LHCf achievements at pp and pPb

Opportunities of OO and pO collisions at the LHC, 4-10 Feb 2021

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

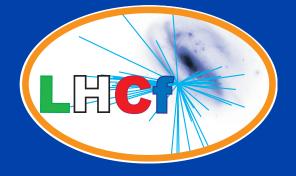


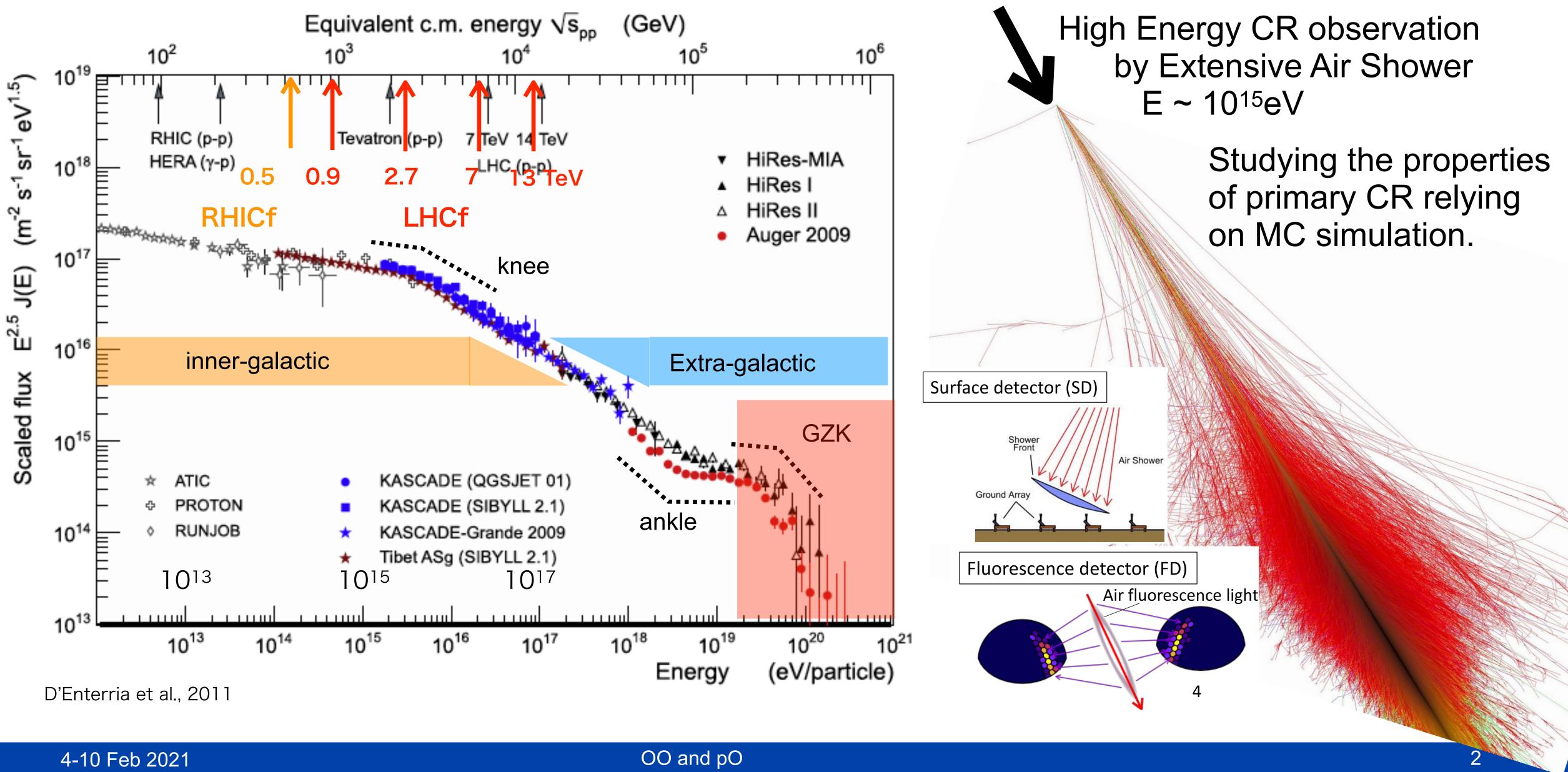
Institute for -Earth Environmental Research

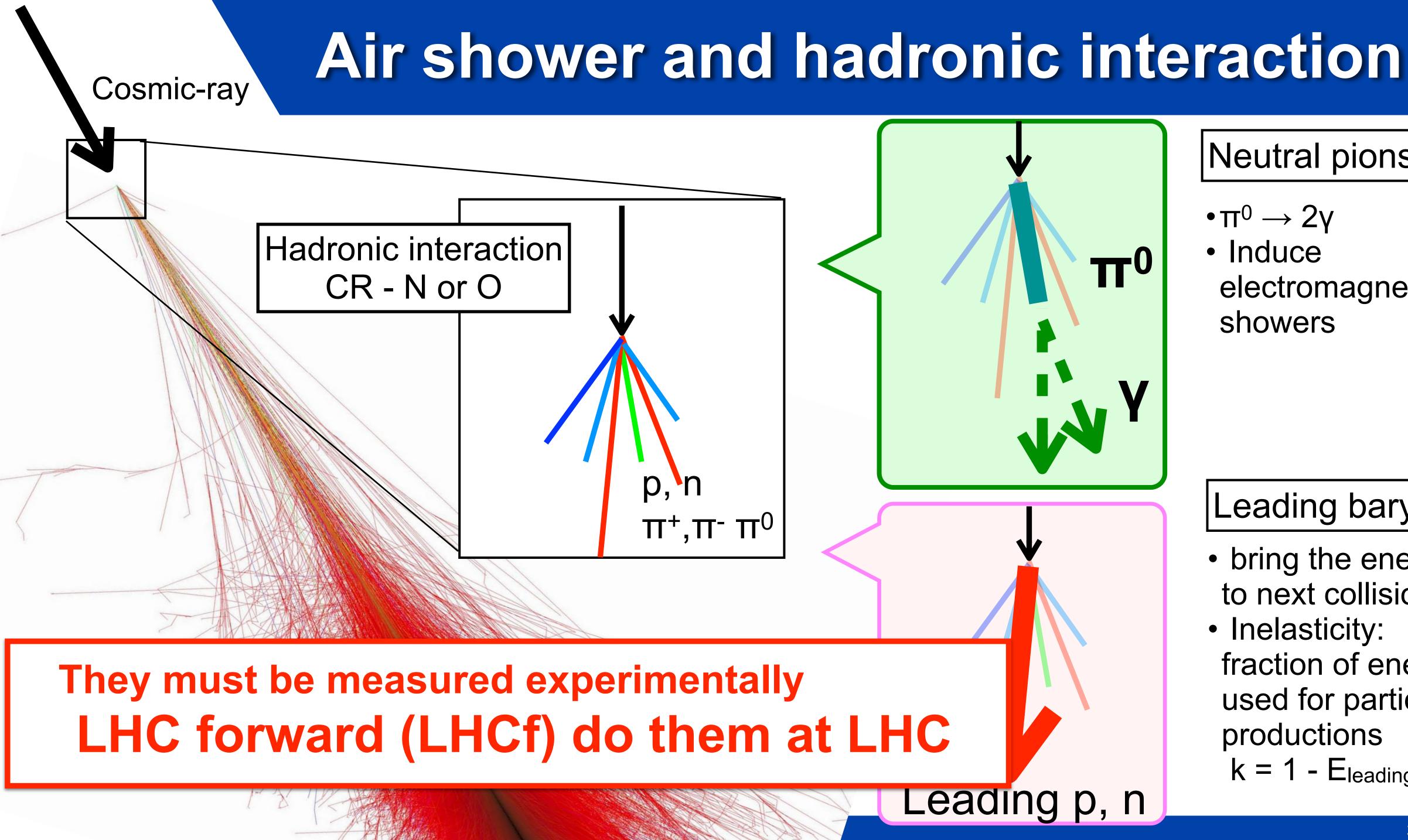




High Energy Cosmic-ray







Neutral pions

- $\pi^0 \rightarrow 2\gamma$
- Induce electromagnetic showers

Leading baryons

- bring the energy to next collisions
- Inelasticity: fraction of energy used for particle productions $k = 1 - E_{leading}/E_{CR}$



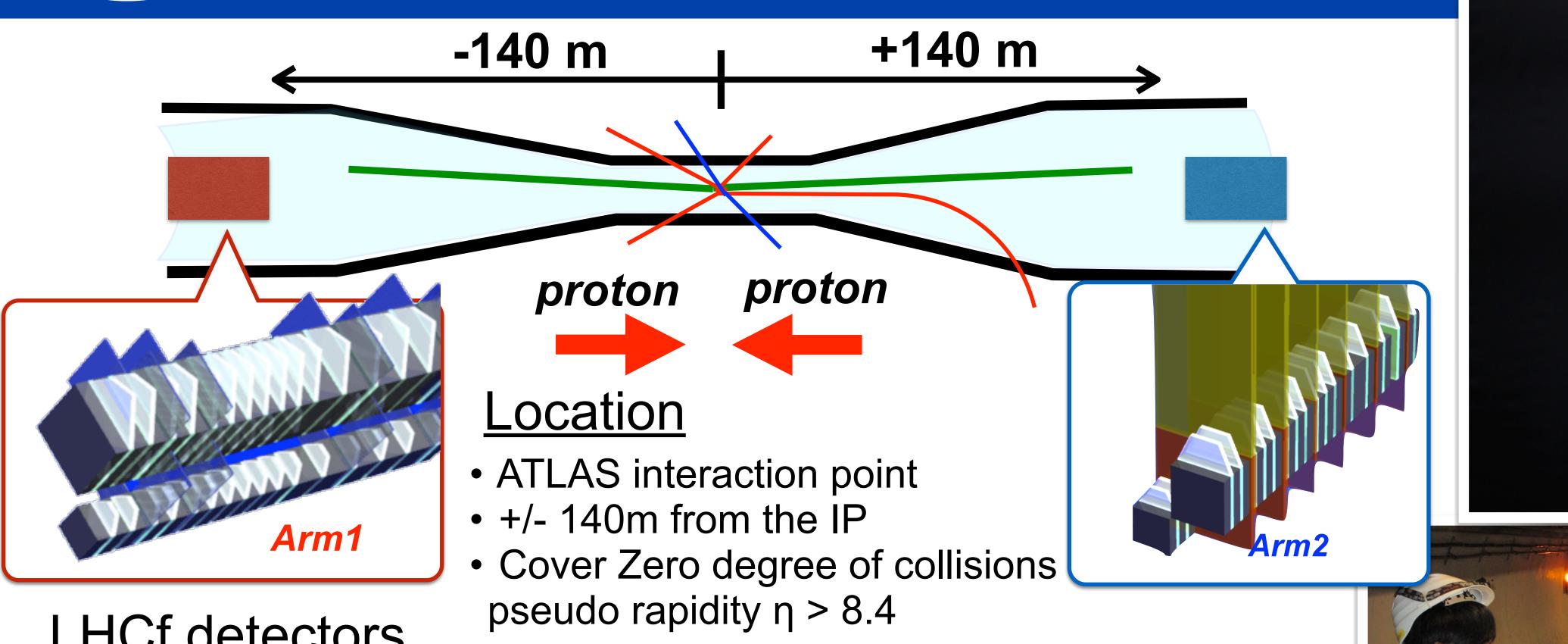










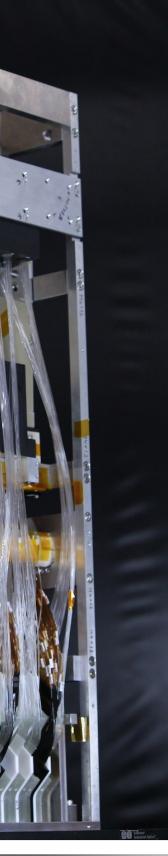


LHCf detectors

- Sampling and positioning calorimeters
- Two towers, 20x20, 40x40mm² (Arm1), 25x25, 32x32mm²(Arm2)
- Tungsten layers, 16 GSO scintillators, 4 position sensitive layers (Arm1: GSO bar hodoscopes, Arm2: Silicon strip detectors)
- Thickness: 44 r.l. and 1.7 λ

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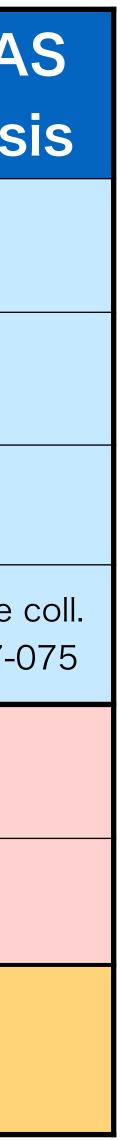




Run	Elab (eV)	Photon	Neutron	ПO		LHCf-ATLA joint analys
p-p √s=0.9TeV (2009/2010)	4.3 x10 ¹⁴	PLB 715, 298 (2012)		_		
p-p √s=2.76TeV (2013)	4.1x10 ¹⁵			PRC 86, 065209 (2014)	PRD 94 032007 (2016)	
p-p √s=7TeV (2010)	2.6x10 ¹⁶	PLB 703, 128 (2011)	PLB 750 360 (2015)	PRD 86, 092001 (2012)		
p-p √s=13TeV (2015)	9.0x10 ¹⁶	PLB 780, 233 (2018)	JHEP 2018, 73 (2018) JHEP 2020, 016 (2020)	nreliminary		Photon in diffractive ATLAS-CONF-2017-0
p-Pb √s _{NN} =5TeV (2013,2016)	1.4x10 ¹⁶			PRC 86, 065209 (2014)		
p-Pb √snn=8TeV (2016)	3.6x10 ¹⁶	Preliminary				
RHICf p-p √s=510GeV (2017)	1.4x10 ¹⁴			Spin Asymmetry PRL 124 252501 (2021)		with STAR

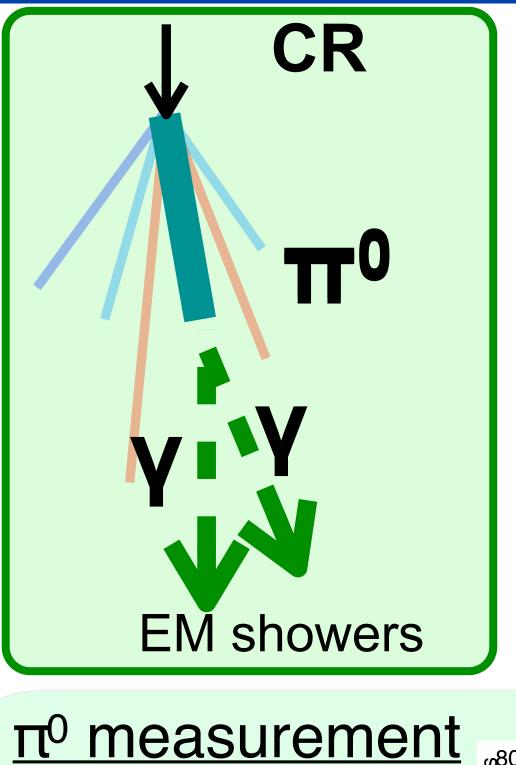
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LHCf Operations and Analyses

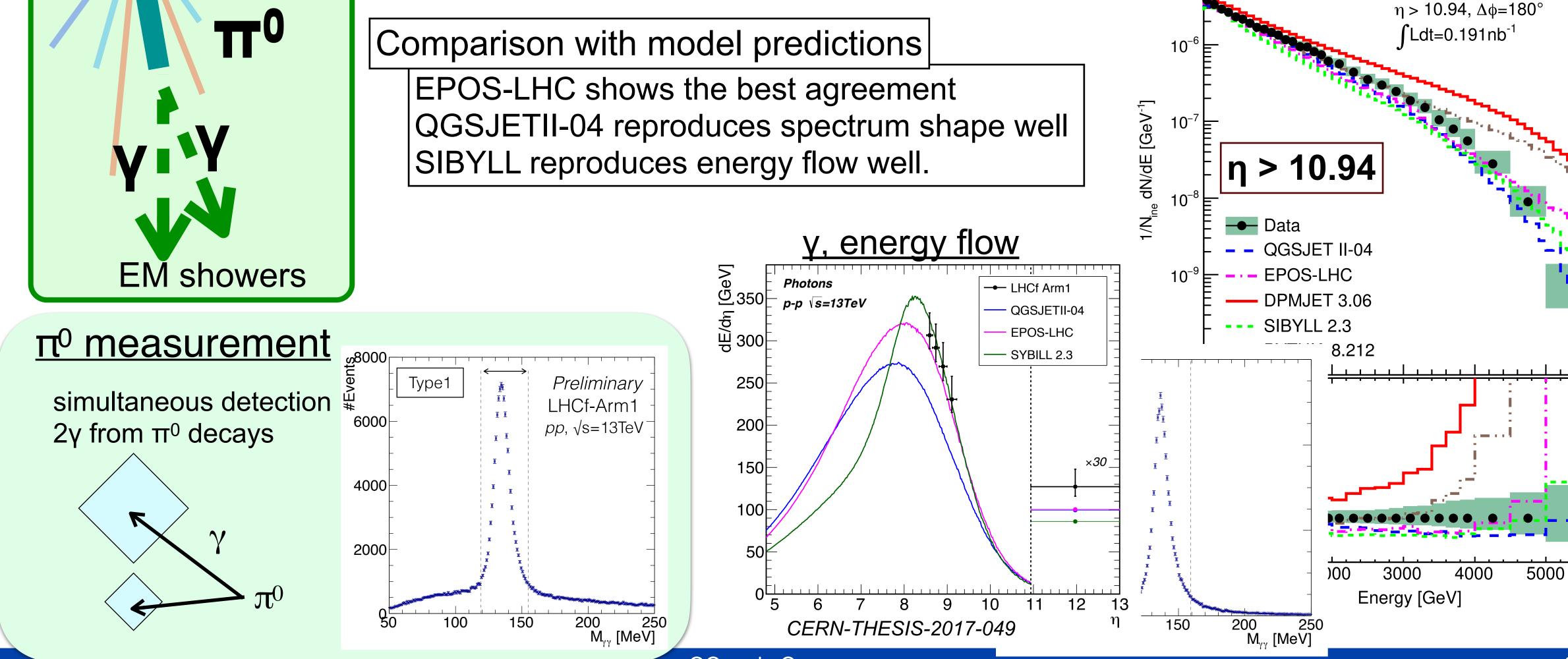




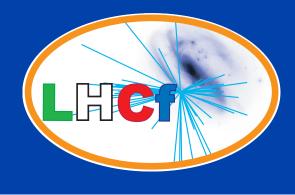
Photon (π^{0}) measurement at pp



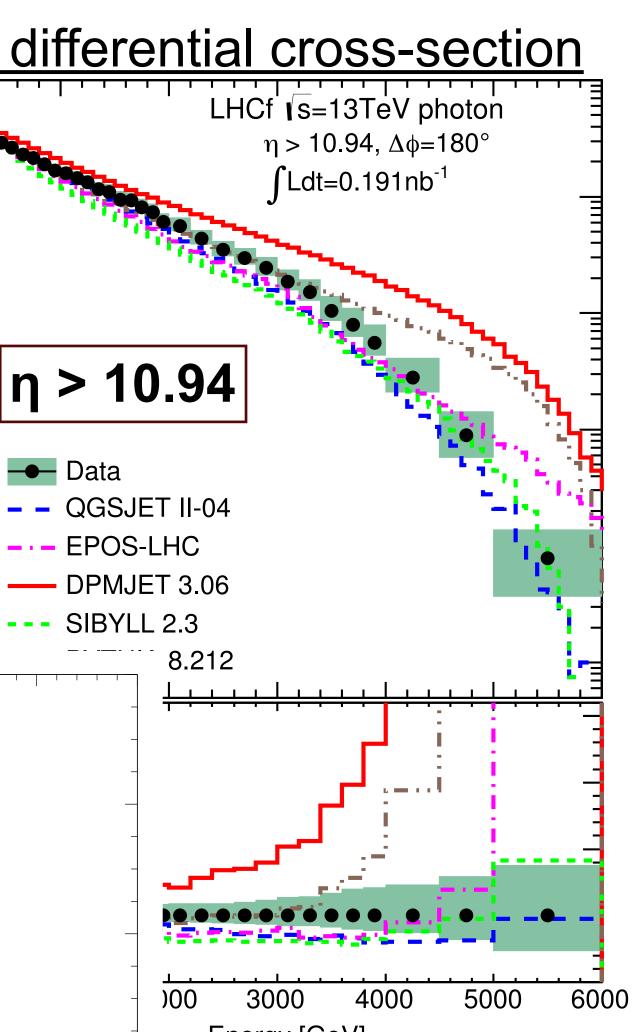
- Source of EM components in CR-air showers
- γ 's originate from π^0 and η decays
- LHCf covers high energy photons $X_F > \sim 0.1$



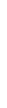
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LHCf s=13TeV photon





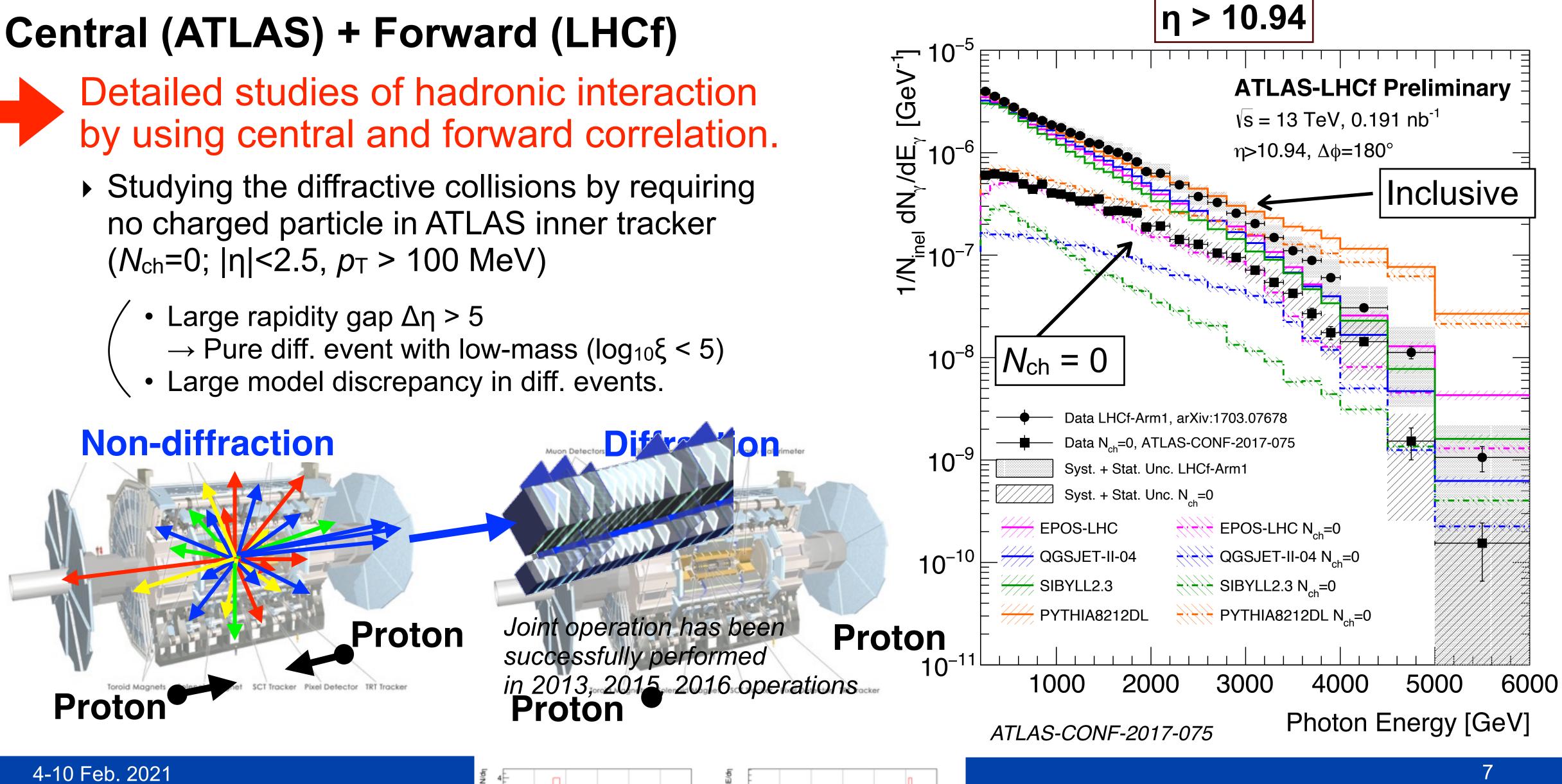






LHCf+ATLAS joint analysis

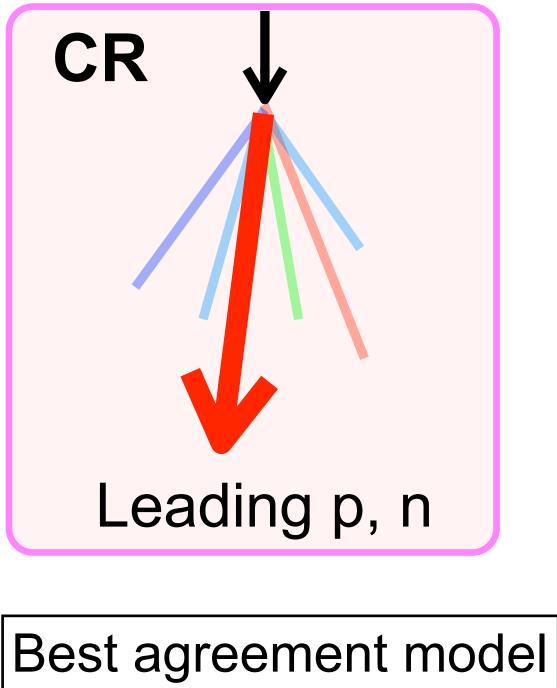
- (*N*_{ch}=0; |η|<2.5, *p*_T > 100 MeV)
 - Large rapidity gap $\Delta \eta > 5$
 - Large model discrepancy in diff. events.



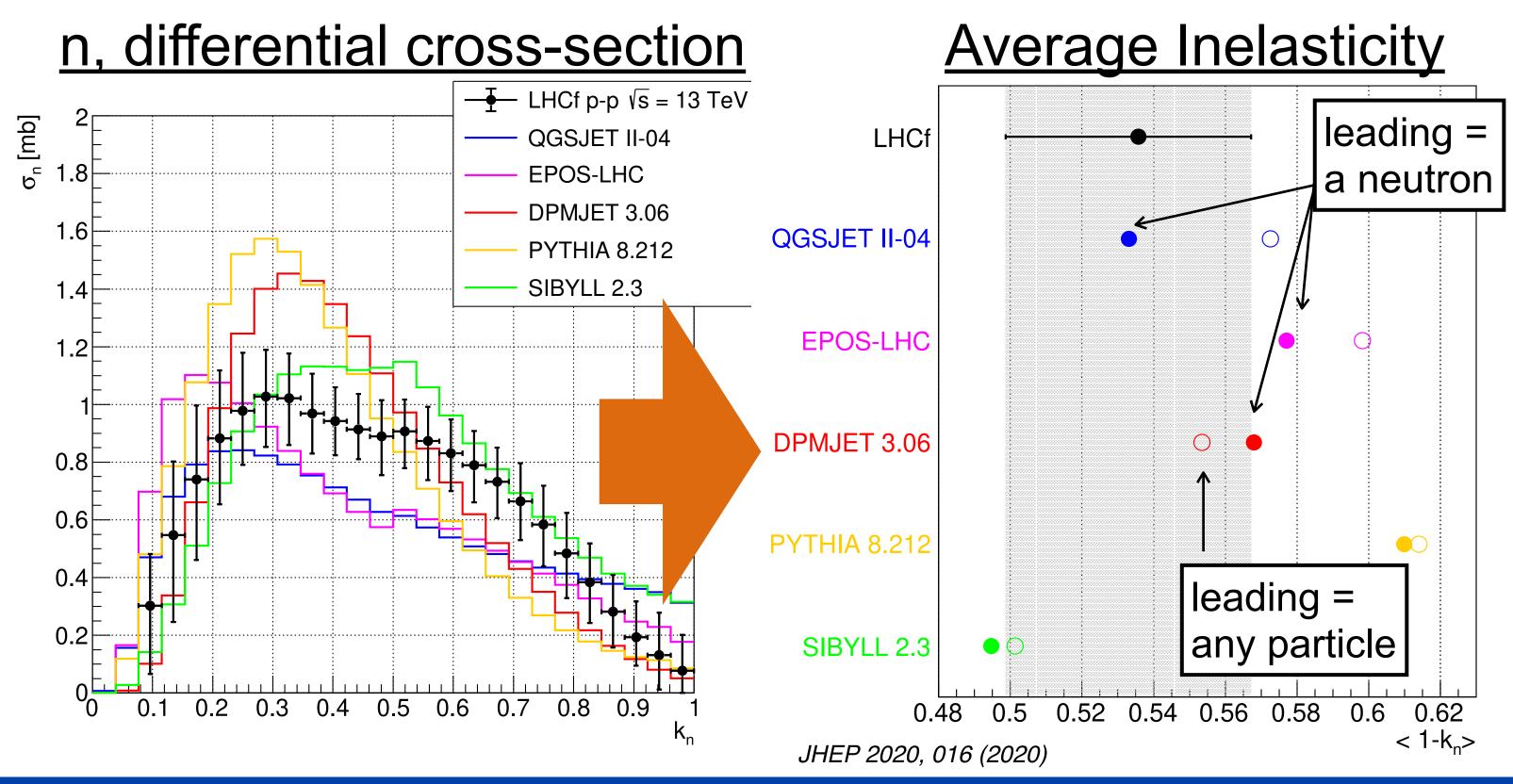


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Inelasticity measurement at pp



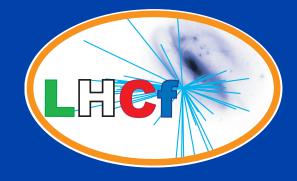
- Inelasiticity ($k = 1 E_{\text{leading}}/E_{CR}$), energy fraction used for particle productions, is one of the most important parameters for understanding CR-air shower development. LHCf measures high energy neutrons, which can be leading baryons.
- 40% energy resolution for neutrons. ~ 10% contamination of K_0 , Λ



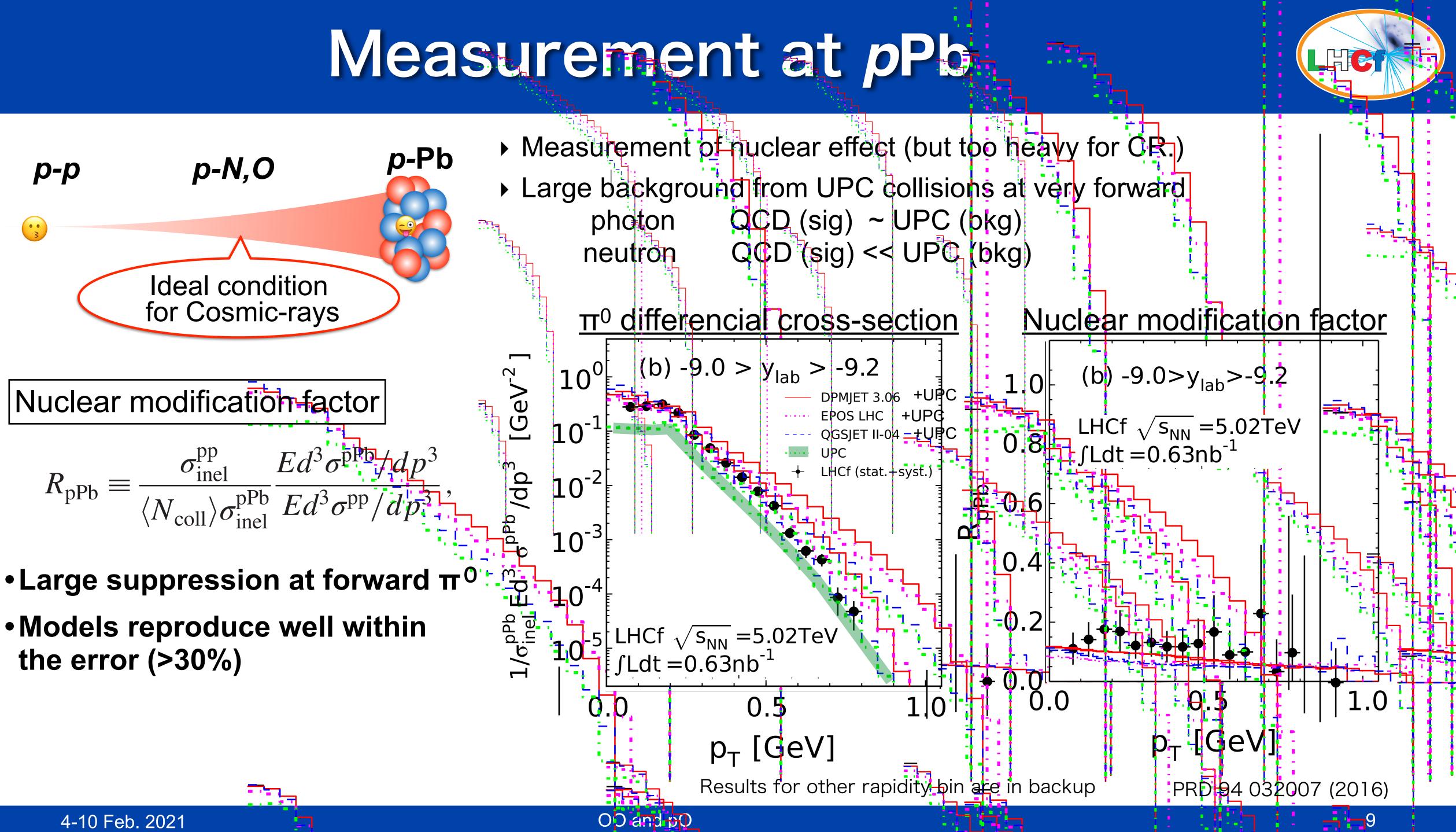
Average Inelasiticity: QGSJET II-4 Energy spectrum: EPOS, SIBYLL Energy flow: EPOS

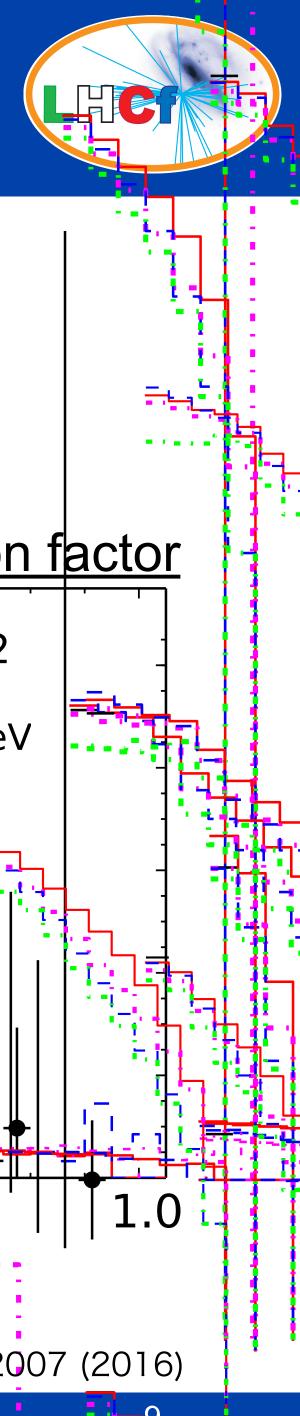
LHCf-ATLAS joint analysis is on-going with LHCf-neutron samples.

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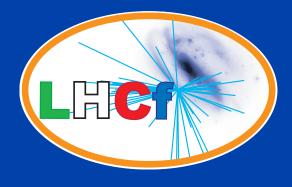






Summary and Prospects

- LHCf measured forward γ , π^0 , n at pp and pPb
 - Any model reproduces a part of LHCf data well but no model reproduces all of LHCf data simultaneously.
 - ^D Nuclear effect has been measured for π^0 at pPb, and it is consistent with model predictions within the error (> 30%). Neutron measurement is very difficult due to huge background from UPC.
- Prospects at Run3 Operations
 - □ pp \sqrt{s} =13 or 14 TeV
 - Increase statistics of high energy π^0
 - $\eta (\rightarrow 2\gamma), K^{0}_{s}(\rightarrow 2\pi^{0}\rightarrow 4\gamma)$ measurements
 - Joint operation with ZDC for improvement of energy resolution for neutrons (40% \rightarrow 20%) pO (or OO) collisions (Next talk by A. Tiberio)

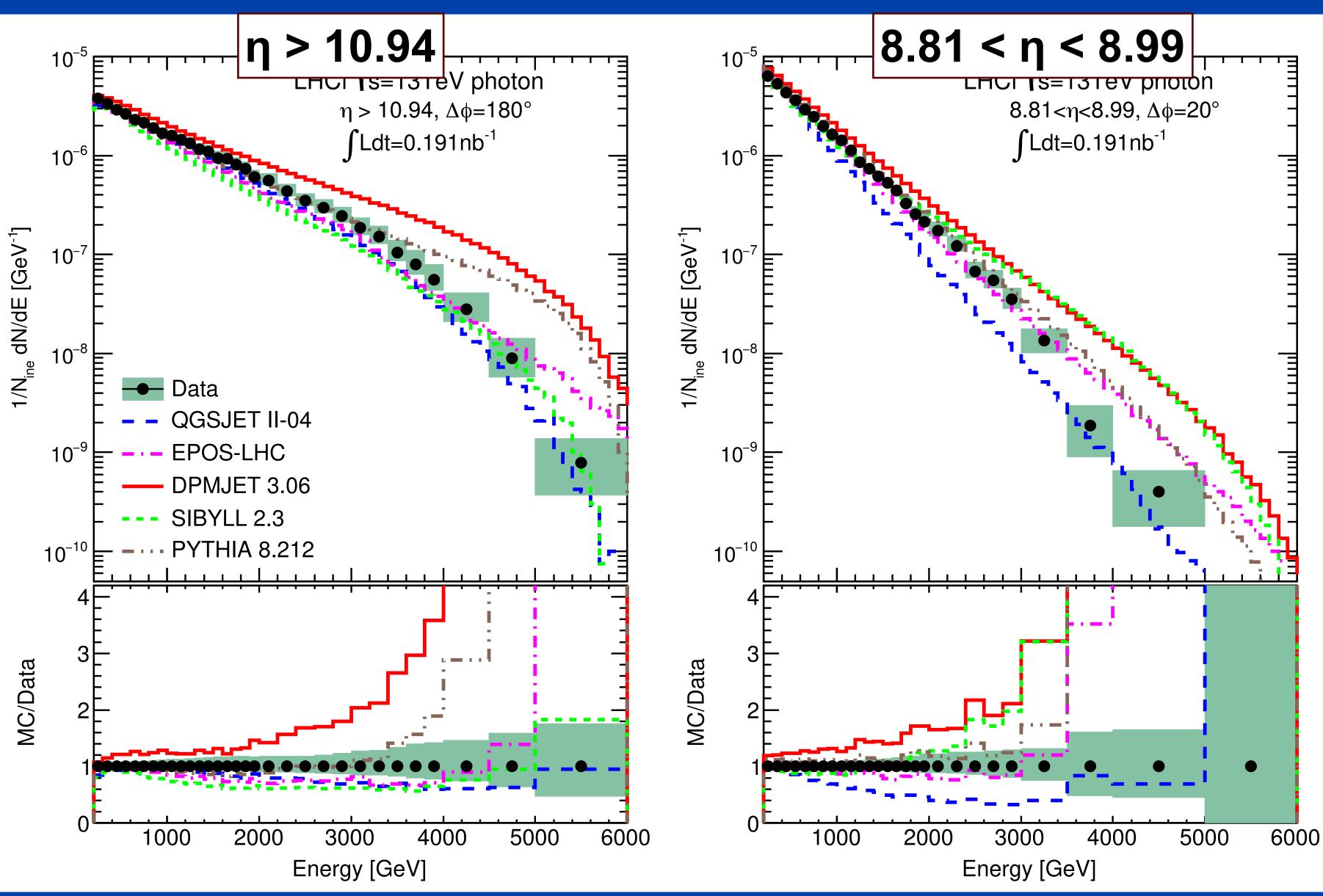






Backup

Inclusive photon at pp /s=13TeV



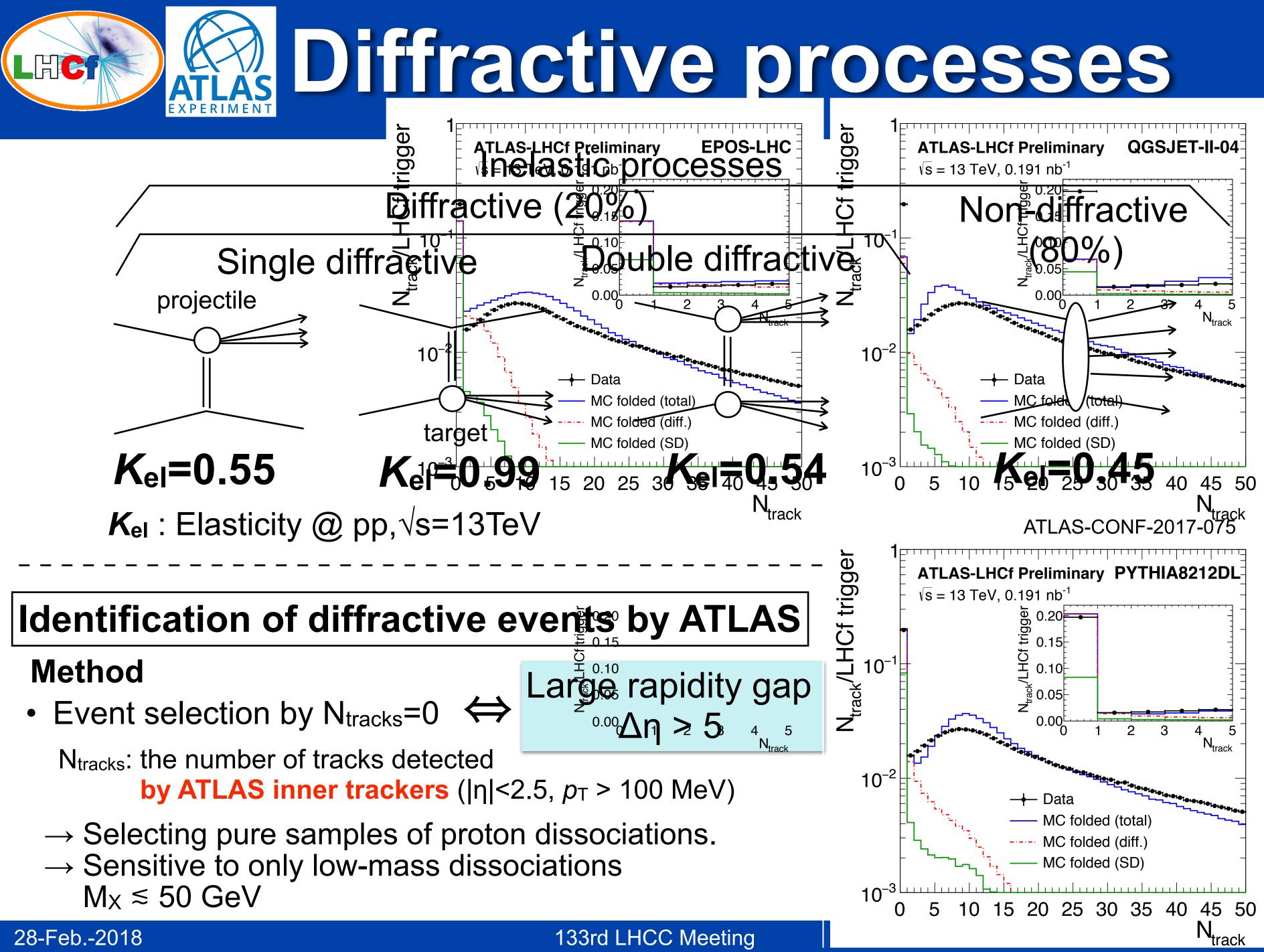
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OO and pO





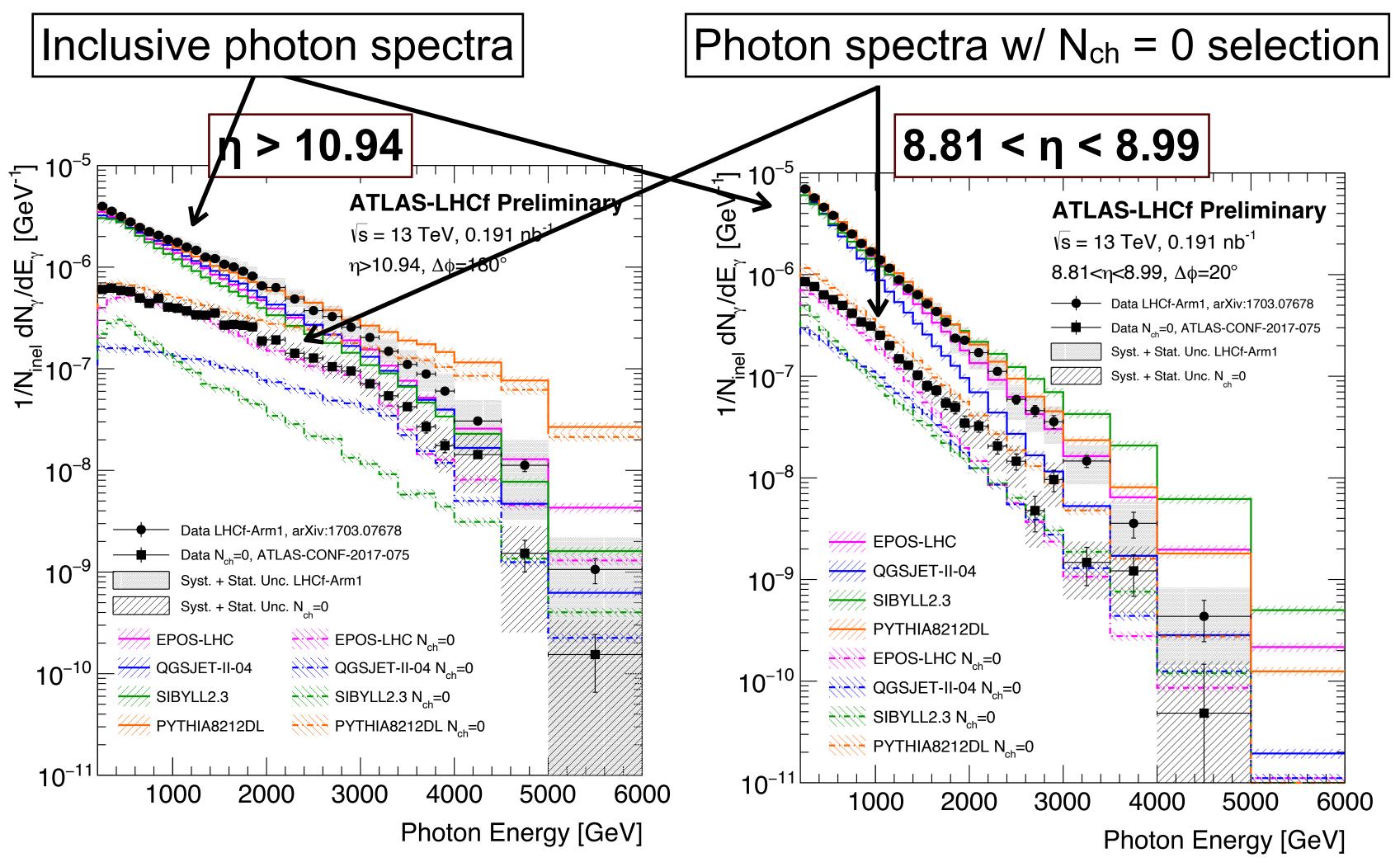
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ATLAS Measurement of contributions of diffractive processes to forward photon spectra in *pp* collisions at $\sqrt{s} = 13$ TeV

Preliminary result of the measurement for forward photons is published in a conference-note; ATLAS-CONF-2017-075

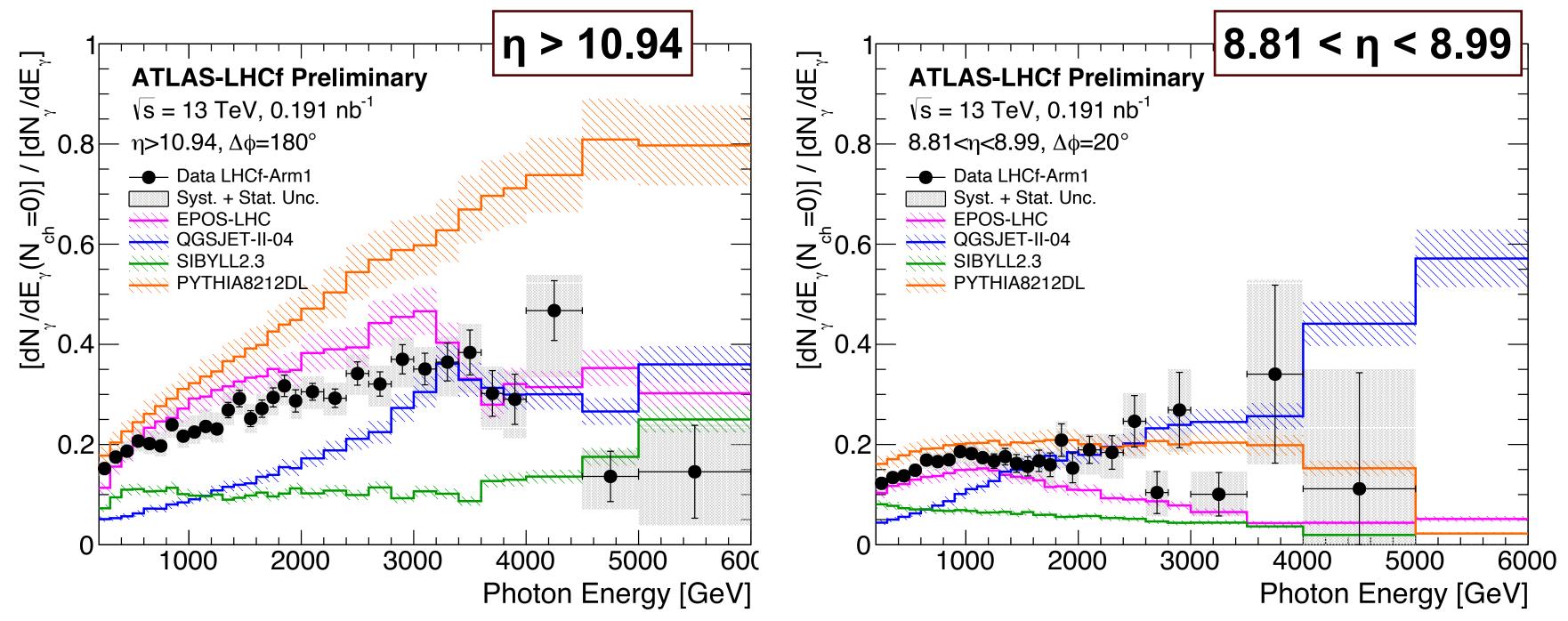


28-Feb.-2018



Measurement of contributions of diffractive processes to forward photon spectra in pp collisions at $\sqrt{s} = 13$ TeV

Ratio (N_{ch=0}/Inclusive)



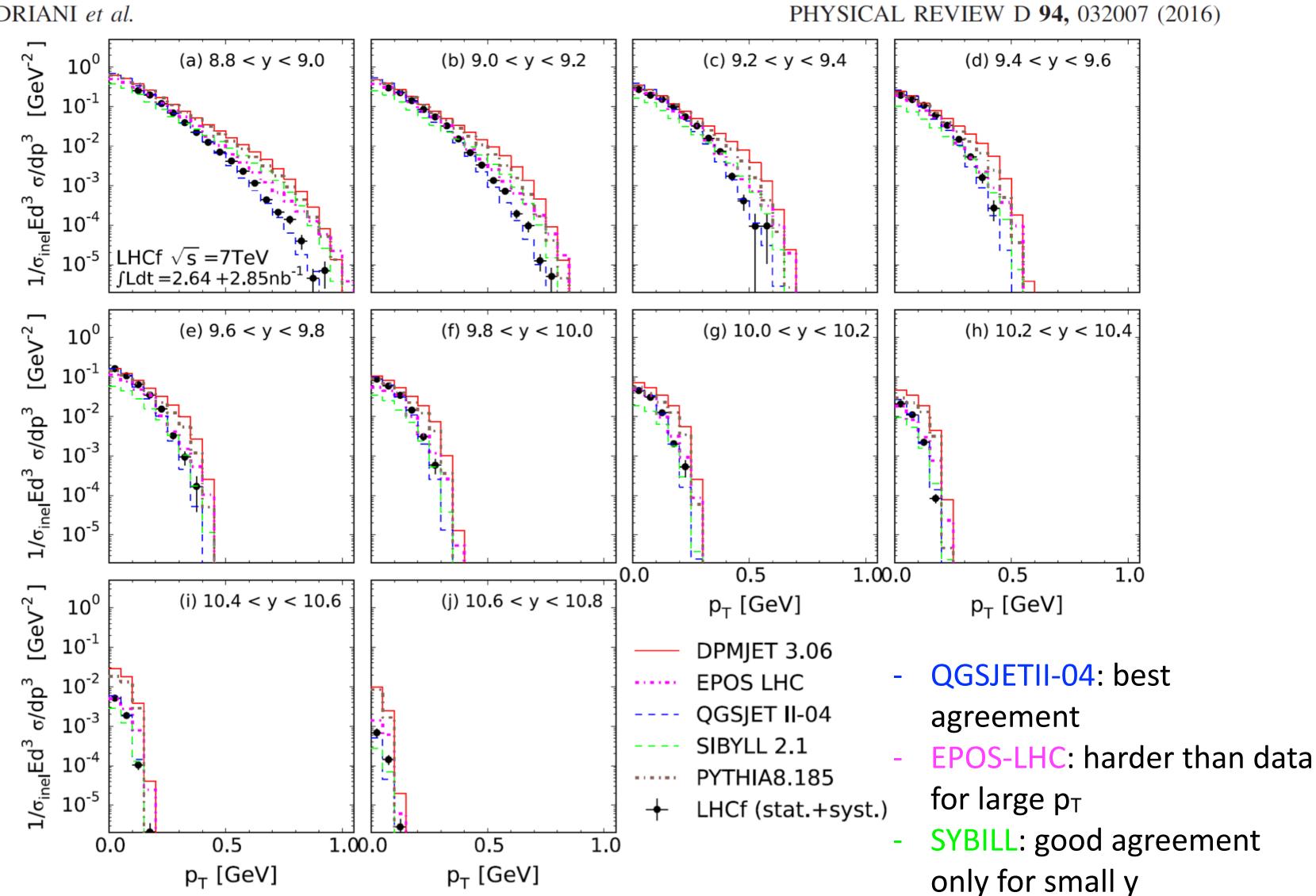
- At $\eta > 10.94$, the ratio of data increased from 0.15 to 0.4. with increasing of the photon energy up to 4TeV.
- PYTHIA8212DL predicts higher fraction at higher energies.
- SIBYLL2.3 show small fraction compare with data at $\eta > 10.94$.
- At 8.81 < η < 8.99, the ratio of data keep almost constant as 0.17.
- EPOS-LHC and PYTHIA8212DL show good agreement with data at 8.81 < η < 8.99.

28-Feb.-2018



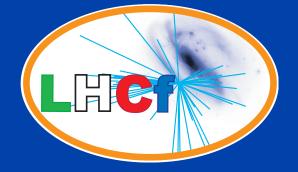
π^{0} pT spectra at p+p,7TeV

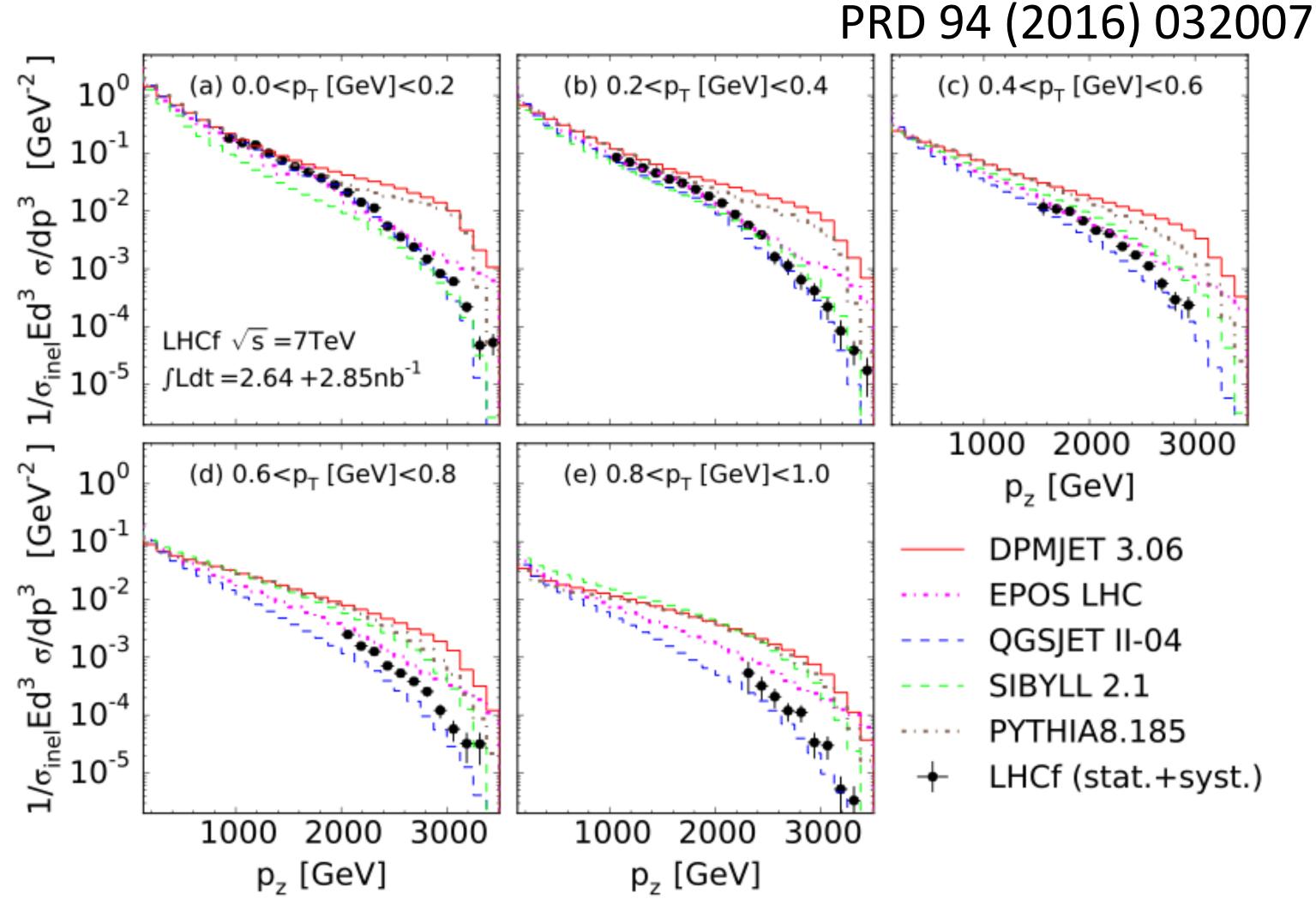
O. ADRIANI et al.





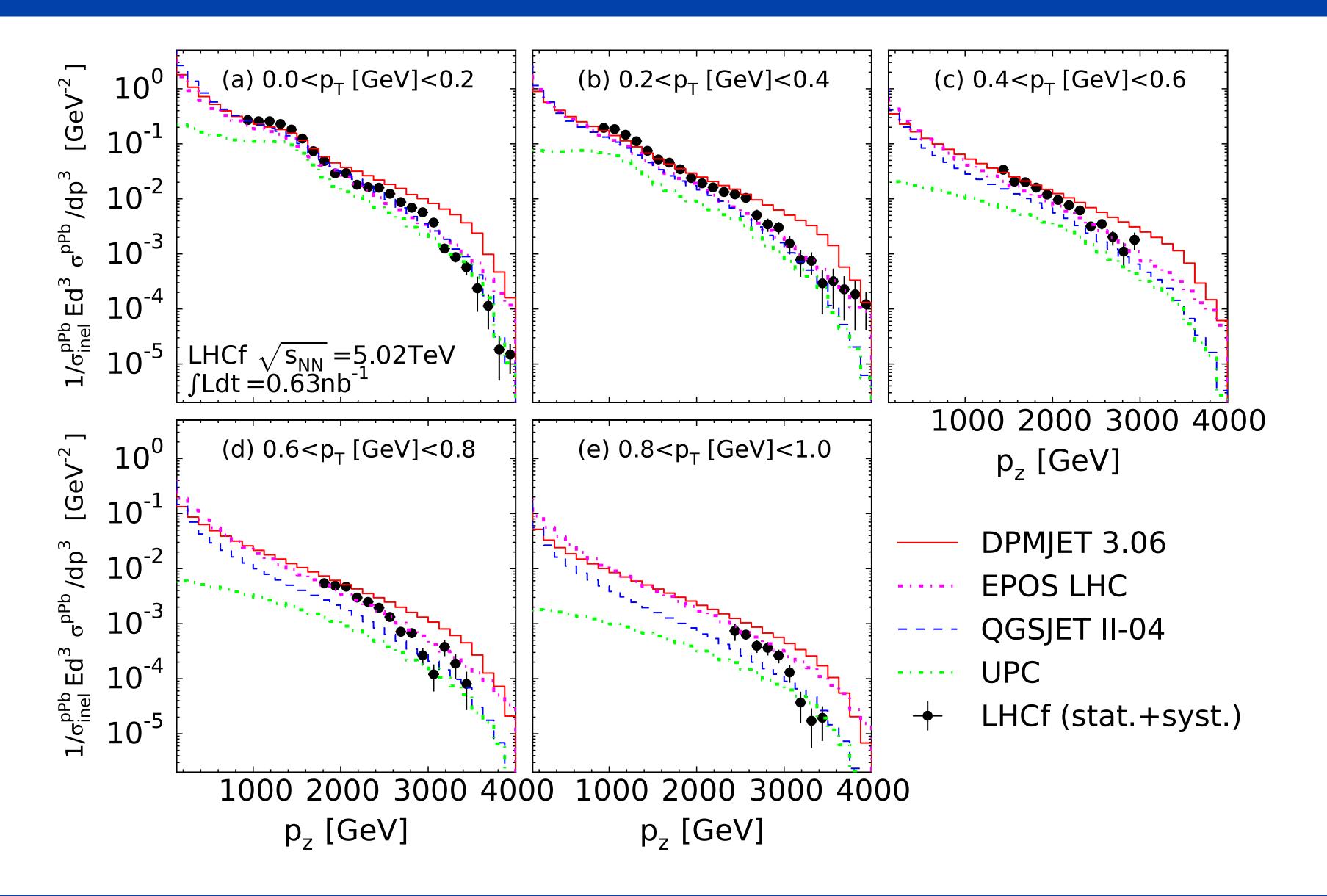
π^o pz (~E) spectra at p+p,7TeV

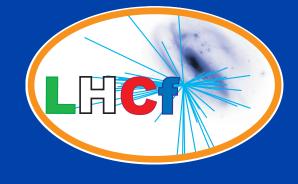




DPMJET and **Pythia** overestimate over all E-p_T range

π^o pz (~E) spectra at pPb,5TeV

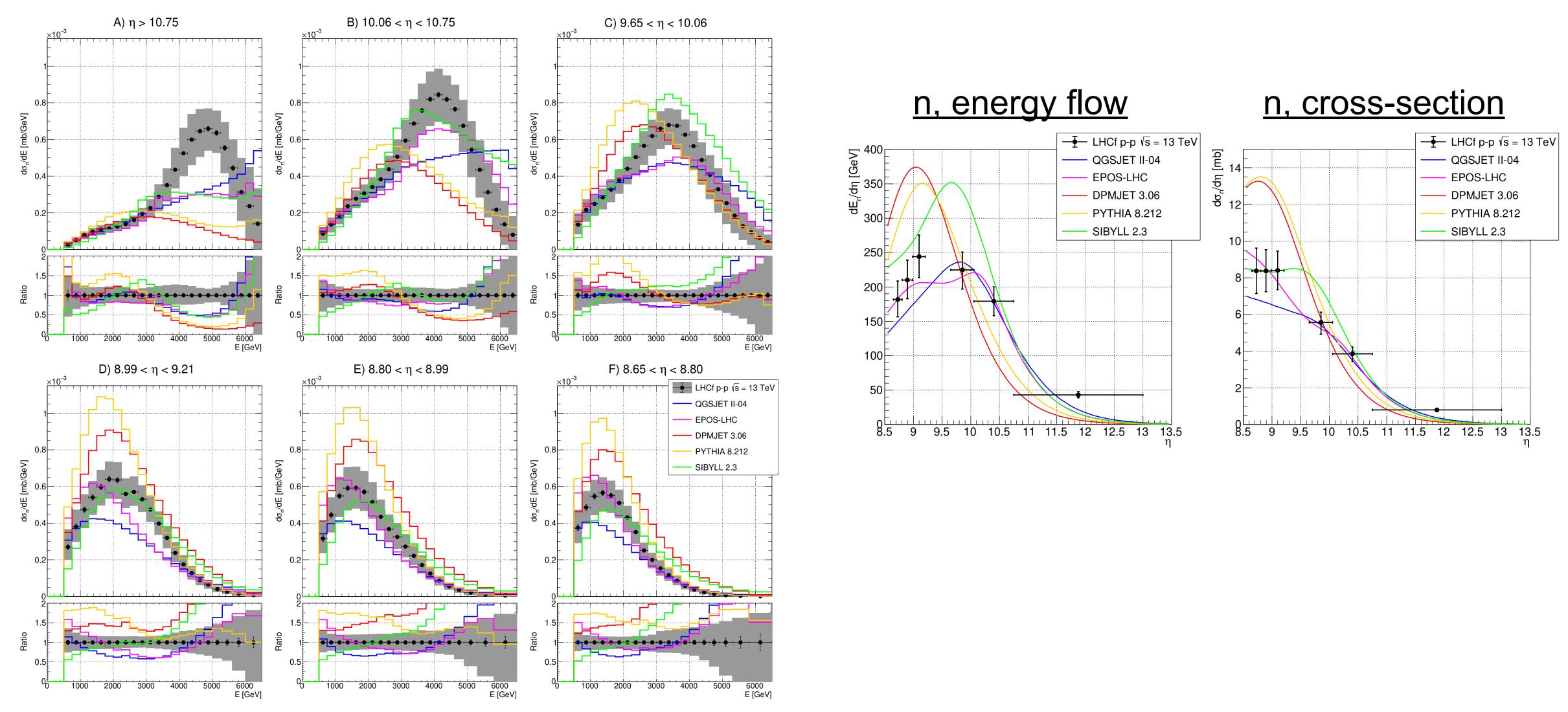




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neutron at pp, 13 TeV

n, differential cross-section for each psuedorapidity bin.



4-10 Feb. 2021

OO and pO





