ATLAS highlights from small systems

Dominik Derendarz
on behalf of the ATLAS collaboration

ATLAS heavy ion datasets

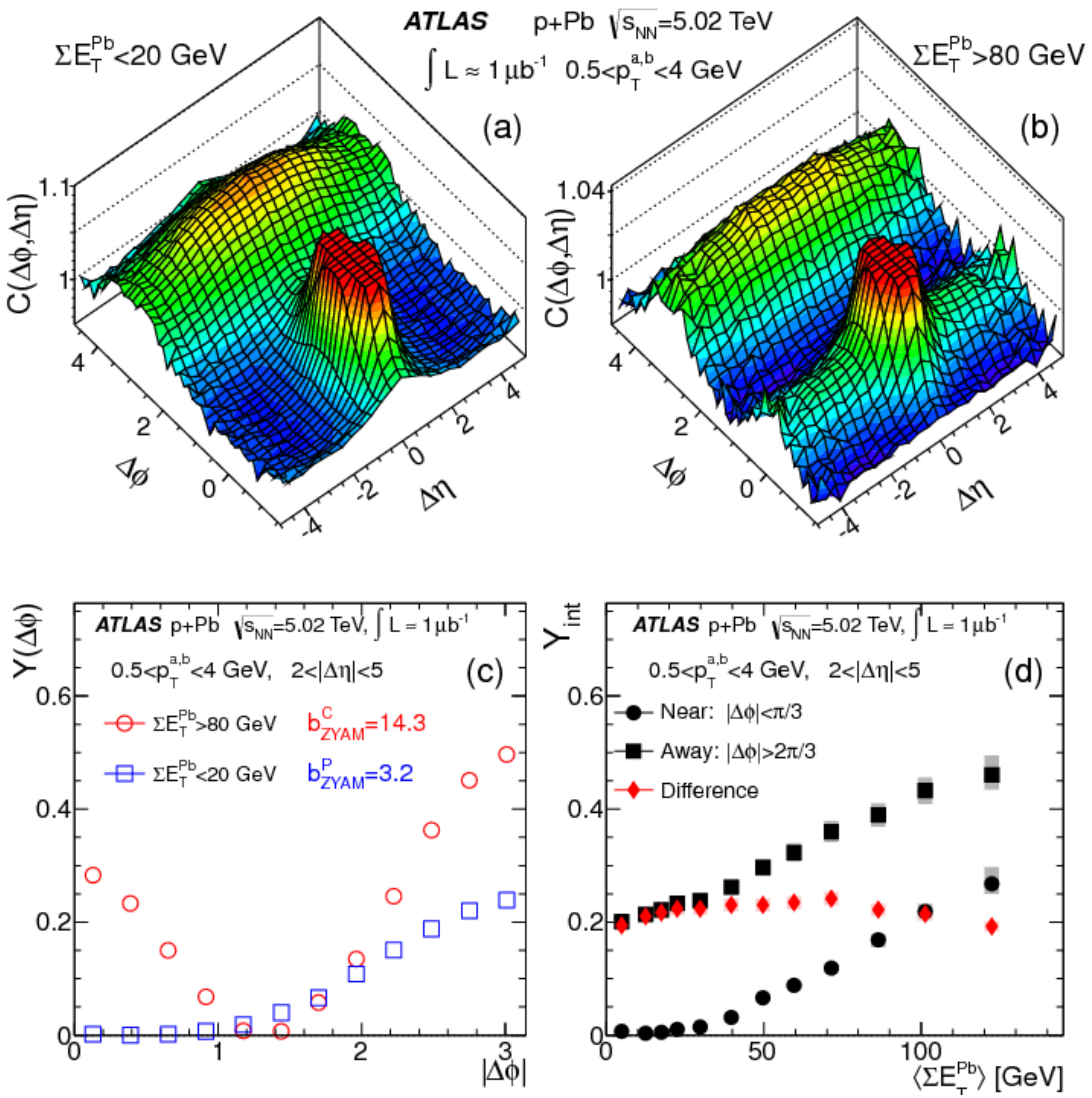
	System	Year	sqrt(s_{NN}) [TeV]	L_{int}
Run 1	**Pb+Pb**	2010	2.76	7 μb^{-1}
	Pb+Pb	2011	2.76	0.14 nb^{-1}
	pp	2012	8	19.4 fb^{-1}
	p+Pb	2012	5.02	1 μb^{-1}
	pp	2013	2.76	4 pb^{-1}
	p+Pb	2013	5.02	29 nb^{-1}
Run 2	**low <μ> pp**	2015-16	13	0.9 pb^{-1}
	pp	2015	5.02	28 pb^{-1}
	Pb+Pb	2015	5.02	0.49 nb^{-1}
	p+Pb	2016	5.02	0.5 nb^{-1}
	p+Pb	2016	8.16	0.16 pb^{-1}
	Xe+Xe	2017	5.44	3 μb^{-1}
	pp	2017	5.02	270 pb^{-1}
	Pb+Pb	2018	5.02	1.76 nb^{-1}
Run 3	**Pb+Pb**	2023	5.36	1.63 nb^{-1}
	pp	2024	5.36	425 pb^{-1}
	Pb+Pb	2024	5.36	
	O+O	2025		

ATLAS HI public results:
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HeavyIonsPublicResults

Chapter 1
Collectivity in small systems

First collectivity results in small system from ATLAS in p+Pb

Phys. Rev. Lett. 110 (2013) 182302

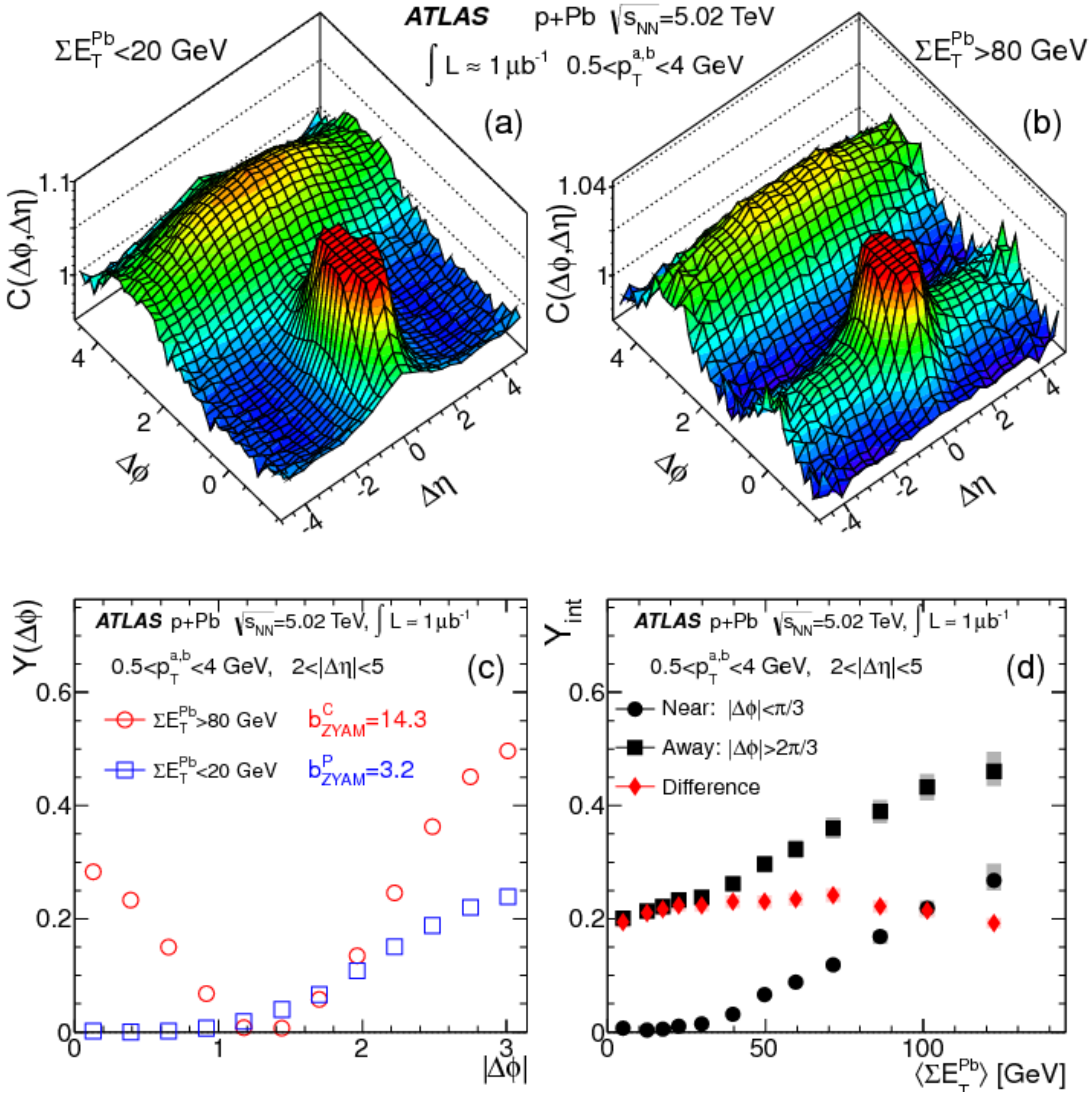


Measurement with 1μb-1 of data recorded in pilot p+Pb run.

Strength of the long-range component is quantified by the per-trigger yields with the zero-yield-at-minimum pedestal estimate.

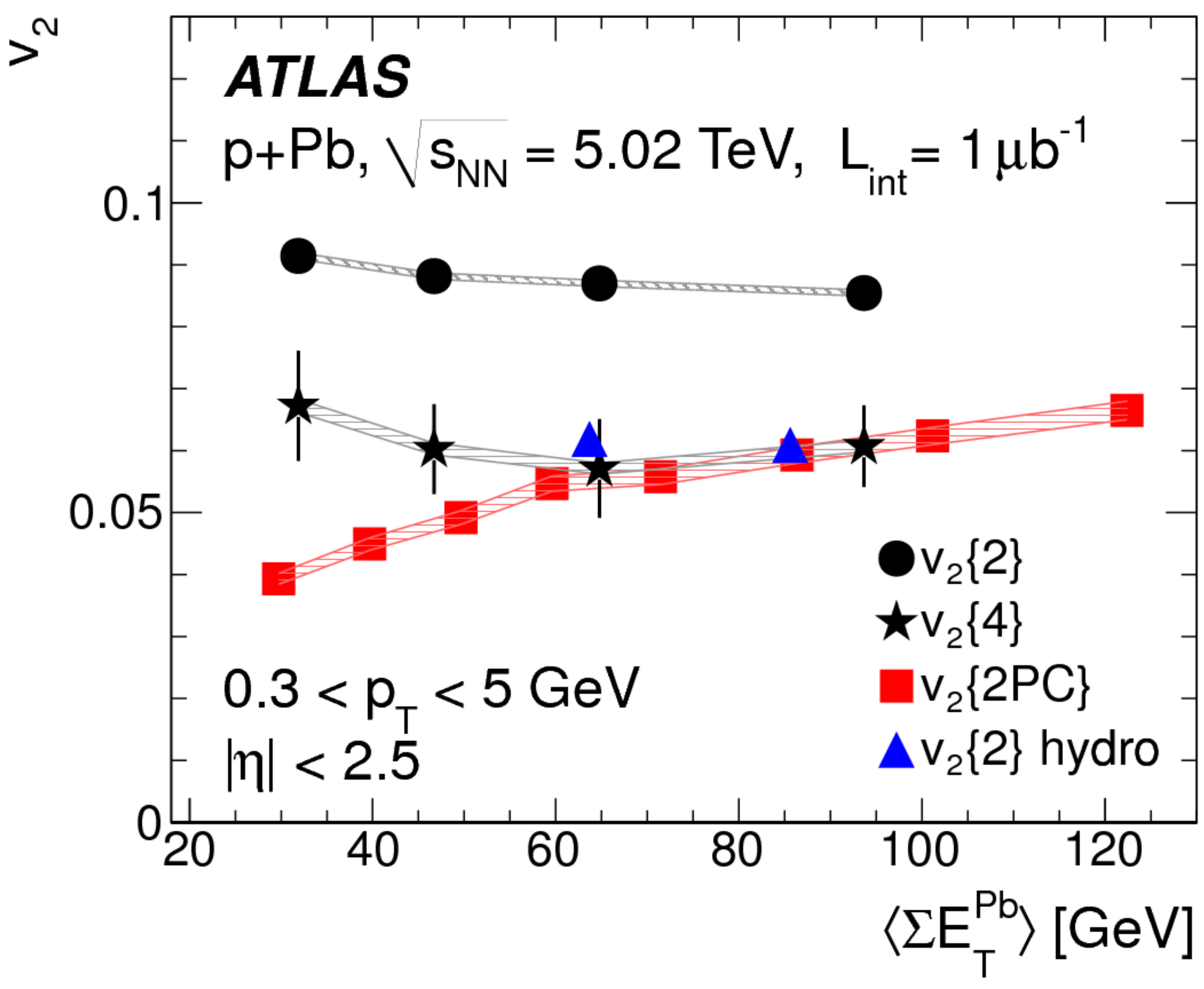
First collectivity results in small system from ATLAS in p+Pb

Phys. Rev. Lett. 110 (2013) 182302



Measurement with 1μb-1 of data recorded in pilot p+Pb run.

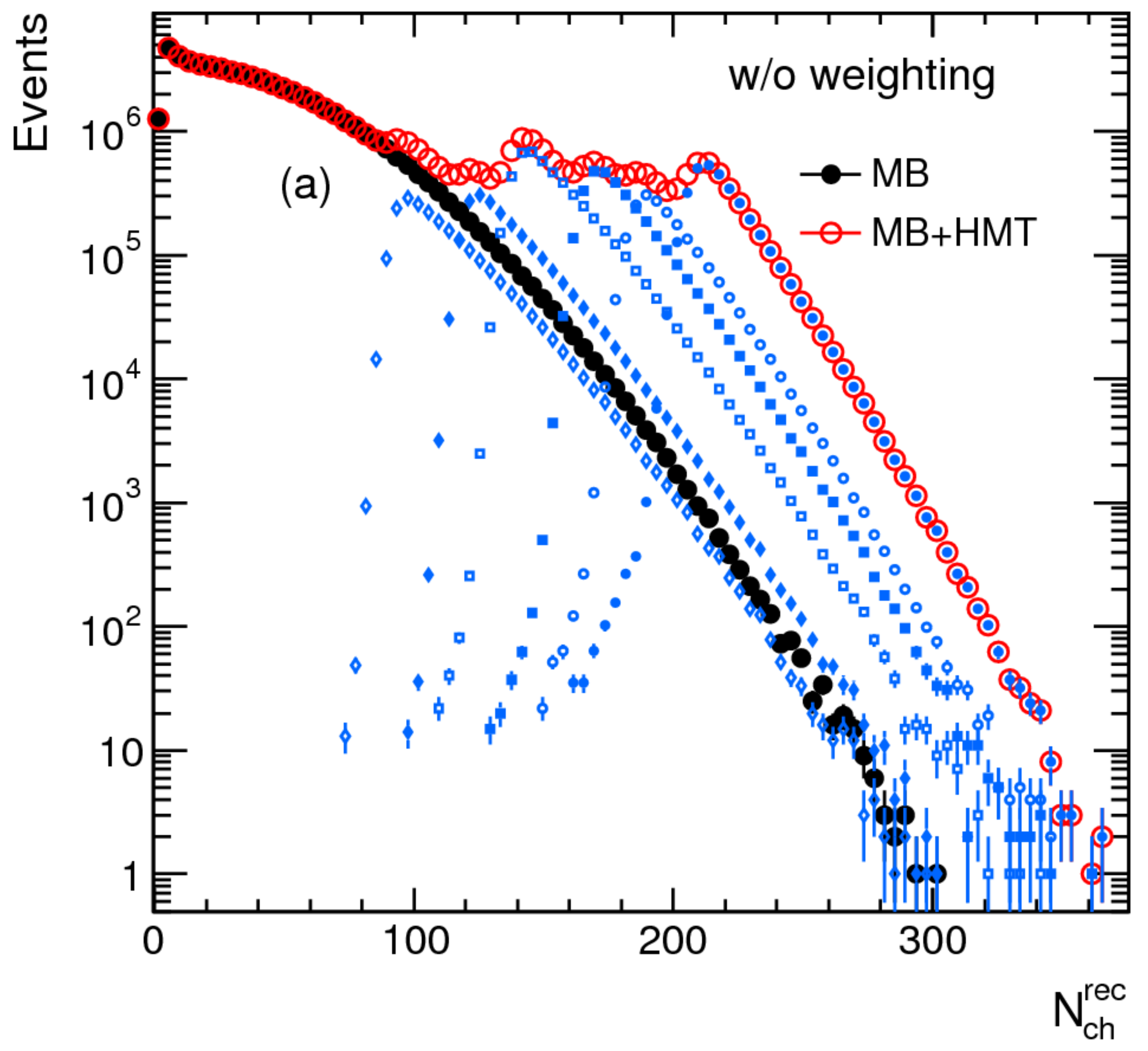
Phys. Lett. B 725 (2013), pp. 60-78



v_2 extracted with 4 particle cumulants

Improved 2PC method for peripheral subtraction

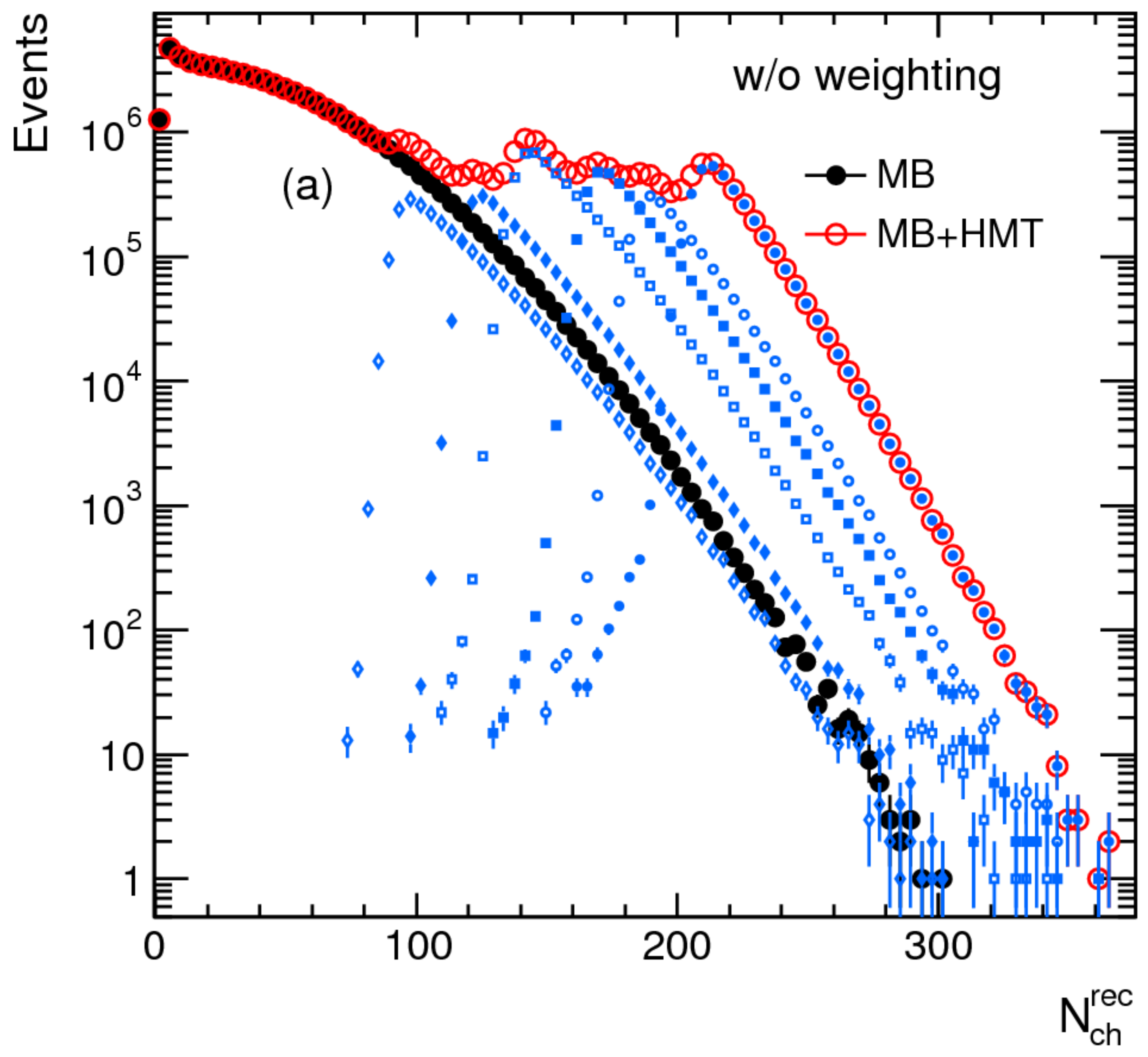
Phys. Rev. C 90, 044906

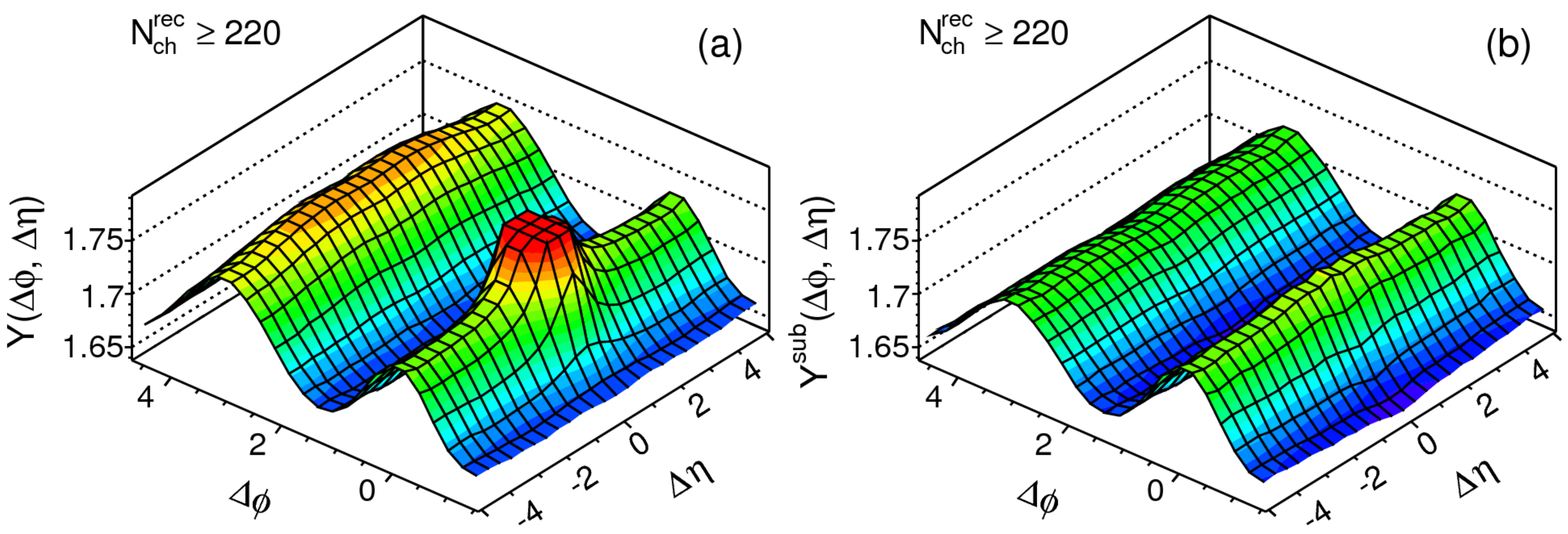


Era of high multiplicity triggers started.

Improved 2PC method for peripheral subtraction

Phys. Rev. C 90, 044906





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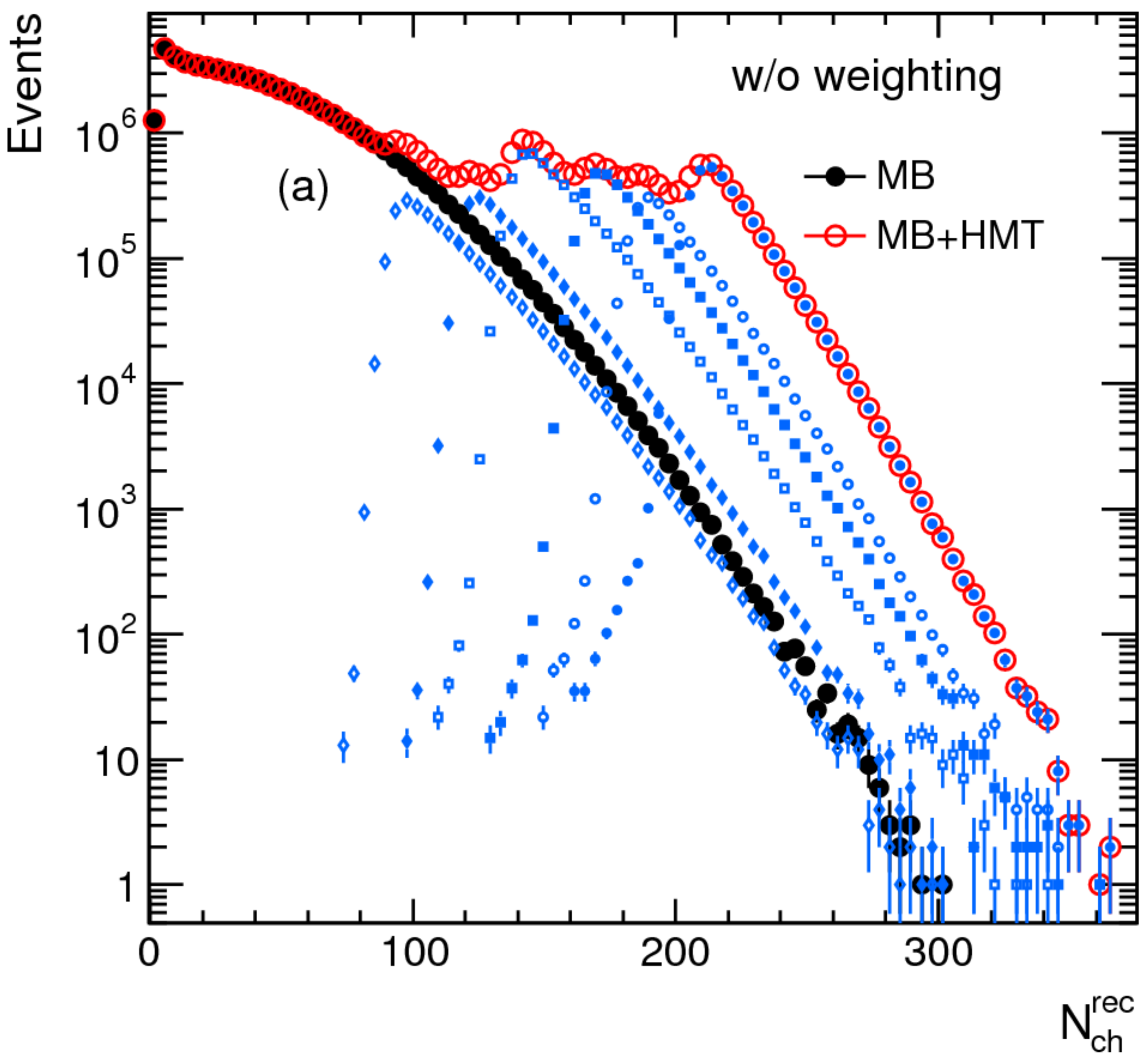

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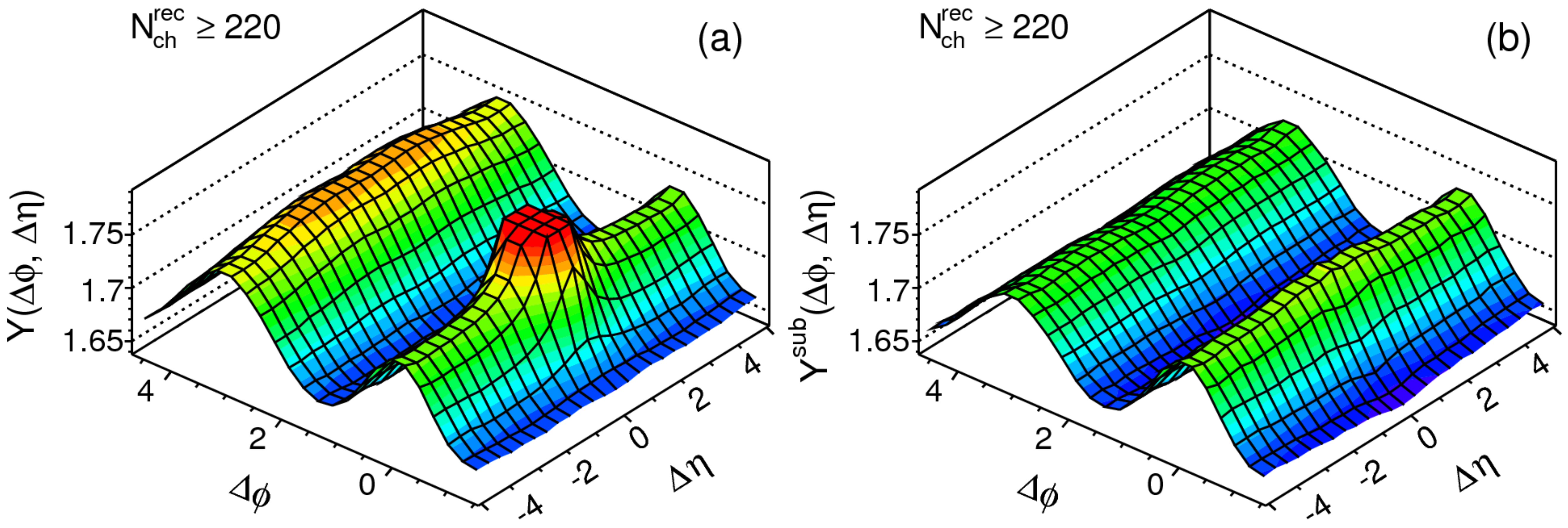
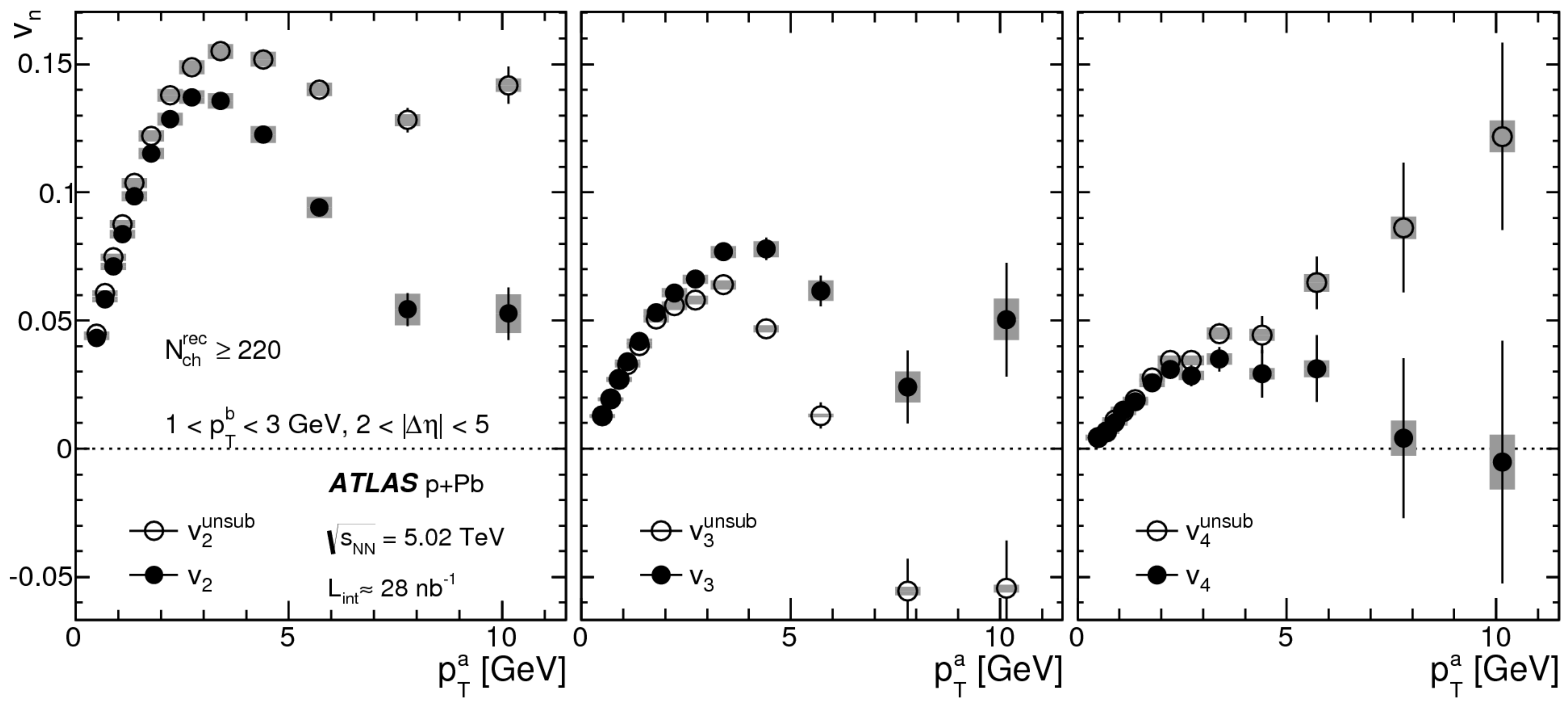
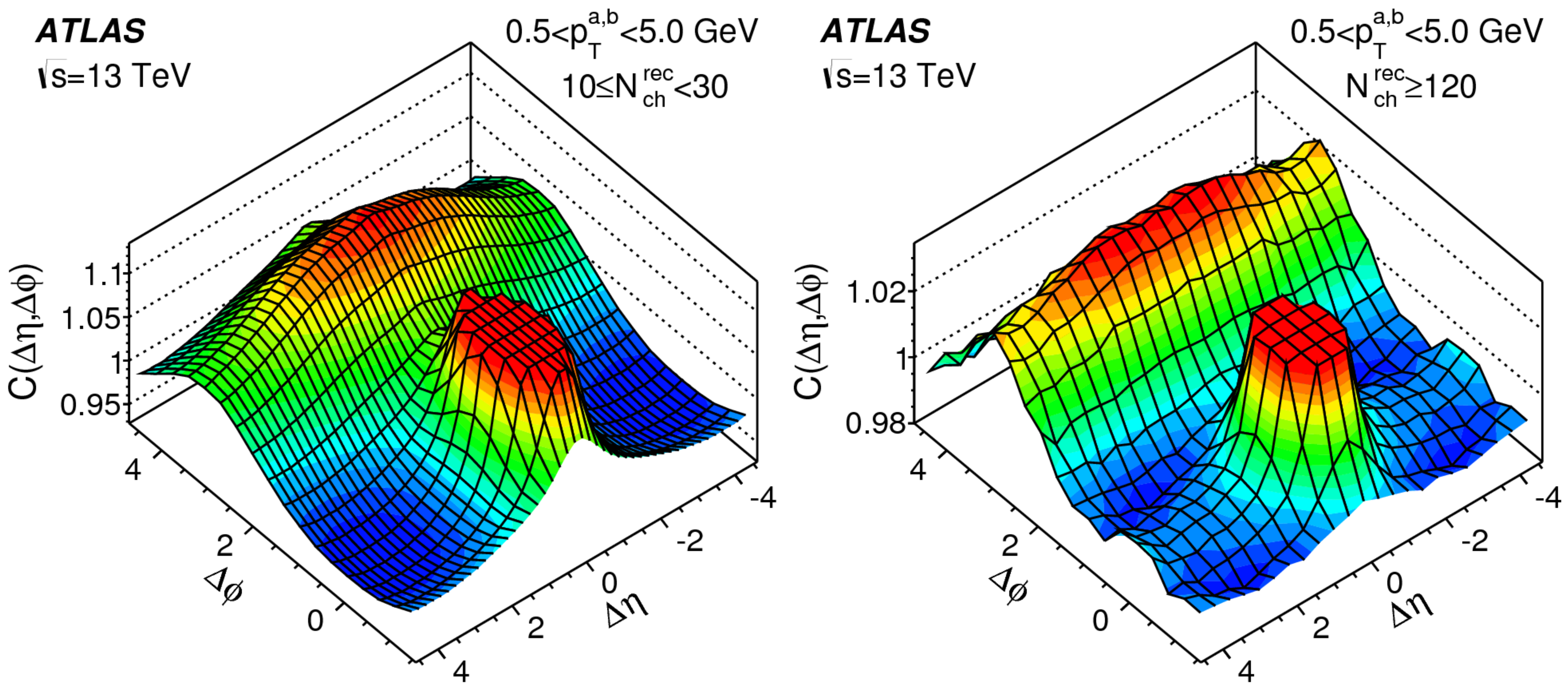




Subtraction the recoil contribution estimated using the 2PC in low-activity events (but still with ZYAM).

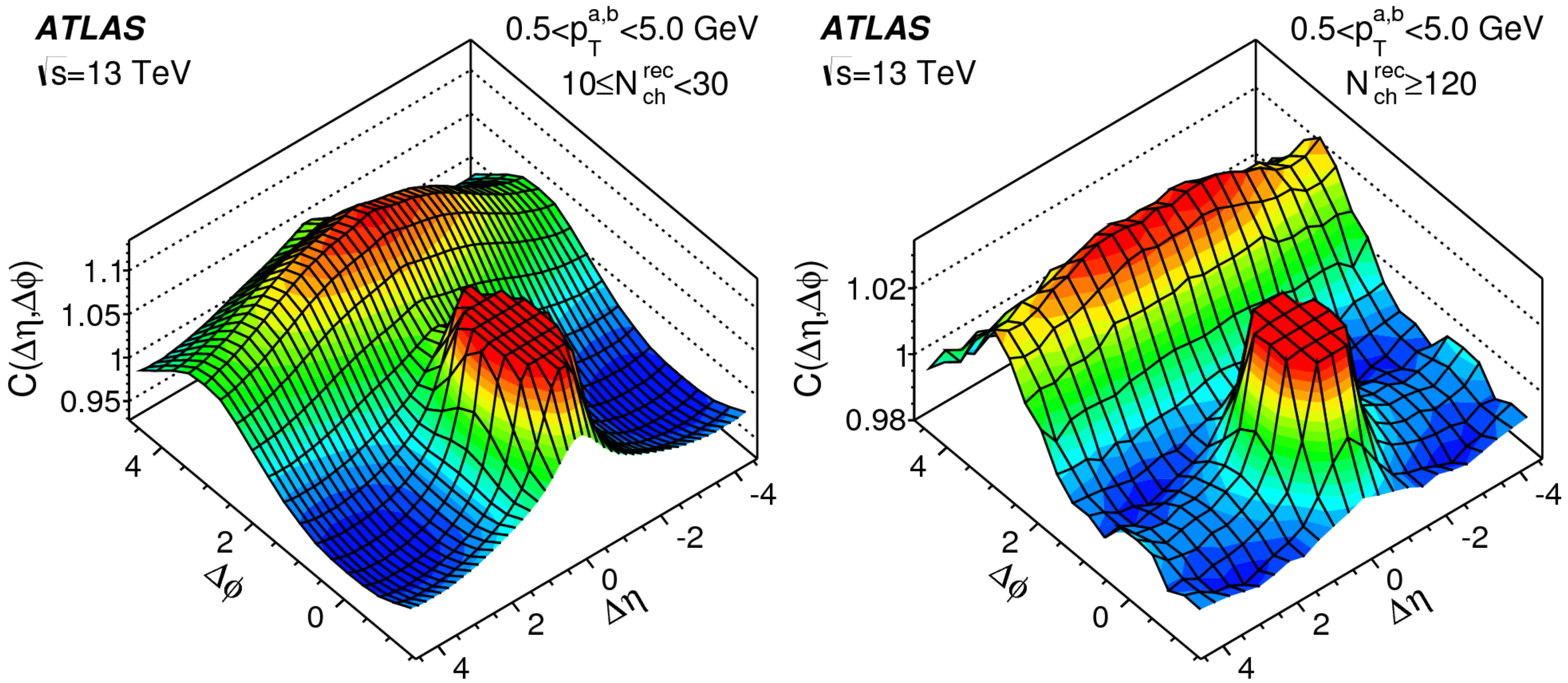
Collectivity in pp - template fit

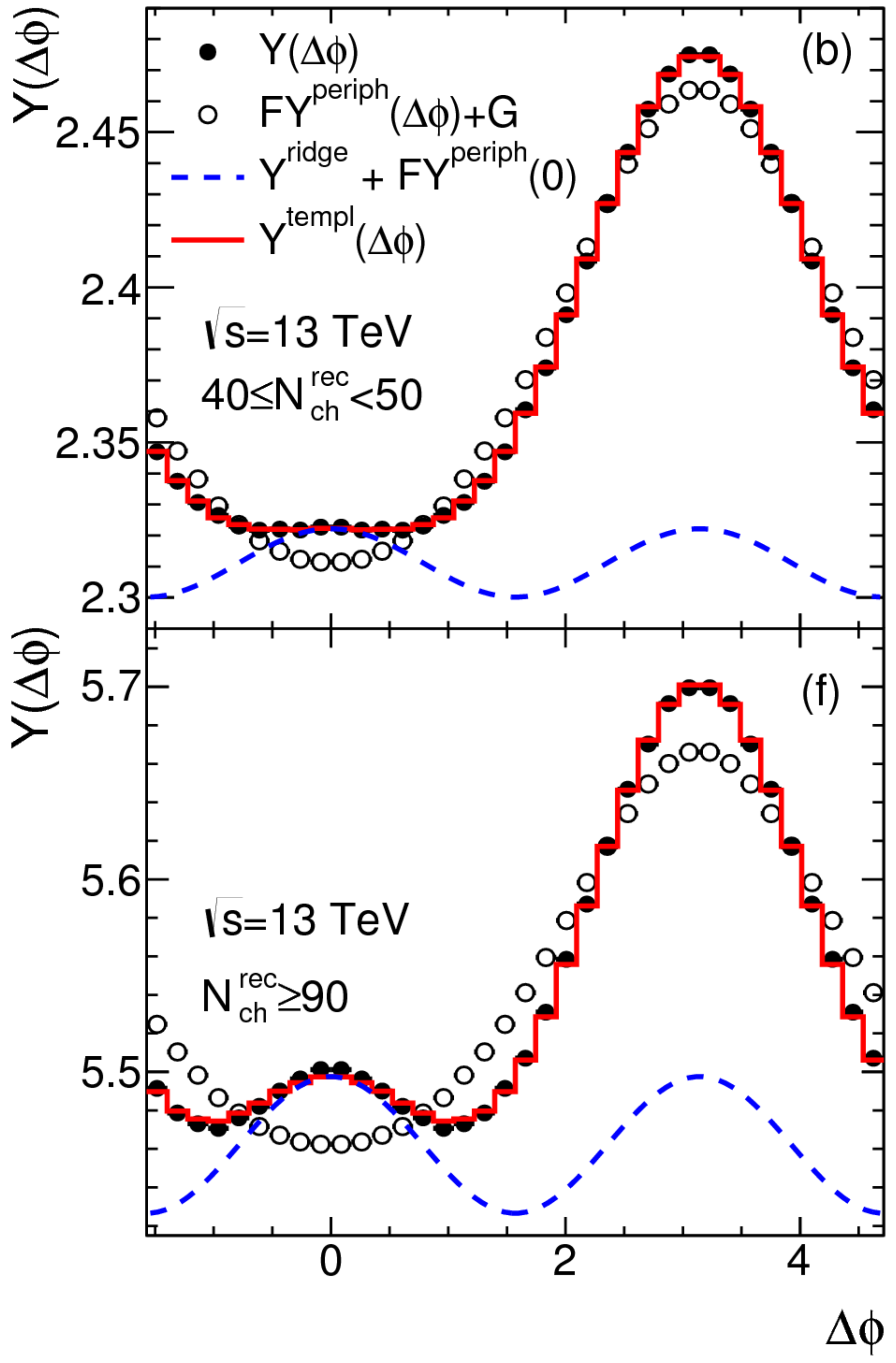
Phys. Rev. Lett. 116 (2016) 172301



Collectivity in pp - template fit

Phys. Rev. Lett. 116 (2016) 172301

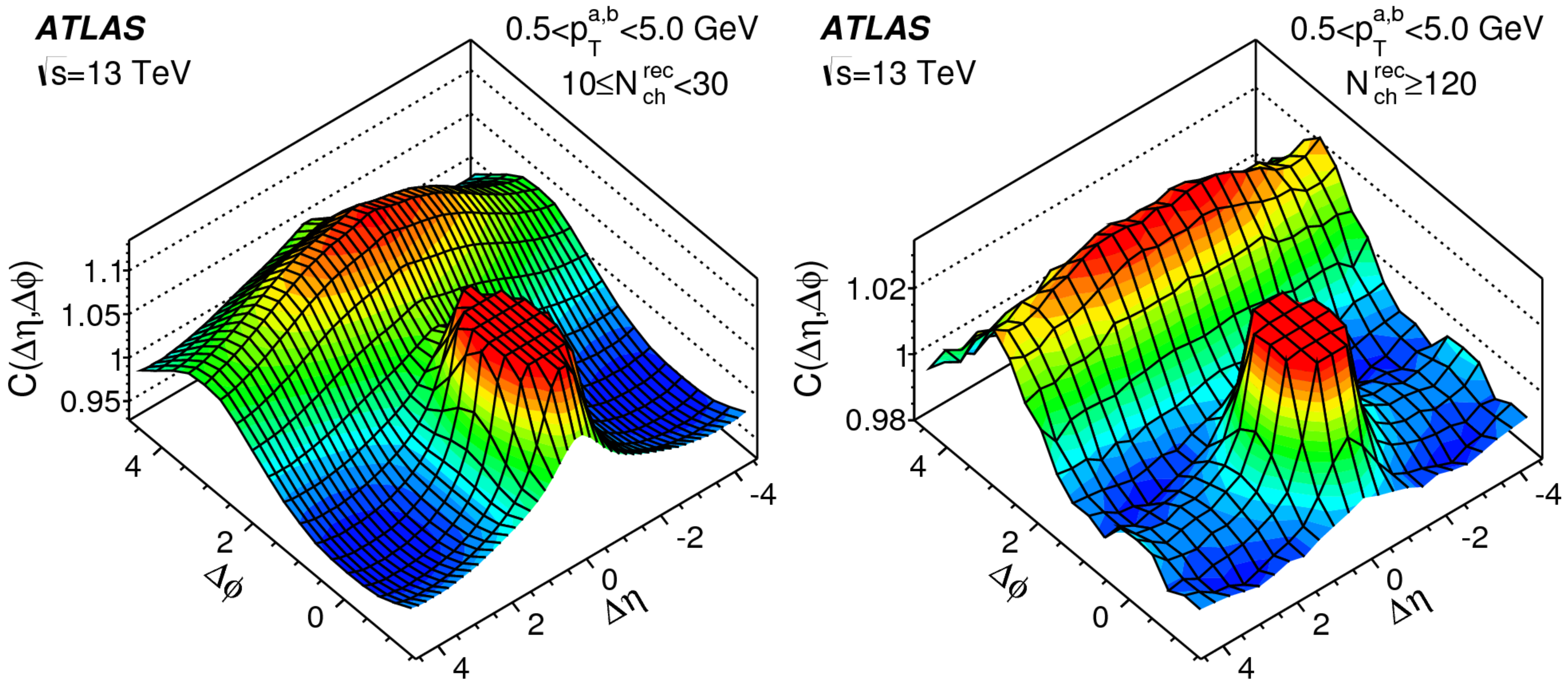


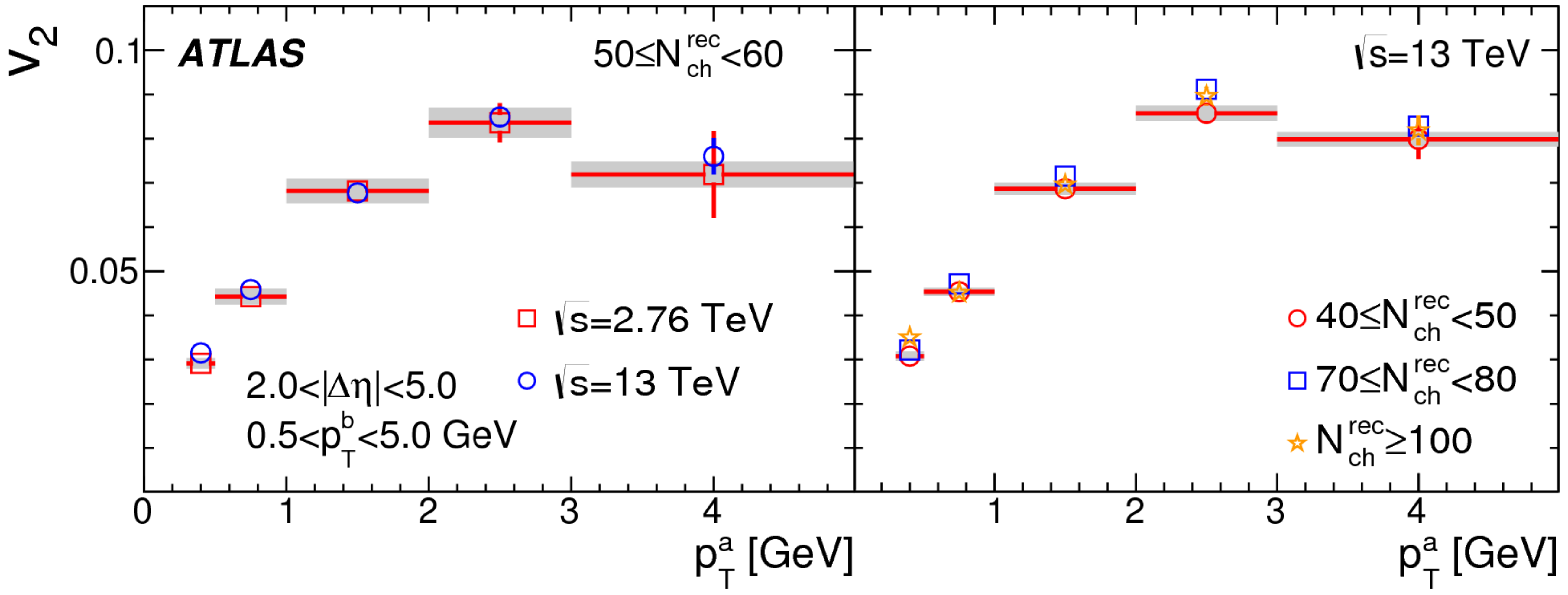


New method (template fit) reduces bias in ZYAM

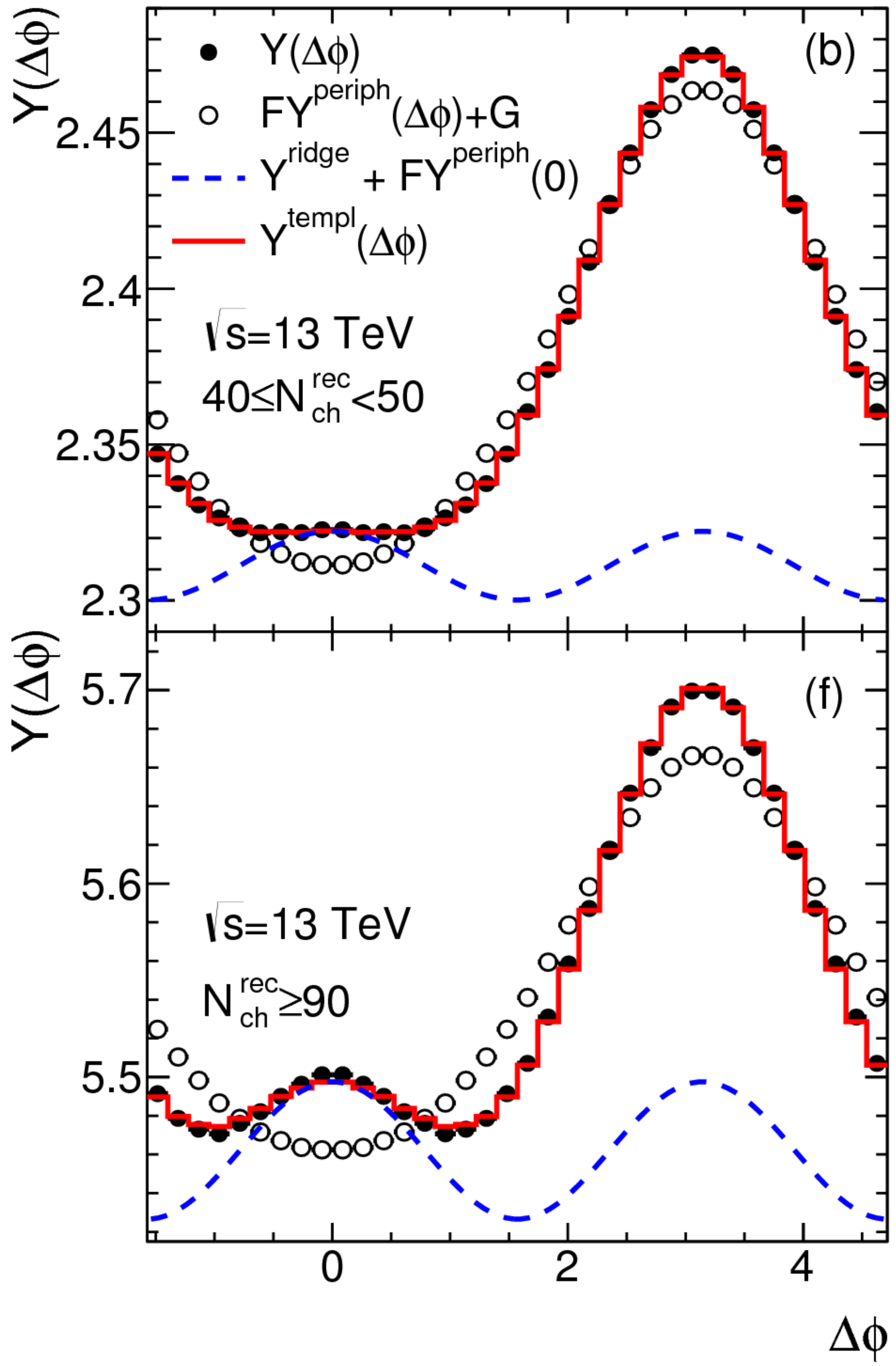
Collectivity in pp - template fit

Phys. Rev. Lett. 116 (2016) 172301





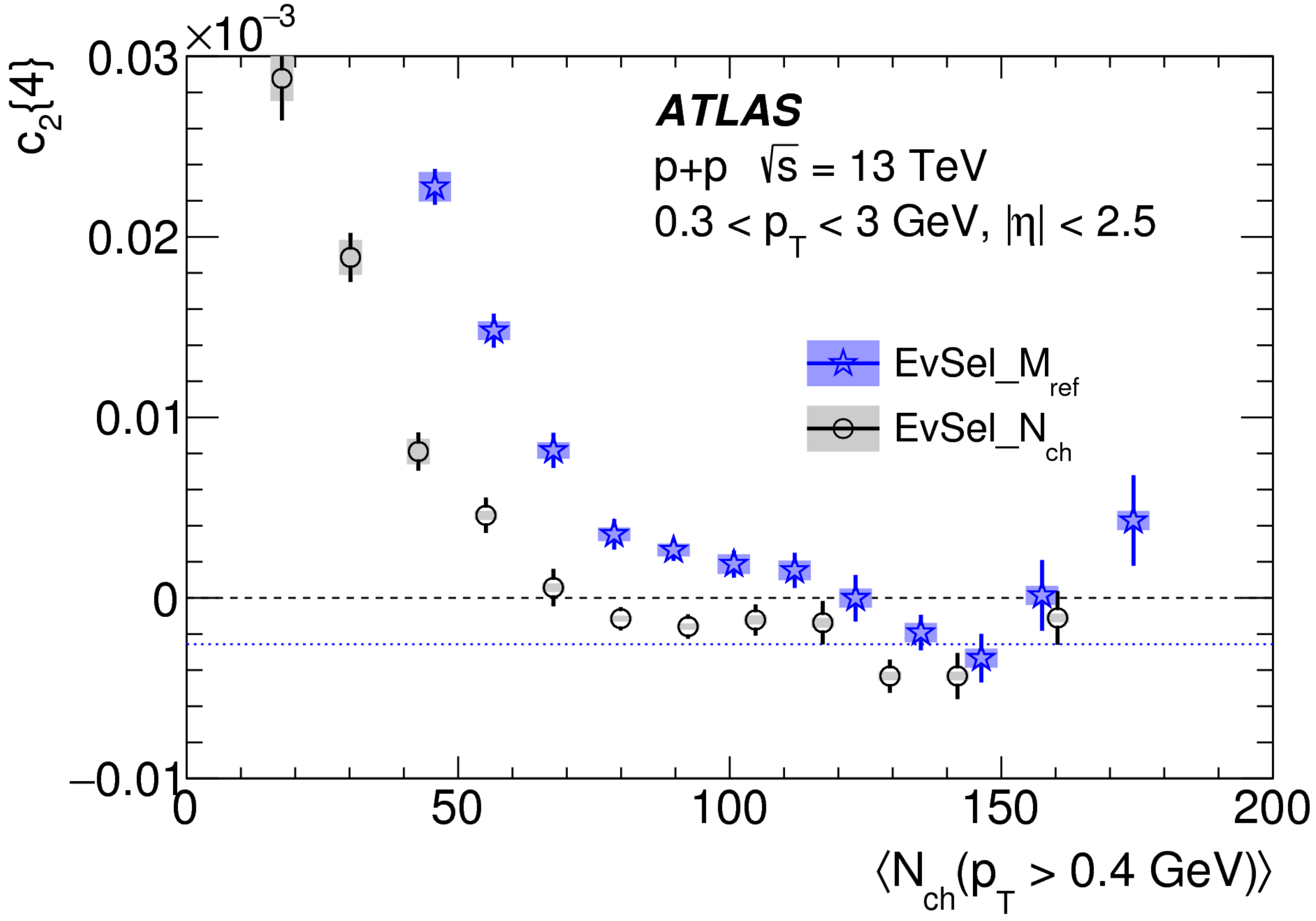
Characteristic hydro p_T dependence (independent of energy and N_{ch})



New method (template fit) reduces bias in ZYAM

Collectivity in pp - cumulants

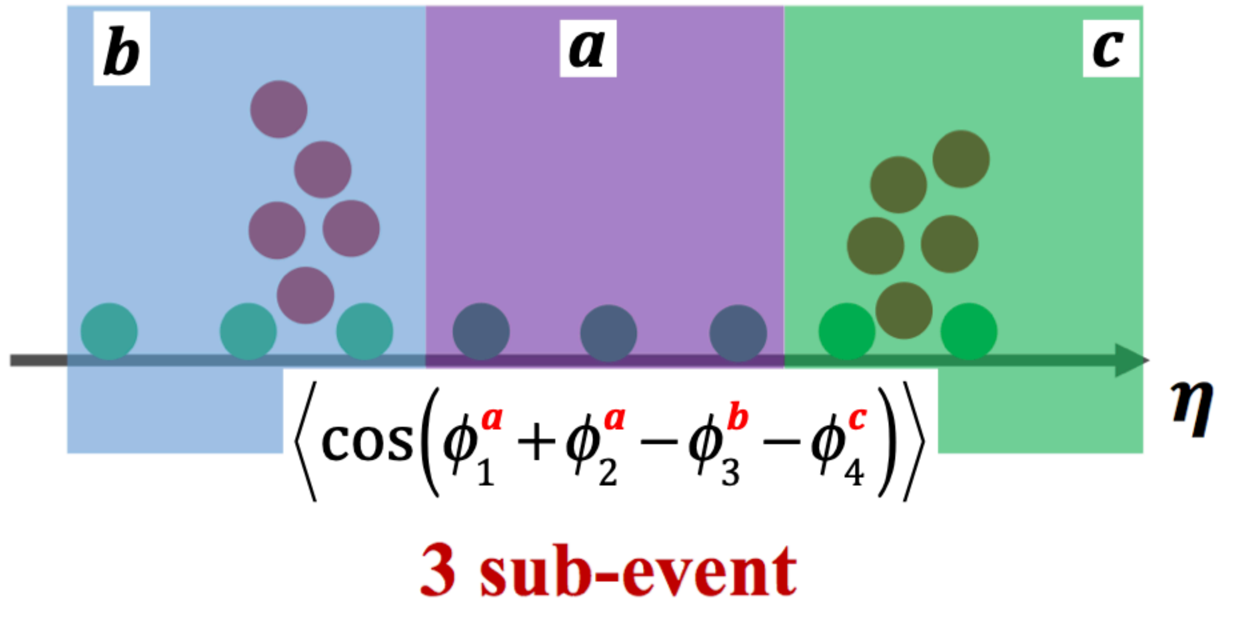
Eur. Phys. J. C 77 (2017) 428



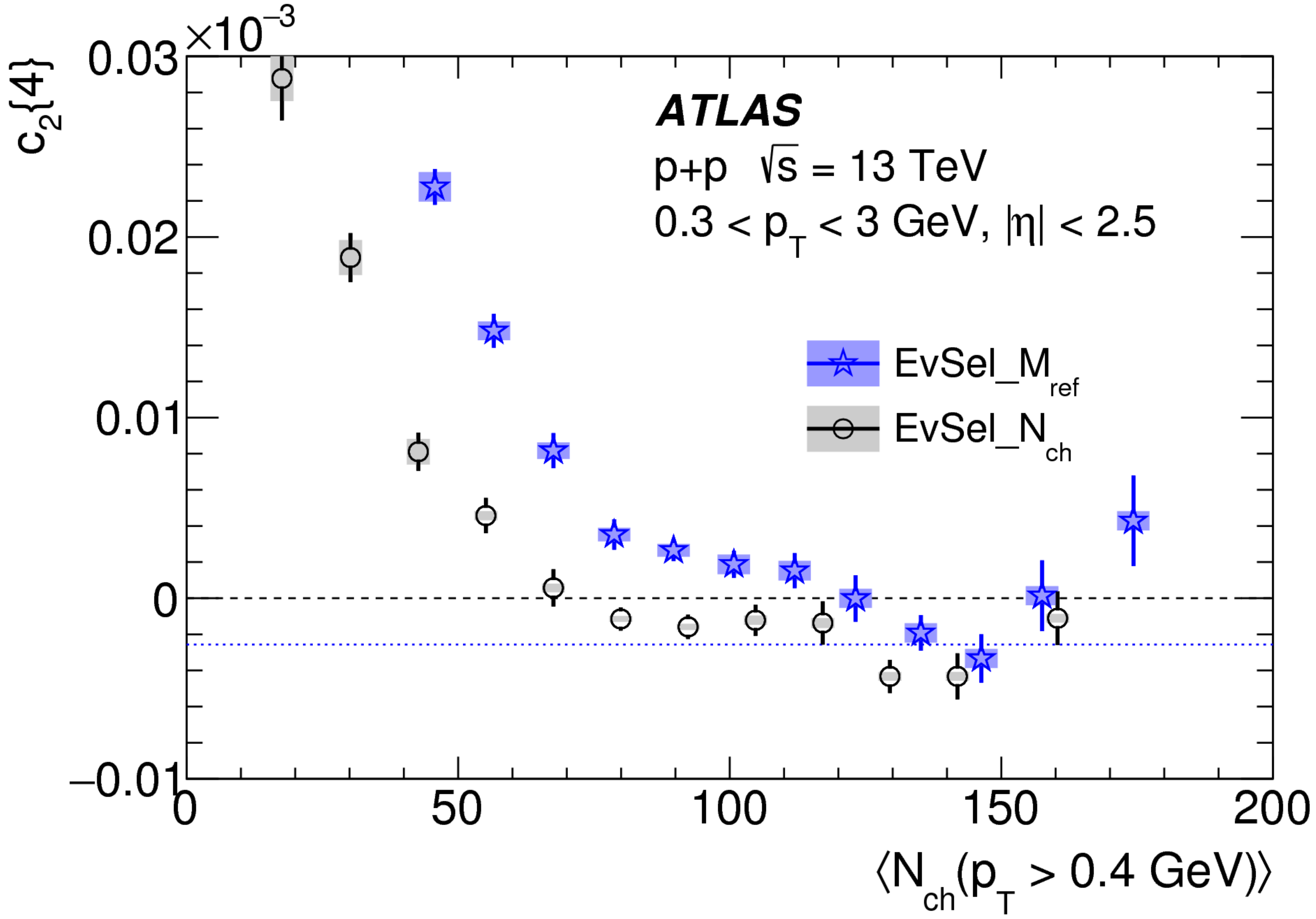
4 particle cumulants sensitive to reference event selection.

Collectivity in pp - cumulants

QM 2017 J. Jia

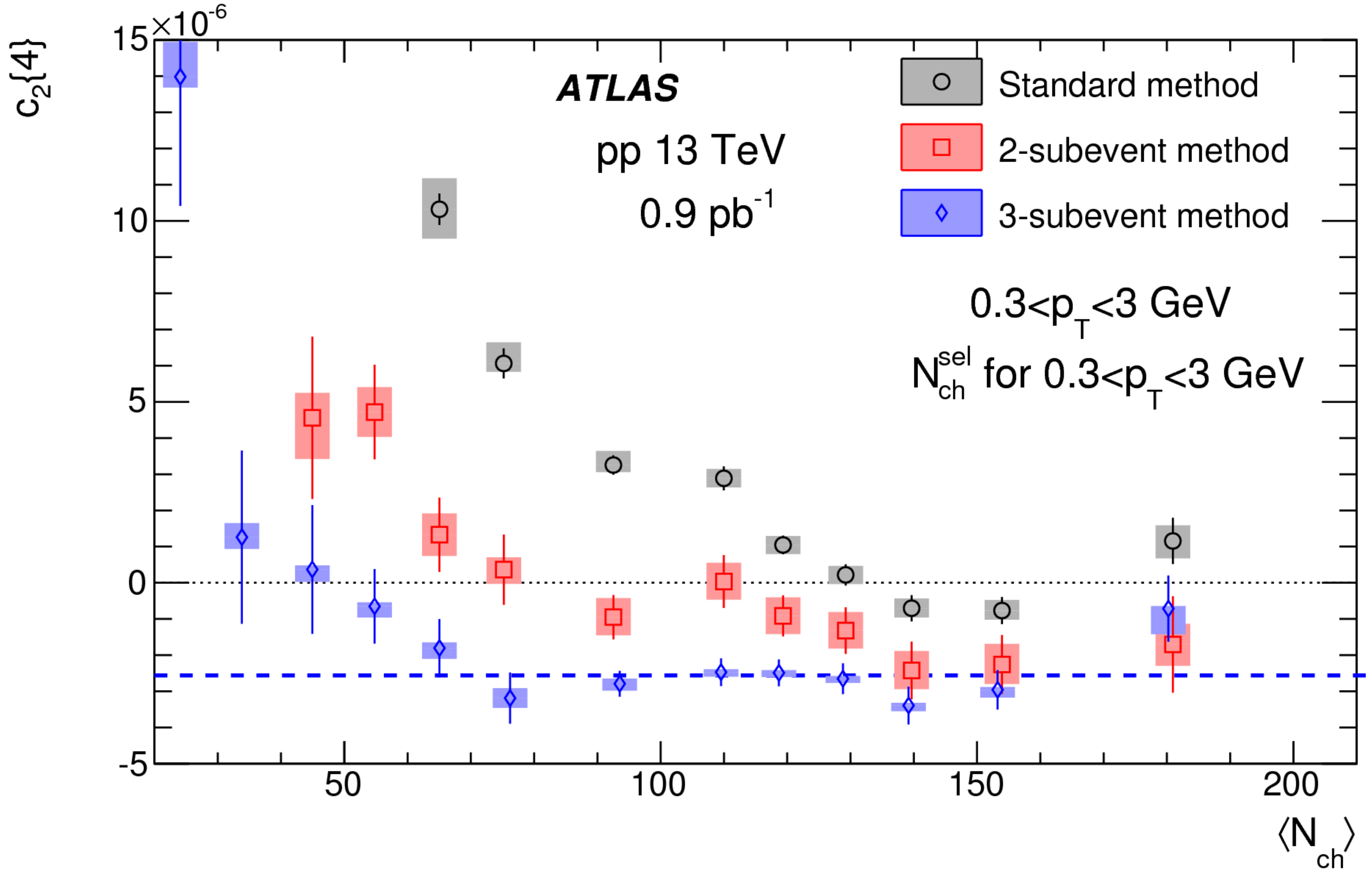


Eur. Phys. J. C 77 (2017) 428



4 particle cumulants sensitive to reference event selection.

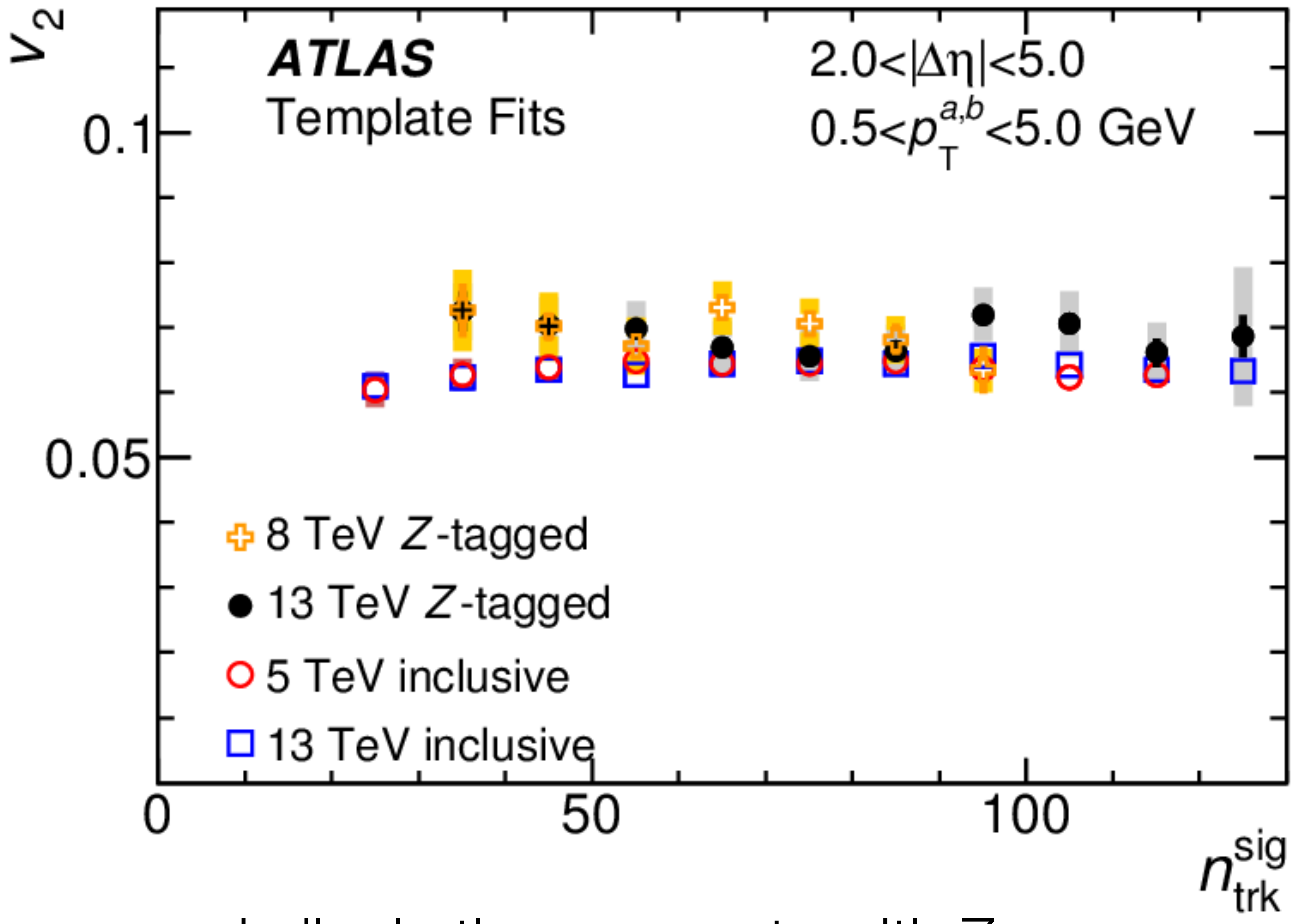
Phys. Rev. C 97 (2018) 024904



Sub-event cumulants gives a way to handle remaining non-flow correlation in pp.

Detailed collectivity studies with 2PC template fit method

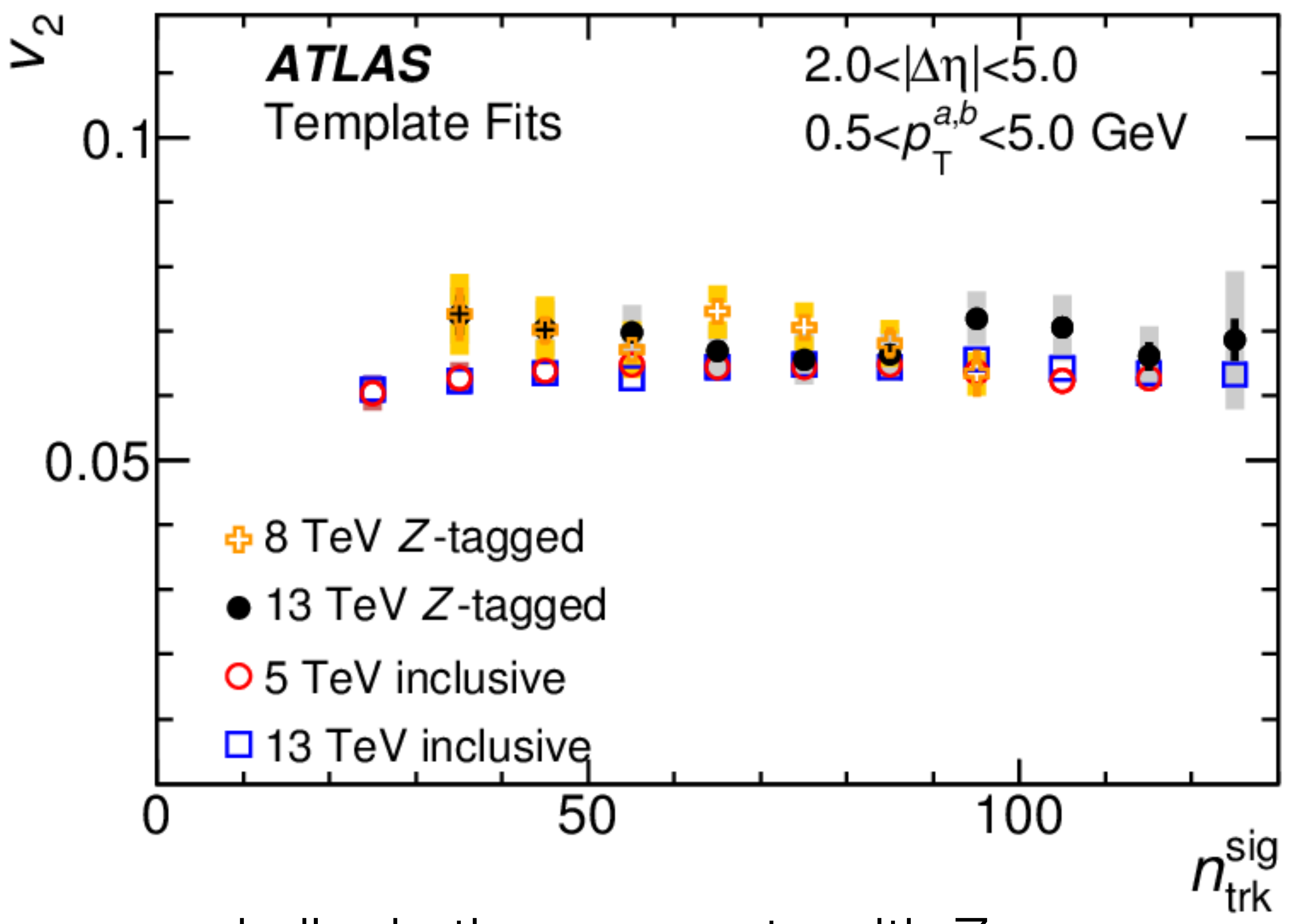
Eur. Phys. J. C 80 (2020) 64



v_2 similar in the pp events with Z boson and inclusive pp collisions.

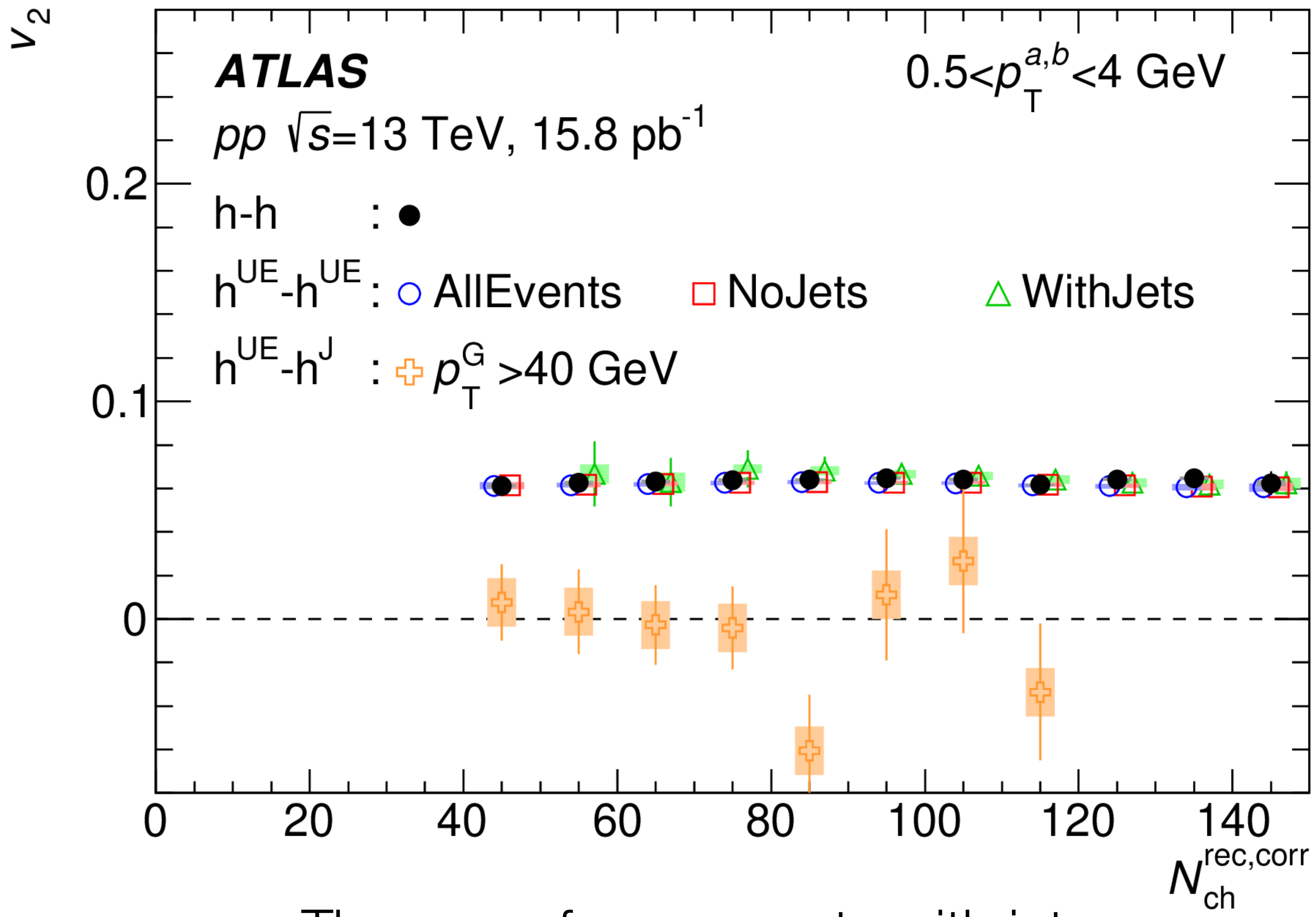
Detailed collectivity studies with 2PC template fit method

Eur. Phys. J. C 80 (2020) 64



v_2 similar in the pp events with Z boson and inclusive pp collisions.

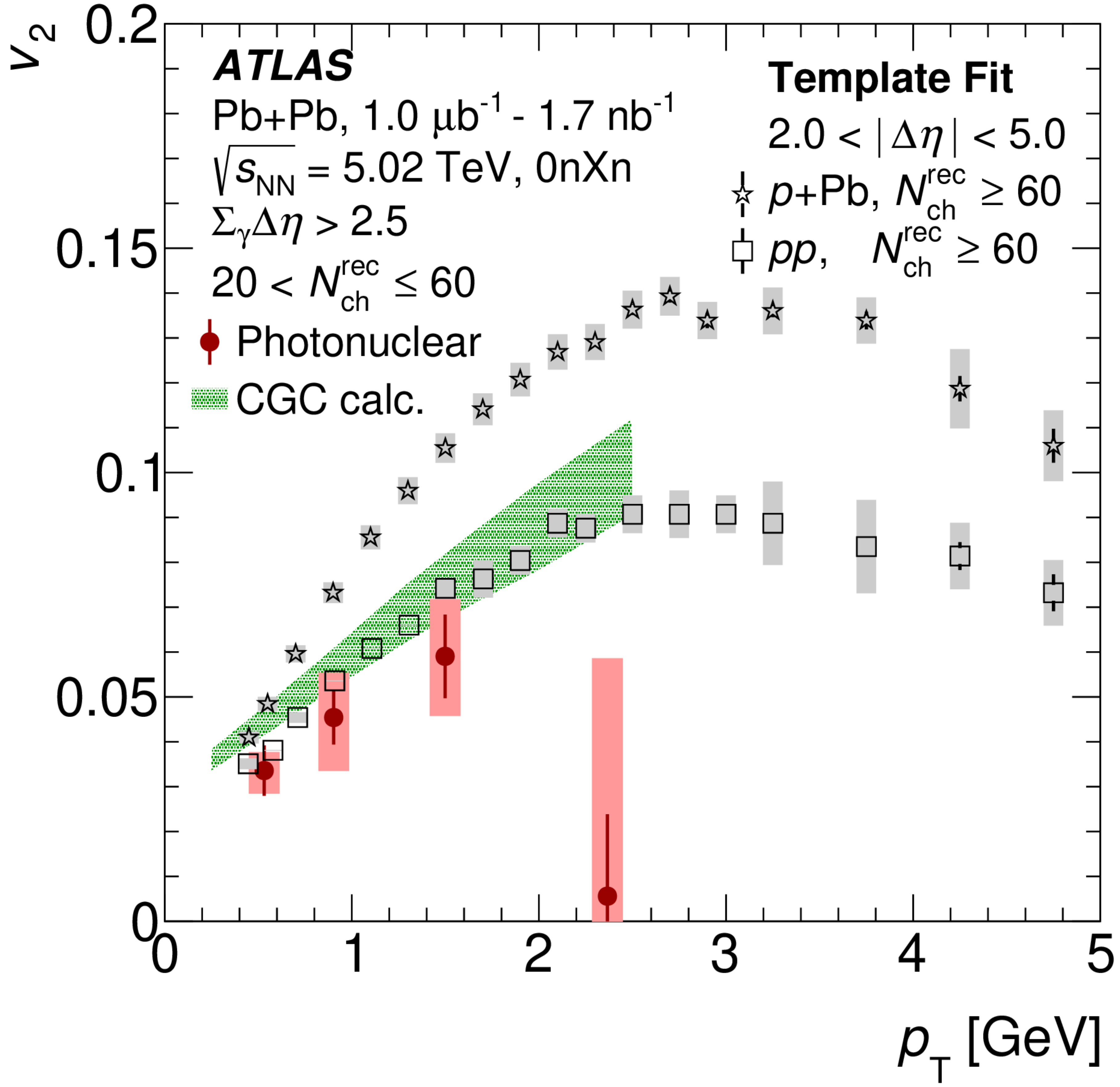
Phys. Rev. Lett. 131 (2023) 162301



The same for pp events with jets.
Also corrections between jet particles and UE is consistent with zero.

Detailed collectivity studies with 2PC template fit method

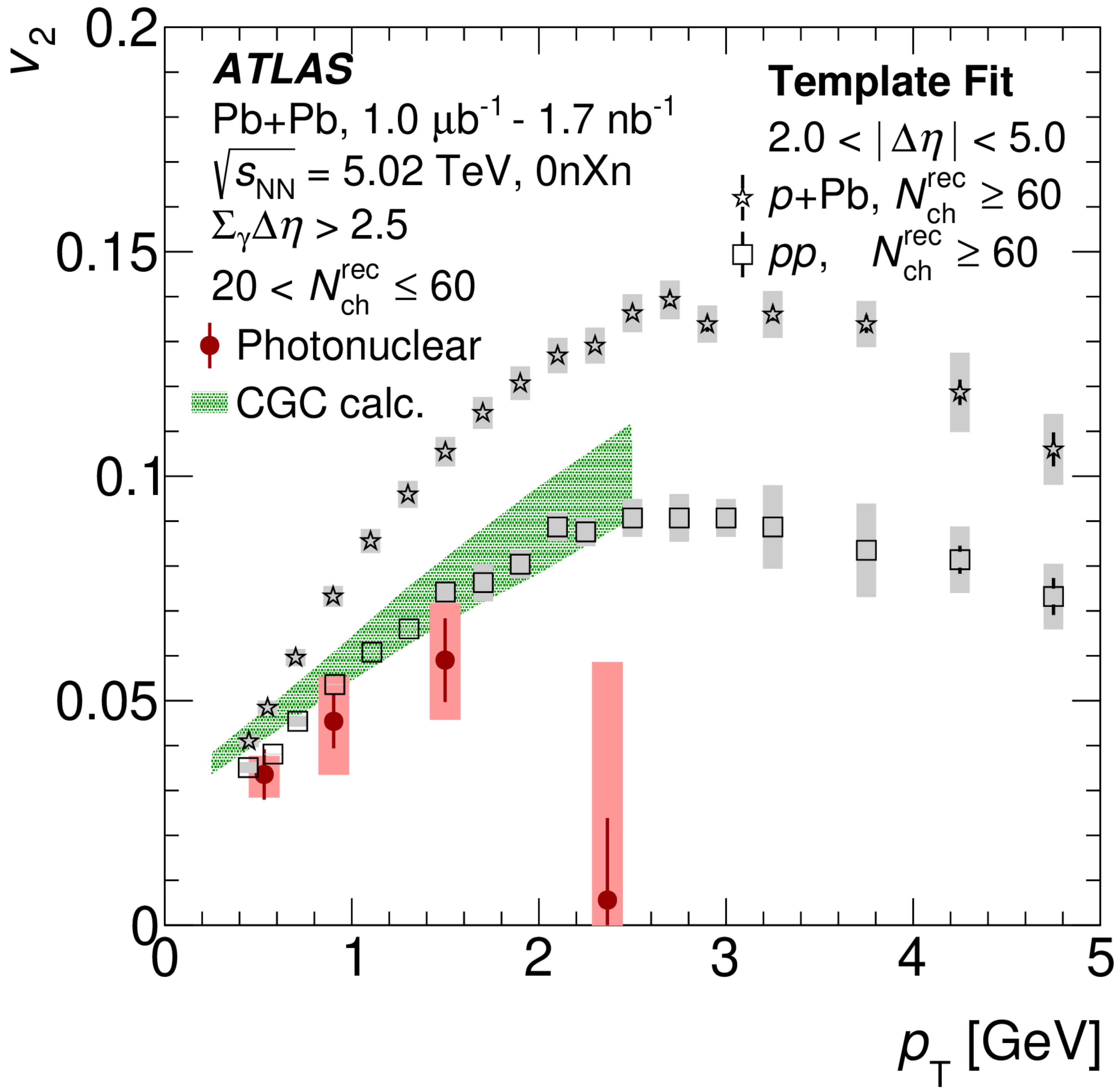
[Phys. Rev. C. 104 (2021) 014903]



Flow in photo-nuclear (**γ**+A) could be understood as a consequence of **ρ**+A collision (even smaller system)

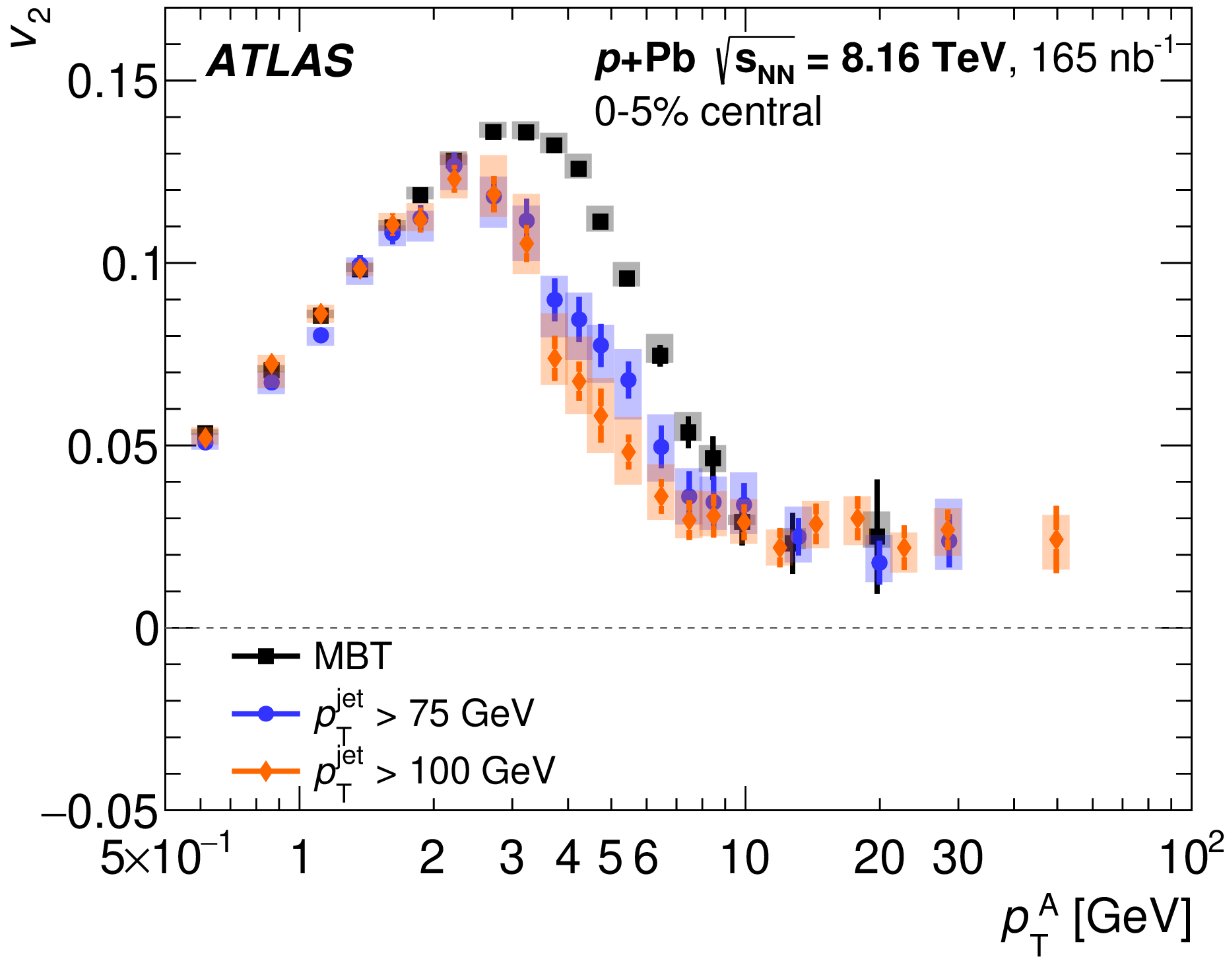
Detailed collectivity studies with 2PC template fit method

Phys. Rev. C. 104 (2021) 014903



Flow in photo-nuclear (γ+A) could be understood as a consequence of ρ+A collision (even smaller system)

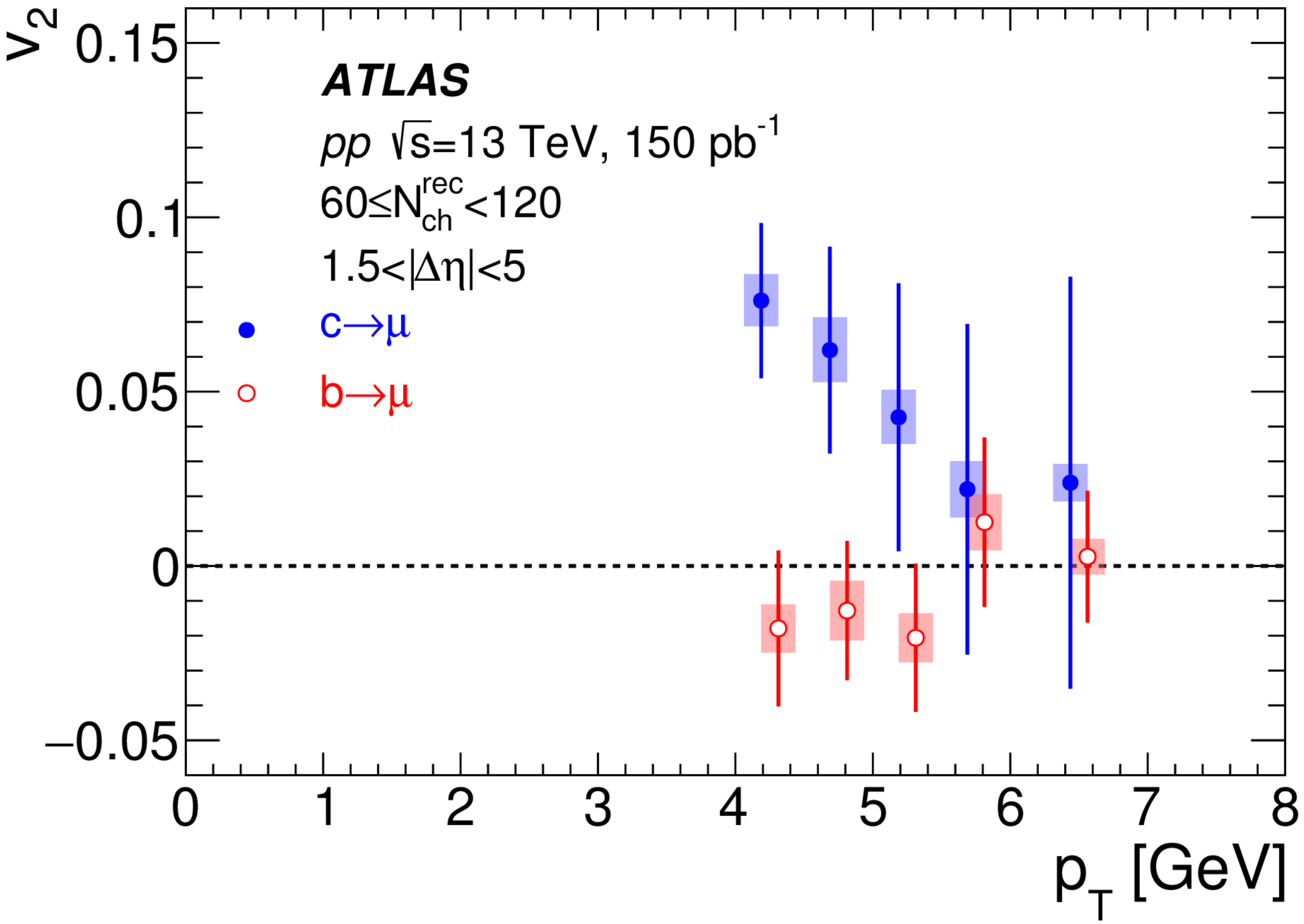
Eur. Phys. J. C 80 (2020) 73



Non zero v_2 at high p_T in p+Pb (will come back to this in chapter 2)

Detailed collectivity studies with 2PC template fit method

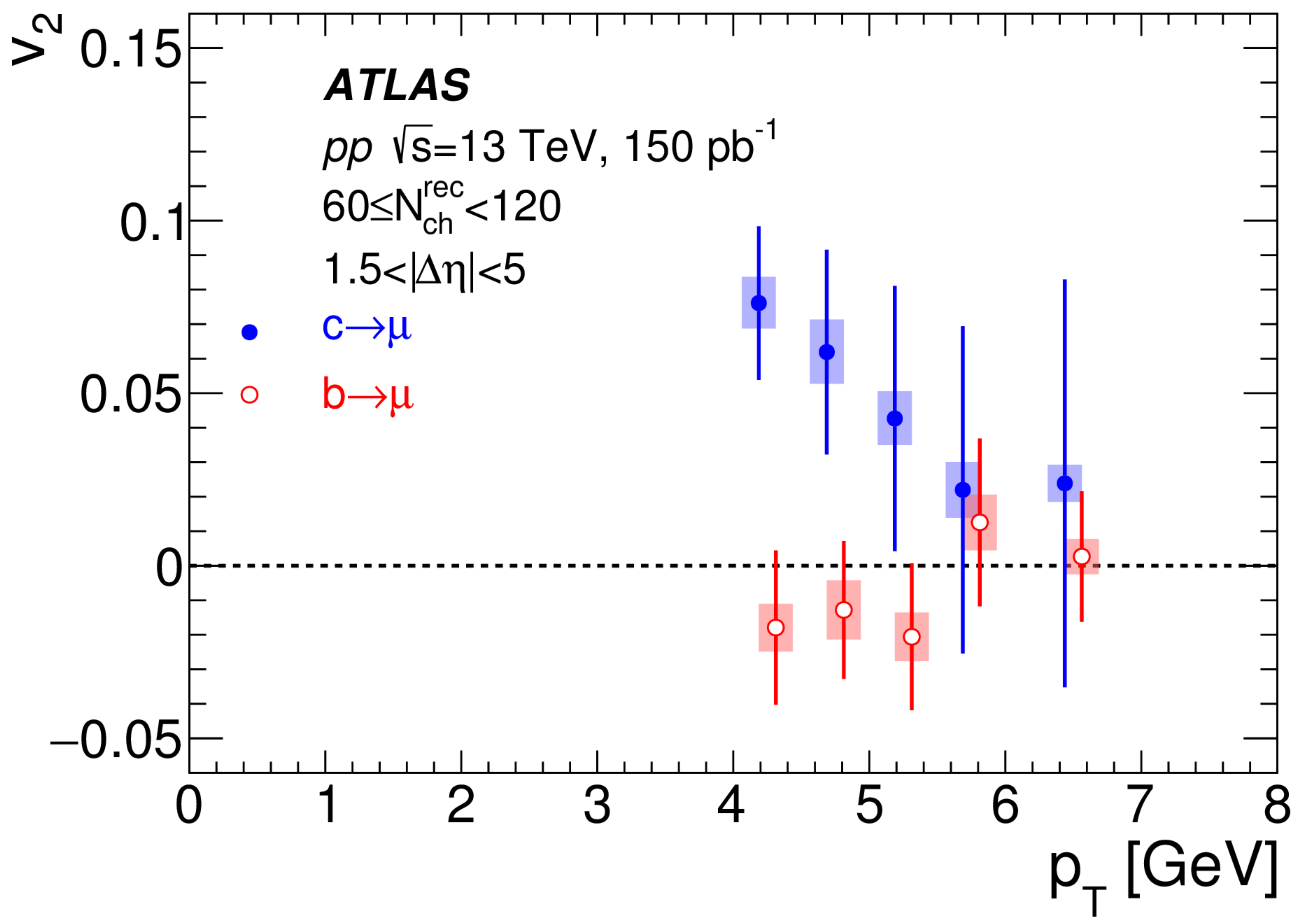
Phys. Rev. Lett. 124 (2020) 082301



Mass splitting of muons from ***charm*** and ***bottom*** decays at low p_T v_2, but converge at high p_T.

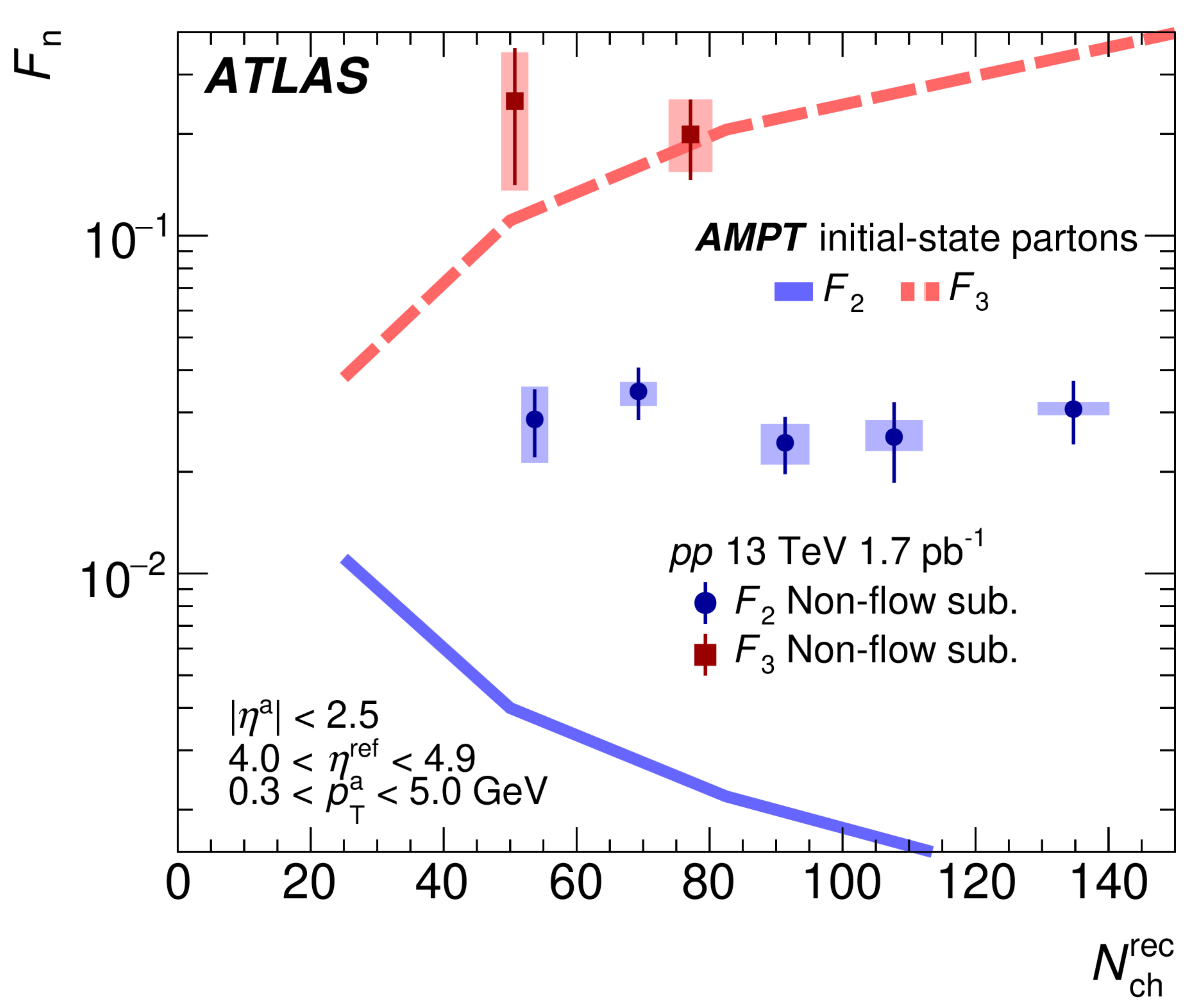
Detailed collectivity studies with 2PC template fit method

Phys. Rev. Lett. 124 (2020) 082301



Mass splitting of muons from ***charm*** and ***bottom*** decays at low p_T v_2, but converge at high p_T.

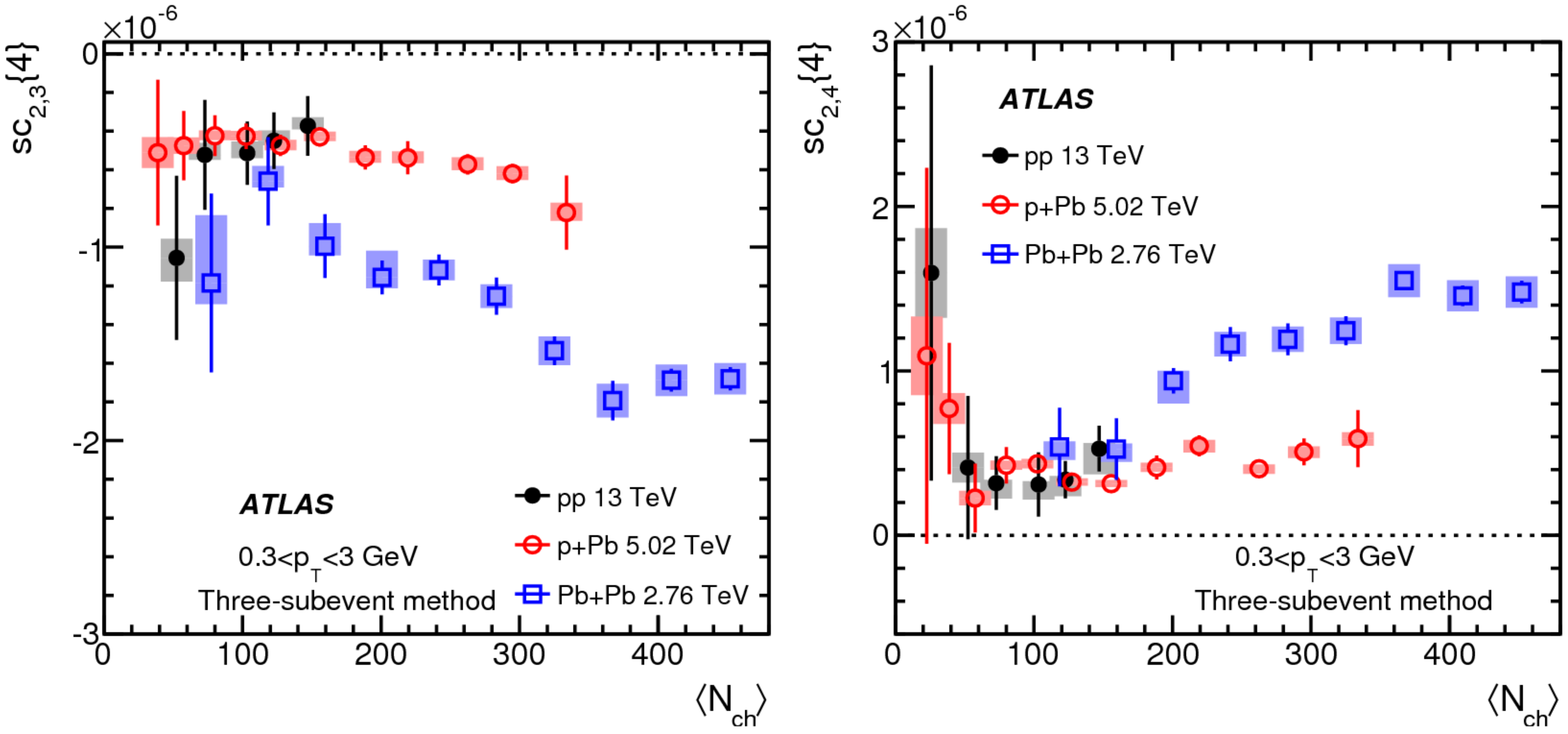
arXiv:2308.16745



Flow decorrelation in pp - constrain geometry in longitudinal direction (2PC in two regions of η).

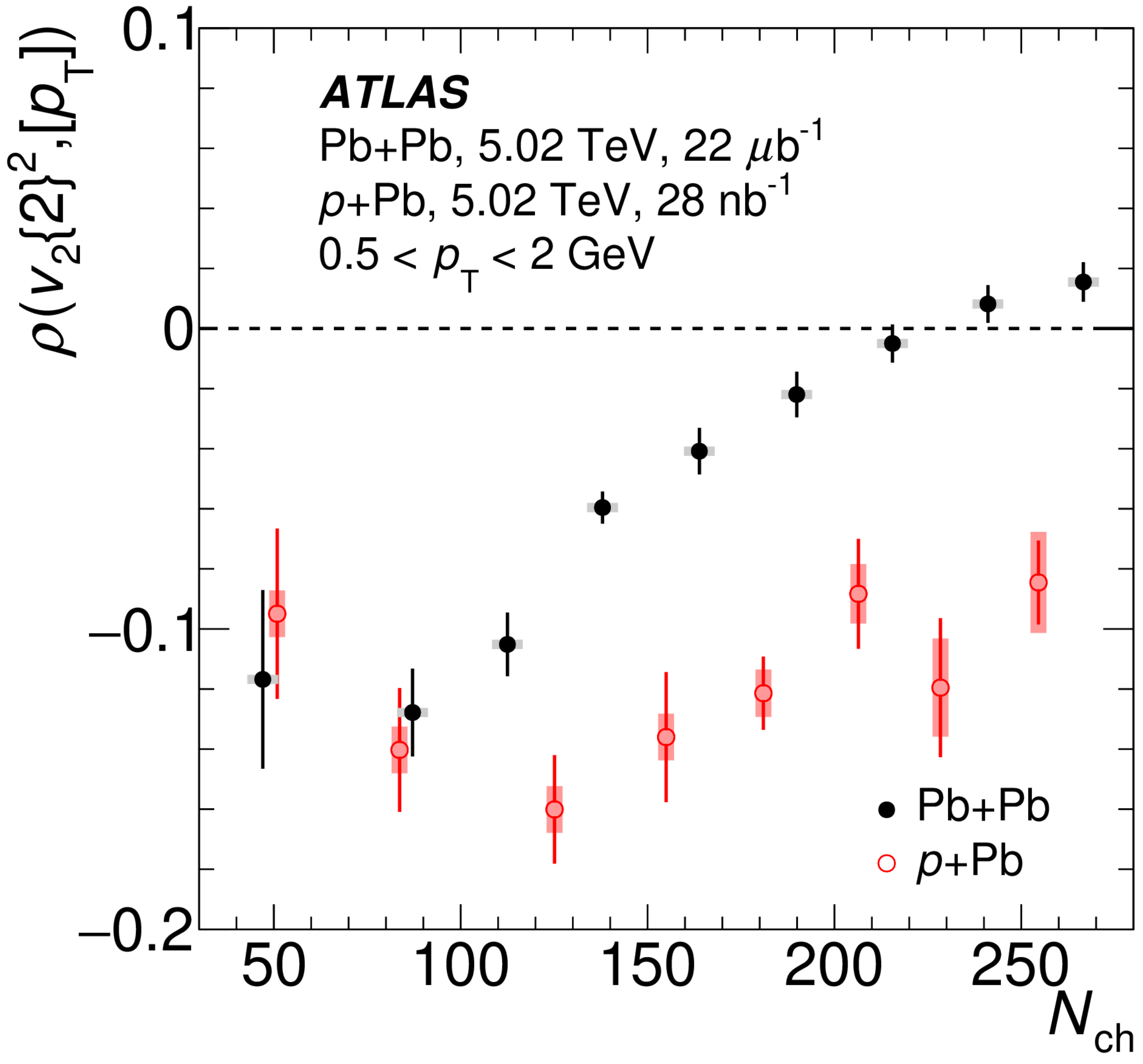
Collectivity across collision systems

Phys. Lett. B 789 (2019) 444



Symmetric cumulants measure ($sc_{2,3}\{4\}$ and $sc_{2,4}\{4\}$) correlations strength between harmonics of different orders.

Eur. Phys. J. C 79 (2019) 985

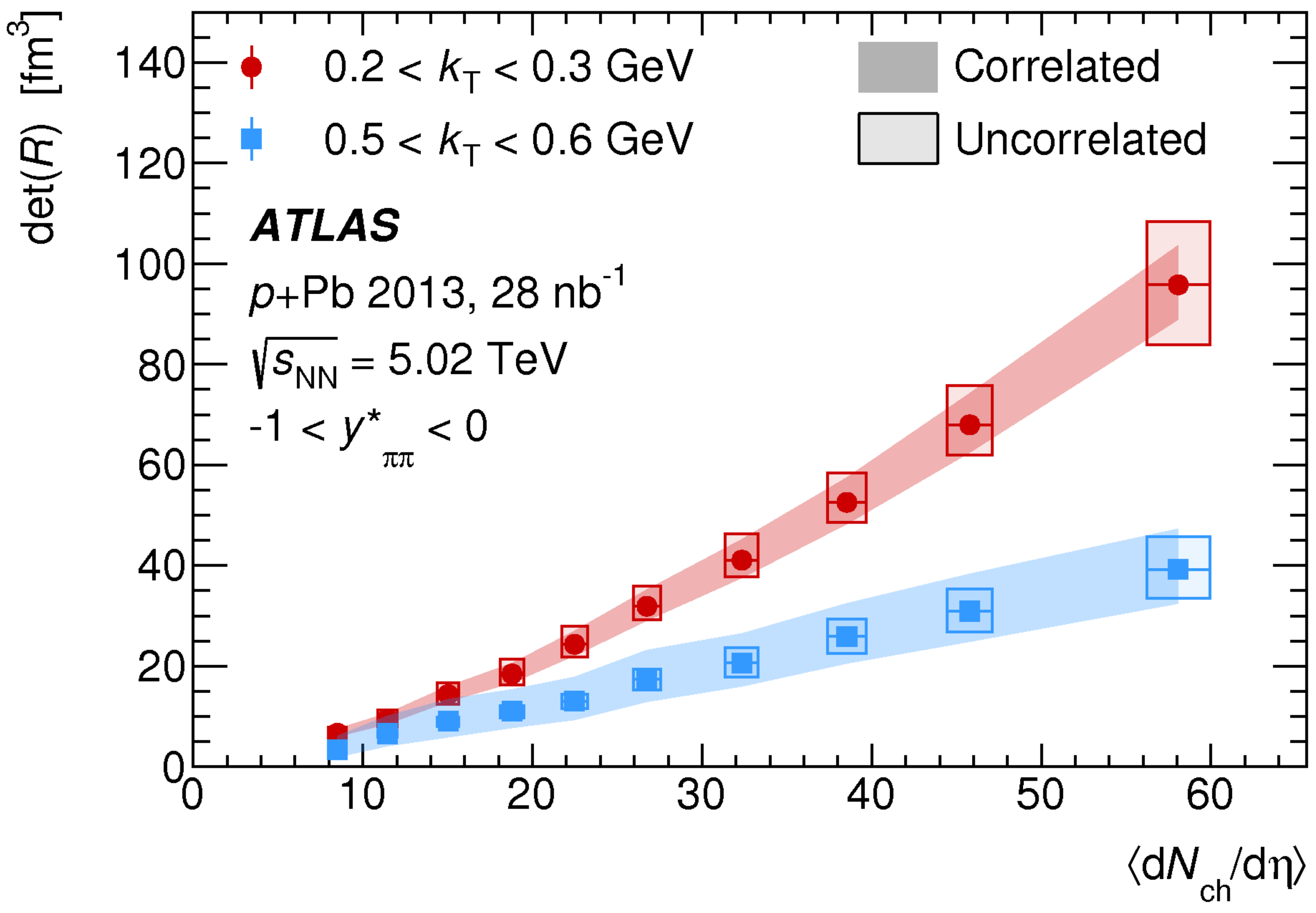


Correlation between v_n and mean p_T in the event.

Chapter 2
Search of the effect of energy loss in small systems

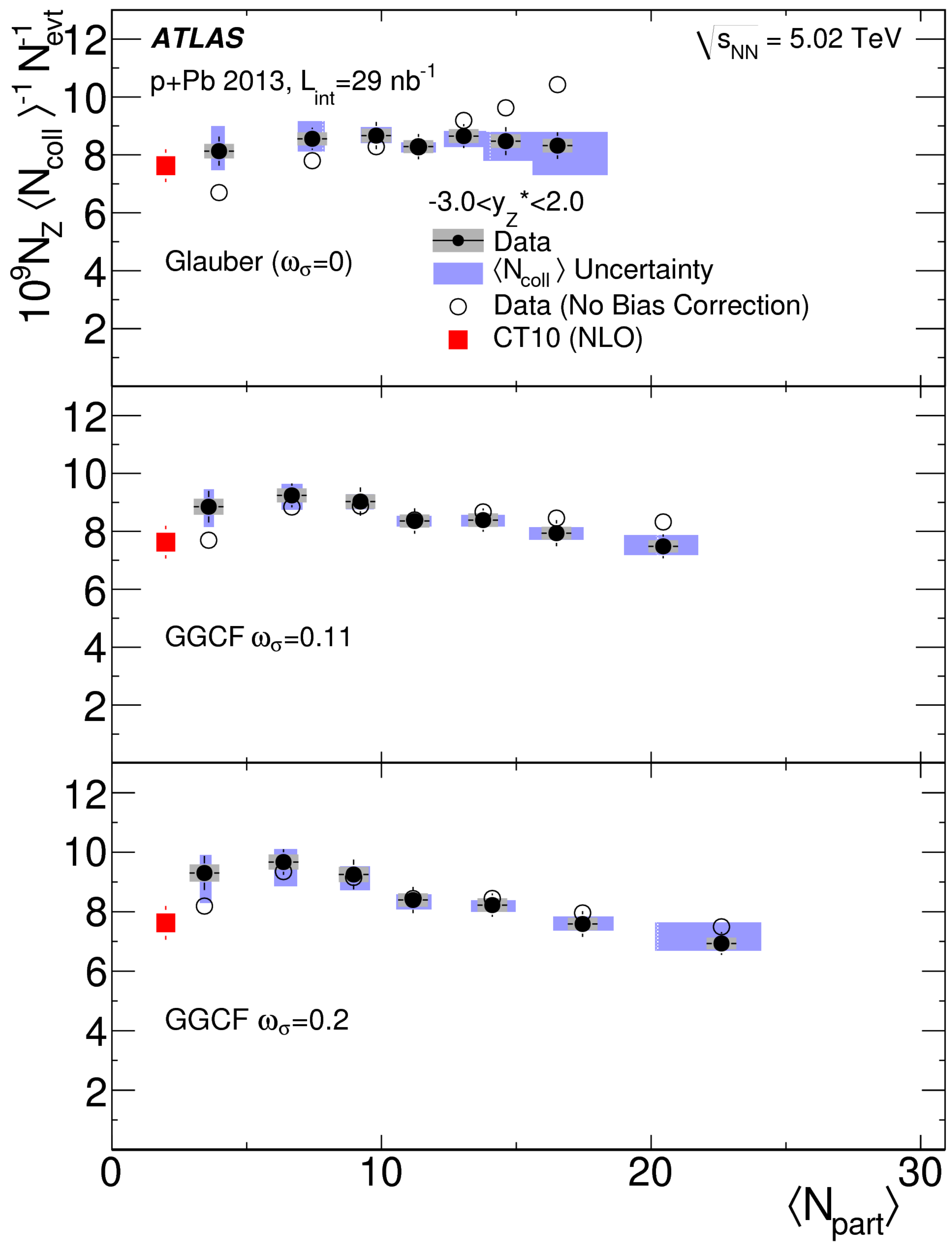
Setting the stage

Phys. Rev. C 96 (2017) 064908



Measurements of HBT correlations in p+Pb.
All there radii (as well as source volume) show linear scaling with Nch.

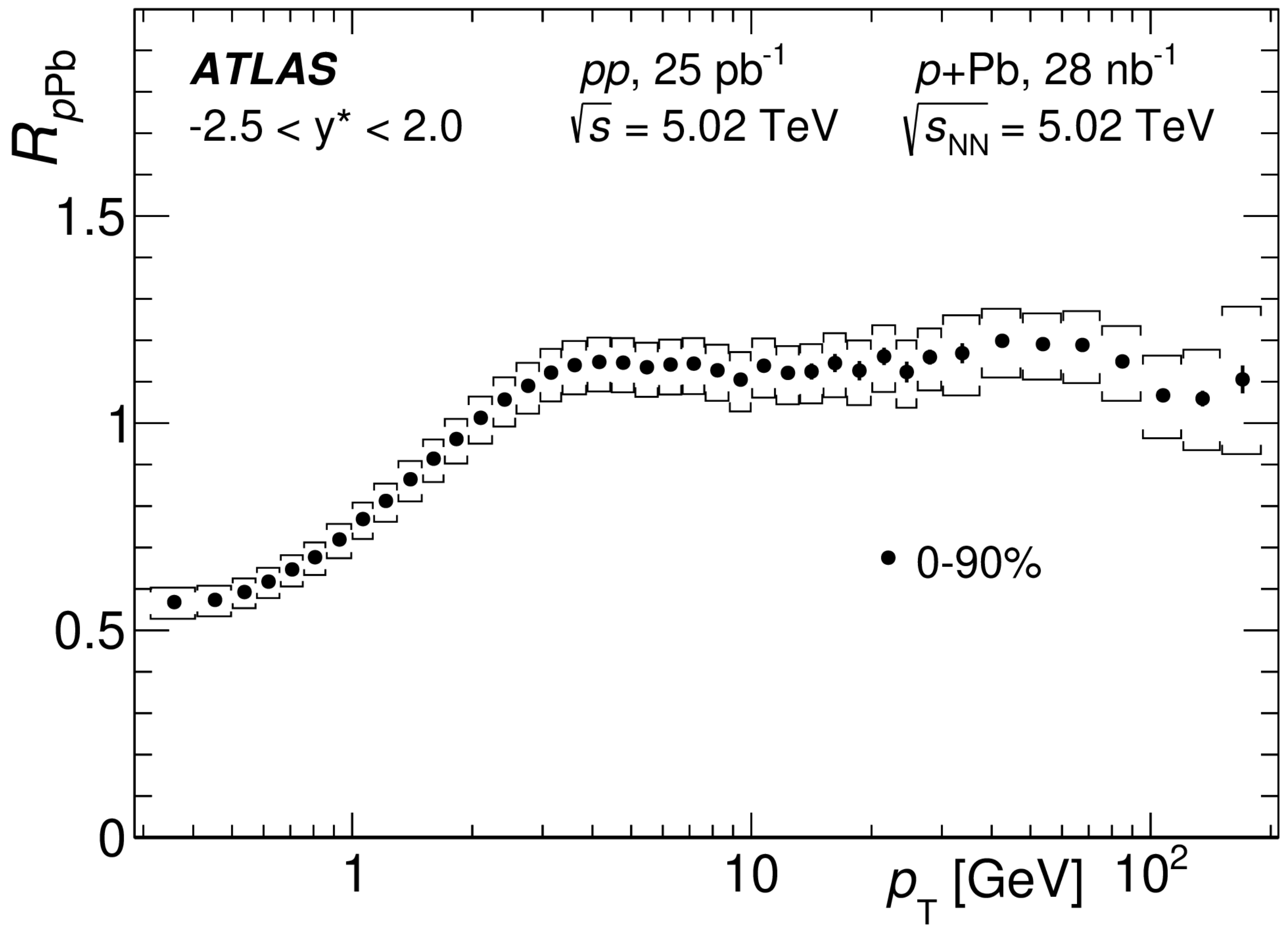
Phys. Rev. C 92 (2015) 044915



Centrality-dependent Z boson yield is found to scale with $\langle N_{coll} \rangle$.

Nuclear modification factors in p+Pb

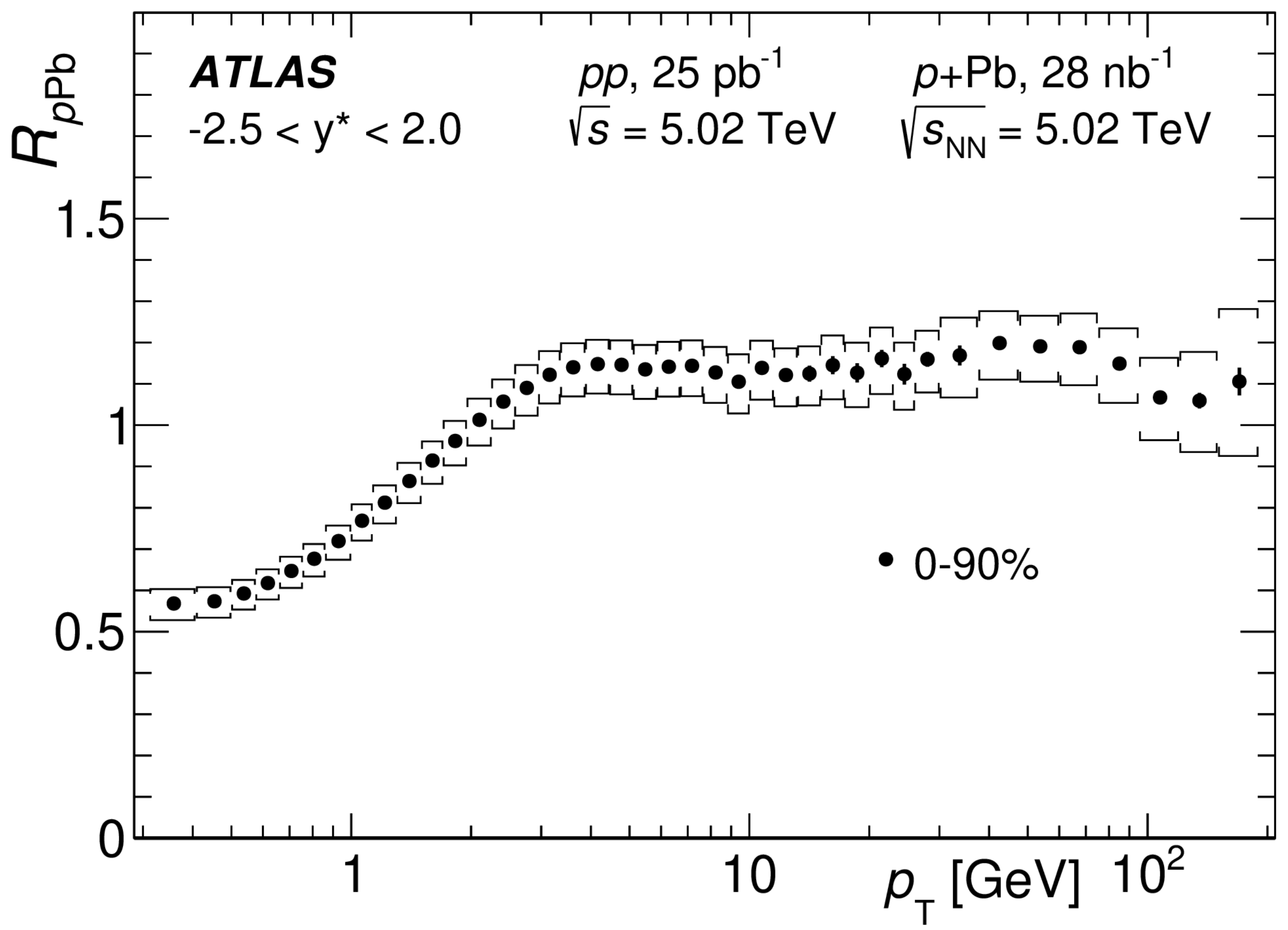
JHEP 07 (2023) 074



Charged hadrons consistent with no modification.

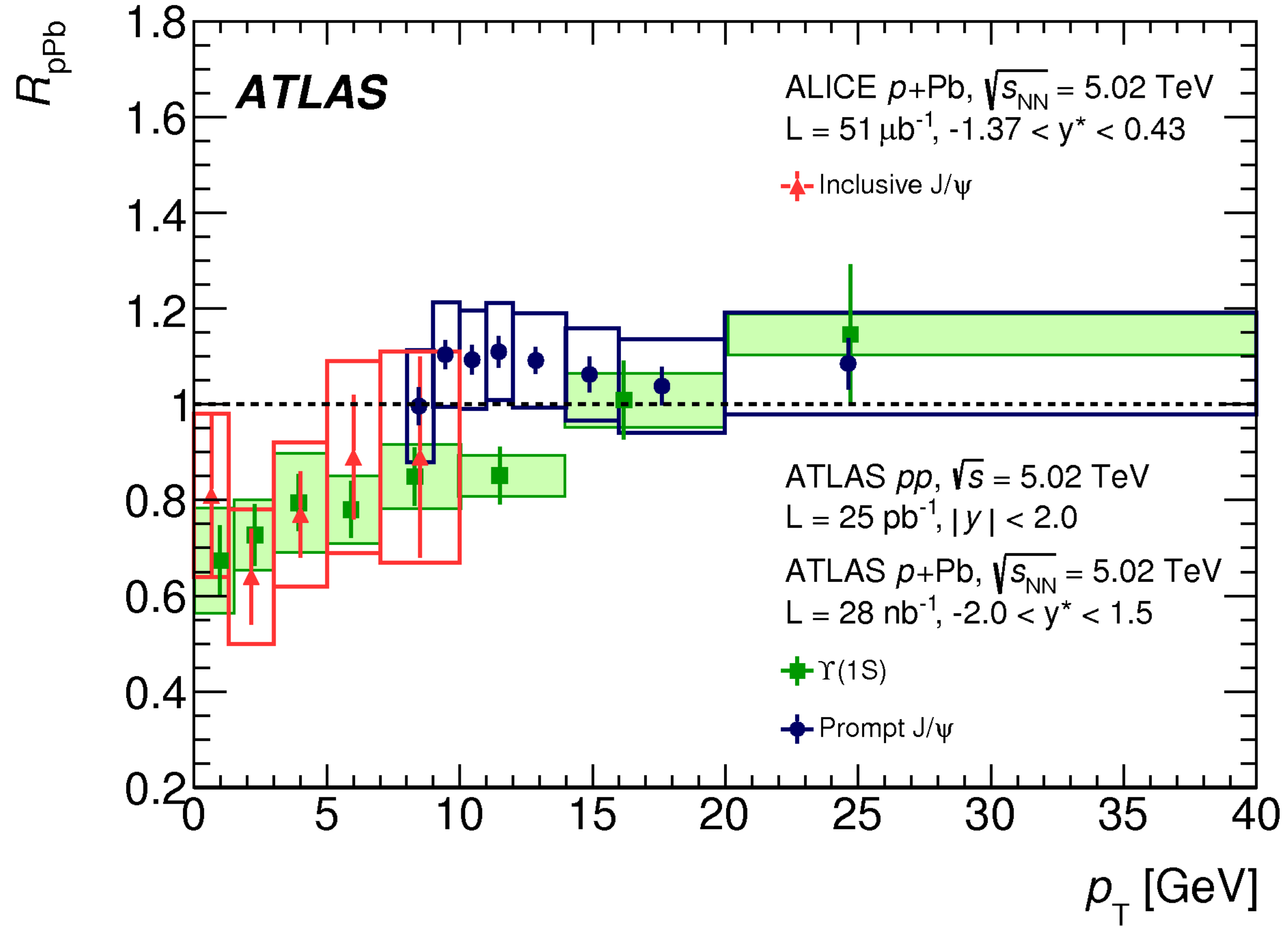
Nuclear modification factors in p+Pb

JHEP 07 (2023) 074



Charged hadrons consistent with no modification.

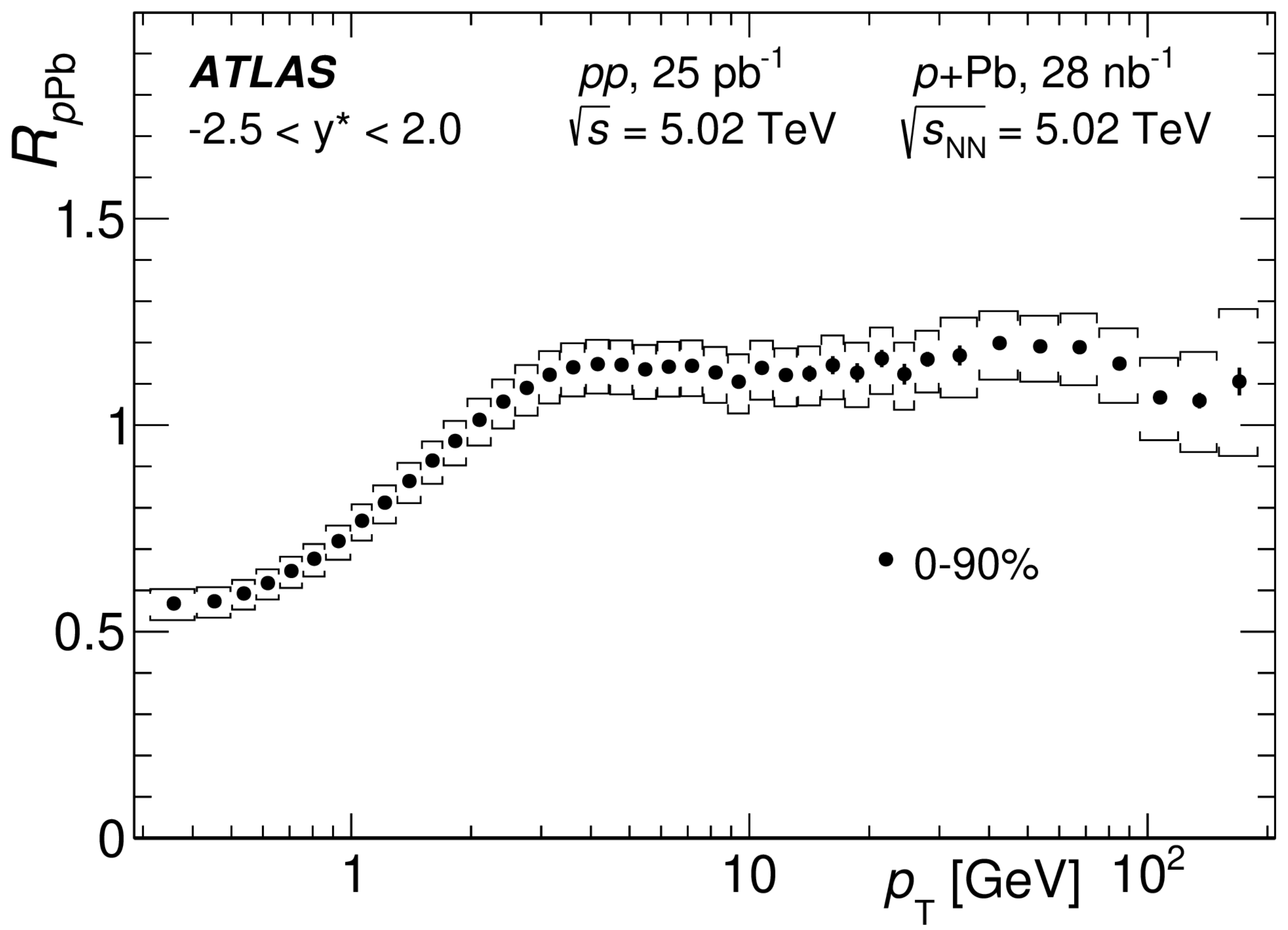
Eur. Phys. J. C 78 (2018) 171



Similar trend with quarkonia.

Nuclear modification factors in p+Pb

JHEP 07 (2023) 074



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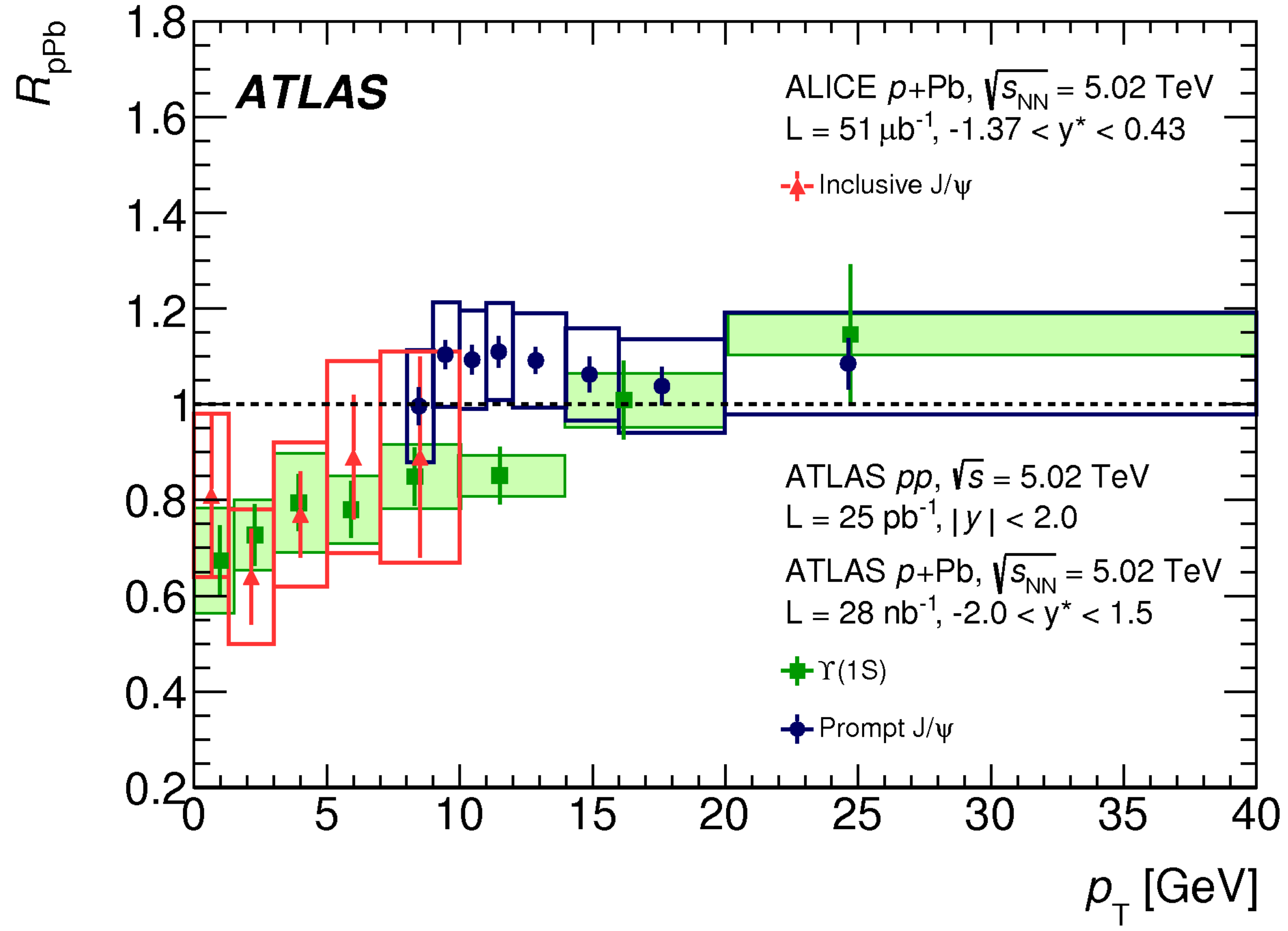
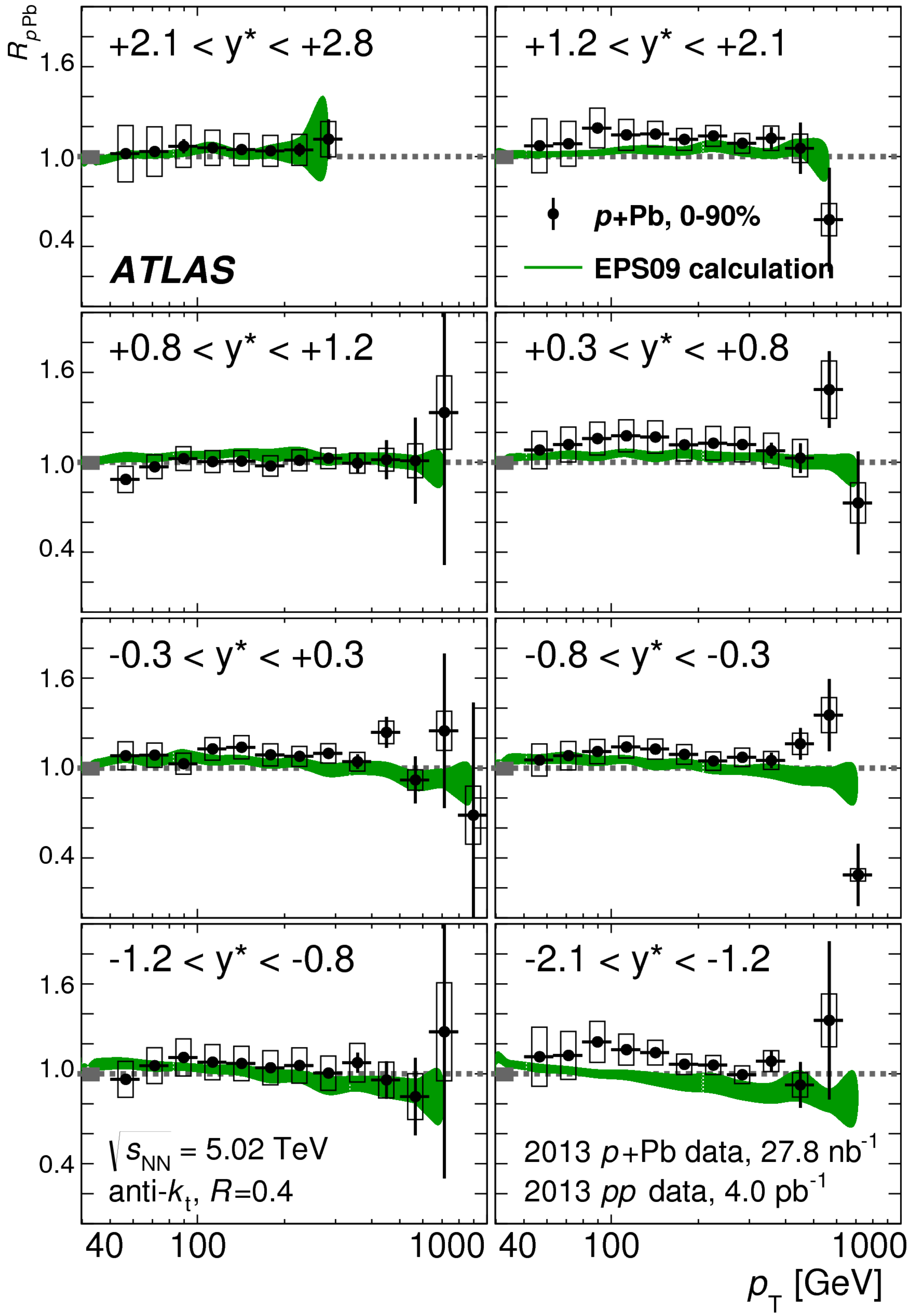
Eur. Phys. J. C 78 (2018) 171



Similar trend with quarkonia.

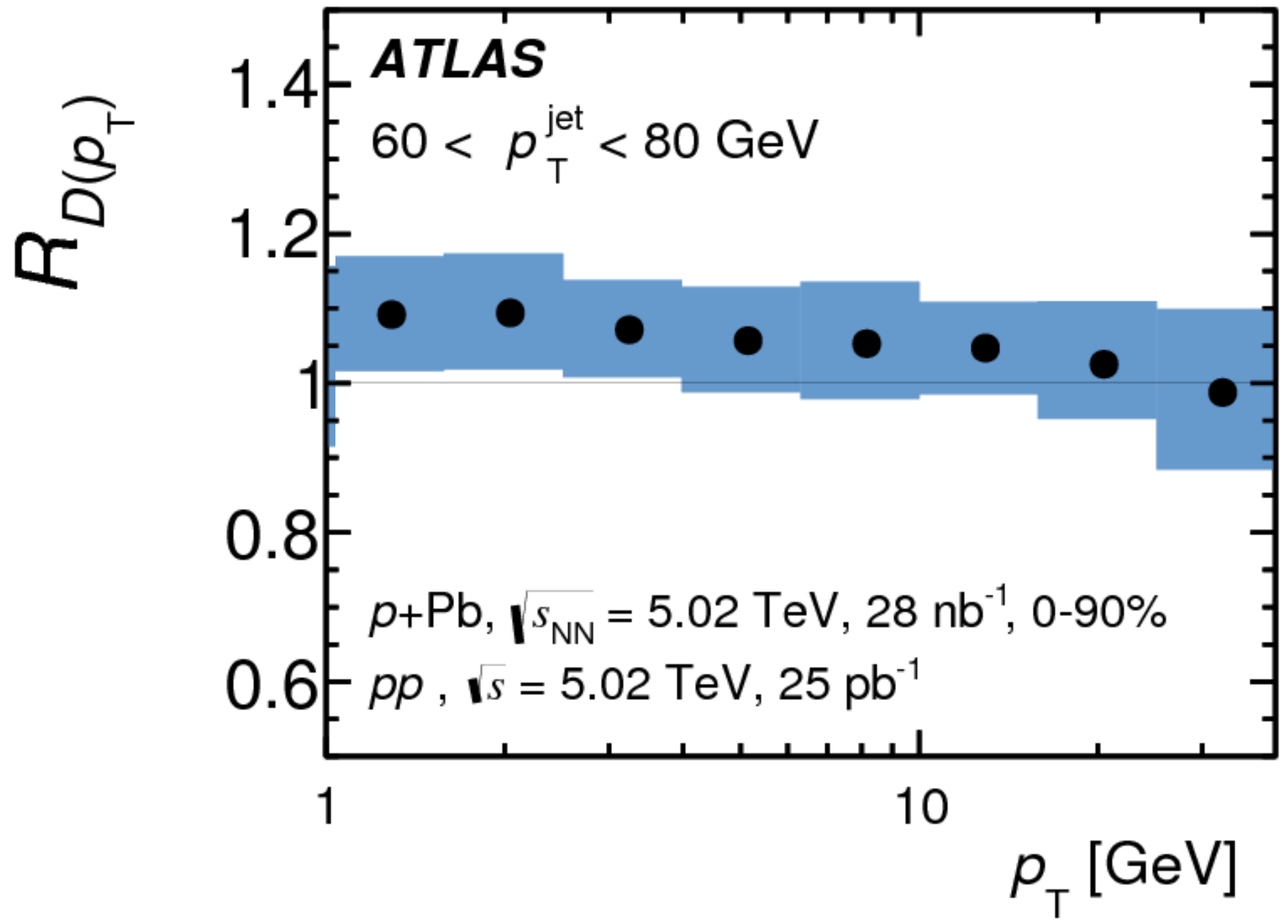
Phys. Lett. B 748 (2015) 392-413



The same with inclusive jets.

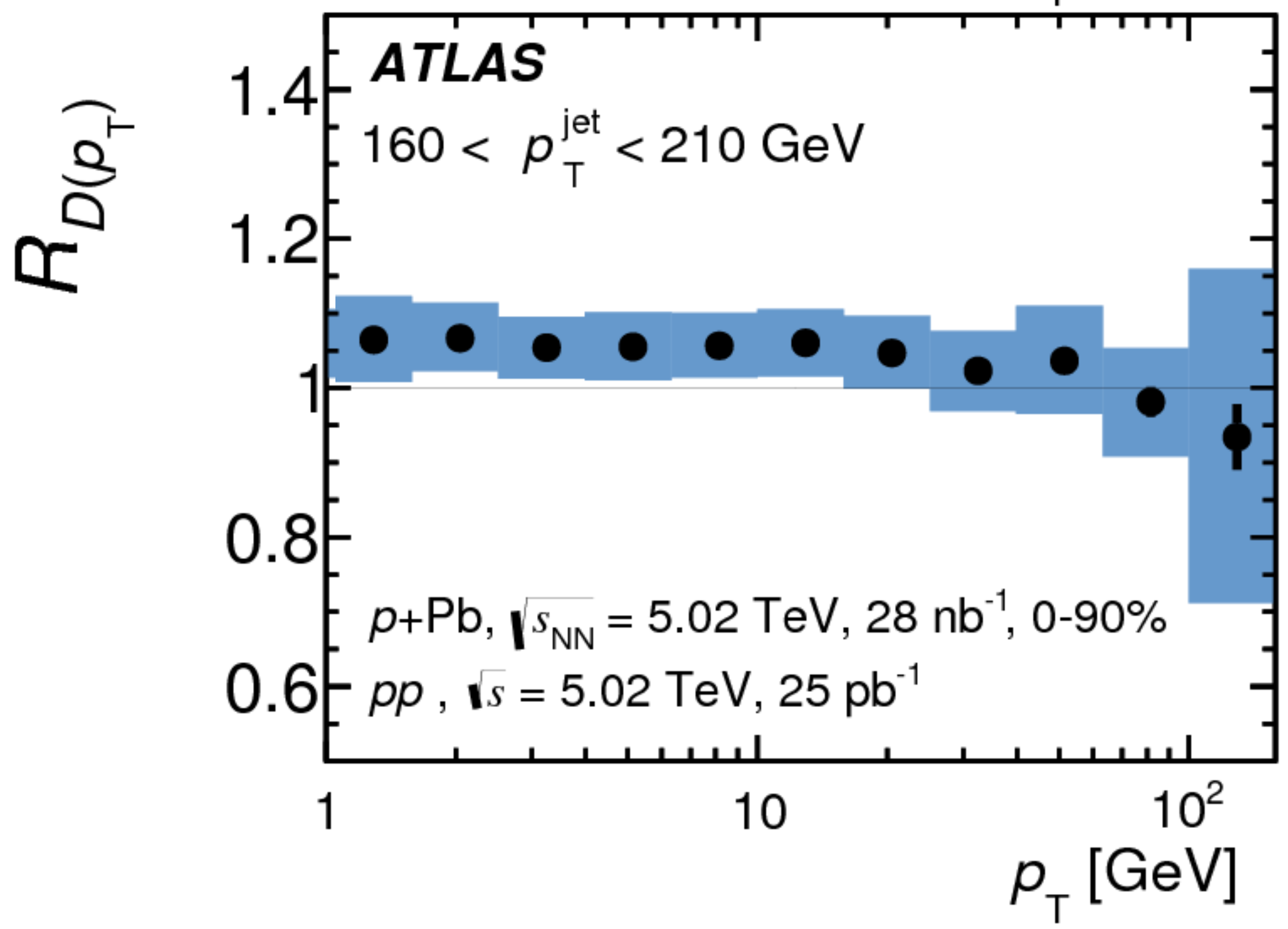
Closer look at the jet fragmentation

Nucl. Phys. A 978 (2018) 65



$$D(z) \equiv \frac{1}{N_{\rm jet}} \frac{dN_{\rm ch}}{dz}$$

$$R_{D(z)} \equiv \frac{D(z)_{p\rm Pb}}{D(z)_{pp}}$$

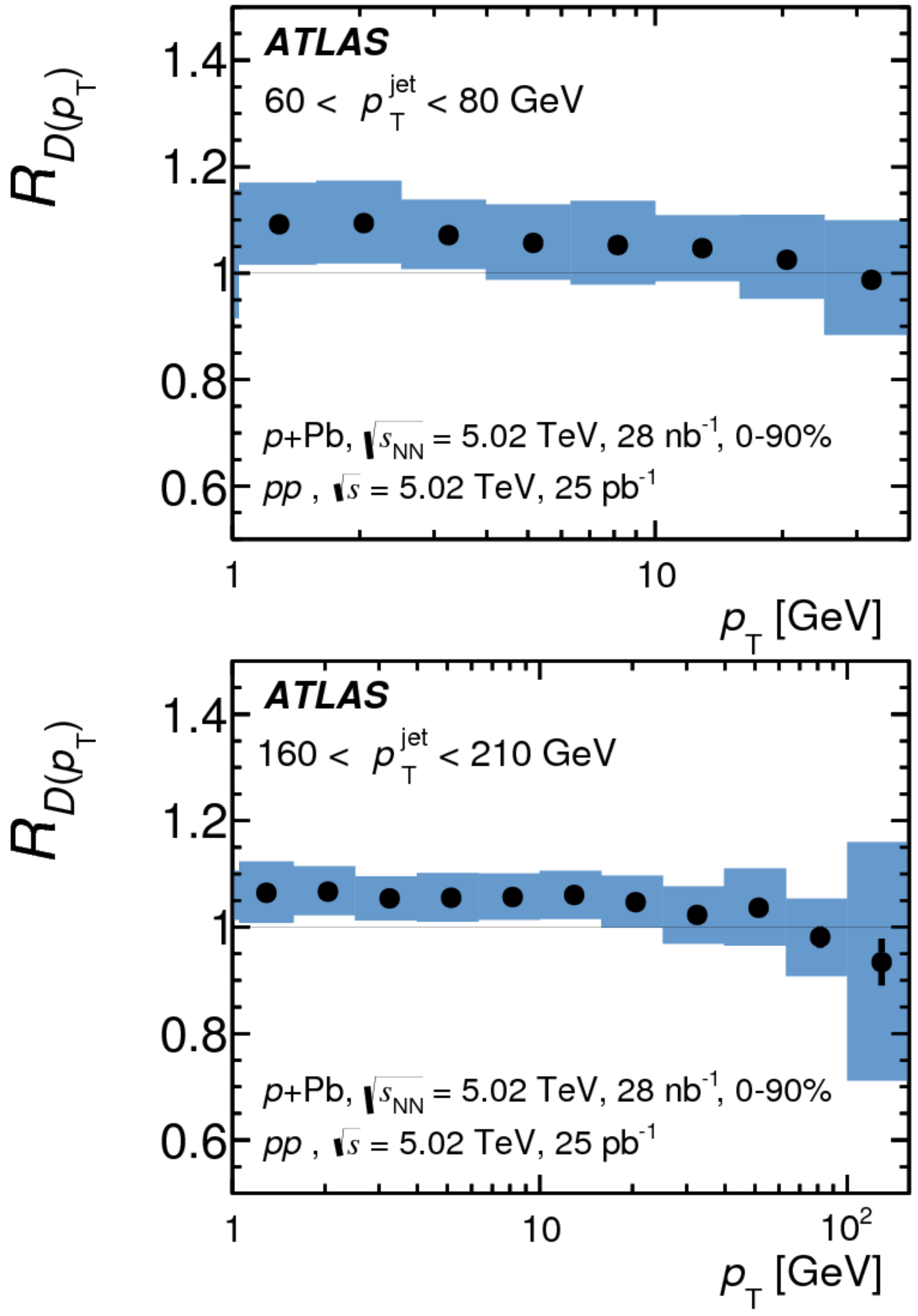


Jet fragmentation not modified in p+Pb.

Closer look at the jet fragmentation

$\Delta\phi_{ch,jet} > 7\pi/8$

Nucl. Phys. A 978 (2018) 65

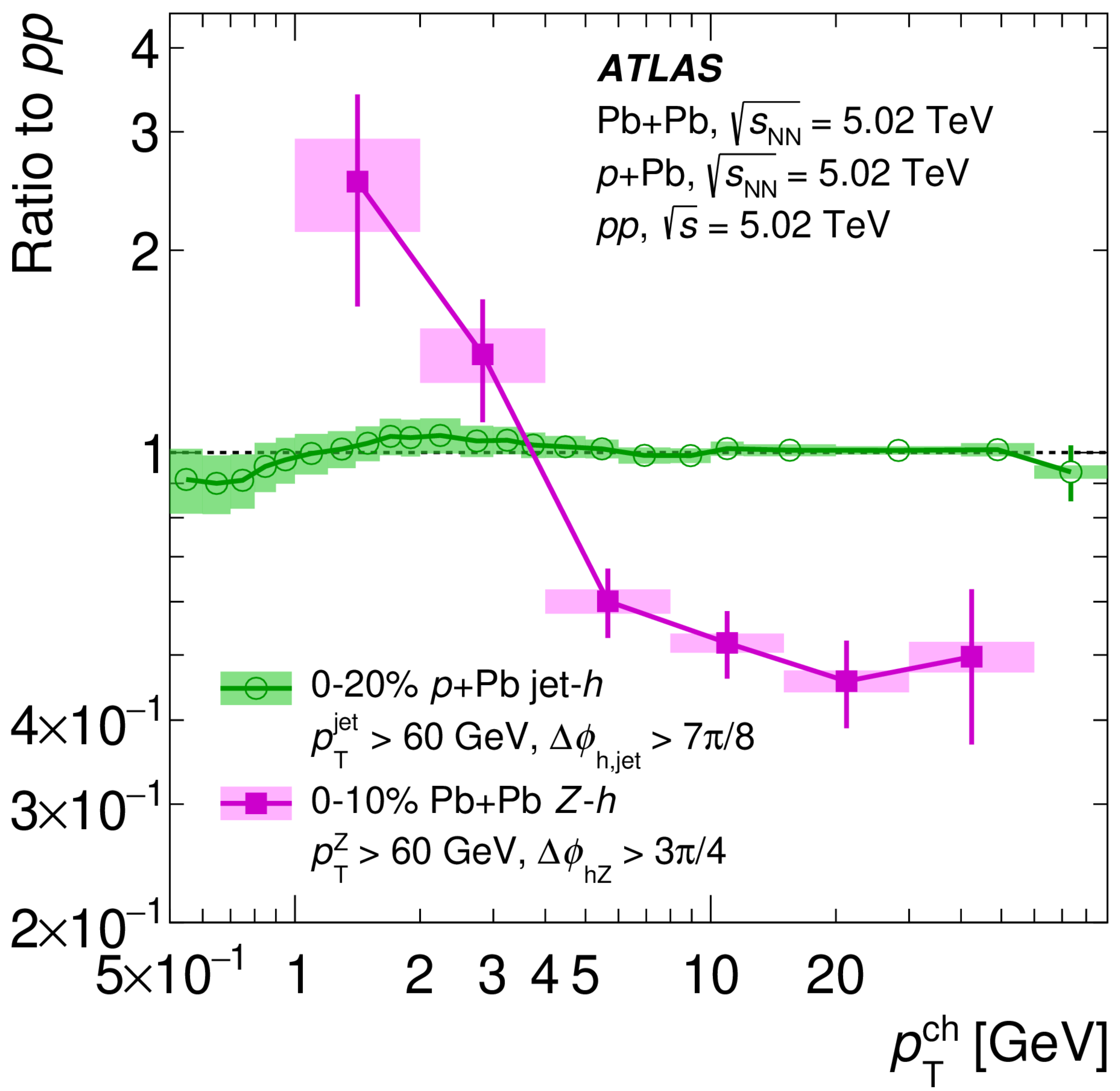


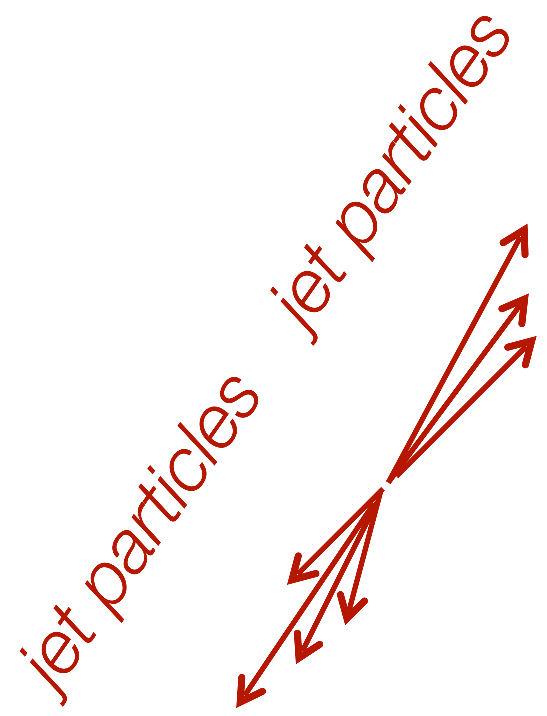
$$D(z) \equiv \frac{1}{N_{jet}} \frac{dN_{ch}}{dz}$$

$$R_{D(z)} \equiv \frac{D(z)_{pPb}}{D(z)_{pp}}$$

Jet fragmentation not modified in p+Pb.

Phys. Rev. Lett. 131 (2023) 072301





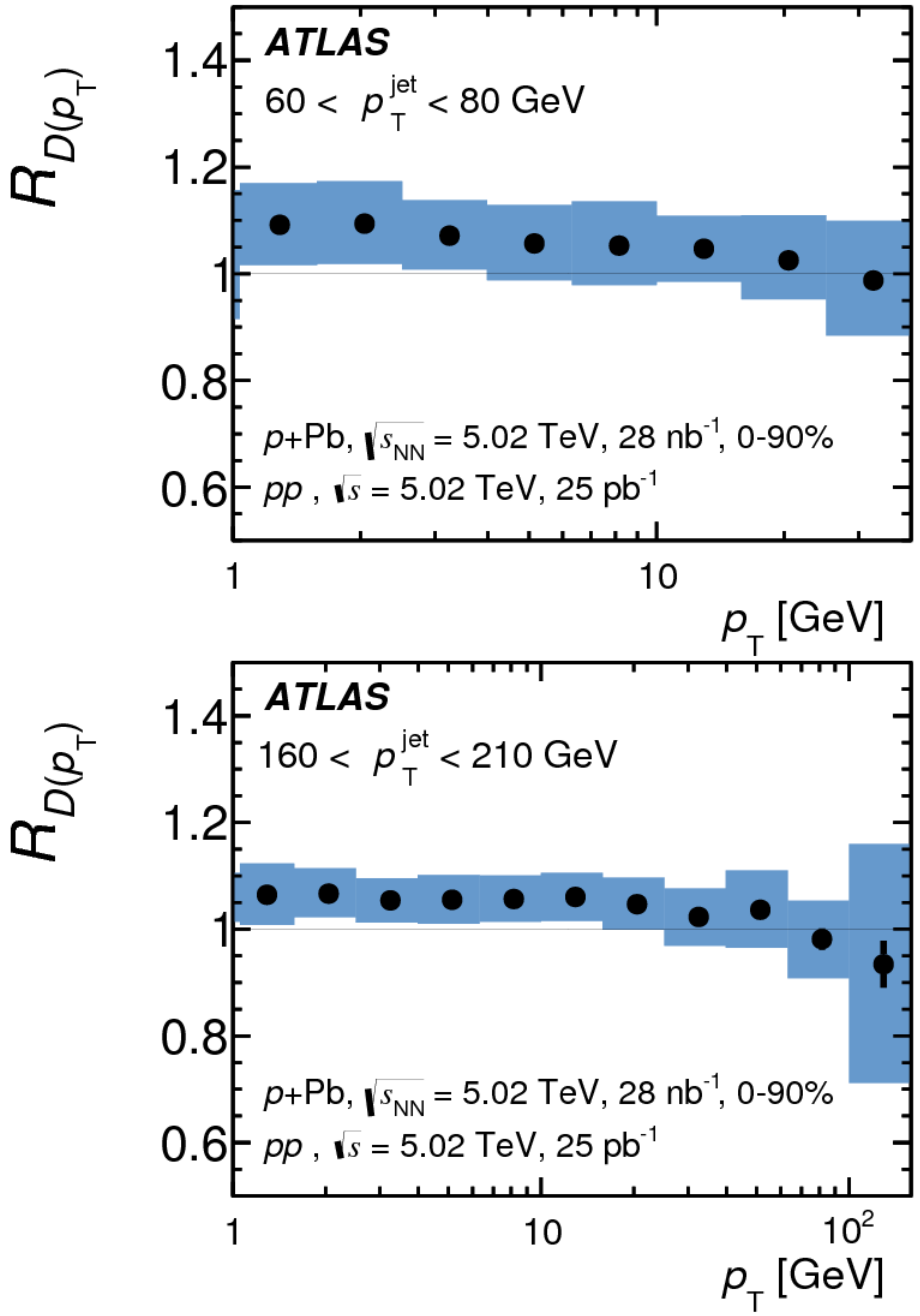
$\Delta\phi_{ch,jet} < \pi/8$

Little to *no modifications of hadron yields* observed in *central p+Pb collisions!*

Strong constraints on E-loss scenarios.

Closer look at the jet fragmentation

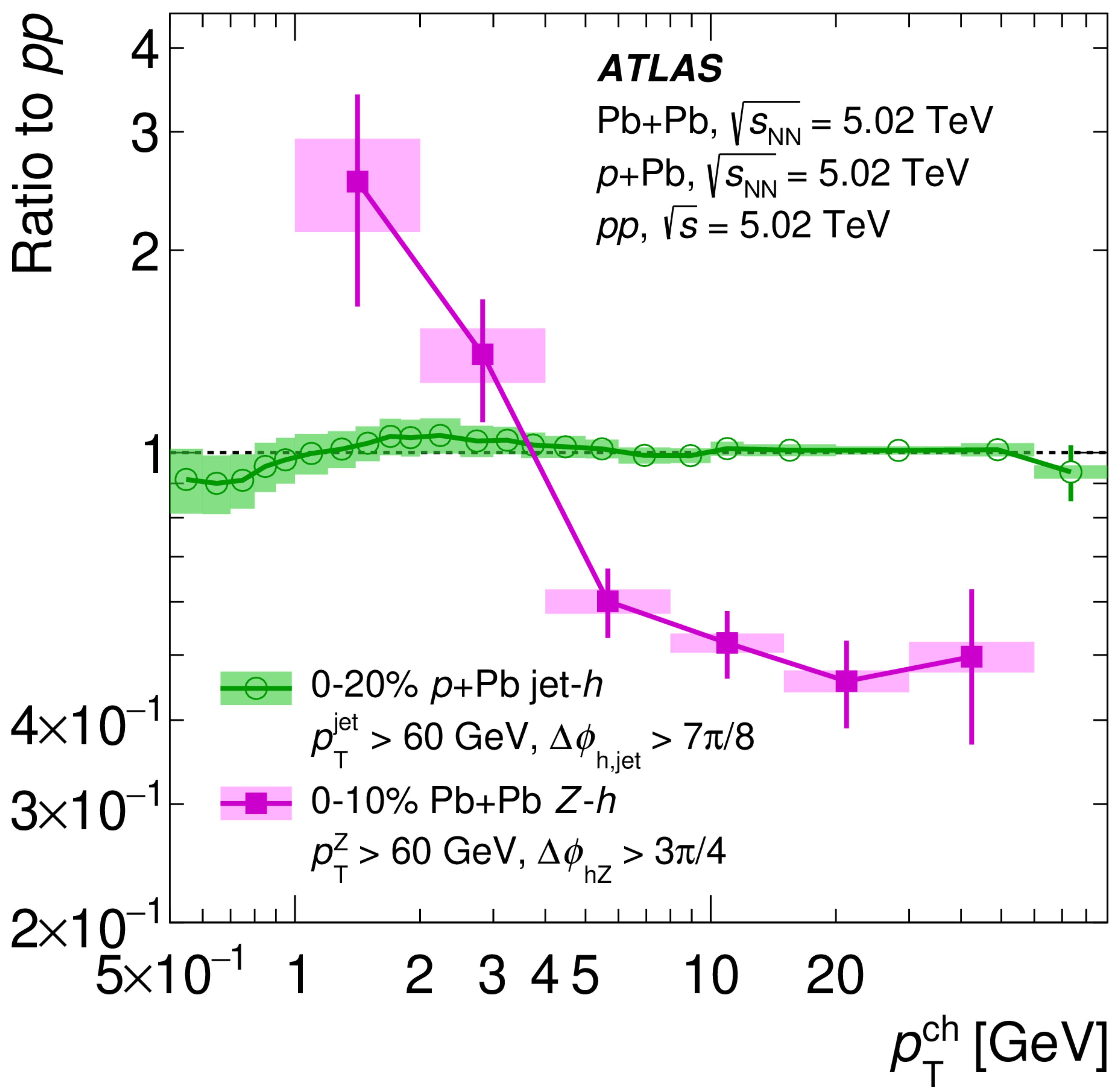
[Nucl. Phys. A 978 (2018) 65]



$$D(z) \equiv \frac{1}{N_{jet}} \frac{dN_{ch}}{dz}$$

$$R_{D(z)} \equiv \frac{D(z)_{pPb}}{D(z)_{pp}}$$

[Phys. Rev. Lett. 131 (2023) 072301]



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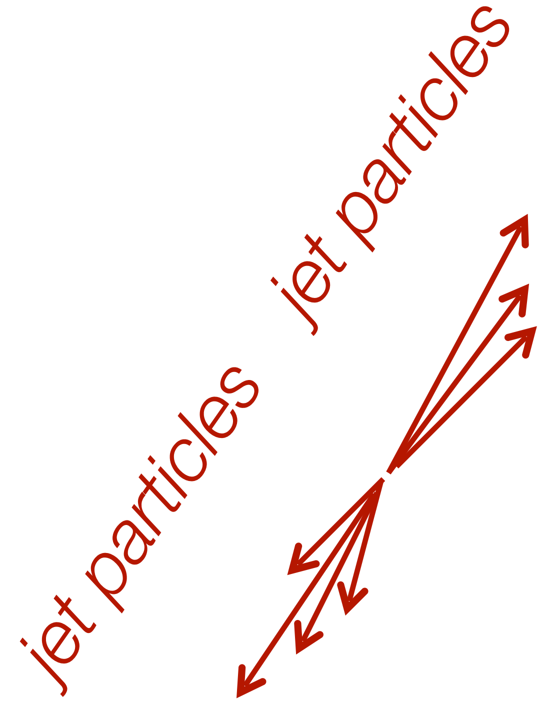


$\Delta\phi_{ch,jet} < \pi/8$

Little to *no modifications of hadron yields* observed in *central p+Pb collisions!*

Strong constraints on E-loss scenarios.

Jet fragmentation not modified in p+Pb.

No jet quenching observed in ***p+Pb*** despite of collectivity of high p_T particles

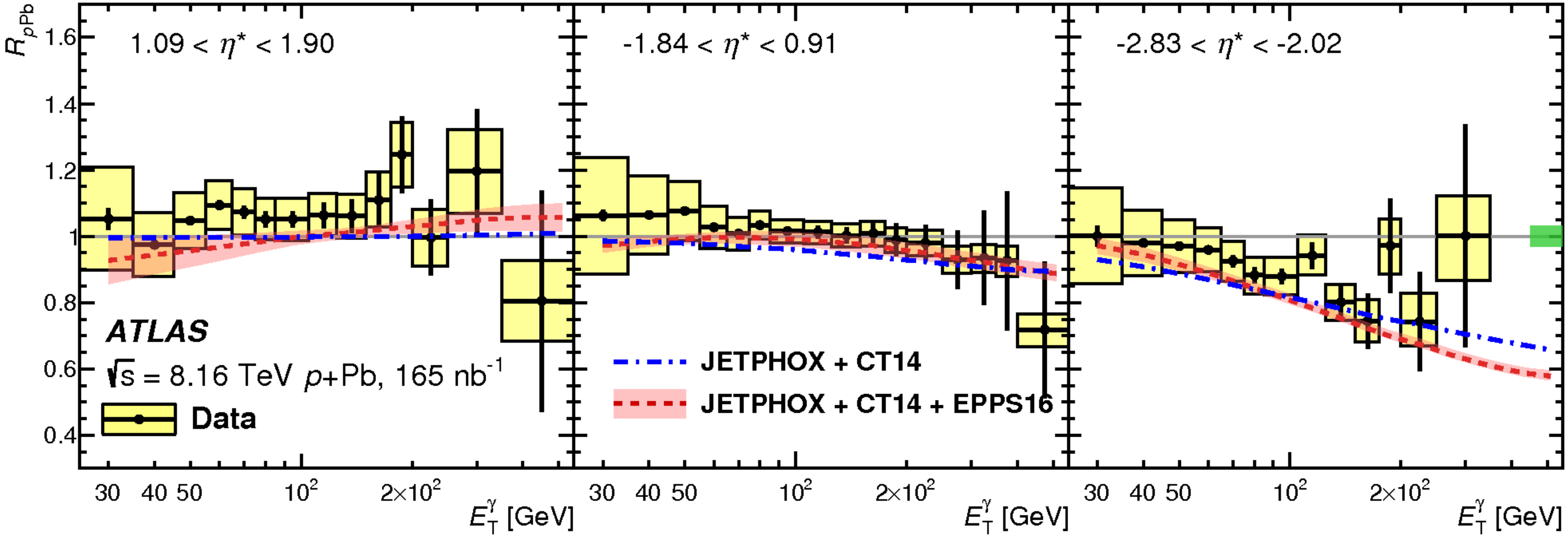
Chapter 3
Nuclear modification of parton densities

Inclusive photons in p+Pb

At forward and central rapidity R_{pPb} consistent with unity.

R_{pPb}<1 for η*<-2 due to isospin effects.

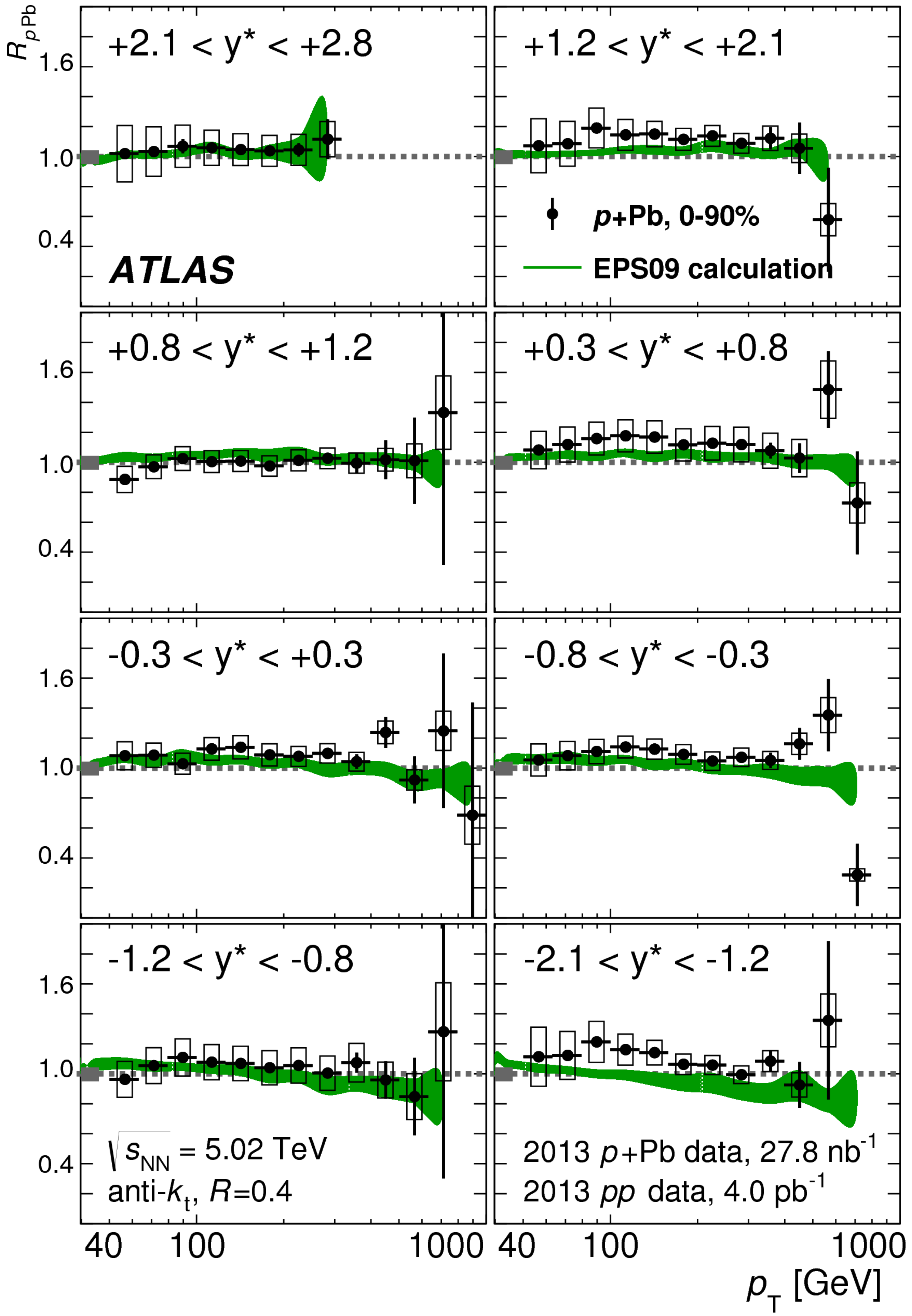
Phys. Lett. B 796 (2019) 230



With the current uncertainties, the data is unable to constraint nPDF.

Jet production in p+Pb

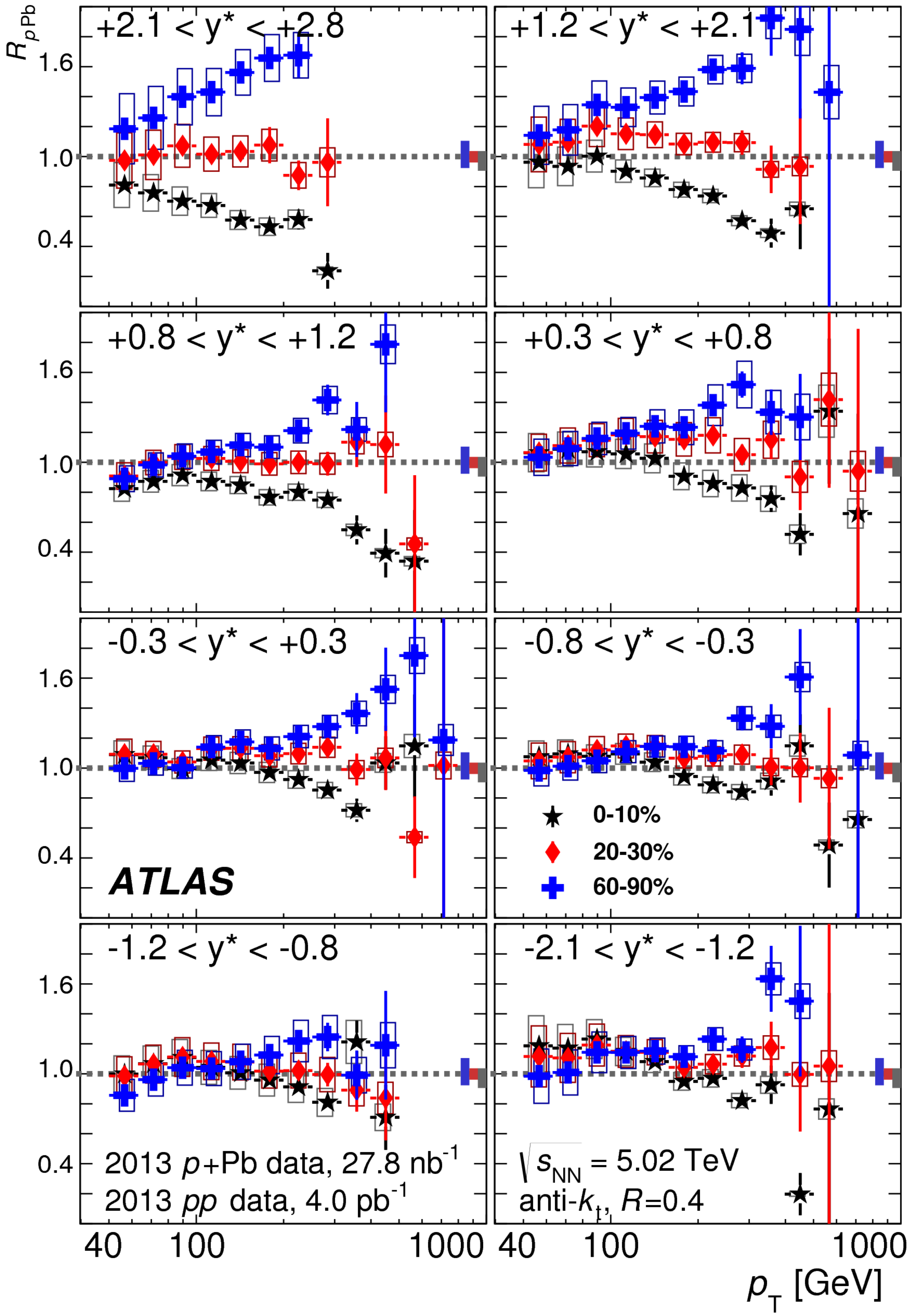
Phys. Lett. B 748 (2015) 392-413



0-90%

Jet production in p+Pb

Phys. Lett. B 748 (2015) 392-413



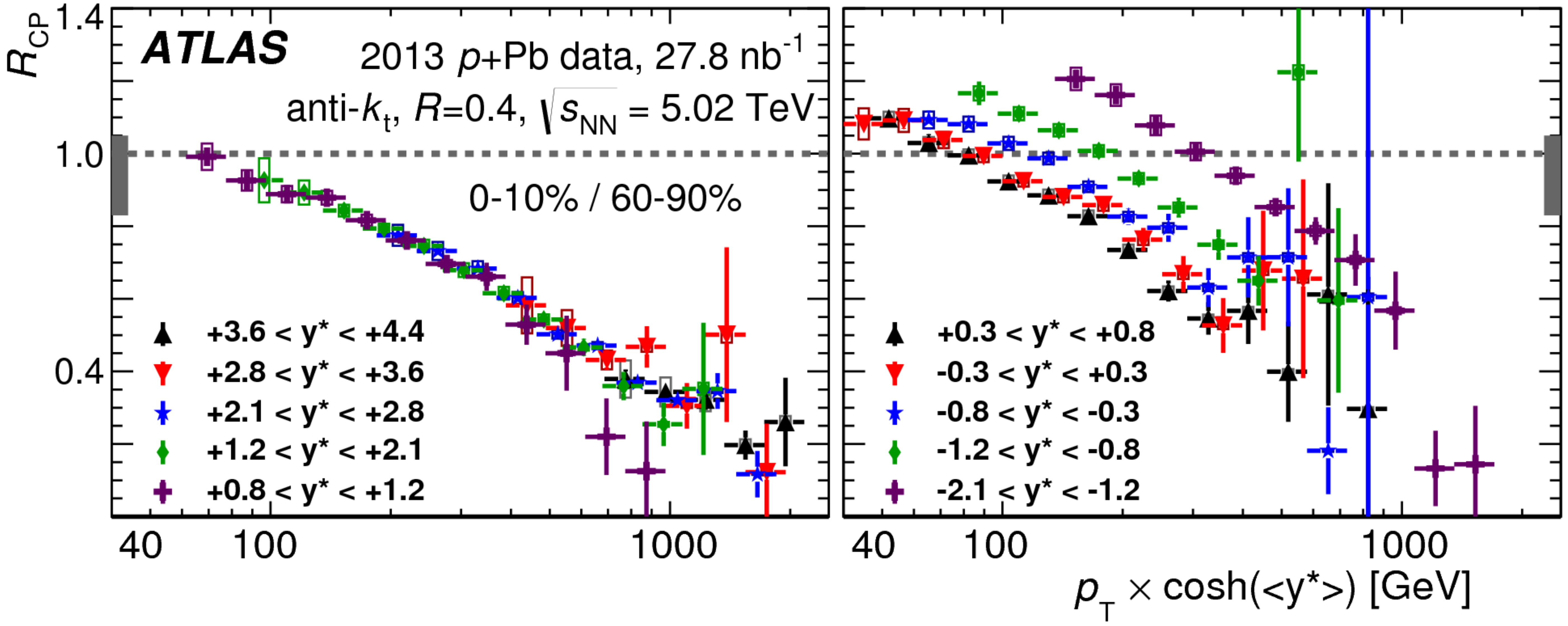
0-10%

20-30%

60-90%

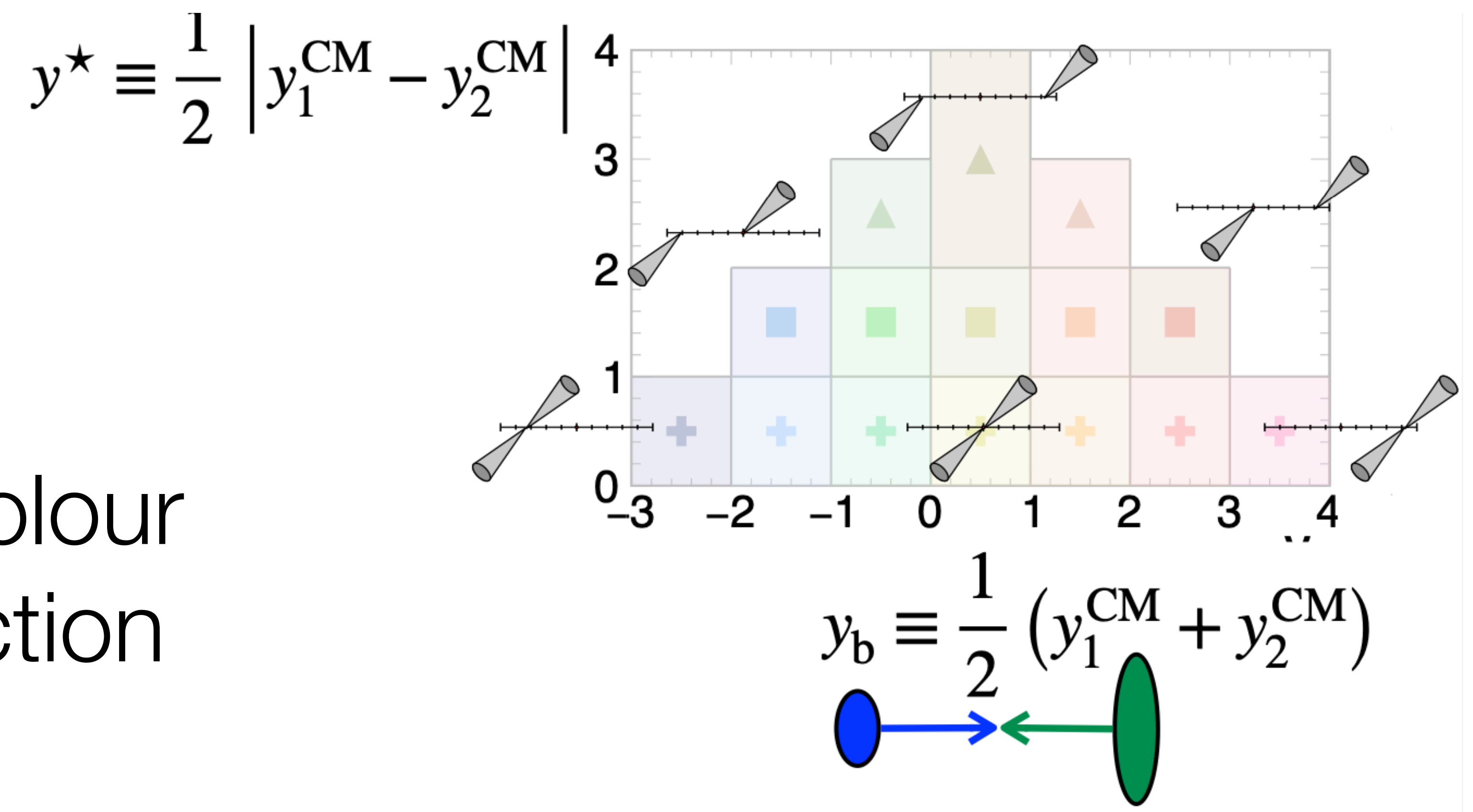
Interesting kinematic dependence: increases with p_T with a slope that depends on rapidity (looks like cosh y)

In the forward region depends on E ~ p_T *cosh y



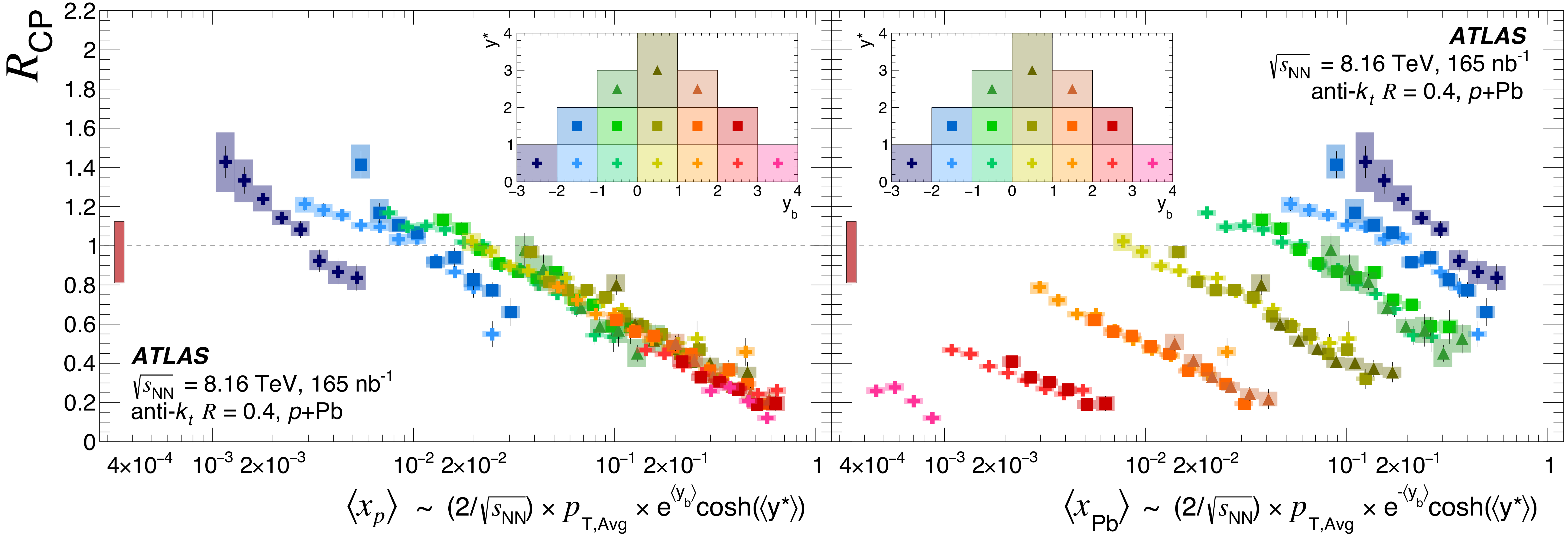
Di-jet production in p+Pb

Using dijets to constrain parton kinematics.
Can repeat previous mapping but separately for effective x_p, x_{Pb}



$R_{CP}(x_p)$ is qualitatively described by the colour fluctuations: smaller than average interaction strength at large x_p.

Phys. Rev. Lett. 132 (2024) 102301



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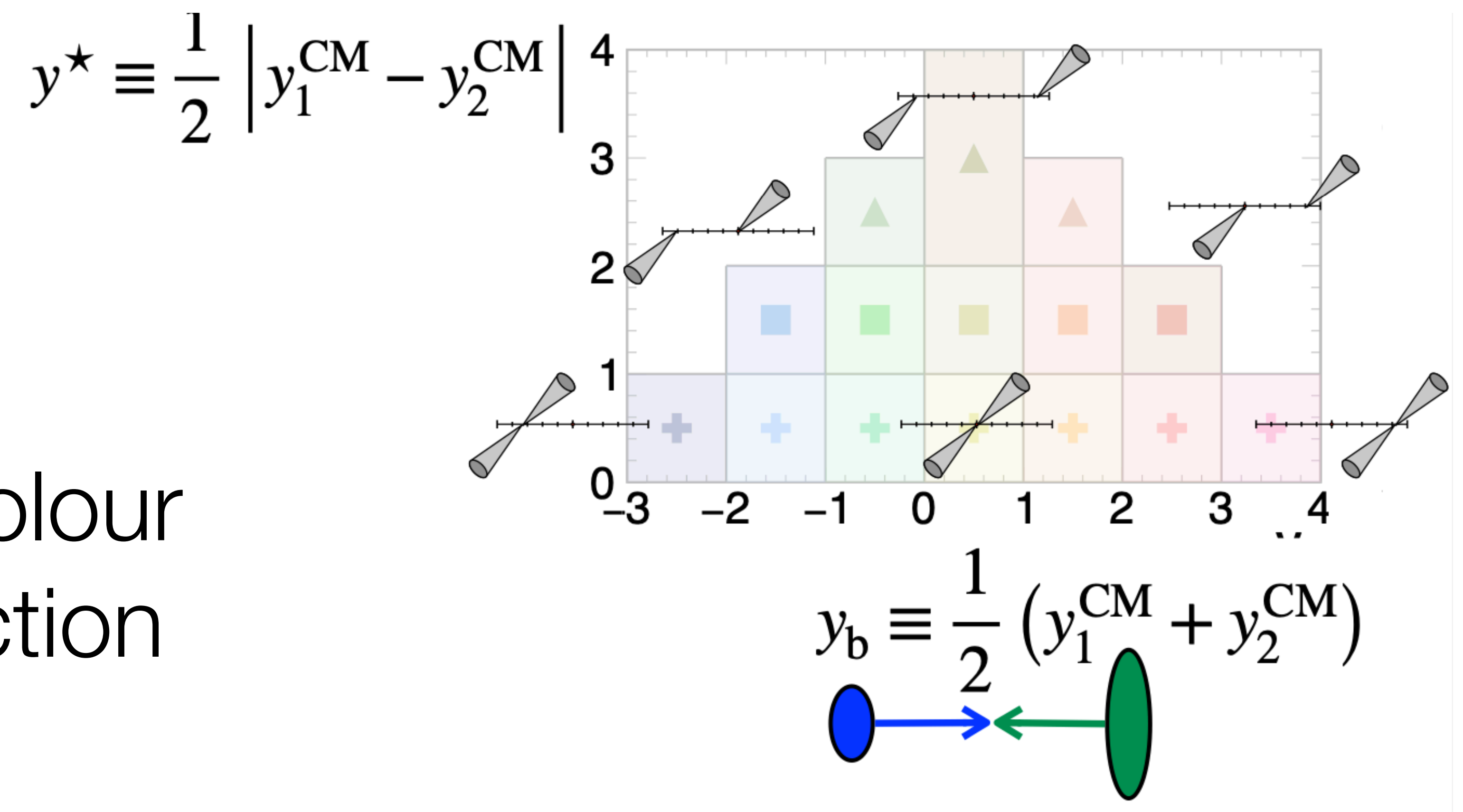
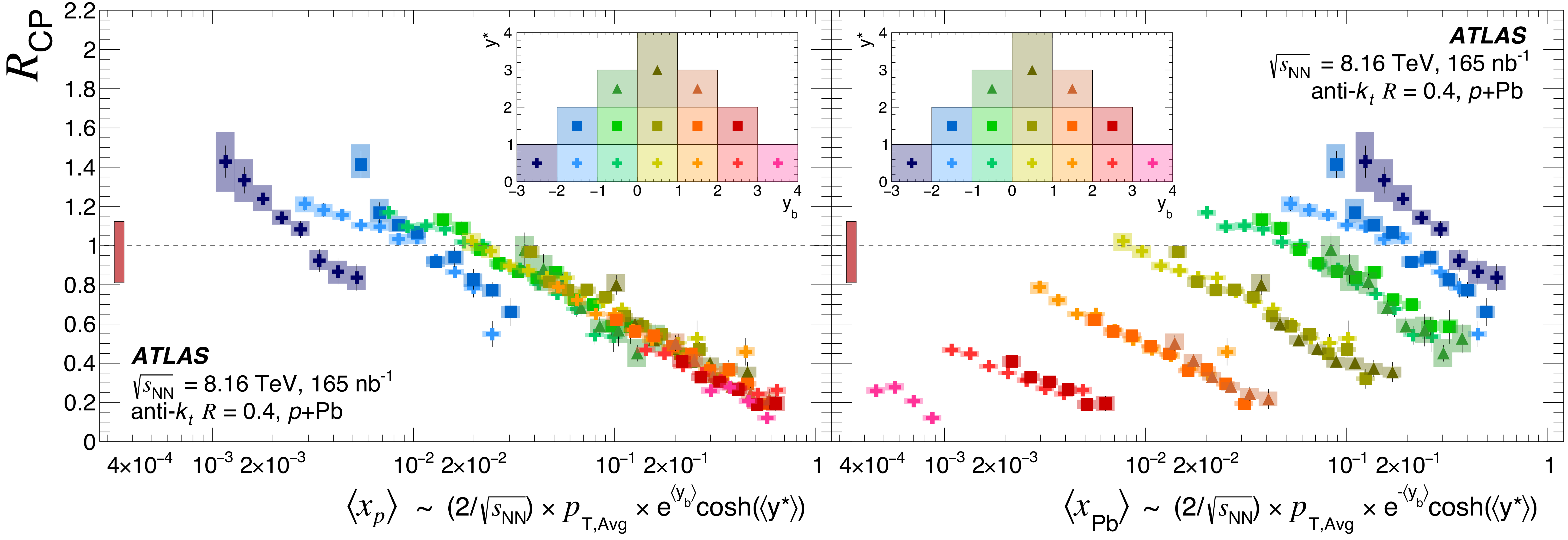
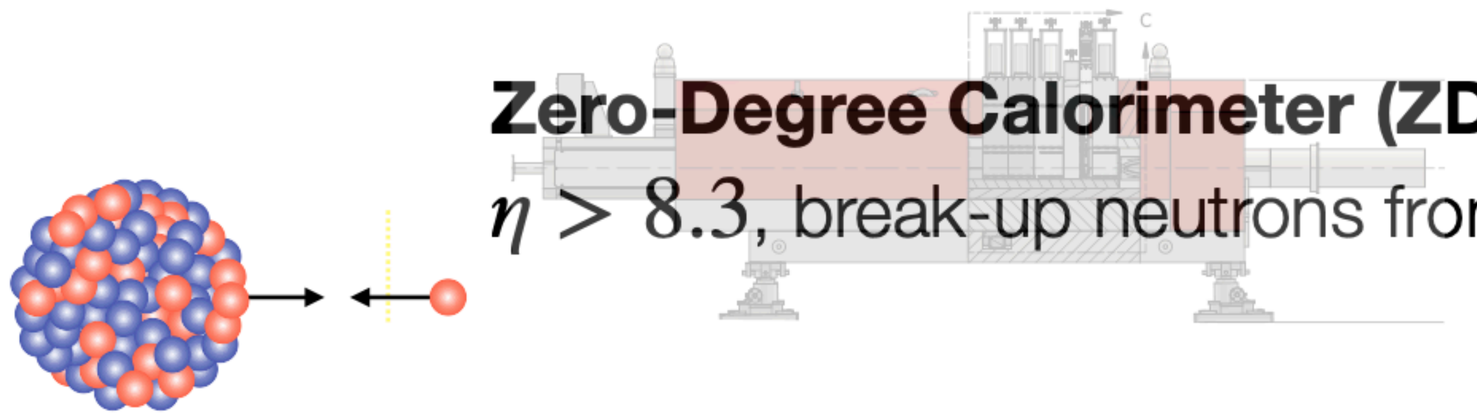


$R_{CP}(x_p)$ is qualitatively described by the colour fluctuations: smaller than average interaction strength at large x_p.

Phys. Rev. Lett. 132 (2024) 102301

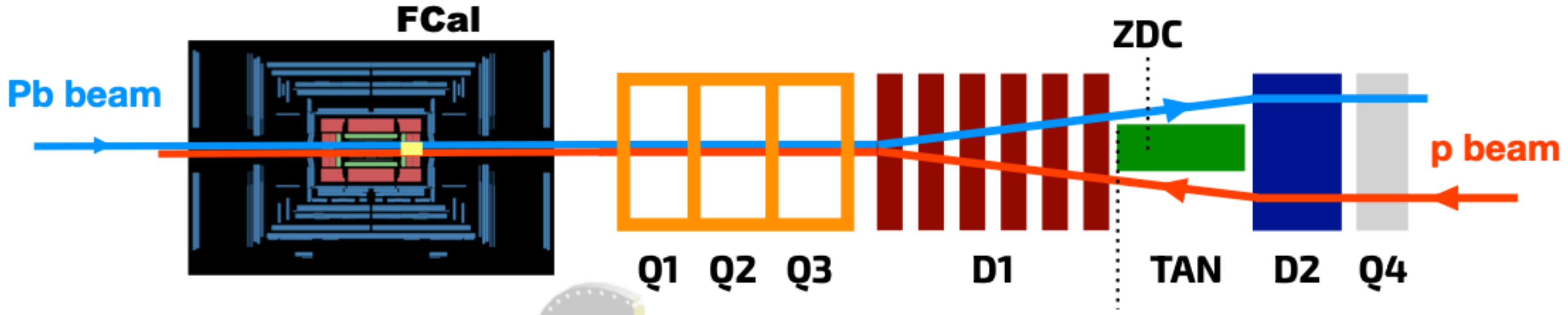


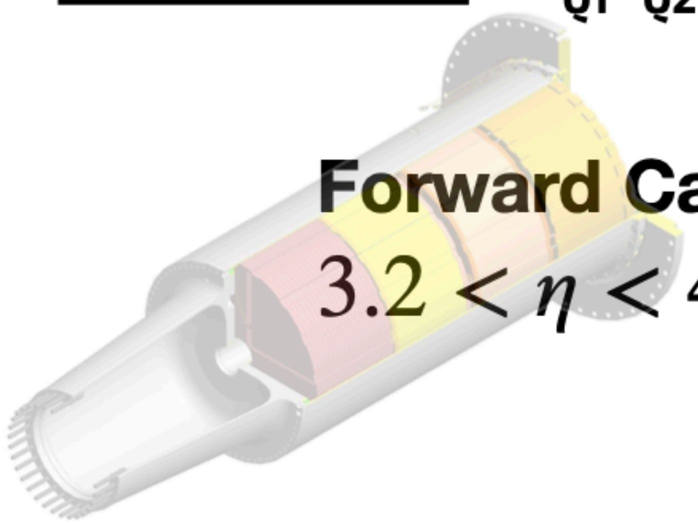
Di-jet production in p+Pb - nuclear break-up



Zero-Degree Calorimeter (ZDC)

$\eta > 8.3$, break-up neutrons from nucleus

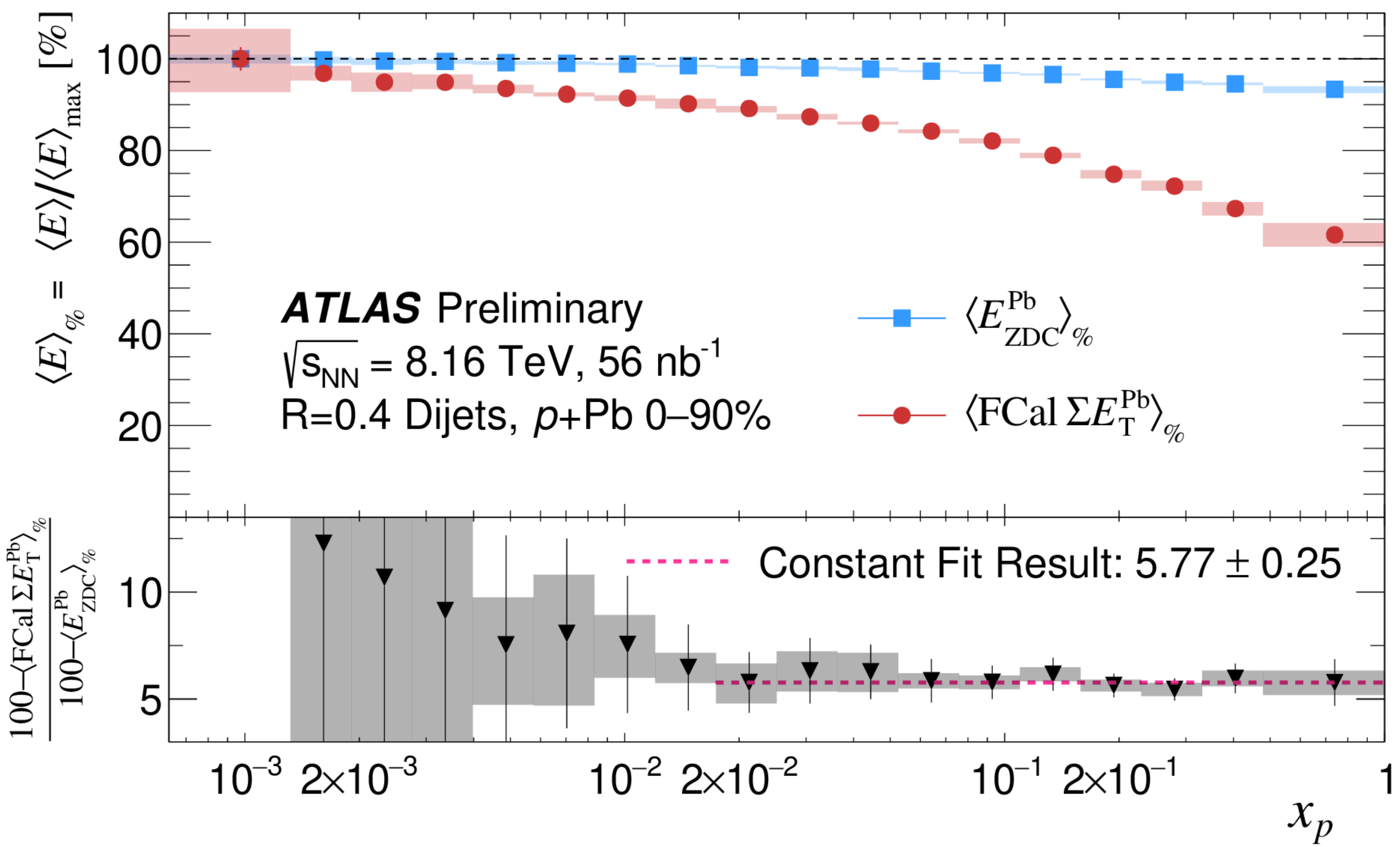




Forward Calorimeter (FCal)

$3.2 < \eta < 4.9$, underlying events activity

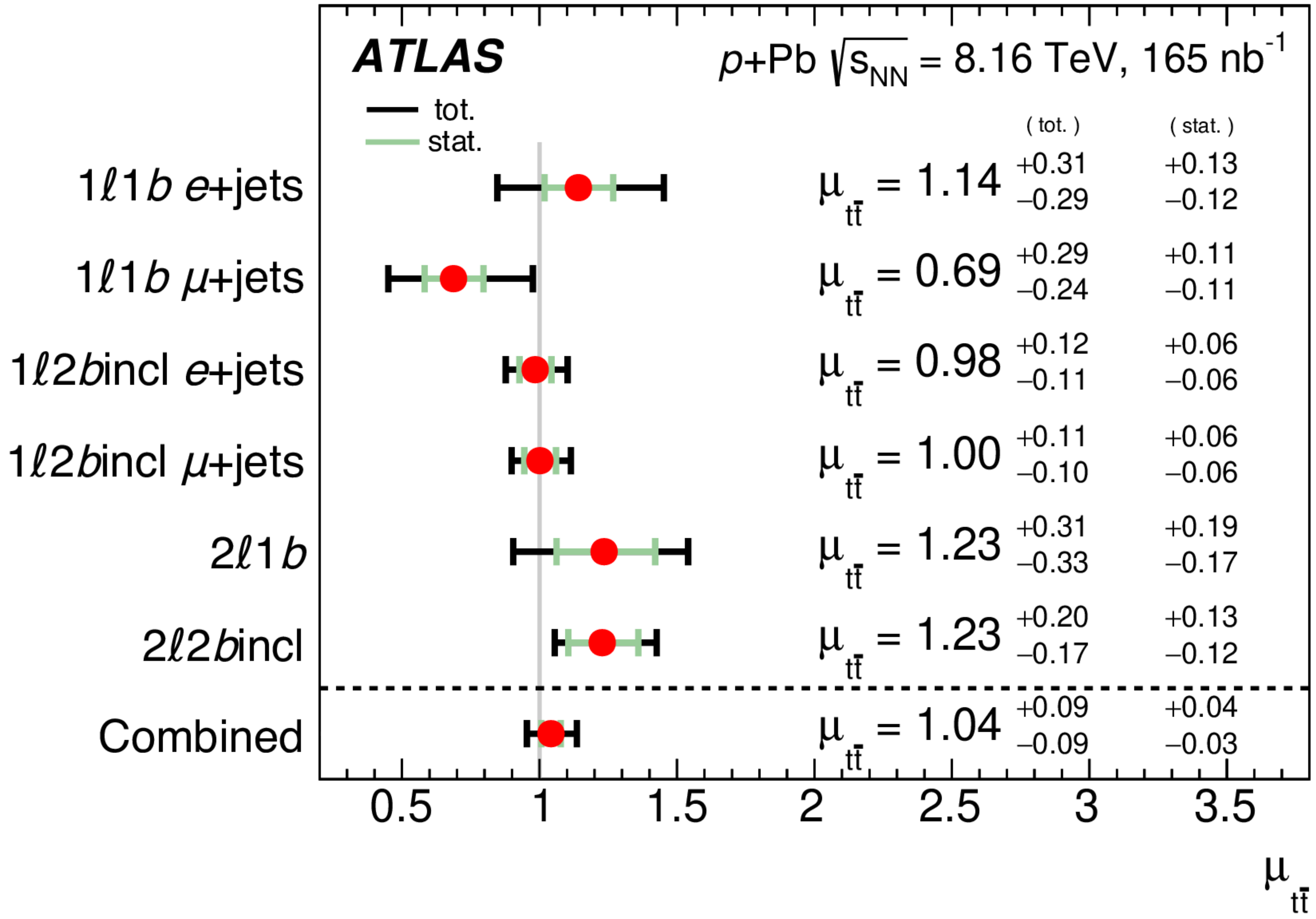
ATLAS-CONF-2024-013

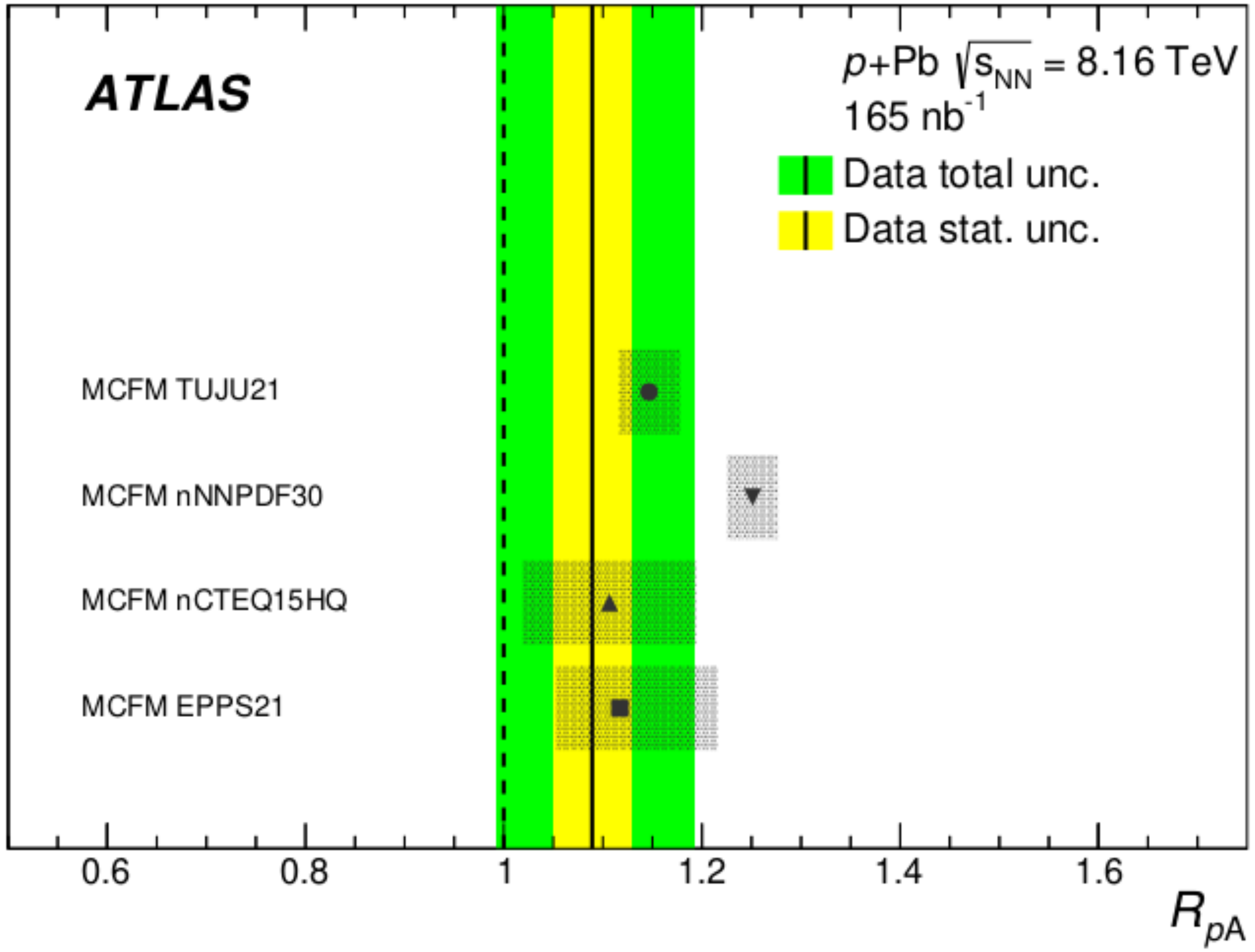


Decreasing UE energy (FCal E_T) and break-up neutrons (ZDC E) with increasing x_p

ttbar production in p+Pb

arXiv:2405.05078

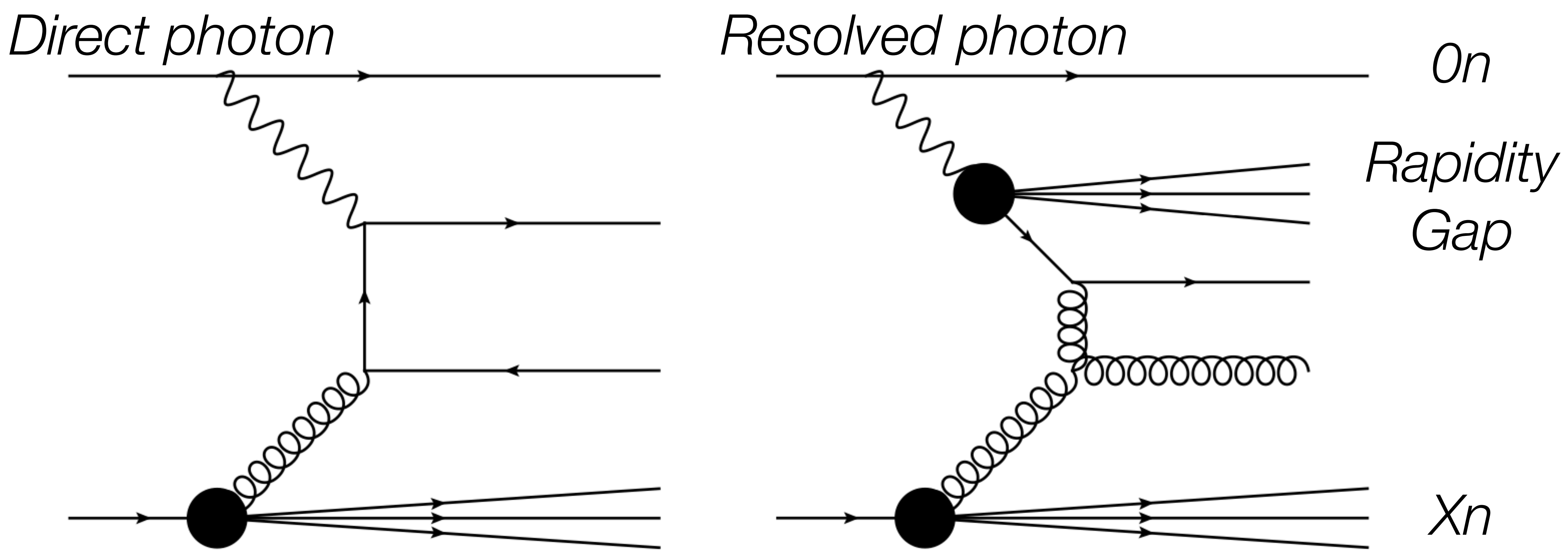




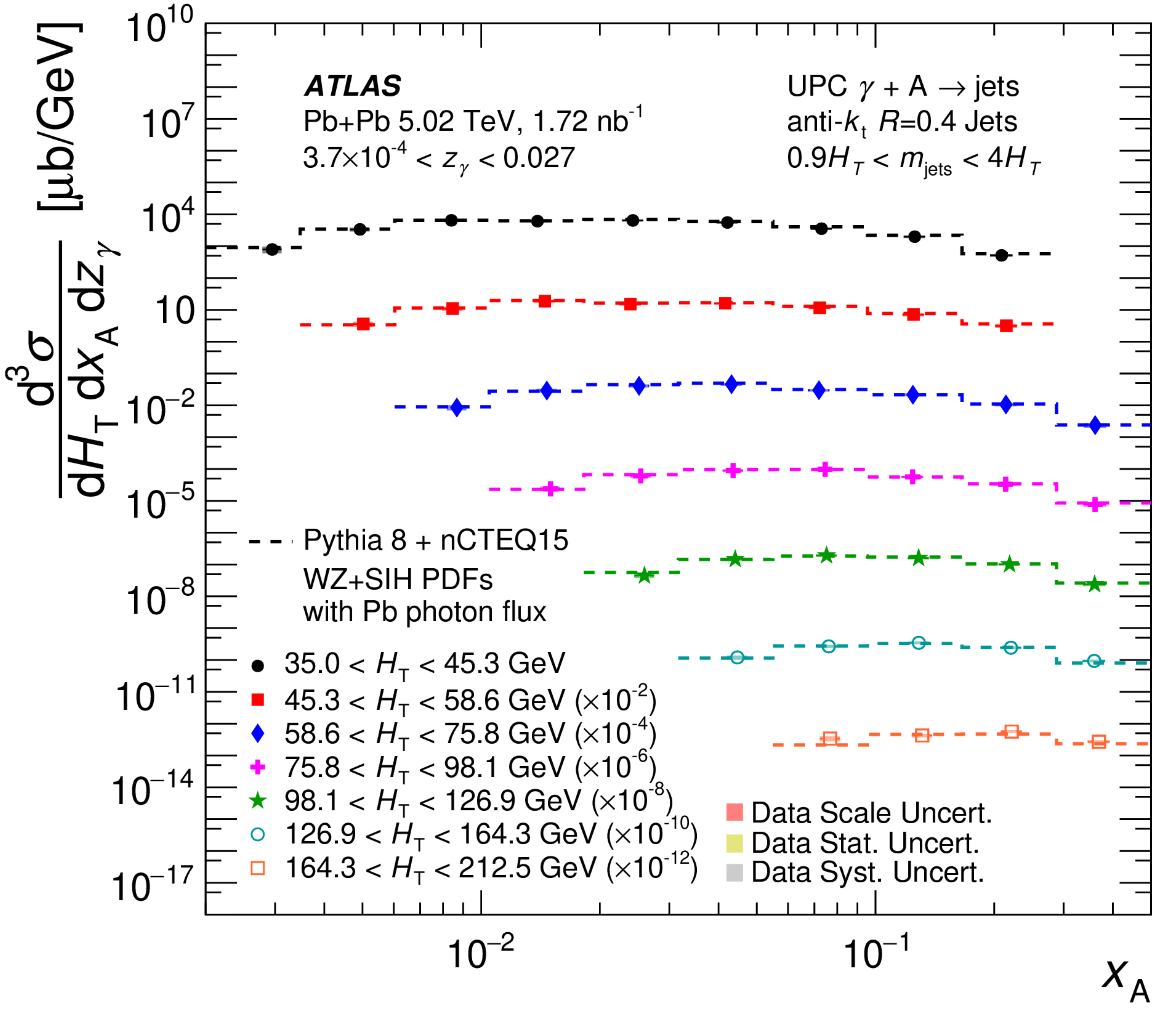
ttbar cross section measured to be 58.1 +/- 2.0 $^{+4.8}_{-4.4}$ nb^{-1}

R_{pA} consistent with unity - nNNPDF slightly overestimate R_{pA}

Photo-nuclear production of di-jets



arXiv:2409.11060



Di-jet kinematics corresponds to the hard scattering kinematics

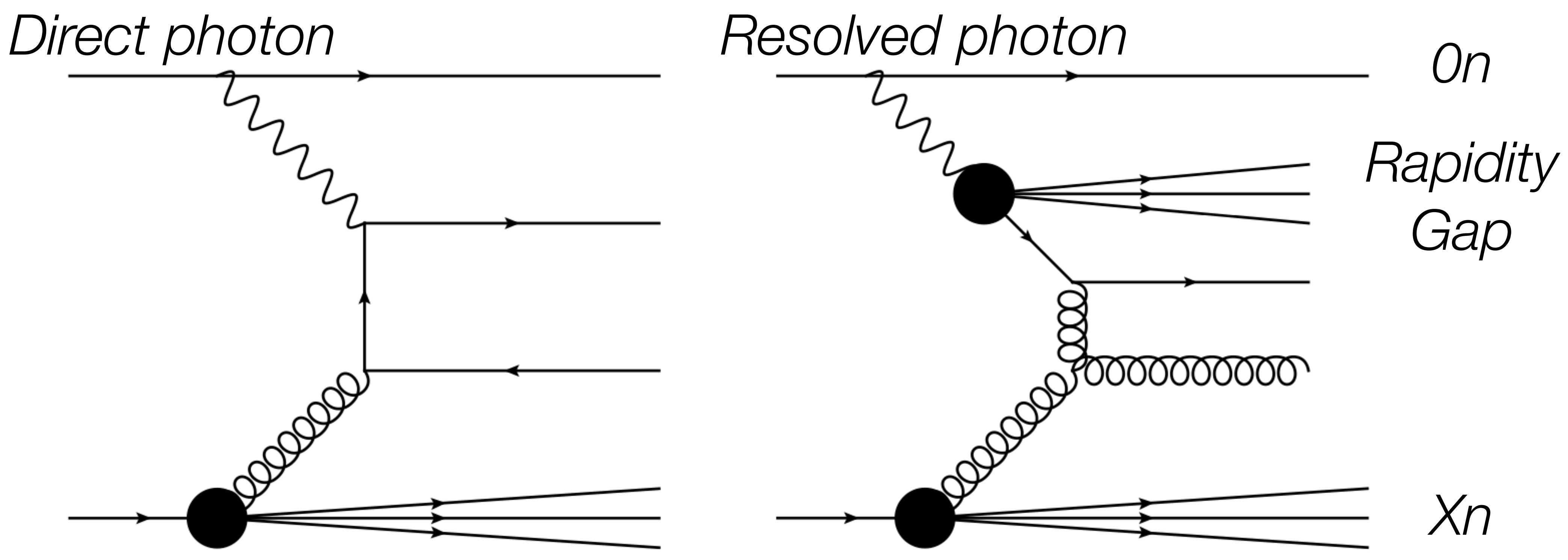
$$H_T \equiv \sum_i p_{T\,i} \qquad z_\gamma \equiv \frac{M_{\text{jets}}}{\sqrt{s}} e^{+y_{\text{jets}}} \qquad x_A \equiv \frac{M_{\text{jets}}}{\sqrt{s}} e^{-y_{\text{jets}}}$$

Unfolded for detector response

Potential to constrain nuclear PDFs!

Clean probe to explore poorly constrained region at low-x and intermediate Q^2

Photo-nuclear production of di-jets



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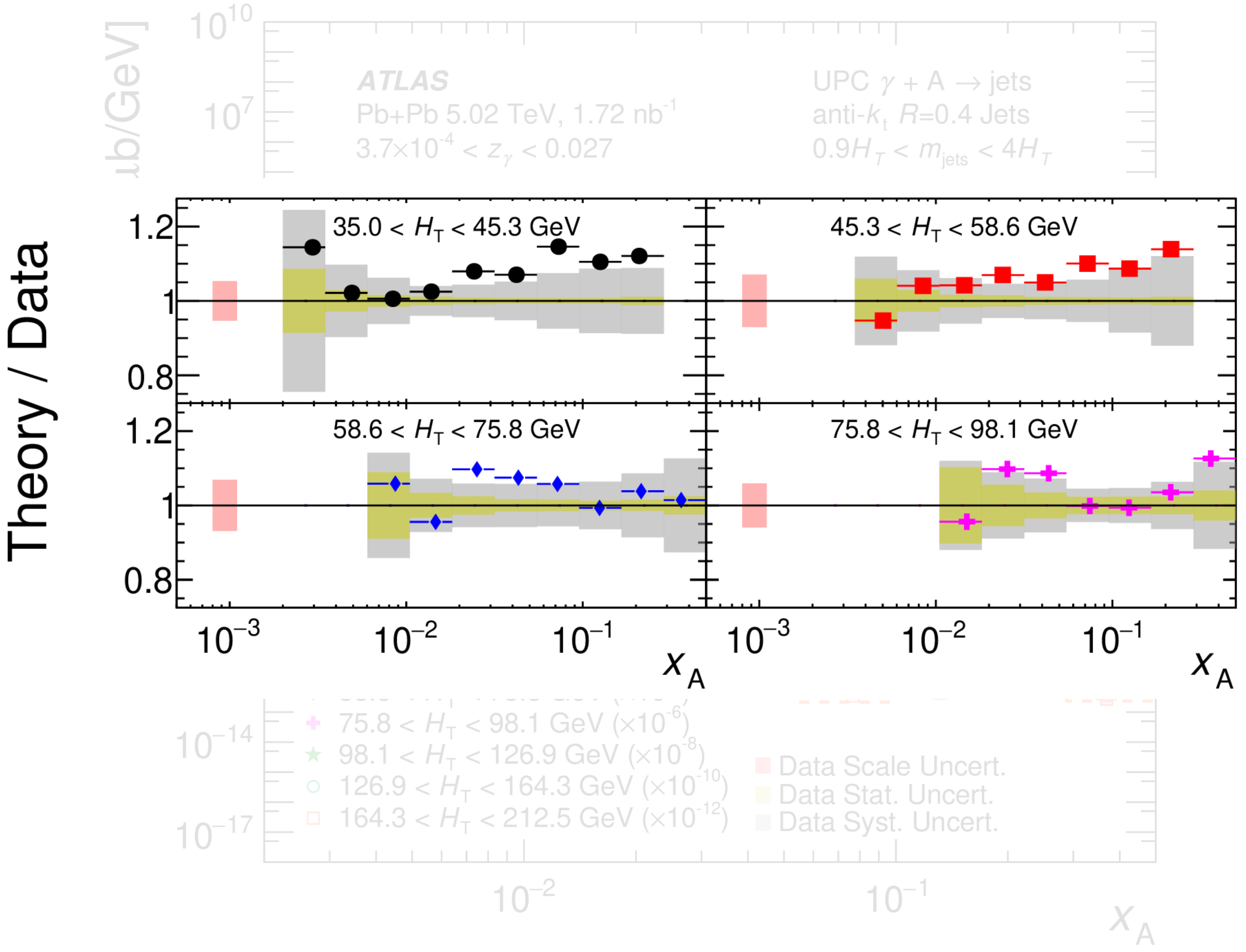

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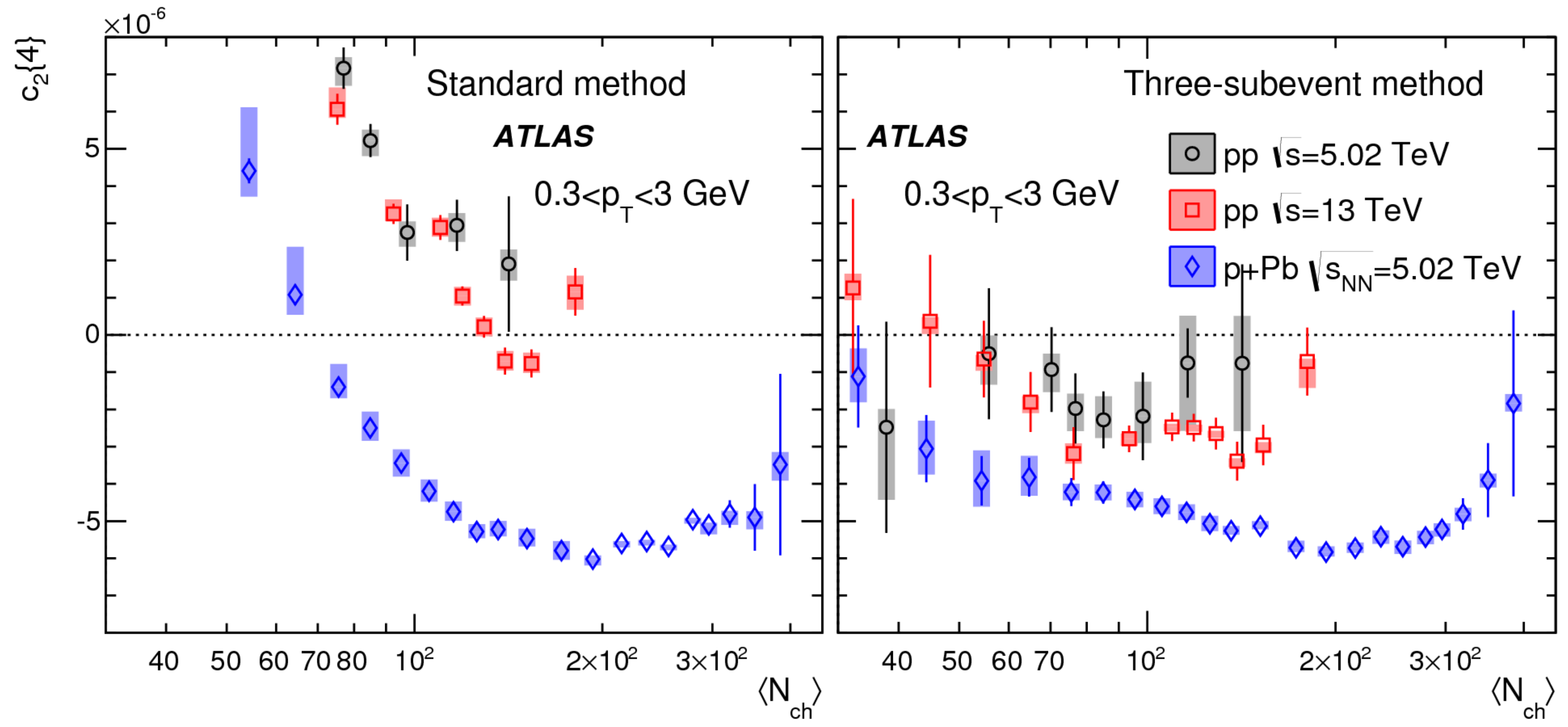
Summary

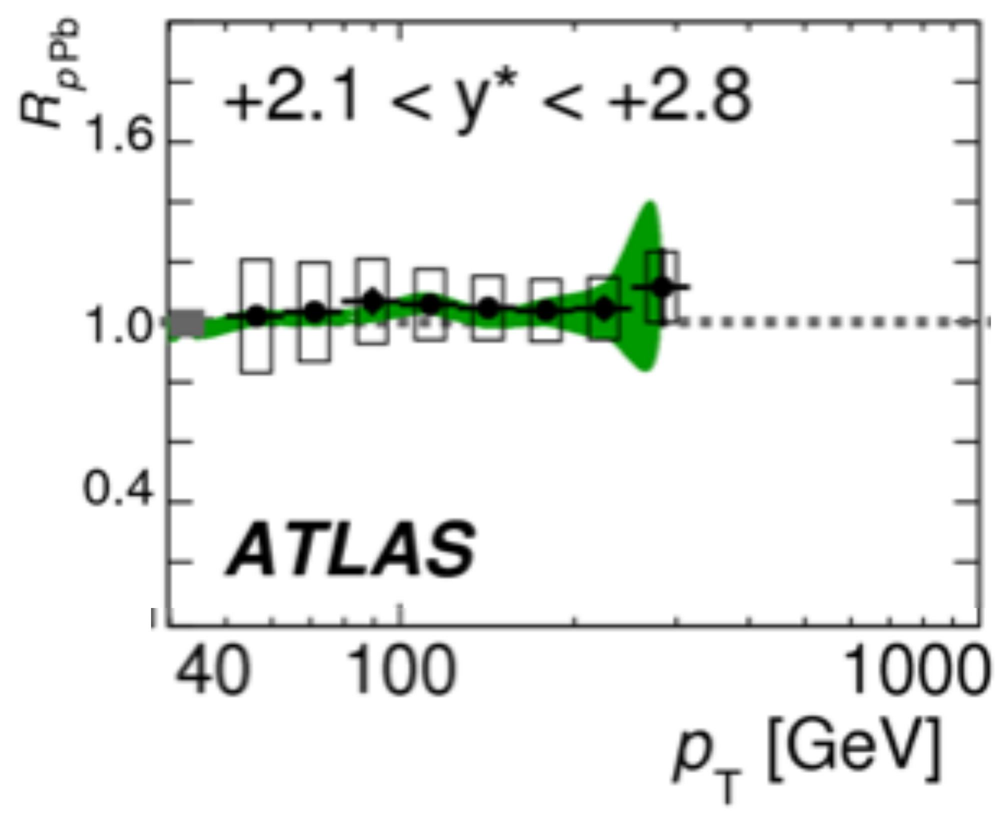
Chapter 1
Collectivity in small systems

Well establish collective behaviour in small system
Many developments on the measurements technics that also benefit in large systems.



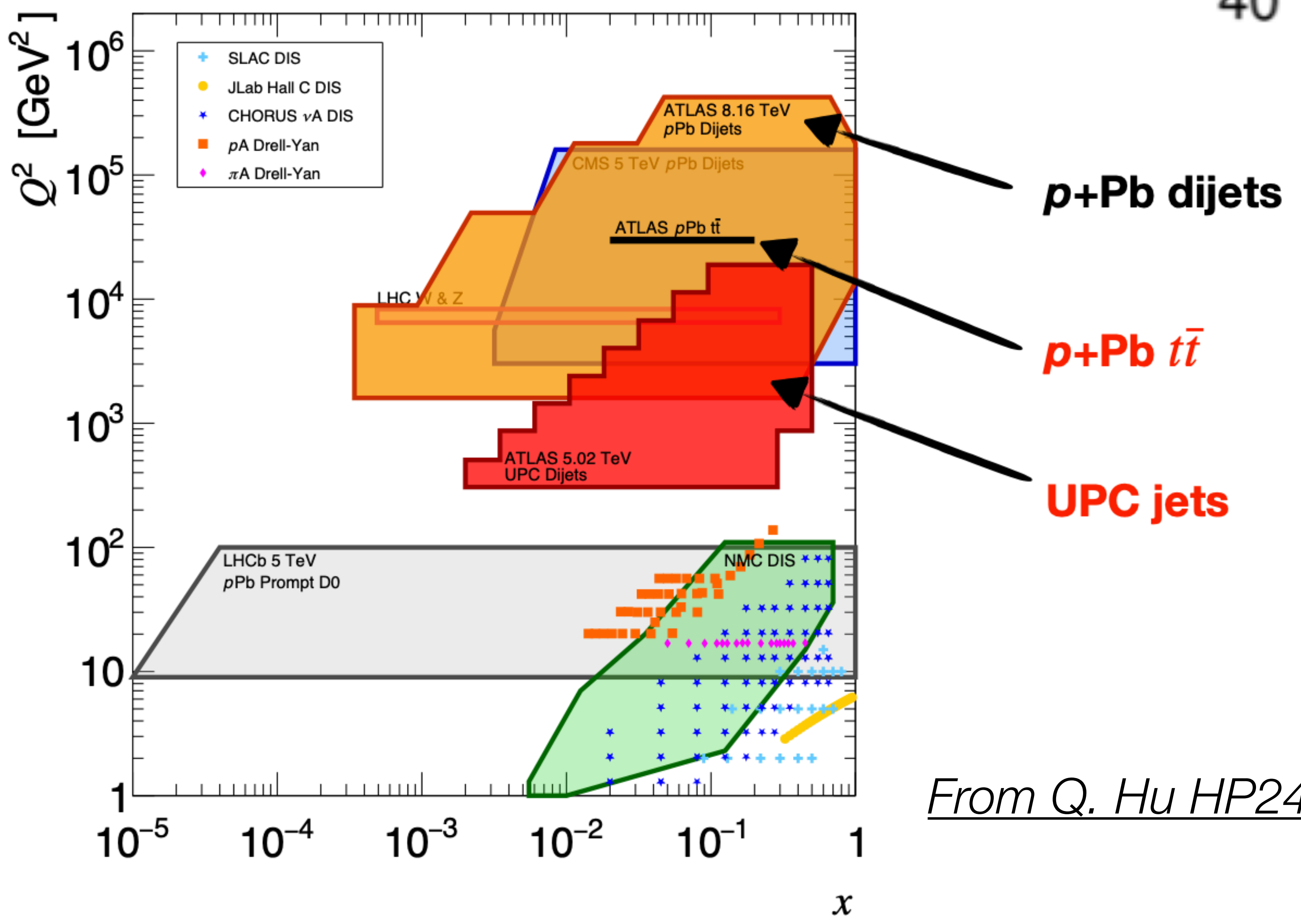
Chapter 2
Search of the effect of energy loss in small systems

Still no sign of energy loss while we see signs of collectivity at high p_T



Chapter 3
Nuclear modification of parton densities

Potential to constraint nPDFs if more data available.



From Q. Hu HP24 talk