Experiment Summary

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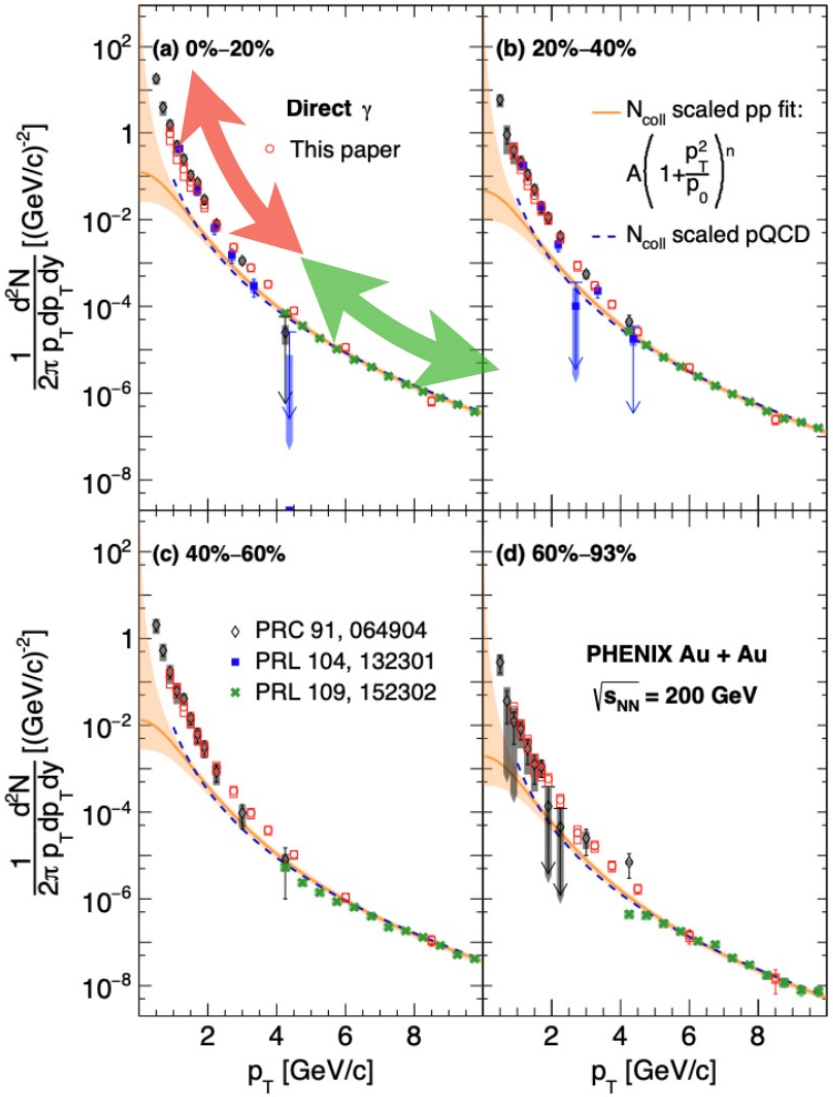
- Electromagnetic probes
- Heavy quarks and quarkonia
- Jets
- Strangeness

Direct Photon Measurement

Nihar Sahoo



PHENIX: arXiv:2203.17187

- High p_T (> 5 GeV/c):
  N_{coll}-scaled p+p results and pQCD calculation
  → Prompt direct photon

- Low p_T (< 5 GeV/c):
  Excess yield compared to prompt photon

Being emitted from hot-expanding fireball
→ Non-prompt direct photon

Direct Photon Measurement

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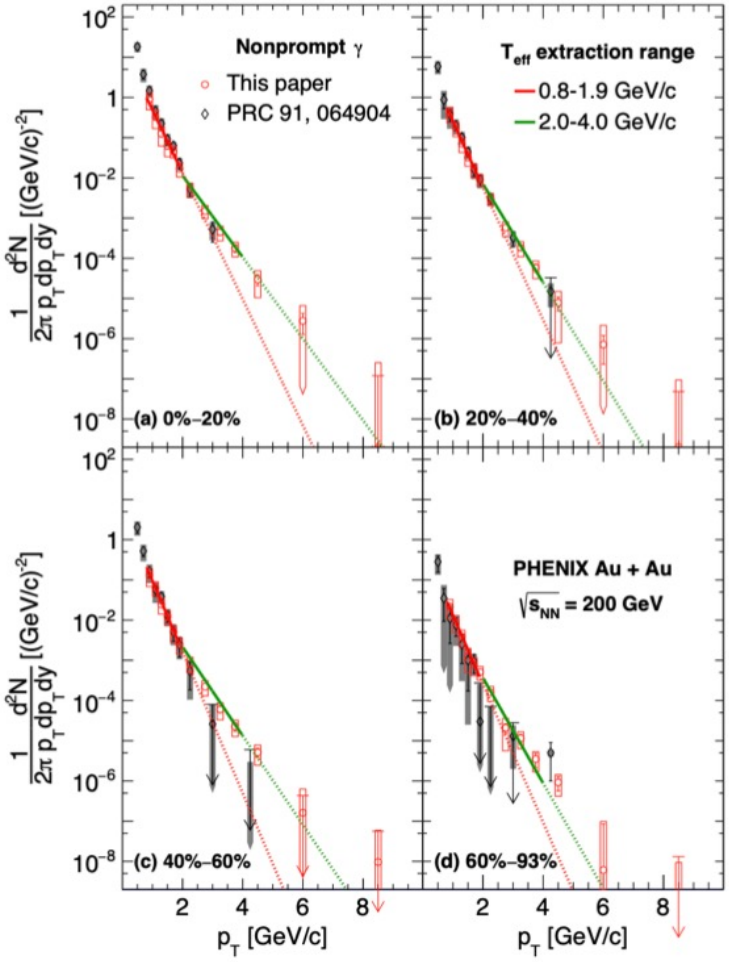
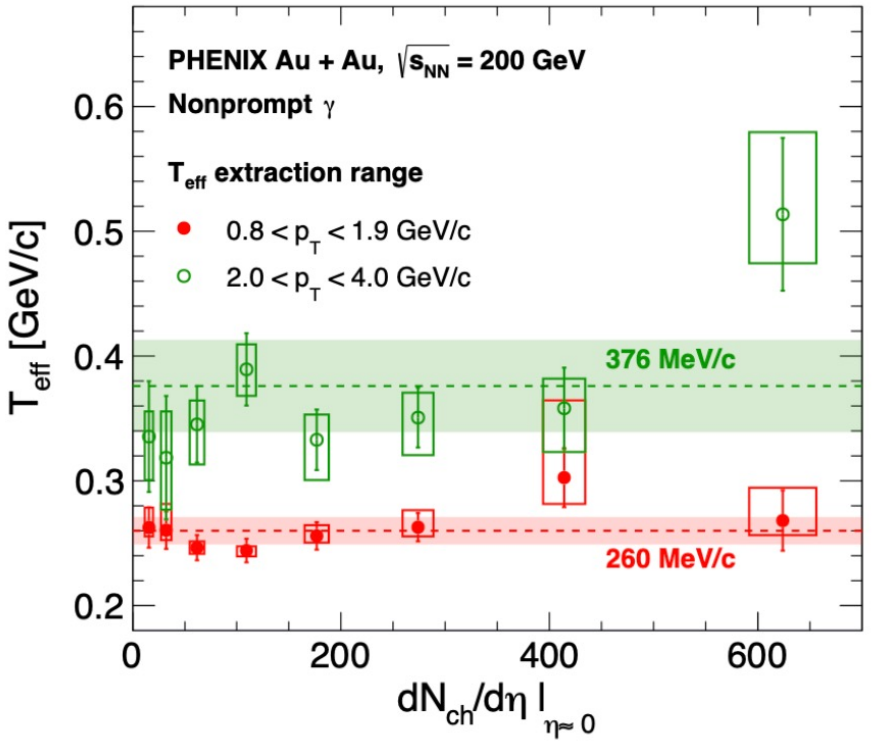




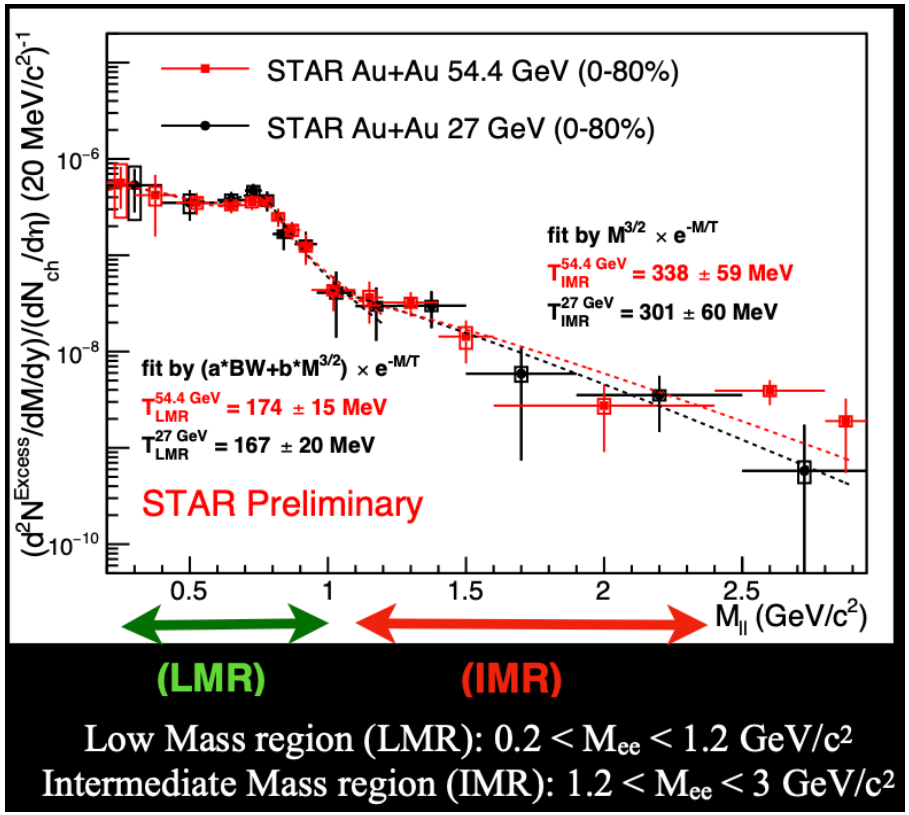
PHENIX: arXiv:2203.17187

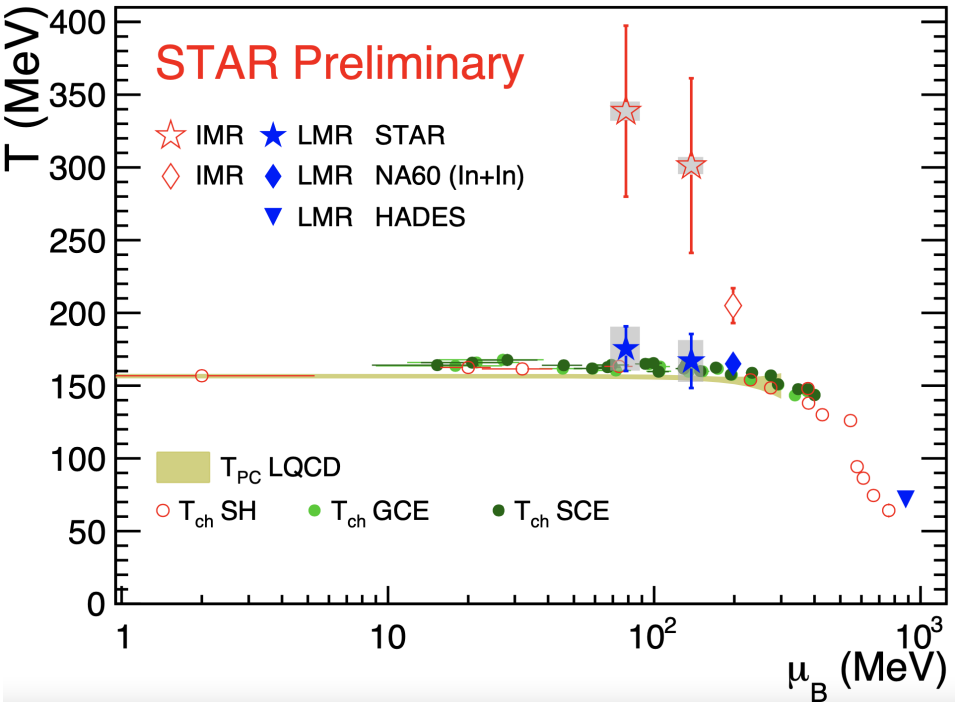
- Non-prompt direct photon by subtracting of scaled p+p yields

High-p_T (Teff = 376 MeV): from earlier phase the evolution
Low-p_T (Teff = 260 MeV): from QGP phase until FO → Blue shifted

Dilepton Measurement

Nihar Sahoo





IMR thermal dielectron: T_{IMR} ~ 320 MeV

First QGP temperature measurement at RHIC

Vector Meson Photoproduction

Subash Chandra Behera

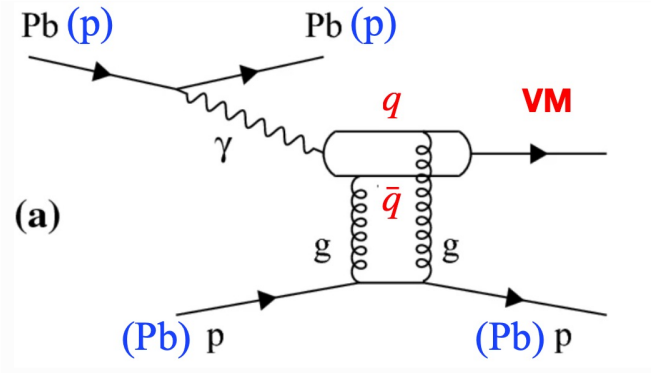
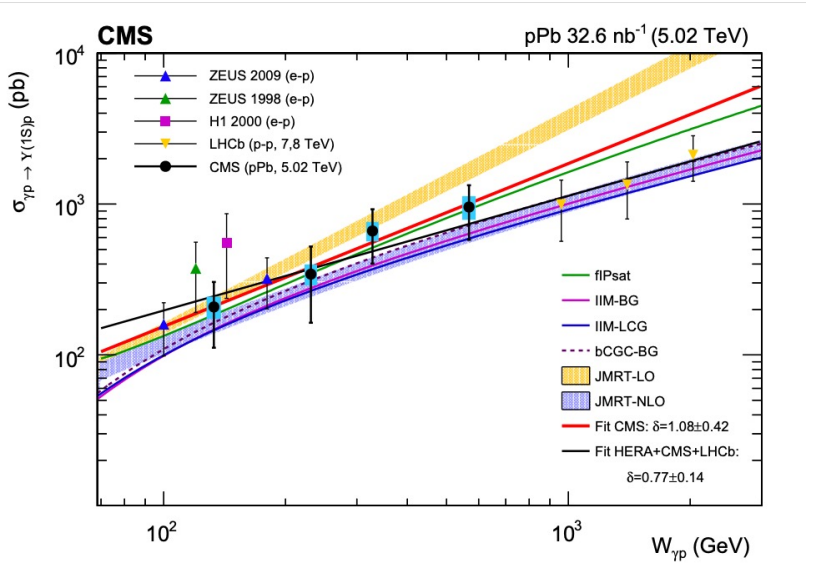


Photo-nuclear interactions

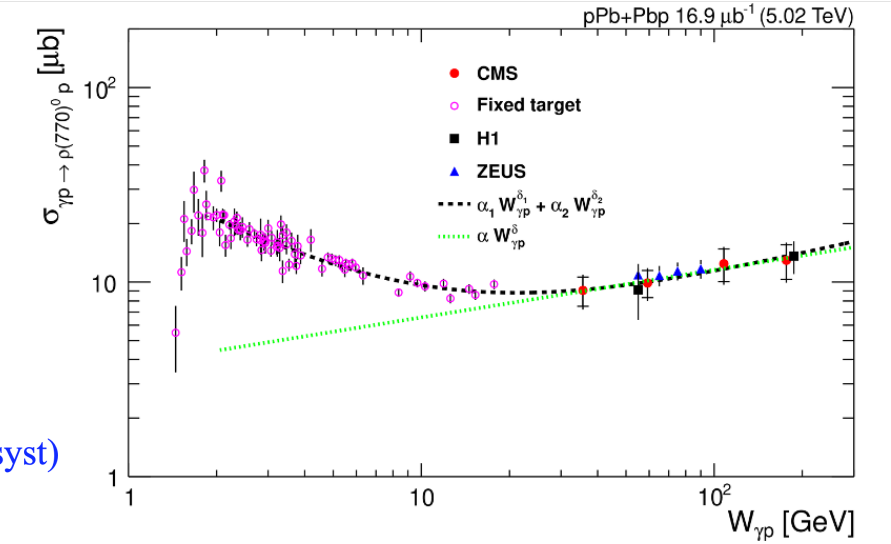


Eur. Phys. J. C (2019) 79:277

- Power law dependent photoproduction cross section for exclusive Y(1S) : $\sigma_{\Upsilon}(W_{\gamma p}) = A \times (W/400)^{\delta}$

CMS : $\delta = 1.08 \pm 0.42$ and $A = 690 \pm 183$

ZEUS : $\delta = 1.2 \pm 0.8$ PLB 680 (2009) 4



Eur. Phys. J. C (2019) 79 :702

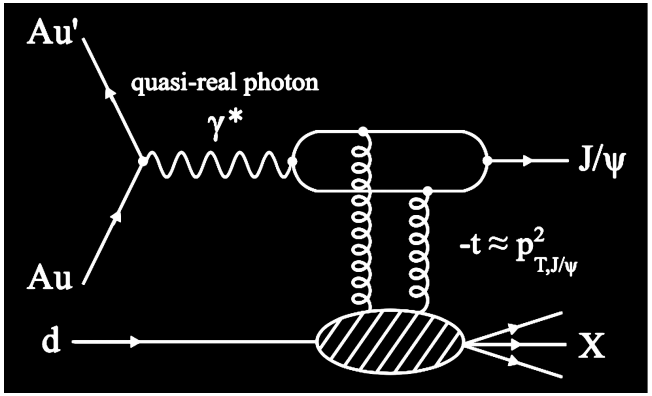
- Power law dependent cross section for exclusive $\rho(770)^0$:

$\delta_1 = -0.81 \pm 0.04$ (stat) ± 0.09 (syst), $\delta_2 = 0.36 \pm 0.07$ (stat) ± 0.05 (syst)

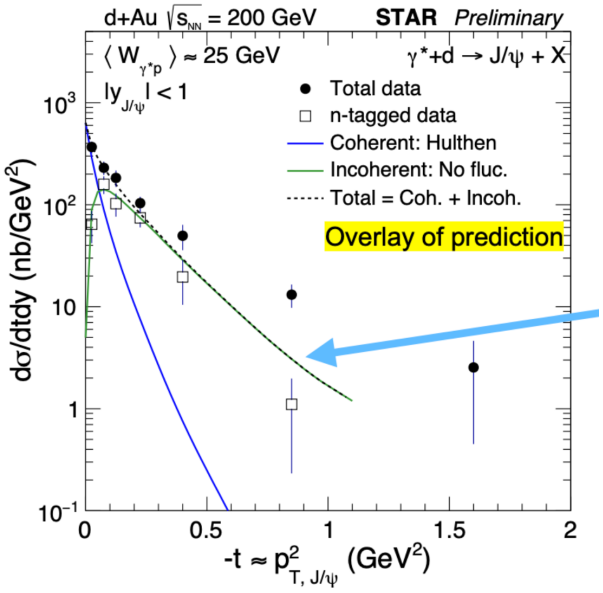
$\delta = 0.24 \pm 0.13$ (stat) ± 0.04 (syst)

J/ψ Photoproduction in d+Au Collisions

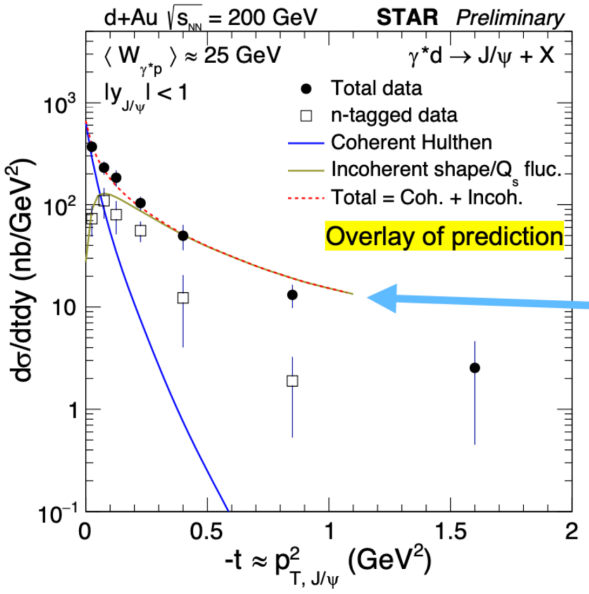
Ashik Ikbal



- Total cross-section consists of coherent and incoherent sources
- CGC without subnucleonic fluctuations describes data at low t (mostly coherent)
- The coherent component extracted constrains gluon distribution inside deuteron



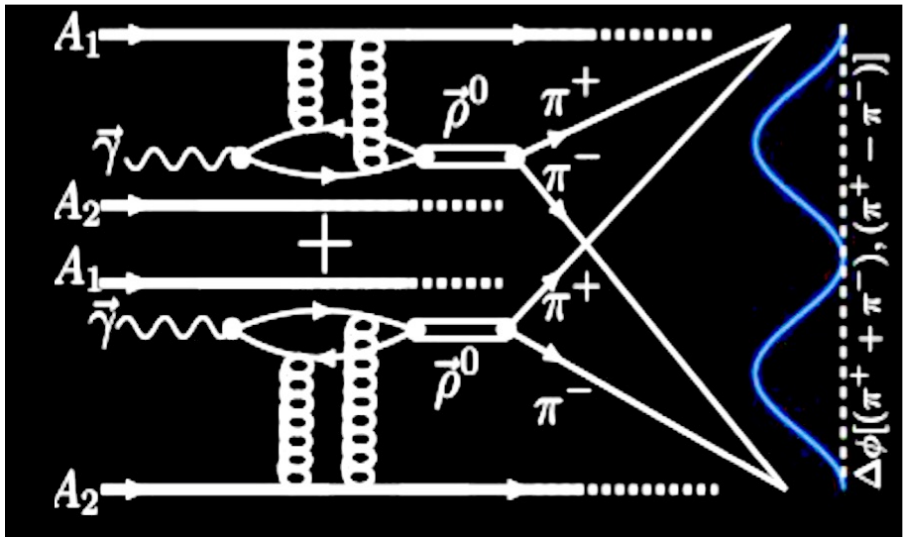
without subnucleonic fluctuations

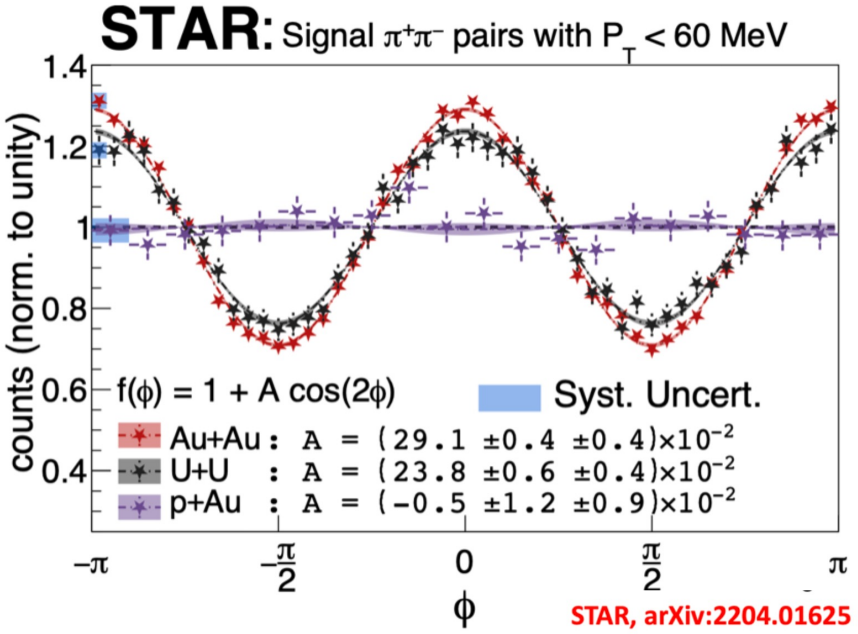


with subnucleonic fluctuations

Spin interference effect for ρ^0 in UPC

Ashik Ikbal

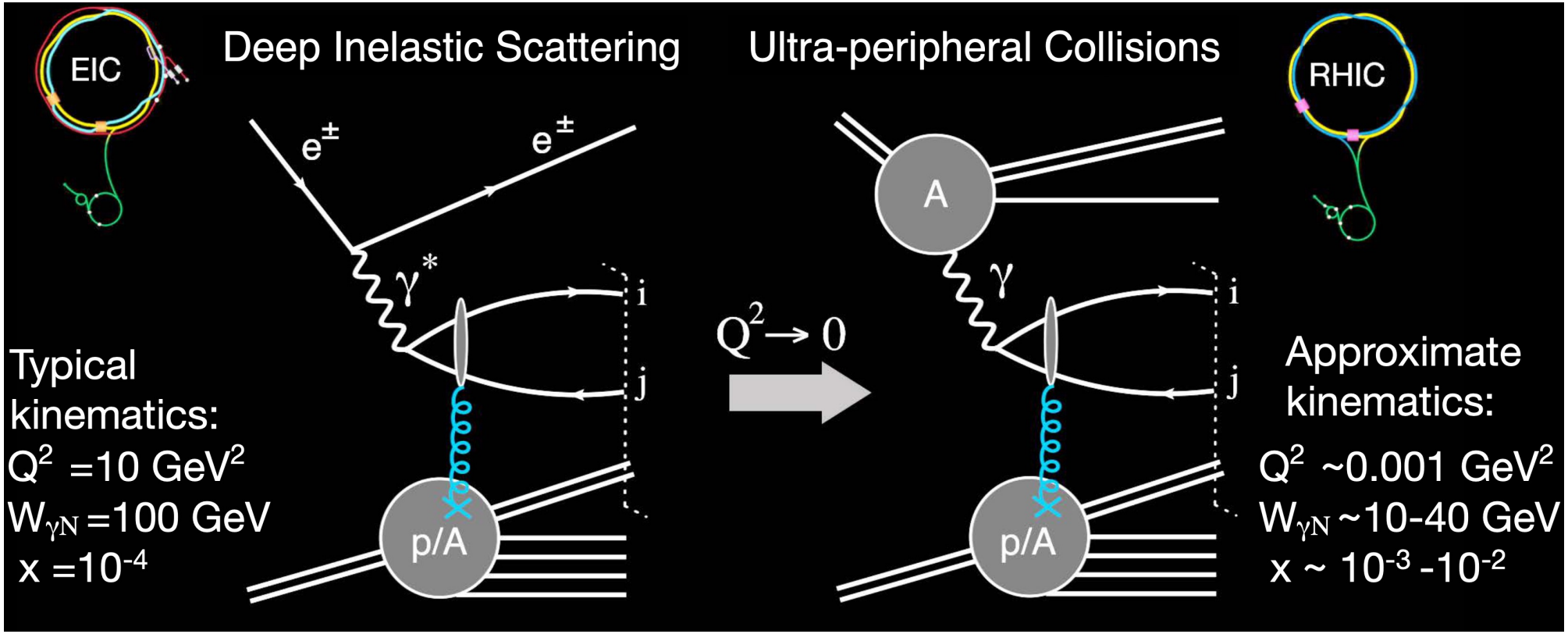




- cos(2φ) oscillation pattern is measured for ρ0 decay in UPCs, φ angle between ρ0 and one of its decay daughters
- Interference between two identical sources in Au+Au and U+U collisions
- Oscillation is absent in p+Au system => Needs two photon sources to observe this effect
- Interference measurement for J/ψ is important to further understand this phenomenon

Photon Induced Processes

Prithwish Tribedy



- Ultra-peripheral p/A+A collisions provide opportunities to study photoproduction

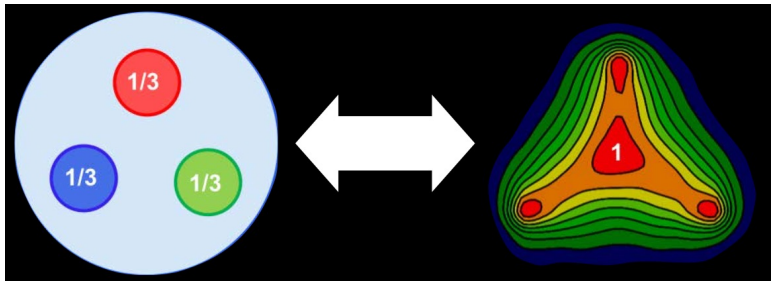
Testing the baryon junction conjecture

Prithwish Tribedy

- Predictions form Regge theory & baryon junction picture:

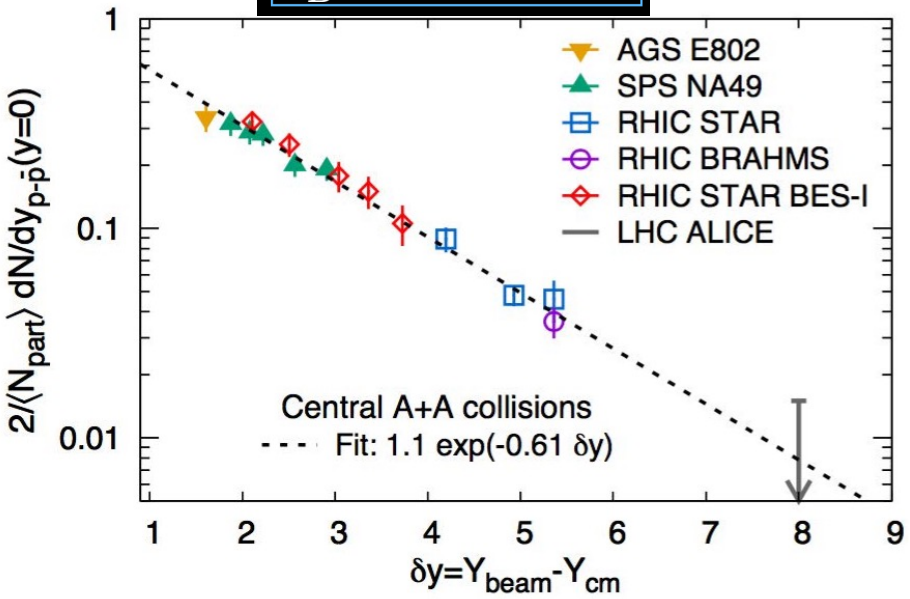
$$\frac{2}{N_{\rm part}}\left.\frac{dN_{\rm p-\bar{p}}}{dy}\right|_{A+A} = N_B\, e^{-\alpha_B(Y_{\rm beam}-Y_{\rm cm})}$$

$$0.42 \le \alpha_B \le 1$$

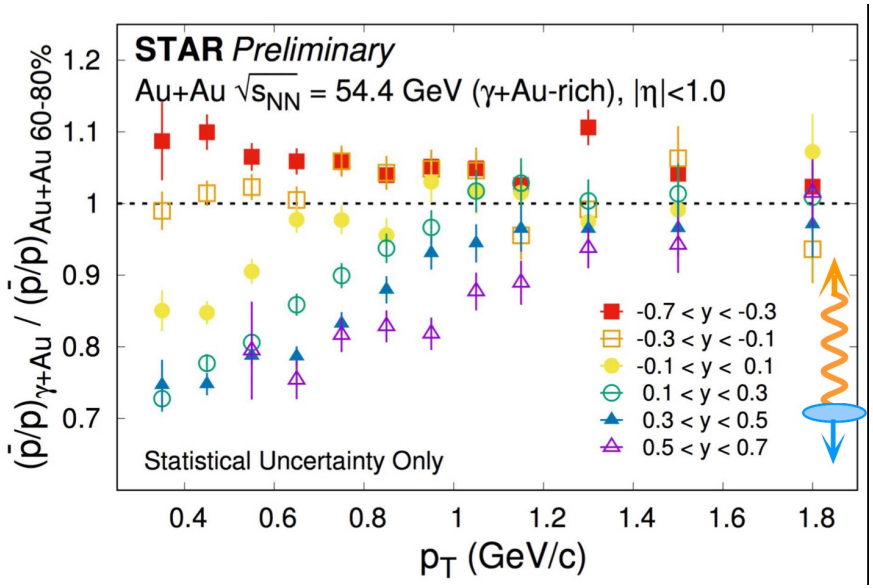


Midrapidity baryon density slope is consistent with baryon junction prediction

$$\alpha_B = 0.61 \pm 0.03$$

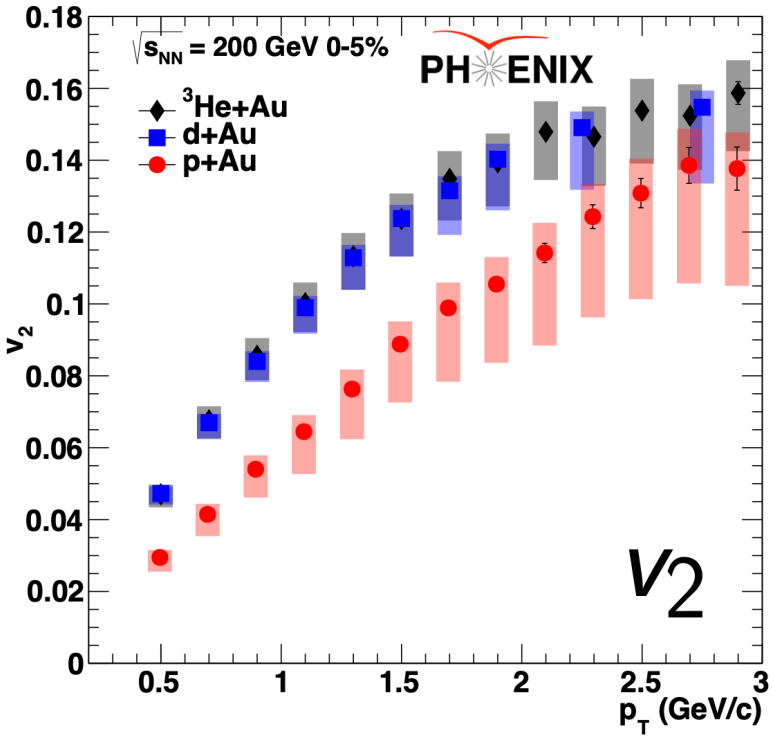


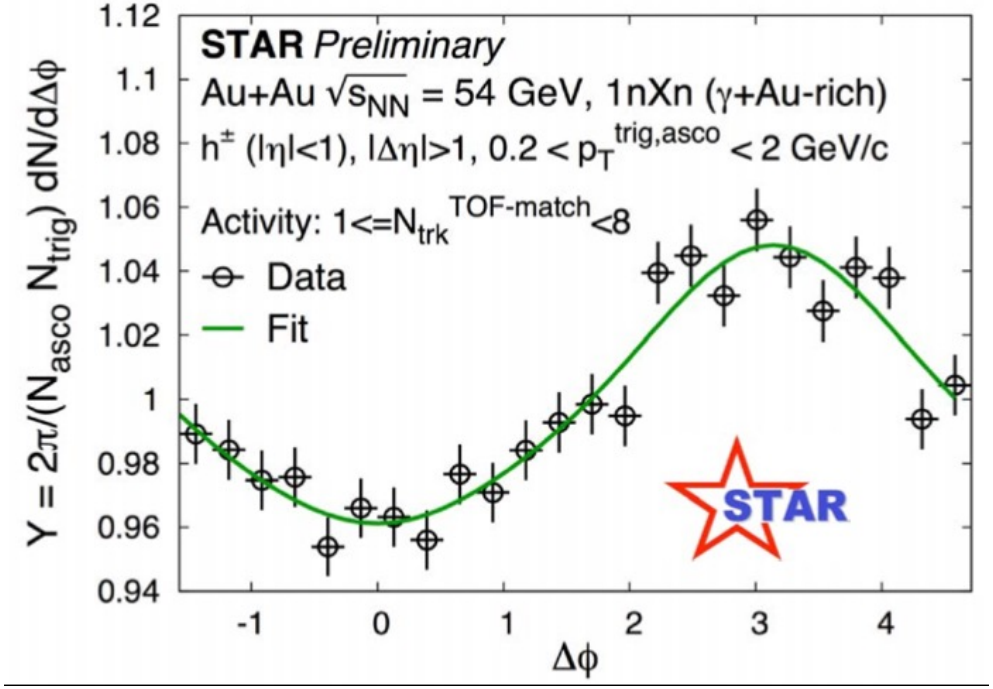
Rapidity dependence of soft baryon stopping observed in RHIC photonuclear events



Collectivity in small collision systems

Prithwish Tribedy





- Color Glass Condensate (initial state momentum):

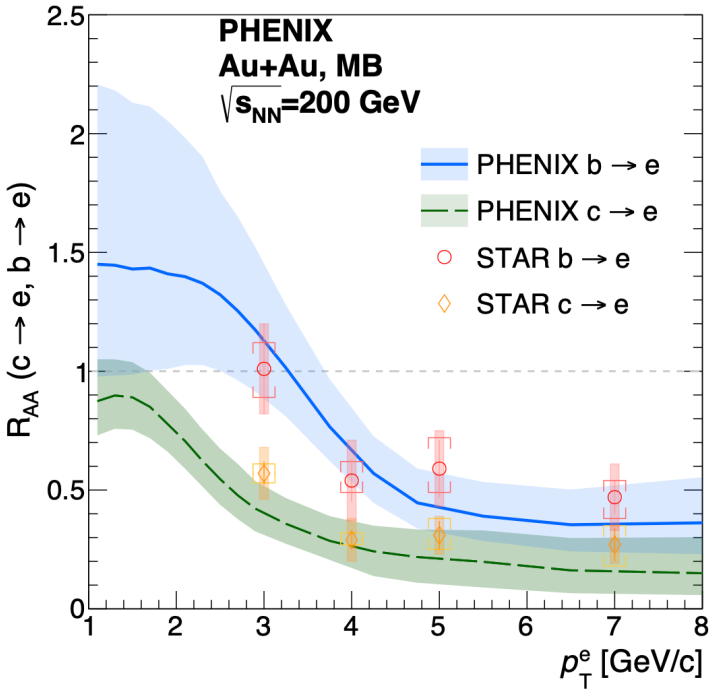
$$v_2(^3\text{He+Au}) < v_2(\text{d+Au}) < v_2(\text{p+Au})$$

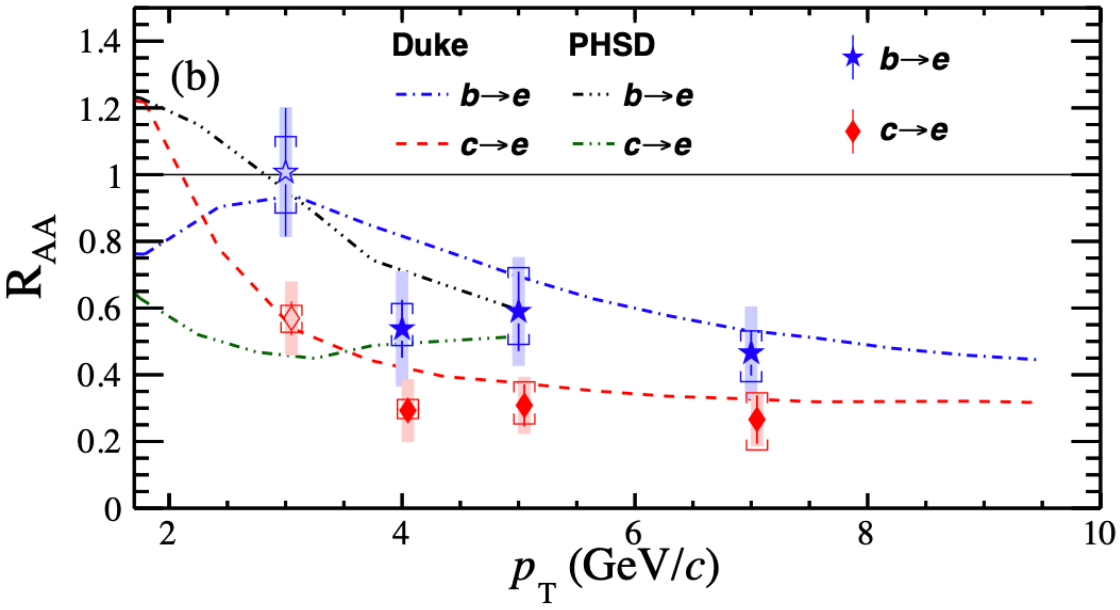
- Hydrodynamics (final state) $v_2(^3\text{He+Au}) \sim v_2(\text{d+Au}) > v_2(\text{p+Au})$

PHENIX results decisively establishes hydrodynamic final state is essential

Heavy Flavour: R_{AA}

Nihar Ranjan Sahoo



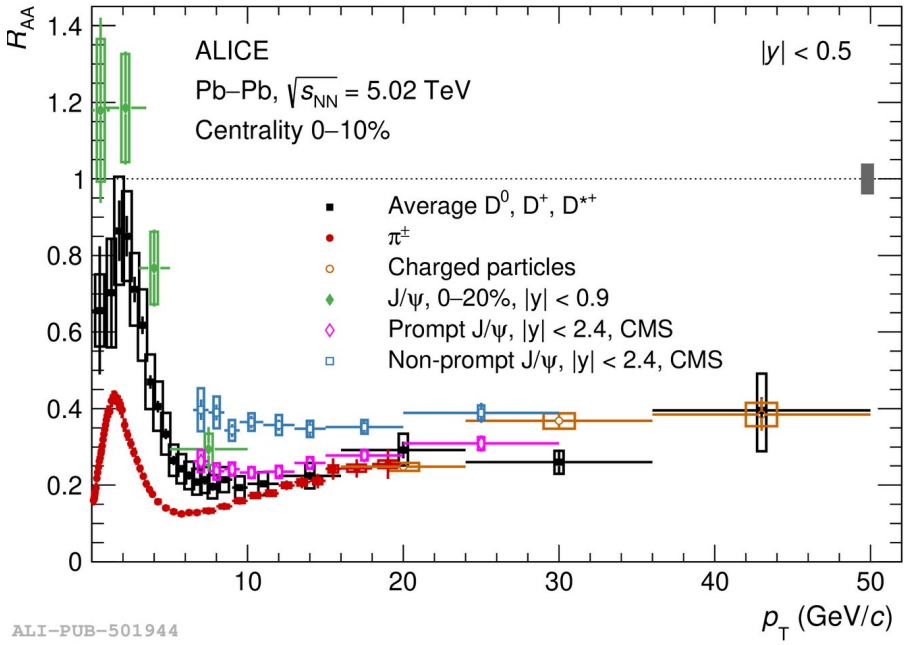


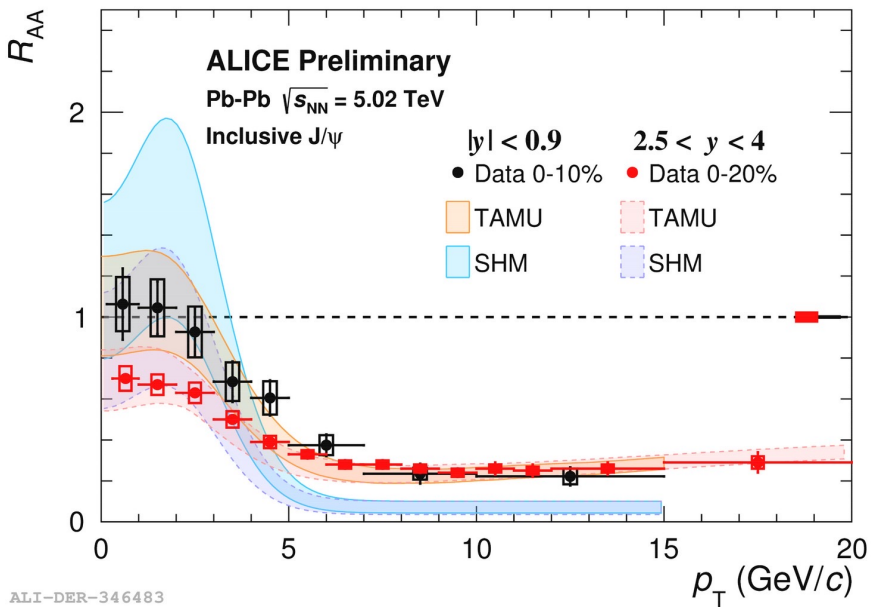
PHENIX, arXiv:2203.17058

- R_{AA} of bottom-decay electron less than that of charm-decay

Heavy Flavour: R_{AA}

Biswarup Paul



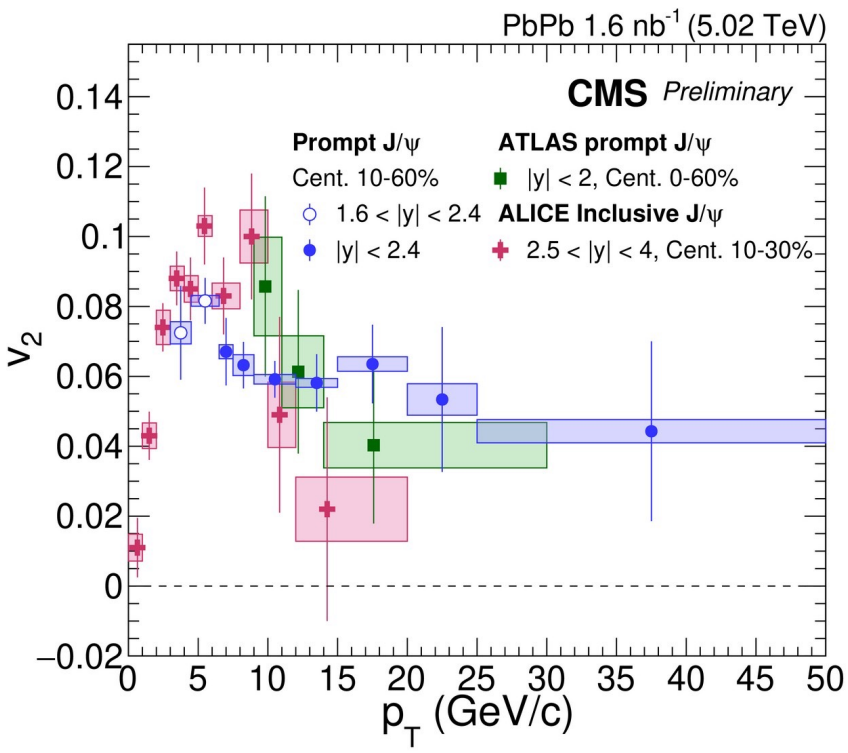


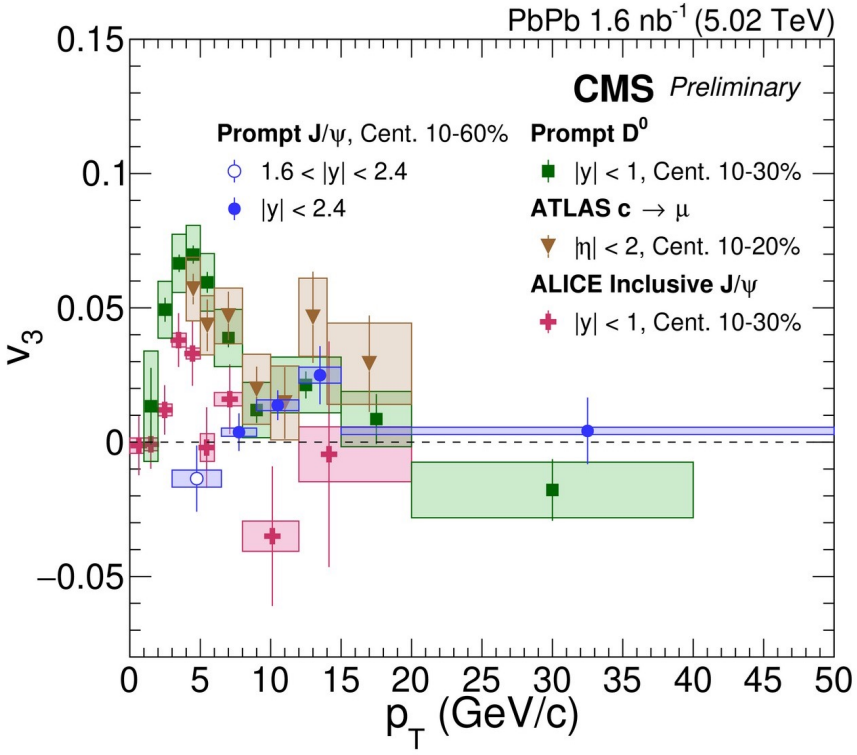
- Rise of inclusive J/ψ R_{AA} at low p_T, stronger effect at midrapidity in central events
  -> strong signature of recombination

- Models that include regeneration either at the phase boundary (SHMc) or during the medium evolution (TAMU) are both in agreement with data at low p_T

Charmonium: Flow

Biswarup Paul

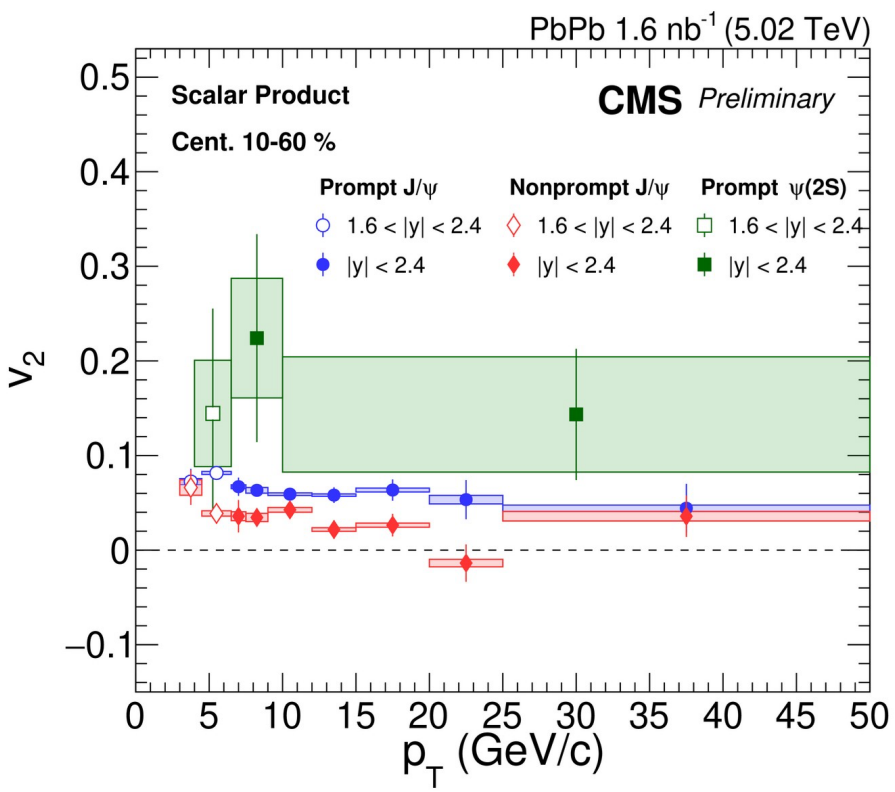


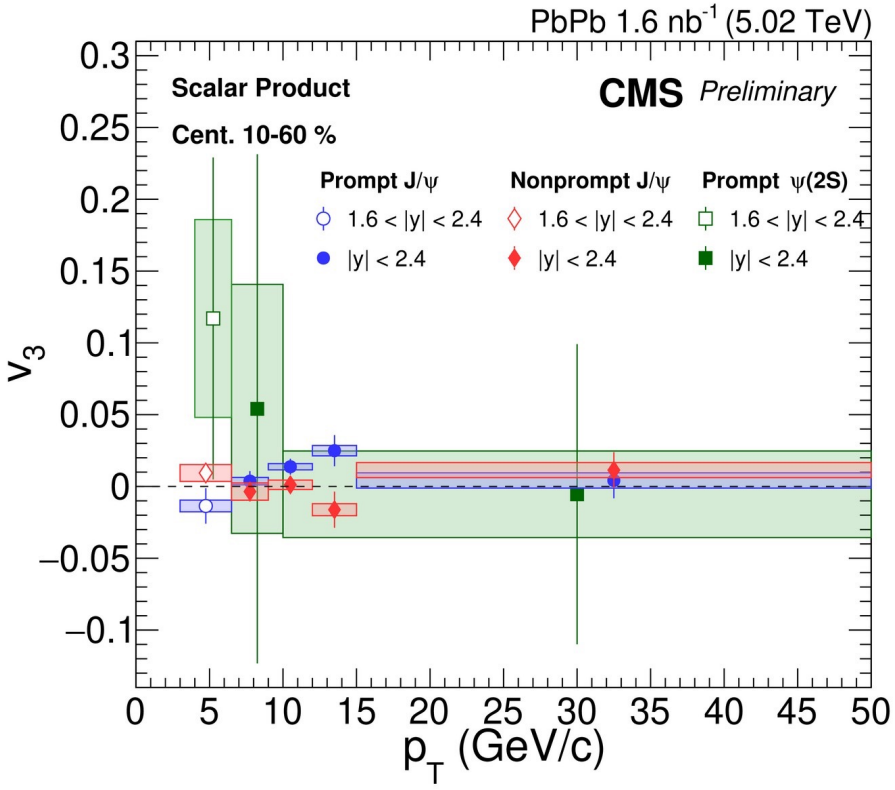


- Prompt J/ψ: significant v_2 up to high p_T (~30 GeV/c), while triangular flow (v_3) is smaller
- Largest J/ψ v_2 at low p_T (~5 GeV/c, expected from recombination)
- High p_T v_2: path-length dependence effect at play for all particles

Charmonium: Flow

Biswarup Paul

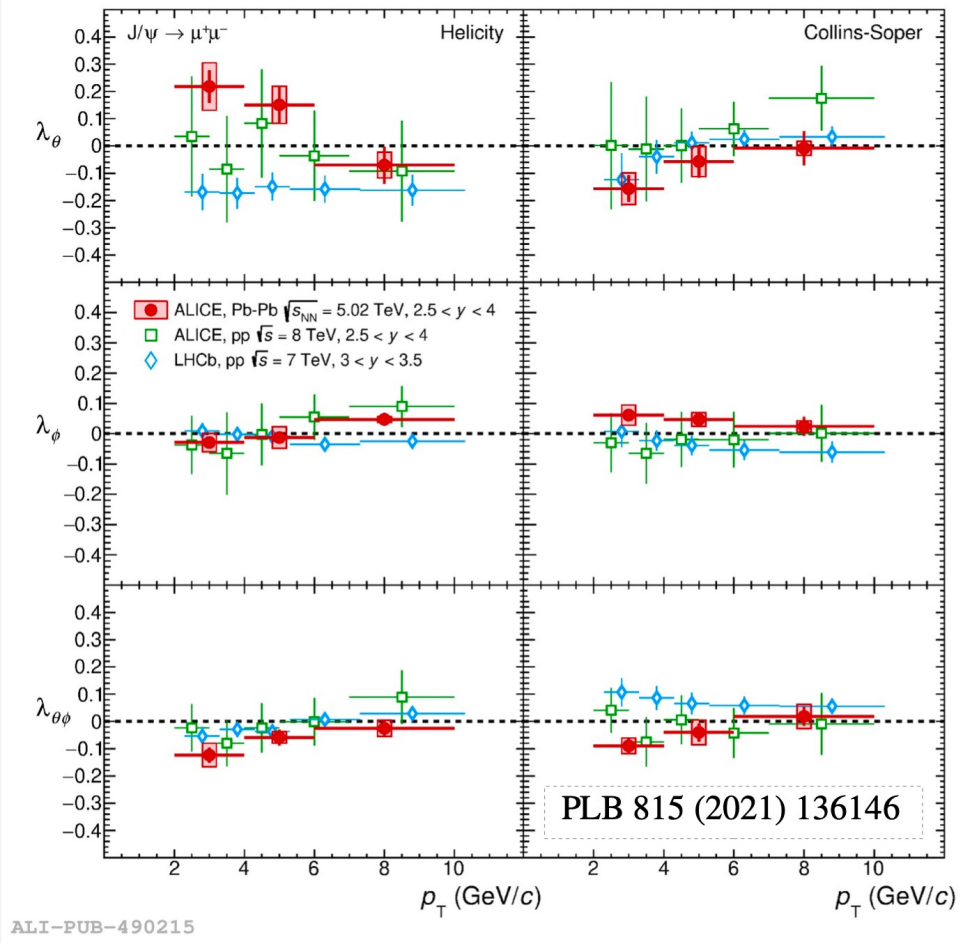


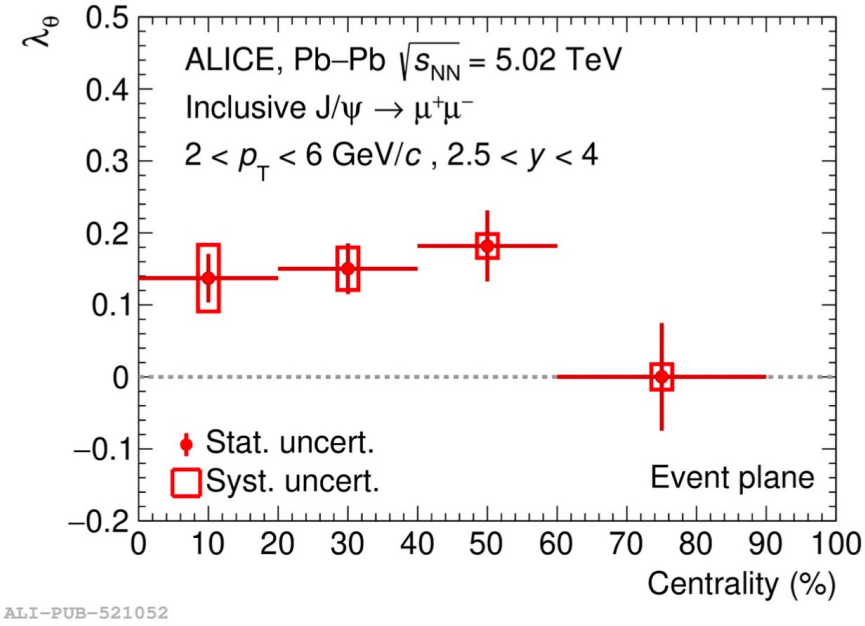


- Hint of prompt ψ(2S) $v_2 > 0$ ($p_T > 5$ GeV/c), larger than v_2 of prompt and non-prompt J/ψ
- Prompt ψ(2S) v_3 found compatible with 0 and with J/ψ v_3

J/ψ polarization in Pb–Pb

Biswarup Paul





arXiv:2204.10171

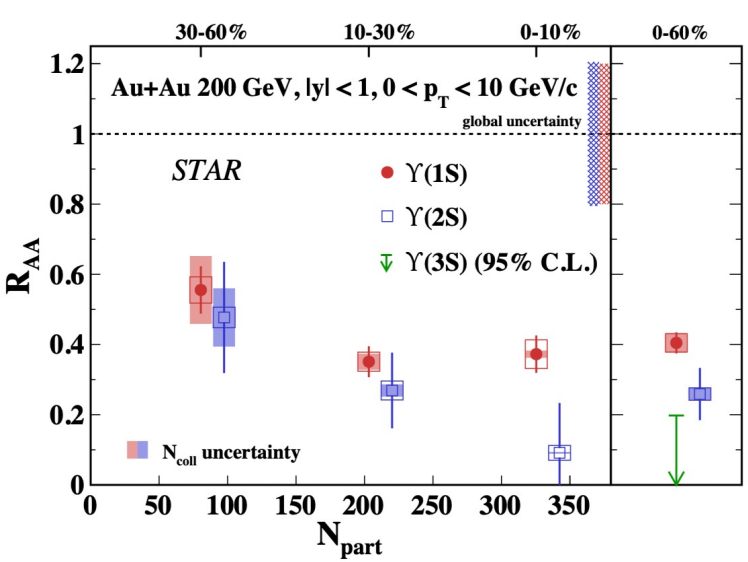
- The angular distribution of the leptons in the quarkonium rest frame:

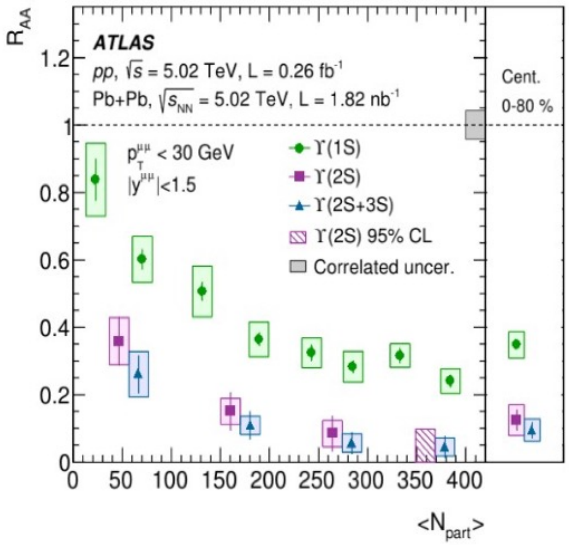
$$W(\theta,\phi) \propto \frac{1}{3+\lambda_\theta} \times \left(1+\lambda_\theta \cos^2\theta + \lambda_\phi \sin^2\theta \cos 2\phi + \lambda_{\theta\phi} \sin 2\theta \cos\phi\right)$$

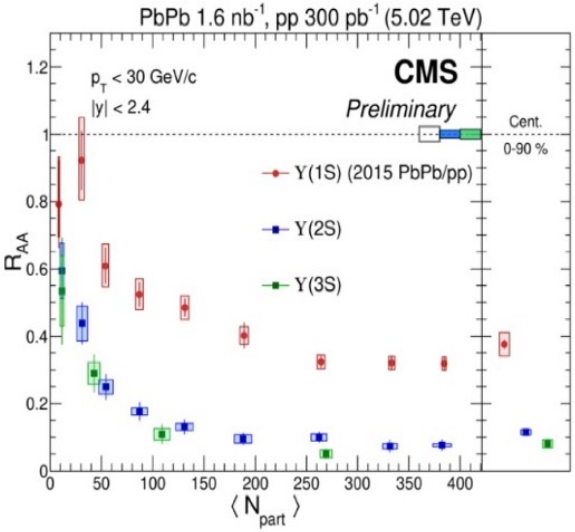
- Significant non-zero polarization (3.5σ) observed in the 40-60% centrality interval for $2 < p_T < 6$ GeV/c

$(\lambda_\theta,\lambda_\phi,\lambda_{\theta\phi})$ = (+1,0,0) → Pure longitudinal polarisation
= (0,0,0) → No polarisation
= (-1,0,0) → Pure transverse polarisation

Bottomonium: R_{AA} *Subikash Choudhury*







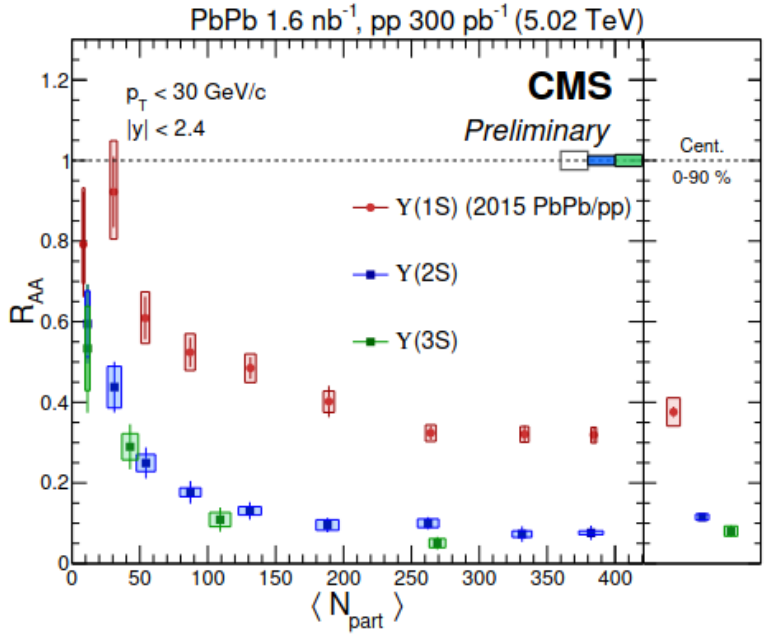
- Clear indication sequential melting both at RHIC and LHC

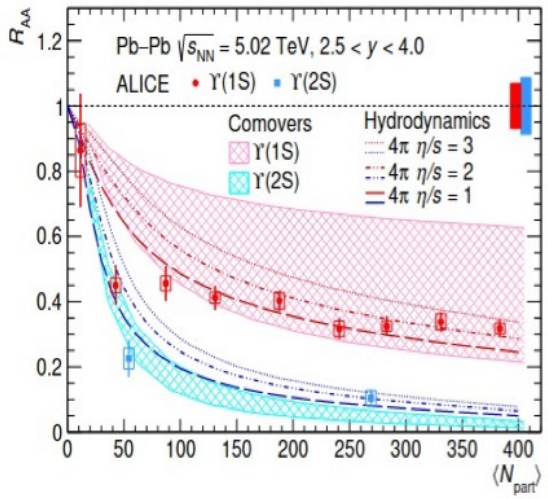
Ordering in R_{AA} :

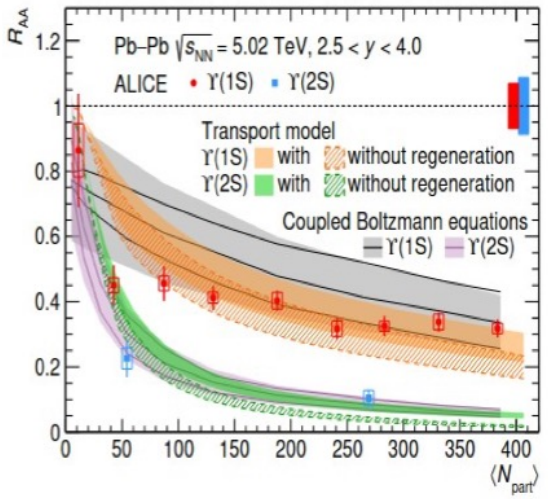
$\Upsilon(1S) > \Upsilon(2S) > \Upsilon(2S+3S / 3S)$

Bottomonium: R_{AA}

Subikash Choudhury



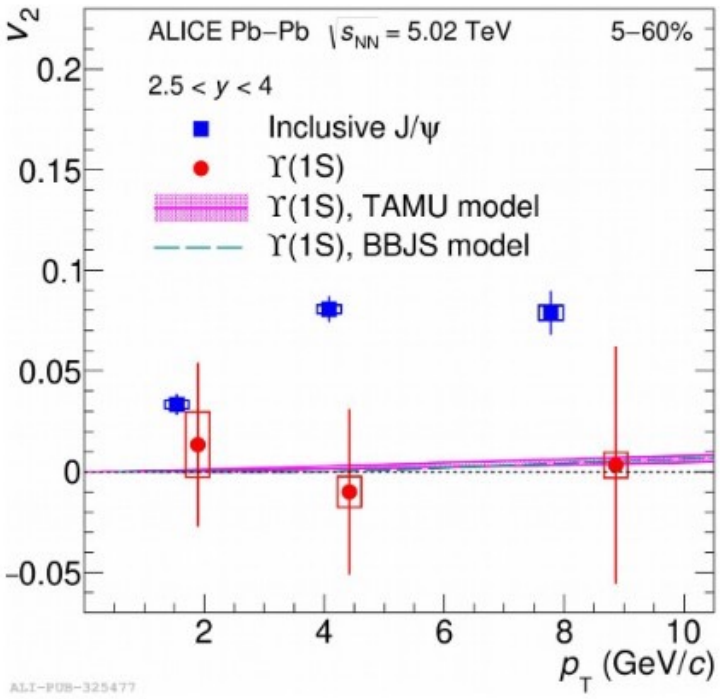


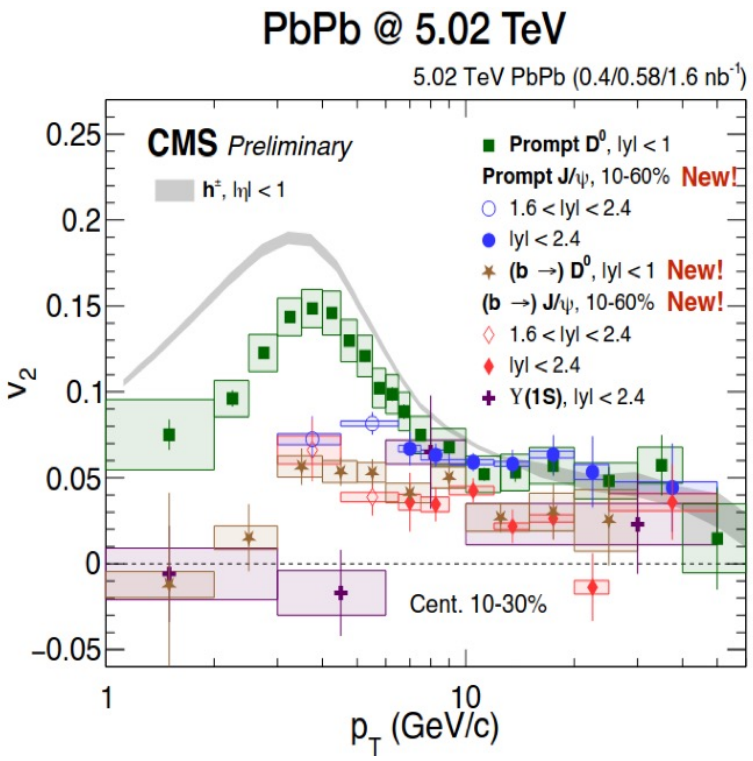


- Sequential suppression both at mid and forward rapidity
- No rapidity dependence
- Model calculations suggest regenaration effect is insignificant

Bottomonium: Flow

Subikash Choudhury

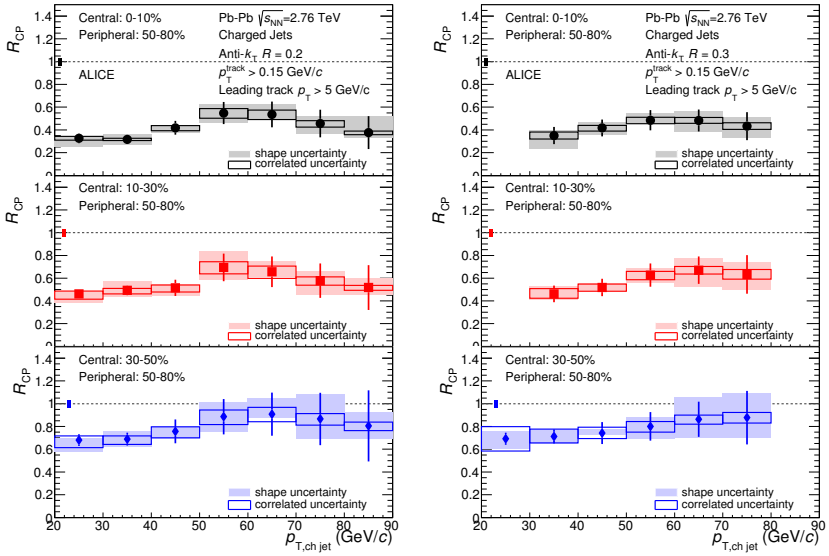


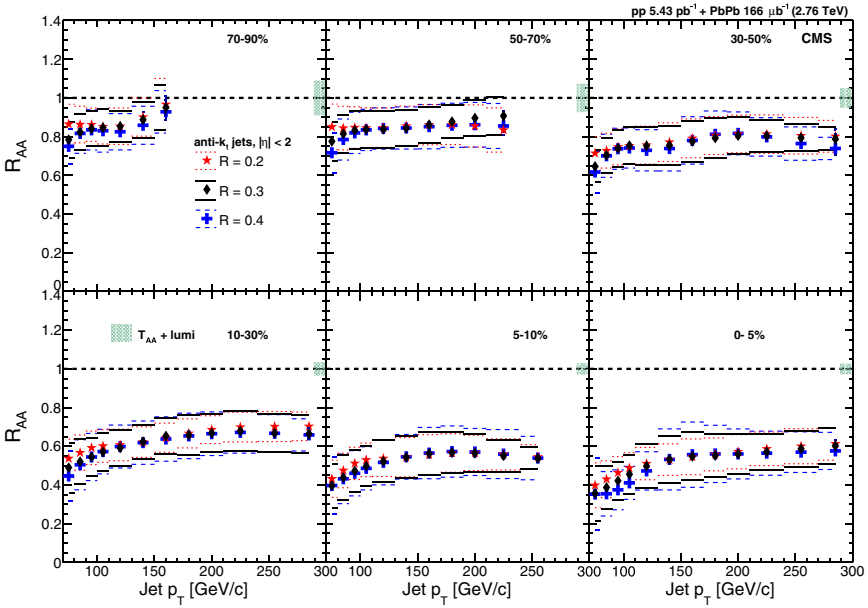


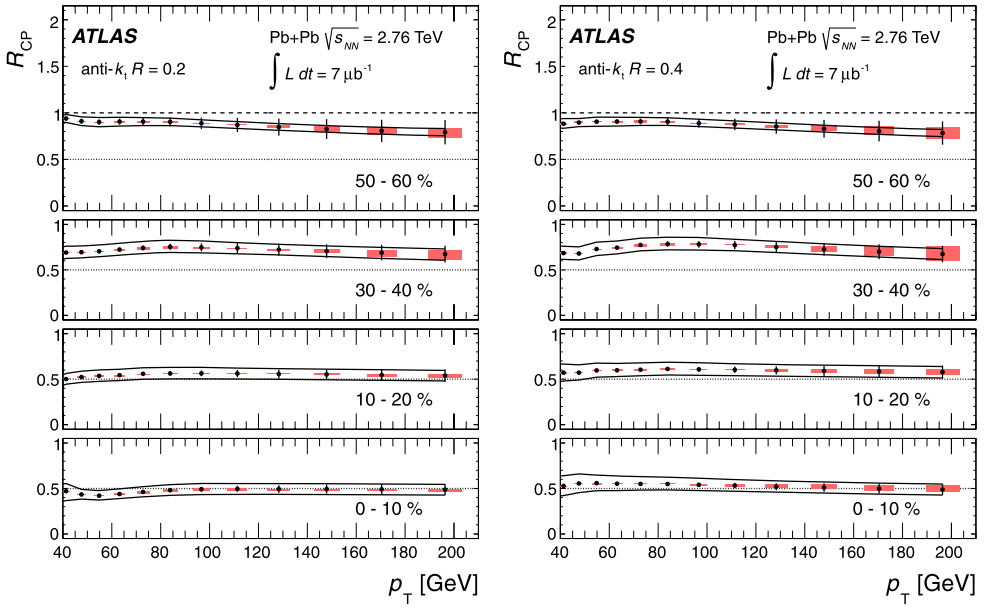
- Y(1S) v_2 consistent with zero -> Leaves the medium very early
- Simultaneous description of R_{AA} & v_2 can constrain model parameters better

Jet: Nuclear Modification Factor

Sidharth Kumar Prasad



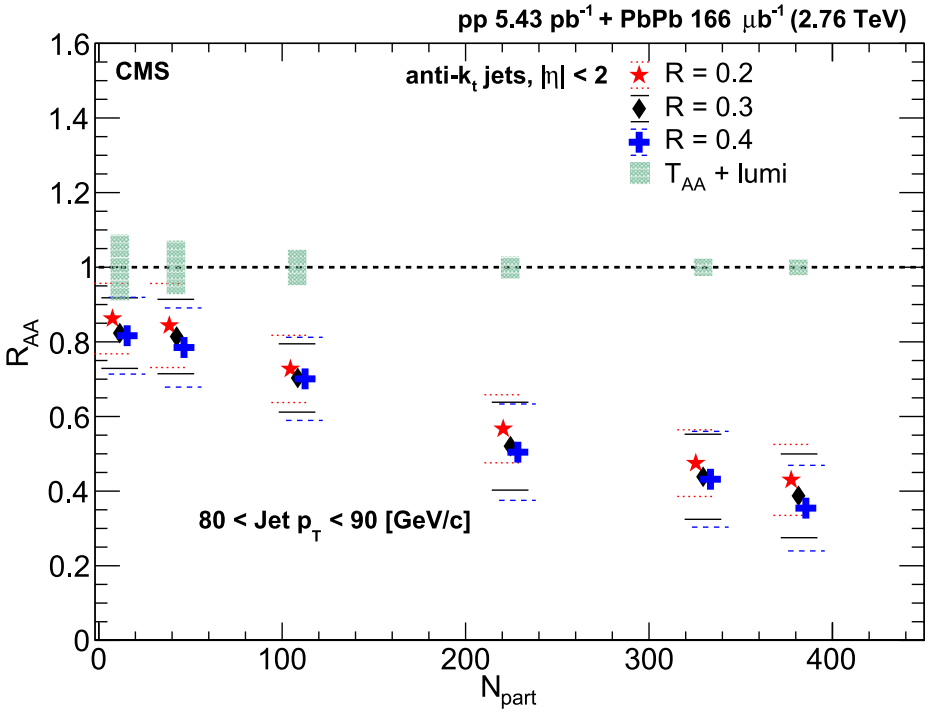


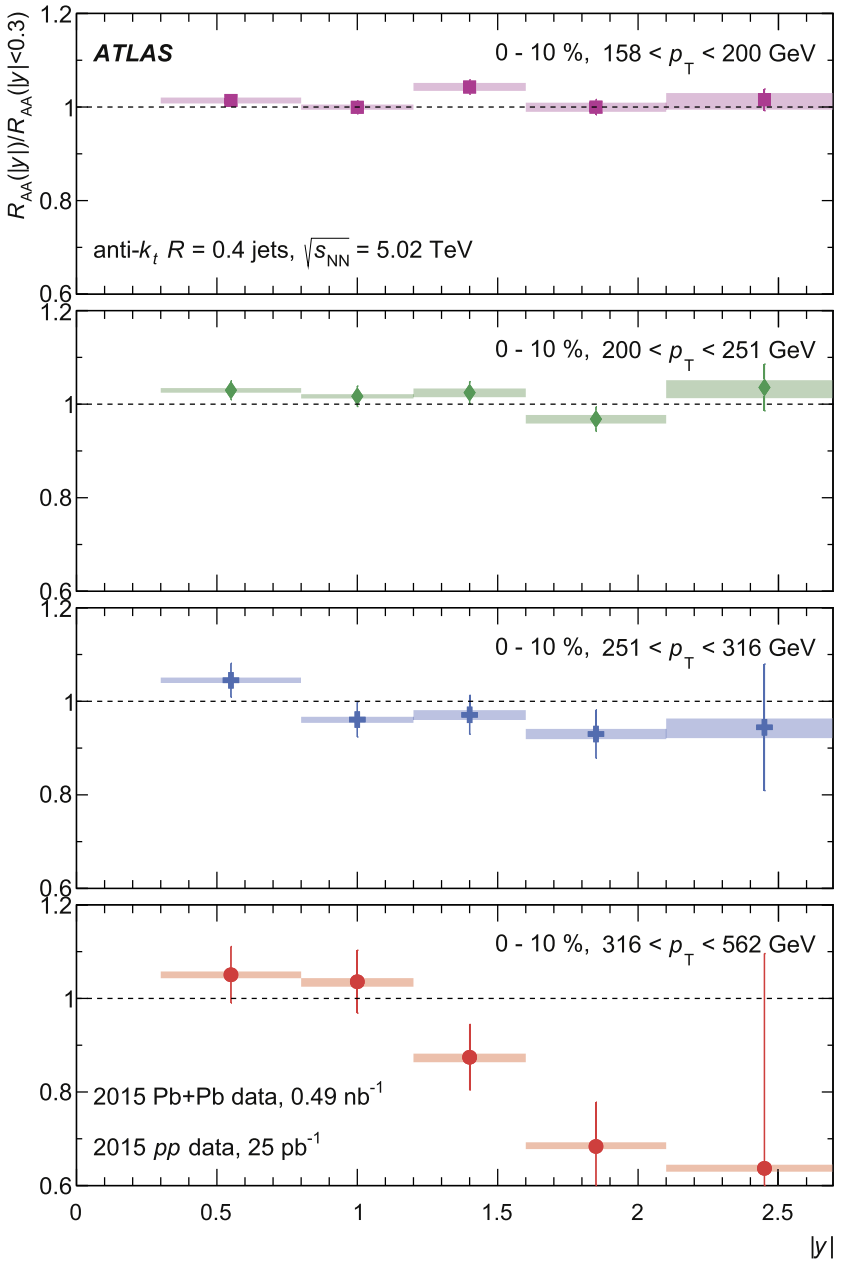


- Centrality dependent R_{AA}/R_{CP} in PbPb collisions at 2.76 TeV
- Strong jet suppression in central collisions
- R_{AA}/R_{CP}: mild p_T dependent
- Dense medium formation in central collisions

Jets

Sidharth Kumar Prasad

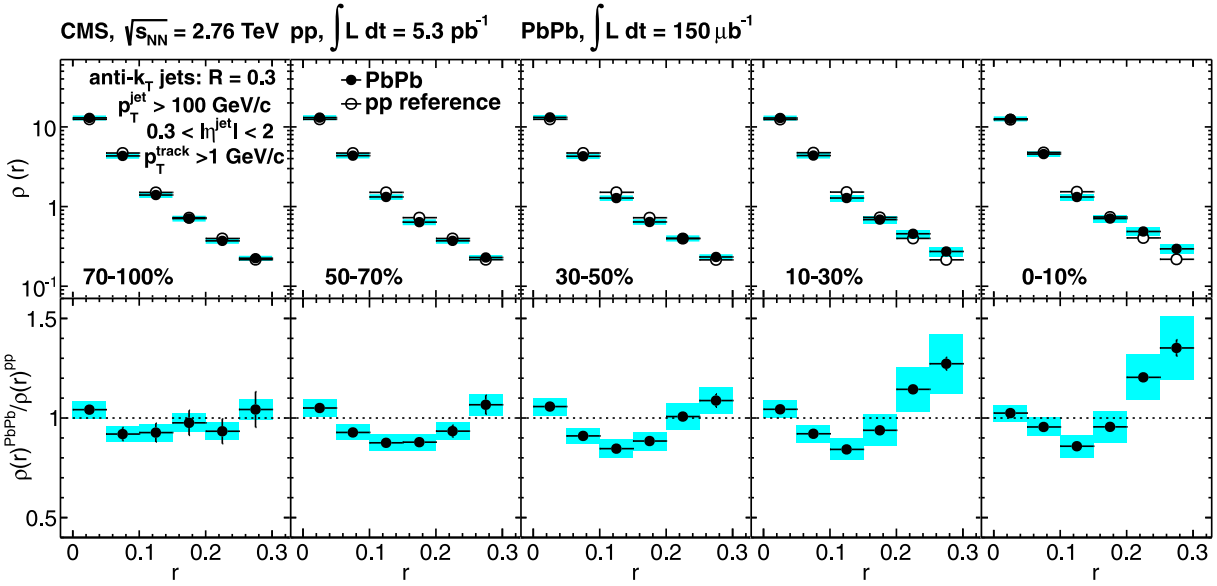




- R_{AA}/R_{CP} decreases monotonically with increasing $\langle N_{part} \rangle$
- At low jet p_T: no significant rapidity dependence
- At higher jet p_T: suppression towards higher rapidity

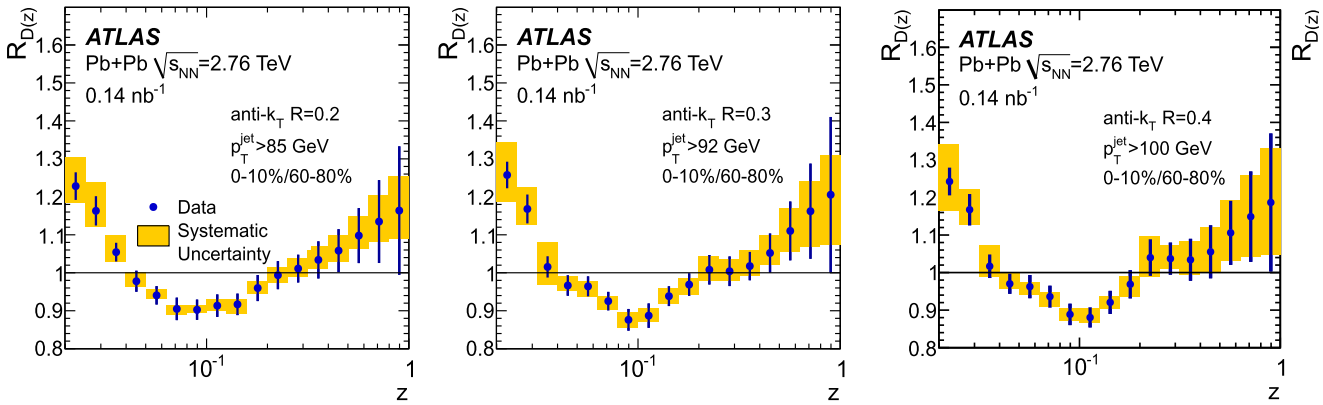
Jet Shapes and Fragmentation

Sidharth Kumar Prasad



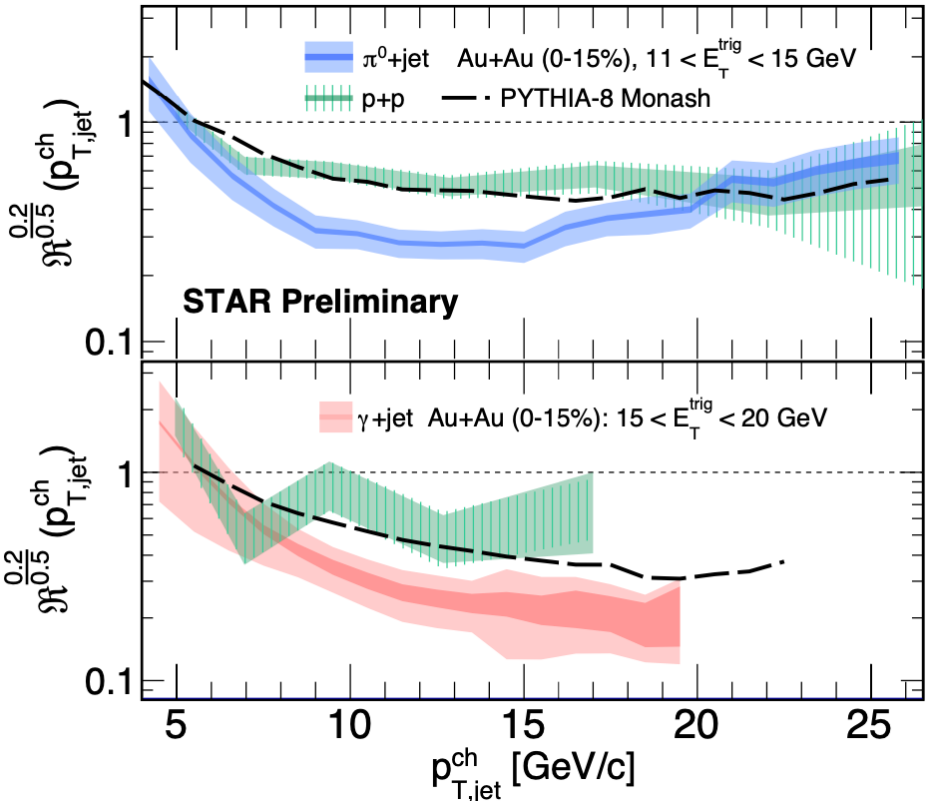
- Deviations from unity indicate a modification of jet structure in the nuclear medium
- Peripheral: Ratio is close to unity
- Central: No change at core, depletion at intermediate r and enhancement at larger r

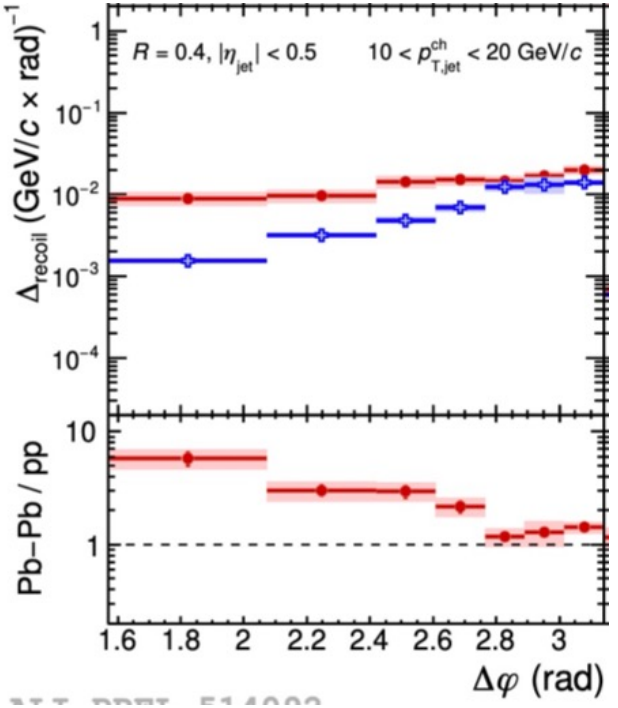
- Jet fragmentation ratios D(z) central/peripheral
- Enhanced yield of low and high z fragments and a suppressed yield of fragments at intermediate z values



Jets

Nihar Ranjan Sahoo

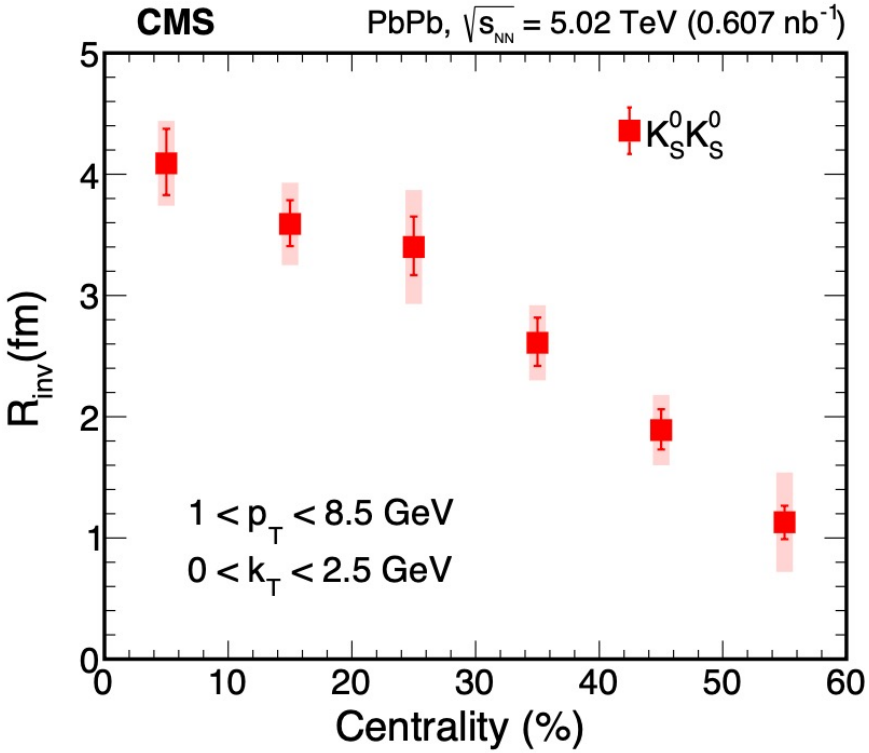


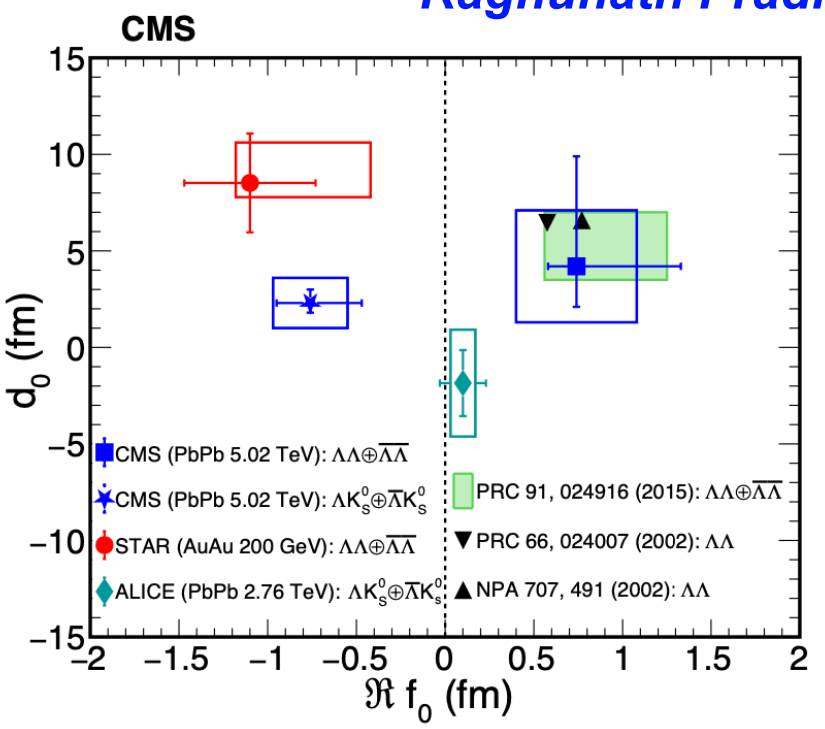


- First indication of jet shape modification due to medium induced gluon radiations at RHIC

Strange Particles Femtoscopy

Raghunath Pradhan





- Source size is extracted from $K^0_S K^0_S$ correlation and it is increases from peripheral to central collisions as expected.

- First measurement of $\Lambda\Lambda \oplus \bar{\Lambda}\bar{\Lambda}$ correlation in PbPb collisions at LHC

  $\Lambda\Lambda \oplus \bar{\Lambda}\bar{\Lambda}$ interaction : Attractive -> Not strong enough to produce the H-dibaryon

Summary

- Impressively rich harvest of data obtained from RHIC and LHC:

- Electromagnetic probes
- Heavy quarks and quarkonia
- Jets
- Strangeness

- Many more exciting analyses are ongoing/planned at RHIC and LHC:

- Hot-QCD program: Study the microstructure of the QGP

- Cold-QCD program: Transition towards EIC program

Stay tuned!

Thank you

Photon Interactions in UPC

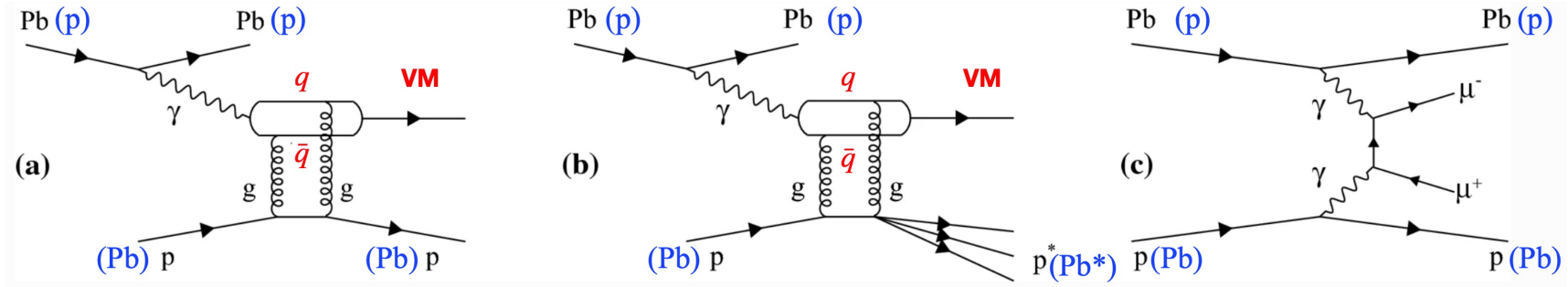


Photo-nuclear interactions

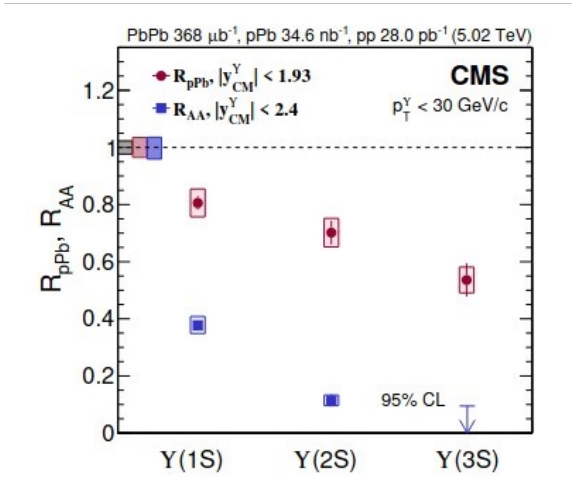
Proton dissociations

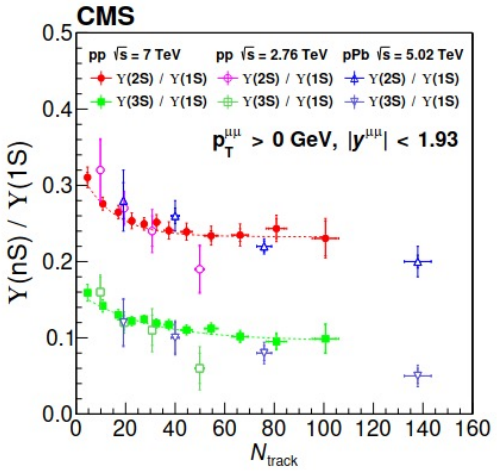
Photon-photon interactions

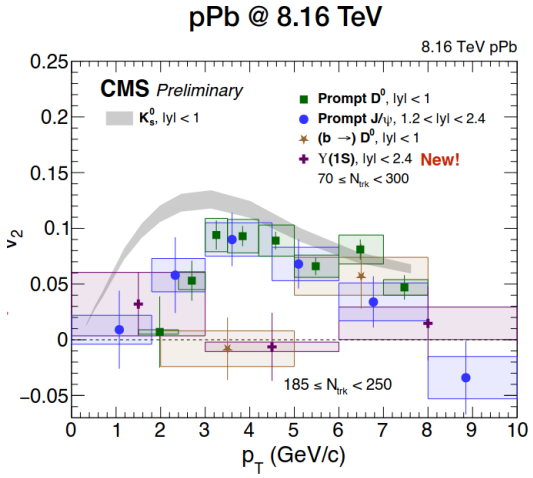
Signal

Background

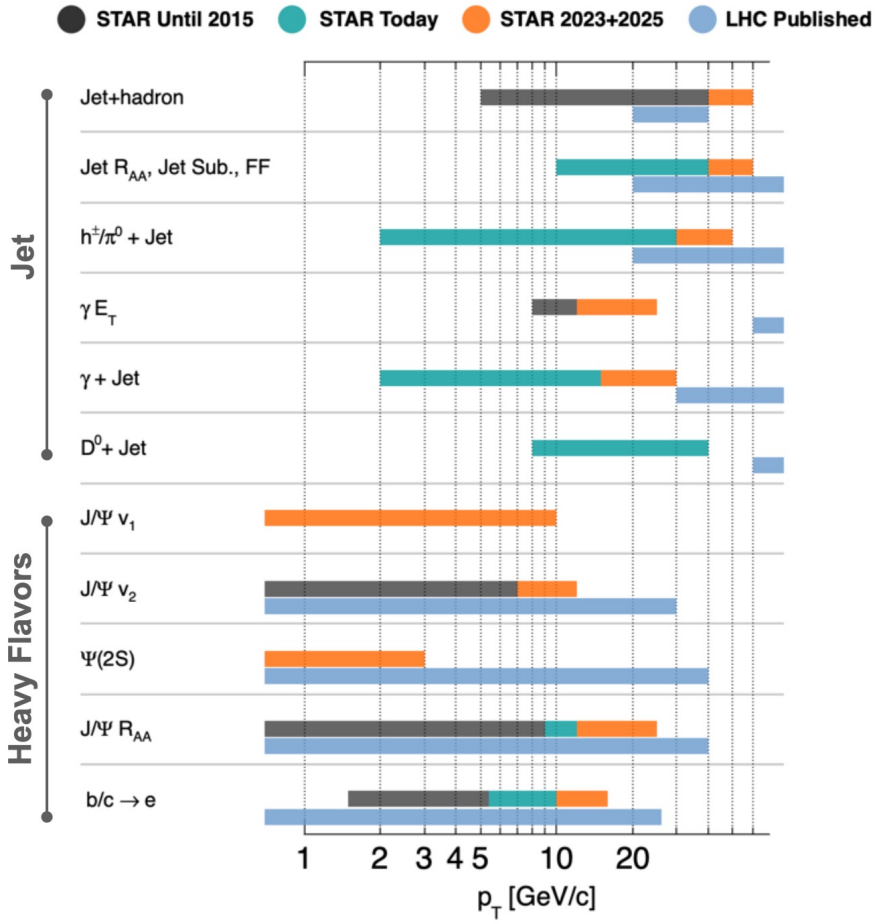
Heavy Flavour



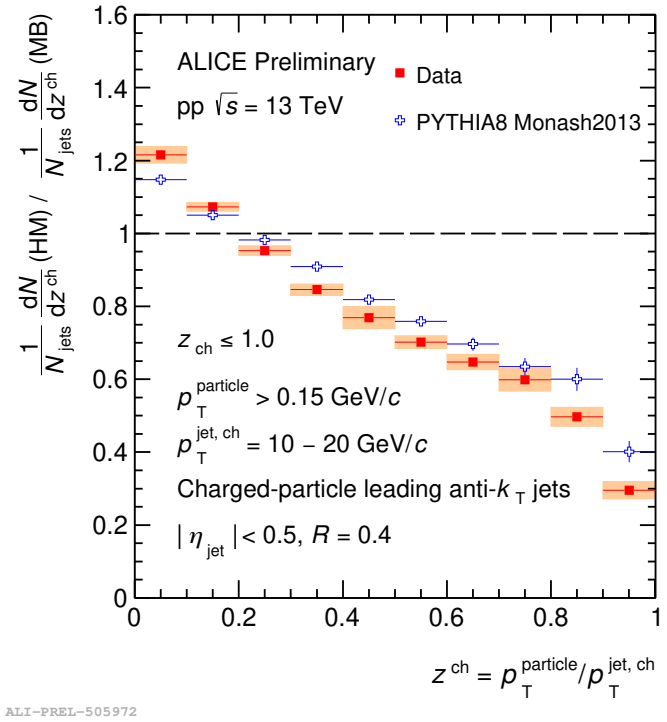


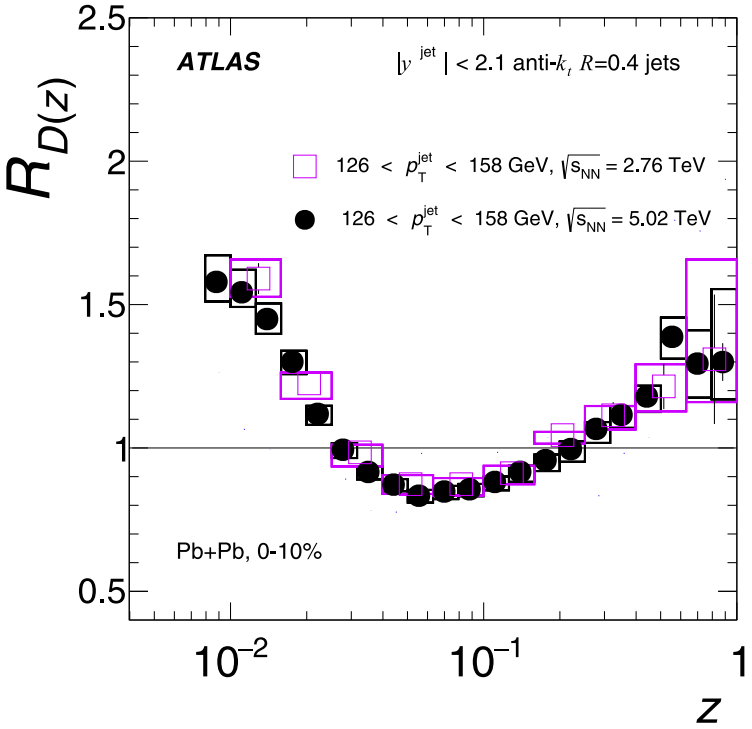


Jets: Future


STAR Until 2015
STAR Today
STAR 2023+2025
LHC Published
Jet
Heavy Flavors
Jet+hadron
Jet R_AA, Jet Sub., FF
h±/π0 + Jet
γ E_T
γ + Jet
D0+ Jet
J/Ψ v1
J/Ψ v2
Ψ(2S)
J/Ψ R_AA
b/c → e
1
2
3
4
5
10
20
p_T [GeV/c]

Jets


ALICE Preliminary
pp $\sqrt{s}$ = 13 TeV
Data
PYTHIA8 Monash2013
$z_{ch} \leq 1.0$
$p_T^{particle} > 0.15$ GeV/c
$p_T^{jet, ch}$ = 10 – 20 GeV/c
Charged-particle leading anti-k_T jets
$|\eta_{jet}| < 0.5$, $R = 0.4$
$\frac{1}{N_{jets}} \frac{dN}{dz^{ch}}$ (HM) / $\frac{1}{N_{jets}} \frac{dN}{dz^{ch}}$ (MB)
$z^{ch} = p_T^{particle}/p_T^{jet, ch}$
ALI-PREL-505972


ATLAS
$|y^{jet}| < 2.1$ anti-k_t R=0.4 jets
126 < p_T^{jet} < 158 GeV, $\sqrt{s_{NN}}$ = 2.76 TeV
126 < p_T^{jet} < 158 GeV, $\sqrt{s_{NN}}$ = 5.02 TeV
Pb+Pb, 0-10%
$R_{D(z)}$
z