  - Full analysis of π^0 (Type-II π^0)
- Plan
  - Strangeness particles ($\Lambda \rightarrow \pi^0 n$, $Ks \rightarrow 2\pi^0(4\gamma)$)
  - Feed back to the models and air shower experiments

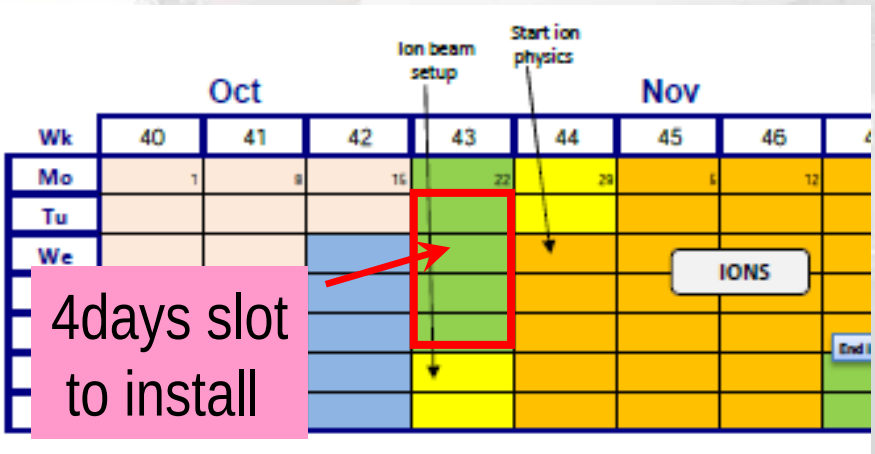
Now we have established analysis methods
Great progress in understanding detector

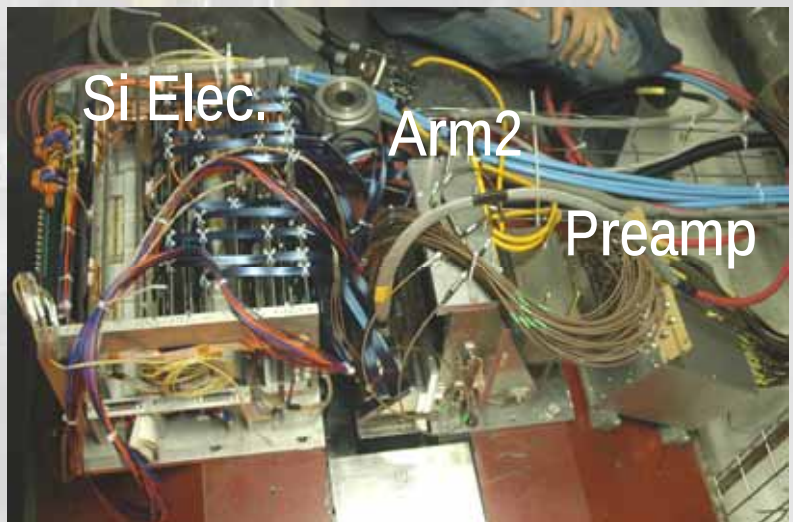
Preparation for 2012 p-Pb run



- Installed multi-pole connectors in tunnel (Feb)
- Transportation frame for Arm2+electronics
- Discussion with experts and prepare documentation (DIMR in Apr)
- 1-2 experts will stay at CERN from Sep for DAQ commissioning

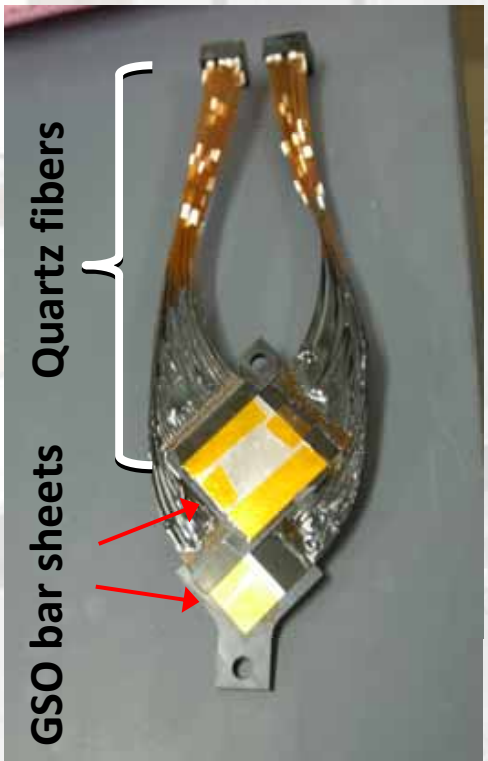






Status of Arm1 upgrade

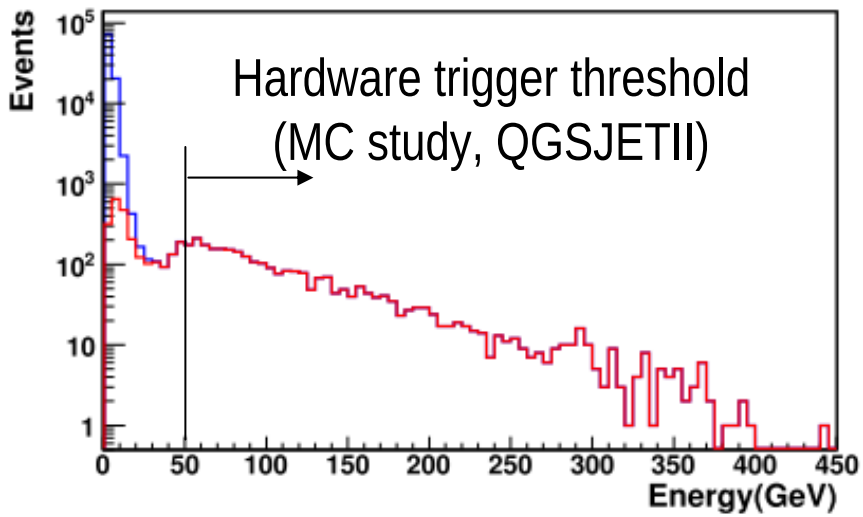
- GSO position dependence calibrated by a 400MeV/c ^{12}C beam in Nov 2011.
- Final ^{12}C test of GSO bars by a C beam in this June
- Arm1 full reassembly in this July
- First SPS beam test of upgraded Arm1 in this Aug
- Upgrade Arm2 in 2013, need SPS beam in 2013

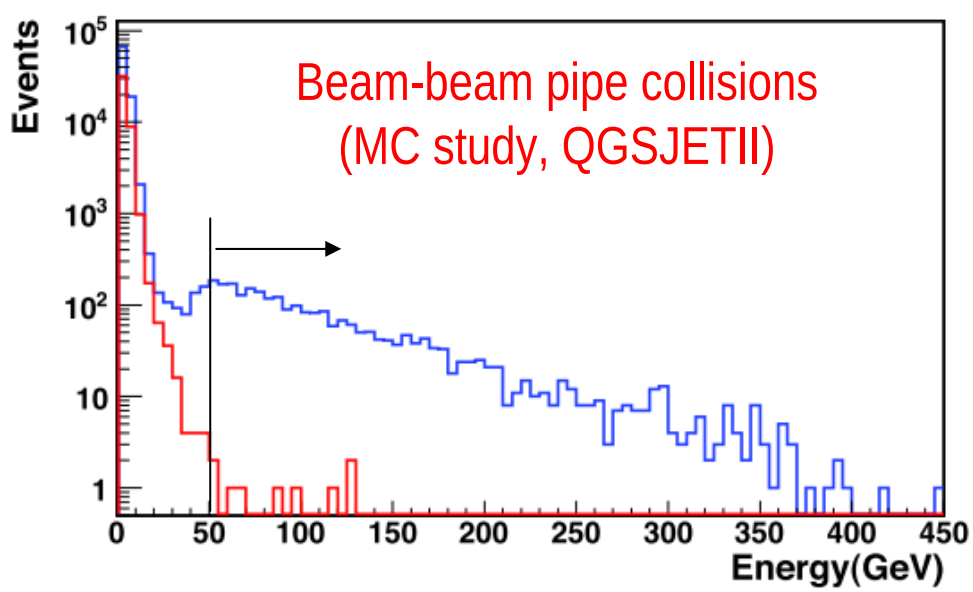


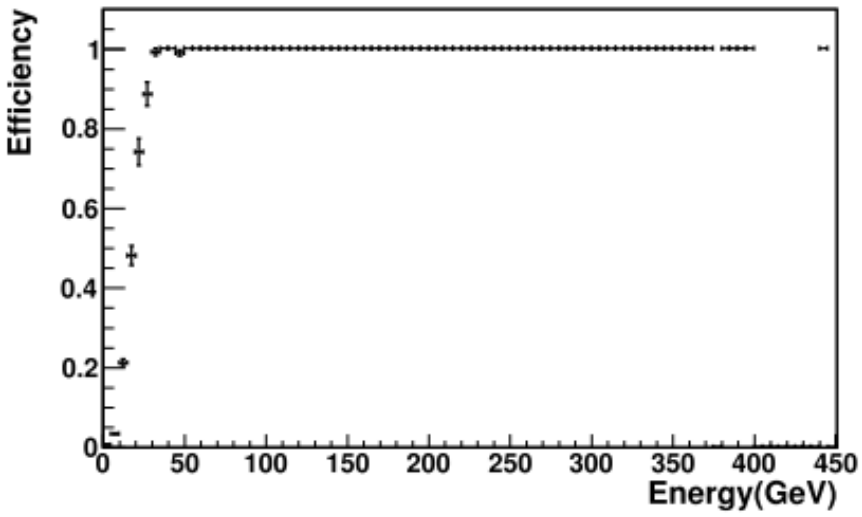
Summary

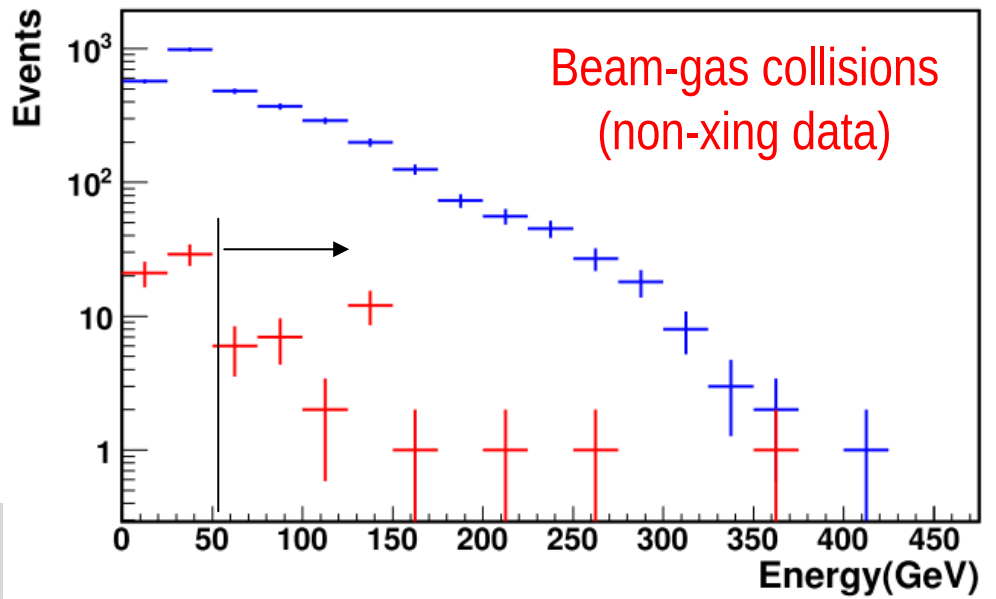
- Many thanks to LHC for these precious data indispensable for UHECR physics.
- LHCf new results (published soon)
  - 7TeV π^0 p_T spectra in 8.9<y<11.0.
  - 900GeV single γ energy spectra in 8.77<η<9.46, η>10.95.
  - Analysis framework established. Full data analysis next.
  - Progress in detector understanding, squeezing sys errors.
- Preparation for p-Pb run
  - Preparation for quick installation of Arm2.
- Detector upgrade of Arm1
  - Completed R&D of GSO layers and bars.
  - Pre-calibration finishes in June, SPS test beam in Aug.
  - Upgrading Arm2 detector in 2013 (Need one more SPS).

900 GeV trigger/analysis threshold

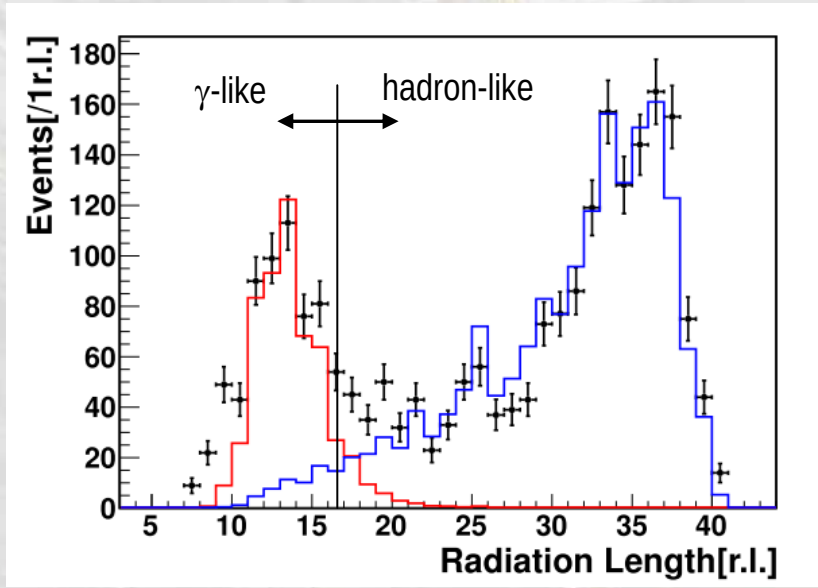


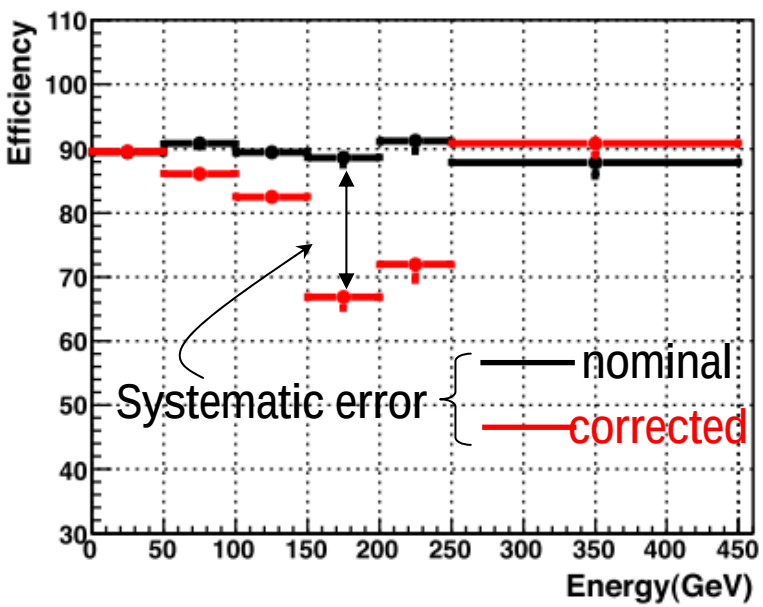


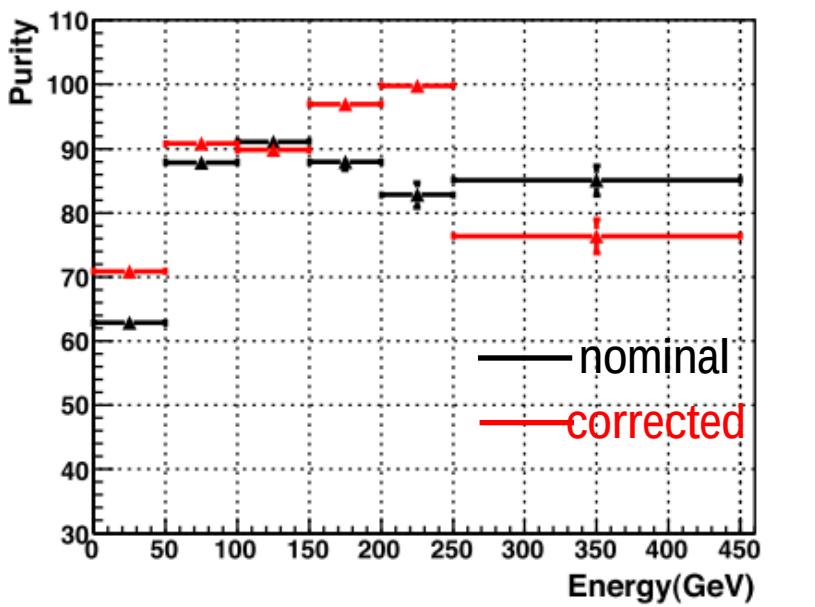




PID (γ/had) by L90

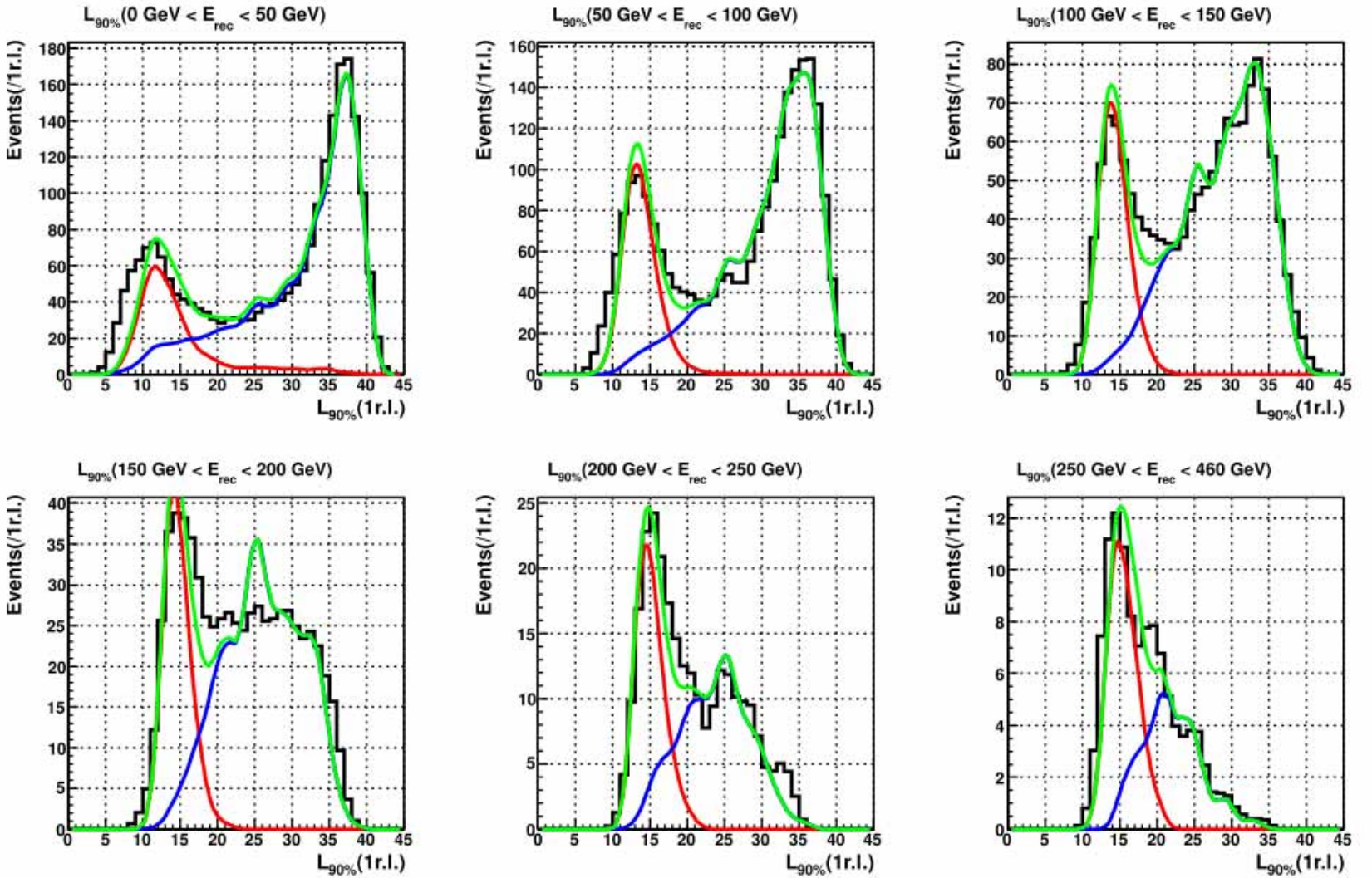




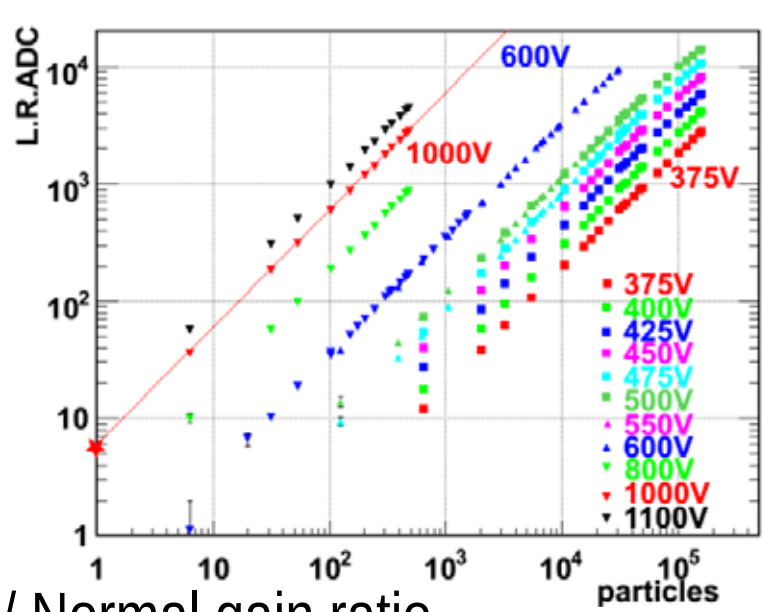


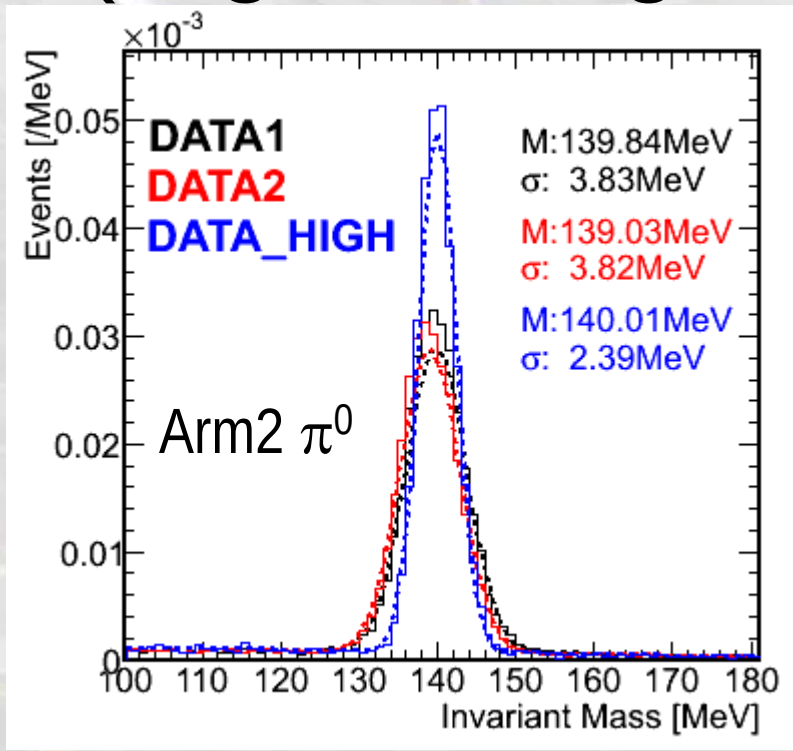
900 GeV PID (L90)

Arm1 small / Nominal

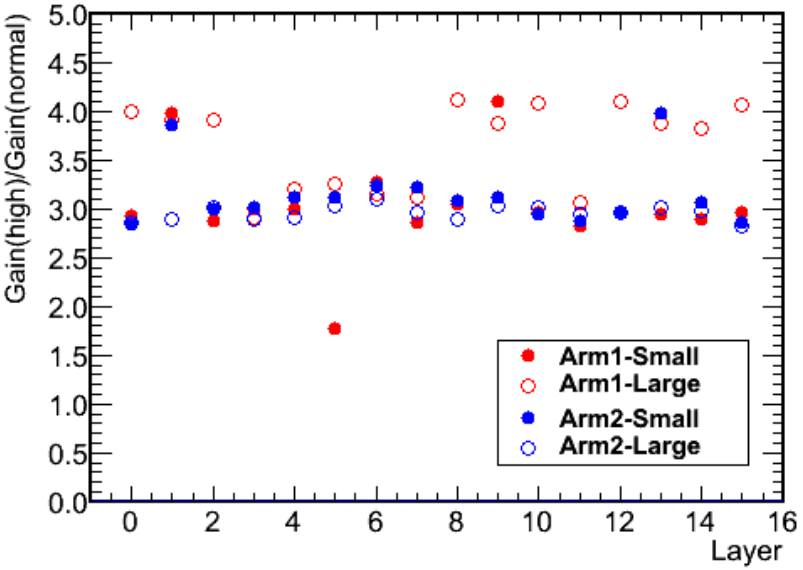


900 GeV energy scale (High PMT gain)





High / Normal gain ratio

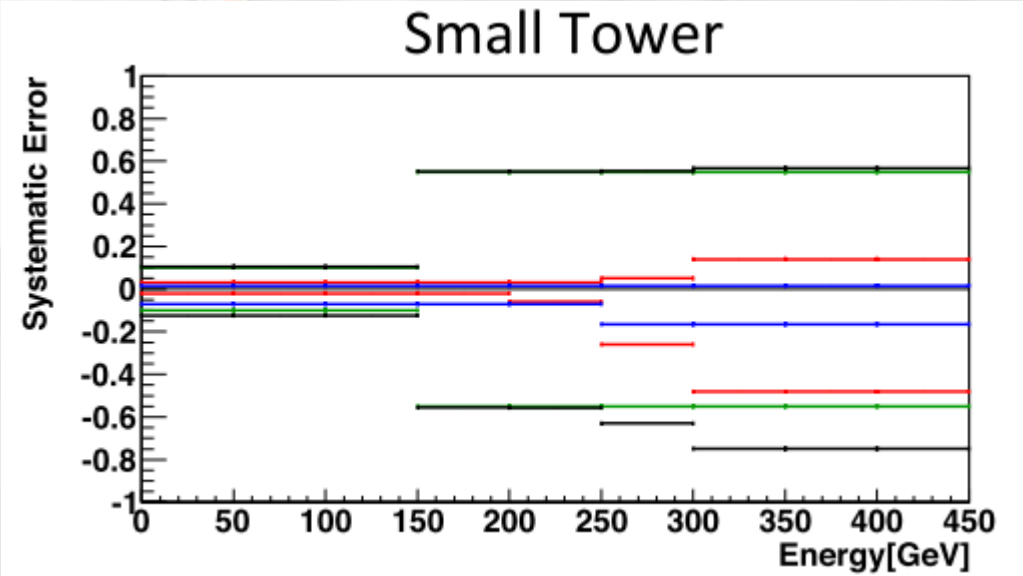


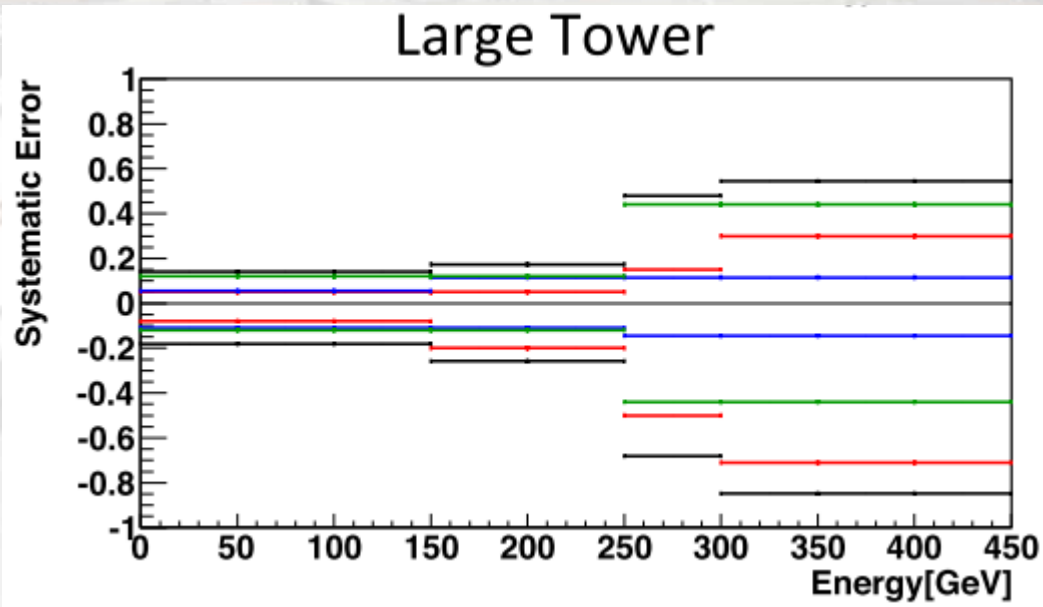
High gain/ Normal gain bias

Arm1 +2.7%

Arm2 +0.1%

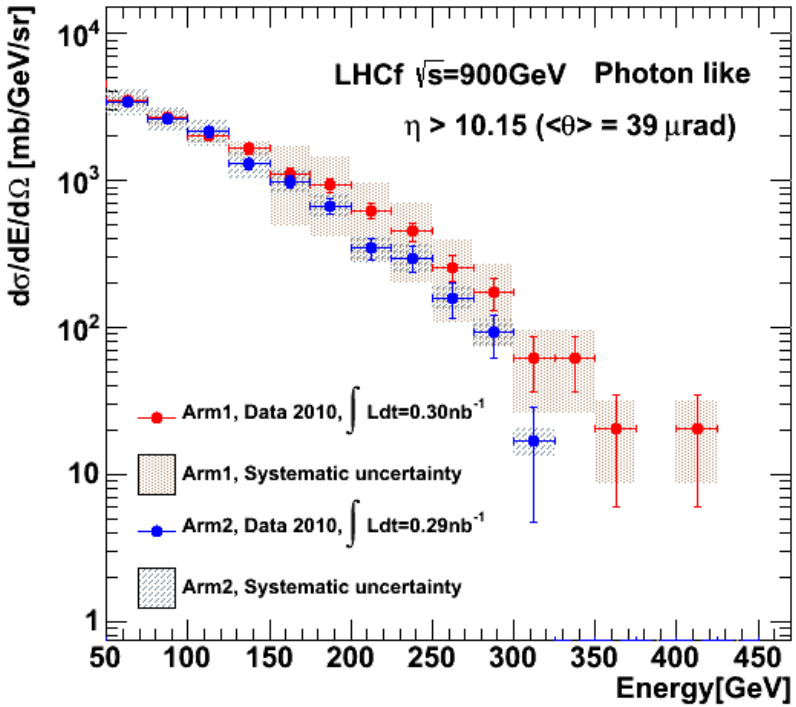
Systematic errors in 900GeV analysis

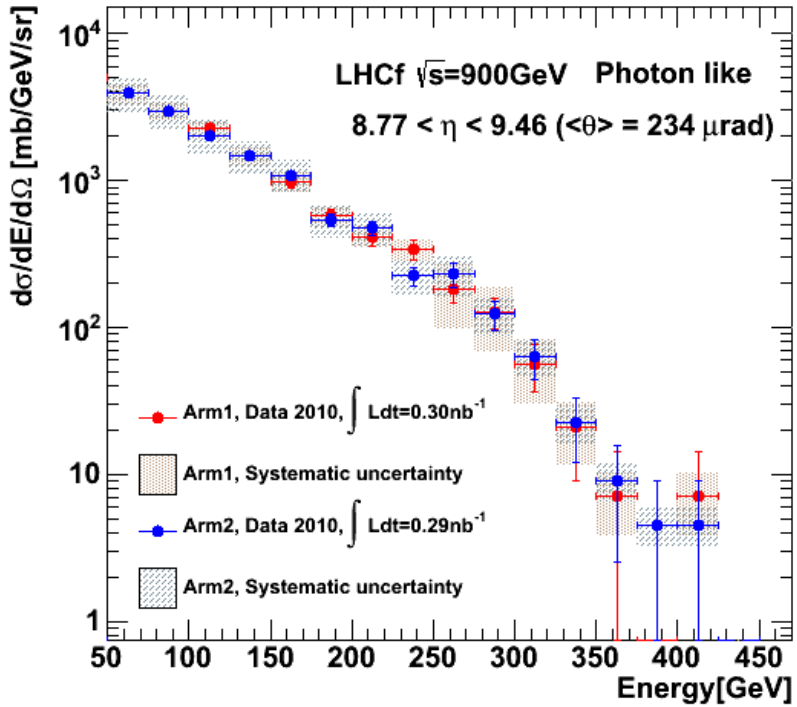




TOTAL
ENERGY
PID
BEAM

900 GeV / comparison of 2 arms

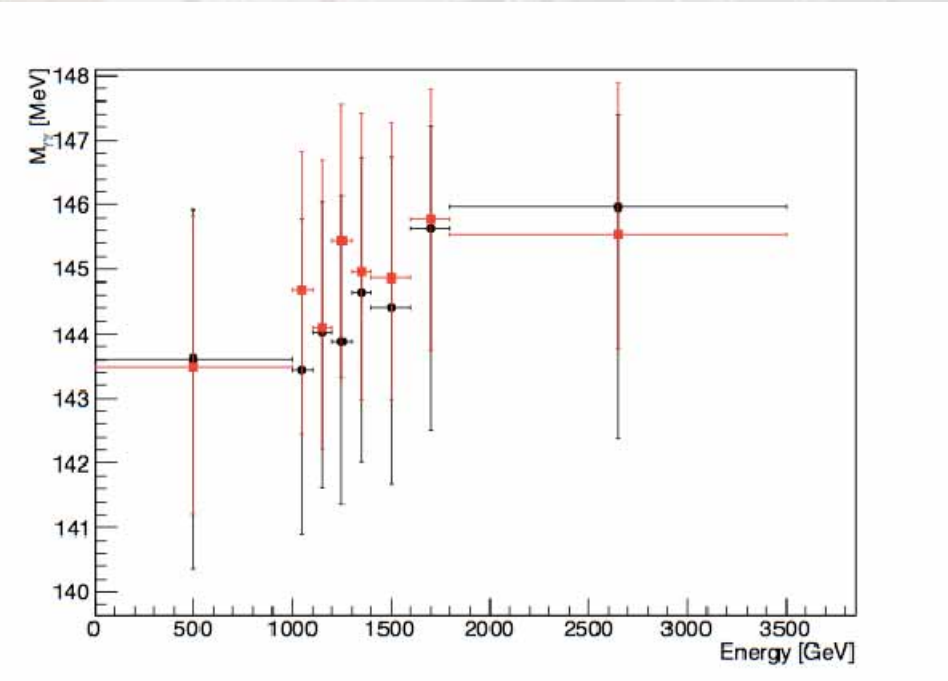


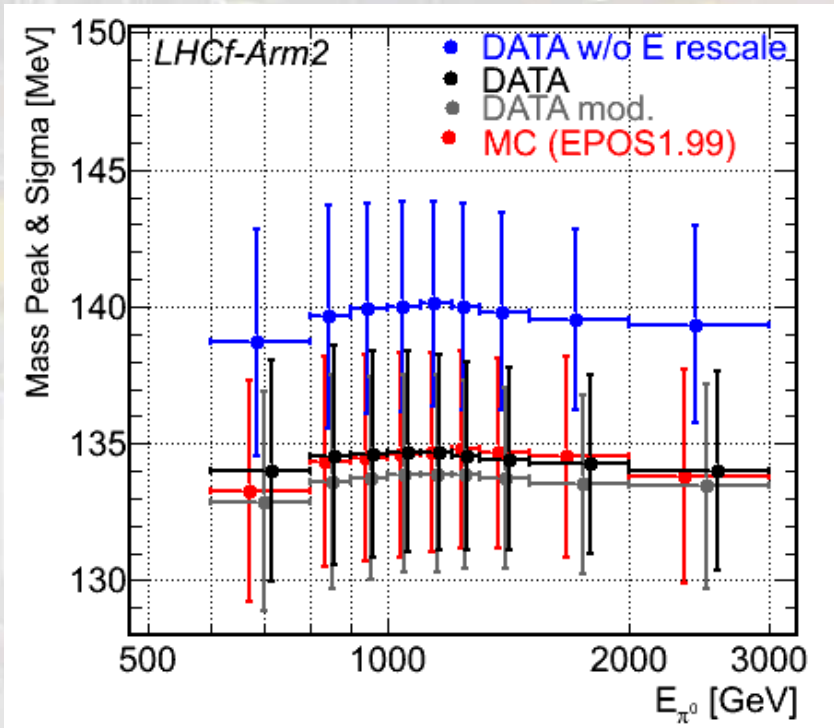


Energy rescaling by π^0

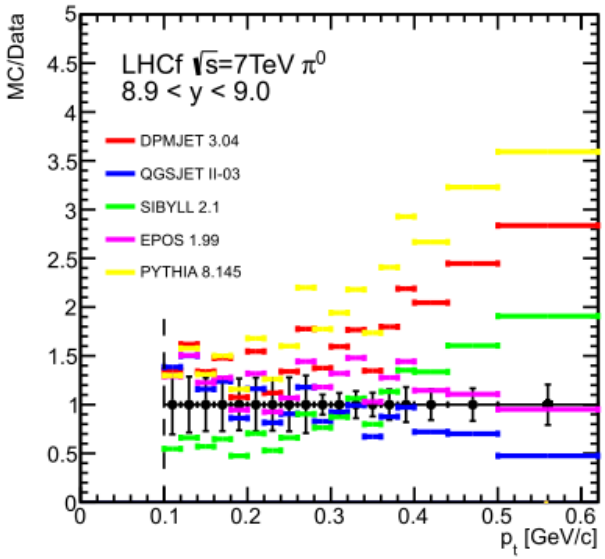
- Detail check of π^0 systematics
- Detail re-analysis of SPS beam test data
- Detail check of shower leakage effect

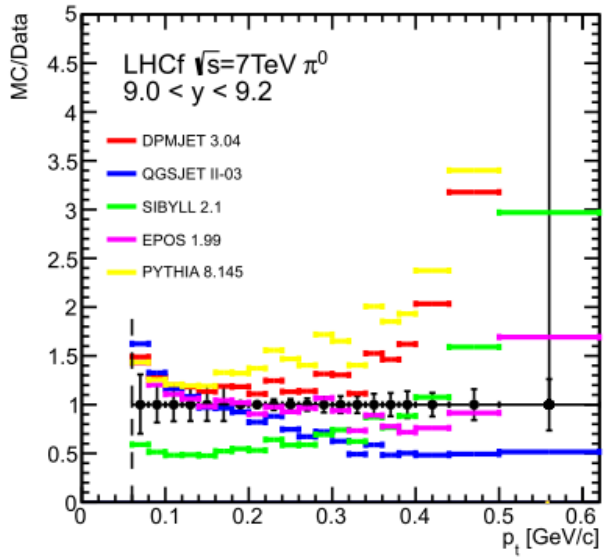
- No hint for energy dependent scale error
- Energy scale by π^0 is now convincing

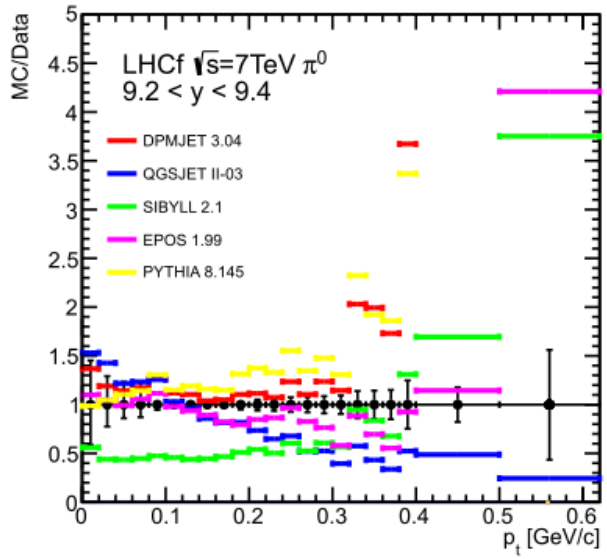


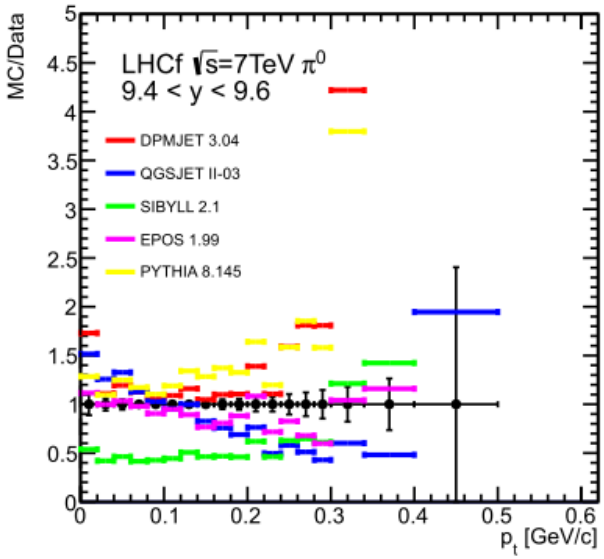


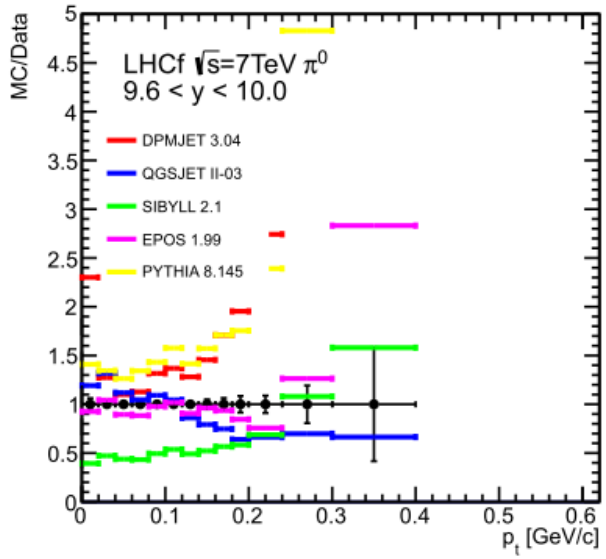
LHCf π^0 P_T at 7TeV (MC/Data) (Preliminary)

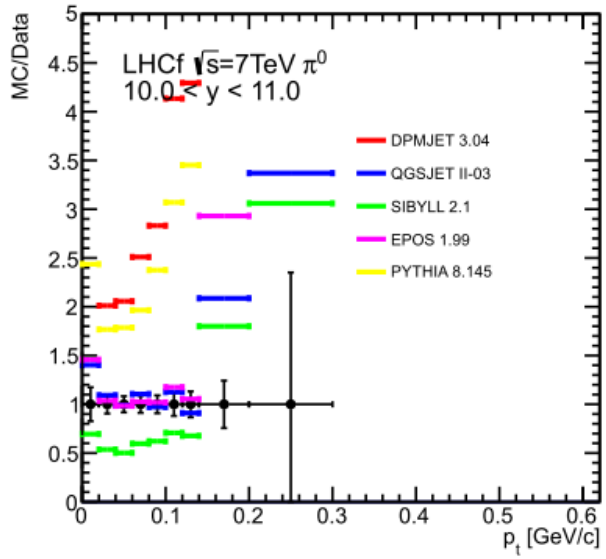




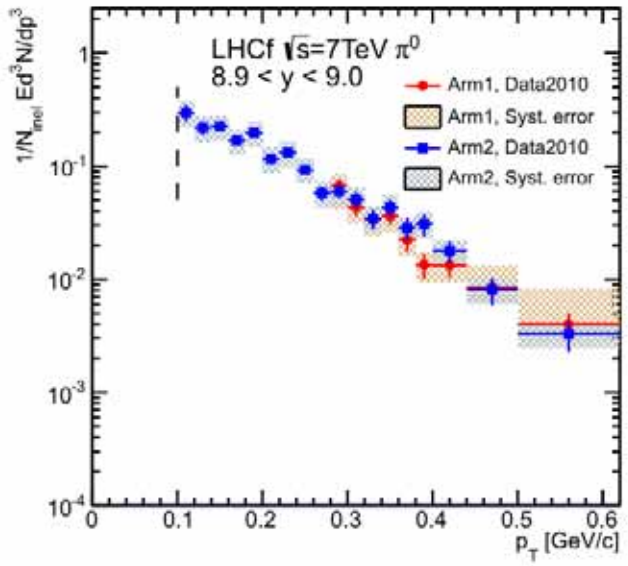


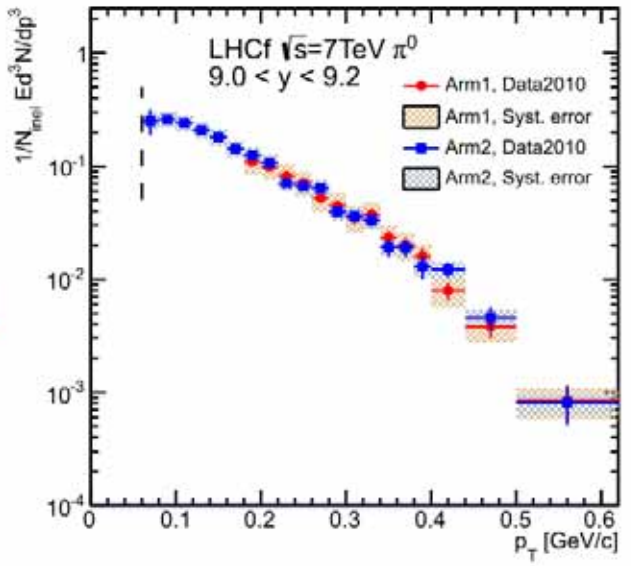


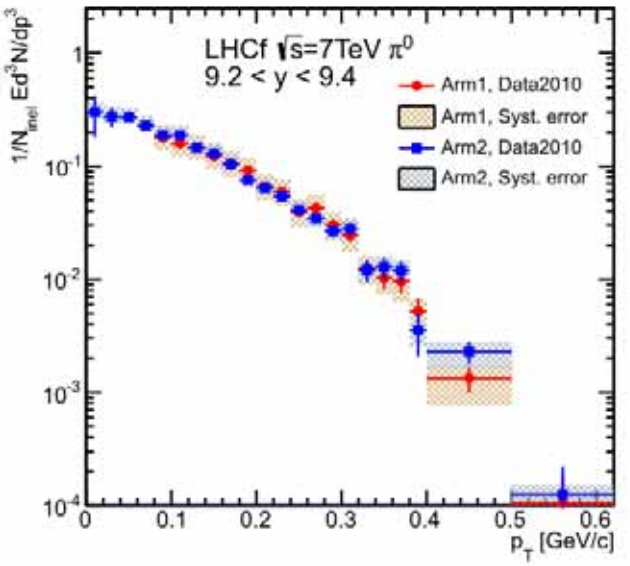


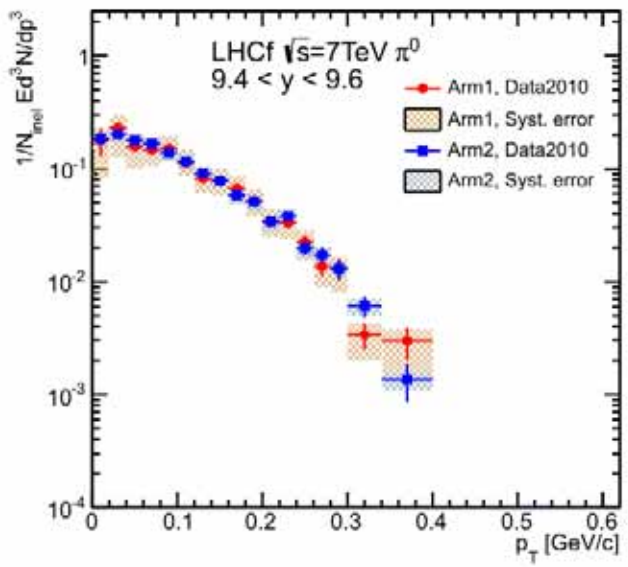


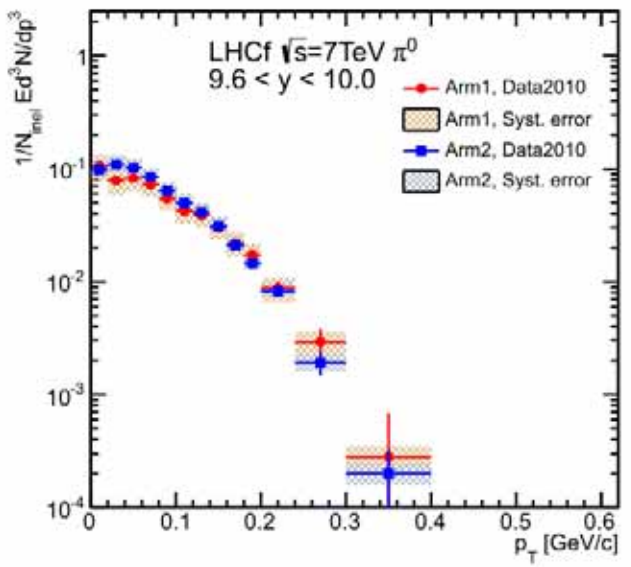
LHCf π^0 P_T at 7TeV (Arm1/Arm2 comparison)

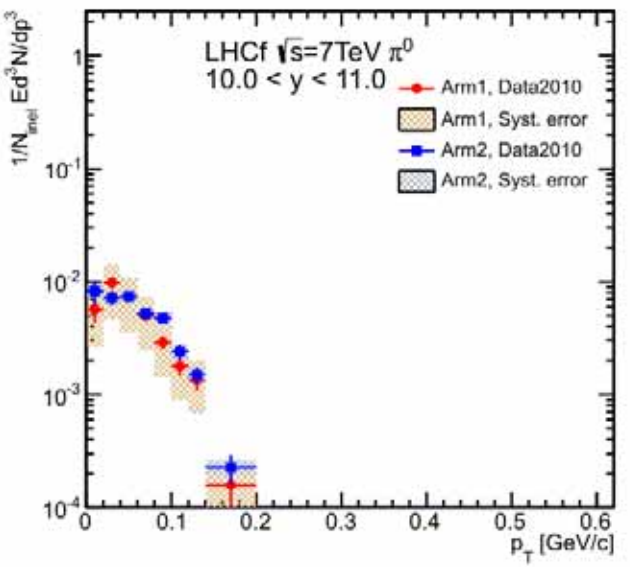




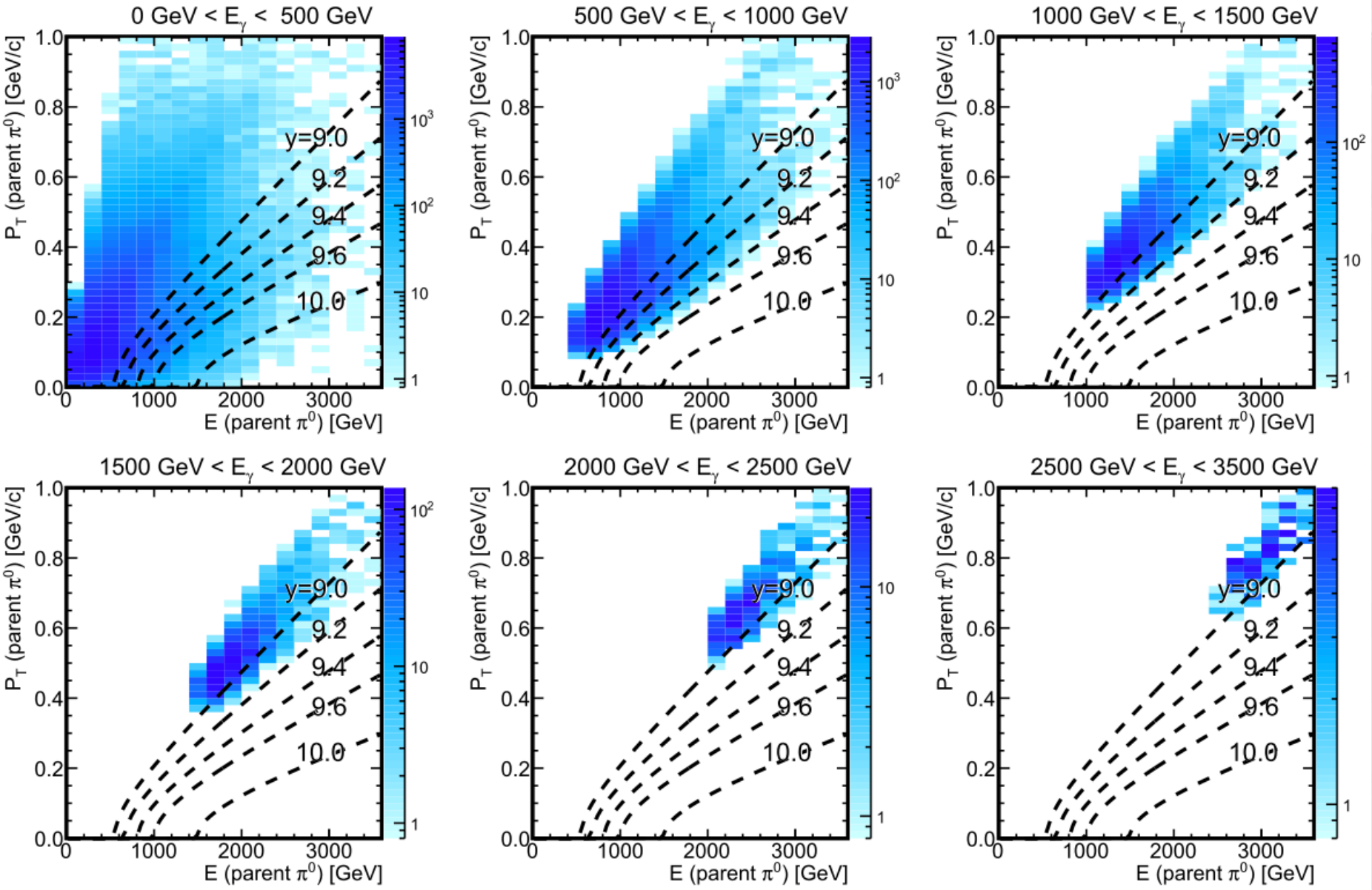




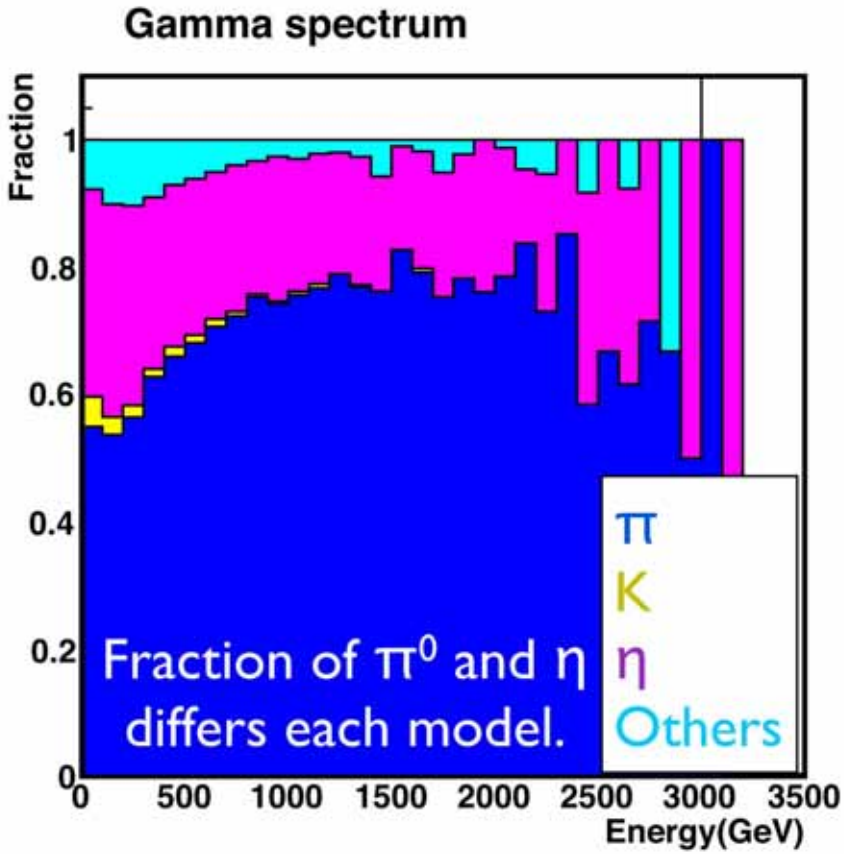


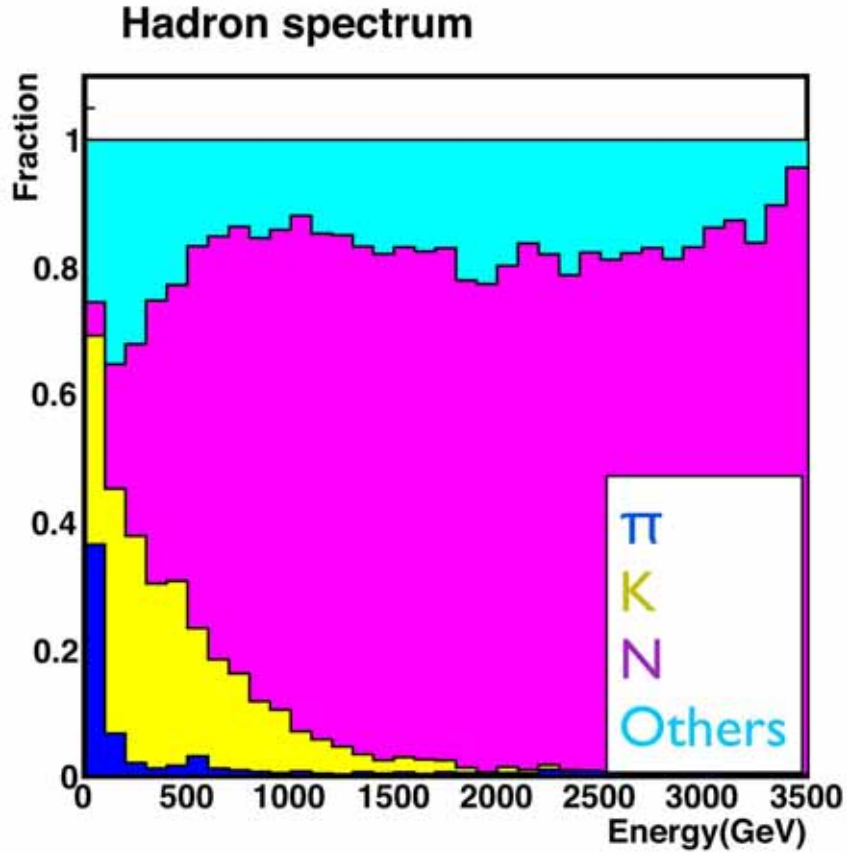


Kinematical region observed by "single γ"



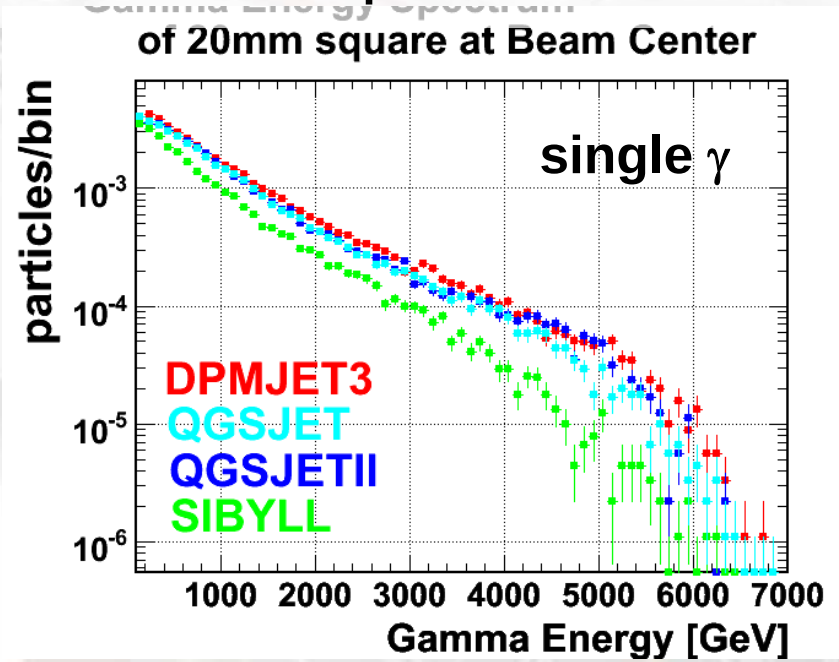
Parent particles relevant for LHCf observations

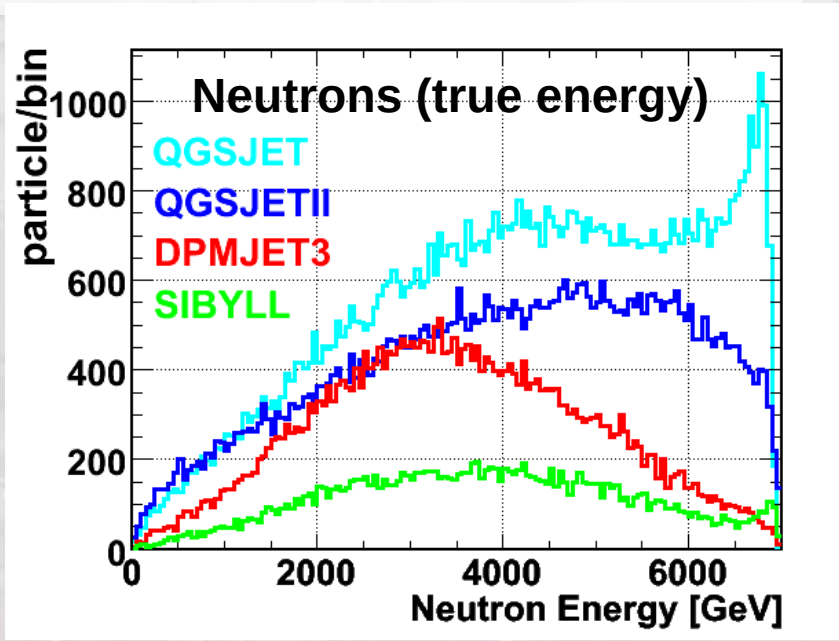


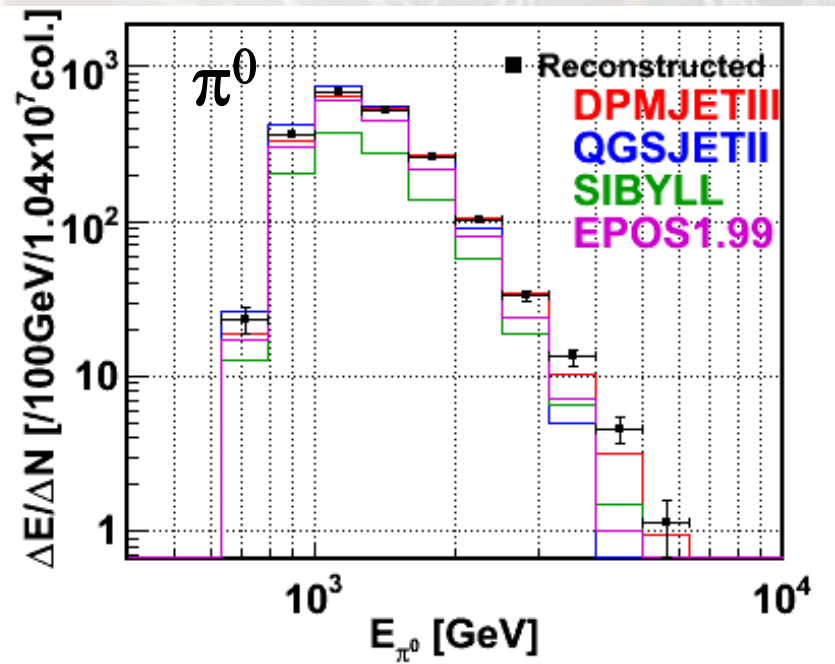


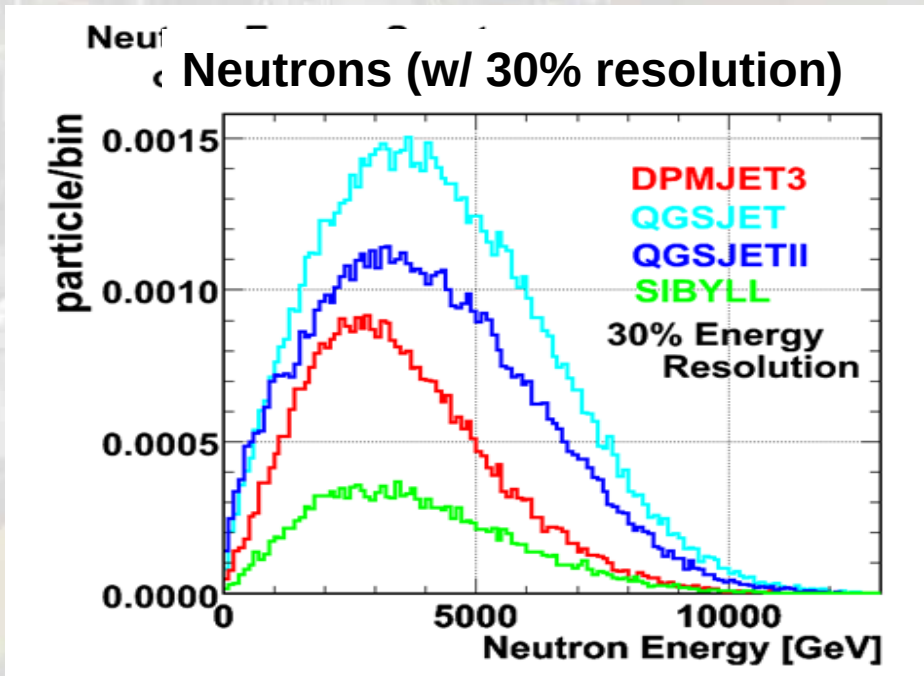
Sybill at 7TeV

Forward E spectra forseen at 14TeV (MC for ~0.1nb^{-1})







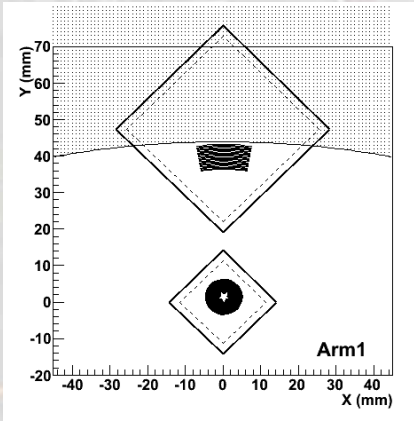


The single photon energy spectra at 0 degree

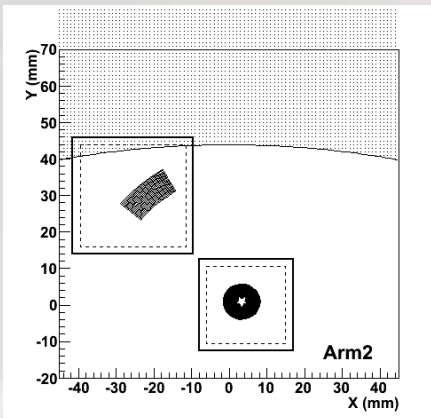
(O.Adriani et al., PLB**703 (2011) 128-134**

- DATA
  - 15 May 2010 17:45-21:23, at Low Luminosity $6\times10^{28}cm^{-2}s^{-1}$, no beam crossing angle
  - 0.68 nb-1 for Arm1, 0.53nb-1 for Arm2
- MC
  - DPMJET3.0**4**, QGSJETII03, SYBILL2.1, EPOS1.99 PYTHIA 8.145 with the default parameters.
  - 10^7 inelastic p-p collisions by each model.
- Analysis
  - Two pseudo-rapidity, **η**>10.94 and 8.81< **η** <8.9.
  - No correction for geometrical acceptance.
  - Combine spectra between Arm1 and Arm2.
  - **Normalized by number of inelastic collisions**

  with assumption as σ_{inela} = 71.5mb.
  (c.f. $73.5\pm0.6^{+1.8}_{-1.3}$ mb by TOTEM)

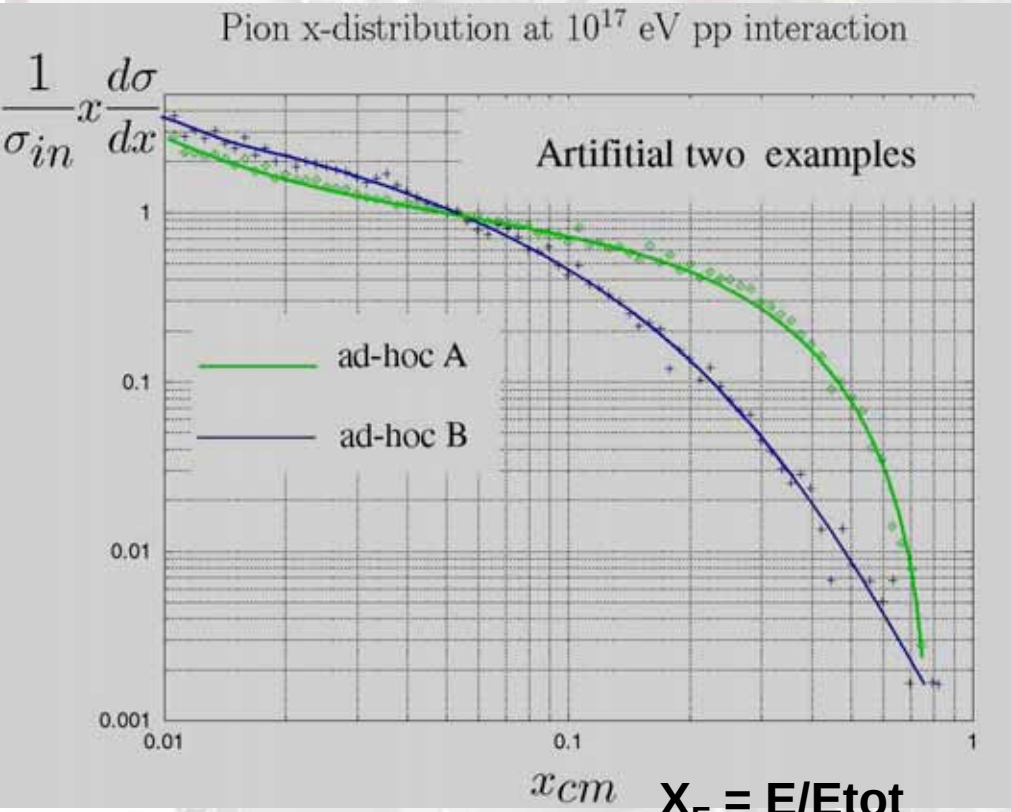


Arm1

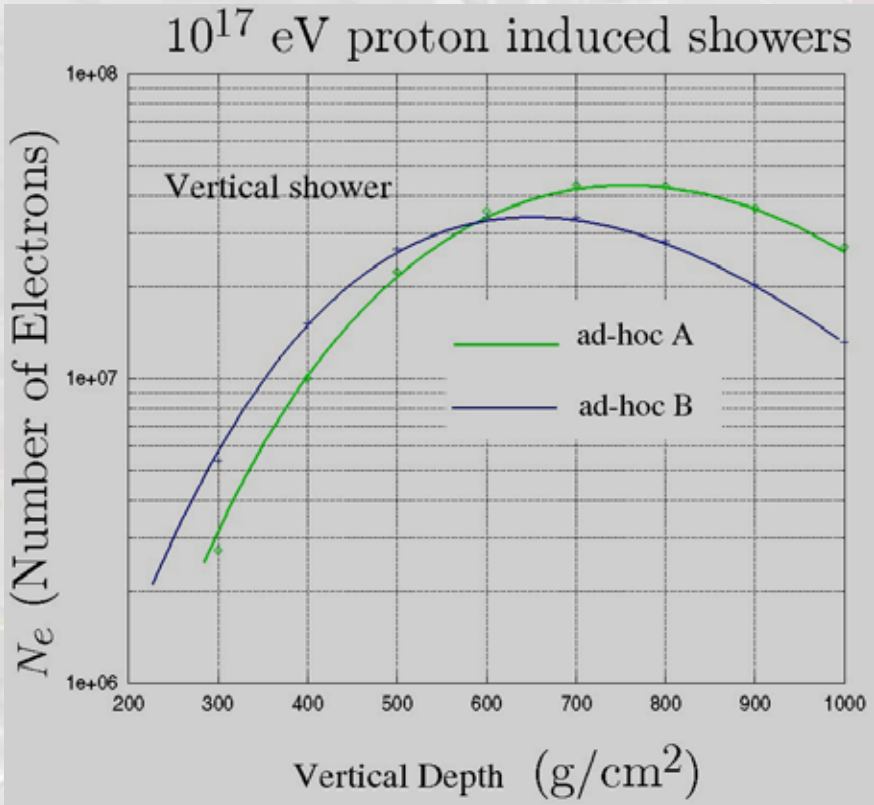


Arm2

Forward production spectra vs Shower curve



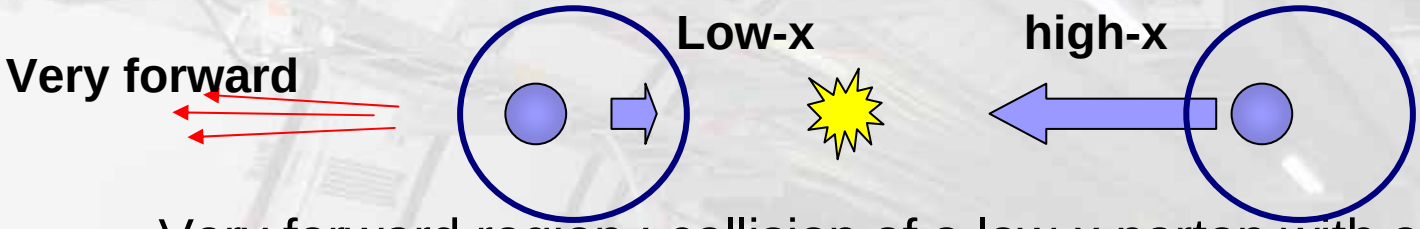
X_F = E/Etot



Half of shower particles comes from large X_F γ

Measurement at very forward region is needed

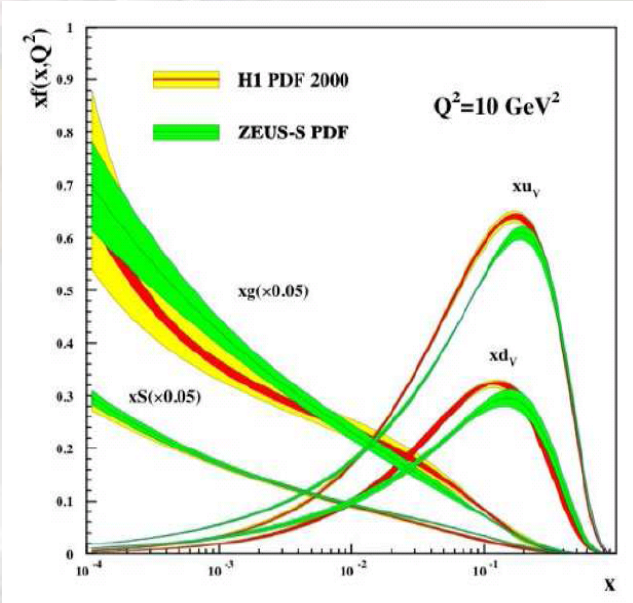
Very forward – connection to low-x physics



- Very forward region : collision of a low-x parton with a large-x parton
- Small-x gluon become dominating in higher energy collision by self interaction.
- But they may be saturated (Color Glass Condenstation)

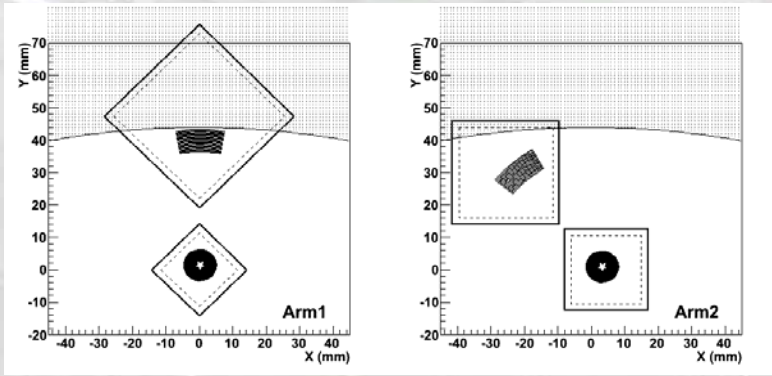
Naively CGC-like suppression may occur in very forward at high energy

→ However situation is more complex (not simple hard parton collsions, but including soft + semi-hard)

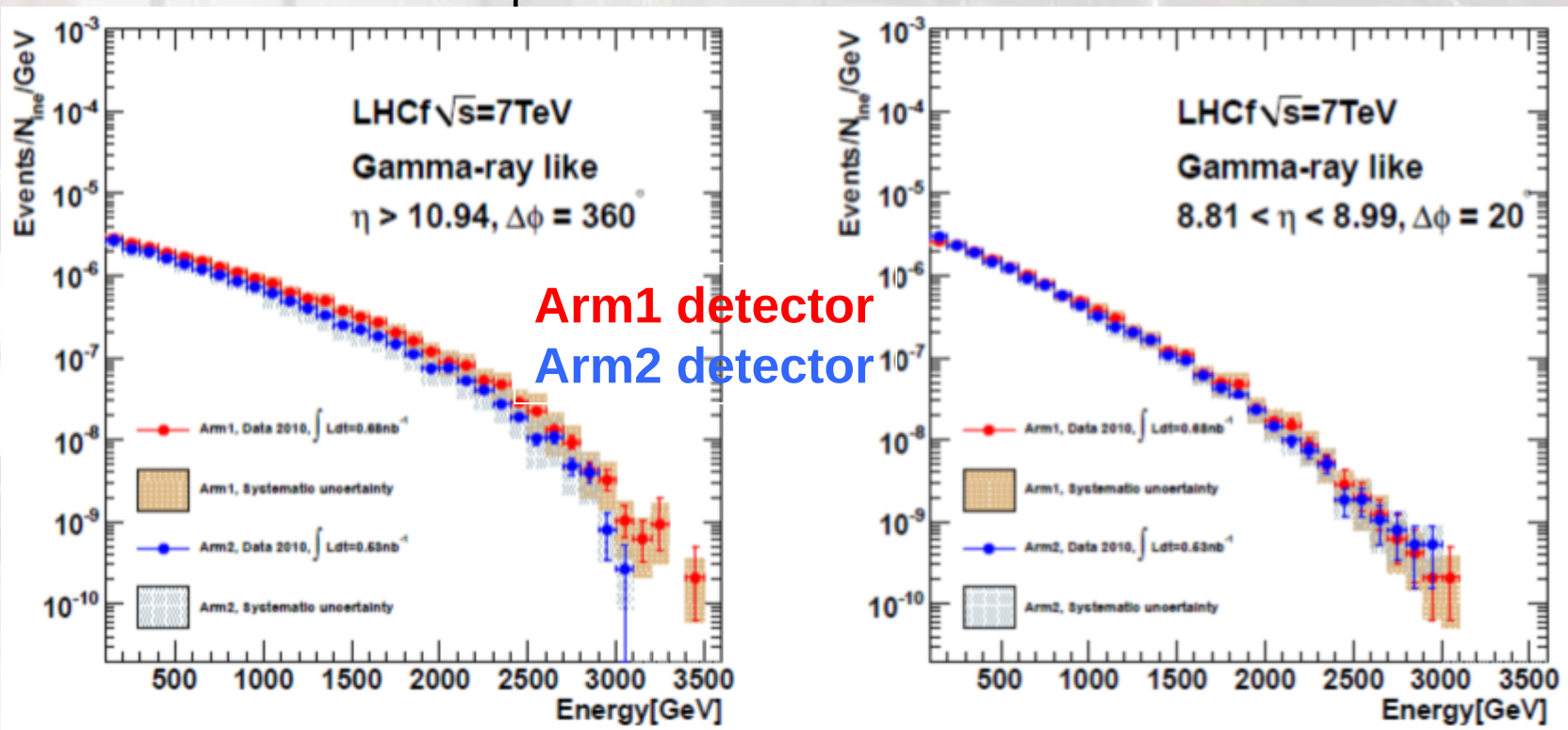


Comparison between the two detector

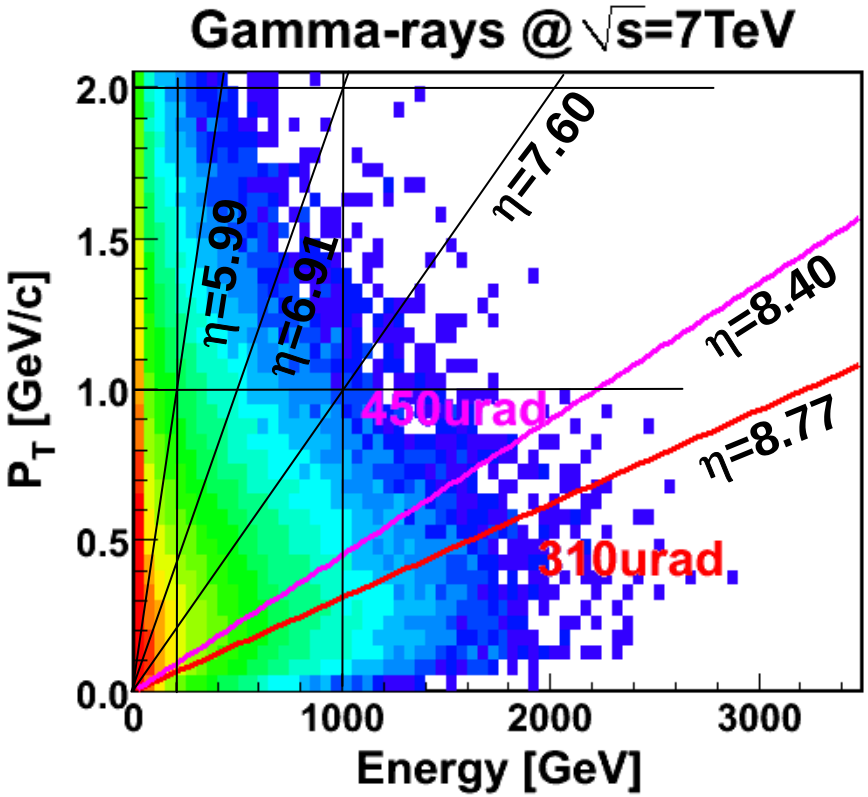
- Pseudo-rapidity selection, η >10.94 and 8.81< η <8.9
- Normalized by number of inelastic collisions with assumption as σ_{inela} = 71.5mb (<->73.5$\pm$0.6$^{+1.8}_{-1.3}$ mb by TOTEM)
- Spectra in the two detectors are consistent within errors.

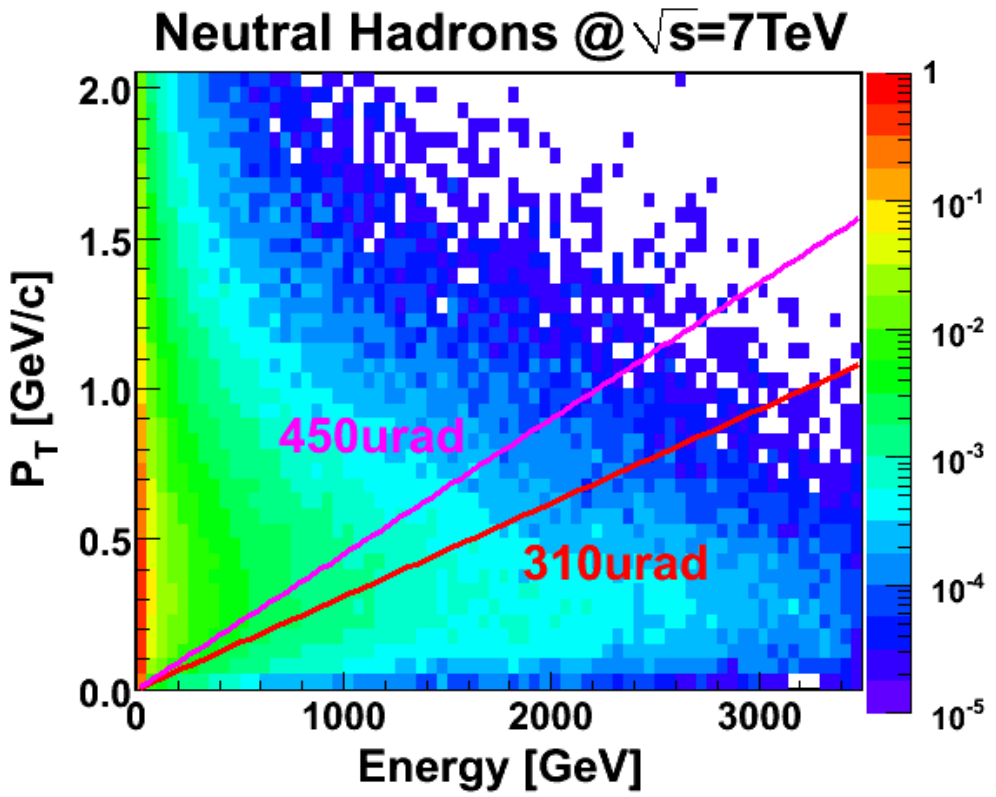


➔ Combined between spectra of Arm1 and Arm2



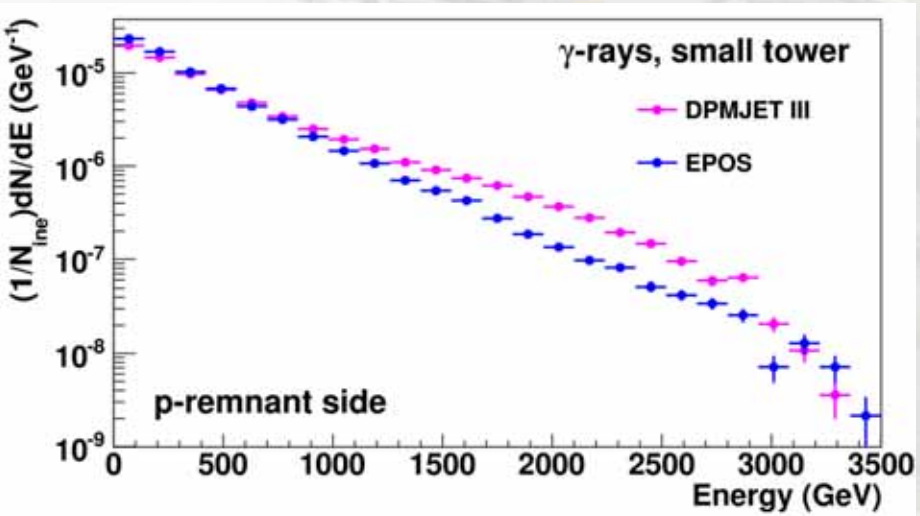
Forward energy spectra

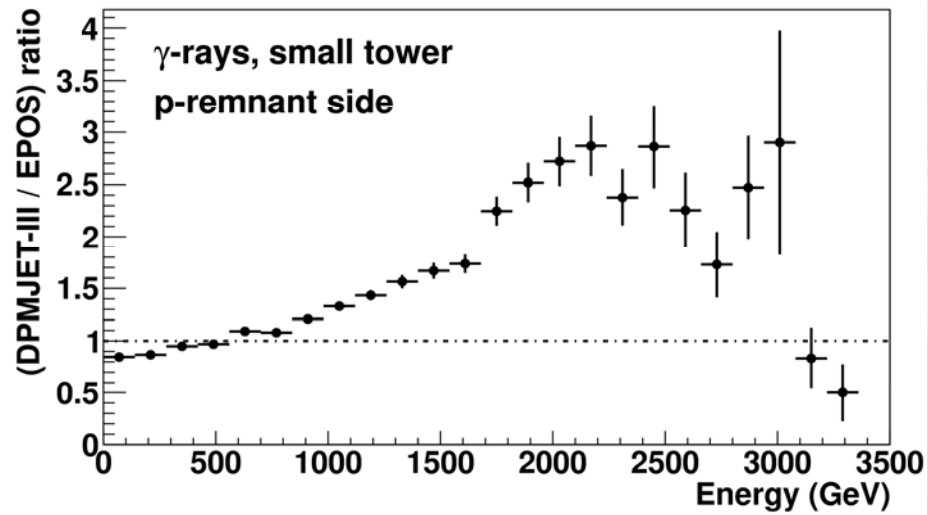




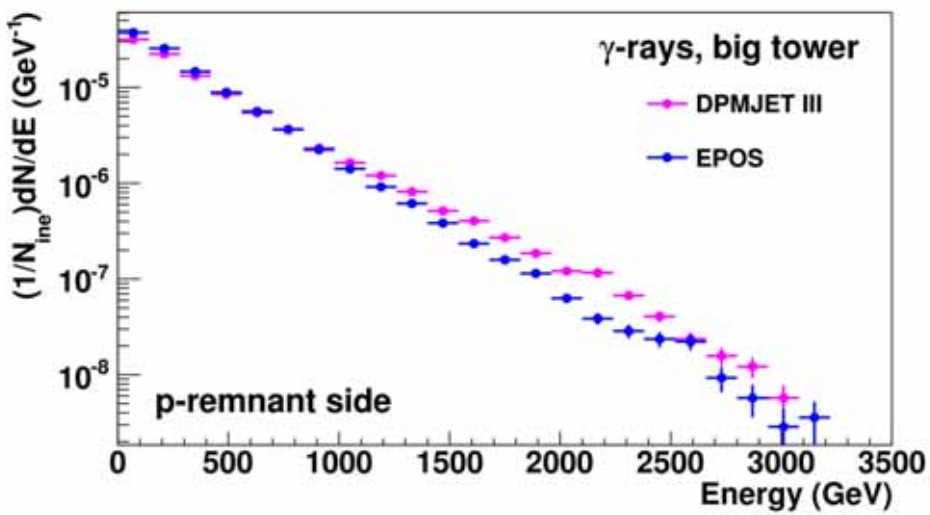
spectrum

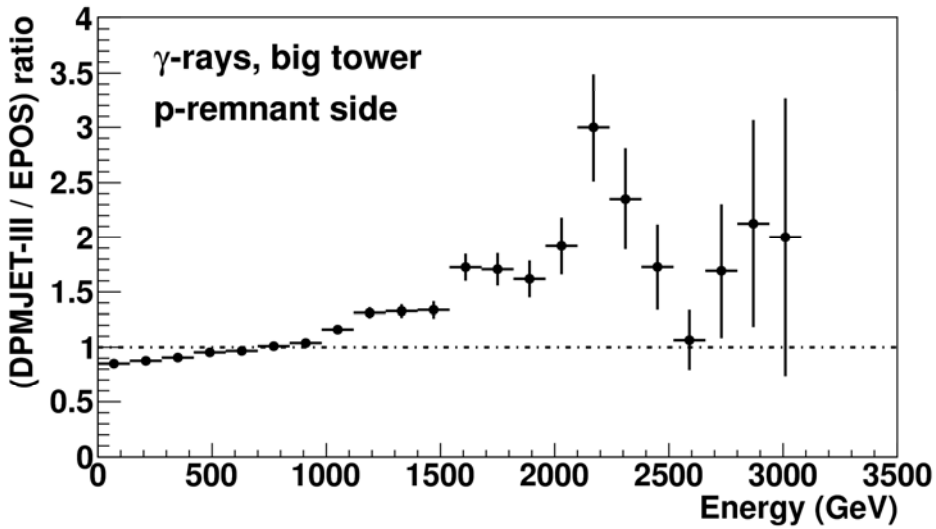
Small tower



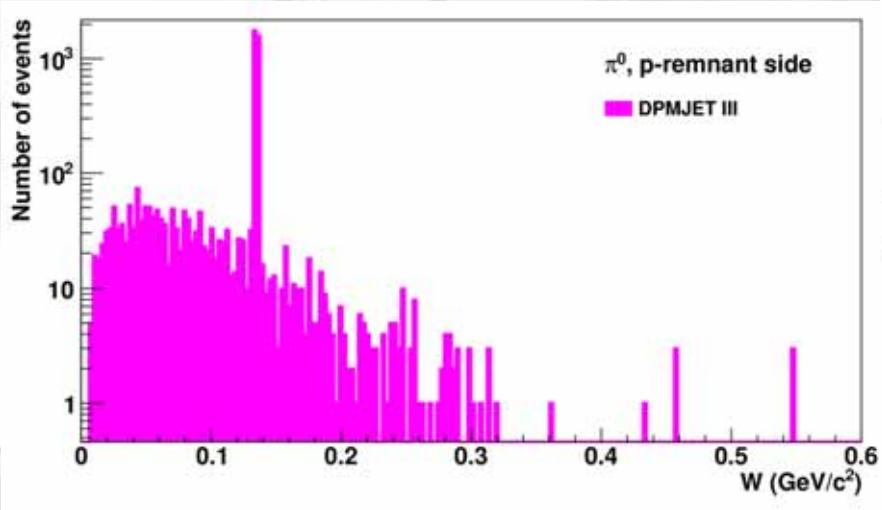


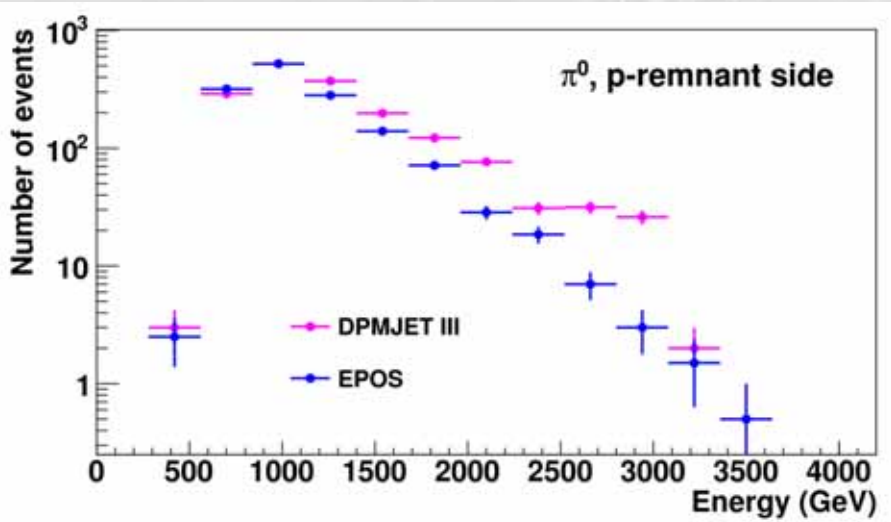
Big tower



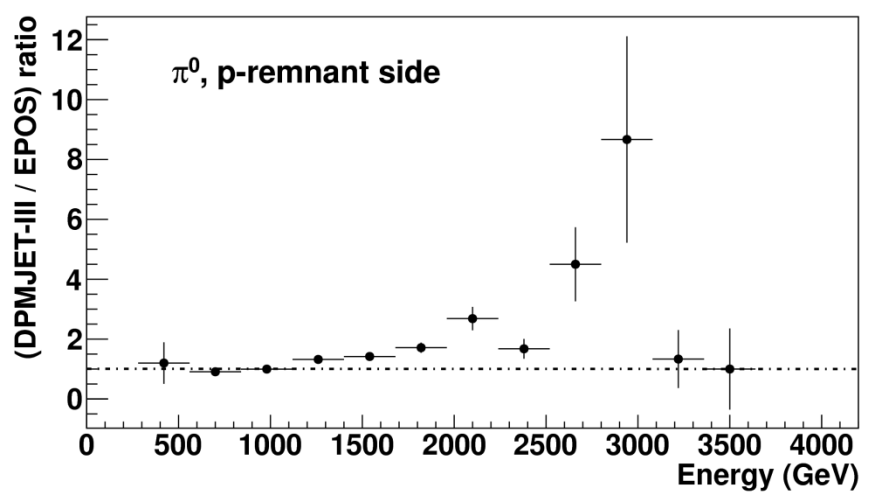


Proton-remnant side – π^0





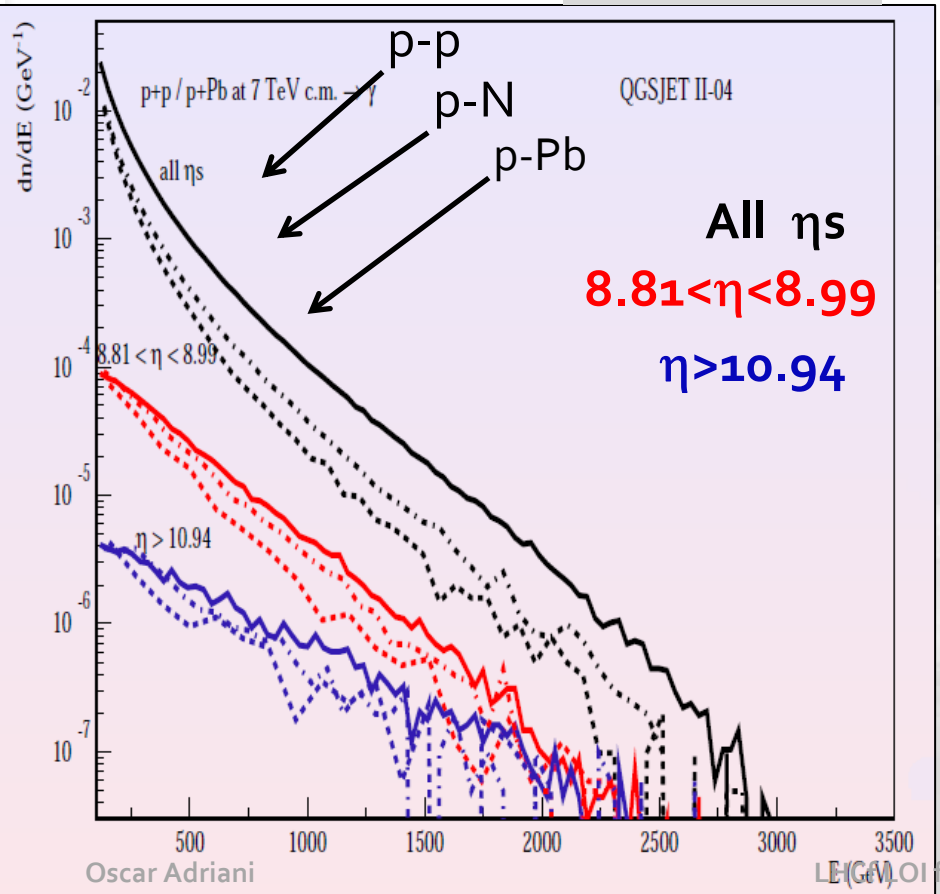
We can detect π^0!
Important tool for energy scale
And also for models check.....

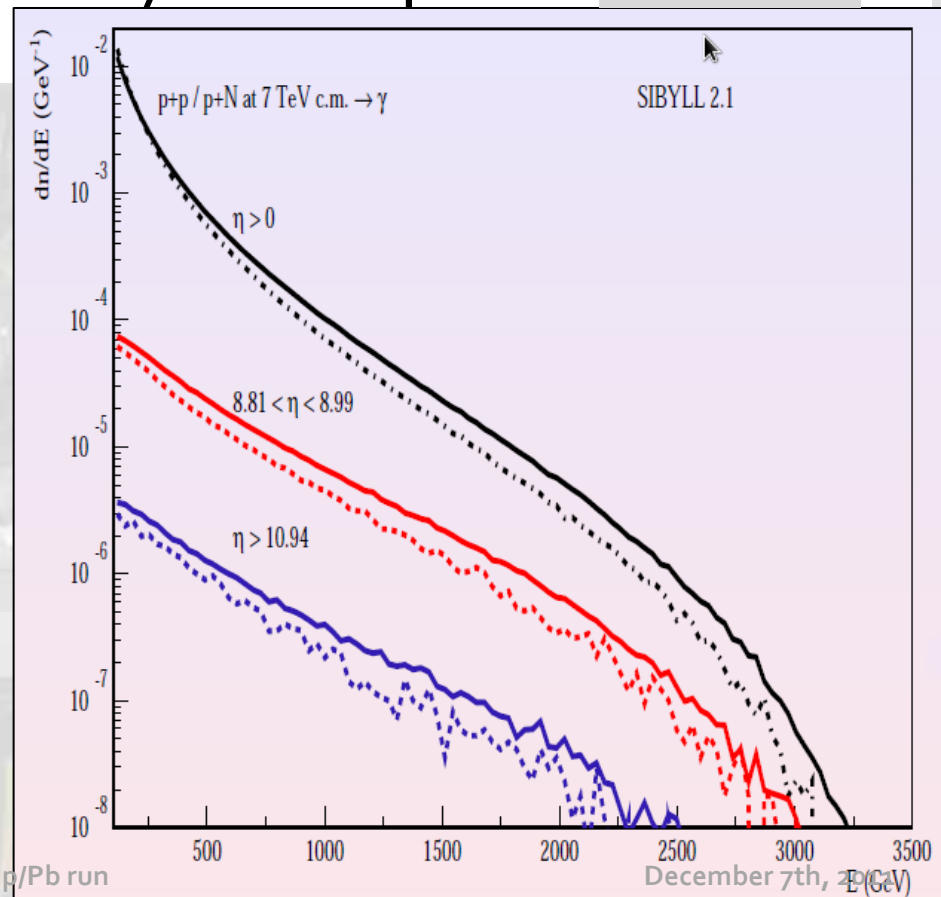


Photons on the proton remnant side

- Photon energy distrib. in different η intervals at $\sqrt{s_{NN}}$ = 7 TeV
- Comparison of p-p / p-N / p-Pb
- **Enhancement of suppression for heavier nuclei case**

QGSJET II-04 Courtesy of S. Ostapchenko **SIBYLL 2.1**





Some estimations based on reasonable machine parameters….

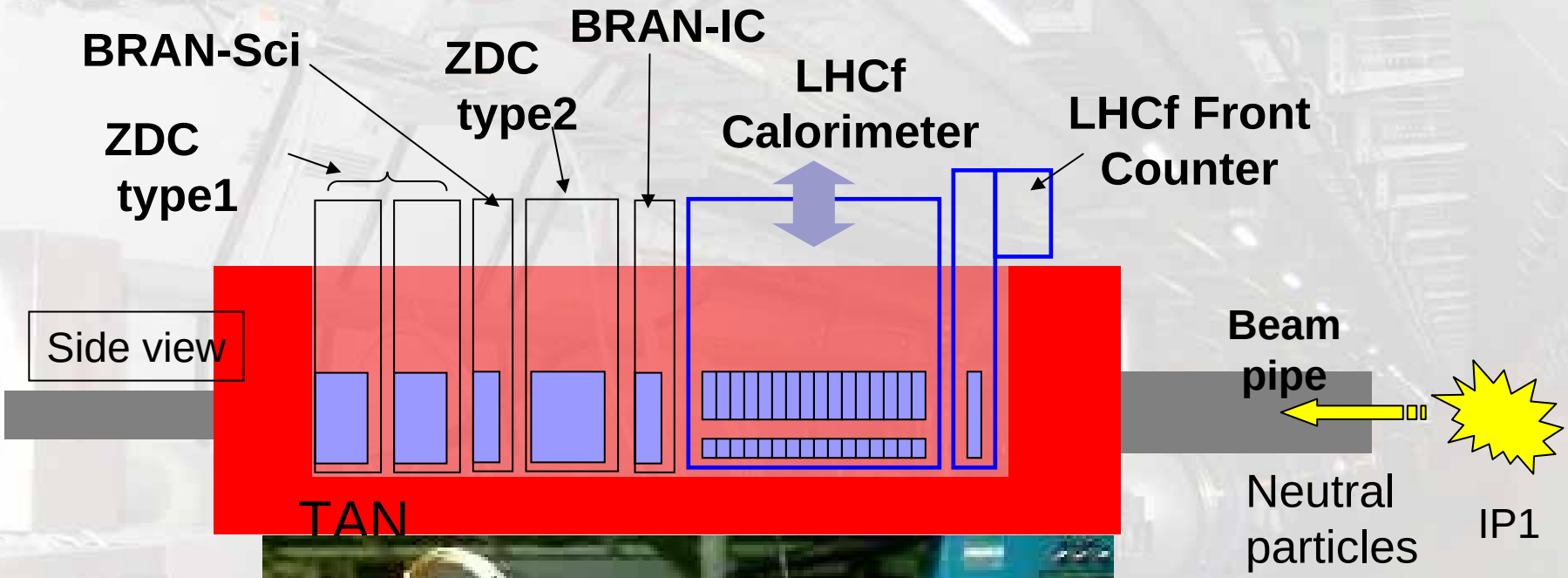
- Considering machine/physics parameters:
  - Number of bunches, **n = 590** (150 ns spacing)
  - Luminosity up to **10^{28} cm^{-2}s^{-1}**
  - Interaction cross section **2 b**
- **PILE-UP** effect
  - Around **3×10^{-3} interactions per bunch crossing**
  - **1%** probability for one interaction in 500 ns (typical time for the development of signals from LHCf scintillators after 200 m cables from TAN to USA15)
  - Some **not interacting bunches** required for beam-gas subtraction

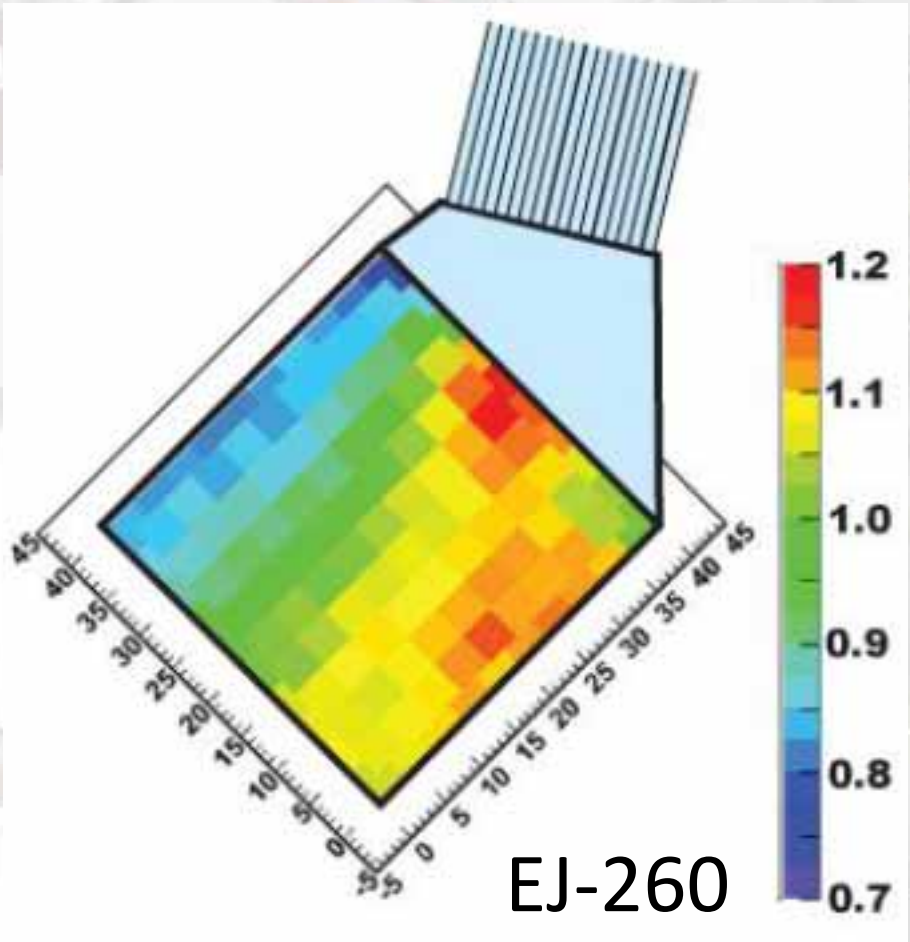
Required statistics for the p/Pb physics run

- Minimum required number of collision: $\mathbf{N_{coll} = 10^8}$
  - Integrated luminosity $\mathbf{L^{int} = 50\ \mu b^{-1}}$
    - **2×10^6 single photons expected on p-remnant side**
    - **35000 π^0 expected on same side**
- Assuming a value of luminosity $\mathbf{L = 10^{26}\ cm^{-2}s^{-1}}$:
  - Minimum running time for physics

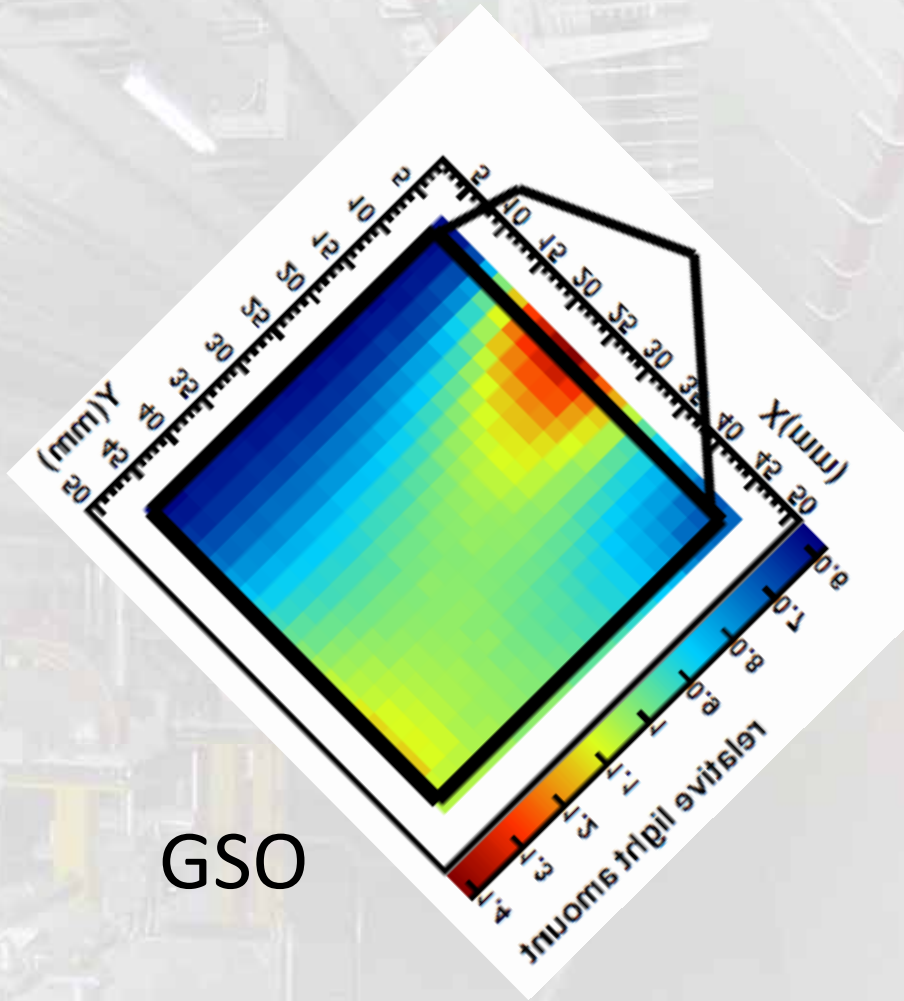
t = 140 h (6 days)

Setup in IP1-TAN (side view)





EJ-260



GSO

- Beautiful map!
- Almost same structure, but…
- Larger contrast than EJ-260
- Non-uniformity-shower spread convoluted correction function may be necessary