Preliminary measurement of the forward η meson production cross section in p-p collisions at $\sqrt{s}$=13 TeV with the LHCf Arm2 detector

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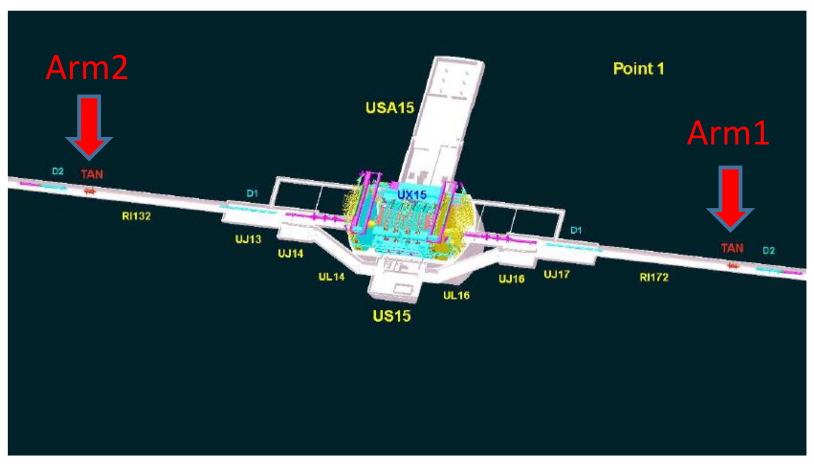
1. INTRODUCTION AND MOTIVATION

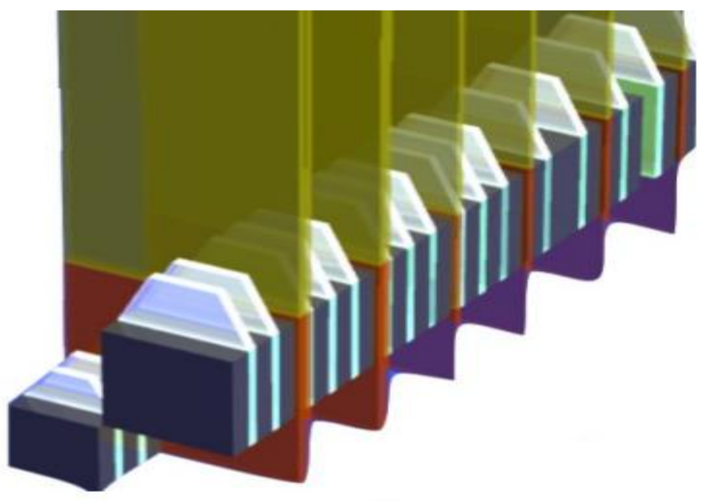
In the past years, cosmic ray air shower experiments, like the **Pierre Auger Observatory** and the **Telescope Array**, have contributed to fundamental progress in the knowledge of **ultra-high energy cosmic rays** (**UHECR**). However, despite this significant improvement , the results are still largely affected by uncertainties since they are sensitive to the choice of the **hadronic interaction model** used for the data analyses. The current measurements leave several open questions on the nature of UHECRs, mainly relative to their **acceleration mechanisms** and **mass composition** at high energies. The purpose of the **LHC-forward** (**LHCf**) experiment is to tune and test the main hadronic interaction models, thank to excellent performance of this experimental apparatus, composed by two sampling calorimeters, called **Arm1** and **Arm2**, located at about 140 m from the LHC interaction point 1 (IP1), with a pseudorapidity coverage of $|\eta| > 8.4$. The model tests are performed by detecting the forward neutral particle production in proton-proton and proton-ion collisions.

2. ARM2 DETECTOR

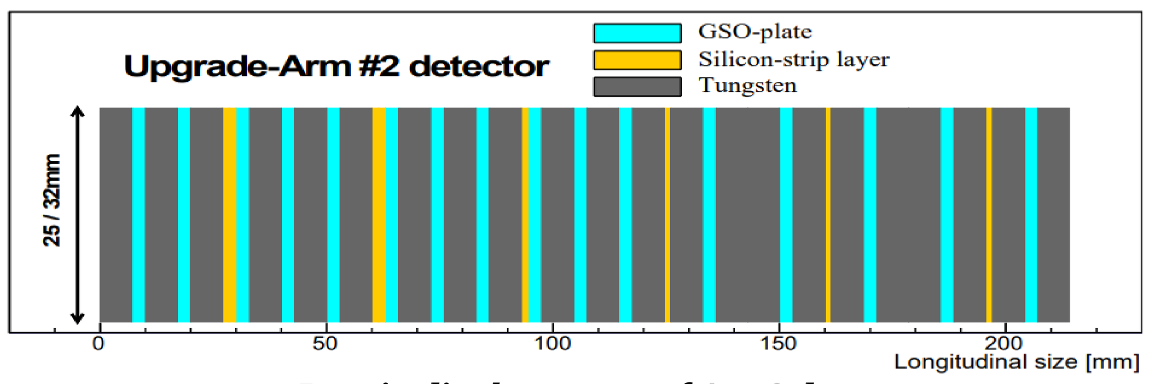
- **Arm2** consists of two calorimetric towers made by **16 Gd_2SiO_5** (**GSO**) **scintillator layers** interleaved with **22 tungsten plates.**
- The detector employs **4 XY imaging layers** placed at different depths in the calorimeter, made by 160 μm read-out pitch **silicon microstrip detectors.**
- The total length is about 21 cm, equivalent to 44 X_0 and 1.6 λ_I.
- The transverse sizes of the two towers, called small tower and large tower, are respectively 25 mm × 25 mm and 32 mm × 32 mm.
- Energy resolution is better than 3% for photons with energies above 200 GeV and 35÷40% for neutrons.
- The position resolution for electromagnetic showers is about 40 μm.



Geometry of the IP1 area at LHC



The Arm2 detector



Longitudinal structure of Arm2 detector

3. DATA AND MC SAMPLES

- The measurement is based on data collected by the LHCf experiment during June 2015, in p-p collisions at $\sqrt{s}$ = 13 TeV.
- Two samples with different **pileup parameter** μ were considered, with an **integrated luminosity** of $\int Ldt \approx 0.194\ nb^{-1}$ and $\int Ldt \approx 1.9378\ nb^{-1}$ for the datasets with μ = 0.01 and μ = 0.03, respectively.
- The **inelastic cross section** for p-p collisions at $\sqrt{s}$ = 13 TeV, used to normalize the spectrum, is $\sigma_{inel} = 79.5 \pm 1.8\ mb$.
- **MC datasets** are obtained by using the **EPICS** and **COSMOS** libraries, which act as the front-end for the hadronic interaction models used for the analysis.

4. EVENT RECONSTRUCTION AND SELECTION

- The **η meson selection** is carried out by reconstructing the **two photons** originated in the decay:

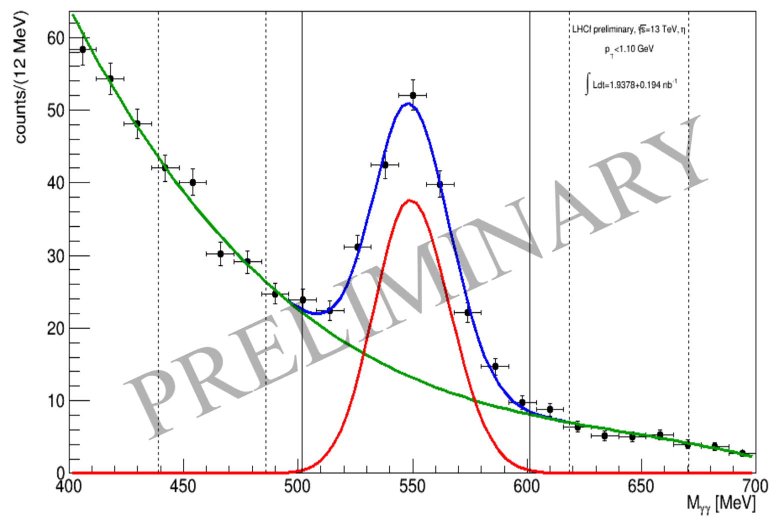
$$\eta \rightarrow \gamma\gamma.$$

- Only η events having one photon in each tower of the Arm2 detector were selected for this work (**Type-I events**).
- Several **selection criteria** are applied to photon candidates.
- Candidate η events are selected using the characteristic peak in the **two-photon invariant mass** distribution, corresponding to the η rest mass.
- The preliminary distribution is fitted with a composite model consisting of an **asymmetric Gaussian distribution** for the signal component and a **third-order Chebyshev polynomial function** for the background.
- The η candidates are separated from the background contamination using **a sideband method**. In this way about **1650** η candidates were selected.
- It should be noted that an **artificial shift** of 3.2% on **single photon energies** was needed to bring the η rest mass peak into agreement with the world averaged η rest mass.
- The **η production cross-section** was expressed in function of the **Feynmann variable**, defined as:

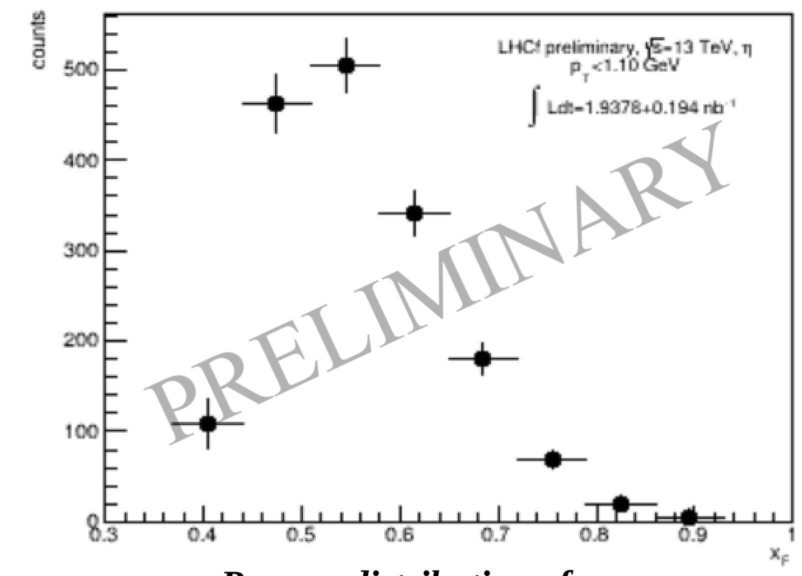
$$x_F = 2p_z/\sqrt{s}.$$

Event type	Type-I
Energy threshold	E_{photon}>200 GeV
Incident position	Within 2 mm from the edge of calorimeter
Number of hits	Single hit in each tower
Particle identification	Photonlike in each tower($L_{90} < L_{thr}(E)$)

Criteria for event selections of the η sample



Reconstructed invariant mass distribution

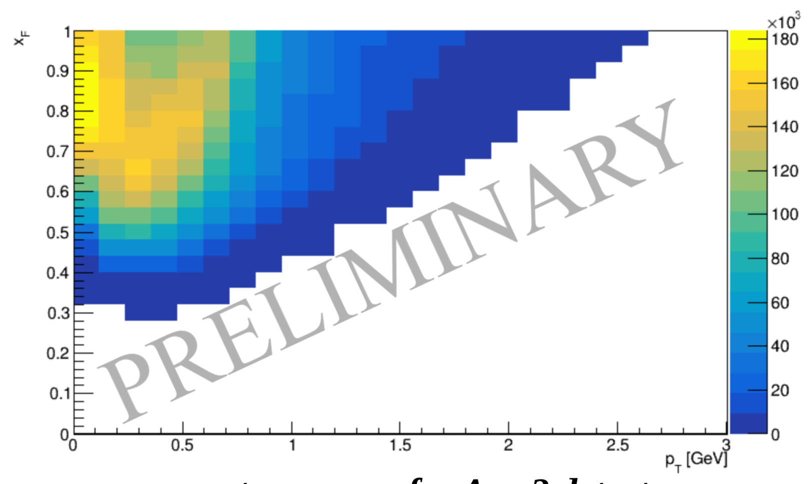


Raw x_F distribution of η mesons

5. EXPERIMENTAL CORRECTIONS

The preliminary x_F distribution were corrected for several **experimental effects**:

- η selection inefficency.
- Geometrical acceptance.
- Loss of events due to multihit cut (events with more than one photon in the same calorimeter).
- Branching ratio corrections.

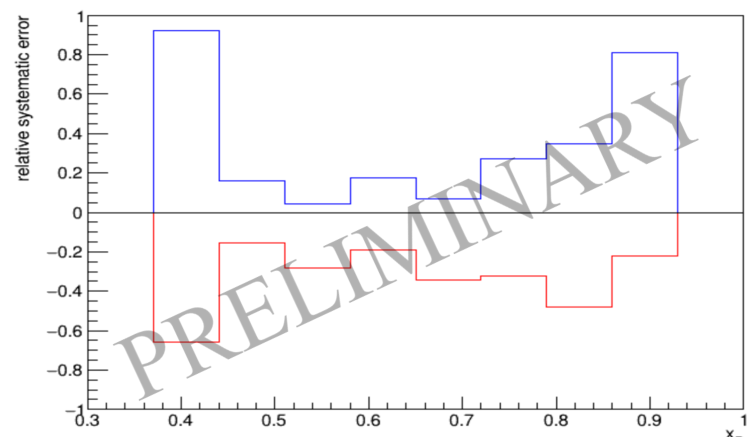


η acceptance map for Arm2 detector

6. SYSTEMATIC UNCERTAINTIES

The **systematic uncertainties** were estimated by using both the data sample and the results of the reconstructed **QGSJETII-04 model simulation**. Three kind of systematic error have been considered:

- Energy scale error.
- PID error.
- Background subtraction error.



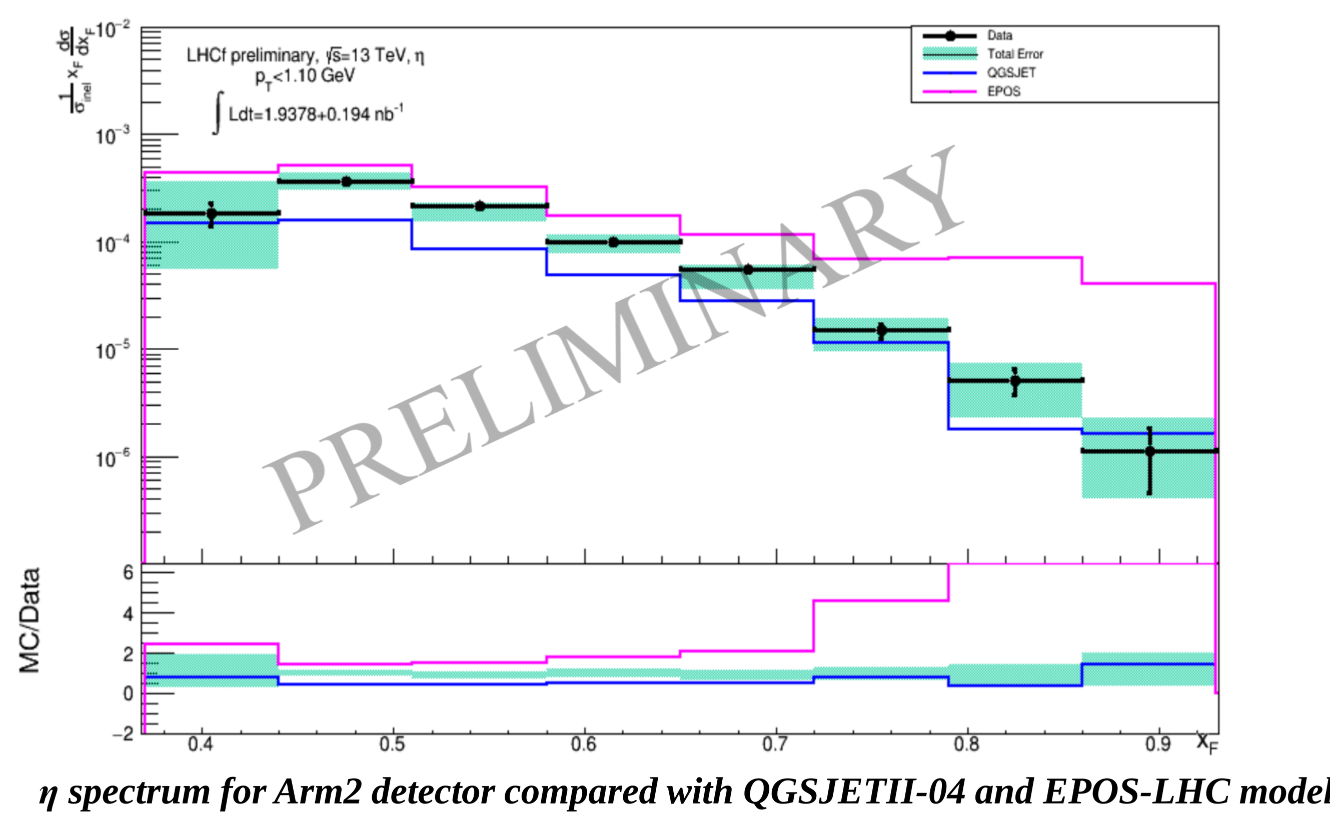
Total systematic relative error

7. PRELIMINARY RESULTS AND COMPARISON TO MODEL PREDICTIONS

- The **production cross section** as function of x_F were be expressed as:

$$\frac{x_F}{\sigma_{inel}}\frac{d\sigma}{dx_F}.$$

- In this form it is possible both to **compare the data with model expectations** and to verify the **Feynman scaling hypothesis** when experimental results at different center-of-mass energy will be available.
- The obtained preliminary η spectrum has been compared with the prediction of two hadronic interaction models**, QGSJETII-04** and **EPOS-LHC**.
- **None of the two models** reproduce the preliminary experimental distribution in the whole x_F range.
- **QGSJETII-04** underestimates the production cross section for low x_F and presents a good agreement with data at high x_F.
- **EPOS-LHC** presents a harder spectrum than the data one in the entire x_F range.



η spectrum for Arm2 detector compared with QGSJETII-04 and EPOS-LHC models