12th MPI at LHC

WG5: Heavy-Ions

Summary

Liliana Apolinário and Daniel Tapia Takaki

12th MPI at LHC

Our big thanks to all the speakers of our sessions!

WG3 + WG5 Joint session (Wed)

Opportunities of OO and pO collisions at the LHC (20+5)	*Jasmine Brewer*	
Auditorium, LIP Lisbon		10:00 - 10:20
QCD and Relativistic Hydrodynamics from pp to AA (20+5)	*Christopher Plumberg*	
Auditorium, LIP Lisbon		10:30 - 10:50

WG5 Round-table discussion (Fri)

Role of MPI to HI	*Nestor Armesto*
Auditorium, LIP Lisbon	11:00 - 11:10
Double and triple parton scatterings in heavy-ion collisions	*David d'Enterria*
Auditorium, LIP Lisbon	11:10 - 11:20
Role of MPI to HI	*Leif Lonnblad*
Auditorium, LIP Lisbon	11:20 - 11:30
Role of MPI to HI	*Andreas Morsh*
Auditorium, LIP Lisbon	11:30 - 11:40
Round-table discussion	*Andreas Morsch et al.*
Auditorium, LIP Lisbon	11:40 - 12:00

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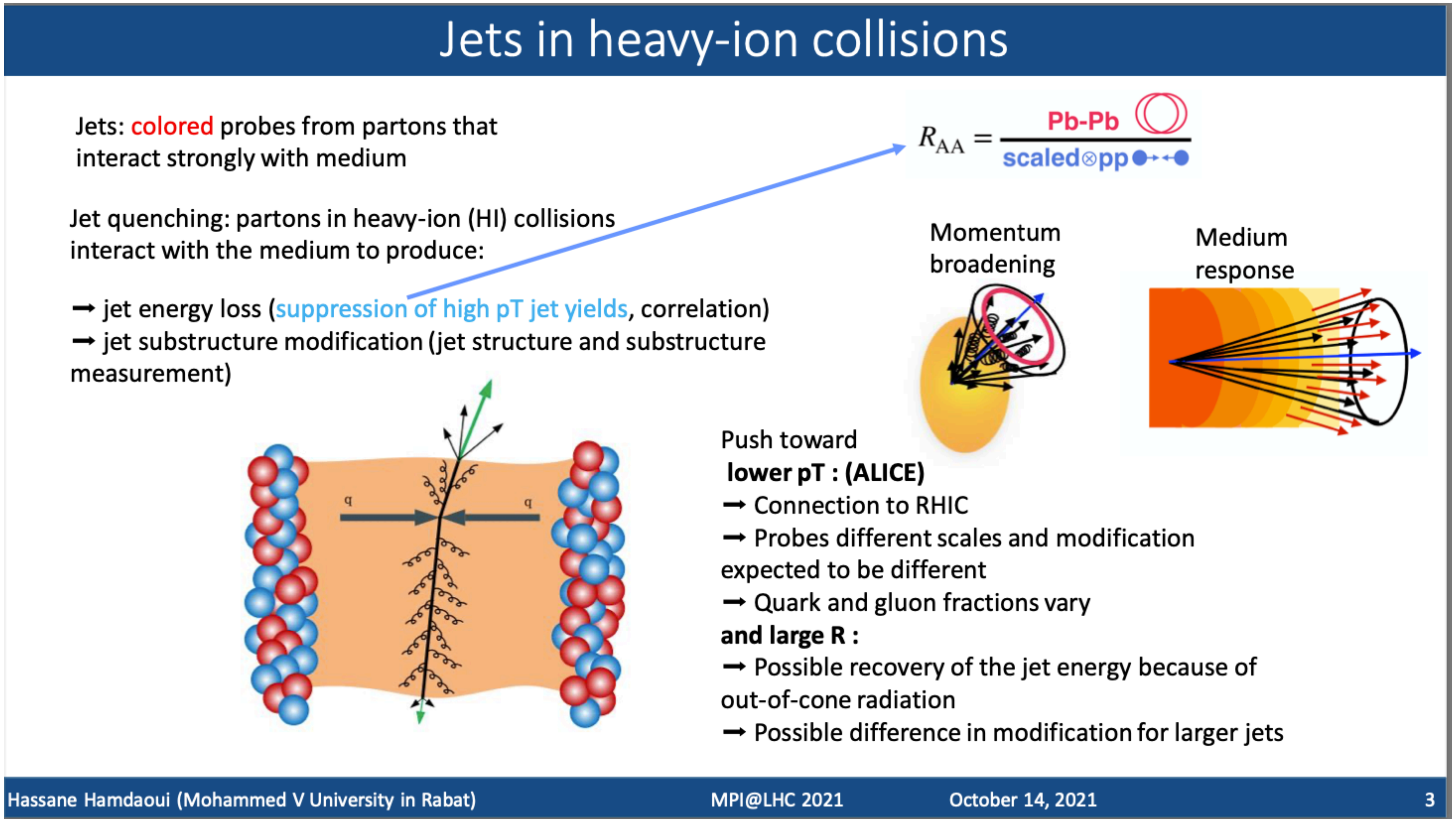
Our big thanks to all the speakers of our sessions!

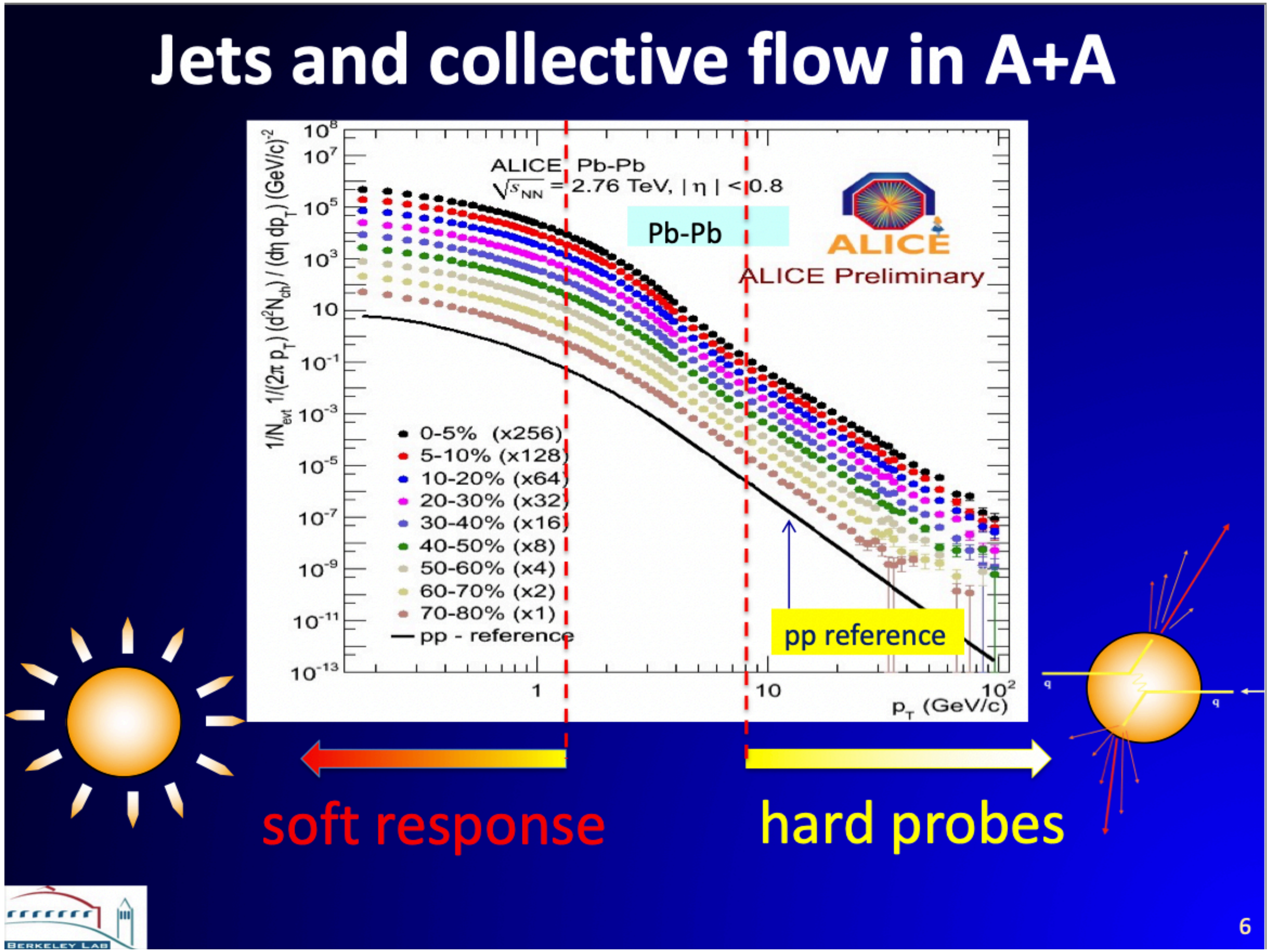
WG5 session (Thu)

Accessing the initial conditions of ultrarelativistic heavy-ion collisions	You Zhou	Auditorium, LIP Lisbon	10:00 - 10:25
Overview on quarkonia and heavy-flavor physics at the LHC	Luca Micheletti	Auditorium, LIP Lisbon	10:30 - 10:55
Recent results on soft and hard probes at RHIC	Yue Hang Leung	Auditorium, LIP Lisbon	13:55 - 14:20
Overview talk on recent soft probes in heavy-ion physics at the LHC	Prabhat Ranjan Pujahari	Auditorium, LIP Lisbon	14:25 - 14:50
Two-particle correlations triggered with strange hadrons in pp collisions at 13 TeV measured with ALICE	Lucia Anna Tarasovicova		
Neutron production in ZDC as a probe of the dynamics of hard gamma A and pA interactions	Mark Strikman	Auditorium, LIP Lisbon	15:45 - 16:00
Heavy-Ion Physics at the LHCb	Cesar Luis da Silva	Auditorium, LIP Lisbon	16:05 - 16:20
MPI & Jet Physics in Heavy-Ion Collisions	Xin-nian Wang	Auditorium, LIP Lisbon	16:25 - 16:50
Jets and UPC physics in heavy-ion collisions at the LHC	Hassane HAMDAOUI	Auditorium, LIP Lisbon	16:55 - 17:20

Jets and High-Pt objects



Several effects playing a role:
- **Energy loss (gluon radiation induced by interactions with the medium)**
- **Momentum broadening (jets become more “fat”)**
- **Medium response (medium excitations from jet-medium interaction)**



- Spectrum and jet energy is depleted.
- Jet quenching dominates high part of the spectrum
- MPI dominates low part of the spectrum

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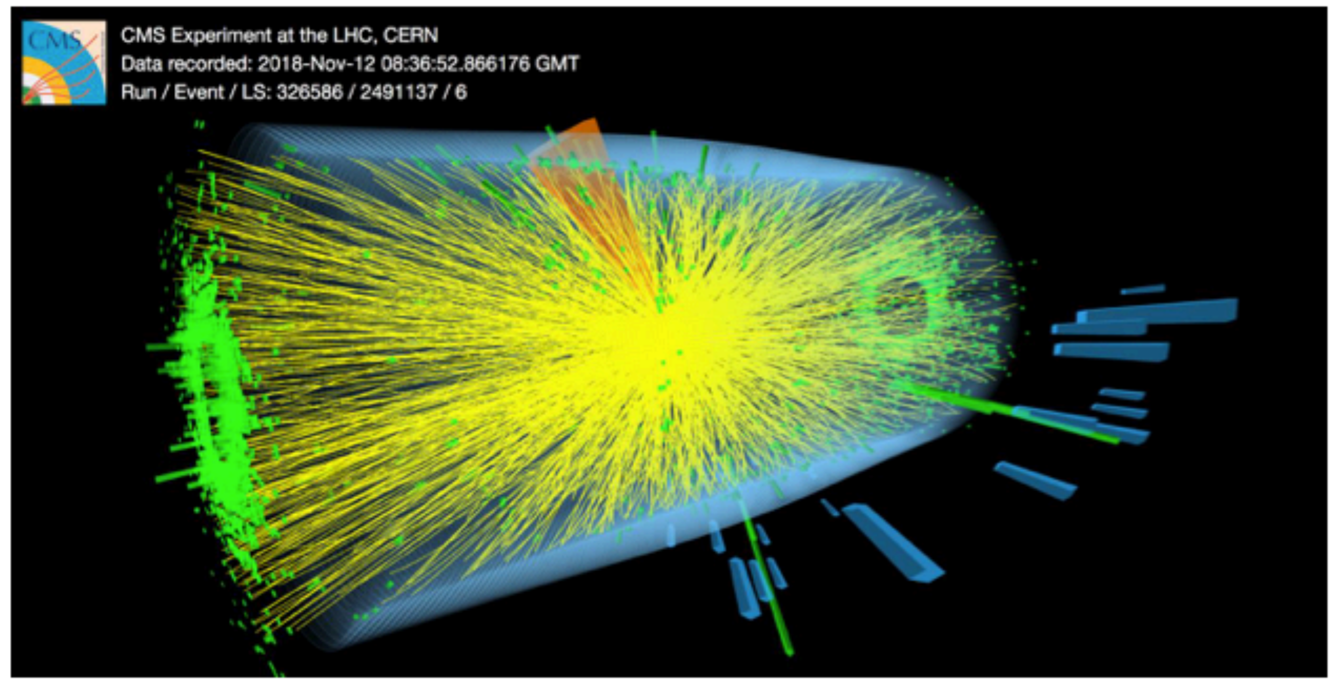
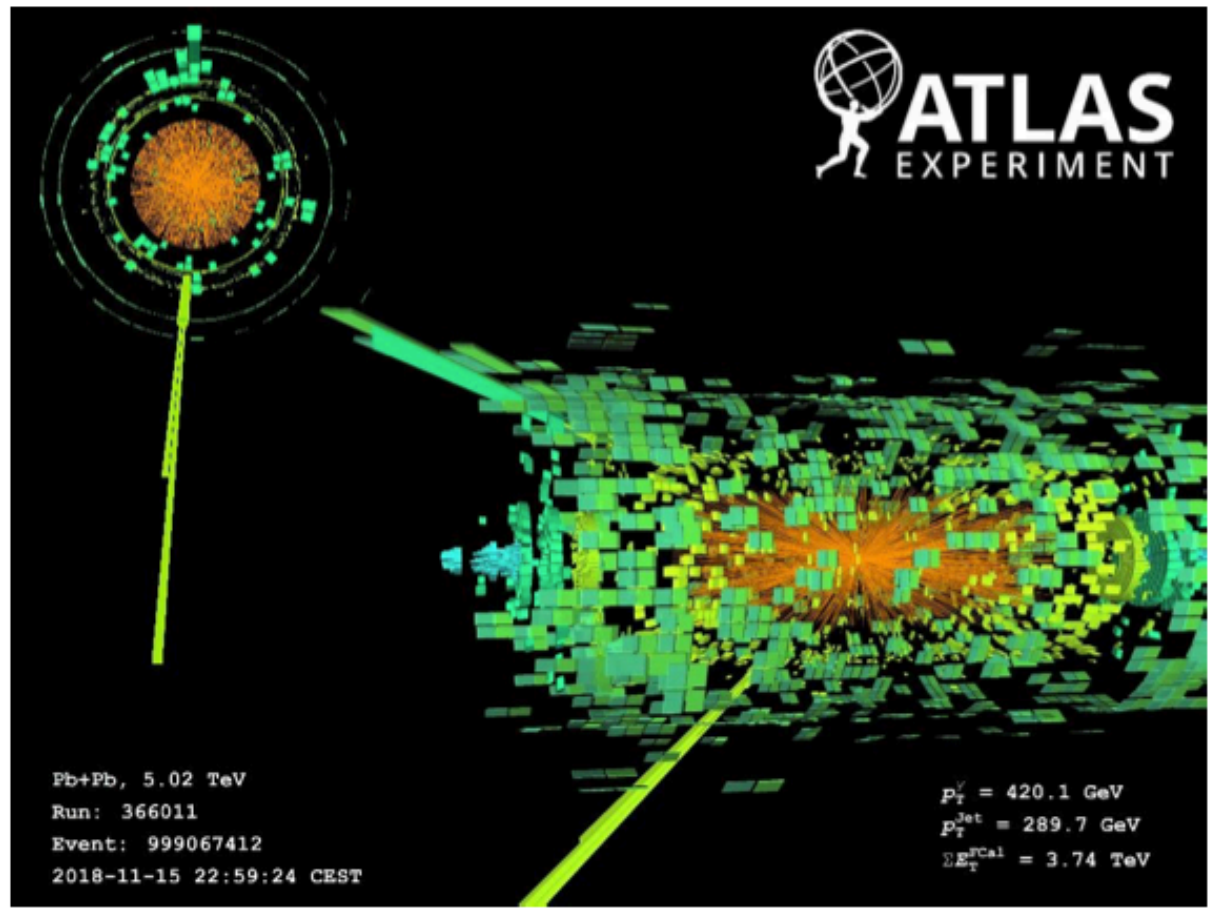
H. Hamdaoui

Z+Jet



photon+jet



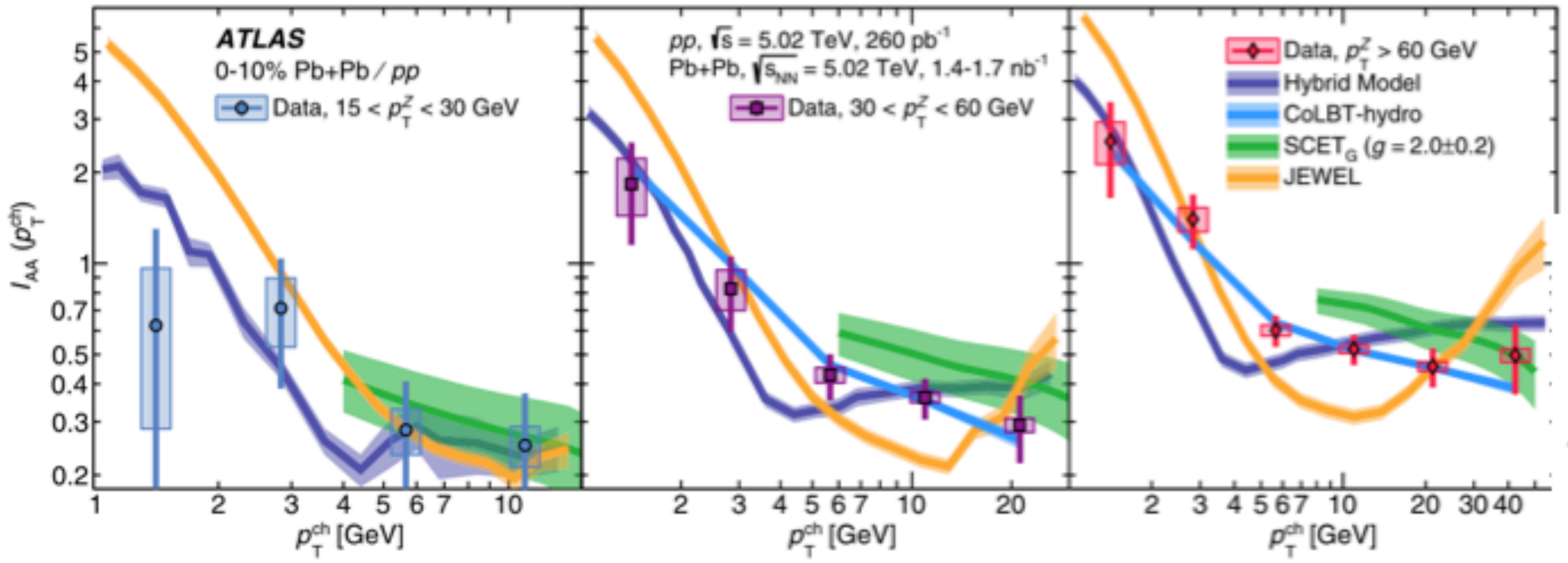
Z-hadron correlations in Pb+Pb and pp collisions

- What is the new information compared to the inclusive measurement ?
- Quark dominated jet sample.
- Testing role of parton virtuality when comparing Z- and Ɣ-tagged measurements.
- Access to low pT (jet) region.

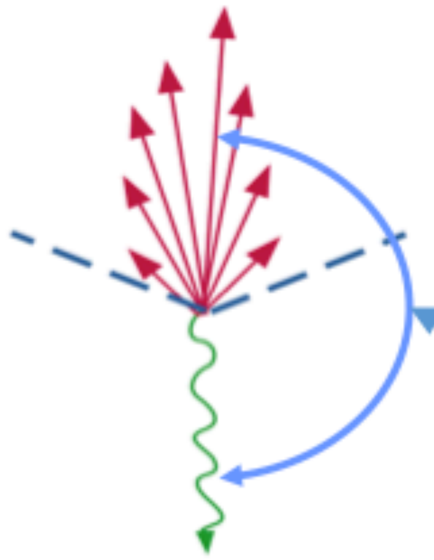
arXiv:2103.04377v1

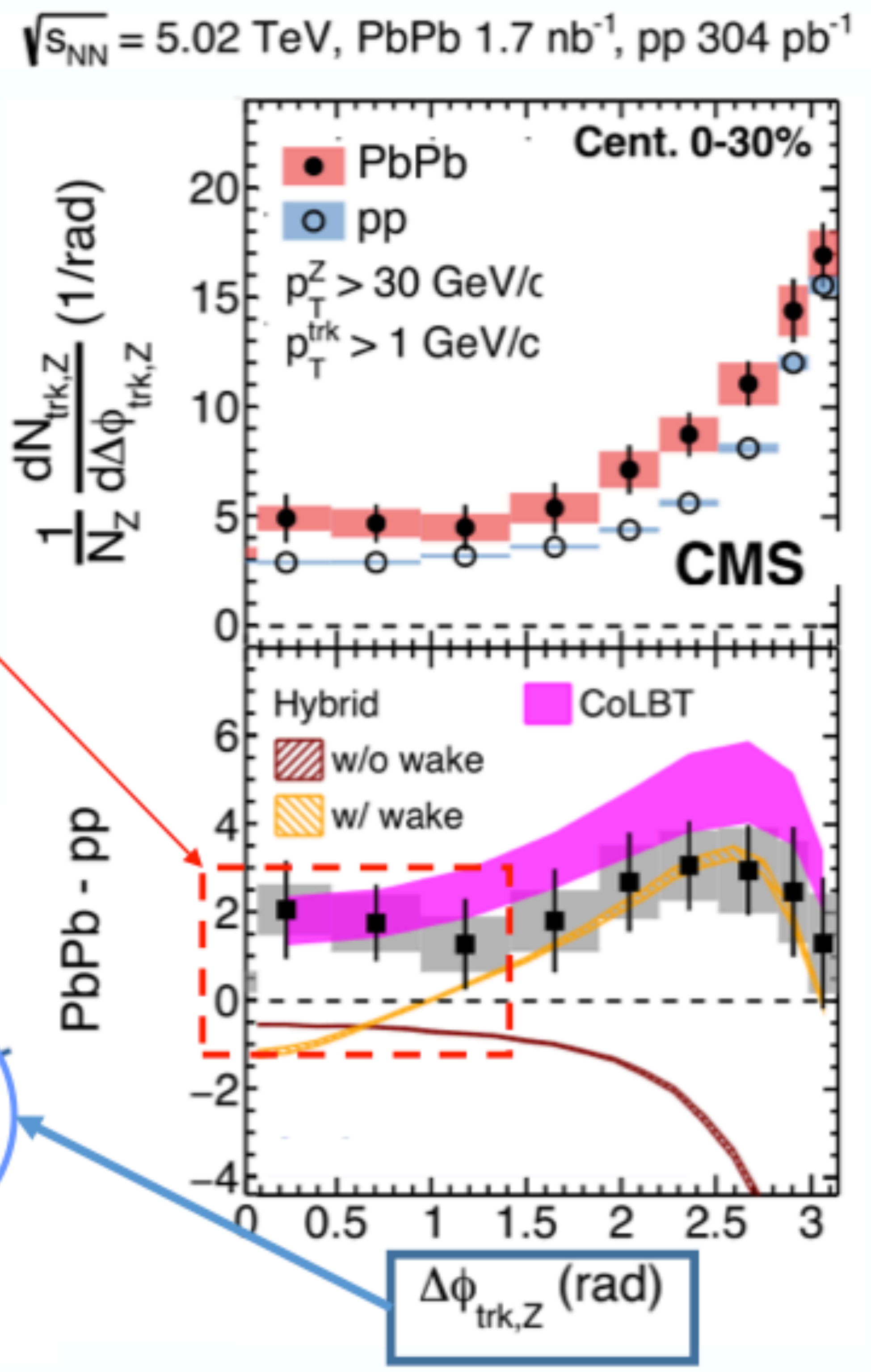
Excess Not described by any model

Phys. Rev. Lett. 126 (2021) 072301

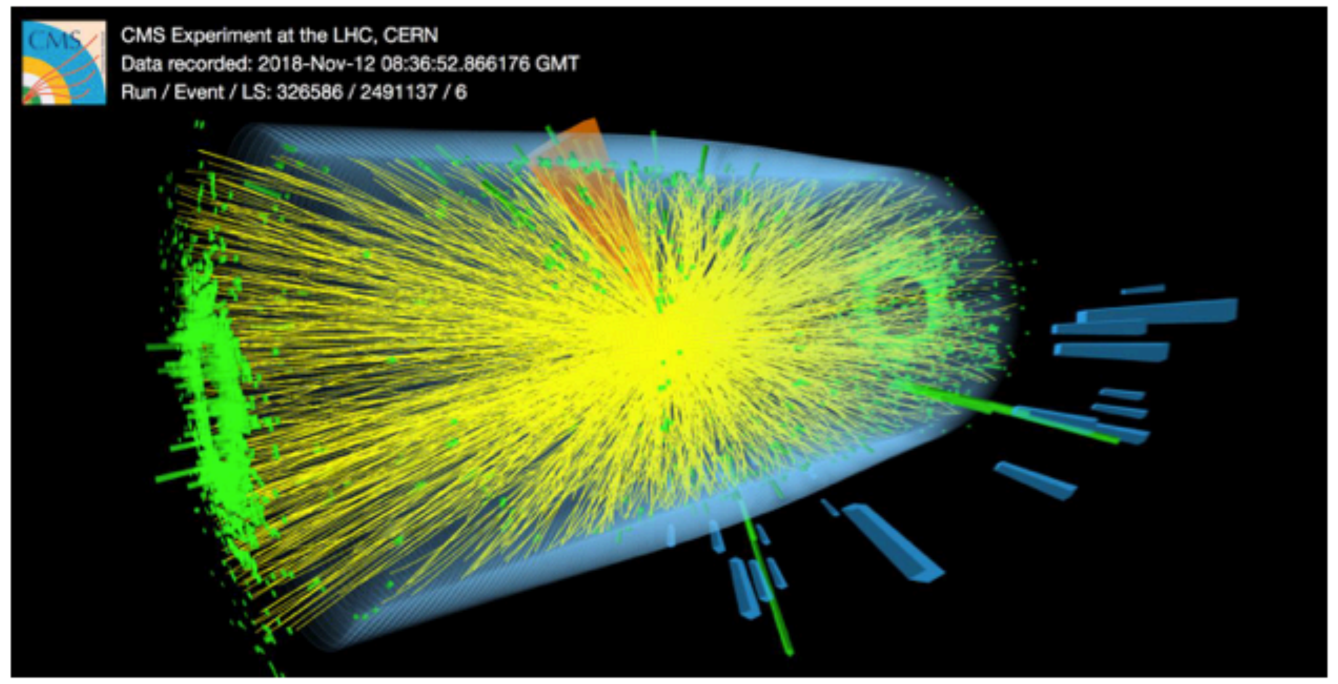


Similar trend to what we see in photon tagged jets.

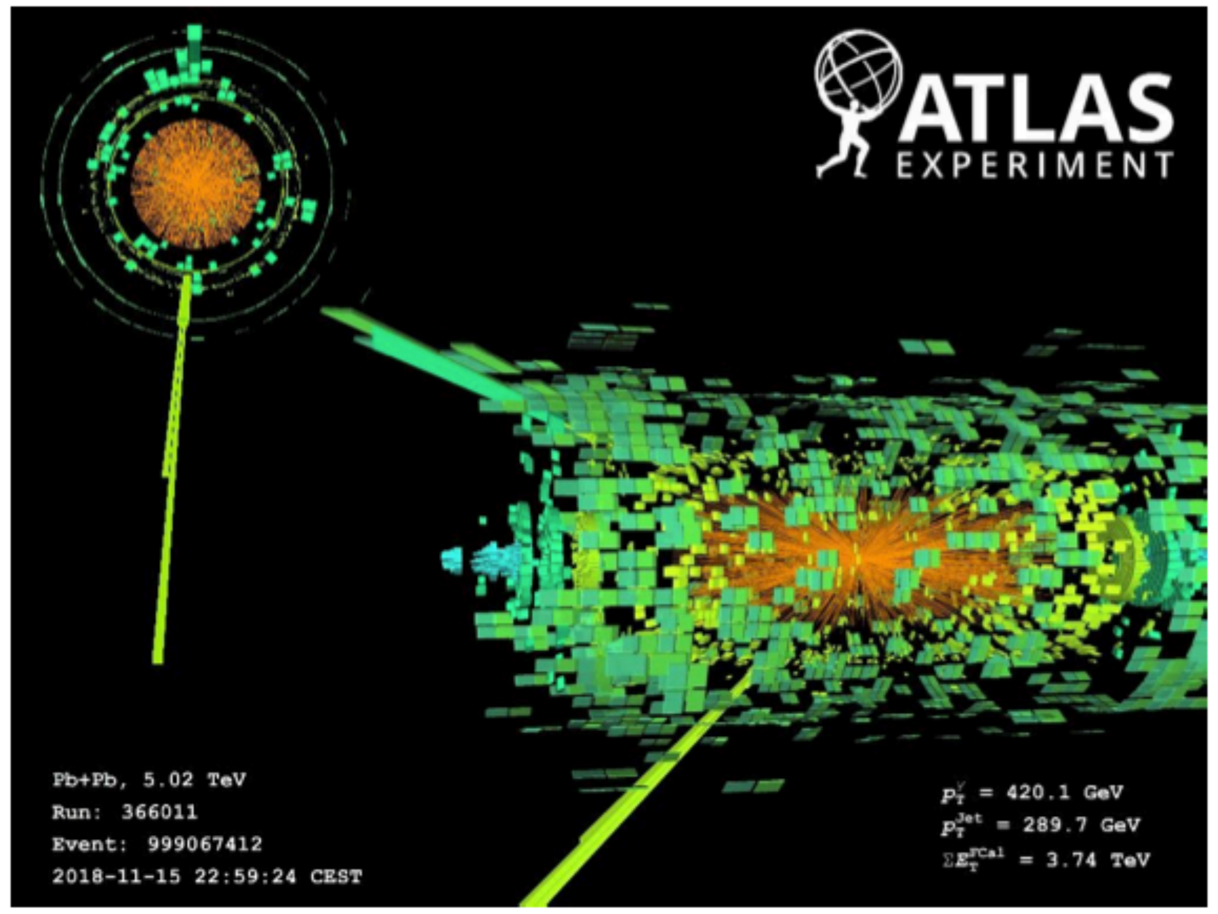




Z+Jet



photon+jet



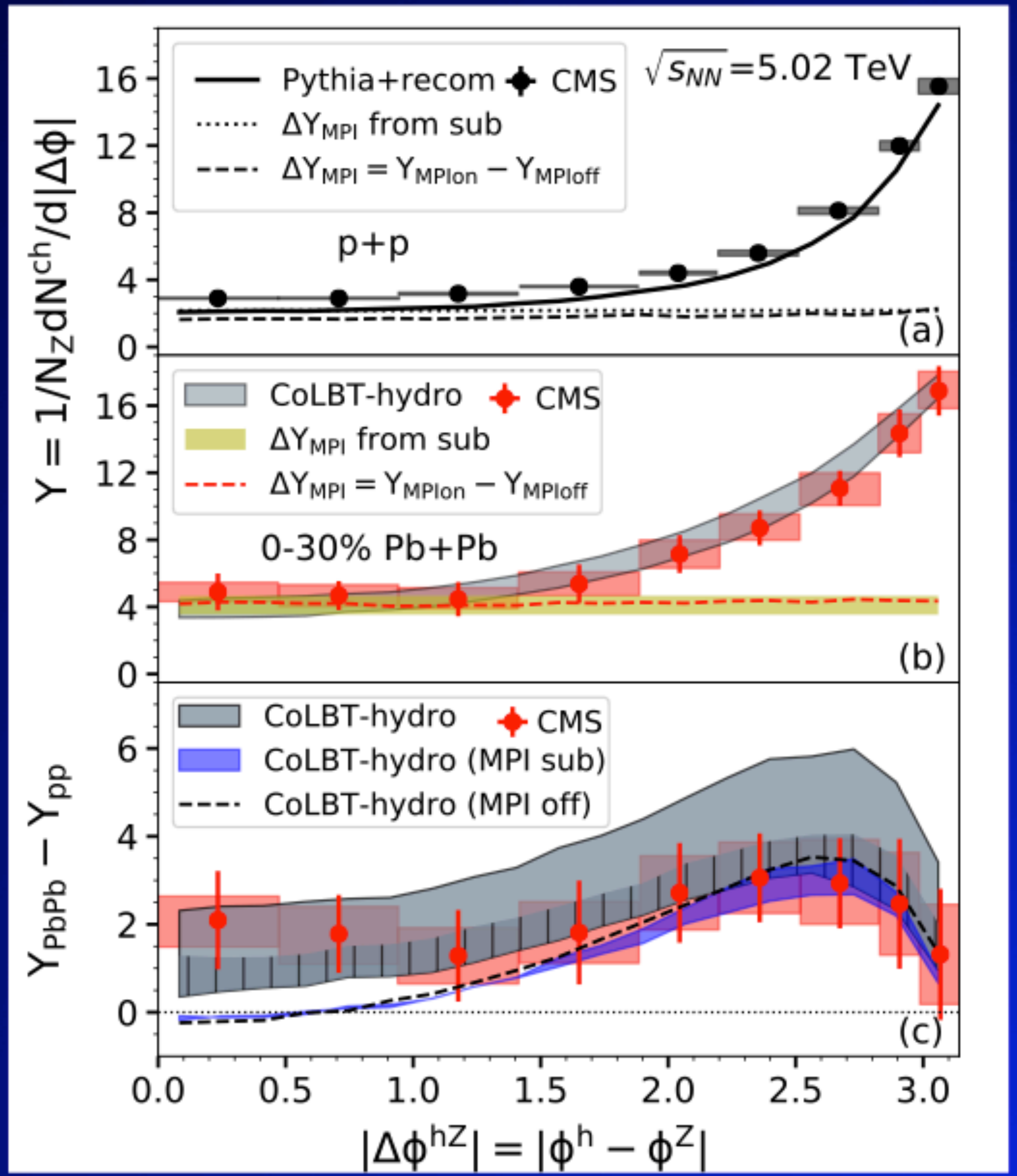
MPI will induce constant background on away-side jet

X-N. Wang

MPI subtraction in Z-hadron correlation

Medium modification of MPI: low pT enhancement and high pT suppression

No correlation with Z/γ-jet



Mixed event subtraction

$$\frac{dN^{hZ}_{\rm MPI}}{d\phi} = \frac{dN^{hZ}_{\rm mix}}{d\phi} - \int_1^{\pi} \frac{d\phi}{\pi}\left(\frac{dN^{hZ}}{d\phi} - \frac{dN^{hZ}}{d\phi}|_{\phi=1}\right)$$

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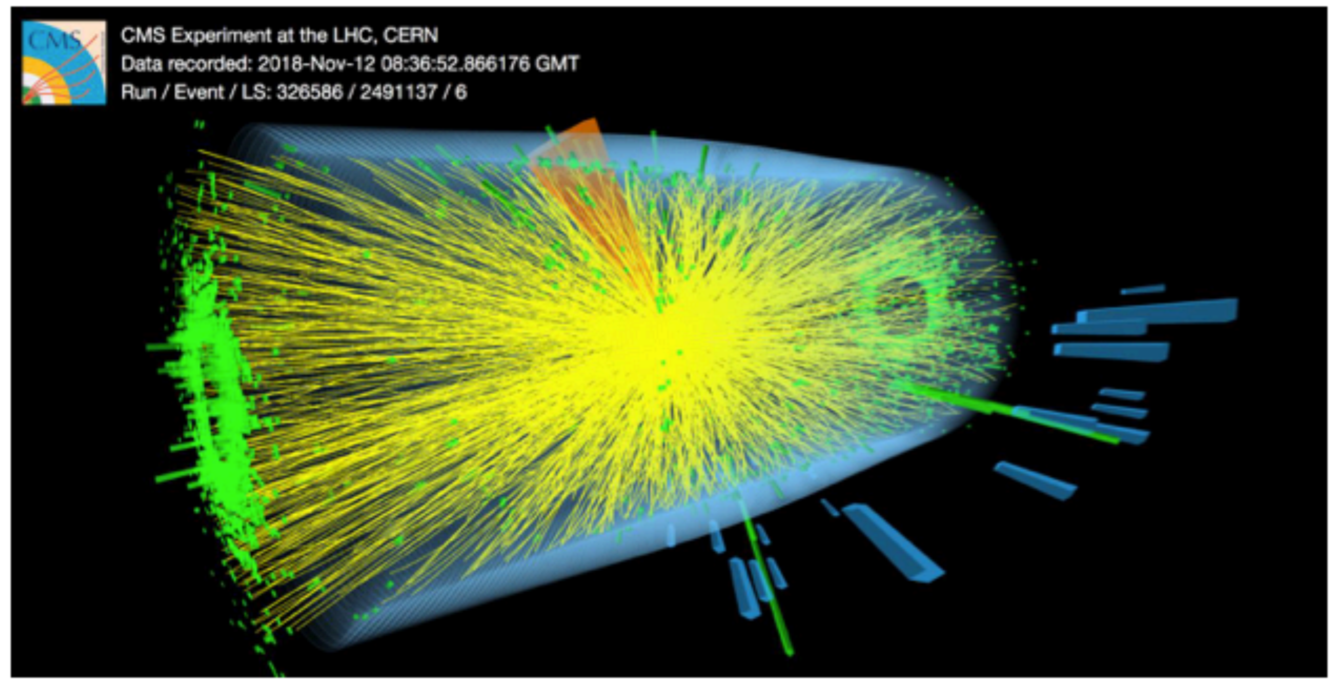
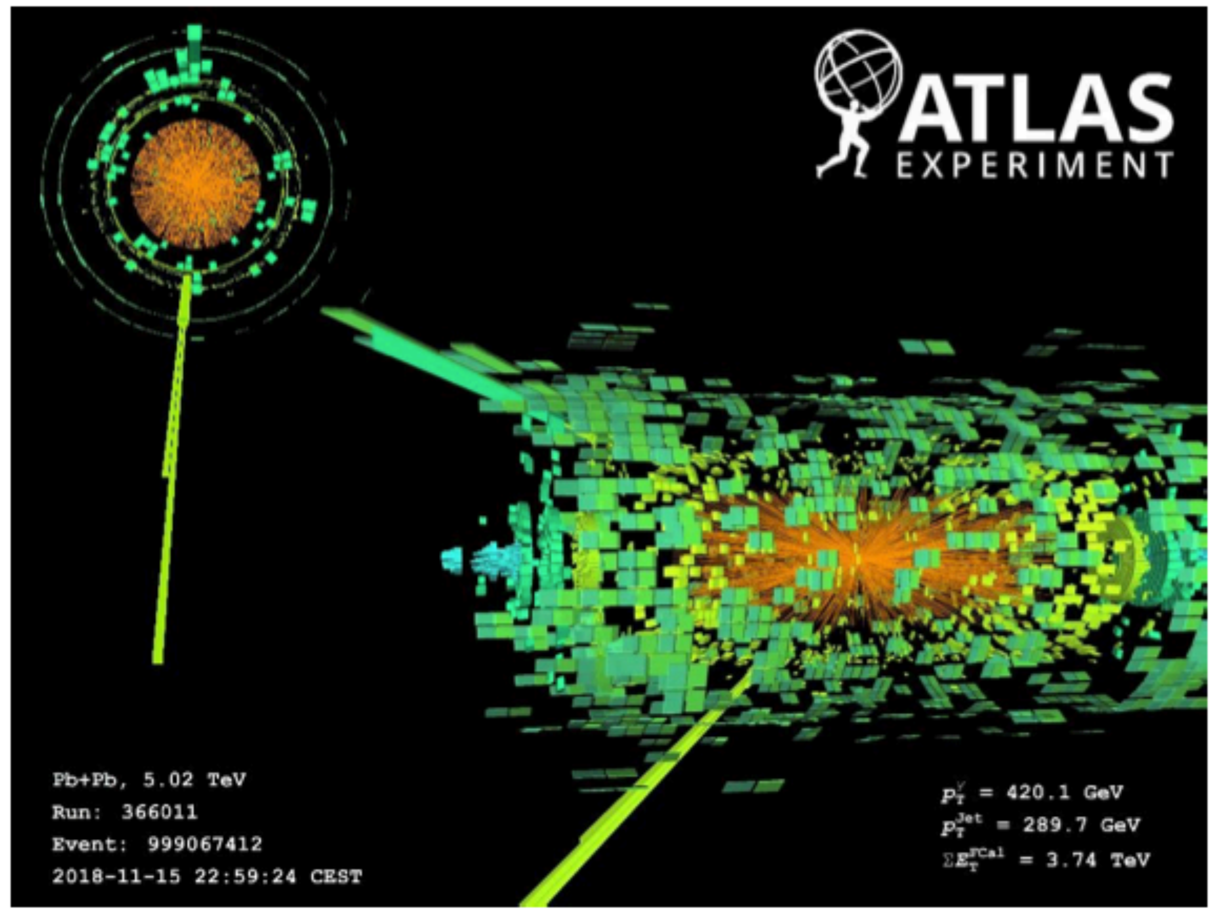
Z+Jet



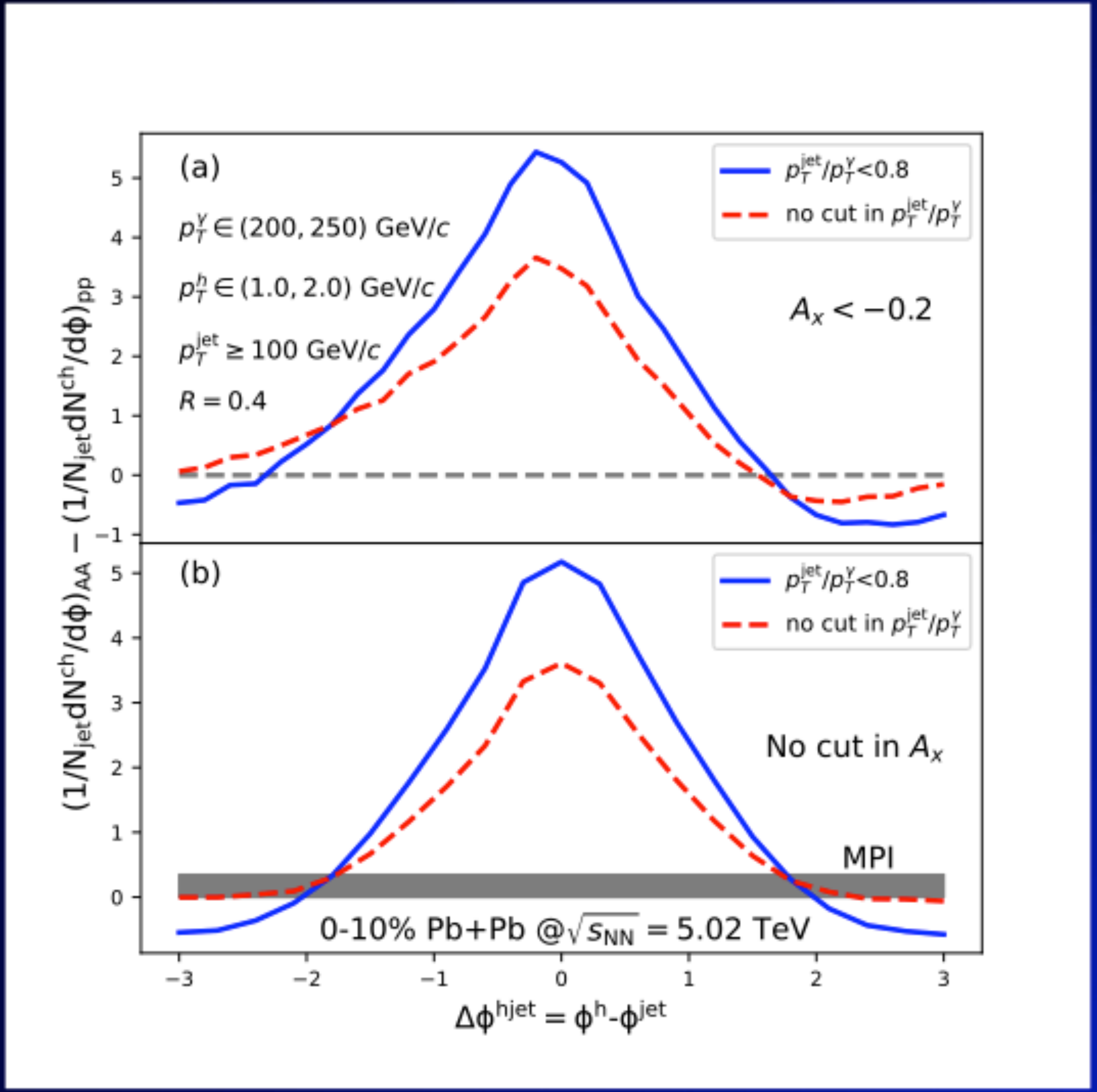
photon+jet

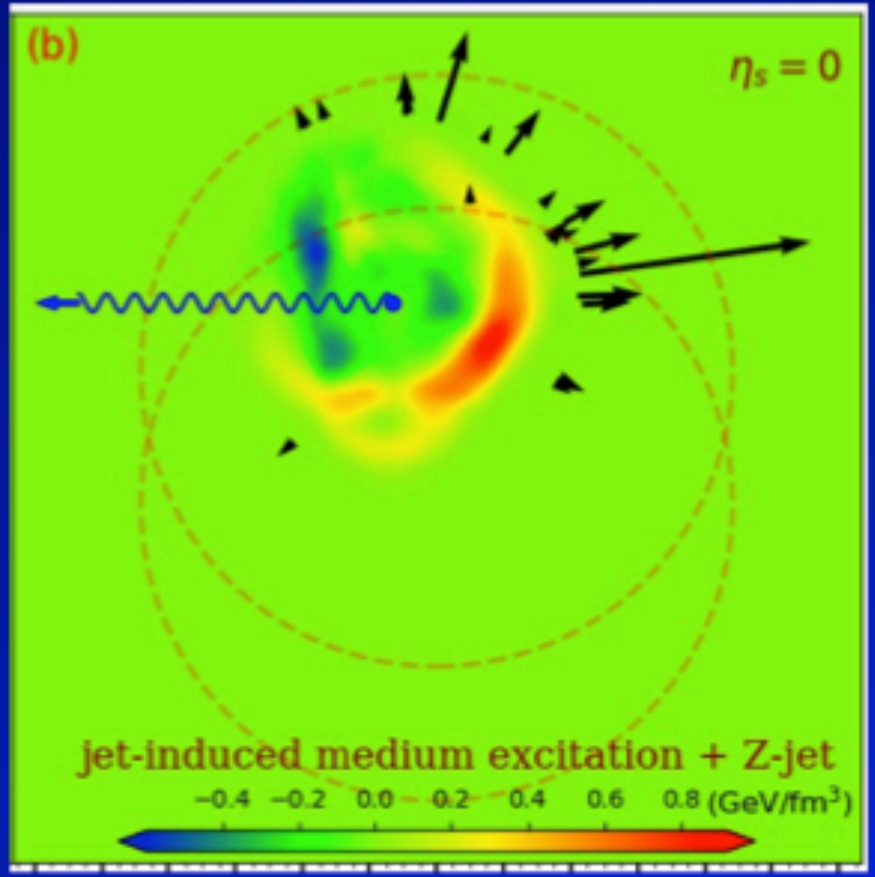


Diffusion wake visible in asymmetry classes

X-N. Wang

Enhancing the diffusion wake





Deferential jet yields measurement w.r.t. reaction plane.

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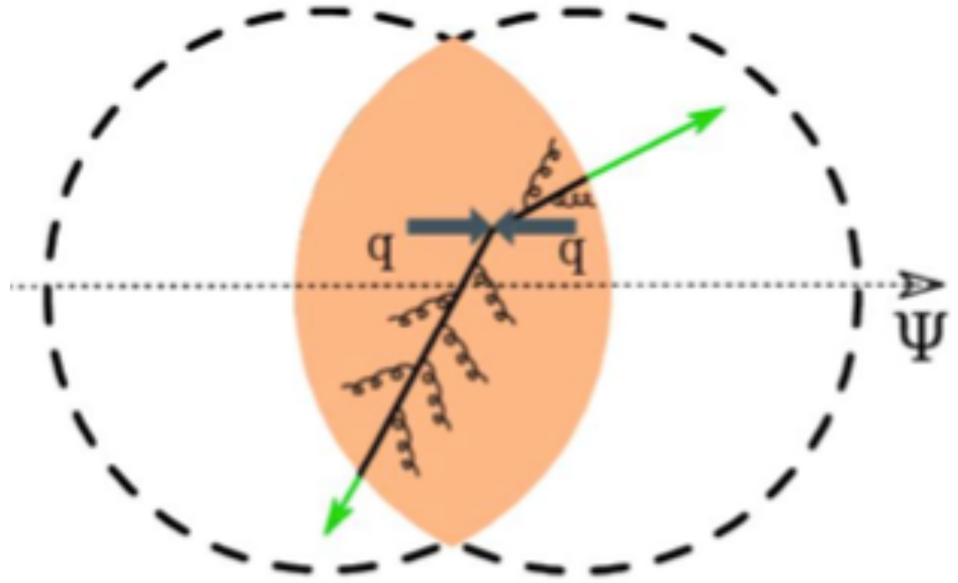
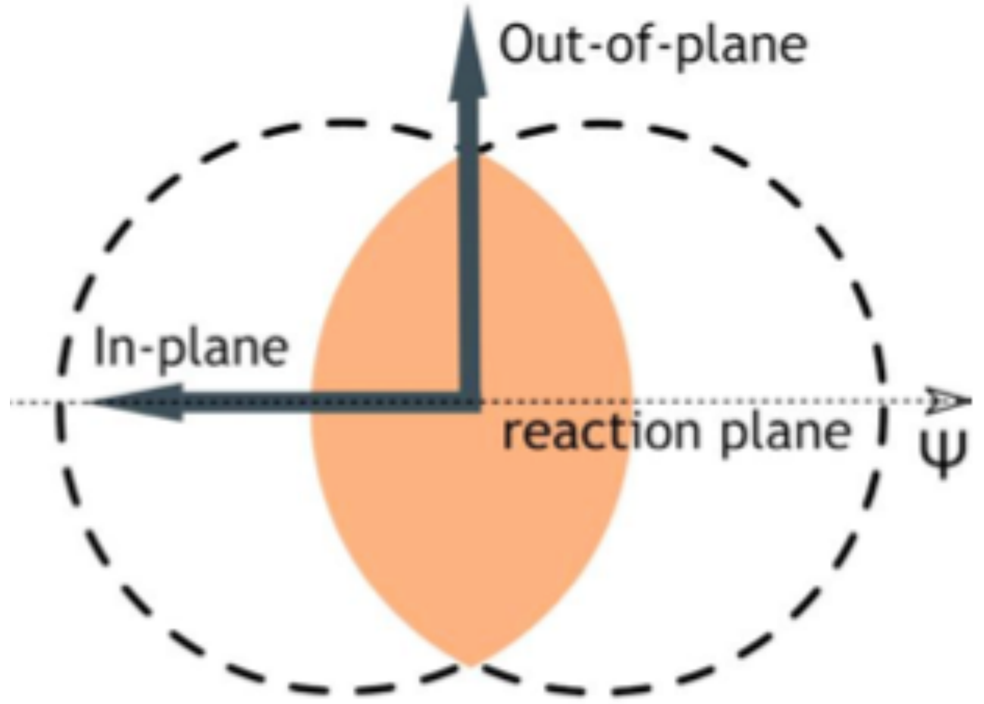
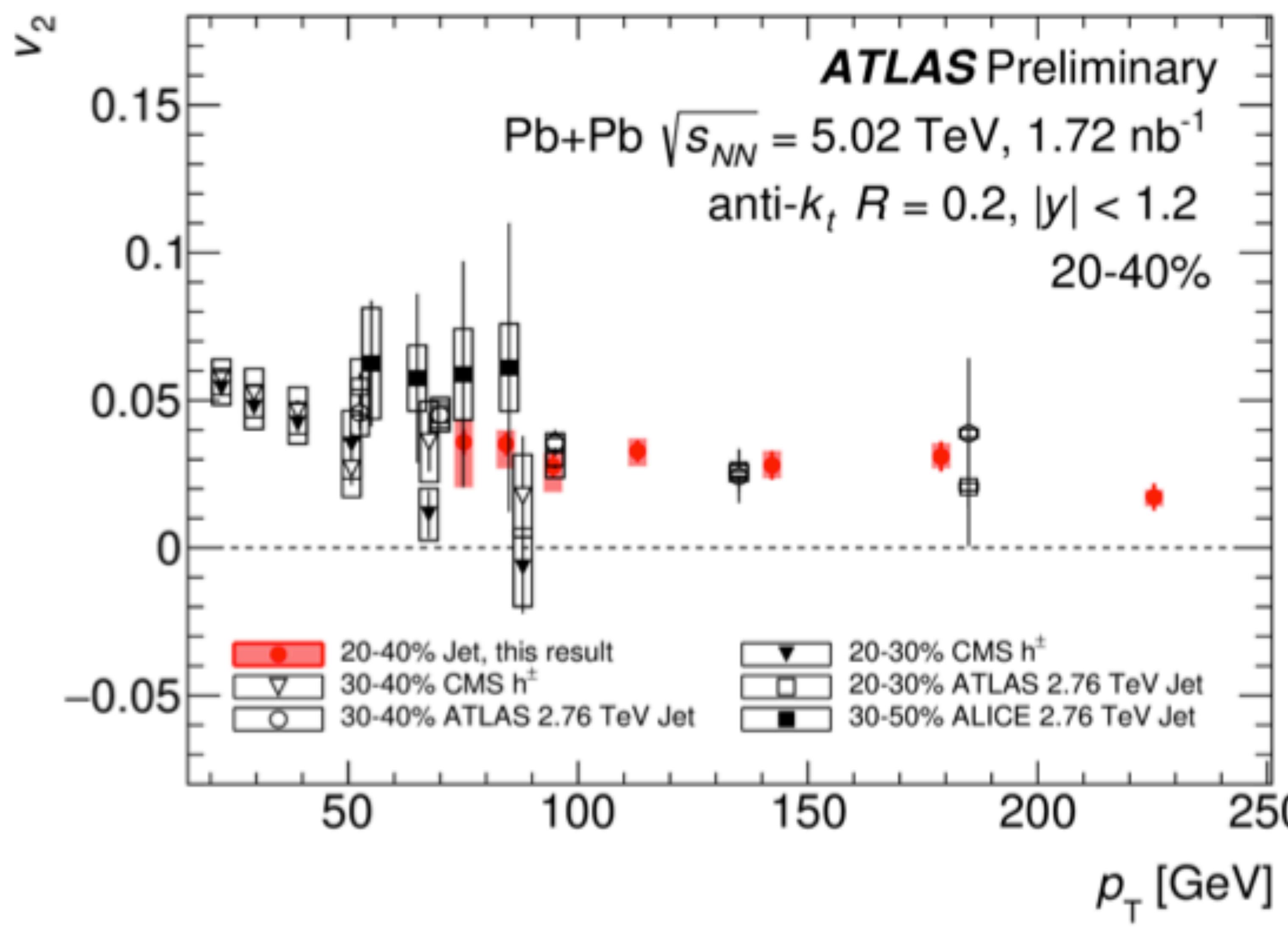
H. Hamdaoui



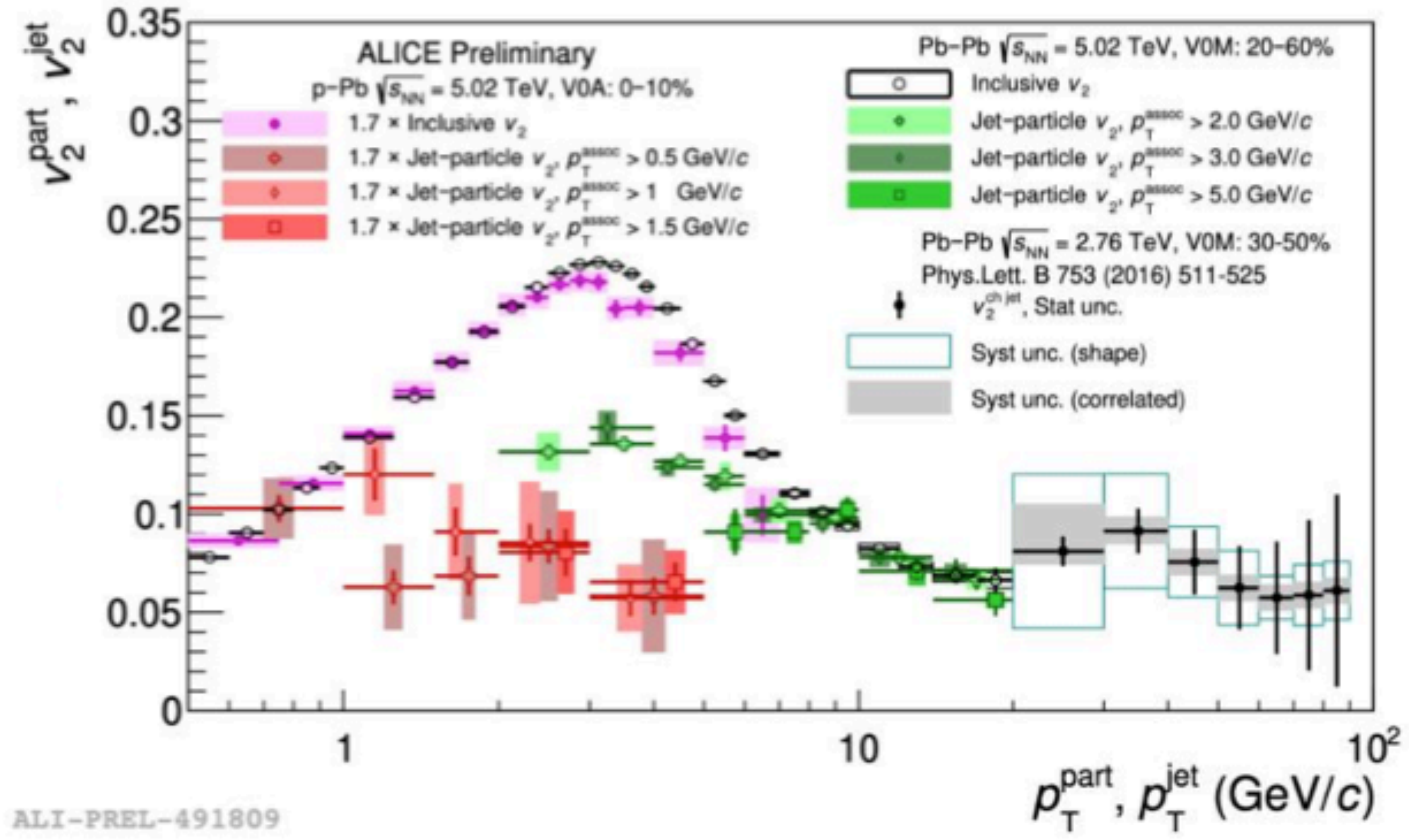


Jet anisotropies

ATLAS-CONF-2020-019



alice-figure.web.cern.ch



Consistent results from the LHC experiments

Lower pT reach in ALICE allowing a general picture of v2 measurement

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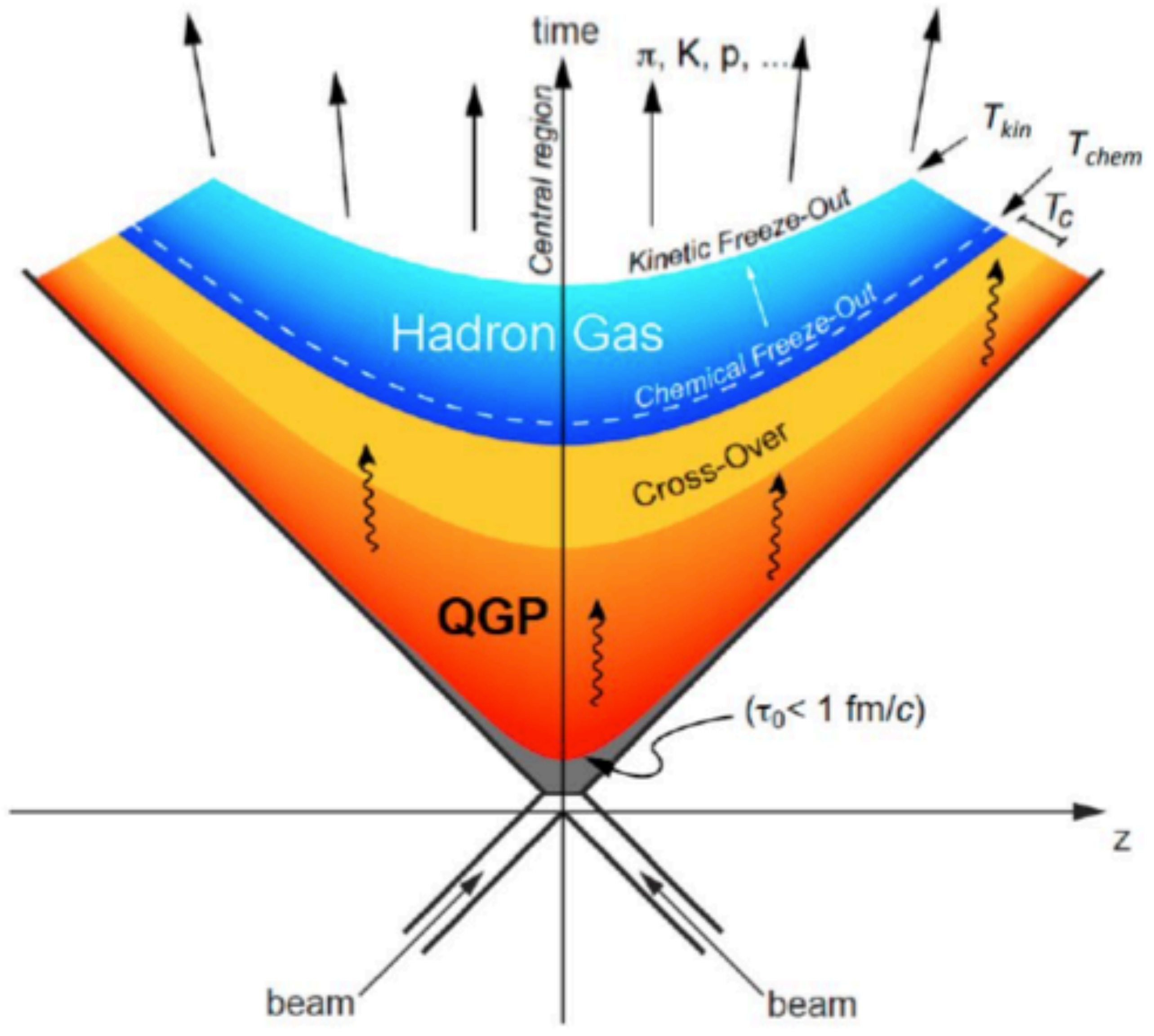
Heavy-Flavour & Quarkonia

Heavy flavors & QGP

- Quark-Gluon plasma (QGP): state of matter in which quarks and gluons are no more confined into hadrons



➢ From Lattice QCD calculations:
  - $\varepsilon_c \sim 0.5$ GeV/fm^3
  - $T_c \sim 150$ MeV

➢ Very rapid space/time evolution

$$\tau_{\rm QGP} \sim 10 \text{ fm}/c$$

- Heavy quarks produced in the **first phases of the collision**

$$\tau_{\rm HQ} \sim 0.05 - 0.1 \text{ fm}/c$$

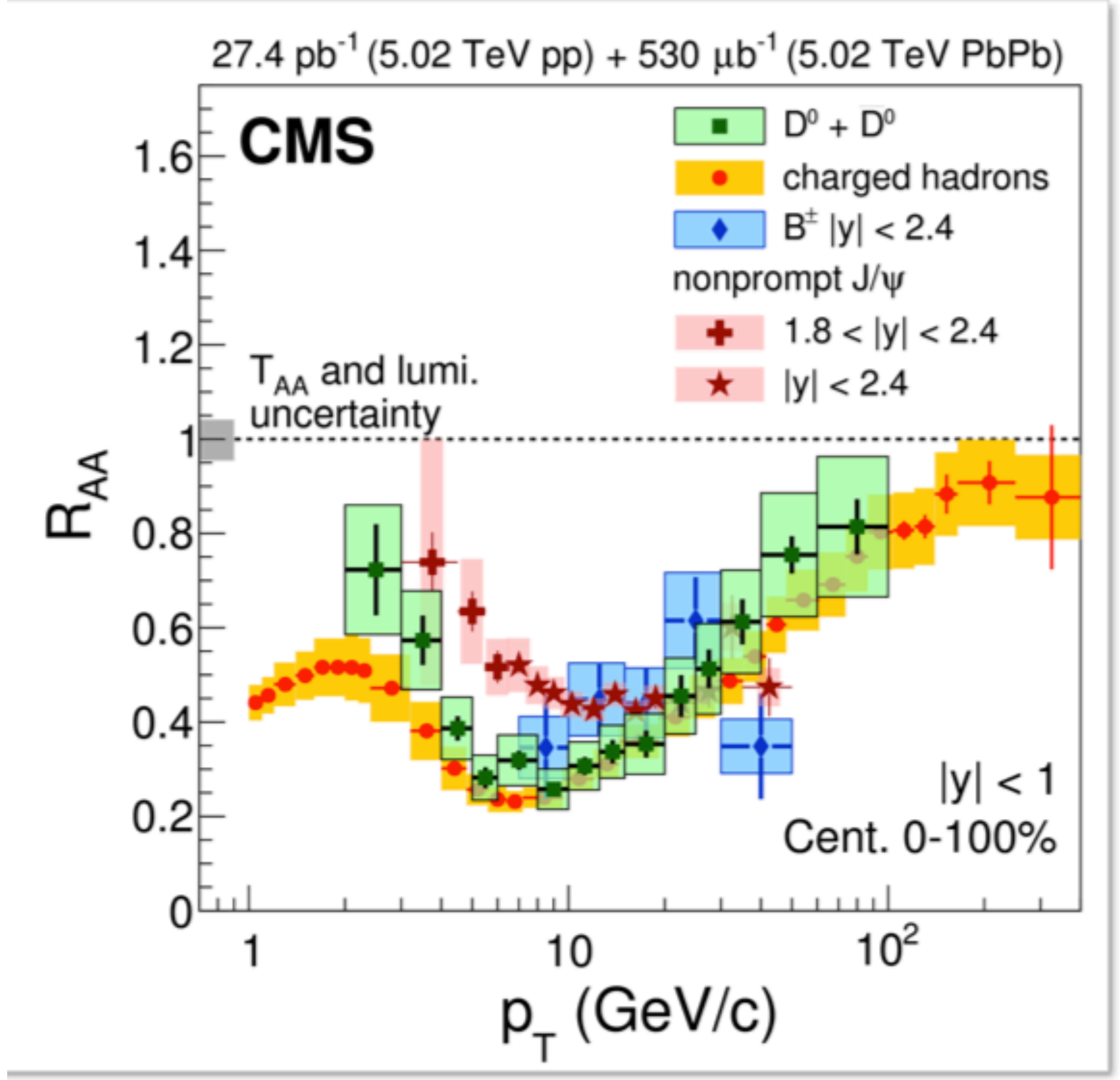
! Open HF and quarkonia ideal probes to study QGP

- Open heavy-flavor hadrons and quarkonia experience the **evolution of the QGP**

❑ Open Heavy Flavors (HF)
  ➢ **Partonic energy** loss characterization in QGP
  ➢ **Coalescense** vs **Fragmentation**

❑ Quarkonia
  ➢ **Quarkonium suppression**
  ➢ **Regeneration** of heavy quarkonia in QGP

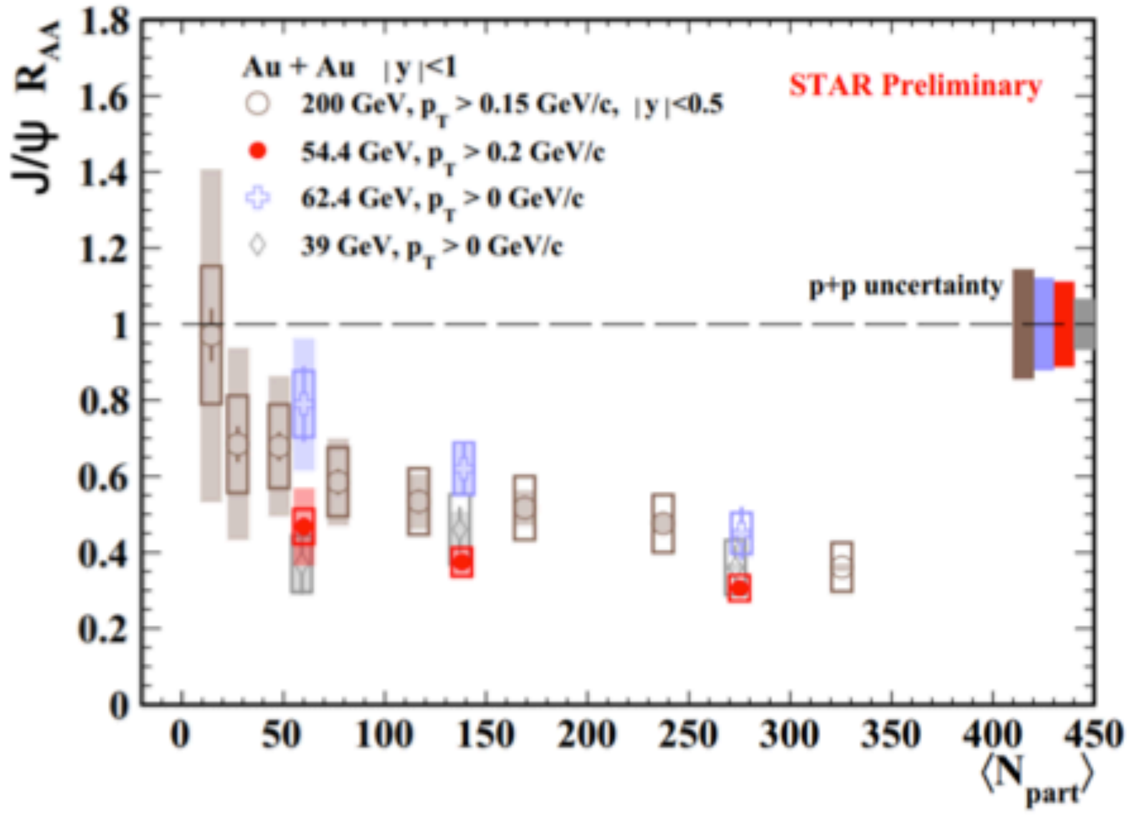
L. Micheletti

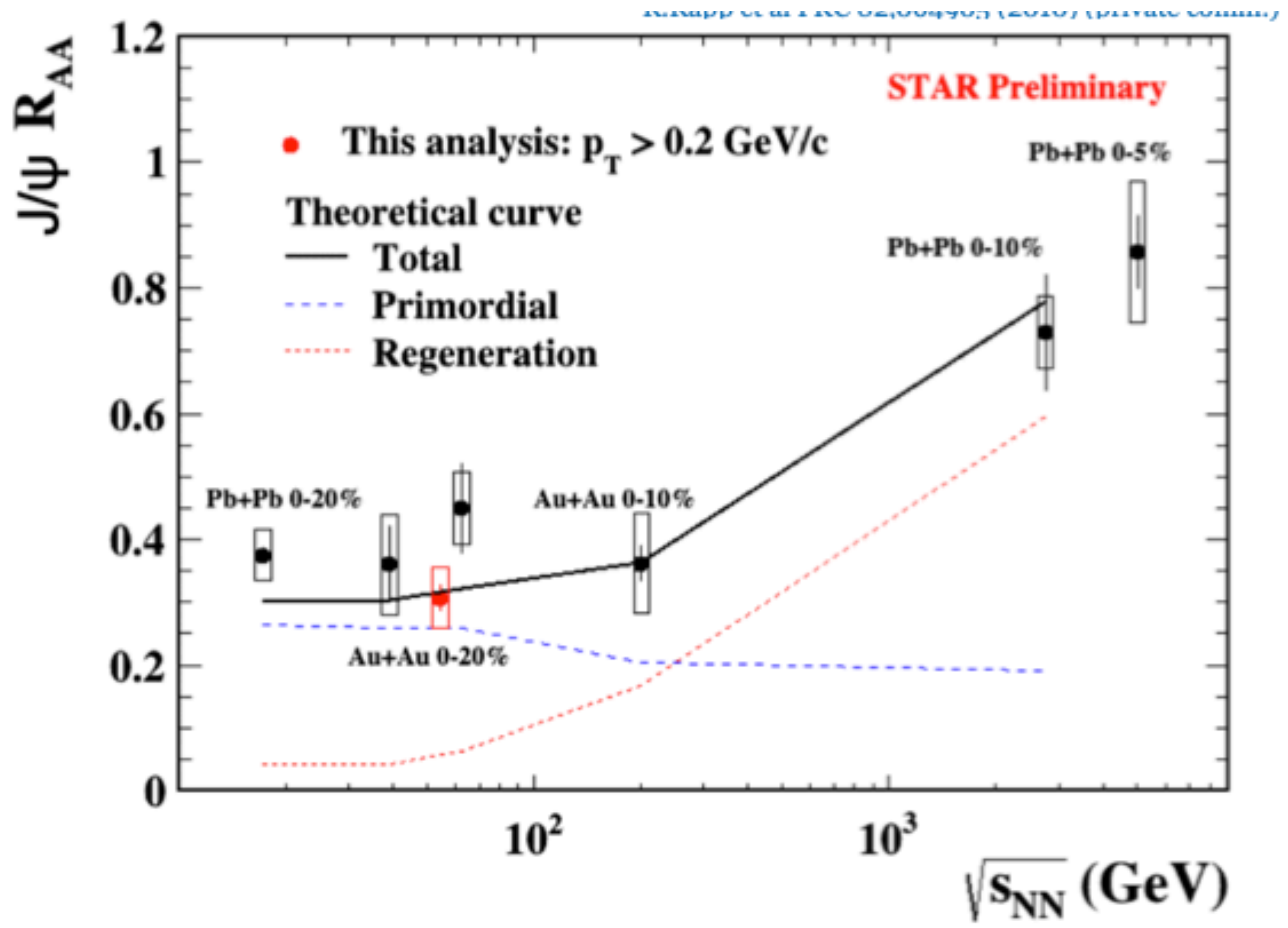


➢ Differet trend for $p_T < 20$ GeV/c for different hadron species

➢ For $p_T > 20$ GeV/c universal trend for all the hadron species (dominated by energy loss?)

Y. Hang Leung





- Suppression of J/ψ in Au + Au collisions at 54.4 GeV observed with high precision

- No significant energy dependence of J/ψ R_{AA} in central collisions from 17.2 to 200 GeV
- At LHC energies, J/ψ R_{AA} increases due to regeneration
  - **Interplay among dissociation, regeneration**

L. Micheletti

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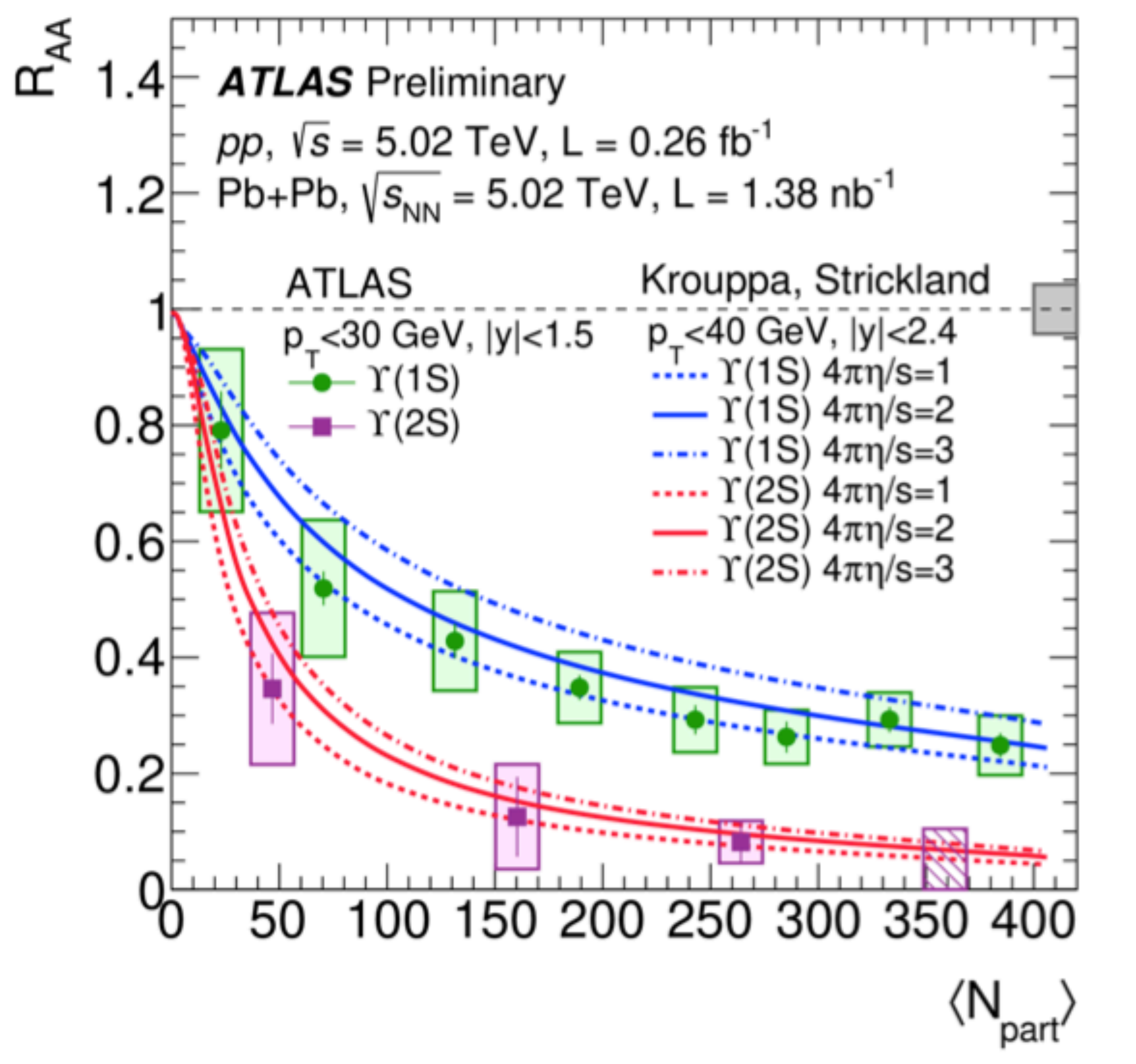
Bottomonia in Pb-Pb collisions



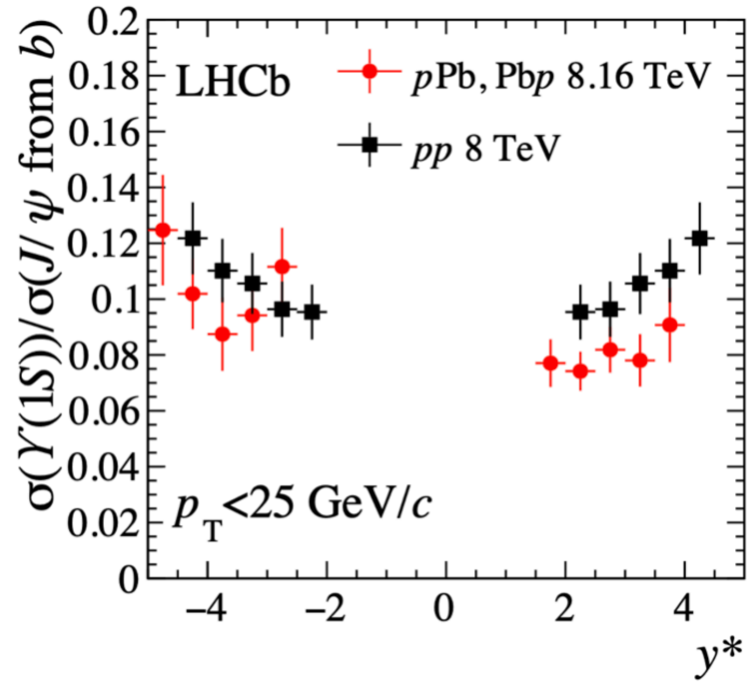
ATLAS measured $\Upsilon(nS)$ nuclear modification factor in Pb-Pb collisions

➢ Results in agreement with model including **hydro + in-medium dissociation**

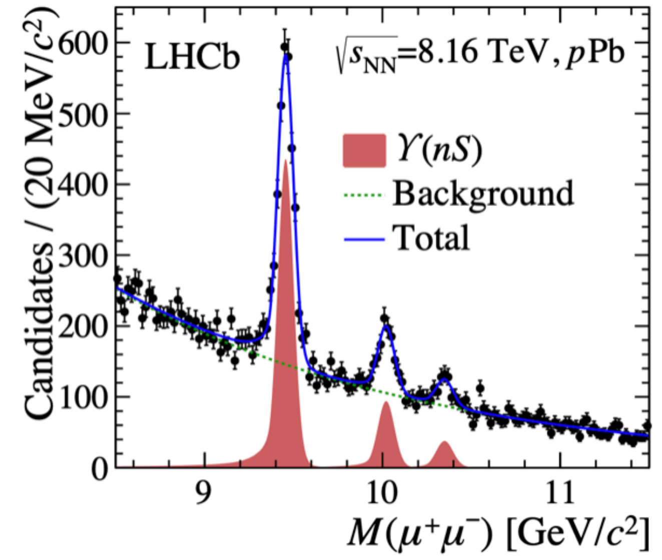
arXiv:1605.03561

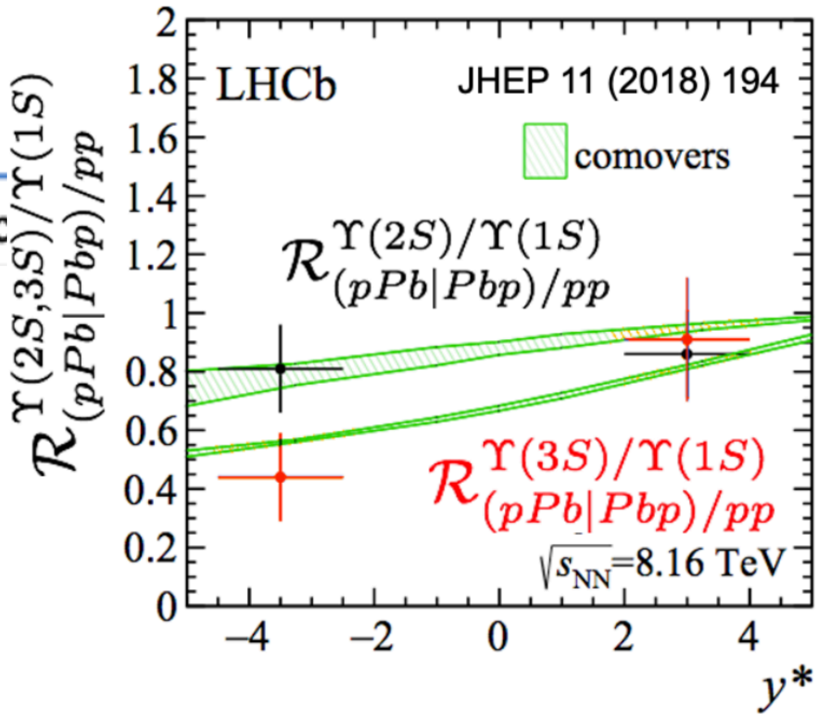
C. Da Silva

Bottomonia pPb and Pbp



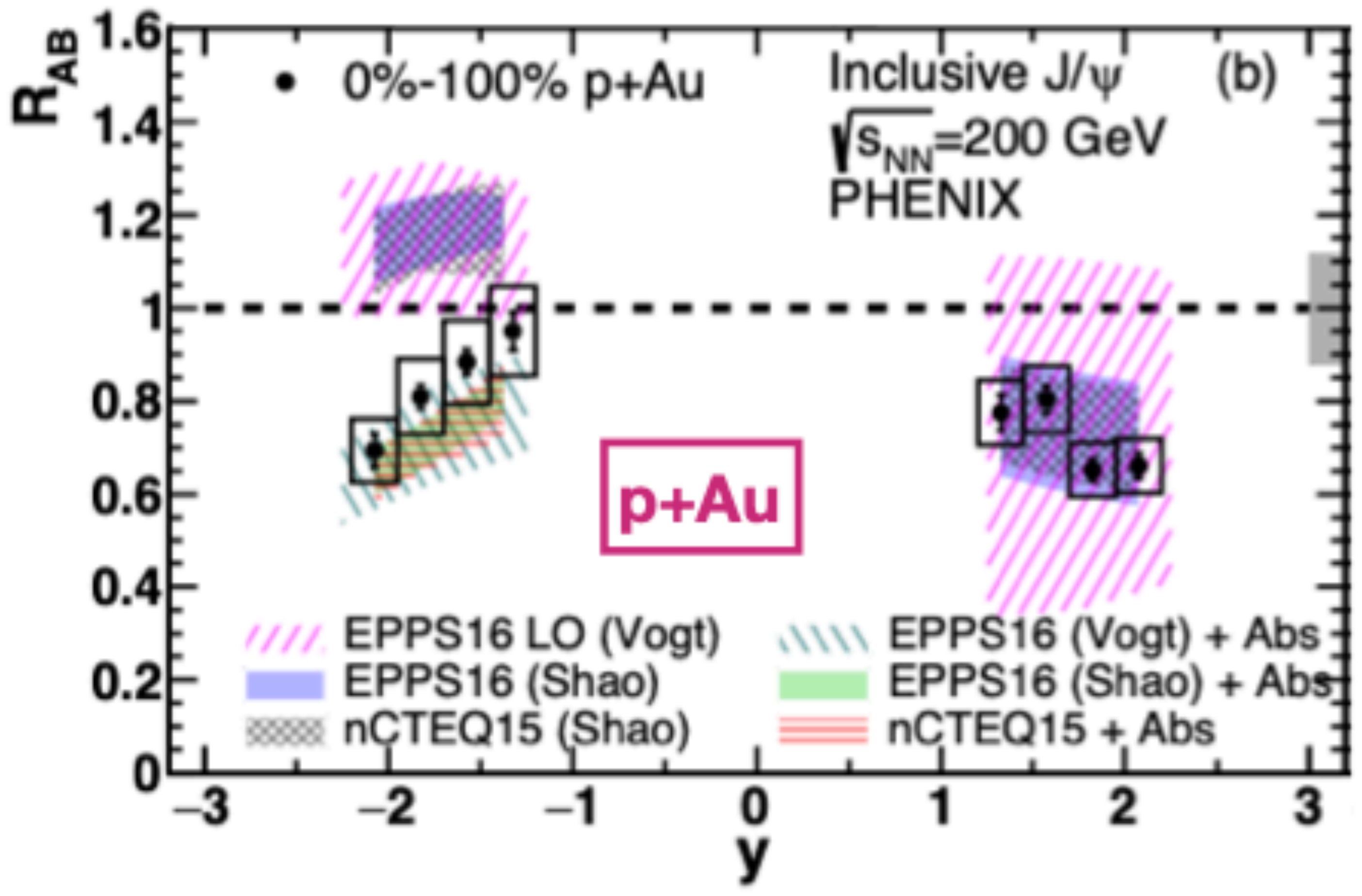
JHEP 11 (2018) 194



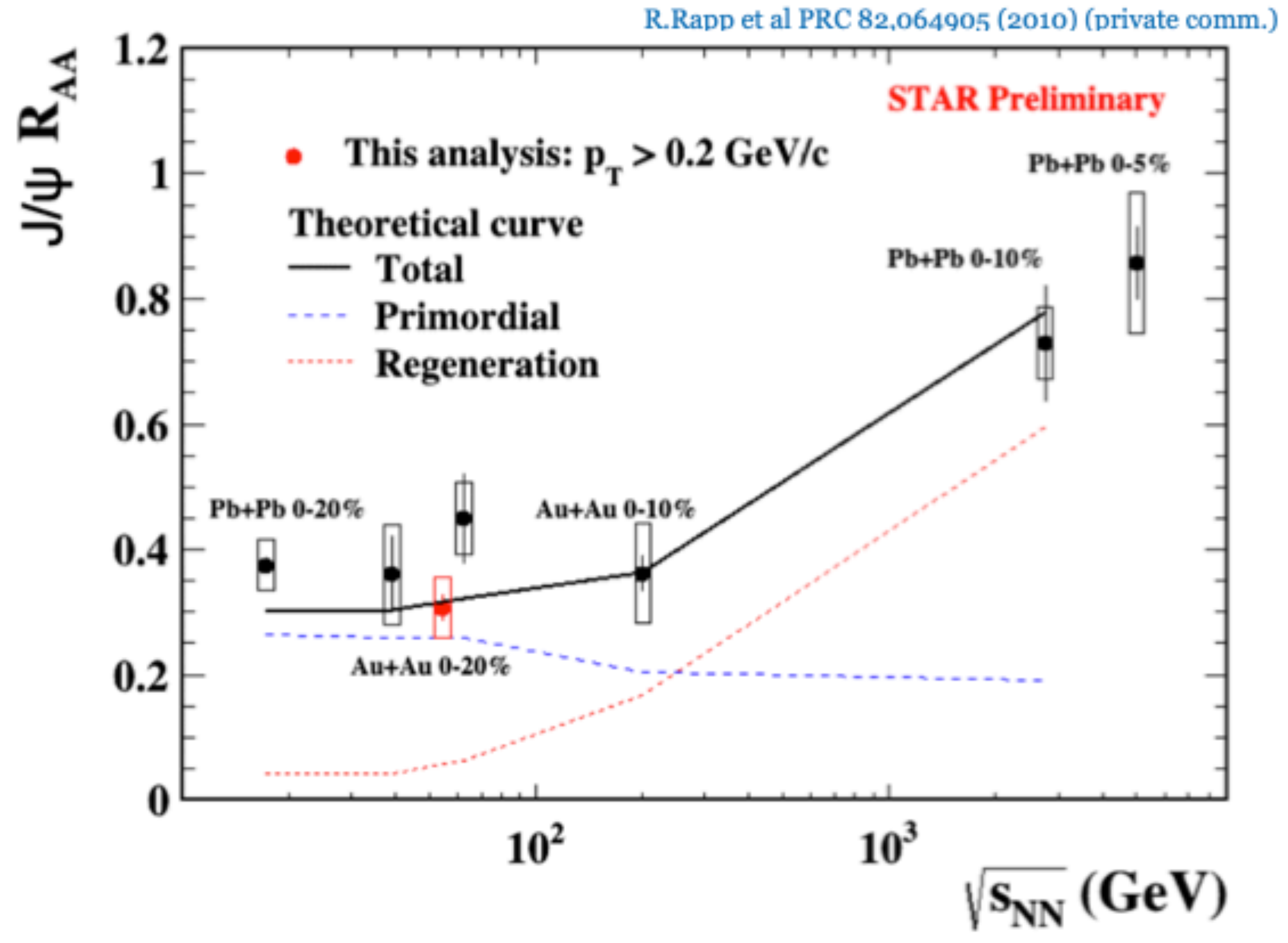


- No apparent breaking of $\Upsilon(1S)$ and $\Upsilon(2S)$
- Significant breaking of $\Upsilon(3S)$ at backward rapidity as observed in $\psi(2S)$

Energy Dependence of J/ψ Suppression



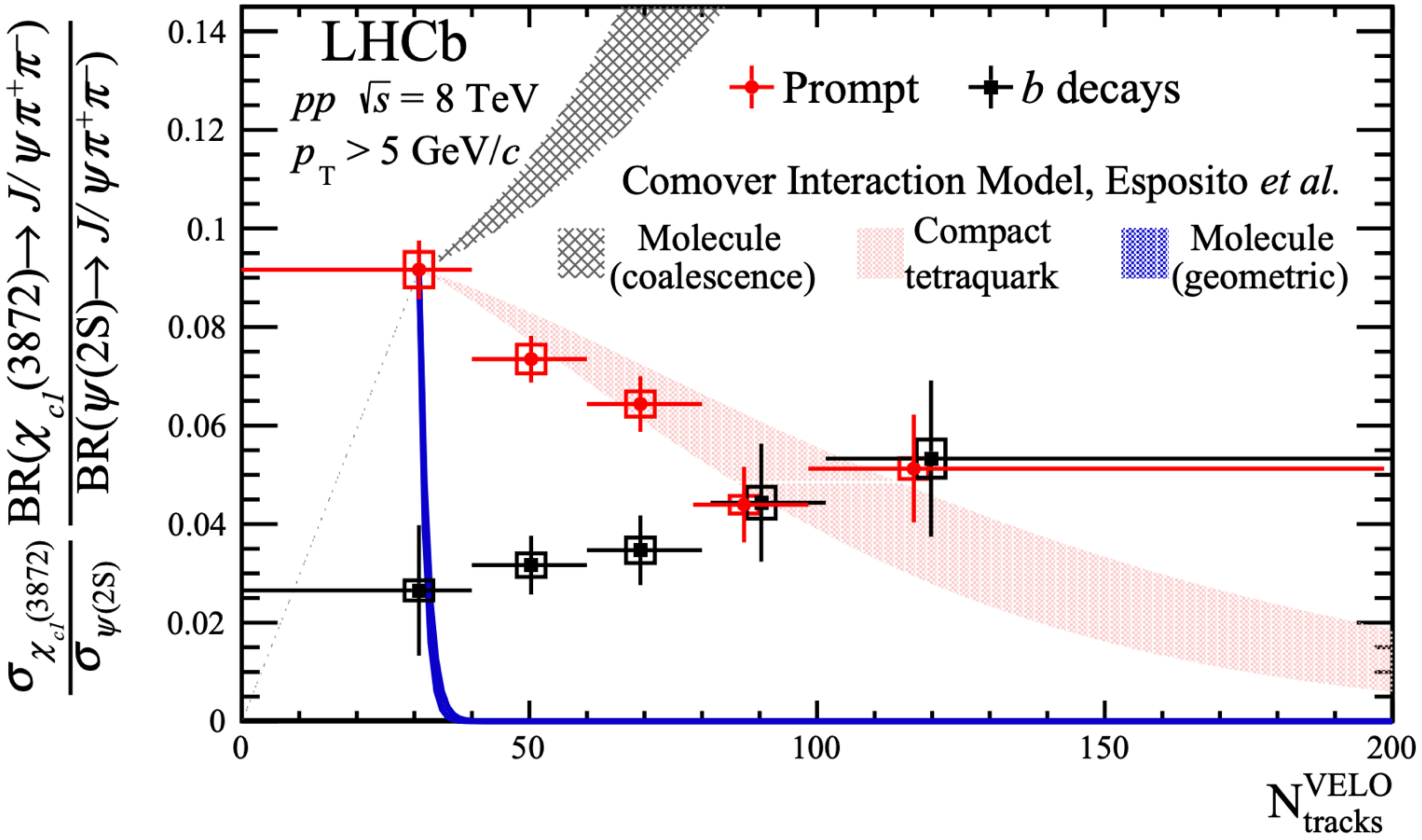
- Effects beyond nPDF modification alone are required to describe quarkonia production in **p+Au** at backward rapidity

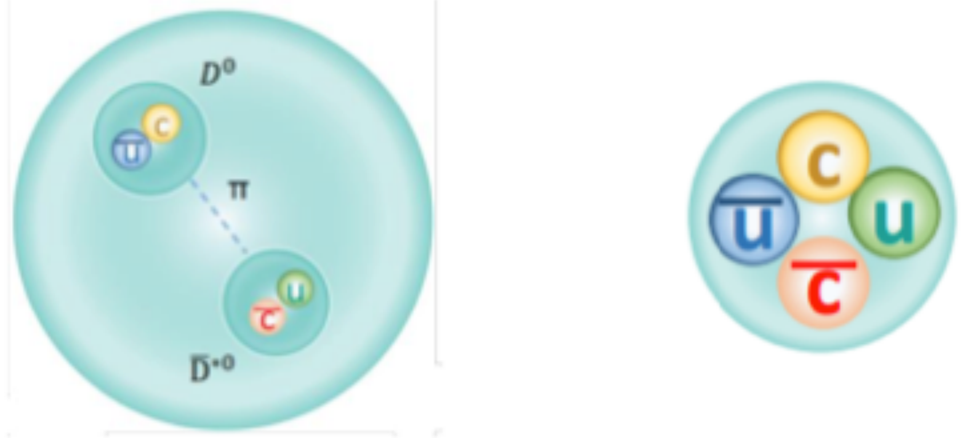


- No significant energy dependence of J/ψ R_{AA} in central collisions from 17.2 to 200 GeV
- At LHC energies, J/ψ R_{AA} increases due to regeneration
  - **Interplay among dissociation, regeneration, cold nuclear matter effects**

X(3872) Suppression

PRL 126, 092001 (2021)





? Tetraquark or $D^0 - D^{*0}$ molecule?

Particle comovers break X(3872) on a level consistent with tightly bound tetraquarks [EPJC81, 669 (2021)].

However, in PRD103, 071901 (2021) the suppression is consistent with a X(3872) being a molecule.

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Soft Sector

Y. Hang Leung

arXiv:2108.00908 [nucl-ex]
STAR

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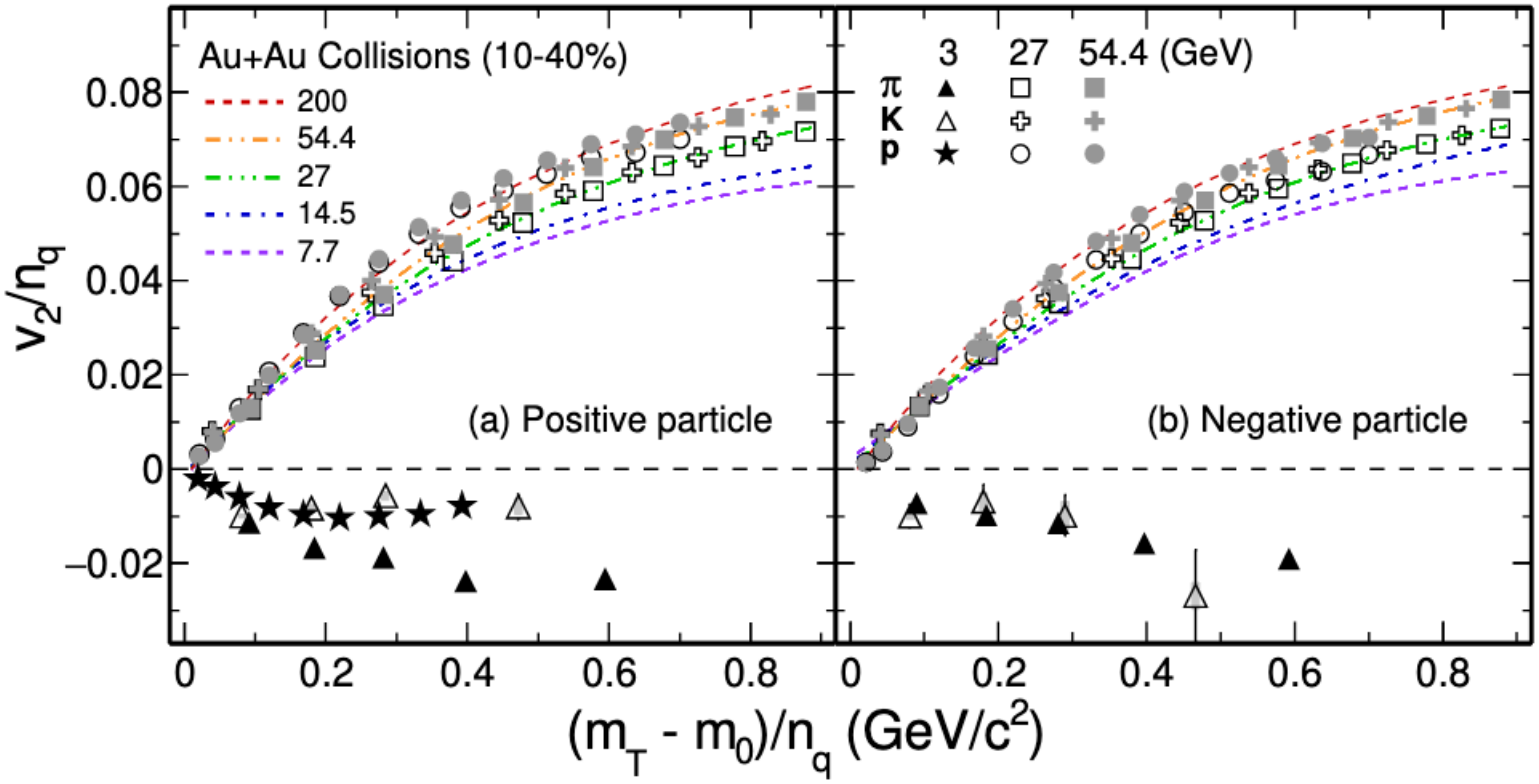
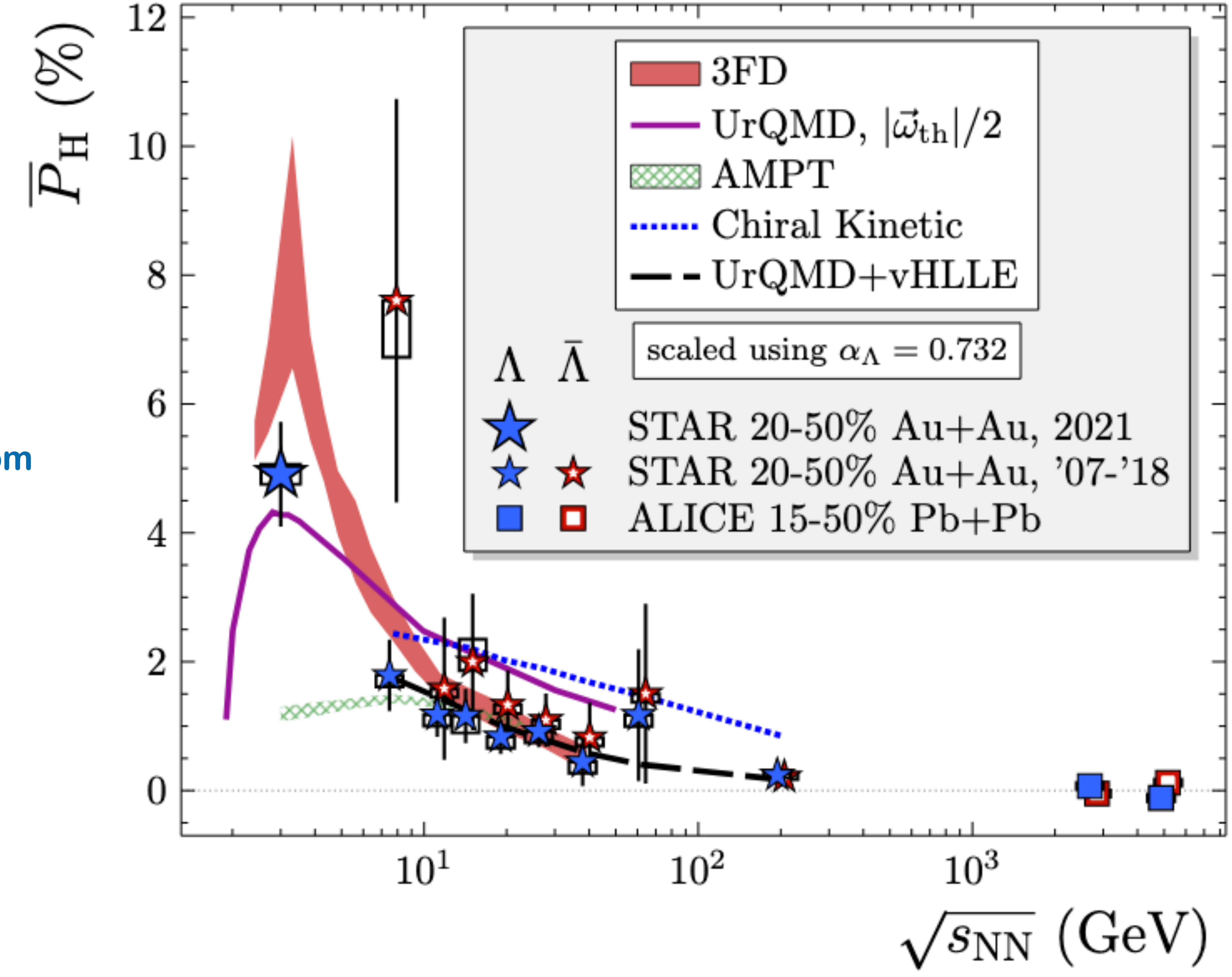


NEW 3 GEV RESULTS

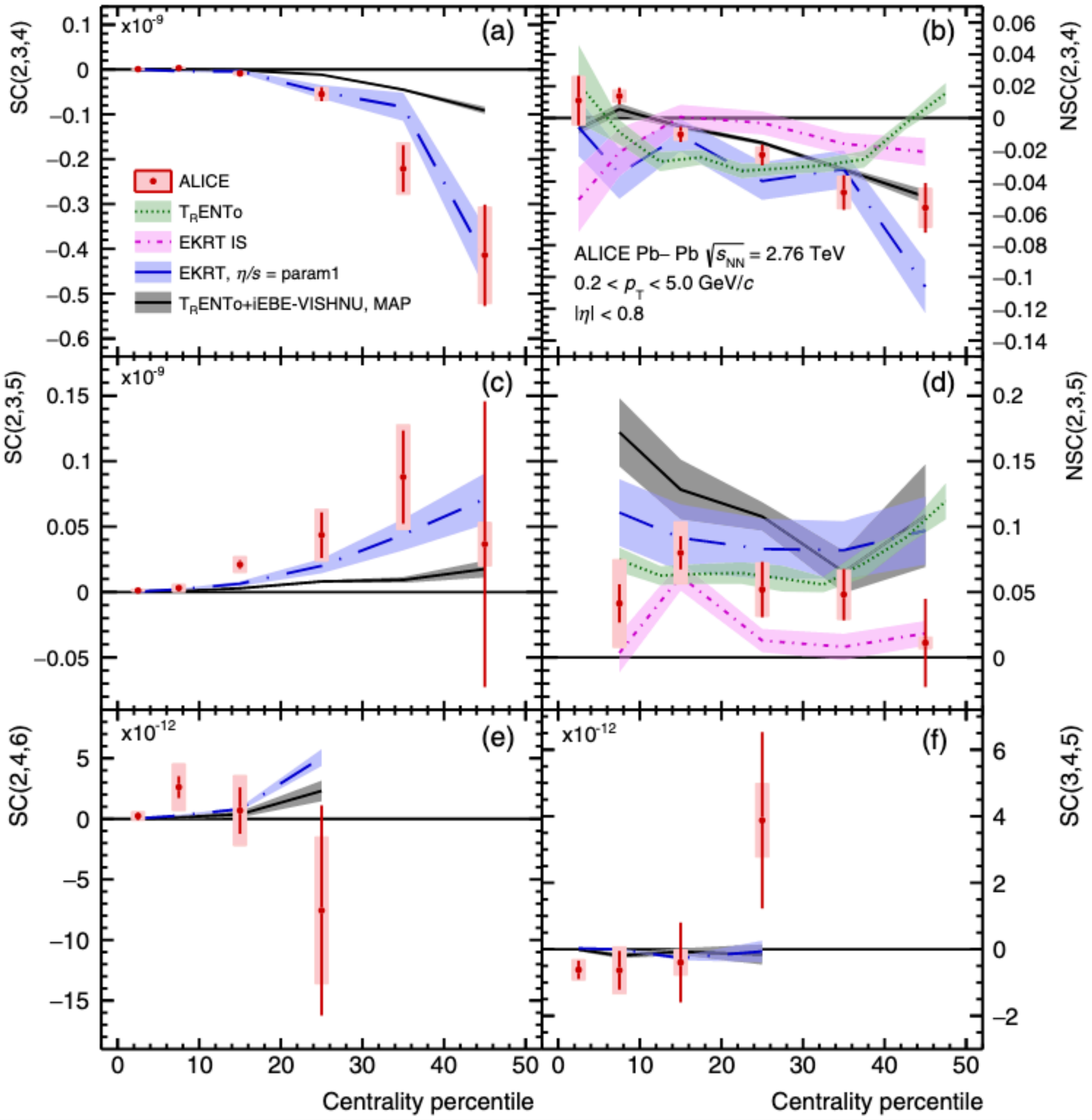
NEW:
- **Disappearance of partonic collectivity at 3 GeV**
- **Transport models with baryonic mean field reproduce the data trend (new EoS?)**

Y. Hang Leung

arXiv:2108.00044 [nucl-ex]
STAR



Energy dependence:
- Vorticity is strongly affected
- Λ Global Polarization strongly affected at 3 GeV (very different from high energy)



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Multi-harmonic flow correlations in PbPb collisions

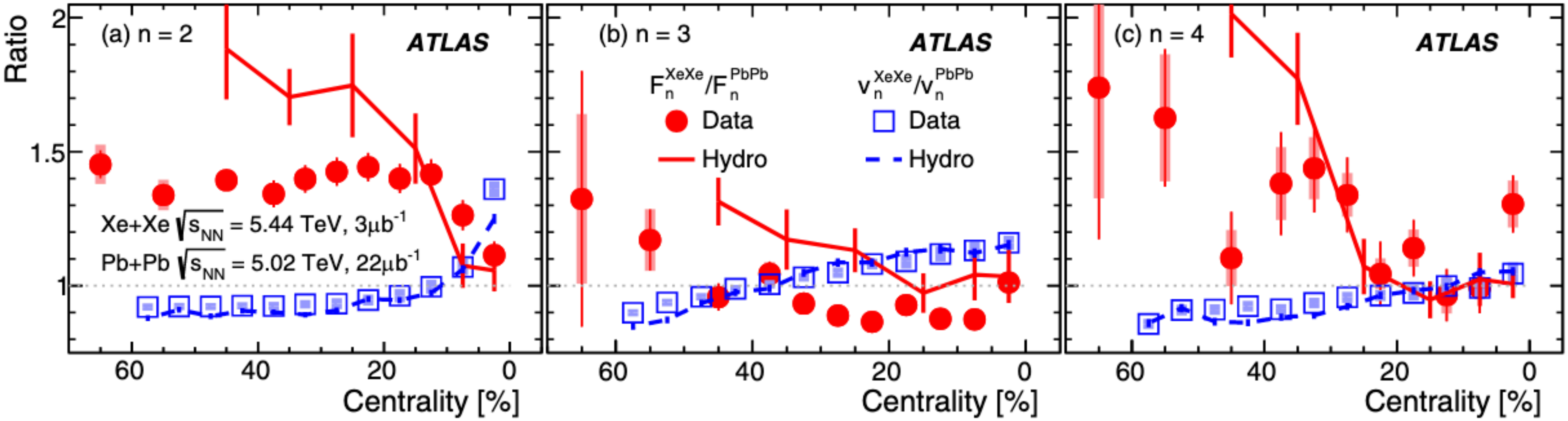
ALICE
Phys. Rev. Lett. 127, 092302 (2021)

Centrality dependence of the SC(k,l,m) are in good agreement with the predictions from the hydrodynamical models

Indication of correlation between flow harmonics (v2, v3, v4) during the medium evolution

PRL 126, 122301 (2021)
ATLAS

Longitudinal decorrelations for harmonic flow: PbPb vs XeXe



- $F_2^{XeXe} > F_2^{PbPb}$
- $F_3^{XeXe} < F_3^{PbPb}$
- $F_4^{XeXe} \approx F_4^{PbPb}$

Reverse ordering for n=2 and 3

Hydrodynamical models fail to describe the longitudinal flow decorrelations

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Round Table

- What can we learn about MPIs in Heavy-Ion collisions?
- What are the current experimental and theoretical challenges?
- Complementary of future LHC data with next machines like FCC, EIC, etc for studying MPI in nuclear targets

Questions raised this morning

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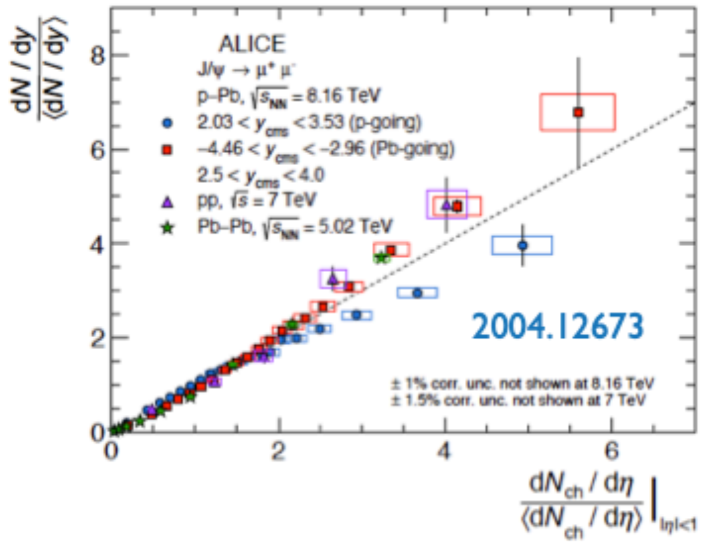
Challenges:

- How can we constrain multiparton densities? Can we design a program analogous to that of PDFs (or TMDs)?

- Better evolution towards small x. What we have, JIMWLK@resumNLO, has several limitations.
- Can we extend the relation between the TMD formalism and the CGC at small x to multiparton densities? We need it if we want to use low energy results for higher energies.

- Is there a relation between different, strong and weak coupling approaches, for the initial stage? As examples:
  - ➜ CGC → Glasma → flux tubes → string models.
  - ➜ Kinetic theory or AdS/CFT → macroscopic description by viscous hydrodynamics.



- Final state effects, if any, are also enhanced in the nuclear case.

- Centrality dependence of nuclear effects?

Role of MPI to HI. *N. Armesto, 15.10.2021* 5

N. Armesto

D. d'Enterria

Summary: TPS studies with heavy ions

- What's the parton transverse density of a proton? Its energy evolution? How do partons correlate (kinemat., quantum numbers) transversely?
- Triple hard parton scatterings in p-p collisions:

$$\sigma^{TPS}_{hh'\to a_1 a_2 a_3} = \left(\frac{m}{3!}\right) \frac{\sigma^{SPS}_{hh'\to a_1} \cdot \sigma^{SPS}_{hh'\to a_2} \cdot \sigma^{SPS}_{hh'\to a_3}}{\sigma^2_{\rm eff,TPS}}$$

(closely related to DPS in the absence of parton correlations):

$\sigma_{\rm eff,TPS} = (0.82 \pm 0.11)\, \sigma_{\rm eff,DPS}$

- Triple charm amounts to ~15% of inclusive charm x-sections in p-p collisions at the LHC. Triple-J/Ψ fully dominated by DPS/TPS: "golden channel" to extract $\sigma_{\rm eff,pp}$: 1st-ever observation by CMS.
- Derived TPS x-sections "pocket formula" for p-A:

$$\sigma^{TPS}_{pA\to abc} = \left(\frac{m}{6}\right) \frac{\sigma^{SPS}_{pN\to a} \cdot \sigma^{SPS}_{pN\to b} \cdot \sigma^{SPS}_{pN\to c}}{\sigma^2_{\rm eff,TPS,pA}}$$

$$\sigma_{\rm eff,TPS,pA} = \left[\frac{A}{\sigma^2_{\rm eff,TPS}} + \frac{3\,F_{pA}[{\rm mb}^{-1}]}{\sigma_{\rm eff,DPS}} + C_{pA}[{\rm mb}^{-2}]\right]^{-1/2}$$

- Large TPS yields in p-Pb, e.g. σ_{TPS}(triple-ccbar)=200 mb (~20% of incl. ccbar x-section): provide useful independent extractions of $\sigma_{\rm eff,pp}$. [Don't be shy to attempt a 1st-ever measurement in p-Pb...].

Questions raised this morning

Strings (MPI) vs. the conventional *AA* thinking

- MPI+strings similar to Glasma?
- Shoving similar to (2+1)D longitudinally invariant QGP?
- Ropes similar to strangeness enhancement in QGP?
- Swing similar to jet quenching?

MPI in *AA* 9 Leif Lönnblad Lund University

L. Lonnblad

A. Morsch

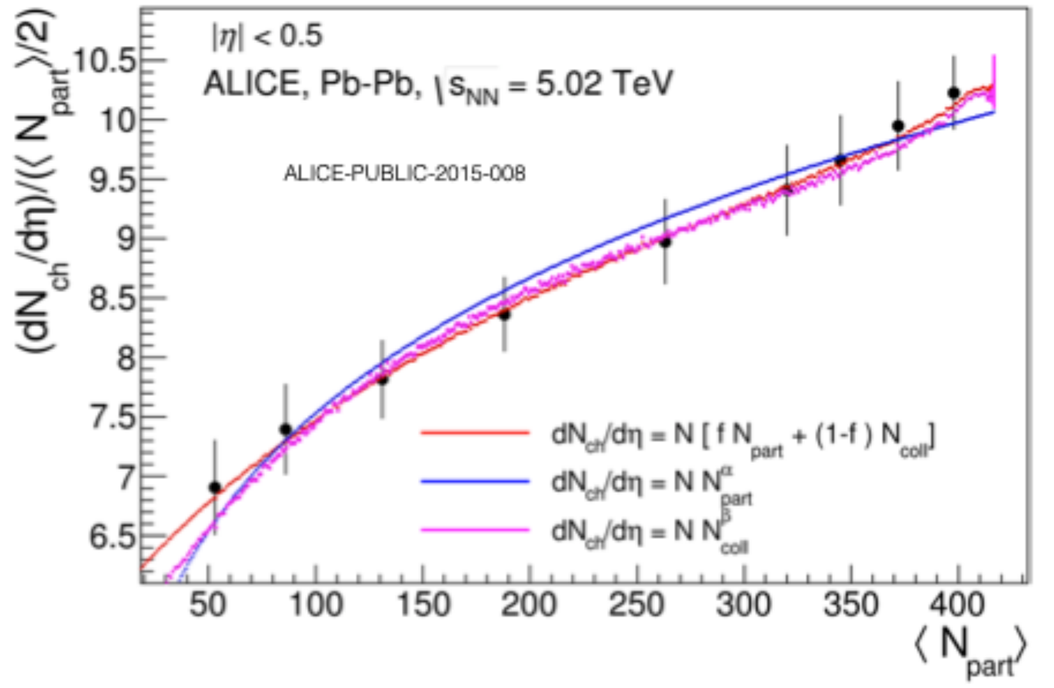
What can we learn about MPIs in Heavy-Ion collisions?

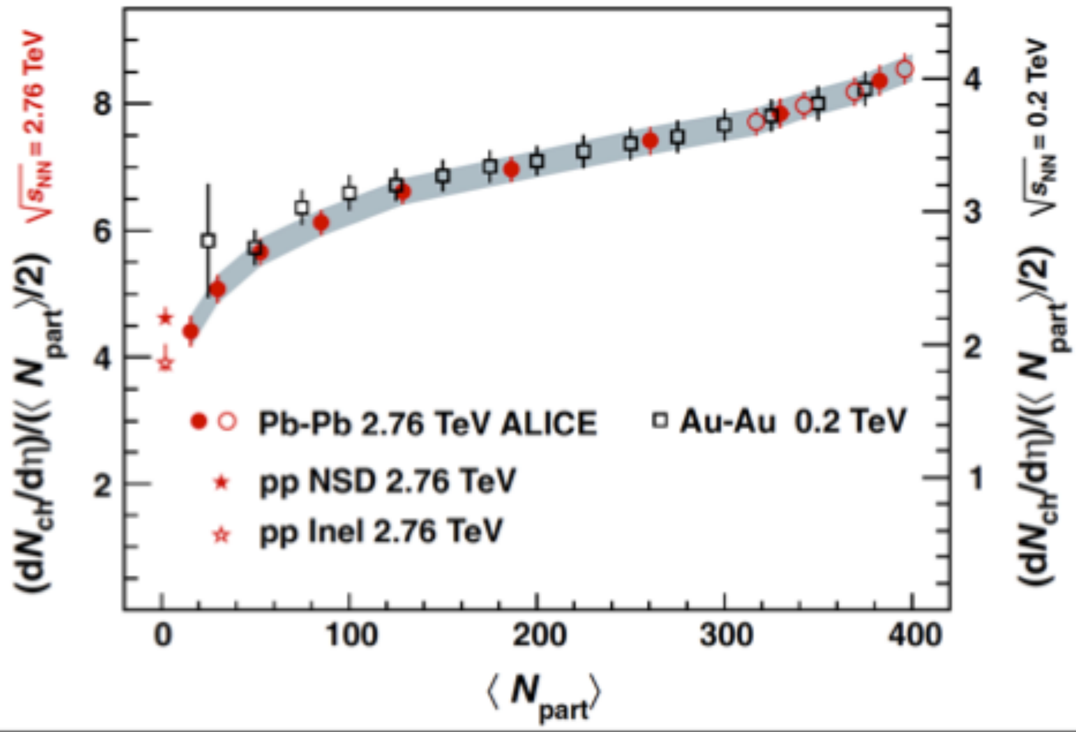
- → What can we learn about Heavy-Ion collisions from MPI?

- Centrality dependence of mid-rapidity multiplicity
- *S*-shape consistent with "hard+soft scaling"

$$fN_{\rm part} + (1-f)N_{\rm coll}$$

  - But shape almost energy independent!
- Simple explanation for this geometric scaling ?
- Higher $\sqrt{s}$ would provide additional lever-arm.





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