Quo Vadis? Future Steps in Heavy Flavor Studies

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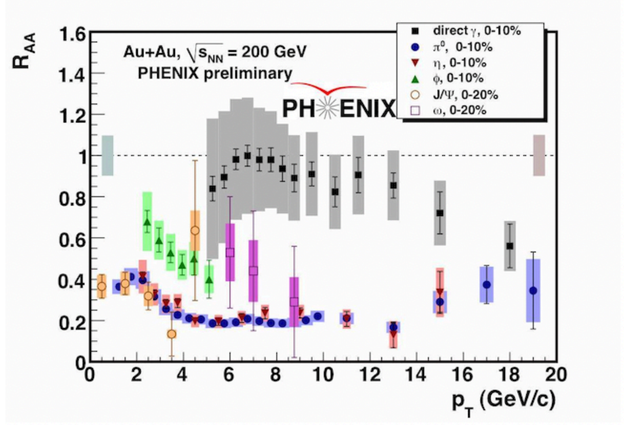
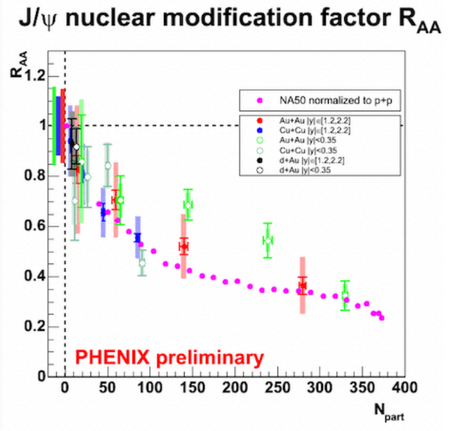
Personal J/ψ History

After the Matsui-Satz suggestion of J/ψ suppression as a QGP signal in the 80's, and the NA50 claim of an anomalous J/ψ suppression in the 90's at SPS, the early days of J/ψ studies at RHIC/PHENIX were very exciting. Among the first things we observed for $R_{\rm AA}$ were rather similar J/ψ suppressions:

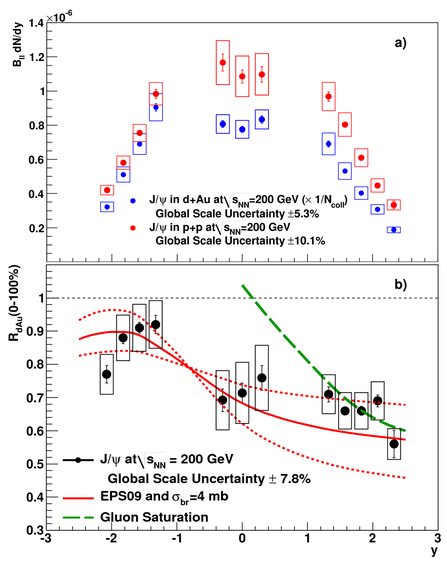
- vs $p_{\rm T}$: as for other hadrons at RHIC...
- vs $N_{\rm part}$: as at SPS/NA50 energies...

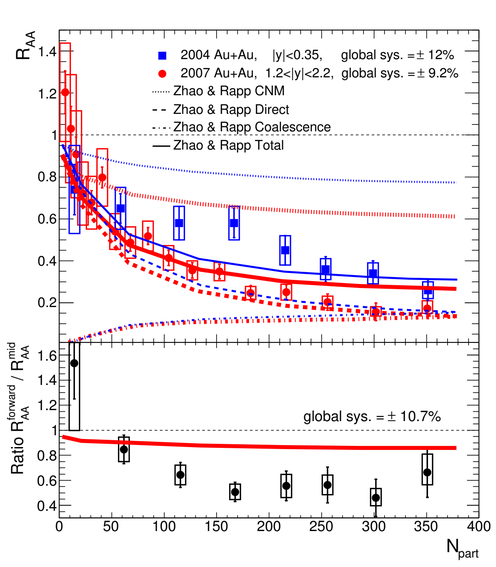




This, together with the uncertainties in p-p and d-Au results, lead to some confusion re. the influence of various effects (cold nuclear matter effects, such as shadowing etc.). After some time of digesting the fact that we also saw more suppression at forward rather than mid-rapidity, the ideas of statistical hadronization or recombination, such as in the models of Andronic et al., and Rapp et al. took hold.

- $R_{\rm dA}$ and $R_{\rm AA}$ at RHIC energies :



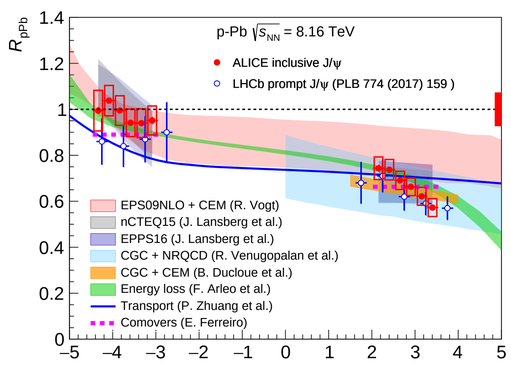


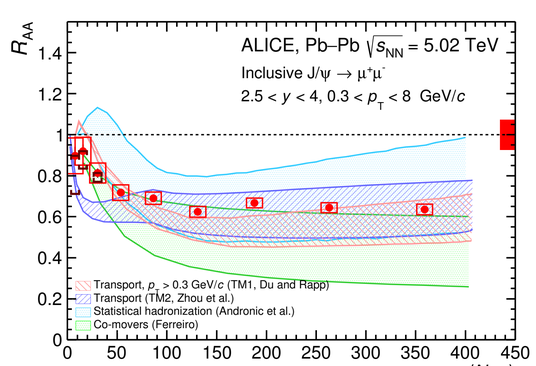
ALICE Results

The results from LHC continued to shed light on heavy flavor production:

- Less $R_{\rm AA}$ suppression than at RHIC became the new J/ψ QGP signal.....
- UPC-like contributions are important for the most peripheral (lowest $N_{\rm part}$) collisions.

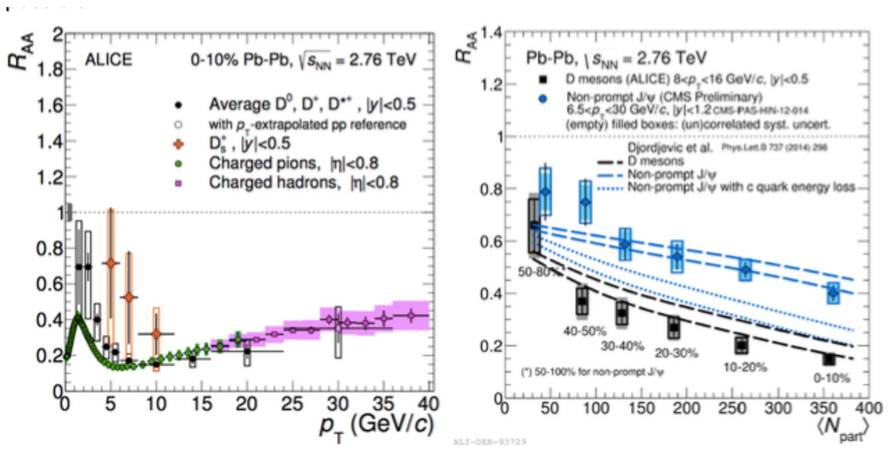
Figure shows $R_{\rm pA}$ and $R_{\rm AA}$ at RHIC energies :





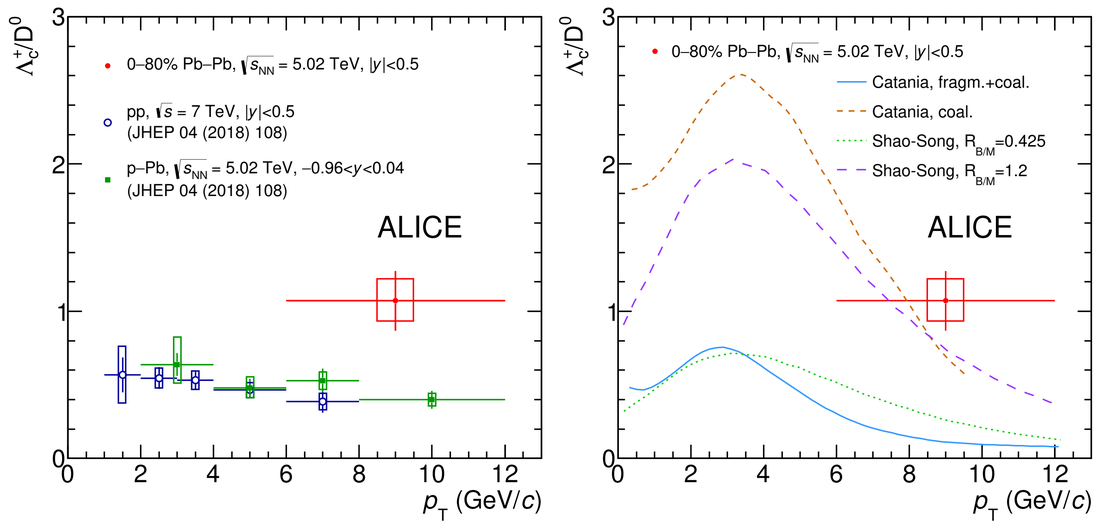
Unexpected results can give the most insight.
How much do we learn about the QGP properties via J/ψ studies?

Another important front is the study of open charm hadrons, i.e. hadrons containing one charm quark (not $c\bar{c}$ as in the case for J/ψ). Recent results are summarized in the figure below.

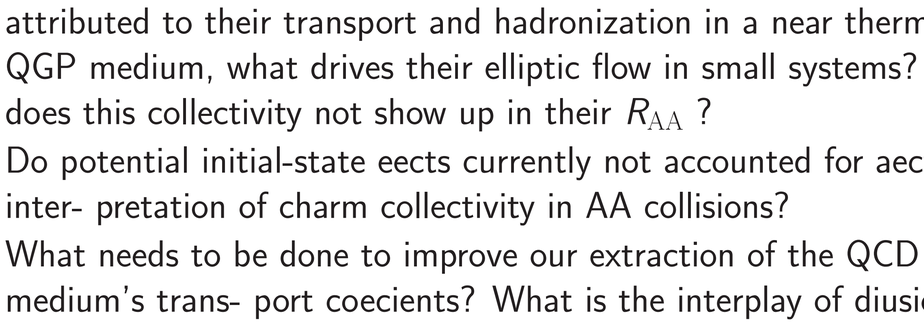


ALICE Future

A lot of the focus in the CLASH workshop is to explain the amount of strangeness as a function of charged particle multiplicity, for instance for Λ/K ratio.
A natural next step will be to study similar quantities for charmed baryons and mesons, e.g. the Λ_c/D^0 ratio. The current status of those measurements in pp, p-Pb and Pb-Pb collisions, are shown below.



The expected performance with the upgraded ALICE, to be compared with the earlier plot with existing ALICE results, are shown here:



There is a large increase in expected significance, and other novel interesting measurements should also be possible. What other quantities that have not yet been measured would help in the understanding of charm production, and/or quantifying QGP properties? To be discussed...

CLASH Heavy Flavor Synopsis Questions

From the nice HF synopsis by Anton and Ralf:

1. What is the nature of the hadronization mechanism of charm in pp collisions (string fragmentation, statistical hadronization, or else), and how does it evolve when going to pA and AA collisions?
2. Is there a connection between the multiplicity dependence of charmonium production in pp collisions vs. AA collisions?
3. While the collectivity of HF particles in AA collisions is successfully attributed to their transport and hadronization in a near thermalized QGP medium, what drives their elliptic flow in small systems? Why does this collectivity not show up in their $R_{\rm AA}$?
4. Do potential initial-state eects currently not accounted for aect our inter- pretation of charm collectivity in AA collisions?
5. What needs to be done to improve our extraction of the QCD medium's trans- port coecients? What is the interplay of diusion and hadronization?
6. How can bottom/onium observables or HF exotics (such as X(3872)) improve our understanding of the issues in (1)-(5)?

References: PHENIX and ALICE results shown here are from the following publications (arxiv ref): 1010.1246, 1103.6269, 1805.04381, 1809.10922.