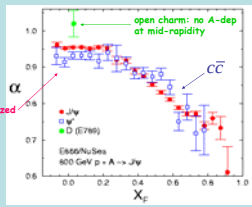
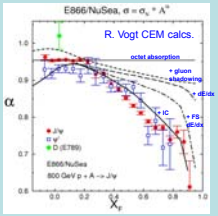
J/ψ Production and Nuclear Effects for d + Au and p + p Collisions at √s = 200 GeV

M.J. Leitch for the PHENIX Collaboration

J/ψ cold-nuclear matter dependence is well known, but complicated

$\sigma_A = \sigma_p A^\alpha$

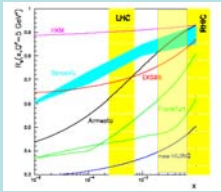




- J/Ψ and Ψ' similar at large x_F where they both correspond to a $c\bar{c}$ traversing the nucleus
- but Ψ' absorbed more strongly than J/Ψ near mid-rapidity (x_F ~ 0) where the resonances are beginning to be hadronized in nucleus
- open charm not suppressed at x_F ~ 0; what about at higher x_F?

- but many ingredients needed [absorption, shadowing, energy loss, intrinsic charm (IC)] to explain the J/ψ nuclear dependence (R. Vogt *Phys.Rev. C61 (2000) 035203*)
- on the other hand, Kopeliovich explains the falloff at large x_F as Sudakov suppression (see below)

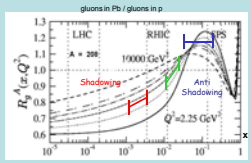
Gluon shadowing is poorly known!



N. Armesto & C. Salgado hep-ph/0308248

Gluon shadowing – "a depletion of the gluon population in a nucleon embedded in a nucleus at small momentum fraction (x) compared to that of the free nucleon."
Many models:
- global fits based on Q^2 dependence of deep-inelastic scattering and Drell-Yan data, e.g. EKS
- gluon saturation at small x, e.g. Color-glass condensate model
- coherence based "shadowing"

PHENIX momentum fraction (x) ranges:
- shadowing (x~2 x 10^{-3}) one muon arm
- anti-shadowing (~10^{-1}) 2nd muon arm
- neither (~2x10^{-2}) central arm (ee)



Eskola, Kolhinen, Vogt Nucl. Phys. A696 (2001) 729-746.

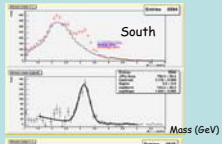
Submitted to PRL (7/28/05) & nucl-ex/

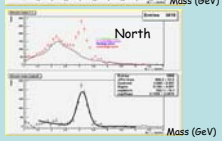
J/ψ Production and Nuclear Effects for $d+Au$ and $p+p$ Collisions at $\sqrt{s_{NN}} = 200$ GeV

J/ψ production in $d+Au$ and $p+p$ collisions at $\sqrt{s_{NN}} = 200$ GeV has been measured by the PHENIX experiment at rapidities $-2.2 < y < +2.4$. The cross sections and nuclear dependence of J/ψ production versus rapidity, transverse momentum, and centrality are obtained and compared to lower energy $p+A$ results and to theoretical models. The observed nuclear dependence in $d+Au$ collisions is found to be modest, suggesting that the absorption in the final state is weak and the shadowing of the gluon distributions is small and consistent with DGLAP-based parameterizations that fit deep-inelastic scattering and Drell-Yan data at lower energies.

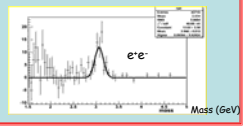
Mass peaks

J/ψ signal for dAu collisions in the South and North muon arms. The random-pair background (black in the top panel of each figure) is calculated from single muons as 2√(++)(– –) then subtracted from the +- spectrum (red points in top panels). The subtracted spectrum in the bottom panel of each figure is fit to a Gaussian for the J/ψ yield + an exponential underneath to account for physics backgrounds (e.g. open-charm pairs and Drell-Yan). Variations on these procedures allow determining additional systematic uncertainties in the yields.

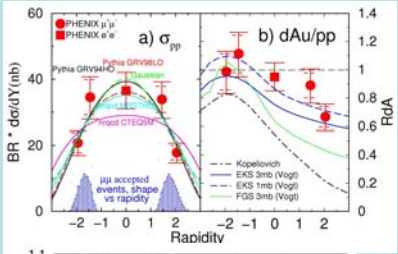




Typical J/ψ signal from di-electrons in the central arms after random background subtraction. Yield is obtained by counting in a 2.6 to 3.6 GeV mass window.



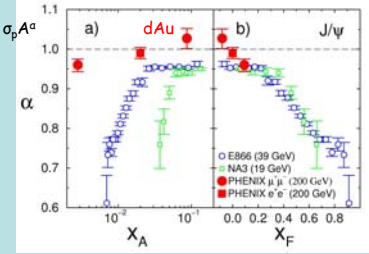
Rapidity, X_A & x_F dependence of pp cross section & nuclear dependence



Total J/ψ cross section at 200 GeV σ_{total} = 2.61 ± 0.20 ± 0.26 μb

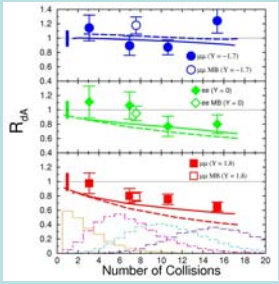
Data favors (weak) shadowing + (weak) absorption (α > 0.92). Theoretical curves from *R. Vogt PRC 71 054902 (2005)*
With limited statistics difficult to disentangle nuclear effects
Will need another dAu run! (more pp data also)

$\sigma_A = \sigma_p A^\alpha$



Not universal versus X_A : shadowing is not the main story.
BUT does scale with x_F ! - why?
- initial-state gluon energy loss -which goes as x_1~x_F - expected to be weak at RHIC energy
- maybe Sudakov suppression?
Kopeliovich et al. hep-ph/0501260
"closing down phase space at larger x_F due to energy conservation" or "you can't make a high-x_F J/ψ if you radiate too many gluons in the final state; and the nuclear environment makes the chance of radiating a gluon larger"

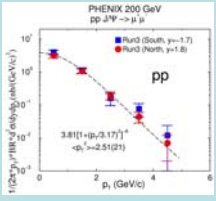
Centrality dependence of nuclear dependence

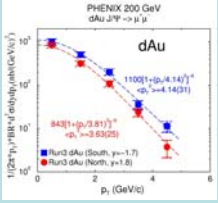


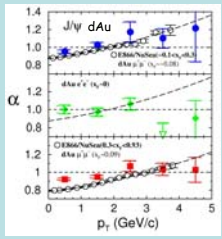
Theoretical curves are from Vogt and show the predicted centrality dependence for EKS (solid) and FGS (dashed) shadowing for each rapidity range
R. Vogt PRC 71 054902 (2005)

Gradual falloff wrt centrality for positive rapidity (small-x) presumably due to shadowing density/path-length dependence. Negative & zero rapidity (larger x's) flat within uncertainties.

p_T shapes & nuclear modifications



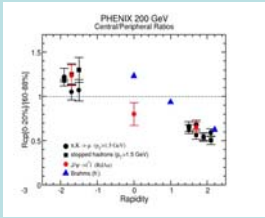




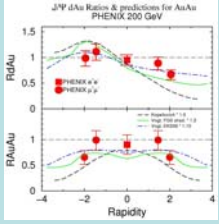
p_T broadening for dAu comparable to lower energy (√s = 39 GeV in E866) within present statistical precision

Thought to be caused by initial-state multiple scattering, sometimes called the "Cronin effect"

Comparisons with hadron data & baseline for AA collisions



Comparison of RdAu(J/ψ) with Rcp for hadrons from PHENIX – *PRL 94, 082302 (2004)* & Brahms - *PRL 93, 242303 (2004)*



AuAu nuclear modification factor derived from dAu. Points with errors in bottom panel are not measured, rather are derived from the dAu points above. Clearly we need higher statistics dAu data from a new dAu (or pAu) run to give a more precise baseline for AA studies.