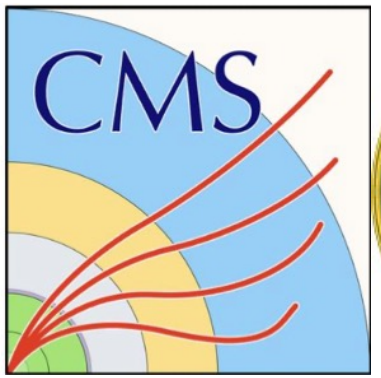
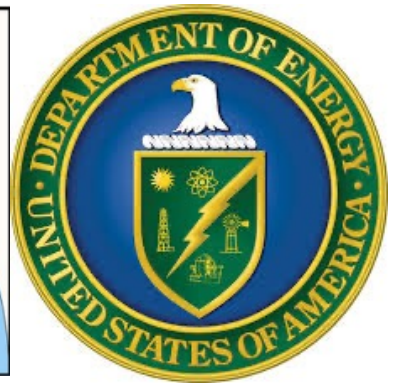
Charged particle nuclear modification factor in OO and NeNe collisions at 5.36 TeV with CMS

Vipul Pant for the CMS Collaboration

vpant4@uic.edu

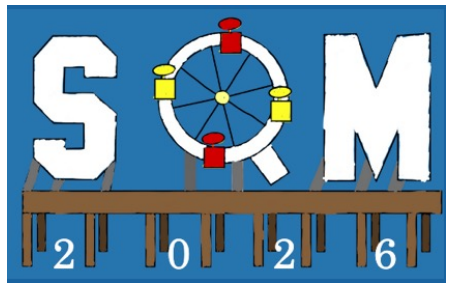
University of Illinois Chicago





SQM2026, Los Angeles, CA

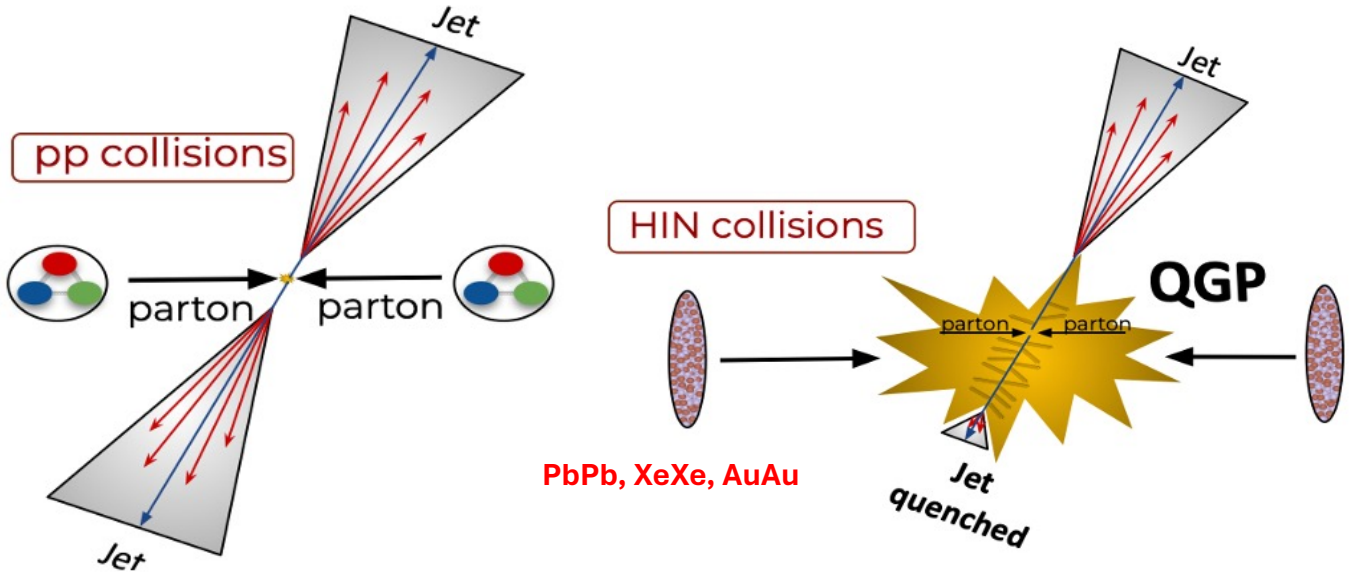
March 24, 2026



UIC heavy ion group's work is supported by US DOE

QGP formation in heavy-ion collisions

- Formation of a dense medium evident in AA collisions
- **QGP signatures**: Jet quenching, strangeness enhancement, collective flow etc.



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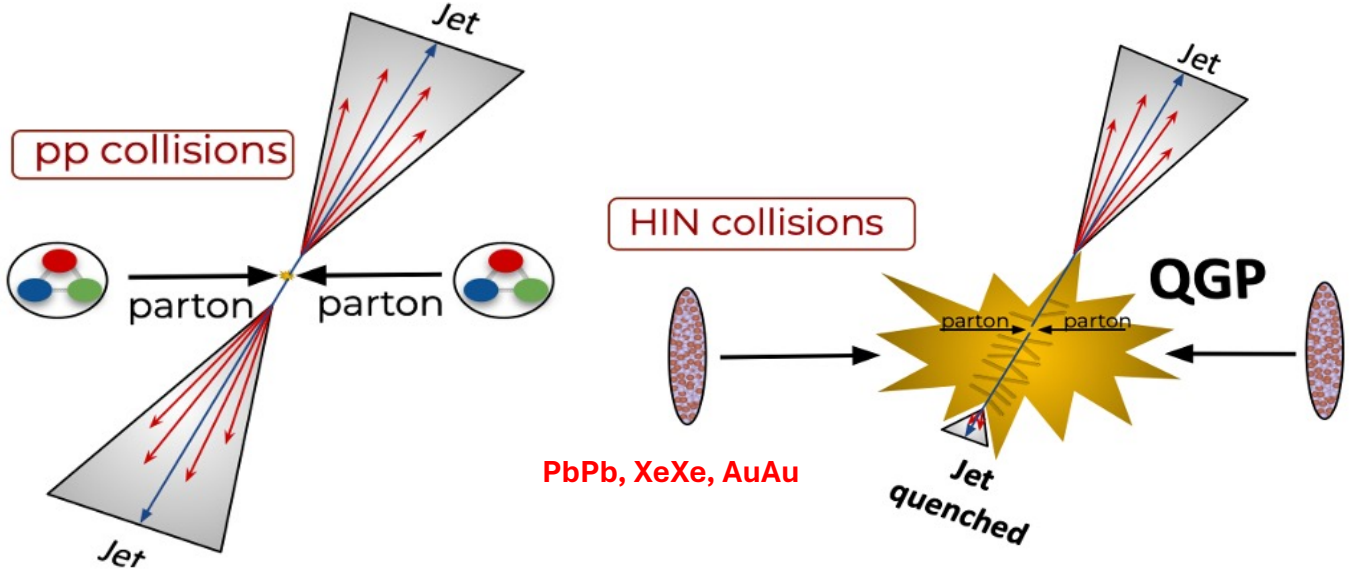
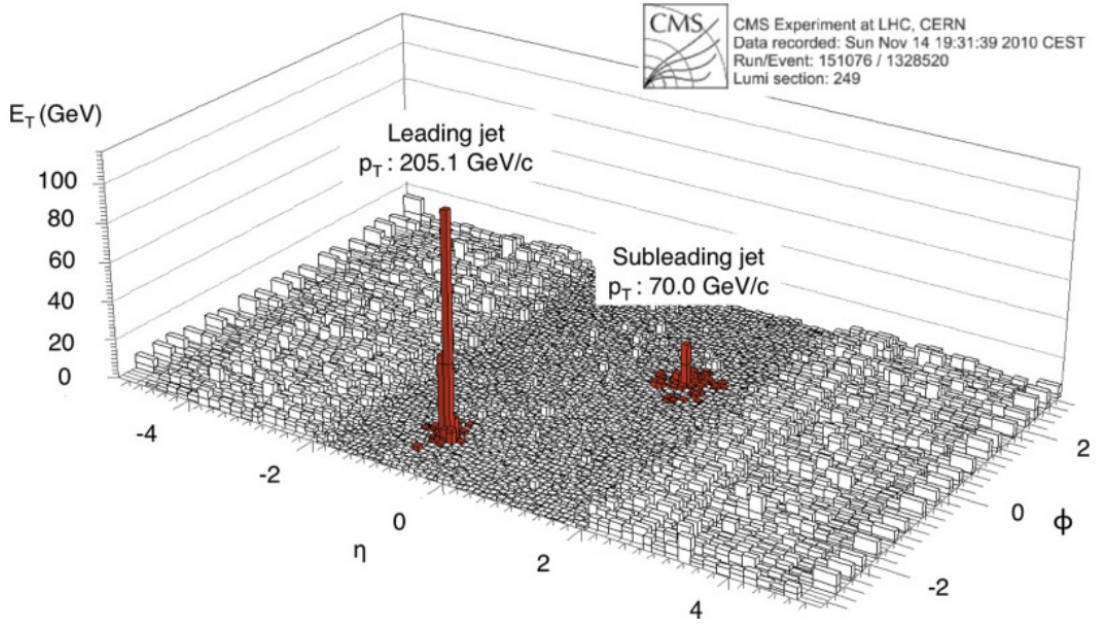


An unbalanced dijet in PbPb collision

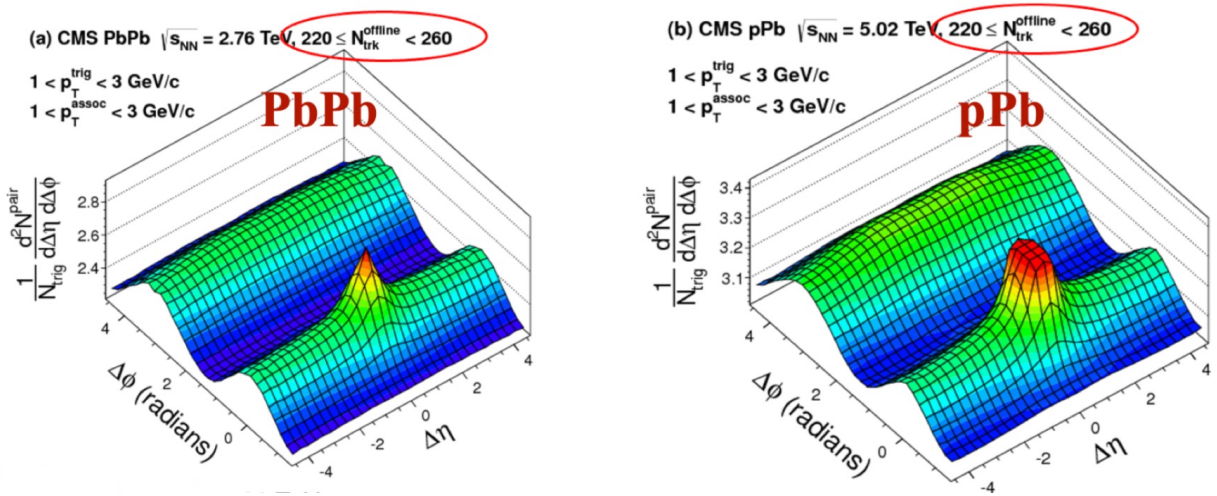
PRC 84, 024906 (2011)



QGP signatures in small systems

- QGP like features discovered in high multiplicity pp and pPb collisions

PLB 718 (2013) 795–814
JHEP 2011, 76 (2011)



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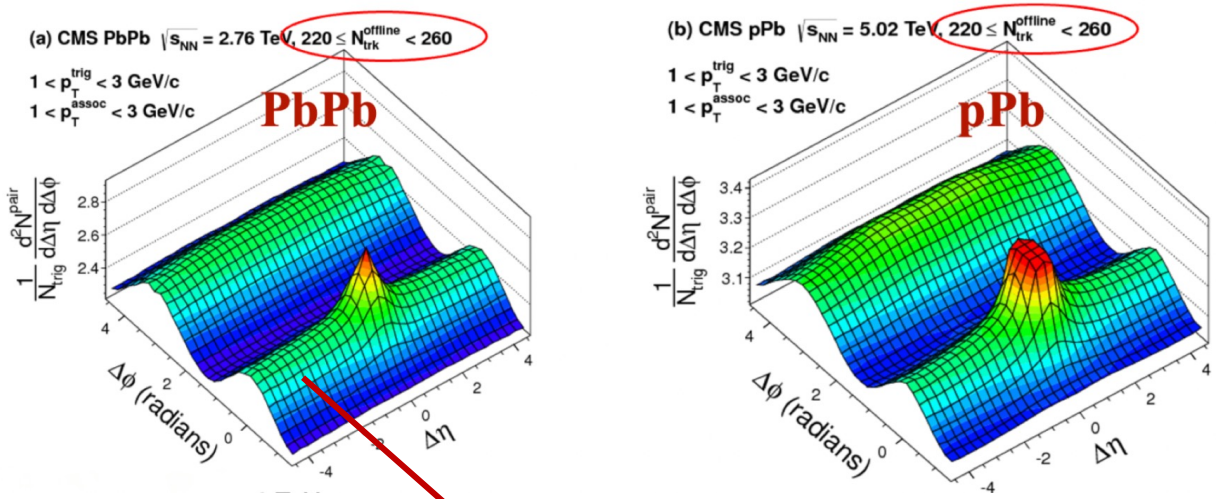

Ridge formation : Interpreted as collective effect due to QGP formation

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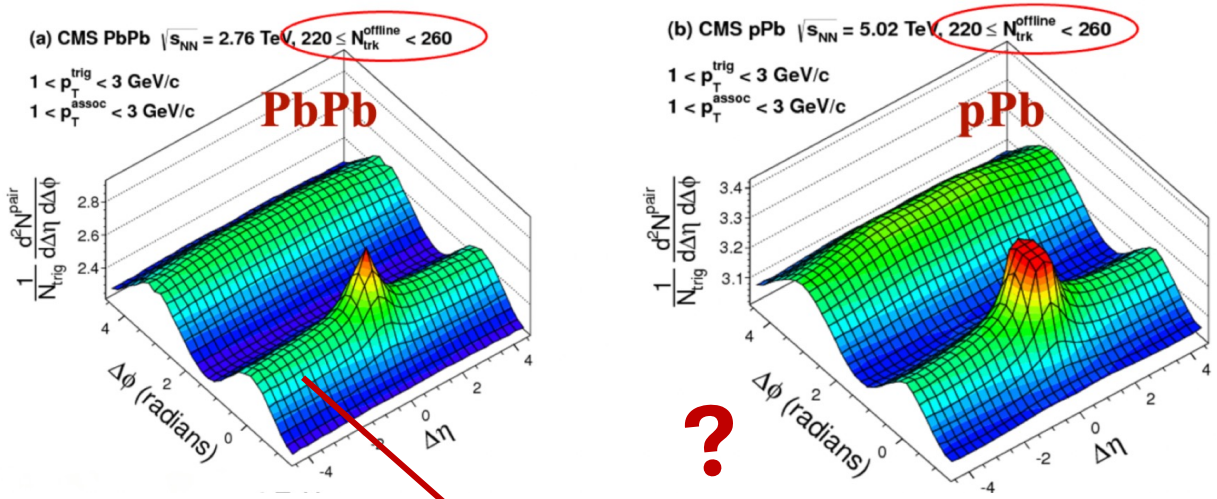

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JHEP, 2017 39 (2017)

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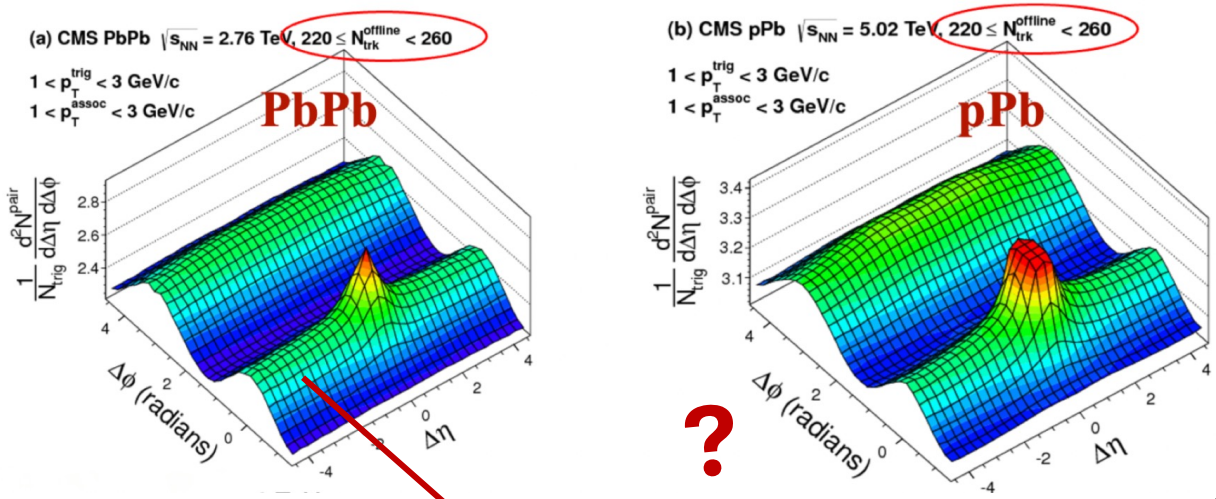

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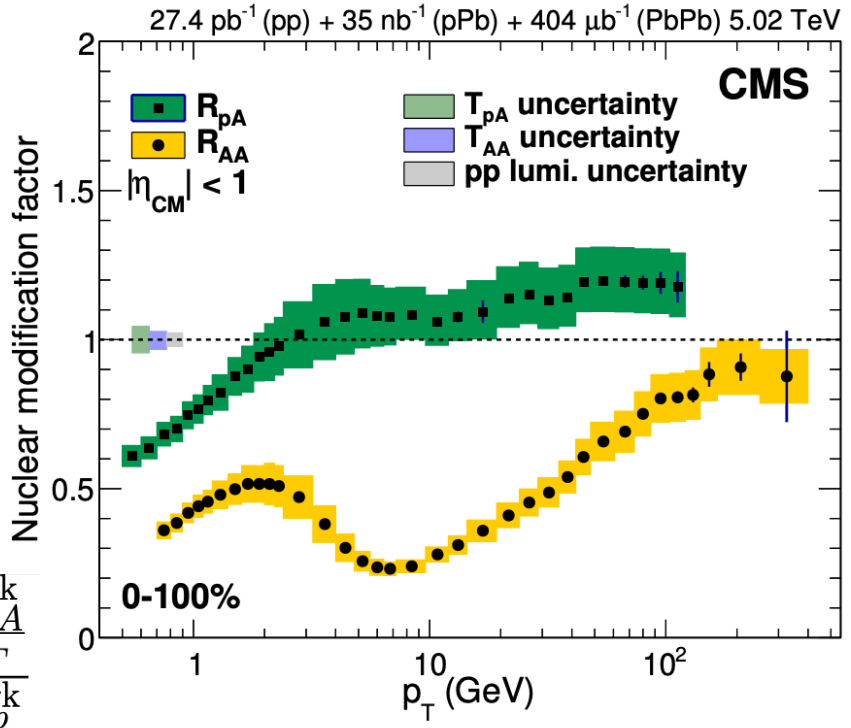
$$R_{AA} = \frac{1}{A^2}\frac{\frac{d\sigma_{AA}^{\mathrm{trk}}}{dp_T}}{\frac{d\sigma_{pp}^{\mathrm{trk}}}{dp_T}}$$

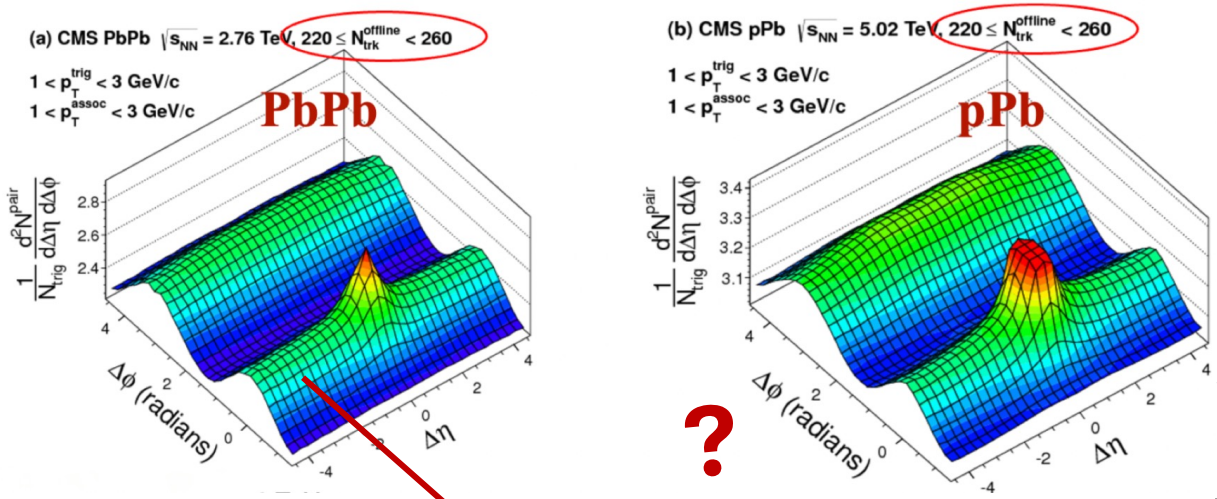


QGP signatures in small systems

pPb close to 1

- QGP like features discovered in high multiplicity pp and pPb collisions

PLB 718 (2013) 795–814
JHEP 2011, 76 (2011)



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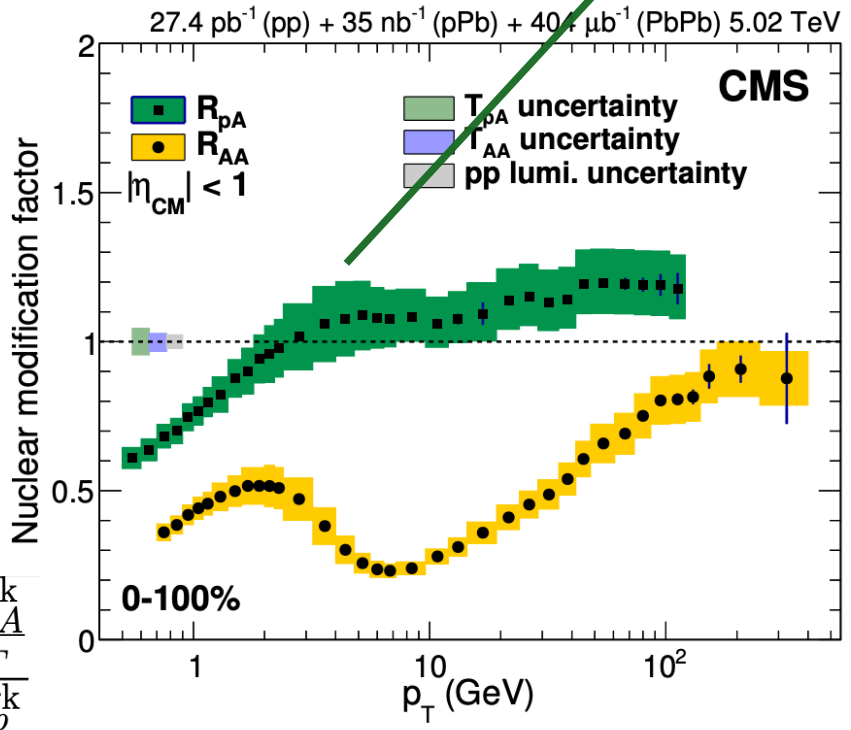
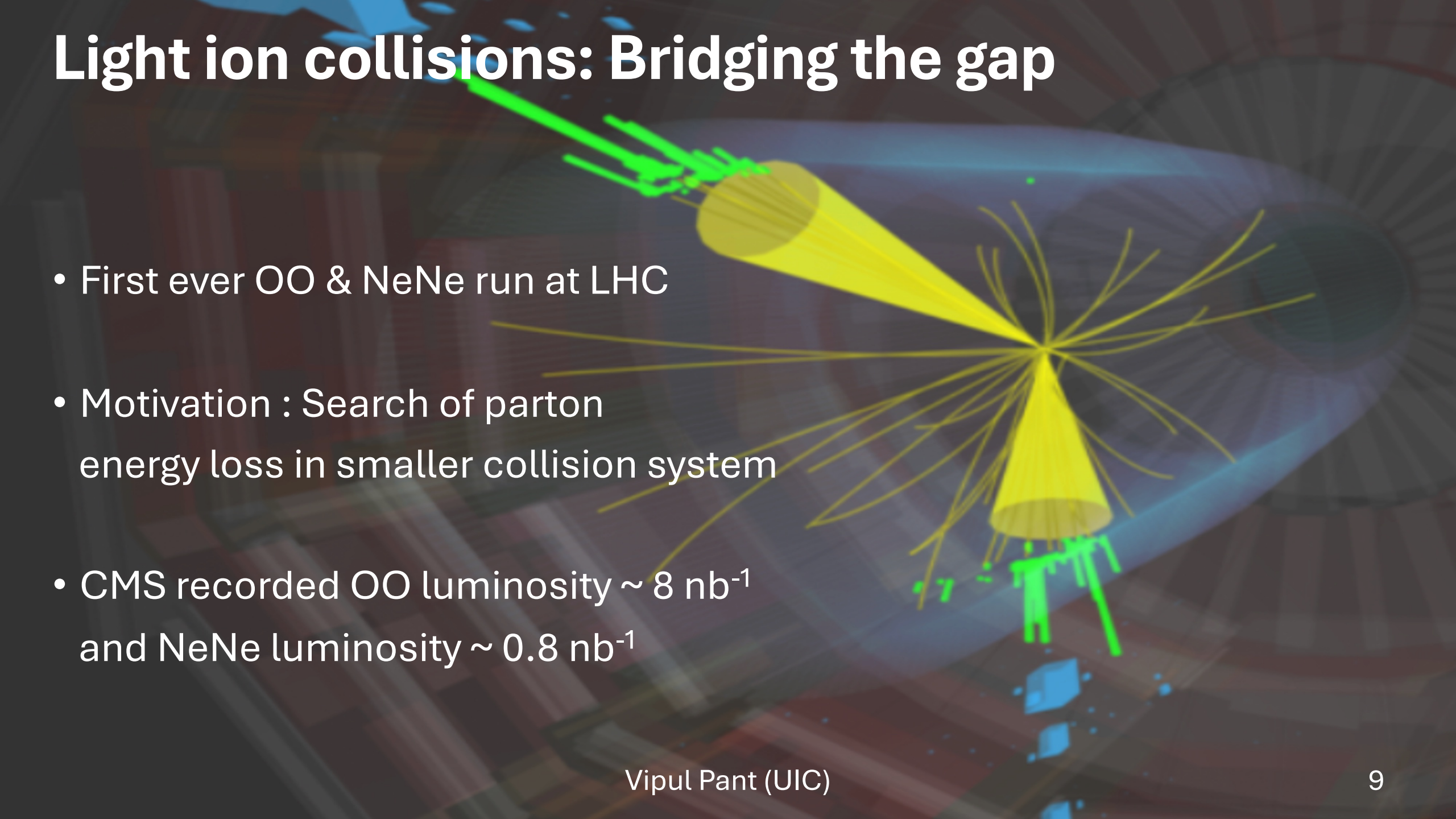
JHEP, 2017 39 (2017)



Parton energy loss in small systems remain inconclusive

Light ion collisions: Bridging the gap



- First ever OO & NeNe run at LHC
- Motivation : Search of parton energy loss in smaller collision system
- CMS recorded OO luminosity ~ 8 nb^{-1} and NeNe luminosity ~ 0.8 nb^{-1}

R_{AA} in OO & NeNe collsions at 5.36 TeV

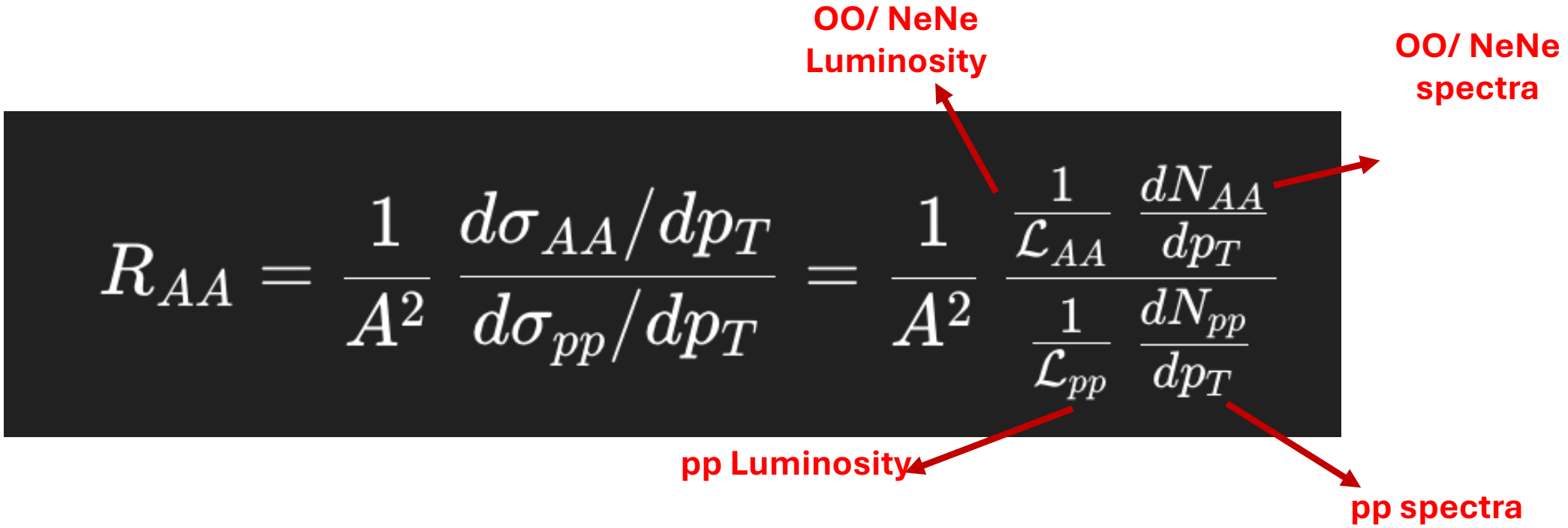
- Inclusive R_{AA} measured for OO & NeNe at 5.36 TeV

$$R_{AA} = \frac{1}{A^2} \frac{d\sigma_{AA}/dp_T}{d\sigma_{pp}/dp_T} = \frac{1}{A^2} \frac{\frac{1}{\mathcal{L}_{AA}} \frac{dN_{AA}}{dp_T}}{\frac{1}{\mathcal{L}_{pp}} \frac{dN_{pp}}{dp_T}}$$

- No Glauber uncertainty needed in this definition

R_{AA} in OO & NeNe collsions at 5.36 TeV

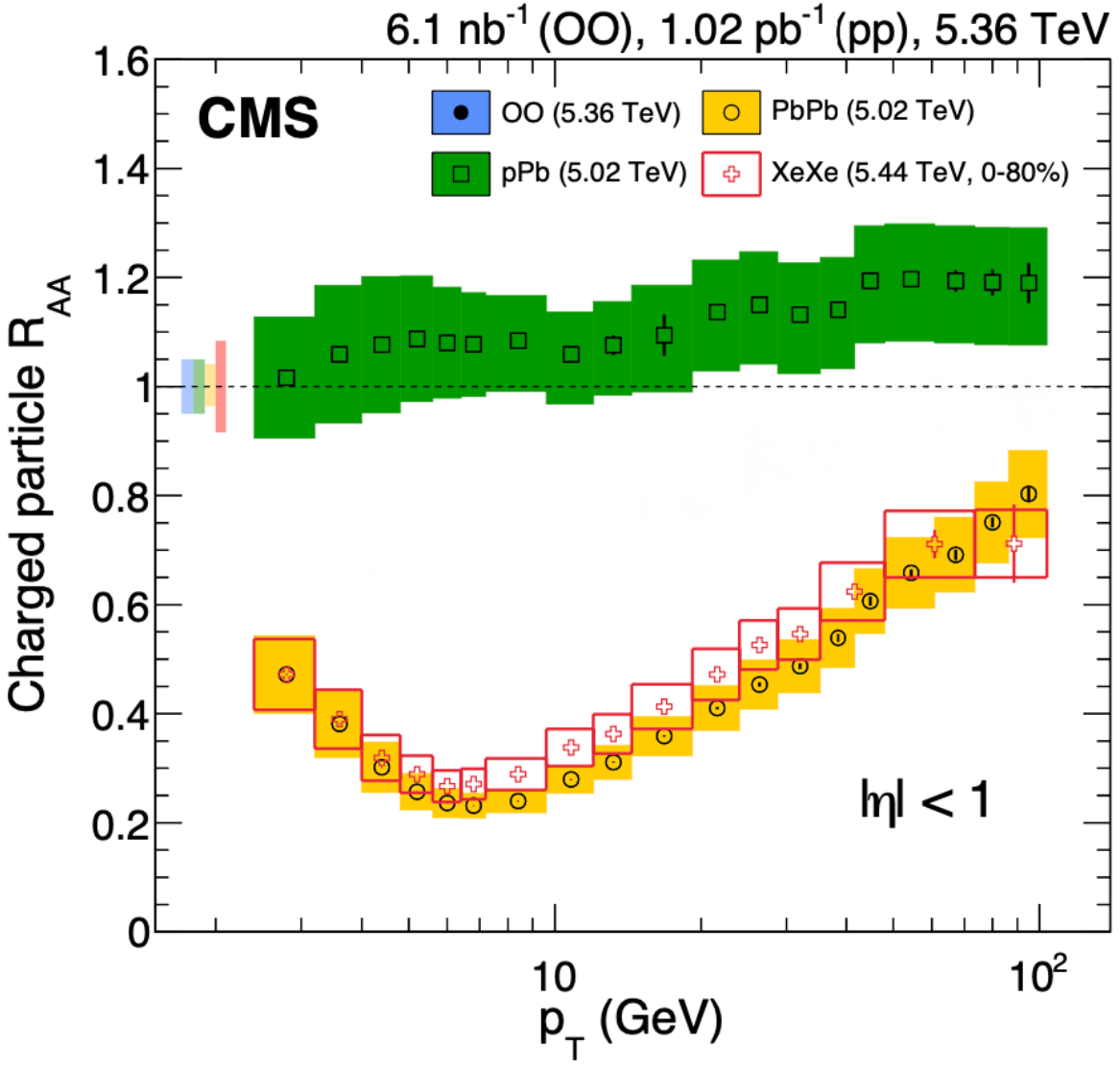
- Inclusive R_{AA} measured for OO & NeNe at 5.36 TeV



- No Glauber uncertainty needed in this definition

OO Charged particle R_{AA}

arxiv:2510.09864v1
Accepted by PRL (editor's suggestions)



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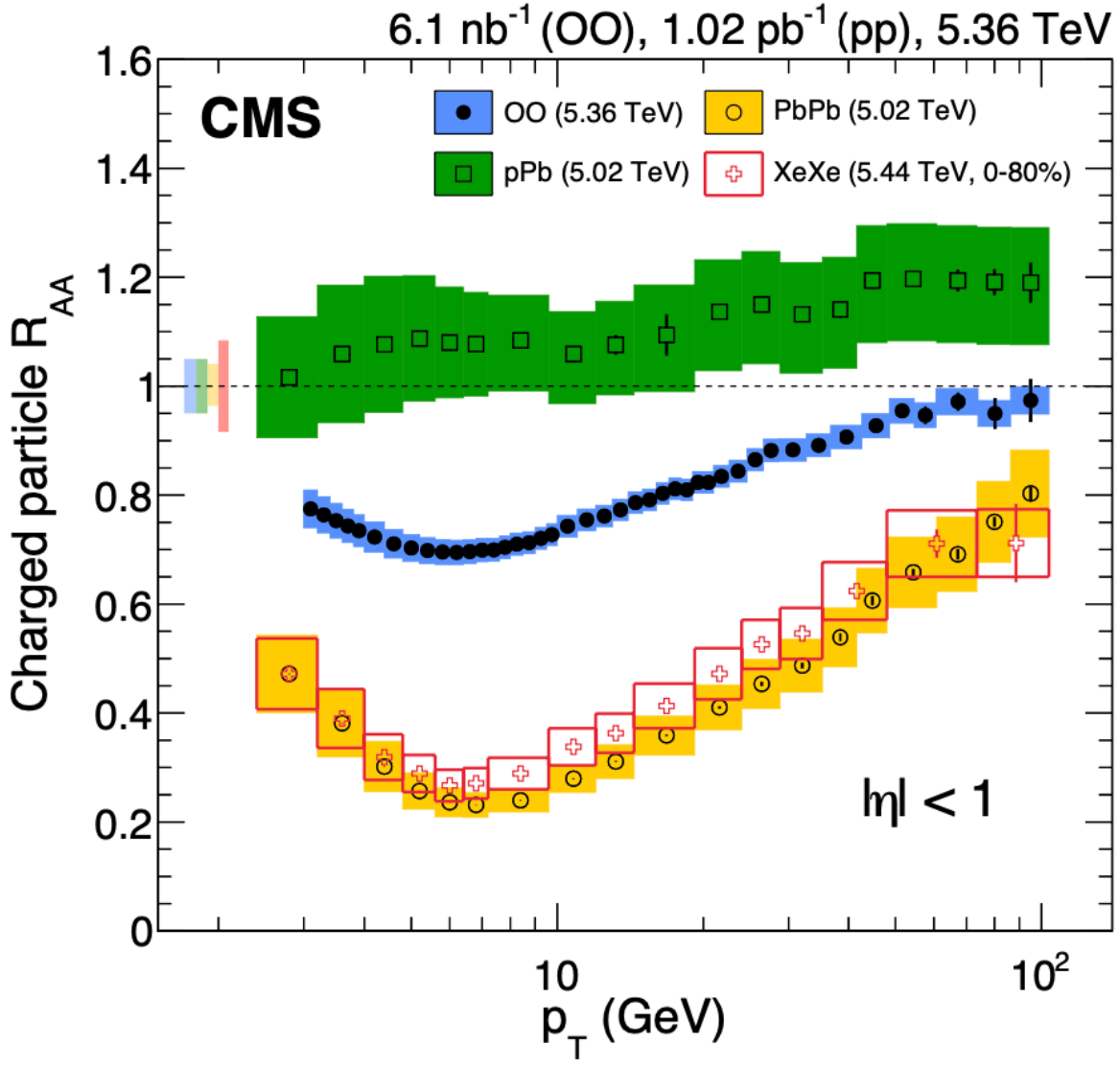
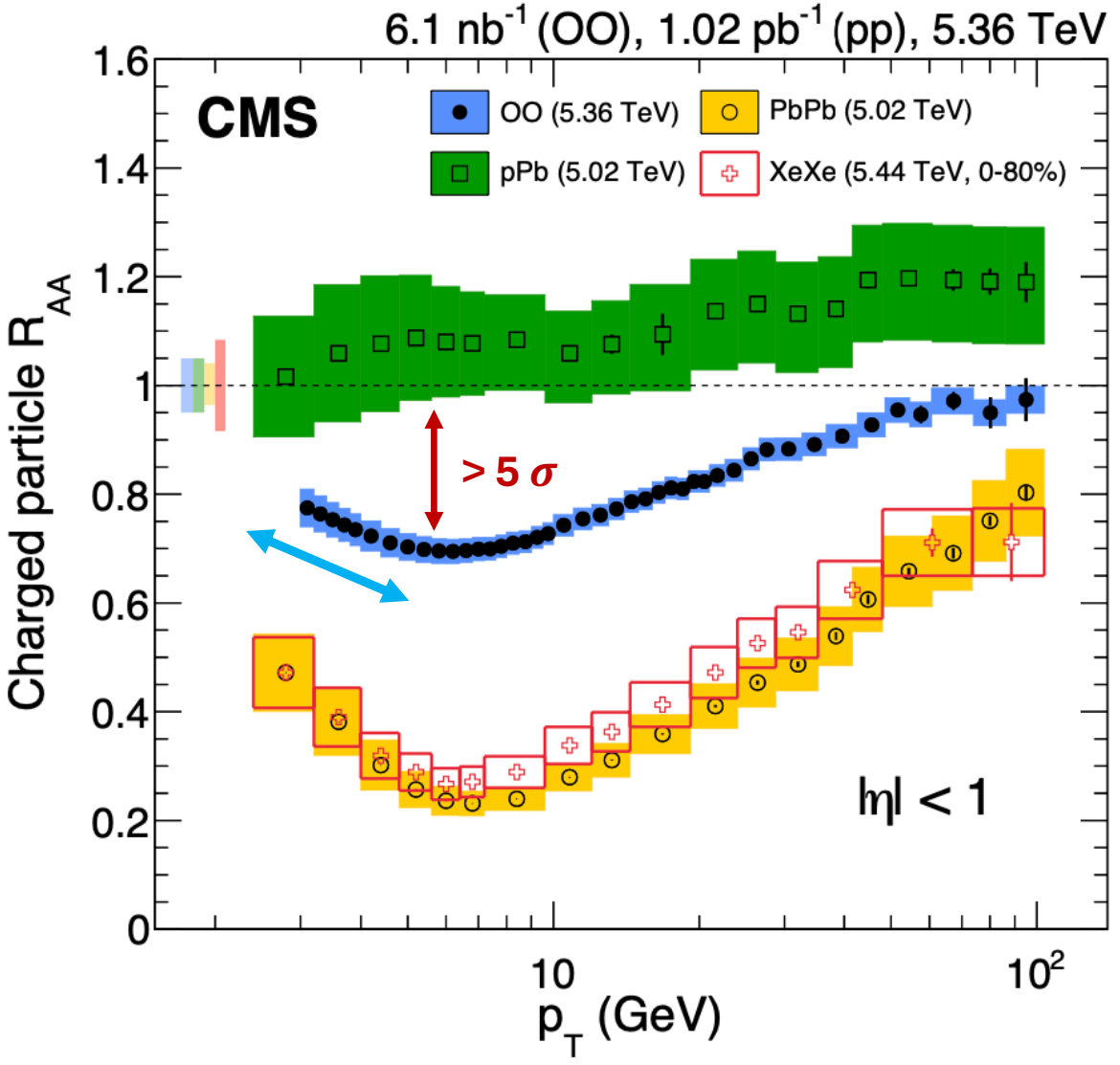


OO Charged particle R_{AA}

arxiv:2510.09864v1
Accepted by PRL (editor's suggestions)

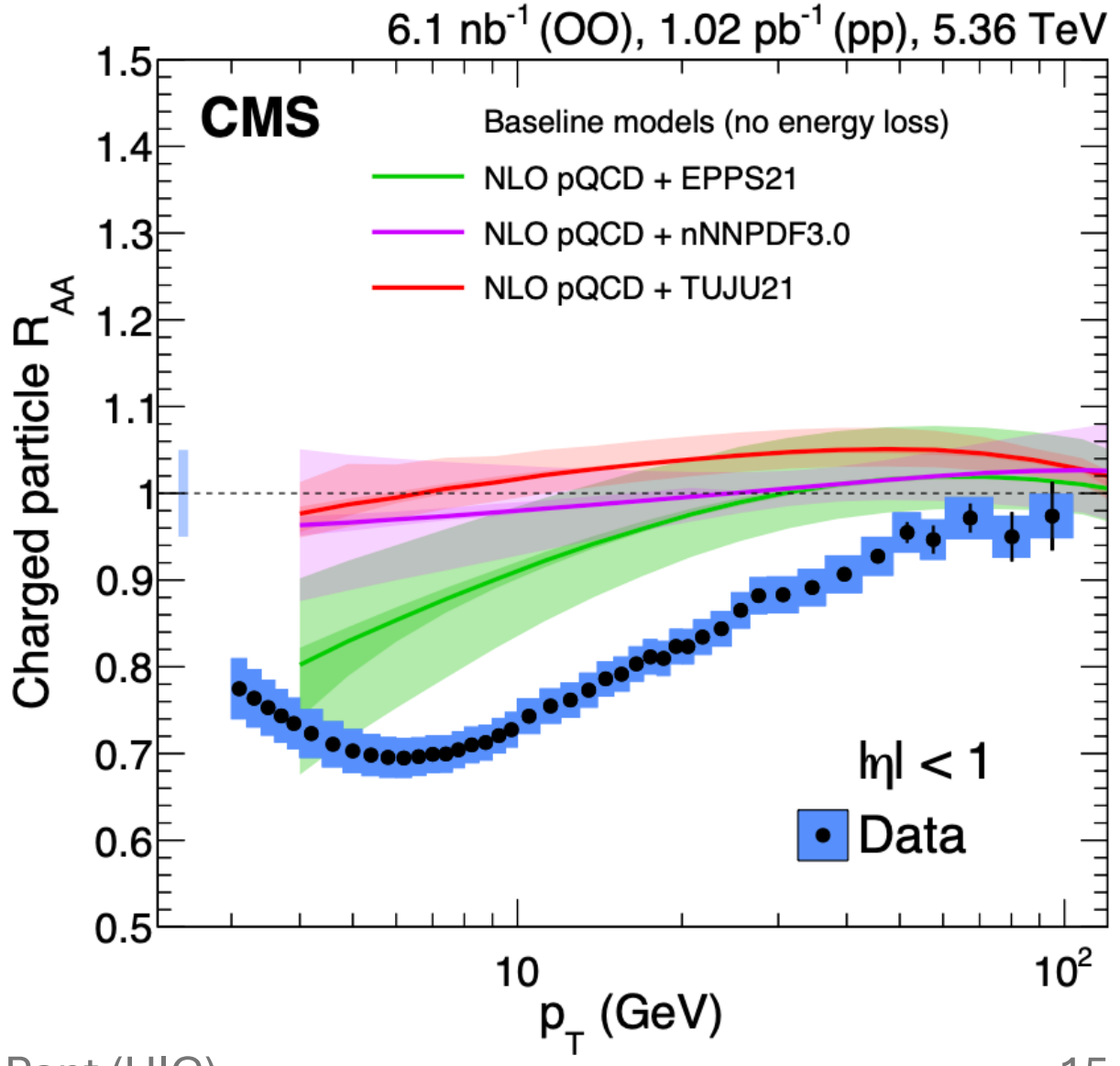
- Clear suppression observed
- Trend similar to PbPb and XeXe
- Flattens at higher p_T to value consistent with 1
- Radial flow effect can also be seen in lower p_T values



Comparison with baseline models

arxiv:2510.09864v1
Accepted by PRL (editor's suggestions)

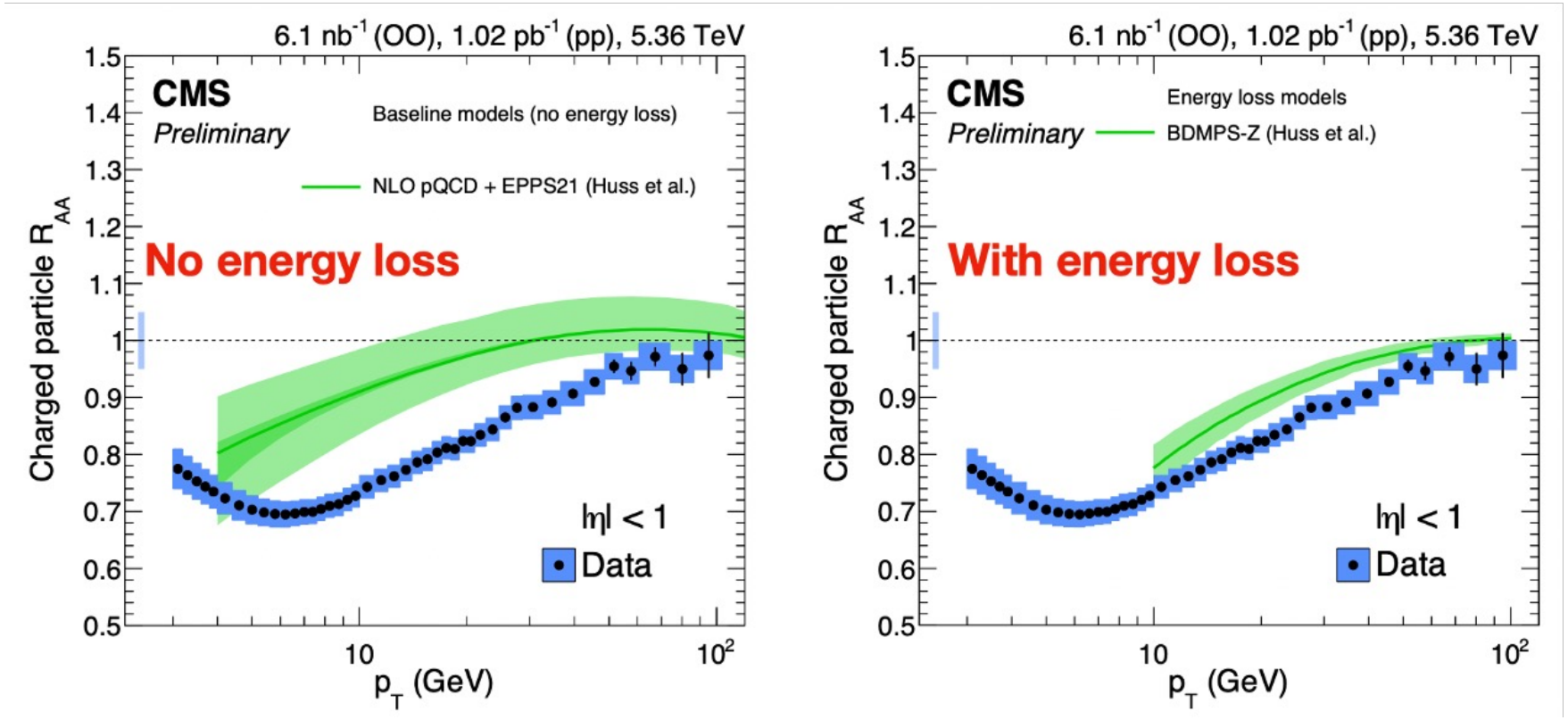
- nPDF comparison important to isolate quenching effects
- nPDF effects contribute towards low-p_T suppression
- EPPS21 alone can explain substantial suppression



Energy loss model 1

PRL 126 (2021) 192301
PRC 103(2021) 054903

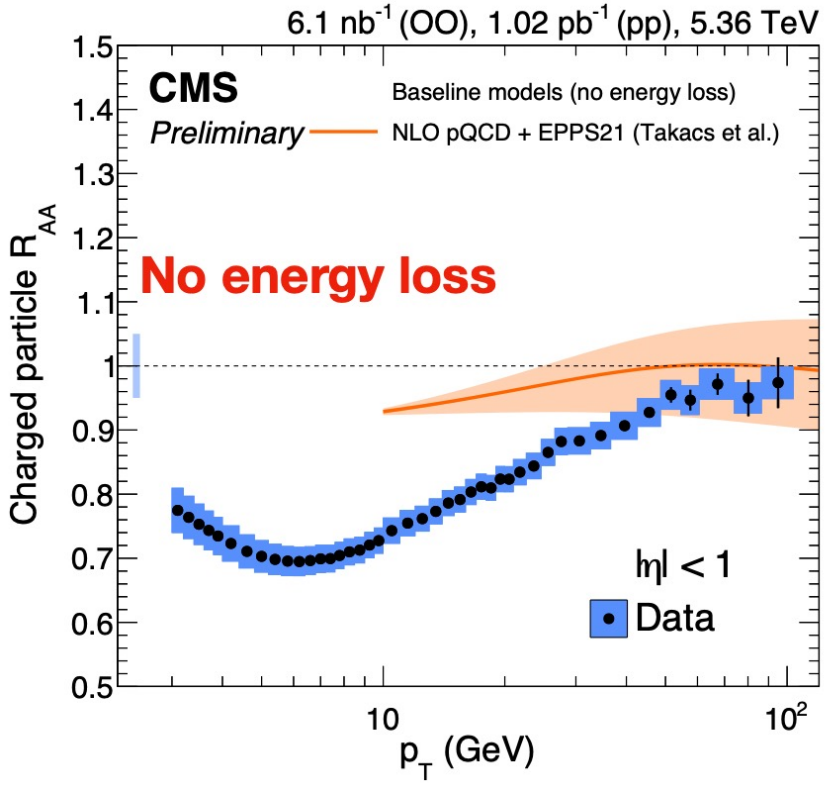
- Baseline : pQCD + EPPS21
- BDMPS-Z energy loss model

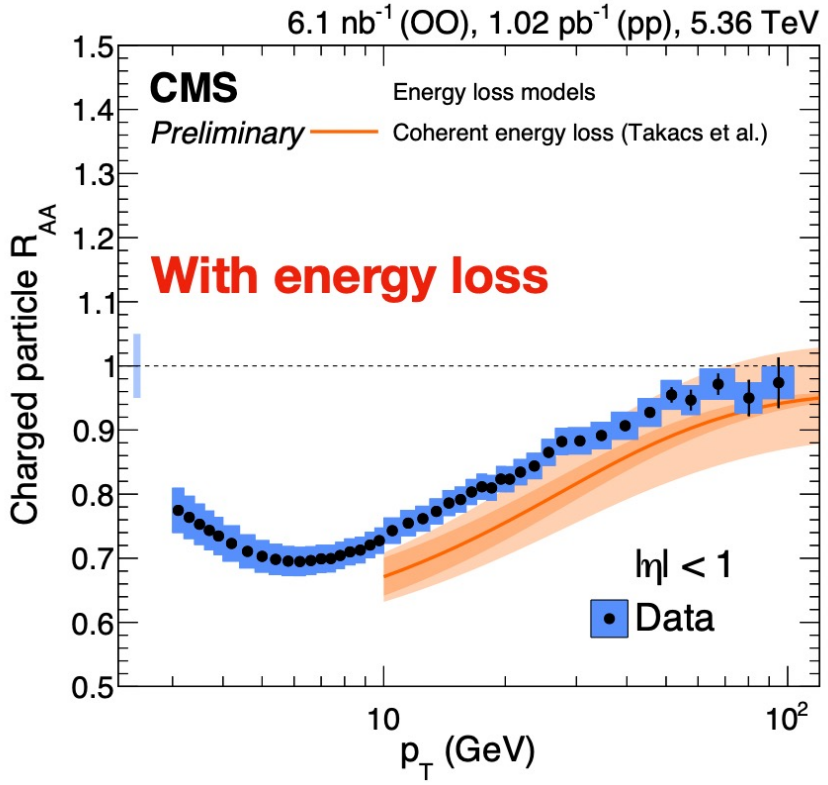


Energy loss model 2

PRL 127 (2021) 252301
JHEP 2021 (2021) 38
JHEP 04 (2025) 034

- Baseline : pQCD + EPPS21
- Bayesian constrained coherent energy loss models

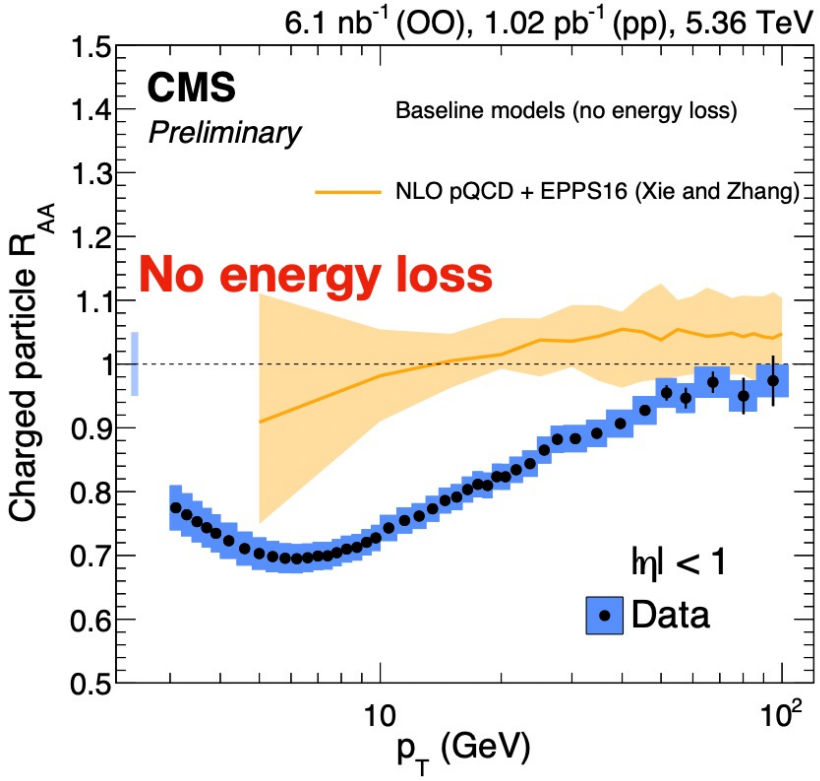


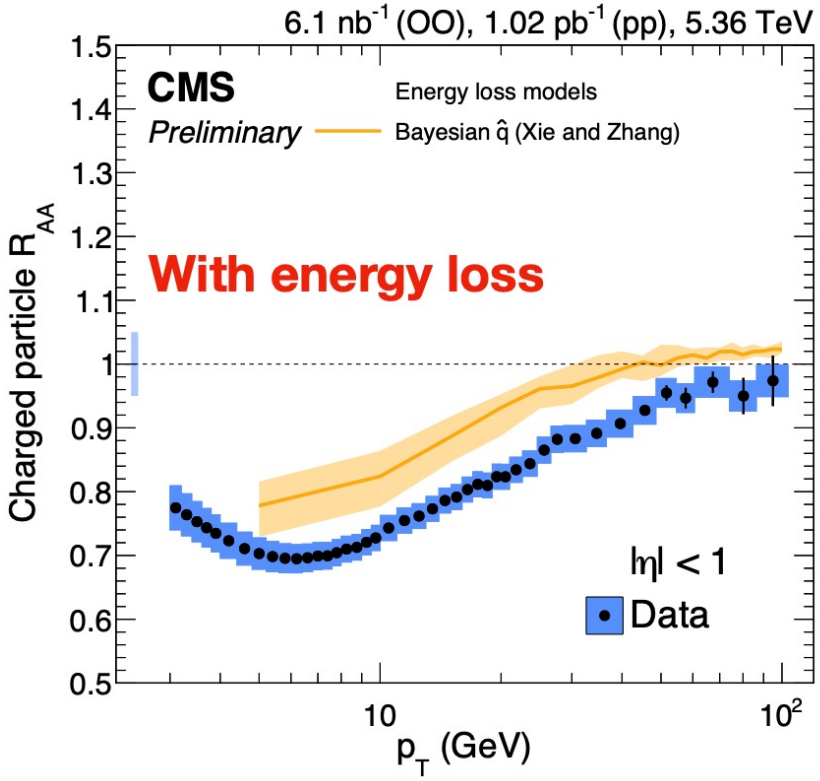


Energy loss model 3

PRC 108 (2023) L011901

- NLO pQCD + EPPS16 baseline
- Bayesian constrained $\hat{q}$ energy loss model

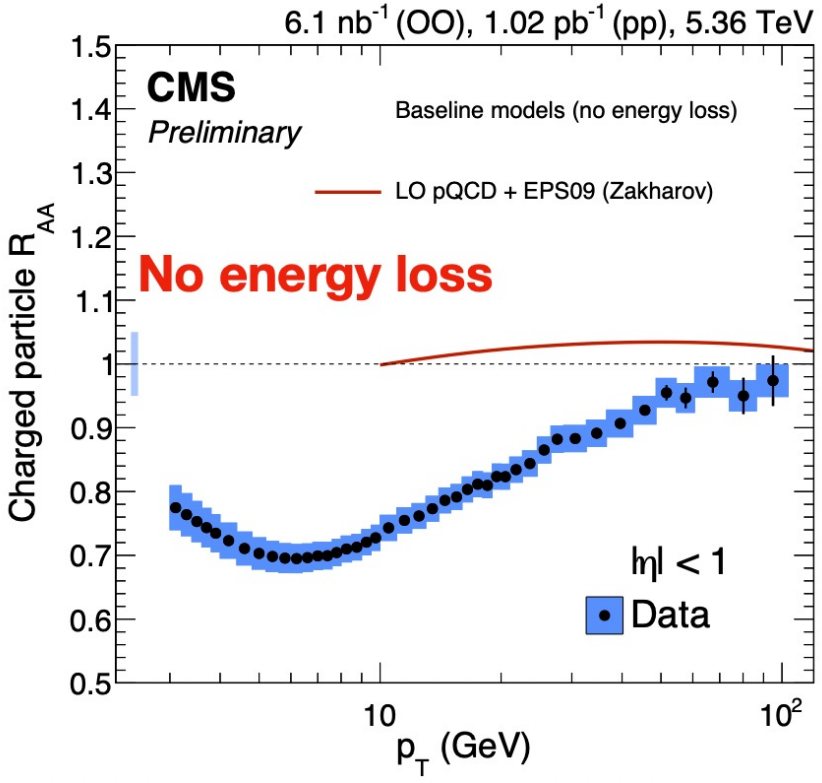


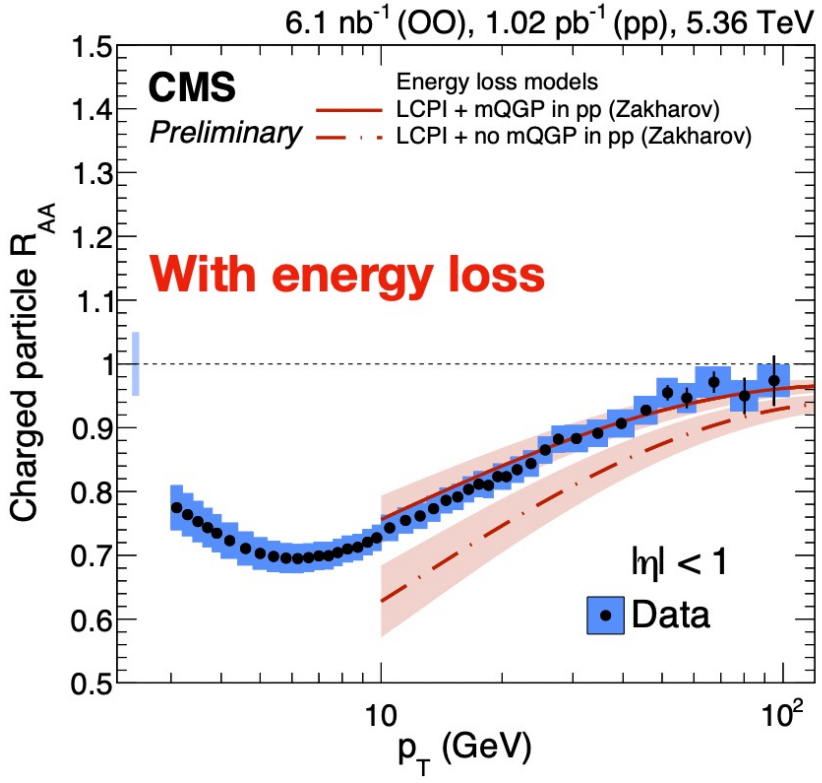


Energy loss model 4

JHEP 09(2021) 087

- LO pQCD + EPS09 baseline
- LCPI model with two scenarios : with/without m-QGP formation in pp

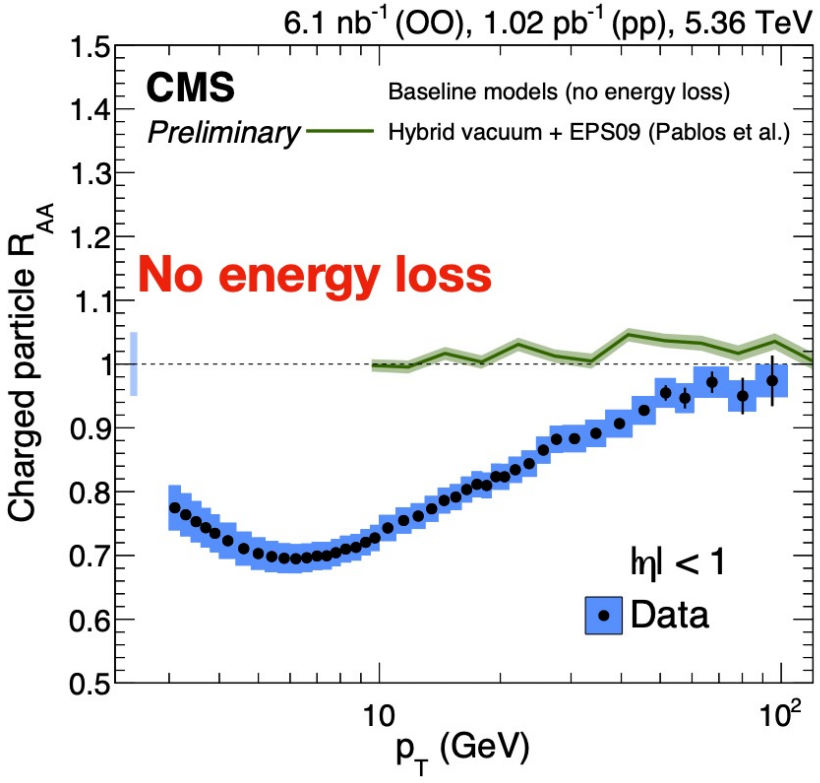


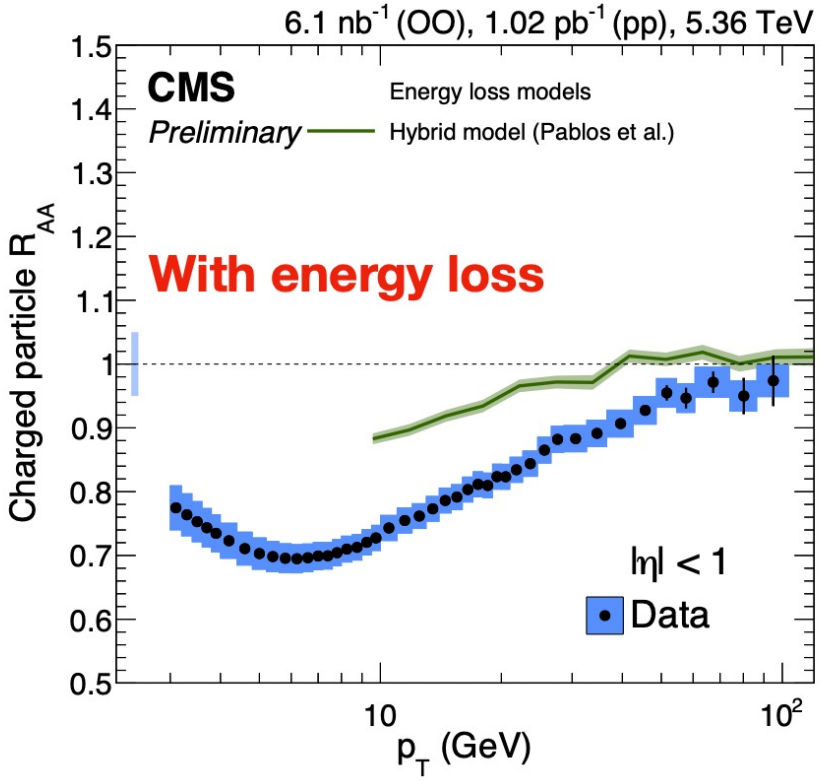


Energy loss model 5

JHEP 10 (2014) 019

- EPS09 baseline
- Hybrid model interfaced with event by event hydro

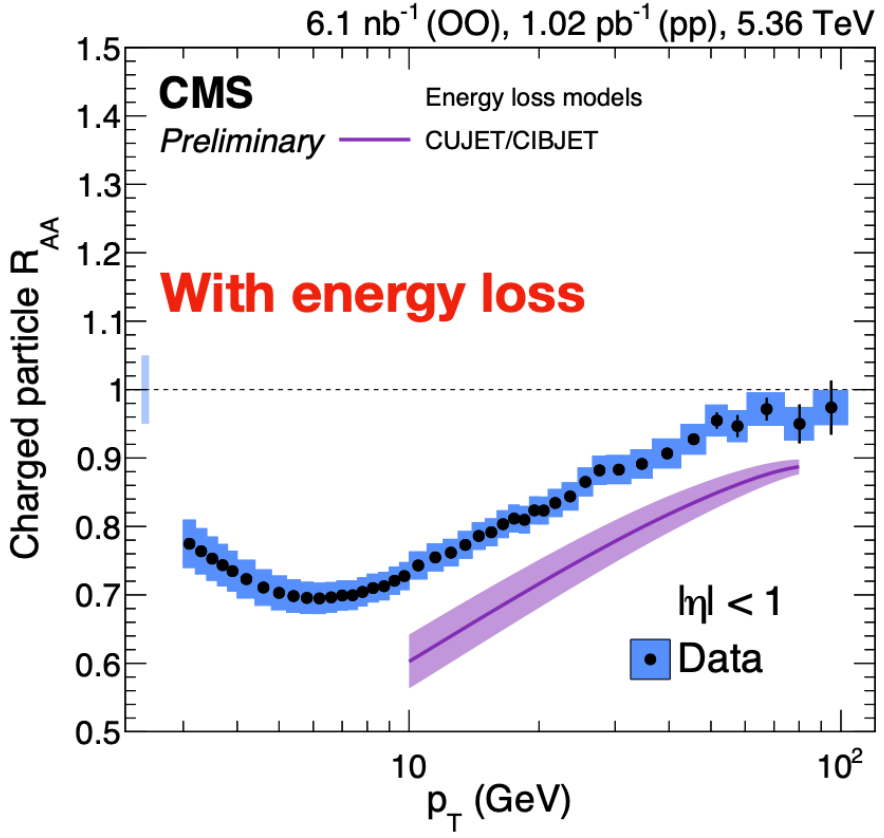




Energy loss model 6

JHEP 10 (2014) 019

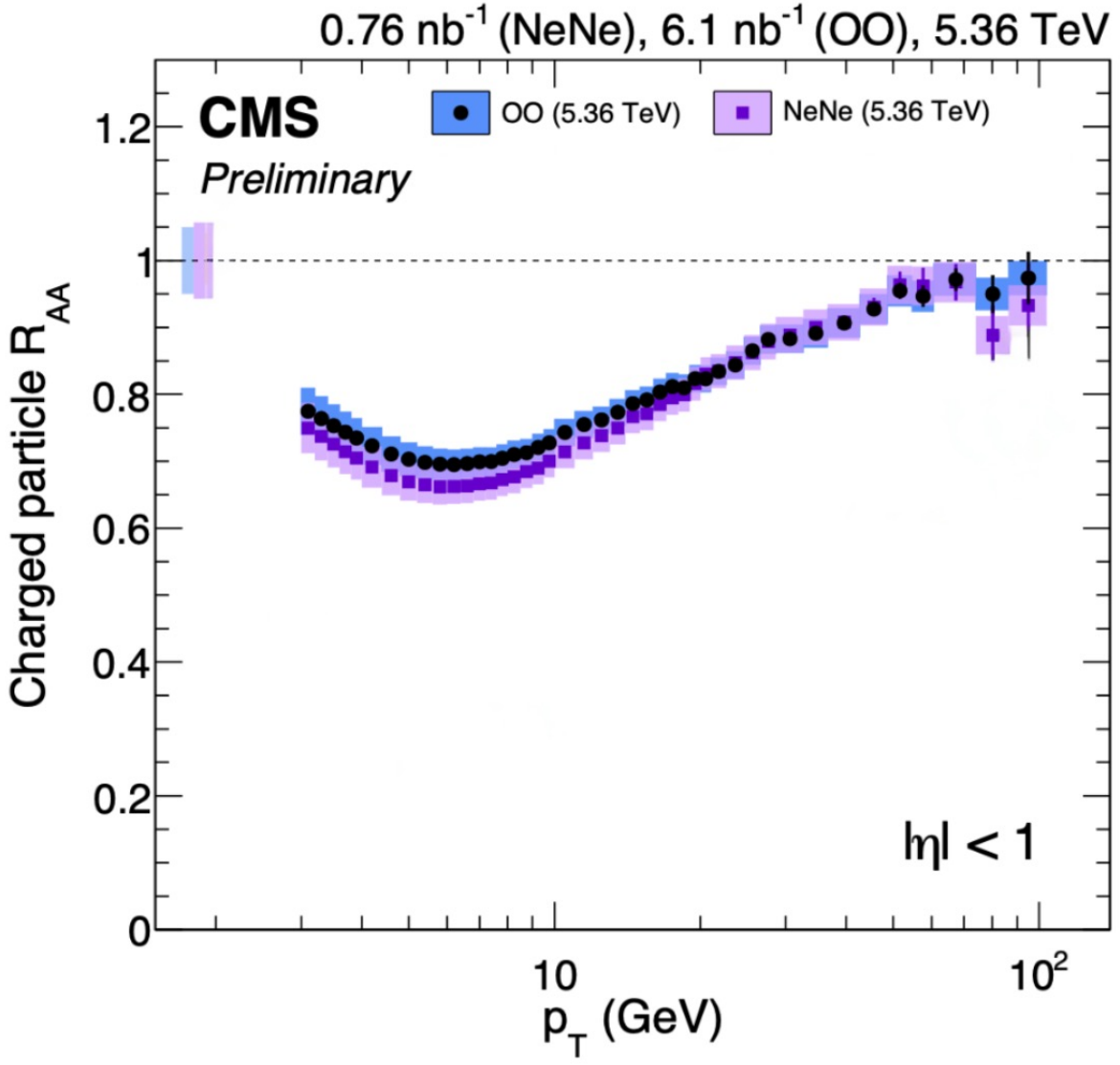
- Unity baseline
- CUJET/CIBJET with DGLV energy loss



Neon Charged particle R_{AA}

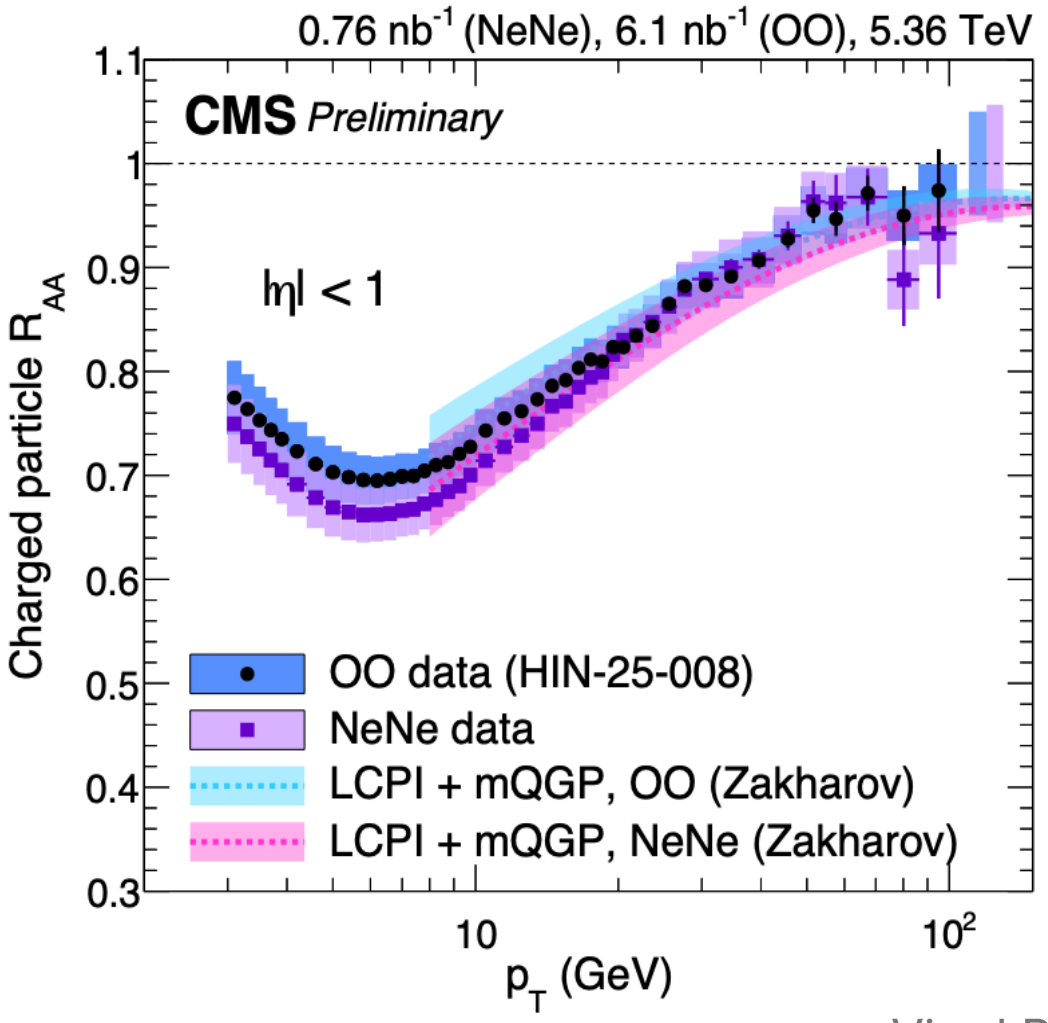
arxiv:2602.21325v2

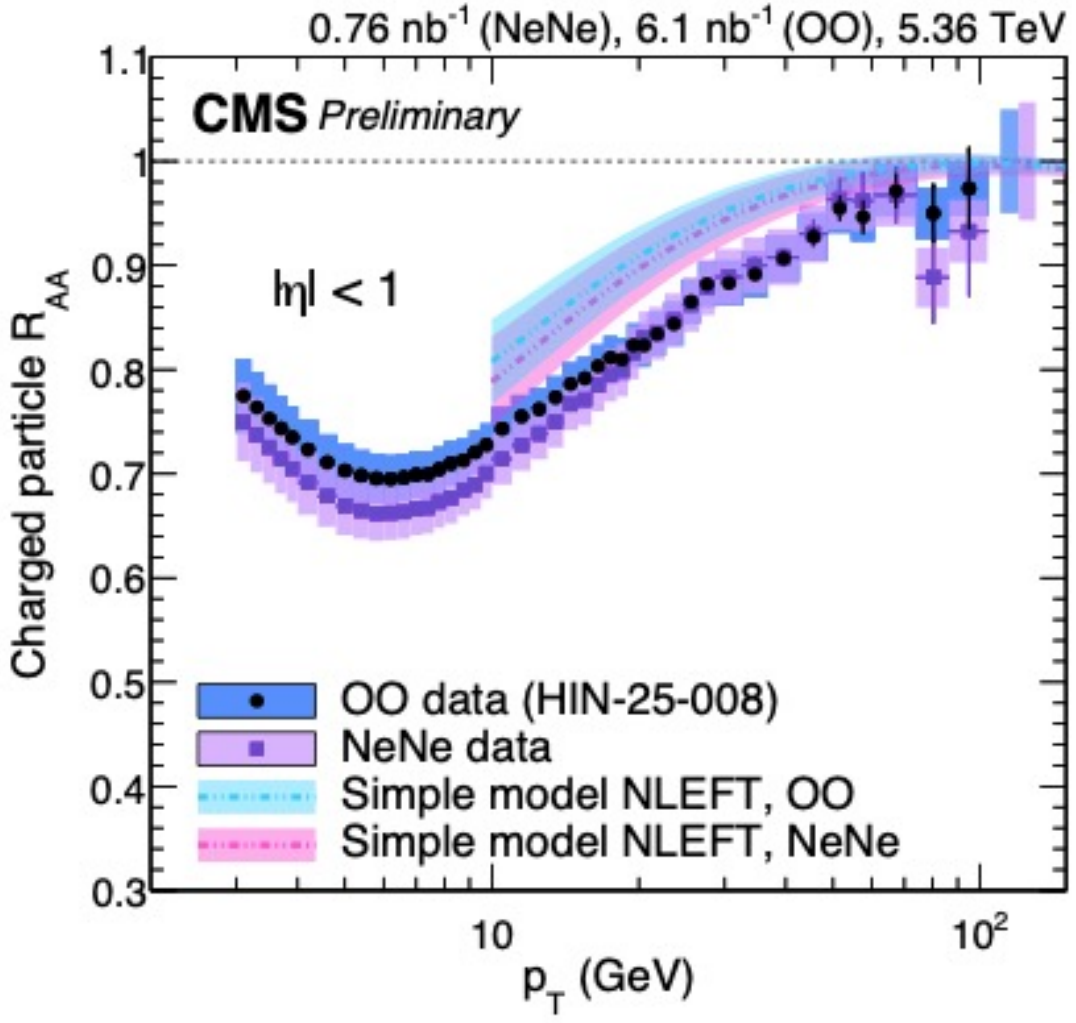
- Hints of stronger suppression below ~ 20 GeV
- Two systems converge at higher p_T values
- Luminosity uncertainties important to consider before making comparisons



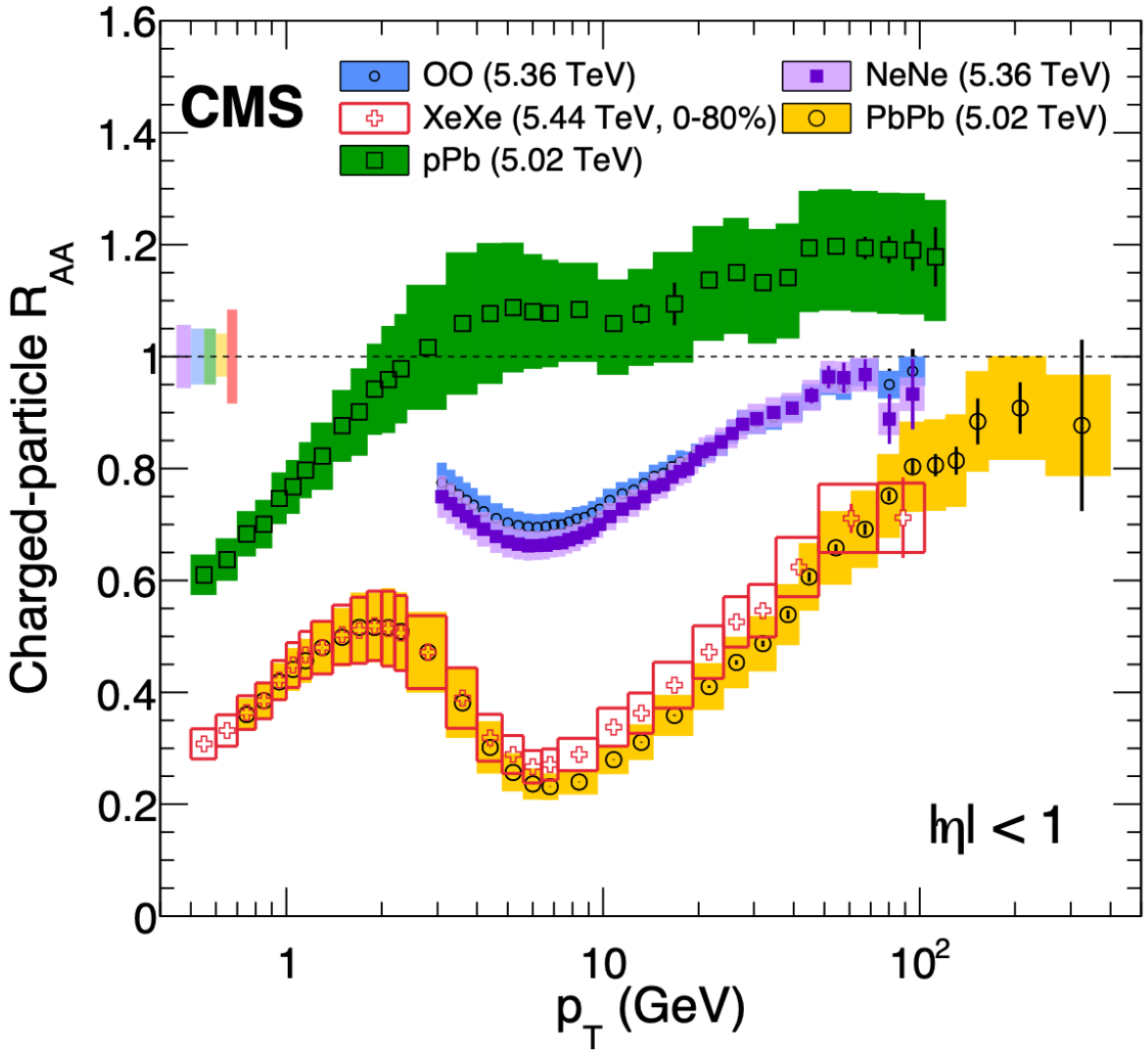
Neon models

- Models qualitatively capture the observed data trend





Overview: from heavy to light collisions



Light ions data bridges the gap between pPb and PbPb

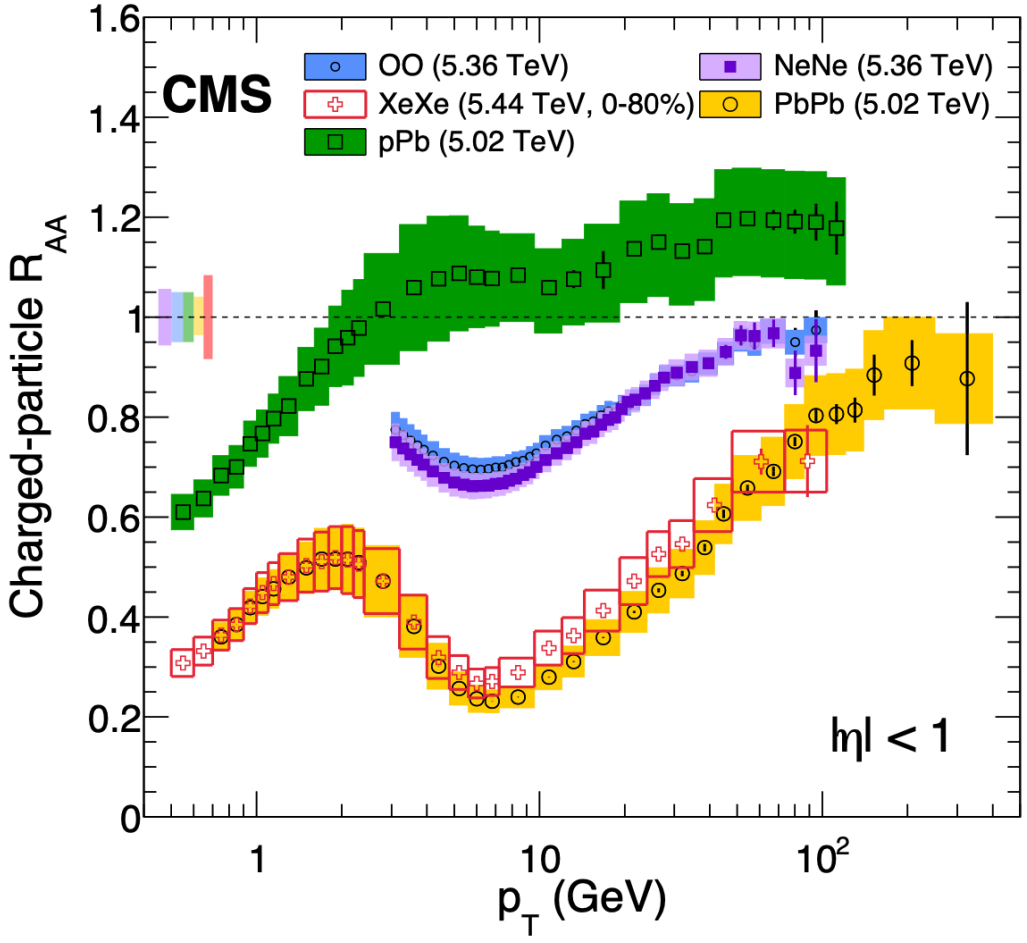
Summary

- Charged particle production measured in light-ion systems at 5.36 TeV by CMS

- R_{AA} in OO and NeNe shows significant suppression that is consistent with energy loss models

- R_{AA} measurements enable study of system size dependence of energy loss

arxiv:2602.21325v2



Back up

Analysis method

- About 1.02 pb^{-1} and 6.1 nb^{-1} of pp and OO data used respectively
- Charged primary particles selected ($c\tau > 1cm$)

Spectra measurement

Event selections :

- Vz < 15 cm
- For OO, HF energy > 13 GeV

Track selections :

- High purity tracks
- $|\eta|$<1
- xy and z DCA significance < 3
- pT resolution < 0.1

Corrections :

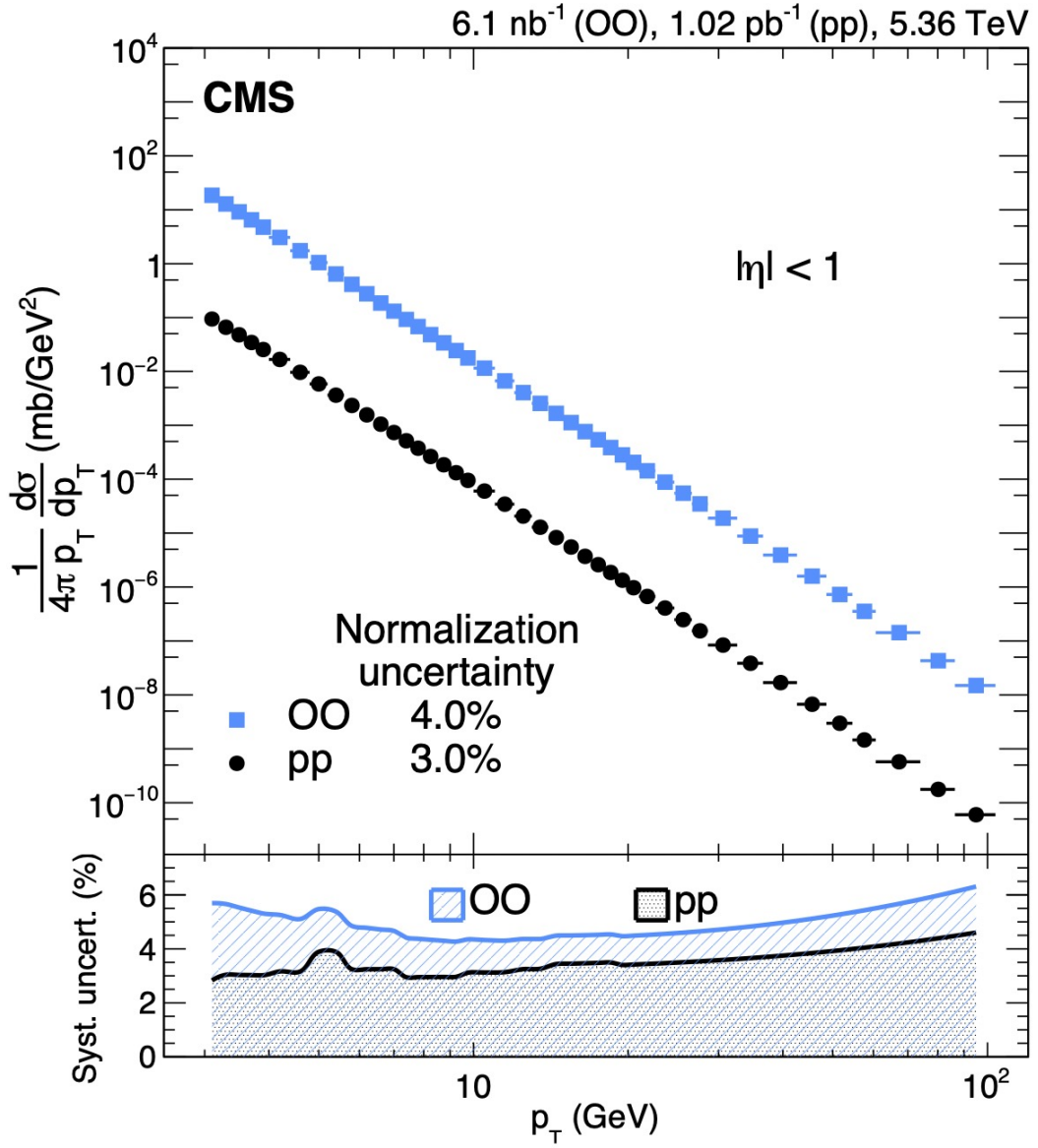
- Efficiency correction using PYTHIA and PYTHIA+HIJING
- Pile up correction (pp)
- Event selection correction
- Particle species correction

Luminosity measurement

Two methods used :

- Preliminary van der meer scan
- Z-counting method

Charged particle spectra in pp and OO collsions

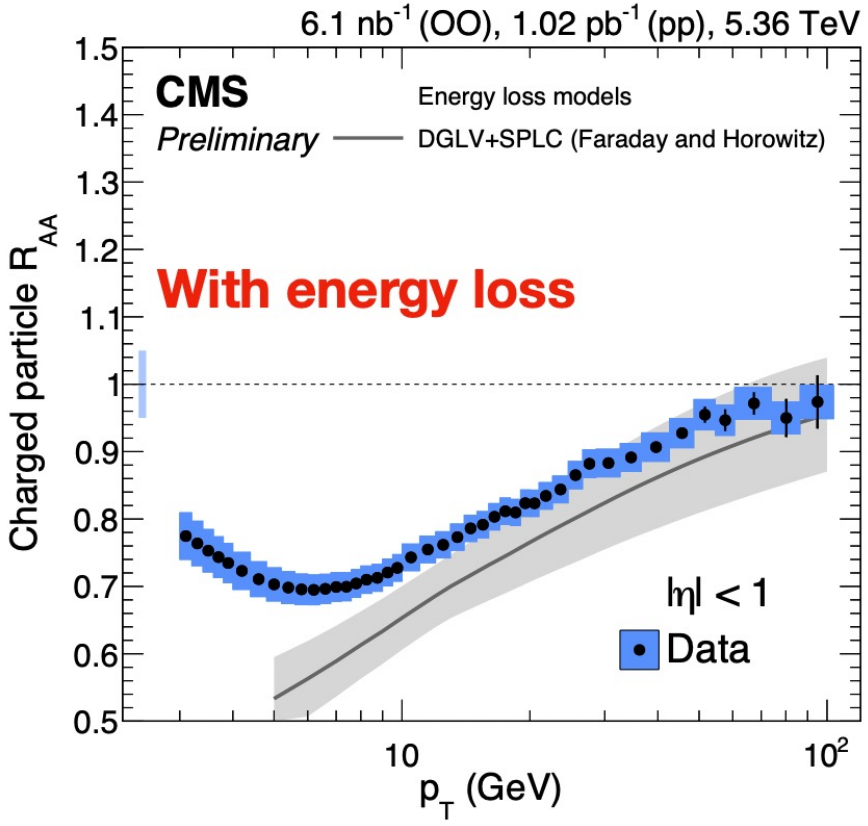


- p_T differential cross-section: $E\frac{d\sigma}{dp_T} = \frac{1}{4\pi p_T L}\frac{dN^{trk}}{dp_T}$
- Spectra reported within $3 < p_T$ (GeV) < 103.6, $|\eta|<1$

Energy loss model 7

https://arxiv.org/abs/2505.14568

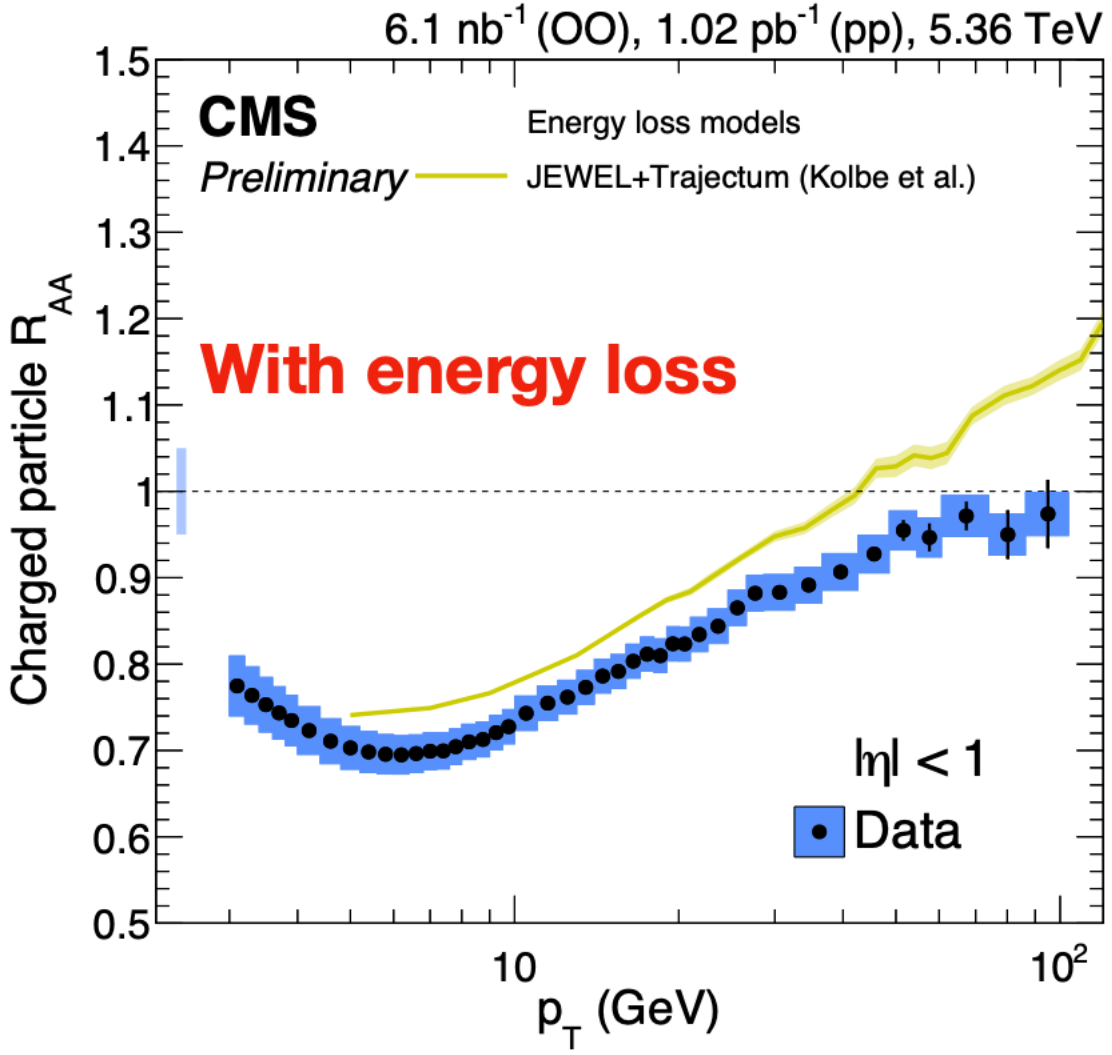
- Unity baseline
- Faraday/Horowitz model with DGLV formalism
- Short path length correction and collisional energy loss



Energy loss model 8

https://arxiv.org/abs/2509.04299

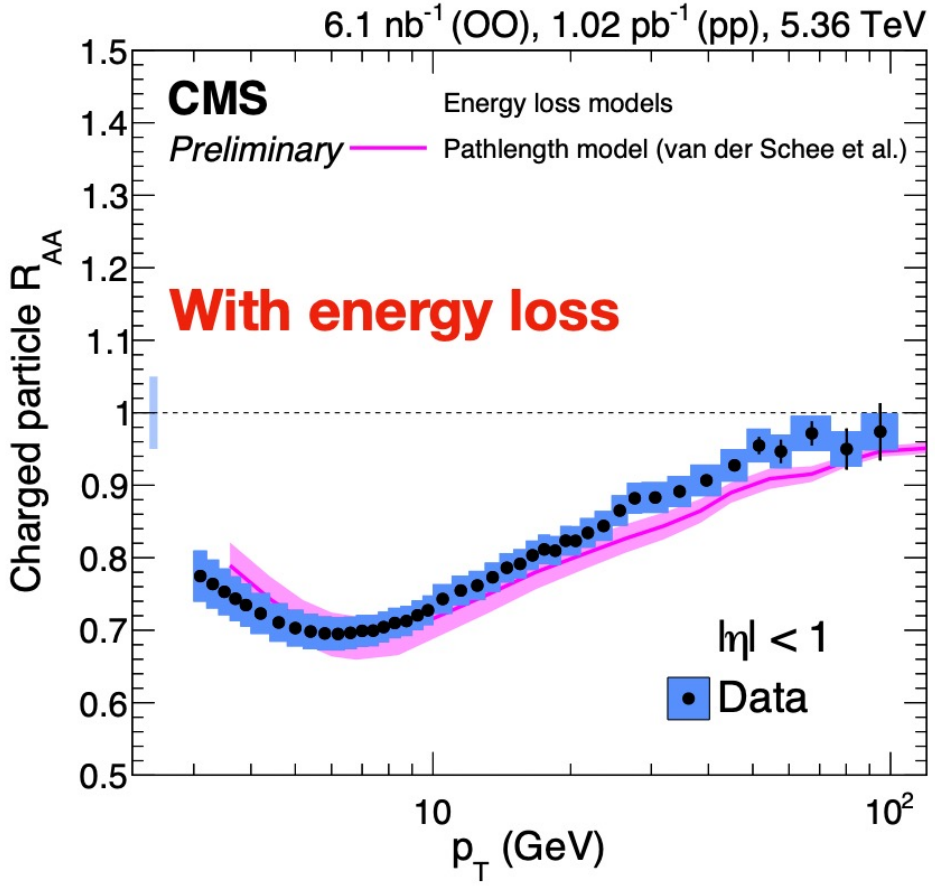
- Unity baseline
- JEWEL+Trajectum



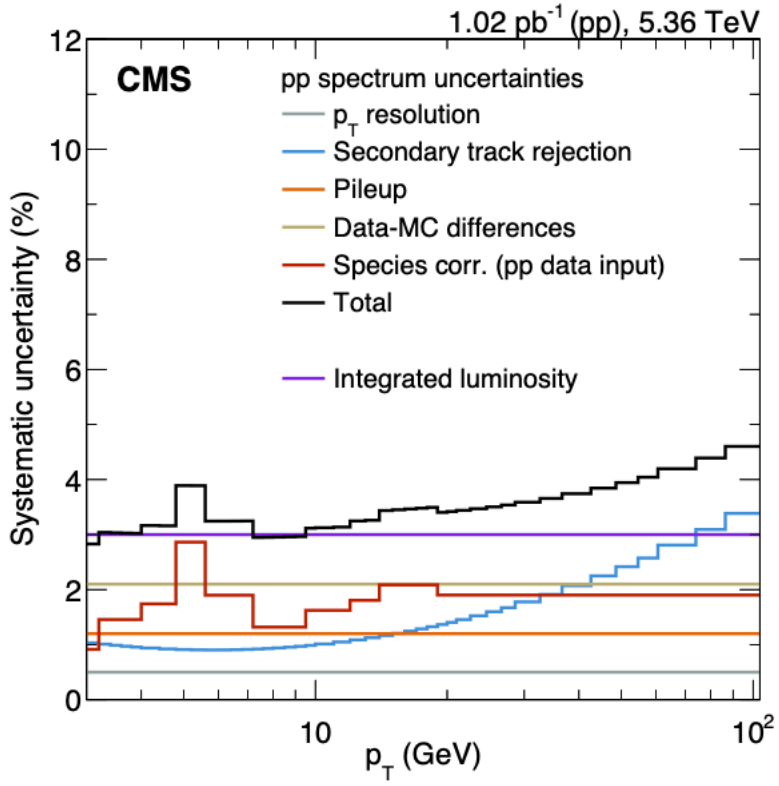
Energy loss model 9

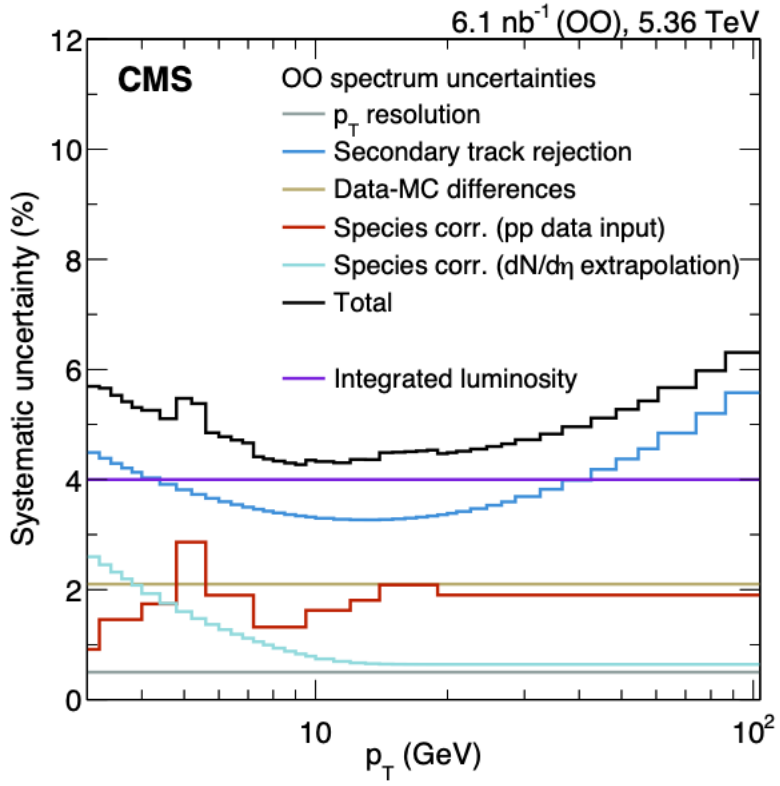
https://arxiv.org/abs/2509.04299

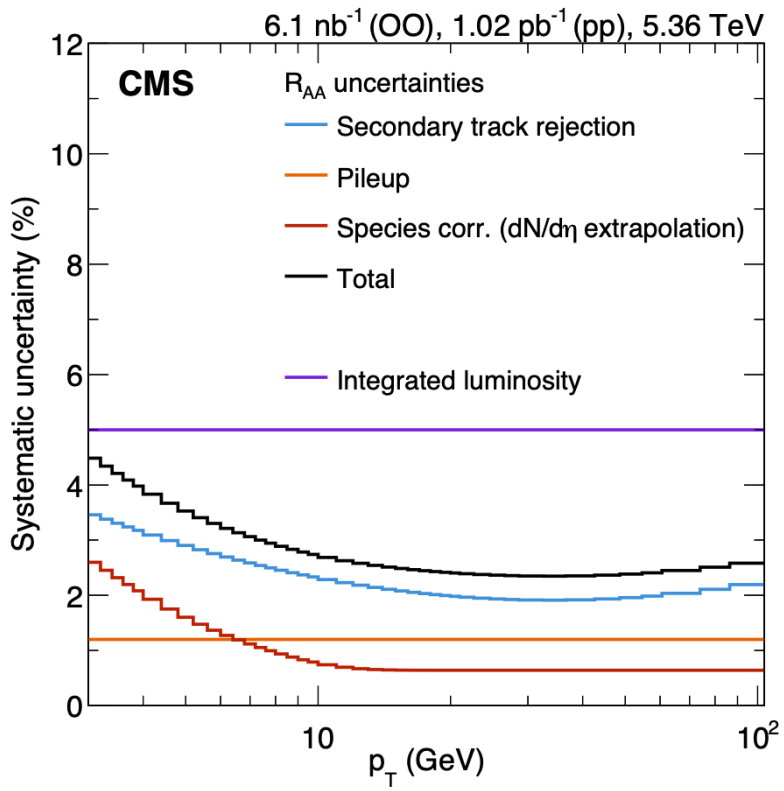
- Unity baseline
- Path length dependent scaling for heavy-ion system



Systematic uncertainties



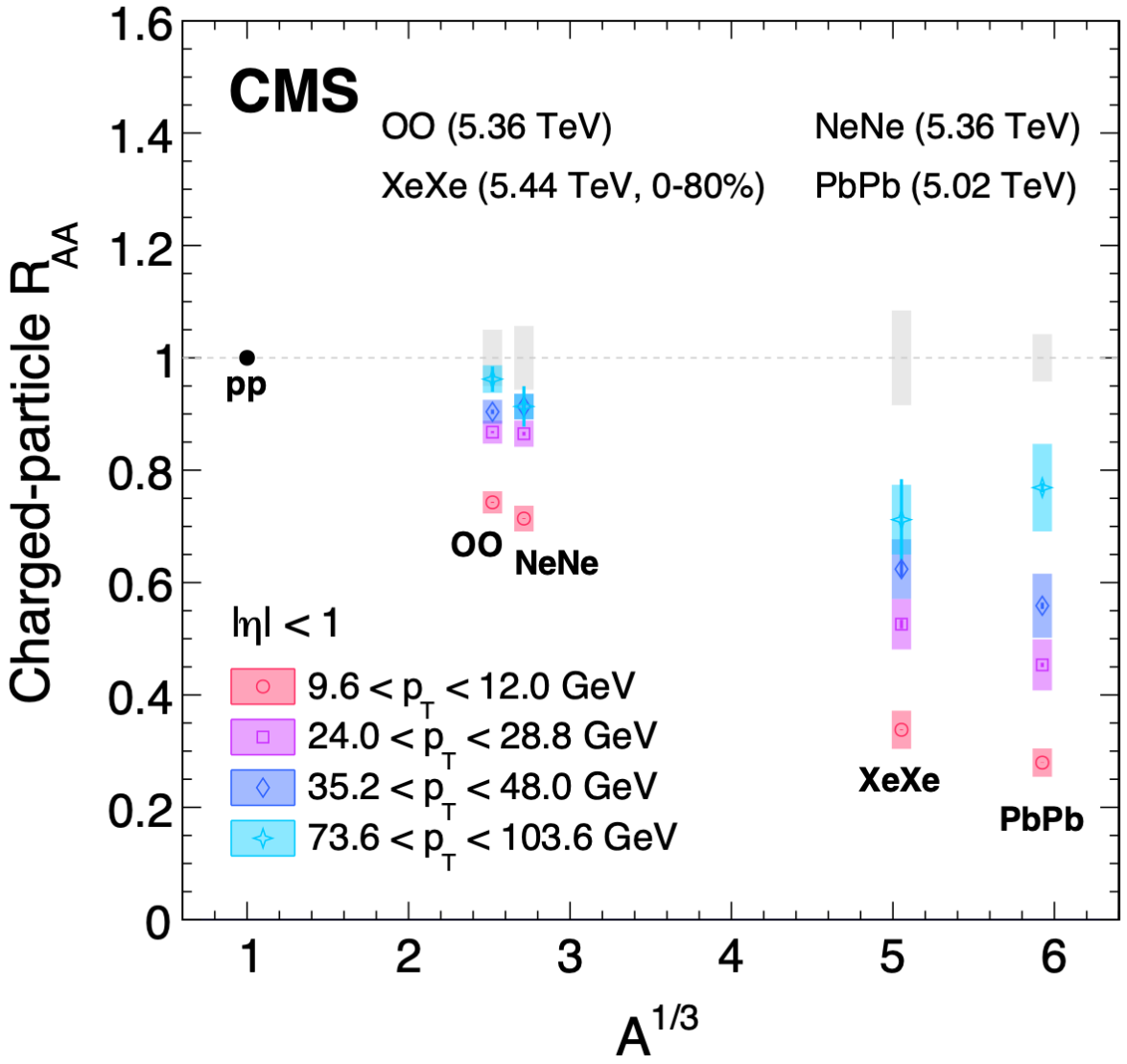




Glauber predictions

System	Glauber (HS)	Rel.unc.	Glauber ($\omega = 0.3$)	Rel.unc.	$\langle N_{\rm coll} \rangle$
OO, $\sqrt{s_{\rm NN}} = 5.36$ TeV	$\sigma_{\rm OO}^{\rm HS} = 1.31 \pm 0.04$ b	3.4%	$\sigma_{\rm OO}^{\rm MC} = 1.36 \pm 0.09$ b	6.8%	12.8
NeNe, $\sqrt{s_{\rm NN}} = 5.36$ TeV	$\sigma_{\rm NeNe}^{\rm HS} = 1.68 \pm 0.03$ b	1.8%	$\sigma_{\rm NeNe}^{\rm MC} = 1.73 \pm 0.08$ b	4.8%	15.7
pPb, $\sqrt{s_{\rm NN}} = 5.36$ TeV	$\sigma_{\rm pPb}^{\rm HS} = 2.10 \pm 0.03$ b	2.0%	$\sigma_{\rm pPb}^{\rm MC} = 2.14 \pm 0.07$ b	3.3%	6.6
PbPb, $\sqrt{s_{\rm NN}} = 5.36$ TeV	$\sigma_{\rm PbPb}^{\rm HS} = 7.66 \pm 0.15$	1.5%	$\sigma_{\rm PbPb}^{\rm MC} = 7.80 \pm 0.30$	3.8%	340
pO, $\sqrt{s_{\rm NN}} = 9.62$ TeV	$\sigma_{\rm pO}^{\rm HS} = 466 \pm 9$ mb	1.9%	$\sigma_{\rm pO}^{\rm MC} = 481 \pm 24$ mb	5.0%	2.3

R_{AA} dependence of A



Jet-triggered hadron R_{AA}