Measurement of nuclear modification of J/ψ and ψ' production at the E-906/SeaQuest experiment

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Abstract

A measurement of the suppression of J/ψ and ψ' production in high-energy heavy ion interactions has been suggested to be an important probe in identifying the presence and properties of quark-gluon plasma (QGP). However, a similar quarkonium production depletion observed in p-A interactions at lower energies makes it pivotal to understand the effects of cold nuclear matter (CNM) [1]. By doing so, it will be possible to not only kinematically isolate the sources of this suppression but also better constrain presumed QGP signatures. We perform measurements seeking to obtain a better quantitative understanding of this suppression due to CNM effects in the E906/SeaQuest experiment at Fermi National Accelerator Laboratory, a fixed-target experiment producing Drell-Yan, J/ψ and ψ' signals from a 120-GeV proton beam colliding with protons and different heavy nuclear targets. In this poster, we will discuss QGP and CNM effects on charmonium production in more detail and report the status of the analysis at SeaQuest as well as results from E-866, SeaQuest's predecessor with an 800-GeV incident proton beam.

QGP vs. CNM

How could **QGP** cause charmonium production suppression?

- The confinement linear potential between c and c-bar quarks will be less than the thermal kinetic energy because the temperature of the QGP plasma is so high, bringing the J/ψ particle to a state of deconfinement.

- The color-Coulomb interaction between the c and c–bar quarks will be modified because the light quarks, antiquarks and gluons of the plasma can move around from other locations to screen the c-quark color charge from the c-bar quark.

- Eventually, hadronization of the charm (and anti-charm) particles with lighter quarks can take place to form D-mesons instead of J/ψ [3].

CNM effects could also be causing a suppression via several mechanisms, most notably, for the J/ψ and its excited states, via **nuclear absorption**.

- In A-A or A-p collisions, the produced cc–bar pairs interact with the nuclear medium before emerging out.
- Via this interaction, the magnitude of the relative momentum of the pair increases.
- For some pairs, the relative momentum could increase enough to cross into the open charm meson sector reducing the cross-section of J/ψ production relative to that of the p-p cross-section [2,4].

Each of these effects has been shown to be dominant in different energy regimes and evolve uniquely at varying energy densities.

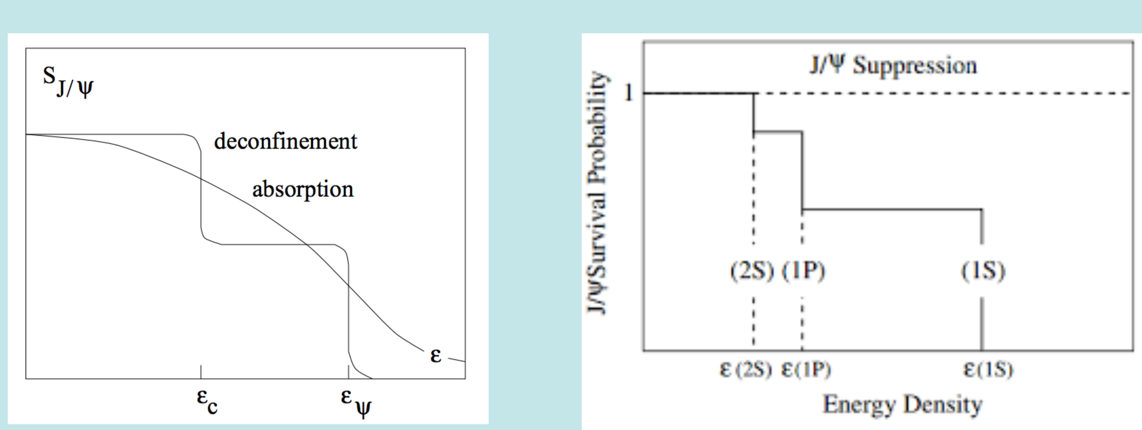
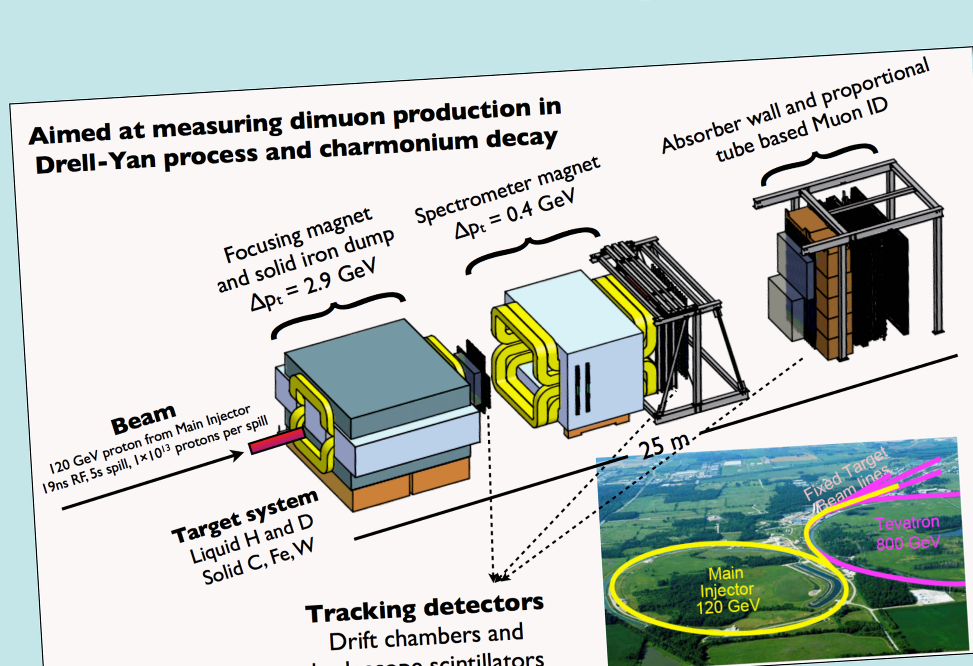


Figure 1. (left) The J/ψ survival probability as a function of energy density for suppression by deconfinement and by hadronic absorption. (right) Sequential quarkonium suppression, where 1S-state is J/ψ [3].

The SeaQuest spectrometer



References

[1] M. Leitch, Eur. Phys. J. A (2004) 19(Suppl 1): 129. https://doi.org/10.1140/epjad/s2004-03-020-2
[2] C. Lourenco, et al., JHEP (2009), https://arxiv.org/pdf/0901.3054.pdf
[3] H. Satz, JHEP (1998), https://arxiv.org/pdf/hep-ph/9806319.pdf
[4] A. Adare, et al., Phys.Rev.Lett. 112 (2014) no.25, 252301. https://arxiv.org/pdf/1310.1005.pdf

J/ψ and ψ' production at SeaQuest

The SeaQuest experiment was designed for the measurement of dimuons resulting from the Drell-Yan (DY) process as well as the decay of the J/ψ and ψ' mesons. The muonic decay products are recorded by the SeaQuest spectrometer.

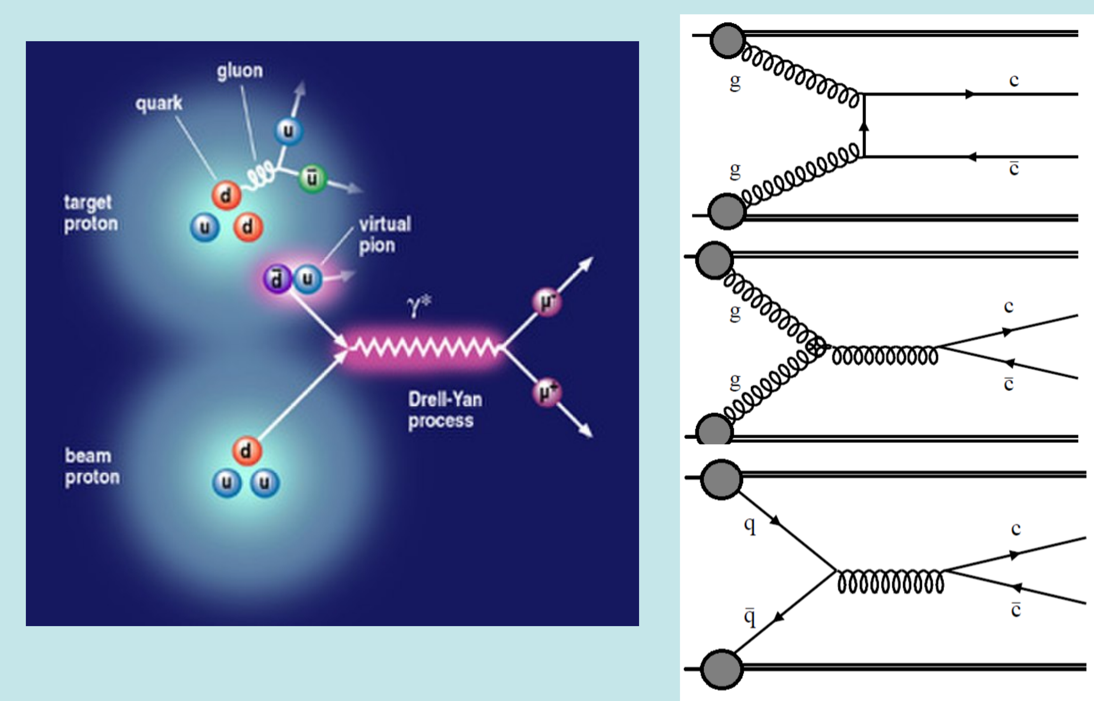


Figure 2. (left) Diagram of the Drell-Yan process. (right) Charmonium production diagram due to gluon-gluon fusion and quark anti-quark annihilation.

Results and current status of the analysis at SeaQuest

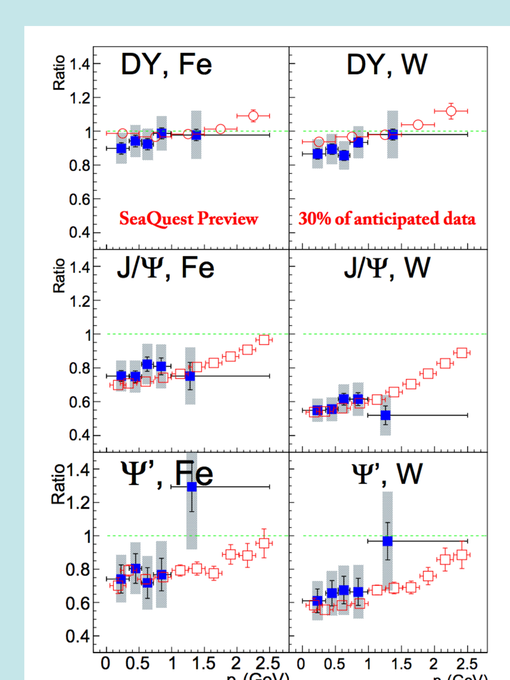


Figure 3. E-866 (red-open points) and SeaQuest (blue points, <50% of data) results for nuclear dependence as a function of pT for DY, J/ψ and ψ' processes. E-866 used beryllium and SeaQuest used carbon as the reference target in these ratio measurements. The inner red and black error bars represent statistical uncertainties and the grey bars represent the systemic uncertainty for SeaQuest.

Ongoing studies

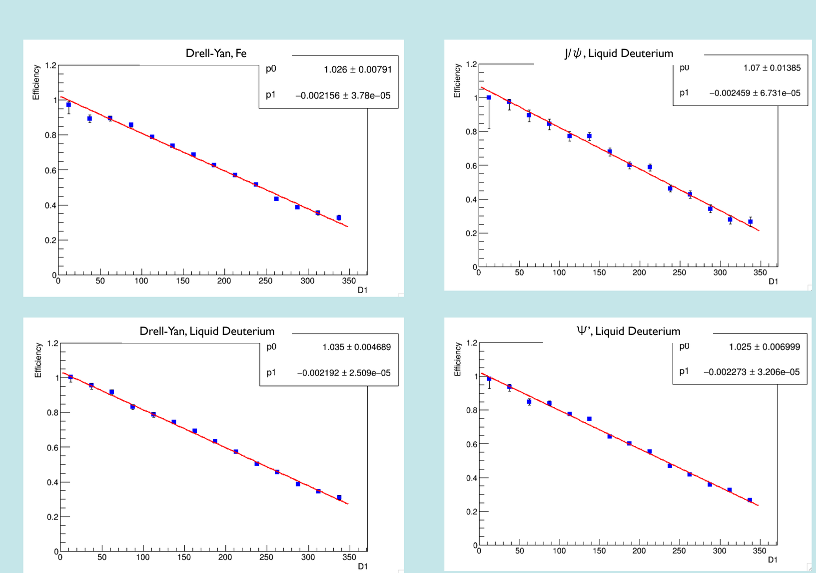


Figure 4. Dimuon reconstruction efficiency as a function of drift chamber 1 occupancy (D1) evaluated using Monte Carlo data samples. Left panel shows tracking efficiency of the Drell-Yan process for Fe and liquid deuterium. Right panel shows tracking efficiency for J/ψ and ψ' processes for liquid deuterium. Efficiency calculations are shown to be target and process independent which is favorable for ratio measurements.

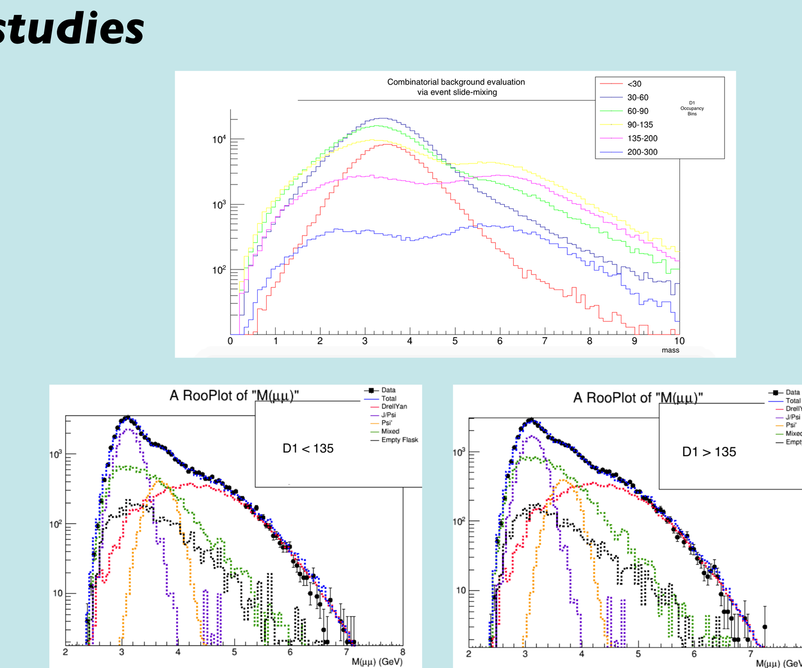


Figure 5. New combinatorial background estimation using an event slide mixing method to pair positive and negative muon tracks. Each "dimuon" is then binned in drift chamber occupancy (D1). This method captures the differences in combinatorial background at varying intensities and allows for a better characterization of our signals.

Conclusion

The SeaQuest measurement will help understand modifications of charmonium due to CNM effects thanks to both the nucleonic diversity of the probed targets and the energy-momentum regimes covered. This will allow models of different CNM mechanisms to be tested and can in turn be used as input to understand what effects in high-energy heavy ion collisions are in fact due to QGP. Analysis efforts are underway and the results shown are preliminary before all the new, above mentioned efficiency and background corrections.

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