

## ALICE “overview” *and the near future...*

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ALICE

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# The ALICE detector: RUN1 & 2

## RUN1 (2009-2013)

Pb-Pb @  $\sqrt{s_{NN}}=2.76$  TeV

p-Pb @  $\sqrt{s_{NN}}=5.02$  TeV

p-p @  $\sqrt{s_{NN}}=0.9, 2.76, 7$  and  $8$  TeV

## RUN2 (2015-2018)

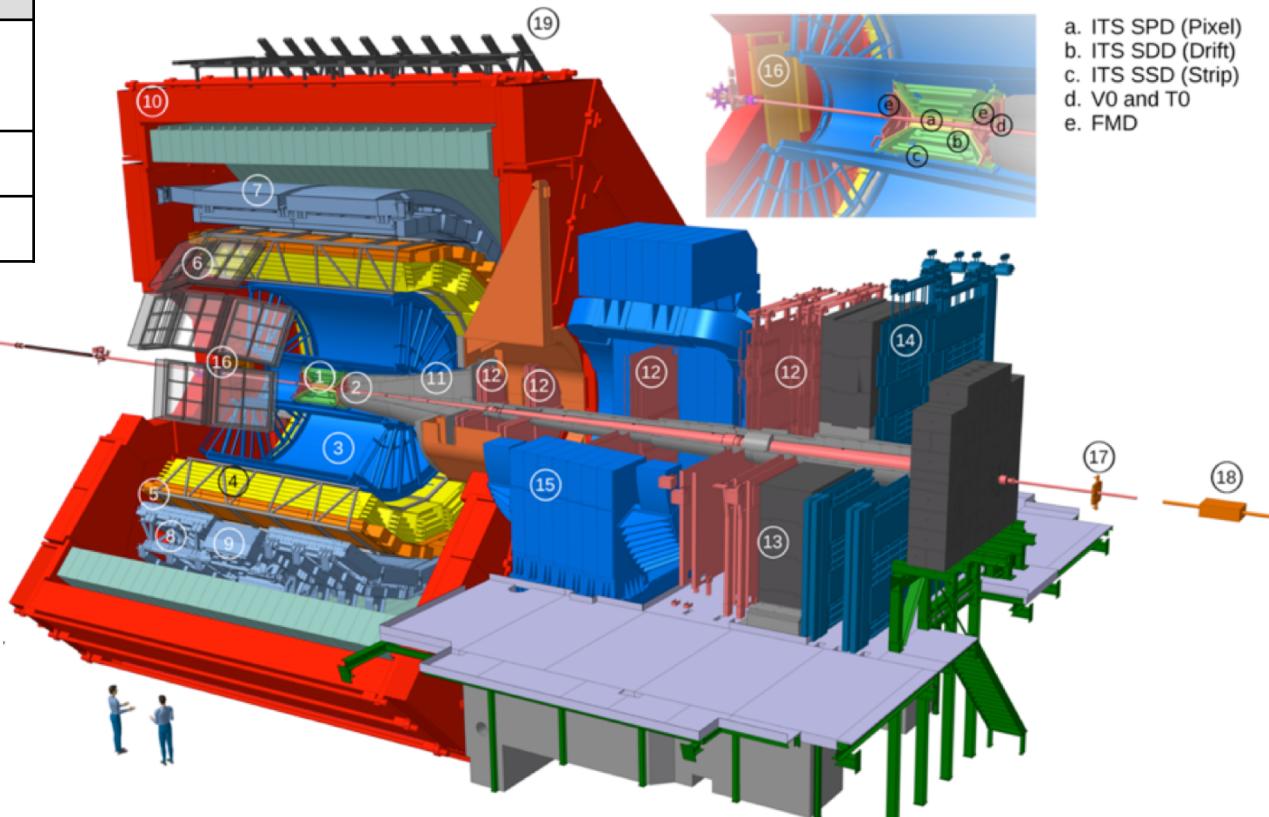
Pb-Pb @  $\sqrt{s_{NN}}=5.02$  TeV

Xe-Xe @  $\sqrt{s_{NN}}=5.44$  TeV

p-Pb @  $\sqrt{s_{NN}}=5.02$  and  $8.16$  TeV

p-p @  $\sqrt{s_{NN}}=5$  and  $13$  TeV

- Tracking and PID over large kinematic range
- High resolution vertexing
- Central barrel:  $-0.9 < \eta < 0.9$
- Muon spectrometer:  $-4.0 < \eta < -2.5$
- Forward detectors: trigger, centrality, luminosity, ...



## **Study emergent QCD phenomena via nuclear collisions**

### **A-A collisions: QGP characterization**

- System thermalization
- Hydro. expansion
- In-medium hadronization
- In-medium energy loss
- Quarkonium production
- ...

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- Investigate shadowing
- Study possible final state effect ( $E_{\text{loss}}$ , ...)
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- Test of pQCD calculation
- Study fragmentation and hadronization
- Baseline for A-A and p-A
- ...

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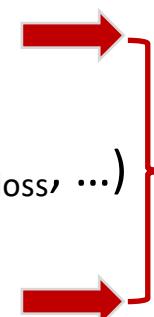
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### Small systems vs. multiplicity

- Dilute vs. dense
- Collectivity
- Strangeness enhancement
- Role of MPI
- ...

## Rencontres QGP-France

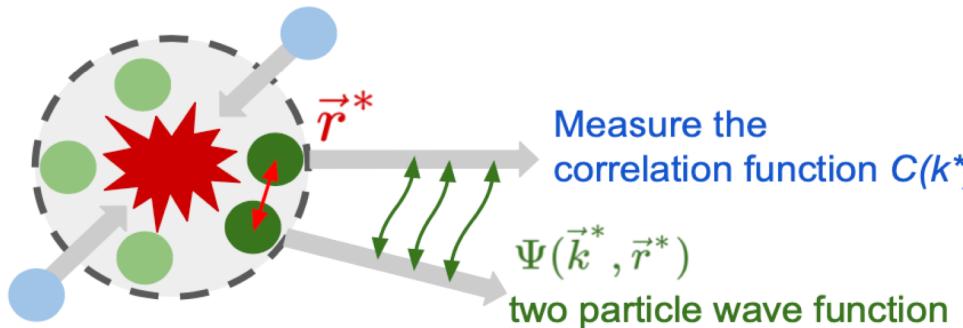
### Etretat 5-8 juillet 2021



Photo © G. Faillagne

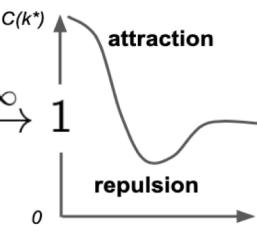


# *Probing scattering parameters using hadron correlations*



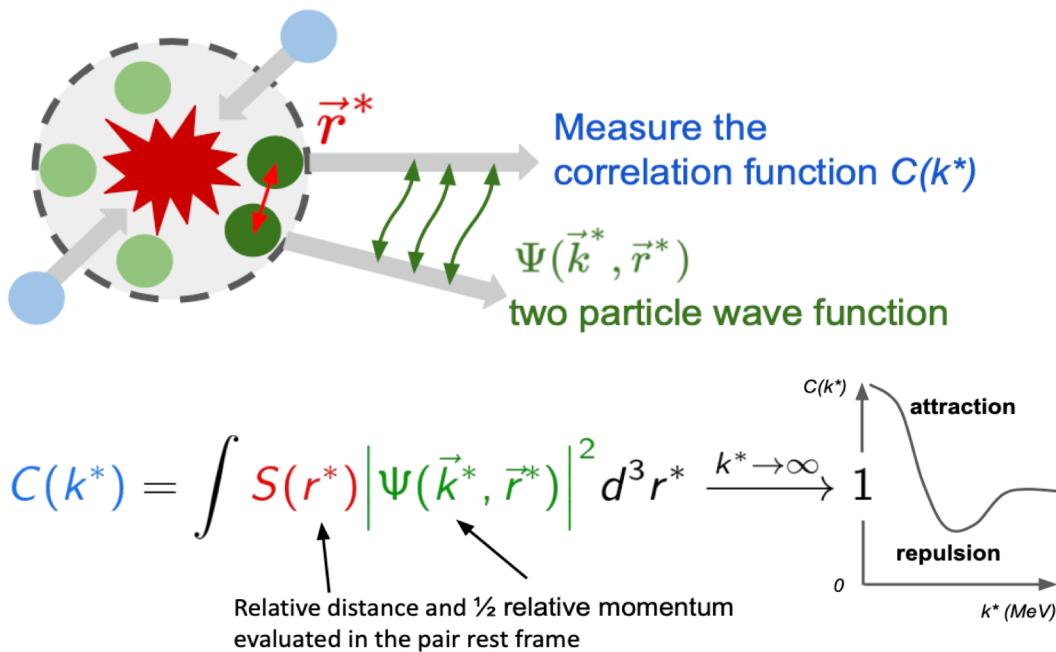
$$C(k^*) = \int S(r^*) |\Psi(\vec{k}^*, \vec{r}^*)|^2 d^3 r^* \xrightarrow{k^* \rightarrow \infty} 1$$

Relative distance and  $1/2$  relative momentum evaluated in the pair rest frame

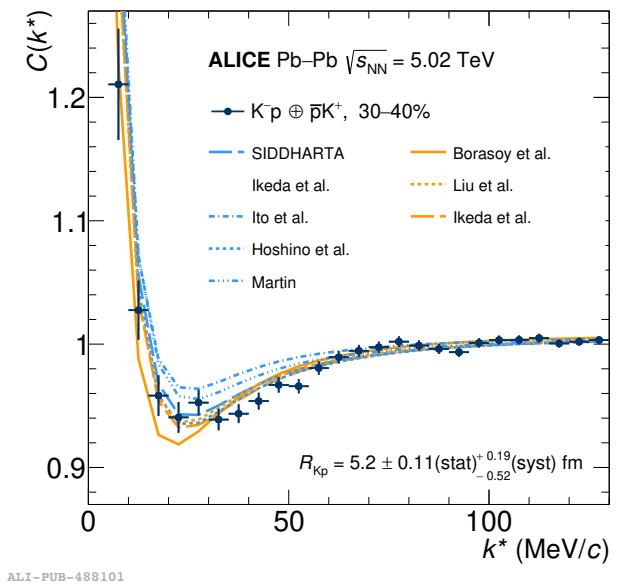
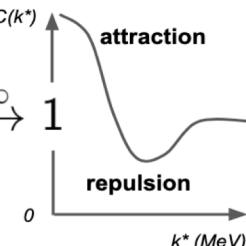


Measure  $C(k^*)$ , fix  $S(r^*)$ , study the interaction

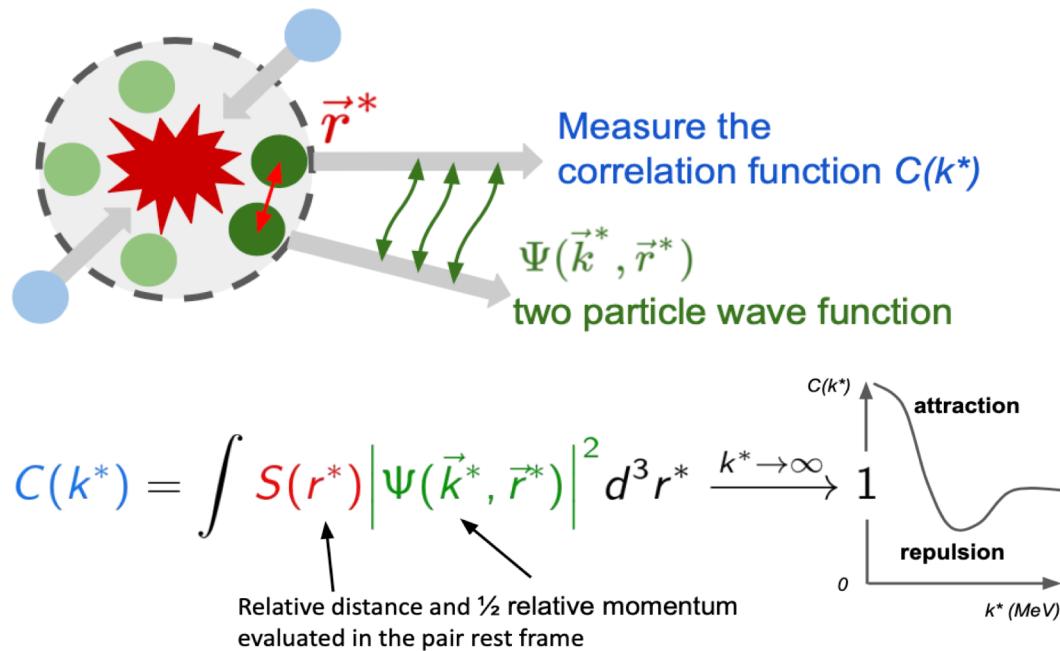
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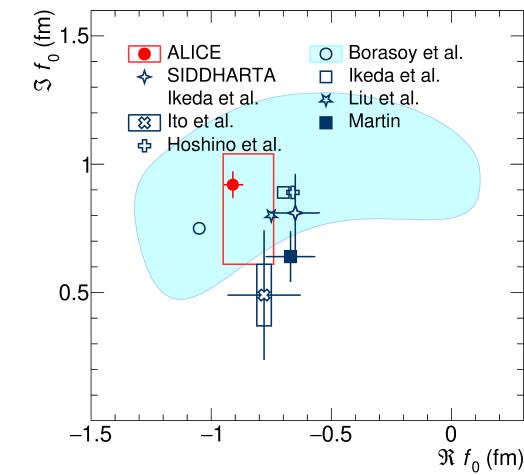
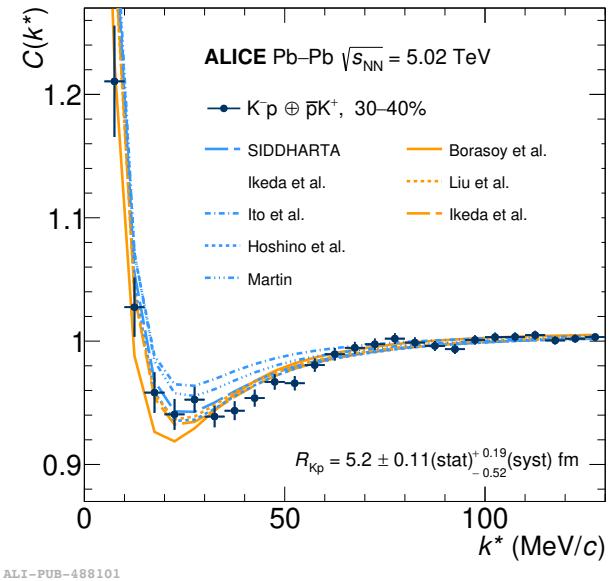


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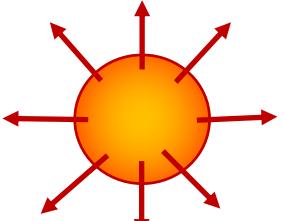


Measure  $C(k^*)$ , fix  $S(r^*)$ , study the interaction

- Alternative to scattering experiment
  - Pb-Pb:  $r^* > 3$  fm – only elastic channels
  - New input to world data and theoretical calculations

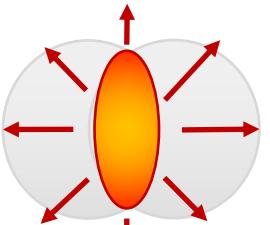


## ➤ Radial flow



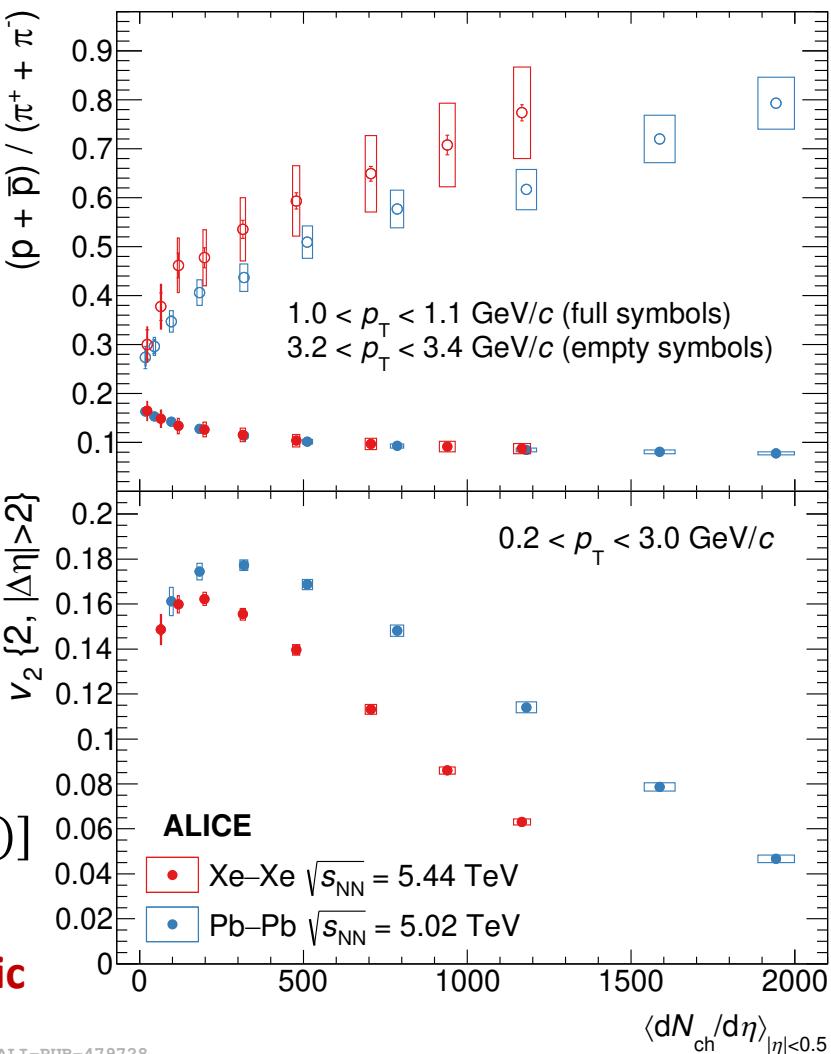
- Modify particle spectra at low  $p_T$
- $p = p_0 + \beta m$

## ➤ Elliptic flow in the transverse plane



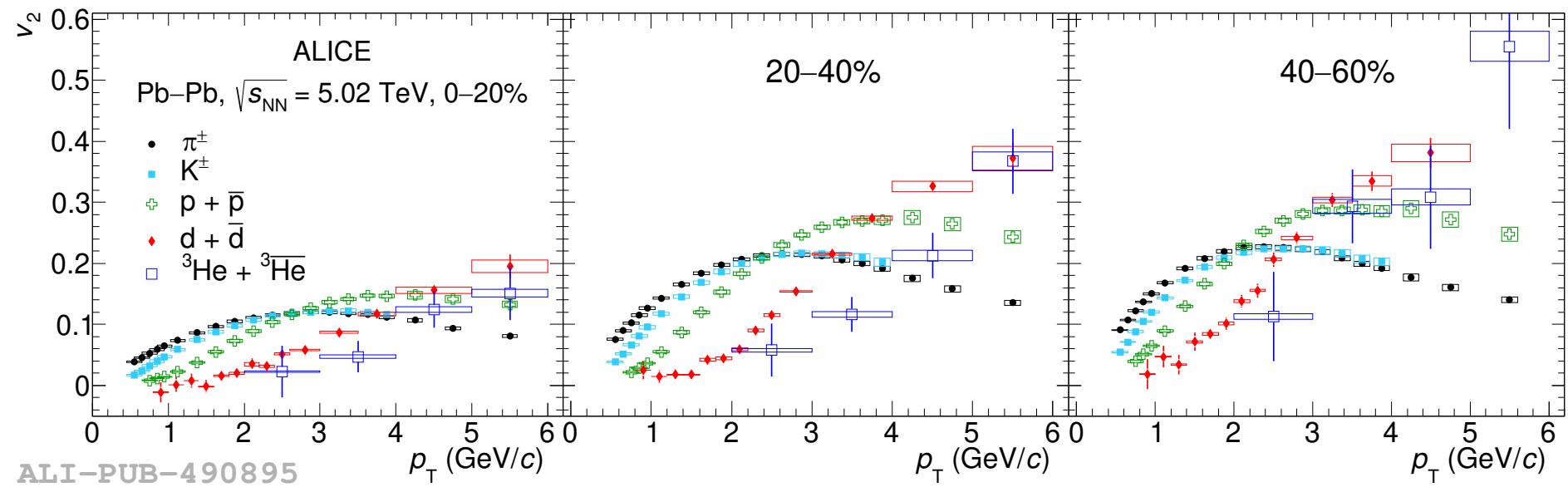
- Sensitive to initial geometry
- $\frac{d^3N}{dp_T^2 d\phi dy} = \frac{1}{2\pi} \frac{d^2N}{p_T dp_T dy} [1 + 2v_2 \cos(\phi - \Psi_{RP})]$

**Radial flow depends only on multiplicity while elliptic flow depends also on colliding system geometry**

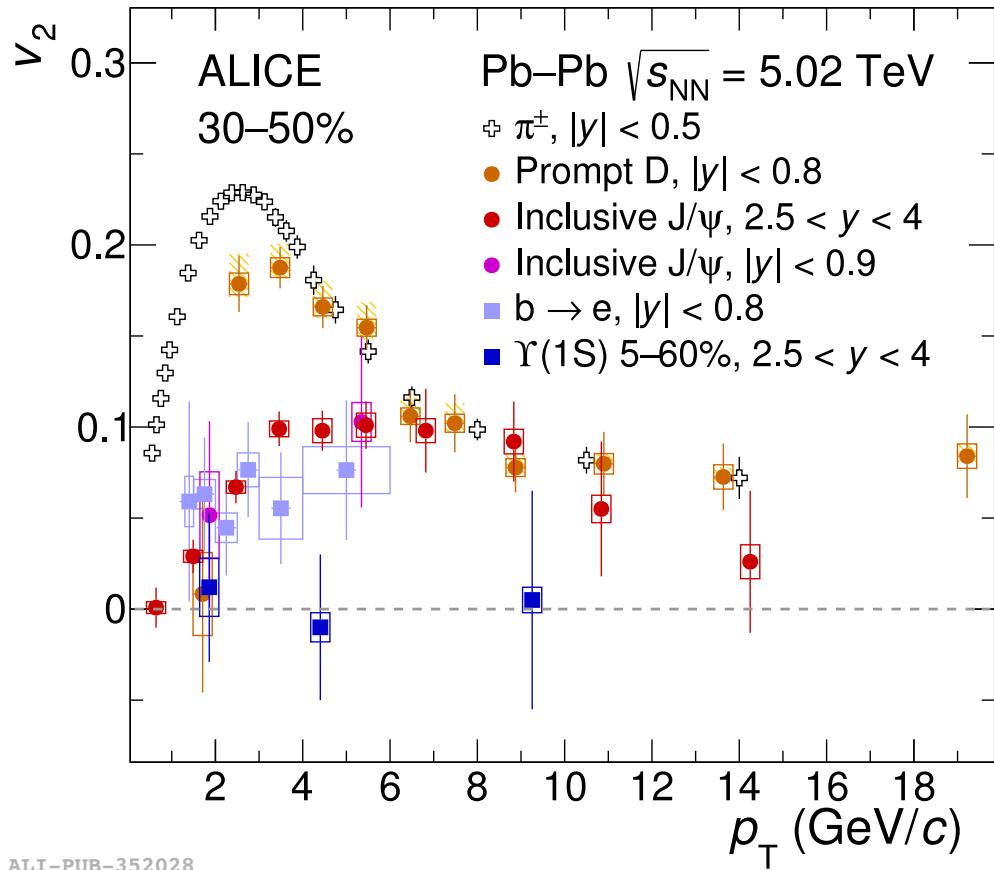


# Identified light flavor elliptic flow

- Measurement performed from  $\pi^\pm$  to  ${}^3\text{He}$ 
  - Collective expansion confirmed up to light nuclei
  - Expected mass ordering observed (radial flow)



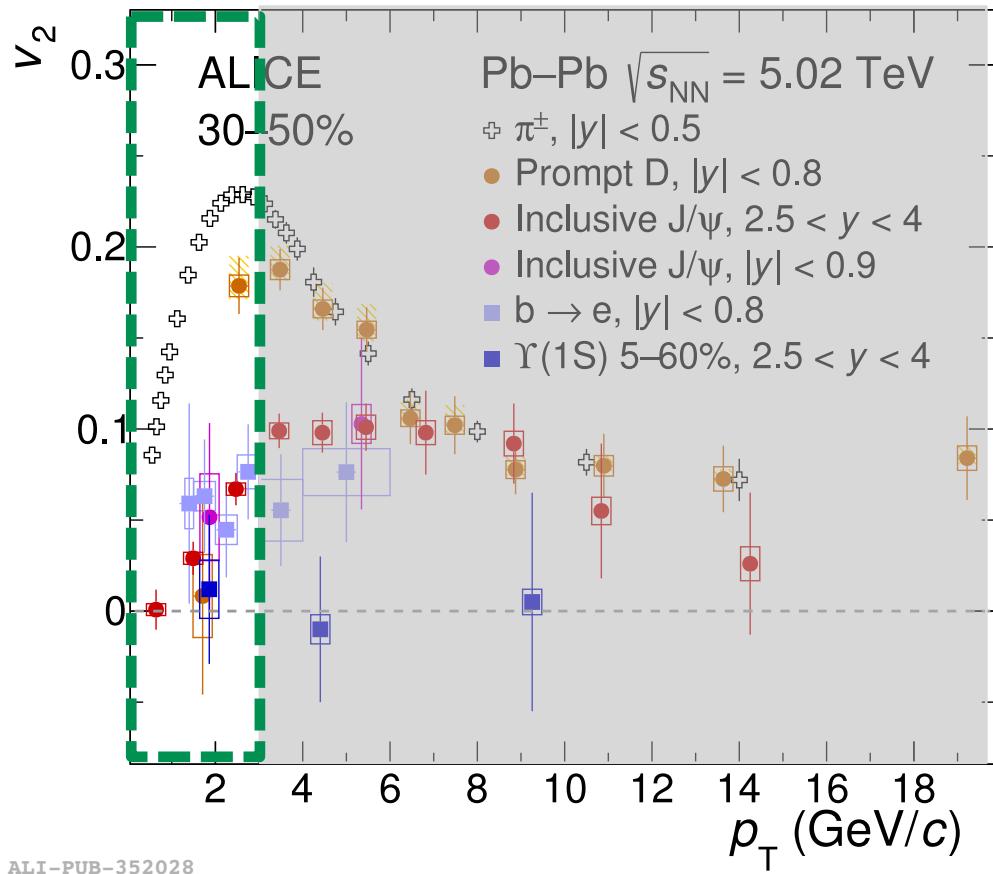
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## ➤ $p_T < 3 \text{ GeV}/c$

- $v_2(\text{J}/\psi) < v_2(\text{D}) < v_2(\pi^\pm)$
- consistent with hydrodynamics



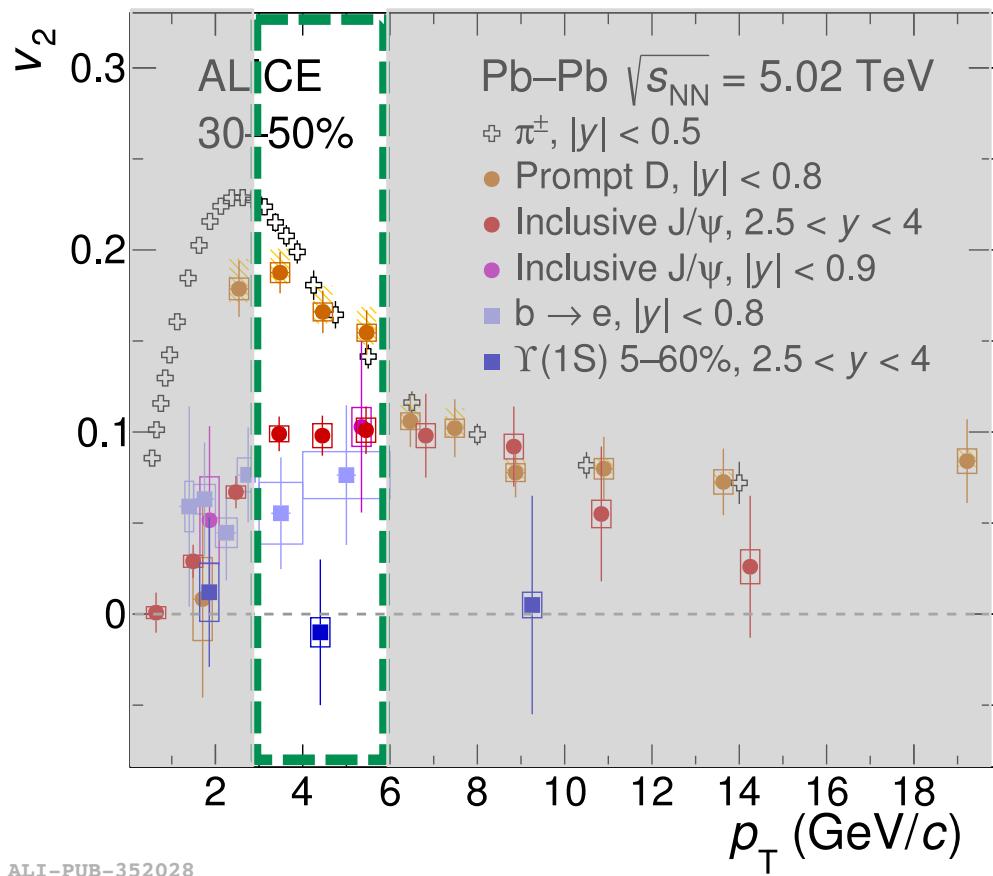
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- $v_2(\text{J}/\psi) < v_2(D) \sim v_2(\pi^\pm)$
- heavy quark hadronization via coalescence with flowing light quark



# Heavy Flavor elliptic flow

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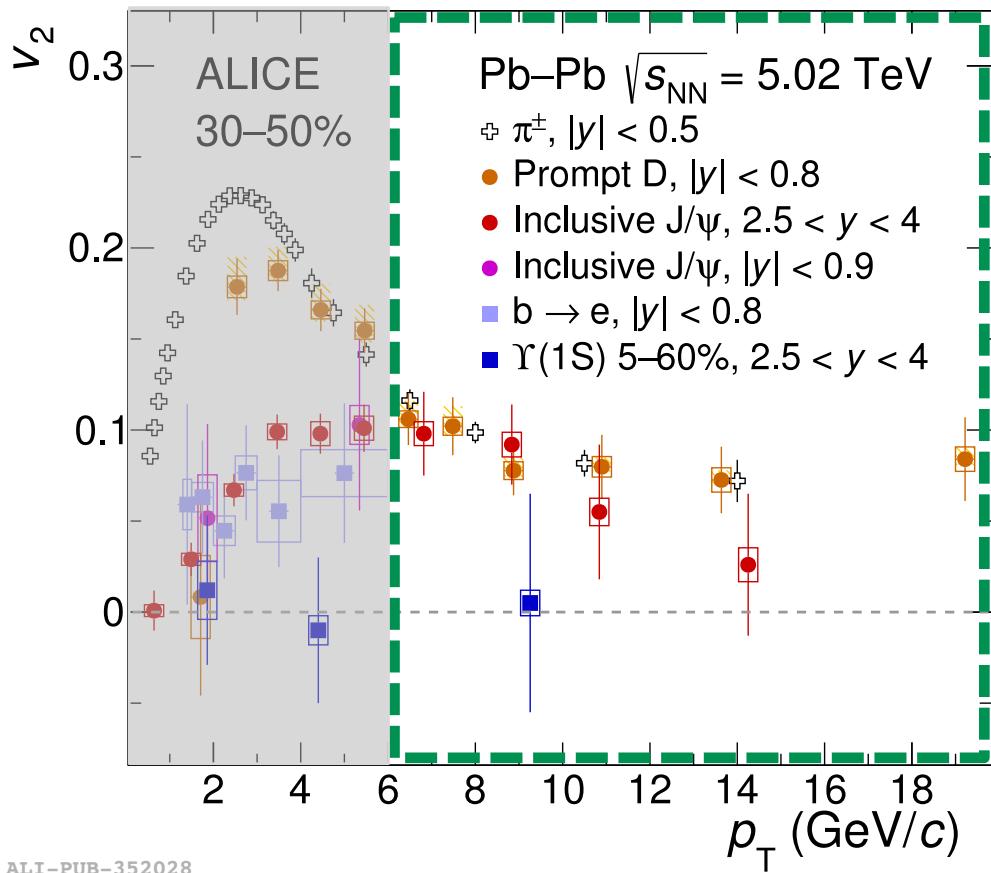
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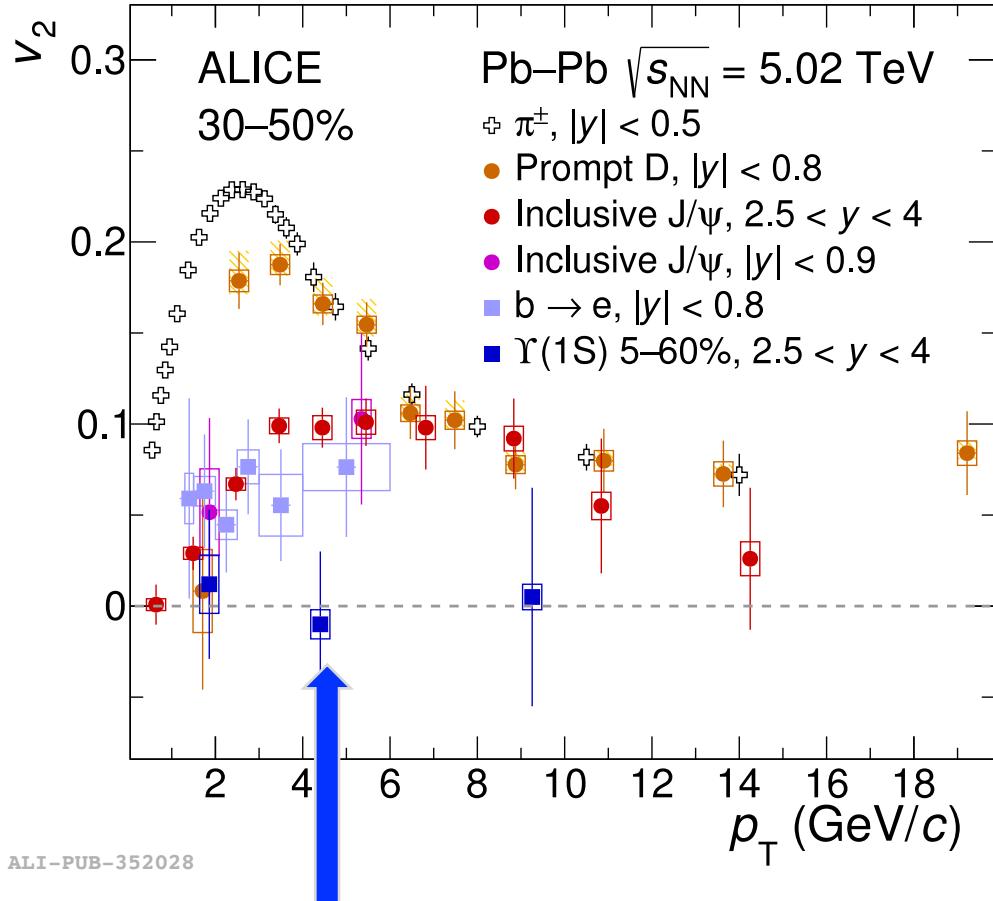
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- Similar path-length energy loss for heavy and light quark



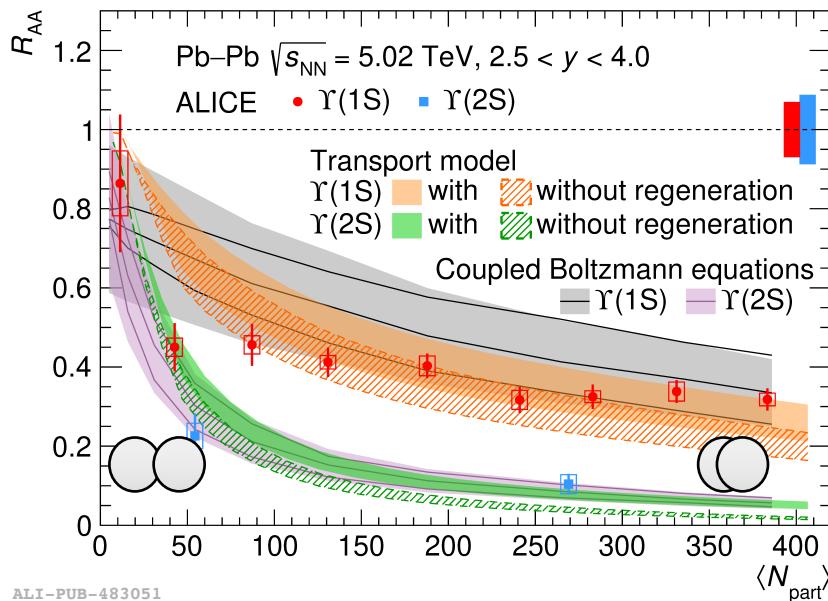
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- **No flow from  $\Upsilon$ :** expected from smaller regeneration contribution



## ➤ Botomonia heavily suppressed

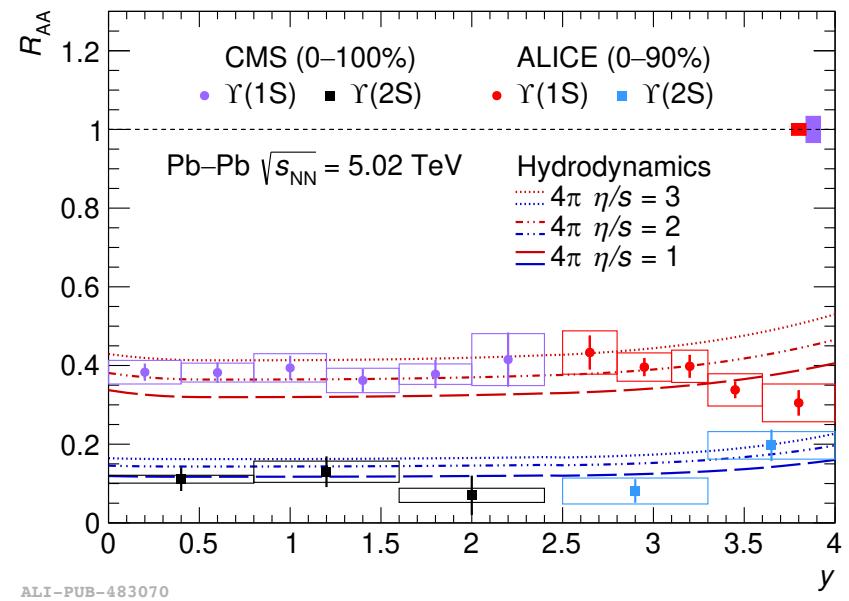
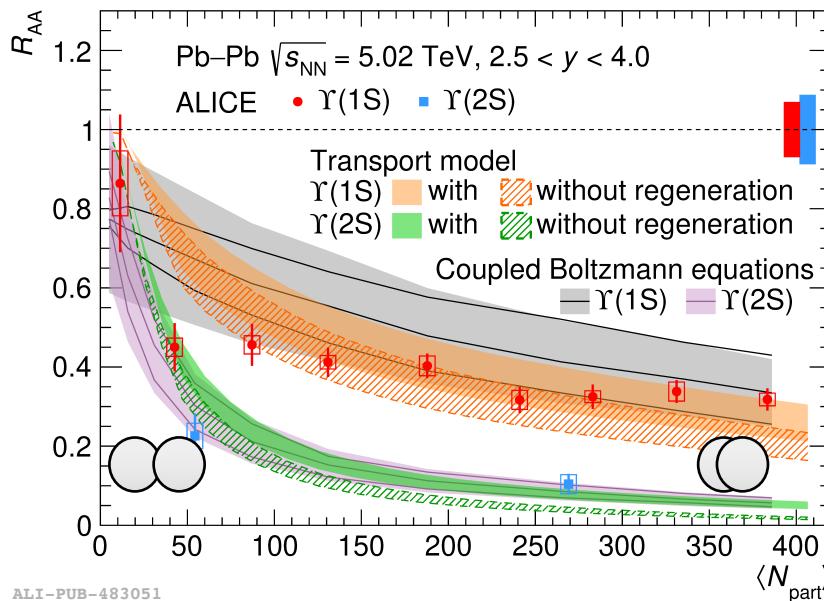
- $\Upsilon(1S)$  suppressed by a factor 3 w.r.t p-p
- $\Upsilon(2S)$  suppressed by a factor 2-3 w.r.t  $\Upsilon(1S)$



# Botomonia production in Pb-Pb

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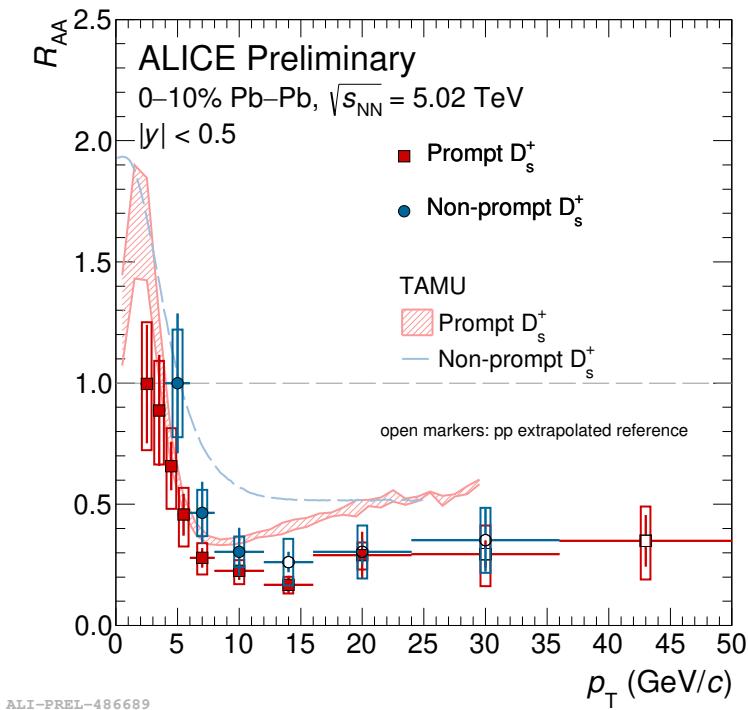
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## ➤ Intriguing reversal trend as a function of rapidity

# Heavy quarks, energy loss and hadronization mechanism

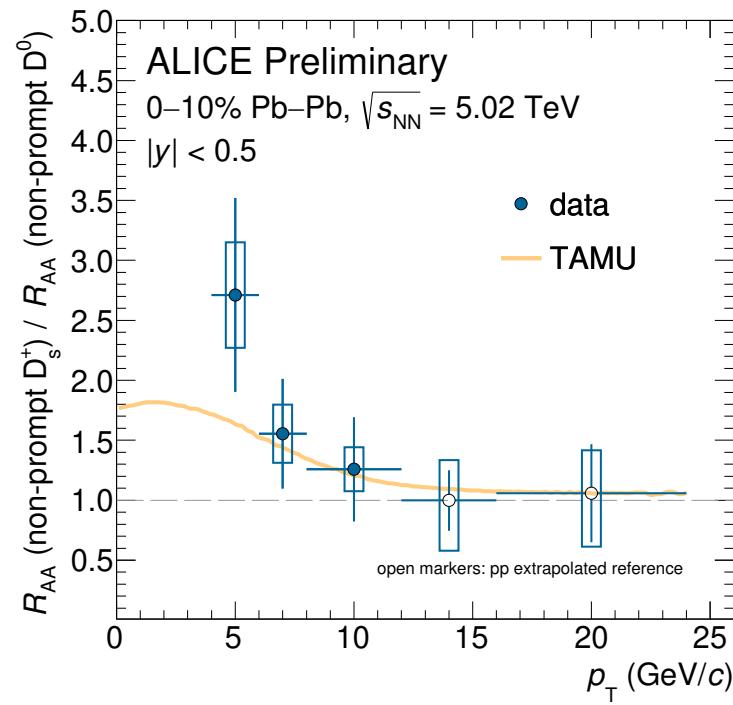
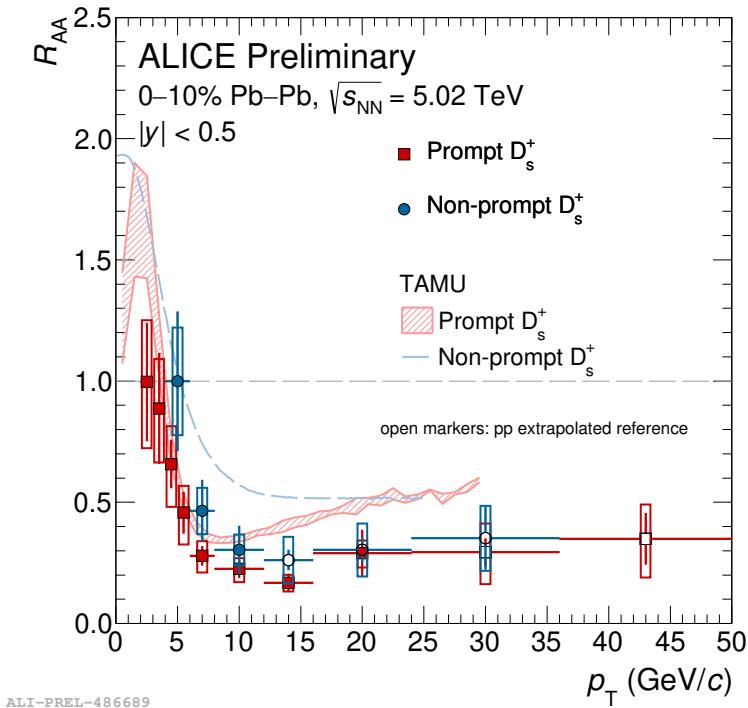
- Beauty loses less energy in QGP compared to charm
  - Dead-cone effect!



- $R_{AA}$  follows expectations

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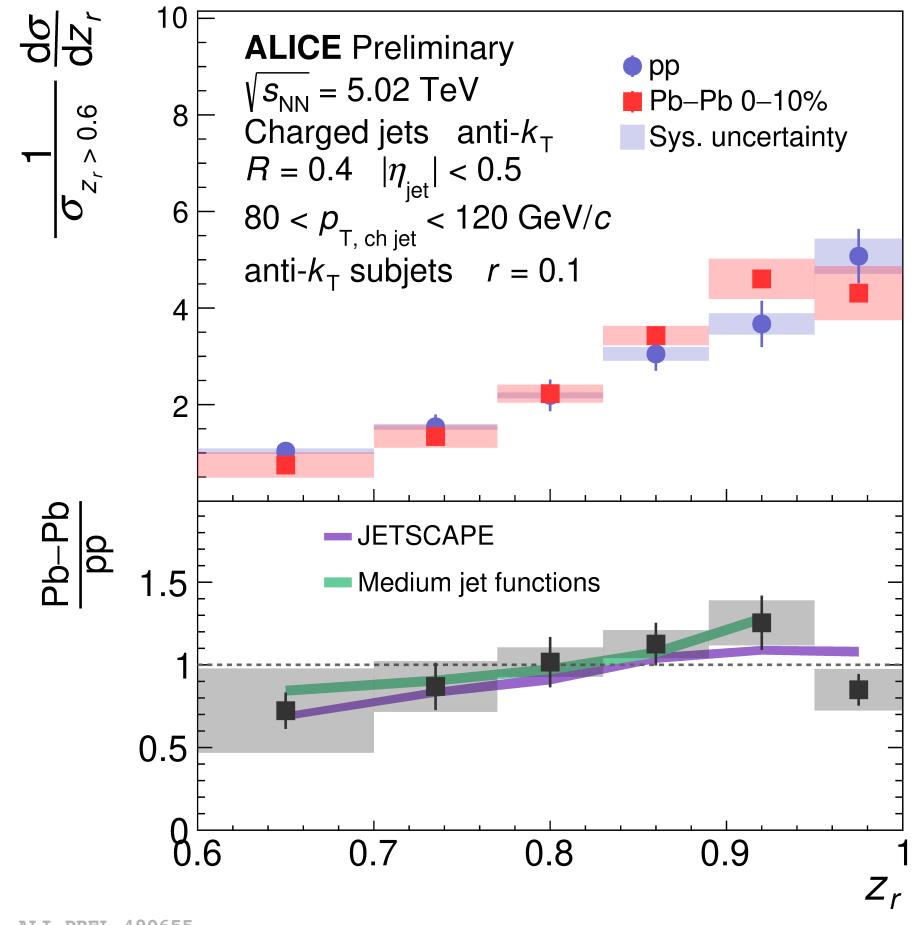
- $R_{AA}$  follows expectations
- $B_s^0$  enhanced from beauty hadronization via coalescence

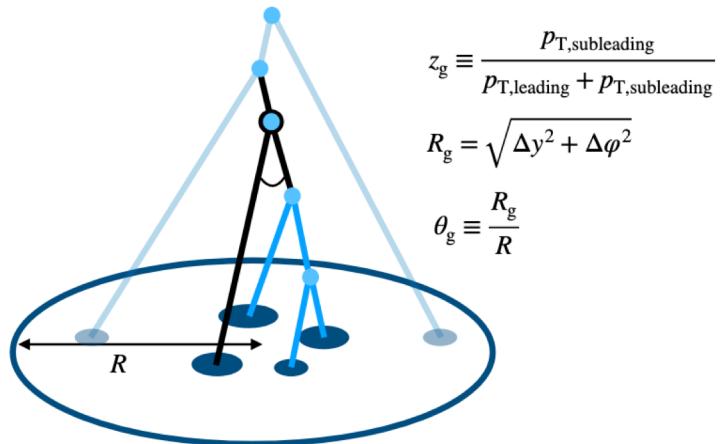
# Studying jet substructures in central *Pb-Pb collisions (I)*



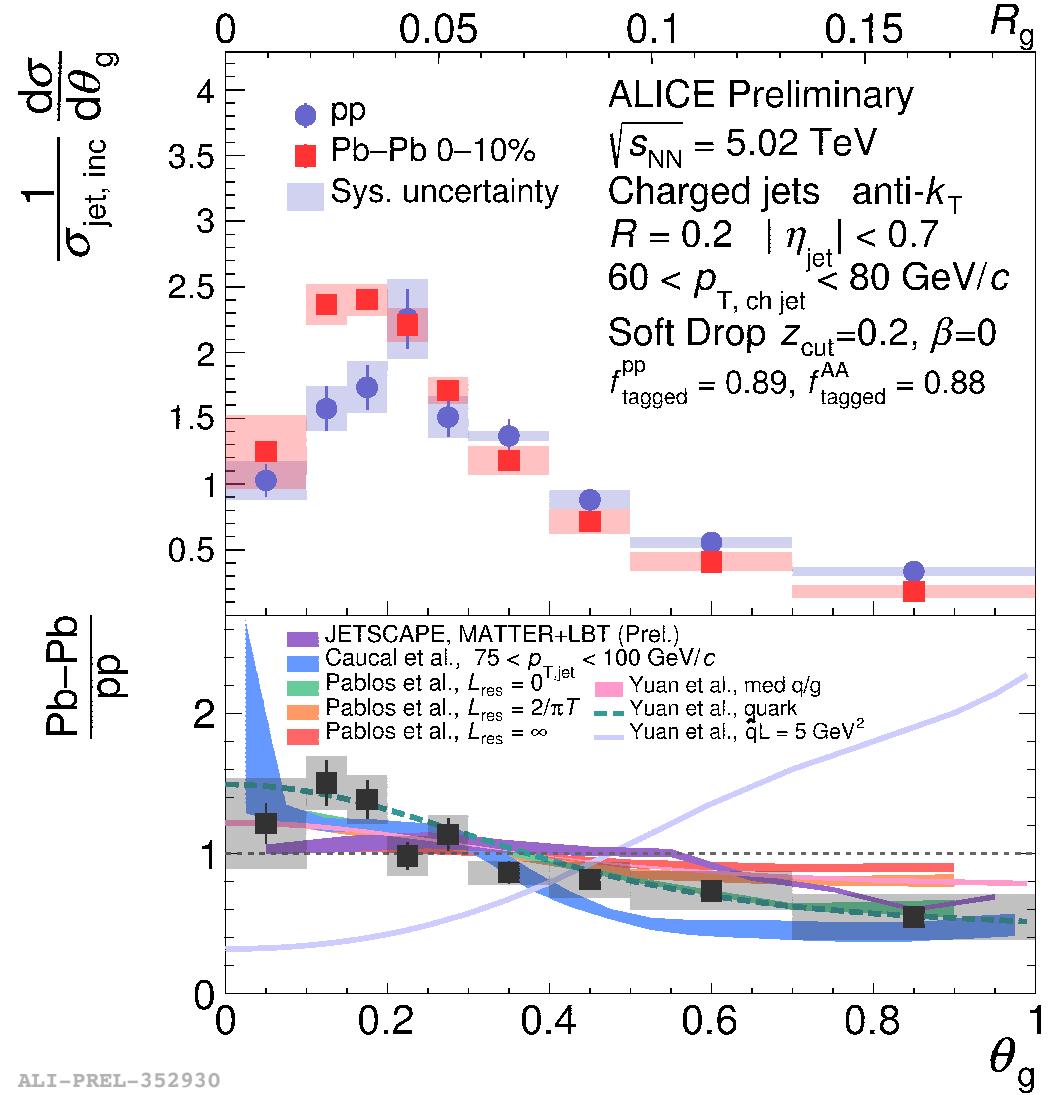
$$z_r = \frac{p_T^{\text{ch subjet}}}{p_T^{\text{ch jet}}}$$

- Groomed jet substructures
- Redistribution of energy from leading subjet
  - Collimation
  - $z_r \sim 1$  suppression
- May be sensitive to quark vs. gluon jet in medium energy loss at high  $z_r$



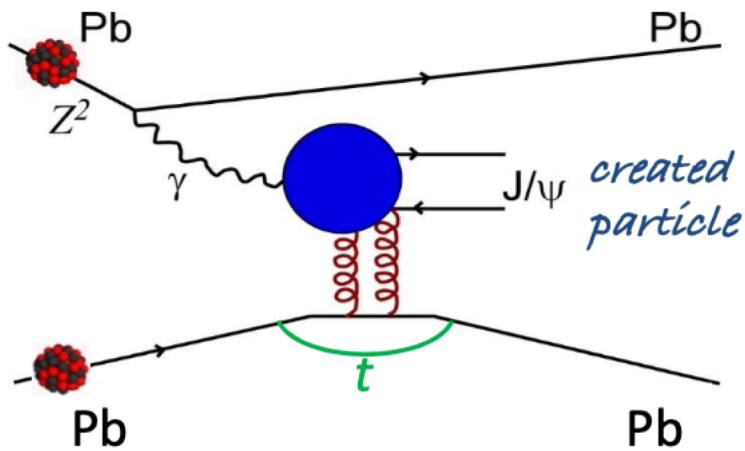


- Sensitive to path length and coherence effects
  - Jet hard core is narrower



# *J/ψ coherent photoproduction in Pb-Pb UPC events*

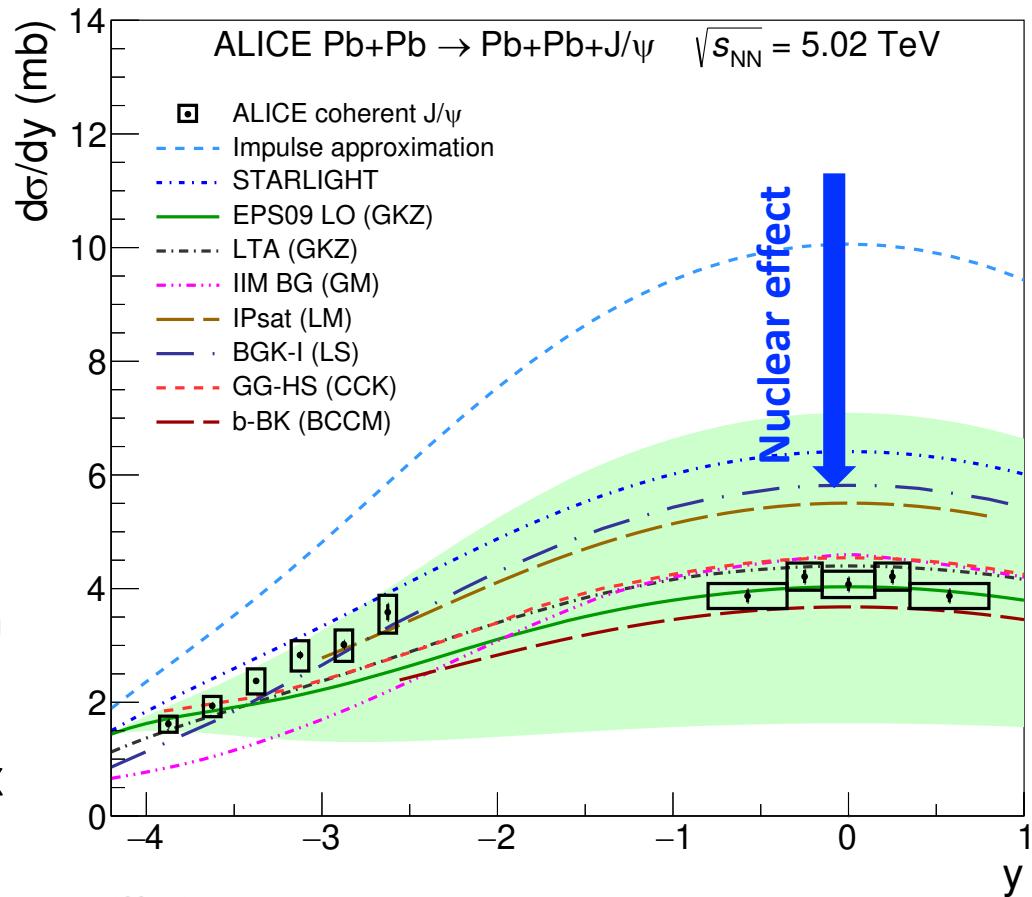
## ➤ Probing nuclear gluon density



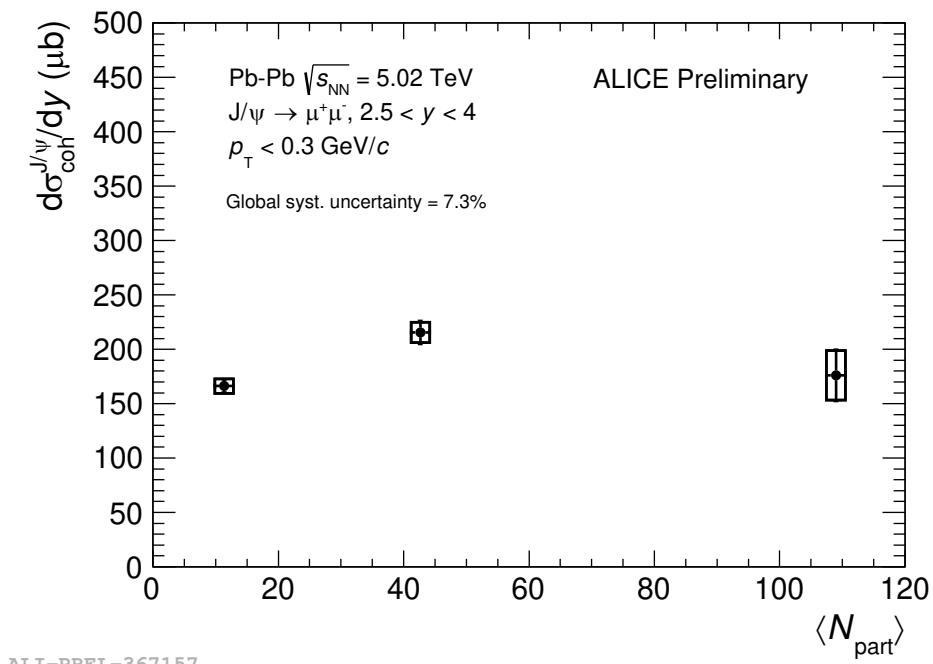
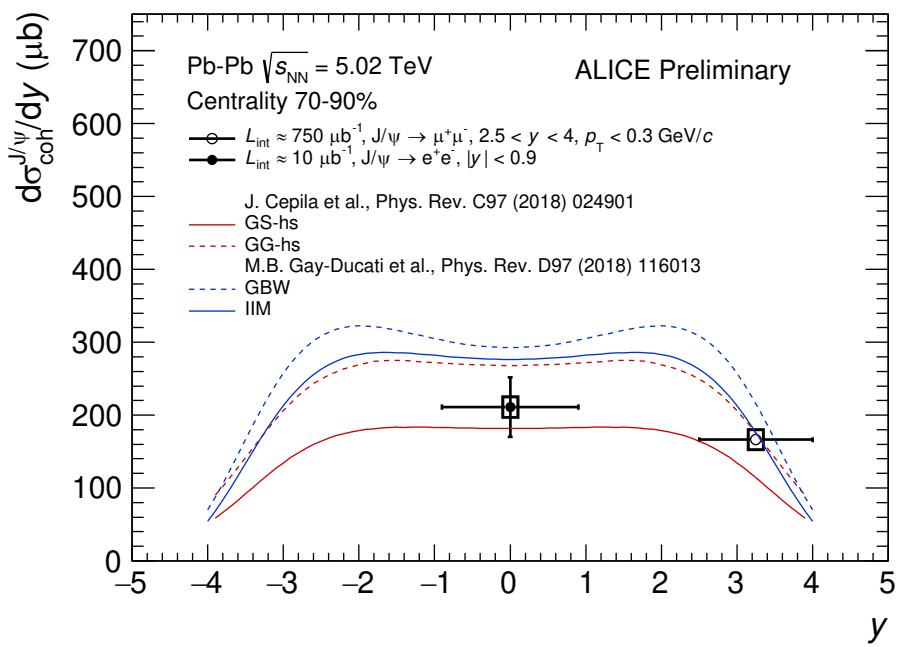
- Cross section sensitive to gluon distribution function

## ➤ New measurement probes low- $x$ gluon nuclear PDFs

- Extracted gluon shadowing factor:  $R_g = 0.65 \pm 0.03, x \sim 10^{-3}$



- Extraction as a function of centrality down to 30-50%
  - Measurement of coherent  $J/\Psi$  photoproduction
  - May open the door for new probes for QGP



ALI-PREL-367210

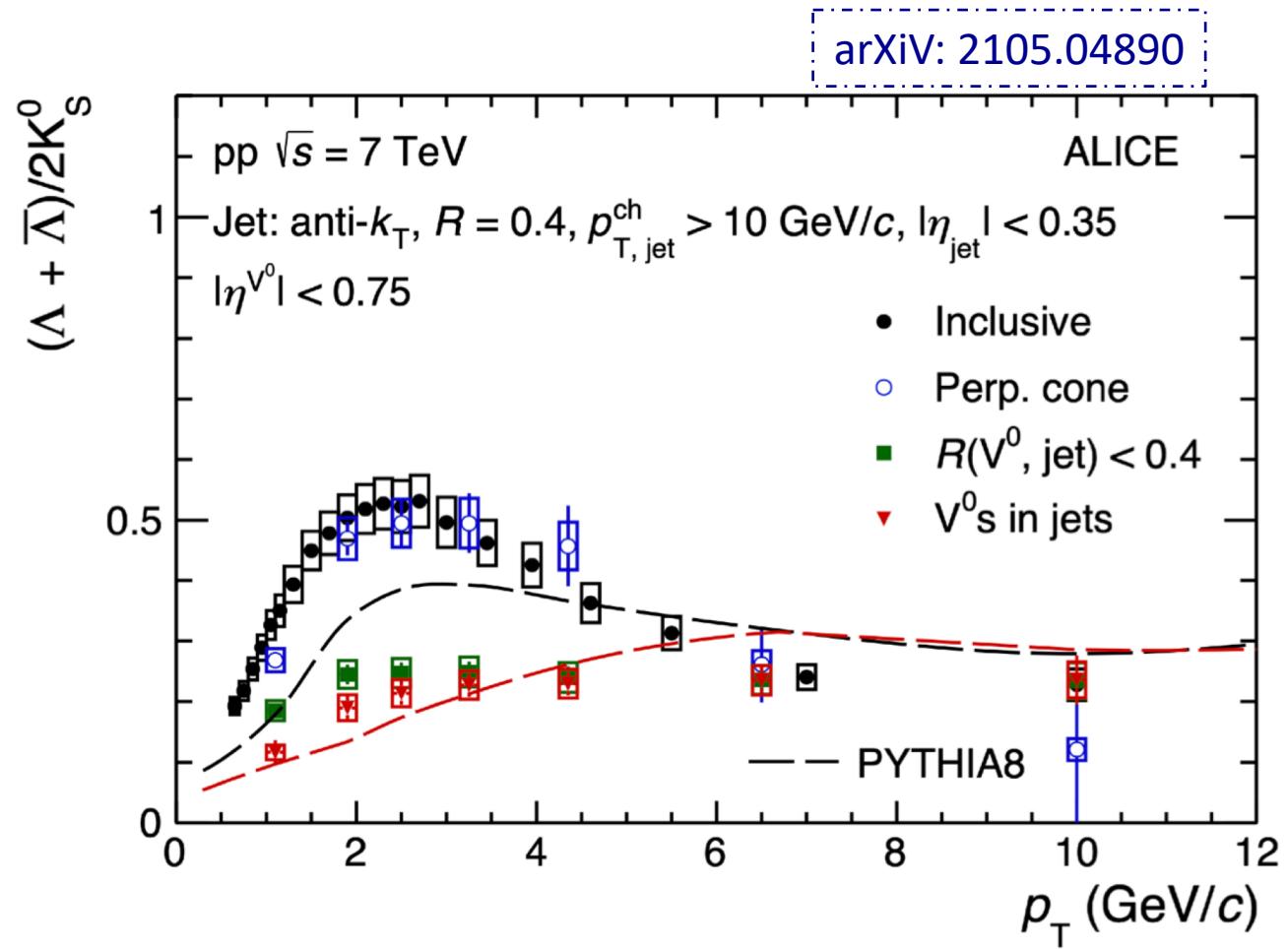
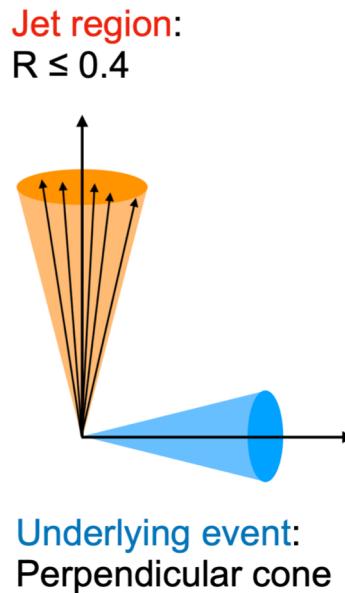
ALI-PREL-367157

## **Rencontres QGP-France**

### **Etretat 5-8 juillet 2021**

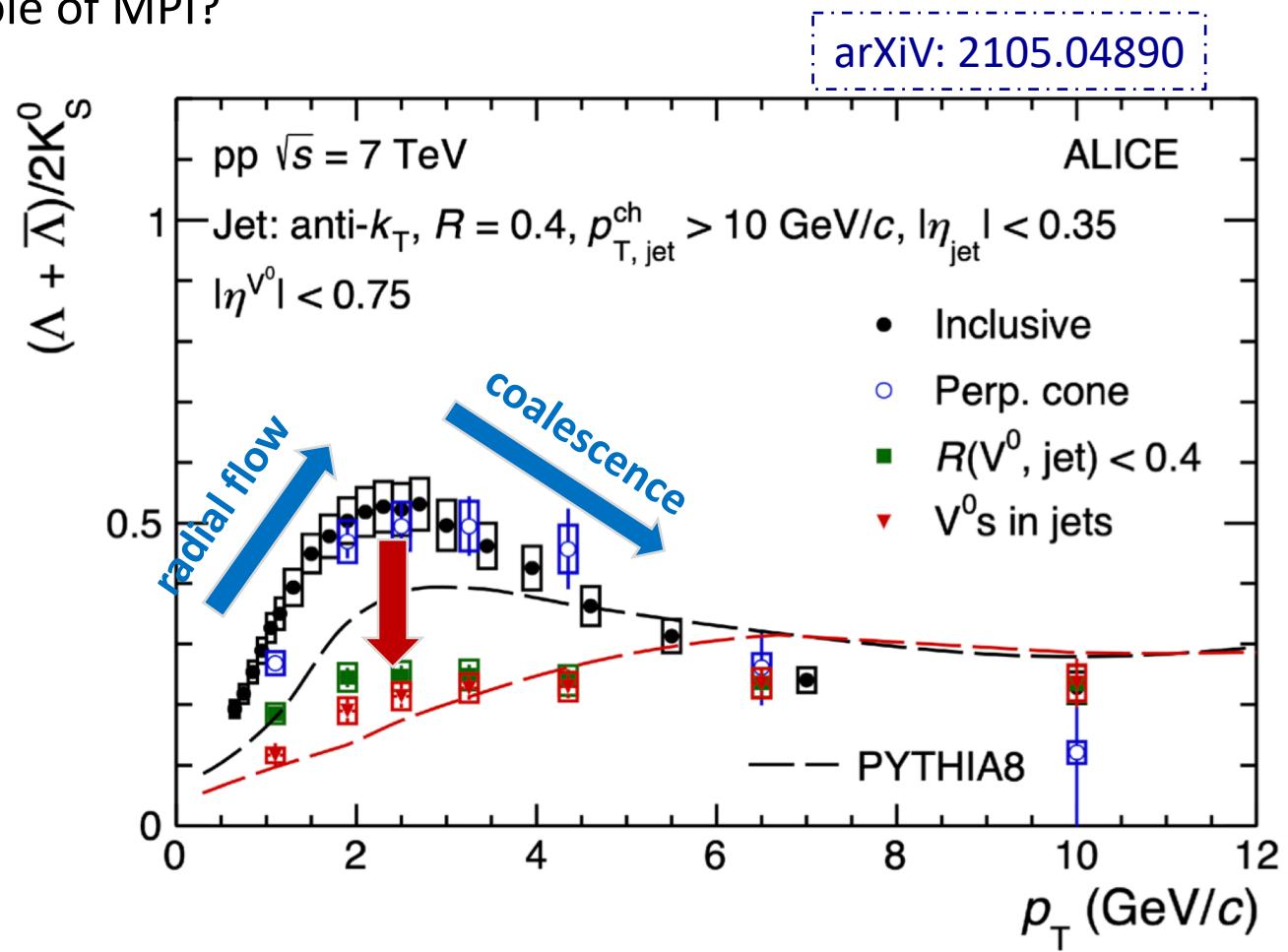
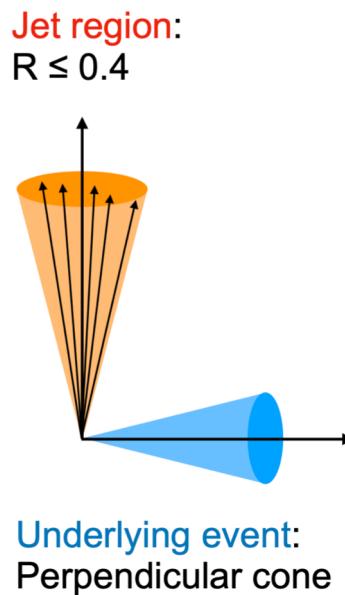


# Strangeness enhancement



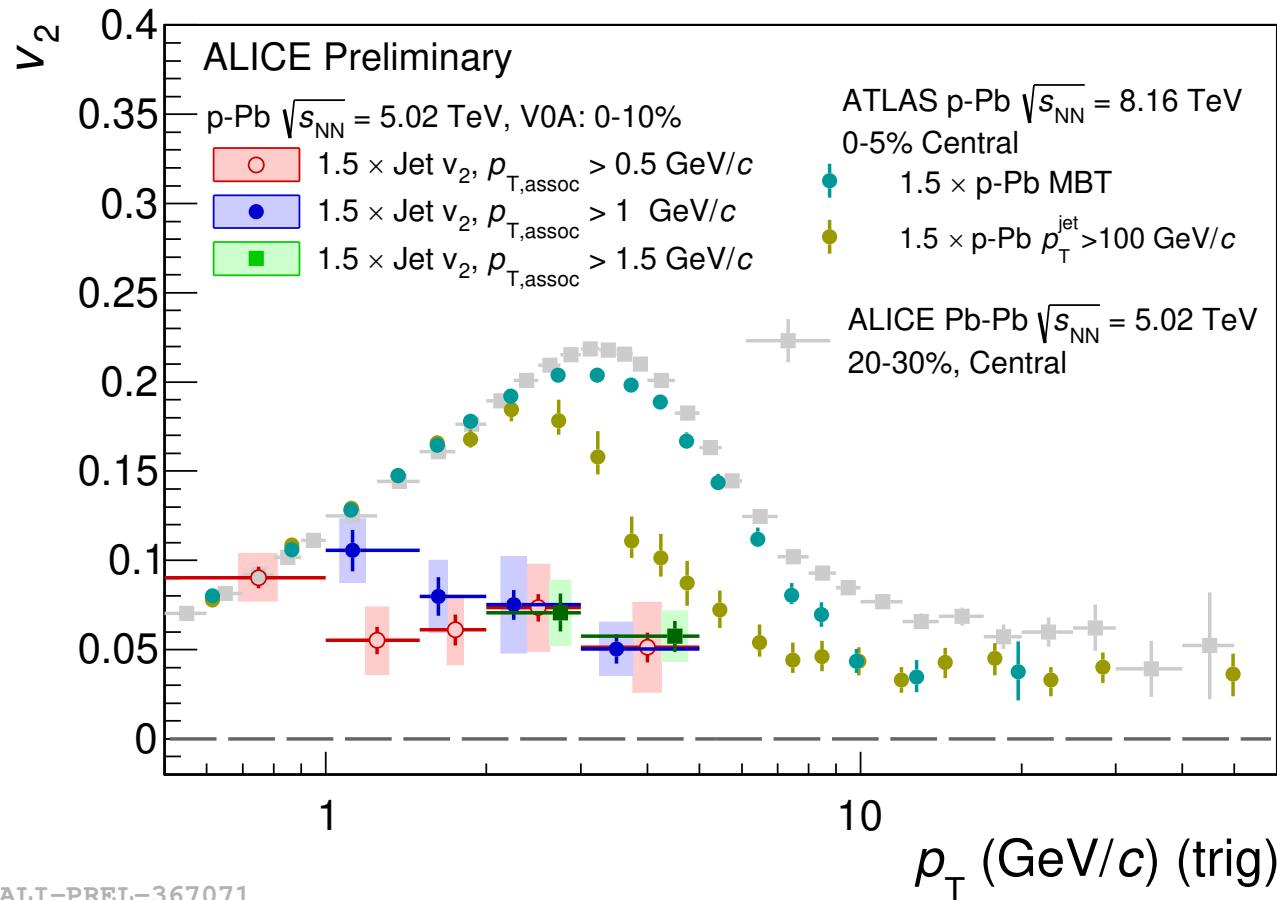
# Strangeness enhancement

- Small relative contribution from jet to strangeness production
  - UE dominant – role of MPI?



# $v_2$ of jet associated particles

- Azimuthal flow ( $v_2$ ) observed for jet associated particles
  - Not expected from jet quenching/e-loss in small systems
  - Comparable to high- $p_T$   $v_2$  in p-Pb and Pb-Pb



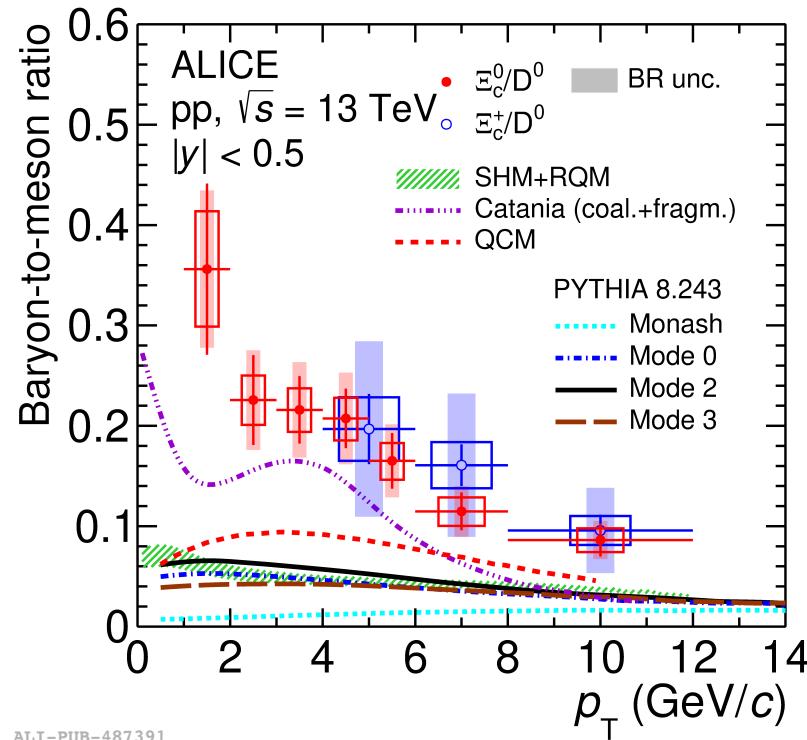
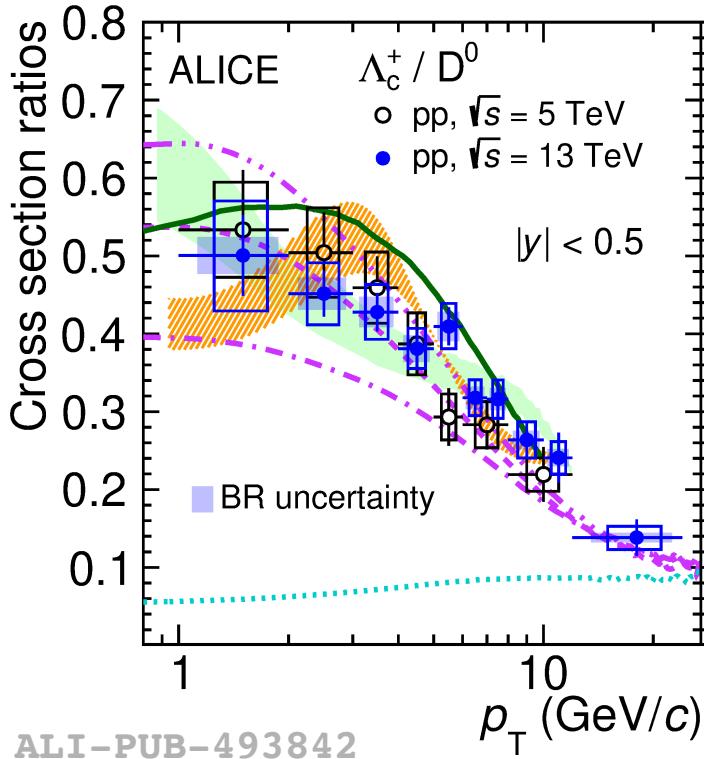
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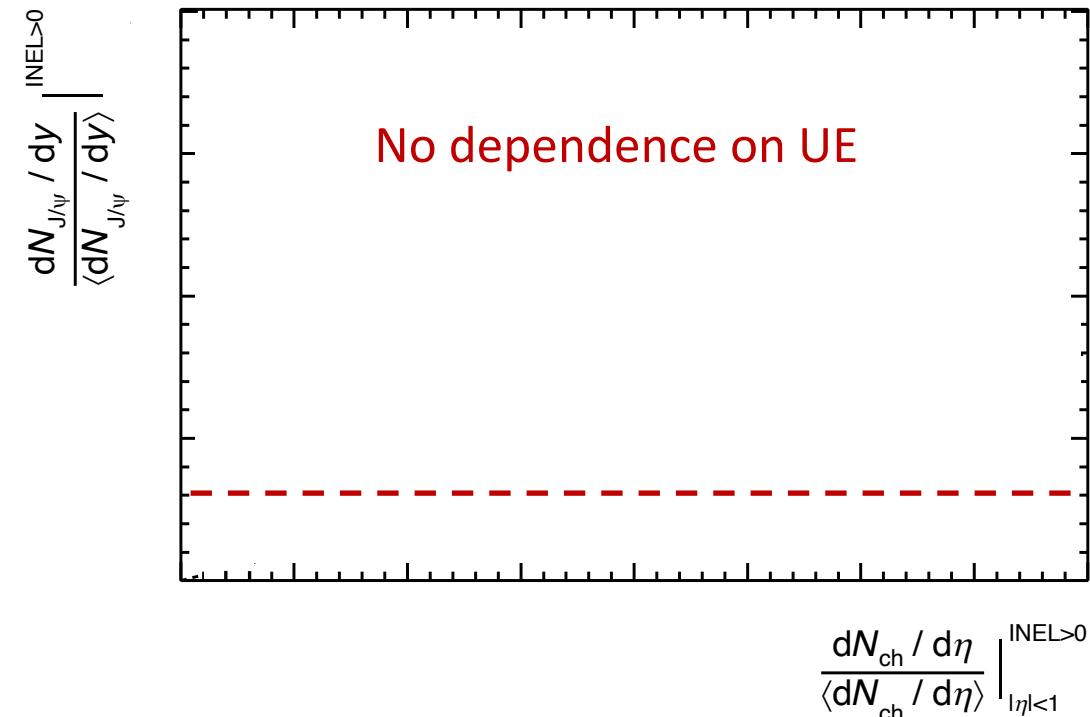


# Charmed baryons

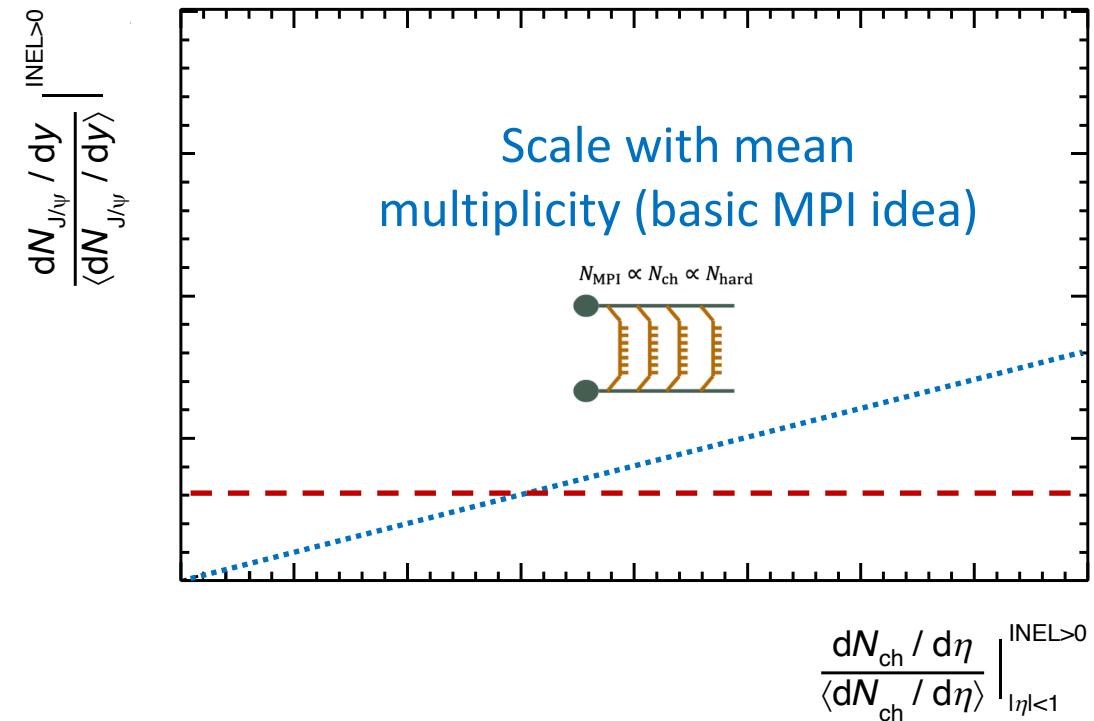
- Cross section larger than expected
  - Breaking universality between colliding systems
- Baryon/meson ratio: similar features
  - Characteristic for parton (re-)combination at hadronization



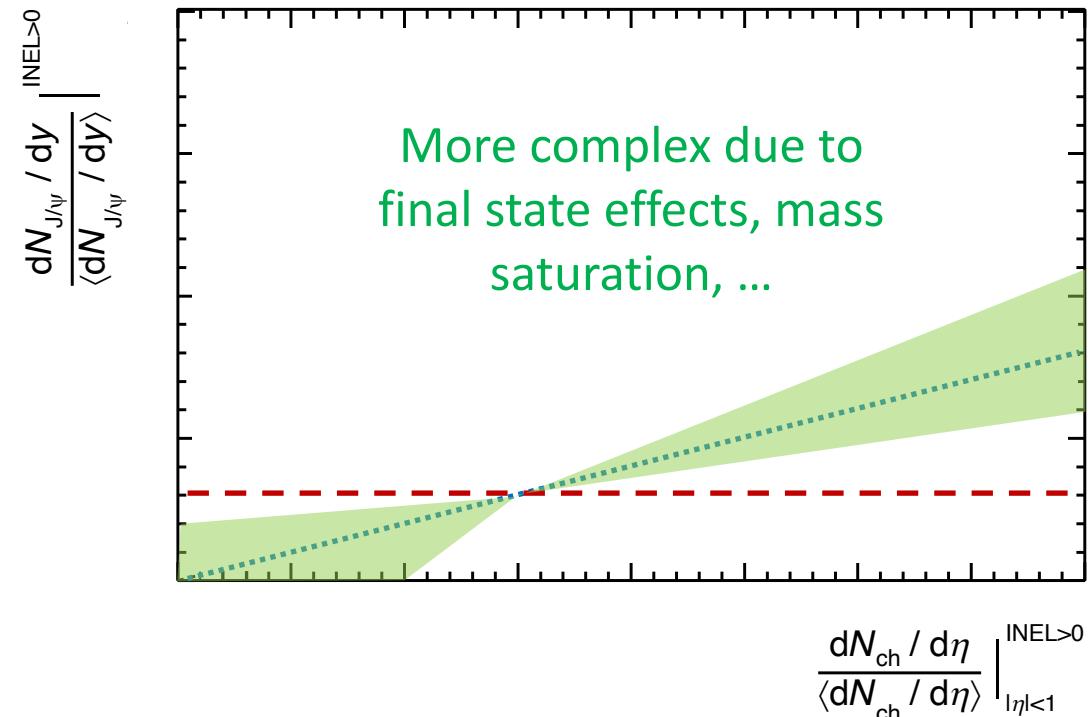
# Quarkonia multiplicity dependence



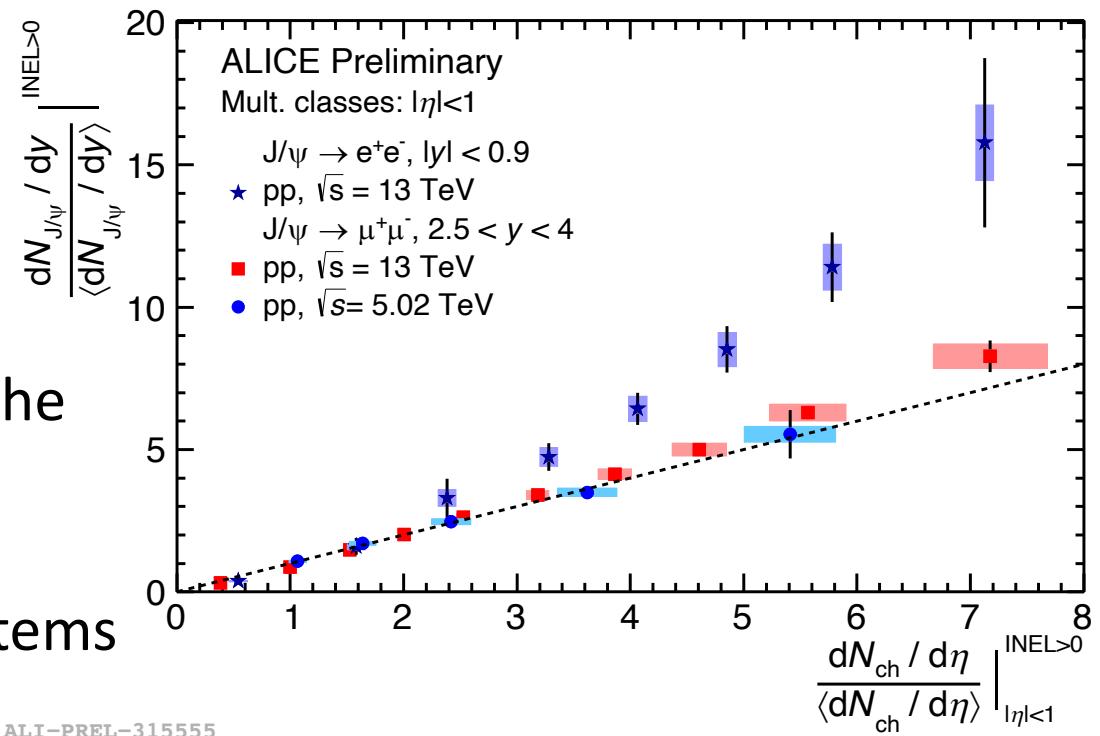
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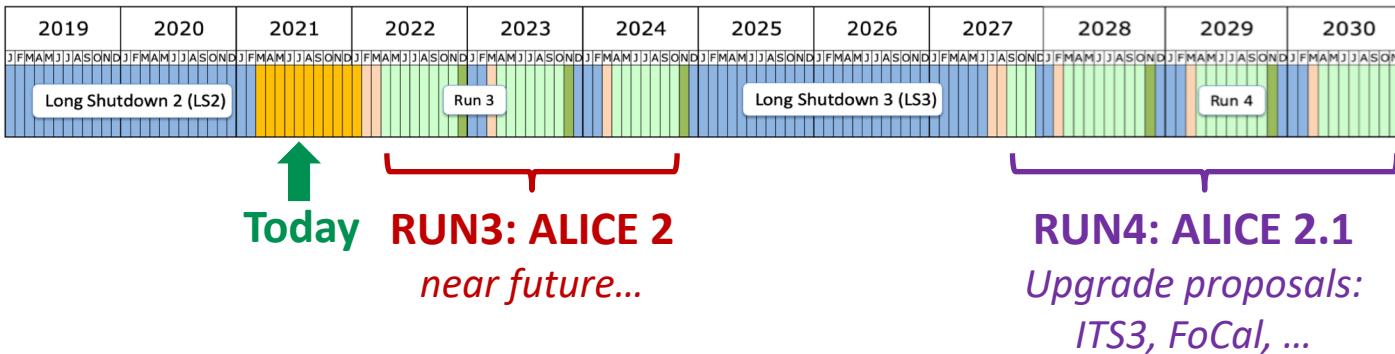
# Quarkonia multiplicity dependence



- Non trivial correlation in ALICE central barrel
  - Correlation similar using mid-rapidity or forward multiplicity estimator
  - No model able to reproduce this qualitatively
- Forward rapidity
  - With central multiplicity estimator
  - Linear trend observed
  - No energy dependence
- Important to understand the interplay soft-hard here
- More results for other systems and particles

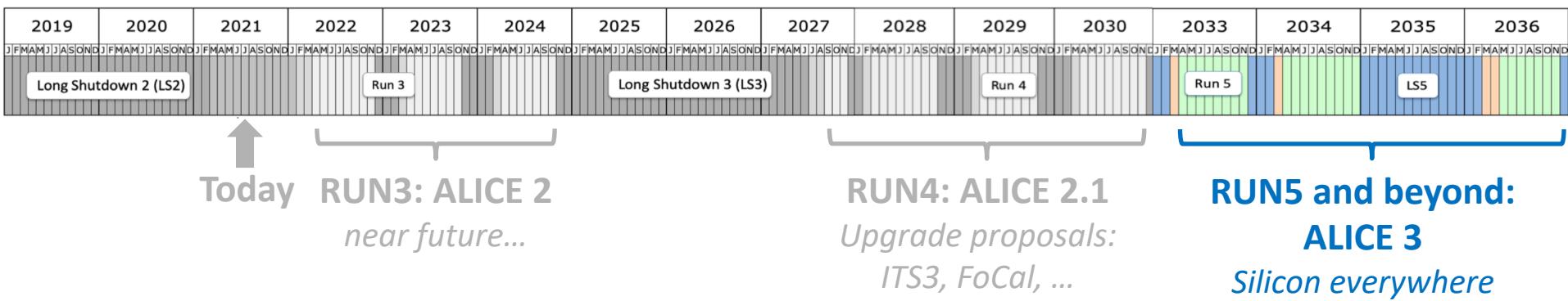


# RUN3 ALICE upgrades & beyond



- Starting from RUN3: *New ALICE data taking strategy*
  - 50 kHz Pb-Pb event readout rate (~1 kHz in central barrel previously)
  - Up to 1 MHz p-p event readout rate
- Implementation
  - Untriggered data sample: **Continuous readout**
  - Improve tracking efficiency and momentum resolution at low- $p_T$ : **ITS2 & MFT**
  - Preserve PID capabilities
  - Synchronous data processing (reconstruction and calibration): **New Online/Offline ( $O^2$ ) farm**

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# ALICE 2: New setup

## Inner Tracking System 2 (ITS2)

- CMOS pixel, MAPS technology
- Improved resolution, less material, faster readout

## New Muon Forward Tracker (MFT)

- CMOS pixel, MAPS technology
- Vertex tracker at forward rapidity

## New TPC Readout Chambers (ROCs)

- GEM technology
- New electronics (SAMPA), continuous readout

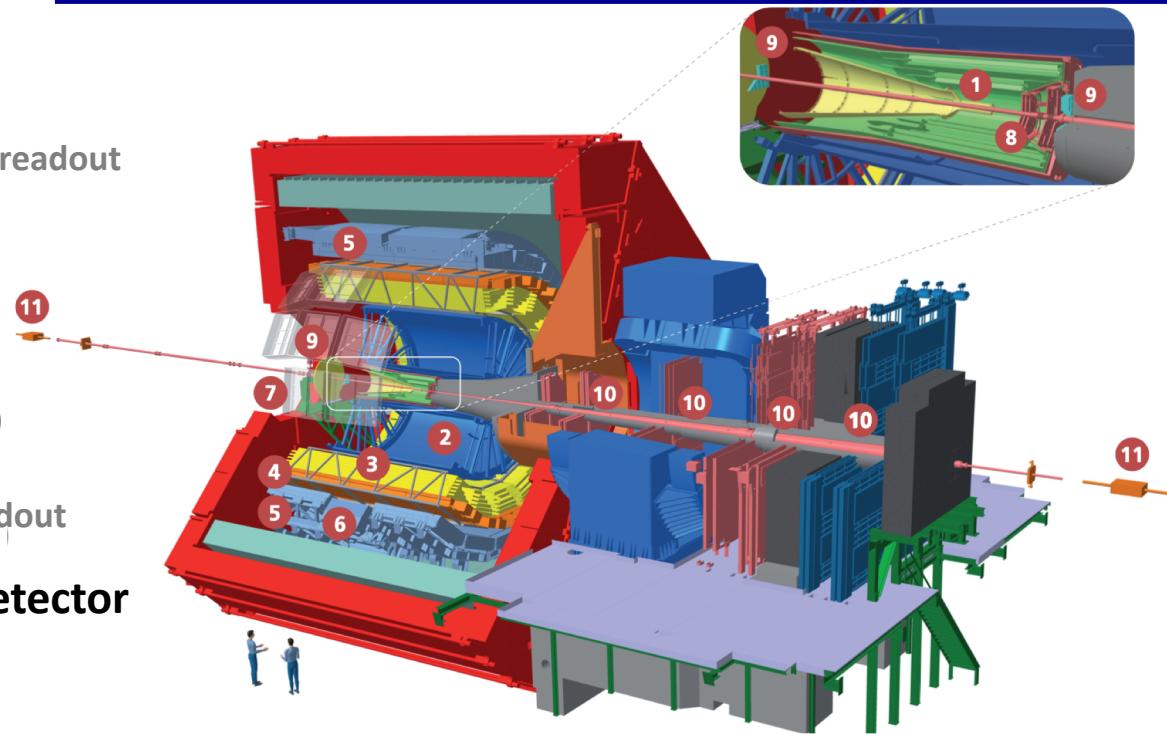
## New Fast Interaction Trigger (FIT) detector

- Centrality, event plane, luminosity, ...

## Integrated Online-Offline system (O2)

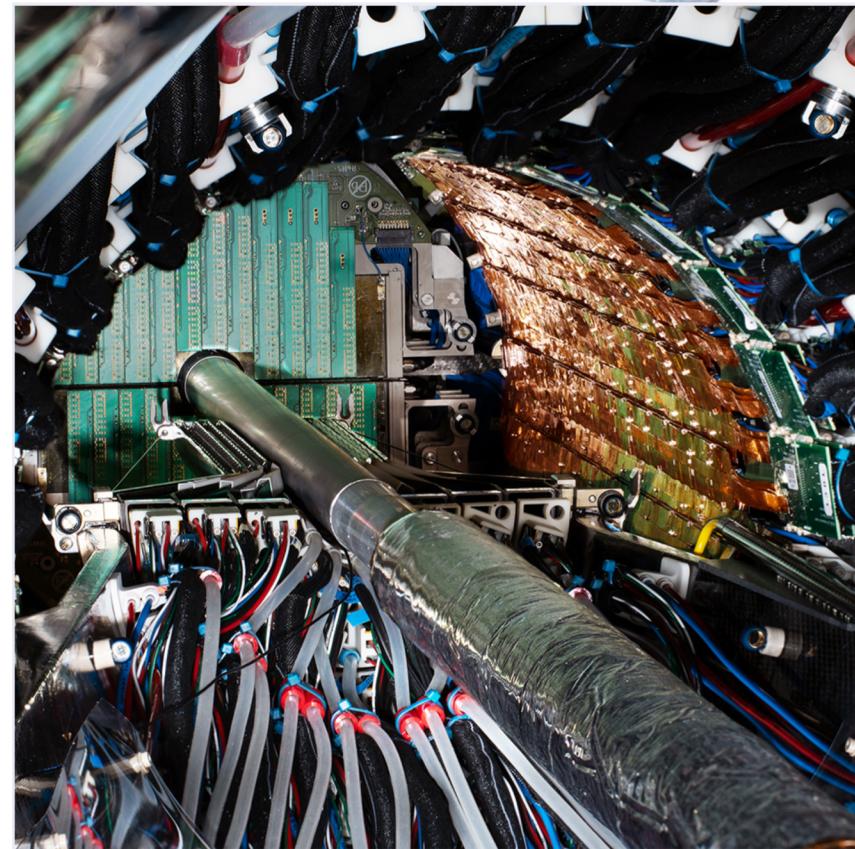
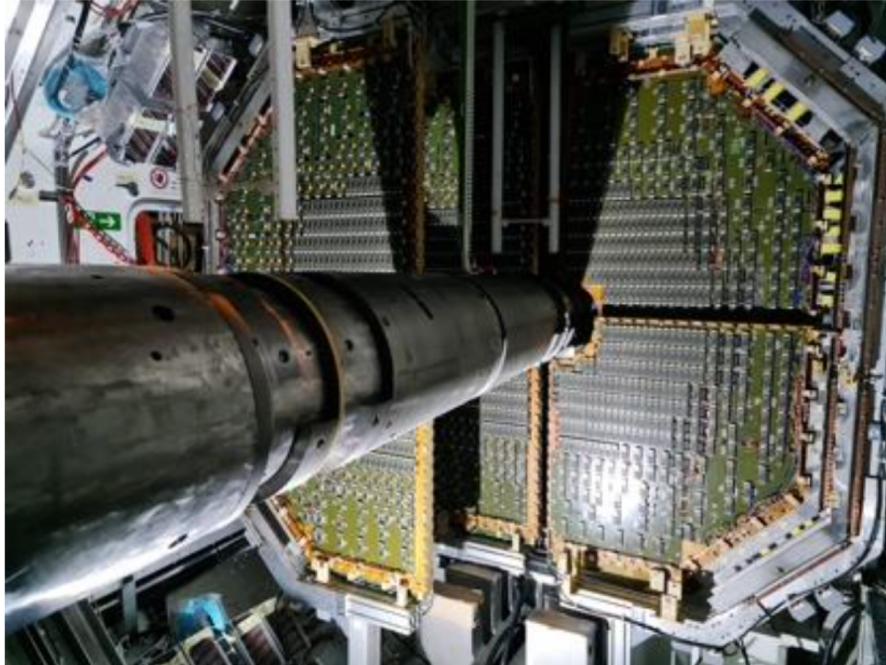
## Readout upgrade for all other detectors

- TOF, TRD, MUON, ZDC, calorimeters



- |    |  |    |   |
|----|--|----|---|
| 1  | <b>ITS  </b> Inner Tracking System         | 6  | <b>PHOS / CPV  </b> Photon Spectrometer                       |
| 2  | <b>TPC  </b> Time Projection Chamber       | 7  | <b>HMPID  </b> High Momentum Particle Identification Detector |
| 3  | <b>TRD  </b> Transition Radiation Detector | 8  | <b>MFT  </b> Muon Forward Tracker                             |
| 4  | <b>TOF  </b> Time Of Flight                | 9  | <b>FIT  </b> Fast Interaction Trigger                         |
| 5  | <b>EMCal  </b> Electromagnetic Calorimeter | 10 | <b>Muon Spectrometer</b>                                      |
| 11 |  | 11 | <b>ZDC  </b> Zero Degree Calorimeter                          |

# Some pictures...



# Conclusion

- Still some exciting results coming out of RUN1-2 data
  - Large variety of observable from soft to hard probes
  - More to come this week ☺
- RUN3 is around the corner with major physics goals
  - Heavy flavour hadrons down to low  $p_T$
  - Charmonium states
  - Low mass vector mesons and dileptons from QGP thermal radiations
  - High-precision measurement of light and hyper nuclei
- Target luminosity for RUN3+4

| Collision system                            | Luminosity            |
|---|-----------------------|
| Pb-Pb @ $\sqrt{s_{NN}}=5 - 5.5 \text{ TeV}$ | $13 \text{ nb}^{-1}$  |
| p-Pb @ $\sqrt{s_{NN}}=8 - 8.8 \text{ TeV}$  | $0.6 \text{ pb}^{-1}$ |
| p-p @ $\sqrt{s_{NN}}=14 \text{ TeV}$        | $200 \text{ pb}^{-1}$ |

Thanks...