Physics of ridge and hard processes in proton-lead and lead-lead collisions with ATLAS

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10th Exited QCD Conference
March 11-15, 2018, Kopaonik, Serbia

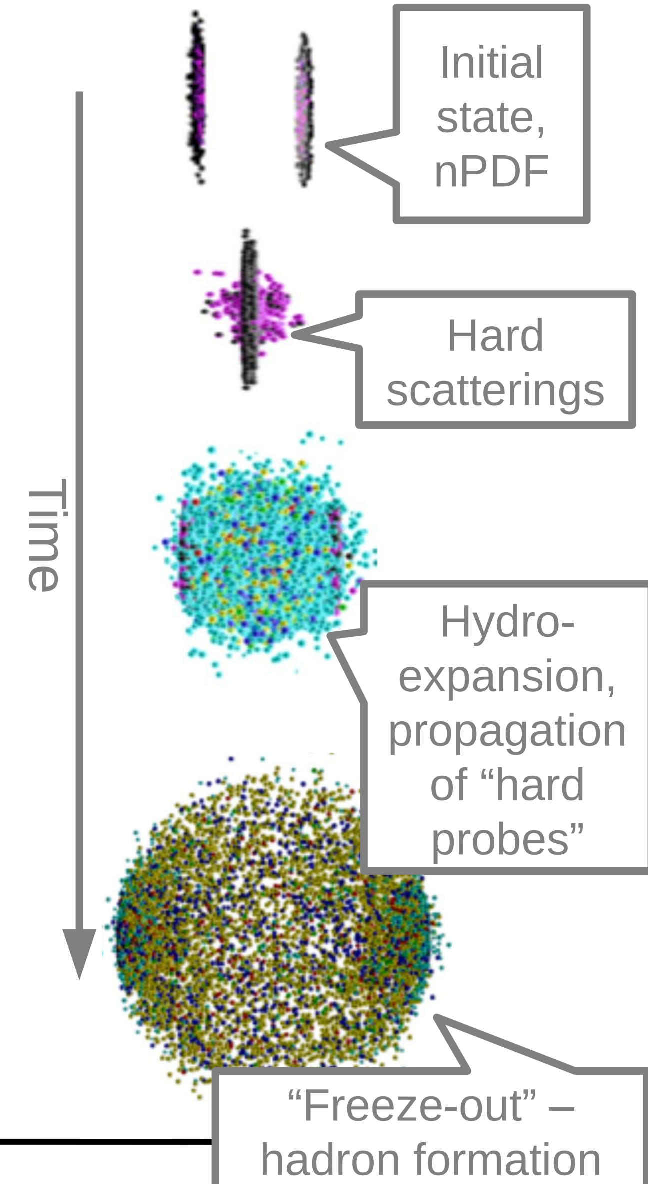
Introduction

Hot and dense **deconfined matter** is created in heavy ion collisions, called quark-gluon plasma (QGP). This matter allows to:

- Study **non-perturbative** aspects of QCD and **collective phenomena** connected with the strong interaction.
- Study the **phase transition** between quarks and gluons and hadrons.
- Study matter which is similar to the matter present in the **early stages of the universe.**

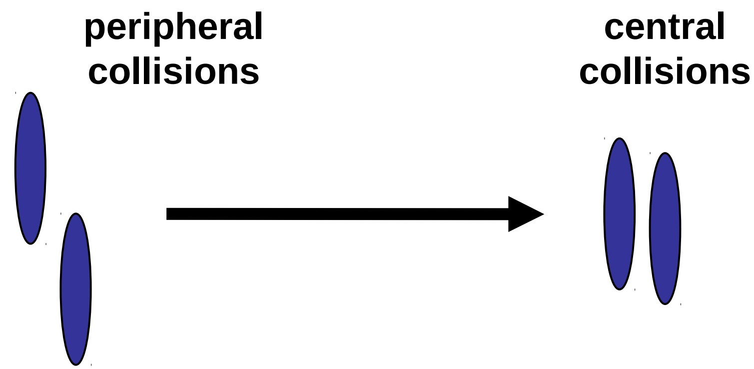
How to access the information? Measure different processes:

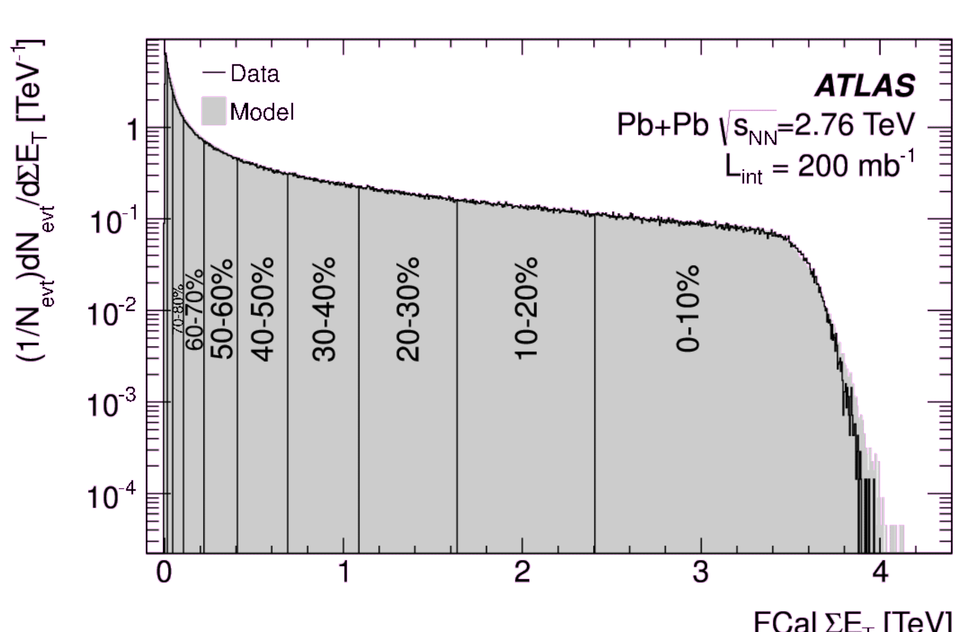
- **hard processes** (e.g. jets and quarkonia)
- **soft processes** (e.g. flow harmonics and the ridge)



Centrality

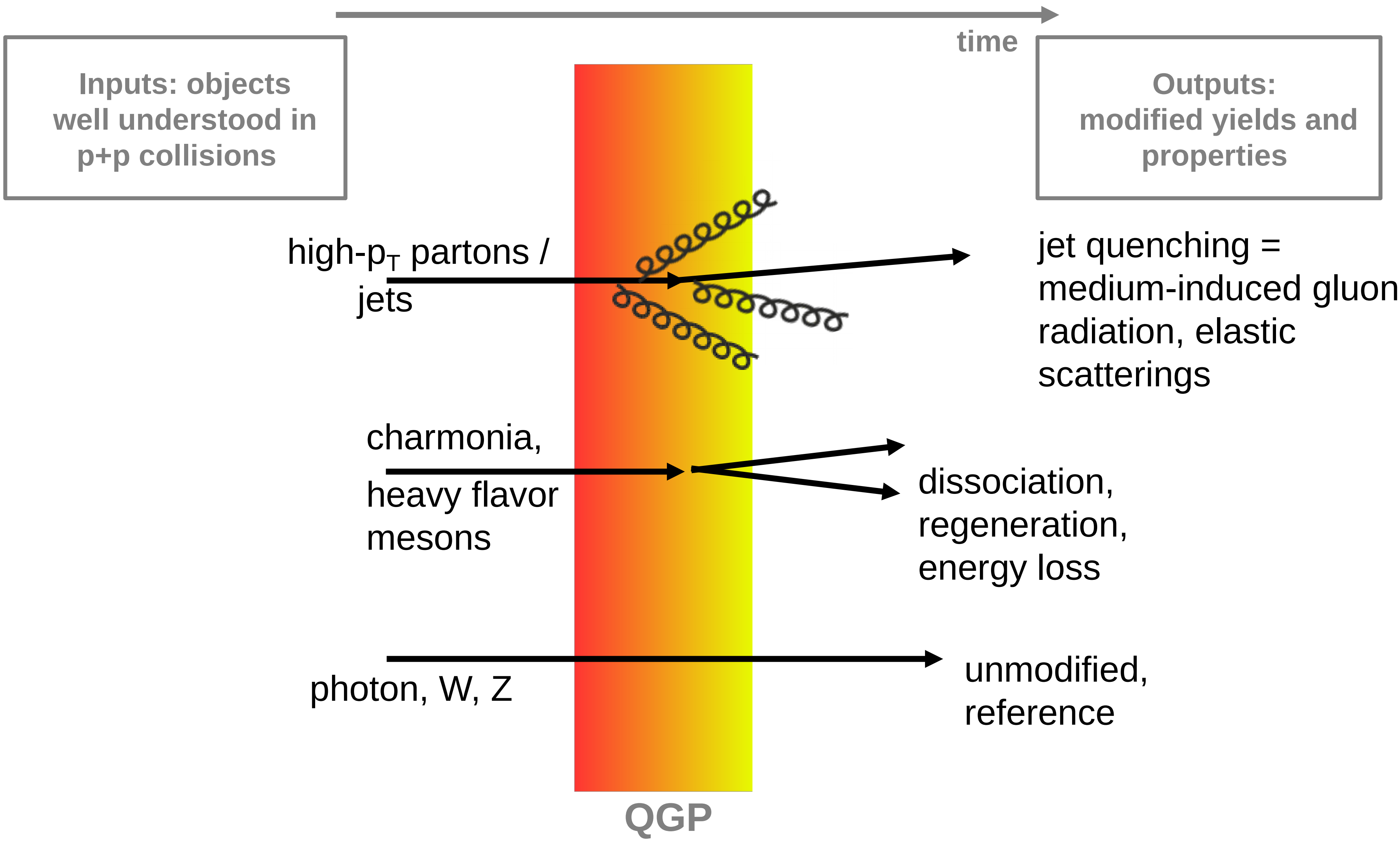
- Centrality quantifies the **degree of overlap** of two colliding nuclei.
- More central collisions – higher deposited energy.
- Centrality quantified by the energy measured in Forward Calorimeters.





Hard processes
(jets & quarkonia)

Hard processes



Inclusive jet suppression in Pb+Pb collisions

$$R_{AA} = \frac{\left.\frac{1}{N_{\mathrm{evnt}}}\frac{\mathrm{d}^2 N_{\mathrm{jet}}^{PbPb}}{\mathrm{d}p_{\mathrm{T}}\mathrm{d}y}\right|_{\mathrm{cent}}}{\langle T_{\mathrm{AA}}\rangle_{\mathrm{cent}} \times \frac{\mathrm{d}^2\sigma_{\mathrm{jet}}^{pp}}{\mathrm{d}p_{\mathrm{T}}\mathrm{d}y}}$$

Jet yield in heavy ion collisions

Mean nuclear tickness fuction

Jet cross-section in *pp* collisions

Expected jet yield in the case of no quenching

The **nuclear modification factor**, R_{AA}, quantifies the magnitude of jet suppression, which arise mainly from final-state interactions with constituents of the medium.

Jet R_{AA}: p_T-dependence, $\sqrt{s_{NN}}$ = 5.02 TeV

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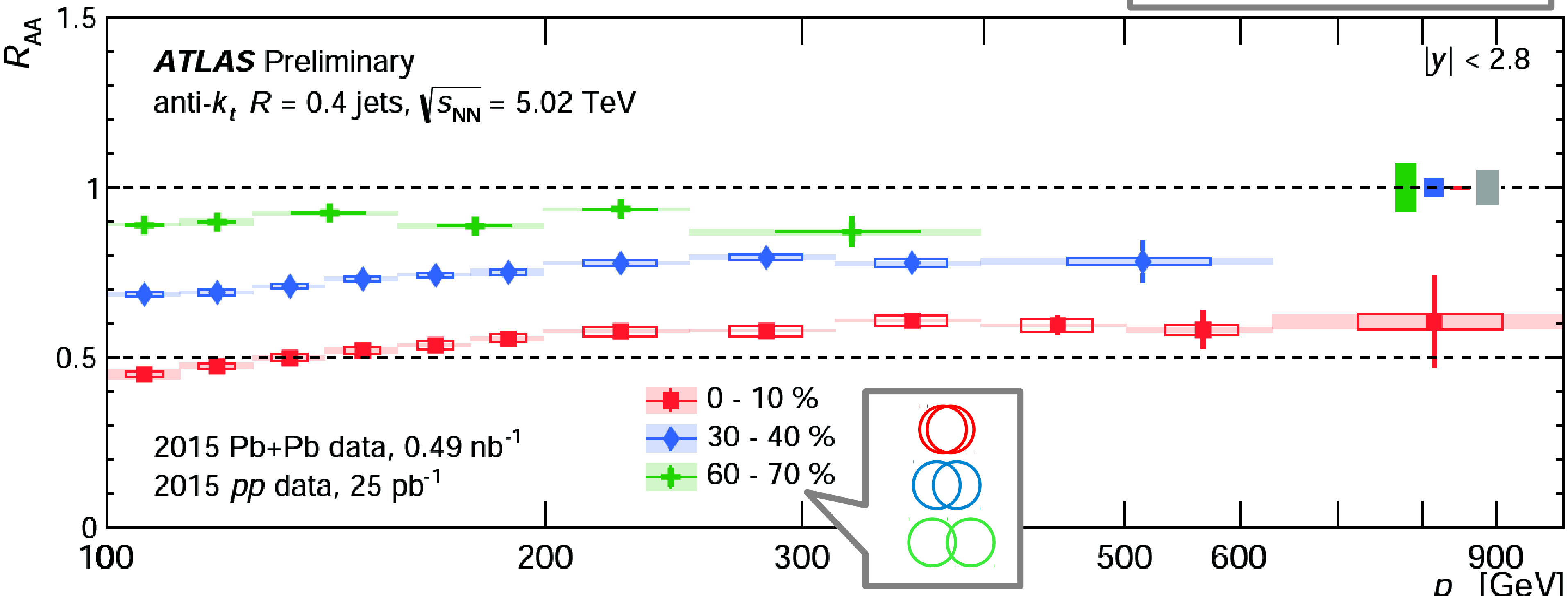

- Central collisions (0-10%): R_{AA} ~ 0.6 **up to TeV scale**.
- Peripheral collisions (60-70%): still significant suppression.
- Measured also differentially in rapidity (more suppression in the forward region).

Jet R_{AA}: p_T-dependence, 2.76 TeV versus 5.02 TeV

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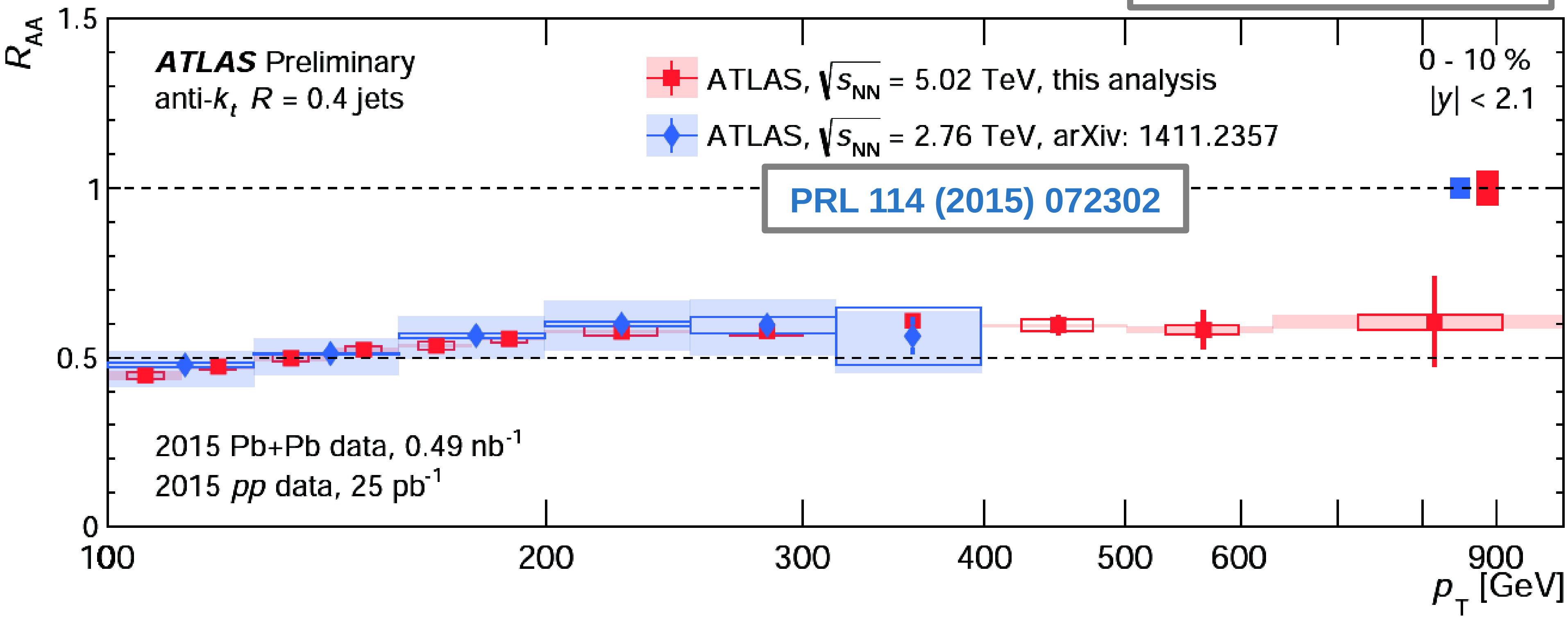

- **Same magnitude** of R_{AA} within systematic uncertainties observed at the two different center-of-mass energies.

Internal structure of jets in Pb+Pb at 5.02 and 2.76 TeV

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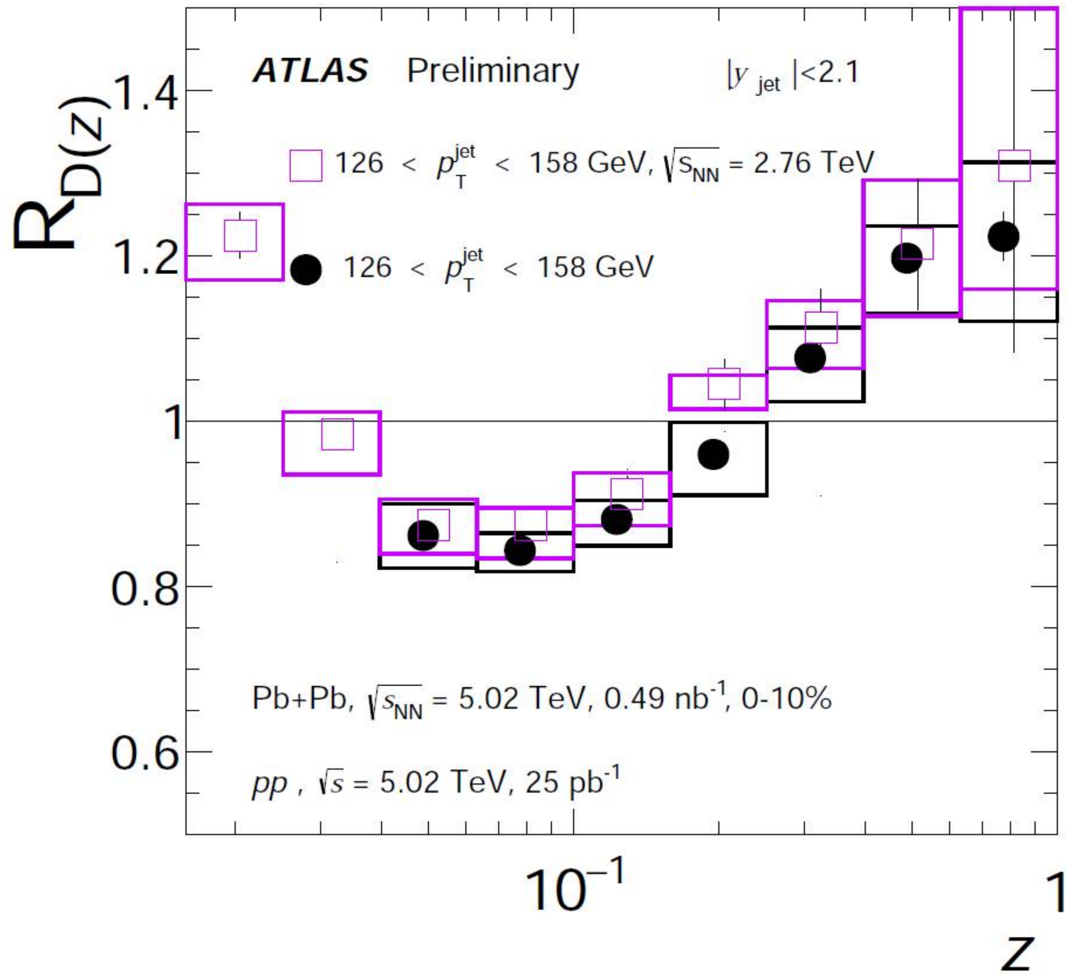
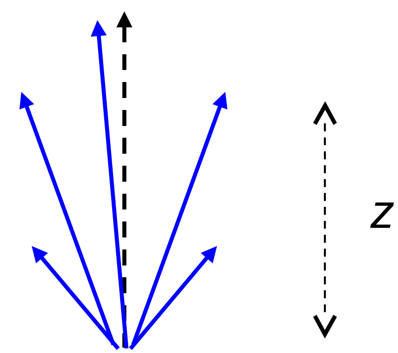
EPJC 77 (2017) 379



$$R_{D(z)} = \frac{D(z)|_{\mathrm{cent}}}{D(z)|_{pp}}$$

$$D(z) = \frac{1}{N_{jet}} \frac{\mathrm{d}N}{\mathrm{d}z}$$

$$z = \frac{p_{\mathrm{T}}}{p_{\mathrm{T}}^{jet}} \cos \Delta R$$



Internal structure of jets in Pb+Pb at 5.02 and 2.76 TeV

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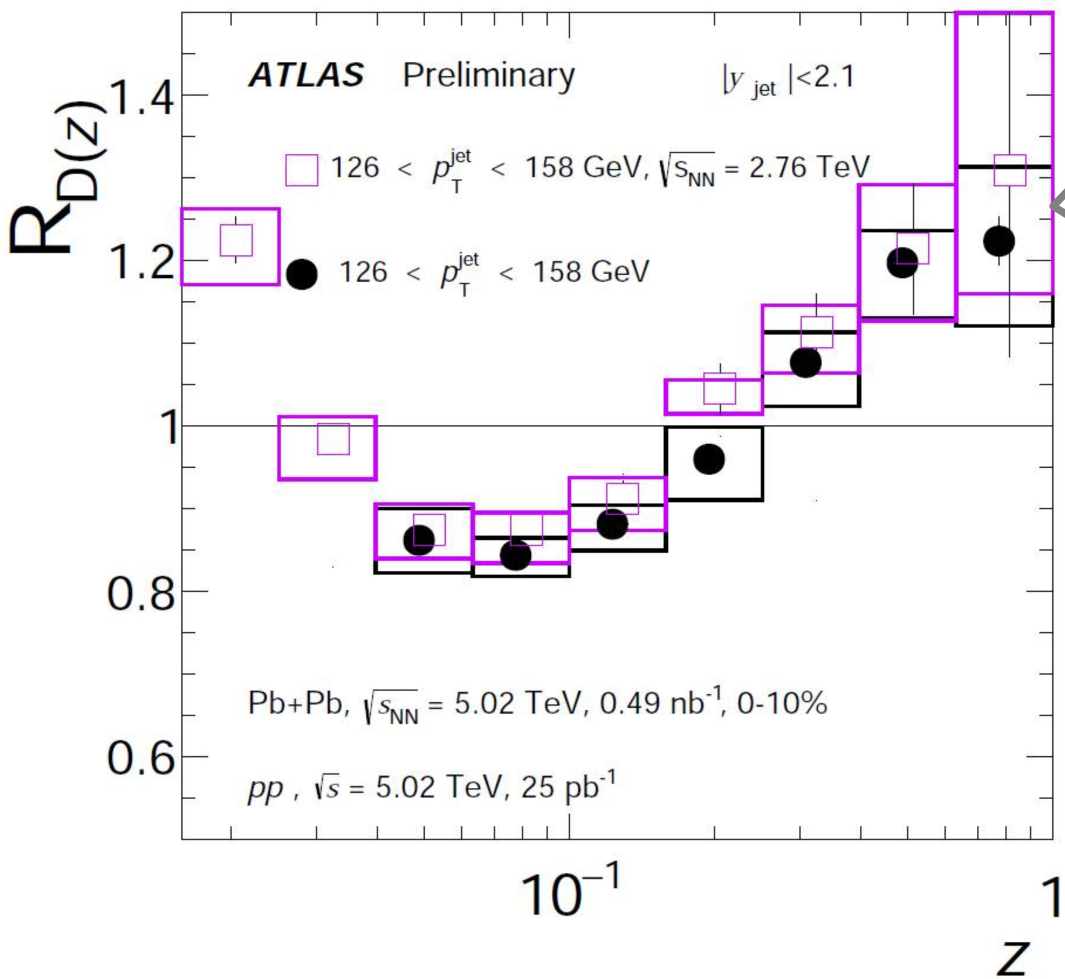


Fragmentation (at 2.76 TeV) **measured for:**

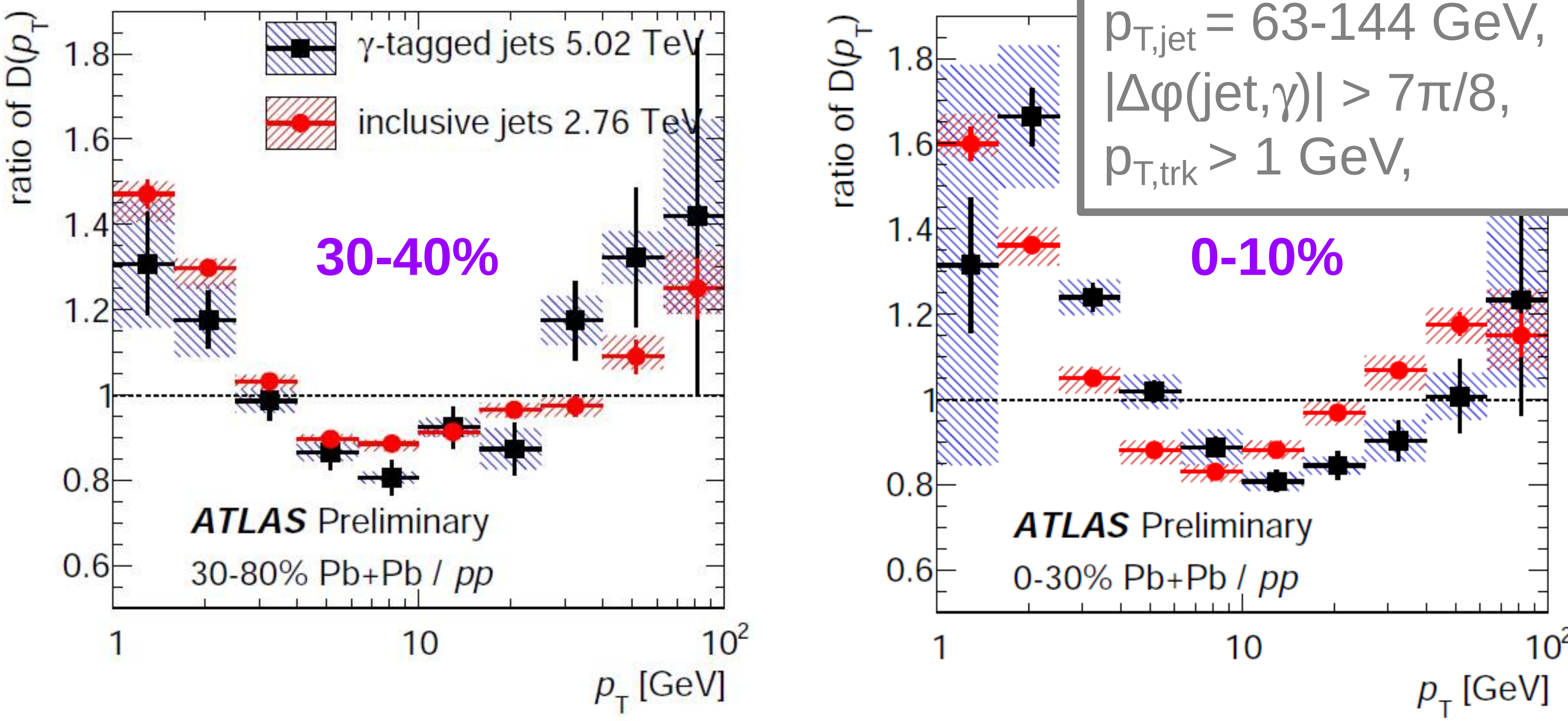
- $p_{T,jet}$ >100 GeV,
- $p_{T,trk}$>1 GeV,
- $|y_{jet}|$<2.1

- **Enhancement** at low *z* and at high *z*, **suppression** at intermediate *z*
- Result **fully corrected** to particle level
- **No √s** dependence
- **No $p_{T,jet}$** dependence observed

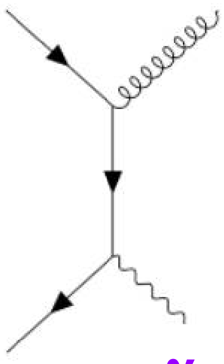
Photon-tagged jet fragmentation in Pb+Pb at 5.02 TeV

ATLAS-CONF-2017-074

$p_{T,\gamma}$ = 80-126 GeV,
$p_{T,jet}$ = 63-144 GeV,
$|\Delta\varphi(jet,\gamma)| > 7\pi/8$,
$p_{T,trk} > 1$ GeV,



jet

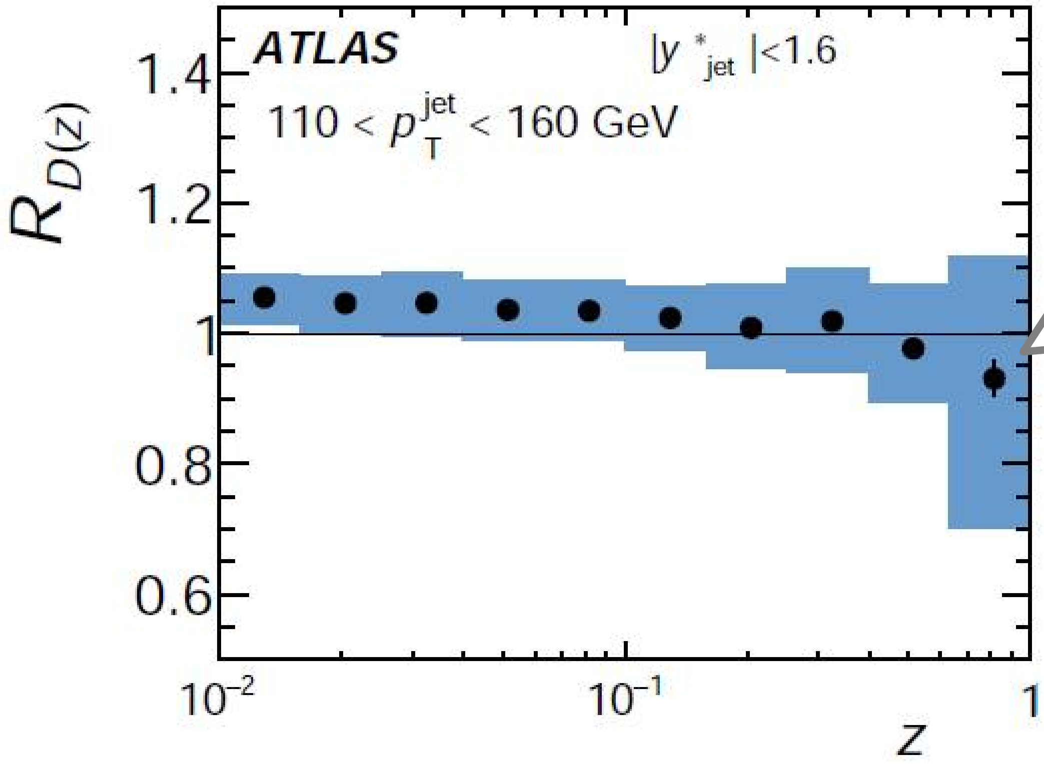


γ

- γ-tagged jet fragmentation: **q/g dependence**. Unquenched γ kinematics!
- More peripheral bin: ratios similar between photon-tagged and inclusive.
- **Central bin: ratios different** between photon-tagged and inclusive.
- Result **fully corrected** to particle level.

Jet fragmentation in p+Pb at 5.02 TeV

arxiv:1706.02859



Measured for:

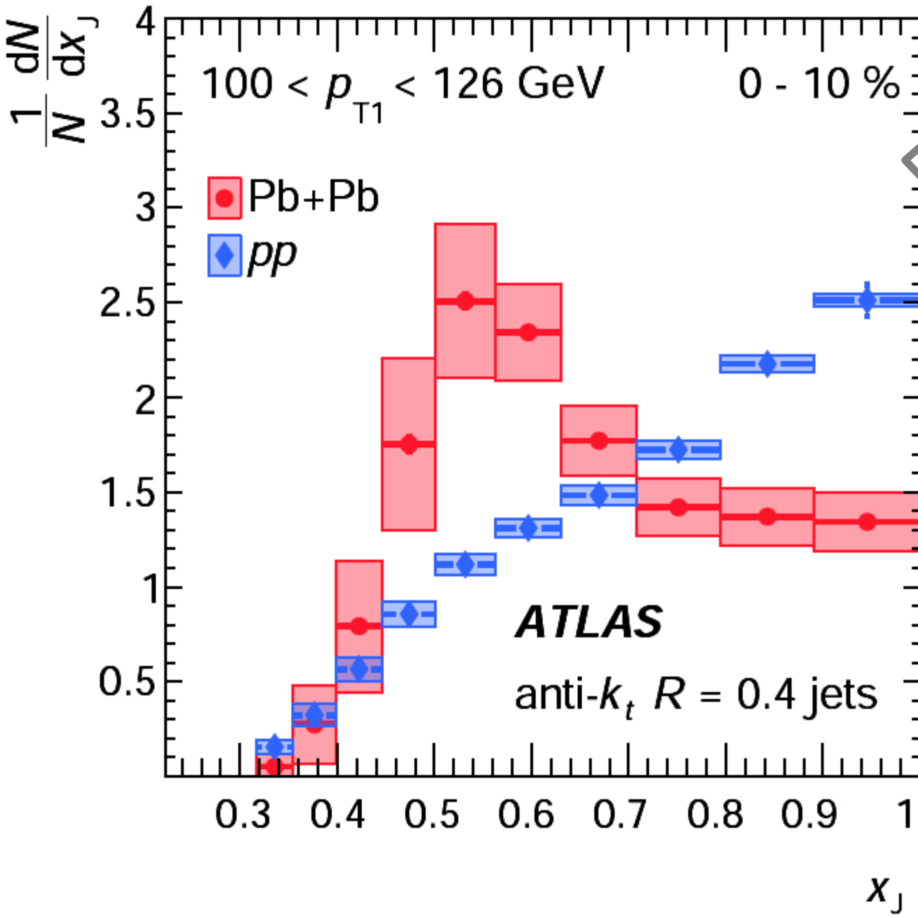
- $p_{T,jet}$ = 45-260 GeV,
- $p_{T,trk}$ > 1 GeV,
- $|y_{jet}^*|$ < 1.6

- **No modifications** of jet internal structure seen in the p+Pb environment.

Dijet production in Pb+Pb at 2.76 TeV

PLB 774 (2017) 379

$$x_J = \frac{p_{T,1}}{p_{T,2}}$$



Measured for:

- $p_{T,subleadning}$ >25 GeV,
- $p_{T,leadning}$ >100 GeV (various bins),
- $|\Delta\varphi(jet,\gamma)| > 7\pi/8$
- $|\eta| < 2.1$
- R=0.4, R=0.3 jets

- First **fully corrected** dijet measurement in heavy ions (using **2D bayesian unfolding**).
- Energy **loss very different** for the second jet.
- Similar difference between *pp* and Pb+Pb measured also in gamma-jet system.

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Dijet production Pb+Pb at 2.76 TeV

pt of jet

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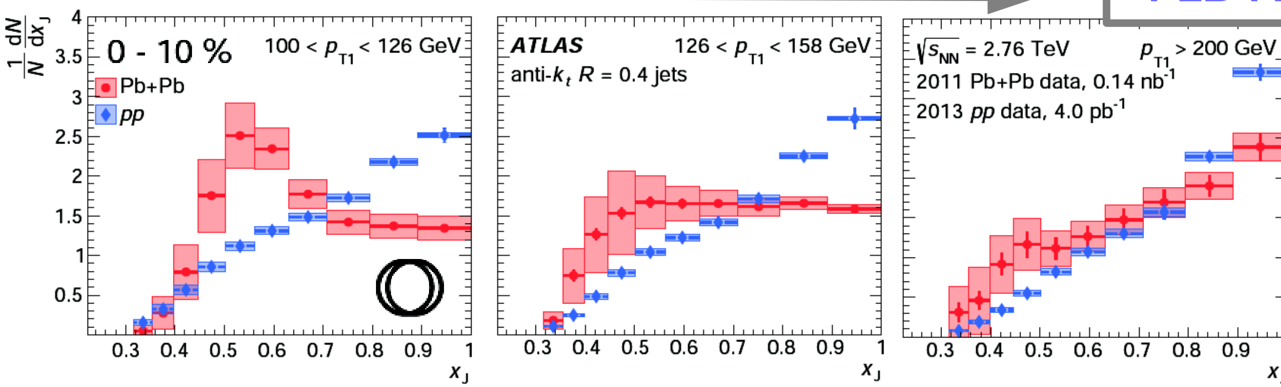
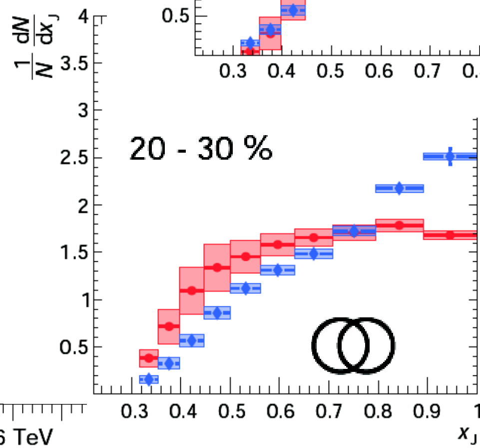
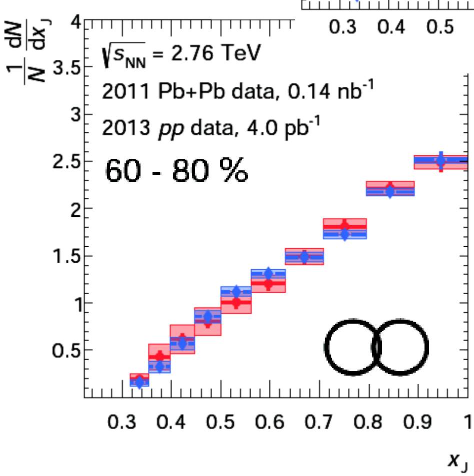
centrality







Pb+Pb

pp

Pronounced jet pt dependence, high-p_T jets almost unmodified

Clear centrality dependence.
0-10%: most probable value ~0.5.
60-80%:consistent with pp.

Quarkonia in **Pb+Pb**, 5.02 TeV

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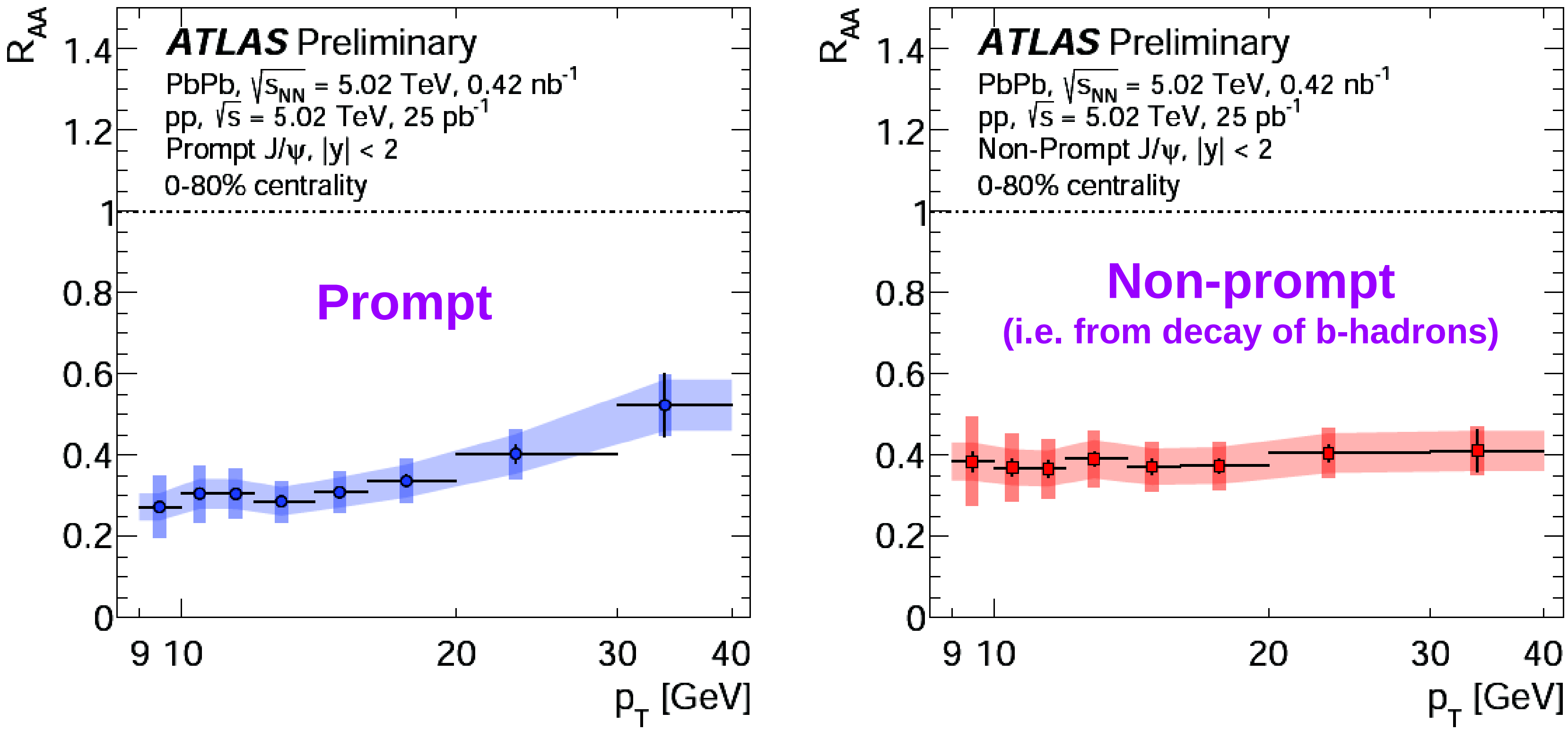


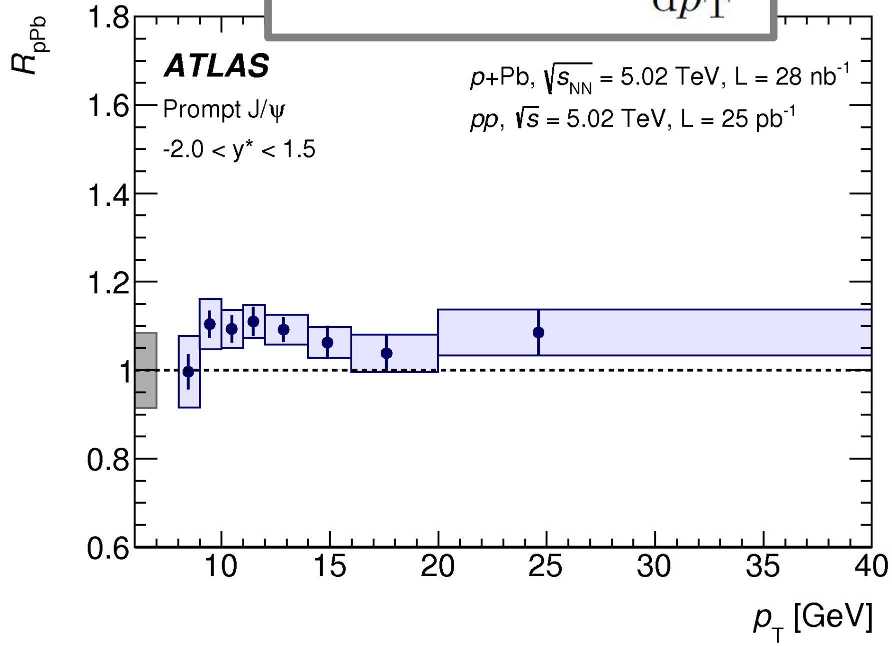
- **Strong suppression** of quarkonia in Pb+Pb.
- **Similar suppression** of prompt and non-prompt J/ψ, but different for prompt and non-prompt ψ(2S) (not shown).
- Non-prompt fraction in Pb+Pb consistent with *pp* (not shown).

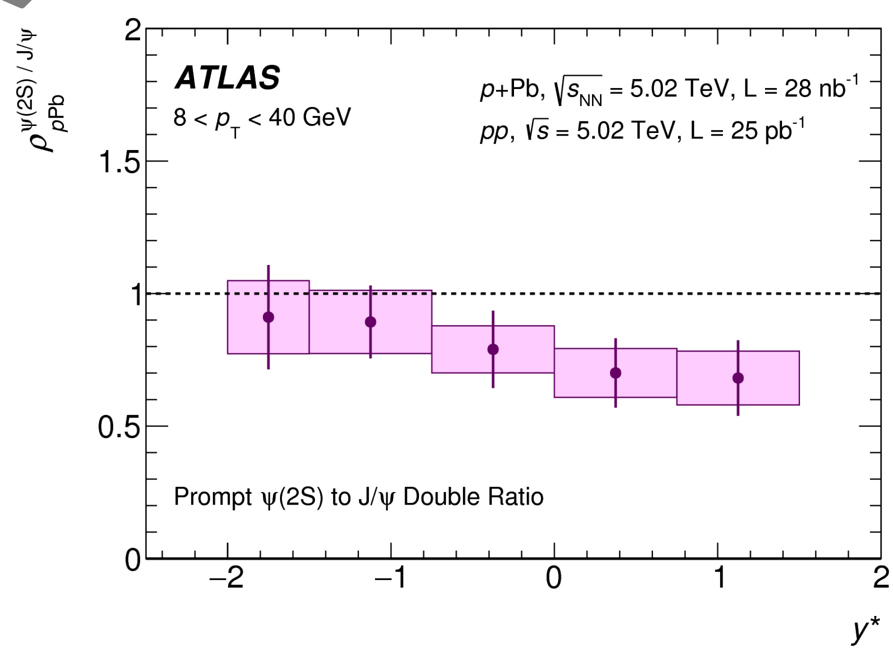
Quarkonia in **p+Pb**, 5.02 TeV

$$R_{pPb} = \frac{\frac{d\sigma^{pPb}}{dp_T}}{A \times \frac{d\sigma^{pp}}{dp_T}}$$

~ ratio of R_{pPb}

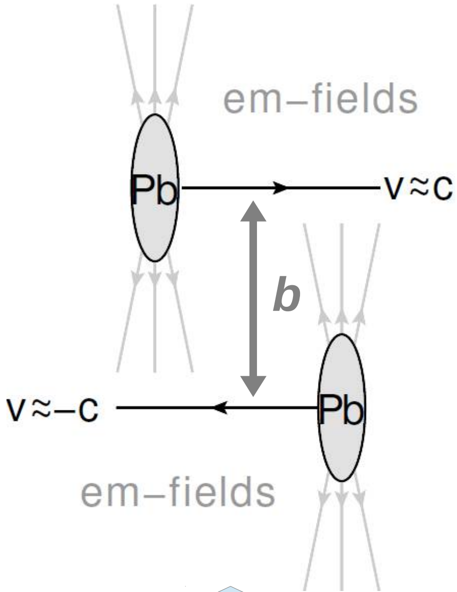
arxiv:1709.03089

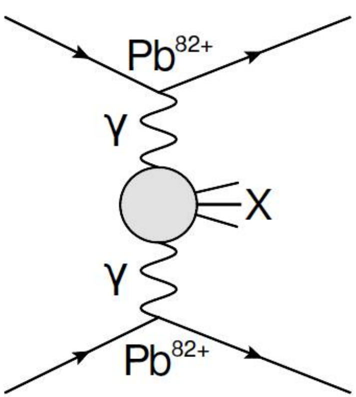




- J/ψ R_{pPb} consistent with unity, ψ(2S) **suppressed** wrt J/ψ (1σ).
- Prompt and non-prompt J/ψ, ψ(2S), cross-sections **consistent with NRQCD and FONLL** predictions, respectively (not shown).
- Significant modifications seen also for Υ(1S,2S,3S) in p+Pb collisions.

Ultra-peripheral collisions





- Qualitatively different collisions compared to ordinary Pb+Pb collisions.
- EM interactions dominate **at large impact parameters (b), photons of small virtuality** ($Q^2<1/R^2=10^{-3}GeV^2$).
- Photon density **$45\cdot10^6$ larger in Pb+Pb** compared to p+p.
- Allowed to measure **light-by-light scattering** (Nature Physics 13 (2017) 852).
- May allow to access **beyond-SM** physics.
- Allows to restrict **nuclear parton distribution functions** at low *x*.

Photo-nuclear dijet production

- Motivation: restrict nuclear parton distribution functions (nPDF) at low *x*
- **nPDF** exhibit **non-trivial behavior**:
  - suppression at low *x* called “shadowing“
  - enhancement at larger *x* called “anti-shadowing“
  - suppression at the largest *x* called “EMC effect“

$$f_i^{p/A}(x, Q^2) = R_i^A(x, Q^2)\, f_i^p(x, Q^2)$$

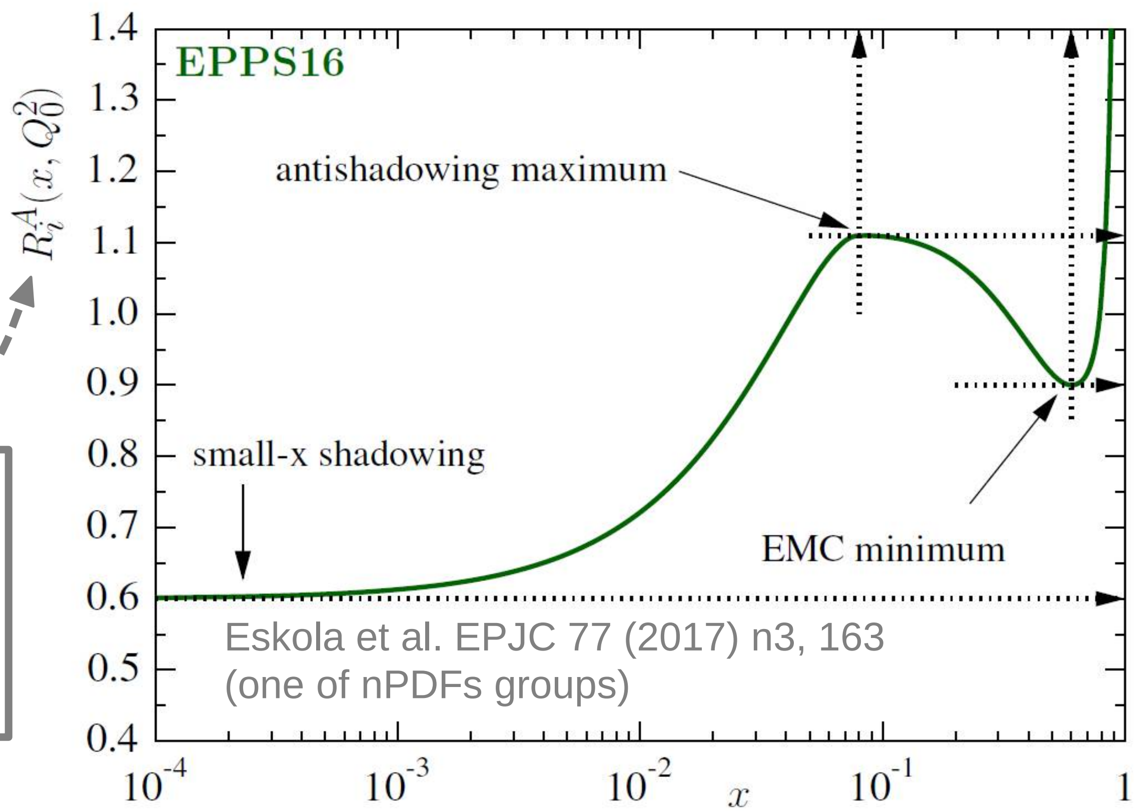
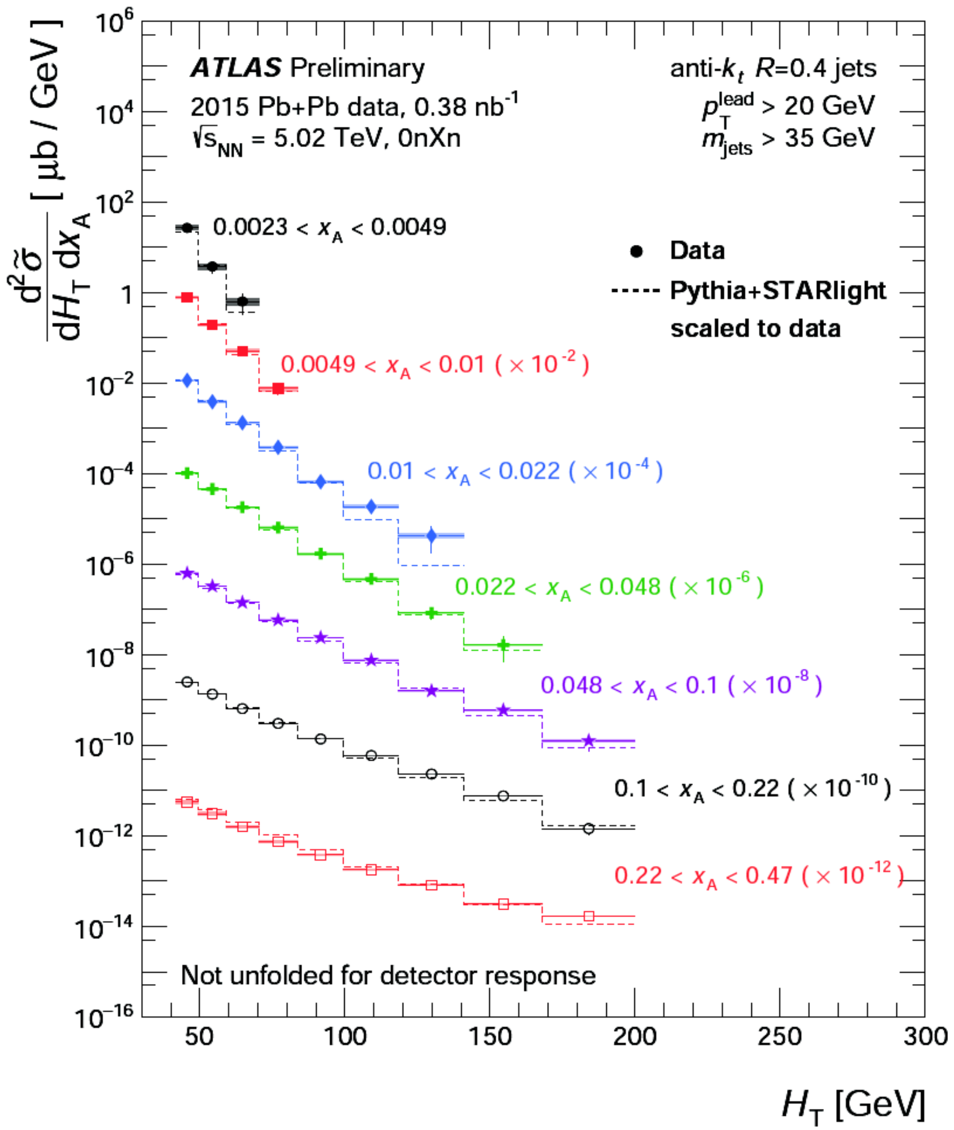


Photo-nuclear dijet production



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$$H_T \equiv \sum_i p_{T\,i}$$ ~ Q

$$x_A \equiv \frac{m_{jets}}{\sqrt{s}} e^{-y_{jets}}$$ ~ x of struck parton in nucleus

- Not the same as $F_2(x,Q^2)$, e.g. still contains $1/Q^4$ dependence.
- MC close to data but matching is not expected.
- Measurement not-yet unfolded.
- Also measured other slices of cross-section.

Photo-nuclear dijet production: new inputs for nPDF

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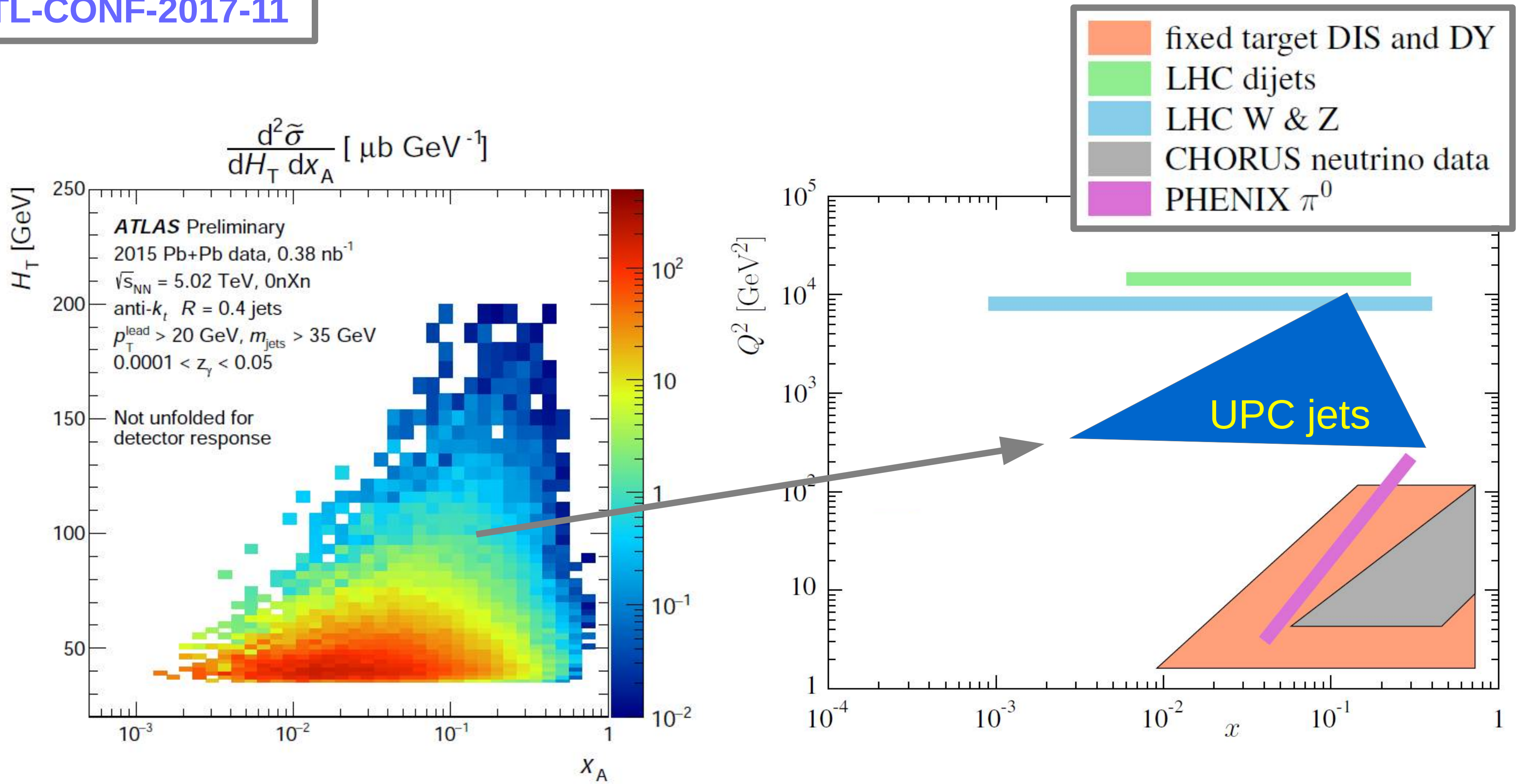
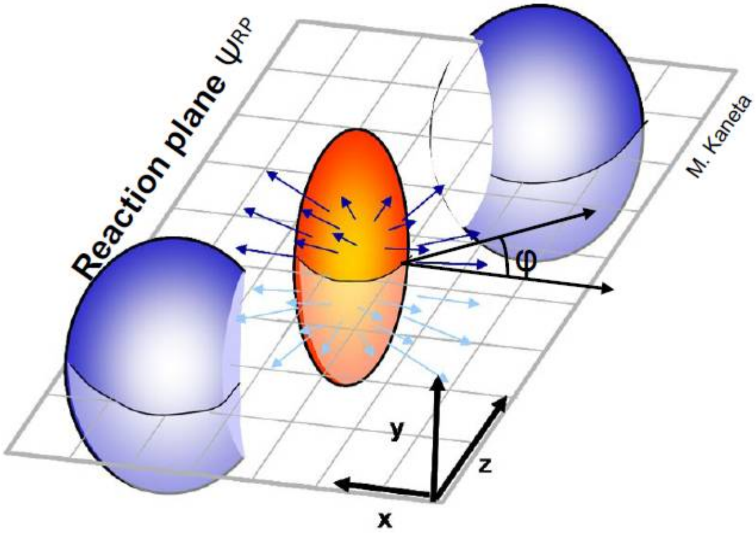


… allows to restrict nPDFs in the not-yet-explored subspace of x,Q^2 space

Soft processes
(physics of ridge and azimuthal anisotropies)

Soft processes – azimuthal anisotropies



- Initial shape and its fluctuations lead to pressure gradients giving rise to azimuthal anisotropies in particle production.
- Quantified by **Fourier decomposition**:

$$\frac{\mathrm{d}N}{\mathrm{d}\phi} = N_0\left(1 + 2\sum_{i=1} v_n \cos n(\phi - \Phi_n)\right)$$

$$v_n = \left\langle e^{in(\phi-\Phi_n)}\right\rangle = \langle \cos n(\phi - \Phi_n)\rangle$$

- **Initial shape** of the interaction region drives **elliptic flow**, v_2.
- Initial **spatial fluctuations** of interacting nucleons dictate **higher order flow**, v_n.
- Expected in Pb+Pb. Non-zero v_n seen in *pp*, *p*+Pb !? … How about non-flow contributions (di-jets, resonances,…)?

Cumulants for flow

- Cumulant method: Fourier harmonics are obtained from **2k-particle azimuthal correlations.** Example:

$$\langle corr_n\{2k\}\rangle = \left\langle\left\langle e^{in(\phi_1+\ldots+\phi_k\ -\phi_{k+1}-\ldots-\phi_{2k})}\right\rangle\right\rangle$$

$\downarrow$

2 particle cumulant

$$c_n\{2\} = \langle corr_n\{2\}\rangle$$

$\downarrow$

$$v_n\{2\} = \sqrt{c_n\{2\}}$$

- Cumulants remove lower order correlations from non-flow effects.
- But still sensitive to fluctuations of the non-flow component.

Cumulants for flow

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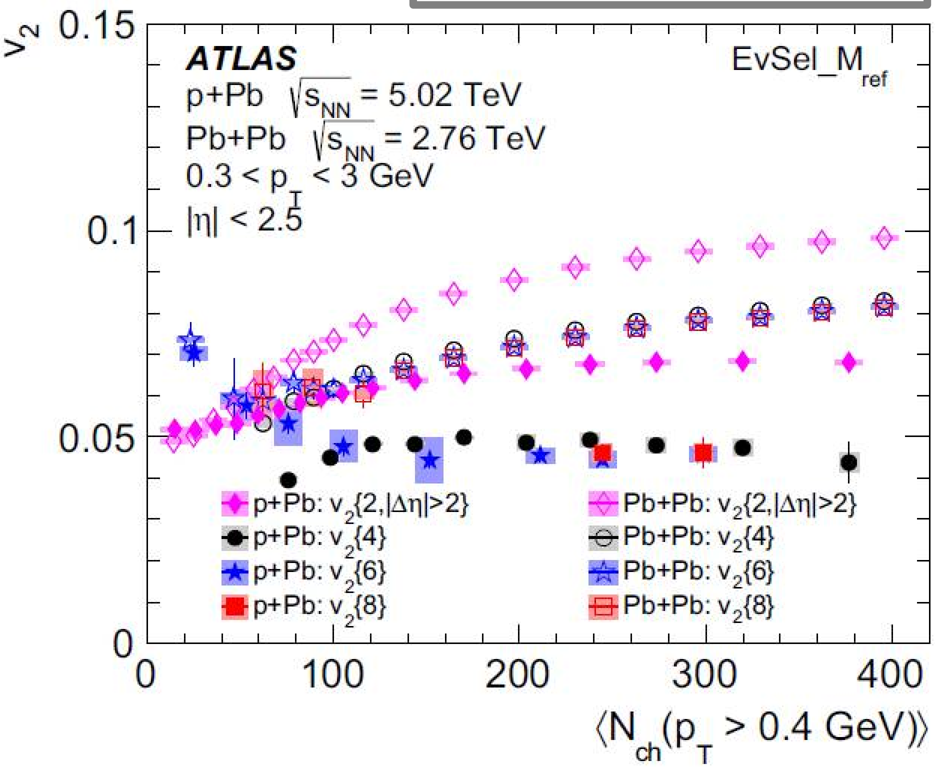

- Cumulants remove lower order correlations from non-flow effects.
- v_2 harmonics from cumulants **larger for Pb+Pb** then for *p*+Pb.
- $v_2\{4\} \approx v_2\{6\} \approx v_2\{8\}$.

Cumulants and sub-event cumulants – small systems

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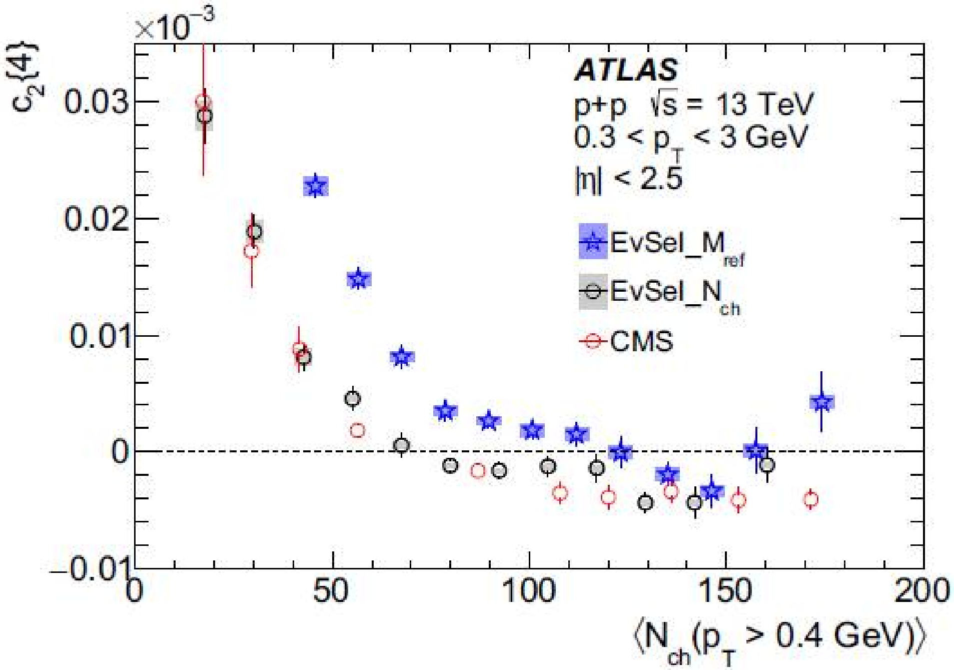
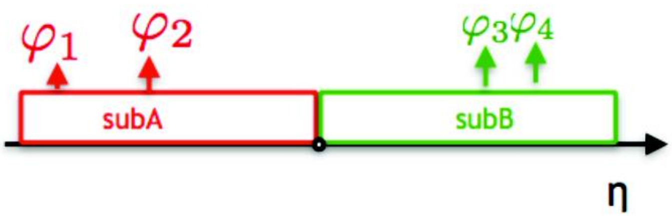
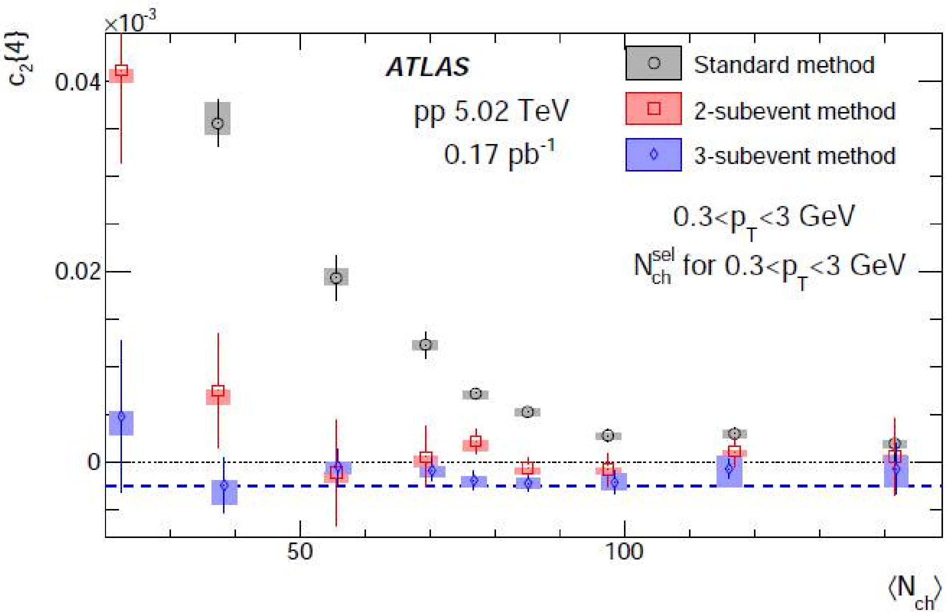


- Strong dependence on the definition of the event class.
- Still sensitive to fluctuations of non-flow component. Can we do better?
- Is there a collectivity in small systems or not?

Cumulants and sub-event cumulants – small systems



arXiv:1708.03559



- Strong dependence on the definition of the event class.
- Still sensitive to fluctuations of non-flow component. Can we do better?
- Is there a collectivity in small systems or not?

$\Downarrow$

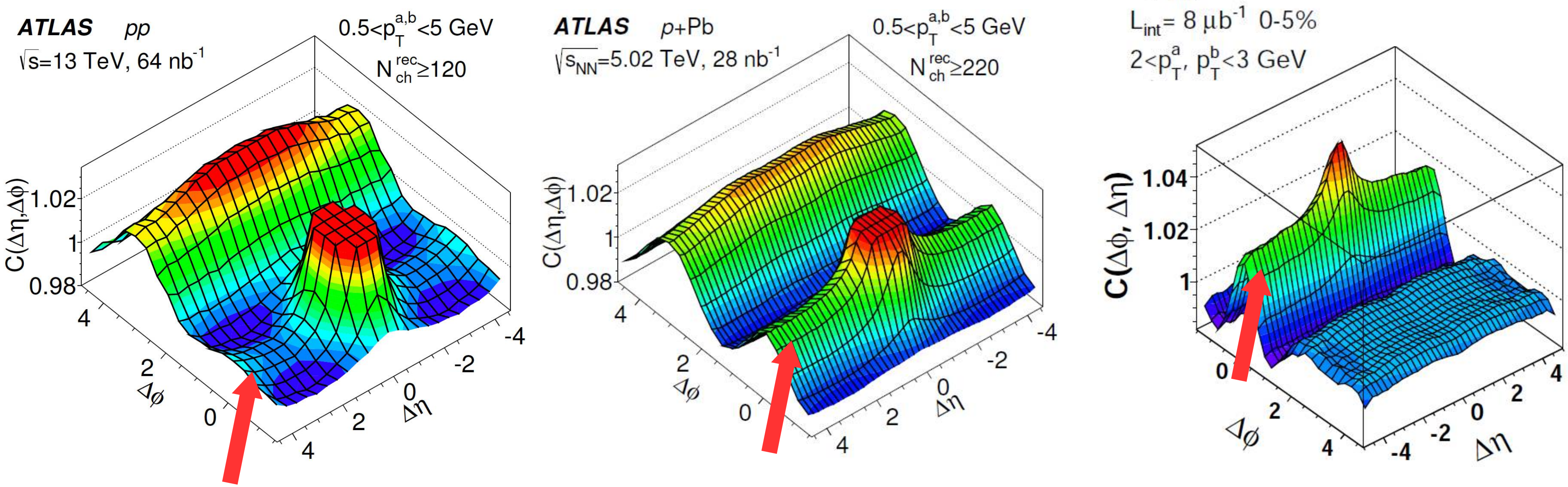
- **Sub-event cumulants** – correlator calculated using particles from 2 or 3 subevents => removing non-flow contribution

$$v_n\{4\} = \sqrt[4]{-c_n\{4\}}$$

- … direct evidence for **collectivity in small systems**

Ridge in small systems

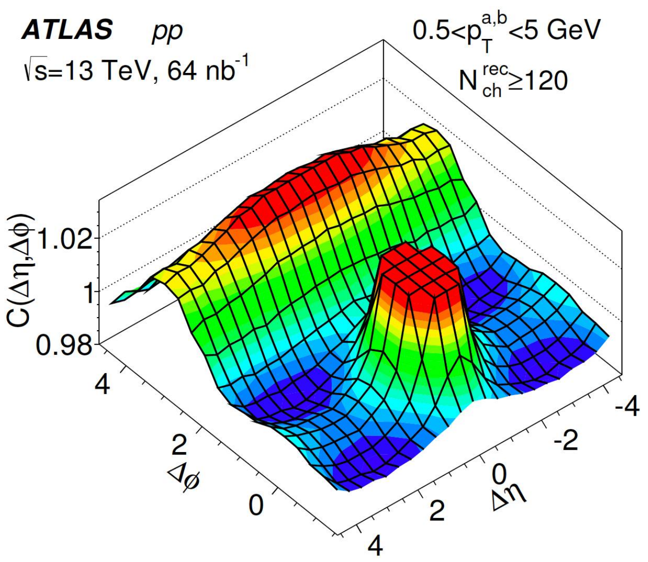
pp **p+Pb** **Pb+Pb**



- Two particle correlations in ΔηxΔφ – long range, **near side** and away side correlations = the ridge.
- Seen in Pb+Pb, but also in ***p*+Pb, *pp* collisions**.
- Template fitting method to suppress non-flow contribution.

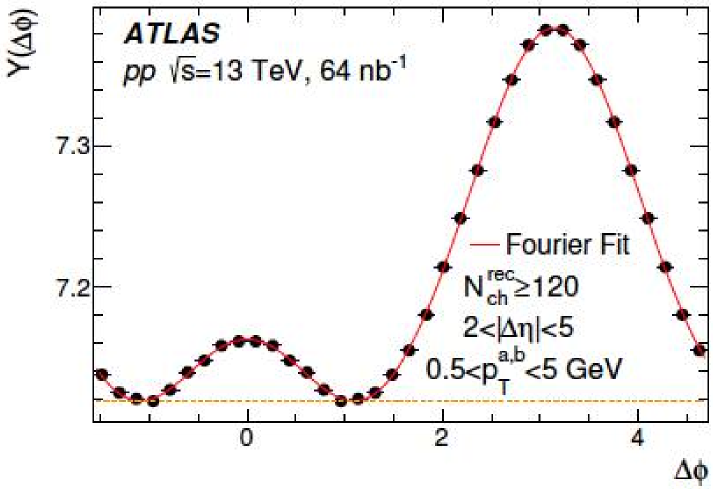
Ridge in small systems

pp



2<|Δη|<5

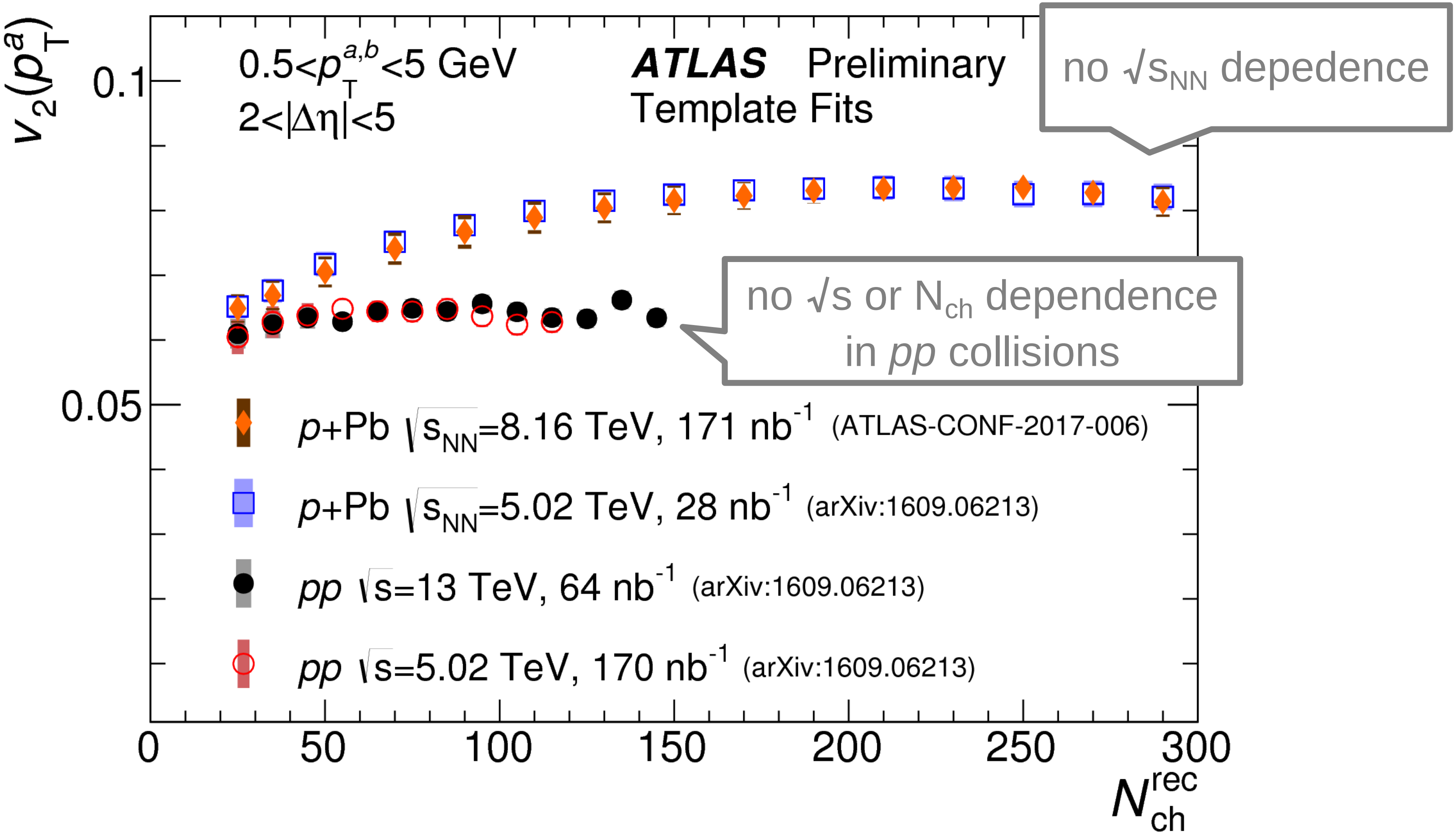
PRL 116 (2016) 172301



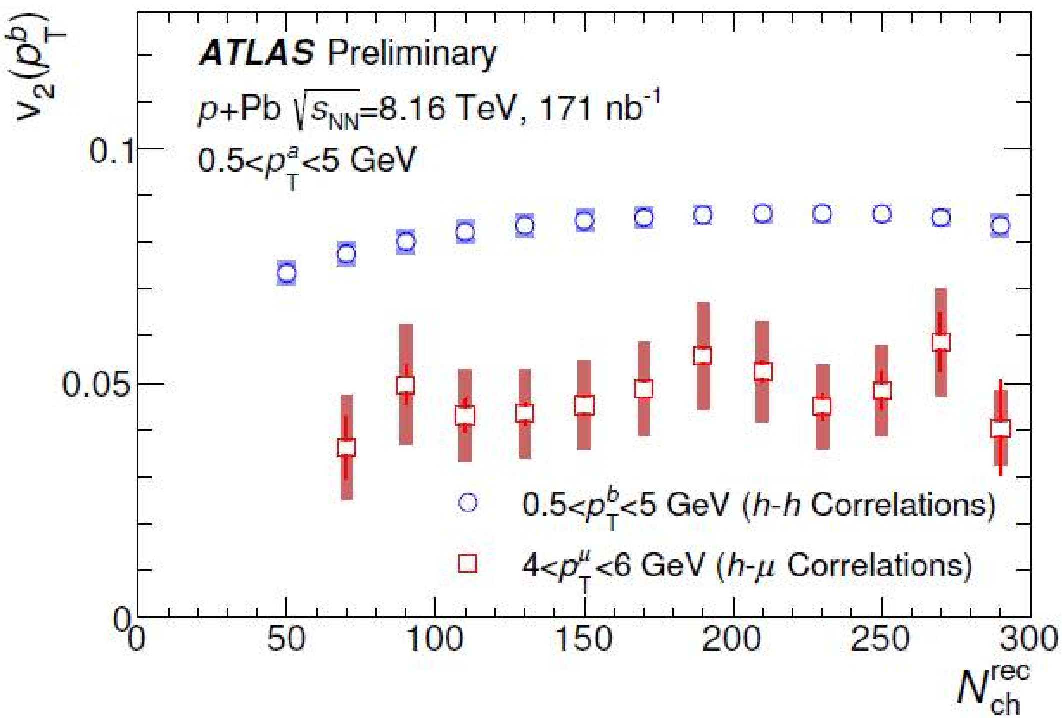
$$Y^{template}(\Delta\phi) = Y^{ridge}(\Delta\phi) + F\, Y^{periph}(\Delta\phi)$$

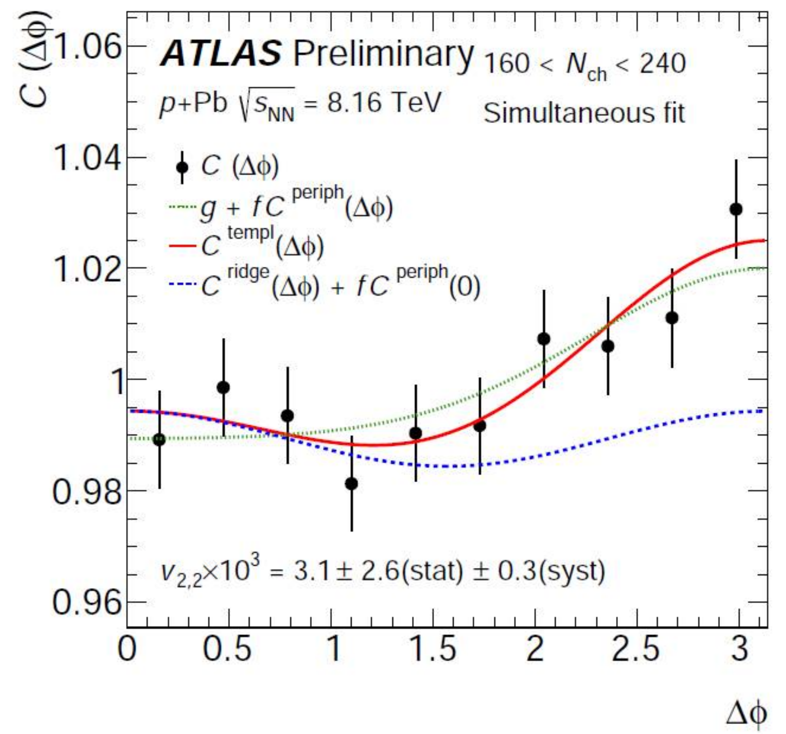
- Two particle correlations in ΔηxΔϕ – long range, **near side** and away side correlations = the ridge.
- Seen in Pb+Pb, but also in ***p*+Pb, *pp* collisions**.
- Template fitting method to suppress non-flow contribution.

Ridge in small systems



Ridge in small systems: heavy flavor





- Ridge also present **for heavy flavor**:
  - muon-hadron correlations
  - D*-hadron correlations

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ATLAS-CONF-2017-006

Ridge in small systems: impact parameter dependence

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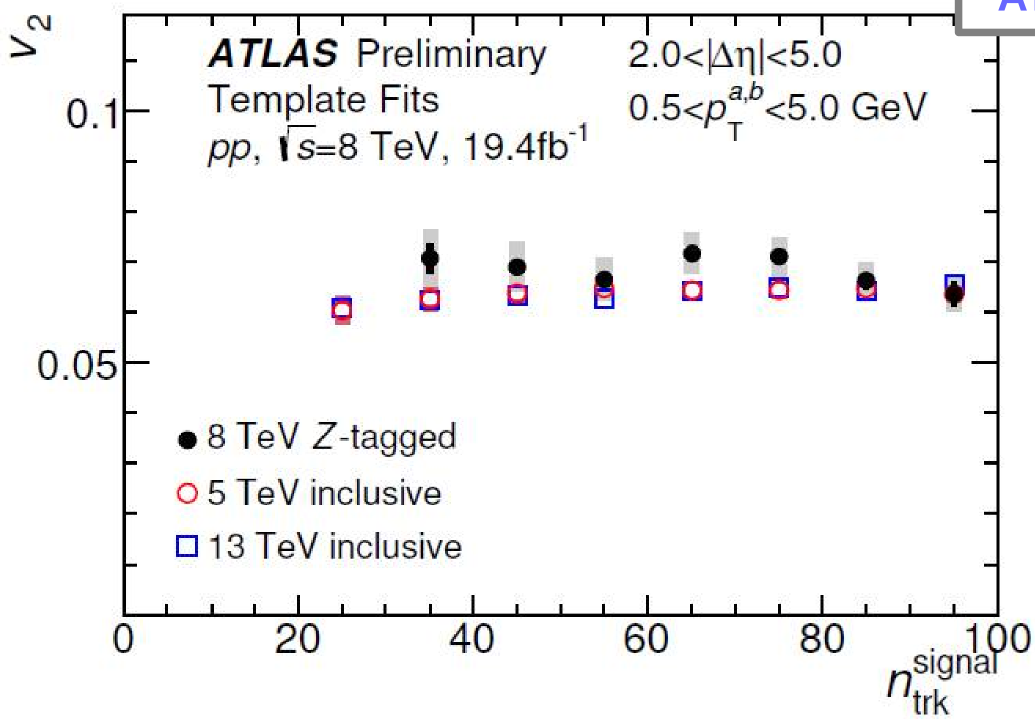


- Selecting on high-Q^2 processes: **Z-tagged ridge.** May primarily select **smaller impact parameter** *pp* collisions.
- New method to measure the ridge in events with **large pile-up**.
- v_2 **8% ± 6% larger** in Z-tagged events compared to inclusive.

Short, basic summary

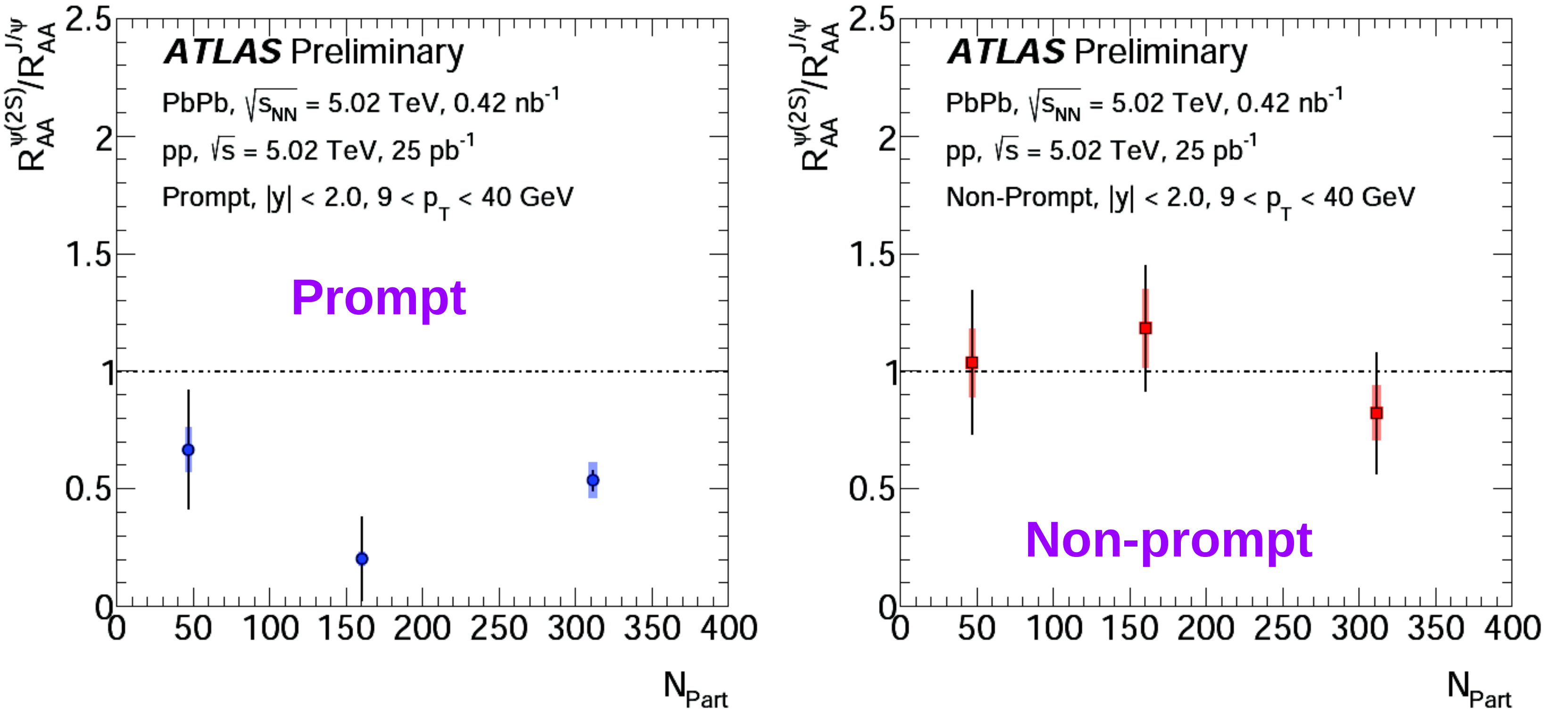
- **Jets** remain **quenched up to a TeV** scale.
- Jet **fragmentation** is modestly but significantly **modified**. Modifications are different for inclusive jets and gamma-tagged jets.
- **Quarkonia** production is modestly modified in *p*+Pb and **strongly modified in Pb+Pb** wrt pp production. The modification in Pb+Pb is similar for prompt and non-prompt charmonia.
- **Ultra-peripheral collisions** allows e.g. for studying nuclear modifications to parton distribution functions.
- Strong evidence is seen for **flow in small systems** by sub-event cumulants, ridge also present for heavy flavor.

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HeavyIonsPublicResults

Backup slides

Quarkonia in **Pb+Pb**, 5.02 TeV

ATLAS-CONF-2016-109



- **Prompt ψ(2S)** suppressed by a factor of **~2 more** than prompt J/ψ.
- **Non-prompt ψ(2S)** exhibits **similar suppression** as non-prompt J/ψ.

Gamma-jet production in Pb+Pb at 5.02 TeV

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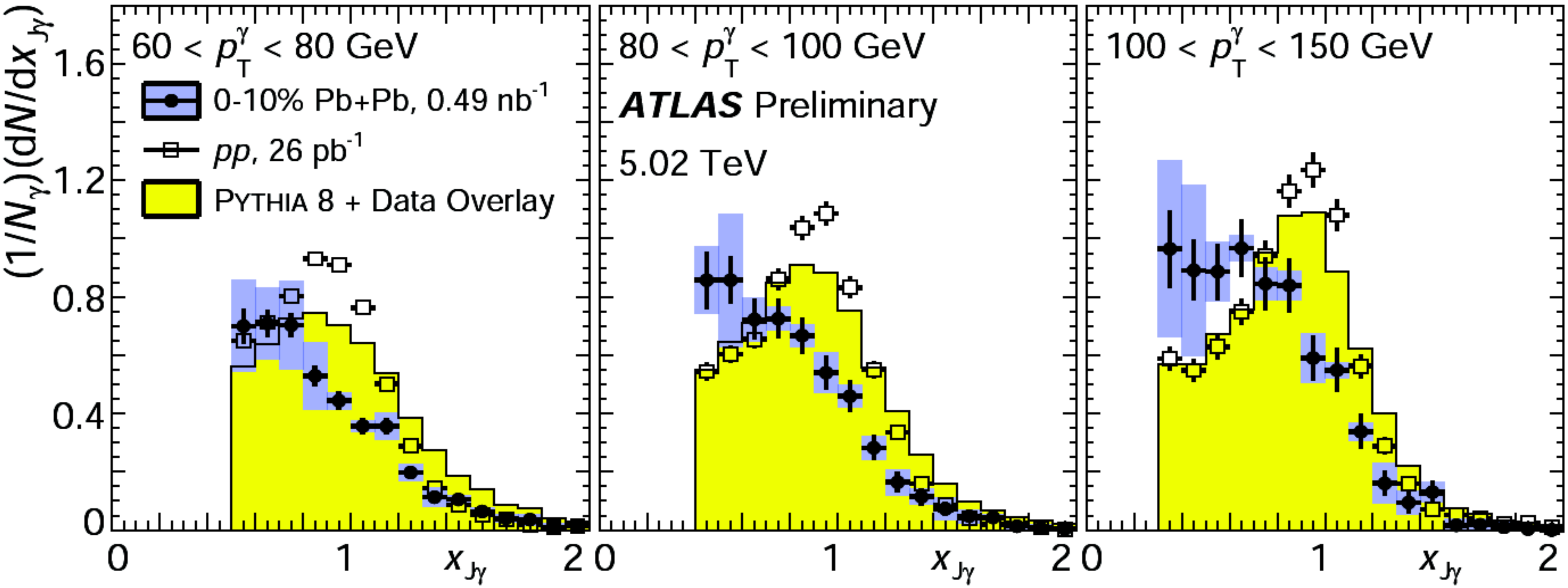

- Clear modification (downward shift) due to the parton **energy loss of the balancing jet**.
- Not yet unfolded for the detector response.
- Smaller suppression in peripheral collisions (not shown).

$$x_{J\gamma} = \frac{p_{T,jet}}{p_{T,\gamma}}$$

Gamma-jet production

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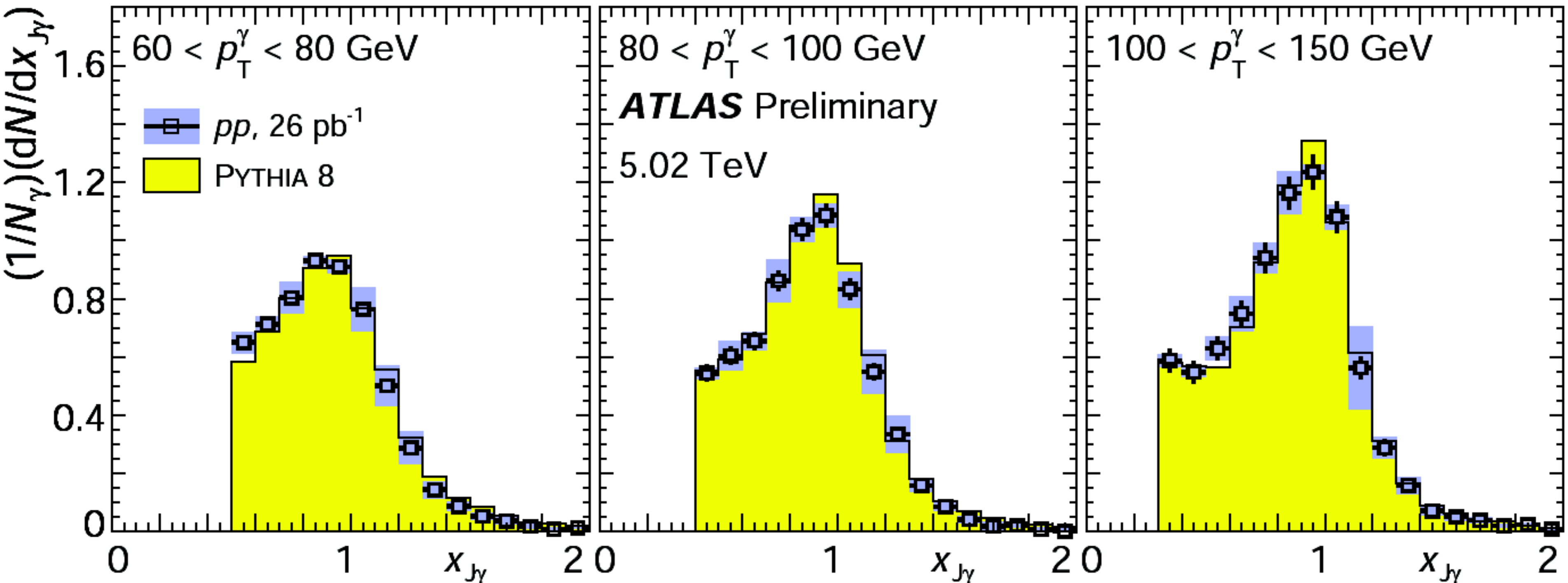


$$x_{J\gamma} = \frac{p_{T,jet}}{p_\gamma}$$

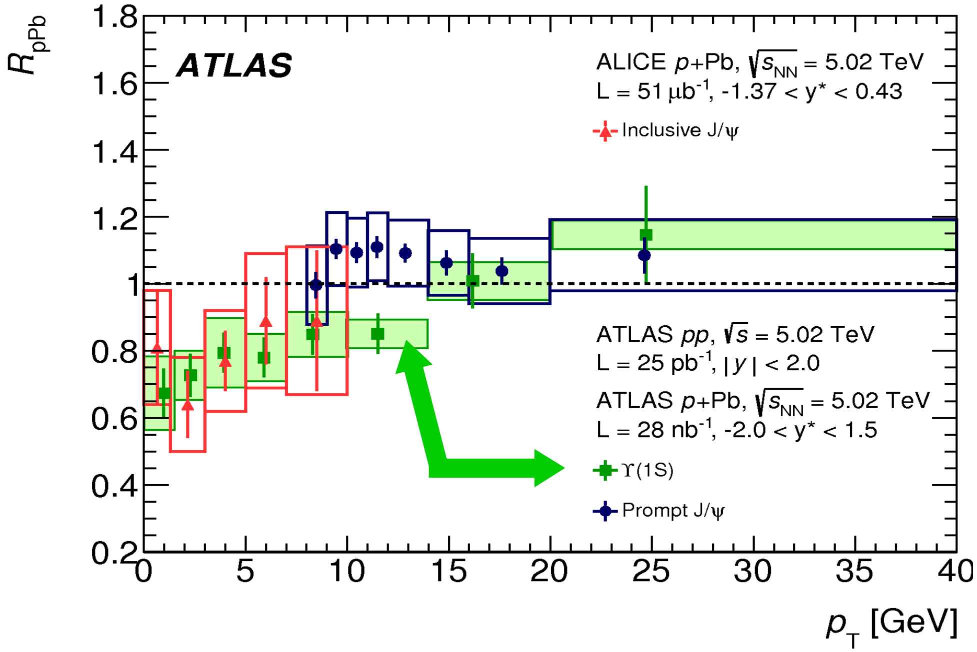
- Good agreement between PYTHIA8 and *pp* data
- Not unfolded for the detector response

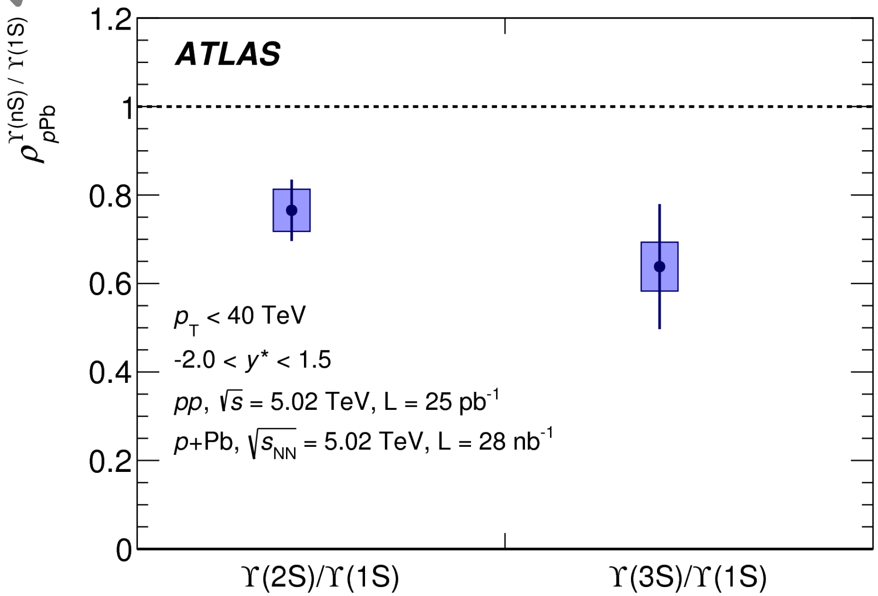
Quarkonia in **p+Pb**, 5.02 TeV

$$R_{\mathrm{pPb}} = \frac{\frac{\mathrm{d}\sigma^{\mathrm{pPb}}}{\mathrm{d}p_{\mathrm{T}}}}{A \times \frac{\mathrm{d}\sigma^{\mathrm{pp}}}{\mathrm{d}p_{\mathrm{T}}}}$$

~ ratio of R_{pPb}

arxiv:1709.03089



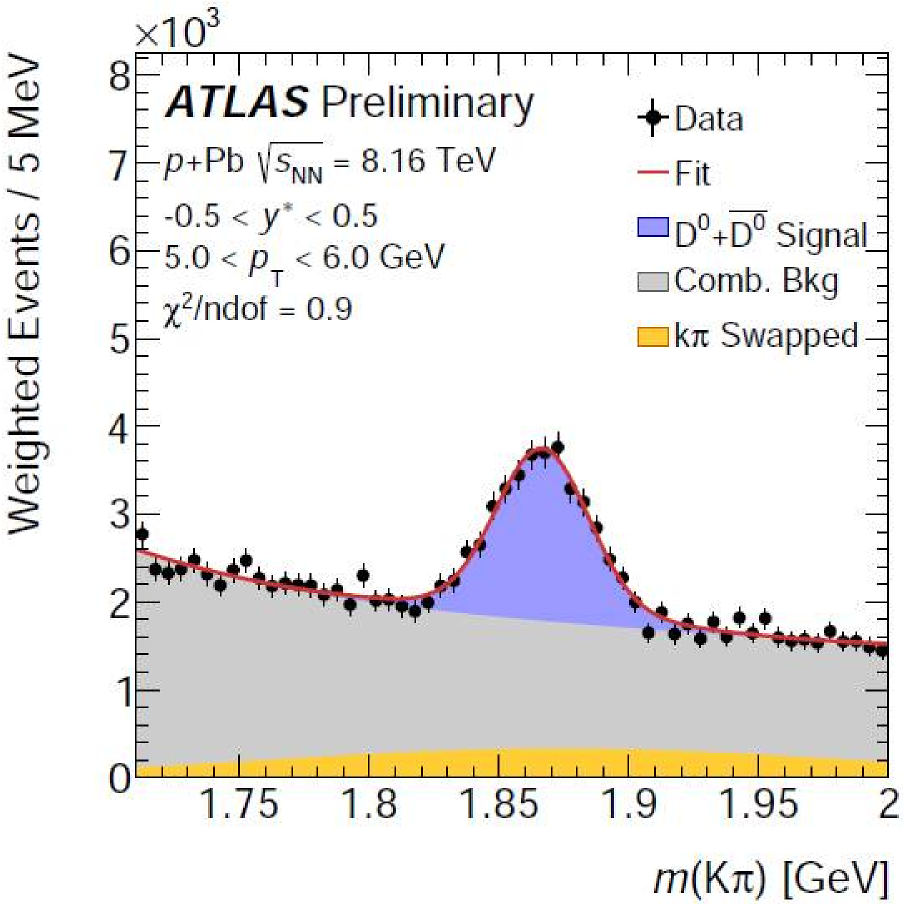


- Y(1S) suppressed **at low-p_T**.
- Y(2S),Y(3S) suppressed **wrt Y(1S)**.

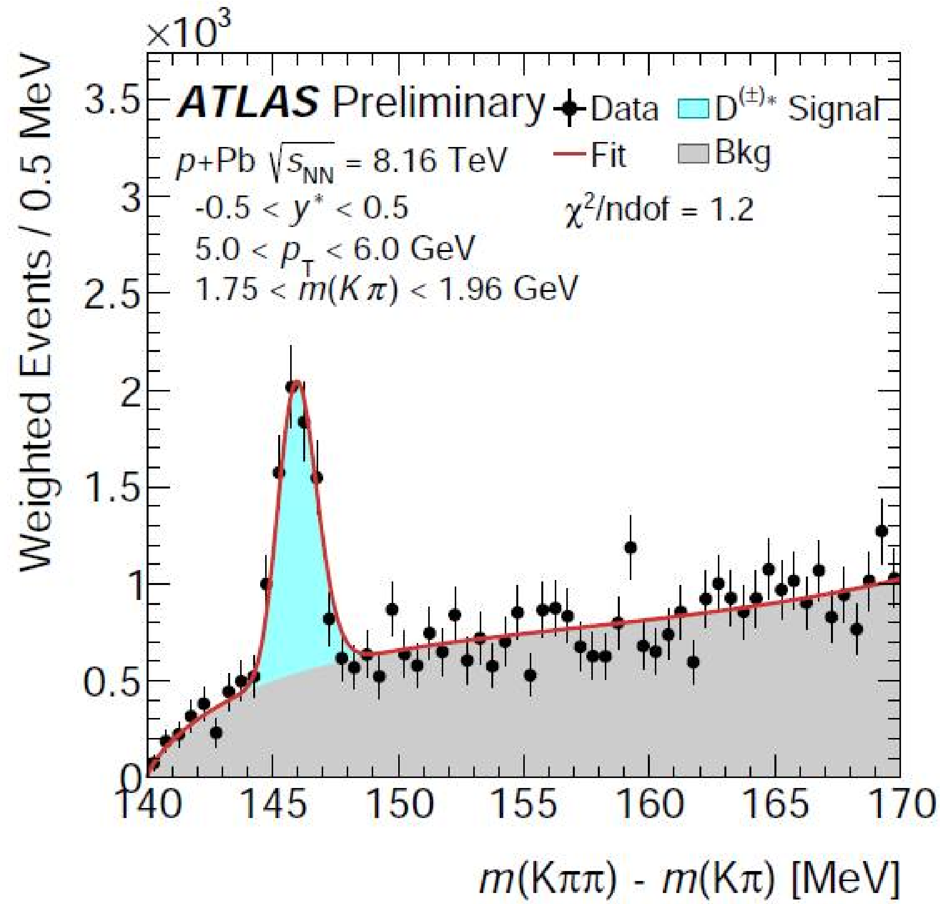
D meson in **p+Pb**, 8.16 TeV

ATLAS-CONF-2017-073

$D^0+\overline{D^0}$

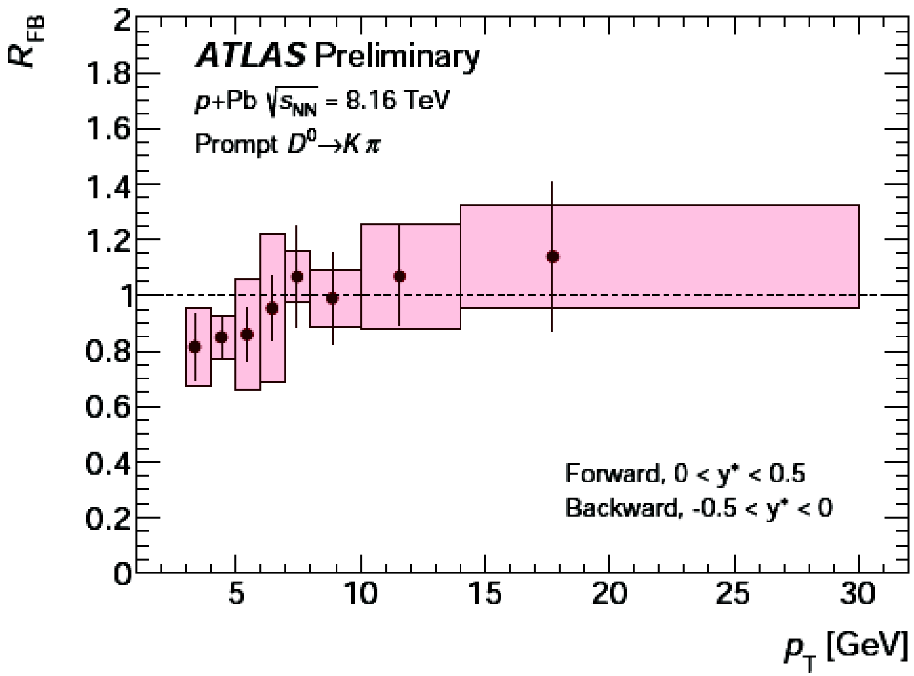


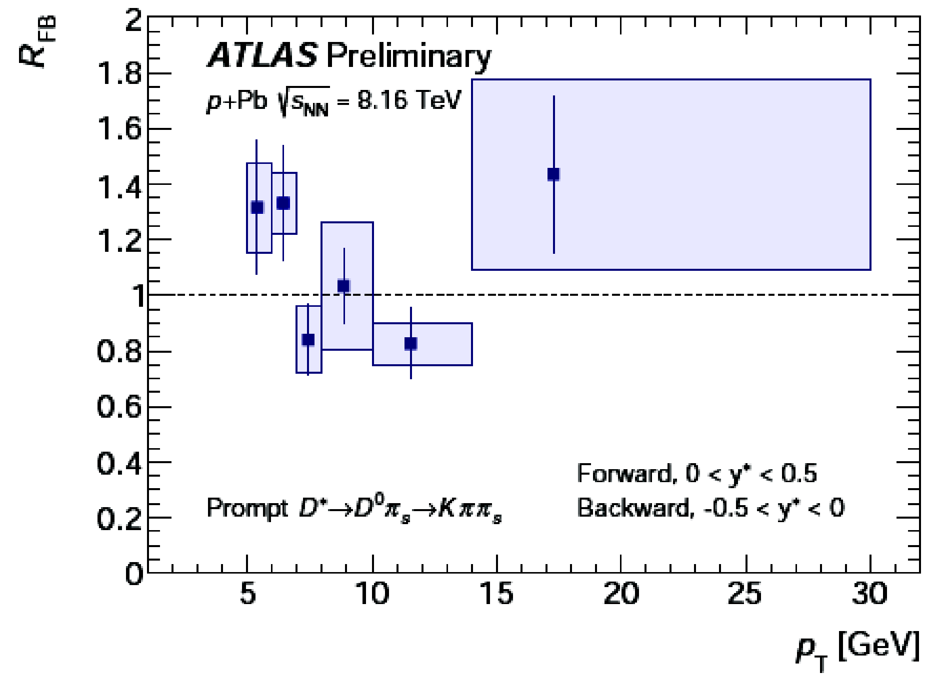
$D^{(\pm)*}$



D meson in **p+Pb**, 8.16 TeV

ATLAS-CONF-2017-073



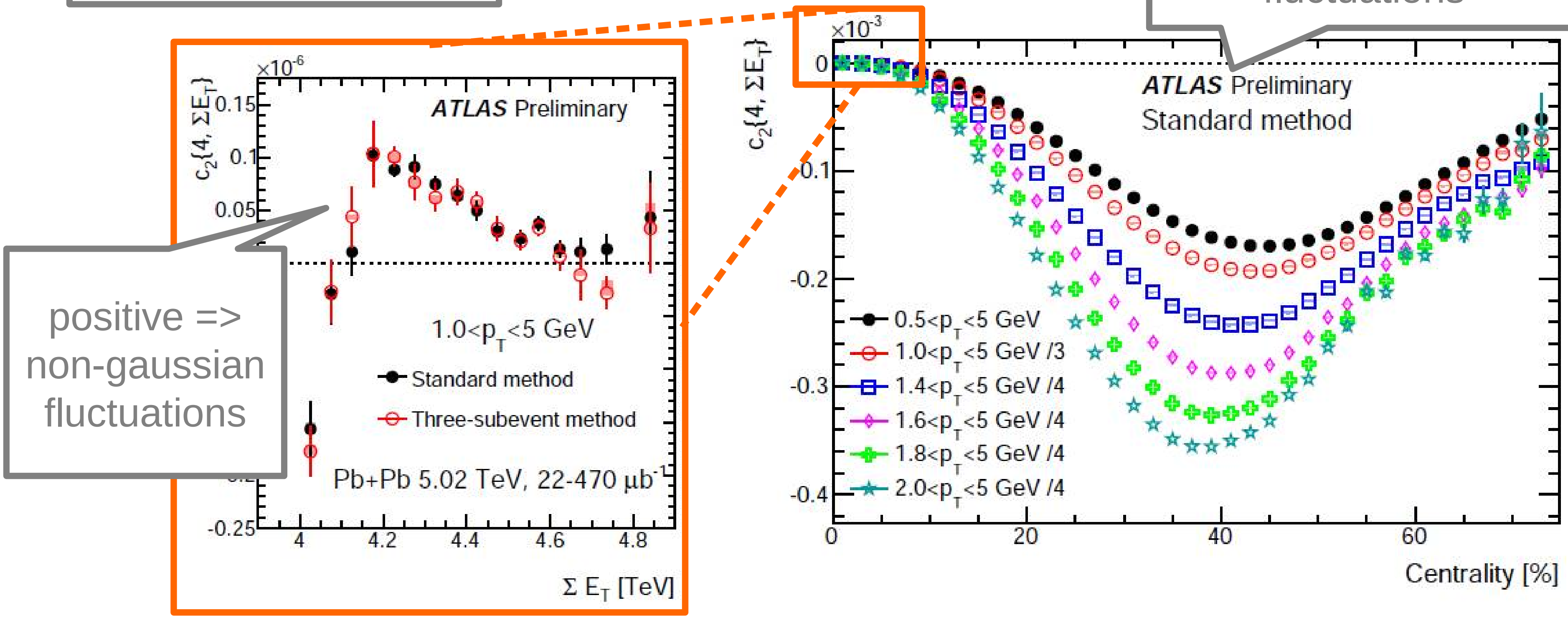


- Forward-backward ratio, **R_{FB} consistent with unity** for both D^0 and D*.
- Cross-sections **consistent with FONLL** predictions (not shown).

Cumulants in Pb+Pb

- Measured $c_n\{4\}$ (n=1-4) allows to understand the nature of **flow fluctuations**.
- $c_1\{4\}$: negative, constraints on **dipolar eccentricity fluctuations**.
- $c_2\{4\}$: **non-gaussian** fluctuations of v_2 in **ultra-central collisions**.

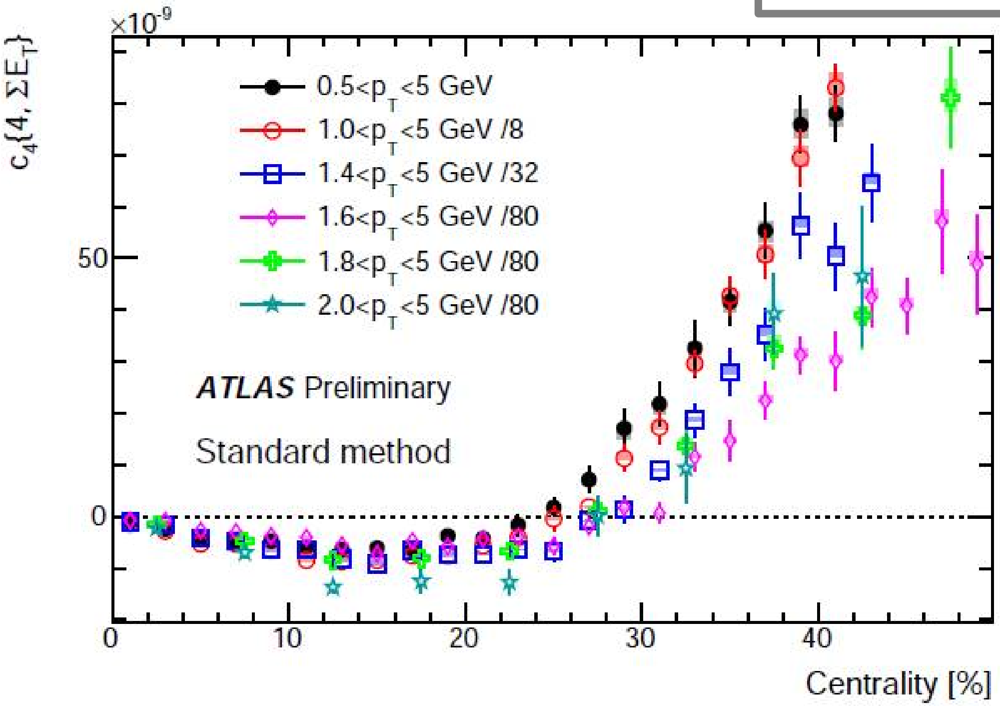
ATLAS-CONF-2017-066



Cumulants in Pb+Pb

- Measured $c_n\{4\}$ (n=1-4) allows to understand the nature of **flow fluctuations**.
- $c_1\{4\}$: negative, constraints on **dipolar eccentricity fluctuations**.
- $c_2\{4\}$: **non-gaussian** fluctuations of v_2 in **ultra-central collisions**.
- $c_4\{4\}$: non-linear contribution of **v_2^2 to v_4.**

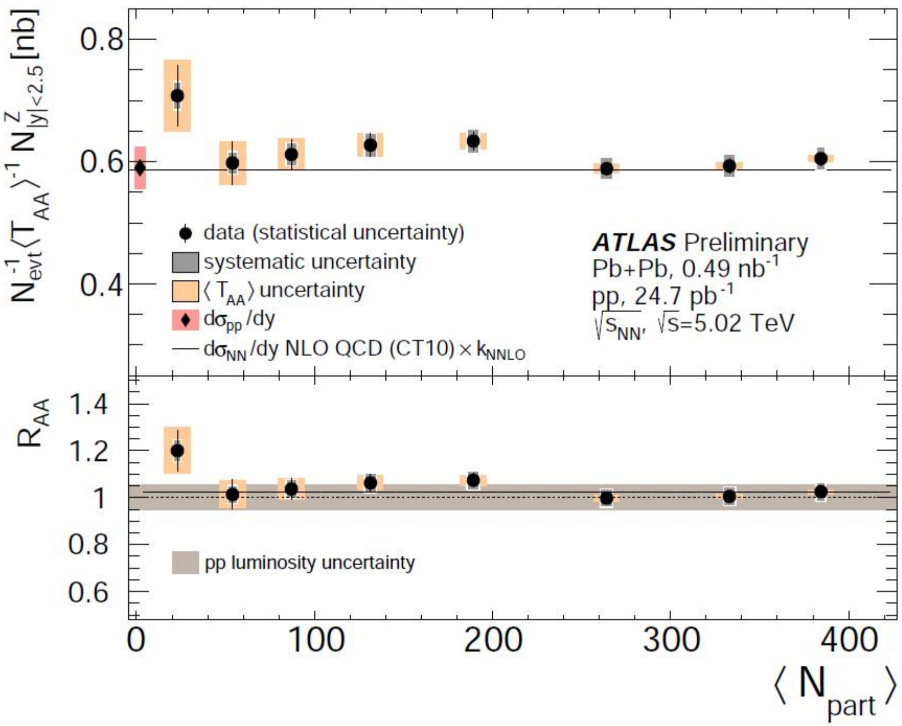
ATLAS-CONF-2017-066

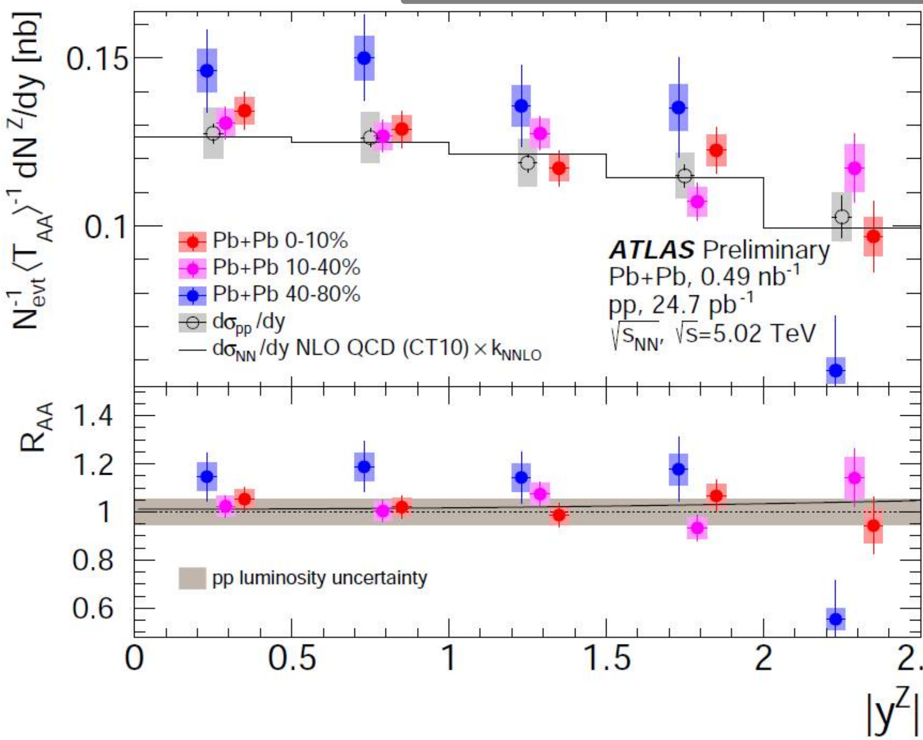


Electroweak bosons

Z in Pb+Pb, 5.02 TeV

ATLAS-CONF-2017-010

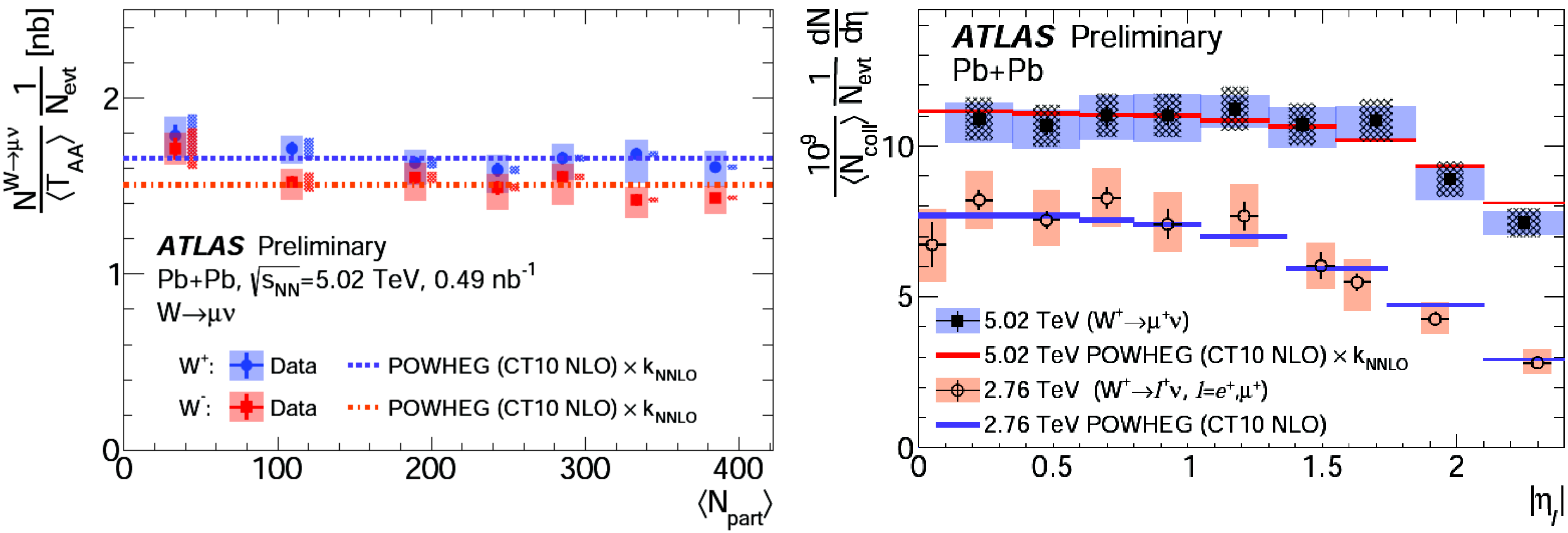




- Studying rapidity and centrality dependence.
- Data consistent with POWHEG scaled to NNLO accuracy.
- No modifications seen in T_{AA}-scaled yields – good **understanding of geometry**.
- No precision to **distinguish nPDF** effects yet.

W in Pb+Pb, 5.02 TeV

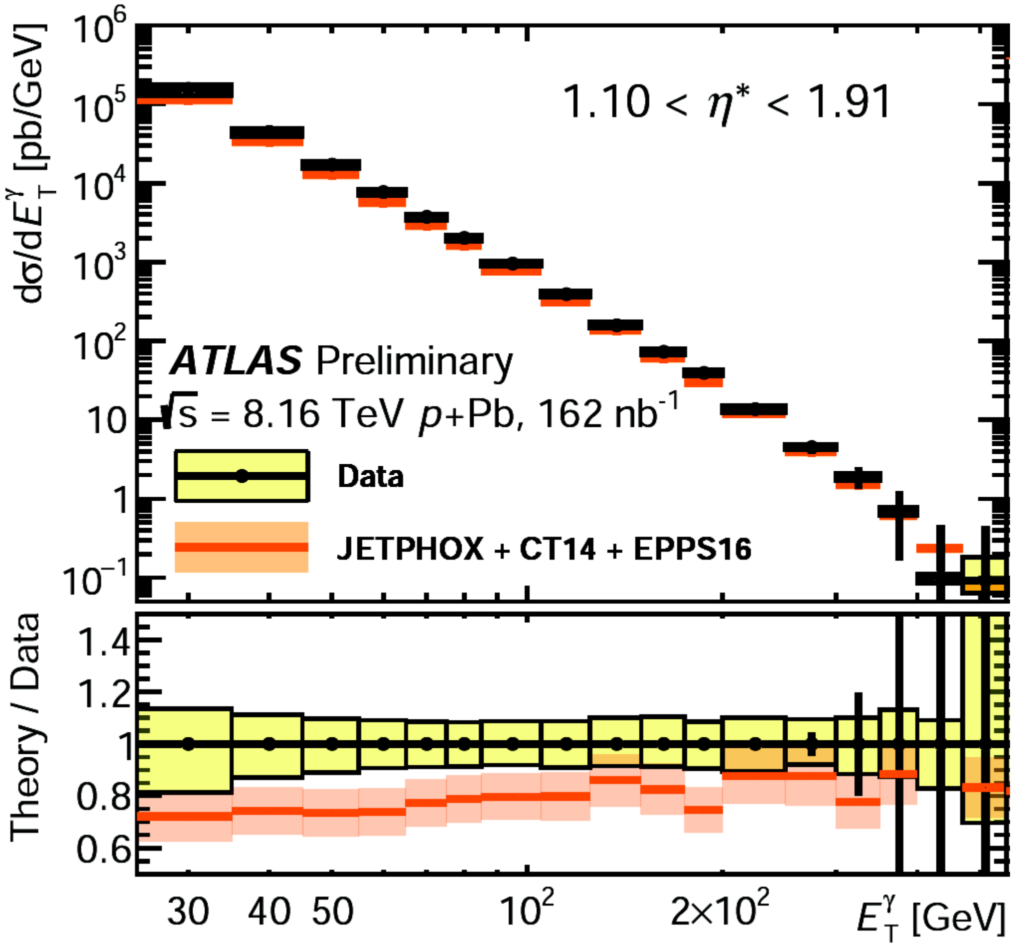
ATLAS-CONF-2017-067



- Studying rapidity and centrality dependence: **same conclusions** as for Z. Data consistent with POWHEG scaled to NNLO accuracy.
- **Isospin effect**: d-quark excess => ~10% larger W^+ yield.
- Lepton charge asymmetry consistent with theory prediction (not shown).

Prompt photons in p+Pb, 8.16 TeV

ATLAS-CONF-2017-072



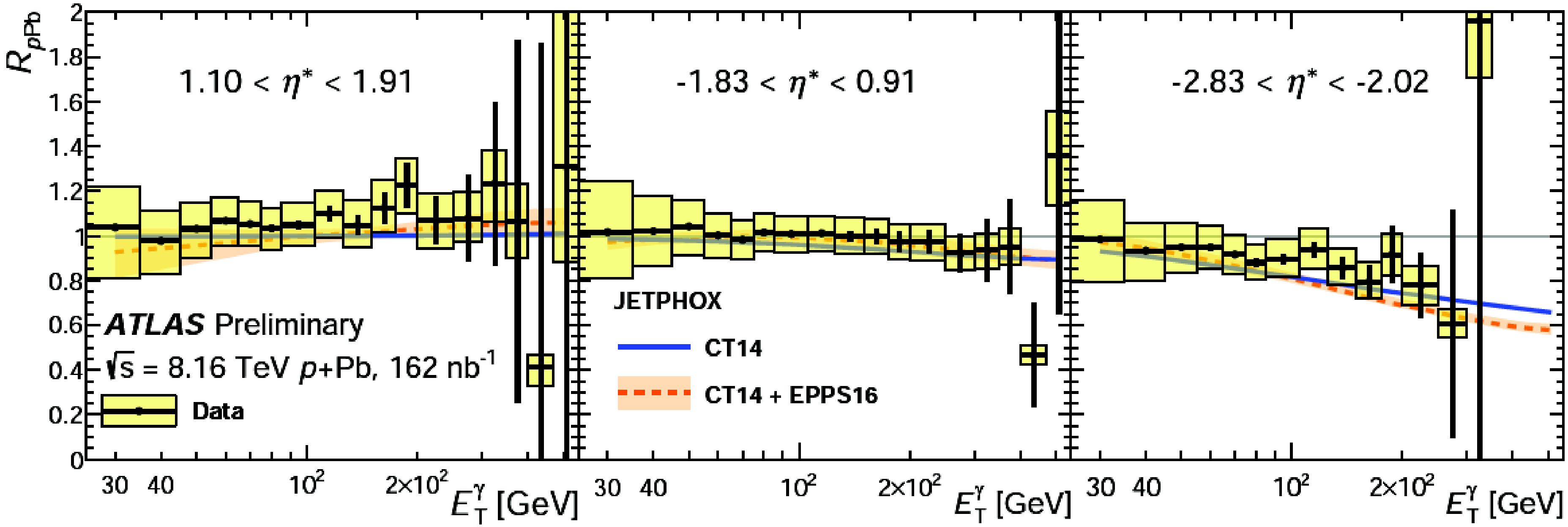
- Measured up to E_T = 500 GeV.
- JETPHOX with CT14+EPPS16 **underpredict data by ~ 20%** (similar disagreement seen in pp, JHEP 08 (2016) 005).
- Evaluating ratios wrt to *pp* collisions:

$$R_{\mathrm{pPb}} = \frac{\frac{d\sigma^{\mathrm{pPb}}}{dE_{\mathrm{T}}^{\gamma}}}{A \times \frac{d\sigma^{pp}}{dE_{\mathrm{T}}^{\gamma}}}$$

… next slide

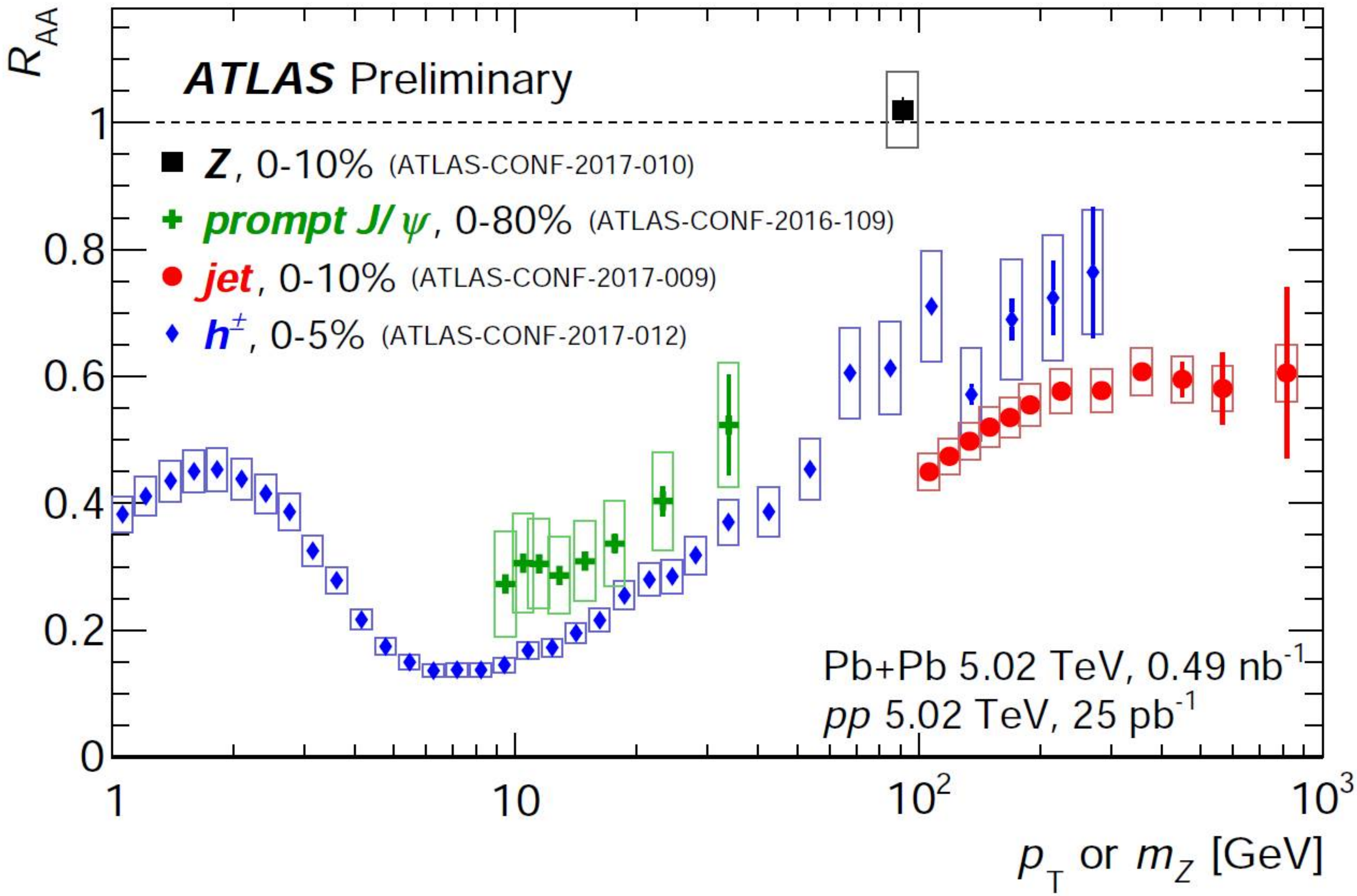
Prompt photons in p+Pb, 8.16 TeV

ATLAS-CONF-2017-072

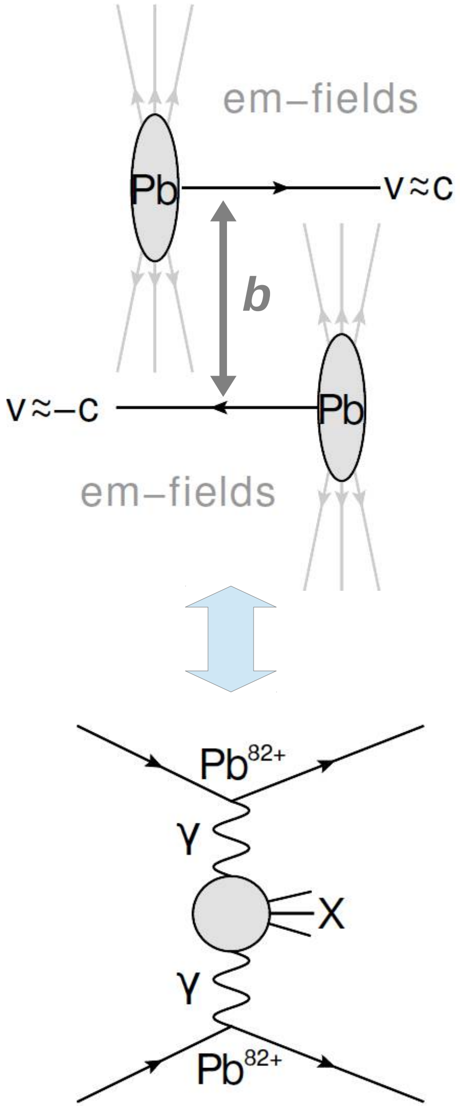


- Consistent with **unity** except in backward rapidity (isospin effects)
- Data compared to two nPDF sets: CT14+EPPS16, nCTEQ15 and initial state energy loss model (multiple scatterings in nuclear matter before hard process):
  - **no** ability to distinguish **nPDF effects**
  - **no** signs of initial state **energy loss**

Landscape of the suppression measurements



UPC



Boosted protons/nuclei are source of photons of small virtuality ($Q^2 < 1/R^2 = 10^{-3}\,\mathrm{GeV}^2$) described using equivalent photon approximation (EPA)

$$n(k,b) = Z^2 \frac{\alpha}{\pi^2} \frac{k}{(\hbar c)^2} \frac{1}{\gamma^2} K_1^2(x)$$

photon number density for one nucleus in EPA

where $x = \dfrac{kb}{\gamma \hbar c}$

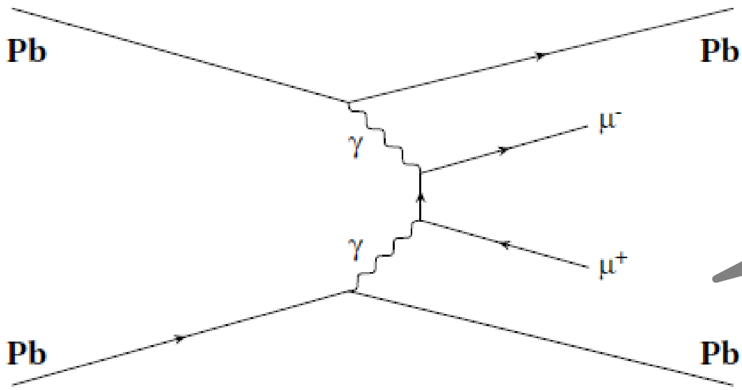
45·10⁶ larger photon density compared to *pp*

e.g. for two photon interaction

$$\sigma^{\mathrm{EPA}}(A_1 A_2 \xrightarrow{\gamma\gamma} A_1 A_2 X) =$$
$$= \int \mathrm{d}k_1 \mathrm{d}k_2\, f(\mathrm{geometry})\, n_1(k_1)\, n_2(k_2)\, \sigma(\gamma_1\gamma_2 \to X)$$

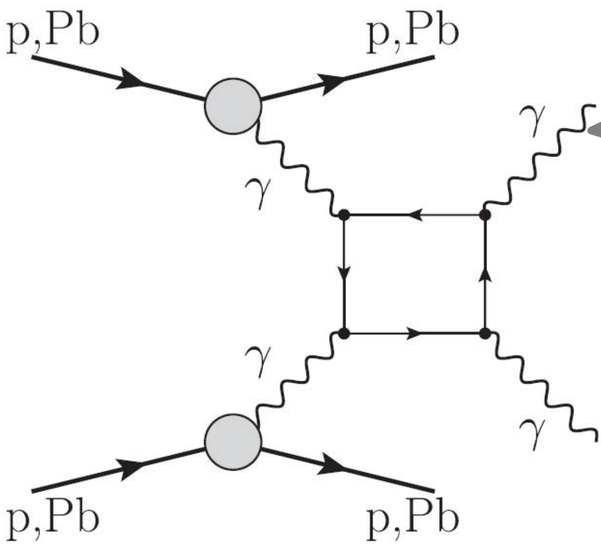
… EM interactions dominate at large *b*, qualitatively different collisions compared to ordinary Pb+Pb

Three UPC measurements ...

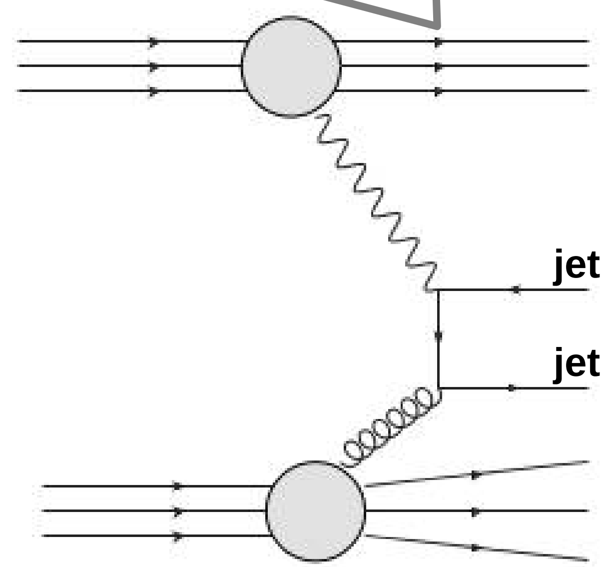


Measurement of high mass dimuons (ATLAS-CONF-2016-025)

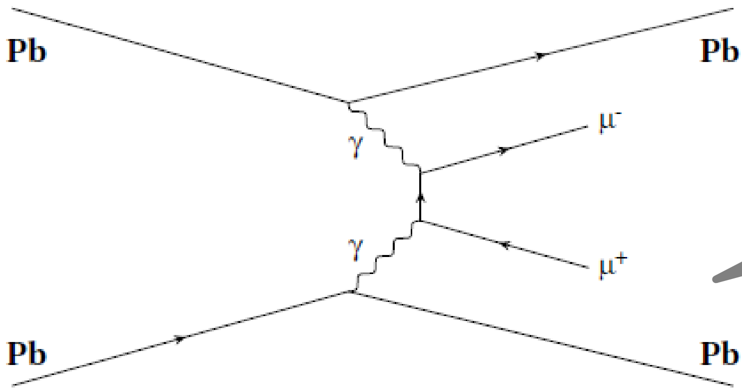
Photo-nuclear dijet production (ATLAS-CONF-2017-011)



Search for light-by-light scattering (Nature Physics 13 (2017) 852)



Three UPC measurements ...



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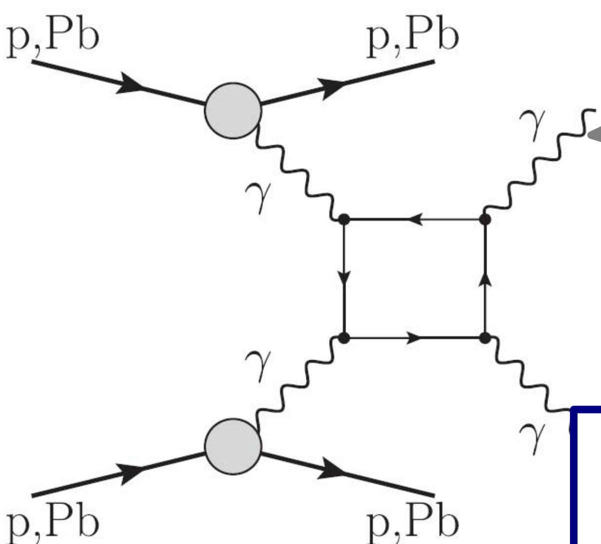
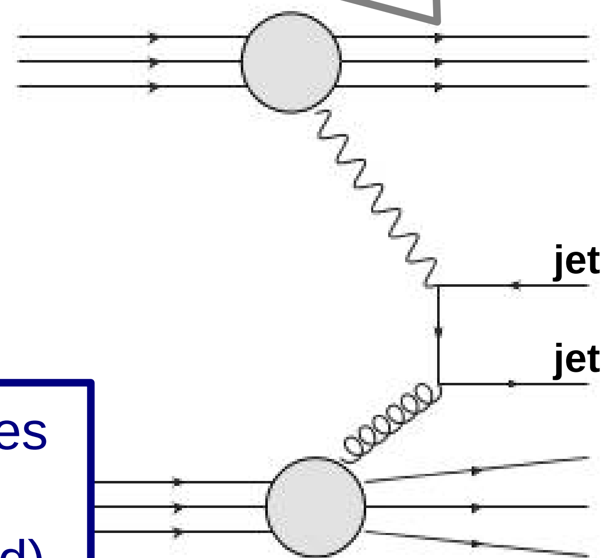
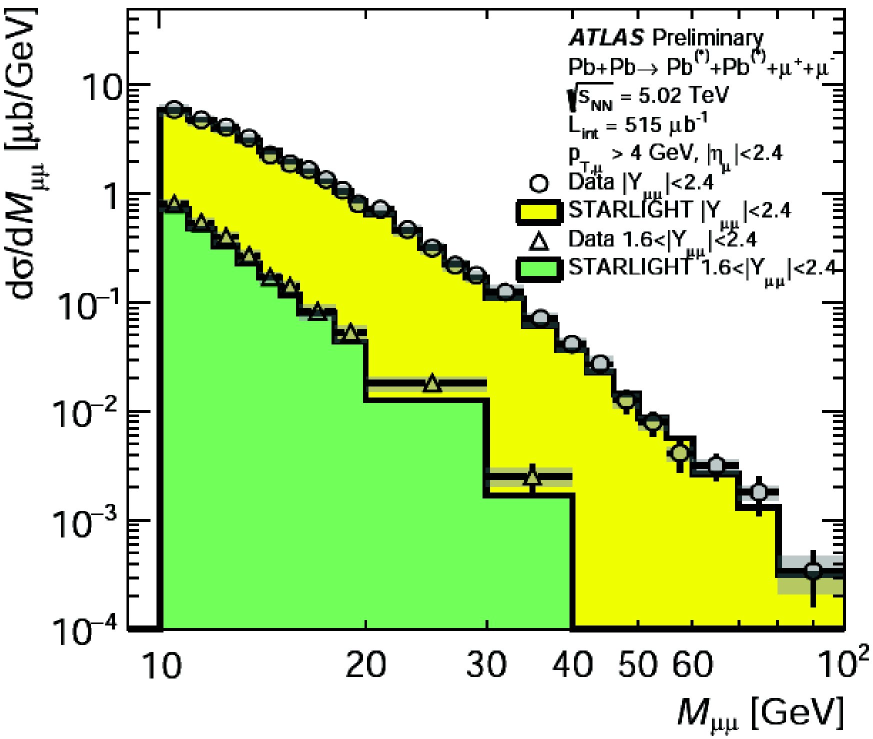


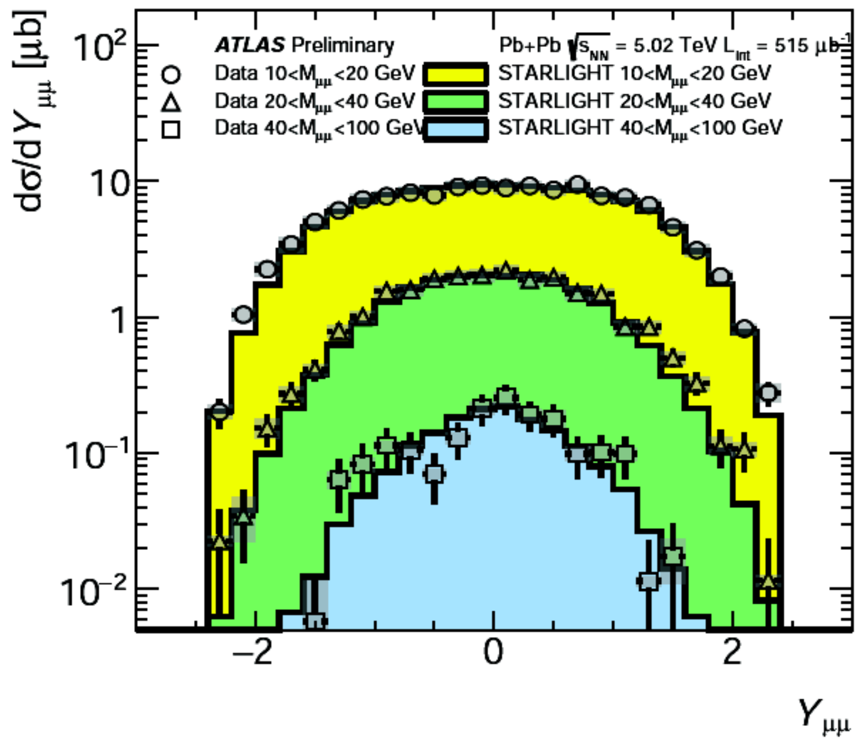
Evidence for light-by-light scattering (Nature Physics 13 (2017) 852)



... all exclusive final states (i.e. nothing else is expected to get produced)

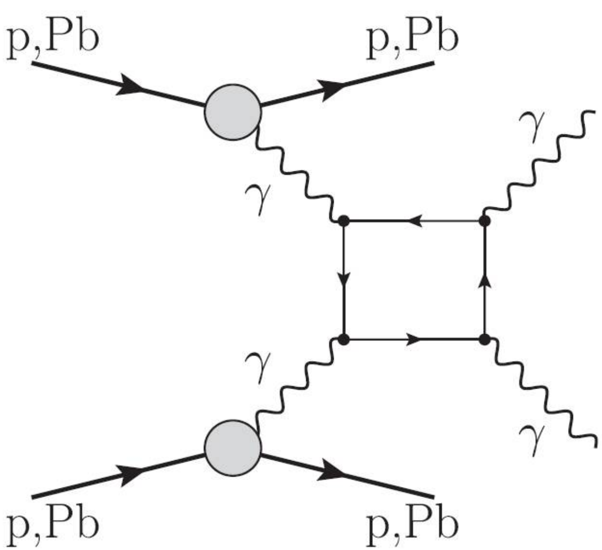
Measurement of high-mass dimuons

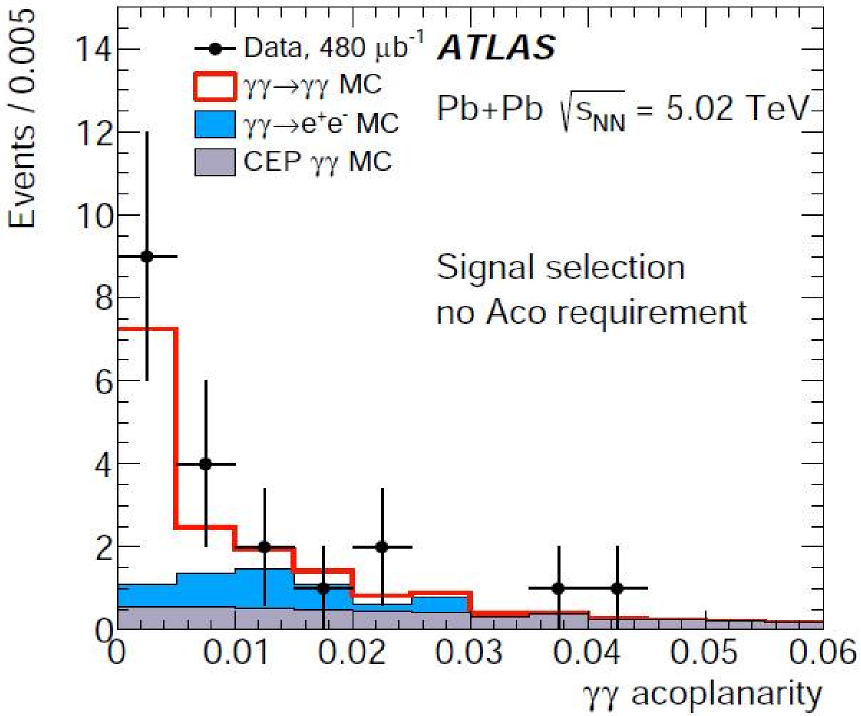




- Good **agreement with Starlight MC** – but the higher order QED corrections needs to be implemented into the MC
- Verifies the **Z^4 scaling** of cross-section and photon flux
- Significant **kinematic extension** over previous measurement by ALICE (EPJC 73 (2013) 2617)

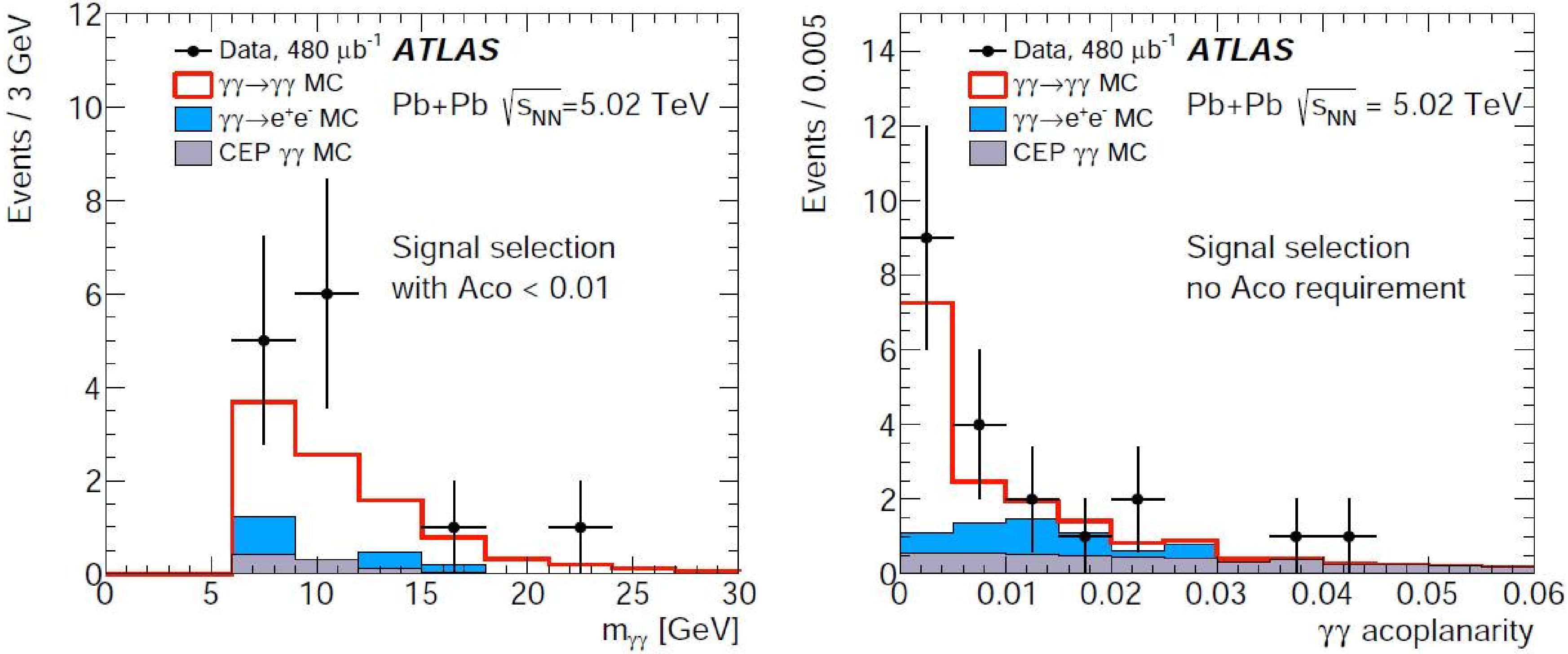
Evidence for light-by-light scattering





- Event selection: 2 photons: E_T>6 GeV, $|\eta|$<2.37, $m_{\gamma\gamma}$ > 6 GeV,
  $p_{T\gamma\gamma}$ < 2 GeV, Aco = $(1-\Delta\phi/\pi)$<0.01; no tracks
- **13 events** seen in the data, expects: 7.3 signal, 2.6 background
- p-value for the background-only hypothesis: 5×10^{-6} <=> **4.4 sigma significance** (3.8 sigma expected)

Search for light-by-light scattering



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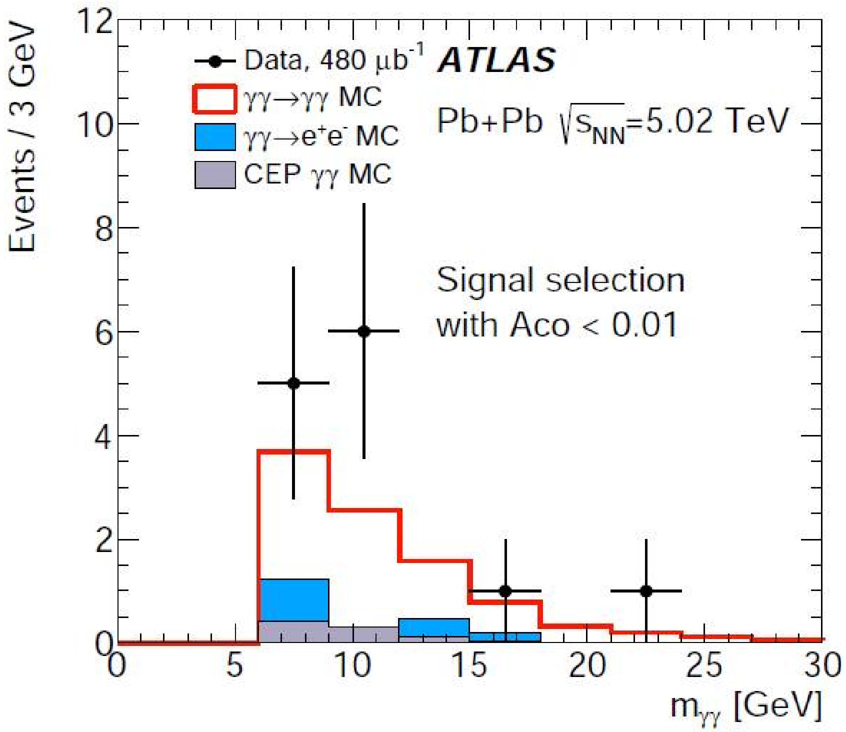
Search for light-by-light scattering



$$\sigma_{\text{fid}} = \frac{N_{\text{data}} - N_{\text{bkg}}}{C \times \int L \mathrm{d}t}$$

C=0.31 ± 0.07,
corrects for:
trigger, diphoton, PID efficiencies and photon energy and angular resolutions

- Measured cross-section: **70 ±20 (stat.) ±17 (syst.) nb**
- SM predictions:
  - 45 ± 9 nb (PRL 111 (2013) 080405),
  - 49 ± 10 nb (PRC 93 (2016) no.4, 044907)

Photo-nuclear dijet production

- Motivation: restrict nuclear parton distribution functions (nPDF) at low *x*
- **nPDF** exhibit **non-trivial behavior**:
  - suppression at low *x* called “shadowing“
  - enhancement at larger *x* called “anti-shadowing“
  - suppression at the largest *x* called “EMC effect“

$$f_i^{p/A}(x, Q^2) = \\ = R_i^A(x, Q^2) f_i^p(x, Q^2)$$

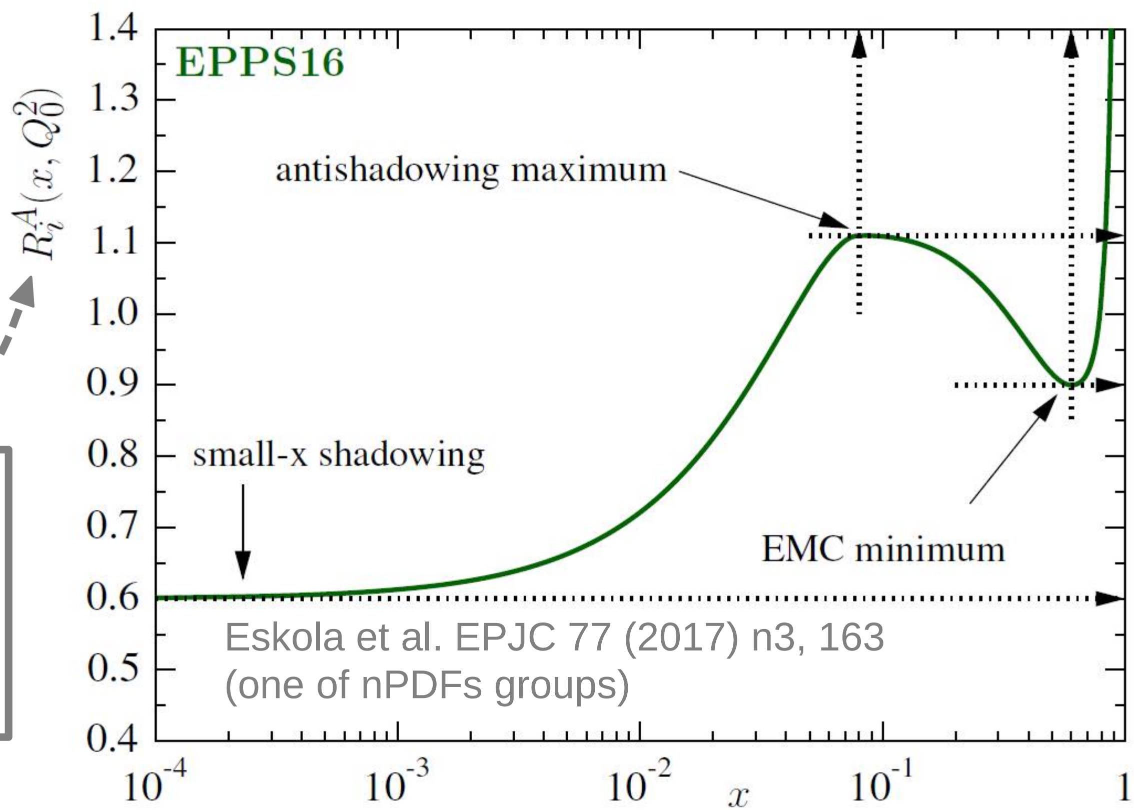
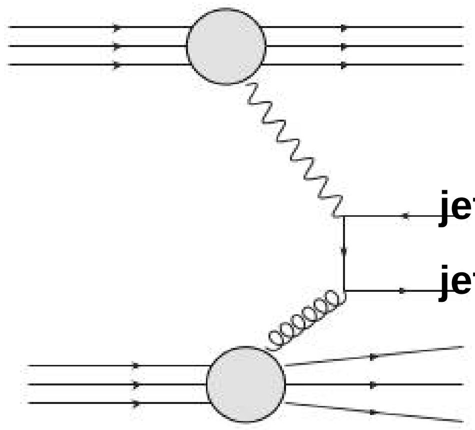


Photo-nuclear dijet production: observables



2 –> 2 scattering limit:

$$H_T \equiv \sum_i p_{T\,i}$$ → 2Q

$$x_A \equiv \frac{m_{\text{jets}}}{\sqrt{s}} e^{-y_{\text{jets}}}$$ → x of struck parton in nucleus

$$z_\gamma \equiv \frac{m_{\text{jets}}}{\sqrt{s}} e^{+y_{\text{jets}}}$$ → $x_\gamma\, y_\gamma$ (y_γ … E fraction of γ, x_γ … fraction of γ's E carried by parton in γ)

… where

$$y_{\text{jets}} \equiv \frac{1}{2} \ln \left(\frac{\sum_i E_i + \sum_i p_{z\,i}}{\sum_i E_i - \sum_i p_{z\,i}} \right)$$

$$m_{\text{jets}} \equiv \left[\left(\sum_i E_i \right)^2 - \left| \sum_i \vec{p}_i \right|^2 \right]^{1/2}$$

… *i* goes through all the jets

Photo-nuclear dijet production: new inputs for nPDF

$$\frac{d^3\tilde{\sigma}}{dH_\mathrm{T} x_\mathrm{A} dz_\gamma} = \frac{1}{\mathcal{L}} \frac{\Delta N}{\Delta H_\mathrm{T}\, \Delta x_\mathrm{A}\, \Delta z_\gamma} \frac{1}{\varepsilon_\mathrm{trig}\, \varepsilon_\mathrm{sel}}$$

… measuring triple differential cross-section
not unfolded for the response –> projections

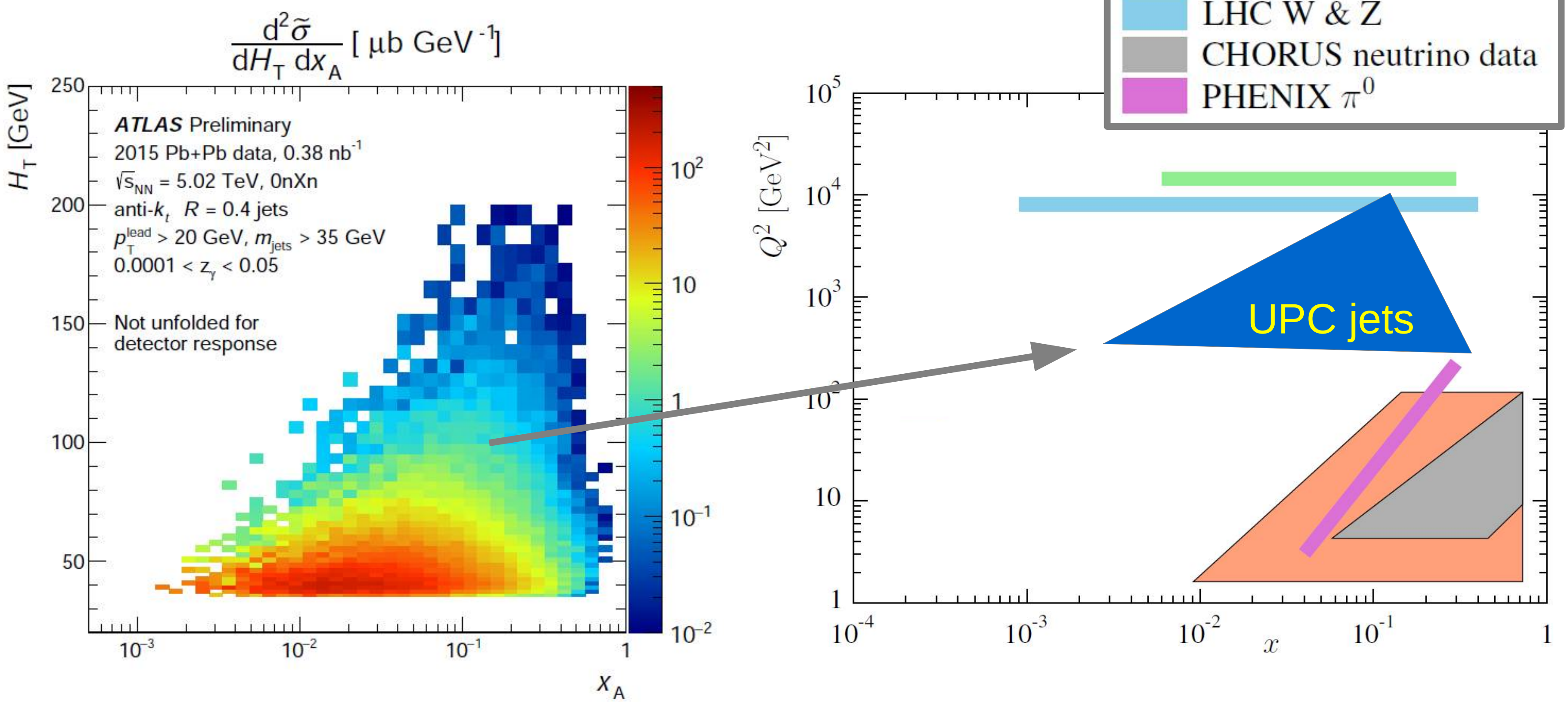
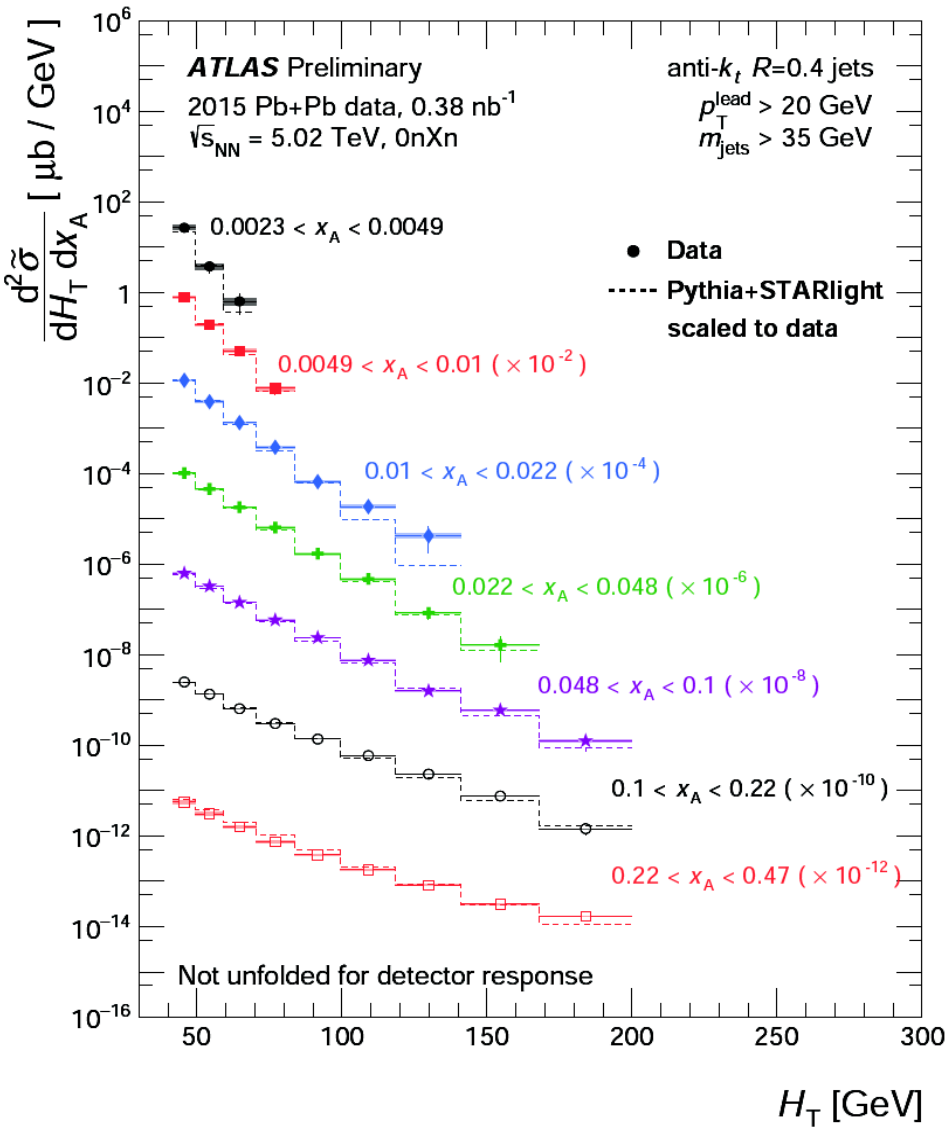
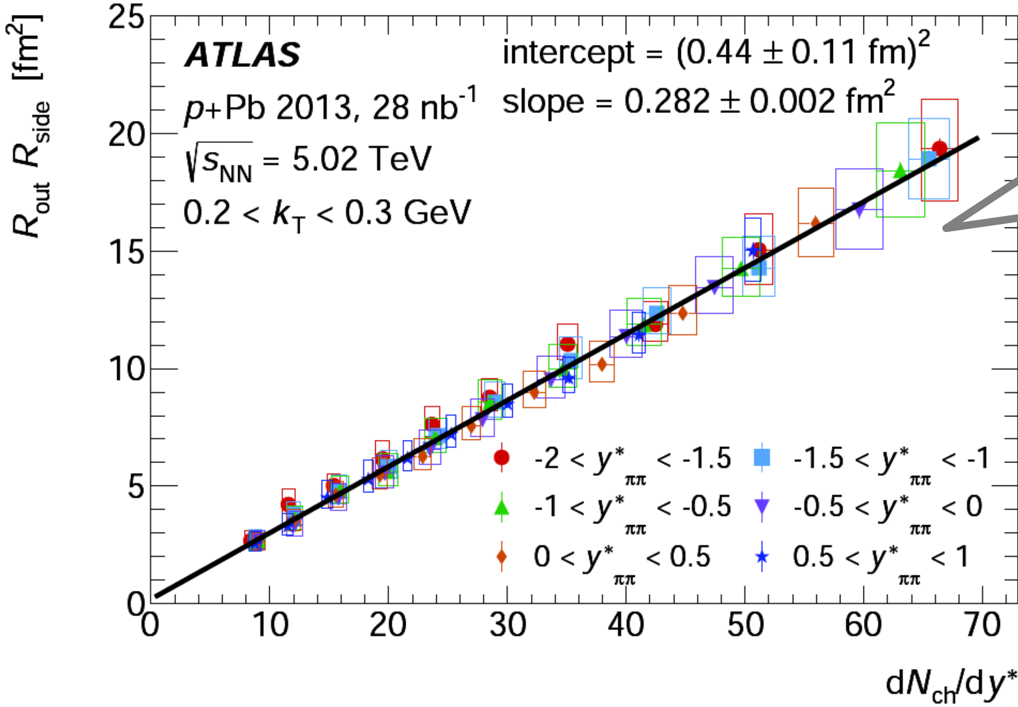


Photo-nuclear dijet production: slices of x_A

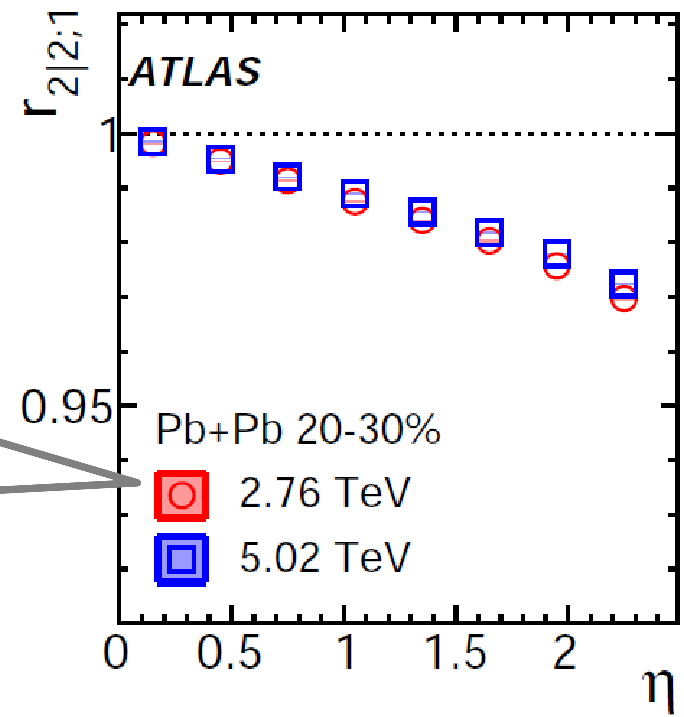


- Not the same as $F_2(x,Q^2)$
  - still contains $1/Q^4$ and z_γ dependence
- MC close to data but matching is not expected
- Also measured slices of H_T and z_g

… more results



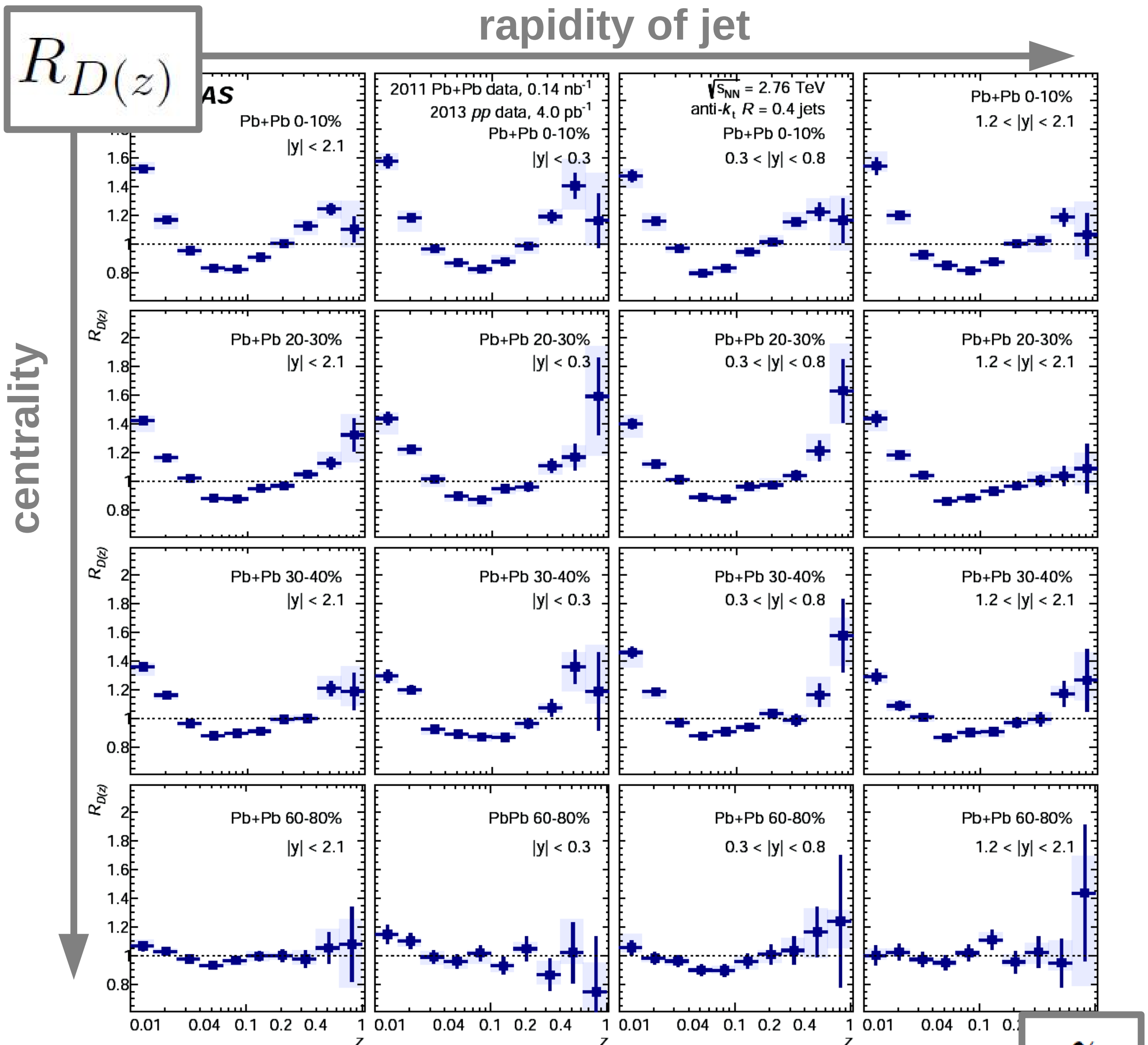
Femtoscopy with identified charged pions in p+Pb (Phys. Rev. C 96 (2017) 064908)



Longitudinal flow decorrelations in Pb+Pb (arXiv:1709.02301)

Internal structure of jets in Pb+Pb at 2.76 TeV

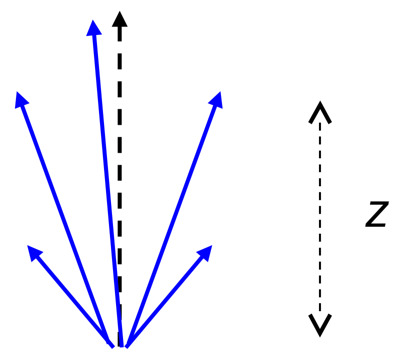
EPJC 77 (2017) 379



$$R_{D(z)} = \frac{D(z)|_{\text{cent}}}{D(z)|_{pp}}$$

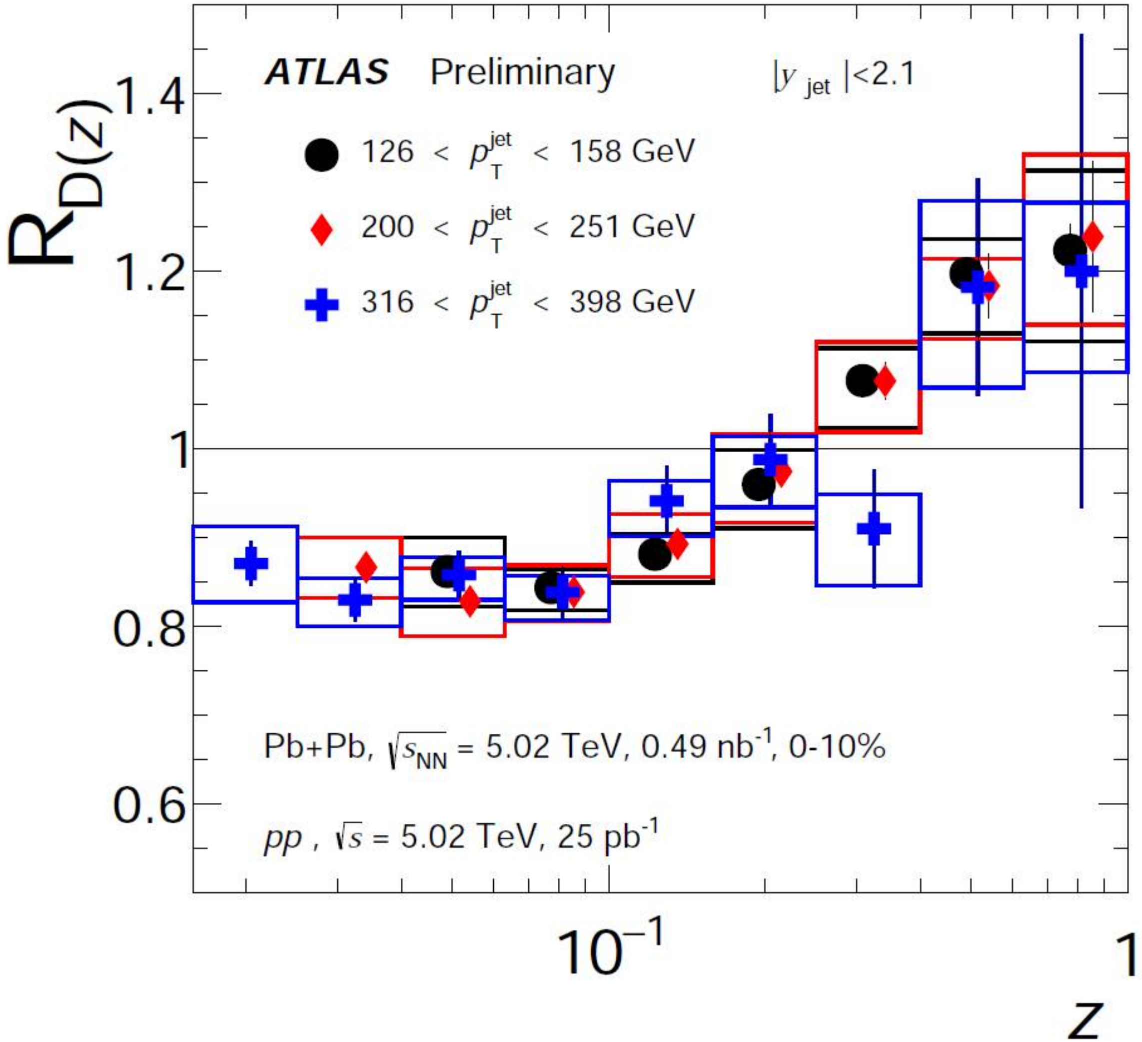
$$D(z) = \frac{1}{N_{jet}} \frac{\mathrm{d}N}{\mathrm{d}z}$$

$$z = \frac{p_{\mathrm{T}}}{p_{\mathrm{T}}^{jet}} \cos \Delta R$$



Internal structure of jets at 5.02 TeV

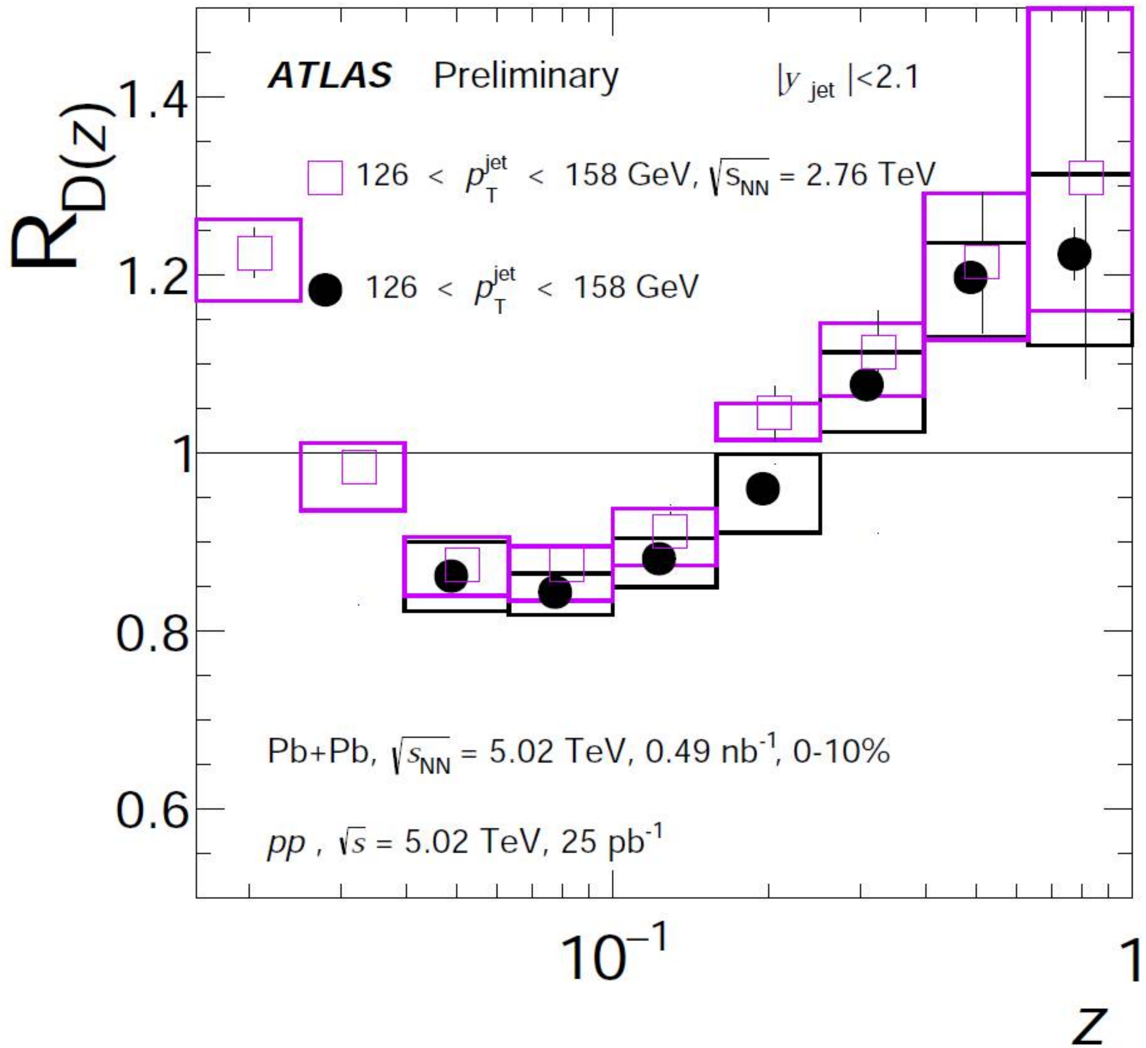
ATLAS-CONF-2017-005



… no jet p_T dependence observed

Internal structure of jets at 5.02 TeV

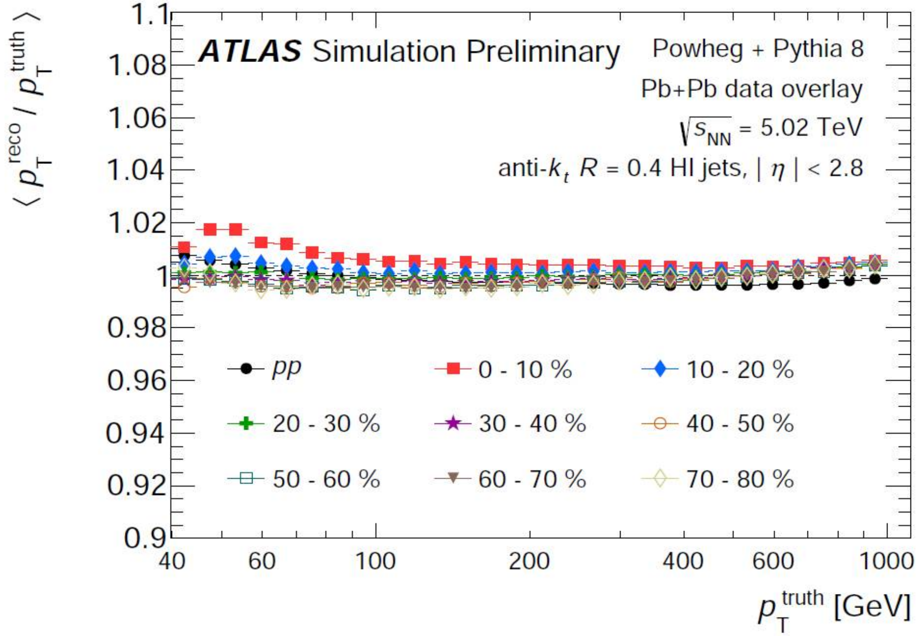
ATLAS-CONF-2017-005



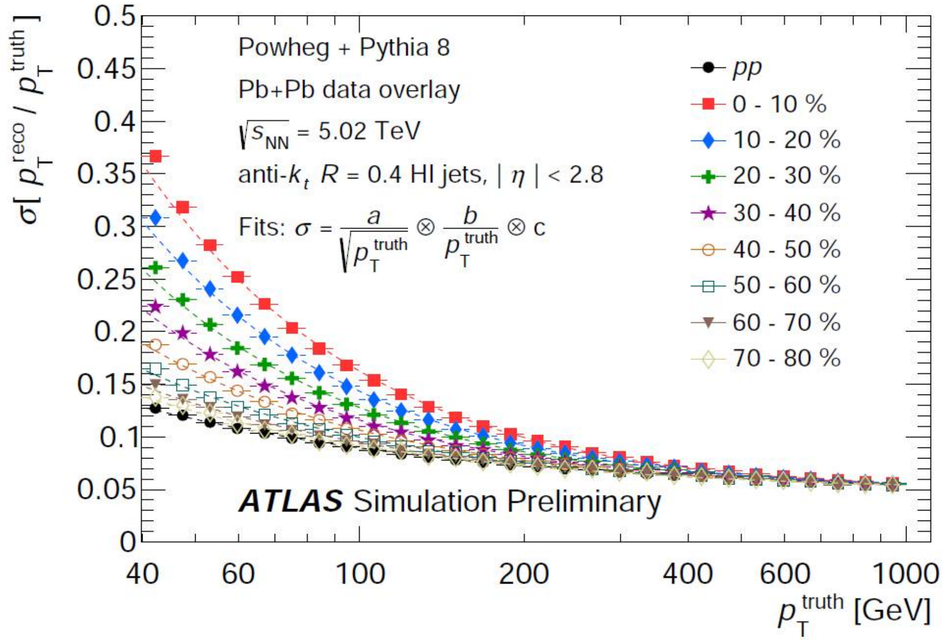
… 5.02 TeV measurement agrees with 2.76 TeV measurement at the comparable *z* domain

Jet reconstruction performance in run 2

Jet energy scale

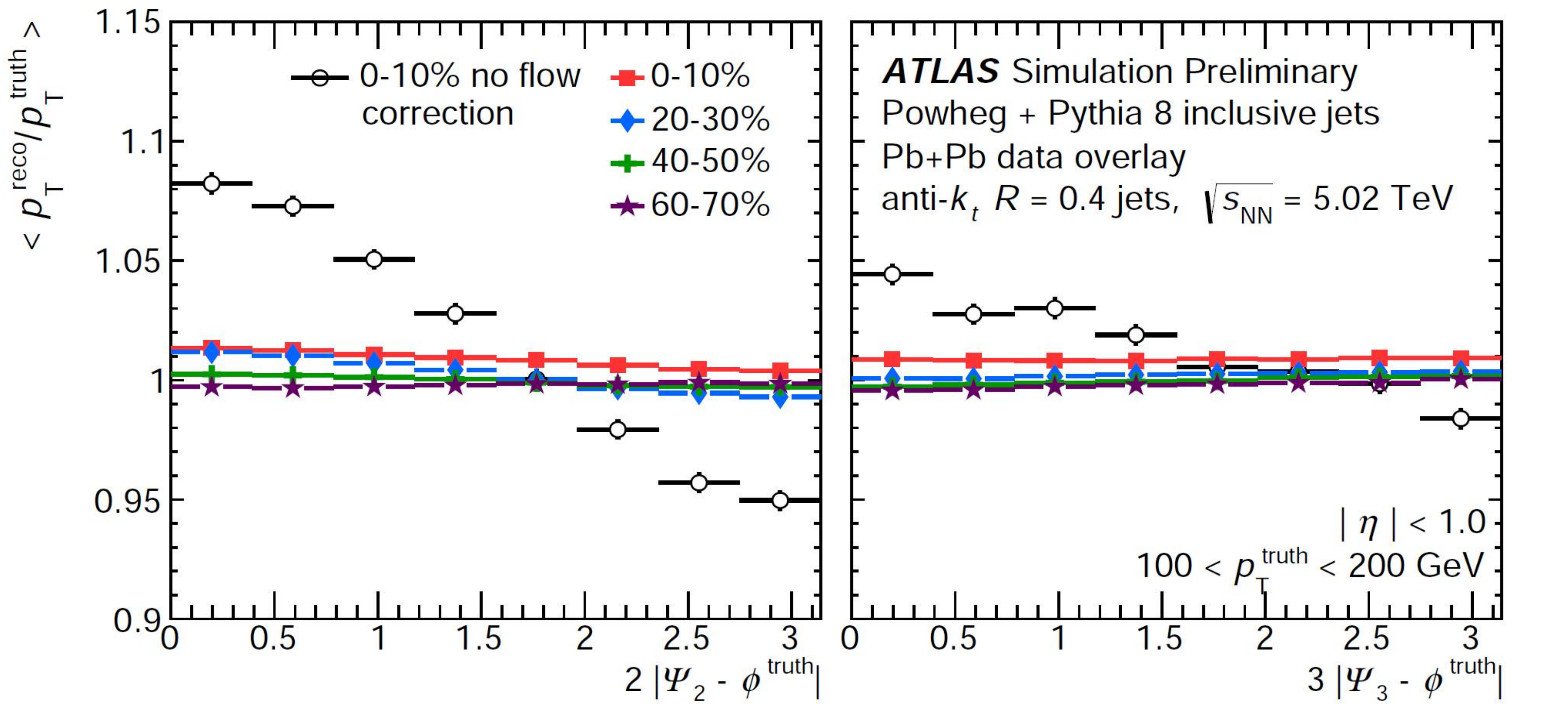


Jet energy resolution



- Realistic jet simulations: NLO POWHEG+PYTHIA8 MC + minimum bias Pb+Pb data overlay.
- Good understanding of jet energy scale.
- Expected behavior of jet energy resolution.

Jet reconstruction performance in run 2



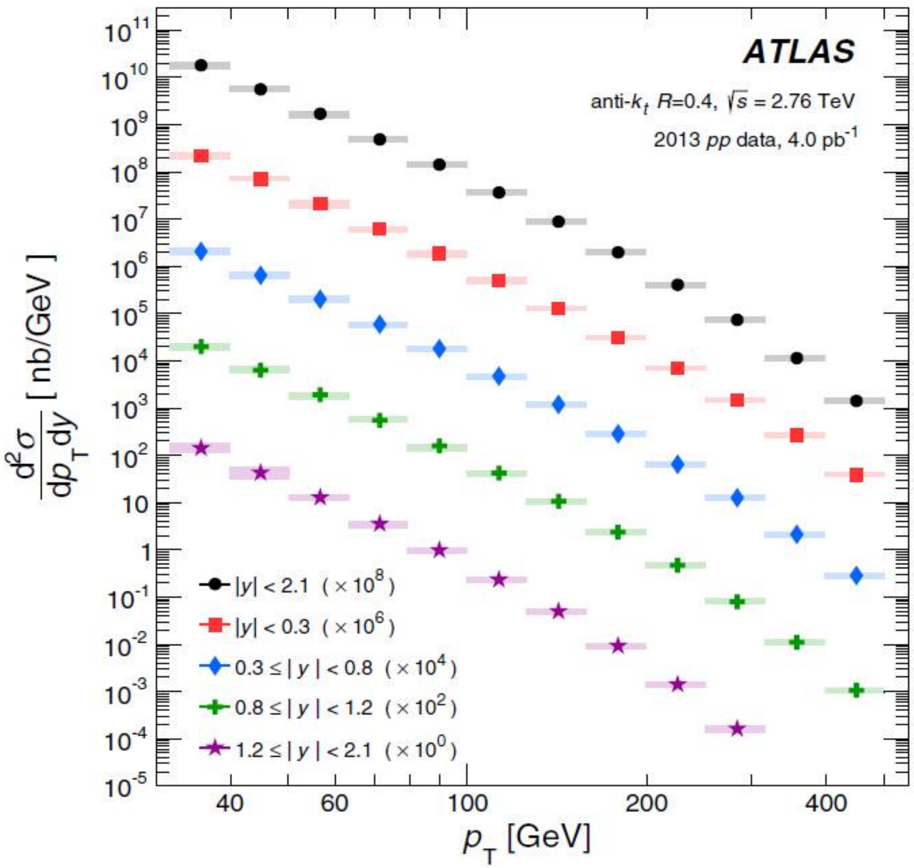
… Example of the improvement in the jet energy scale: implementing the higher order flow corrections.

=> Jet energy scale does not dependent on the orientation with respect to the reaction plane.

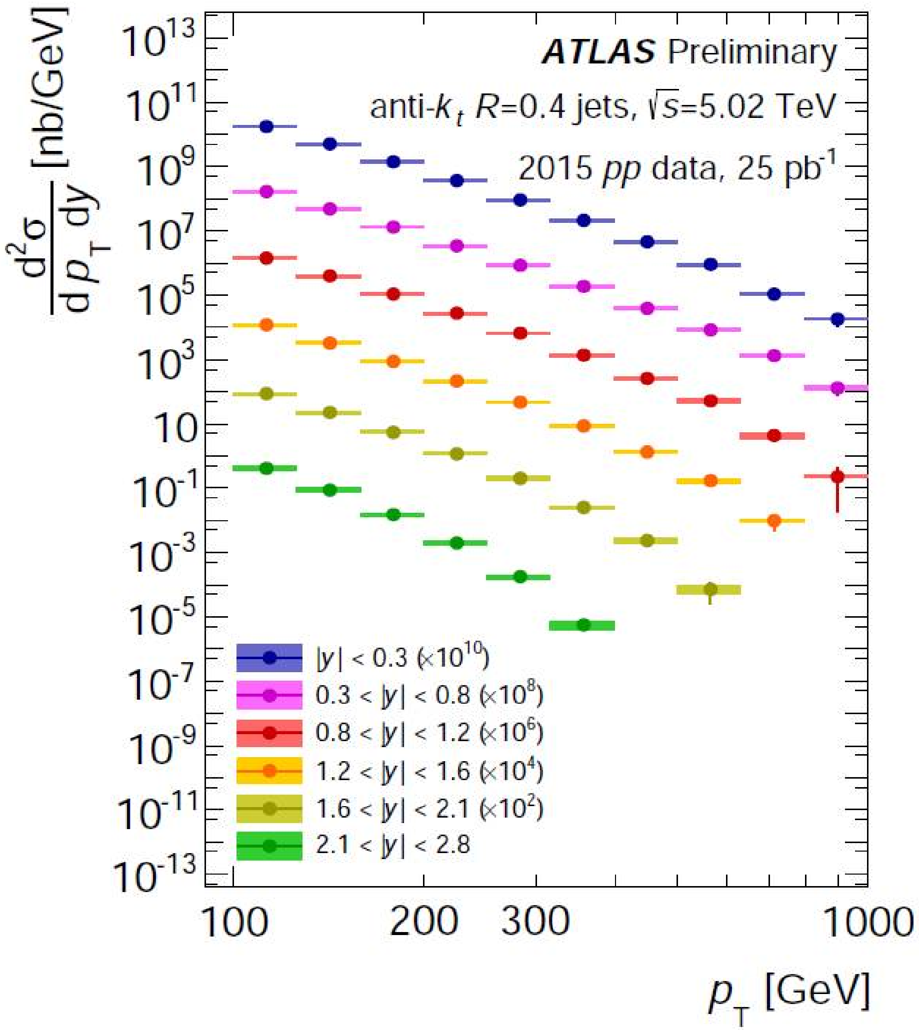
See also poster by Akshat Puri

Jet cross-section in pp collisions

2.76 TeV



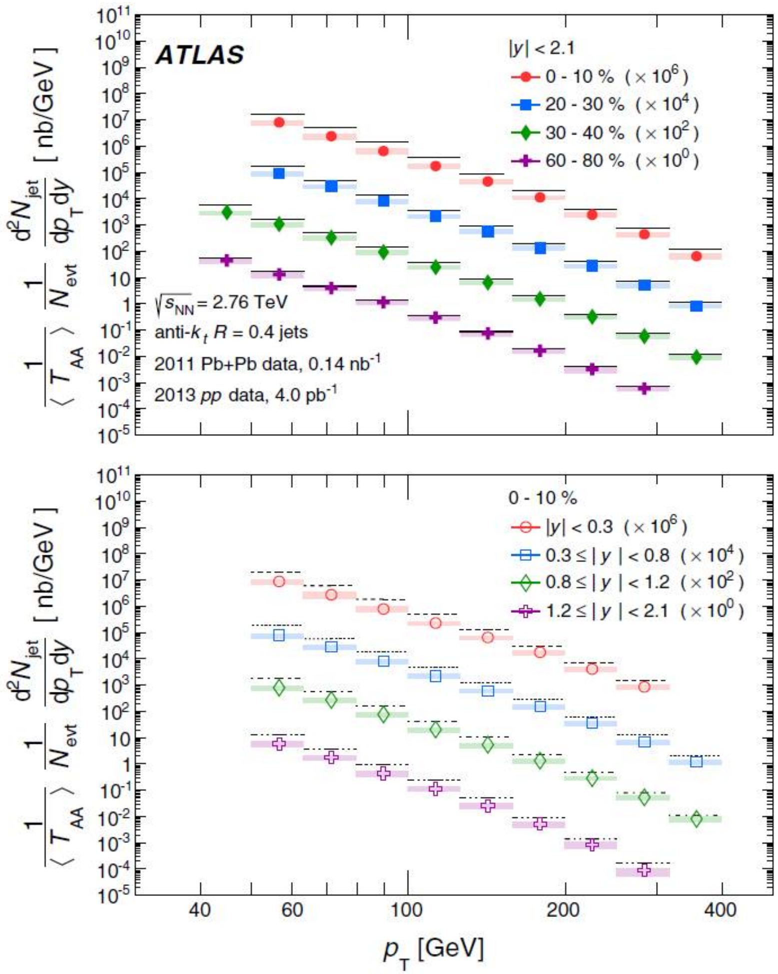
5.02 TeV

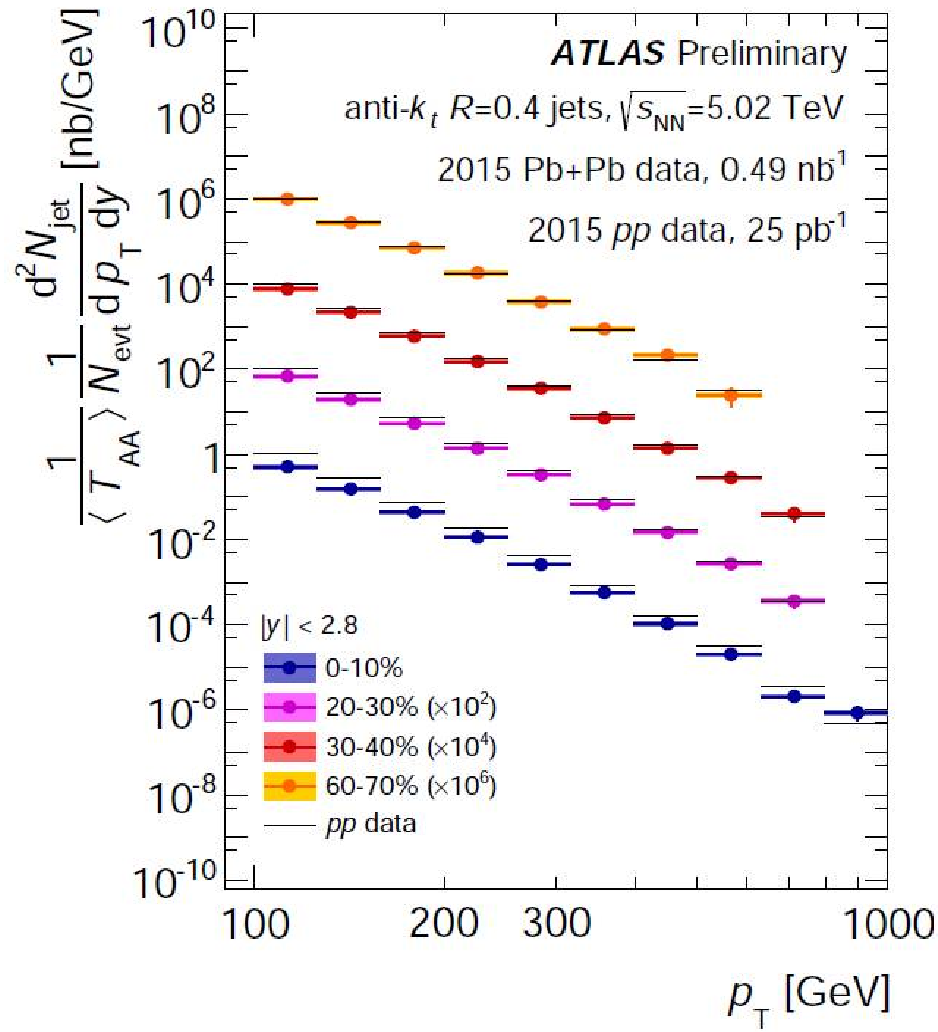


Jet yeilds in Pb+Pb collisions

2.76 TeV

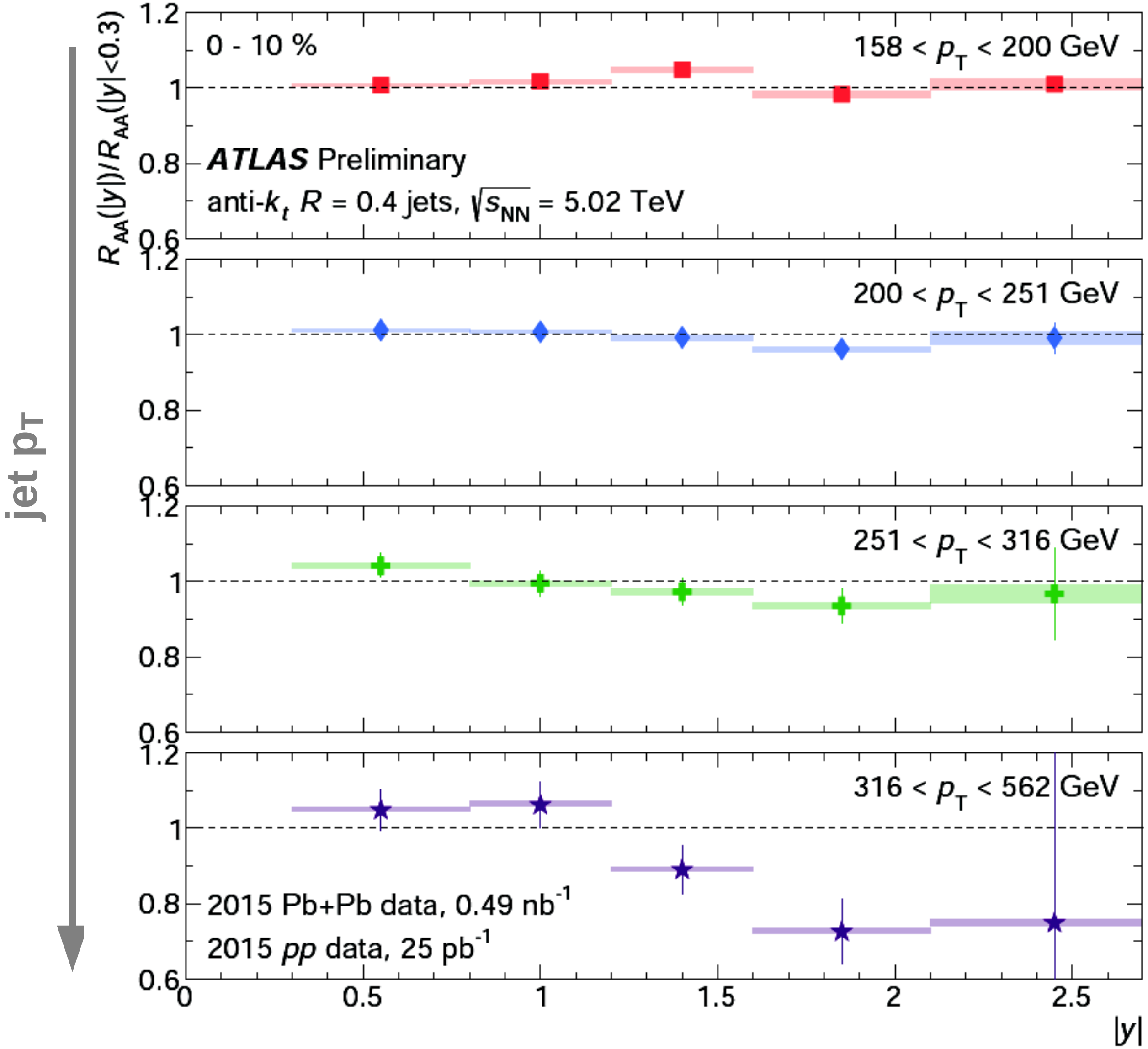
5.02 TeV





Jet R_{AA}: *y*-dependence, $\sqrt{s_{NN}}$ = 5.02 TeV

ATLAS-CONF-2017-009



- Vertical-axis: ratio of R_{AA} in a given rapidity to the R_{AA} for jets with $|y|<0.3$.
- With increasing jet p_T R_{AA} getting **smaller in the forward region** as compared to the mid-rapidity region (predicted in arXiv:1504.05169).