

# L'esperimento LHCf

## Misura delle distribuzioni di energia e impulso trasverso delle particelle prodotte in avanti a LHC

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a nome della Collaborazione LHCf

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# The LHCf Collaboration



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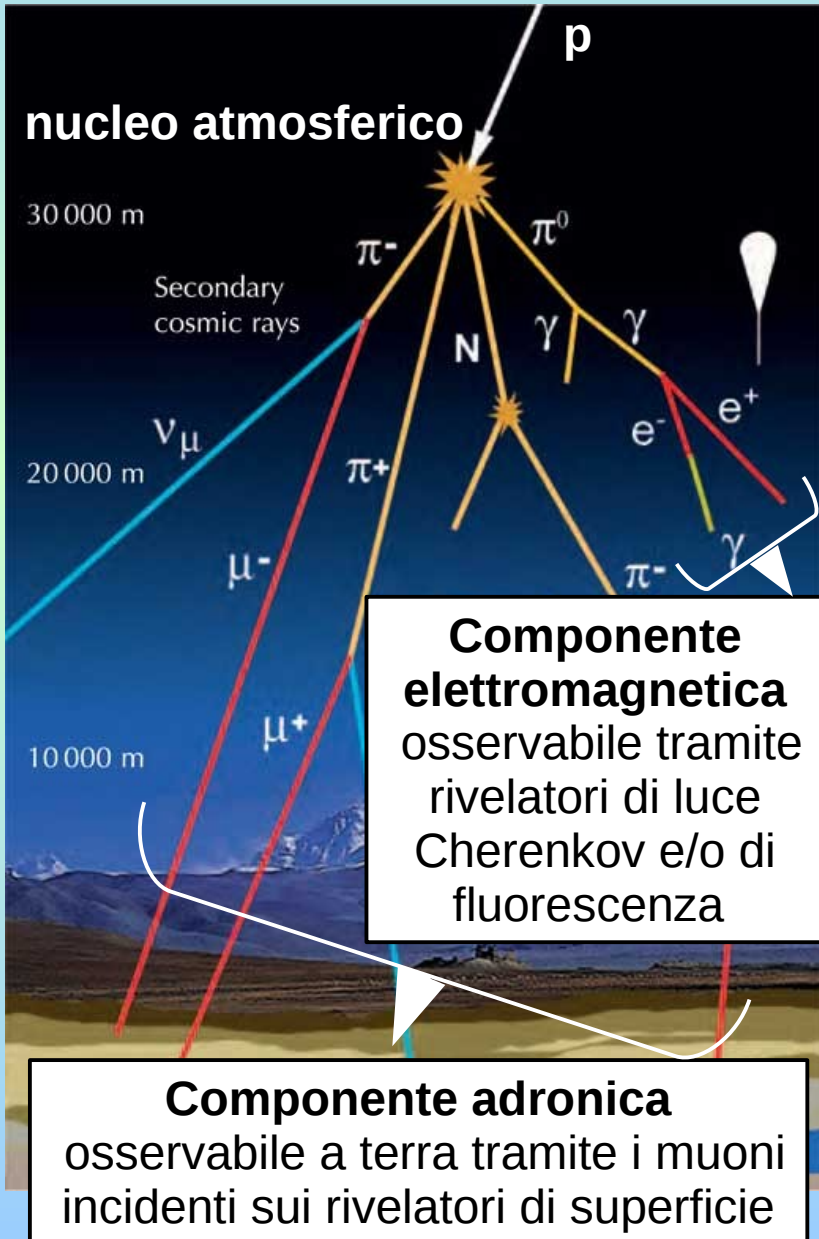
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# Ultra High Energy Cosmic Rays (UHECR)



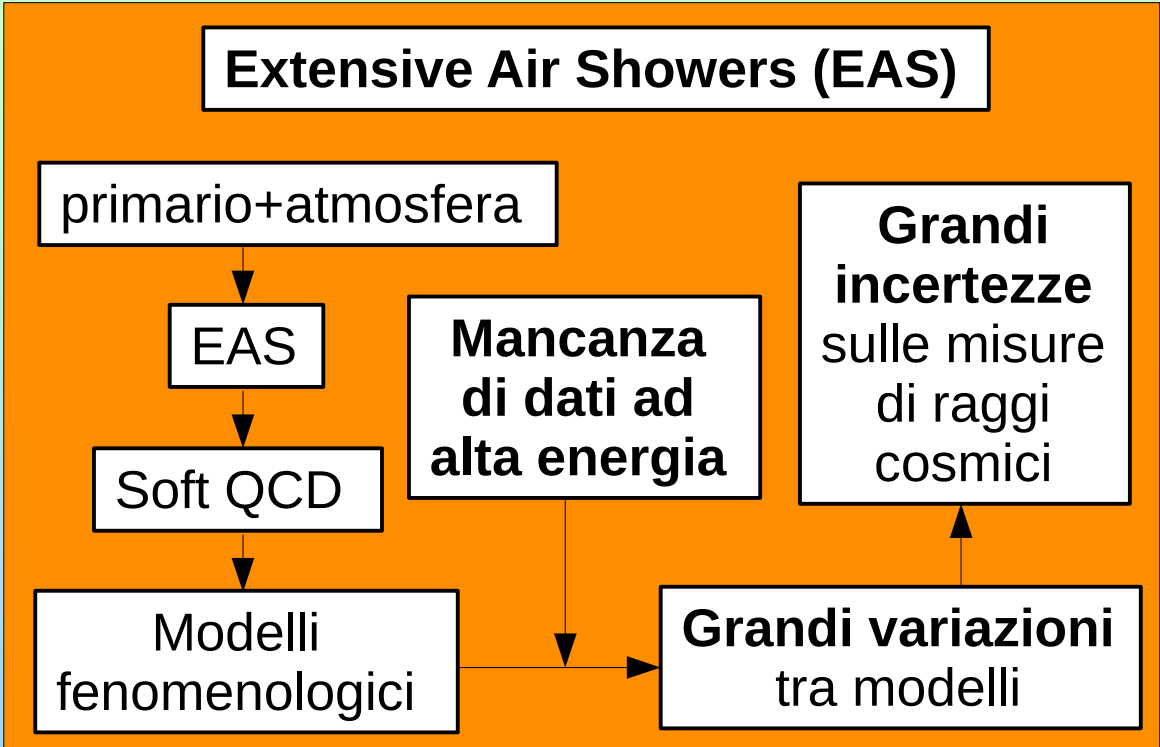
Gli **UHECR** sono i raggi cosmici di energia superiore a  $10^{18}$  eV

Flusso inferiore a 1 particella per  $\text{km}^2$  all'anno

**Misure indirette** tramite grandi apparati di rivelatori disposti a terra

**Componente elettromagnetica** osservabile tramite rivelatori di luce Cherenkov e/o di fluorescenza

**Componente adronica** osservabile a terra tramite i muoni incidenti sui rivelatori di superficie



# Calibrazione dei modelli

## Cosa misurare?

- **sezione d'urto** (TOTEM, ATLAS, CMS, ALICE)
- **molteplicità** (ATLAS, CMS)
- **distribuzioni di E e  $p_t$  nella forward region** e **inelasticità  $k = 1 - p_{\text{lead}}/p_{\text{beam}}$**  (LHCf)

## Perché LHC?

- misurare le **caratteristiche delle EAS** ad un'energia vicina a quella degli UHECR

Run p-p  $\sqrt{s}=14$  TeV  $\longrightarrow$   $10^{17}$  eV p su p a riposo

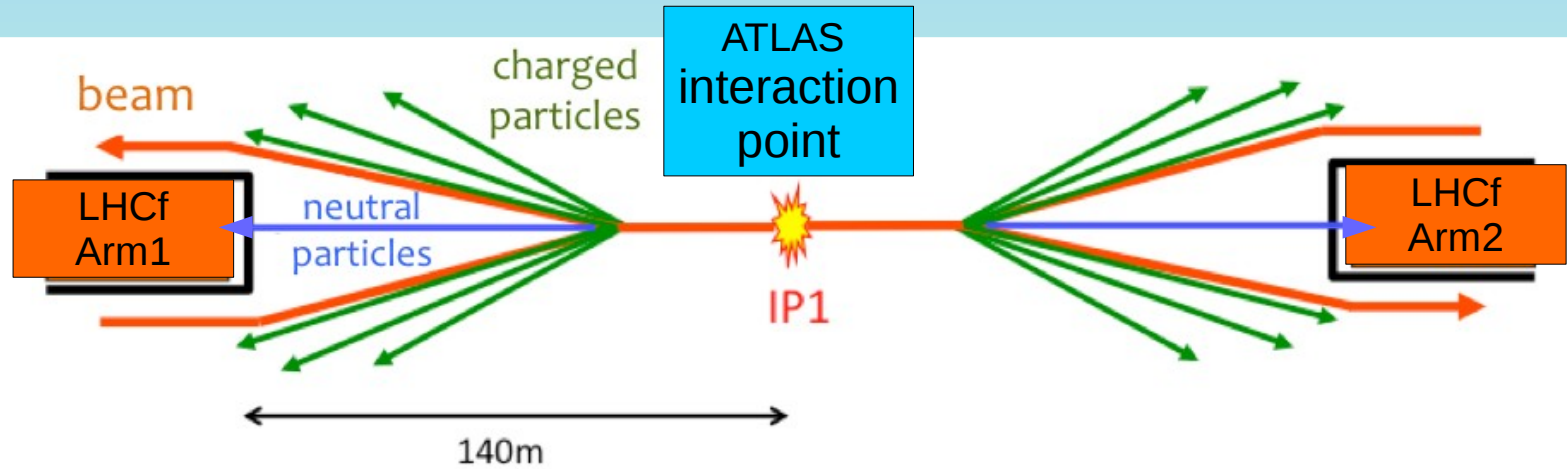
- verificare la validità di **leggi di scala** (Feynman scaling,  $\langle p_T \rangle$  scaling, limiting fragmentation) utili per estrapolare i parametri ad energie superiori a  $10^{17}$  eV

Run p-p  $\sqrt{s}=0.9, 2.76, 7, 13$  TeV

- studiare la dipendenza del rate di produzione delle particelle secondarie al variare del **numero di nucleoni del bersaglio**

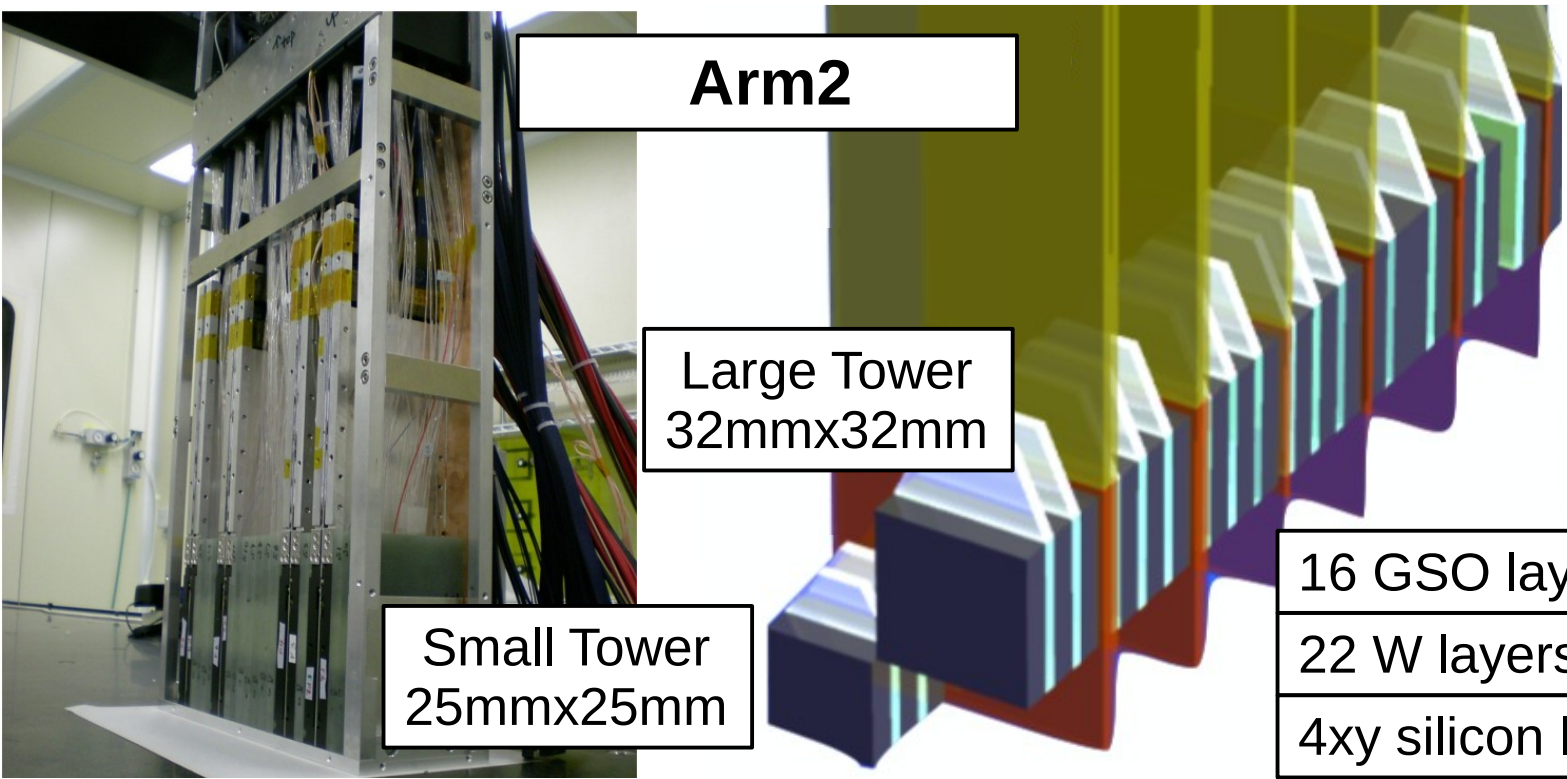
Run p-p, p-Pb

# L'esperimento LHCf



Rivelazione delle particelle neutre prodotte in avanti ( $\eta > 8.4$ )

- fotoni
- $\pi^0$  ( $\pi^0 \rightarrow 2\gamma$ )
- neutroni



$\sigma_{\text{pos}} : \sim 40 \text{ mm}$

$\sigma_E/E$ :

- <5% per  $\gamma$
- $\sim 40\%$  per h

# Distribuzione di energia dei neutroni

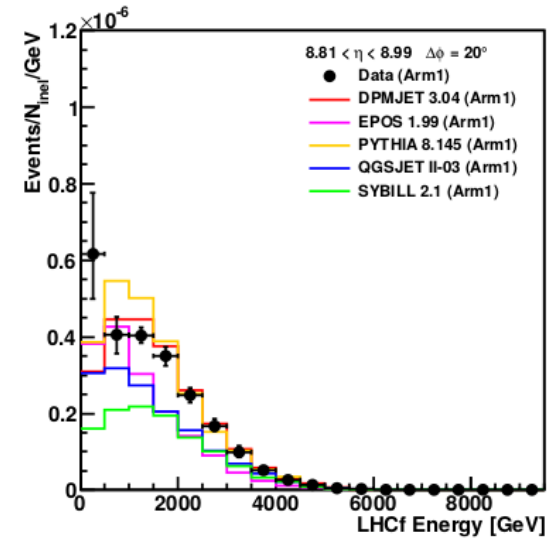
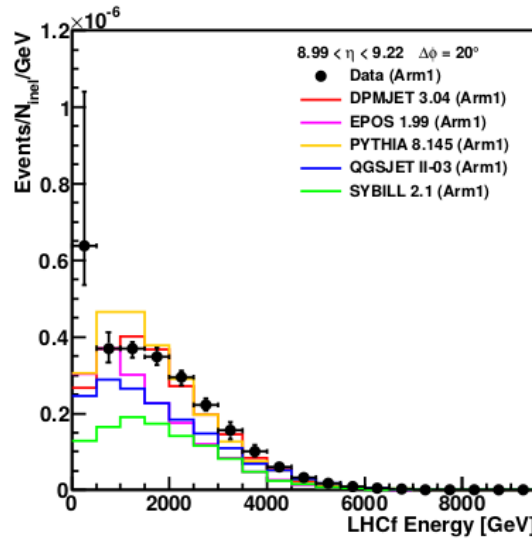
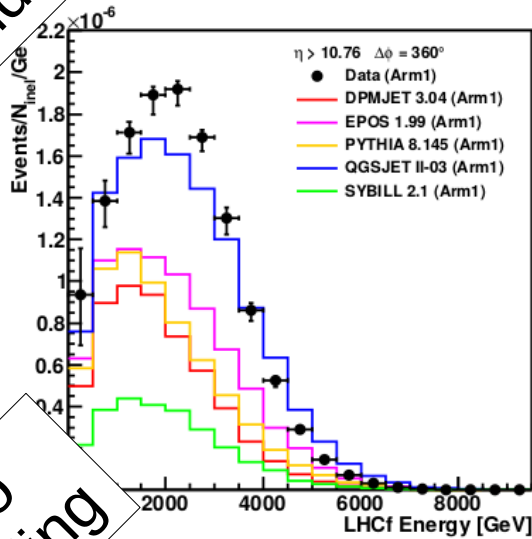
## p-p $\sqrt{s} = 7$ TeV

Prima di unfolding

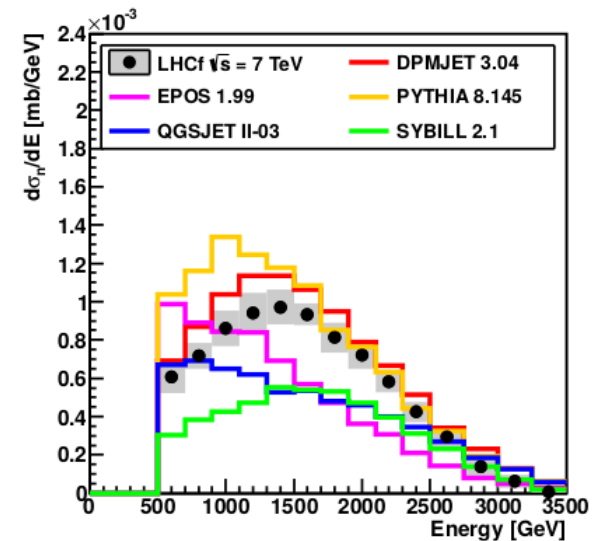
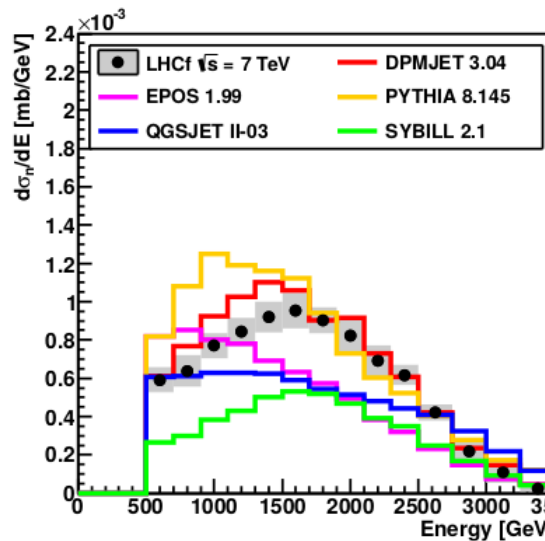
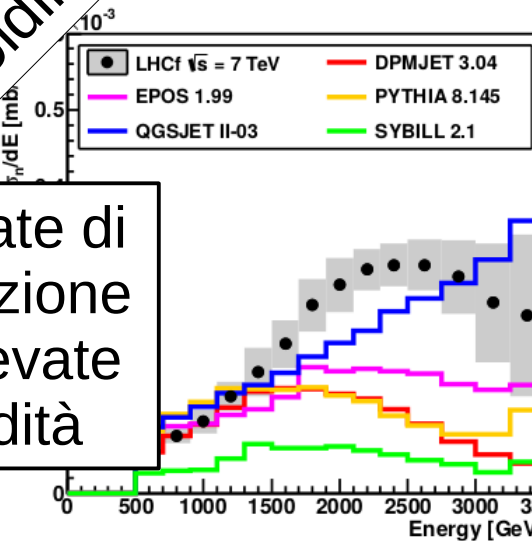
$\eta > 10.76$

$8.99 < \eta < 9.22$

$8.81 < \eta < 8.99$



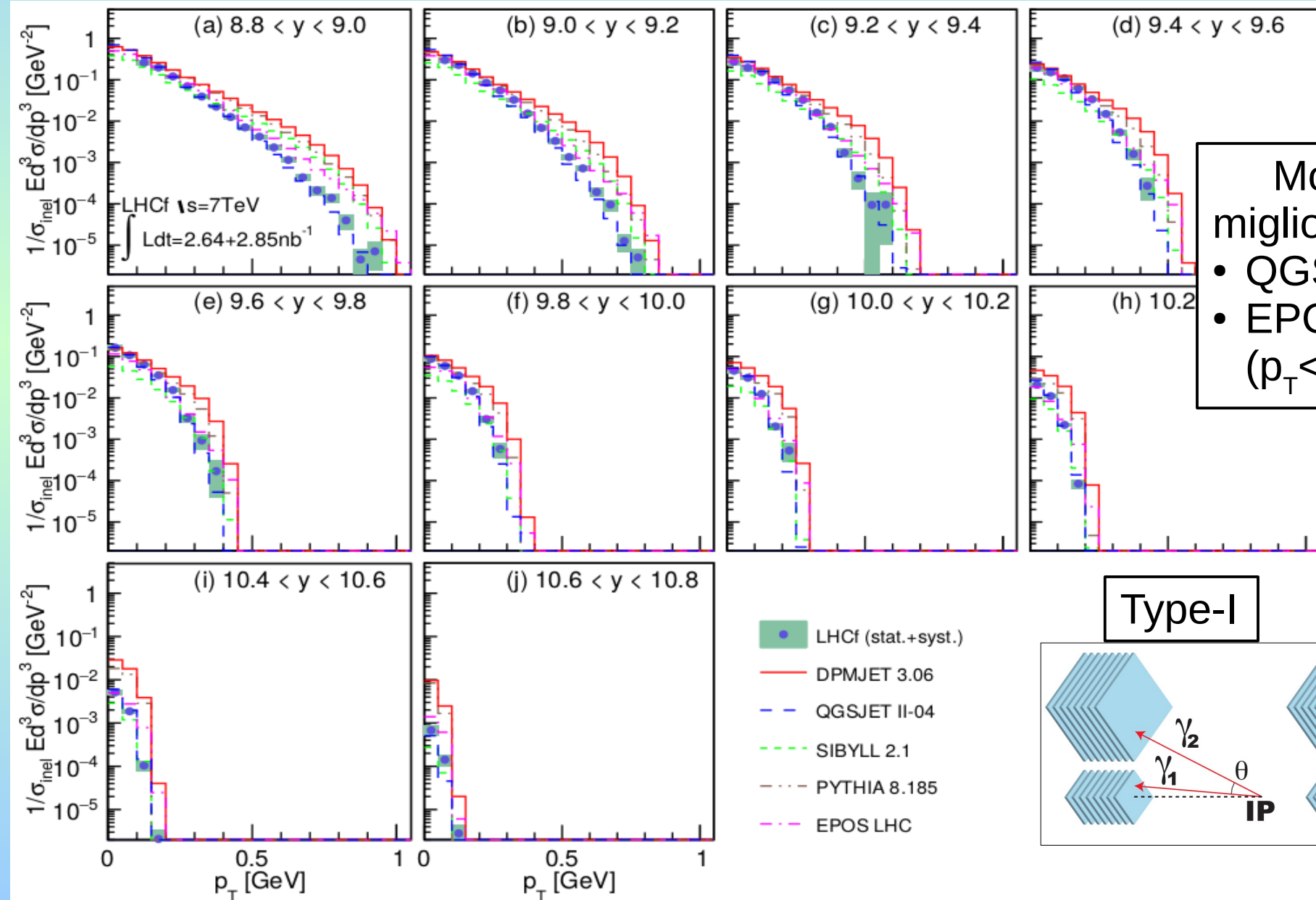
Dopo unfolding



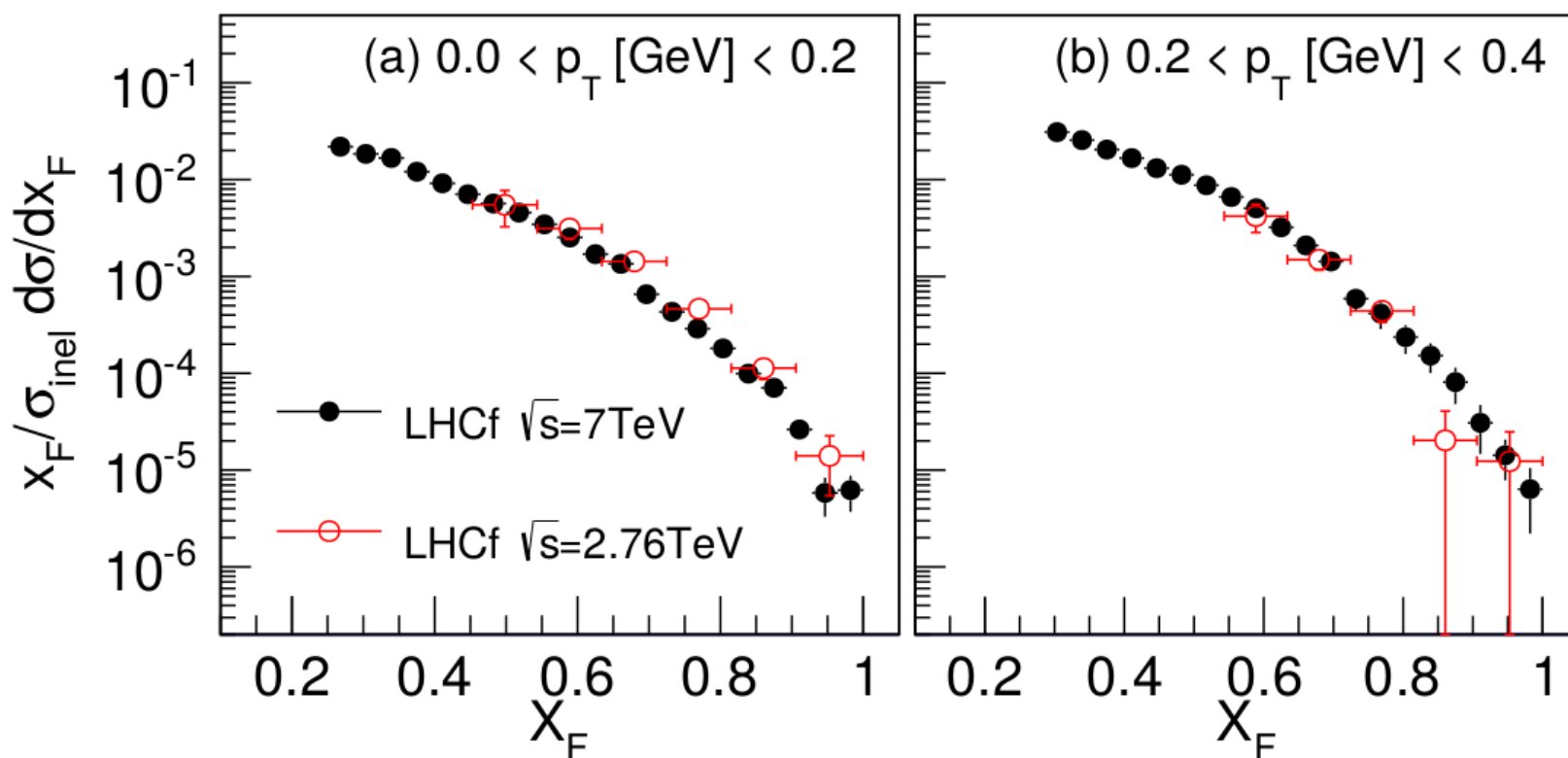
Alto rate di produzione ad elevate rapidità

# Distribuzione di $p_T$ dei $\pi^0$

## p-p $\sqrt{s} = 7$ TeV



# Feynman scaling ed altre leggi di scala



**Feynman scaling**  
 la sezione d'urto di produzione espressa in funzione della variabile  $x_F$  è indipendente da  $\sqrt{s}$

$$x_F = 2p_z / \sqrt{s}$$

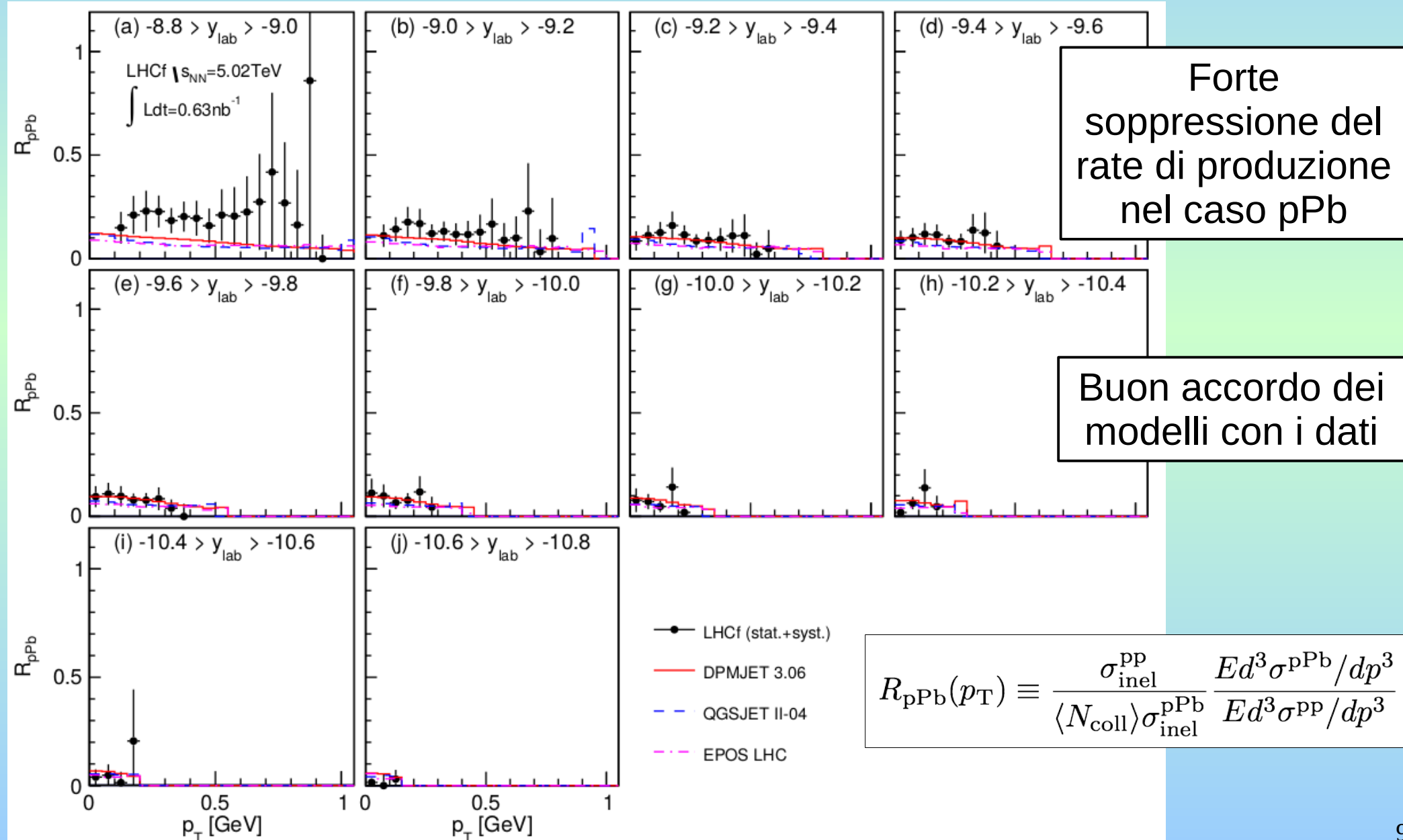
## Validità delle leggi di scala verificate da LHCf

- **<math>\langle p\_T \rangle</math> scaling**  $\pm 10\%$
- **limiting fragmentation**  $\pm 15\%$
- **Feynman scaling**  $\pm 20\%$

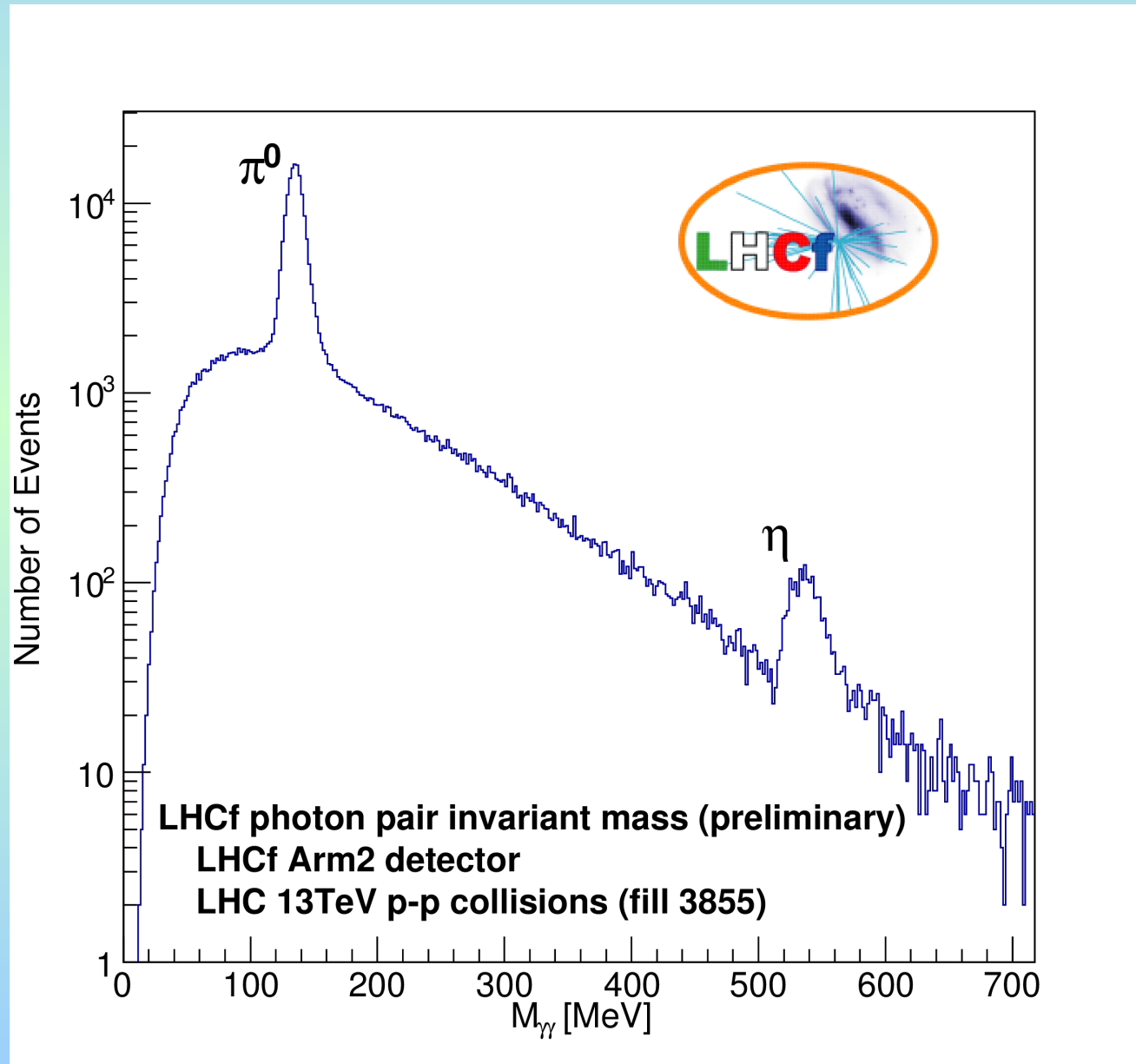
Buona validità  
delle leggi di scala



# Nuclear modification factor

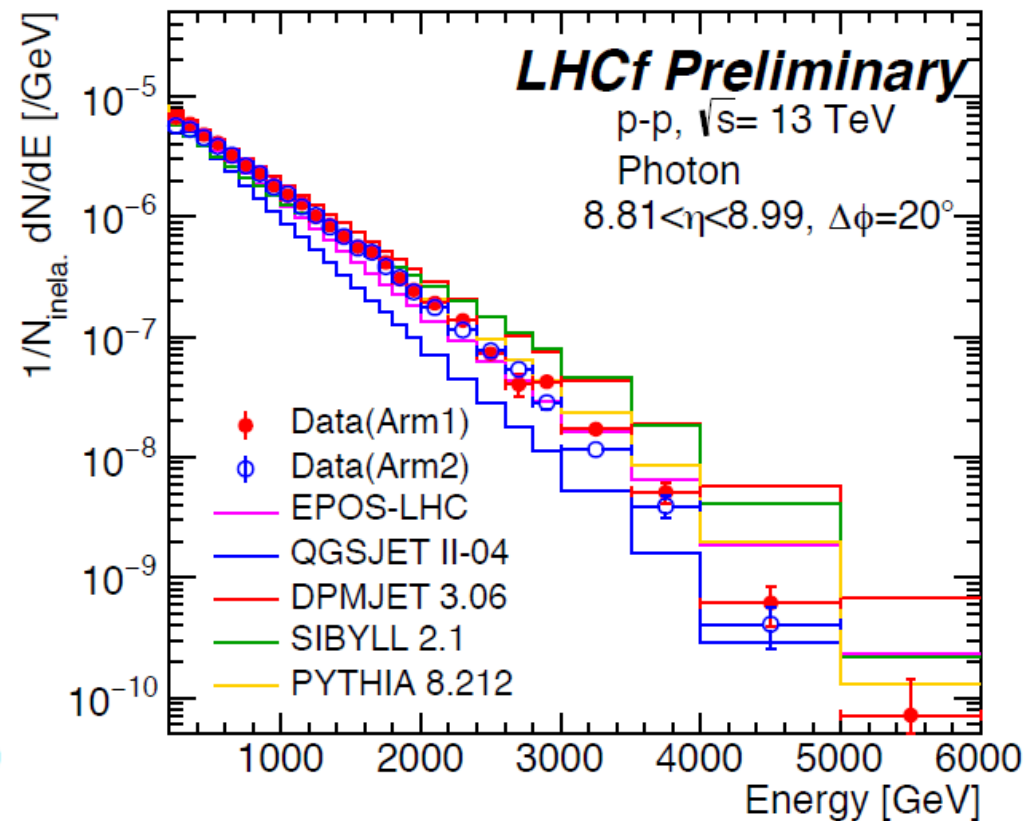
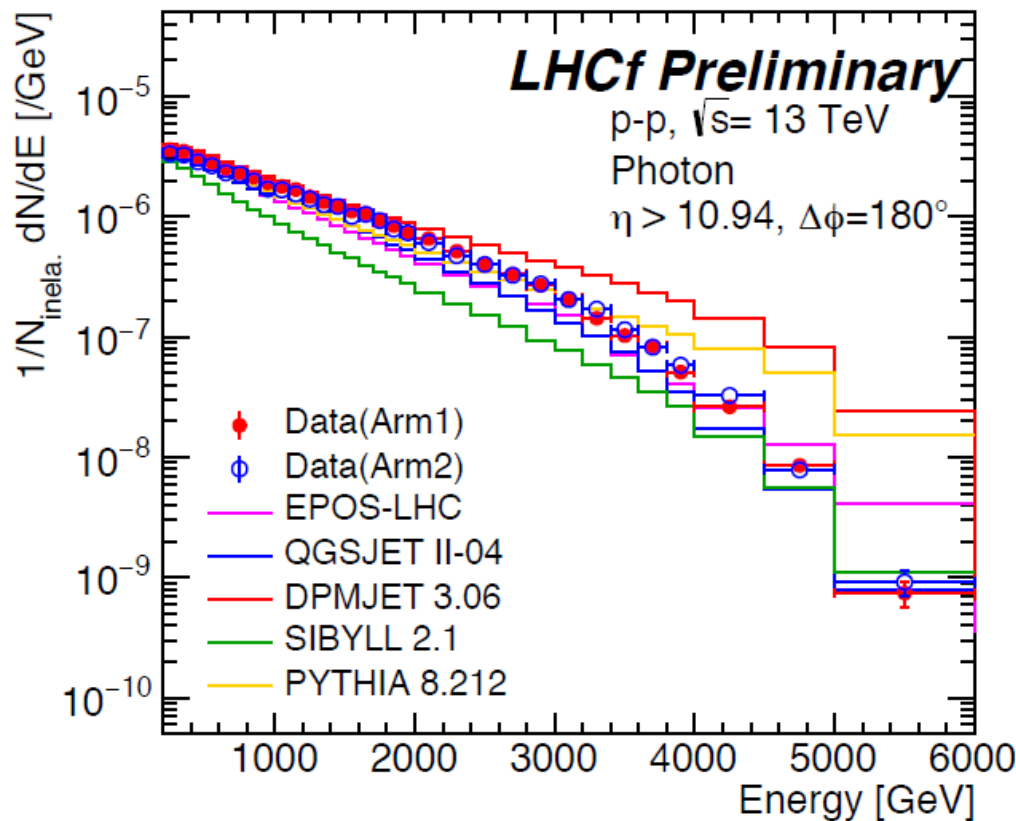


# Plot preliminari p-p $\sqrt{s} = 13$ TeV massa invariante $M_{\gamma\gamma}$



# Plot preliminari p-p $\sqrt{s} = 13$ TeV

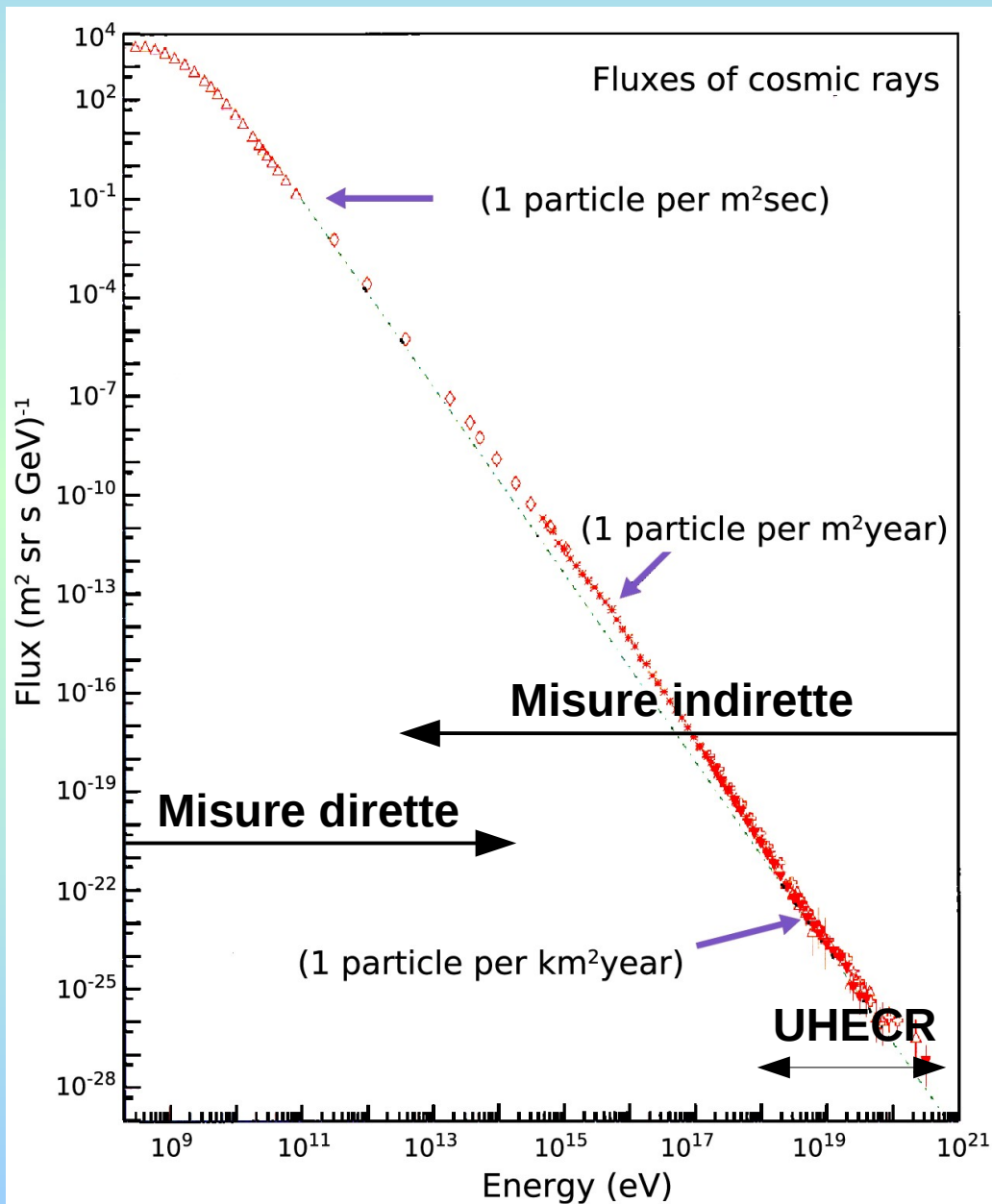
## Distribuzioni di energia dei fotoni



Error bars show only the statistical errors.

Back Up

# La fisica dei raggi cosmici



## Obiettivo

Verifica dei modelli di accelerazione e propagazione dei raggi cosmici

Misure accurate di flusso e composizione in funzione dell'energia

**Misure dirette**  
(palloni stratosferici e satelliti)

**Misure indirette**  
(grandi apparati sulla superficie terrestre)

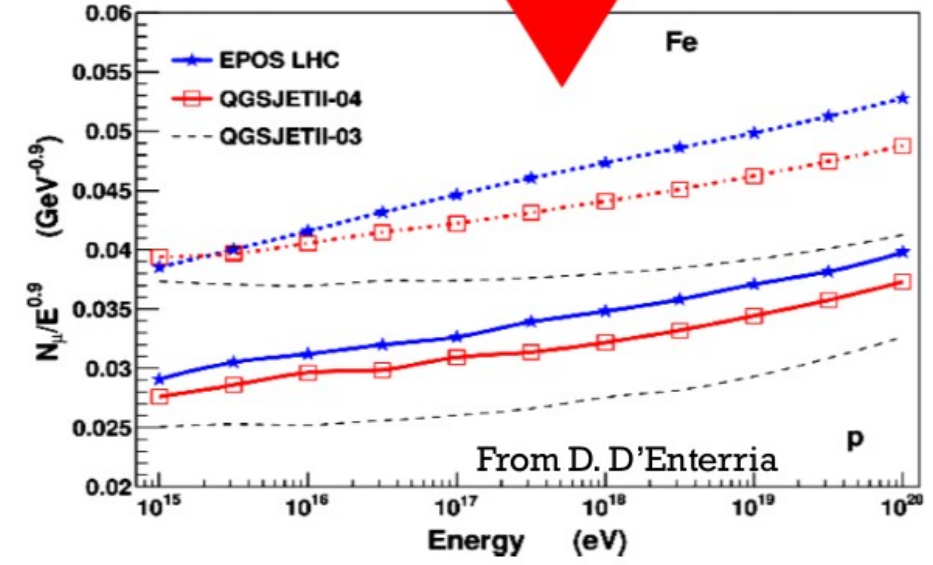
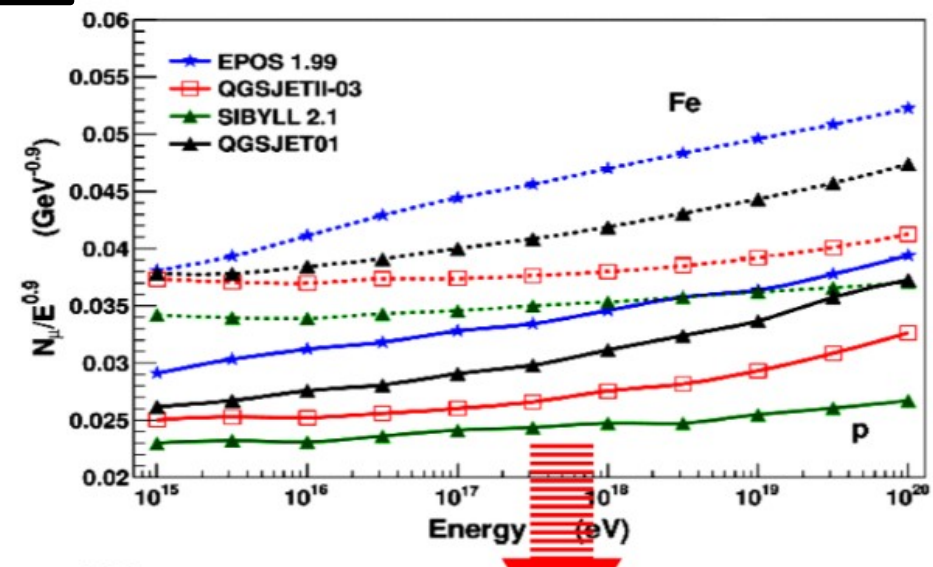
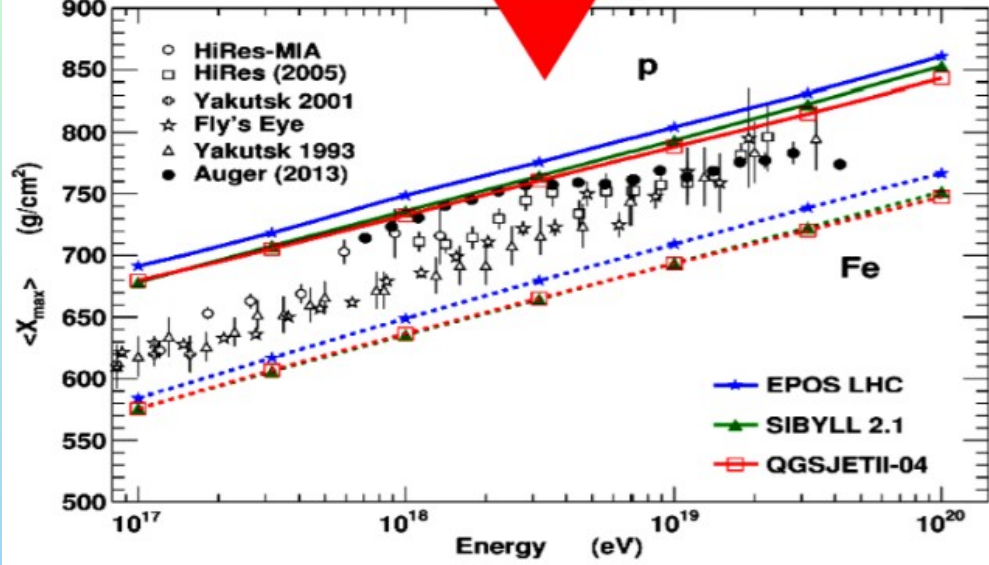
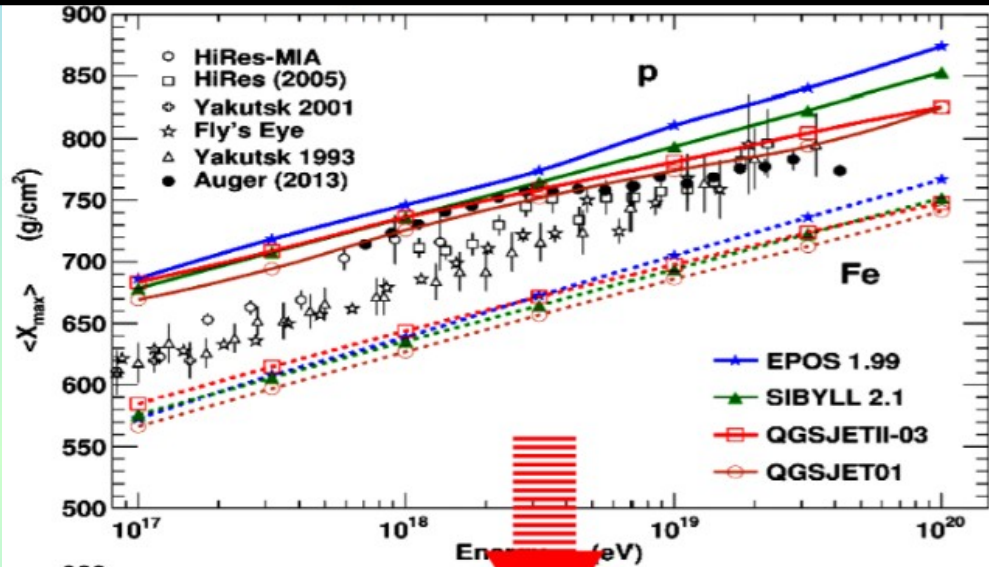
# Componente elettromagnetica

Profondità media attraversata dallo sciame a cui il numero di particelle è massimo

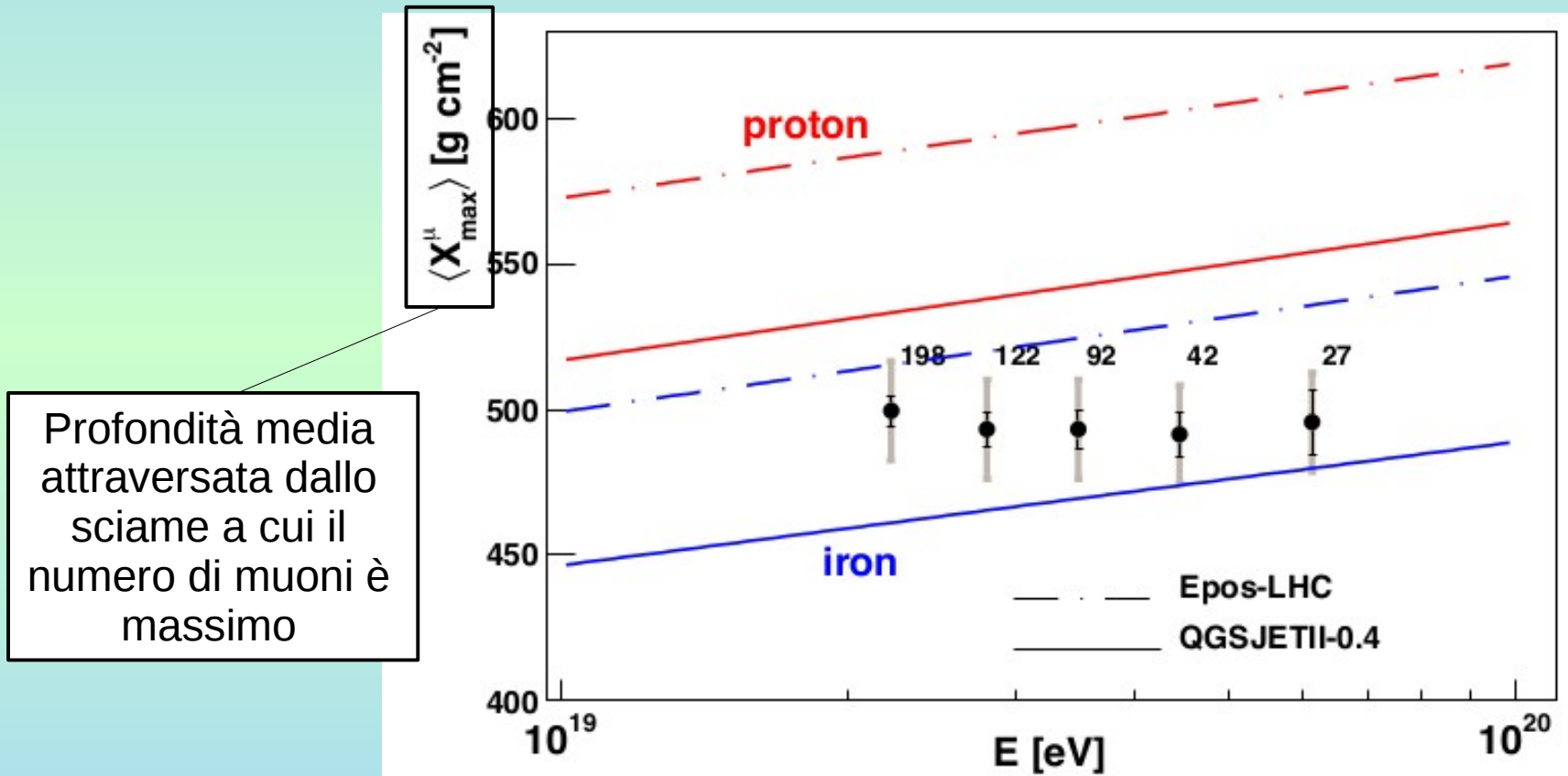
Numero di muoni a terra

Pre-LHC

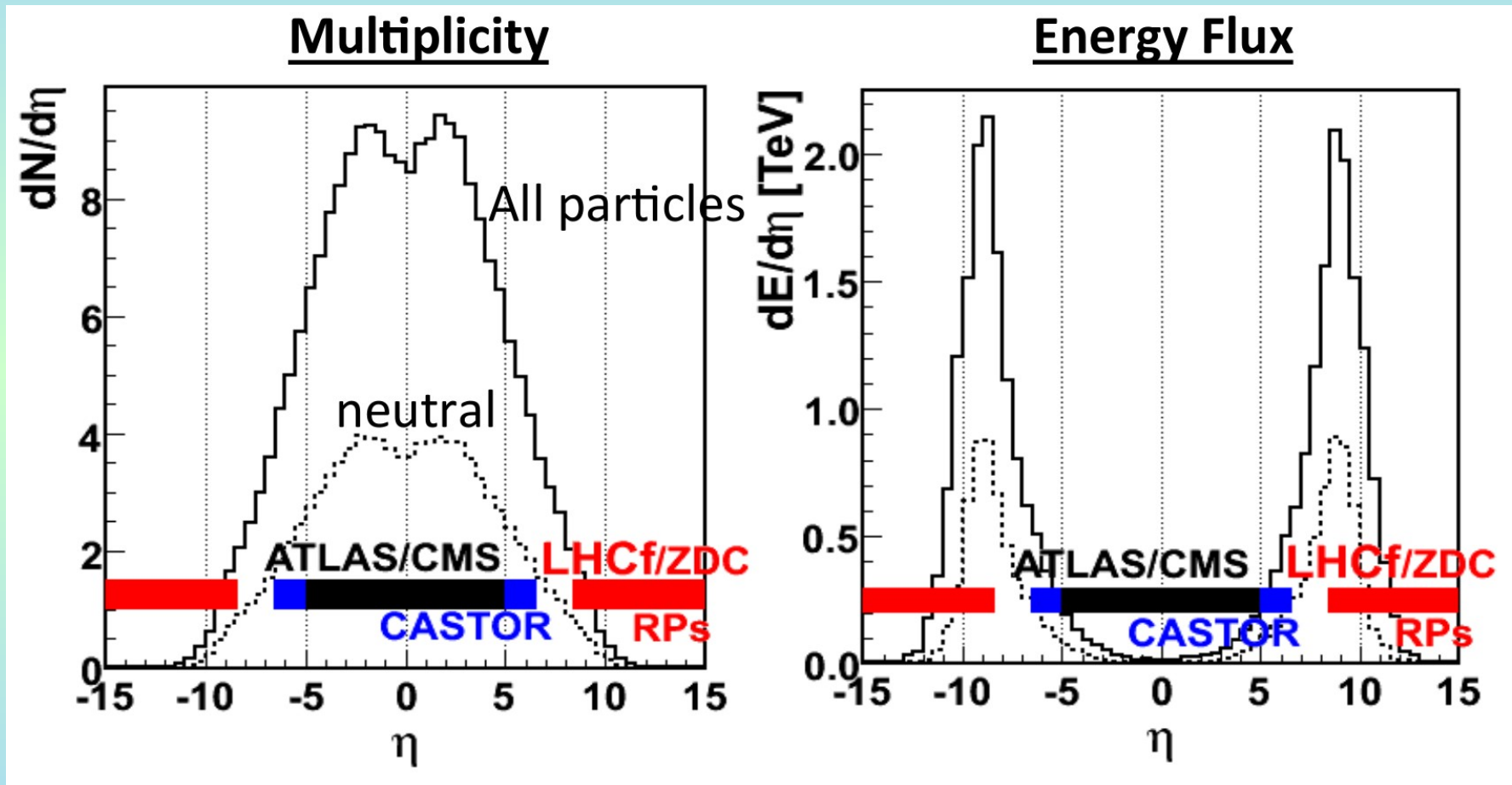
Post-LHC



# Componente muonica

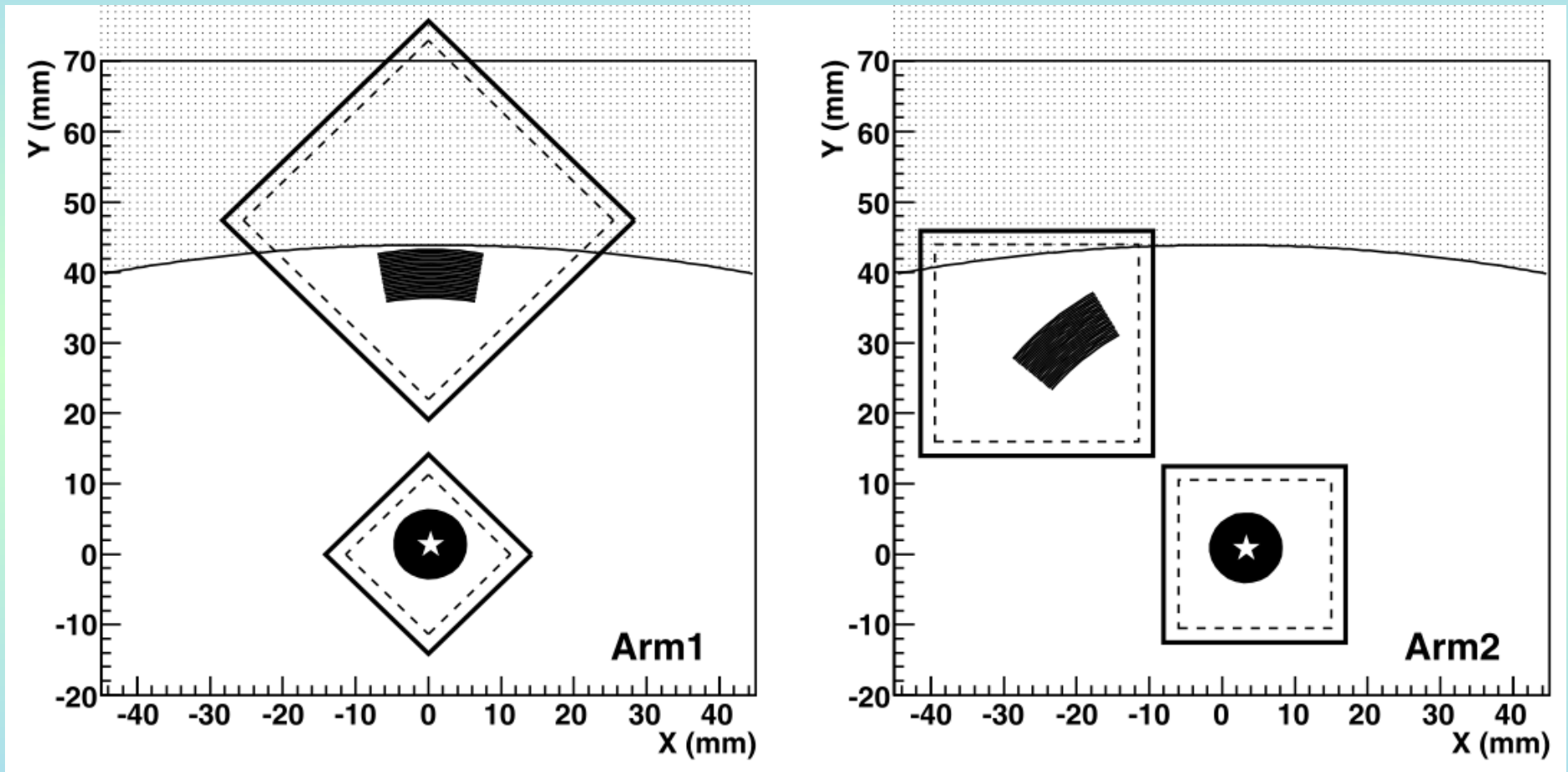


# Flusso di energia a LHC





# Disposizione dei rivelatori di LHCf



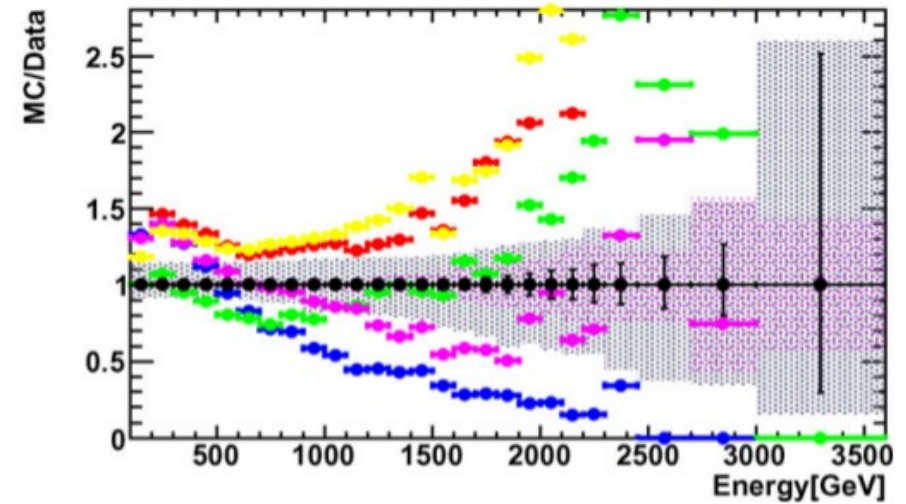
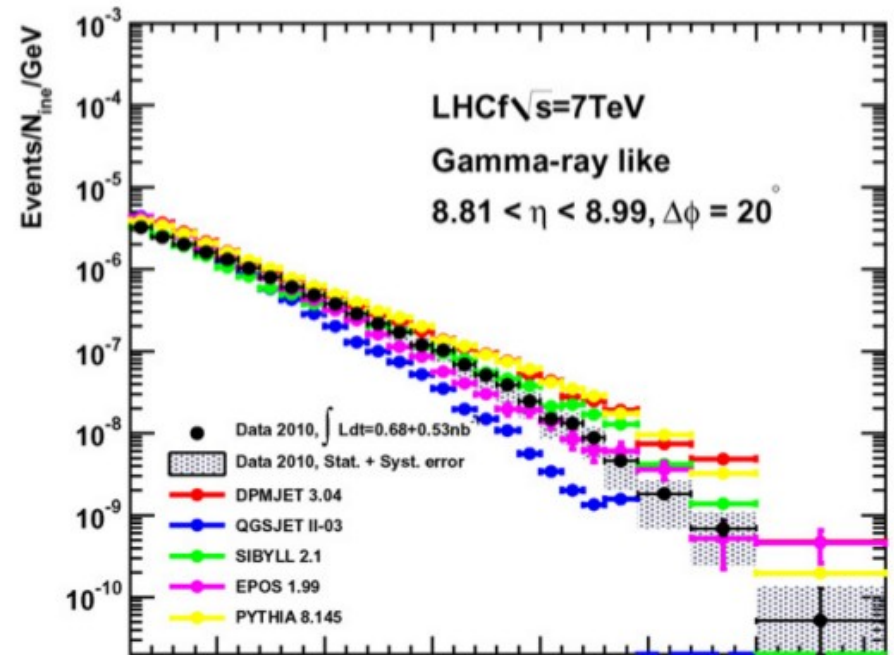
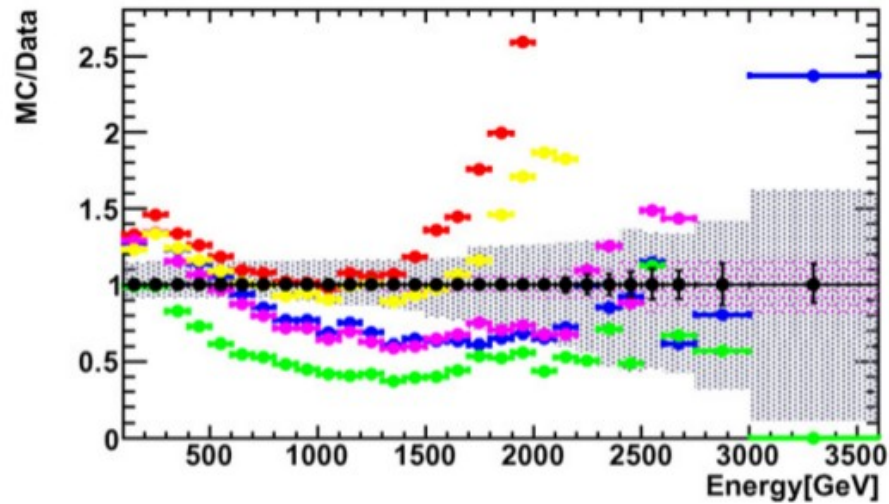
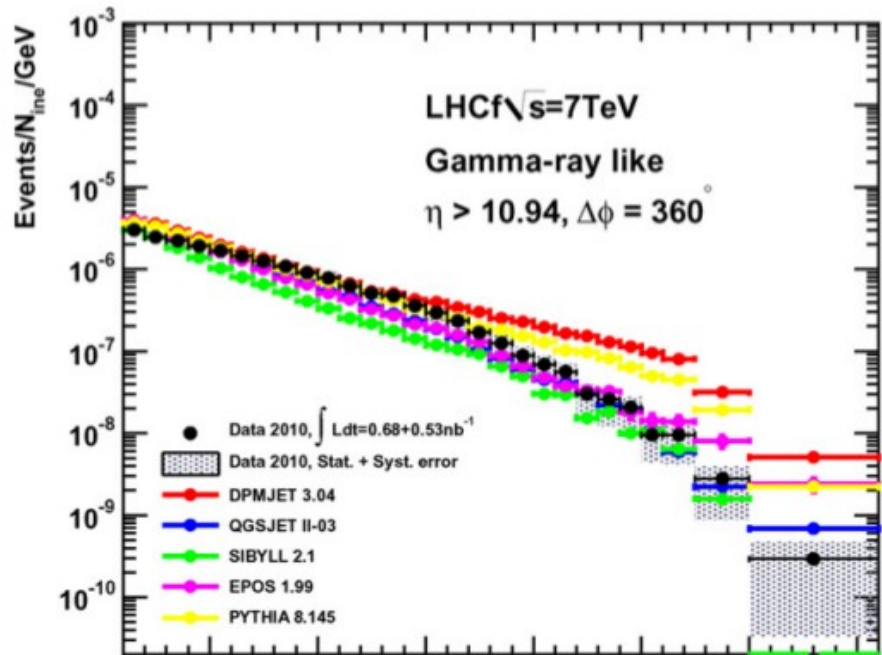
# Risultati pubblicati

	Proton equivalent energy in LAB (eV)	$\gamma$	n	$\pi^0$
<b>SPS test beam</b>		NIM A, 671, 129 (2012)	JINST 9 P03016 (2014)	
<b>p+p 900 GeV</b>	$4.3 \times 10^{14}$	Phys. Lett. B 715, 298 (2012)		
<b>p+p 7 TeV</b>	$2.6 \times 10^{16}$	Phys. Lett. B 703, 128 (2011)	Phys. Lett. B 750 (2015) 360-366	Phys. Rev. D 86, 092001 (2012) + Submitted to Phys. Rev. D (Type-II)
<b>p+p 2.76 TeV</b>	$4.1 \times 10^{15}$			Phys. Rev. C 89, 065209 (2014) + Submitted to Phys. Rev. D (Type-II)
<b>p+Pb 5.02 TeV</b>	$1.4 \times 10^{16}$			Submitted to Phys. Rev. D (Type-II)
<b>p+p 13 TeV</b>	$9.0 \times 10^{16}$	Data taken in June 2015 after the restart of LHC Analysis is on-going		
<b>p+Pb 8.1 TeV</b>	$3.6 \times 10^{16}$	Letter of Intent just submitted to the LHC Committee...		

Presa dati comune LHCf + ATLAS

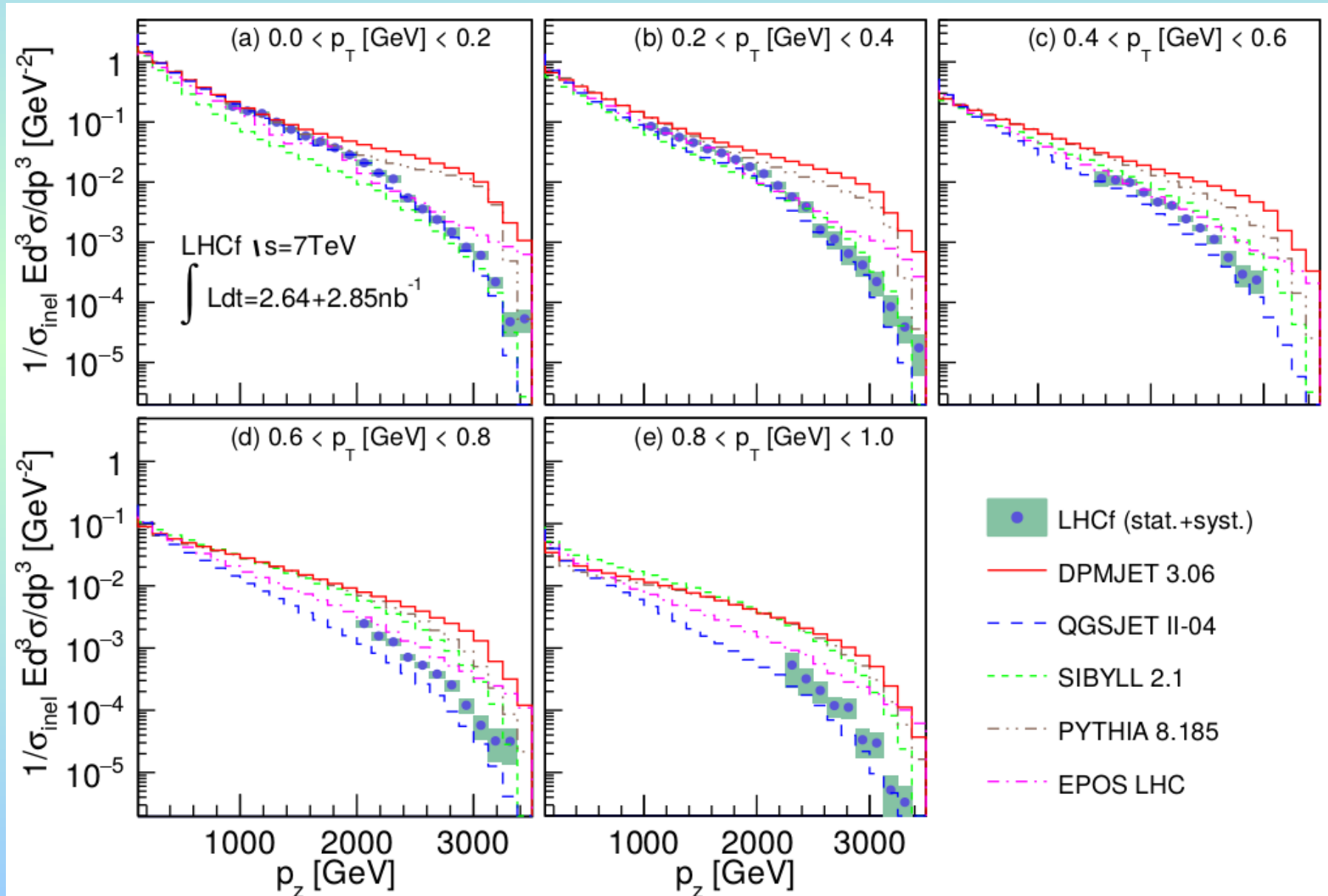
# Distribuzione di energia dei fotoni

## p-p $\sqrt{s} = 7$ TeV



# Distribuzione di $p_z$ dei $\pi^0$

## p-p $\sqrt{s} = 7$ TeV



# Plot preliminari p-p $\sqrt{s} = 13$ TeV Type-I $\pi^0$ event



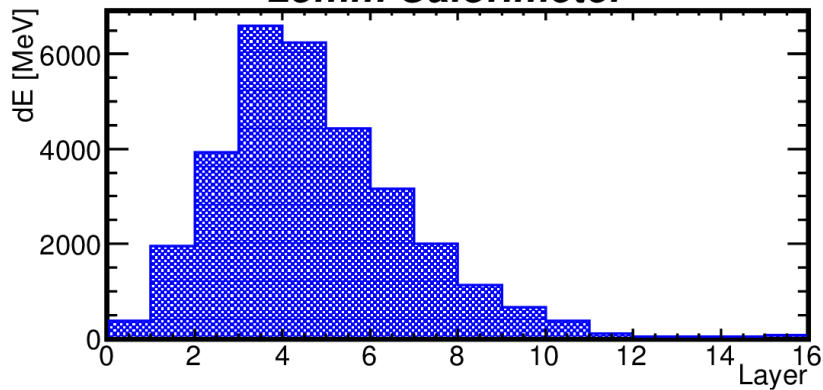
LHCf Arm2 Detector

$\pi^0$  Candidate Event

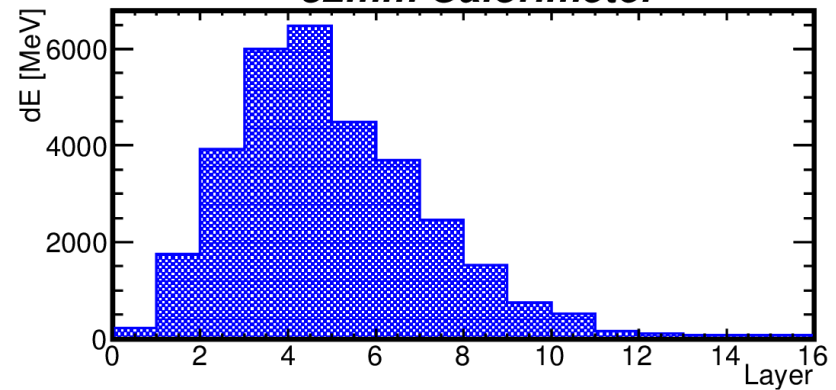
LHC p-p,  $\sqrt{s} = 13$  TeV Collisions

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

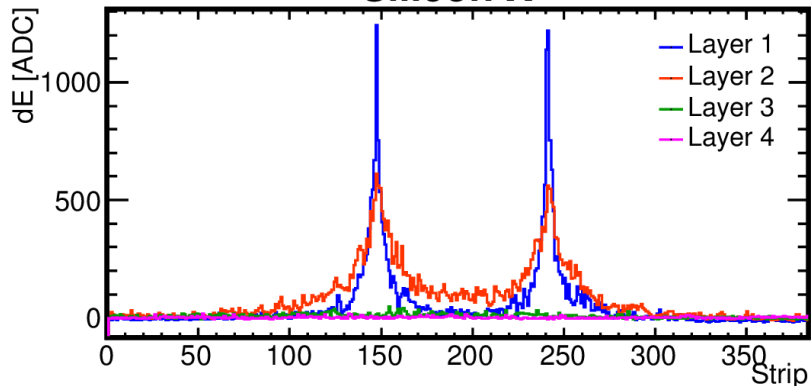
*25mm Calorimeter*



*32mm Calorimeter*



*Silicon X*



*Silicon Y*

