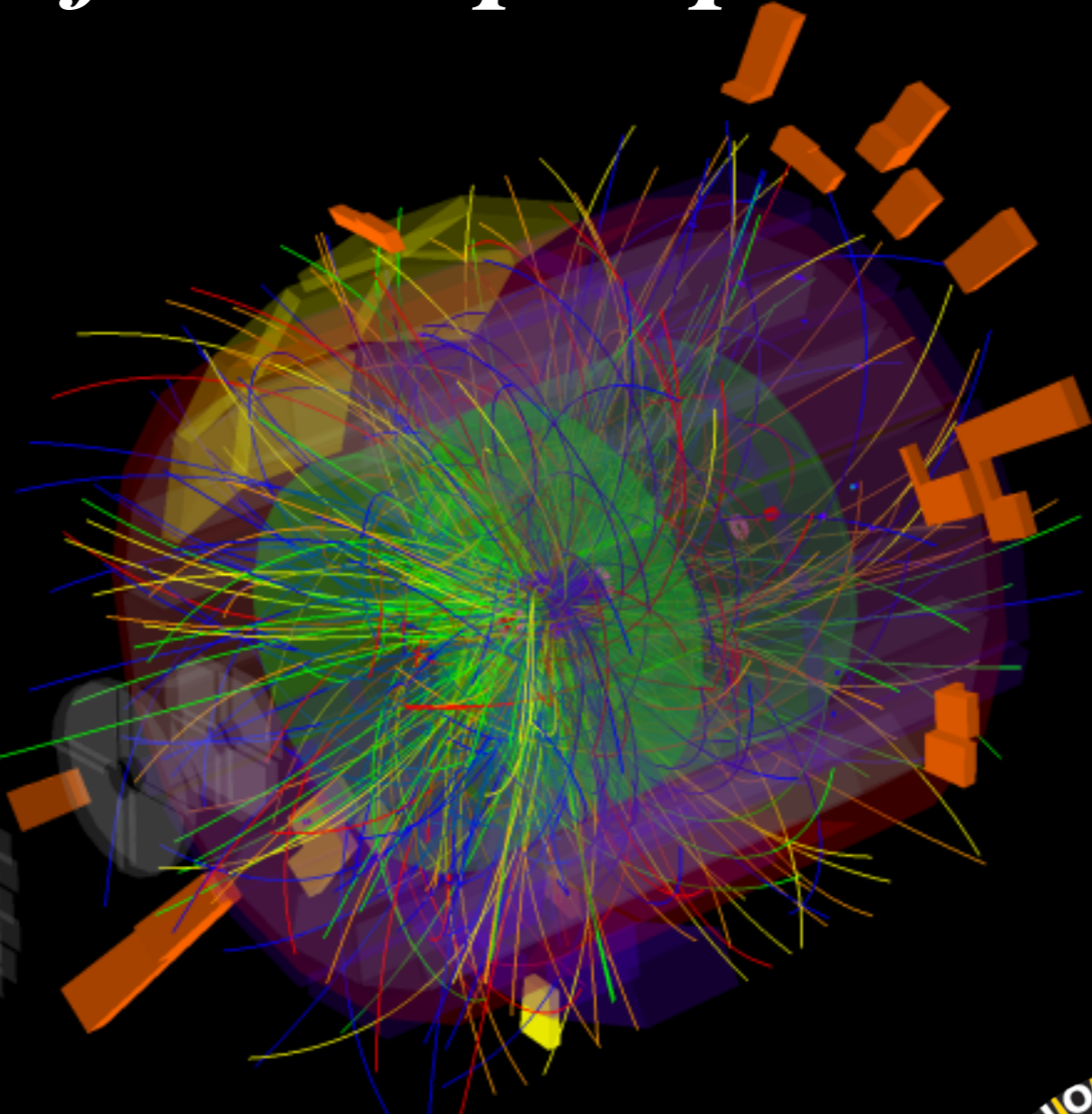




ALICE

ALICE at the LHC

Heavy-flavour perspective



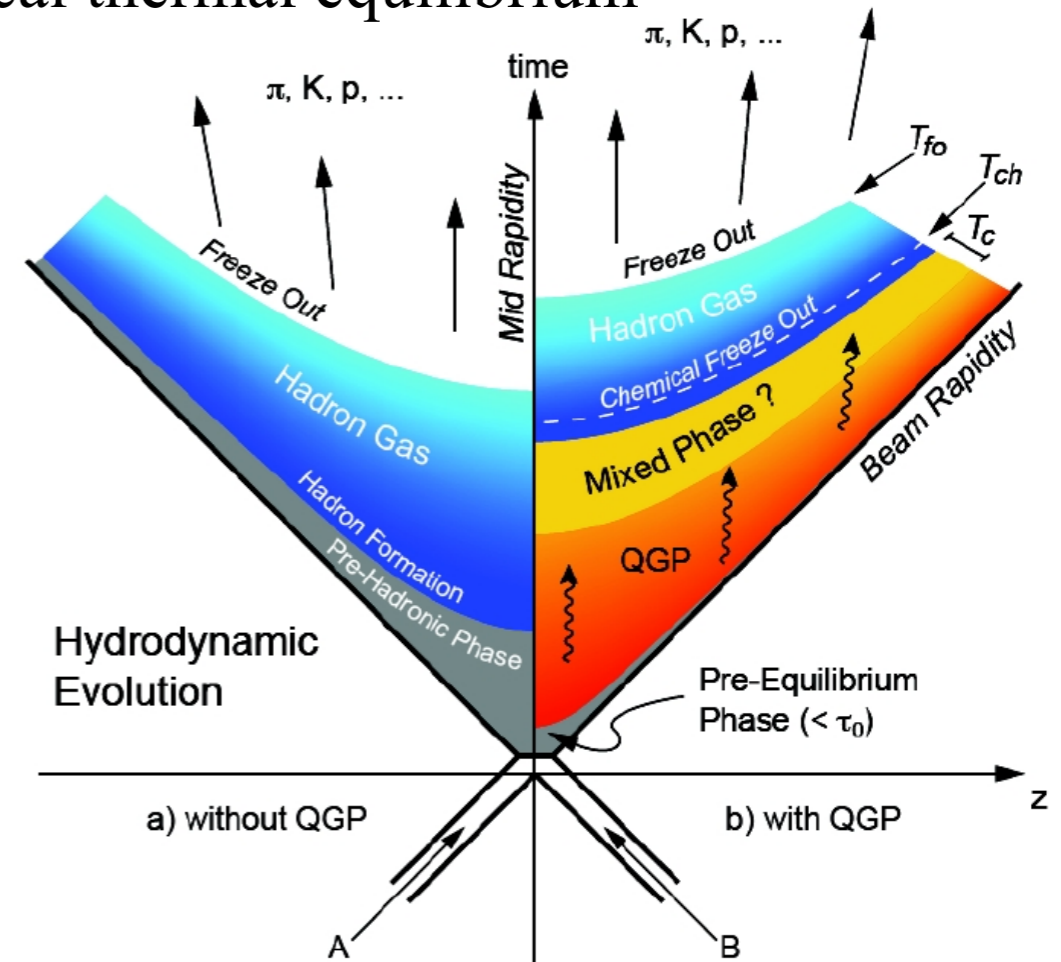
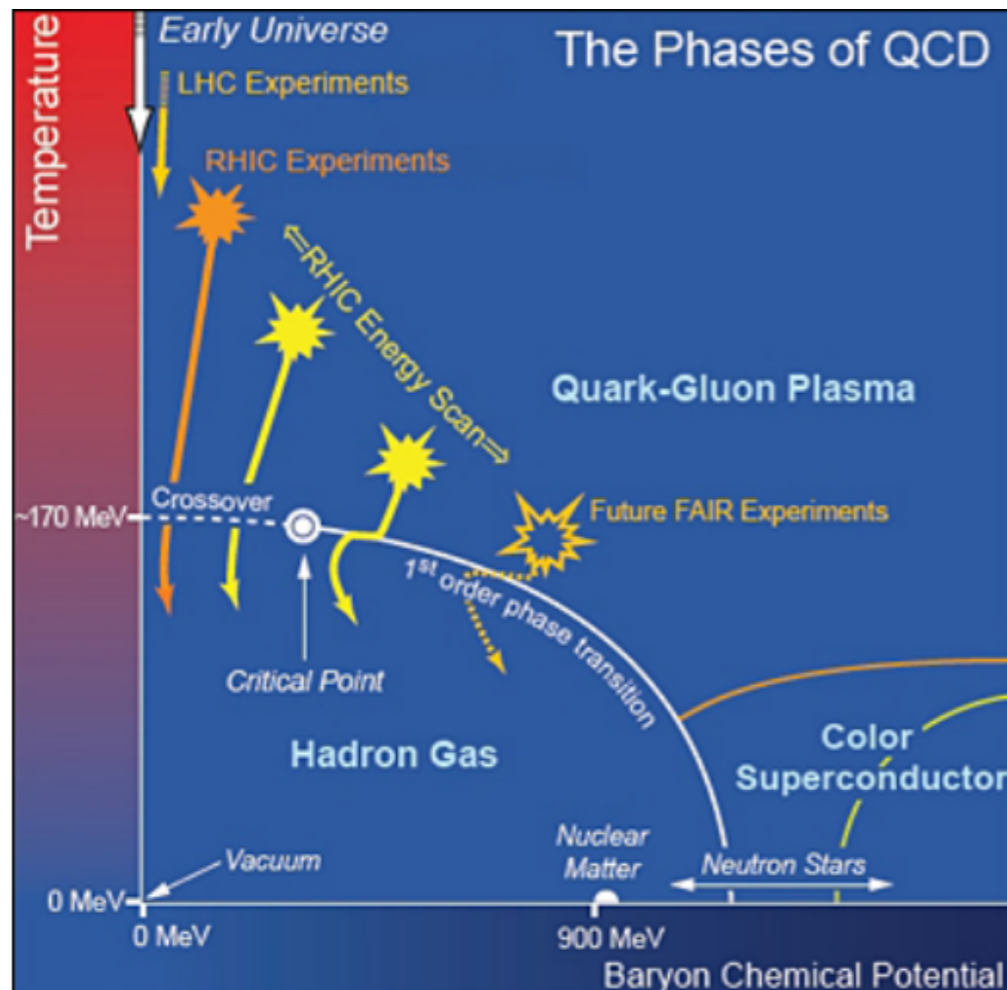
Cristina Bedda
Barbara Trzeciak
Utrecht University

December 12th, 2017



ALICE: Probing the QGP properties

- ✓ **Quark-Gluon Plasma (QGP)** - new state of matter with liberated quarks and gluons
 - Early evolution of the Universe
 - Can be created in high-energy heavy-ion collisions
 - LHC: high temperature, low baryon chemical potential (~ 0)
 - Phase transition to a deconfined state
 - System of strongly interacting matter, local thermal equilibrium



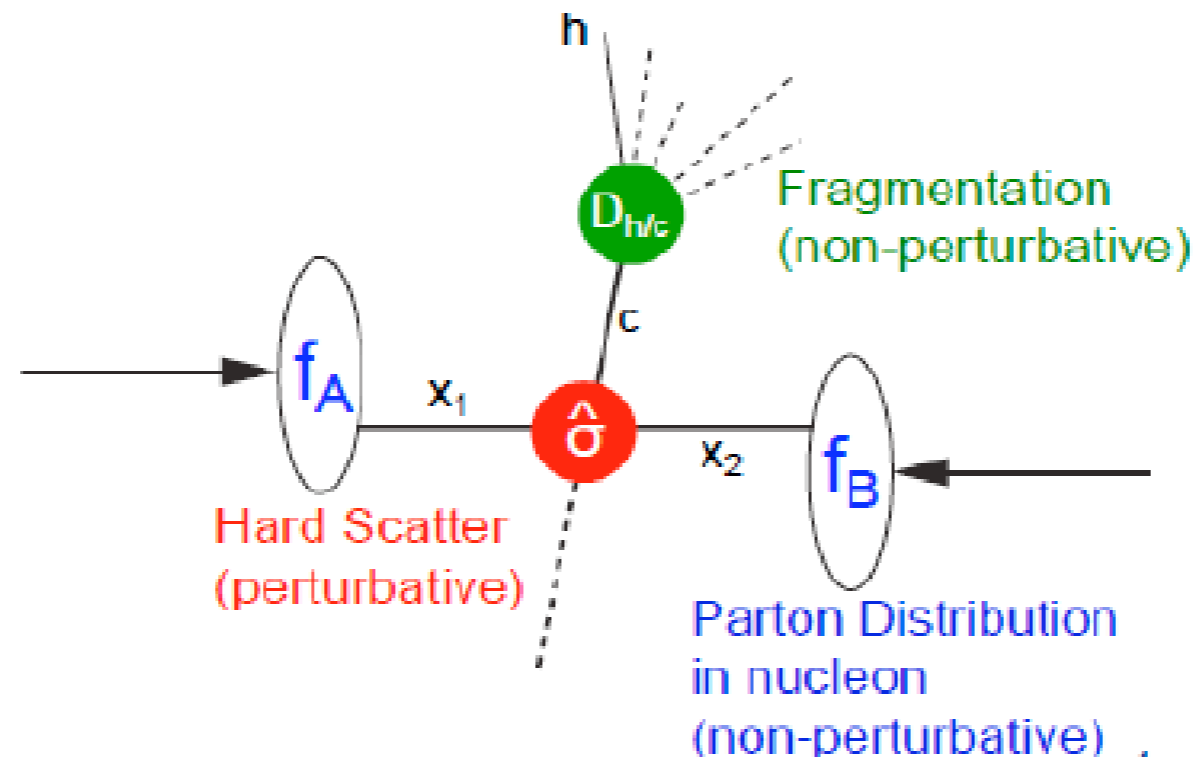
What probe to use to characterize the properties of the QGP ?



Heavy c and b quarks

Large masses $\gg \Lambda_{\text{QCD}}$

- ✓ Produced mostly at the very early stage of a collision, in hard-scattering processes
- ✓ Production cross-section can be calculated with pQCD
- ✓ Hard fragmentation – i.e. D meson is a good proxy for the charm quark



$$\sigma_{hh \rightarrow Hx} = \boxed{PDF(x_a, Q^2) PDF(x_b, Q^2)} \otimes \boxed{\sigma_{ab \rightarrow q\bar{q}}} \otimes \boxed{D_{q \rightarrow H}(z_q, Q^2)}$$



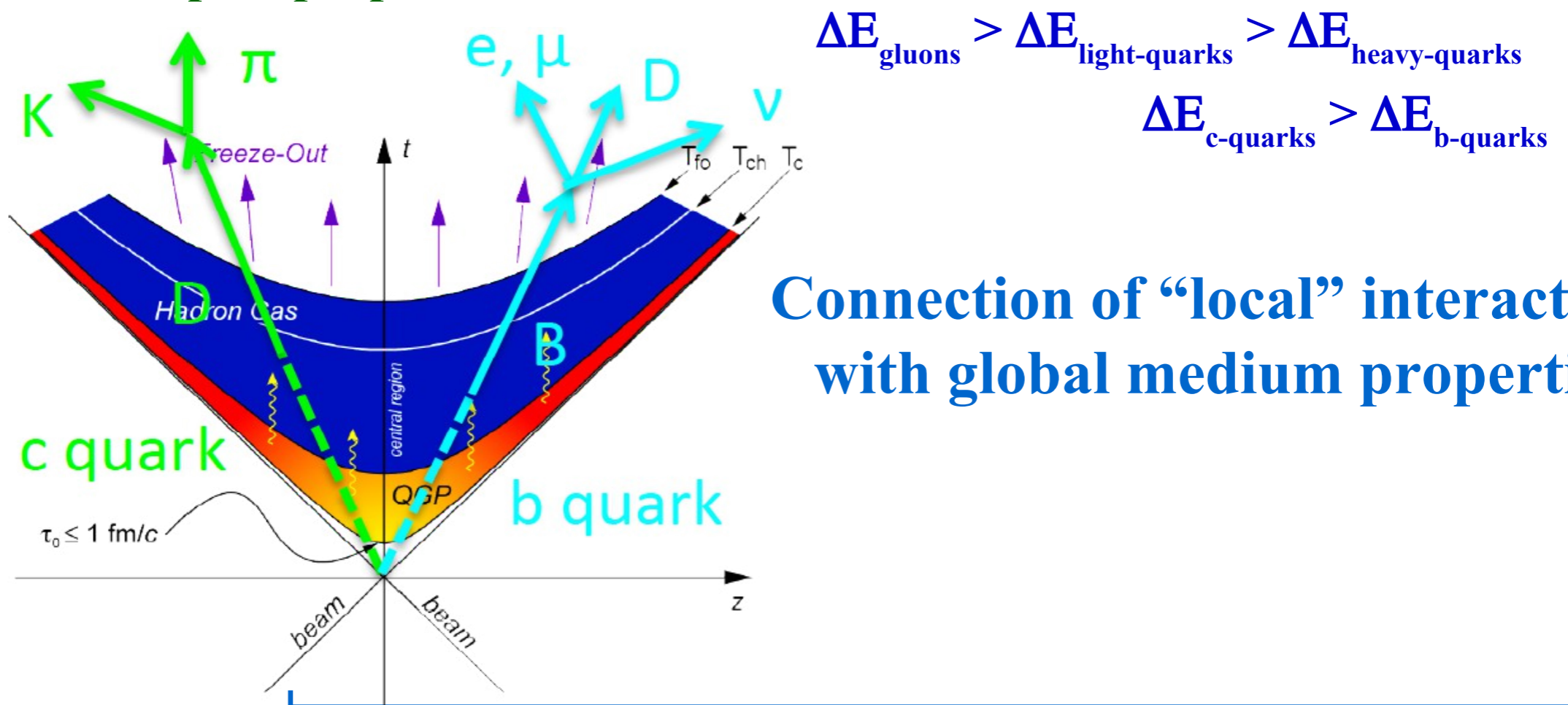
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In relativistic heavy-ion collisions

- ✓ Heavy quarks interact strongly with the medium
- ✓ **Energy loss of parton due to interactions with the medium \rightarrow medium transport properties**



Connection of “local” interactions with global medium properties



Measuring the medium effects, R_{AA}

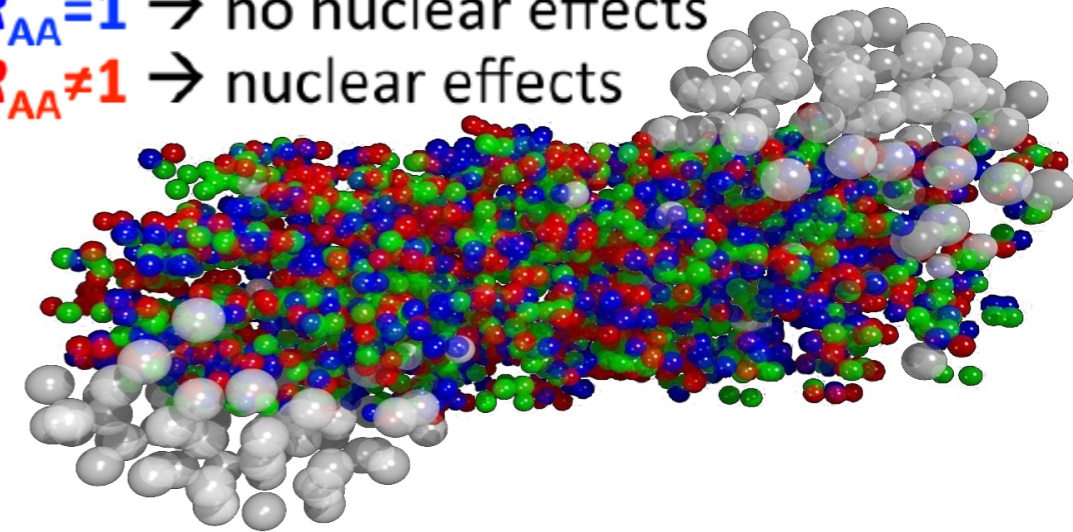
Nuclear Modification Factor (R_{AA})

- ✓ Compare particle production in heavy-ion collisions (Pb-Pb) to the production in elementary collisions (pp)

$$R_{AA}(p_T) = \frac{dN_{AA}/dp_T}{\langle T_{AA} \rangle \times d\sigma_{pp}/dp_T}$$

Nuclear overlap function \rightarrow
collision geometry

If $R_{AA}=1$ \rightarrow no nuclear effects
If $R_{AA}\neq 1$ \rightarrow nuclear effects



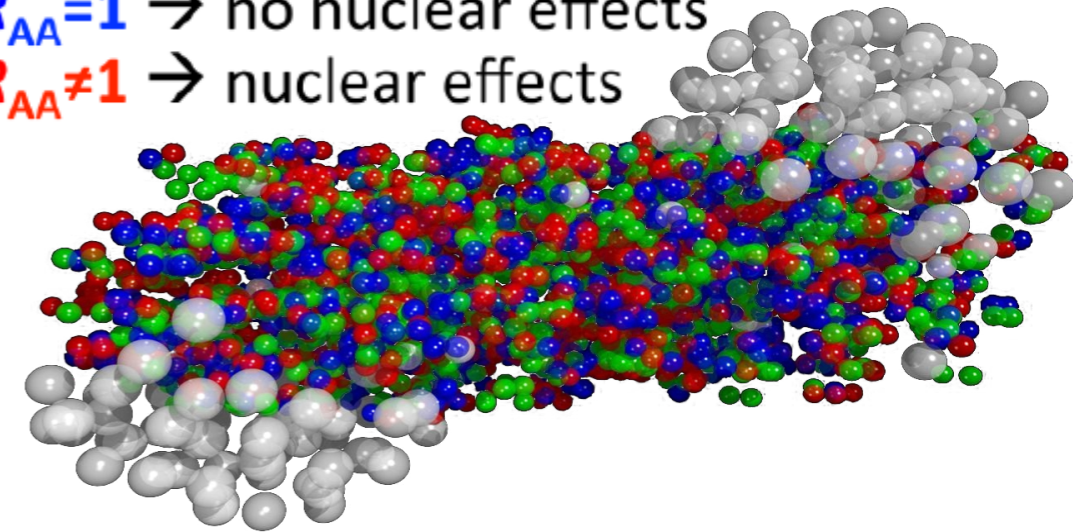
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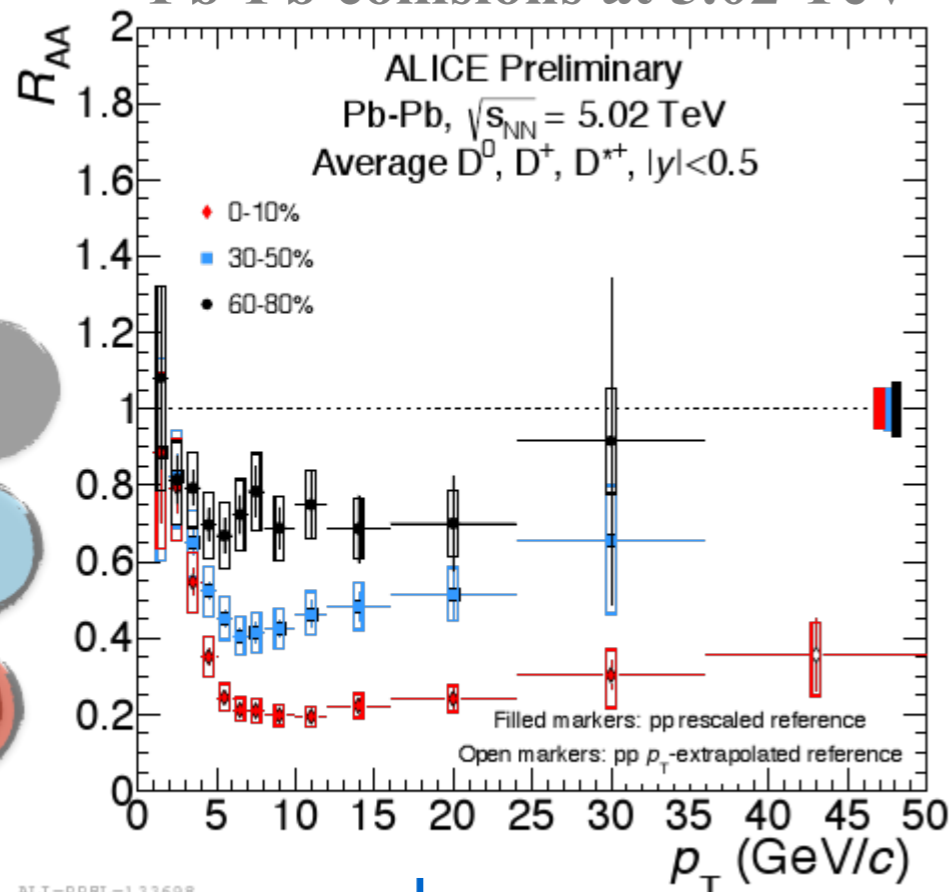
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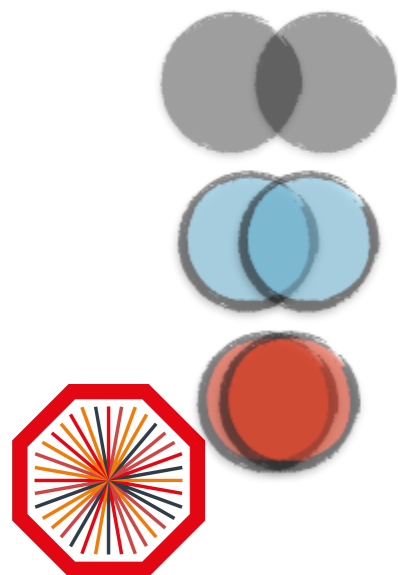


Nuclear overlap function → collision geometry

D meson R_{AA}
 Pb-Pb collisions at 5.02 TeV

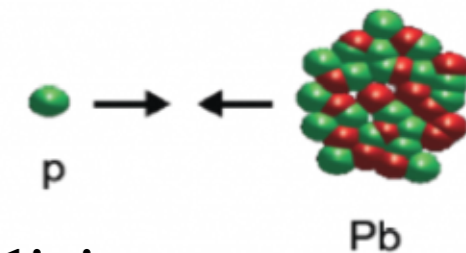


- ✓ Increasing suppression from peripheral to central collisions Pb-Pb collisions
- Energy loss in the hot and dense medium



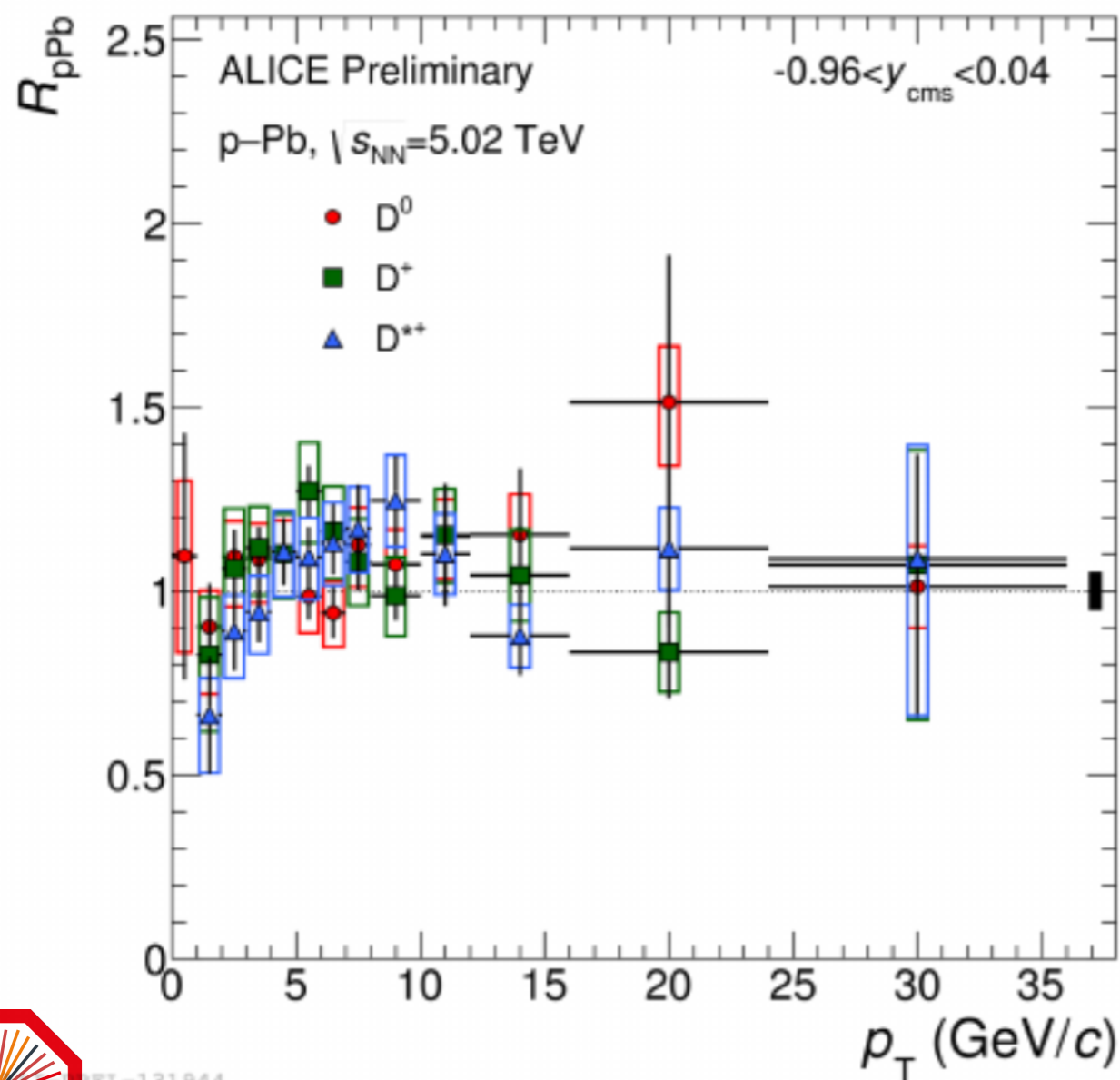
ALI-PRBL-133698

p-Pb collisions: D mesons R_{AA}



- ✓ Reference for hot and dense medium effects observed in Pb-Pb collisions
- Cold nuclear matter effects: nPDFs, k_T broadening, energy loss ...

D meson R_{AA}
p-Pb collisions at 5.02 TeV



Nuclear Modification Factor

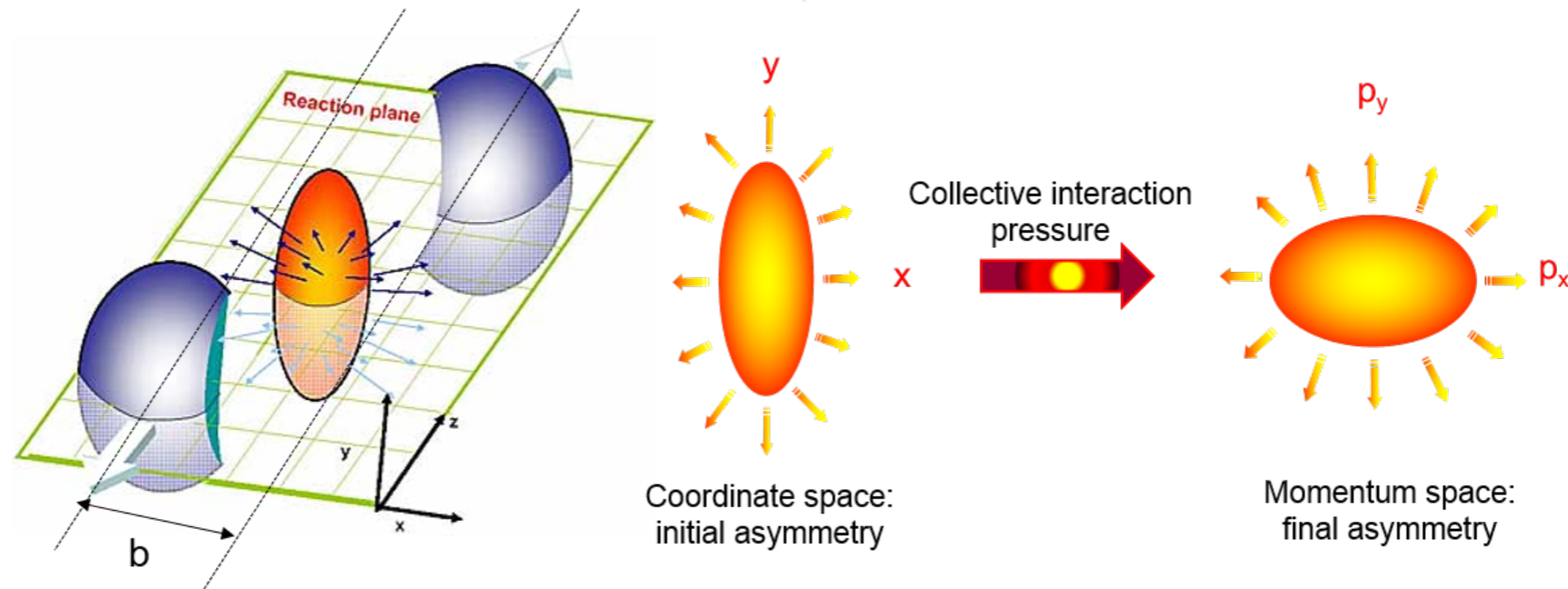
- ✓ No modification observed, $R_{AA} = 1$
- ✓ Uncertainties dominated by the pp reference – will be updated with the last month's pp dataset at 5 TeV



Measuring the medium effects, v_2

R_{AA} does not tell the whole story

✓ Collective motion of the system → **Azimuthal anisotropies**

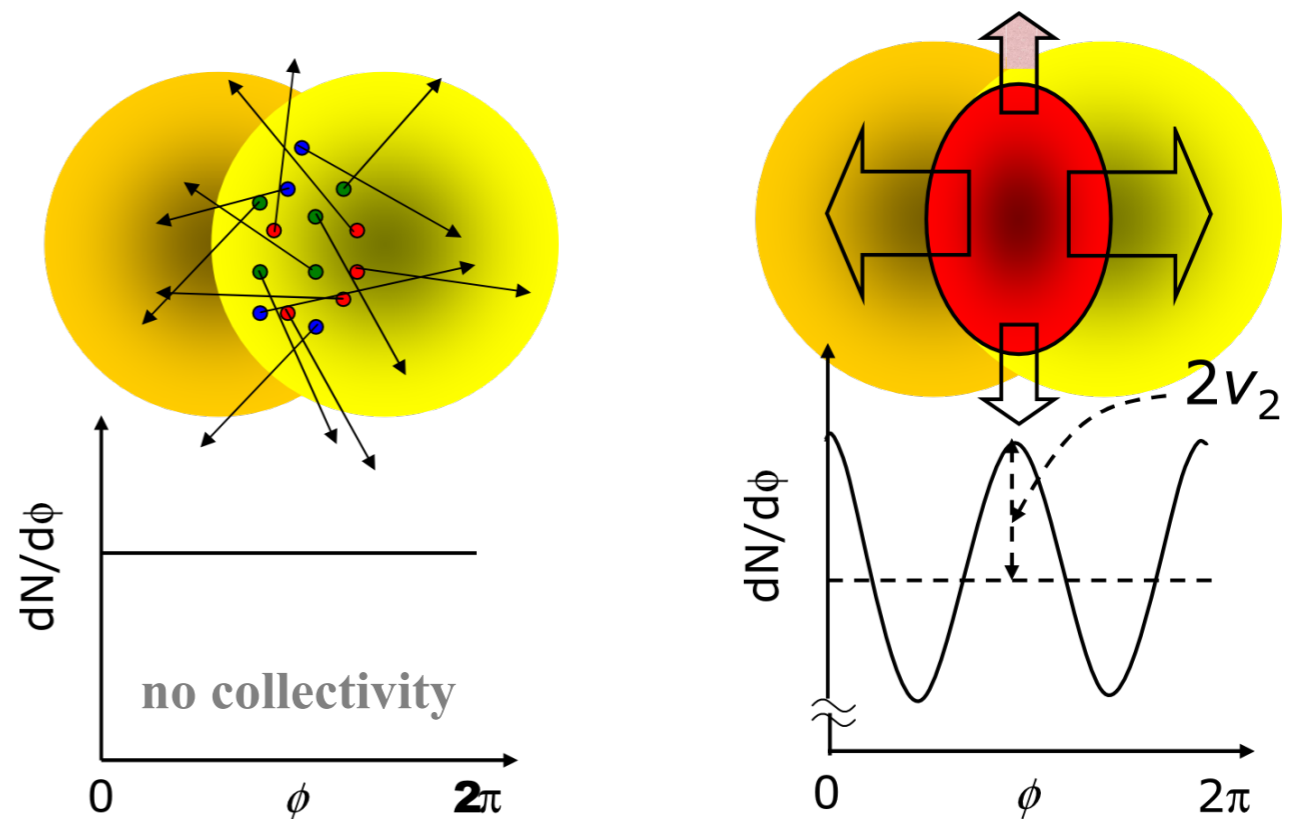


Azimuthal anisotropy of produced particles:

$$E \frac{d^3N}{dp^3} = \frac{1}{2\pi} \frac{d^2N}{p_T dp_T dy} \left(1 + \sum_{n=1}^{\infty} 2v_n \cos[n(\phi - \Psi_n)] \right)$$

Elliptic flow

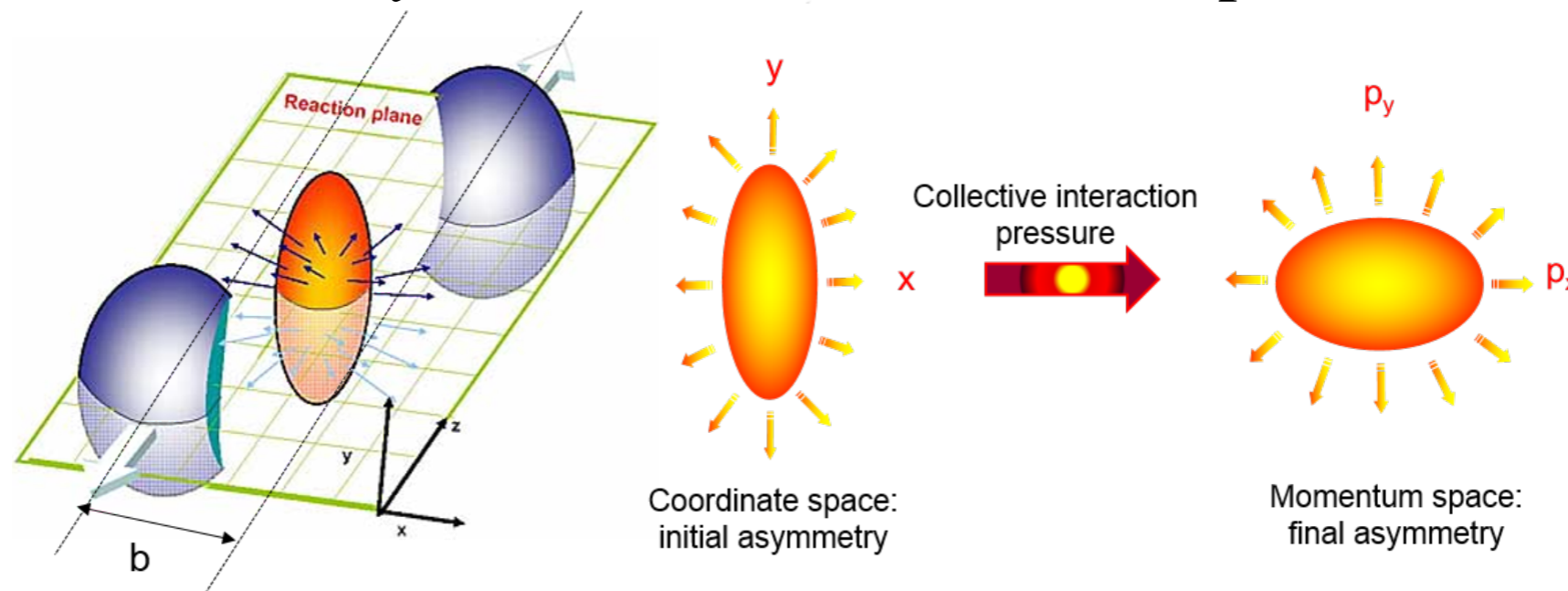
$$v_2 = \langle \cos[2(\phi - \Psi_2)] \rangle$$



Measuring the medium effects, v_2

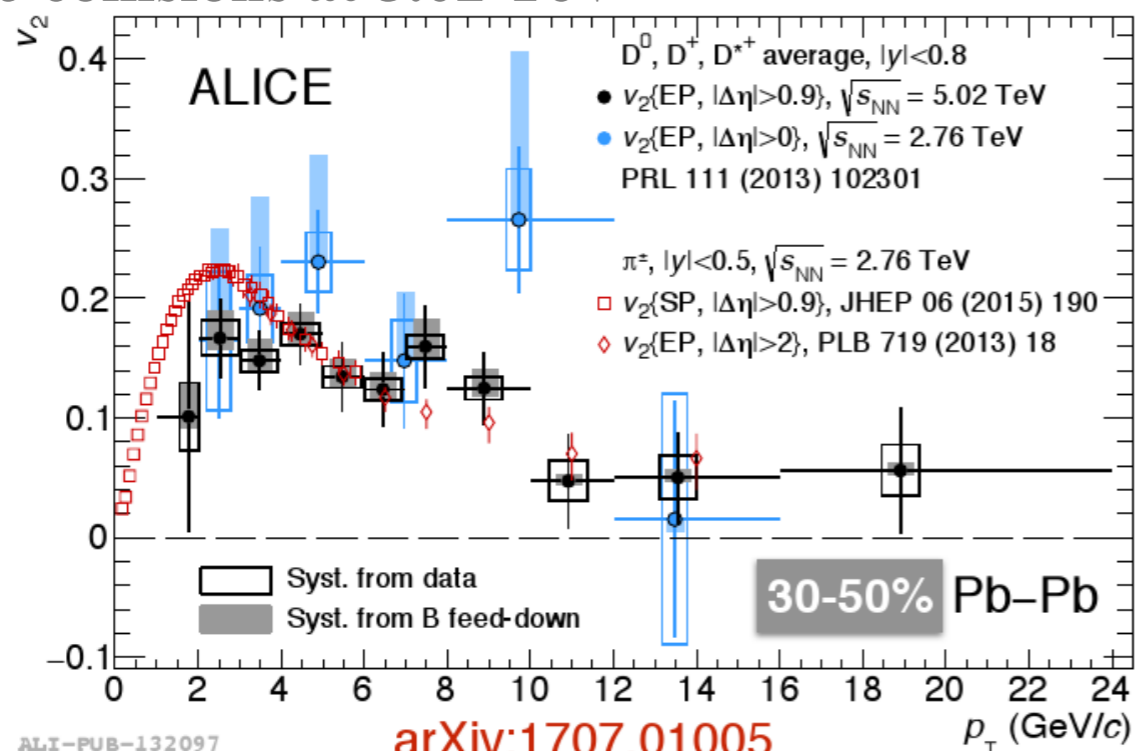
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D meson v_2

Pb-Pb collisions at 5.02 TeV

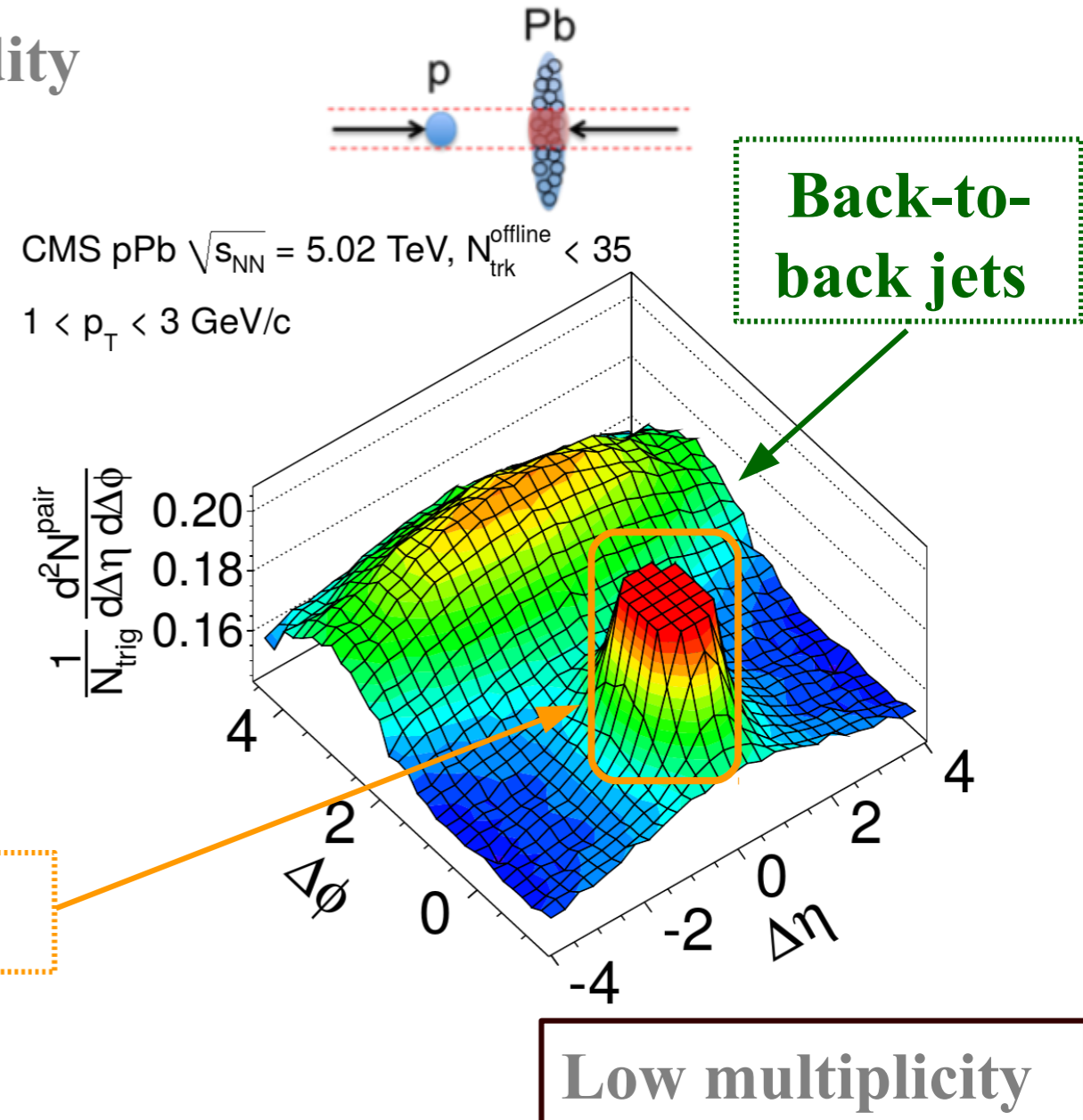
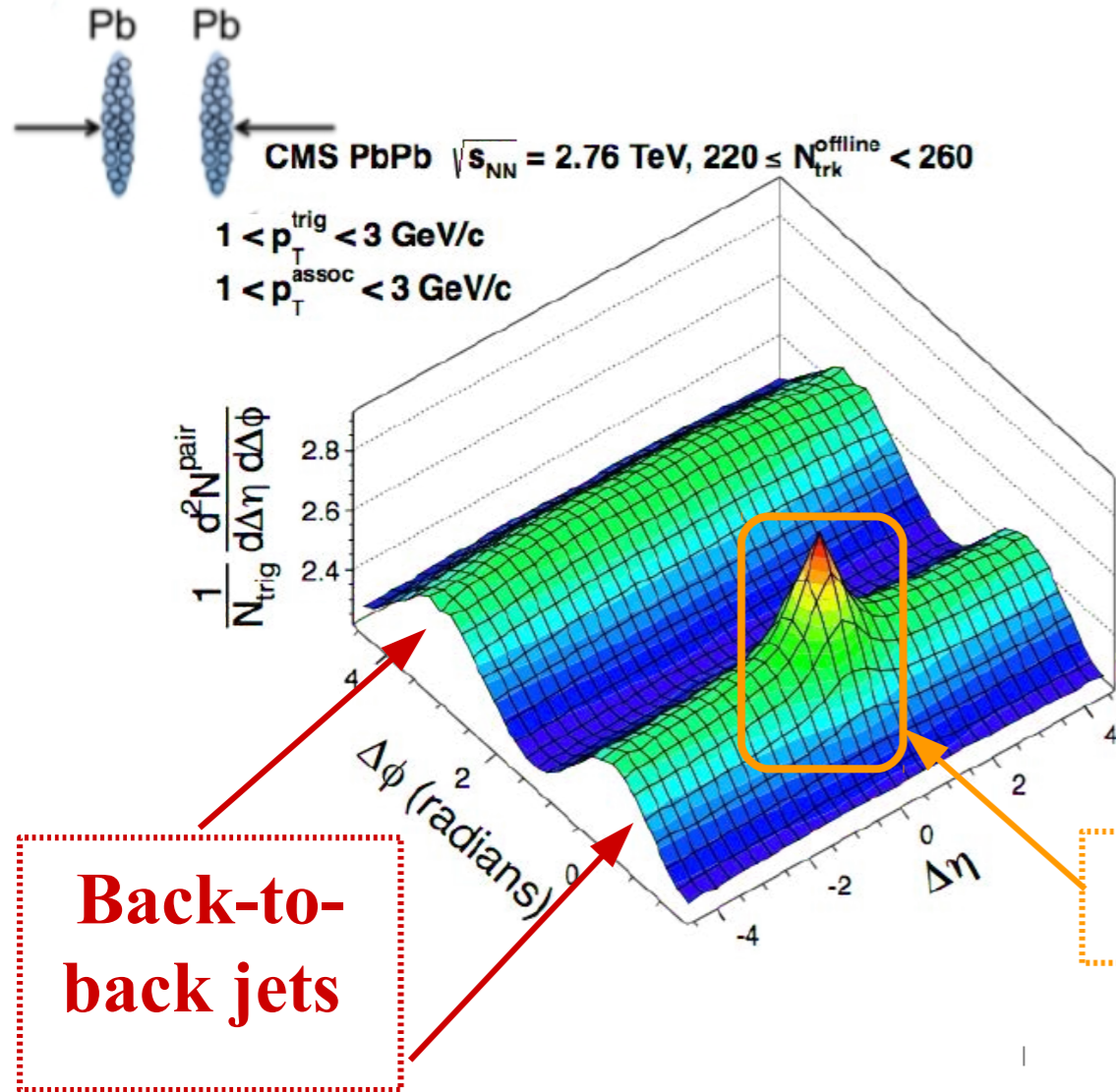


✓ D meson $v_2 > 0$ → charm quarks sensitive to medium collective motion



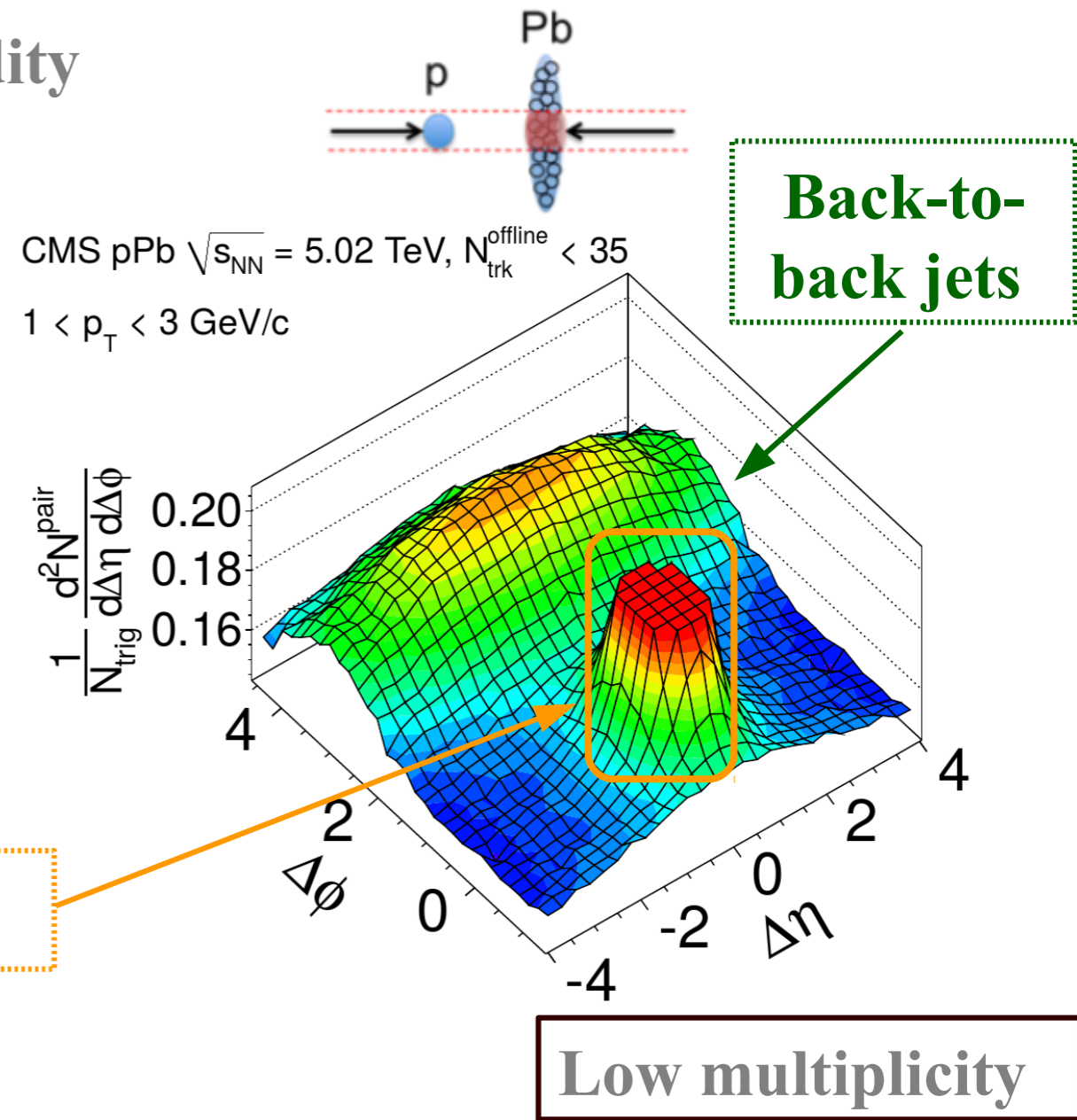
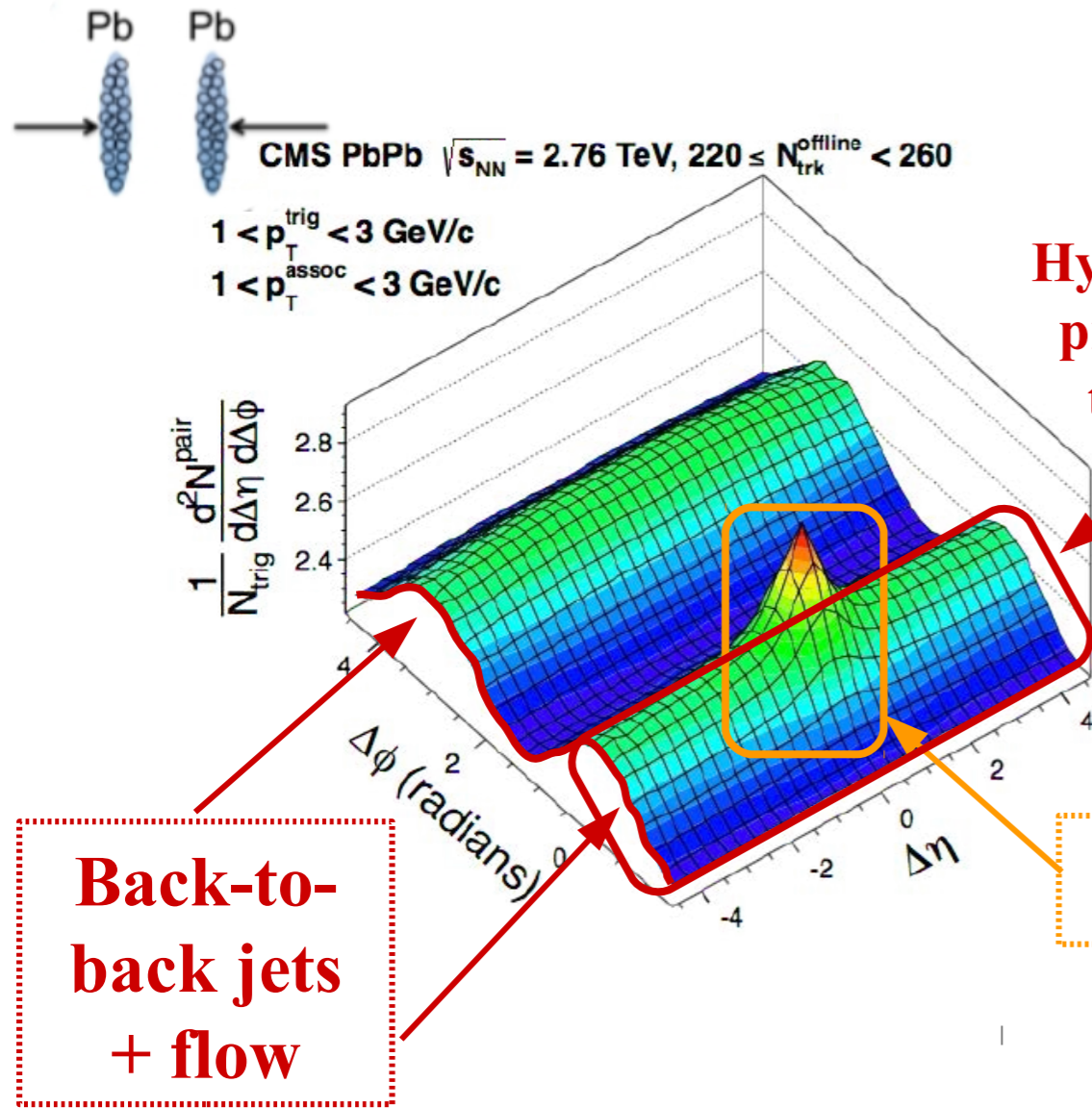
p-Pb collisions: Azimuthal anisotropy

Di-hadron correlations in azimuth and pseudorapidity



p-Pb collisions: Azimuthal anisotropy

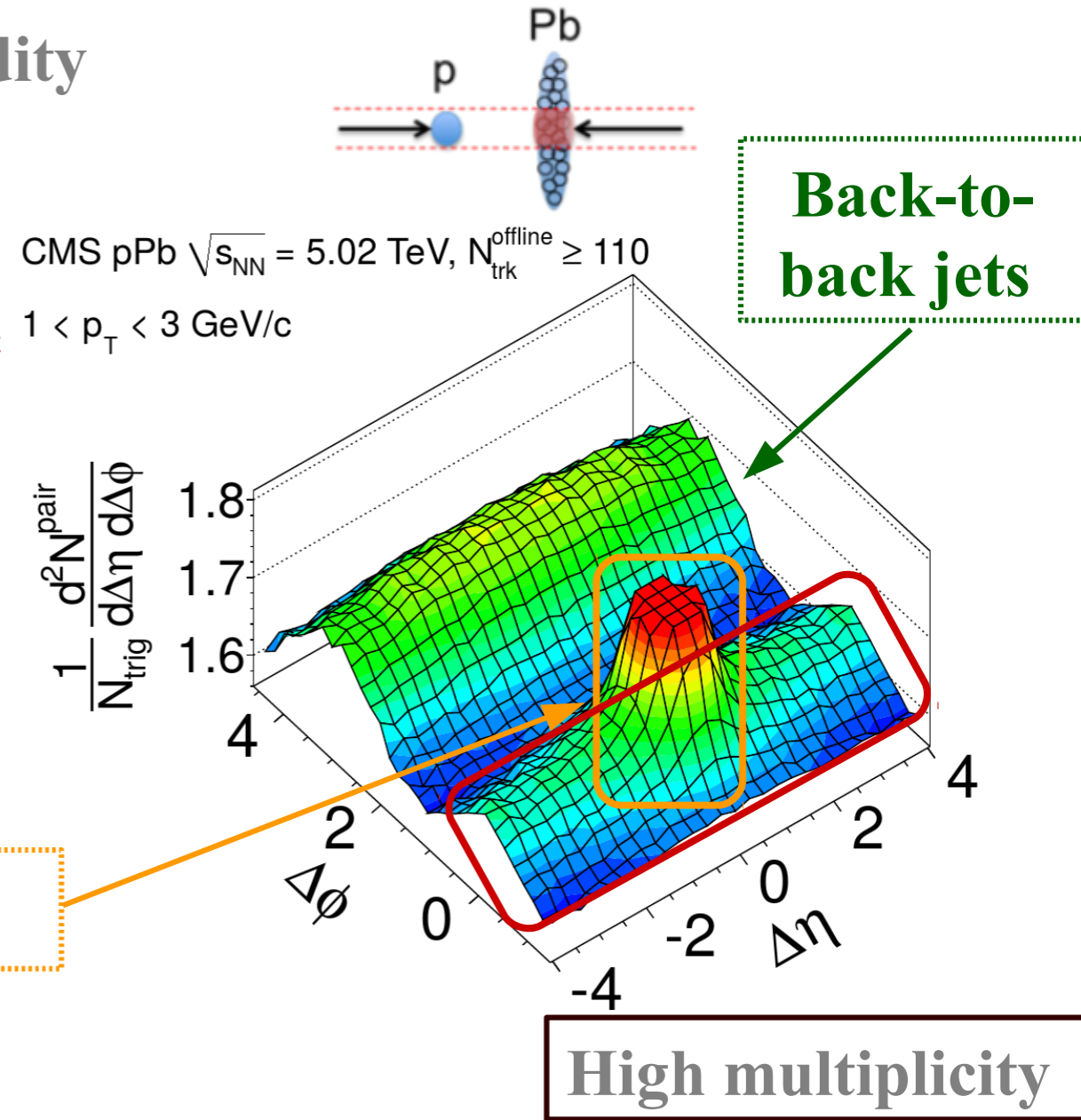
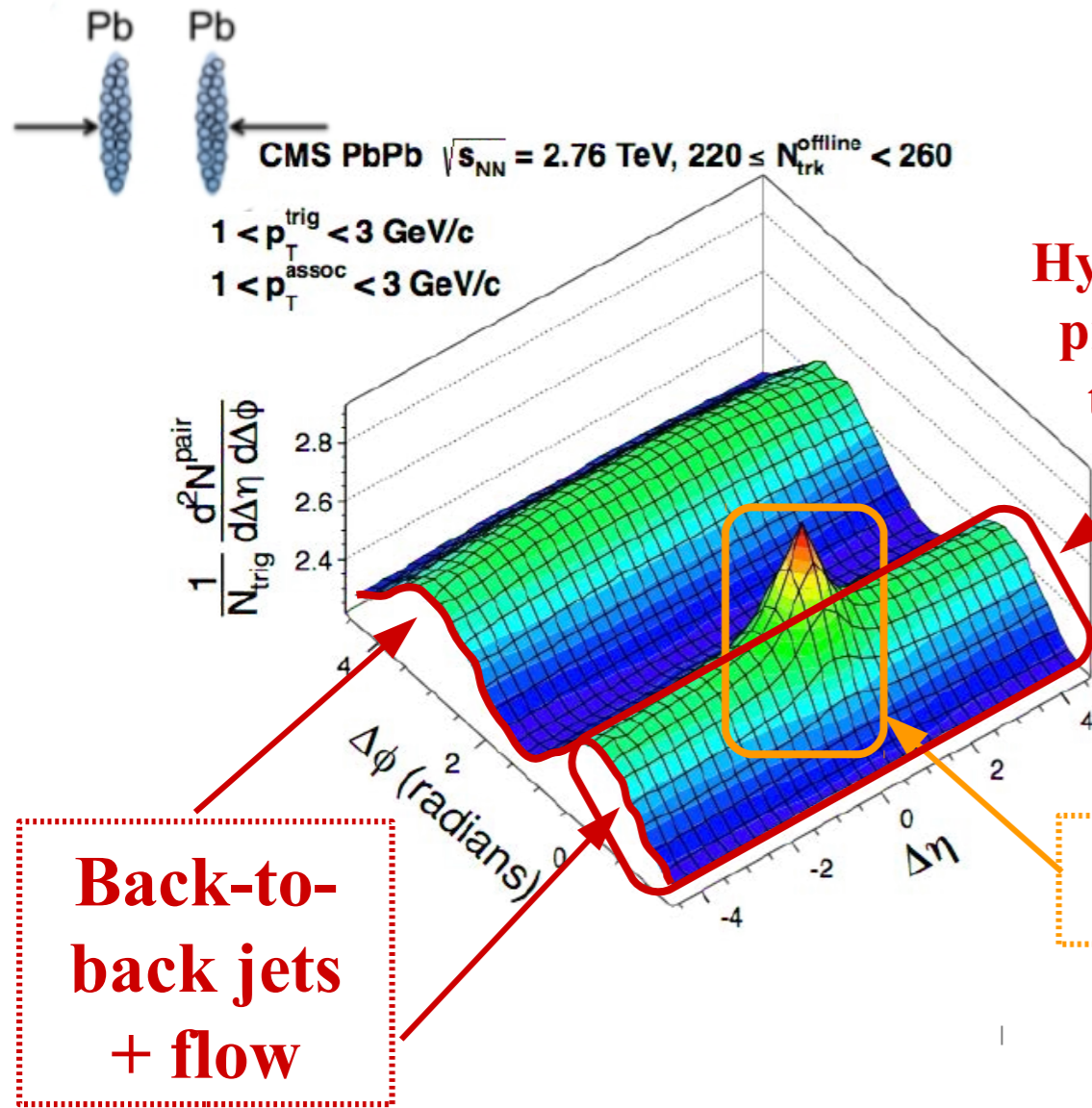
Di-hadron correlations in azimuth and pseudorapidity



- ✓ In Pb-Pb the double-ridge structure dominated by $v_2 \rightarrow$ collective behavior

p-Pb collisions: Azimuthal anisotropy

Di-hadron correlations in azimuth and pseudorapidity

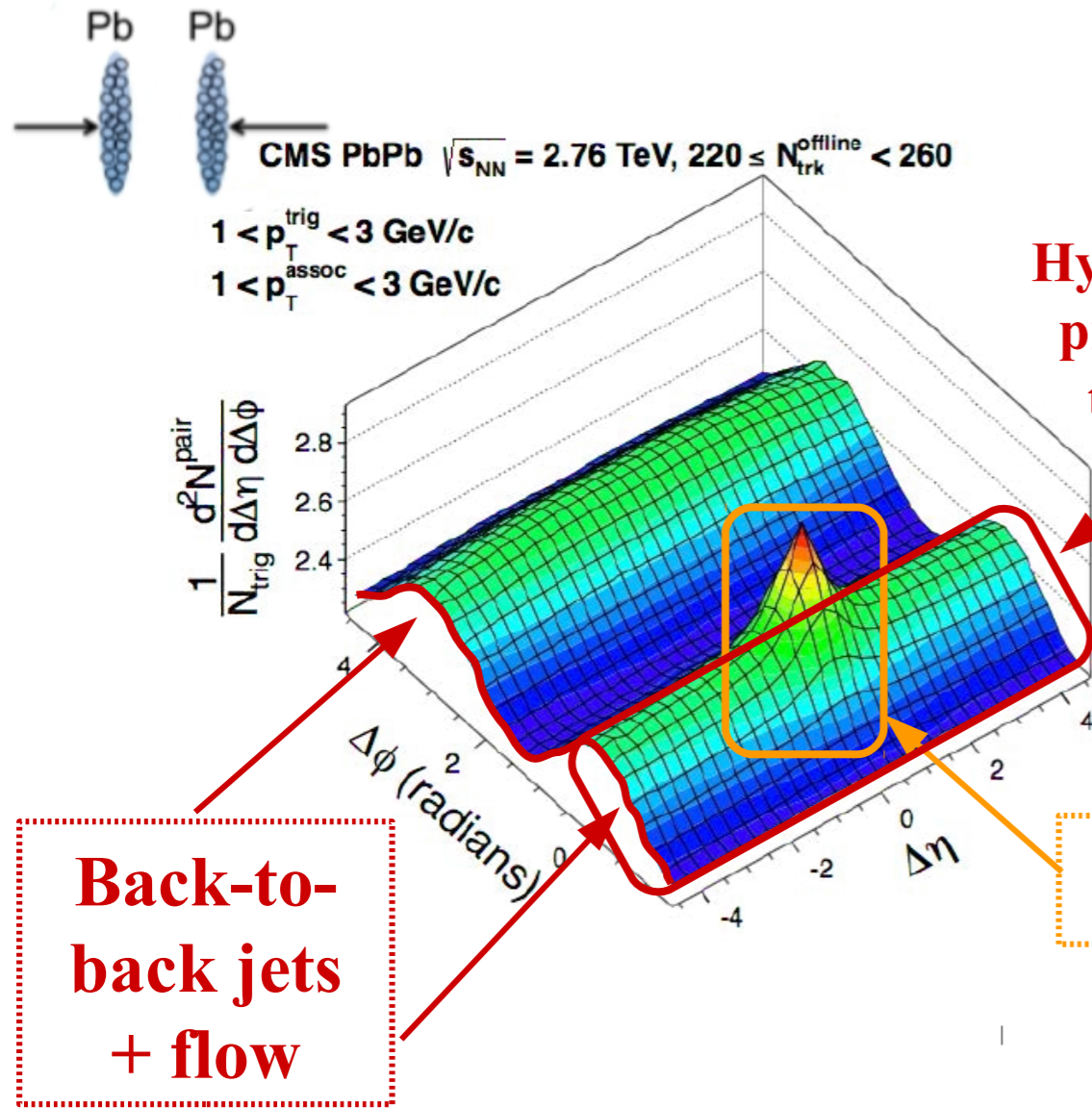


- ✓ In Pb-Pb the double-ridge structure dominated by $v_2 \rightarrow$ collective behavior
- ✓ Unexpected long-range near-side angular correlation in p-Pb



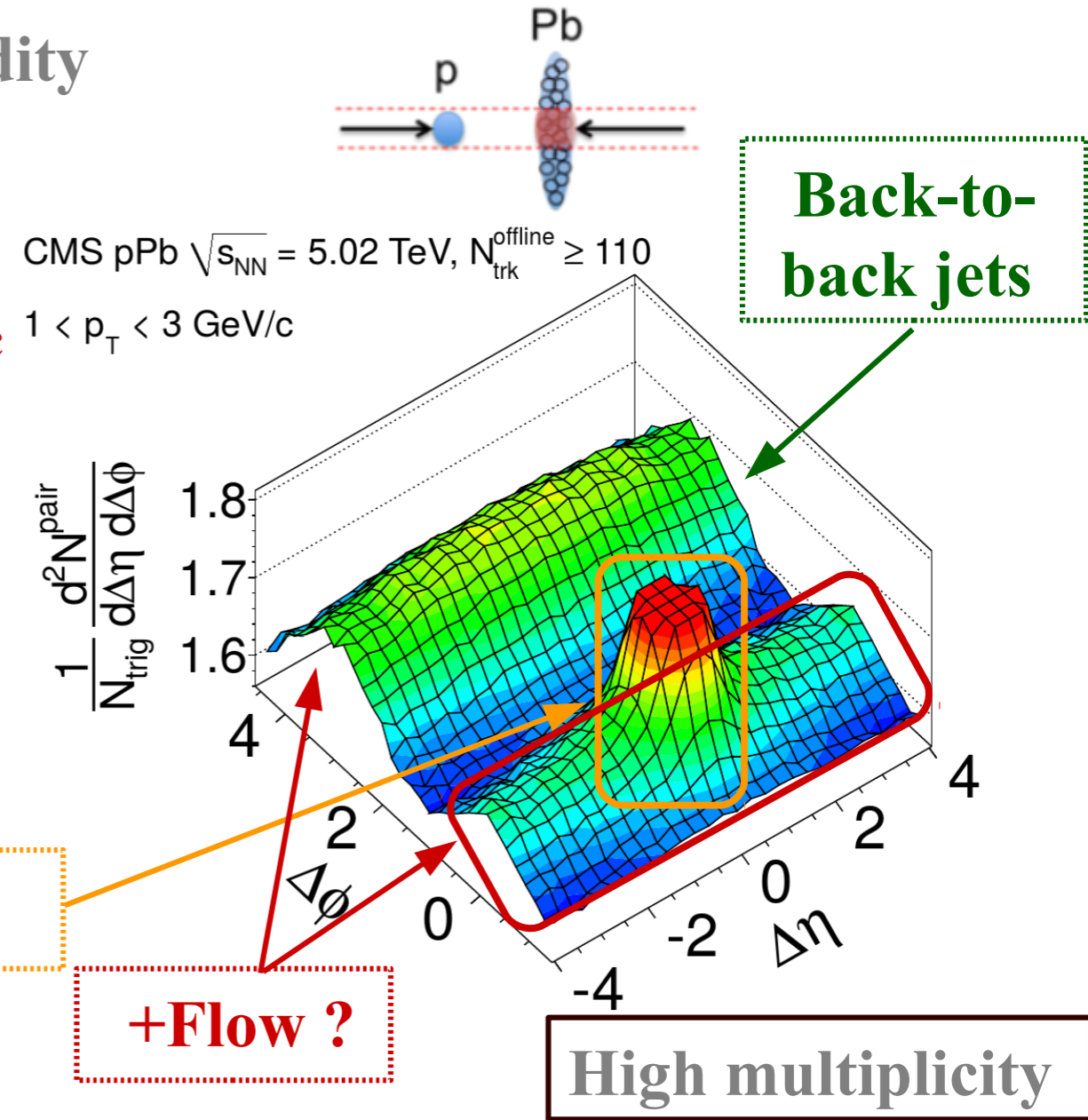
p-Pb collisions: Azimuthal anisotropy

Di-hadron correlations in azimuth and pseudorapidity



Hydrodynamic properties of the system

Jets



- ✓ Initial state effects ?
- ✓ Final-state effects – system collectivity in p-Pb ?

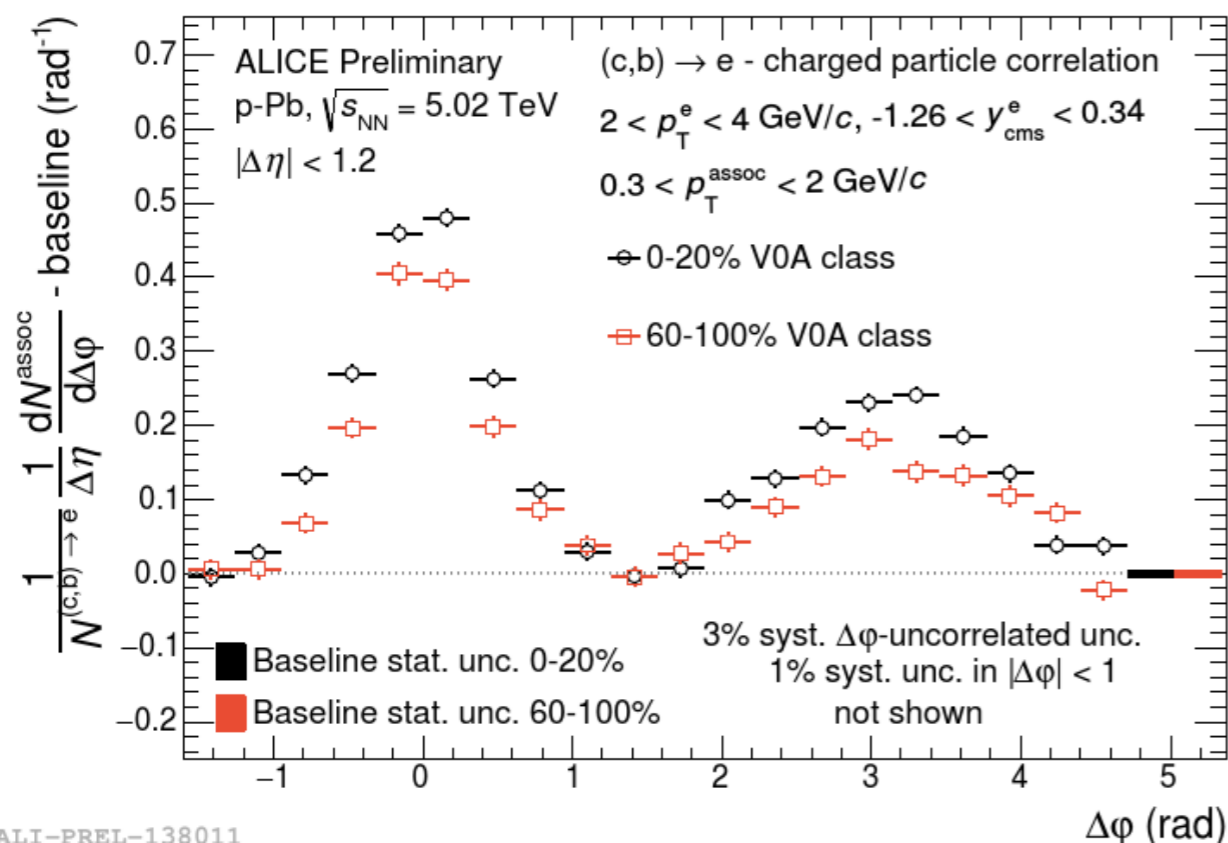
Not so trivial “reference” for Pb-Pb



p-Pb collisions: Heavy-flavour v_2

Correlation of electrons coming from heavy-flavour hadron decay with charge particles

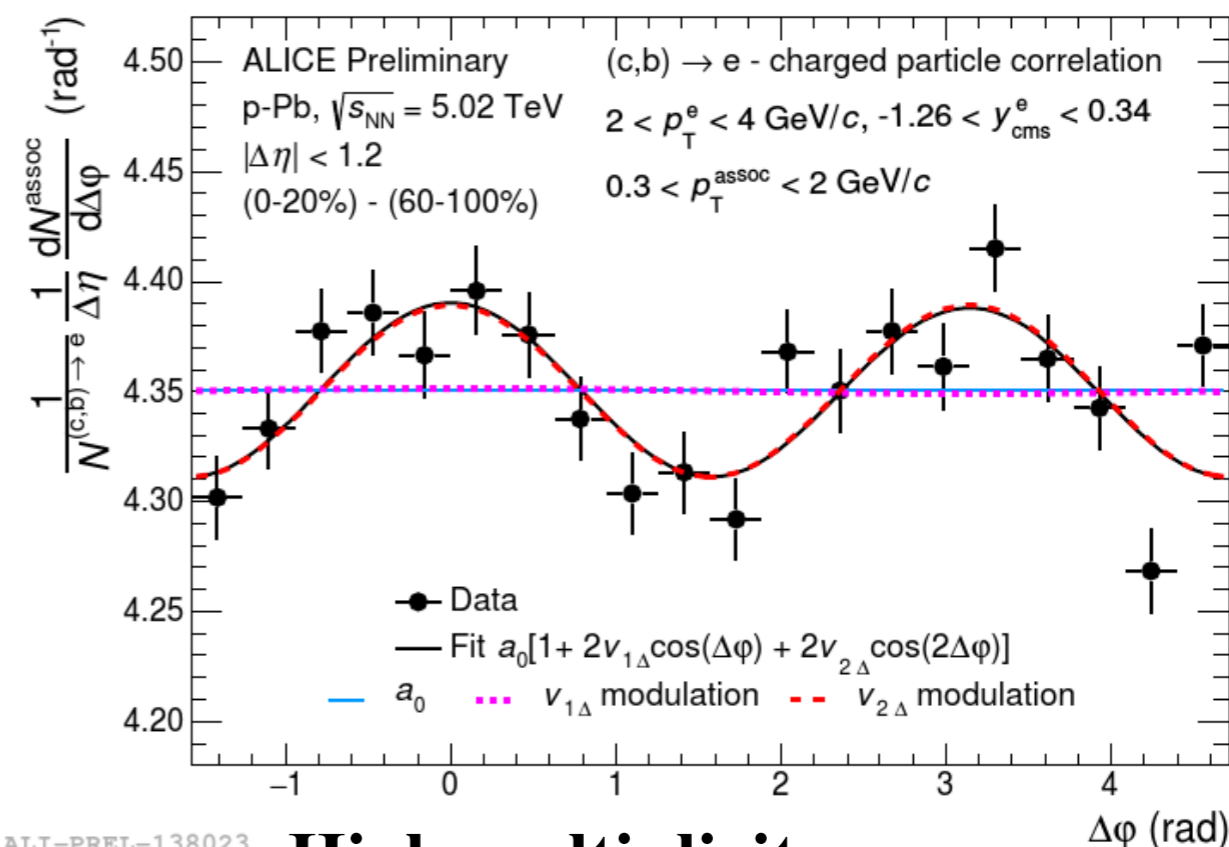
Search for a possible v_2 -like modulation in p-Pb



ALI-PREL-138011

High multiplicity

Low multiplicity



ALI-PREL-138023

High multiplicity

—

Low multiplicity

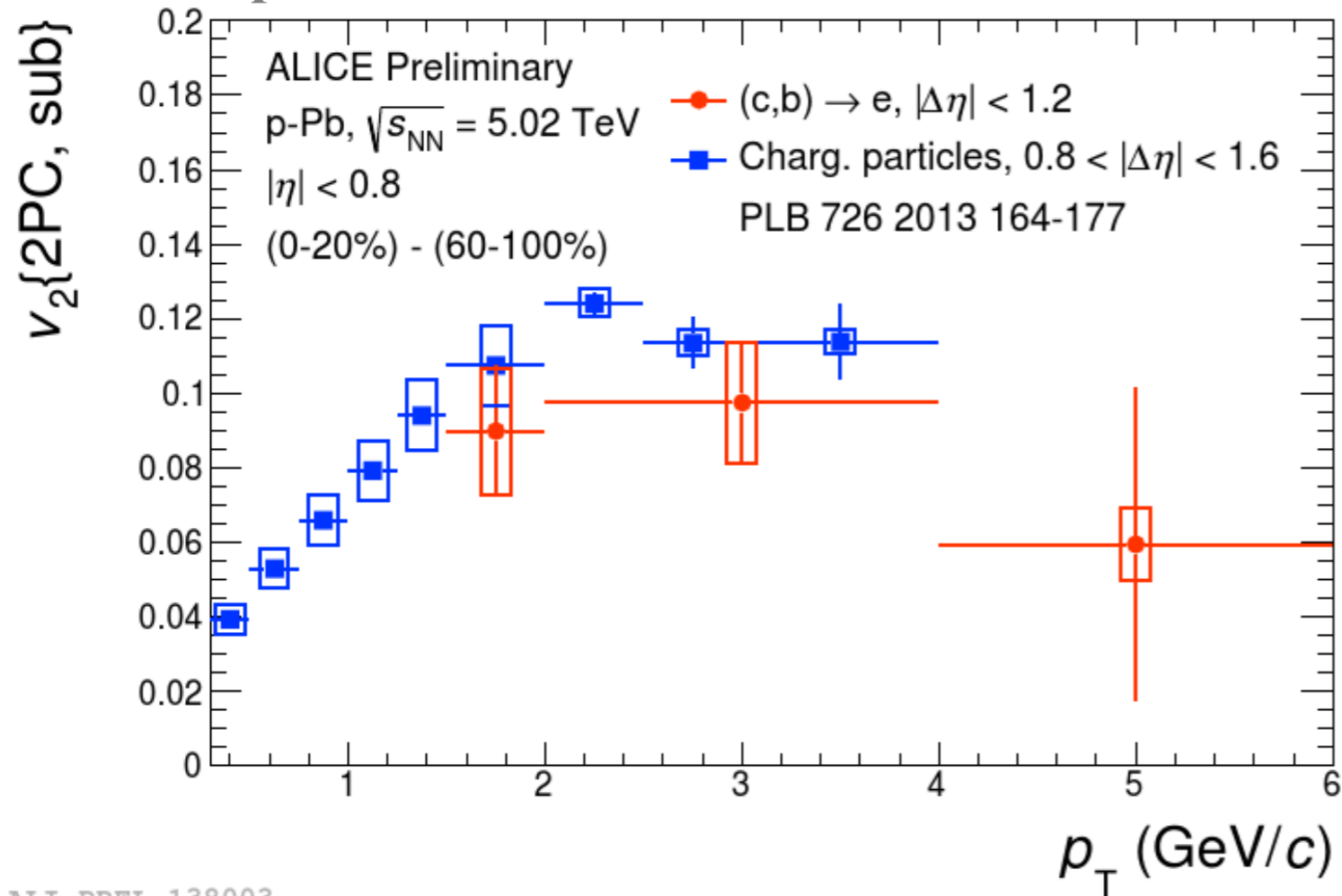
$$C_{HM}(\Delta\phi) - C_{LM}^{sub} = a_0(1 + 2V_{1\Delta} \cos(\Delta\phi) + 2V_{2\Delta} \cos(2\Delta\phi)).$$



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p-Pb collisions: Heavy-flavour v_2

Heavy-flavour electron v_2
p-Pb collisions at 5.02 TeV



- ✓ Indication of heavy-flavour flow in p-Pb collisions !
- ✓ Effect qualitatively similar to the one observed in the light flavour sector

ALI-PREL-138003

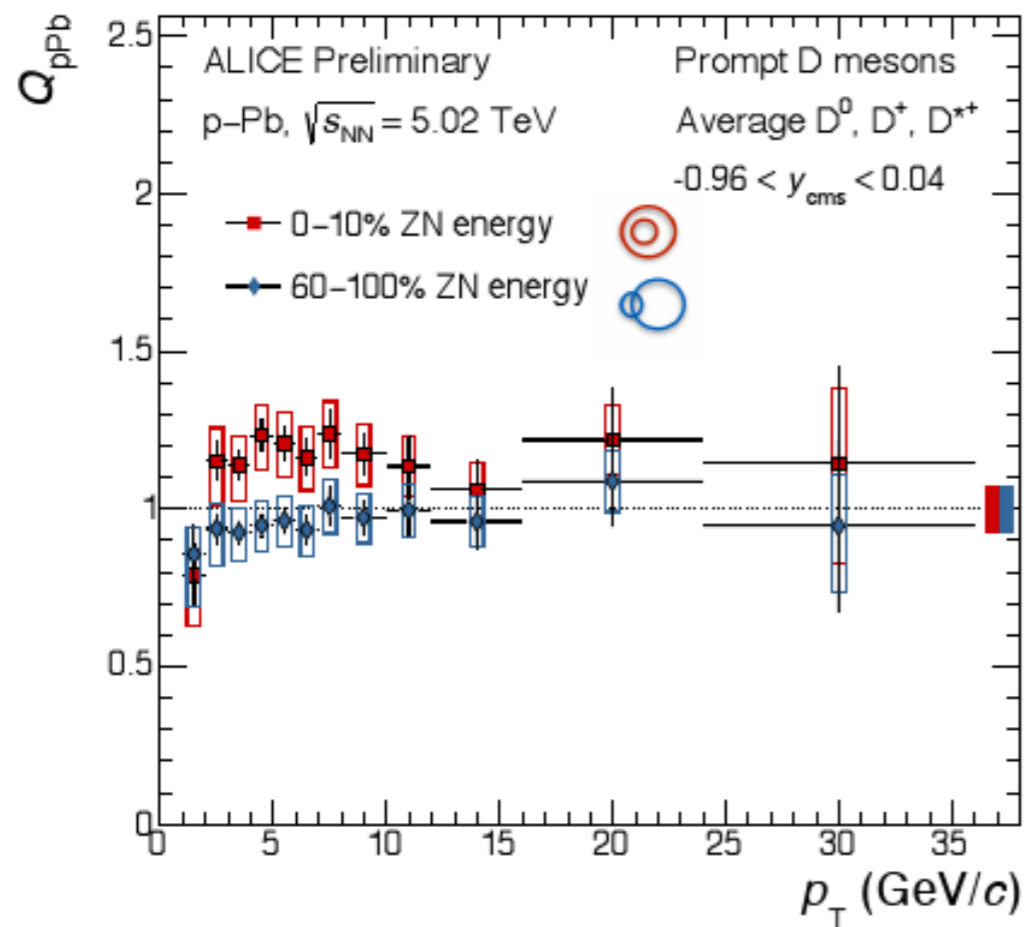


ALICE

Paper in preparation

p-Pb collisions: D mesons R_{AA} vs centrality

Nuclear Modification Factor in centrality classes



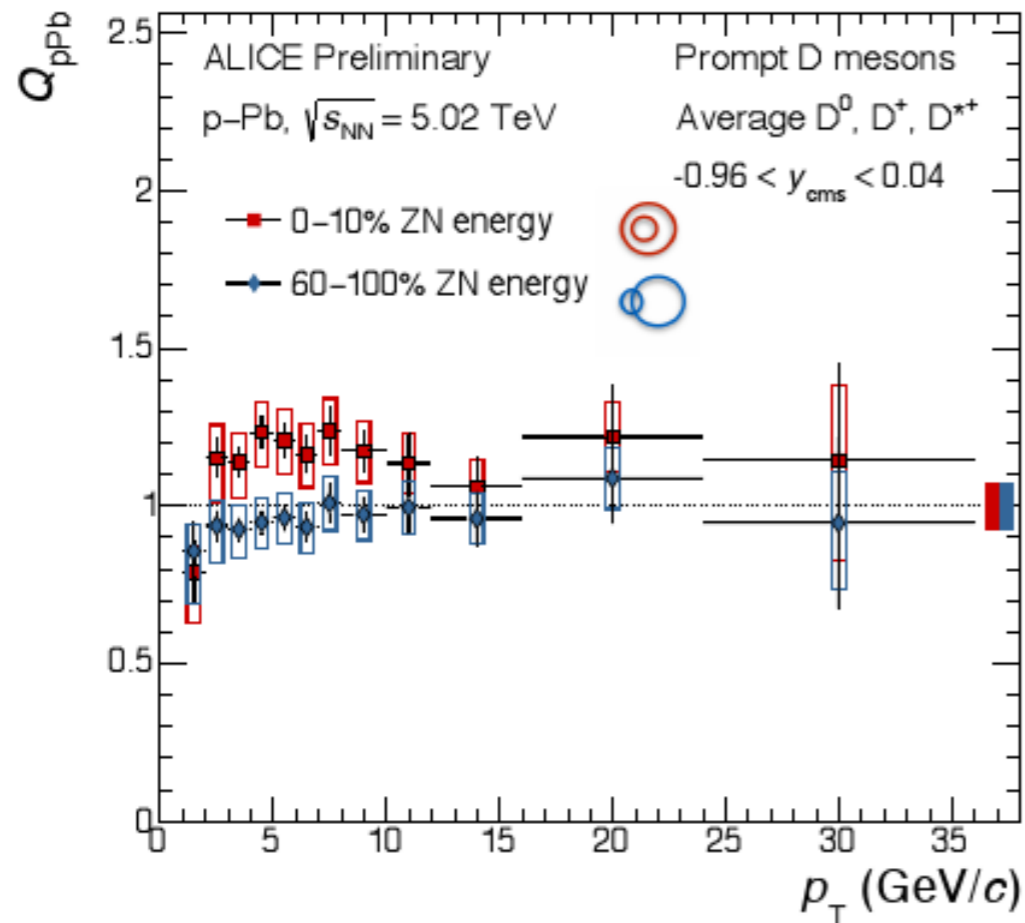
Central
Peripheral

- ✓ Compatible nuclear modification factors in central and peripheral collisions within the uncertainties

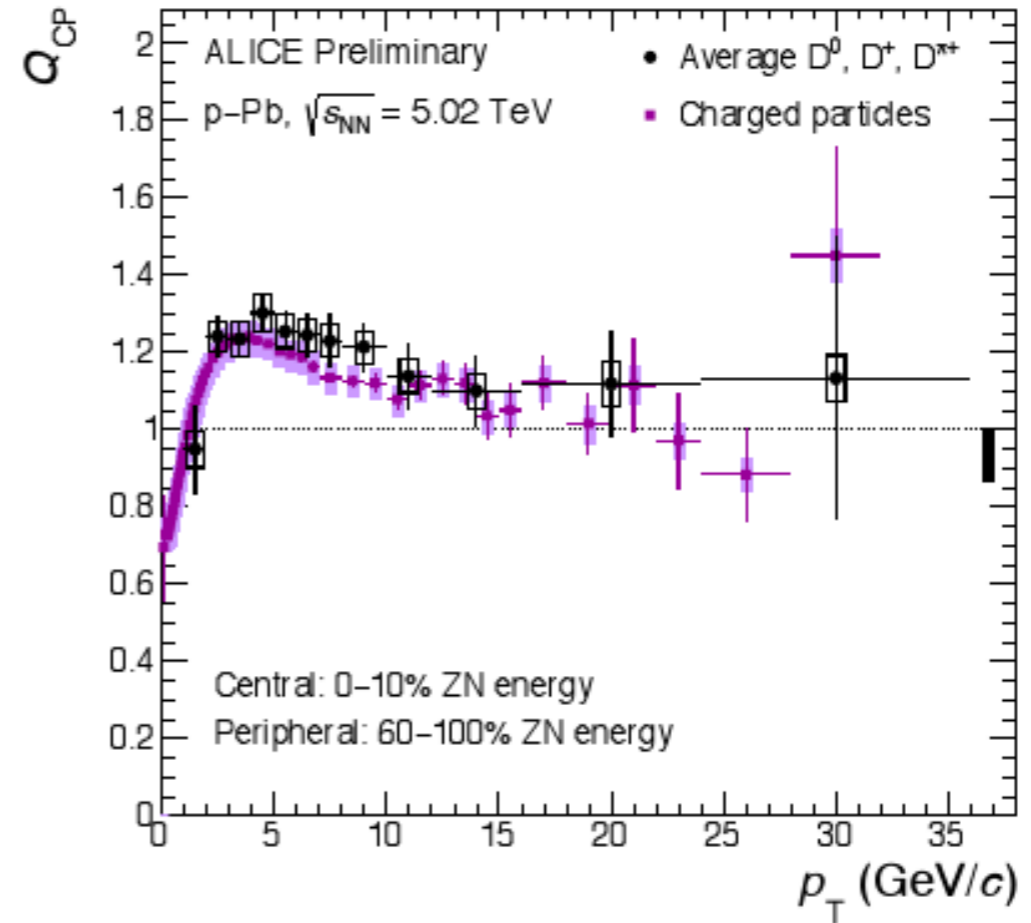


p-Pb collisions: D mesons R_{AA} vs centrality

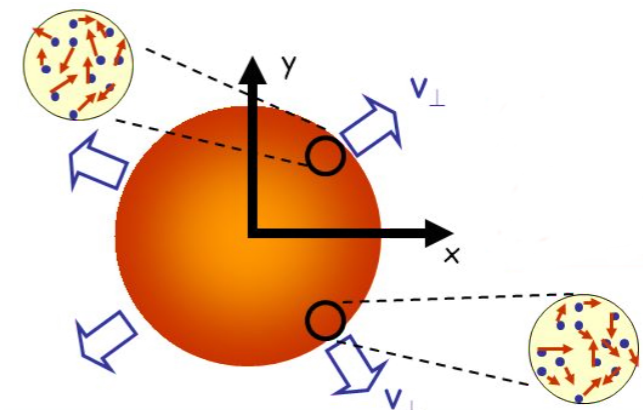
Nuclear Modification Factor
in centrality classes



Central/
Peripheral
better statistical precision



- ✓ Hint of enhancement in central collisions compare to peripheral (in 3-8 GeV/c with 1.5σ)
- **Initial or final state effect?**
- **Radial flow: Hint of collective effects ?**



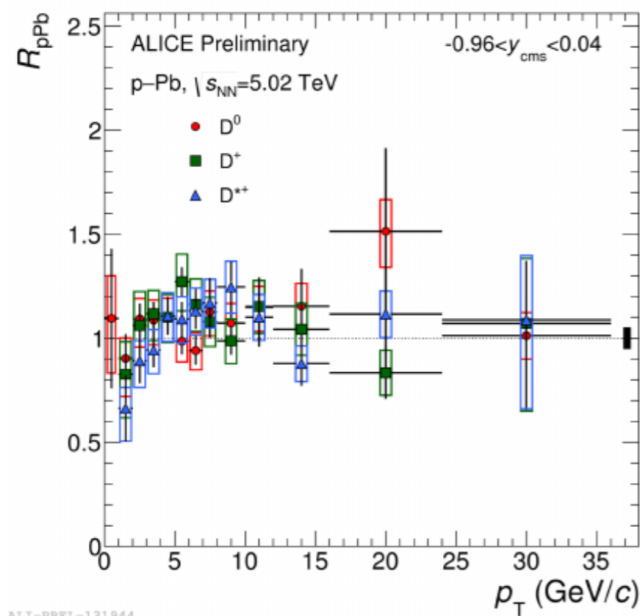
Paper in preparation



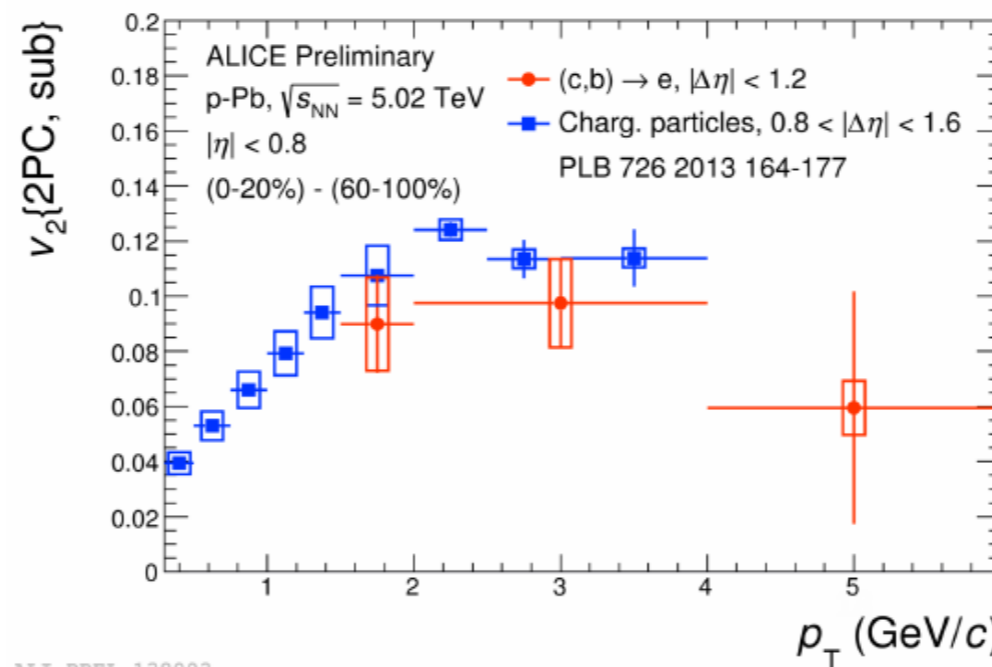
ALICE

Conclusions

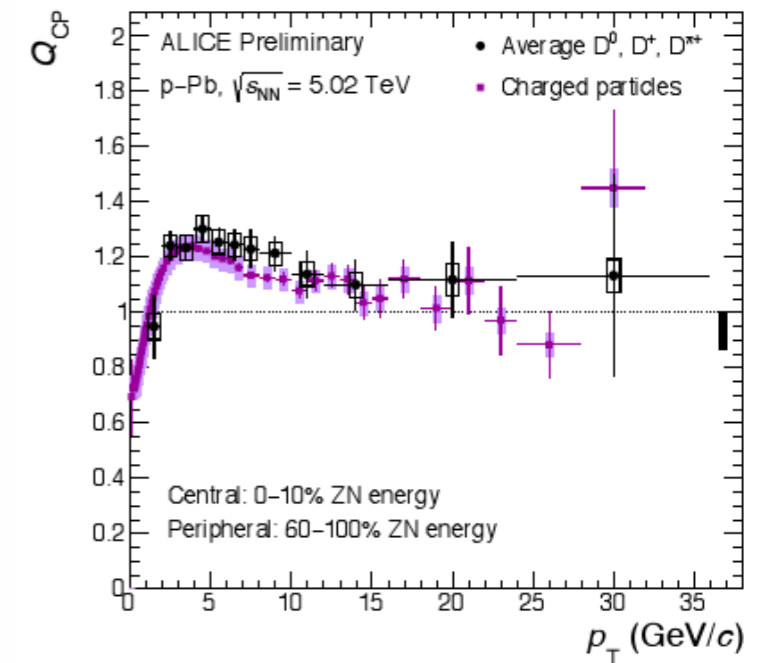
- ✓ Small systems created in p-Pb collisions still not fully understood
- ✓ Status in heavy-flavour results:
 - No modification in centrality integrated R_{AA}
 - Hint of D-meson enhancement in central p-Pb collisions
 - Indication of heavy-flavour elliptic flow in p-Pb
 - **Collectivity in p-Pb ?**



ALI-PREL-131944



ALI-PREL-138003

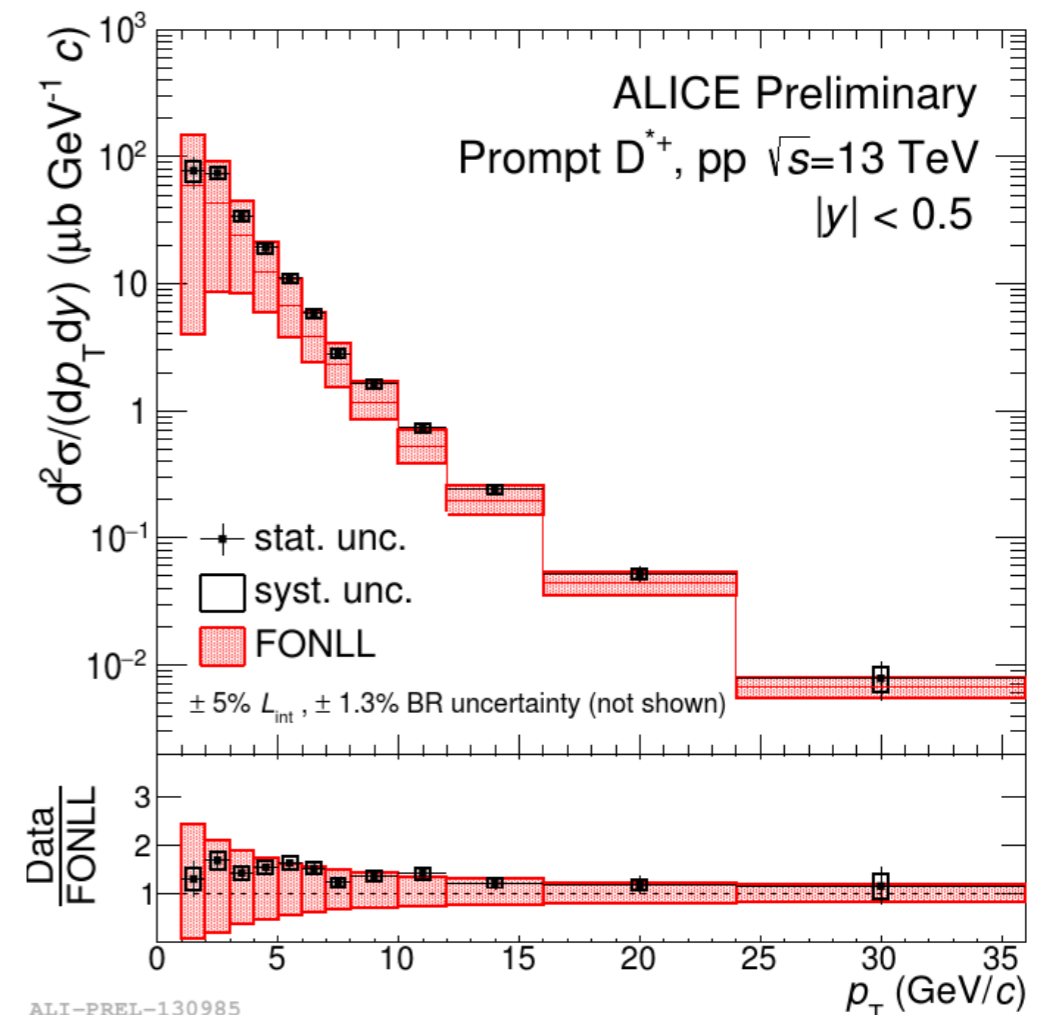
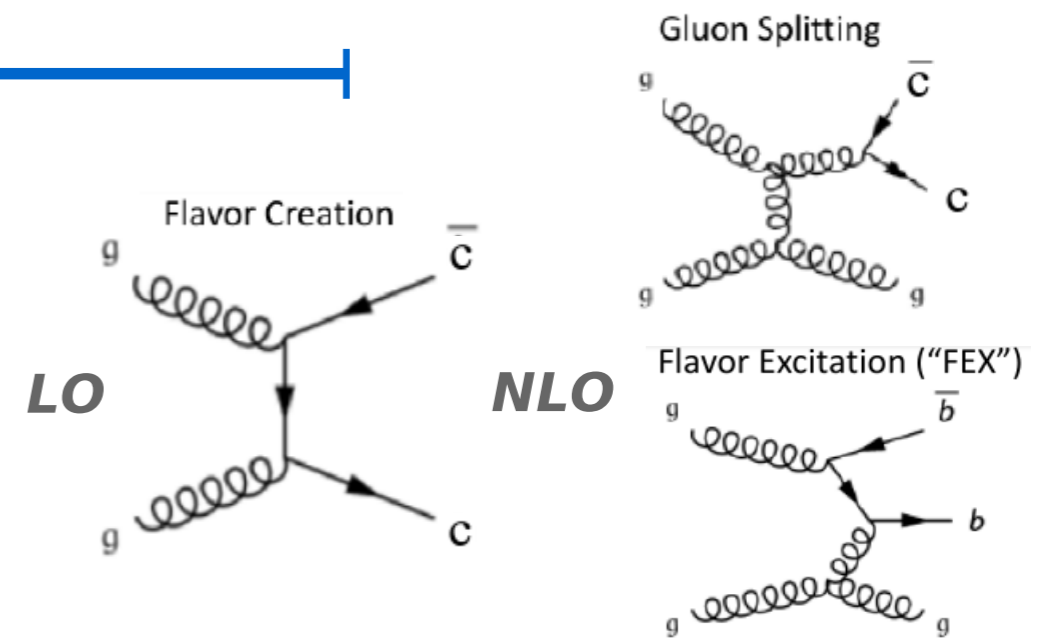


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Outlook →

Heavy-flavour jets

- ✓ Heavy-quark cross-section in pp collisions described by pQCD models
 - However agreement on the upper band of predictions
- ✓ Heavy-flavour jets – kinematics closer to the initial parton:
 - Powerful additional test of pQCD
 - Constrain charm production mechanism
 - Access to the fragmentation function

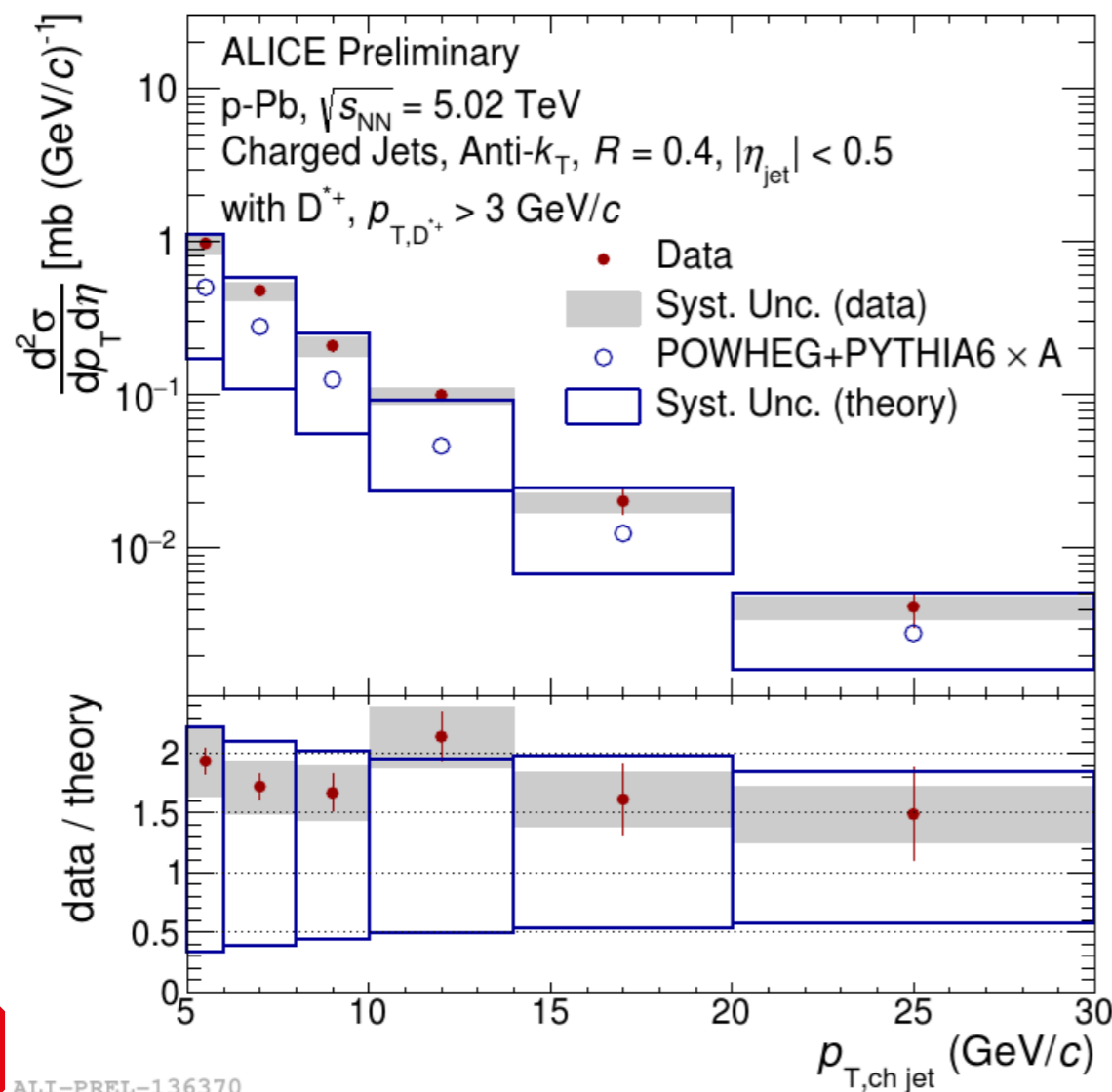


p-Pb collisions: D-jets

- ✓ Modification of heavy-flavour jets in p-Pb ?
- ✓ Reference for Pb-Pb: how the lost energy in the medium is radiated and dissipated
- ✓ Modification of the fragmentation function in the medium ?

Low p_T reach with ALICE

D^{*+} -tagged jets, p-Pb at 5.02 TeV



- ✓ Agreement with NLO QCD model without medium nuclear modifications (large model uncertainties)

Measurement of the fragmentation function and of D^0 -tagged jets in progress $\rightarrow R_{AA}$ in p-Pb and Pb-Pb



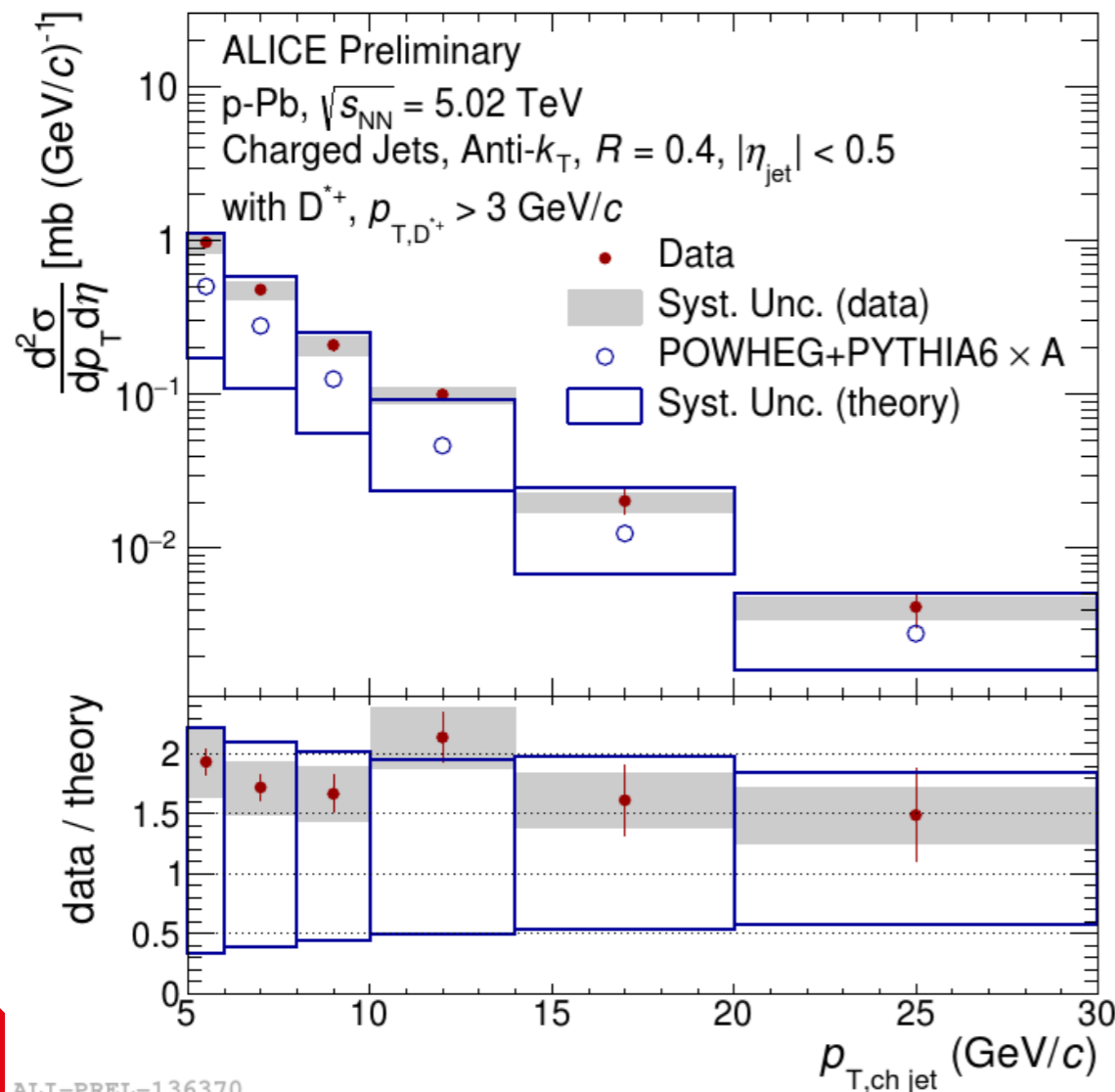
ALI-PREL-136370

p-Pb collisions: D-jets

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Low p_T reach with ALICE

D^{*+} -tagged jets, p-Pb at 5.02 TeV



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Measurement of the fragmentation function and of D^0 -tagged jets in progress $\rightarrow R_{AA}$ in p-Pb and Pb-Pb

Thank you !



ALI-PREL-136370

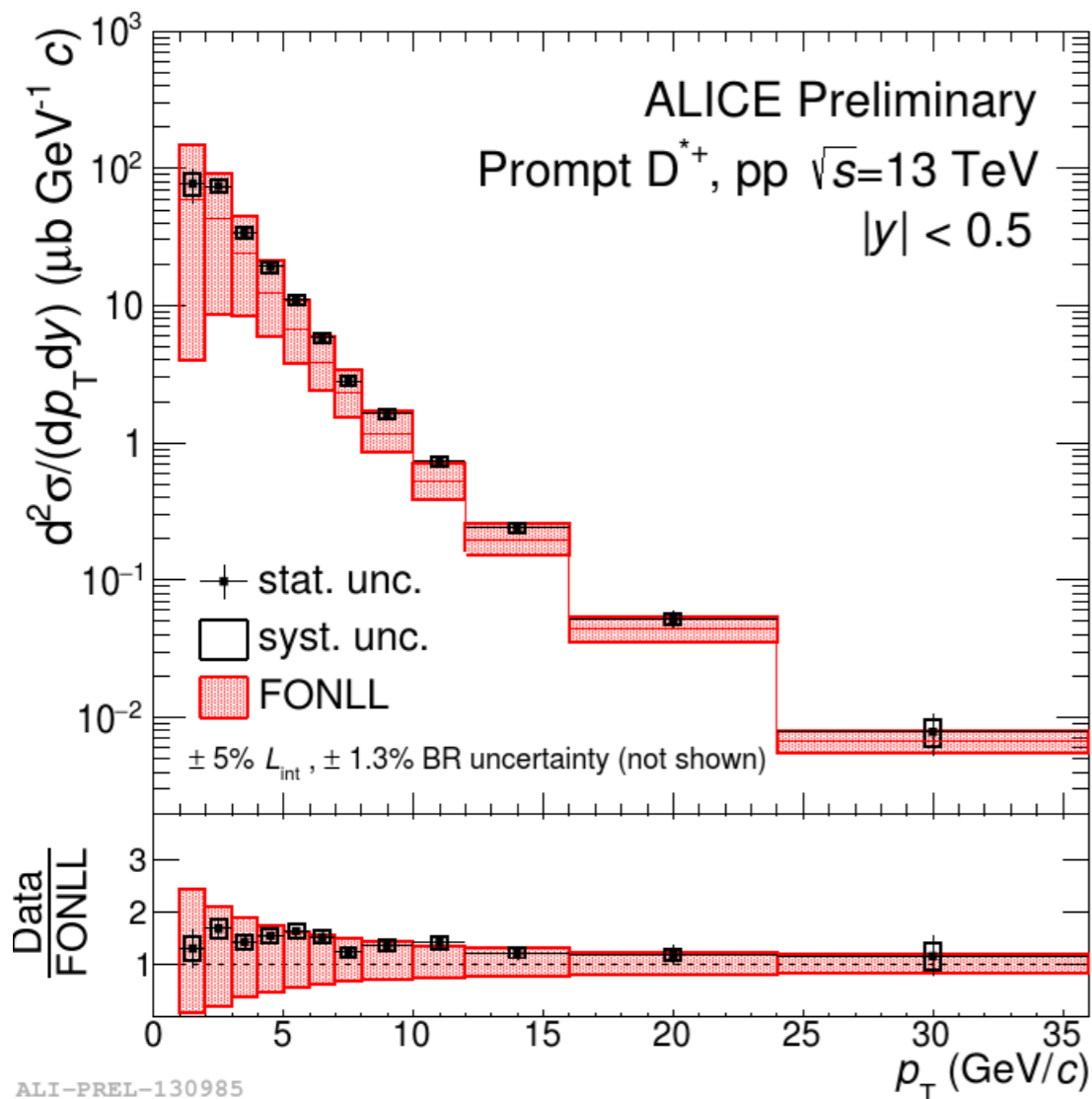
Extra



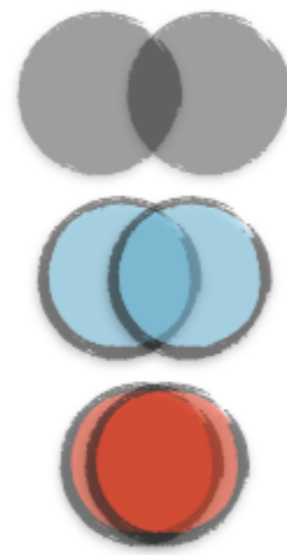
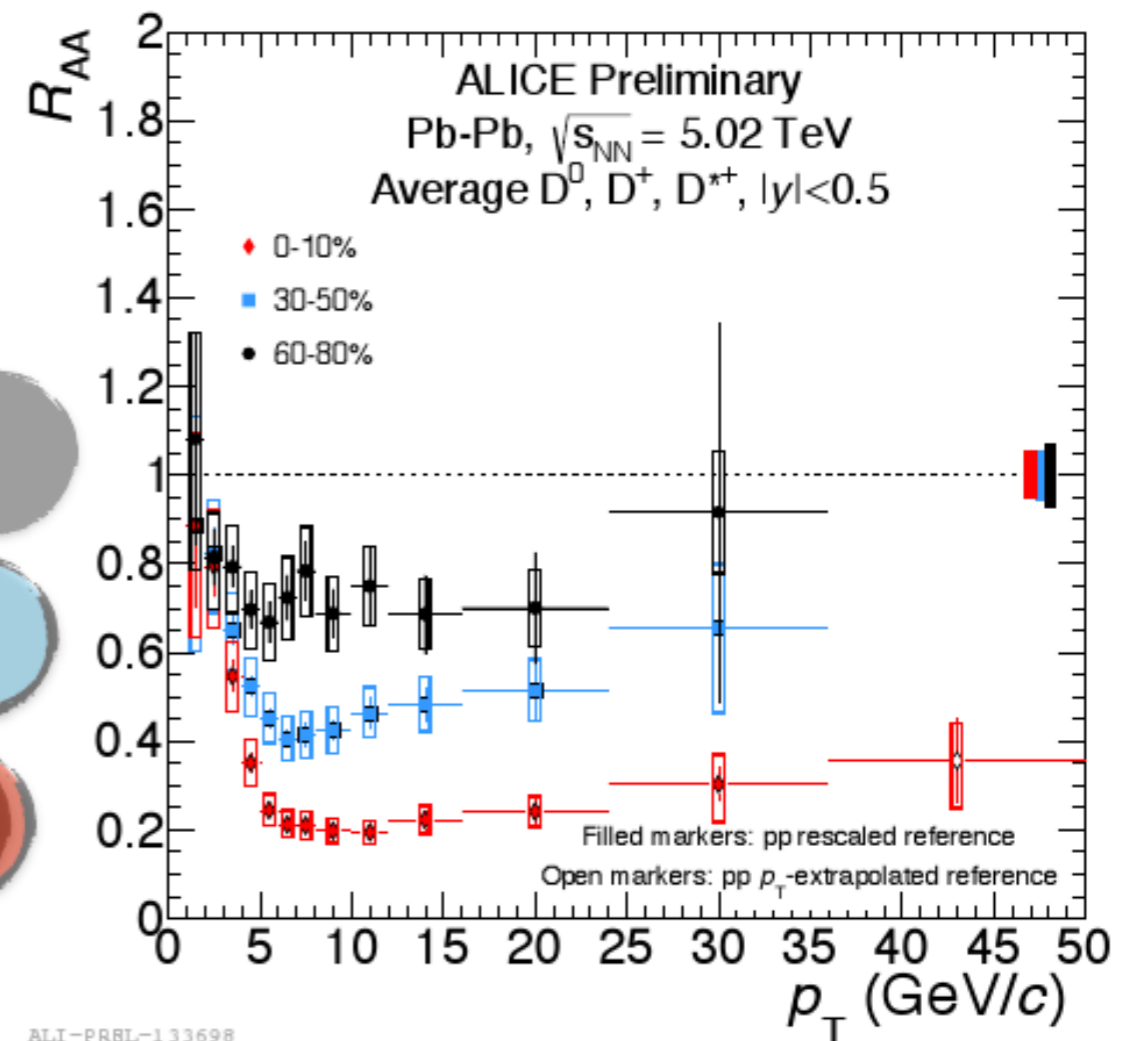
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D mesons in pp and Pb-Pb collisions

D^{*+} meson cross-section
pp collisions at 13 TeV



D meson R_{AA}
Pb-Pb collisions at 5.02 TeV

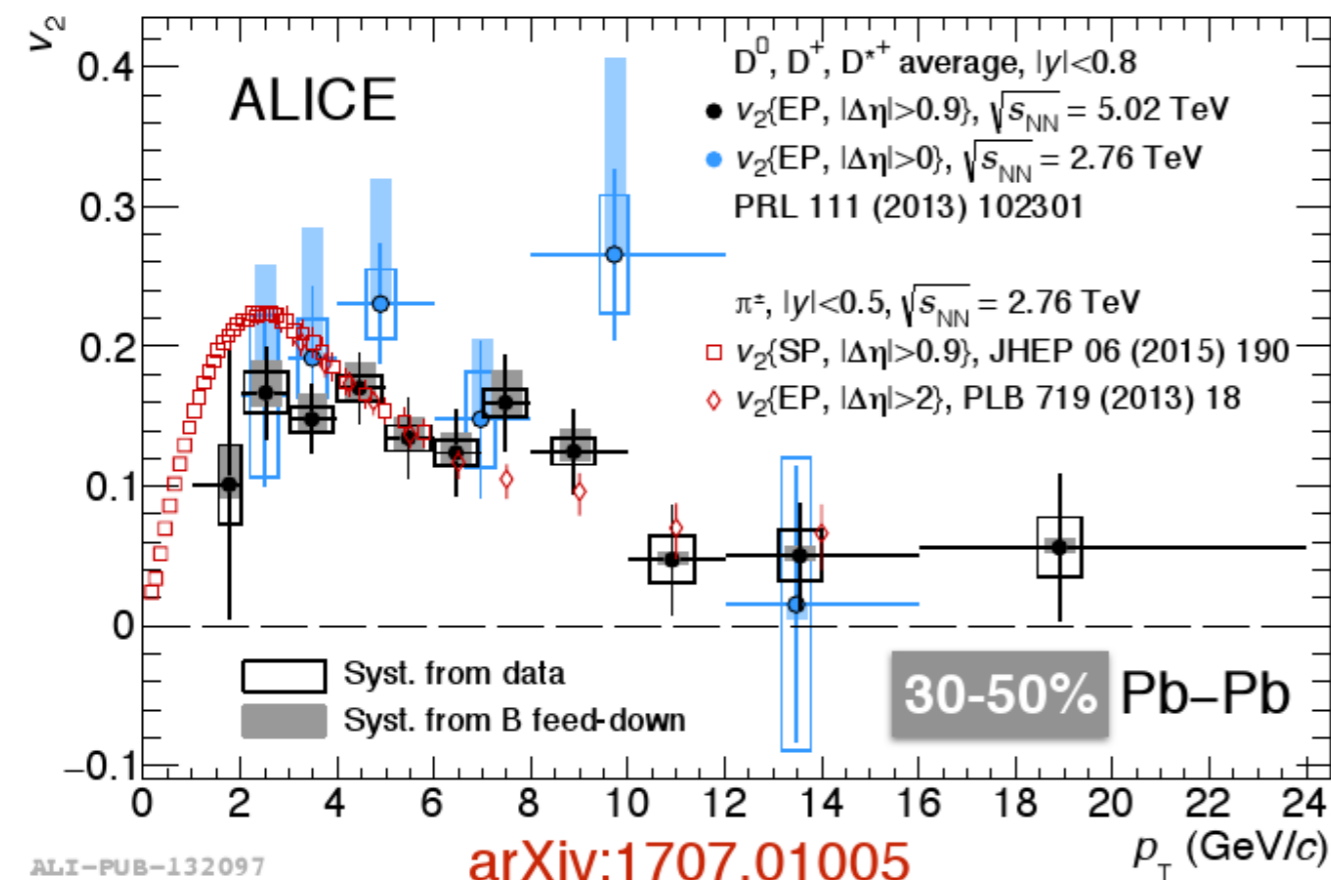


- ✓ D^{*+} cross-section described well by pQCD calculations
- ✓ Increasing suppression from peripheral to central collisions Pb-Pb collisions
 - Energy loss in the hot and dense medium

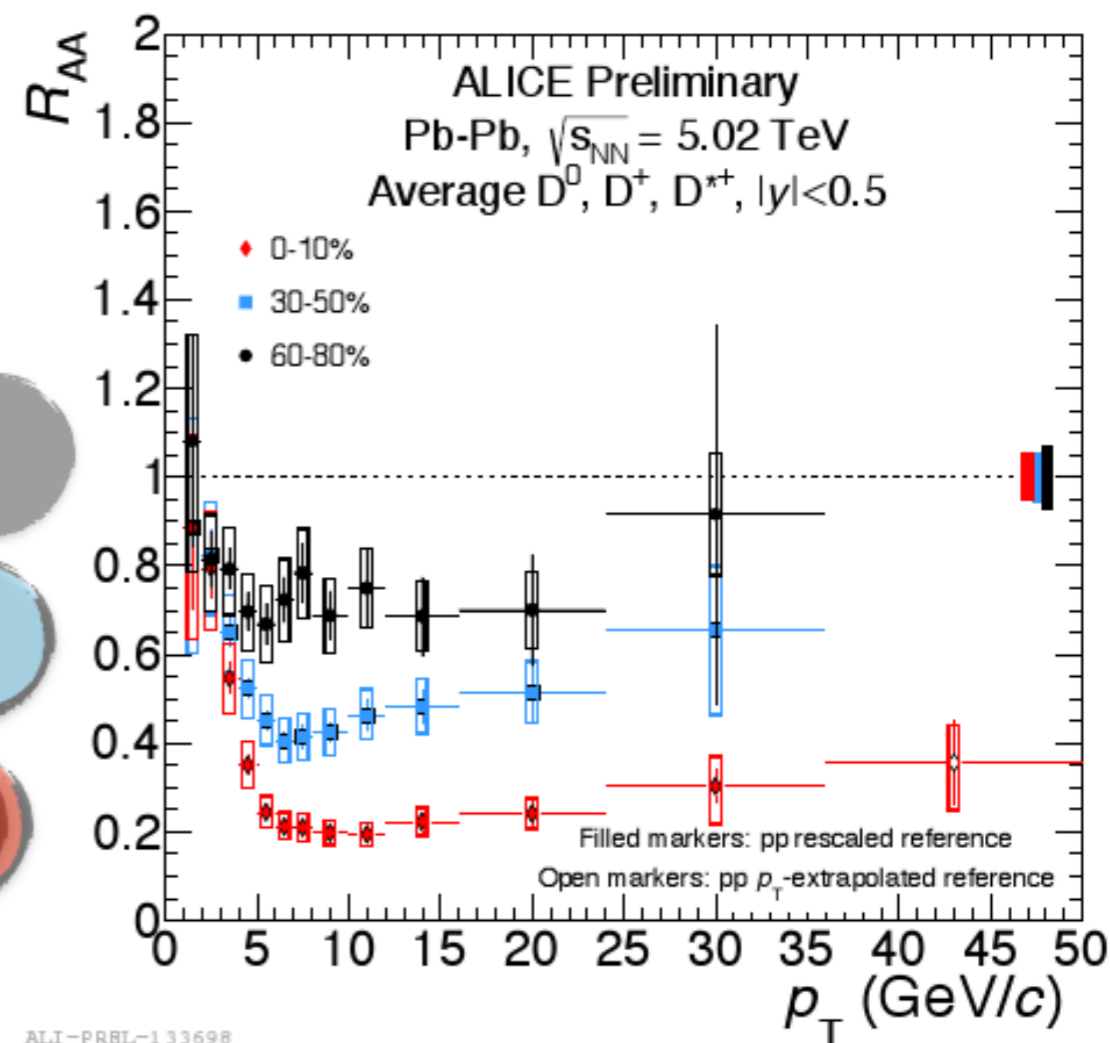


D mesons in Pb-Pb collisions

D meson v_2 Pb-Pb collisions at 5.02 TeV



D meson R_{AA} Pb-Pb collisions at 5.02 TeV



- ✓ D meson $v_2 > 0 \rightarrow$ charm quarks sensitive to medium collective motion
- ✓ Similar to charged hadrons
- ✓ Increasing suppression from peripheral to central collisions Pb-Pb collisions
 - Energy loss in the hot and dense medium



Outline

- i. Motivation**
- ii.**
- iii. Summary**

