Measurement of isolated photons in pp collisions at $\sqrt{s}$ = 8 TeV with the ALICE detector at LHC

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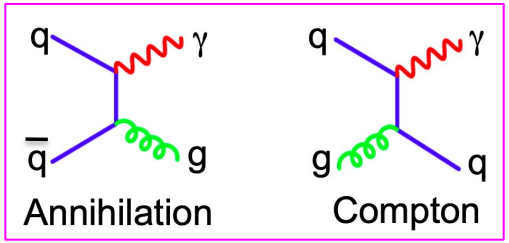
On behalf of the ALICE Collaboration

Motivation

Study of direct photons in high energy hadronic collisions:

- Direct photons are those photons which are directly produced in elementary processes:
  - Quark-gluon Compton scattering
  - Quark-antiquark annihilation
- They are not products of hadronic decays.
- They are colourless probes of QCD processes.
- They are probes of the initial state of protons or nuclei, as they are emitted at the early stages of hadron collisions.
- These photons come directly from parton-parton hard scatterings, allowing one to constrain parton distribution functions.

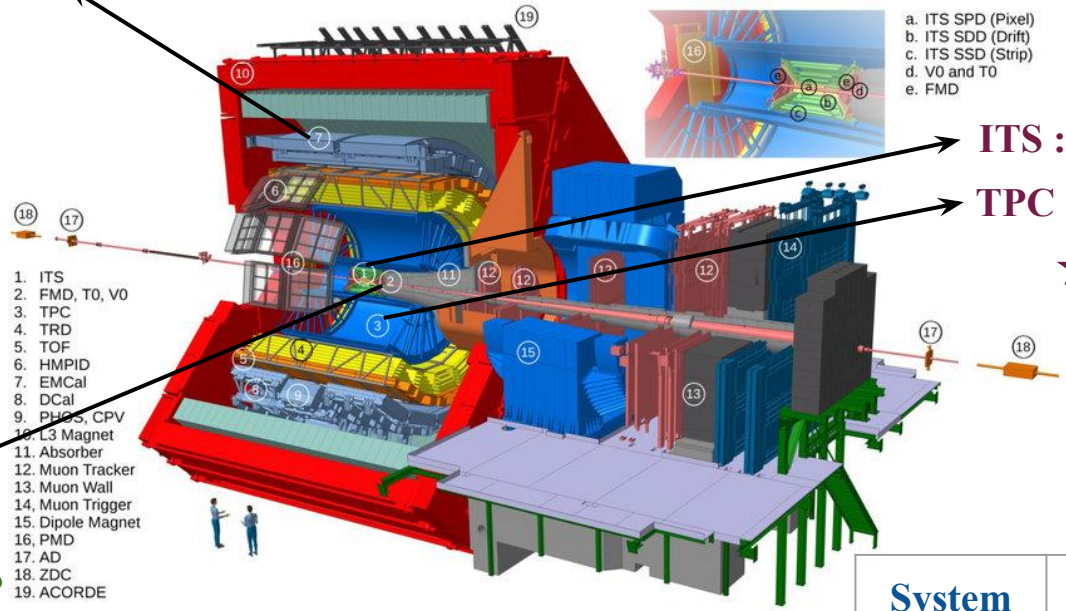


The ALICE detector

EMCal : $|\eta| < 0.7$; $80° < \varphi < 187°$

★ Used for photon reconstruction

★ Used as trigger detector (photons/jets)



ITS : $|\eta| < 0.9$; $\Delta\varphi = 360°$

TPC : $|\eta| < 0.9$; $\Delta\varphi = 360°$

★ Used for track reconstruction

V0A : $2.8 < \eta < 5.1$; $\Delta\varphi = 360°$

V0C : $-3.7 < \eta < -1.7$; $\Delta\varphi = 360°$

★ Used as MB trigger detector

System	$\sqrt{s}$ (TeV)
pp	8

Photons in hadronic collisions

$$\gamma_{\text{inclusive}} = \underbrace{\gamma_{\text{LO}} + \gamma_{\text{fragmentation}}}_{\gamma_{\text{prompt}}} + \underbrace{\gamma_{\text{thermal}}}_{\text{in Pb–Pb}} + \underbrace{\gamma_{\text{decay}}}_{\pi^0,\ \eta\ldots}$$

- Signal: Leading Order (LO) direct photons - Emitted in hard QCD processes at the early stage of hadron collisions (p_{T}^{γ} > a few GeV/c)
  - Quark-gluon Compton scattering & Quark-antiquark annihilation
- Background: Fragmentation and decay photons.
- **Isolation** is a tool to access: LO direct photons
- **Isolation** techniques: Strongly suppress fragmentation and decay components.

Photon identification

Cluster shower shape

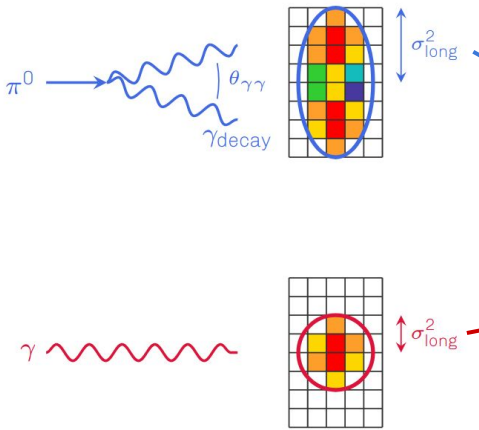
$$\sigma^2_{\text{long}} = (\sigma^2_{\varphi\varphi} + \sigma^2_{\eta\eta})/2 + \sqrt{(\sigma^2_{\varphi\varphi} - \sigma^2_{\eta\eta})^2/4 + \sigma^4_{\eta\varphi}}$$

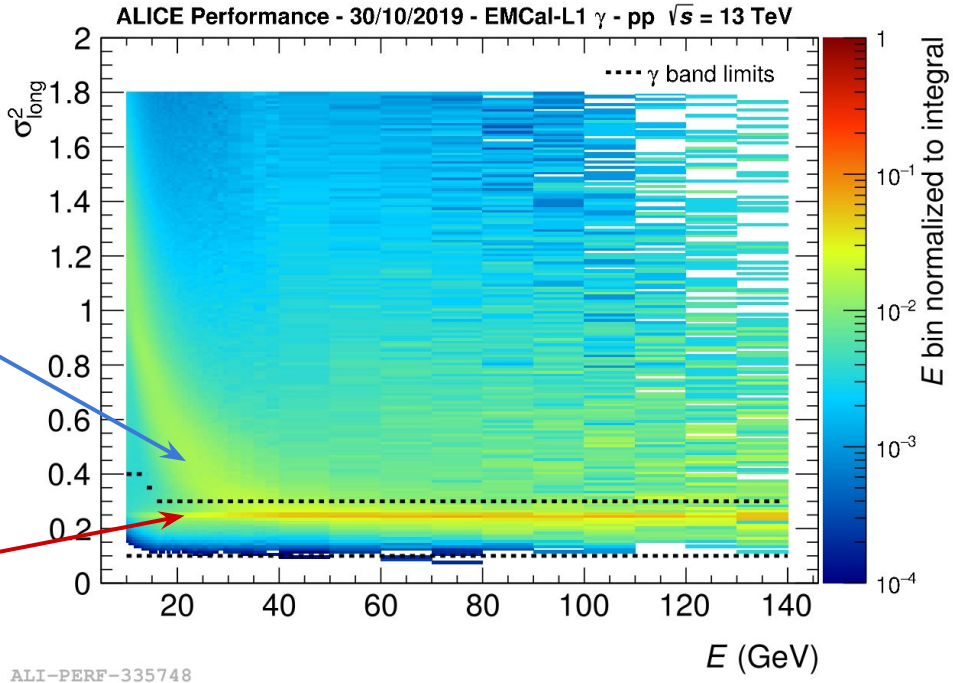
$$\sigma^2_{xz} = \langle xz \rangle - \langle x \rangle \langle z \rangle \qquad \langle x \rangle = (1/w_{\text{tot}}) \sum w_i x_i$$

Weighted over all cells associated with the cluster in η, φ plane.

$$w_i = \max(0, 4.5 + \ln(E_i/E_{\text{cluster}}))$$

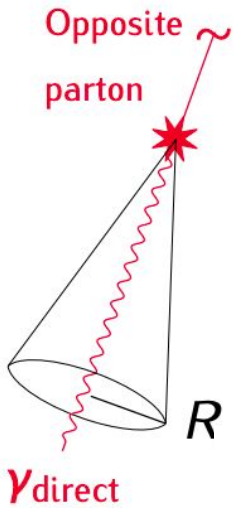
$$w_{\text{tot}} = \sum w_i$$



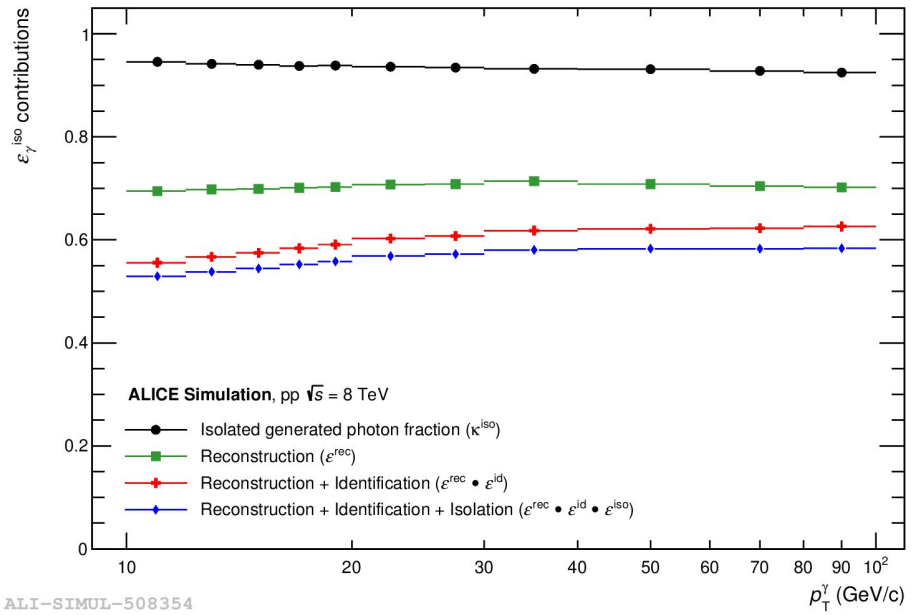


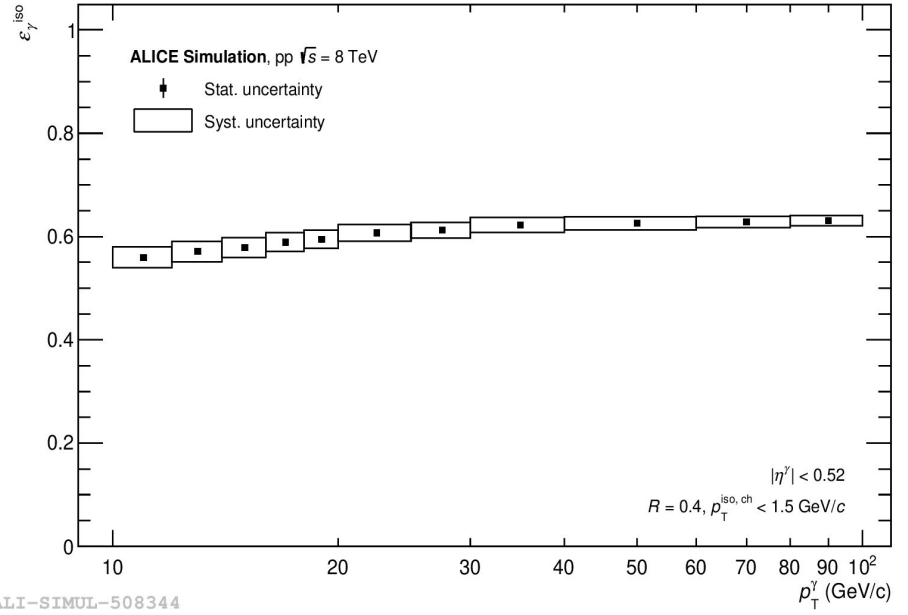
Photon isolation

- **"Isolated photons" - no hadronic activity surrounding the photons from hard processes.**
- Sum the p_T of charged particles i, inside a cone of radius $R = \sqrt{(\eta_i - \eta_\gamma)^2 + (\varphi_i - \varphi_\gamma)^2}$
- Set an isolation threshold
  - $p_T^{\text{iso, ch}} = \Sigma p_T^{\text{track}} - \text{UE}\ (\rho_{\text{UE}}\ \pi\ R^2) < 1.5\ \text{GeV}/c$
- Underlying event (UE) estimation:
  - Using **perpendicular cone** method
  - For a given cluster with position (η,φ), rotate cone by ± 90° in φ
  - Calculate sum of all charged track p_T inside the perpendicular cones
  - Divide by area of both the cones to estimate ρ_{UE}



Efficiency estimation for isolated photons





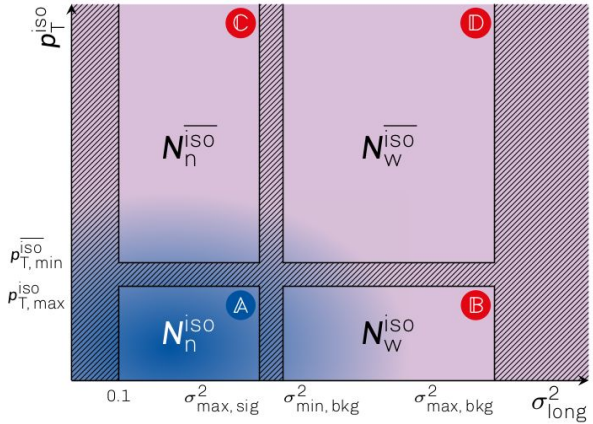
$$\varepsilon_\gamma^{iso} = \frac{\varepsilon^{rec} \cdot \varepsilon^{id} \cdot \varepsilon^{iso}}{\kappa^{iso}}$$

κ^{iso} – Fraction of generated photons which are isolated

Identification – Shower shape cut ($0.1 < \sigma_{long}^2 < 0.3$)

Isolation – $R = 0.4$, $p_T^{iso,ch} < 1.5$ GeV/c

Purity estimation for isolated photons

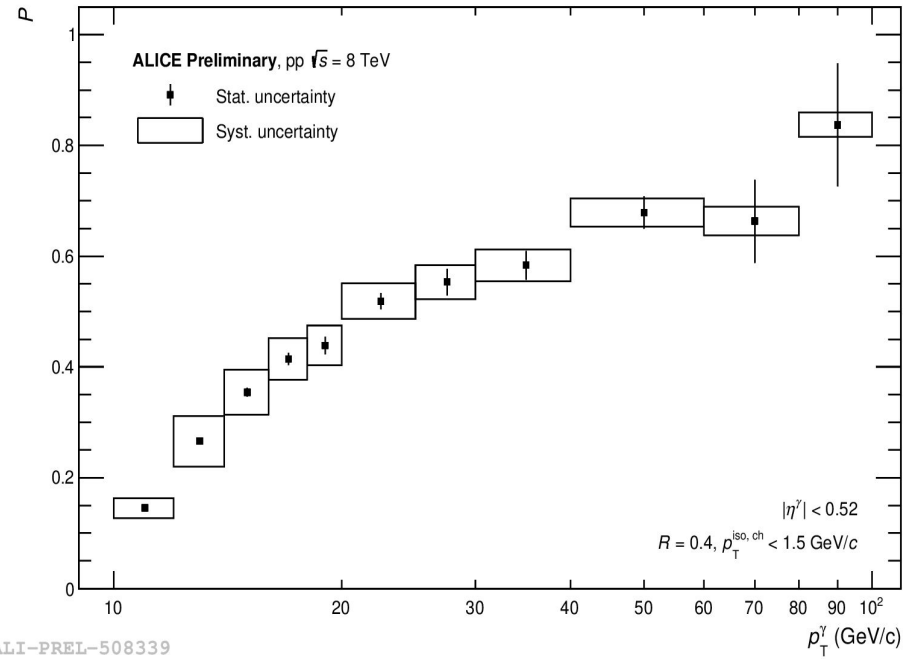


The ABCD Method

$$N = S + B$$

$$P = 1 - \left(\frac{N_n^{\overline{iso}}/N_n^{iso}}{N_w^{\overline{iso}}/N_w^{iso}}\right)_{data} \times \left(\frac{B_n^{iso}/N_n^{\overline{iso}}}{N_w^{iso}/N_w^{\overline{iso}}}\right)_{MC}$$

The three background dominated regions (BCD) are used to estimate the background contribution in the signal region (A).

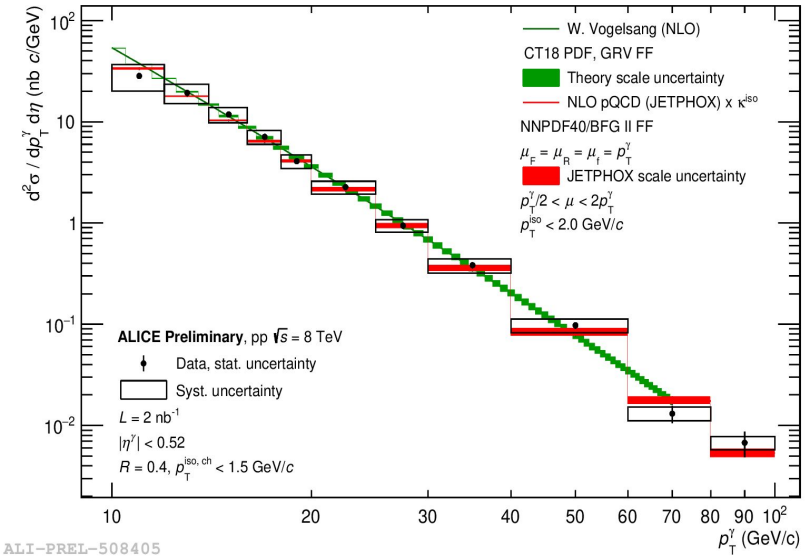


Isolated photon cross section in pp $\sqrt{s}$ = 8 TeV

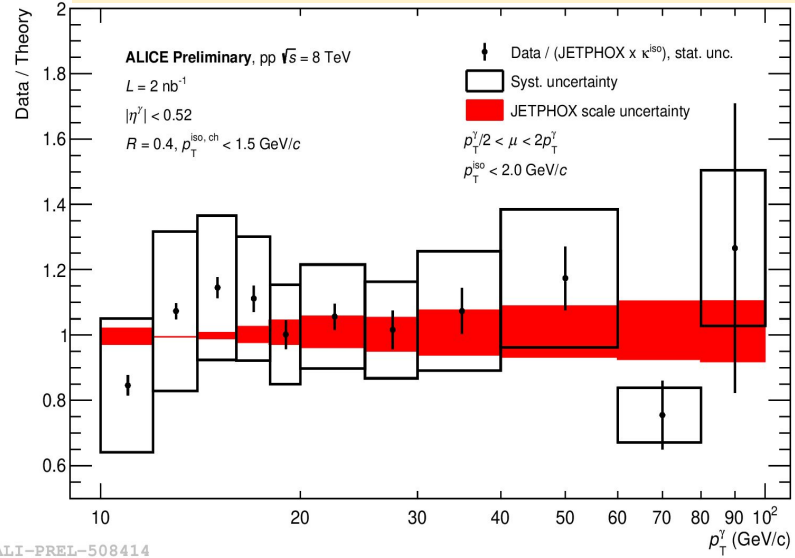
JETPHOX NLO calculations scaled by the PYTHIA isolation fraction at generator level, κ^{iso} to consider the parton to hadron fragmentation.

Charged isolation using ITS+TPC tracks, UE subtracted.

$R = 0.4$, $p_T^{iso,\,ch} < 1.5$ GeV/c



ALI-PREL-508405



ALI-PREL-508414

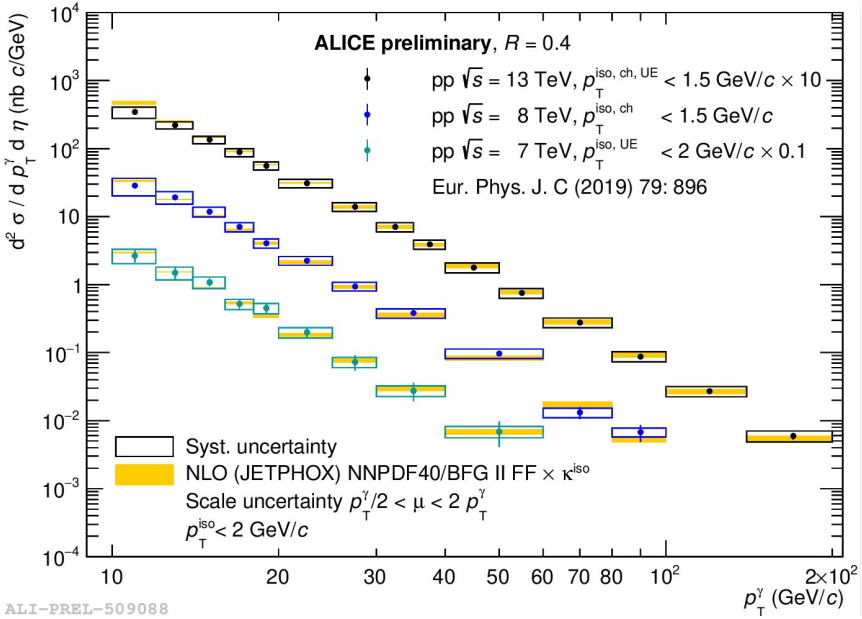
JETPHOX model calc. – NNPDF40, BFG II FF

NLO calc. Werner Vogelsang – CT18 PDF, GRV FF

NNPDF Collaboration: arXiv.2109.02653

Summary

- Measured isolated photon cross section
  - In pp collisions at $\sqrt{s}$ = 8 TeV.
- Measurements in pp collisions at $\sqrt{s}$ = 7, 13 TeV have also been done.
- Results are compatible with pQCD calculations.
- Establishes a benchmark for these measurements in p–Pb, Pb–Pb collisions.



Thank you!

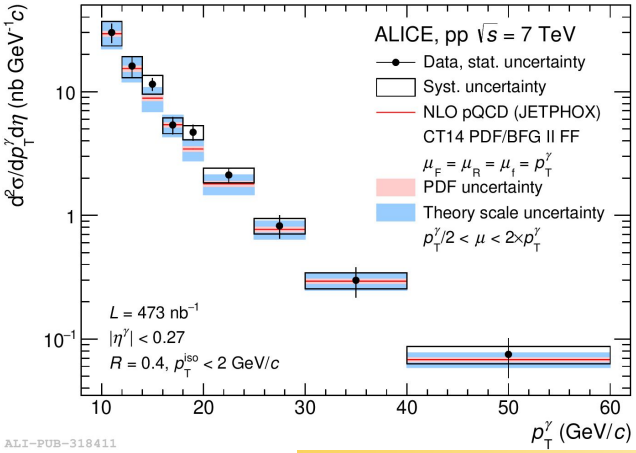
Back up

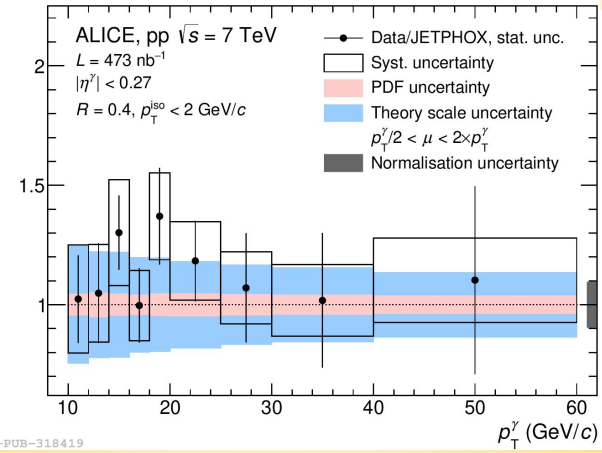
Isolated photon cross section in pp $\sqrt{s}$ = 7 TeV

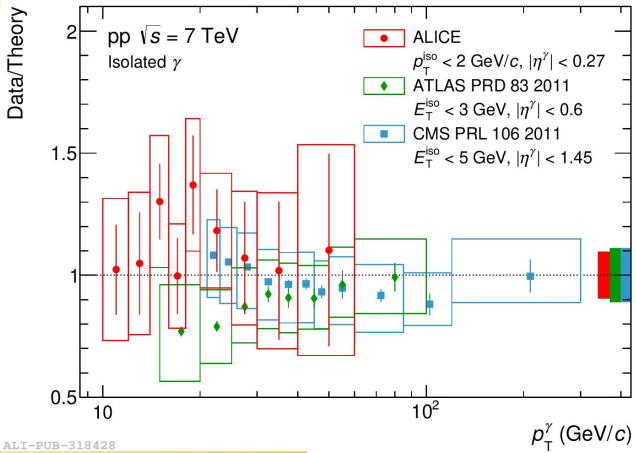
Eur. Phys. J. C 79: 896 (2019)
JETPHOX 1.3.1 (JHEP 0205 (2002) 028,
Phys. Rev. D 73 (2006) 094007)
PDF, CT14 (Phys. Rev. D 93 (2016), 033006)

Charged+Neutral isolation using ITS+TPC tracks and EMCal clusters, UE not subtracted.

$R = 0.4$, $p_T^{\text{iso, UE}} < 2$ GeV/c







ALICE data – compared to pQCD calculations with JETPHOX. Good agreement is observed between data and theory within uncertainties.

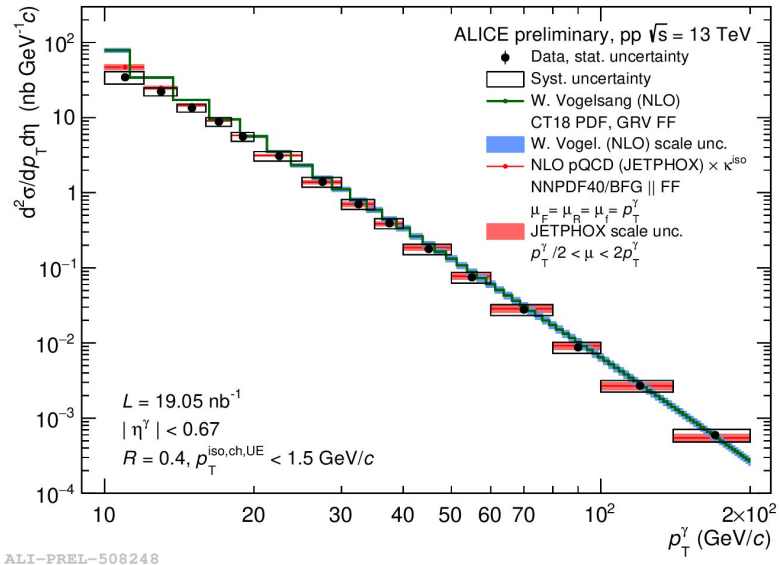
ALICE measurements: extends other LHC experiments toward lower p_T.

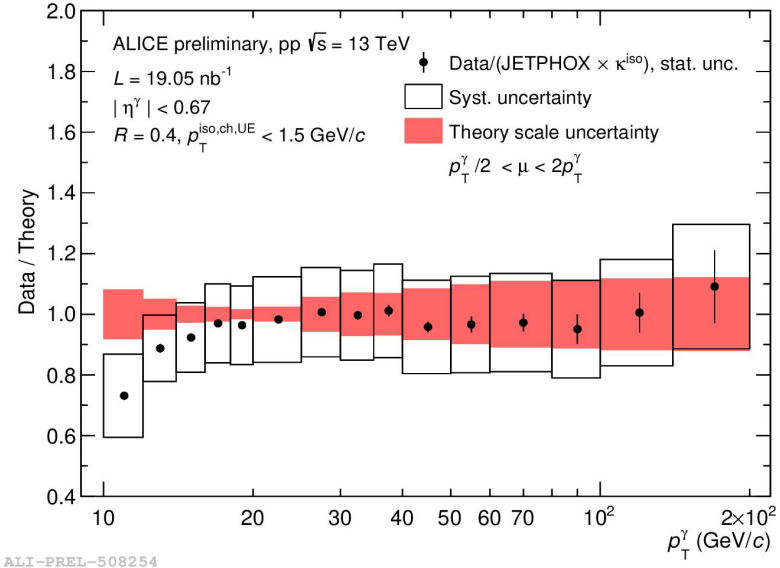
Isolated photon cross section in pp $\sqrt{s}$ = 13 TeV

JETPHOX NLO calculations scaled by the PYTHIA isolation fraction at generator level, κ^{iso} to consider the parton to hadron fragmentation.

Charged isolation using ITS+TPC tracks, UE not subtracted.

$R = 0.4, p_T^{iso, ch, UE} < 1.5$ GeV/c





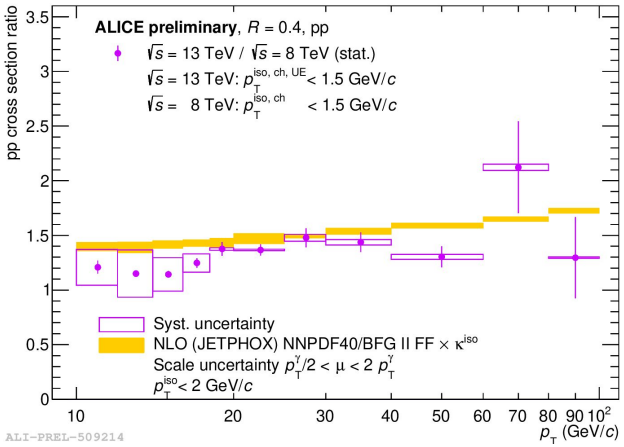
JETPHOX model calc. – NNPDF40, BFG II FF

NLO calc. Werner Vogelsang – CT18 PDF, GRV FF

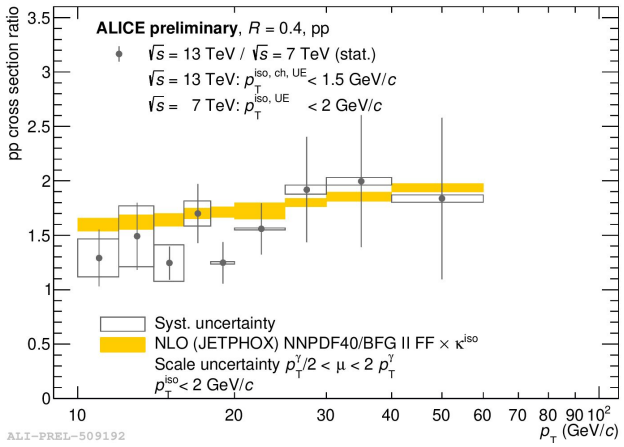
NNPDF Collaboration: arXiv.2109.02653

Isolated photon cross section ratios in pp collisions

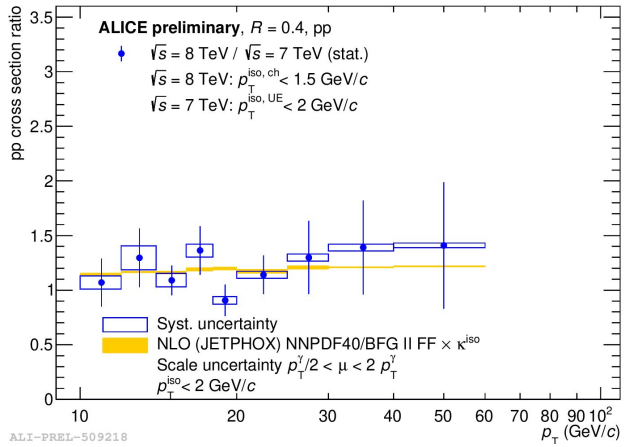
$\sqrt{s}$ = 13 TeV / $\sqrt{s}$ = 8 TeV



$\sqrt{s}$ = 13 TeV / $\sqrt{s}$ = 7 TeV



$\sqrt{s}$ = 8 TeV / $\sqrt{s}$ = 7 TeV



All NLO calculations scaled by the PYTHIA isolation fraction at generator level, κ^{iso} to consider the parton to hadron fragmentation.

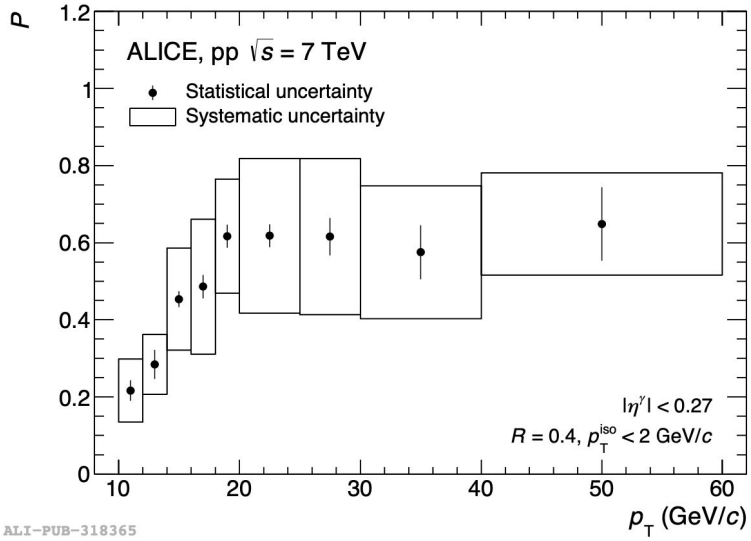
The data ratios are compared with corresponding ratios in NLO JETPHOX (NNPDF40/BFG II FF) calculations.

Good agreement is seen between them within uncertainties.

Isolated photons purity

Purity is similar at different energies

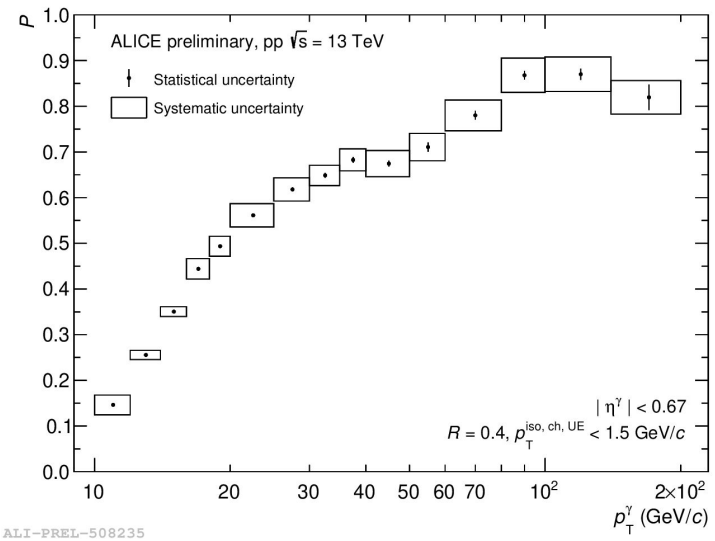
pp $\sqrt{s}$ = 7 TeV



Charged+neutral isolation using ITS+TPC tracks and EMCal clusters, UE not subtracted.

$R = 0.4$, $p_T^{iso, UE} < 2$ GeV/c

pp $\sqrt{s}$ = 13 TeV

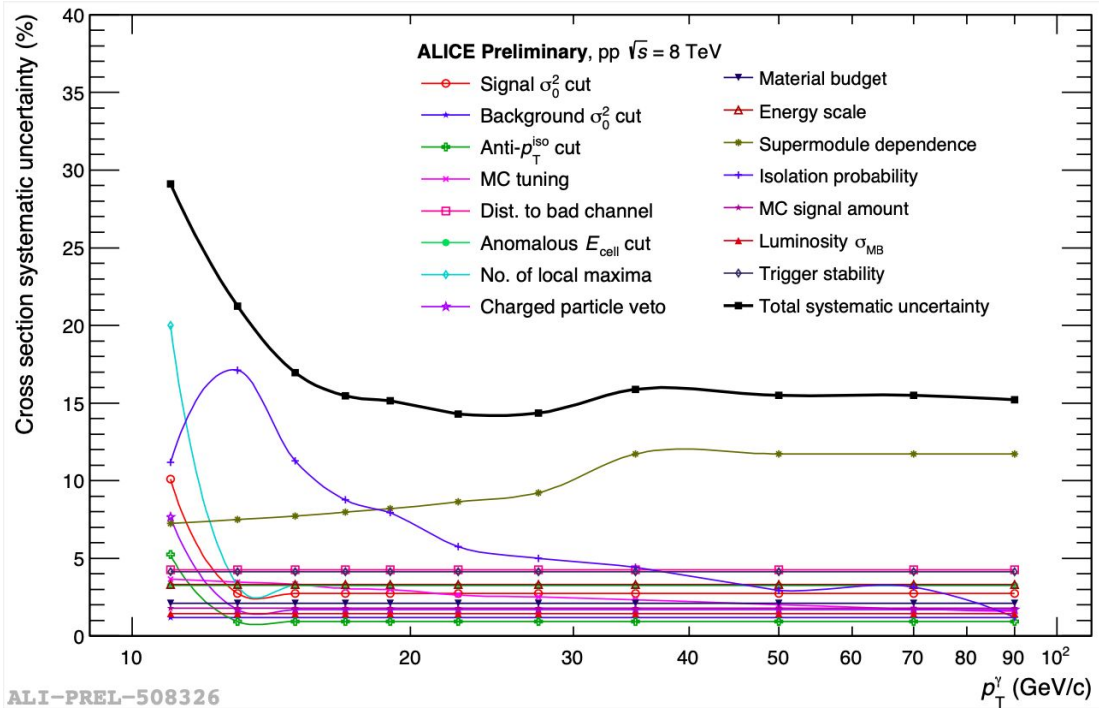


Charged isolation using ITS+TPC tracks and EMCal+DCal clusters, UE not subtracted.

$R = 0.4$, $p_T^{iso, ch, UE} < 1.5$ GeV/c

Systematic Studies

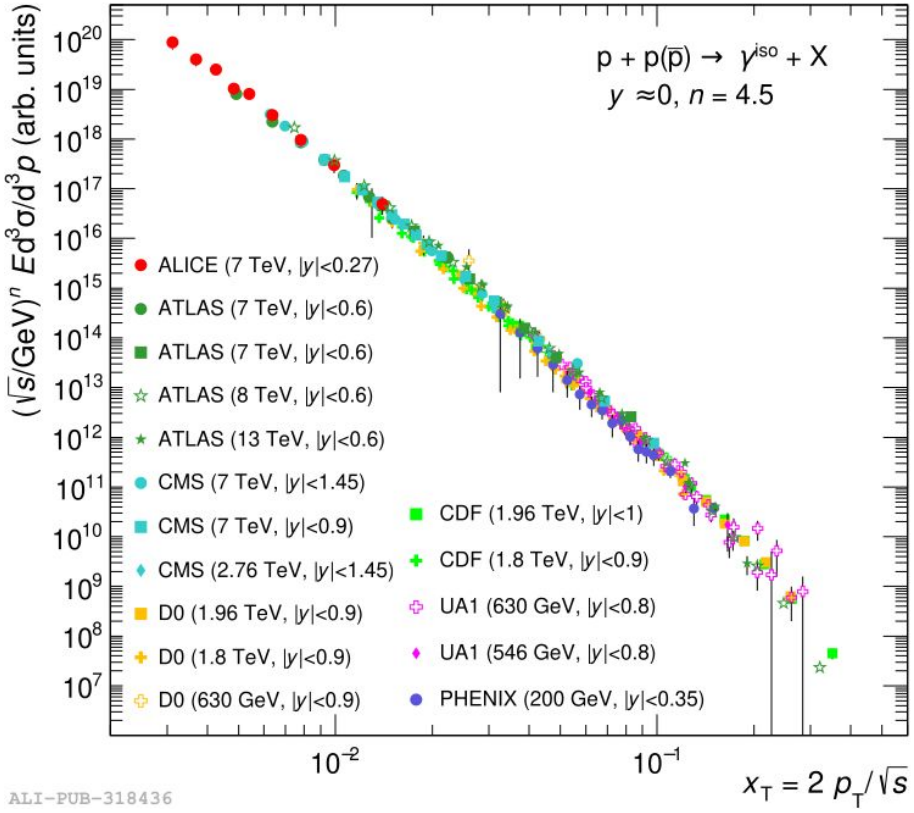
- Signal shower shape distribution
- Background shower shape distribution
- Anti-isolation minimum thresholds
- Different crosstalk parameters (MC tuning)
- Number of local maxima
- Distance to bad channel
- Track matching (CPV)
- Exoticity Cut
- MC mixing
- Isolation probability
- Trigger stability, luminosity
- Material budget, energy scale
- Super-module dependence



Isolated photons

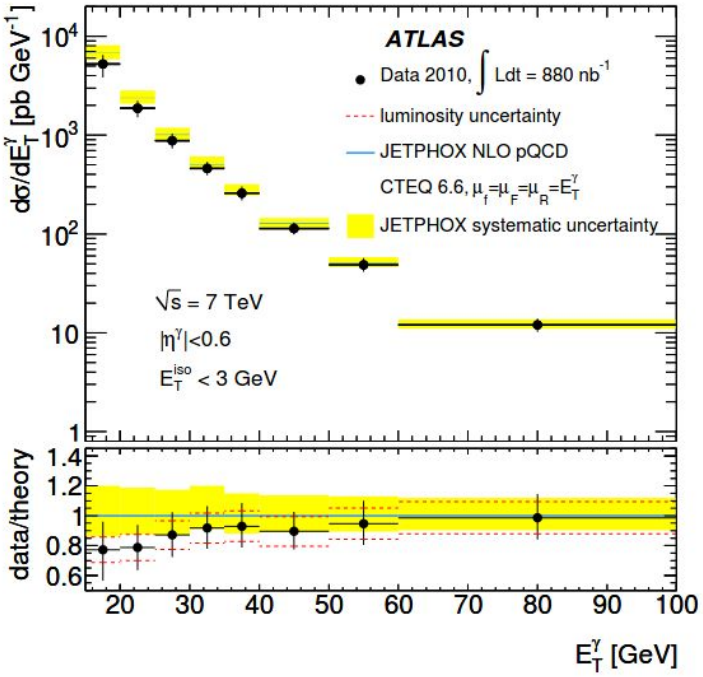
ALICE data compared to the world's data of isolated photon spectra measured in pp and $p\bar{p}$ collisions as a function of x_T. The ALICE measurement allows us to extend the x_T reach to lower values.

https://arxiv.org/pdf/1906.01371.pdf



ATLAS & CMS results

ATLAS Collaboration: PRD83(2011)052005



CMS Collaboration: PRL 106(2011)082001