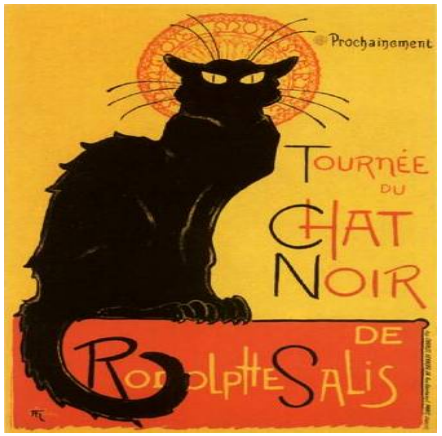
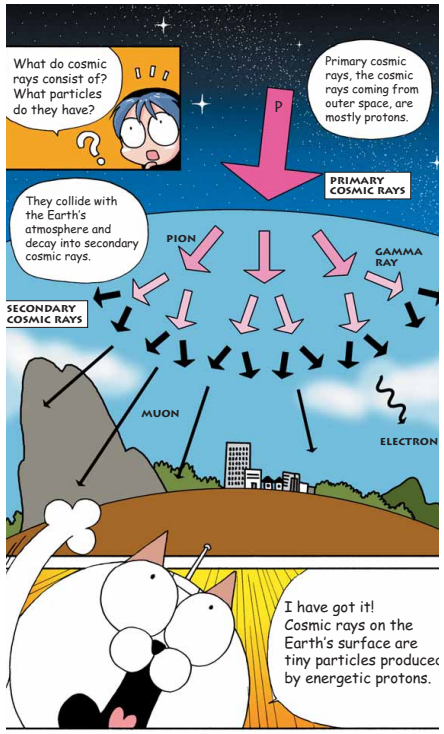
Results from LHCf

Alessia Tricomi
Univesity & INFN Catania

Hadron Collider Physic Symposium 2011
Paris 14-18 November 2011



- Forward photon energy spectrum at $\sqrt{s}$ = 7 TeV p-p collisions
- Prospects for new analyses
- Prospects for new data taking
- Detector upgrade



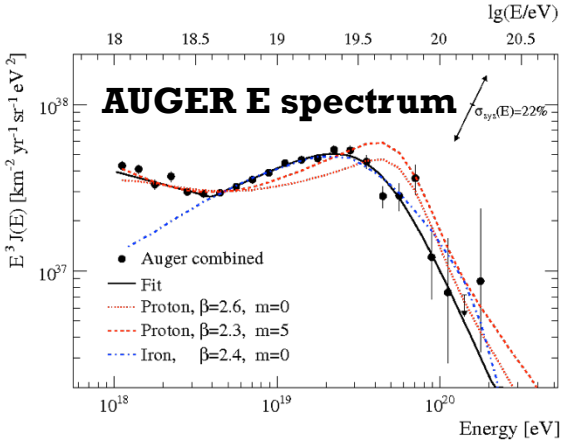
Physics Motivations

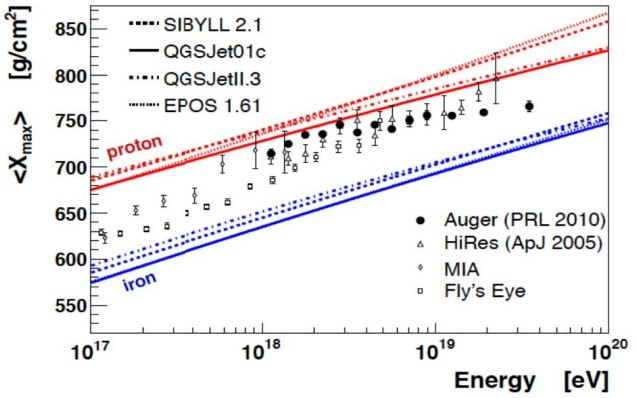
Impact on HECR Physics

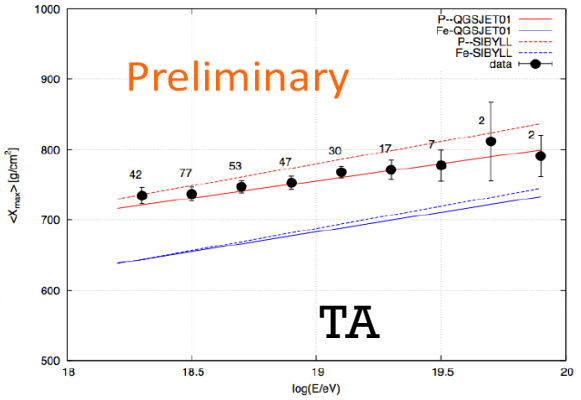
Alessia Tricomi

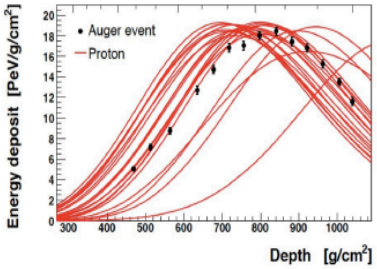
Results from LHCf

HECR Open questions (E/X_{max})

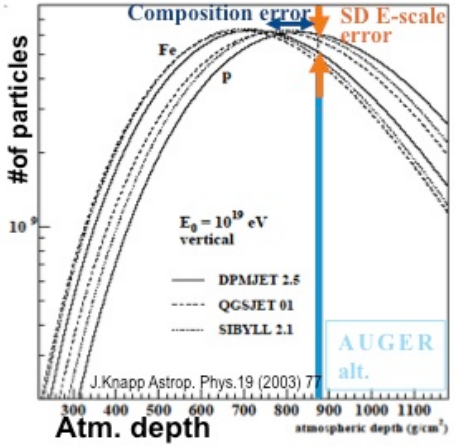


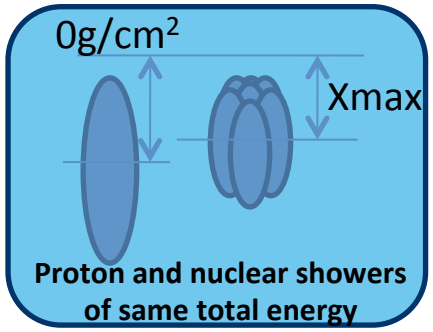




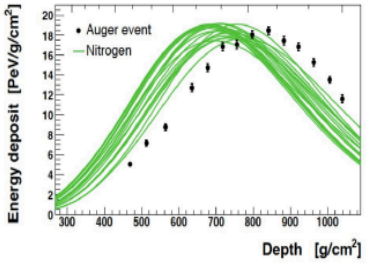


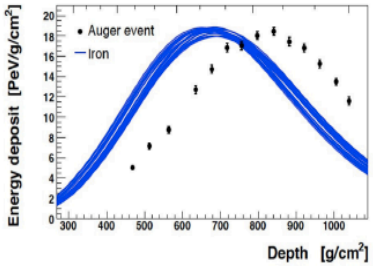
$$E \simeq 10^{20}\ \text{eV}$$





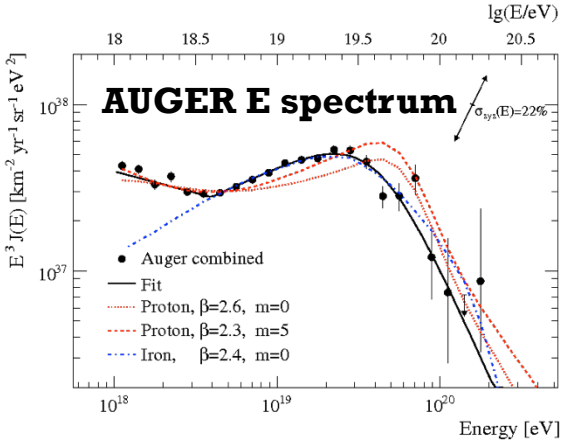
Courtesy P. LIPARI

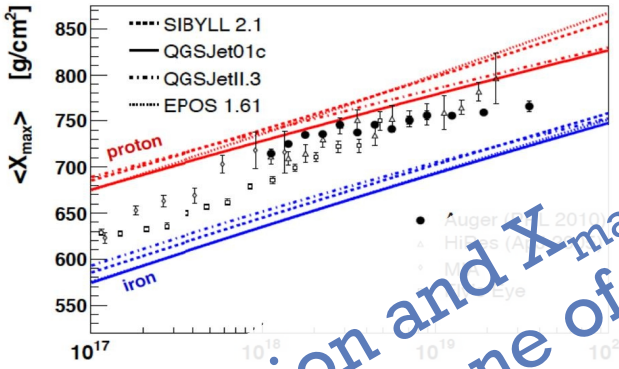


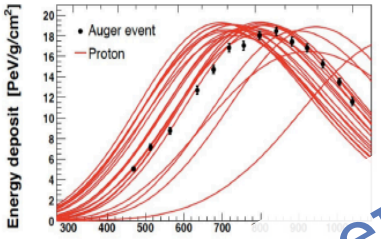


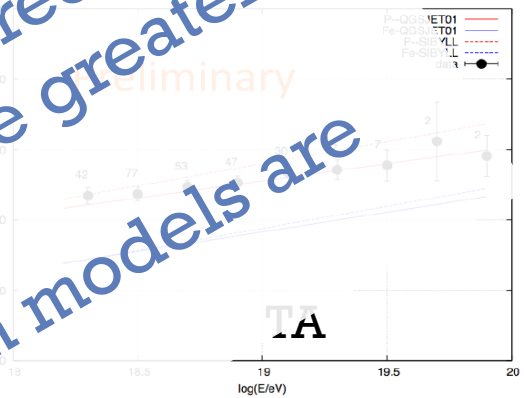
- ✓ X_{max} gives information on the primary particle
- ✓ Results are different between experiments both for E spectra and composition measurements
- ✓ Interpretation relies on the MC prediction and has quite strong model dependence

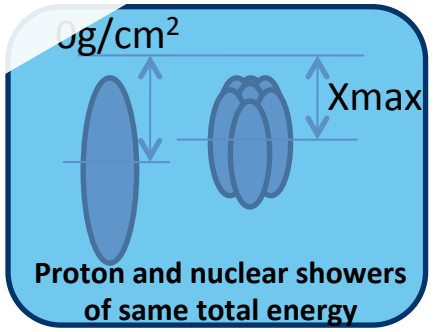
HECR Open questions (E/X_{max})









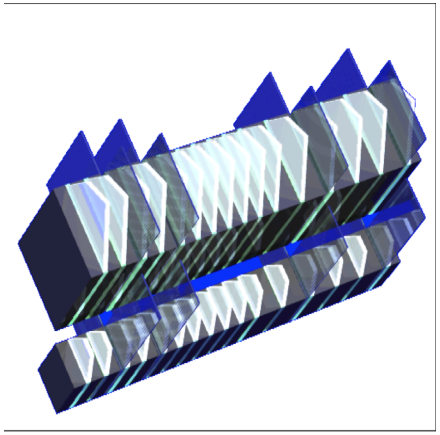


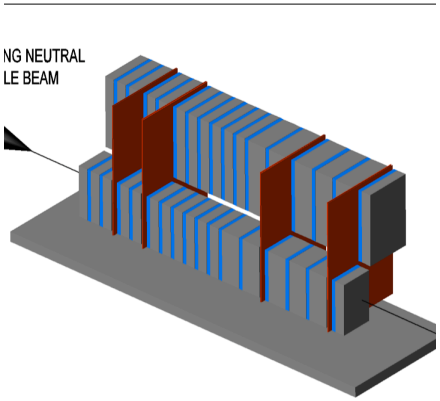
Both in the energy determination and X_{max} prediction MC simulations are used, and are one of the greater sources of uncertainty. Experimental tests of hadron interaction models are necessary! → LHCf

- ✓ X_{max} gives information on the primary particle
- ✓ Results are different between experiments both for E spectra and composition measurements
- ✓ Interpretation relies on the MC prediction and has quite strong model dependence

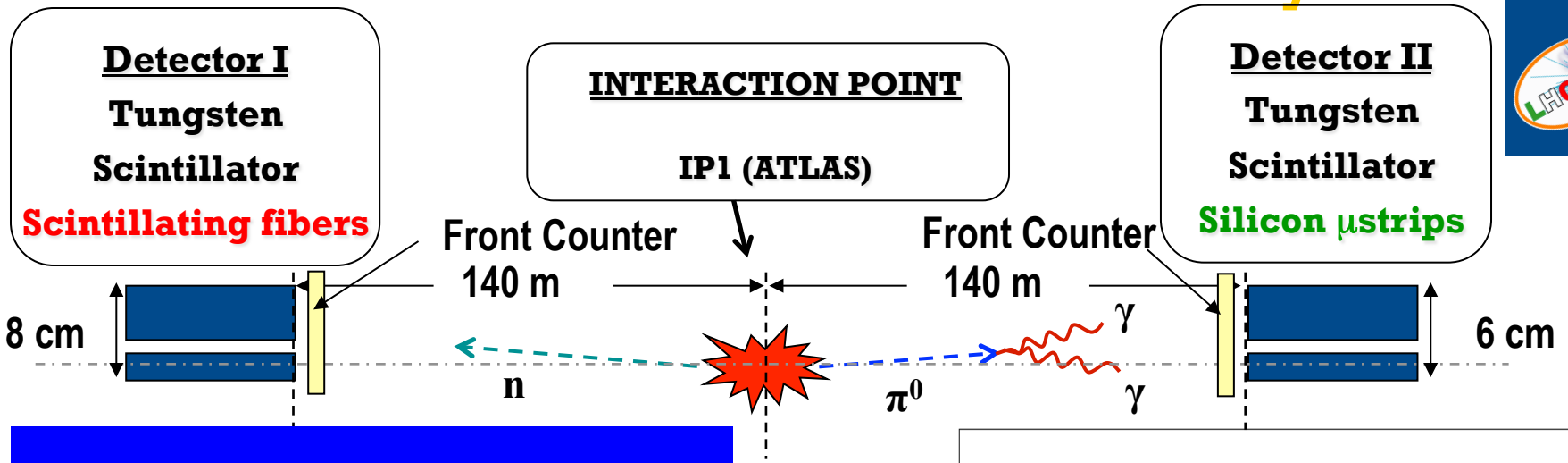
LHCf @ LHC

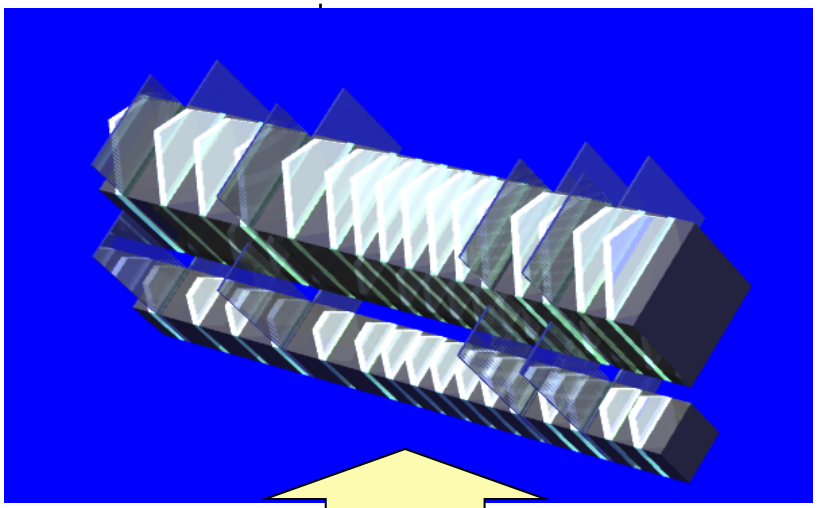
The experimental set-up



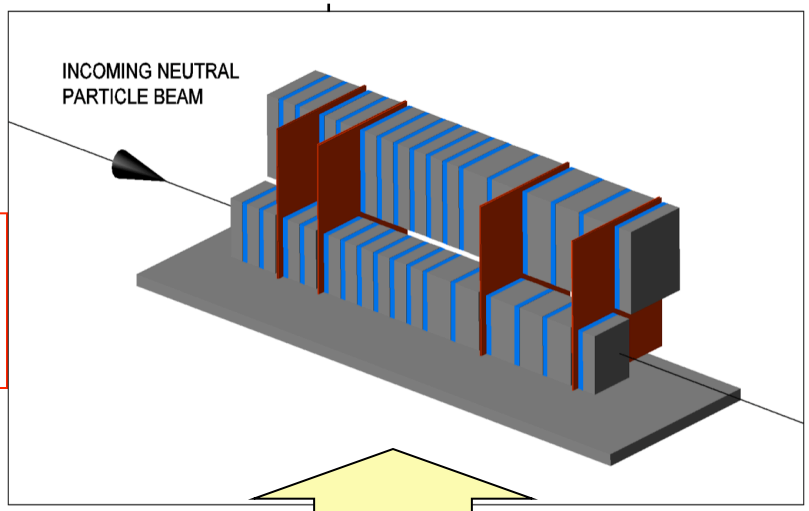


LHCf: location and detector layout





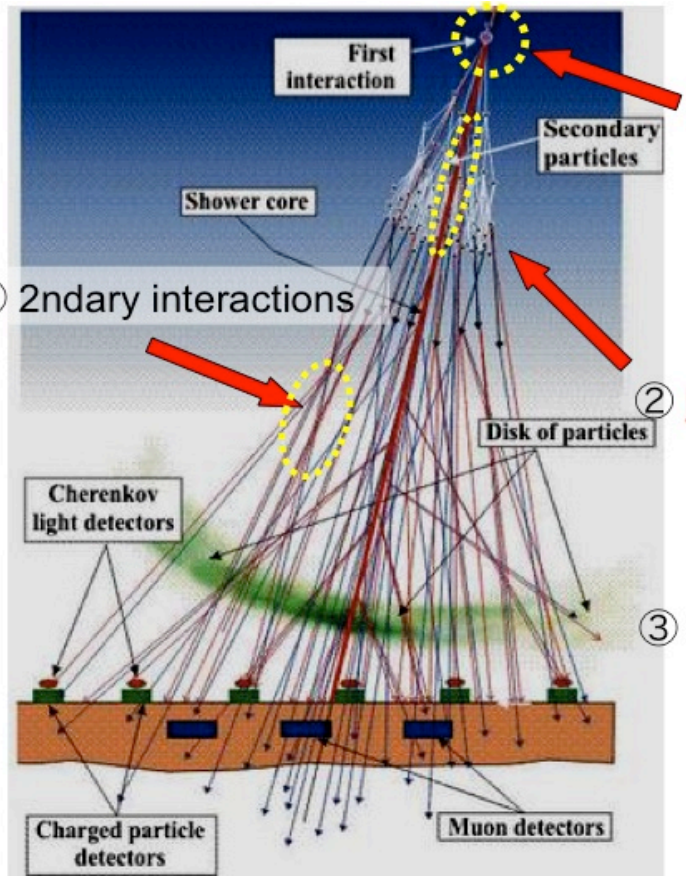
$44X_0$,
$1.6\ \lambda_{int}$



Arm#1 Detector
20mmx20mm+40mmx40mm
4 X-Y SciFi tracking layers

Arm#2 Detector
25mmx25mm+32mmx32mm
4 X-Y Silicon strip tracking layers

How LHCf can contribute?



① Inelastic cross section

If large σ
rapid development
If small σ
deep penetrating

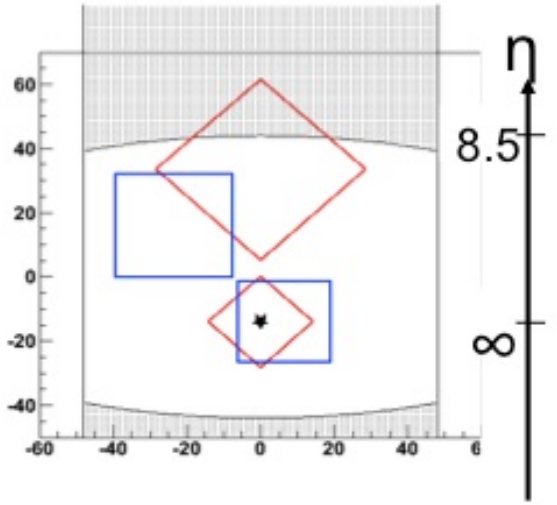
σ_{inela} =73.5±0.6 mb (TOTEM)

② Forward energy spectrum

If softer
shallow development
If harder
deep penetrating

③ Inelasticity k

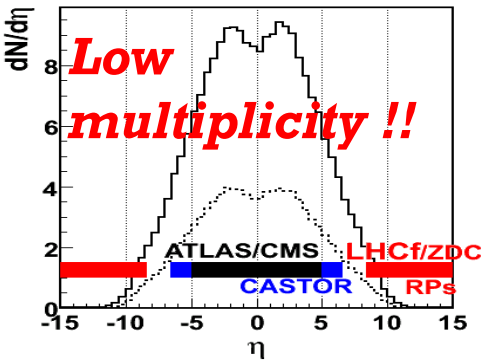
If large k
rapid development
If small k
deep penetrating

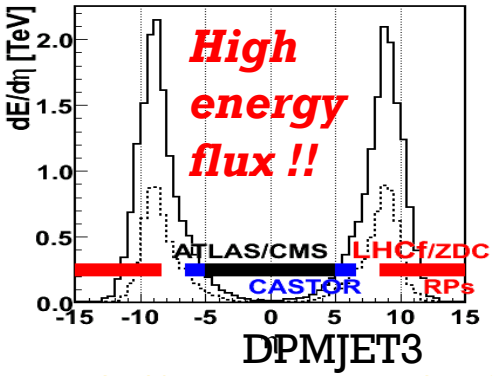


➔ Forward region is very effective on air shower development

LHC gives a unique opportunity to measure hadronic interactions at 10^{17} eV

7TeV+7TeV	→ $E_{lab} = 10^{17}$eV
3.5TeV+3.5TeV	→ $E_{lab} = 2.6\times10^{16}$eV
450GeV+450GeV	→ $E_{lab} = 2\times10^{14}$eV

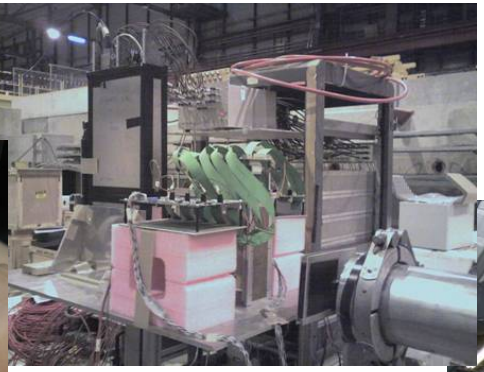




Brief LHCf photo-story

- May 2004 LOI
- Feb 2006 TDR
- June 2006 LHCC approved

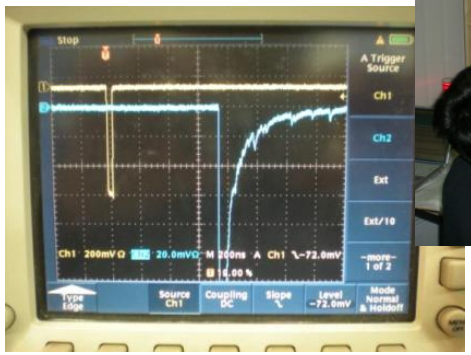
Jul 2006
construction



Aug 2007
SPS beam test

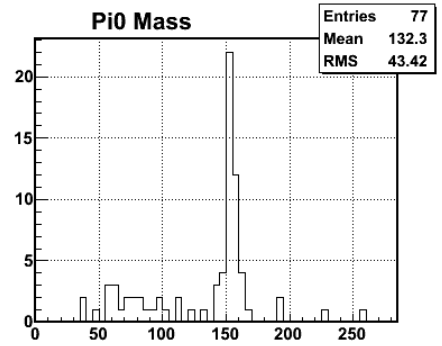
Jan 2008
Installation

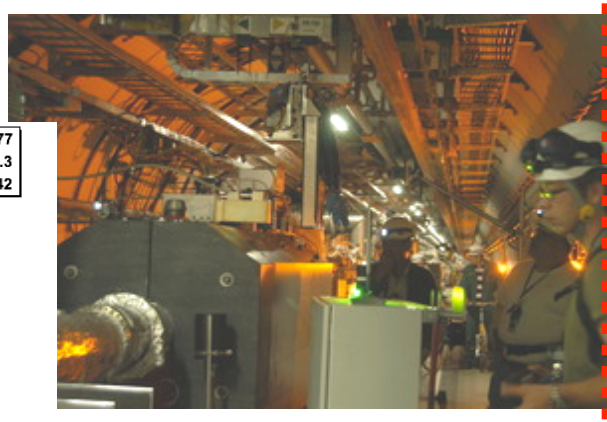
Sep 2008
1st LHC beam



Dec 2009
1st 900GeV run

Mar 2010
1st 7TeV run



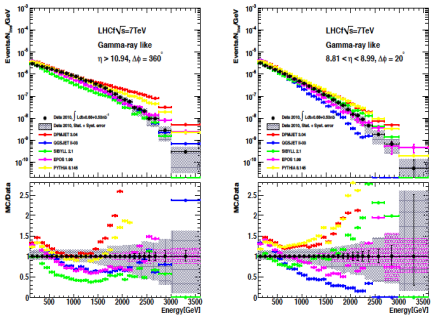


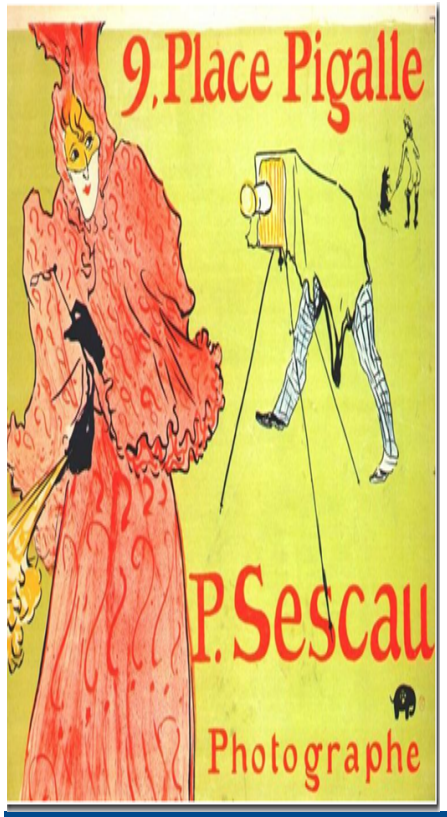
Jul 2010
Detector removal

Inclusive photon spectrum analysis

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

PLB 703 (2011) 128



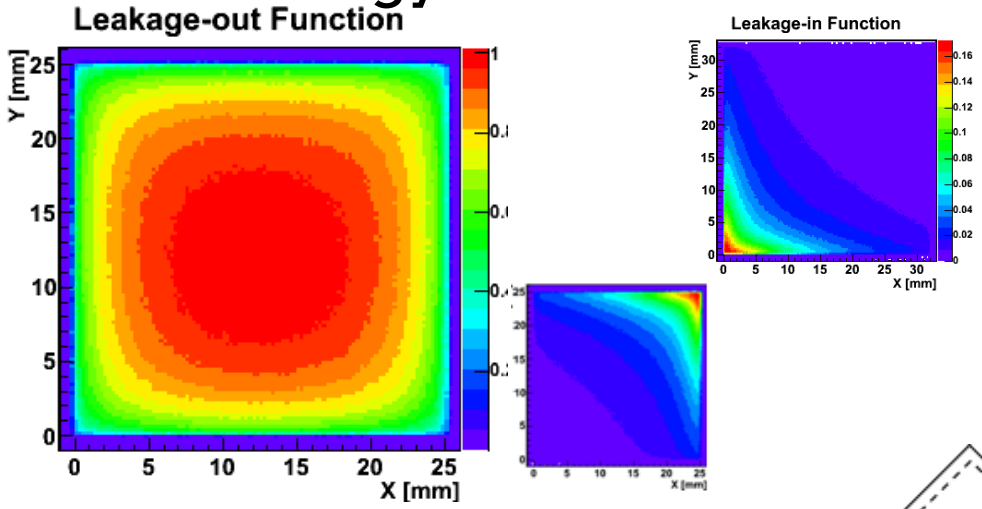


Data Set for inclusive photon spectrum analysis

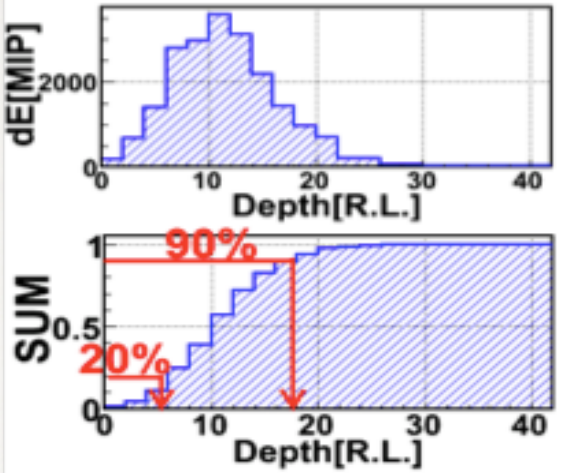
- Data
  - Date : 15 May 2010 17:45-21:23 (Fill Number : 1104)
    except runs during the luminosity scan.
  - Luminosity : $(6.5\text{-}6.3)\times10^{28}\,cm^{-2}s^{-1}$,
  - DAQ Live Time : 85.7% for Arm1, 67.0% for Arm2
  - Integrated Luminosity : $0.68\ nb^{-1}$ for Arm1, $0.53 nb^{-1}$ for Arm2
  - Number of triggers : 2,916,496 events for Arm1
    3,072,691 events for Arm2
  - Detectors in nominal positions and Normal Gain
- Monte Carlo
  - QGSJET II-03, DPMJET 3.04, SYBILL 2.1, EPOS 1.99 and PYTHIA8.145: about 10^7 pp inelastic collisions each

Analysis WORKFLOW

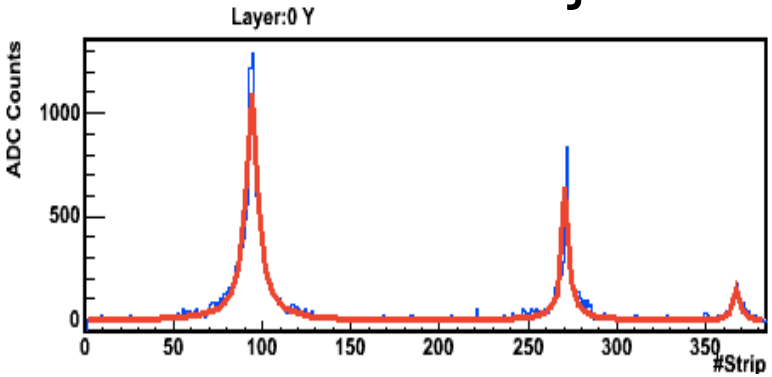
1. Energy Reconstruction

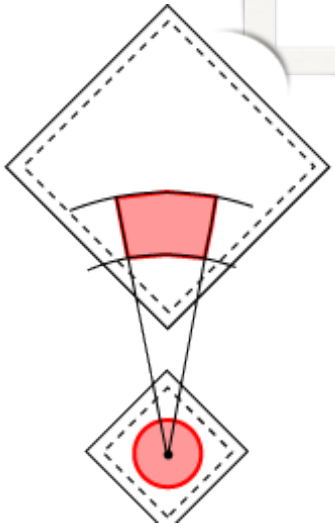


2. PID

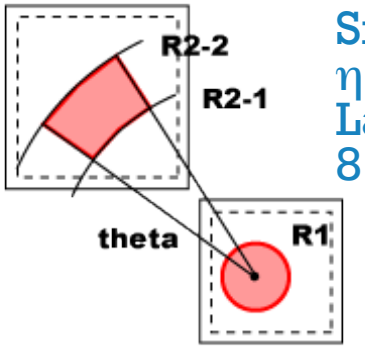


3. Multi-Hit rejection





4. Acceptance cut

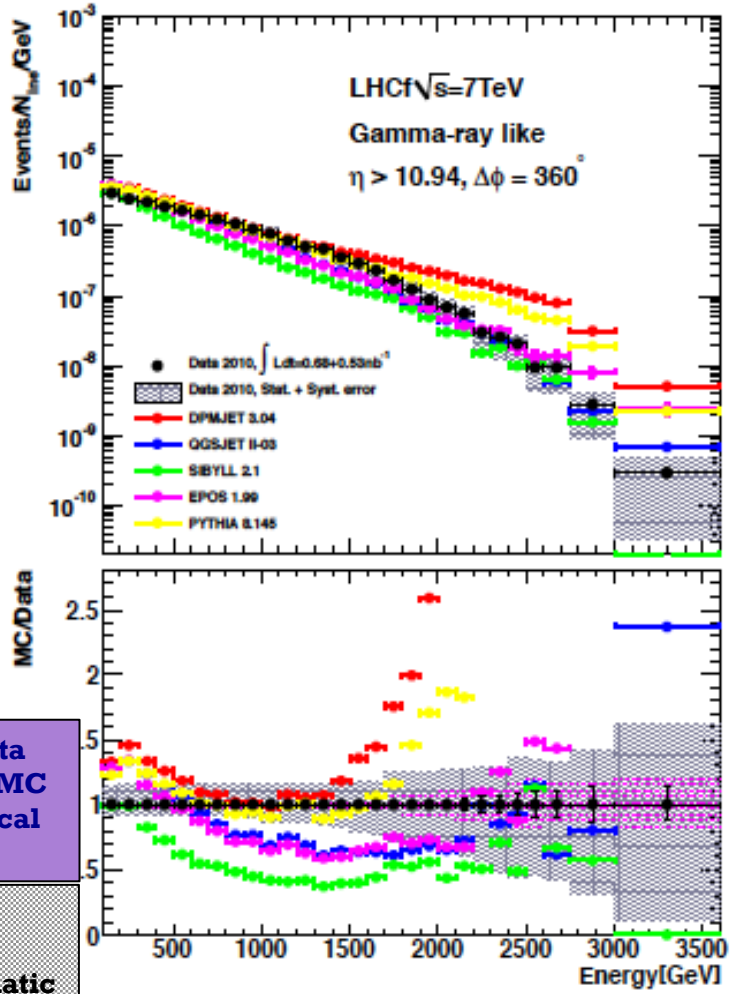


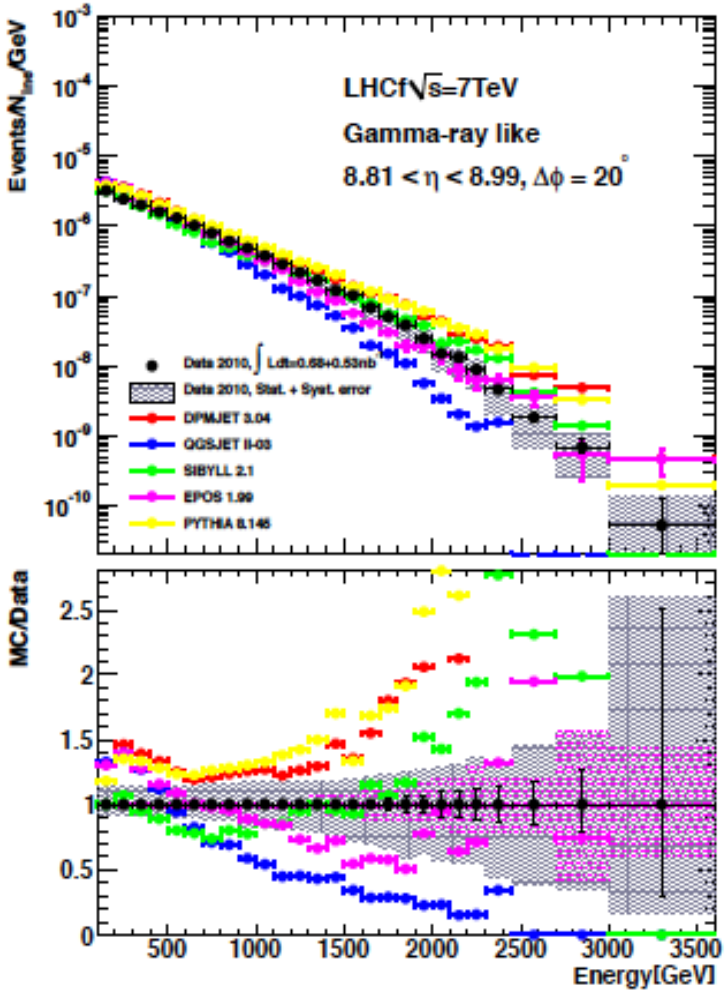
Small Tower
$\eta > 10.94$
Large Tower
$8.81 < \eta < 8.99$

5. Systematic uncertainties

+ Comparison between Models

DPMJET 3.04 SIBYLL 2.1 EPOS 1.99 PYTHIA 8.145 QGSJET II-03



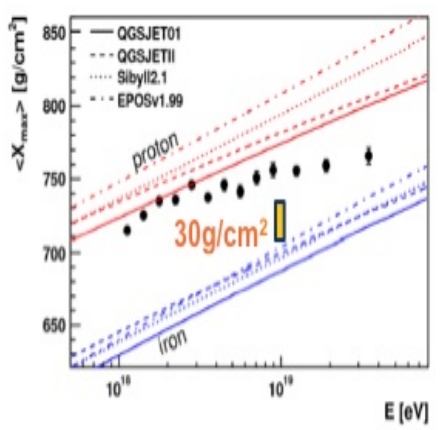


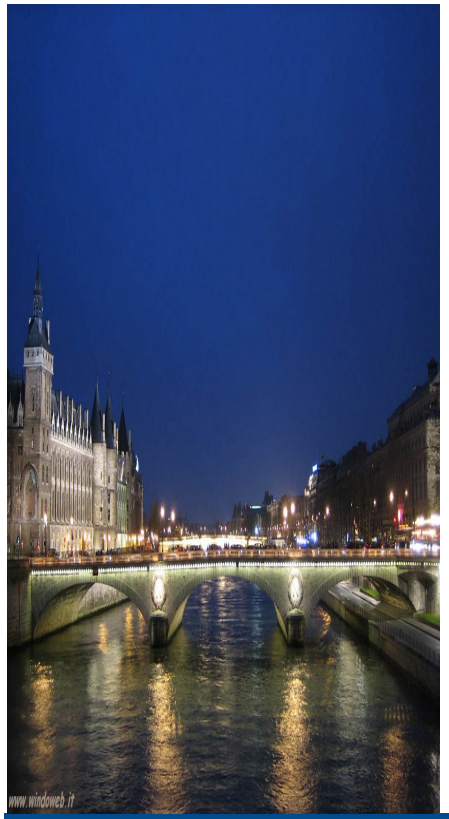
Magenta hatch: MC Statistical errors

Gray hatch : Systematic Errors

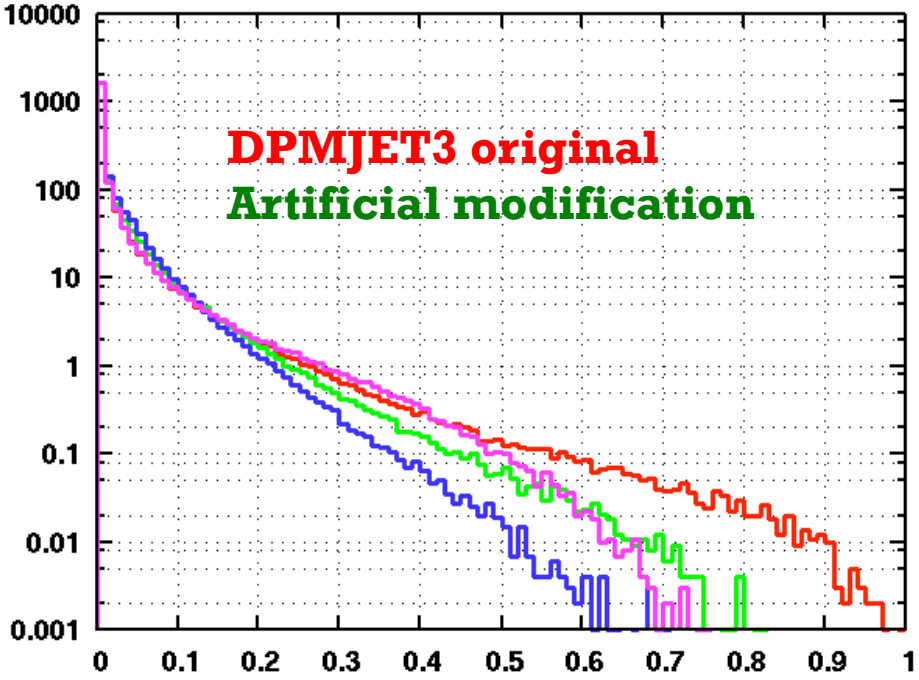
Impact on HECR Physics

Understanding the impact of our measurements



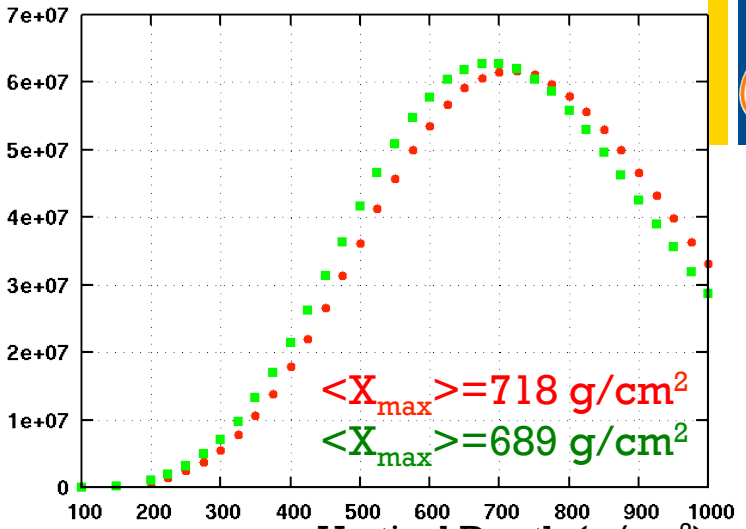


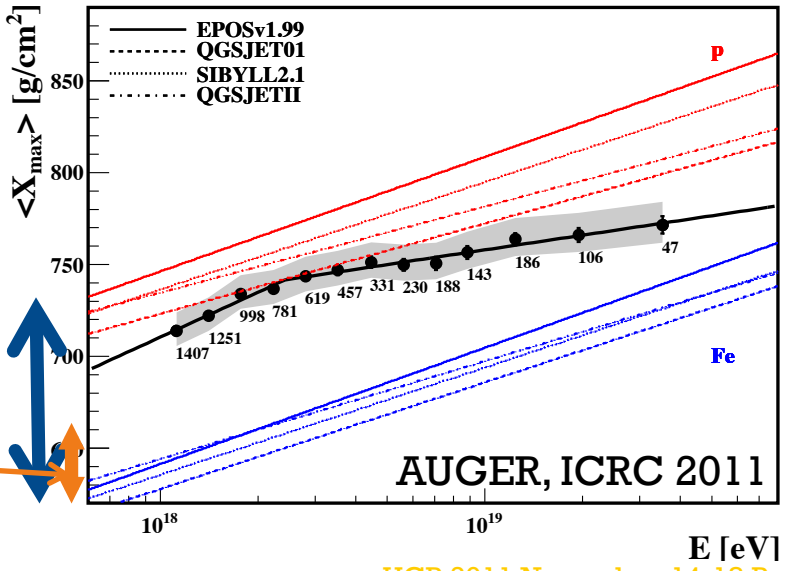
π^0 spectrum and air shower



π^0 spectrum at $E_{lab} = 10^{17}$eV

Longitudinal AS development



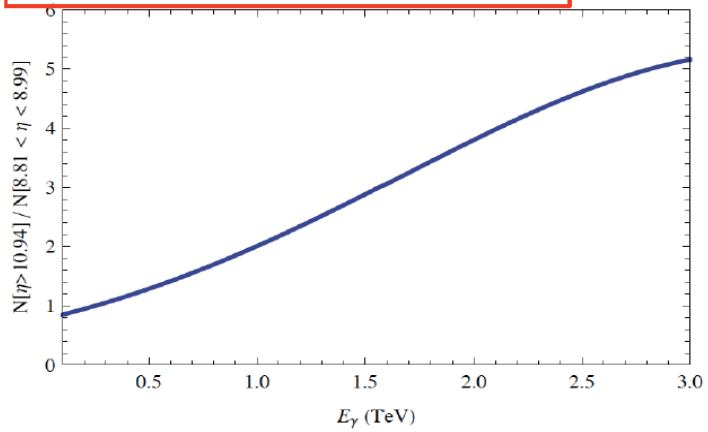


- ✓ Artificial modification of meson spectra (in agreement with differences between models)
- ✓ $\Delta\langle X_{max}(\text{p-Fe})\rangle \sim 100$ g/cm^2
- ✓ Effect to air shower ~ 30 g/cm^2

p_T distribution dependence

Ratio [High Rapidity] / [Low Rapidity]

for LHCf DATA



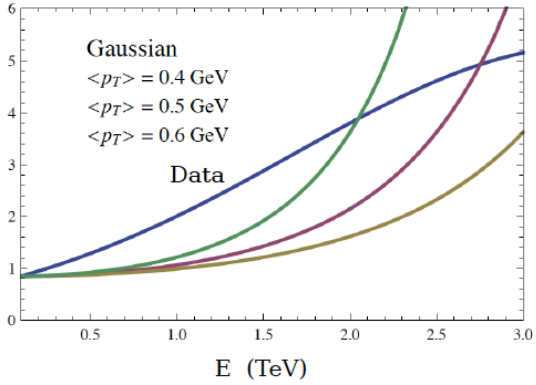
$$\left[\frac{dN_\gamma}{dE_\gamma}(E_\gamma)\right]_{8.81\leq\eta\leq8.99} = \frac{dN_\gamma}{dE_\gamma}(E_\gamma) \times \frac{dN_\gamma[8.81 \leq \eta \leq 8.99]}{dN_\gamma[\text{all } \eta]}$$

$$\left[\frac{dN_\gamma}{dE_\gamma}(E_\gamma)\right]_{\eta>10.94} = \frac{dN_\gamma}{dE_\gamma}(E_\gamma) \times \frac{dN_\gamma[\eta > 10.94]}{dN_\gamma[\text{all } \eta]}$$

Directly relevant for UHECR shower development

pT distribution dependence

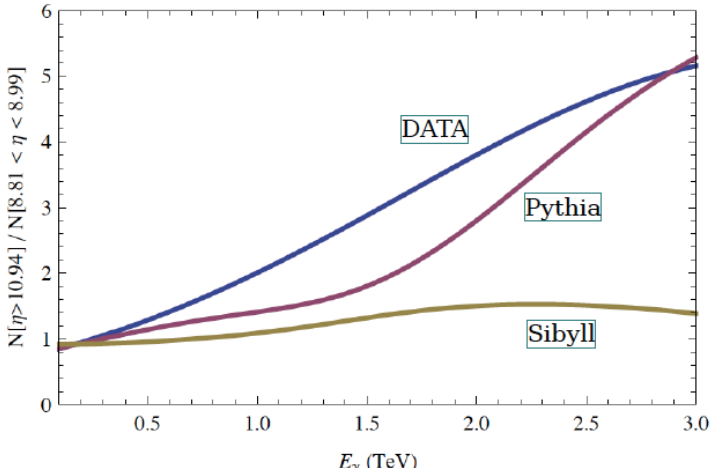
The pT distribution a sqrt[s] = 7 TeV is not a Gaussian of energy independent width.



Courtesy P. LIPARI

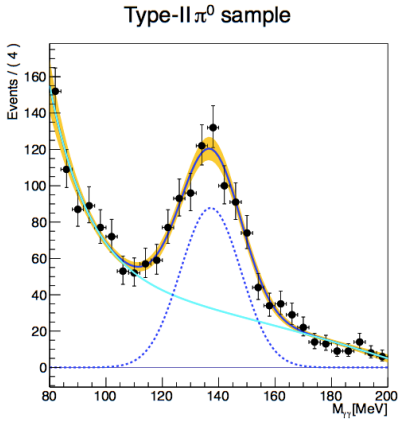
Interplay of LHCf data with HECR Physics Workshop,

Catania, July 6 2011



What's next

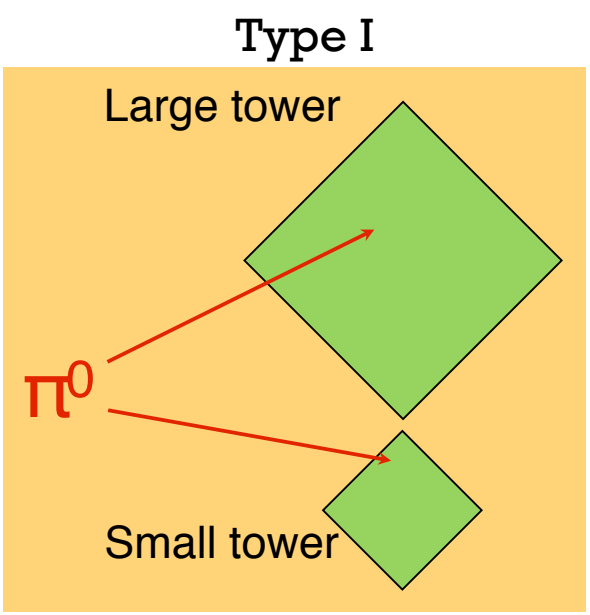
Detector upgrade, analyses, ion runs

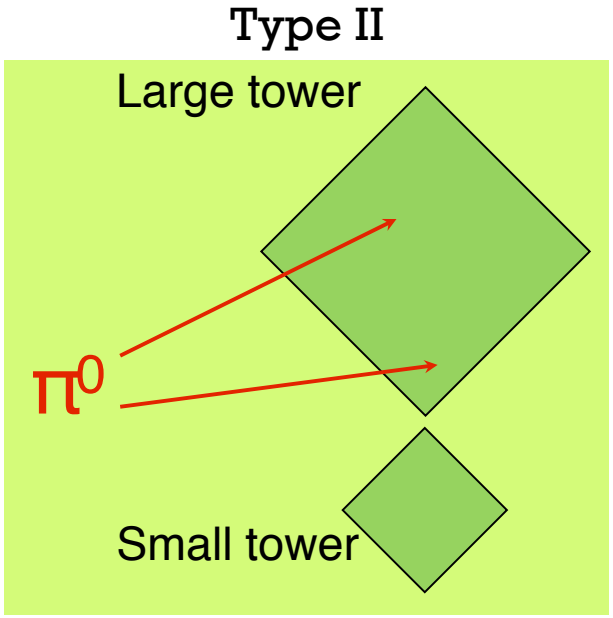


LHCf on going activities (I): new analyses

2011-2012: New analyses

- π^0 measurement
- 900 GeV spectra
- p_T spectra
- Hadron spectra
- η, K^0, Λ ?

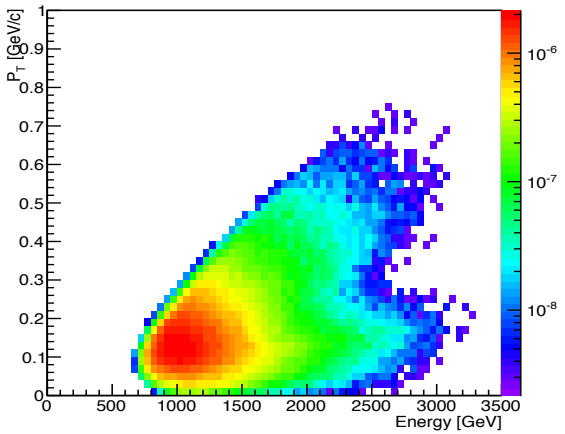




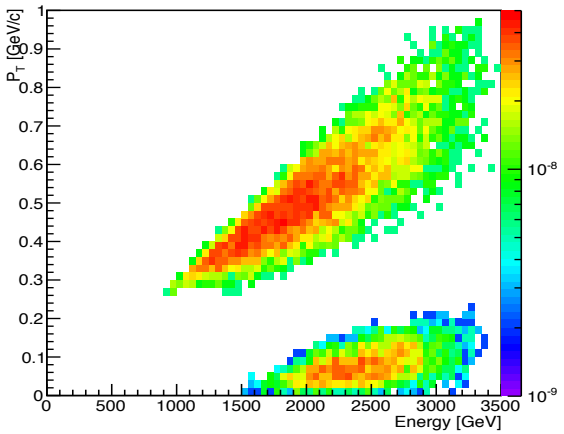
Excellent performance of position sensitive detectors give us the possibility to reconstruct multi-hit event in the same tower

LHCf on going activities: π^0 analysis

Type-I sample



Type-II sample

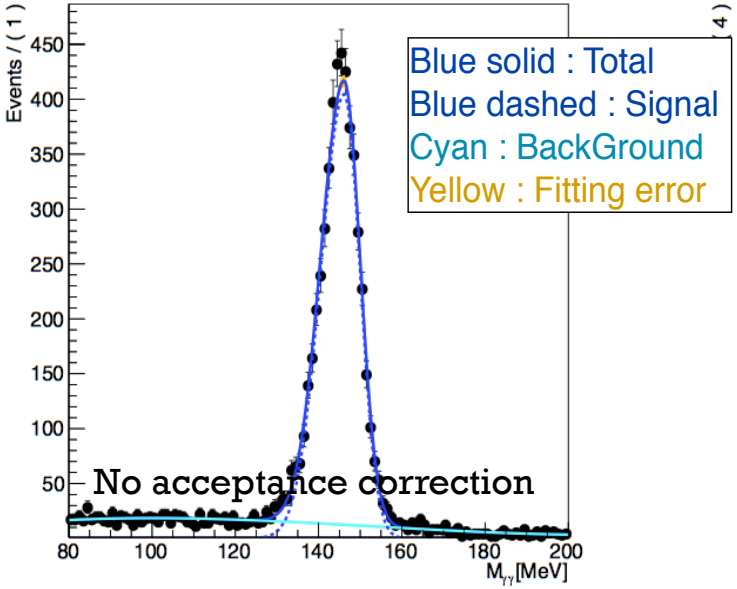


Wide opening angle
Dominate at lower energy

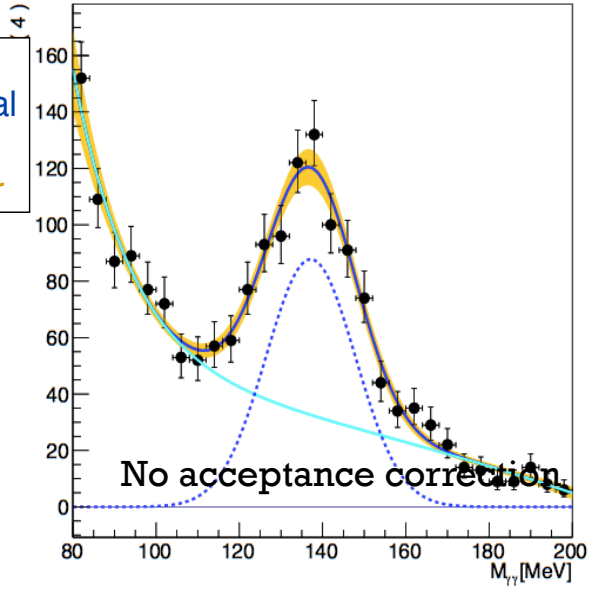
Tight opening angle
Dominate at high energy

Extend our acceptance

Type-I π^0 sample



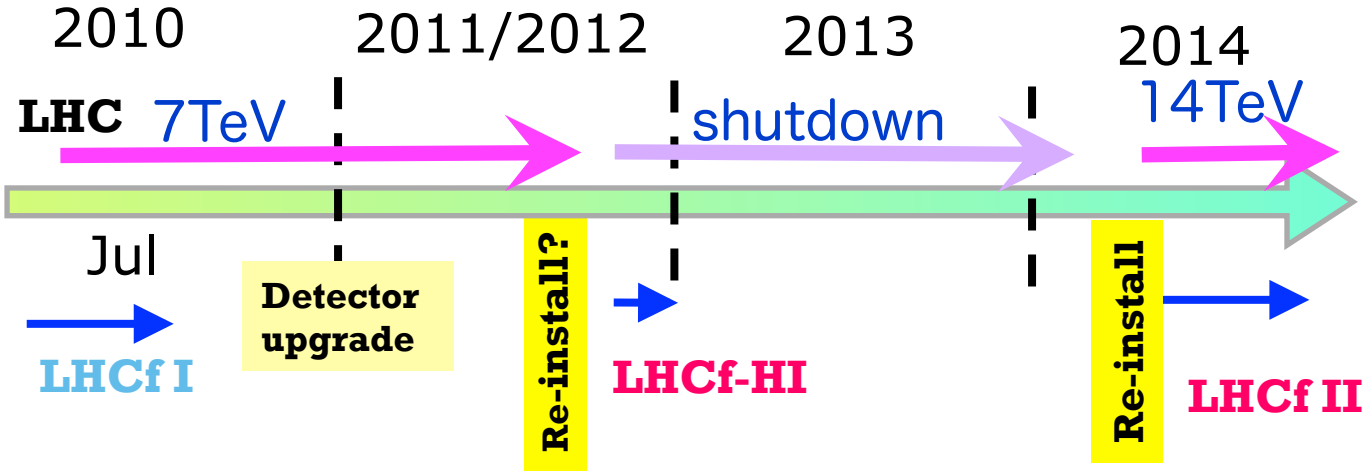
Type-II π^0 sample



Data vs MC~7.8%

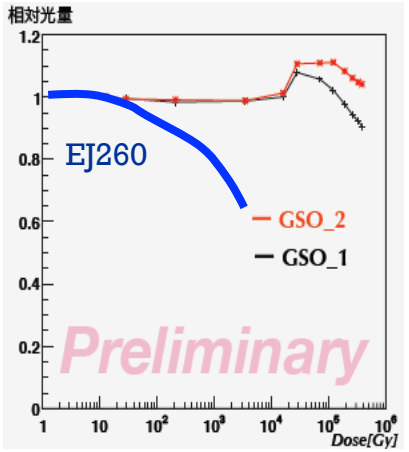
Type-II BG reduction still to b optimised

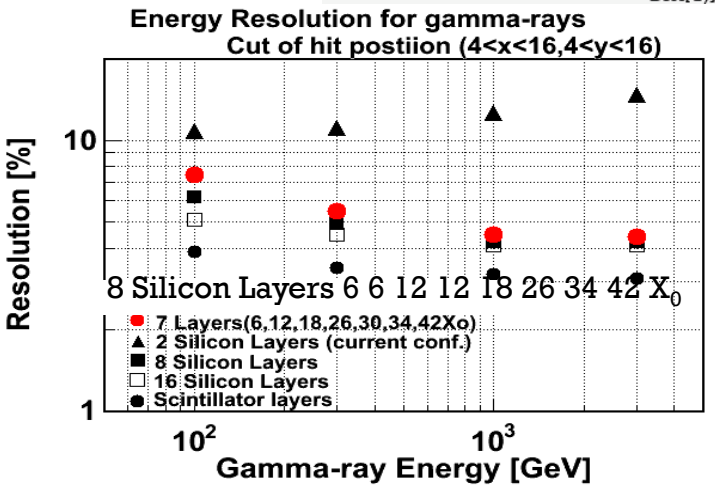
LHCf Future PLANS (I)



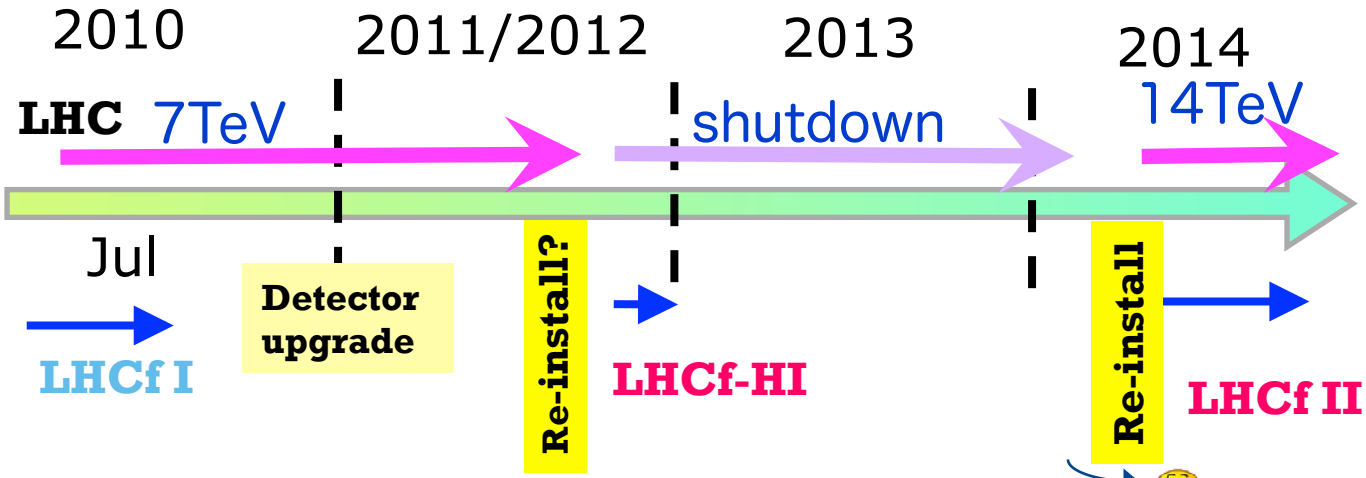
2011-2012: Detector upgrade for 14 TeV run

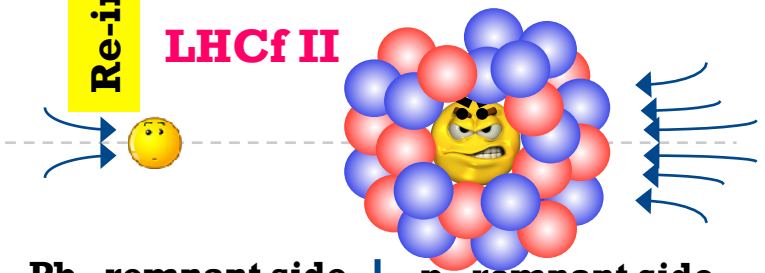
- Replace plastic scintillators with Rad Hard GSO
  - Test beam at HIMAC on going
- Modify the silicon layers positions to improve silicon-only energy resolution
- Test beam at SPS to calibrate Arm1&Arm2
- Improve the dynamic range of silicon



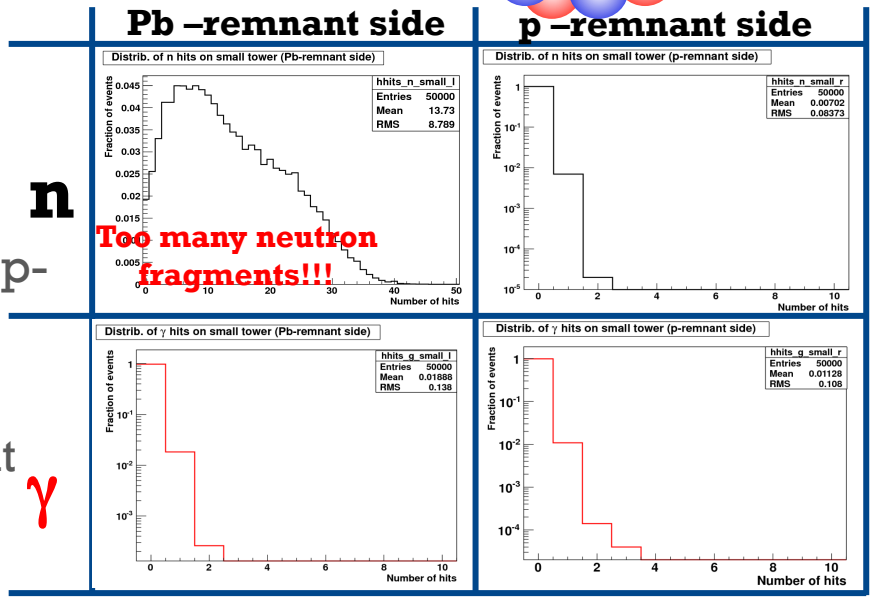


LHCf Future PLANS (II): Ion runs





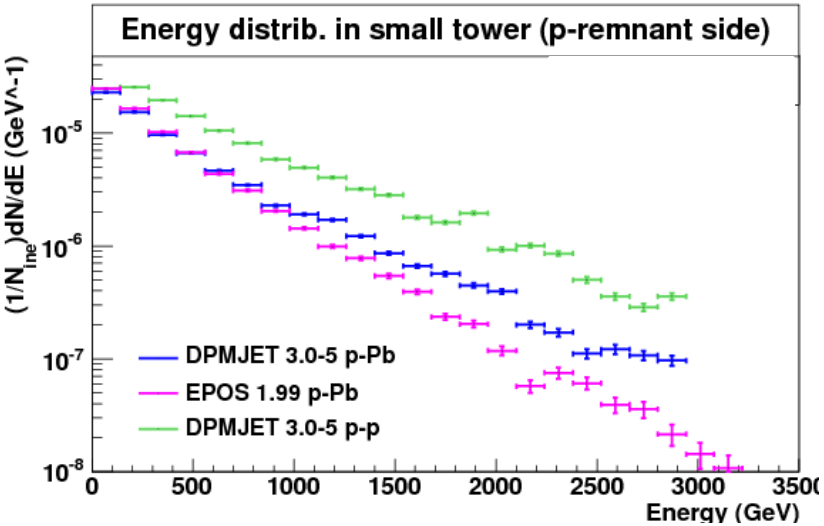
- 2012-2013: p-Pb runs?
  - Interest in Ion runs
  - Physics case study well motivated
  - LHC Ion run and/or RHIC
    - Discussion on going with LHCC, LHC machine, ATLAS about reinstallation on p-remnant side during p-Pb run (end of 2012?)
    - Discussion about possible data taking at RHIC

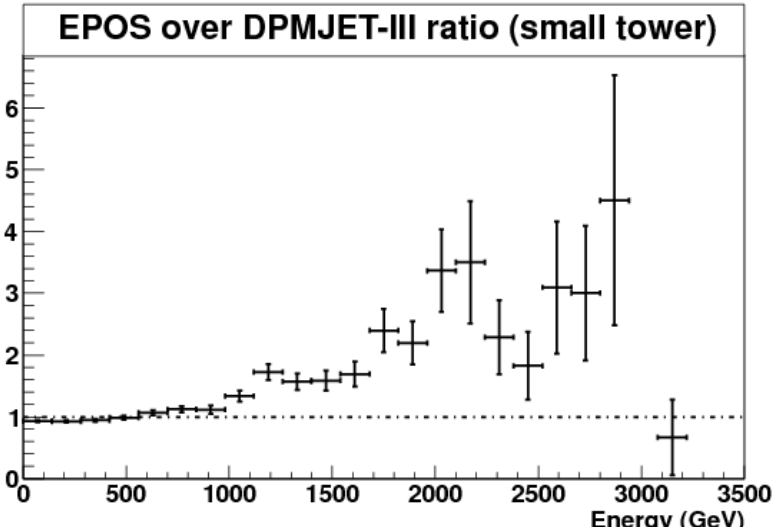


LHCf Future PLANS (II): p-Pb run

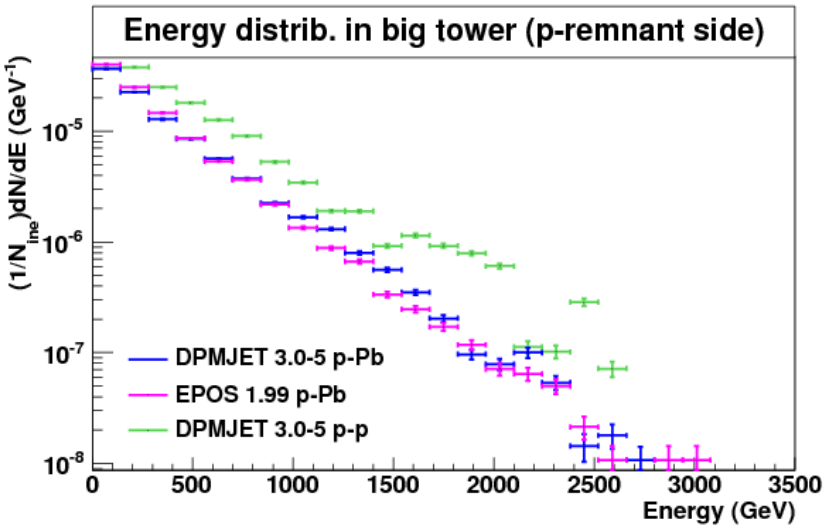
Photon spectra

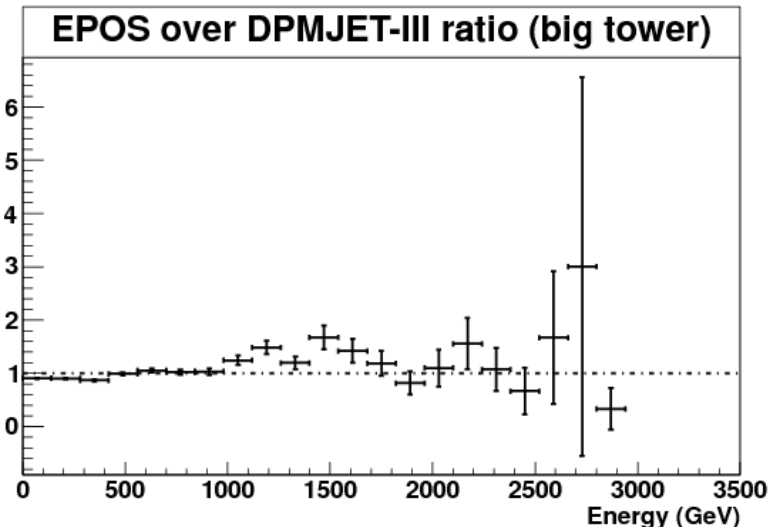
Small tower





Big tower

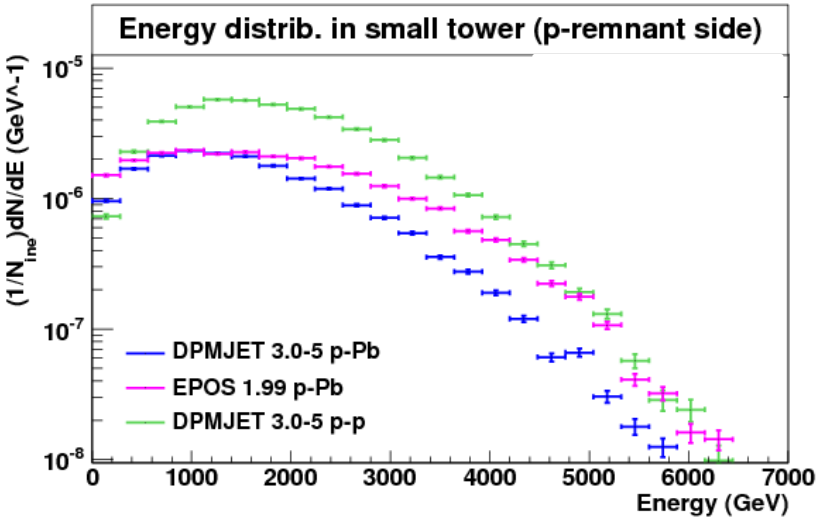




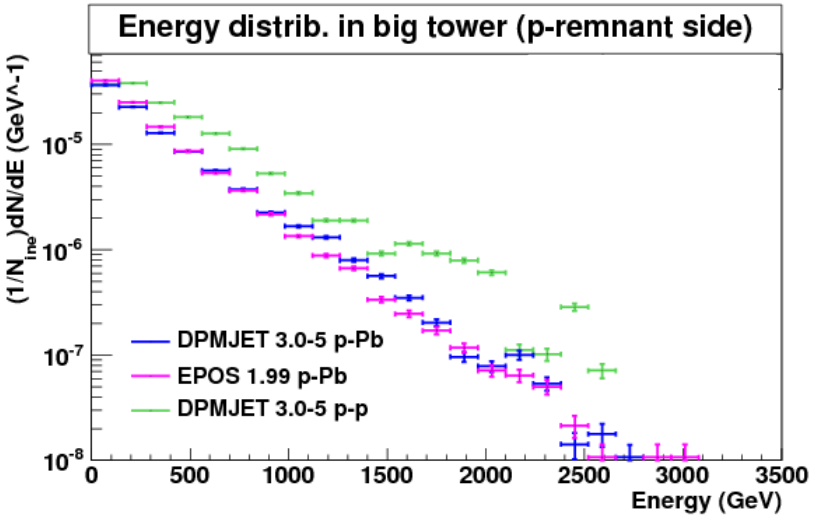
LHCf Future PLANS (II): p-Pb run

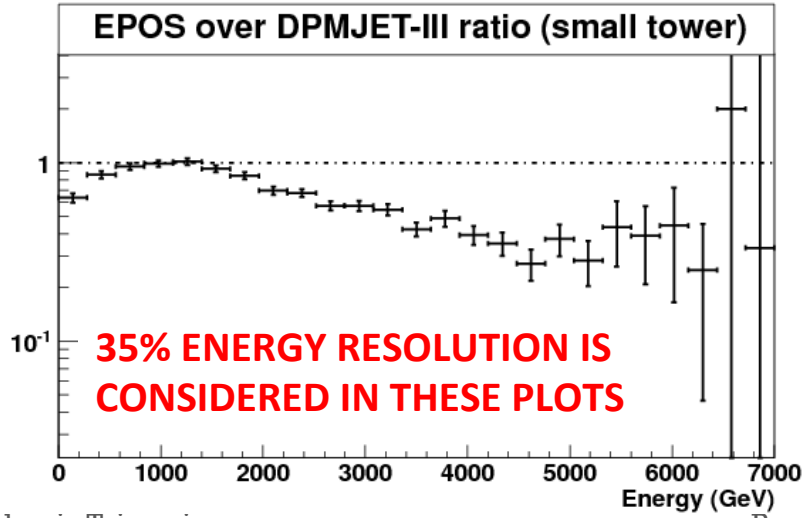
Neutron spectra

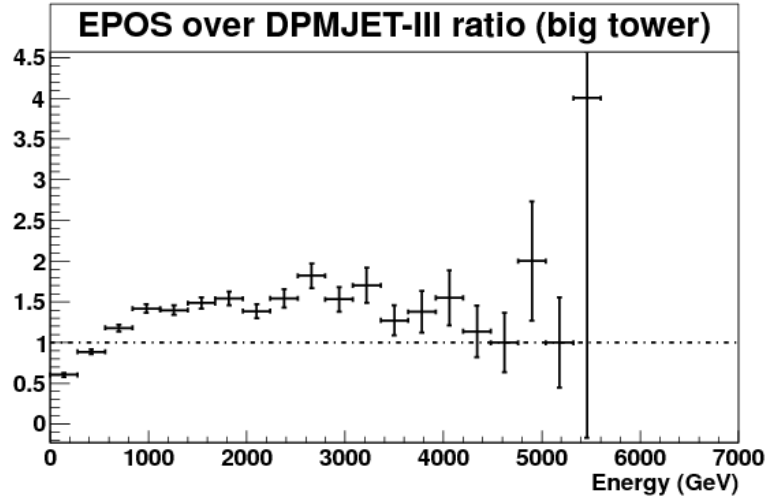
Small tower



Big tower

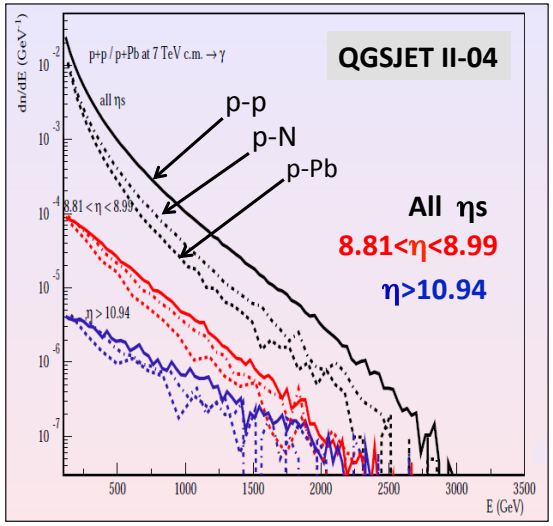


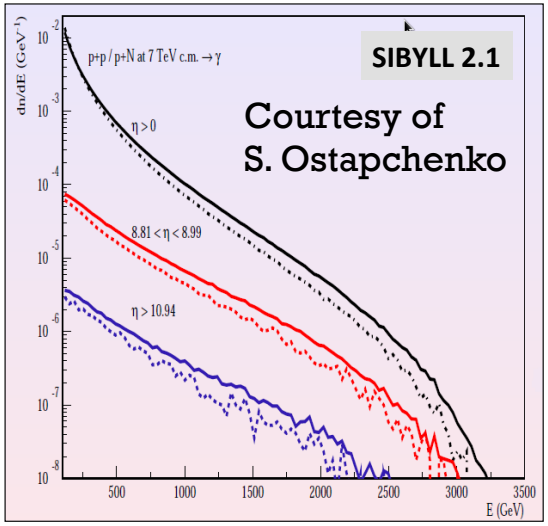




+ LHCf Future PLANS (II): p-Pb run

Additional motivations

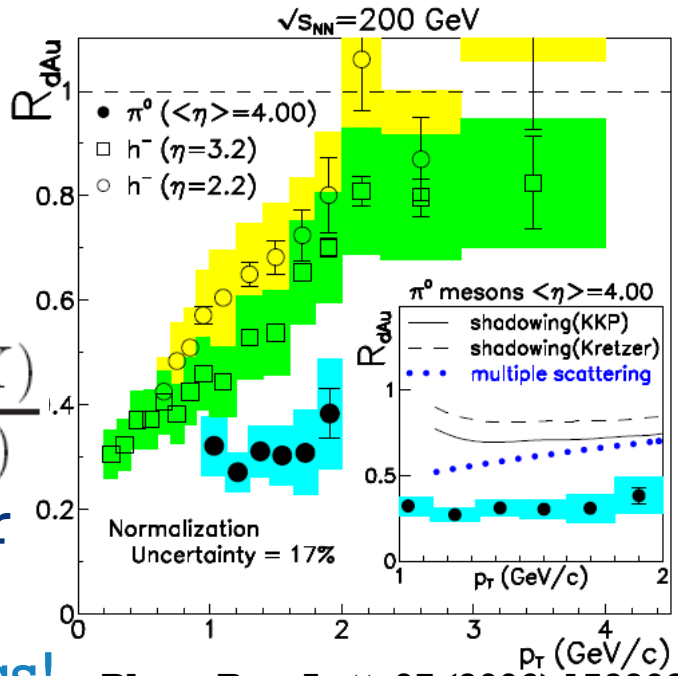




Photon energy distrib. vs η intervals at $\sqrt{s_{NN}} = 7$ TeV
Comparison of p-p/p-N/P-Pb
Enhancement of suppression for heavier nuclei case

Nuclear Modification Factor measured at RHIC (production of π^0): strong suppression for small p_T at $<\eta>=4$

$$R^{Y}_{\mathrm{dAu}} = \frac{\sigma^{pp}_{\mathrm{inel}}}{\langle N_{\mathrm{bin}}\rangle \sigma^{dAu}_{\mathrm{hadr}}} \frac{E\, d^3\sigma/dp^3(d+Au \rightarrow Y+X)}{E\, d^3\sigma/dp^3(p+p \rightarrow Y+X)}$$



Phys. Rev. Lett. 97 (2006) 152302

LHCf can extend the measurent at higher energies and for η>8.4

Important measurement for HECR Physics!

Conclusions

- LHCf Inclusive photon analysis published
  - First comparison of various hadronic interaction models with experimental data in the most challenging phase space region ($8.81 < \eta < 8.99, \eta > 10.94$)
  - Large discrepancy especially in the high energy region with all models
  - Implications on UHECR Physics under study in strict connection with relevant theoreticians and model developers
- Other analyses are in progress (π^0, 900 GeV spectra, P_T spectra, hadrons…)
  - Stay tuned for new results
- We are upgrading the detectors to improve their radiation hardness (GSO scintillators and rearrange silicon layers) for 14 TeV run
- Discussions are under way to come back in the TAN for the possible p-Pb run in 2012 or at RHIC for lower energy p-ions runs
  - Physics case well motivated
  - Discussion are on going (LHCC, LHC, Atlas etc.) for LHCf re-installation
- We will anyway come back in LHC for the 14 TeV run with upgraded detector!!!!