

Jet production in O+O with the sPHENIX detector

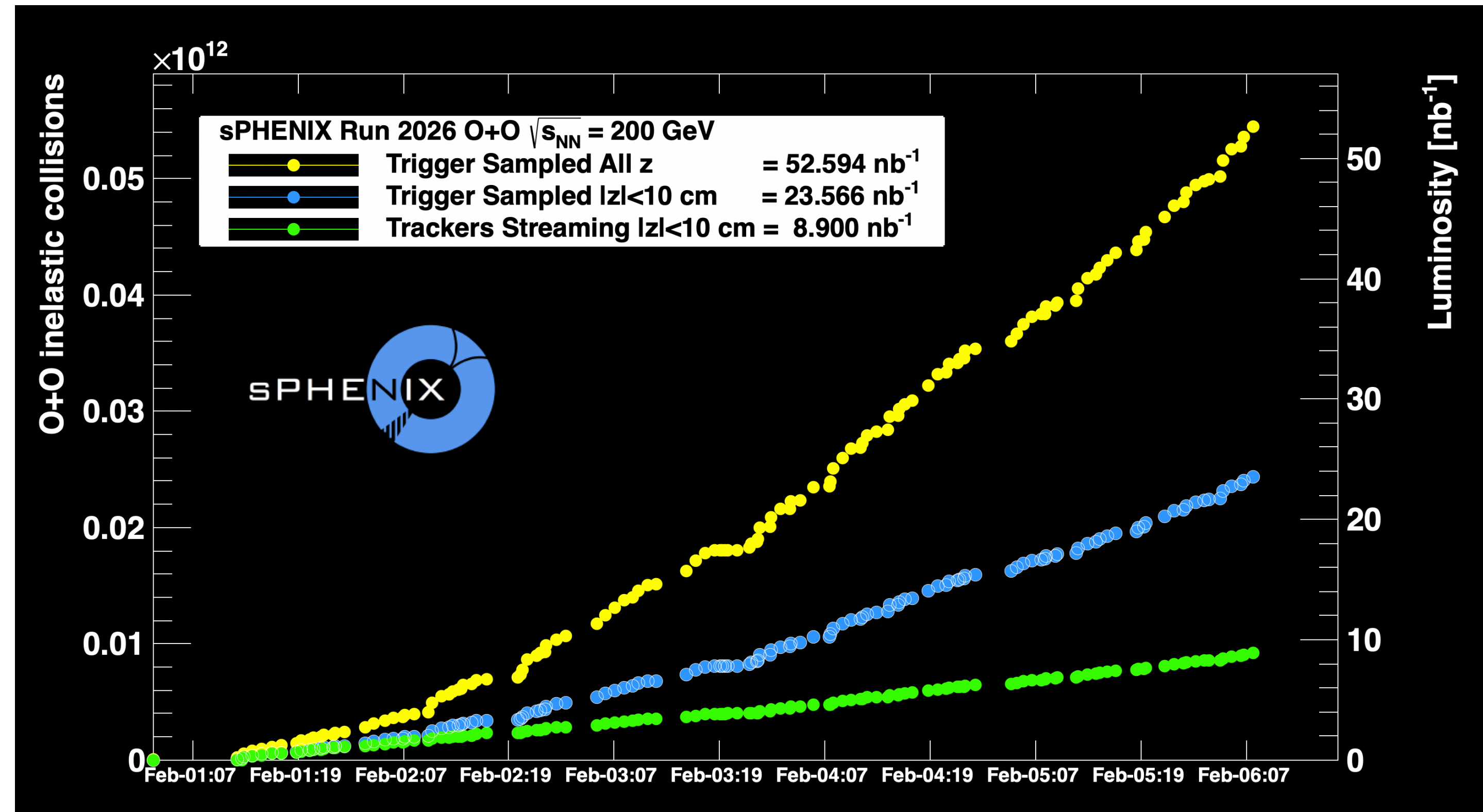
JaeBeom Park (University of Colorado Boulder)
on behalf of the sPHENIX Collaboration
— *EMMI Workshop: Light-ion collisions 2026* —

2026. 09. 22



sPHENIX Oxygen+Oxygen running

sPHENIX Experiment
2026-2-1, Run 82420
Collisions: O+O @ $\sqrt{s_{NN}} = 200$ GeV

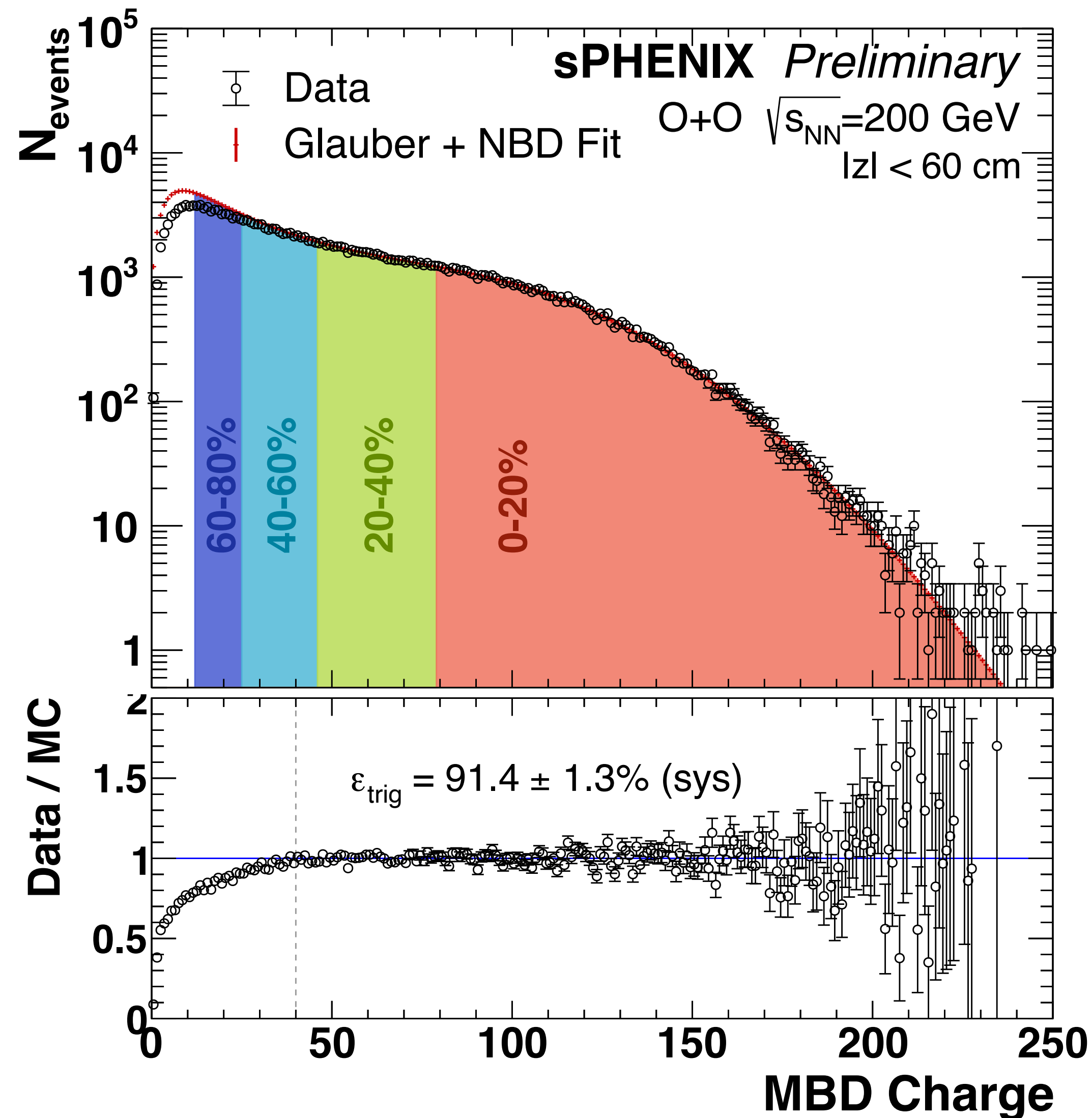


- **53 nb^{-1}** of jet & photon triggered sample
- Valuable for studying **system-size landscape**

*See also Rosi Reed [talk](#) for more details about dataset and detector

Centrality in Oxygen-Oxygen 200 GeV

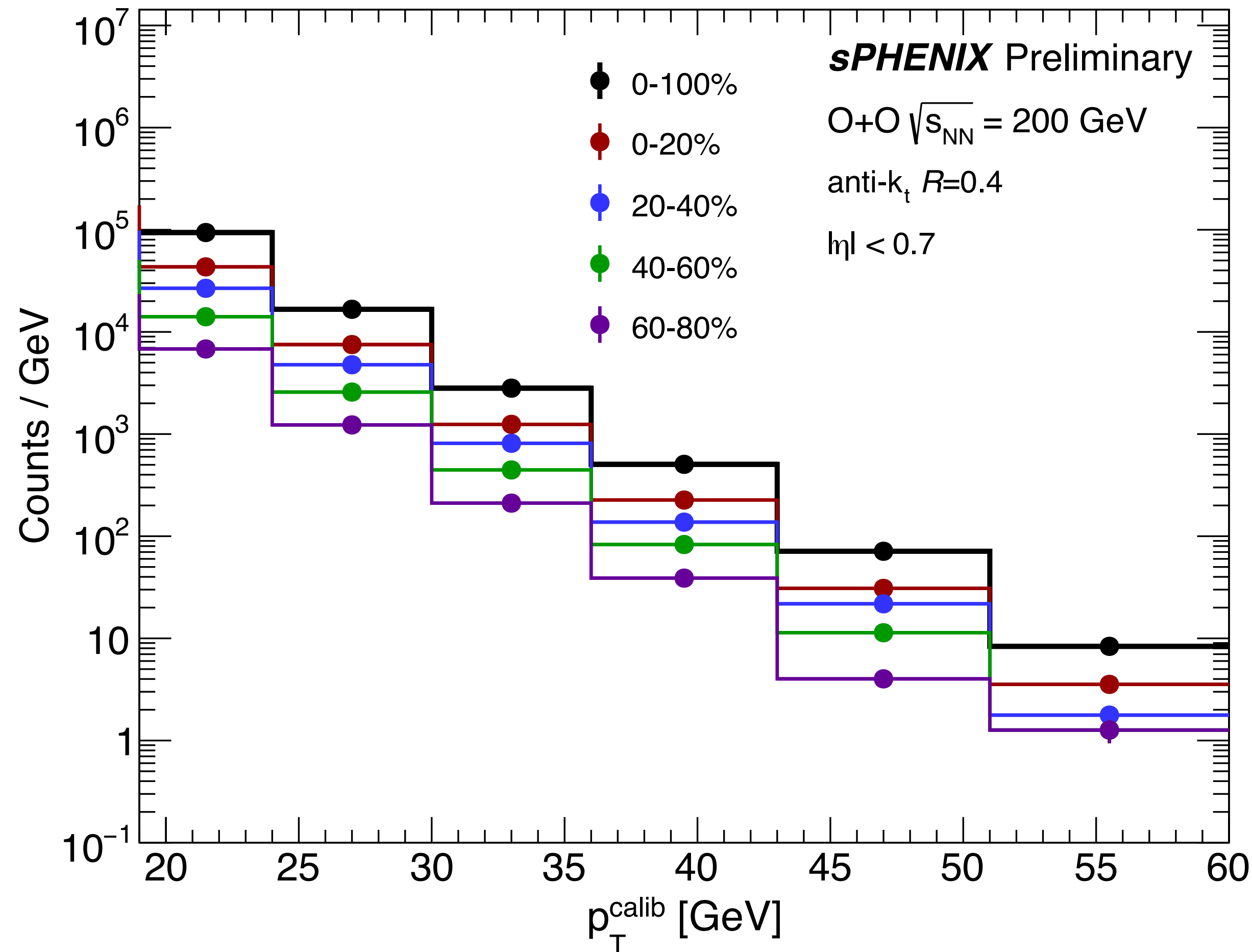
[sPH-CONF-JET-2026-02]



- Forward minimum bias detector (MBD)
 $3.51 < |\eta| < 4.61$ used for centrality calibration
- Centrality calibrated with Glauber + NBD fit using simple N_{part} scaling
- Uncertainties on Glauber variables constrained within $< 5\%$

Jet spectra in Oxygen+Oxygen 200 GeV

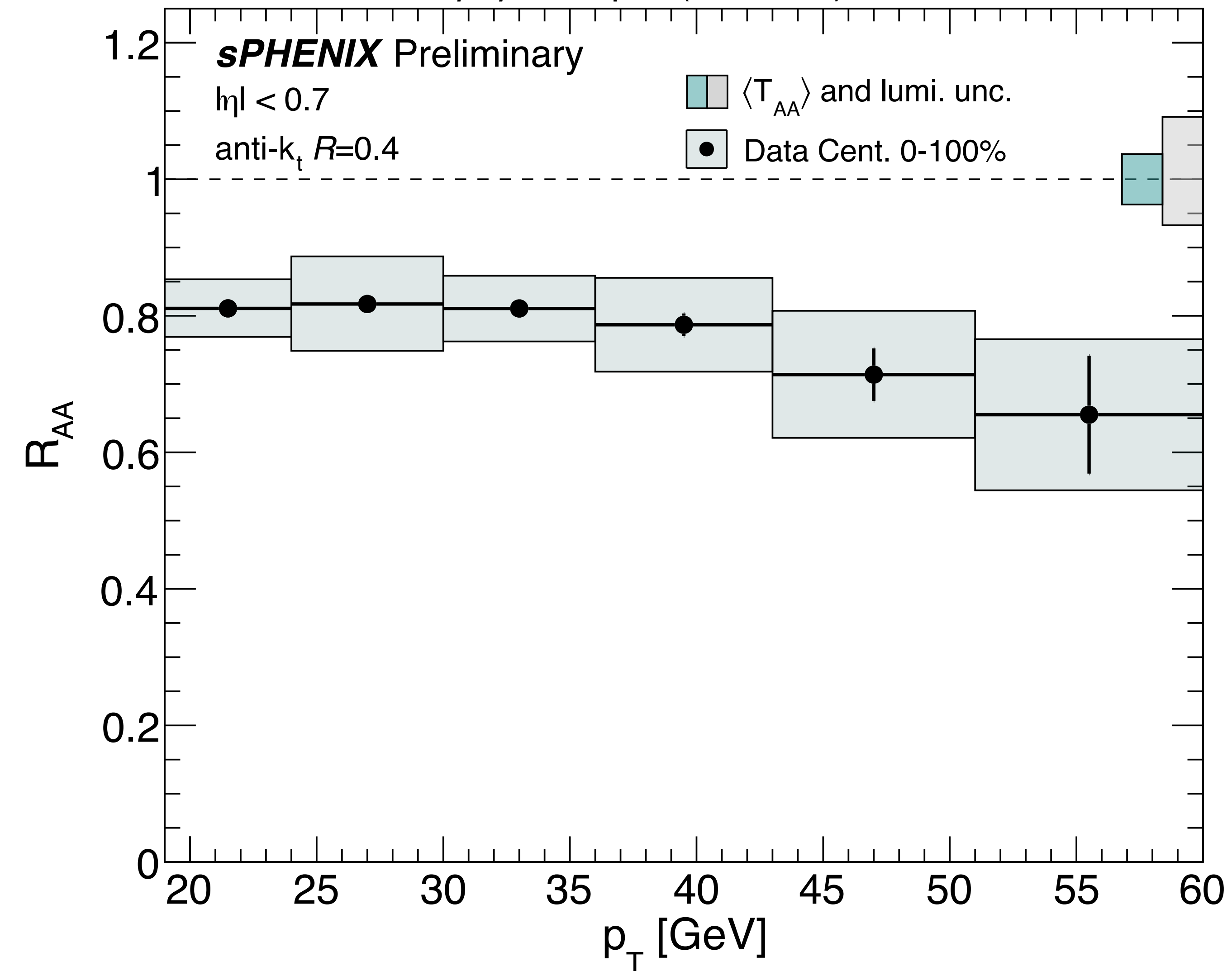
[sPH-CONF-JET-2026-02]



- Jet reconstructed for anti- k_t $R=0.4$
- Measured jet spectra over wide range of p_T 19-60 GeV
- UE estimated using iterative method
 - 0.5-1.0 GeV up to 2.5-3.0 GeV from peripheral to central collisions in $R=0.4$

Jet R_{AA} in Oxygen-Oxygen 200 GeV

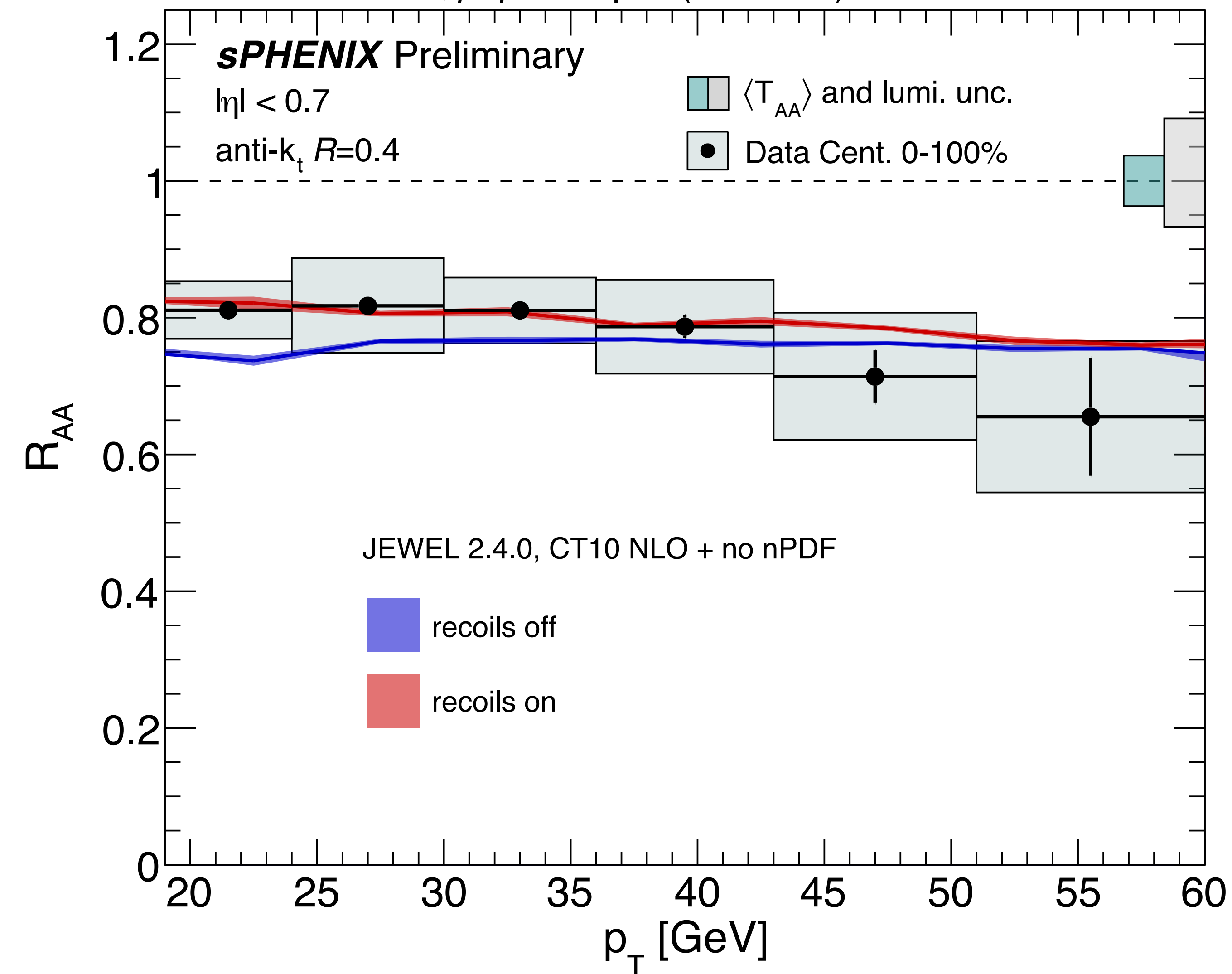
O+O 48.2 nb⁻¹, p+p 21.3 pb⁻¹ (200 GeV) [sPH-CONF-JET-2026-02]



- **Suppression** of jet yields in O+O
- **Weak** dependence on p_T

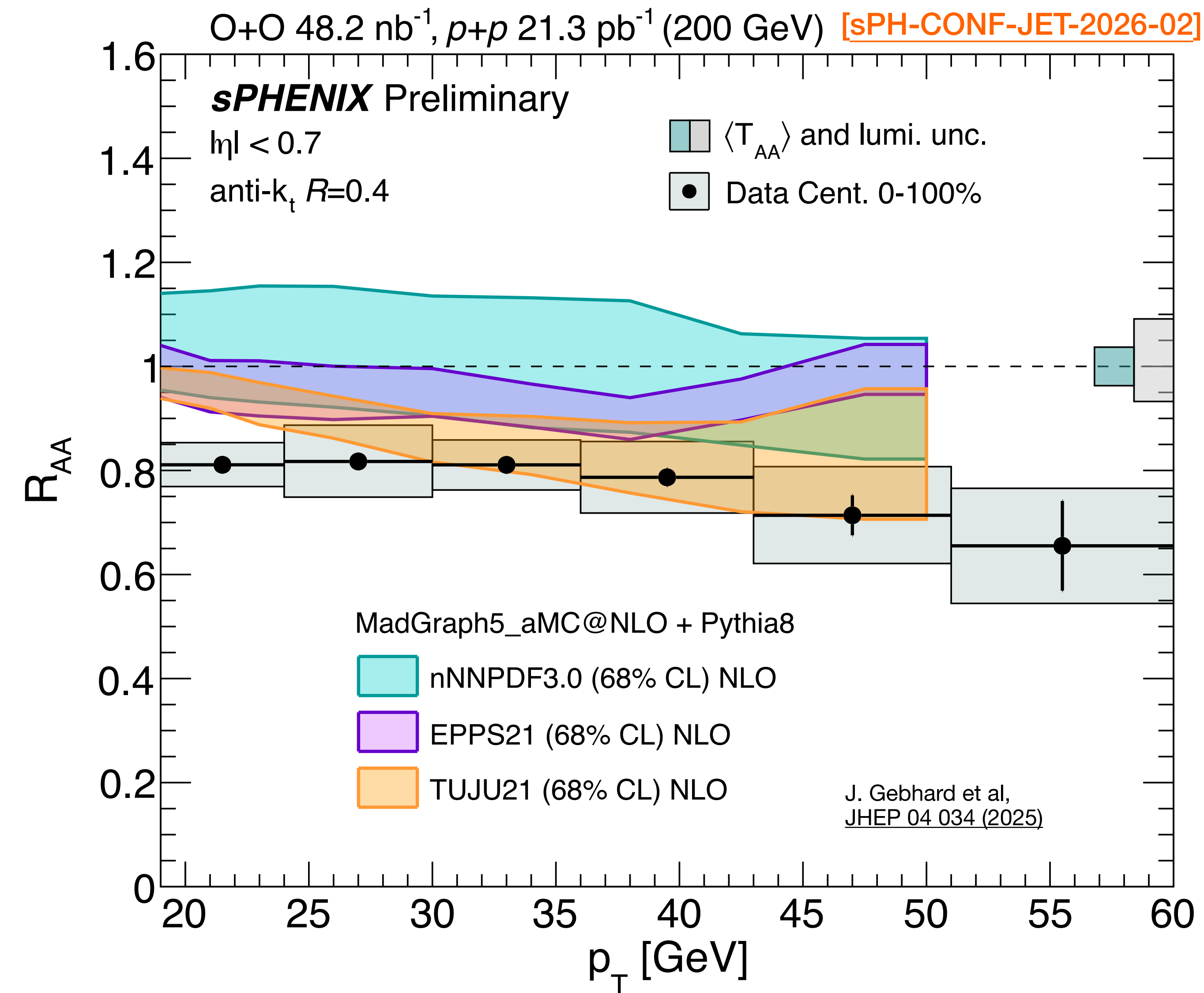
Jet R_{AA} in Oxygen-Oxygen 200 GeV

O+O 48.2 nb⁻¹, p+p 21.3 pb⁻¹ (200 GeV) [sPH-CONF-JET-2026-02]



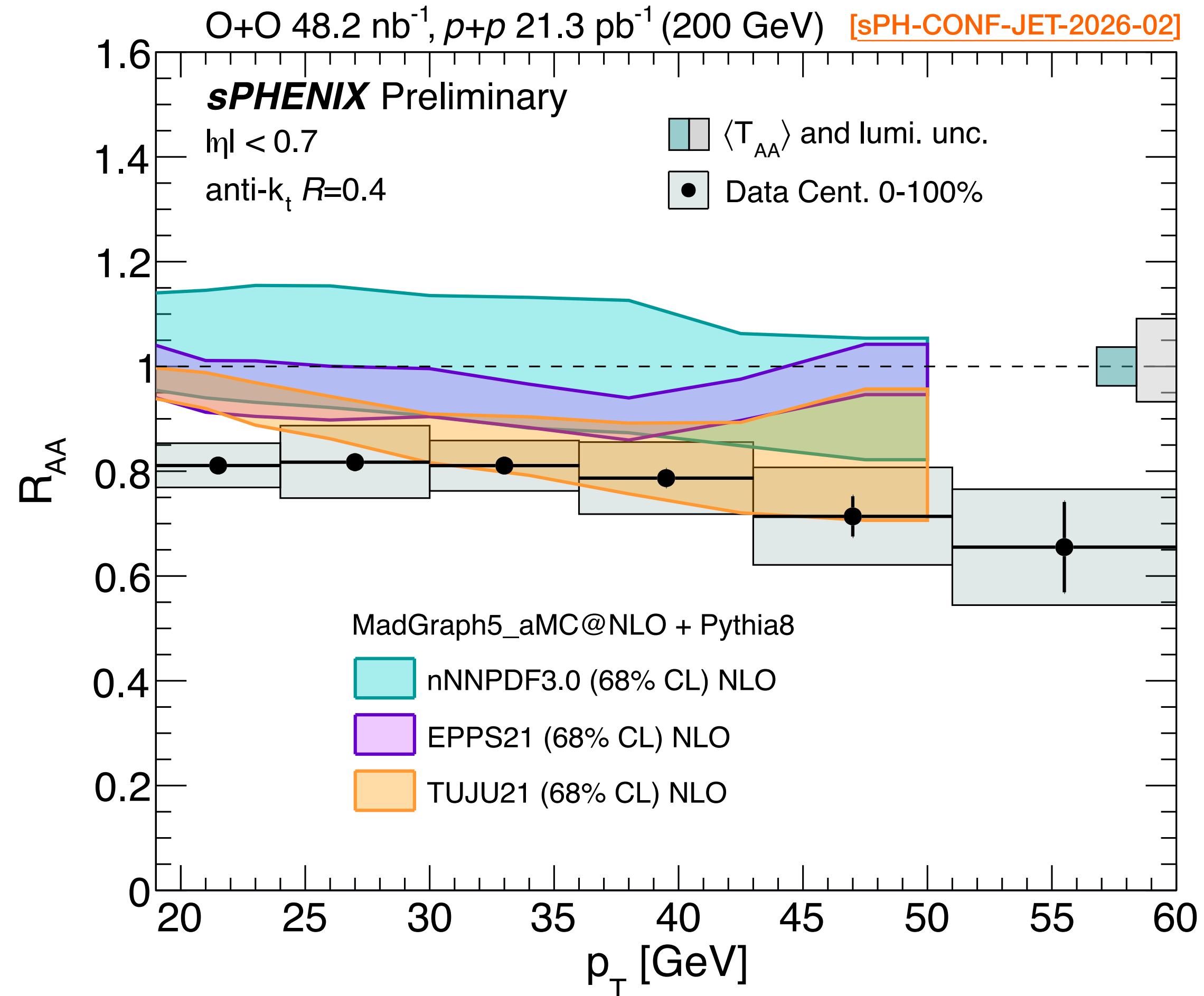
- **Suppression** of jet yields in O+O
- **Weak** dependence on p_T
- Compared to JEWEL calculations
 - **Modest** effect with **recoils** enabled

Jet R_{AA} in Oxygen-Oxygen 200 GeV



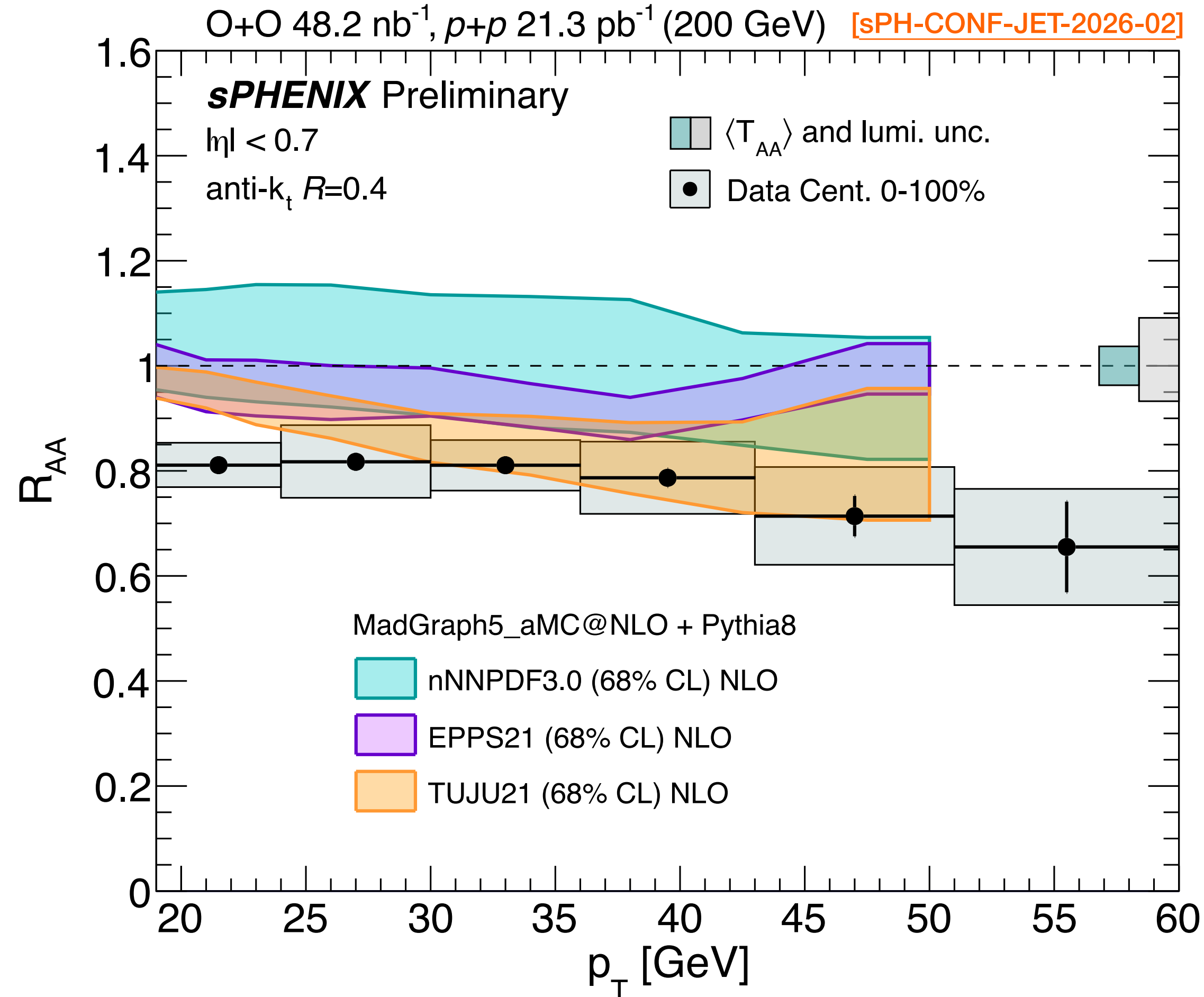
- **Suppression** of jet yields in O+O
- **Weak** dependence on p_T
- Compared to JEWEL calculations
 - **Modest** effect with **recoils** enabled
- Smaller R_{AA} than **no-quenching nPDF** baseline calculations
 - Large uncertainties on nPDF (R_{AA} near the edge of lower band)
 - No p+O at RHIC —> Need other constraining tools

nPDF constraints for O+O for RHIC energies

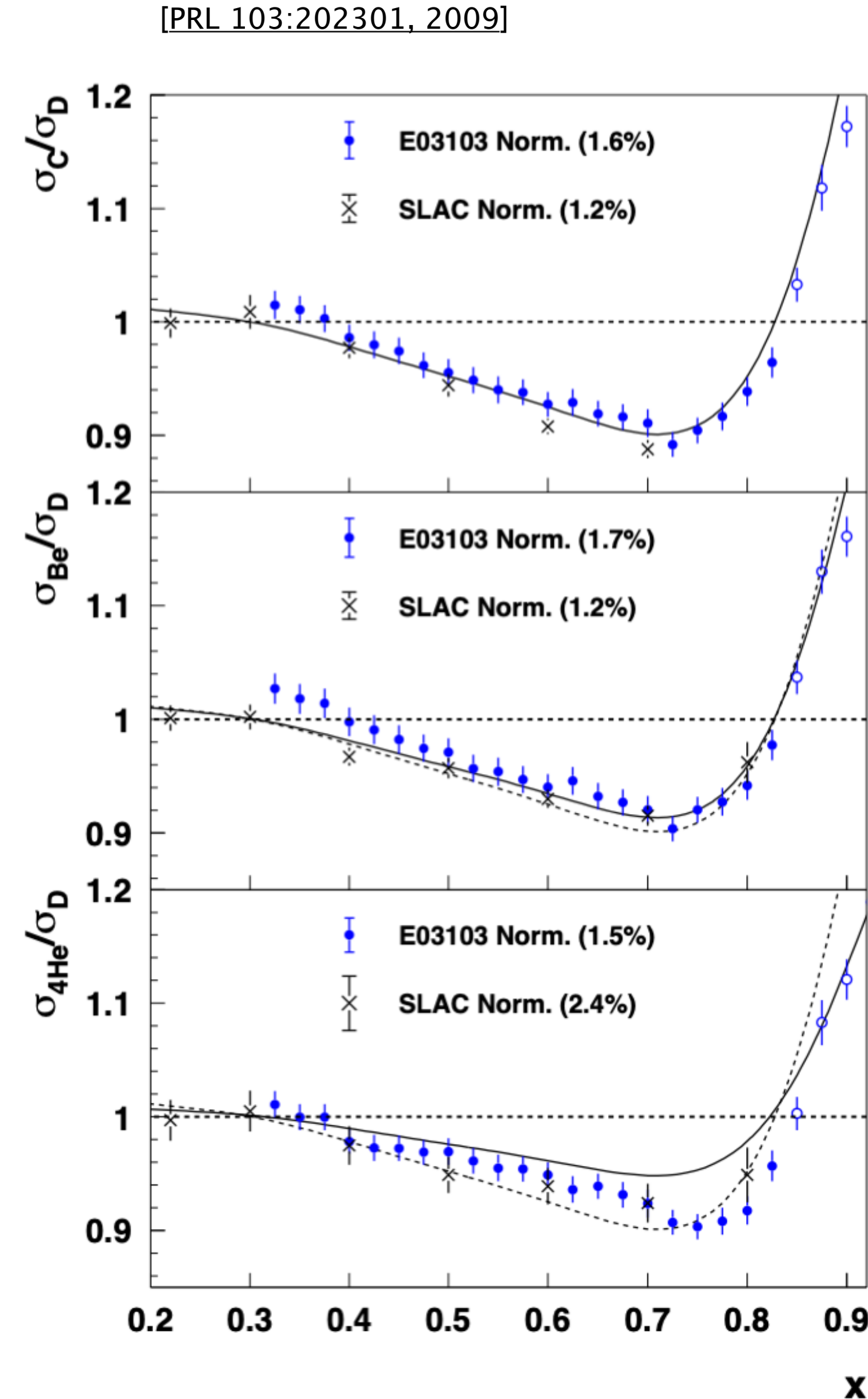


- nNNPDF3.0 using global fit from light & heavy nuclei data
- EPPS21 & TUJU21 applying A-scaling
- **High-x at RHIC** ($x=0.5$ for $p_T=50$ GeV) near **EMC region**

nPDF constraints for O+O for RHIC energies

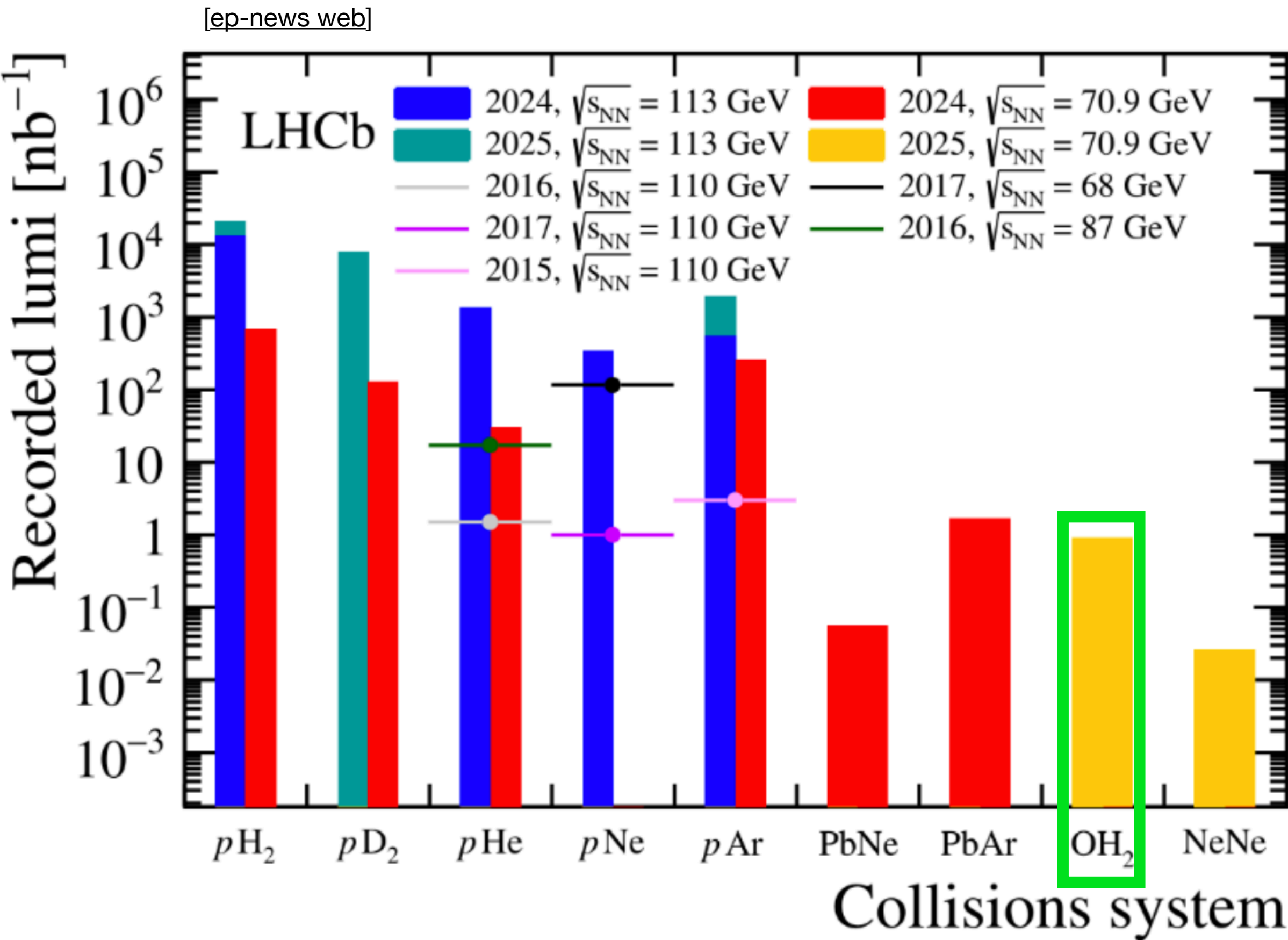
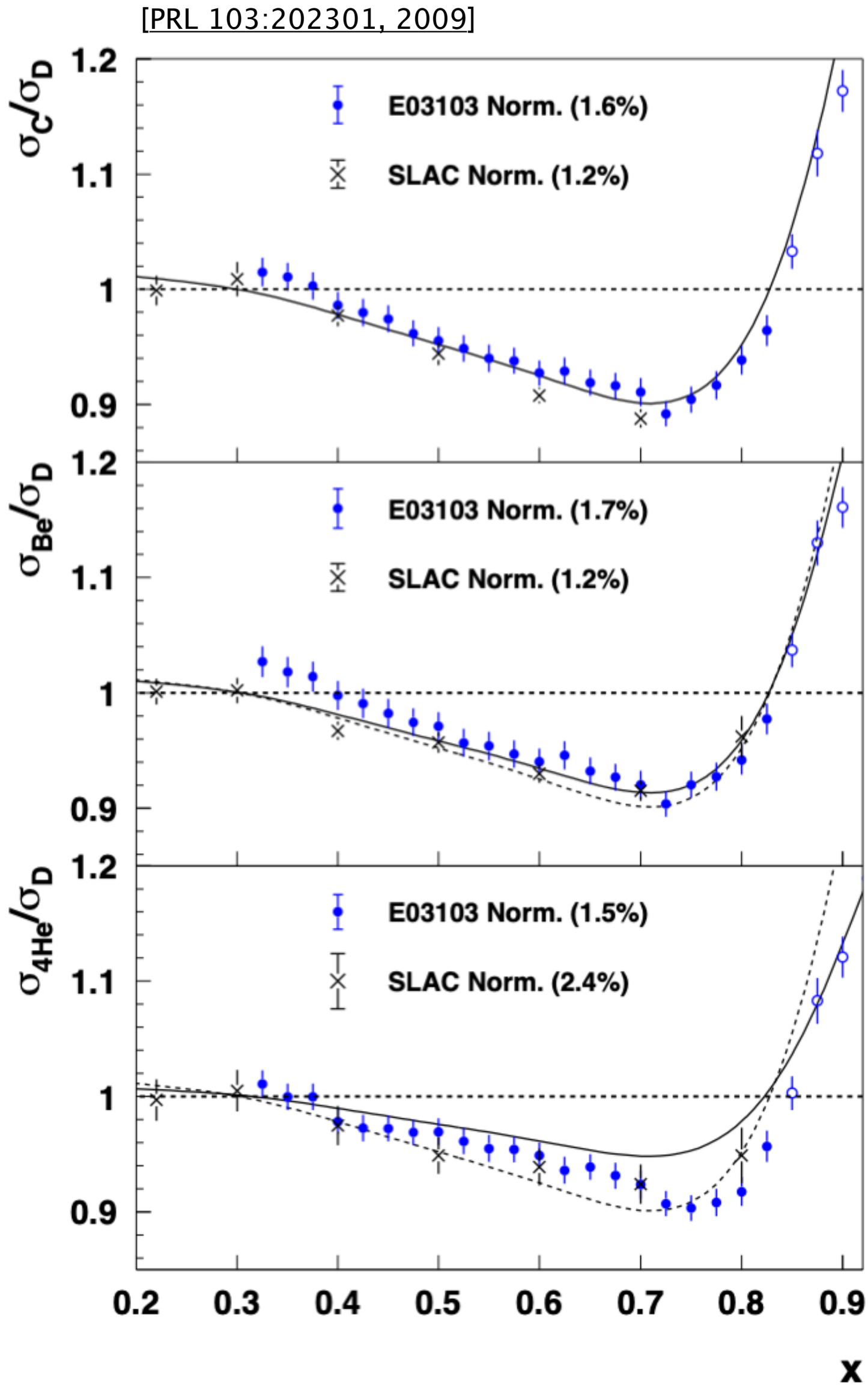


- nNNPDF3.0 using global fit from light & heavy nuclei data
- EPPS21 & TUJU21 applying A-scaling
- **High-x at RHIC** (x=0.5 for p_T=50 GeV) near **EMC region**



- EMC effect measured at JLab for 3He, 4He, 9Be, 12C etc.
- EMC effect max. 10% with **no strong A-dependence**
- Possible to constrain nPDF high-x for Oxygen using other light ion results

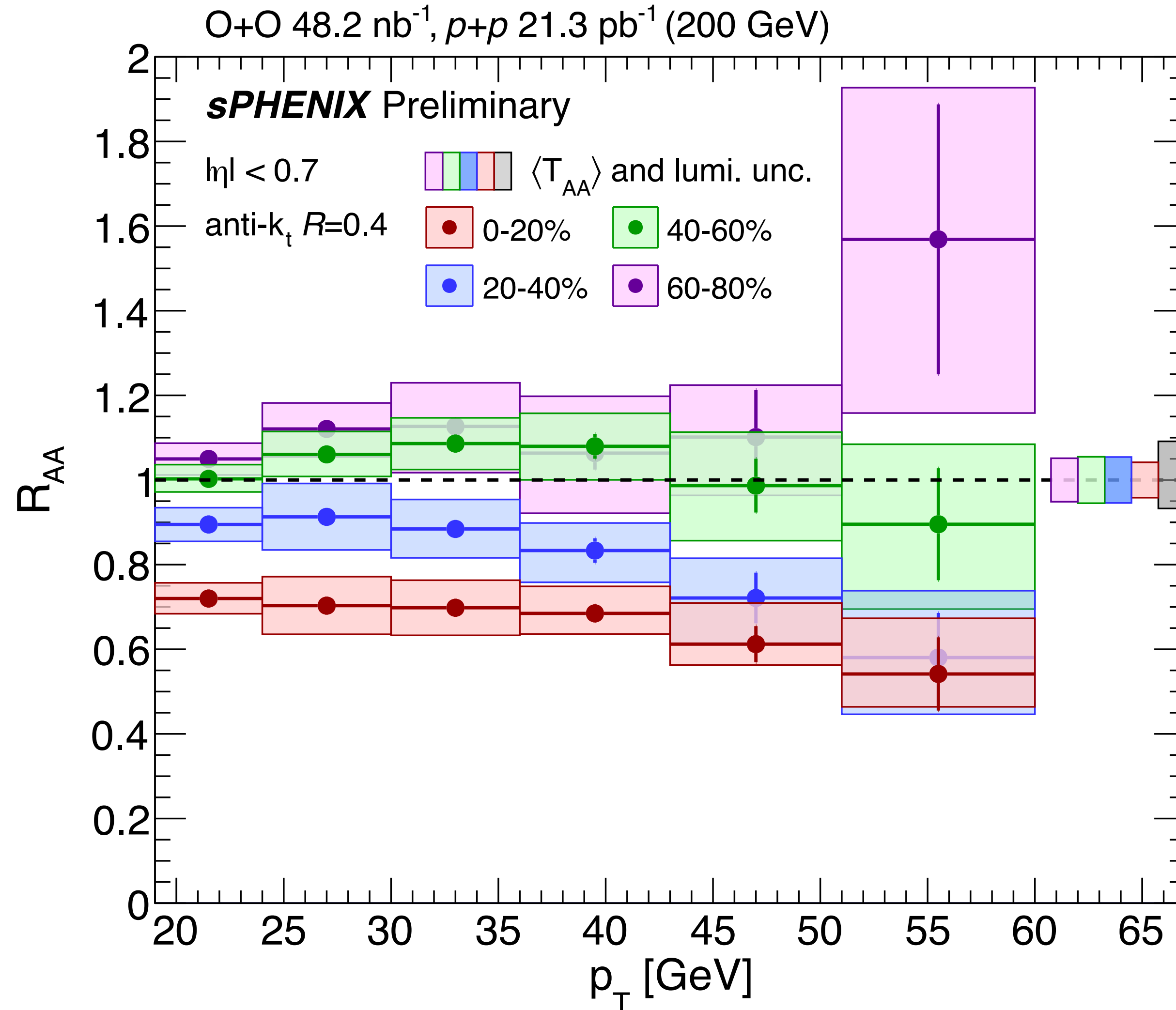
nPDF constraints for O+O for RHIC energies



- **Oxygen + H₂** experiment with SMOG2 at LHCb
- J/ ψ , D⁰ mesons can probe up to $x \sim 0.5-0.6$

Centrality dependent jet suppression

[sPH-CONF-JET-2026-02]

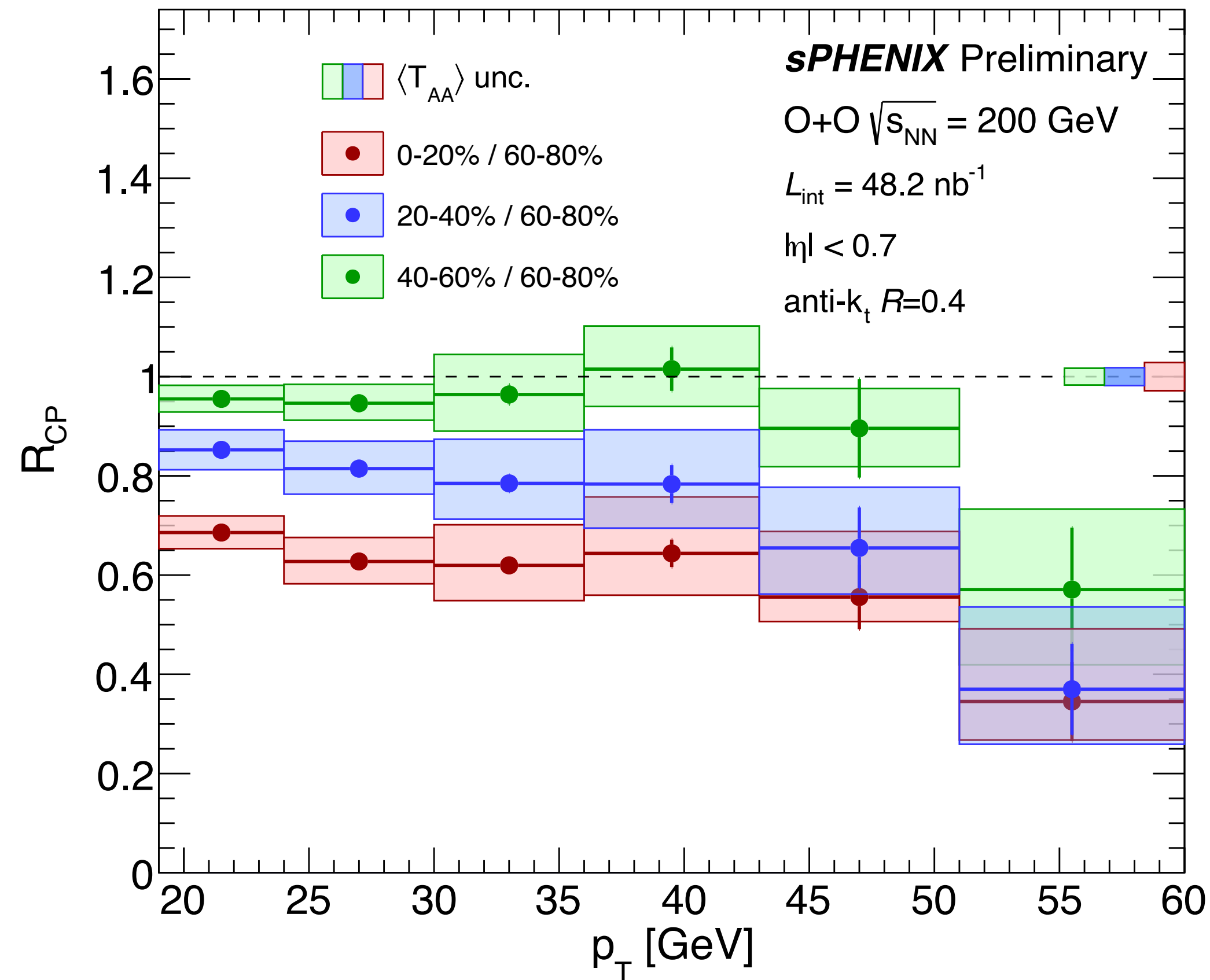


- **Centrality-dependent** absolute yield comparison between **p+p** and **O+O**
- **Clear hierarchy** towards central collisions
- Large cancellation in systematic uncertainties (JES & JER)

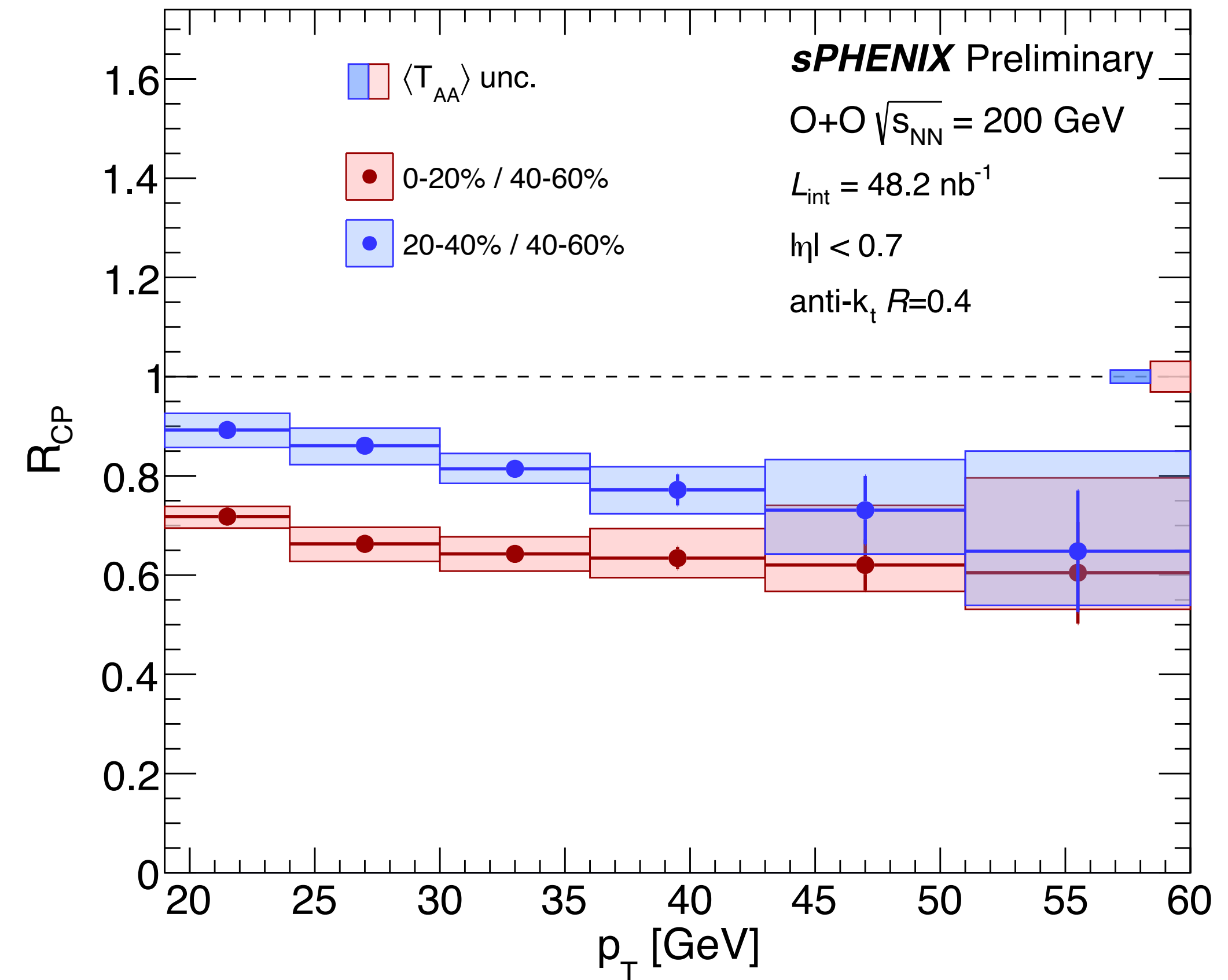
Jet R_{CP} in Oxygen-Oxygen 200 GeV

[sPH-CONF-JET-2026-02]

60-80% reference



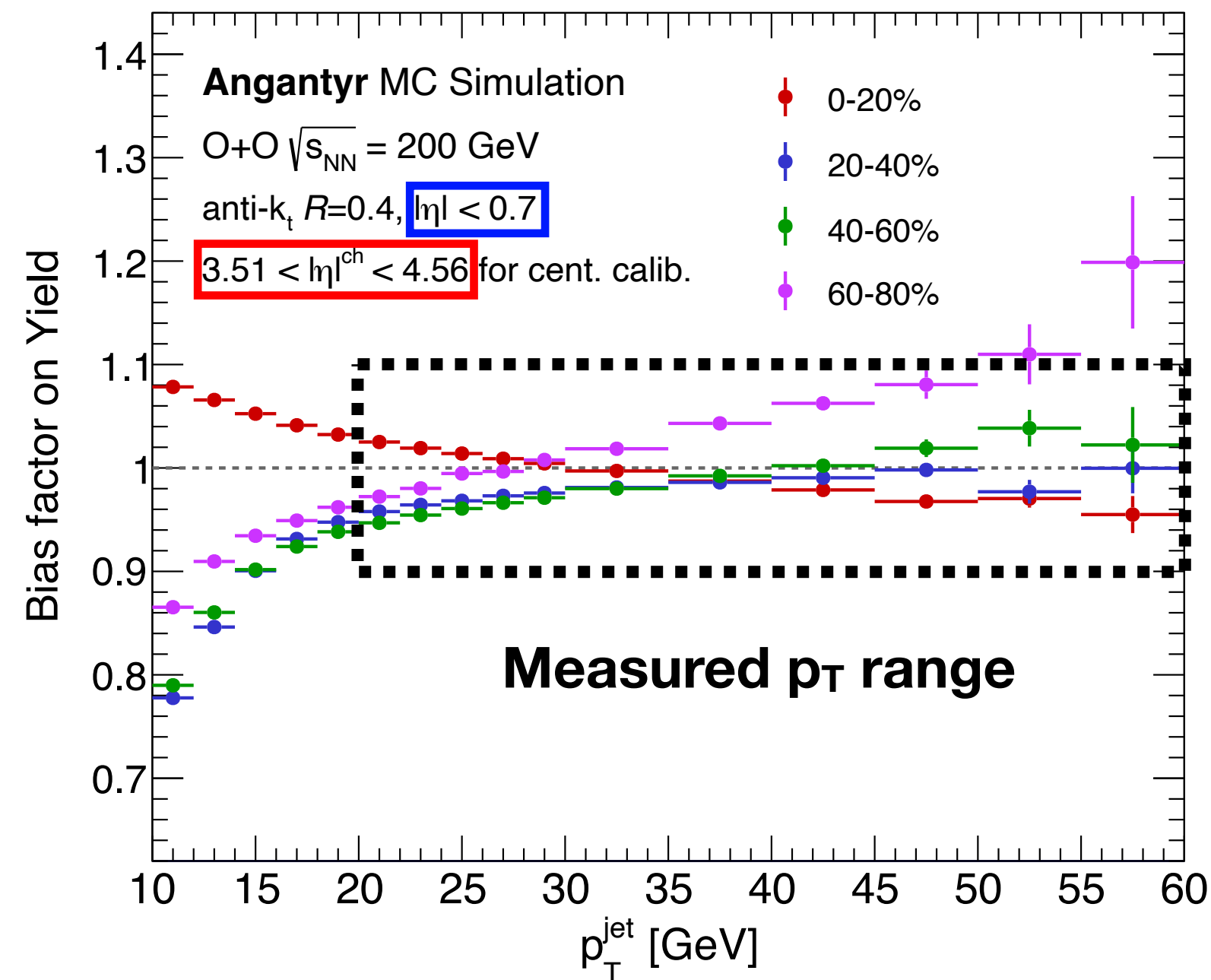
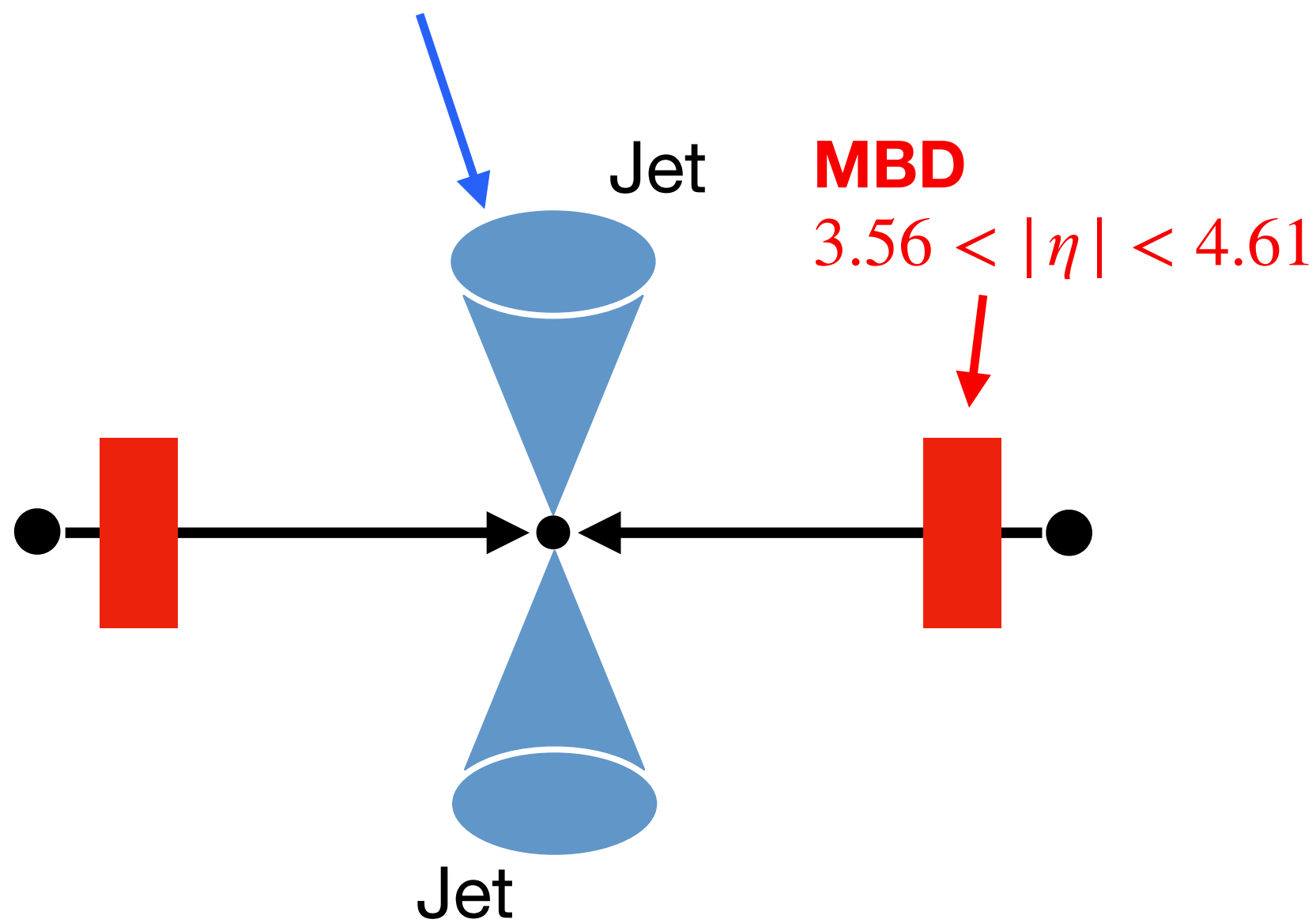
40-60% reference



- **Clearer** dependence in R_{CP} measurements with reduced uncertainties

Centrality bias effects in small collision systems

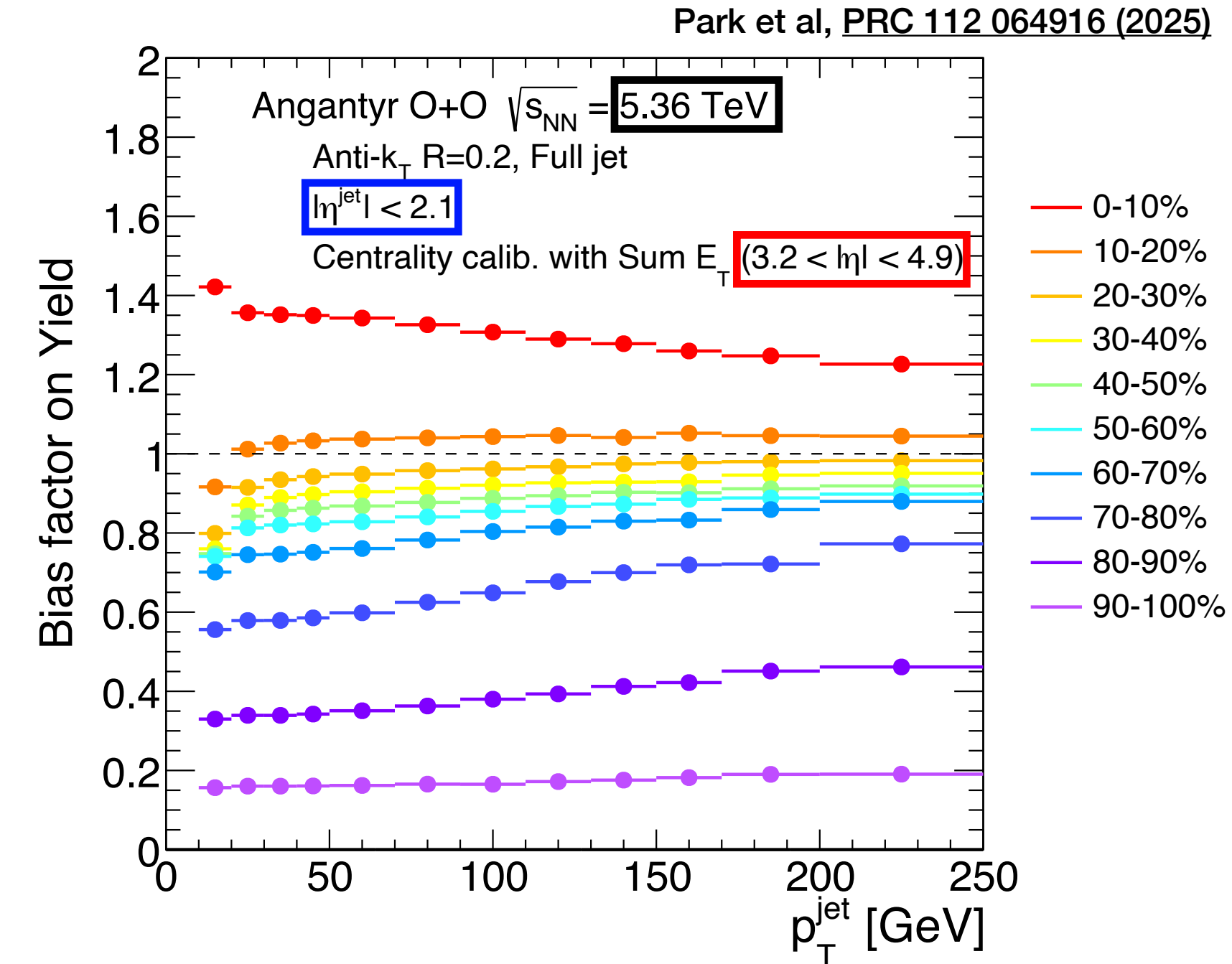
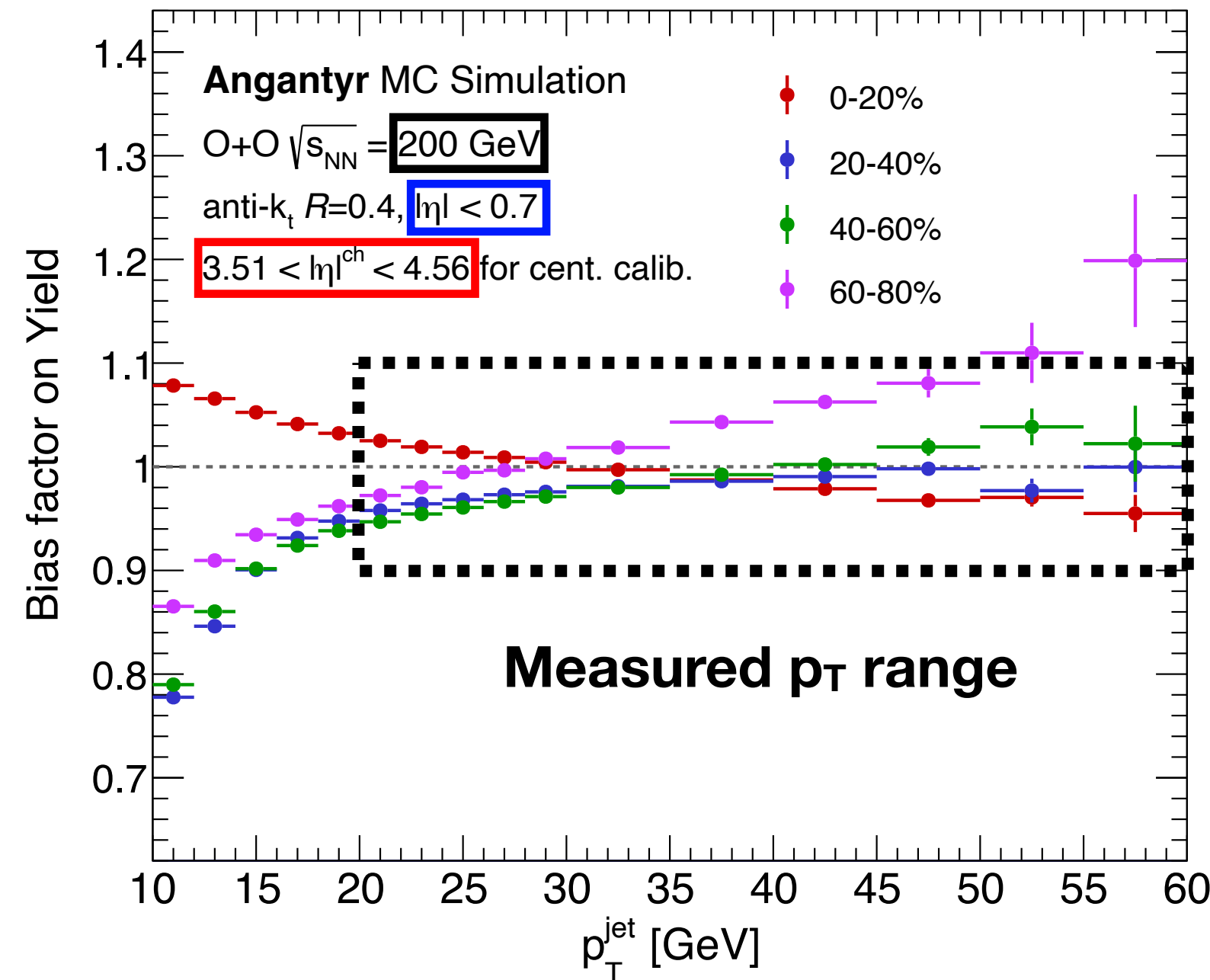
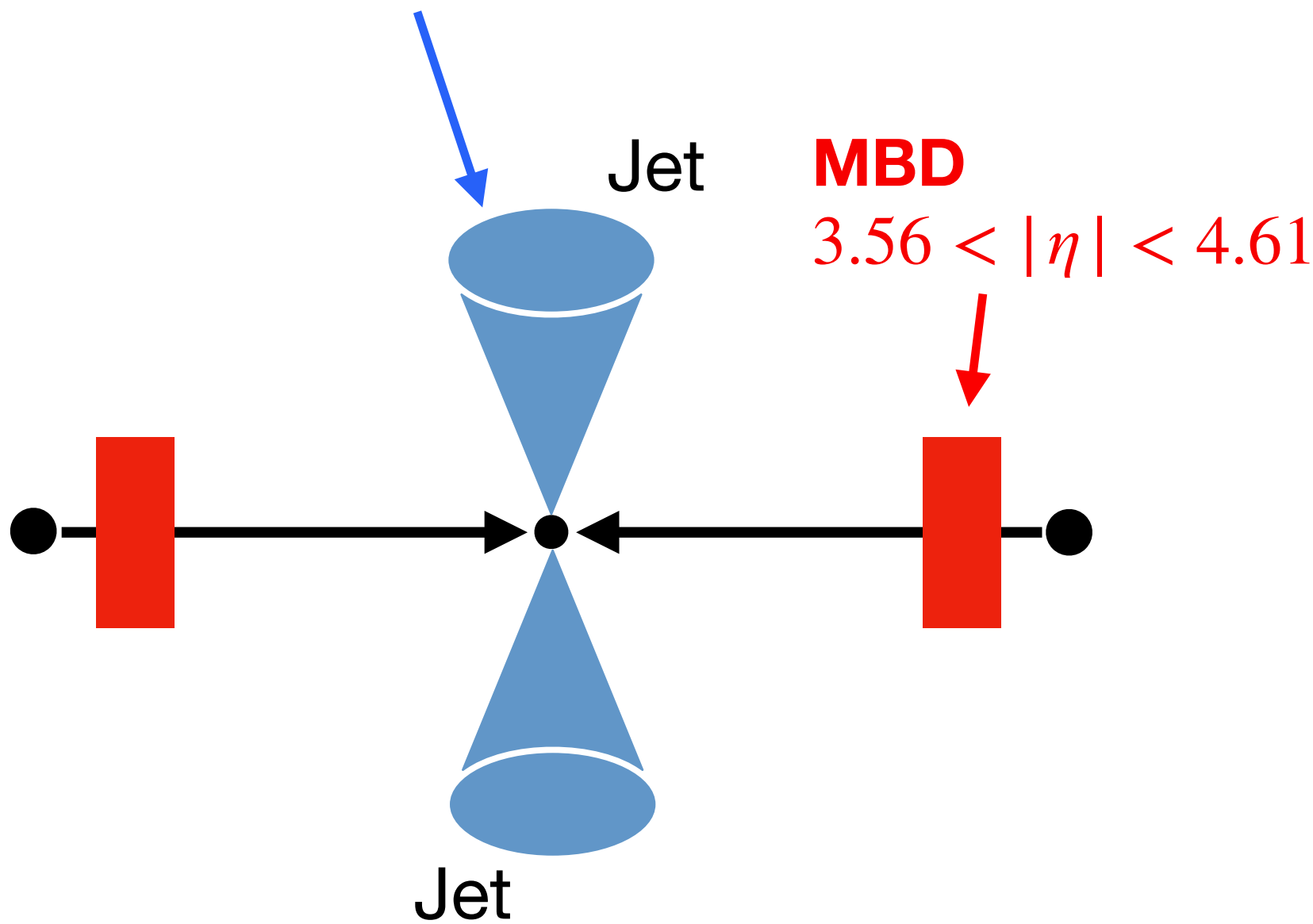
Calorimeter jet $R=0.4$ $|\eta| < 0.7$



- Centrality bias caused by **hard probes** in **mid- η** and **soft particle** production in **forward- η**

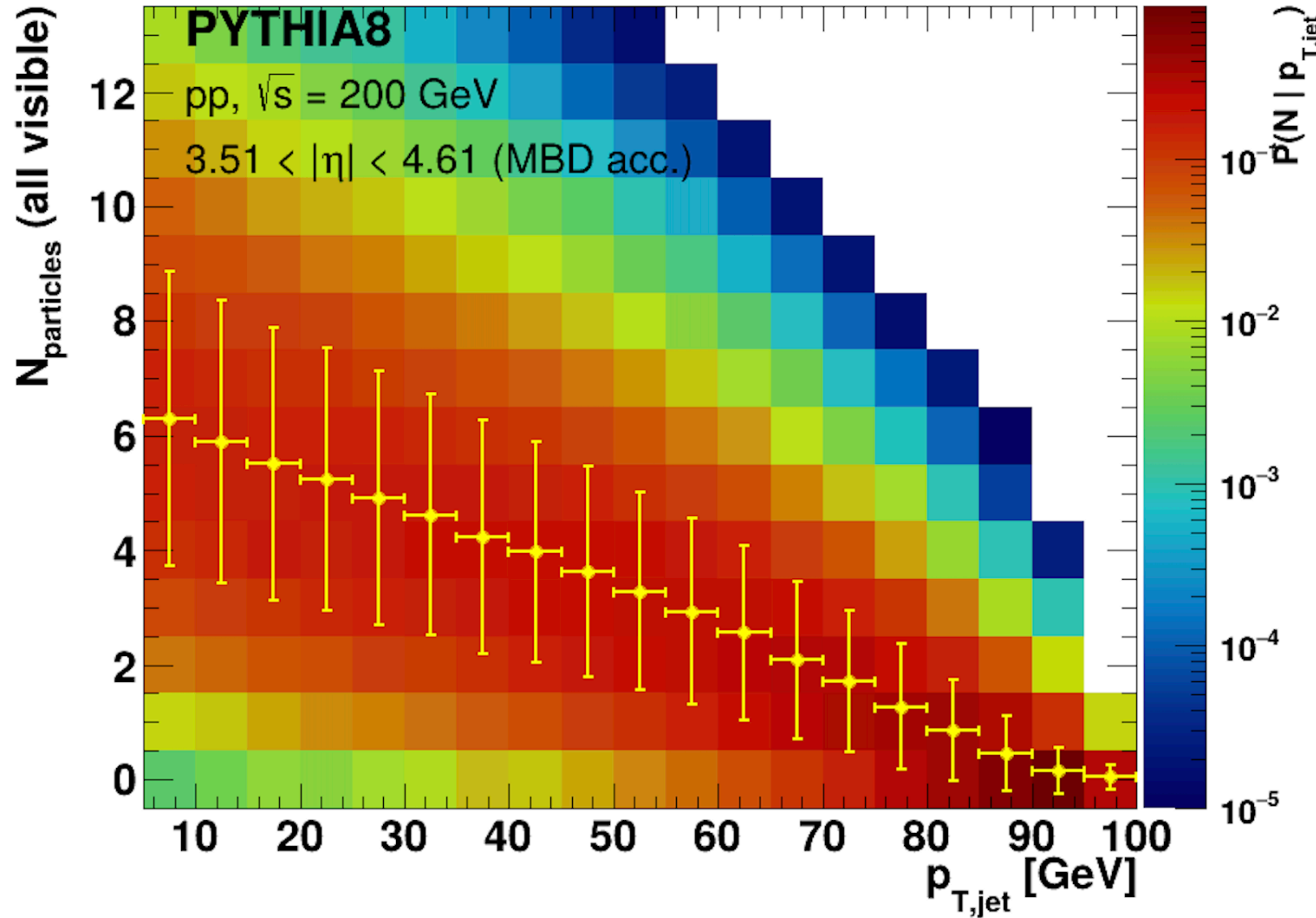
Centrality bias effects in small collision systems

Calorimeter jet $R=0.4$ $|\eta| < 0.7$



- Centrality bias caused by **hard probes** in **mid- η** and **soft particle** production in **forward- η**
- Much smaller bias effects at **RHIC energy** with **sPHENIX acceptance**

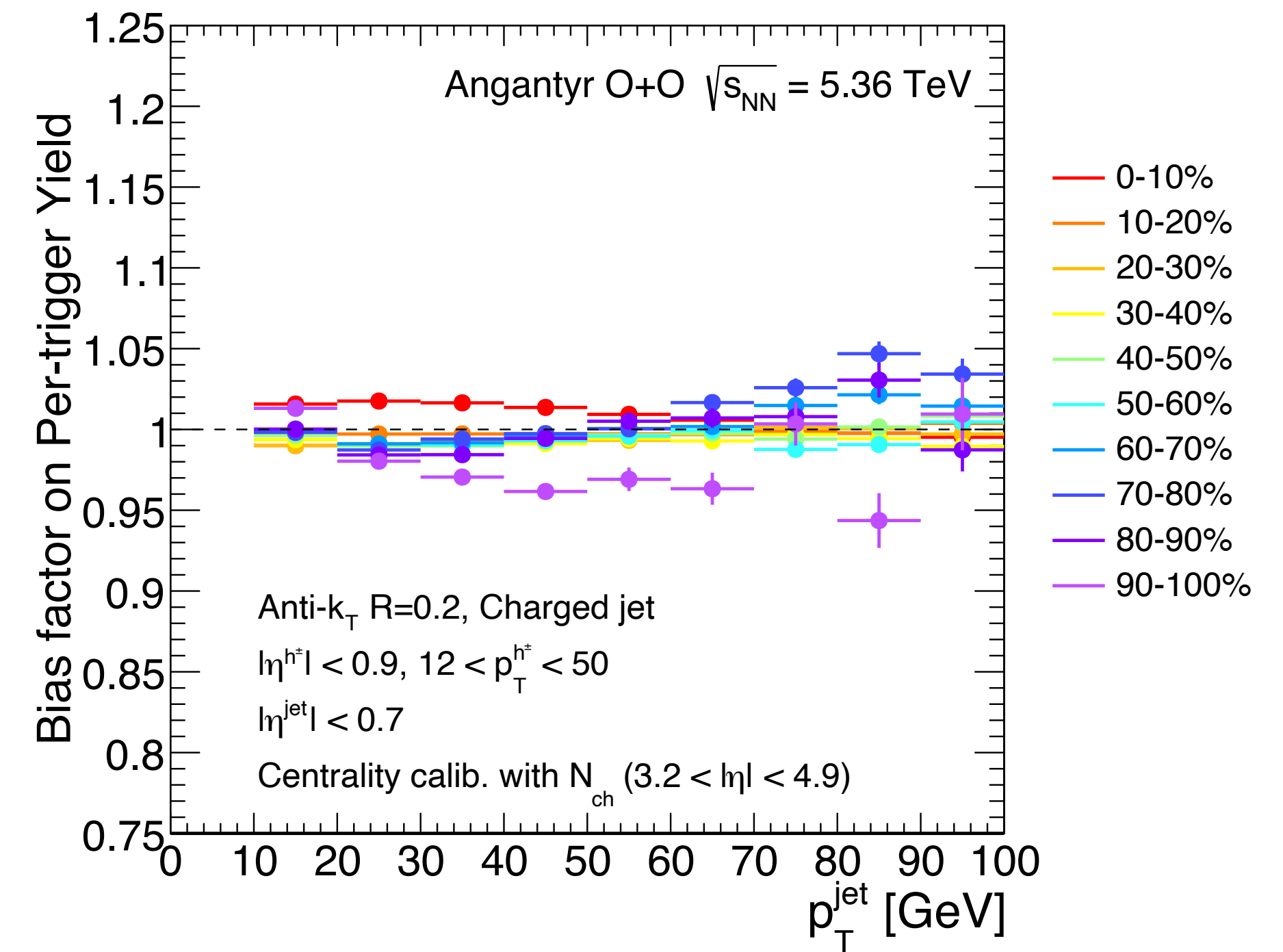
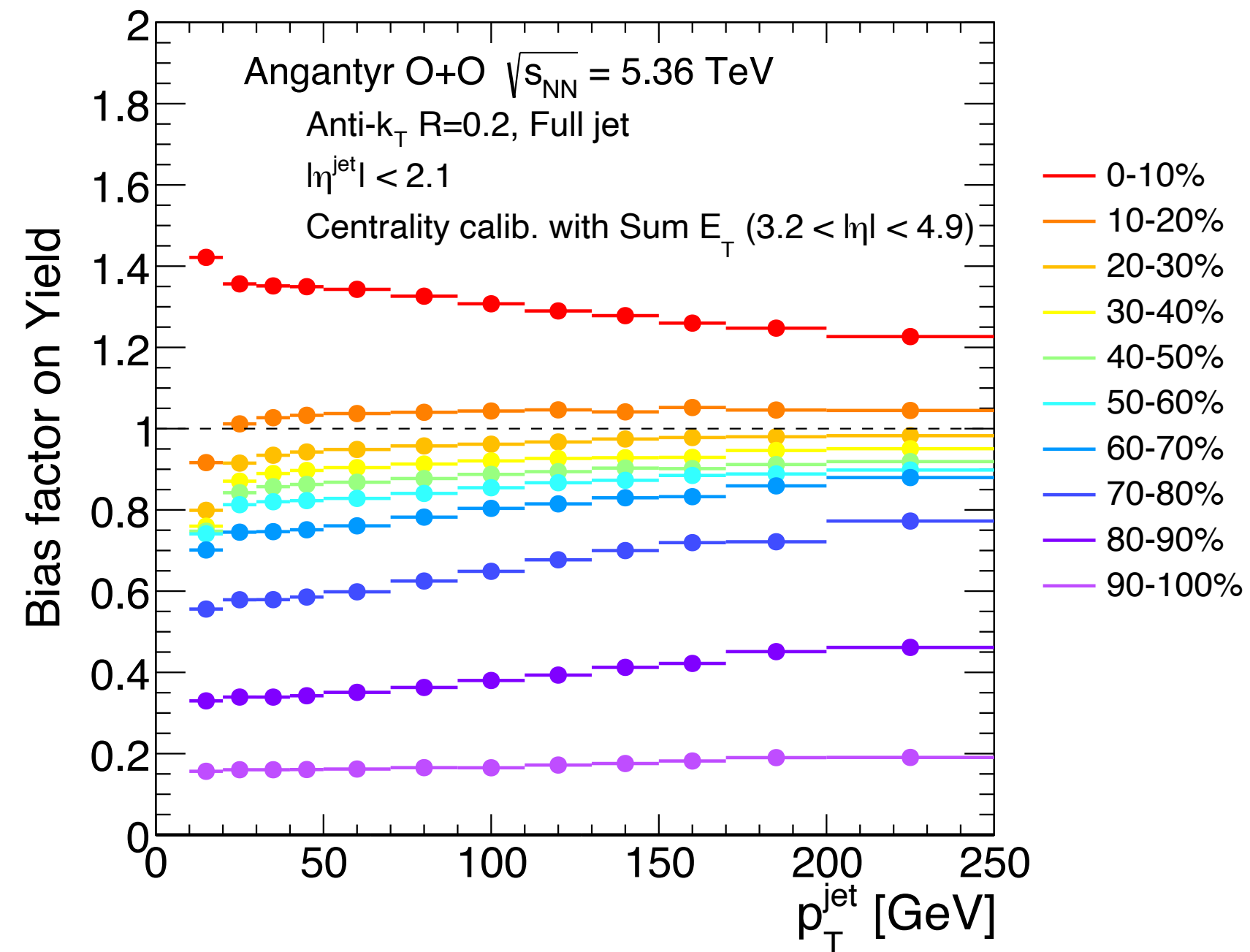
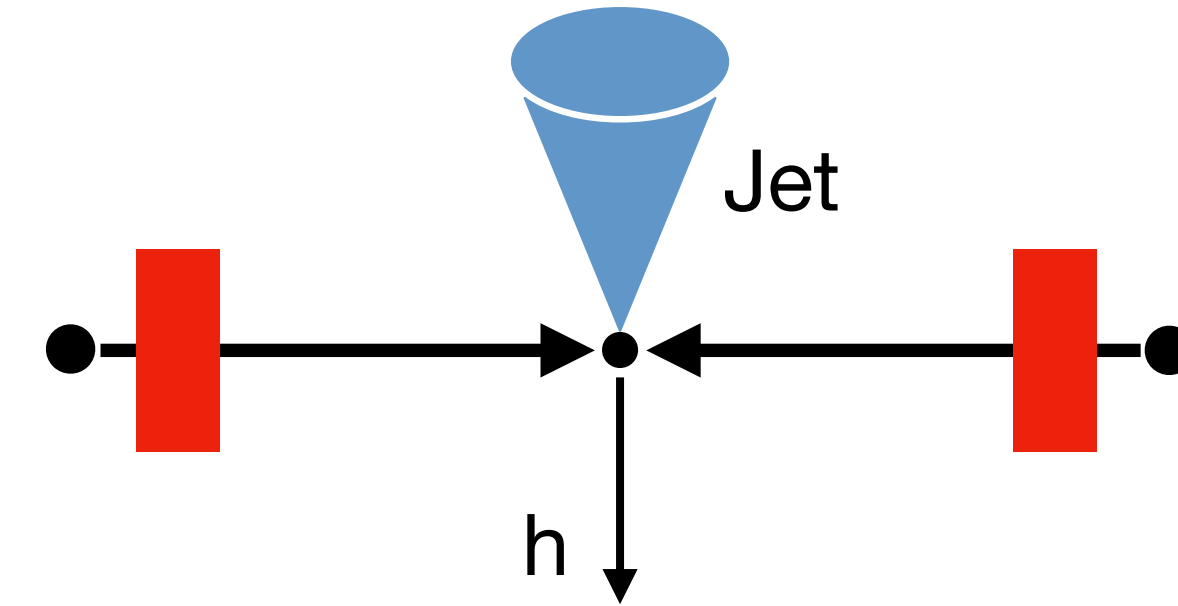
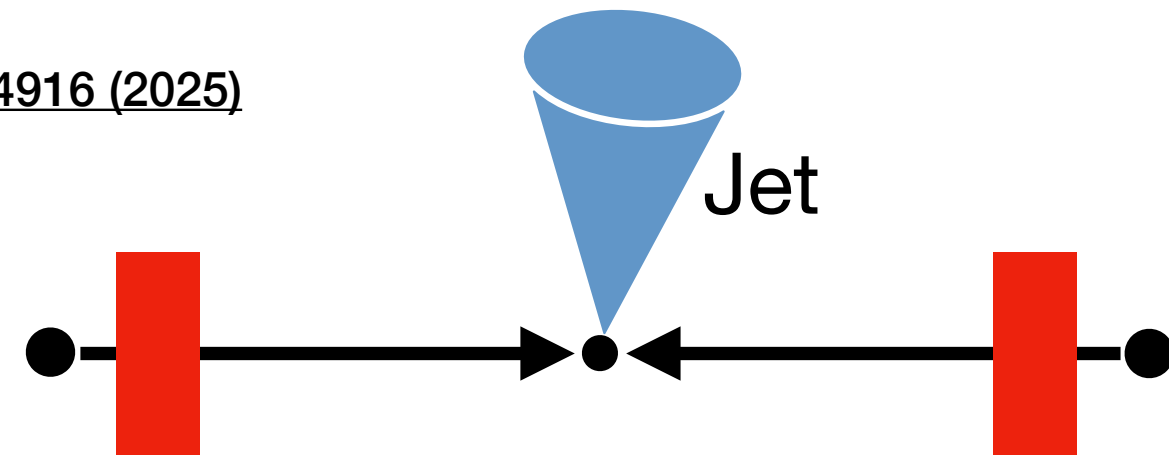
Energy conservation for bias effect



- Particle production in **forward** region decrease for higher p_T **hard probes in mid-rapidity**
- **Bias effect** strongly correlated with **energy conservation** in small systems at RHIC

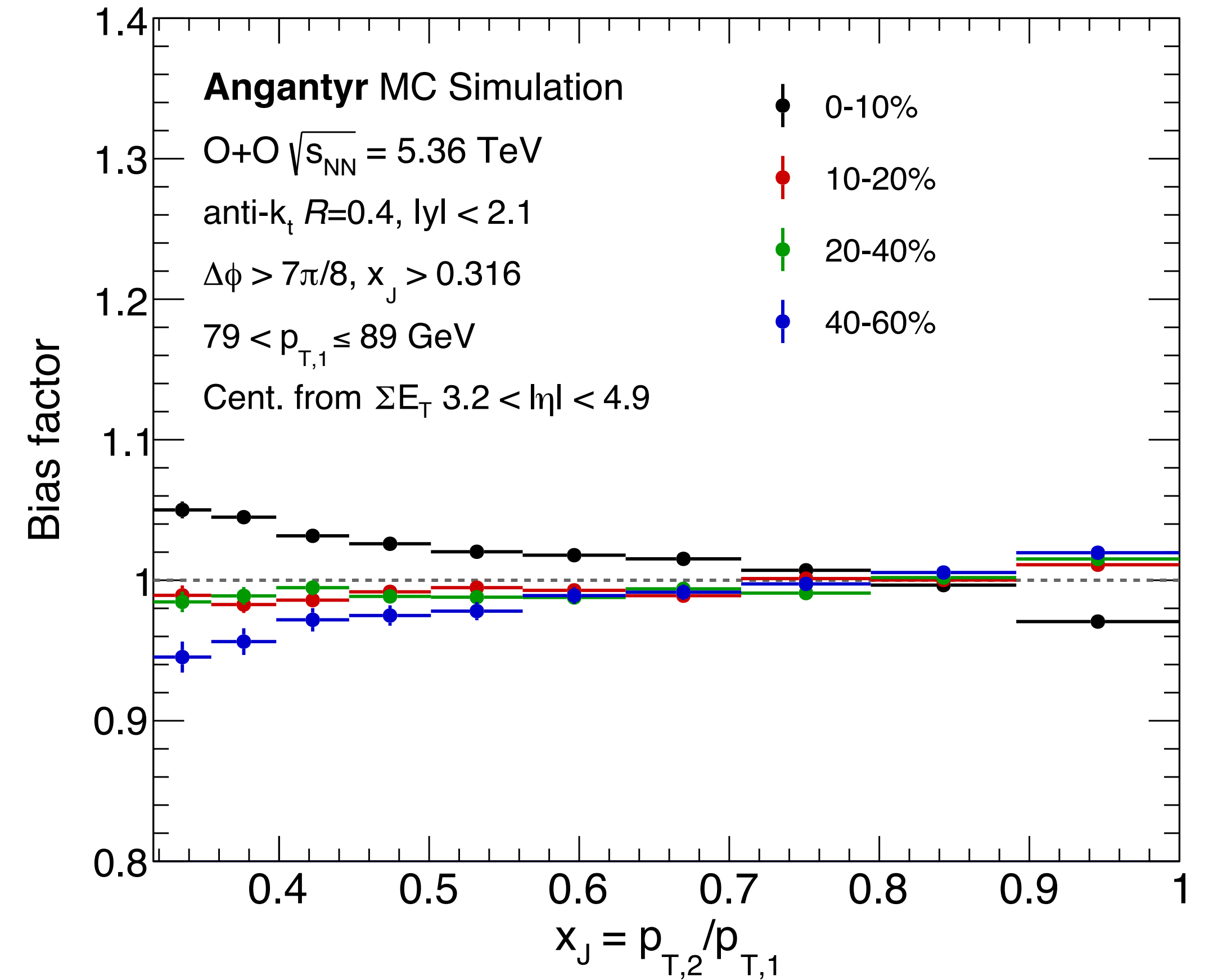
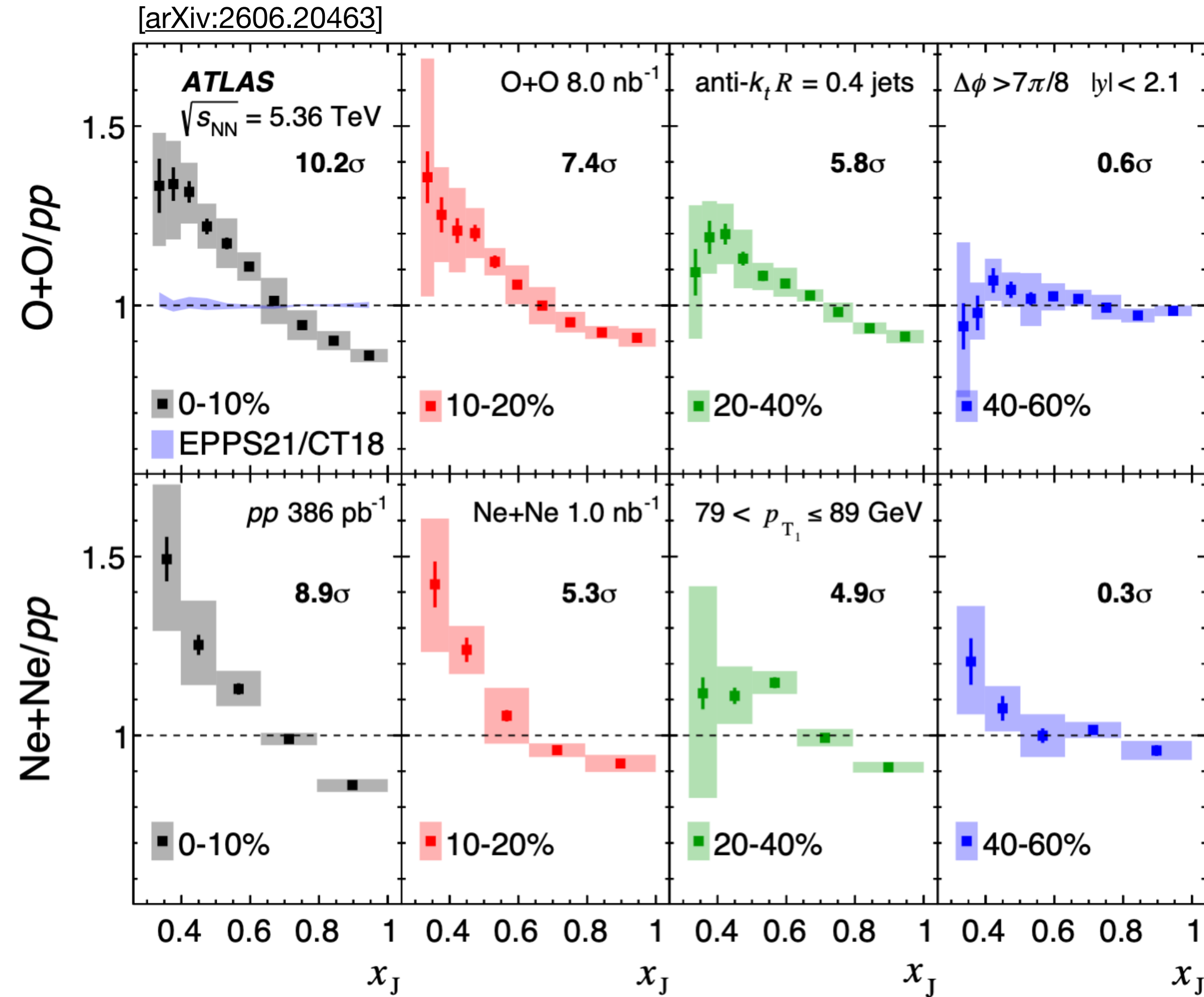
Bias effects study on correlation observables

Park et al, PRC 112 064916 (2025)



- Bias effect significantly suppressed by correlation measurements

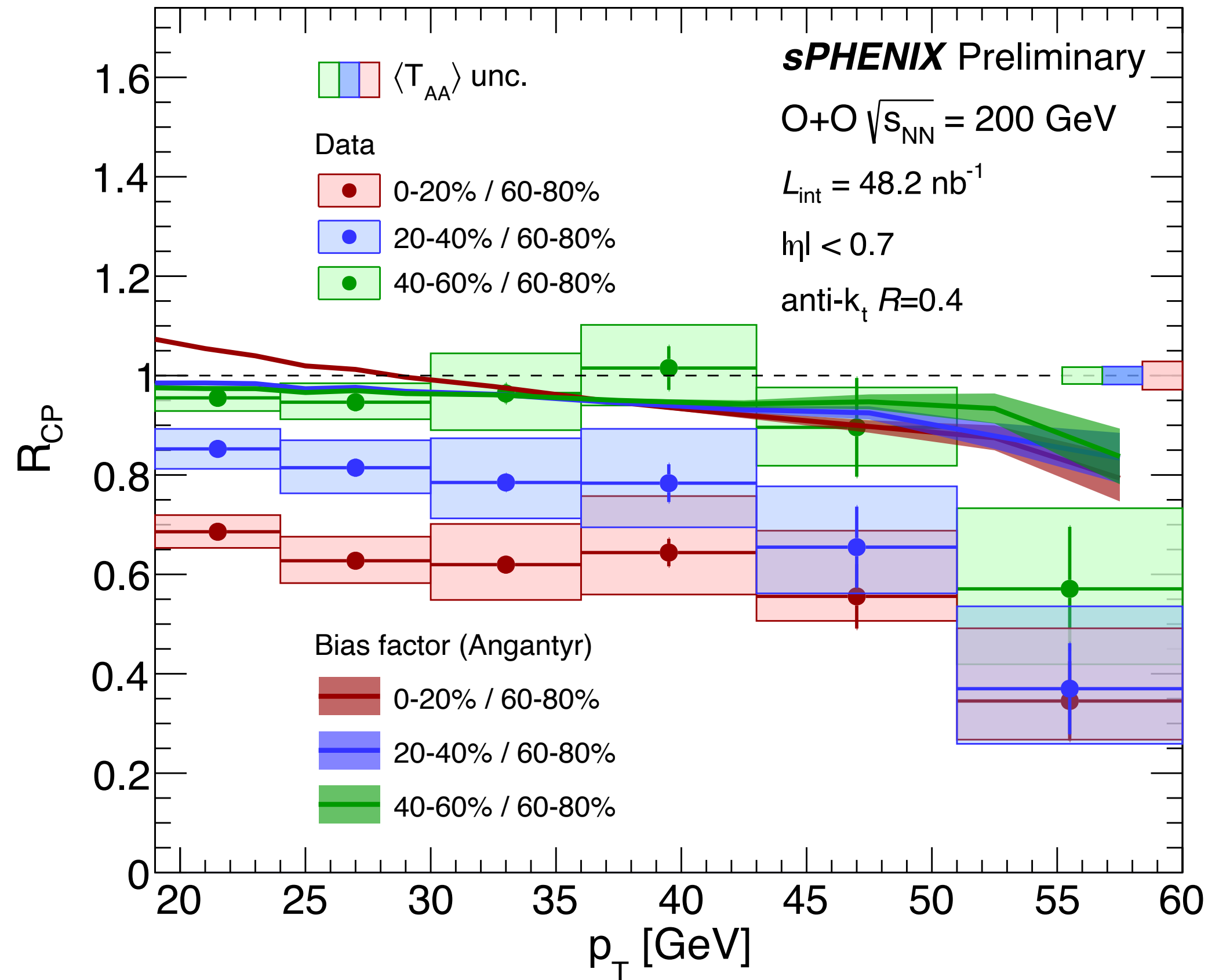
Bias effects study on physics observables



- Bias effect significantly suppressed in **dijet selection** down to at most 5%
— residual bias coming from subleading pT dependence (fixed leading pT bin)

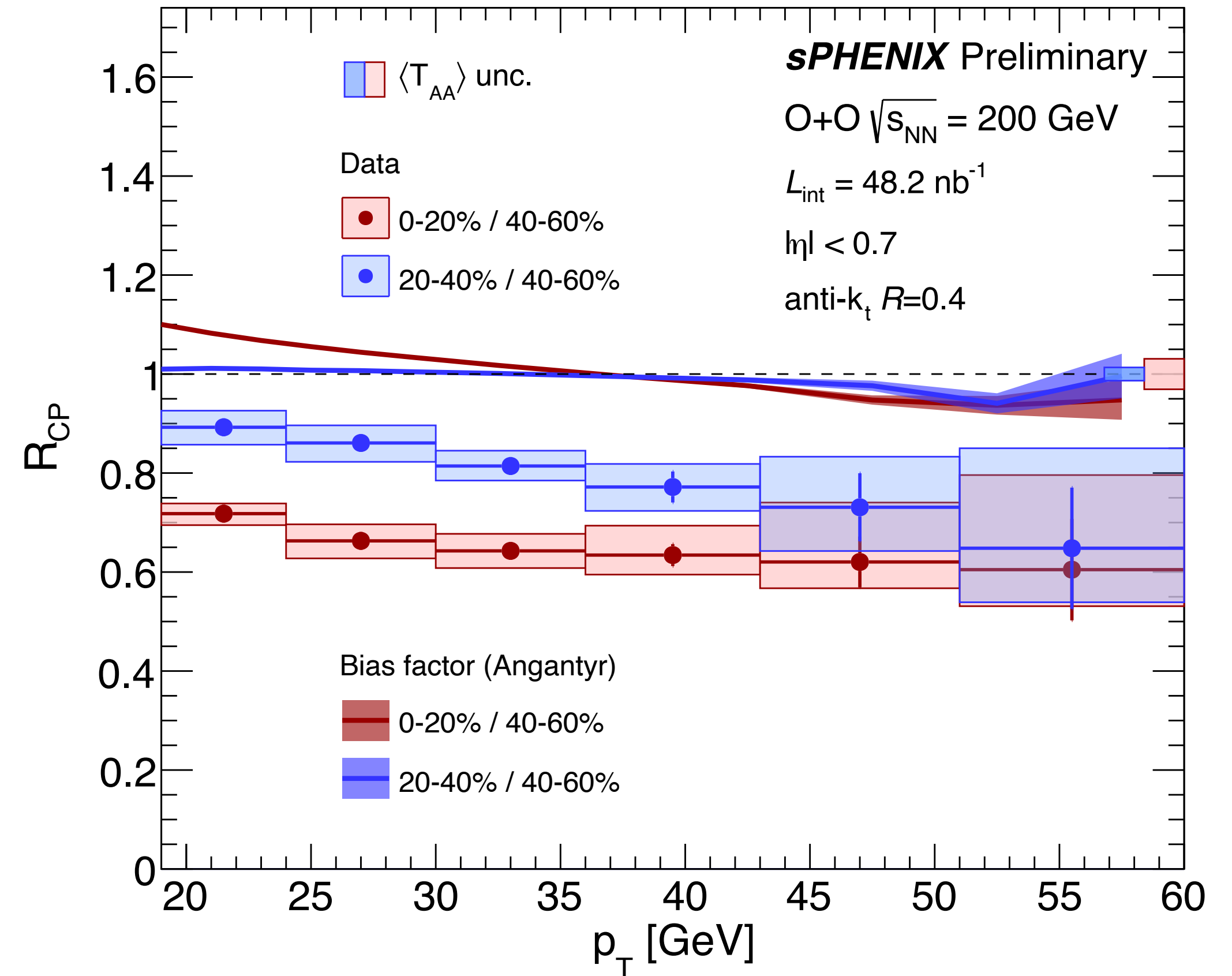
Results compared with bias factors

60-80% reference



40-60% reference

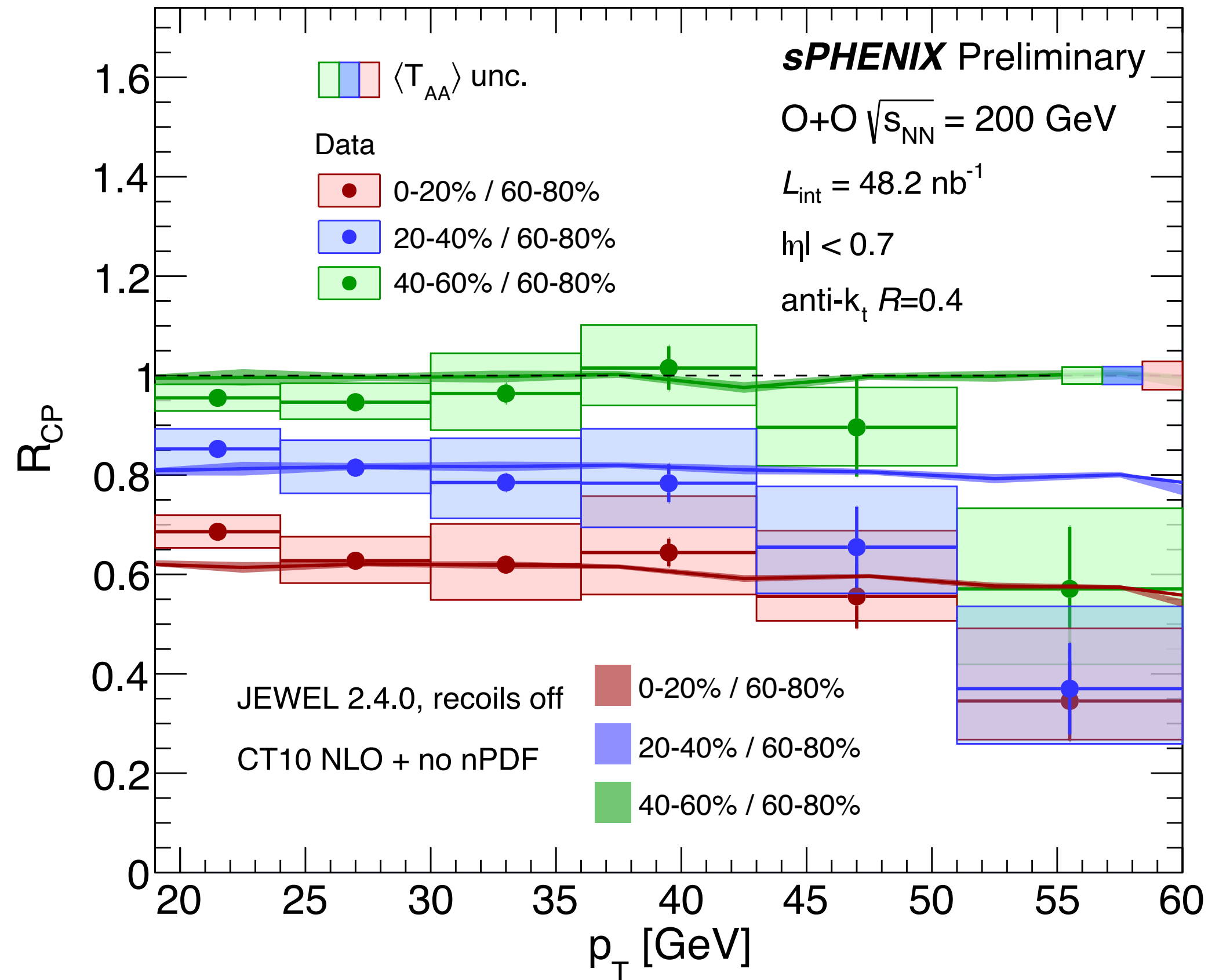
[sPH-CONF-JET-2026-02]



- Bias factors** are typically within $\pm 5\%$ $\rightarrow$ **Centrality hierarchy** in data is **beyond the bias**

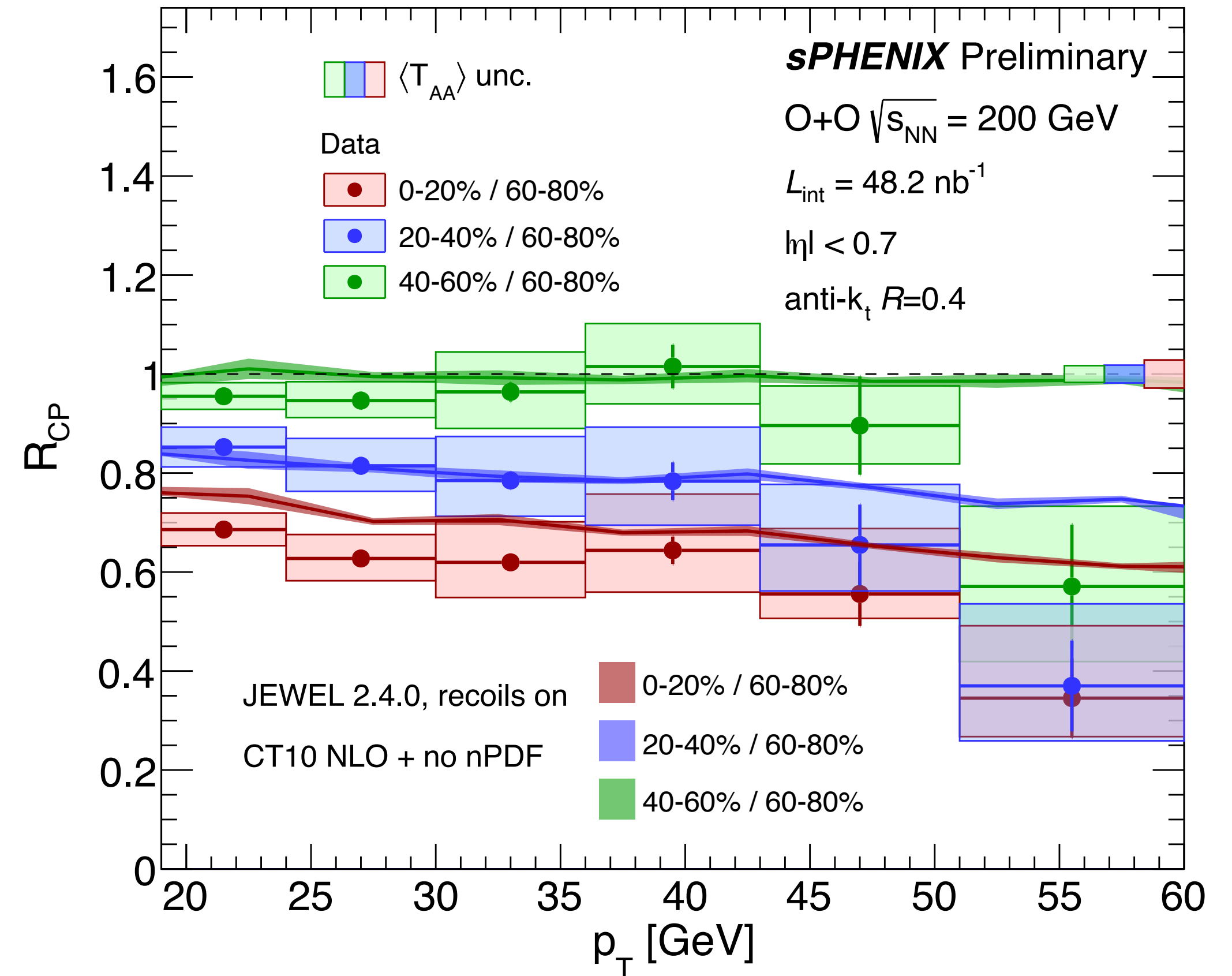
Results compared with theory calculations

60-80% reference recoil off



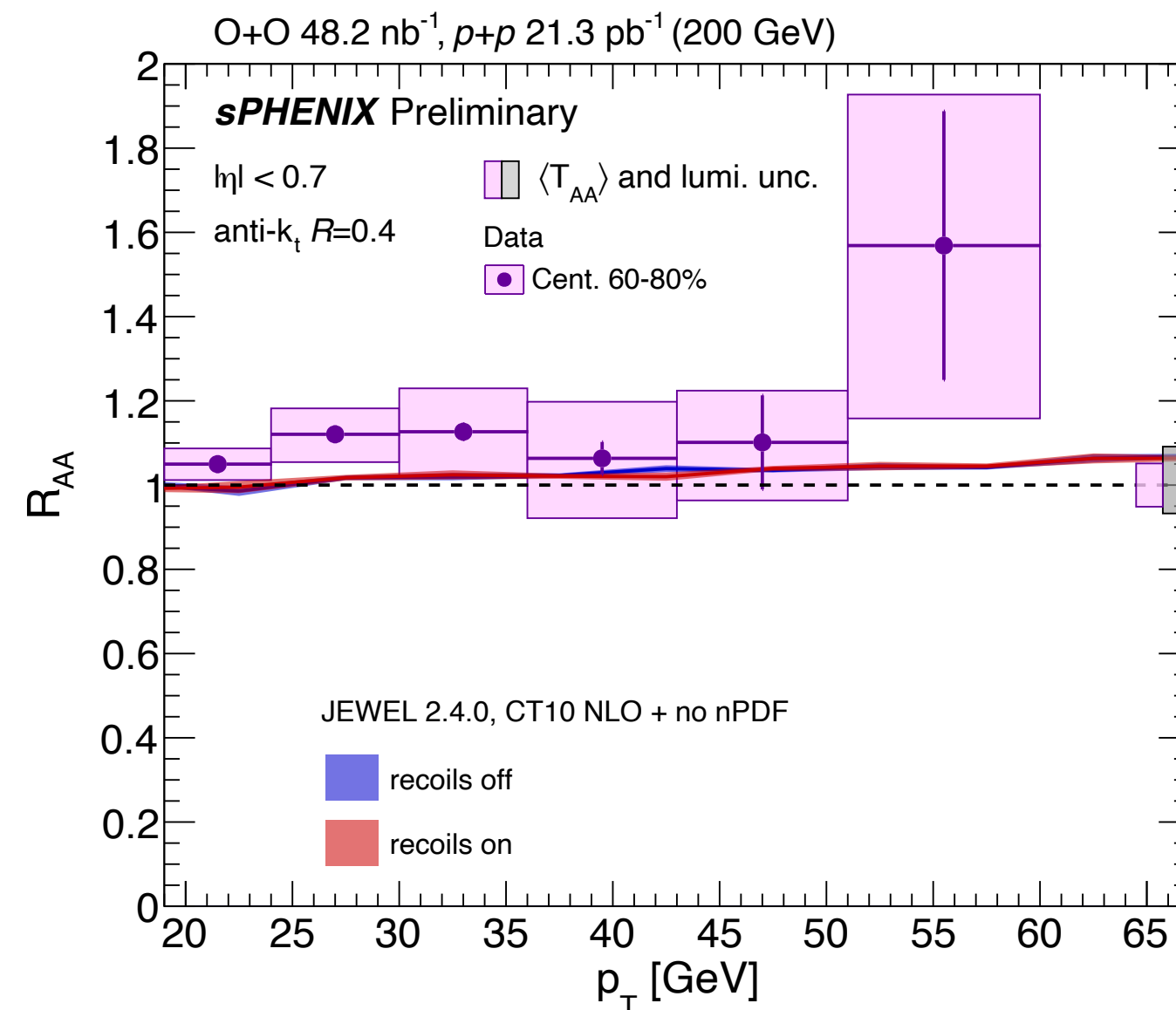
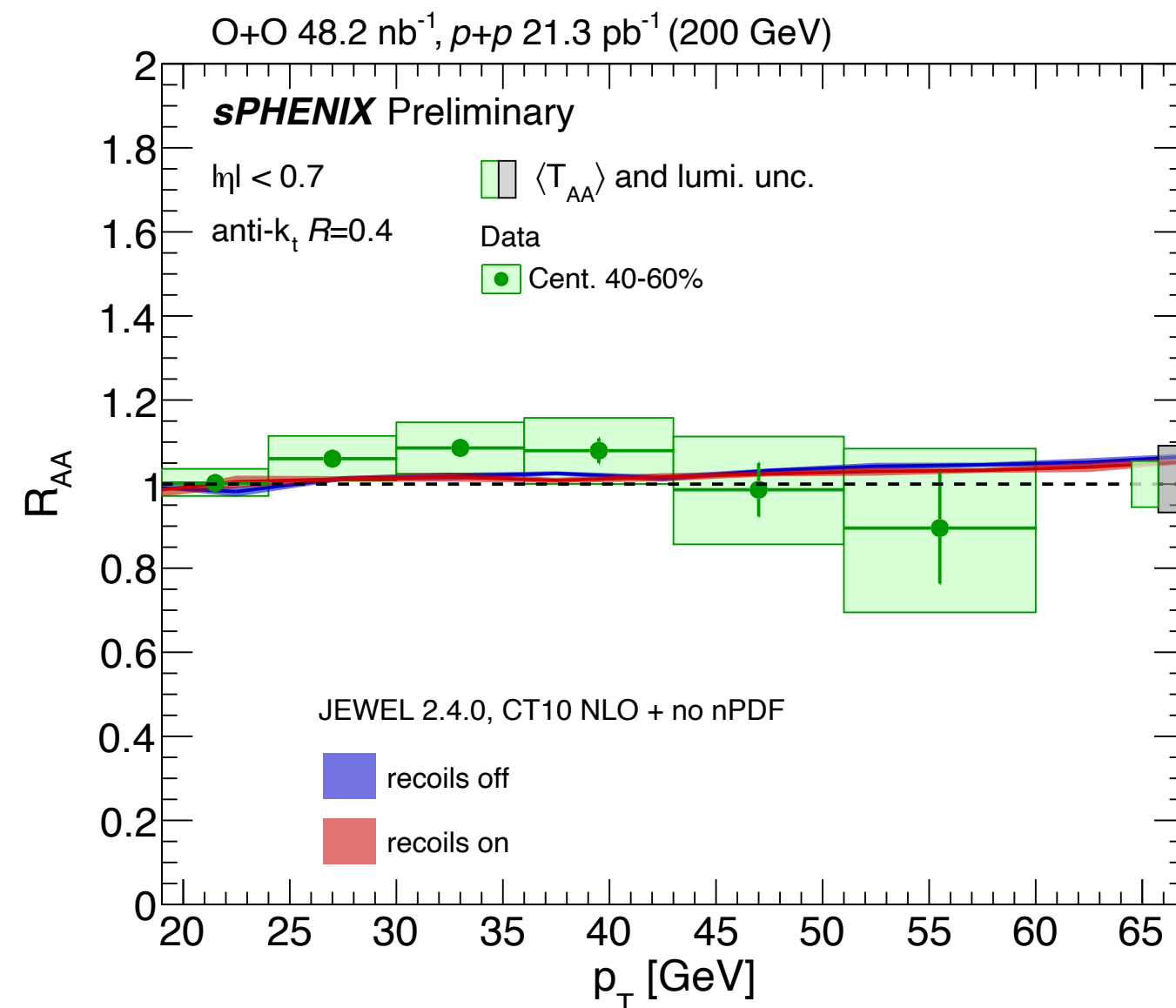
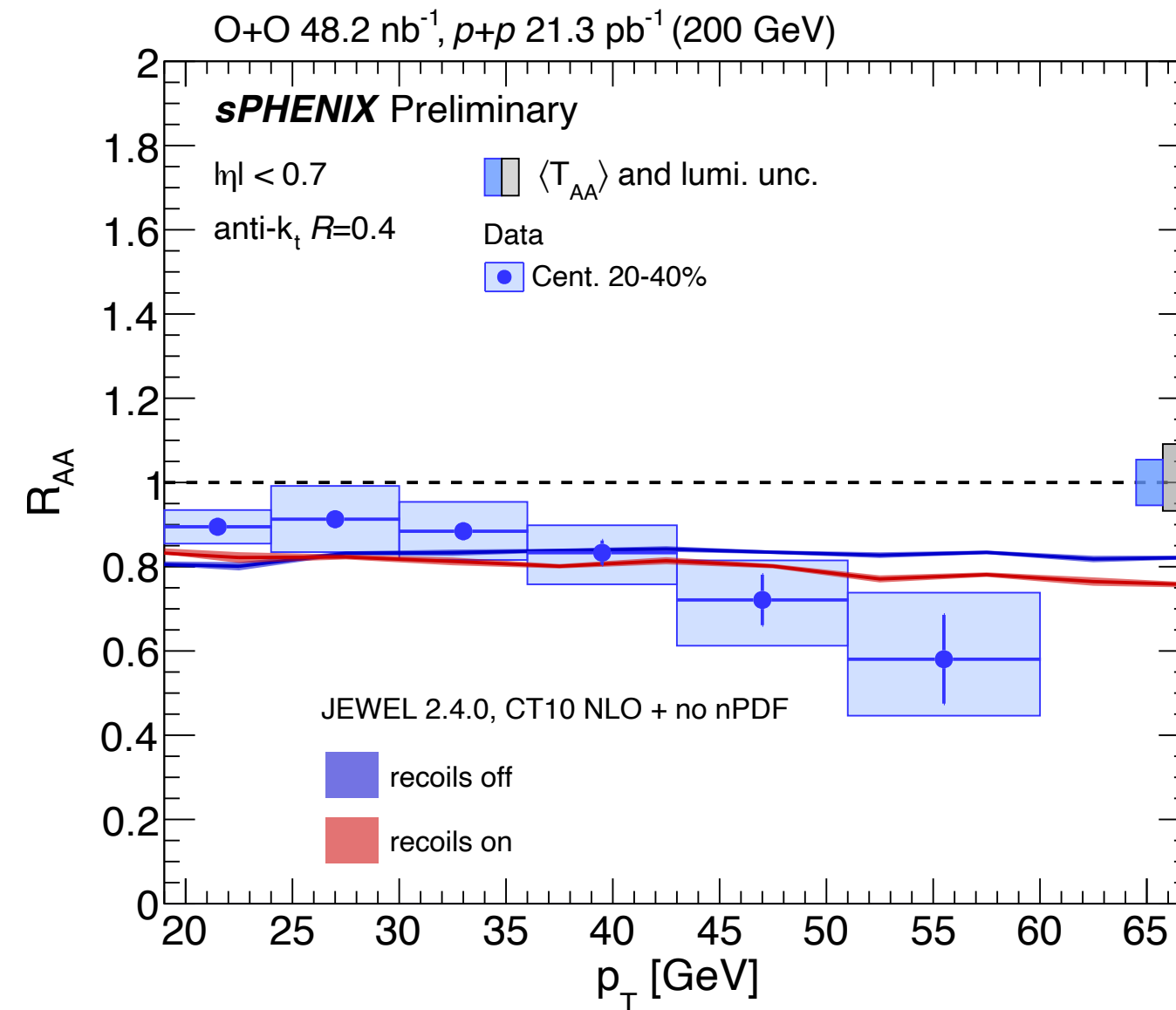
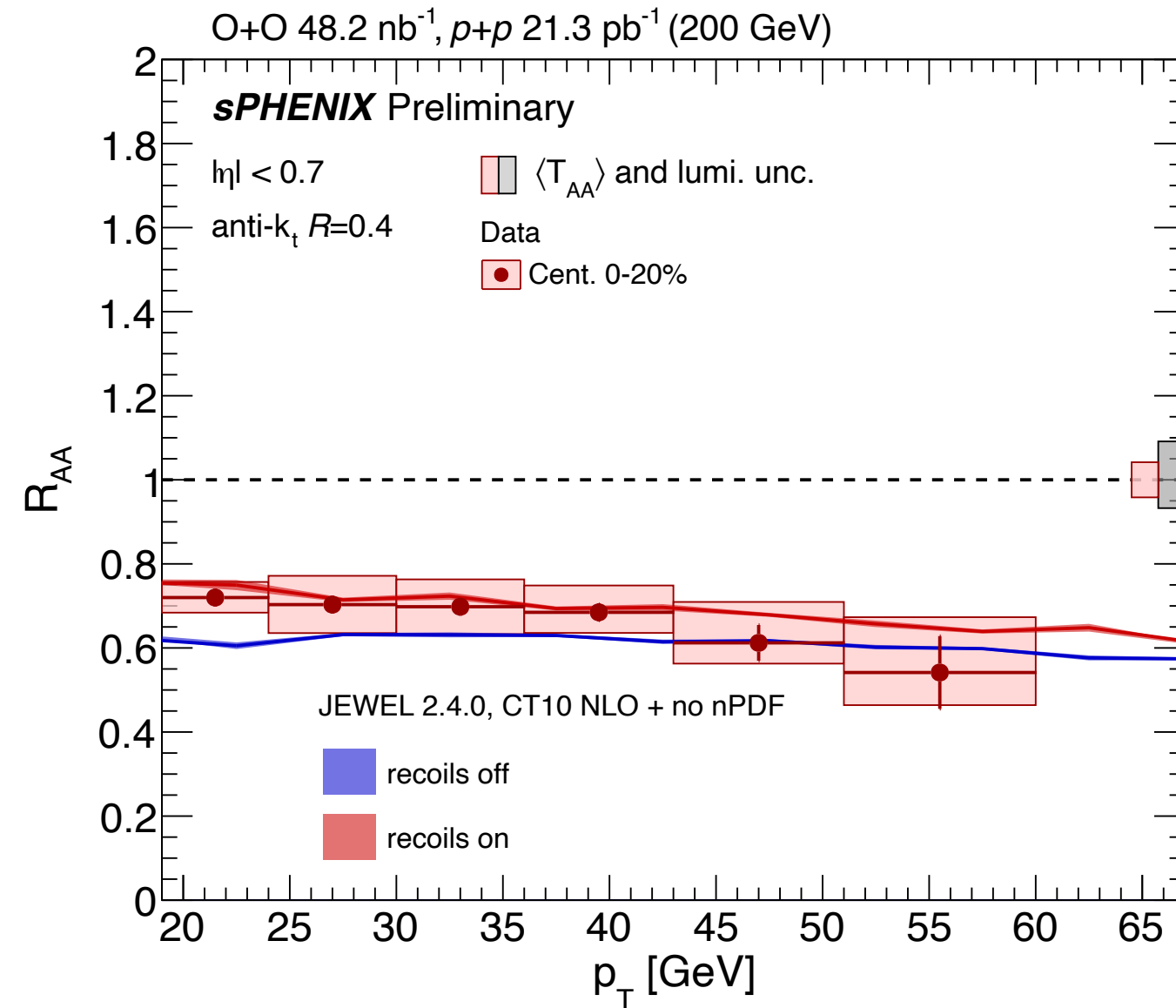
60-80% reference recoil on

[sPH-CONF-JET-2026-02]



- **JEWEL (no nPDF) with recoil on vs recoil off** predictions in agreement with data

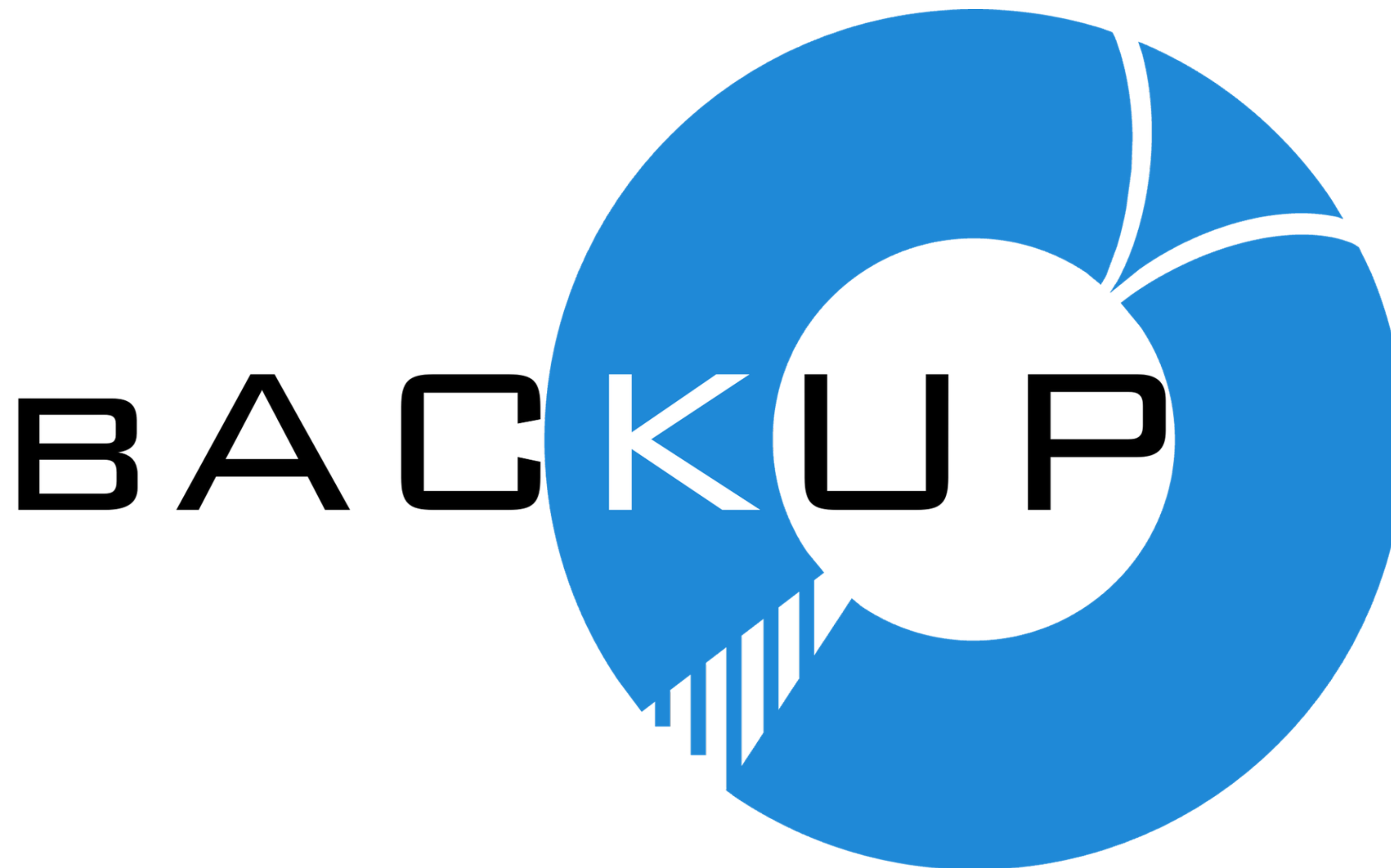
Results compared with theory calculations



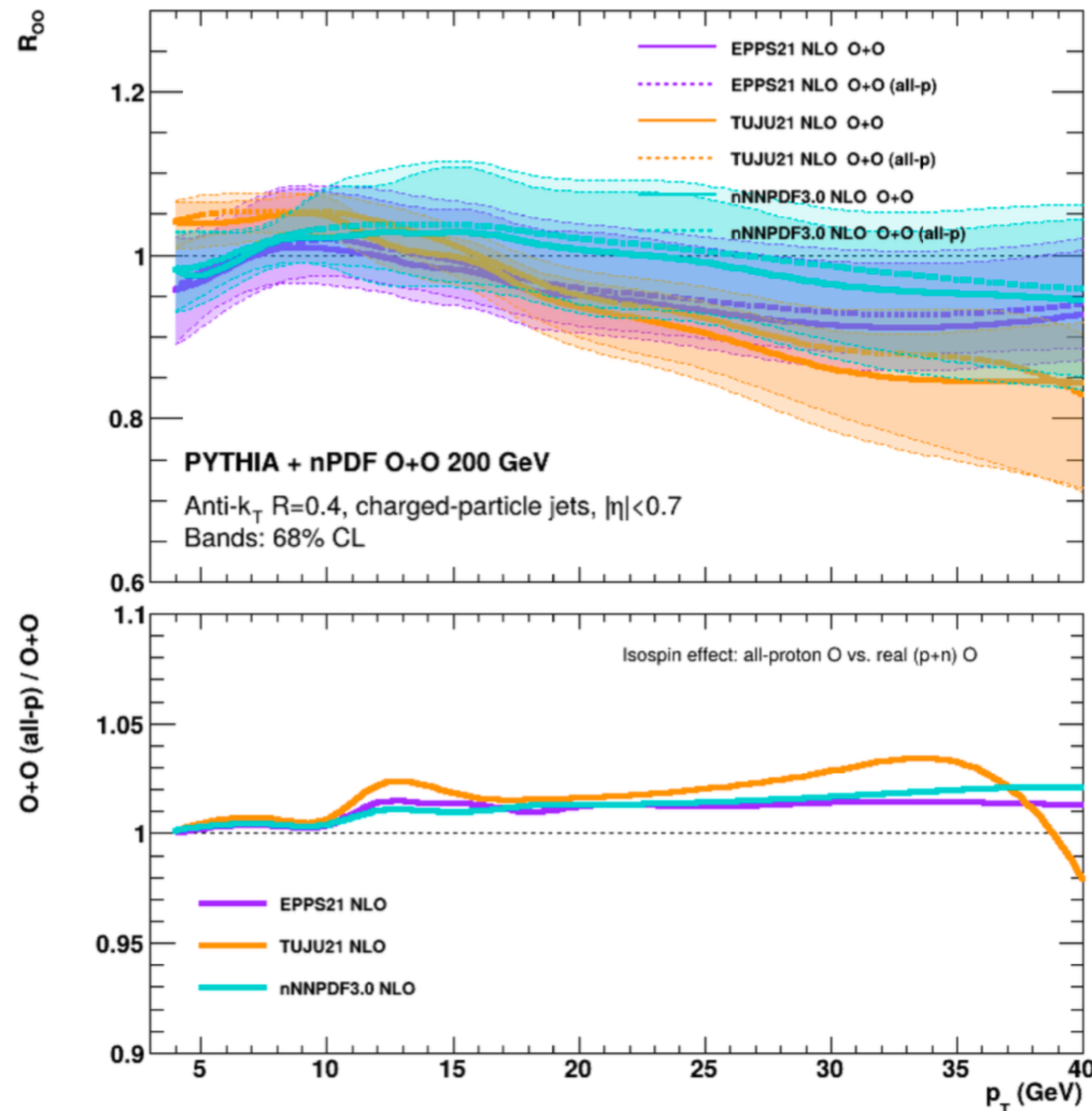
- **JEWEL predictions** with centrality dependence found to be consistent with results
- Modest effect with recoils
 - Maximum only 10% in most central collisions

Comprehensive jet physics program for O+O

- Successful **centrality calibration** with simple N_{part} **scaling** using Glauber + NBD
- **Bias factor** for O+O found to be typically **within 5%** for sPHENIX acceptance of **jet measurement** and **centrality calibration detector**
- Jet suppression observed with clear **centrality ordering** beyond **selection bias**
- JEWEL predictions in agreement with data
- Useful measurement in constraining theory calculations together with LHC results

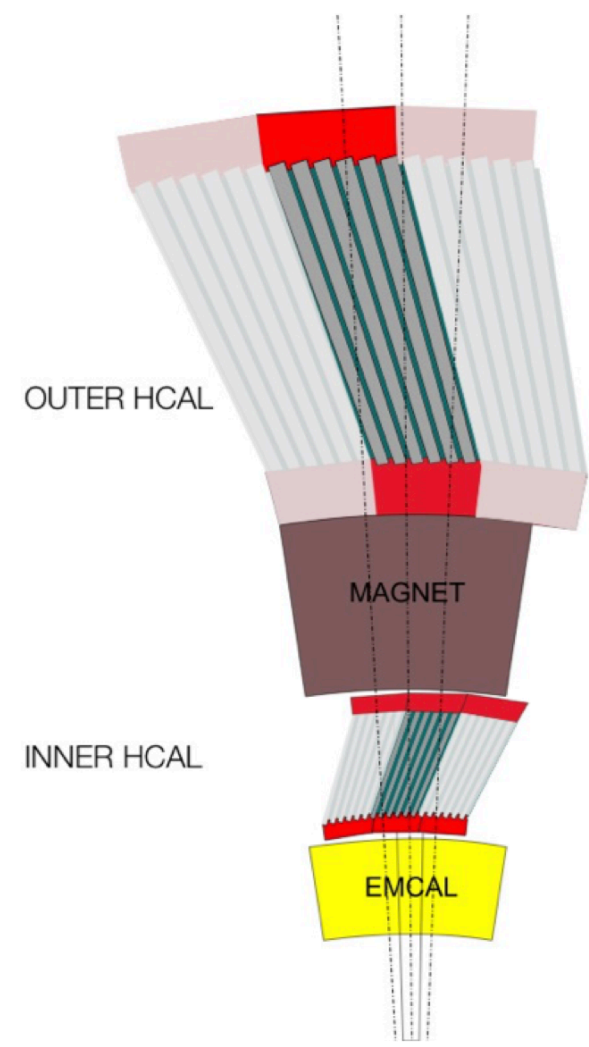


nPDF studies with MC generators



- Check on isospin dependence as Oxygen nucleus has the same number of protons and neutrons
- Validation test on Oxygen as if for 16 protons (all-p) compared to nominal proton/neutron ratio
- Effect found to be max. $\sim 3\%$ (very small)

sPHENIX jet measurement

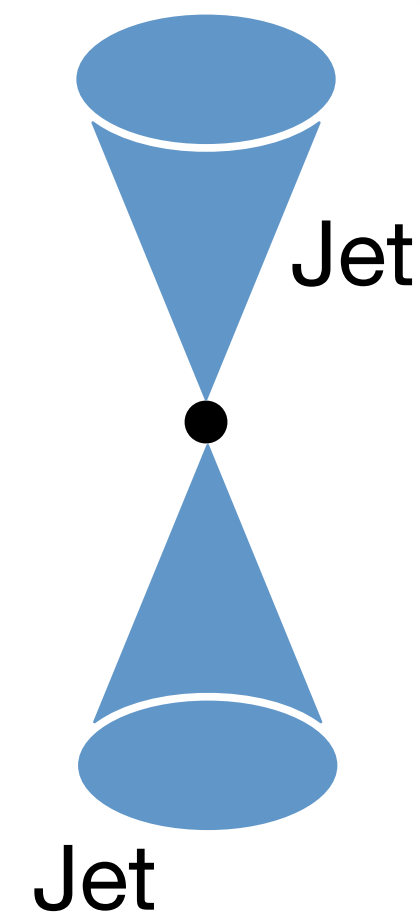


Full jet reconstruction
using EMCal + HCal

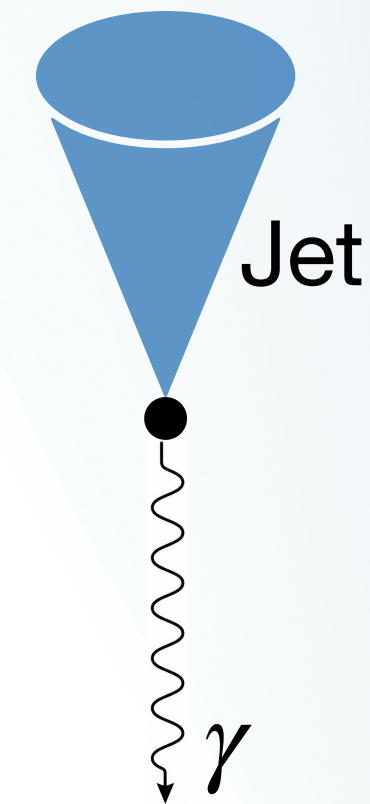
Full unfolding for detector
response + UE subtraction
in heavy ion collisions

In situ jet energy scale
(JES) and jet energy
resolution (JER) correction

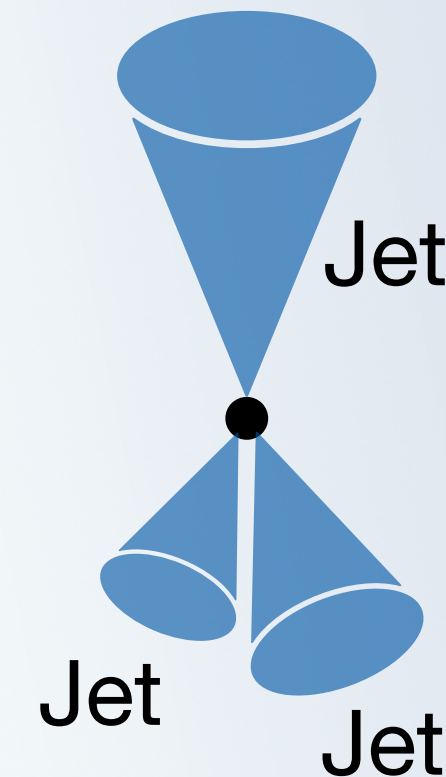
Dijet



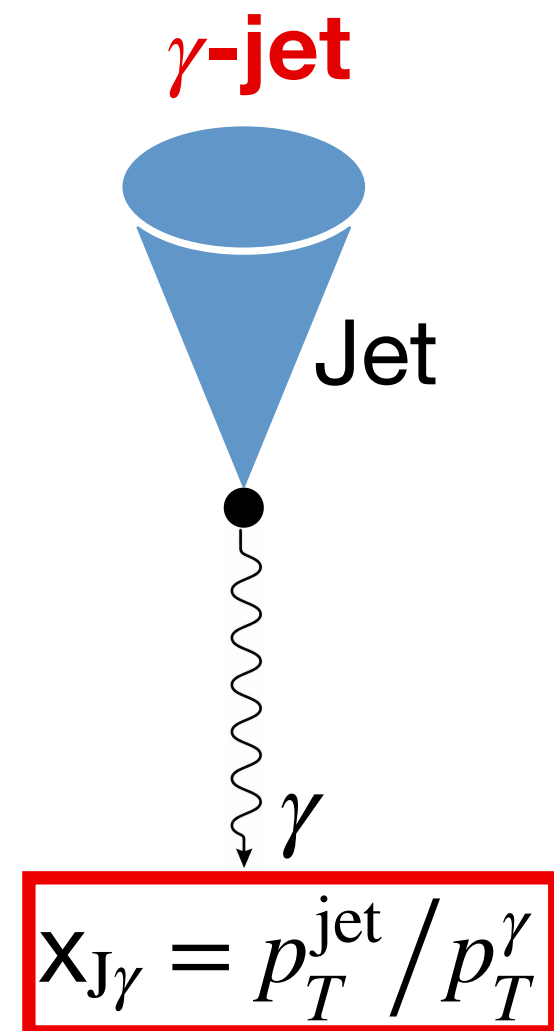
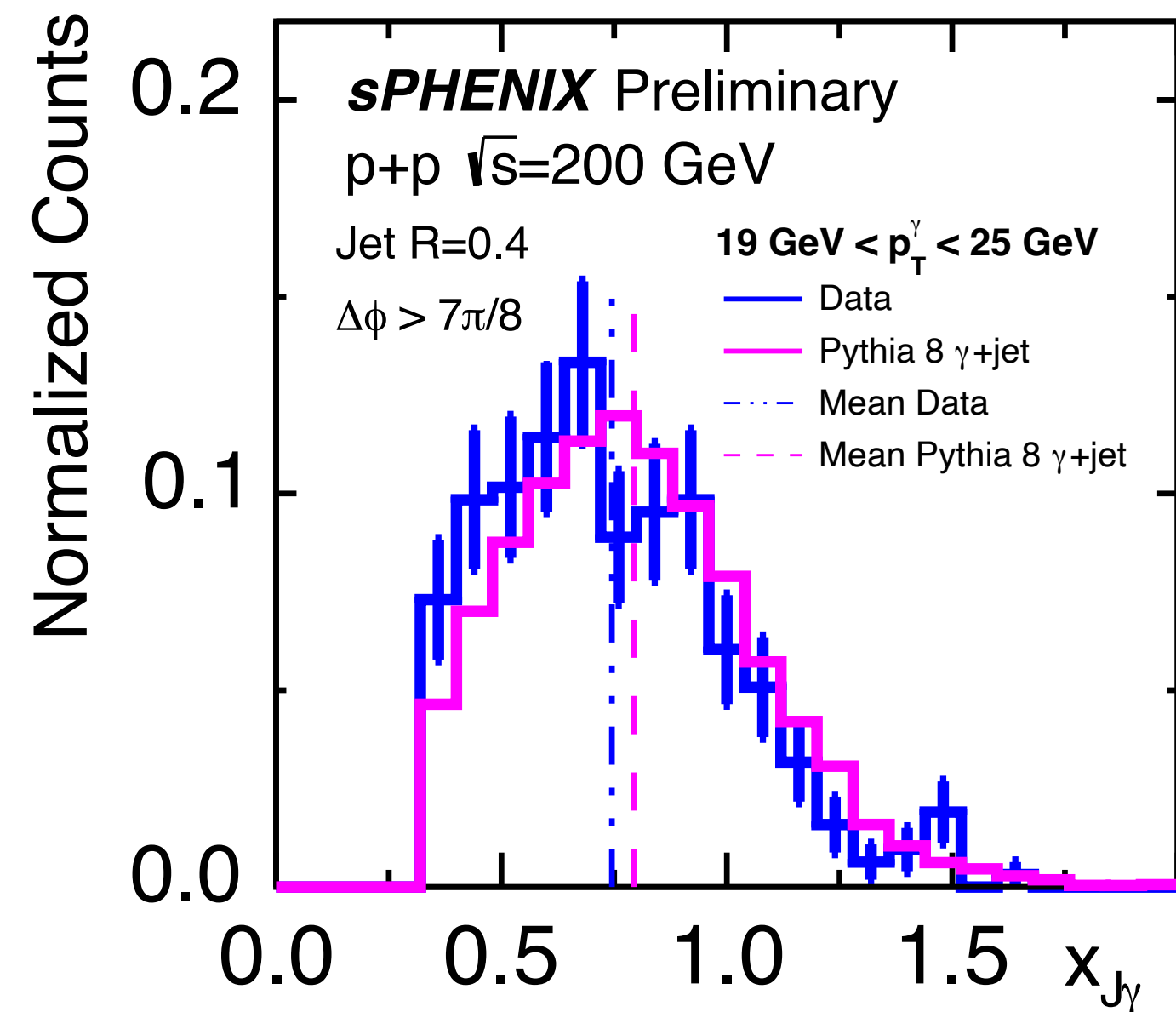
γ -jet



Multi-jet

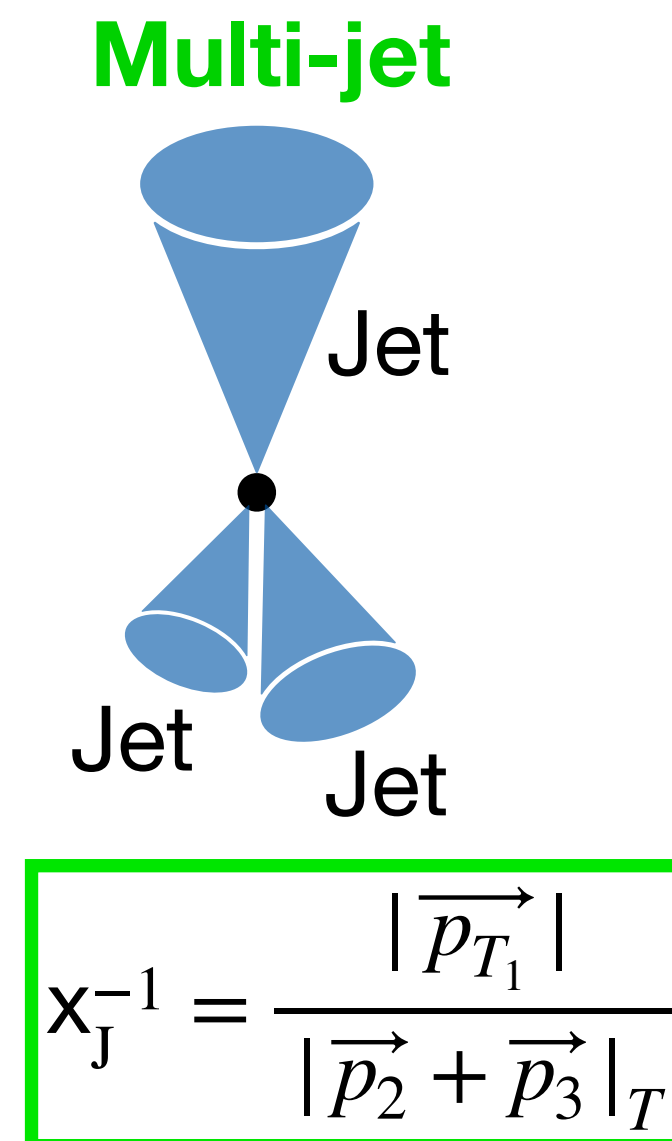
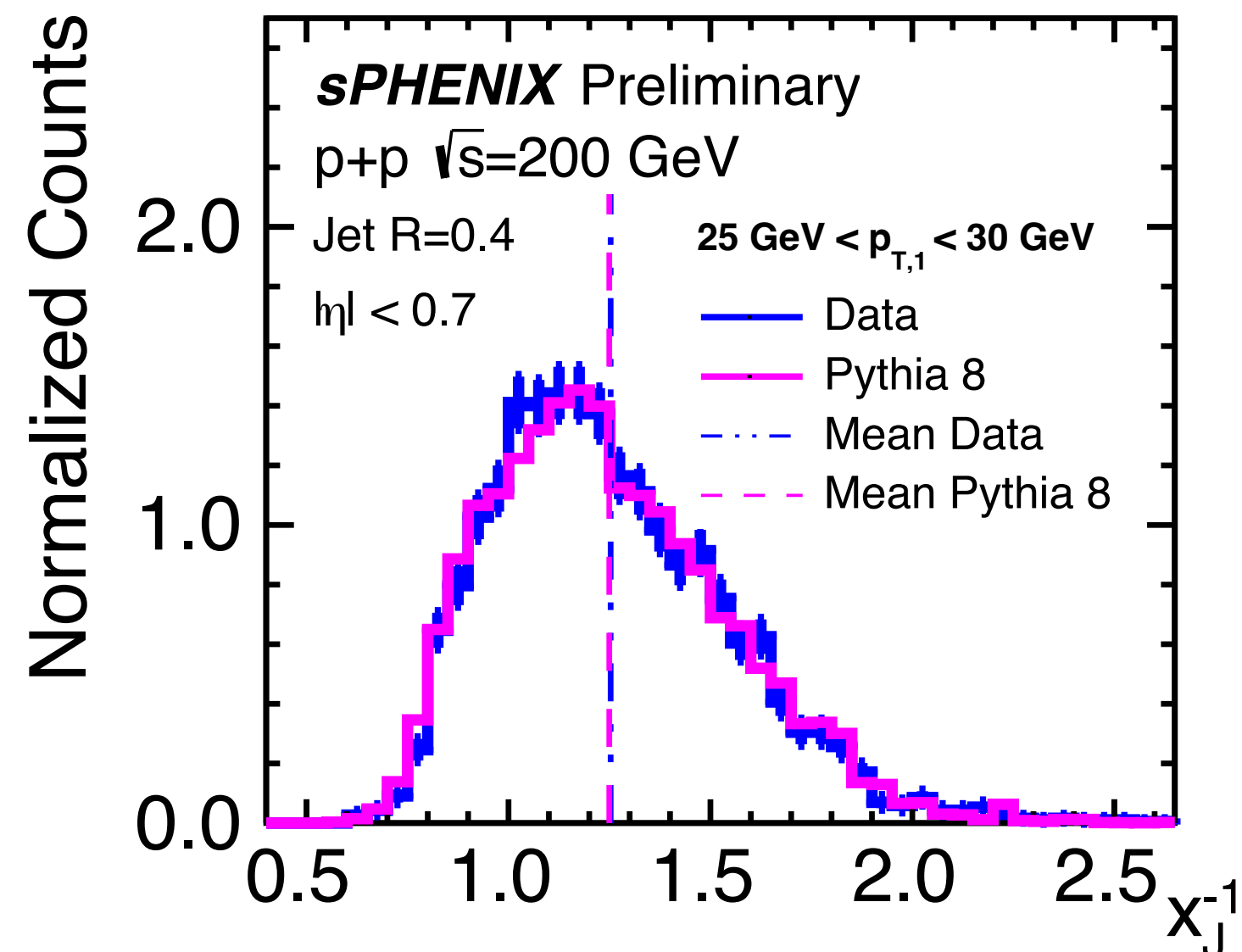


In-situ jet energy scale (JES)

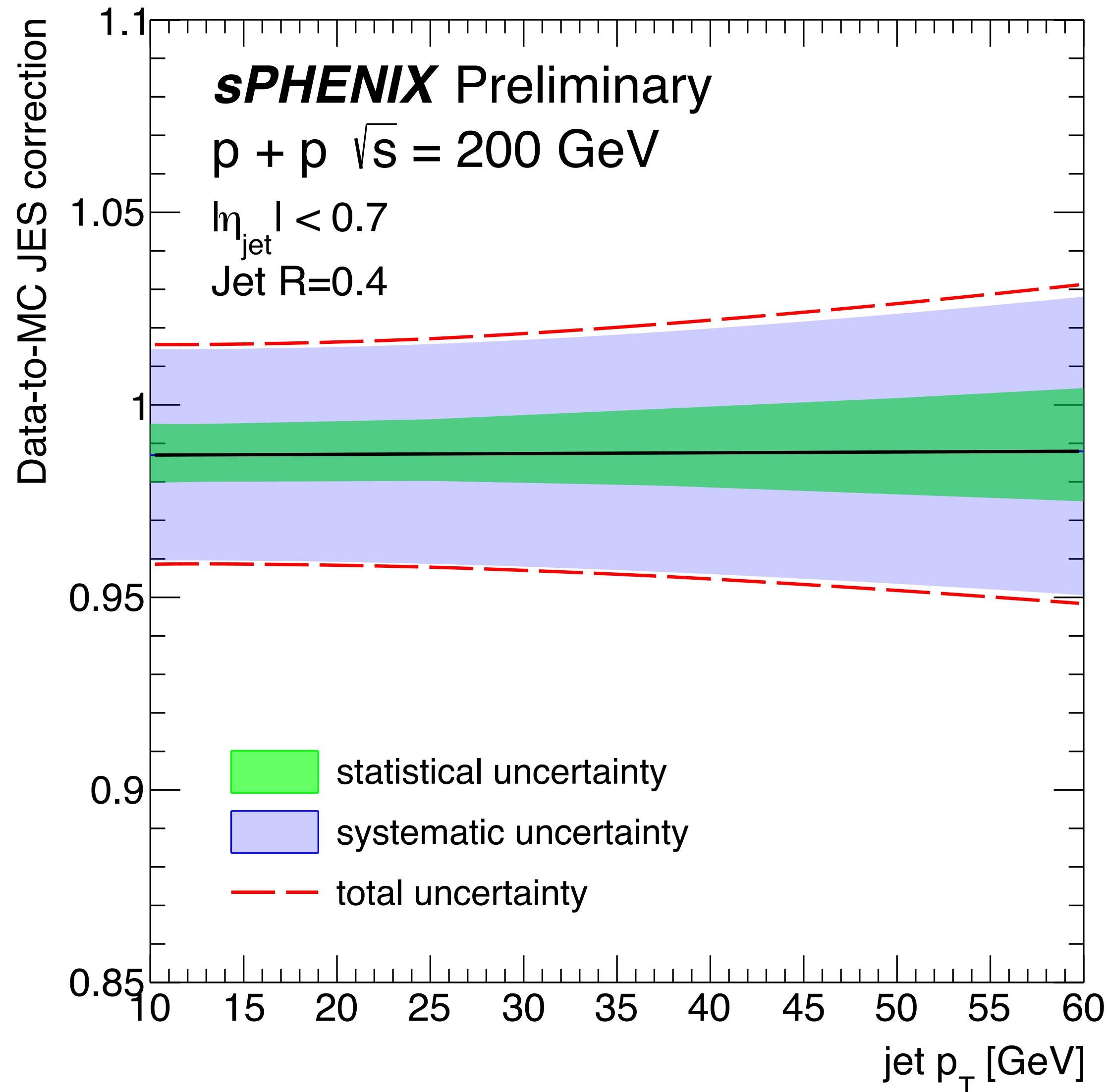


Preliminary absolute jet energy scale

- Use **γ -jet** and **multi-jet** channels to calibrate the jet energy scale over a wide range $10 < p_T^{\text{jet}} < 60 \text{ GeV}$



In-situ jet energy scale (JES)



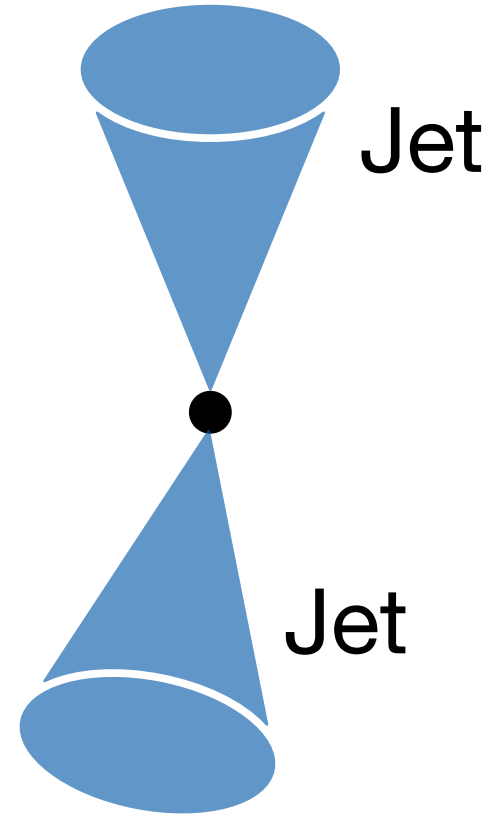
Preliminary absolute jet energy scale

- Use **γ -jet** and **multi-jet** channels to calibrate the jet energy scale over a wide range $10 < p_T^{\text{jet}} < 60 \text{ GeV}$
- **Global Data-to-MC fit** derived using both channels to determine absolute JES correction and uncertainties

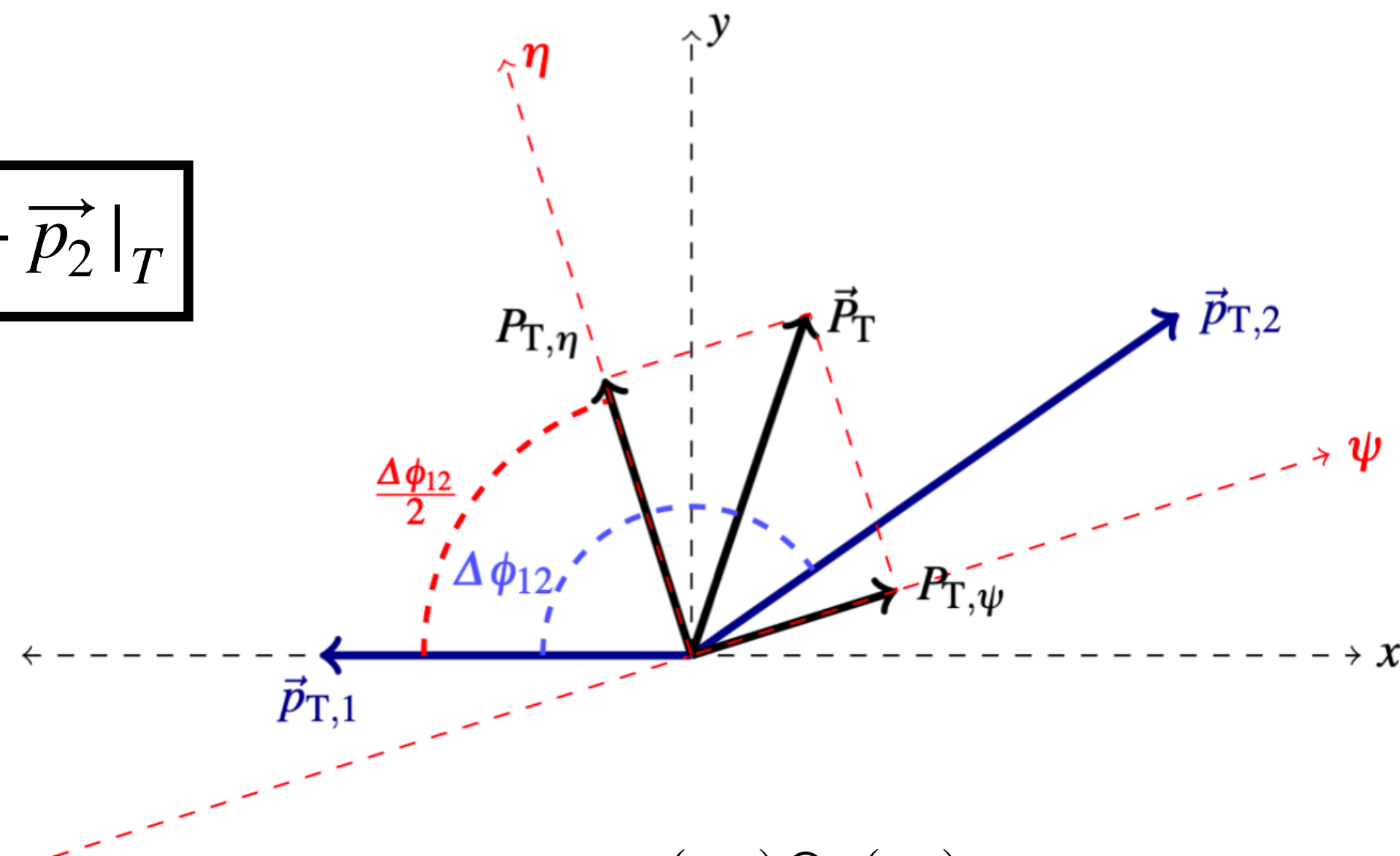
Data-driven jet energy resolution (JER)

1. Bisector method

- Assuming soft radiation imbalance is isotropic
- Detector smearing affects only jet magnitude into ψ projection



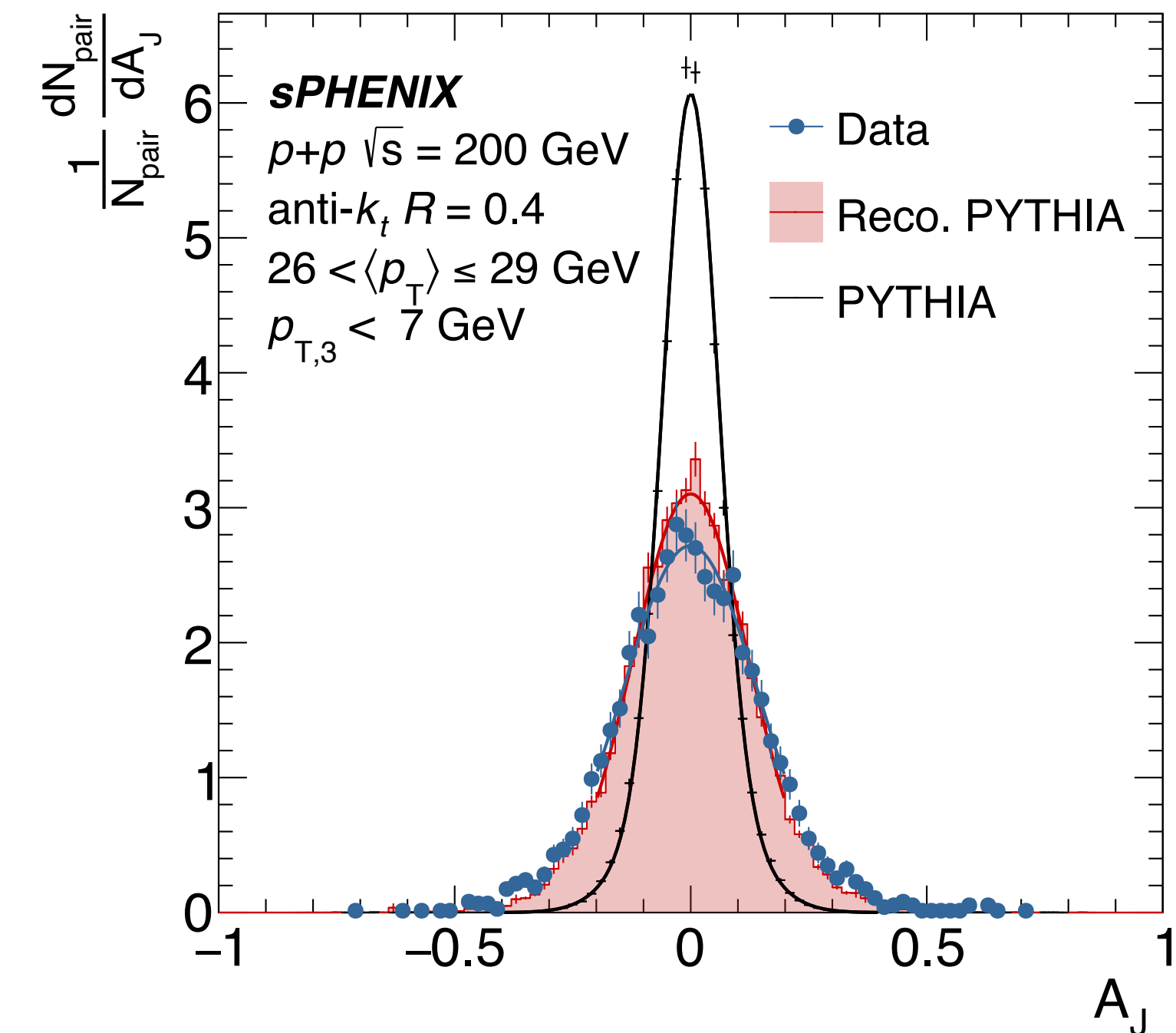
$$\langle p_T \rangle = |\vec{p}_1 + \vec{p}_2|_T$$



$$\frac{\sigma(p_T)}{p_T} = \frac{\sigma(p_{T\psi}) \ominus \sigma(p_{T\eta})}{\sqrt{2} \langle p_T \rangle \sqrt{\langle |\cos \Delta\phi| \rangle}}$$

2. Momentum imbalance

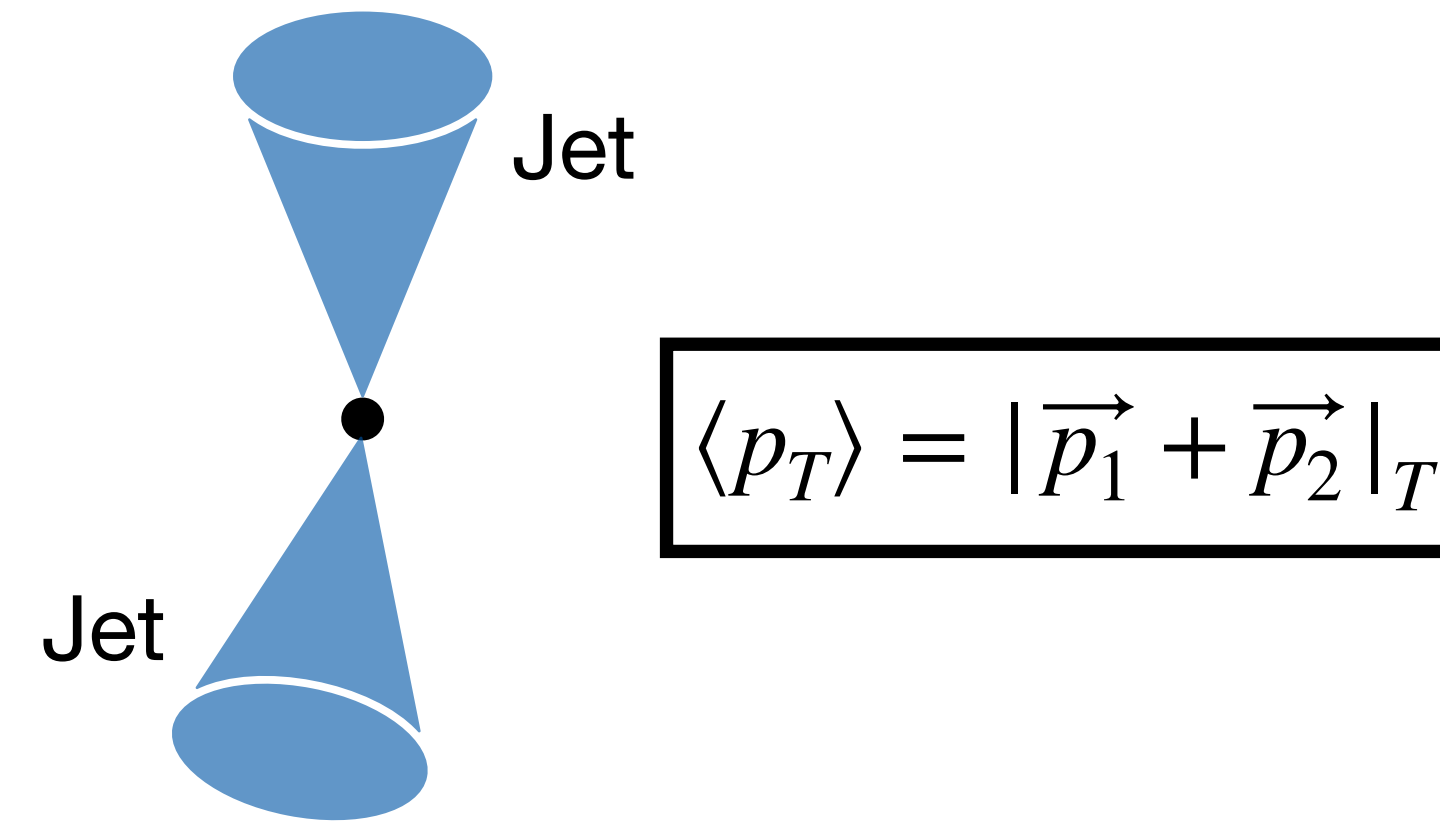
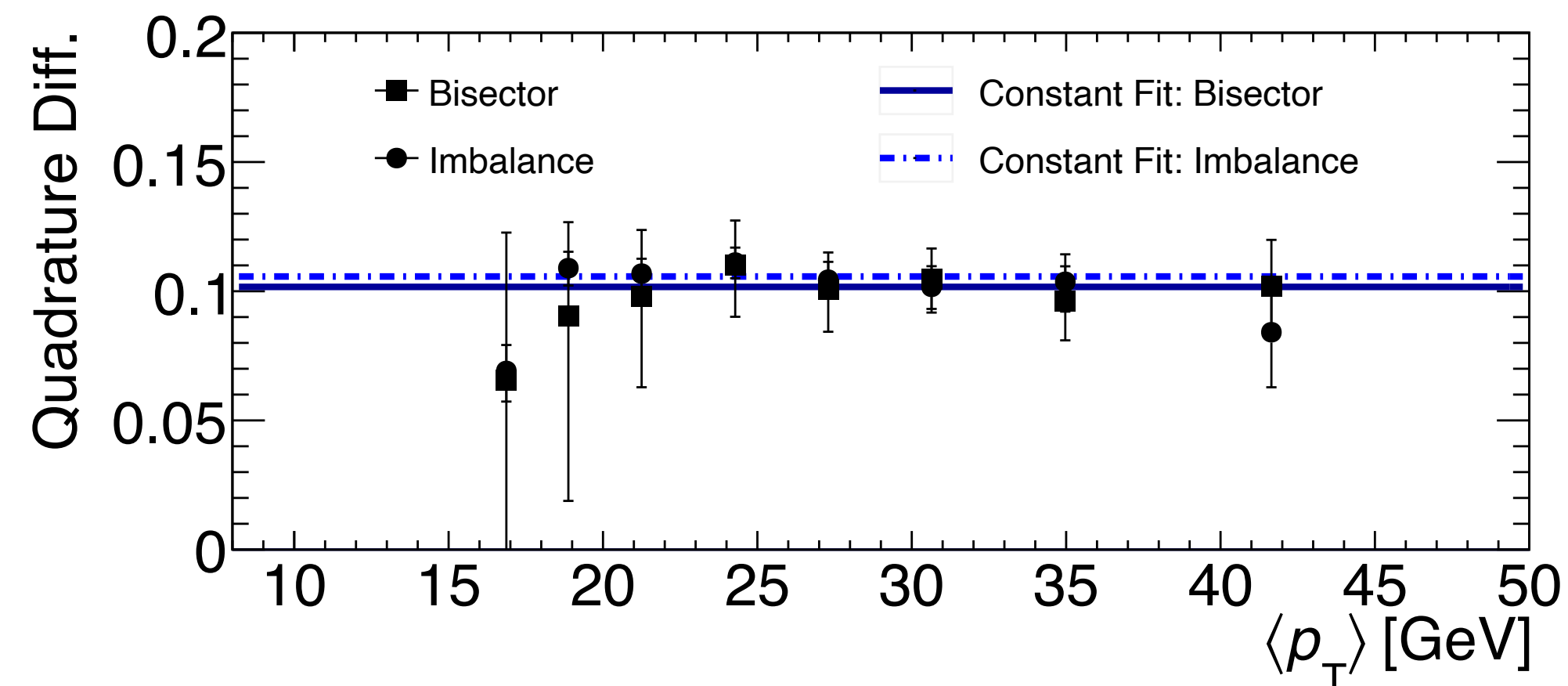
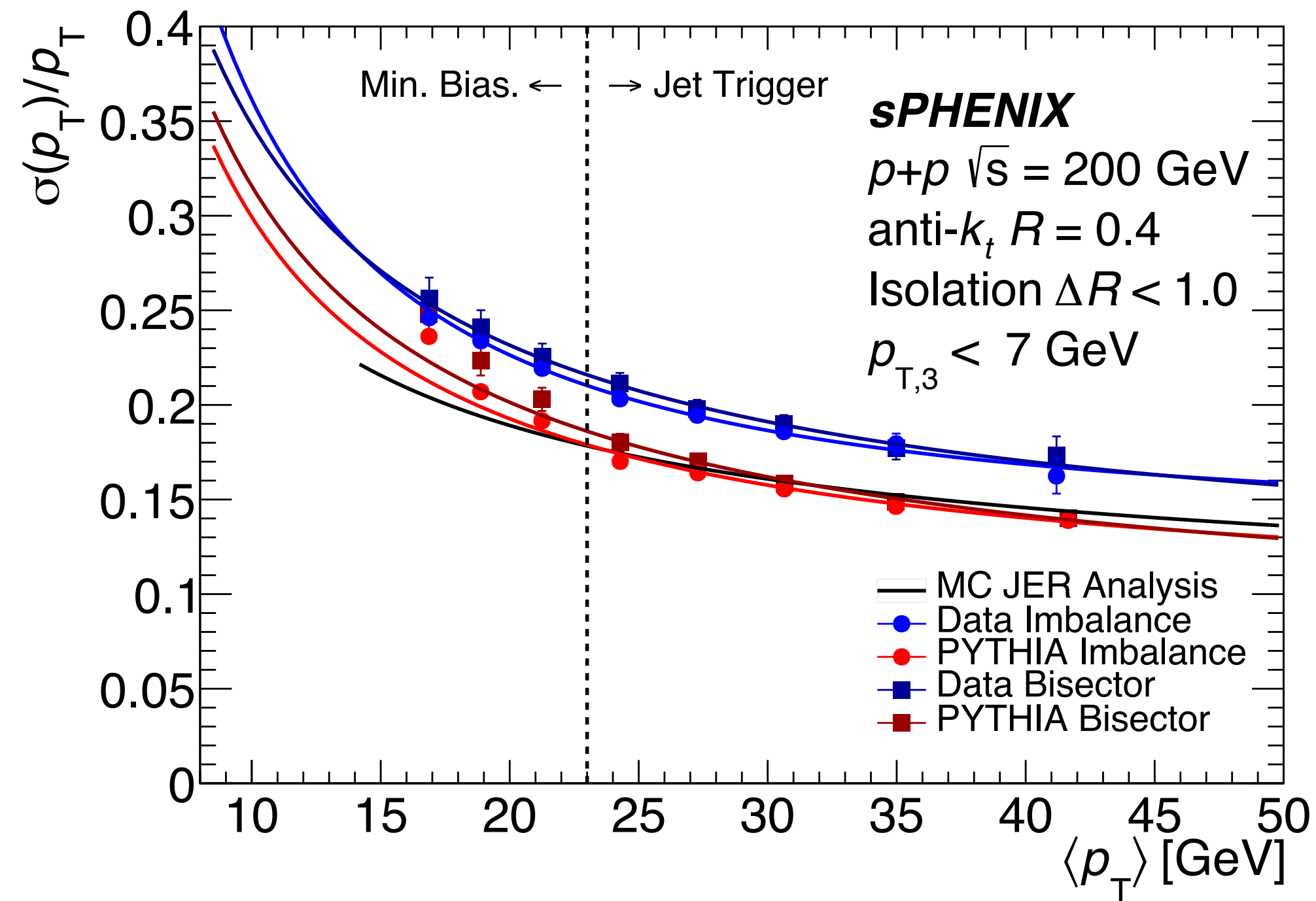
- Assuming detector smearing and physics are in quadrature (Gaussian independent)
- Extrapolating to no third jet (hard veto)



$$A_J = \frac{p_{T1} - p_{T2}}{p_{T1} + p_{T2}}$$

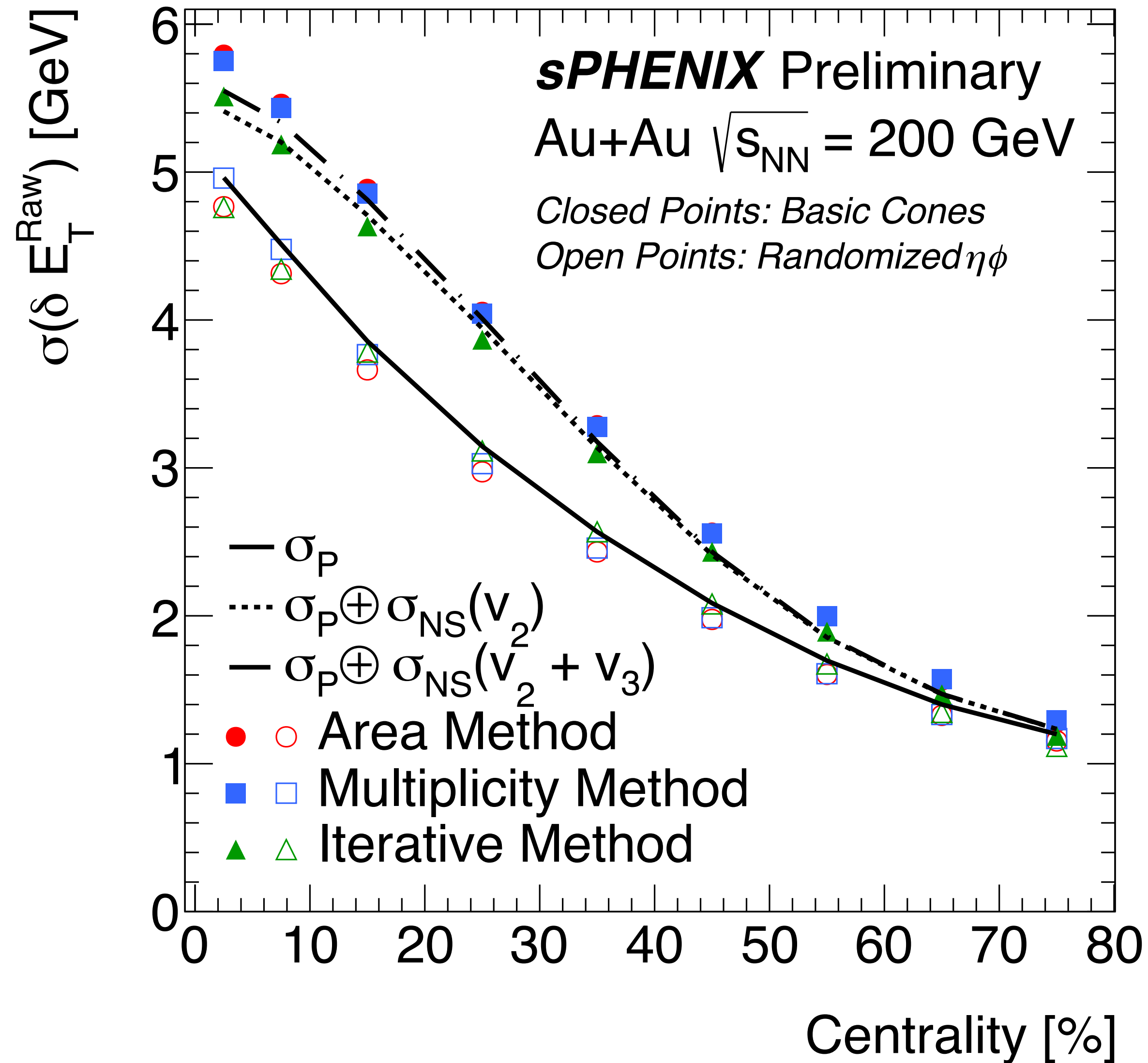
$$\frac{\sigma(p_T)}{p_T} = \frac{\sigma_{A_J, \text{det}}}{\sqrt{2}} = \frac{\sqrt{\sigma_{A_J, \text{reco}}^2 - \sigma_{A_J, \text{truth}}^2}}{\sqrt{2}}$$

Data-driven jet energy resolution (JER)



- **JER** compared for **data** and **MC** using **bisector & imbalance** methods
- **Similar results** within data and MC for the **two method** (very different assumptions)
- **MC smeared** to match the JER in data

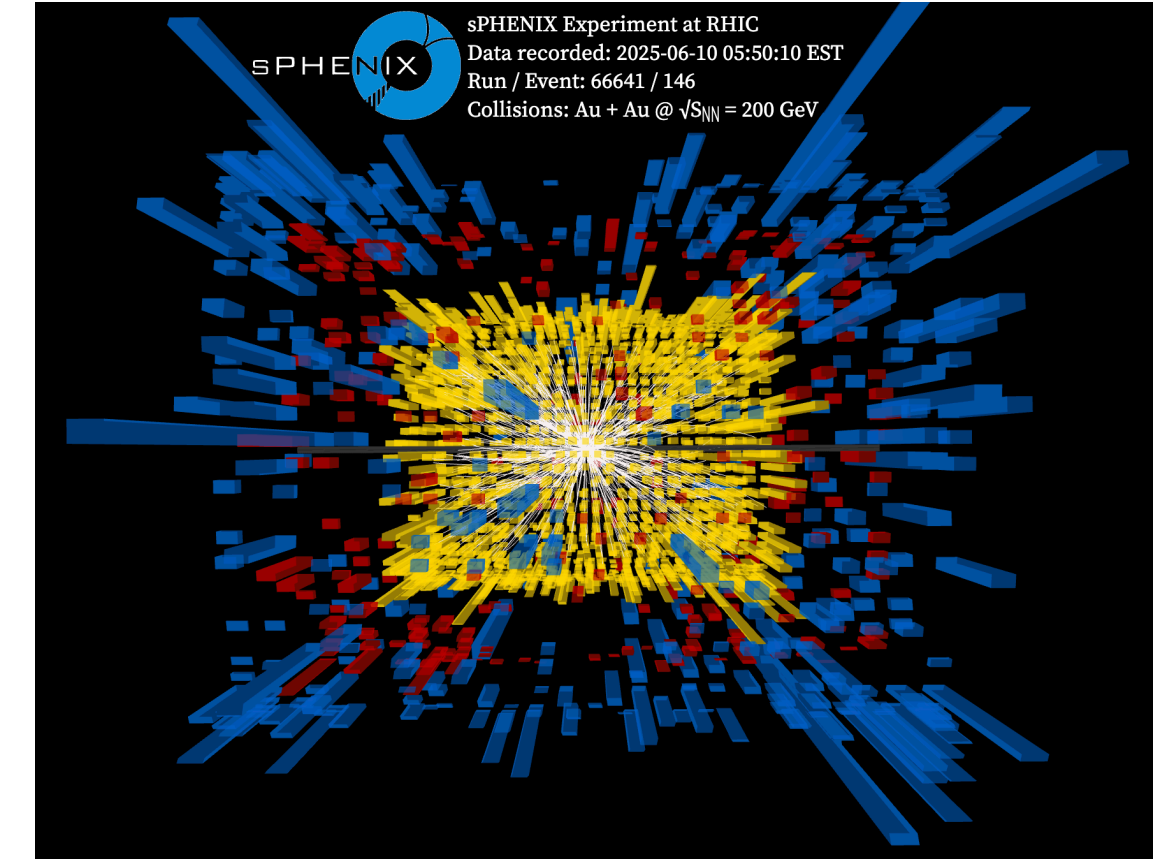
Underlying event characterization



$$\delta E_T^{\text{Area}} = \sum_{i=0}^N E_{T,i} - \rho_A \cdot A_{\text{cone}}$$

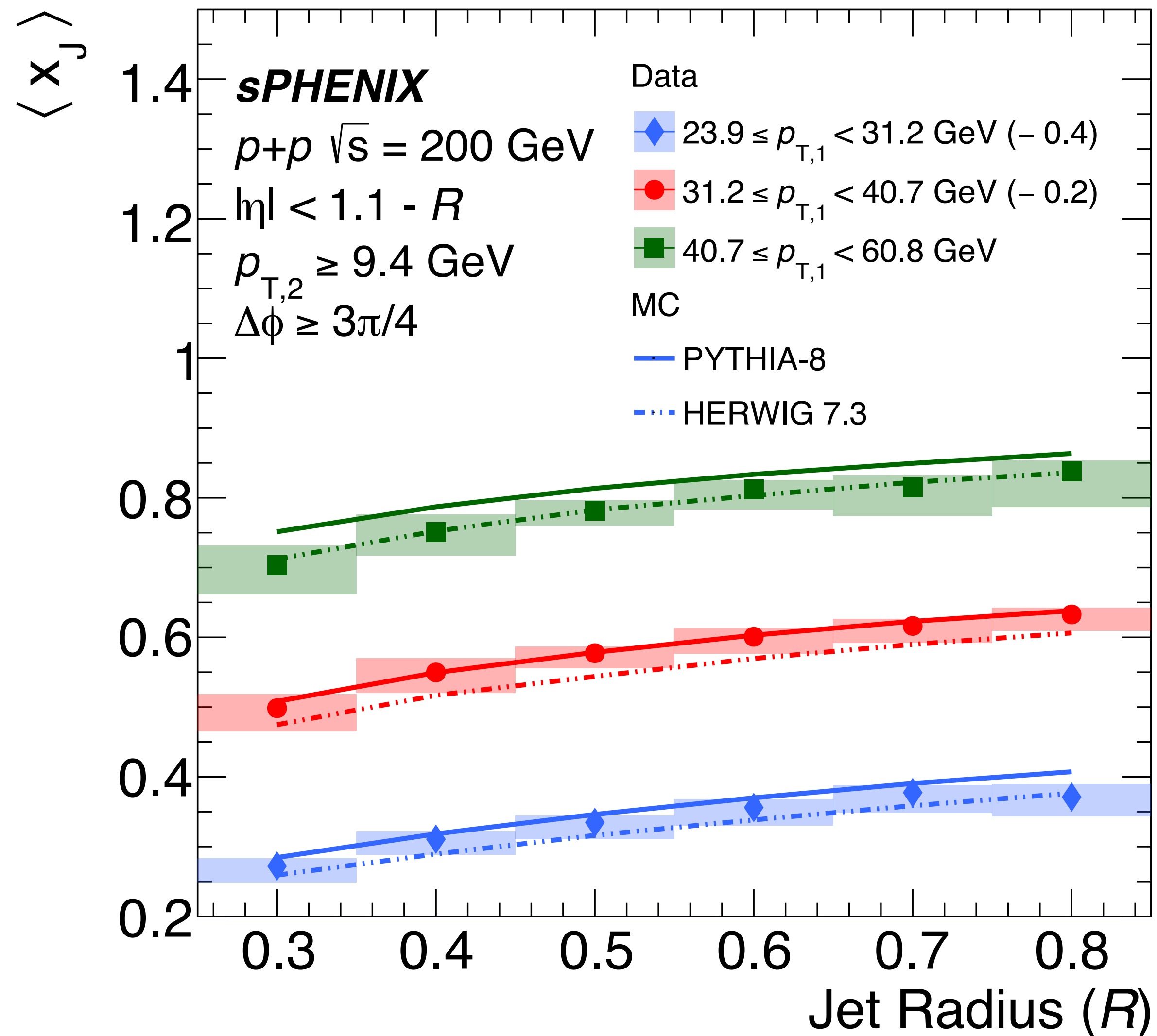
$$\delta E_T^{\text{Mult}} = \sum_{i=0}^N E_{T,i} - \rho_M \cdot N$$

$$\delta E_T^{\text{Iter}} = \sum_{i=0}^N E_{T,i}^{\text{sub}}$$



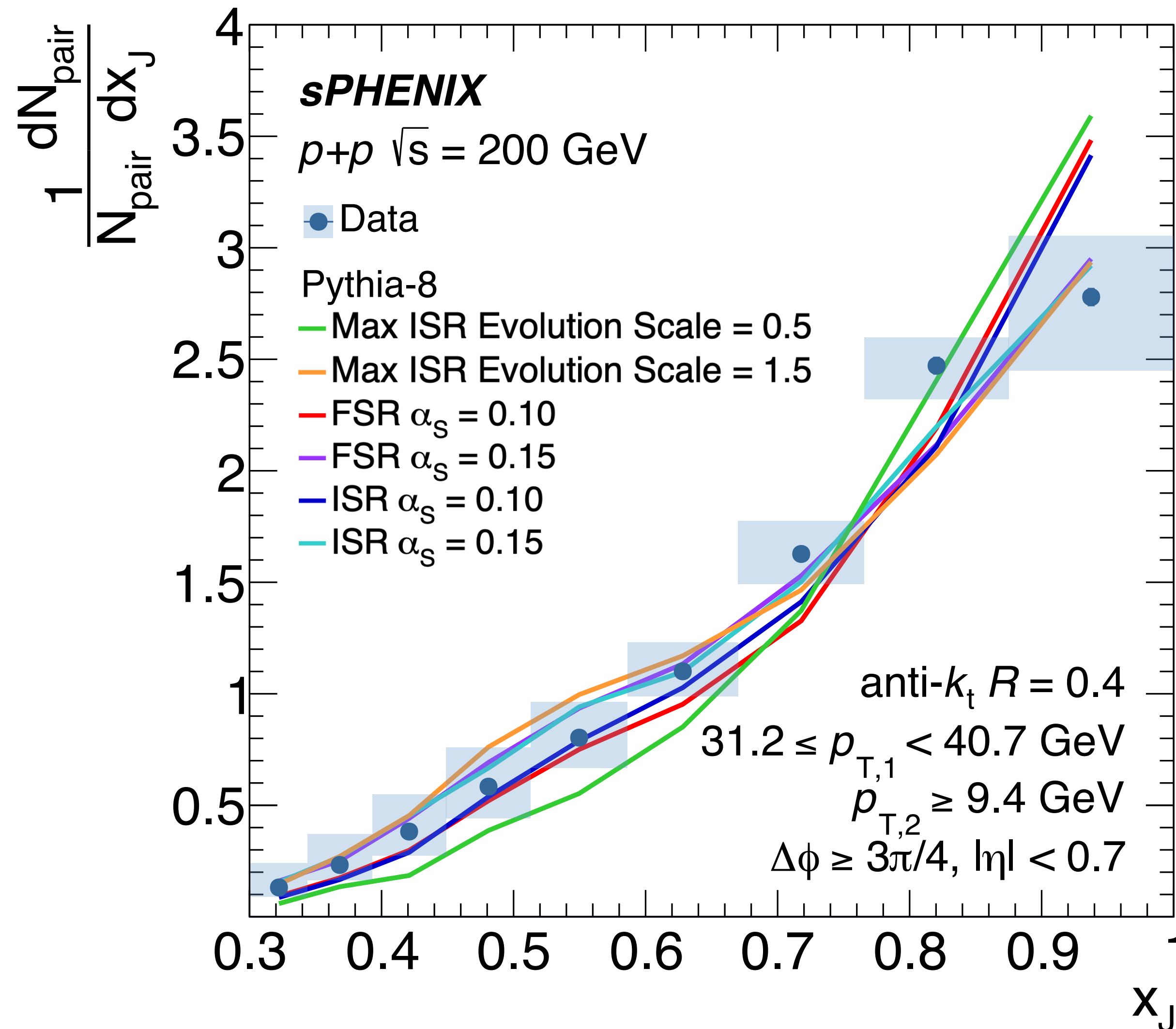
- **Underlying event** studied using various subtraction methods
- Absolute fluctuation described by **statistical multiplicity-fluctuations** and **hydrodynamic correlations**

Dijet Asymmetry in p+p 200 GeV



- Measurements for spanning over wide jet radius range **$R=0.3-0.8$**
- Useful for a comprehensive understanding on **MPI, hadronization, and non-perturbative corrections**

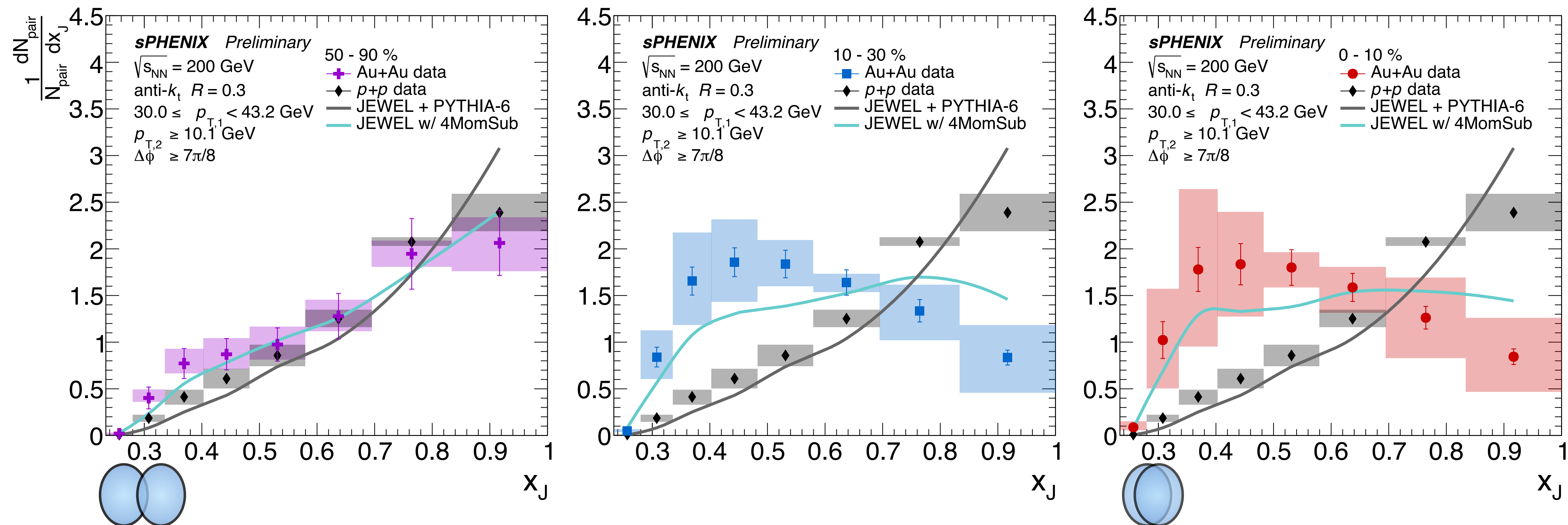
MC tuning with dijet asymmetry in pp 200 GeV



Sensitivity to **MC tuning**

- **ISR** / **FSR** bounds tuned for LHC jet measurements
- Current uncertainties in envelope of parameter variations
 - Multi-differential measurements providing useful constraints at RHIC energies

Dijet Asymmetry in p+p / Au+Au 200 GeV



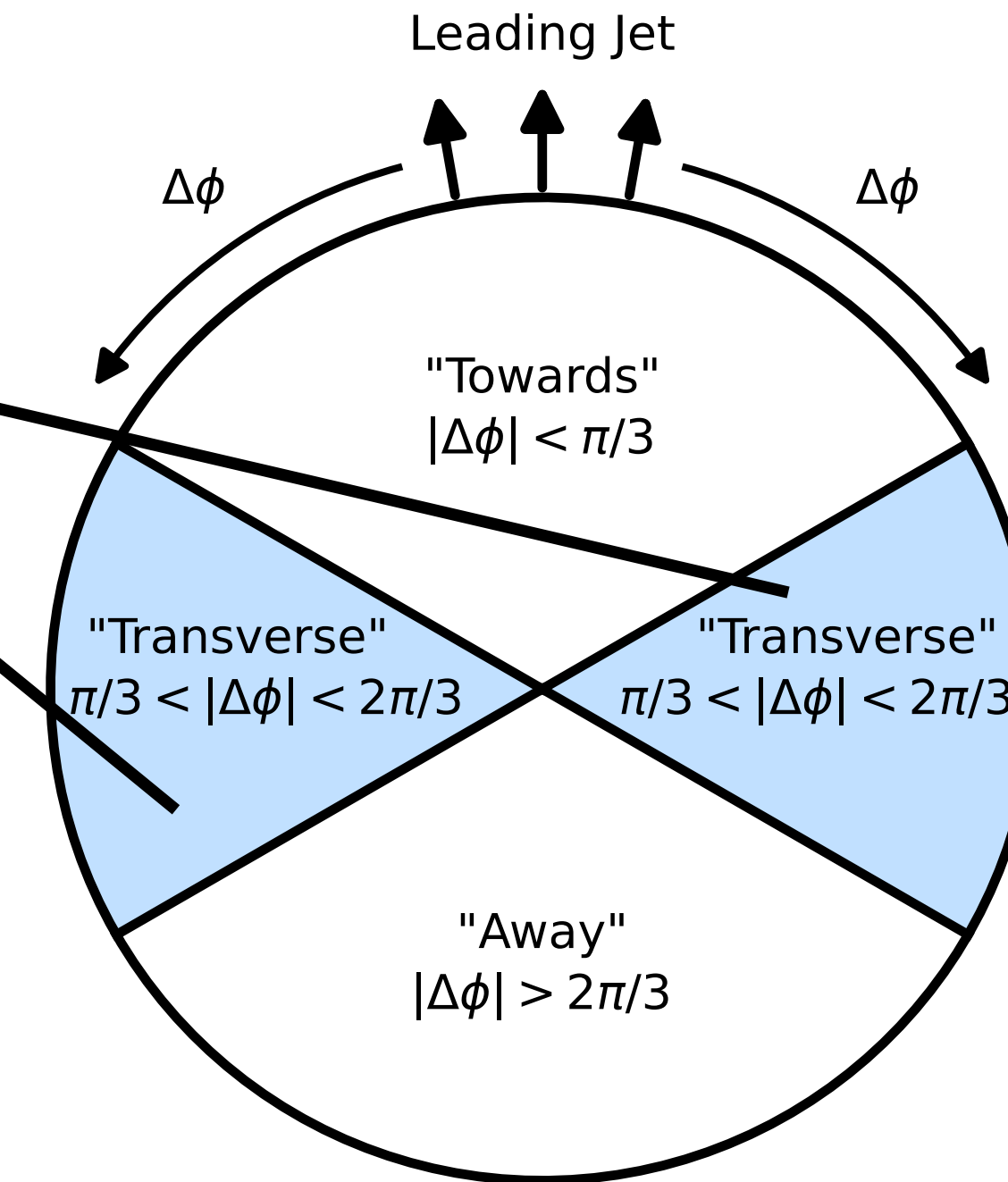
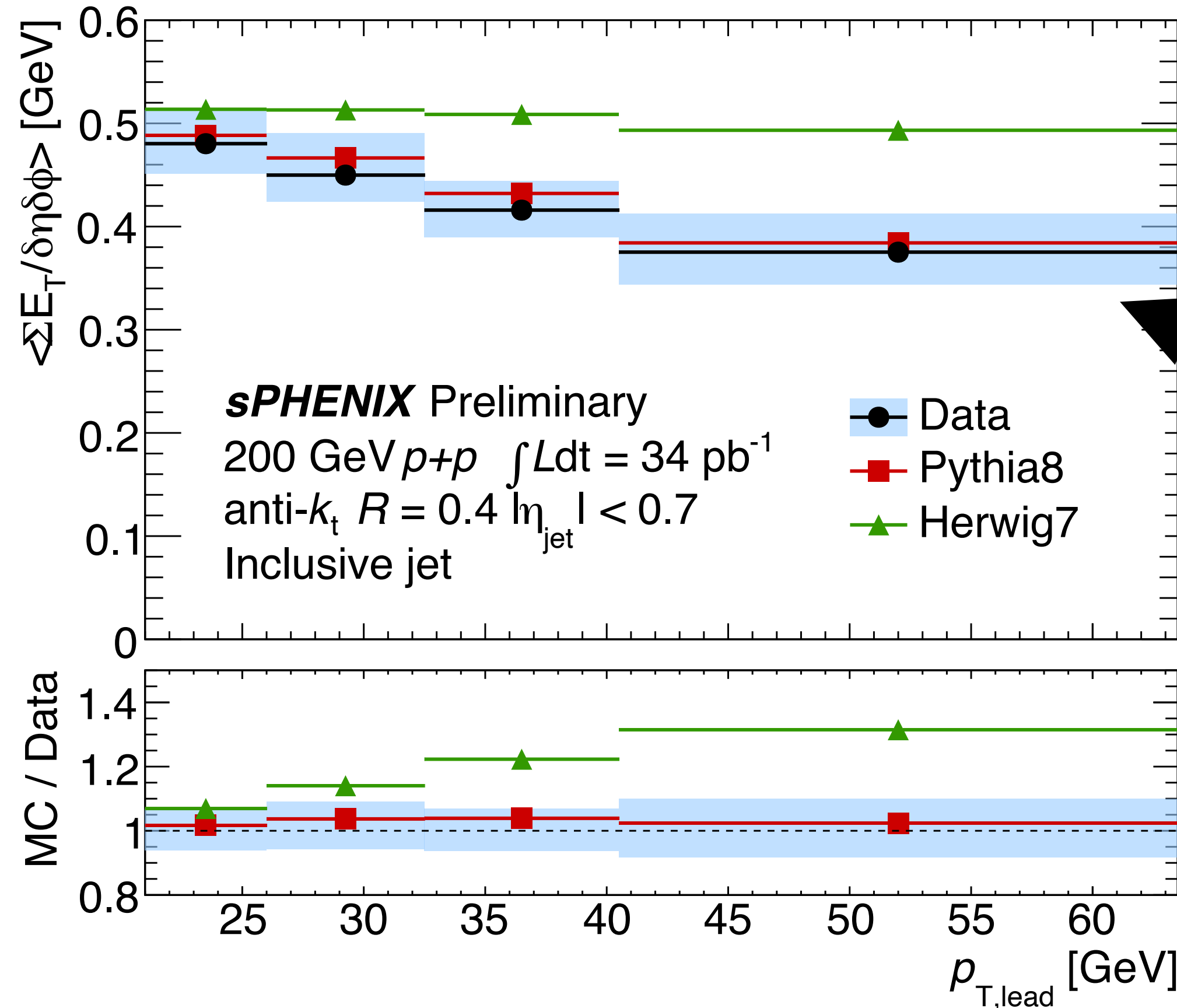
- **Strong modification** in x_J from **peripheral collisions** to **central collisions**
- Only using **1%** of the **full sampled luminosity**
- **Trend** described by **jet-quenching** calculations

Selected sPHENIX Jet physics analyses



- Dijet momentum imbalance in p+p 200 GeV (Final) : [arXiv:2606.17184](#)
- Isolated photon cross section p+p 200 GeV (Final) : [arXiv:2607.03892](#)
- Dijet momentum imbalance in Au+Au 200 GeV (Preliminary) : [sPH-CONF-JET-2025-05](#)
- Inclusive jet cross section in p+p 200 GeV (Preliminary) : [sPH-CONF-JET-2025-03](#)
- Underlying event fluctuations in Au+Au 200 GeV (Preliminary) : [sPH-CONF-JET-2025-04](#)
- Jet and UE correlation in p+p 200 GeV (Preliminary) : [sPH-CONF-JET-2026-03](#)
- In-situ jet energy scale in p+p 200 GeV (Preliminary) : [sPH-CONF-JET-2026-01](#)
- Jet R_{AA} / R_{CP} in O+O 200 GeV (Preliminary) : [sPH-CONF-JET-2026-02](#)

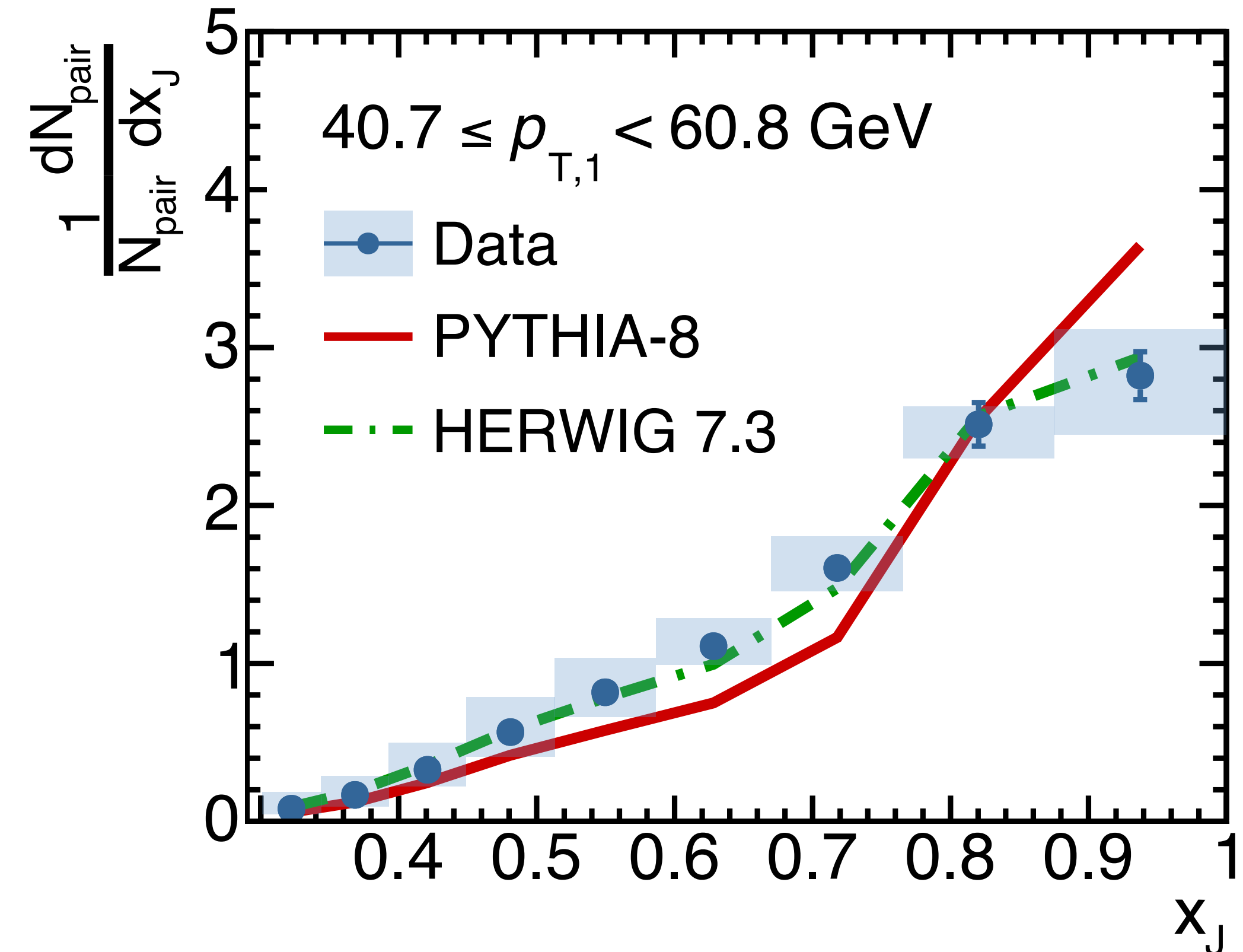
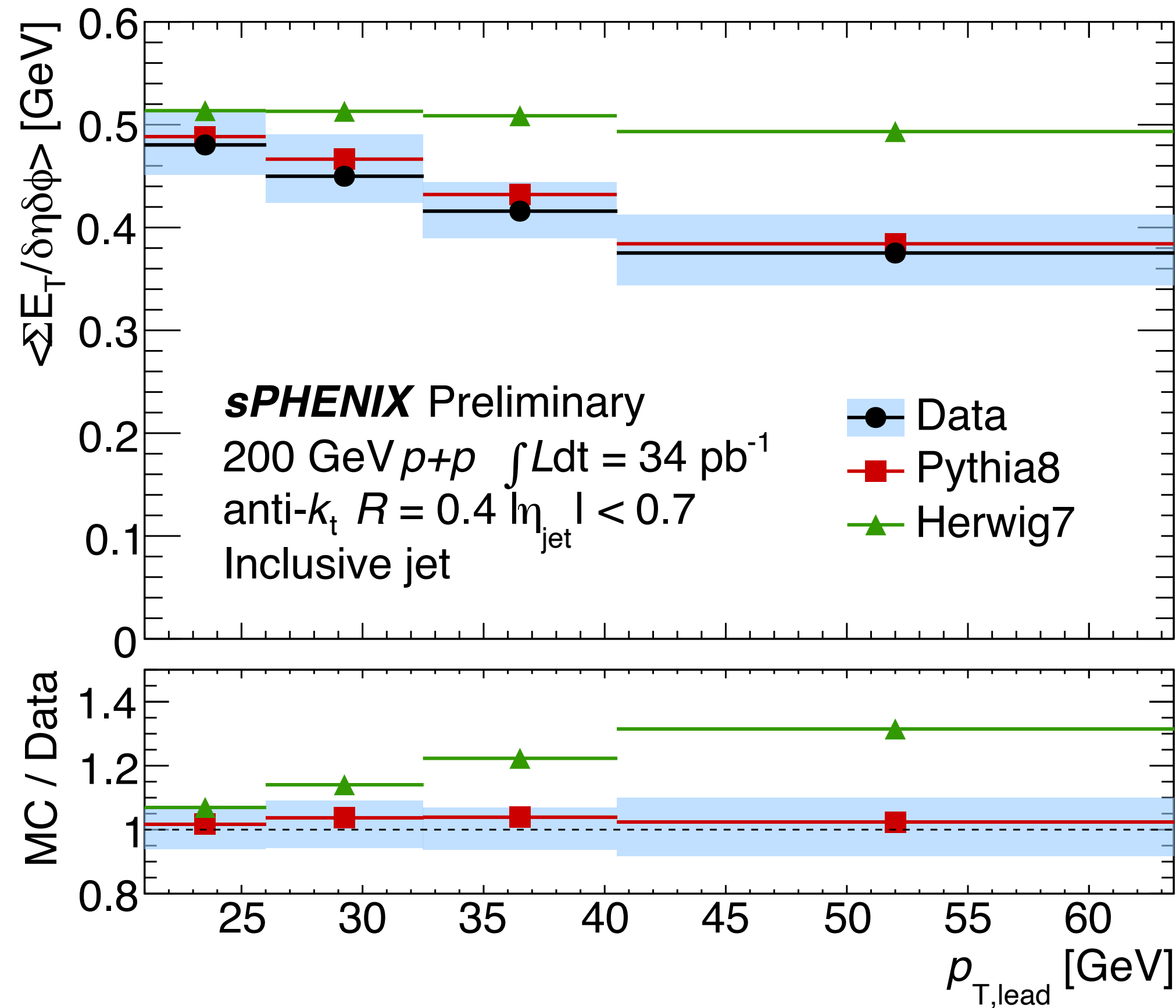
Underlying event and jet production correlation



**UE in transverse
region of leading jet**

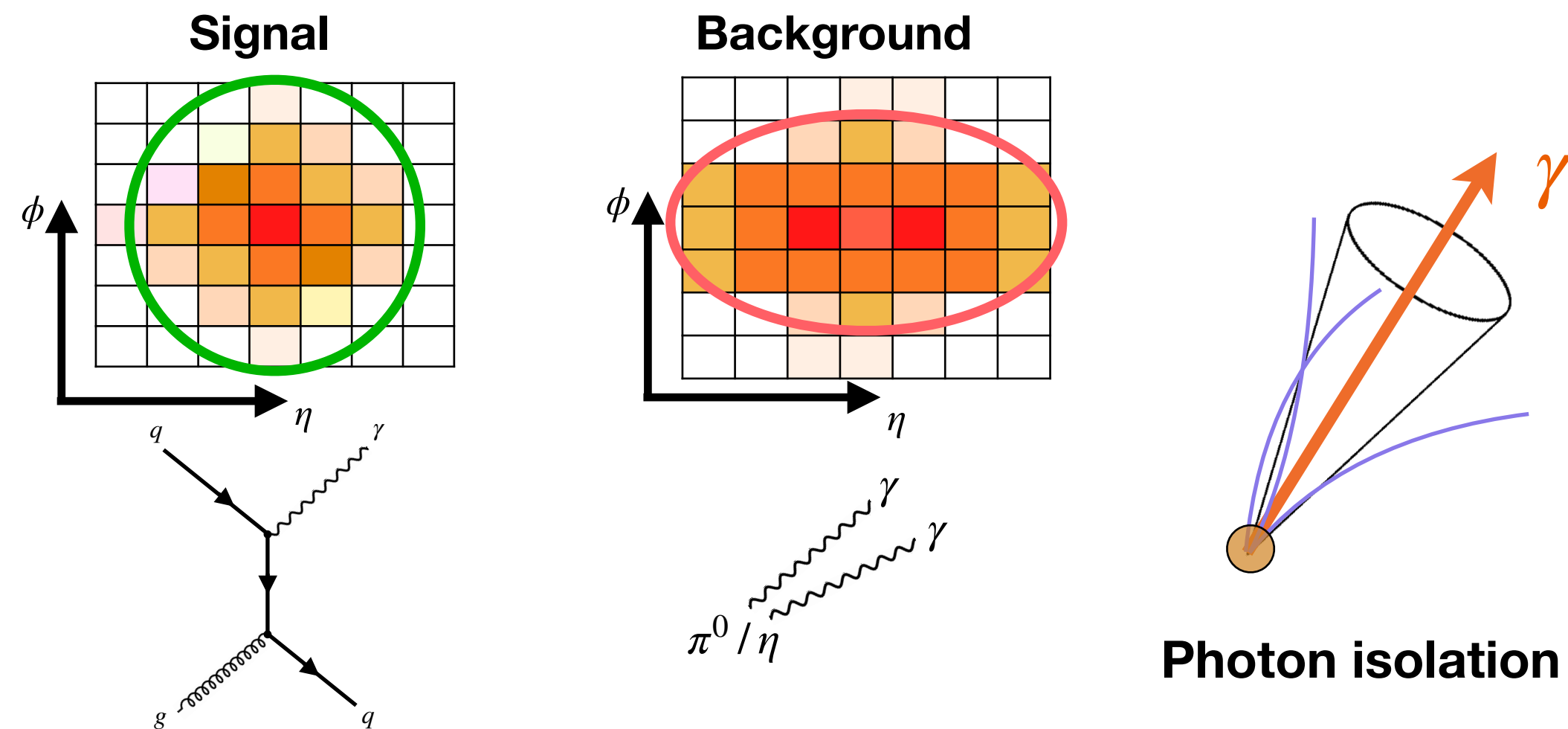
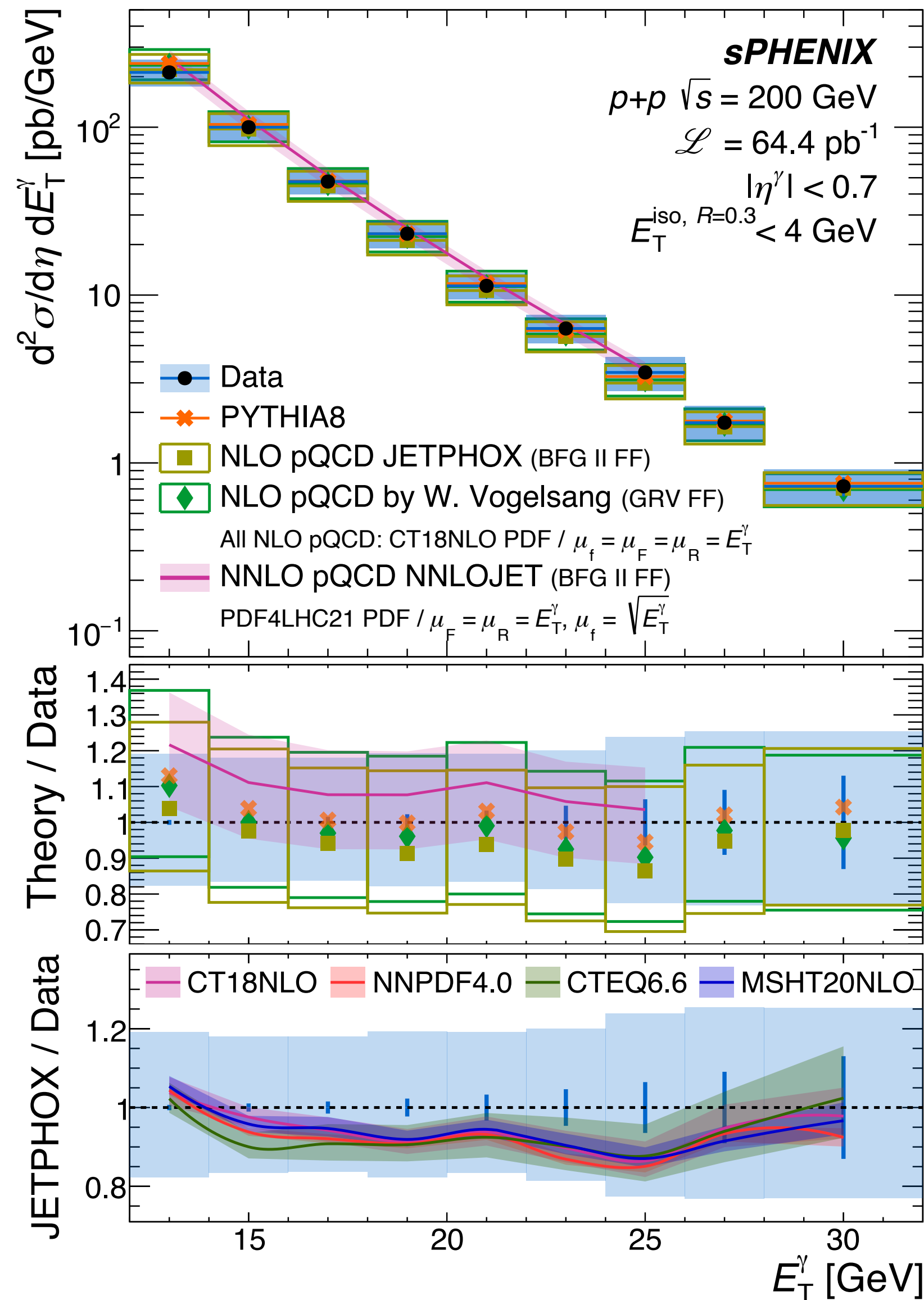
- **Clear correlation** observed between **soft** and **hard** processes
 - Related to modeling MPI & parton shower
- **Significant deviation** compared to **Herwig** generator

MC constraints with sPHENIX jet results

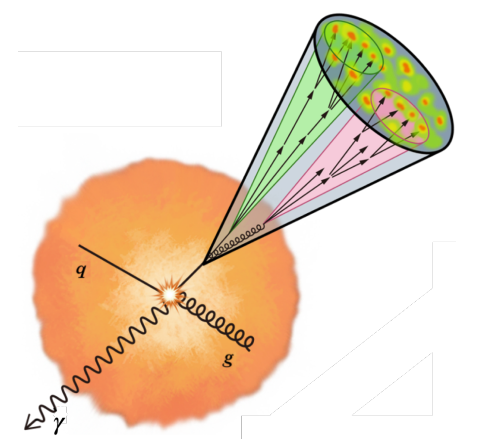


- **Strong constraints** using multiple measurements with sPHENIX on **MC generators at RHIC energies**

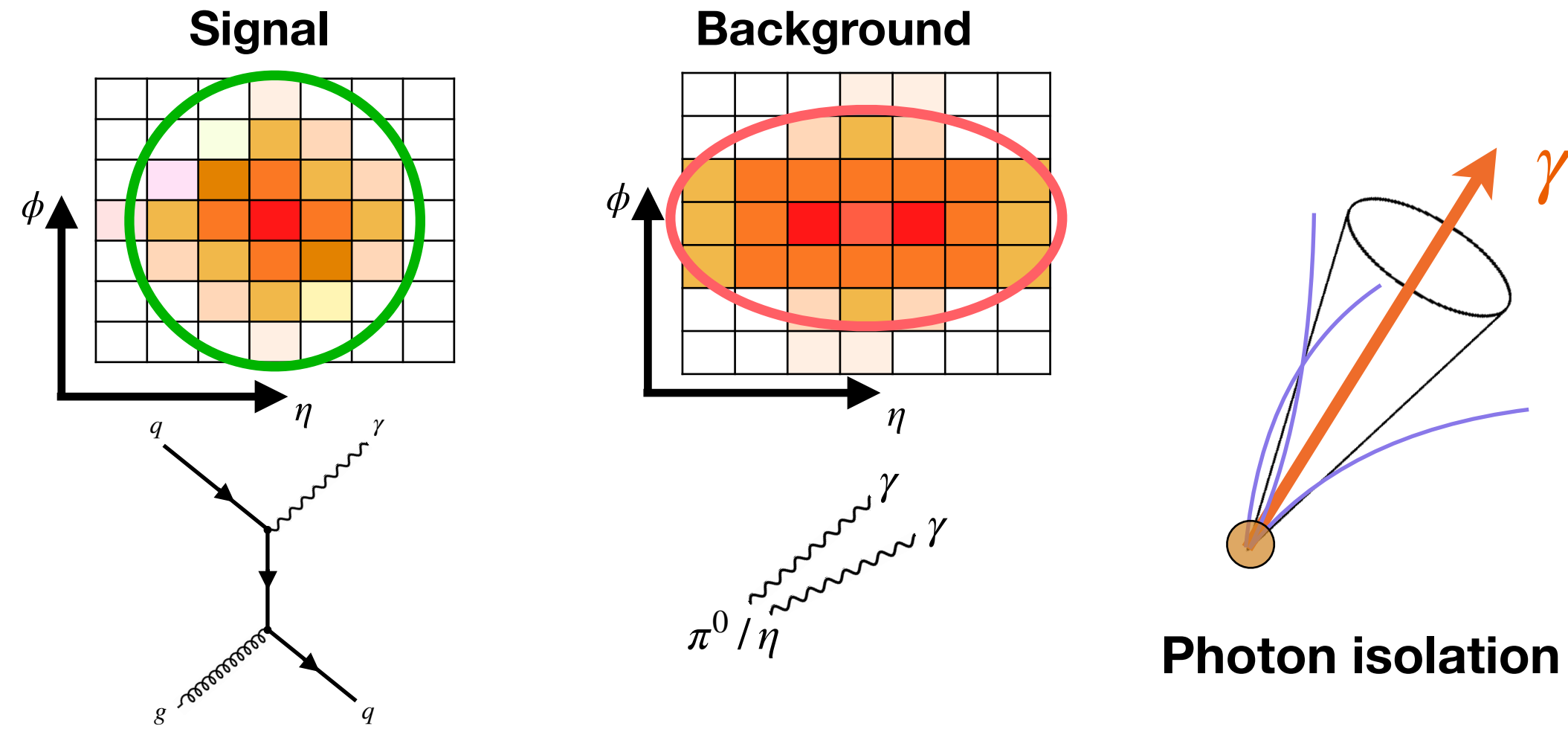
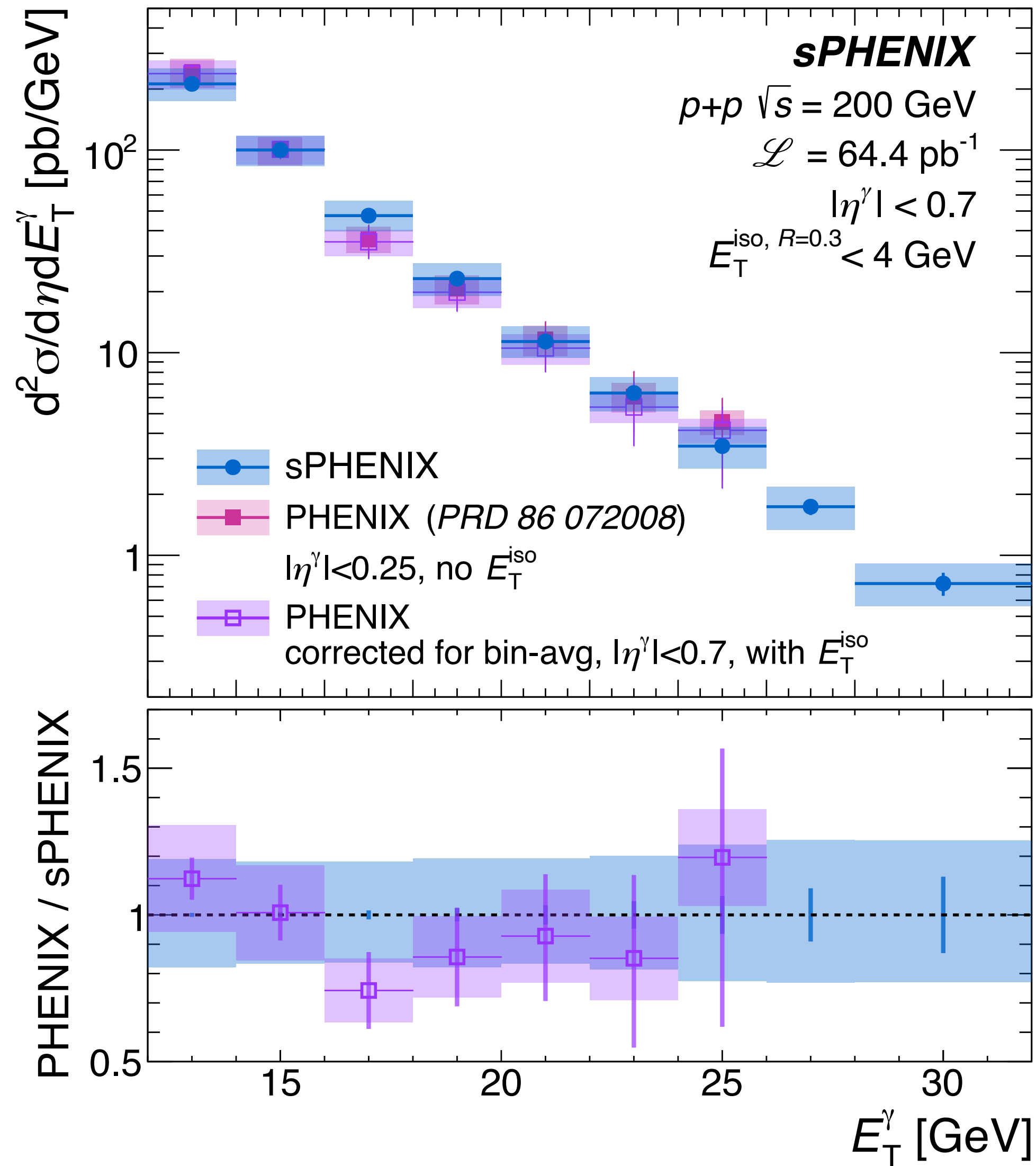
Isolated prompt-photon in p+p 200 GeV



- **2D side-band analysis with ML-based shower shape analysis** and **isolation with EMCal + HCal**
- **pQCD calculations** in good agreement with data
- Gateway to flagship **γ -jet** measurements



Isolated prompt-photon in p+p 200 GeV



- **2D side-band analysis with ML-based shower shape analysis and isolation with EMCal + HCal**
- **Extended p_T range** with better statistical precision than previous RHIC measurements