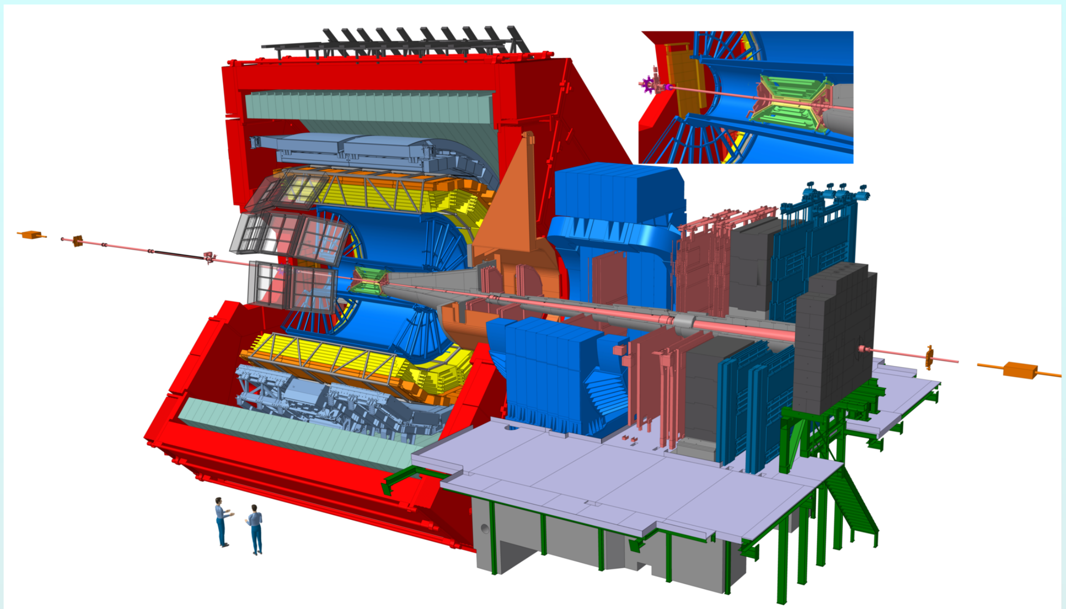
Probing the initial state of nuclear collisions using isolated prompt photons with ALICE



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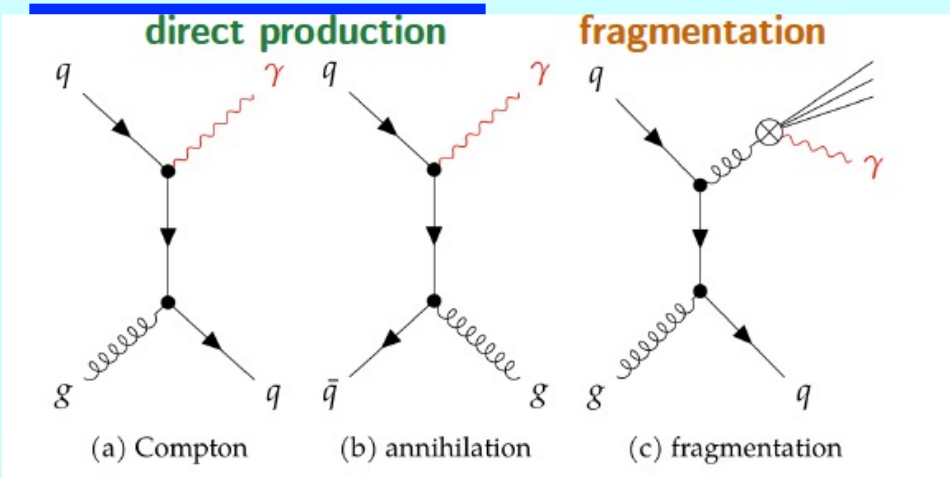
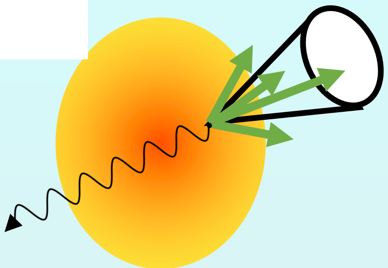
Motivation

Photon production:

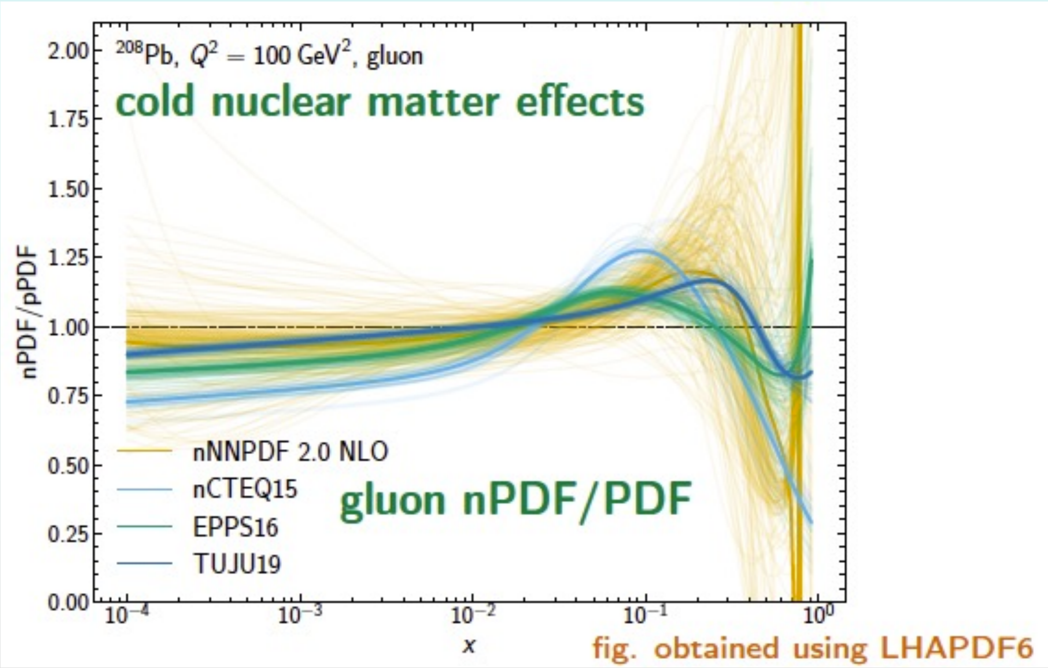
No strong interaction

Exit nuclei unaffected

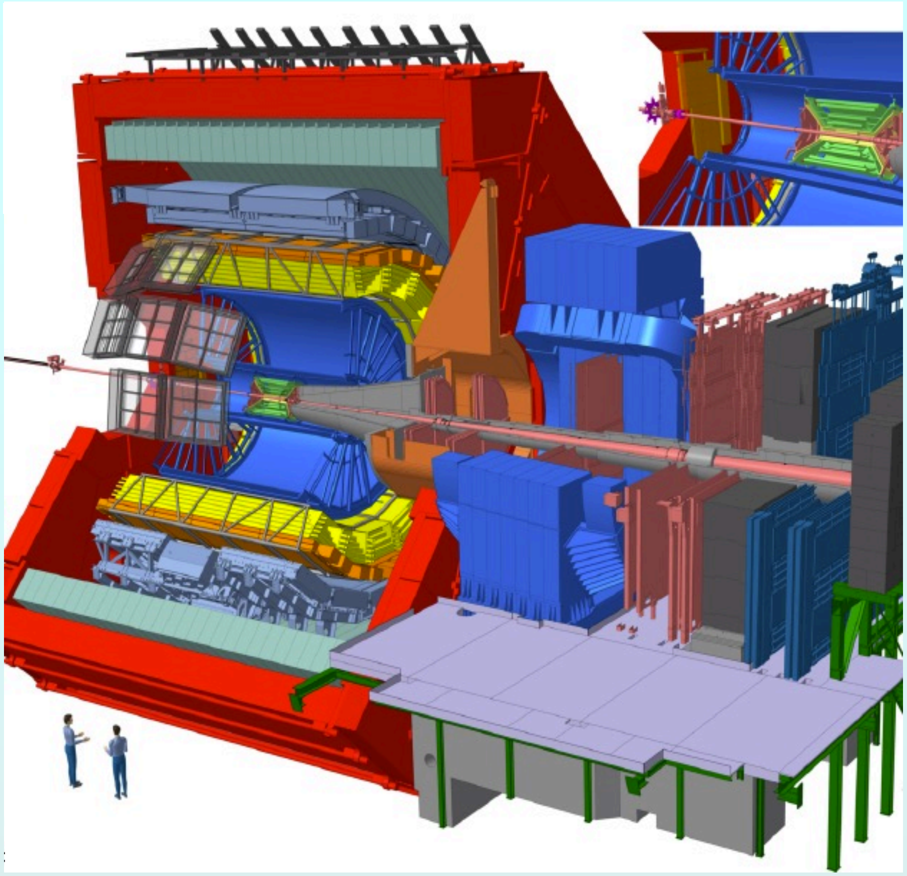




- **Measure direct γ to test pQCD description at NLO**
- **Constrain gluon PDFs at low x**
- **Quantify cold nuclear matter effects in Pb**



Measure photons in ALICE



Photons in EMCal & Dcal

$|\eta| < 0.68$ and $|\eta_{DCal}| > 0.23$

$\Delta\phi_{EMCal} = 107°$ and $\Delta\phi_{DCal} = 67°$

identify via shower shape & track veto

Isolation in TPC & ITS

use charged tracks

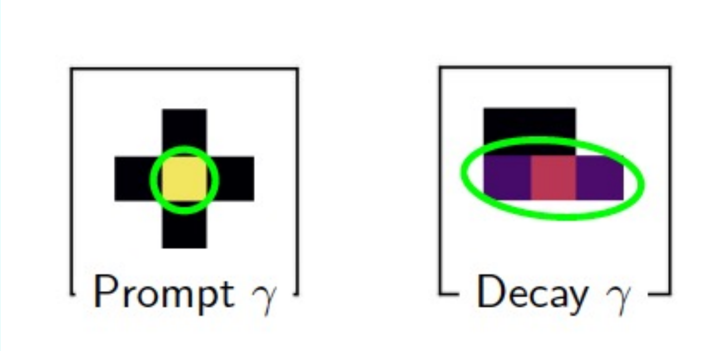
$|\eta| < 0.9$ in full azimuth

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

underlying event subtracted with $\perp$ cones or Voronoi area

1) prompt, isolated photons in EMCal

- **Clusters from prompt vs. decay photons**



EM shower shapes differ

Calculate $\sigma^2_{long(5x5)}$

signal: 0.1 – 0.3 (round)

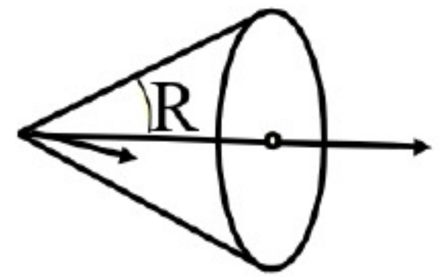
background: 0.6 – 1.6 (not)

- **Apply isolation energy cut to reduce fragmentation & decay photons**

Calculate from charged particles

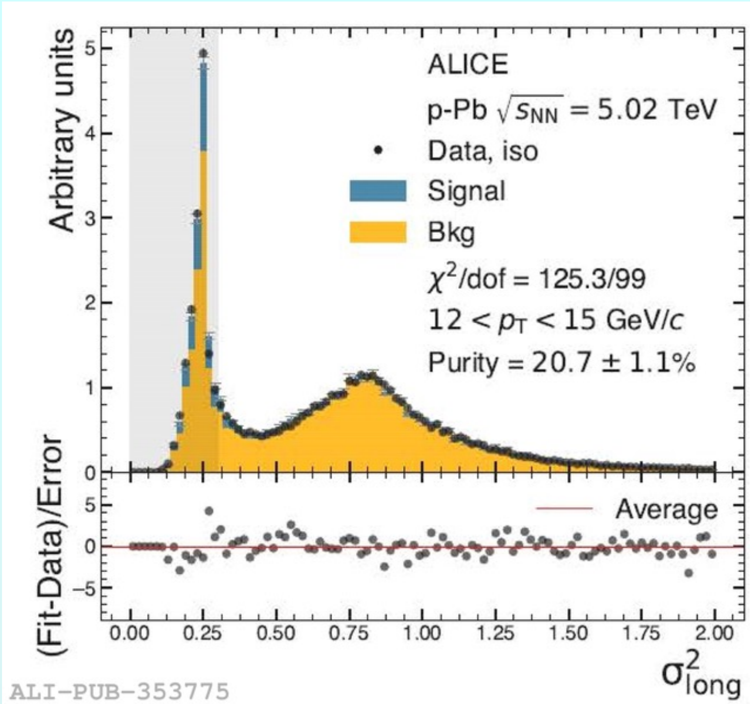
in R = 0.4 cone

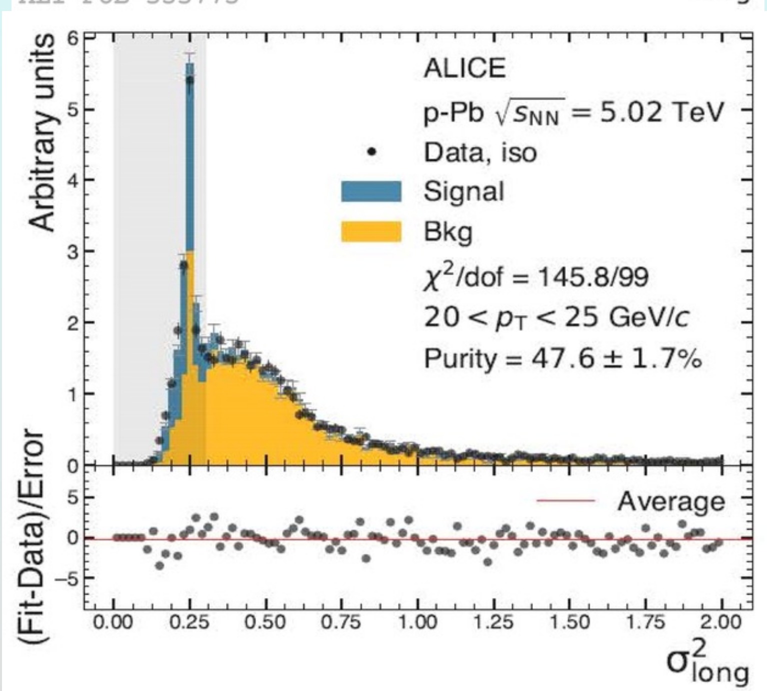
$p_T^{iso,ch}$ < 1.5 GeV/c



$$p_T^{\text{iso, ch}} = \Sigma_{\text{tracks}} p_T^{\text{track}} - \rho(\pi R^2)$$

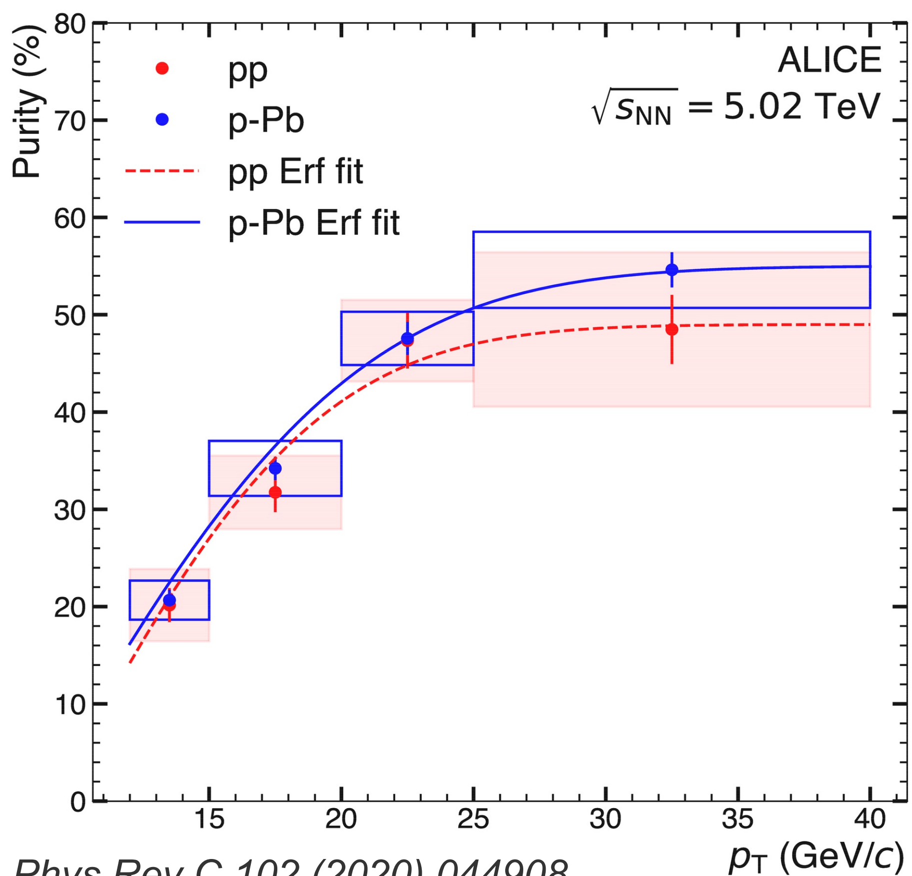
2) Measure resulting photon purity





- Template fit to the shower shape distribution
- Linear combination of signal template from MC background from data
- Adjust y axis scales to optimize χ^2
- purity = Signal / (S+B)

Purity



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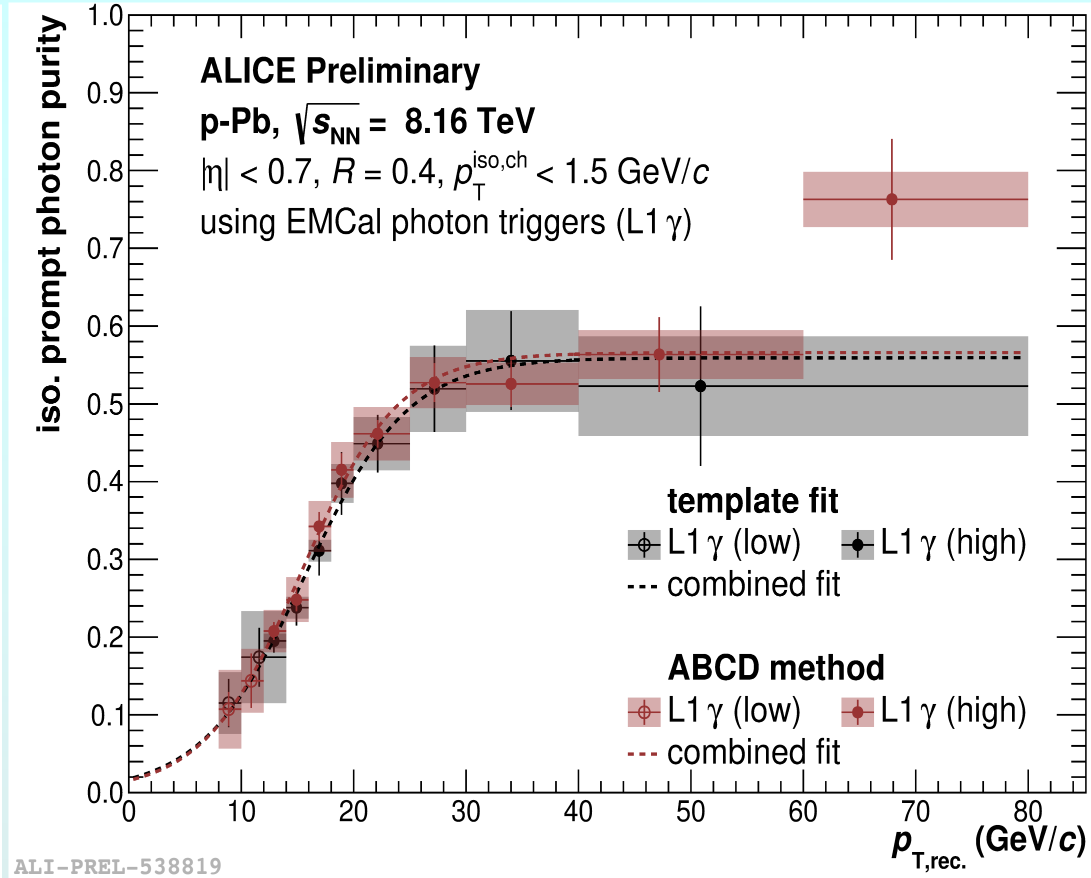
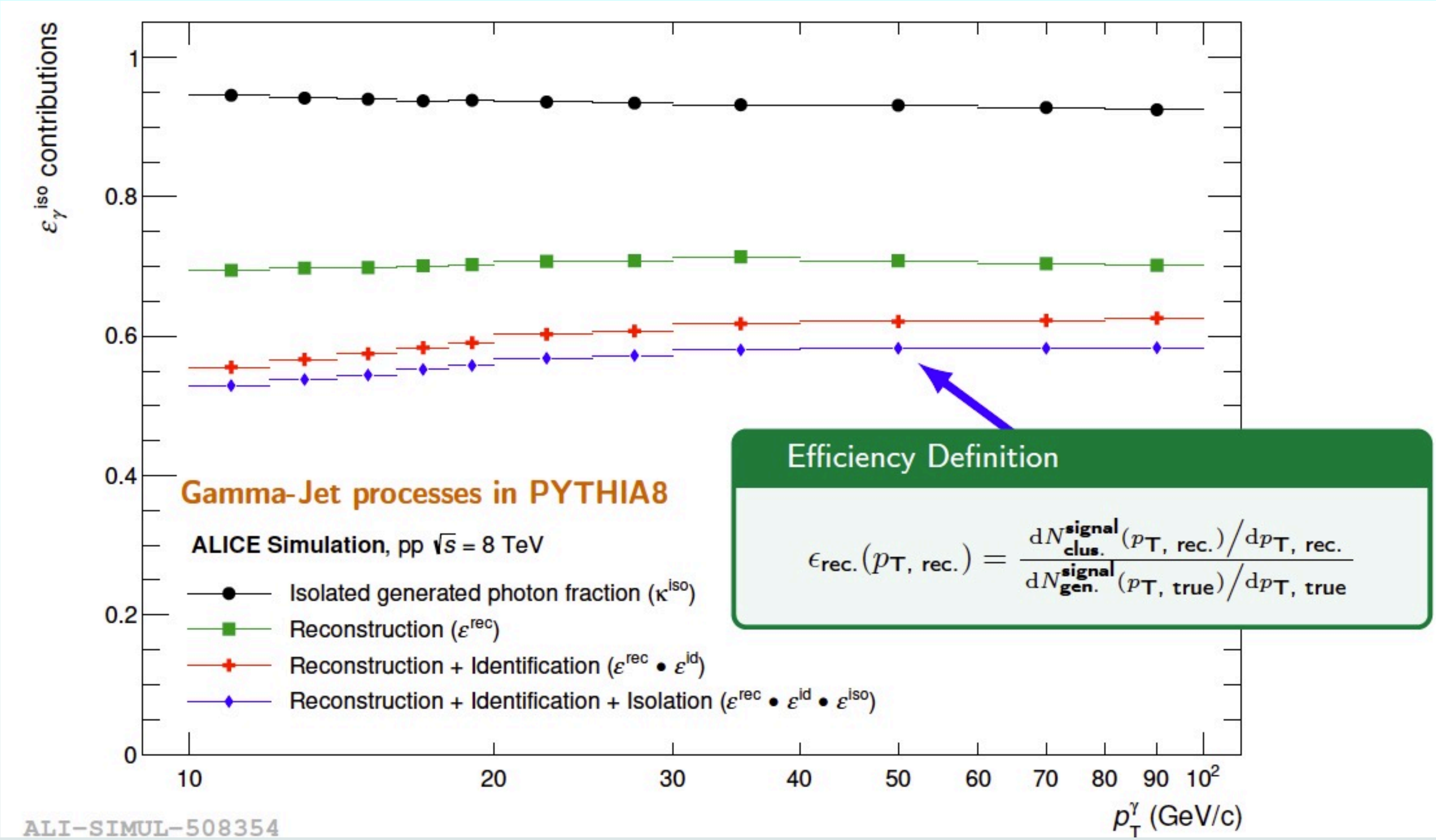


A small fraction of π^0 decay asymmetrically and sneak through

Photon S/B is reasonable above 12 GeV/c

3) γ Efficiency



Similar for the other data sets

Putting it all together

N_{ev} is the number of events which passed my event selection criteria: EG1 or EG2 trigger (if event has both EG1 or EG2, only the lowest fired trigger is counted), $|Z_v| < 10$ cm, and pile up rejection

P is the isolated photon purity, which is applied as a weight when filling the cluster p_T

$\frac{d^2N}{N_{ev}dp_T d\eta}$ is the event normalized differential cluster distribution (cluster spectra)

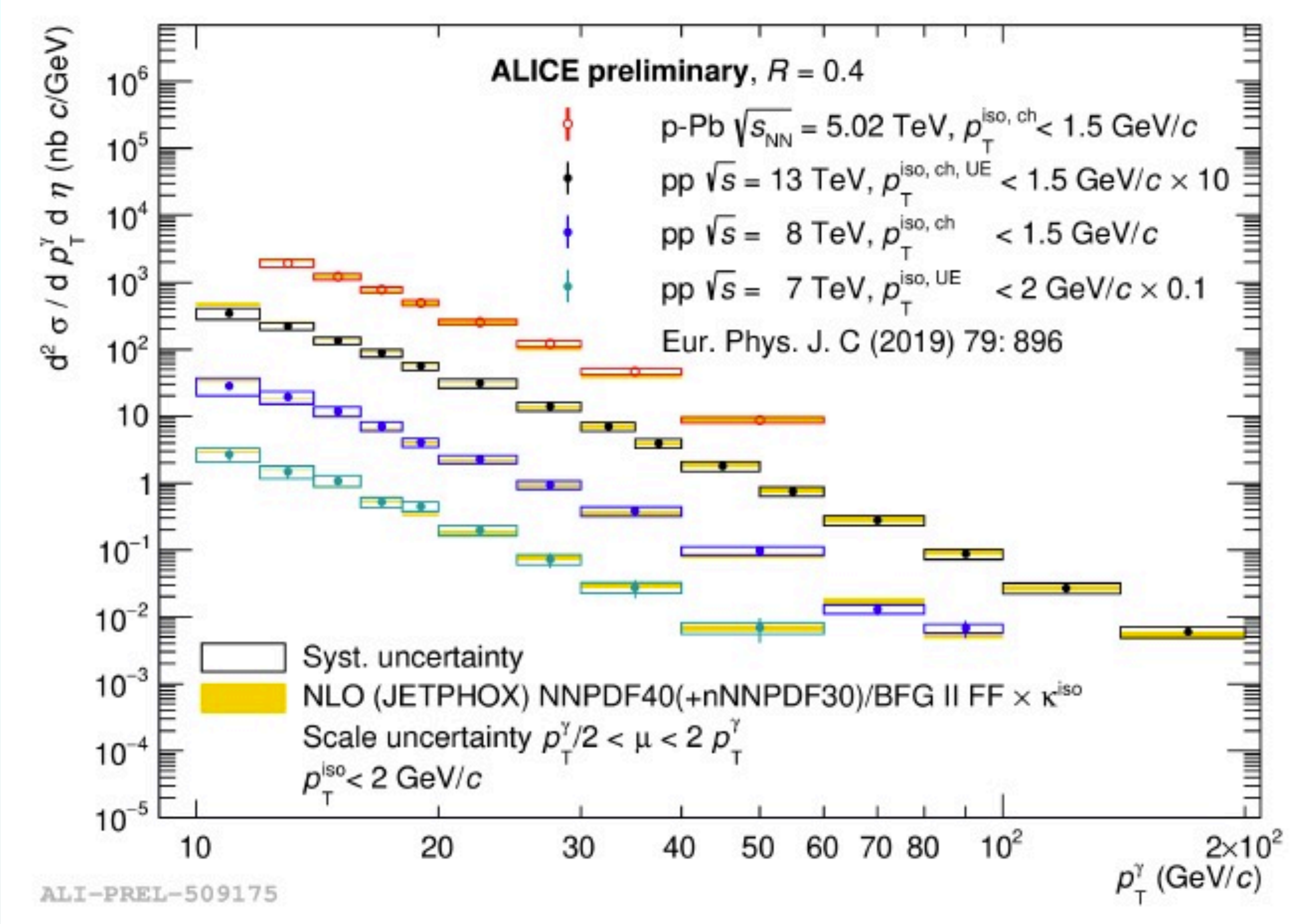
$$\frac{d^2\sigma}{dp_T d\eta} = \frac{N_{ev} \times P}{\mathcal{L}_{int} \times \varepsilon_{\gamma}^{iso}} \times \frac{d^2N}{N_{ev}dp_T d\eta}$$

$\mathcal{L}_{int}$ is the integrated luminosity calculated using $\mathcal{L}_{int} = \frac{N_{ev}^{EGi} \times R_{trig}^{EGi}}{\sigma_{MB}}$ and $R_{trig}^{EGi} = \left(\frac{1}{N_{ev}^{EGi}} \frac{dN_{clus}^{EGi}}{dp_T}\right) / \left(\frac{1}{N_{ev}^{MB}} \frac{dN_{clus}^{MB}}{dp_T}\right)$ which are the trigger rejection factors (RF)

$\varepsilon_{\gamma}^{iso}$ is the isolated photon global efficiency. It is the ratio of all reconstructed isolated photons divided by all generated photons

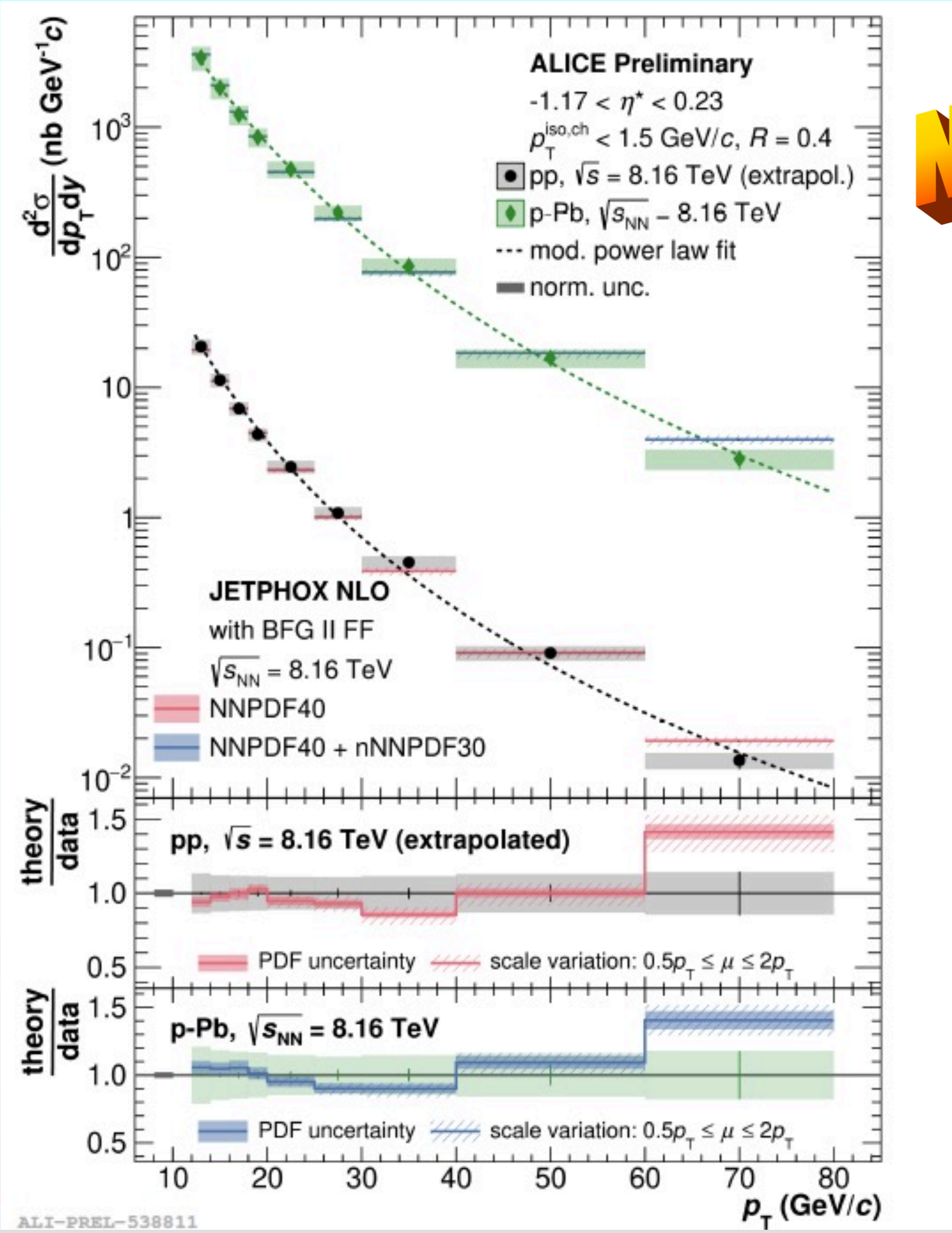
$d\eta = 2\pi\Delta\phi\Delta\eta$

Photon spectra in pp and p-Pb



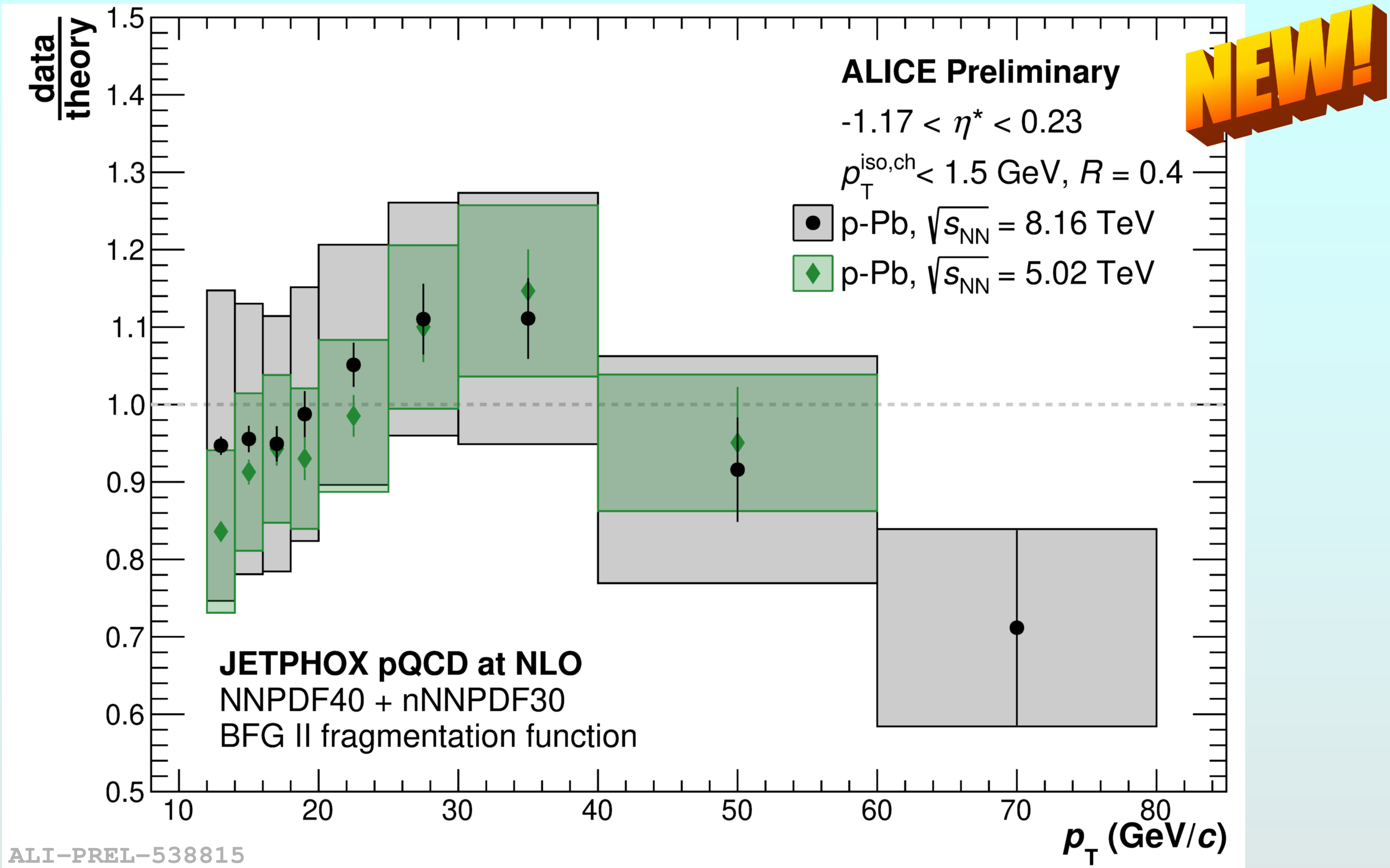
Note comparison to JETPHOX

Spectra at 8.16 TeV



Consistent with theory using recent PDF's and fragmentation functions

p-Pb 8.16 vs. 5.02 TeV

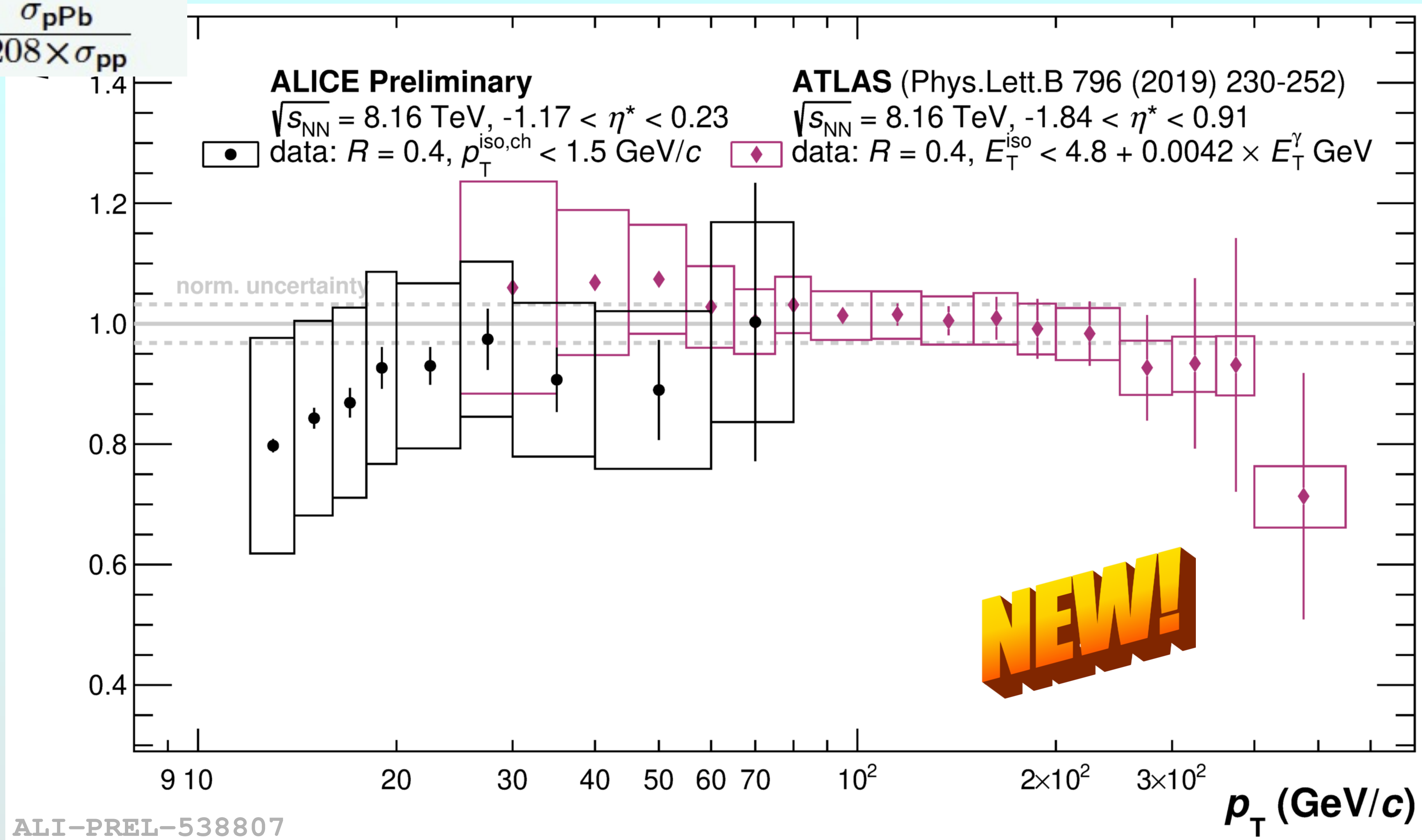


Both consistent with pQCD at NLO

Maybe a hint of overprediction at low p_T

Nuclear modification in p-Pb

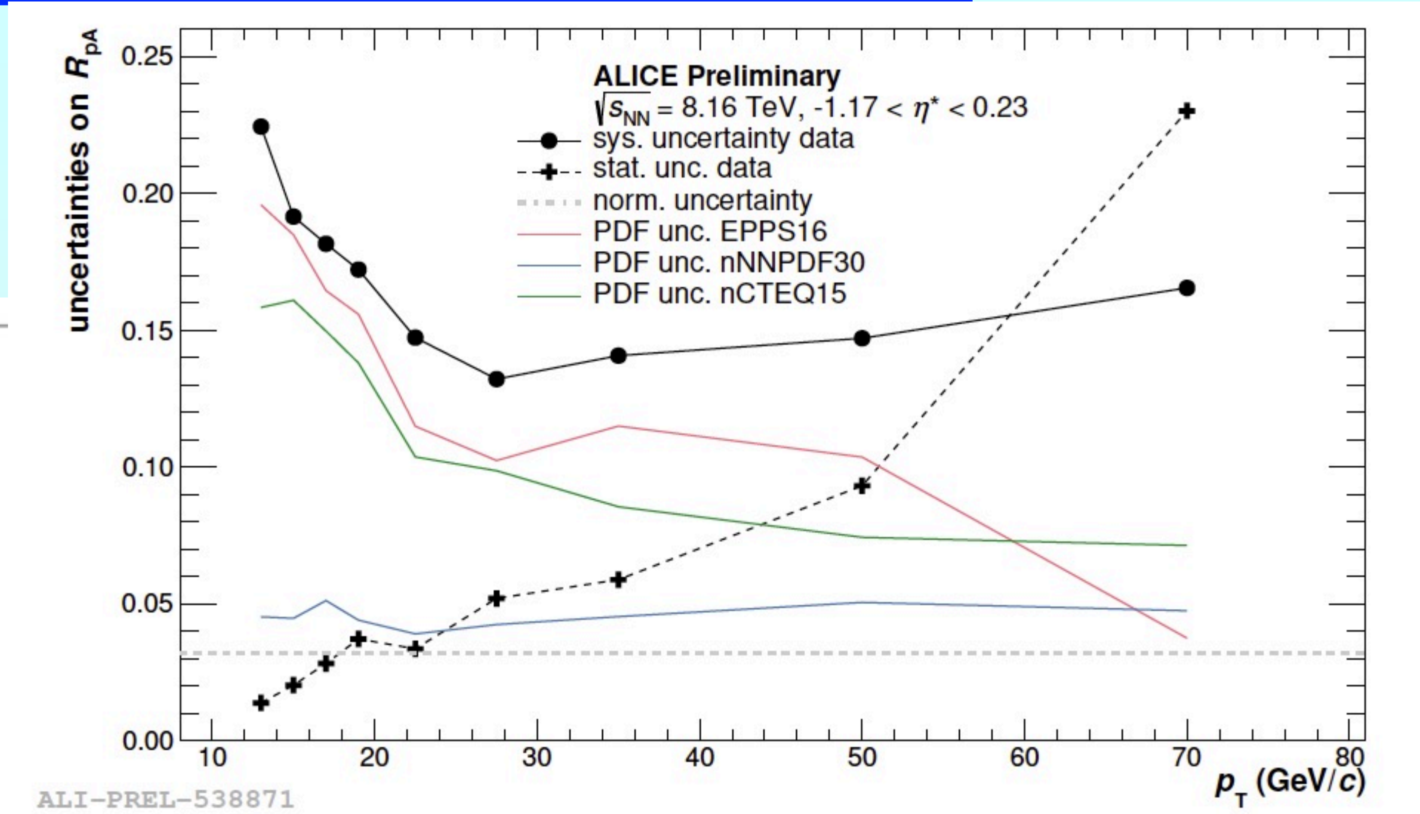
$$R_{pA} = \frac{\sigma_{pPb}}{208 \times \sigma_{pp}}$$

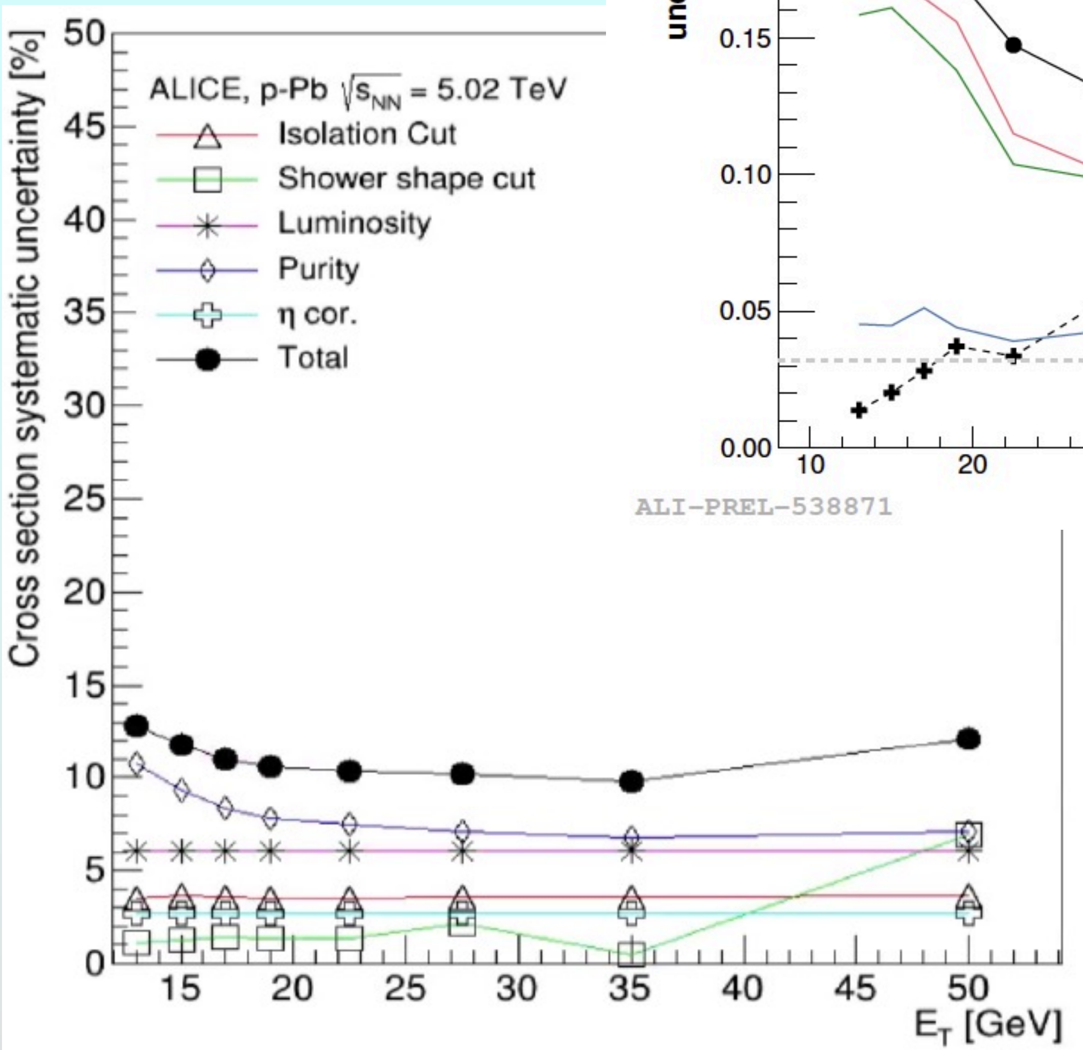


ALICE reaches lower p_T (and x); agree with ATLAS

Trend below 1 at low p_T: gluon shadowing

4) Systematic uncertainty



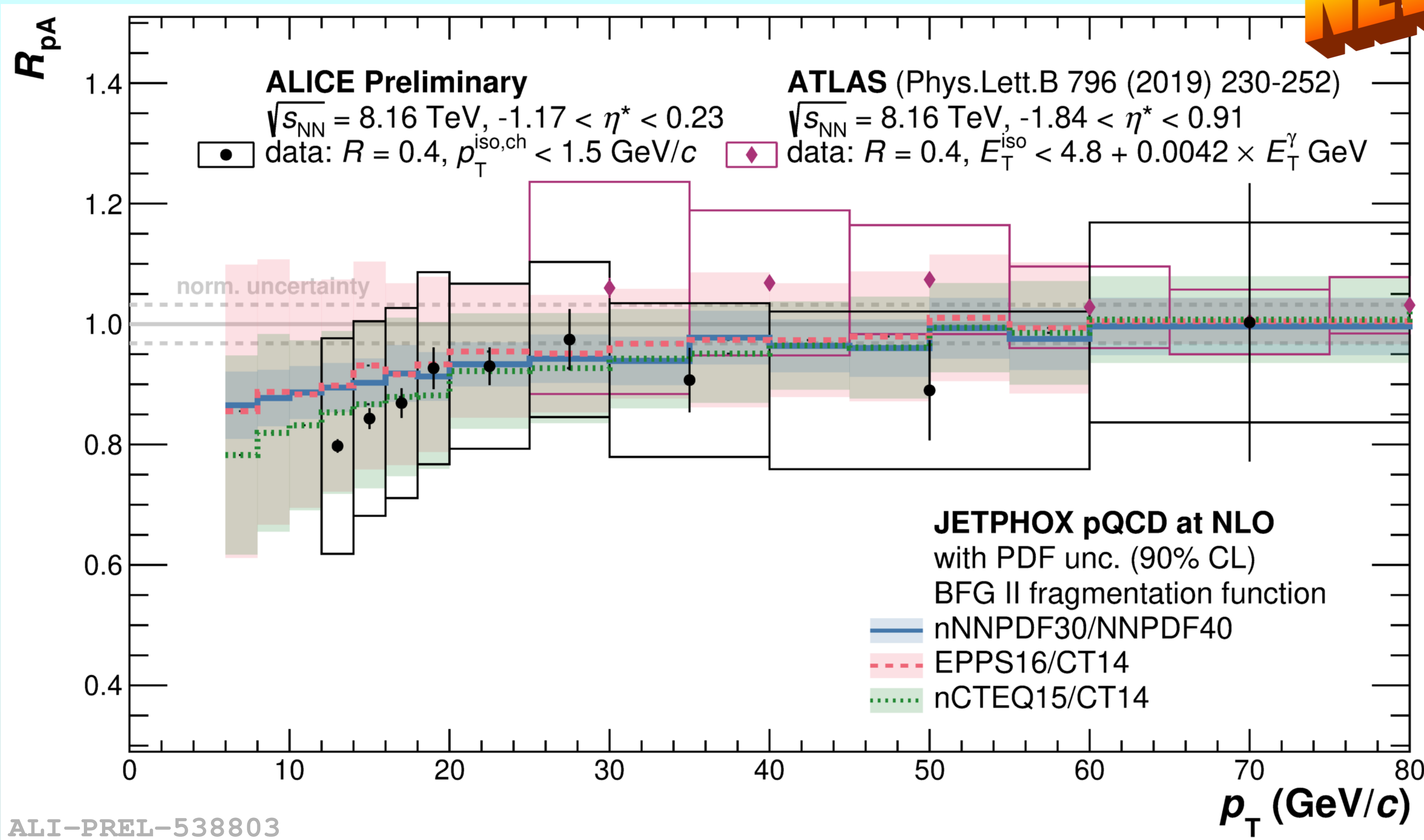


Systematic uncertainty dominated by purity uncertainty

Lower p_T and smaller σ_{syst} would improve discriminating power

Compare to JETPHOX

NEW!

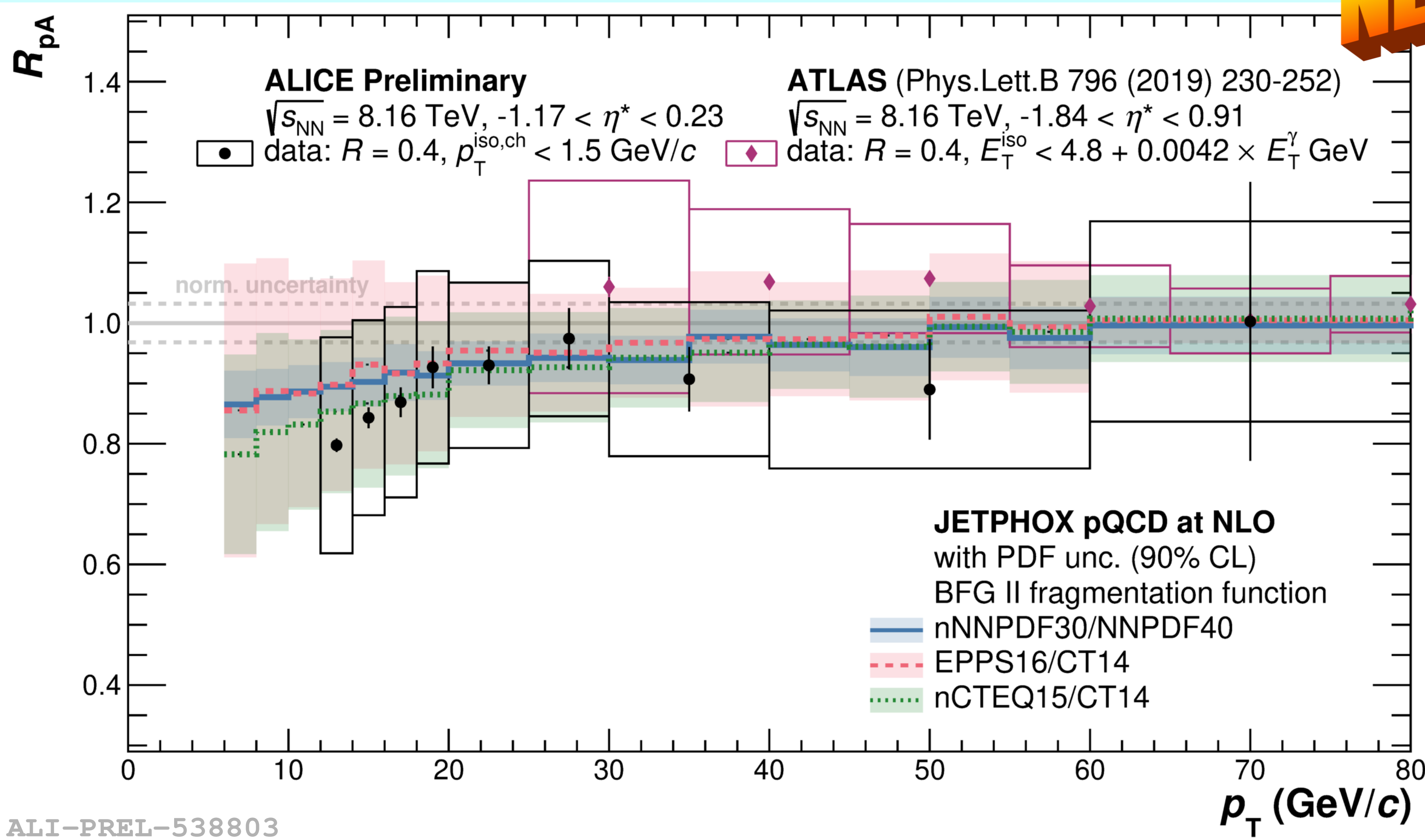


Suppression expected from nPDF's with shadowing

data should help refine nPDFs

Compare to JETPHOX

NEW!



Suppression expected from nPDF's with shadowing

data should help refine nPDFs

Reaching lower p_T and improved precision will help

Summary

- ALICE measured isolated photons at several energies in pp and p-Pb collisions
- Reasonable agreement with NLO calculations using
  Recent PDFs and nPDFs and BDGII fragmentation
- First nuclear modification R_{pA} for p_T < 20 GeV/c
  Hint of γ suppression at low p_T
  Consistent with p-Pb vs. pp expected from nPDFs
  Better precision will yield improved nPDFs

- We look forward to Run-3 Pb+Pb!
- In Run-4, new FOCAL at $3.4 < \eta < 5.8$
  Extend reach at low-x
  Perhaps see gluon saturation?

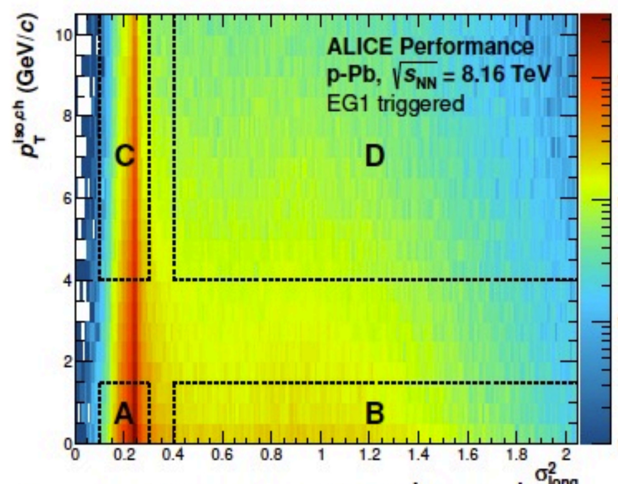
- **Backup**

Purity determination

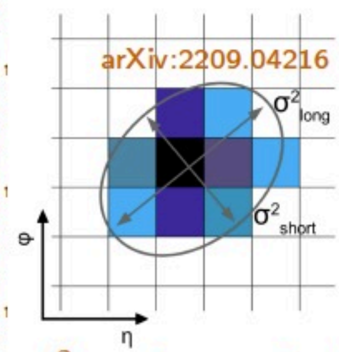
ABCD method (default)

- idea: σ^2_{long} - isolation plane of clusters divided into 4 regions → three background dominated regions are used to estimate background contribution in signal region
- data-driven approach; only requires PYTHIA for corrections of correlations between σ^2_{long} and iso. energy

$$P = \left(\frac{C/A}{D/B}\right)_{\text{data}} \times \left(\frac{A/C}{B/D}\right)_{\text{PYTHIA}}$$



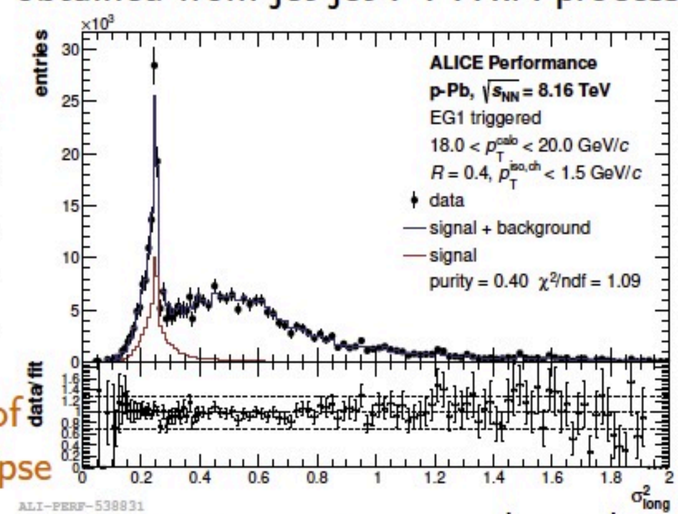
narrow ↔ elongated



σ^2_{long}= long axis of shower shape ellipse

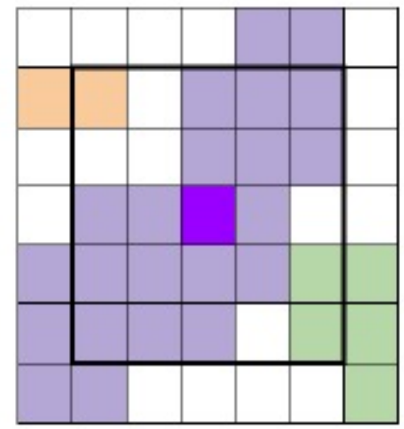
Template fit (cross-check)

- a template fit to the σ^2_{long} distribution is used to obtain purity
  - data: iso. photons from data
  - signal: iso. prompt + frag photons from γ-jet PYTHIA processes
  - background: anti-isolated photons from data
- correlation weights for background temp. obtained from jet-jet PYTHIA processes



narrow ↔ elongated

$\sigma^2_{\text{long(5x5)}}$ definition



Variant of "traditional" ALICE σ^2_{long} variable: use the indices of the 5×5 cells around the cell with the highest energy in the cluster to calculate the square of the larger eigenvalue of the energy distribution in the $\eta - \varphi$ plane:

$$\sigma^2_{\text{long(5x5)}} = \frac{\sigma^2_{\varphi\varphi} + \sigma^2_{\eta\eta}}{2} + \sqrt{\frac{\sigma^2_{\varphi\varphi} - \sigma^2_{\eta\eta}}{4} + \sigma^2_{\varphi\eta}}$$

- $\sigma^2_{\varphi\eta} = \langle\varphi\eta\rangle - \langle\varphi\rangle\langle\eta\rangle$ are the covariance matrix elements
- Integers φ and η are the cell indices in their respective directions
- $\langle\varphi\eta\rangle$ is the second and $\langle\varphi\rangle$, $\langle\eta\rangle$ are the first moments of the position of the cells within the cluster
- Position is log-weighted by the energy with cutoff