Contributions of diffraction to forward photon production at 13 TeV with the ATLAS-LHCf detectors

Qi-Dong Zhou
Nagoya University (JP)
on behalf of the ATLAS and LHCf Collaborations

HESZ 2017, Nagoya Japan, 26-29 Sep. 2017

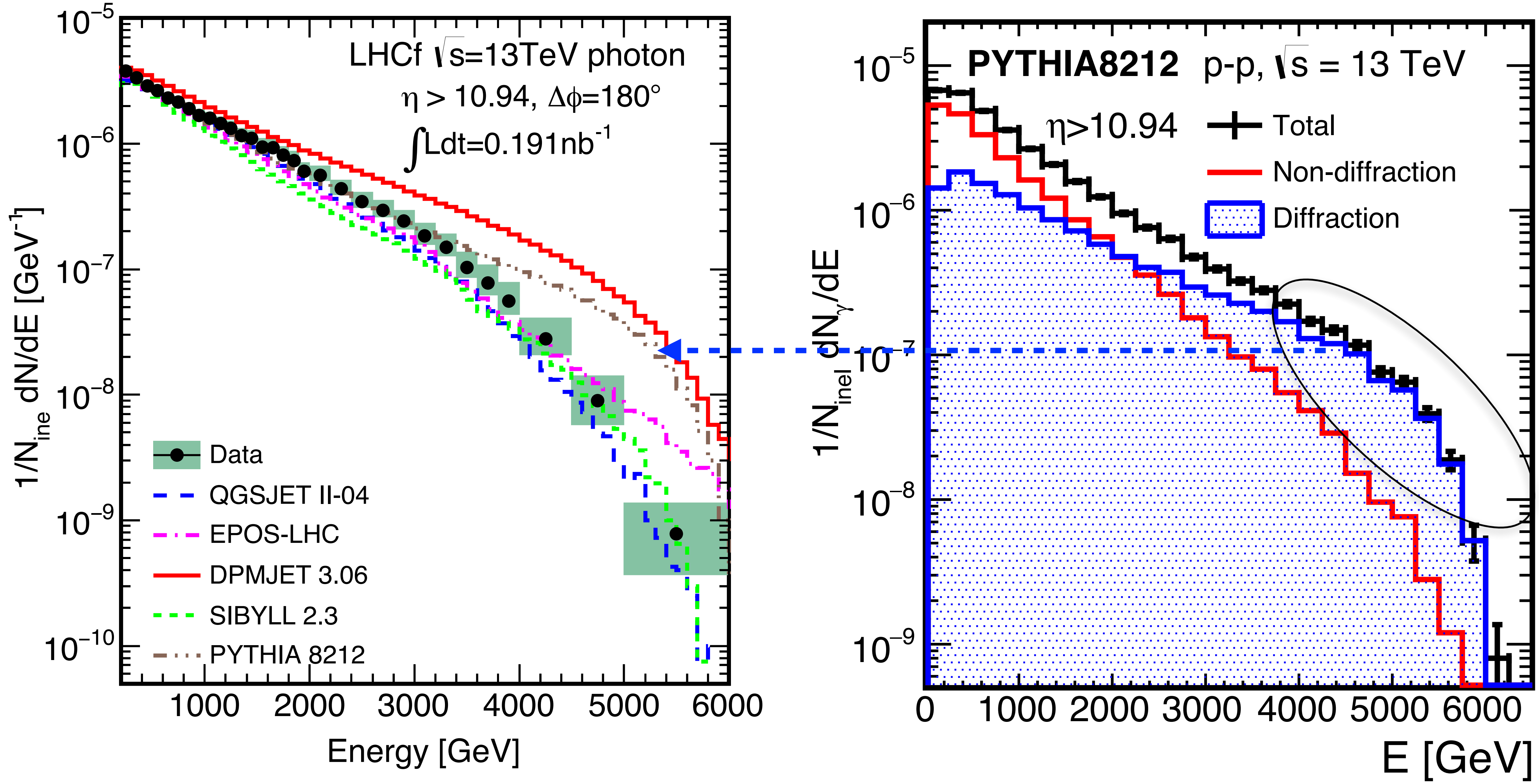
Outline

- Introduction
  - Motivation of measurement of diffractive contribution to LHCf results
- MC study for diffraction identification.
  - Methodology of diffraction selection
  - Efficiency and purity of diffraction identification by common data
  - Low mass diffraction selection
- First ATLAS-LHCf joint analysis.
  - Data analysis method
  - Systematic uncertainties
  - Results
- Summary

Motivation

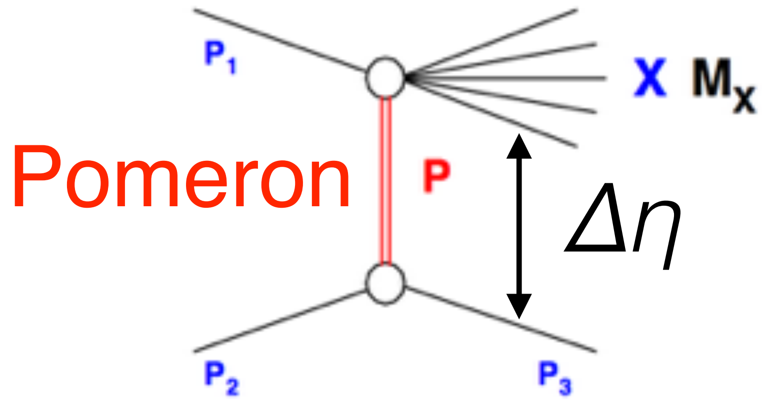
✦ Measurement of forward neutral energy spectra is important for verifying and improving the hadronic interaction models (widely used to simulate the cosmic-ray air showers).

CERN-EP-2017-051

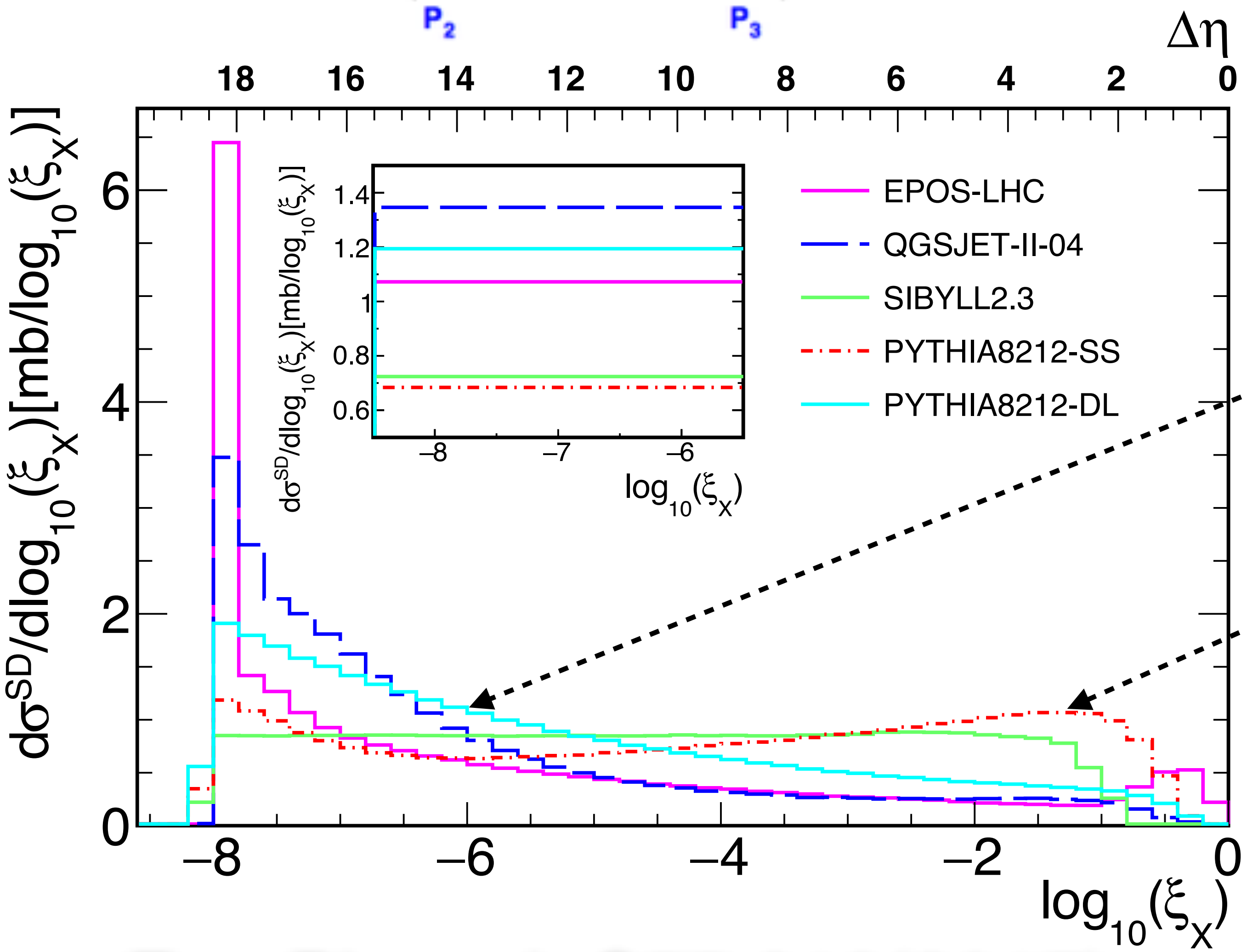


✦ Discrepancies between data and model predictions for the forward photon spectra in pp √s = 13 TeV collisions.
✦ The excess of PYTHIA8 at E>3TeV due to over contribution from diff. processes.

Diffractive mass distribution

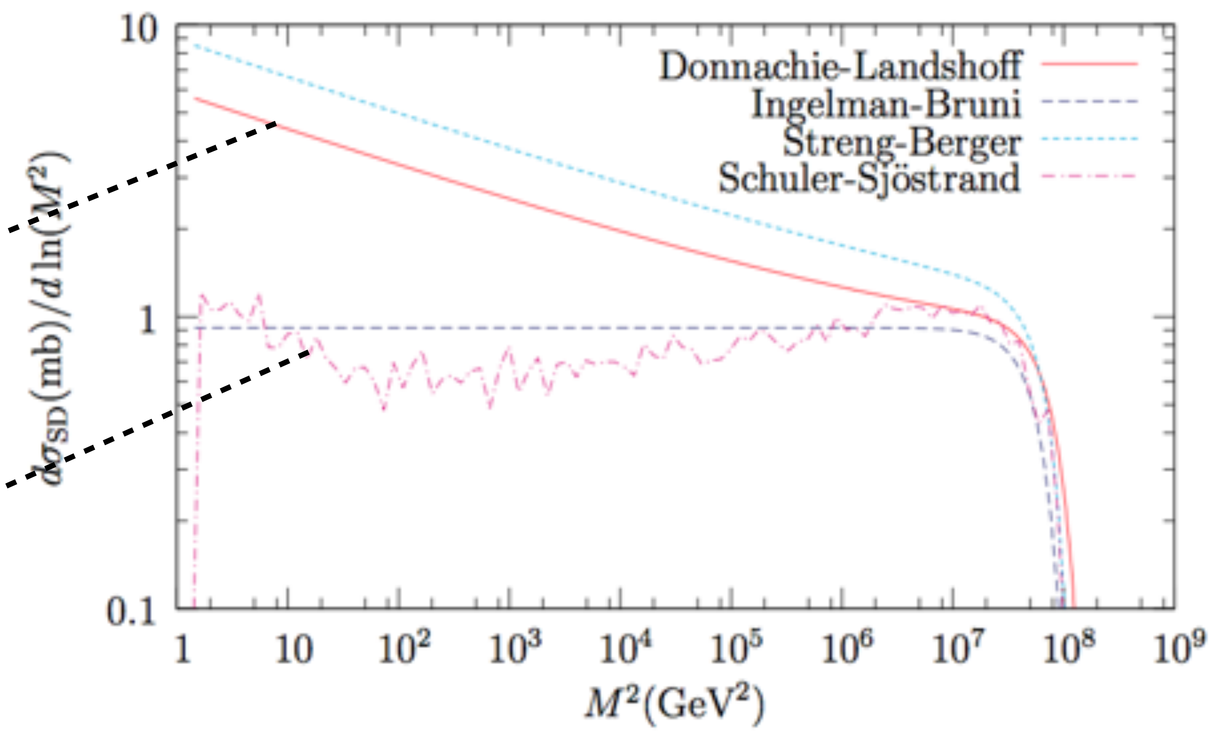


$$\xi_x = (M_{(x)}/\sqrt{s})^2 \sim e^{-\Delta\eta}$$



Eur. Phys. J. C77:212(2017)

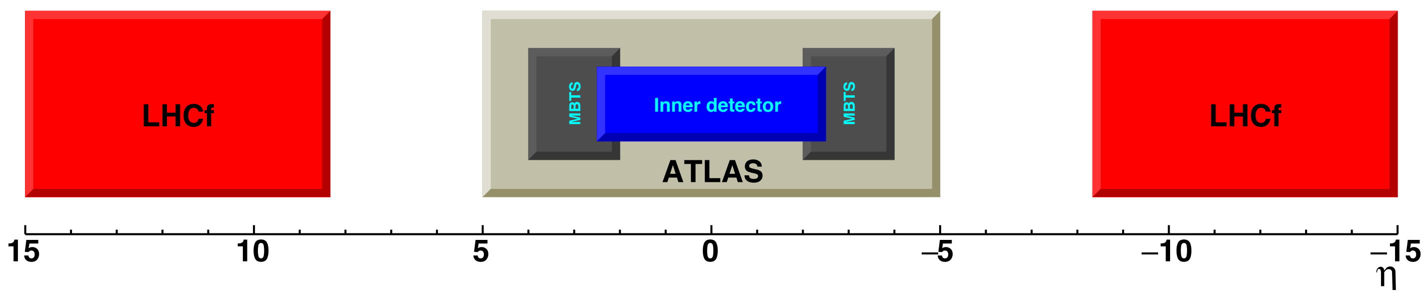
Pomeron flux options in PYTHIA



arXiv:1005.3894v1

- Large discrepancy exists between models, especially, at low mass.
- Approaches to the diffraction treatment, implemented in the models are different, data is essential to constrain the parameters.

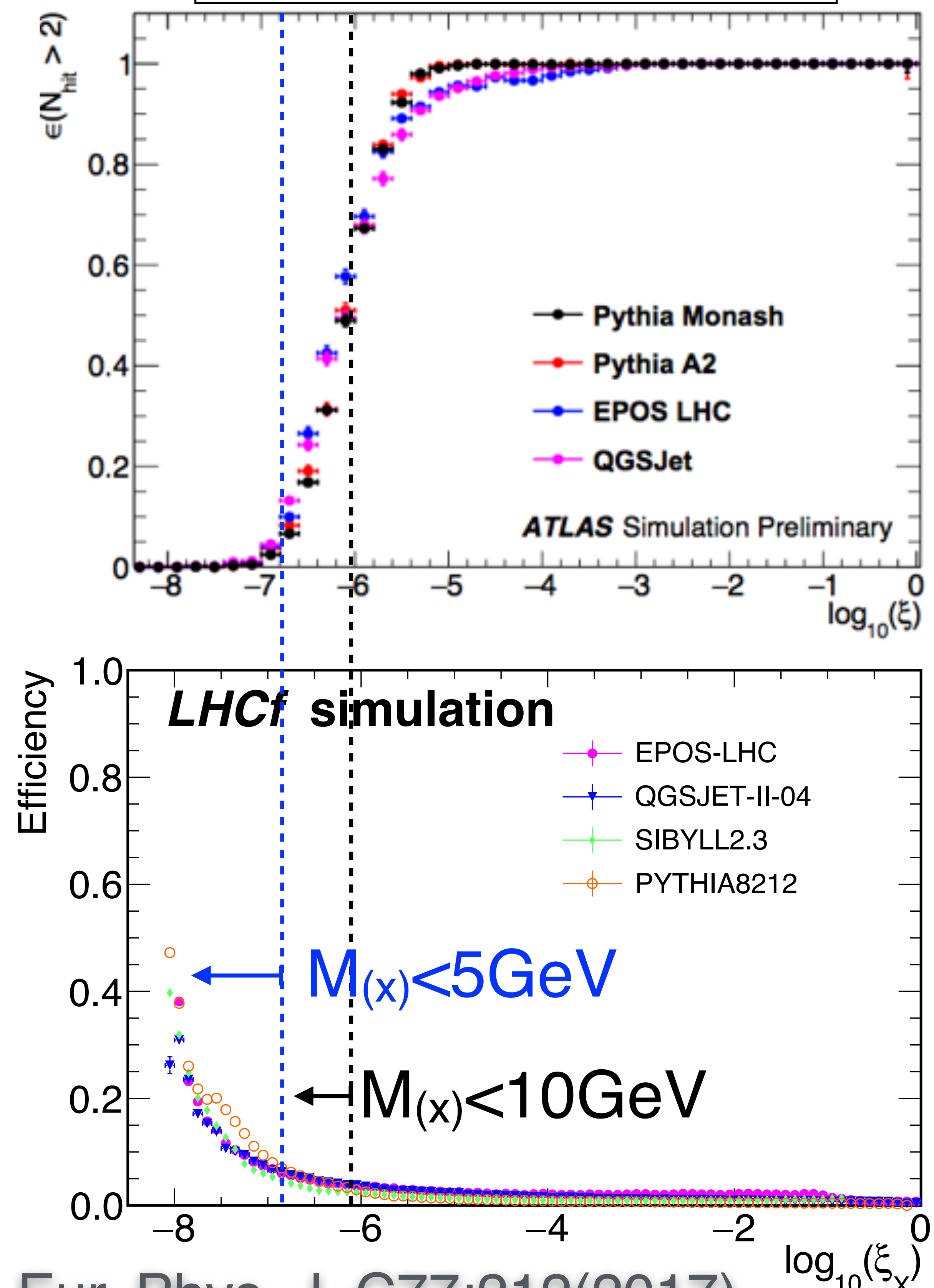
Detector acceptance



- Trigger efficiency (only for SD)
- Trigger condition of LHCf
  Photon: $E_\gamma > 200\text{GeV}$
  Neutron: $E_n > 500\text{GeV}$
- ATLAS
  Pass MBTS hit selection
  $N_{hit}>2$

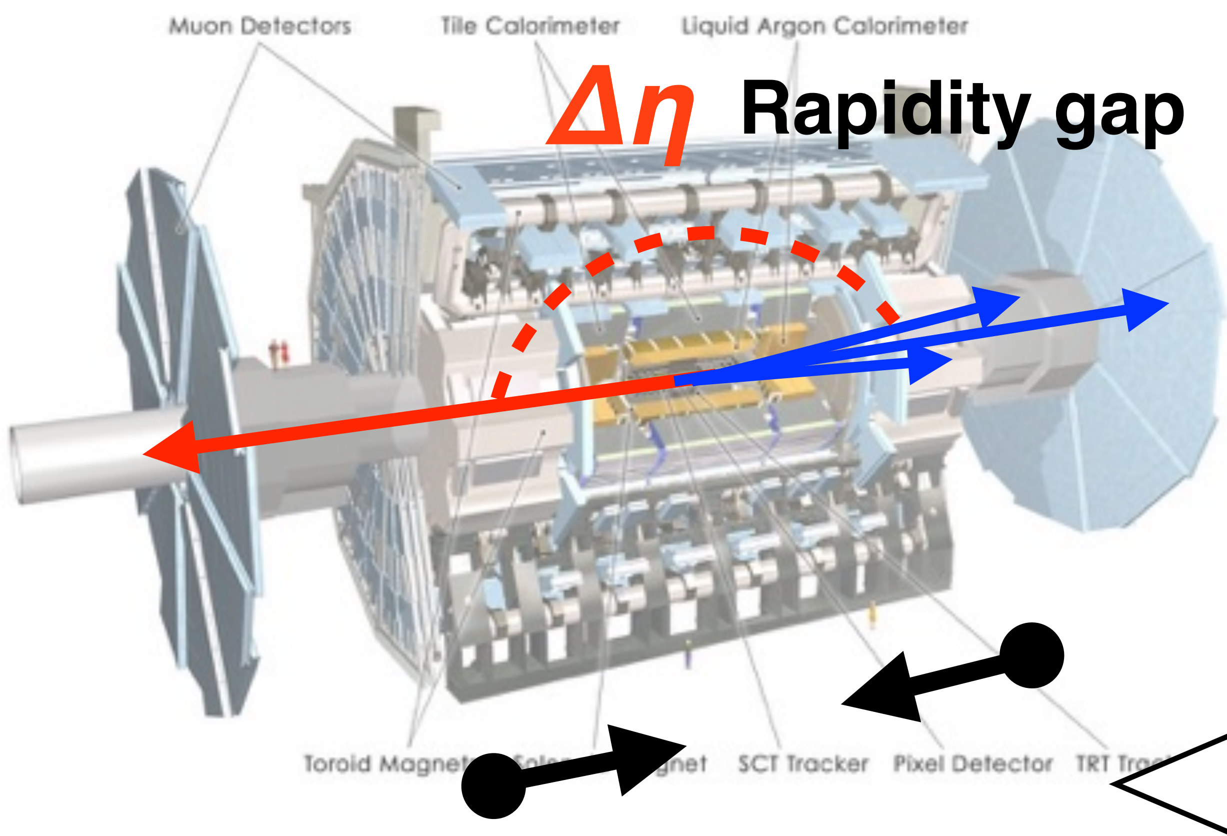
> ✦ LHCf and ATLAS cover different diffractive mass range,
> ✦ Rapidity gap measured by ATLAS allows to distinguish the low mass diffractive contributions.

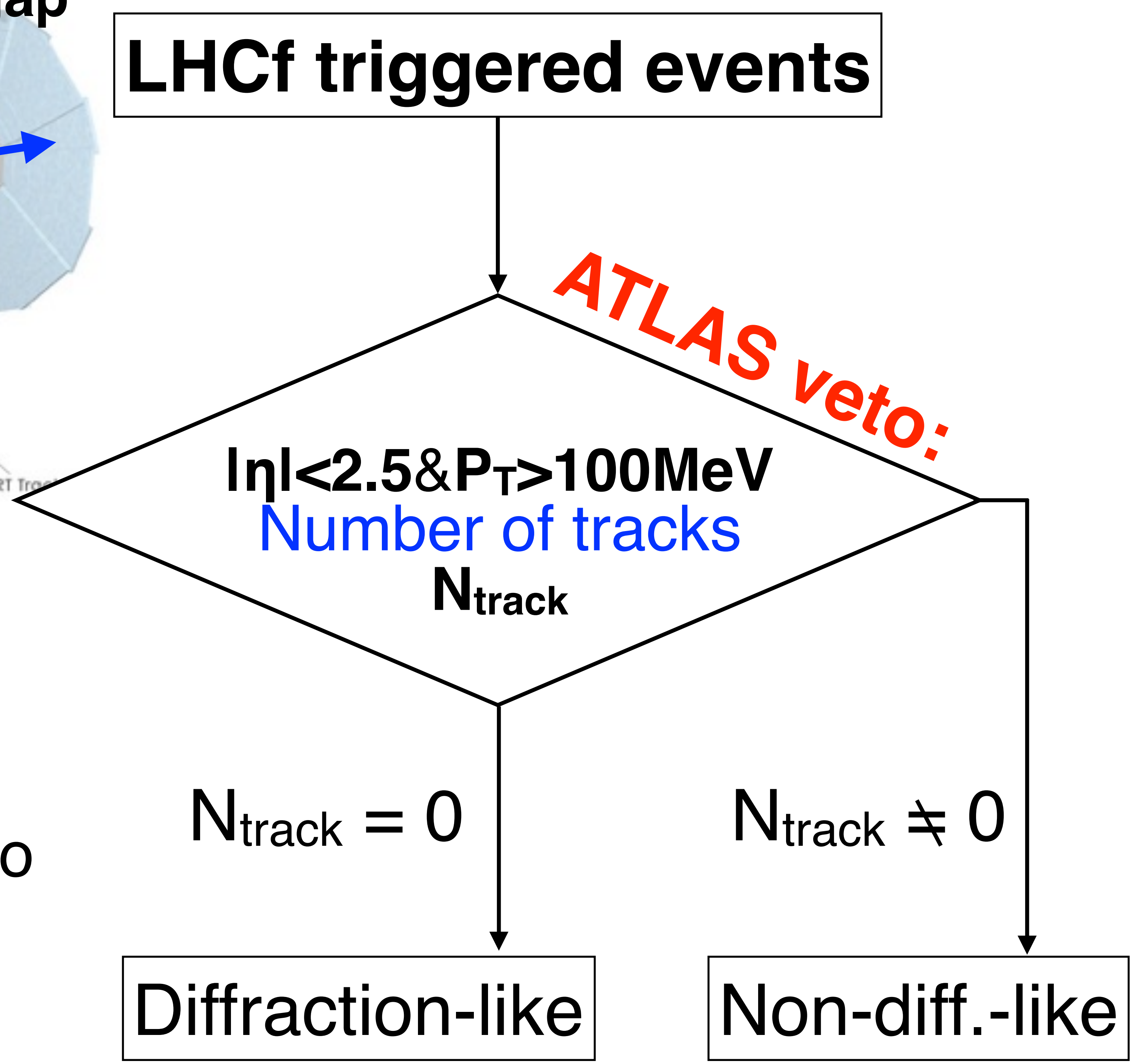
ATLAS-CONF-2015-038



Eur. Phys. J. C77:212(2017)

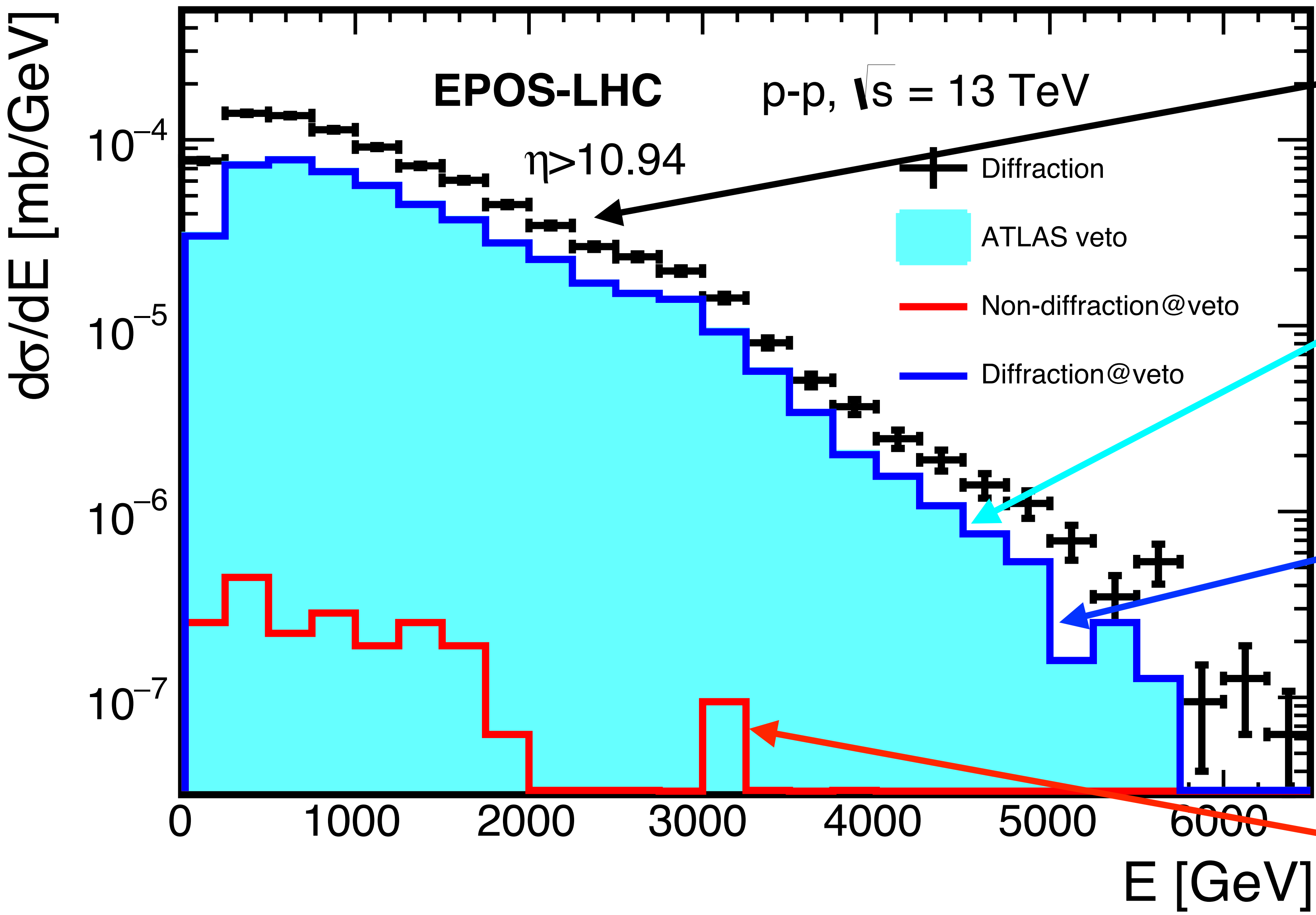
Diffraction identification by ATLAS-veto





- Rapidity gap measured by ATLAS to distinguish the events triggered by LHCf to diff.-like or non-diff.-like

Performance of ATLAS-veto selection



①Diffraction

②Events selected by ATLAS-veto

③Diffractive events identified by ATLAS-veto

② & ③ are mostly consistent

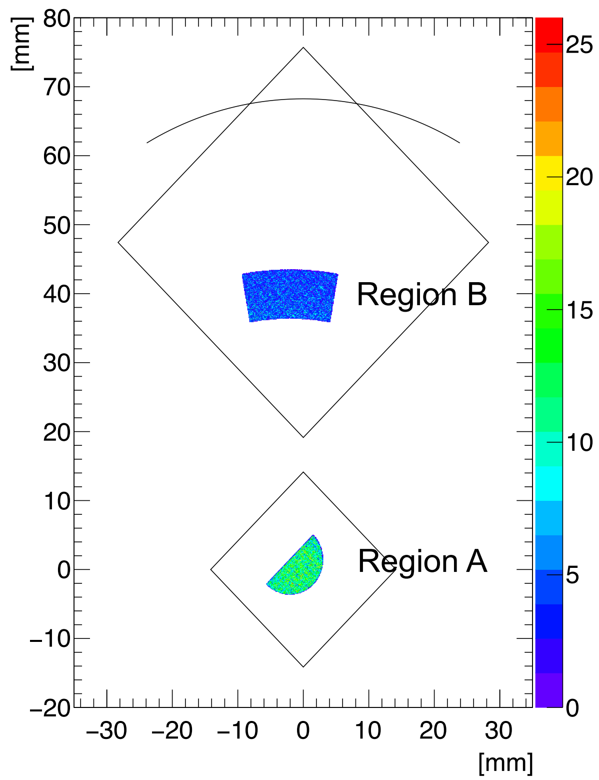
④Non-diff. events mis-identified by ATLAS-veto (②-③)

efficiency = ② / ①

purity = ③ / ②

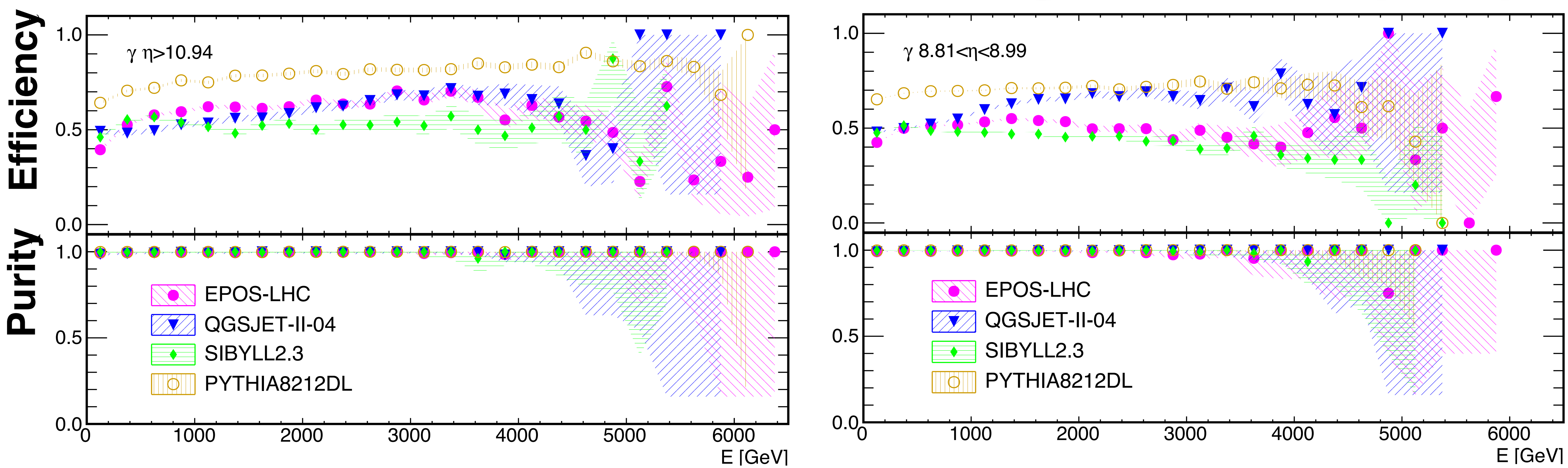
ATLAS-veto enable diffraction selection with high purity

Performance of ATLAS-veto selection



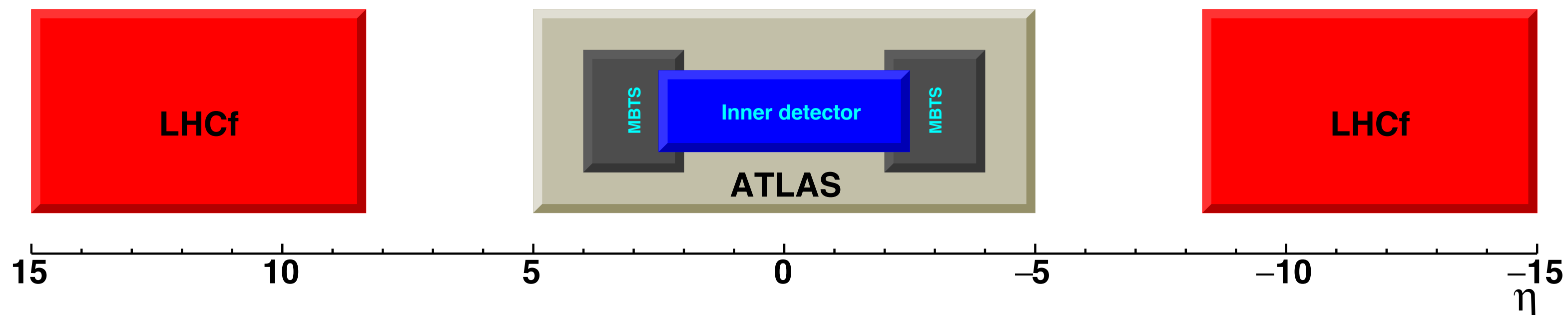
- ✦ Incident positions of photons on the LHCf-Arm1 calorimeter towers (region A and B) were reconstructed for the analyses.
  - A: $\eta > 10.94$ and $\Delta\phi = 180°$
  - B: $8.99 > \eta > 8.81$ and $\Delta\phi = 20°$
- ✦ Photon energy larger than 200 GeV.

Eur. Phys. J. C77:212(2017)

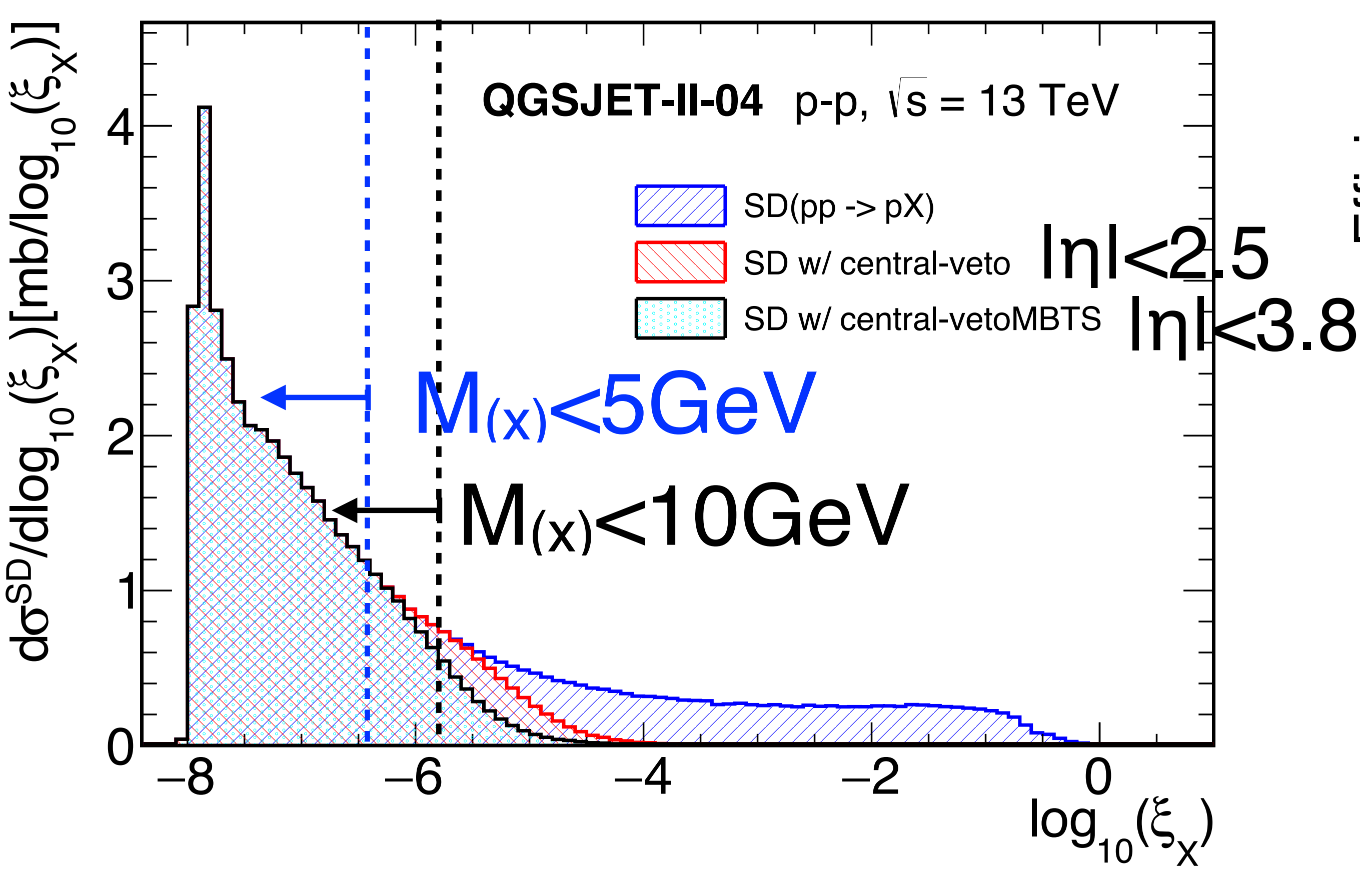


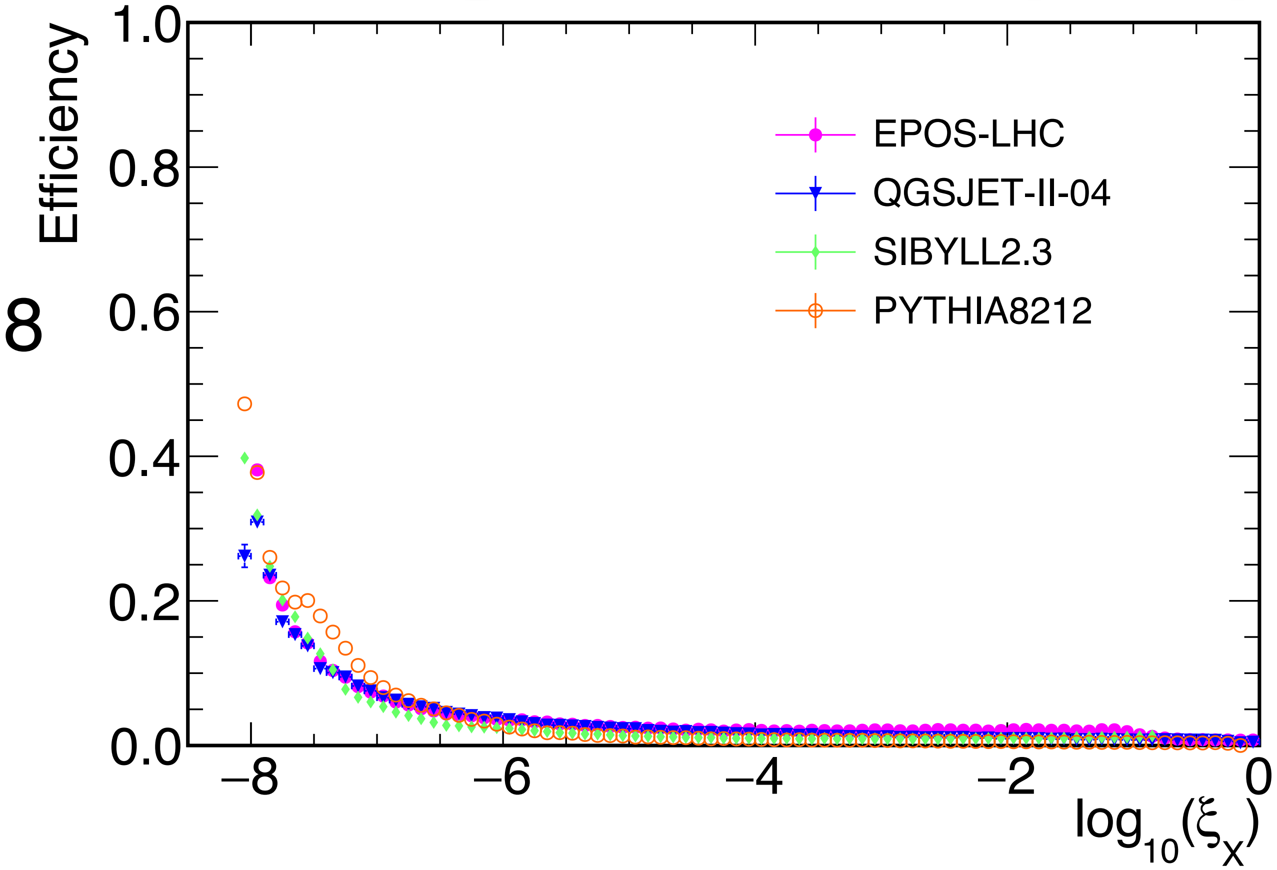
ATLAS-veto enable diffraction selection with high purity

Low mass diffraction



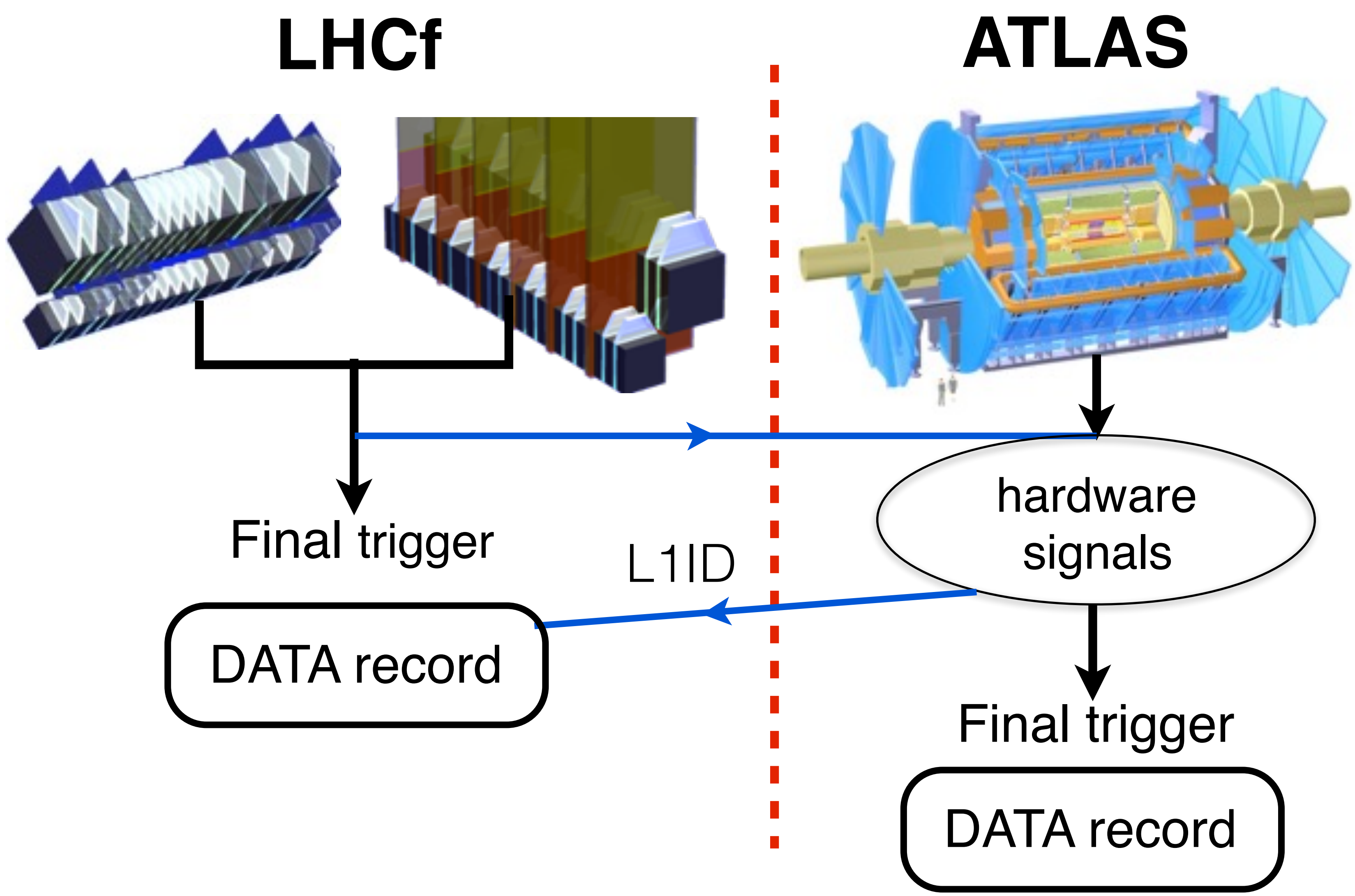
Eur. Phys. J. C77:212(2017)





- The inefficiency parts of ATLAS-veto are non-diff. and high mass diff..
- ATLAS-LHCf can access the low mass diffraction region, with high detection efficiency, experimentally.

Data used for ATLAS-LHCf joint analysis



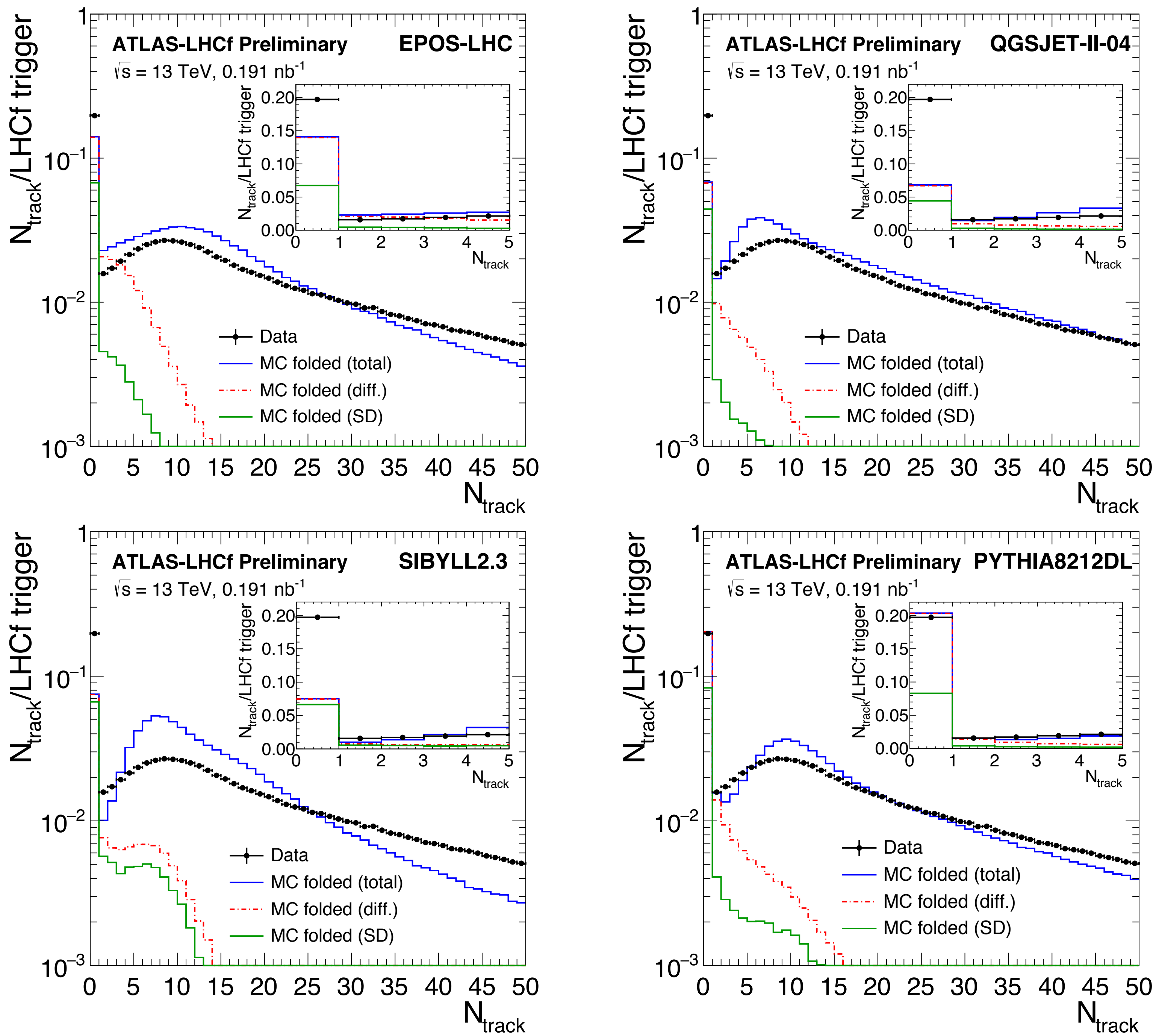
Beam condition
β^*=19m
μ=0.01~0.03

- Common data acquisition with low luminosity configuration ($3\text{-}5\times10^{28}$ cm^2 s^{-1}).
- Data taken at 22:32 - 1:30 (CEST) on June 12-13, 2015 during *pp* collisions at $\sqrt{s}$ = 13 TeV
- Data used for this analysis corresponding to 0.191 nb^{-1}

Supplement: N_{tracks} distributions

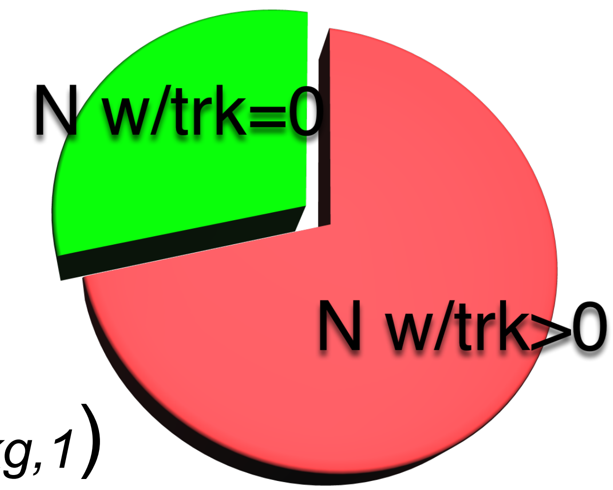
- The contribution of non-diff. events at N_{track} = 0 is less than 2%.
- Most of the 2% are contamination of this analysis form non-zero charged particle events due to inefficiency of the track detection.
- 20% contribution of N_{tracks} = 0 in data while 5-20% predicted by models.
- SIBYLL2.3 and QGSJET-II-04 predict very small contribution of DD process to N_{track}=0.

ATLAS-CONF-STDM-2017-02



Analysis method

- Photon spectra for two samples: w/o selection on ATLAS tracks $N_{w/o\ sel}(E)$, and w/ ATLAS-veto selection $N_{w/trk>0}(E)$



- Unfold the photon spectra for all inclusive events

$$N'_{ALL}(E) = C^{MH}{}_{all}(E)\ C^{PID}{}_{all}(E)\ N_{w/o\ sel}(E) \times (1 - R_{bkg,1})$$

- Unfold the photon spectra with at least ONE reconstructed track in InDet.

$$N'_{ch>0}(E) = C^{Track}(E)\ C^{MH}{}_{trk>0}(E)\ C^{PID}{}_{trk>0}(E)\ N_{w/trk>0}(E) \times (1 - R_{bkg,2})$$

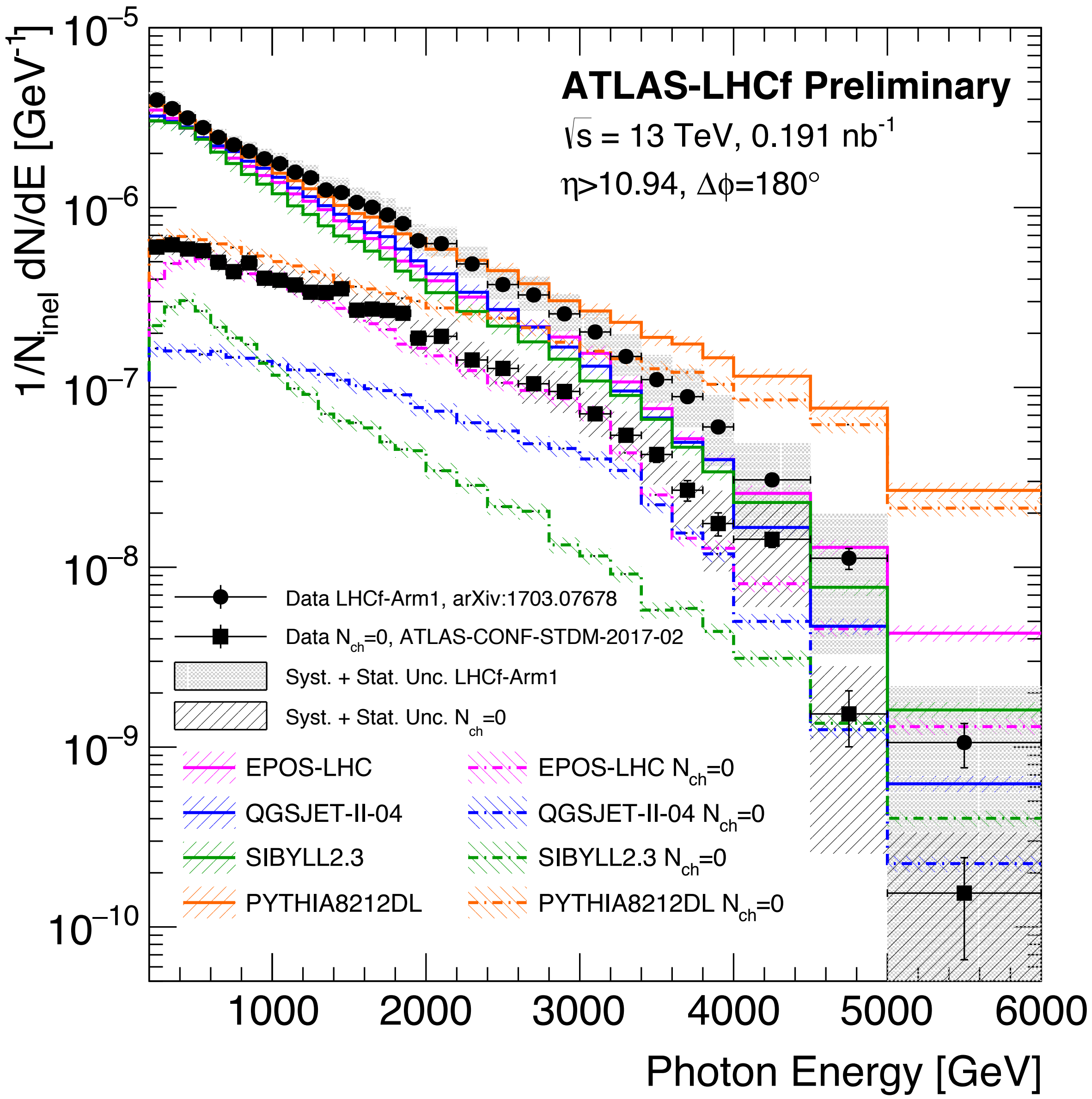
$C^{PID}{}_{all}$, $C^{PID}{}_{trk>0}$: PID correction factor
$C^{MH}{}_{all}$, $C^{MH}{}_{trk>0}$: Multi-hit rejection correction factor (MC base)
C^{Track}: Correction factor of ATLAS inner track detection (MC base)

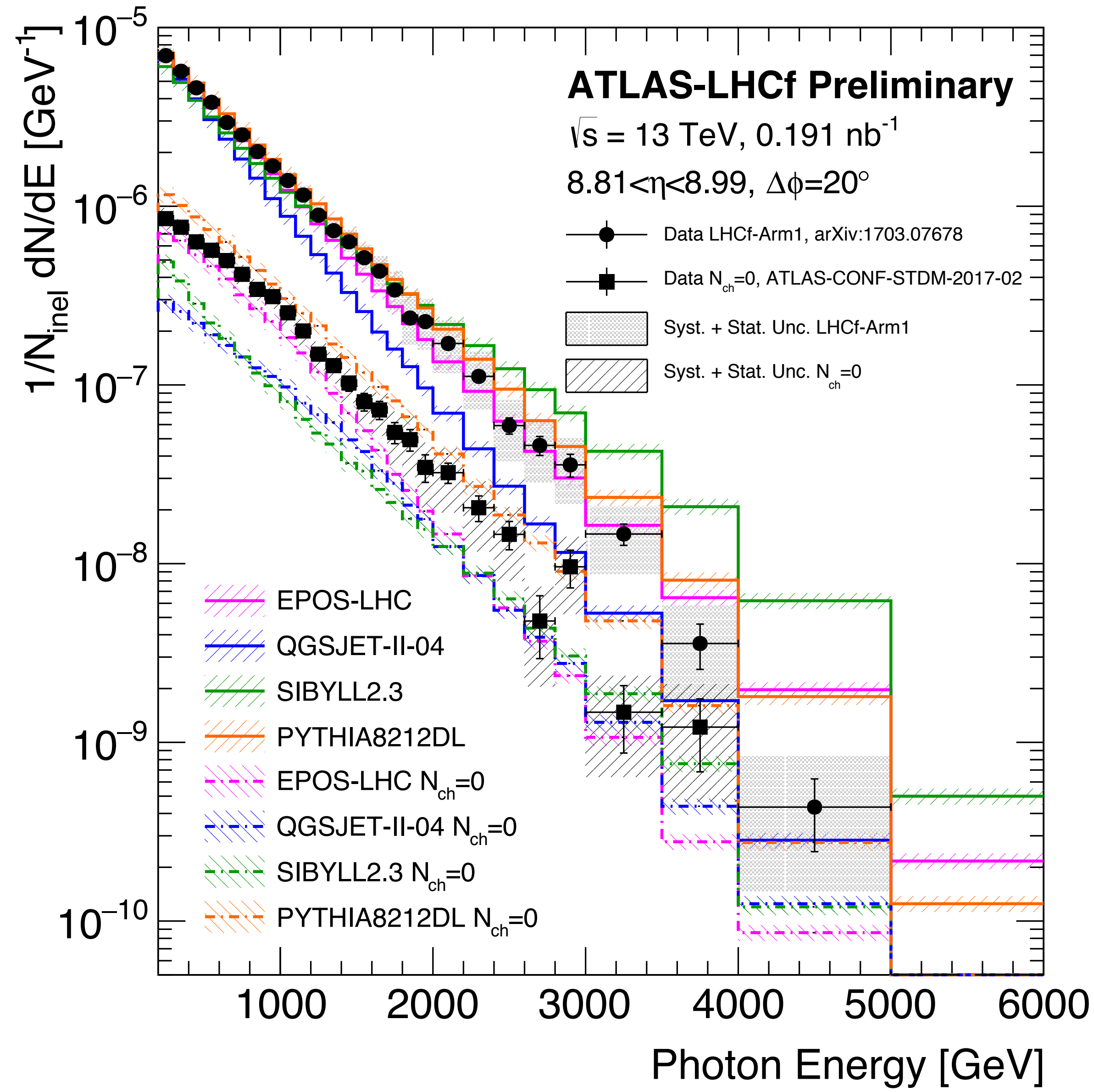
- Calculate the photon spectra with no charged particle at $|\eta|<2.5$

$$N'_{ch=0}(E) = N'_{ALL}(E) - N'_{ch>0}(E)$$

Results: Photon spectra

ATLAS-CONF-STDM-2017-02

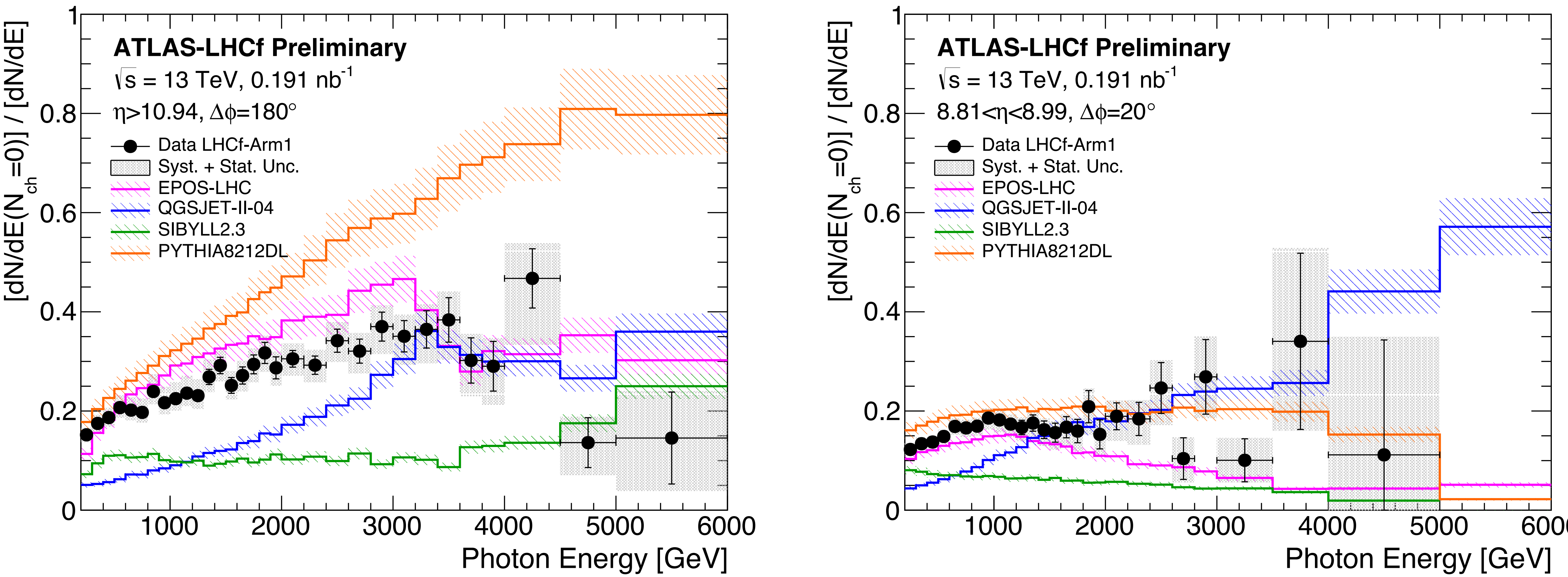




- Comparison between data w/ $N_{ch} = 0$ and model predictions
  - EPOS-LHC show a good agreement with data.
  - PYTHIA8212DL is a good agreement at the region of $8.81 < \eta < 8.99$.

Results: Spectra ratios $N'_{ch=0}(E)$ / $N'_{ALL}(E)$

ATLAS-CONF-STDM-2017-02



- At η>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 η>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.

Summary

- ✦ Diffraction is one of the poor constraint parts of the hadronic interaction models -> ATLAS-LHCf joint analysis.
- ✦ The efficiency and purity of diffractive event identification by ATLAS-LHCf joint analysis were estimated.
- ✦ ATLAS-veto can select the low mass diffraction.
- ✦ The diffractive contribution to the forward photon spectra were measured by ATLAS-LHCf joint analysis for the first time.
- ✦ EPOS-LHC show a good agreement with data on both spectra and ratio results.