Isolated γ production in pp, p–Pb & Pb–Pb collisions measured with ALICE

- Differential p_T cross section
  - pp at $\sqrt{s}$ = 13 TeV arXiv:2407.01165 New *accepted last week by EPJ C!*
  - pp at $\sqrt{s}$ = 8 TeV & p–Pb at $\sqrt{s_{NN}}$ = 5.02, 8.16 TeV preliminary
  - pp & Pb–Pb at $\sqrt{s_{NN}}$ = 5.02 TeV arXiv:2409.12641, ALICE-PUBLIC-2024-003 New
- Isolated γ-hadron correlation
  - Pb–Pb at $\sqrt{s_{NN}}$ = 5.02 TeV preliminary

Gustavo CONESA BALBASTRE
LPSC Grenoble — IN2P3-CNRS-UGA
for the ALICE Collaboration

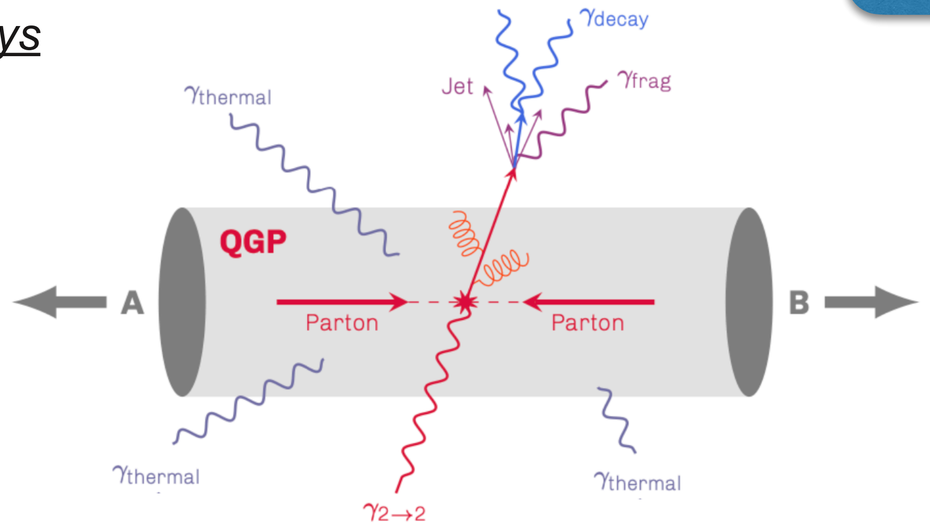
LPSC GRENOBLE | MODANE

cnrs IN2P3 Les deux infinis

Motivation

- **γ** are **color neutral: not affected** by *"quark-gluon plasma" (QGP)* presence in *heavy-ion collisions* unlike **partons** that **lose energy**
- Direct **γ**, *not originating from hadronic decays*

$$R_{AA} = \frac{1}{\langle N_{coll} \rangle} \frac{d^2\sigma_{AA} / (dp_T\, d\eta)}{d^2\sigma_{pp} / (dp_T\, d\eta)}$$



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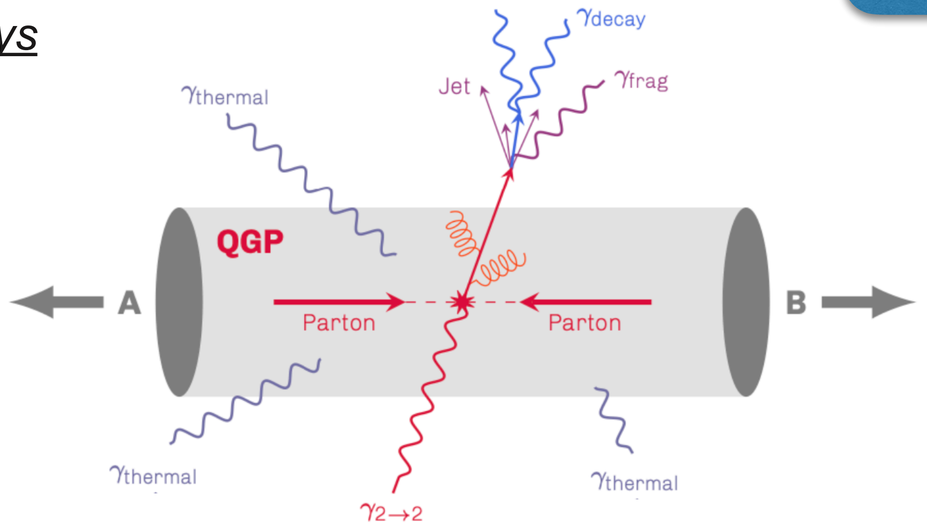

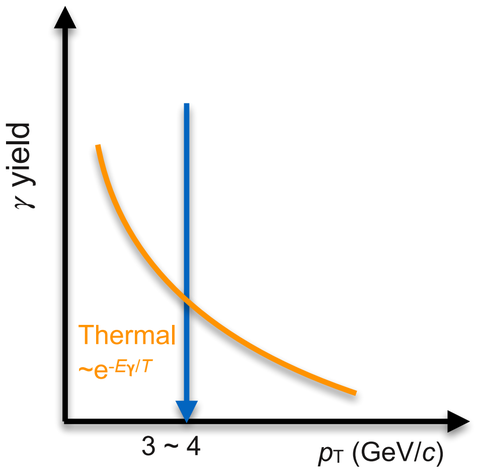

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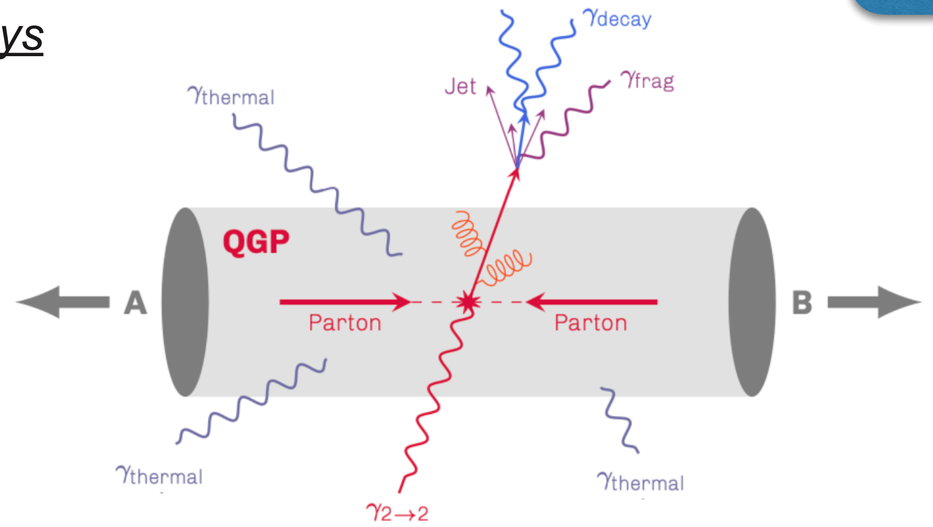

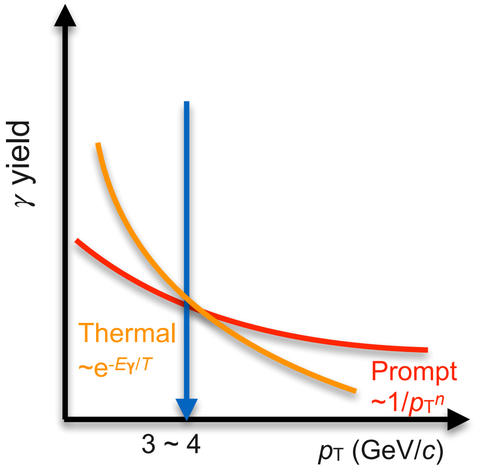

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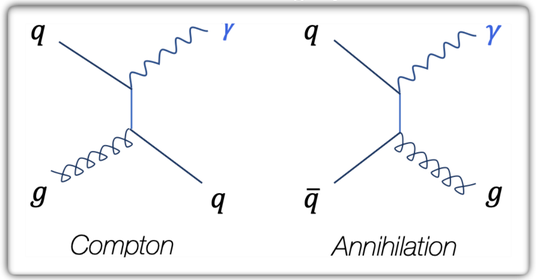

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PDFs — *Hard scattering (pQCD)* — *Fragmentation function (FF)*

– **Test pQCD** predictions, **constrain (n)PDFs & FF**

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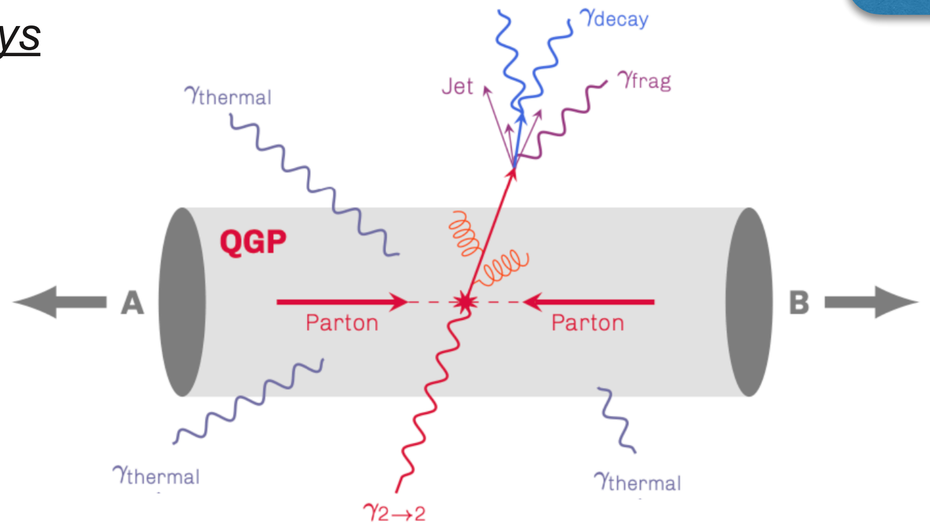

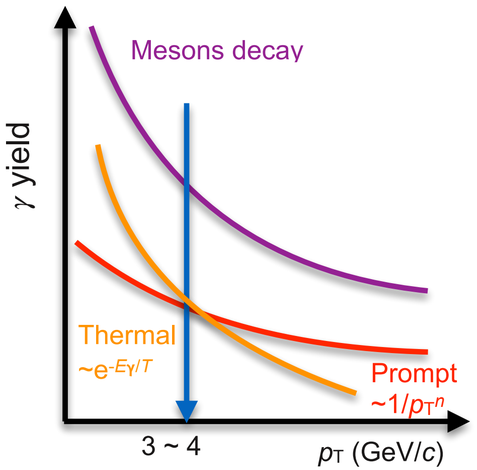

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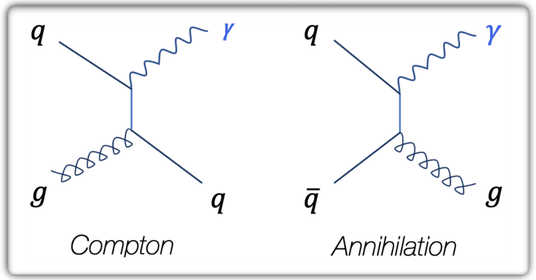

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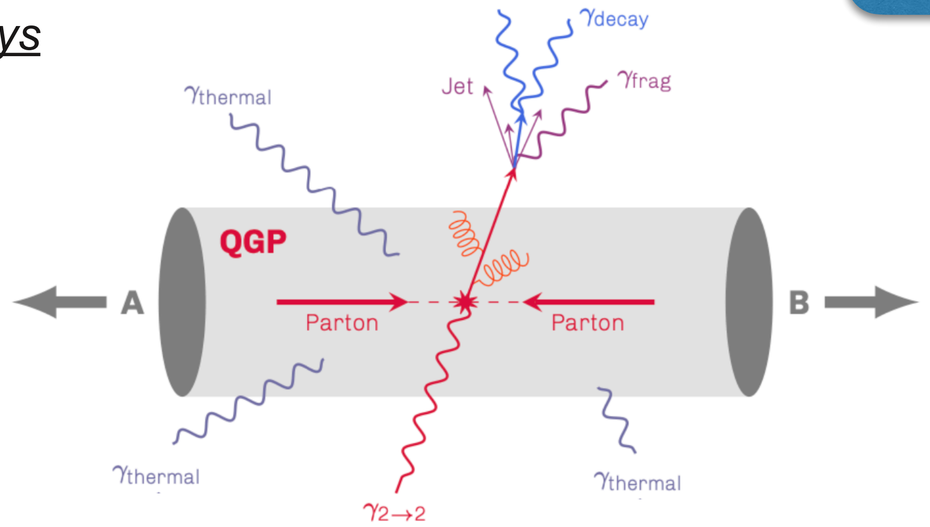

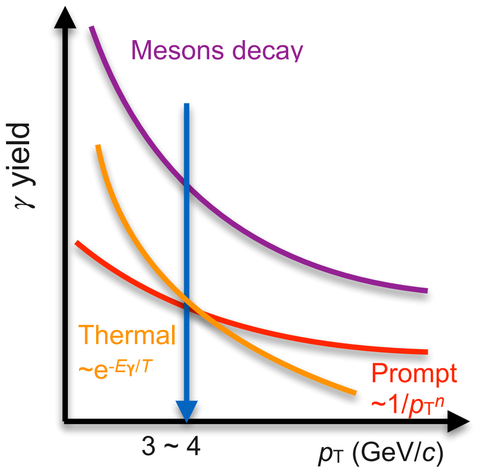

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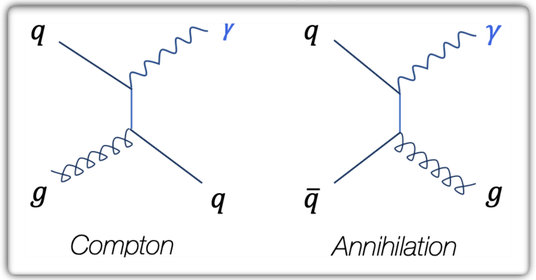

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➡ **Other direct γ sources:**

– Fragmentation γ: $R_{AA} < 1$ comparable yield to direct prompt γ

– QGP pre-equilibrium γ? $R_{AA} > > 1$ (glasma phase)

– Jet-QGP interaction γ? $R_{AA} > > 1$ (hard partons scattering)

Prompt γ identification in ALICE: EM shower spread shape & isolation with tracks

Prompt γ at LO 2→2: *isolated*

- TPC+ITS charged tracks
  - ITS only for pp col. at $\sqrt{s}$ = 5.02 TeV
- Select γ with low hadronic activity in R, small $p_{\mathrm{T}}^{\mathrm{iso,\,ch}}$

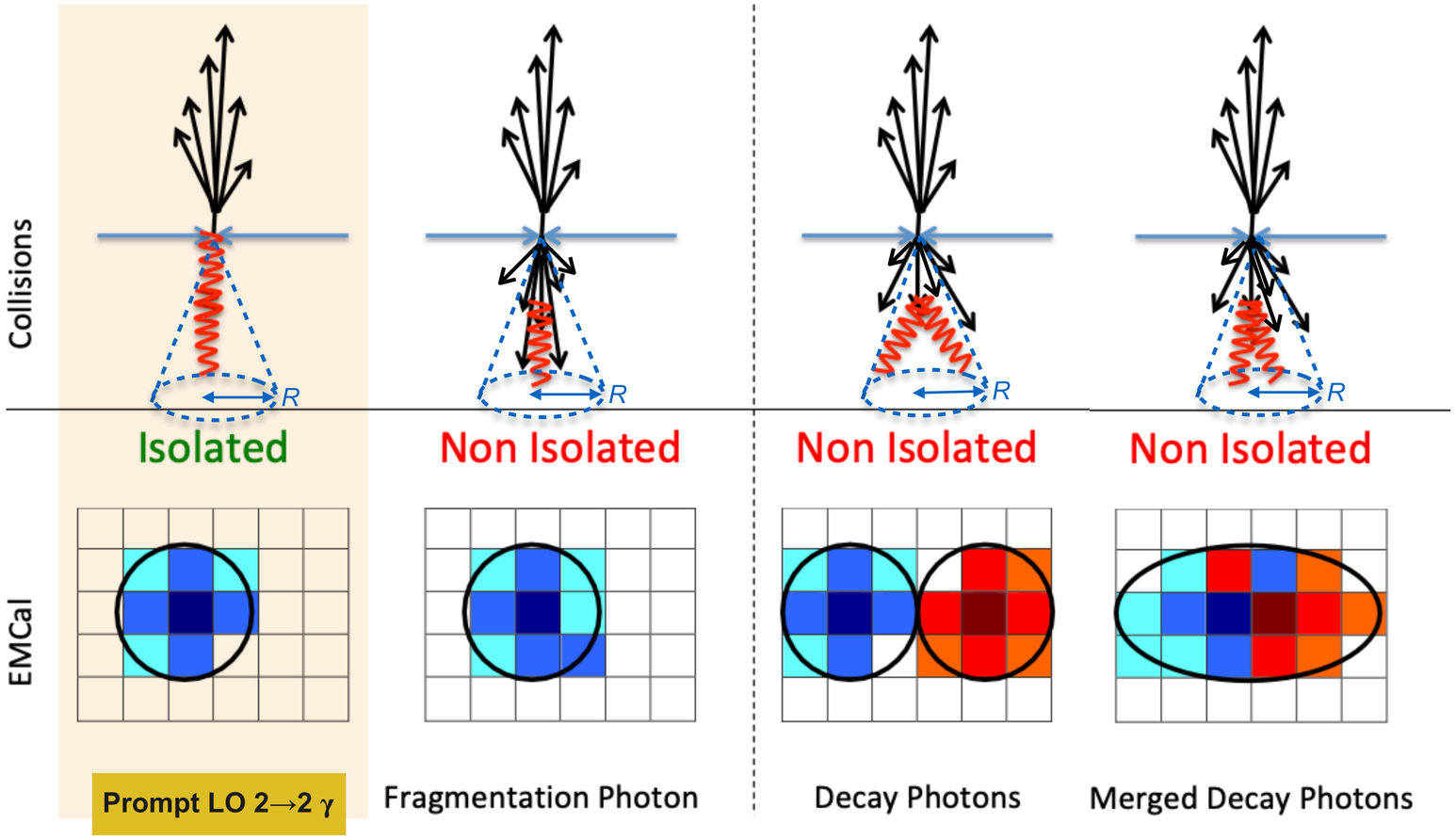
$$\sqrt{(\eta_{\mathrm{track}}-\eta_{\gamma})^2+(\varphi_{\mathrm{track}}-\varphi_{\gamma})^2} < R = 0.4\ (0.2)$$

$$p_{\mathrm{T}}^{\mathrm{iso,\,ch}} = \sum p_{\mathrm{T}}^{\mathrm{tracks\ in\ cone}} - \rho_{\mathrm{UE}} \cdot \pi \cdot R^2 < \mathbf{1.5}\ \mathrm{GeV}/c$$

  - Underlying event (UE) subtracted event-by-event, ρ_{UE} density estimation (back-up slide)

EM shower discrimination

- EMCal
- Shower elongation σ^2_{long}
  - pp & Pb–Pb collisions at $\sqrt{s}$ = 5.02 TeV: Calculated in 5 × 5 cells around the highest energy cell → $\sigma^2_{\mathrm{long,\,5\times5}}$



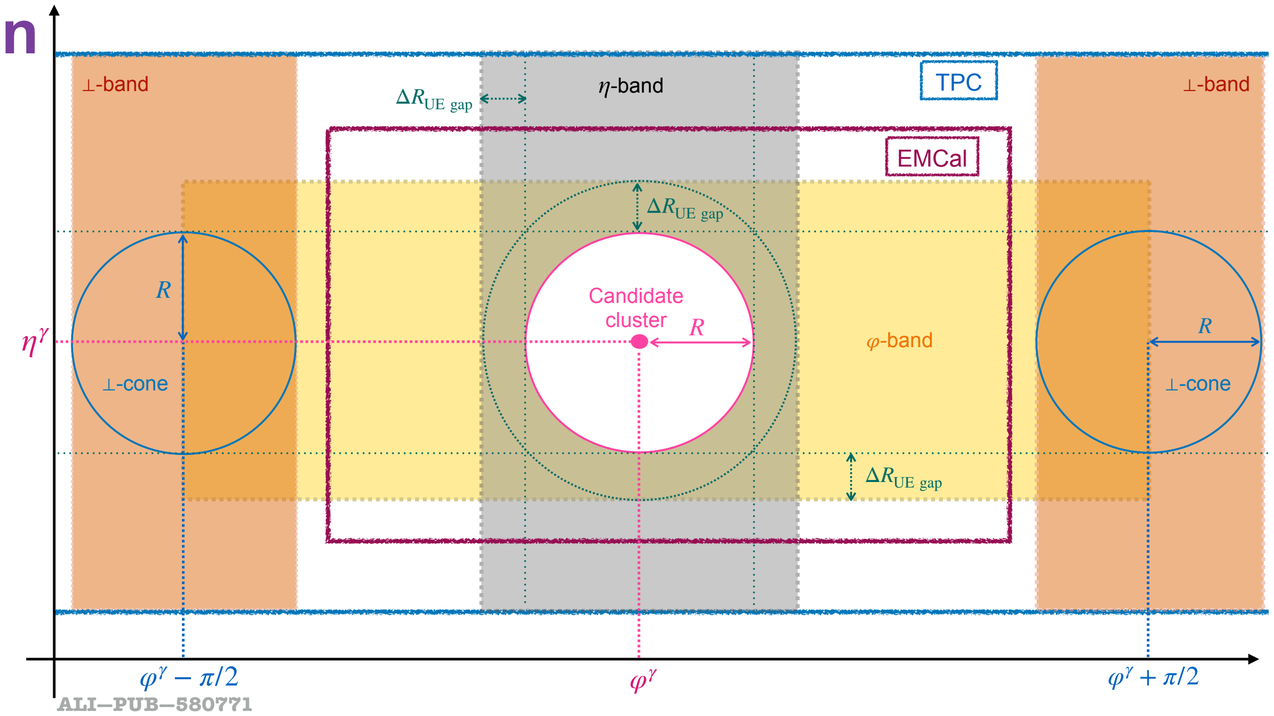
- **circular "narrow" cluster**
- circular narrow clusters, potentially wider due to jet particles nearby merging
- decay γ merge, E_{π^0} > 6 GeV **elliptical "wide" cluster**

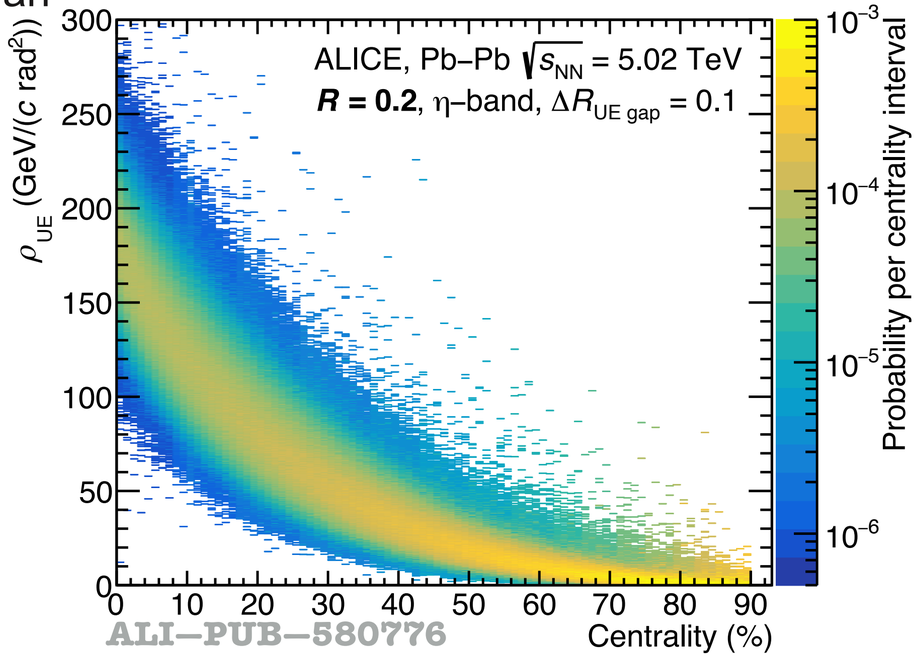
Underlying event estimation

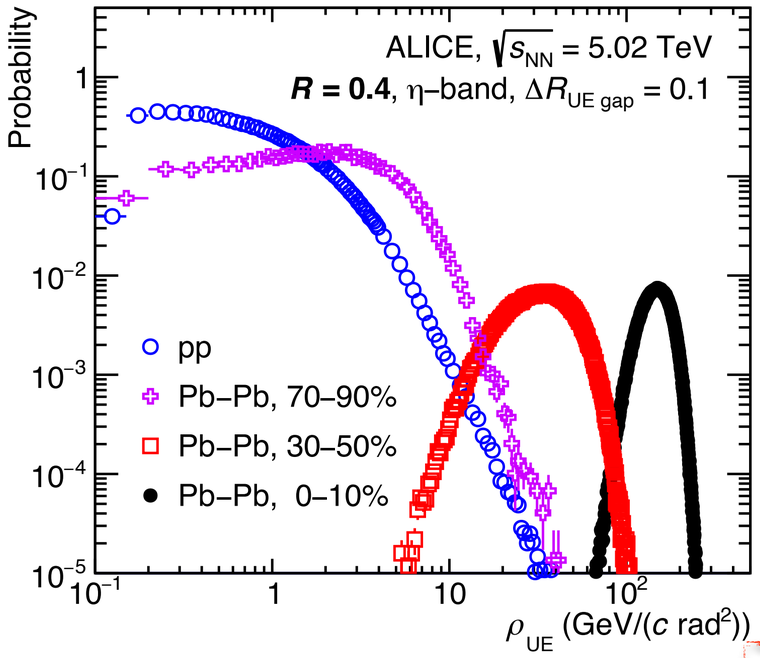
Track p_T UE density estimated on:

- Pb–Pb & pp at $\sqrt{s_{NN}}$ = 5.02 TeV:
  - ➡ Sum of tracks p_T normalised by **η-band** area
    → *Avoid flow effects*
  - ➡ Gap between cone and band of $\Delta R_{UE\ gap}$= 0.1
    → *Avoid jet remnants*
- p–Pb $\sqrt{s_{NN}}$ = 5.02, 8.16 TeV, pp $\sqrt{s}$ = 8 TeV
  - ➡Perpendicular cone & jet-median

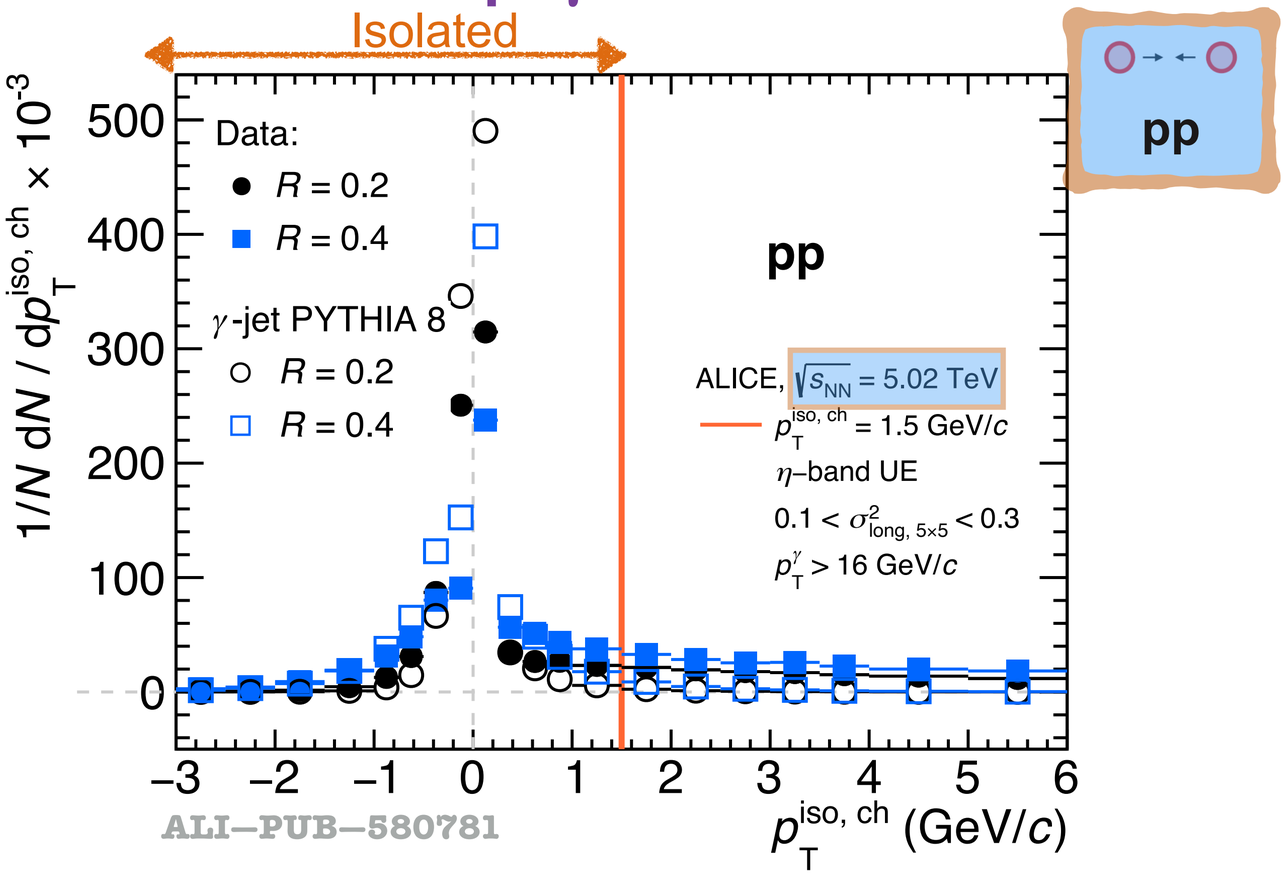
Remark: UE was not subtracted in pp $\sqrt{s}$ = 7 & 13 TeV measurements, UE small

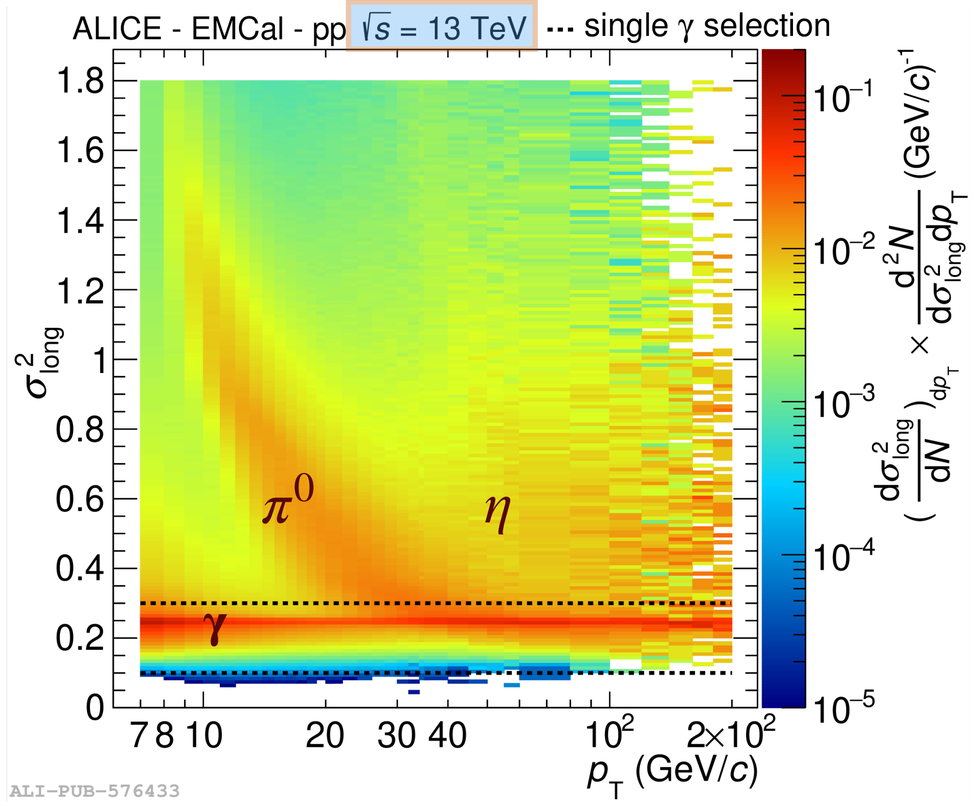






Prompt γ identification in ALICE: EM shape & isolation





- Isolated if $p_{\mathrm{T}}^{\mathrm{iso,\,ch}} < 1.5$ GeV/c with $R = 0.4$ or 0.2
- Symmetric in PYTHIA 8 γ-jet process simulation

- In data, more asymmetric and less peaked distribution due to jet contribution
- Wider for $R = 0.4$ due to UE fluctuations

- Visible bands for γ (narrow clusters) & π^0 (wide clusters)
- Select as γ clusters with $0.1 < \sigma^2_{\mathrm{long,\,5\times5}} < 0.3$

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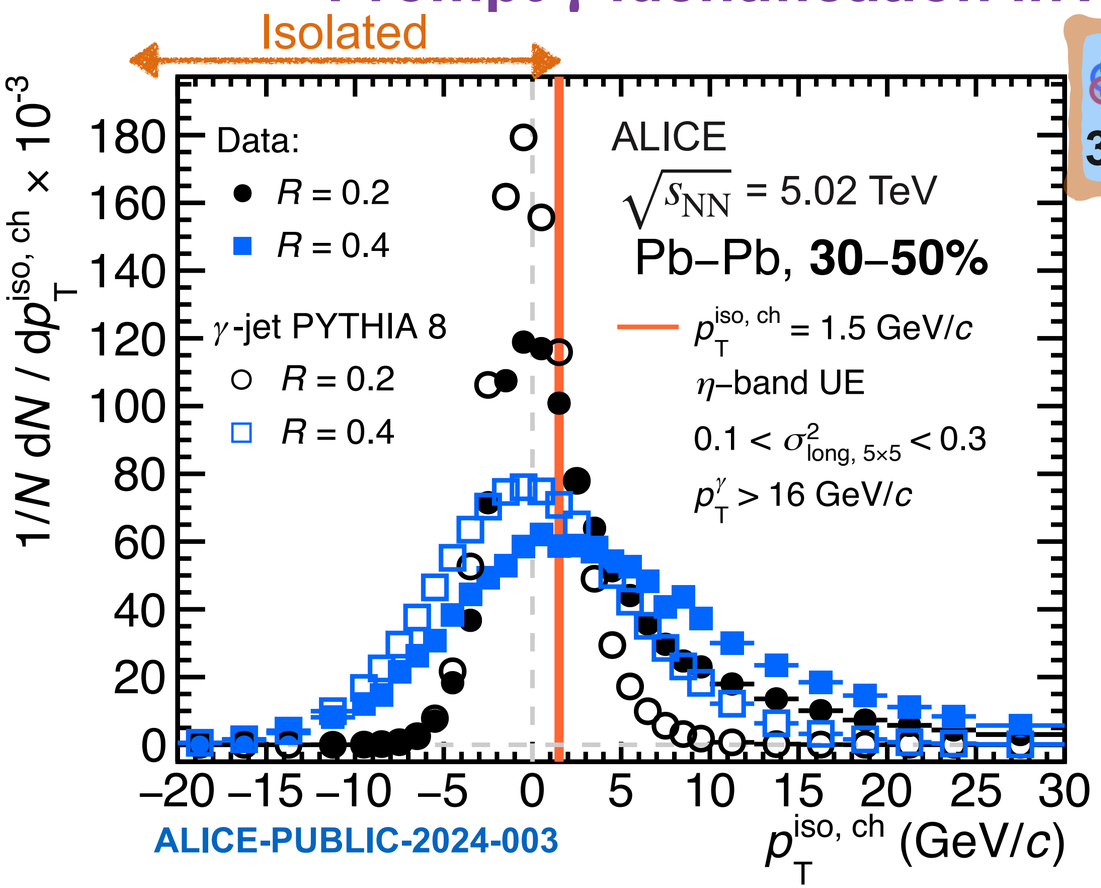

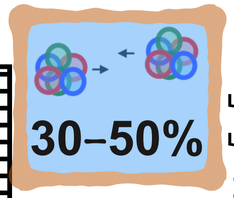

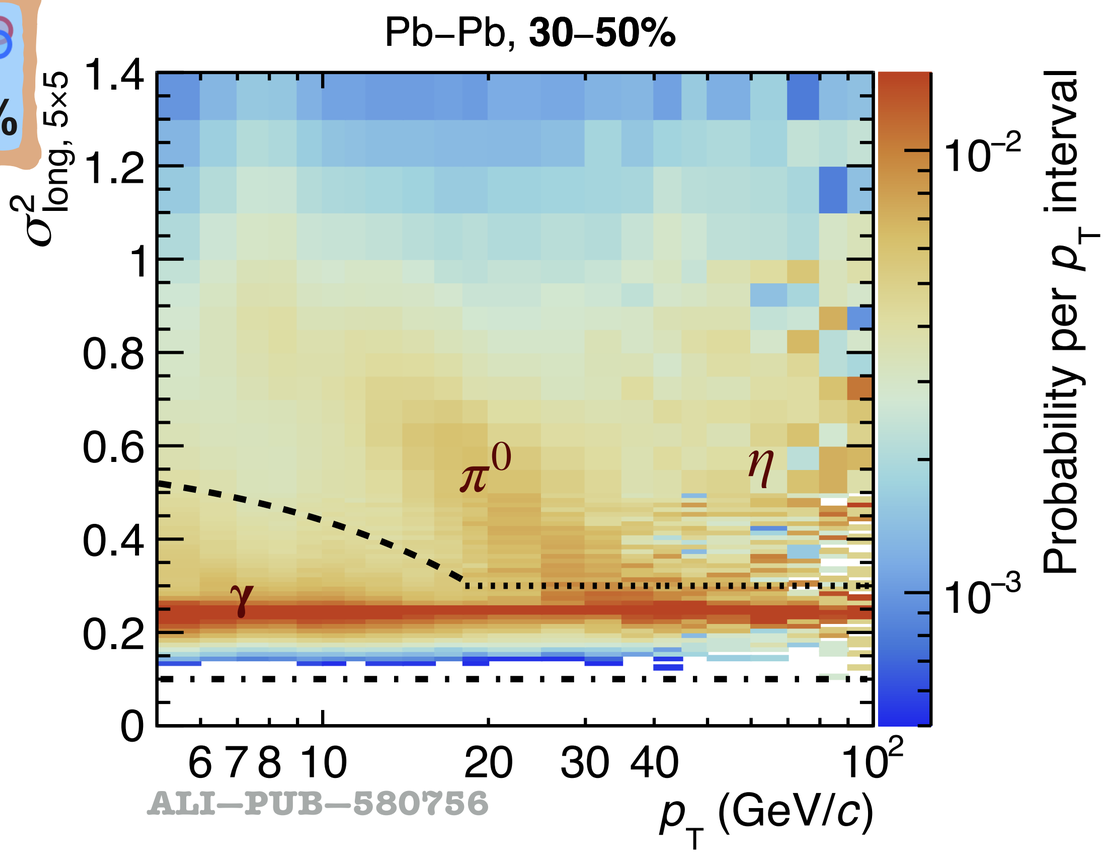

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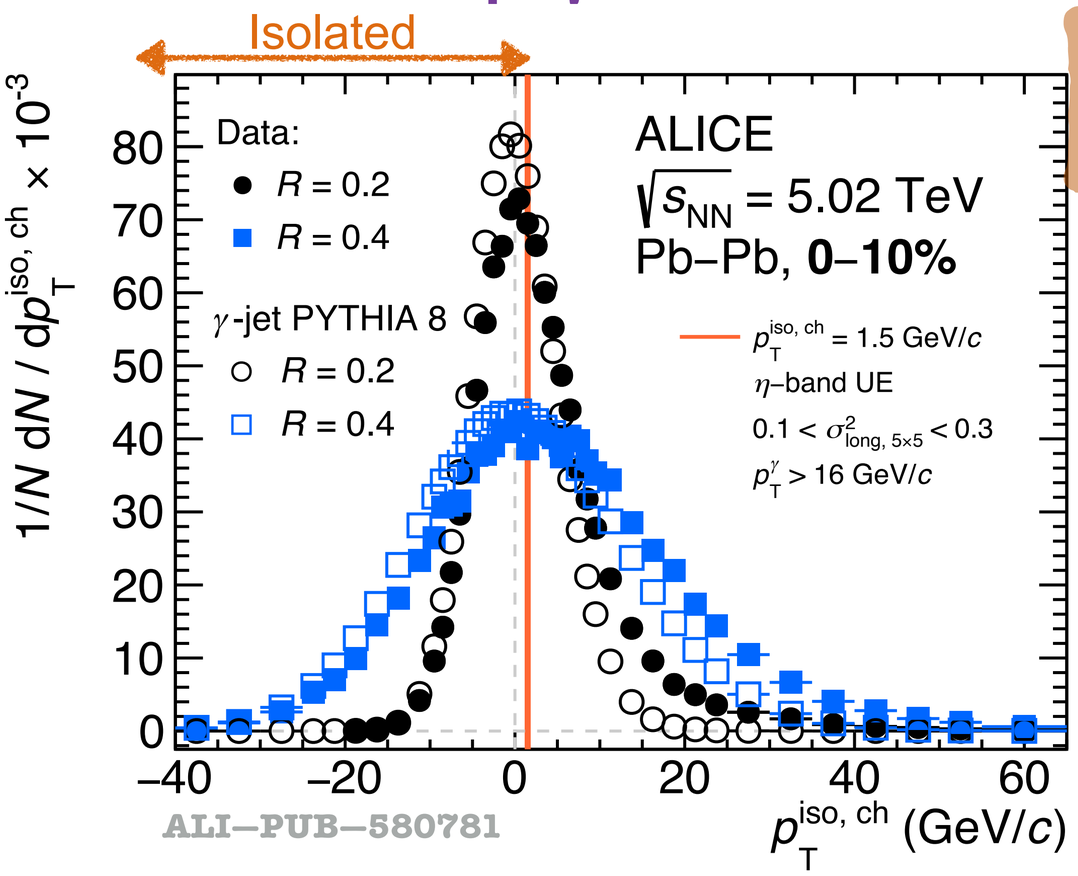

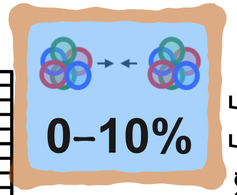

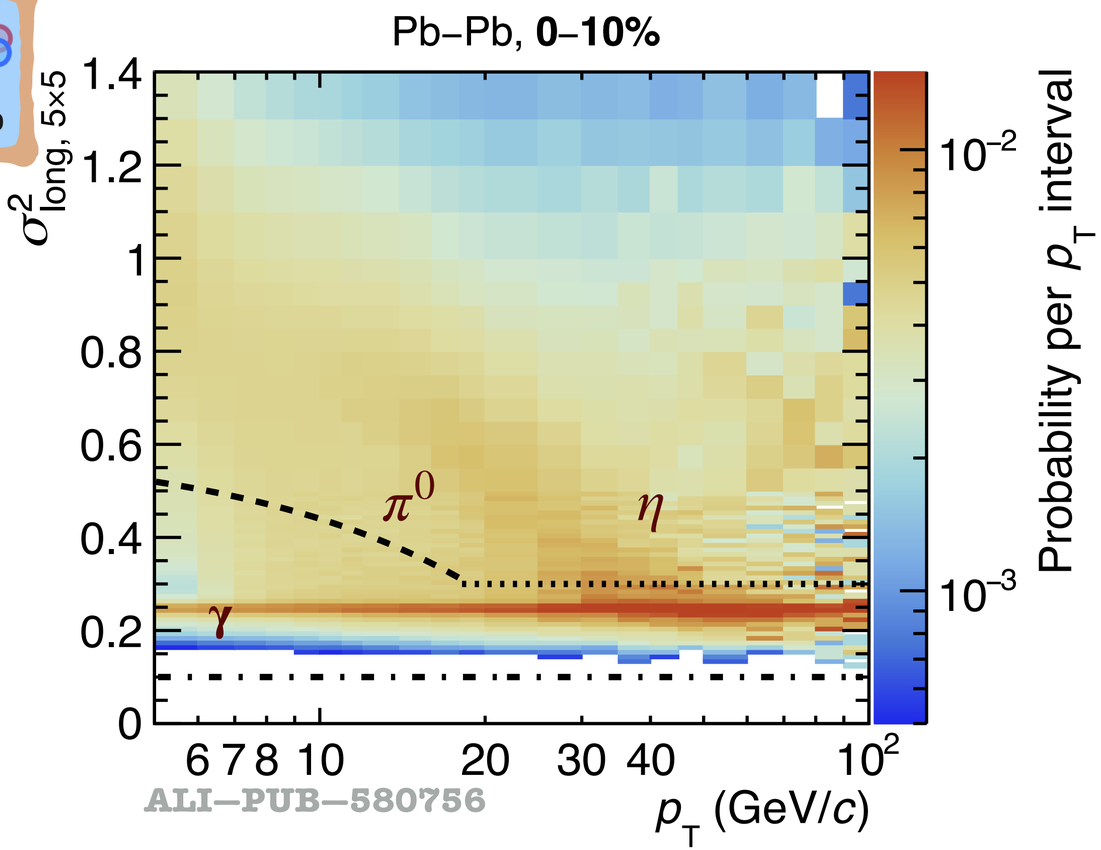

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γ increase their $\sigma^2_{\mathrm{long,\,5\times5}}$ due to the UE

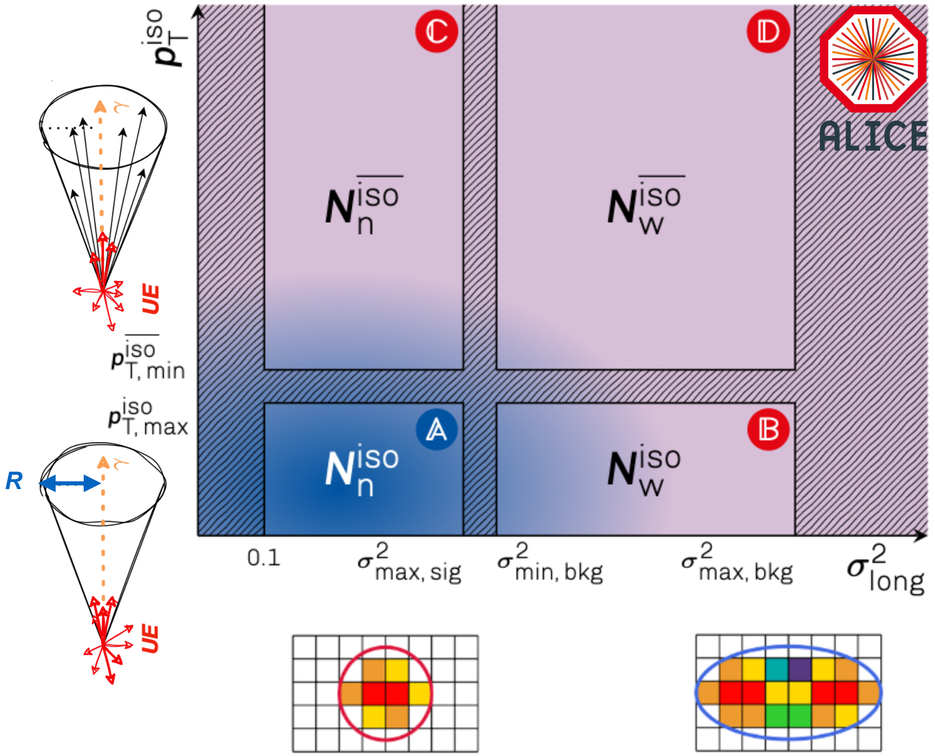
Purity

- Purity, ABCD method: Phase space of calorimeter clusters divided in 4 regions: $\mathbb{A}$, signal dominated & $\mathbb{B}$-$\mathbb{C}$-$\mathbb{D}$, background dominated

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

$N_{n,w}^{\text{iso},\overline{\text{iso}}}$= jet-jet ($B_{n,w}^{\text{iso},\overline{\text{iso}}}$) + γ-jet ($S_{n,w}^{\text{iso},\overline{\text{iso}}}$)

➡ Semi data-driven approach, simulation used to correct correlations between $p_{\text{T}}^{\text{iso, ch}}$ and σ^2_{long}



Purity, pp $\sqrt{s}$ = 13 TeV

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Data driven PYTHIA

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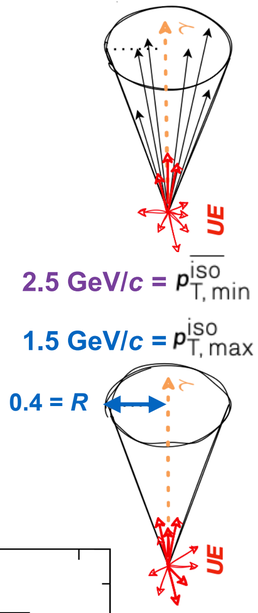

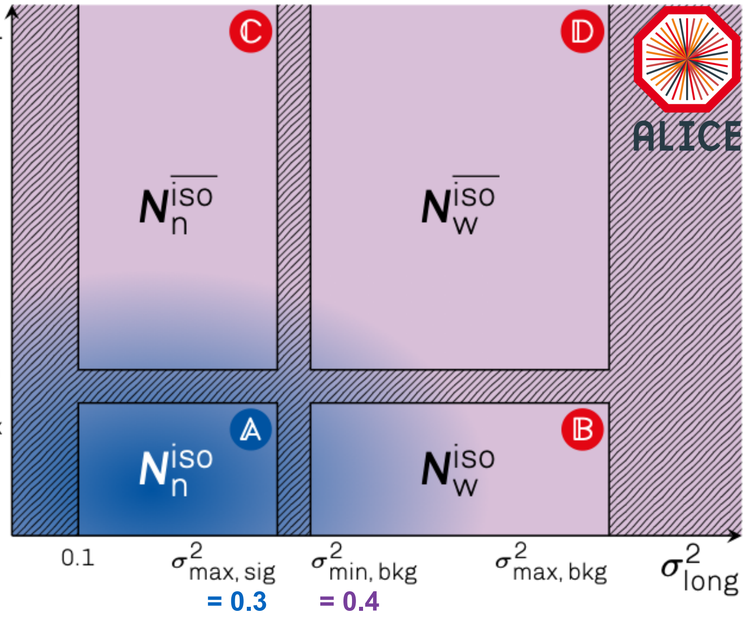

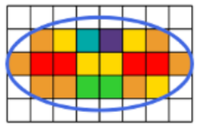

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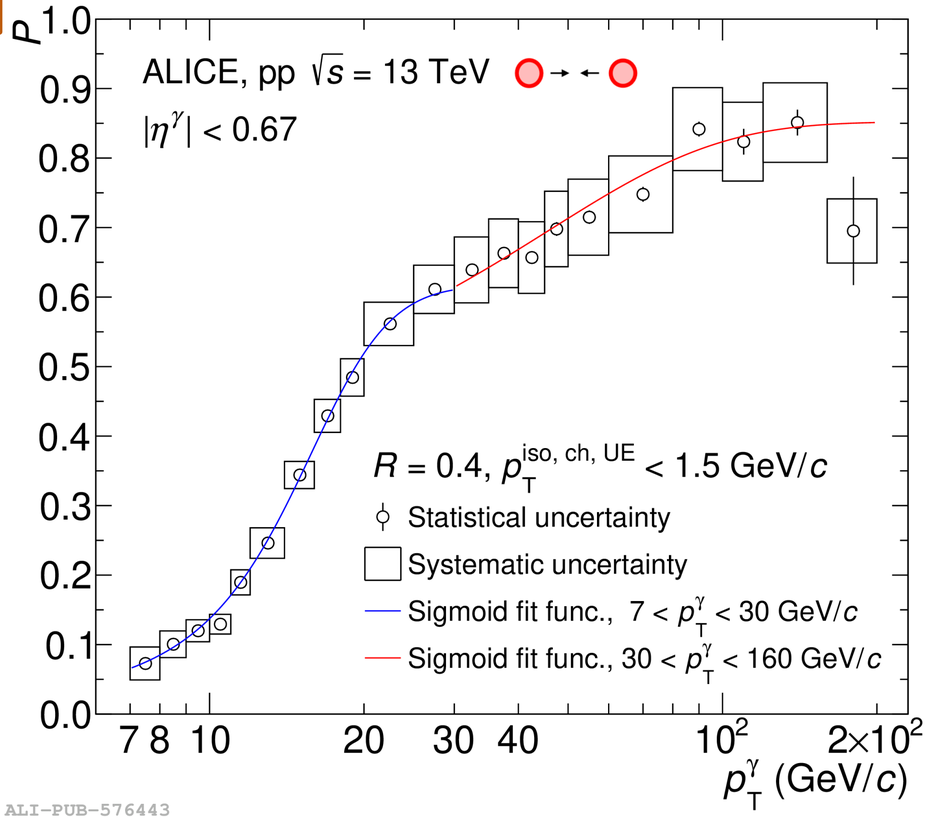

- Reduce the influence of statistical fluctuations with sigmoid function fits

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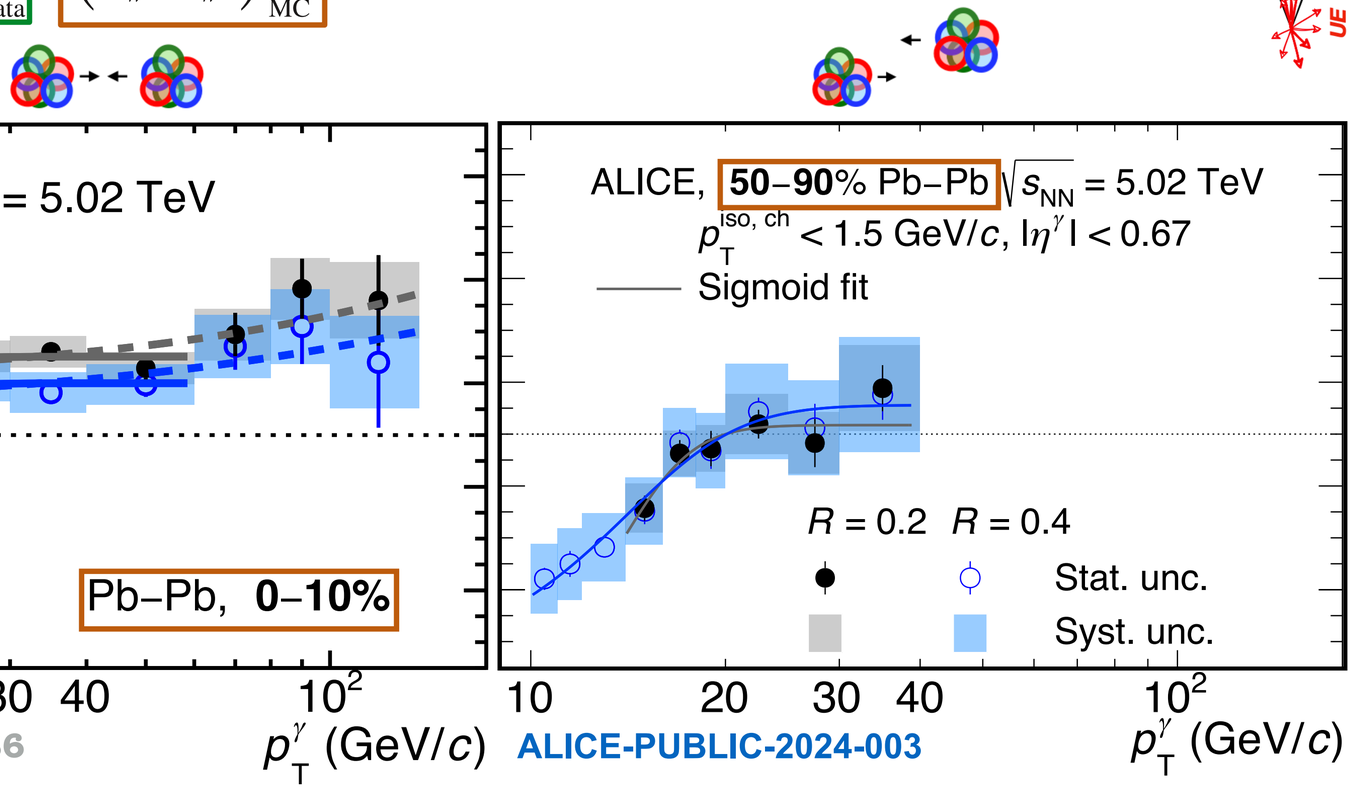
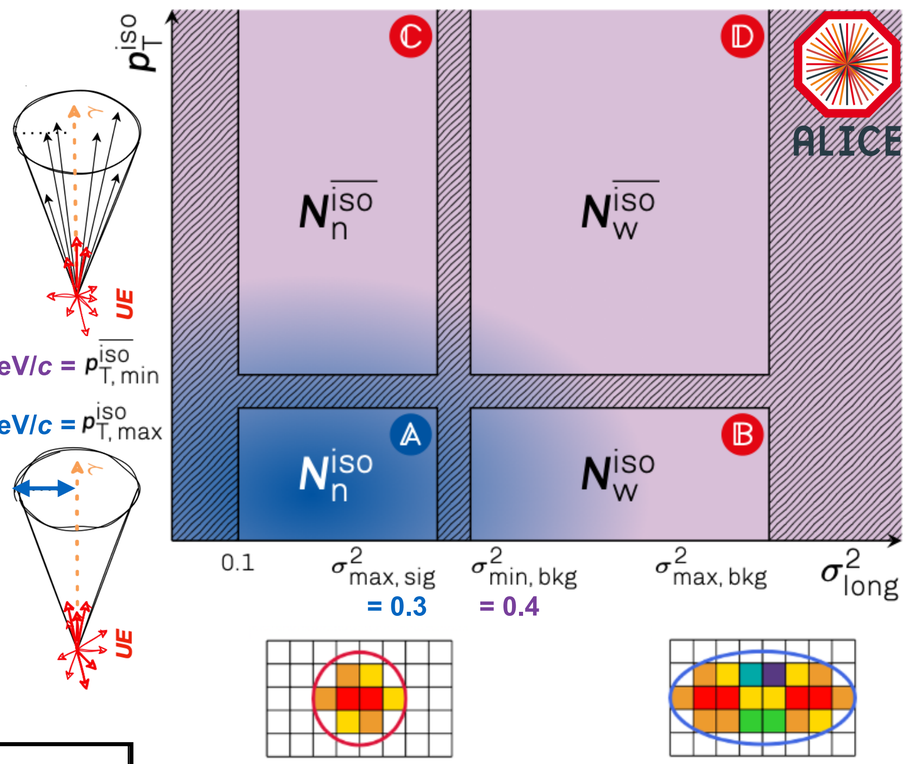
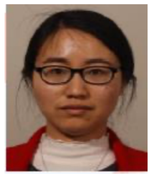
$N_{n,w}^{\mathrm{iso},\overline{\mathrm{iso}}}$ = jet-jet ($B_{n,w}^{\mathrm{iso},\overline{\mathrm{iso}}}$) + γ-jet ($S_{n,w}^{\mathrm{iso},\overline{\mathrm{iso}}}$)



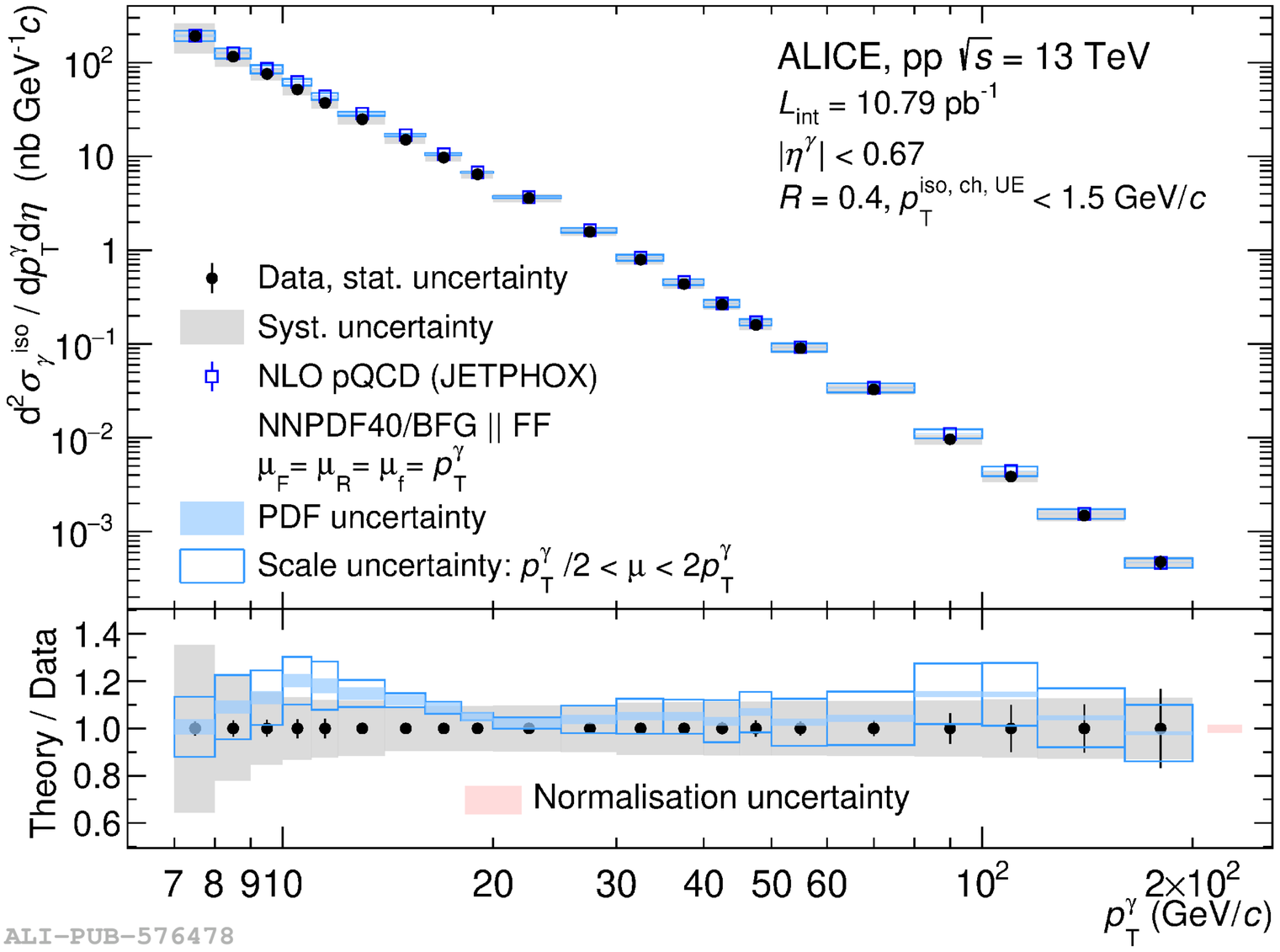


- Reduce the influence of statistical fluctuations with sigmoid function fits

Cross section, pp $\sqrt{s}$ = 13 TeV



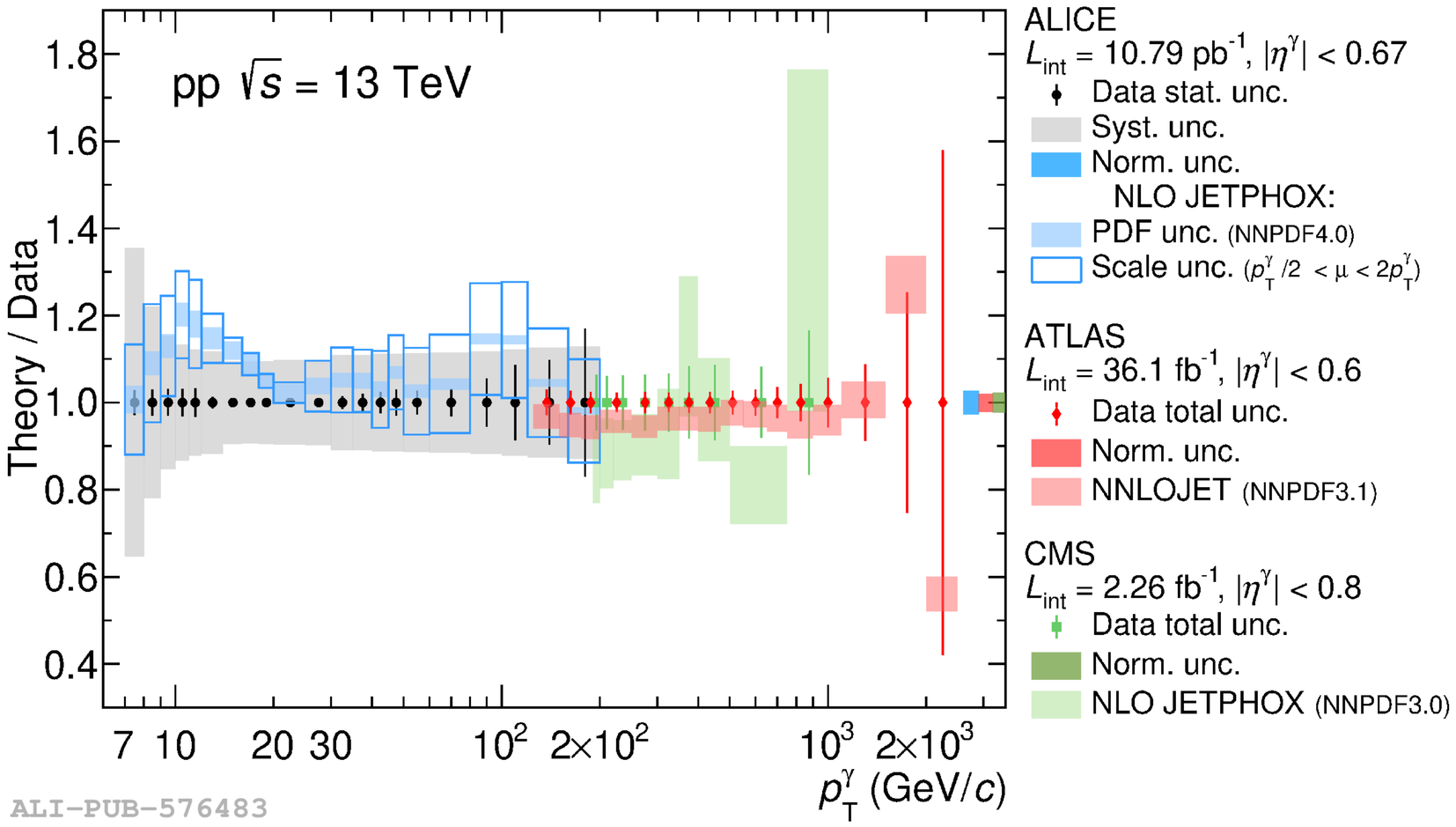
Ran Xu thesis
Publication
accepted by EPJ C



ALI-PUB-576478

- NLO pQCD predictions (JETPHOX) and data agree
- Significantly lower p_T than CMS and ATLAS at $\sqrt{s}$ = 13 TeV
- Lowest x_T at mid-rapidity

Cross section, pp $\sqrt{s}$ = 13 TeV



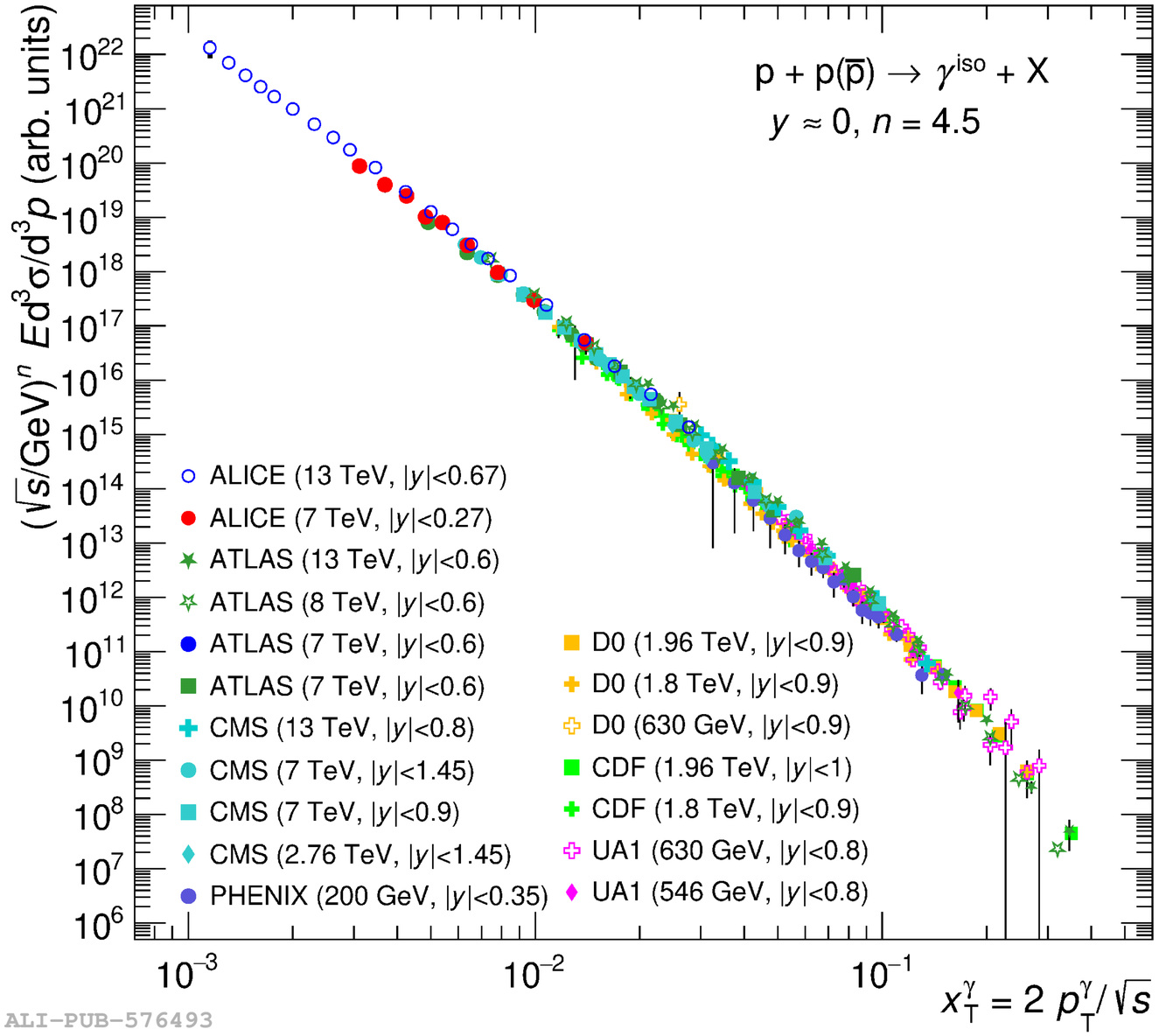
ALI-PUB-576483

ATLAS JHEP 2019 (2019) 203
arXiv:1908.02746 [hep-ex]

CMS Eur. Phys. J. C 79 (2019) 20
arXiv:1807.00782 [hep-ex]

- NLO pQCD predictions (JETPHOX) and data agree
- Significantly lower p_T than CMS and ATLAS at $\sqrt{s}$ = 13 TeV
- Lowest x_T at mid-rapidity

Cross section, pp $\sqrt{s}$ = 13 TeV



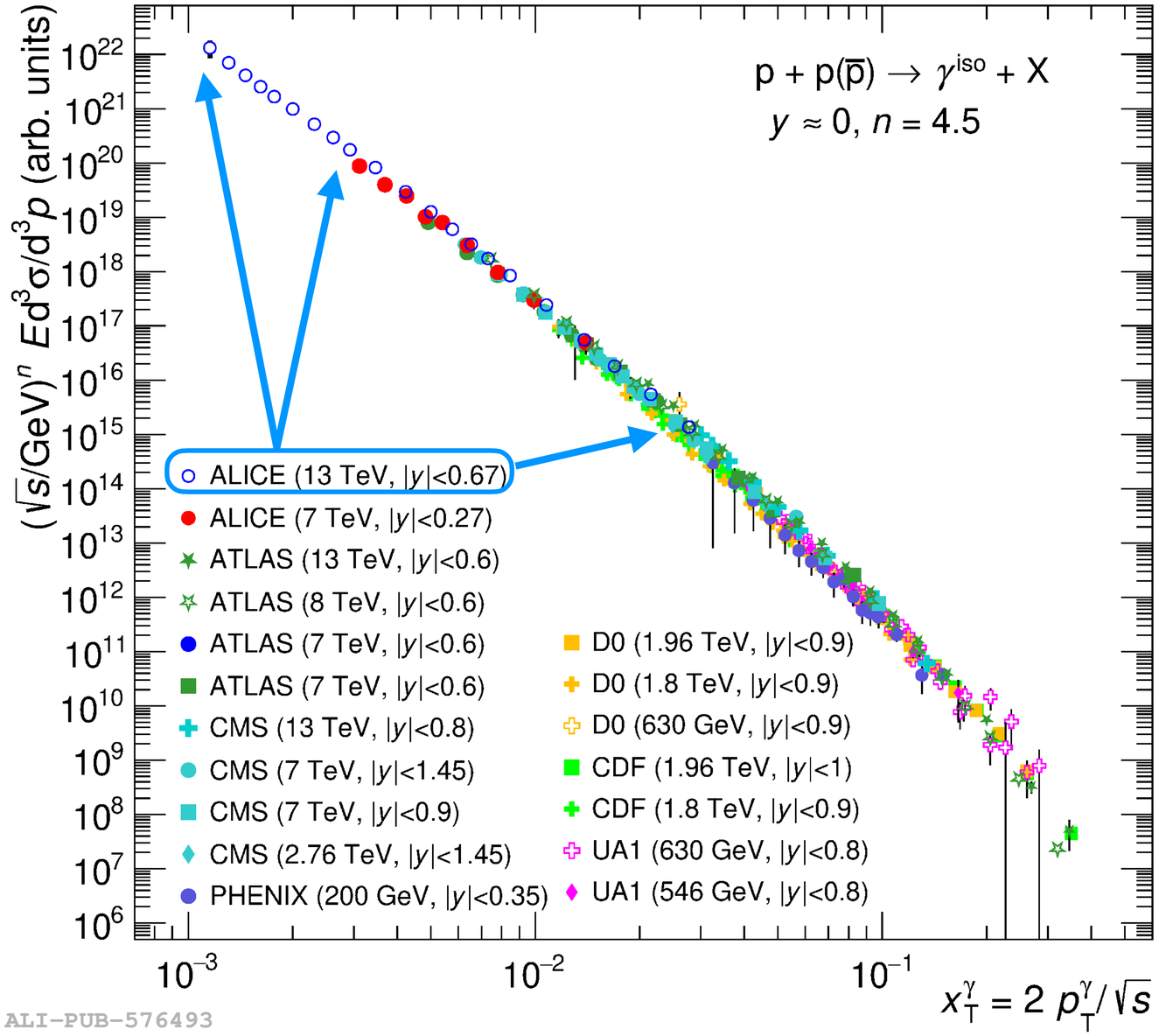
ALI-PUB-576493

- NLO pQCD predictions (JETPHOX) and data agree
- Significantly lower p_T than CMS and ATLAS at $\sqrt{s}$ = 13 TeV
- Lowest x_T at mid-rapidity
  - $\left(\sqrt{s}\right)^{4.5}$ scale from x_T ~10^{-3} to 10^{-1}

Full list of older results compiled in D. D'Enterria & J. Rojo Nucl. Phys. B 860 (2012), arXiv:1202.1762 [hep-ph]

Cross section, pp $\sqrt{s}$ = 13 TeV

Ran Xu thesis



ALI-PUB-576493

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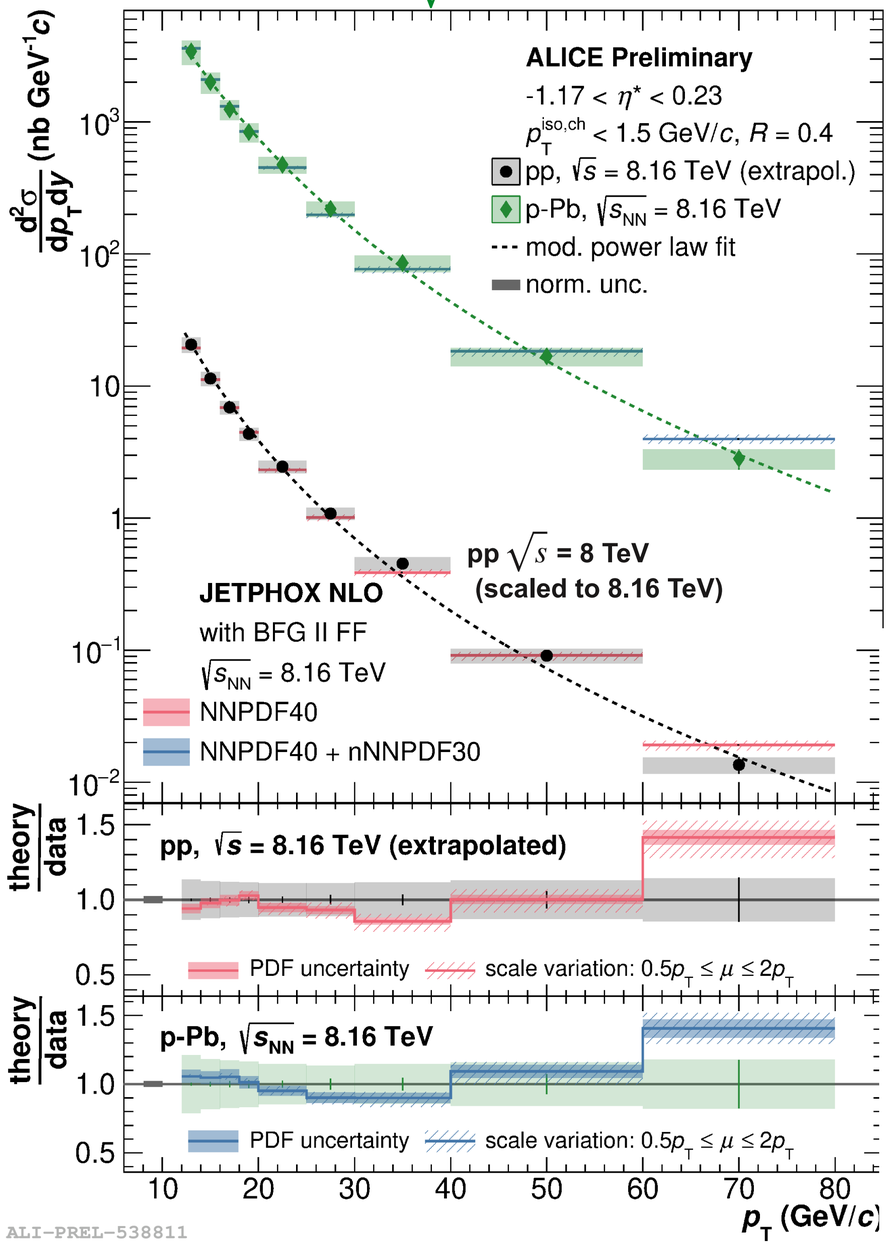
Full list of older results compiled in D. D'Enterria & J. Rojo Nucl. Phys. B 860 (2012), arXiv:1202.1762 [hep-ph]

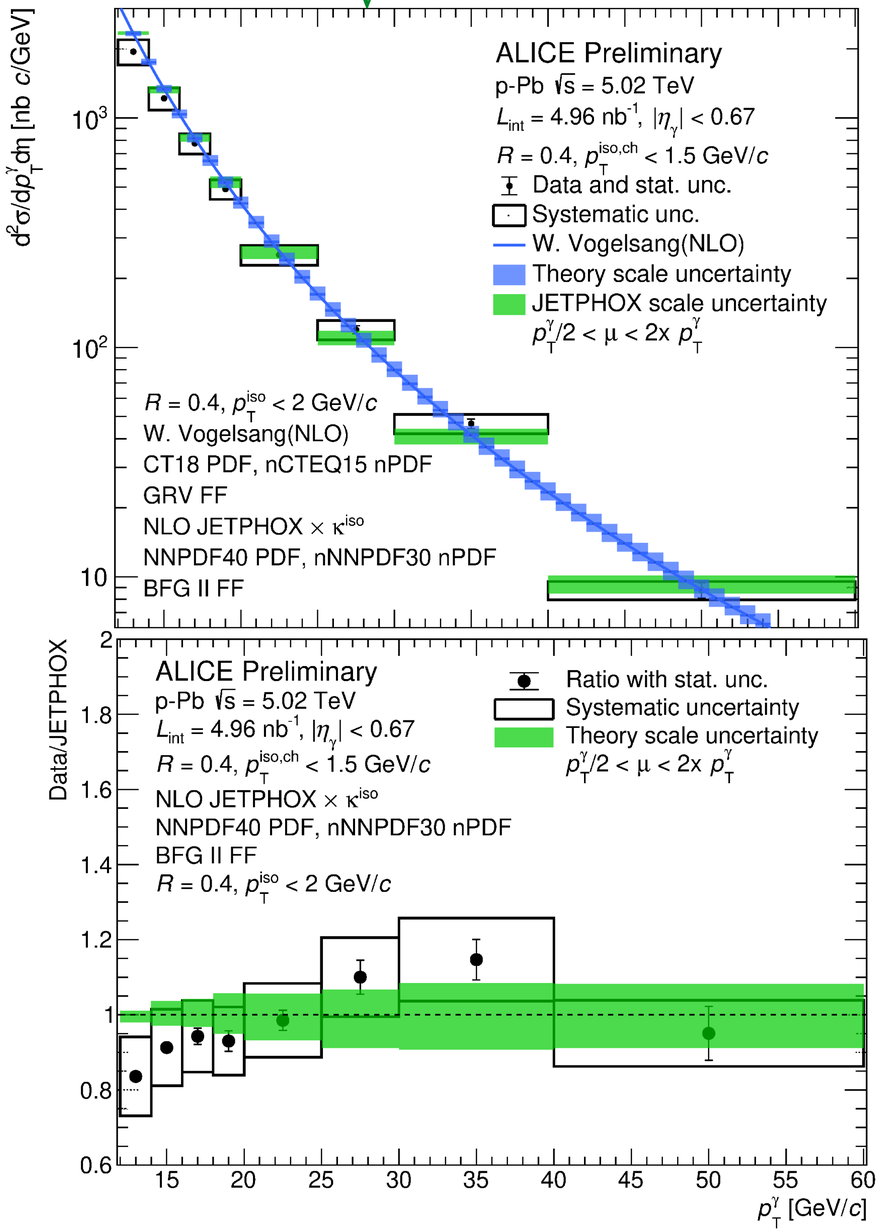
Cross section, p–Pb

pp, p-Pb, $\sqrt{s_{NN}}$ = 8.16 TeV



ALI-PREL-538811

p-Pb, $\sqrt{s_{NN}}$ = 5.02 TeV

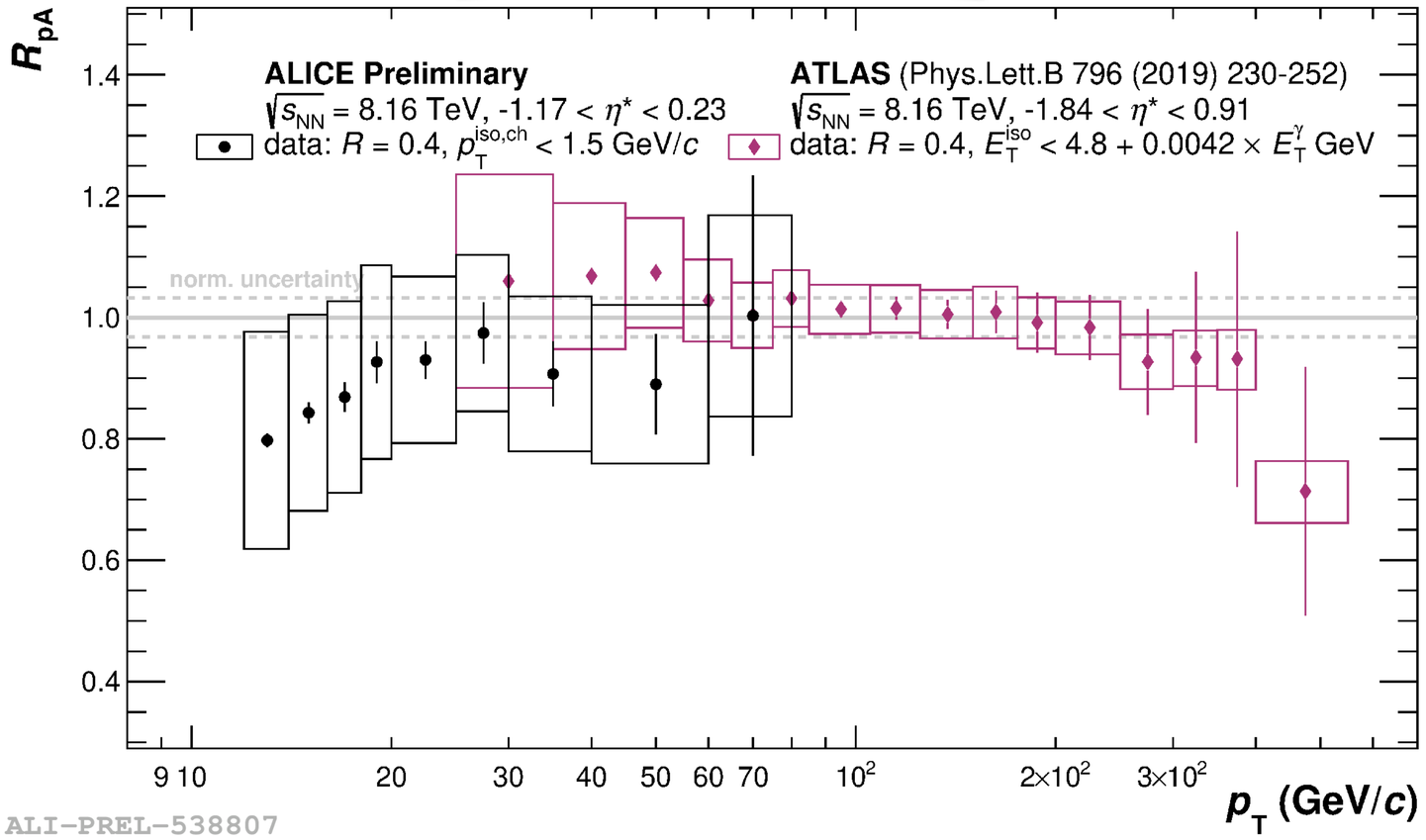


ALI-PREL-508690

➡ NLO pQCD predictions (JETPHOX) and data agree

Nuclear modification factor R_{pA}

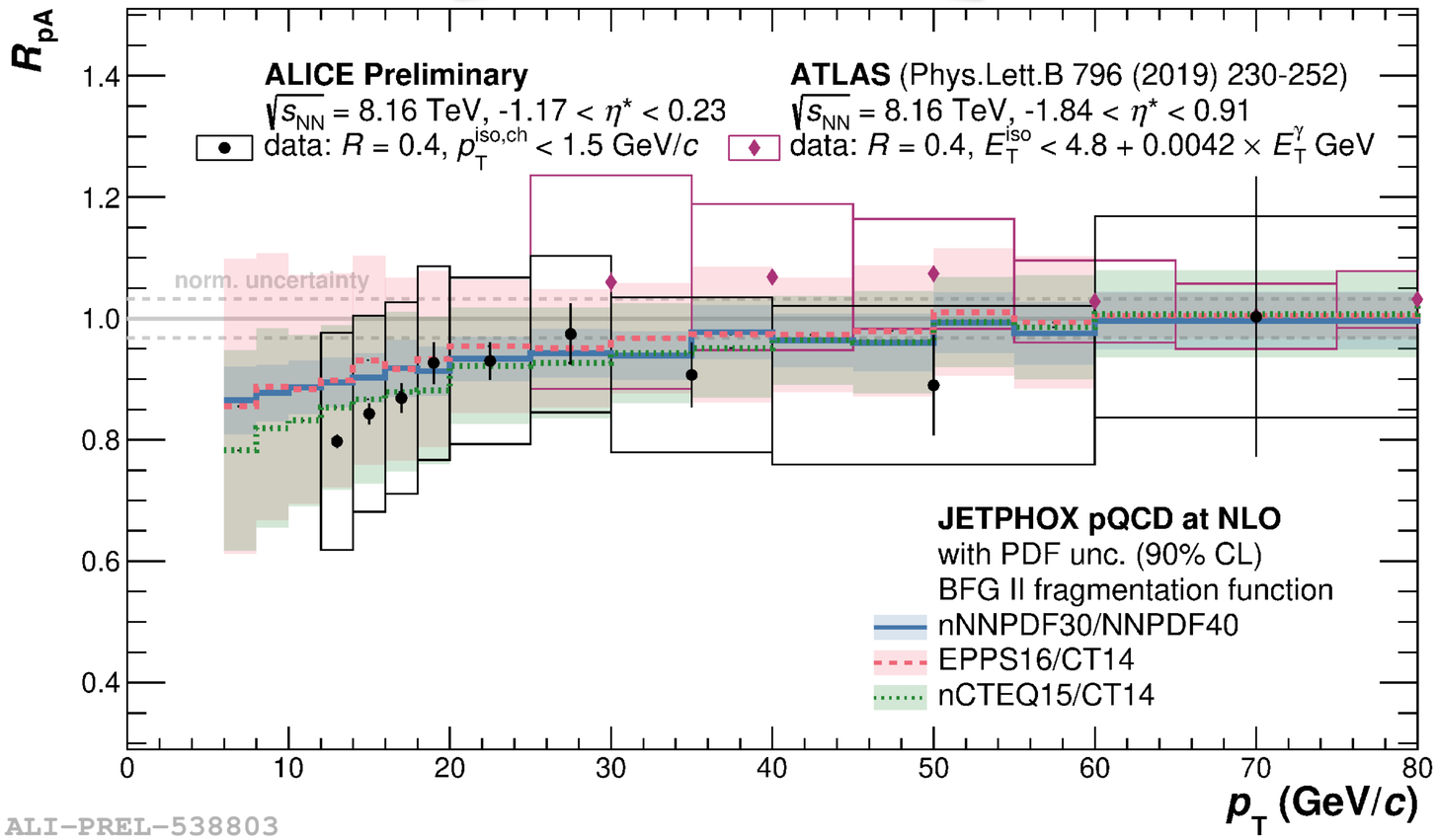
$$R_{pA} = \frac{d^2\sigma^{\gamma}_{pA}/dp_T dy^*}{A_{Pb} \times d^2\sigma^{\gamma}_{pp}/dp_T dy^*}$$



- R_{pA} in agreement with unity
  - No suppression at high p_T, agreement with ATLAS
  - Hints of lower than unity for p_T < 20 GeV/c, expected in theory, cold nuclear matter effects, shadowing

Nuclear modification factor R_{pA}

$$R_{pA} = \frac{d^2\sigma^{\gamma}_{pA}/dp_T dy^*}{A_{Pb} \times d^2\sigma^{\gamma}_{pp}/dp_T dy^*}$$

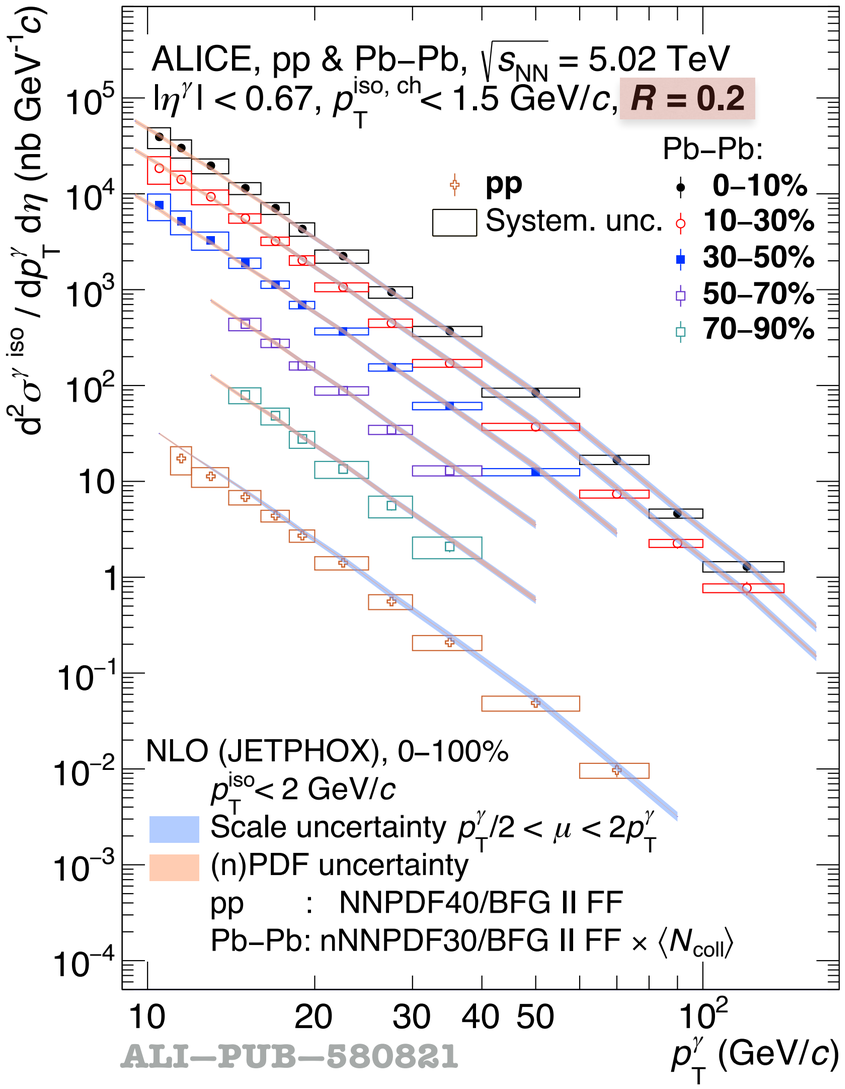


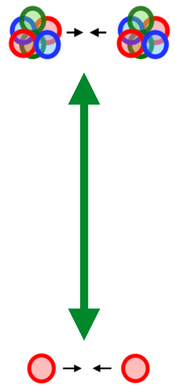
ALI-PREL-538803

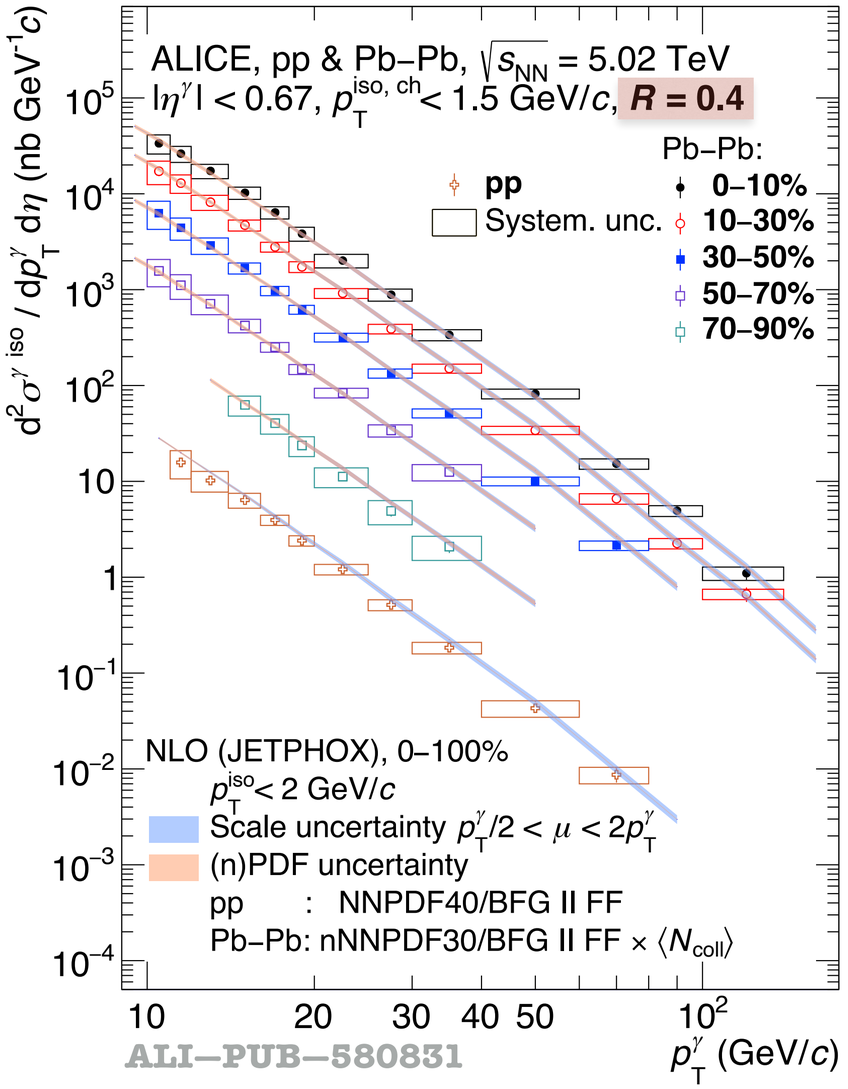
- R_{pA} in agreement with unity
  - No suppression at high p_T, agreement with ATLAS
  - Hints of lower than unity for p_T < 20 GeV/c, expected in theory, cold nuclear matter effects, shadowing

Cross section, pp & Pb–Pb at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV

$$\frac{\mathrm{d}^2\sigma^{\gamma\ \mathrm{iso}}}{\mathrm{d}p_{\mathrm{T}}\,\mathrm{d}\eta} = \frac{\sigma_{\mathrm{NN}}^{\mathrm{INEL}}}{N_{\mathrm{events}} \times \mathrm{RF}_{\varepsilon_{\mathrm{trig}}}} \times \frac{\mathrm{d}^2N}{\mathrm{d}p_{\mathrm{T}}\,\mathrm{d}\eta} \times \frac{P}{\mathrm{Acc} \times \varepsilon_{\gamma}^{\mathrm{iso}} \times \varepsilon_{\mathrm{trig}}}$$

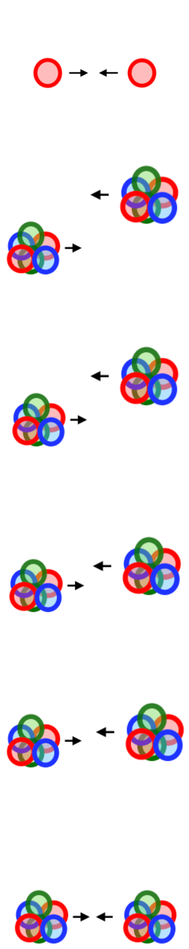


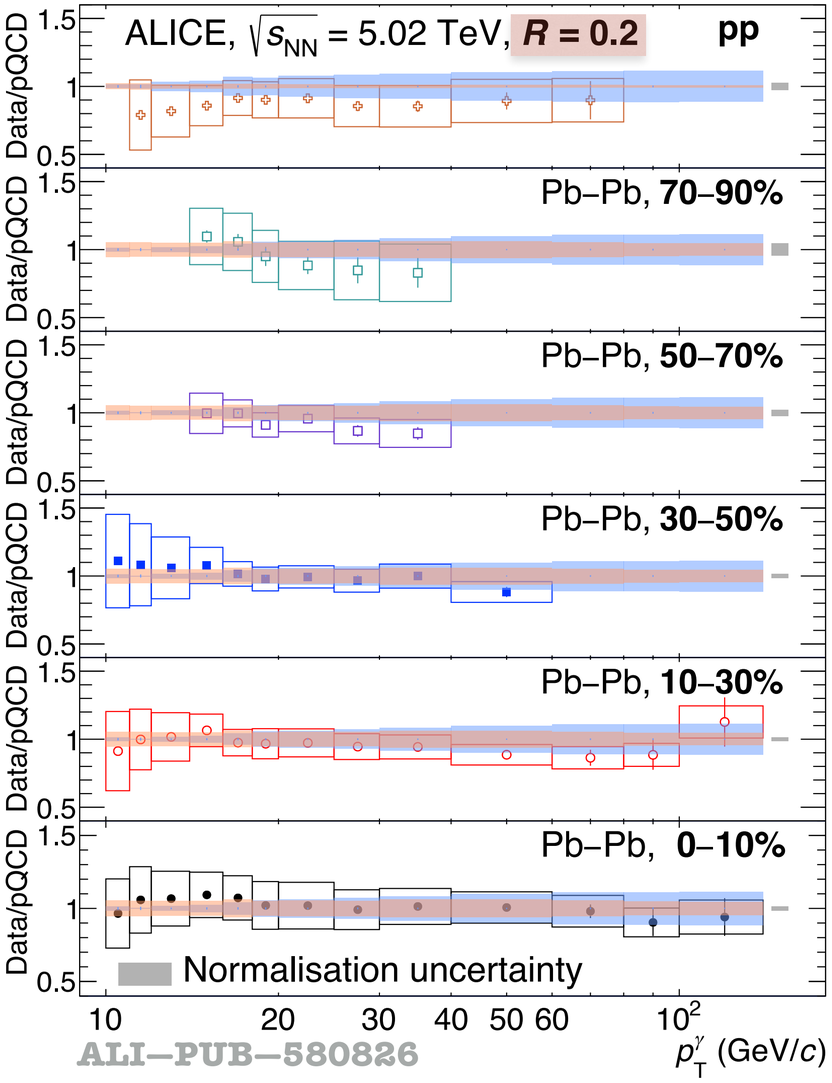


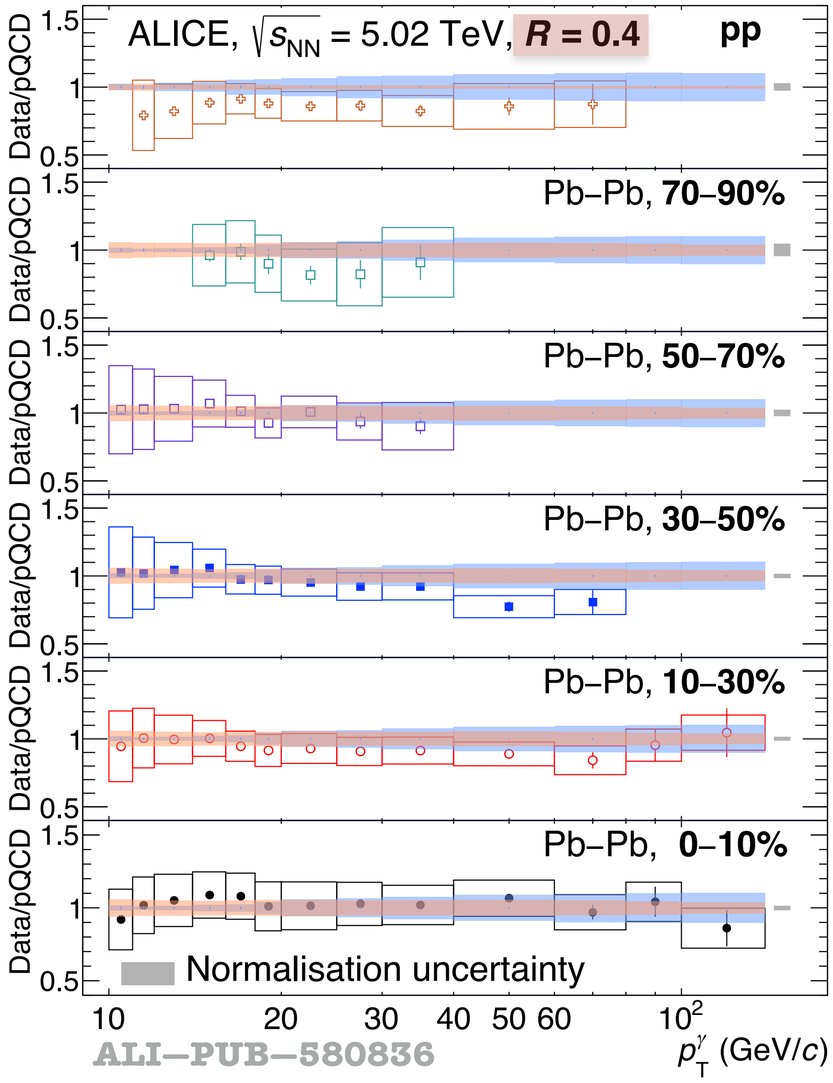


- Wide range: $10 < p_{\mathrm{T}} < 140$ GeV/c in Pb–Pb 0-30% & $11 < p_{\mathrm{T}} < 80$ GeV/c in pp
- NLO pQCD predictions (JETPHOX)
  - ➡ Note: Theory calculated for 0–100%, **PDF (pp) & nPDF** $\times N_{\mathrm{coll}}$ **(Pb–Pb)**

Cross section, pp & Pb–Pb at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV





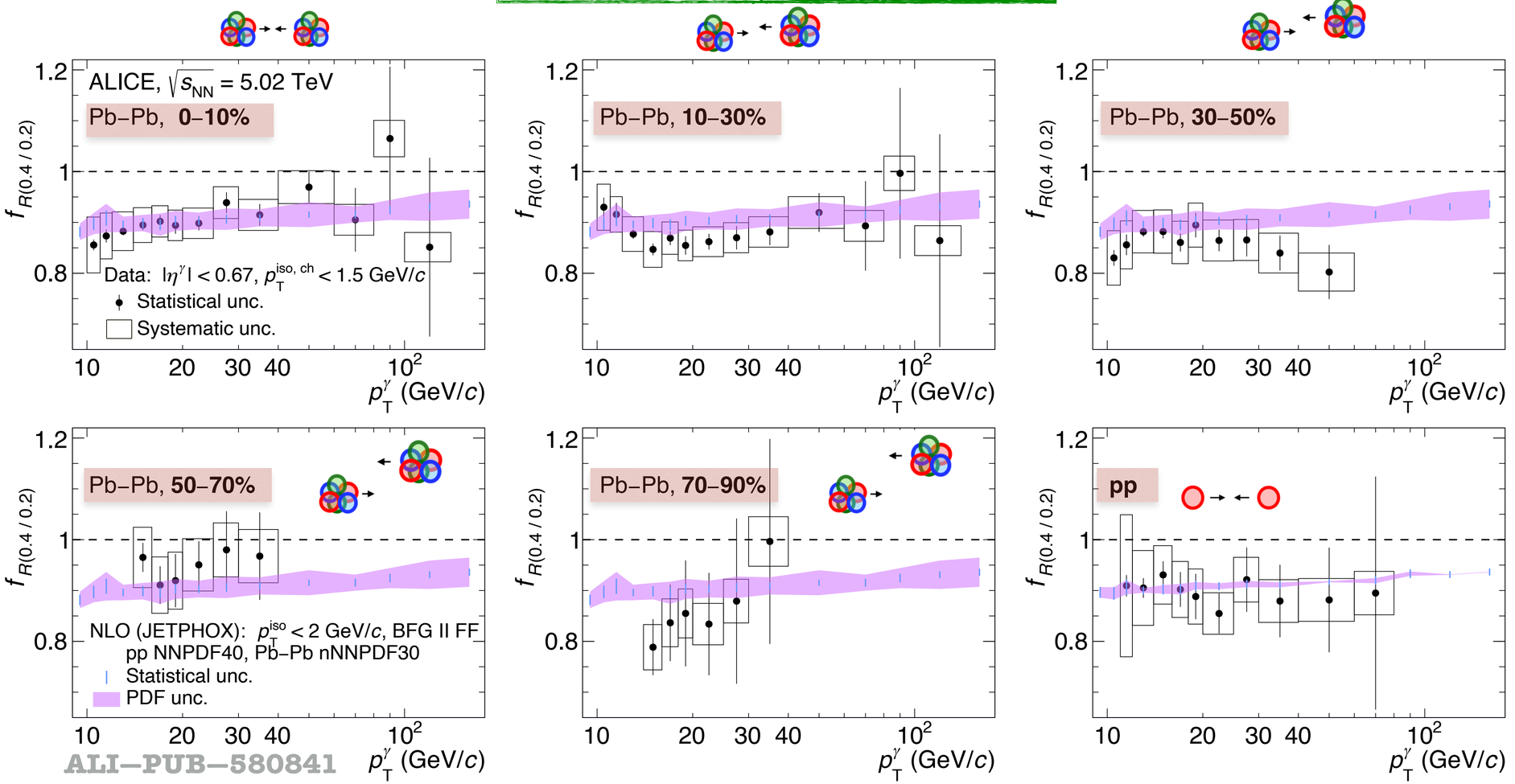


- NLO pQCD predictions (JETPHOX)
  - ➡ Note: Theory calculated for 0–100%, **PDF (pp) & nPDF** $\times N_{\mathrm{coll}}$ **(Pb–Pb)**
- Theory & data agreement for both *R* and collision system

Cross section *R* ratio, pp & Pb–Pb at $\sqrt{s_{NN}}$ = 5.02 TeV

$$f_{R(0.4/0.2)} = \left.\frac{d^2\sigma}{dp_T\, d\eta}\right|_{(R=0.4)} \Big/ \left.\frac{d^2\sigma}{dp_T\, d\eta}\right|_{(R=0.2)}$$

- Sensitive to fraction of fragmentation γ surviving the isolation selection
  - ➡ Interesting for theory models
- Agreement with theory and between collision systems
  - ➡ Theory (NLO): controls the isolation mechanism, fragmentation γ & prompt γ production even in Pb–Pb

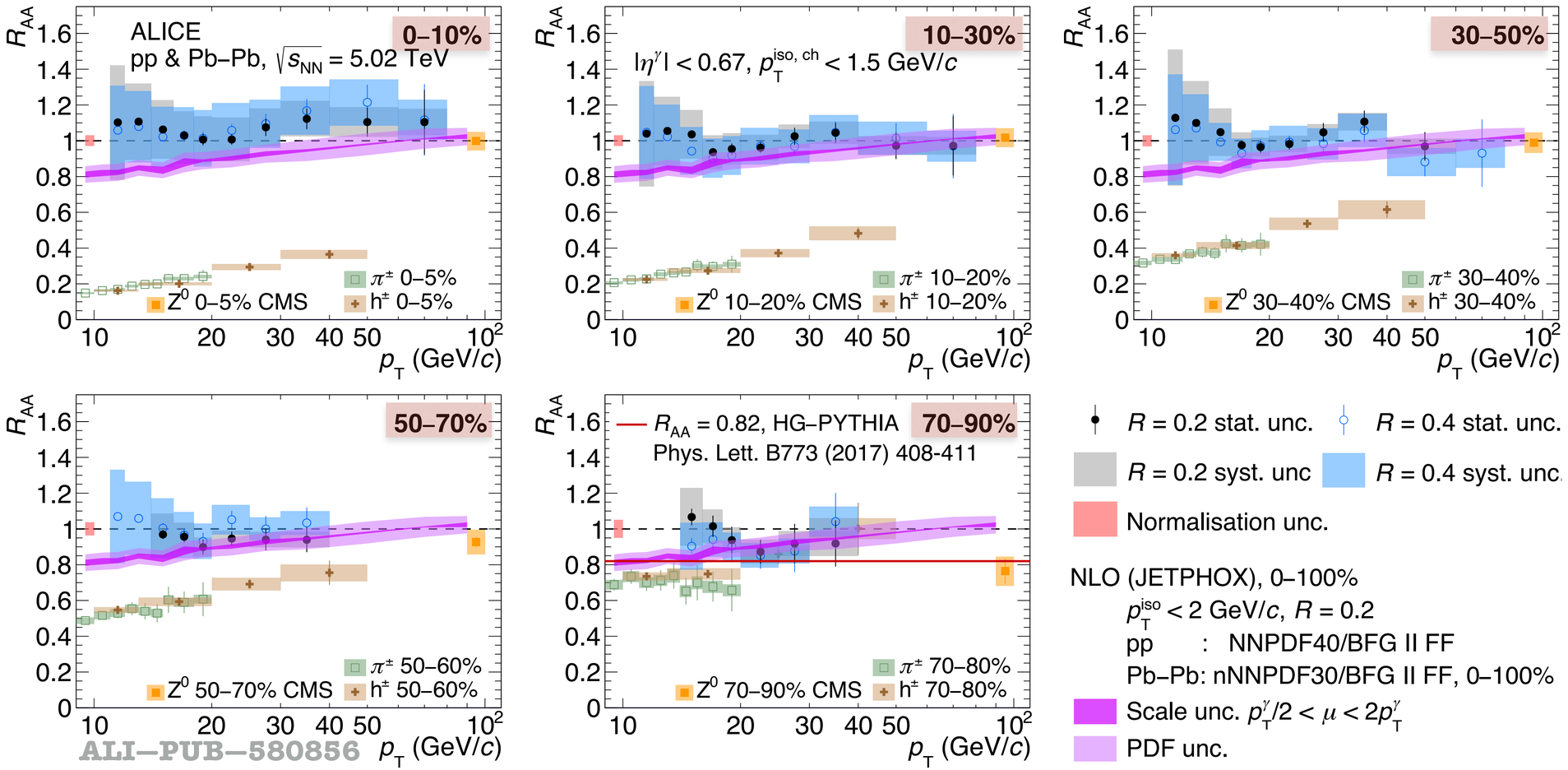


✳ Not shown (back-up): ATLAS pp $\sqrt{s}$ =13 TeV, for p_T > 250 GeV/c
JHEP 07 (2023) 86 arXiv:2302.00510

Nuclear modification factor R_{AA}, pp & Pb–Pb at $\sqrt{s_{NN}}$ = 5.02 TeV

$$R_{AA} = \frac{1}{\langle N_{coll} \rangle} \frac{d^2\sigma_{AA} / (dp_T\, d\eta)}{d^2\sigma_{pp} / (dp_T\, d\eta)}$$

- 0-70%
  - ➡ Consistent with unity within the unc. for both R
    - ✤ No modification of the prompt γ yield due to the QGP as expected
  - ➡ Agreement with NLO pQCD incorporating cold matter nuclear effects: PDF vs nPDF



Nuclear modification factor R_{AA}, pp & Pb–Pb at $\sqrt{s_{NN}}$ = 5.02 TeV

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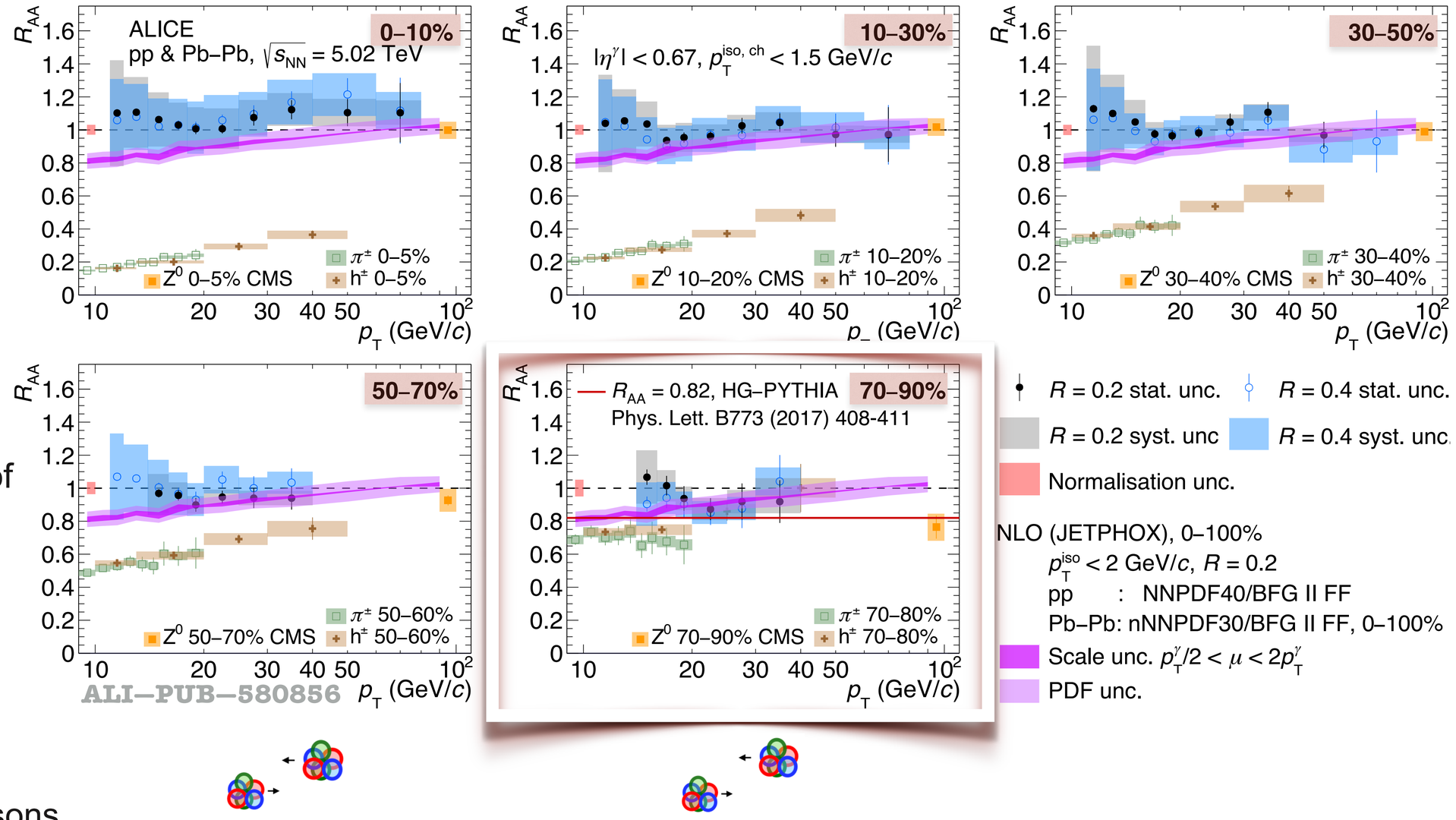
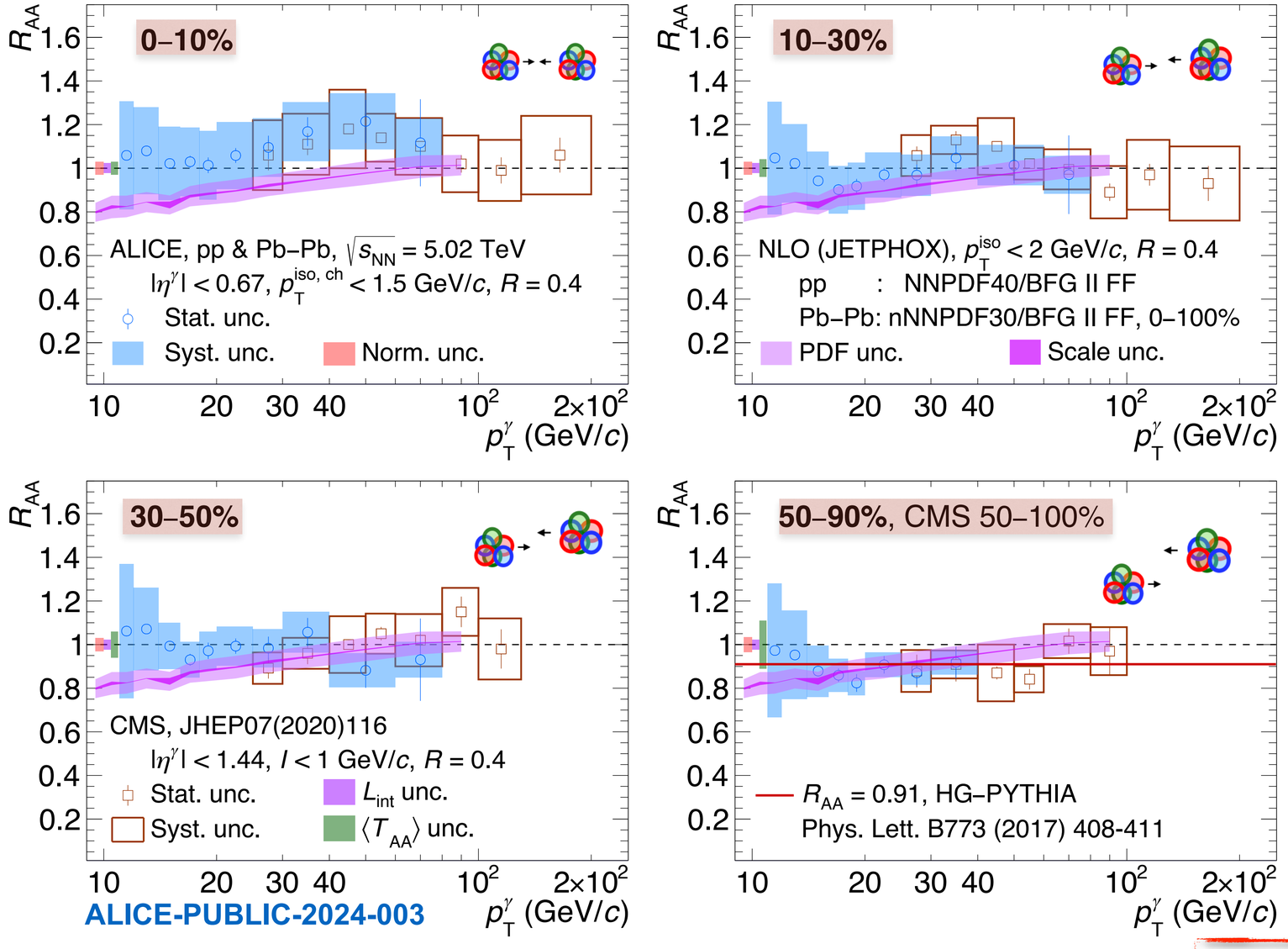
- 0-70%
  - ➡ Consistent with unity within the unc. for both *R*
    - ✤ No modification of the prompt γ yield due to the QGP as expected
  - ➡ Agreement with NLO pQCD incorporating cold matter nuclear effects: PDF vs nPDF
- 70-90%
  - ➡ Closer to 0.9 than 1 for both *R* likely due to centrality selection bias of Glauber model
  - ➡ Model by C. Loizides & A. Morsch (Phys. Lett. B773 (2017) 408-411) yields a value at 0.82
    - ✤ In agreement within the uncertainties
  - ➡ Seen by CMS with Z^0 bosons



Nuclear modification factor R_{AA}, pp & Pb–Pb at $\sqrt{s_{NN}}$ = 5.02 TeV

$$R_{AA} = \frac{1}{\langle N_{coll} \rangle} \frac{d^2\sigma_{AA} / (dp_T\, d\eta)}{d^2\sigma_{pp} / (dp_T\, d\eta)}$$

- **ALICE** & **CMS**: good agreement in the overlapping region 25 < p_T < 40–80 GeV/c

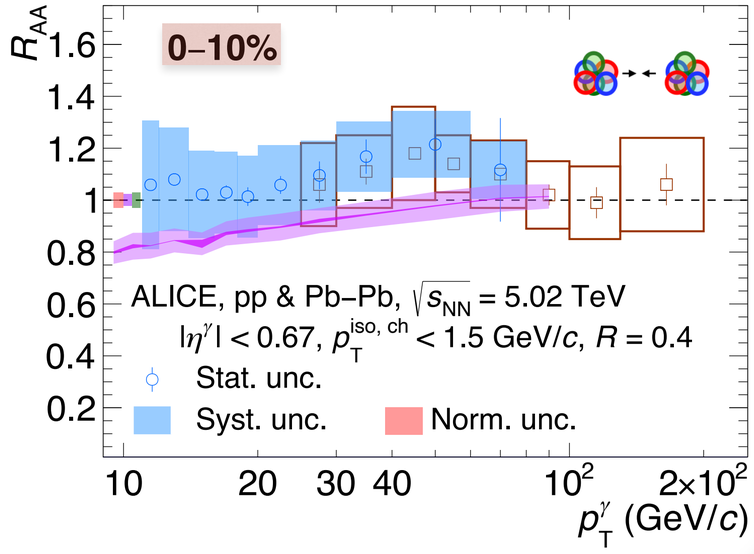


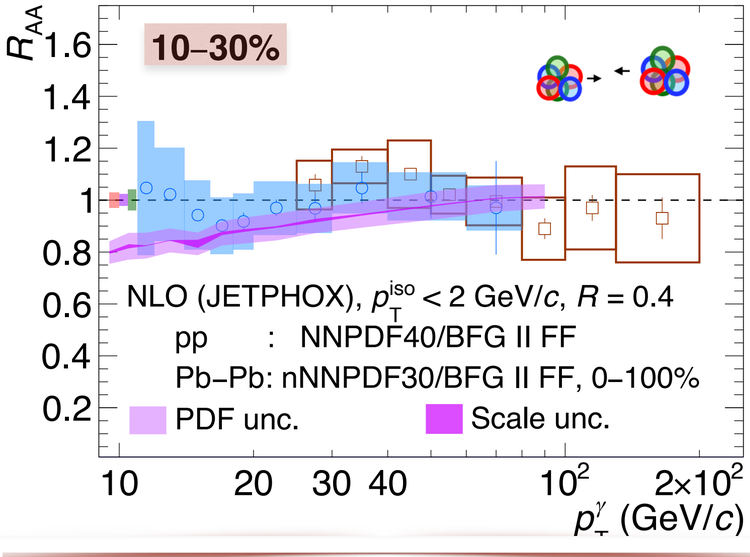
Nuclear modification factor R_{AA}, pp & Pb–Pb at $\sqrt{s_{NN}}$ = 5.02 TeV

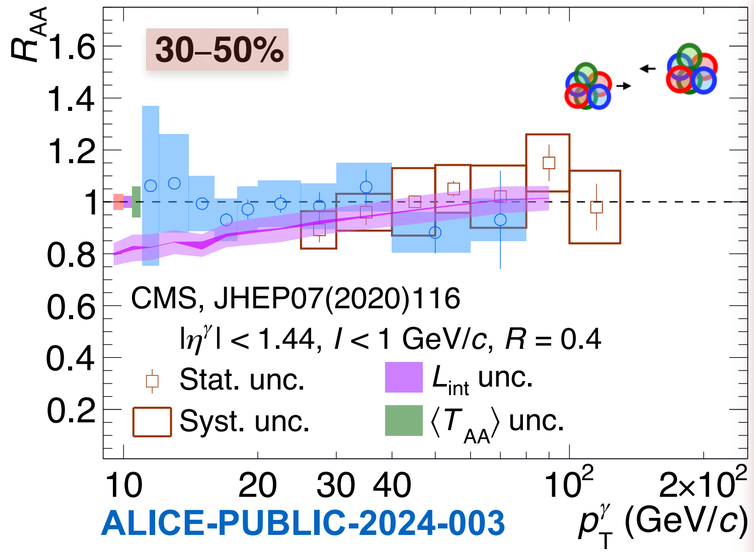
$$R_{AA} = \frac{1}{\langle N_{coll} \rangle} \frac{d^2\sigma_{AA} / (dp_T\, d\eta)}{d^2\sigma_{pp} / (dp_T\, d\eta)}$$

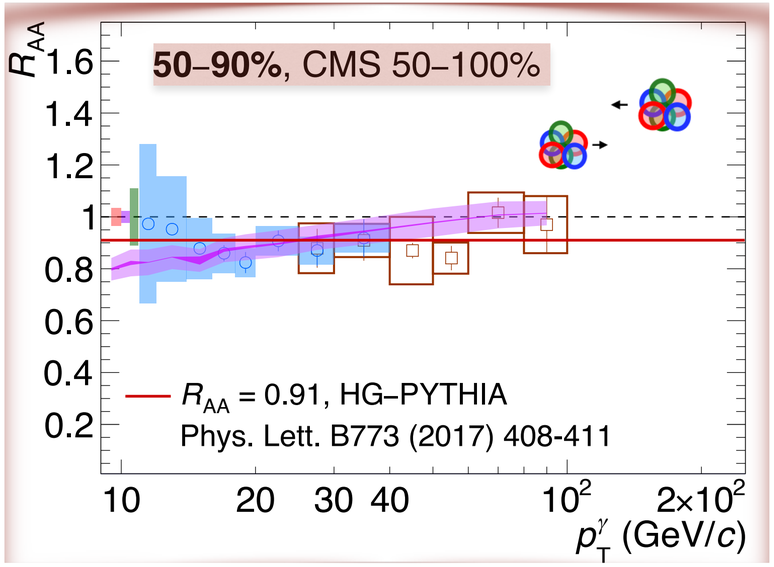
- **ALICE & CMS**: good agreement in the overlapping region $25 < p_T < 40$–80 GeV/c

- 50-90%
  - ➡ Closer to 0.9 than 1 for both R likely due to centrality selection bias of Glauber model
  - ➡ Model by C. Loizides & A. Morsch (Phys. Lett. B773 (2017) 408-411) yields a value at 0.91
    - ✤ In agreement within the uncertainties



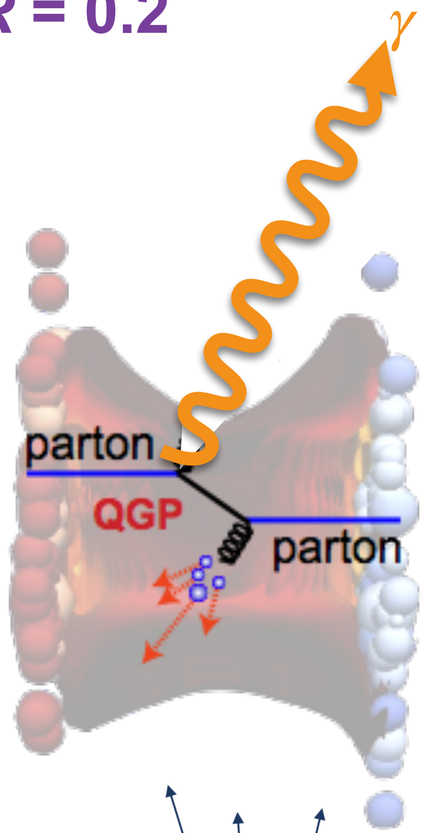




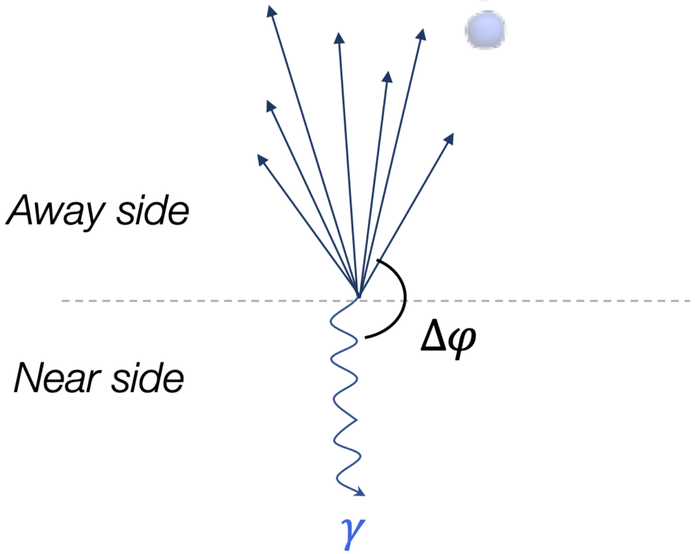


Isolated γ-hadron correlations in Pb–Pb at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV, R = 0.2

- Prompt γ associated to a parton emitted in opposite side
- **Tags the parton initial energy** $p_{\mathrm{T}}^{\gamma} \simeq p_{\mathrm{T}}^{\mathrm{parton}}$, before losing Δ$E$ in QGP
  - ➡ Aim: Measure FF modifications, where is the ΔE radiated?



- Observables:
  - ➡ Trigger: isolated narrow or wide clusters, R = 0.2 & $p_{\mathrm{T}}^{\mathrm{iso\ ch}}$ < 1.5 GeV/c
  - ➡ Azimuthal correlation: $\Delta\varphi = \varphi^{\mathrm{trigger}} - \varphi^{\mathrm{track}}$ with
  - ➡ $z_{\mathrm{T}} = \dfrac{p_{\mathrm{T}}^{\mathrm{track}}}{p_{T}^{\mathrm{trigger}}}$ and $\mathrm{D}(z_{\mathrm{T}}) = \dfrac{1}{N^{\mathrm{trigger}}} \dfrac{\mathrm{d}\ N^{\mathrm{track}}}{\mathrm{d}\ z_{\mathrm{T}}}$ for tracks in $|\Delta\varphi| > 3/5\pi$ rad (mirrored)
  - ➡ **When trigger = prompt γ, $\mathrm{D}(z_{\mathrm{T}})$ is a proxy for FF**
  - ➡ Measurement: 18 < p_{T}^{trigger} < 40 GeV/c & p_{T}^{track} > 0.5 GeV/c
    - Details in back-up



Such kind of analysis pursued by different thesis at LPSC and CCNU:
Yaxian Mao (pp, 7 TeV, 2011), Nicolas Arbor (pp, 7 TeV, Pb-Pb, 2.76 TeV, 2013),
Astrid Vauthier (p-Pb, 5 TeV, 2016) and Carolina Arata (Pb-Pb, 5 TeV, 2024)

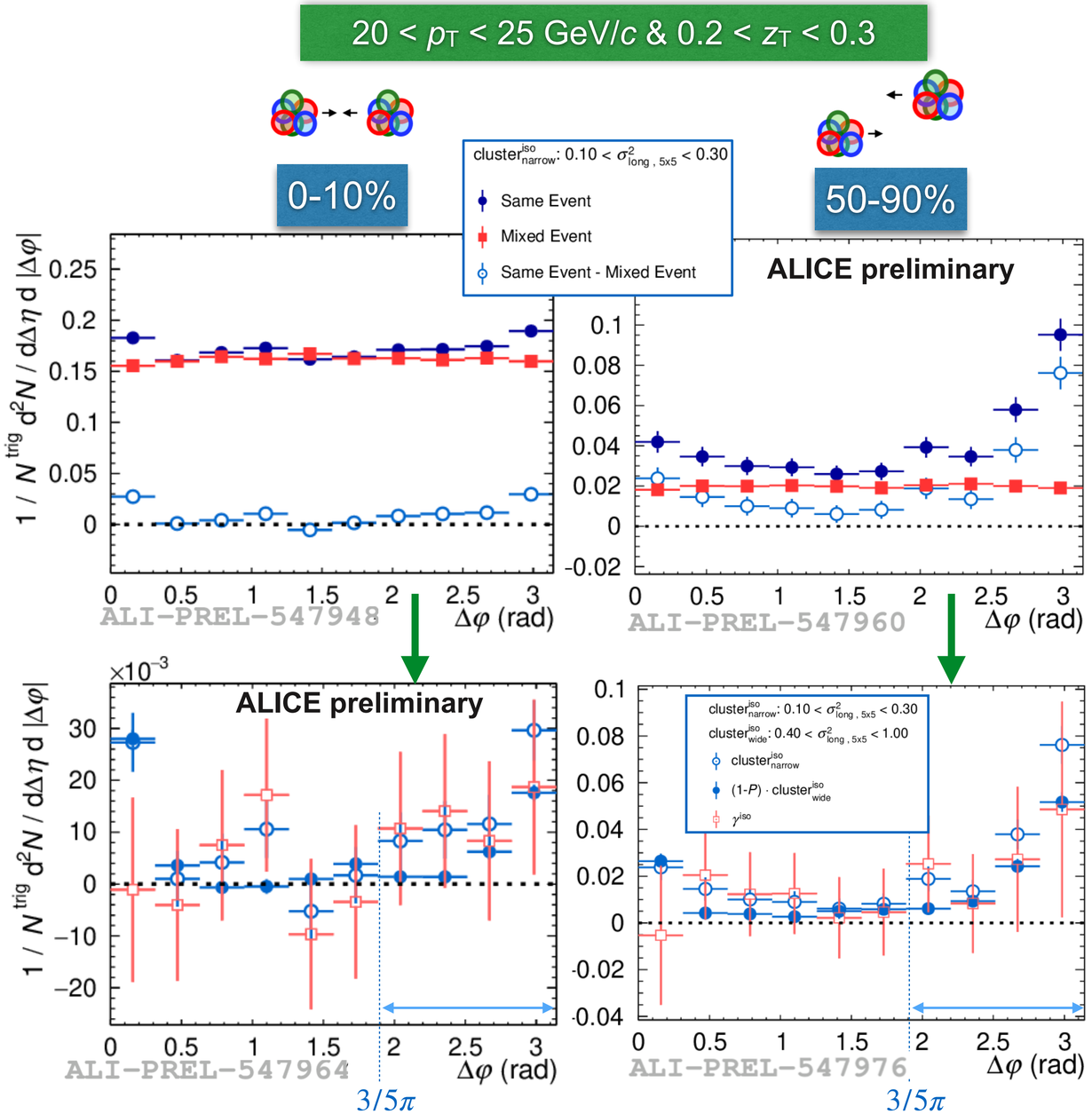
Isolated γ-hadron correlations in Pb–Pb: Azimuthal distribution

- UE in $\Delta\varphi$: uncorrelated tracks shift up the distribution
- *UE subtraction with mixed event*: artificial dataset created combining the trigger cluster with tracks on different collisions

- Purity < 1, considering $f(\Delta\varphi^{\mathrm{cls}^{\mathrm{iso}}_{\mathrm{narrow}}})$ bkg = $f(\Delta\varphi^{\mathrm{cls}^{\mathrm{iso}}_{\mathrm{wide}}})$:

$$f(\Delta\varphi^{\gamma^{\mathrm{iso}}}) = \frac{f(\Delta\varphi^{\mathrm{cls}^{\mathrm{iso}}_{\mathrm{narrow}}}) - (1-P)\cdot f(\Delta\varphi^{\mathrm{cls}^{\mathrm{iso}}_{\mathrm{wide}}})}{P}$$

➡ $D(z_T)$: Integrate $f(\Delta\varphi^{\gamma^{\mathrm{iso}}})$ in $3/5\pi < |\Delta\varphi| < \pi$ rad



Isolated γ-hadron correlations in p–Pb & pp, $R = 0.4$: $D(z_T)$

- Previous published results in p–Pb and pp collisions
  - ➡ Agreement between systems and with PYTHIA
  - ➡ Note: Pb–Pb collisions measurement (next slides) done in different p_T ranges and is compared directly to pQCD predictions

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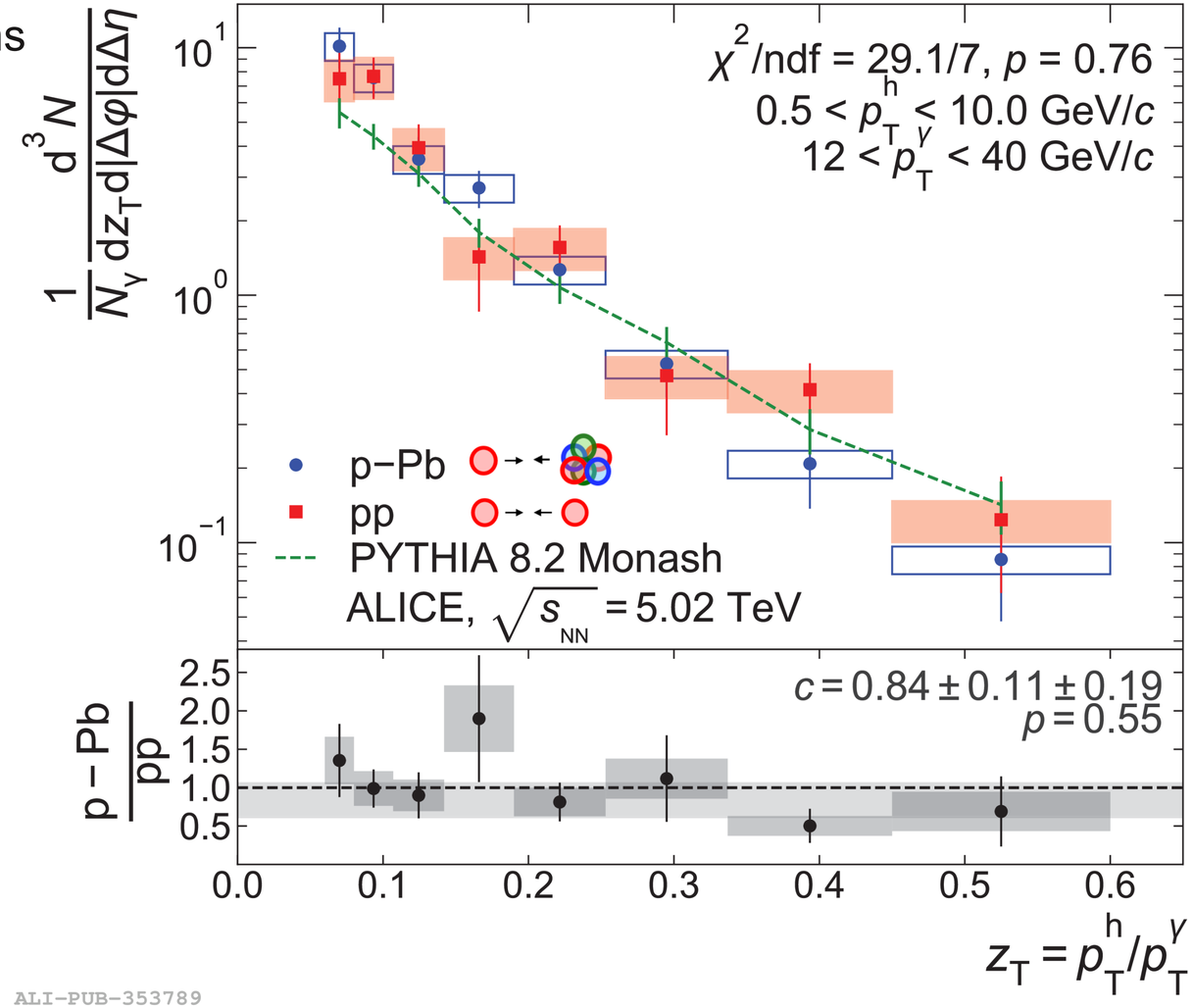
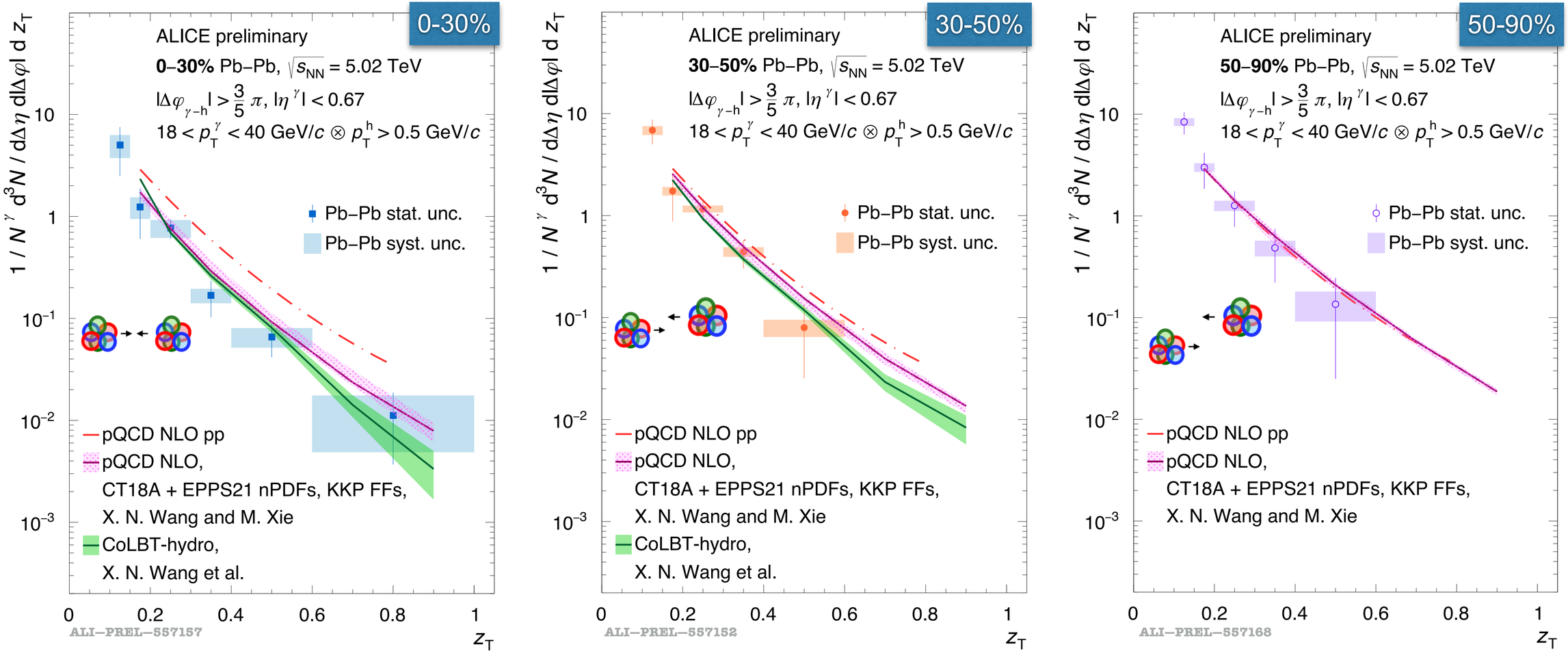


ALI-PUB-353789

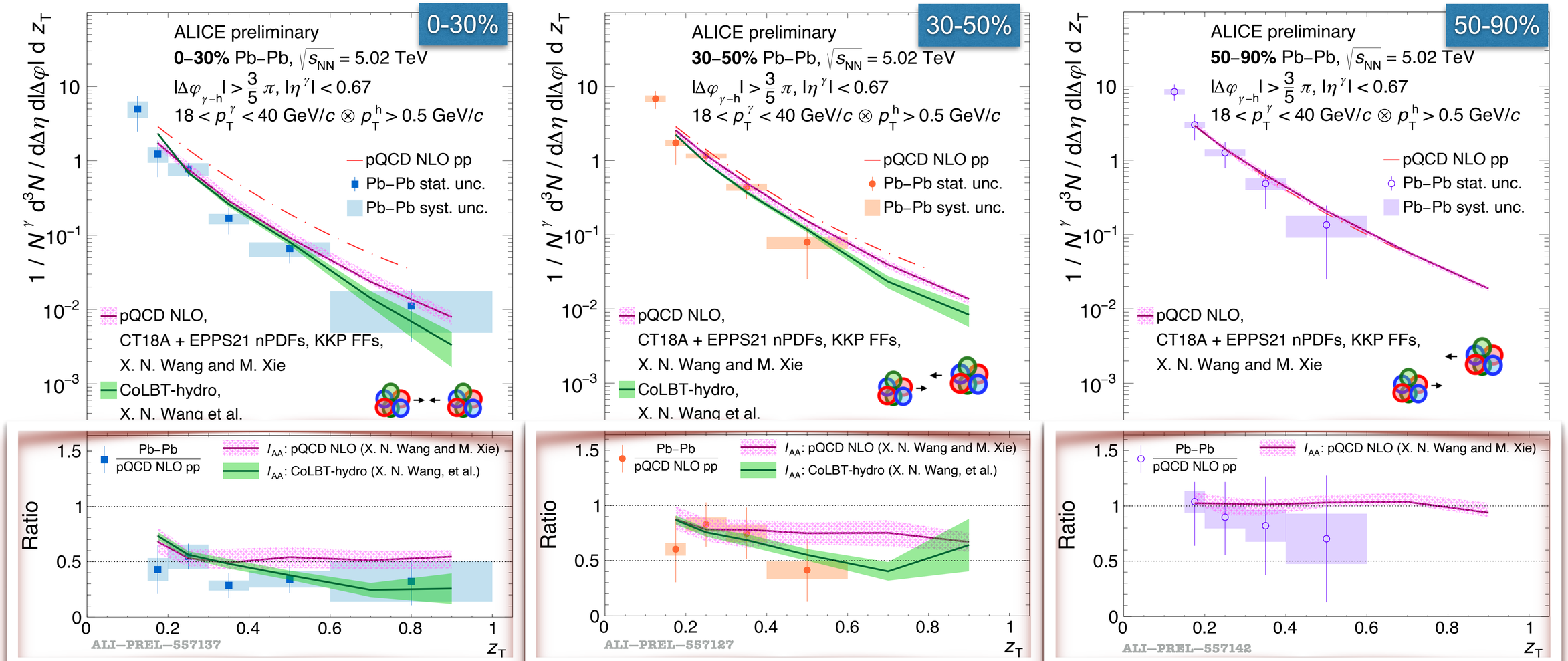
Isolated γ-hadron correlations in Pb–Pb: $D(z_T)$



- Pb–Pb data compared with theory: *NLO pQCD* and *CoLBT* (0-50% only)
  - ➡ In agreement with both models
  - ➡ Discrimination not possible yet

- *Phys. Rev. C 103, 034911, Xie, Wang and Zhang,*
- *Phys. Rev. Lett. 103, 032302, Xie, Wang and Zhang*
- *Phys.Lett.B 777 (2018) 86-90 , Chen et al.*

Isolated γ-hadron correlations in Pb–Pb: $D(z_T)$

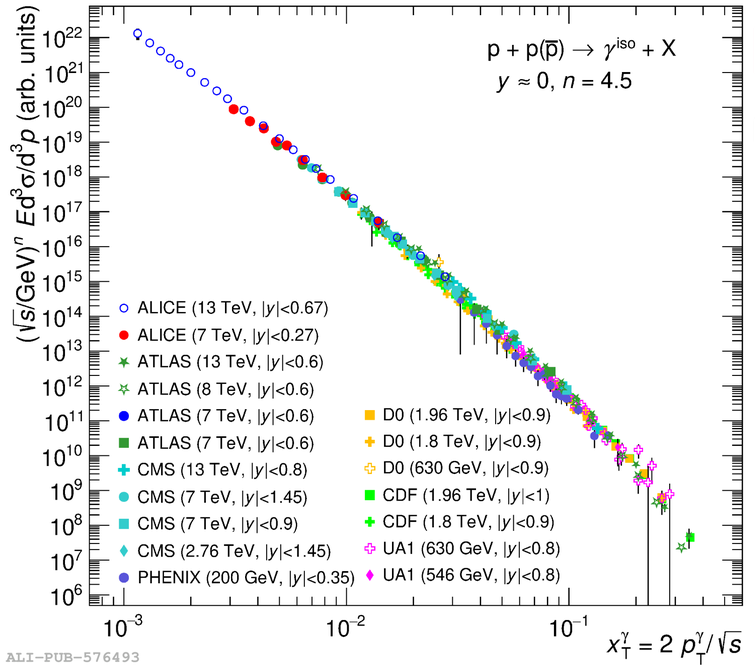


- Ratio with respect to NLO pQCD pp collision simulation → A proxy for $I_{AA} = \frac{D(z_T)_{\text{Pb–Pb}}}{D(z_T)_{\text{pp}}}$
- Clear modifications in data with respect to NLO pQCD pp simulation
- Comparison with I_{AA} from NLO pQCD and CoLBT models → agreement

Summary

➡ Cross section

- ✱ Data in agreement with NLO pQCD in multiple collision systems & $\sqrt{s_{\mathrm{NN}}}$
- ✱ Lowest measured x_{T} at mid-rapidity in pp collisions at $\sqrt{s}$ = 13 TeV
- ✱ Ratio of cross sections for different R in agreement with theory and within the different collision systems

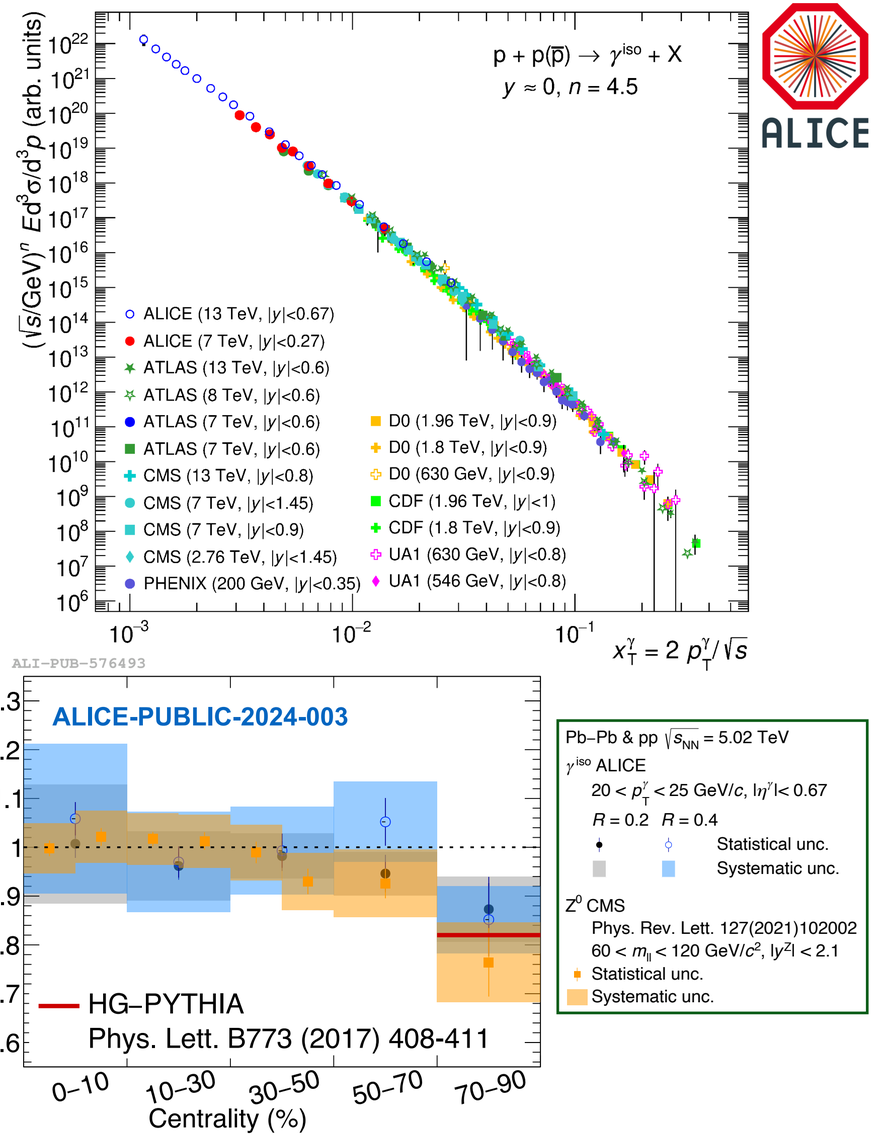


Summary

➡ Cross section

- ✱ Data in agreement with NLO pQCD in multiple collision systems & $\sqrt{s_{\rm NN}}$
- ✱ Lowest measured $x_{\rm T}$ at mid-rapidity in pp collisions at $\sqrt{s}$ = 13 TeV
- ✱ Ratio of cross sections for different R in agreement with theory and within the different collision systems

- ✱ Pb–Pb: $R_{\rm AA} \simeq 1$, no γ production modification by QGP
  - ▶ but for 50–90% & 70–90%: $R_{\rm AA} \simeq 0.9$, agreement (1σ) with HG-PYTHIA, model of the centrality selection bias
  - ▶ Pb-Pb col. agree with nPDF prediction
- ✱ p–Pb: $R_{\rm pA} \simeq 1$, no γ production modification
  - ▶ Hints of suppression for $p_{\rm T}$ < 20 GeV/c in p–Pb, in agreement with pQCD nPDF / PDF at low $p_{\rm T}$



Summary

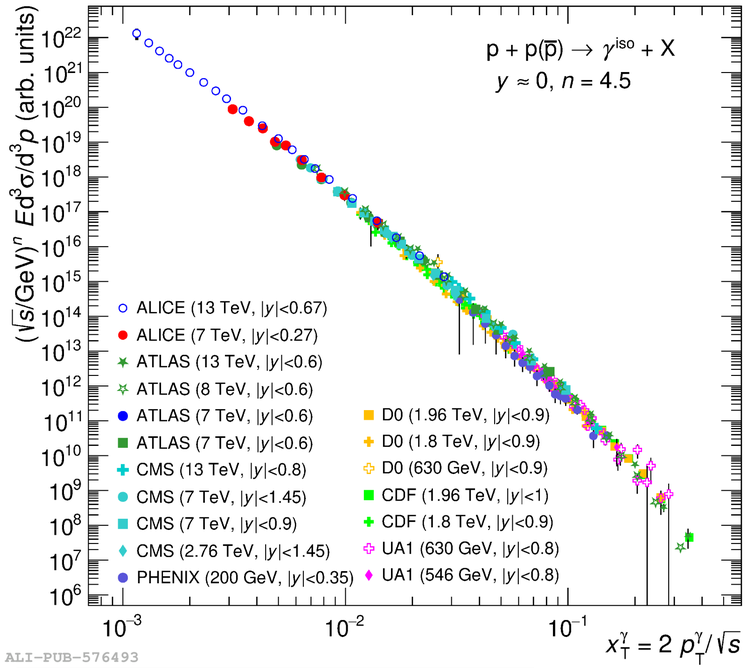
➡ Cross section

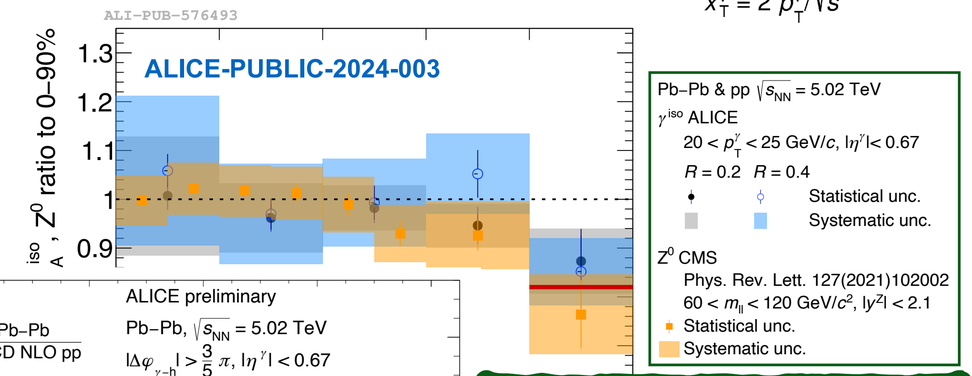
- ✱ Data in agreement with NLO pQCD in multiple collision systems & $\sqrt{s_{\rm NN}}$
- ✱ Lowest measured $x_{\rm T}$ at mid-rapidity in pp collisions at $\sqrt{s}$ = 13 TeV
- ✱ Ratio of cross sections for different R in agreement with theory and within the different collision systems

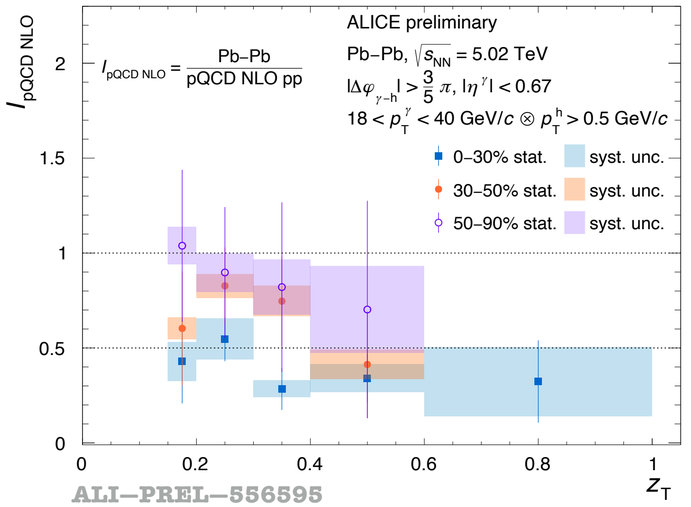
- ✱ Pb–Pb: $R_{\rm AA} \simeq 1$, no γ production modification by QGP
  - ▶ but for 50–90% & 70–90%: $R_{\rm AA} \simeq 0.9$, agreement (1σ) with HG-PYTHIA, model of the centrality selection bias
  - ▶ Pb-Pb col. agree with nPDF prediction
- ✱ p–Pb: $R_{\rm pA} \simeq 1$, no γ production modification
  - ▶ Hints of suppression for $p_{\rm T}$ < 20 GeV/c in p–Pb, in agreement with pQCD nPDF / PDF at low $p_{\rm T}$

➡ γ–hadron corr. in Pb–Pb at $\sqrt{s_{\rm NN}}$ = 5.02 TeV

- ✱ **Very statistically limited, challenging!**
- ✱ $z_{\rm T}$ distribution significantly lower than pp NLO pQCD in central
  - ▶ FF modification: stronger for central compared to peripheral
- ✱ Results described by two models, model discrimination not possible



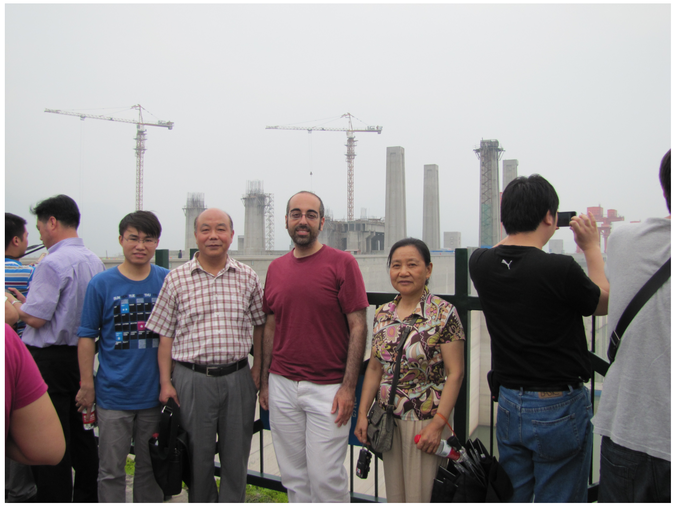




Expected improvement with Run 3 + Run 4 data samples, in particular γ-hadron correlations

2002 Xiaomei + PHOS rusian friends

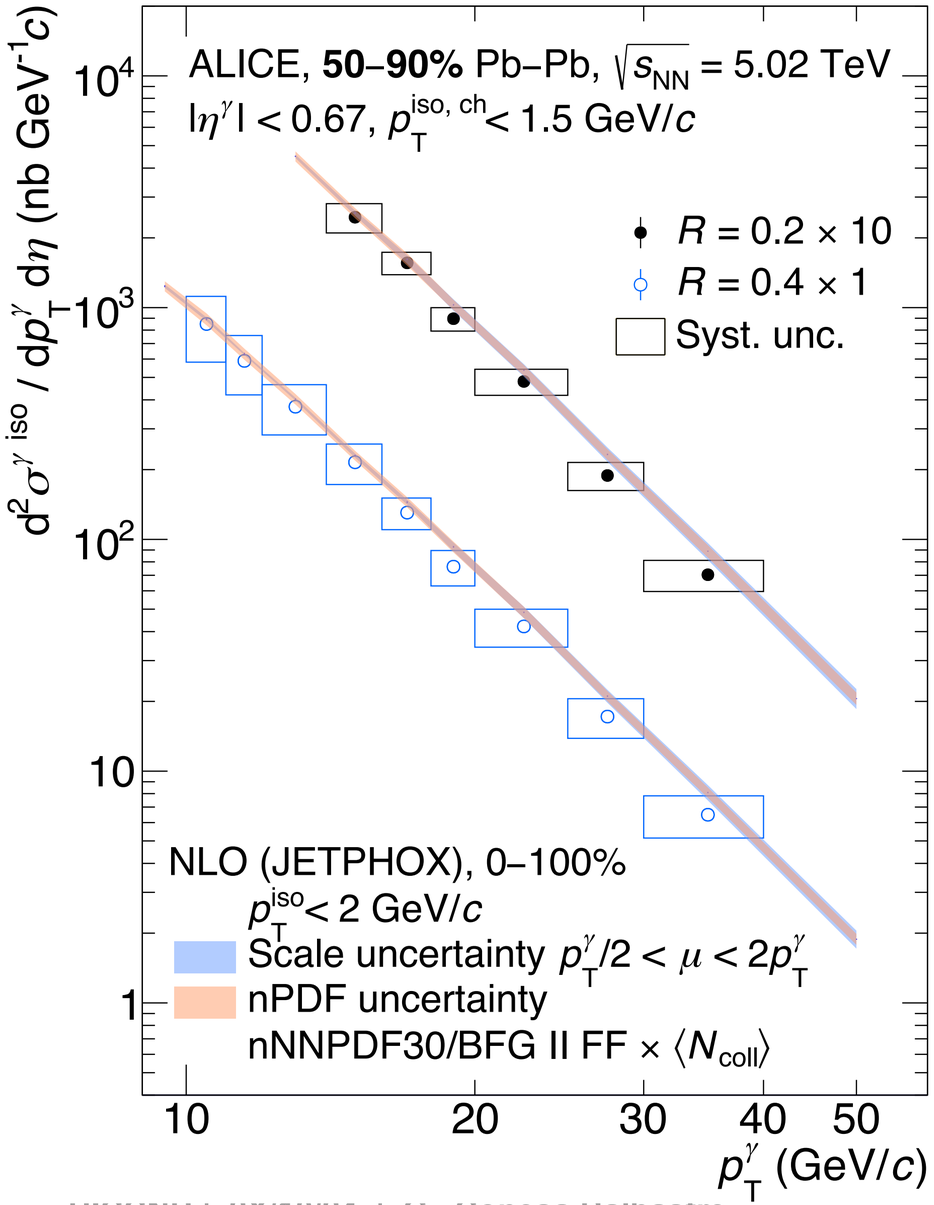
2011 Renzhuo & Yaxian Thesis

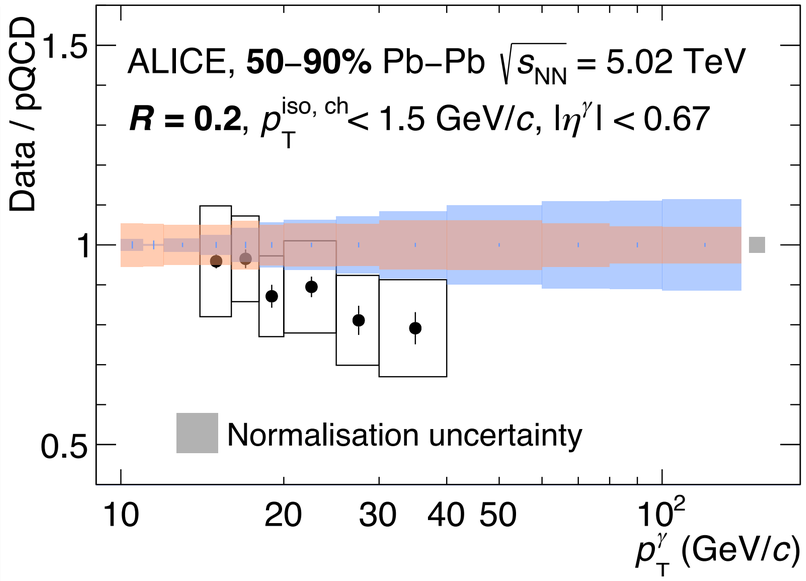


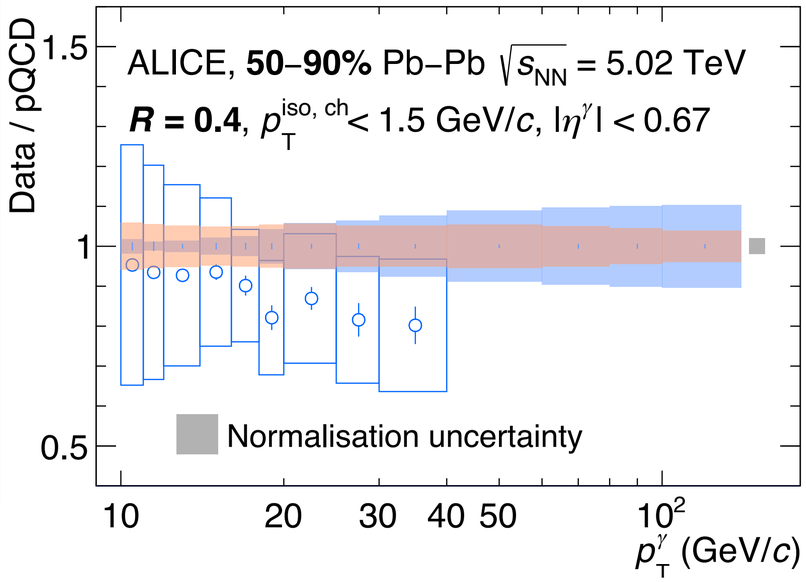
Thanks to all our chinese colleagues and students all over the many years!

+ the students Xianrong, Haitao, Xinye, Ran and many others

Pb–Pb 50-90%: cross section and ratios







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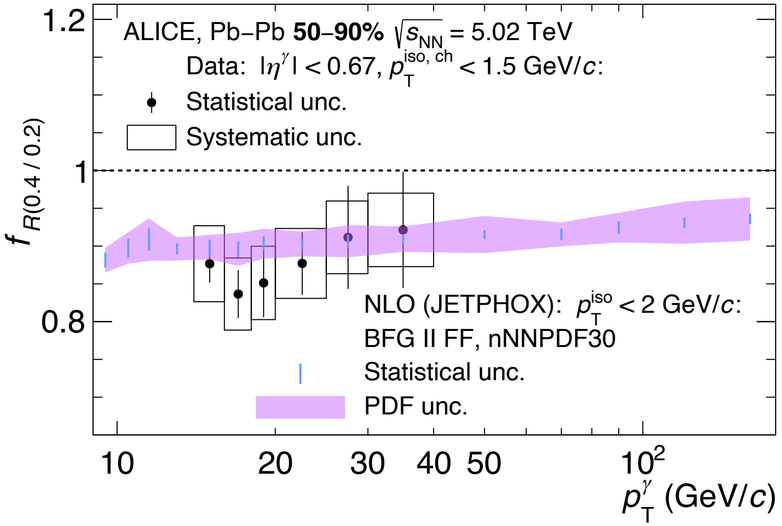
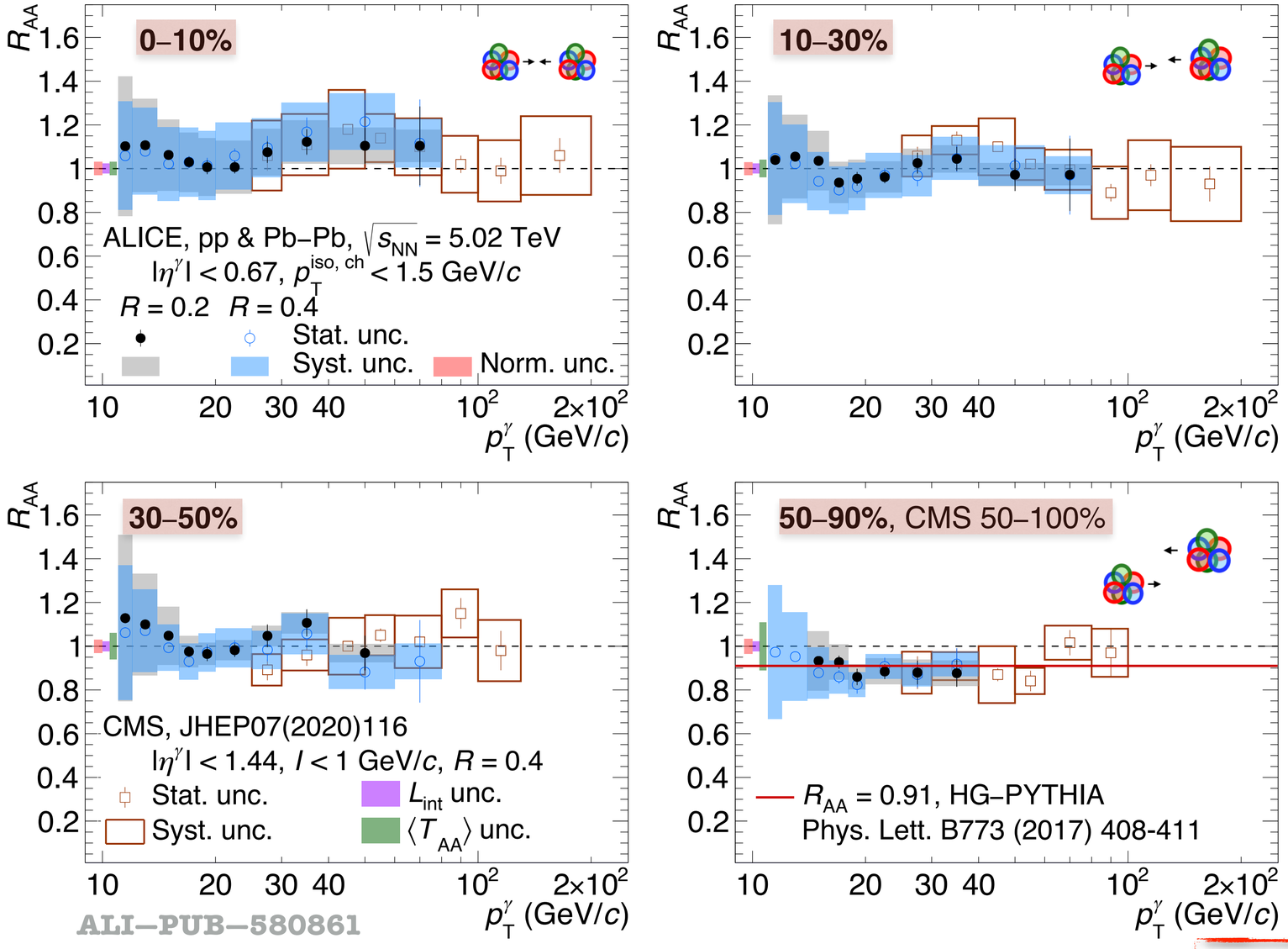


Nuclear modification factor R_{AA}, pp & Pb–Pb at $\sqrt{s_{NN}}$ = 5.02 TeV

$$R_{AA} = \frac{1}{\langle N_{coll} \rangle} \frac{d^2\sigma_{AA} / (dp_T\, d\eta)}{d^2\sigma_{pp} / (dp_T\, d\eta)}$$

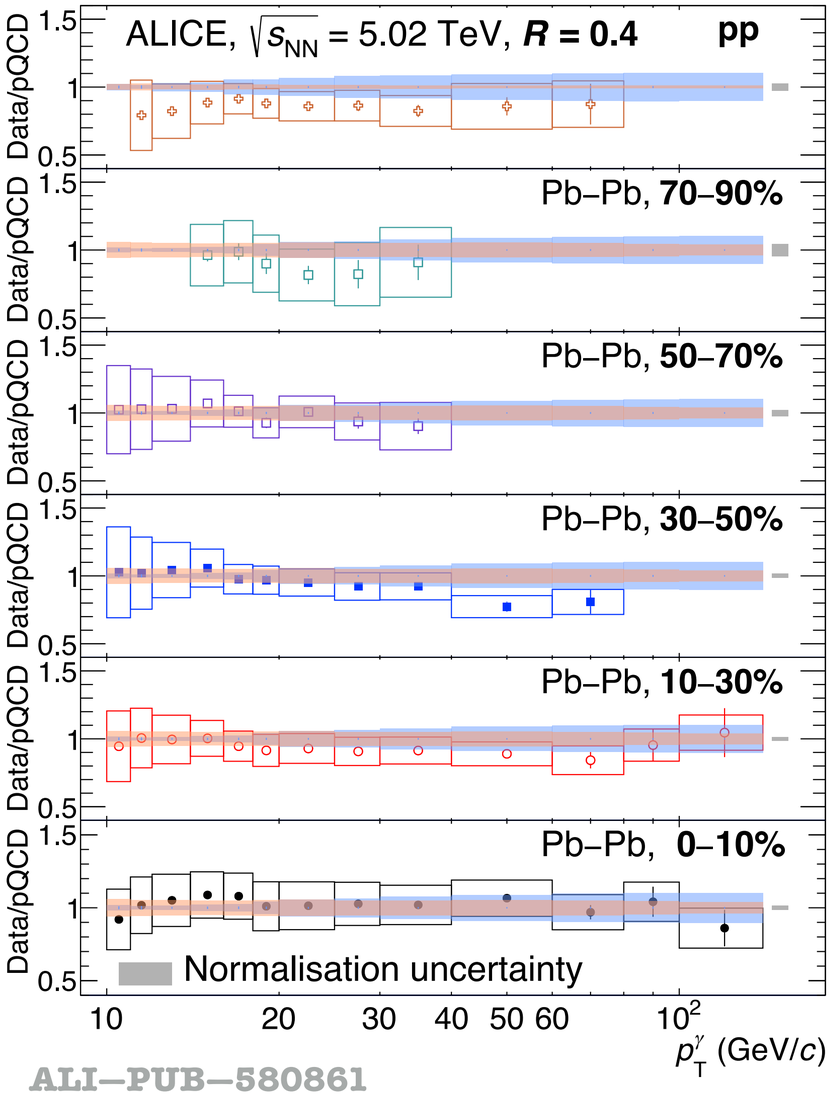
- **ALICE** & **CMS**: good agreement in the overlapping region 25 < p_T < 40–80 GeV/c

- 50-90%
  - ➡ Closer to 0.9 than 1 for both R likely due to centrality selection bias of Glauber model
  - ➡ Model by C. Loizides & A. Morsch (Phys. Lett. B773 (2017) 408-411) yields a value at 0.91
    - ✤ In agreement within the uncertainties



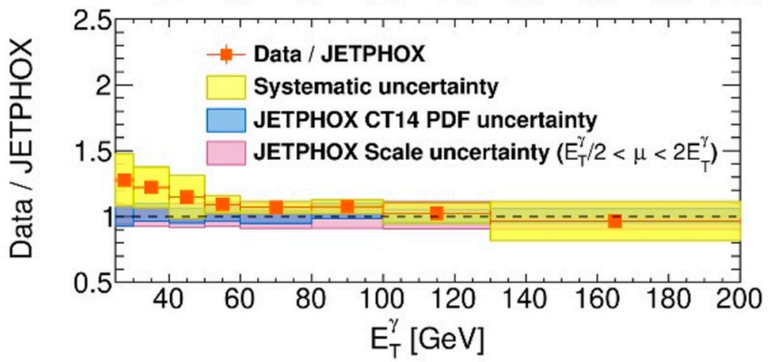
Data over theory, R = 0.4, pp & Pb–Pb at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV

ALICE



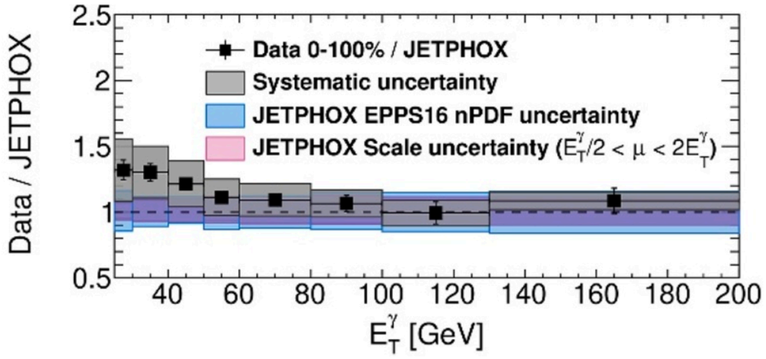
ALI–PUB–580861

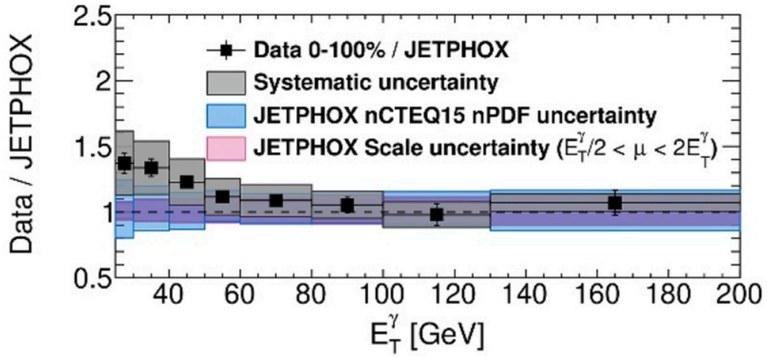
CMS



pp

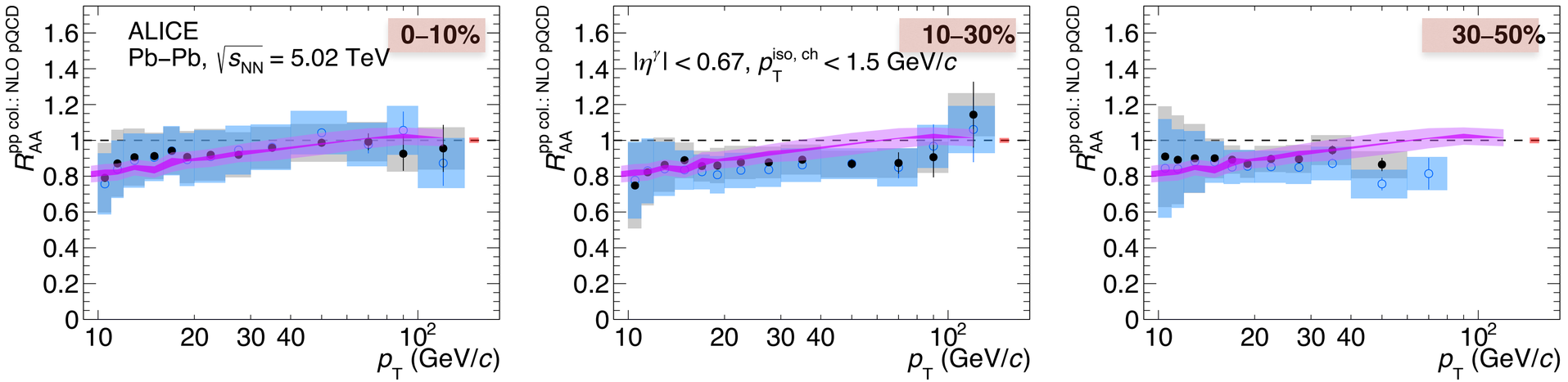
CMS JHEP 07 (2020) 116
arXiv:2003.12797 [hep-ex]

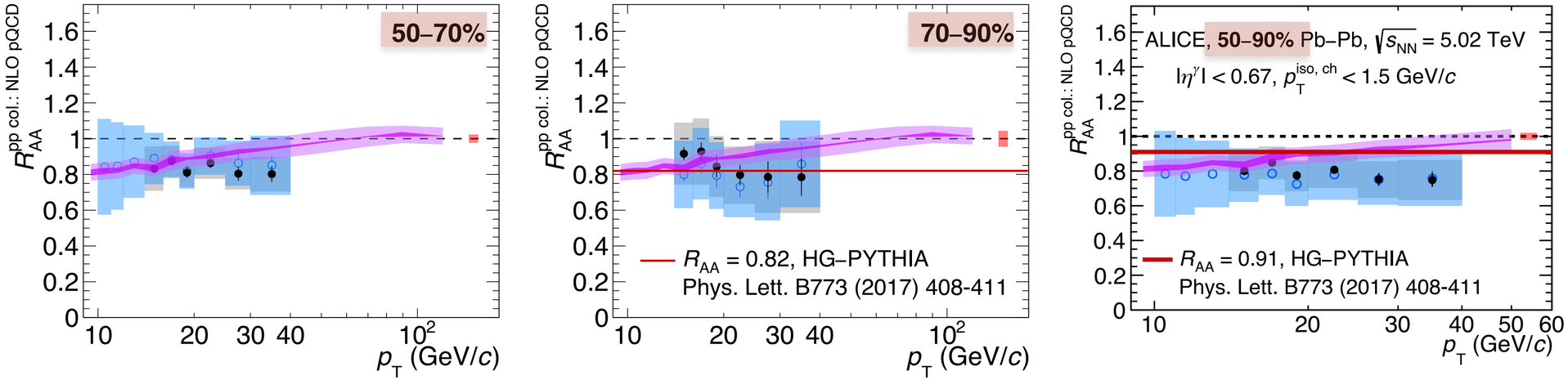




Pb–Pb 0–100%

Nuclear modification factor
pp data denominator replaced by pp NLO pQCD





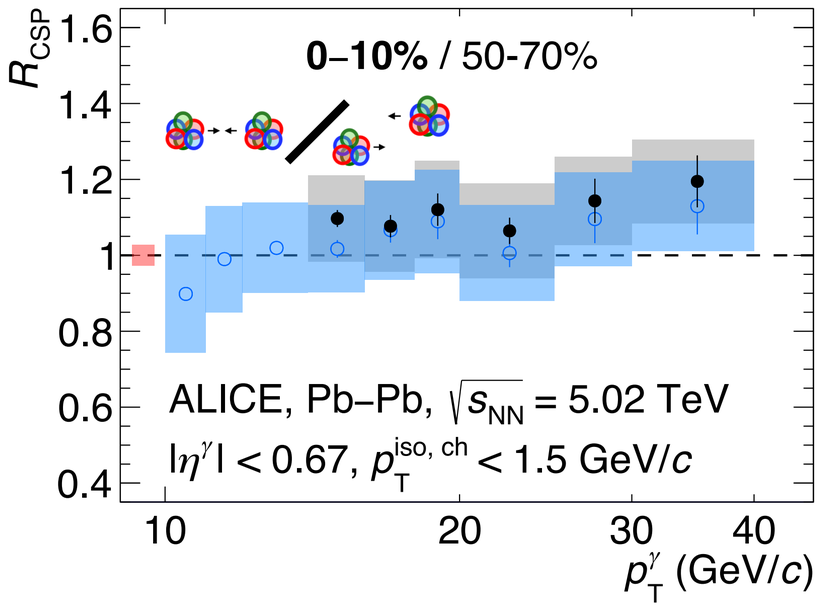
ALICE-PUBLIC-2024-003

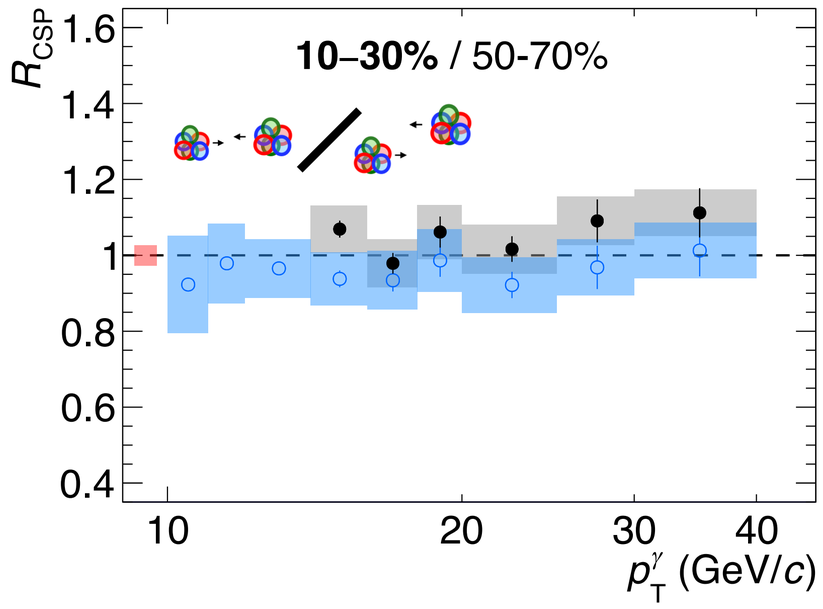
R = 0.2 stat. unc.
R = 0.4 stat. unc.
R = 0.2 syst. unc.
R = 0.4 syst. unc.
Normalisation unc.

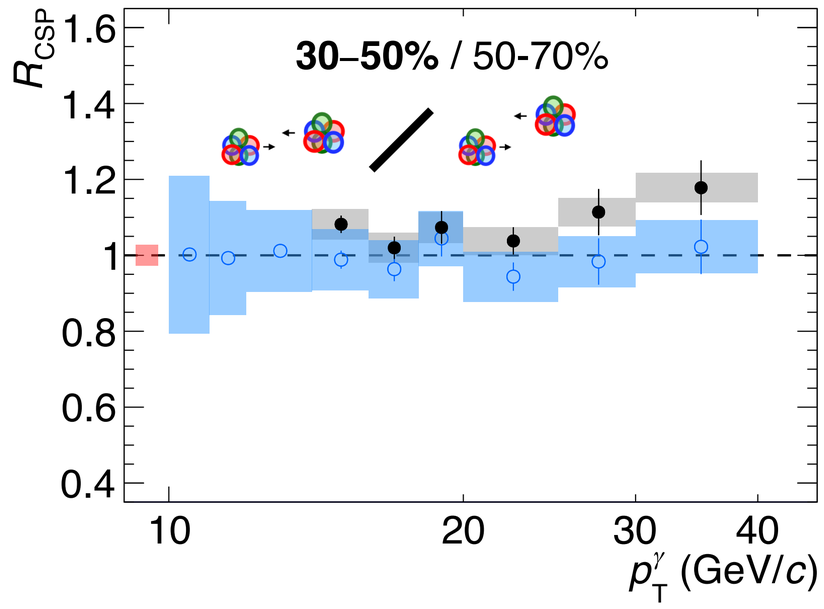
NLO (JETPHOX), $p_T^{iso} < 2$ GeV/c, R = 0.2
pp : NNPDF40/BFG II FF
Pb–Pb: nNNPDF30/BFG II FF, 0–100%
Scale unc. $p_T^{\gamma}/2 < \mu < 2p_T^{\gamma}$
PDF unc.

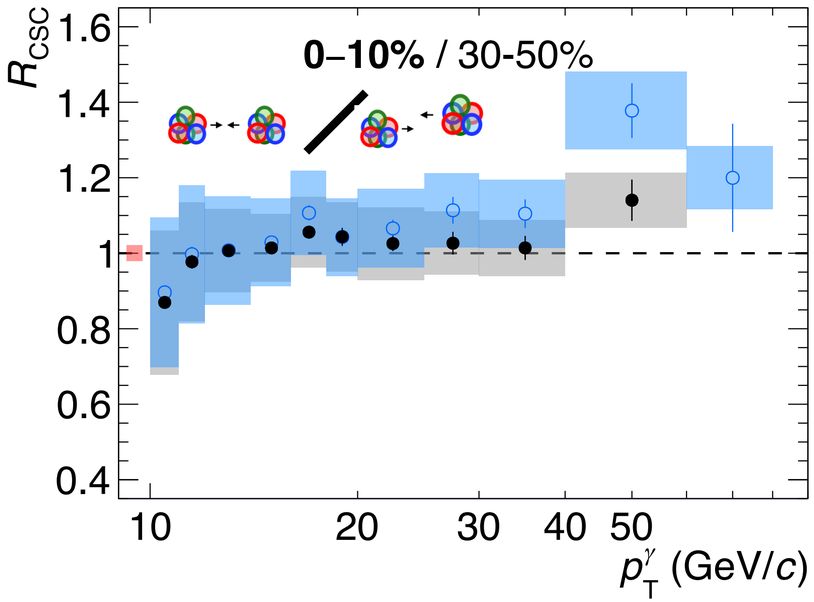
Pb–Pb cross section ratios

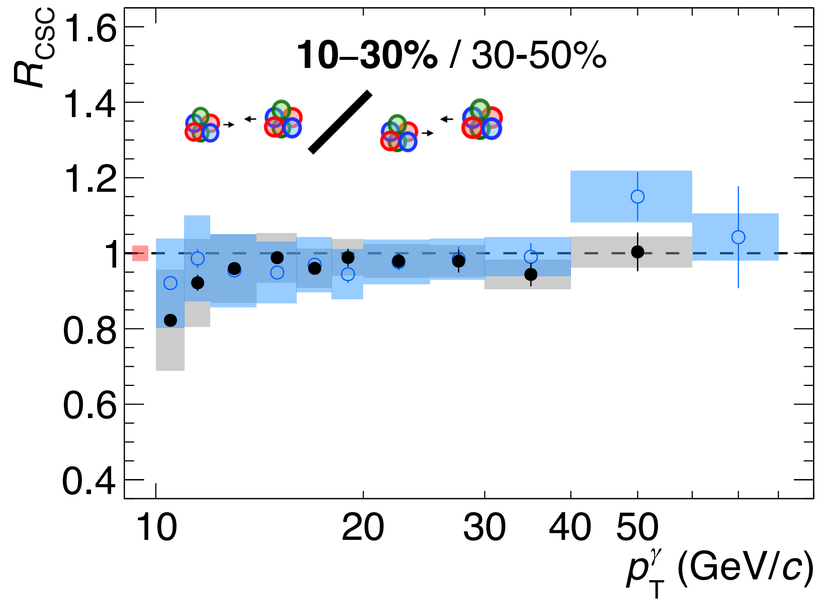
$$R_{\mathrm{CSP}} = \frac{\langle N_{\mathrm{coll}} \rangle^{50-70\%}}{\langle N_{\mathrm{coll}} \rangle^{k}} \frac{\mathrm{d}^2\sigma^{\gamma\ \mathrm{iso}}_{\mathrm{Pb-Pb}}/(\mathrm{d}p_{\mathrm{T}}\,\mathrm{d}\eta)|_{k}}{\mathrm{d}^2\sigma^{\gamma\ \mathrm{iso}}_{\mathrm{Pb-Pb}}/(\mathrm{d}p_{\mathrm{T}}\,\mathrm{d}\eta)|_{50-70\%}}, \qquad R_{\mathrm{CSC}} = \frac{\langle N_{\mathrm{coll}} \rangle^{30-50\%}}{\langle N_{\mathrm{coll}} \rangle^{k}} \frac{\mathrm{d}^2\sigma^{\gamma\ \mathrm{iso}}_{\mathrm{Pb-Pb}}/(\mathrm{d}p_{\mathrm{T}}\,\mathrm{d}\eta)|_{k}}{\mathrm{d}^2\sigma^{\gamma\ \mathrm{iso}}_{\mathrm{Pb-Pb}}/(\mathrm{d}p_{\mathrm{T}}\,\mathrm{d}\eta)|_{30-50\%}}$$











Normalisation unc.

$R = 0.2$ $R = 0.4$

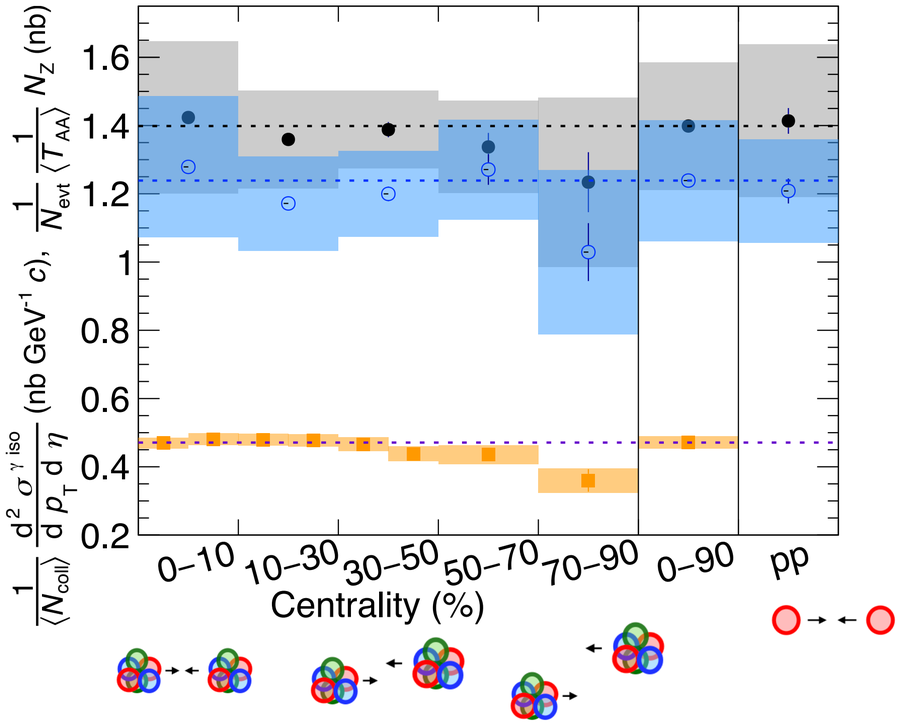
Statistical unc.

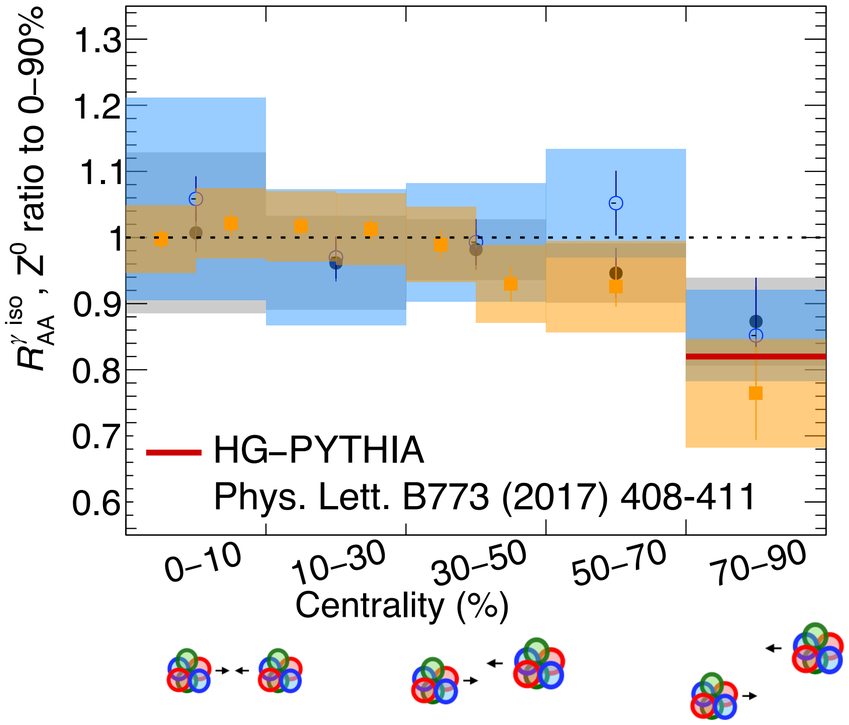
Systematic unc.

ALICE-PUBLIC-2024-003

Nuclear modification factor R_{AA}, pp & Pb–Pb at $\sqrt{s_{NN}}$ = 5.02 TeV

ALICE-PUBLIC-2024-003





Pb–Pb & pp $\sqrt{s_{NN}}$ = 5.02 TeV

γ^{iso} ALICE

$20 < p_T^{\gamma} < 25$ GeV/c, $|\eta^{\gamma}| < 0.67$

$R = 0.2$ $R = 0.4$

Statistical unc.

Systematic unc.

Z^0 CMS

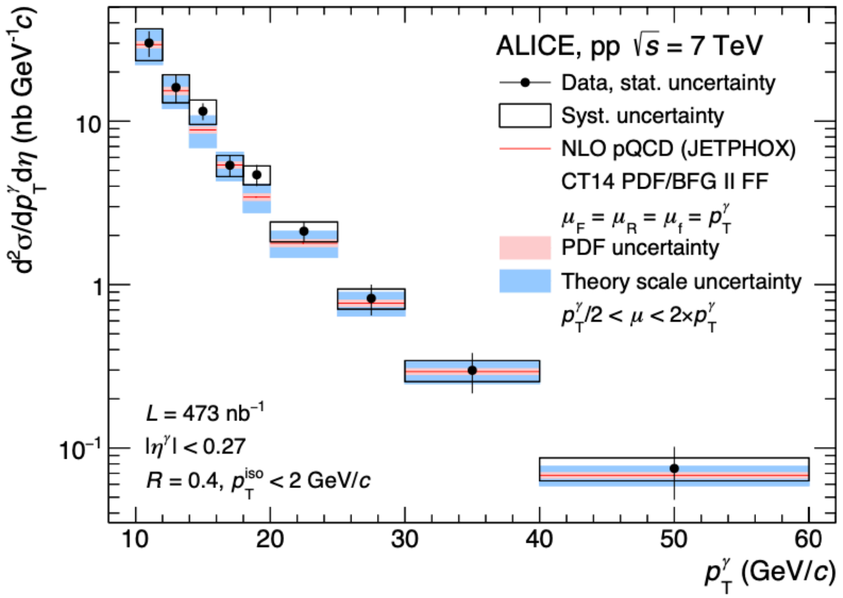
Phys. Rev. Lett. 127(2021)102002

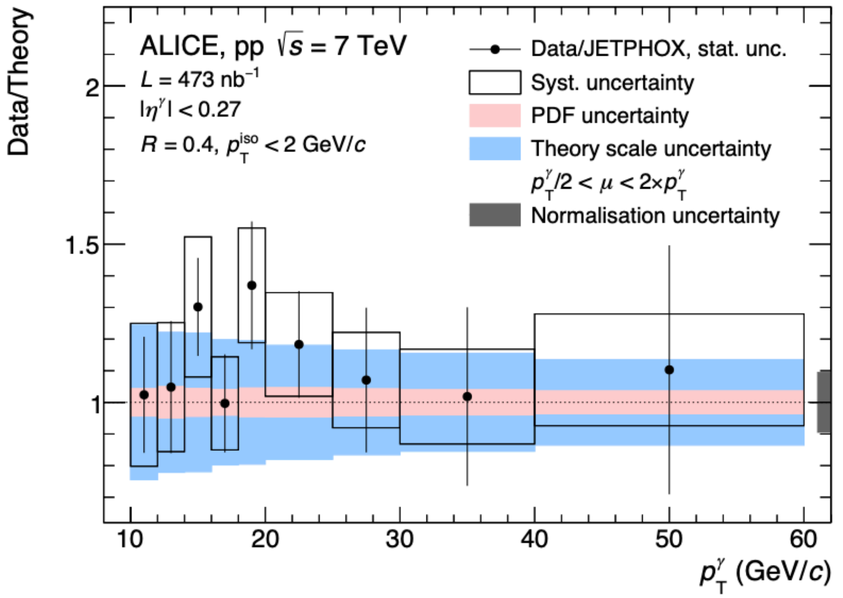
$60 < m_{ll} < 120$ GeV/c^2, $|y^Z| < 2.1$

Statistical unc.

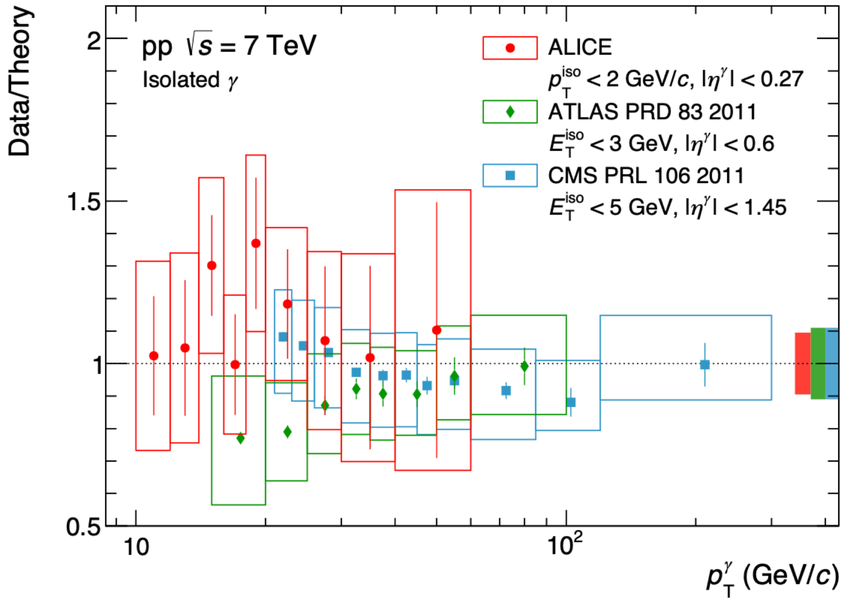
Systematic unc.

Cross section, pp $\sqrt{s}$ = 7 TeV

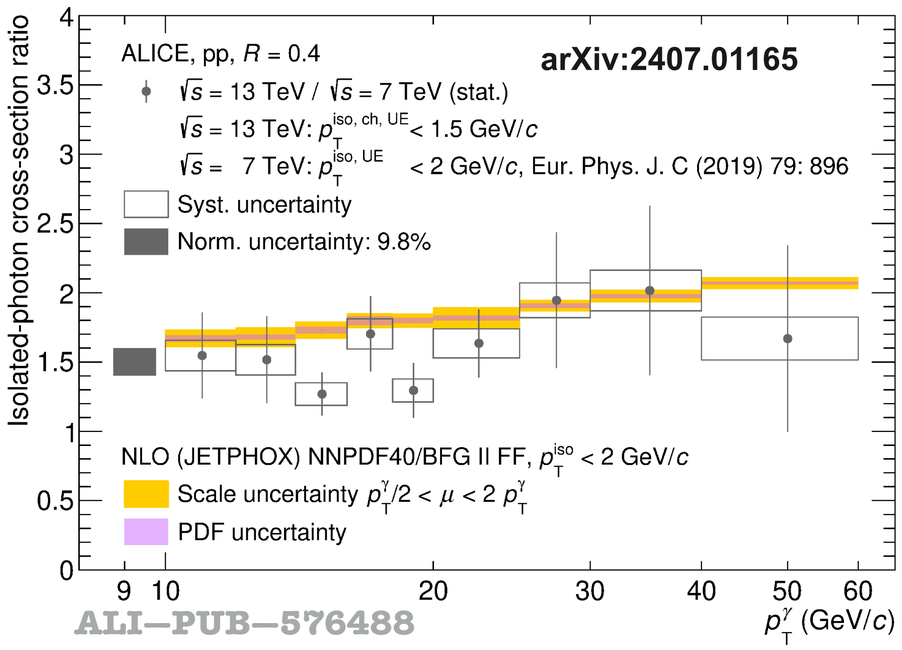


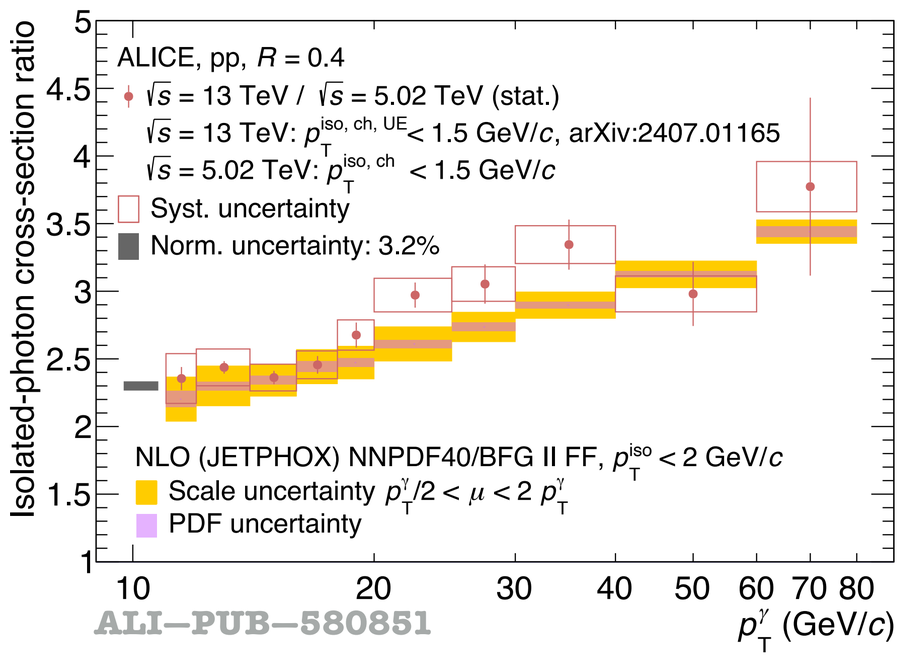


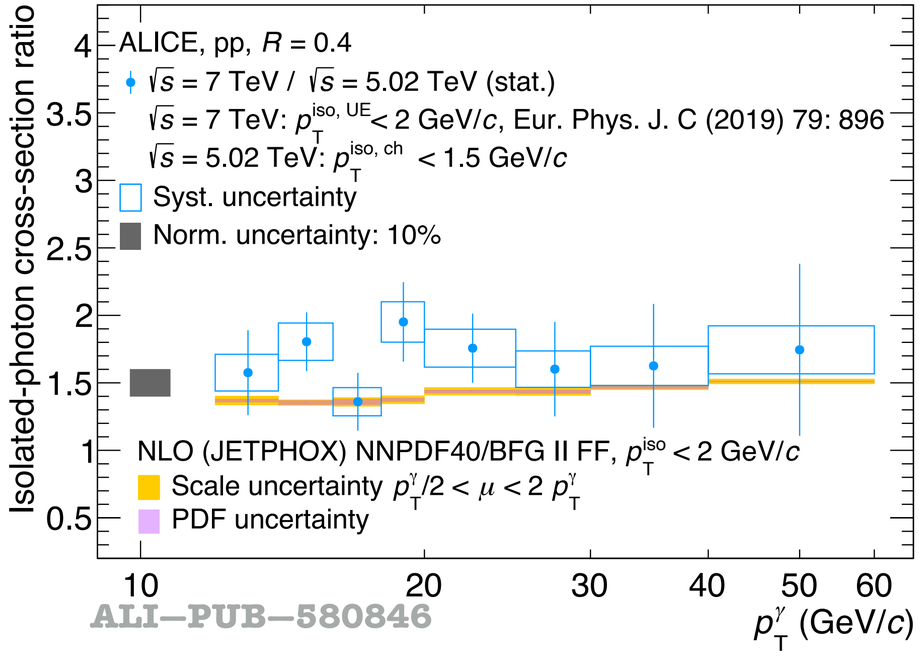
- arXiv:1906.01371
- Eur. Phys. J. C 79, 896 (2019)



Cross section ratios in pp collisions



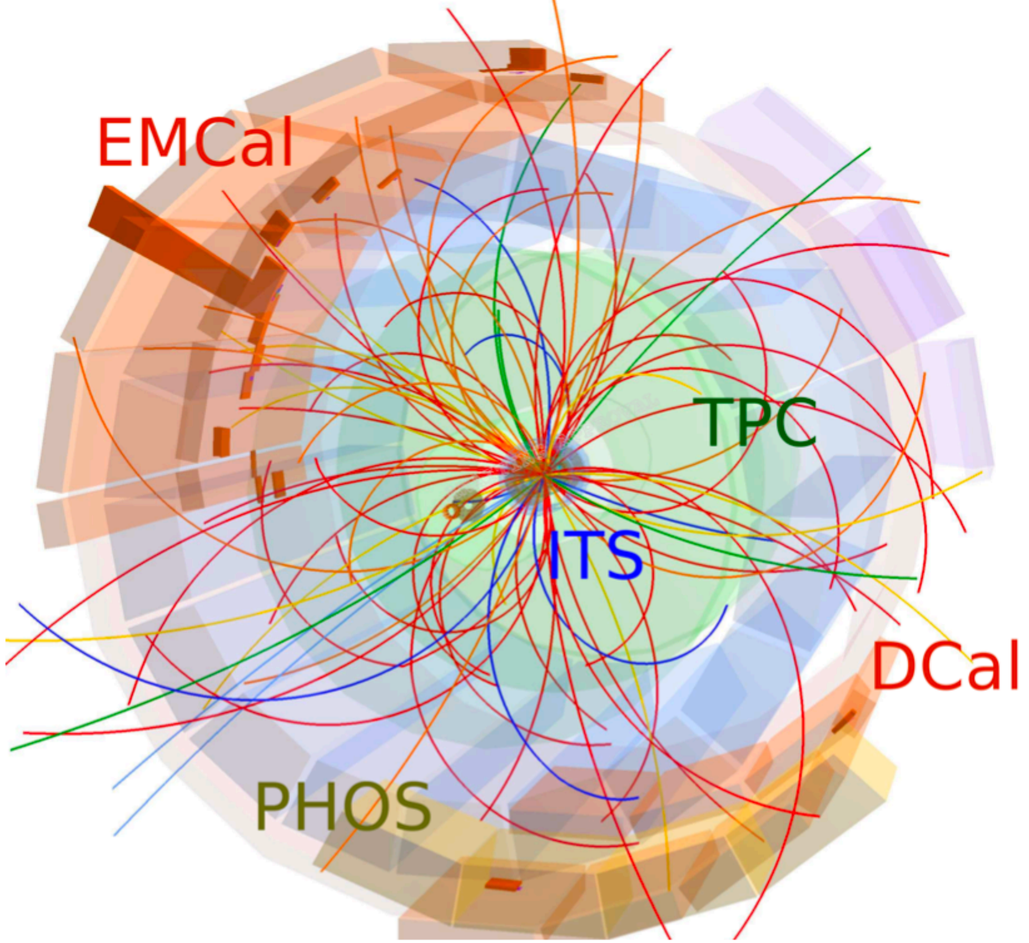




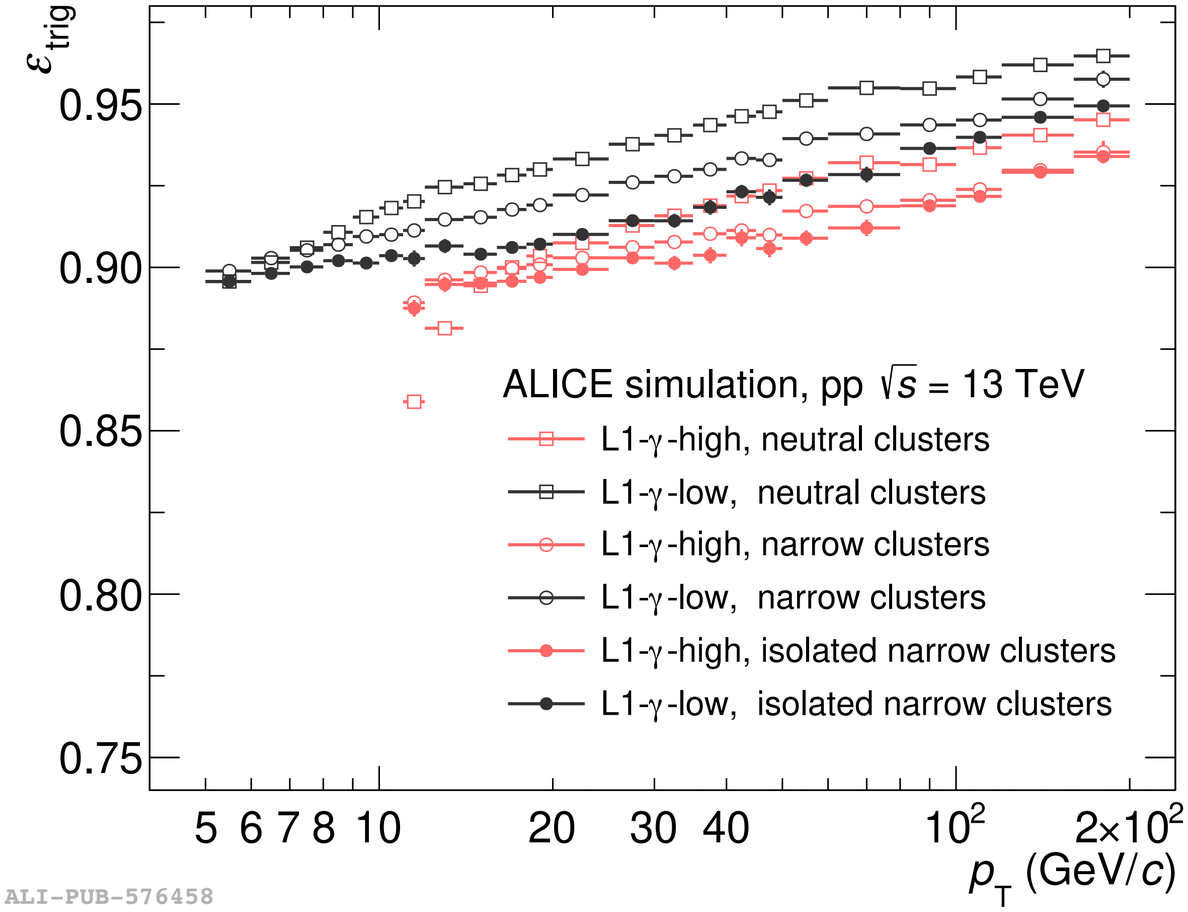
γ measurement in ALICE

- γ measurement
  - ➡ Calorimeters
    - EMCal: Pb/scintillator towers (6 × 6 cm)
      - 4.4 m from interaction point (IP)
      - $|\eta| < 0.67$ for $\Delta\varphi = 107°$, $0.22 < |\eta| < 0.67$ for $\Delta\varphi = 60°$ (DCal);
      - Identification via EM shower dispersion selection
      - E_γ > 700 MeV
  - ➡ Tracking, TPC & ITS
    - γ conversion method (PCM)
      - R < 180 cm
      - 8% conversion probability
      - $|\eta| < 0.9$ for $\Delta\varphi = 360°$
      - E_γ > 100 MeV
- γ identification combining tracking+calorimeter
  - ➡ Inclusive γ: Charged particle veto
  - ➡ Prompt γ: Isolation (next slides)

- PHOS: PWO_4 crystals (2.2 × 2.2 cm)
  - 4.6 m from IP
  - $|\eta| < 0.13$ for $\Delta\varphi = 70°$
  - Identification via EM shower dispersion selection
  - E_γ > 200 MeV

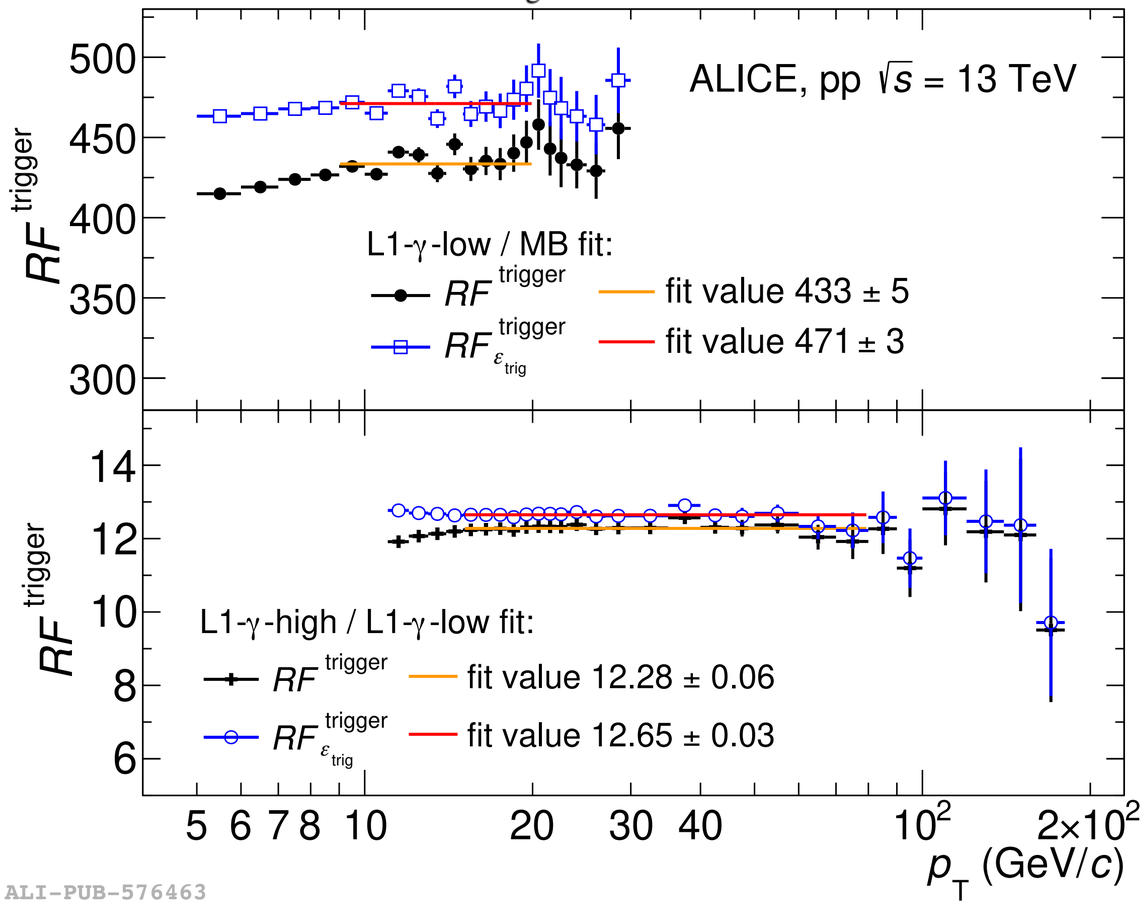


EMCal trigger performance, pp $\sqrt{s}$ = 13 TeV



ALI-PUB-576458

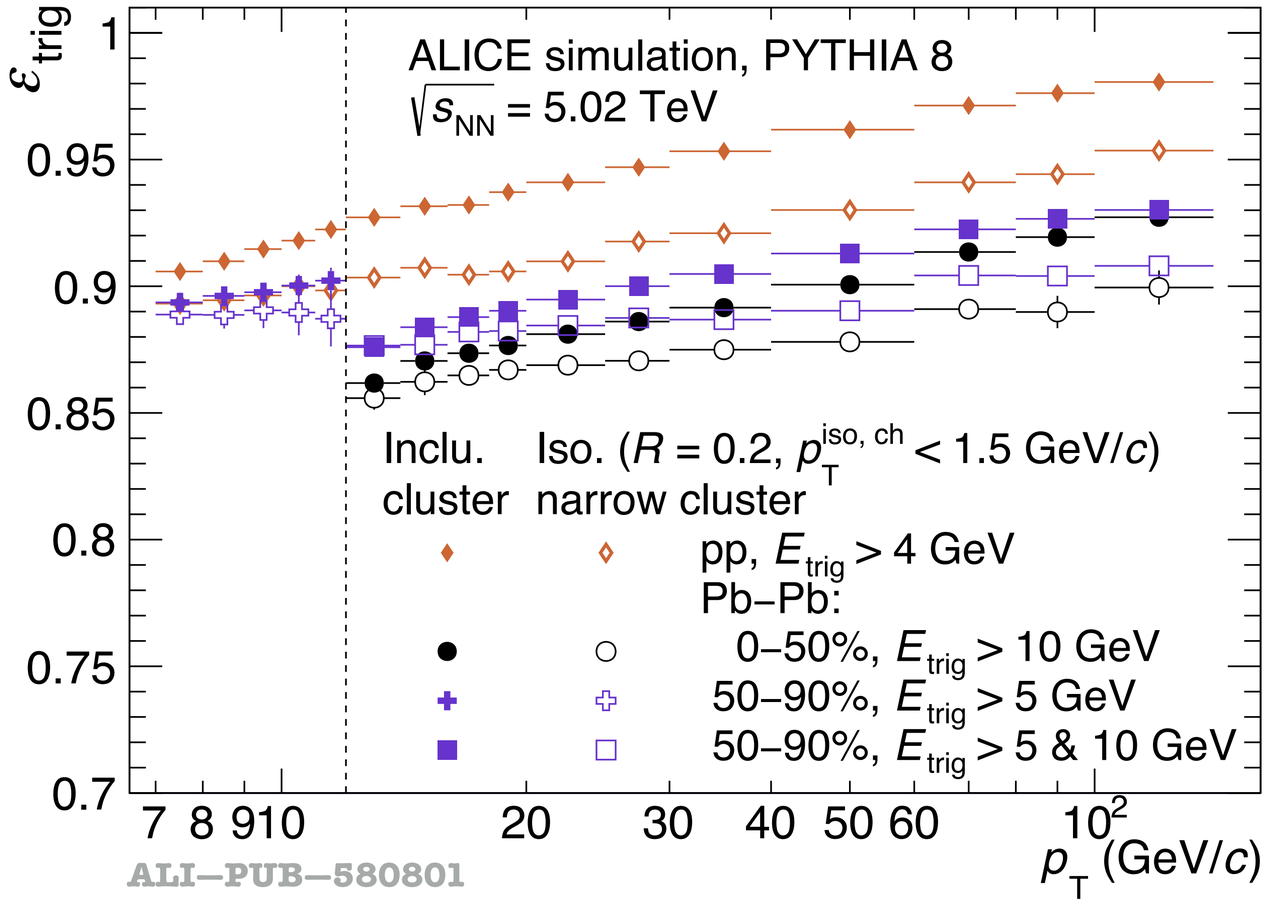
$$RF^{\text{trig}}_{\varepsilon_{\text{trig}}} = \frac{1}{\varepsilon^{\text{clus}}_{\text{trig}}} \frac{1/N^{\text{L1-}\gamma}_{\text{evt}} \times \mathrm{d}N^{\text{L1-}\gamma}/\mathrm{d}p_T}{1/N^{\text{MB}}_{\text{evt}} \times \mathrm{d}N^{\text{MB}}/\mathrm{d}p_T}$$

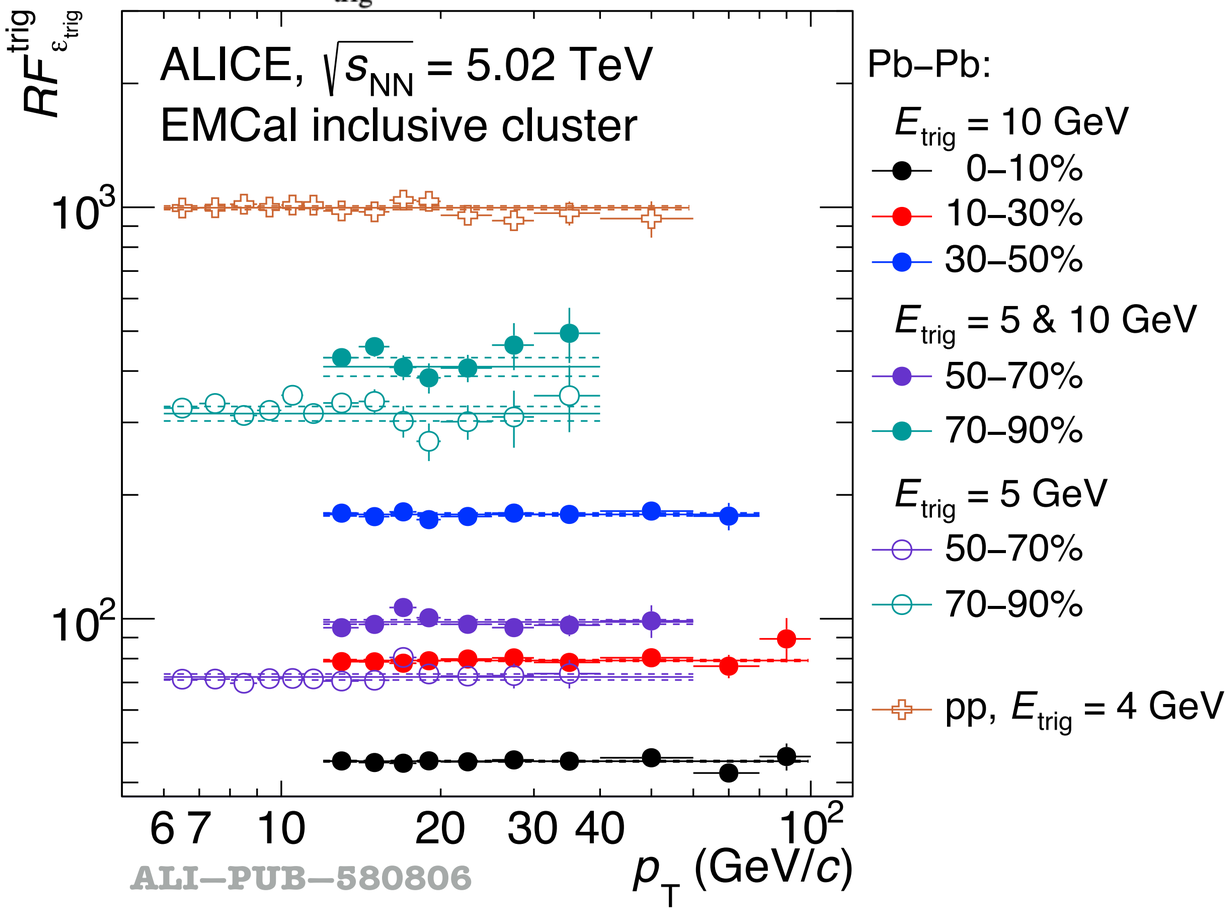


ALI-PUB-576463

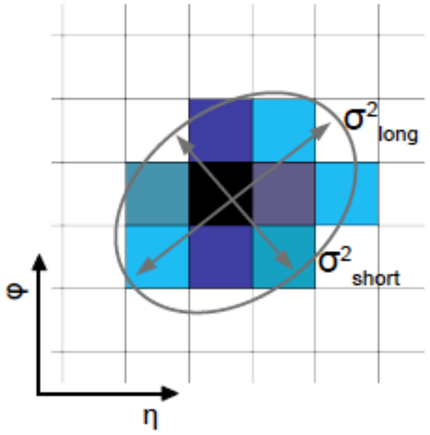
EMCal trigger performance, pp & Pb–Pb $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV

$$RF_{\varepsilon_{\mathrm{trig}}}^{\mathrm{trig}} = \frac{1}{\varepsilon_{\mathrm{trig}}^{\mathrm{clus}}} \frac{1/N_{\mathrm{evt}}^{\mathrm{L1\text{-}\gamma}} \times \mathrm{d}N^{\mathrm{L1\text{-}\gamma}}/\mathrm{d}p_T}{1/N_{\mathrm{evt}}^{\mathrm{MB}} \times \mathrm{d}N^{\mathrm{MB}}/\mathrm{d}p_T}$$





EMCal cluster shower lateral dispersion parameter



- Shower shape parameter σ^2_{long} is related to the longer axis of the cluster ellipse
- Parameter depends on cluster cells location and its energy

$$w_i = \text{Maximum}(0, w_0 + \ln(E_{\text{cell},\,i}/E))$$

$$\sigma^2_{\alpha\beta} = \sum_i \frac{w_i \alpha_i \beta_i}{w_{\text{tot}}} - \sum_i \frac{w_i \alpha_i}{w_{\text{tot}}} \sum_i \frac{w_i \beta_i}{w_{\text{tot}}}$$

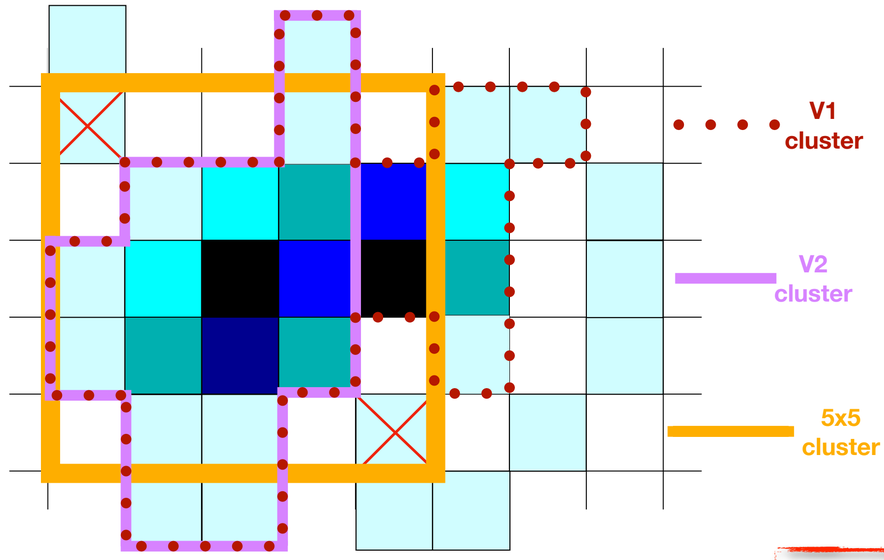
$$w_{\text{tot}} = \sum_i w_i,$$

$$\sigma^2_{\text{long}} = 0.5(\sigma^2_{\varphi\varphi} + \sigma^2_{\eta\eta}) + \sqrt{0.25(\sigma^2_{\varphi\varphi} - \sigma^2_{\eta\eta})^2 + \sigma^2_{\eta\varphi}},$$

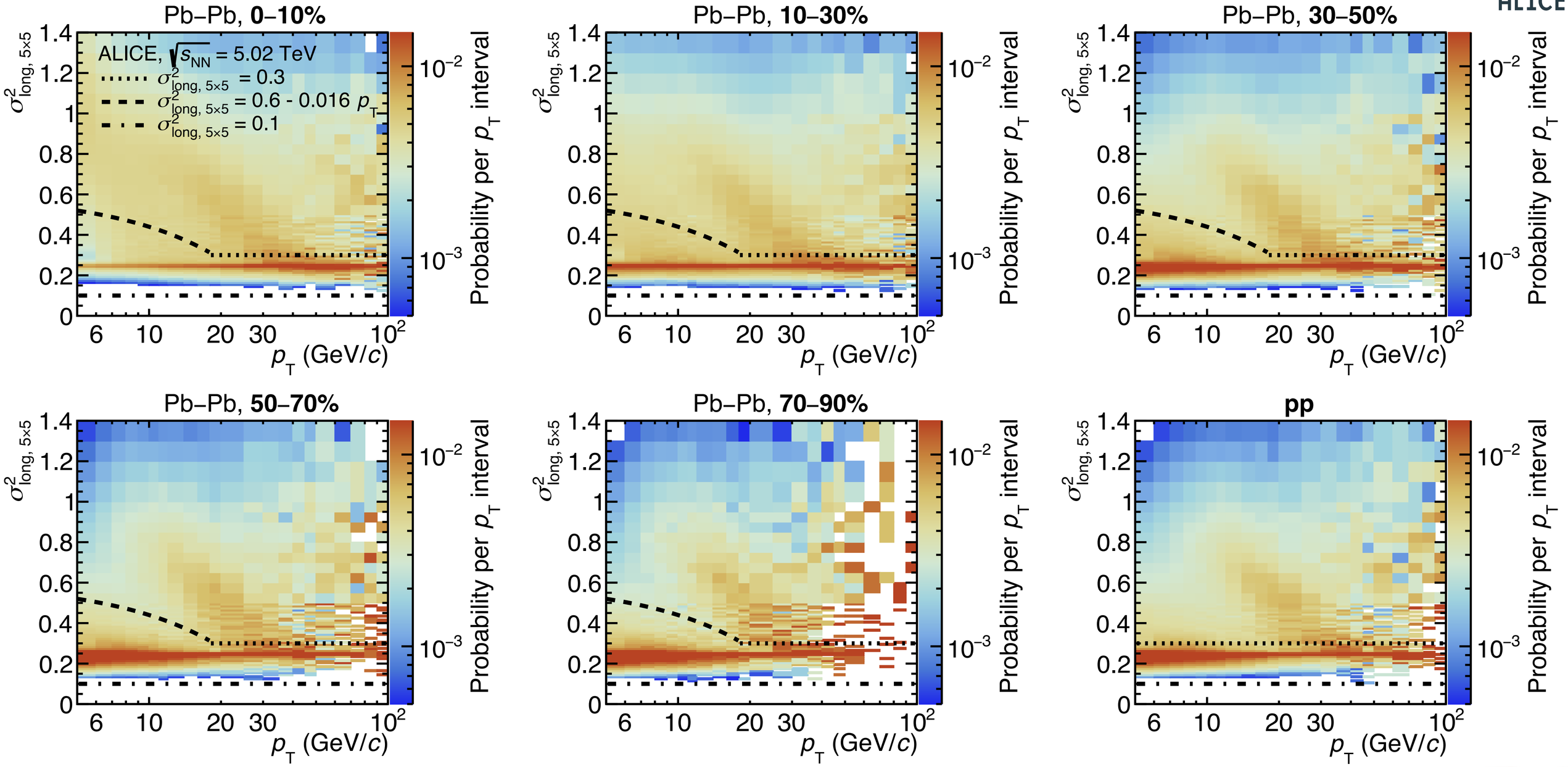
$$\sigma^2_{\text{short}} = 0.5(\sigma^2_{\varphi\varphi} + \sigma^2_{\eta\eta}) - \sqrt{0.25(\sigma^2_{\varphi\varphi} - \sigma^2_{\eta\eta})^2 + \sigma^2_{\eta\varphi}},$$

- V2 clusters: Used in pp & Pb–Pb at $\sqrt{s_{\text{NN}}}$ = 5.02 TeV to get *E* and position
  - In other pp and p–Pb measurements V1 clusters are used
- For the σ^2_{long} calculation: consider the neighbour cells around the highest energy cell in a 5x5 fixed window
  - Increase meson decay merging but limiting UE merging

ALICE-PUBLIC-2024-003



EMCal cluster shower shape, pp & Pb–Pb $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV



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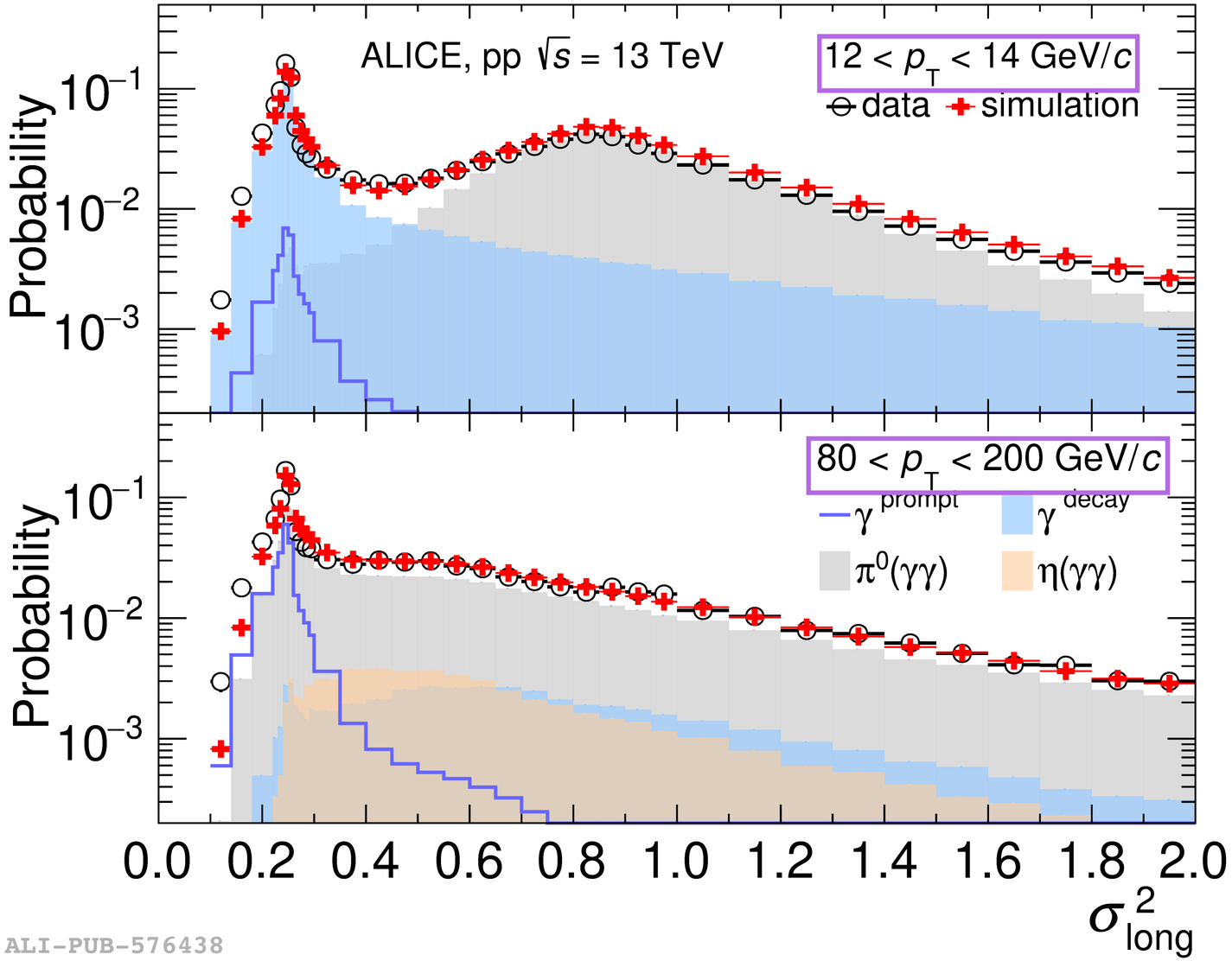
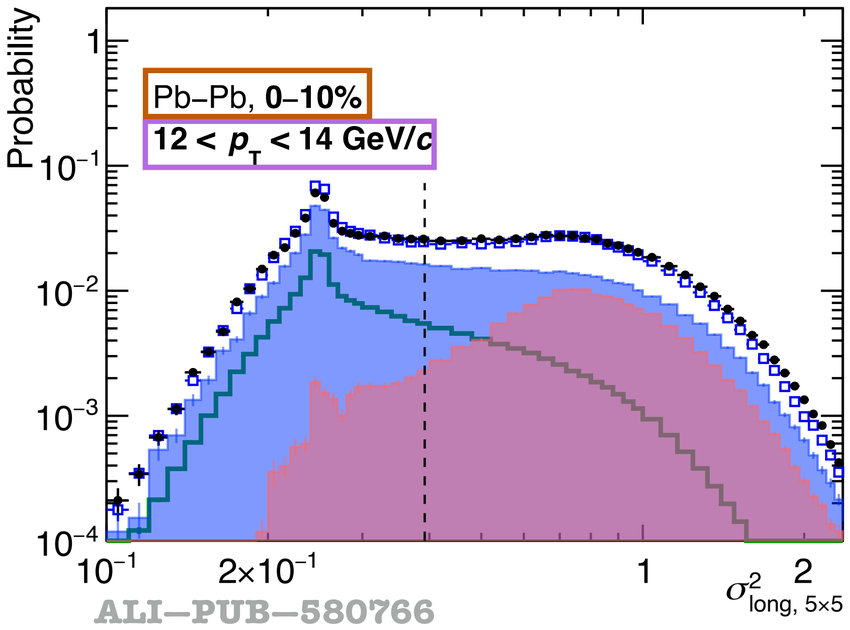
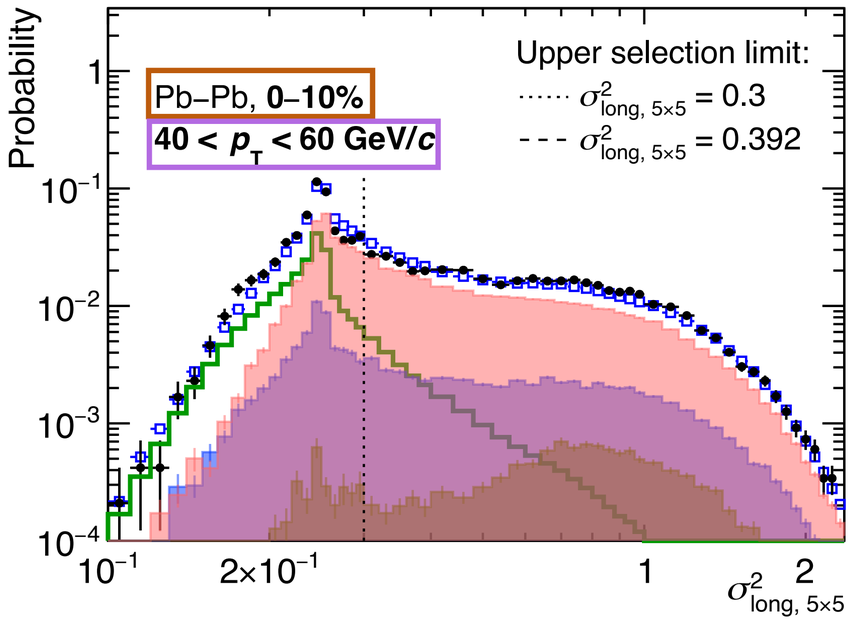
EMCal cluster shower shape, pp $\sqrt{s}$ = 13 TeV

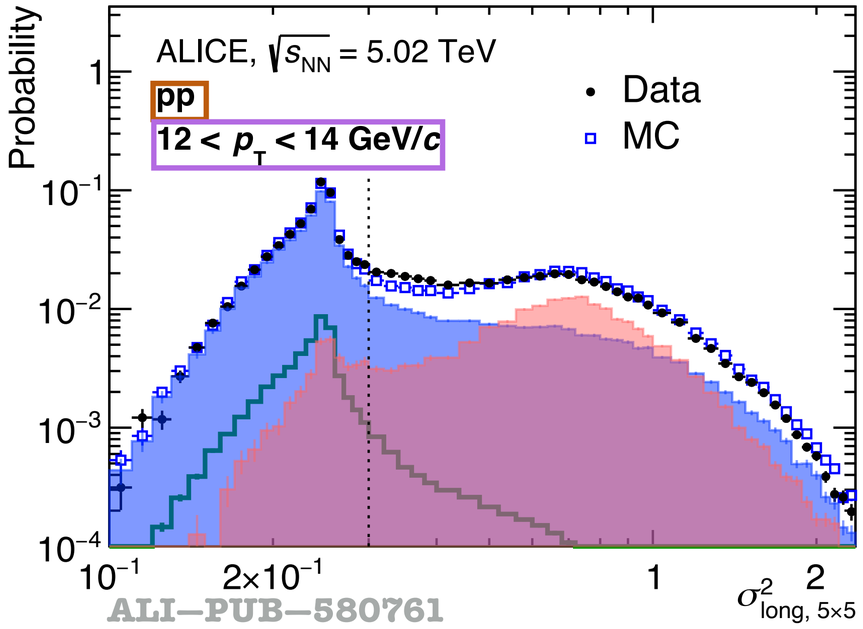


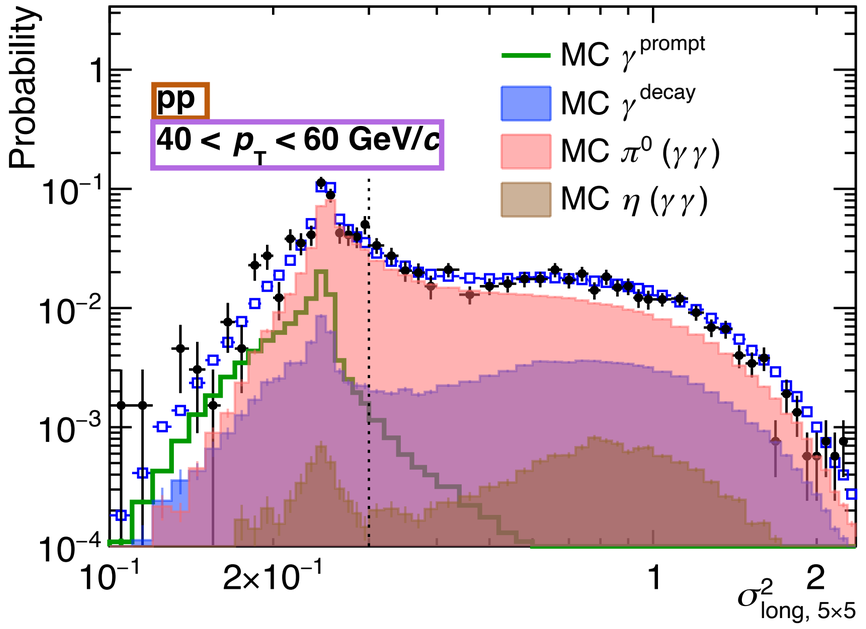
ALI-PUB-576438

EMCal cluster shower shape, pp & Pb–Pb $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV

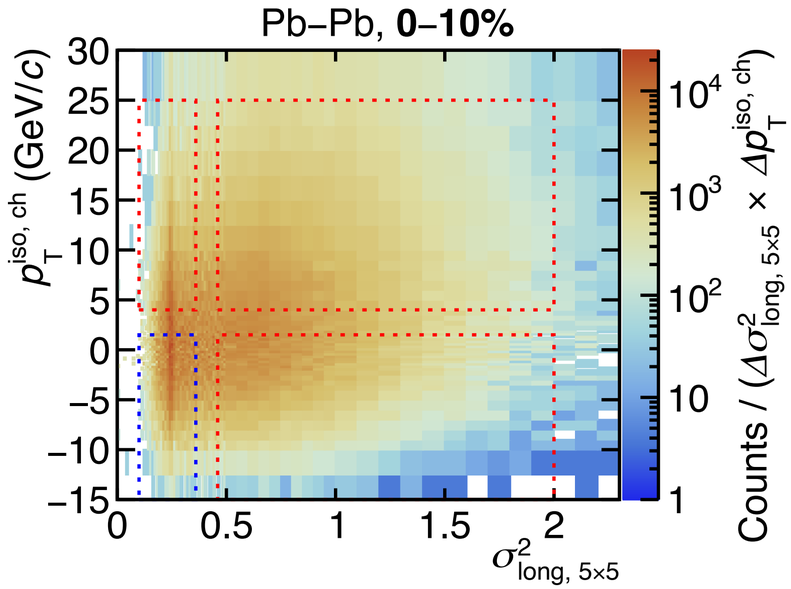


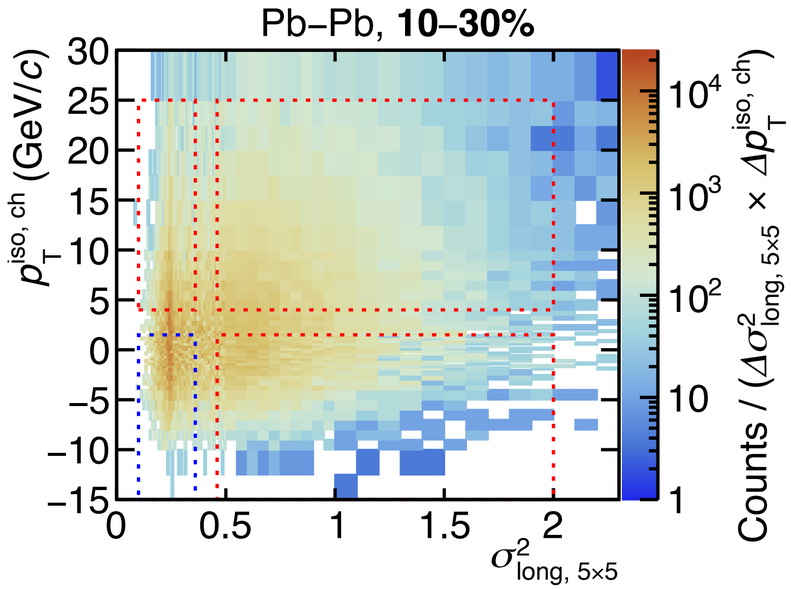


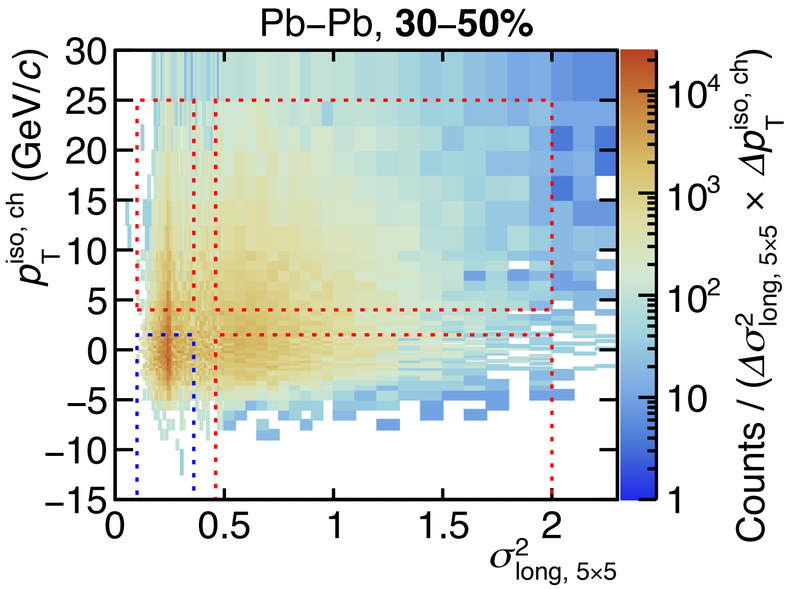


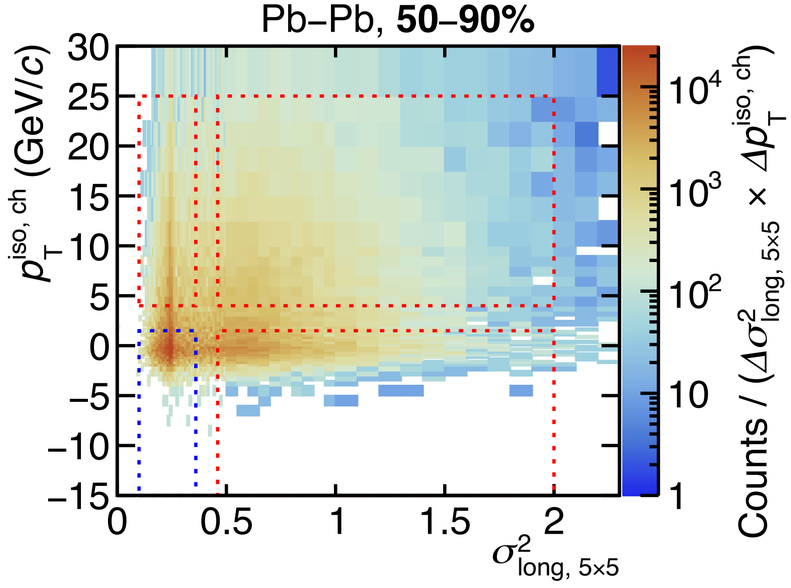


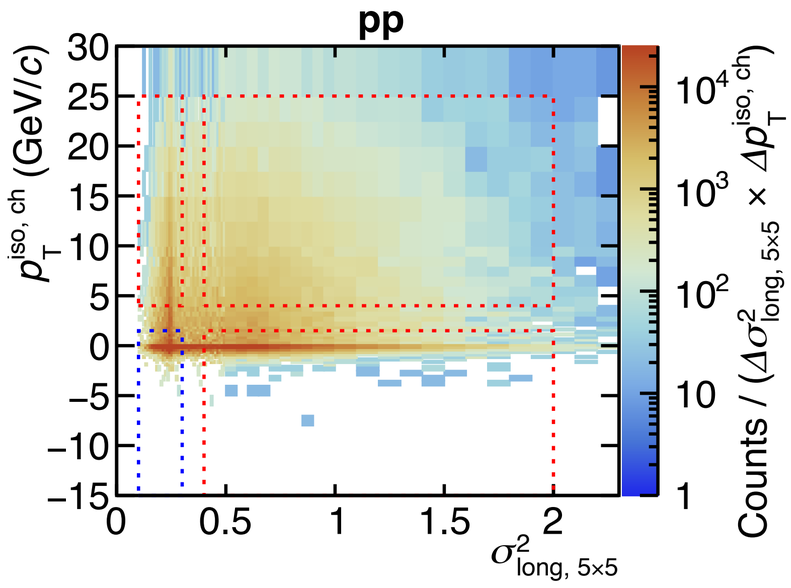
ABCD regions, R = 0.2, pp & Pb–Pb $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV











ALICE, $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV

$14 < p_{\mathrm{T}} < 16$ GeV/c

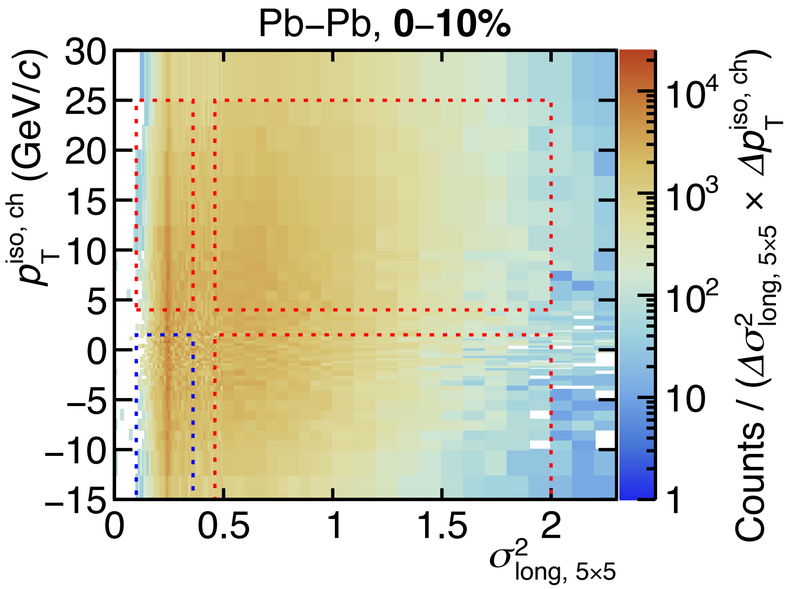
R = 0.2

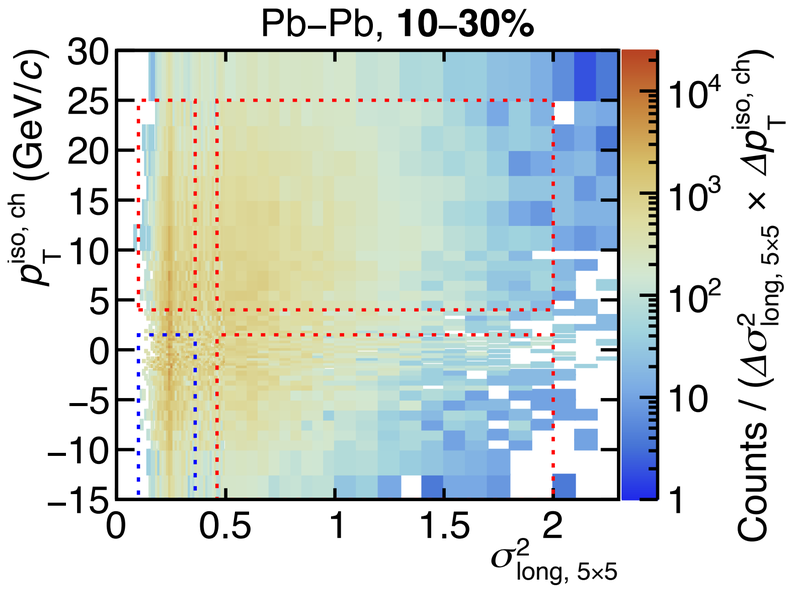
Signal limits (A)

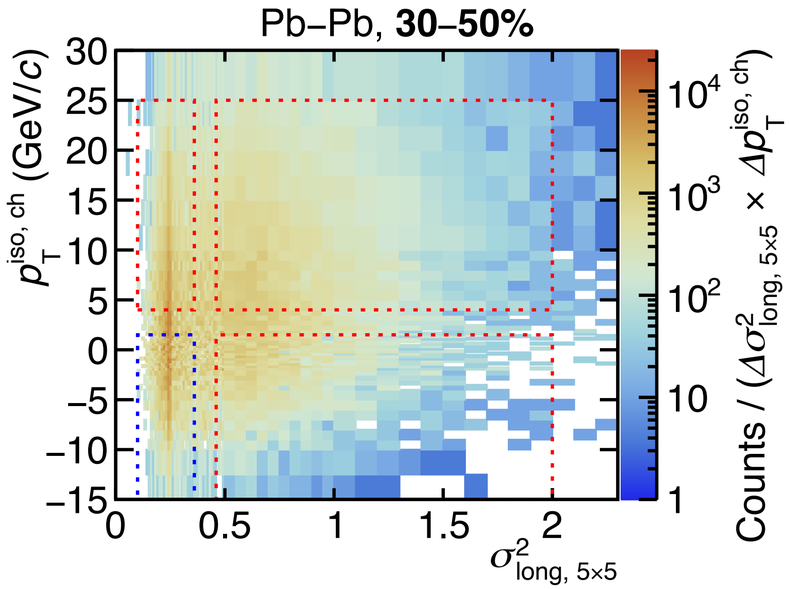
Bkg. control limits (B, C, D)

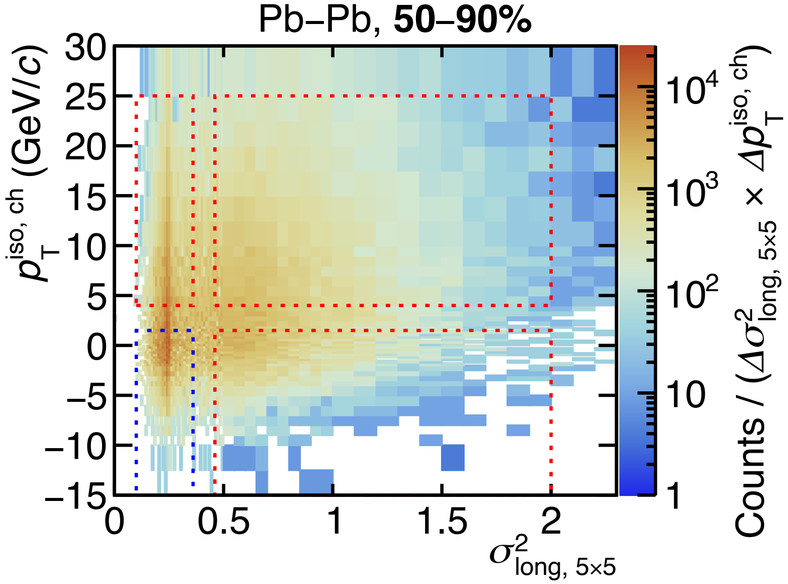
ALICE-PUBLIC-2024-003

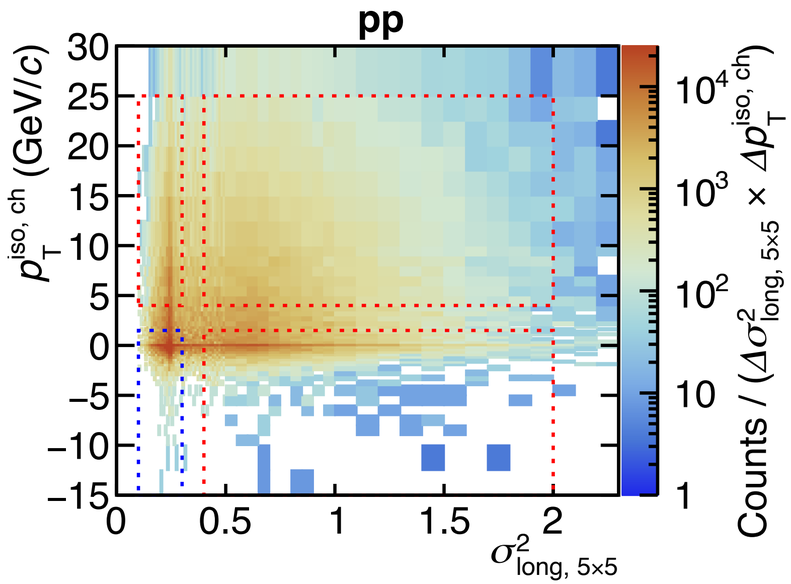
ABCD regions, R = 0.4, pp & Pb–Pb $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV











ALICE, $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV

$14 < p_{\mathrm{T}} < 16$ GeV/c

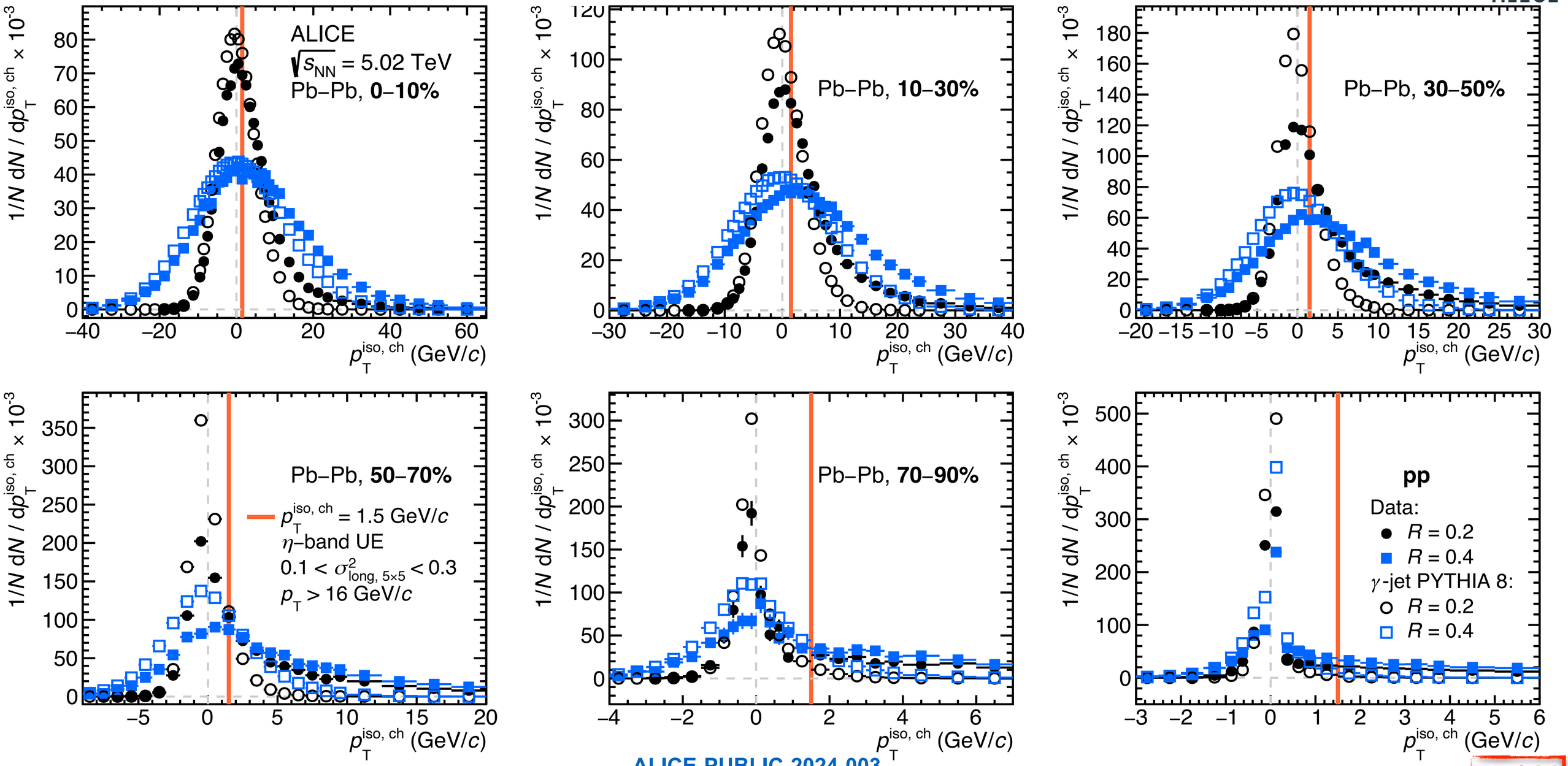
R = 0.4

Signal limits (A)

Bkg. control limits (B, C, D)

ALICE-PUBLIC-2024-003

Isolation momentum in cone, pp & Pb–Pb $\sqrt{s_{NN}}$ = 5.02 TeV



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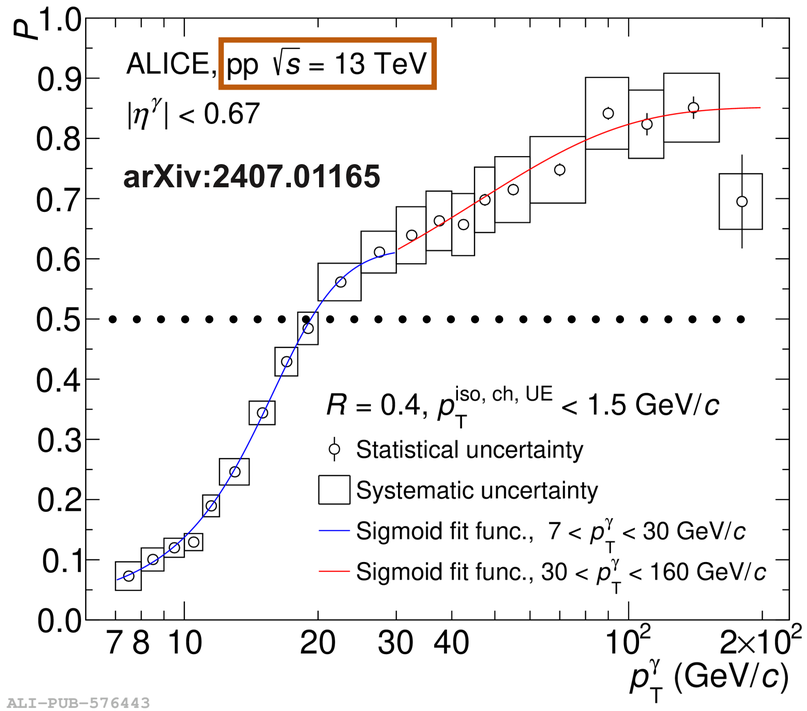
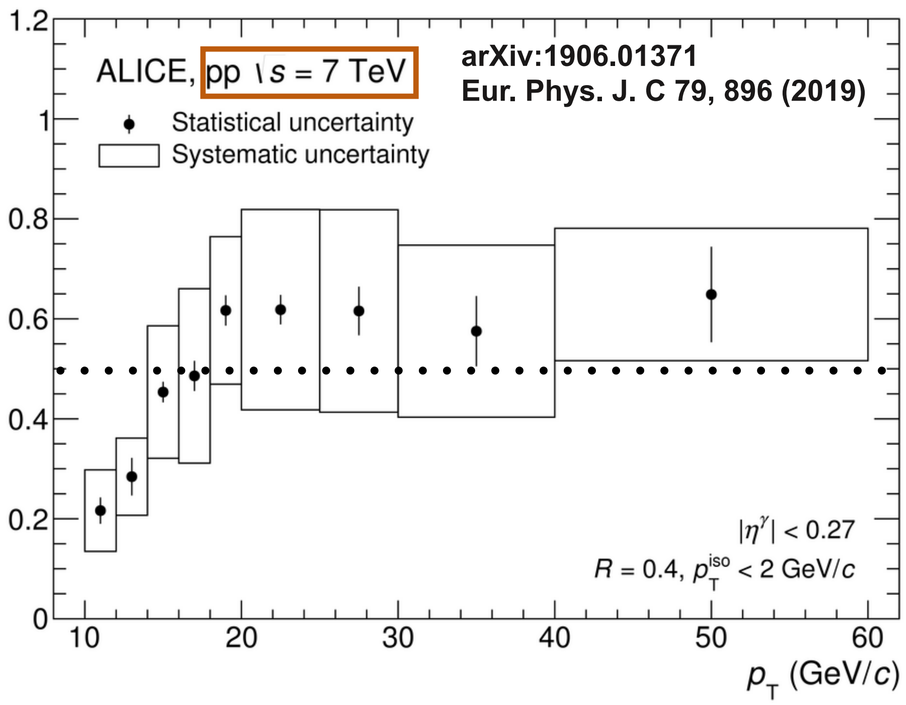
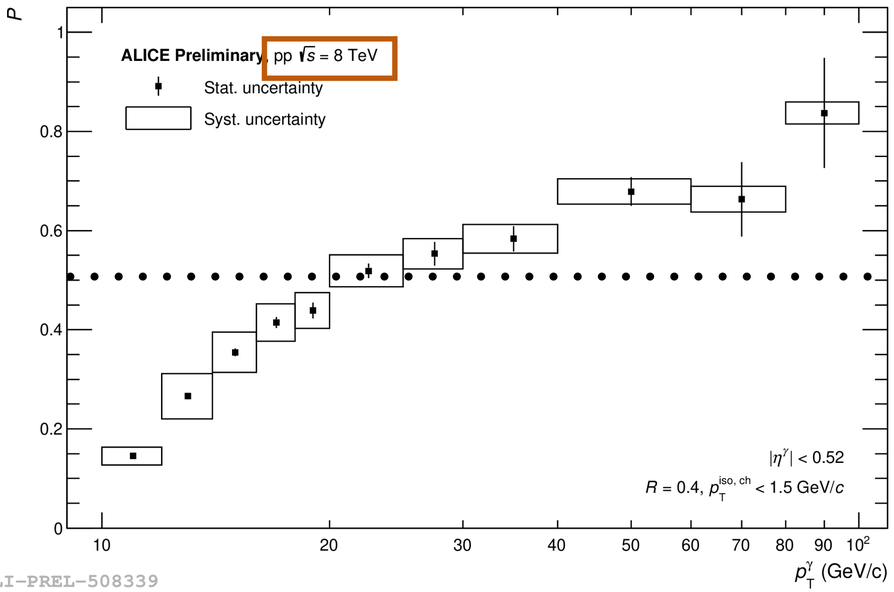
Isolated γ purity in pp collisions, $R = 0.4$



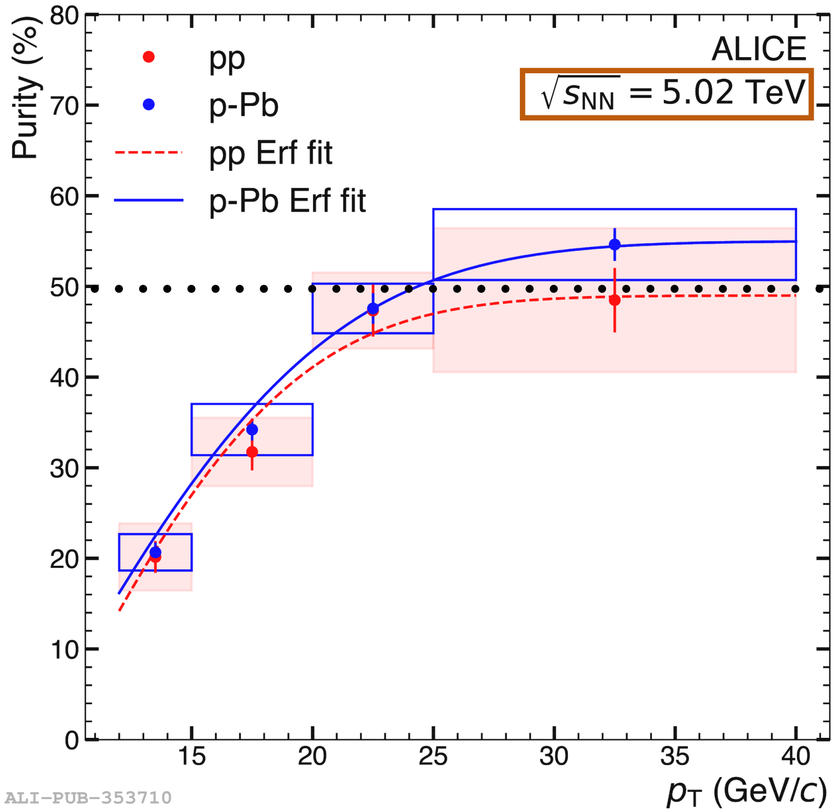


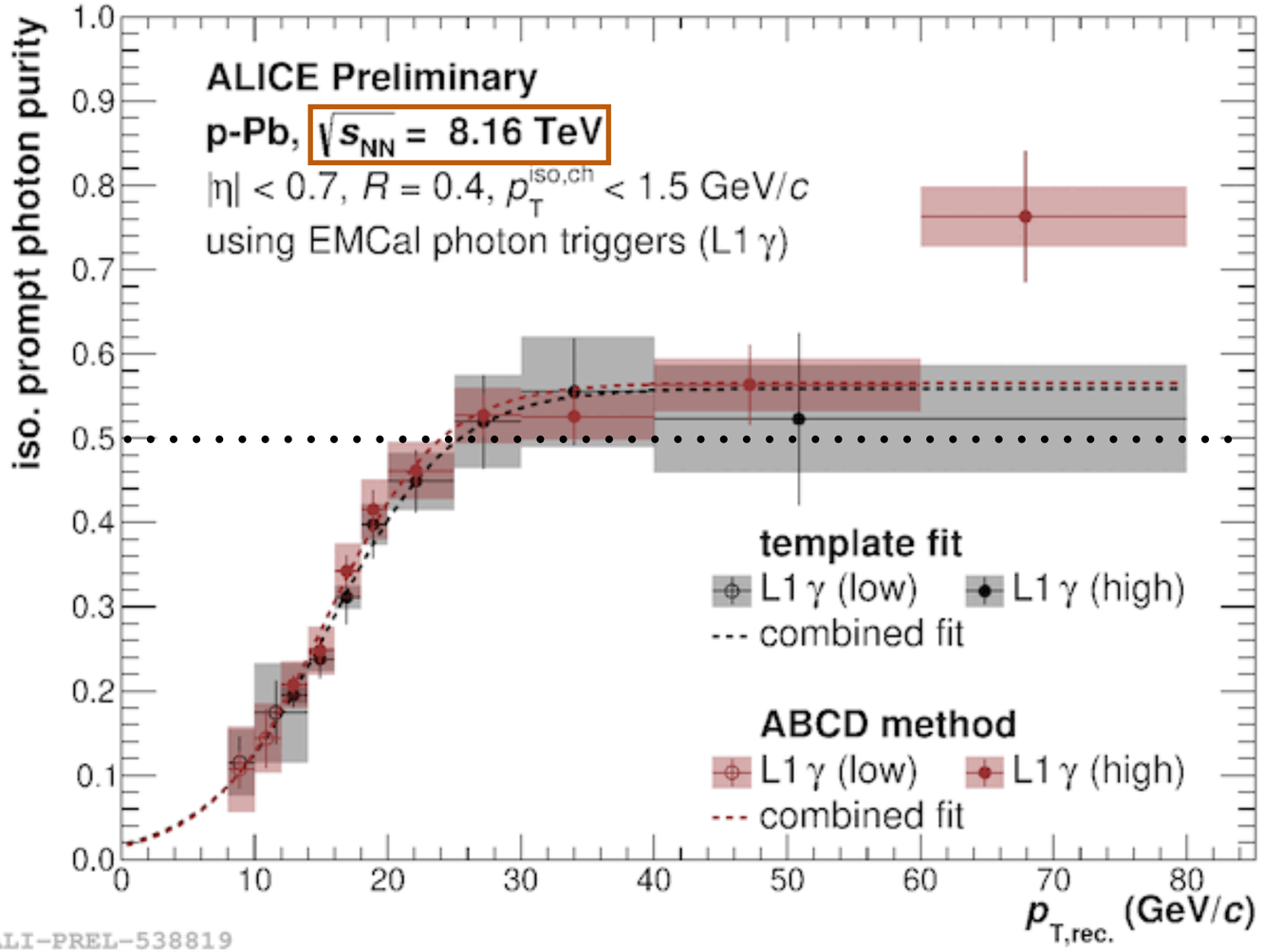
ALI-PUB-576443



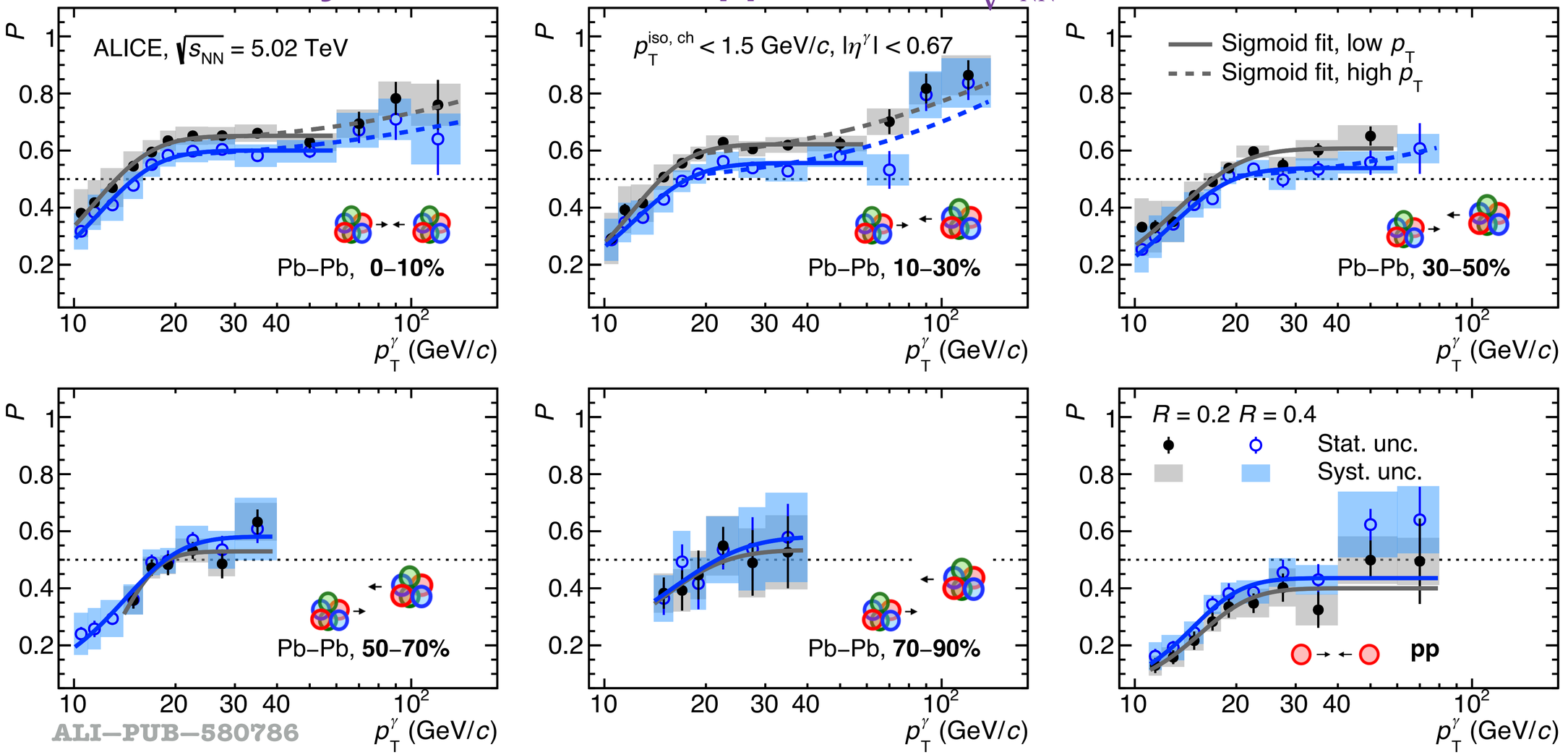
ALI-PREL-508339

Isolated γ purity in p–Pb collisions, $R = 0.4$





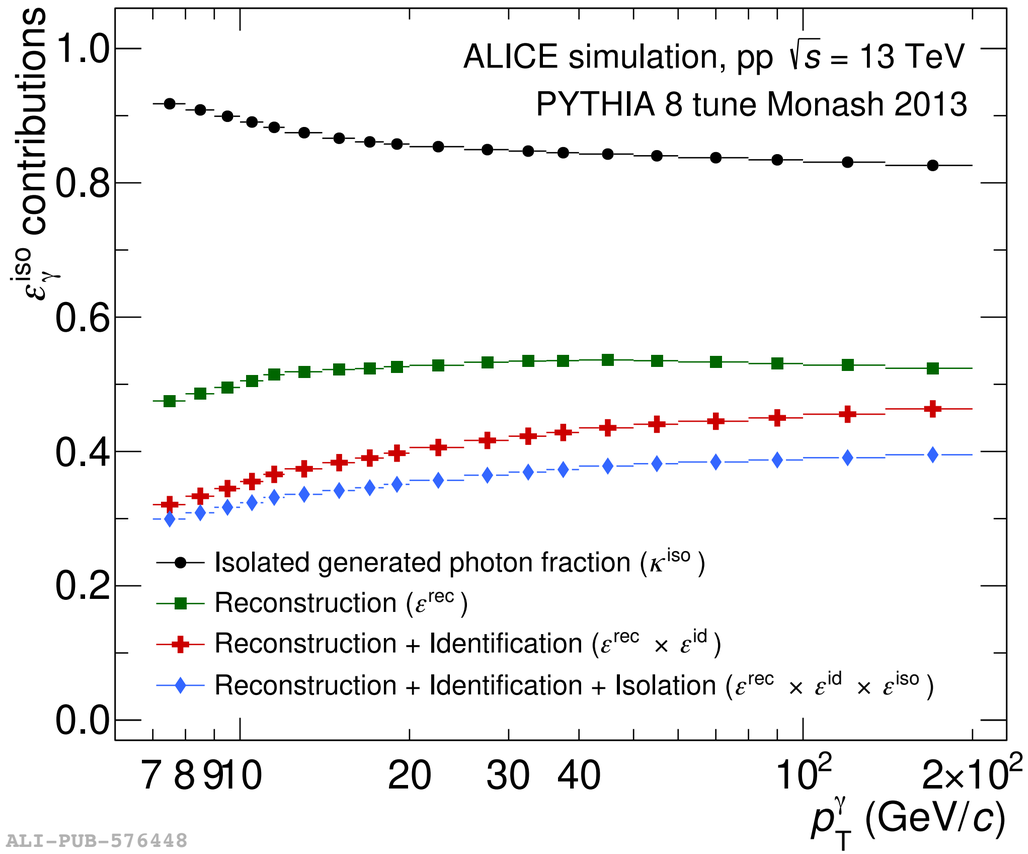
Purity for R = 0.2 & 0.4, pp & Pb–Pb $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV



- Distributions fitted to sigmoid function to reduce influence of fluctuations, fits used to correct the spectra
- P (R = 0.4) > P (R = 0.2) in pp collisions, more jet particles in cone, but decreasing centrality P (R = 0.2) > P (R = 0.4), due to UE fluctuations, although not significantly different
- P (Pb–Pb) > P (pp) due to better tracking and higher N (γ) / N (π^0) ratio ($R_{AA}(\pi^0) << 1$)

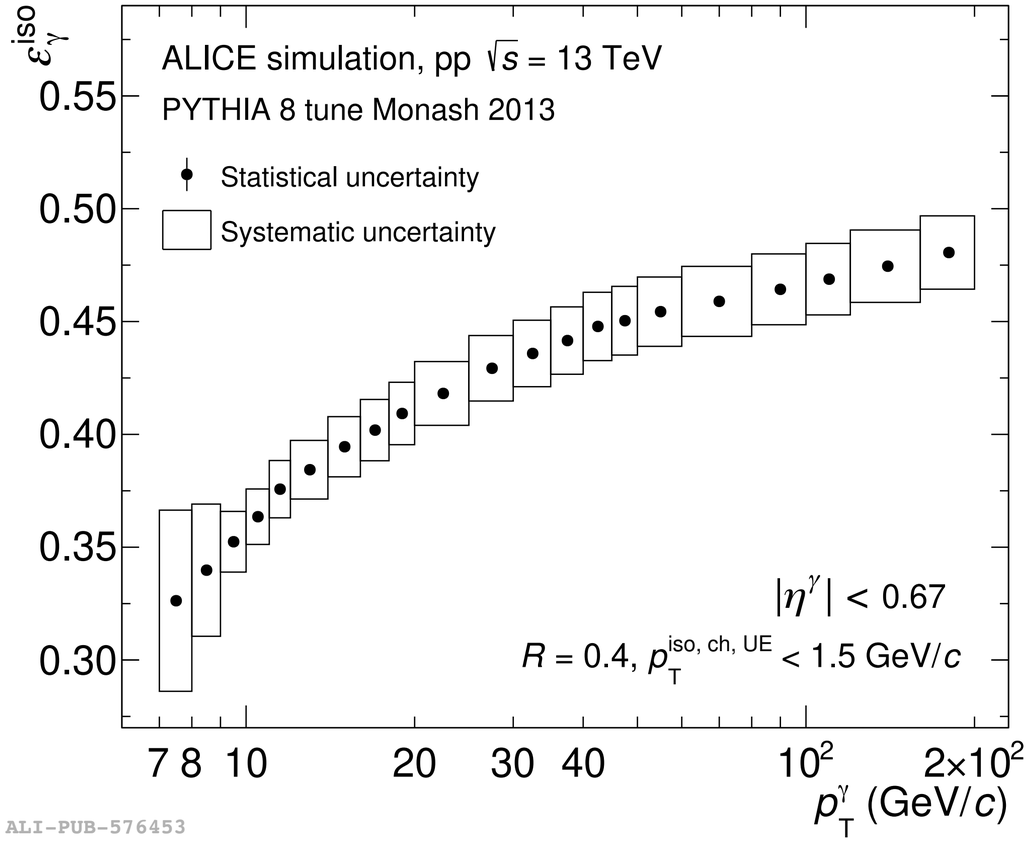
Isolated γ efficiency components, pp $\sqrt{s}$ = 13 TeV

$$\varepsilon^{\mathrm{sel}} = \frac{\mathrm{d}N^{\text{cluster sel.}}_{\gamma_{\mathrm{prompt}}}/\mathrm{d}p_{\mathrm{T}}^{\mathrm{rec}}}{\mathrm{d}N^{\text{gener.}}_{\gamma_{\mathrm{prompt}}}/\mathrm{d}p_{\mathrm{T}}^{\mathrm{gen}}}$$



ALI-PUB-576448

$$\varepsilon_{\gamma}^{\mathrm{iso}} = \frac{\mathrm{d}N^{\text{cluster iso. narrow}}_{\gamma_{\mathrm{prompt}}}/\mathrm{d}p_{\mathrm{T}}^{\mathrm{rec}}}{\mathrm{d}N^{\text{gener. iso.}}_{\gamma_{\mathrm{prompt}}}/\mathrm{d}p_{\mathrm{T}}^{\mathrm{gen}}}$$

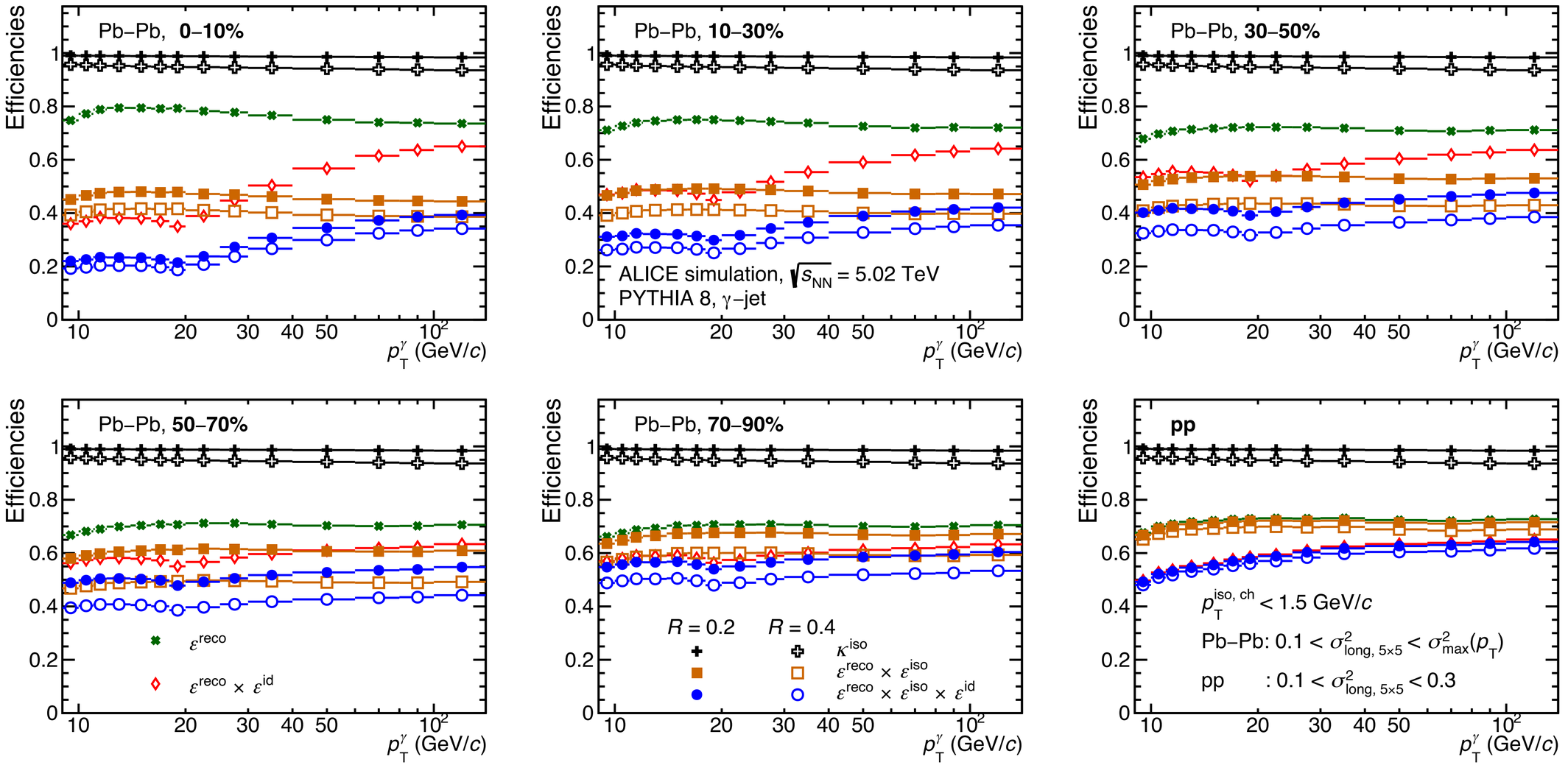


ALI-PUB-576453

Isolated γ efficiency components, pp & Pb–Pb $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV

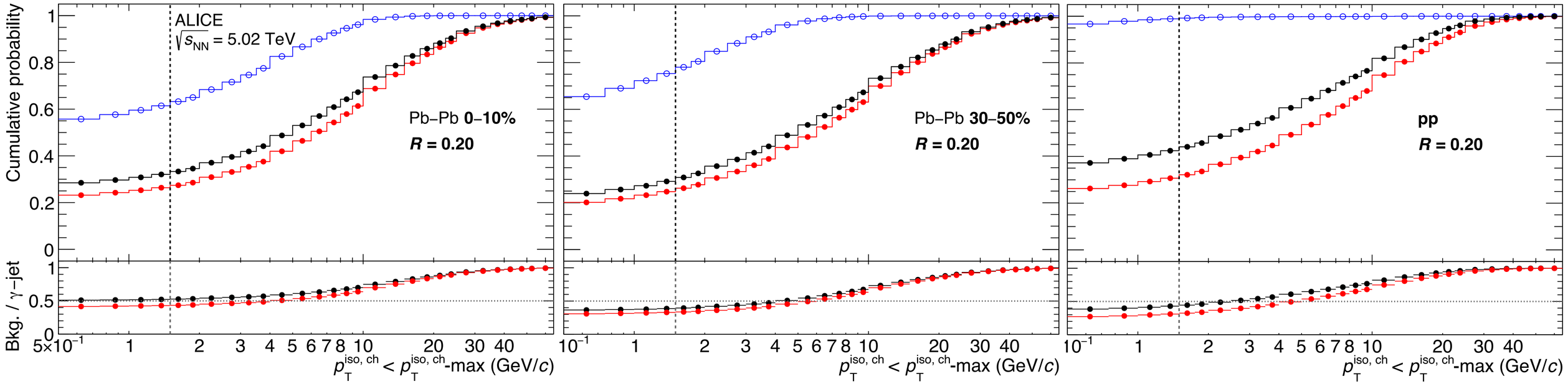
$$\varepsilon^{\mathrm{sel}} = \frac{\mathrm{d}N^{\mathrm{cluster\ sel.}}_{\gamma_{\mathrm{prompt}}}/\mathrm{d}p_{\mathrm{T}}^{\mathrm{rec}}}{\mathrm{d}N^{\mathrm{gener.}}_{\gamma_{\mathrm{prompt}}}/\mathrm{d}p_{\mathrm{T}}^{\mathrm{gen}}}$$

ALICE-PUBLIC-2024-003



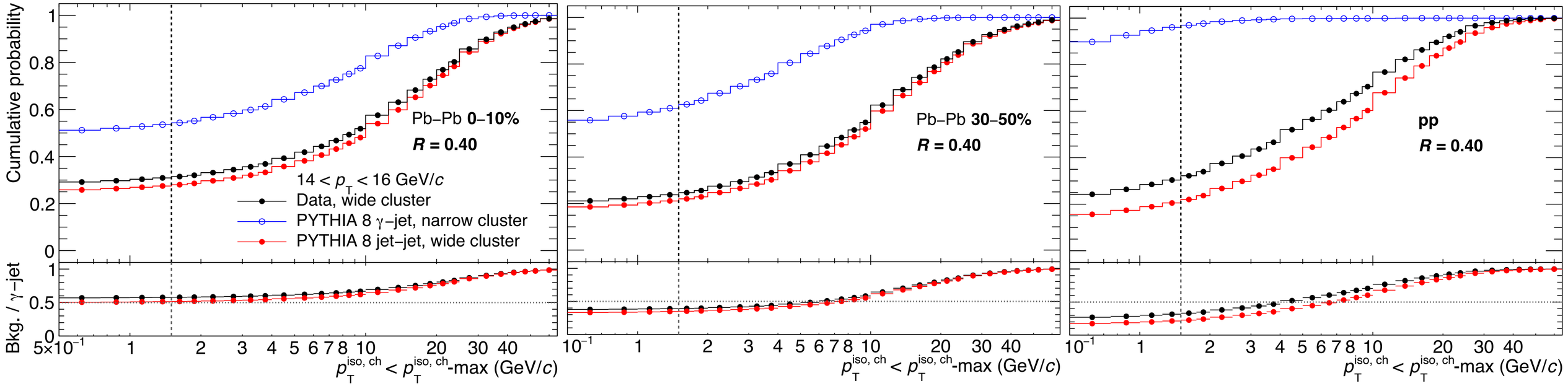
Selection probability depending isolation threshold, R = 0.2, pp & Pb–Pb $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV

ALICE-PUBLIC-2024-003

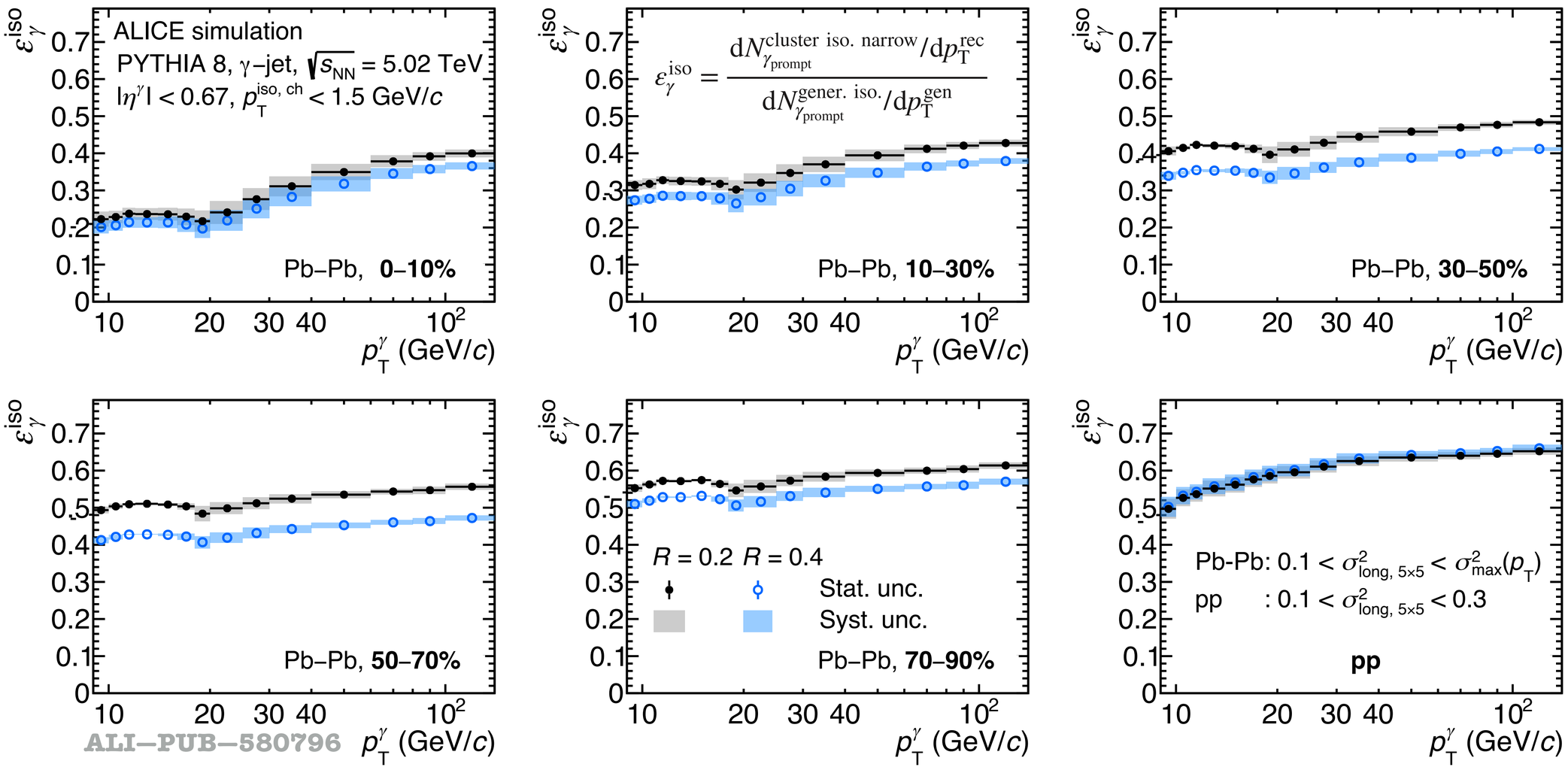


Selection probability depending isolation threshold, R = 0.4, pp & Pb–Pb $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV

ALICE-PUBLIC-2024-003



Efficiency, R = 0.2 & 0.4, pp & Pb–Pb $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV



$$\varepsilon_\gamma^{\mathrm{iso}} = \frac{\mathrm{d}N_{\gamma_{\mathrm{prompt}}}^{\mathrm{cluster\ iso.\ narrow}}/\mathrm{d}p_{\mathrm{T}}^{\mathrm{rec}}}{\mathrm{d}N_{\gamma_{\mathrm{prompt}}}^{\mathrm{gener.\ iso.}}/\mathrm{d}p_{\mathrm{T}}^{\mathrm{gen}}}$$

- $\varepsilon_\gamma^{\mathrm{iso}}$ (*0-10%*) < $\varepsilon_\gamma^{\mathrm{iso}}$ (50-90%): UE increases cluster size in more central collisions
- In Pb–Pb, $\varepsilon_\gamma^{\mathrm{iso}}$ (R = 0.2) > $\varepsilon_\gamma^{\mathrm{iso}}$ (R = 0.4) a factor ~0.9 due to lower UE fluctuations
- In pp, $\varepsilon_\gamma^{\mathrm{iso}}$ (R = 0.2) ≈ $\varepsilon_\gamma^{\mathrm{iso}}$ (R = 0.4), due to the less performing ITS-only tracks

Pb–Pb 50-90%: efficiency and purity

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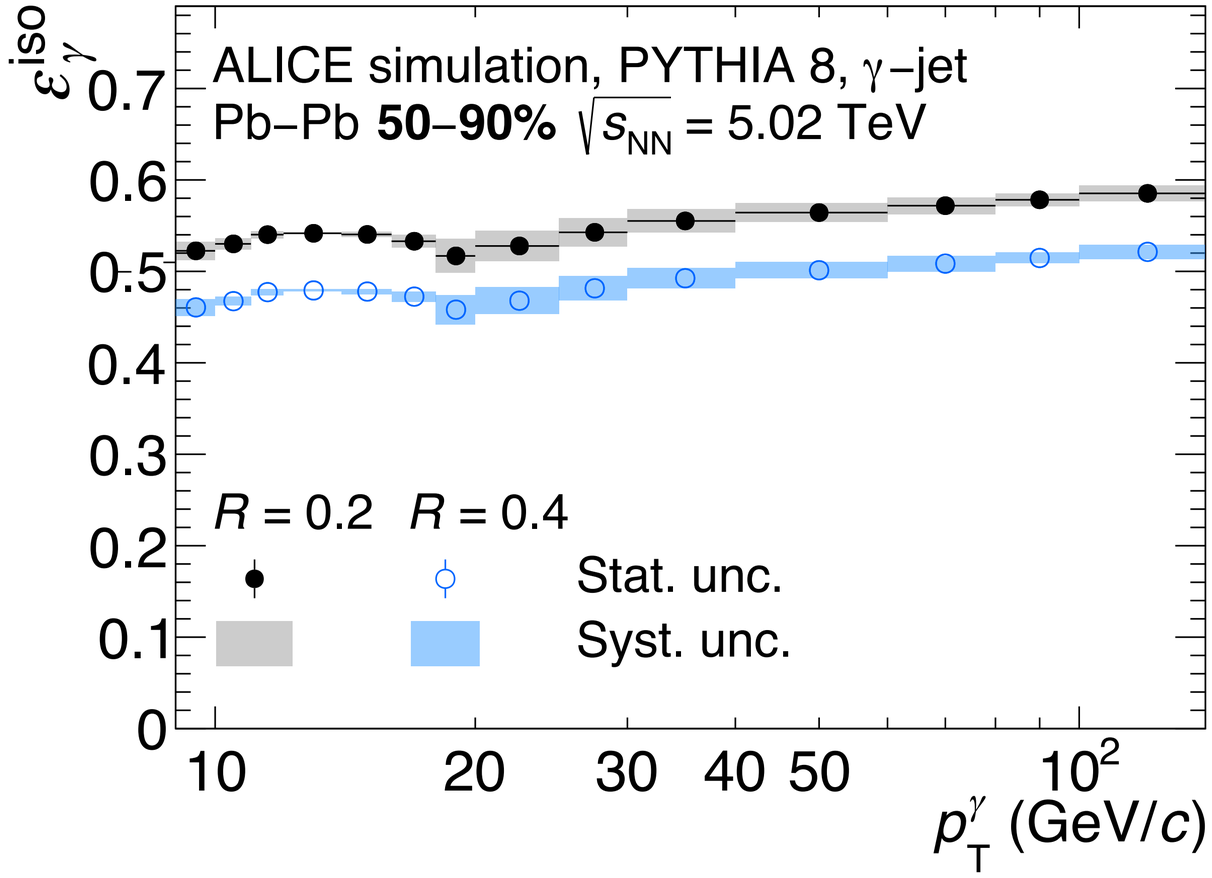
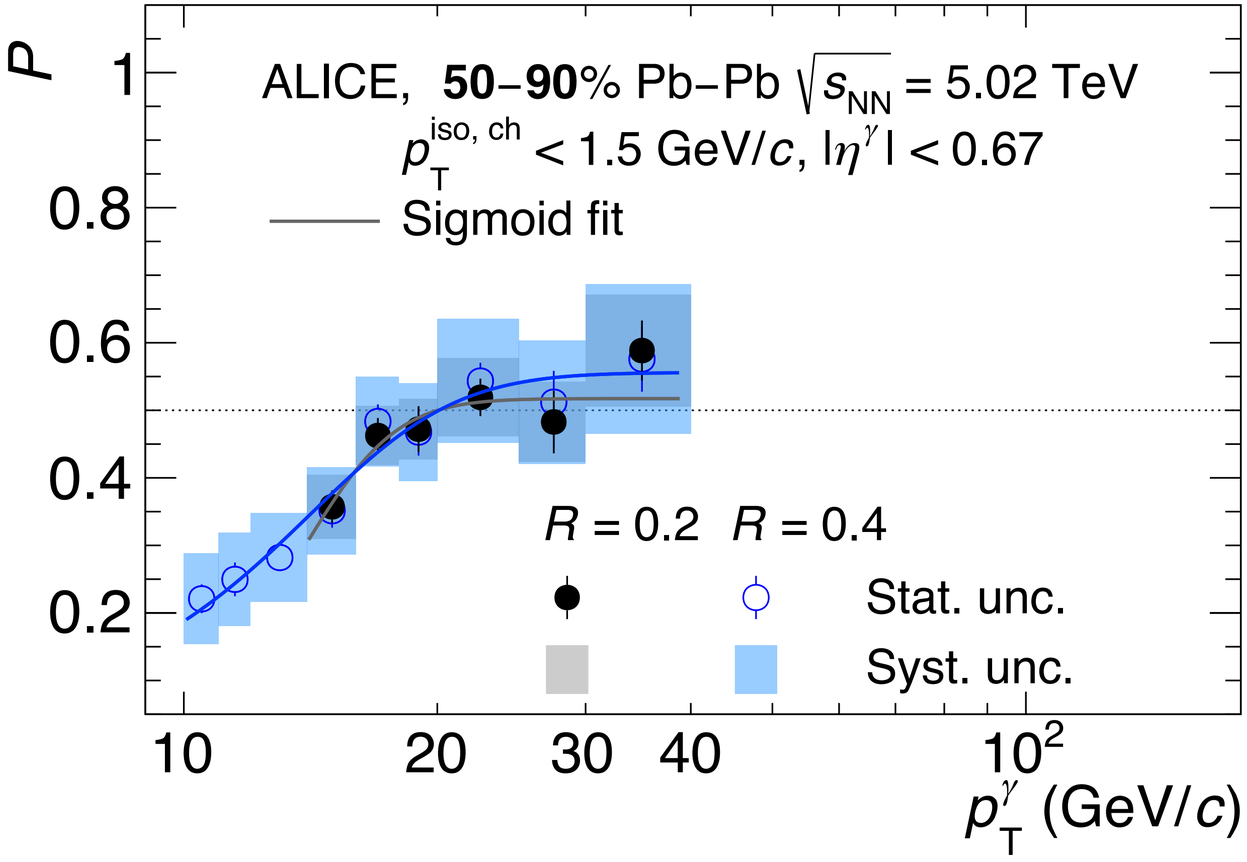
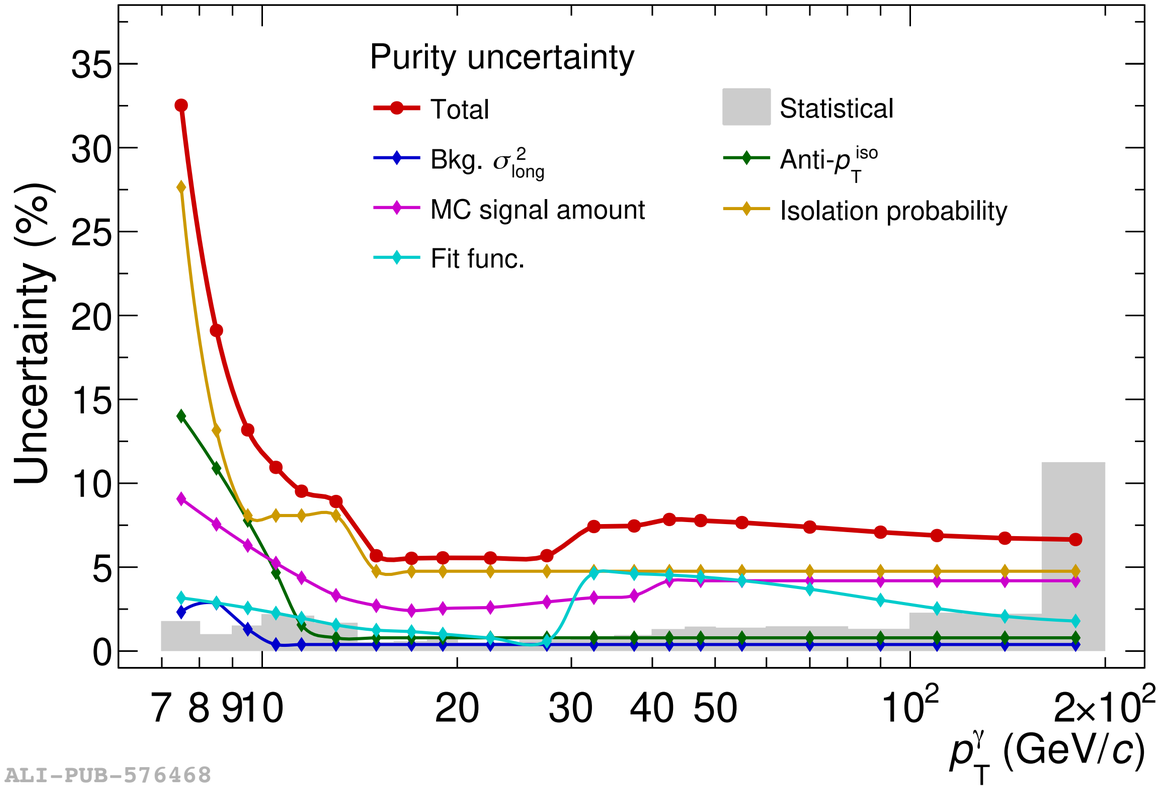
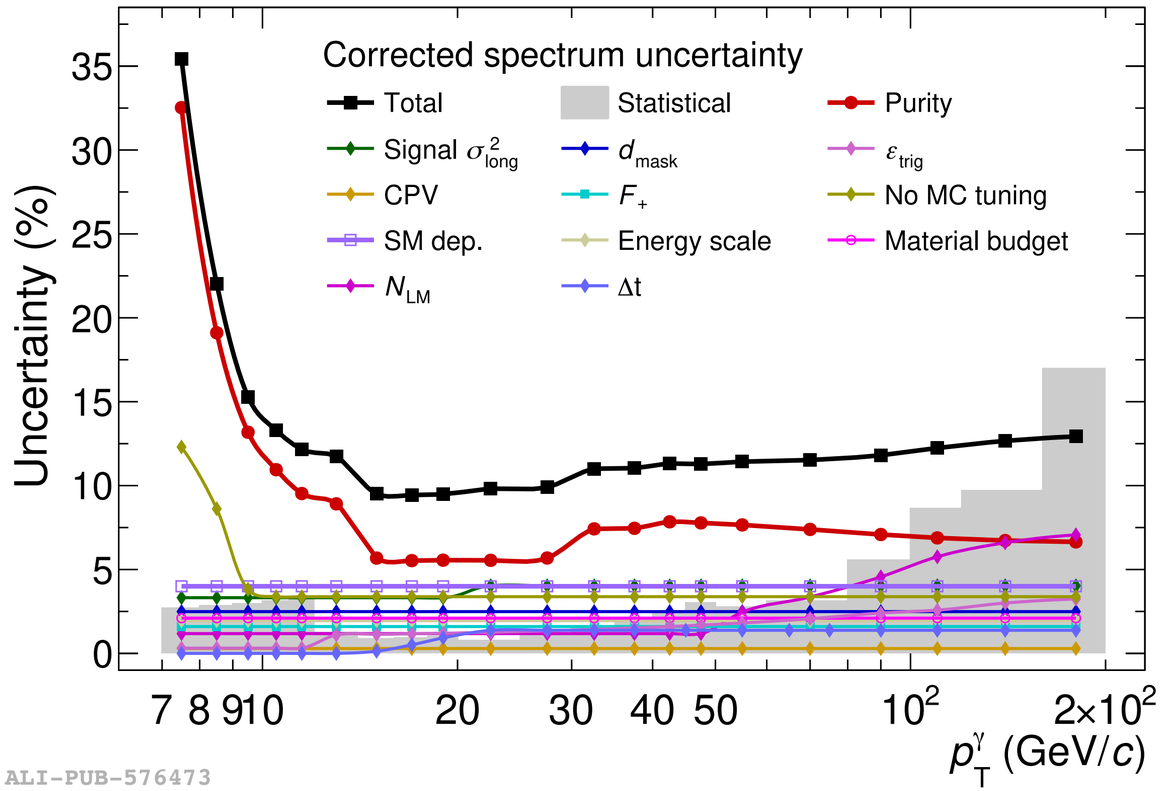


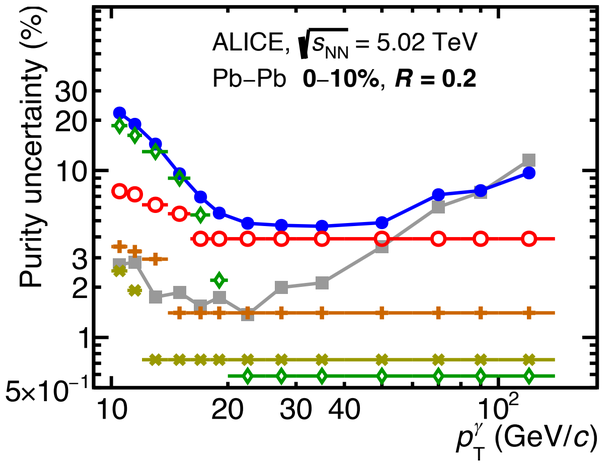


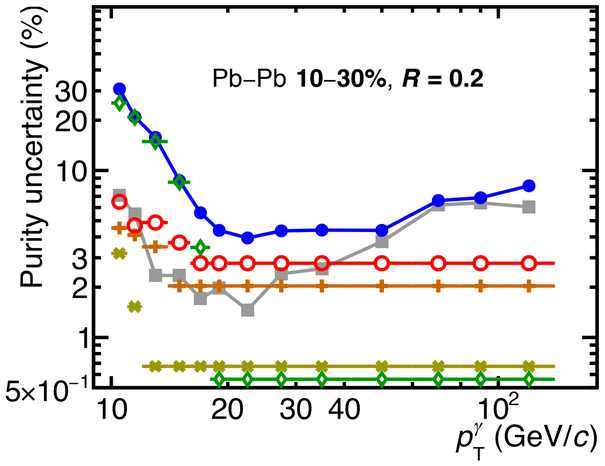
Uncertainties, pp $\sqrt{s}$ = 13 TeV

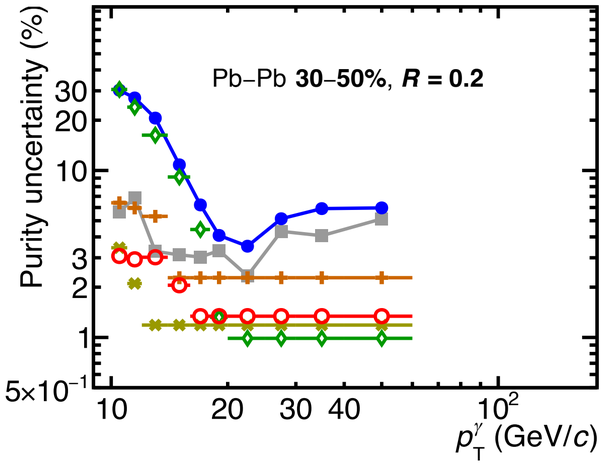


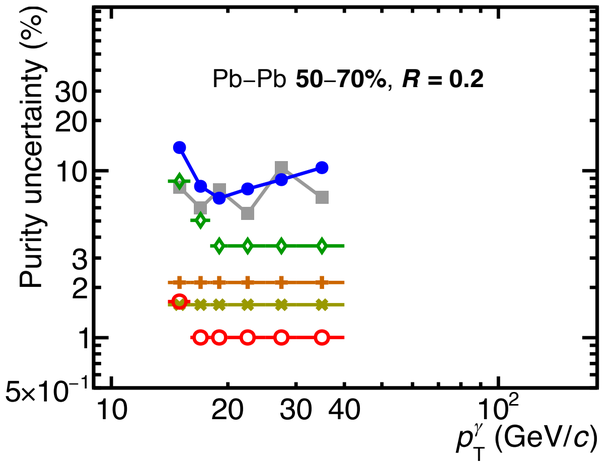


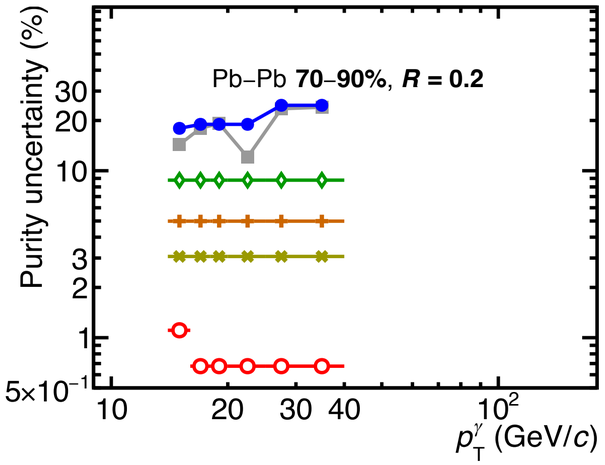
Purity uncertainties, pp & Pb–Pb $\sqrt{s_{NN}}$ = 5.02 TeV, R = 0.2

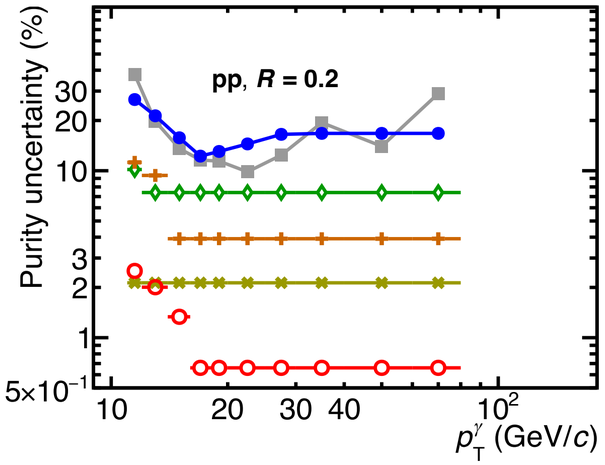








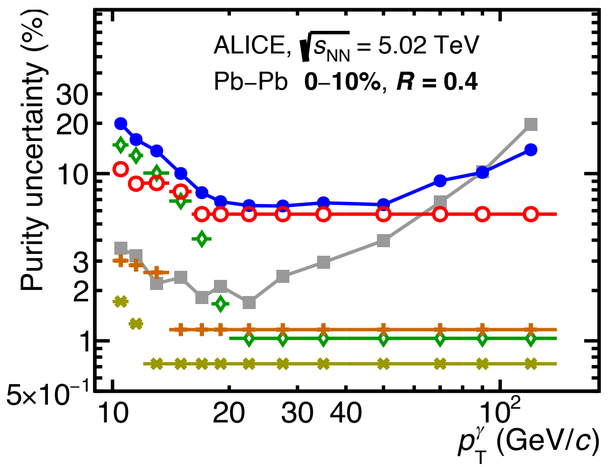


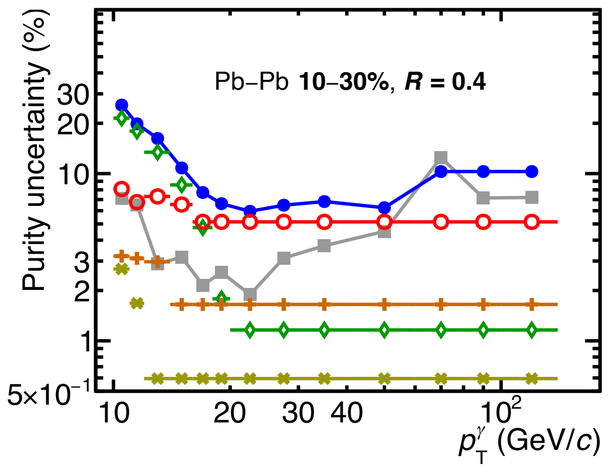


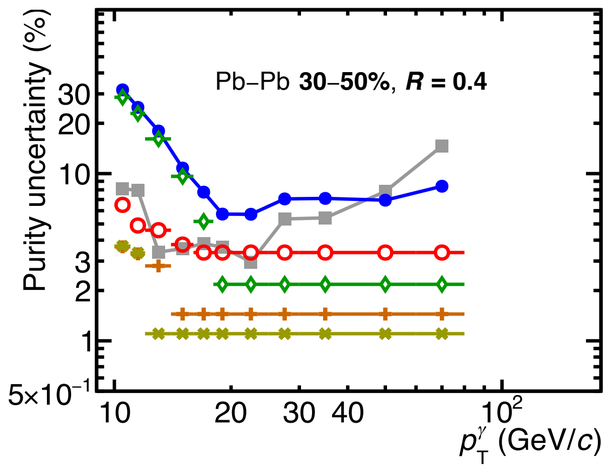
- Total, including fit.
- Statistical
- Isolation probability
- Bkg. $\sigma^2_{\text{long, 5×5}}$
- Bkg. $p_T^{\text{iso, ch}}$
- MC signal amount

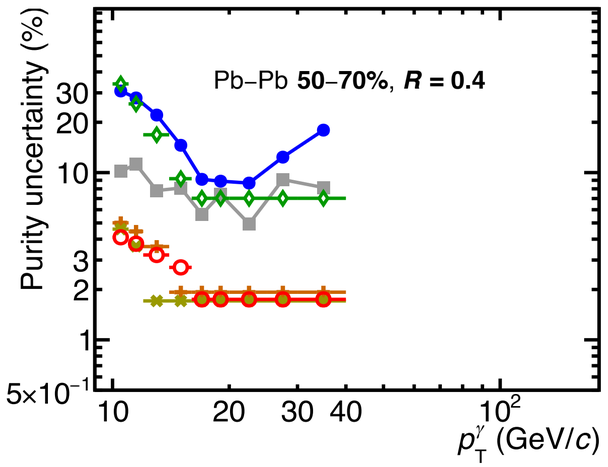
ALICE-PUBLIC-2024-003

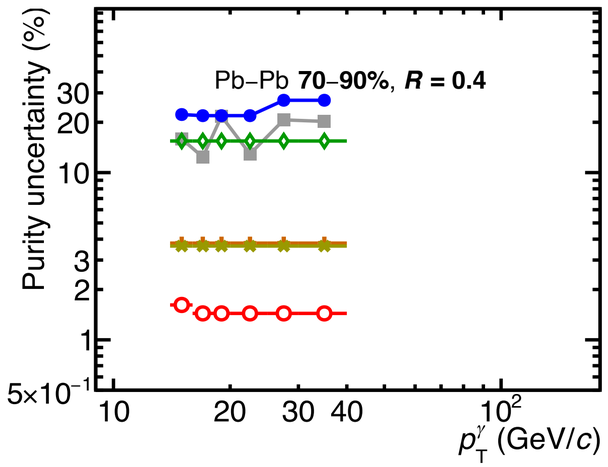
Purity uncertainties, pp & Pb–Pb $\sqrt{s_{NN}}$ = 5.02 TeV, R = 0.4

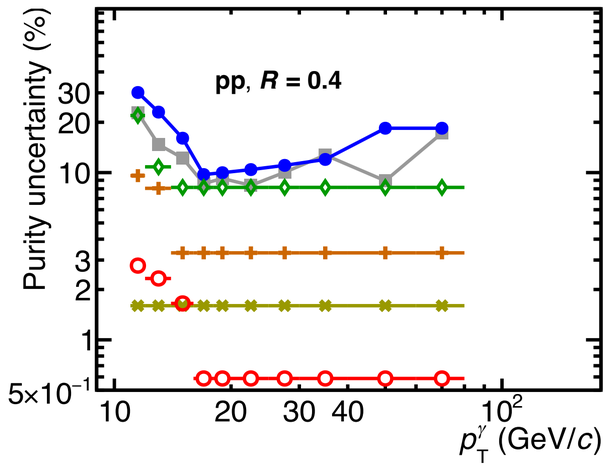








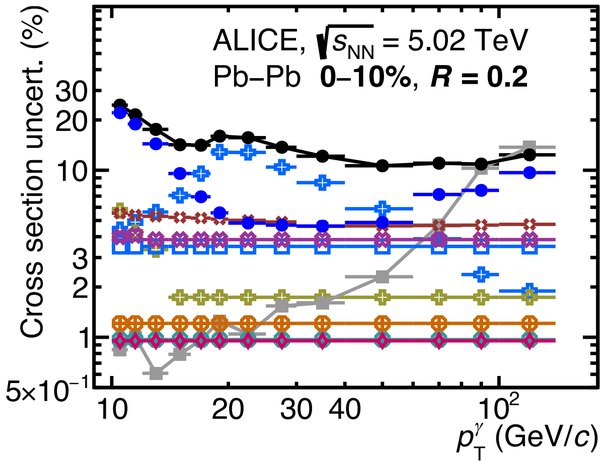


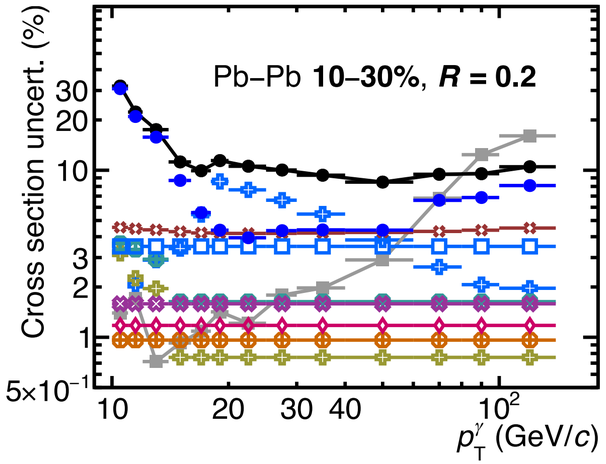


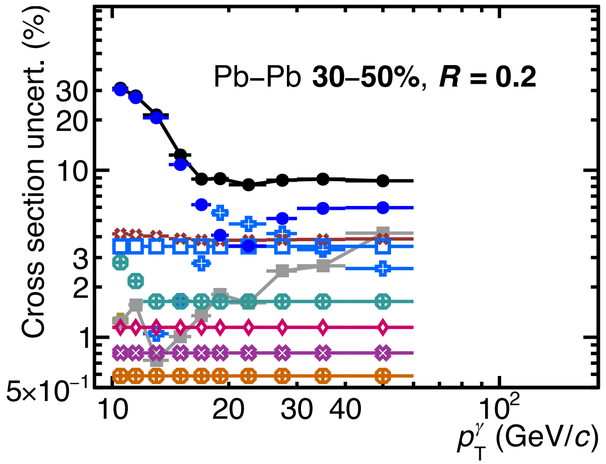
- Total, including fit.
- Statistical
- Isolation probability
- Bkg. $\sigma^2_{\text{long, 5×5}}$
- Bkg. $p_T^{\text{iso, ch}}$
- MC signal amount

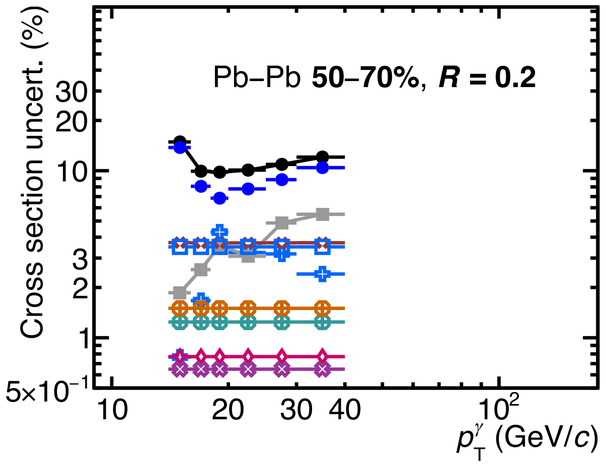
ALICE-PUBLIC-2024-003

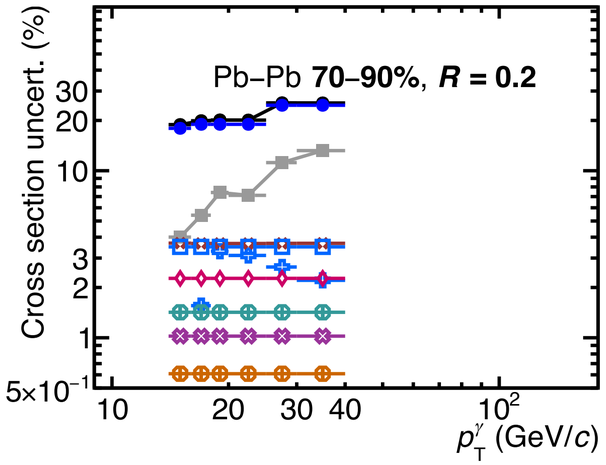
Cross section uncertainties, pp & Pb–Pb $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV, R = 0.2

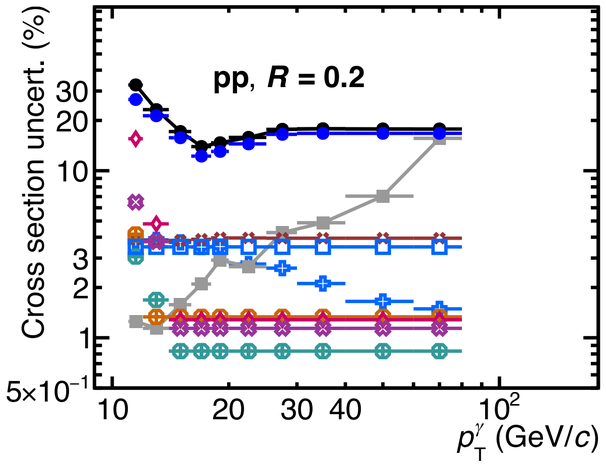








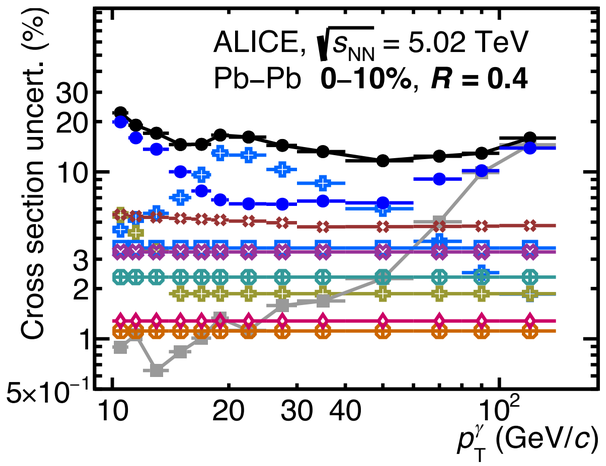


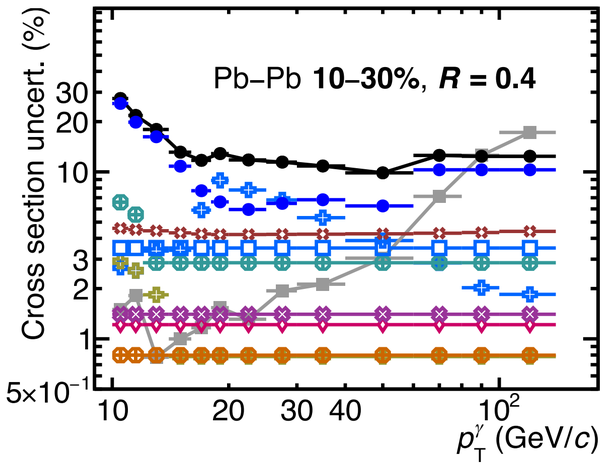


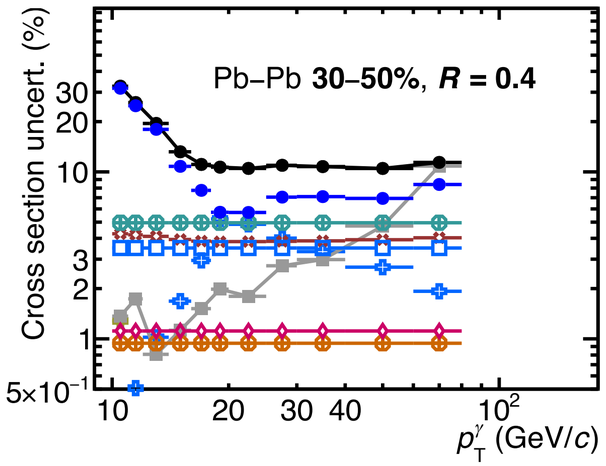
- Total systematic
- Statistical
- Purity
- No MC tuning
- Spectra shape
- UE area
- UE gap
- Sig. $\sigma^2_{\mathrm{long,\,5\times5}}$
- F_+
- SM dependence
- Other systematic

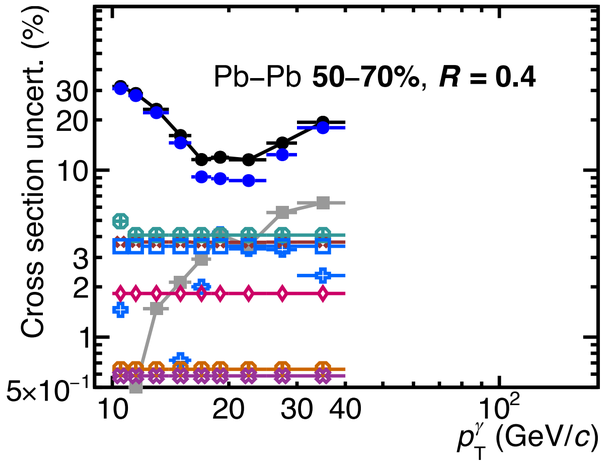
ALICE-PUBLIC-2024-003

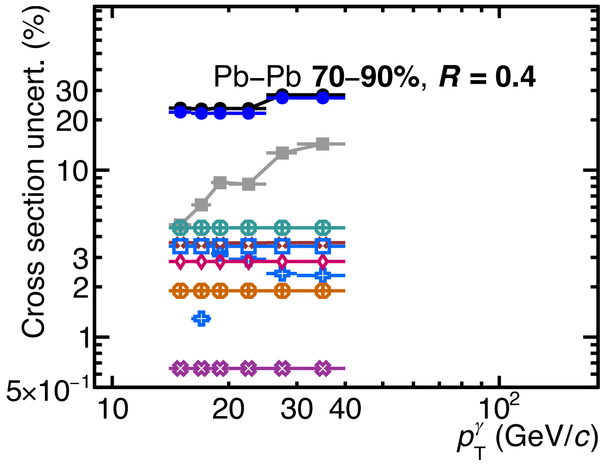
Cross section uncertainties, pp & Pb–Pb $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV, R = 0.4

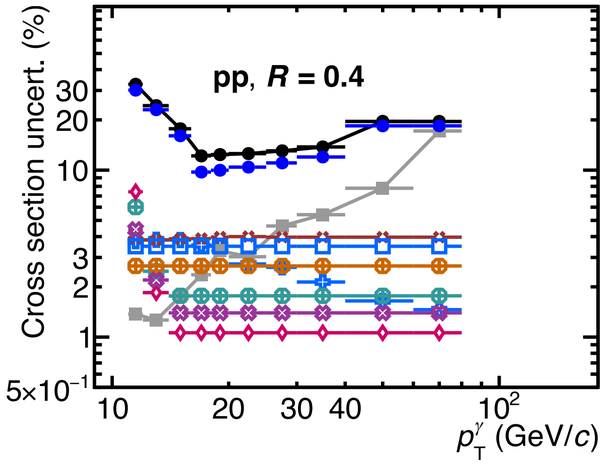








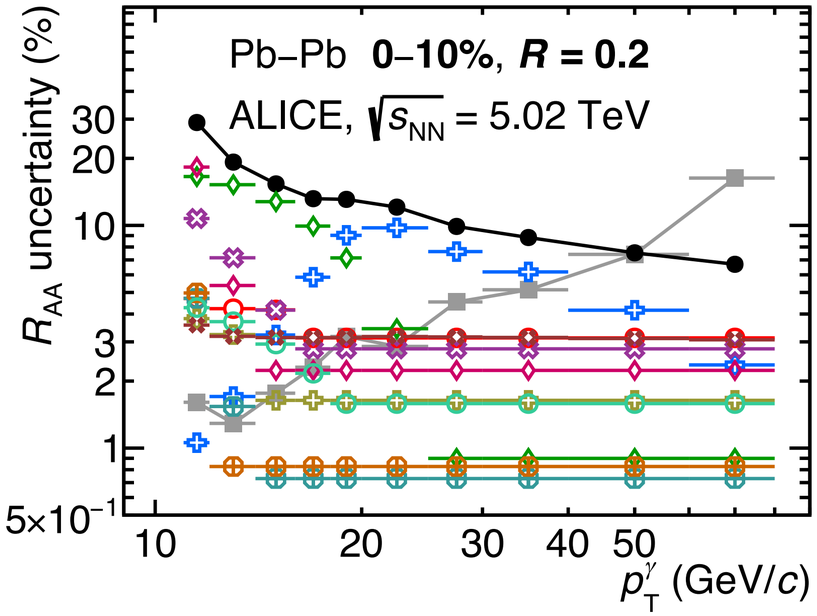


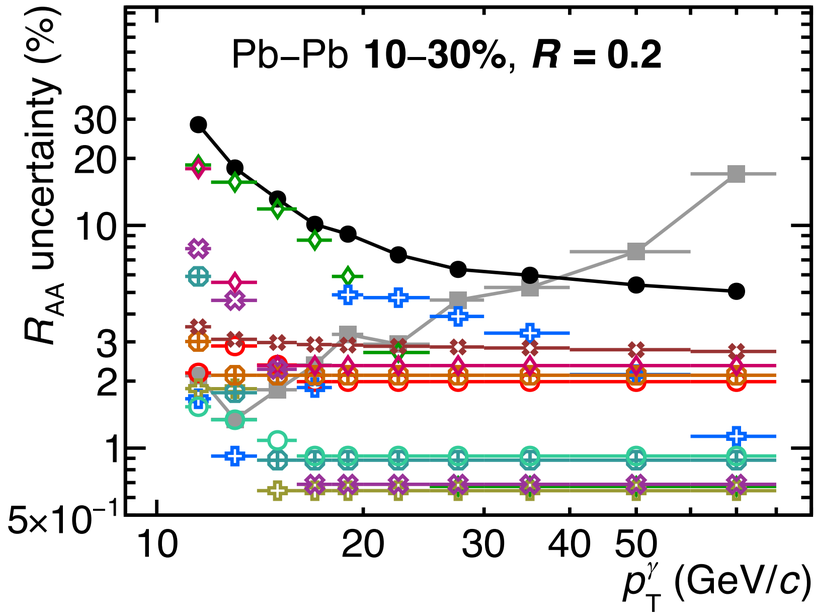


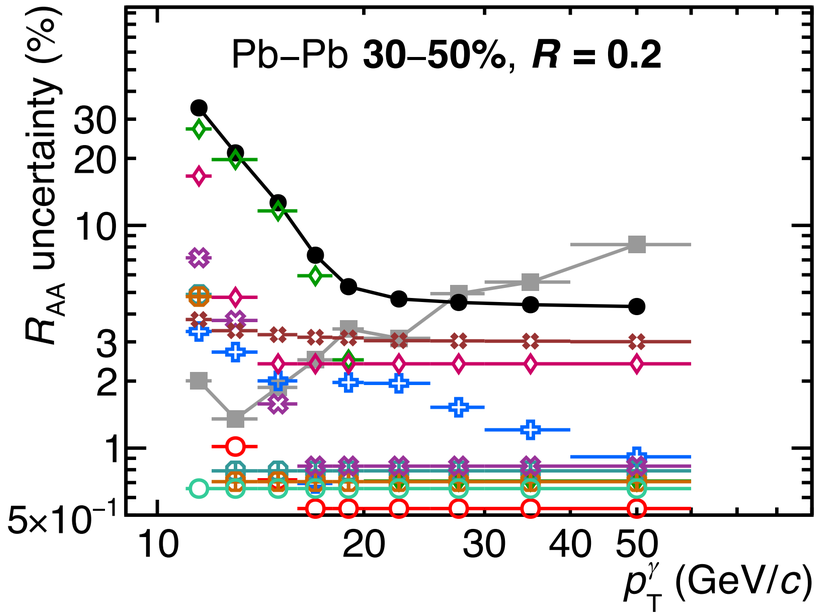
- Total systematic
- Statistical
- Purity
- No MC tuning
- Spectra shape
- UE area
- UE gap
- Sig. $\sigma^2_{\mathrm{long,\,5\times5}}$
- F_+
- SM dependence
- Other systematic

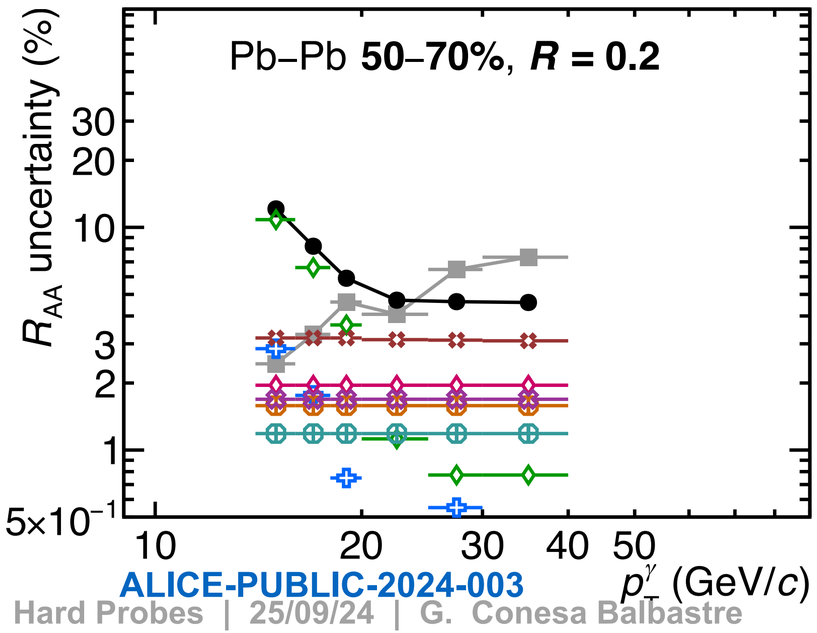
ALICE-PUBLIC-2024-003

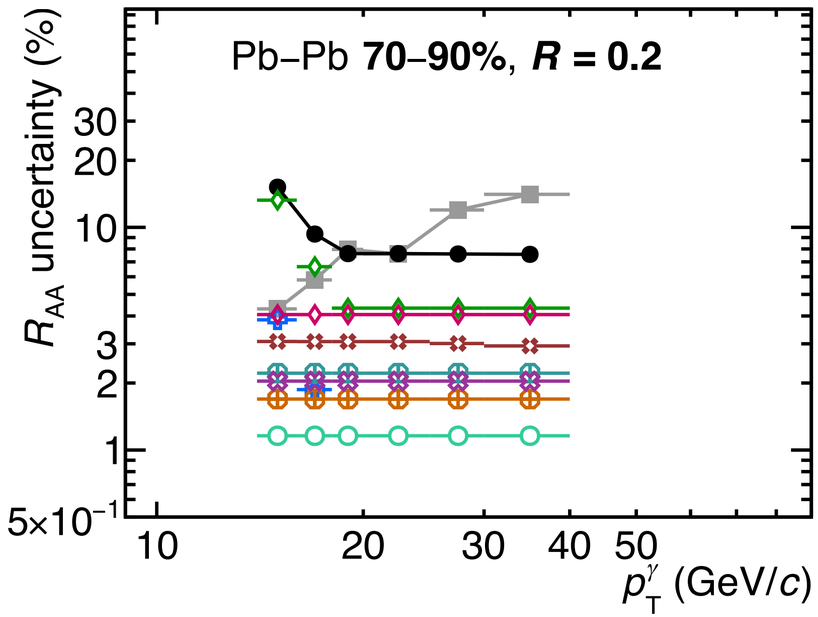
R_{AA} uncertainties, R = 0.2





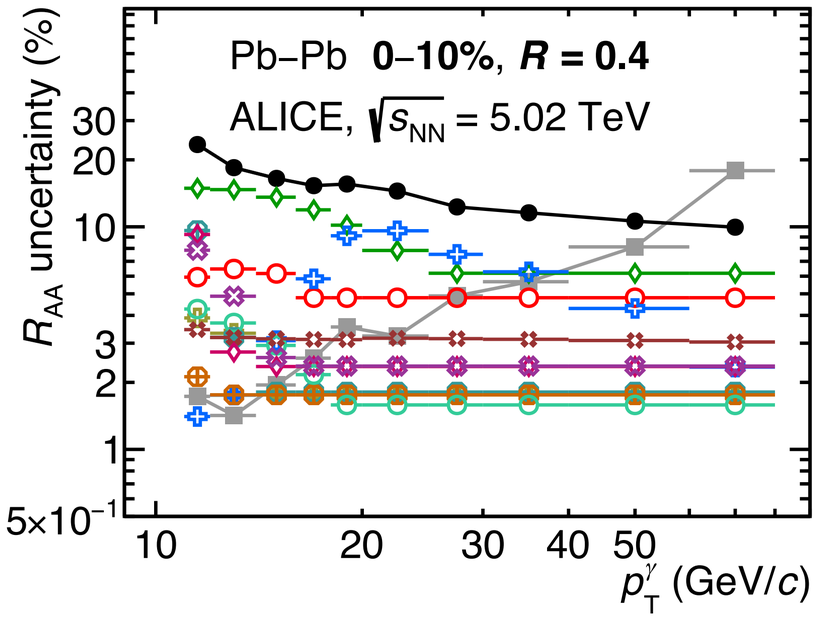


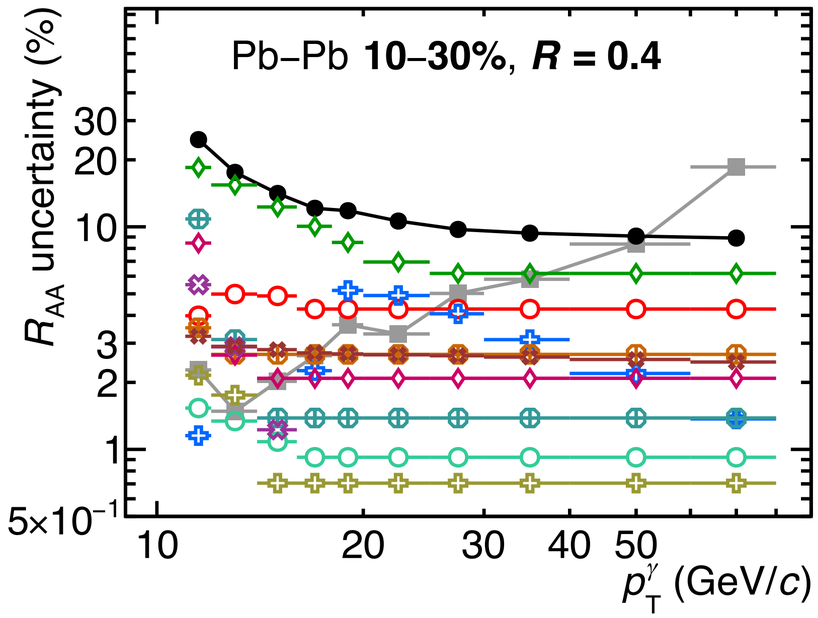


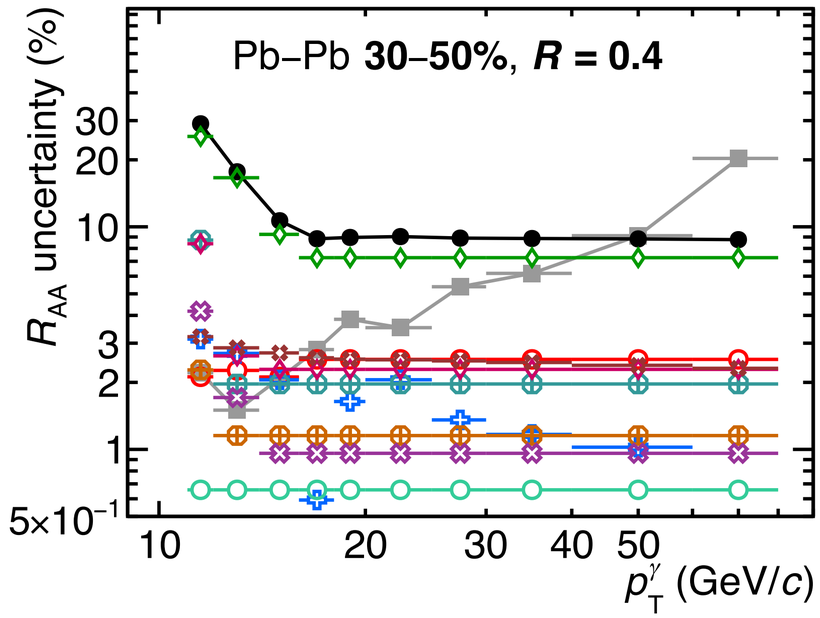


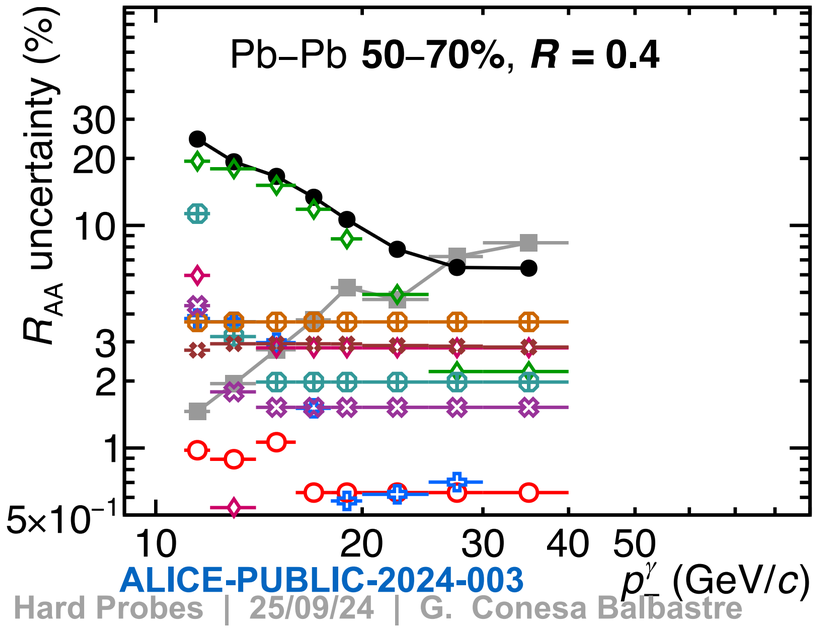
- Total systematic
- Statistical
- Isolation probability
- MC signal amount
- No MC tuning
- Spectra shape
- UE area
- UE gap
- Sig. $\sigma^2_{\text{long, 5×5}}$
- Time
- F_+
- Other systematic

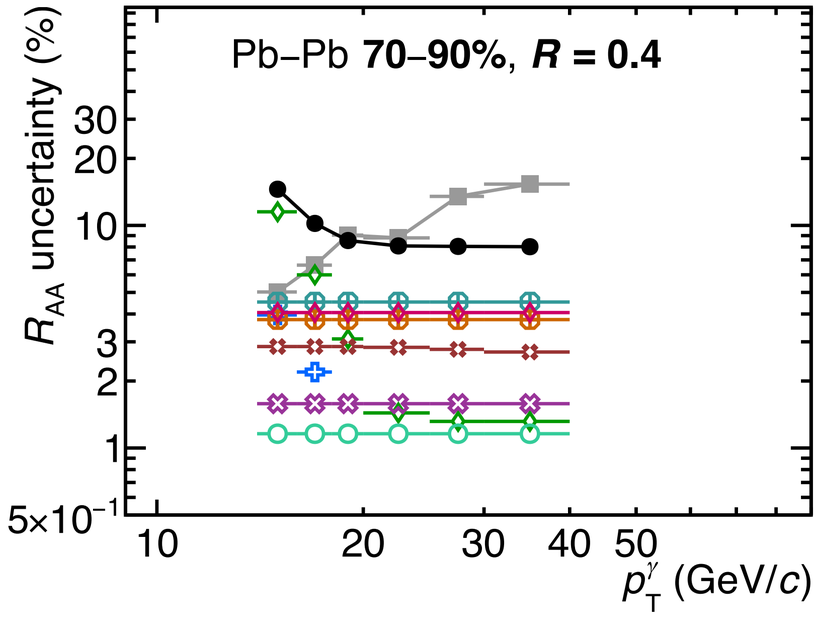
R_{AA} uncertainties, $R = 0.4$





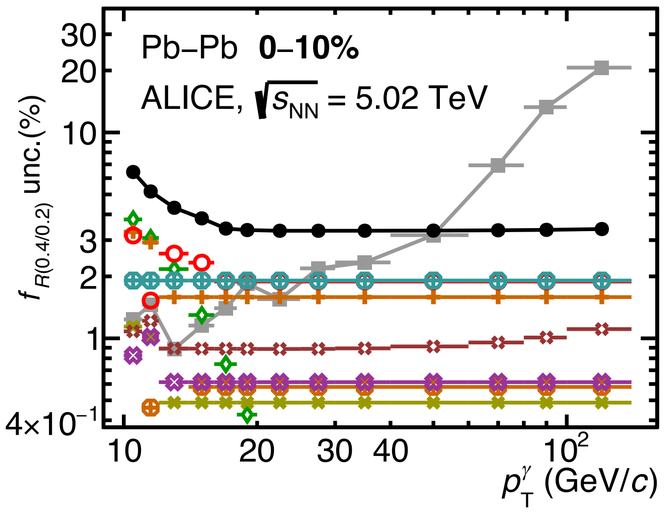


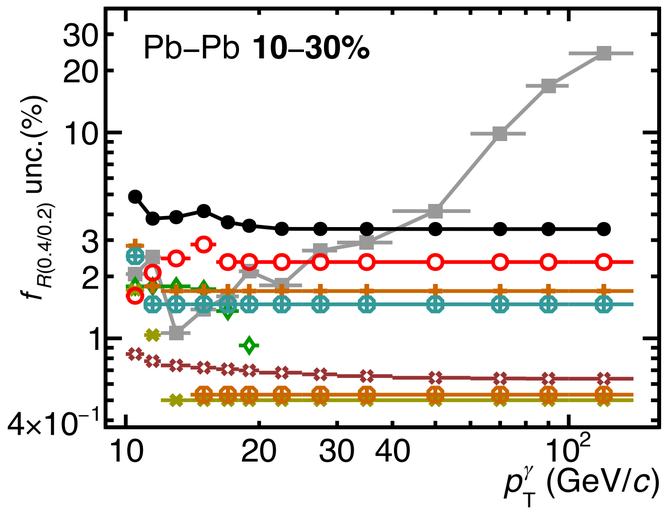


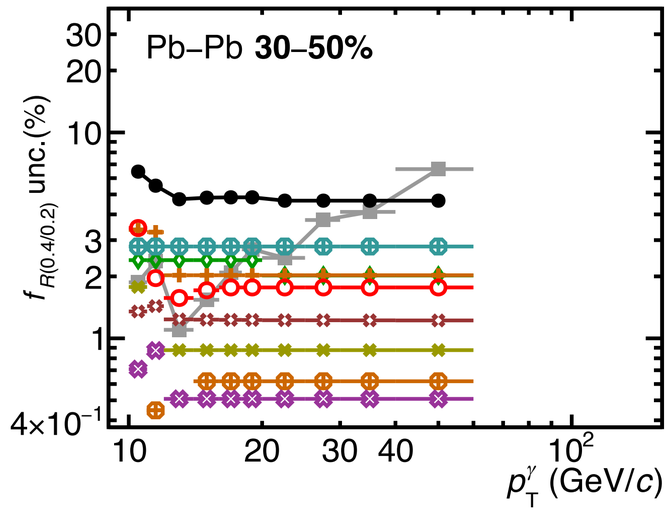


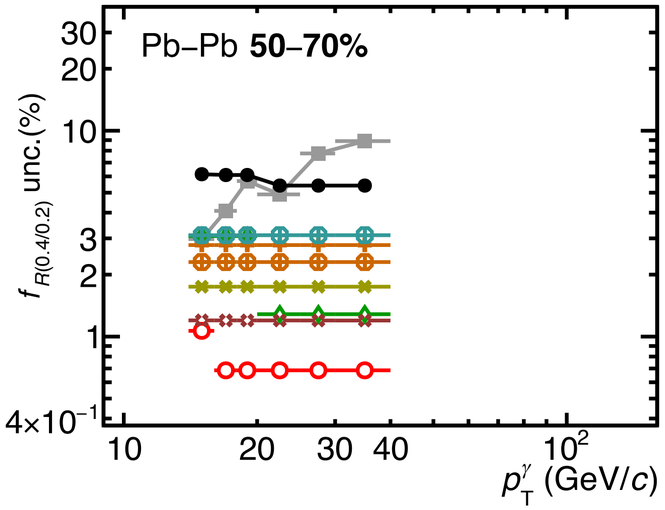
- Total systematic
- Statistical
- Isolation probability
- MC signal amount
- No MC tuning
- Spectra shape
- UE area
- UE gap
- Sig. $\sigma^2_{\text{long, 5×5}}$
- Time
- F_+
- Other systematic

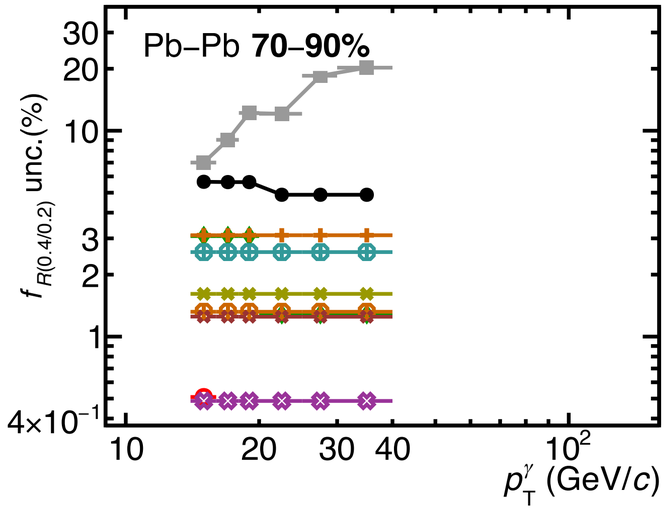
$R = 0.4$ over $R = 0.2$ ratio uncertainties, pp & Pb–Pb $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV

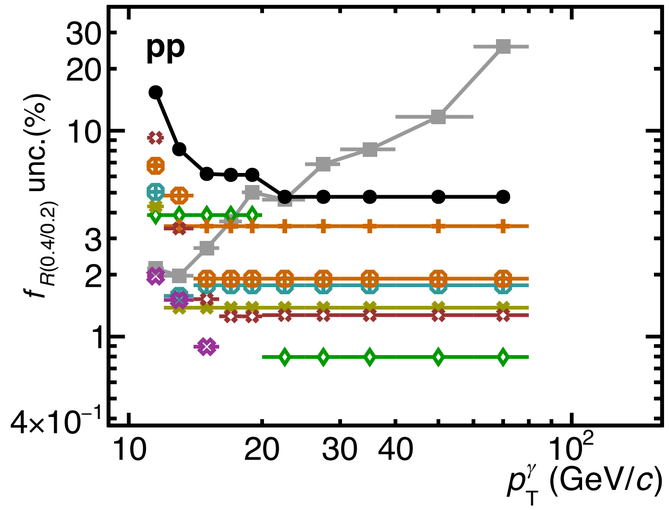












- Total systematic
- Statistical
- Isolation probability
- Bkg. $p_{\mathrm{T}}^{\mathrm{iso,\ ch}}$
- Bkg. $\sigma^2_{\mathrm{long,\ 5\times5}}$
- MC signal amount
- UE area
- UE gap
- F_+
- Other systematic

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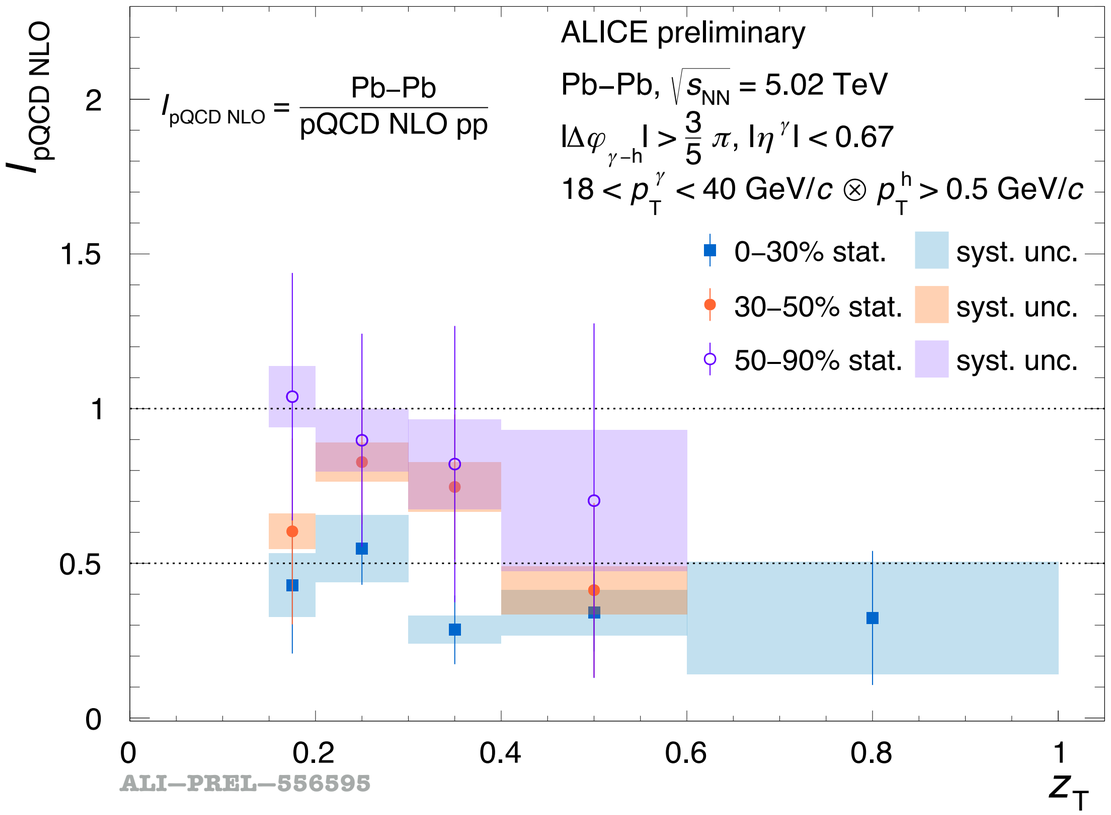
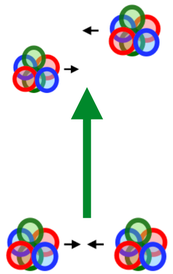
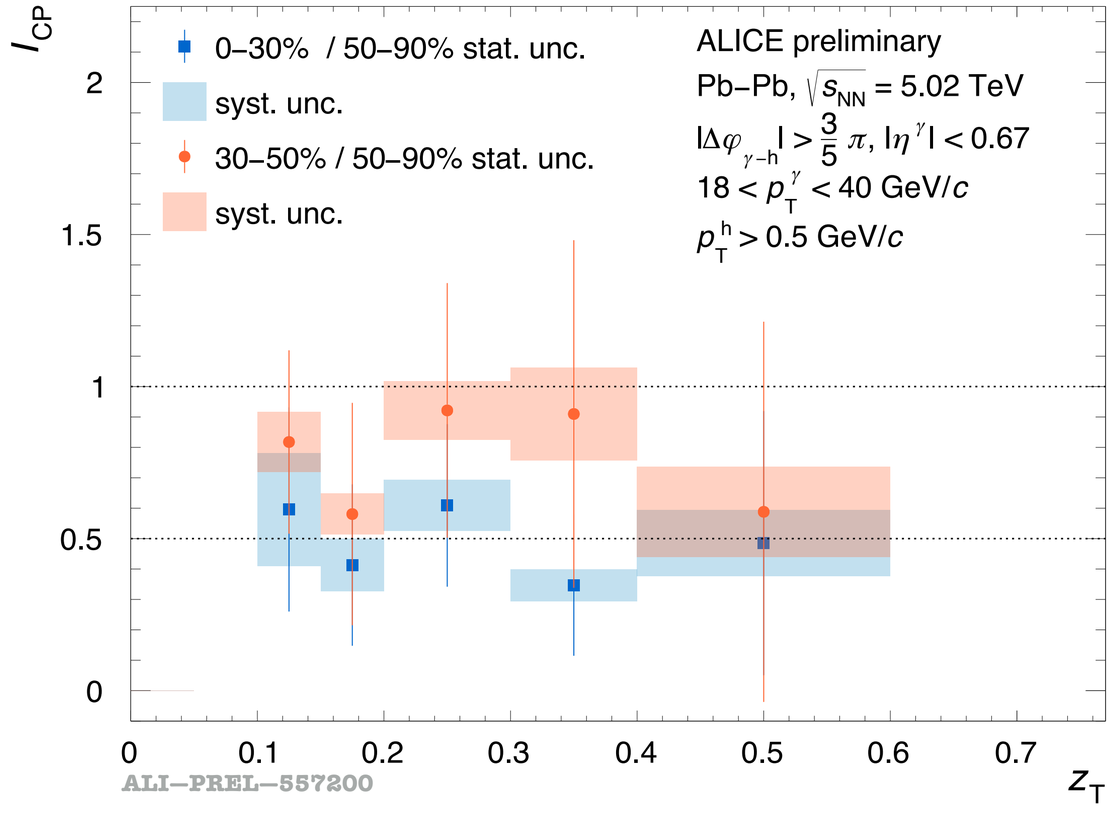
Isolated γ–hadron correlations in Pb–Pb: $D(z_T)$

I_{pQCD} = Pb–Pb Data / pp pQCD

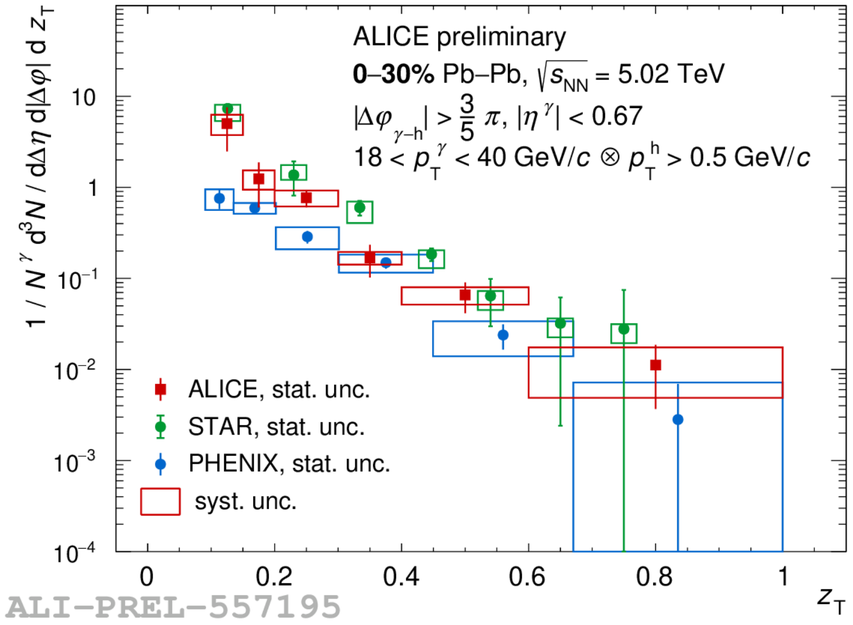
I_{CP} = Pb–Pb (semi) central / peripheral

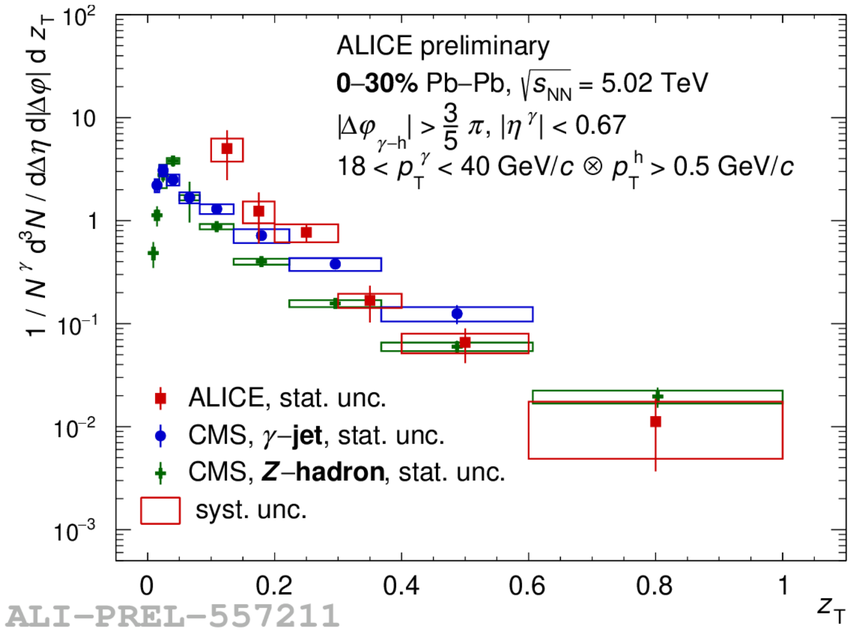






Isolated γ-hadron correlations in Pb–Pb: RHIC & LHC





STAR, Phys.Lett.B 760 (2016) 689-696

0–12% Au–Au, $\sqrt{s_{NN}}$ = 200 GeV

$|\Delta\varphi_{\gamma\text{–h}} - \pi| \leq 1.4$

$12 < p_T^{\gamma} < 20$ GeV/c ⊗ $p_T^{h} > 1.2$ GeV/c

PHENIX, PRL 111, 032301 (2013)

0–40% Au–Au, $\sqrt{s_{NN}}$ = 200 GeV

$|\Delta\varphi_{\gamma\text{–h}} - \pi| < \pi/2$, $|y| < 0.35$

$5 < p_T^{\gamma} < 9$ GeV/c ⊗ $0.5 < p_T^{h} < 7$ GeV/c

CMS, Phys.Rev.Lett. 121 (2018) 24, 242301, 2018

γ–jet, 0–10%

anti-k_T jet R = 0.3, $p_T^{jet} > 30$ GeV/c, $|\eta^{jet}| < 1.6$

$|\Delta\varphi_{\gamma\text{–jet}}| > \frac{7}{8}\pi$, $|\eta^{\gamma}| < 1.44$, $p_T^{\gamma} > 60$ GeV/c ⊗ $p_T^{h} > 1$ GeV/c

CMS, Phys.Rev.Lett. 128 (2022) 12, 122301, 2022

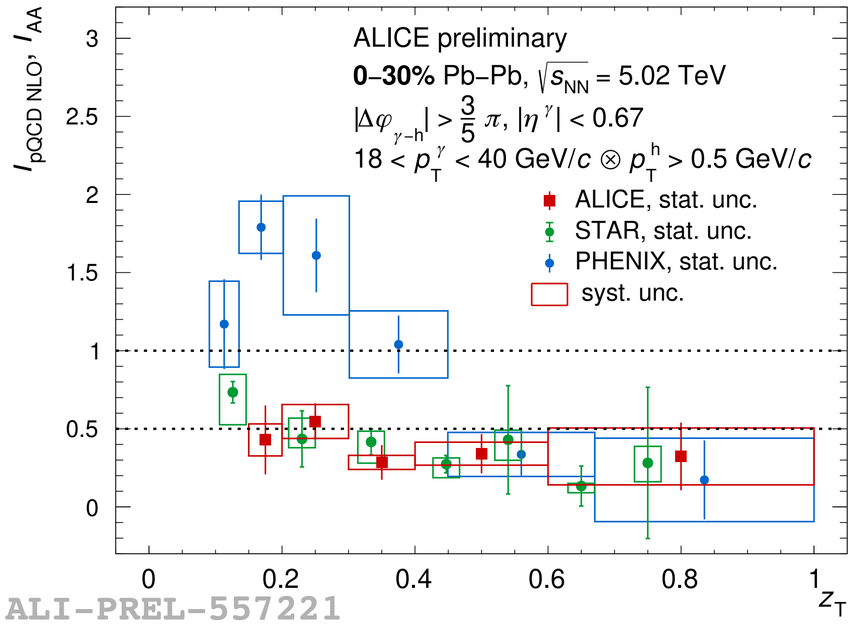
***Z*–hadron, 0–30%**

$|\Delta\varphi_{Z\text{–h}}| > \frac{7}{8}\pi$, $p_T^{Z} > 30$ GeV/c ⊗ $p_T^{h} > 1$ GeV/c

Central

- Similar behaviour as observed at RHIC and LHC experiments
  - ➡ Note: not completely apple-to-apple comparisons!

Isolated γ-hadron correlations in Pb–Pb: RHIC & LHC



STAR, Phys.Lett.B 760 (2016) 689-696

0–12% Au–Au, $\sqrt{s_{NN}}$ = 200 GeV

$|\Delta\varphi_{\gamma-h} - \pi| \leq 1.4$

$12 < p_T^{\gamma} < 20$ GeV/c ⊗ $p_T^{h} > 1.2$ GeV/c

PHENIX, PRL 111, 032301 (2013)

0–40% Au–Au, $\sqrt{s_{NN}}$ = 200 GeV

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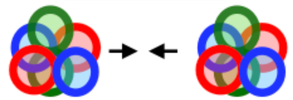
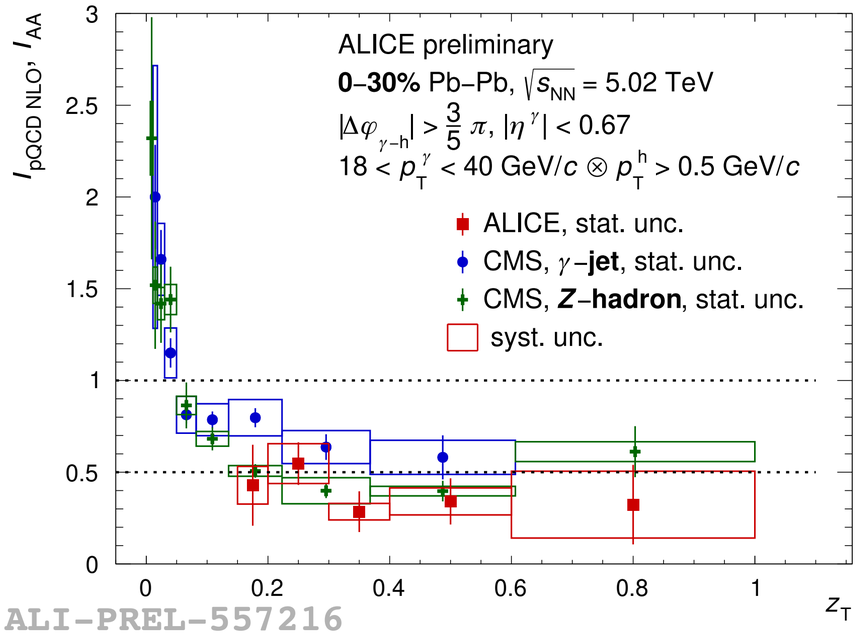
$5 < p_T^{\gamma} < 9$ GeV/c ⊗ $0.5 < p_T^{h} < 7$ GeV/c

Central



$$I_{AA}(z_T) = \frac{D(z_T, \mathbf{Pb-Pb})}{D(z_T, \mathbf{pp})}$$

- Similar behaviour as observed at RHIC and LHC experiments
  - ➡ Note: not completely apple-to-apple comparisons!



CMS, Phys.Rev.Lett. 121 (2018) 242301, 2018

γ–jet, 0–10%

anti-k_T jet R = 0.3, $p_T^{jet} > 30$ GeV/c, $|\eta^{jet}| < 1.6$

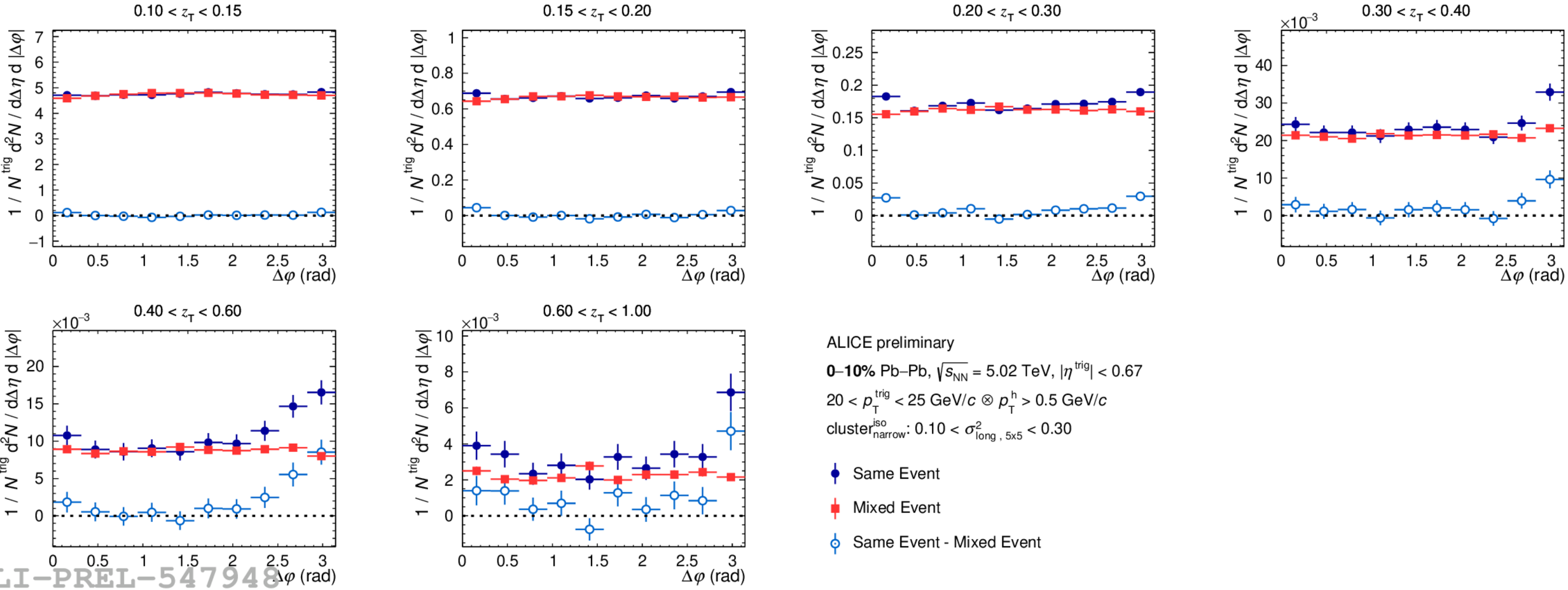
$|\Delta\varphi_{\gamma-jet}| > \frac{7}{8}\pi$, $|\eta^{\gamma}| < 1.44$ $p_T^{\gamma} > 60$ GeV/c ⊗ $p_T^{h} > 1$ GeV/c

CMS, Phys.Rev.Lett. 128 (2022) 122301, 2022

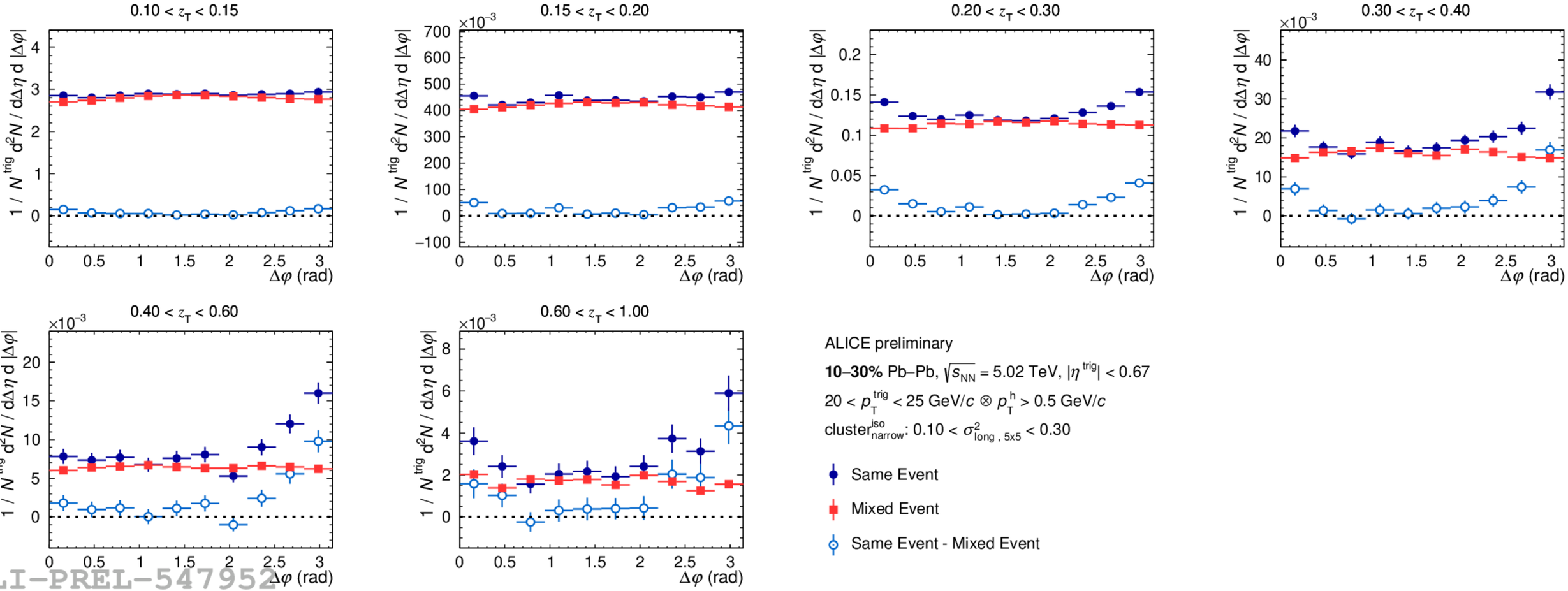
Z–hadron, 0–30%

$|\Delta\varphi_{Z-h}| > \frac{7}{8}\pi$, $p_T^{Z} > 30$ GeV/c ⊗ $p_T^{h} > 1$ GeV/c

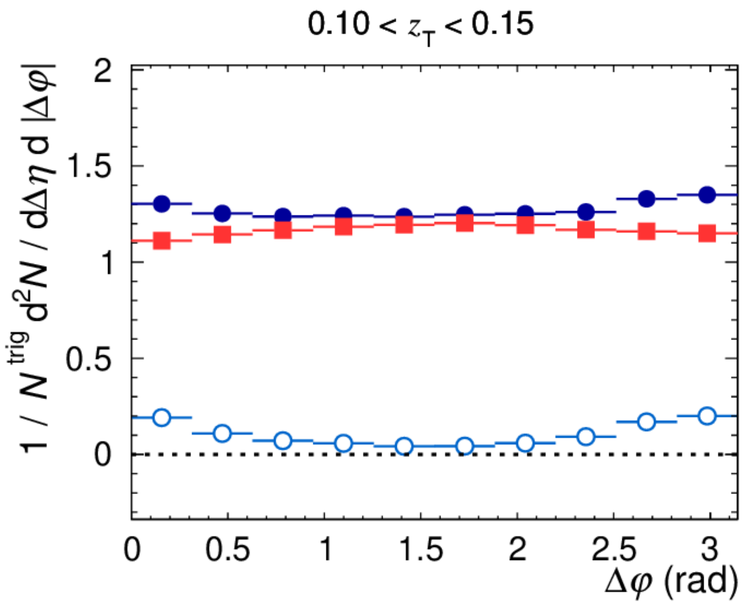
Isolated γ-hadron correlations in Pb–Pb: $D(z_T)$

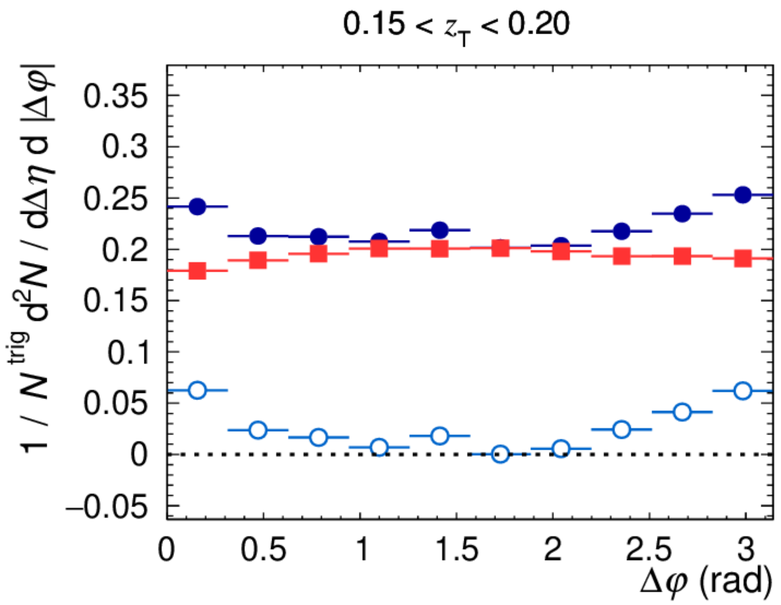


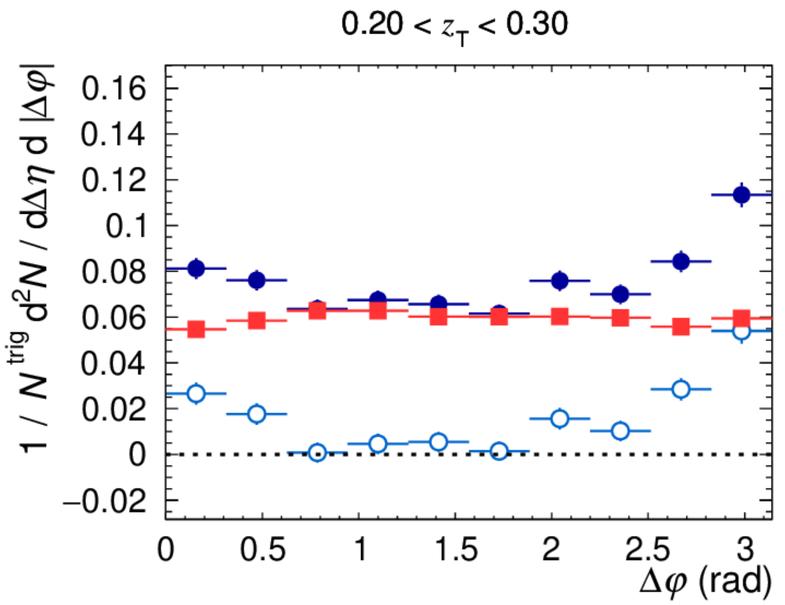
Isolated γ-hadron correlations in Pb–Pb: $D(z_T)$

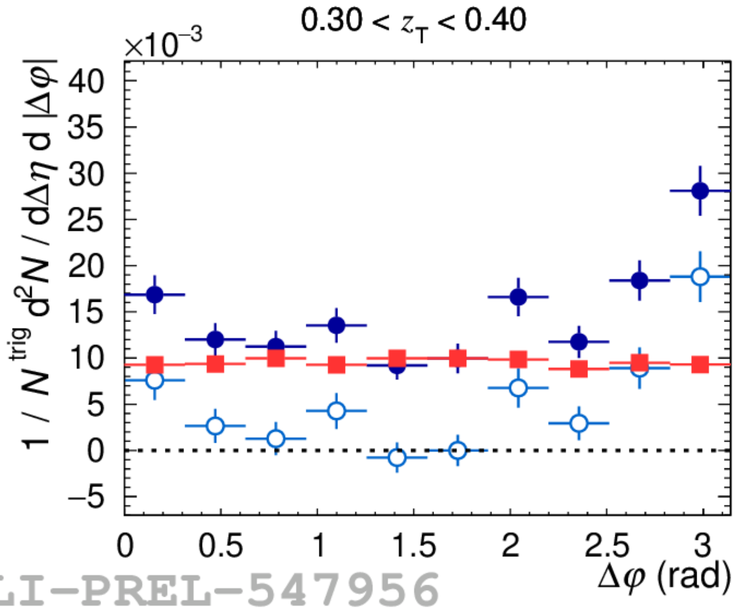


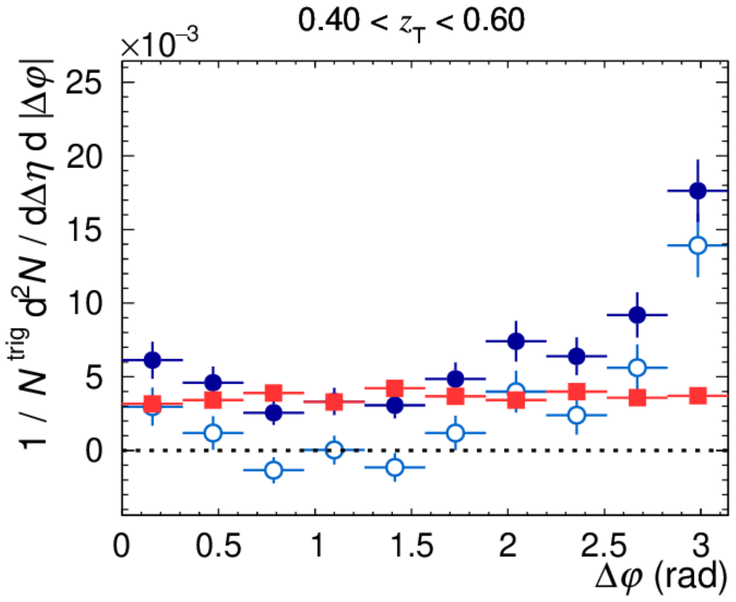
Isolated γ-hadron correlations in Pb–Pb: $D(z_T)$











ALICE preliminary

30–50% Pb–Pb, $\sqrt{s_{NN}}$ = 5.02 TeV, $|\eta^{trig}| < 0.67$

$20 < p_T^{trig} < 25$ GeV/c ⊗ $p_T^h > 0.5$ GeV/c

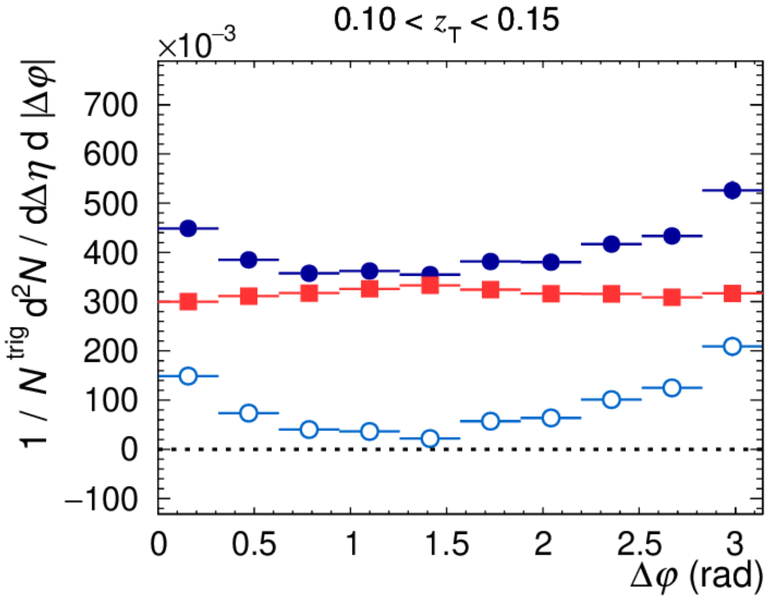
$cluster^{iso}_{narrow}$: $0.10 < \sigma^2_{long,\,5x5} < 0.30$

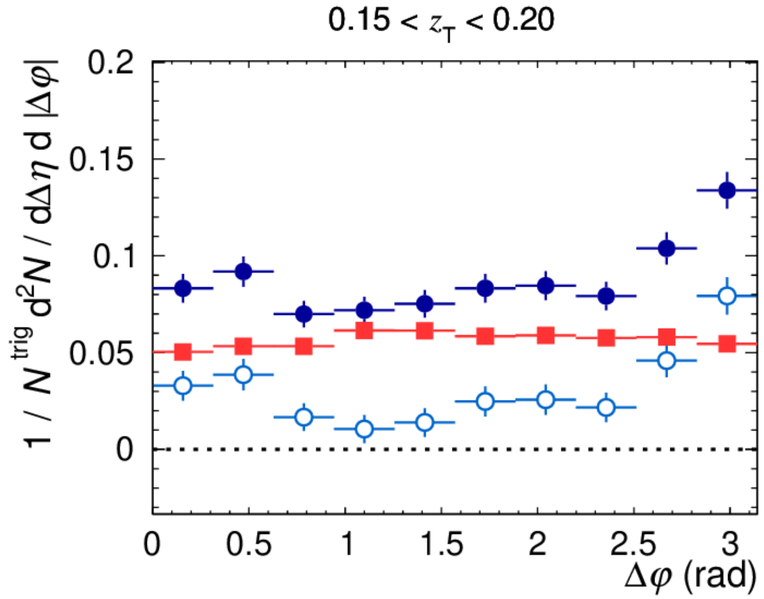
Same Event

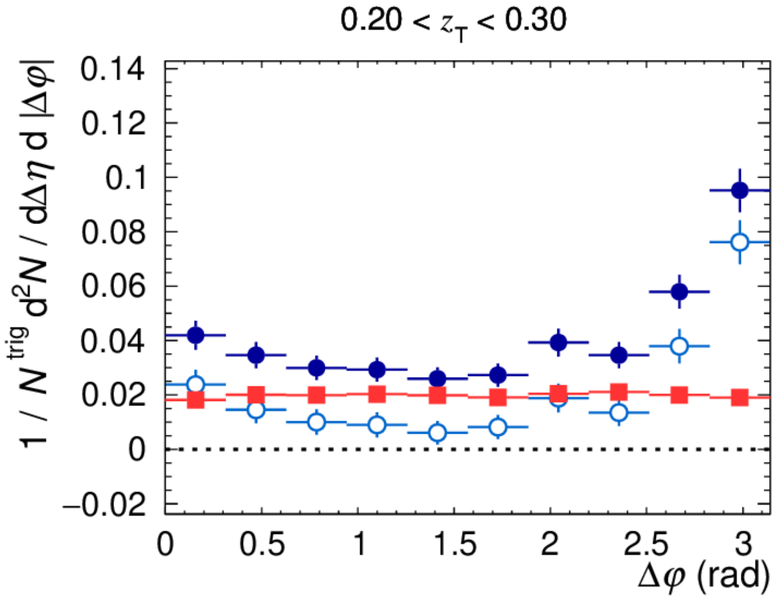
Mixed Event

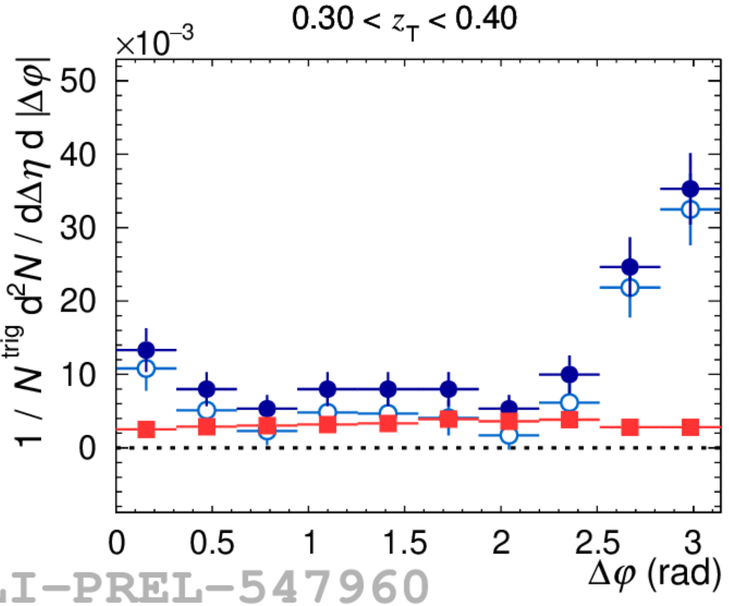
Same Event - Mixed Event

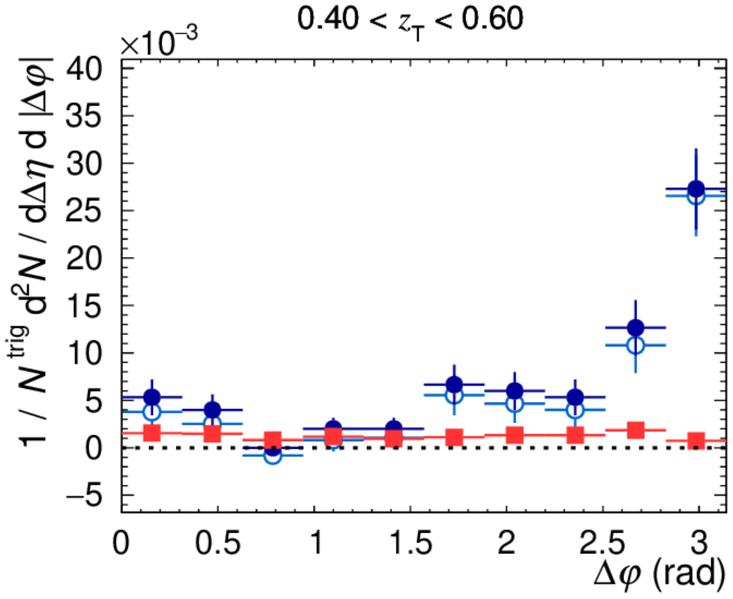
Isolated γ-hadron correlations in Pb–Pb: $D(z_T)$











ALICE preliminary

50–90% Pb–Pb, $\sqrt{s_{NN}}$ = 5.02 TeV, $|\eta^{trig}| < 0.67$

$20 < p_T^{trig} < 25$ GeV/c ⊗ $p_T^h > 0.5$ GeV/c

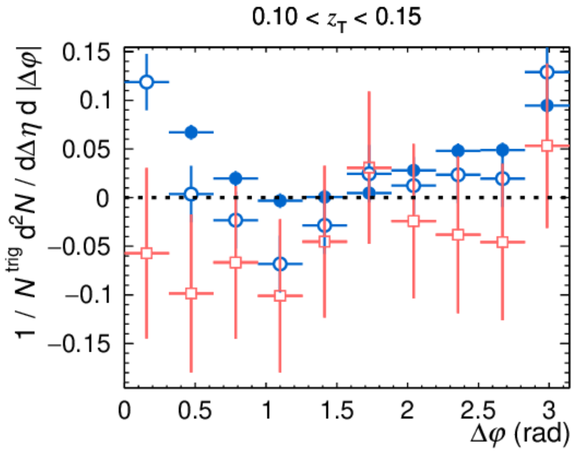
$cluster^{iso}_{narrow}$: $0.10 < \sigma^2_{long,\,5x5} < 0.30$

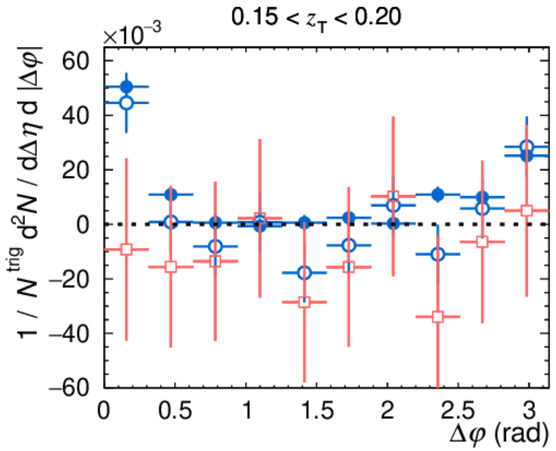
Same Event

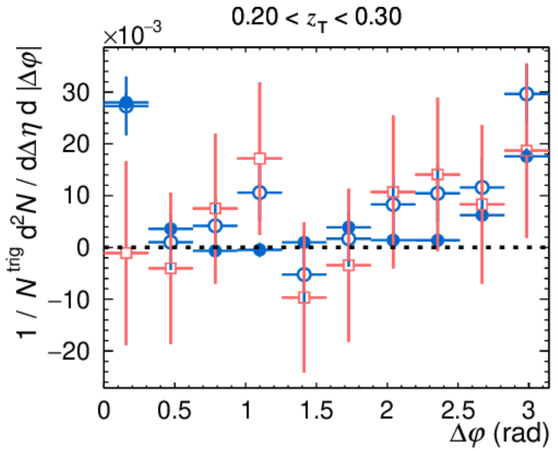
Mixed Event

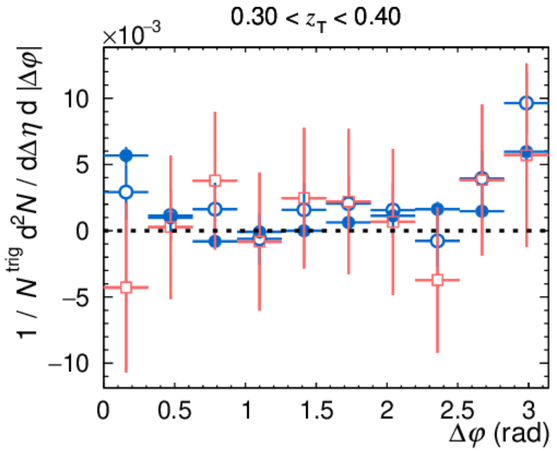
Same Event - Mixed Event

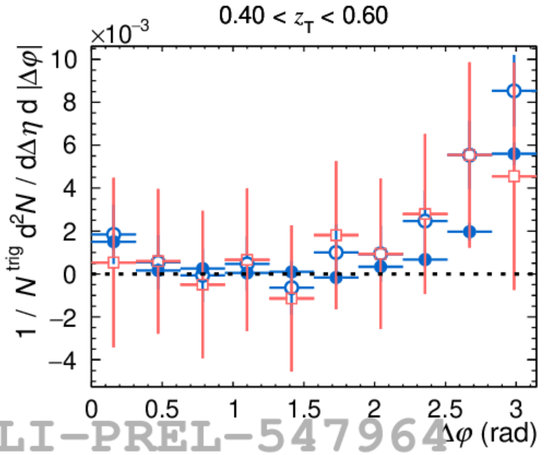
Isolated γ-hadron correlations in Pb–Pb: $D(z_T)$

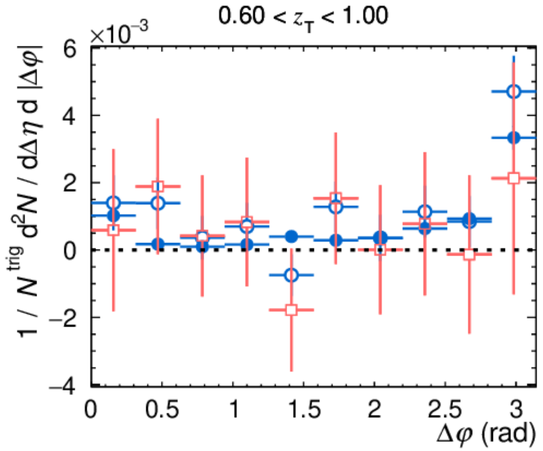












ALICE preliminary

0–10% Pb–Pb, $\sqrt{s_{NN}}$ = 5.02 TeV, $|\eta^{trig}| < 0.67$

$20 < p_T^{trig} < 25$ GeV/c ⊗ $p_T^h > 0.5$ GeV/c

$\text{cluster}^{iso}_{narrow}$: $0.10 < \sigma^2_{long,\,5x5} < 0.30$

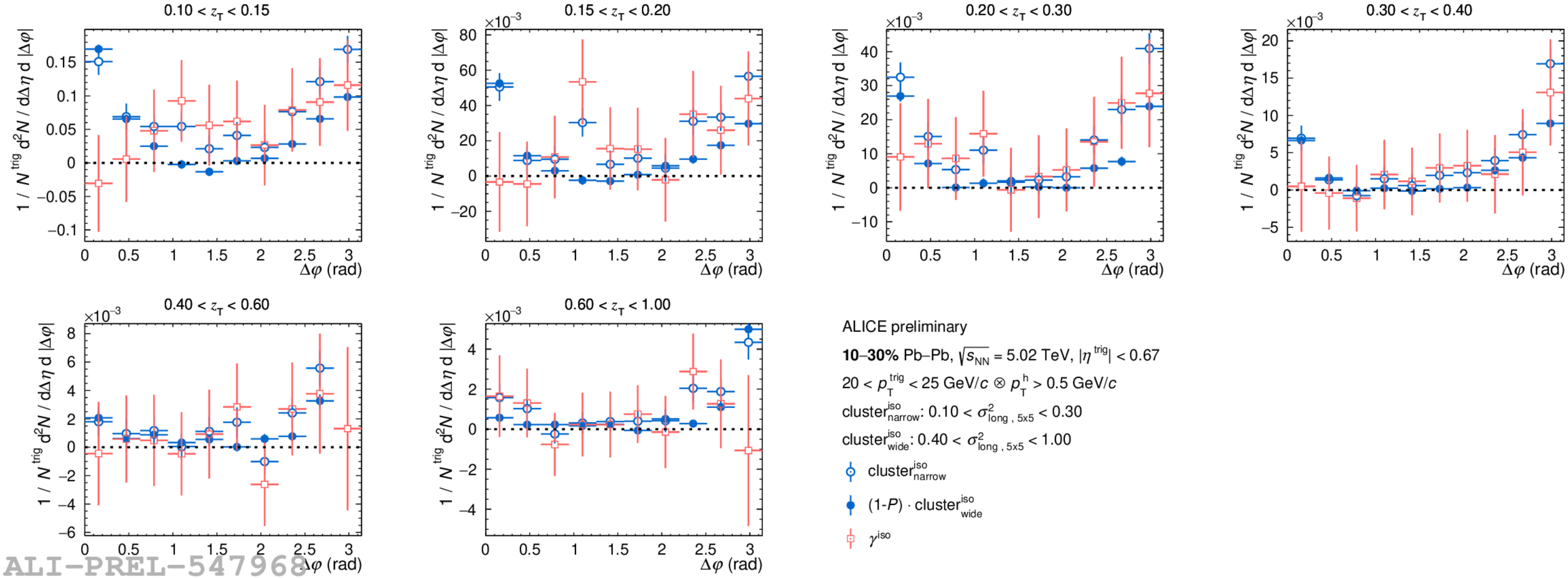
$\text{cluster}^{iso}_{wide}$: $0.40 < \sigma^2_{long,\,5x5} < 1.00$

$\text{cluster}^{iso}_{narrow}$

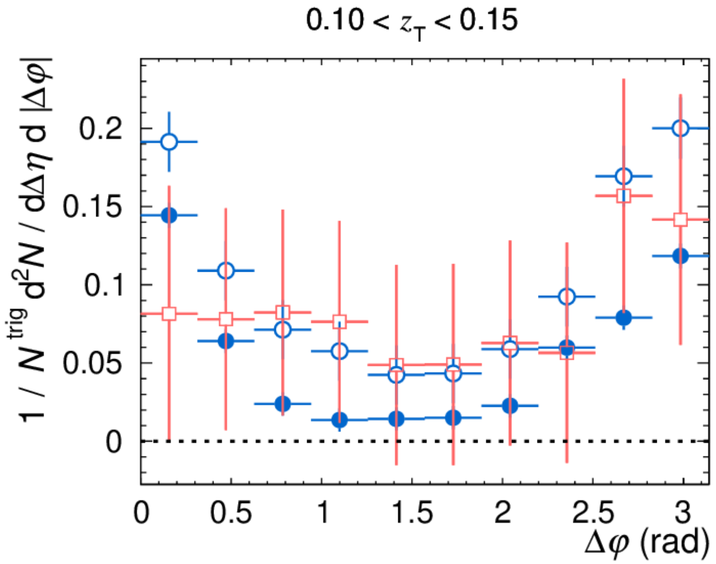
(1-P) · $\text{cluster}^{iso}_{wide}$

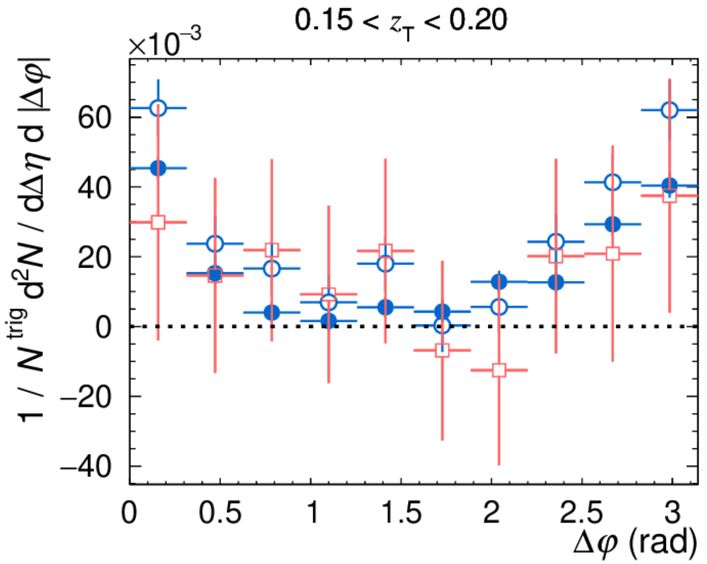
γ^{iso}

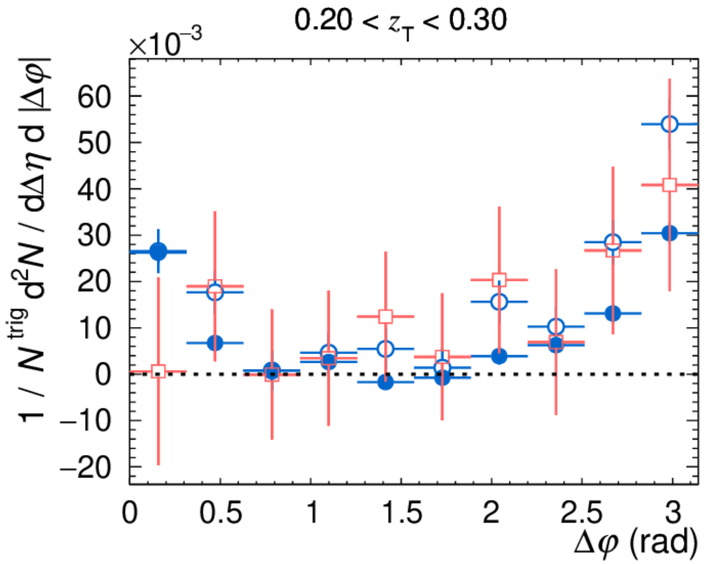
Isolated γ-hadron correlations in Pb–Pb: $D(z_T)$

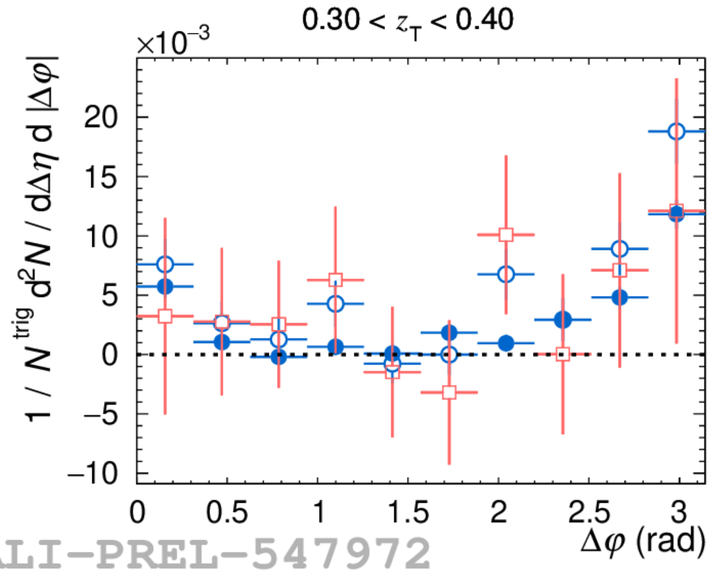


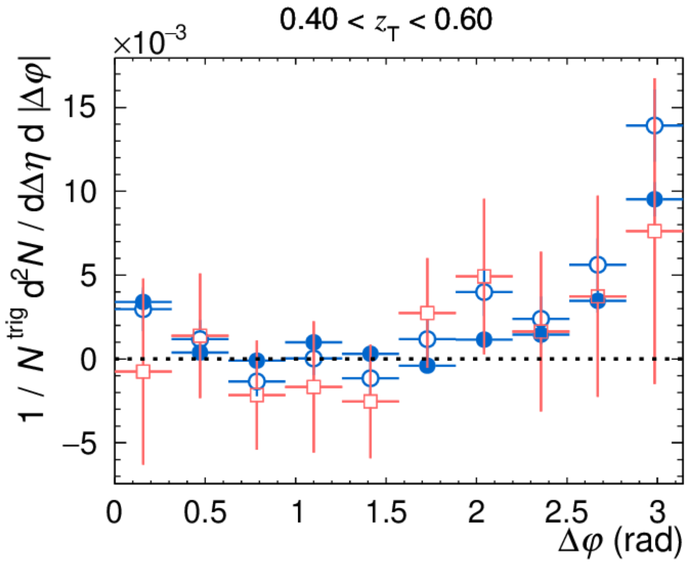
Isolated γ-hadron correlations in Pb–Pb: $D(z_T)$











ALICE preliminary

30–50% Pb–Pb, $\sqrt{s_{NN}}$ = 5.02 TeV, $|\eta^{trig}| < 0.67$

$20 < p_T^{trig} < 25$ GeV/c ⊗ $p_T^h > 0.5$ GeV/c

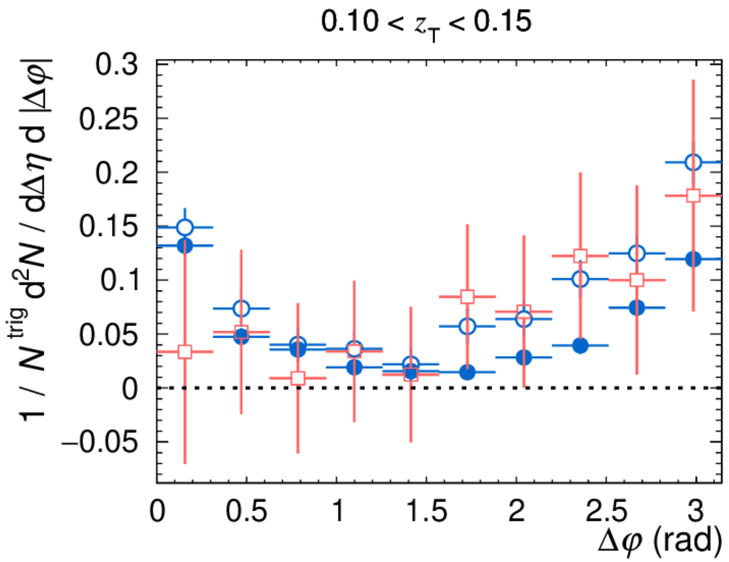
$cluster^{iso}_{narrow}$: $0.10 < \sigma^2_{long,\,5x5} < 0.30$

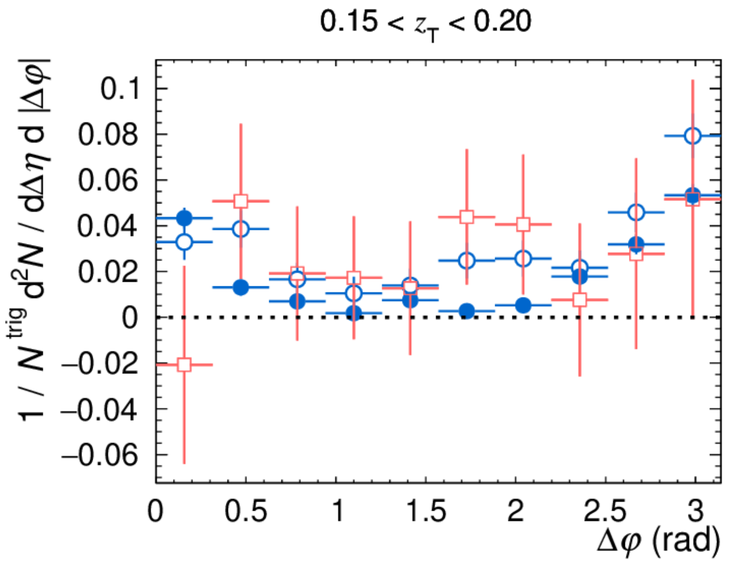
$cluster^{iso}_{wide}$: $0.40 < \sigma^2_{long,\,5x5} < 1.00$

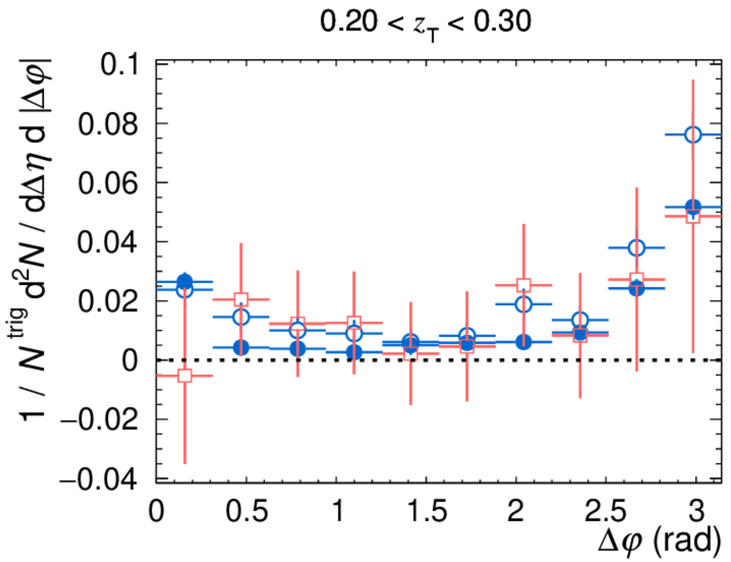
- $cluster^{iso}_{narrow}$
- $(1\text{-}P) \cdot cluster^{iso}_{wide}$
- γ^{iso}

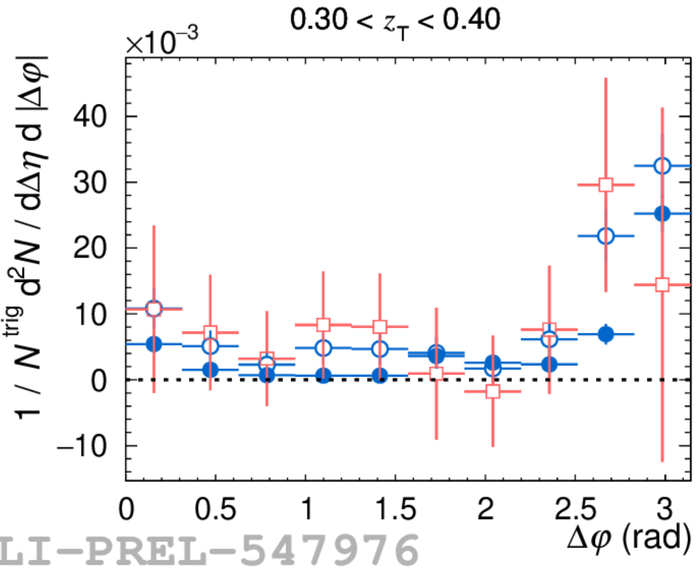
ALI-PREL-547972

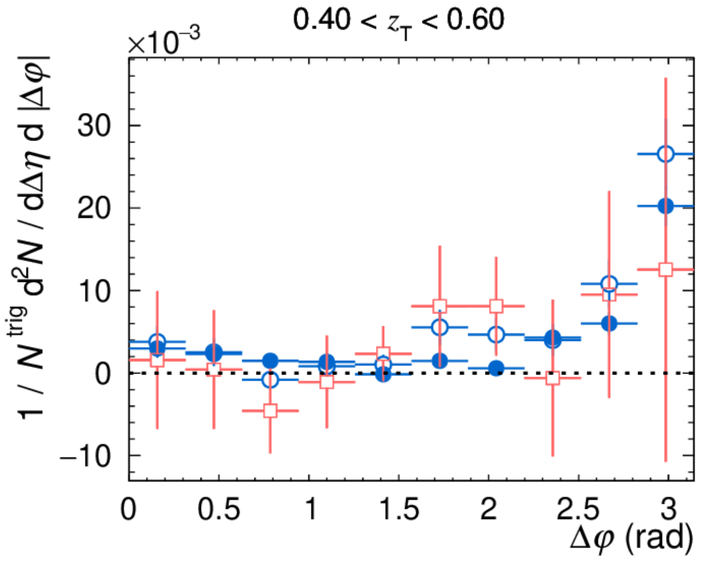
Isolated γ-hadron correlations in Pb–Pb: $D(z_T)$











ALICE preliminary

50–90% Pb–Pb, $\sqrt{s_{NN}}$ = 5.02 TeV, $|\eta^{trig}| < 0.67$

$20 < p_T^{trig} < 25$ GeV/c ⊗ $p_T^h > 0.5$ GeV/c

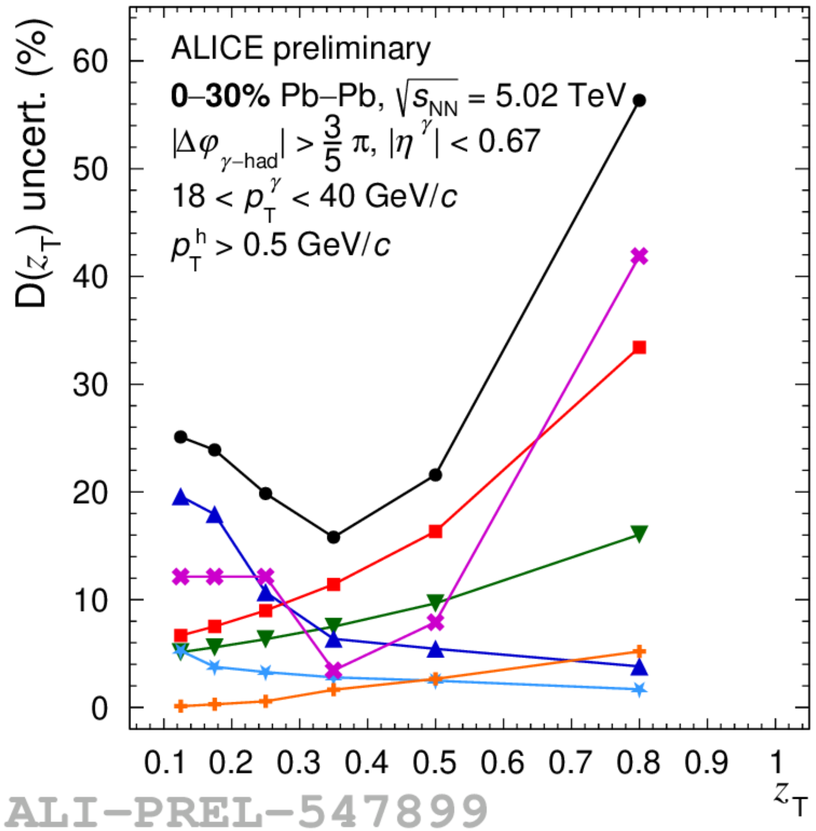
$cluster^{iso}_{narrow}$: $0.10 < \sigma^2_{long,\,5x5} < 0.30$

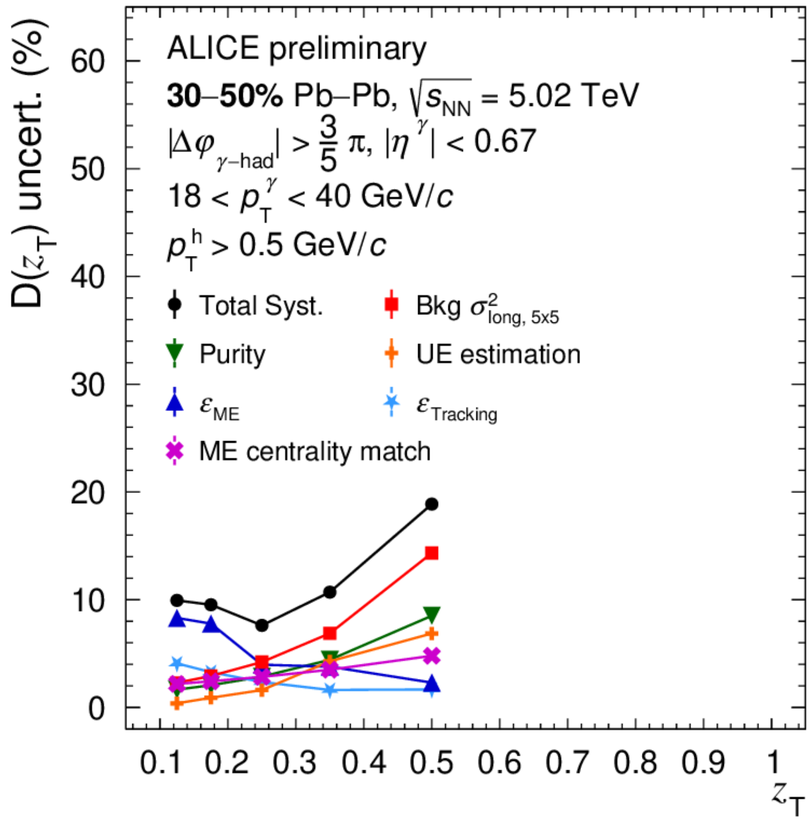
$cluster^{iso}_{wide}$: $0.40 < \sigma^2_{long,\,5x5} < 1.00$

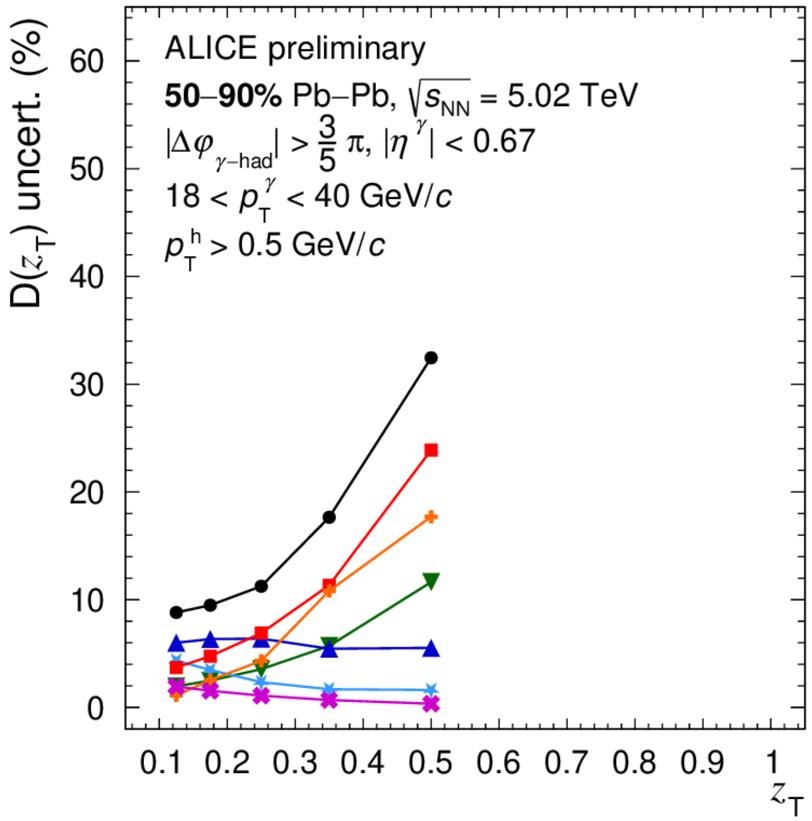
- $cluster^{iso}_{narrow}$
- (1-P) · $cluster^{iso}_{wide}$
- γ^{iso}

ALI-PREL-547976

Isolated γ-hadron correlation uncertainty: $D(z_T)$







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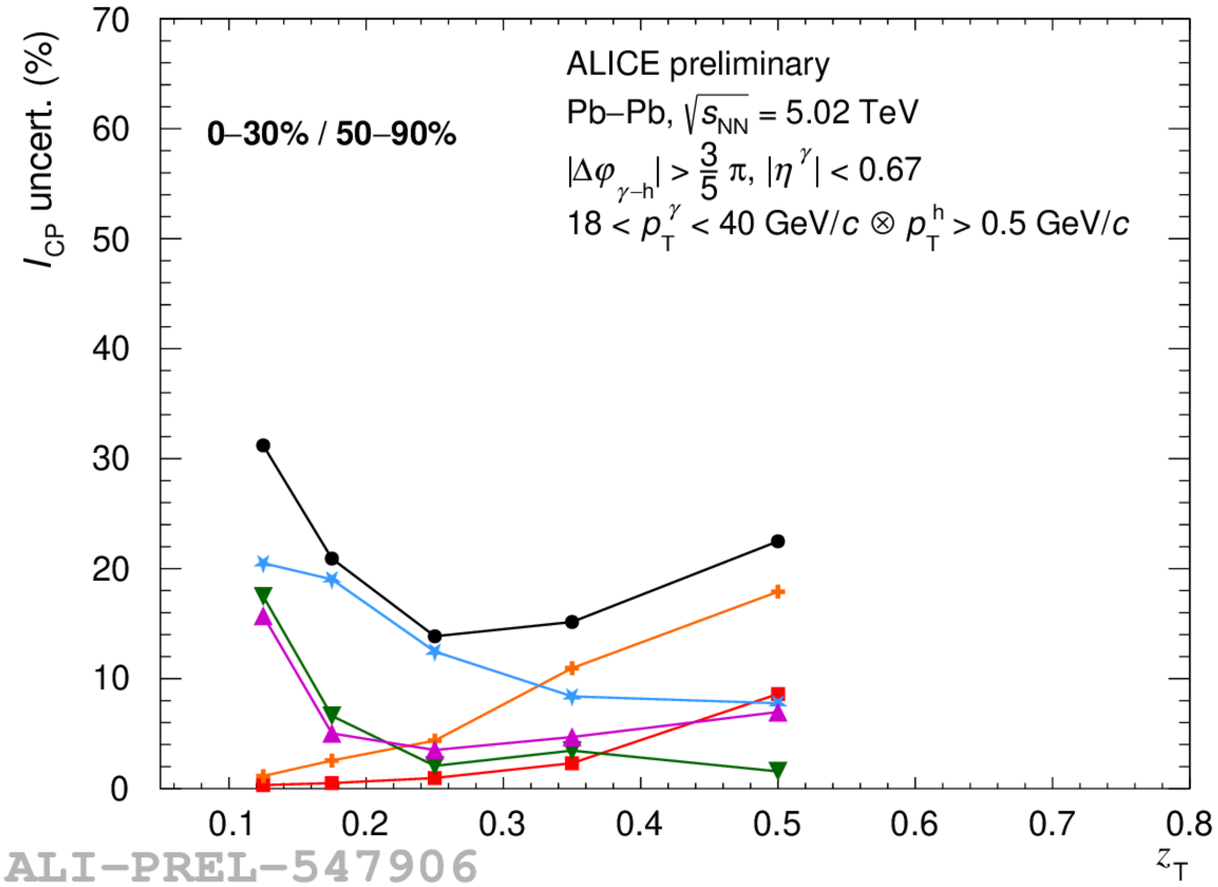
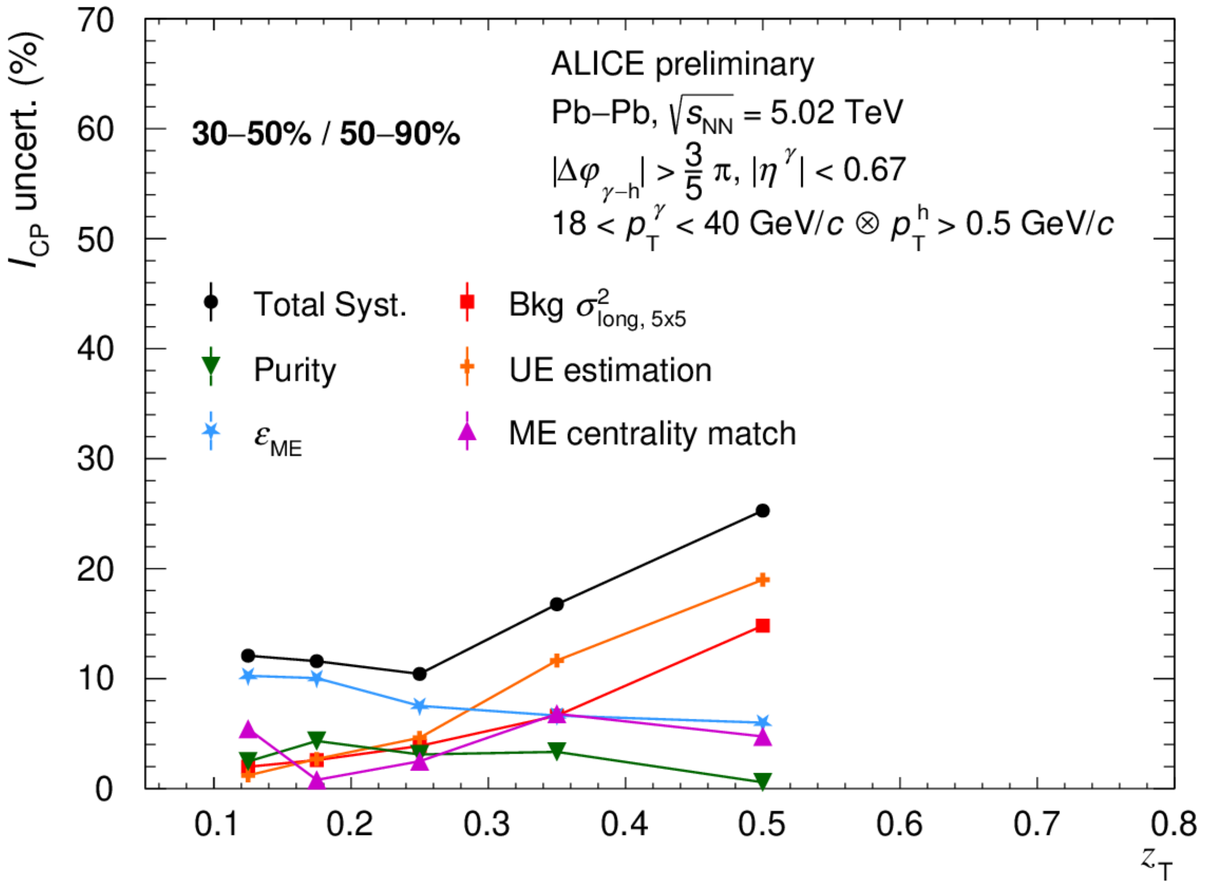
Isolated γ-hadron correlation uncertainty: I_{CP}





Isolated γ cross section *R* ratio in ATLAS, pp $\sqrt{s}$ = 13 TeV

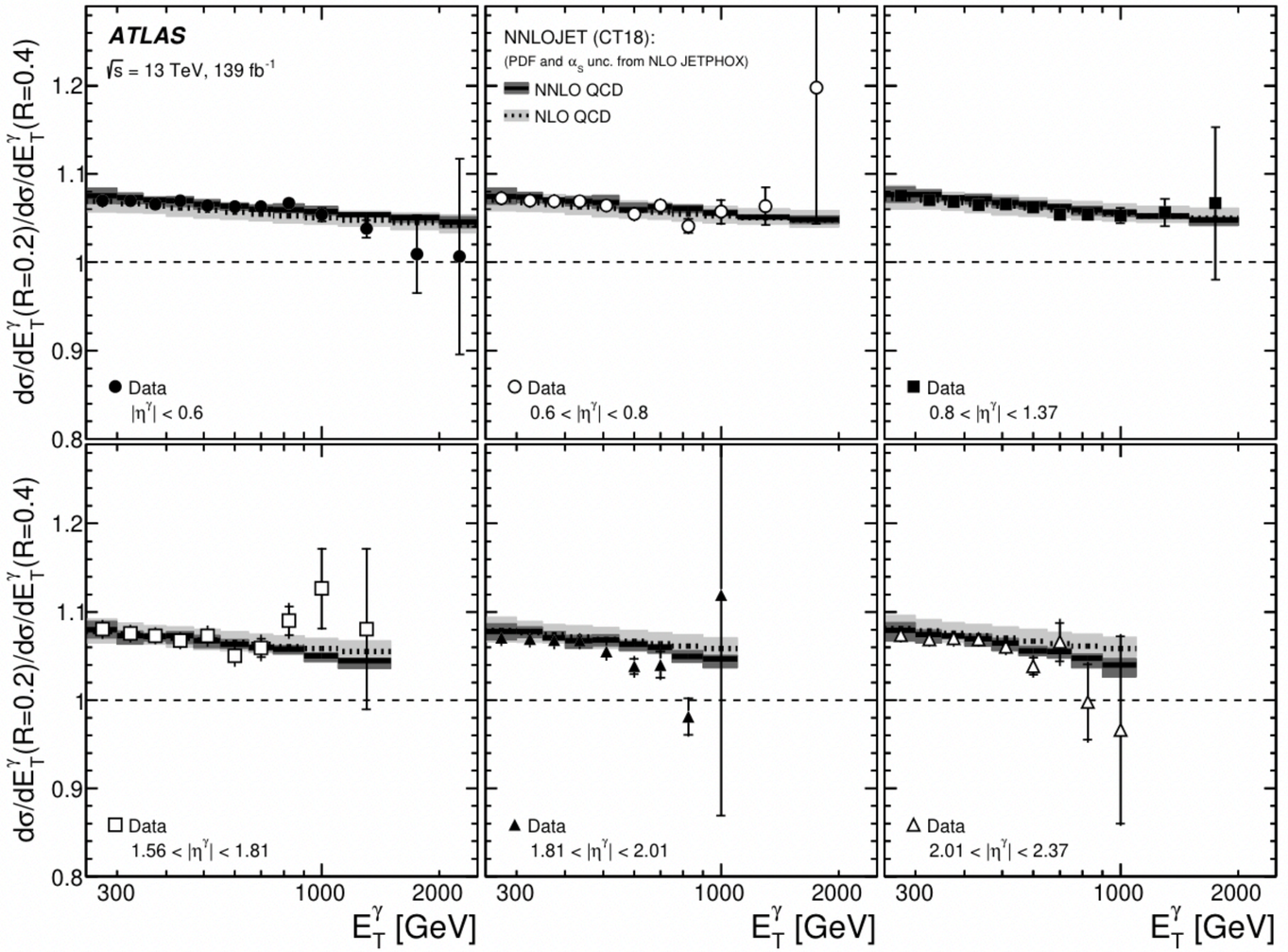


Figure 21: Measured ratios of the differential cross sections for inclusive isolated-photon production for $R = 0.2$ and $R = 0.4$ as functions of E_{T}^{γ} in different η^{γ} regions. The NLO (dotted lines) and NNLO (solid lines) pQCD predictions from NNLOJET based on the CT18 PDF set are also shown. The inner (outer) error bars represent the statistical uncertainties (statistical and systematic uncertainties added in quadrature) and the shaded bands represent the theoretical uncertainties. For some of the points, the inner and outer error bars are smaller than the marker size and, thus, not visible.

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