Update* on J/ψ cold nuclear matter $R_{AA}$ estimates from fits to dAu $R_{CP}$ data

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*Update of results presented in “Looking for the cold nuclear matter baseline for J/ψ production at RHIC” at the quarkonium workshop at ECT, Trento, May 2009.
Estimating the cold nuclear matter $R_{AA}$ from fits to d+Au data

This is an extension of work (reported at the quarkonium workshop in Trento) to estimate the $R_{AA}$ for heavy ions that would be expected from cold nuclear matter effects alone, using measured d+Au J/$\psi$ data.

I will not describe the calculation details here, please see my Trento slides for those. Briefly, the $R_{AuAu}(CNM)$ calculations there were made by:

- Fitting PHENIX d+Au $R_{CP}$ data with $R_{dAu}$ vs impact parameter calculations by Ramona Vogt ($\sigma_{\text{breakup}}$ + a shadowing model – EKS98, nDSG, or EPS08).
- Parameterizing the d+Au $R_{CP}$ data independently at $y= -1.7, 0, +1.7$.
- Using the parameterizations in a Glauber calculation for Au+Au to calculate for each nucleon-nucleon collision the $R_{dAu}$ for each colliding nucleon in its target nucleus.
- Accumulating $R_{AuAu}(CNM)$ vs centrality for 250,000 Glauber AuAu events.
- Dividing the measured $R_{AA}$ by $R_{AA}(CNM)$ to get “survival probability”.

The effective absorption cross sections from fits of Ramona's calculations to PHENIX d+Au $R_{CP}$ data are shown for each shadowing model.

This is **not** an attempt to extract physics from the d+Au $R_{CP}$! This is just a parameterization of the data that is independent at each rapidity.

The red points are the averages at $y = -1.7$ and $+1.7$. 
The resulting “survival probability” for PHENIX data on J/ψ production in Au+Au collisions shown at the ECT in May was:

This is a brief **update** describing minor improvements to the estimates of $R_{AA}$(CNM) for Au+Au, and the addition of **new estimates for Cu+Cu**.
Changes since May

- The $R_{AuAu}$ (CNM) calculation presented in May was made using theoretical $R_{dAu}$ values vs impact parameter, instead of $R_{pAu}$, in the Glauber model.
- I have now replaced the $R_{dAu}$ theory curves used to calculate $R_{AA}$ (CNM) with new $R_{pAu}$ calculations from Ramona. It turns out that the difference is significant for the most peripheral bins (only).
- I have added a calculation of $R_{CuCu}$ (CNM) made using $R_{pCu}$ calculations by Ramona.
Effect of using $R_{pAu}$ instead of $R_{dAu}$ in Glauber calculation

![Graph showing the ratio of $R_{AA}$ to $R_{AA}$ (CNM) against $N_{part}$ with data points for AuAu at $y=0$ and $y=1.75$. EKS98 CNM baseline is indicated with narrow boxes for correlated systems and wide boxes for CNM baseline system.]
Effect of using $R_{pAu}$ instead of $R_{dAu}$ in Glauber calculation

![Graph showing the comparison of $R_{AA}$ to $R_{AA(CNM)}$ for different $N_{part}$ with EKS98 CNM baseline and correlated sys for Au$\text{Au} y=0$ and Au$\text{Au} y=1.75$. The narrow boxes represent correlated sys, and the wide boxes represent CNM baseline sys.](image)
The Cu+Cu calculations use the same breakup cross sections as those for Au+Au, namely the independent best fit cross sections at each rapidity from the d+Au $R_{CP}$ data with EKS98, nDSg and EPS08 shadowing calculations of $R_{dAu}$ by Ramona (see slide 4).

The $R_{CuCu}(CNM)$ calculations are identical to those for Au+Au with two exceptions:

- The Glauber calculation is for CuCu collisions.
- The shadowing model (EKS98, nDSg, EPS08) for CuCu is used.

We will start by looking at the $R_{AA}(CNM)$ values obtained for the three shadowing models for AuAu and CuCu.
$R_{AA}^{(CNM)}$ for Au+Au and Cu+Cu made with the EKS98 shadowing model and the d+Au best fit breakup cross sections.

Nice agreement of the Npart dependence!
$R_{AA}(\text{CNM})$ for Au+Au and Cu+Cu made with the EPS08 shadowing model and the d+Au best fit breakup cross sections.

Again, nice agreement of the $N_{\text{part}}$ dependence.
$R_{AA}(\text{CNM})$ for Au+Au and Cu+Cu made with the nDSg shadowing model and the d+Au best fit breakup cross sections.

Different Npart dependence for Au+Au and Cu+Cu for the nDSg case! **Why?**
Ramona Vogt pointed me to slide 49 of her Trento presentation, showing the $x$ dependence of various gluon shadowing parameterizations for $J/\psi$ for different nuclear sizes.

Note the smooth behavior of the EKS98 and EPS08 parameterizations with nuclear size, and the non-smooth behavior for nDSg.

Given that the PHENIX Cu+Cu and Au+Au data show reasonable agreement for $R_{AA}$ vs Npart, it seems to me that the nDSg result for Cu+Cu is unlikely, so I will not use it.

This makes clear that there is some model dependence in the $R_{CuCu}(CNM)$ estimates.
Results for “survival probability”

The $R_{AA}(CNM)$ values shown on slides 7 and 8, calculated with the EKS98 and EPS08 parameterizations of the $d+Au$ data, have been used to make plots of $R_{AA}/R_{AA}(CNM)$ for the published PHENIX $J/\psi$ $R_{AA}$ data:


Of course, calling it a “survival probability” implies a particular mechanism for $J/\psi$ production that may not be correct or complete.

It is more accurate to think of $R_{AA}(CNM)$ as “folded pA” - an estimate of what we would see if there were no additional effects in AA collisions.

**BUT:** If the rapidity dependence of the effective absorption cross section in $d+Au$ is due to changes in charm pair production (as distinct from destruction of forming $J/\psi$), the $R_{AA}(CNM)$ reference will work as the baseline for any production mechanism – including statistical hadronization.
$R_{AA}/R_{AA}^{\text{(CNM)}}$ for Au+Au and Cu+Cu made with the EKS98 shadowing model and the d+Au best fit breakup cross sections.
\( \frac{R_{AA}}{R_{AA}} \) (CNM) for Au+Au and Cu+Cu made with the EPS08 shadowing model and the d+Au best fit breakup cross sections.
Aside

If a larger fraction of the $\psi'$ and $\chi_c$ are destroyed by cold nuclear matter effects, which seems very likely, then the $R_{AA}/R_{AA}(\text{CNM})$ will not reflect the destruction of those mesons – they are already gone in our d+Au measurements.

We should try to quantify this at RHIC using our d+Au data.

My point is: be careful about looking for evidence of excited charmonia destruction in $R_{AA}/R_{AA}(\text{CNM})$.

→ in the limit where they were all destroyed in the initial collision, they would have no effect in $R_{AA}/R_{AA}(\text{CNM})$. 
Summary and conclusions

The suppression beyond “folded pA” is very similar for y=0 and y=1.7, even though $R_{AA}$ is quite different.

There is very little dependence of $R_{auAu}(\text{CNM})$ on the shadowing model used in the parameterization of d+Au. Not surprising, since the d+Au $R_{CP}$ was fitted with a Au shadowing model.

But caution: There is significant model dependence of the calculated $R_{CuCu}(\text{CNM})$ when using a parameterization of d+Au data.

Even though the EKS98 and EPS08 $R_{CuCu}(\text{CNM})$ look reasonable next to the $R_{AuAu}(\text{CNM})$ it is important to remember that there is still some model dependence there – the data were fitted using a Au shadowing parameterization, not a Cu one, since we do not have d+Cu data.

I should stress that these are my conclusions - I am not speaking for PHENIX here.
Backup slides
The Npart dependence of Au+Au and Cu+Cu is consistent.

**Note** the smaller systematic uncertainties for the Cu+Cu data. This is primarily due to smaller uncertainties on $N_{\text{coll}}$ from the Glauber calculation.

Thus the Cu+Cu data will be much better for studying the **onset** of hot nuclear matter effects.
The stronger Au+Au suppression at forward/backward rapidity has generated considerable interest.

But what is the expected suppression due to cold nuclear matter effects?