



AGH

AGH UNIVERSITY OF KRAKOW

ATLAS Light Ion Collision results

an overview

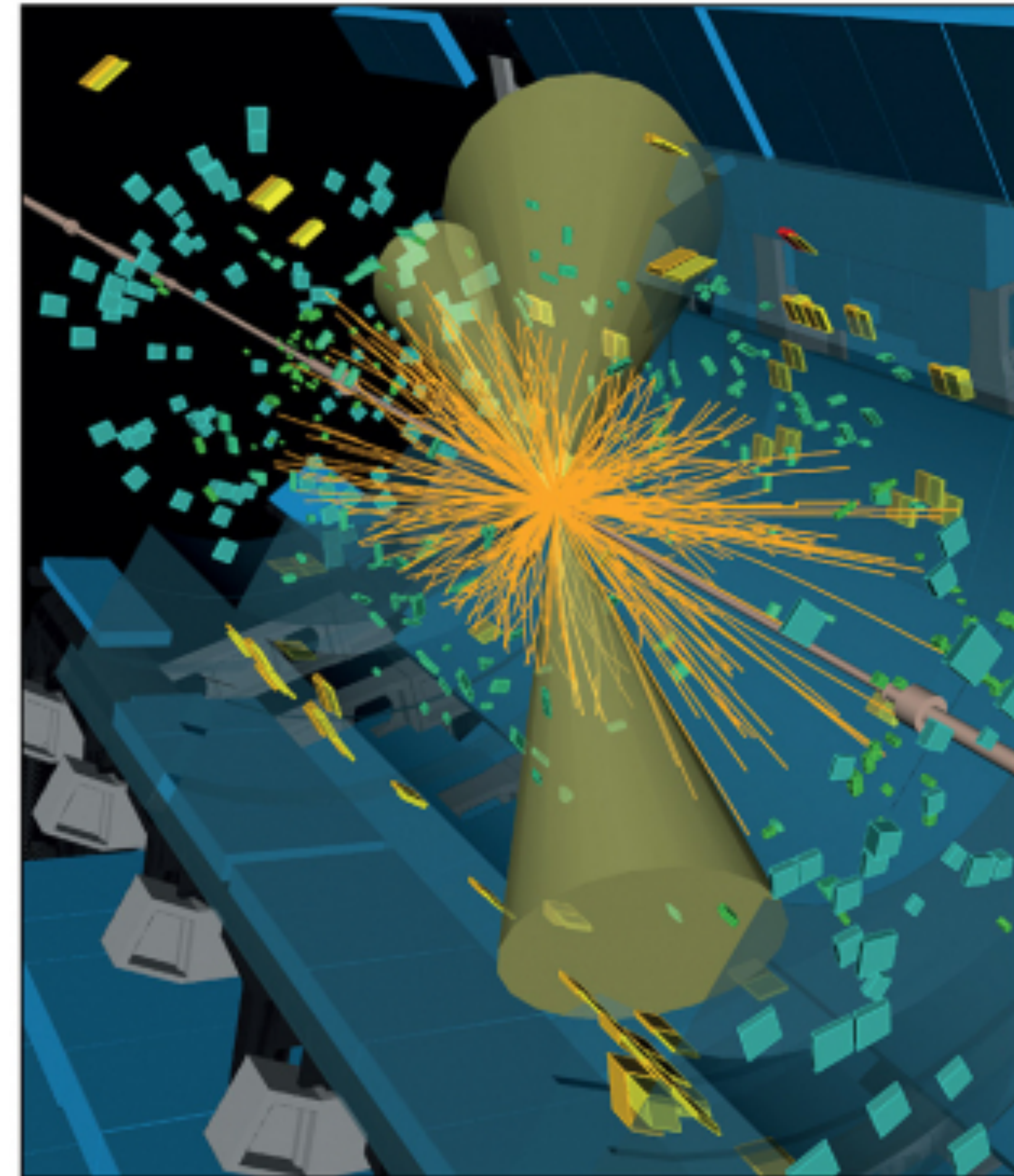
at EMMI Workshop on Light Ion Collisions

On behalf of the ATLAS Collaboration

Tomasz Bold - AGH University of Krakow - 21.09.2026

Why?

- Collisions of light ions allow us to:
 - bridge pp / pA and AA collisions,
 - search for the smallest droplets exhibiting jet quenching,
 - test onset of collectivity,
 - study nuclear geometry effects.



Jets in OO collision in ATLAS

ATLAS light ion data taking

- Excellent machine performance delivered:

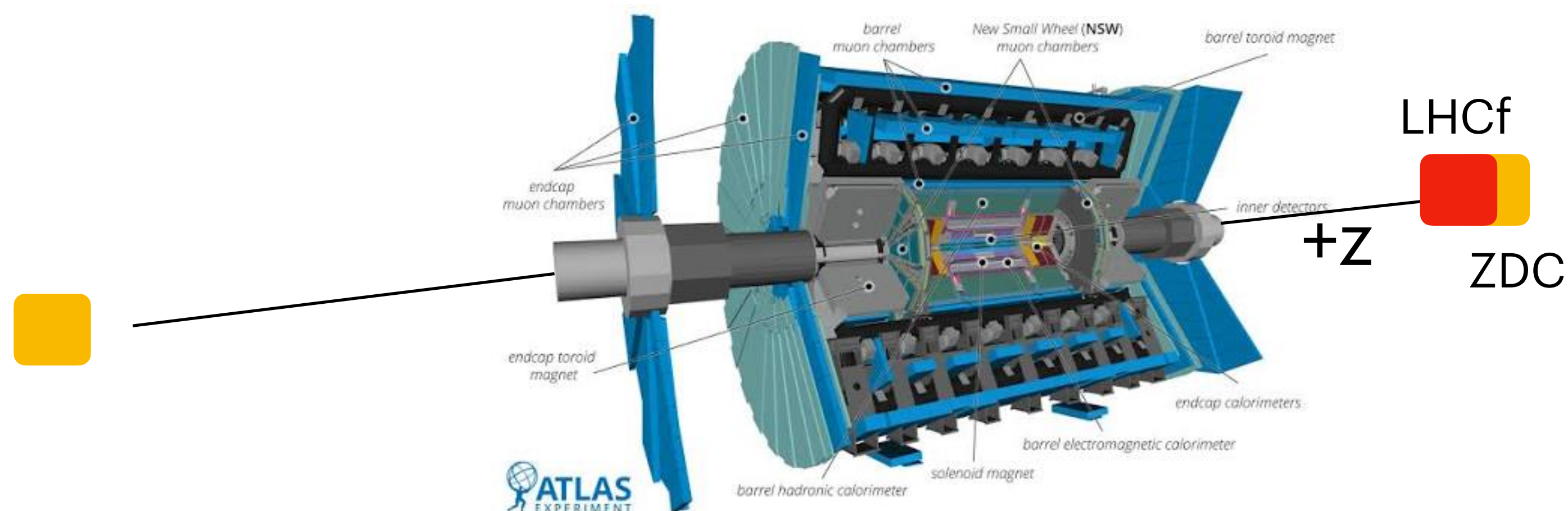
p+O	9.62	11 nb ⁻¹
O+O	5.36	8 nb ⁻¹
Ne+Ne	5.36	1 nb ⁻¹

- „Pilot run” conditions & lifted TDAQ limitations → record most of the MB statistics
- Primary **single-track** trigger based on TRT

- Lower UE and large bunches separation allowed for:

- Wider coverage in reconstruction and analysis:
 - Lower track p_T with reasonable fake fraction
 - Lower jet momenta usable
 - Very high collection efficiency ~99%

- The p-O sample recorded with LHCf



Measurements with LI

- So far several results are published or preliminary:

- soft probes:

- $dN/d\eta$ - for entropy production
- p_T spectra (< 5 GeV) for radial flow
- v_n azimuthal analysis for collectivity and nuclear shapes (this result should be well known)

- hard probes:

- jets: x_J and v_n
- $\gamma - h$ yields

- a few more to be expected for QM2027

dN/deta and pT spectra HION-2025-04

Flow HION-2025-02

Jets imbalance HION-2025-16

gamma-hadron corr. CONF-2026-007

Jet vn CONF-2026-006

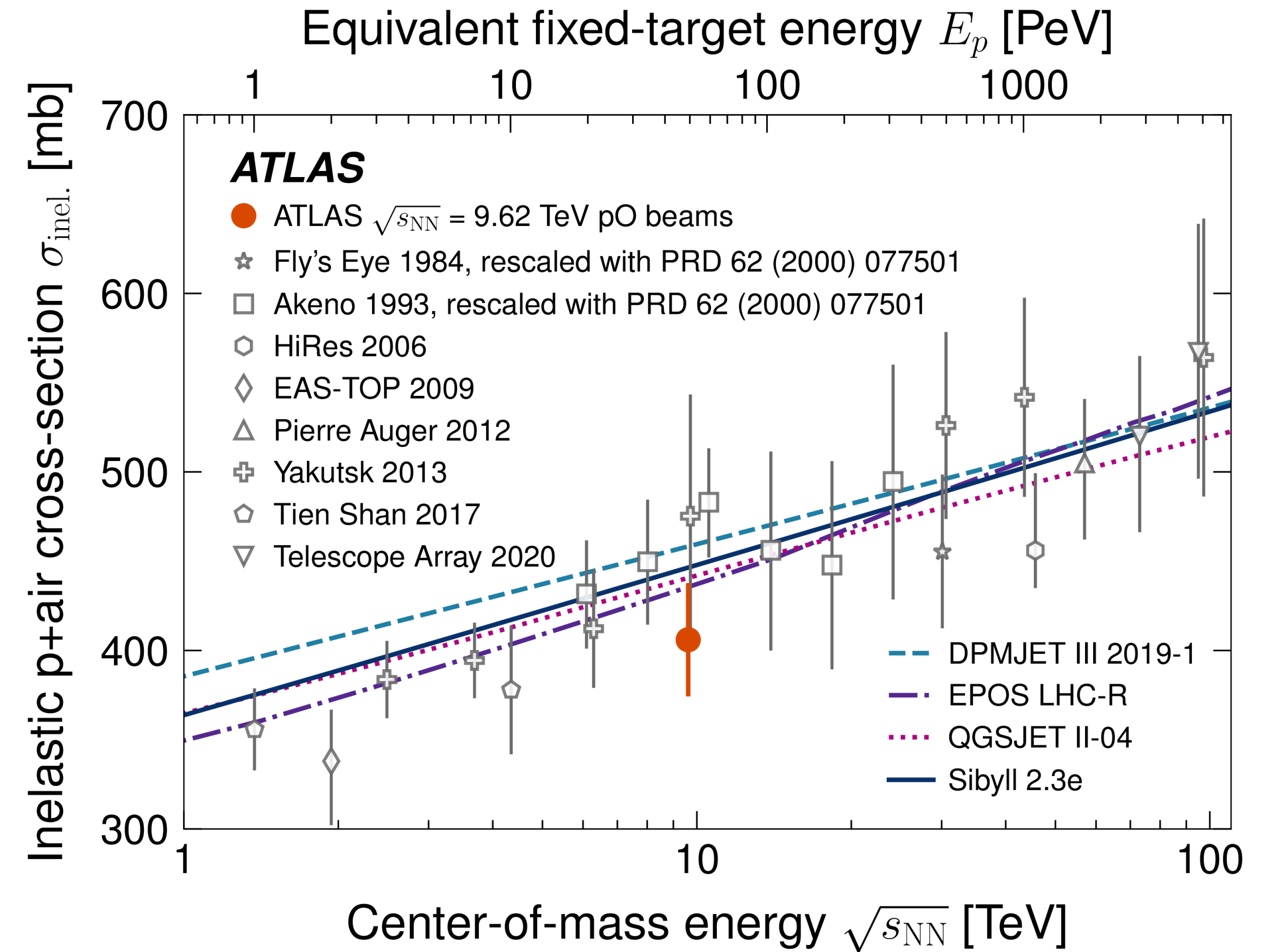
Charged particle production in p-O

- The LI run important for Astrophysics community
 - Essential for Ultra-High-Energy CR
 - Collider setup $\sqrt{s_{\text{NN}}}=9.62$ TeV $\rightarrow$ fixed target 49 PeV (3 orders $<$ GZK limit)
 - dedicated detector: LHCf - to calibrate cosmic-ray models:
in particular production of π^0 and γ at zero angle in p-Nitrogen
(Oxygen is a good proxy)
 - Optimal conditions for LHCf - very low pile-up: $\mu = 0.01$
(and two higher spots)
 $\rightarrow$ ATLAS collected much less $\mathcal{L}$, but the dataset has unique properties
- Key result will come from the LHCf collab. & (LHCf+ATLAS)
 - meantime ATLAS looked at particle production at mid rapidity

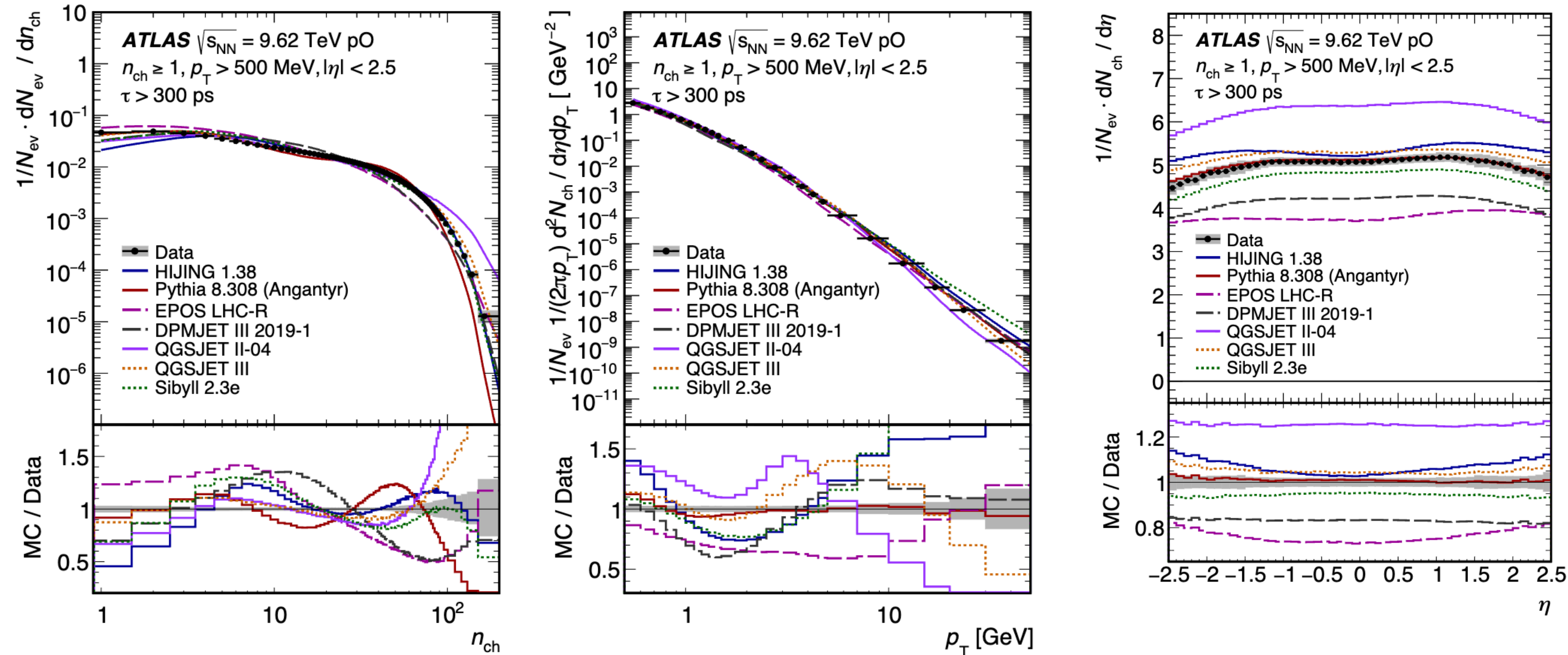
Charged particle production in p-O

- Events selection:
- Track trigger, PV with two low p_T tracks (combined inefficiency $\sim 0.5\%$),
Measurement: a good quality track
 $p_T > 0.5 \text{ GeV}$, $|\eta| < 2.5$ counting
- The fiducial x-section extrapolated to σ_{inel} using several generators:
DPMJET III 2019-1, EPOS LHC-R, Pythia 8.308, QGSJET II-04, Sibyll
- correction estimated to be
- Then corrected for O $\rightarrow$ Air

$$\sigma_{\text{inel.}}^{p+\text{air}} = 406 \pm 6 \text{ (exp.)} \pm 9 \text{ (lumi.)} \pm 28 \text{ (th.) mb.}$$



Charged particle production in p-O



- Also extracted differential distributions
 - All results unfolded e.g. $n_{sel}^{track} \rightarrow n_{ch}$ and compared to predictions of multiple models
- Significant deviations between the models and data
- Pythia seems to get low p_T part (and thus multiplicity) quite right

Charged particle production in OO and NeNe

- The $dN_{\text{ch}}/d\eta$ is important because of:
 - initial energy density
 - informs particle production
 - entropy profile (needed for process hydro)
- The evolution $\langle p_T \rangle$ with centrality is a manifestation of the radial flow $\rightarrow$ confirms hydrodynamisation, expected to rise with centrality
- Difference between OO and NeNe highlights the role of initial conditions

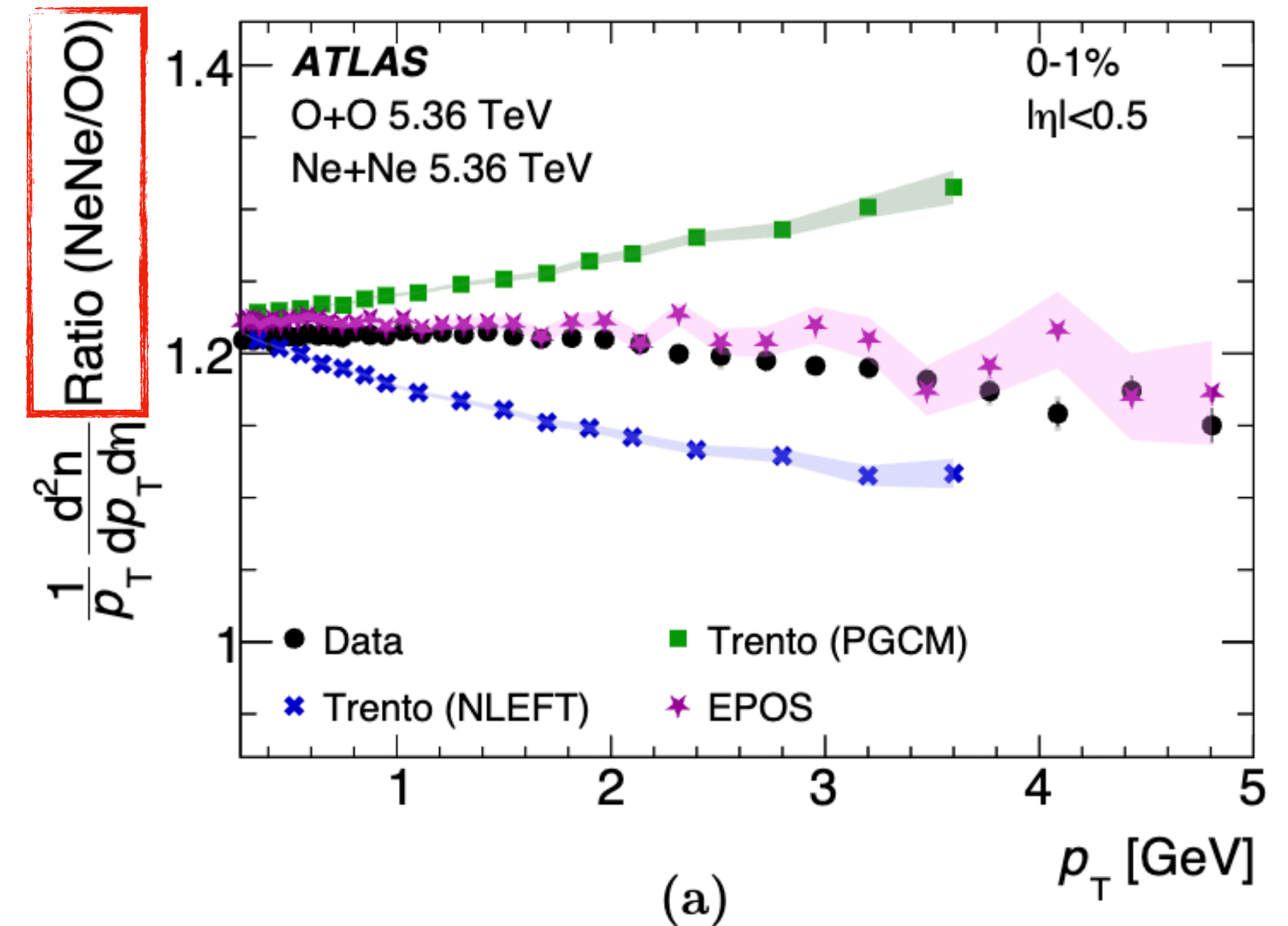
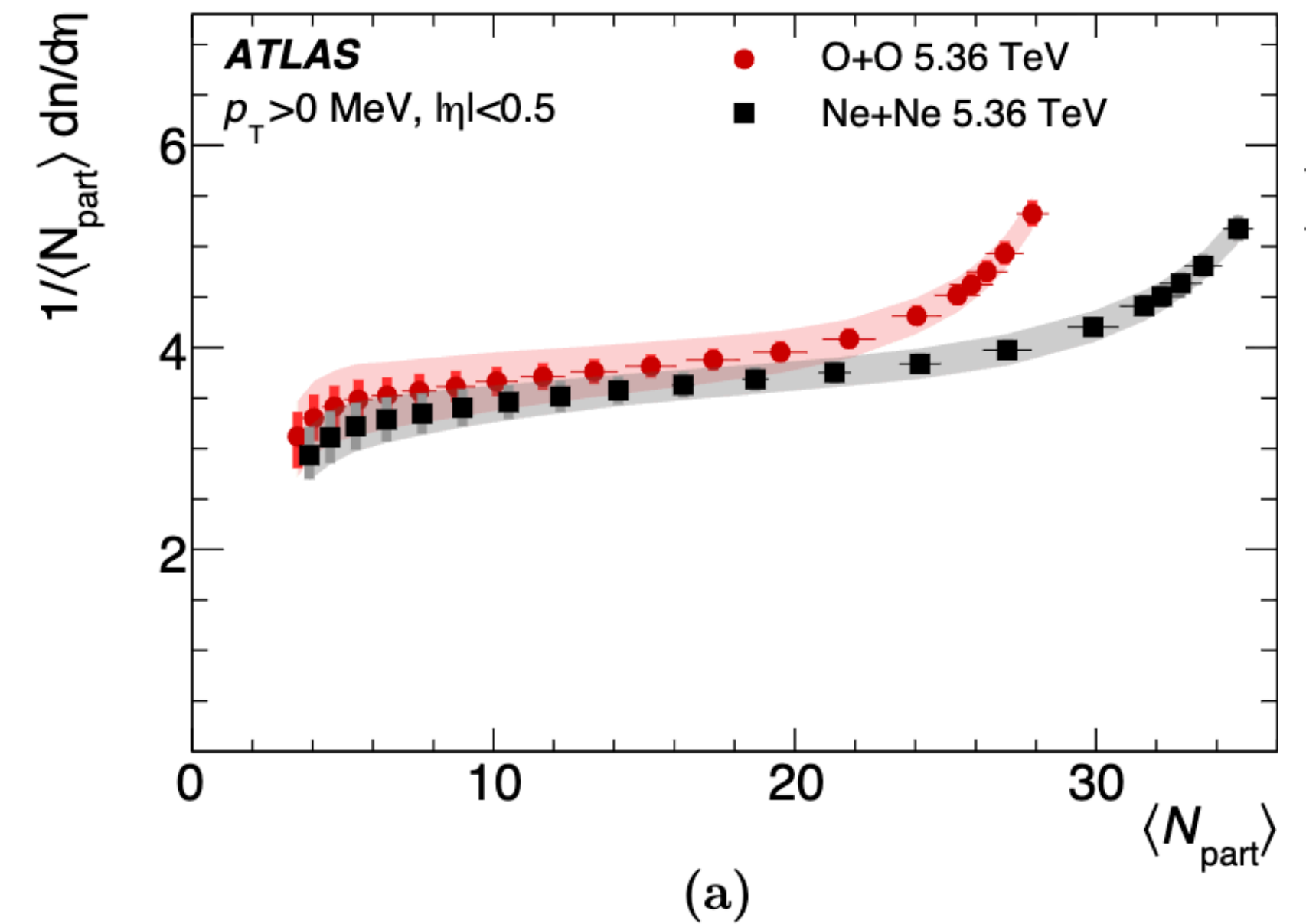
Measurement used ch. part. of p_T down to 0 GeV and up to 5 GeV

Binning in centrality following FCal energy
($\eta=3.2-4.9$) 0–70%

Details of this result will be presented in
dedicated talk by Soumya Mohapatra
Wednesday 2nd morning session

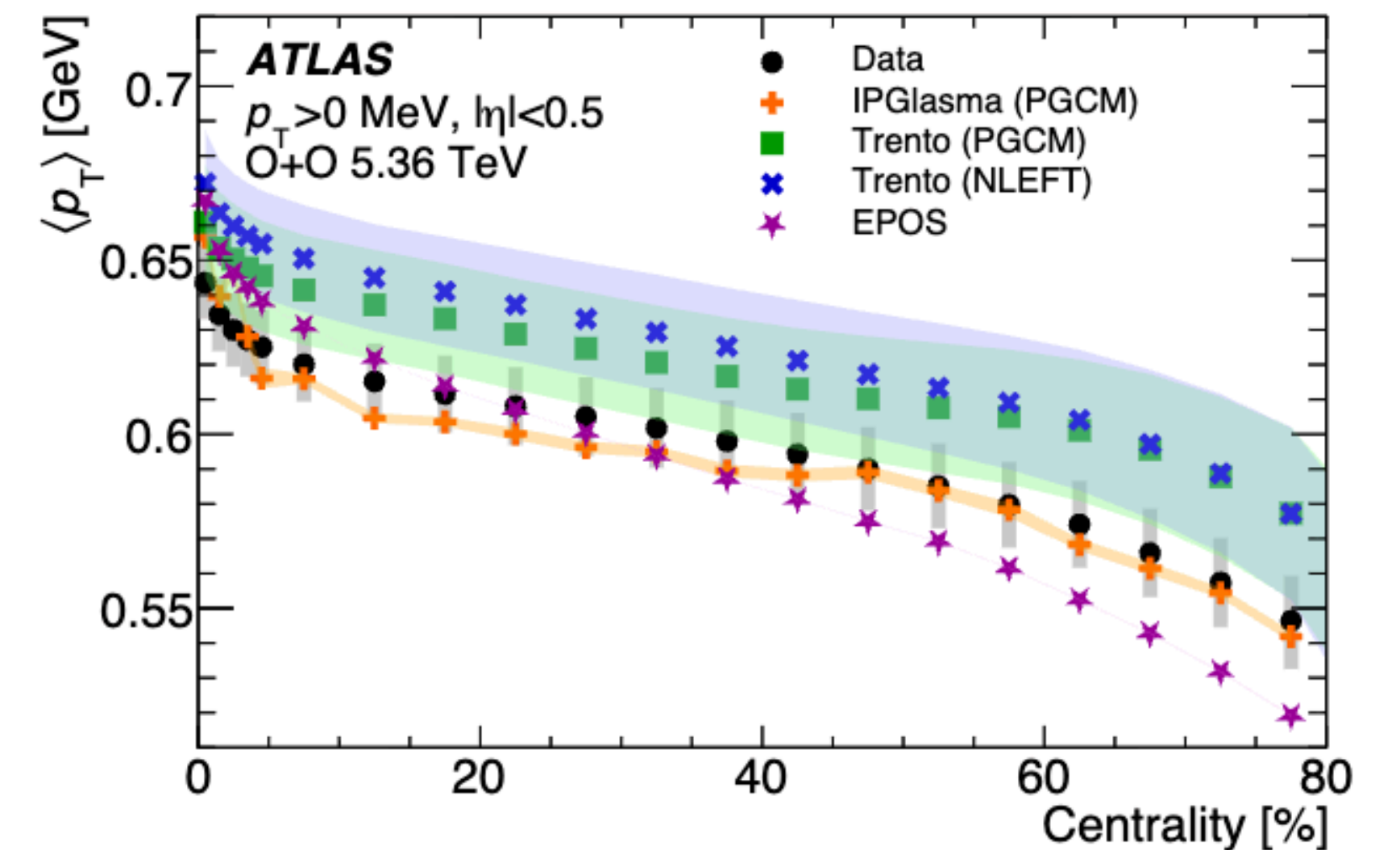
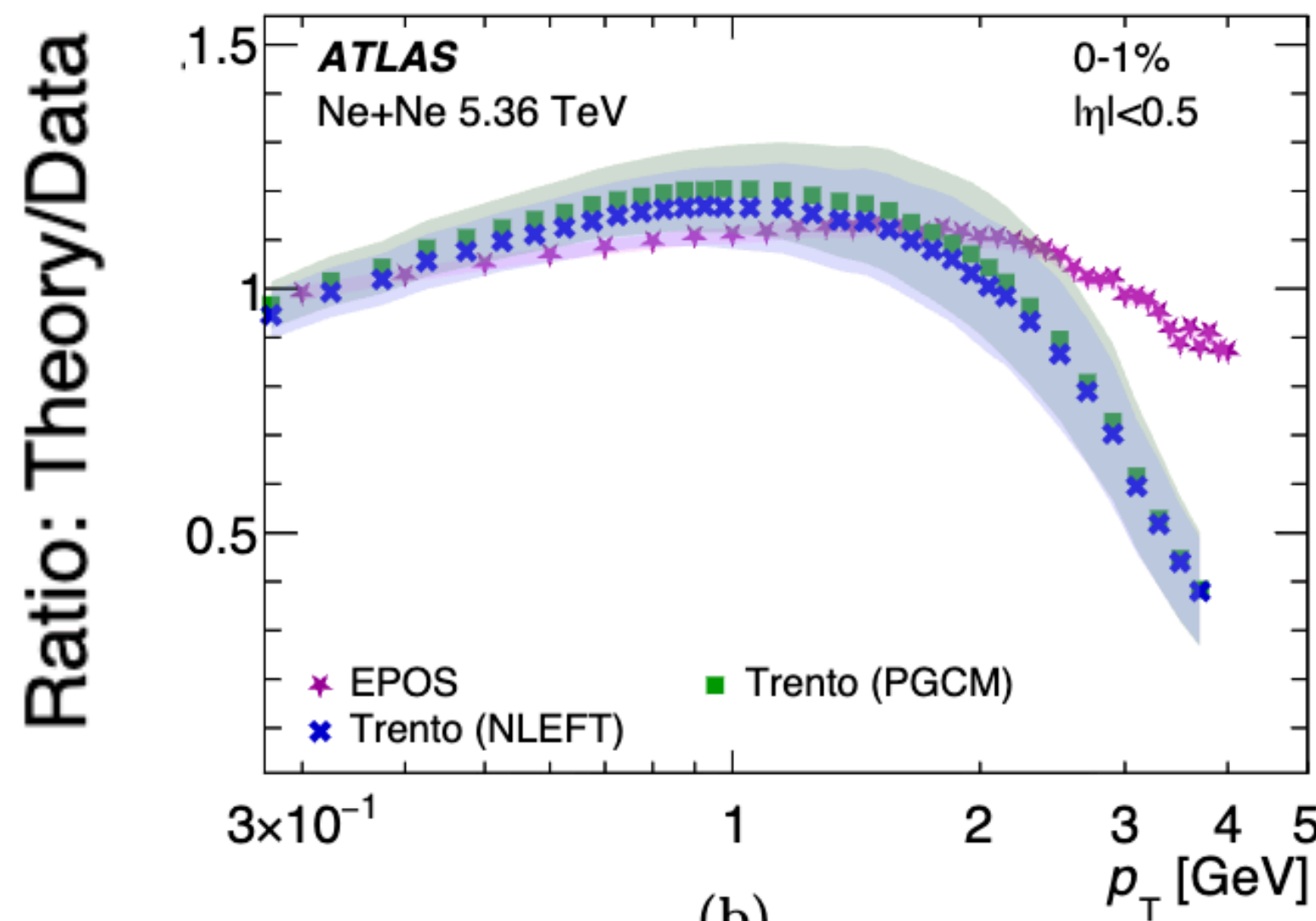
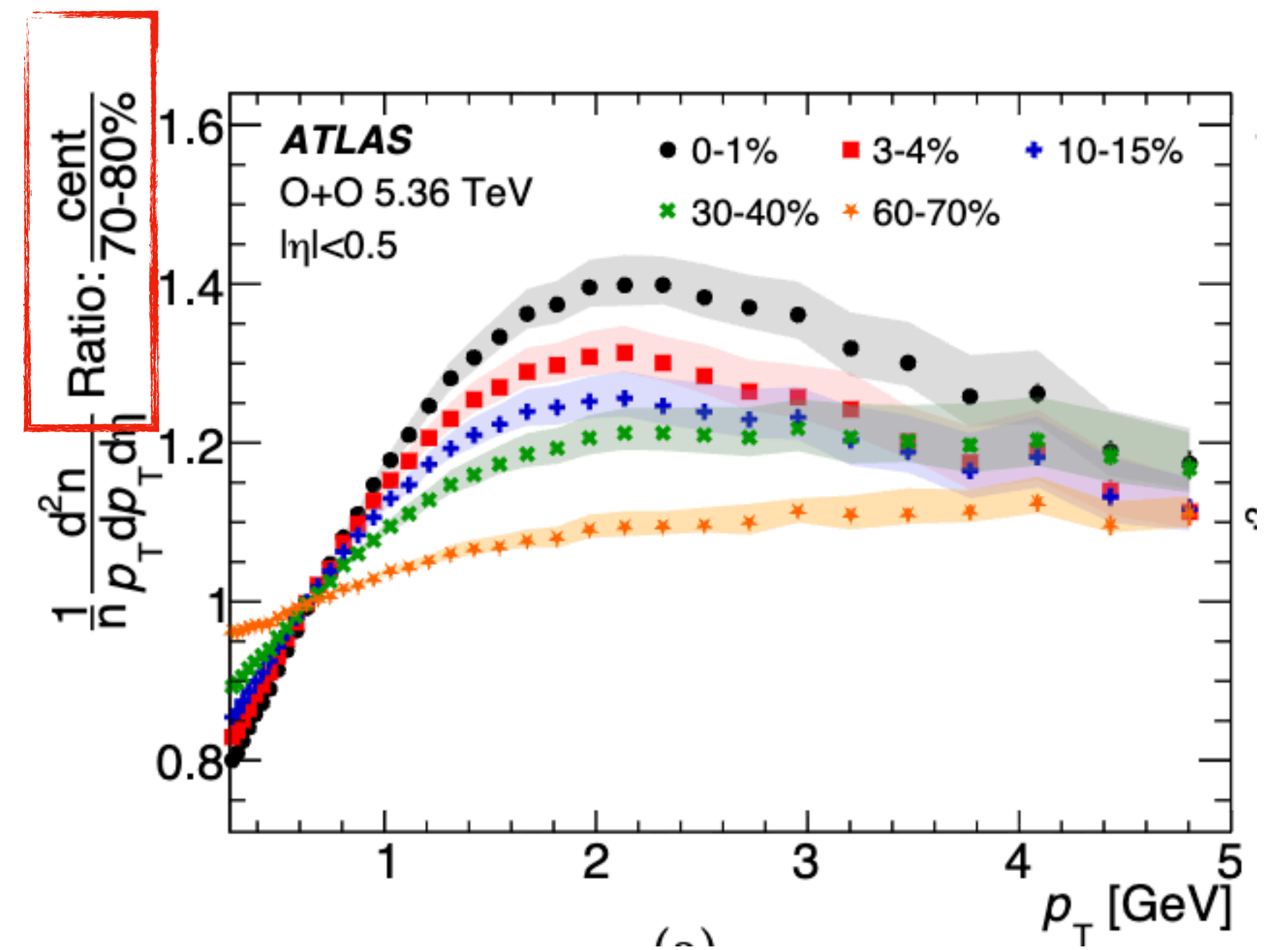
Multiplicity

- Linear rise of ch. part. production with centrality
- Evolution is consistent between NeNe and OO
- Rise in most central $\rightarrow$ constrained radial dimension and energy density fluctuations
- $dN_{\text{ch}}/d\eta|_{\eta \simeq 0}/\langle N_{\text{part}} \rangle$ at same centrality of OO and NeNe different by about 20%
- Spectra is slightly softer in NeNe
- Initial conditions in models: Trento+Trajectum (NLEFT vs PGCM) $\rightarrow$ opposite trend with p_T ! EPOS gets the ratio very well



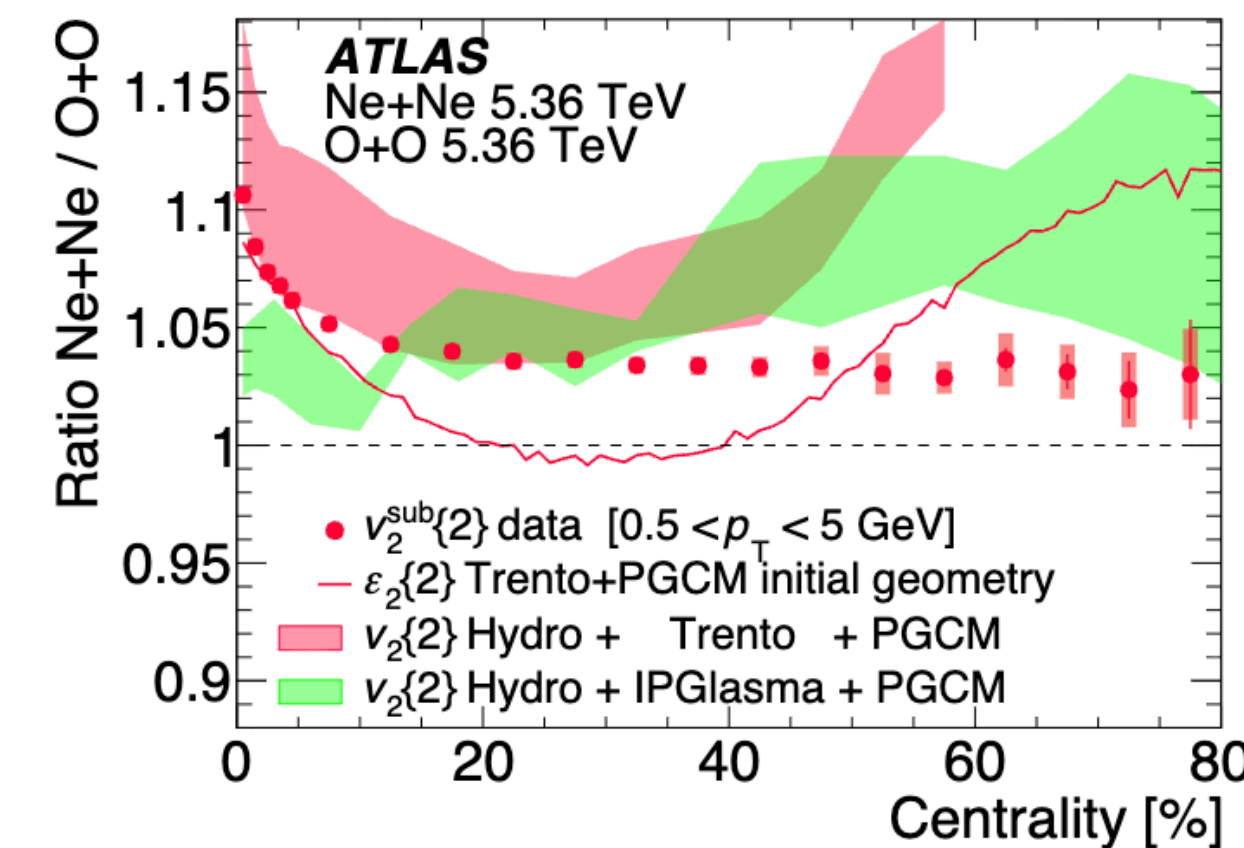
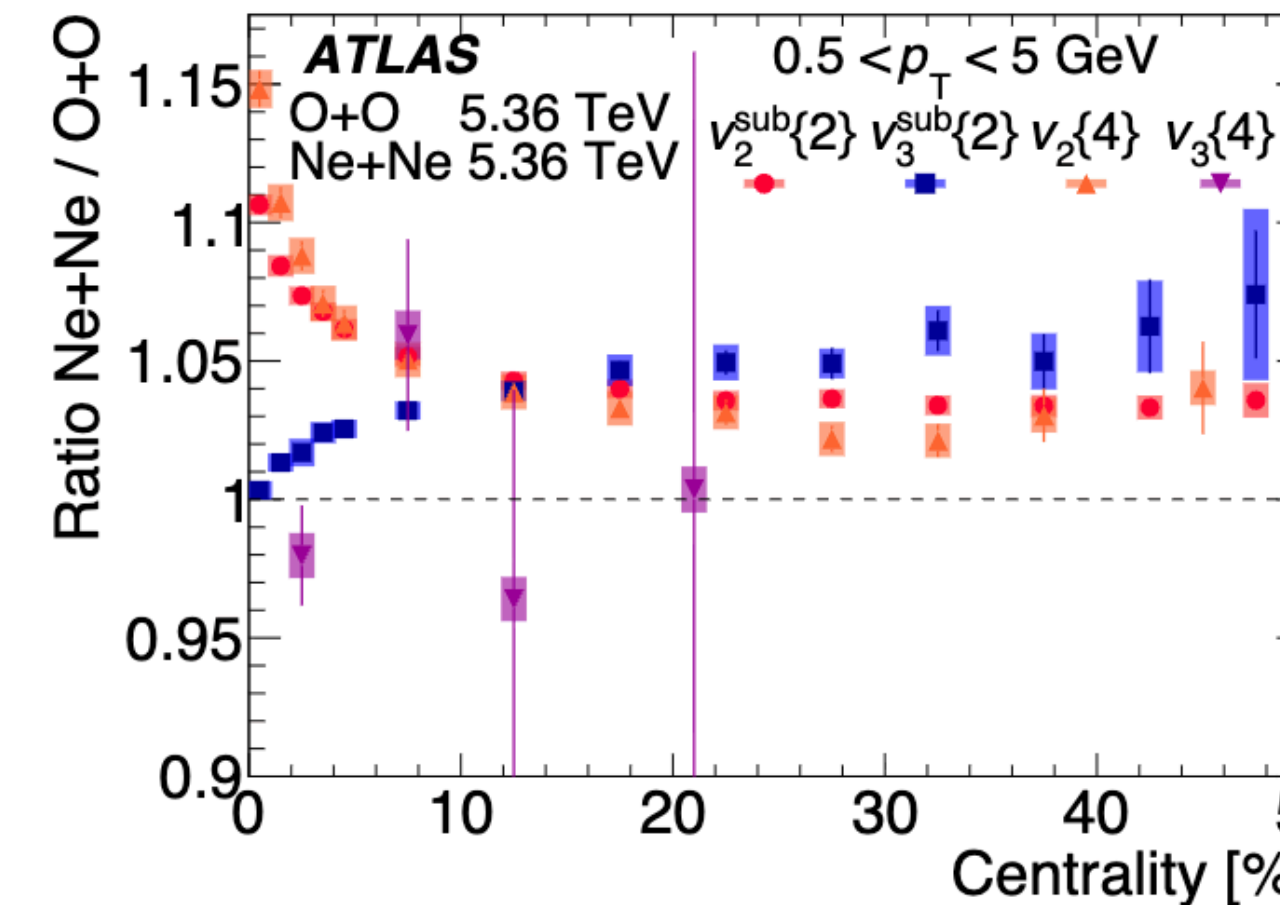
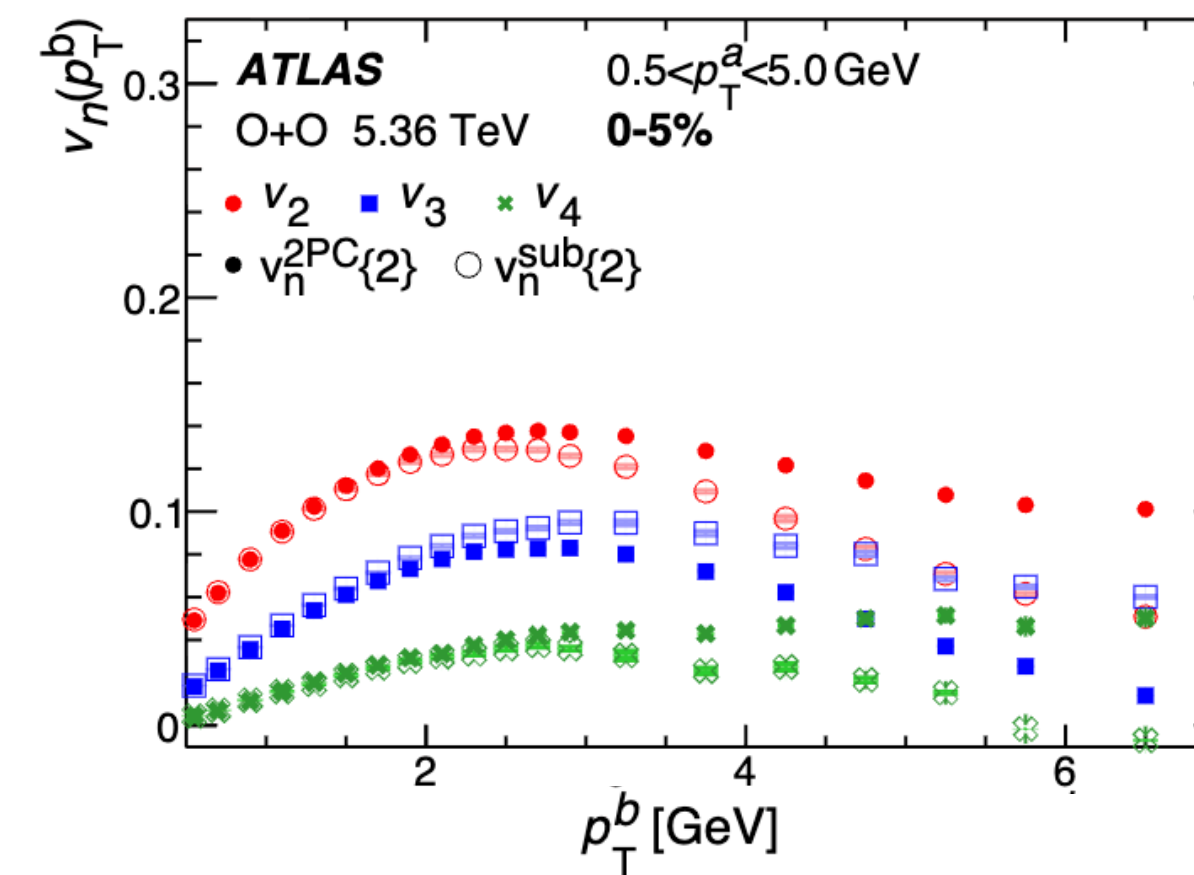
Low p_T spectra

- More central collisions indeed produce harder spectra
- A clear development of the radial flow
 - Same observed at different η
—> boost invariant (in ATLAS acceptance: 2.5)
- The $\langle p_T \rangle$ (low p_T dominated) evolution with centrality well reproduced by models
- IS models + Hydro get the trend roughly correct < 2 GeV but underestimate production above



The anisotropic flow

- Two primary questions addressed:
 - Is there QGP phase created in LI?
 - Do we have sensitivity to initial geometry?
- p_T differential and integrated v_2 , v_3 , v_4 obtained, 2PC with template fit for non-flow subtraction & multi-particle sub-event methods
- The strength of the result lies in ratios
- Existing predictions follow the data but had large uncertainties



Energy loss of high p_T hadrons in QGP

- Can be access via several observables
 - ATLAS performed di-jet balance measurement
 - γ -hadron correlations
 - and jets v_n

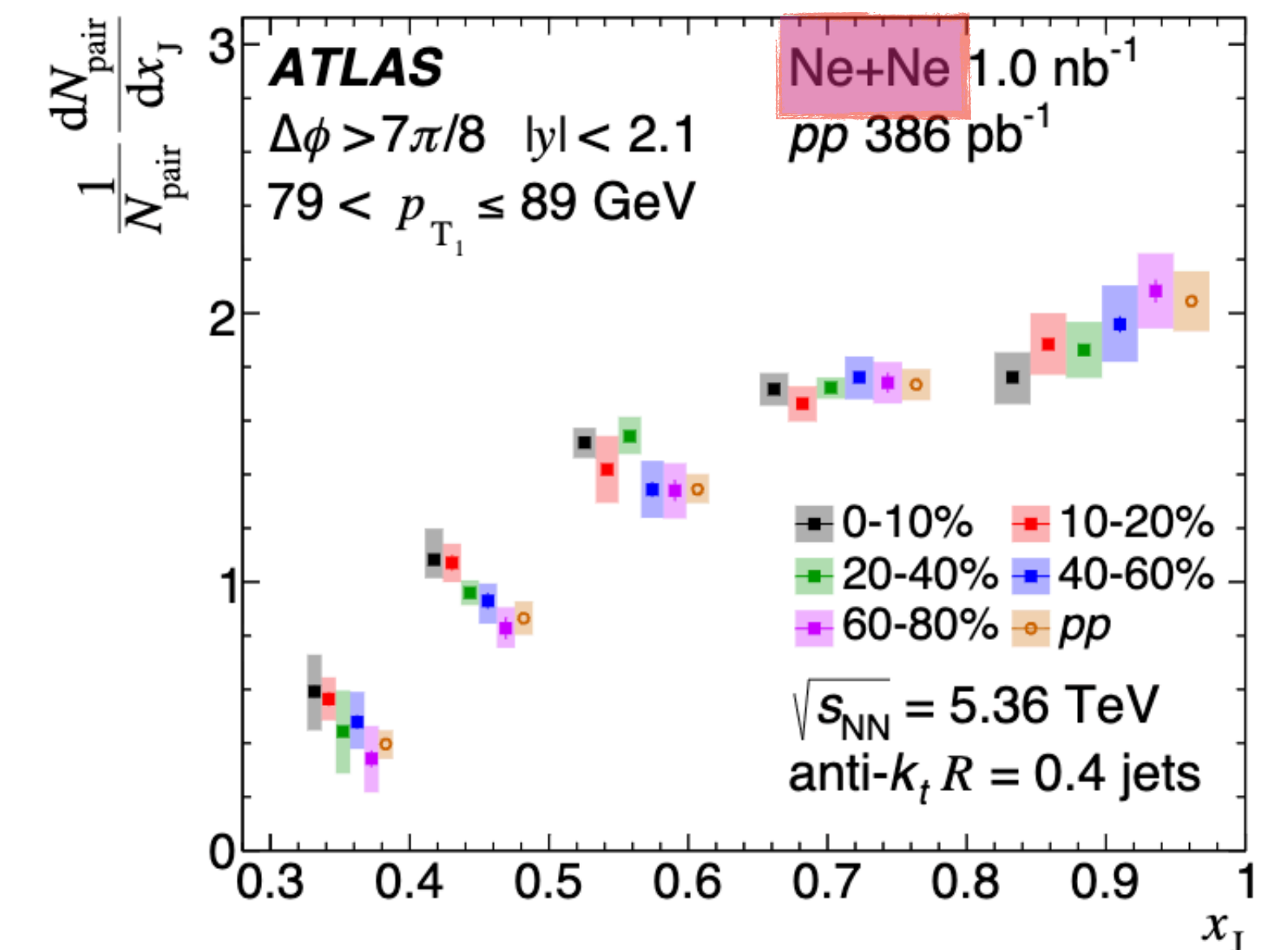
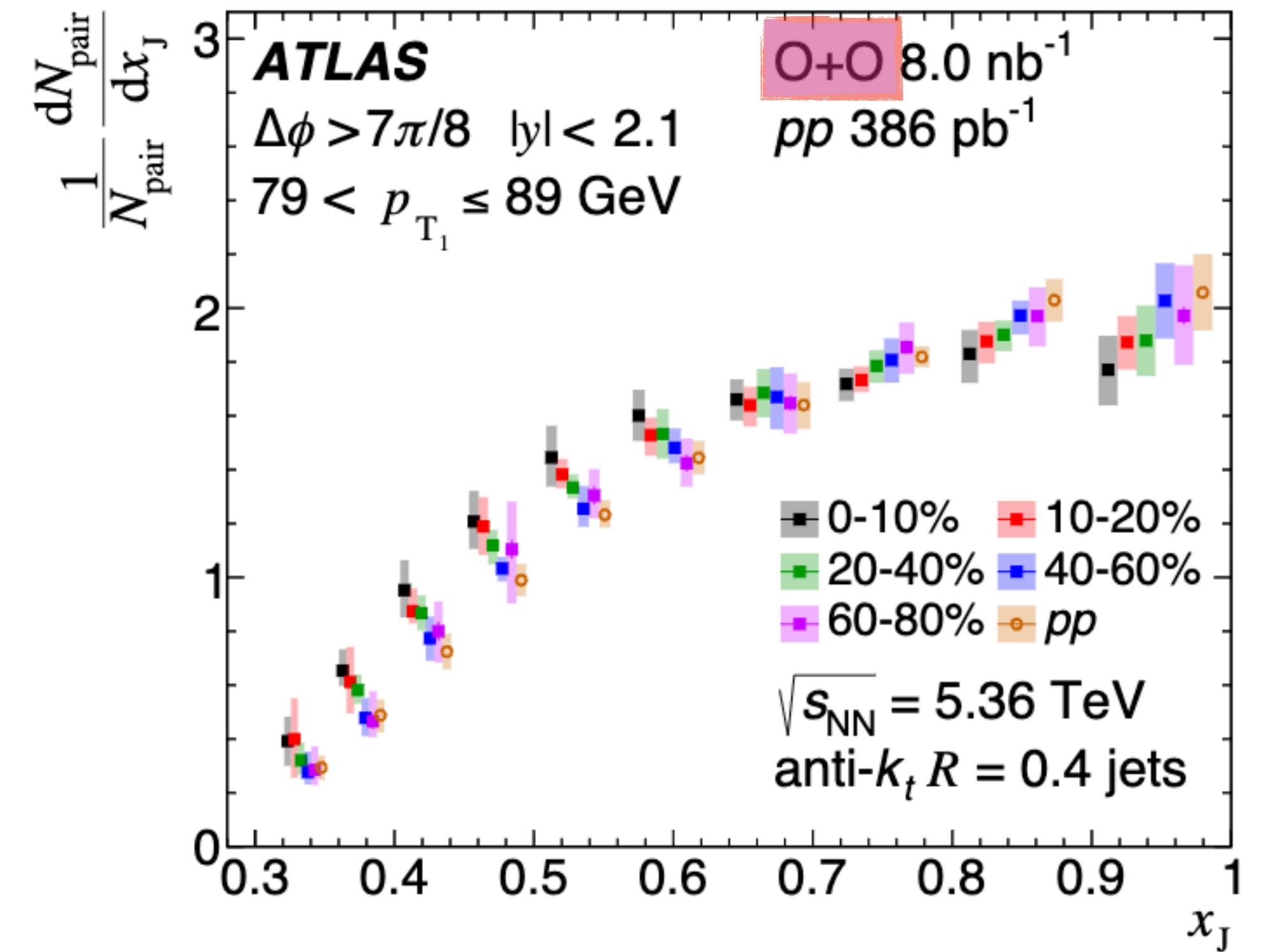
Main advantage - insensitive to overall normalisation (i.e. luminosity, T_{AA} etc.)

More details in talk by Anne Sickles
Tuesday, 2nd afternoon session

Di-jet momentum (im)balance

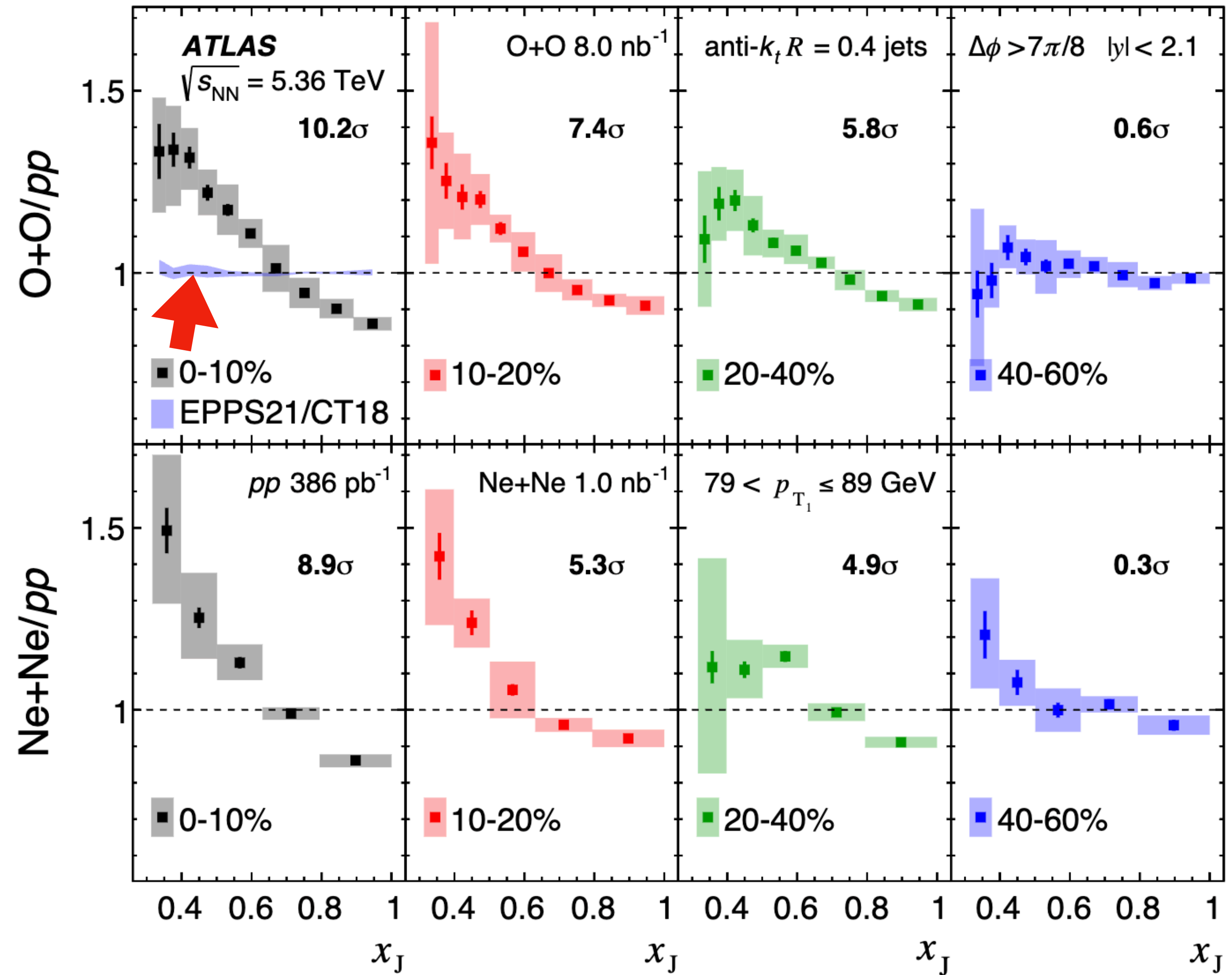
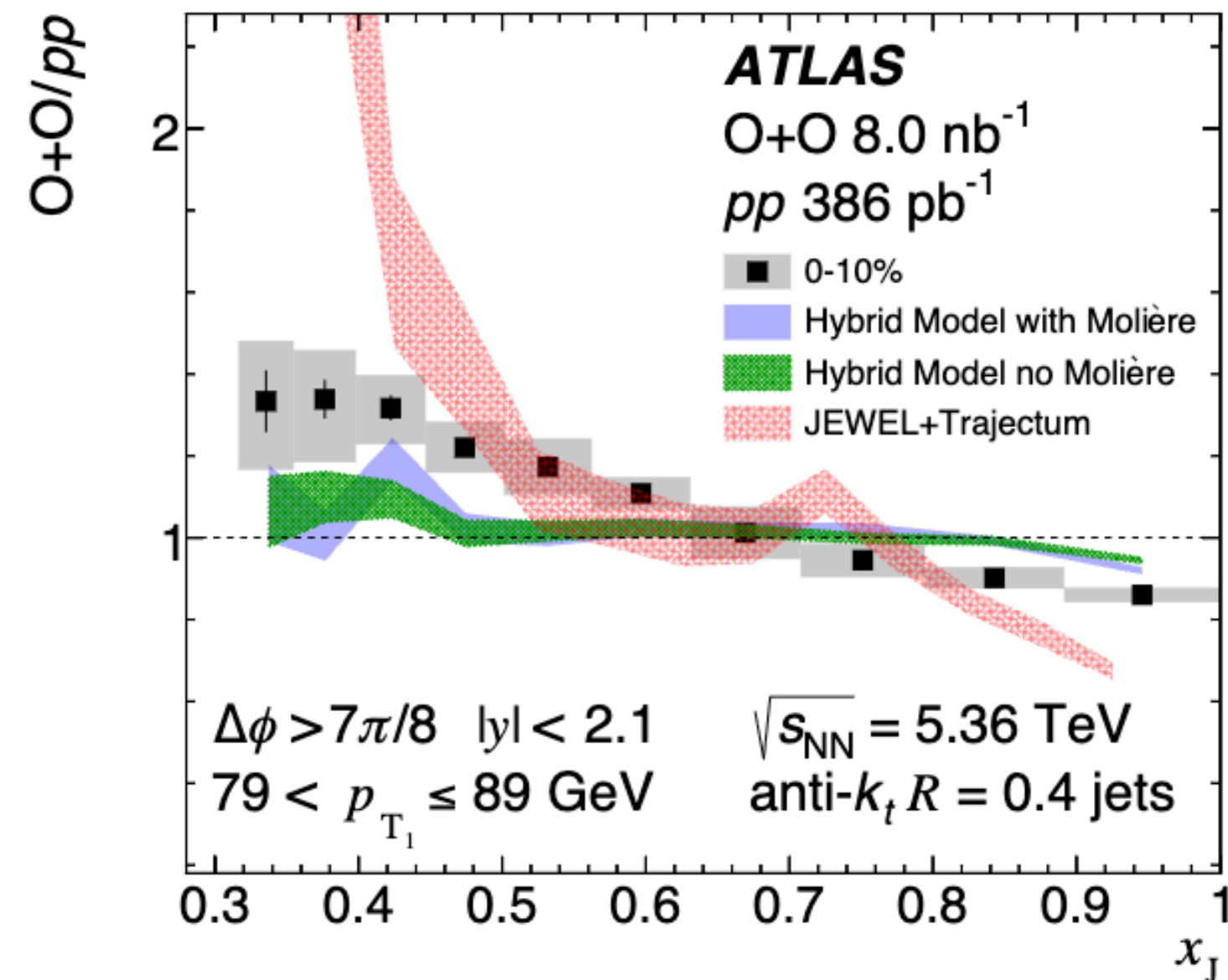
- Measured quantity is:

$$x_J = p_T^{\text{subleading}} / p_T^{\text{leading}}$$
 and compared to pp & across centralities
- Self normalised quantity
- Insensitive to nPDFs in comp. e.g. to R_{AA}
- Well established methodology in ATLAS
 - Enabled by very good understanding of jets calibration (UE subtraction, Data Overlay- JER)
- Lower UE activity $\rightarrow$ lower jet min p_T compared to PbPb



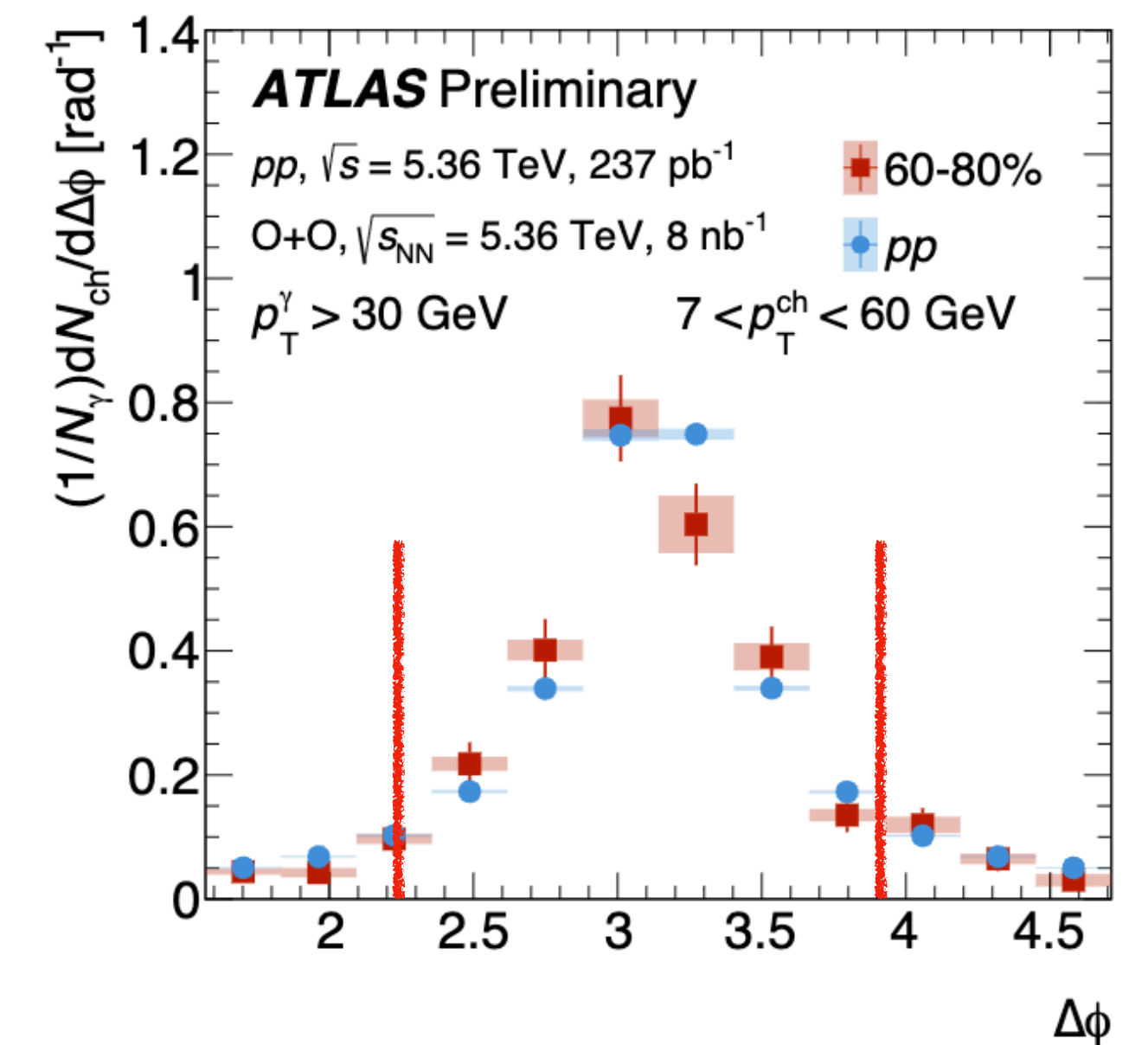
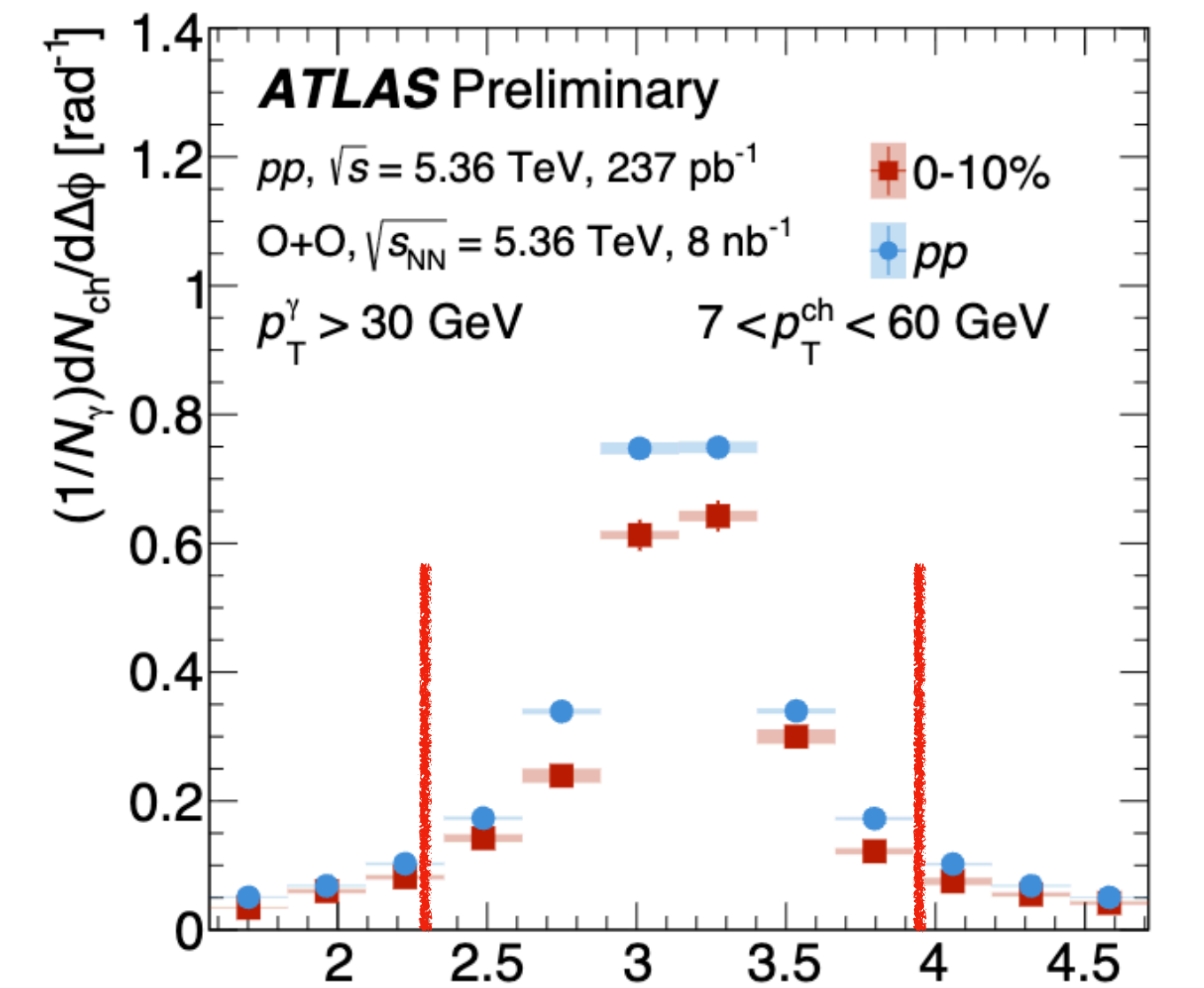
Signal strength

- The double ratio $dN_{pair}/N_{pair}dx_J$
O+O/pp
- Significant effect down to mid-central collisions
(nPDF effect very small)
- Theory predictions at a similar level



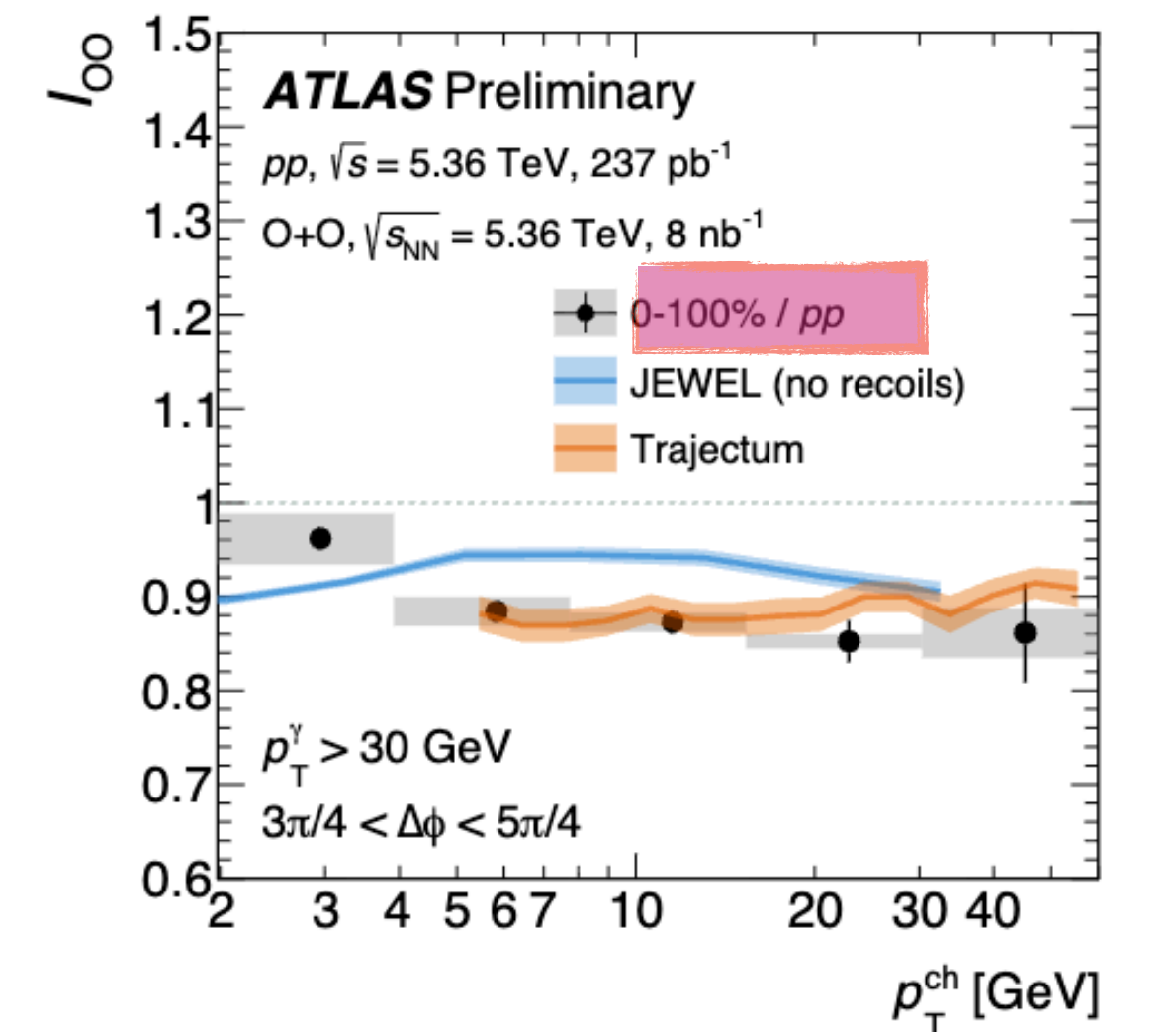
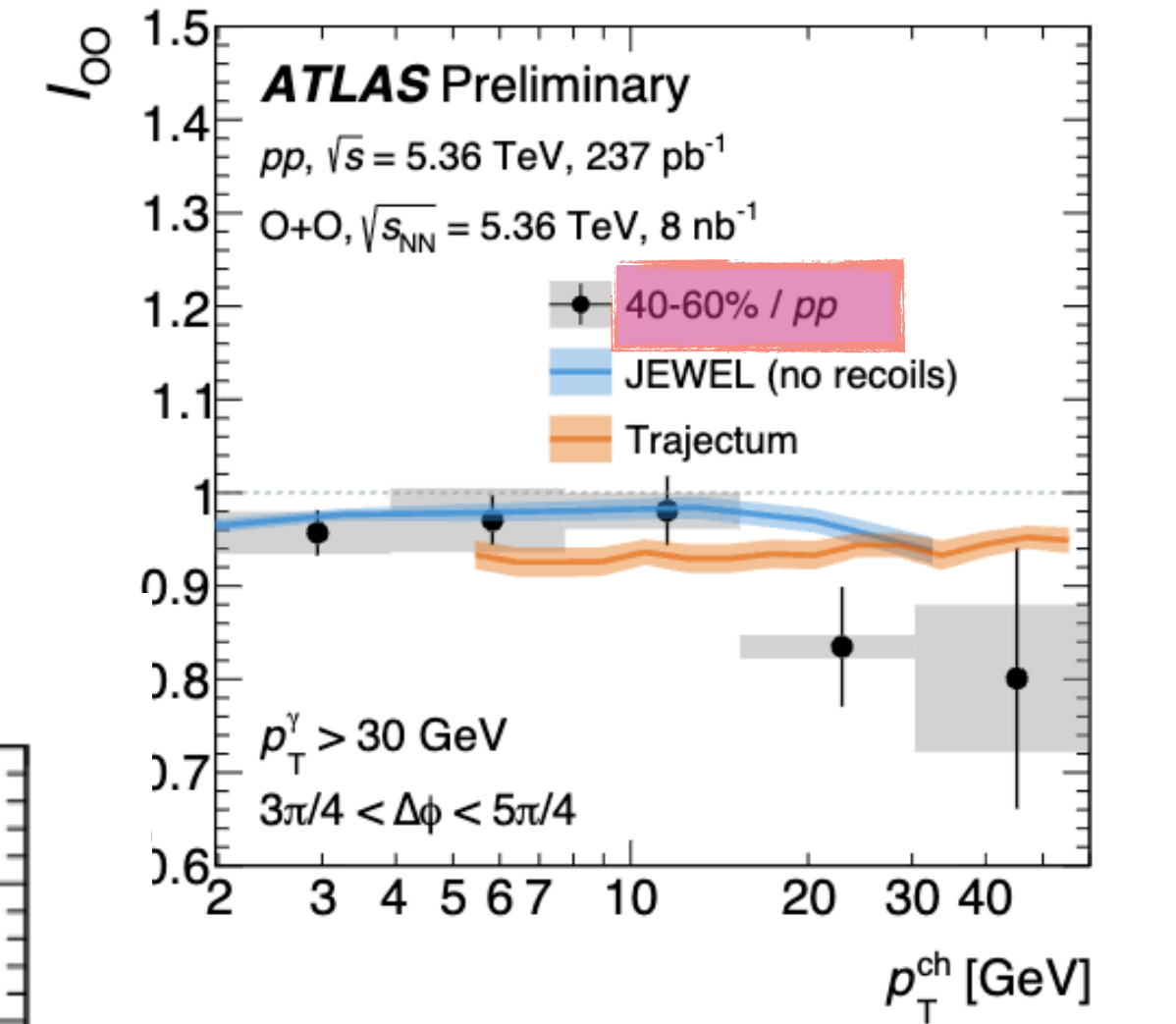
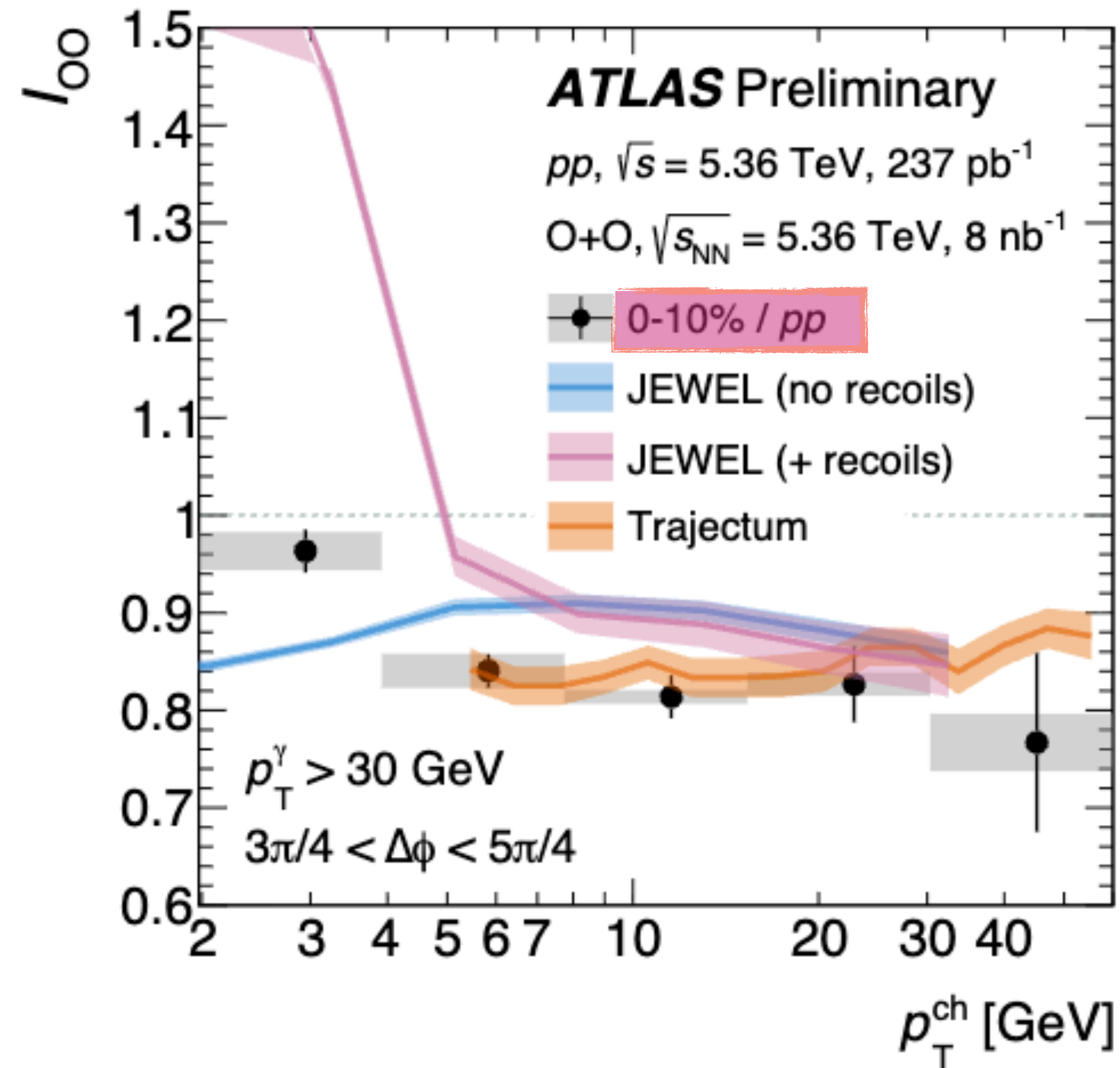
Measurement of γ -h associated yields

- Hadron yields emitted back to back to isolated γ
 $\rightarrow$ energy loss in jet down to a lower $h \cdot p_T$
- Analysis details:
 - hadrons back to back to γ
 $3/4\pi < \Delta\phi < 5/4\pi$
 - $p_T^\gamma > 30$ GeV, hadrons down to 2 GeV
 - UE hadrons estimated from data
 - The yields are obtained in centrality bins
 hadron p_T differentially



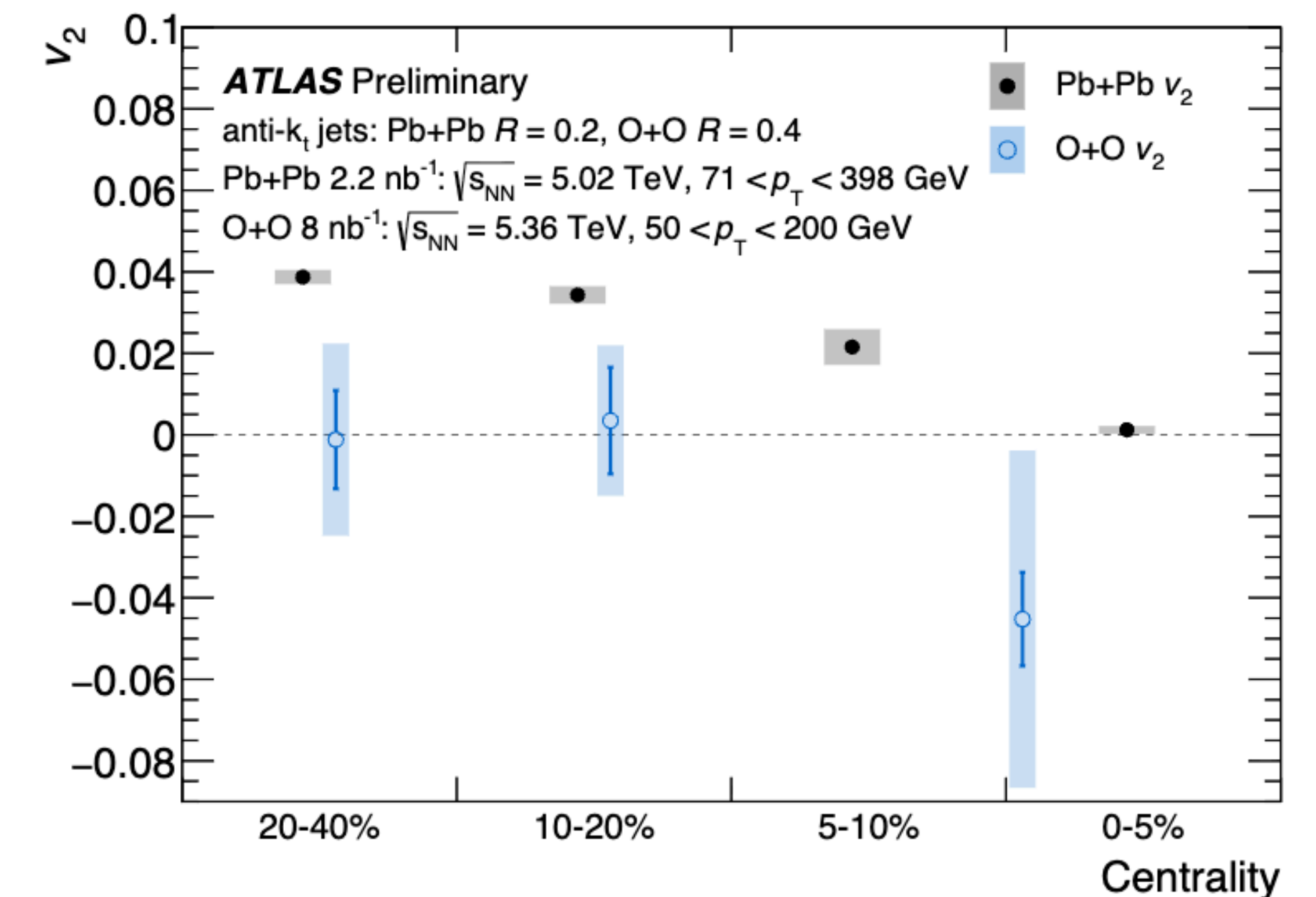
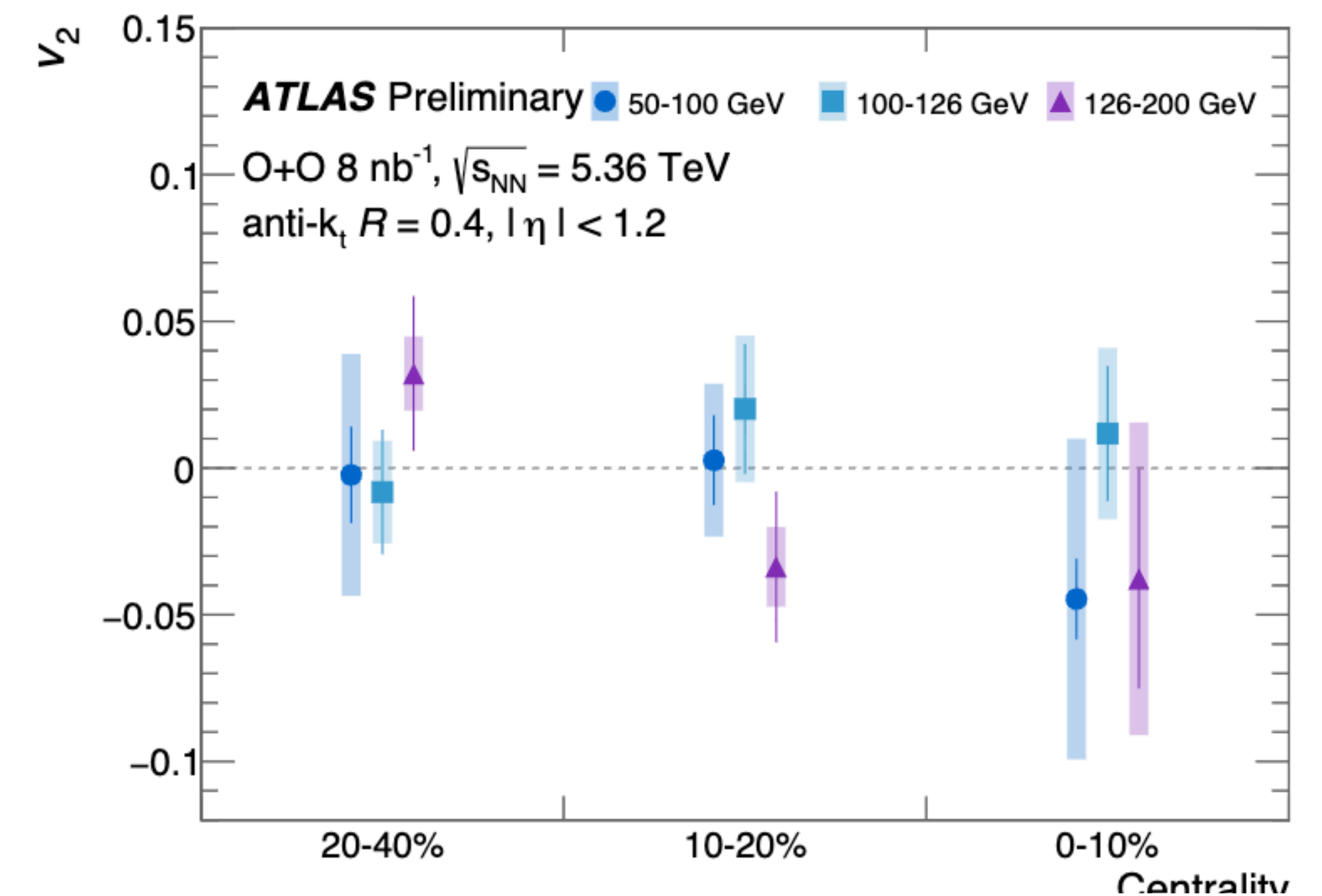
Measurement of γ -h associated yields

- Suppression studied by $I_{OO} = Y_{O+O}/Y_{pp}$
- it is strongest in most central and diminishing ($I_{OO}=1$) for peripheral events
- The suppression is visible for hadrons $p_T > 4$ GeV and is flat with p_T
- Model predictions: JEWEL (two variants, Trajectum) work actually quite well



Jets v_n

- The correlation between azimuthally nonuniform QGP droplet and jets $\rightarrow$ path length e. loss dependence
- It can be observed as high p_T hadrons flow or jets flow
- ATLAS is in the process of extracting the later us Scalar-Product method, non-flow subtracted, unfolded
- So far the signal seems not to be there
 - Uncertainties are too large for now
- Further improvements on methodology are expected for final results



Thoughts about the future

- HI and LI expands the ATLAS physics with unique probes of QCD matter and nuclear structure.
 - Relies on dedicated expertise and capabilities across the experiment:
 - Specialized detector systems (e.g. ZDC) or detector settings
 - Trigger & DAQ developments
 - Reconstruction software and non-standard MC production
- Run 4 and beyond: maximizing the scientific impact of the programme through
 - Priority Pb+Pb measurements and luminosity goals
 - A complementary and **equally important** Light-Ion (LI) programme
- Ongoing discussions focus on optimizing the running strategy to maximize physics output and operational efficiency across all programmes.

Monica Dunford will cover this
aspect on Friday

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Jet vn CONF-2026-006

Thank you