Isolated photon spectrum and photon-hadron correlations in Pb–Pb with ALICE

Assemblée Générale GDR QCD - Carolina Arata

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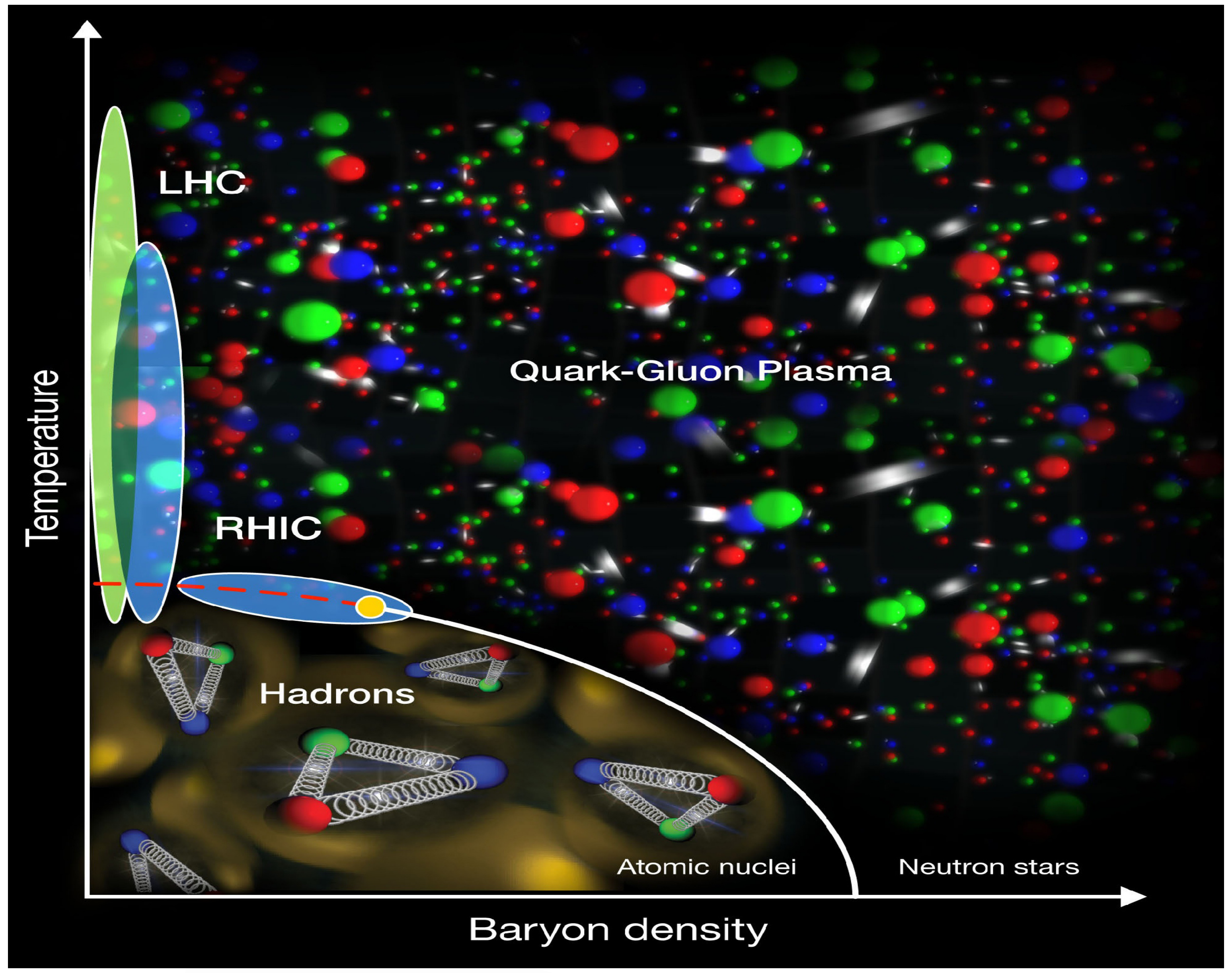
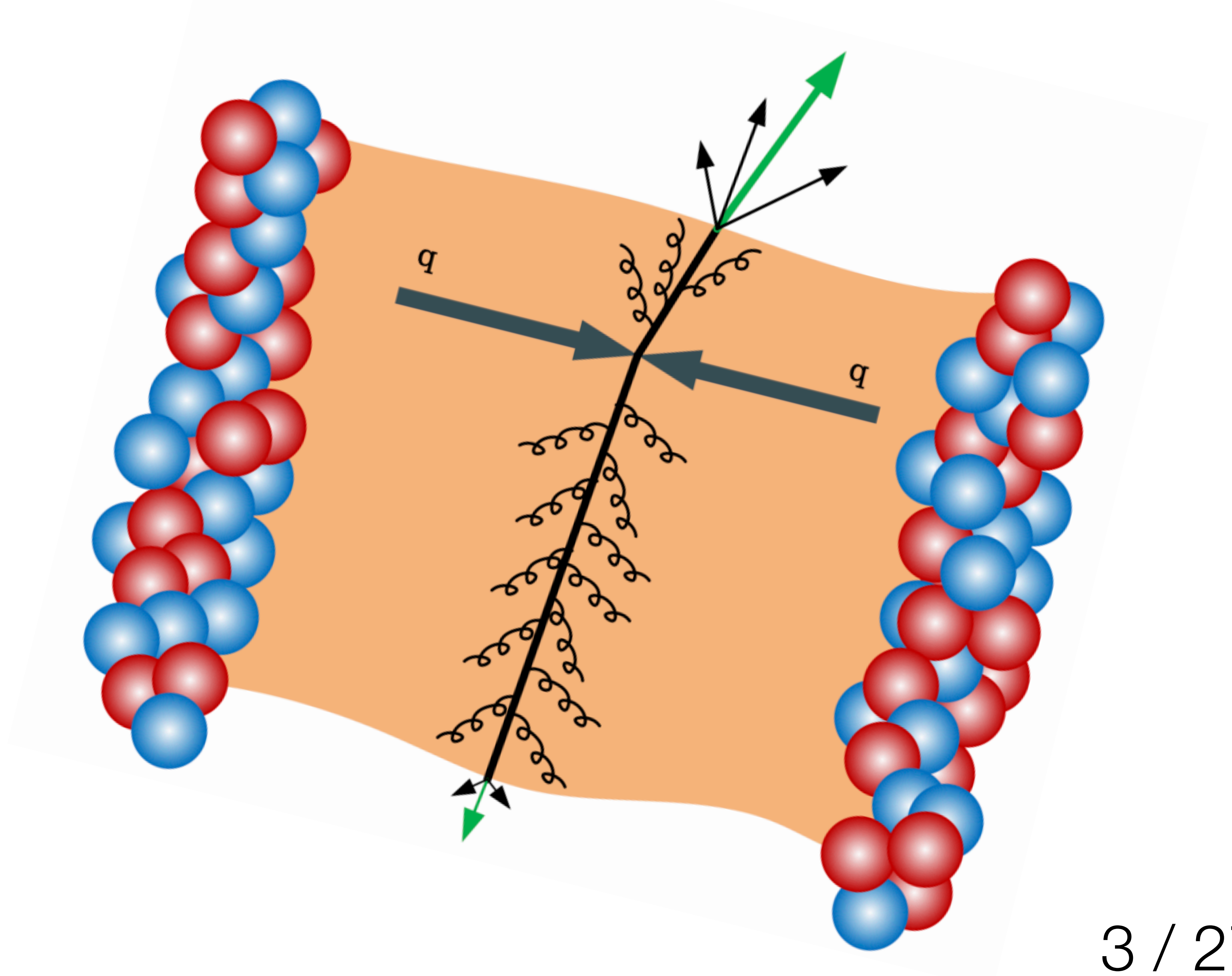
Study quark-gluon plasma with hard probes

- Transition of nuclear matter to a colour-deconfined medium, **quark-gluon plasma (QGP)**, under extreme conditions of temperature and/or density
  - **QGP** created via ultra-relativistic heavy-ion collisions
  - To study strong interaction



- **HARD PROBES:** high energy partons (photons and jets) produced in the early stage of the collision
  - partons traverse the QGP, lose energy then fragment into a **jet**



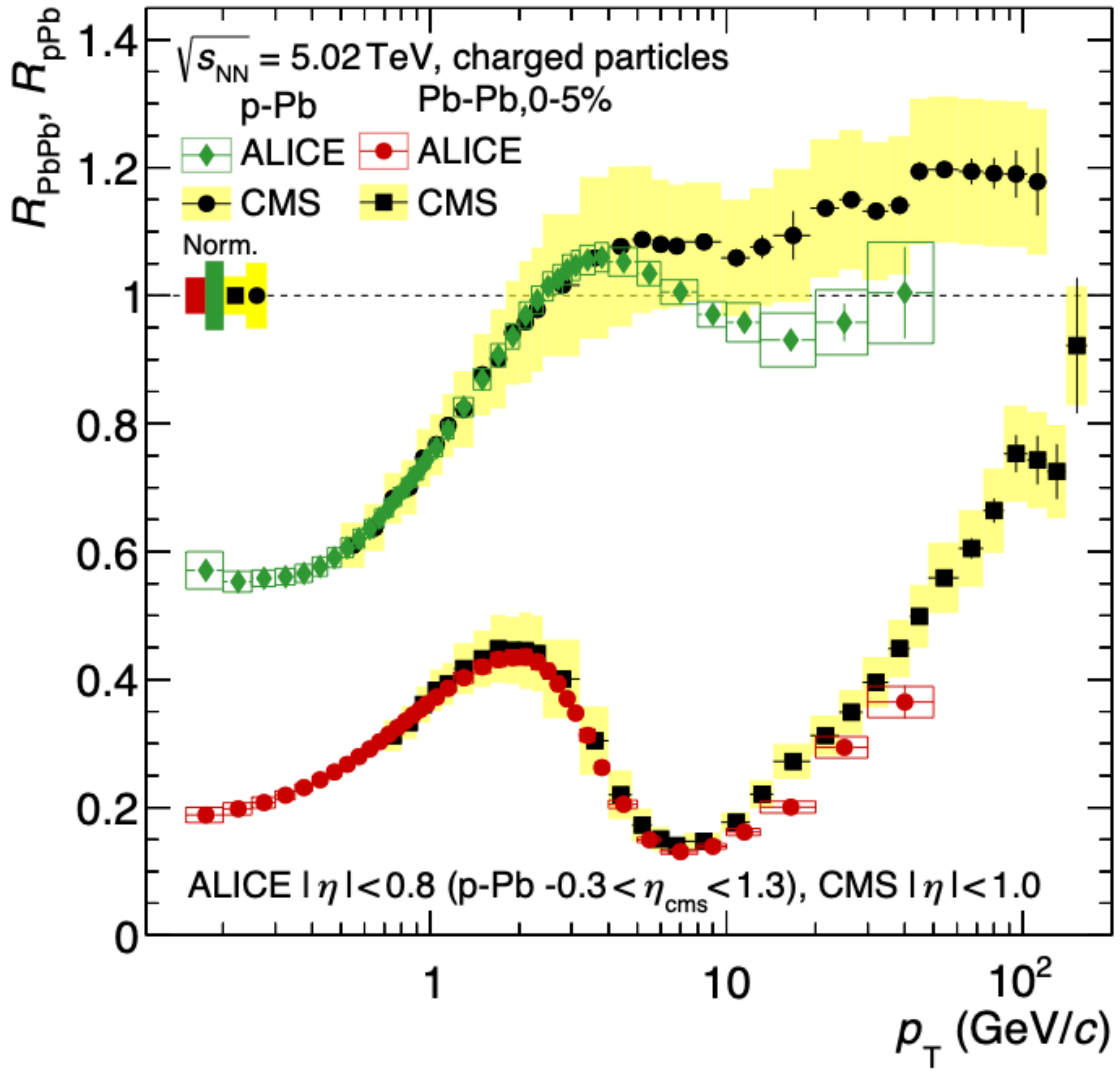
loss of energy in medium = jet quenching

Nuclear modification factor: R_{AA}

Nuclear modification factor:

$$R_{AA} = \frac{1}{N_{\mathrm{coll}}} \frac{\mathrm{d}\ N_{\mathrm{AA}}\ /\ \mathrm{d}\ p_{\mathrm{T}}}{\mathrm{d}\ N_{\mathrm{pp}}\ /\ \mathrm{d}\ p_{\mathrm{T}}}$$

- $R_{\mathrm{AA}} < 1 \rightarrow$ suppressed by medium
- $R_{\mathrm{AA}} = 1 \rightarrow$ transparent to medium
- $R_{\mathrm{AA}} > 1 \rightarrow$ generation in medium



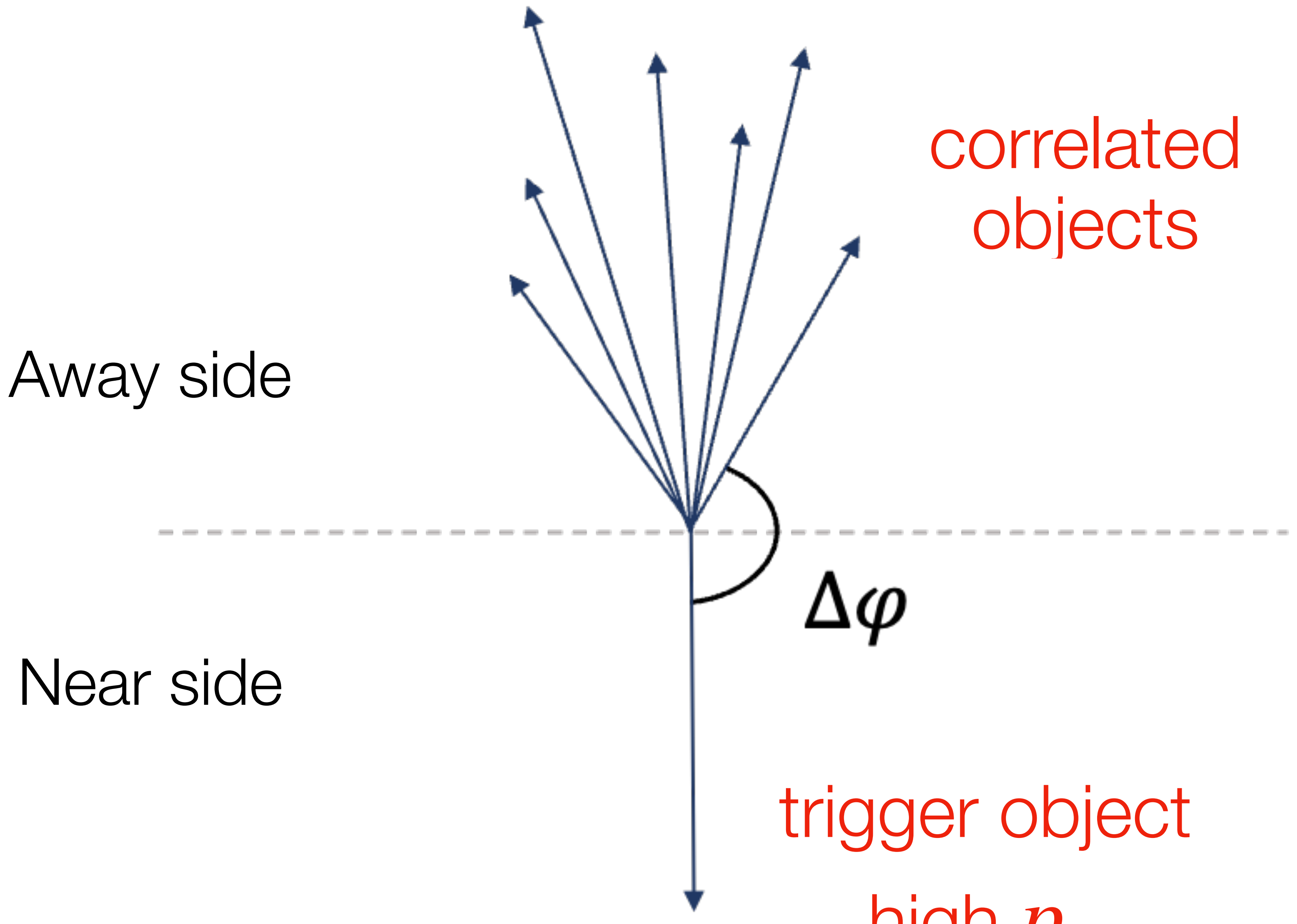
- Direct way to ***observe the jet quenching*** effect
- Not very sensitive to extract quantitative properties of the QGP

High p_{T} trigger particle—hadron correlations: I_{AA}

Azimuthal correlations distribution

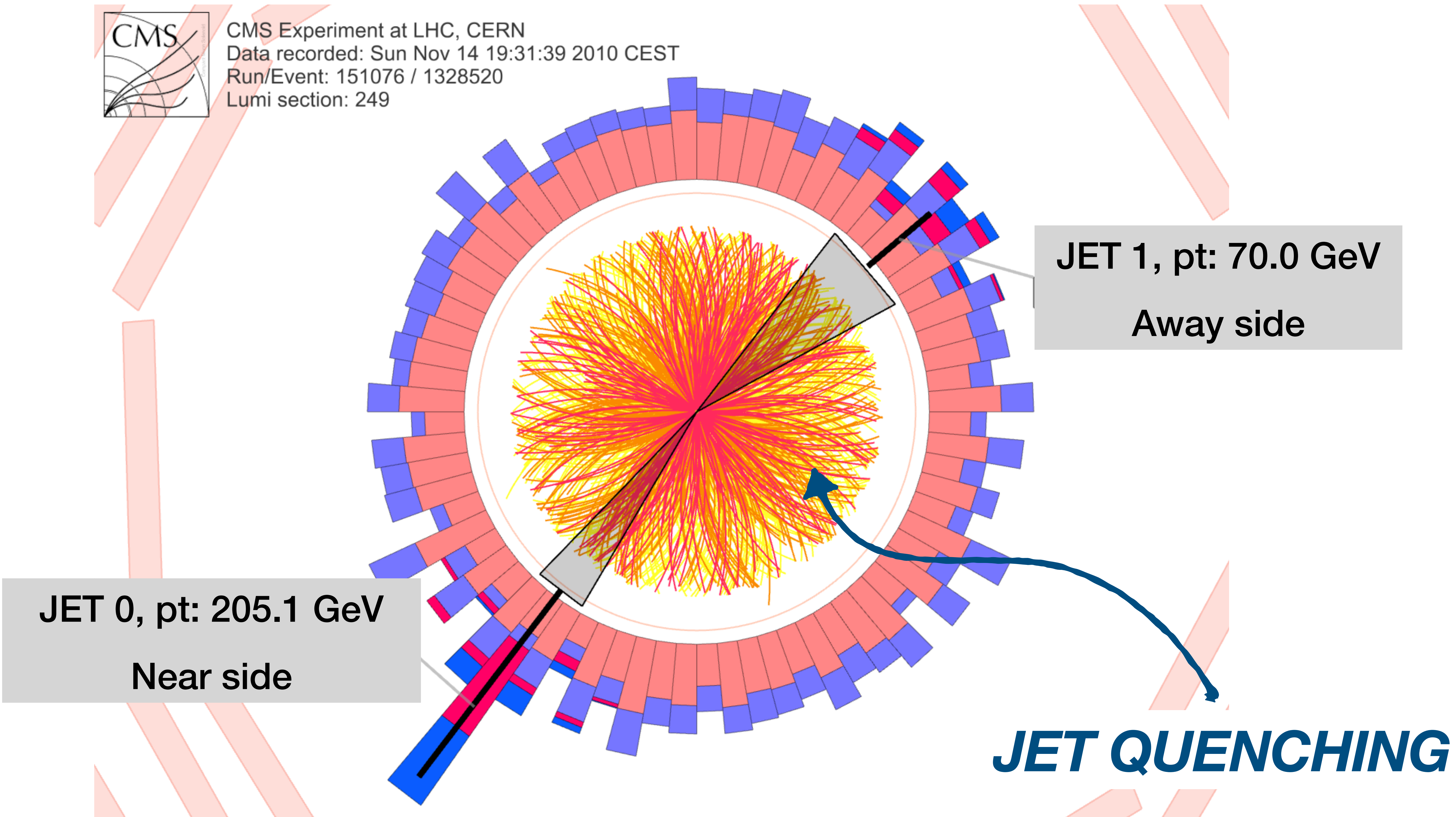
between the trigger and associated particles

$$\Delta\varphi = (\varphi^{\mathrm{trig}} - \varphi^{\mathrm{assoc}})$$



Jet-jet correlations:

CMS, Pb–Pb at $\sqrt{s_{NN}}$ = 2.76 TeV



Y: yield of particles in region opposite to the trigger particle ⟶ $I_{\mathrm{AA}} = Y_{\mathrm{AA}} / Y_{\mathrm{pp}}$

High p_T trigger particle—hadron correlations: I_{AA}

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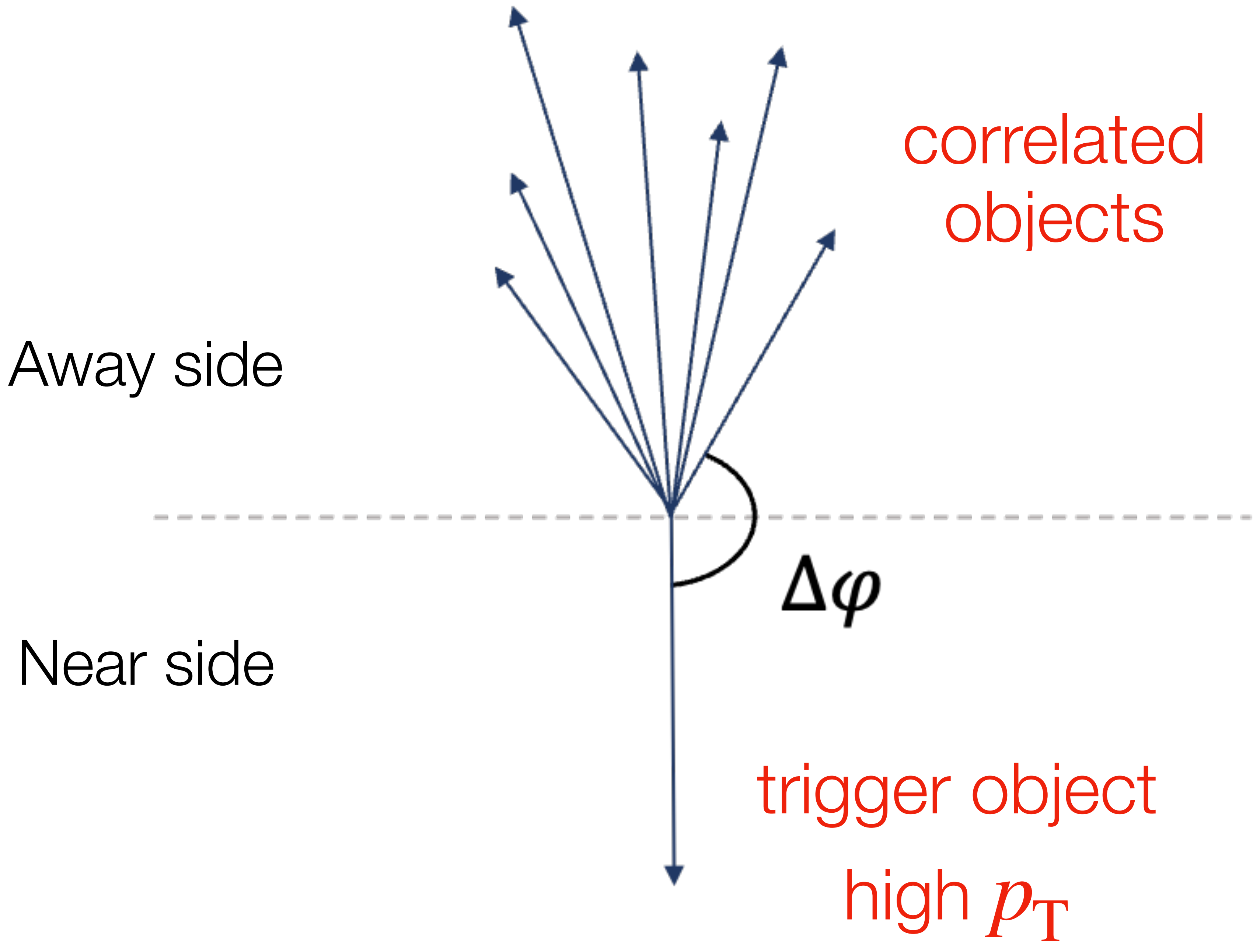
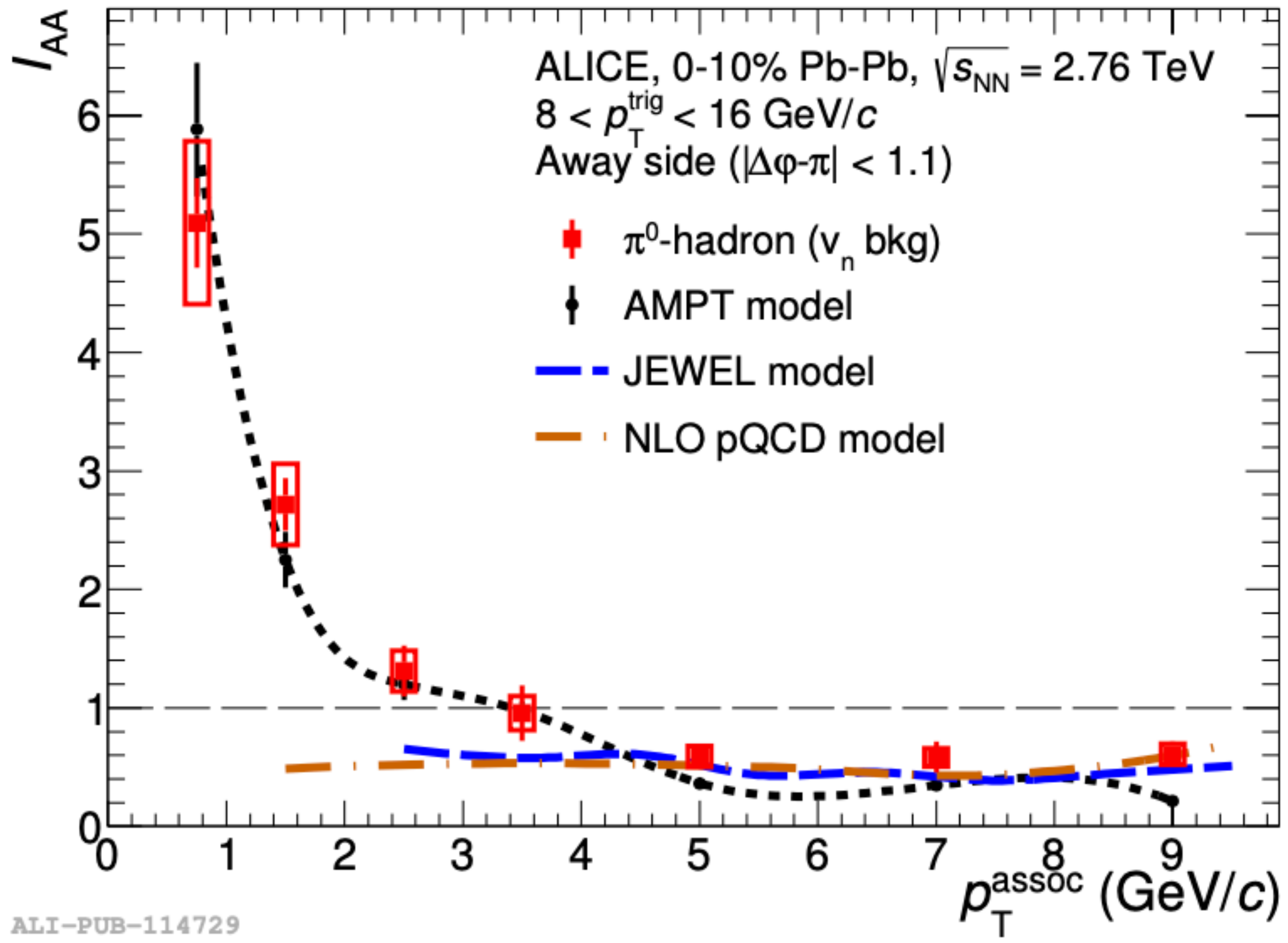


π^0-hadron **correlations:** $I_{AA} = Y_{AA}/Y_{pp}$

- $I_{AA} < 1 \rightarrow$ suppressed by medium
- $I_{AA} > 1 \rightarrow$ generation in medium



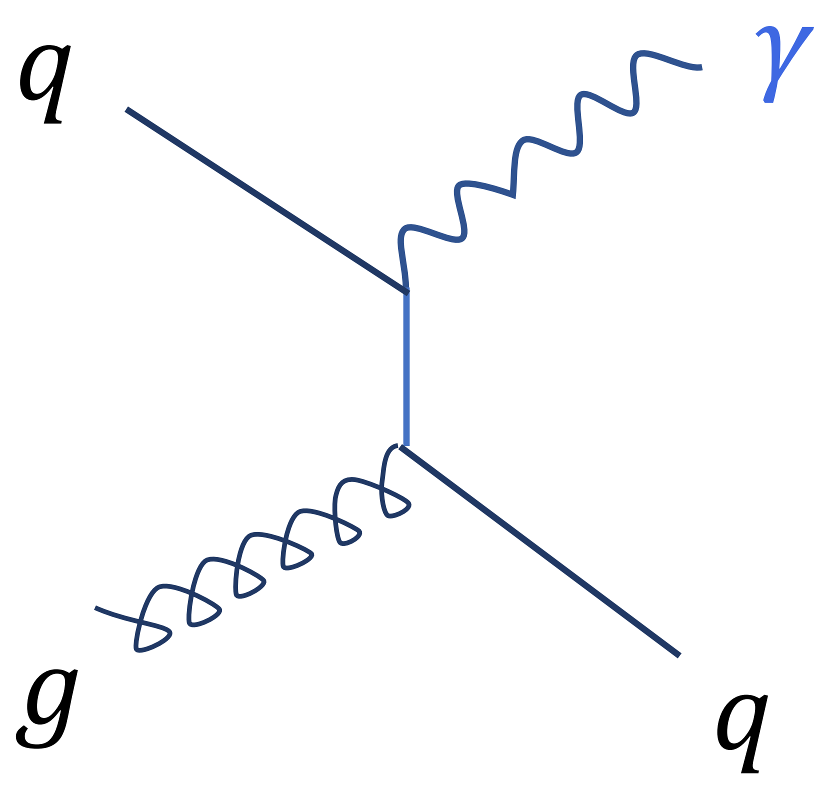
- Way to observe the jet quenching and **how energy is redistributed**

Trigger objects like hadrons **not ideal:**

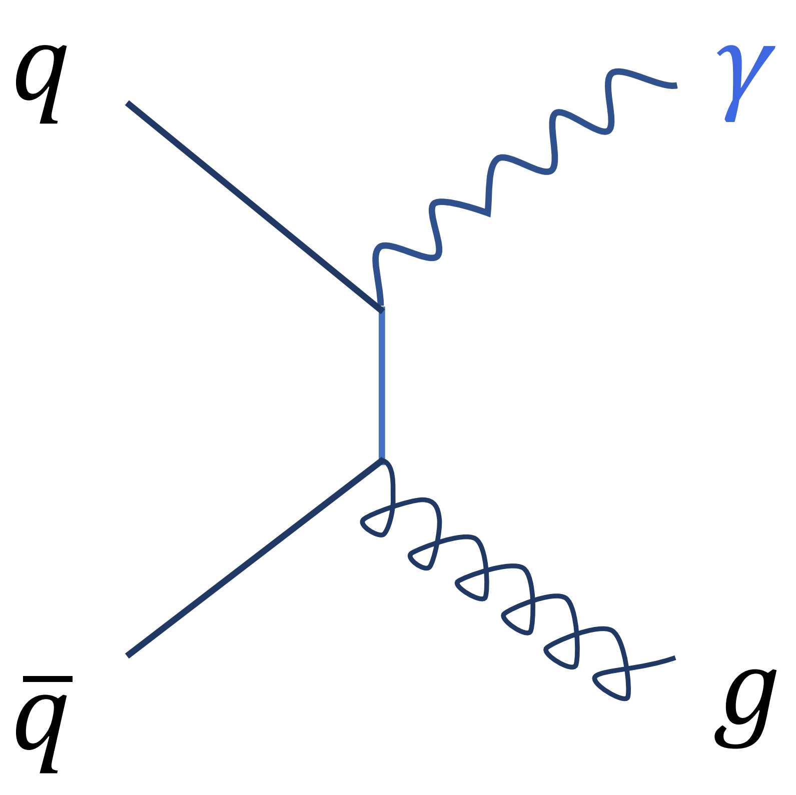
$p_T^{trigger} \neq p_T^{parton}$ **BIASED REFERENCE**

Why photons in heavy-ion collisions?

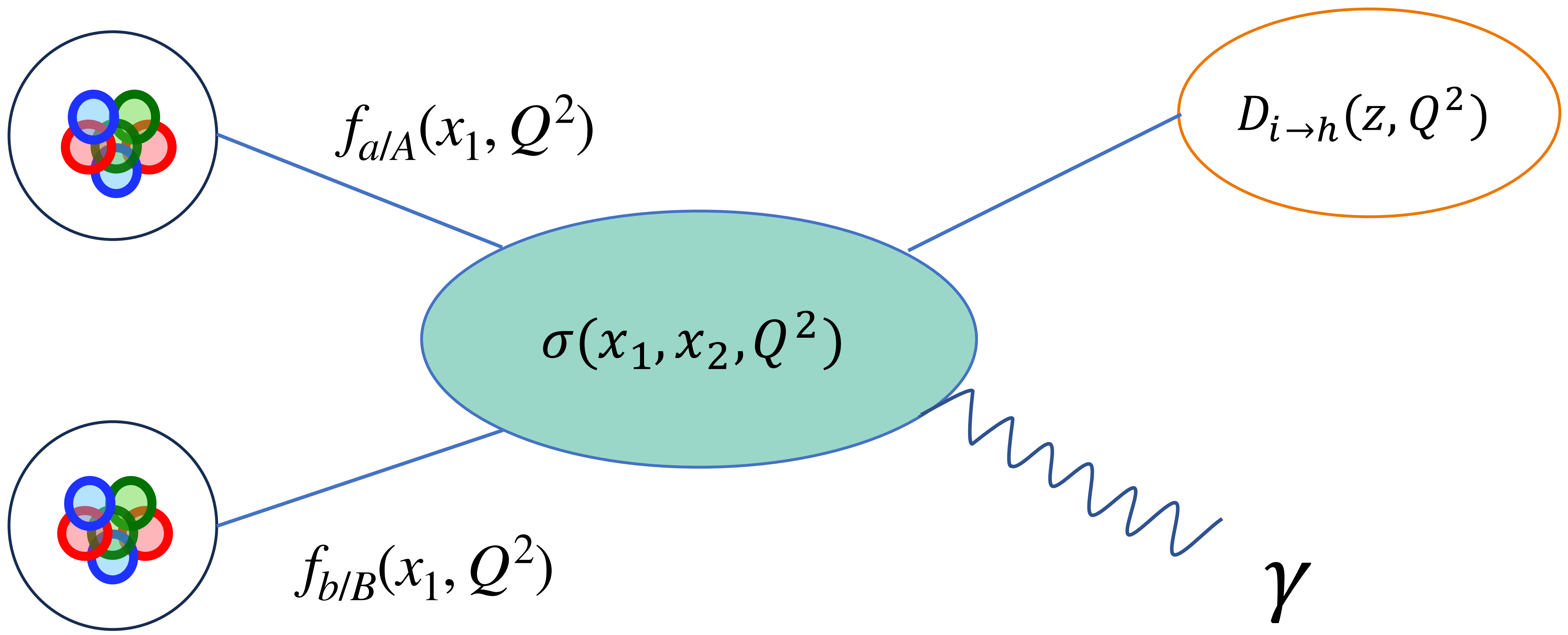
- Photons are colour-neutral: **not affected** by QCD medium
- Direct prompt photons produced in initial hard scattering come from 2→2 processes



Compton



Annihilation



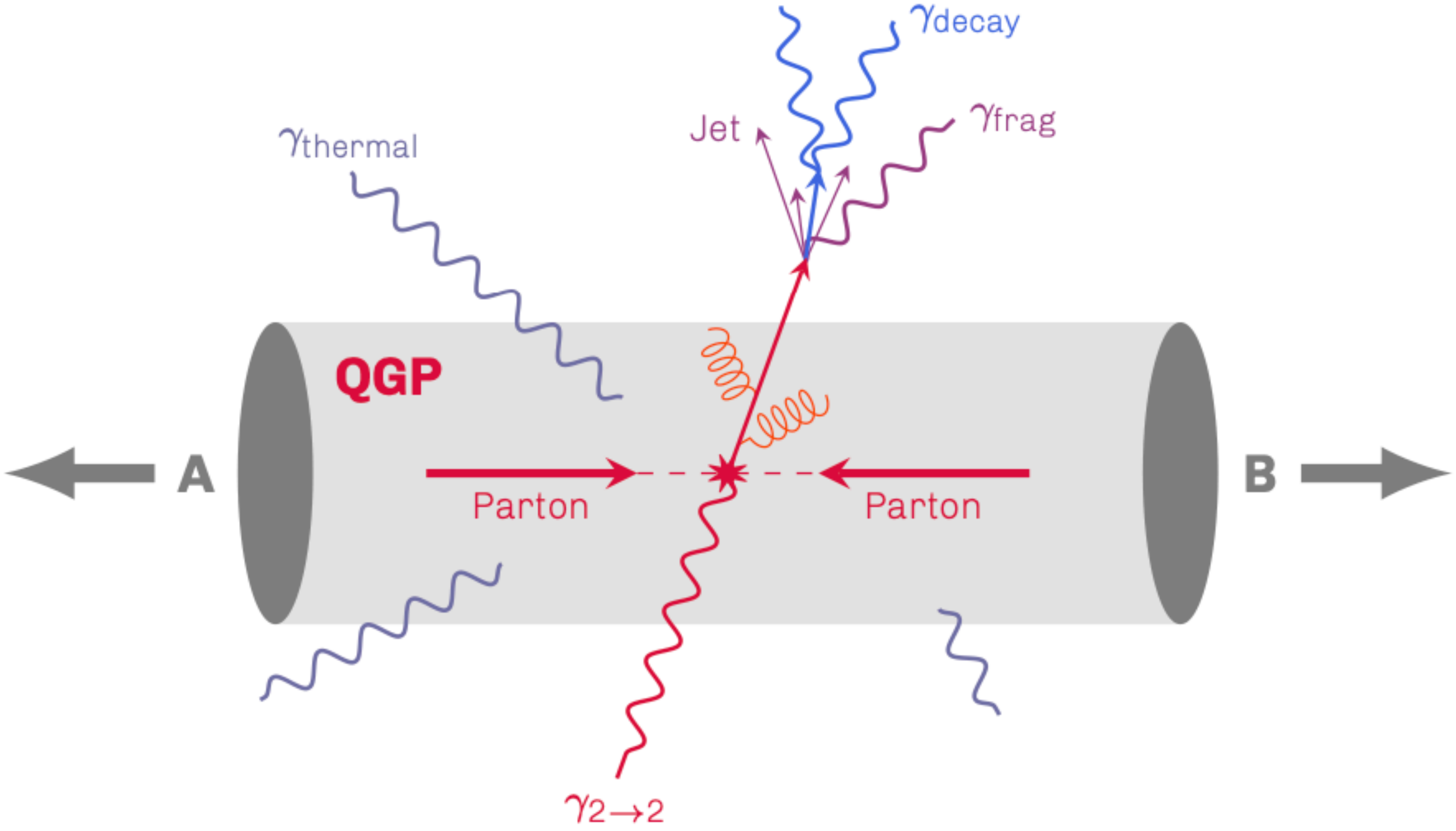
Perturbative QCD is applicable:

$$d\sigma^{hard}_{AB\to h} = f_{a/A}(x_1, Q^2) \otimes f_{b/B}(x_2, Q^2) \otimes d\sigma^{hard}_{ab\to c}(x_1, x_2, Q^2) \otimes D_{c\to h}(z, Q^2)$$

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

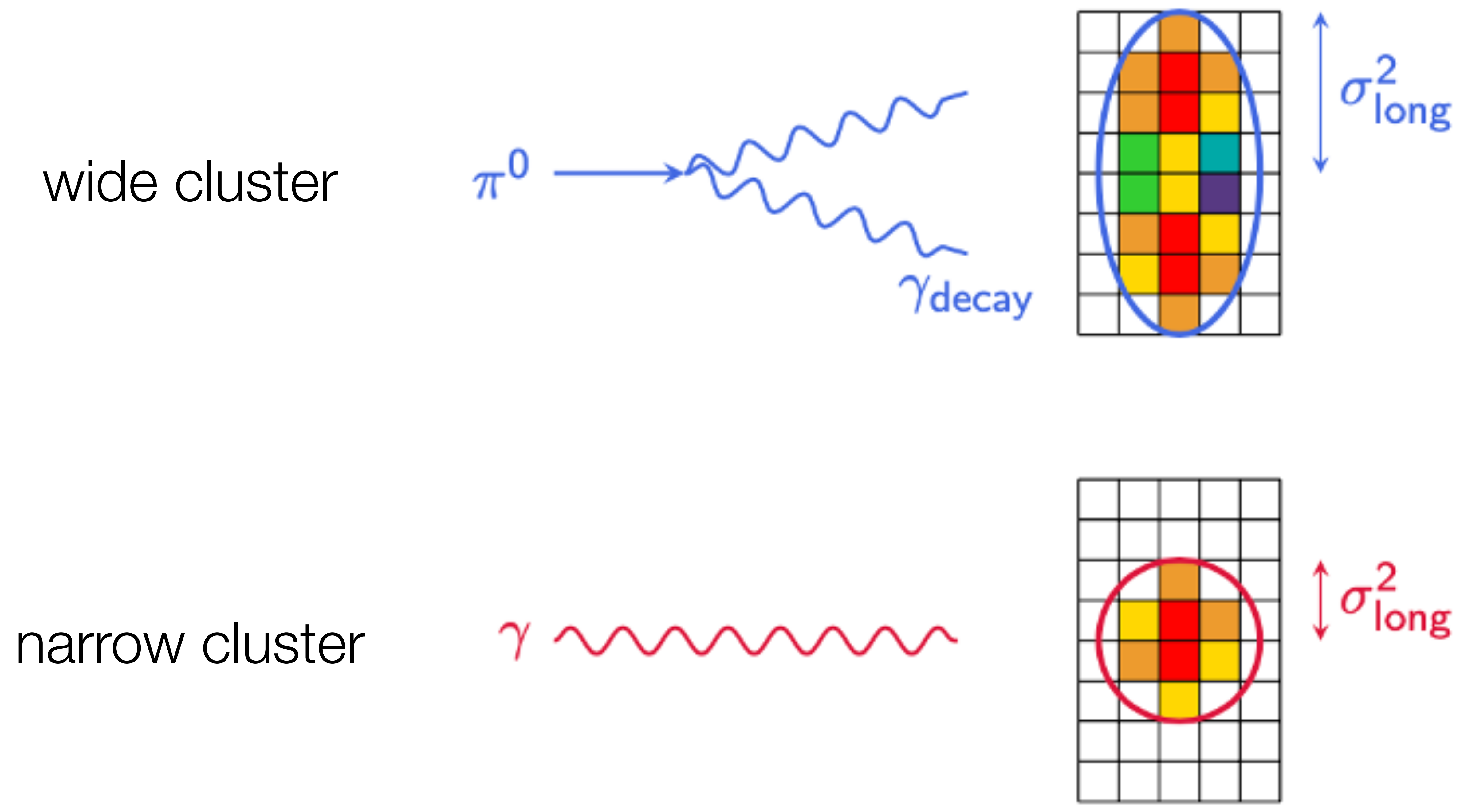
- These photons give a handle to **test pQCD**: constrain PDFs & nPDFs
- Allow to **tag the initial energy** of the parton $p_T^{\gamma} \approx p_T^{\text{parton}}$ = **REFERENCE**

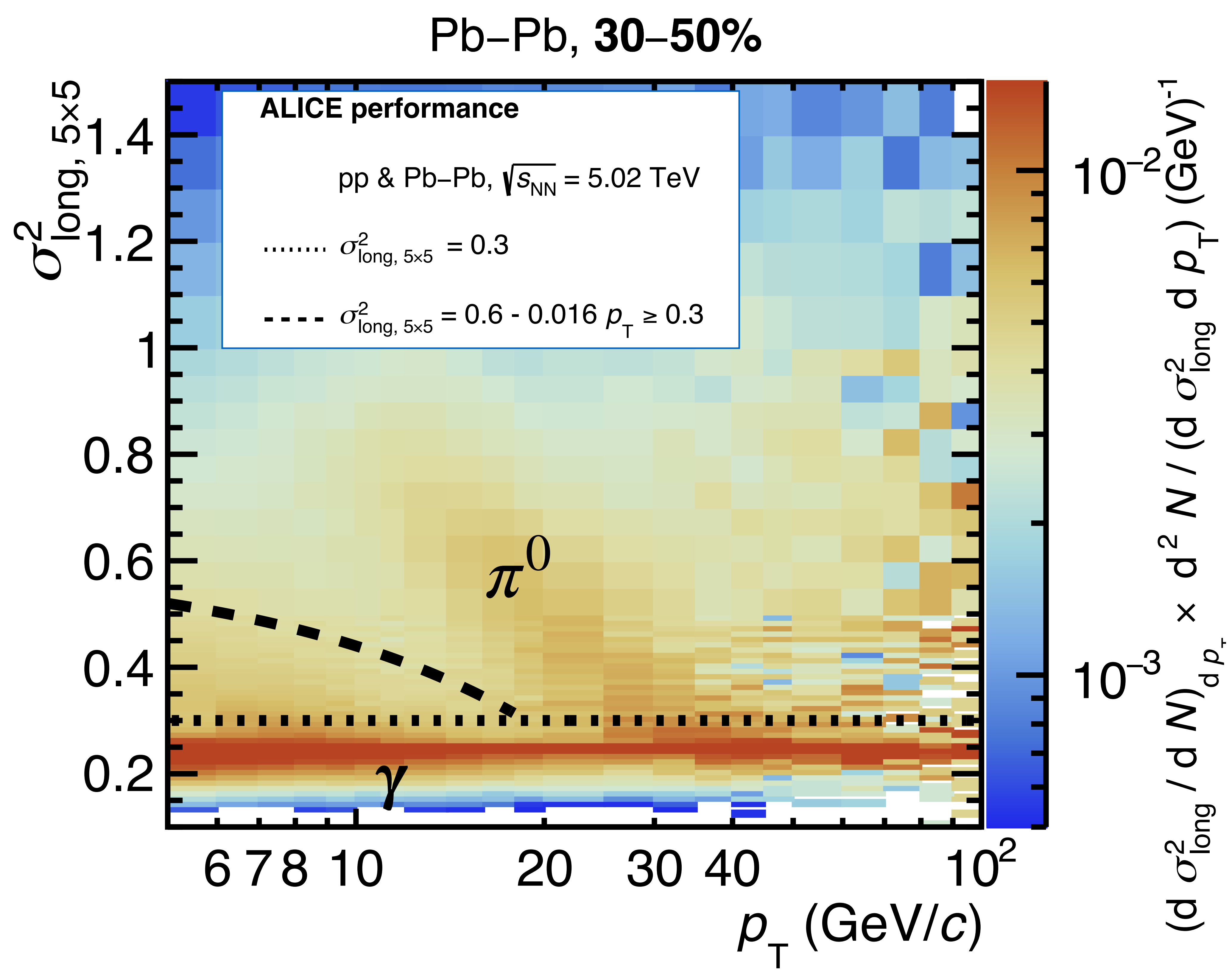
Photon sources



- Main sources: γ_{decay} from hadronic decays
- Same order $\gamma_{\text{fragmentation}}$ (parton fragmentation) and $\gamma_{2\to2}$ (Compton & annihilation)
  - How to identify $\gamma_{2\to2}$? ***Calorimeter identification*** and ***isolation***

Photon identification in ALICE with the EMCal





- ***Clusters***: E deposits in adjacent calorimeter cells

Discrimination between γ and high energy π^0 :

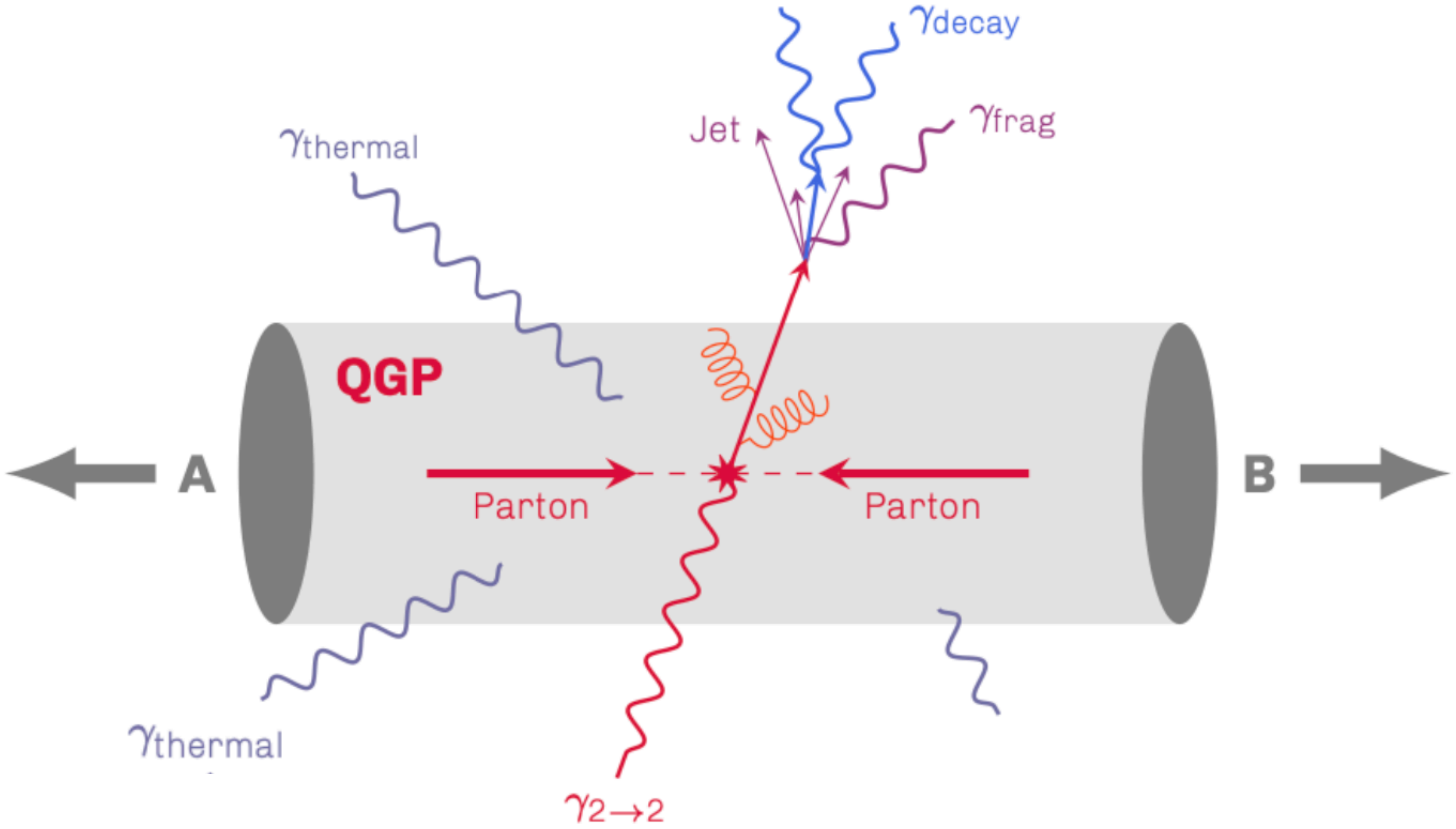
lateral dispersion $\sigma^2_{\text{long, }5\times5}$ of a cluster

- γ : $\sigma^2_{\text{long, }5\times5} < 0.3$
- π^0: - E < 30 GeV → $\sigma^2_{\text{long, }5\times5} > 0.4$

  - E > 30 GeV, π^0 and γ bands overlap

Photon isolation method

- $\sigma^2_{\text{long, }5\times5}$ not enough: necessary to **reject the non $\gamma_{2\to2}$ photons**
  - $\gamma_{2\to2}$ ***photons***: produced far from other particles (*underlying event (UE)* excepted)



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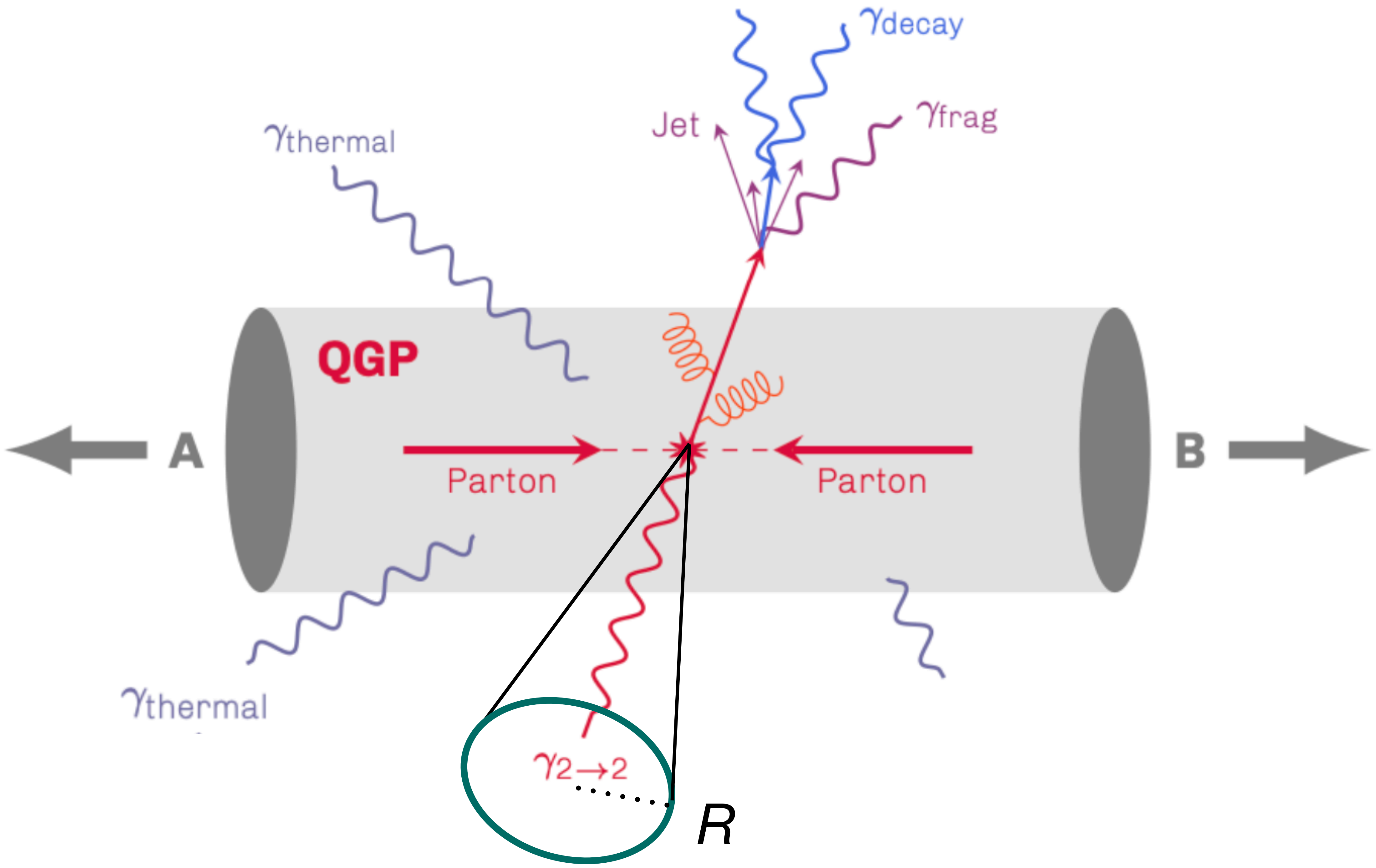
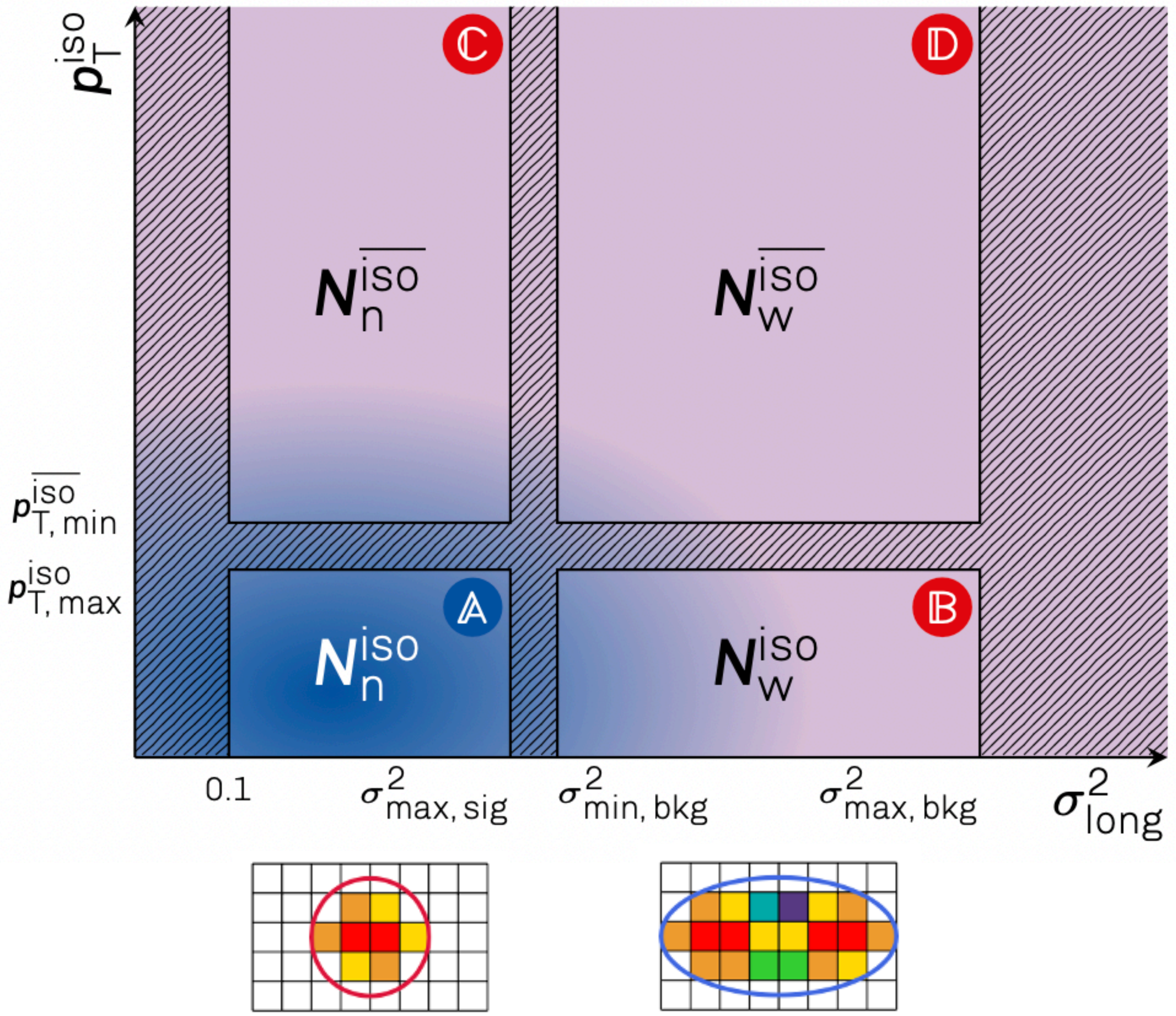


- Define a cone radius around a candidate photon: $R = 0.2$ or 0.4
- Condition on the total p_T inside the cone: $p_T^{\text{iso, ch}} = \sum p_T^{\text{tracks in cone}} - \rho_{UE}\,\pi R^2 < 1.5$ GeV/c
  - ρ_{UE} , UE density estimated with η-band method

Purity: ABCD method



- Phase space of calorimeter clusters divided in 4 regions: the three background dominated regions ($\mathbb{BCD}$) used to estimate the background contribution in the signal region ($\mathbb{A}$)

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

Semi data-driven approach, simulation to correct correlations between $p_T^{iso,\,ch}$ and $\sigma^2_{long,\,5\times5}$

Corrections due to:

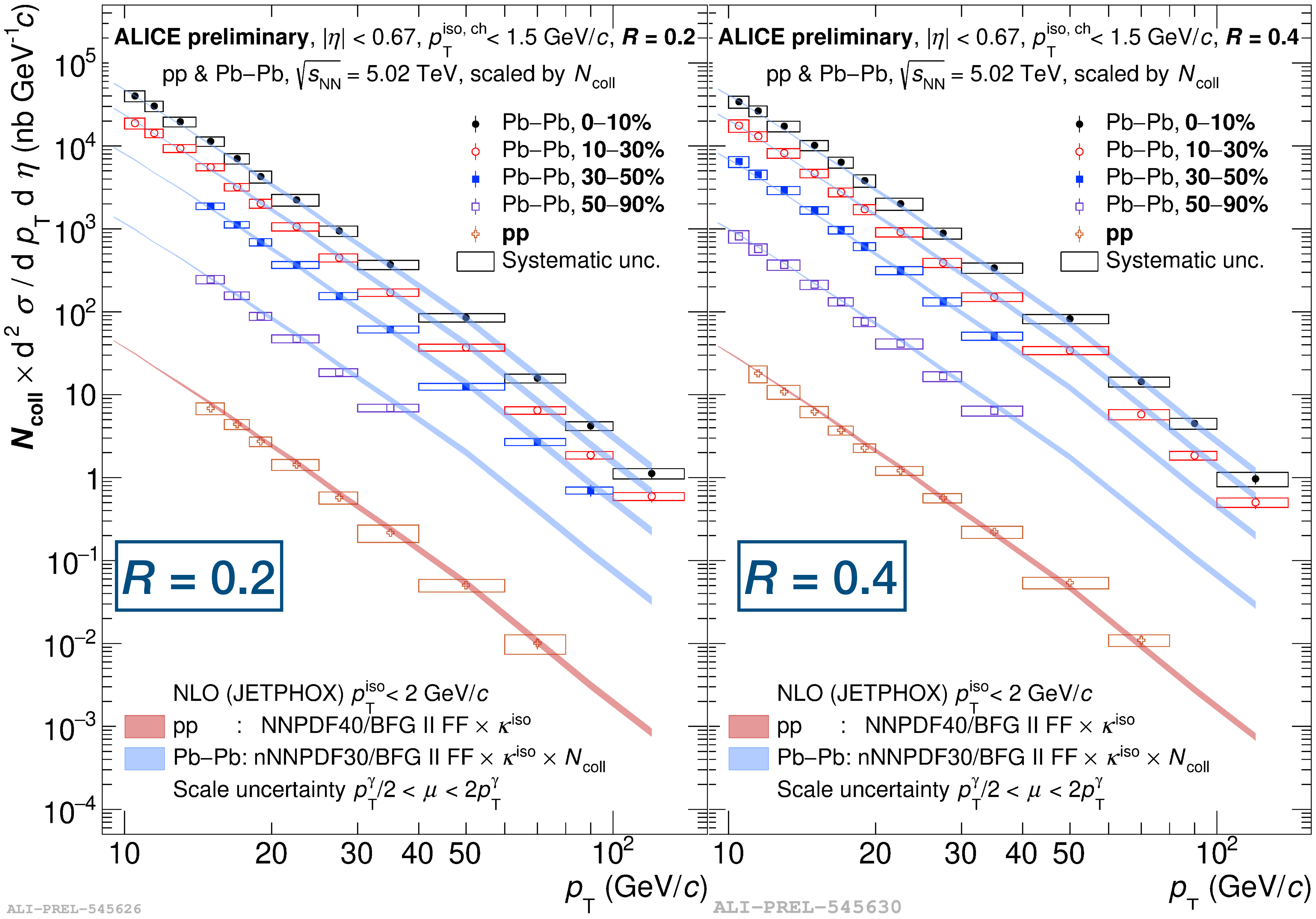
Background isolation fraction depends on the circularity

Signal not contained only in $\mathbb{A}$, it spreads over $\mathbb{B}$, $\mathbb{C}$ and $\mathbb{D}$ regions

Purity - ABCD method in Pb–Pb and pp

- Purity for different collision systems and different R
- Reduce influence of statistical fluctuations with Sigmoid or Erf functions fits → used in spectra

Cross section: R = 0.2 and R = 0.4

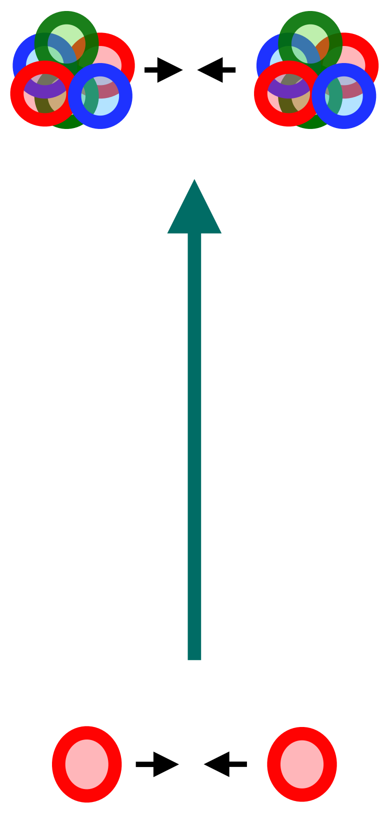


- Wide p_T range
- NLO pQCD predictions (JETPHOX)

Theory is centrality independent

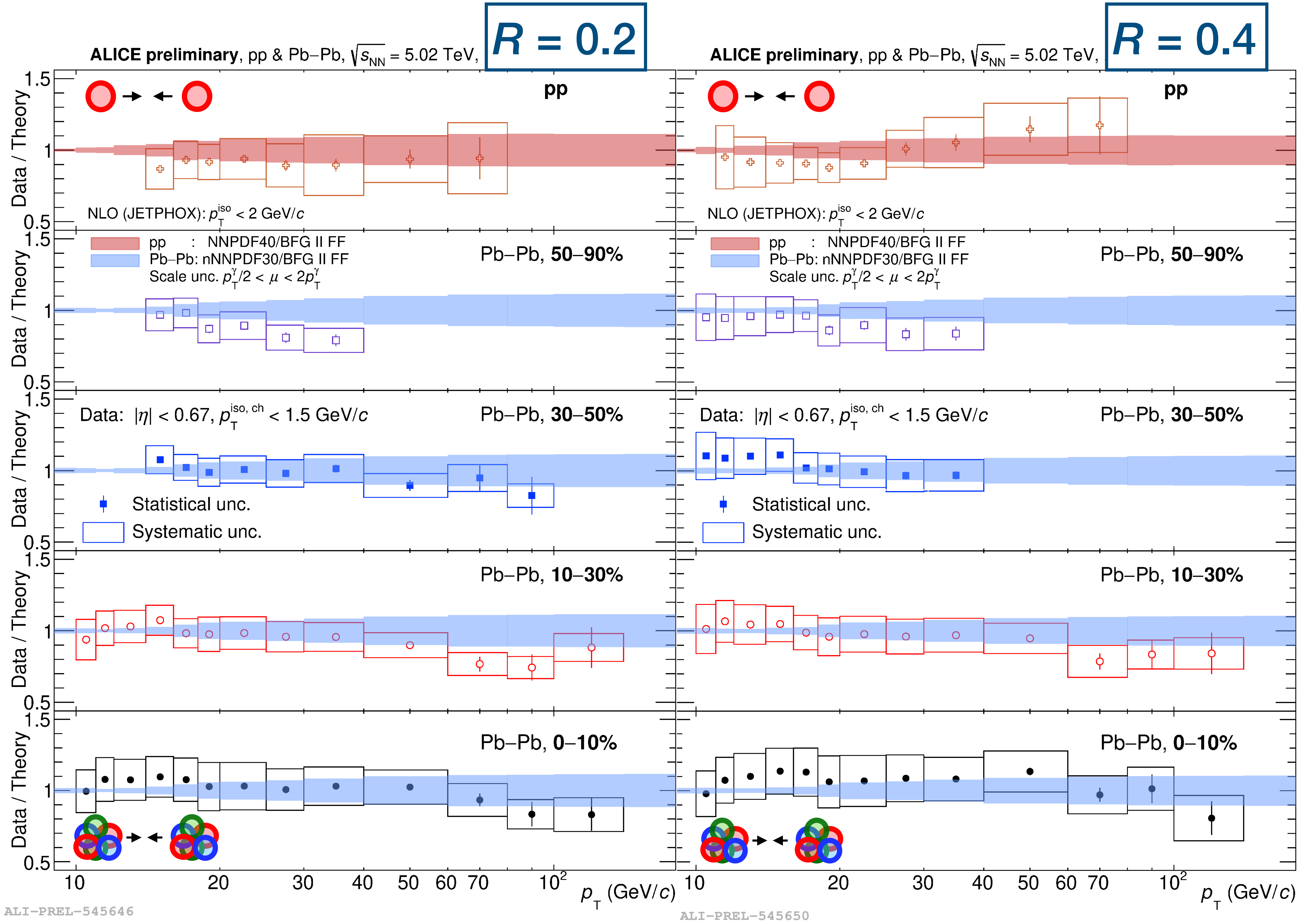
Only difference:

PDF (pp) vs nPDF × N_{coll} (Pb–Pb)



G. Conesa

Cross section Data / Theory: $R = 0.2$ and $R = 0.4$



- Wide p_T range
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Theory is centrality independent

Only difference:

PDF (pp) vs nPDF $\times N_{coll}$ (Pb–Pb)

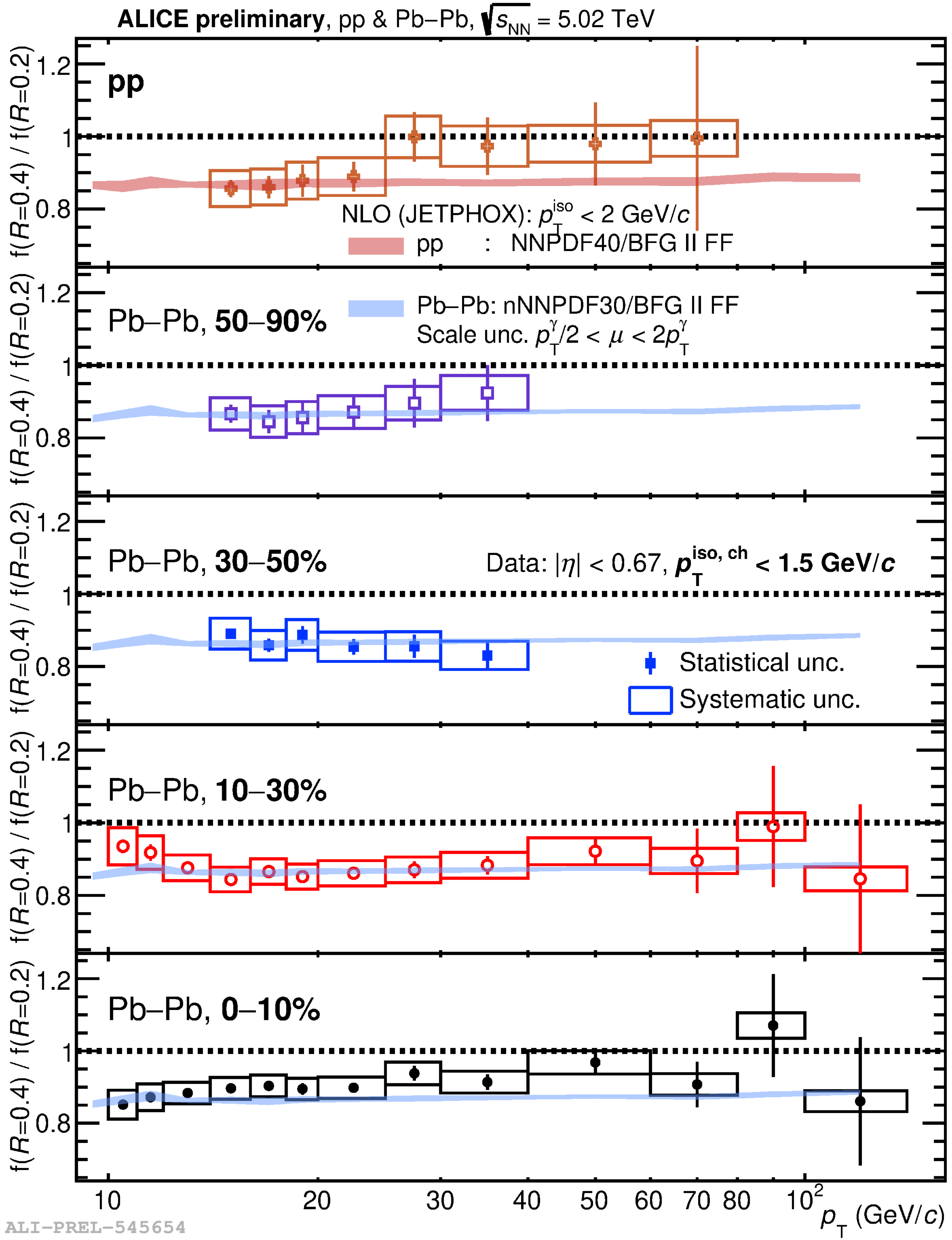
Theory & data agreement for both R and systems within uncertainties

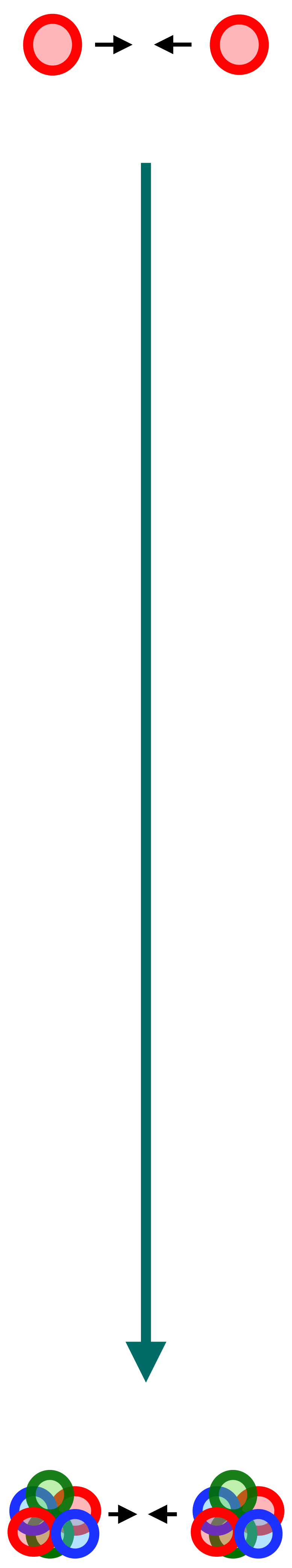
G. Conesa

Ratio of cross sections with different R

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

- Ratio ***sensitive to fraction of*** γ_{fragm} surviving the isolation selection
- ***Quite good agreement with theory in all collision systems***
  - Theory (NLO) seems to control:
    - isolation mechanism in 2→2 processes
    - direct fragmentation + prompt γ production even in Pb–Pb





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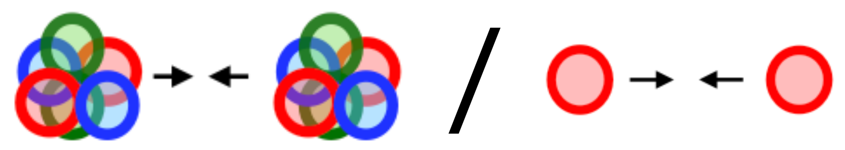
Nuclear modification factor R_{AA}



$$R_{AA} = \frac{1}{N_{\rm coll}} \frac{{\rm d}\, N_{\rm AA} / {\rm d}\, p_T}{{\rm d}\, N_{\rm pp} / {\rm d}\, p_T}$$

- ***0-50%: consistent with 1***

  Model comparison: *NLO pQCD ratio*

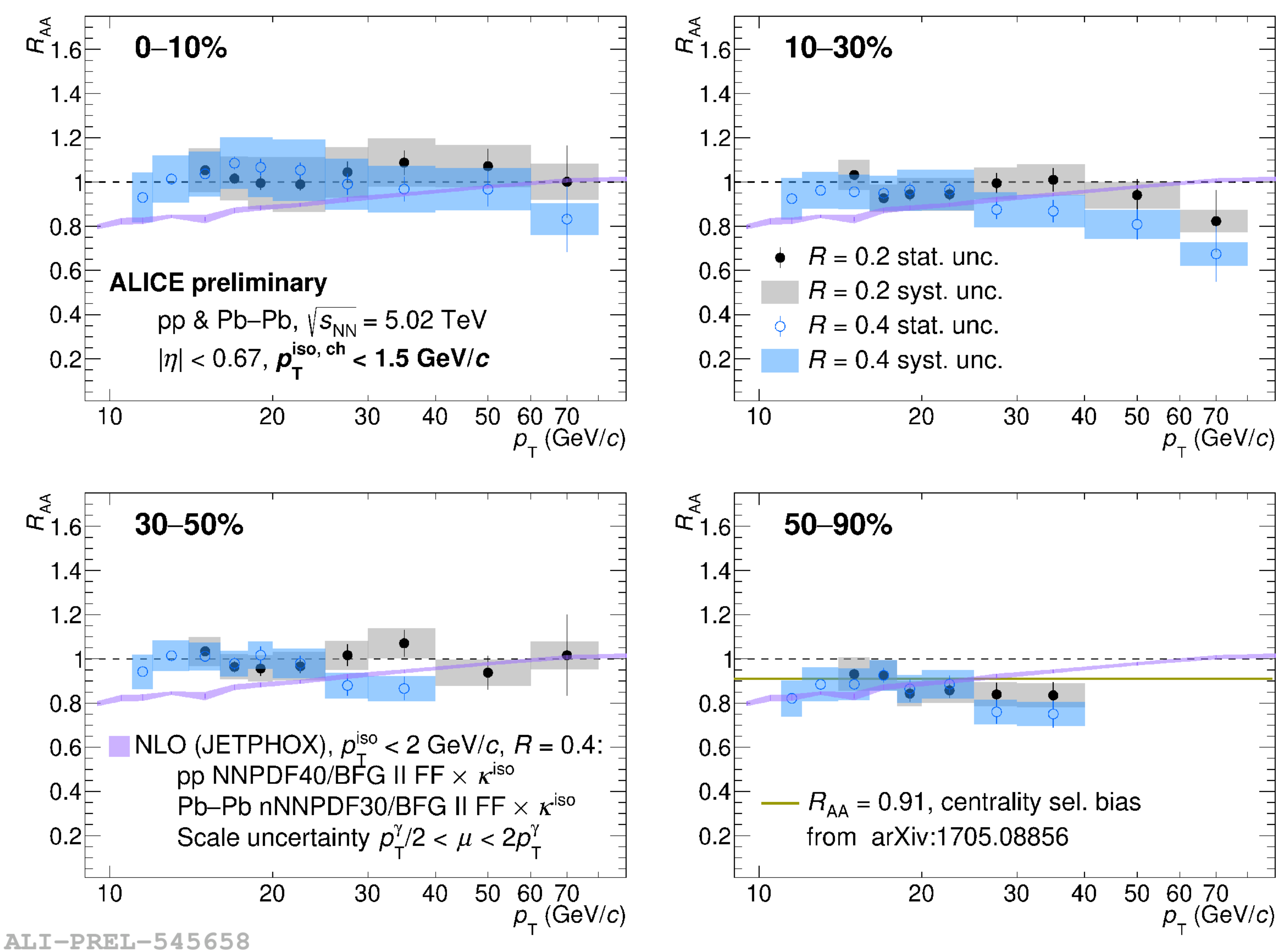
  $p_{\rm T} > 20$ GeV/*c* → agreement

  $p_{\rm T} < 20$ GeV/*c* → **some tension**

- ***50-90% < 1 due to centrality selection bias of Glauber model***

  Agreement *with model* by C. Loizides & A. Morsch [Phys.Lett.B 773 (2017)408-411]

G. Conesa



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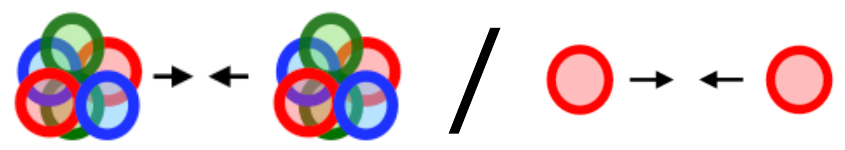
Nuclear modification factor R_{AA}



G. Conesa

$$R_{AA} = \frac{1}{N_{coll}} \frac{d\,N_{AA} / d\,p_T}{d\,N_{pp} / d\,p_T}$$

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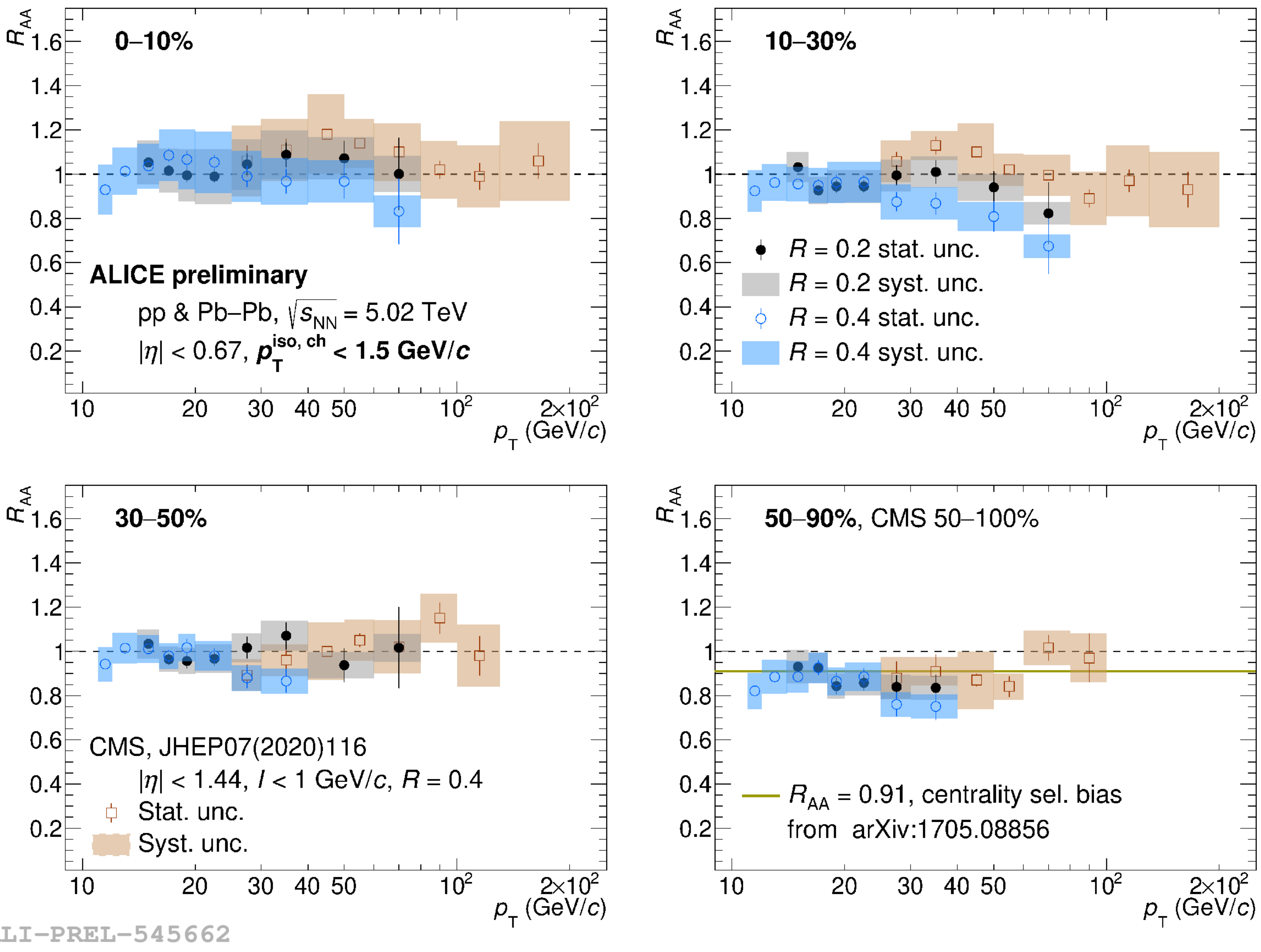
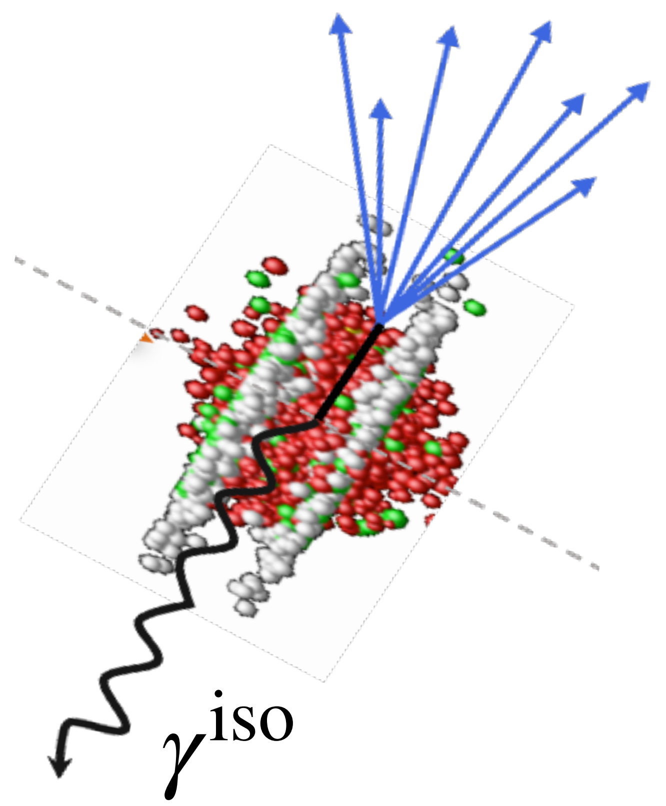
- ***Comparison to CMS***: overall agreement

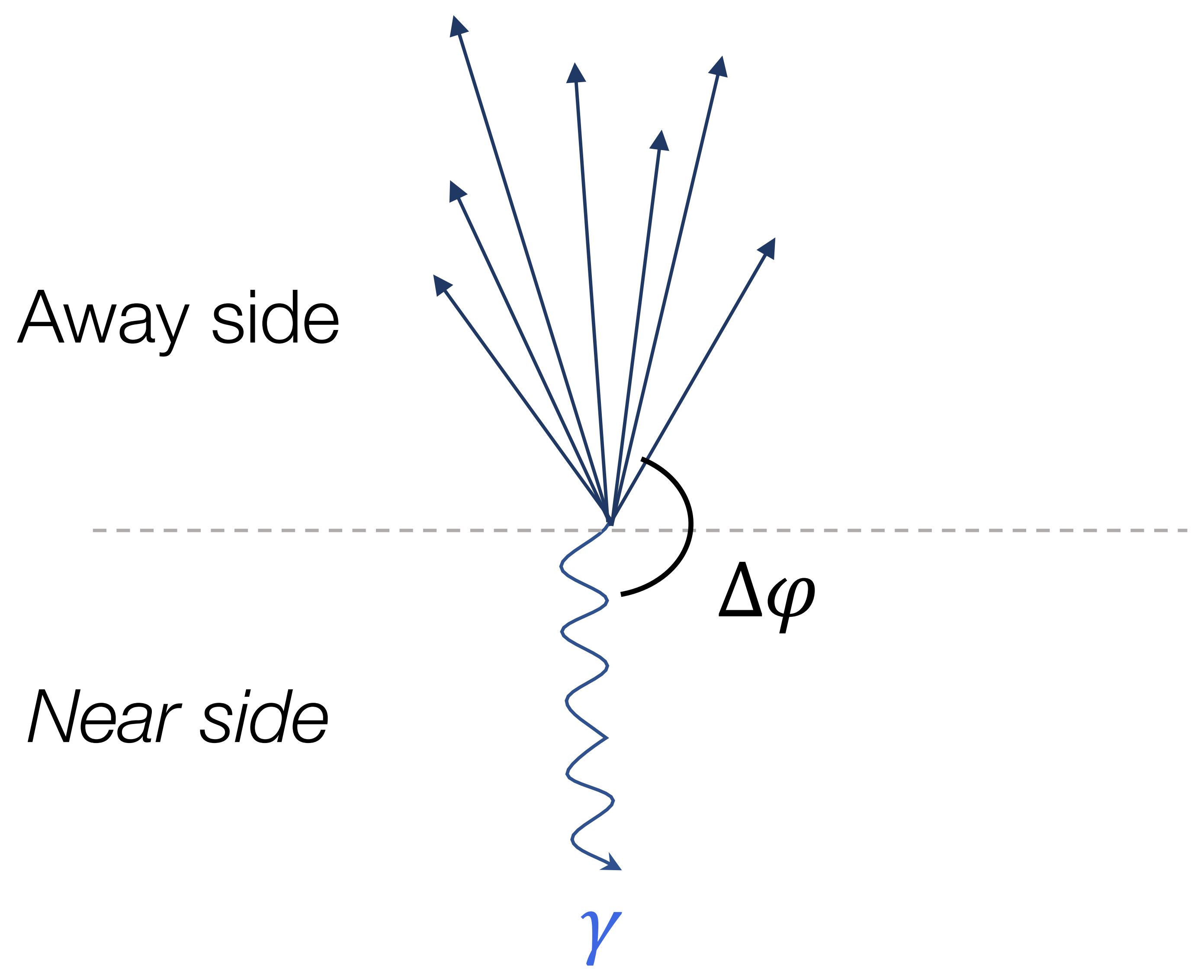
No modification of prompt photon yield due to the QGP

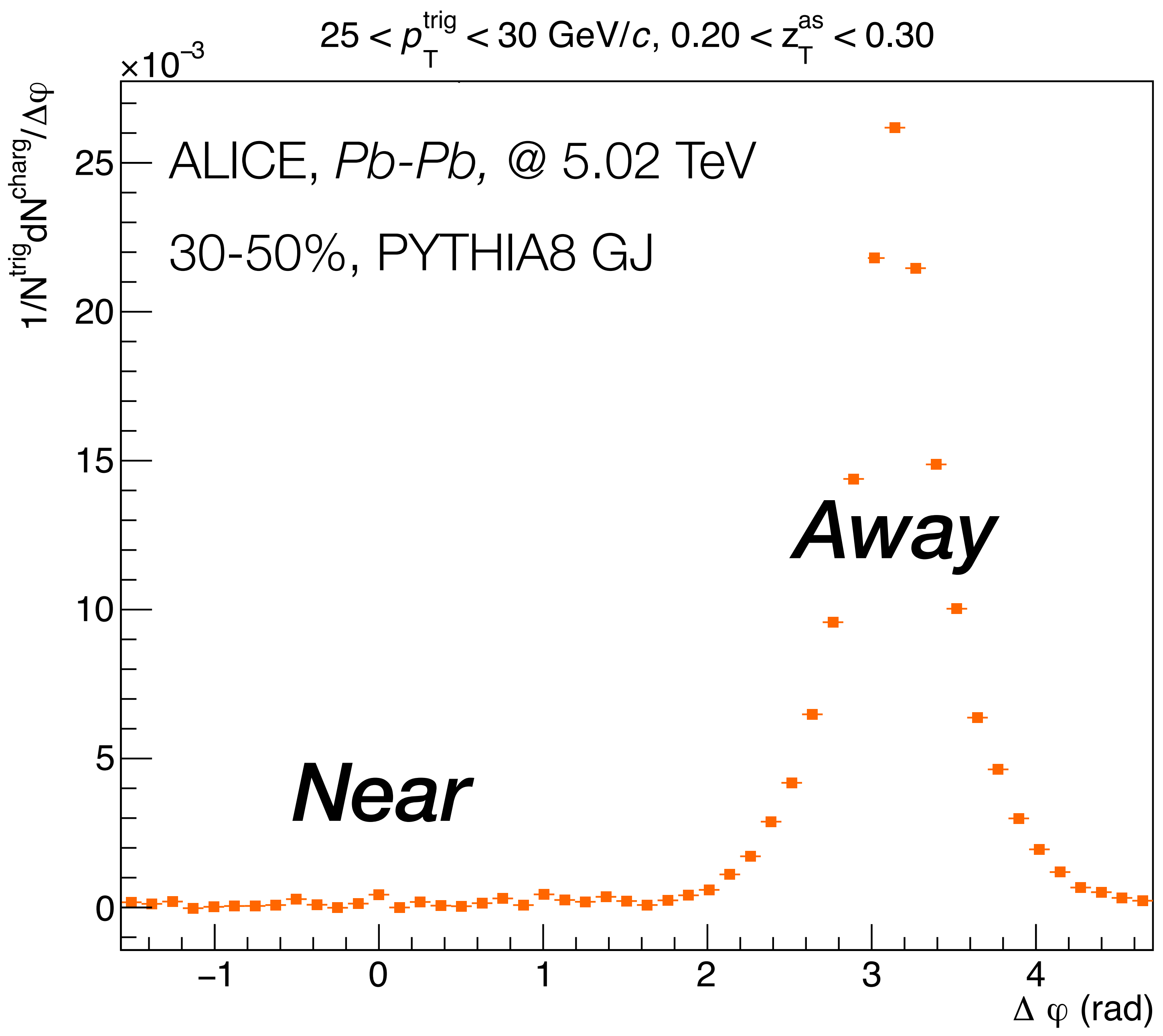


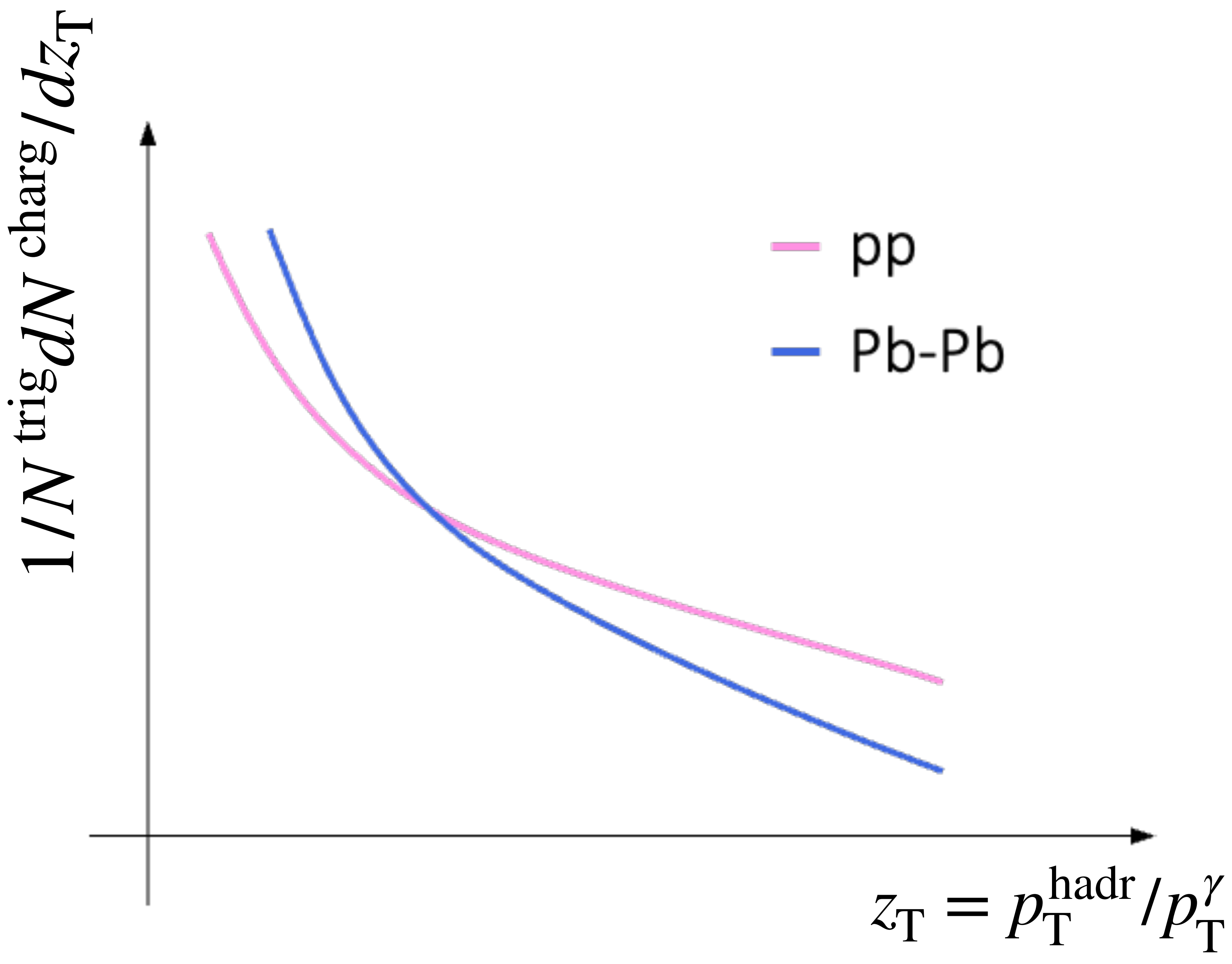
$\gamma^{\rm iso}$—hadron correlations in Pb—Pb

- Prompt γ associated with a parton emitted in opposite direction
- Allow to **tag the initial energy** of the parton $p_T^{\gamma} \approx p_T^{\rm parton}$ = ***REFERENCE***
  - ***Azimuthal correlations distribution*** $\Delta\varphi = (\varphi^{\rm trig} - \varphi^{\rm assoc})$
  - $z_{\rm T} = p_{\rm T}^{\rm hadr}/p_{\rm T}^{\gamma}$ → **Observable:** the hadrons $p_{\rm T}$ distribution
  - $D(z_{\rm T})$ is *a proxy for the jet fragmentation function* → *information on energy redistribution*





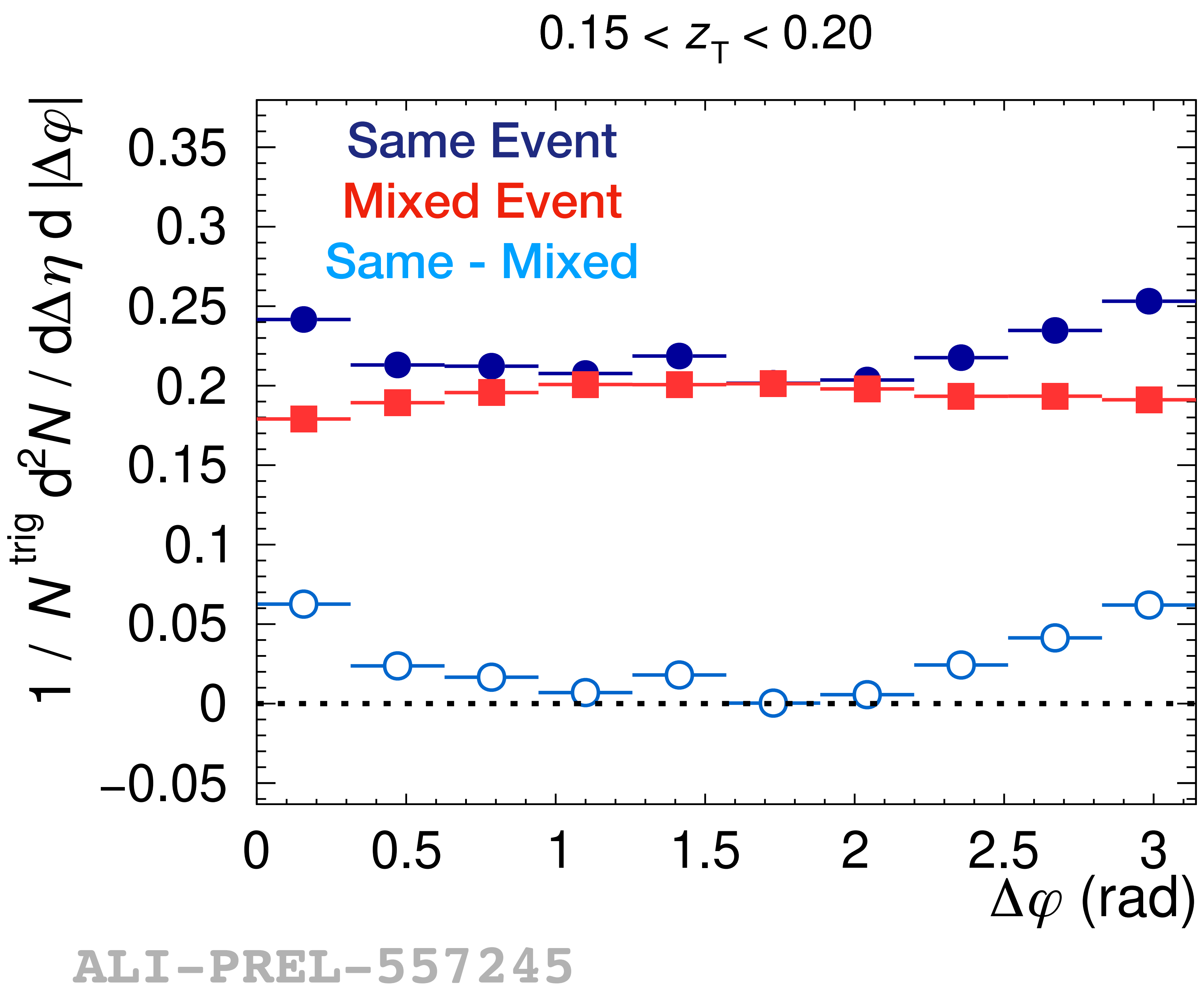




γ^{iso}—hadron correlations in Pb—Pb: analysis flow

My thesis

Underlying event subtraction



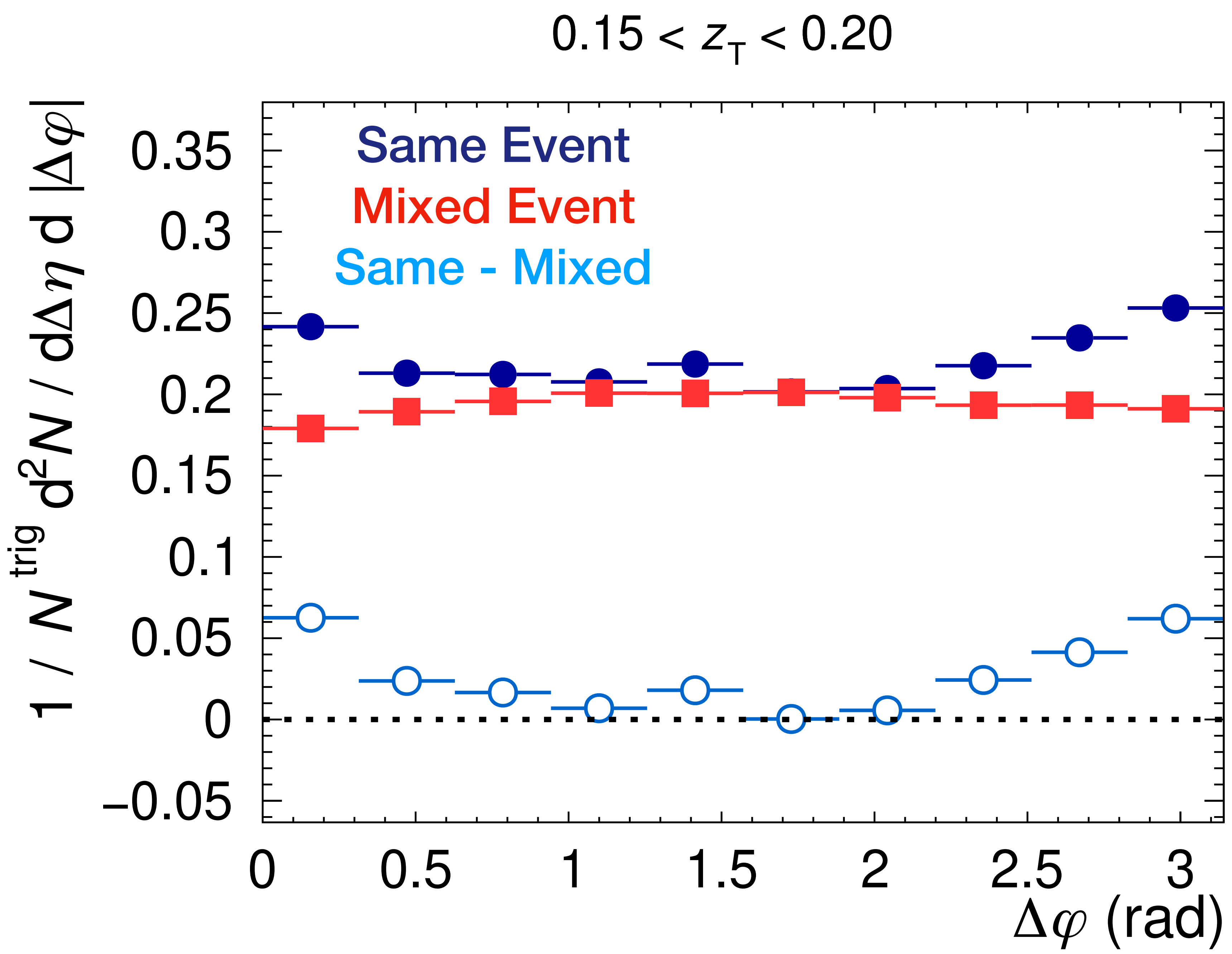
- Remove underlying event (UE) using the Mixed Event
  - UE: uncorrelated tracks shifting up the distribution

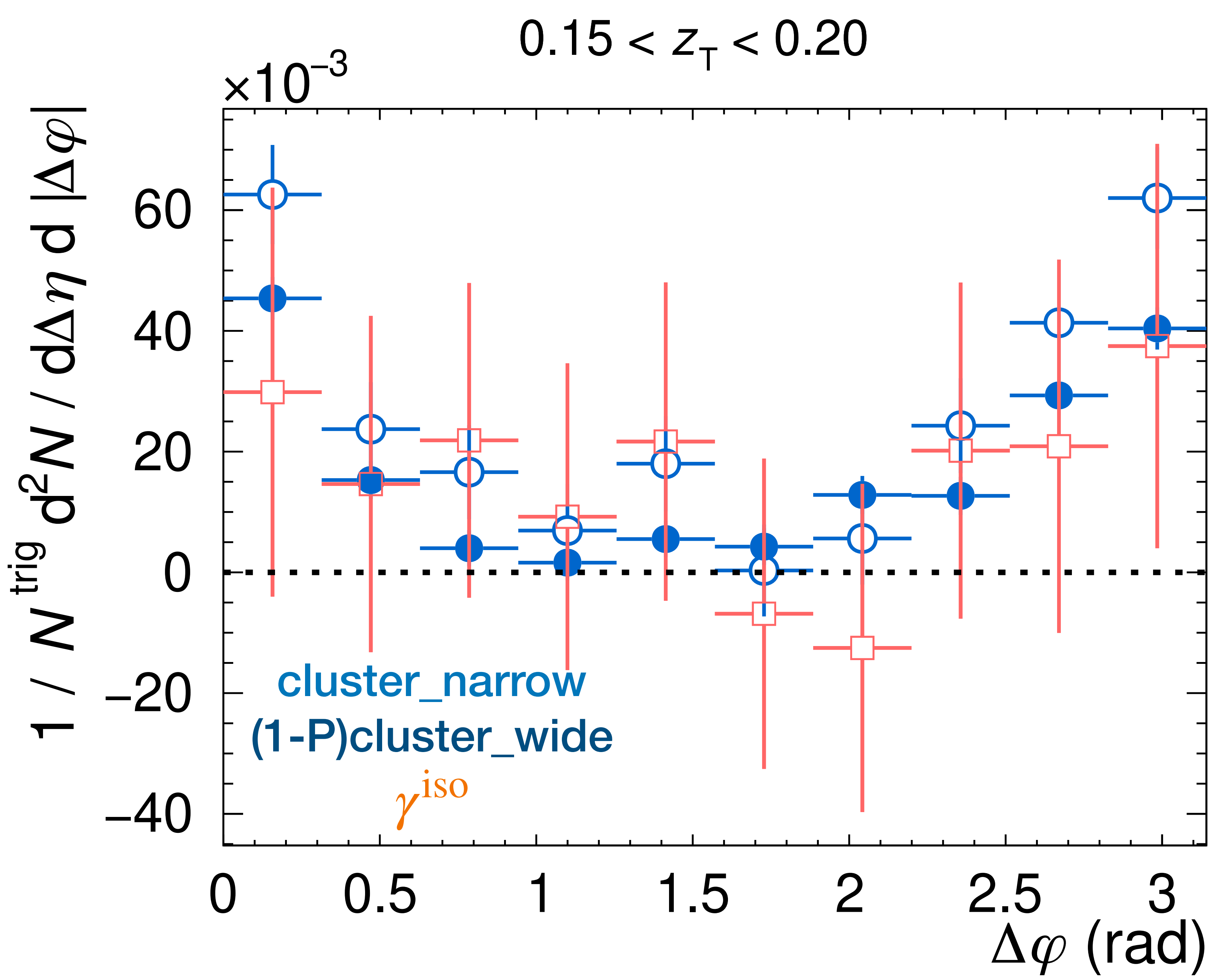
$\gamma^{\rm iso}$—hadron correlations in Pb—Pb: analysis flow

My thesis

Underlying event subtraction

Purity correction





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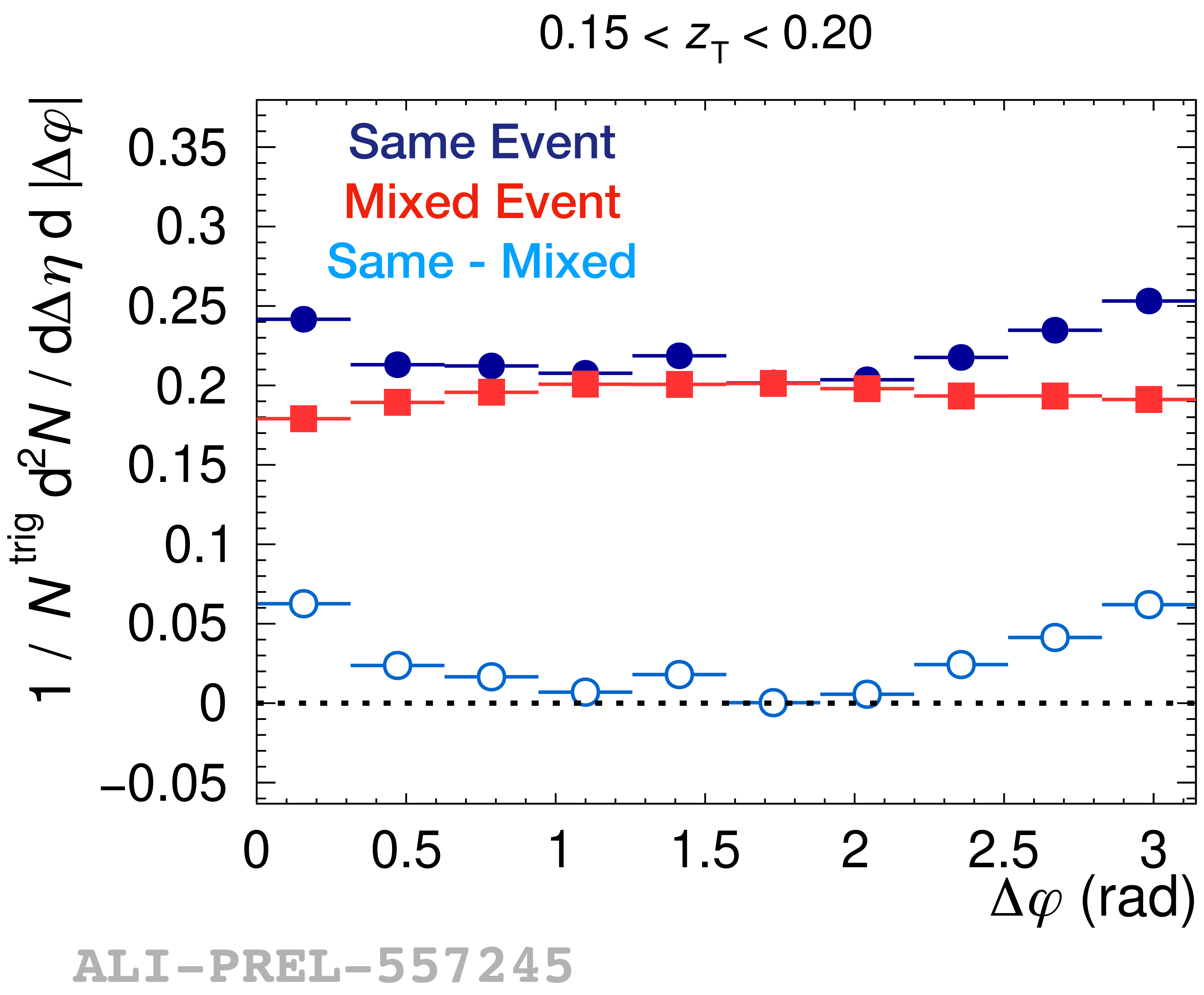
- Remove underlying event (UE) using the Mixed Event
  - UE: uncorrelated tracks shifting up the distribution
- Remove residual background (π^0) using **Purity correction**
- Integrate away-side for every $z_{\rm T} = p_{\rm T}^{\rm hadr}/p_{\rm T}^{\gamma}$ bin

$\gamma^{\rm iso}$—hadron correlations in Pb—Pb: analysis flow

My thesis

Underlying event subtraction



- Remove underlying event (UE) using the **Mixed Event**
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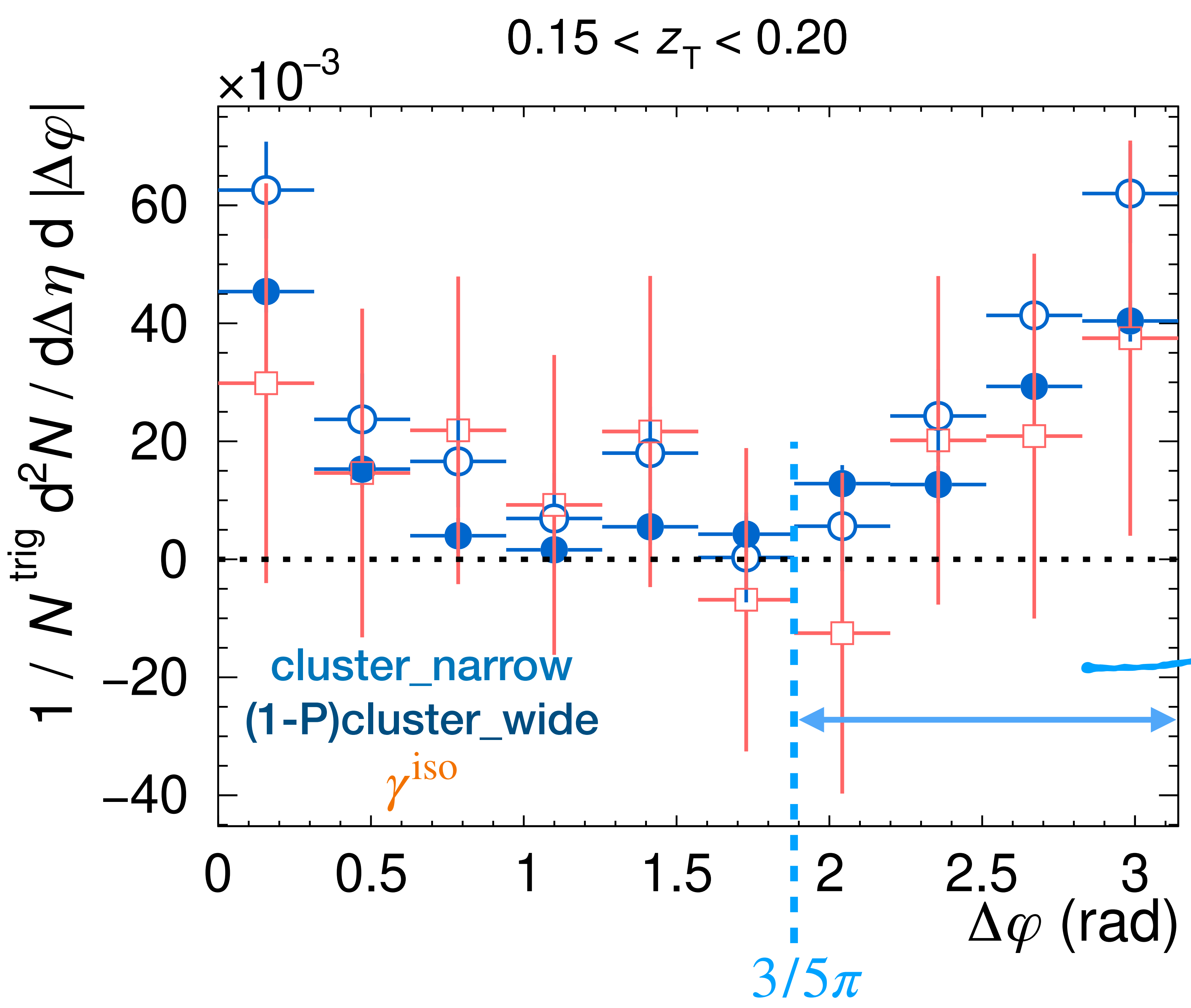
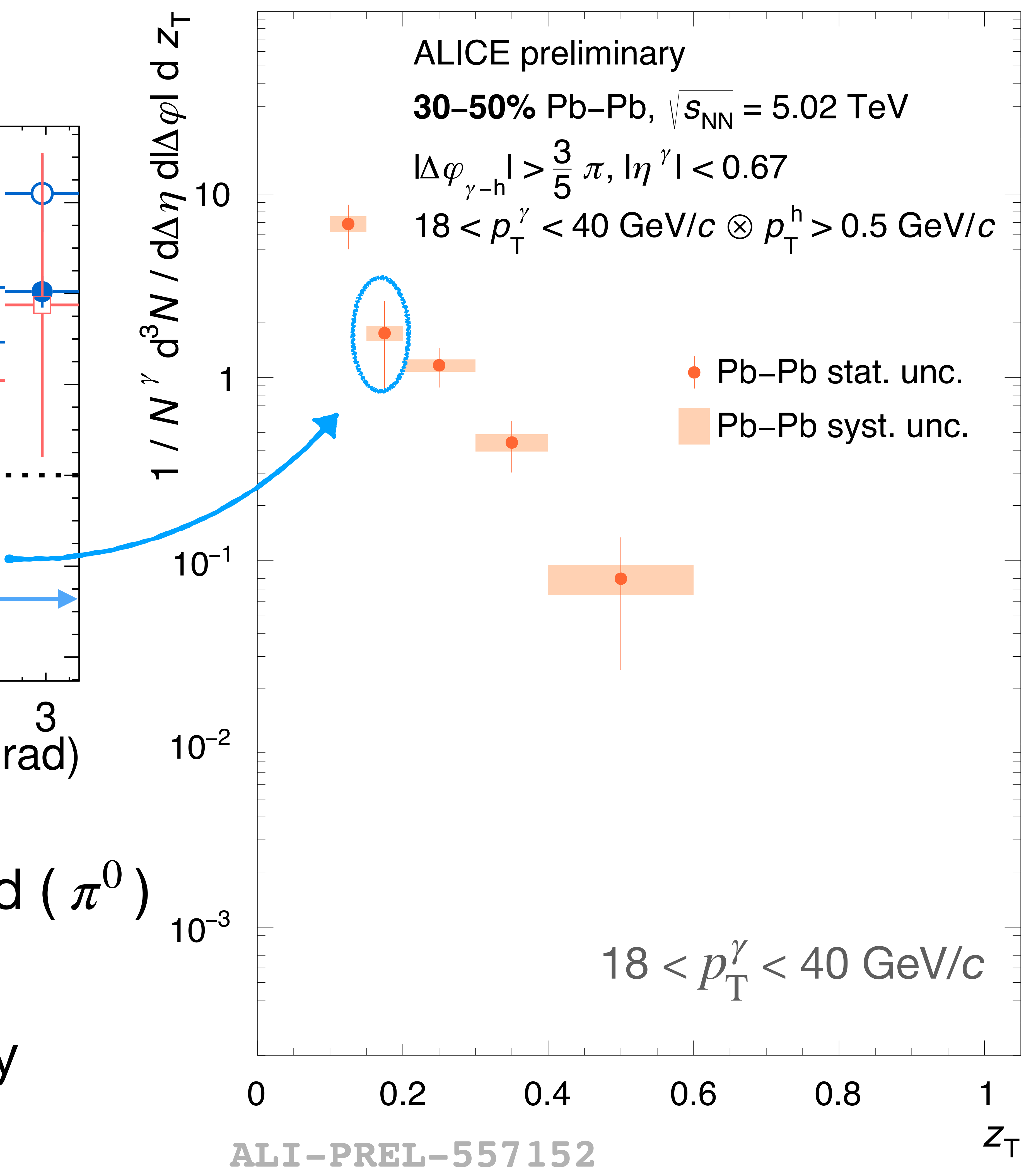
Purity correction

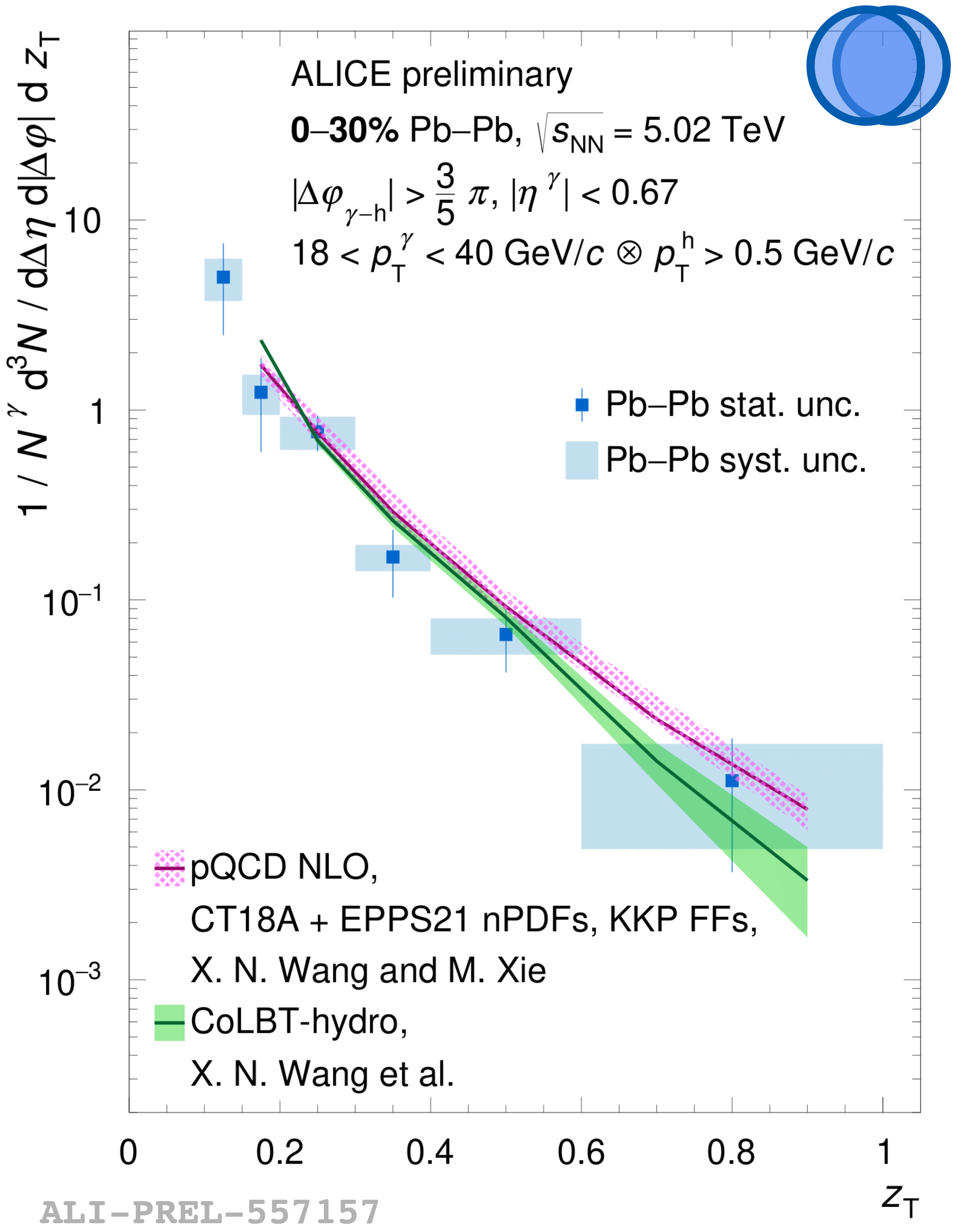


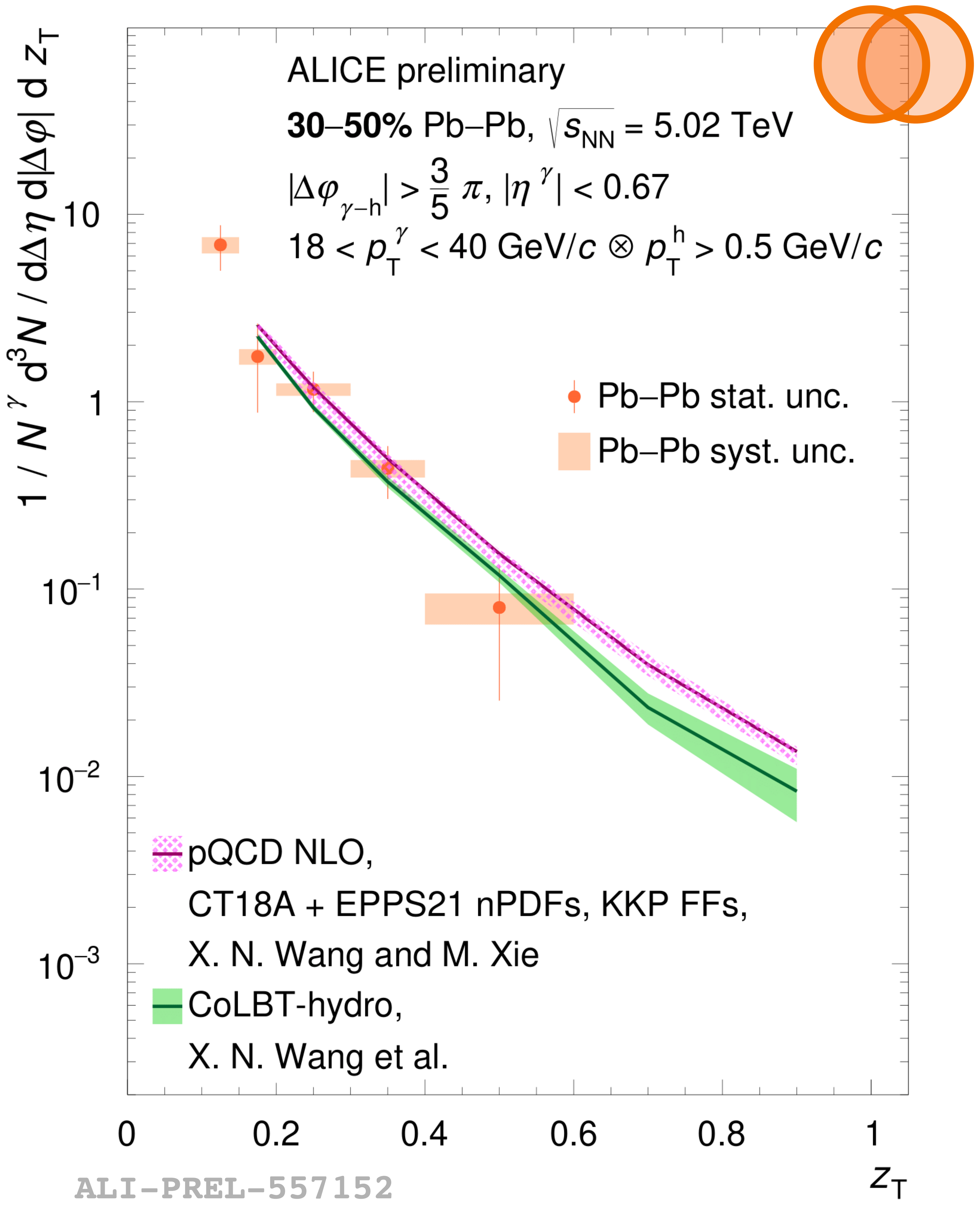
- Remove residual background (π^0) using **Purity correction**
- Integrate away-side for every $z_T = p_T^{\rm hadr}/p_T^{\gamma}$ bin

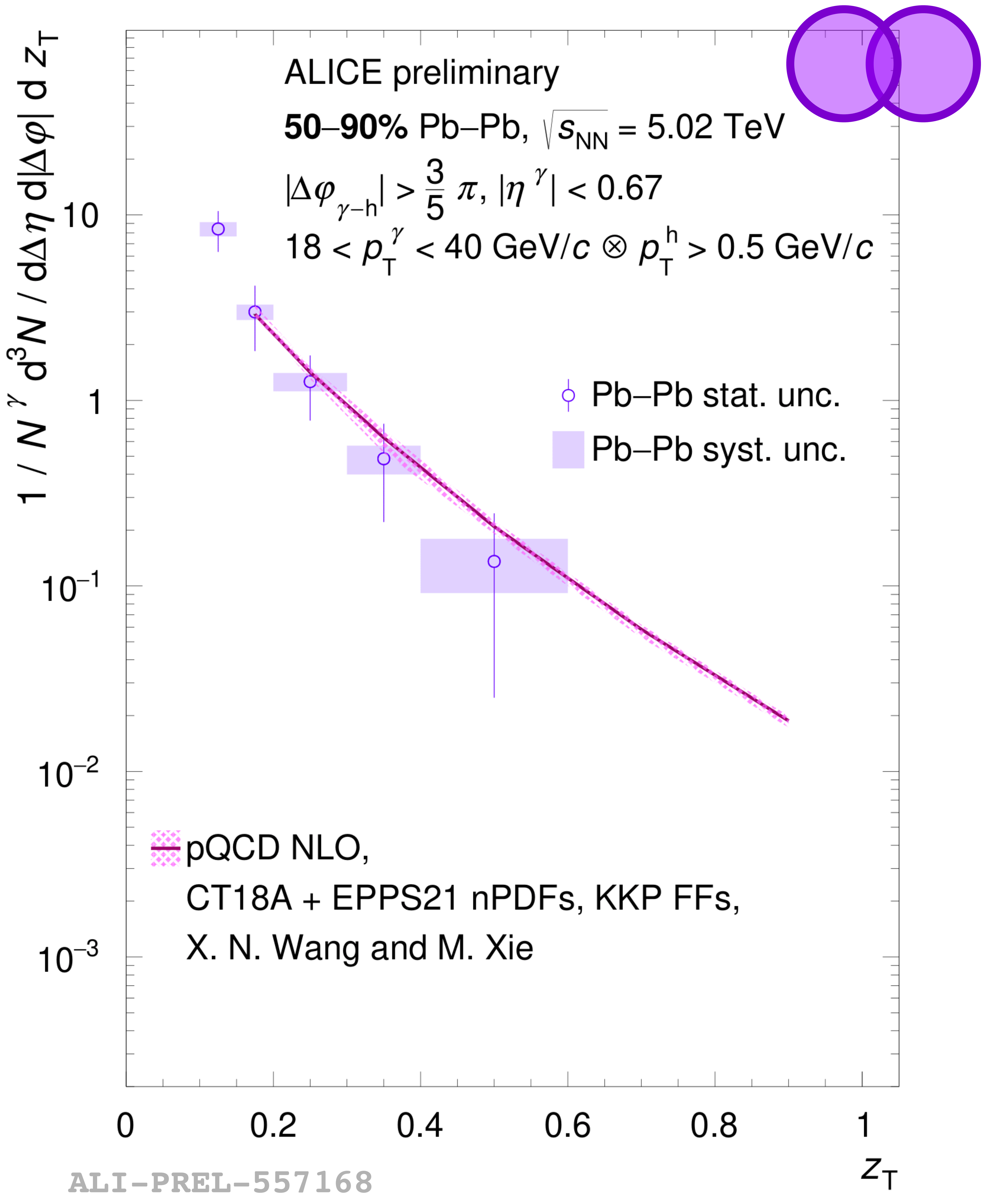
$D(z_T)$



$D(z_T)$ distributions







- Data compared with theory: *NLO pQCD* and *CoLBT* (0-50% only)
  - There seems to be an agreement with both models
  - Discrimination not possible yet

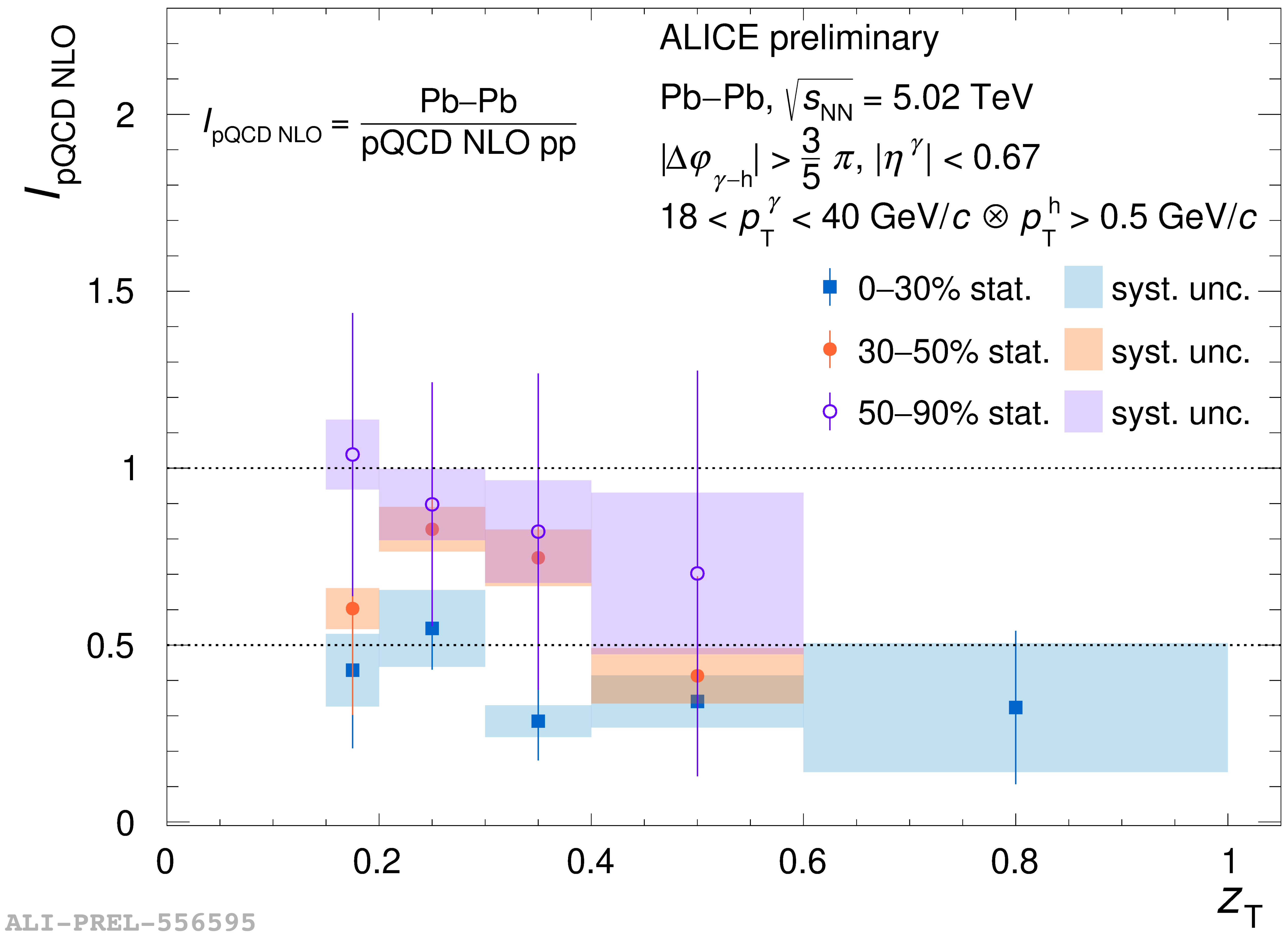
My thesis

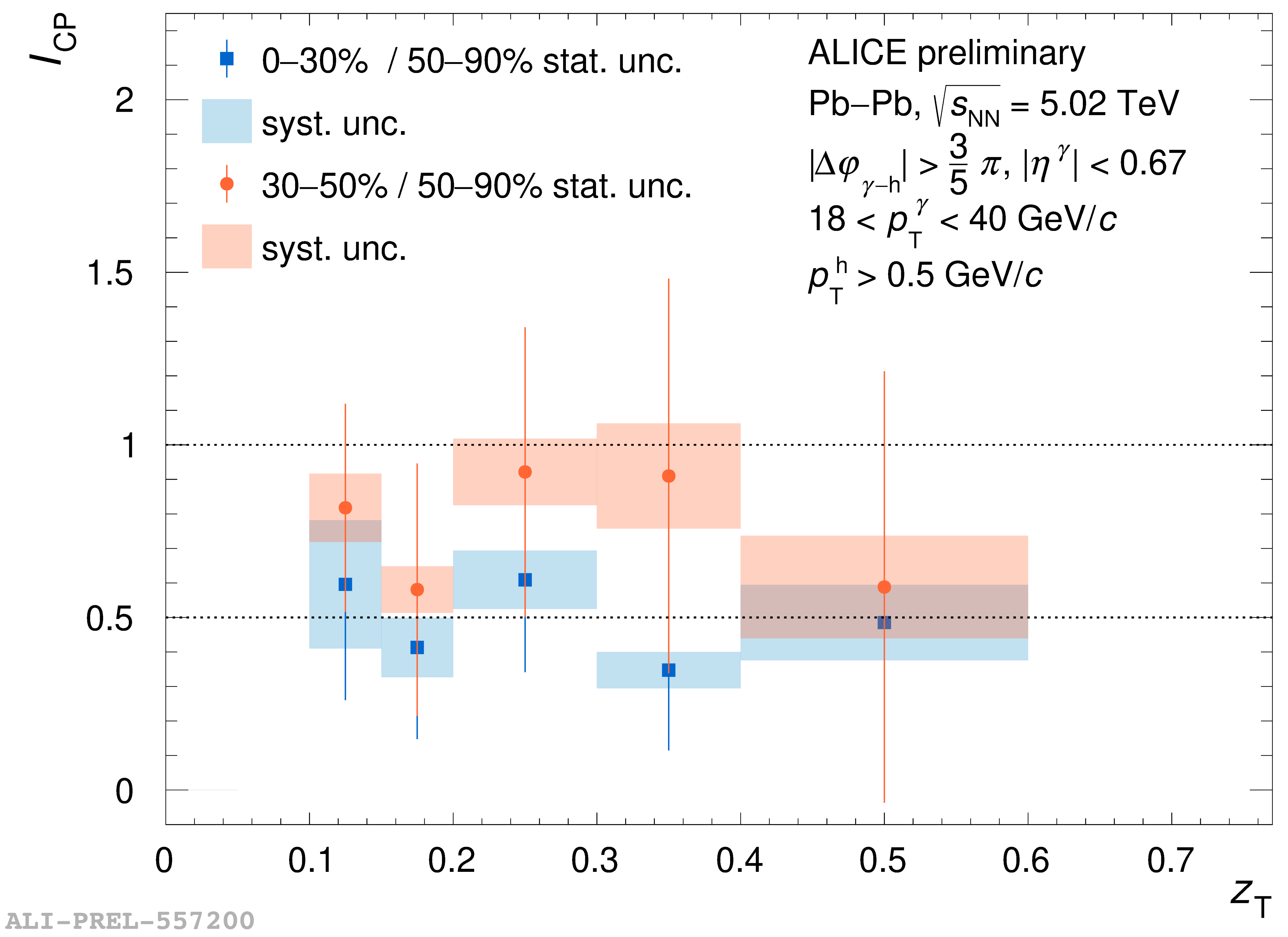
- *Phys. Rev. C 103, 034911*, *Xie, Wang and Zhang,*
- *Phys. Rev. Lett. 103, 032302*, *Xie, Wang and Zhang*
- *Phys.Lett.B 777 (2018) 86-90* , *Chen et al.*

$D(z_T)$ distributions

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

$I_{\mathrm{NLO\ pQCD}}$ and I_{CP}



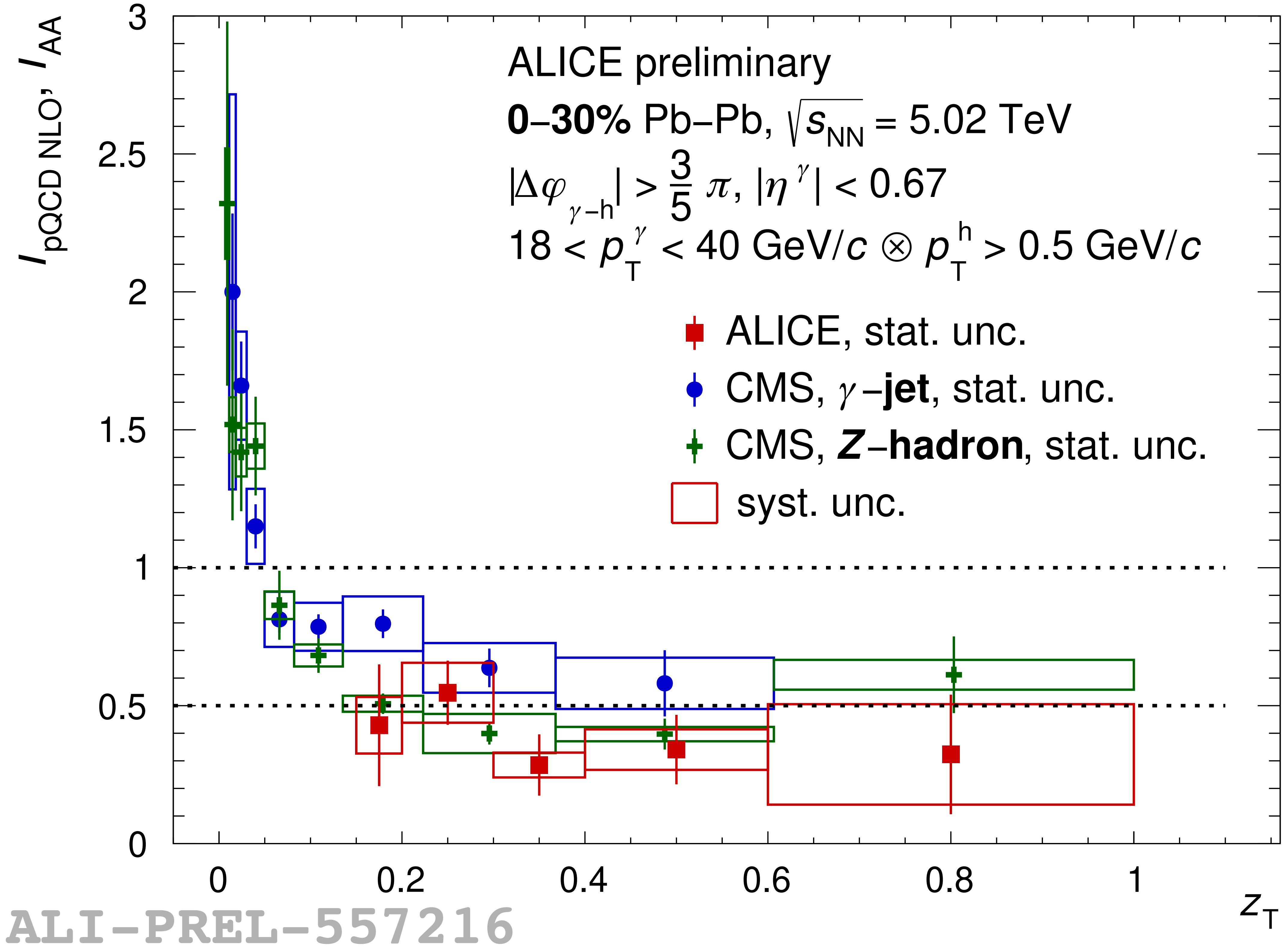


- $I_{\mathrm{pQCD\ NLO}} = \frac{D(z_{\mathrm{T}})_{\mathrm{Pb–Pb}}}{D(z_{\mathrm{T}})_{\mathrm{pp\ NLO\ pQCD}}}$ $\quad$ $I_{\mathrm{CP}} = \frac{D(z_{\mathrm{T}})_{\mathrm{Pb–Pb,\ (semi)central}}}{D(z_{\mathrm{T}})_{\mathrm{Pb–Pb,\ 50–90\%}}}$ $\quad$ *My thesis*
- Ordering between centralities, central more suppressed than peripheral

$\gamma^{\rm iso}$–hadron correlations: LHC and RHIC

My thesis

LHC, Pb–Pb 5.02 TeV



Phys. Rev. Lett. 121, 242301

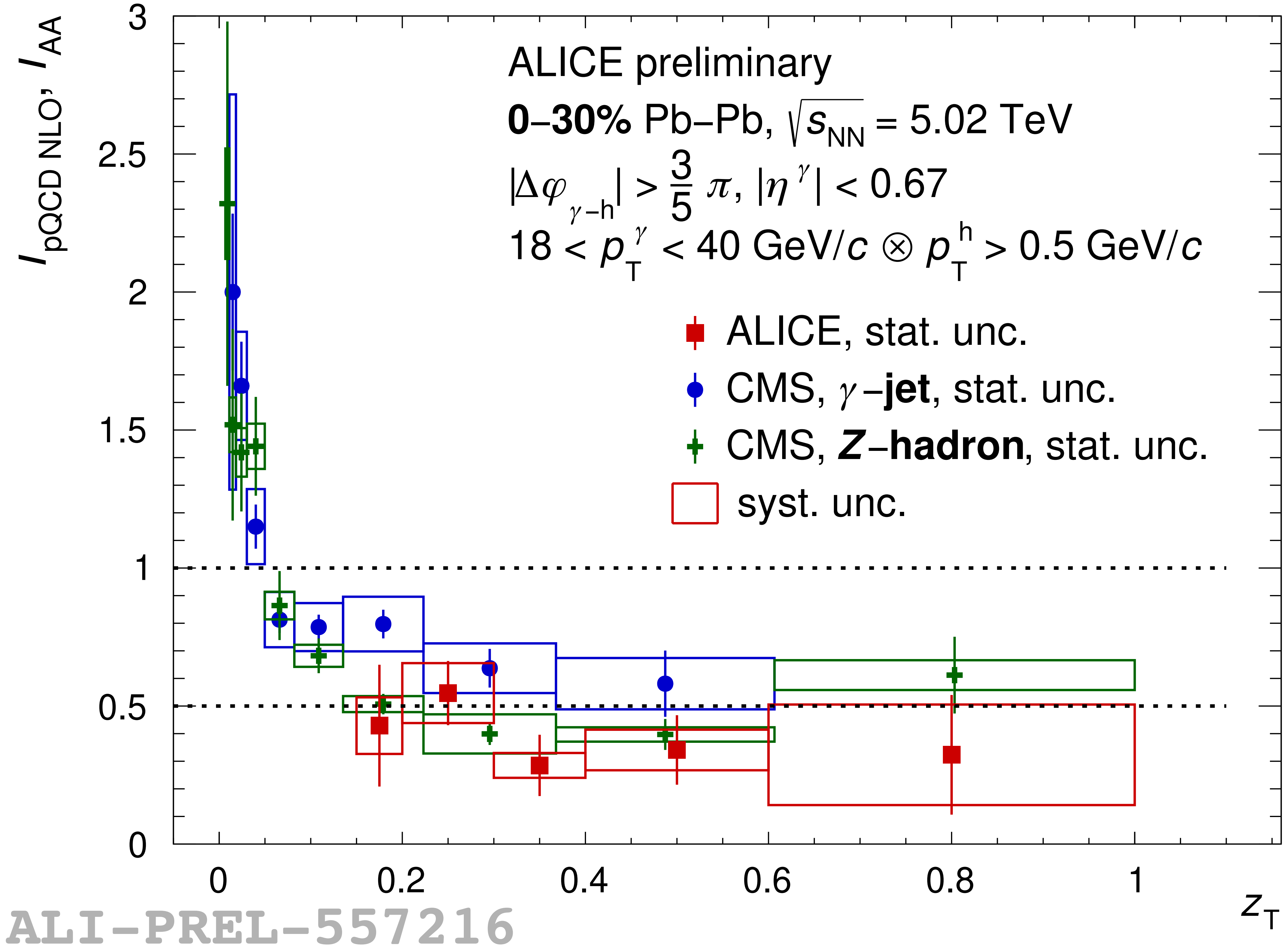
CMS, γ–jet, 0-10% , $p_{\rm T}^{\gamma}$ > 60 GeV/c

Phys. Rev. Lett. 128, 122301

CMS, Z–hadron, 0-30% , $p_{\rm T}^{Z}$ > 30 GeV/c

γ^{iso}–hadron correlations: LHC and RHIC

LHC, Pb–Pb 5.02 TeV



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Phys. Rev. Lett. 121, 242301

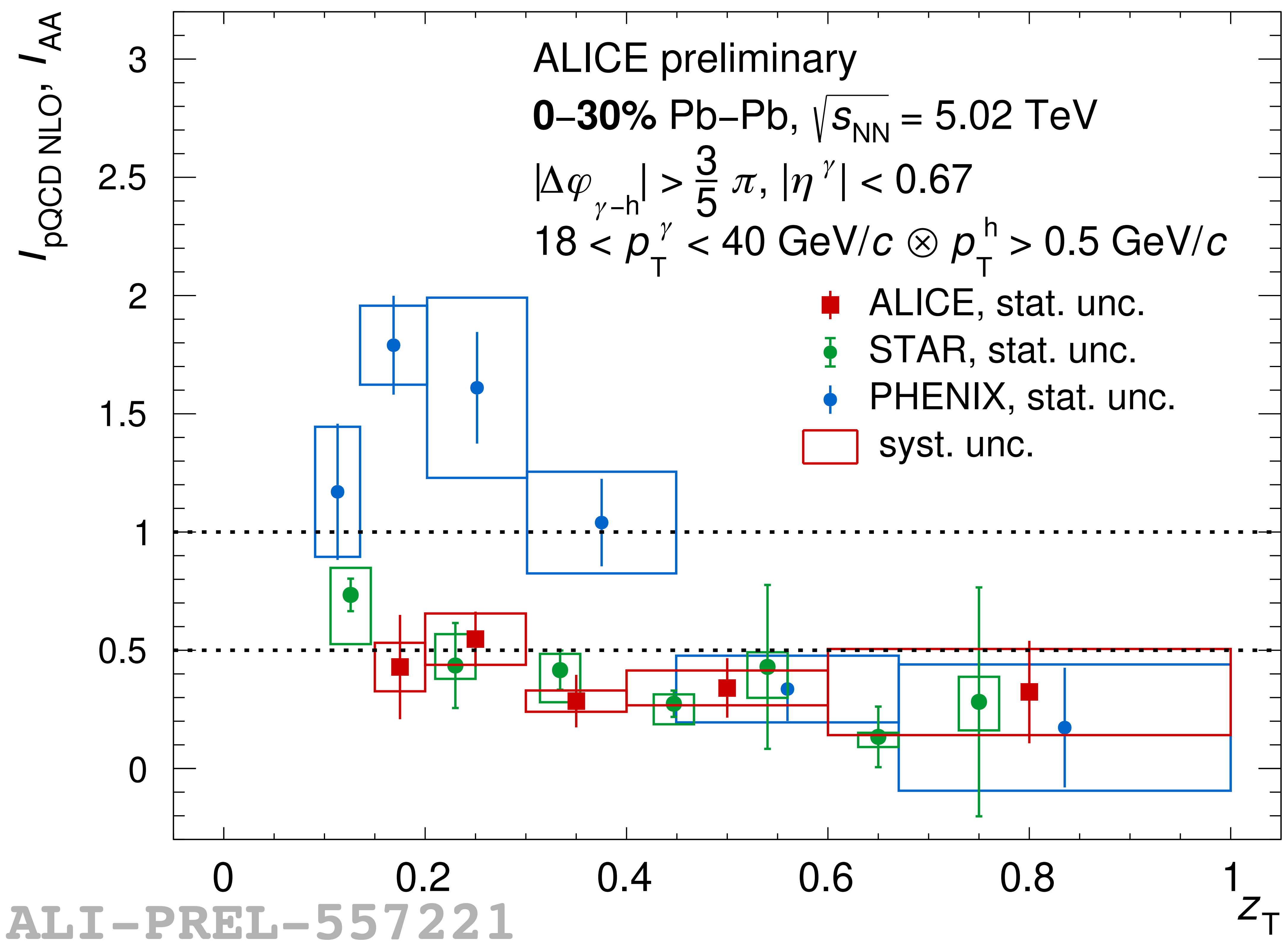
CMS, γ–jet, 0-10% , $p_T^{\gamma} > 60$ GeV/c

Phys. Rev. Lett. 128, 122301

CMS, Z–hadron, 0-30% , $p_T^{Z} > 30$ GeV/c

RHIC, Au–Au 200 GeV

My thesis



ALI-PREL-557221

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

STAR: γ–hadron, **0-12%, 12 < p_T^{γ} < 20 GeV/c**

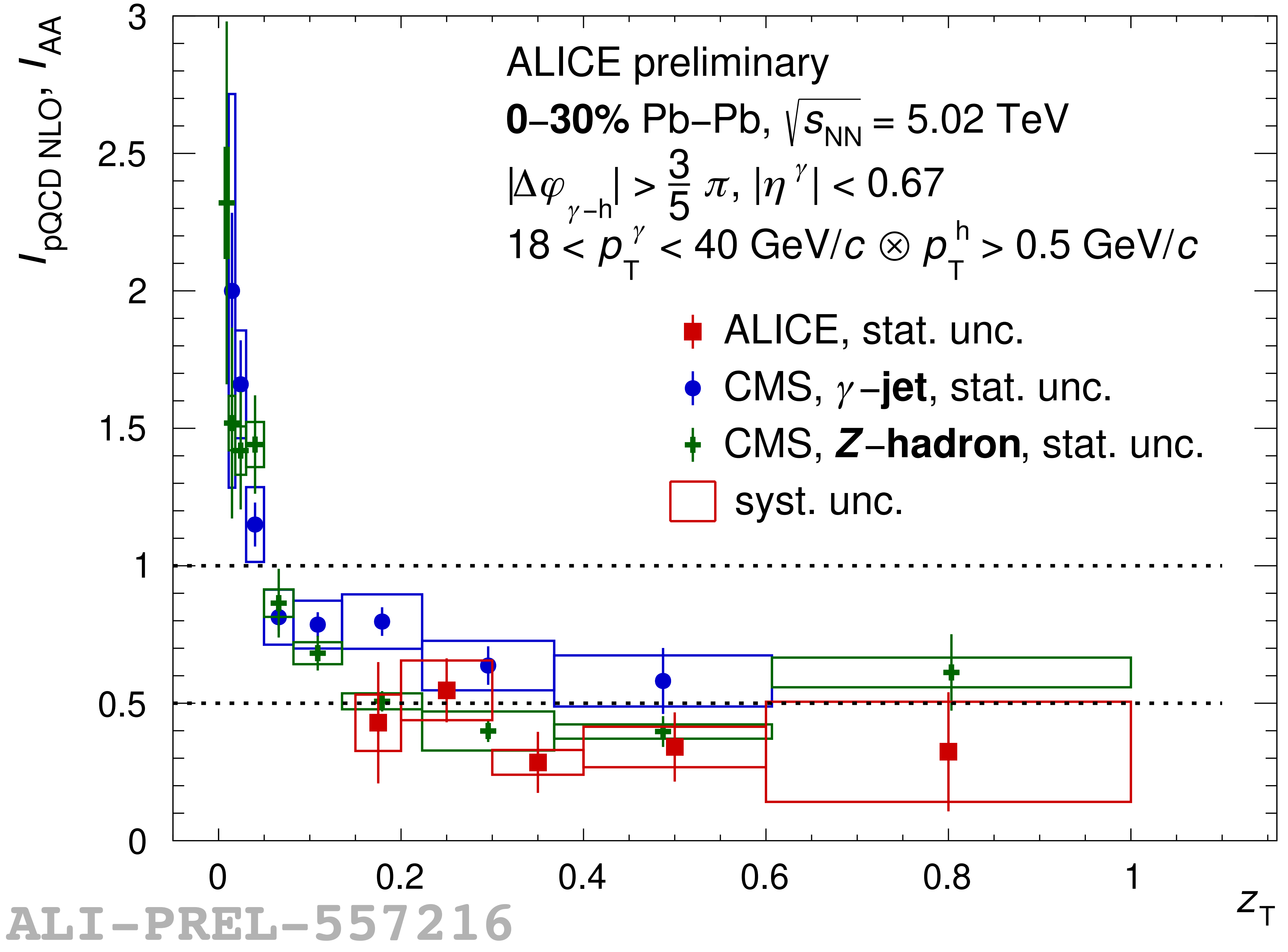
Phys. Rev. Lett. 111, 032301

PHENIX: γ–hadron, **0-40%, 5 < p_T^{γ} < 9 GeV/c**

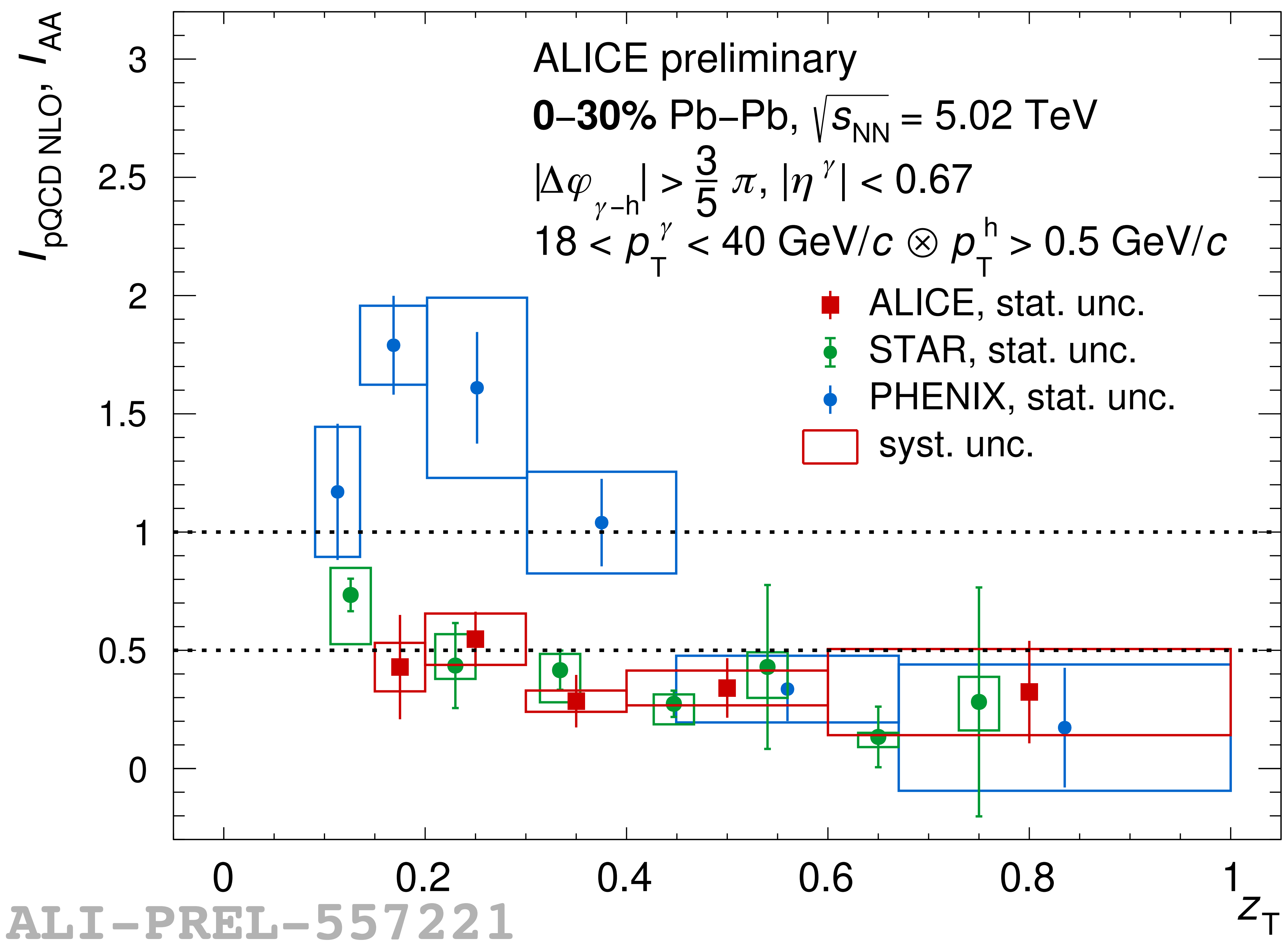
γ^{iso}–hadron correlations: LHC and RHIC

My thesis

LHC, Pb–Pb 5.02 TeV



RHIC, Au–Au 200 GeV



Not completely apples-to-apples comparison

Similar behaviour as observed at LHC and RHIC experiments

Summary and prospects

Various analyses on isolated photon in pp and p-Pb have been released or published during the last years: the *results in Pb—Pb were the last missing step*

Isolated γ spectra in pp and Pb—Pb at $\sqrt{s_{\rm NN}} = 5.02$ TeV

- Cross section measurements with *R*=0.4 and *R*=0.2 → agreement with theory
- $R_{AA} \simeq 1$ in 0–50% and $R_{AA} \simeq 0.9$ in 50—90%

➡ Next steps: extend if possible to lower $p_{\rm T}$ and publication

Isolated γ—hadron correlations in Pb—Pb collisions at $\sqrt{s_{\rm NN}} = 5.02$ TeV

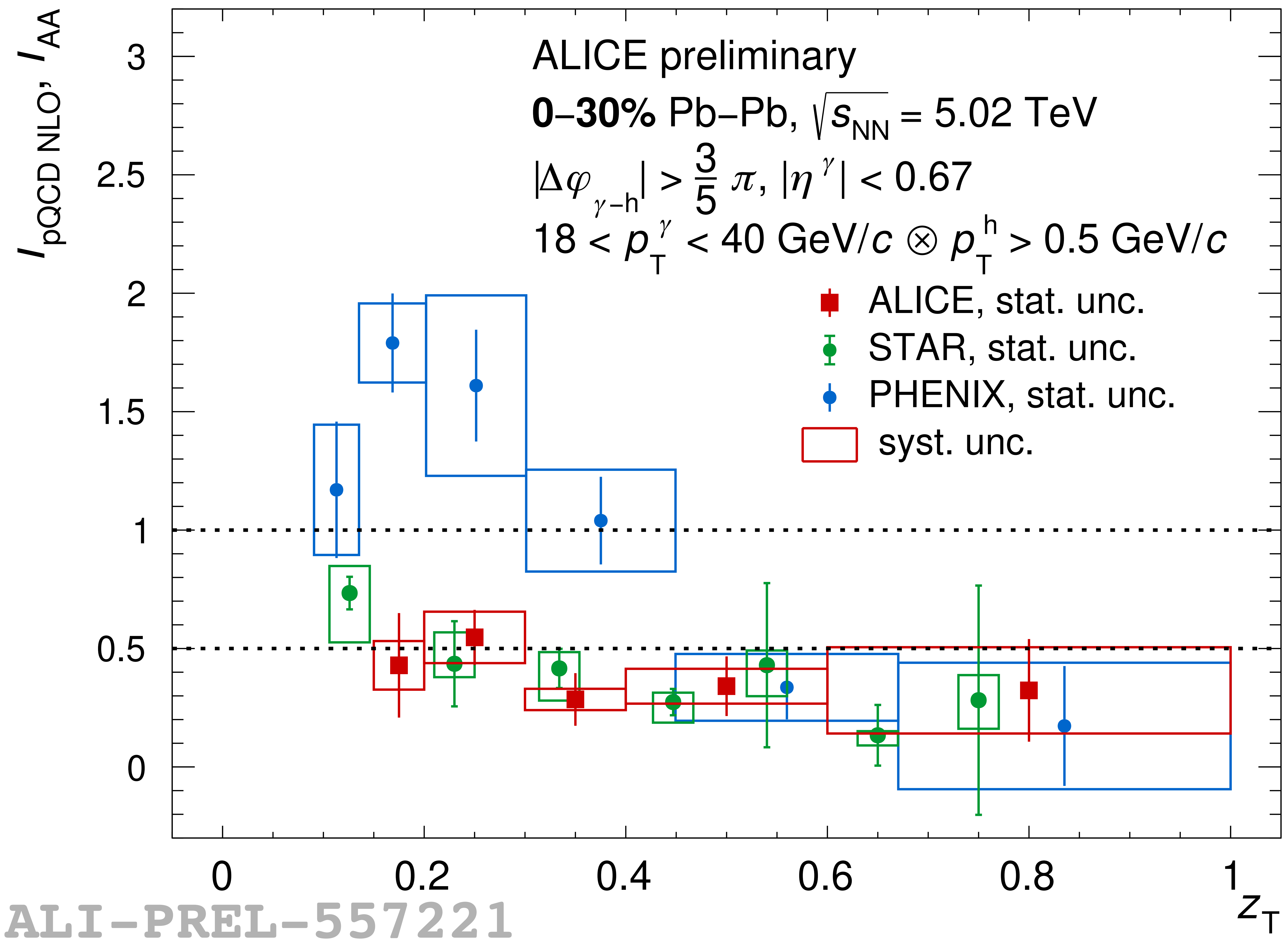
- Modification stronger for central compared to peripheral collisions
- Results described by models, but discrimination not possible yet

➡ Next steps: include a lower $z_{\rm T}$ bin, extend if possible to lower $p_{\rm T}^{\gamma}$ and publication

Thank you all for the attention!

Backup

$\gamma^{\rm iso}$-hadron correlations: LHC and RHIC



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

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

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

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

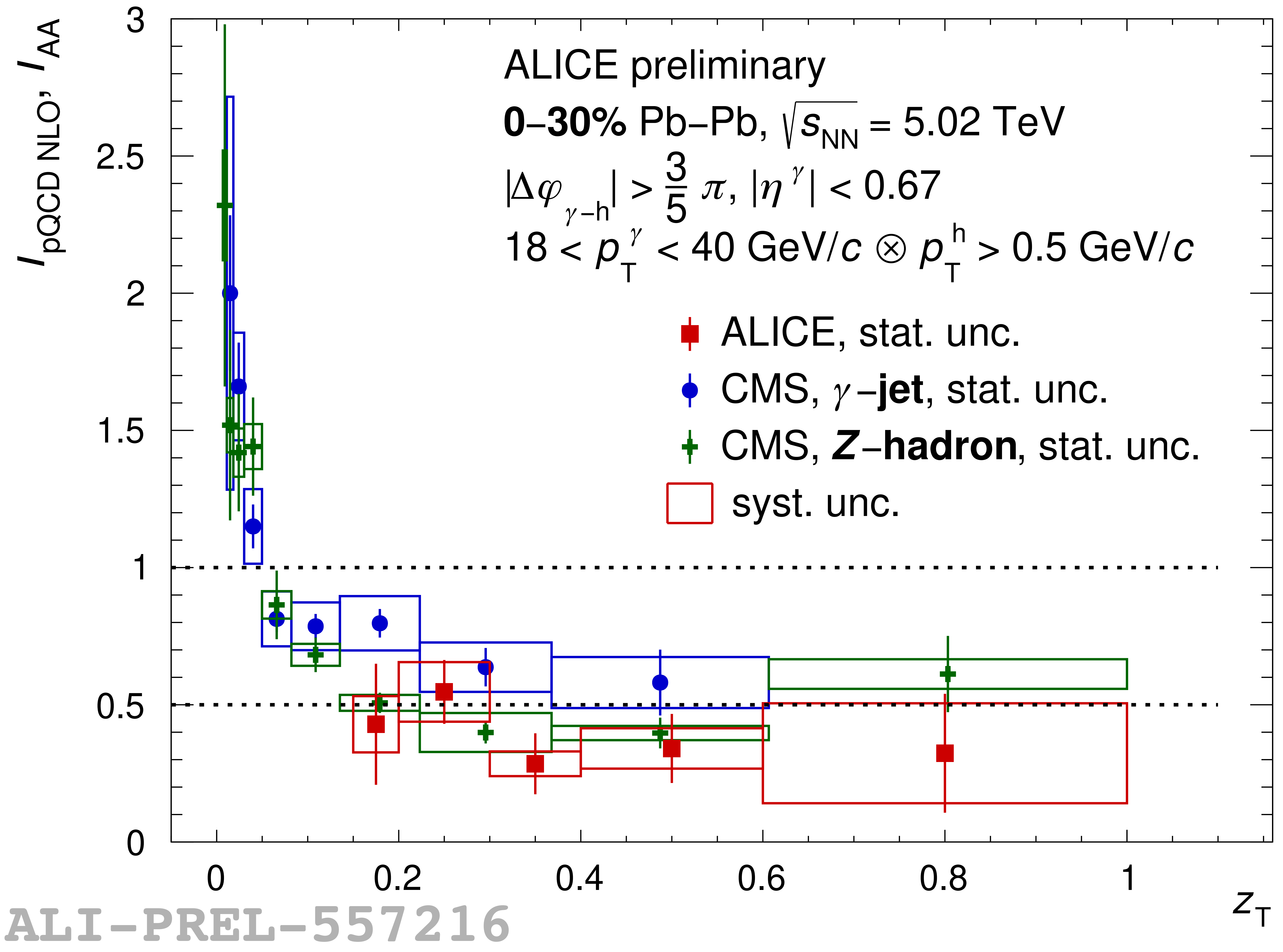
PHENIX, PRL 111, 032301 (2013)

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

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

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

γ^{iso}-hadron correlations: LHC and RHIC



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

γ–**jet**, **0–10%**

anti-k$_{\mathrm{T}}$ jet R = 0.3, $p_{\mathrm{T}}^{\mathrm{jet}} > 30$ GeV/c, $|\eta^{\mathrm{jet}}| < 1.6$

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

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

***Z*–hadron**, **0–30%**

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

Photons sources in heavy-ion collisions

Photon sources:

- γ_{decay}, from hadronic decays
- direct γ, not originated from hadronic decays

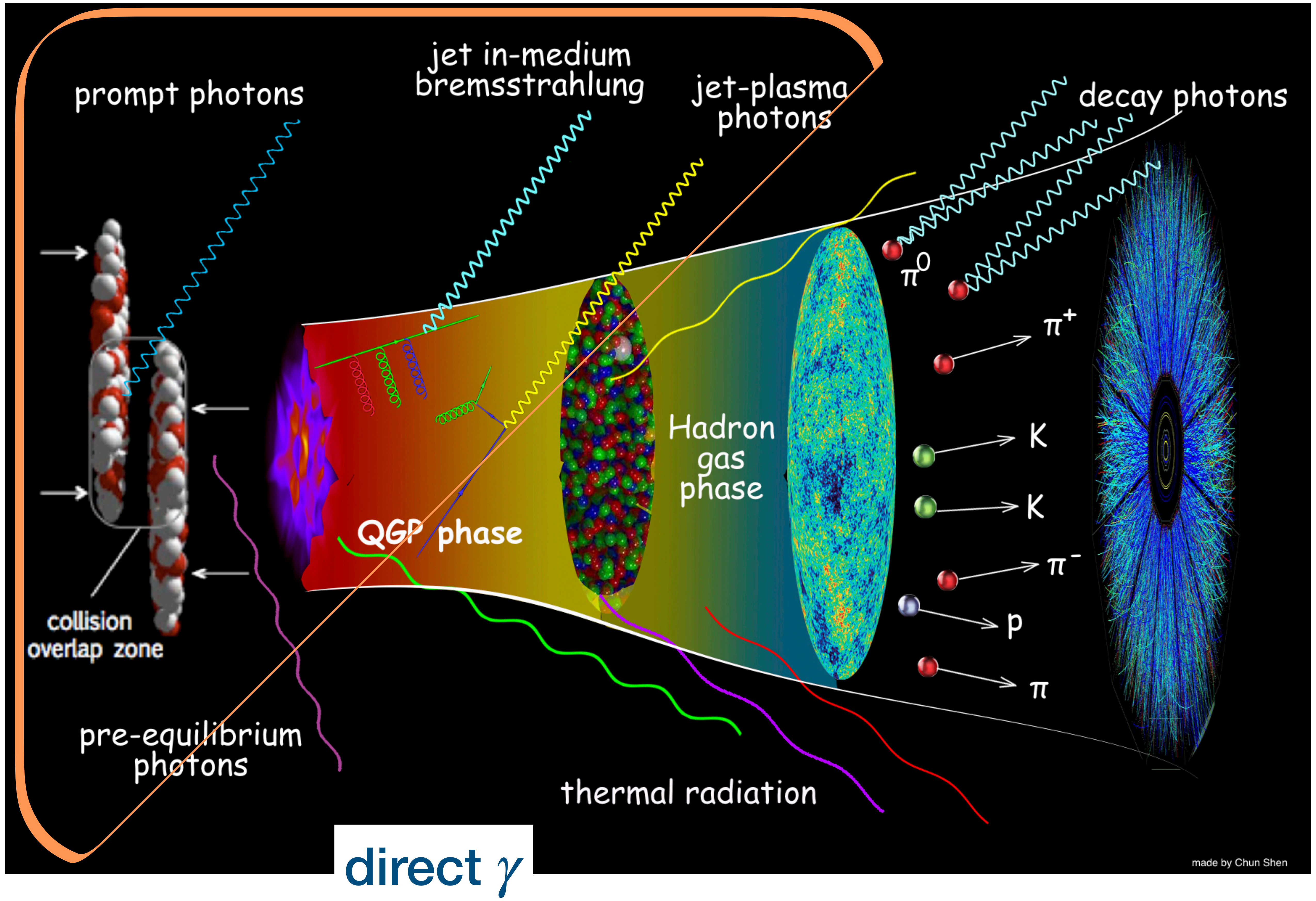
↓

Prompt γ from the initial hard scattering:

- Compton and annihilation: $\gamma_{2\to 2}$
- parton fragmentation: γ_{fragm}

Non−prompt γ during **all** QGP - hadron gas phases:

- pre-equilibrium photons, $\gamma_{\text{pre-eq}}$
- thermal photons, γ_{thermal}



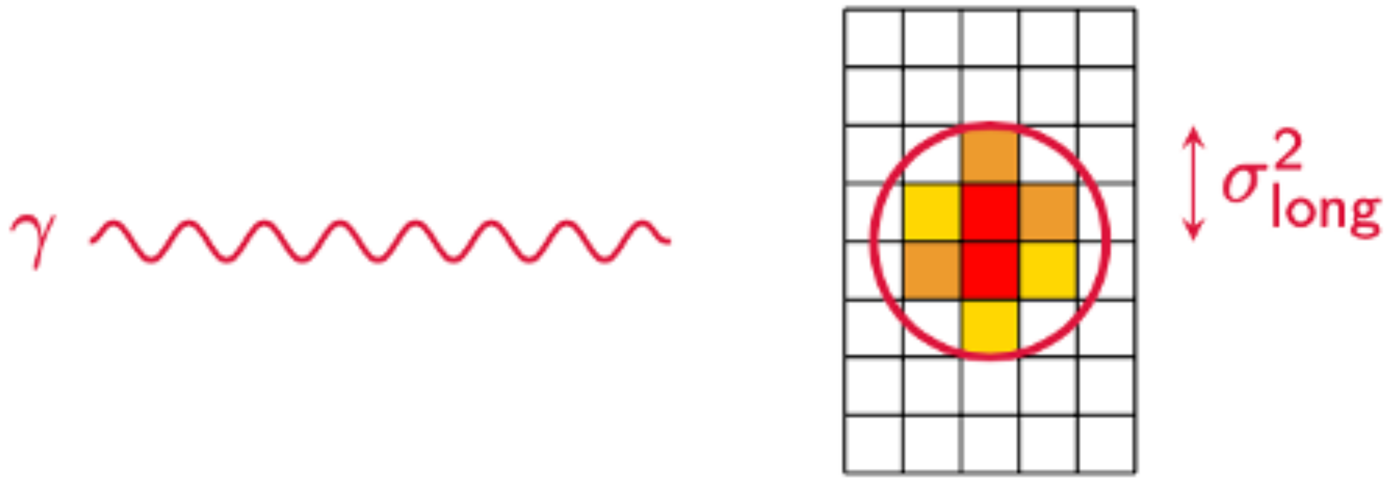
Made by Chun Shen

Photon identification with EMCal

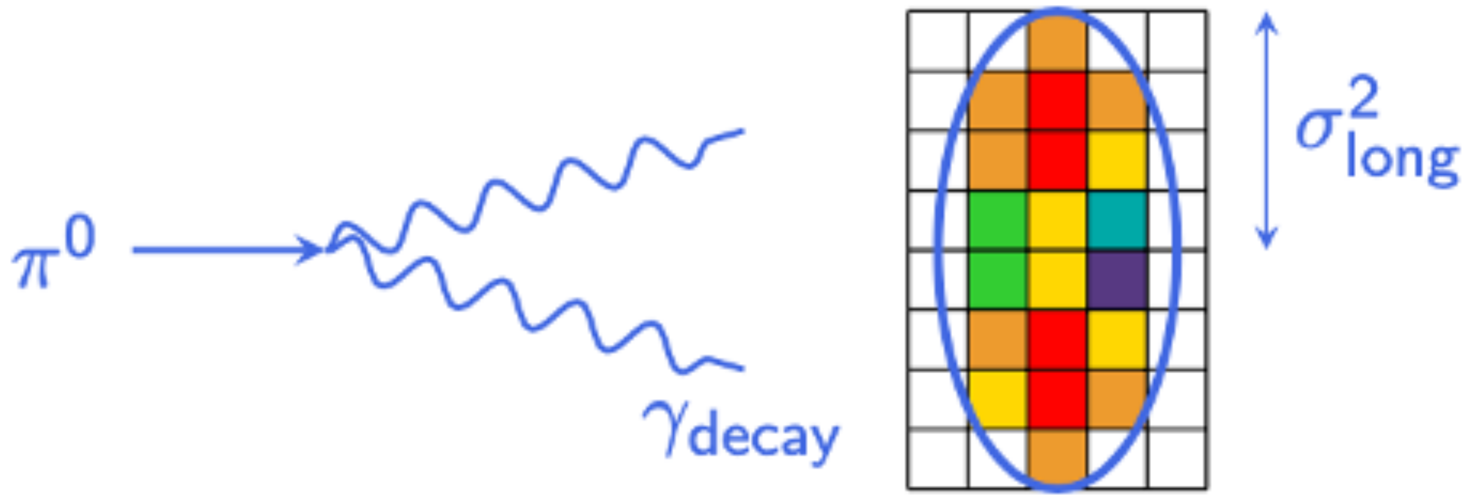
A particle interacting with the ***cell material*** produces a shower spreading its energy over ***neighbouring cells***.

- ***Cluster***: aggregate of cells

The **distribution of energy** within a cluster allows to discriminate between single photons γ shower and overlapping γ showers (γ_{decay}) from high energy $\pi^0 \rightarrow \gamma\gamma$

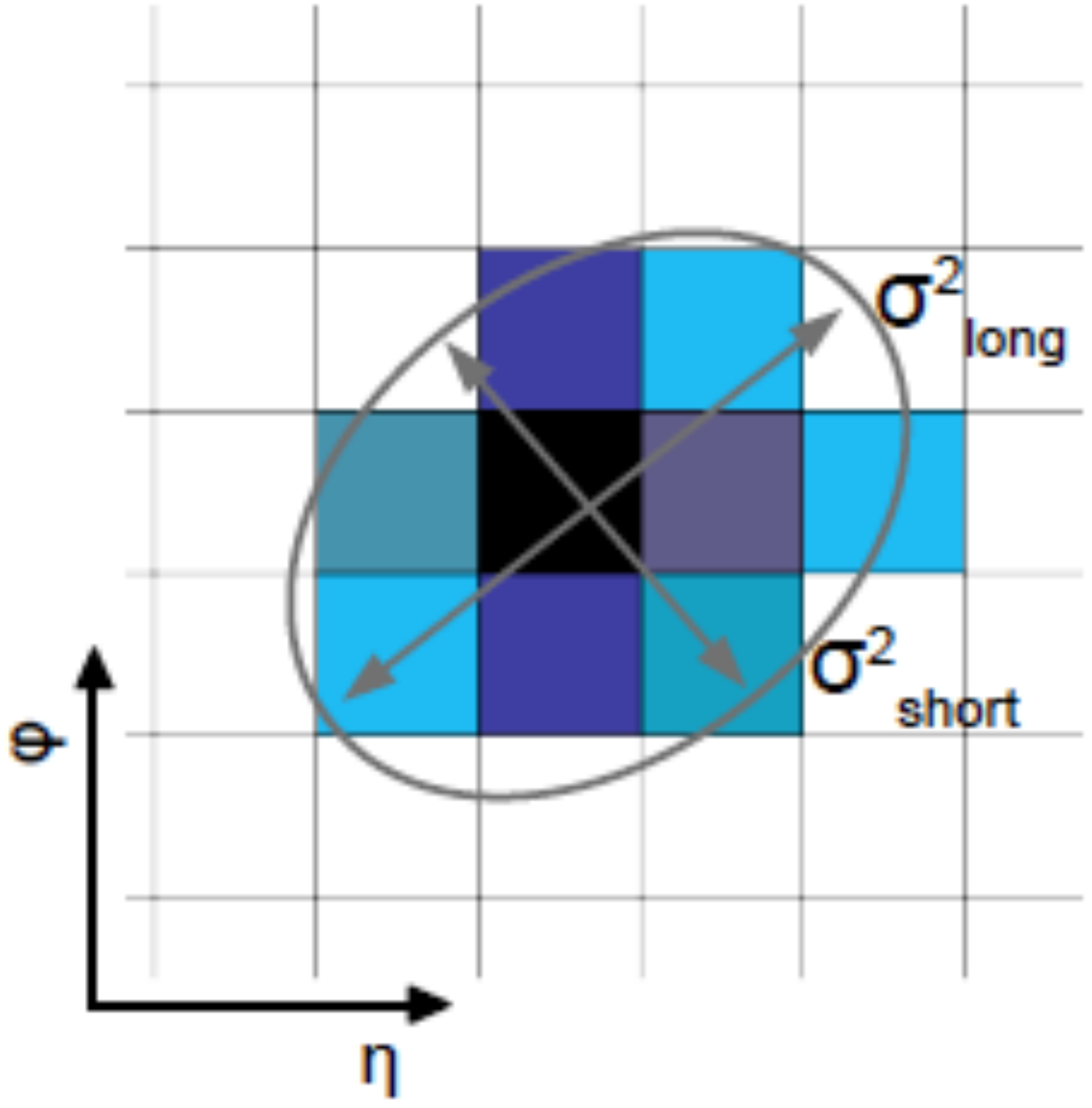


$\gamma \rightarrow \mathrm{cluster}_{\mathrm{narrow}}$: circular cluster



$\pi^0 \rightarrow \mathrm{cluster}_{\mathrm{wide}}$: elliptical cluster

EMCal cluster shower lateral dispersion parameter



- Shower shape parameter $\sigma^2_{\text{long, }5\times5}$ is related to the longer axis of the cluster ellipse
- Parameter depends on cluster cells location and its energy

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

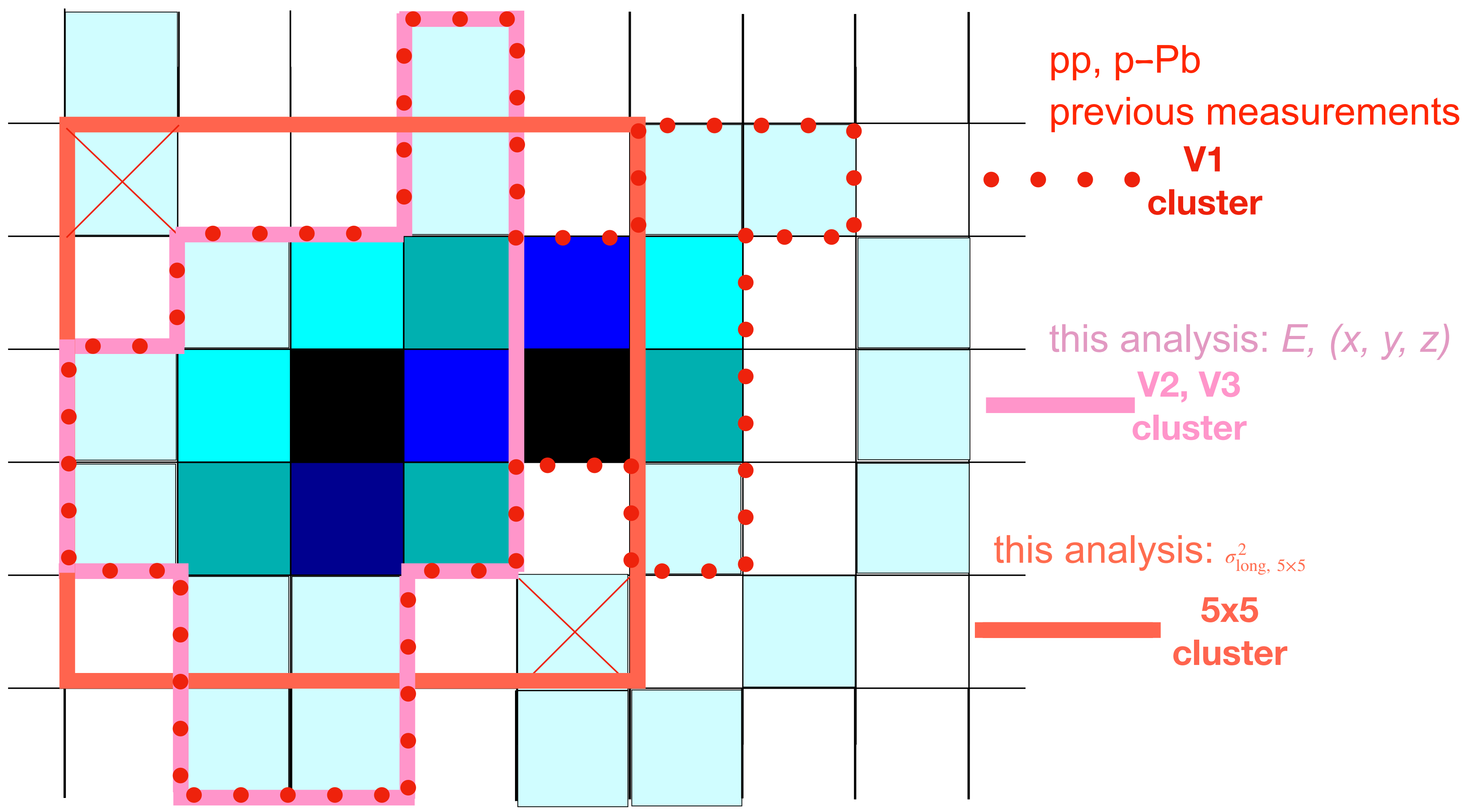
$$w_i = \text{Maximum}(0, w_0 + \ln(E_{\text{cell, }i}/E))$$

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

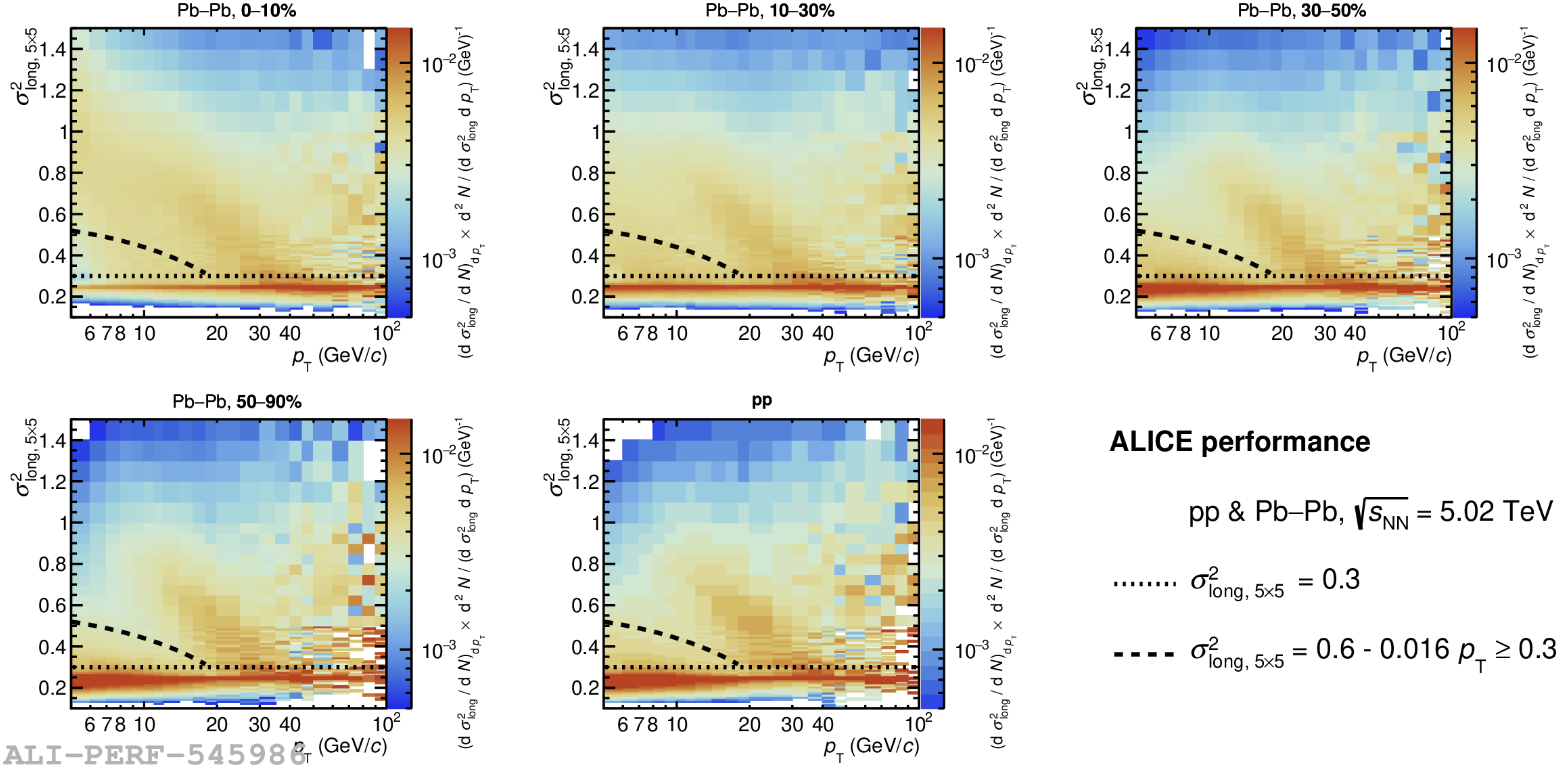
$$\sigma^2_{long} = 0.5(\sigma^2_{\varphi\varphi} + \sigma^2_{\eta\eta}) + \sqrt{0.25(\sigma^2_{\varphi\varphi} - \sigma^2_{\eta\eta})^2 + \sigma^2_{\eta\varphi}},$$

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

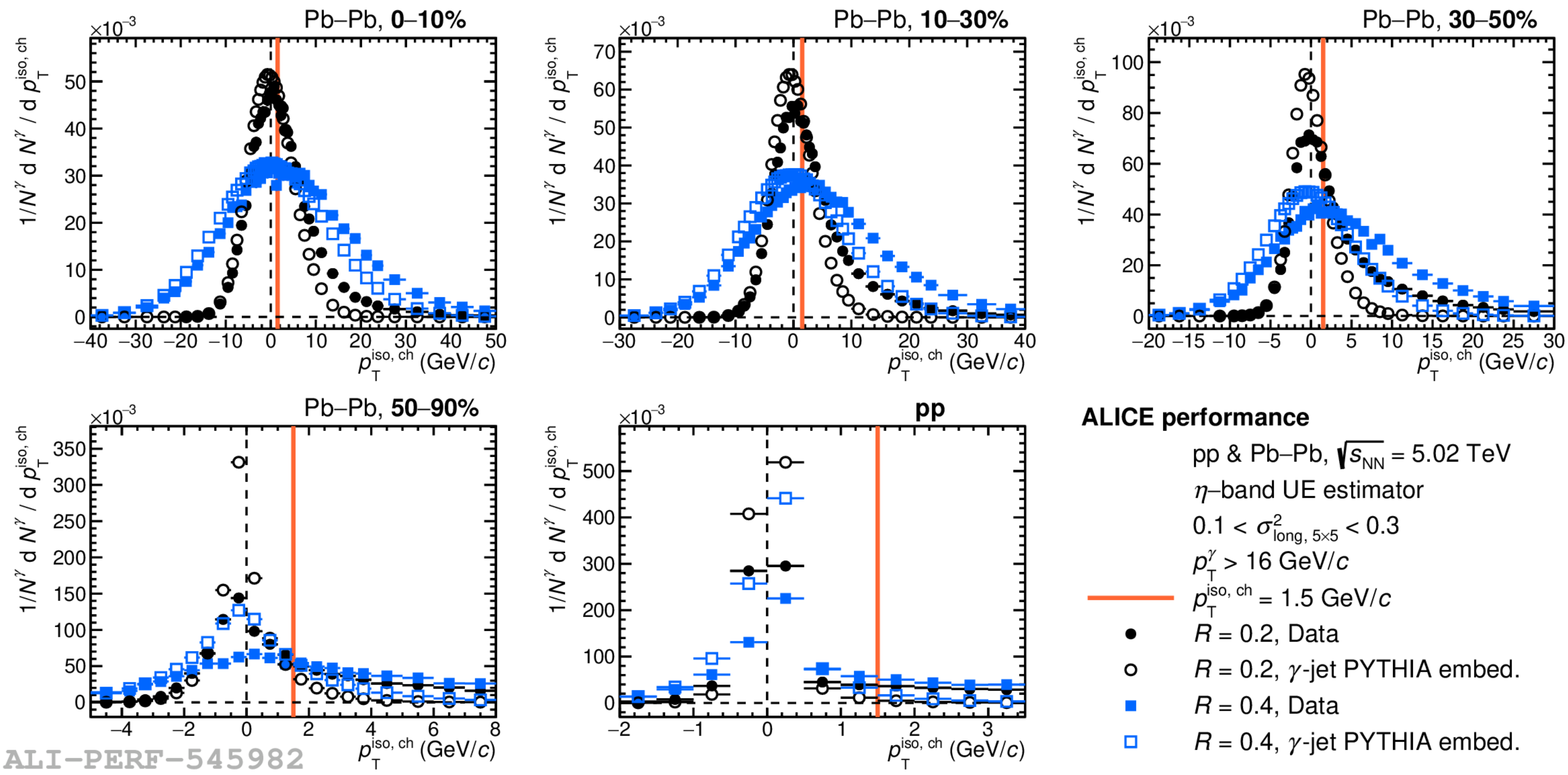
- For Pb–Pb, let's just consider the cells around the highest energy cell in a 5x5 fixed window in the $\sigma^2_{\text{long, }5\times5}$ calculation, independently if cells were assigned to the V3 cluster
  - Those cells must be all neighbours
- The cluster energy and position remains the same as the V3 cluster
- Use same definition in pp and Pb–Pb collisions

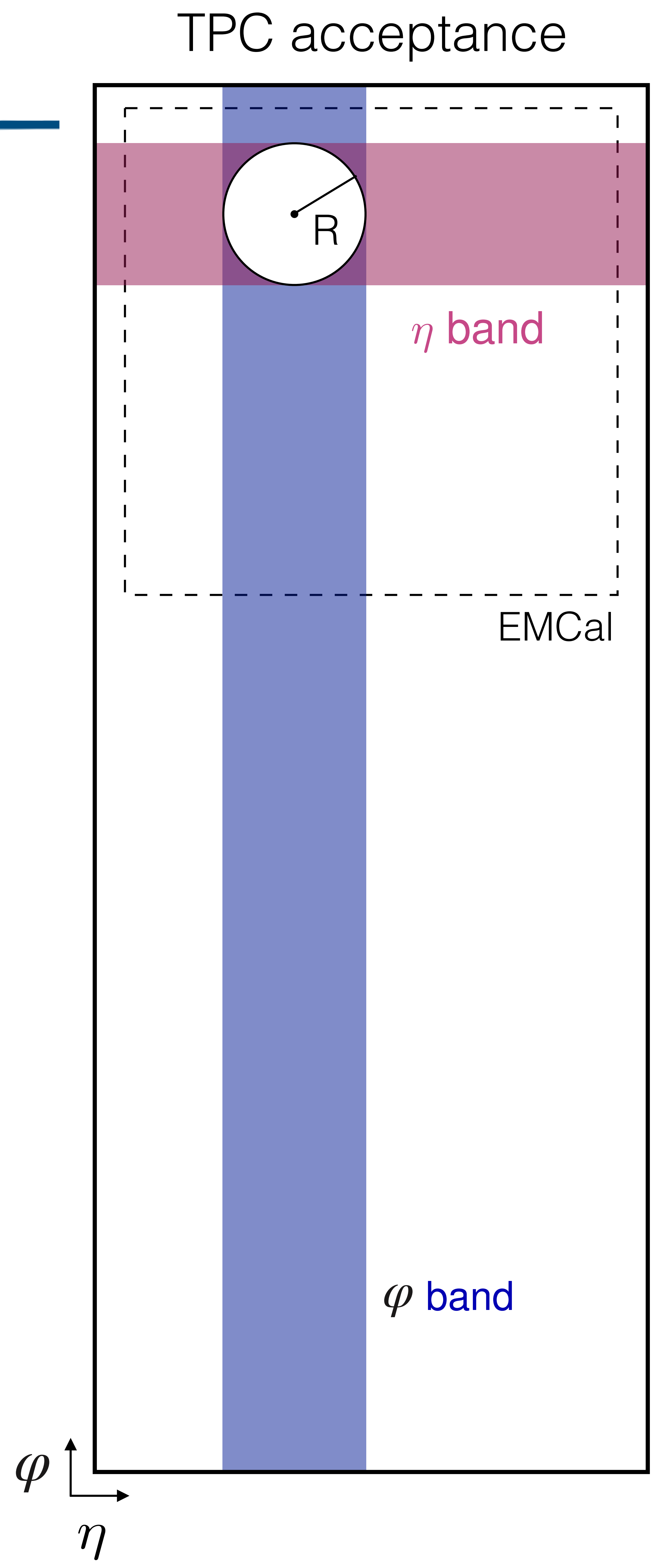


EMCal cluster shower shape



Isolation energy in cone for R = 0.2 & 0.4




TPC acceptance
R
η band
EMCal
φ band
φ
η

Purity

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

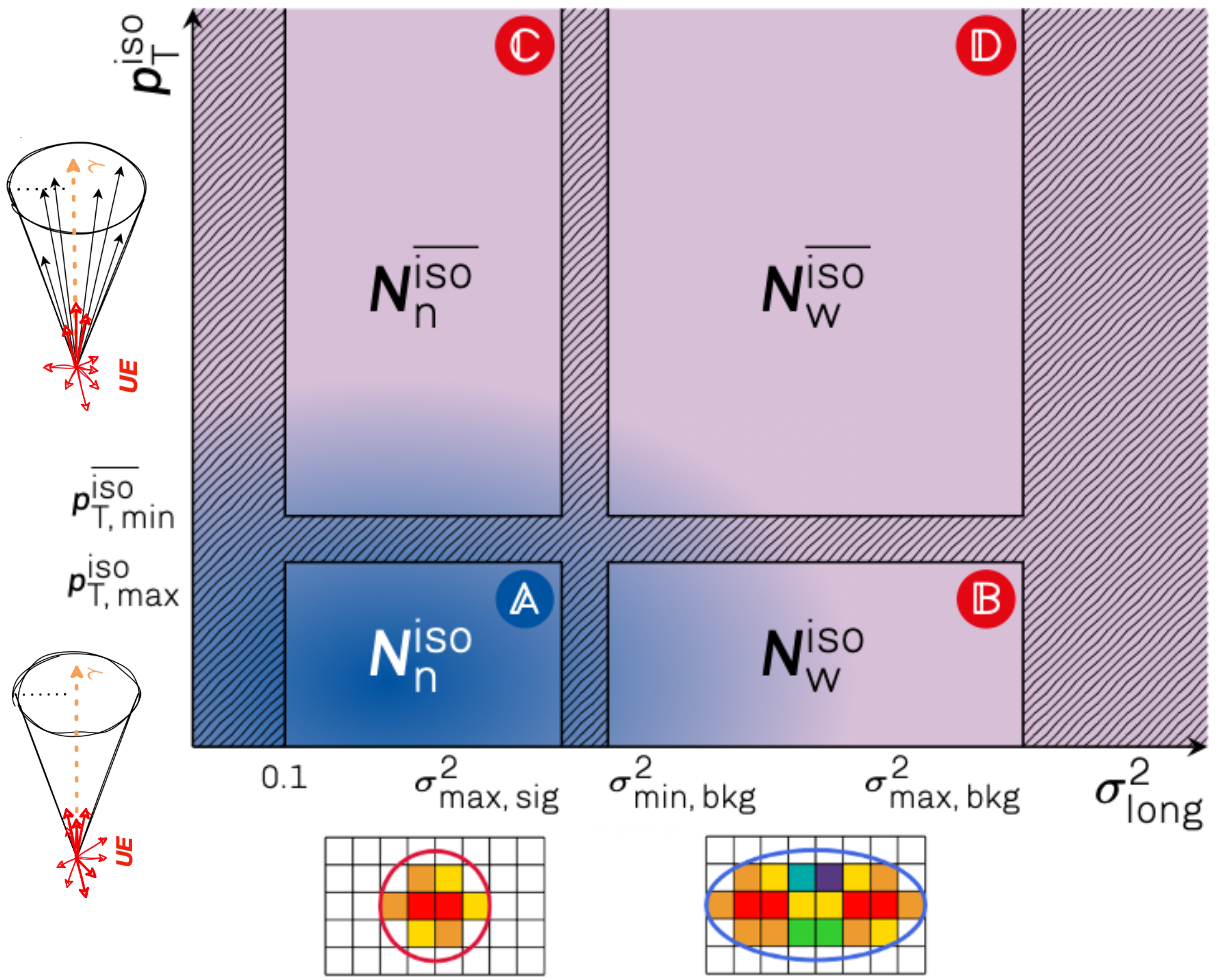
$\mathbb{A}$: $0.1 < \sigma^2_{\mathrm{long,\,5\times5}} < \sigma^2_{\mathrm{max}}(p_{\mathrm{T}})$, $\quad p_{\mathrm{T}}^{\mathrm{iso,\,ch}} < 1.5$ GeV/c

$\mathbb{B}$: $0.1+\sigma^2_{\mathrm{max}}(p_{\mathrm{T}}) < \sigma^2_{\mathrm{long,\,5\times5}} < 2.0$, $\quad p_{\mathrm{T}}^{\mathrm{iso,\,ch}} < 1.5$ GeV/c

$\mathbb{C}$: $0.1 < \sigma^2_{\mathrm{long,\,5\times5}} < \sigma^2_{\mathrm{max}}(p_{\mathrm{T}})$, $\quad 4 < p_{\mathrm{T}}^{\mathrm{iso,\,ch}} < 25$ GeV/c

$\mathbb{D}$: $0.1+\sigma^2_{\mathrm{max}}(p_{\mathrm{T}}) < \sigma^2_{\mathrm{long,\,5\times5}} < 2.0$, $\quad 4 < p_{\mathrm{T}}^{\mathrm{iso,\,ch}} < 25$ GeV/c

with $\sigma^2_{\mathrm{max}} = 0.6 - 0.016 \cdot p_{\mathrm{T}} \geq 0.3$ (Pb–Pb) or $\sigma^2_{\mathrm{max}} = 0.3$ (pp)



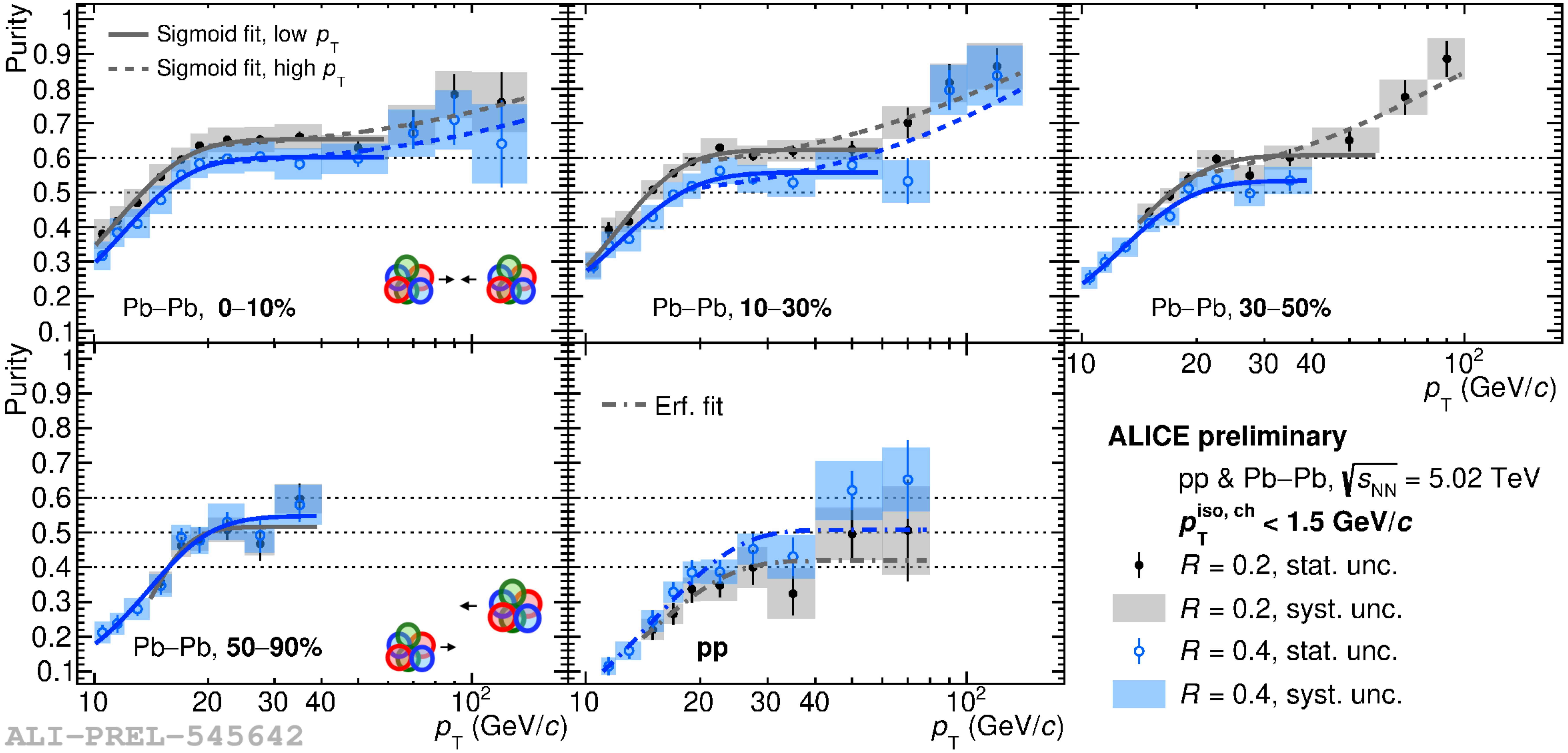
- Purity in $\mathbb{A}$ region extracted as:

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

data-driven

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

Purity for R = 0.2 & 0.4



- Distributions fitted to Sigmoid or Erf functions 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 ($R_{AA}(\pi^0) << 1$)

Cross section calculation

$$\frac{d^2\sigma}{d\,p_T\,d\,\eta} = \frac{\sigma_{MB}}{N_{coll} \times N_{events} \times RF_{\varepsilon_{trig}}} \times \frac{d^2N}{dp_T\,d\eta} \times \frac{P}{Acc. \times \varepsilon_{\gamma}^{iso} \times \varepsilon_{trig}}$$

Ingredients:

- Trigger efficiency: ε_{trig}
- Rejection factor: RF_{trig}
- EMCal acceptance correction Acc: 0.527
- Minimum bias cross section: σ_{MB}
- N_{coll}
- Purity
- Efficiency:

	σ_{MB} (mb)	N_{col}
pp	50.87 (2.1%)	1
Pb–Pb	67.6 (0.88%?)	
0-10%		1572 ± 17.4 (1.1%)
10-30%		783.05 ± 7.0 (0.9%)
30-50%		264.75 ± 3.3(1.2%)
50-90%		38.42 ± 0.6 (1.6%)

Efficiency per selection cut:

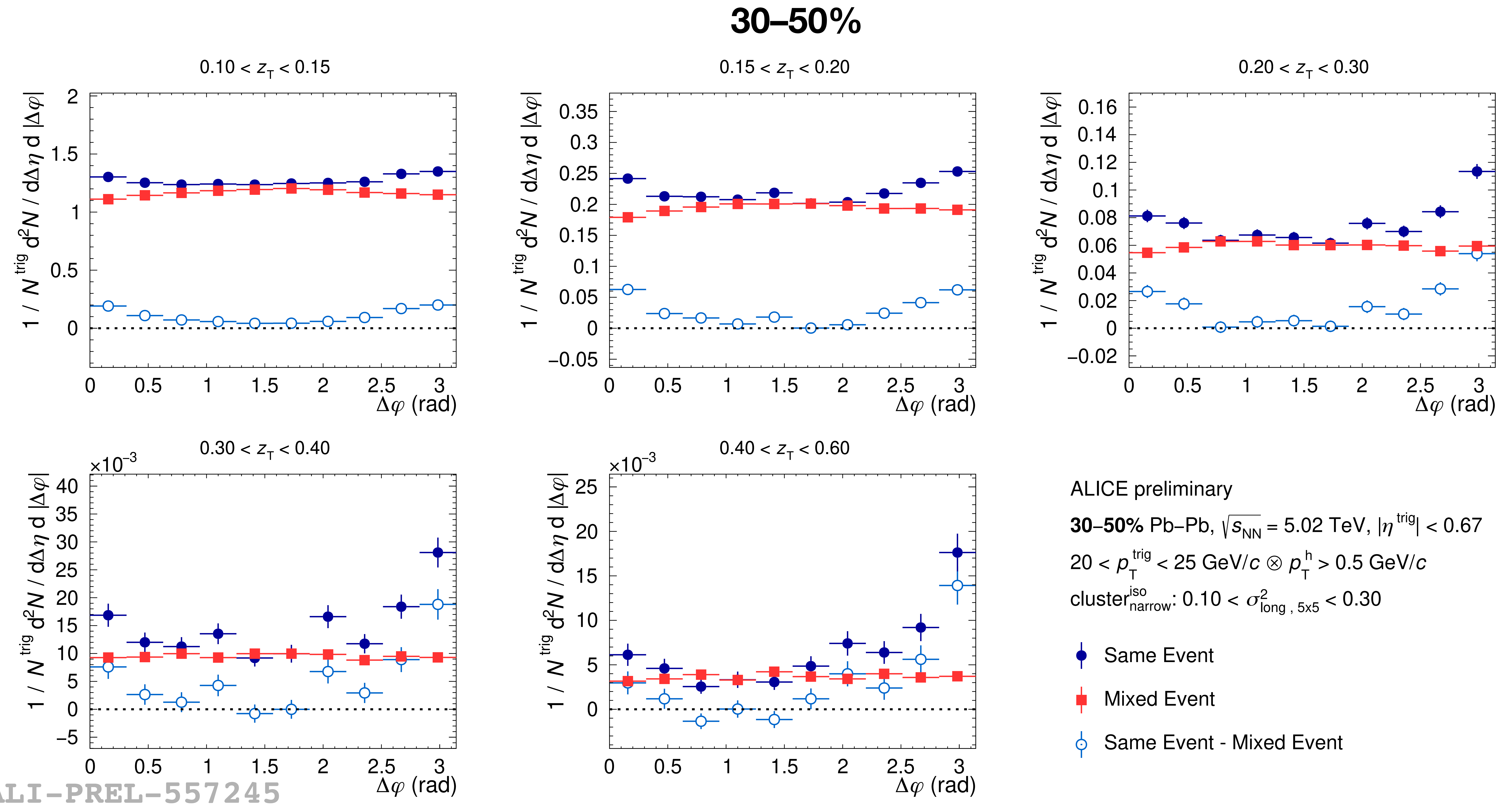
$$\varepsilon^{sel} = \frac{dN_{\gamma_{prompt}}^{cluster\ sel.}/dp_T^{rec}}{dN_{\gamma_{prompt}}^{gener.}/dp_T^{gen}}$$

- Reconstruction
- PID (shower shape)
- Isolation

Final efficiency:

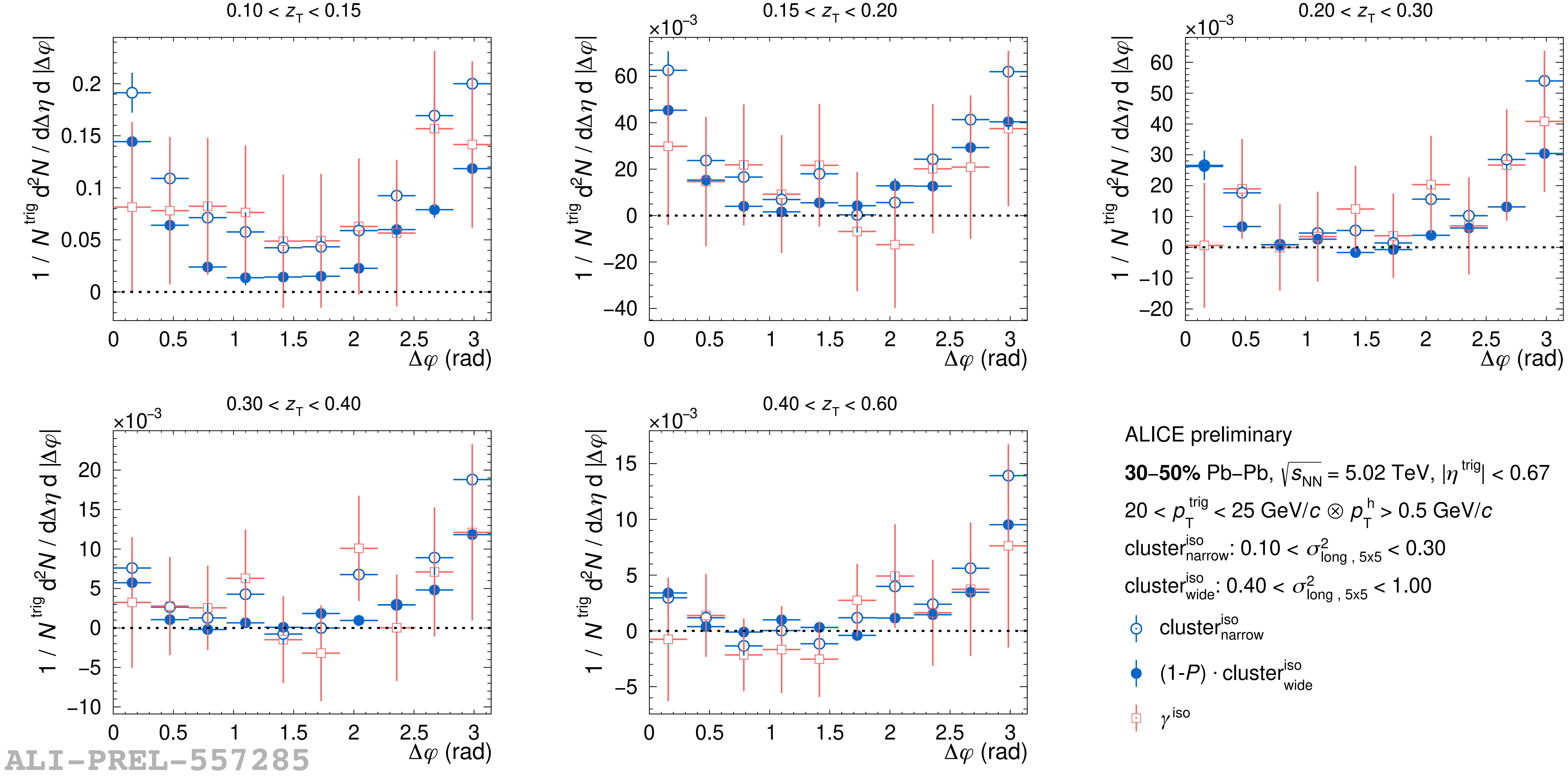
$$\varepsilon_{\gamma}^{iso} = \frac{dN_{\gamma_{prompt}}^{cluster\ iso.\ narrow}/dp_T^{rec}}{dN_{\gamma_{prompt}}^{gener.\ iso.}/dp_T^{gen}}$$

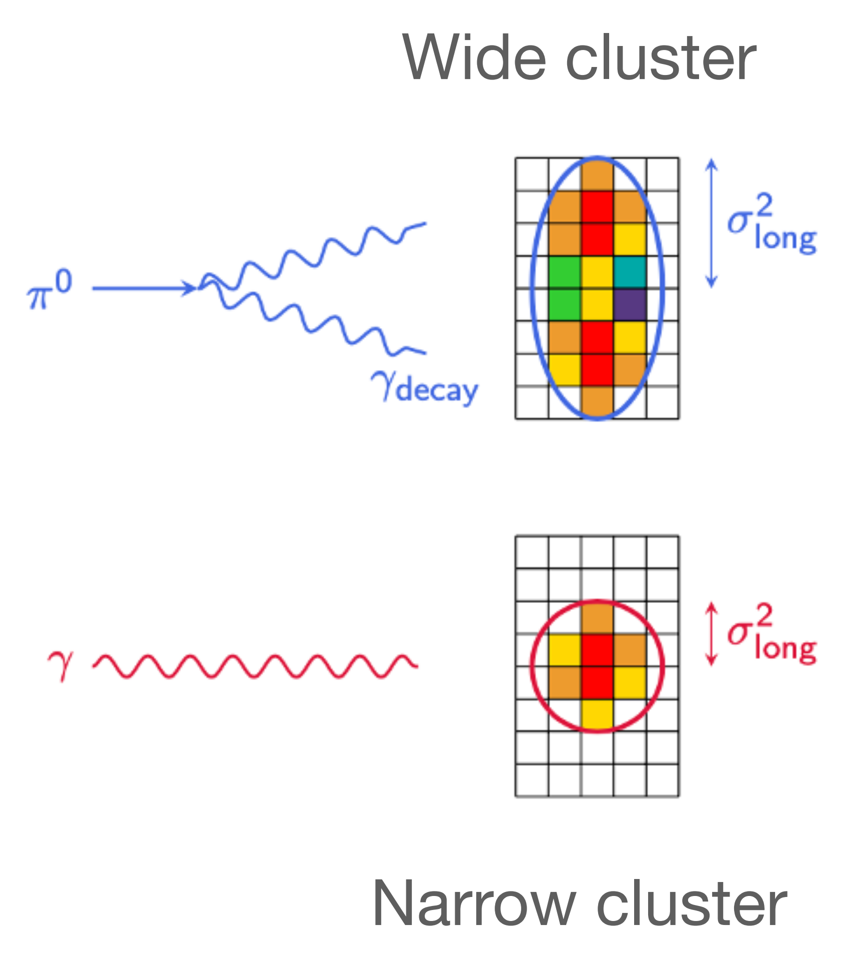
γ^{iso}-hadron correlations in Pb–Pb: UE subtraction



γ^{iso}-hadron correlations in Pb—Pb: purity correction

30–50%



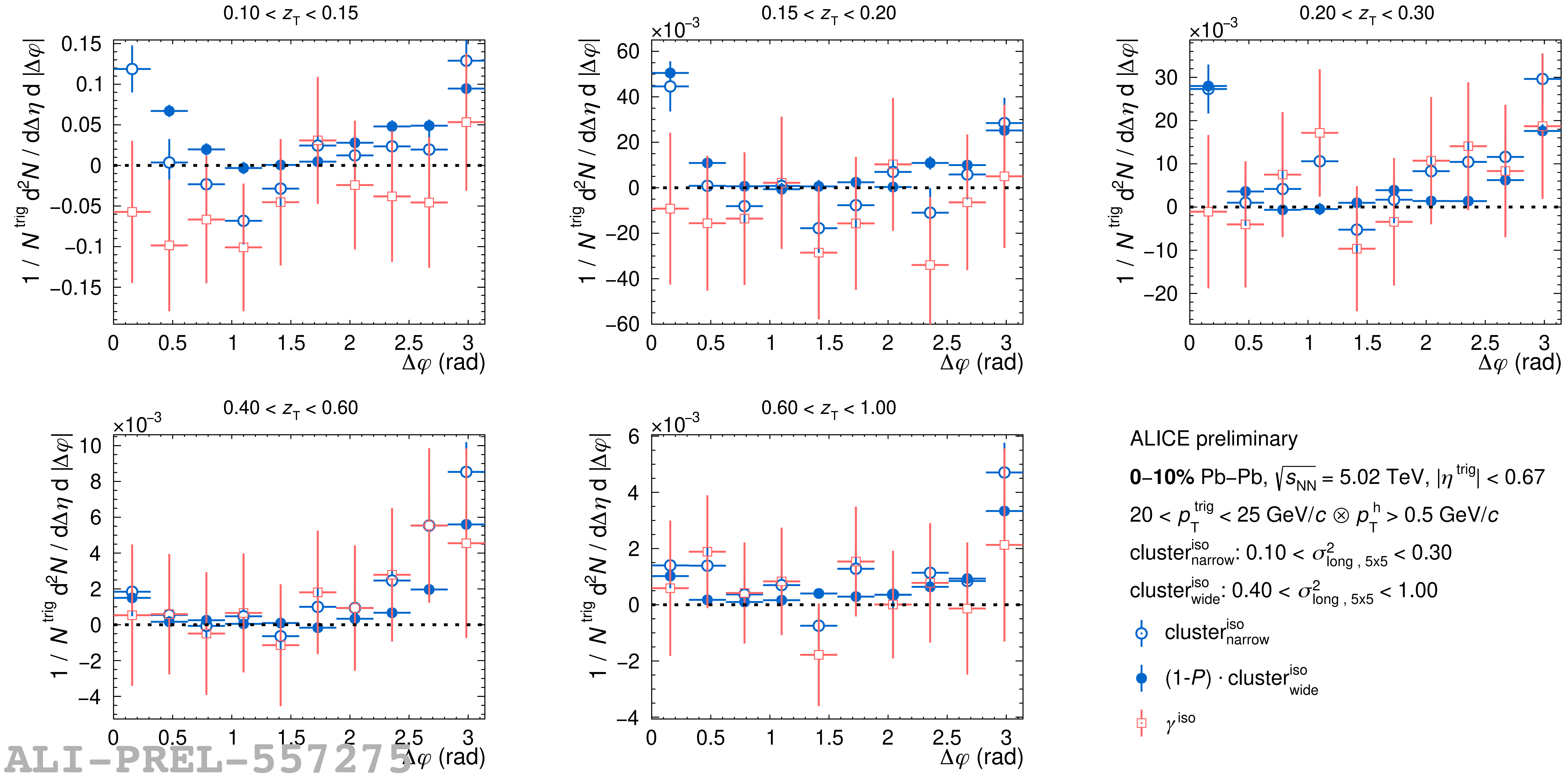


γ^{iso}-hadron correlations in Pb—Pb: UE subtraction

0–10%

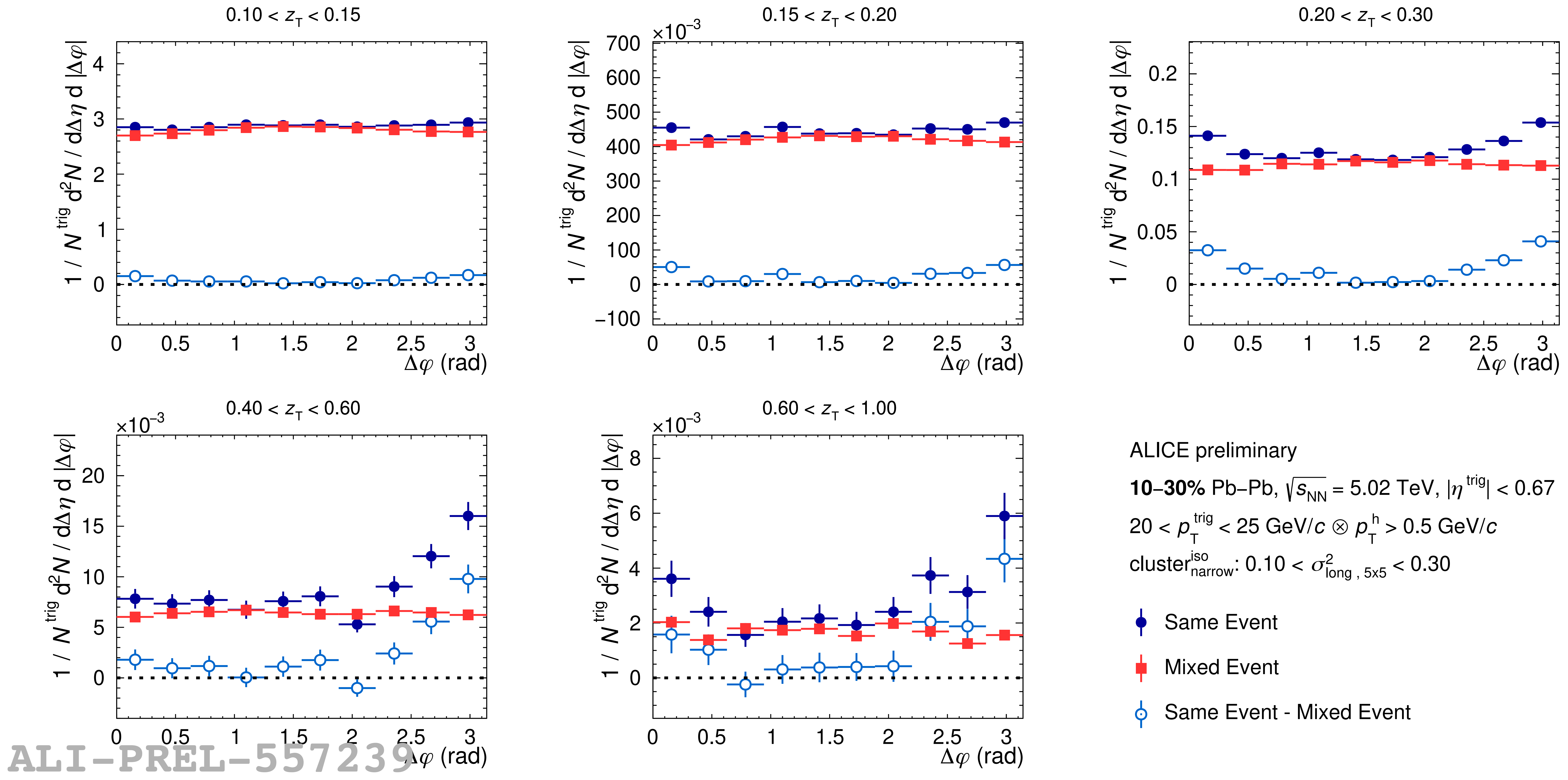
γ^{iso}-hadron correlations in Pb—Pb: purity correction

0–10%



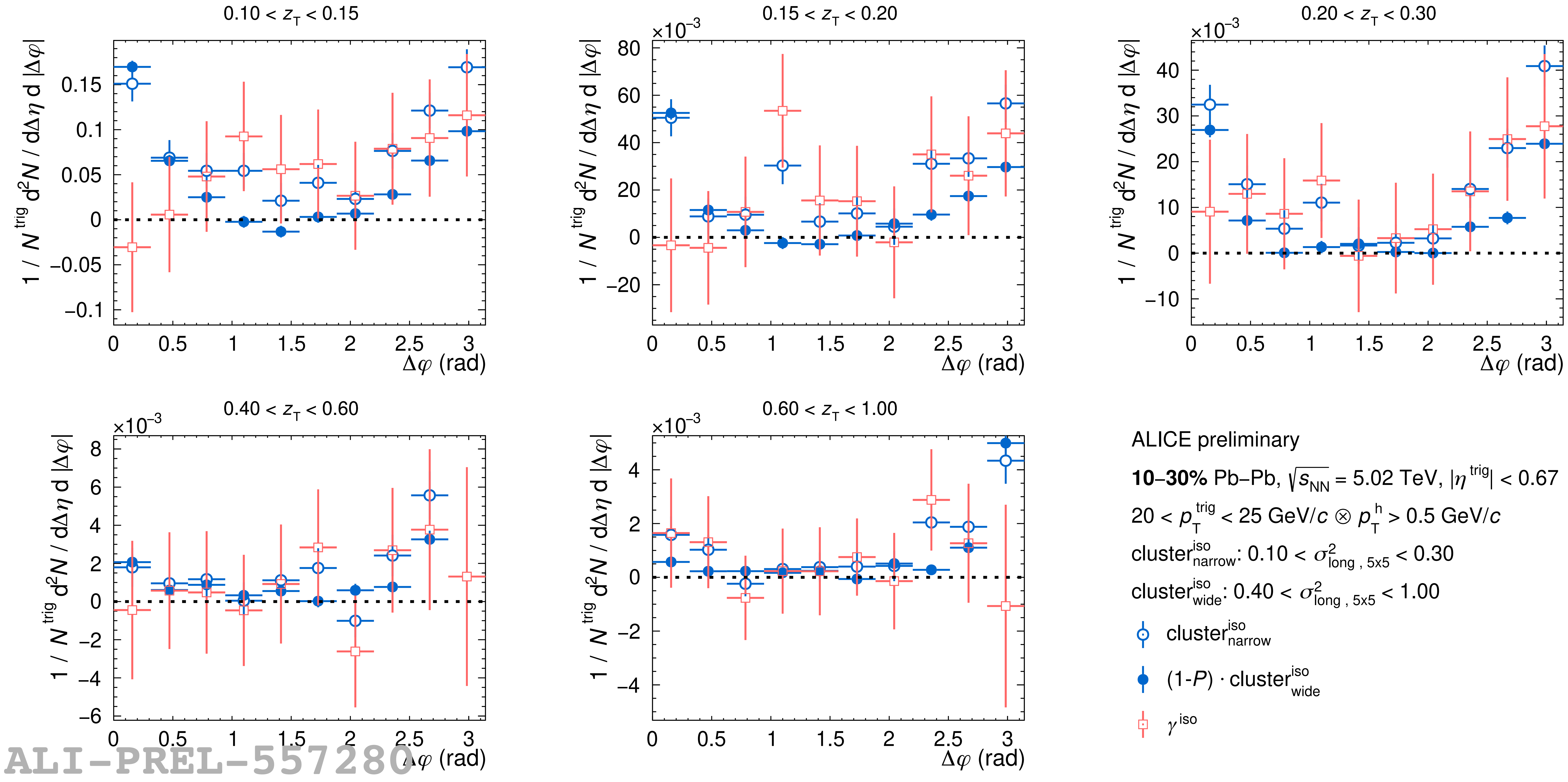
$\gamma^{\rm iso}$-hadron correlations in Pb—Pb: UE subtraction

10–30%



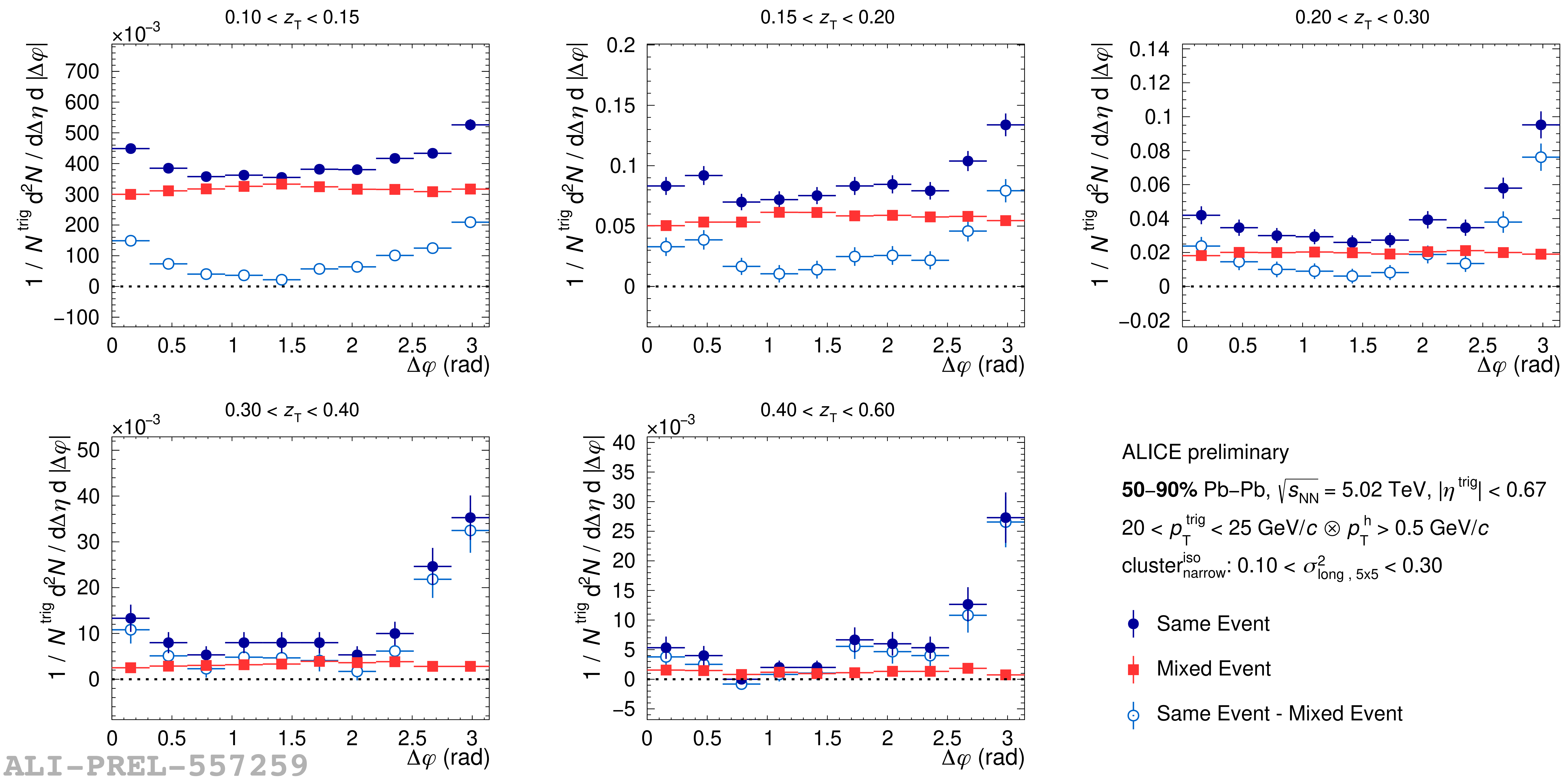
γ^{iso}-hadron correlations in Pb—Pb: purity correction

10–30%



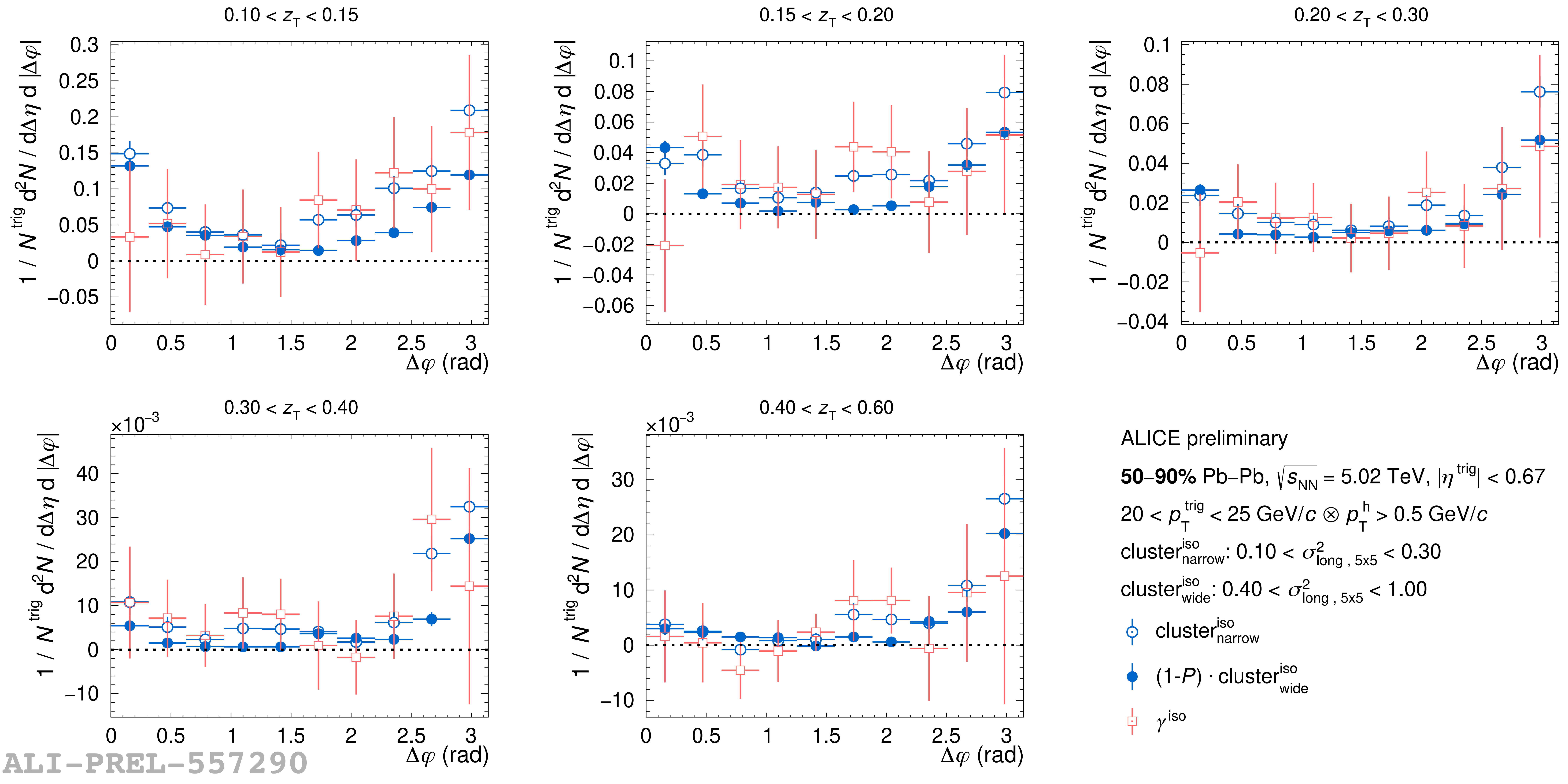
γ^{iso}-hadron correlations in Pb—Pb: UE subtraction

50–90%



γ^{iso}-hadron correlations in Pb–Pb: purity correction

50–90%



γ^{iso}-hadron correlations in Pb–Pb: $D(z_{T})$