Status of the LHCf experiment

- Physics background
- Experiment and current results
- LHC 13 TeV run and future

STE Lab. / Kobayashi-Maskawa Inst.,
Nagoya University
Yoshitaka Itow
ICRC2015
30th Jul 2015

10^{17} eV :Crossroad of accelerators and UHECRs

Telescope Array

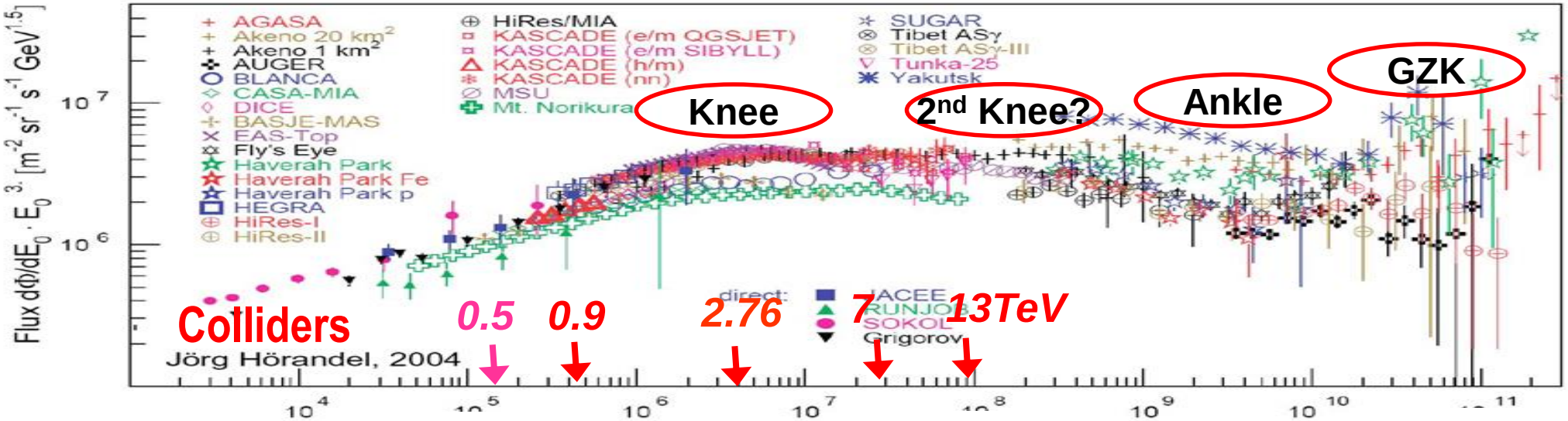
AUGER

Air shower experiments

HEAT

TALE

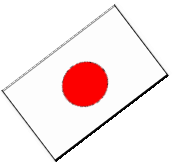
AUGER, TA



Cosmic rays 10^{14} 10^{17} 10^{20} eV

- LHC covers 10^{14} – 10^{17} eV cosmic rays
- LHCf measures forward particle spectra relevant t air showers.

The LHCf experiment



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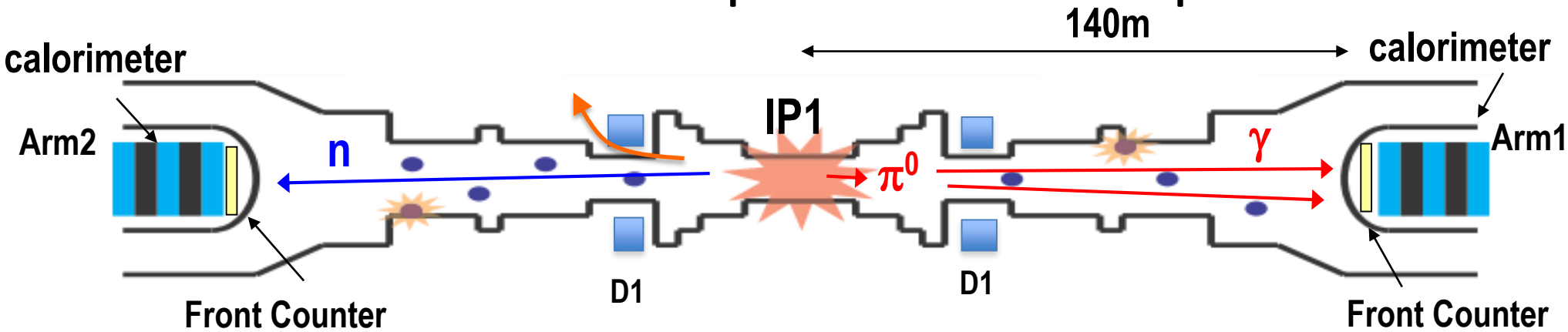
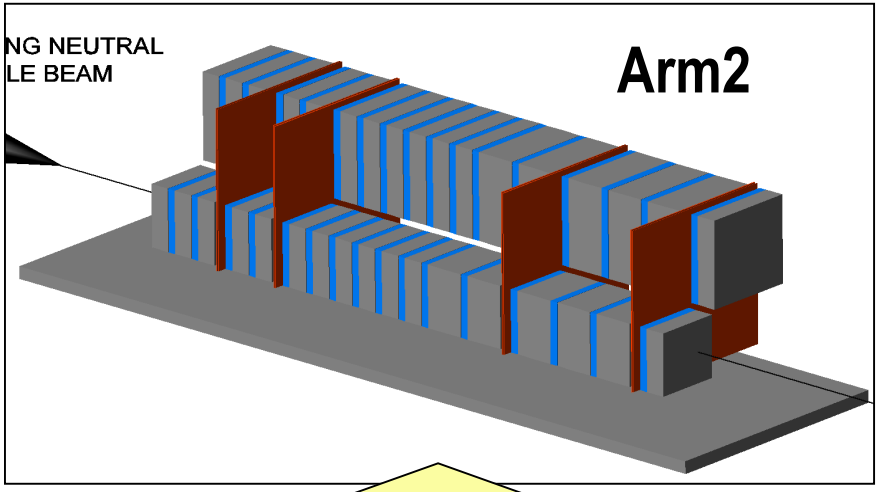
J.Velasco, A.Faus *IFIC, Centro Mixto CSIC-UVEG, Spain*

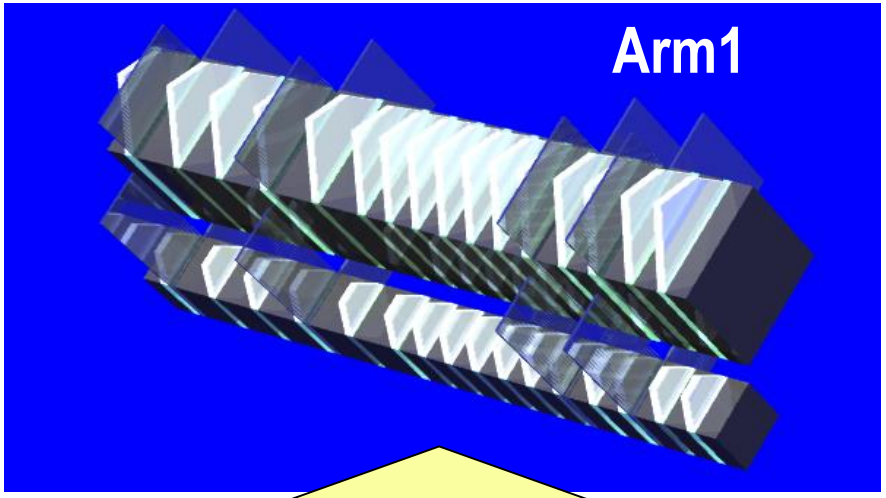
A-L.Perrot *CERN, Switzerland*

The LHCf experimental setup





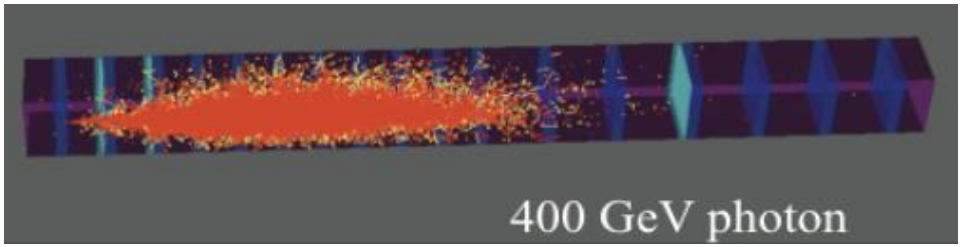
$44X_0$,
$1.6\ \lambda_{int}$

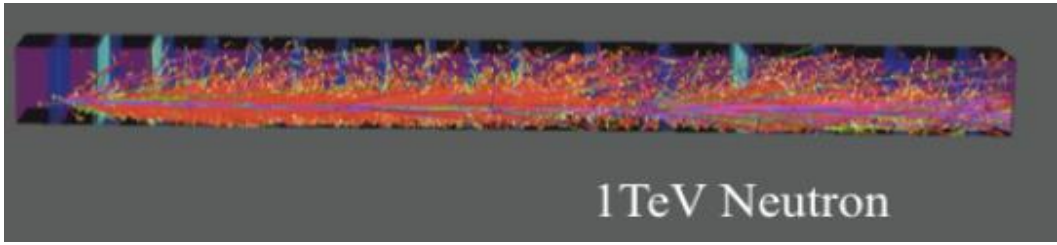


16 tungsten + pl.scinti. layers
25mmx25mm+32mmx32mm
4 Silicon strip tracking layers

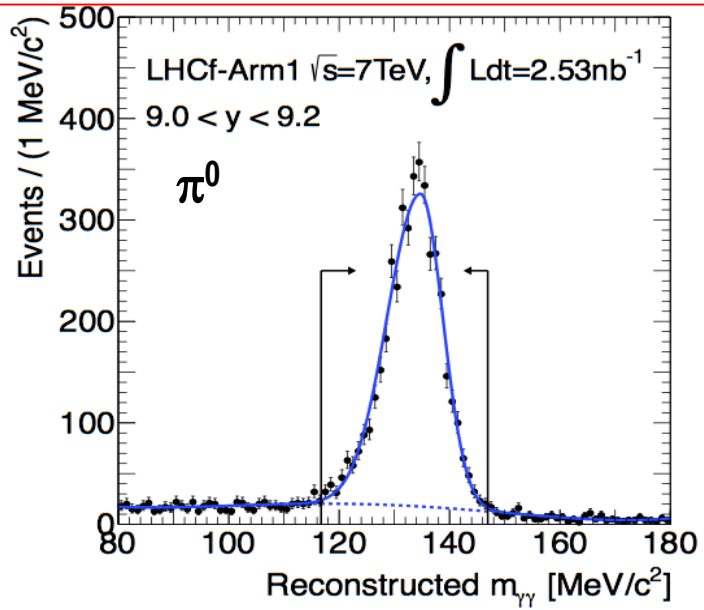
16 tungsten + pl.scinti. layers
20mmx20mm+40mmx40mm
4 SciFi tracking layers

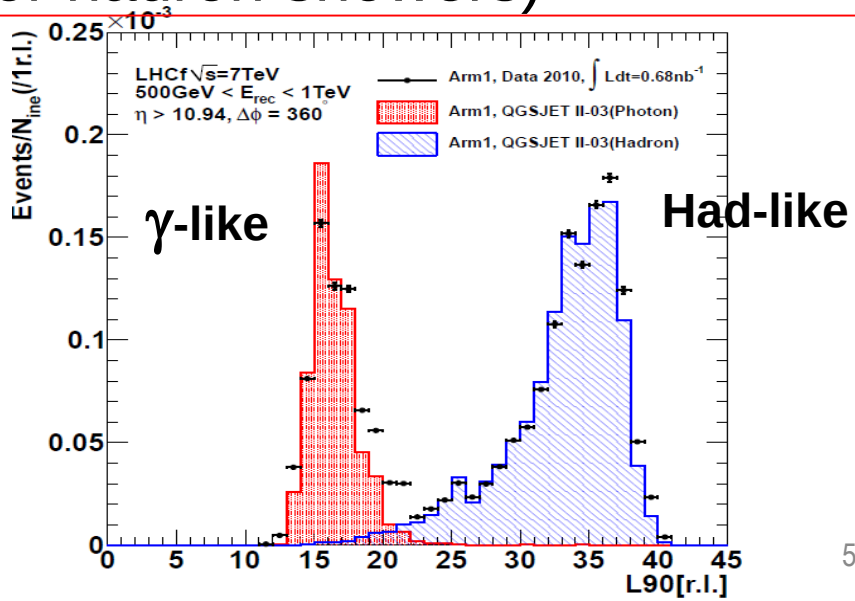
Calorimeter performance





- Gamma-rays (E>100GeV, dE/E<5%)
- Neutral Hadrons (E>a few 100 GeV, dE/E~40%)
- Neutral Pions (E>700GeV, dE/E<3%)
- Shower incident position (170μm / 40μm for γ, Arm1/Arm2)
- (1mm for hadron showers)





Brief history of LHCf

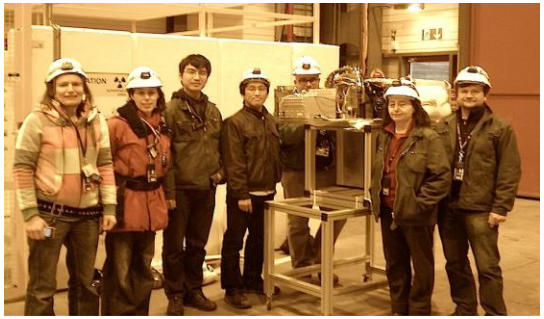
- May 2004 LOI
- Feb 2006 TDR
- June 2006 LHCC approved

Jul 2006
construction

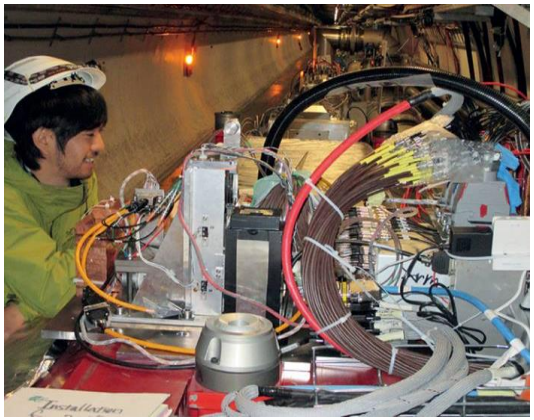
Aug 2007
SPS beam test

Jan 2008
Installation
Sep
1st LHC beam

Dec- Jul 2010
0.9TeV& 7TeV pp
Detector removal



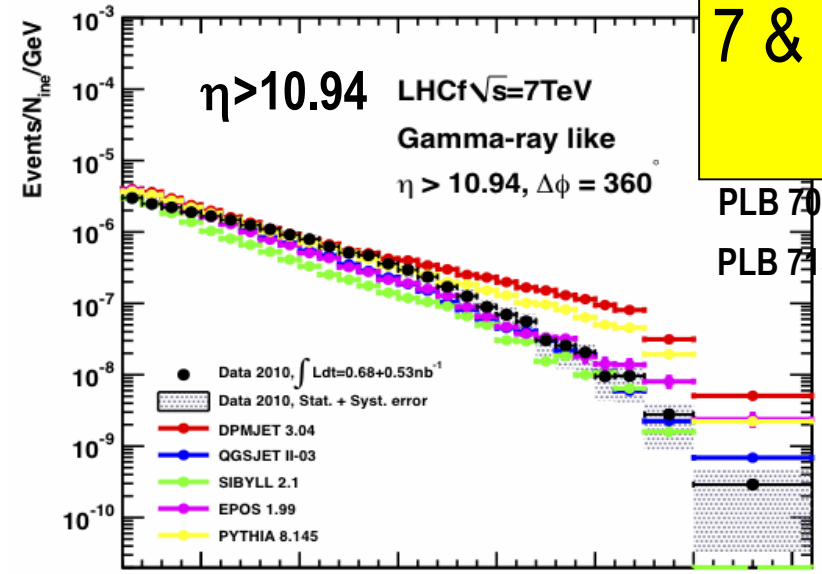
Dec2012- Feb 2013
5TeV/n pPb, 2.76TeVpp
(Arm2 only)
Detector removal



May-June 2015
13 TeVpp
Detector removal

Yltow "Status of LHCf"

7 & 0.9 TeV pp photon

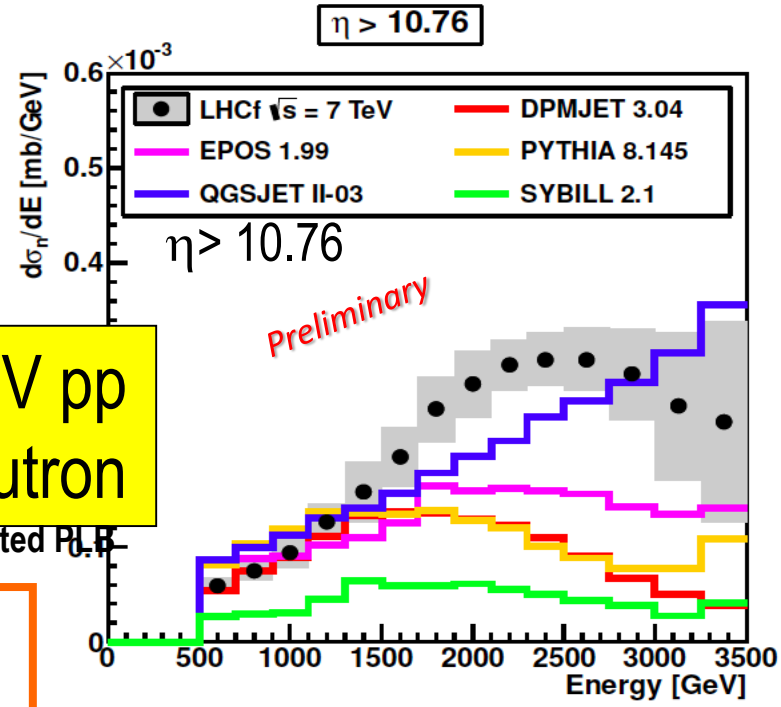


PLB 703 (2011) 128-134

PLB 715 (2012) 298-303

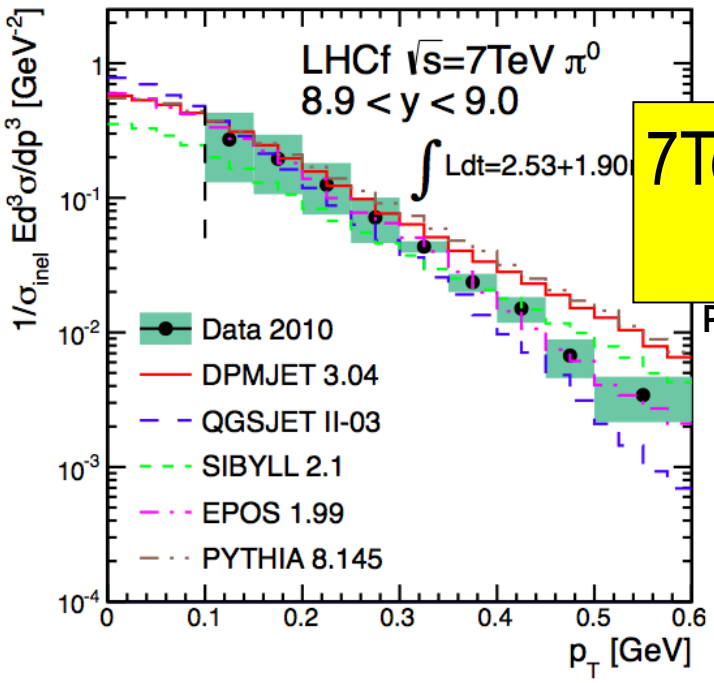
7TeV pp neutron

Submitted PLB



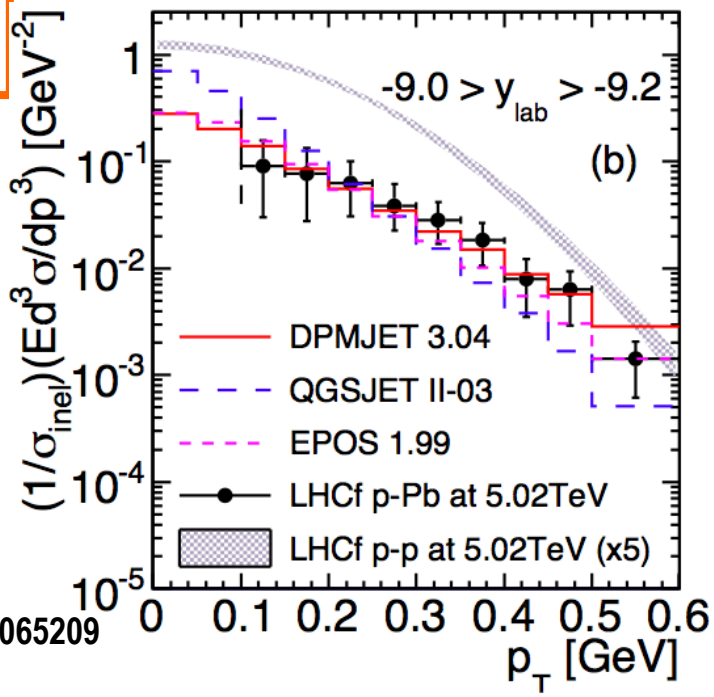
LHCf published results

7TeV pp π^0



PRD 86 (2012) 092001

5TeVn pPb π^0



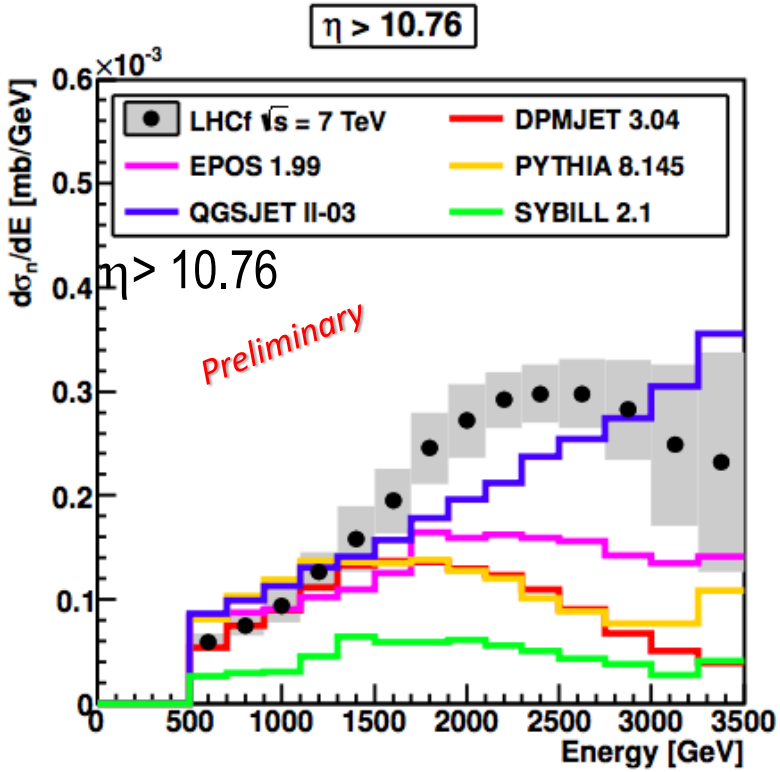
PRC 89 (2014) 065209

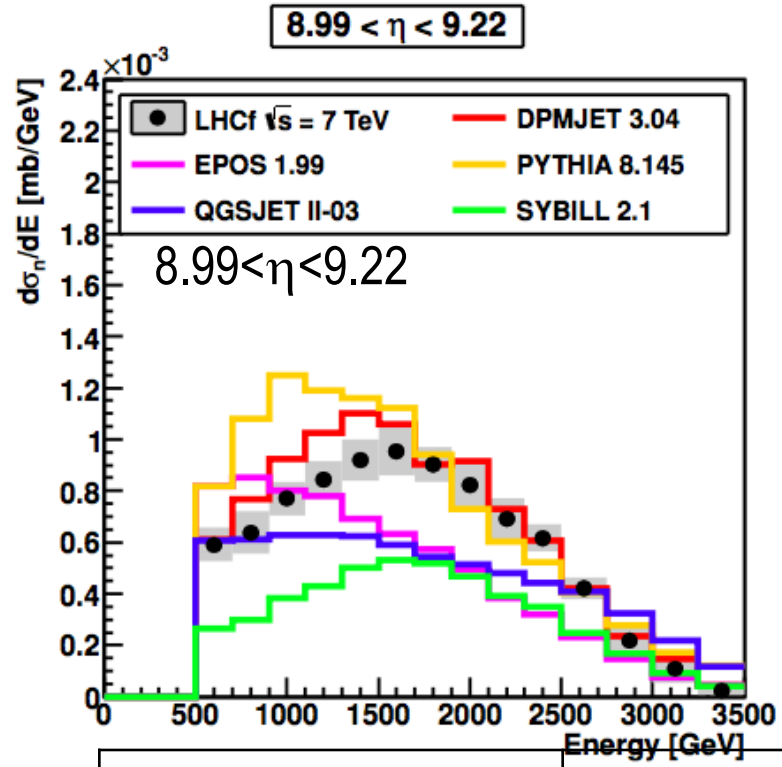
Very forward neutron at 7TeV p-p

Submitted to PLB

- η>10.76 : QGSJET03 good, 8.99>η>9.22 DPMJET3 good
- Larger neutron / gamma ratio than expected

40% E res. unfolded





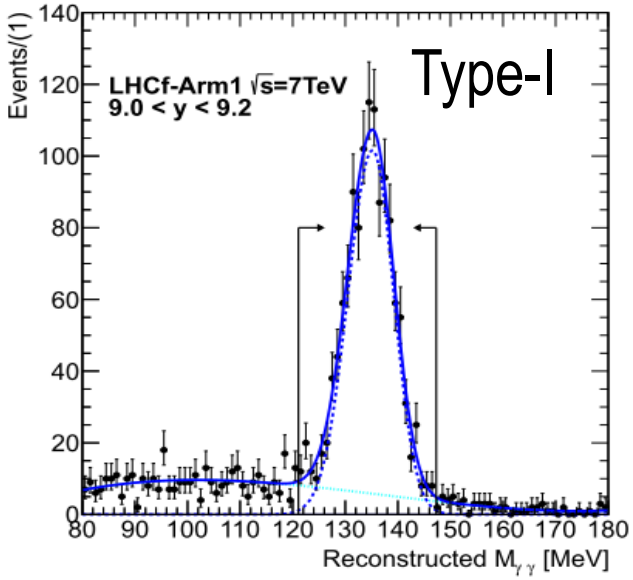
n / γ ratio

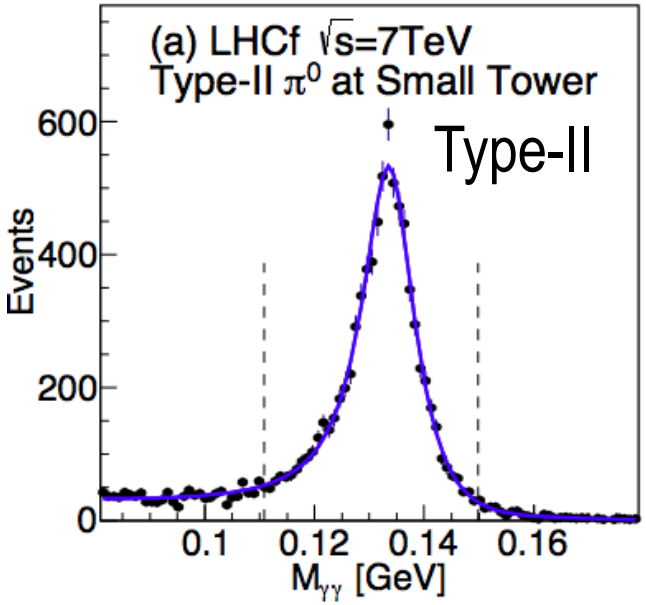
Data	3.05±0.19
DPMJET3.04	1.05
EPOS 1.99	1.80
PYTHIA 8.145	1.27
QGSJET II-03	2.34
SYBILL 2.1	0.88

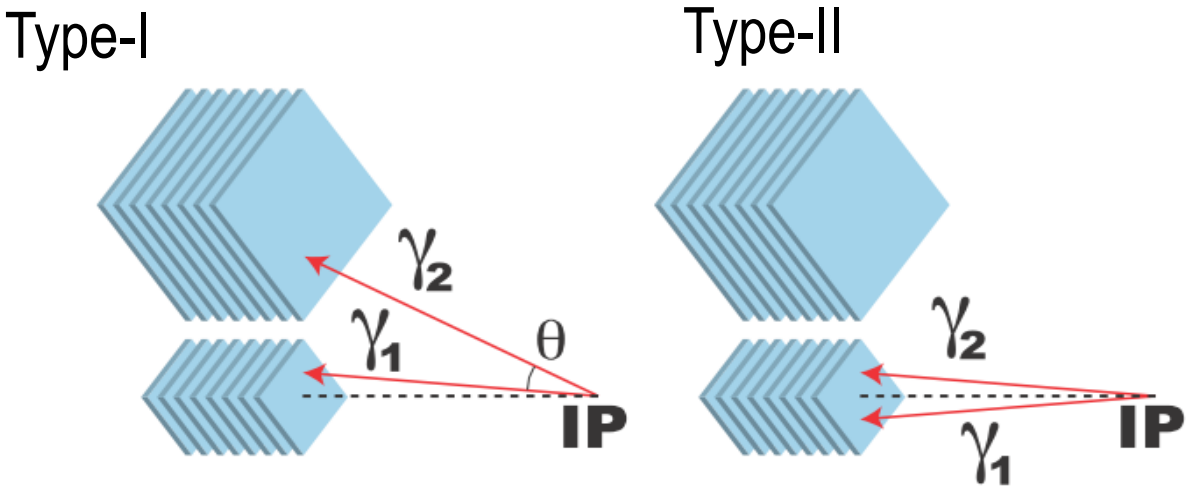
n / γ ratio

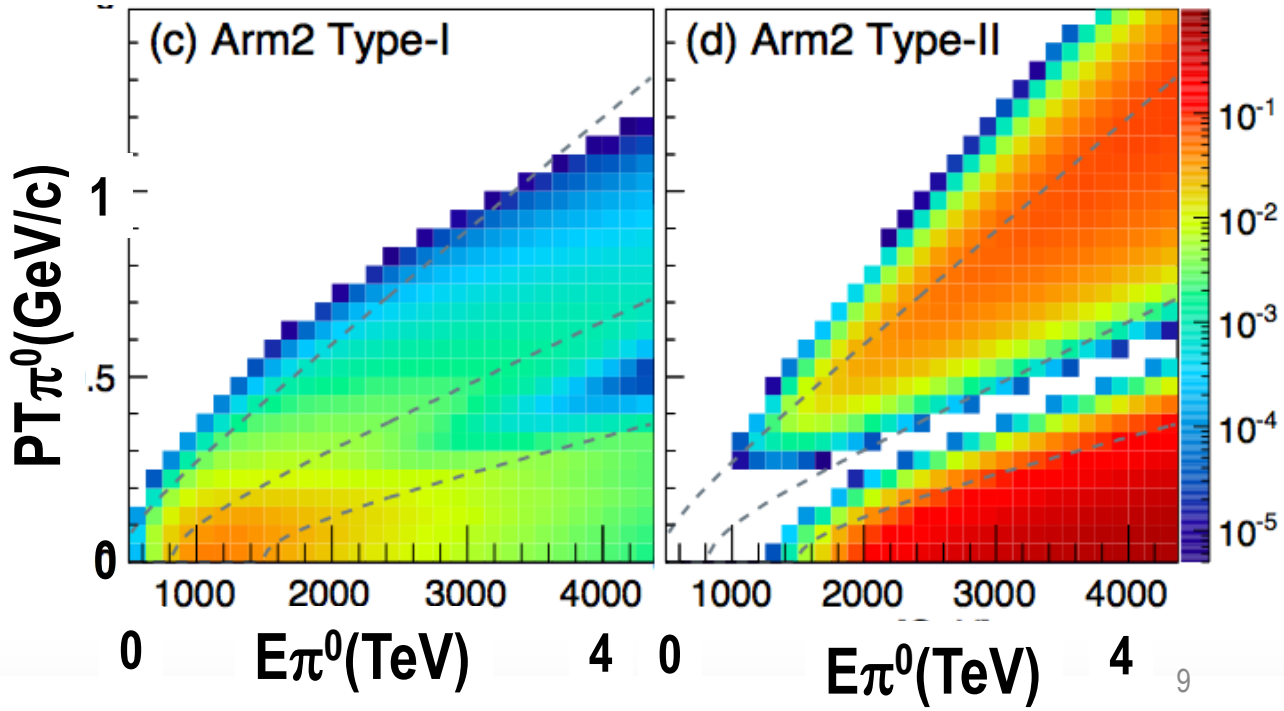
Data	1.26±0.08
DPMJET3.04	0.76
EPOS 1.99	0.69
PYTHIA 8.145	0.82
QGSJET II-03	0.65
SYBILL 2.1	0.57

LHCf Type-I and Type-II π^0 analysis



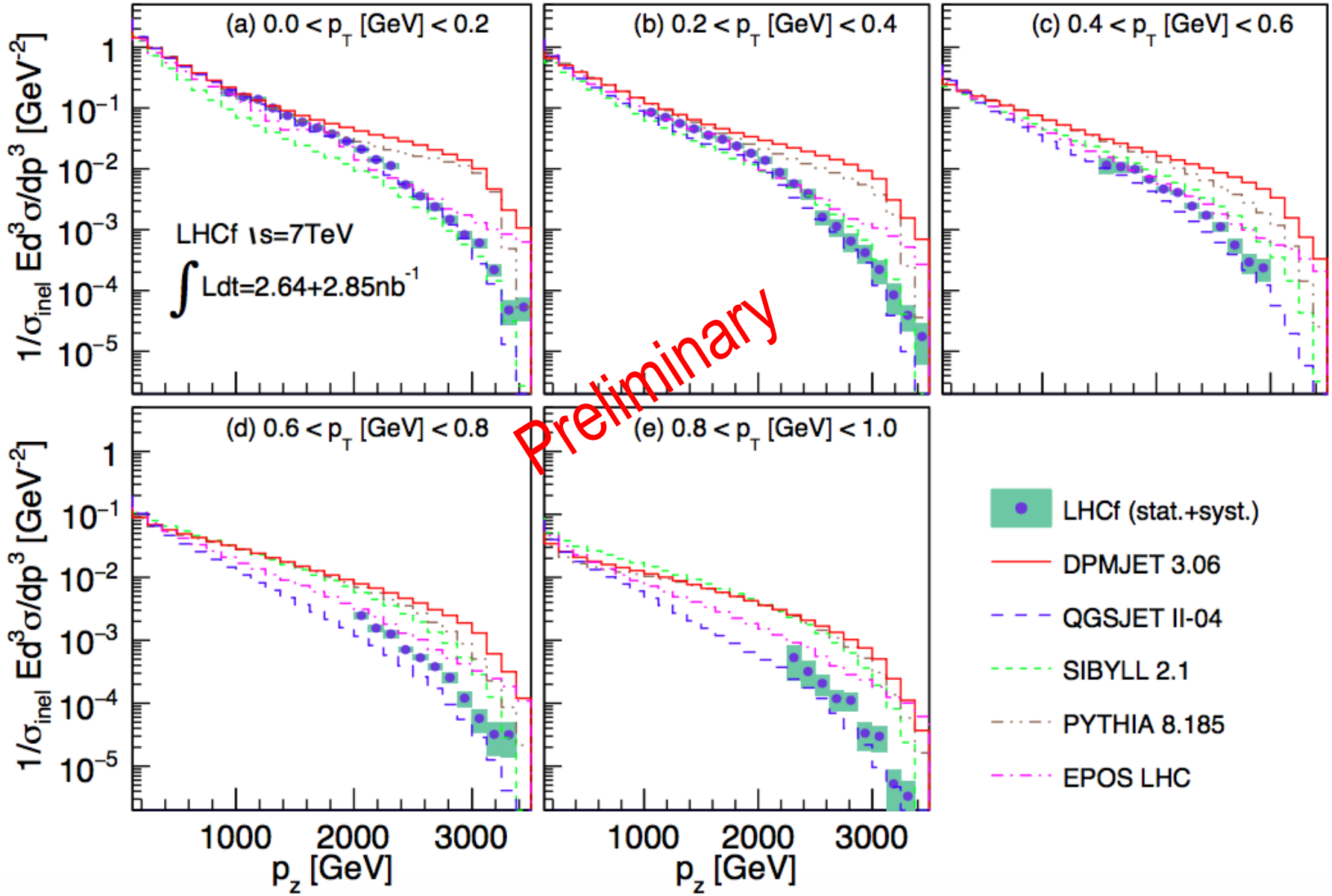






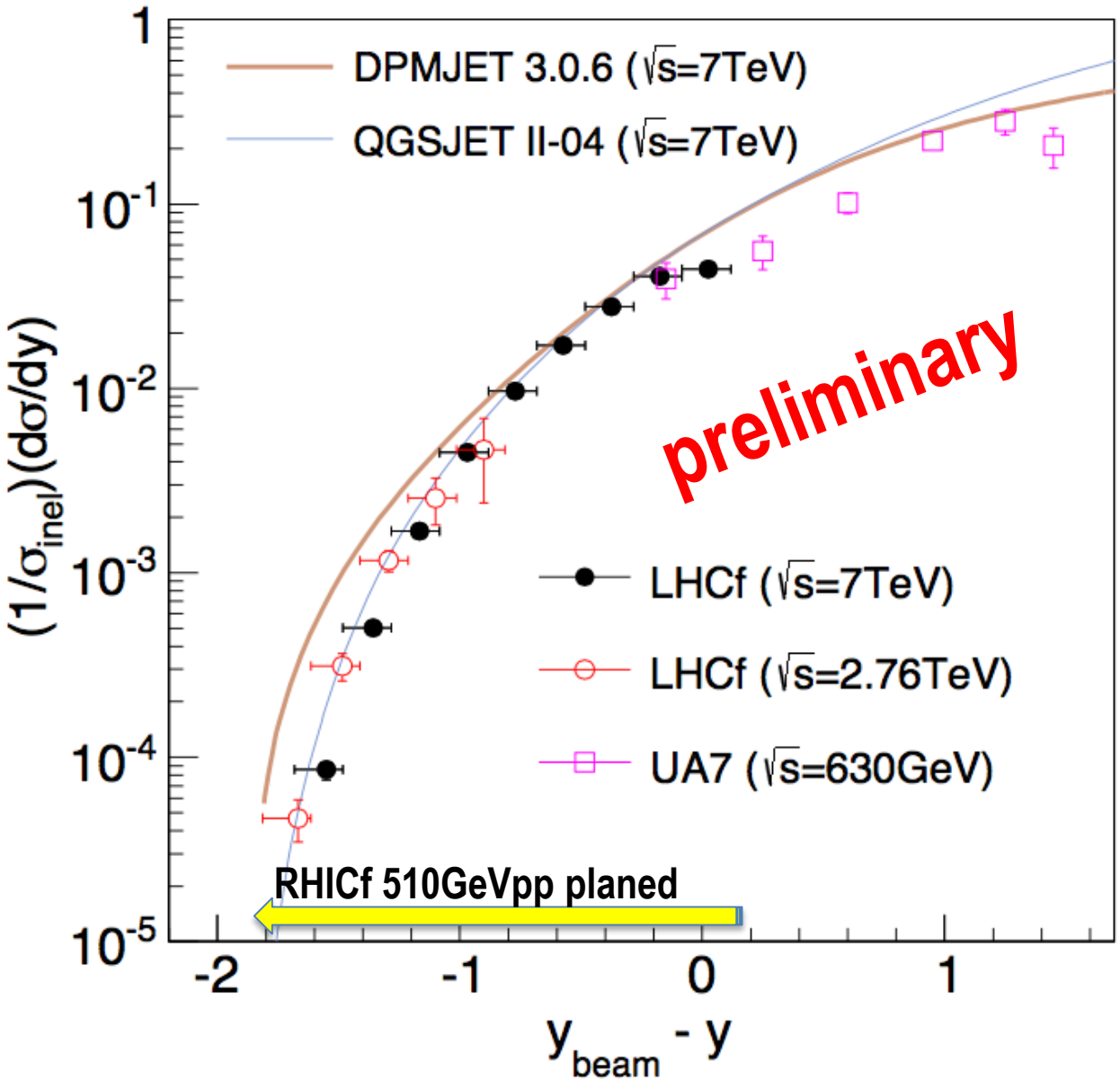
P_z spectra Type-I + Type-II π^0

To be submitted PRD



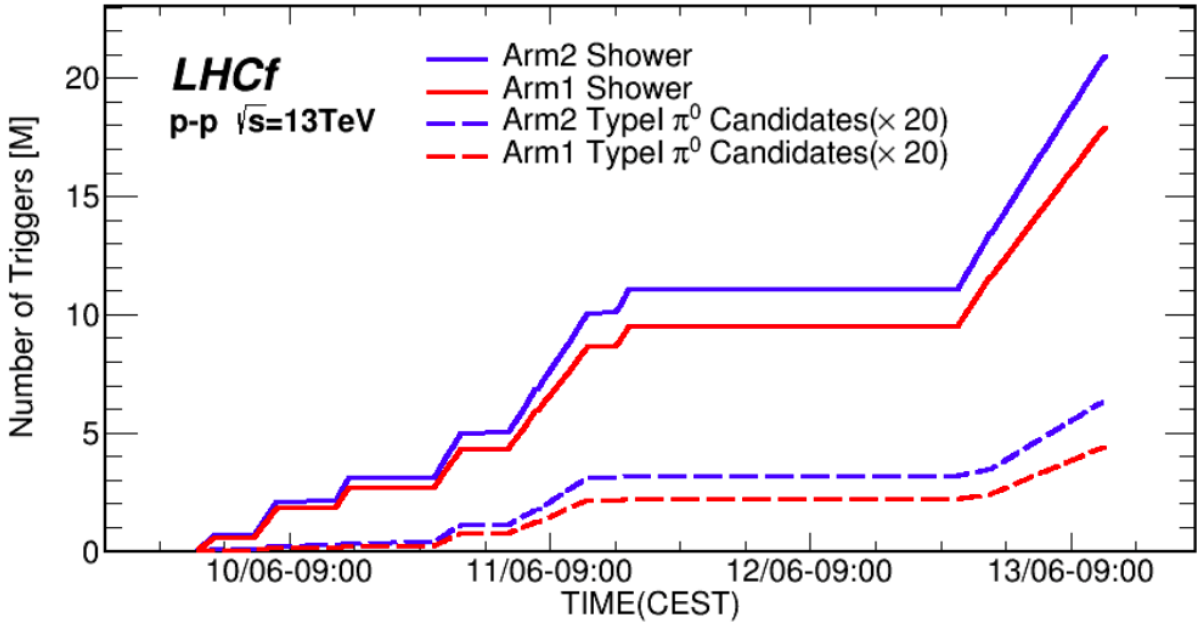
LHCf π^0 yields vs collision energies

To be submitted PRD

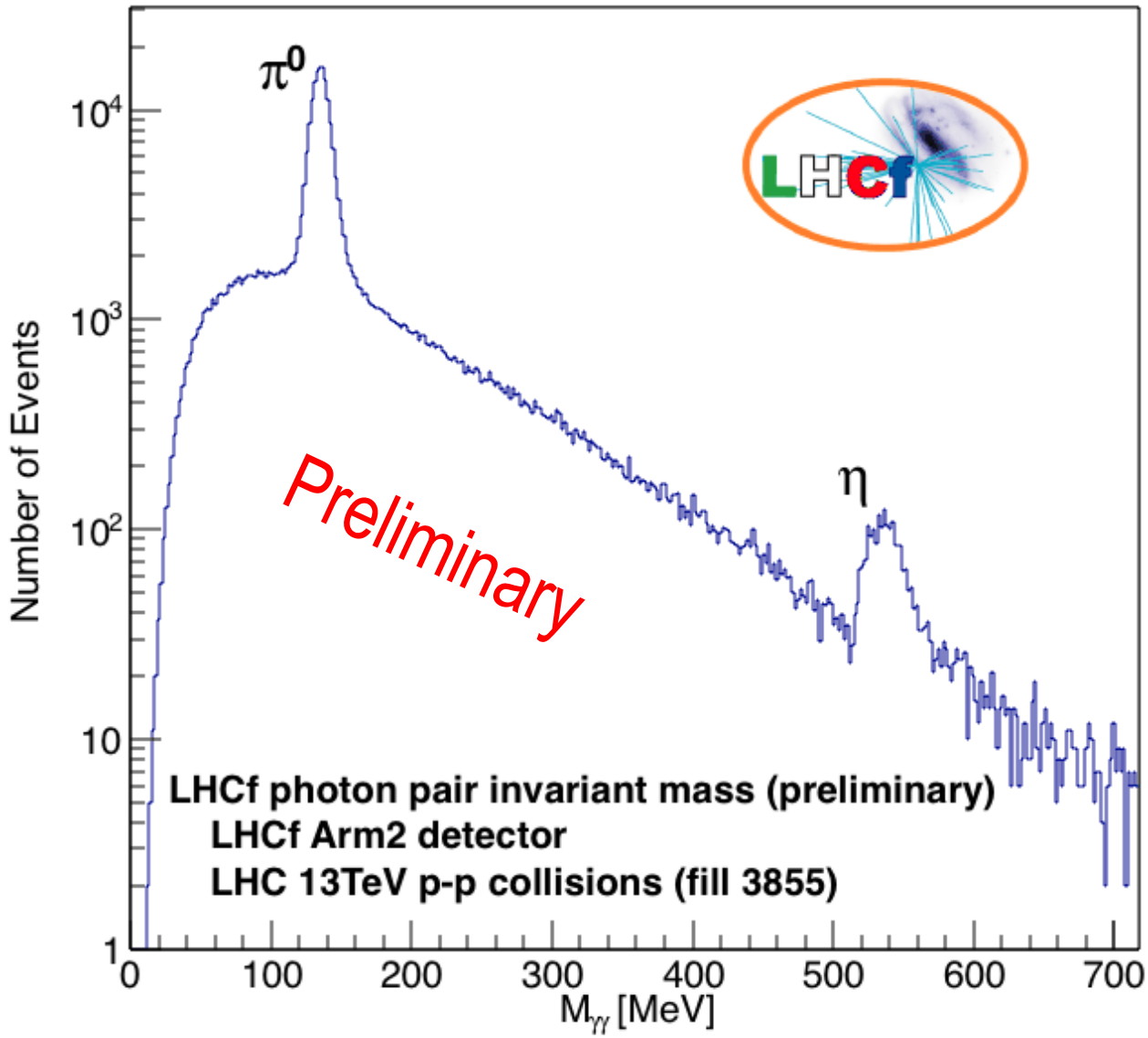


LHC 13TeV LHCf run 2015

- Week24, Jun 9~13, LHCf dedicated low-lumi run
- Total 26.6 hrs w/ L=0.5~1.6e29 cm^2s^{-1}
- ~39 M showers, 0.5 M π^0 obtained
- Trigger exchange with ATLAS
- Detector removal on Jun 15th during TS1

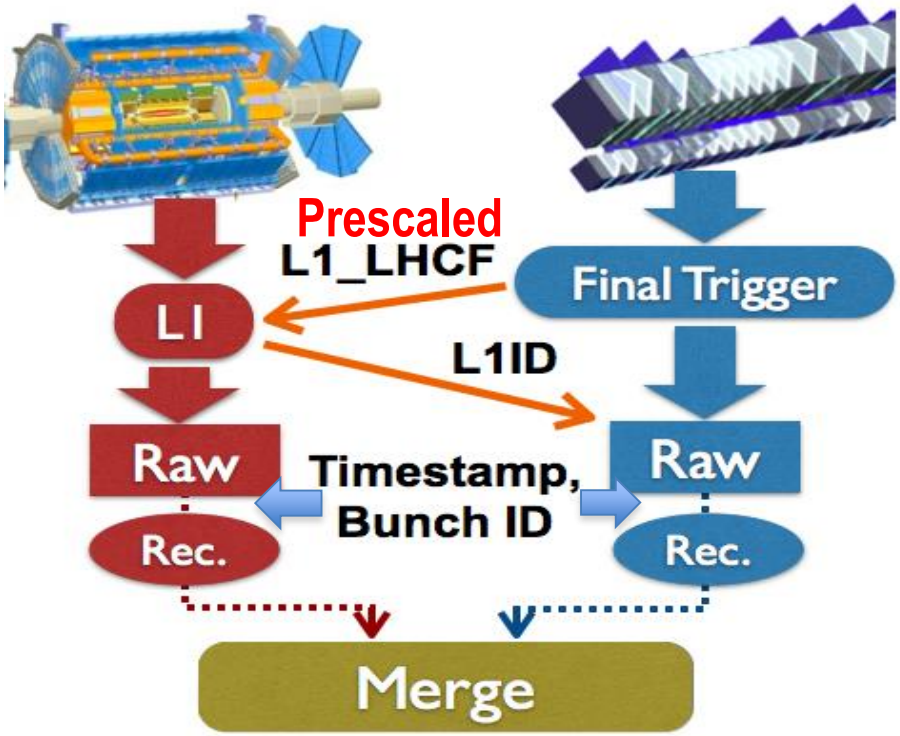


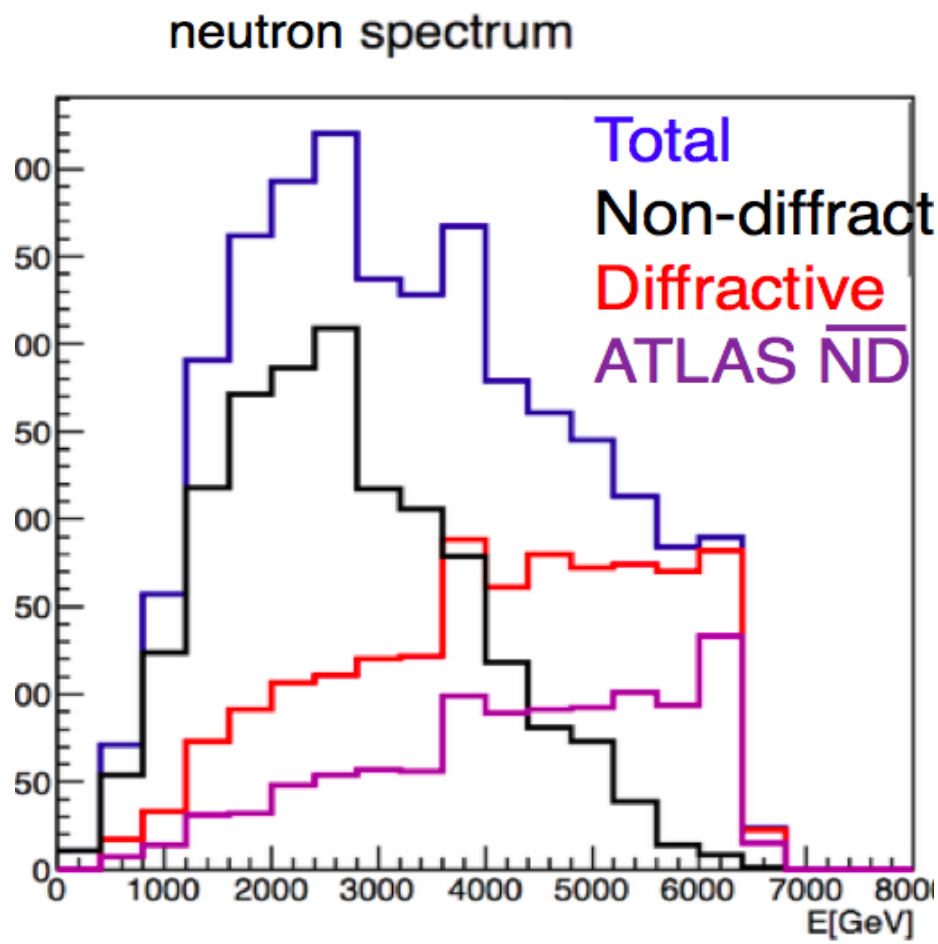
First look from 13 TeV data



ATLAS-LHCf trigger exchange

- Non-diffraction tagging by N_{trk}>=2 in ALTAS |η|<2 (P_T>100 MeV/c)
- Diffraction : 10 % of LHCf data



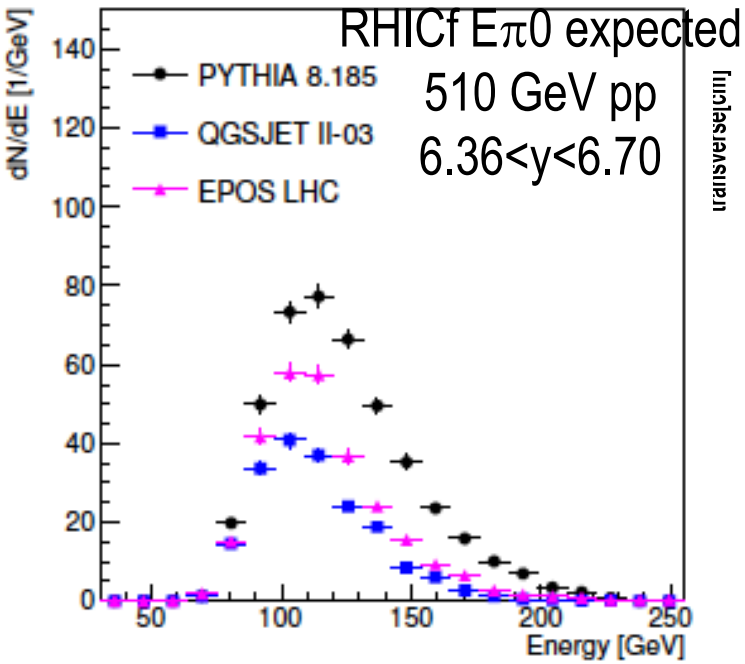


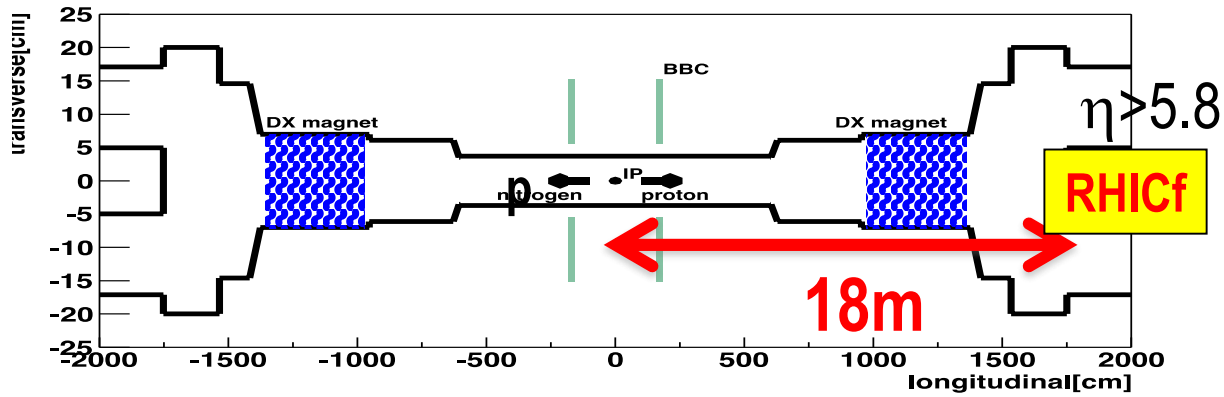
Hadron(neutron)

MC by PYHITA

Future prospects

- RHICf (LHCf detector at RHIC zero degree)
  - Participate Run-17 510 GeV pp at the STAR site
  - Comparison to 7&13TeV data with same p_T coverage





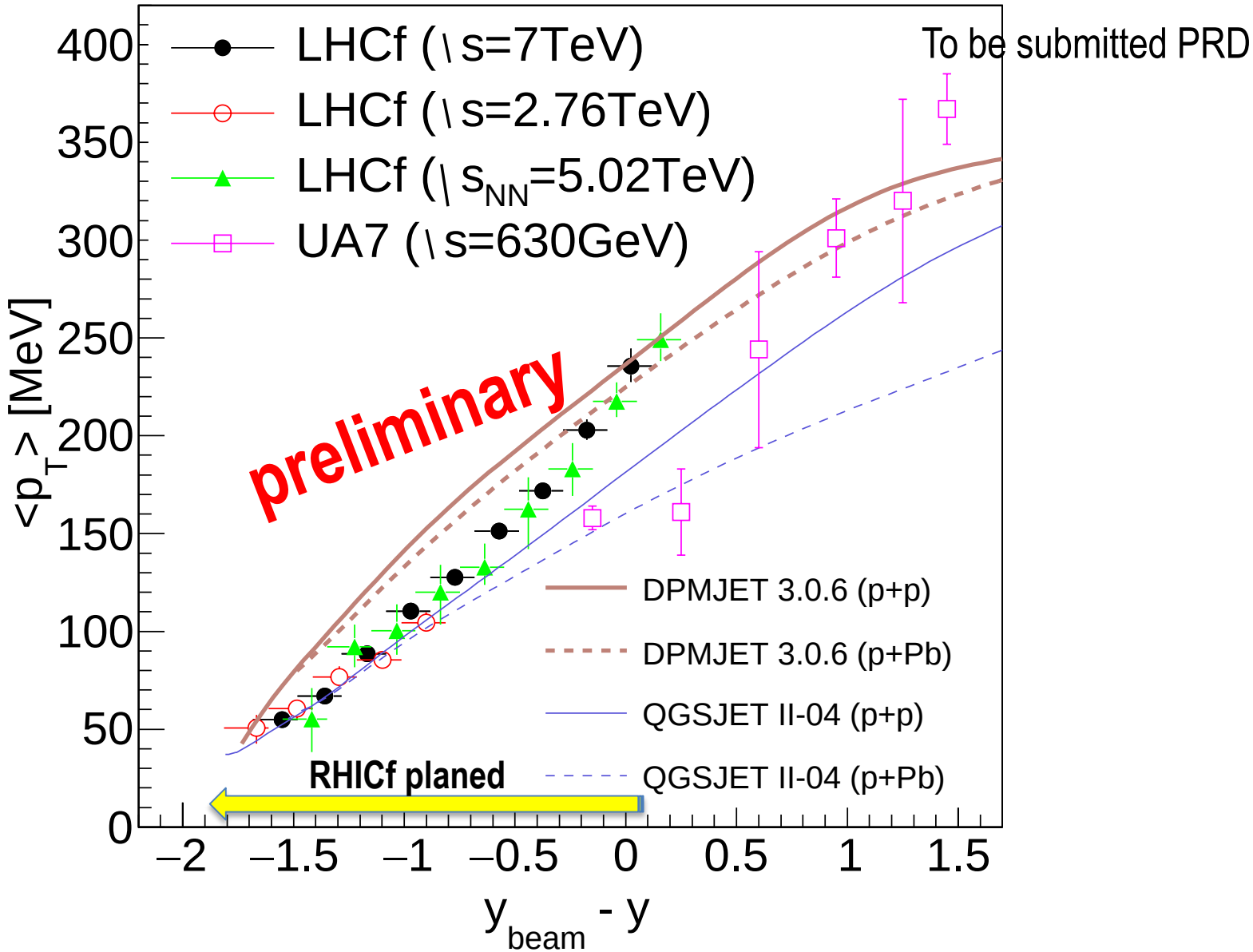
- And also LHC p-Pb run, and future LHC p-Oxygen …

Summary

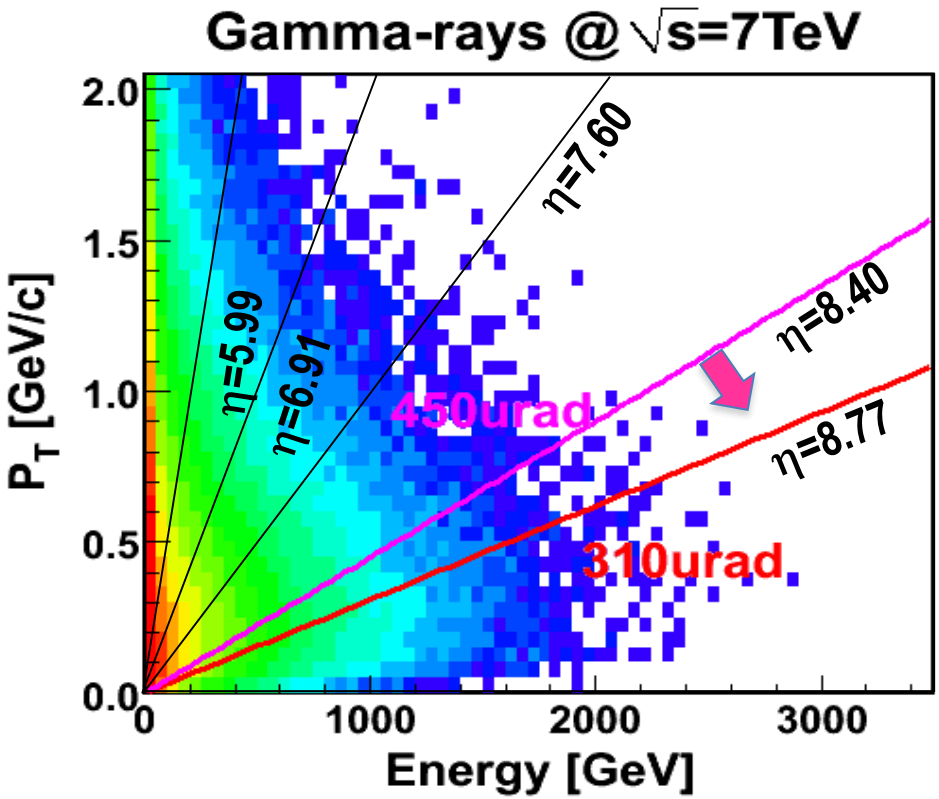
- The LHCf : particles spectra at very forward of LHC
  - $\eta > 8.4$, with nice performance for PID, EM energy and PT
  - So far γ, π^0 ,n from 0.9, 2.76 and 7 TeV p-p, and π^0 5TeV p-Pb
- Energy spectra for very forward neutron
  - Bump at large X_F, data shows more neutron yield than models
- New π^0 analysis
  - Add Type-II π^0, complete acceptance coverage
  - Comparison of 7 TeV and 2.76 TeV p-p
- LHC 13 TeV pp and Future
  - 13 TeV run successfully done in Jun 2015, analysis on-going
  - RHICf 510 GeV pp in 2017, LHC p-Pb, and more

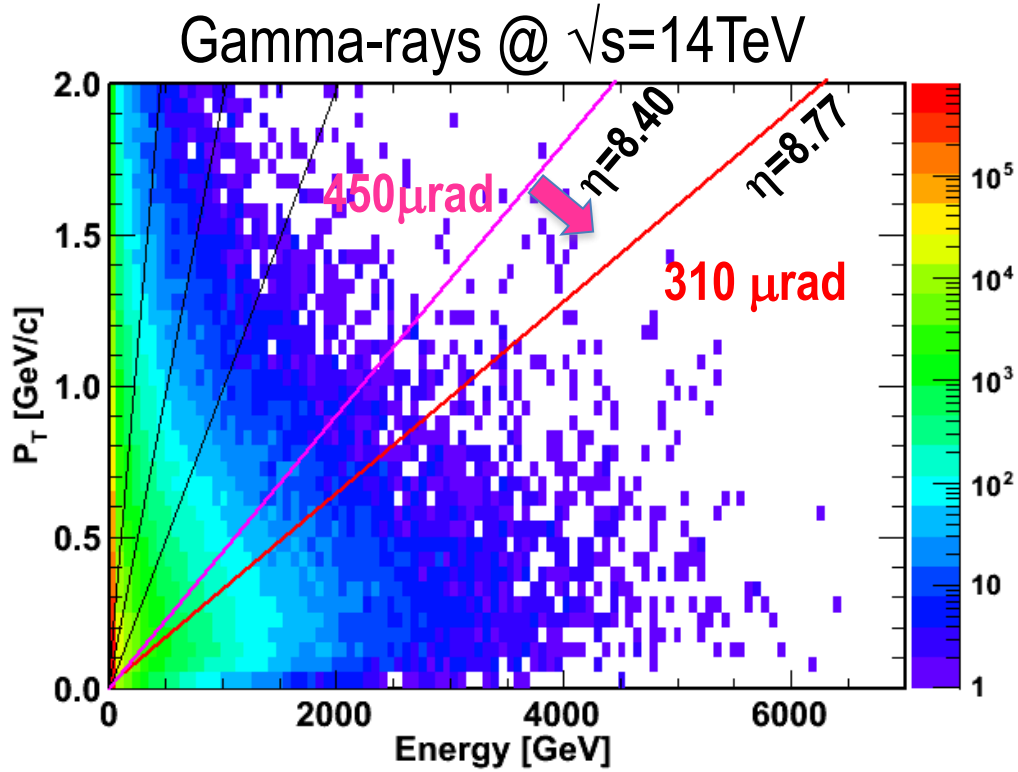
Backup

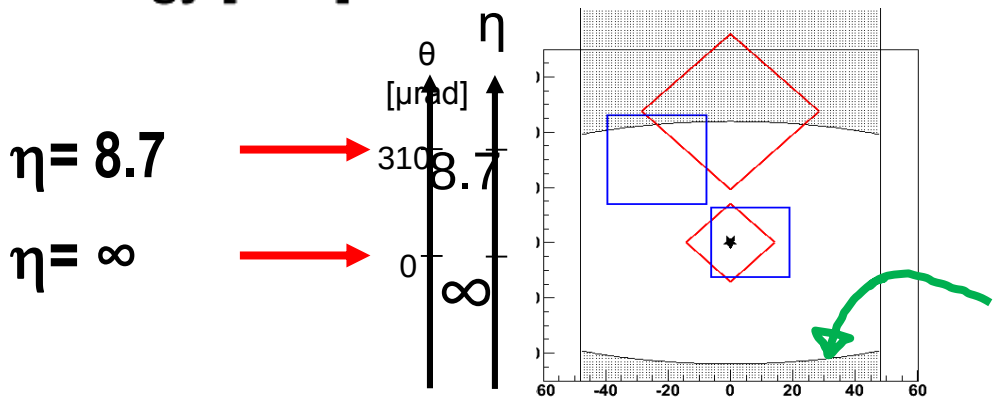
LHCf average P_T of Type-I + Type-II π^0



Rapidity vs Forward energy spectra



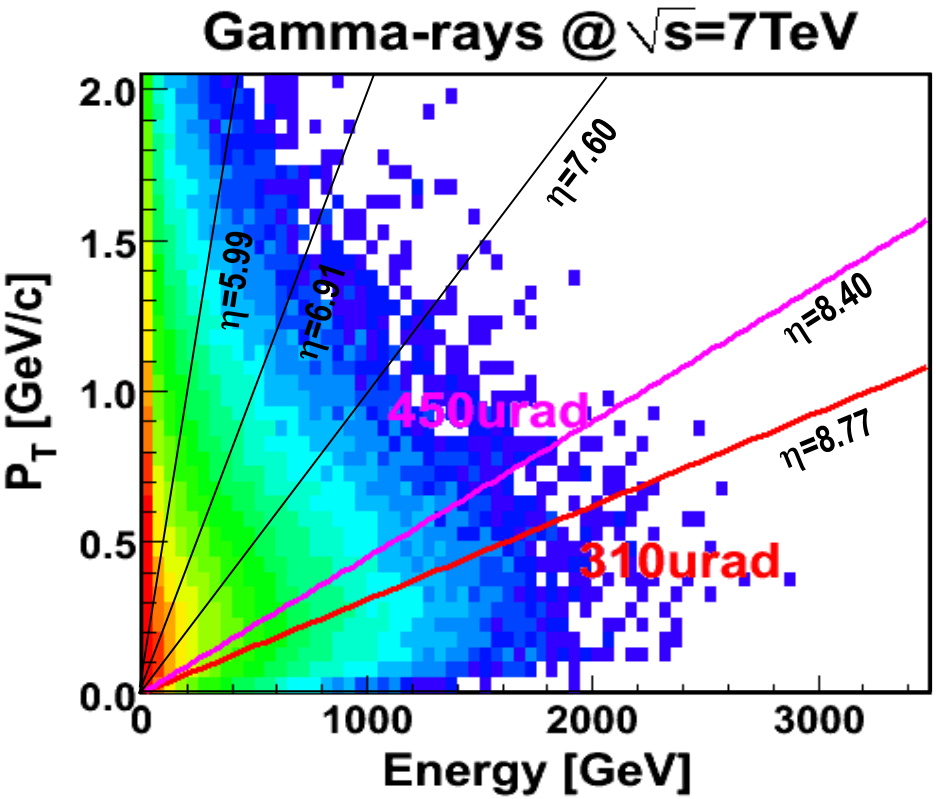


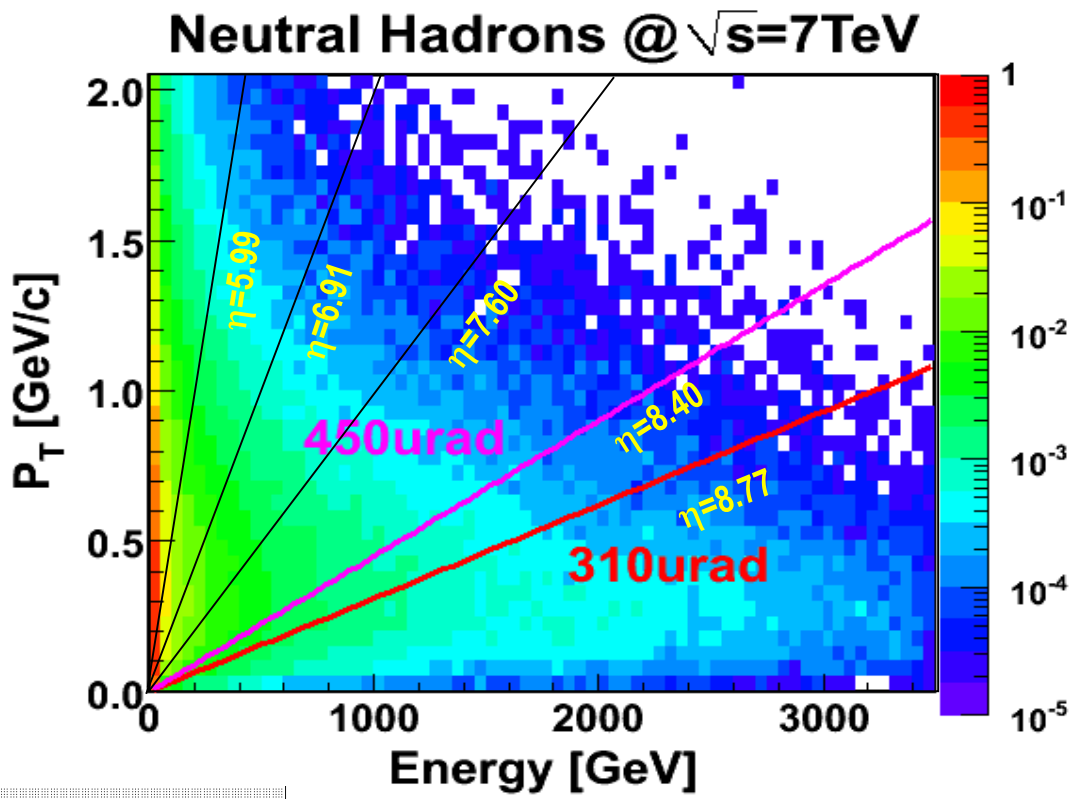


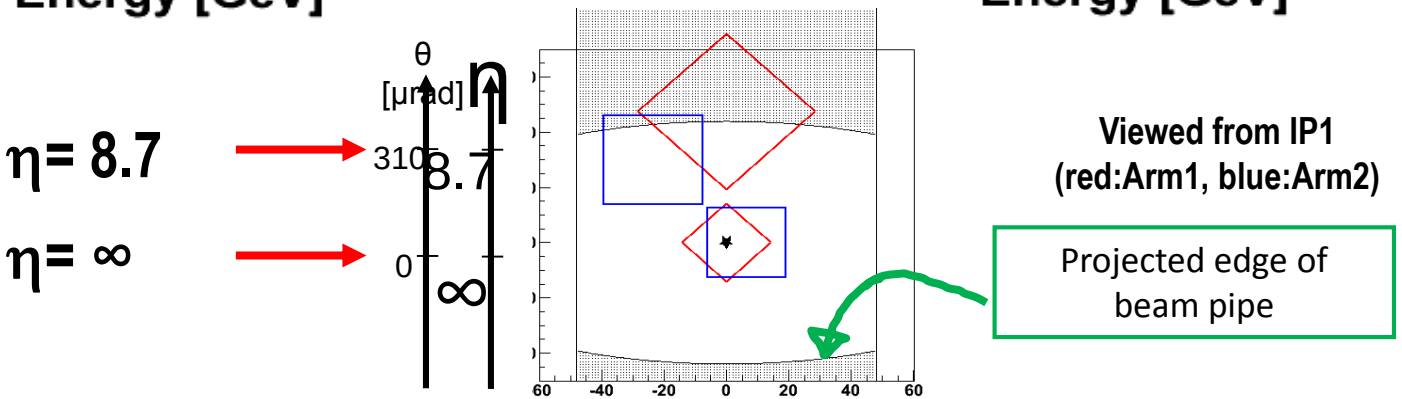
Viewed from IP1 (red:Arm1, blue:Arm2)

Projected edge of beam pipe

Rapidity vs Forward energy spectra



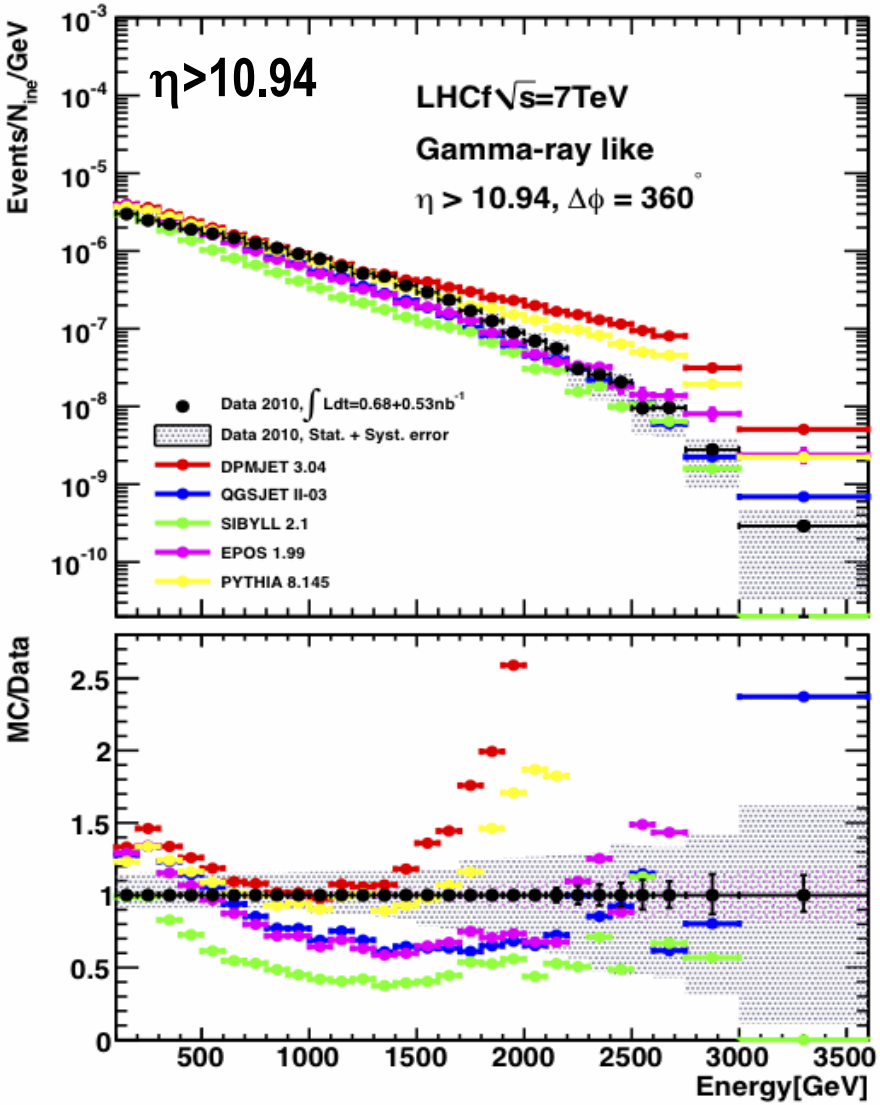


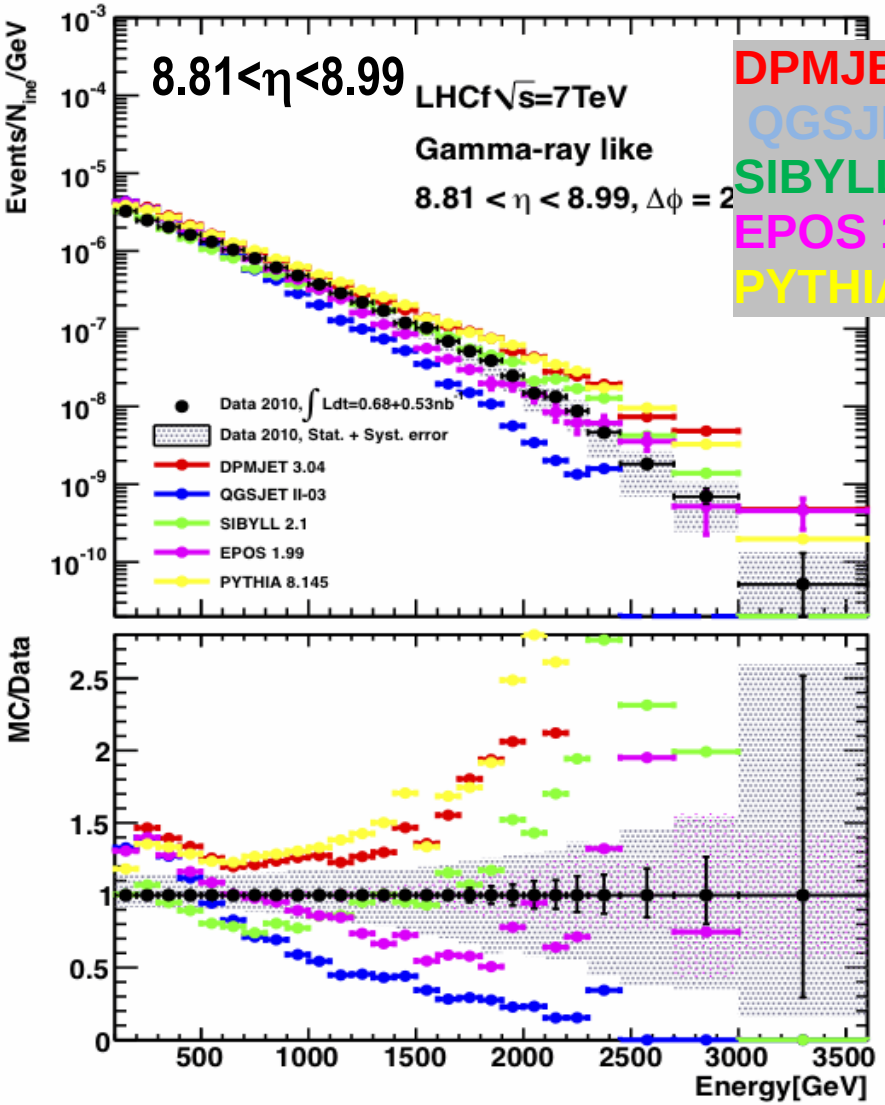


LHCf single γ spectra at 7TeV

PLB 703 (2011) 128-134
0.68 (0.53)nb^{-1} on 15May2010

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

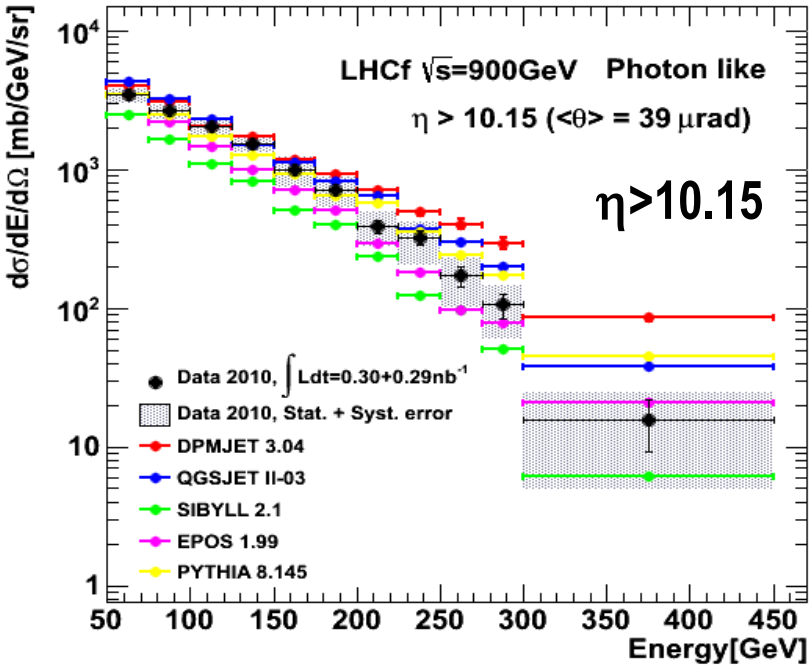


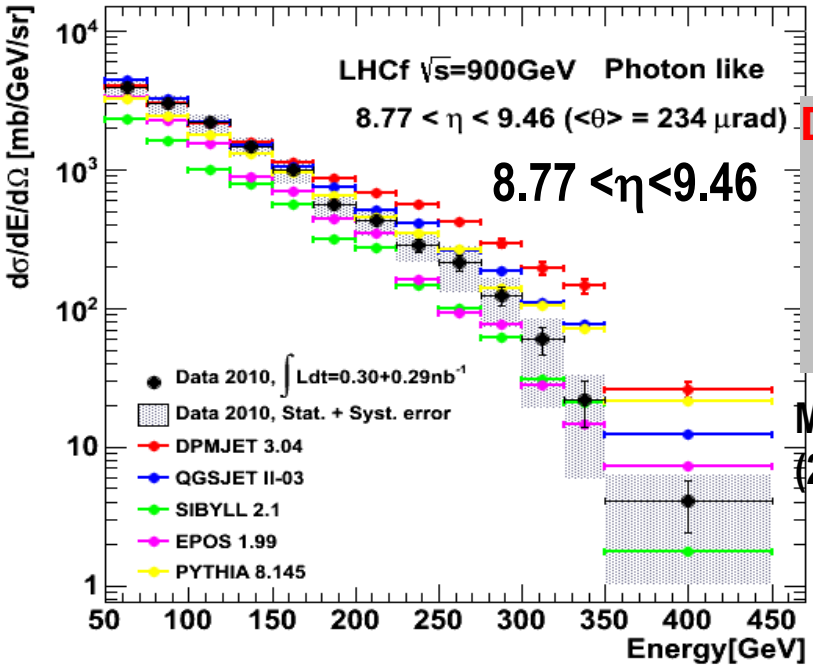


DPMJET 3.04
QGSJETII-03
SIBYLL 2.1
EPOS 1.99
PYTHIA 8.145

LHCf single γ spectra at 900 GeV

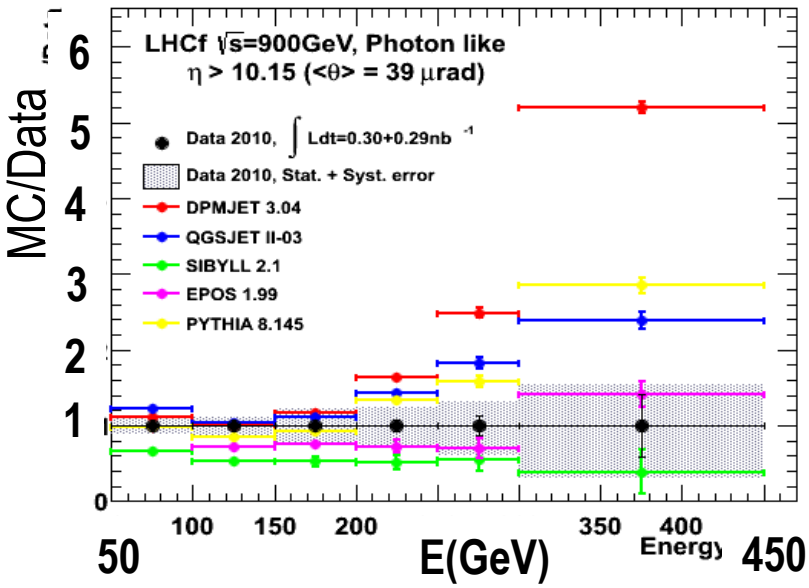
PLB 715 (2012) 298-303

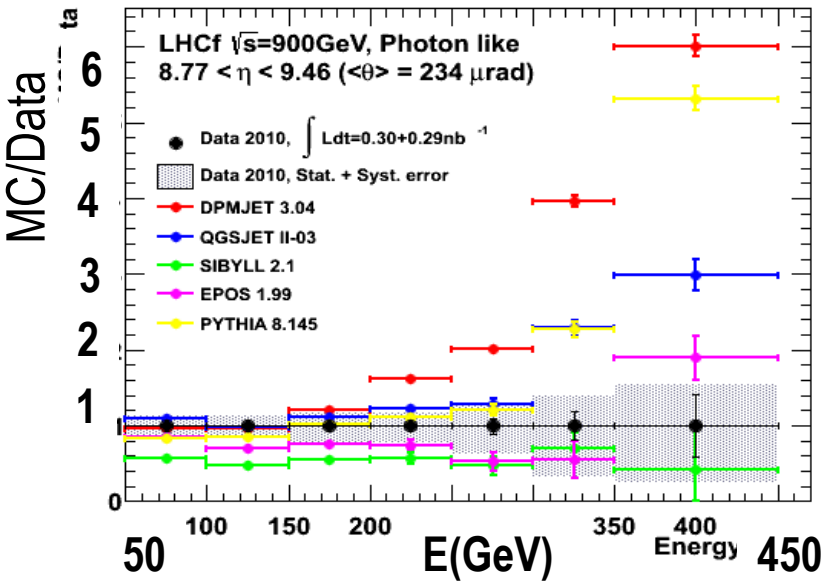




DPMJET 3.04
QGSJETII-03
SIBYLL 2.1
EPOS 1.99
PYTHIA 8.145

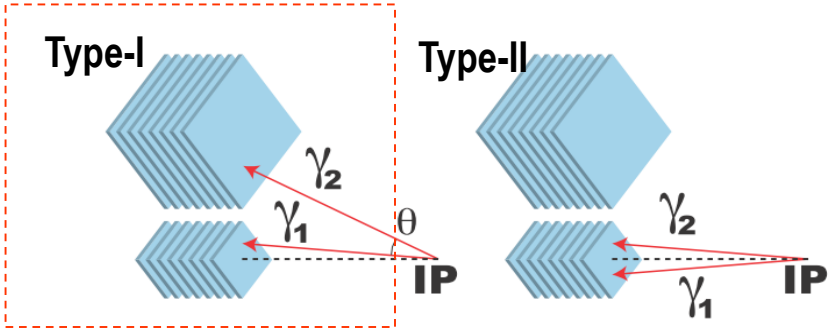
May2010, 0.3nb-1
(21% normalization uncertainty)

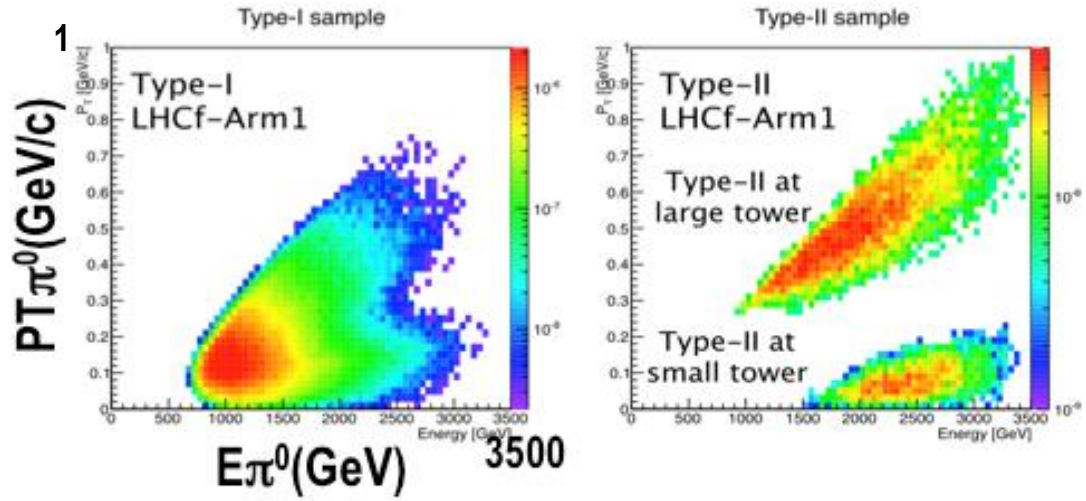


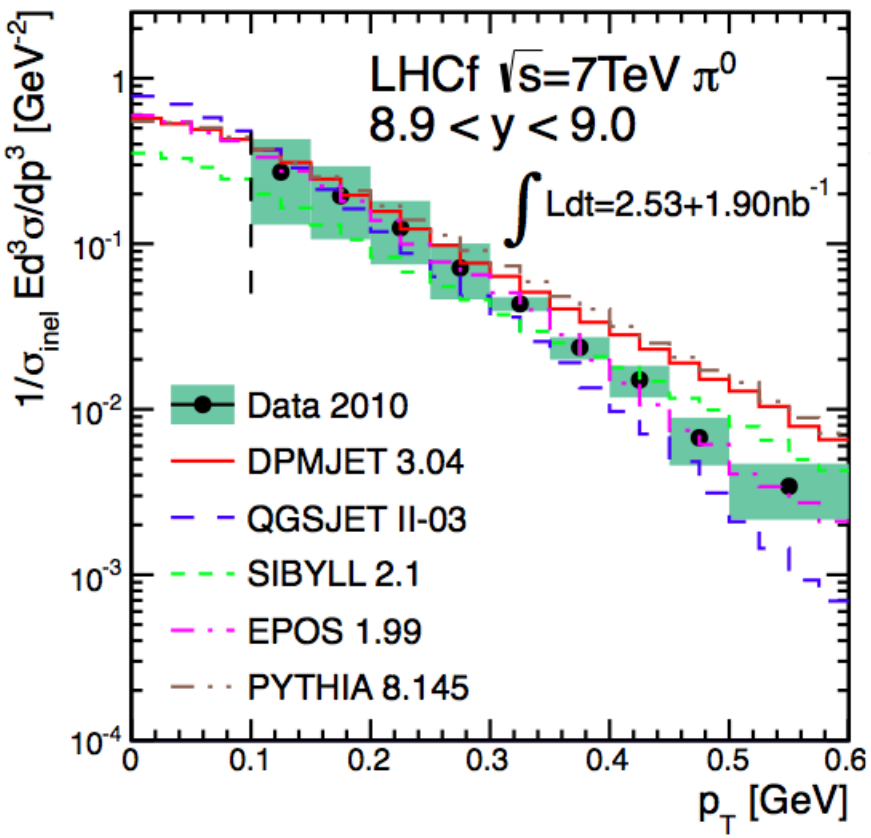


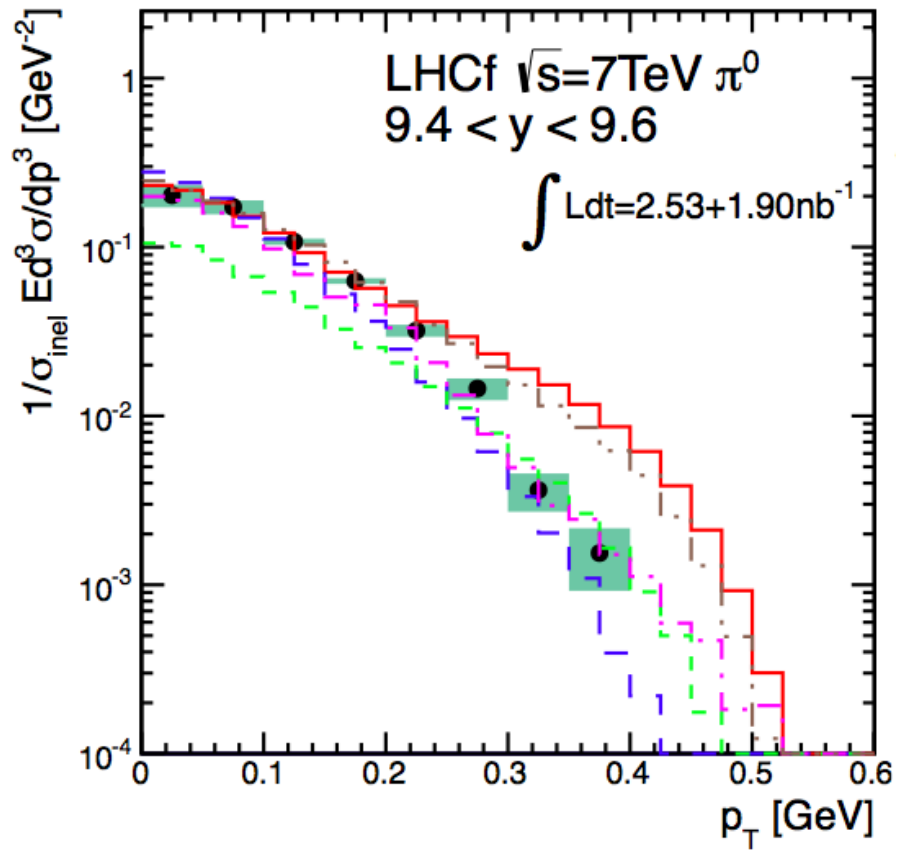
LHCf π^0 P_T spectra at 7TeV

PRD 86 (2012) 092001







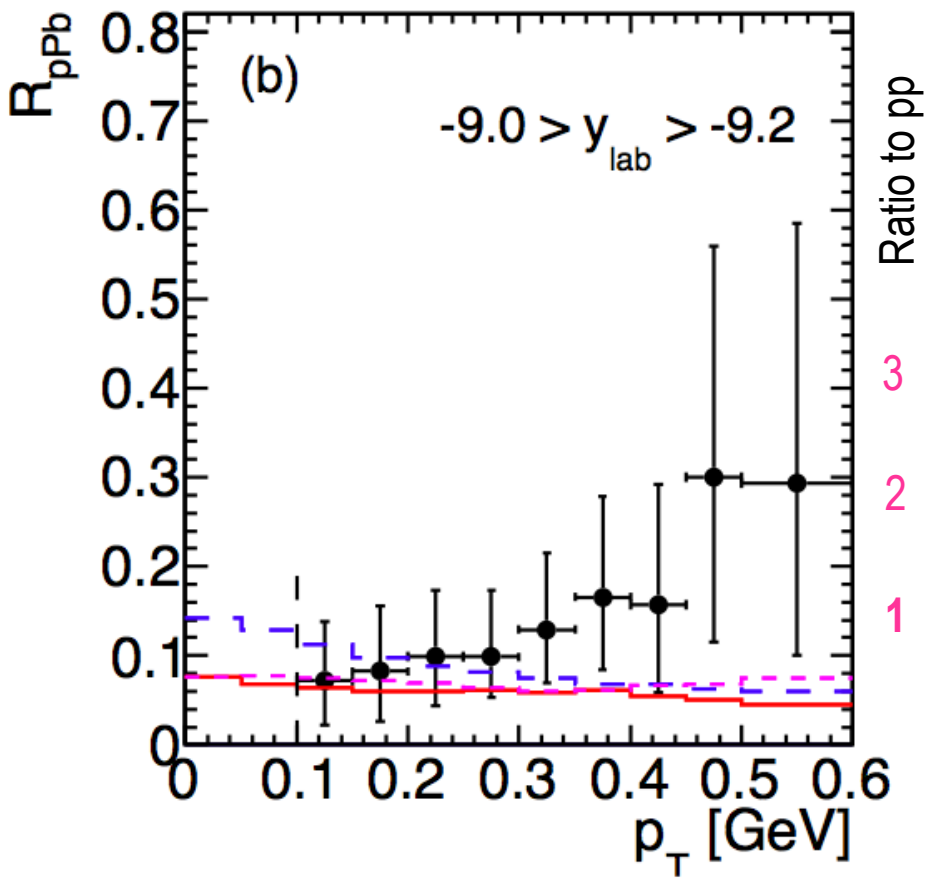


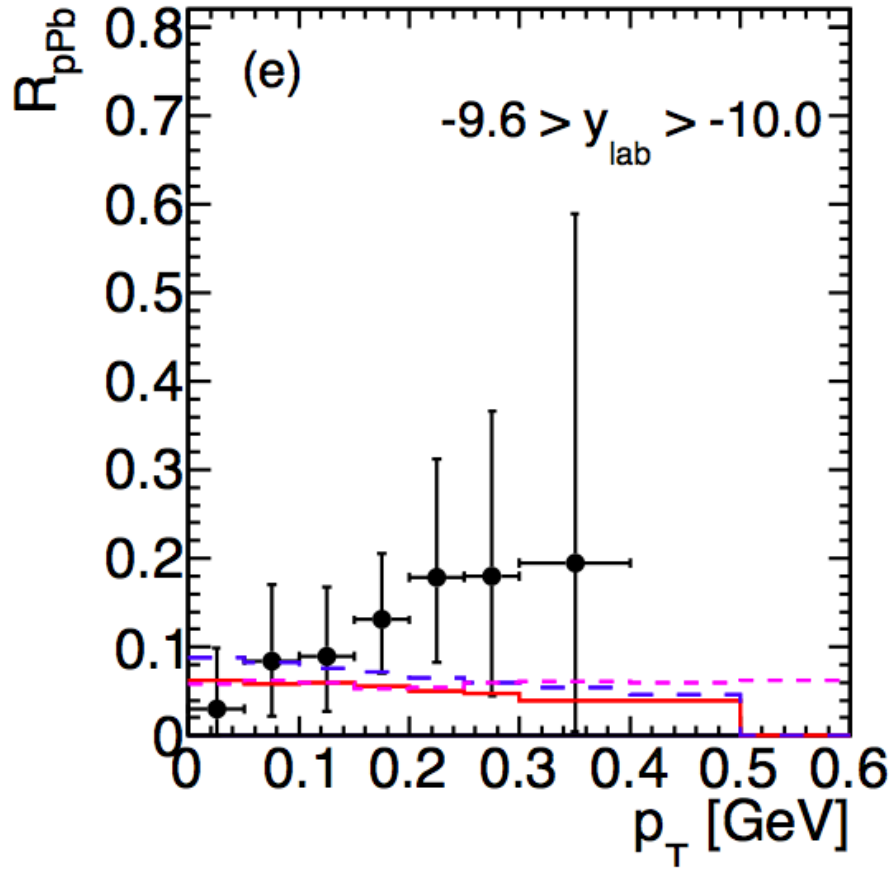
LHCf nuclear modification factor (-11.0>η > -8.9)

- Very large suppression (~ 0.1) at P_T ~ 100MeV region
- Models also show similar large suppression, but PT dependence ?

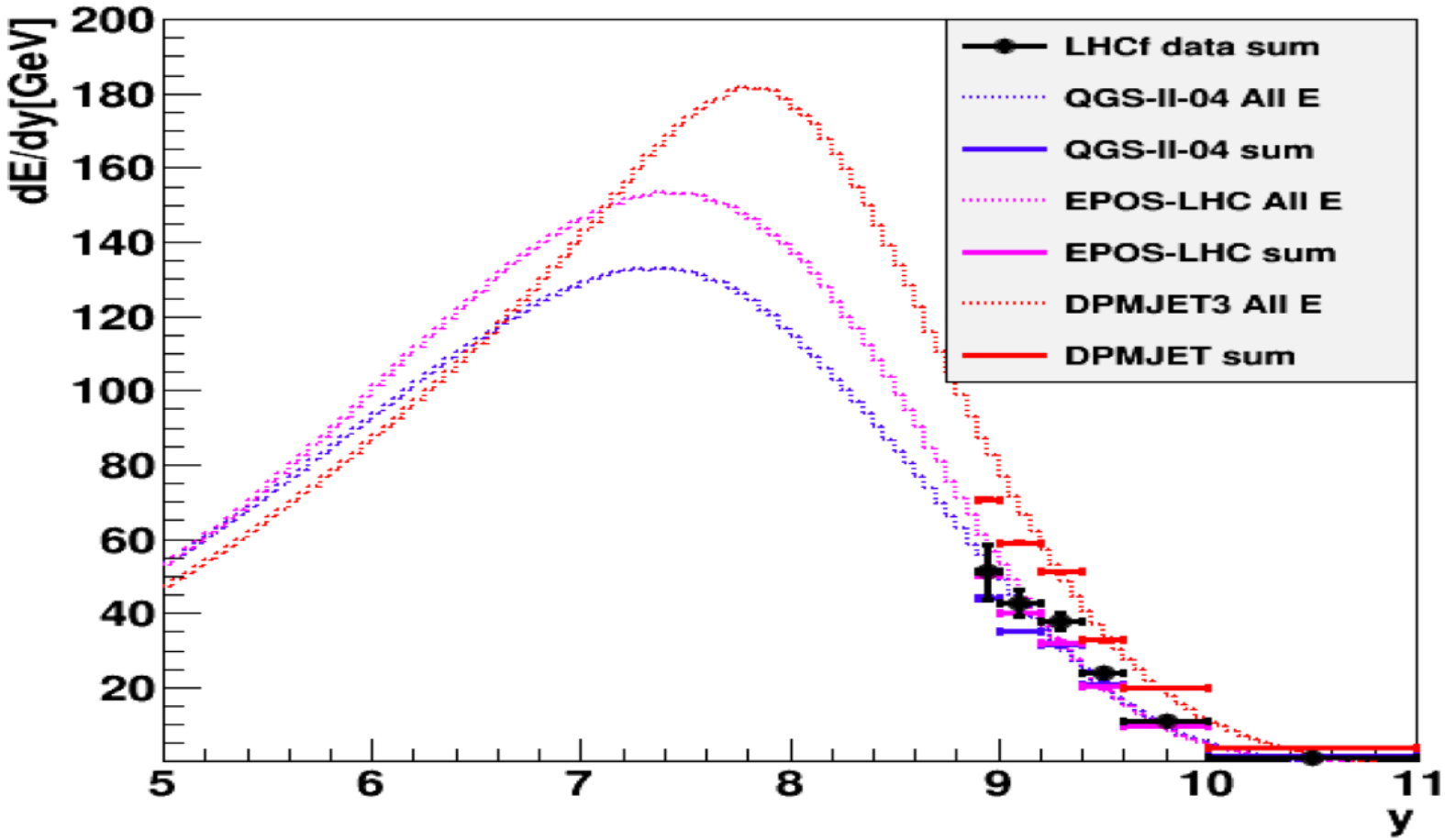
$$R_{\mathrm{pPb}} \equiv \frac{\sigma_{\mathrm{inel}}^{\mathrm{pp}}}{\langle N_{\mathrm{coll}}\rangle \sigma_{\mathrm{inel}}^{\mathrm{pPb}}} \frac{Ed^3\sigma^{\mathrm{pPb}}/dp^3}{Ed^3\sigma^{\mathrm{pp}}/dp^3}$$

<*N*coll>=6.9± 0.7



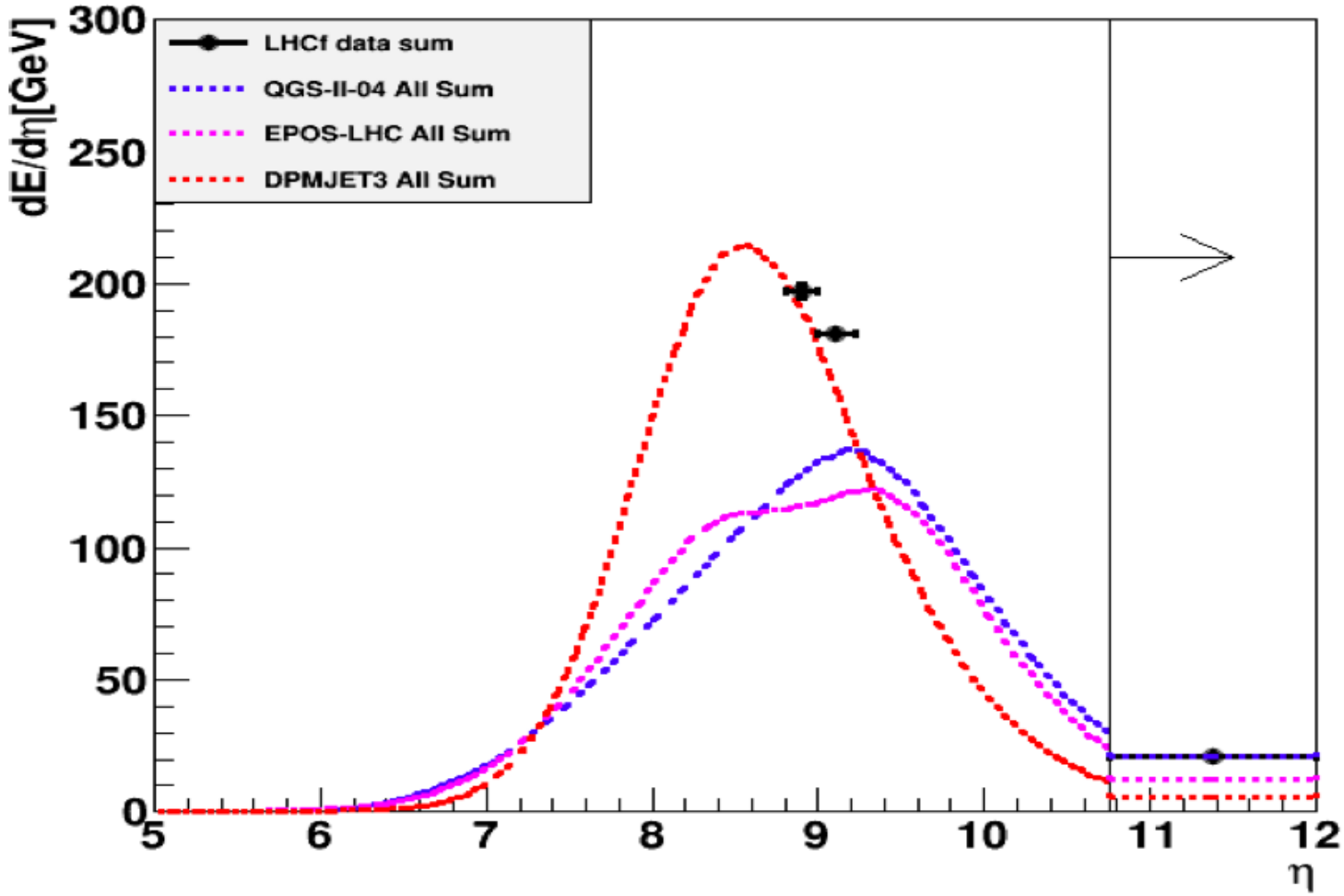


LHCf EM(π^0) energy flow vs rapidity (7TeV)



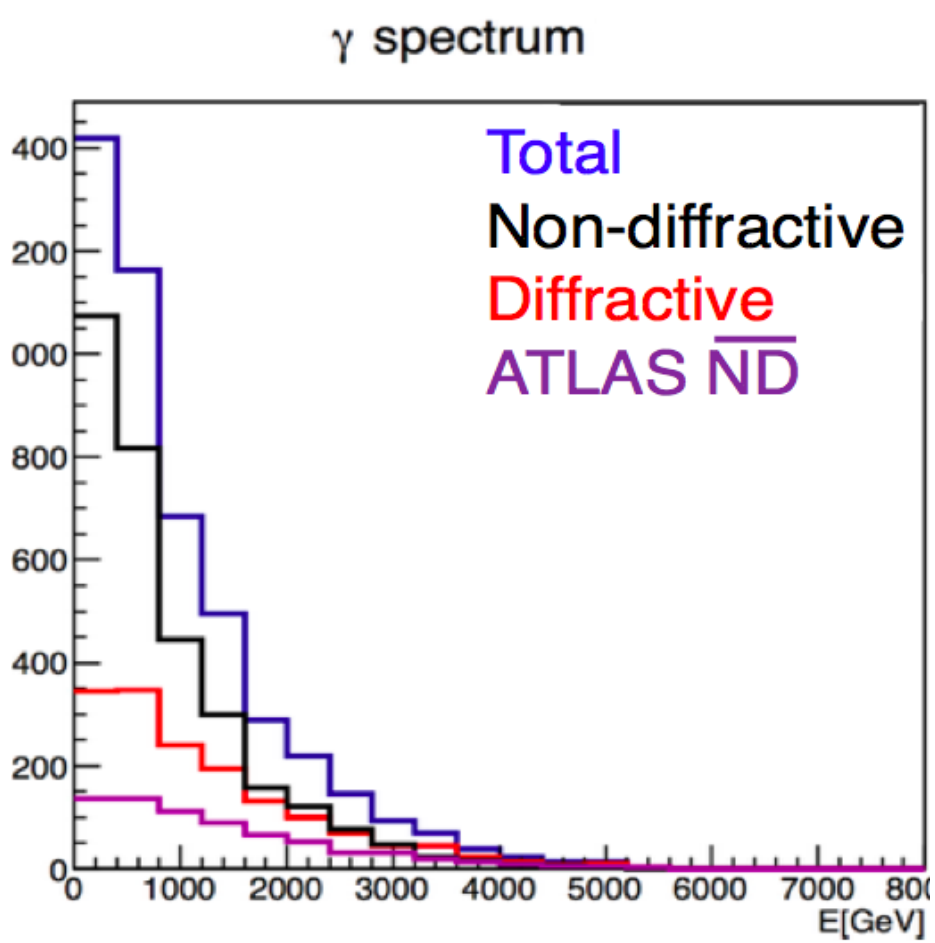
Plot by N.Sakurai

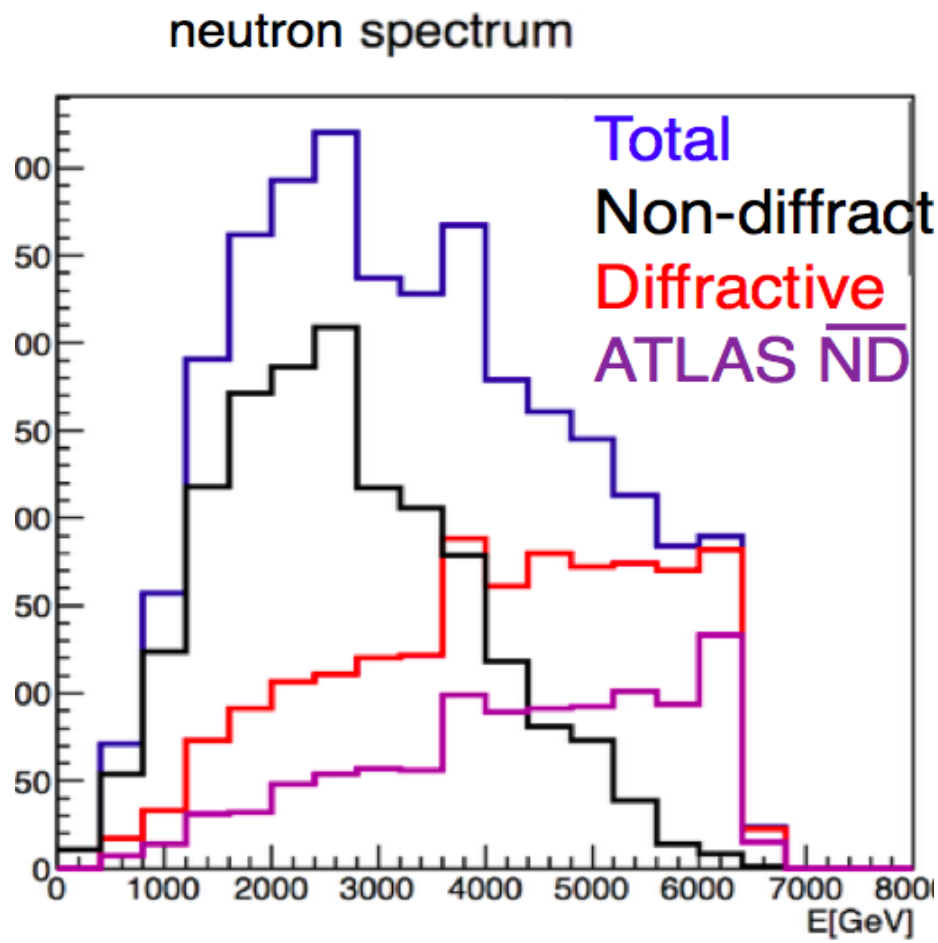
LHCf neutron energy flow vs rapidity



Plot by N.Sakurai

ATLAS ND Tagged LHCf γ and neutrons 13 TeV pp MC (PYTHIA)



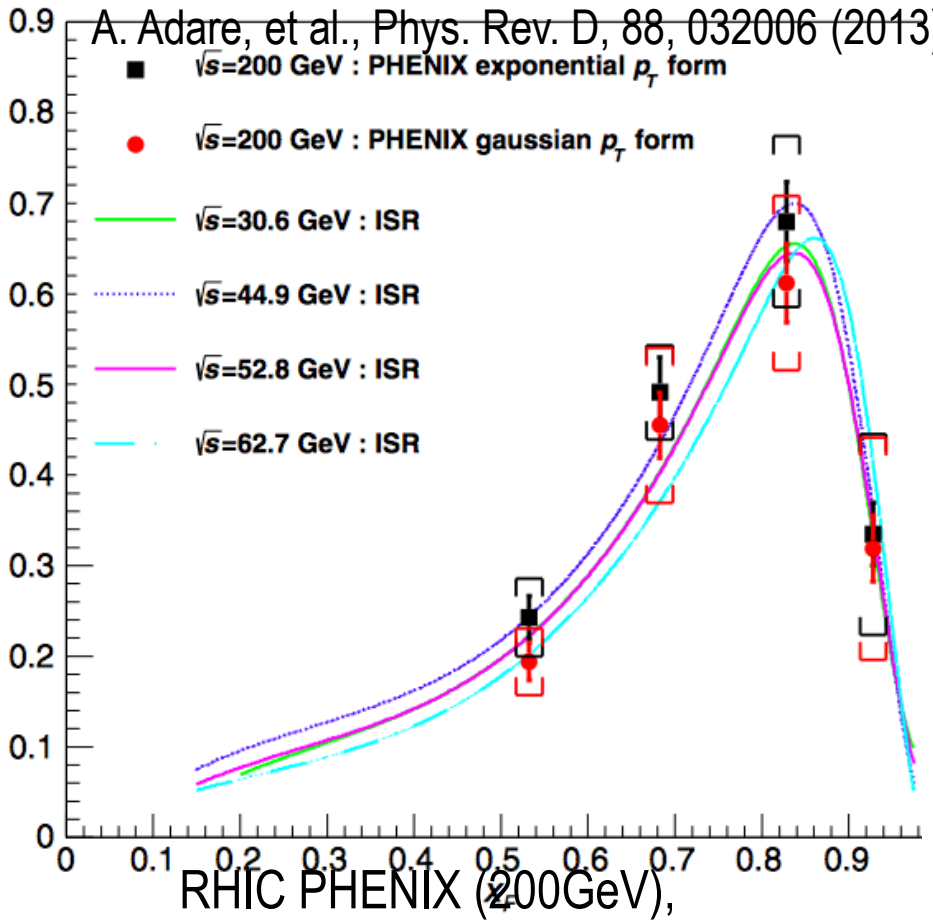


γ

Hadron(neutron)

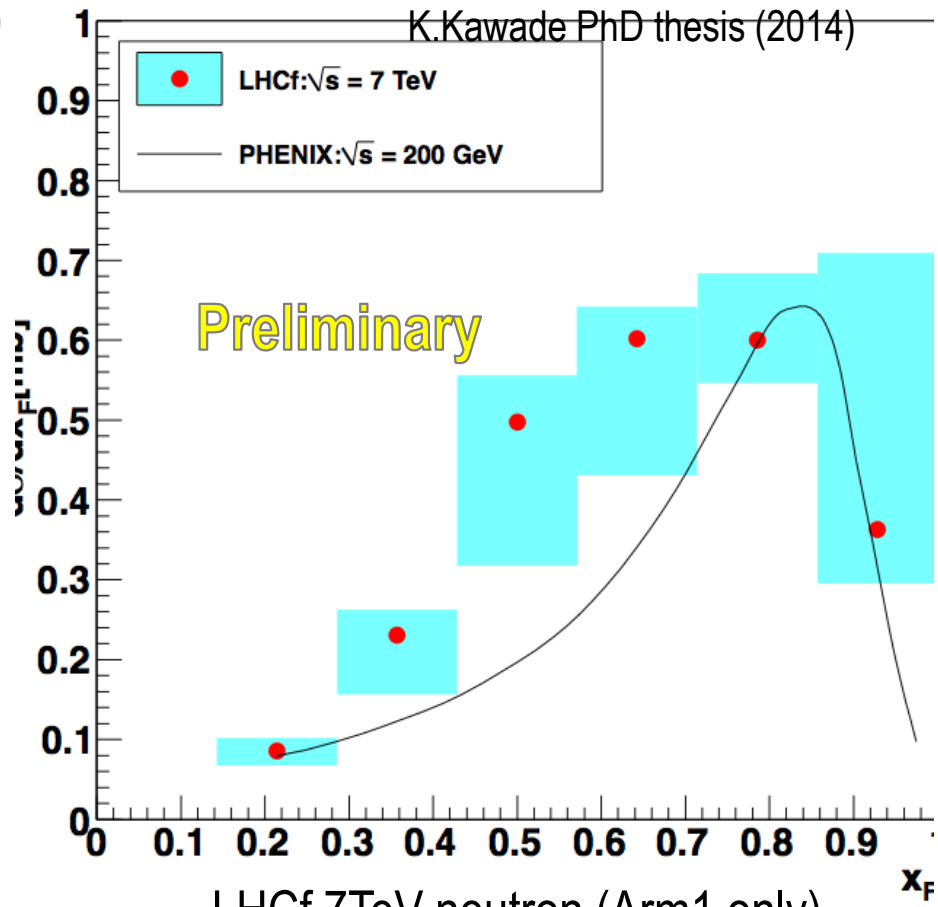
XF scaling of very forward neutron

A. Adare, et al., Phys. Rev. D, 88, 032006 (2013)



RHIC PHENIX (200GeV),
ISR (30.6-62.7 GeV)

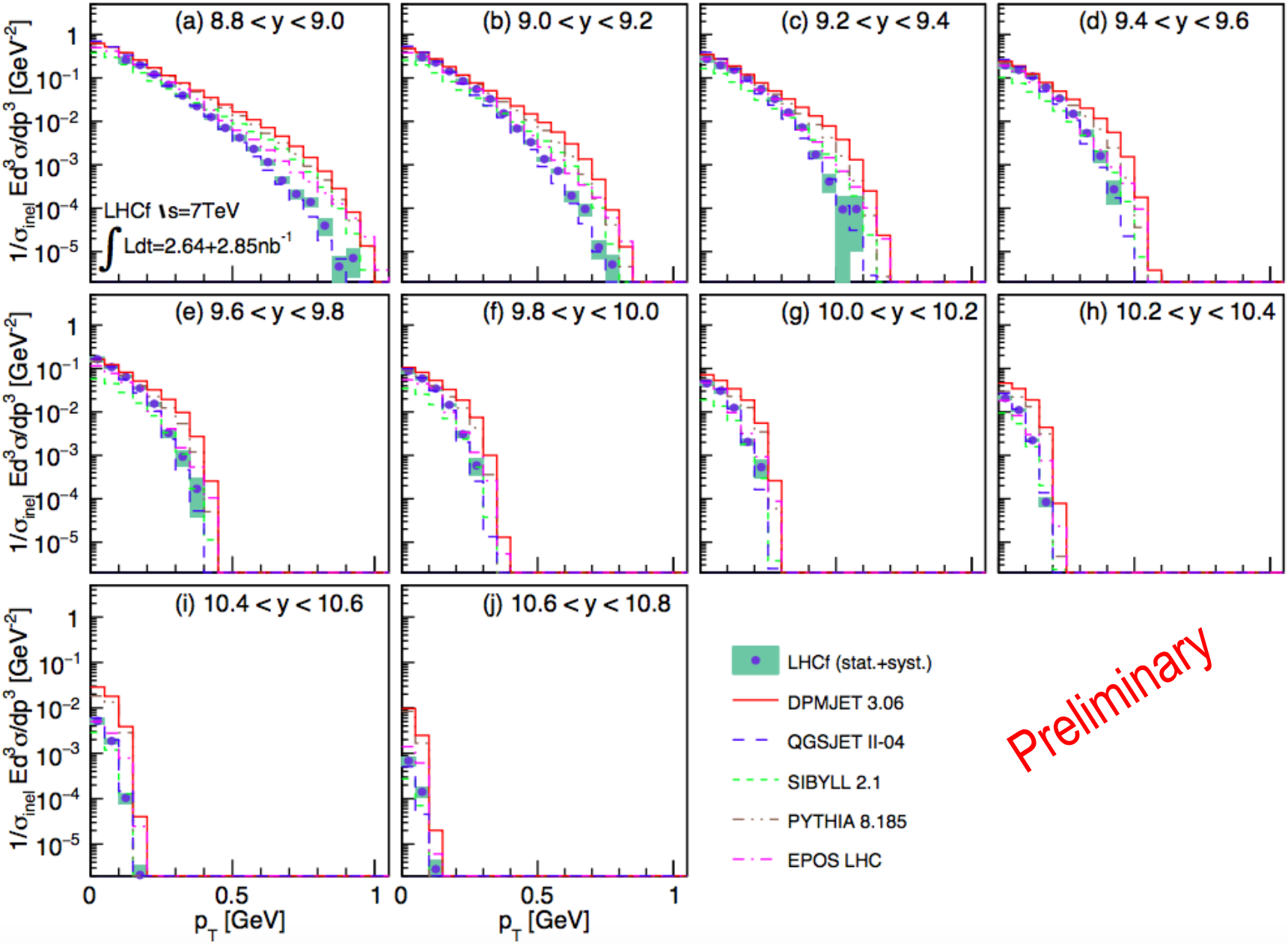
K.Kawade PhD thesis (2014)



LHCf 7TeV neutron (Arm1 only)
$0<P_T<0.11x_F$ GeV/c

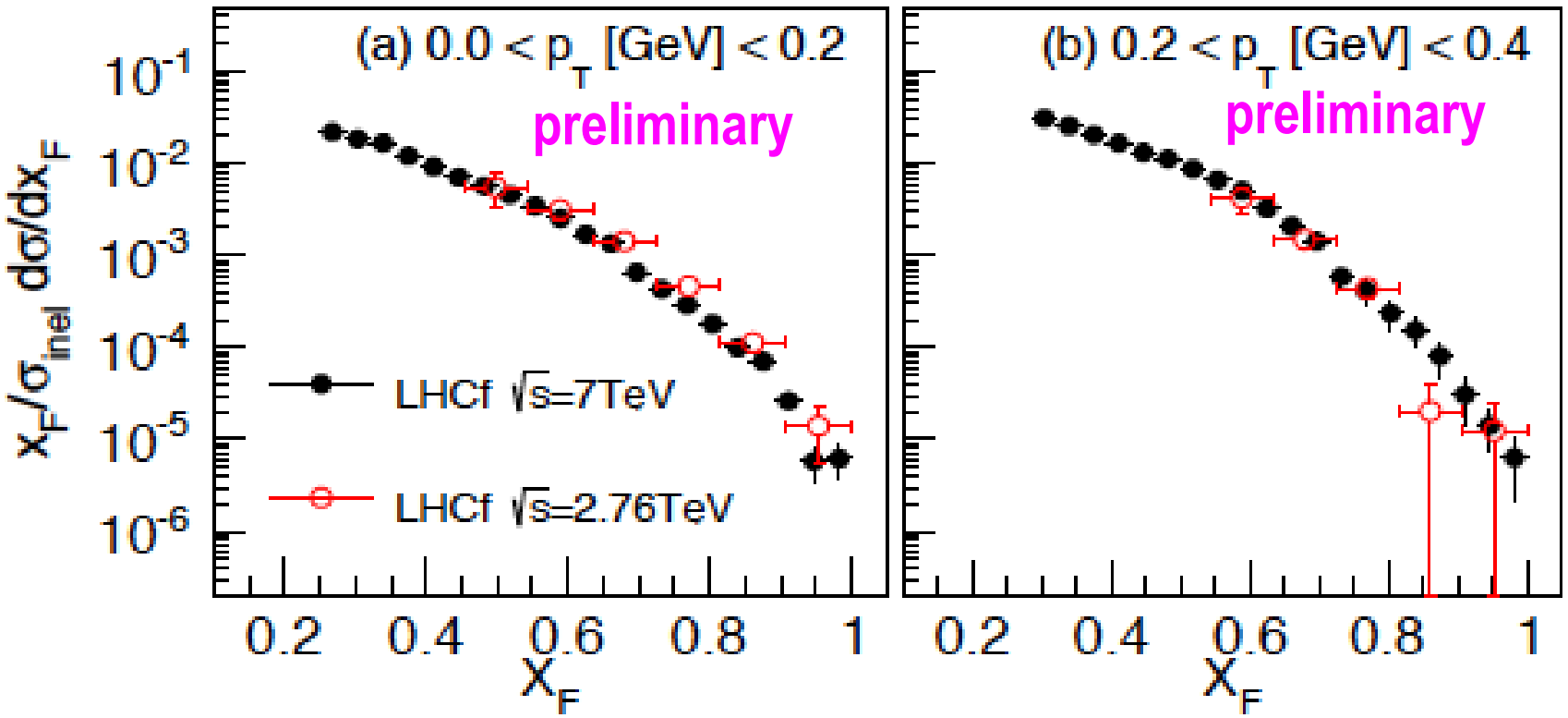
$PT_{\pi 0}$ spectra Type-I + Type-II π^0

To be submitted PRD



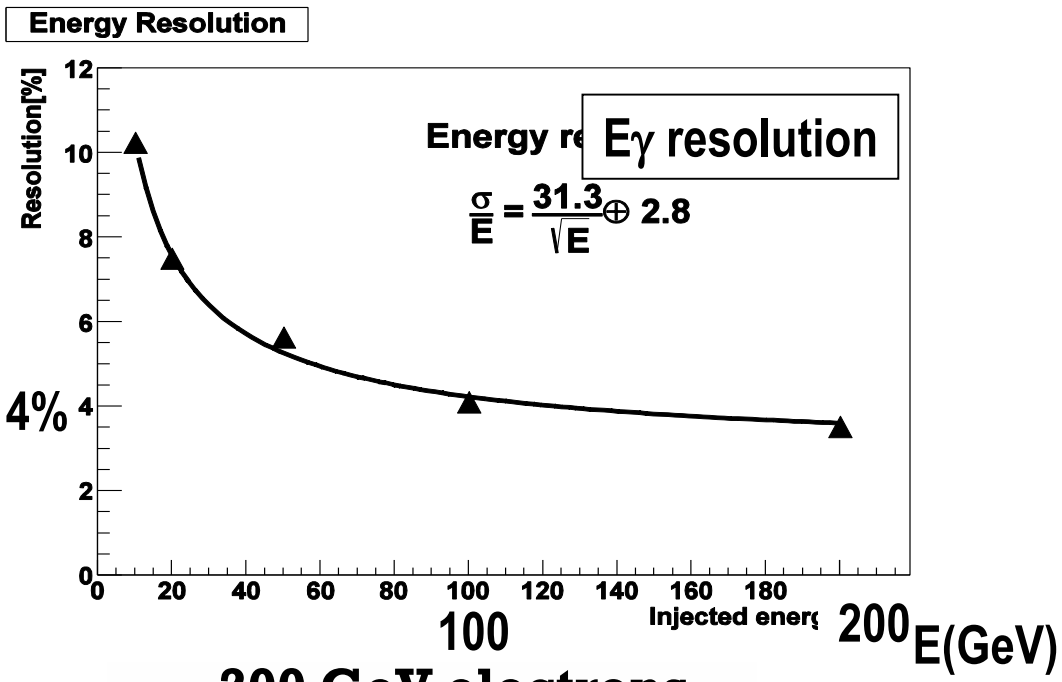
Feynman scaling in π^0 production

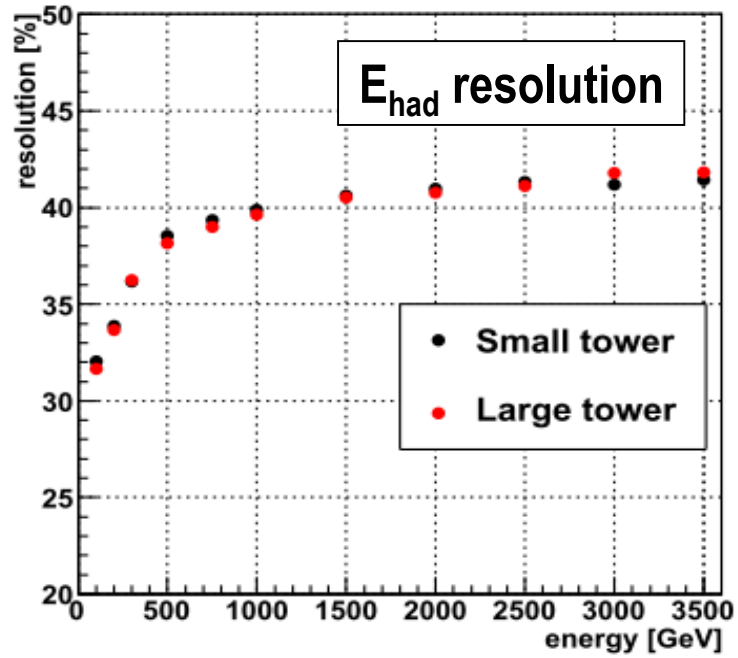
To be submitted PRD



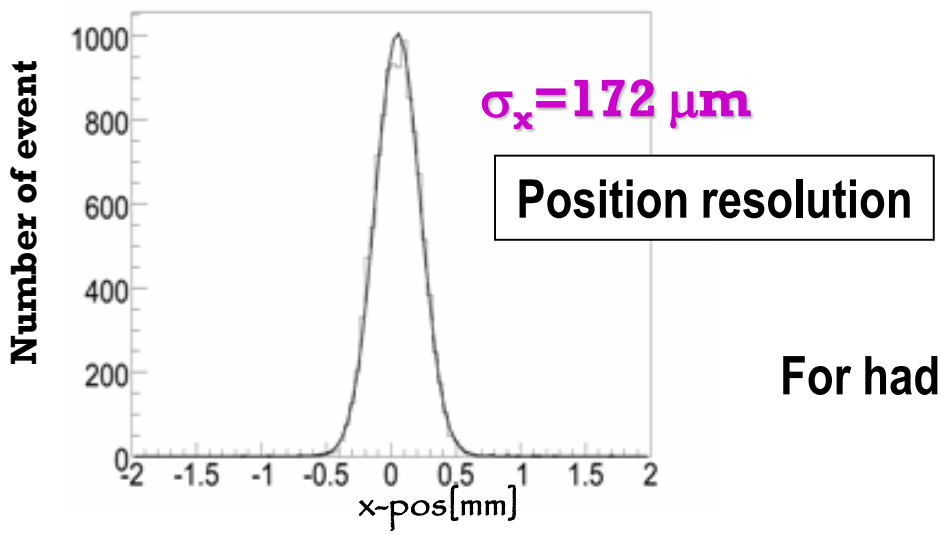
- LHCf π^0 spectra at $\sqrt{s}$= 2.76 and 7 TeV (preliminary)
- Soon compared w/ LHC 13 TeV, and future RHICf (510GeV)

Detector performance

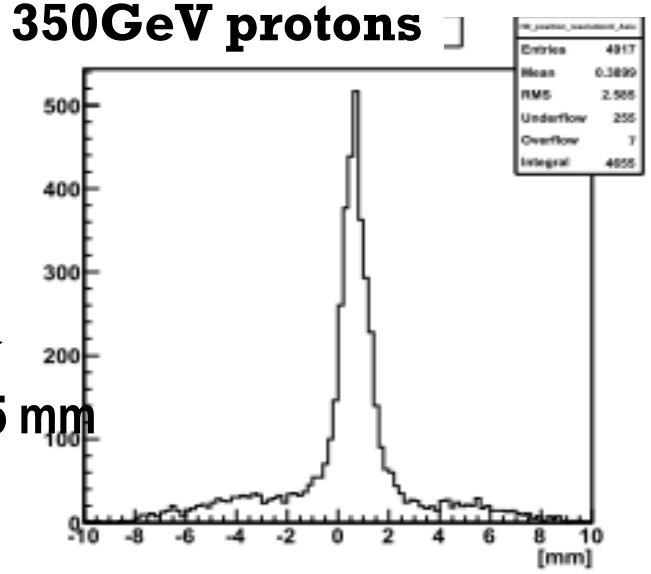




200 GeV electrons

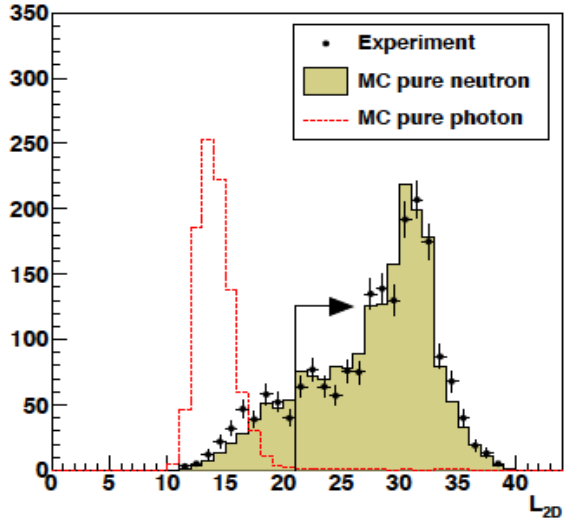


350GeV protons



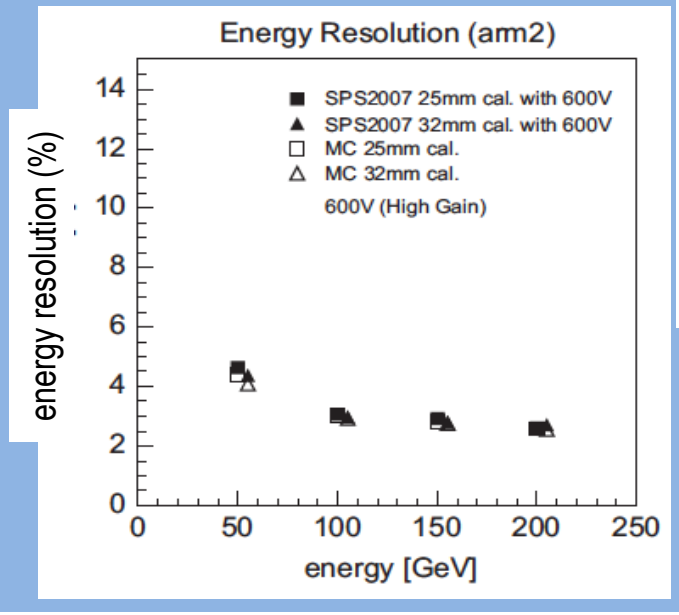
For hadron, Δx~2.5 mm

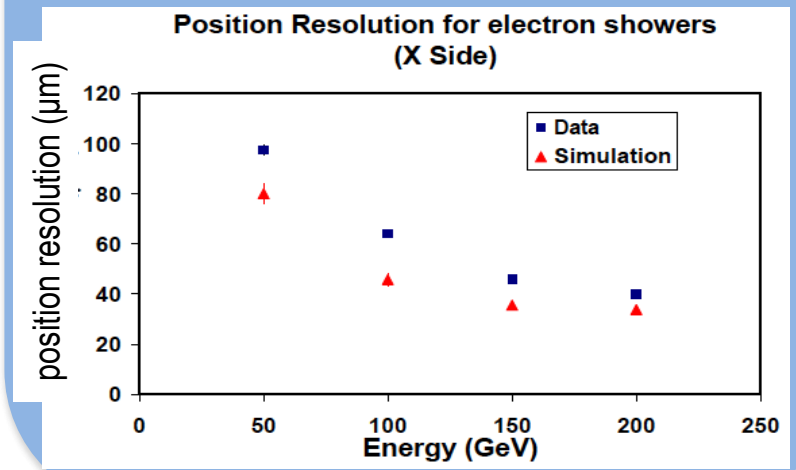
PID (SPS energy)



EM shower (SPS)

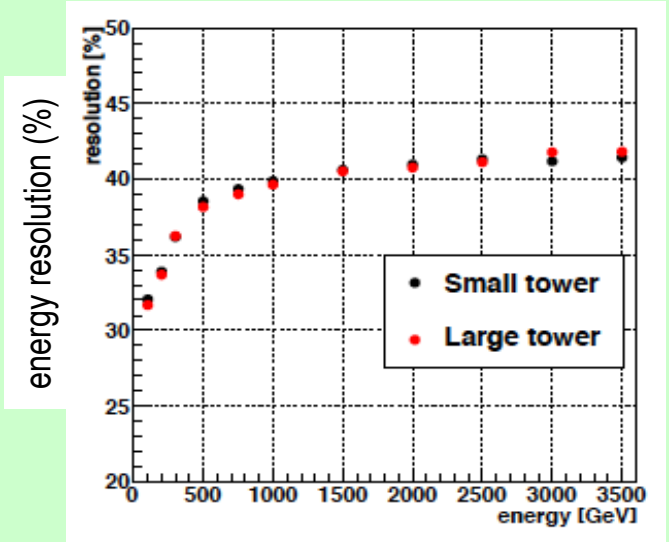
NIM, A671 (2012) 129-136
JINST, 5, P01012, 2010

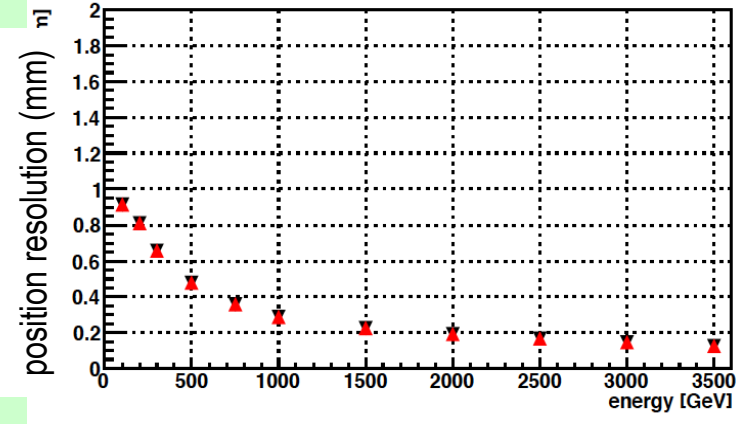




Hadronic shower (LHC MC)

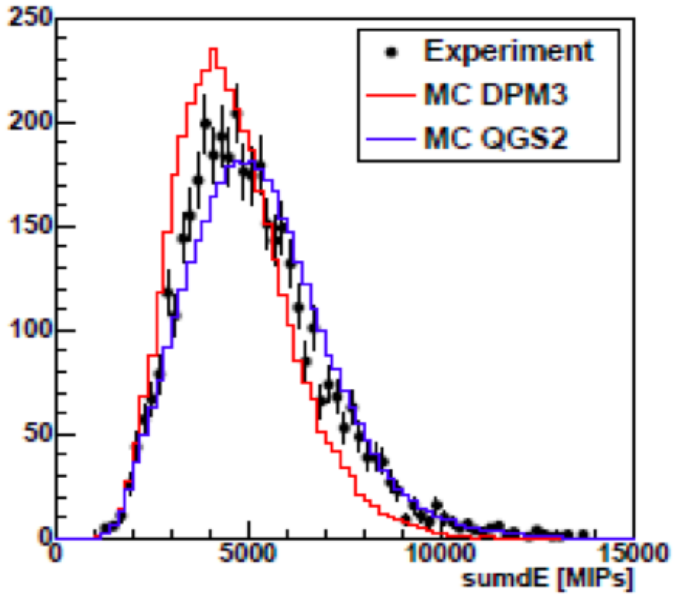
JINST, 9, P03016 (2014)

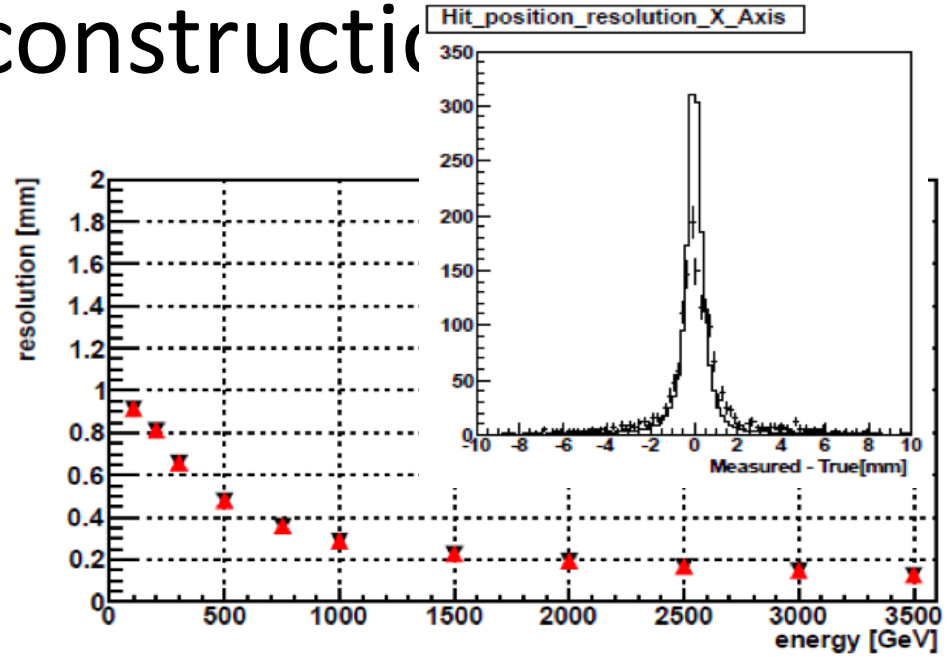


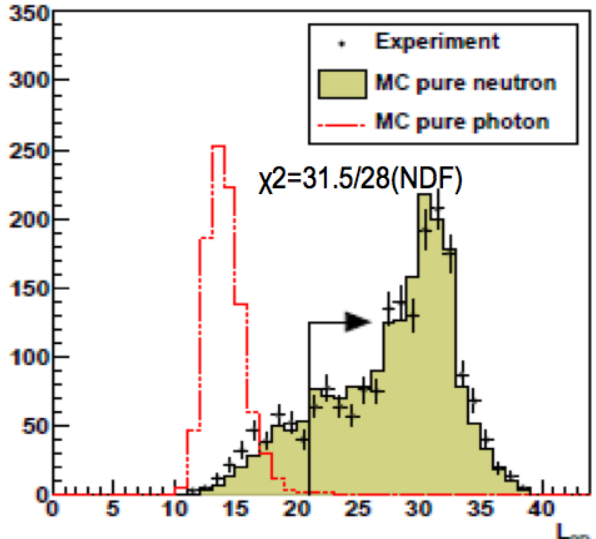


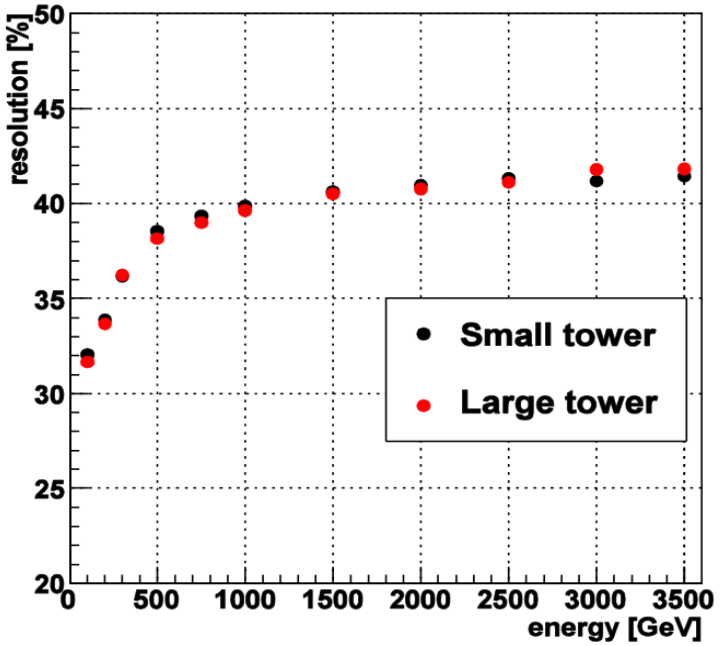
Hadron shower reconstructi

Check by SPS 350GeV p beam

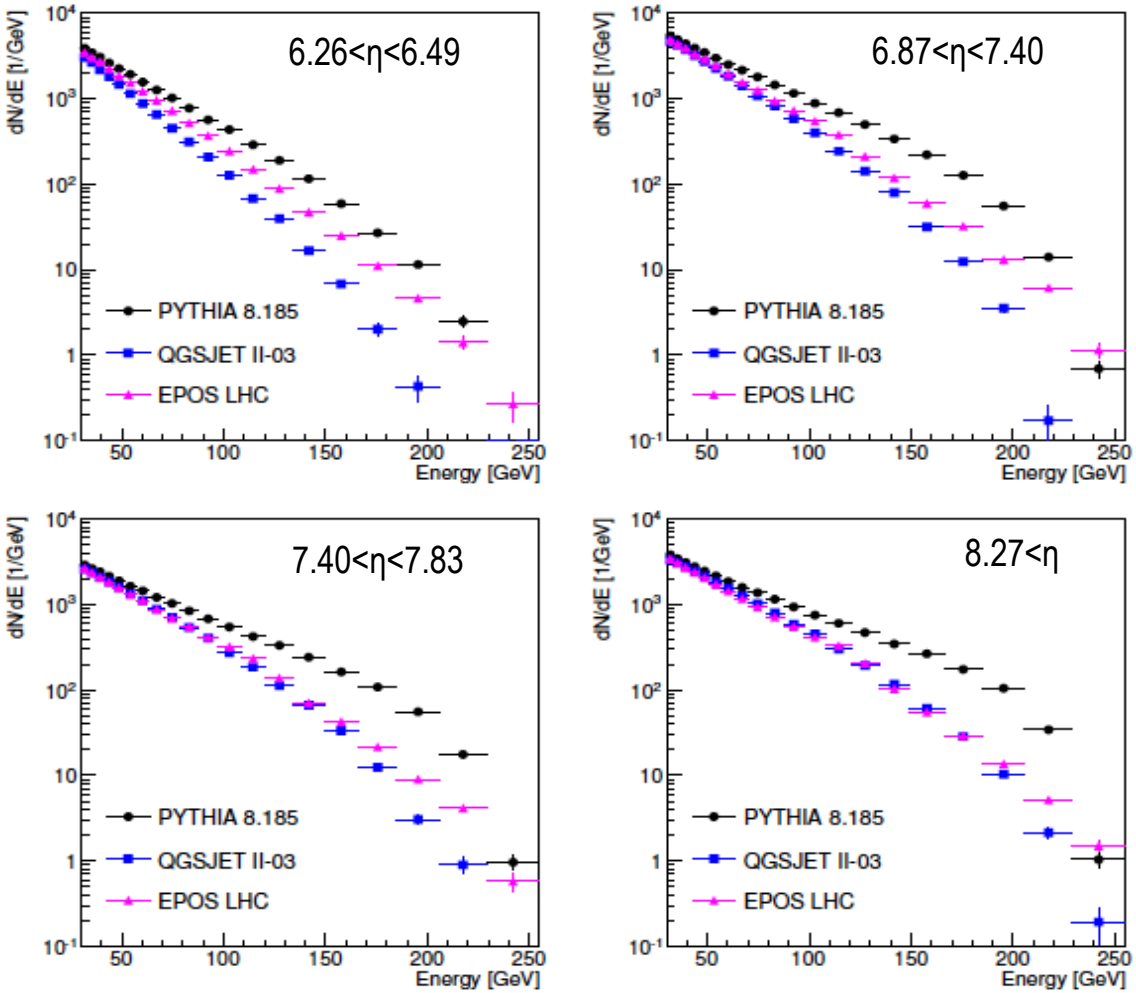






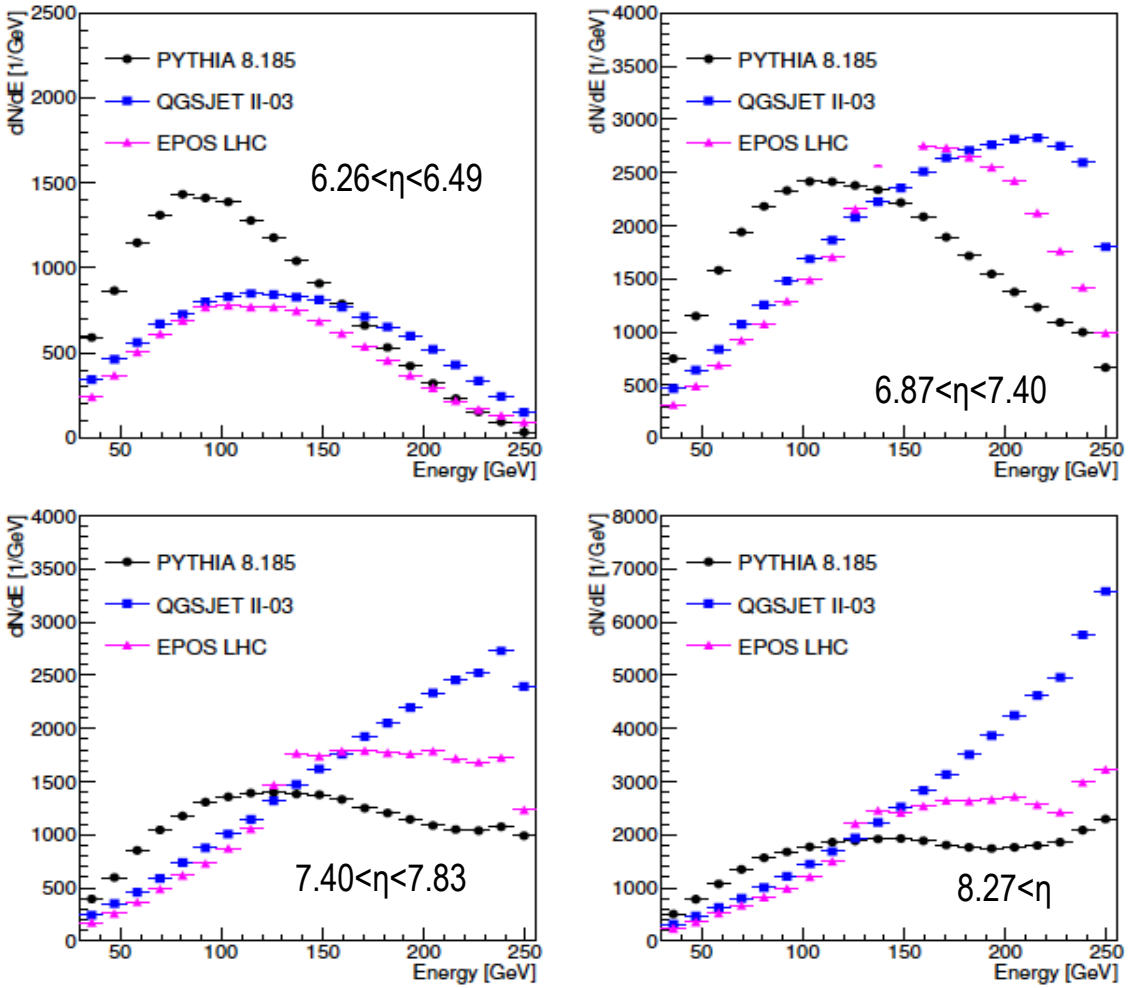


Expected Results (single photons)



- Photon spectra at 4 rapidity samples
- 12 hours statistics (12 nb^{-1} effective luminosity; 360nb^{-1} delivered)
- Statistical error is almost negligible except at the highest energy bins

Expected Results (single neutrons)



- Neutron spectra at 4 rapidity samples
- 12 hours statistics (12 nb^{-1} effective luminosity; 360nb^{-1} delivered)
  - RHICf resolution not considered; true spectra
    - Statistical error is almost negligible

Possible future p-Oxygen run

- Important missing information ; nuclear shadowing
- Large suppression 0.1 for p-Pb for very forward π^0 at low PT
- Less expected for p-Light Ion, but model dependent (~25%)
- Oxygen beam is technically feasible in LHC

Current largest diff. btw 2 models