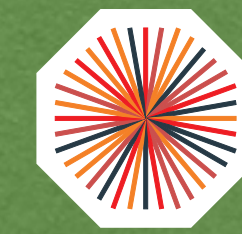


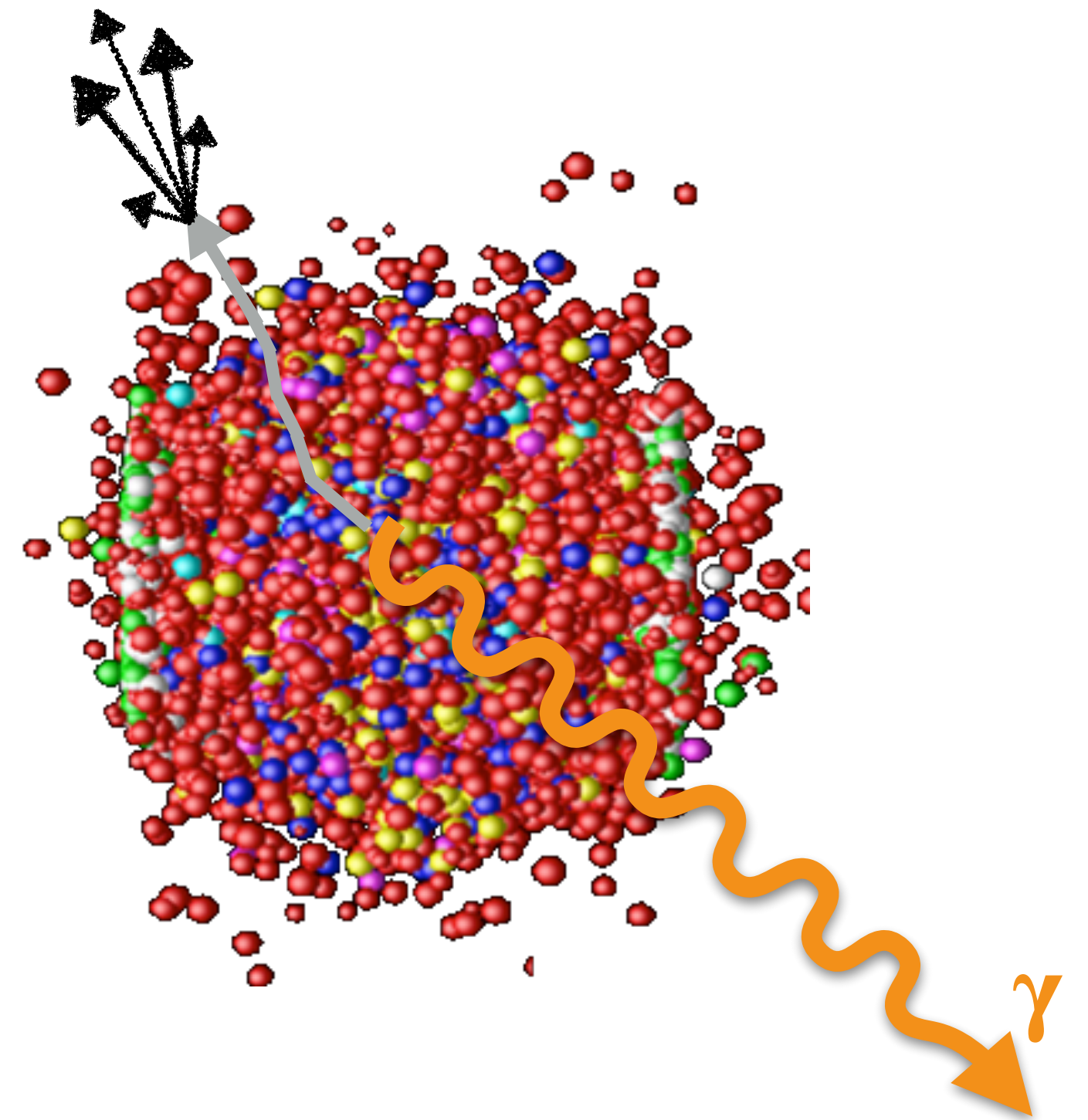
Status of isolated prompt γ measurements in



ALICE: LHC Run 1 & Run 2

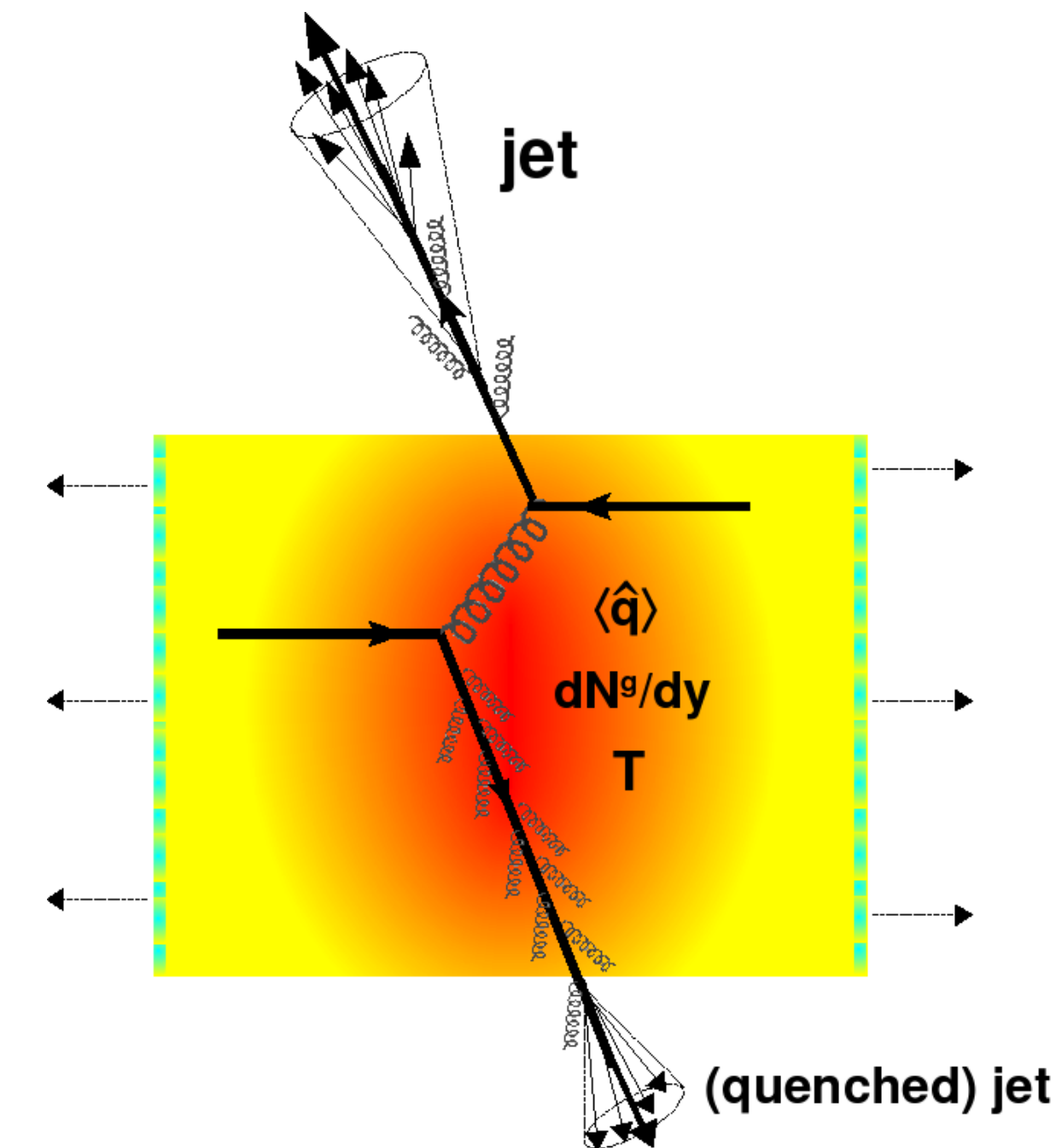
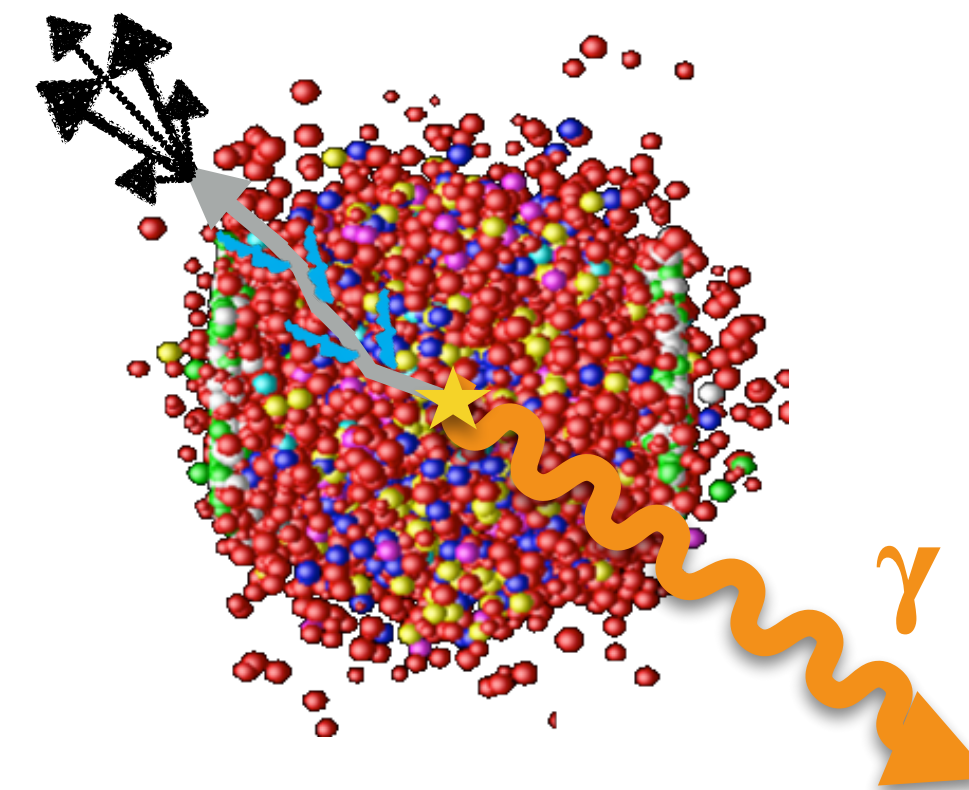


- ➔ Differential p_T cross section
 - * pp at $\sqrt{s} = 13$ TeV: [Eur. Phys. J. C 85 \(2025\) 98](#)
 - * pp at $\sqrt{s} = 7$ TeV: [Eur. Phys. J. C 79 \(2019\) 896](#)
 - * pp at $\sqrt{s} = 8$ TeV & p-Pb at $\sqrt{s_{NN}} = 5.02$ & 8.16 TeV: [Eur. Phys. J. C 85 \(2025\) 1407](#)
 - * pp & Pb-Pb at $\sqrt{s_{NN}} = 5.02$ TeV: [Eur. Phys. J. C 85 \(2025\) 553](#), [ALICE-PUBLIC-2024-003](#), "CERN EP newsletter" April 2025
- ➔ Isolated γ -hadron correlation
 - * pp & p-Pb at $\sqrt{s_{NN}} = 5.02$ TeV: [Phys. Rev. C 102 \(2020\) 044908](#)
 - * Pb-Pb at $\sqrt{s_{NN}} = 5.02$ TeV: [arXiv:2605.02342](#), [ALICE-PUBLIC-2026-001](#)



Probing the QGP in heavy-ion collisions

- ➔ In heavy-ion collisions at the LHC, a dense, hot and strongly interacting coloured QCD medium is produced
→ the “*quark-gluon plasma*” (QGP)
- ➔ The ALICE experiment aims at the characterisation of the QGP (temperature, energy density, etc., the equation of state) via the measurements of different types of probes
- ➔ **Hard probes:** high- E partons (quarks and gluons) and electroweak particles (γ , Z^0 & $W^\pm$) emitted in the first stages of the collision:
→ “*bullets*” passing through the QGP
 - ⦿ **Partons lose energy** via radiational (gluonstrahlung) or collisional processes
→ “*jet quenching*”
 - ⦿ γ , Z^0 & $W^\pm$ are **colourless**: not affected by the QGP
→ **Candle particles**
→ **Associated with a back-to-back parton**



Observation of QGP effects: The nuclear modification factor

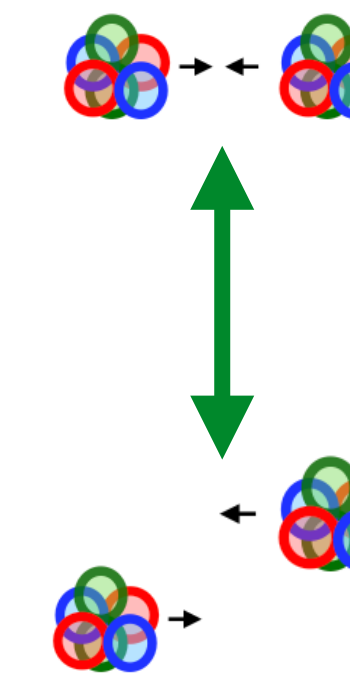
→ Consequence of jet-quenching: modification of jets and high p_T particle production cross sections with respect to pp collisions

→ Observation via the nuclear modification factor

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

$R_{AA} > 1$	Generation in the medium: Thermal γ
$R_{AA} = 1$	Transparent to the medium: Prompt γ
$R_{AA} < 1$	“Suppressed” by the medium: Coloured partons

If no QGP, a Pb–Pb collision is roughly $N_{\text{coll}} \times$ pp collisions



Centrality	$\langle N_{\text{coll}} \rangle$
0–10%	1572 ± 17
10–30%	783 ± 7
30–50%	265 ± 3
50–70%	65.9 ± 1.2
70–90%	10.9 ± 0.2

$\sqrt{s_{NN}} = 5.02 \text{ TeV}$

→ Collision centrality (impact parameter b) variation: Change of the QGP volume → change of R_{AA}

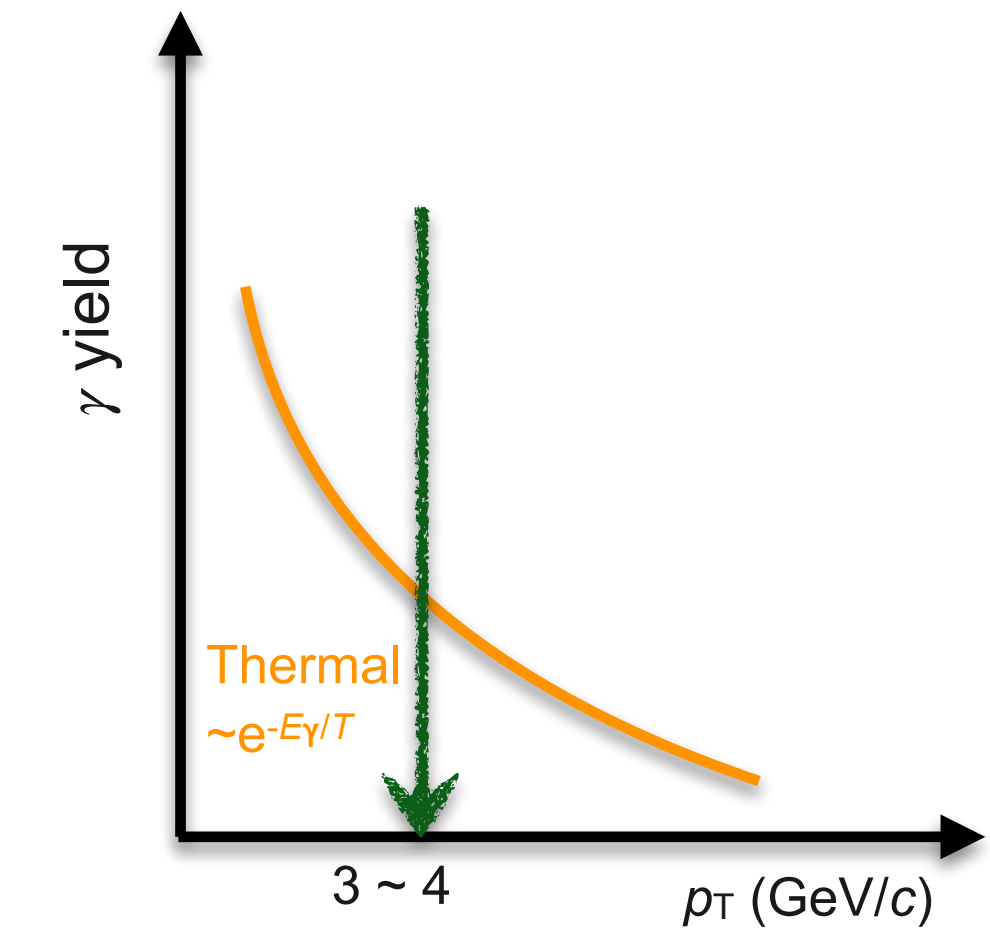
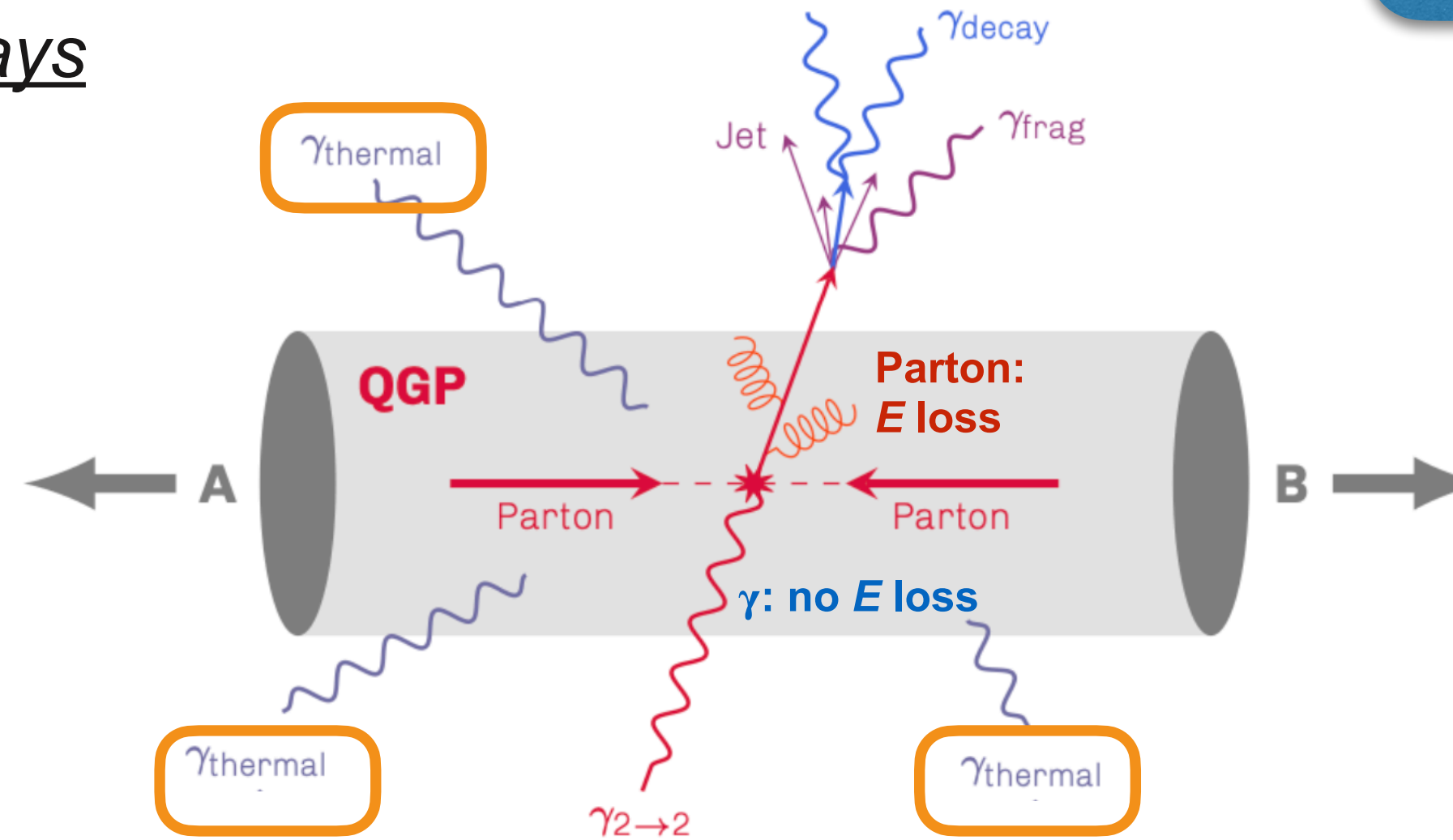
- Higher centrality (larger b) implies smaller modification of the hadronic cross section

Motivation: γ 's as probes of the QGP

- 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

- ➔ **Direct thermal γ** : $R_{AA} \gg 1$
 - QGP thermal radiation
 - Measure **T** & **time/size evolution**

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



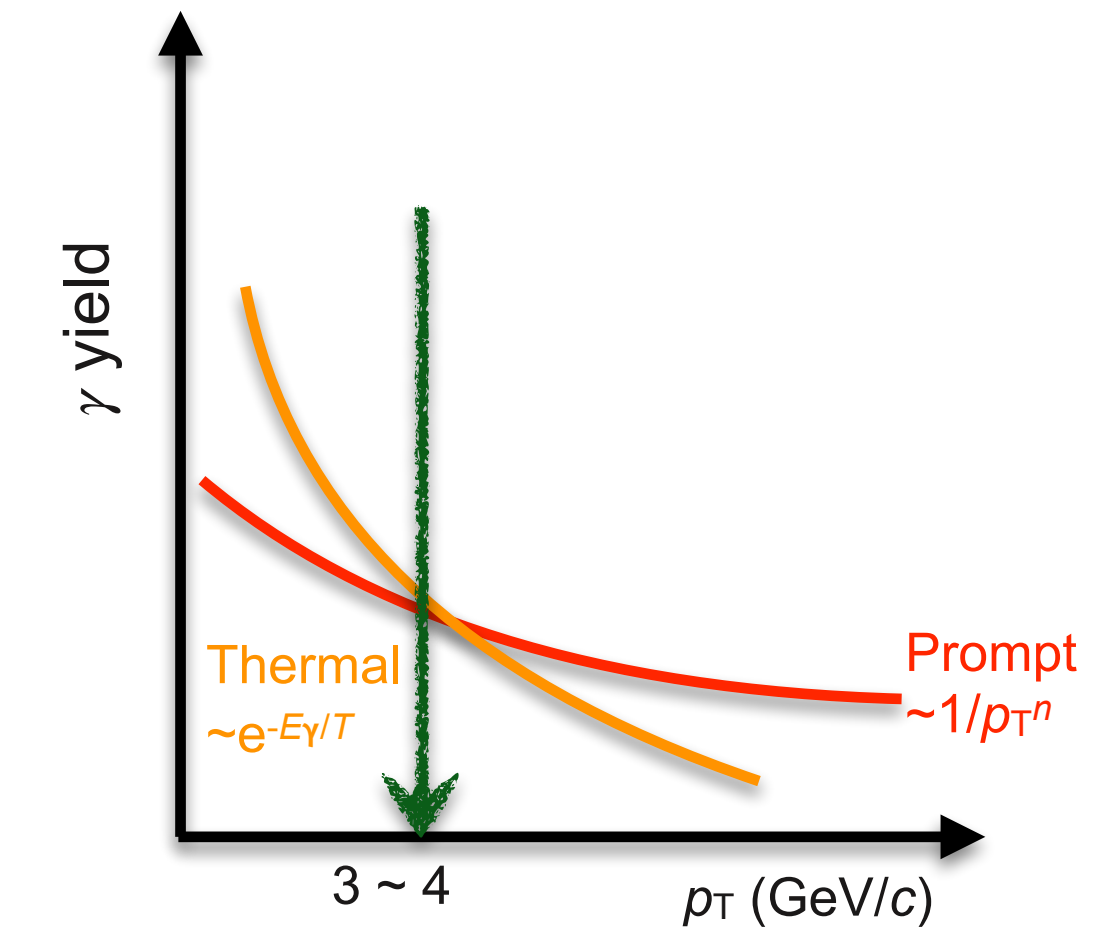
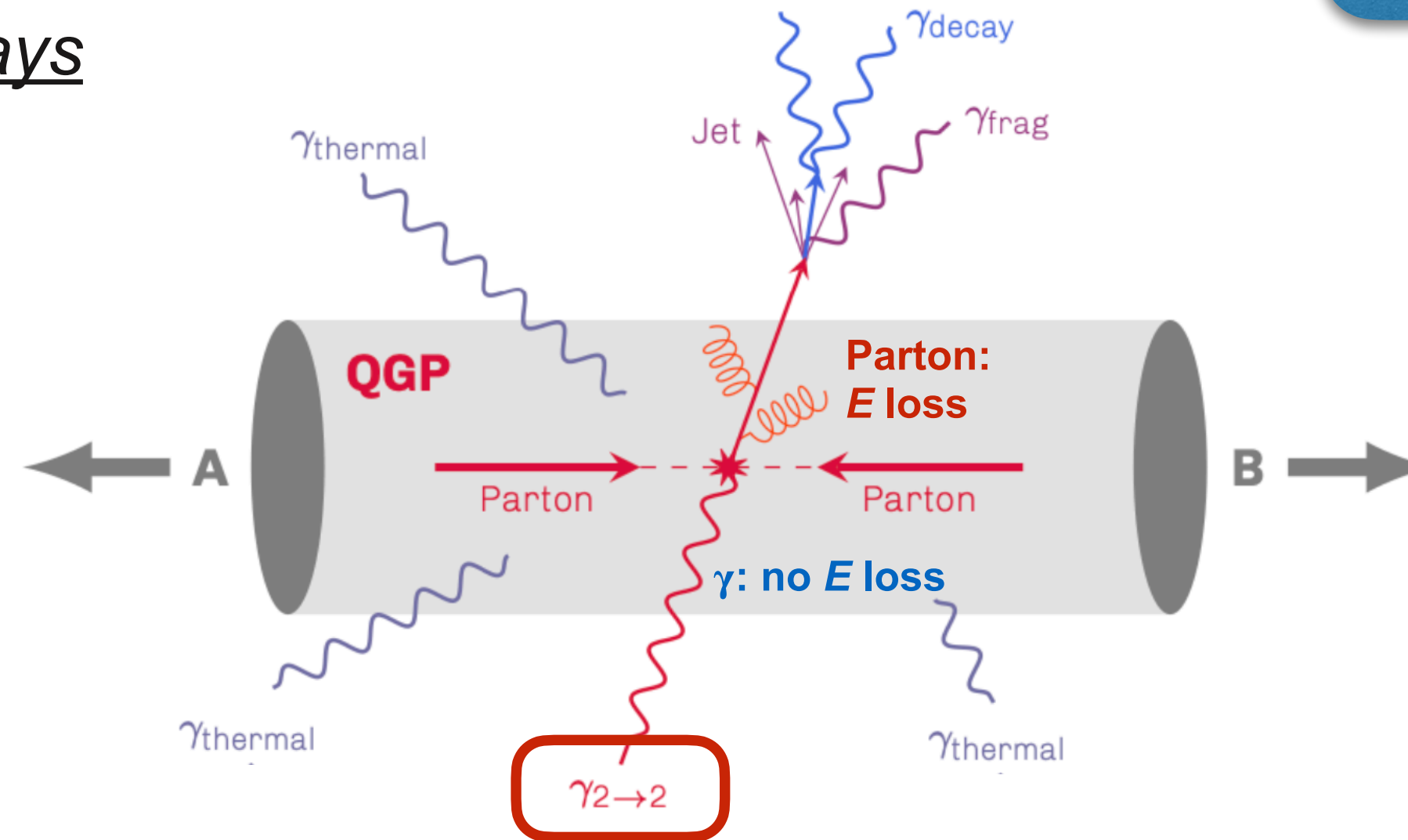
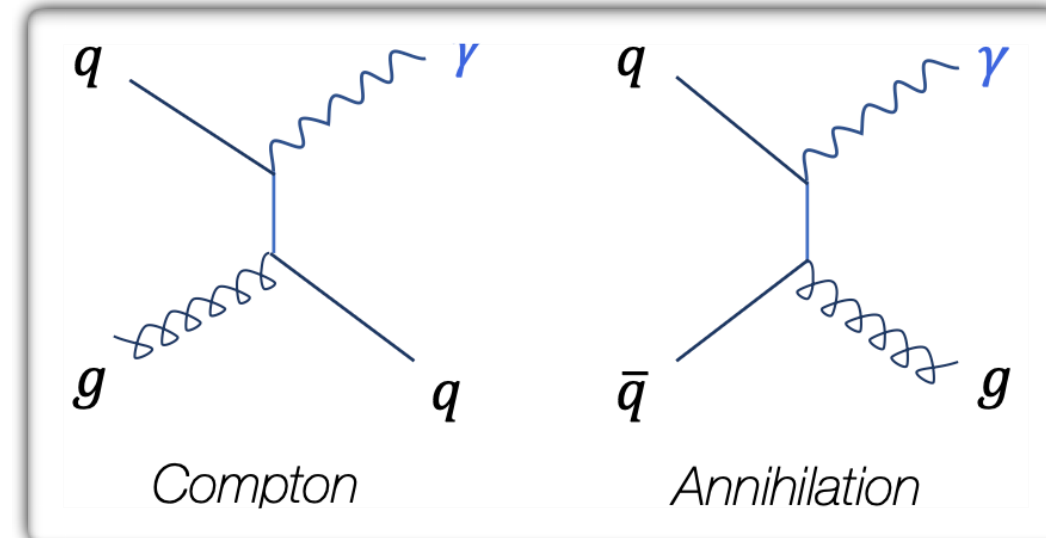
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 - QGP thermal radiation
 - Measure T & time/size evolution

- ➔ **Direct prompt γ** : $R_{AA} \approx 1$
 - Initial hard scattering, processes at LO:



$$d\sigma_{AB \rightarrow h}^{\text{hard}} = \underbrace{f_{a/A}(x_1, Q^2)}_{\text{PDFs}} \otimes \underbrace{f_{b/B}(x_2, Q^2)}_{\text{PDFs}} \otimes \underbrace{d\sigma_{ab \rightarrow c}^{\text{hard}}(x_1, x_2, Q^2)}_{\text{Hard scattering (pQCD)}} \otimes \underbrace{D_{c \rightarrow h}(z, Q^2)}_{\text{Fragmentation function (FF)}}$$

- **Test pQCD predictions, constrain (n)PDFs & FF**
 - Cold nuclear matter (nPDF) effects can lead to $R_{AA} \neq 1$
- $p_T^\gamma \simeq p_T^{\text{parton}}$, before parton loses ΔE in QGP
- Measure **FF modifications**, where is the ΔE radiated?

Main focus of this presentation!

Motivation: γ 's as probes of the QGP

- γ are **color neutral: not affected** by “quark-gluon plasma” (QGP) presence in heavy-ion collisions unlike **partons** that **lose energy**
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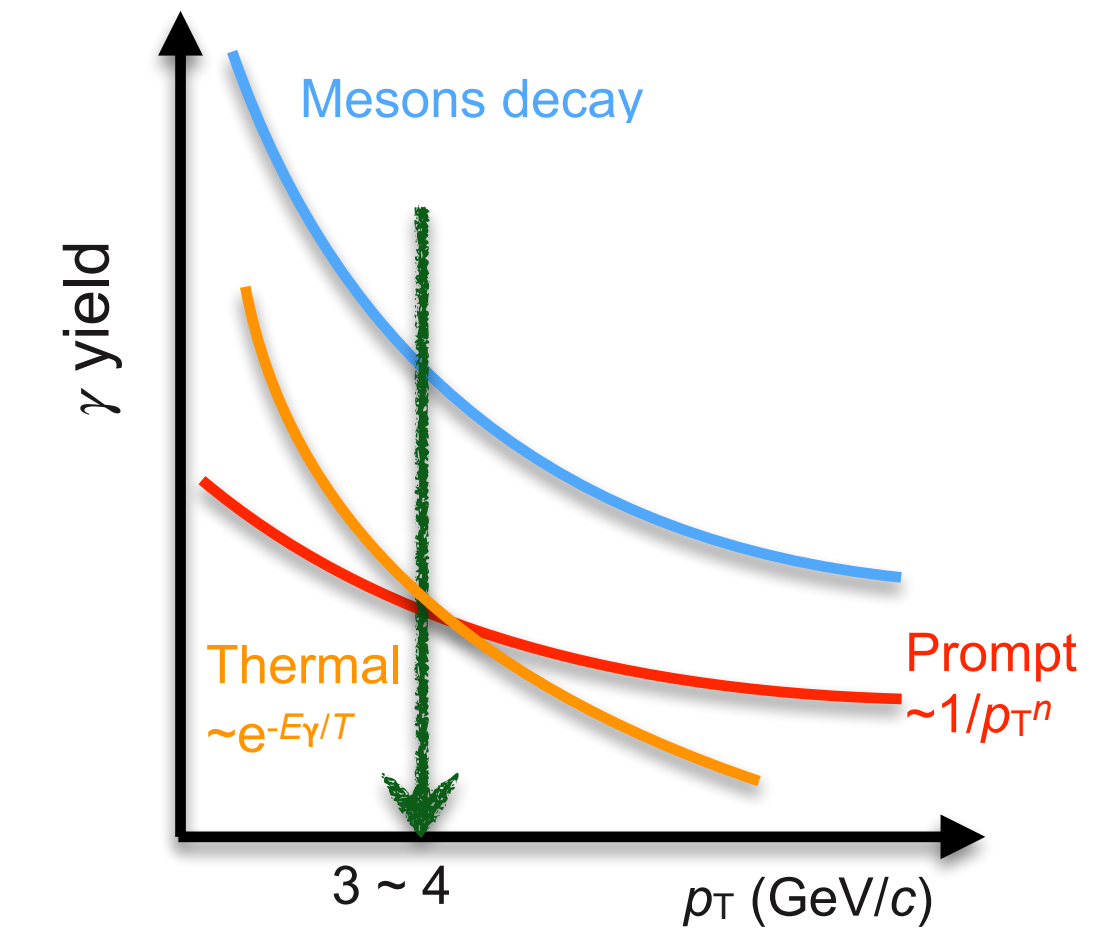
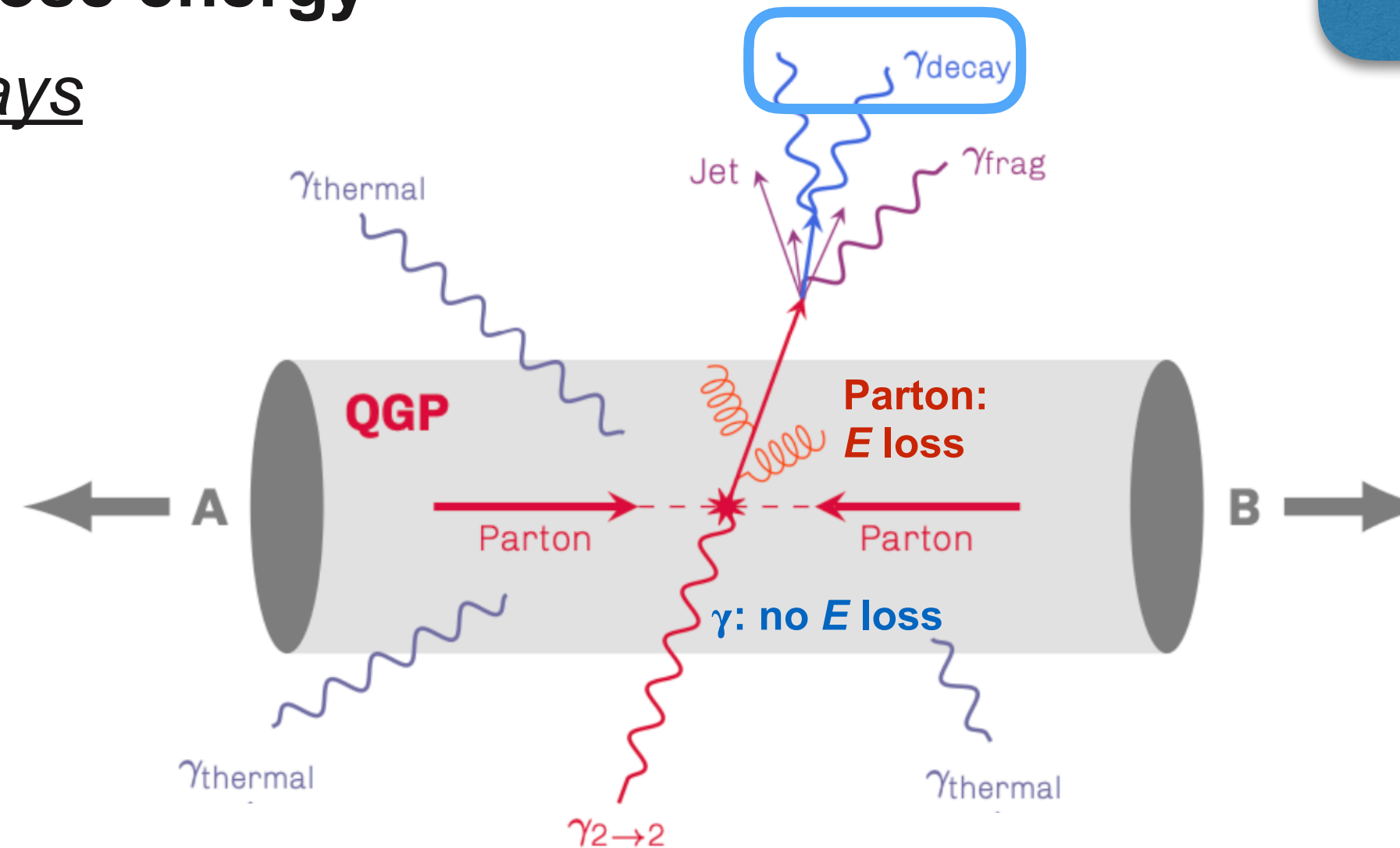
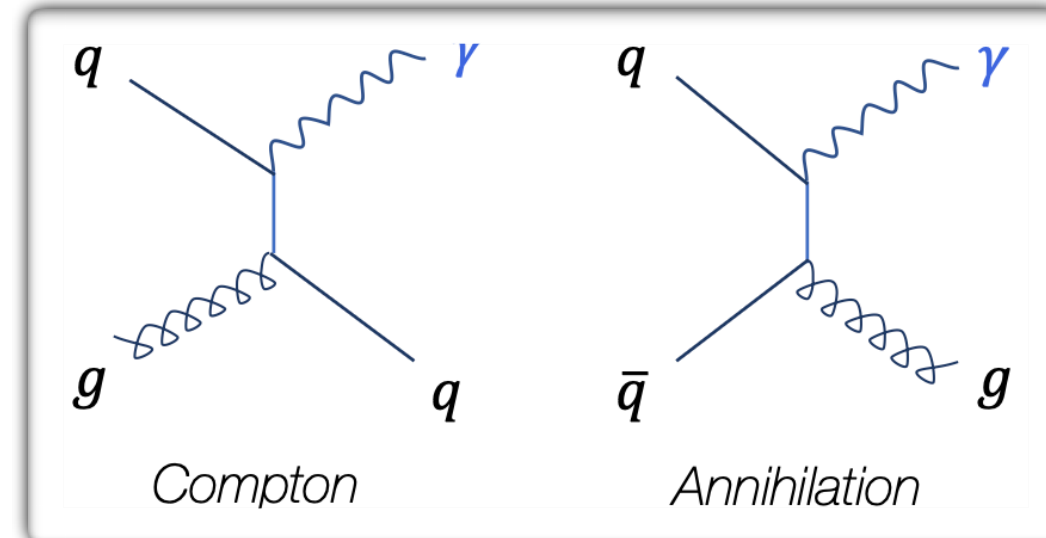
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- Measure T & time/size evolution

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- Measure **FF modifications**, where is the ΔE radiated?

➔ **Decay γ (π^0 & η): $R_{AA} \ll 1$**

- **Main background for direct γ measurements**

Motivation: γ 's as probes of the QGP

- 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

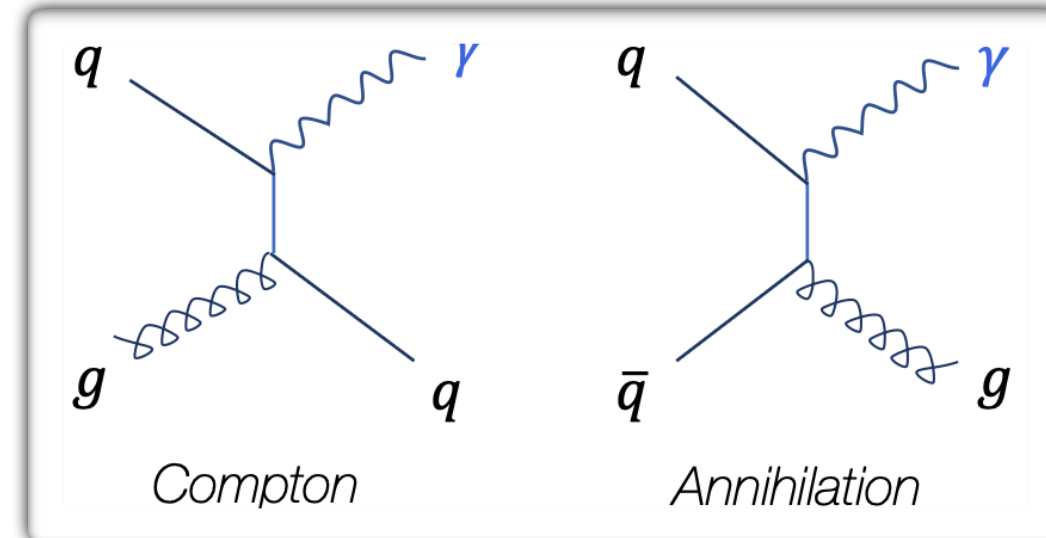
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- Measure T & time/size evolution

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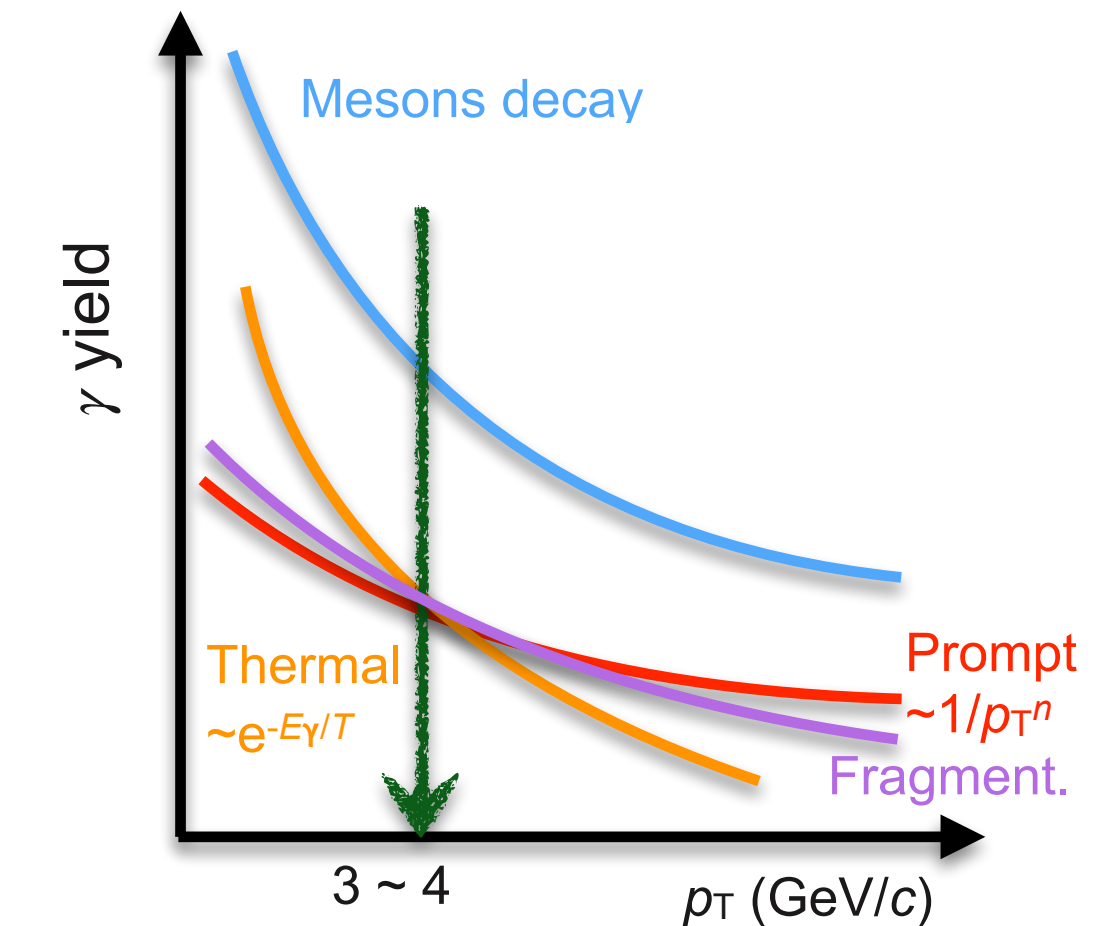
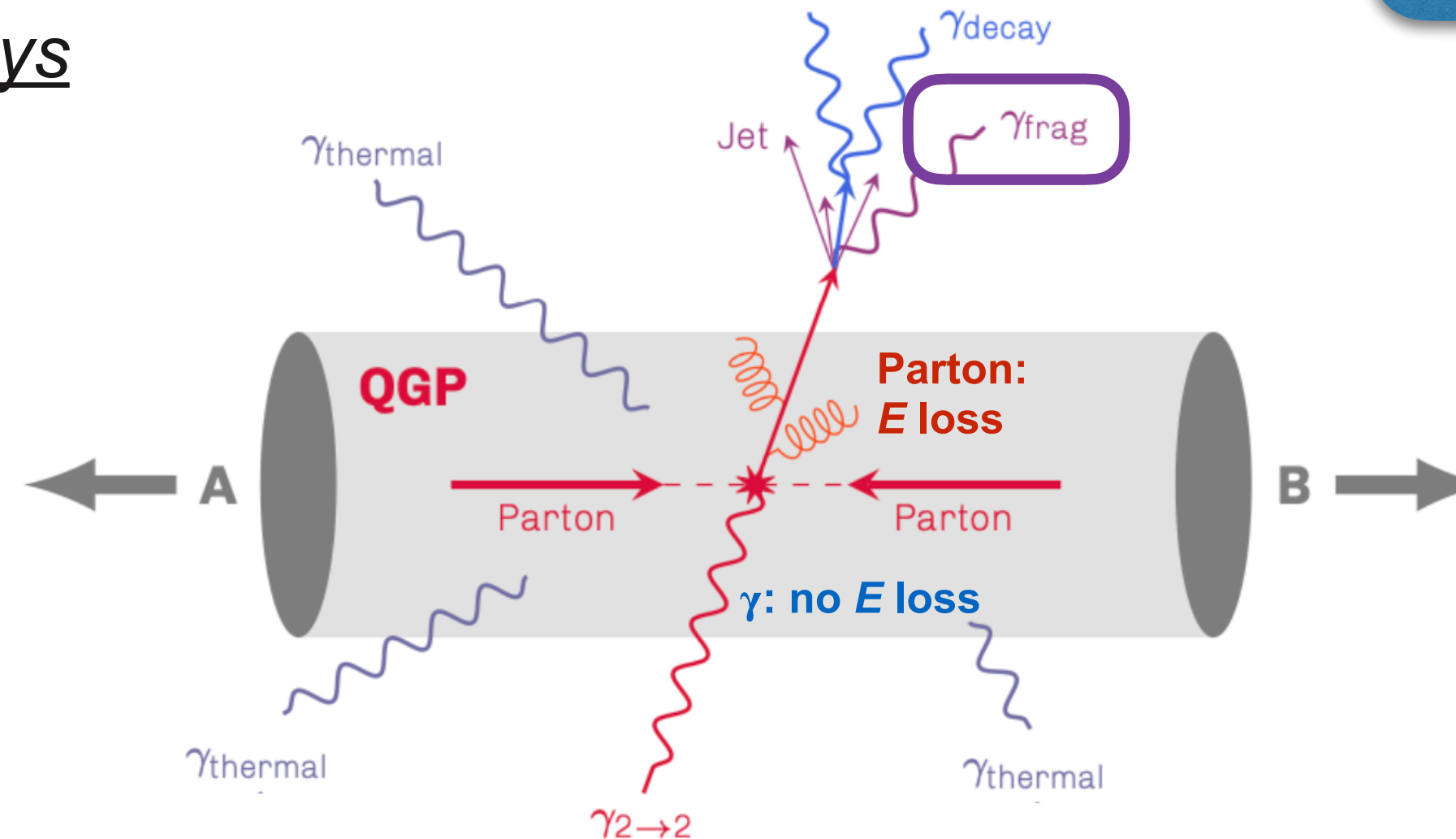
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- $p_T^\gamma \simeq p_T^{\text{parton}}$, before parton loses ΔE in QGP
- Measure **FF modifications**, where is the ΔE radiated?

➔ **Decay γ (π^0 & η):** $R_{AA} \ll 1$

- **Main background for direct γ measurements**



➔ **Other direct γ sources:**

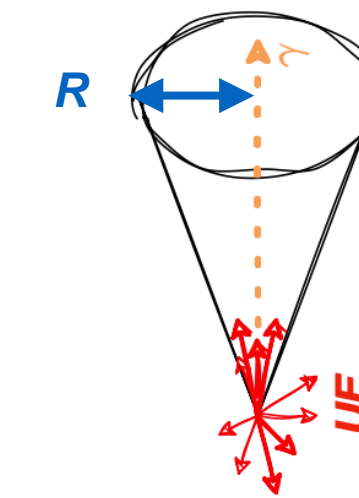
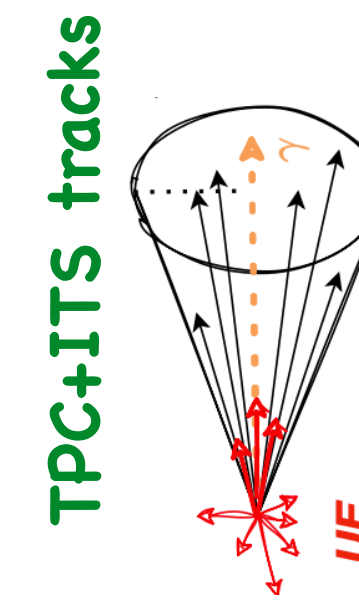
- **Fragmentation γ :** $R_{AA} < 1$ comparable yield to direct prompt γ
- QGP pre-equilibrium γ ? $R_{AA} \gg 1$ (glasma phase)
- Jet-QGP interaction γ ? $R_{AA} \gg 1$ (hard partons scattering)

Prompt γ signal selection & purity

- Photons measured in the EMCal must fulfil:

→ **Isolation**: $p_{T, \min}^{\text{iso, ch}} < \sum p_T^{\text{tracks in cone}} - \rho_{\text{UE}} \cdot \pi \cdot R^2$ in cone radius R

→ **Shower elongation**: σ_{long}^2 for “narrow” clusters



► Selection details in back-up

Prompt γ signal selection & purity

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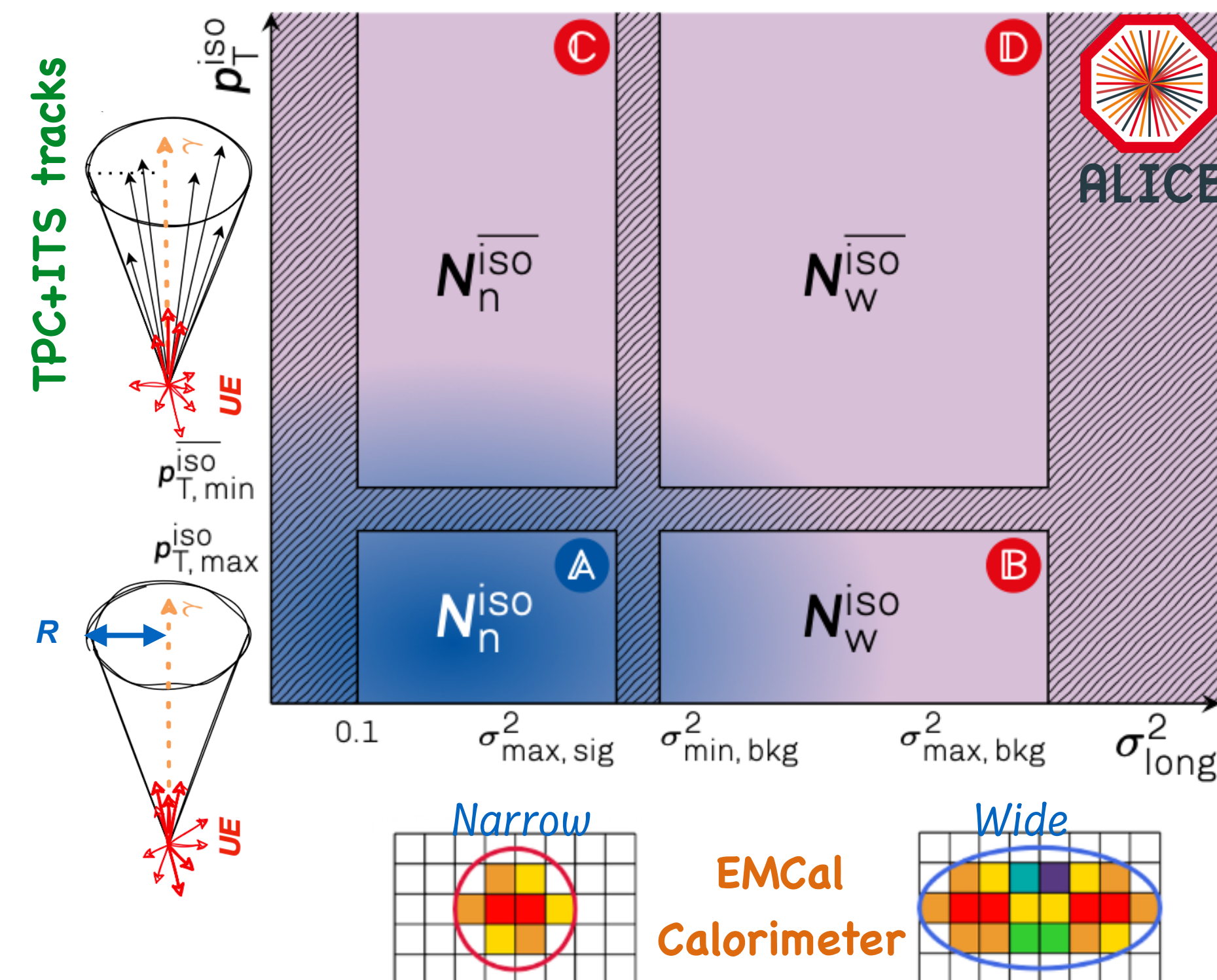
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→ **Shower elongation**: σ_{long}^2 for “narrow” clusters

- Purity, ABCD method: Phase space of calorimeter clusters divided in 4 regions: **A**, **signal dominated** & **B-C-D**, **background dominated**

$$P = 1 - \left(\frac{N_n^{\text{iso}} / N_n^{\text{iso}}}{N_w^{\text{iso}} / N_w^{\text{iso}}} \right)_{\text{data}} \times \left(\frac{B_n^{\text{iso}} / N_n^{\text{iso}}}{N_w^{\text{iso}} / N_w^{\text{iso}}} \right)_{\text{MC}} \quad N_{n,w}^{\text{iso, iso}} = \text{jet-jet} (B_{n,w}^{\text{iso, iso}}) + \gamma\text{-jet} (S_{n,w}^{\text{iso, iso}})$$

- Semi data-driven approach, simulation used to correct correlations between $p_T^{\text{iso, ch}}$ and σ_{long}^2



► Selection details in back-up

Prompt γ signal selection & purity, pp collisions

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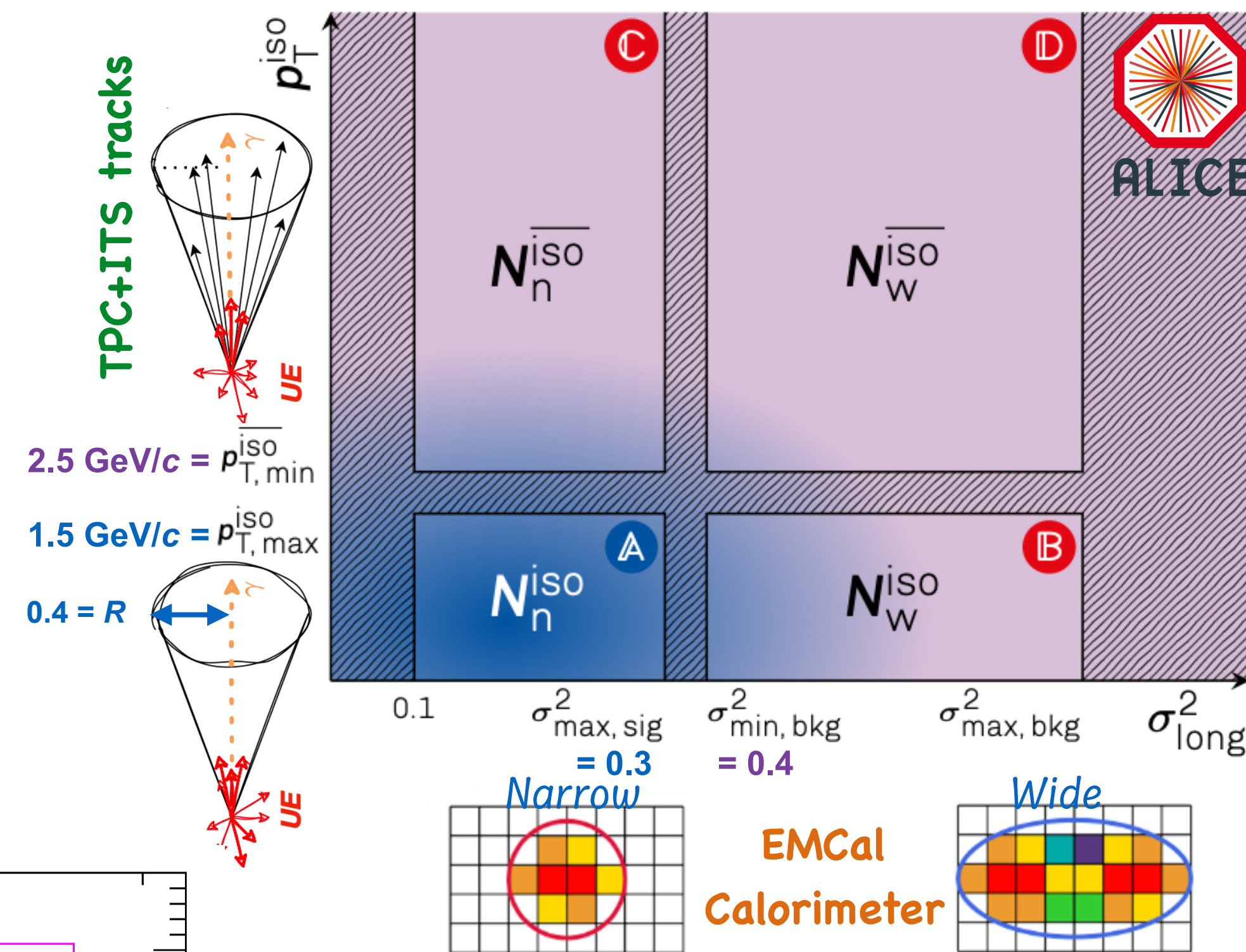
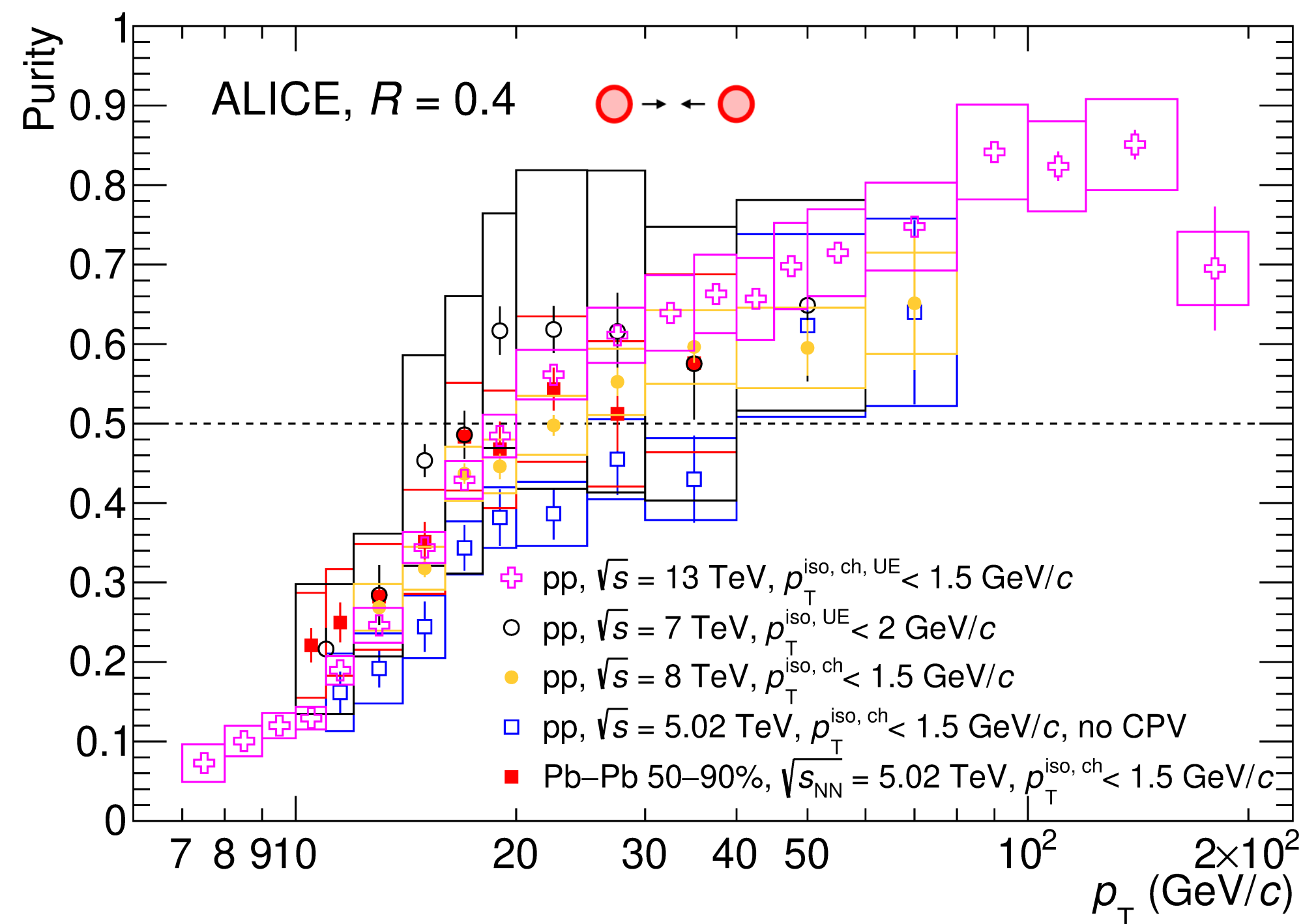
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Data driven PYTHIA

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

- Semi data-driven approach, simulation used to correct correlations between $p_T^{\text{iso, ch}}$ and σ_{long}^2



- ▶ Mostly $\sqrt{s}$ independent, the different identification selection criteria can affect
- ▶ Selection details in the backup
- ▶ Reduce the influence of statistical fluctuations with sigmoid function fits

Prompt γ signal selection & purity, Pb–Pb collisions

- Photons measured in the EMCal must fulfil:

→ **Isolation**: $p_{T, \min}^{\text{iso, ch}} < \sum p_T^{\text{tracks in cone}} - \rho_{\text{UE}} \cdot \pi \cdot R^2$ in cone radius R

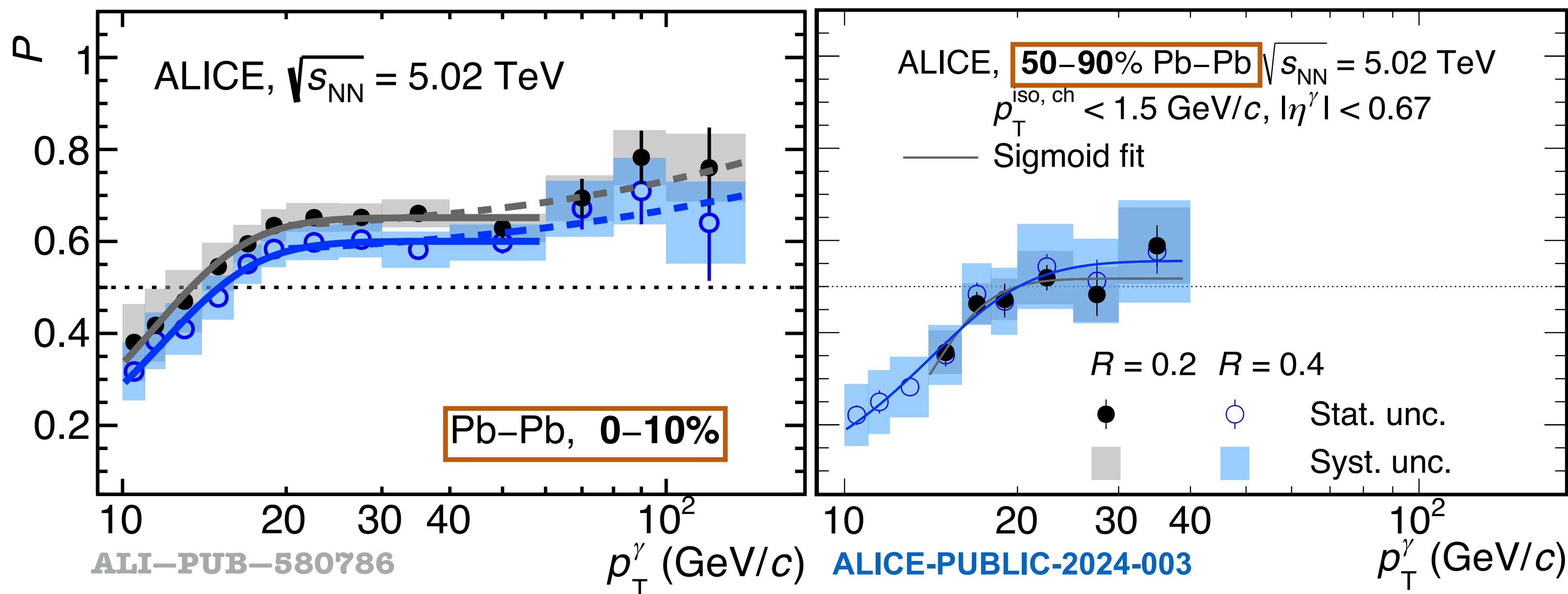
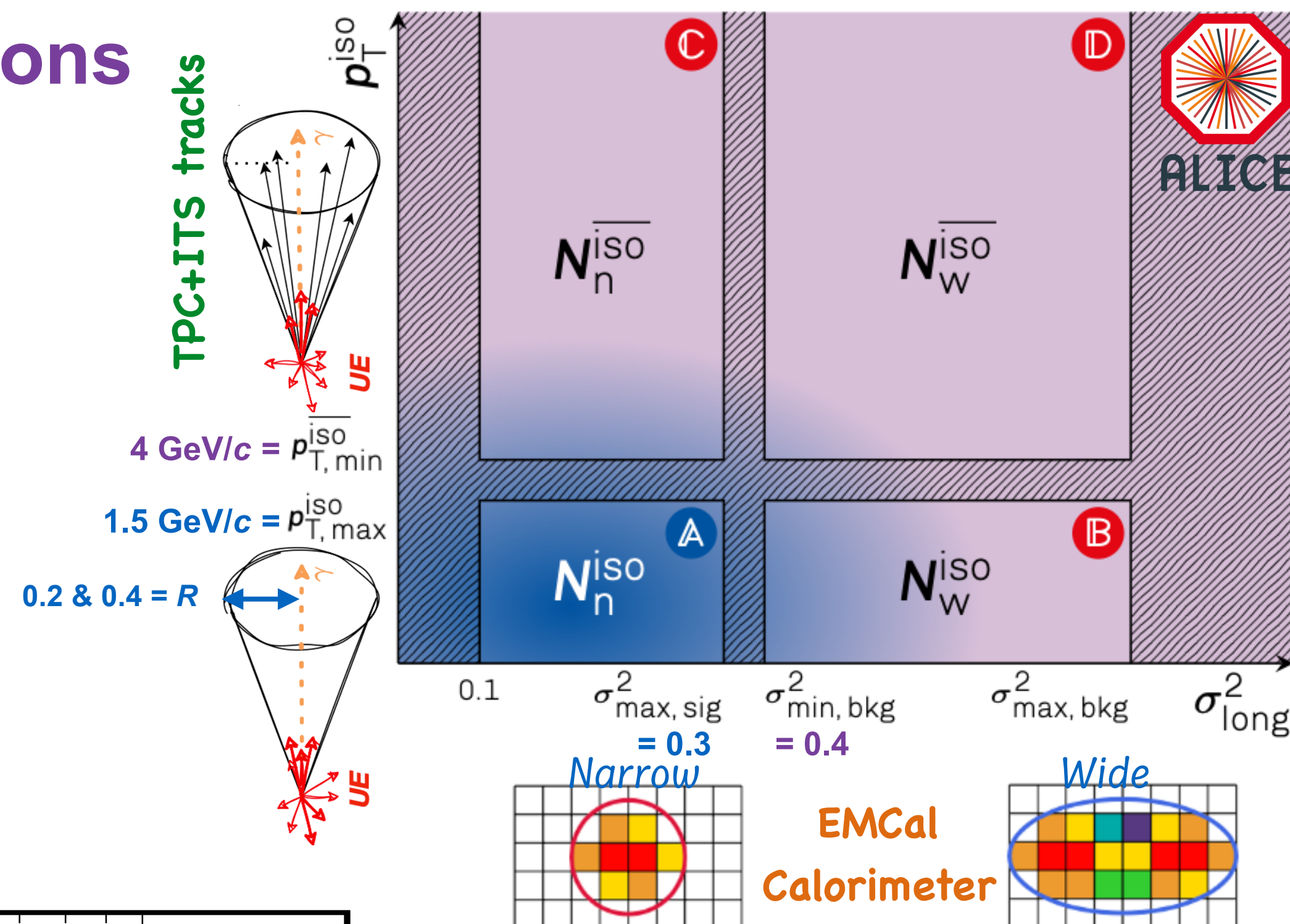
→ **Shower elongation**: σ_{long}^2 for “narrow” clusters

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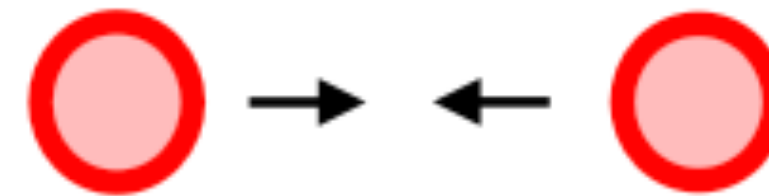
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$N_{n,w}^{\text{iso, iso}} = \text{jet-jet } (B_{n,w}^{\text{iso, iso}}) + \gamma\text{-jet } (S_{n,w}^{\text{iso, iso}})$



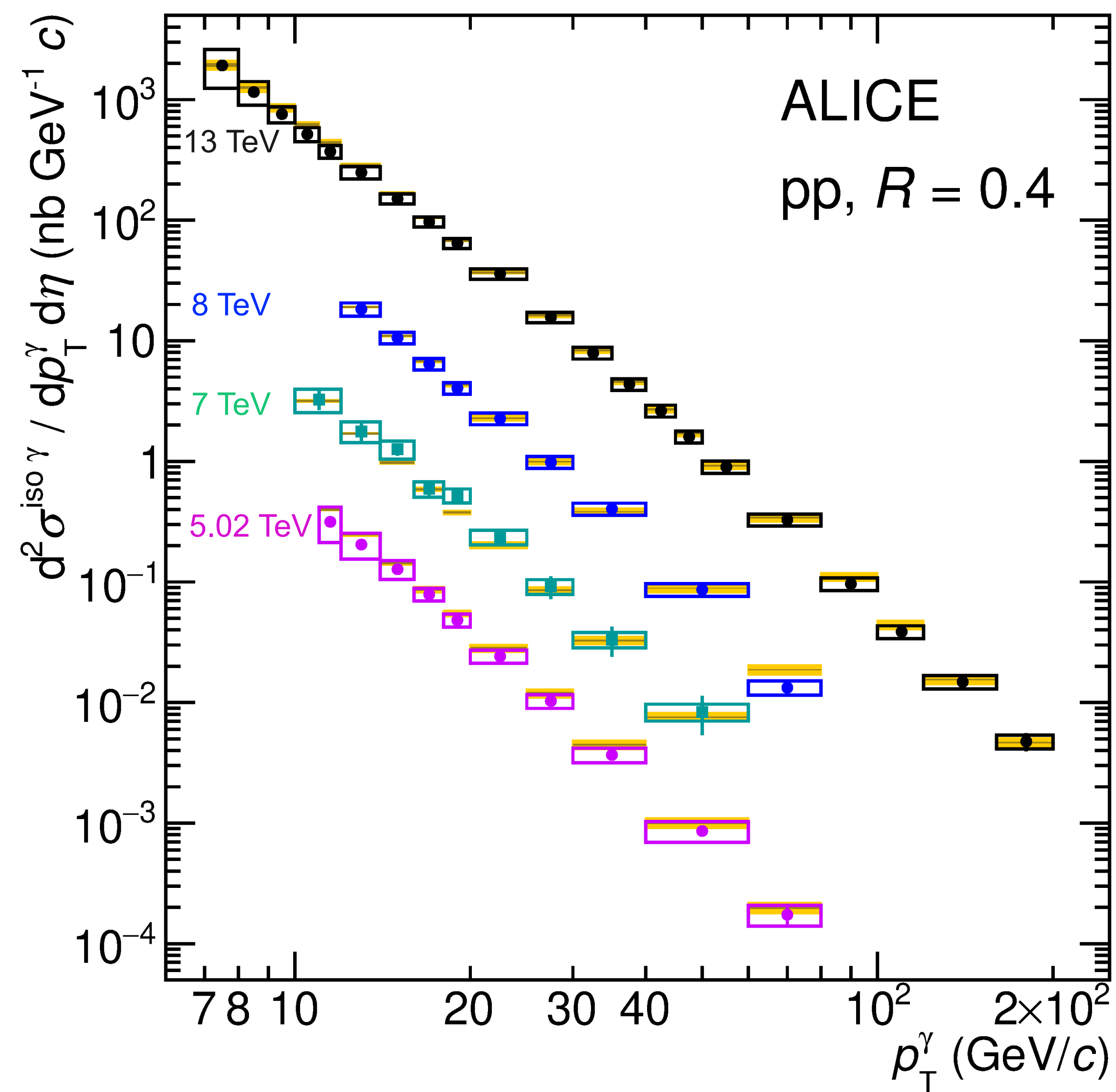
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Isolated prompt γ differential p_T cross section: proton–proton collisions



- * pp at $\sqrt{s} = 13$ TeV: [Eur. Phys. J. C 85 \(2025\) 98](#),
Ran Xu cotutelle thesis UGA-LPSC—IoP-CCNU, tel-05167225, CERN courier jan/feb 2025 issue
- * pp at $\sqrt{s} = 7$ TeV: [Eur. Phys. J. C 79 \(2019\) 896](#)
- * pp at $\sqrt{s} = 8$ TeV & p–Pb at $\sqrt{s_{NN}} = 5.02$ & 8.16 TeV: [Eur. Phys. J. C 85 \(2025\) 1407](#)
- * pp & Pb–Pb at $\sqrt{s_{NN}} = 5.02$ TeV: [Eur. Phys. J. C 85 \(2025\) 553](#), [ALICE-PUBLIC-2024-003](#), "CERN EP newsletter" April 2025

Cross section, pp collisions at different $\sqrt{s}$



Data:

- $\sqrt{s} = 13$ TeV, $p_T^{\text{iso, ch, UE}} < 1.5$ GeV/c $\times 10$
Eur. Phys. J. C **85** (2025) 98
- $\sqrt{s} = 8$ TeV, $p_T^{\text{iso, ch}} < 1.5$ GeV/c
Eur. Phys. J. C **85** (2025) 1407
- $\sqrt{s} = 7$ TeV, $p_T^{\text{iso, UE}} < 2$ GeV/c $\times 0.1$
Eur. Phys. J. C **79** (2019) 896
- $\sqrt{s} = 5.02$ TeV, $p_T^{\text{iso, ch}} < 1.5$ GeV/c $\times 0.02$
Eur. Phys. J. C **85**, 553 (2025)

Systematic uncertainty

NLO (JETPHOX) NNPDF40/BFG II FF:

- $p_T^{\text{iso}} < 2$ GeV/c
- Scale uncertainty $p_T^{\gamma}/2 < \mu < 2 p_T^{\gamma}$
- PDF uncertainty

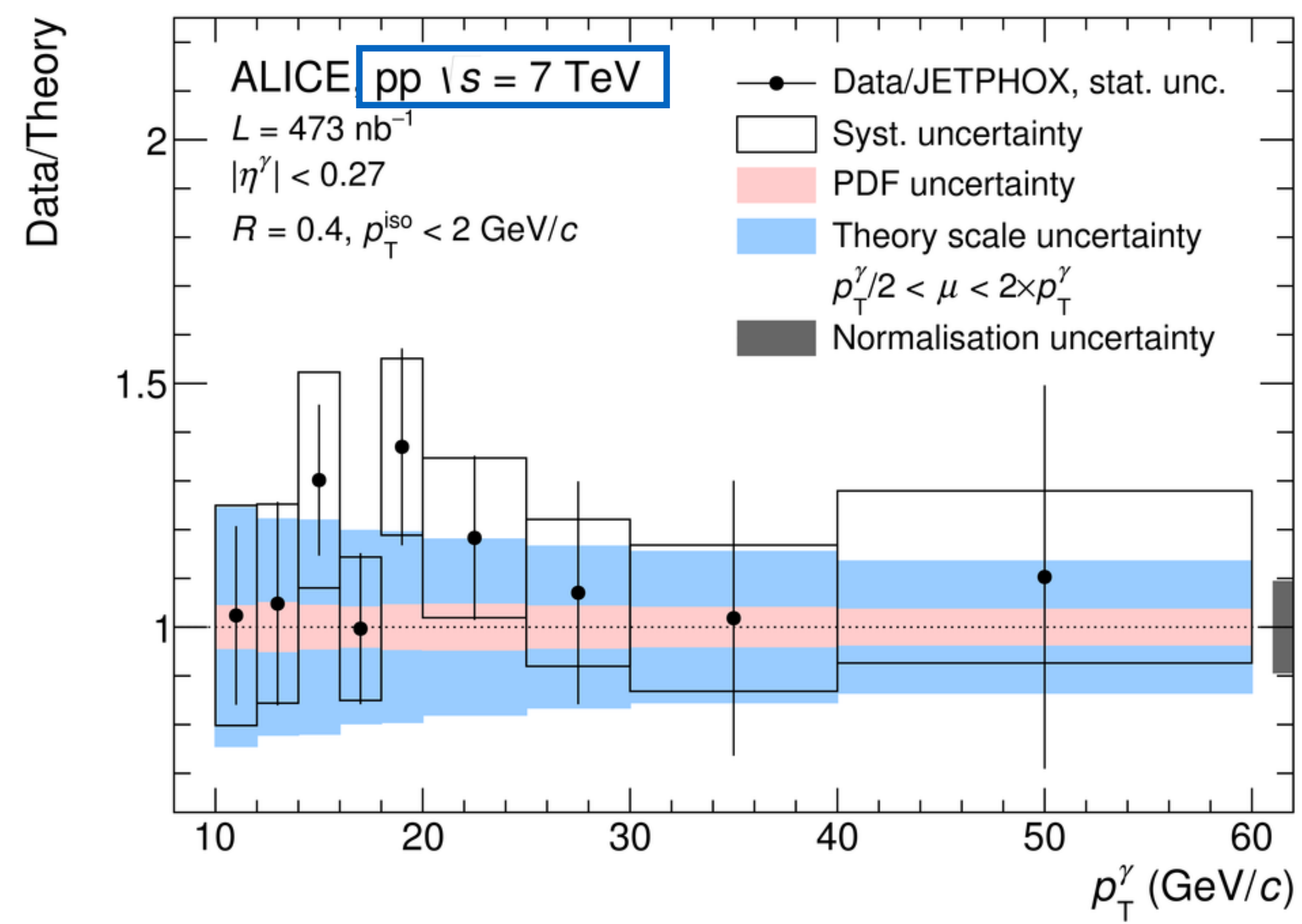


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tel-05167225
CERN courier jan/feb 2025 issue

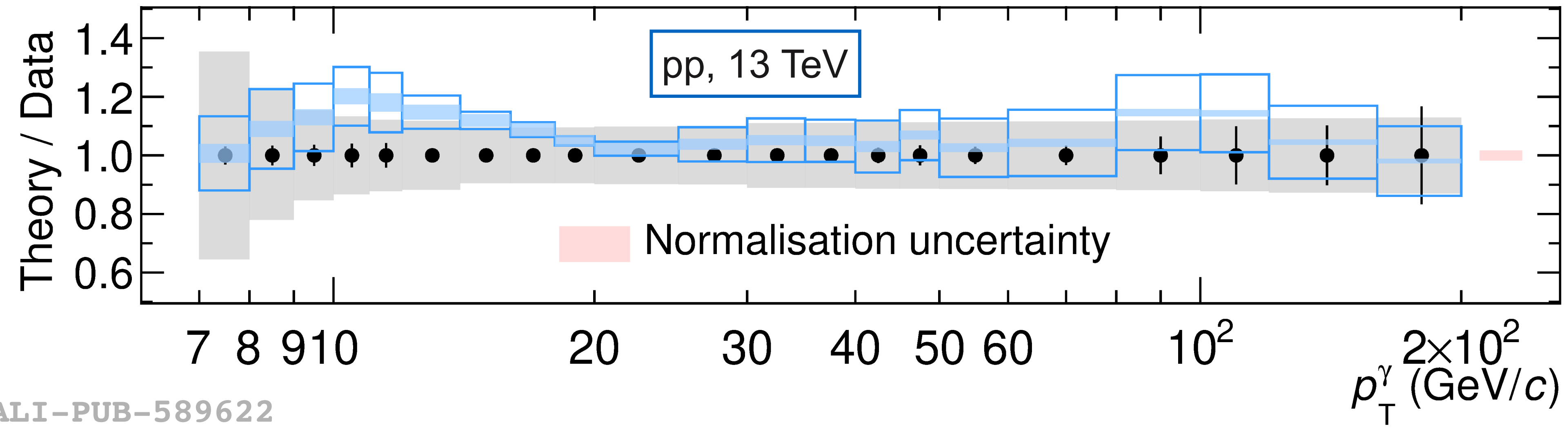
- NLO pQCD predictions (JETPHOX) and data agree
- Significantly lower p_T than CMS and ATLAS at $\sqrt{s} = 13$ TeV
- Lowest x_T at mid-rapidity

ALI-DER-632140

Cross section, pp collisions at $\sqrt{s} = 7 \text{ \& } 13 \text{ TeV}$



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

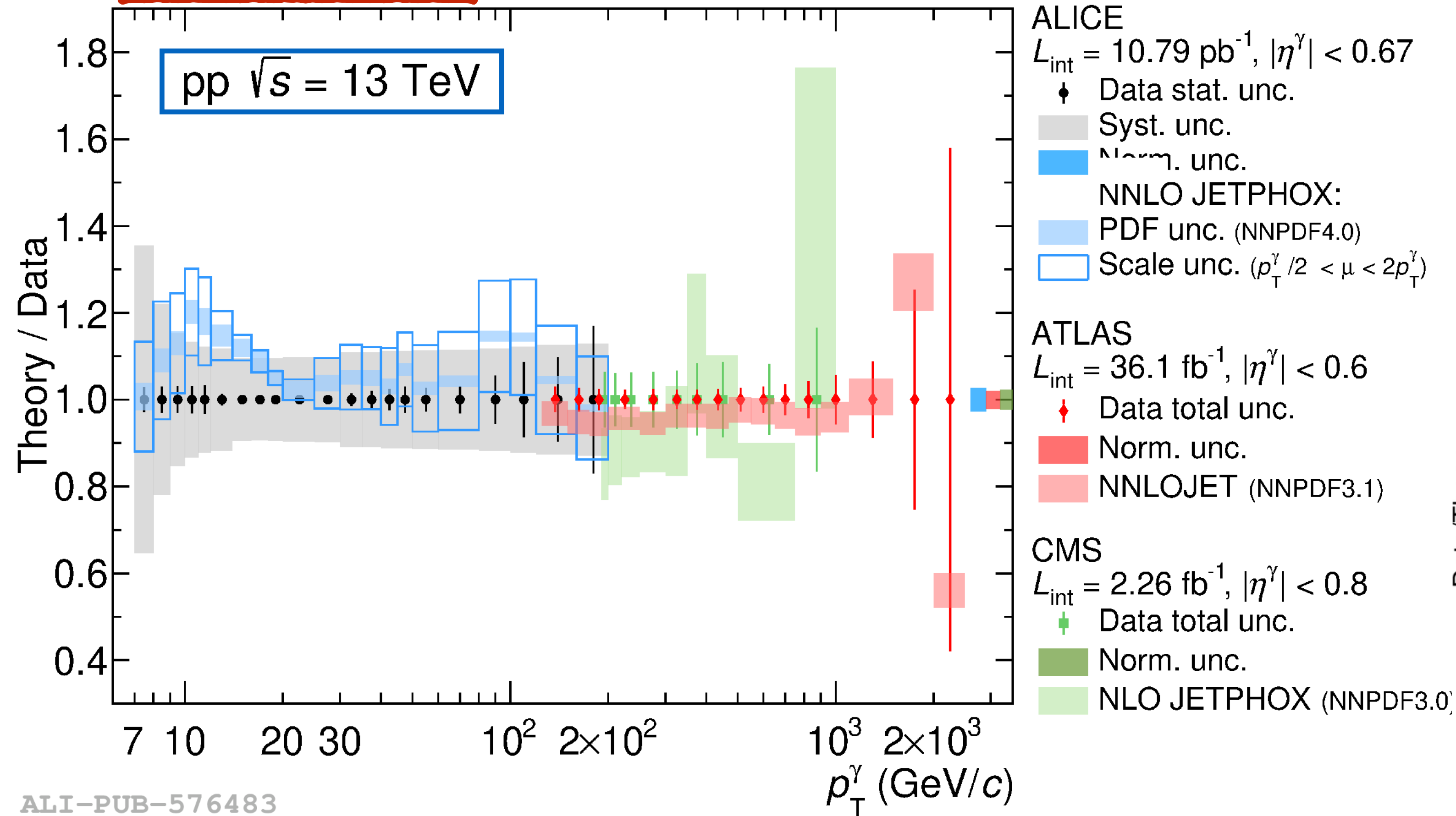


➔ Ran Xu cotutelle thesis
LPSC-CCNU
[tel-05167225](tel:05167225)

Cross section, pp collisions at $\sqrt{s} = 7$ & 13 TeV



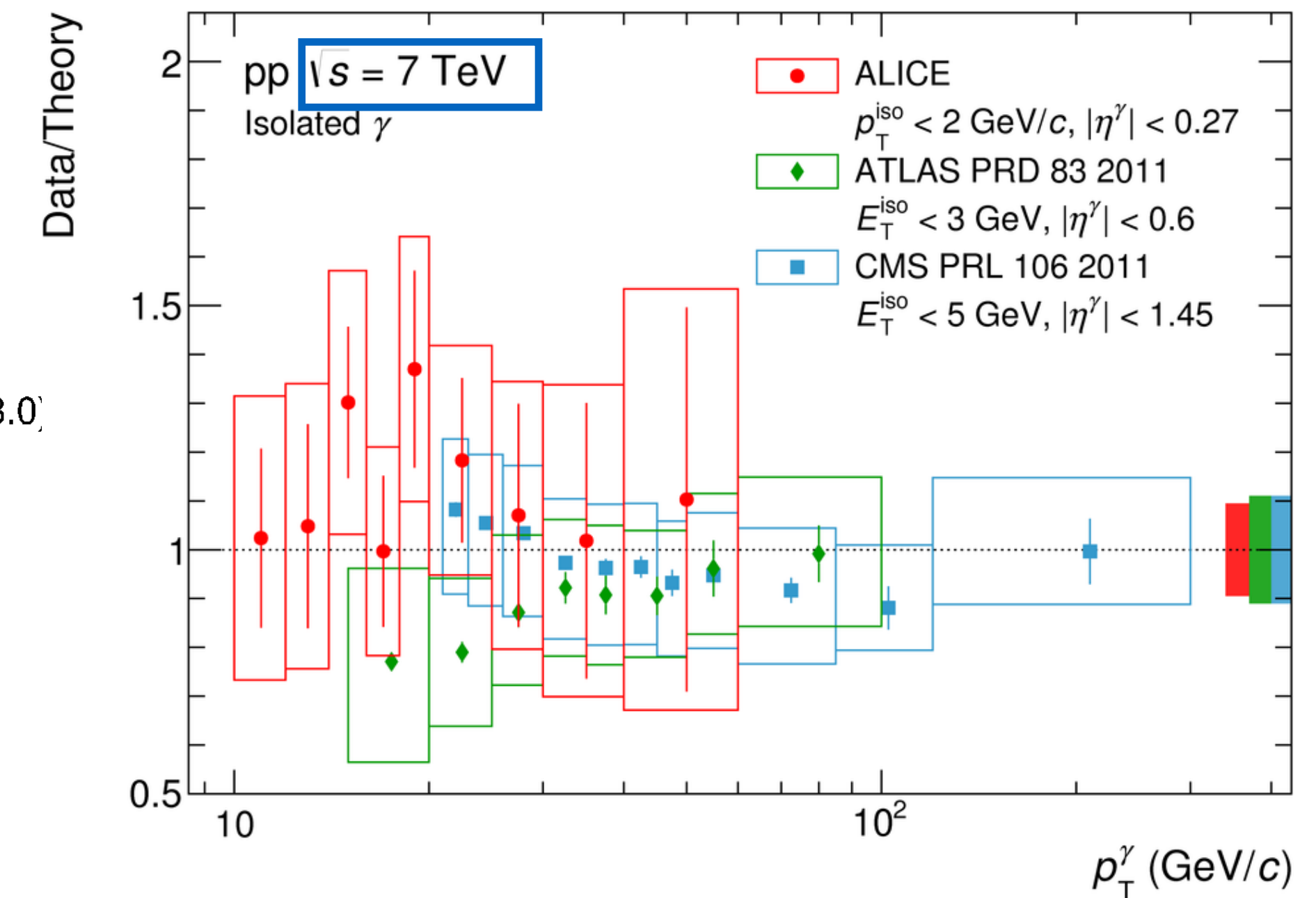
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tel-05167225



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

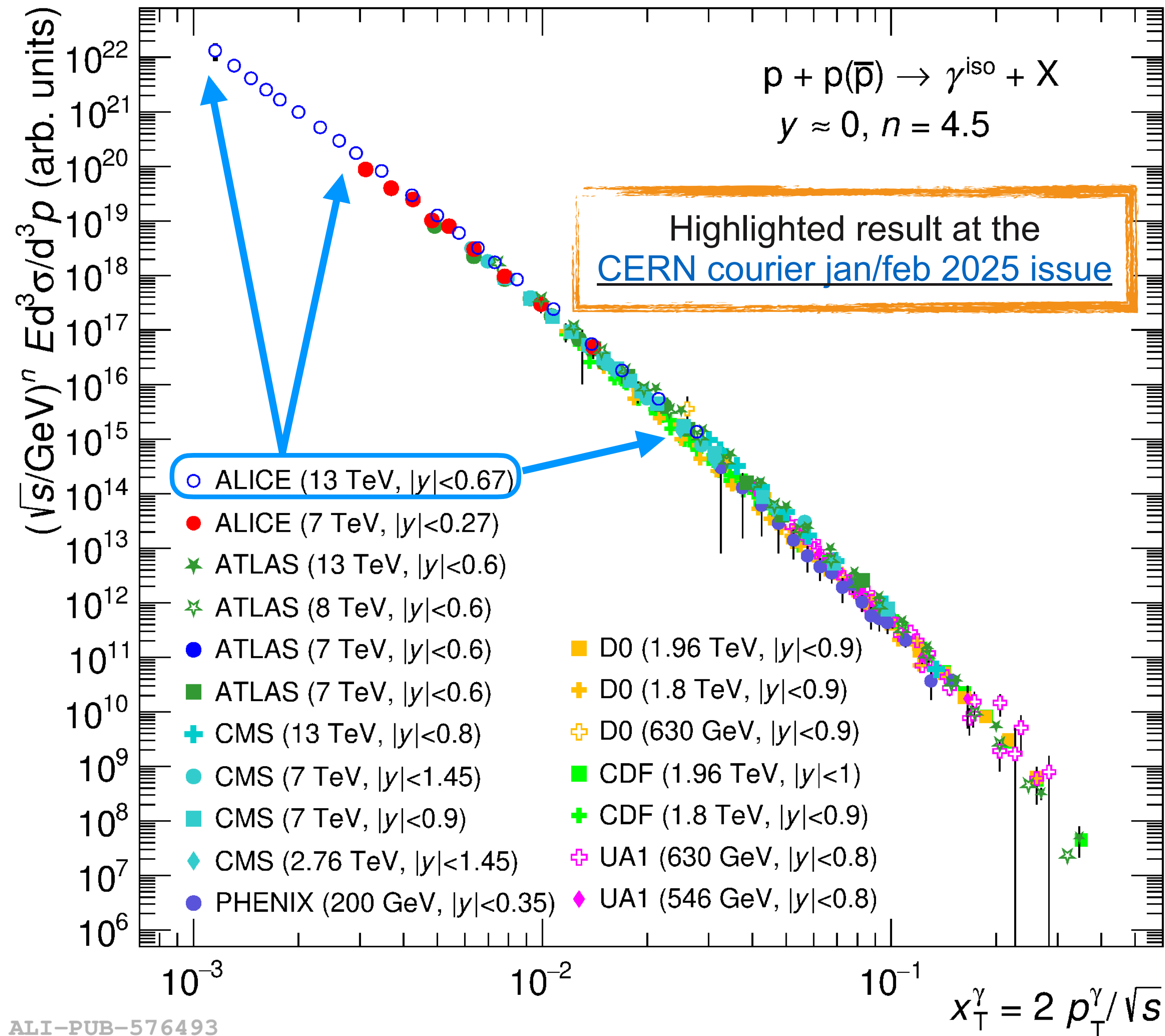
CMS Eur. Phys. J. C 79 (2019) 20
arXiv:1807.00782 [hep-ex]

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Cross section, pp collisions at different $\sqrt{s}$

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LPSC-CCNU
tel-05167225

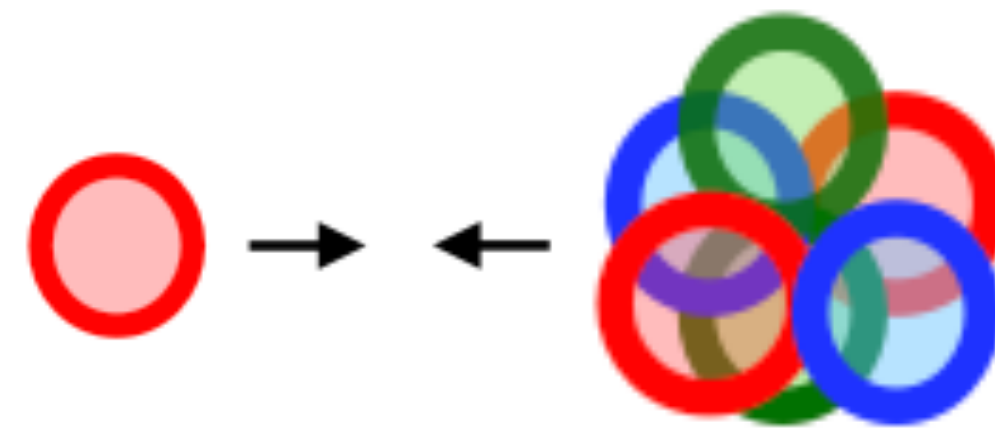


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$(\sqrt{s})^{4.5}$ scale from $x_T \sim 10^{-3}$ to 10^{-1}

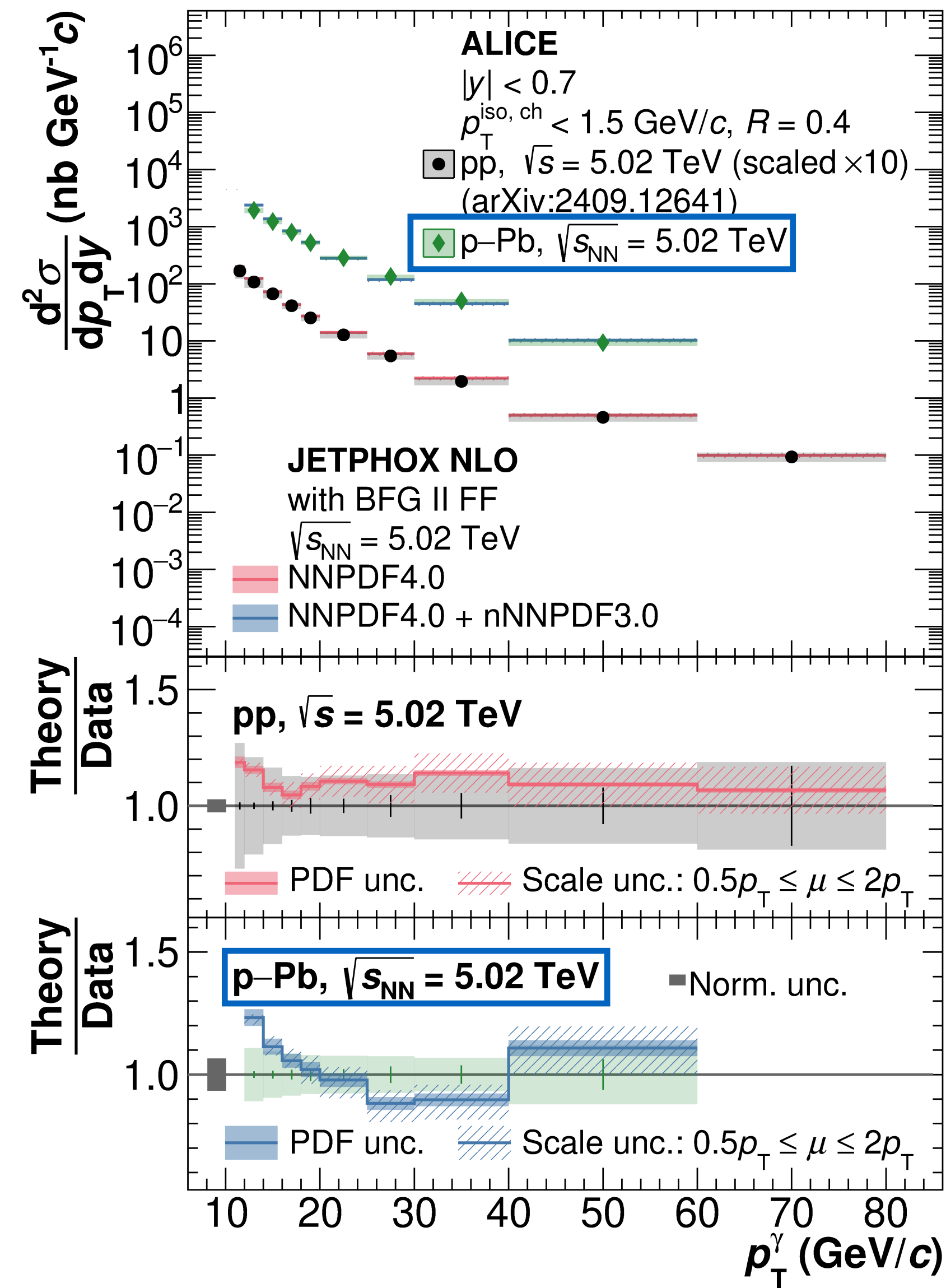
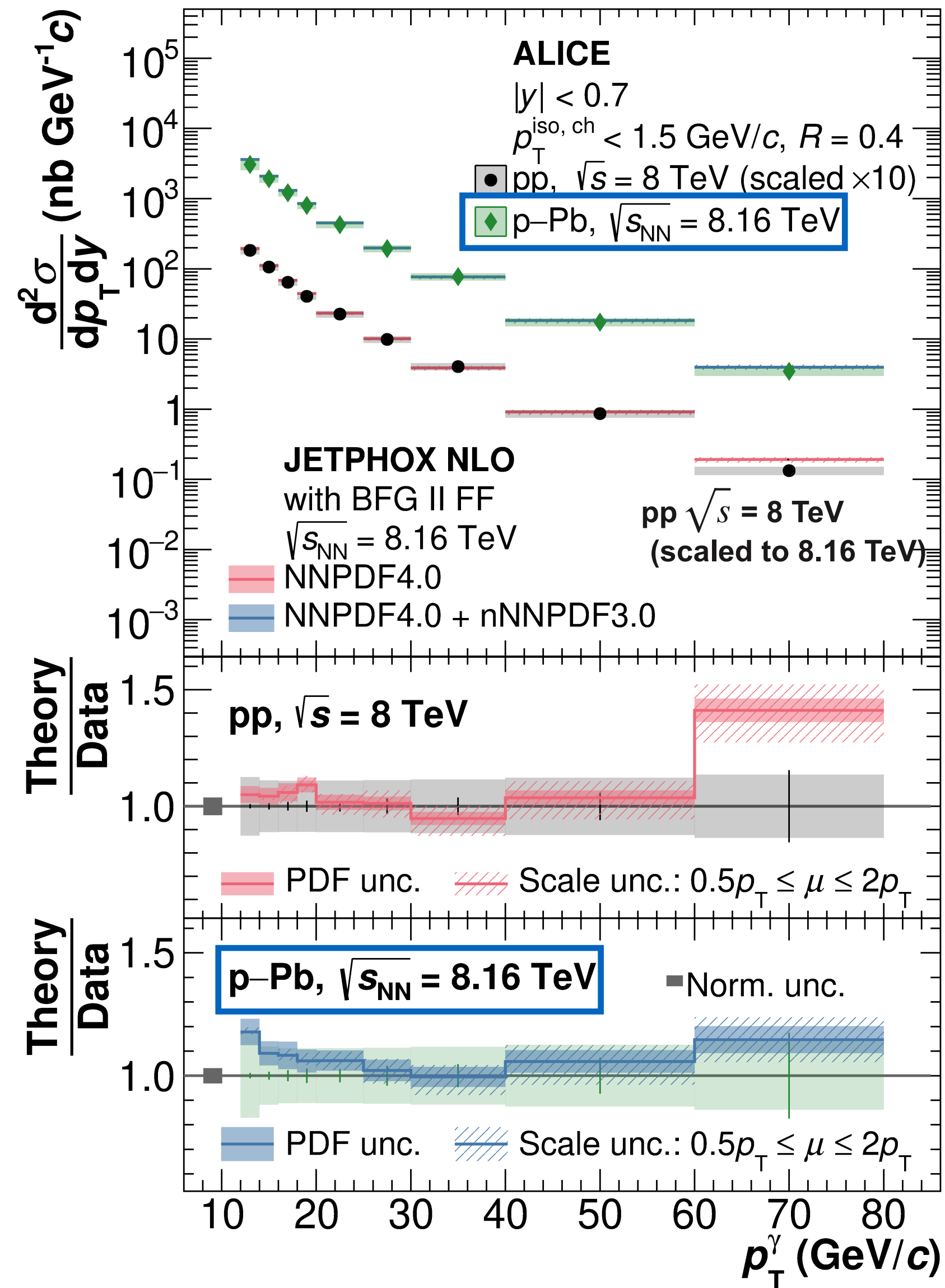
Full list of older results compiled in [D. D'Enterria & J. Rojo Nucl. Phys. B 860 \(2012\), arXiv:1202.1762 \[hep-ph\]](#)

Isolated prompt γ differential p_T cross section: proton-Pb collisions



* pp at $\sqrt{s} = 8$ TeV & p-Pb at $\sqrt{s_{NN}} = 5.02$ & 8.16 TeV: [Eur. Phys. J. C 85 \(2025\) 1407](#)

Cross section, p-Pb $\sqrt{s_{NN}} = 5.02$ & 8.16 TeV

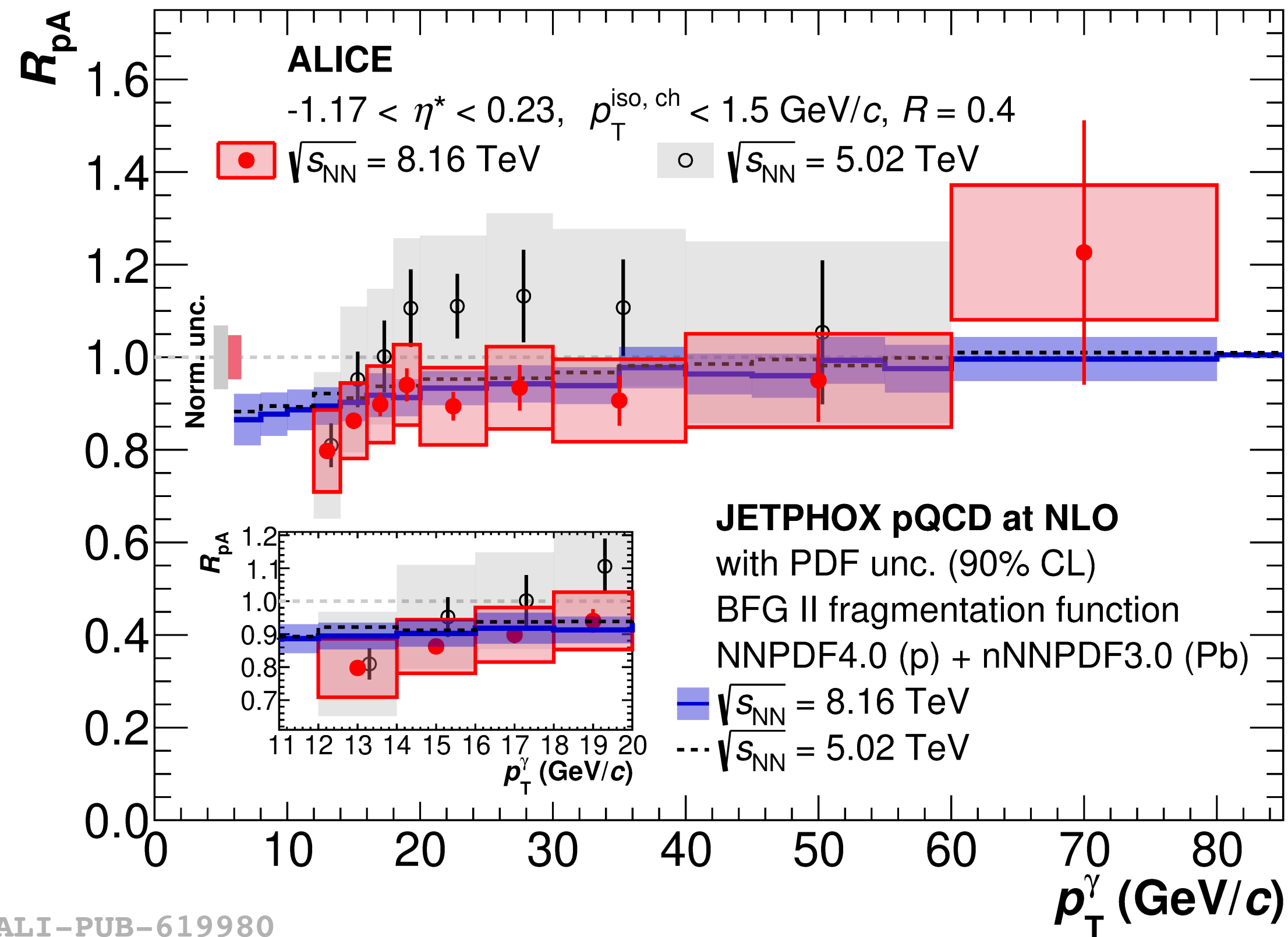


ALI-PUB-619975

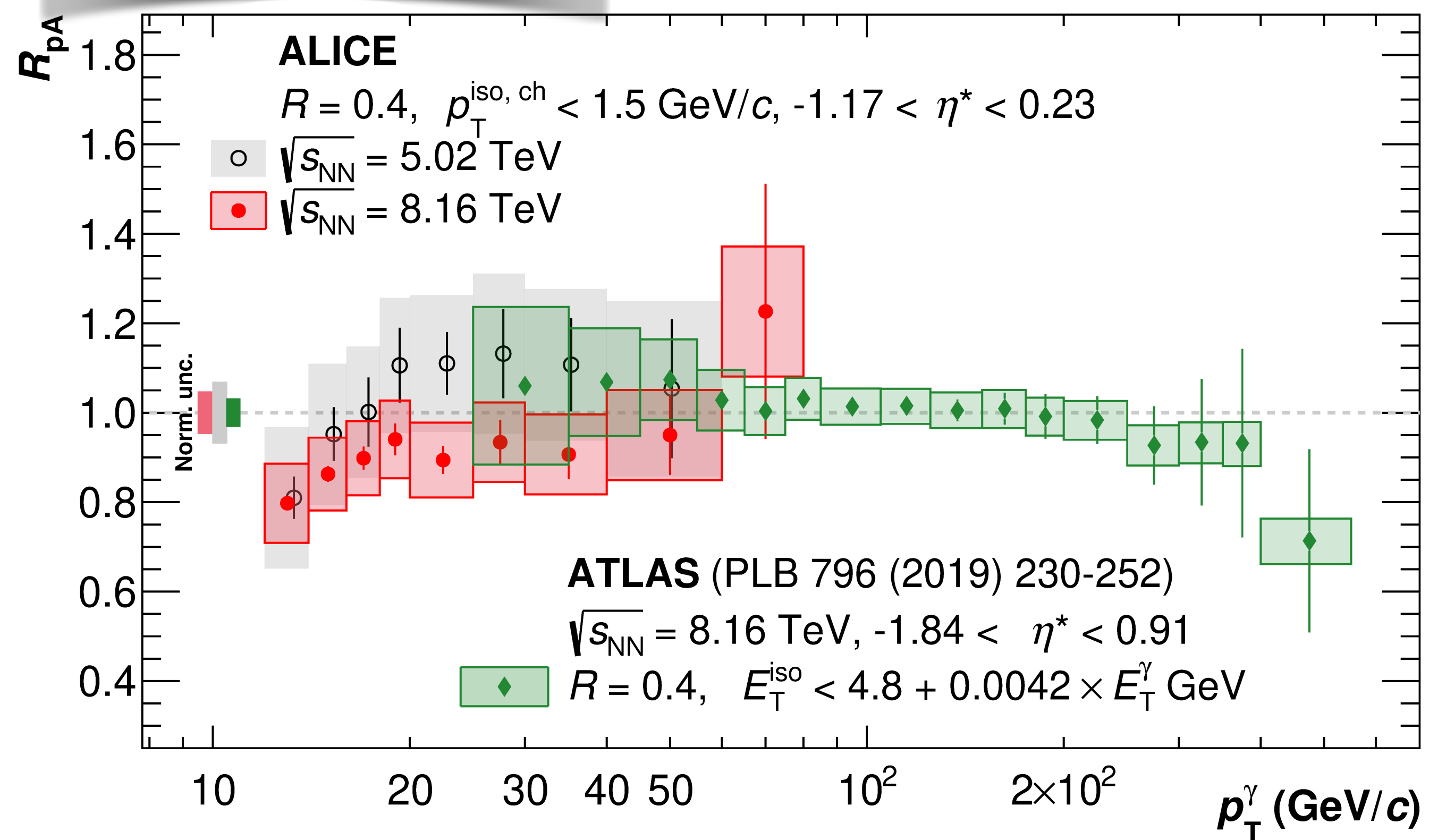
ALI-PUB-619970

- NLO pQCD predictions (JETPHOX) and data agree

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



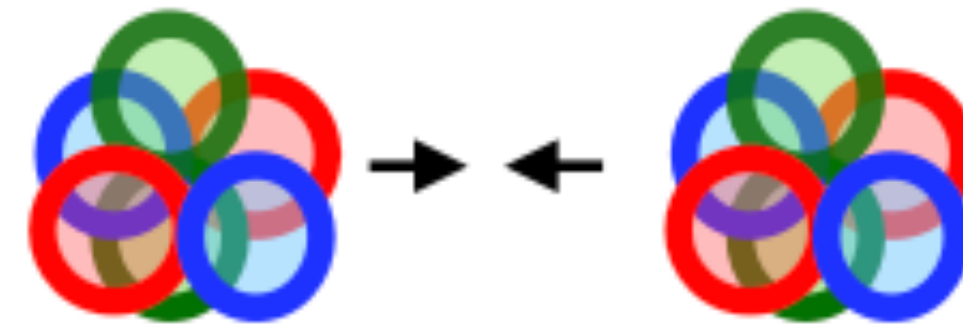
ALI-PUB-619980



ALI-PUB-619990

- R_{pA} in agreement with unity
 - Hints of lower than unity for $p_T < 20 \text{ GeV}/c$, expected in theory, cold nuclear matter effects, shadowing
 - Agreement with ATLAS at high p_T

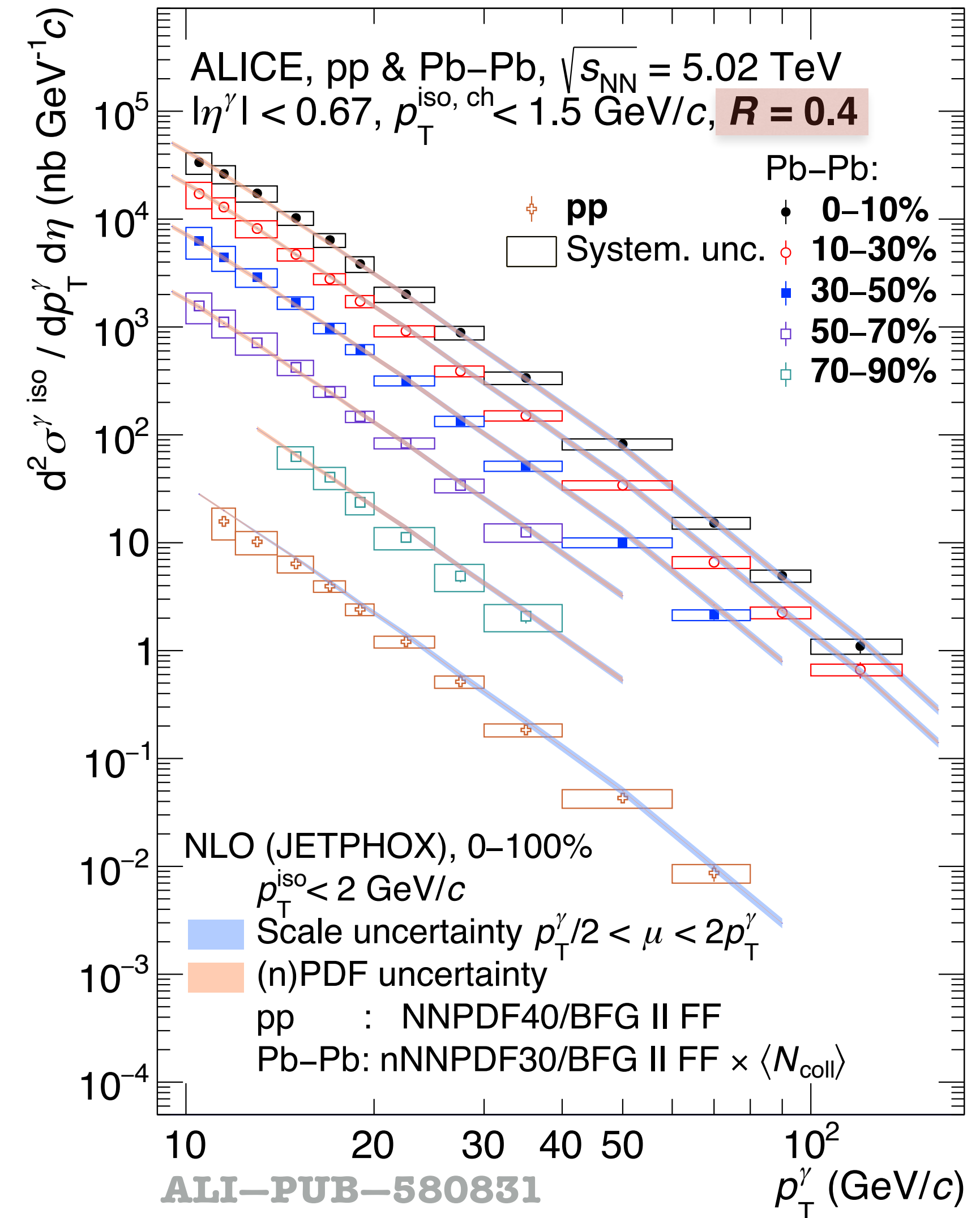
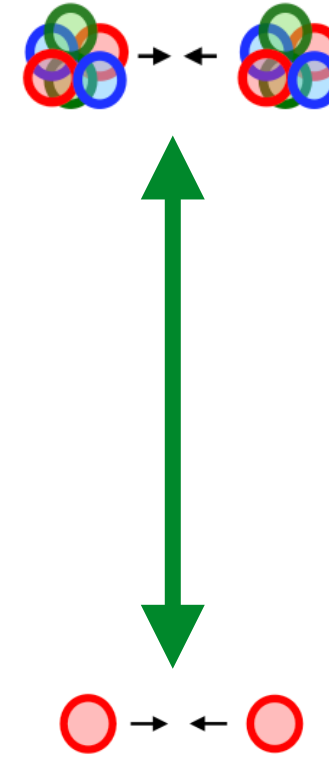
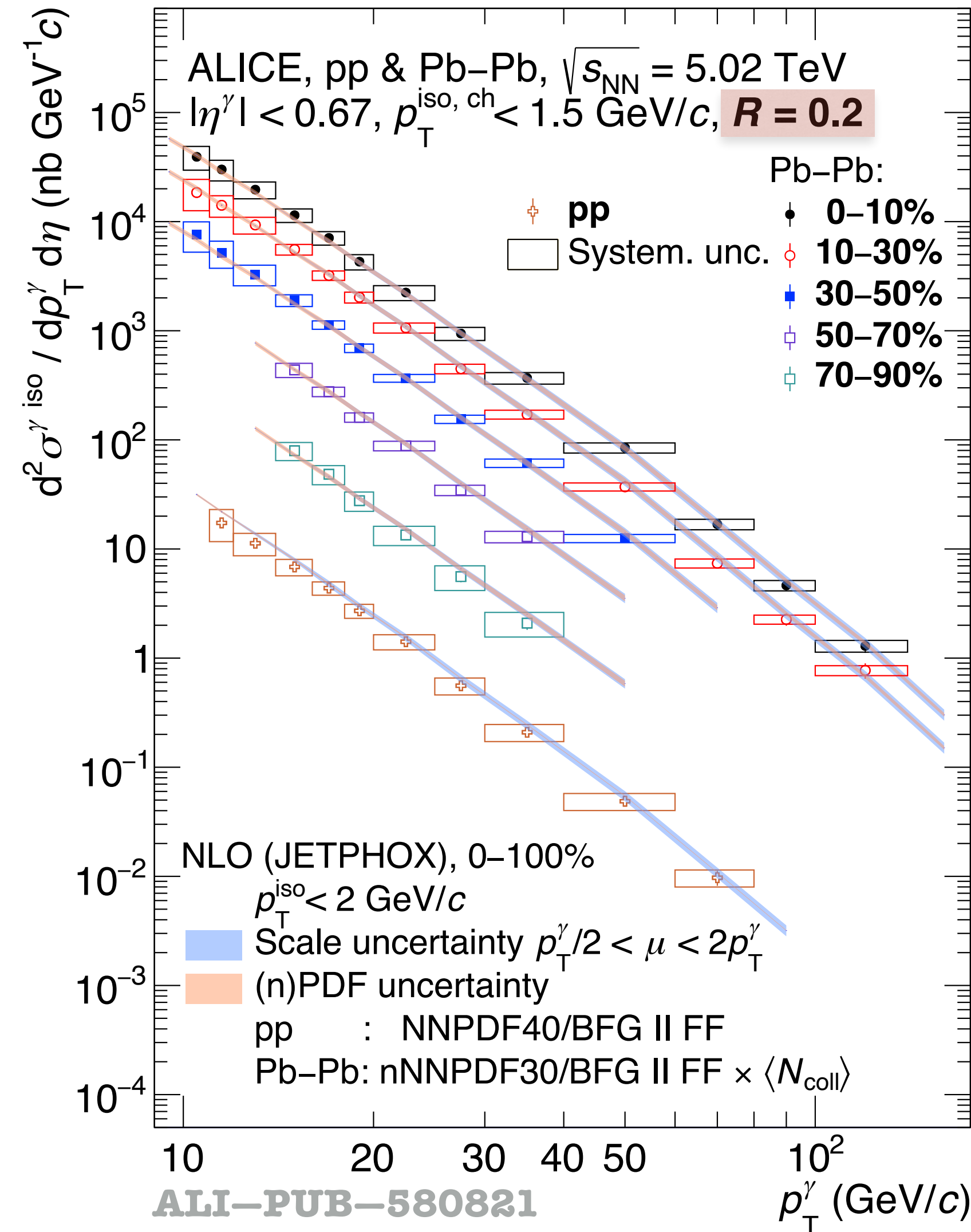
Isolated prompt γ
differential p_T cross section:
Pb–Pb collisions



- * pp & Pb–Pb at $\sqrt{s_{NN}} = 5.02$ TeV: [Eur. Phys. J. C 85 \(2025\) 553](#),
[ALICE-PUBLIC-2024-003](#), "CERN EP newsletter" april 2025

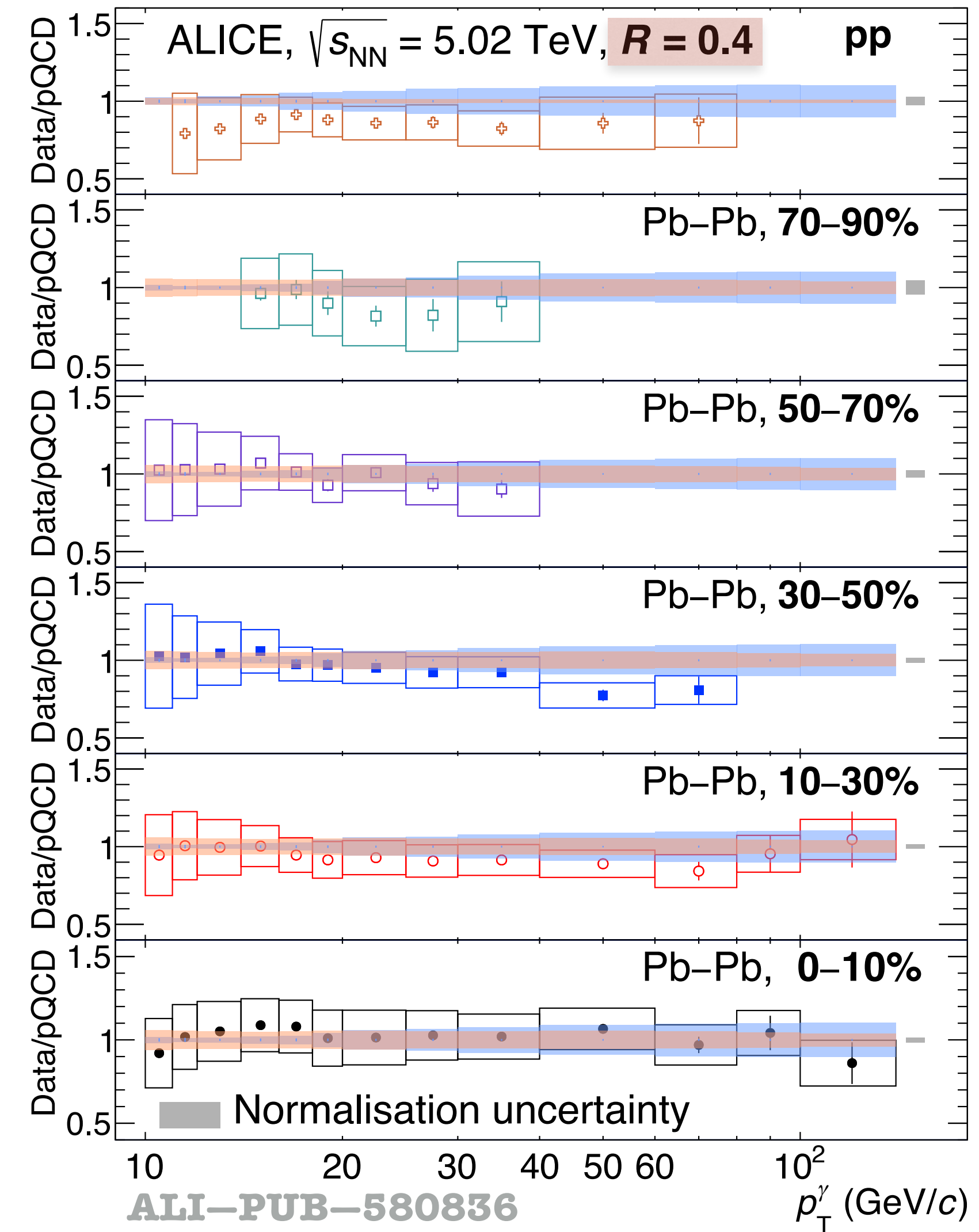
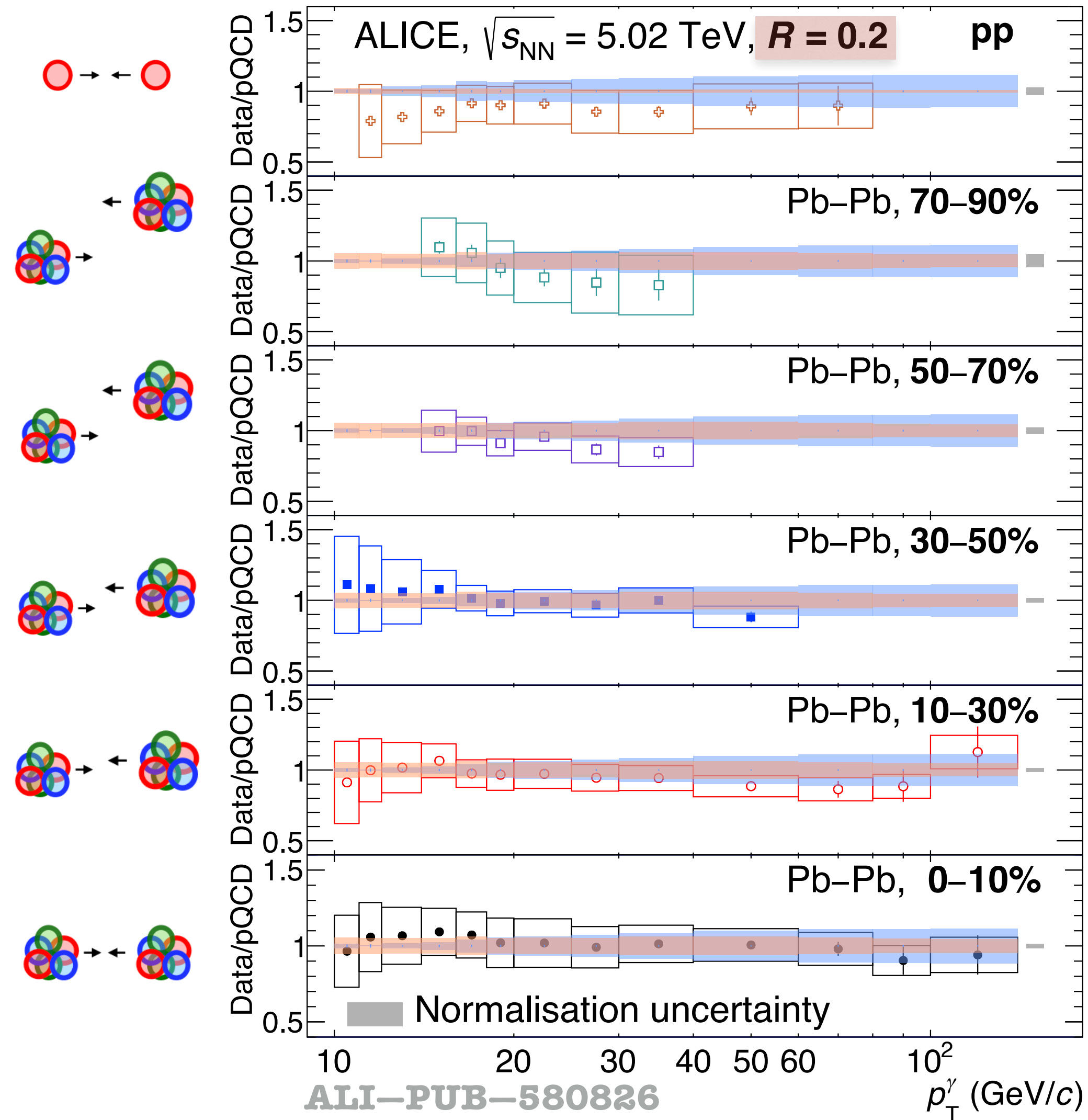
Cross section, pp & Pb–Pb at $\sqrt{s_{NN}} = 5.02$ TeV

$$\frac{d^2\sigma^{\gamma \text{ iso}}}{dp_T d\eta} = \frac{\sigma_{NN}^{\text{INEL}}}{N_{\text{events}} \times \text{RF}_{\text{trig}}} \times \frac{d^2N}{dp_T d\eta} \times \frac{P}{\text{Acc} \times \epsilon_{\gamma}^{\text{iso}} \times \epsilon_{\text{trig}}}$$



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

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

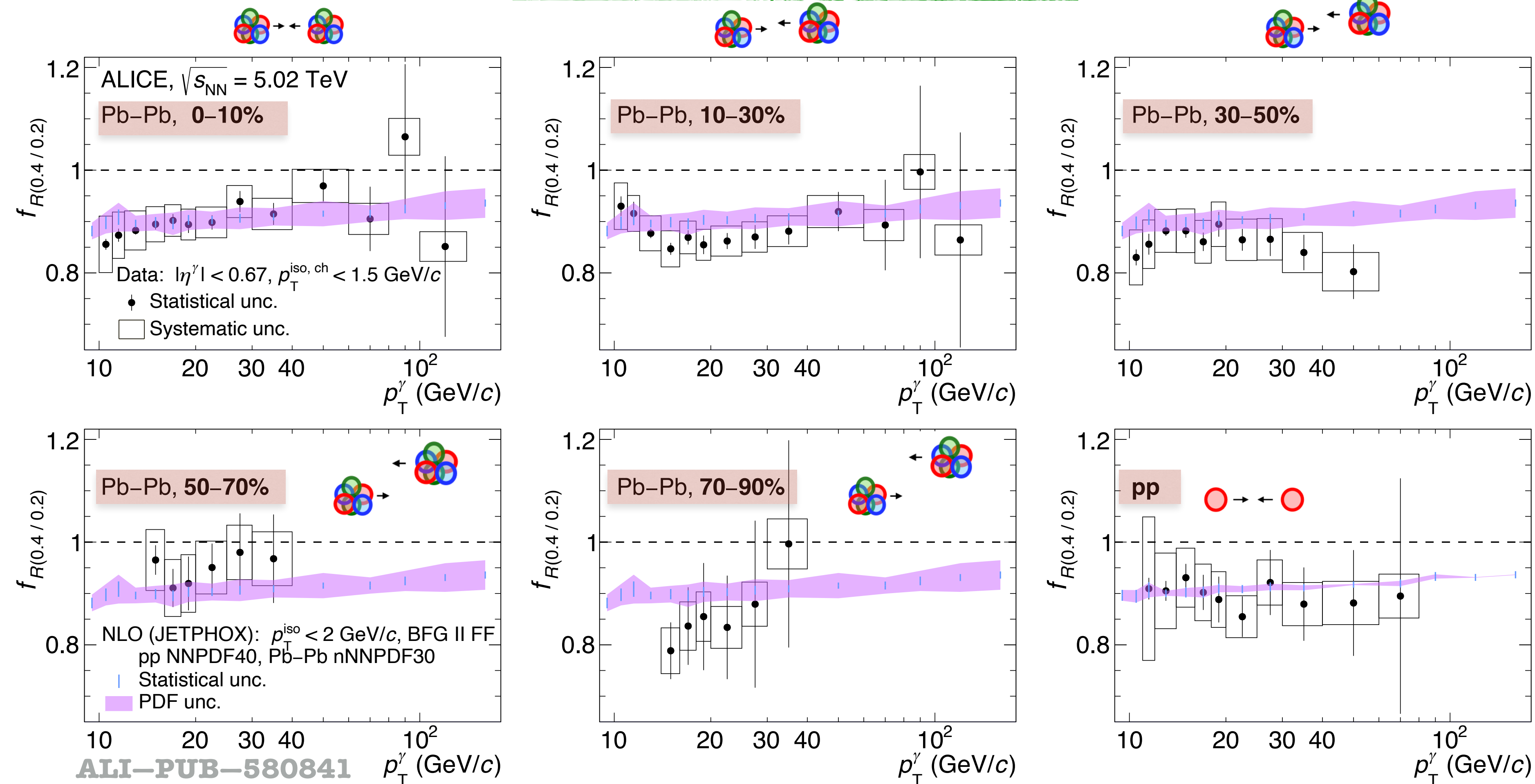


- NLO pQCD predictions (JETPHOX)
 - ➔ Note: Theory calculated for 0–100%, **PDF (pp) & nPDF $\times N_{coll}$ (Pb–Pb)**
- Theory & data agreement for both R and collision system

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

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

- 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



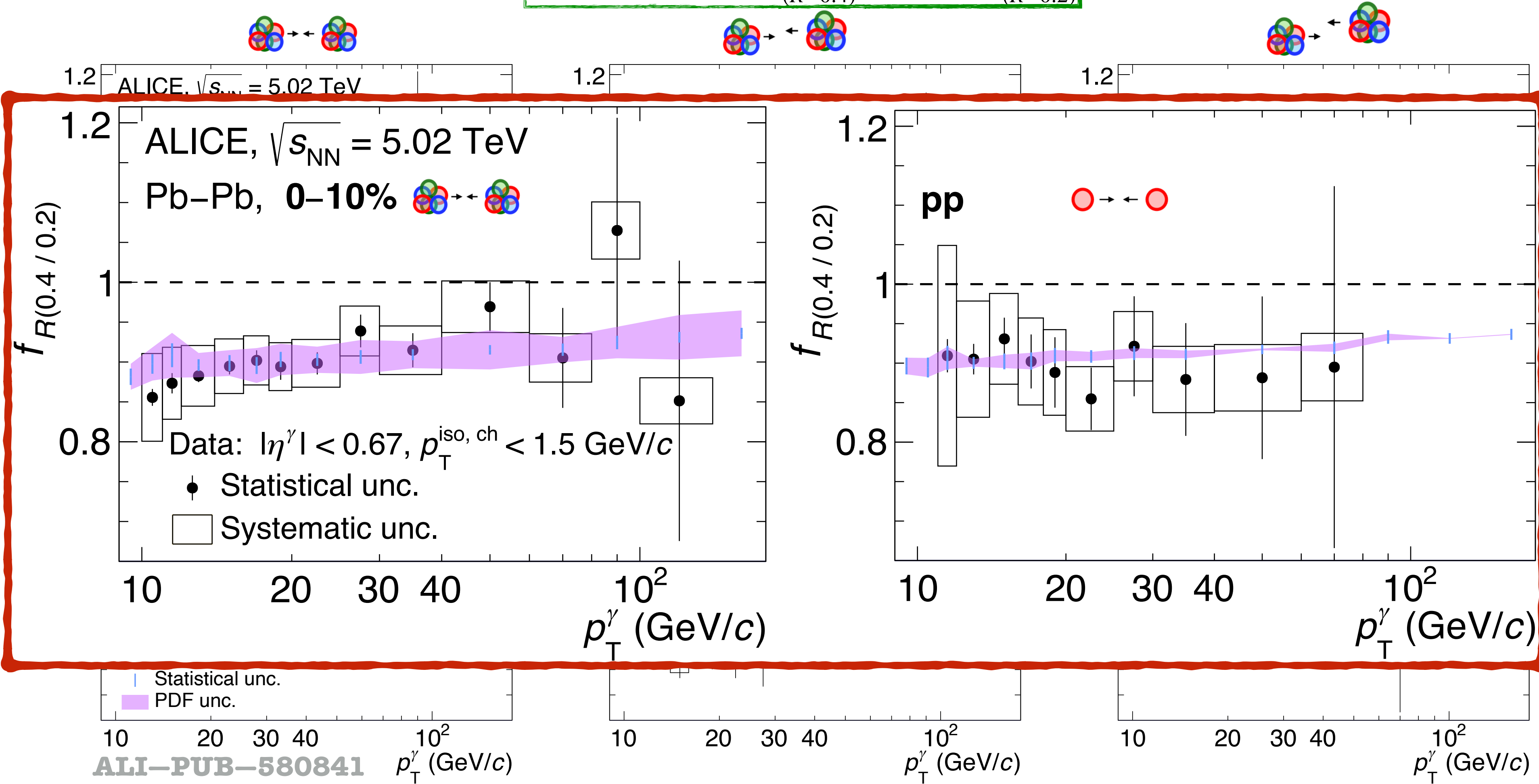
* Not shown: ATLAS pp $\sqrt{s} = 13$ TeV, for $p_T > 250$ GeV/c JHEP 07 (2023) 86 arXiv:2302.00510

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



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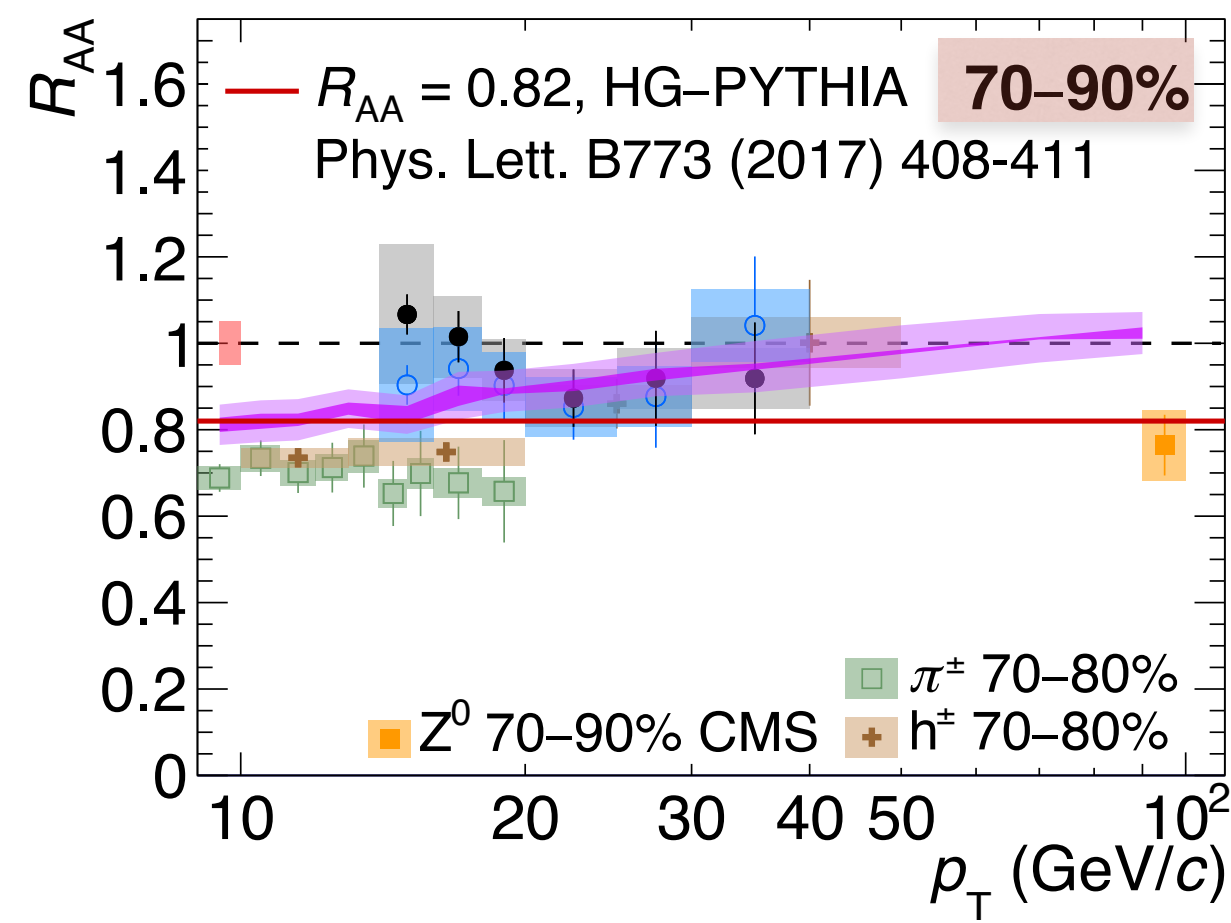
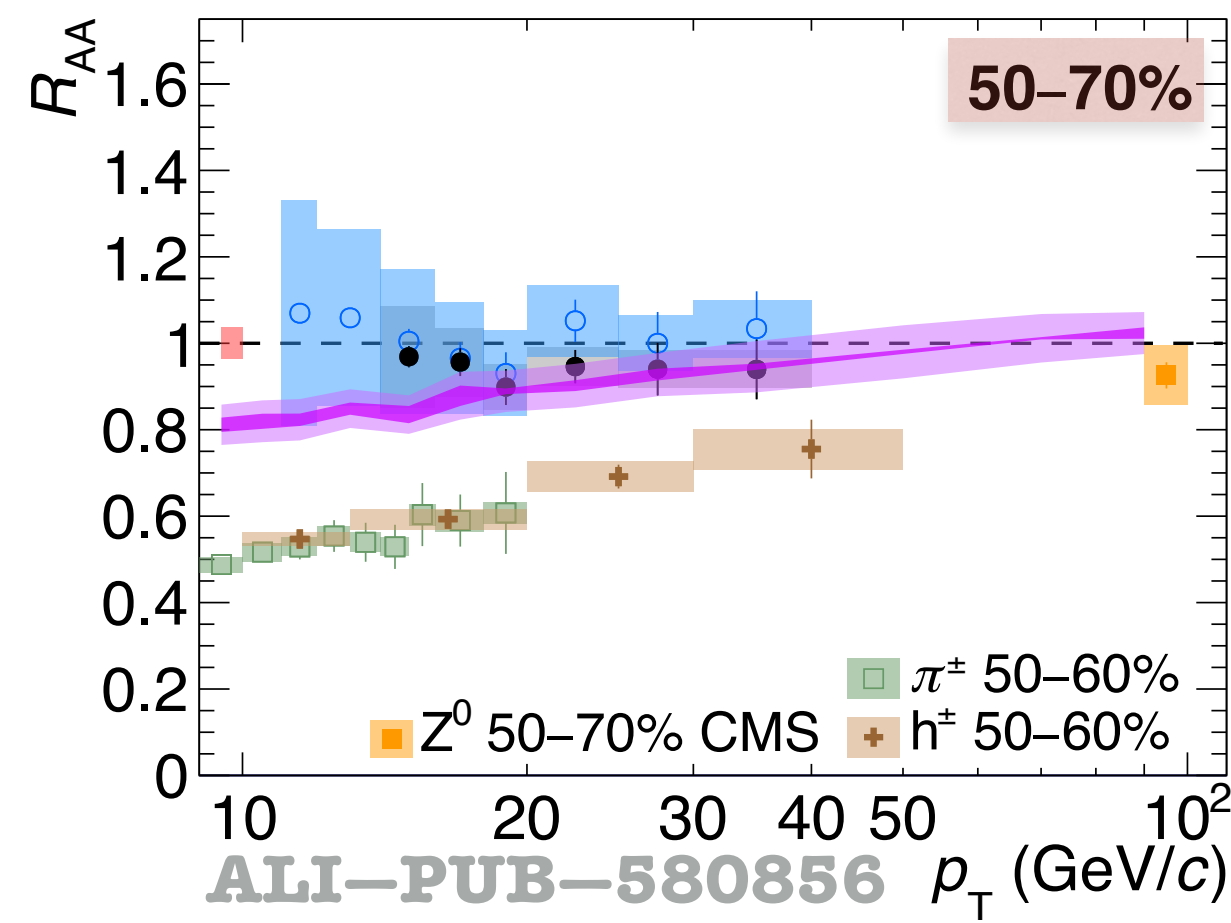
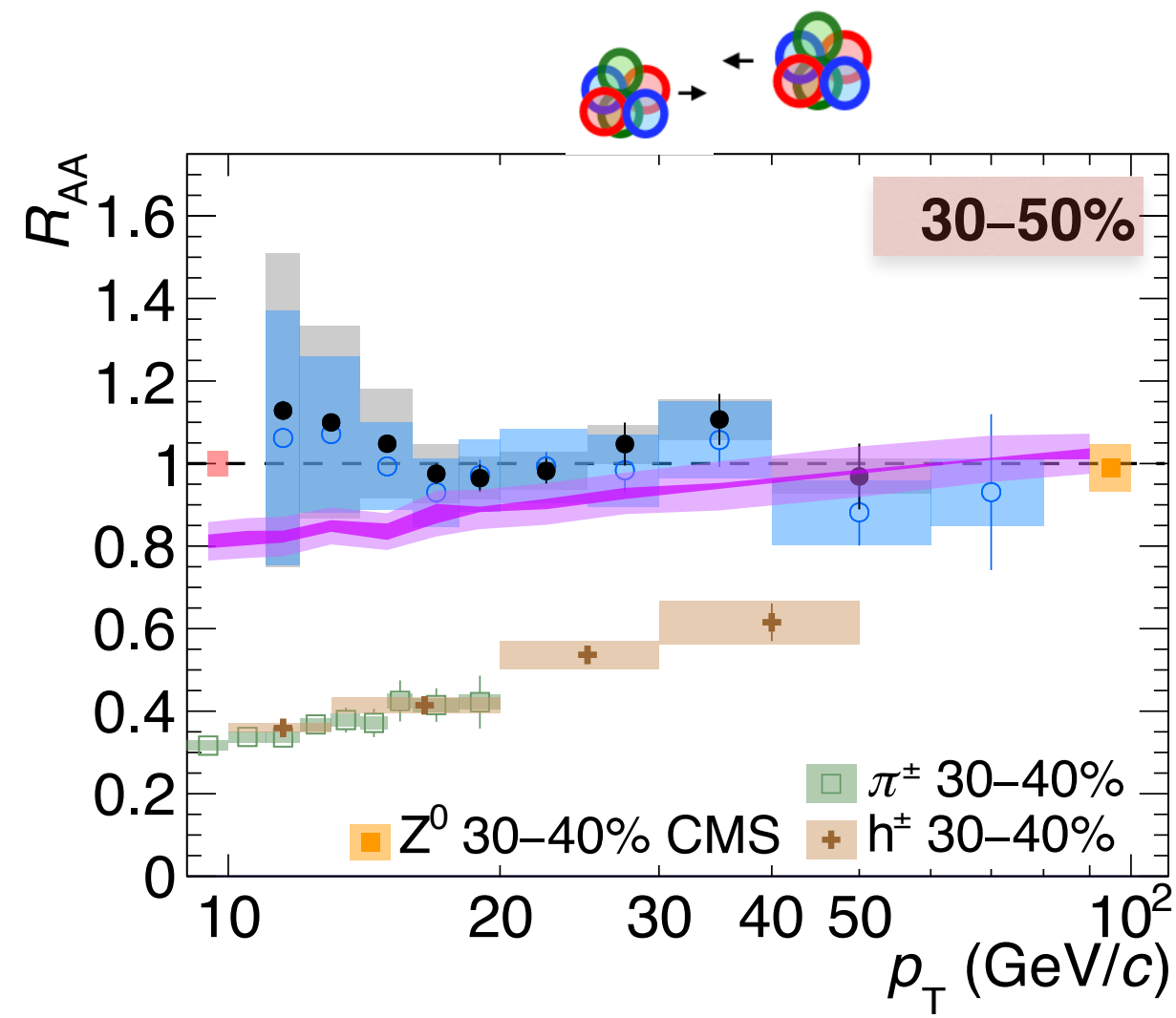
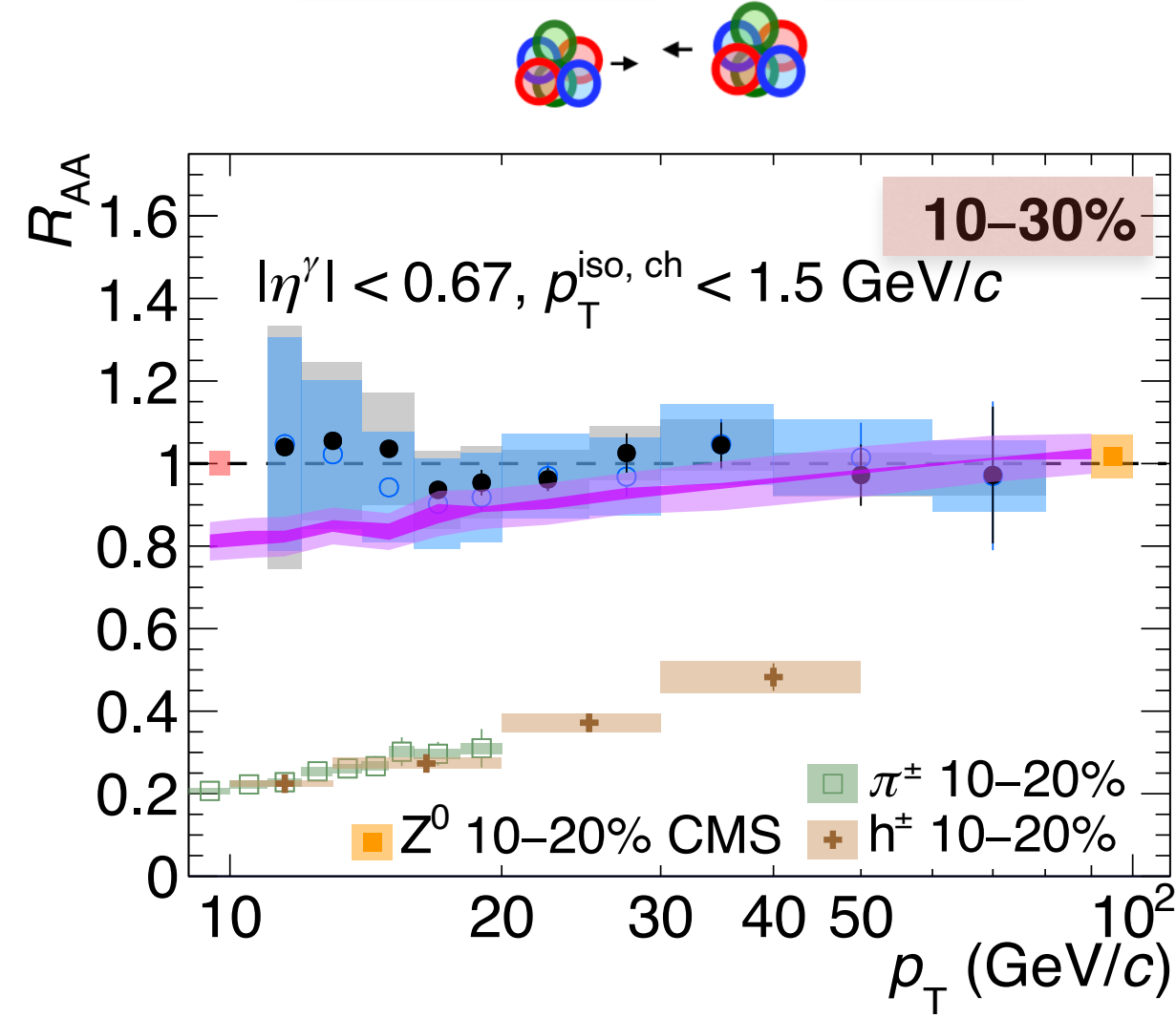
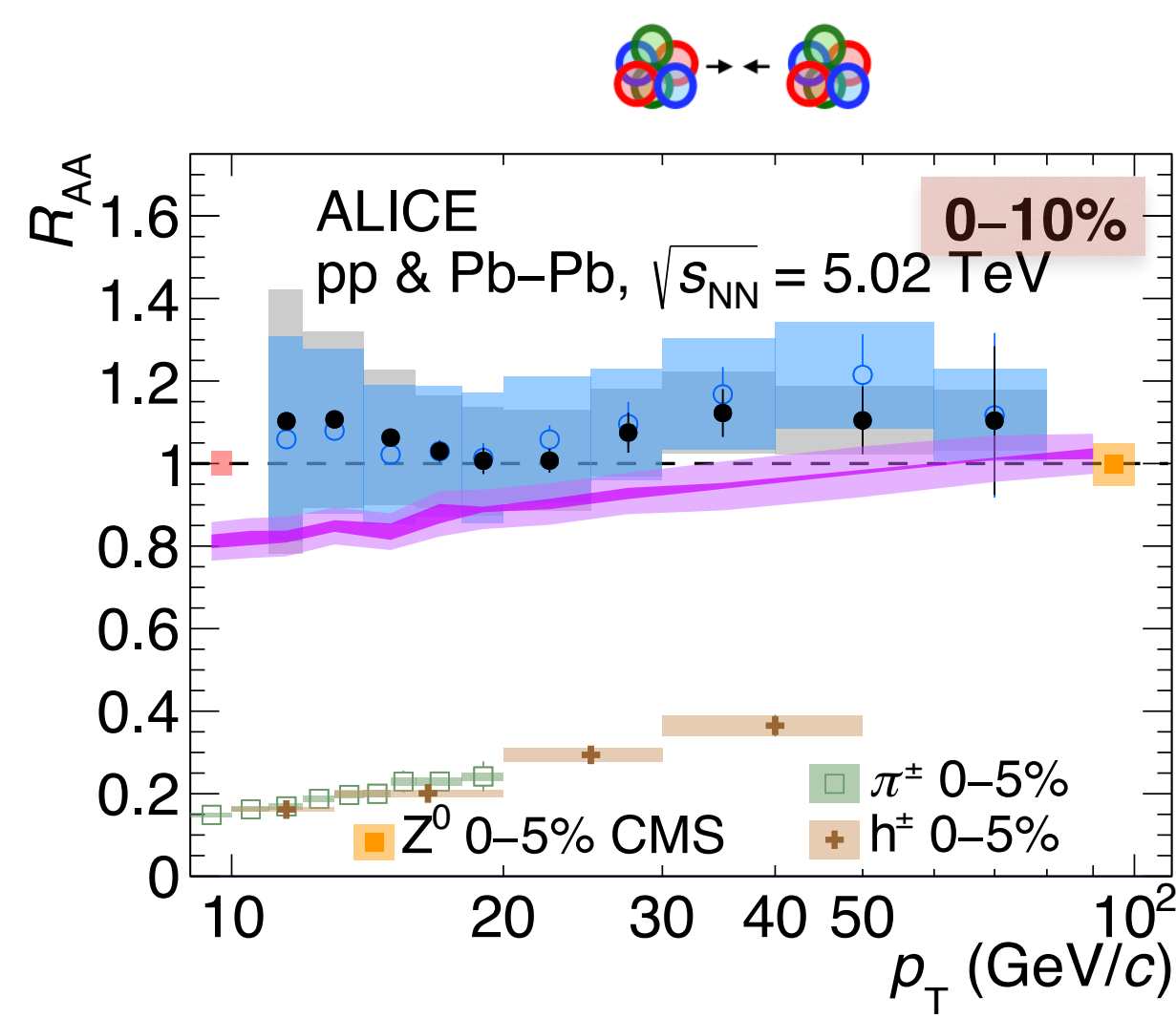


* Not shown: ATLAS pp $\sqrt{s} = 13$ TeV, for $p_T > 250$ GeV/c JHEP 07 (2023) 86 arXiv:2302.00510

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

- 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 nuclear matter effects: PDF vs nPDF
- 70-90%
 - Closer to 0.9 than 1 for both R , likely due to centrality selection bias of the 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

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



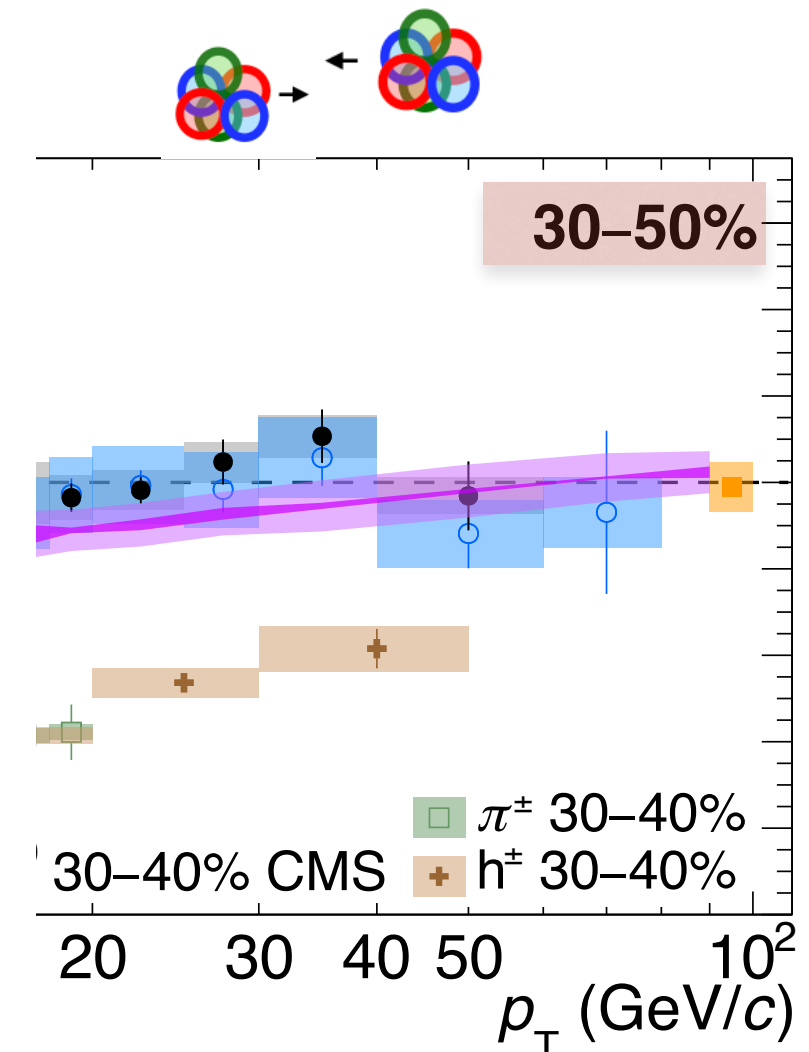
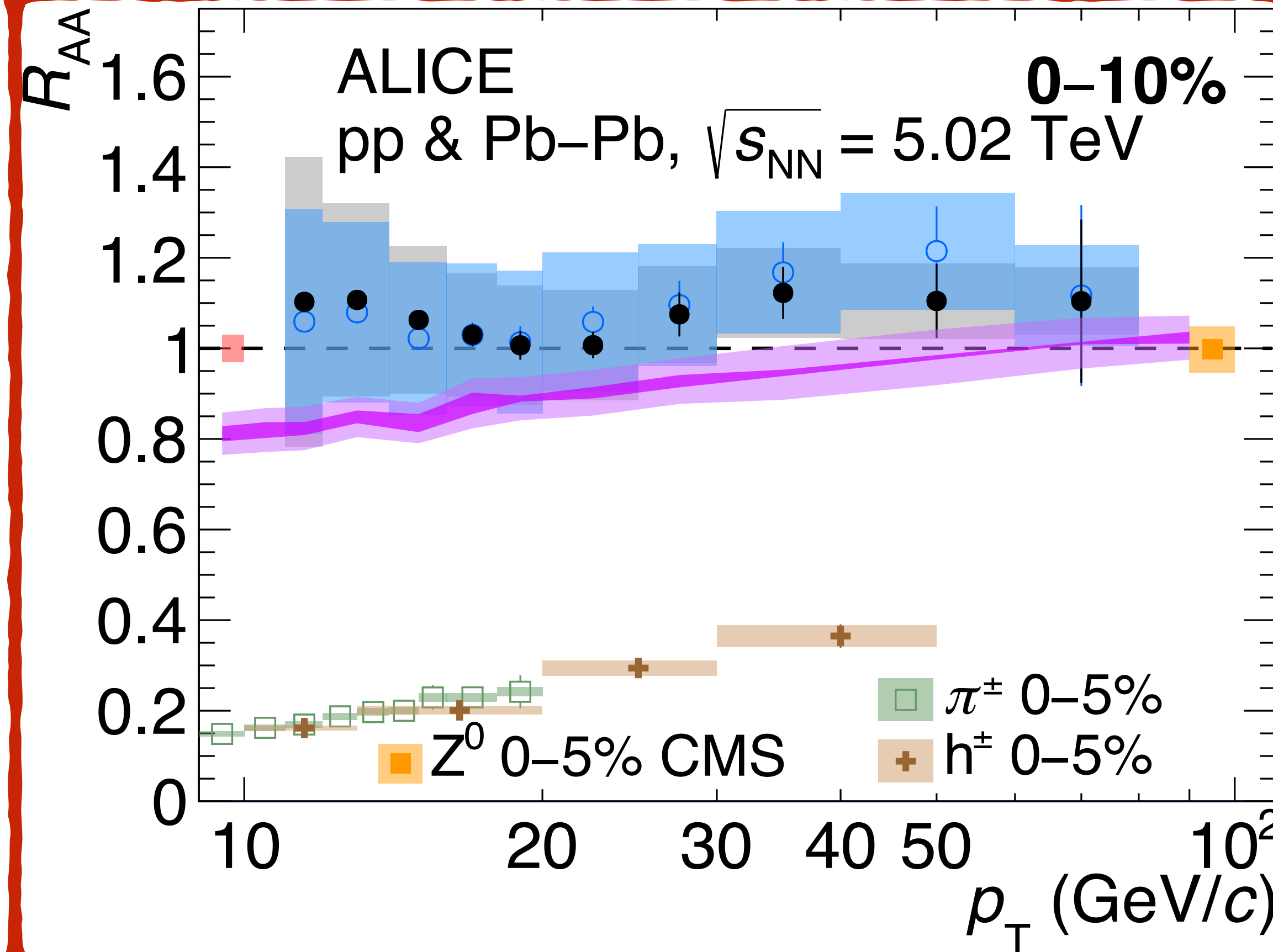
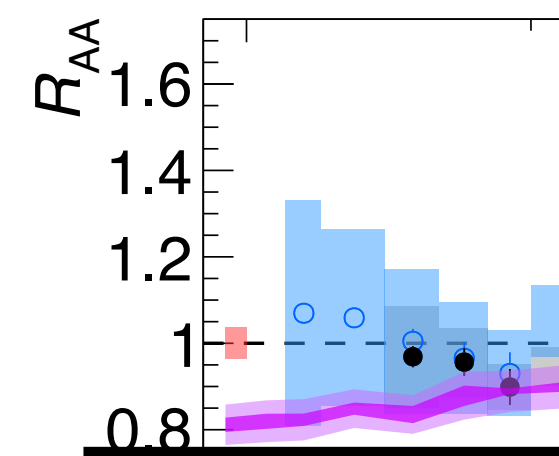
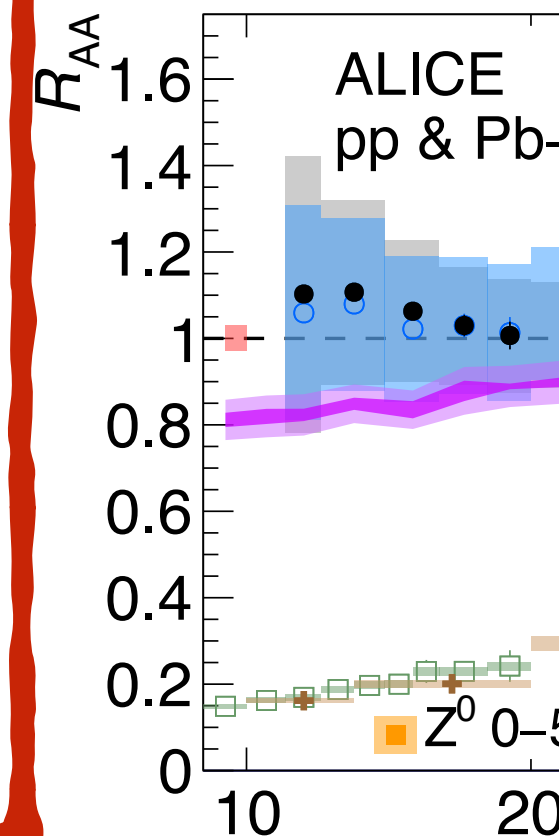
- $\bullet$ $R = 0.2$ stat. unc. $\circ$ $R = 0.4$ stat. unc.
- $\square$ $R = 0.2$ syst. unc. $\blacksquare$ $R = 0.4$ syst. unc.
- $\square$ Normalisation unc.
- NLO (JETPHOX), 0-100%
 $p_T^{iso} < 2$ GeV/c, $R = 0.2$
pp : NNP40/BFG II FF
Pb-Pb: nNNPDF30/BFG II FF, 0-100%
- $\blacksquare$ Scale unc. $p_T^\gamma/2 < \mu < 2p_T^\gamma$
- $\blacksquare$ PDF unc.

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



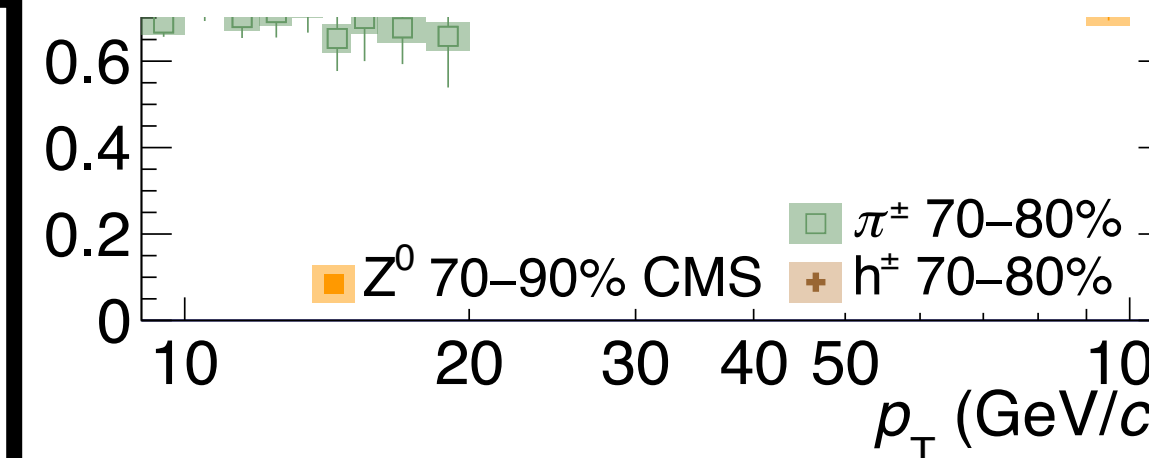
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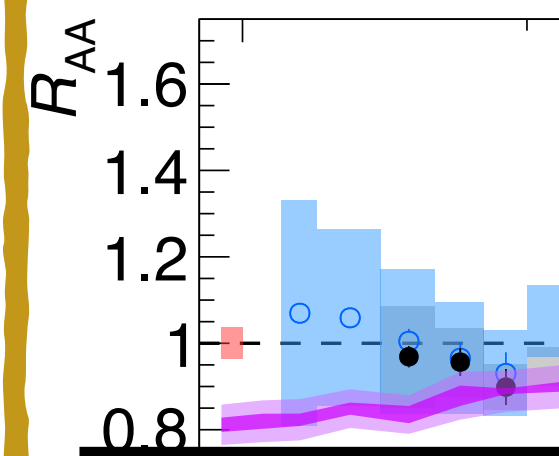
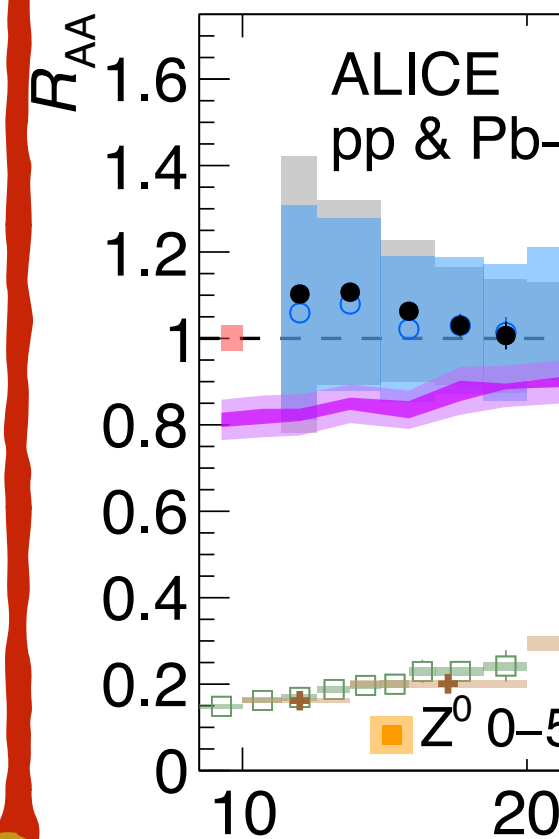
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Nuclear modification factor R_{AA} , pp & Pb-Pb at $\sqrt{s_{NN}} = 5.02$ TeV

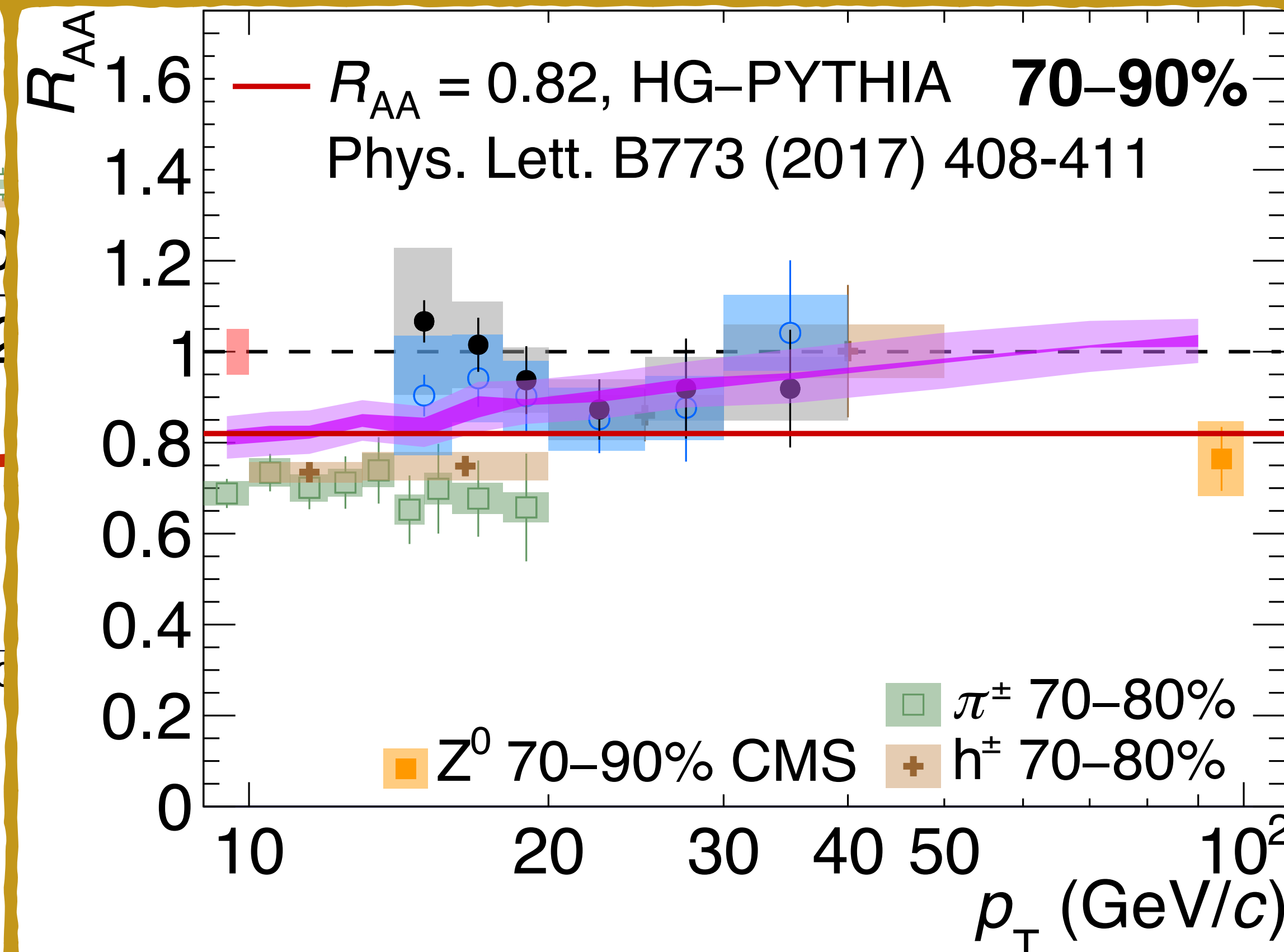
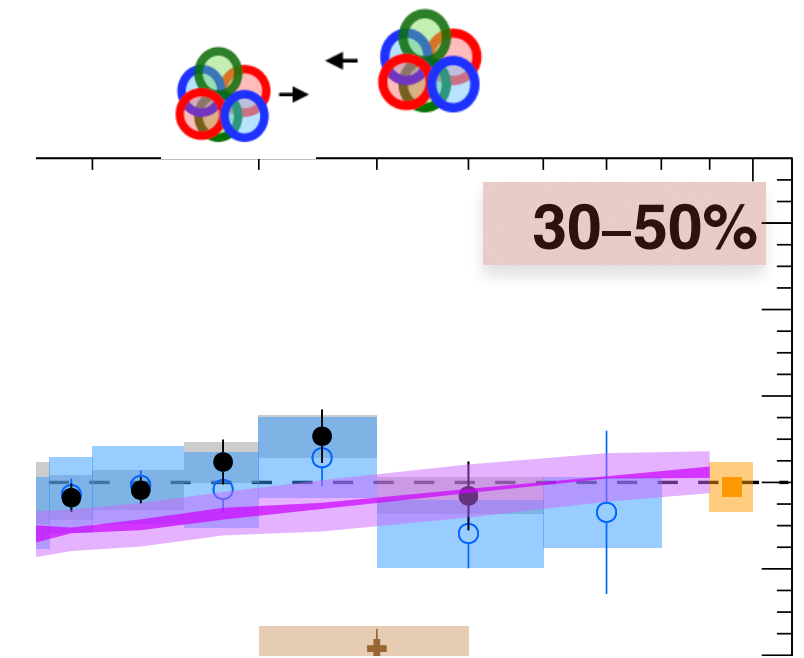
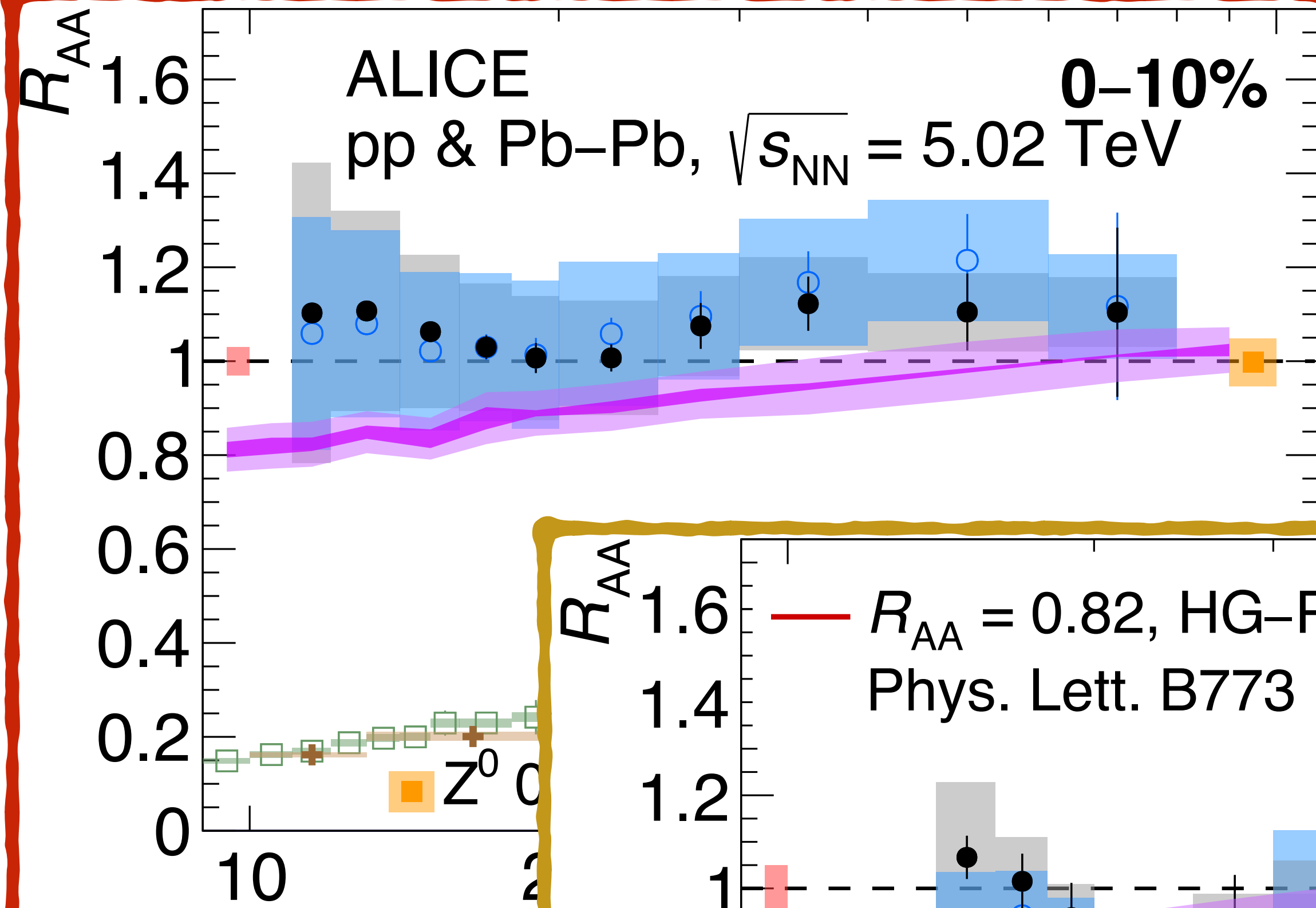


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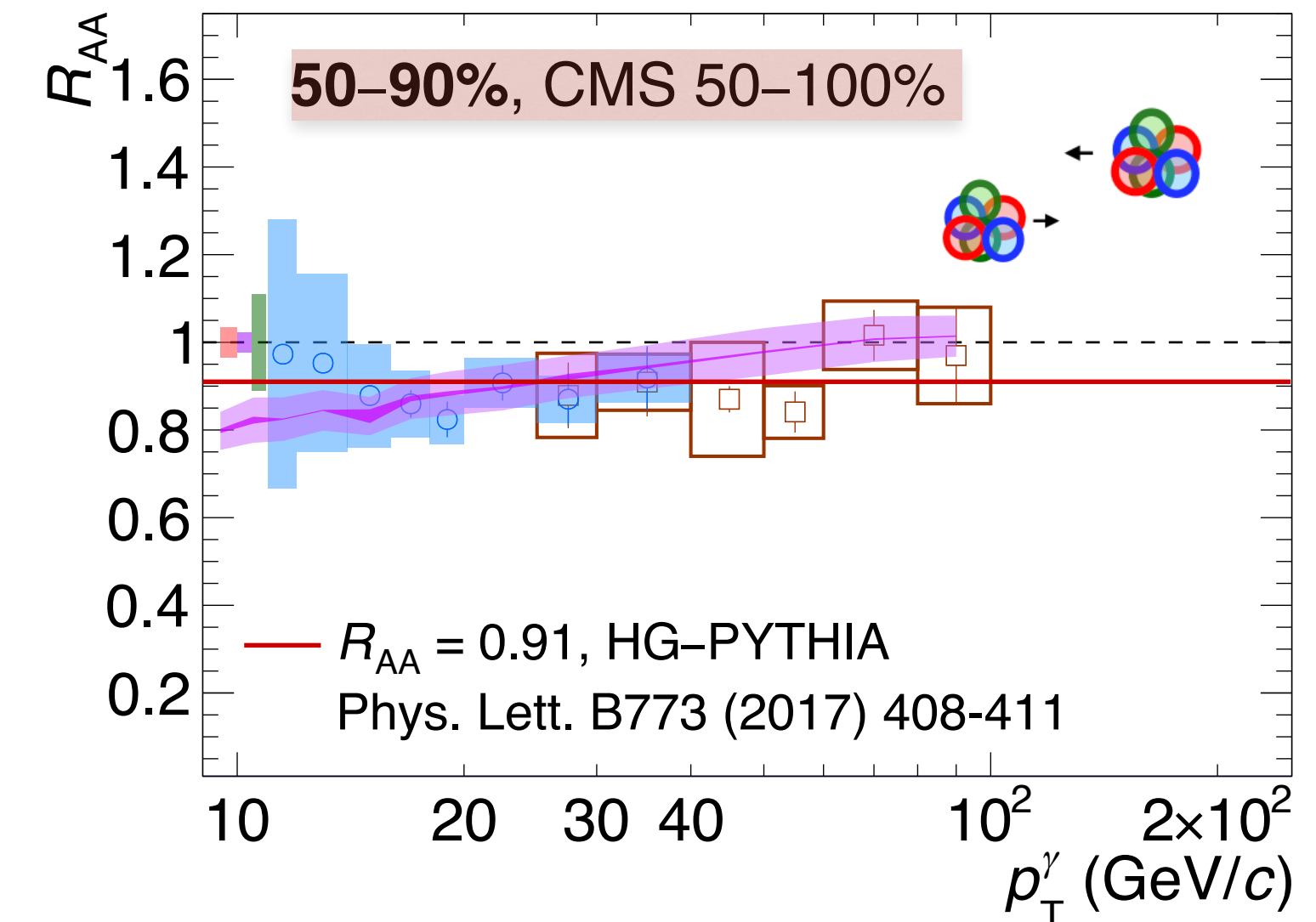
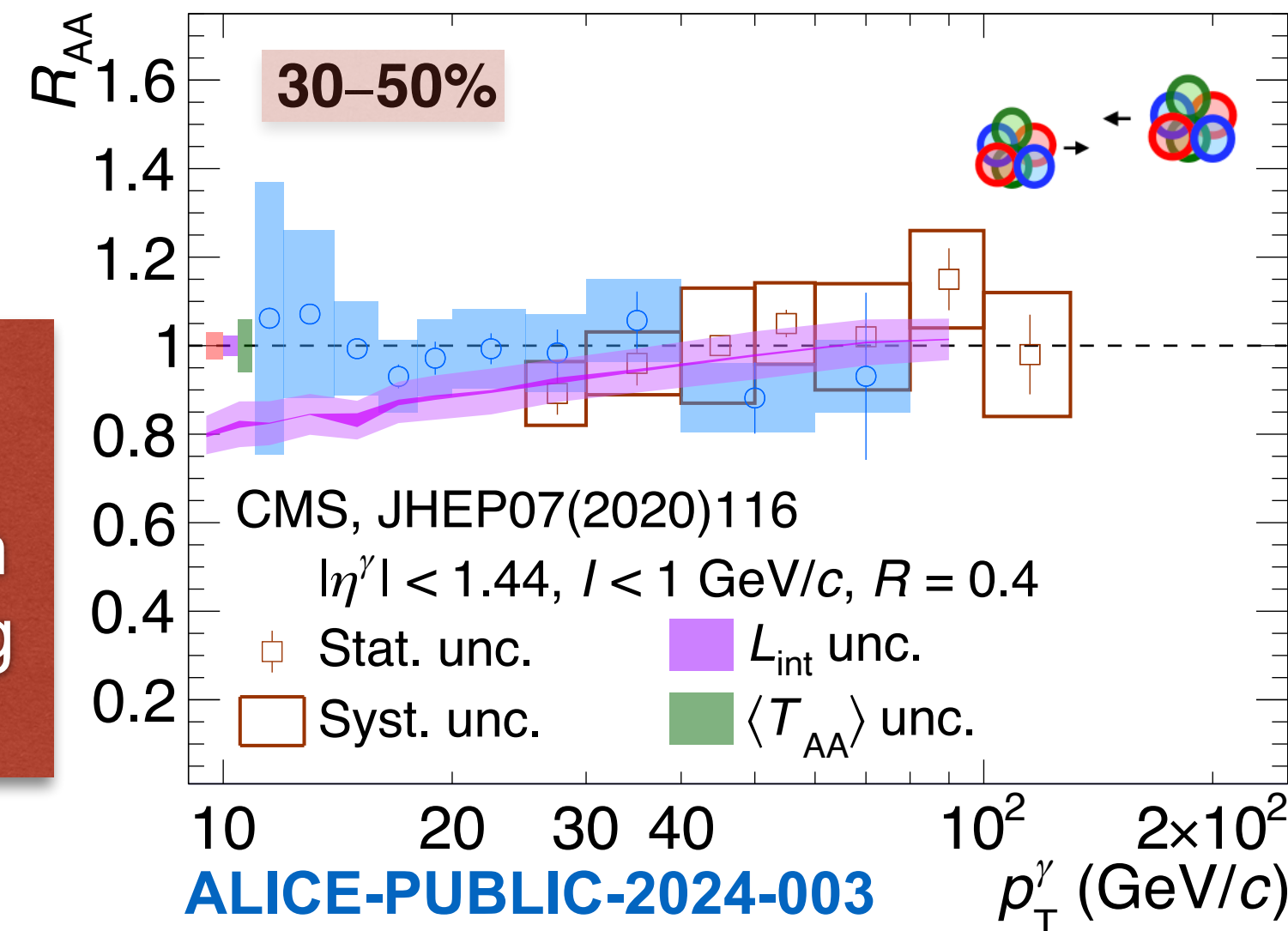
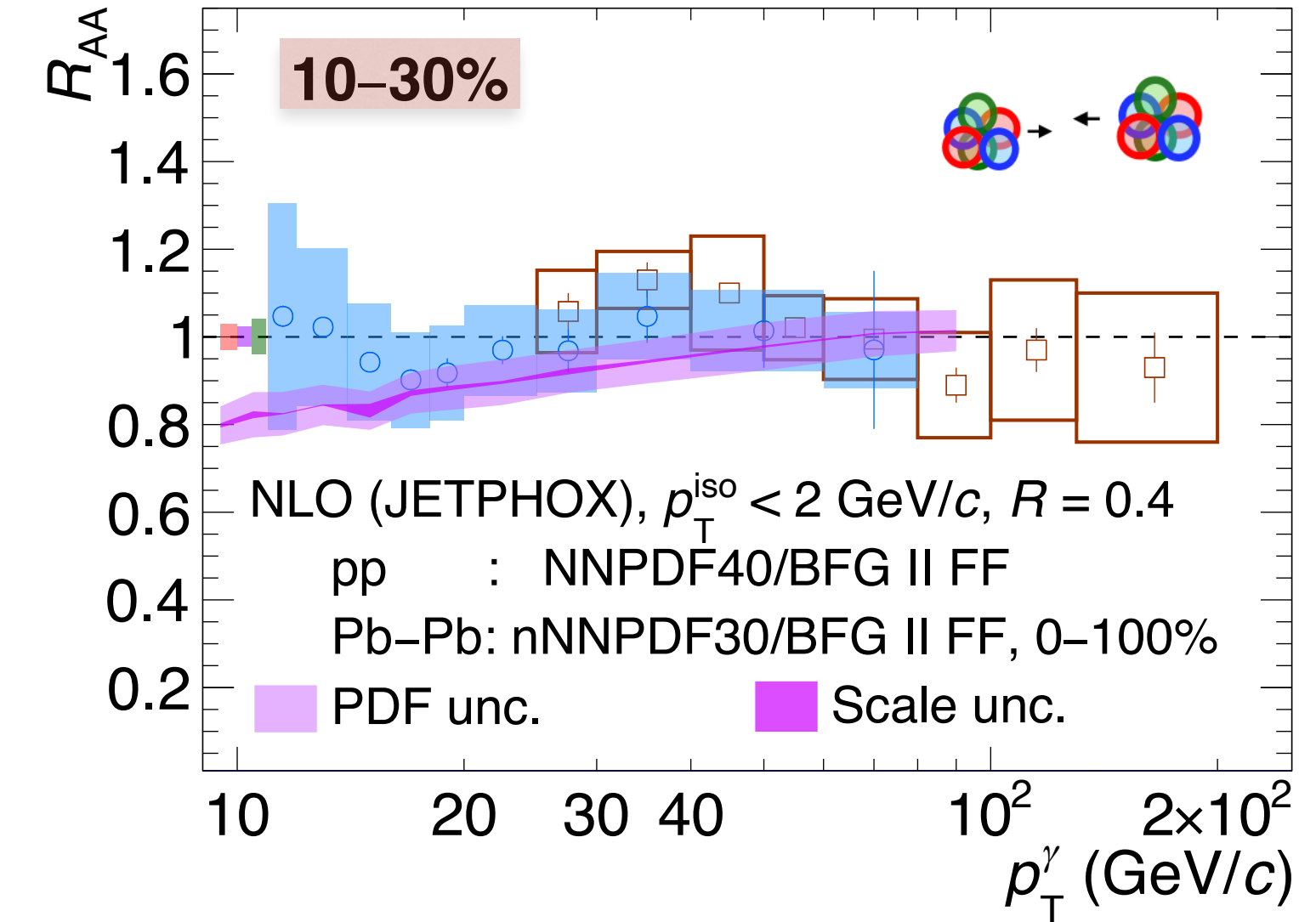
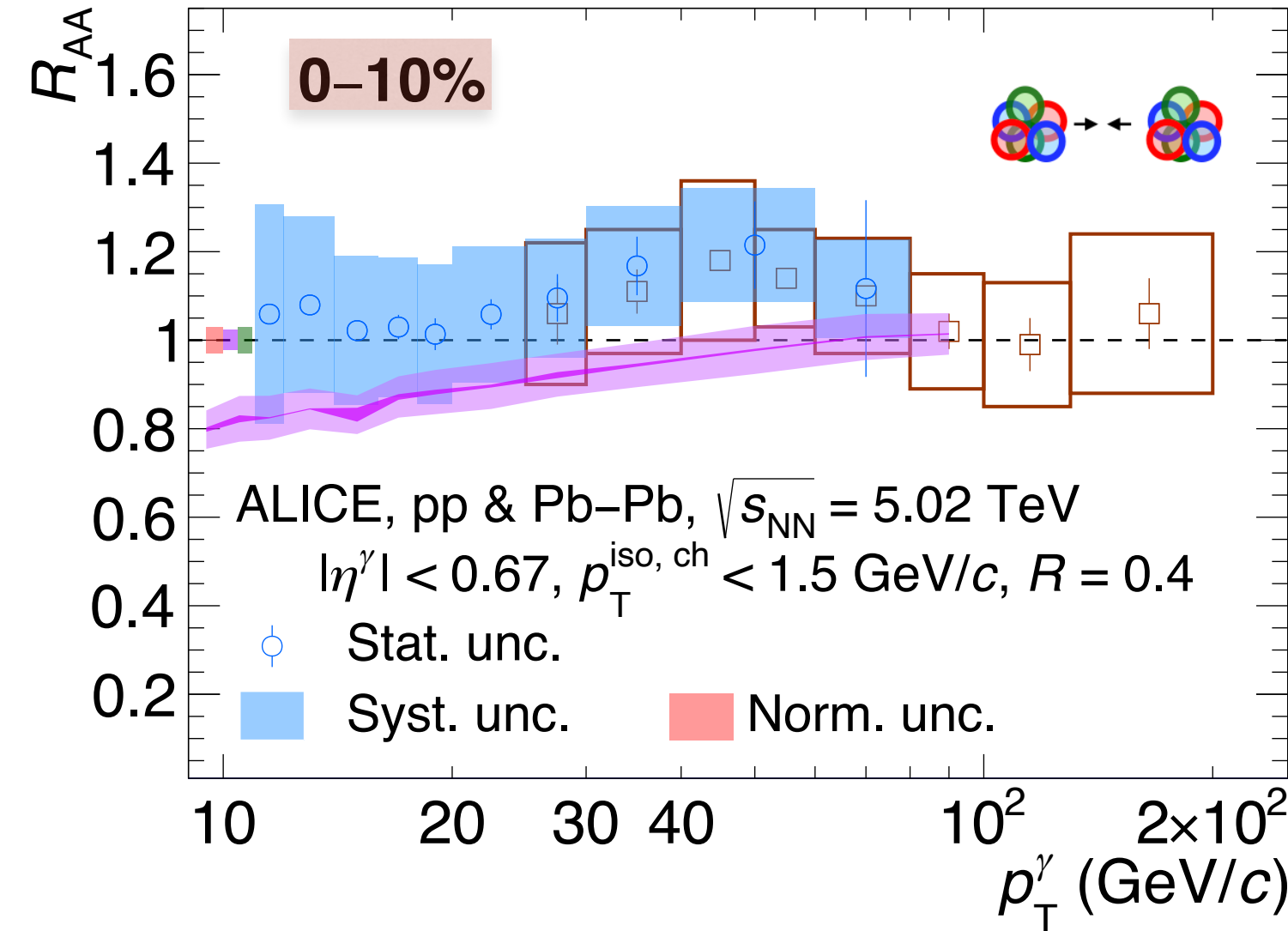
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Nuclear modification factor R_{AA} , pp & Pb-Pb at $\sqrt{s_{NN}} = 5.02$ TeV

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

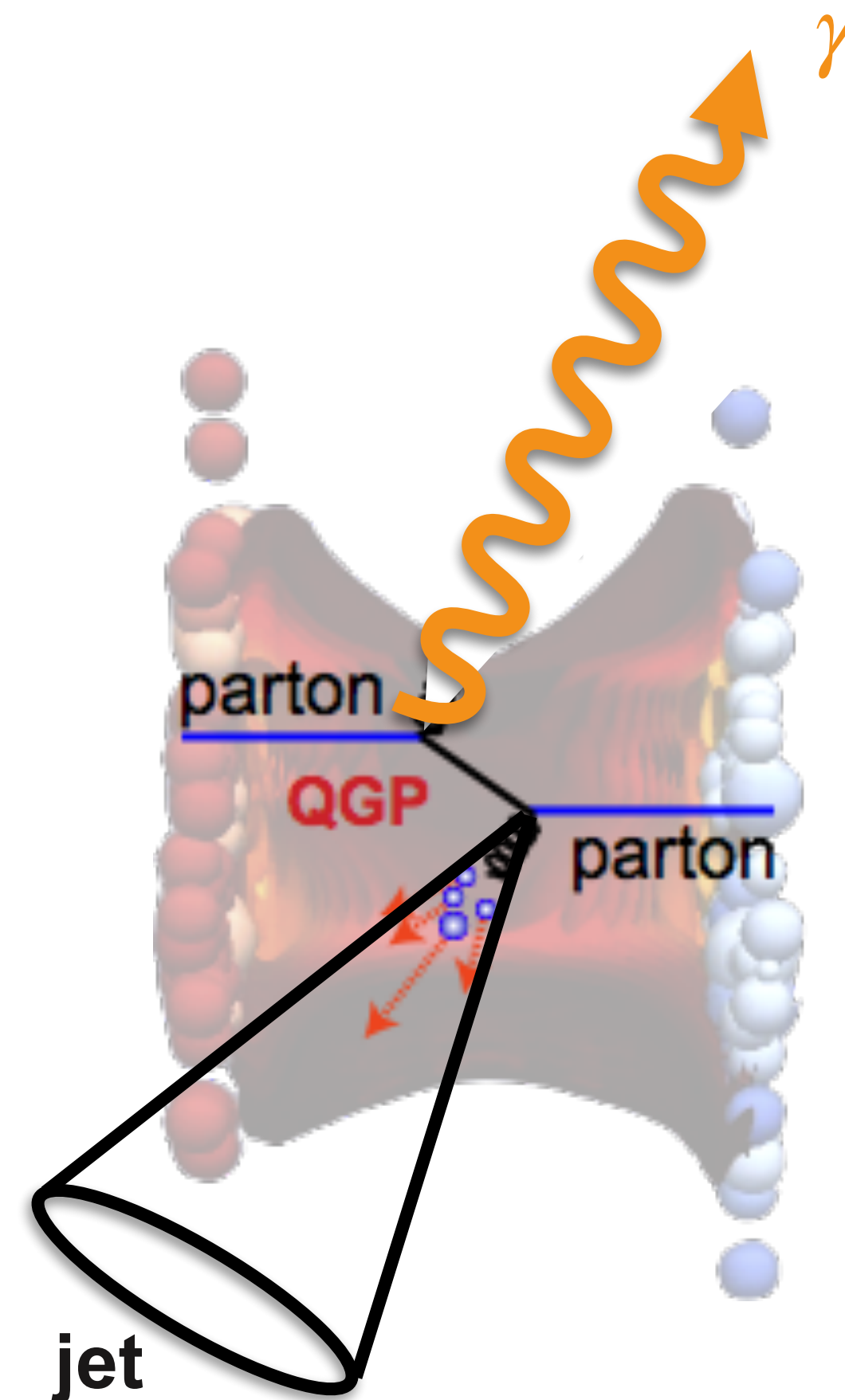
- **ALICE & CMS**: good agreement in the overlapping region $25 < p_T < 40$ – 80 GeV/c



Isolated photons are not modified by the QGP from central to peripheral collisions and are candle/calibrated probes to test the interpretation of other particles R_{AA} and study the jet-quenching of the back-to-back correlated partons

Isolated prompt γ -hadron correlations:

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



* pp & p-Pb at $\sqrt{s_{NN}} = 5.02$ TeV:

[Phys. Rev. C 102 \(2020\) 044908](#)

* Pb-Pb at $\sqrt{s_{NN}} = 5.02$ TeV:

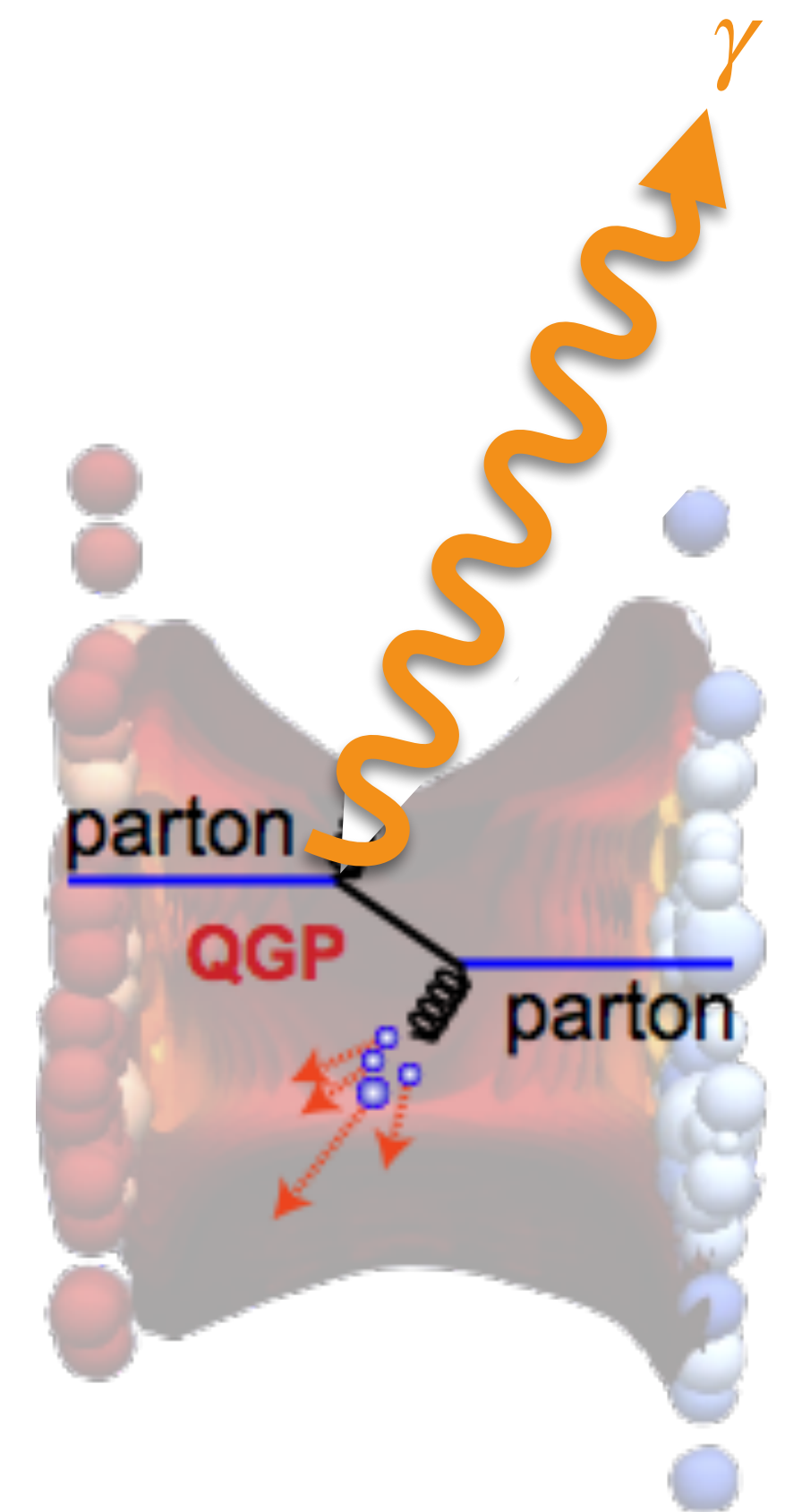
[arXiv:2605.02342](#), [ALICE-PUBLIC-2026-001](#),

Carolina Arata's thesis, UGA-LPSC,

tel-04891584

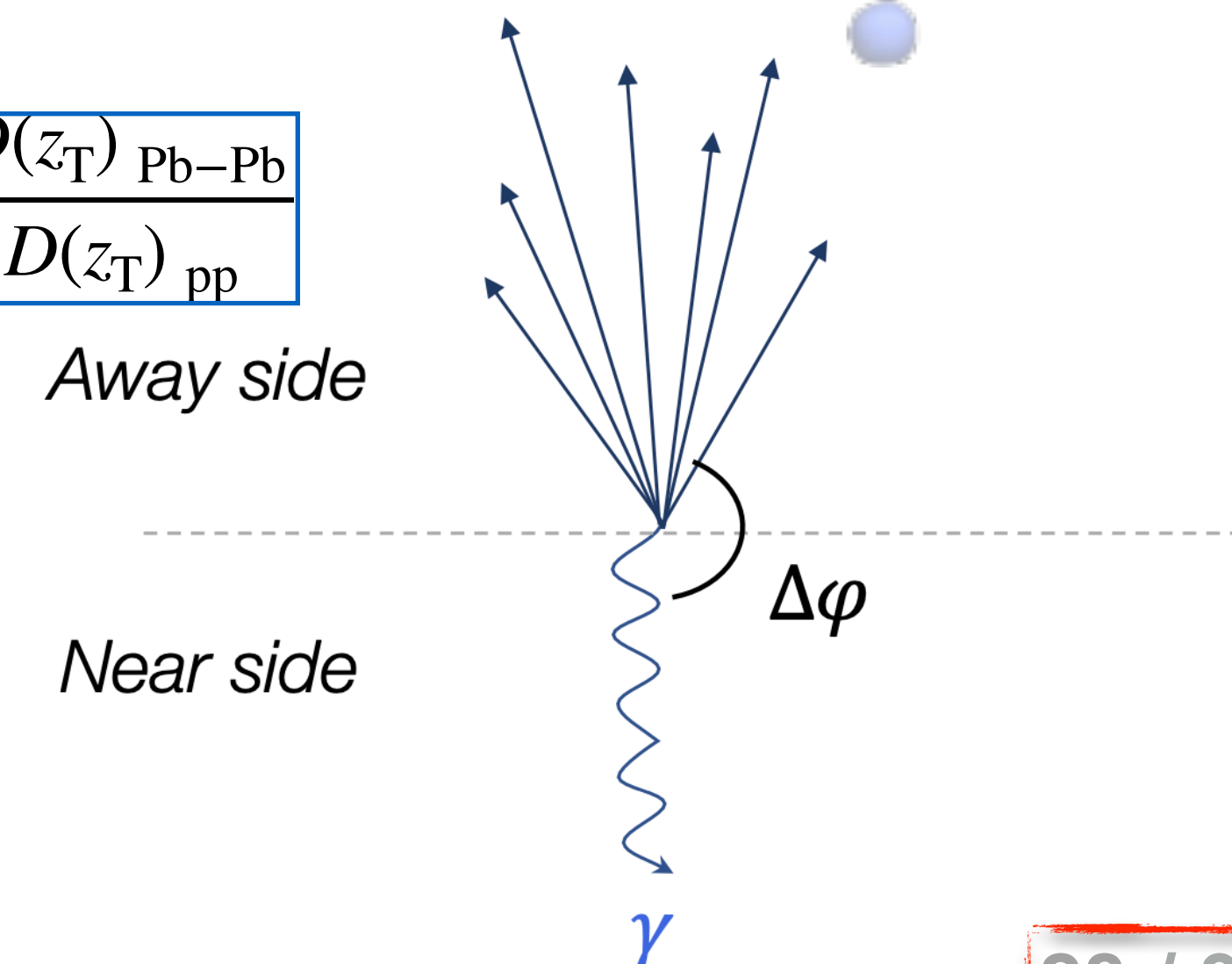
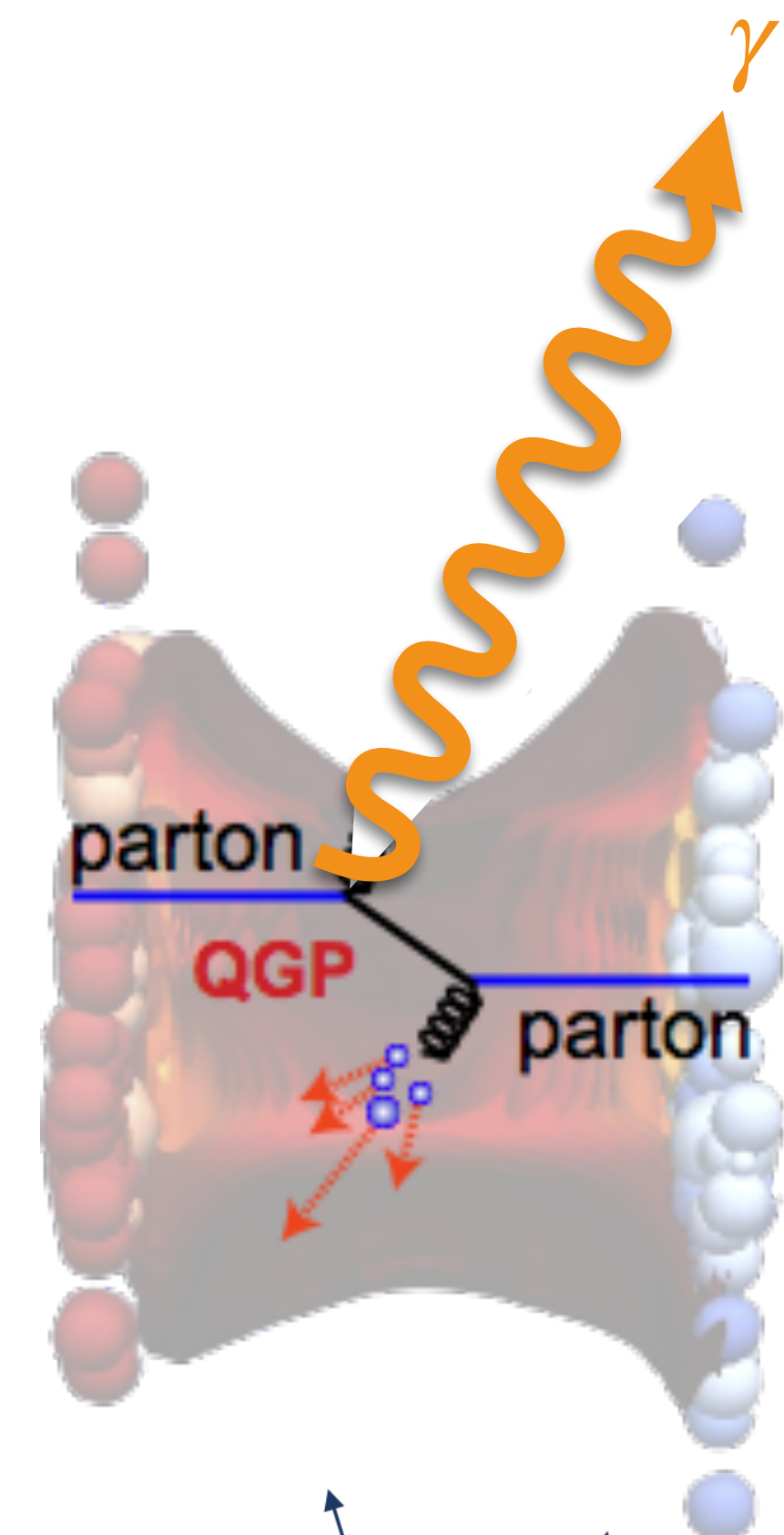
Isolated prompt γ -hadron correlations

- Prompt γ associated to a parton emitted in opposite side
- **Tags the parton initial energy** $p_T^\gamma \simeq p_T^{\text{parton}}$, before losing ΔE in QGP
 - ➔ Aim: Measure fragmentation function modifications, where is the ΔE radiated?



Isolated prompt γ -hadron correlations

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- **Tags the parton initial energy** $p_T^\gamma \simeq p_T^{\text{parton}}$, before losing ΔE in QGP
 - ➔ Aim: Measure fragmentation function modifications, where is the ΔE radiated?
- Observables:
 - ➔ Trigger: isolated narrow or wide clusters, $R = 0.2$ (Pb-Pb), 0.4 (pp, p-Pb)
 $p_T^{\text{iso ch}} < 1.5 \text{ GeV}/c$
 - ➔ Azimuthal correlation: $\Delta\varphi = \varphi^{\text{trigger}} - \varphi^{\text{track}}$ with
 - ➔ $z_T = \frac{p_T^{\text{track}}}{p_T^{\text{trigger}}}$ and $D(z_T) = \frac{1}{N^{\text{trigger}}} \frac{d N^{\text{track}}}{d z_T}$ for tracks in $|\Delta\varphi| > 3/5\pi \text{ rad}$ (mirrored)
 - ➔ **When trigger = prompt γ , $D(z_T)$ is a proxy for FF, check modification with:** $I_{AA} = \frac{D(z_T)_{\text{Pb-Pb}}}{D(z_T)_{\text{pp}}}$
 - ➔ Measurement: 12 (pp, p-Pb) 18 (Pb-Pb) $< p_T^{\text{trigger}} < 40 \text{ GeV}/c$ & $p_T^{\text{track}} > 0.5 \text{ GeV}/c$
 - Analysis details in the backup
 - * Underlying event removed via mixed-event method
 - * Contamination due to photons from neutral mesons is estimated by combining correlations of narrow and wide clusters weighted by the measured purity



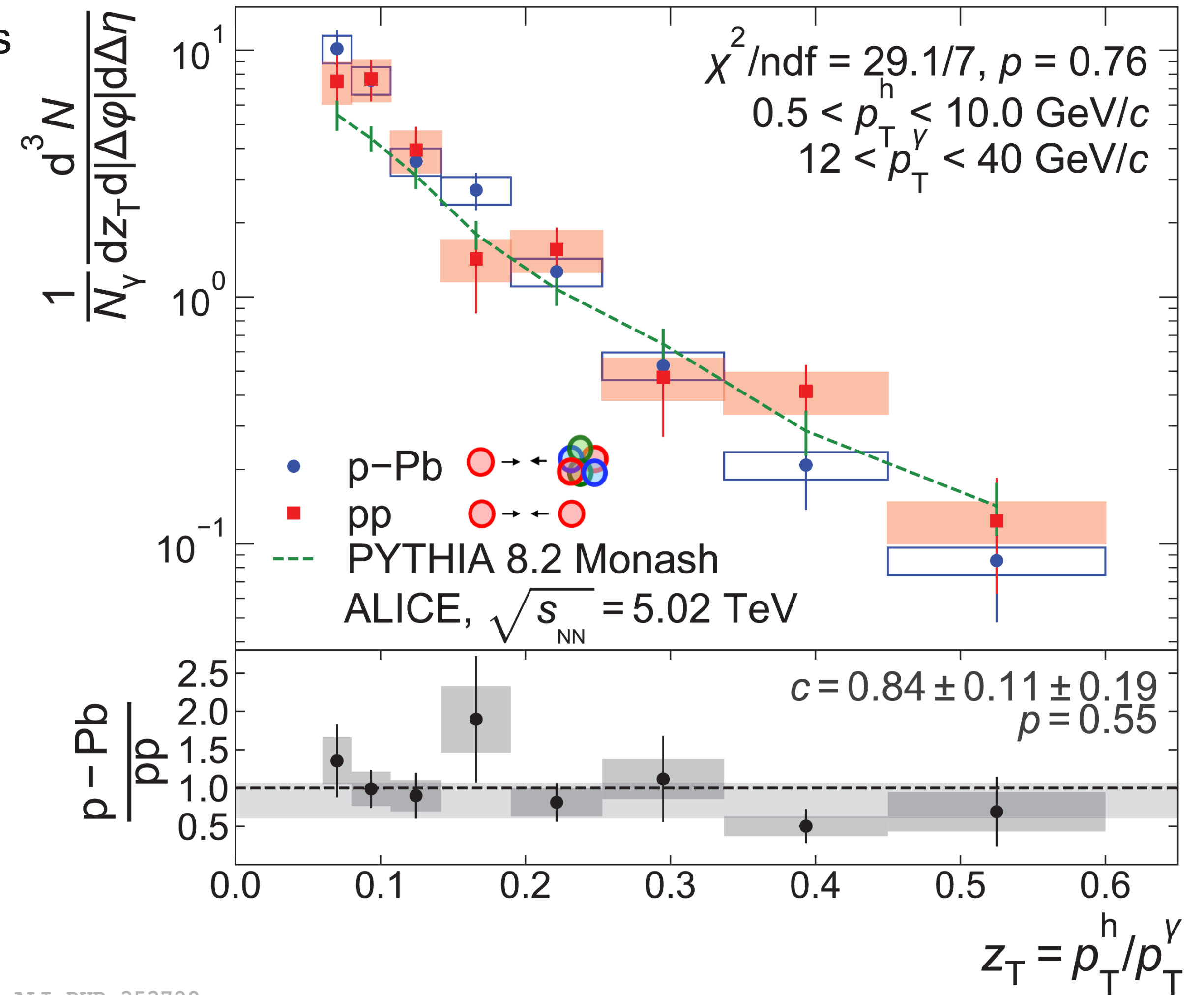
Isolated prompt γ -hadron correlations in p-Pb & pp collisions:

Phys. Rev. C 102 (2020) 044908

- Previous published results in p-Pb and pp collisions

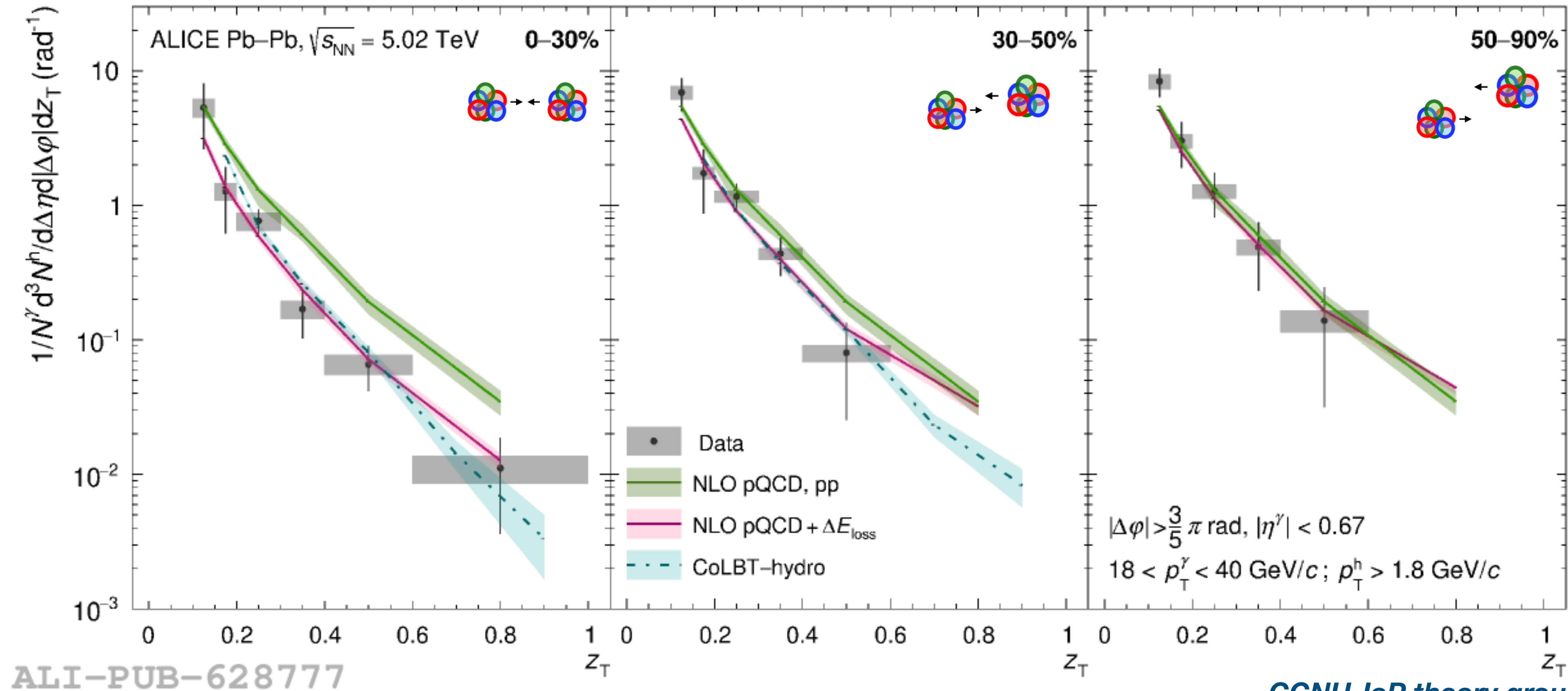
→ Agreement between systems and with PYTHIA

→ Note: Pb-Pb collisions measurement (next slides) done in different p_T ranges and R and is compared directly to pQCD predictions



ALI-PUB-353789

Isolated prompt γ -hadron correlations in Pb-Pb collisions:



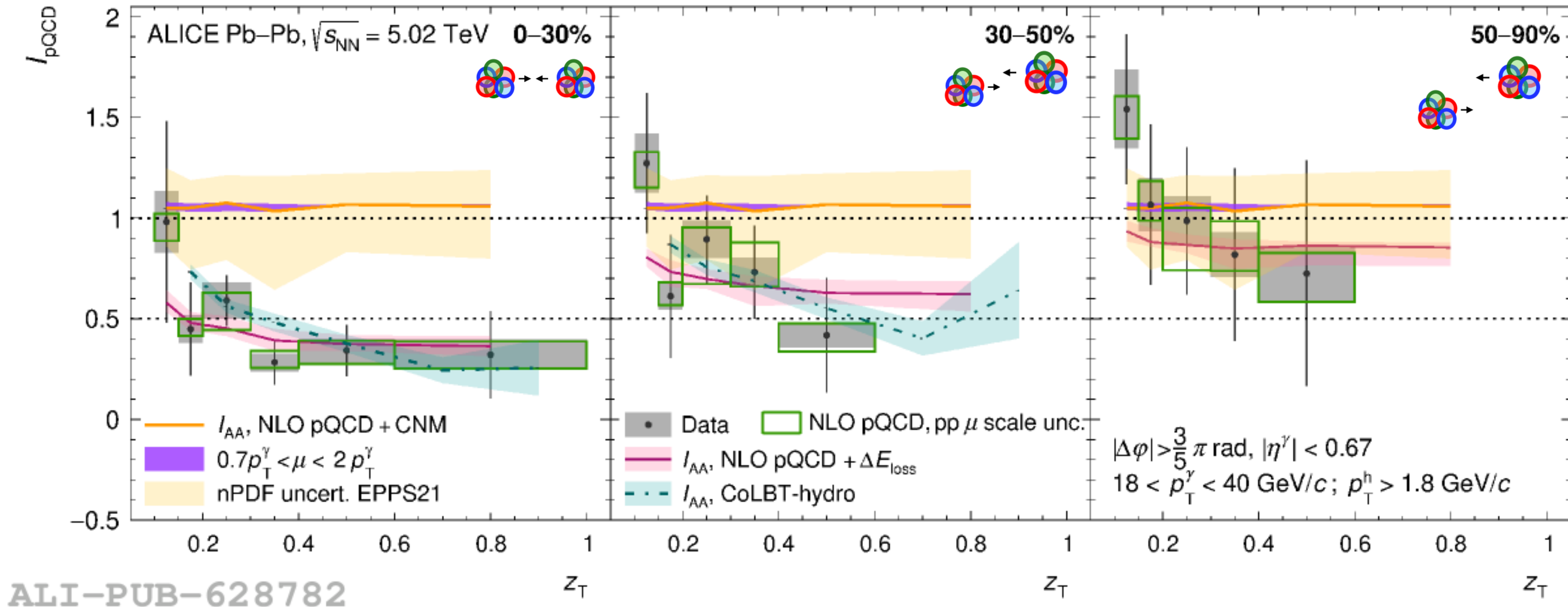
- Pb-Pb data compared with theory: $NLO \text{ pQCD} + \Delta E_{\text{loss}}$ and CoLBT (0-50% only)
 - ➔ In agreement with both models including energy loss in the medium
 - ➔ Discrimination is not possible yet

Carolina Arata's thesis
LPSC
tel-04891584

CCNU-IoP theory group predictions:

- *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 prompt γ -hadron correlations in Pb-Pb collisions:



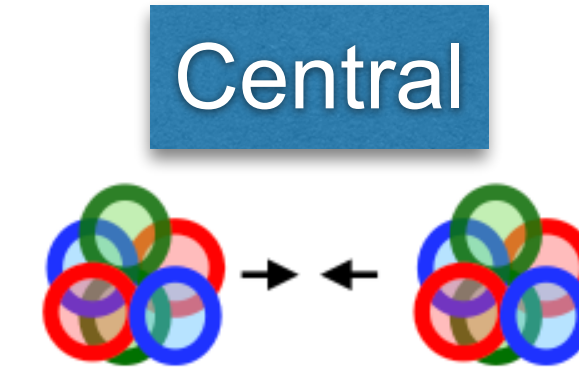
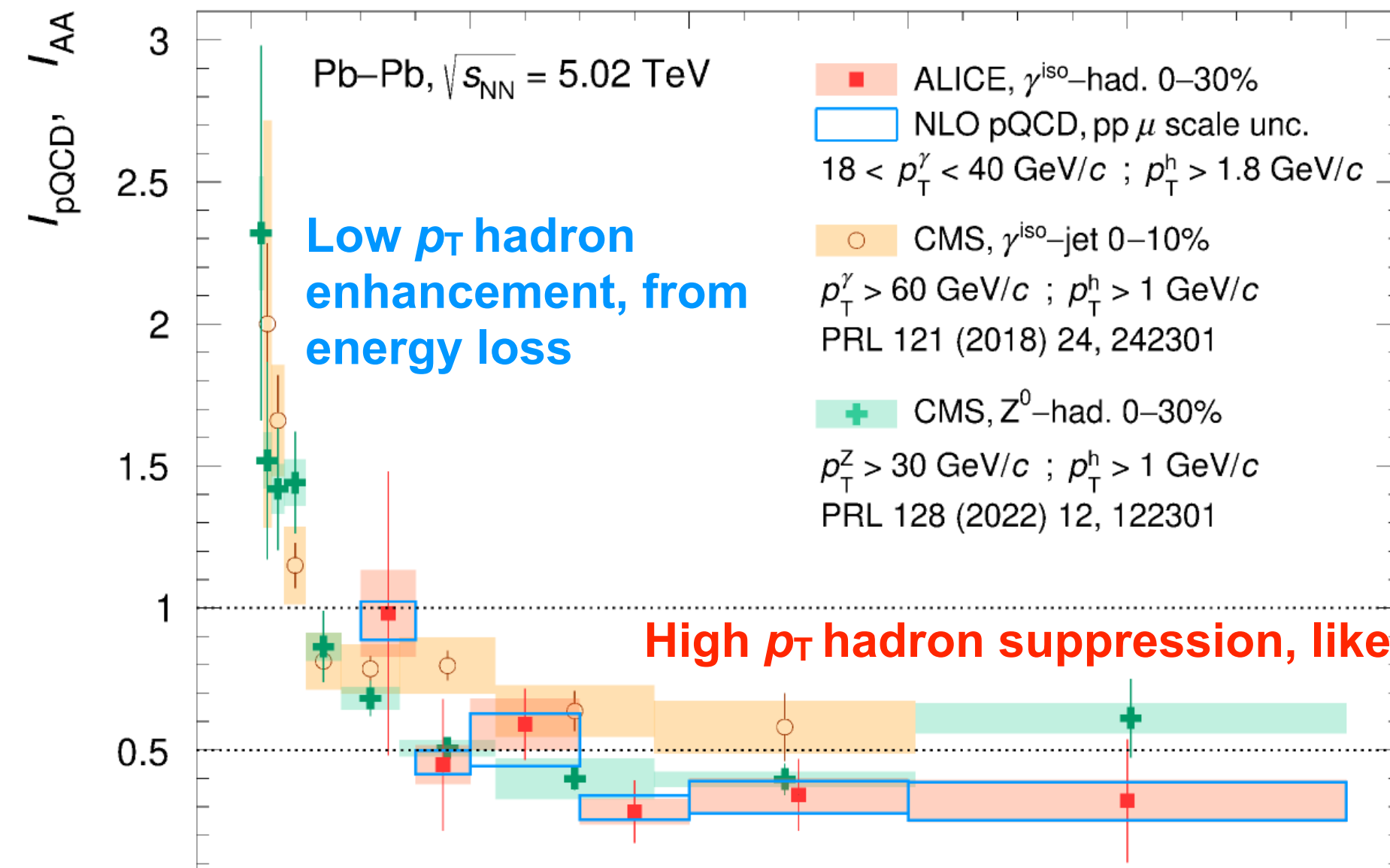
ALI-PUB-628782

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

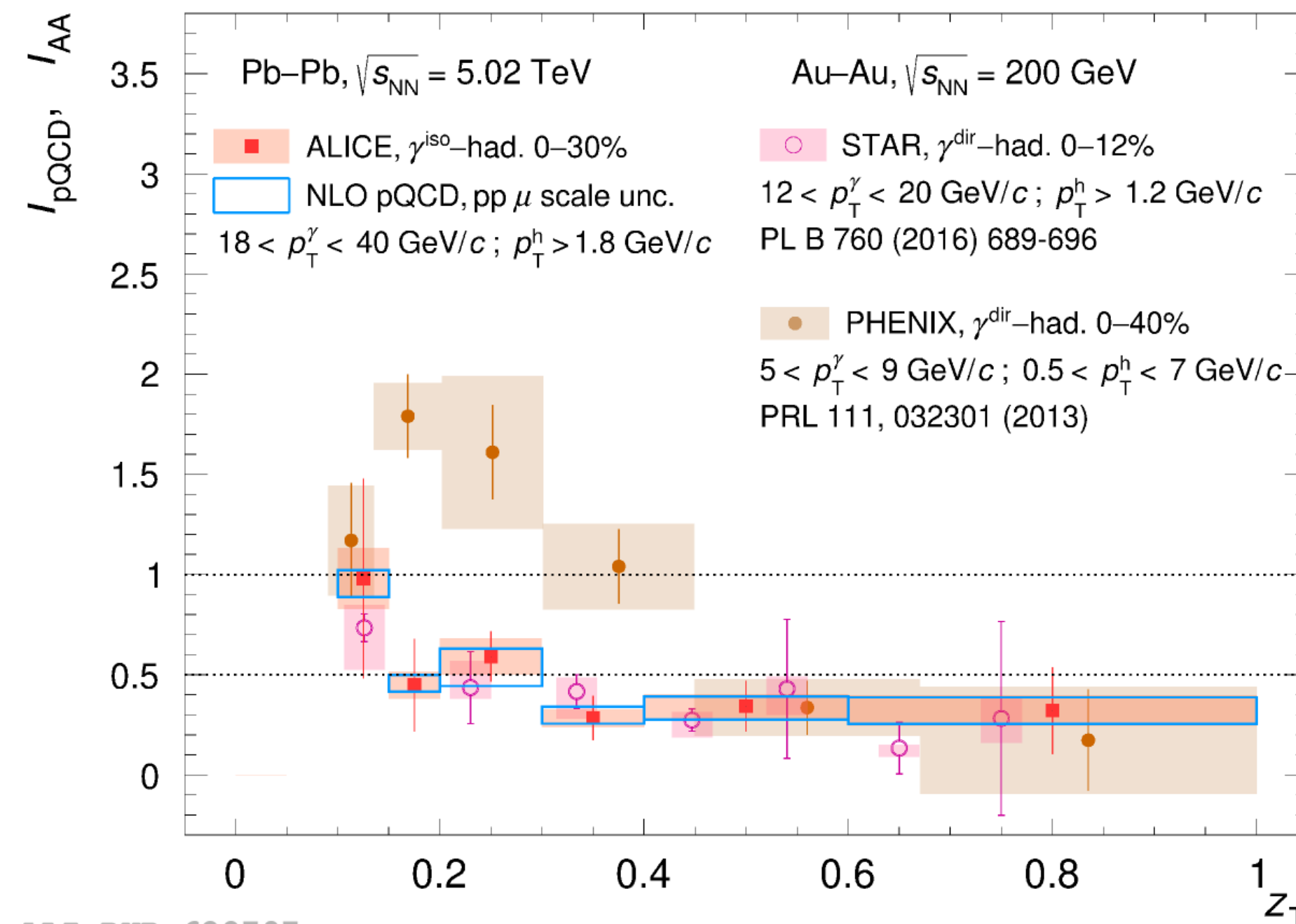
CCNU-IoP theory group
predictions, thanks!

Carolina Arata's thesis
LPSC
tel-04891584

Isolated prompt γ -hadron correlations in Pb-Pb collisions: RHIC & LHC



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



Similar behaviour observed at RHIC and LHC experiments

- ➔ Note: not completely apple-to-apple comparisons!
- ➔ ALICE results closer to STAR and CMS Z-hadron that have closer kinematic and/or centrality selections

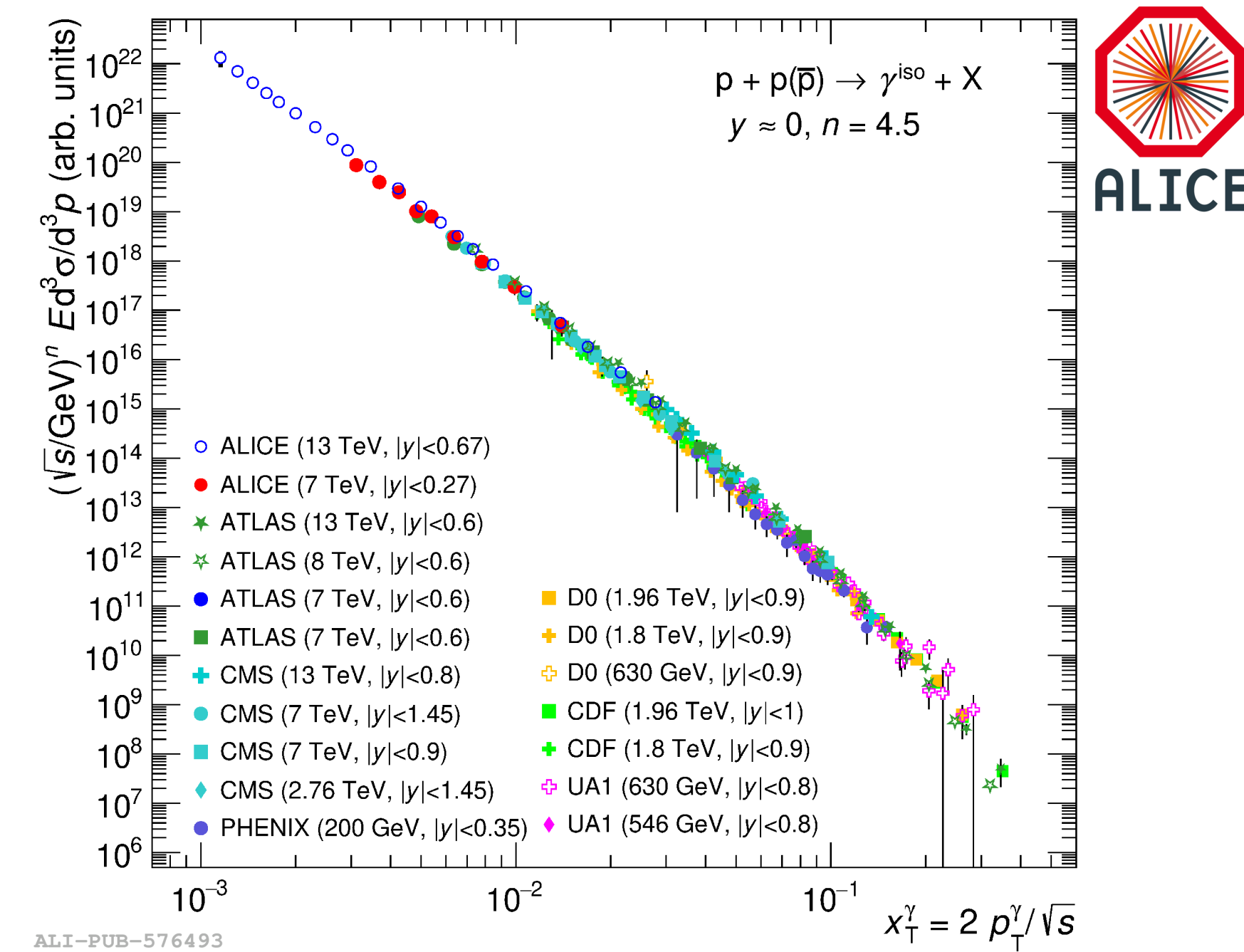
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ALI-PUB-628797

Summary

➔ Cross section

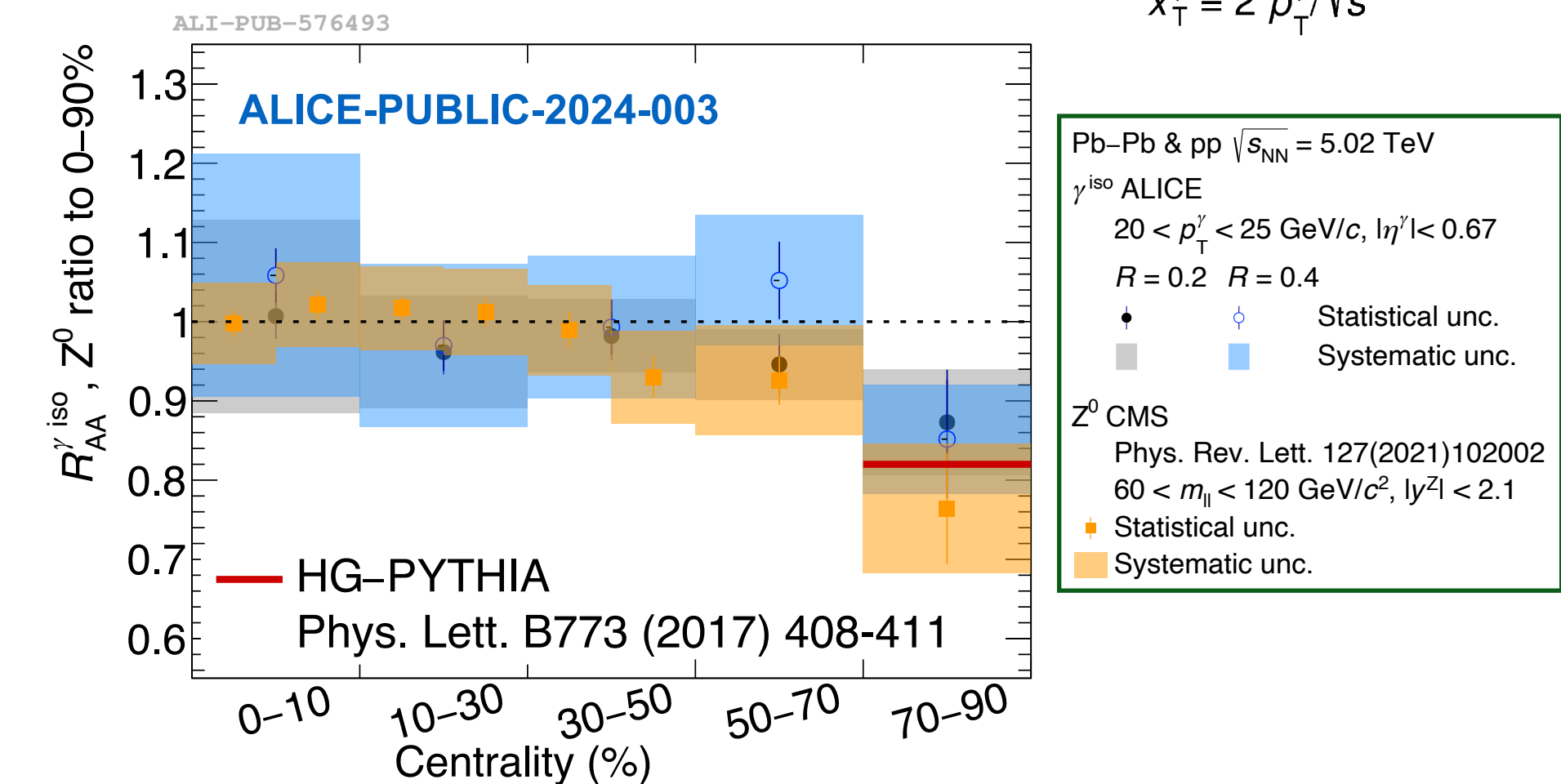
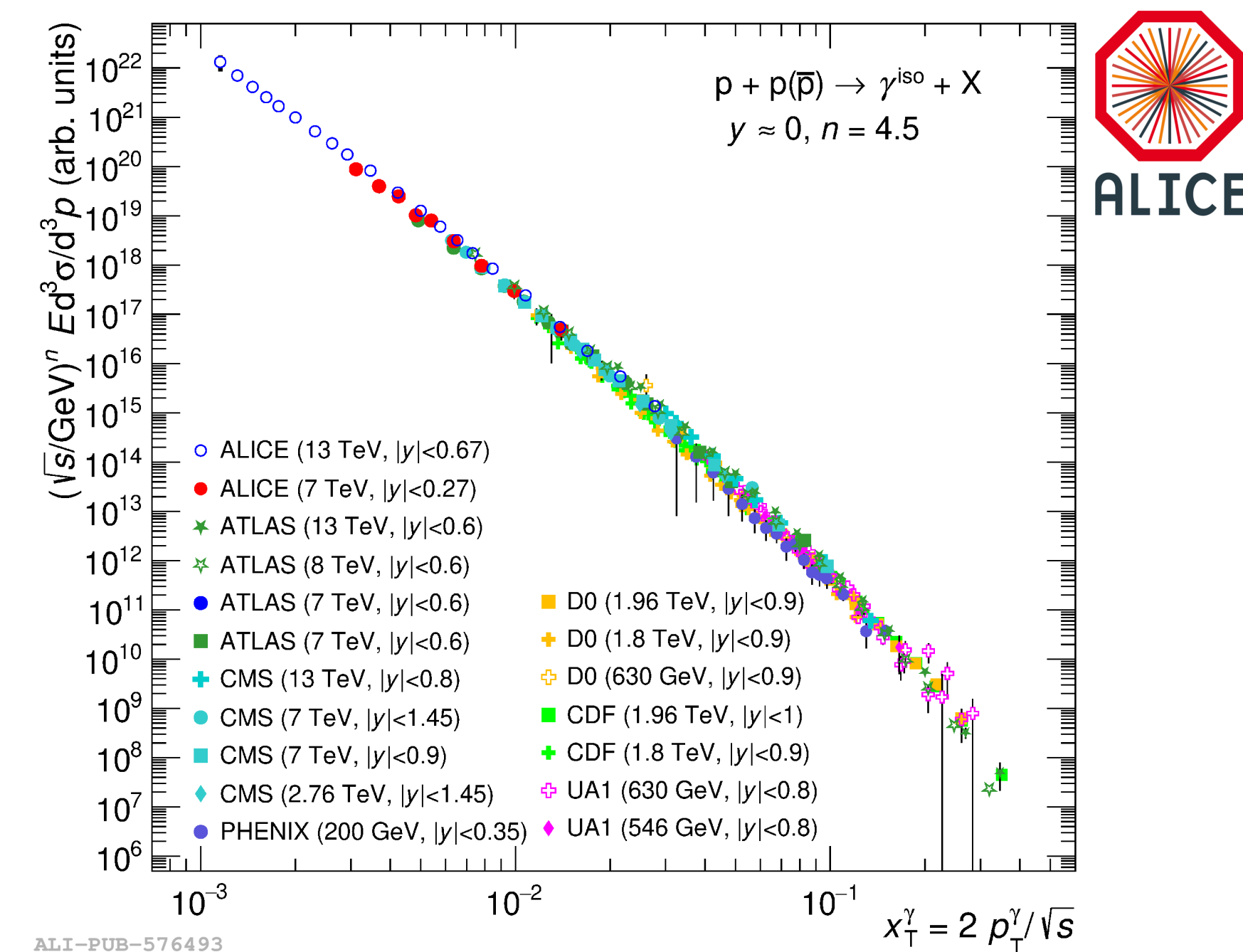
- * Data in agreement with NLO pQCD in multiple collision systems & $\sqrt{s_{\text{NN}}}$
- * Lowest measured x_T at mid-rapidity in pp collisions at $\sqrt{s} = 13$ TeV
- * Ratio of cross sections for different R in agreement with theory and within the different collision systems



Summary

→ Cross section

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



Summary

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- * Data in agreement with NLO pQCD in multiple collision systems & $\sqrt{s_{NN}}$
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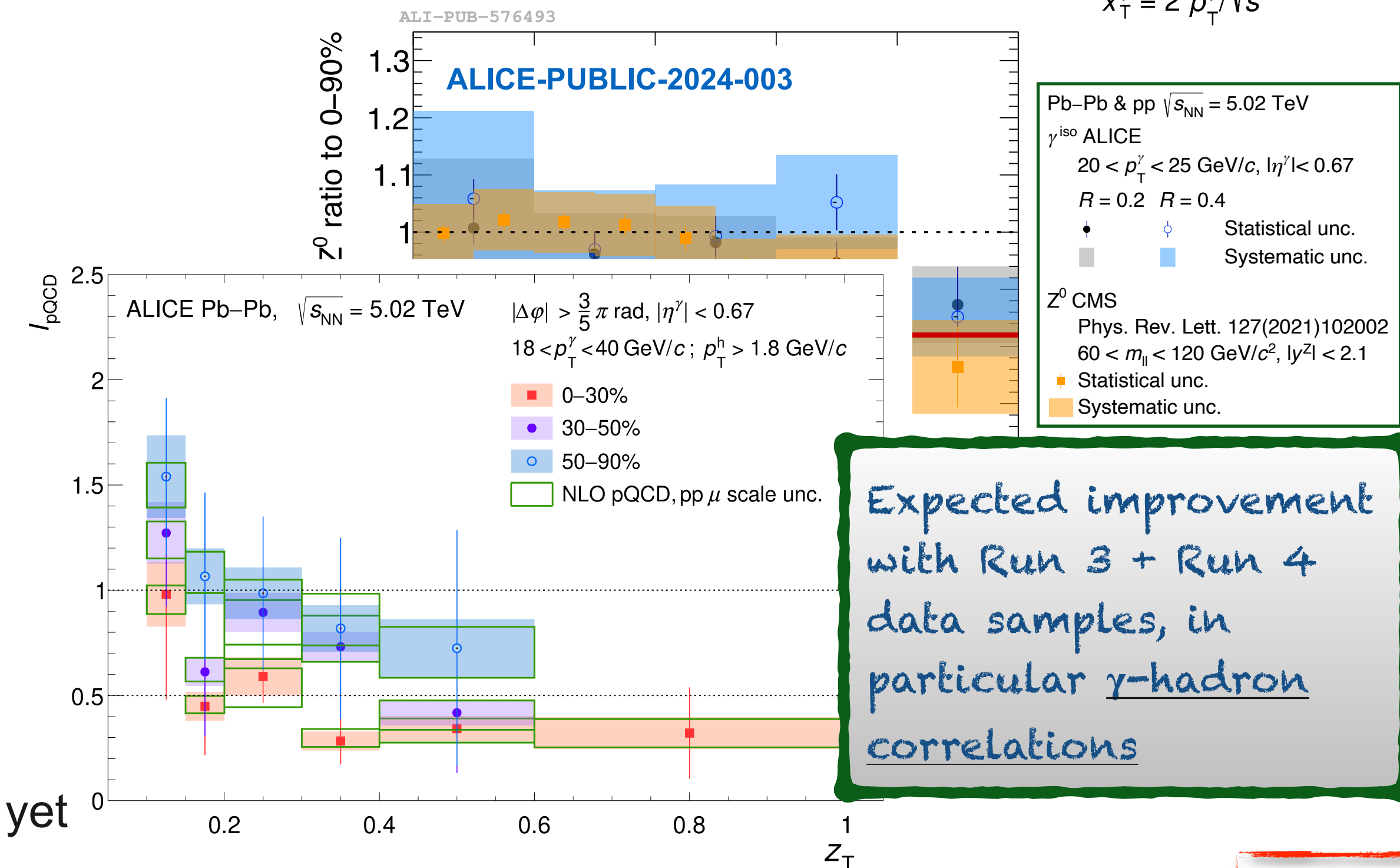
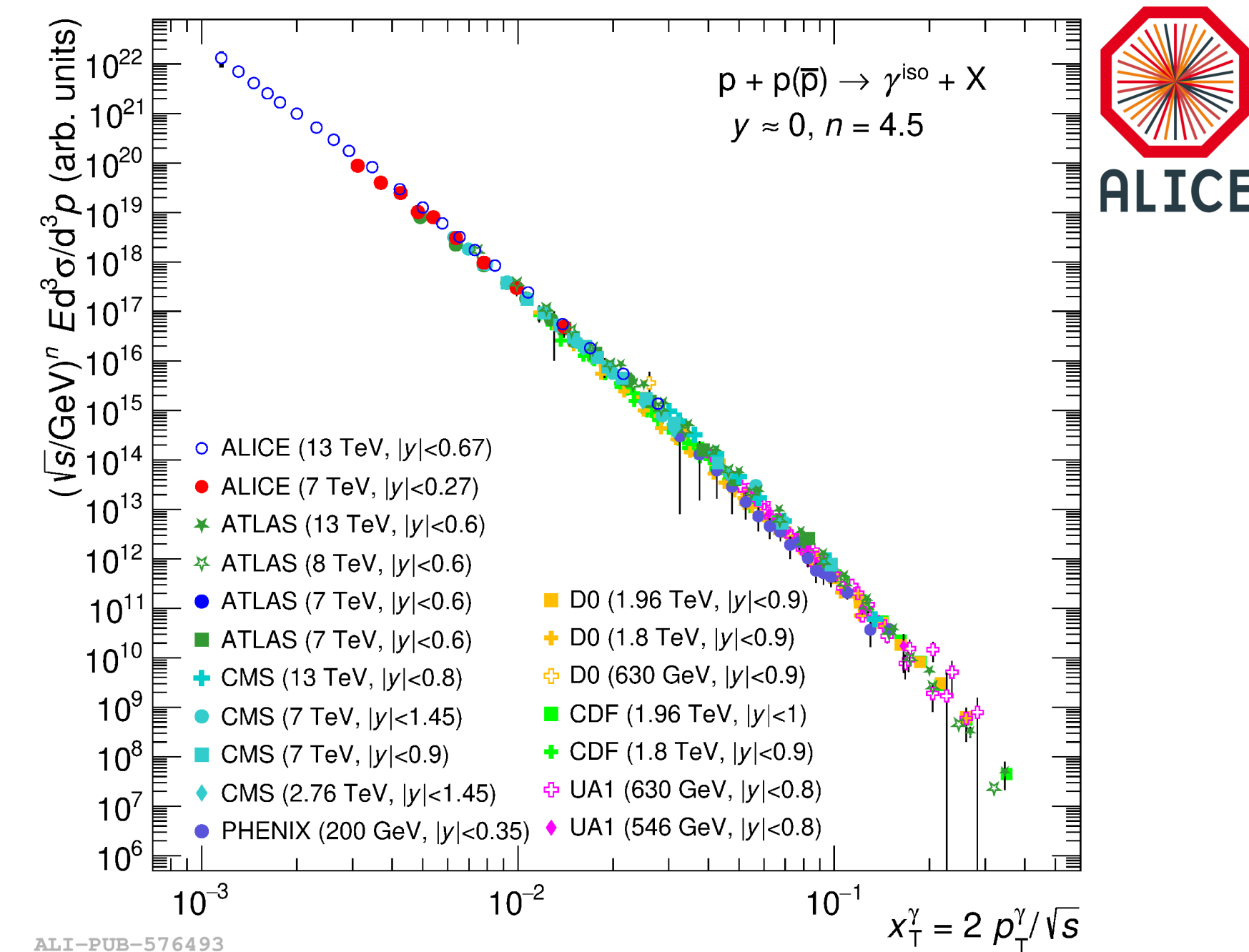
→ γ -hadron correlation in Pb-Pb

* Very statistically limited, challenging!

* z_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 yet



→ Cross section

- * Increased precision with **more than 10 times** the number of events in pp collisions
 - ▶ Reach higher and lower p_T
 - ▶ Improved pp reference measurement: More sensitive to CNM effects in $R_{AA, pA}$ at $p_T < 20$ GeV/c
- * Measurement in **OO** and **Ne–Ne** collisions, *NEW systems*
- * Measurement of prompt photons at **large η** with the new **FoCal** detector
- * Study the production of prompt photons (direct+fragmentation) with novel statistical techniques

→ γ -hadron/jet correlation

- * **Still statistically limited in Pb–Pb collisions ($\times 6$ more events), challenging!** But the gain of statistics will help
- * Quark vs gluon jet-substructure measurements: EECs, Soft Drop, ...

→ γ as a “calibrated” probe

- * Improve centrality selection bias determination in peripheral Pb–Pb collisions and new colliding systems
- * In pp (p–Pb) collisions, measurements of multiplicity-dependent correlations and spectra may allow photons to help understand possible biases in other multiplicity-based measurements.

Thank you for your attention!



- γ measurement

- ➔ Calorimeters

- EMCal: Pb/scintillator towers (6×6 cm)
 - 4.4 m from interaction point (IP)
 - $|\eta| < 0.67$ for $\Delta\varphi = 107^\circ$, $0.22 < |\eta| < 0.67$ for $\Delta\varphi = 60^\circ$ (DCal);
 - Identification via EM shower dispersion selection
 - $E_\gamma > 700$ MeV

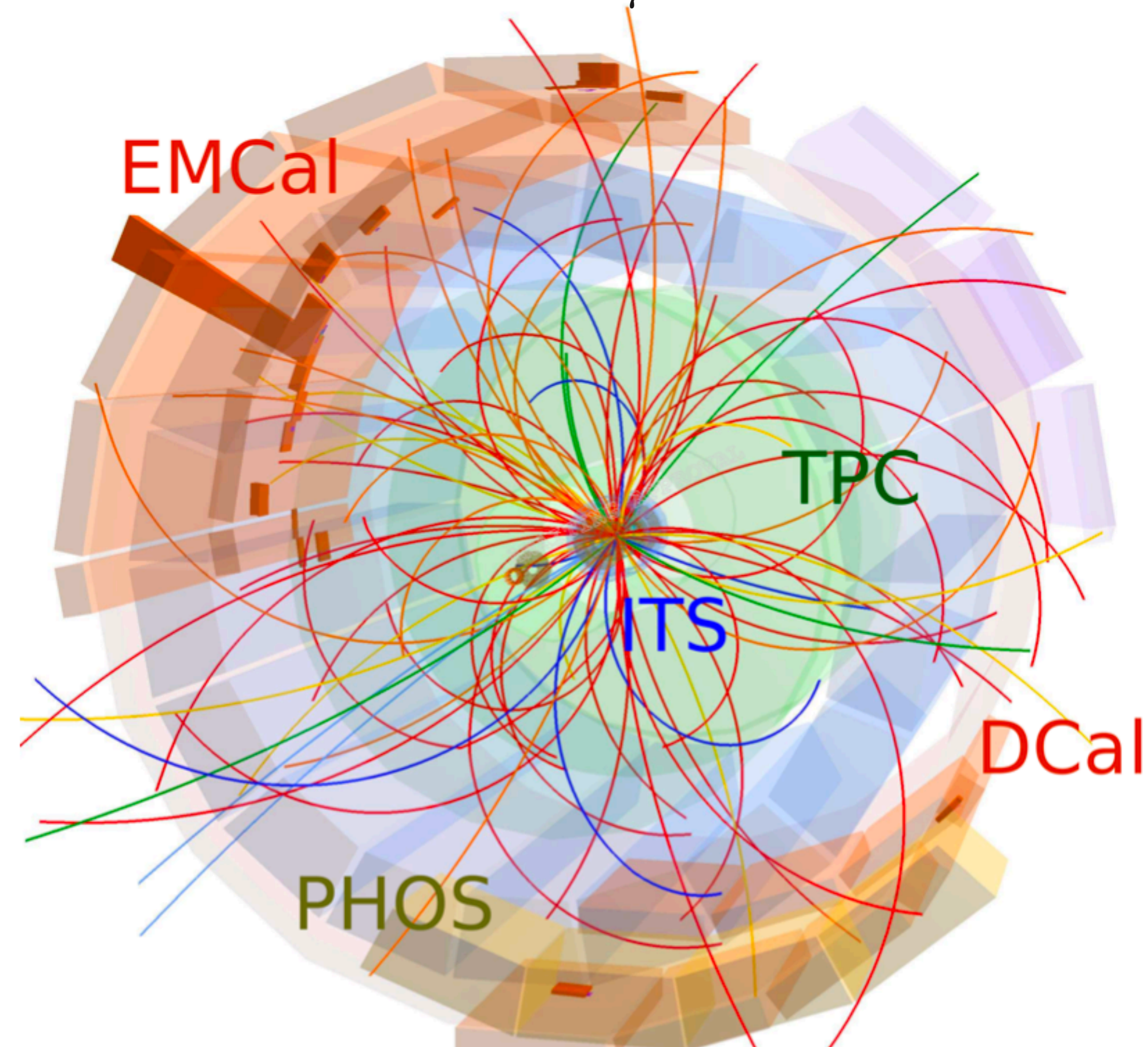
- ➔ Tracking, TPC & ITS

- γ conversion method (PCM)
 - $R < 180$ cm
 - 8% conversion probability
 - $|\eta| < 0.9$ for $\Delta\varphi = 360^\circ$
 - $E_\gamma > 100$ MeV

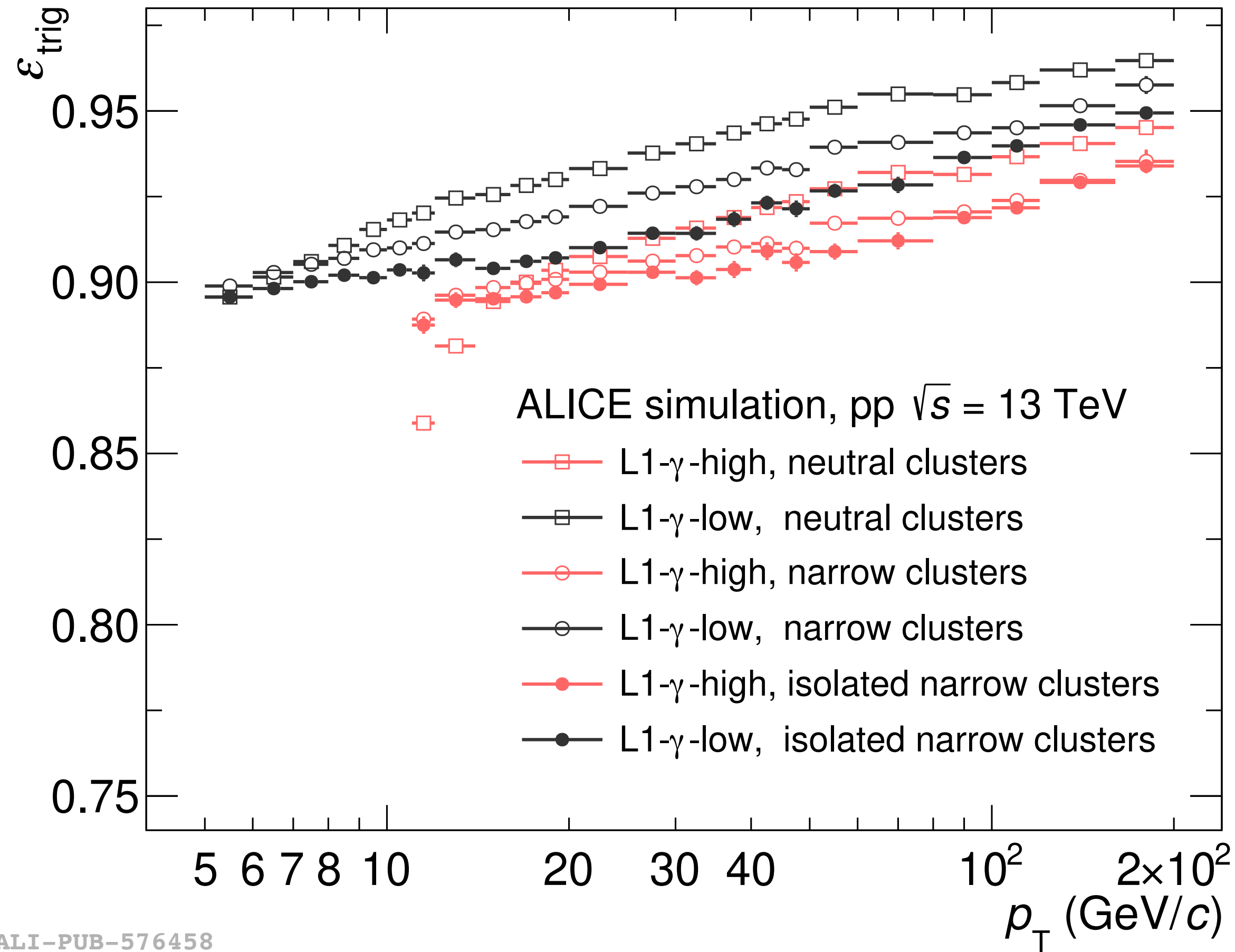
- γ identification combining tracking+calorimeter

- ➔ Inclusive γ : Charged particle veto
- ➔ Prompt γ : Isolation (next slides)

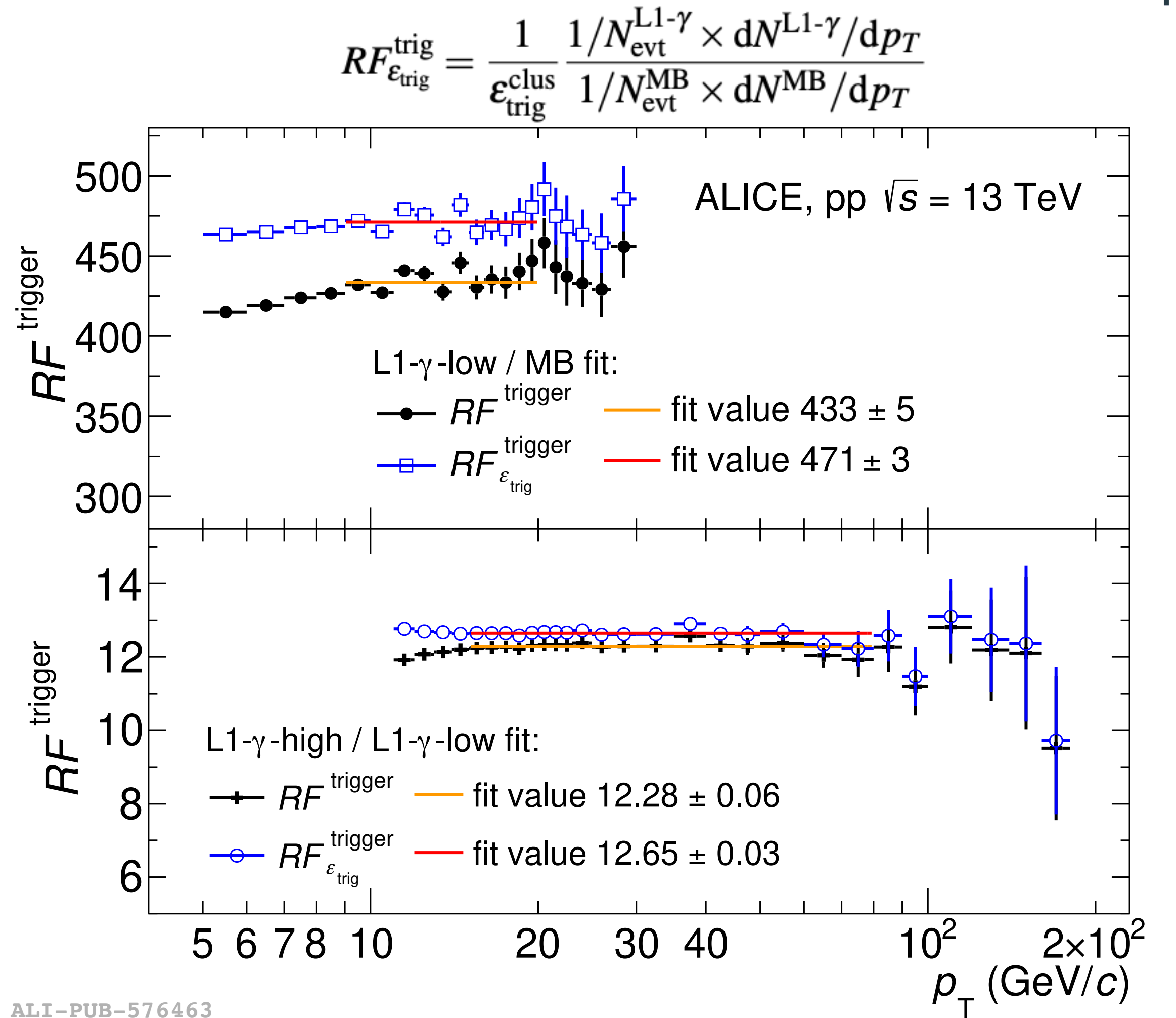
- PHOS: PWO₄ crystals (2.2×2.2 cm)
 - 4.6 m from IP
 - $|\eta| < 0.13$ for $\Delta\varphi = 70^\circ$
 - Identification via EM shower dispersion selection
 - $E_\gamma > 200$ MeV



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



ALI-PUB-576458

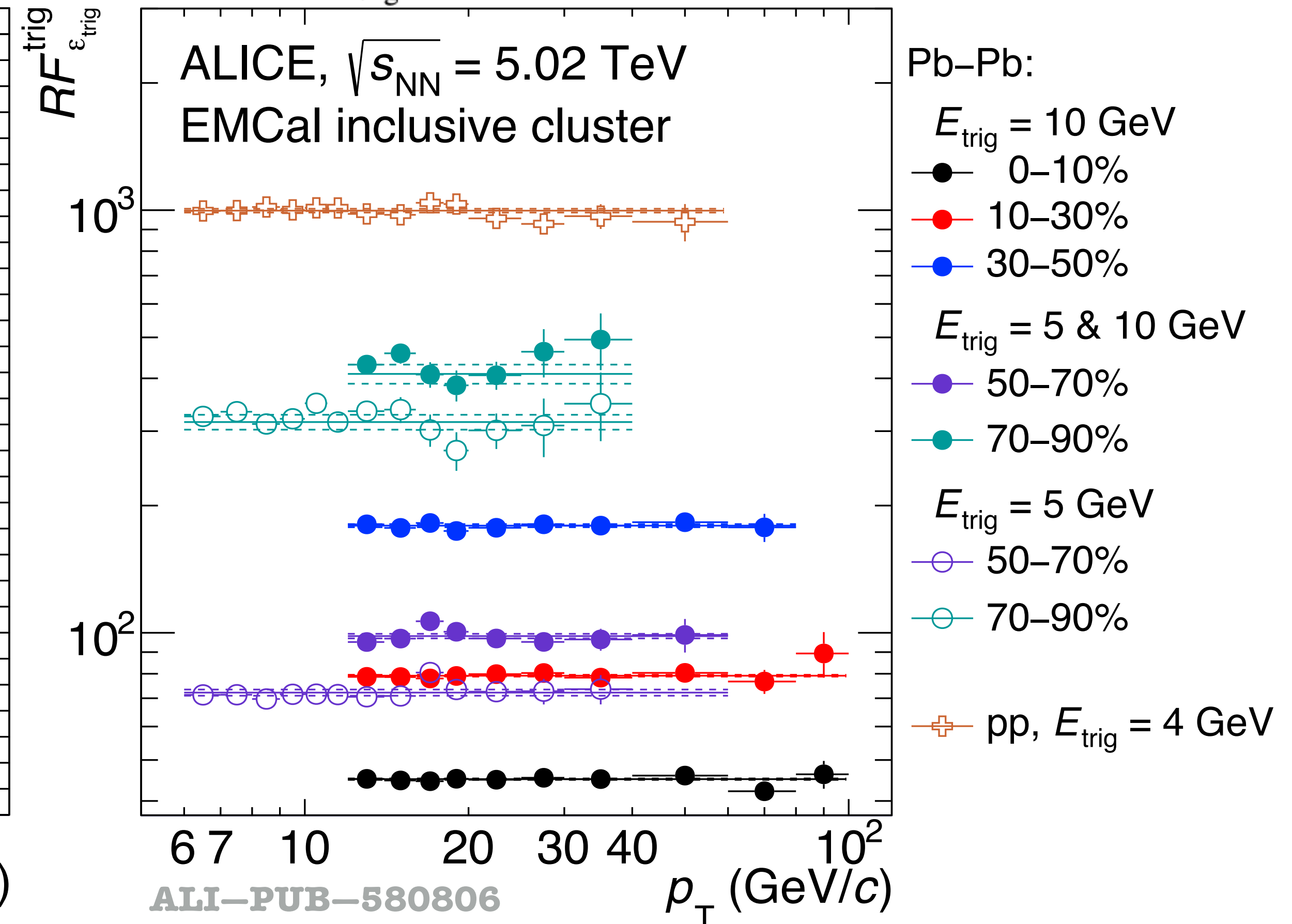
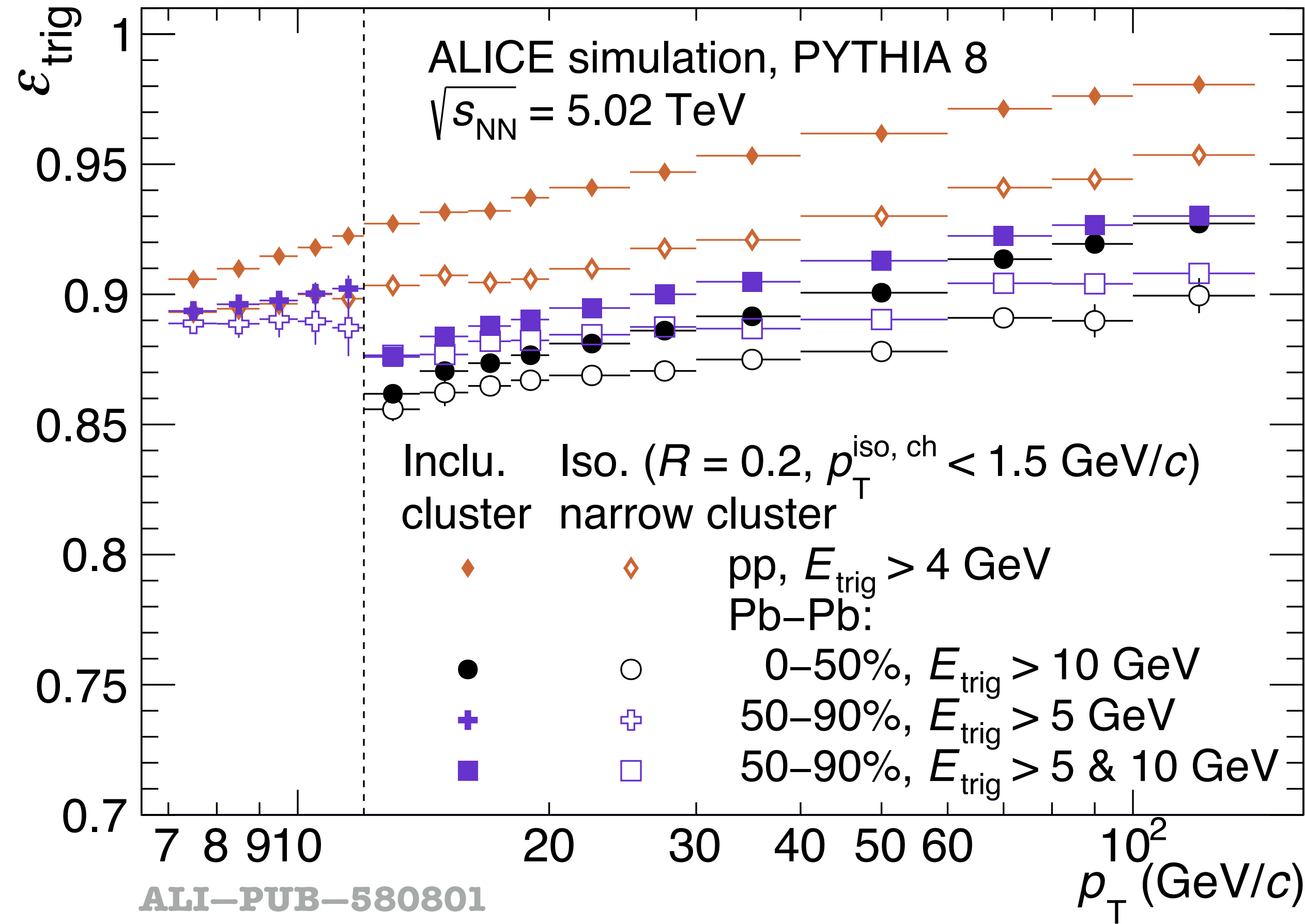


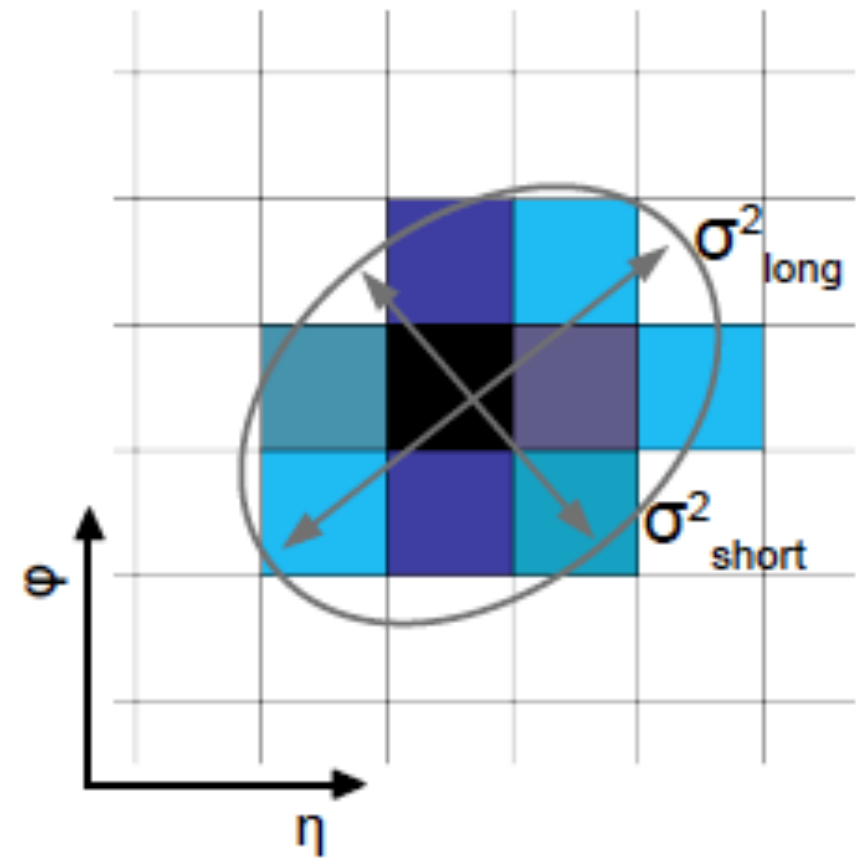
ALI-PUB-576463

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



$$RF_{\epsilon_{\text{trig}}}^{\text{trig}} = \frac{1}{\epsilon_{\text{trig}}^{\text{clus}}} \frac{1/N_{\text{evt}}^{\text{L1-}\gamma} \times dN^{\text{L1-}\gamma}/dp_T}{1/N_{\text{evt}}^{\text{MB}} \times dN^{\text{MB}}/dp_T}$$





- 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

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

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

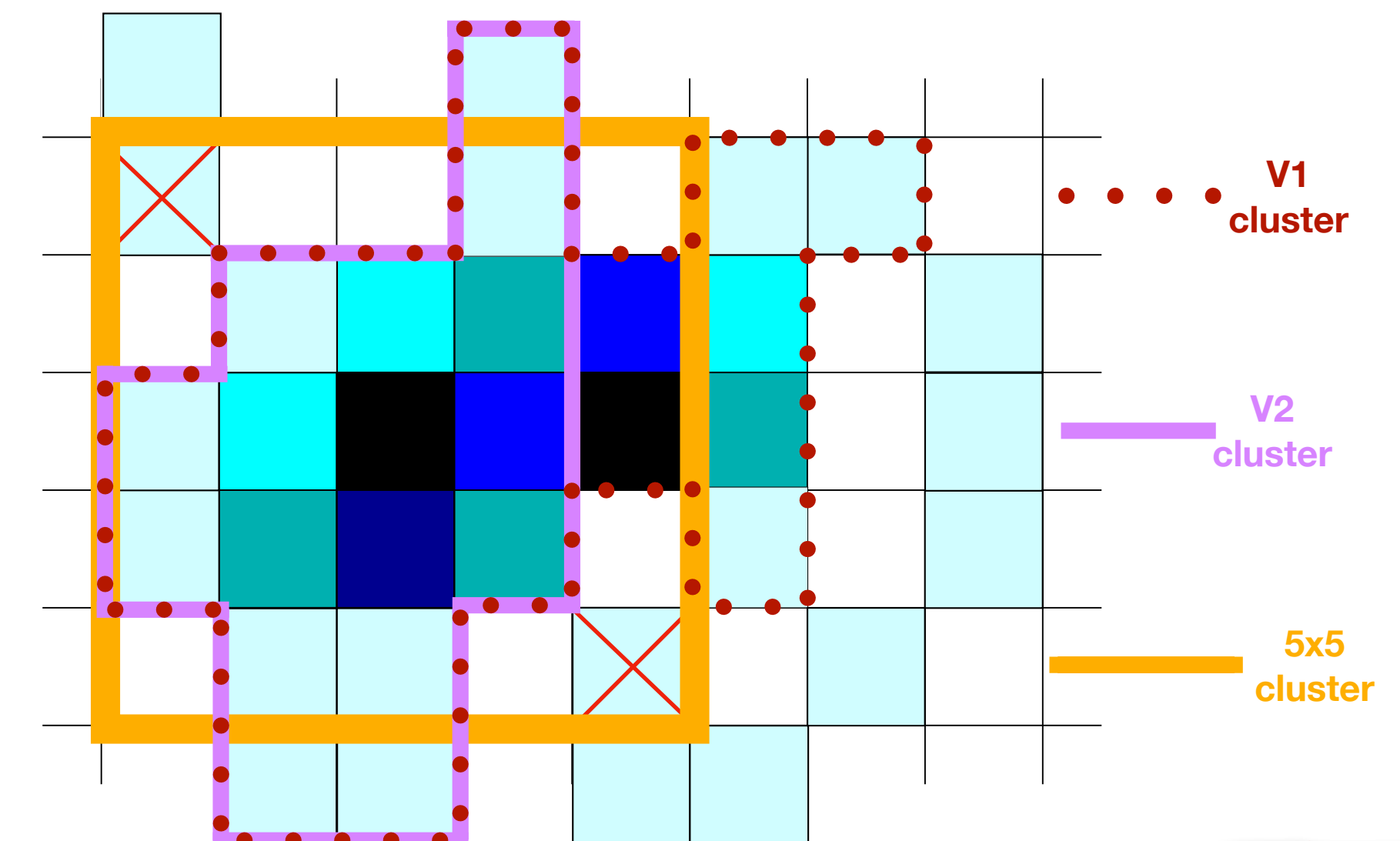
$$w_{\text{tot}} = \sum_i w_i,$$

$$\sigma_{\text{long}}^2 = 0.5(\sigma_{\phi\phi}^2 + \sigma_{\eta\eta}^2) + \sqrt{0.25(\sigma_{\phi\phi}^2 - \sigma_{\eta\eta}^2)^2 + \sigma_{\eta\phi}^2},$$

$$\sigma_{\text{short}}^2 = 0.5(\sigma_{\phi\phi}^2 + \sigma_{\eta\eta}^2) - \sqrt{0.25(\sigma_{\phi\phi}^2 - \sigma_{\eta\eta}^2)^2 + \sigma_{\eta\phi}^2},$$

- 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_{long}^2 calculation: consider the neighbour cells around the highest energy cell in a 5x5 fixed window
 - Increase meson decay merging but limiting UE merging

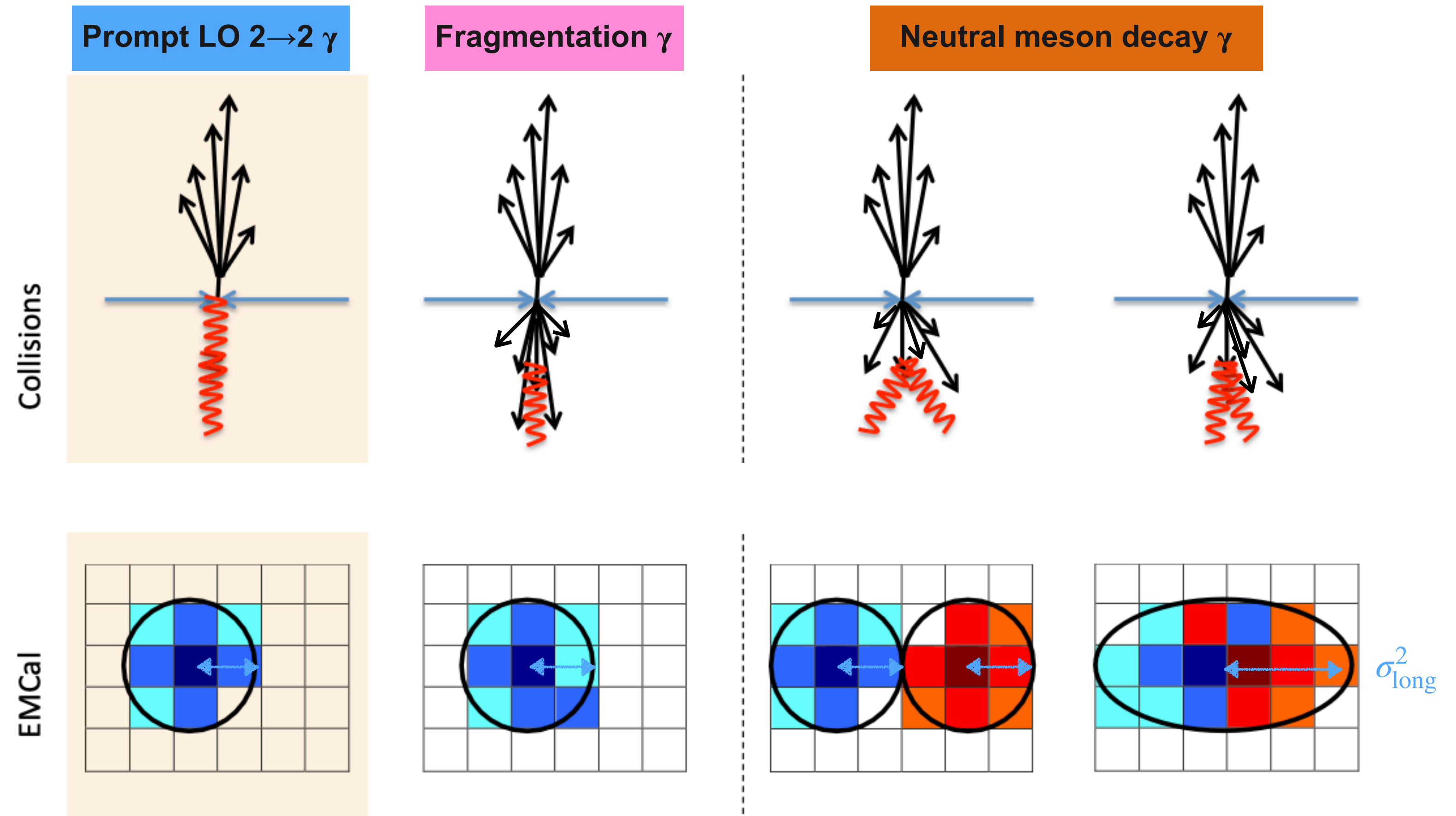
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Prompt γ identification: Shower Shape

EM shower discrimination γ single vs merged decays

- EMCal
- Shower elongation σ_{long}^2 :
longest ellipse axis size



→ circular
"narrow"
cluster

→ circular narrow
clusters, potentially
wider due to jet
particles nearby
merging

→ decay γ merge, $E_{\pi^0} > 6 \text{ GeV}$
elliptical "wide" cluster

Prompt γ at LO 2 $\rightarrow$ 2: *isolated*

- TPC+ITS charged tracks
- Select γ with low hadronic activity in R , small $p_T^{\text{iso, ch}}$

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

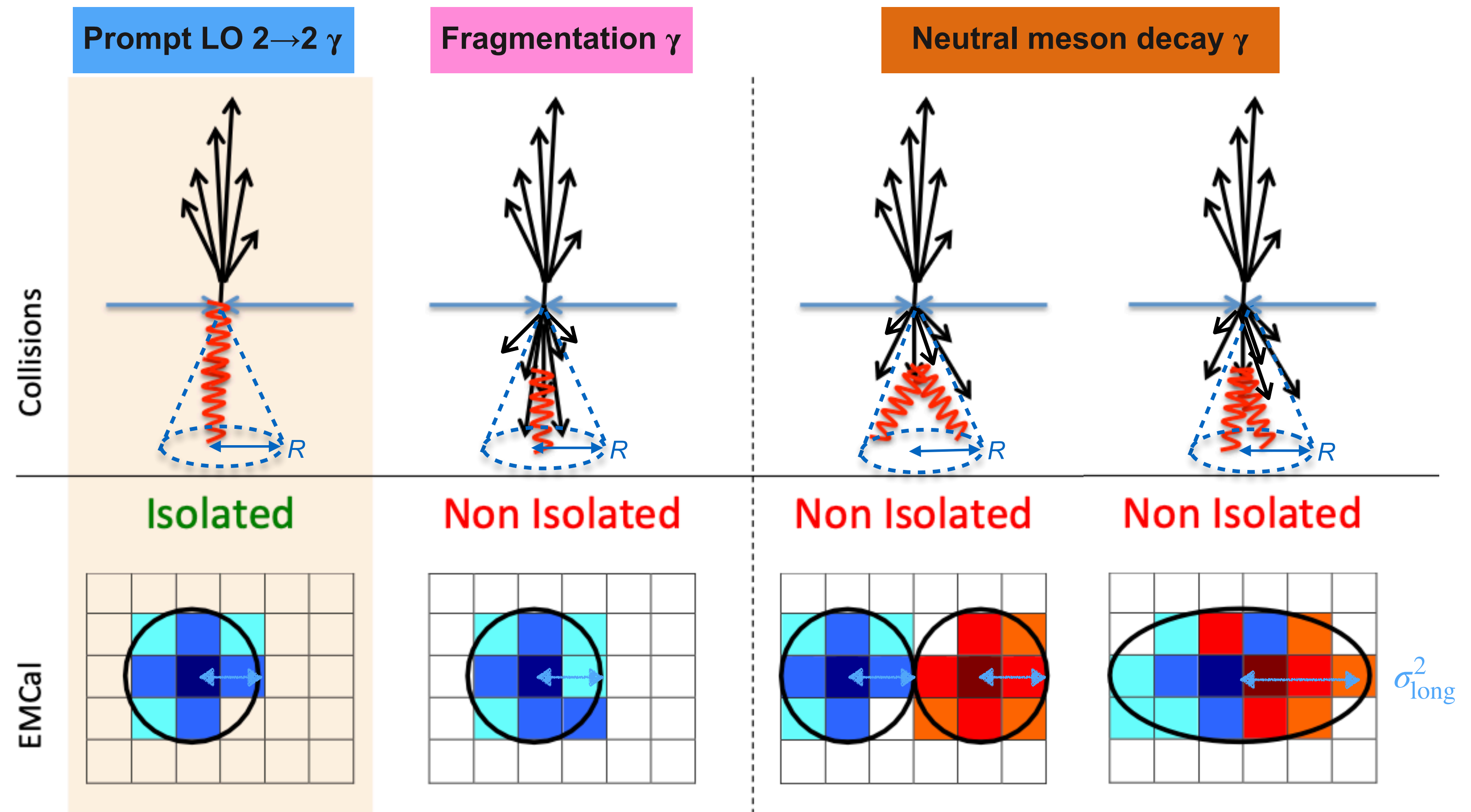
$$p_T^{\text{iso, ch}} = \sum p_T^{\text{tracks in cone}} - \rho_{\text{UE}} \cdot \pi \cdot R^2 < 1.5 \text{ GeV}/c$$

- * Underlying event (UE) subtracted event-by-event, ρ_{UE} density estimation

EM shower discrimination

γ single vs merged decays

- EMCal
- Shower elongation σ_{long}^2 : longest ellipse axis size



→ circular "narrow" cluster

→ circular narrow clusters, potentially wider due to jet particles nearby merging

→ decay γ merge, $E_{\pi^0} > 6 \text{ GeV}$ elliptical "wide" cluster

Prompt γ identification in heavy-ion collisions

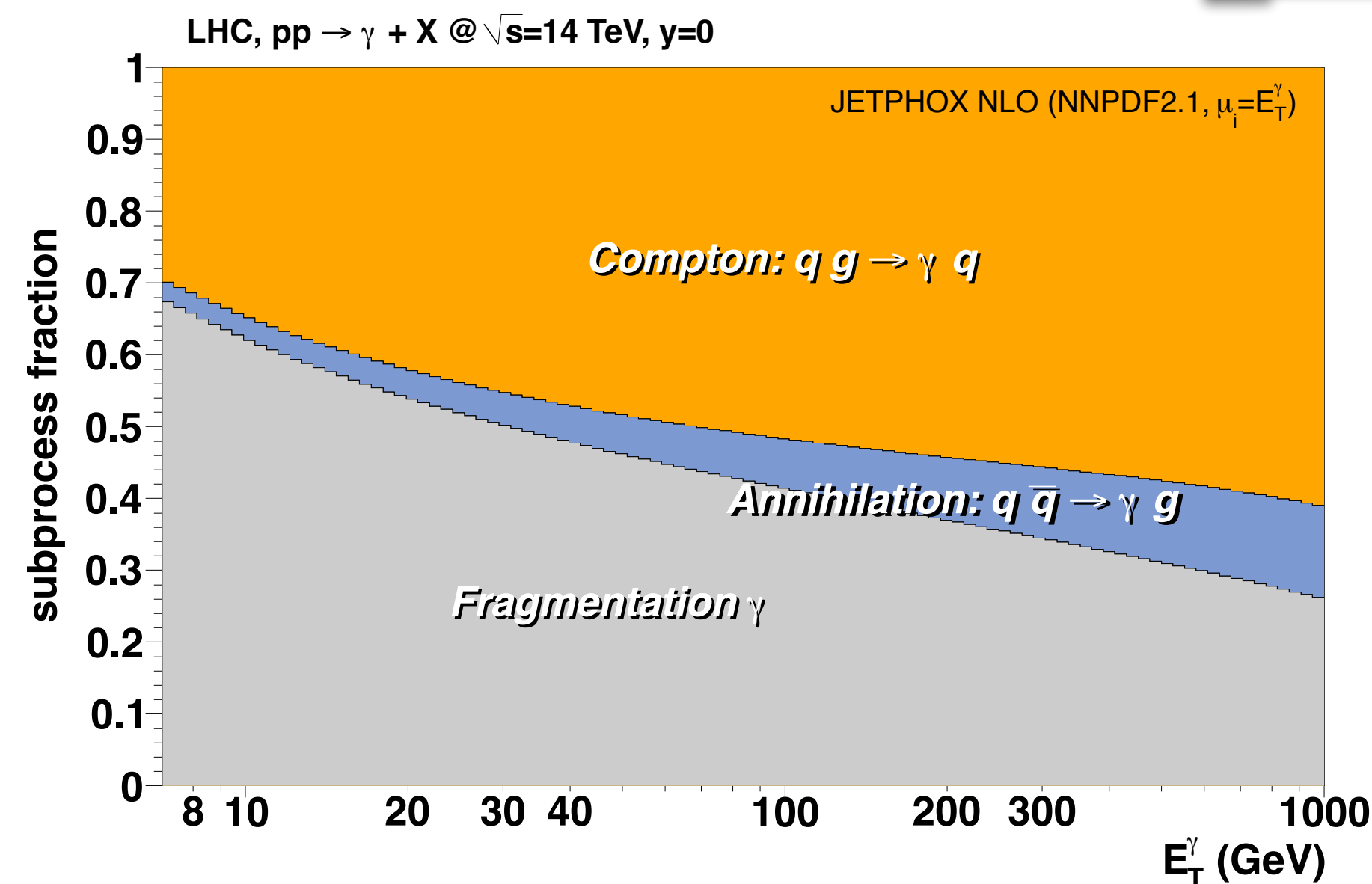
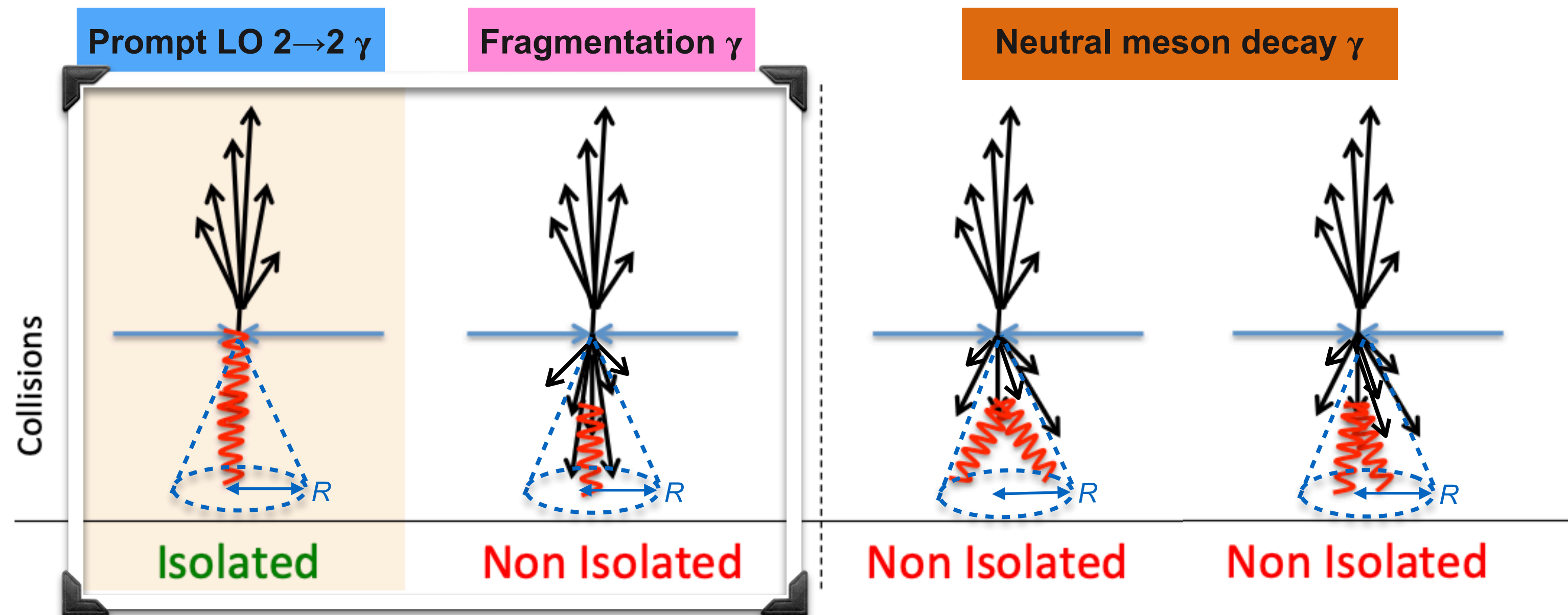
Prompt γ at LO $2 \rightarrow 2$: *isolated*

- TPC+ITS charged tracks
- Select γ with low hadronic activity in R , small $p_T^{\text{iso, ch}}$

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

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

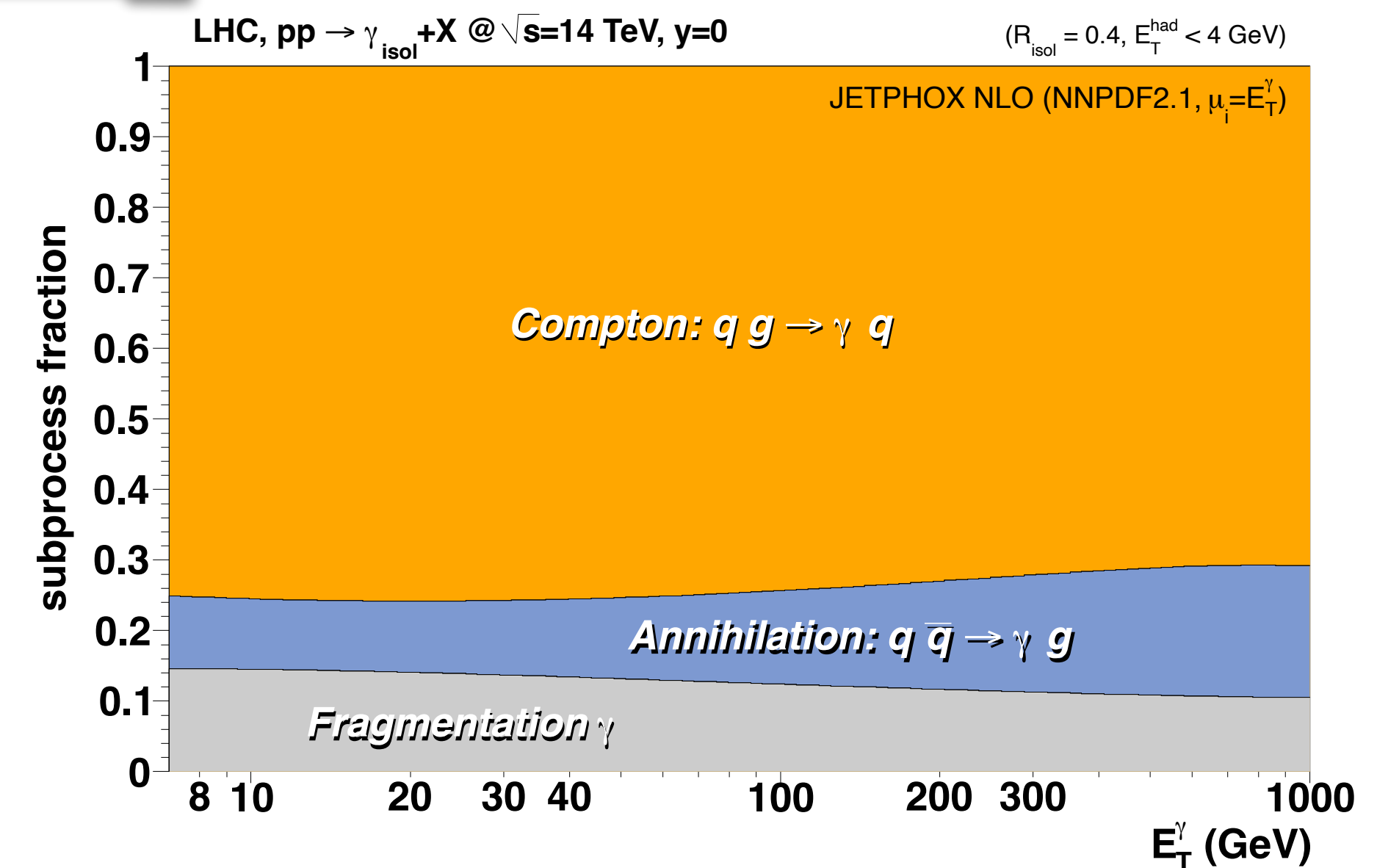
- * Underlying event (UE) subtracted event-by-event, ρ_{UE} density estimation



$pp, \sqrt{s} = 14 \text{ TeV}$

Isolation
 $R = 0.4, E_T^{\text{had}} < 4 \text{ GeV}$

D. D'Enterria & J. Rojo
 Nucl. Phys. B 860 (2012),
 arXiv:1202.1762 [hep-ph]



After isolation: Compton process dominance, 10-15% fragmentation photons!

Prompt γ at LO 2 $\rightarrow$ 2: *isolated*

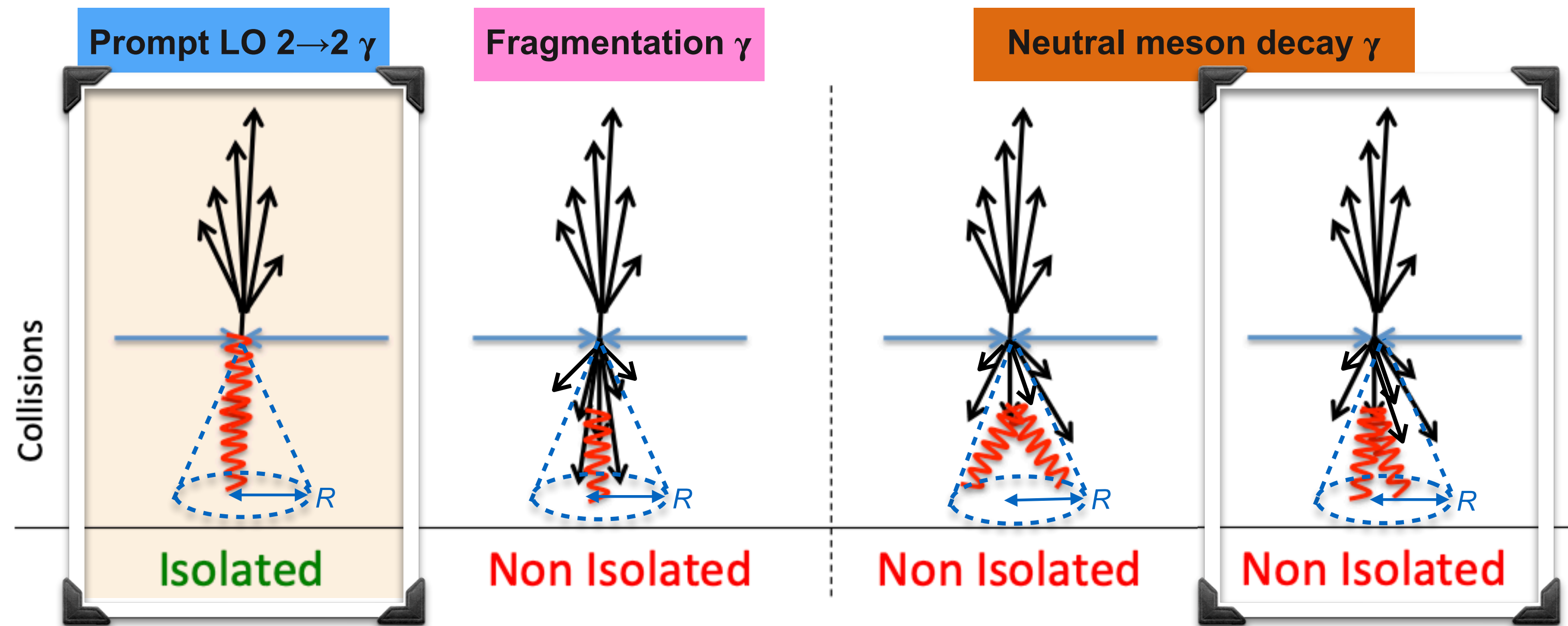
→ TPC+ITS charged tracks

→ Select γ with low hadronic activity in R , small $p_T^{\text{iso, ch}}$

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

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

* Underlying event (UE) subtracted event-by-event, ρ_{UE} density estimation

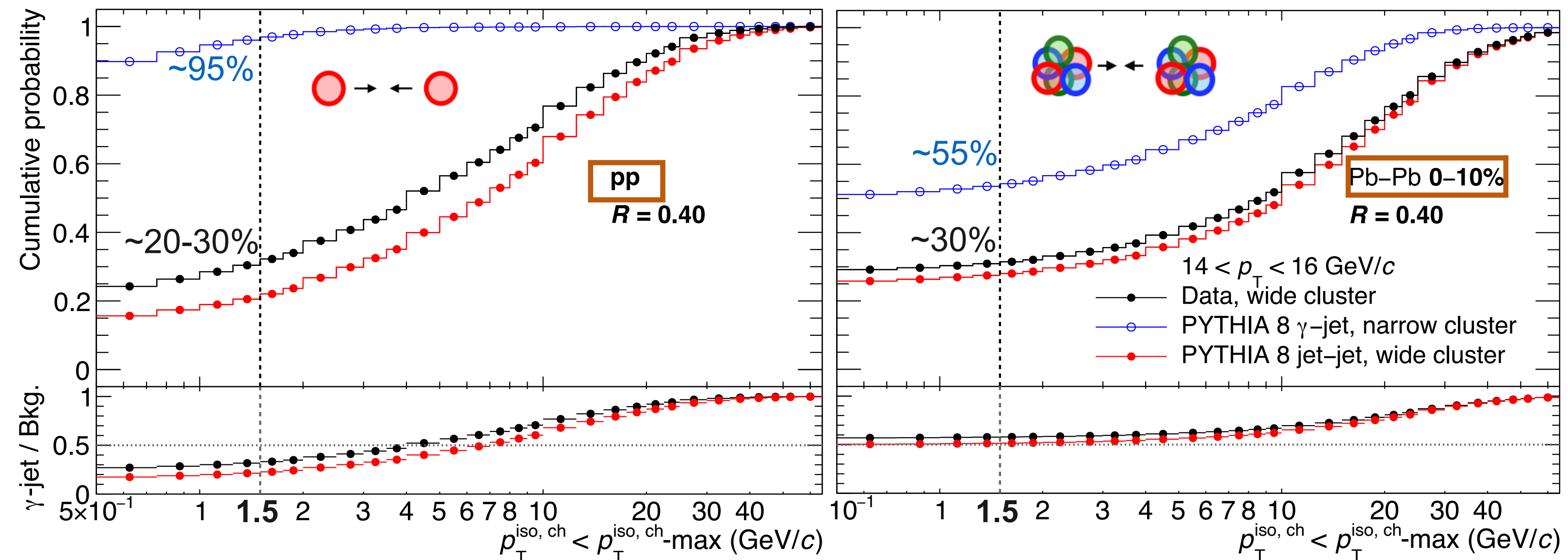


→ Strong neutral meson background rejection

⊙ Remaining cases: parton fragments into meson plus few low p_T particles → low $p_T^{\text{iso, ch}}$

→ Strong effect in central Pb-Pb in signal rejection due to UE fluctuations

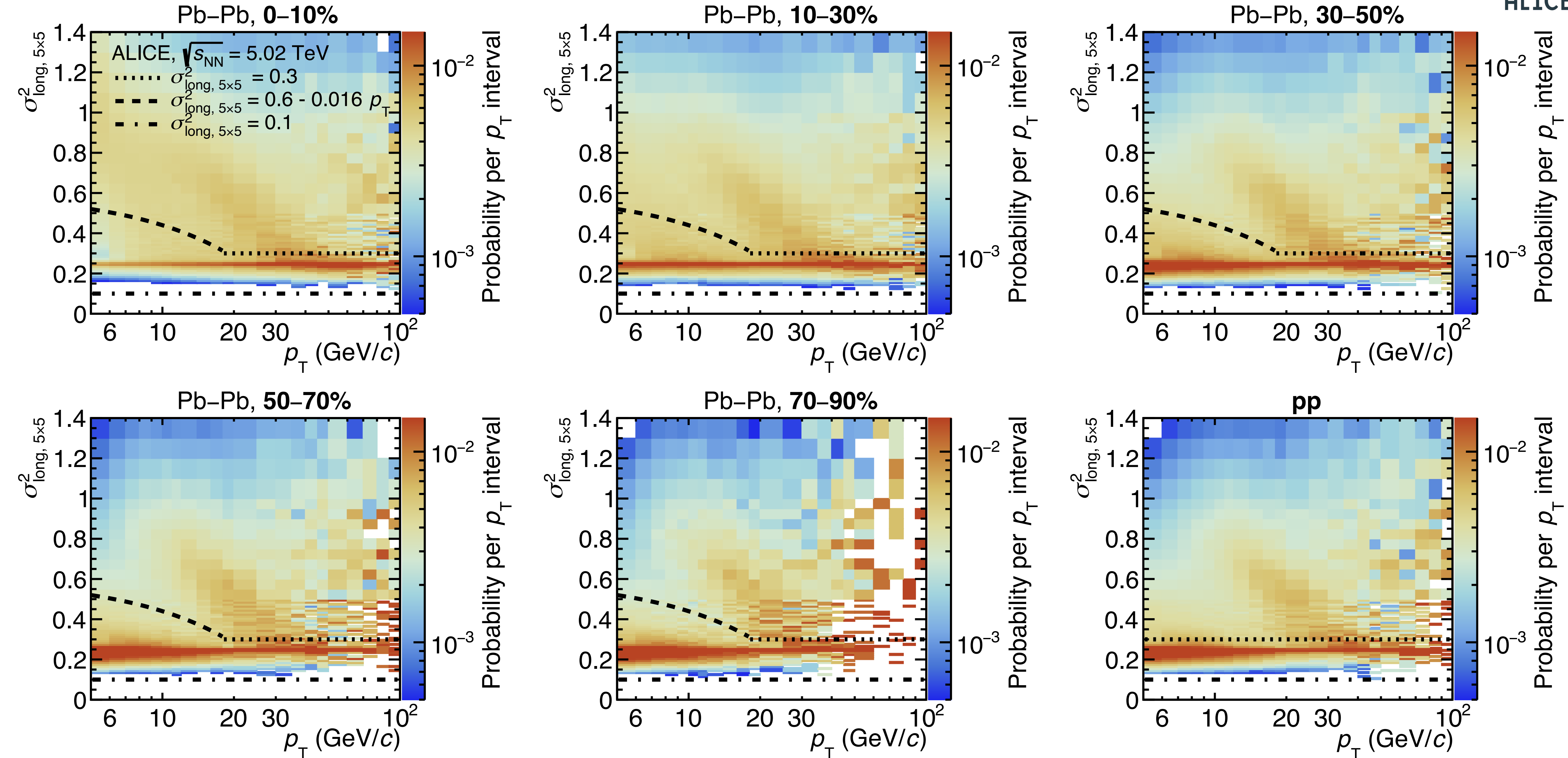
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EMCal cluster shower shape, pp & Pb-Pb $\sqrt{s_{NN}} = 5.02$ TeV

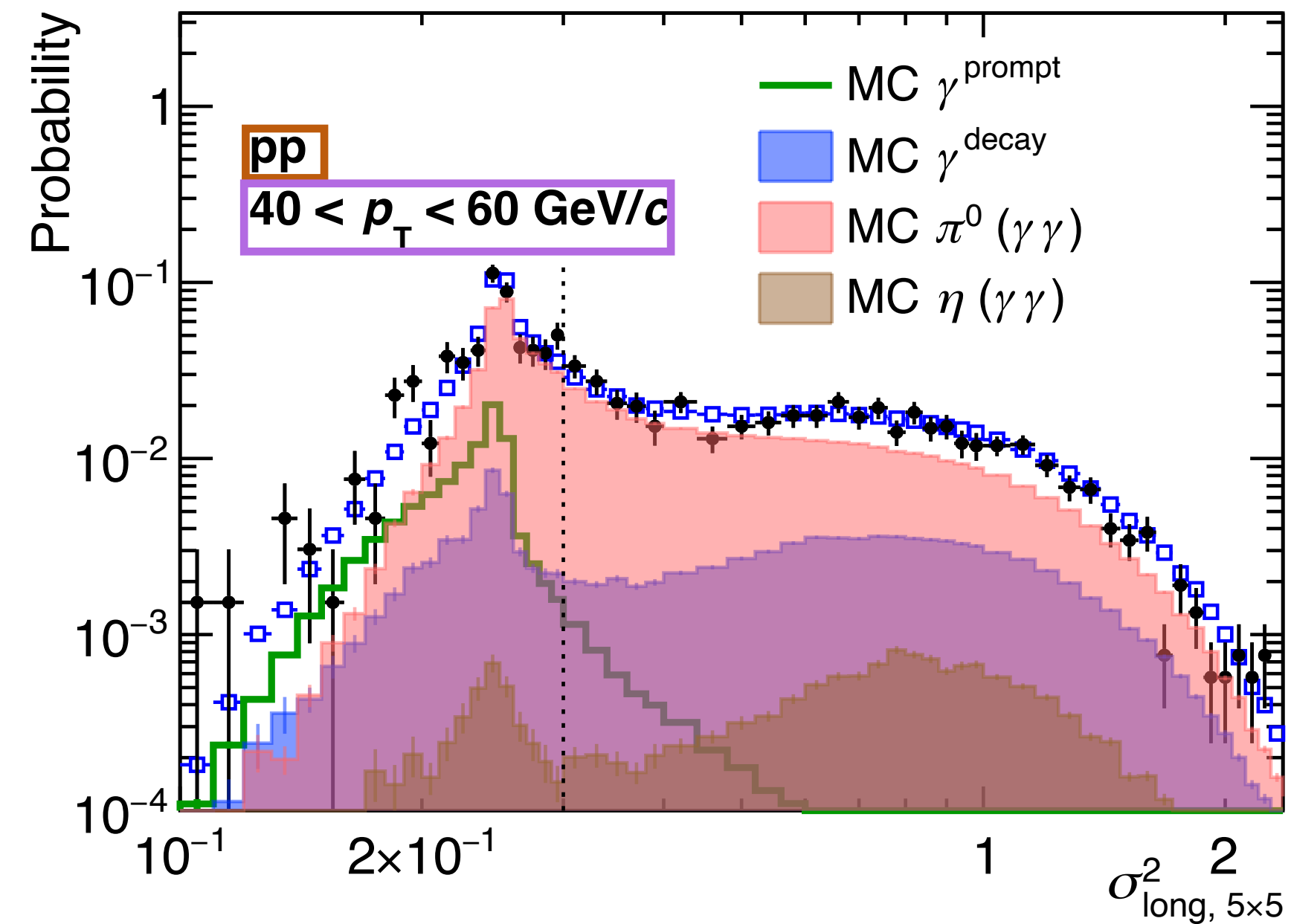
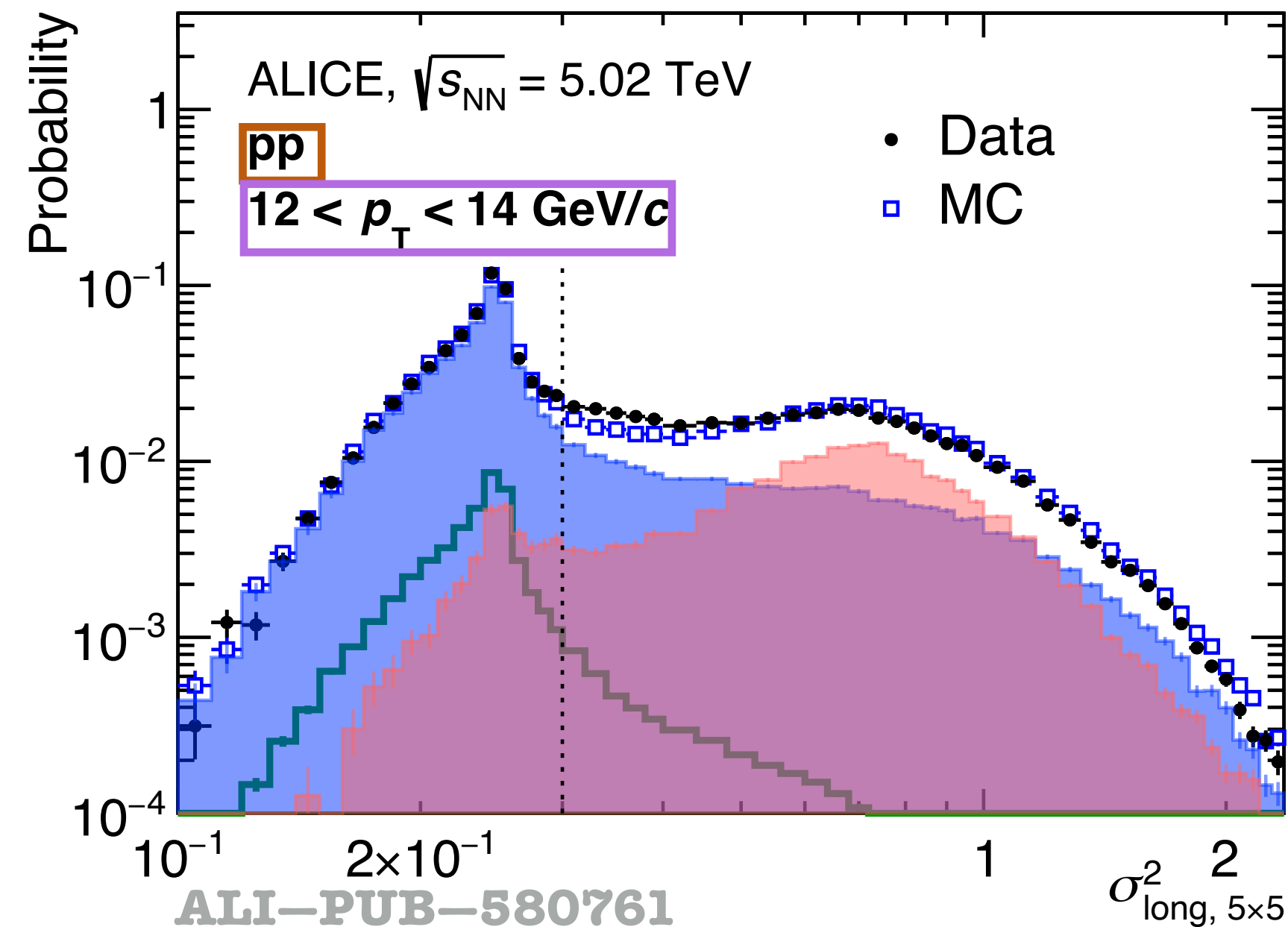
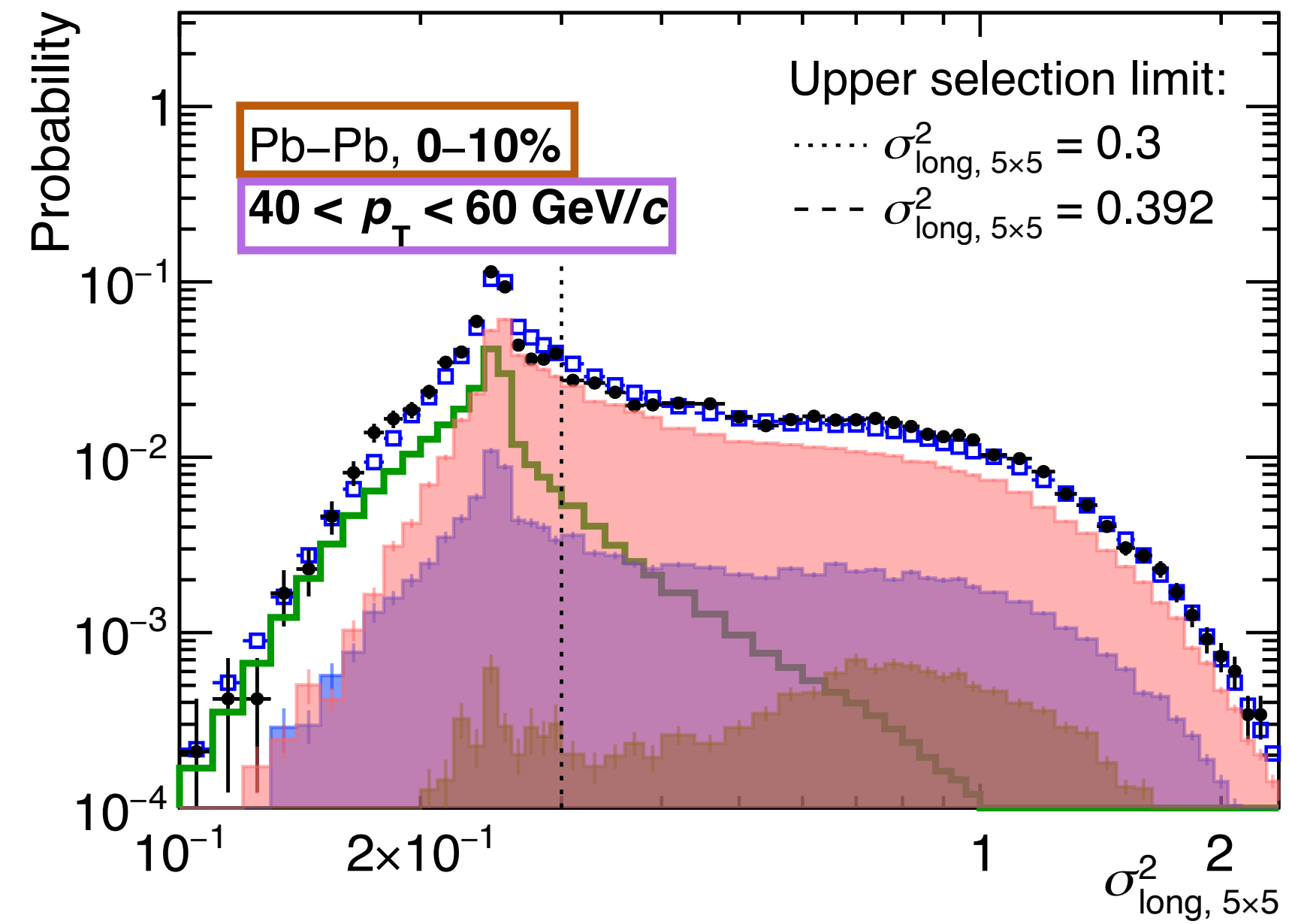
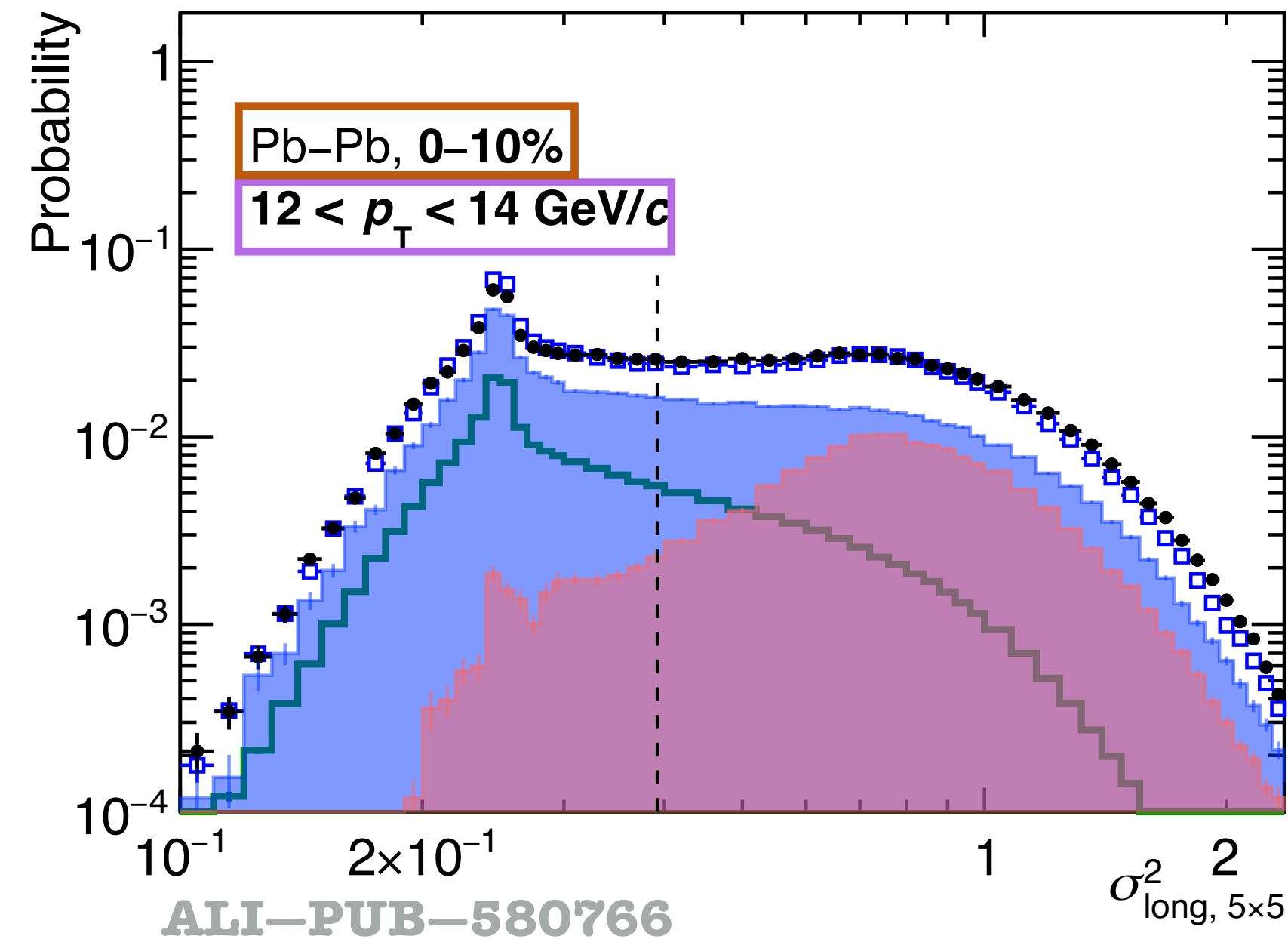


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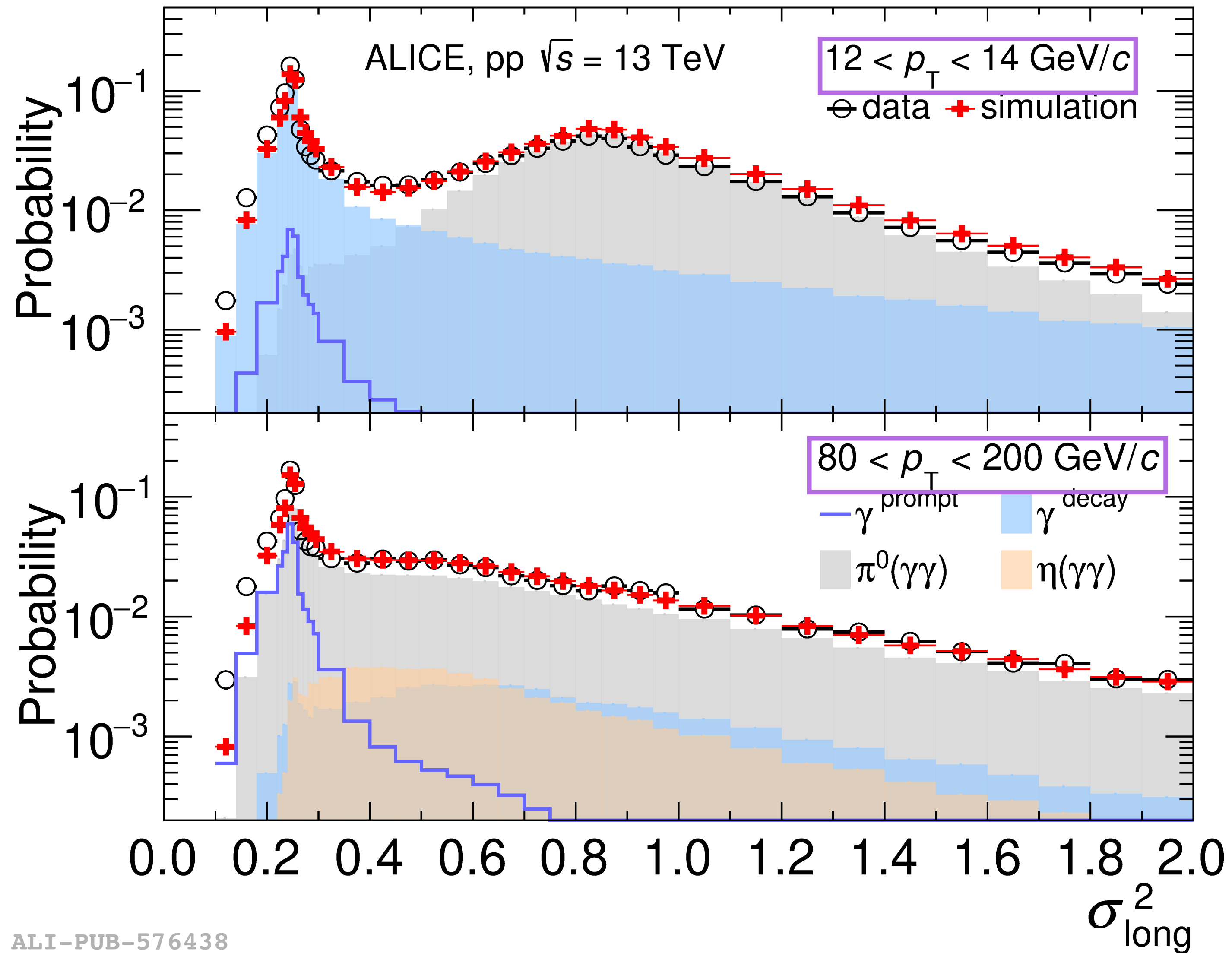


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EMCal cluster shower shape, pp & Pb-Pb $\sqrt{s_{NN}} = 5.02$ TeV



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



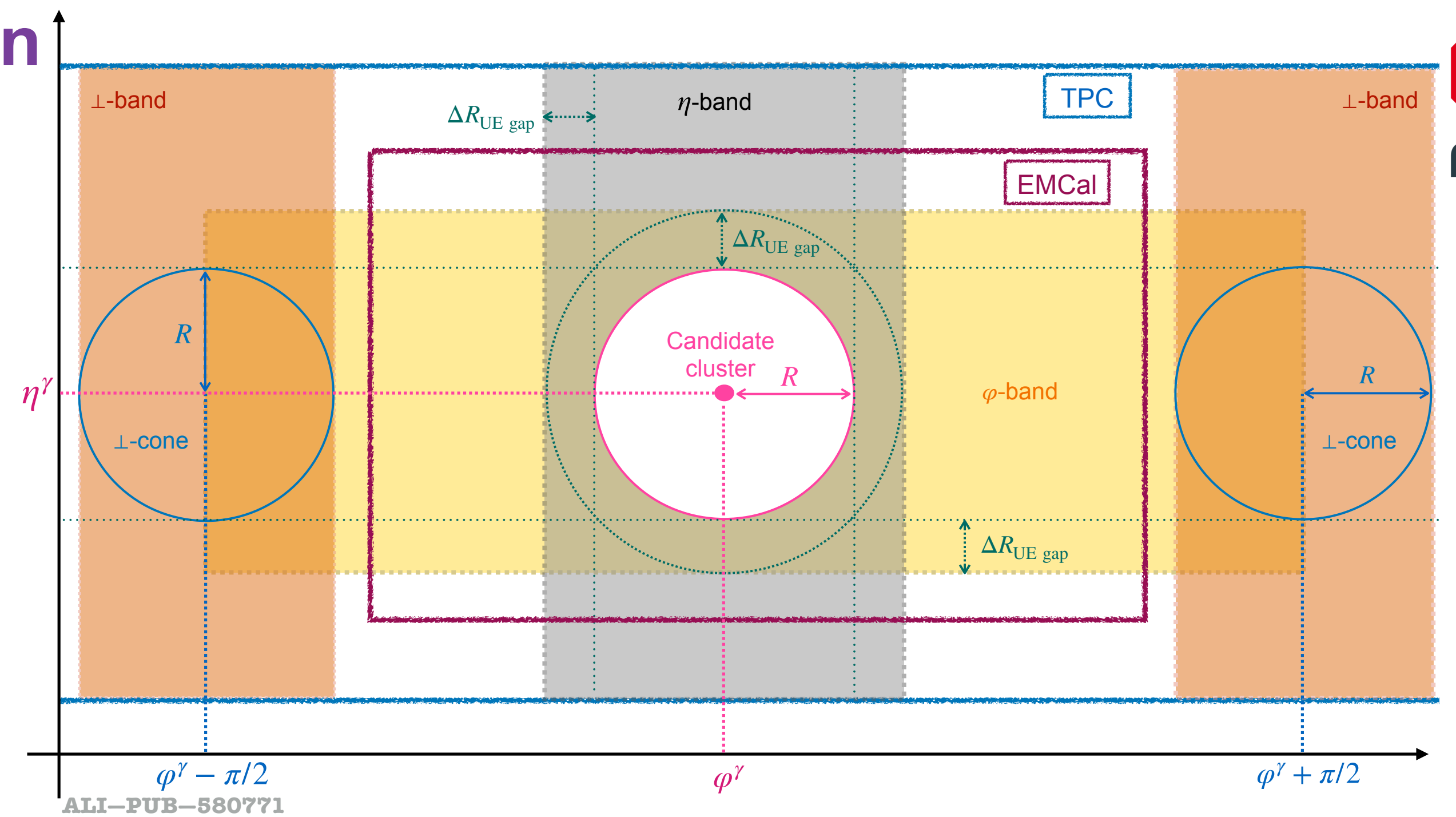
ALI-PUB-576438

Underlying event estimation

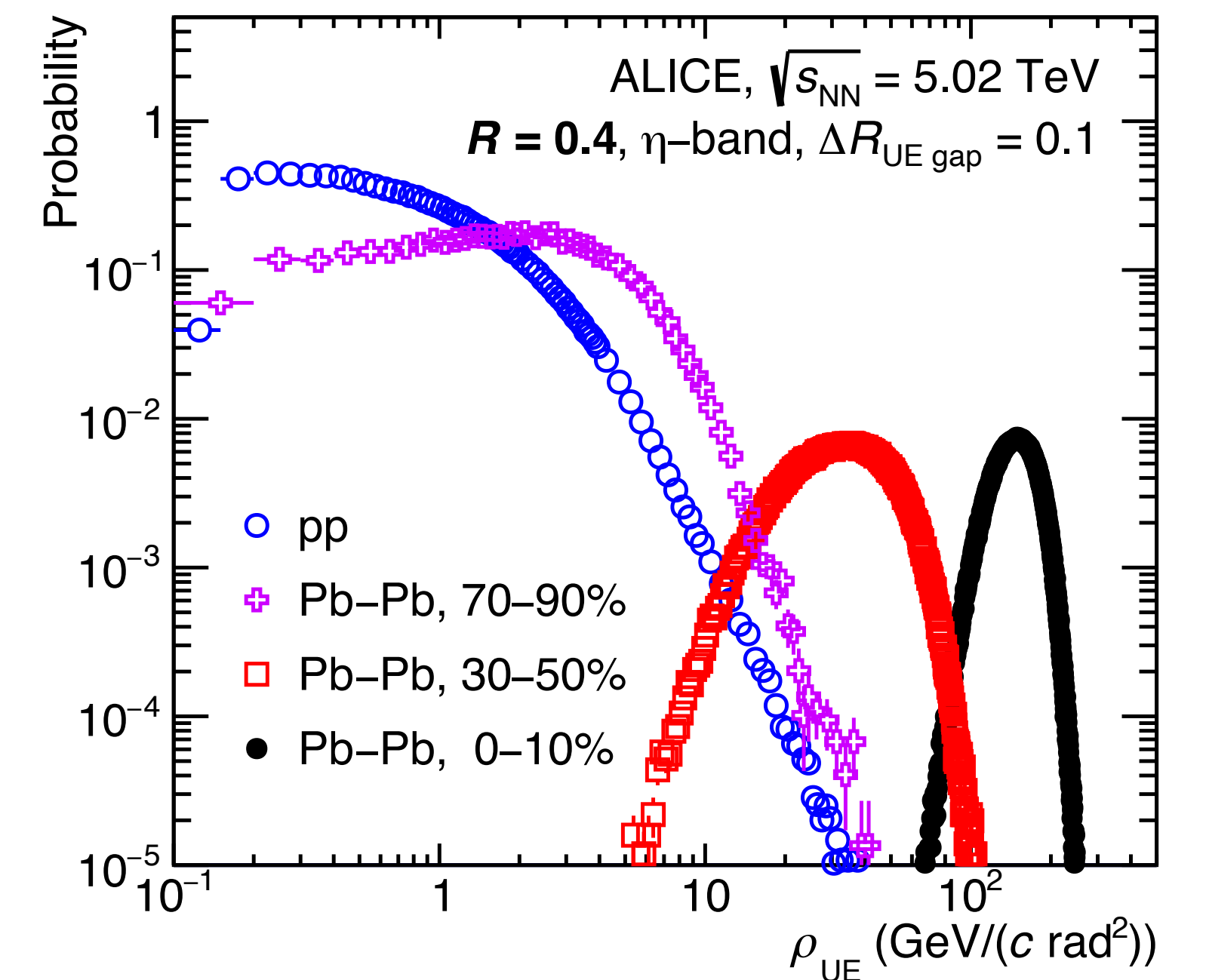
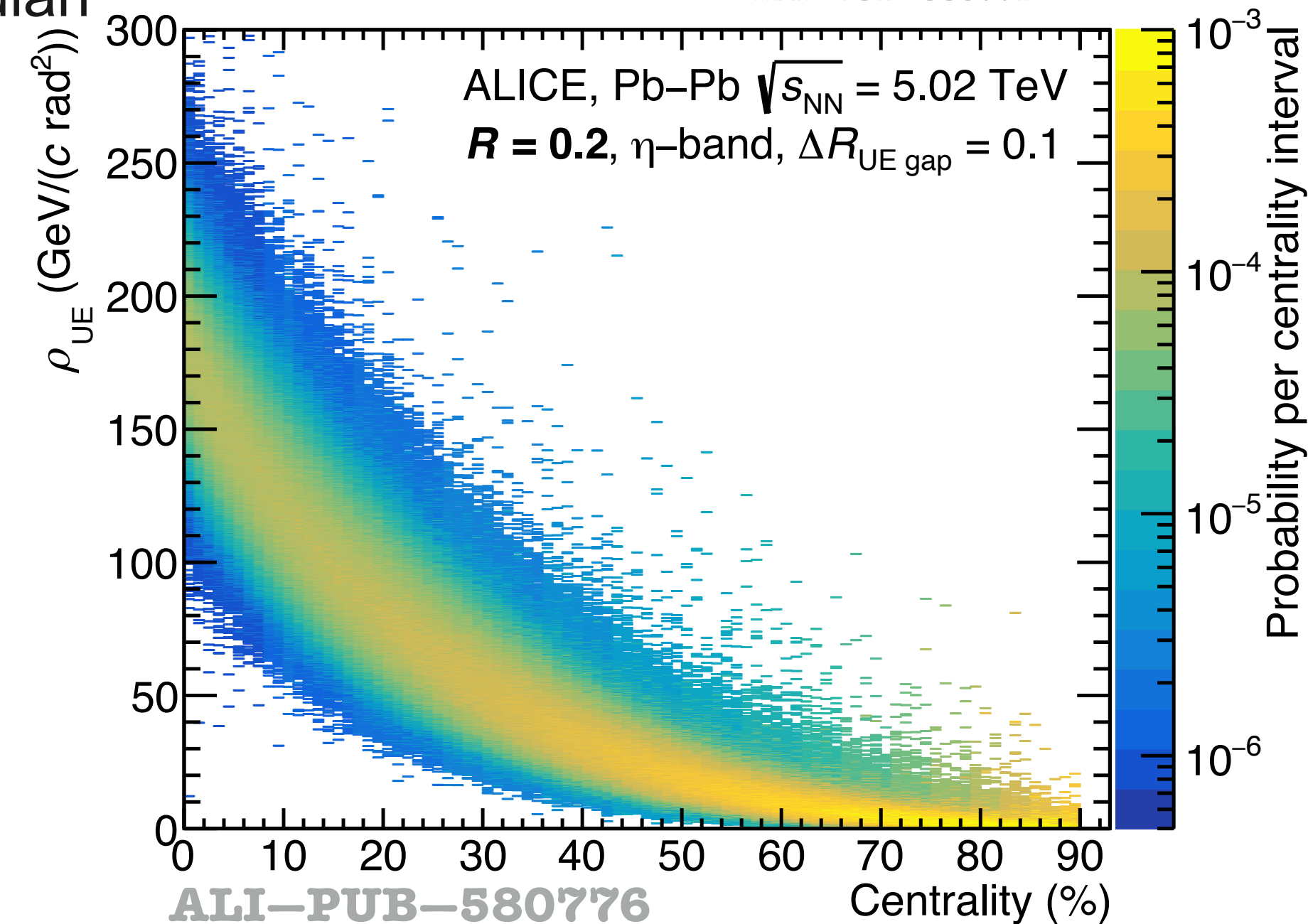


Track p_T UE density estimated on:

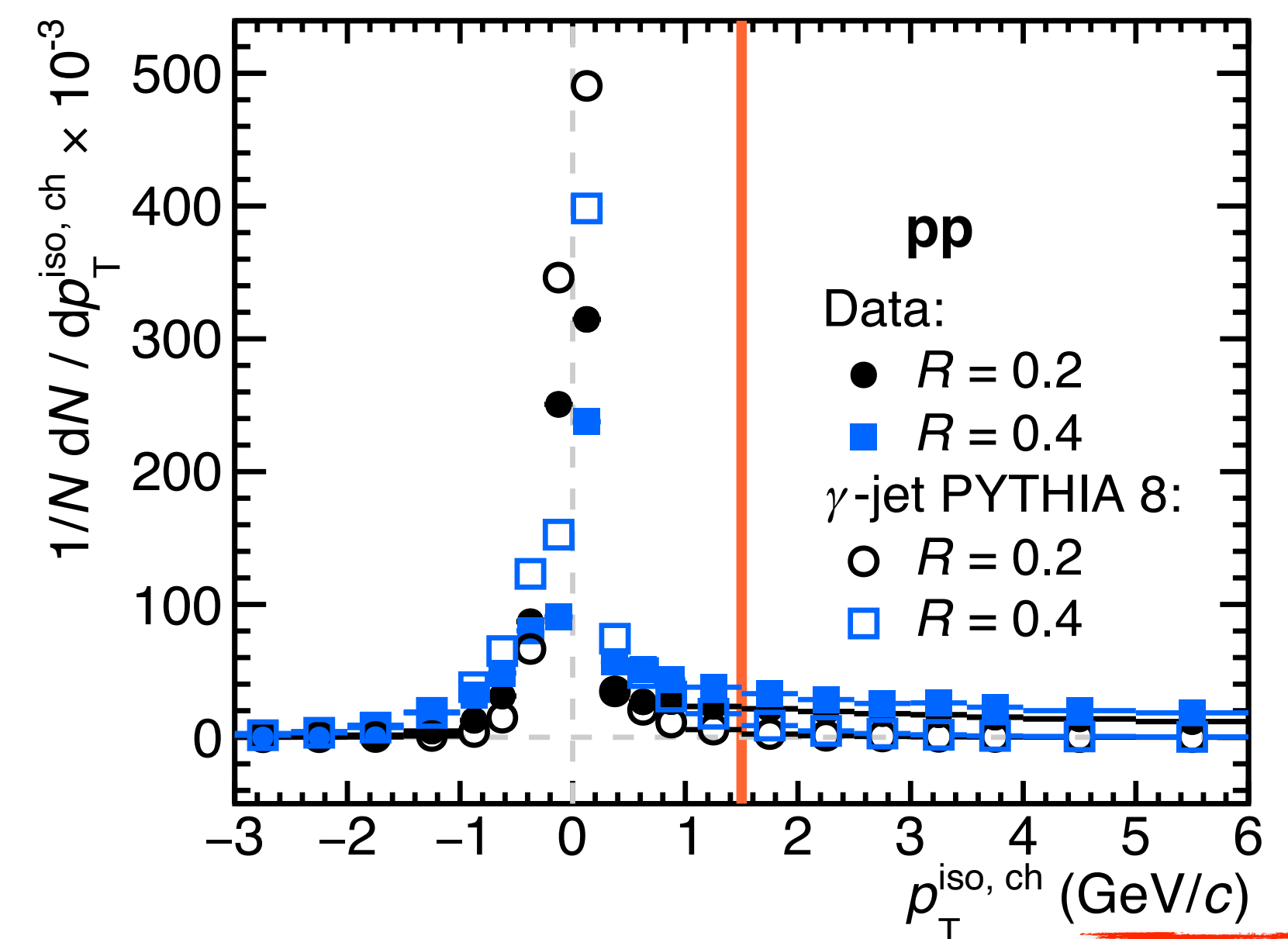
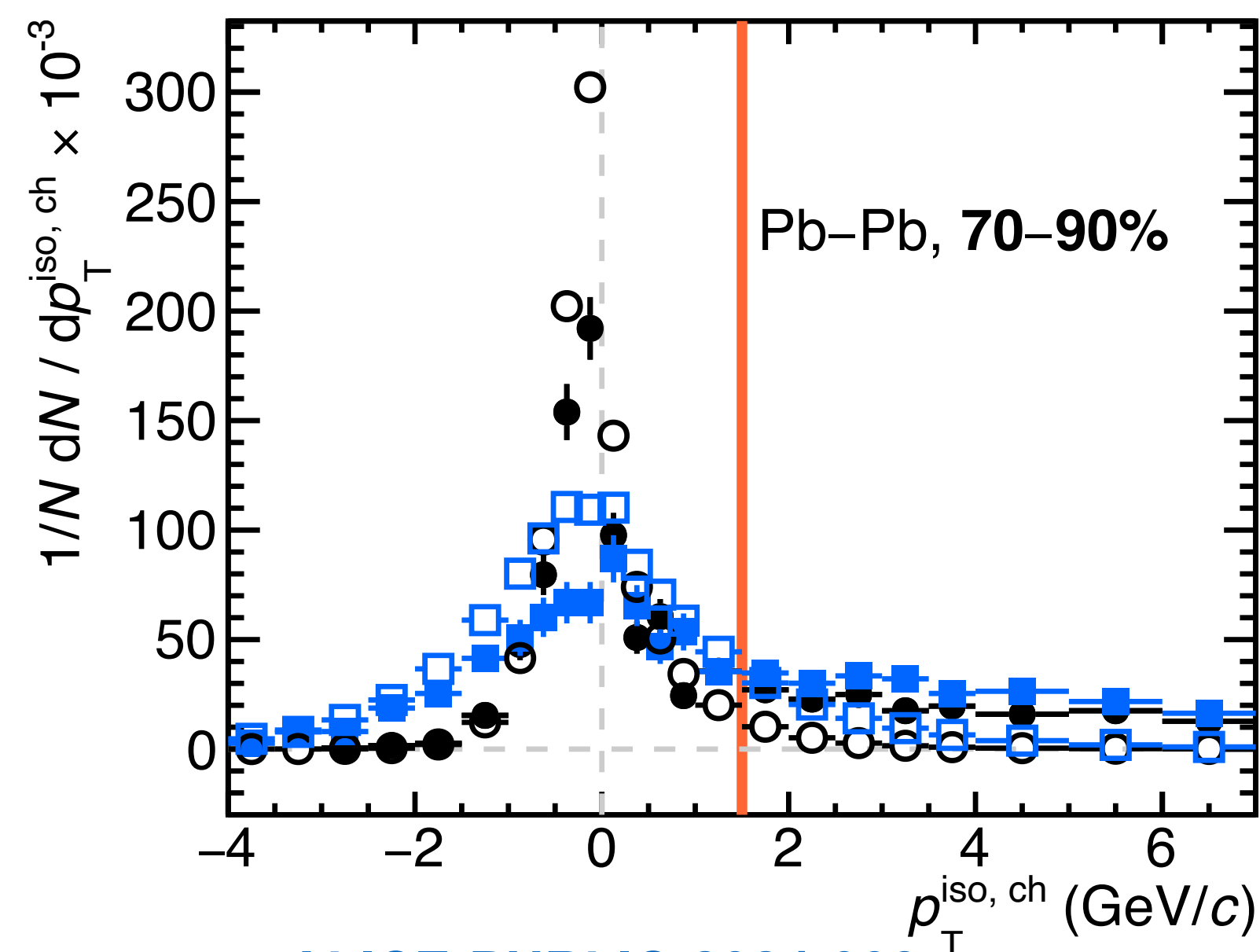
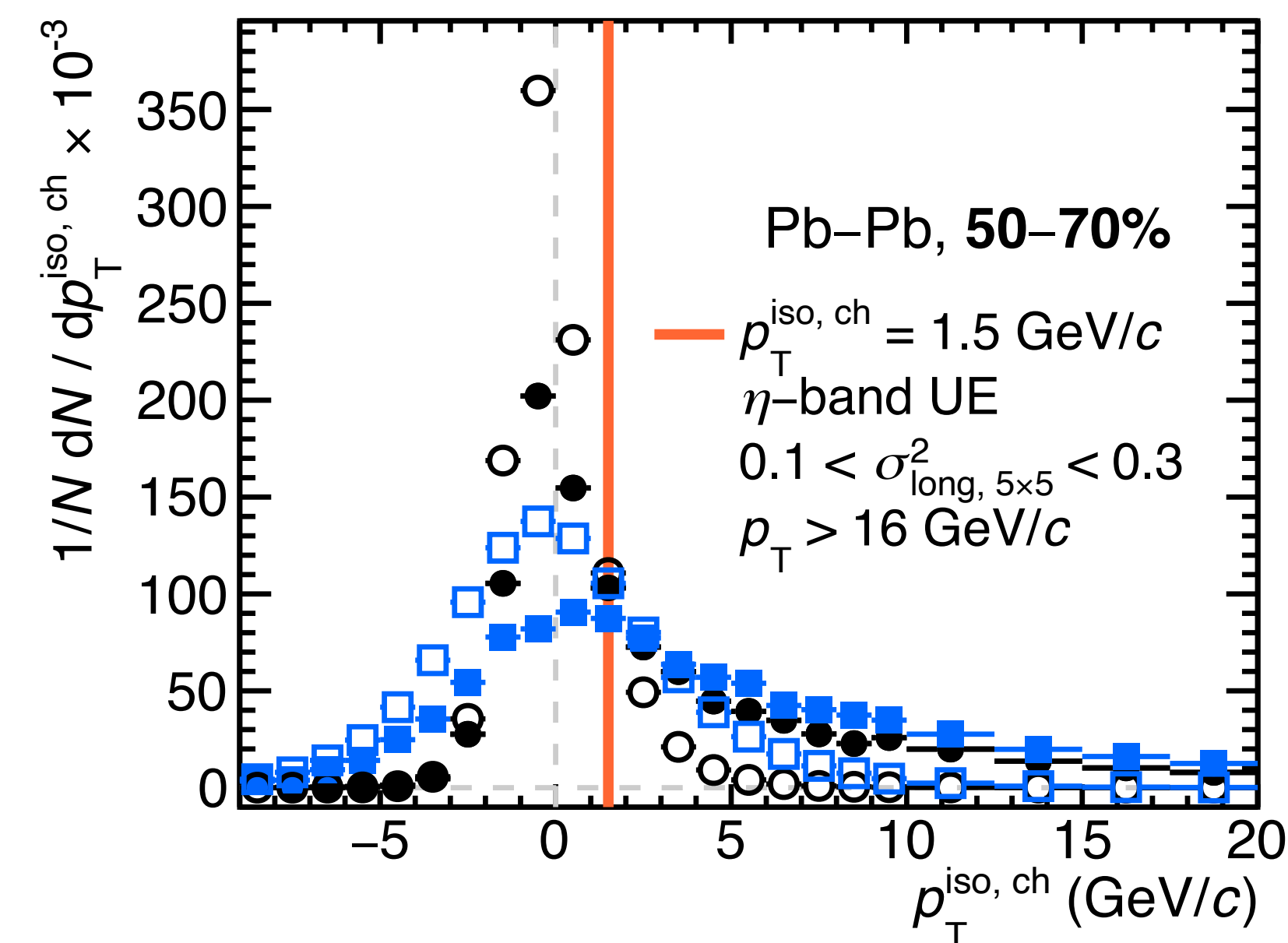
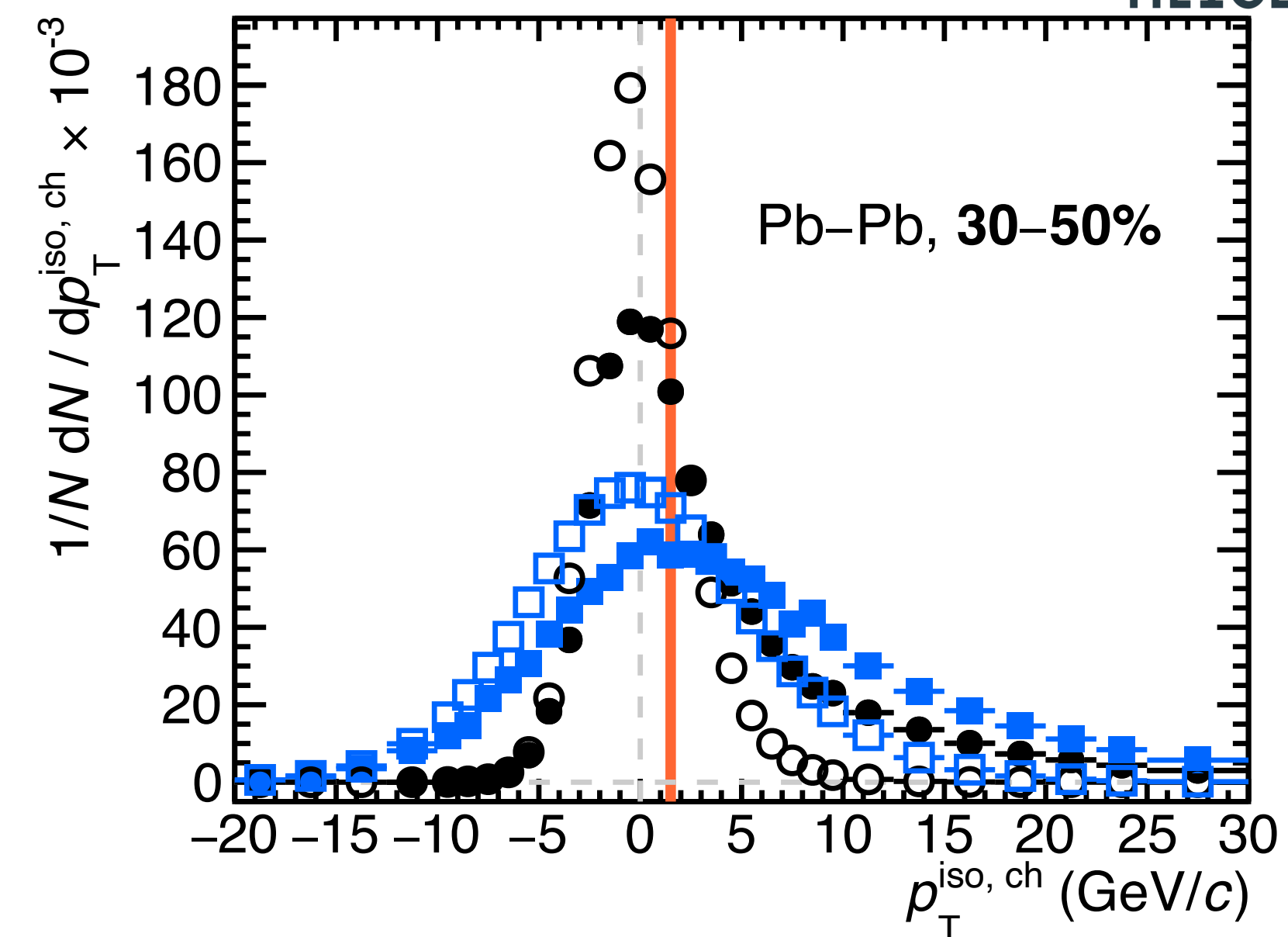
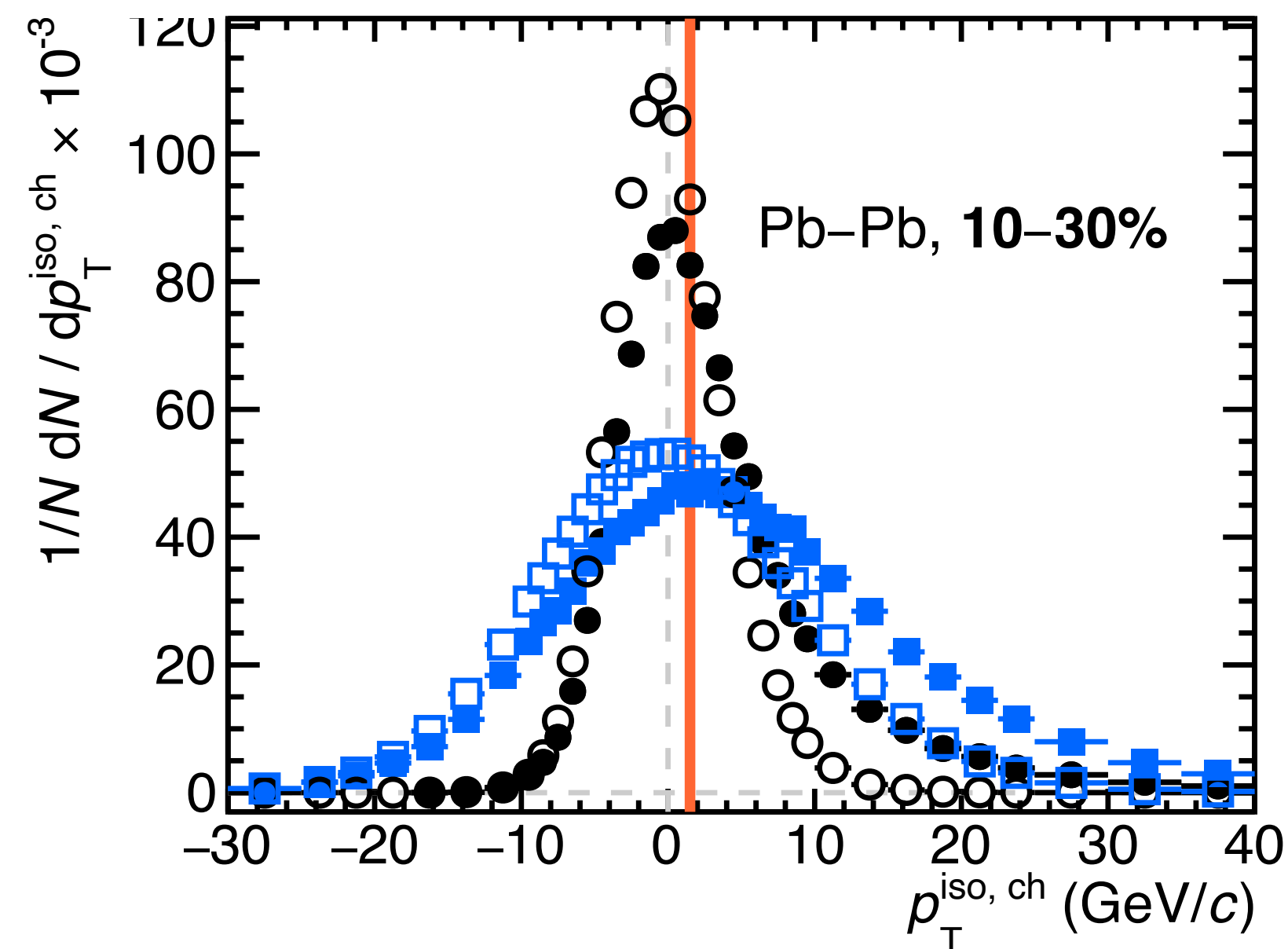
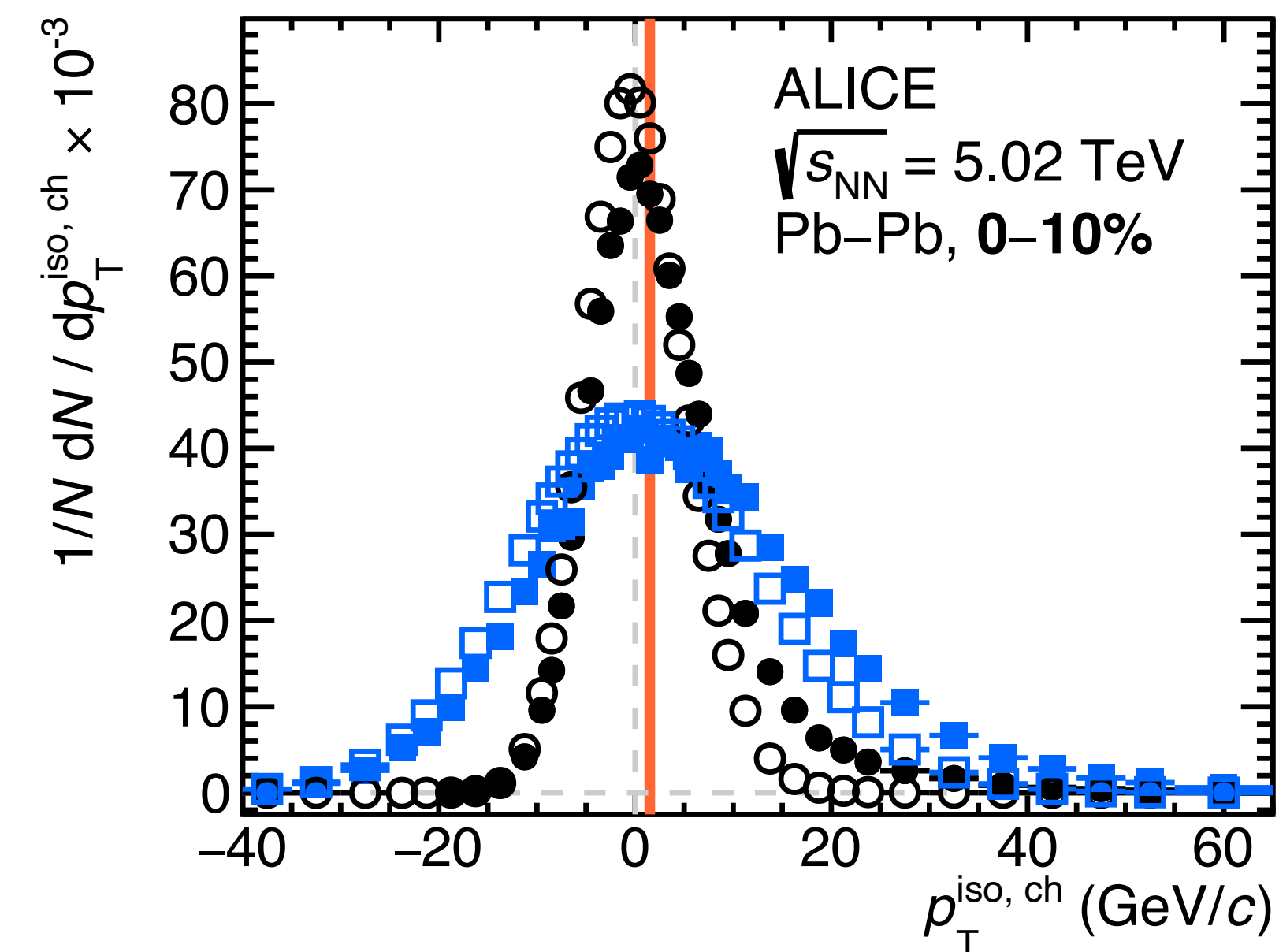
- Pb-Pb & pp at $\sqrt{s_{NN}} = 5.02$ TeV:
 - ➔ Sum of tracks p_T normalised by **η -band** area
→ *Avoid flow effects*
 - ➔ Gap between cone and band of $\Delta R_{UE\ gap} = 0.1$
→ *Avoid jet remnants*
- p-Pb $\sqrt{s_{NN}} = 5.02, 8.16$ TeV, pp $\sqrt{s} = 8$ TeV
 - ➔ Perpendicular cone & jet-median



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



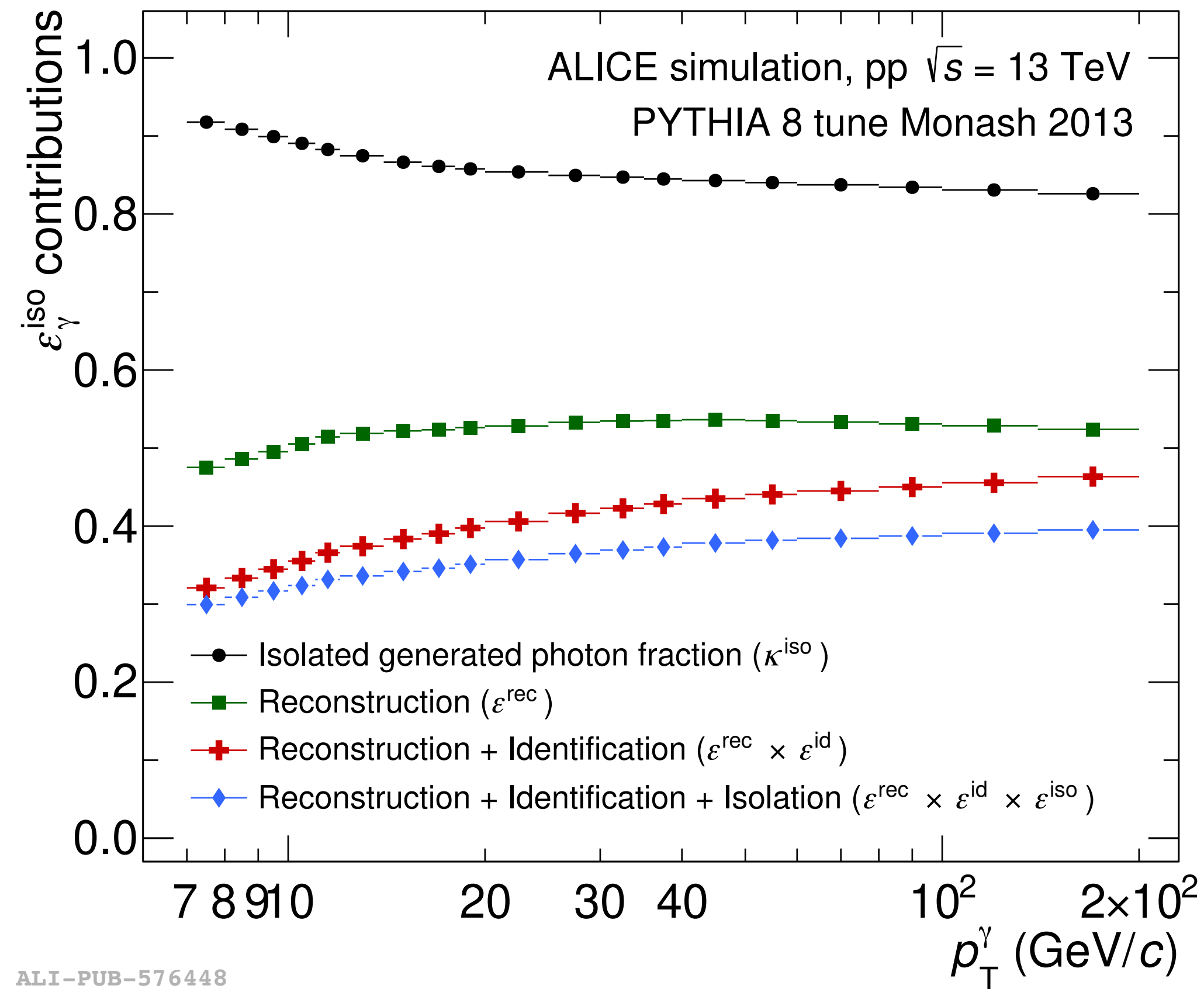
Isolation momentum in cone, pp & Pb-Pb $\sqrt{s_{NN}} = 5.02$ TeV



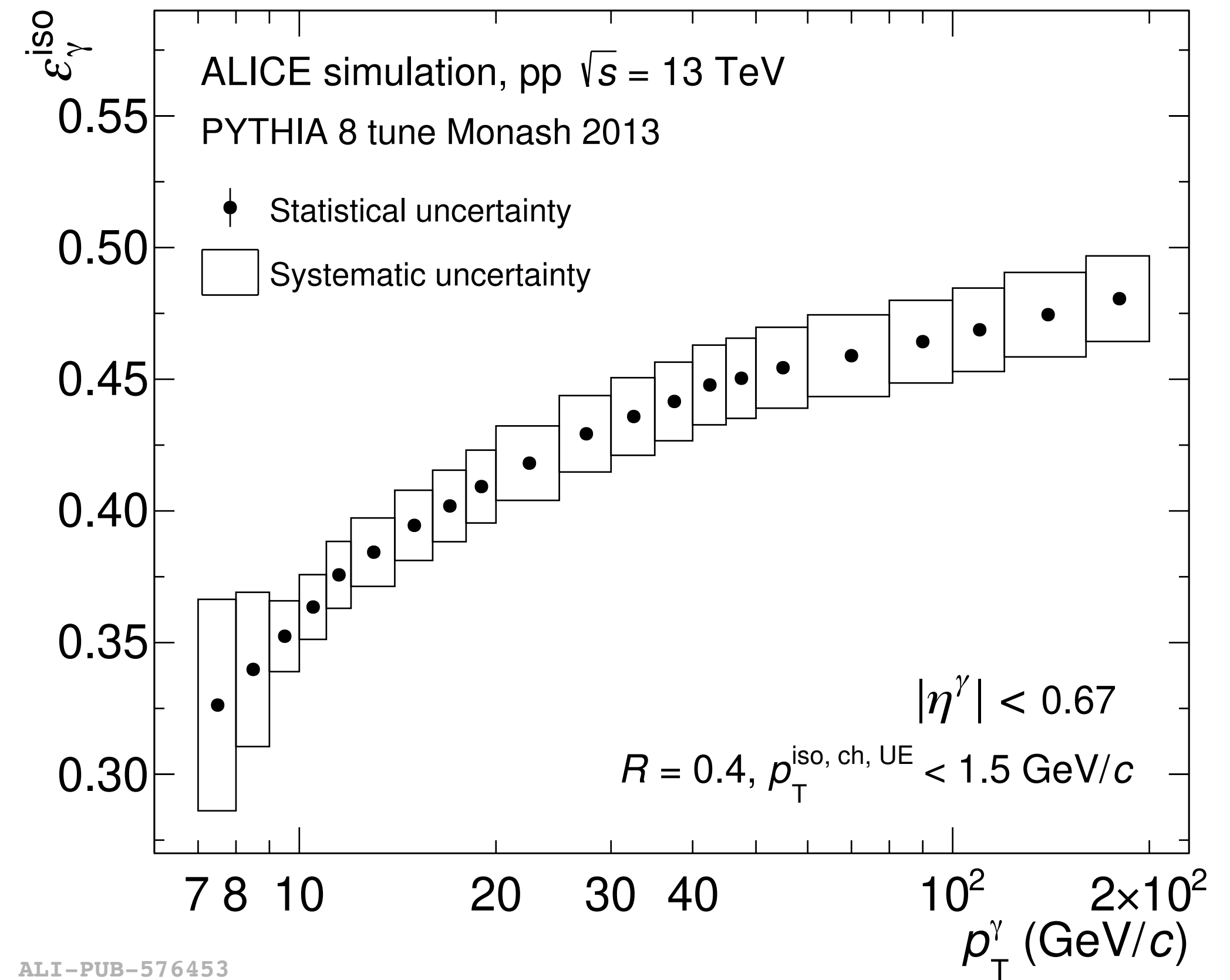
Isolated γ efficiency components, pp $\sqrt{s} = 13$ TeV

$$\varepsilon^{\text{sel}} = \frac{dN_{\gamma_{\text{prompt}}}^{\text{cluster sel.}}/dp_{\text{T}}^{\text{rec}}}{dN_{\gamma_{\text{prompt}}}^{\text{gener.}}/dp_{\text{T}}^{\text{gen}}}$$

$$\varepsilon_{\gamma}^{\text{iso}} = \frac{dN_{\gamma_{\text{prompt}}}^{\text{cluster iso. narrow}}/dp_{\text{T}}^{\text{rec}}}{dN_{\gamma_{\text{prompt}}}^{\text{gener. iso.}}/dp_{\text{T}}^{\text{gen}}}$$



ALI-PUB-576448

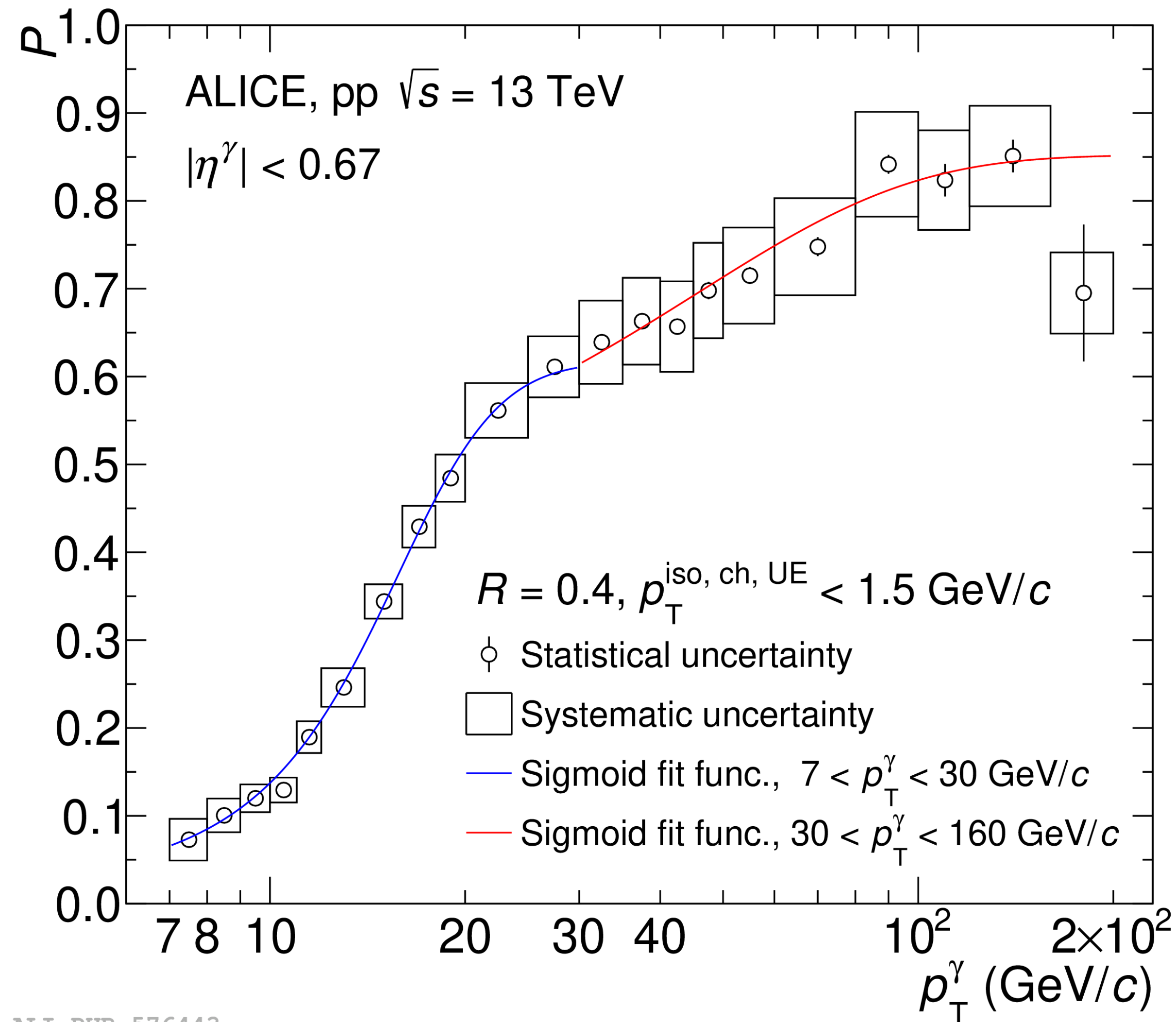


ALI-PUB-576453

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

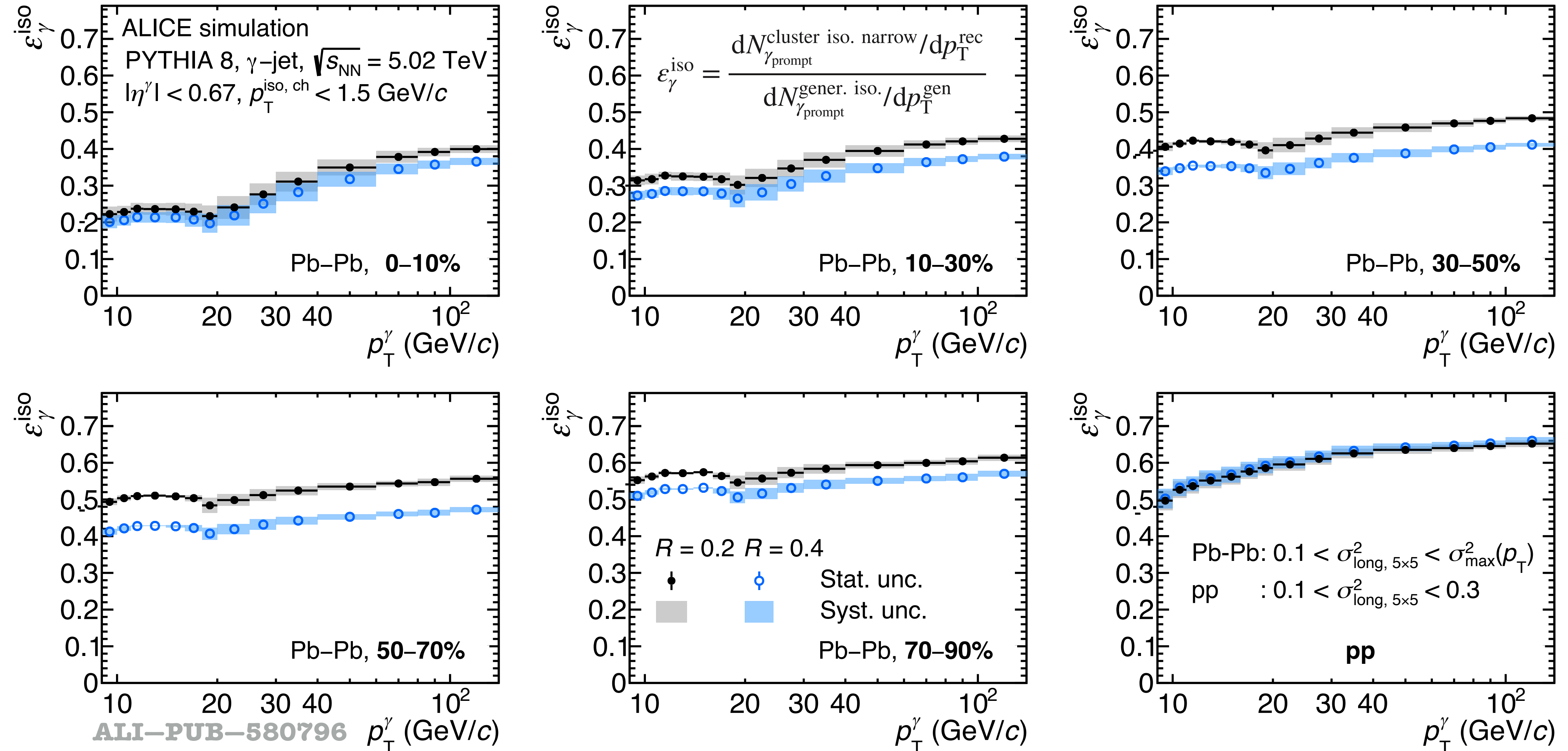
$$P = 1 - \left(\frac{N_n^{\text{iso}}/N_n^{\text{iso}}}{N_w^{\text{iso}}/N_w^{\text{iso}}} \right)_{\text{data}} \times \left(\frac{B_n^{\text{iso}}/N_n^{\text{iso}}}{N_w^{\text{iso}}/N_w^{\text{iso}}} \right)_{\text{MC}}$$

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



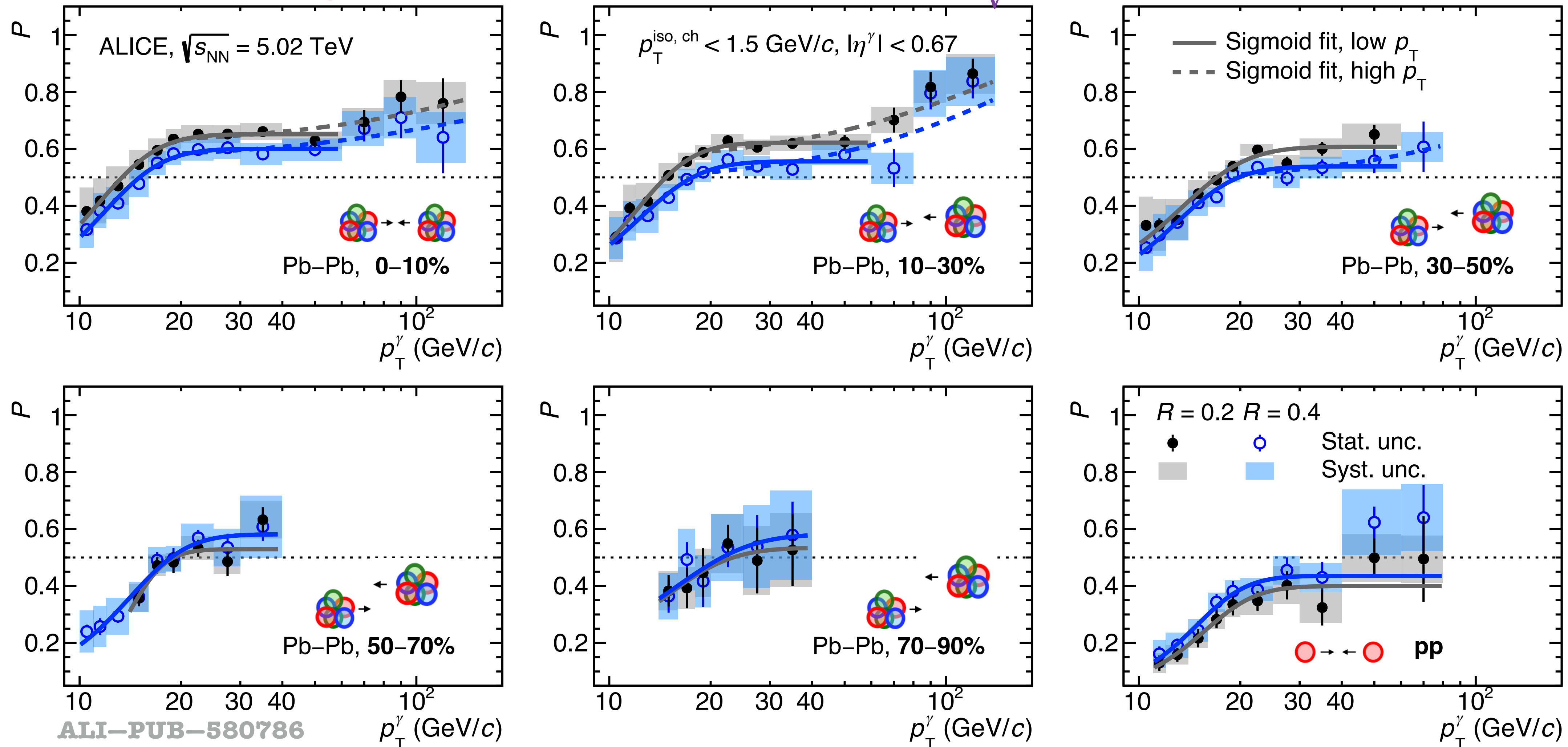
► Reduce the influence of statistical fluctuations with two sigmoid function fits

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



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

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

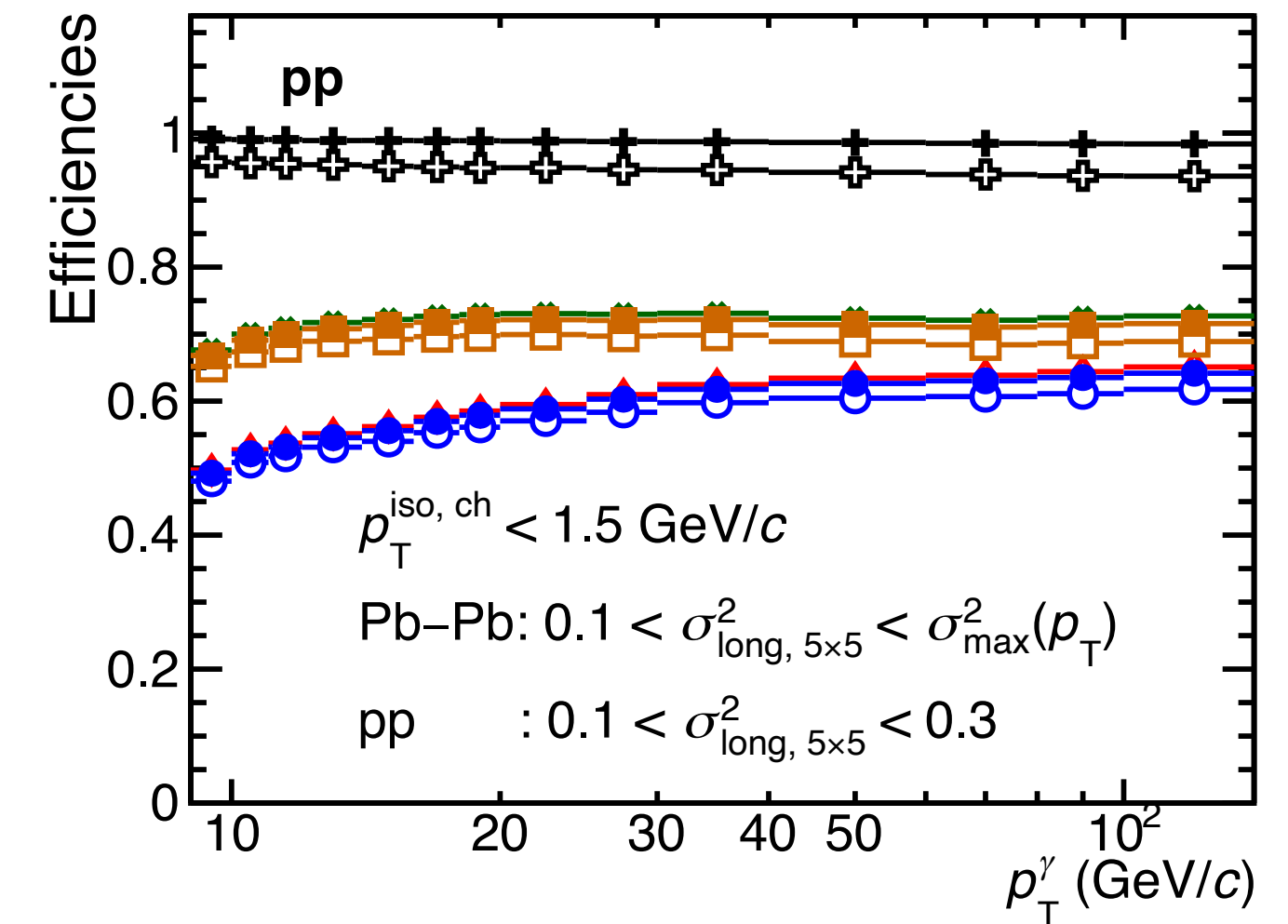
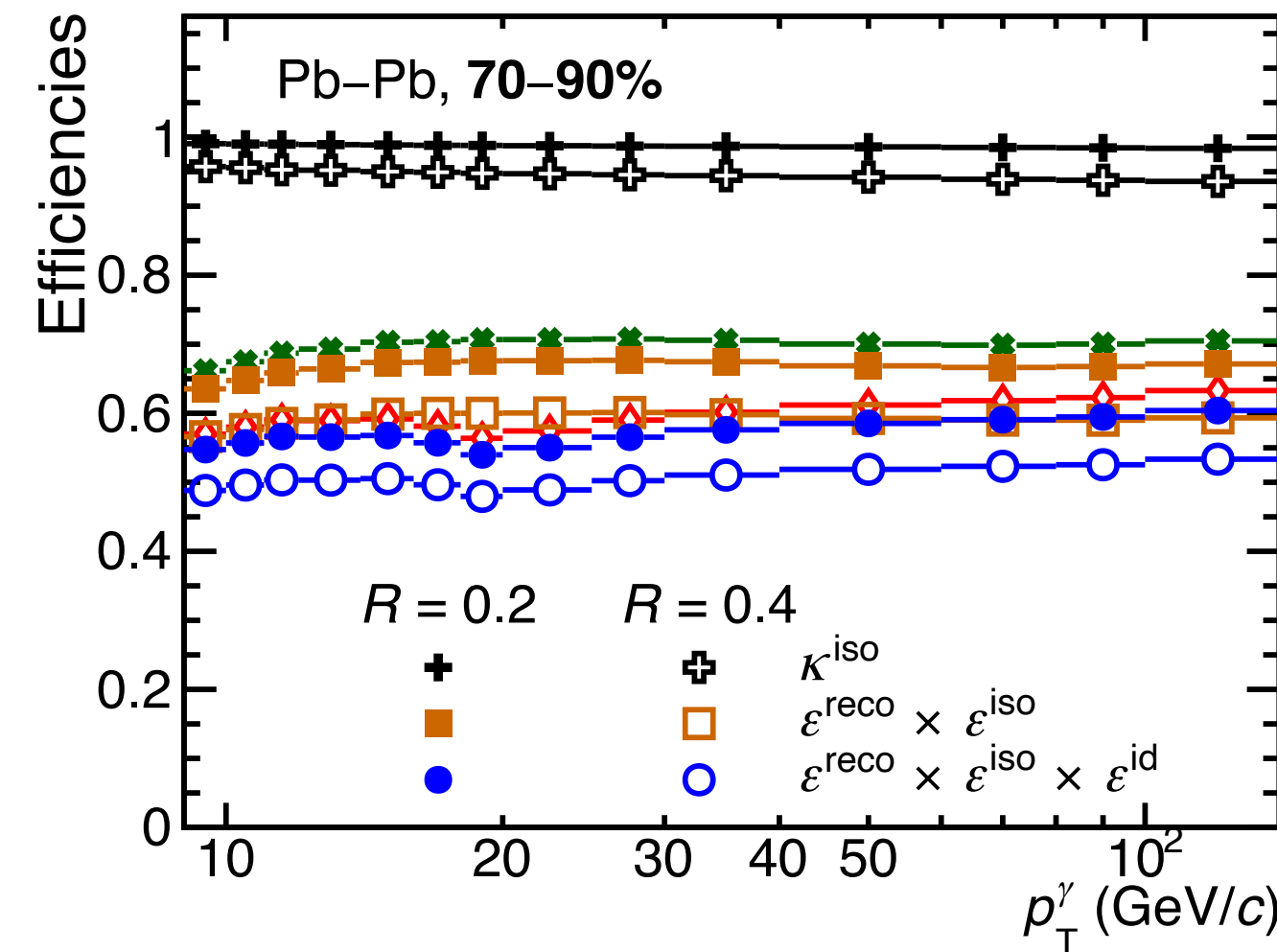
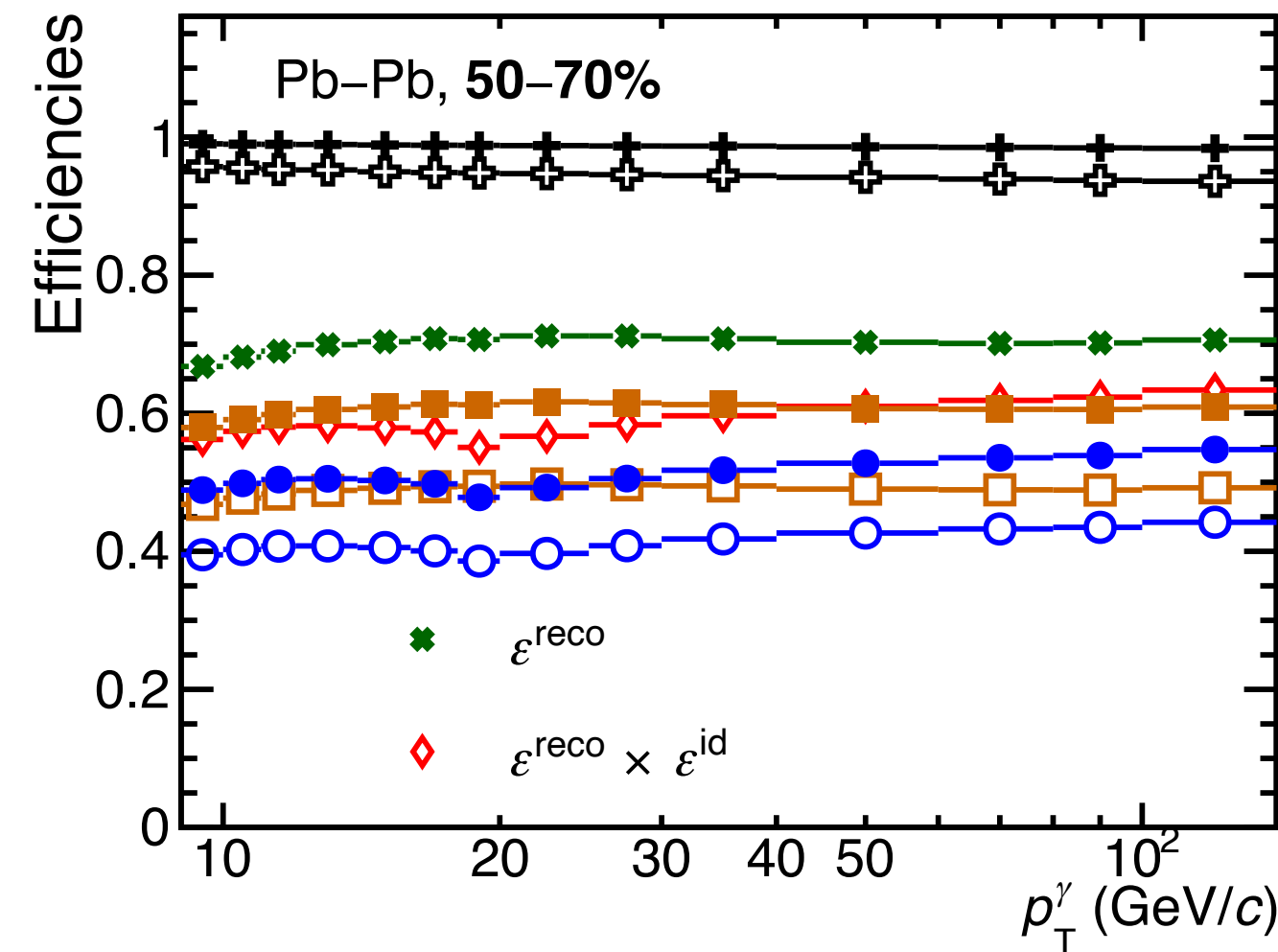
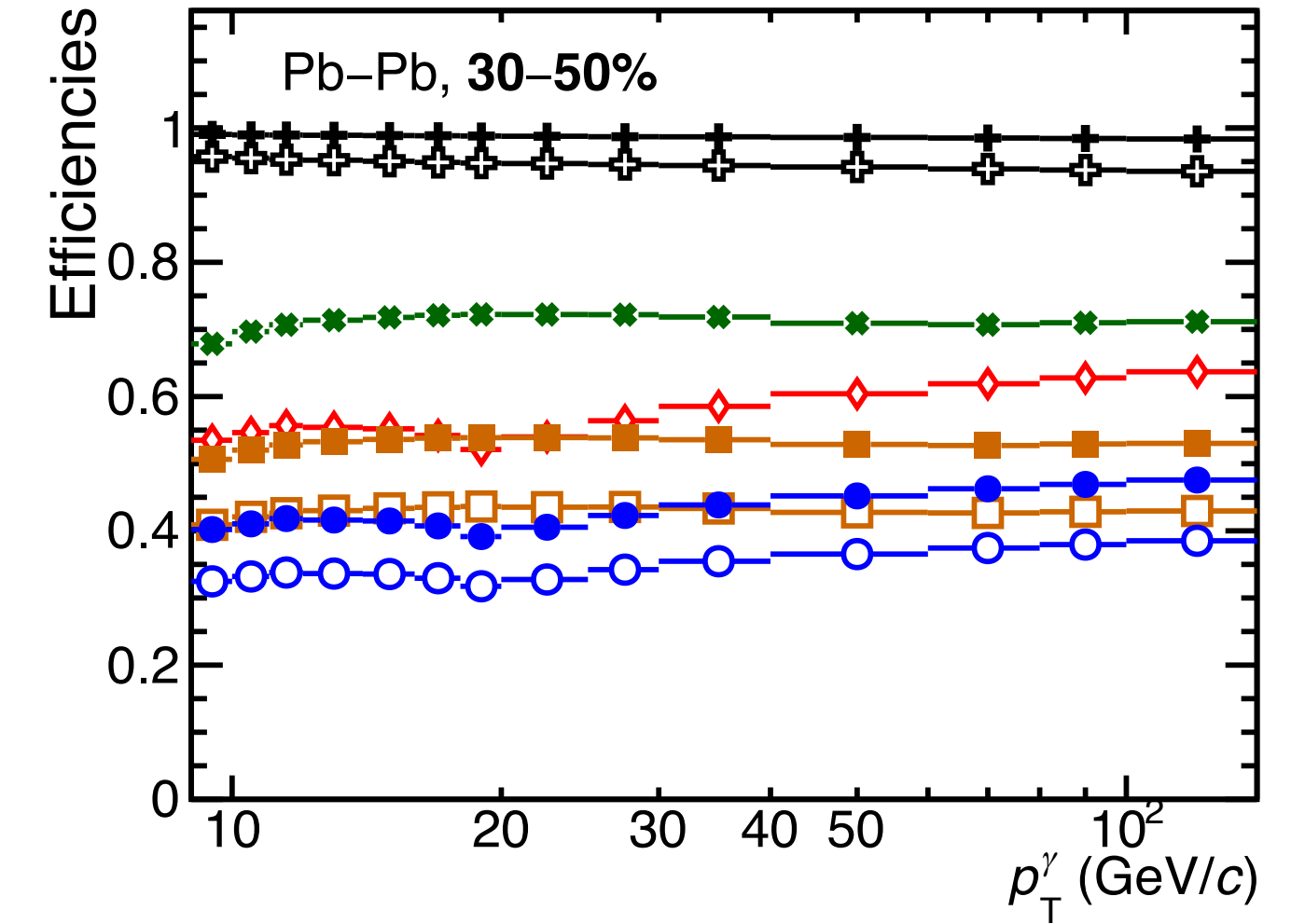
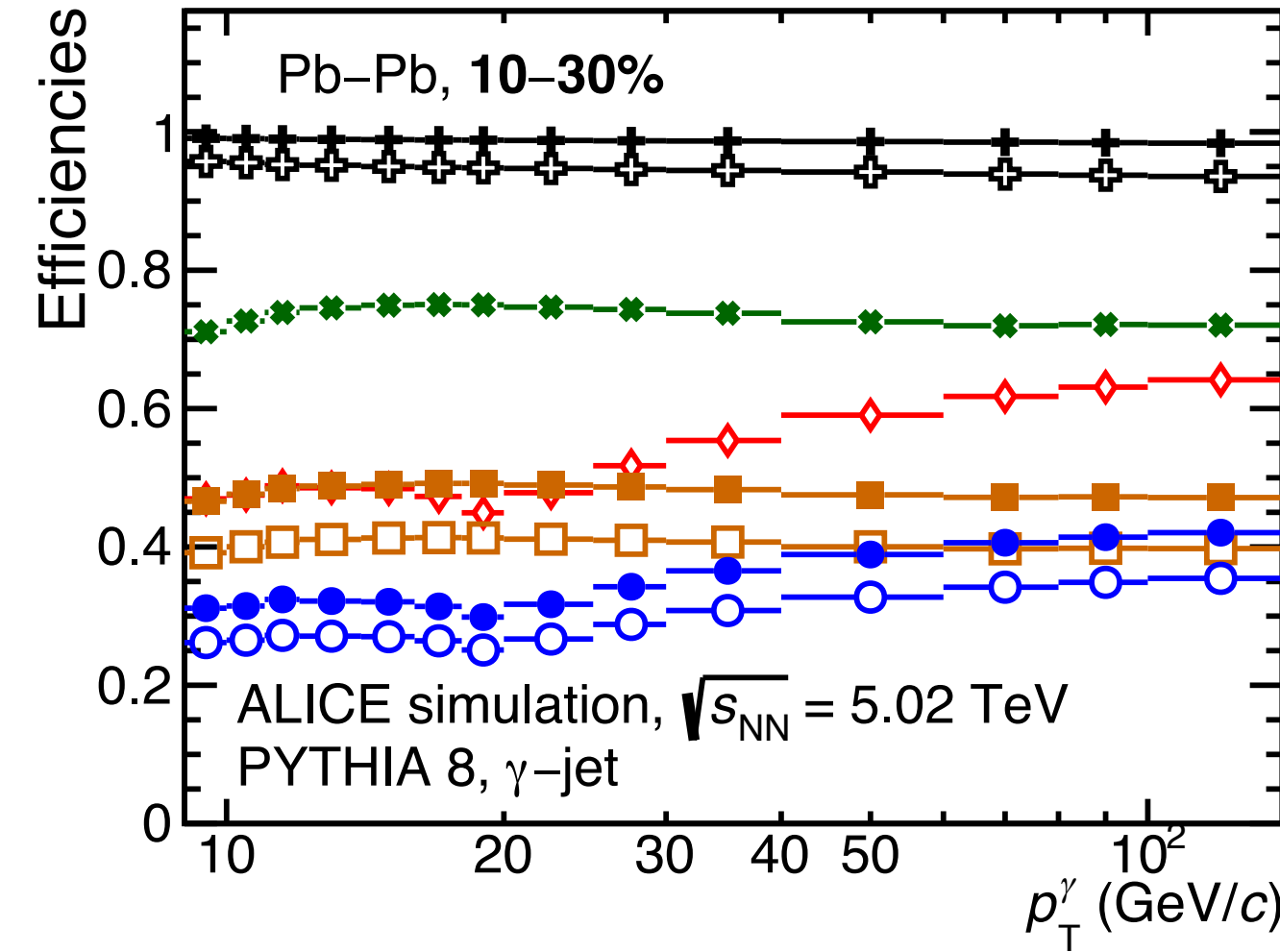
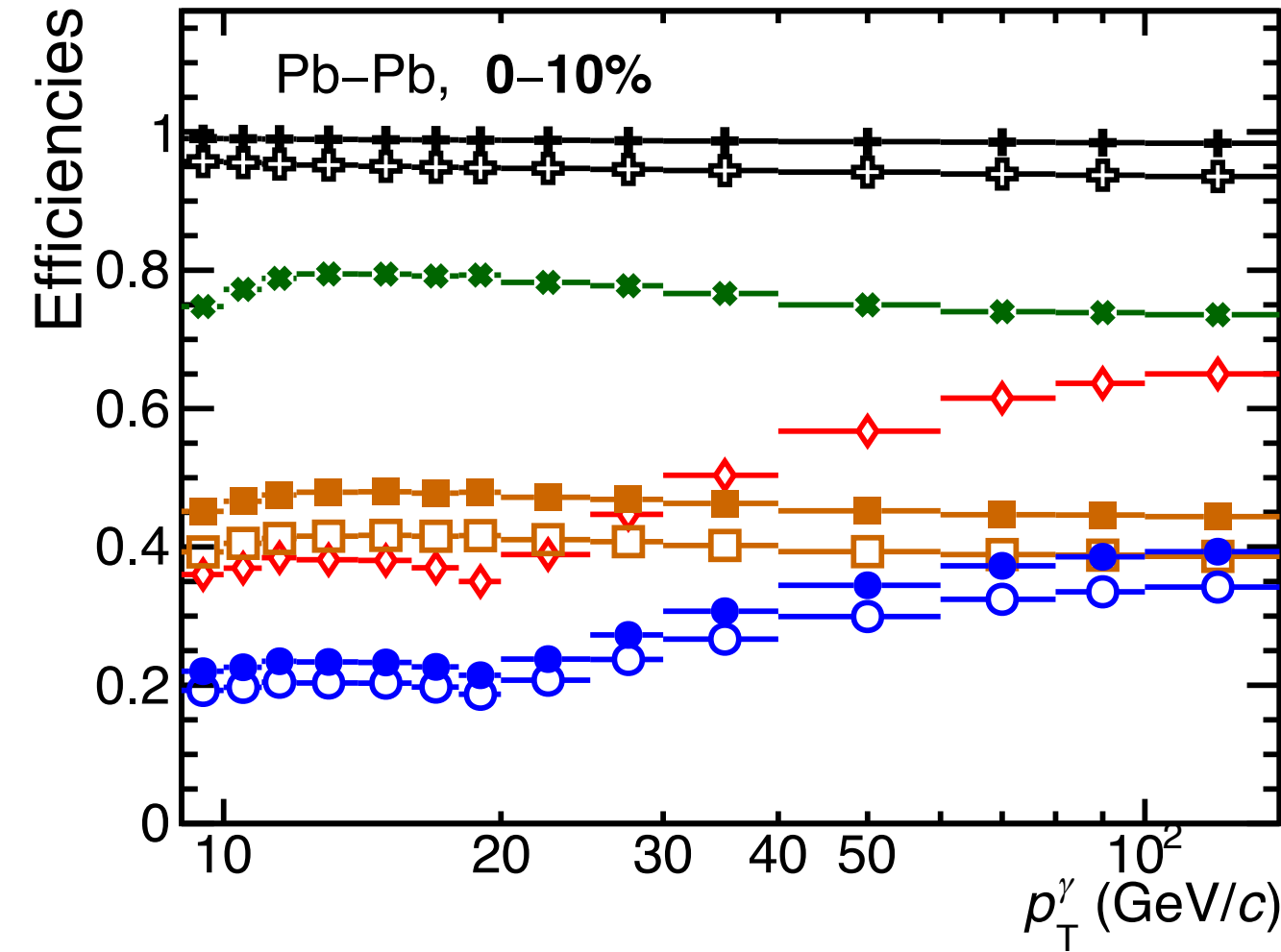


- Distributions fitted to sigmoid function to reduce influence of fluctuations, fits used to correct the spectra
- $P(R = 0.4) > P(R = 0.2)$ in pp collisions, more jet particles in cone, but decreasing centrality $P(R = 0.2) > P(R = 0.4)$, due to UE fluctuations, although not significantly different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

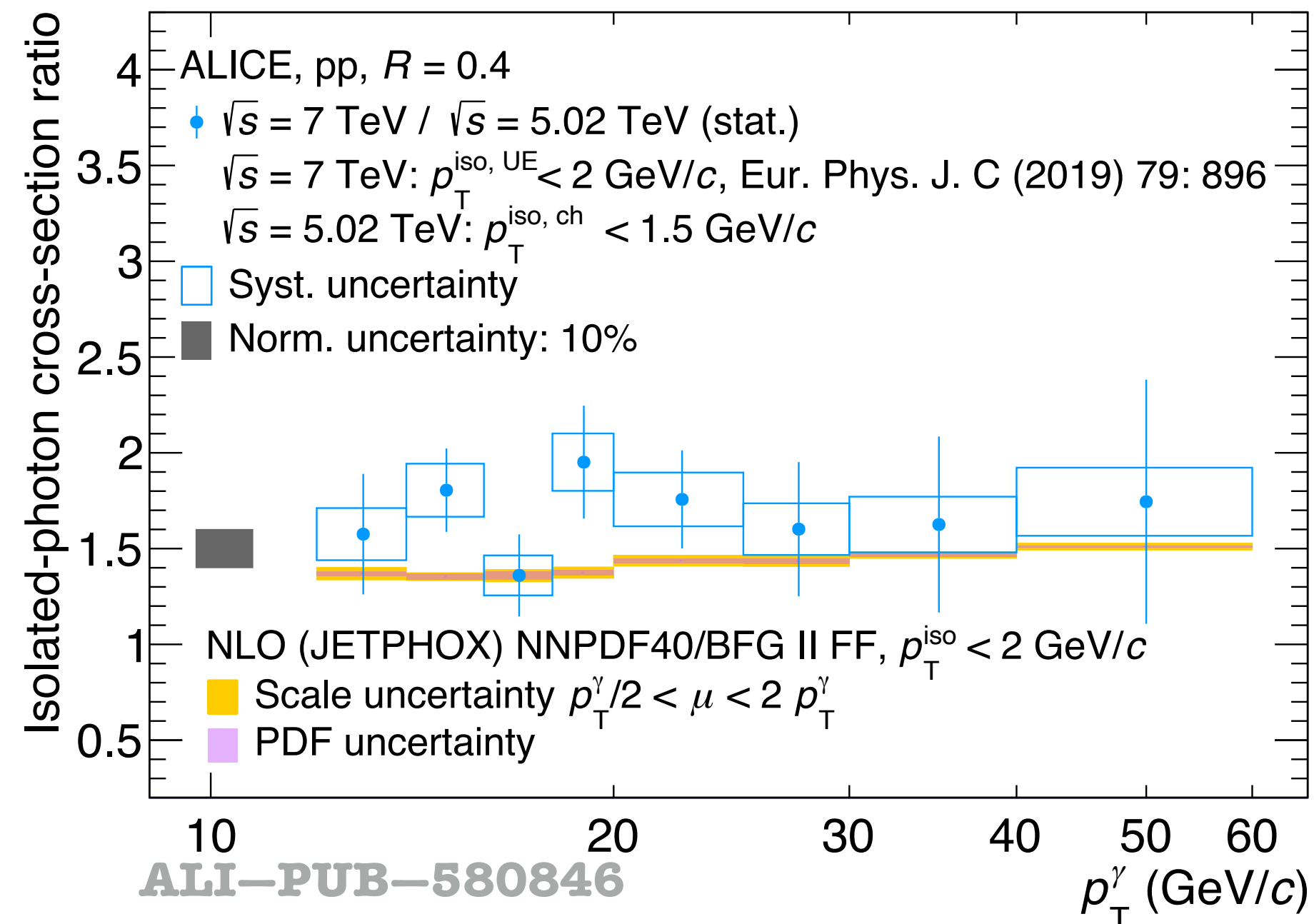
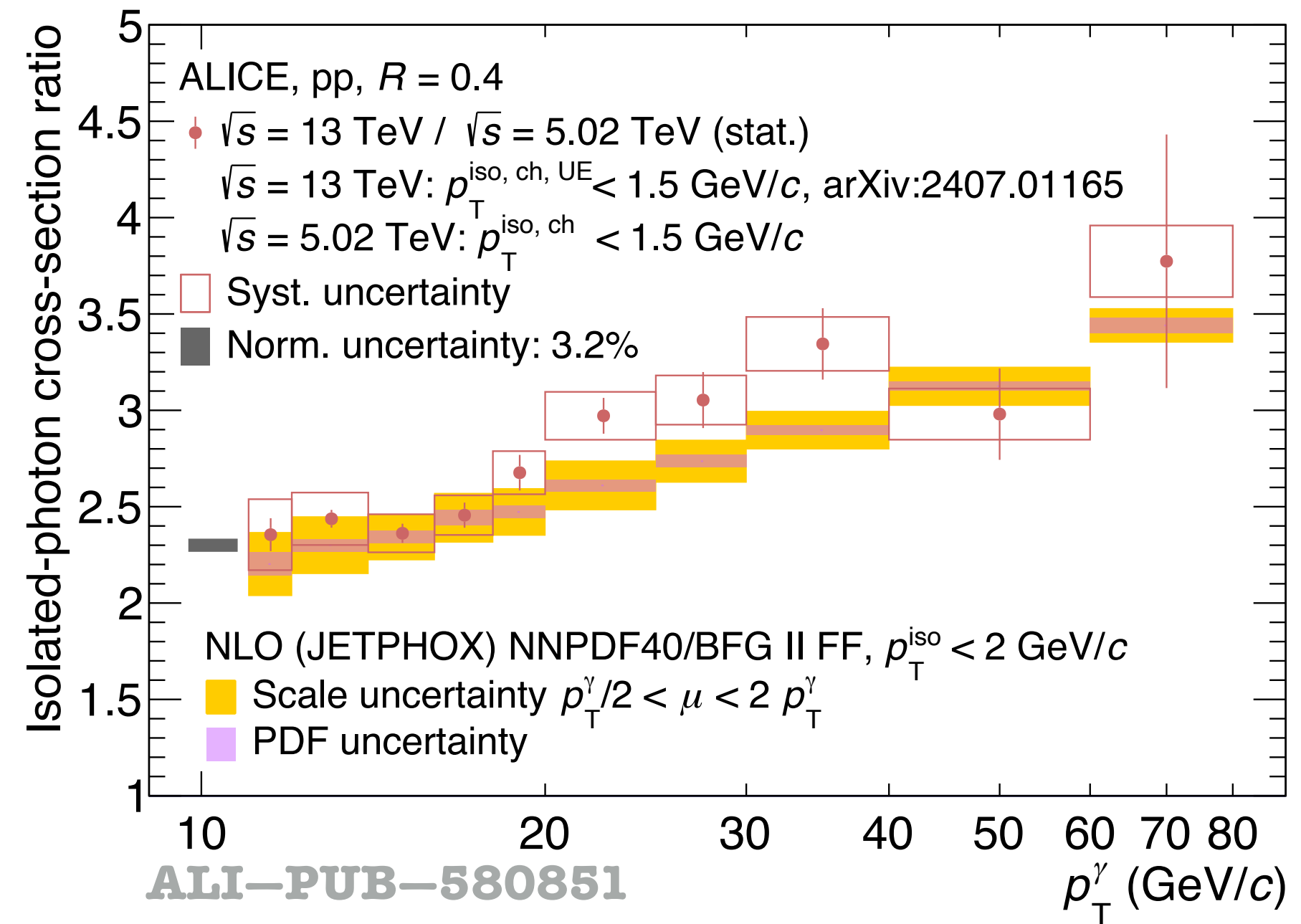
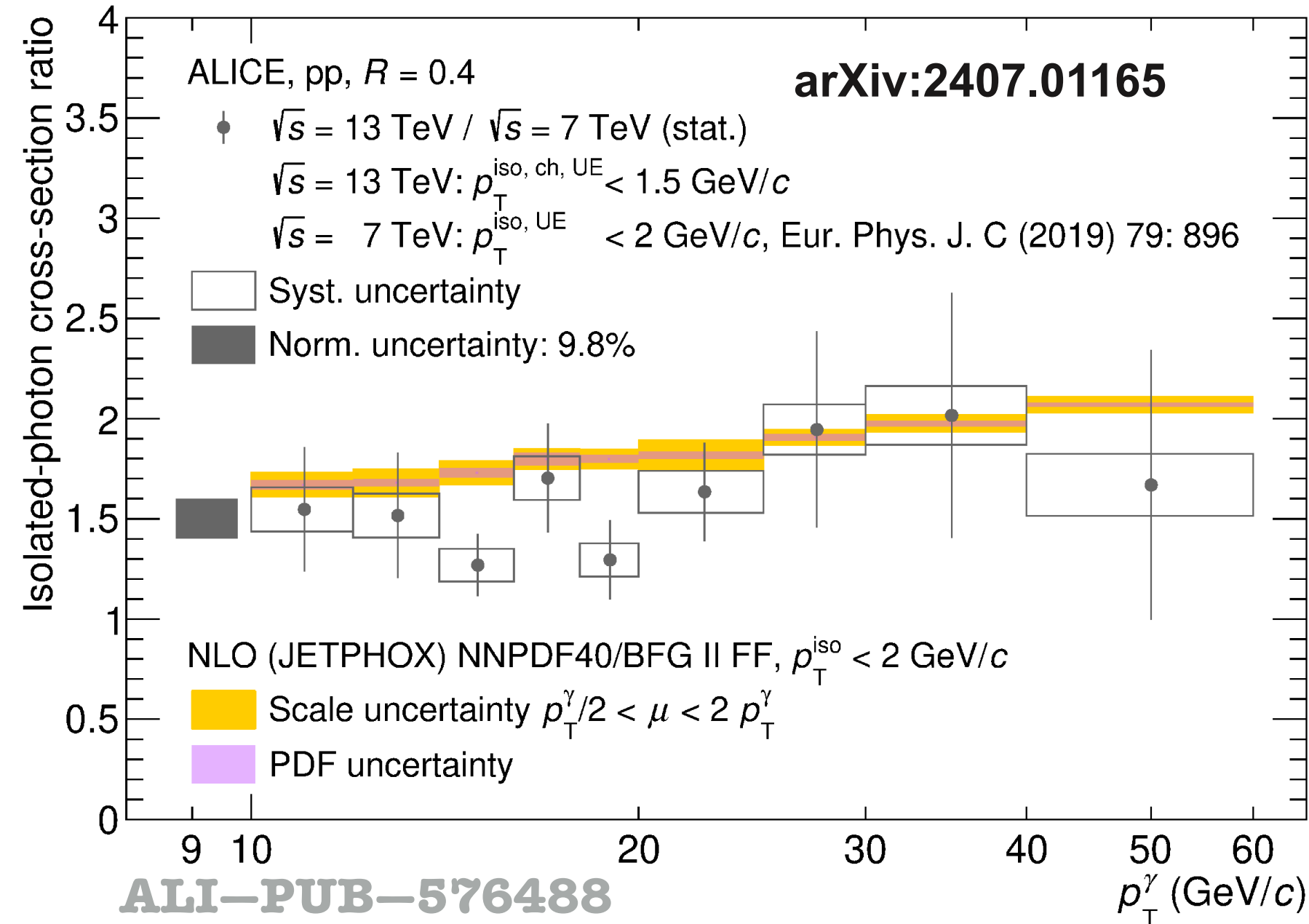
Isolated γ efficiency components, pp & Pb-Pb $\sqrt{s_{NN}} = 5.02$ TeV

$$\varepsilon^{\text{sel}} = \frac{dN_{\gamma_{\text{prompt}}^{\text{cluster sel.}}/dp_T^{\text{rec}}}{dN_{\gamma_{\text{prompt}}^{\text{gener.}}/dp_T^{\text{gen}}}$$

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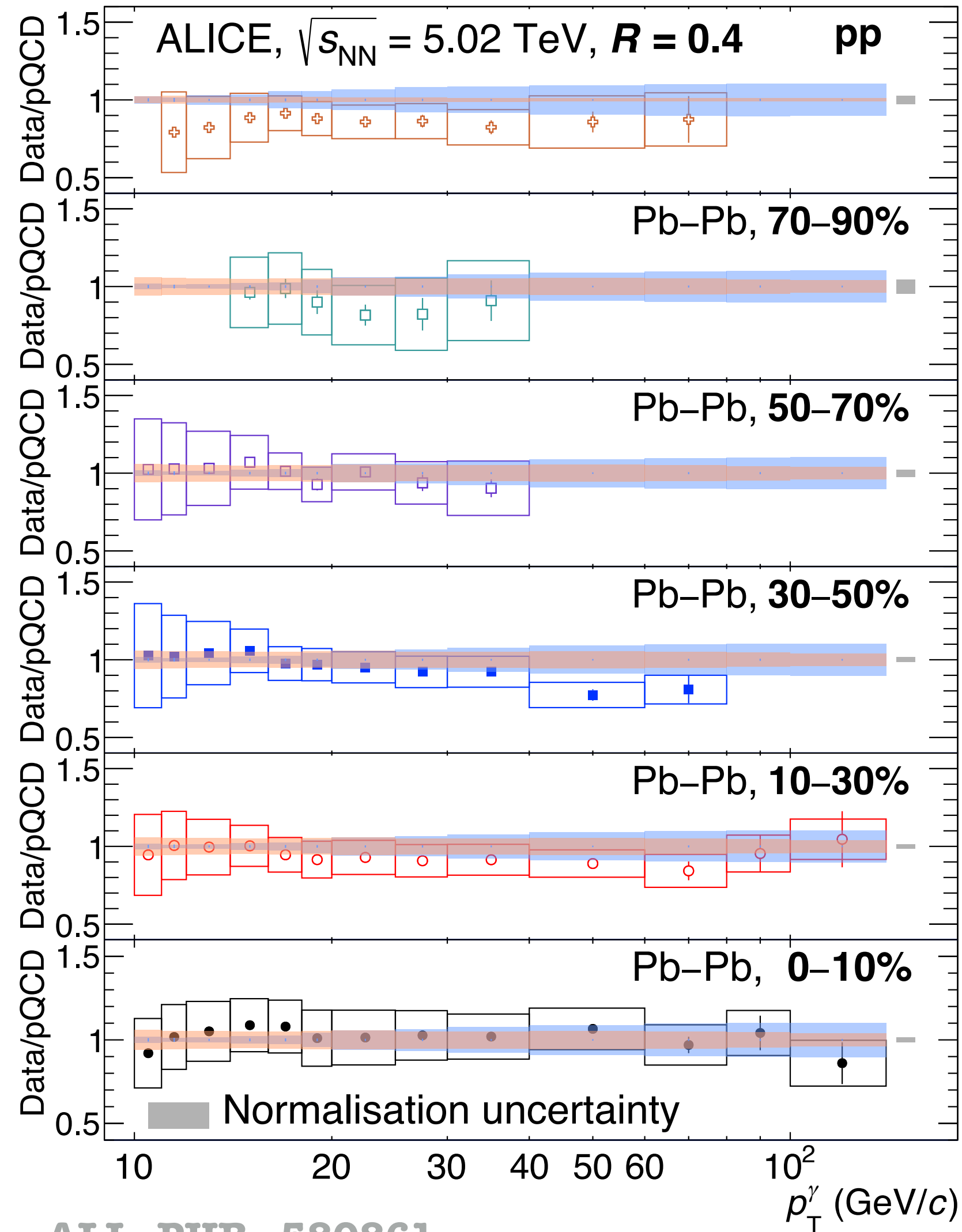
Cross section ratios in pp collisions



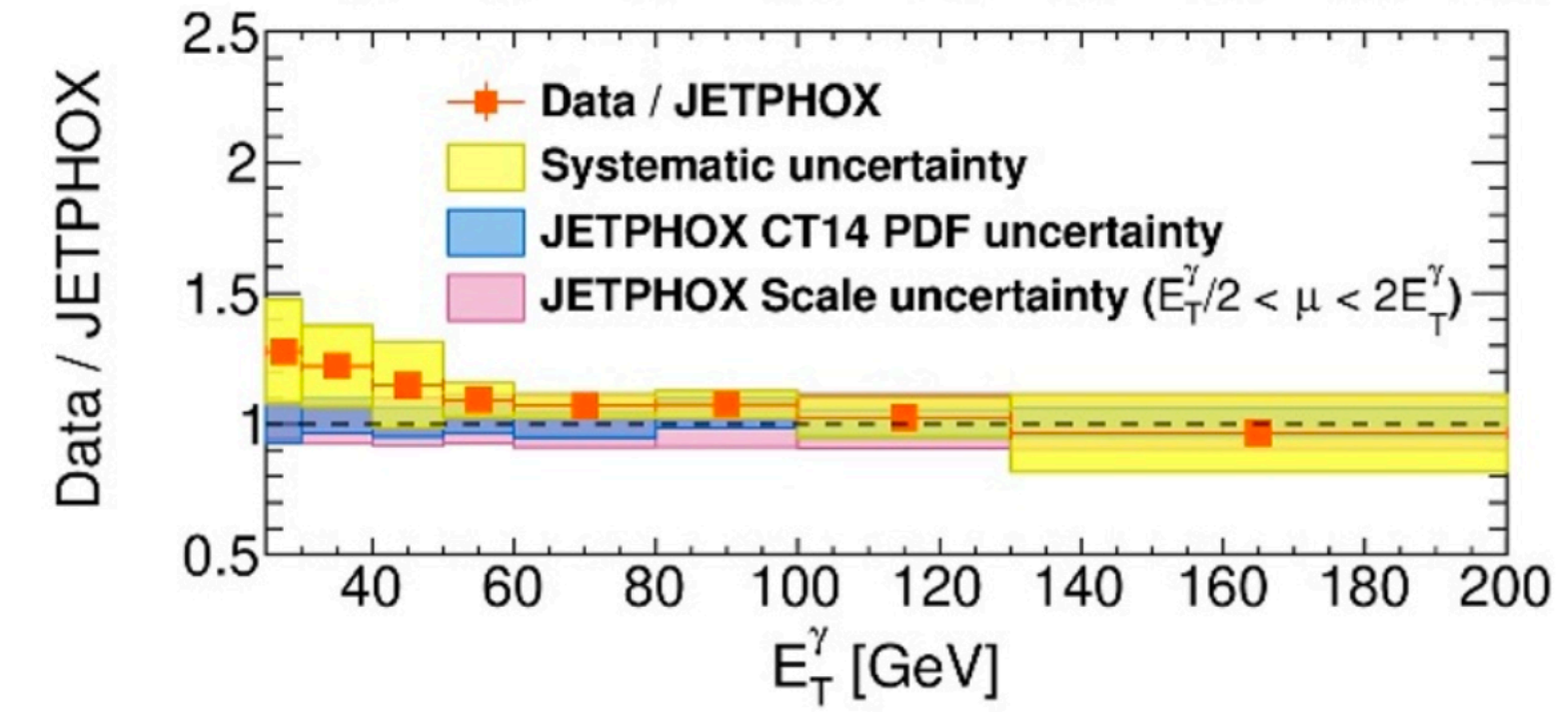
Data over theory, $R = 0.4$, pp & Pb–Pb at $\sqrt{s_{NN}} = 5.02$ TeV

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CMS

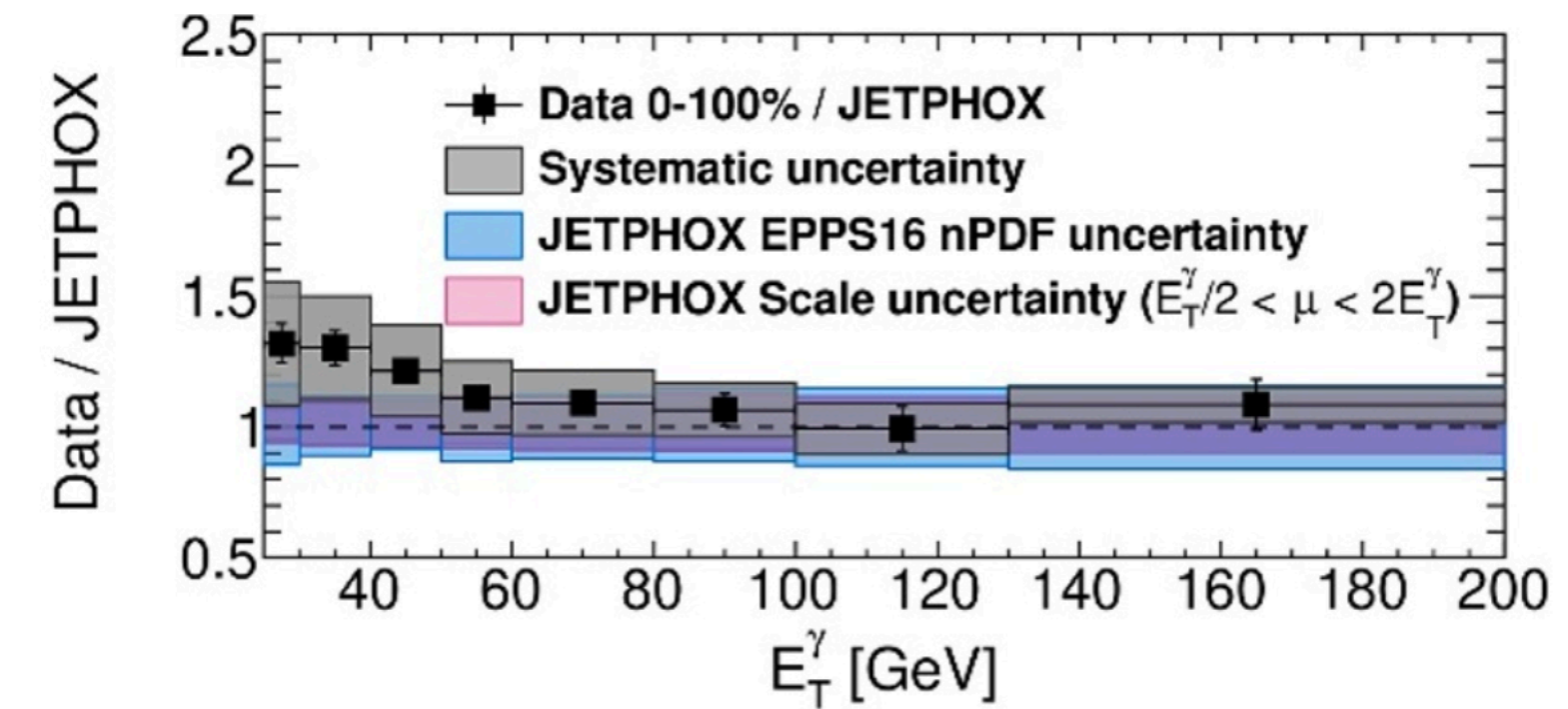


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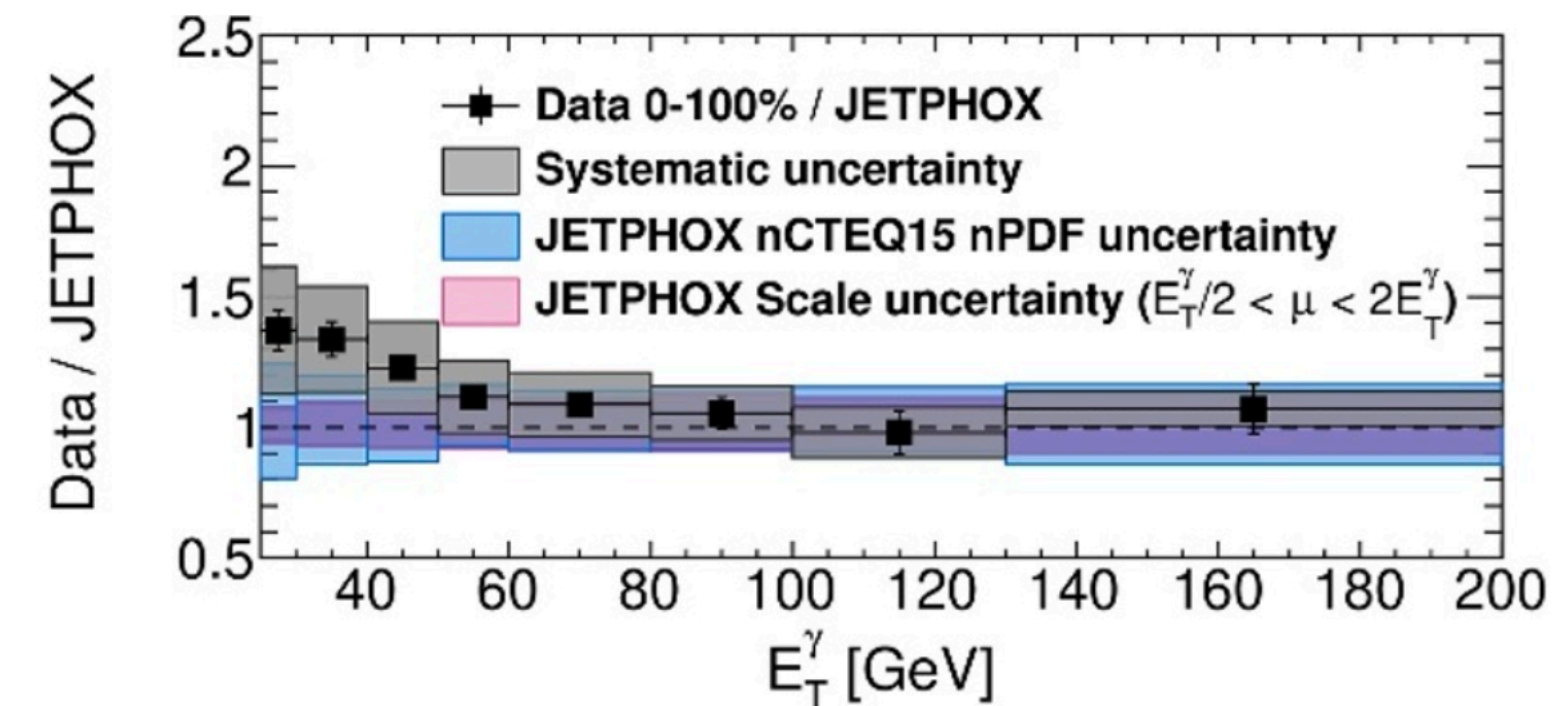


pp

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

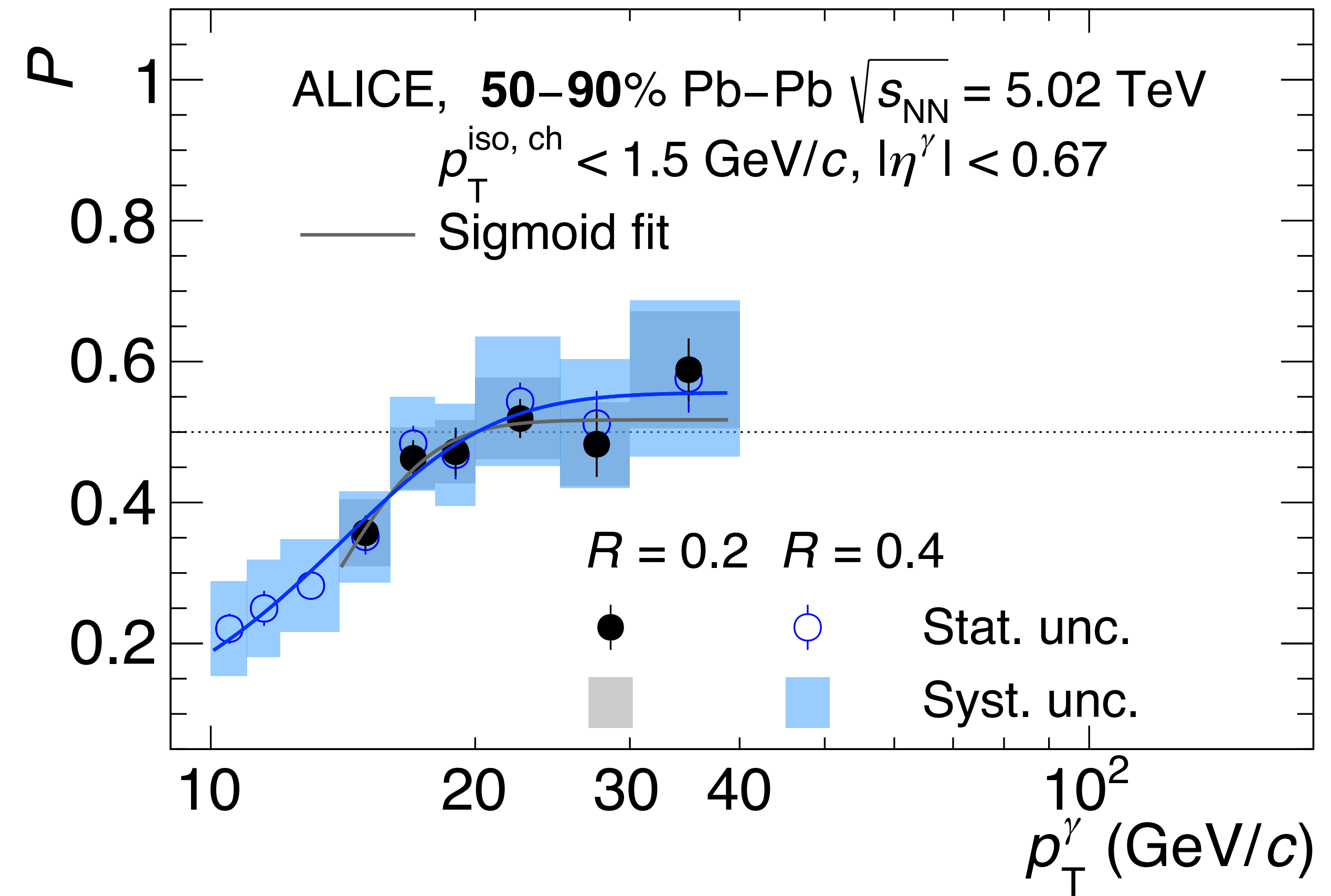
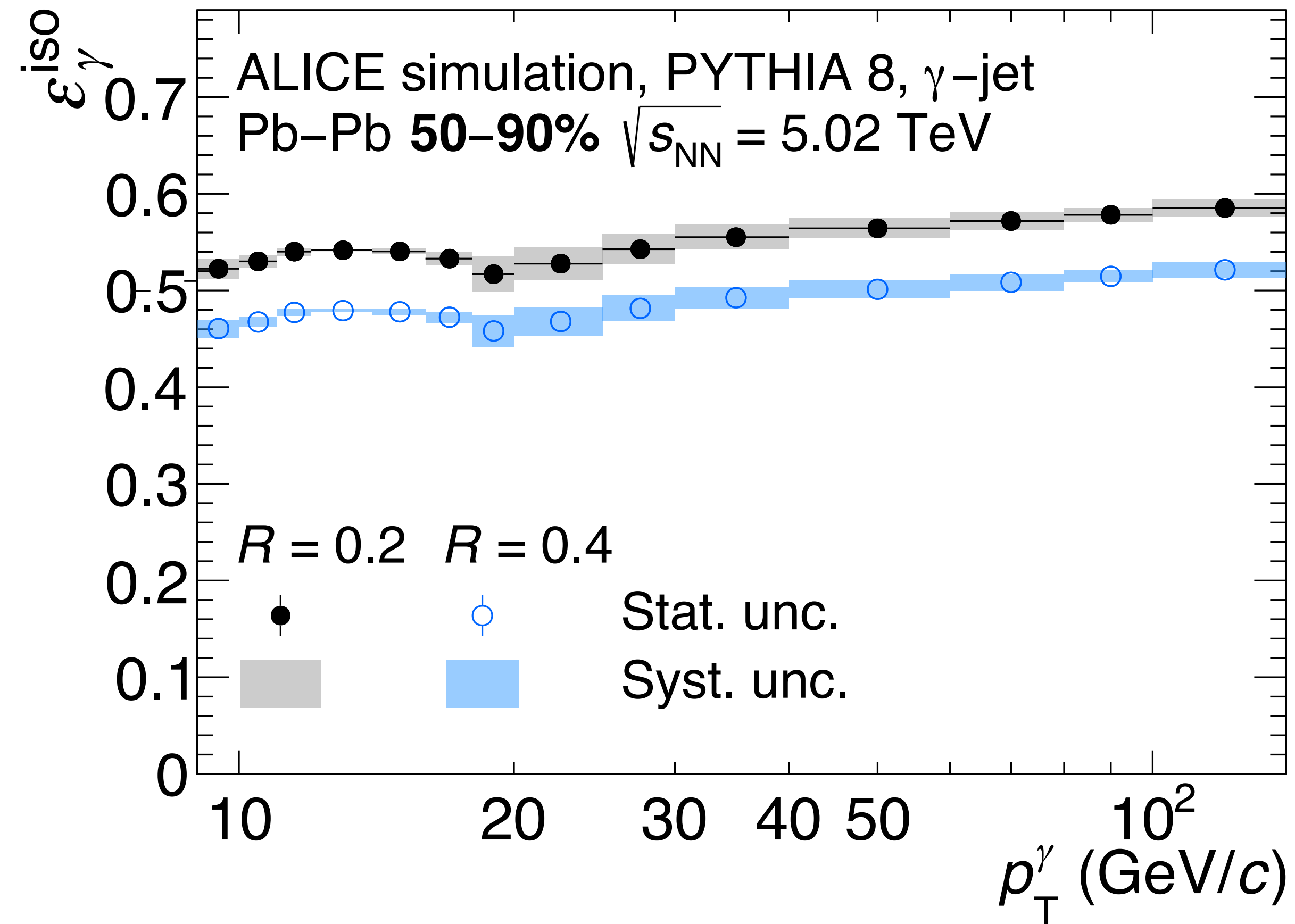


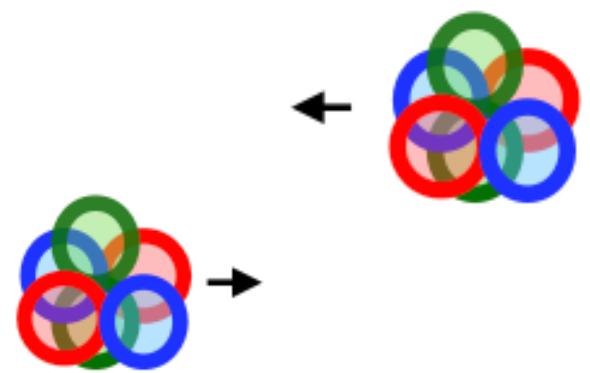
Pb–Pb 0–100%



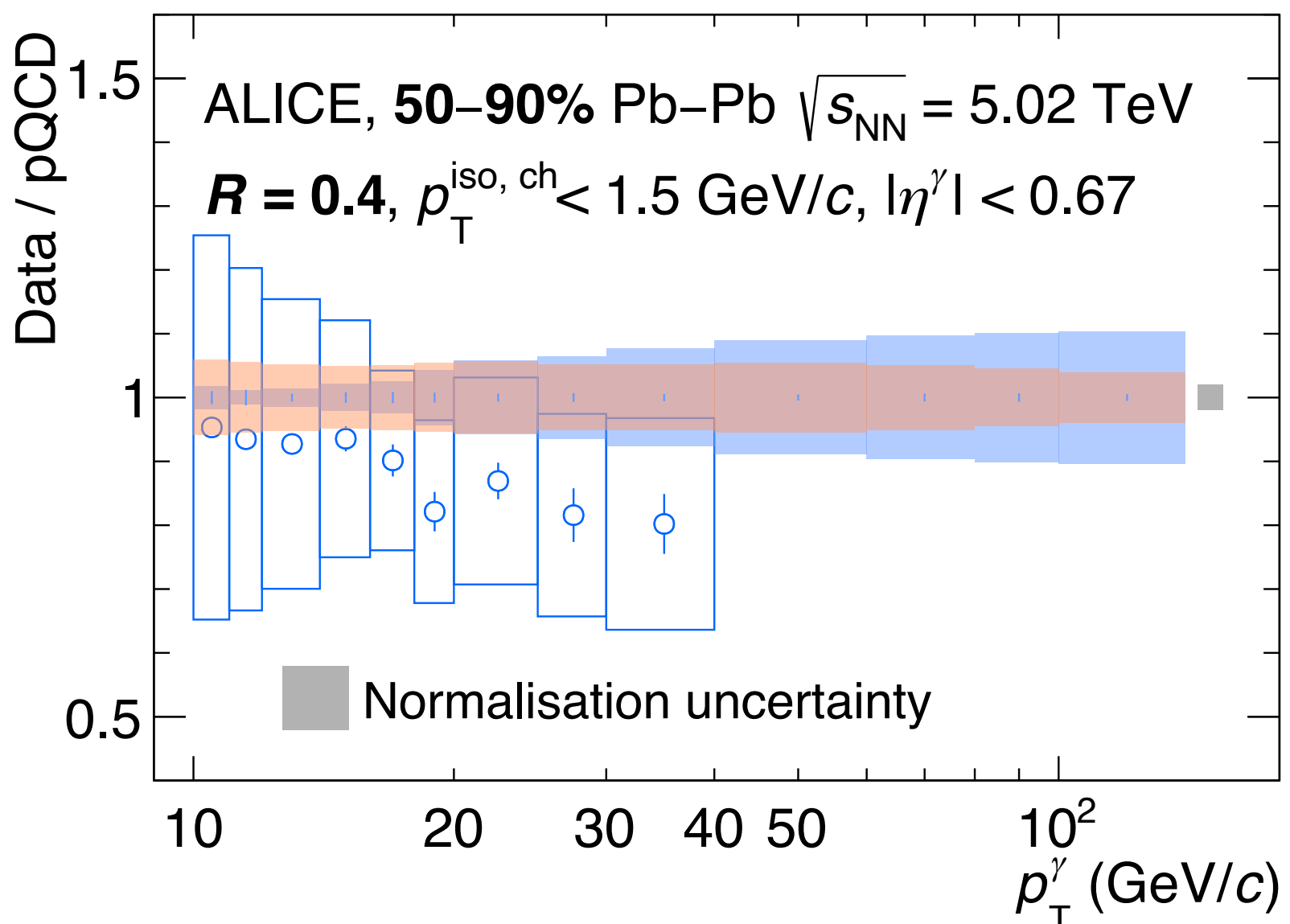
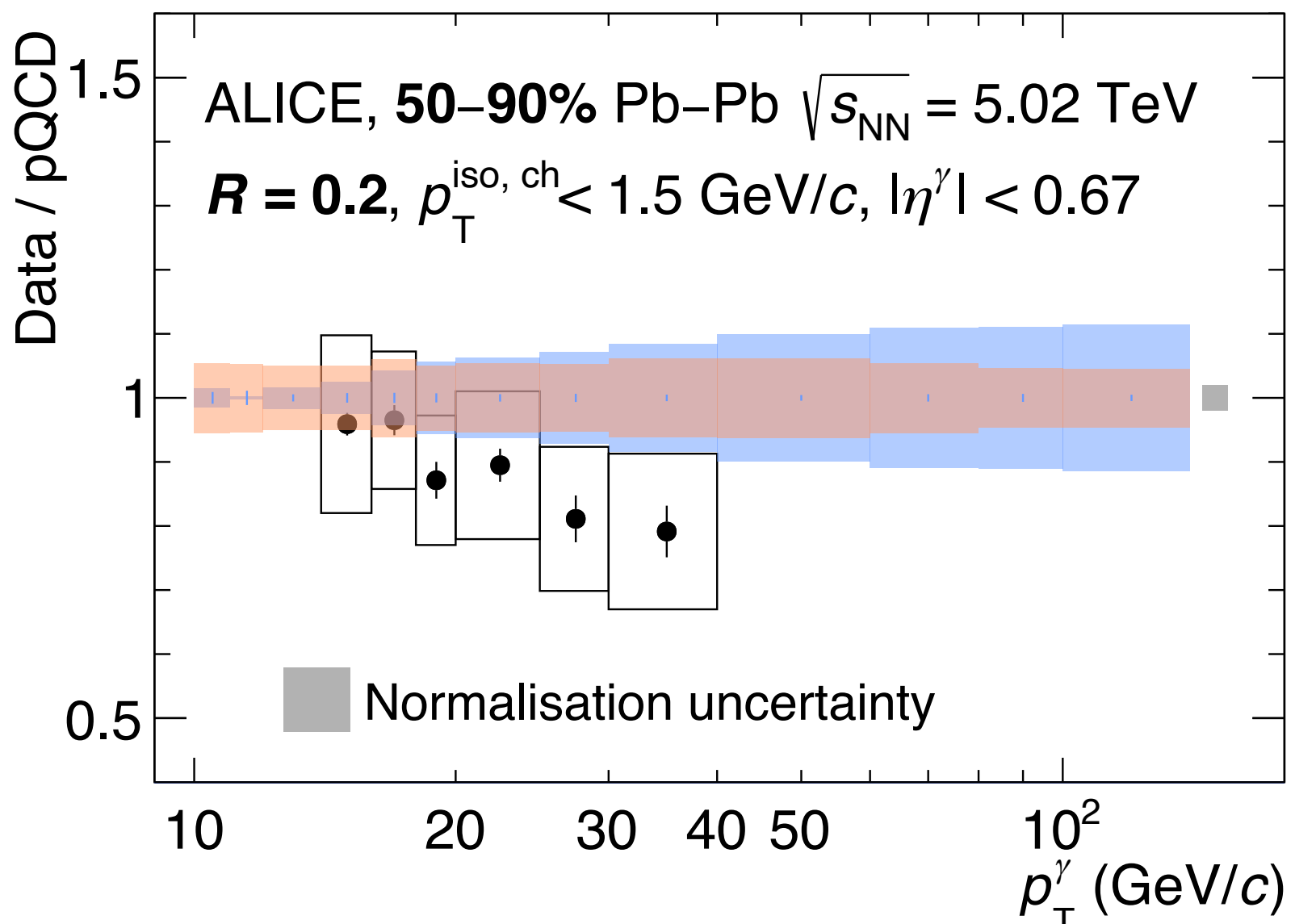
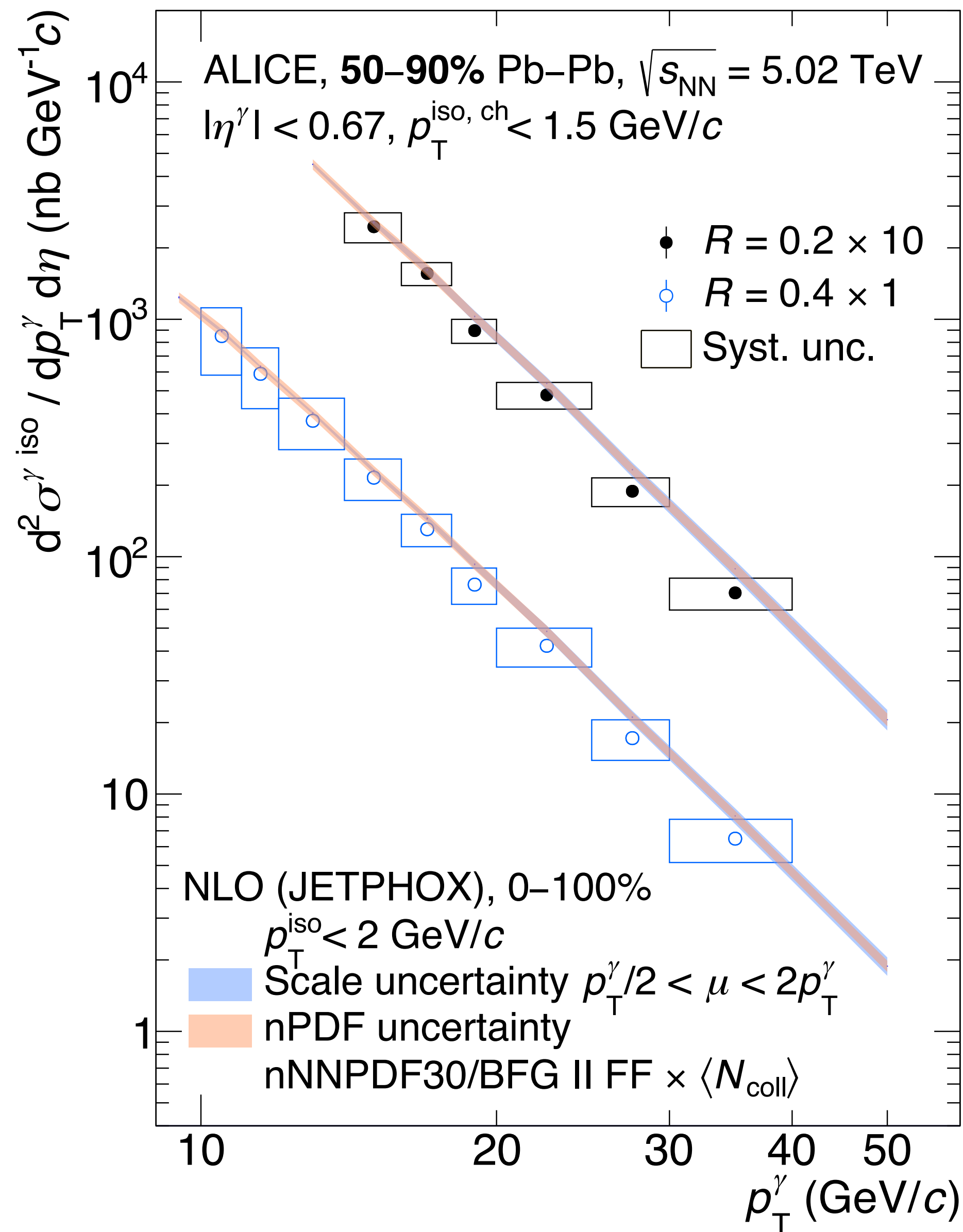
Pb–Pb 50-90%: efficiency and purity

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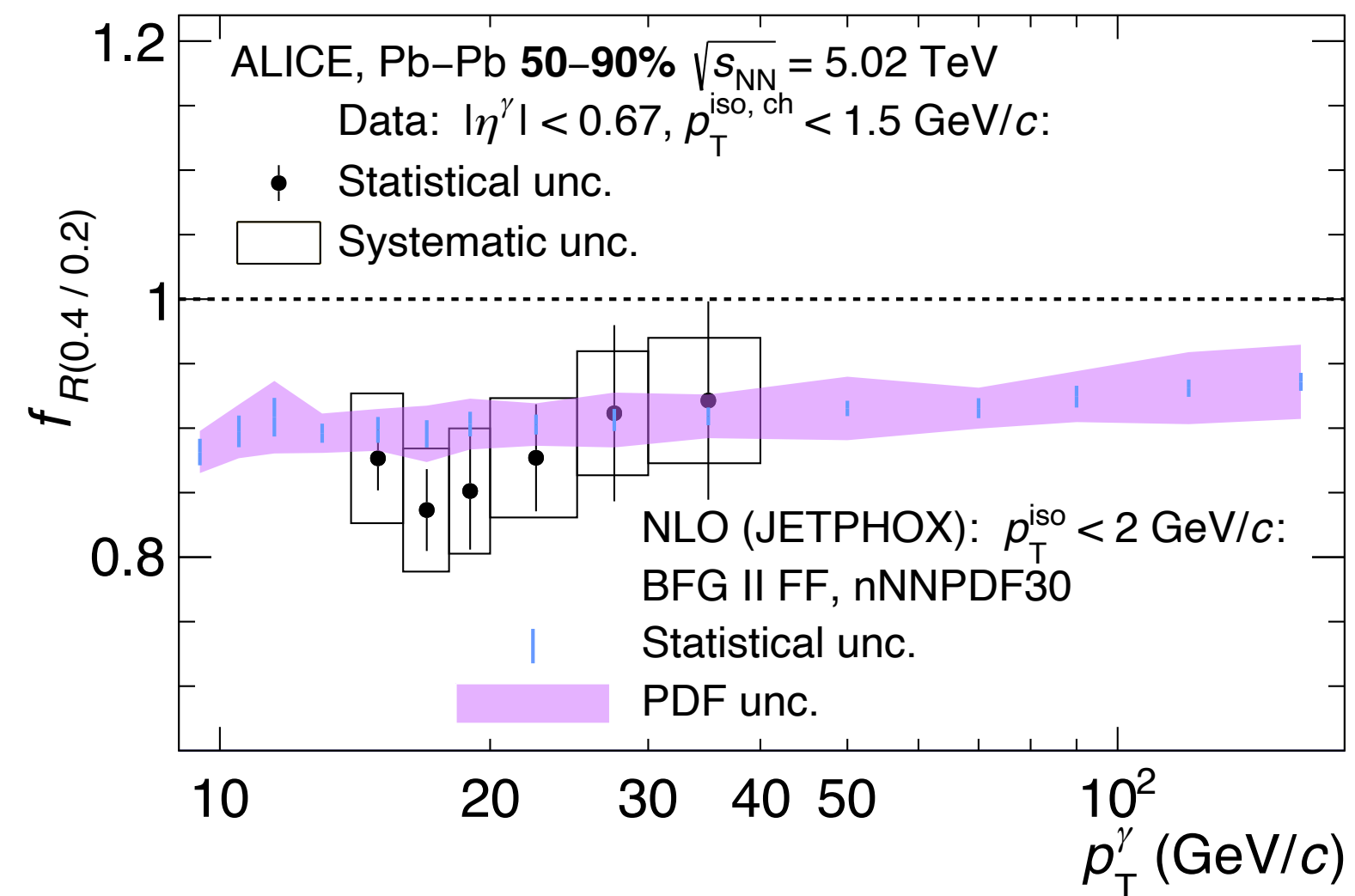




Pb-Pb 50-90%: cross section and ratios

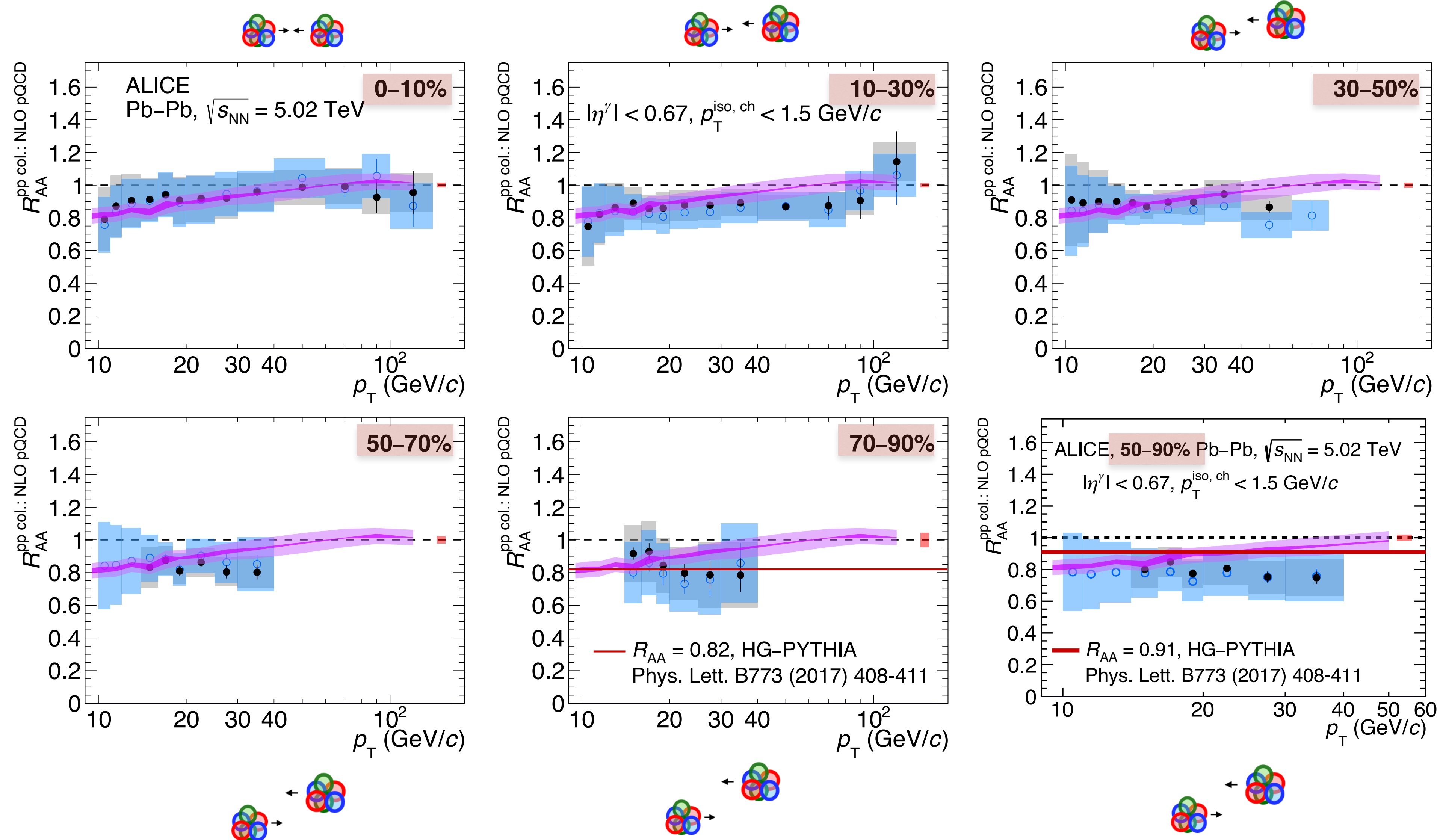


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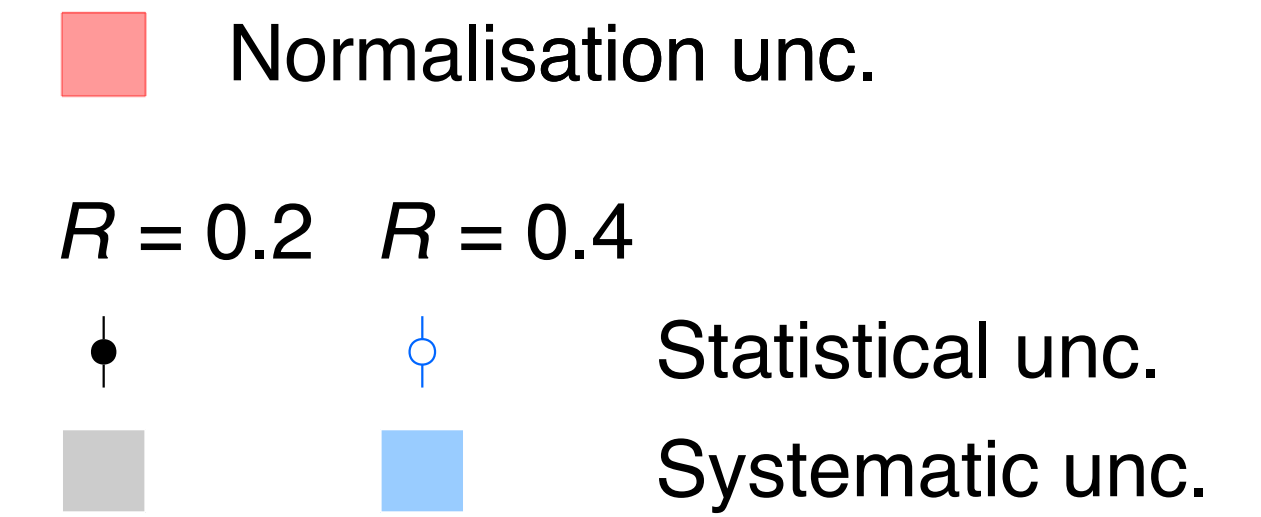
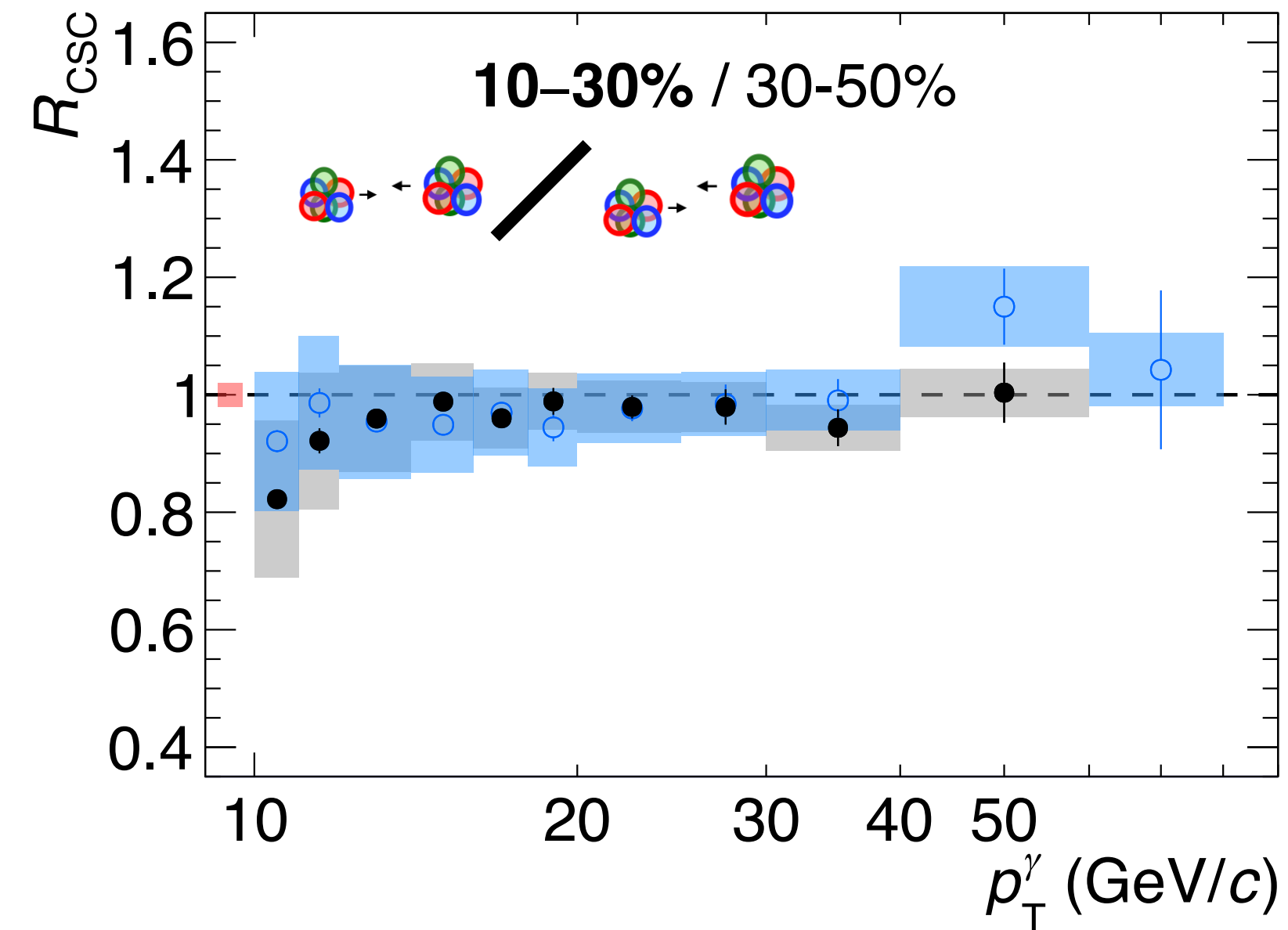
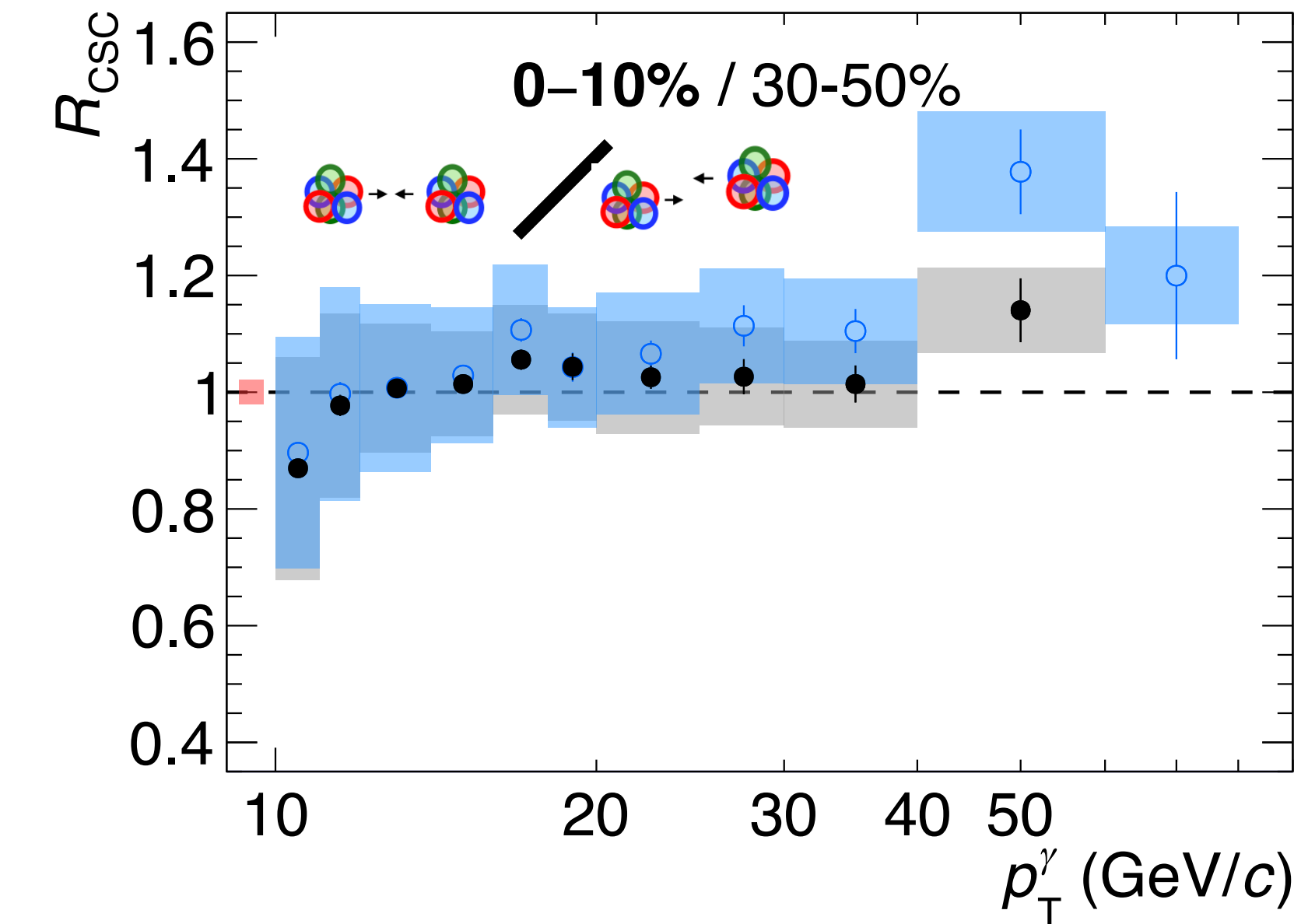
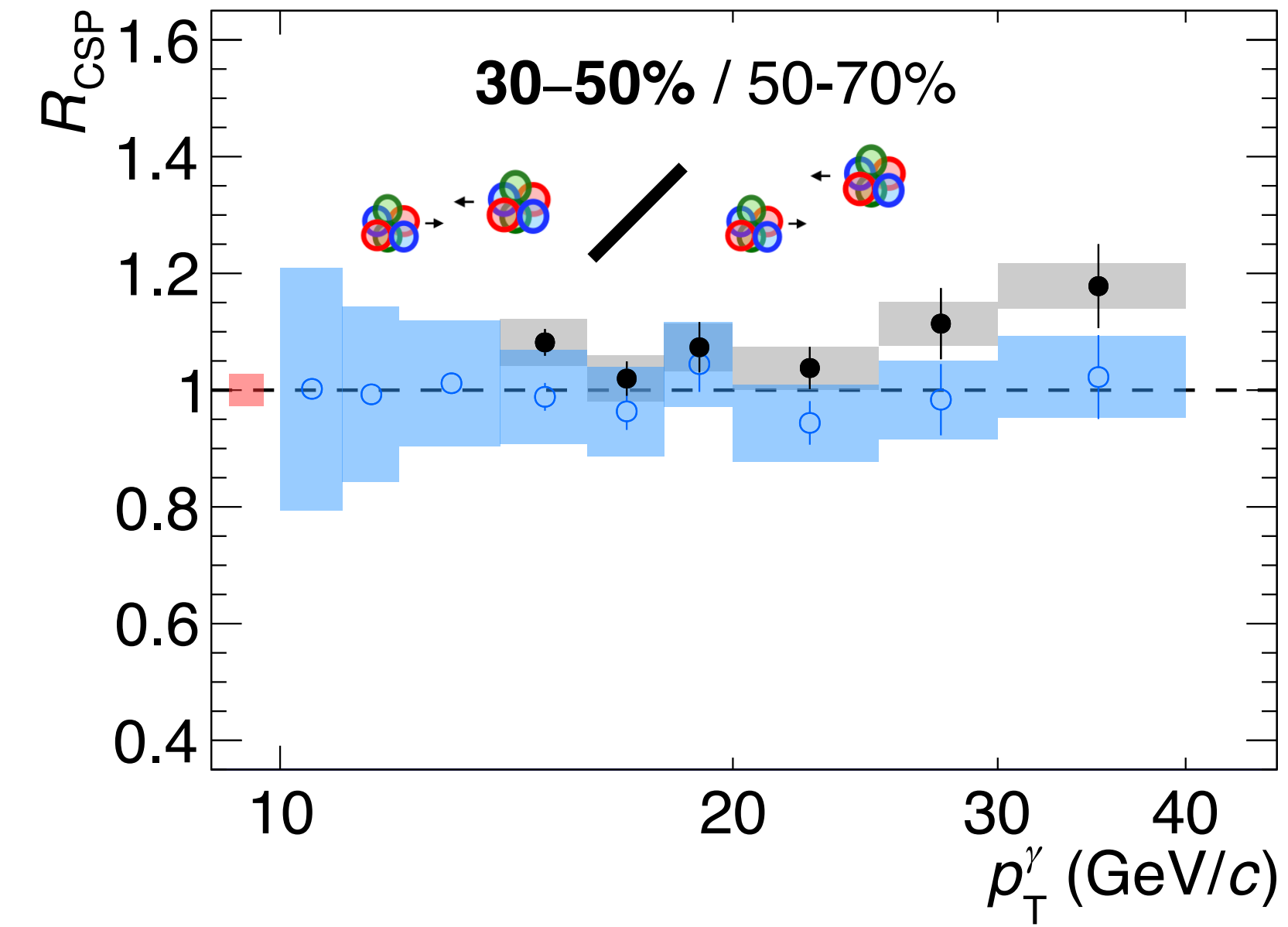
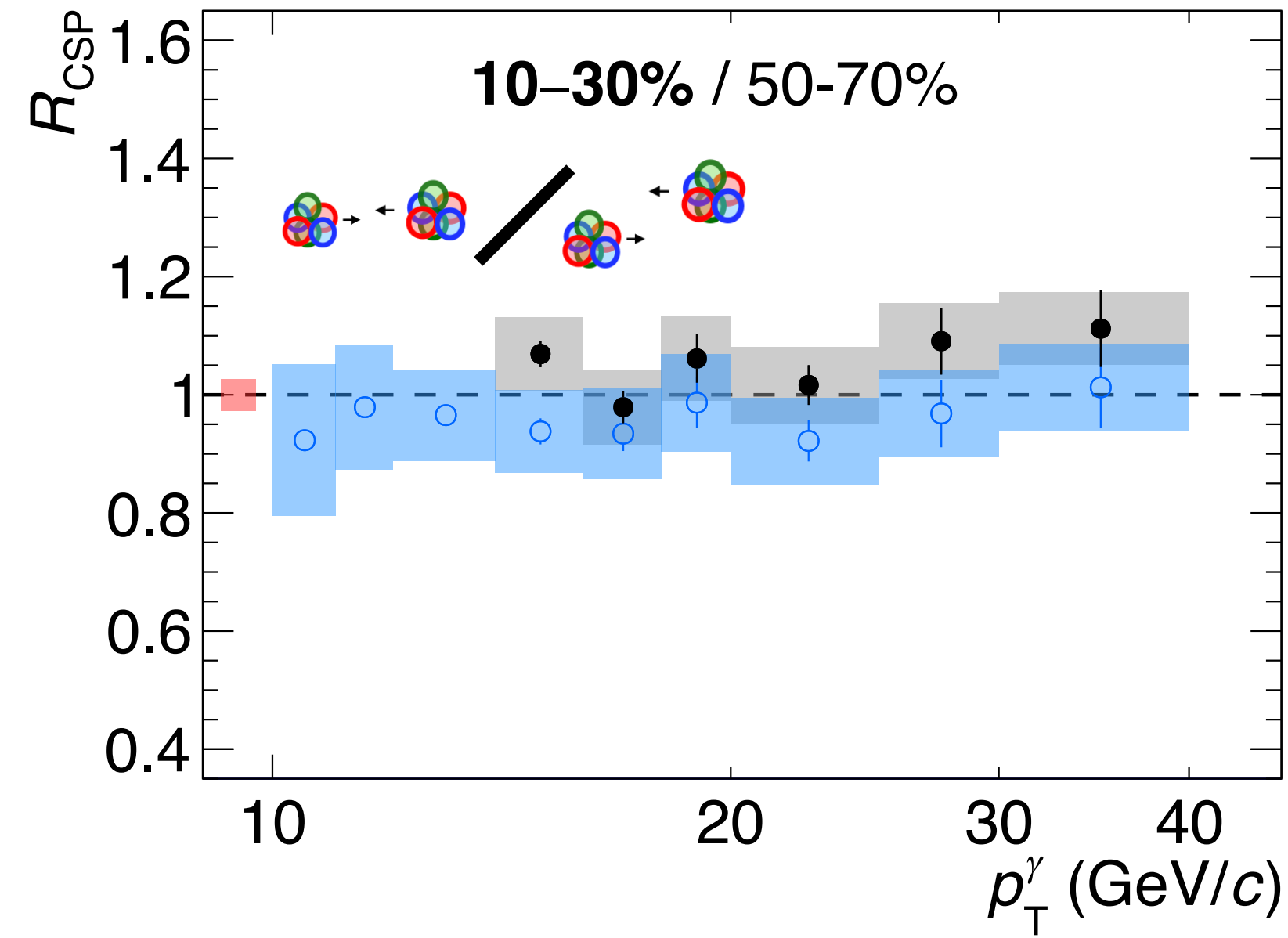
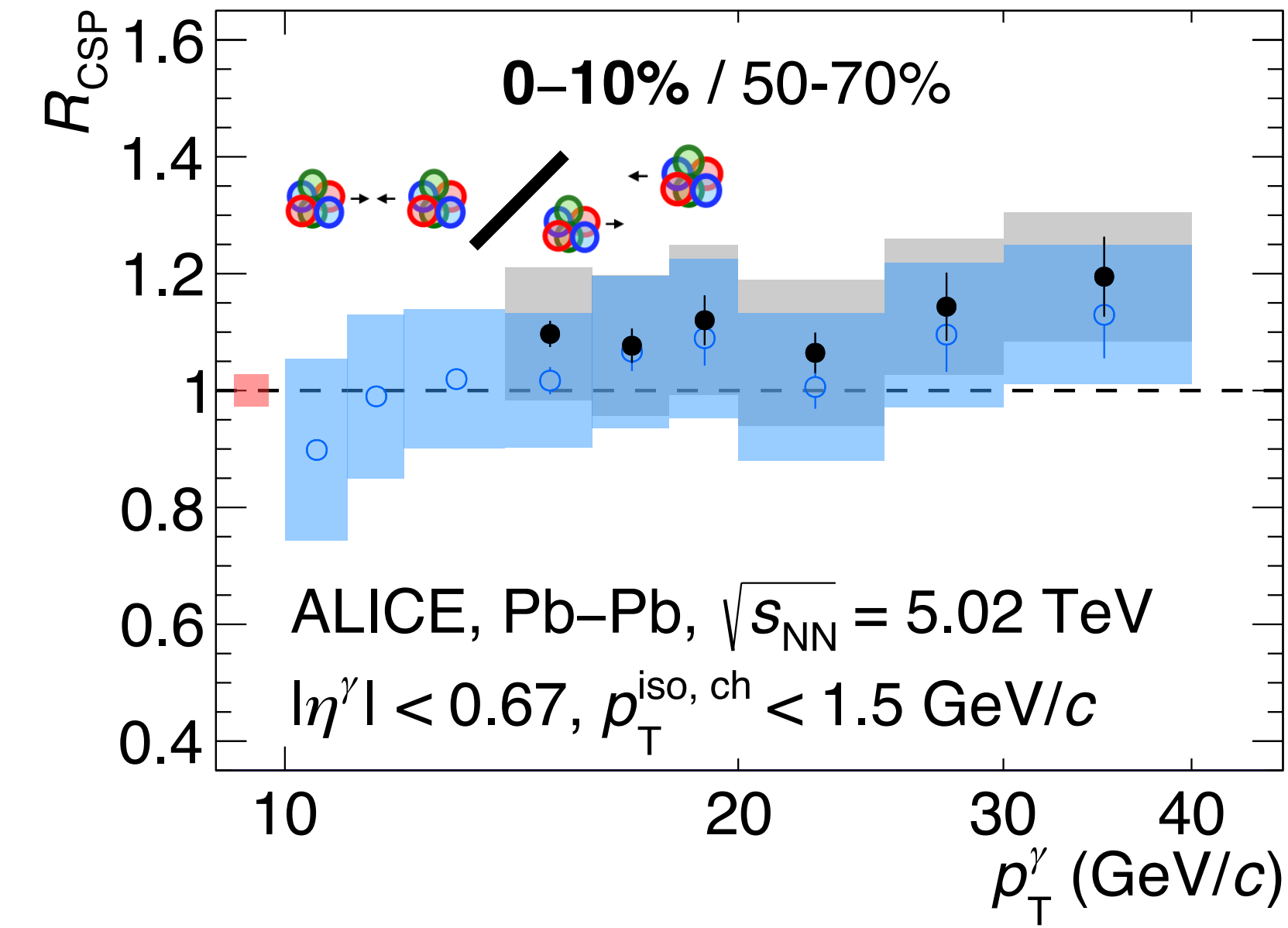
Nuclear modification factor pp data denominator replaced by pp NLO pQCD

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Pb-Pb cross section ratios

$$R_{\text{CSP}} = \frac{\langle N_{\text{coll}} \rangle^{50-70\%}}{\langle N_{\text{coll}} \rangle^k} \frac{d^2 \sigma_{\text{Pb-Pb}}^{\gamma \text{ iso}} / (dp_T d\eta)|_k}{d^2 \sigma_{\text{Pb-Pb}}^{\gamma \text{ iso}} / (dp_T d\eta)|_{50-70\%}}, \quad R_{\text{CSC}} = \frac{\langle N_{\text{coll}} \rangle^{30-50\%}}{\langle N_{\text{coll}} \rangle^k} \frac{d^2 \sigma_{\text{Pb-Pb}}^{\gamma \text{ iso}} / (dp_T d\eta)|_k}{d^2 \sigma_{\text{Pb-Pb}}^{\gamma \text{ iso}} / (dp_T d\eta)|_{30-50\%}}$$



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

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 nuclear matter effects: PDF vs nPDF

70-90%

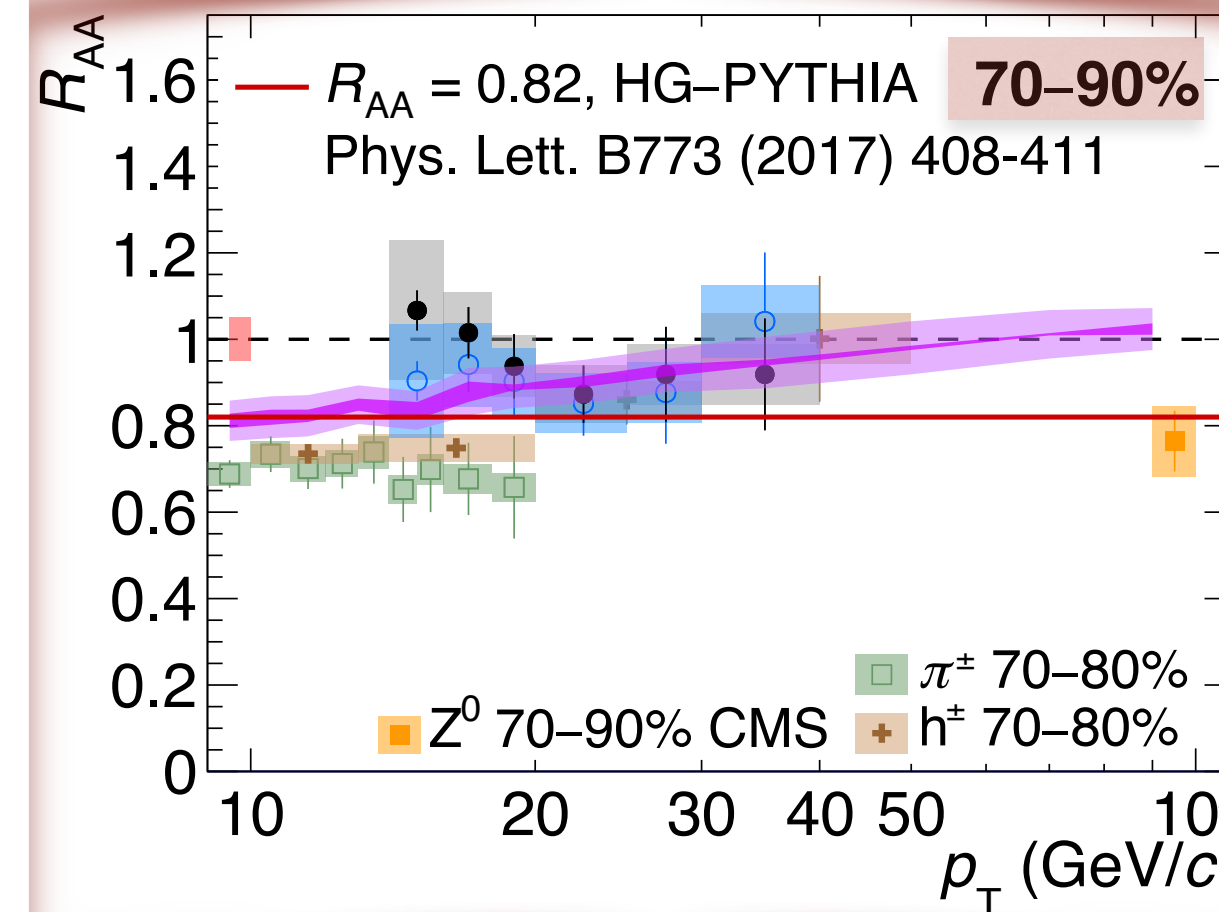
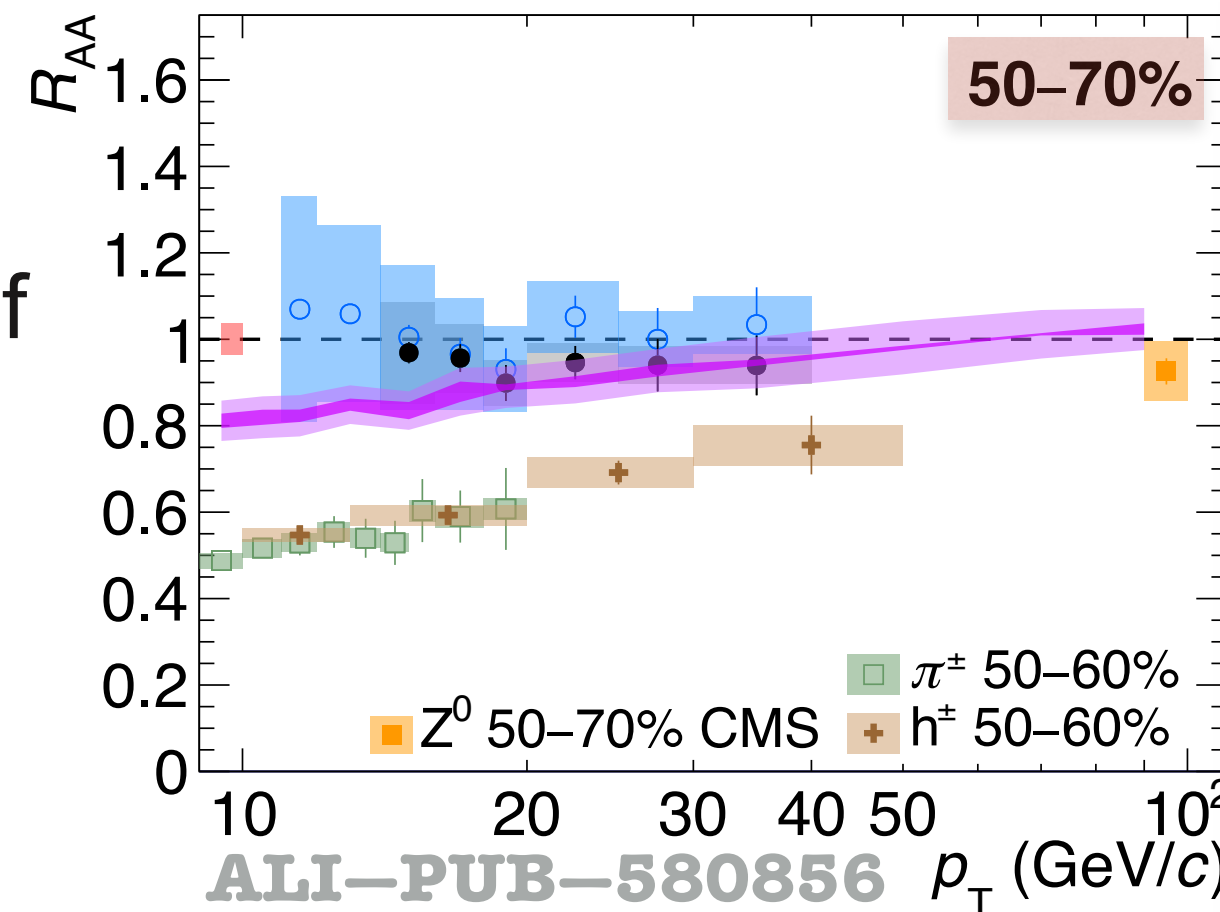
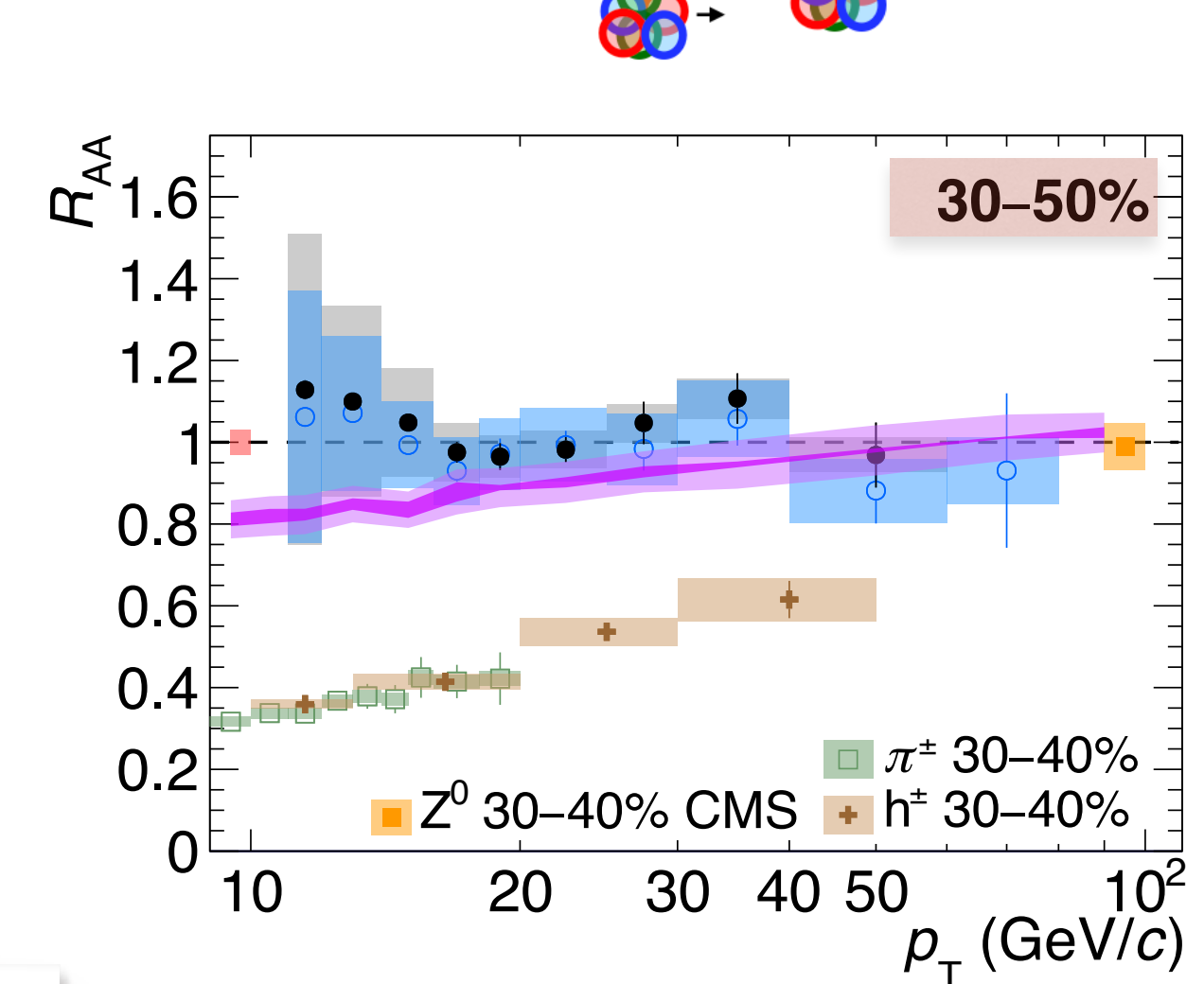
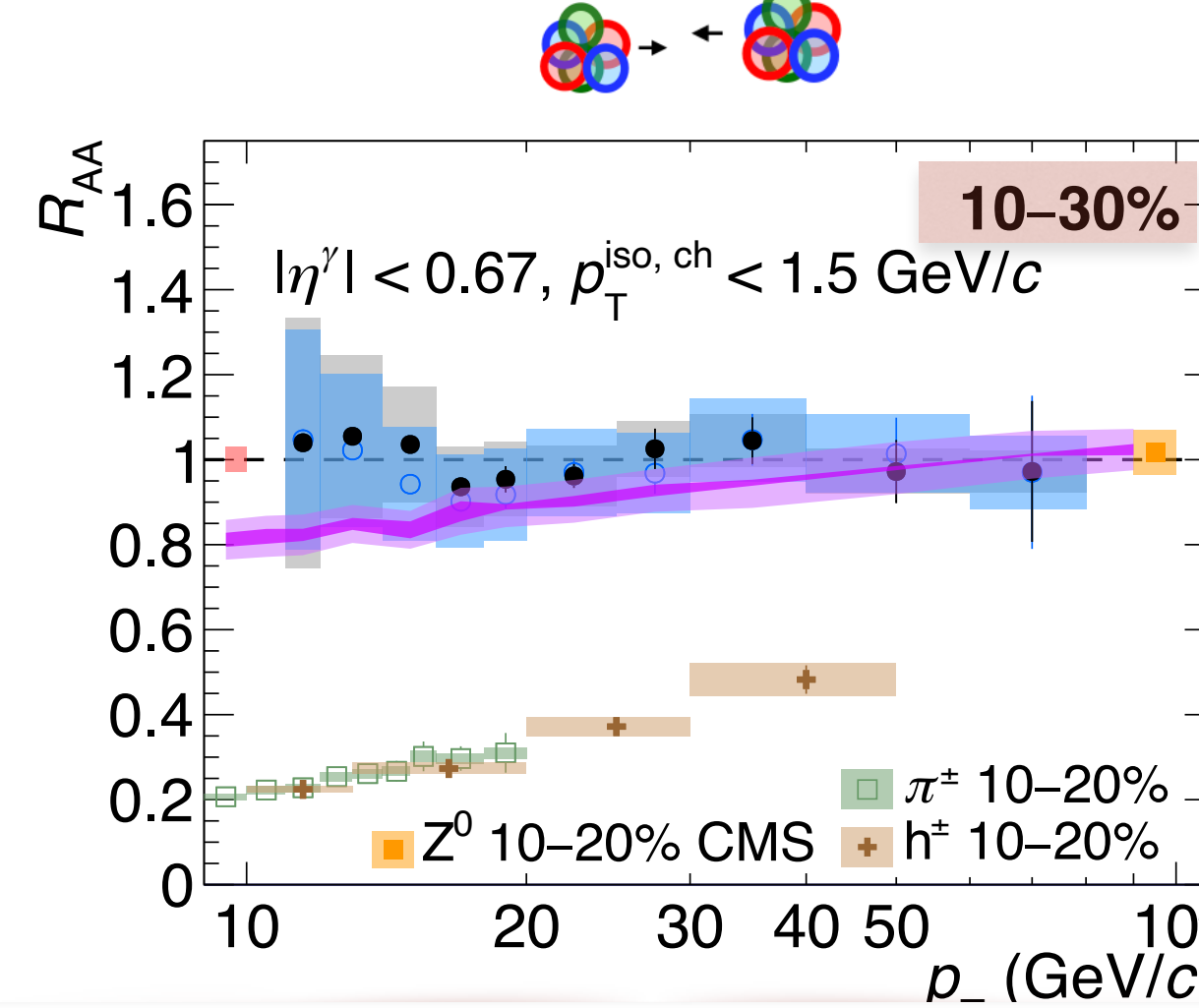
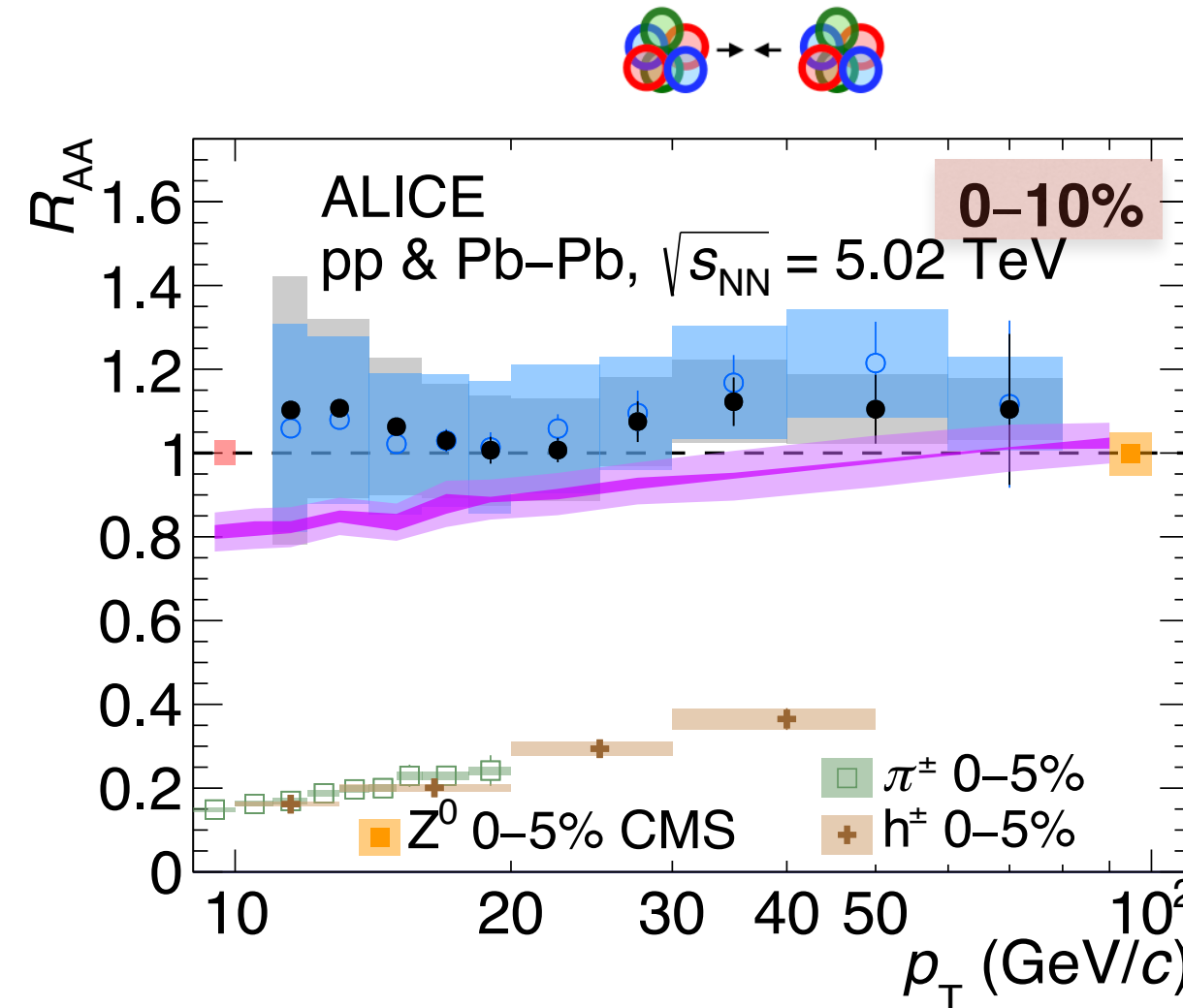
→ Closer to 0.9 than 1 for both R likely due to centrality selection bias of Glauber model

→ 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

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



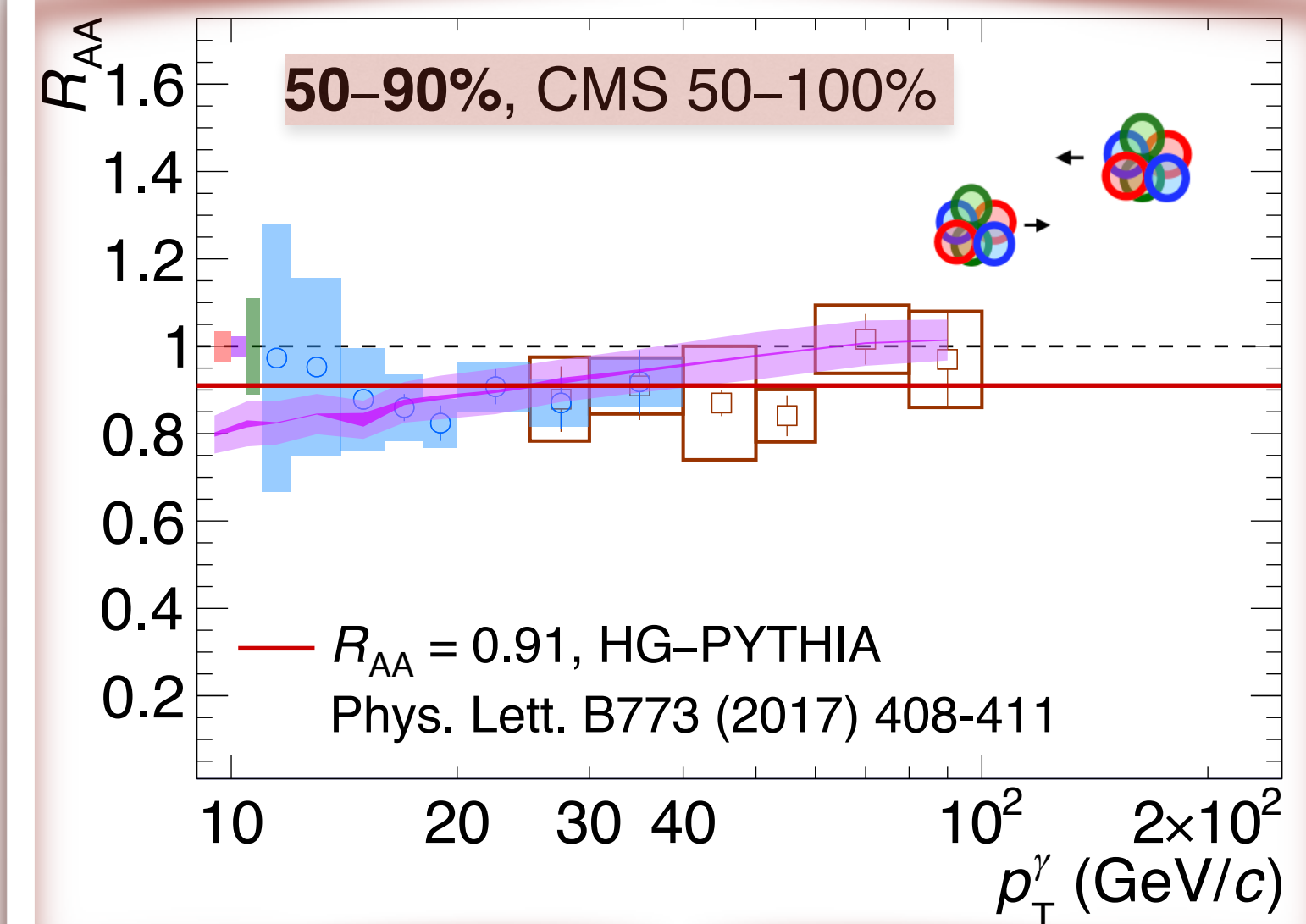
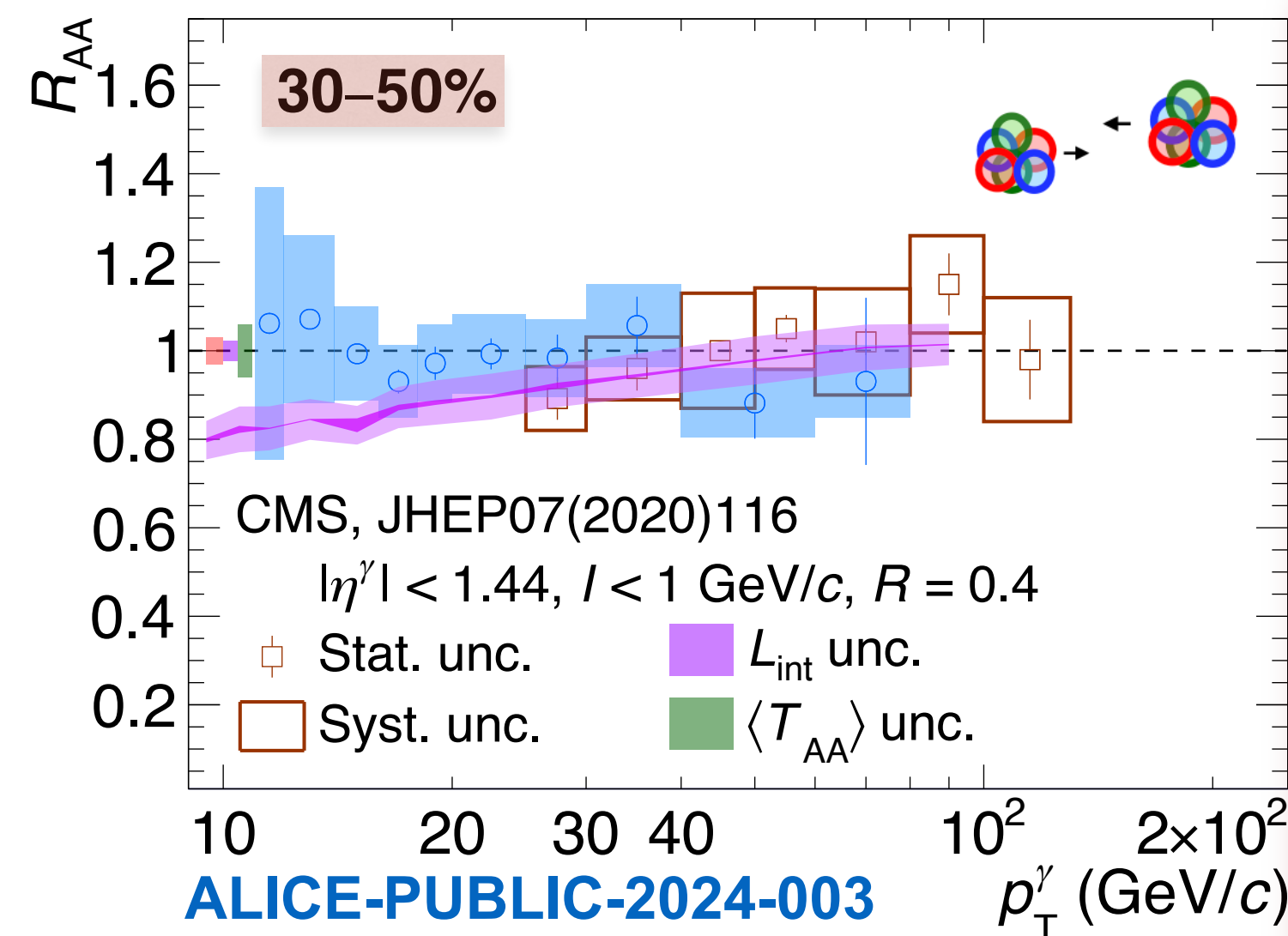
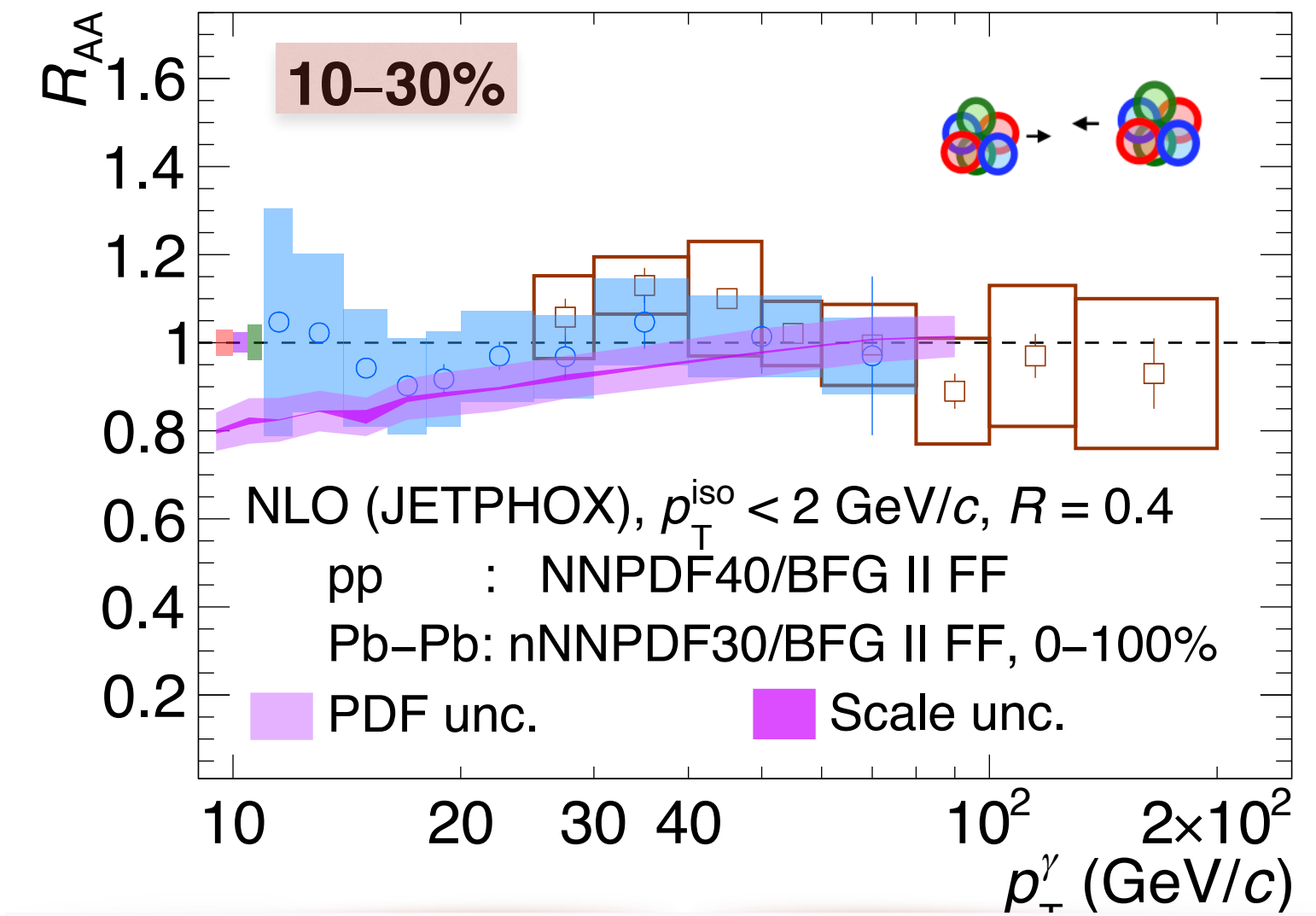
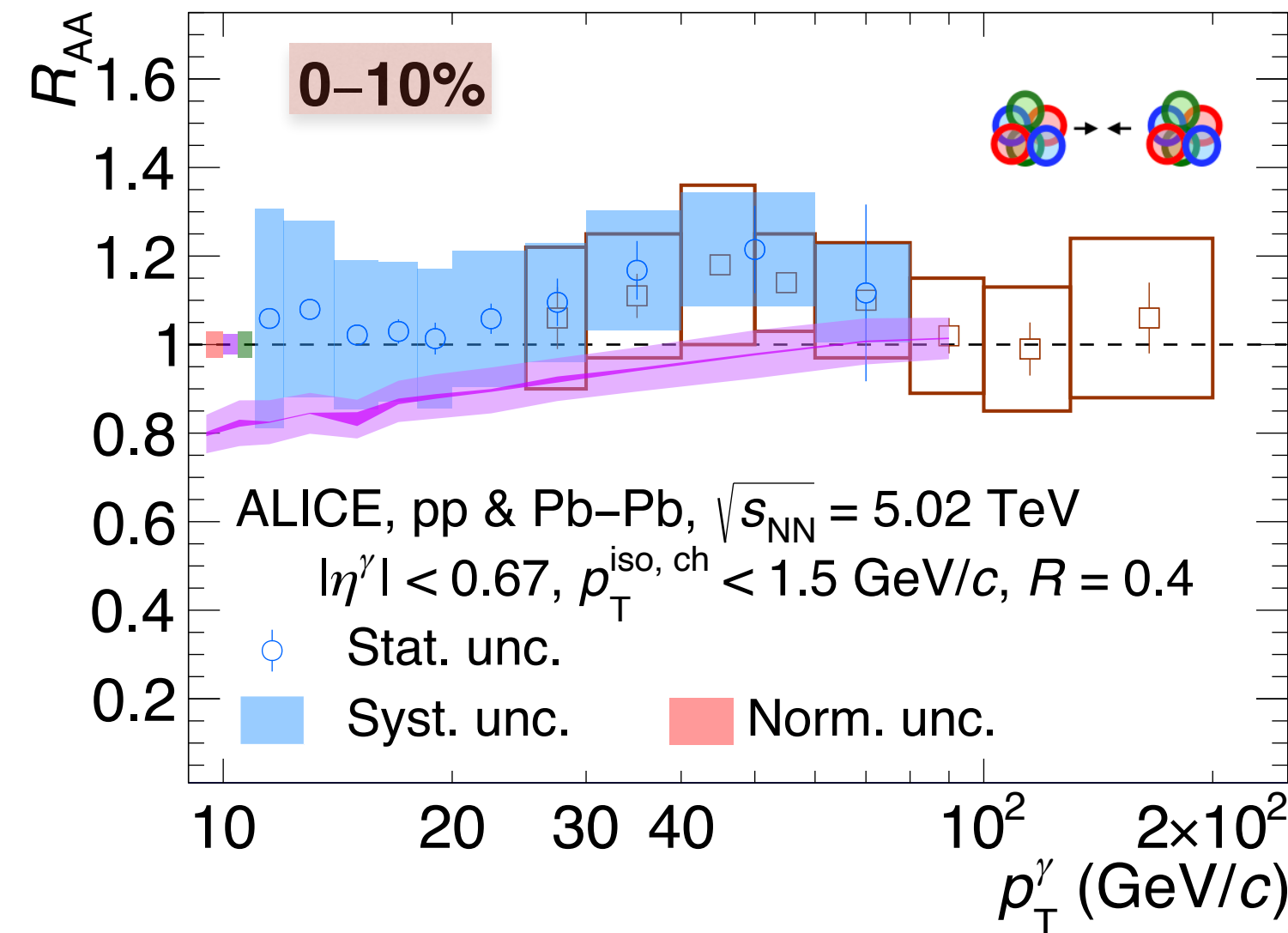
• $R = 0.2$ stat. unc. $R = 0.4$ stat. unc.
■ $R = 0.2$ syst. unc. ■ $R = 0.4$ syst. unc.
■ Normalisation unc.
NLO (JETPHOX), 0-100%
 $p_T^{iso} < 2$ GeV/c, $R = 0.2$
pp : NNP40/BFG II FF
Pb-Pb: nNNPDF30/BFG II FF, 0-100%
■ Scale unc. $p_T^\gamma/2 < \mu < 2p_T^\gamma$
■ PDF unc.

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

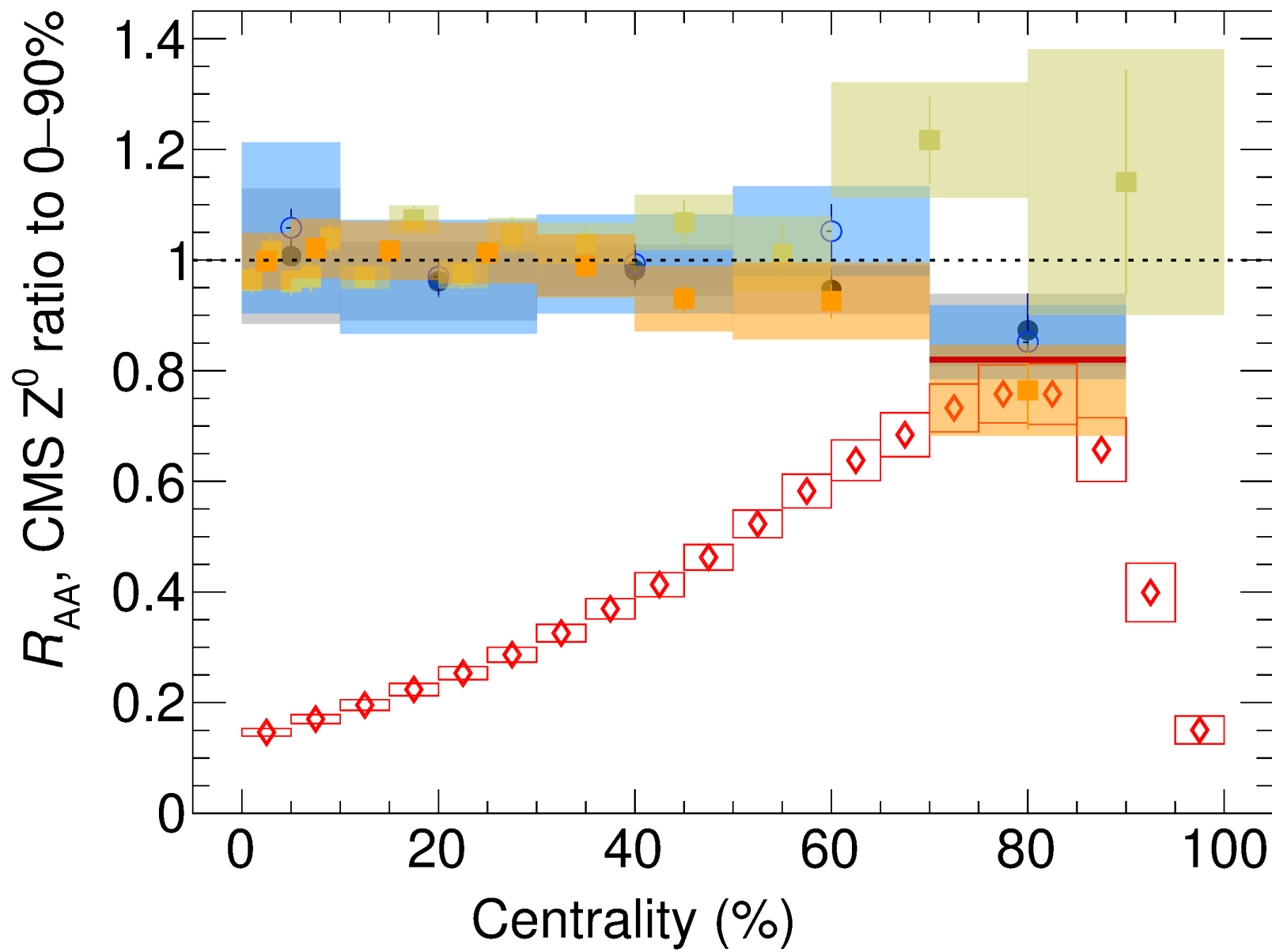
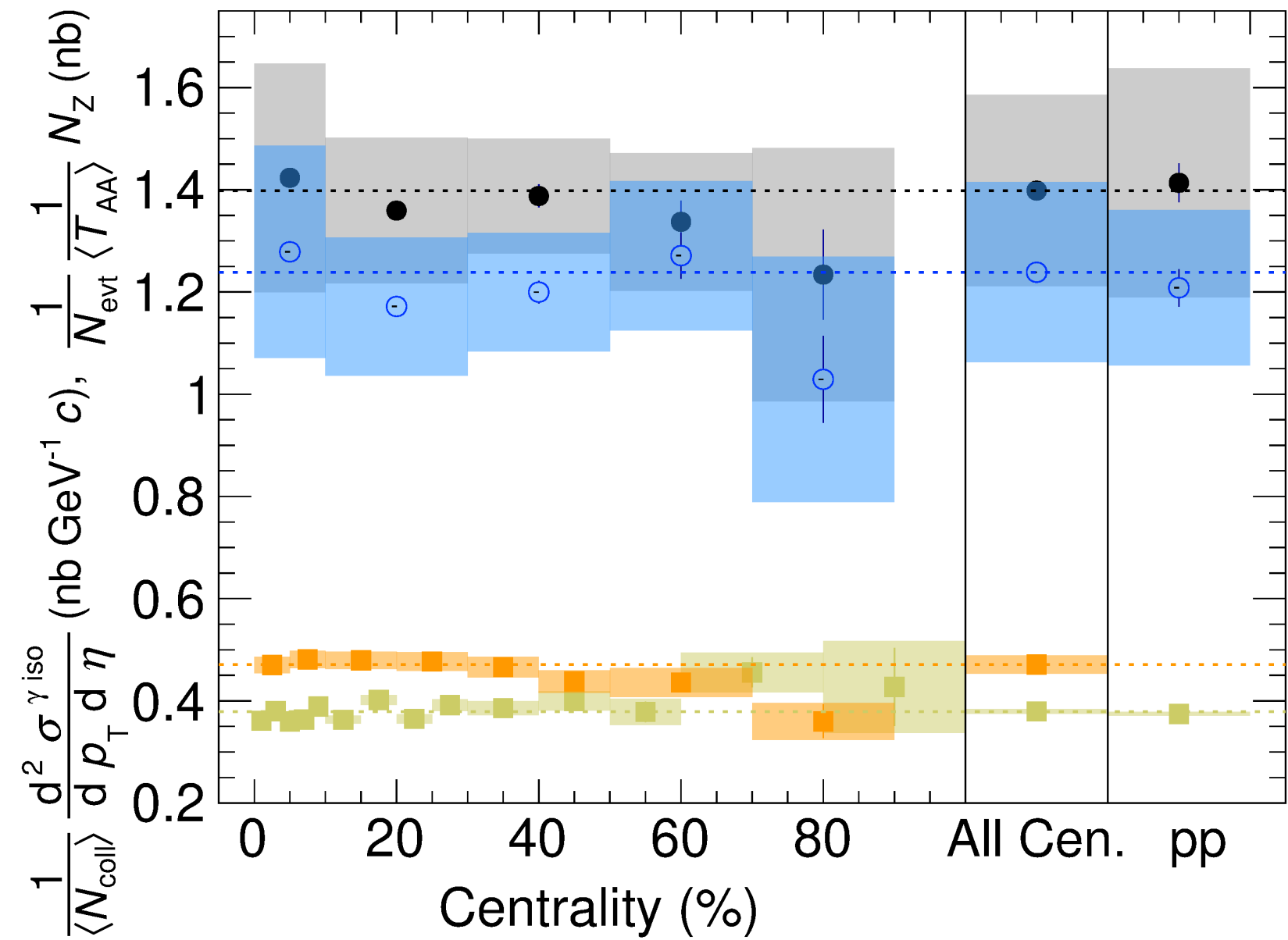
$$R_{AA} = \frac{1}{\langle N_{coll} \rangle} \frac{d^2\sigma_{AA} / (dp_T d\eta)}{d^2\sigma_{pp} / (dp_T d\eta)}$$

- 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



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, $|\eta^\gamma| < 0.67$

$R = 0.2$ $R = 0.4$, $p_T^{iso, ch} < 1.5$ GeV/c

● ○ Statistical unc.

■ ■ Systematic unc.

Charged hadrons ALICE (R_{AA})

Phys. Lett. B793 (2019) 420–432

$8 < p_T^{ch hadron} < 20$ GeV/c, $|\eta^{ch hadron}| < 0.8$

◇ Statistical unc.

□ Systematic unc.

Z^0 CMS

Phys. Rev. Lett. 127 (2021) 102002

$60 < m_{||} < 120$ GeV/c², $|y^Z| < 2.1$

■ Statistical unc.

■ Systematic unc.

Z^0 ATLAS

Phys. Lett. B 802 (2020) 135262

$66 < m_{||} < 116$ GeV/c², $|y^Z| < 2.5$

■ Statistical unc.

■ Systematic unc.

— HG–PYTHIA 70–90%

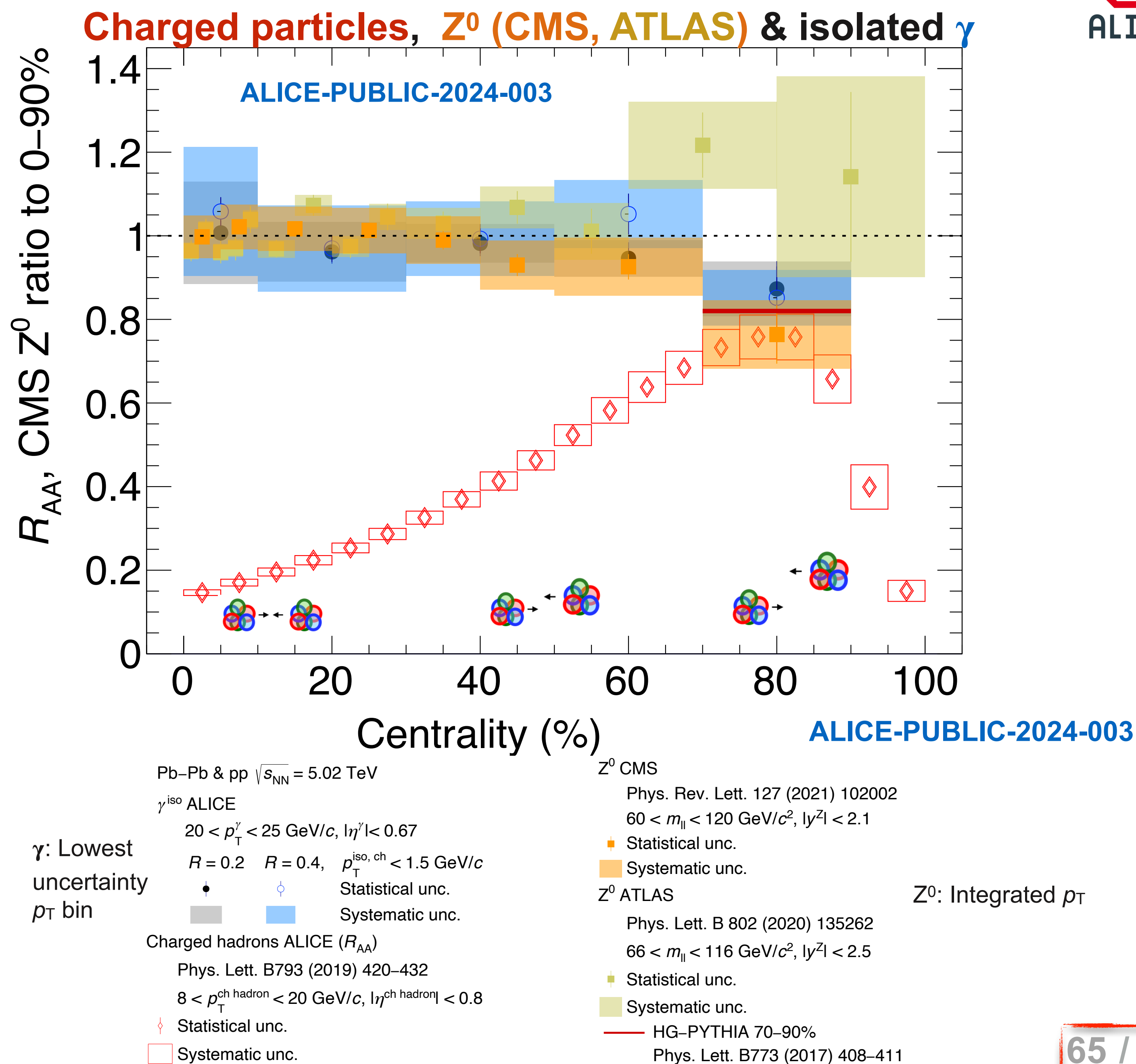
Phys. Lett. B773 (2017) 408–411

ALI-PUB-608272

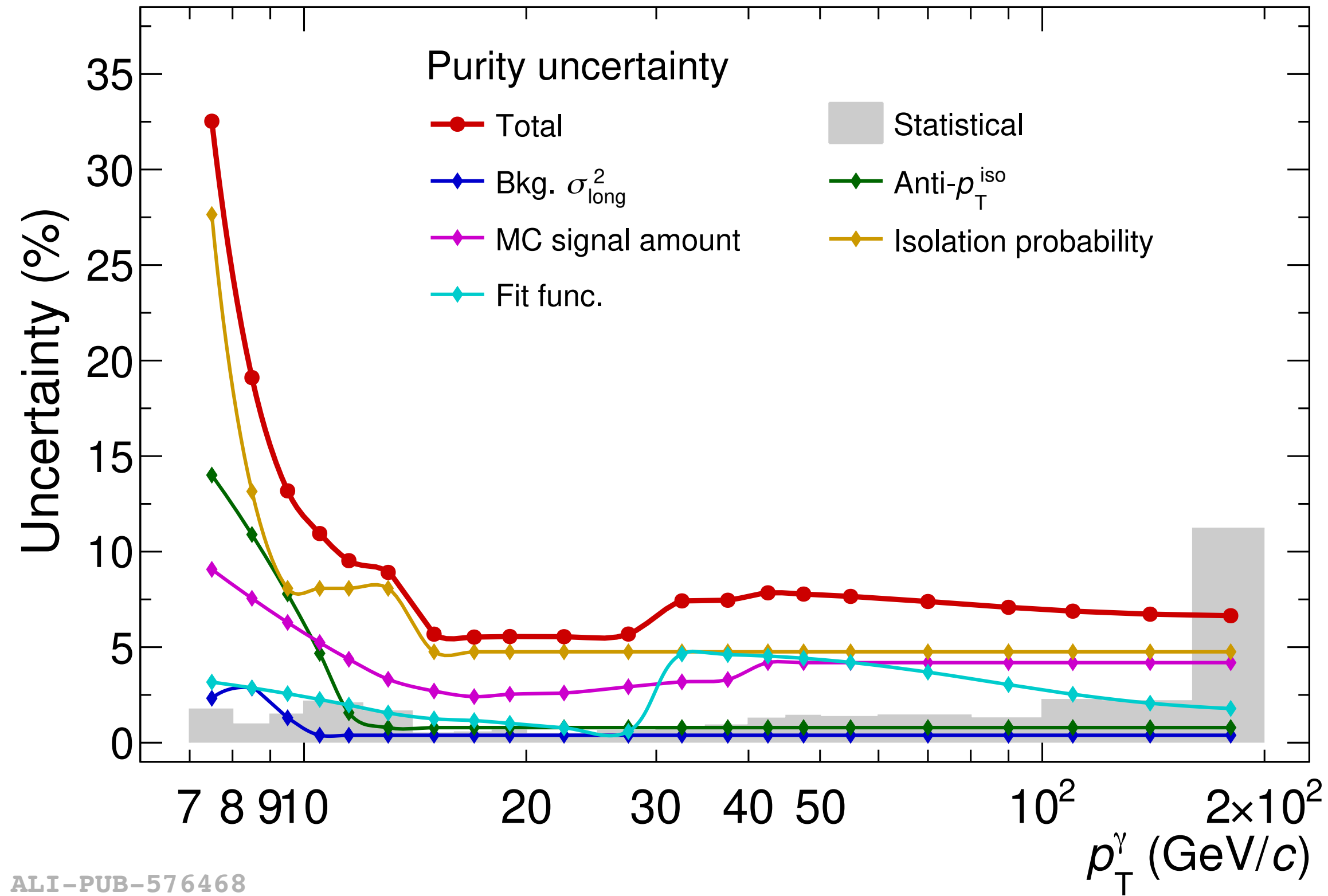
Nuclear modification factor R_{AA} in peripheral Pb–Pb at $\sqrt{s_{NN}} = 5.02$ TeV:

Centrality election bias

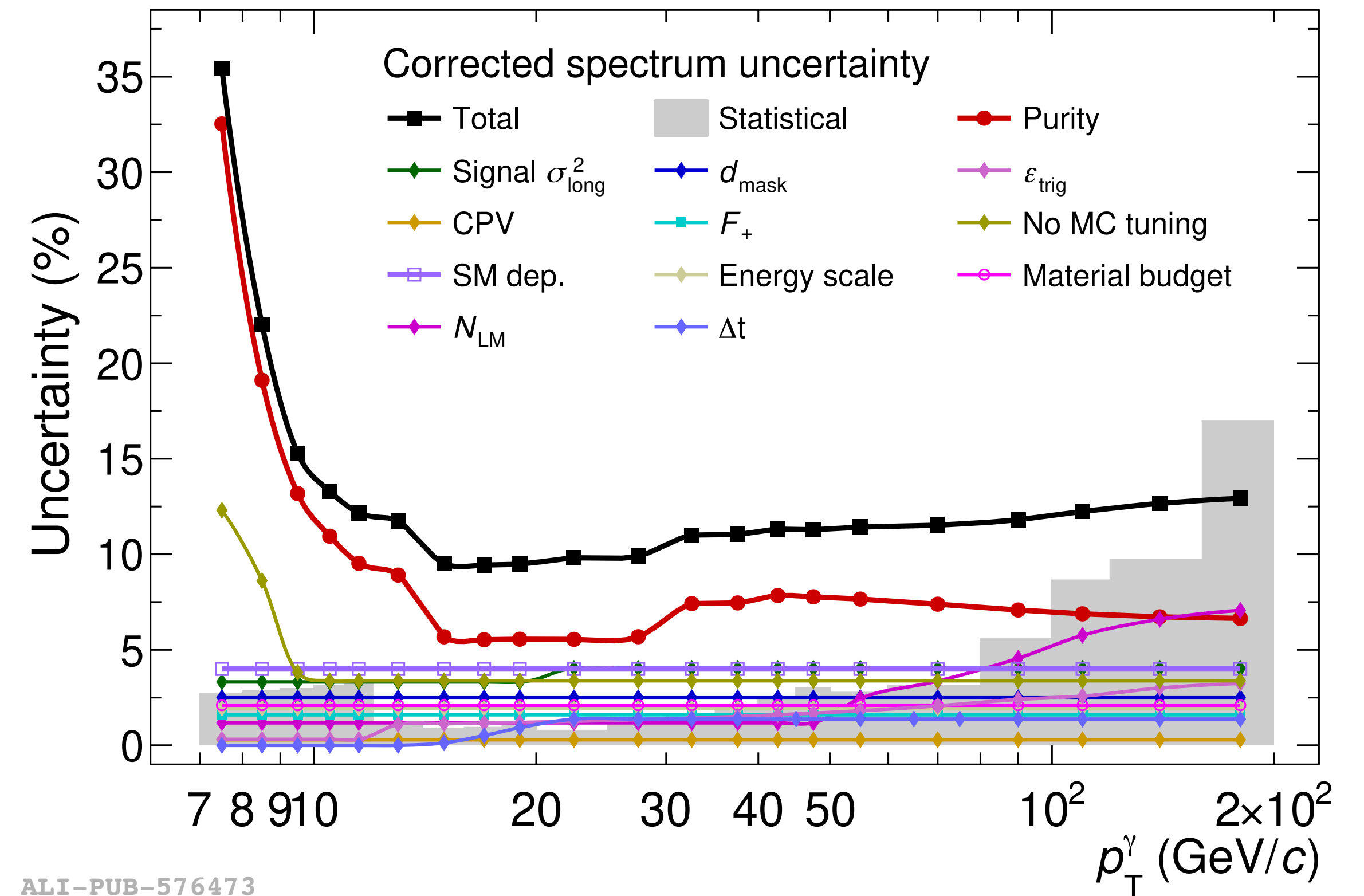
- Centrality calculation in data based typically in the event particle multiplicity and the Glauber model
- Early unexpected observation of rather suppressed hadron cross section in peripheral collision
- Glauber model breaks in peripheral collisions (above ~70%), effects not considered:
 - Colliding ions fluctuating geometry
 - Presence of jets, multi-parton interactions, in the event affects the particle multiplicity
- **HG-PYTHIA** model includes those effects and reproduces observations for charged hadrons and for Z^0 bosons and photons
- **ATLAS Z^0 disagreement in peripheral, possible explanation in *Phys. Rev. C* 104 (2021) 4, 044905**



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

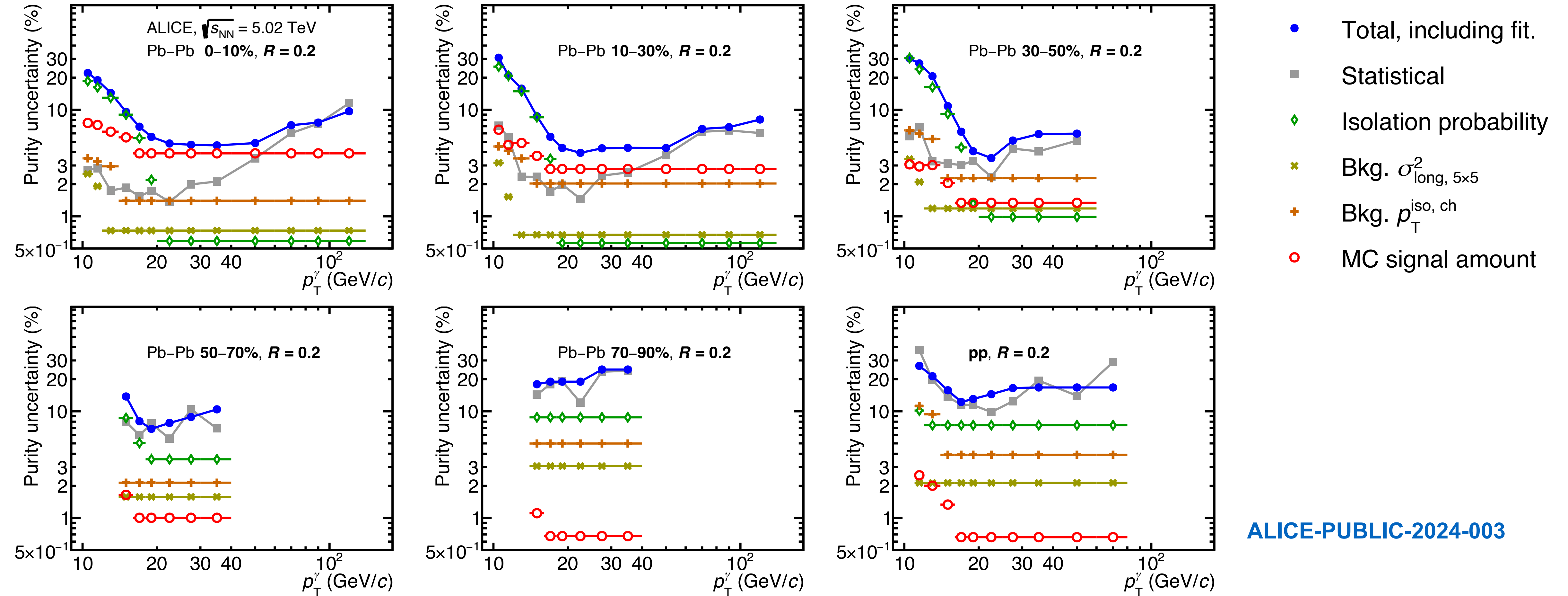


ALI-PUB-576468



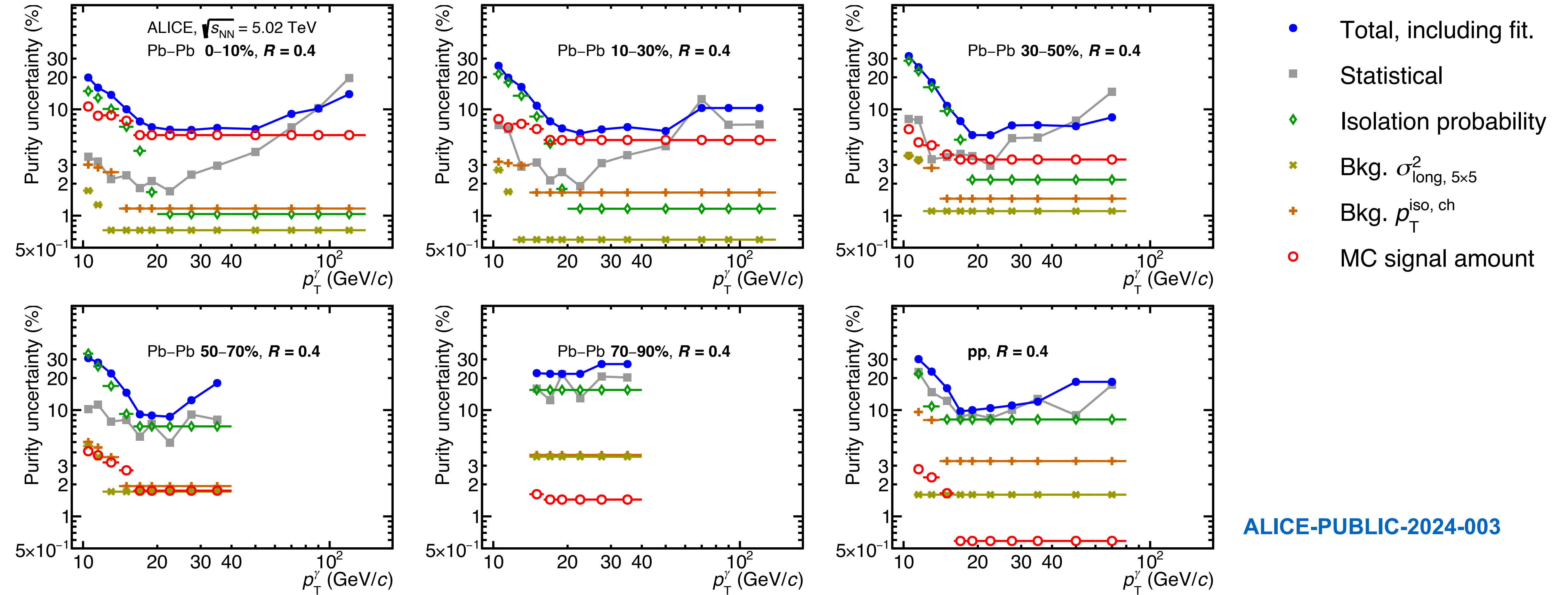
ALI-PUB-576473

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



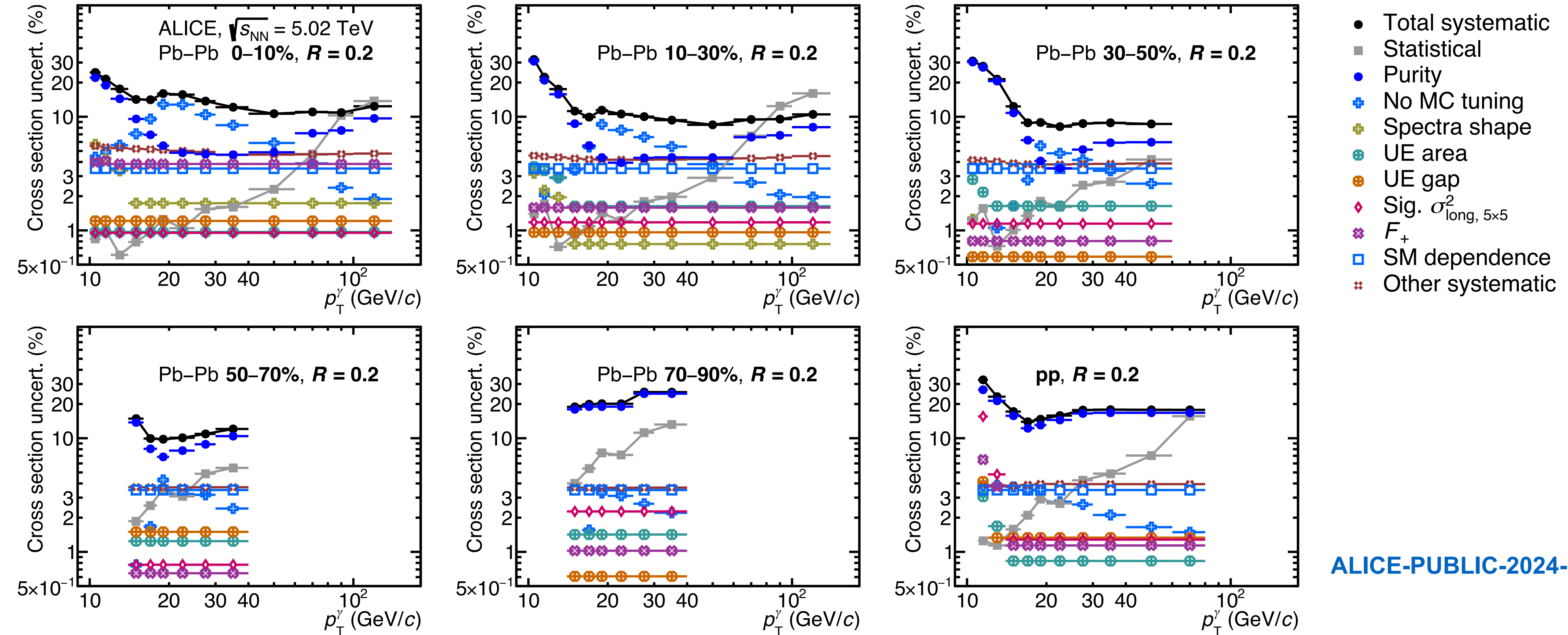
ALICE-PUBLIC-2024-003

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



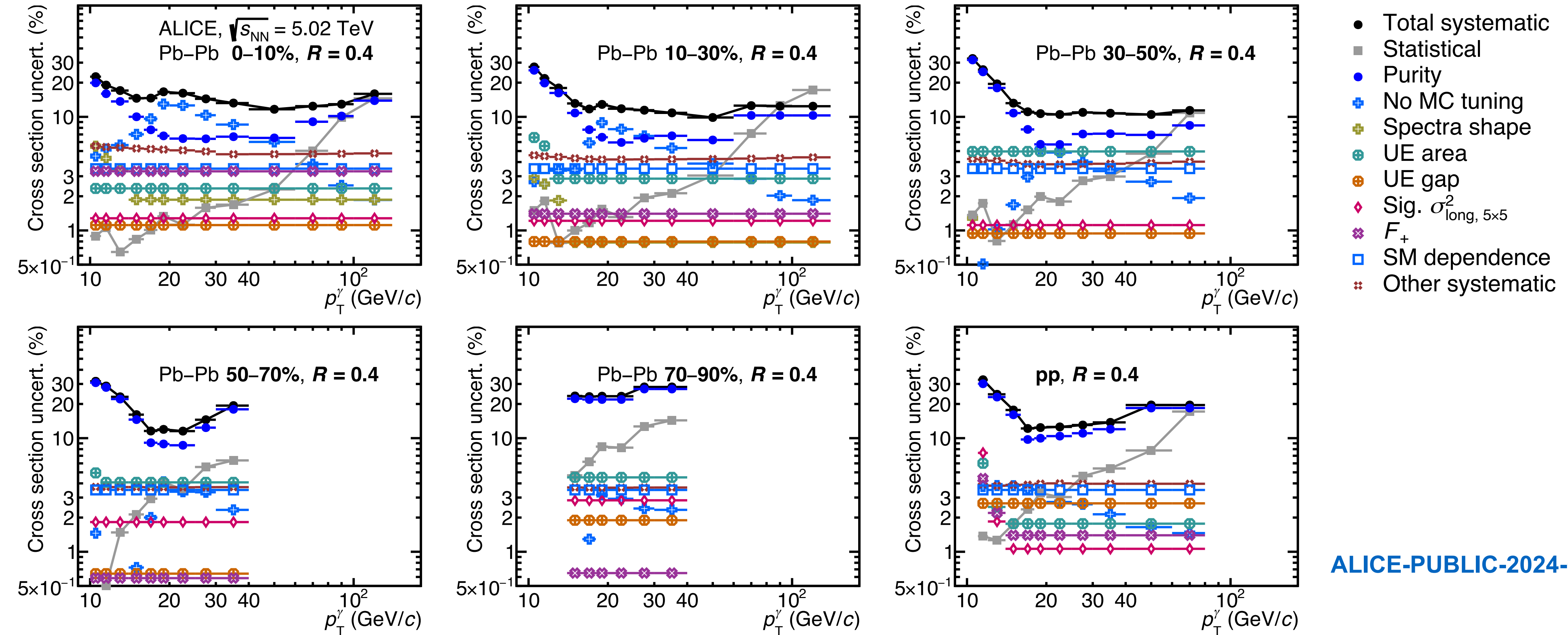
ALICE-PUBLIC-2024-003

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



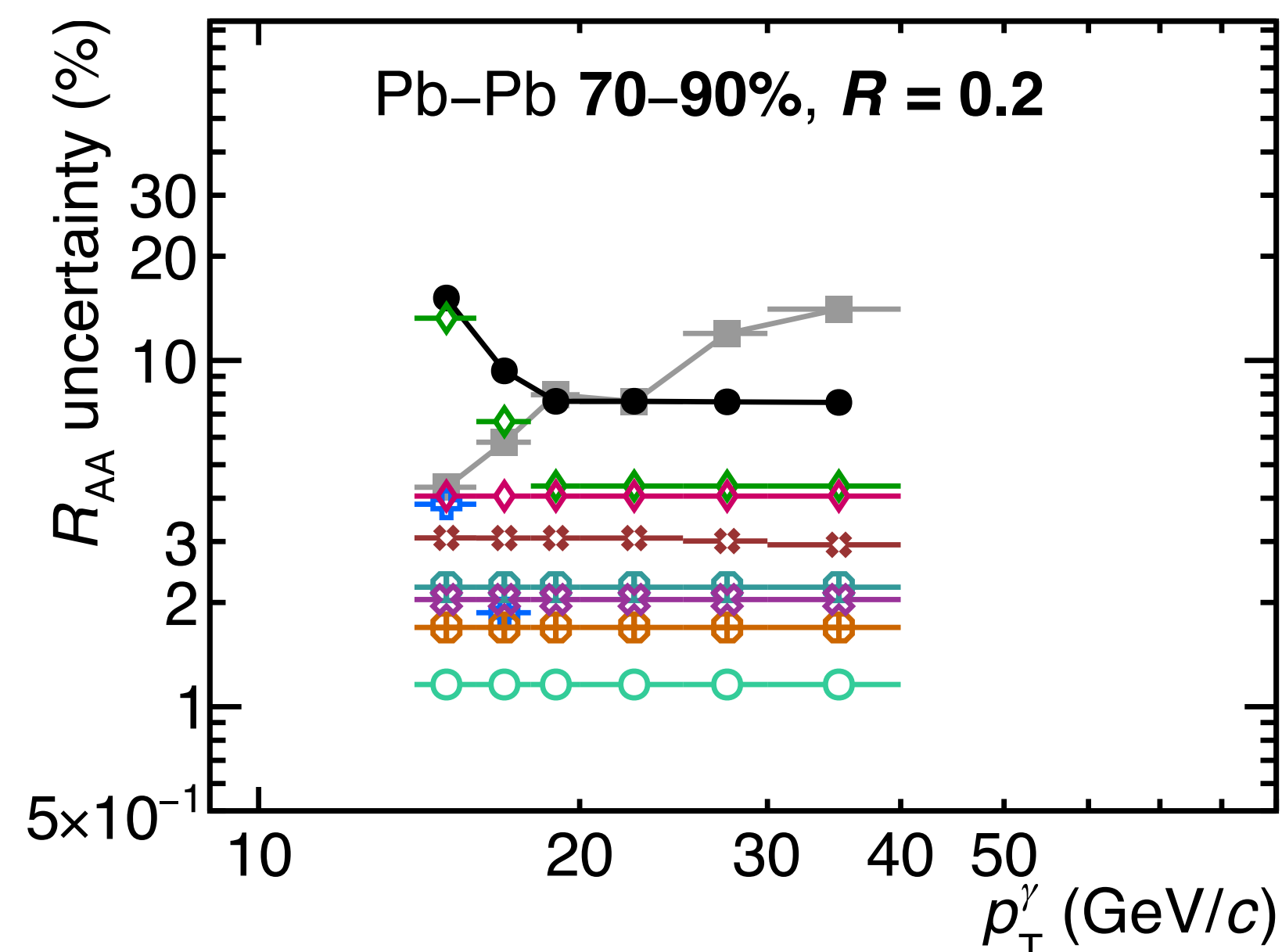
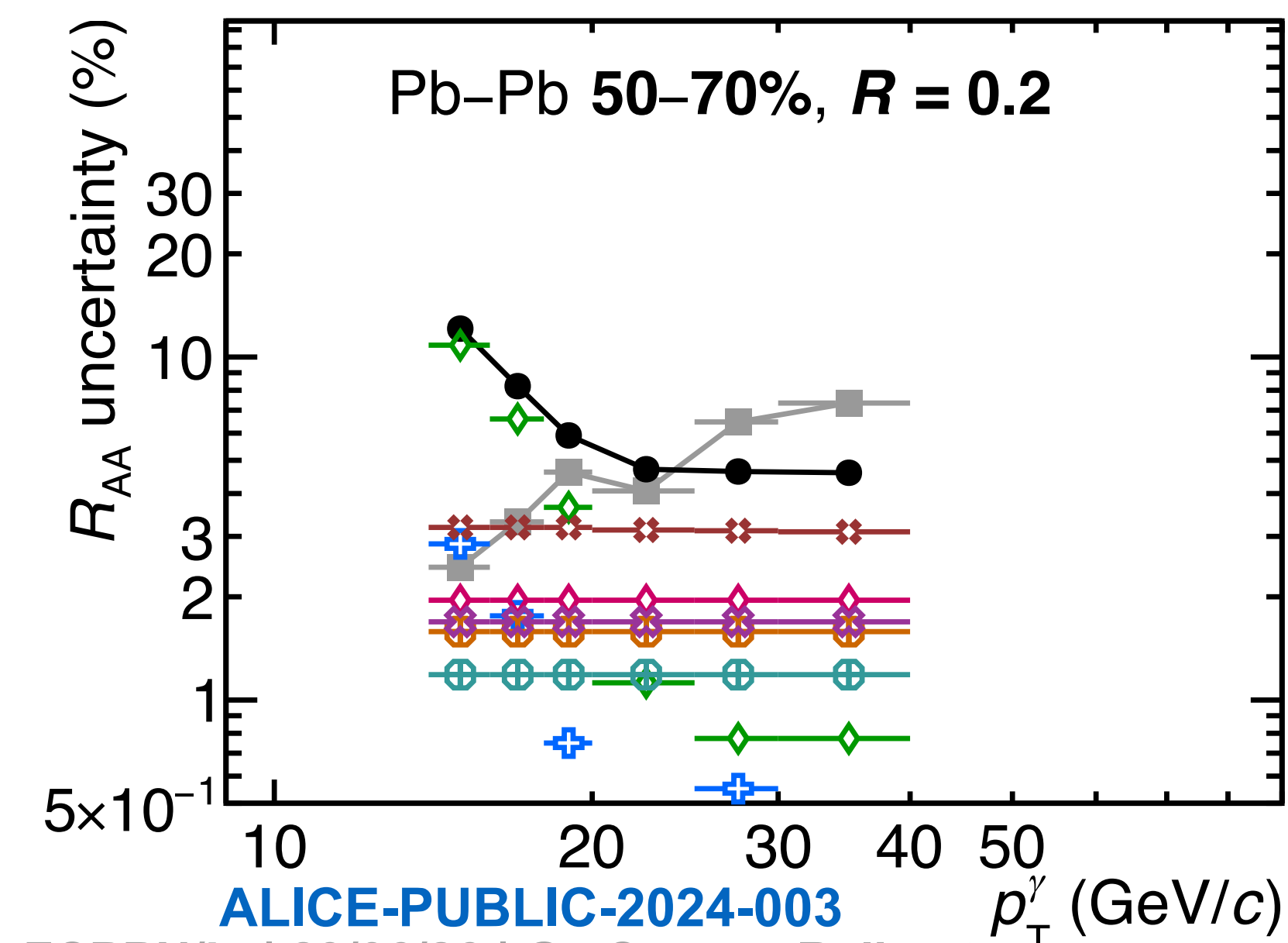
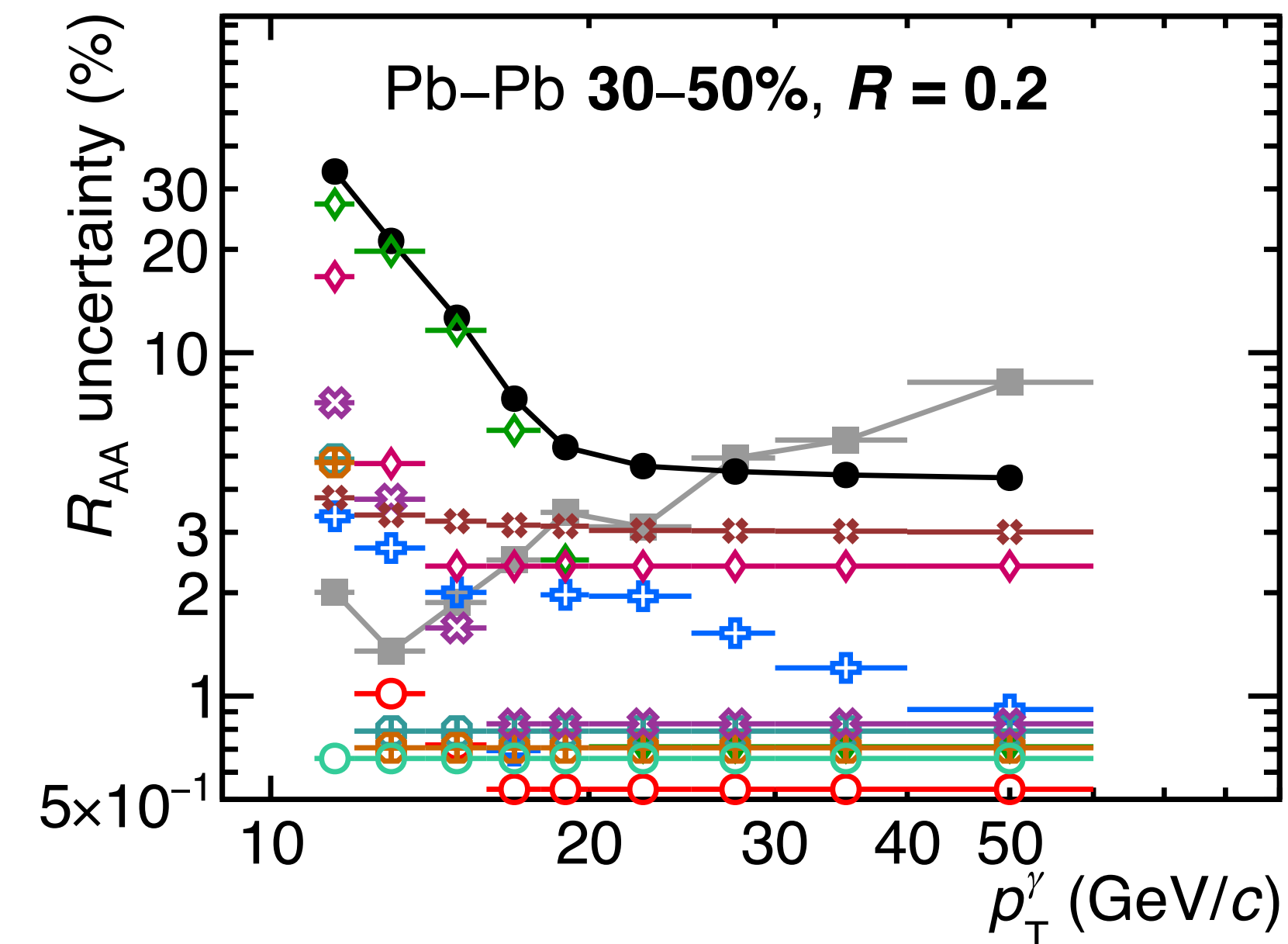
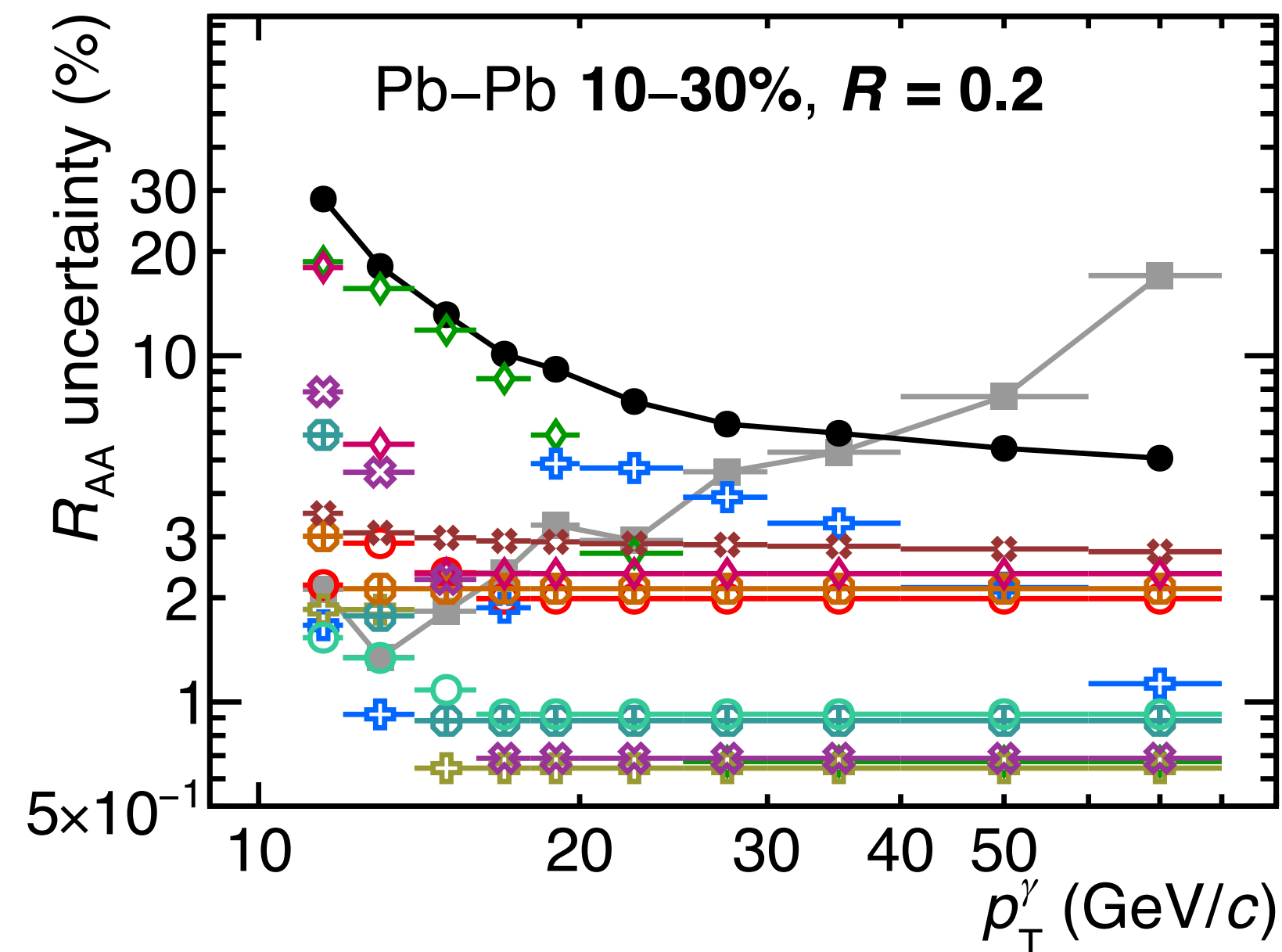
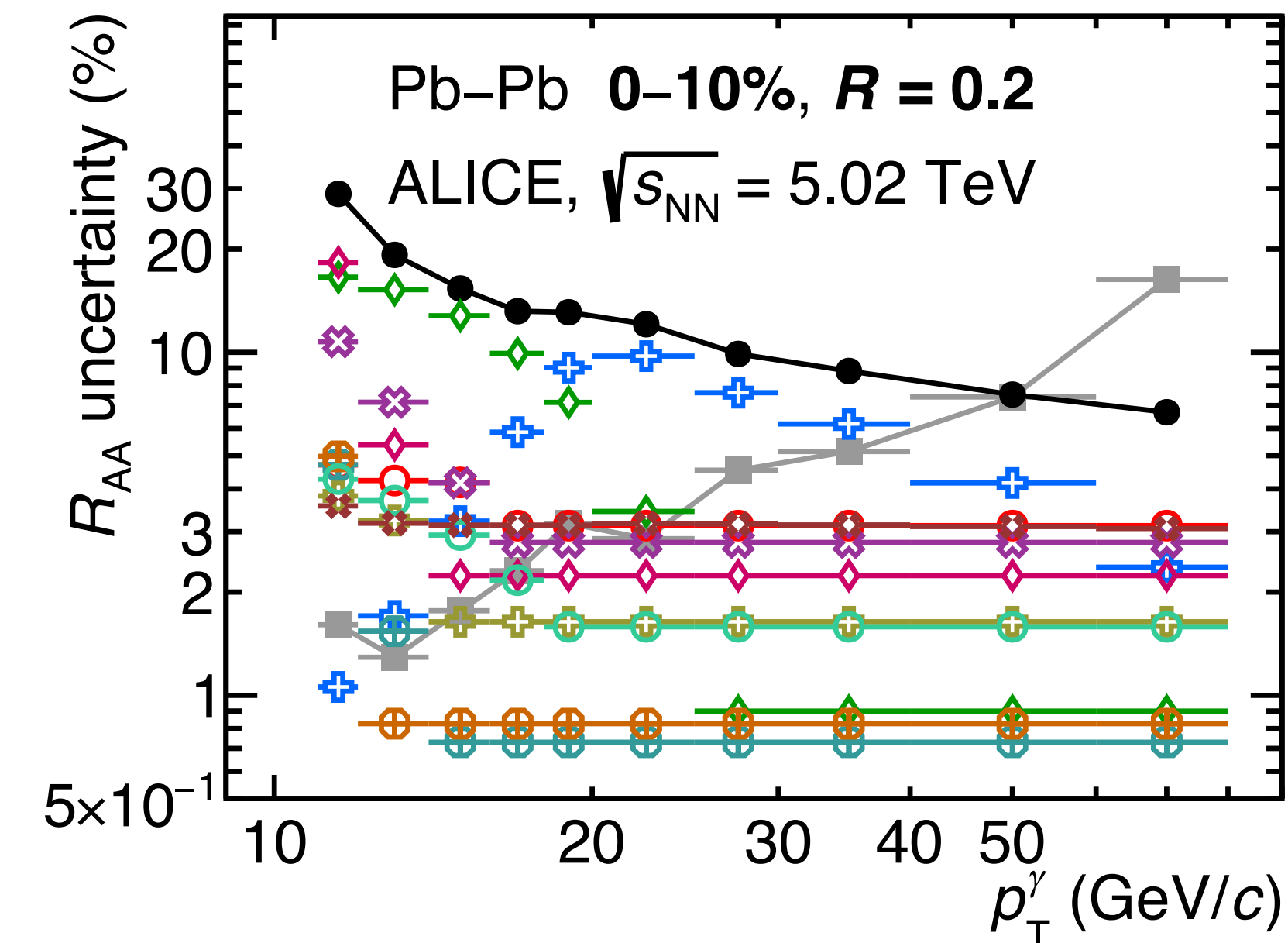
ALICE-PUBLIC-2024-003

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



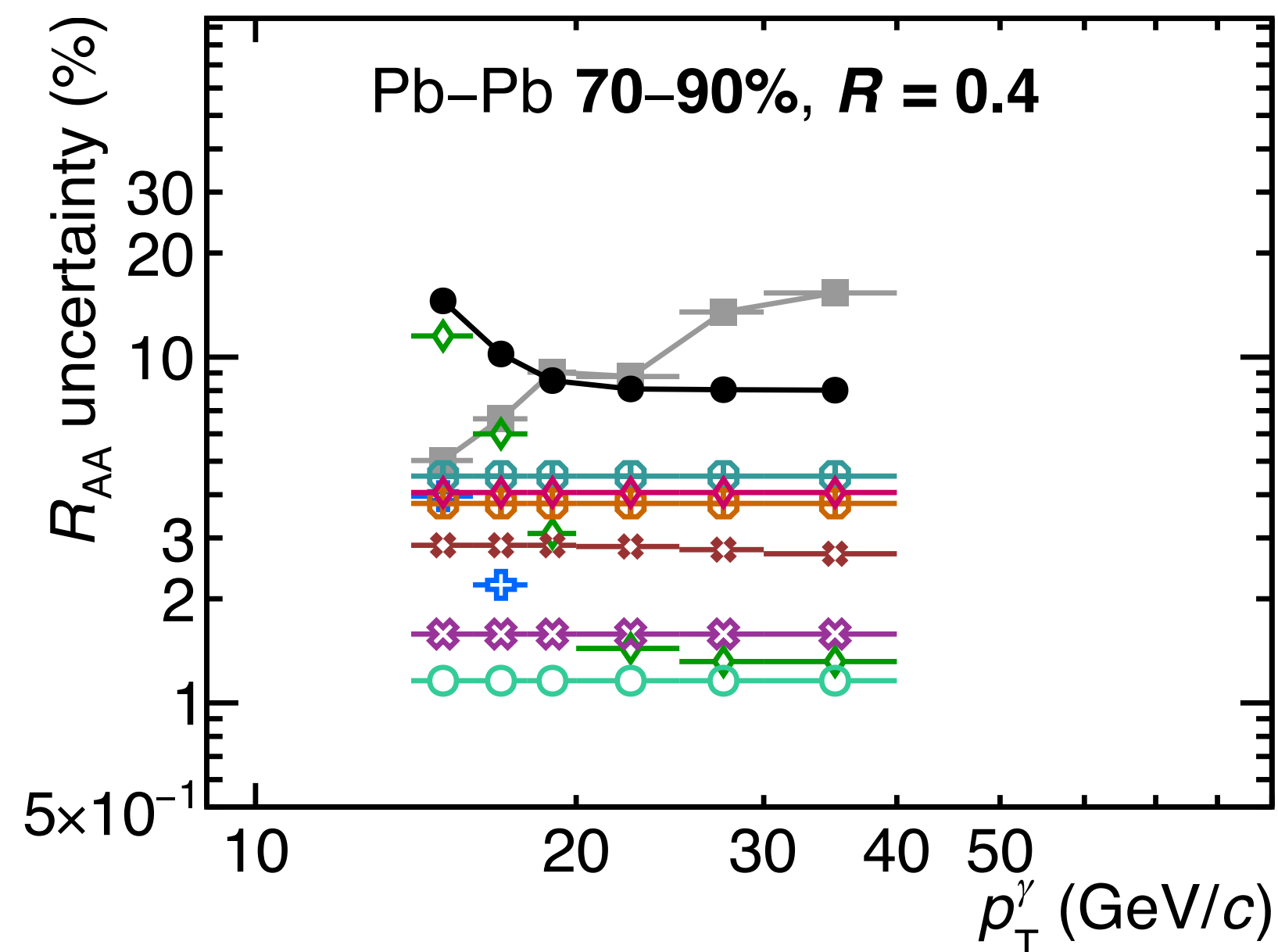
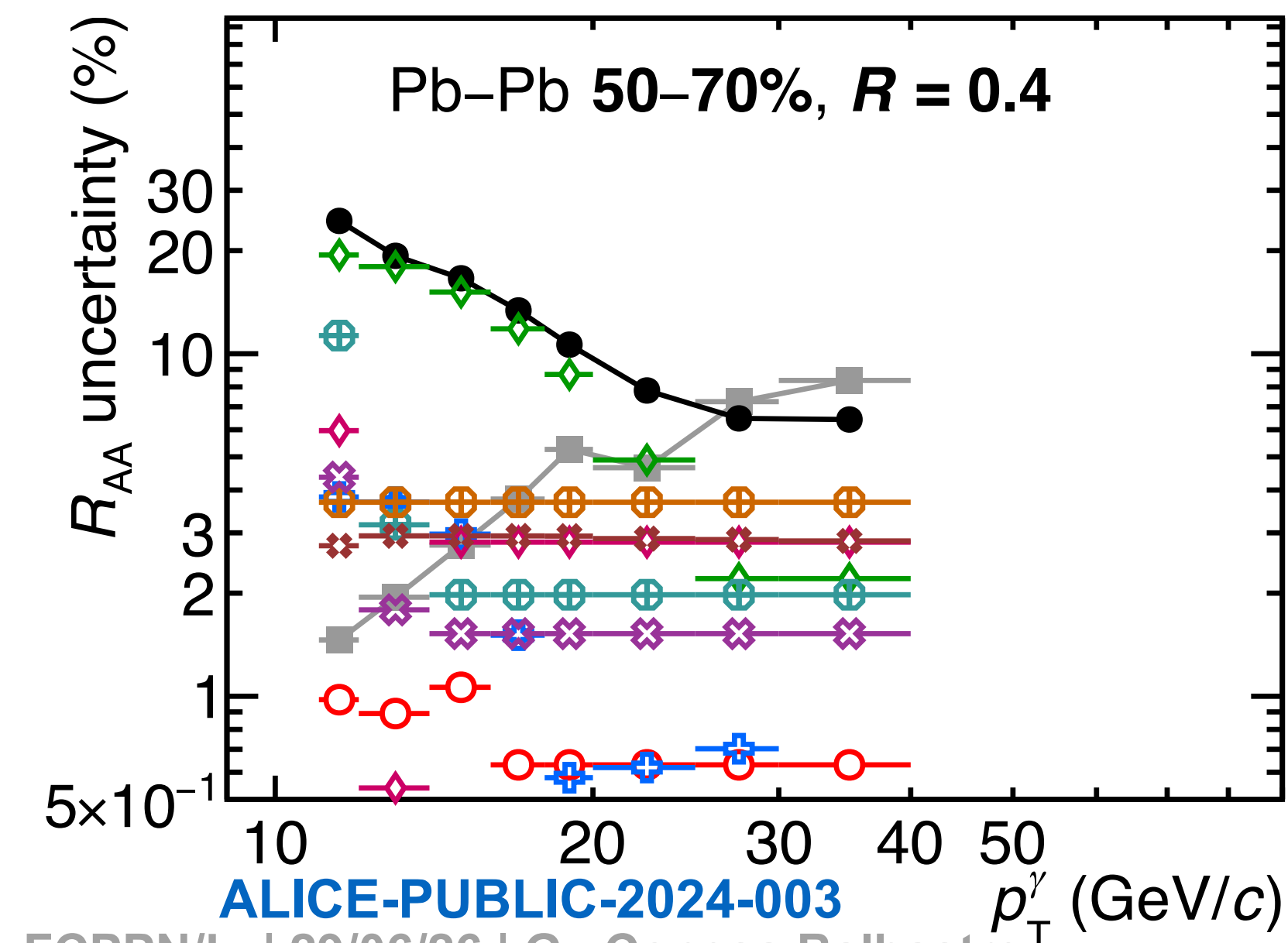
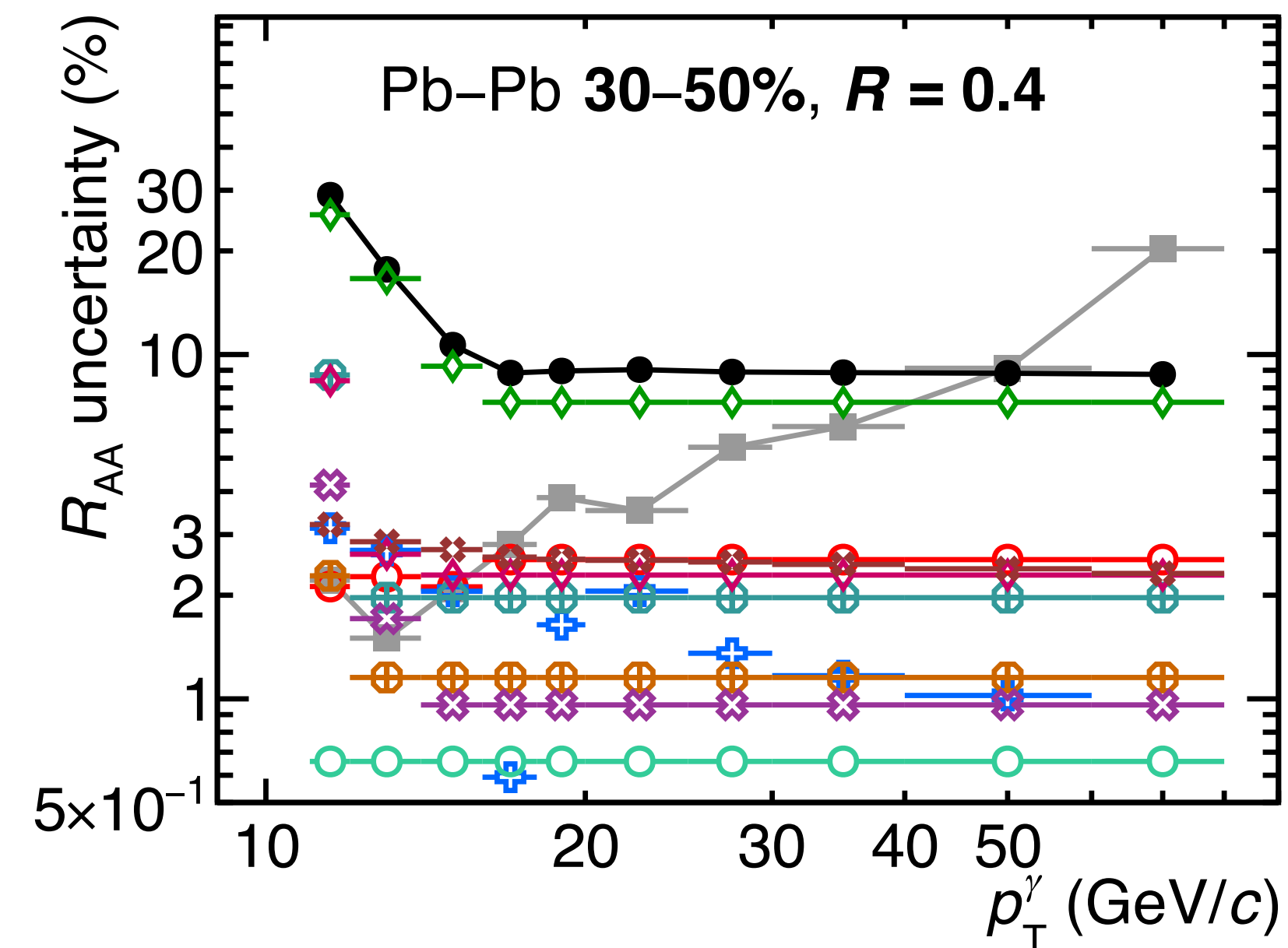
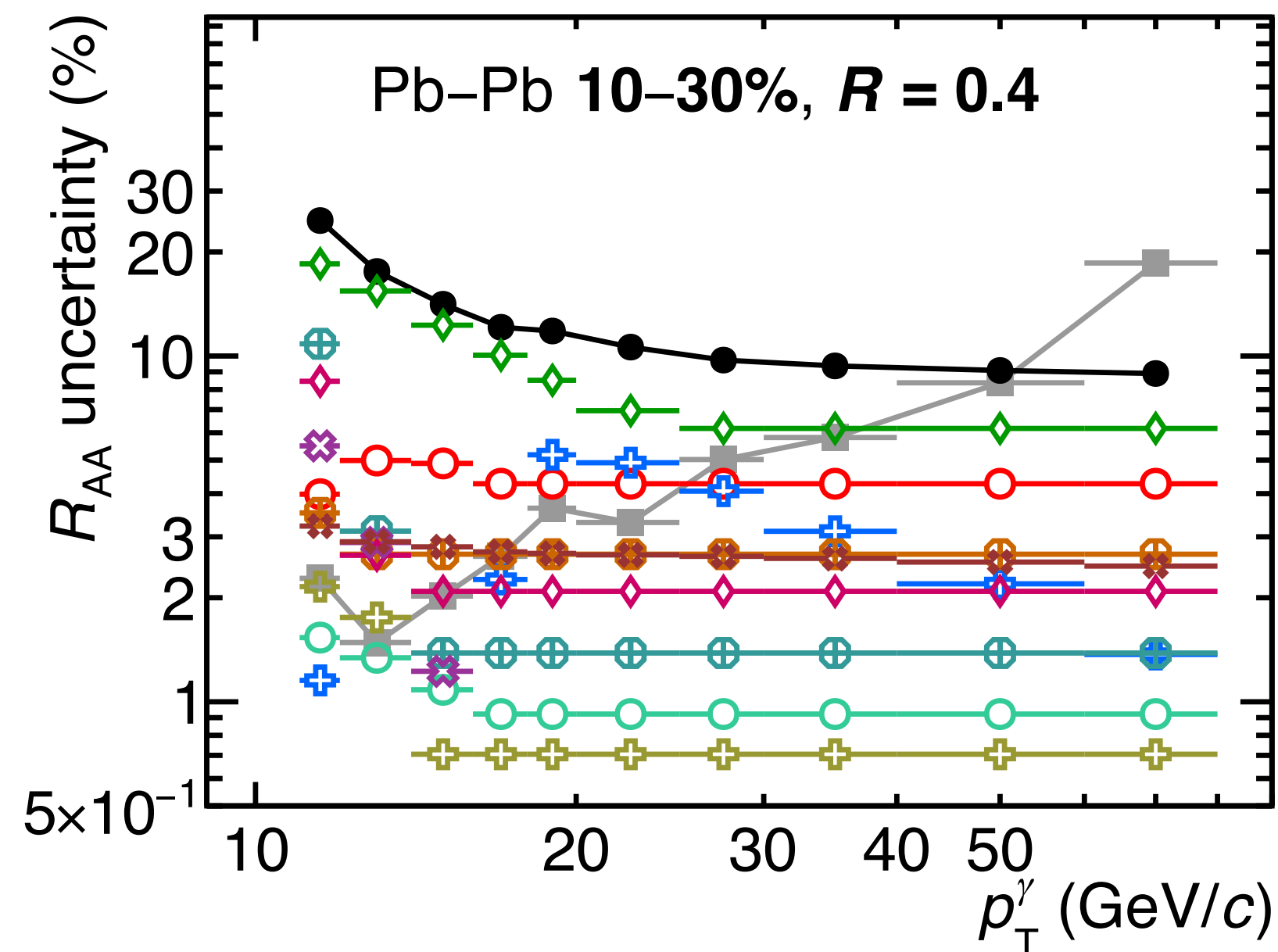
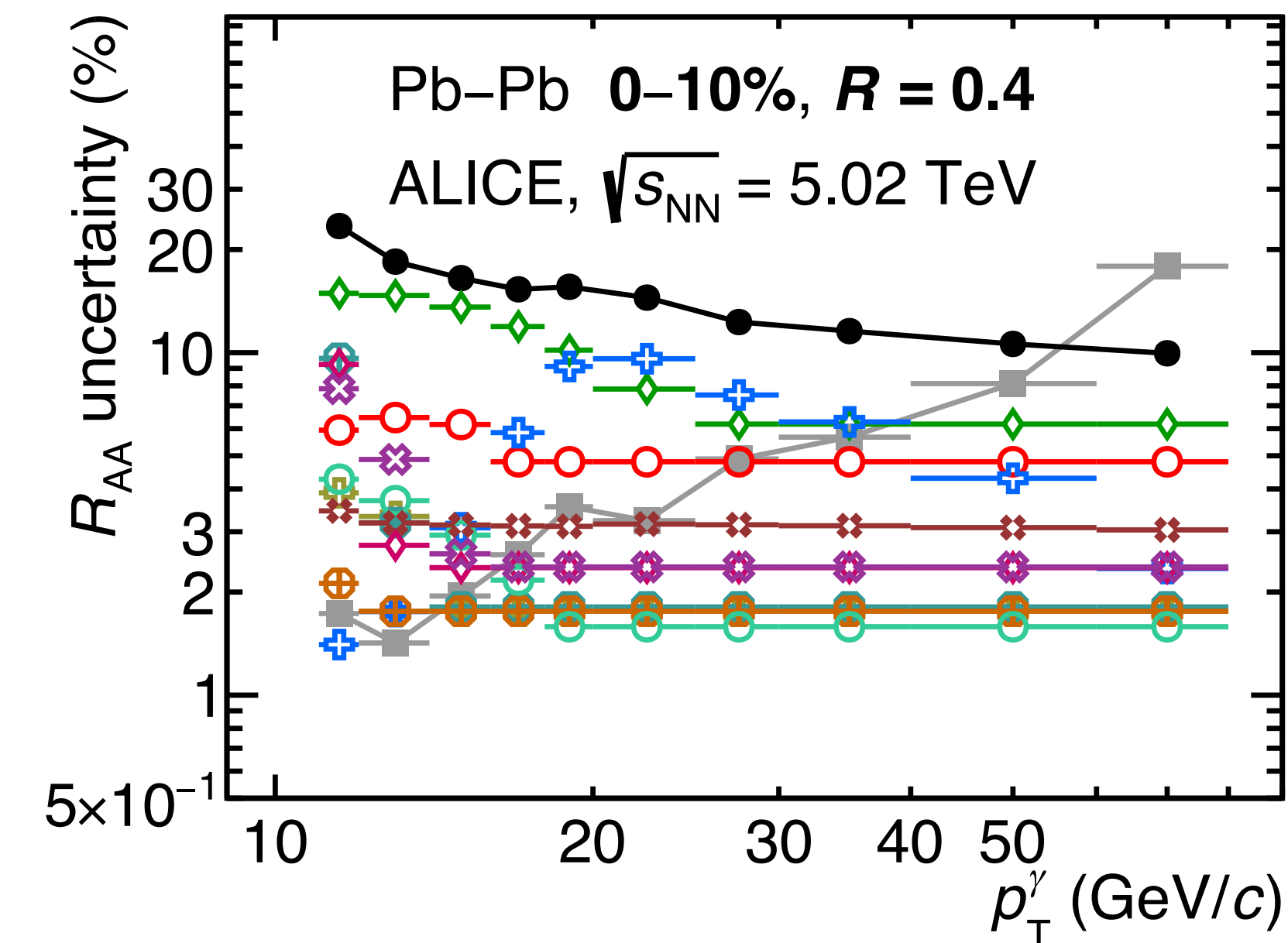
ALICE-PUBLIC-2024-003

R_{AA} uncertainties, $R = 0.2$



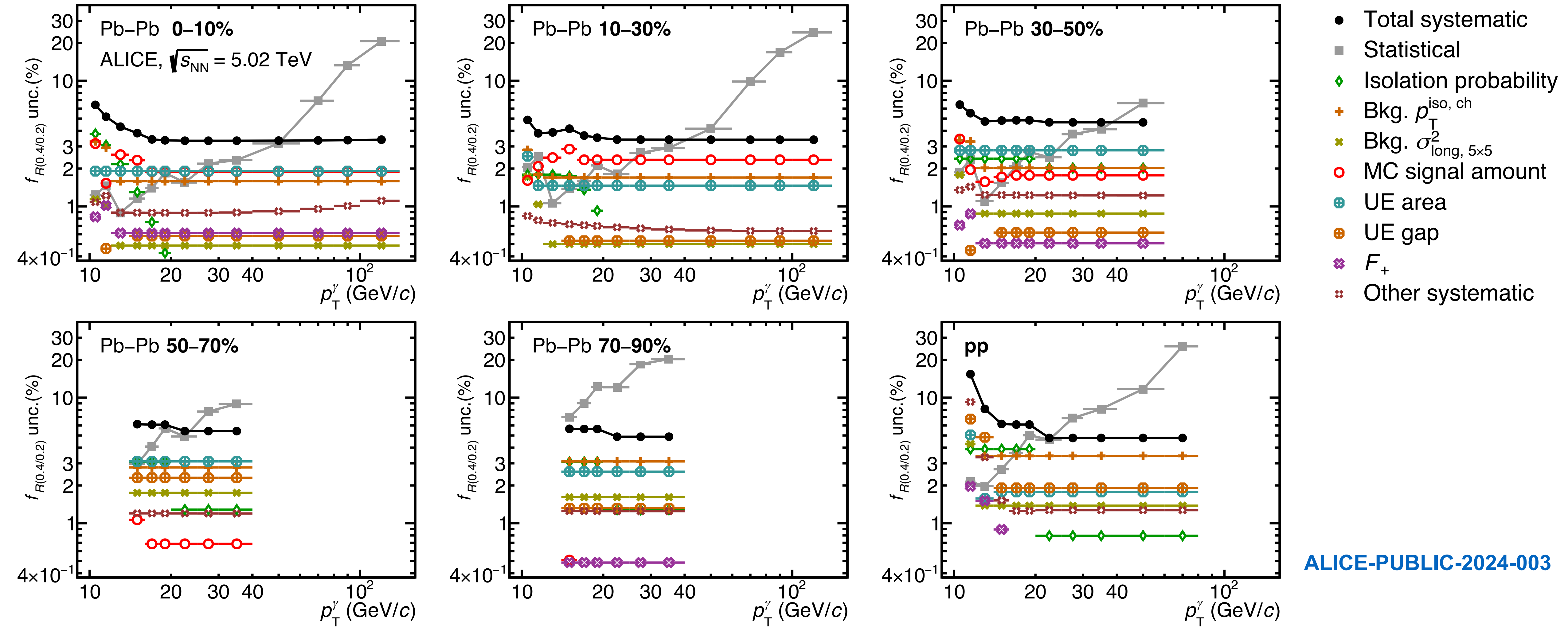
- Total systematic
- Statistical
- ◇ Isolation probability
- MC signal amount
- + No MC tuning
- + Spectra shape
- ⊕ UE area
- ⊕ UE gap
- ◇ Sig. $\sigma_{long, 5 \times 5}^2$
- Time
- ⊗ F_+
- ⊗ Other systematic

R_{AA} uncertainties, $R = 0.4$



- Total systematic
- Statistical
- ◇ Isolation probability
- MC signal amount
- + No MC tuning
- + Spectra shape
- ⊕ UE area
- ⊗ UE gap
- ◇ Sig. $\sigma_{long, 5 \times 5}^2$
- Time
- ⊗ F_+
- ⋈ Other systematic

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

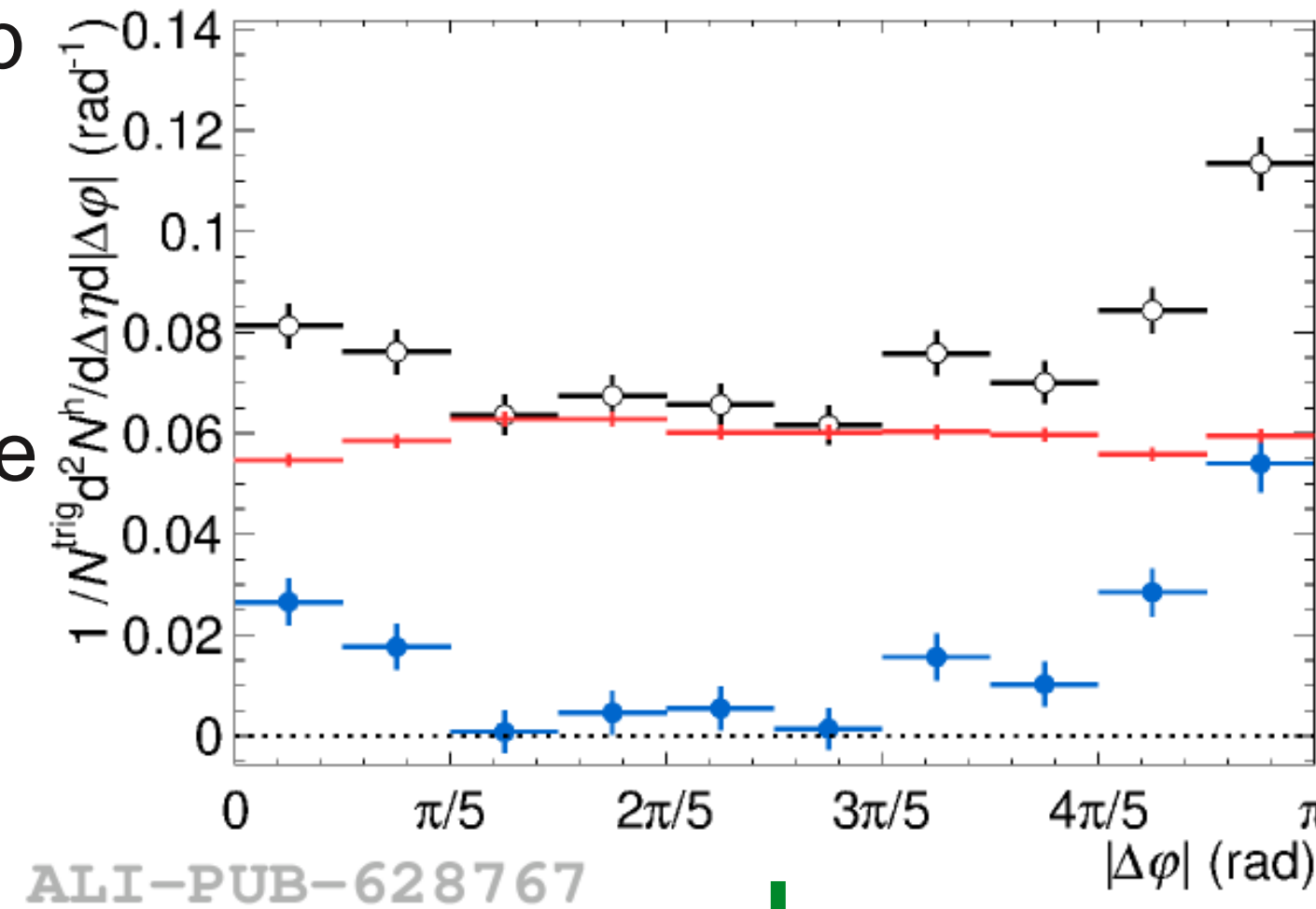


ALICE-PUBLIC-2024-003

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



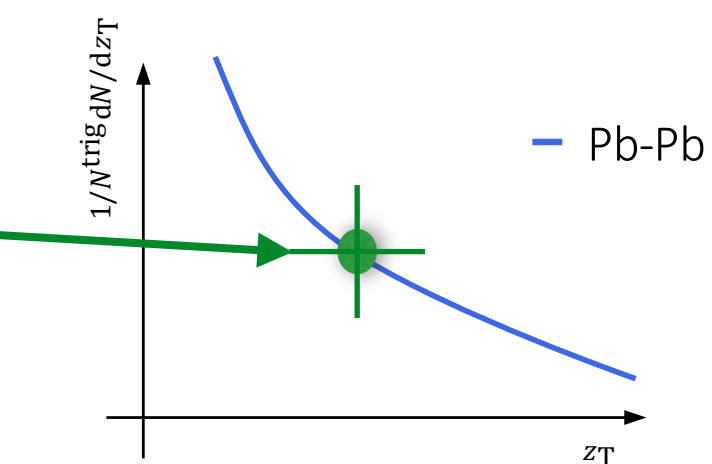
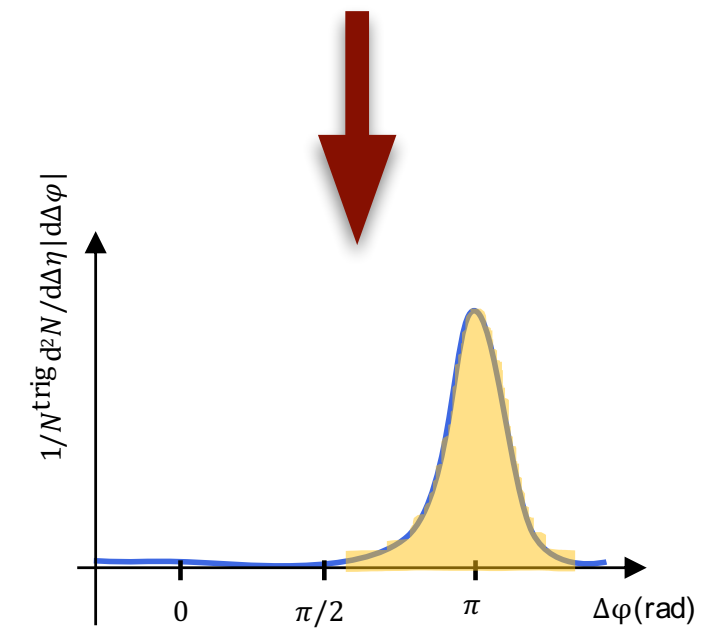
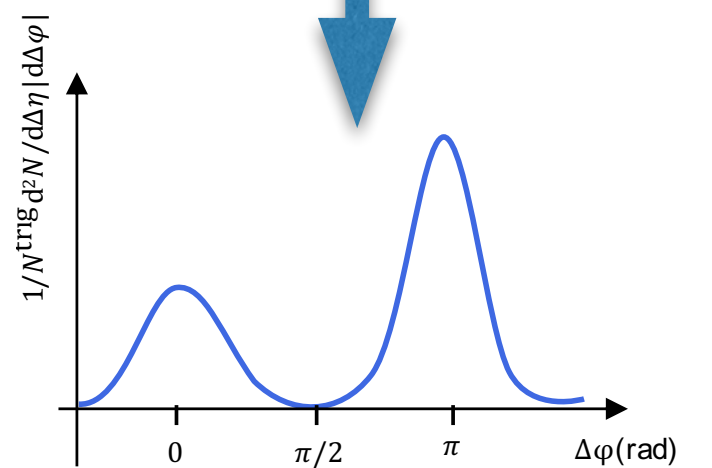
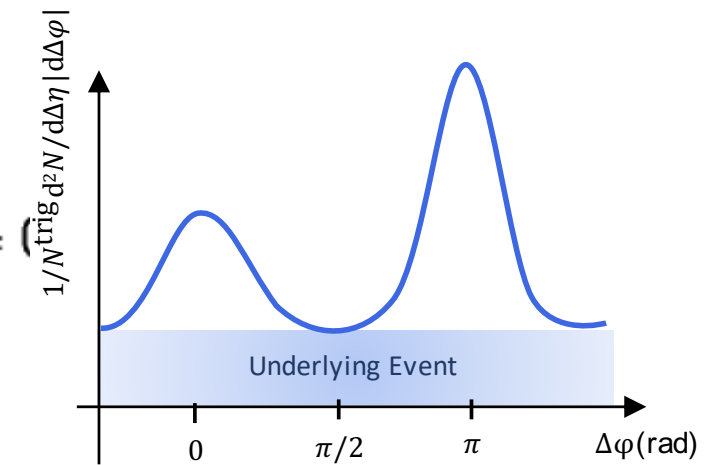
ALICE Pb–Pb, $\sqrt{s_{NN}} = 5.02$ TeV, **30–50%**

Trigger: $20 < p_T^{\text{trig}} < 25$ GeV/c, $|\eta^{\text{trig}}| < 0.67$

$0.1 < \sigma_{\text{long}, 5 \times 5}^2 < 0.3$; $p_T^{\text{iso}, \text{ch}} < 1.5$ GeV/c, $R = 0.2$

Associated: $0.20 < z_T < 0.30$, $|\eta^h| < 0.9$

- Same event
- Mixed event
- Same event - Mixed event

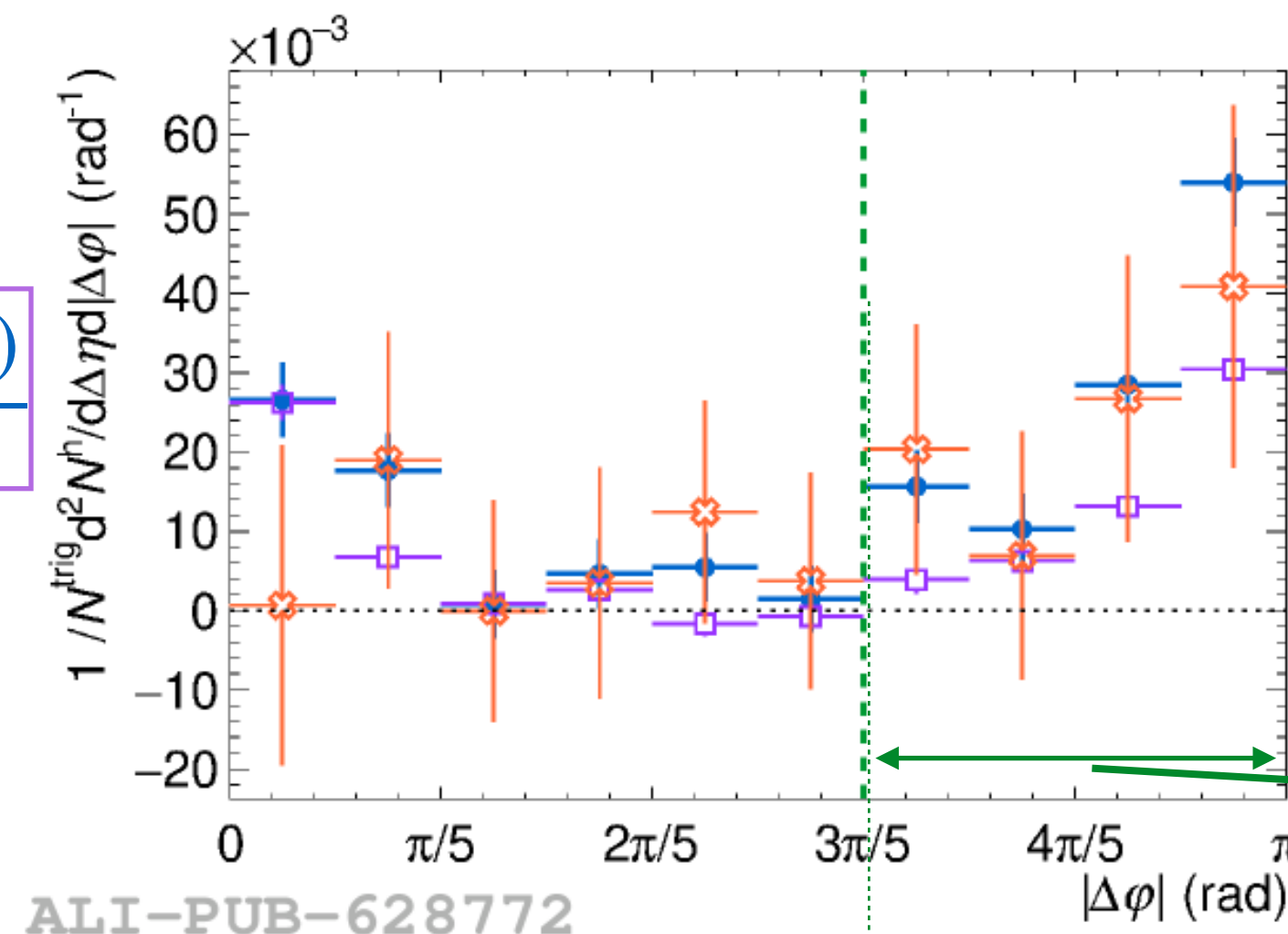


- Purity < 1 , considering

$$f(\Delta\varphi^{\text{cls}_{\text{narrow}}^{\text{iso}}}) \text{ bkg} = f(\Delta\varphi^{\text{cls}_{\text{wide}}^{\text{iso}}})$$

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

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



ALICE Pb–Pb, $\sqrt{s_{NN}} = 5.02$ TeV, **30–50%**

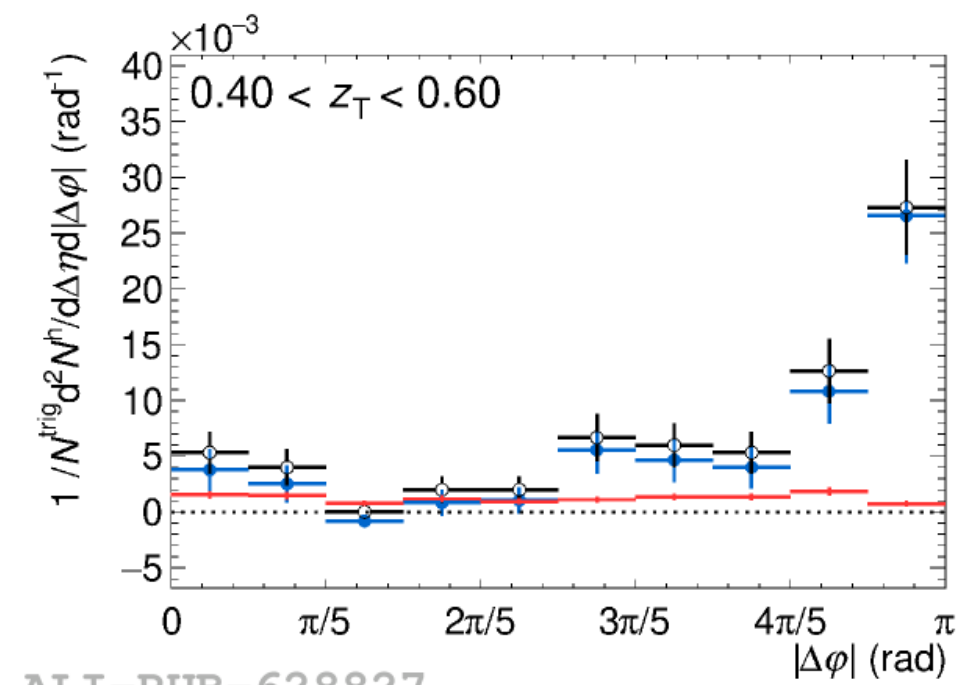
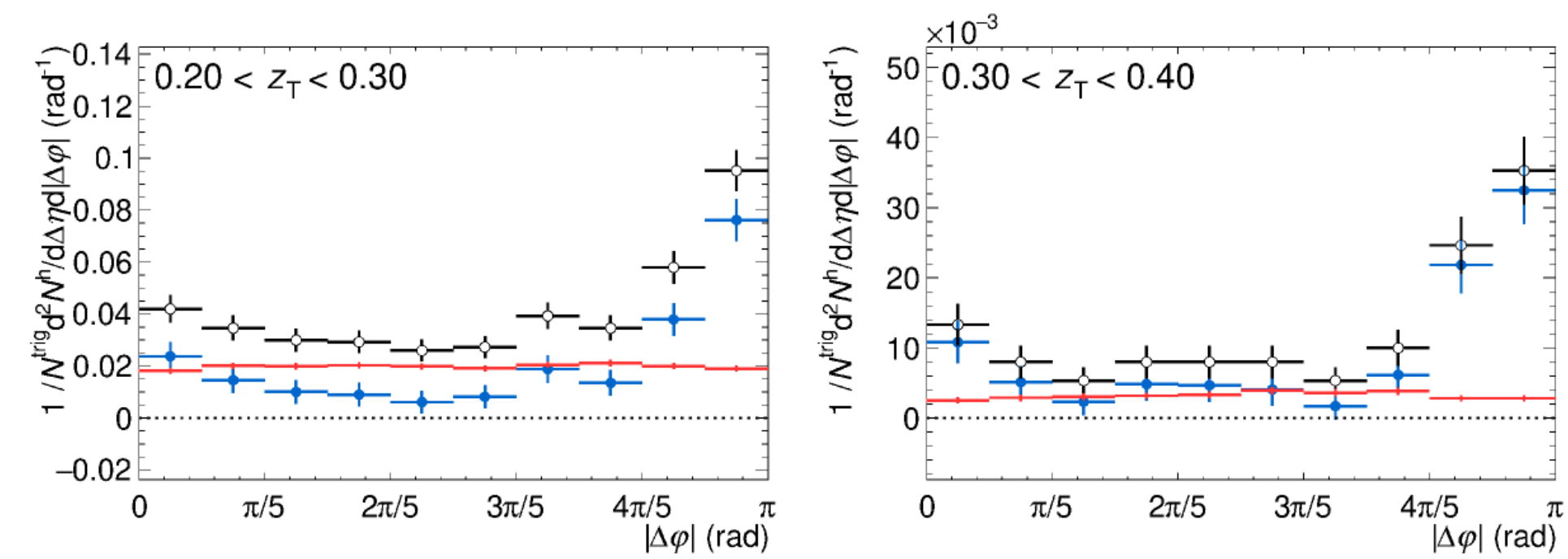
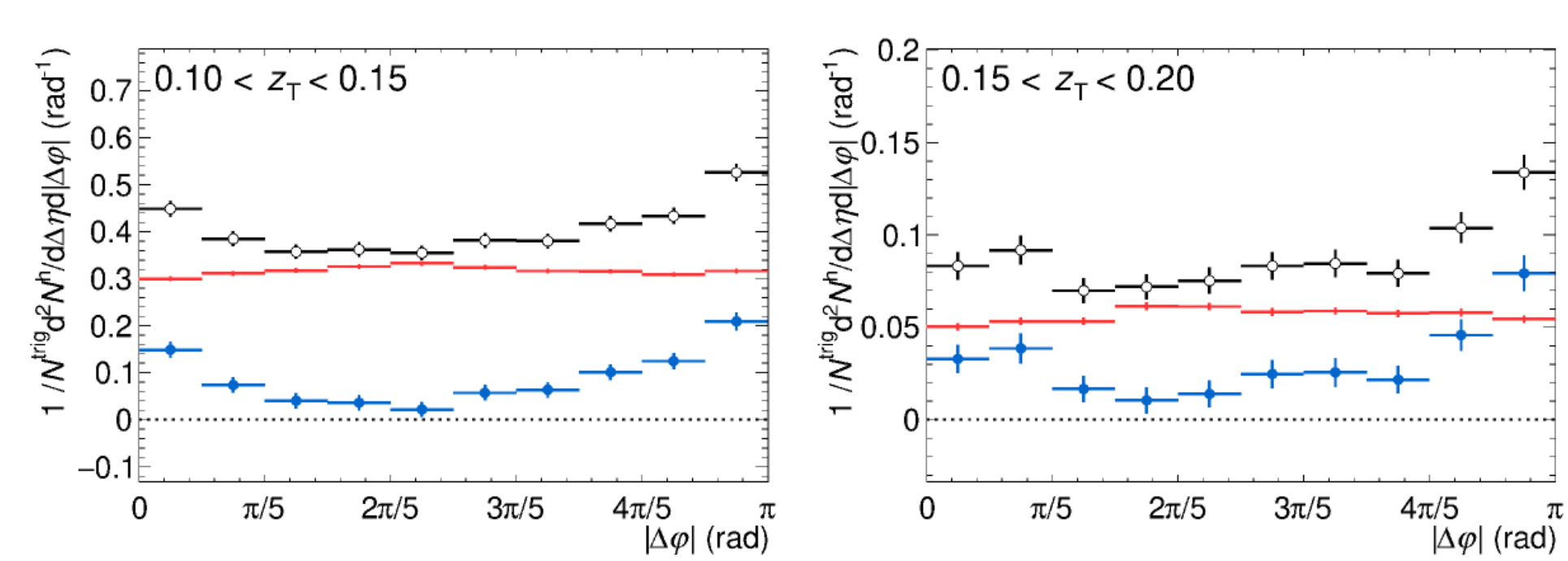
Trigger: $20 < p_T^{\text{trig}} < 25$ GeV/c, $|\eta^{\text{trig}}| < 0.67$

$p_T^{\text{iso}, \text{ch}} < 1.5$ GeV/c, $R = 0.2$

Associated: $0.20 < z_T < 0.30$, $|\eta^h| < 0.9$

- C_{Narrow}
- $C_{\text{Wide}} \times (1 - P)$
- $C_{\gamma^{\text{iso}}} = 1/P \times C_{\text{Narrow}} - (1 - P)/P \times C_{\text{Wide}}$

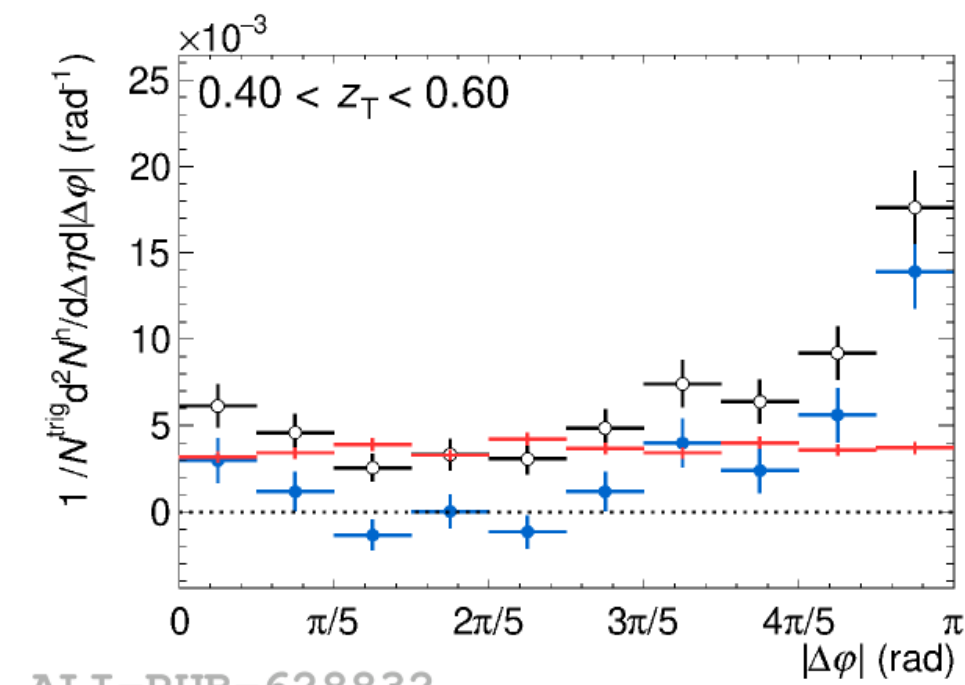
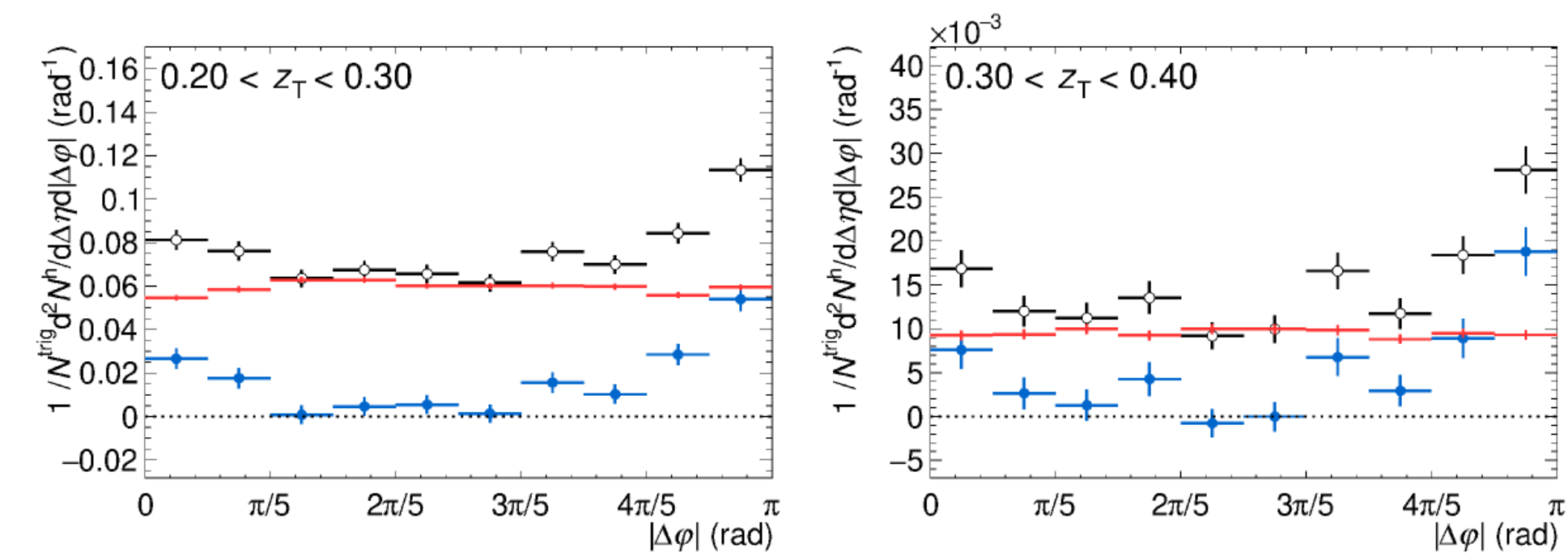
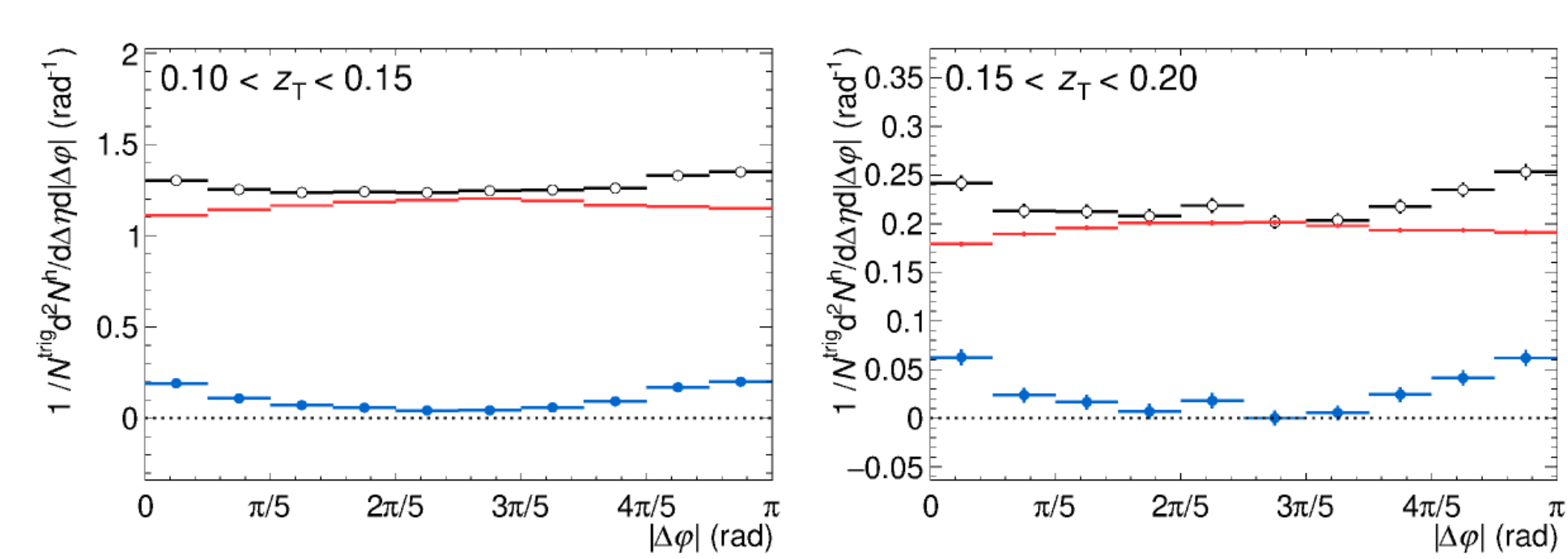
— $|\Delta\varphi| = \frac{3}{5}\pi$ rad



ALI-PUB-628827

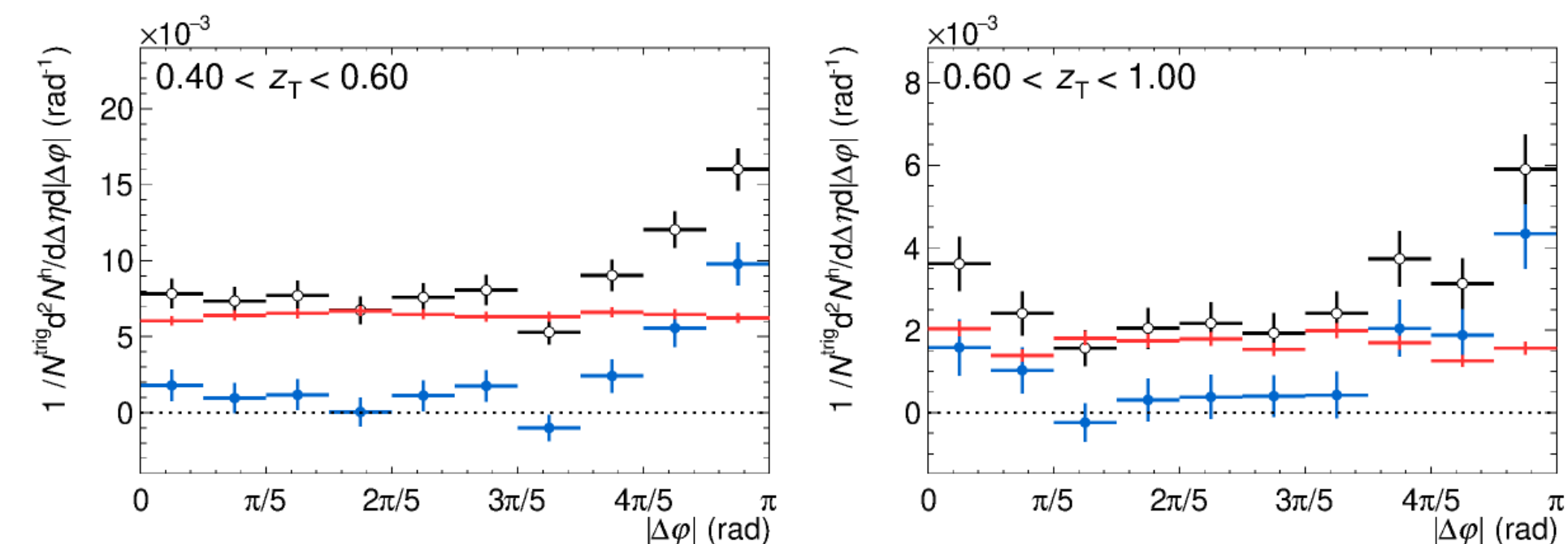
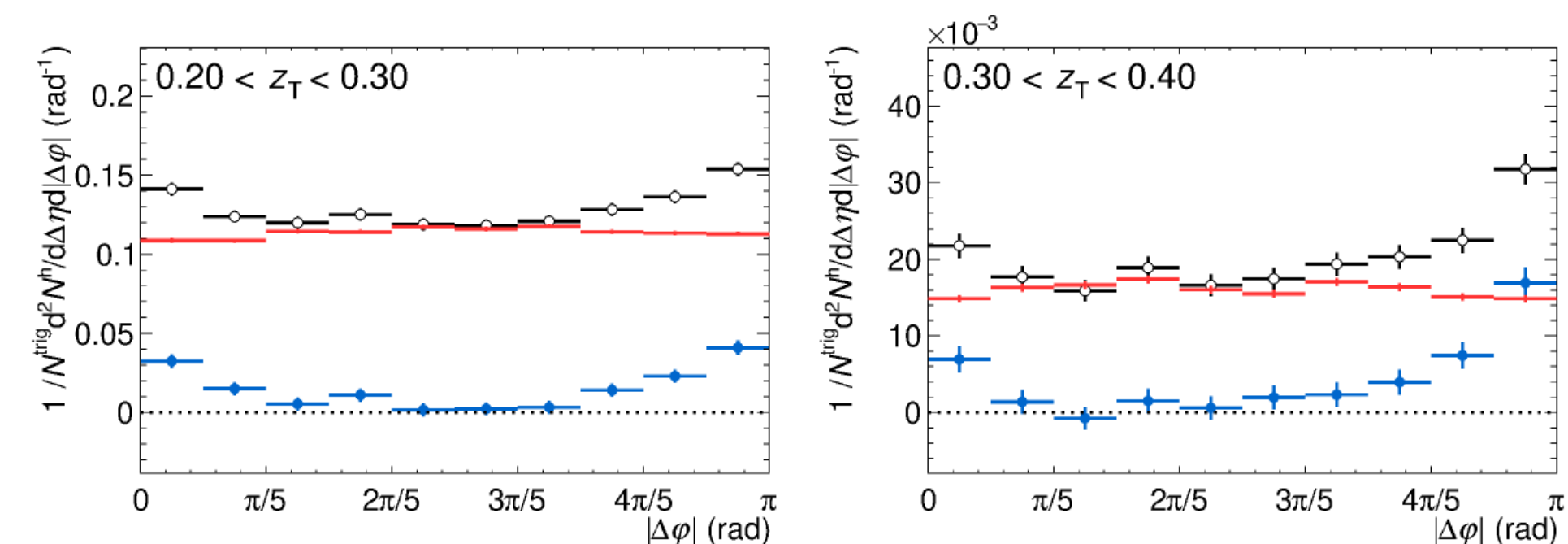
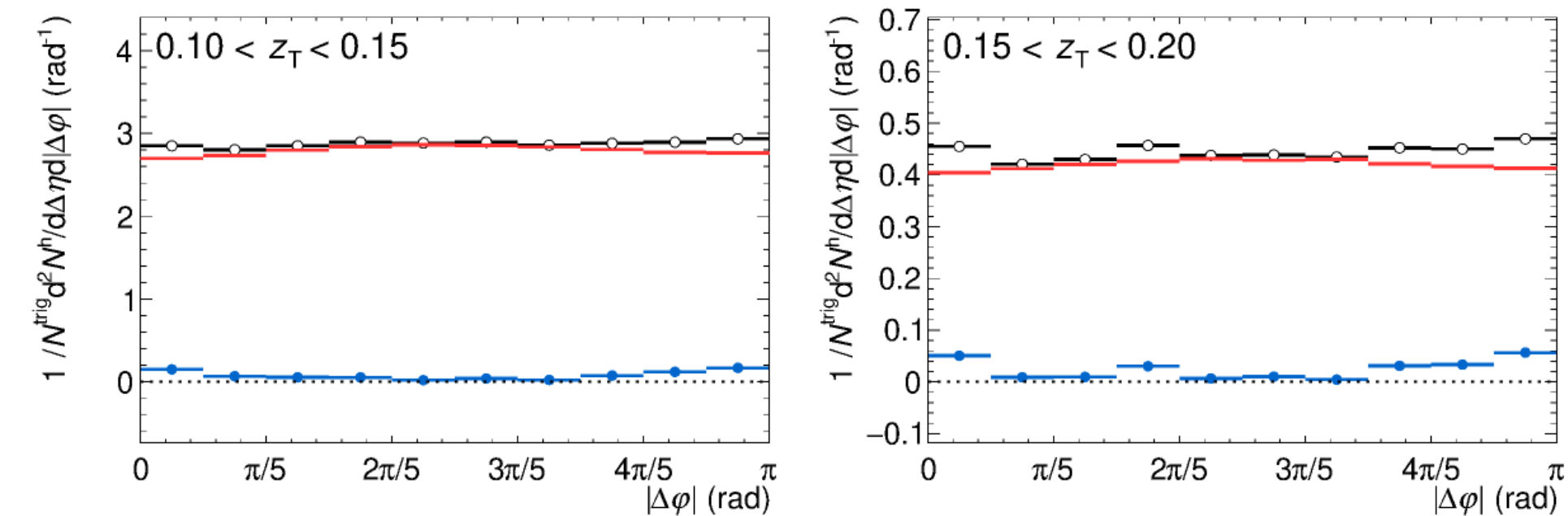
ALICE Pb-Pb, $\sqrt{s_{NN}} = 5.02$ TeV, **50-90%**
 Trigger: $20 < p_T^{\text{trig}} < 25$ GeV/c, $|\eta^{\text{trig}}| < 0.67$
 $0.1 < \sigma_{\text{long}, 5 \times 5}^2 < 0.3$; $p_T^{\text{iso, ch}} < 1.5$ GeV/c, $R = 0.2$
 Associated: $p_T^h > 1.8$ GeV/c, $|\eta^h| < 0.9$
 — Same event
 — Mixed event
 — Same event - Mixed event

ALICE-PUBLIC-2026-001



ALI-PUB-628832

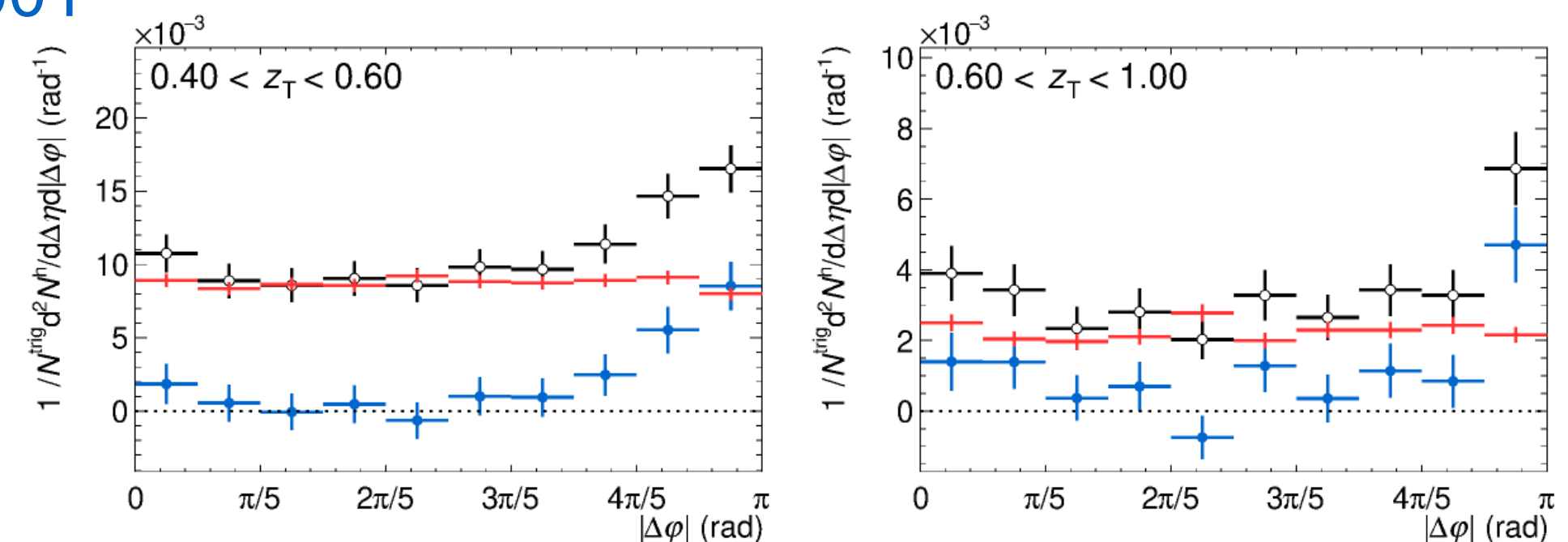
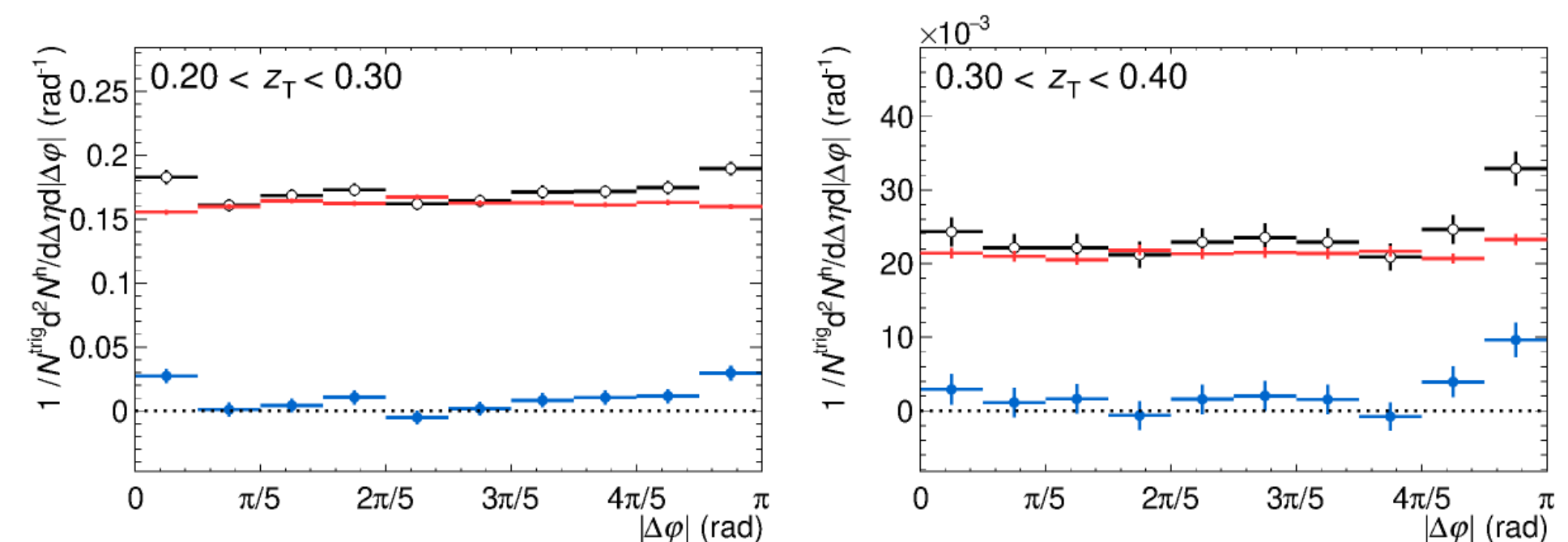
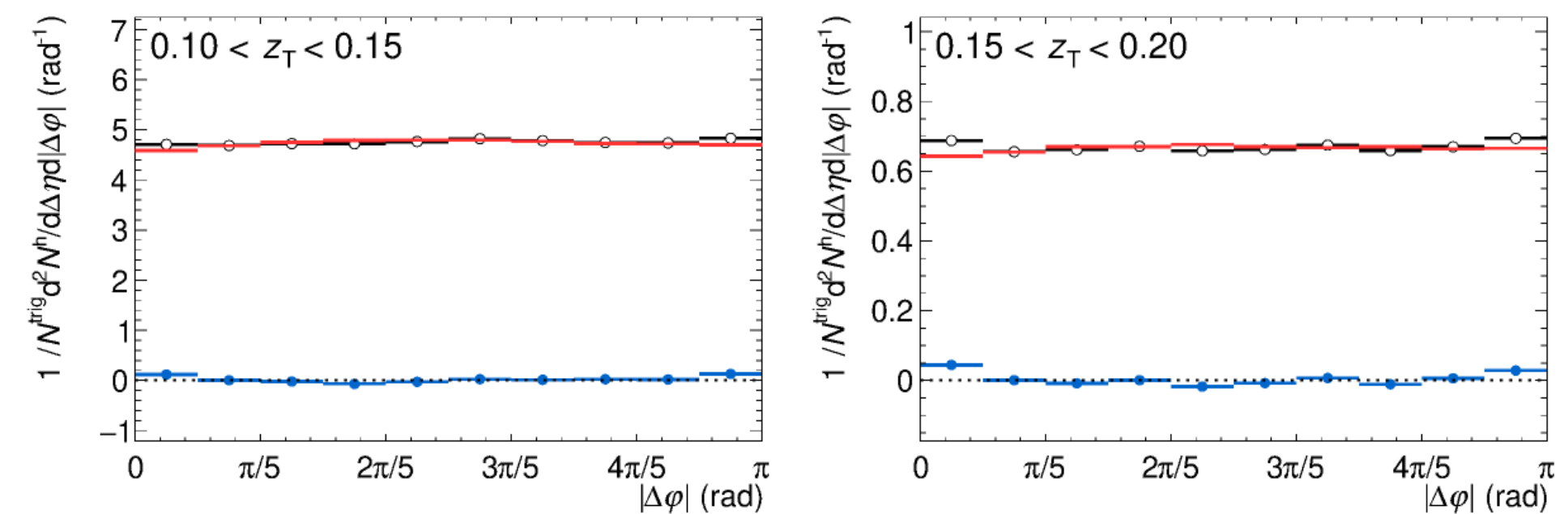
ALICE Pb-Pb, $\sqrt{s_{NN}} = 5.02$ TeV, **30-50%**
 Trigger: $20 < p_T^{\text{trig}} < 25$ GeV/c, $|\eta^{\text{trig}}| < 0.67$
 $0.1 < \sigma_{\text{long}, 5 \times 5}^2 < 0.3$; $p_T^{\text{iso, ch}} < 1.5$ GeV/c, $R = 0.2$
 Associated: $p_T^h > 1.8$ GeV/c, $|\eta^h| < 0.9$
 — Same event
 — Mixed event
 — Same event - Mixed event



ALICE Pb-Pb, $\sqrt{s_{NN}} = 5.02$ TeV, **10-30%**
 Trigger: $20 < p_T^{\text{trig}} < 25$ GeV/c, $|\eta^{\text{trig}}| < 0.67$
 $0.1 < \sigma_{\text{long}, 5 \times 5}^2 < 0.3$; $p_T^{\text{iso, ch}} < 1.5$ GeV/c, $R = 0.2$
 Associated: $p_T^h > 1.8$ GeV/c, $|\eta^h| < 0.9$

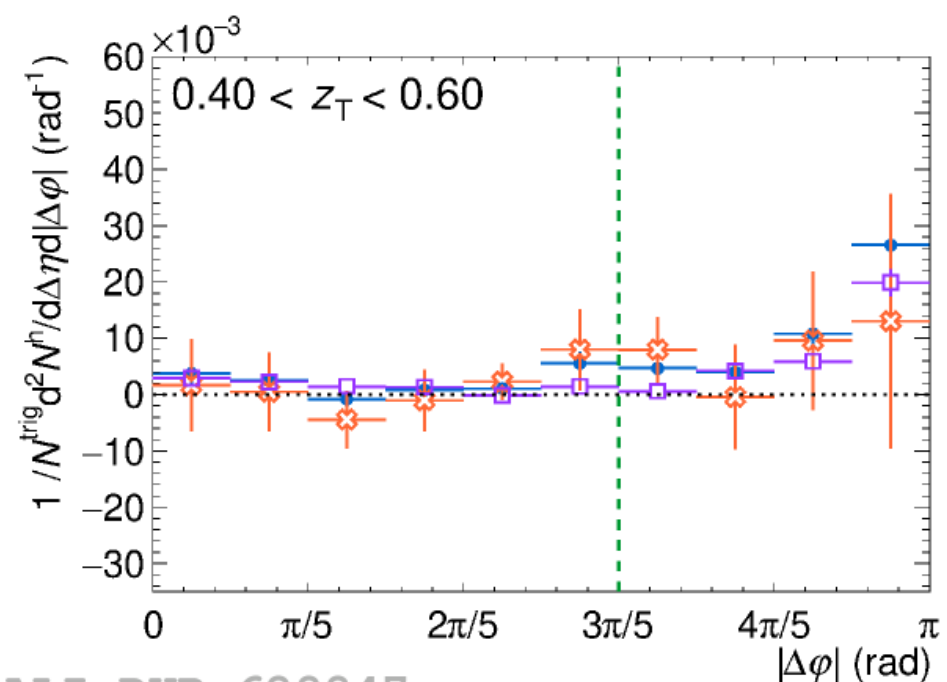
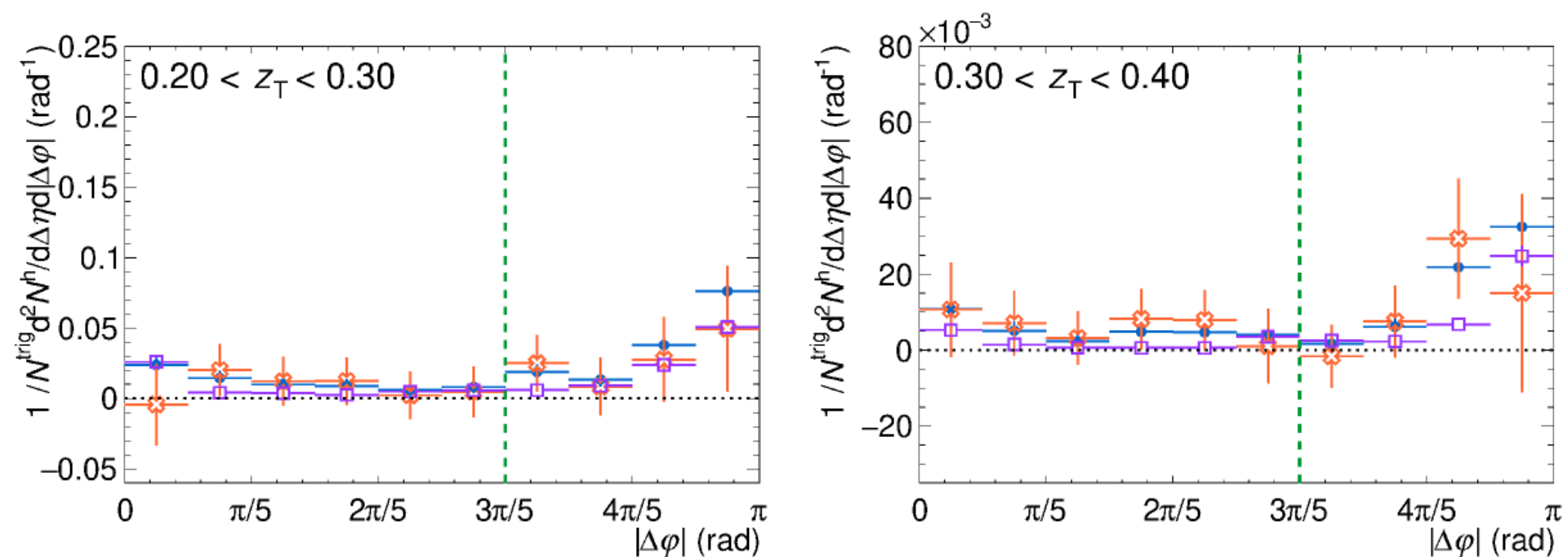
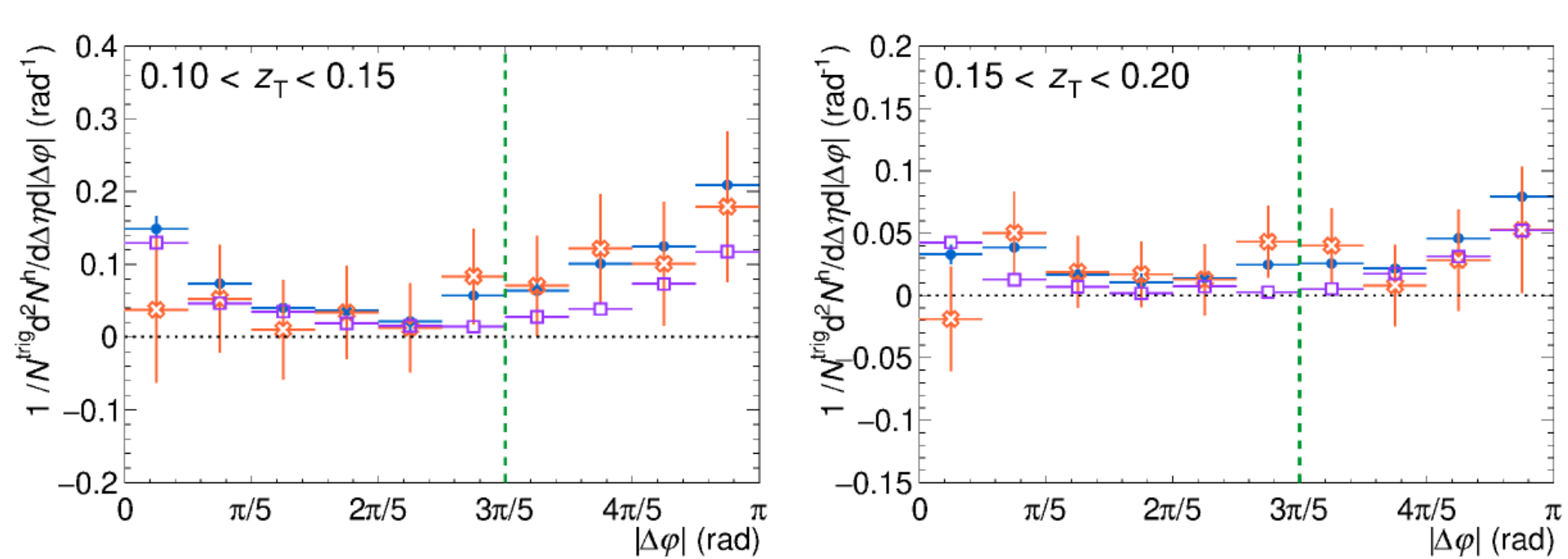
— Same event
 — Mixed event
 — Same event - Mixed event

ALICE-PUBLIC-2026-001



ALICE Pb-Pb, $\sqrt{s_{NN}} = 5.02$ TeV, **0-10%**
 Trigger: $20 < p_T^{\text{trig}} < 25$ GeV/c, $|\eta^{\text{trig}}| < 0.67$
 $0.1 < \sigma_{\text{long}, 5 \times 5}^2 < 0.3$; $p_T^{\text{iso, ch}} < 1.5$ GeV/c, $R = 0.2$
 Associated: $p_T^h > 1.8$ GeV/c, $|\eta^h| < 0.9$

— Same event
 — Mixed event
 — Same event - Mixed event



ALICE Pb–Pb, $\sqrt{s_{NN}} = 5.02$ TeV, **50–90%**

Trigger: $20 < p_T^{\text{trig}} < 25$ GeV/c, $|\eta^{\text{trig}}| < 0.67$

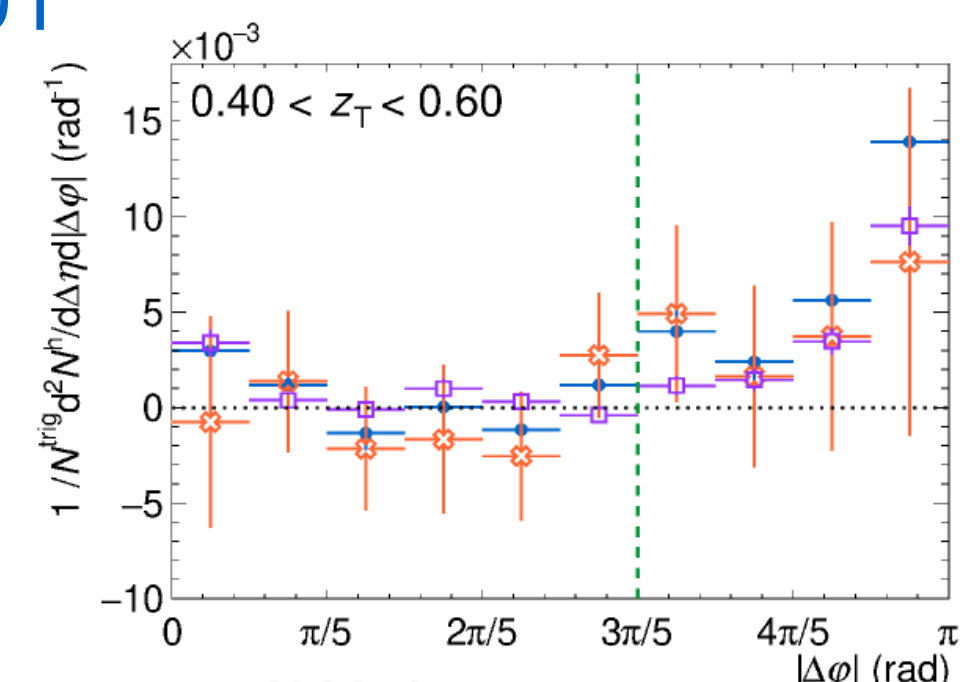
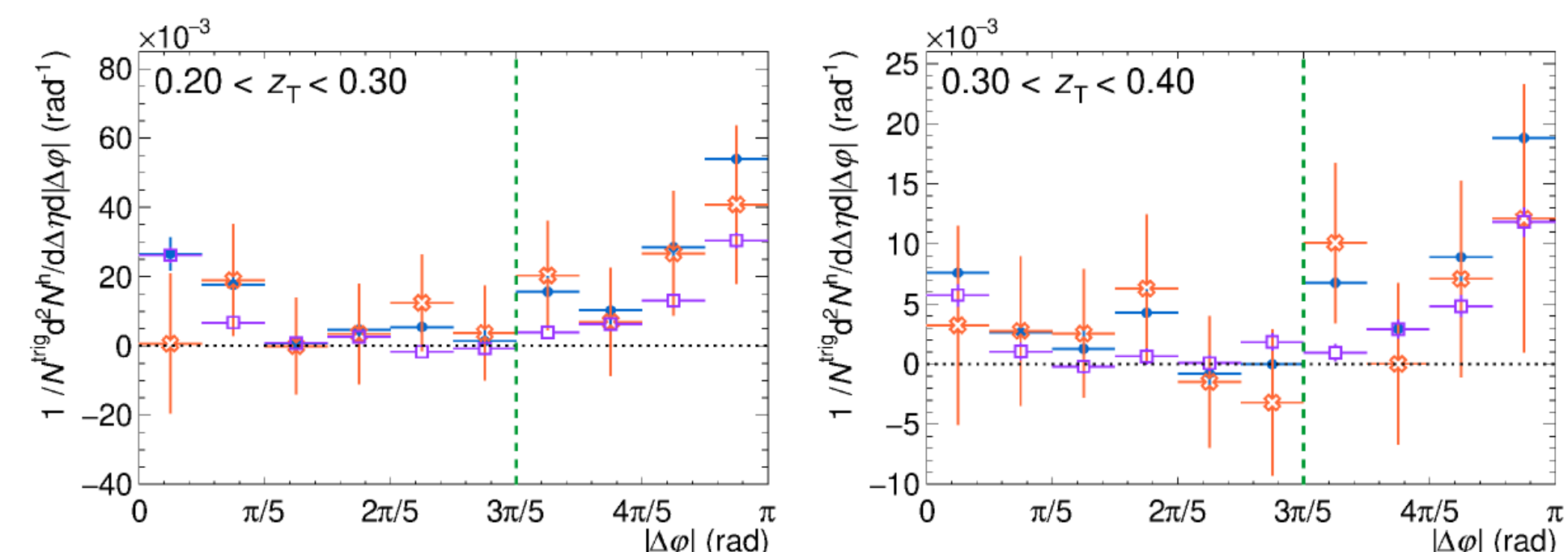
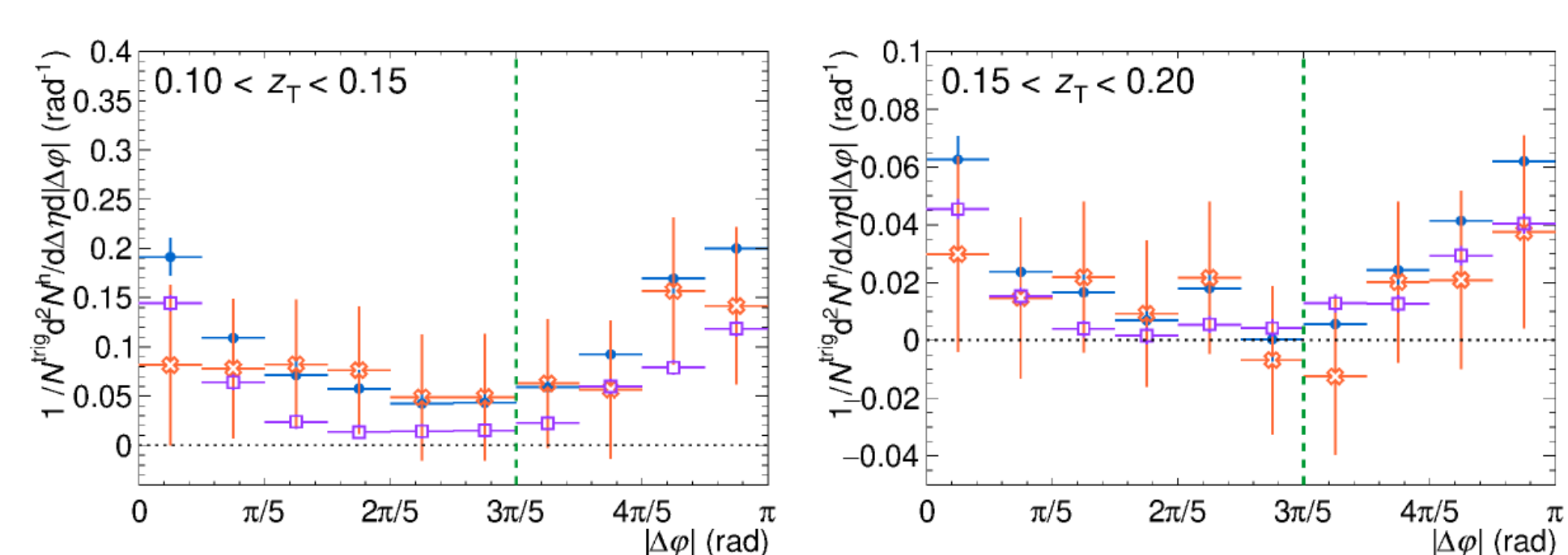
$p_T^{\text{iso, ch}} < 1.5$ GeV/c, $R = 0.2$

Associated: $p_T^h > 1.8$ GeV/c, $|\eta^h| < 0.9$

- C_{Narrow}
- $C_{\text{Wide}} \times (1 - P)$
- ×— $C_{\gamma^{\text{iso}}} = 1/P \times C_{\text{Narrow}} - (1 - P)/P \times C_{\text{Wide}}$
- $|\Delta\phi| = \frac{3}{5}\pi$ rad

ALI-PUB-628847

ALICE-PUBLIC-2026-001



ALICE Pb–Pb, $\sqrt{s_{NN}} = 5.02$ TeV, **30–50%**

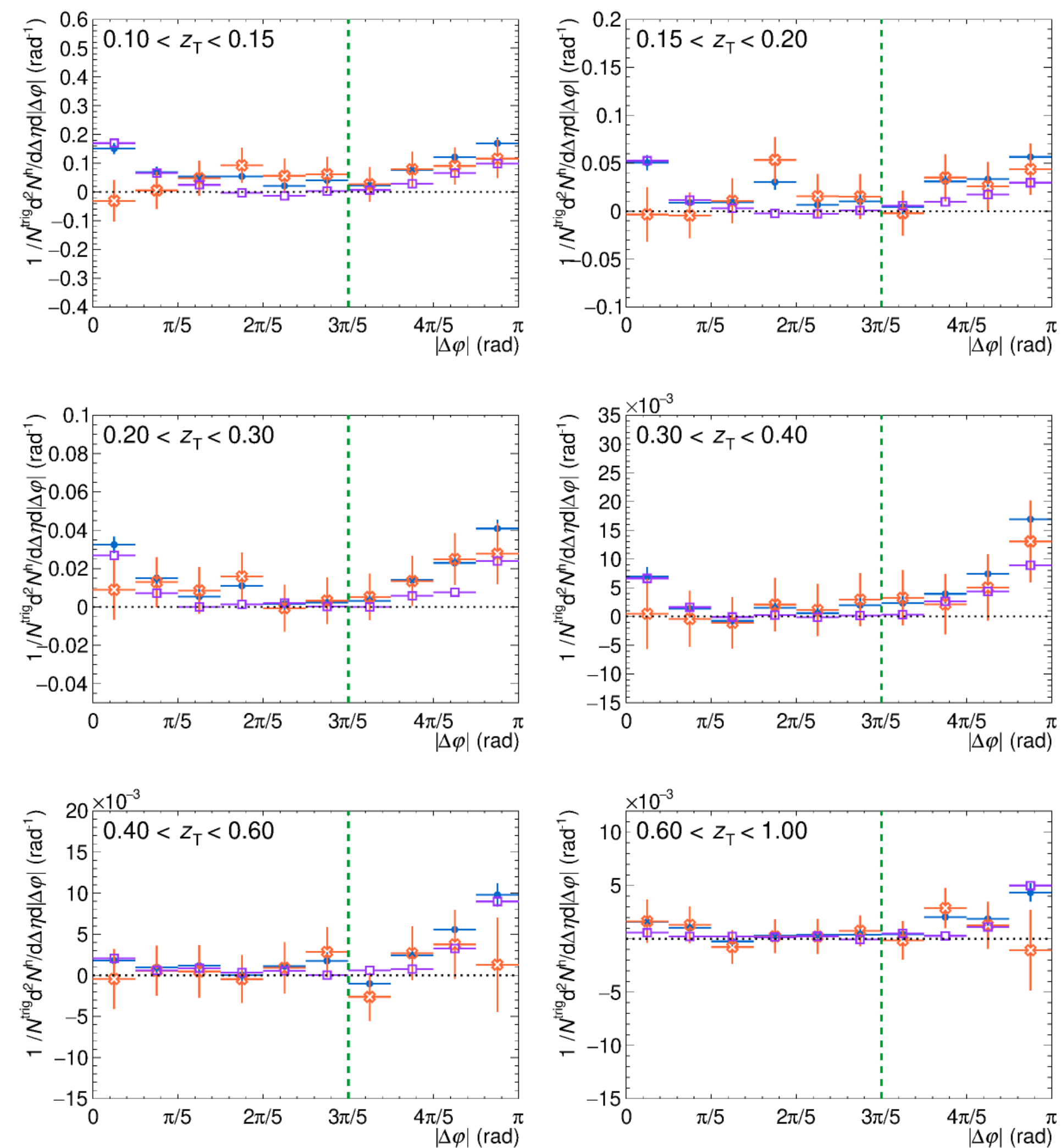
Trigger: $20 < p_T^{\text{trig}} < 25$ GeV/c, $|\eta^{\text{trig}}| < 0.67$

$p_T^{\text{iso, ch}} < 1.5$ GeV/c, $R = 0.2$

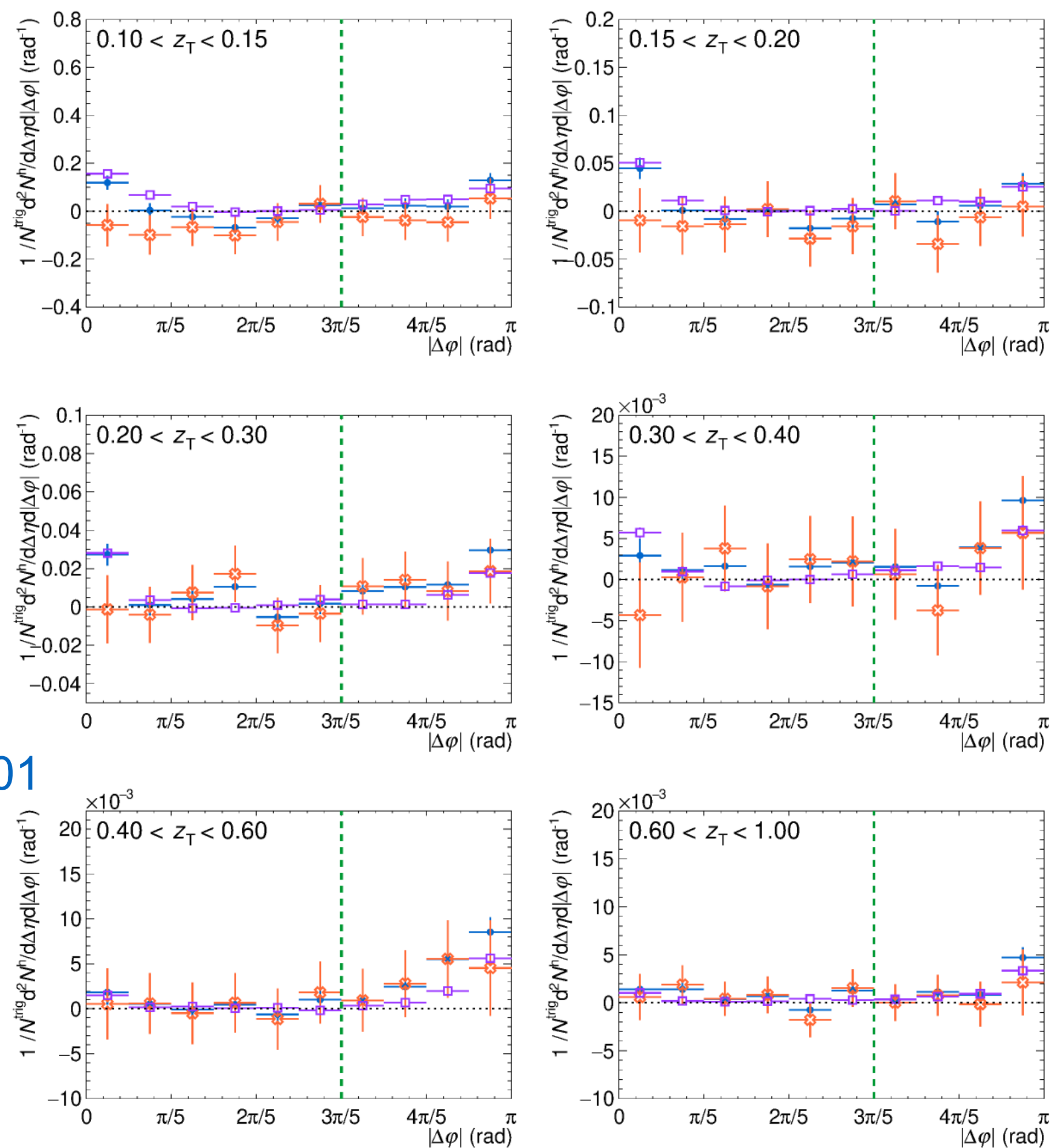
Associated: $p_T^h > 1.8$ GeV/c, $|\eta^h| < 0.9$

- C_{Narrow}
- $C_{\text{Wide}} \times (1 - P)$
- ×— $C_{\gamma^{\text{iso}}} = 1/P \times C_{\text{Narrow}} - (1 - P)/P \times C_{\text{Wide}}$
- $|\Delta\phi| = \frac{3}{5}\pi$ rad

ALI-PUB-628852



ALICE-PUBLIC-2026-001



ALICE Pb–Pb, $\sqrt{s_{NN}} = 5.02$ TeV, **10–30%**

Trigger: $20 < p_T^{\text{trig}} < 25$ GeV/c, $|\eta^{\text{trig}}| < 0.67$

$p_T^{\text{iso, ch}} < 1.5$ GeV/c, $R = 0.2$

Associated: $p_T^h > 1.8$ GeV/c, $|\eta^h| < 0.9$

—●— C_{Narrow}
 —□— $C_{\text{Wide}} \times (1 - P)$
 —×— $C_{\gamma^{\text{iso}}} = 1/P \times C_{\text{Narrow}} - (1 - P)/P \times C_{\text{Wide}}$
 - - - $|\Delta\phi| = \frac{3}{5} \pi$ rad

ALICE Pb–Pb, $\sqrt{s_{NN}} = 5.02$ TeV, **0–10%**

Trigger: $20 < p_T^{\text{trig}} < 25$ GeV/c, $|\eta^{\text{trig}}| < 0.67$

$p_T^{\text{iso, ch}} < 1.5$ GeV/c, $R = 0.2$

Associated: $p_T^h > 1.8$ GeV/c, $|\eta^h| < 0.9$

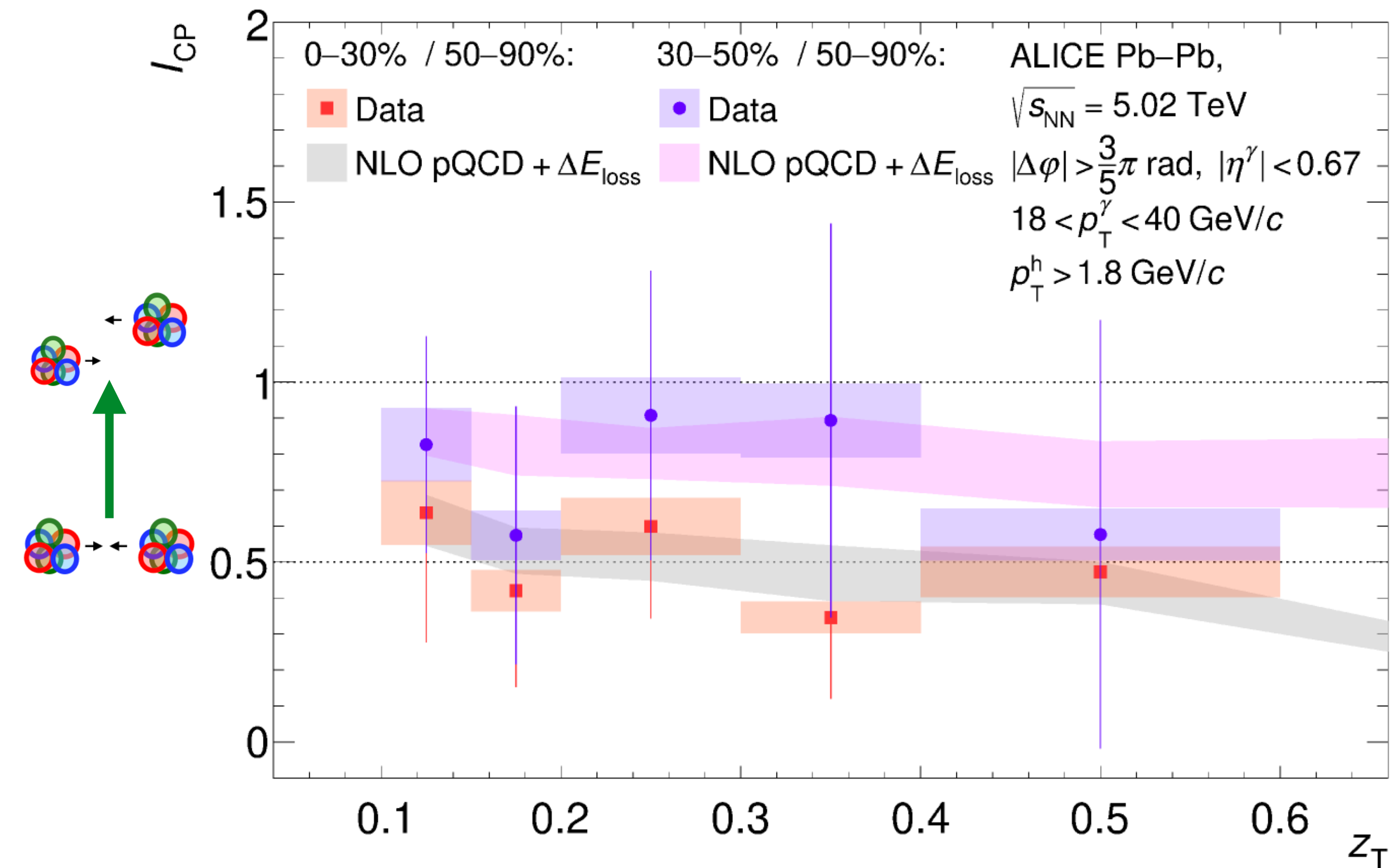
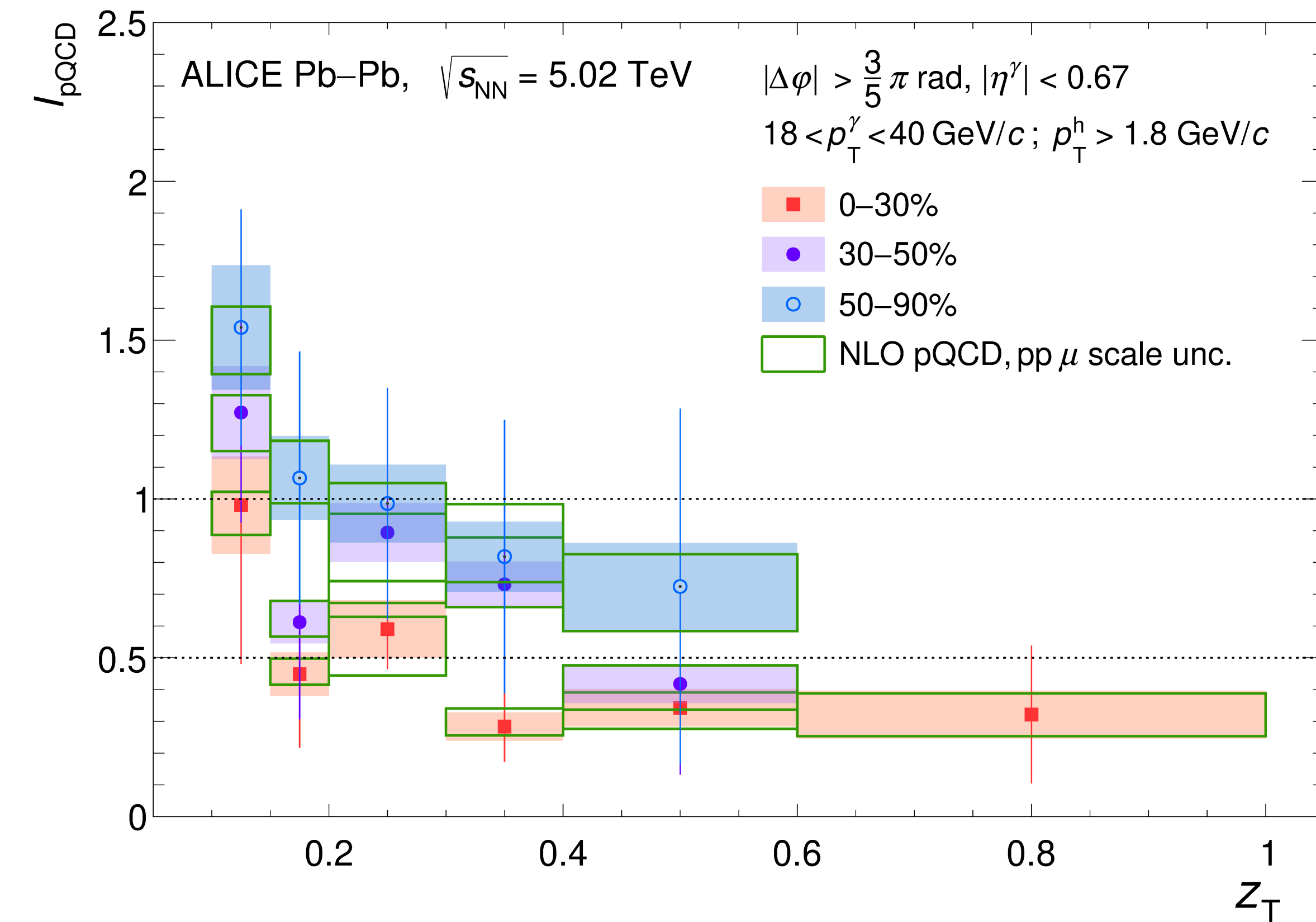
—●— C_{Narrow}
 —□— $C_{\text{Wide}} \times (1 - P)$
 —×— $C_{\gamma^{\text{iso}}} = 1/P \times C_{\text{Narrow}} - (1 - P)/P \times C_{\text{Wide}}$
 - - - $|\Delta\phi| = \frac{3}{5} \pi$ rad

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

$$I_{\text{pQCD}} = \text{Pb-Pb Data} / \text{pp pQCD}$$

$$I_{\text{CP}} = \text{Pb-Pb (semi) central} / \text{peripheral}$$

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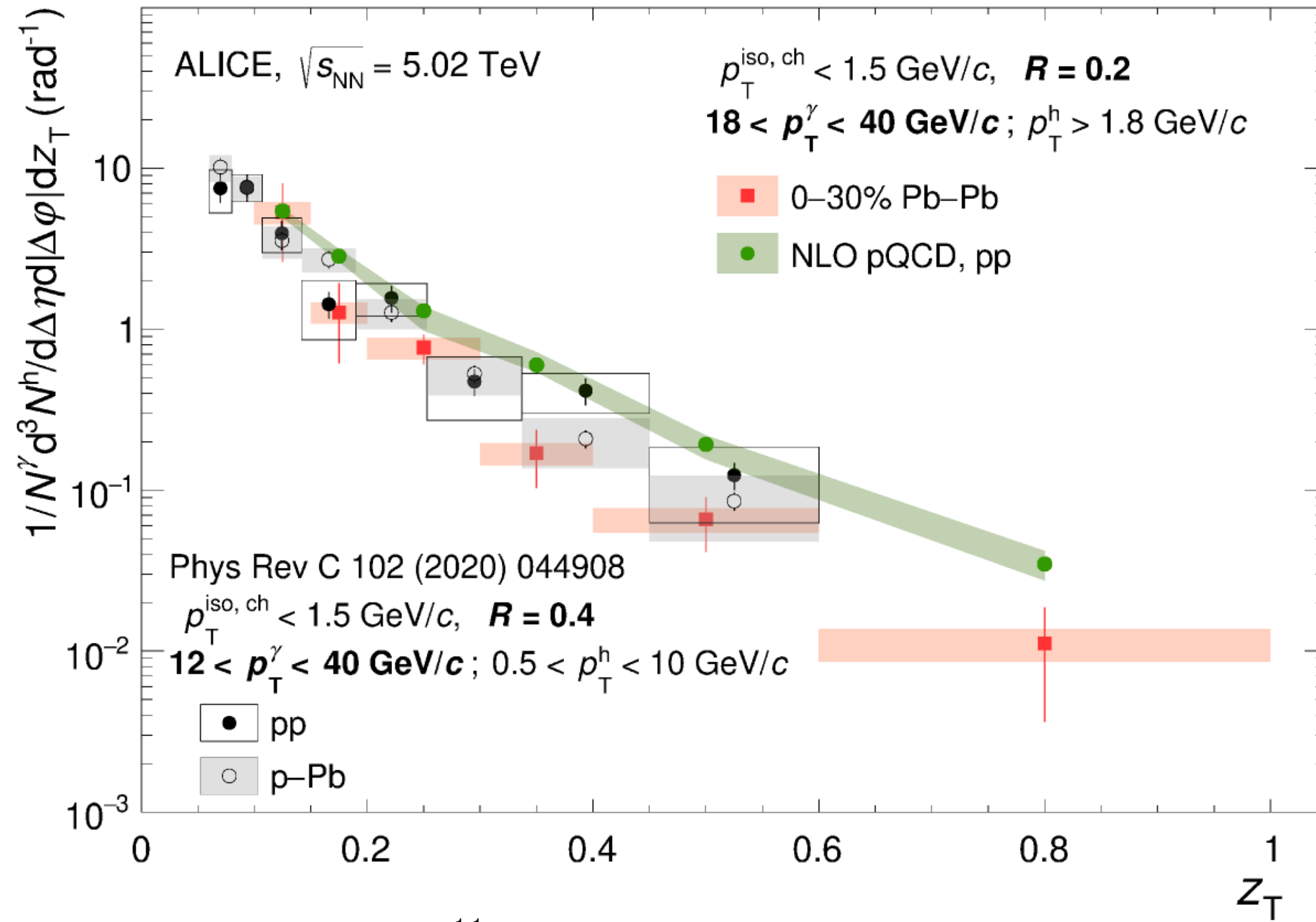
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- Ordering between centralities, central more suppressed than peripheral
- Hints of less suppression at lower z_T in I_{pQCD}

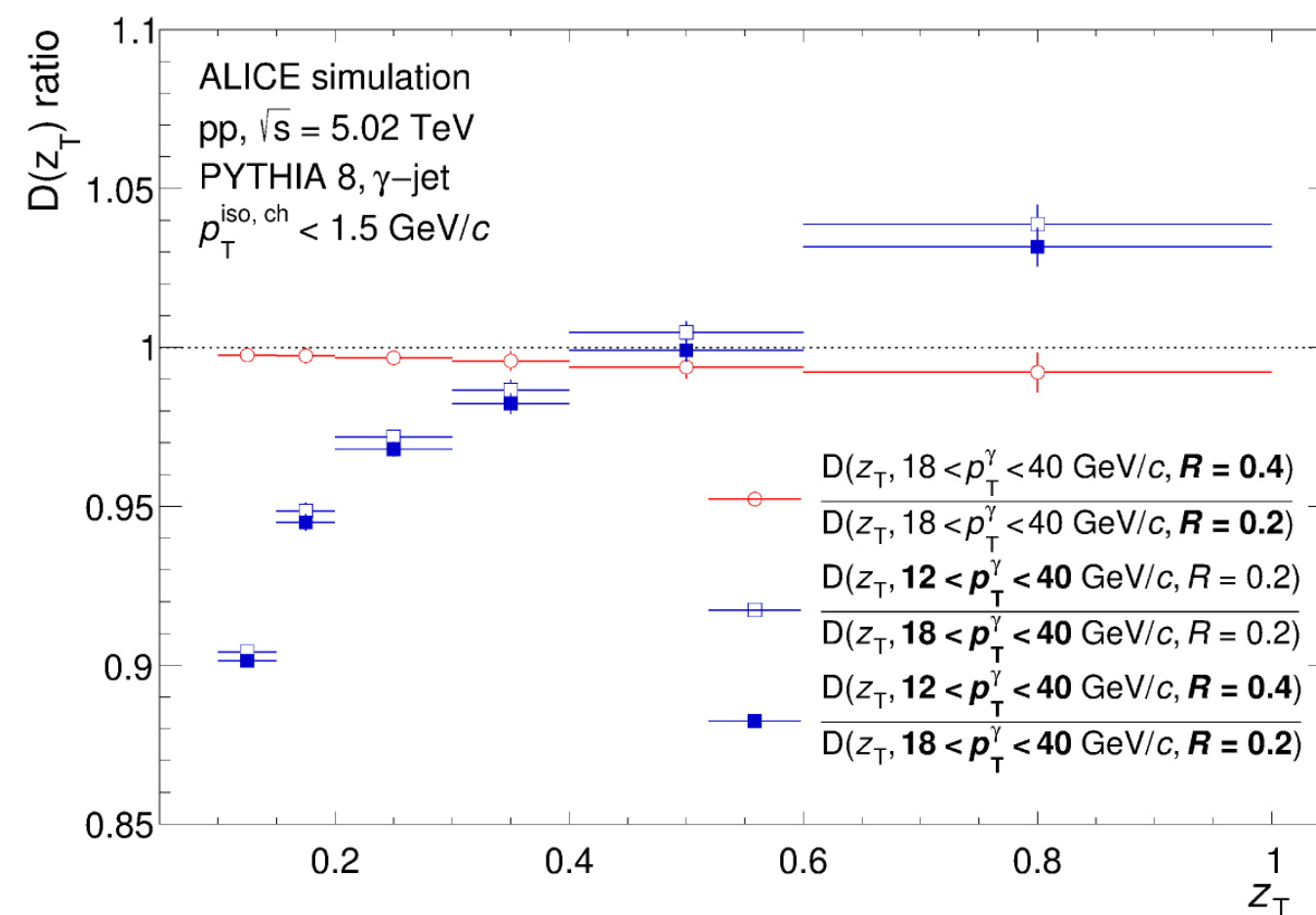
Isolated γ -hadron correlations in pp, p-Pb & 0-10% Pb-Pb



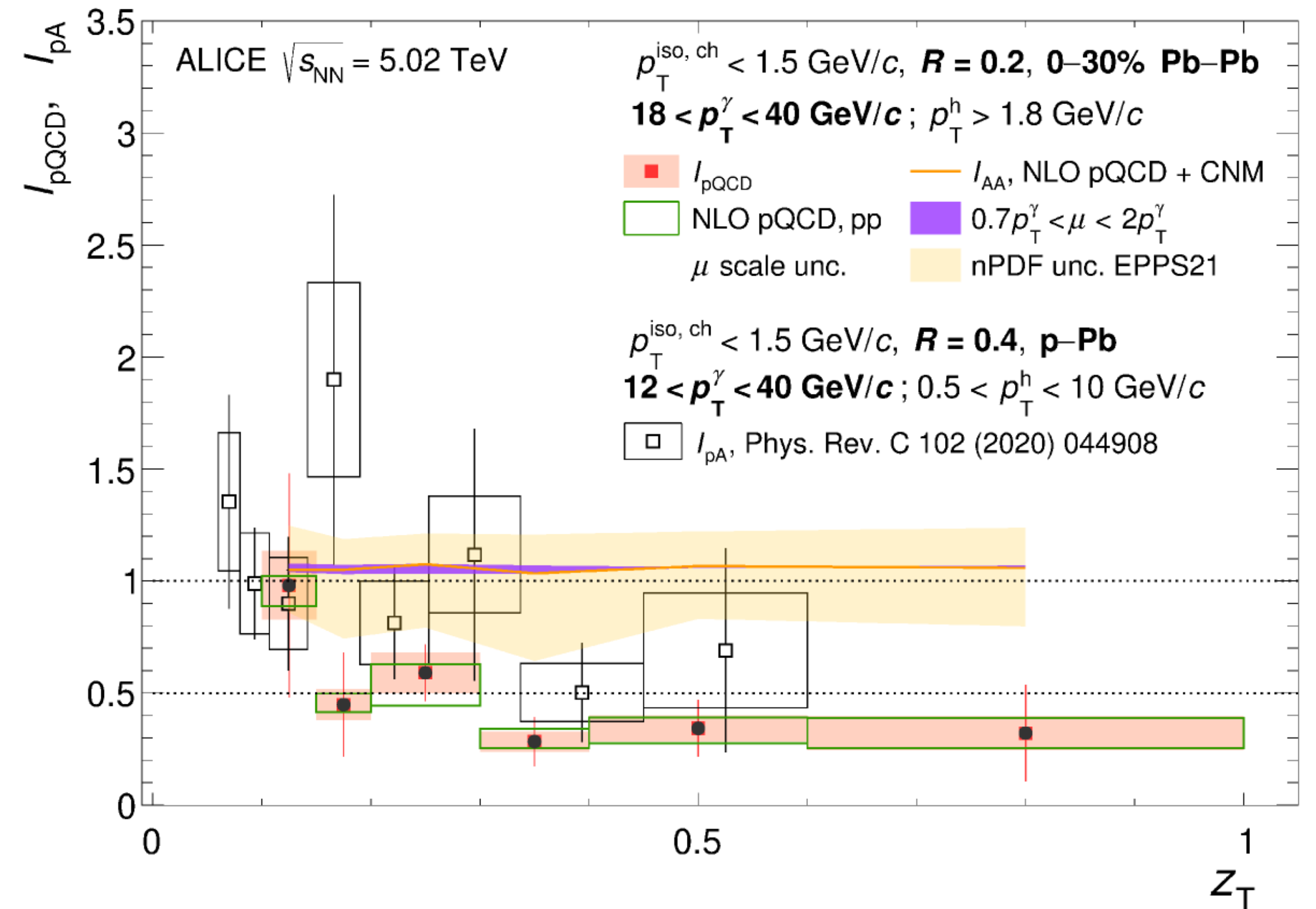
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ALI-PUB-628822

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