Isolated photon measurements in pp collisions at 8 TeV

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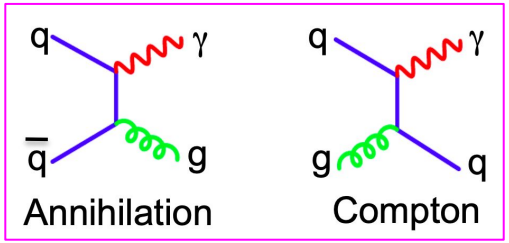
Motivation

Study 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

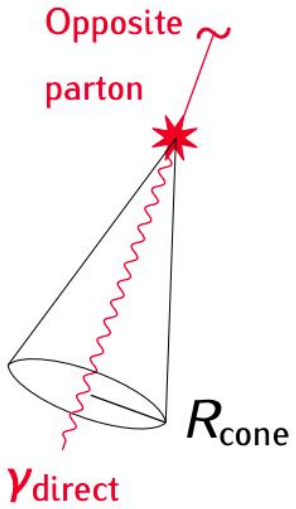


- They are not products of hadronic decays.
- They are colourless probes of QCD processes.
- They are probes of the initial state of protons or nuclei, as they are emitted at the early stages of hadron collisions (having high p_T).
- These photons come directly from parton-parton hard scatterings, allowing one to constrain parton distribution functions.

How to extract direct photon signal

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

- Signal: Leading Order (LO) direct photons
- Background: Fragmentation and decay photons.
- **Isolation** is a tool to access: LO direct photons
- **Isolation** techniques: Strongly suppress fragmentation and decay components.
- **"Isolated photons" - no hadronic activity surrounding the photons from hard processes.**
  - Sum the p_T of charged particles inside a cone of fixed radius
  - Set an isolation threshold: $p_T^{\text{iso, ch}}$



Data Selection pp 8 TeV: LHC12 abcdfhi pass2 + GJ, JJ, JJHigh, JJLow MCs

Cluster Selection *using EMCal*

- V1 Clusterizer with E_{seed} = 500 MeV & E_{min} = 100 MeV
- $E_{cluster}$ > 0.7 GeV; N_{cells} > 1; NLM ≤ 2; $-30 \le t_{cluster}(ns) \le 35$ ns
- Shower shape long axis σ_0^2 : [0.1, 0.3] for photons (narrow clusters)
- Crosstalk used in MC

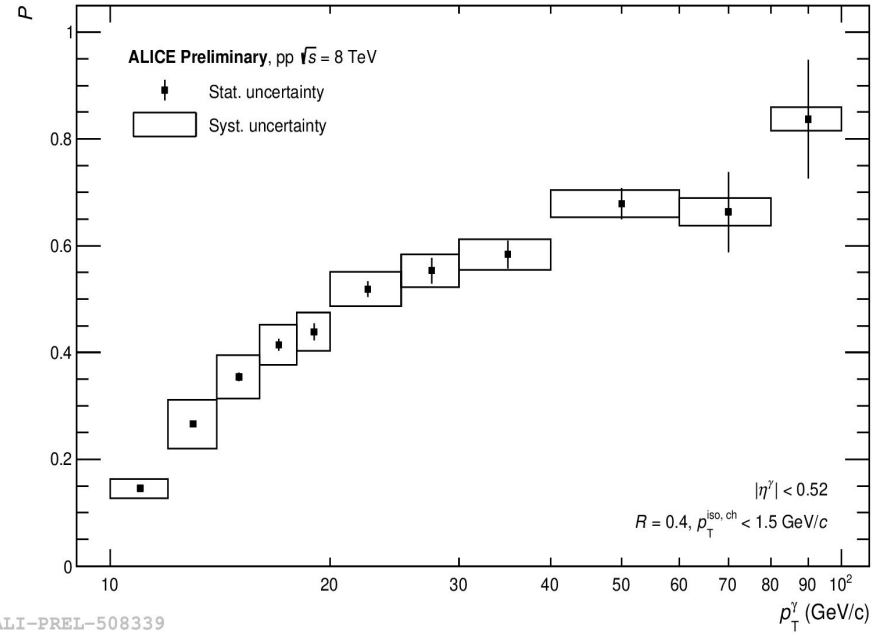
Track Selection

- Track selection: ITS+TPC hybrid tracks with E/p < 1.7
- Rejected charged-particle clusters by track matching – p_T track dependent cut

Photon isolation

- $p_T^{iso,\,ch} < 1.5$ GeV/c in $R = 0.4$
- Underlying event (UE) estimation: Using **perpendicular cone** method

Preliminary results - Purity & Efficiency



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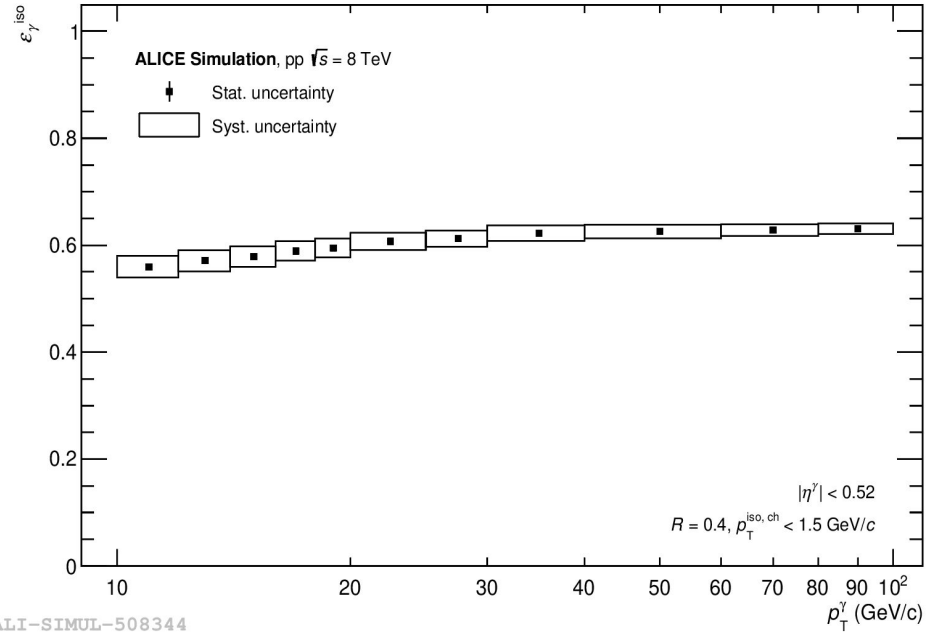

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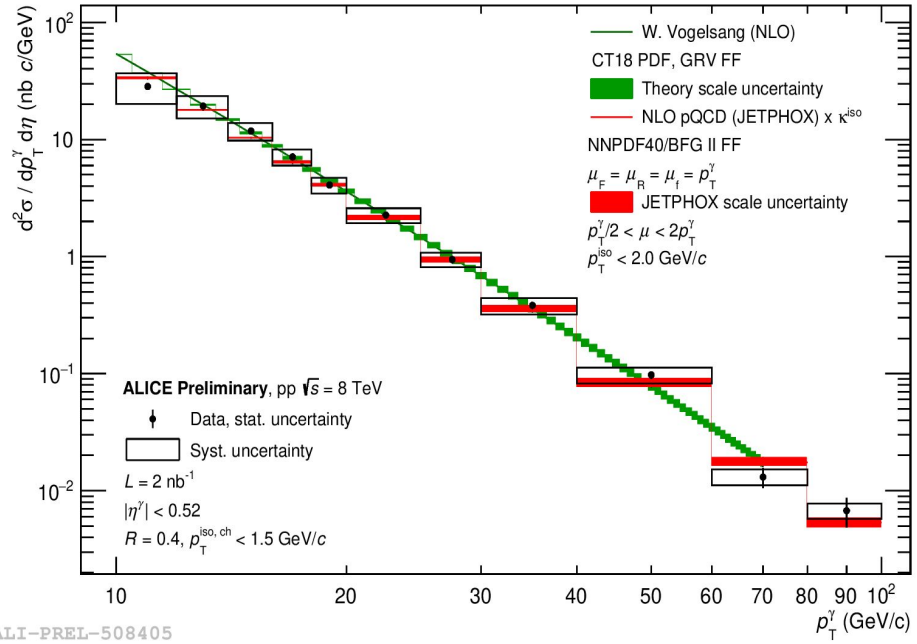
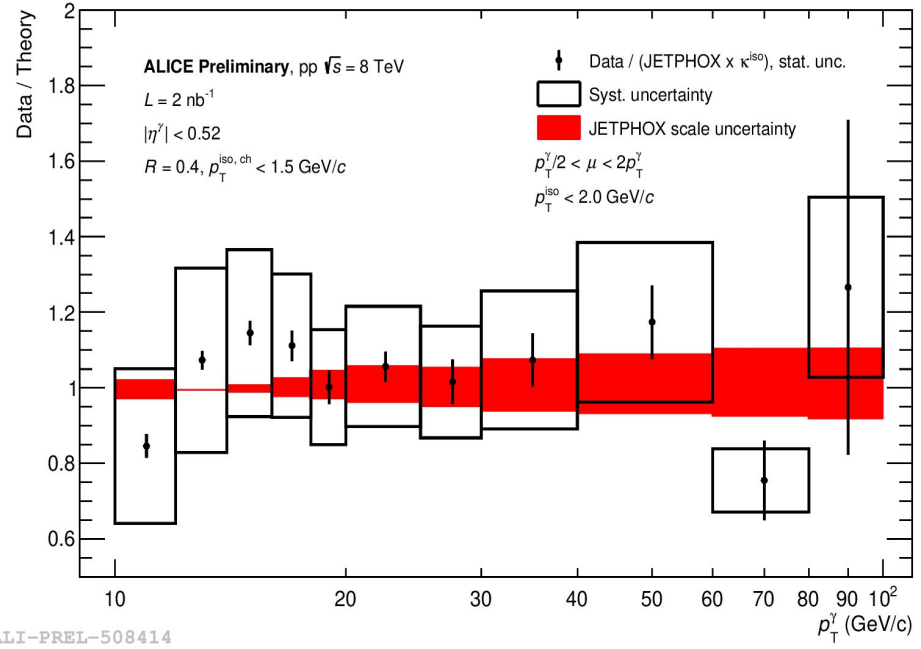
Preliminary results - Cross section



ALI-PREL-508405



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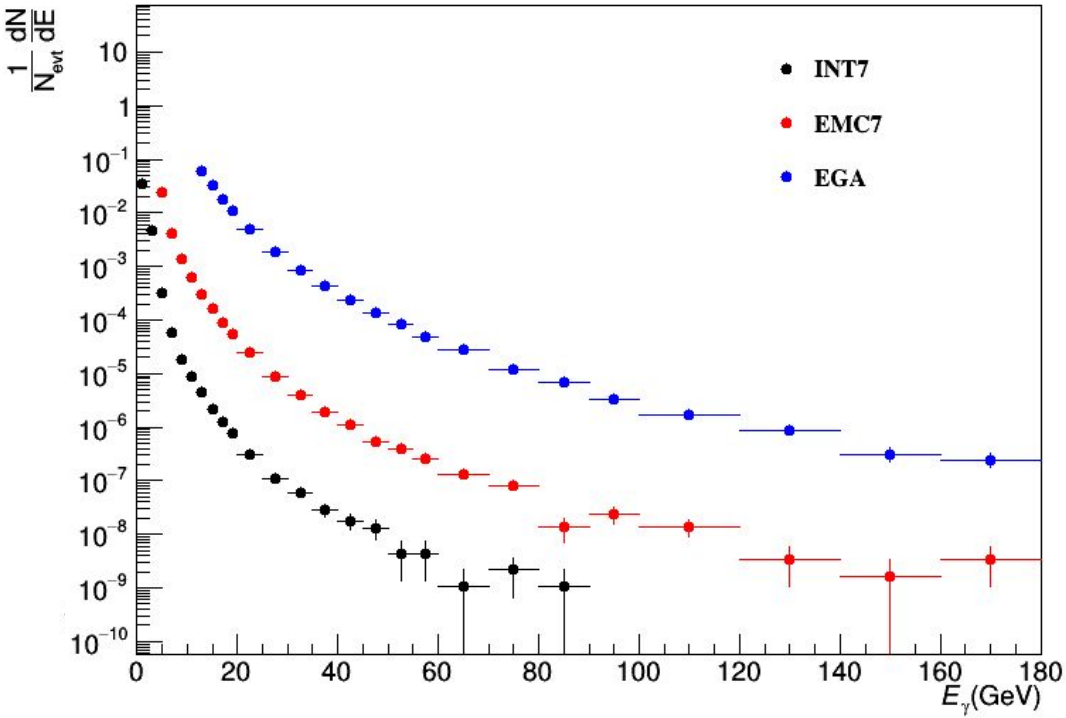
Good agreement is seen between data and NLO calculations within uncertainties.

Changes made to preliminary results

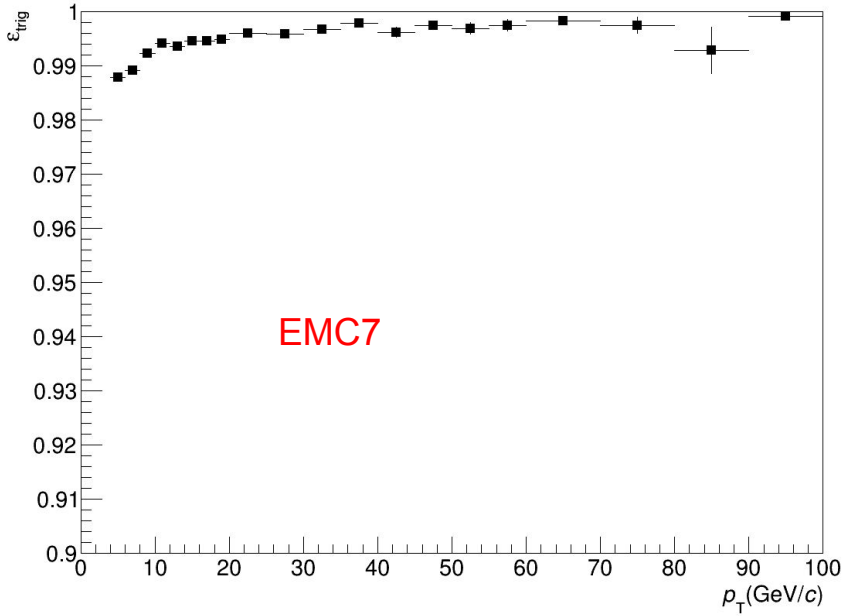
- Implementation of “trigger mask”
  - MB and triggered data masked regions (bad channel maps) can be quite different.
  - Trigger response emulation tools have been applied on MC and data to mask more regions that were found to trigger less than the rest.
- Calculation of “trigger efficiency”
  - The trigger efficiency depends in part on the masked calorimeter regions and thus the inspected calorimeter acceptance.
  - It is estimated in the simulation as the ratio of the selected cluster spectrum in events accepted by the trigger selection tools over all the clusters as a function of the cluster p_{T}.

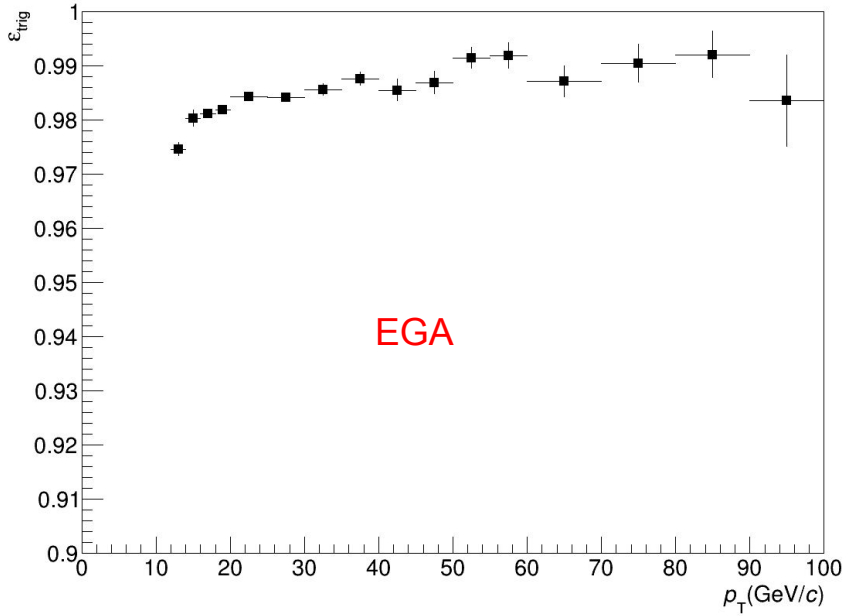
Photon cluster energy distribution

- Triggered sample:
  - EMC7:EMCAL_L0 trigger, E > 2 GeV, ~**29.85 M** events
  - EGA:EMCAL_L1 trigger, E > 10 GeV, ~**1.83 M** events
- Minimum Bias (INT7): ~**92.91 M** events



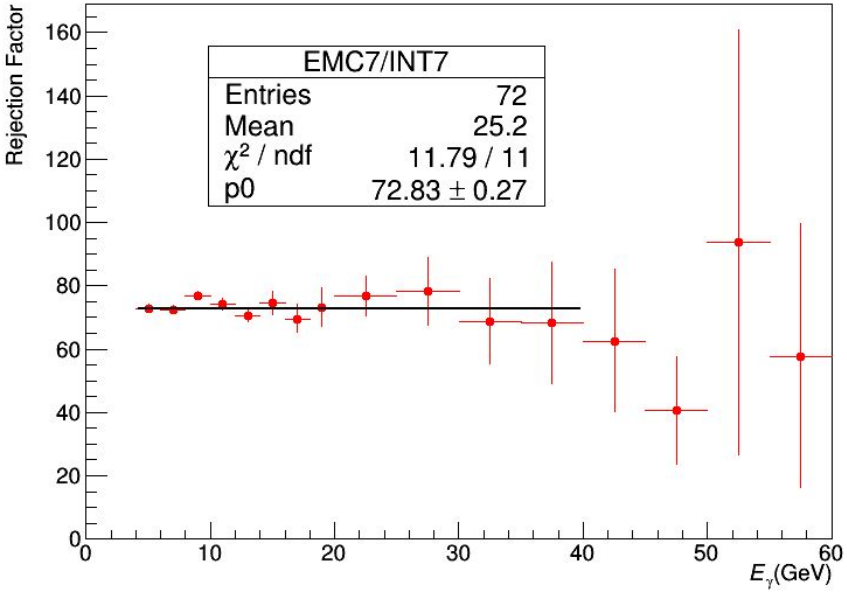
Trigger Efficiency

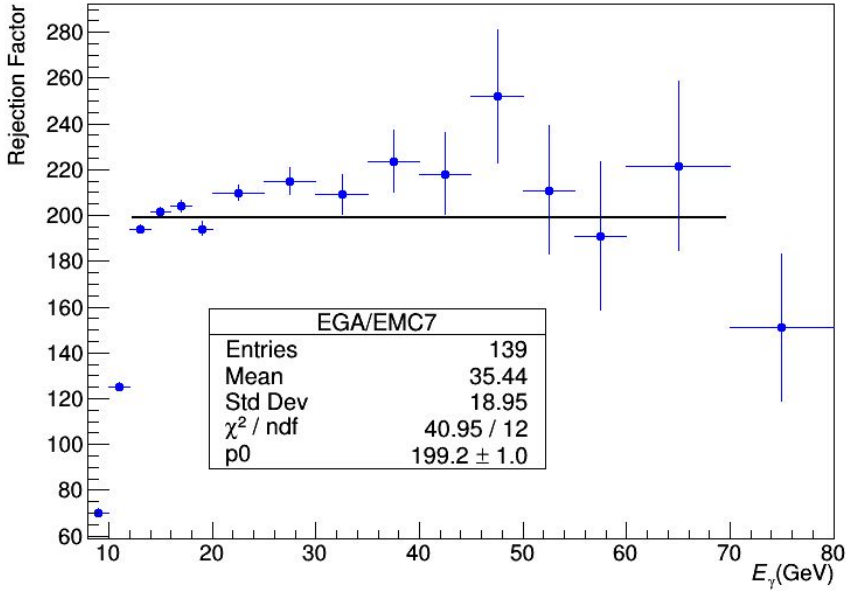




Each cluster spectrum used to determine the trigger rejection factor is divided by the corresponding trigger efficiency — bin-by-bin correction

Rejection Factors

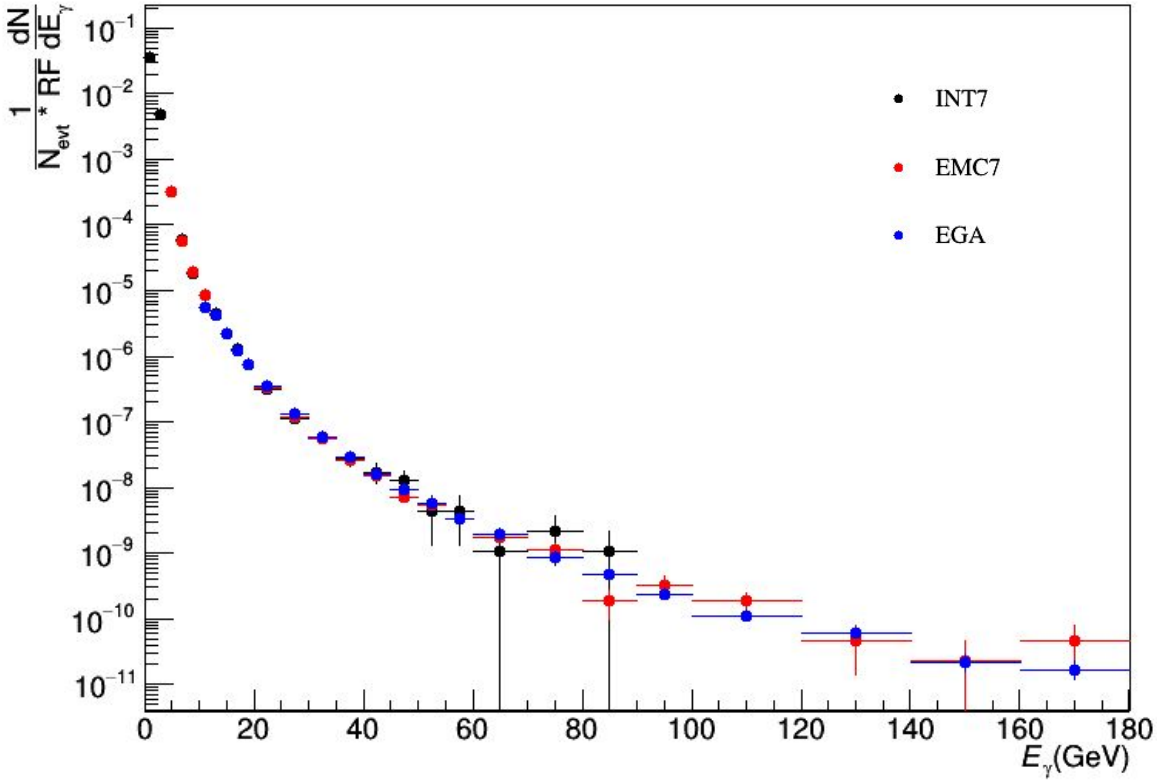




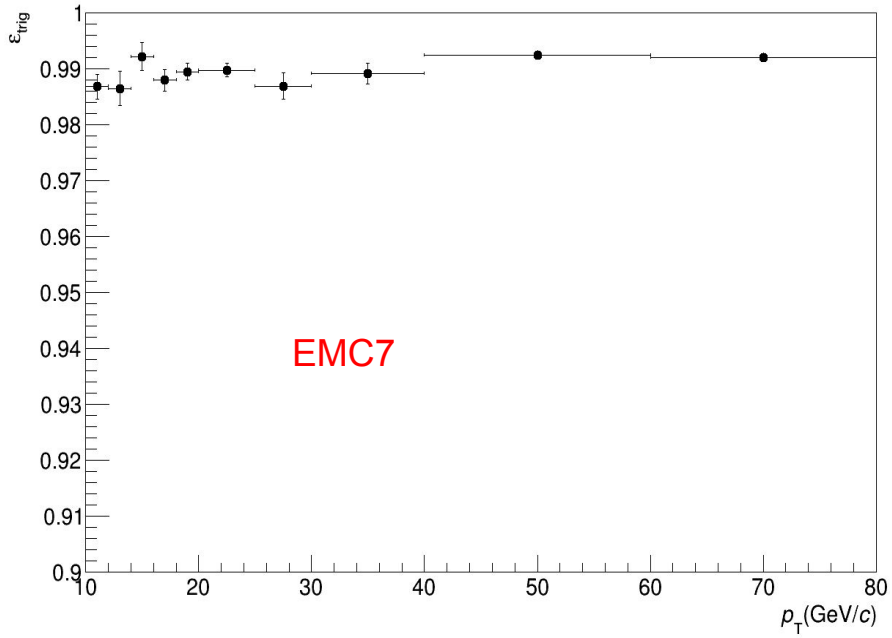
Rejection Factors	**RF1** - EMC7/INT7	**RF2** - EGA/EMC7
Without trigger efficiency	66.8	220.1
With trigger efficiency	72.8	199.2

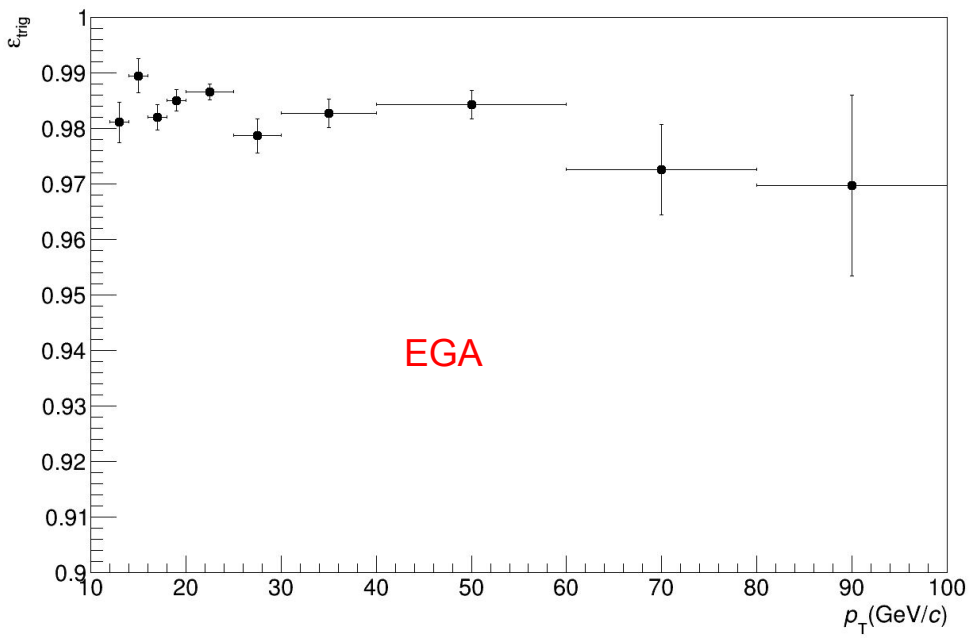
Corrected photon cluster energy distribution

- Cluster spectra scaled by the trigger efficiencies
- EGA scaled by RF1*RF2
- EMC7 scaled by RF1



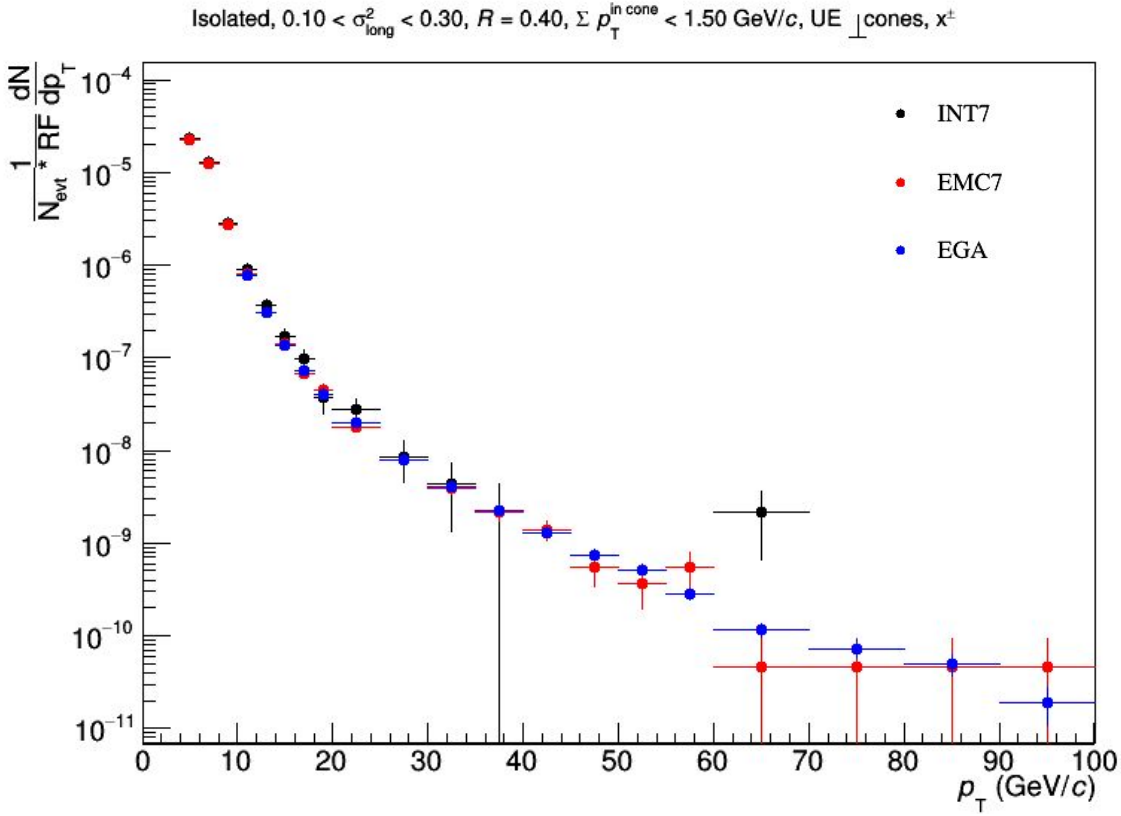
Trigger Efficiency for isolated narrow clusters



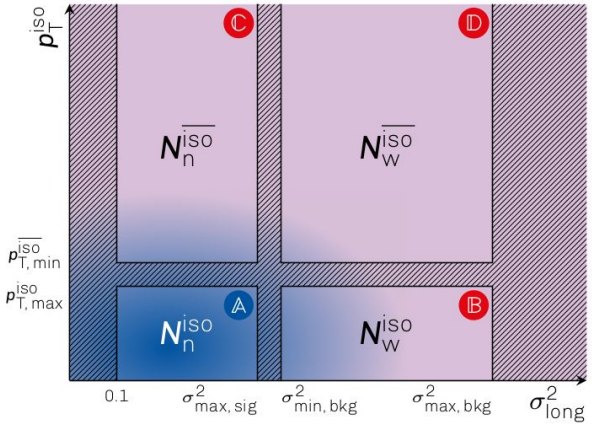


Raw isolated photon spectra

- Scaled by the trigger efficiencies for isolated narrow clusters
- EGA scaled by RF1*RF2
- EMC7 scaled by RF1



Purity & Efficiency estimation for isolated photons



Purity - The ABCD Method

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

$$N = S + B$$

$$P = 1 - (B/N)$$

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

Efficiency - using GJ MC

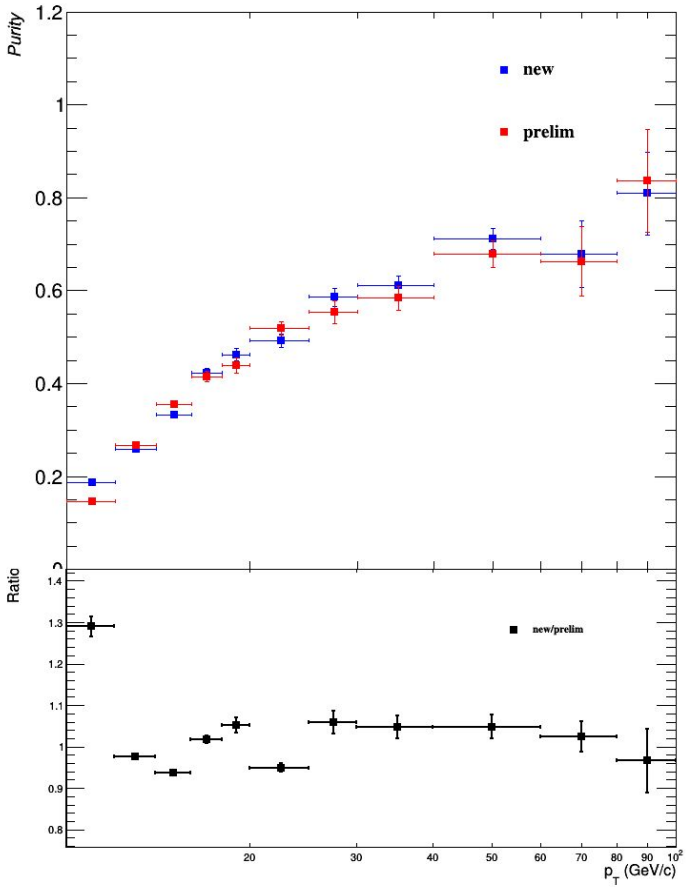
$$\varepsilon_\gamma^{iso} = \frac{\varepsilon^{rec} \bullet \varepsilon^{id} \bullet \varepsilon^{iso}}{\kappa^{iso}}$$

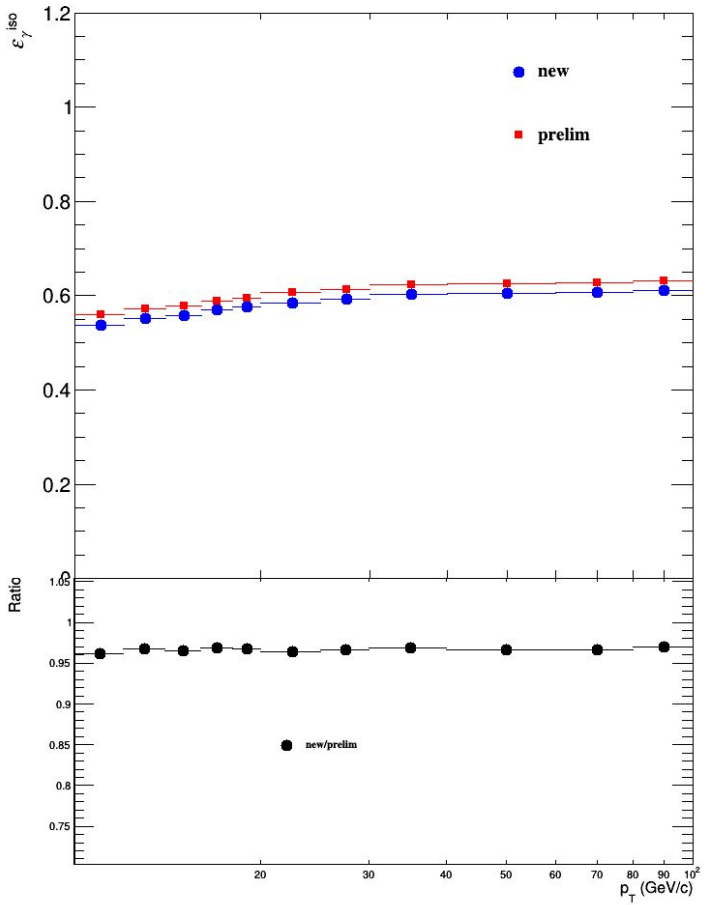
κ^{iso} – Fraction of generated photons which are isolated

Identification – Shower shape cut ($0.1 < \sigma_0^2 < 0.3$)

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

Purity & Efficiency corrections

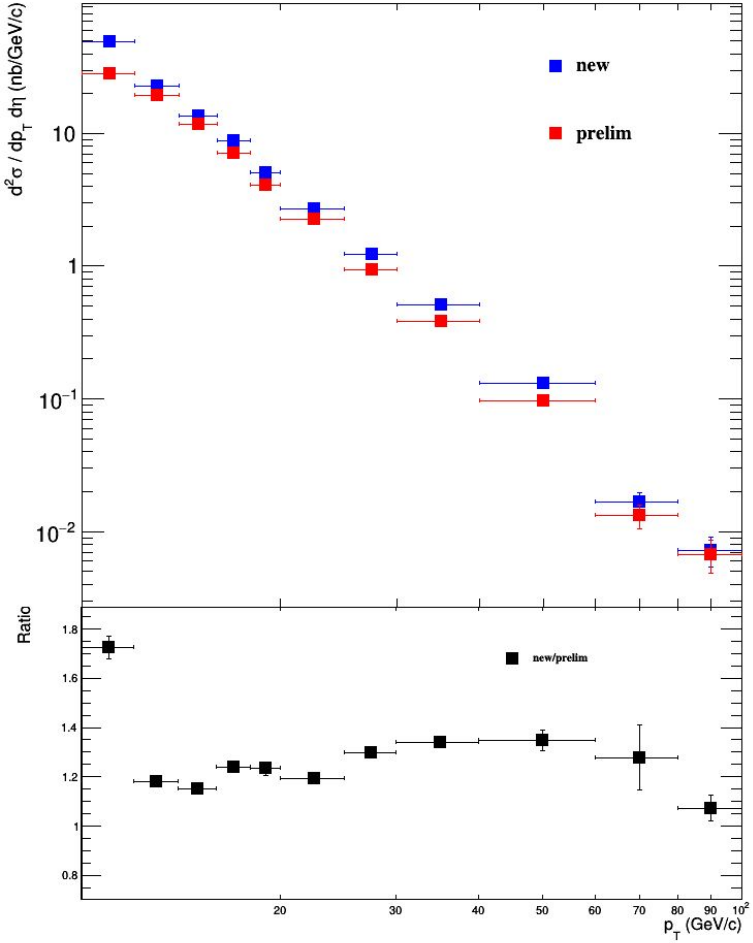




Isolated photons cross section

$$\frac{\mathrm{d}^2\sigma_{\gamma\ \mathrm{iso}}}{\mathrm{d}p_\mathrm{T}\,d\eta} = \sigma_{\mathrm{MB}}^{\mathrm{average}} \times \frac{1}{N_{\mathrm{evt}} \times RF} \frac{\mathrm{d}^2 N_{\mathrm{iso}}}{\mathrm{d}p_\mathrm{T}\,d\eta} \times \frac{1}{\varepsilon_{\mathrm{trig}}} \times \frac{P}{\varepsilon_\gamma^{\mathrm{iso}}}$$

- ~20% discrepancy between the new and preliminary results.
- Still under investigation



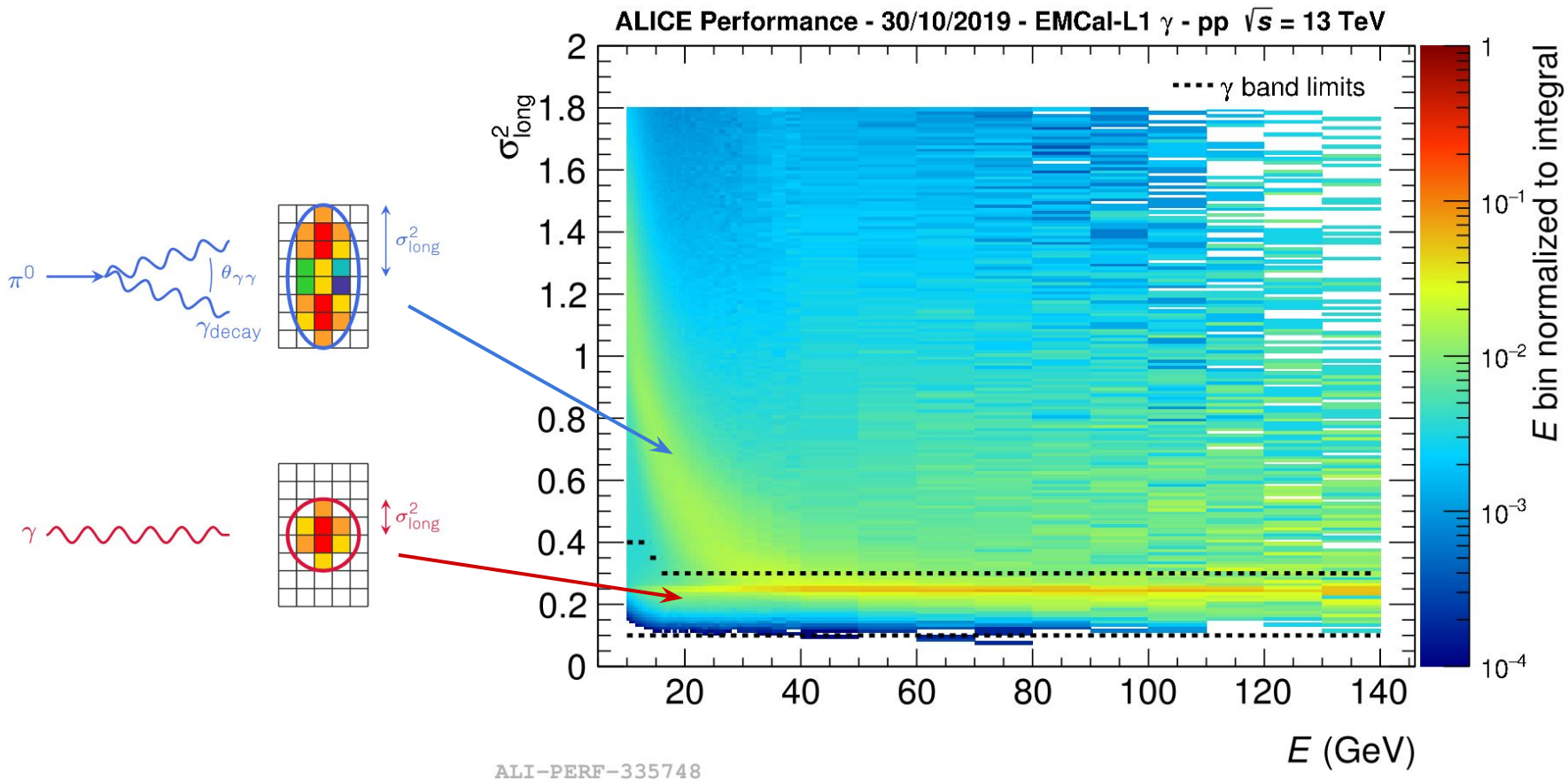
Summary and Outlook

- Preliminary results on isolated photon cross section in pp collisions at 8 TeV has been obtained.
- Implemented EMCal correction changes to the preliminaries.
- Fix the discrepancy between the new spectra and the preliminary one (~20%).
- Re-evaluate the systematics.

Thank you!

BACK UP

Cluster shower shape



Cross section

$$\frac{d^2\sigma}{dp_T d\eta} = \frac{\sigma_{MB_{AND}}}{N_{evt}} \frac{1}{RF} \frac{d^2N_\gamma^{iso}}{dp_T d\eta} \frac{p(p_T)}{\varepsilon(p_T)}$$

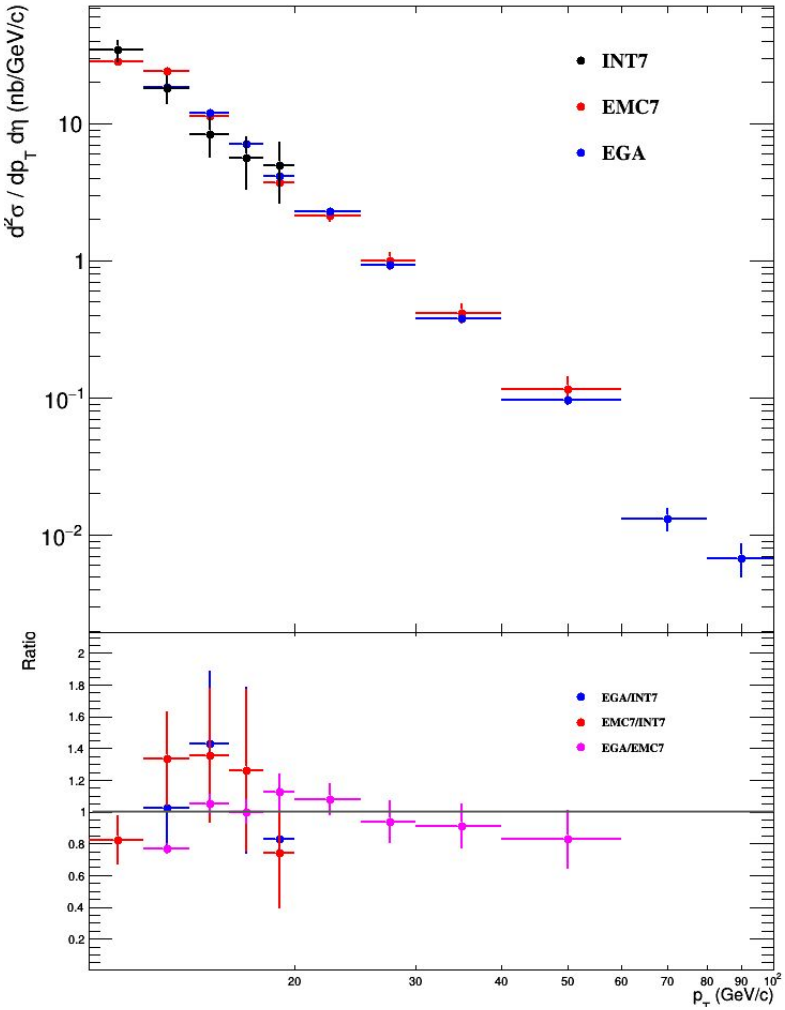
MC = GJ + JJhigh

Ref: https://arxiv.org/pdf/1708.08745.pdf

$\sigma_{MB\ AND}$ = 55.80 ± 1.45 $_{(stat+sys)}$ mb

RF = 1 (INT7)
67.0 (EMC7)
67.0 * 222.5 (EGA)

$|\Delta\eta| < 0.52$ $\Delta\phi = (178.8\text{-}81.2) = 97.6°$



Cross section

Different triggers merged bin-by-bin

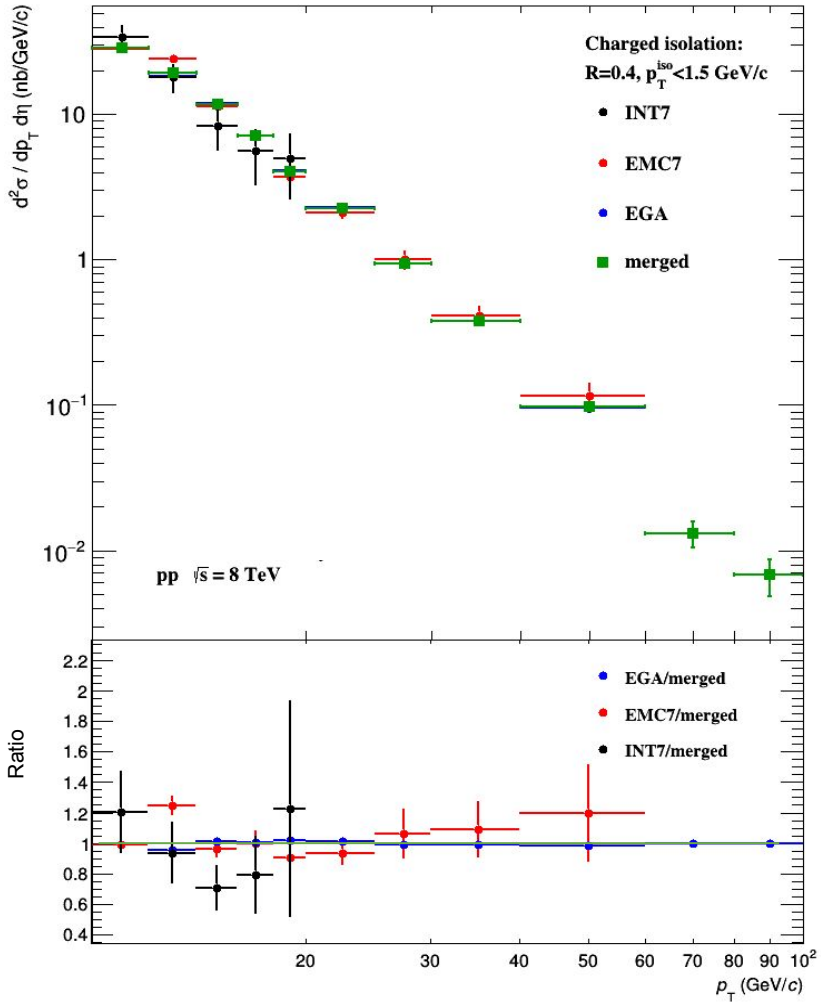
Cross-section

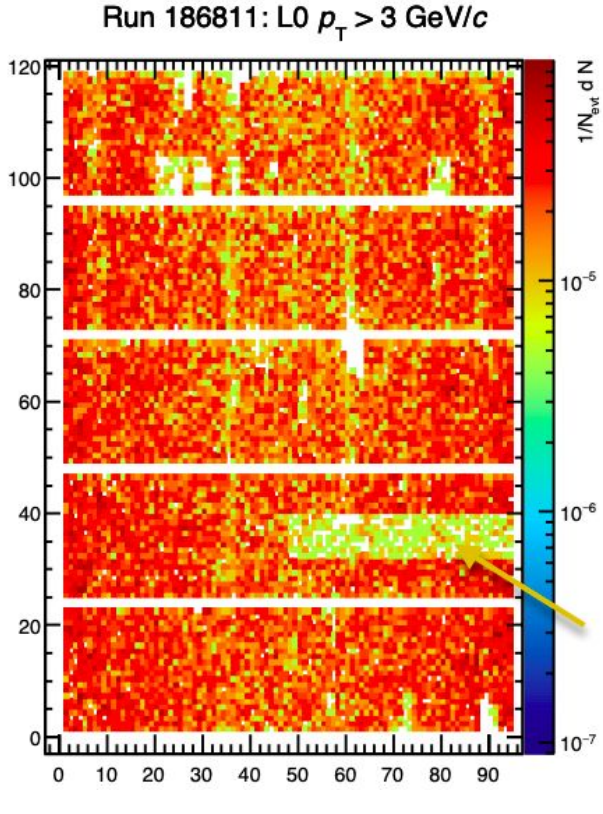
$$\frac{\sum x_i/\sigma_i^2}{\sum 1/\sigma_i^2}$$

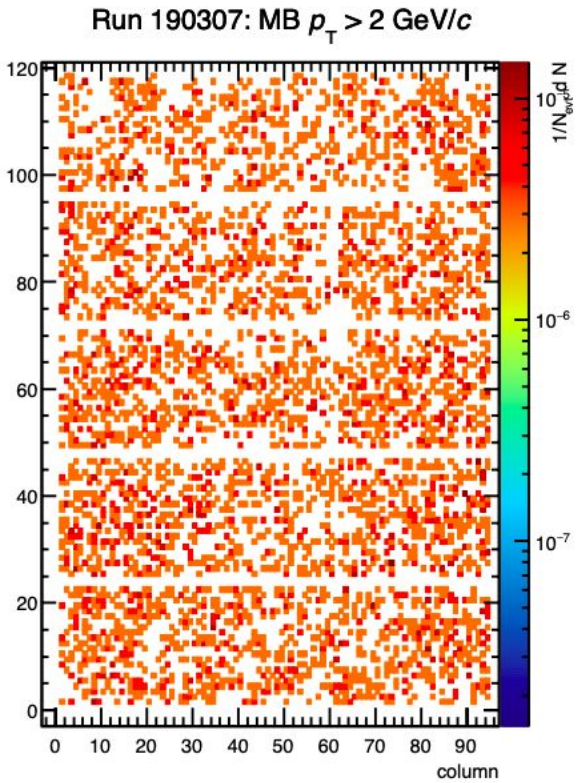
Statistical error :

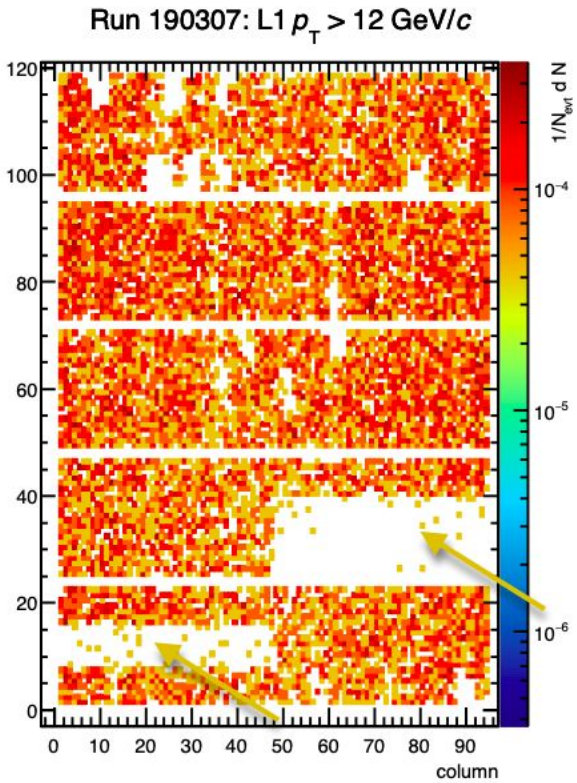
$$\sigma = \sqrt{\frac{1}{\sum 1/\sigma_i^2}}$$

pT range (GeV/c)	Data used
10-12	INT7, EMC7
12-20	INT7, EMC7, EGA
20-60	EMC7, EGA
60-100	EGA



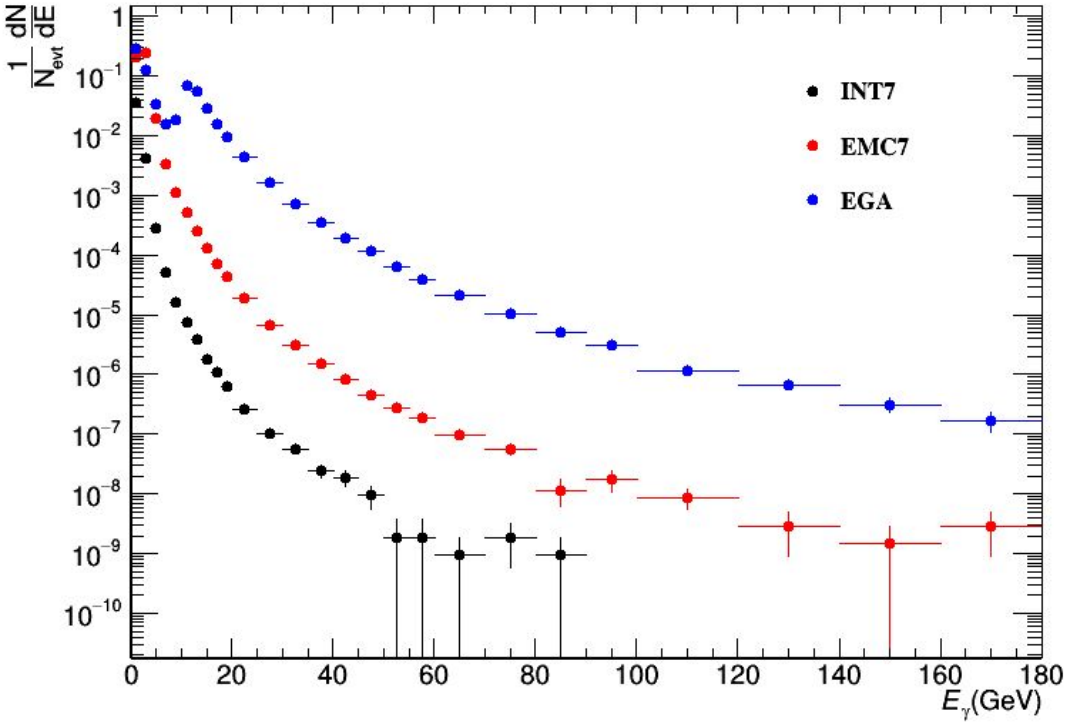

Run 186811: L0 $p_T > 3$ GeV/c
$1/N_{evt}\, d\,N$
10^{-5}
10^{-6}
10^{-7}
0 10 20 30 40 50 60 70 80 90
0 20 40 60 80 100 120


Run 190307: MB $p_T > 2$ GeV/c
$1/N_{evt}\, d\,N$
10^{-5}
10^{-6}
10^{-7}
0 10 20 30 40 50 60 70 80 90
column
0 20 40 60 80 100 120

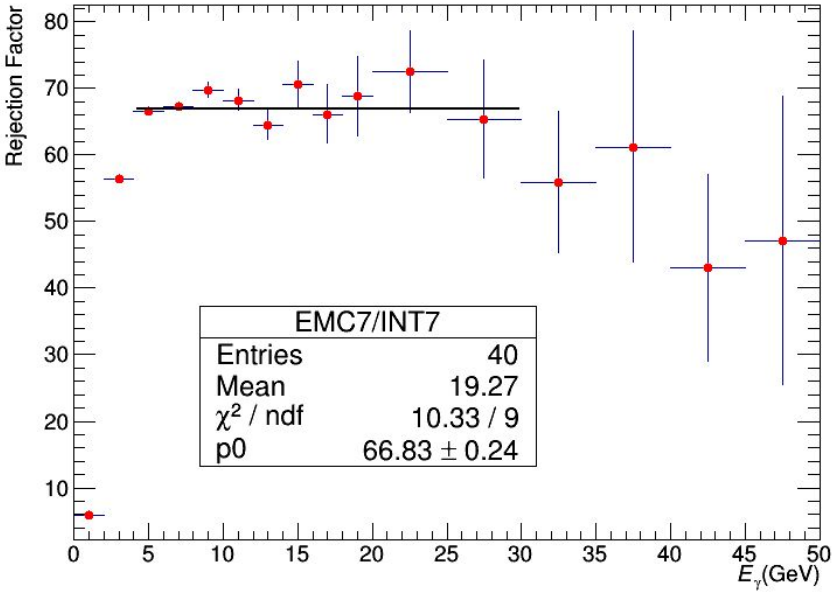

Run 190307: L1 $p_T > 12$ GeV/c
$1/N_{evt}\, d\,N$
10^{-4}
10^{-5}
10^{-6}
0 10 20 30 40 50 60 70 80 90
column
0 20 40 60 80 100 120

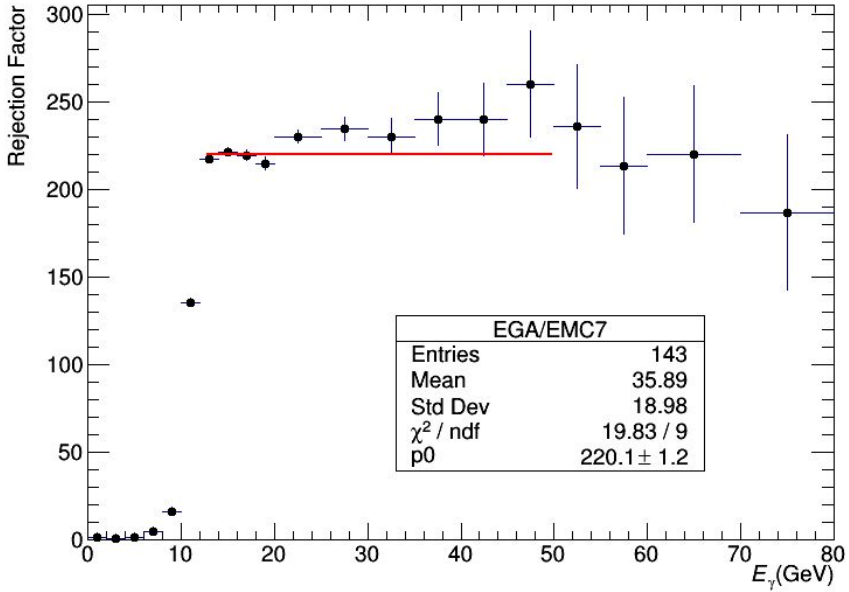
Photon cluster energy distribution (without trigger efficiency)

- Triggered sample:
  - EMC7:EMCAL_L0 trigger, E > 2 GeV, ~**34.56 M** events
  - EGA:EMCAL_L1 trigger, E > 10 GeV, ~**2.06 M** events
- Minimum Bias (INT7): ~**106.53 M** events

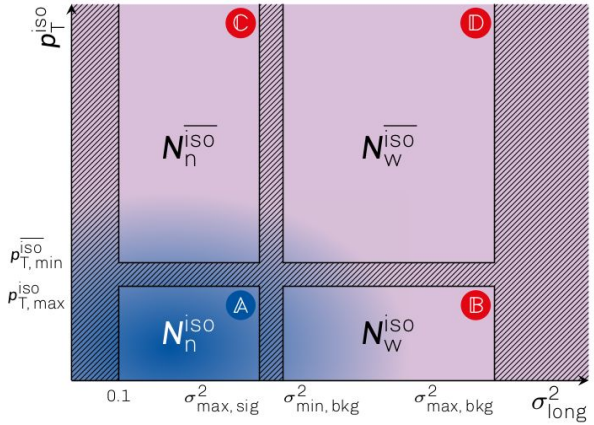


Rejection Factors (without trigger efficiency)





Purity estimation for isolated photons



The ABCD Method

$$N = S + B$$

$$P = 1 - (B/N)$$

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

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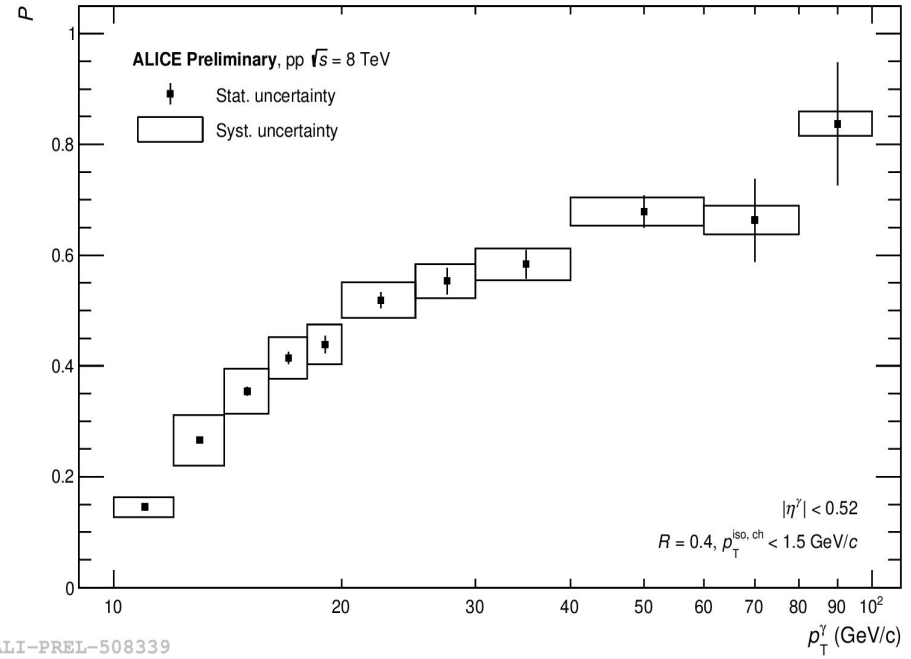
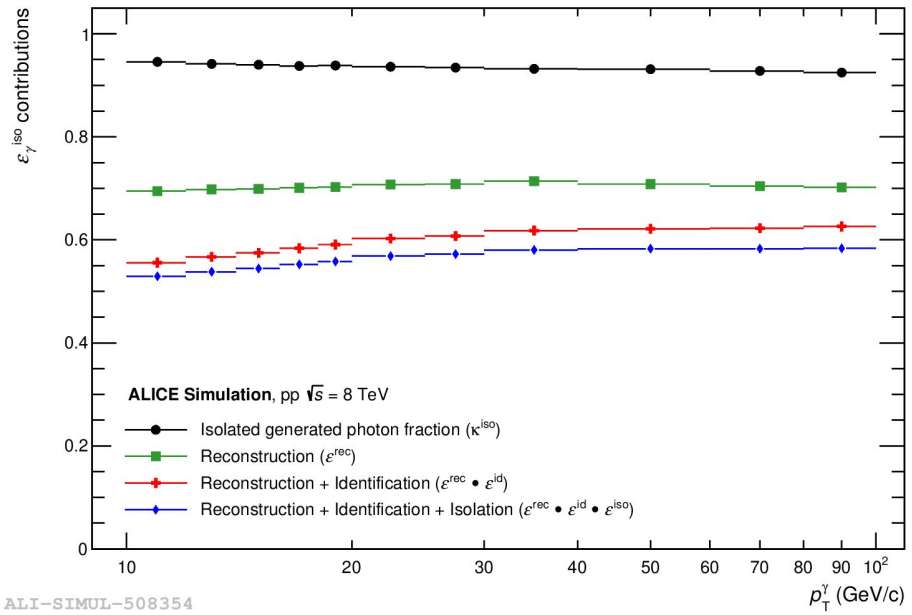
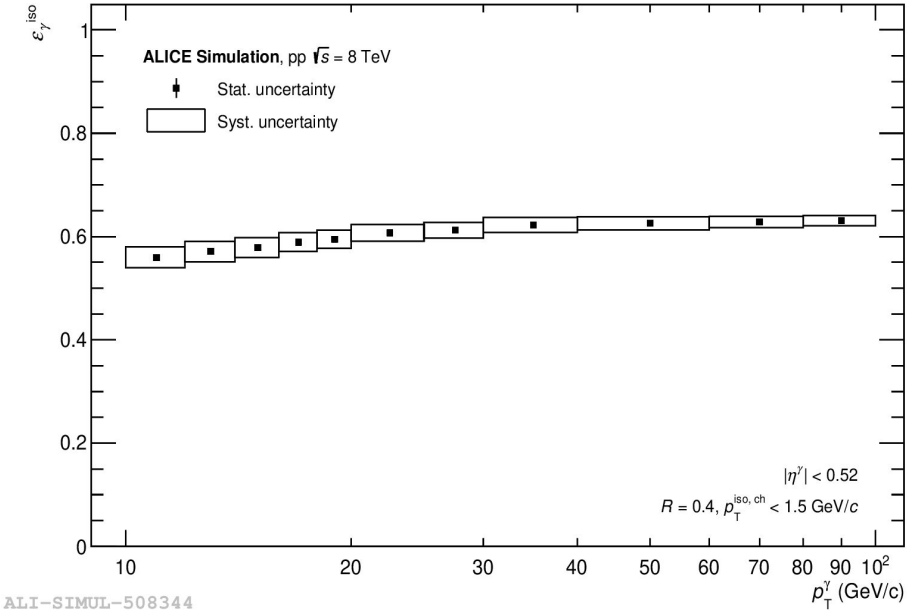


Efficiency estimation for isolated photons





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

Identification – Shower shape cut ($0.1 < \sigma_0^2 < 0.3$)

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

Systematics

- 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