Beam Use Proposal for a PHENIX 2003 d-Au Run

PHENIX d-A Working Group

1 Introduction and Summary

It has long been recognized that p-A collisions serve an important role in the search for quark-gluon plasma (QGP) in relativistic heavy-ion collisions. Since QGP is in general not expected to be produced in p-A collisions, a comparison of the A-A with p-A data at identical kinematic conditions is crucial for identifying signatures for QGP formation. This was demonstrated in the AGS and SPS heavy-ion programs, which benefited greatly from the p-A measurements for interpreting the A-A results. This important role of p-A collisions is clearly valid at RHIC too.

In addition to their connection to A-A physics, the p-A measurements are important in their own right. Many outstanding questions in hadron physics can be well addressed with a p-A program at RHIC. It is important to point out that RHIC, for the first time, will allow us to study p-A interaction in a collider mode. At RHIC, the center-of-mass energy reached in p-A collisions is roughly an order of magnitude higher than any existing fixed-target experiments. Moreover, the large-acceptance collider detectors are capable of measuring many particles produced in the p-A collisions simultaneously, which could provide qualitatively new information not accessible in previous fixed-target experiments.

We propose that eight weeks of beam-commissioning and data-taking be allocated to d-Au collisions at $\sqrt{s} = 200$ GeV for the RHIC 2003 run. The data on the d-Au collision will play an essential role for interpreting the Au-Au data. These d-Au data will also provide unique information on the partonic structures in the nuclei and the propagation of partons in a cold nuclear medium.

Some specific physics results which could be obtained by PHENIX in this initial d-Au run include:

- A study of parton energy-loss and jet quenching in cold nuclear matter via the measurement of high-p_T single hadrons.
- A measurement of J/Ψ production in nucleus covering a wide kinematic regime including small Bjorken-x and negative x_F. Nuclear shadowing of gluons at small x can be studied.

- A measurement of open-charm production and heavy-quark propagation in cold nucleus via the detection of high-p_T single leptons.
- A study of the correlation of various observables with the number of "grey tracks" detected with the forward-angle calorimeter.

In addition, a long list of physics topics at relatively low p_T, including $dN/d\eta$, $dE_T/d\eta$, elliptic flow, HBT, particle/antiparticle ratios, medium effect of Φ production, event-by-event fluctuation, etc., can be well studied in the proposed d+Au run.

We believe this initial d-Au commissioning and running in 2003 is important for demonstrating the capability of colliding asymmetric species at RHIC, and for collecting important first data on d-A. This d-Au run is also crucial for planning future runs to realize the full potential of a p-A program at RHIC.

2 Physics Justification

We briefly summarize some of the physics justifications for a d-Au run. The expected event rates for some measurements are also presented. These rates are calculated based on Tom Roser's model [1] that the length of the data-taking period will be 3 weeks with an average luminosity of 4 $(\mathrm{nb})^{-1}$ per week. We also assume that 50% of the collisions survive the PHENIX interaction vertex cut, and an average up-time of 56% for PHENIX. These are conservative estimates. The trigger and reconstruction efficiencies of various events are also taken into account.

2.1 Jet Quenching

Recent results from PHENIX [2] showed a prominent suppression of high-p_T hadrons in central Au-Au collision at $\sqrt{s} = 130$ GeV. This striking result is consistent with a calculation performed by Wang and Wang [3] incorporating a large rate of energy loss for partons traversing a dense nuclear medium. These authors conclude that the initial gluon density in Au-Au collision at $\tau_0 = 0.2$ fm/c is ~ 15 times higher than that in a cold Au nucleus.

Figure 1 shows the prediction of Wang and Wang on the nuclear modification factors of π^0 p_T spectra at $\sqrt{s} = 200$ GeV for both d+Au and central Au+Au collision. With a three-week d+Au run, a reach in p_T up to 15 GeV/c (***Just a guess, Please check this number***) can be readily accomplished. These d+Au data will shed much light on the origins of the suppression of large p_T hadrons observed at RHIC energies.

2.2 J/Ψ Production

An important physics topics which can be studied with a 3-week d+Au run is the J/Ψ production. A comparison of the J/Ψ productions in p+p, d+Au, and Au+Au is crucial for studying possible evidence for quark-gluon plasma formation. We have calculated the production of J/Ψ in the d+Au reaction at $\sqrt{s} = 200$ GeV and the acceptance of the PHENIX detector for the J/Ψ events.

Calculation for J/Ψ cross section in p+p collision at $\sqrt{s} = 200$ GeV using a color-evaporation model is shown in Fig. 2. The preliminary PHENIX result [4] is also shown for comparison. The normalization factor is adjusted to fit the PHENIX preliminary data, giving a total p+p J/Ψ production cross section of 4.01 μb.

Figure 2 also shows the prediction of the J/Ψ cross section per binary collision in d+Au at $\sqrt{s} = 200$ GeV. The nuclear effect is calculated by using the parametrization of Eskola et al. [5] for nuclear shadowing of the quark and gluon distributions. It is interesting to note that the nuclear shadowing effect causes some asymmetry in the x_F distribution. The J/Ψ cross sections at positive x_F, corresponding to small x_2, are suppressed relative to those at negative x_F. The J/Ψ cross section per binary collision is 3.91 μb (or a total d+Au J/Ψ cross section of 1540 μb).

Kopeliovich et al. recently predicted a strong nuclear shadowing effect for J/Ψ production in p-Au collision [6]. Assuming the same shadowing effect for d-Au collision, the predicted J/Ψ cross section is shown in Fig. 2 as the dotted curve. A comparison of teh dashed and dotted curves in Fig. 2 clearly shows that the J/Ψ data from the d-Au collision can readily distinguish the shadowing model of Eskola et al. from the model of Kopeliovich et al.

From our simulation study [7], we found that the total number of $J/\Psi \rightarrow \mu^+\mu^-$ reconstructed events for the South and North Muon Arms are 2479 and 2259, respectively. The total $J/\Psi \rightarrow e^+e^-$ events reconstructed by the central arm is around 630. The event distributions as a function of x_F, p_T and x_2 are shown in Fig. 3. The coverage in p_T and x_2 is quite broad, allowing a detailed study of the J/Ψ production as a function of these variables.

By comparing the J/Ψ production cross sections of d+Au versus p+p, one can determine the nuclear-dependence parameter α as a function of x_F, p_T, and x_2. The nuclear dependence is parametrized as A^α. Figure 4 shows the expected statistical accuracy for α in a three-week d+Au run. We assume the corresponding p+p run has an integrated luminosity similar to that of d+Au. Also shown in Fig. 4 are the data obtained at the Fermilab fixed-target experiment E866 [8].

2.3 Open-charm Production

Perhaps Y. Akiba and Mike Leitch can help on this section?

2.4 Tagging with Grey Tracks

Brian Cole and Steve Johnson?

3 Machine Issues

Perhaps Sam could help on this section?

4 PHENIX Trigger and DAQ Issues

Brian Cole and Matthias?

References

[1] T. Roser, "RHIC Run 3 (FY2003) Running Projections", June 28, 2002.

[2] K. Adcox et al., Phys. Rev. Lett. 88 (2002) 022301.

[3] E. Wang and X.-N. Wang, hep-ph/0202105.

[4] H. D. Sato and V. Cianciolo, PHENIX analysis note, July 10, 2002.

[5] K. J. Eskola, V. J. Kolhinen and P. V. Ruuskanen, Nucl. Phys. B535 (1998) 351.

[6] B. Kopeliovich, A. Tarasov and J. Hufner, Nucl. Phys. A696 (2001) 669.

[7] J. C. Peng, "J/Ψ Production for a d+Au Run at PHENIX", http://www.phenix.bnl.gov/WWW/publish/jcpeng/da/jpsi.ps

[8] M. J. Leitch et al., Phys. Rev. Lett. 84 (2000) 3256.

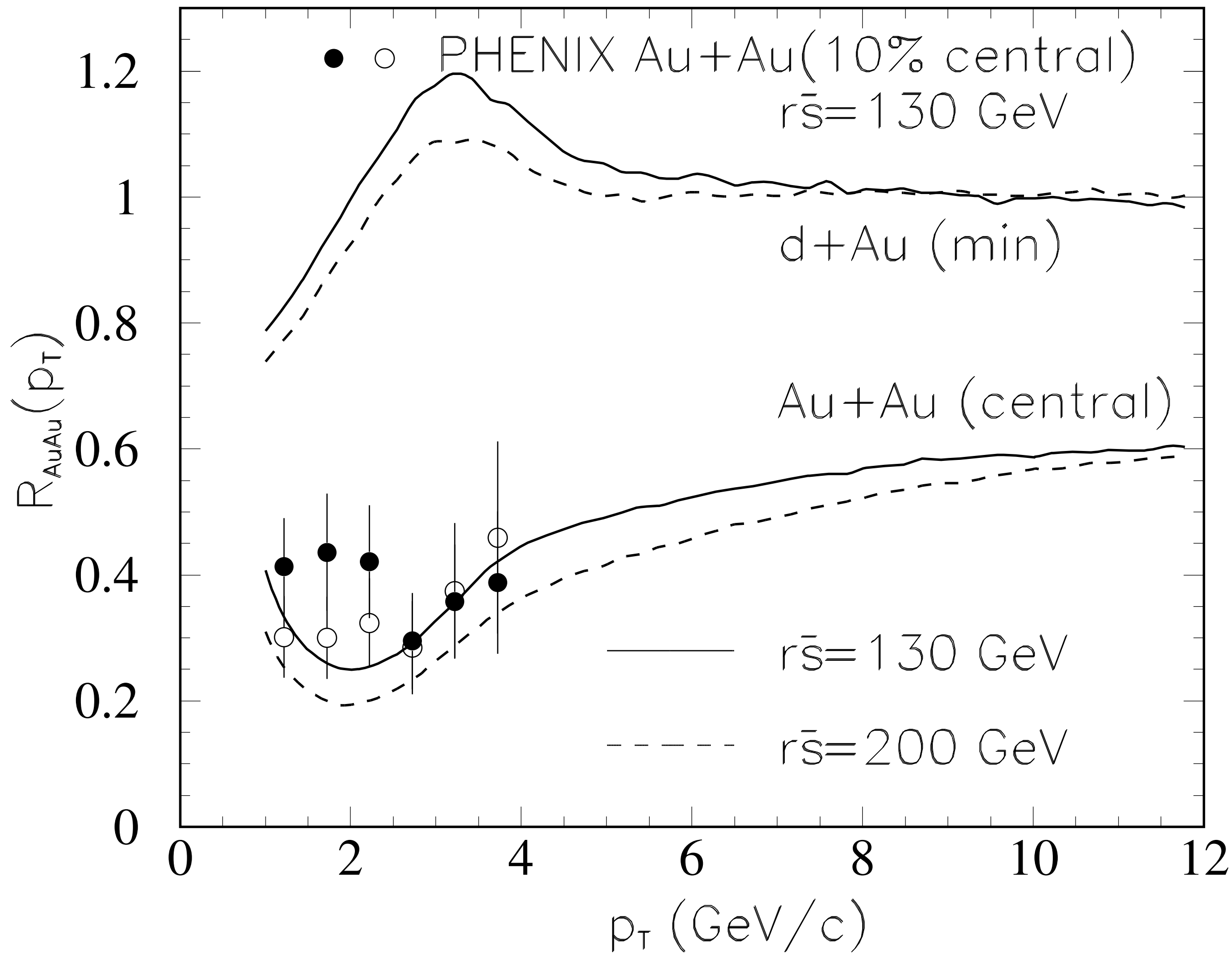

Figure 1: Prediction of nuclear modification factor of π° p_T spectra for d+Au and cetral Au+Au collisions at $\sqrt{s}$ = 130 and 200 GeV [3].

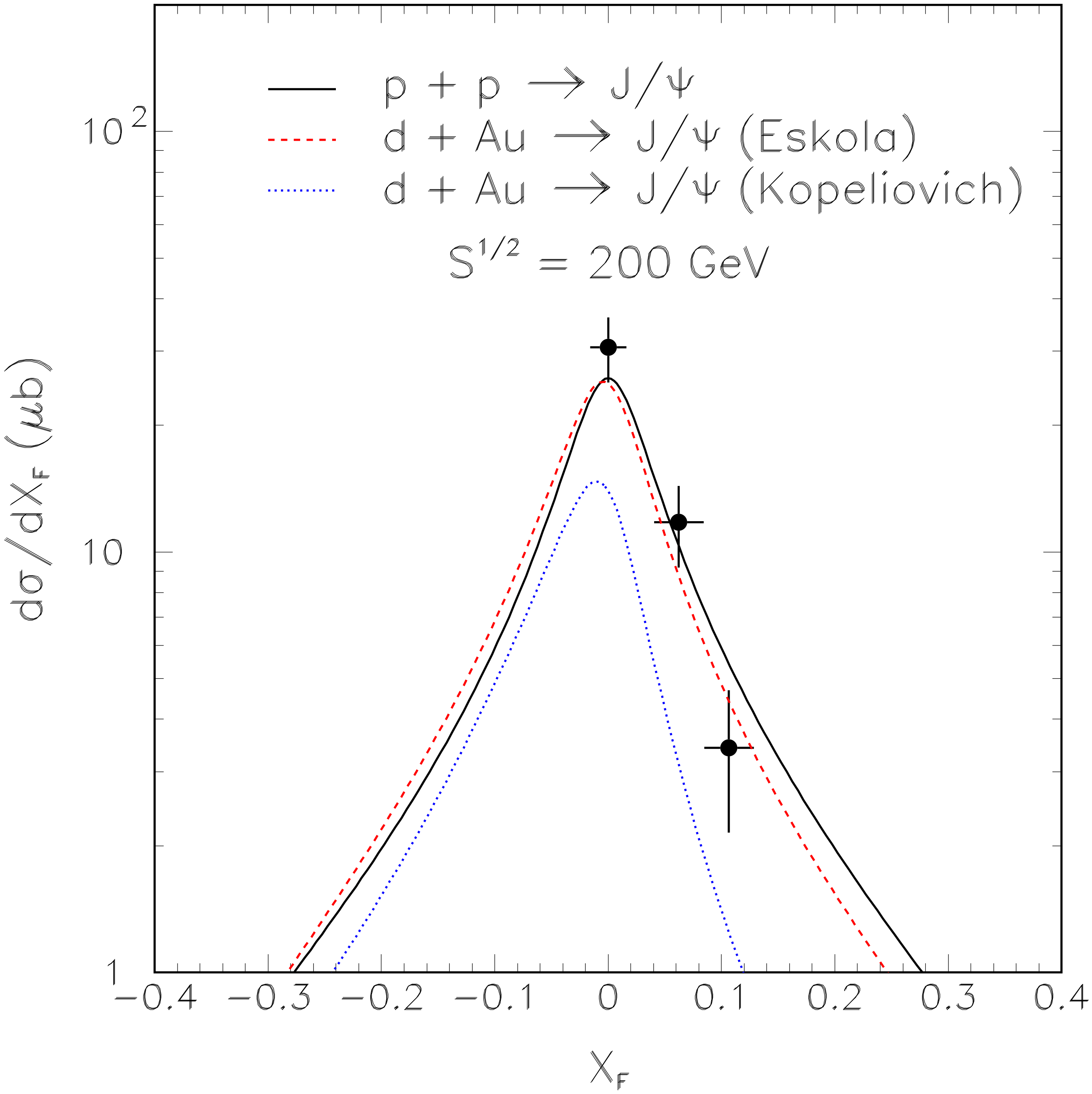

Figure 2: Comparison of the calculation of the color-evaporation model with the p+p preliminary PHENIX data at $\sqrt{s}$ = 200 GeV [4]. The dashed curve is a calculation for d+Au using the parametrization of Eskola et al. [5] for quark and gluon shadowing in nuclei. The dotted curve is a prediction for d+Au using the nuclear J/Ψ suppression calculations by Kopeliovich et al. [6].

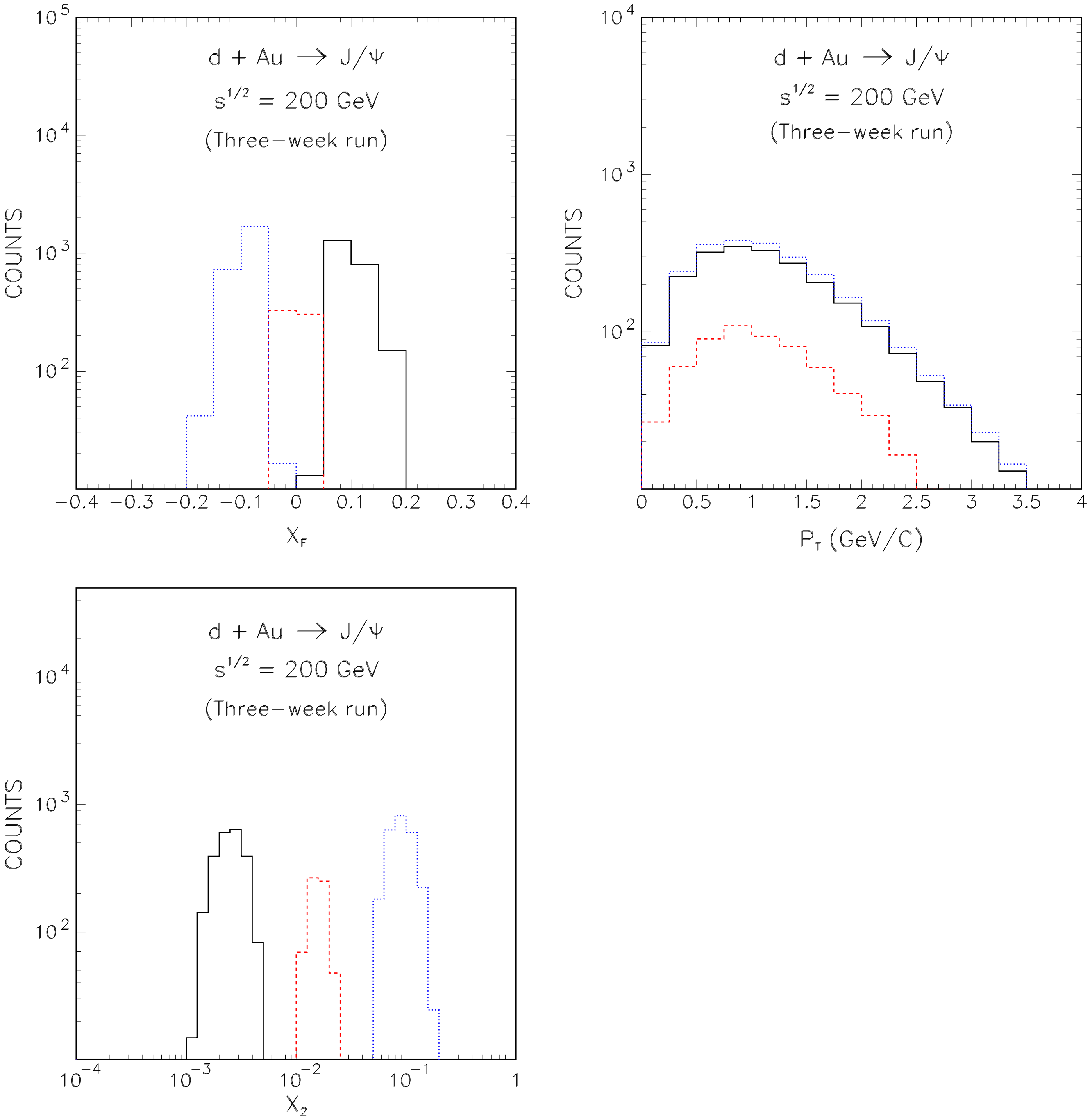

Figure 3: Expected event distributions for J/Ψ in a two-week d+Au run at $\sqrt{s} = 200$ GeV. The solid, dashed, and dotted histograms correspond to the North muon arm, central arm, and South muon arm detection, respectively.

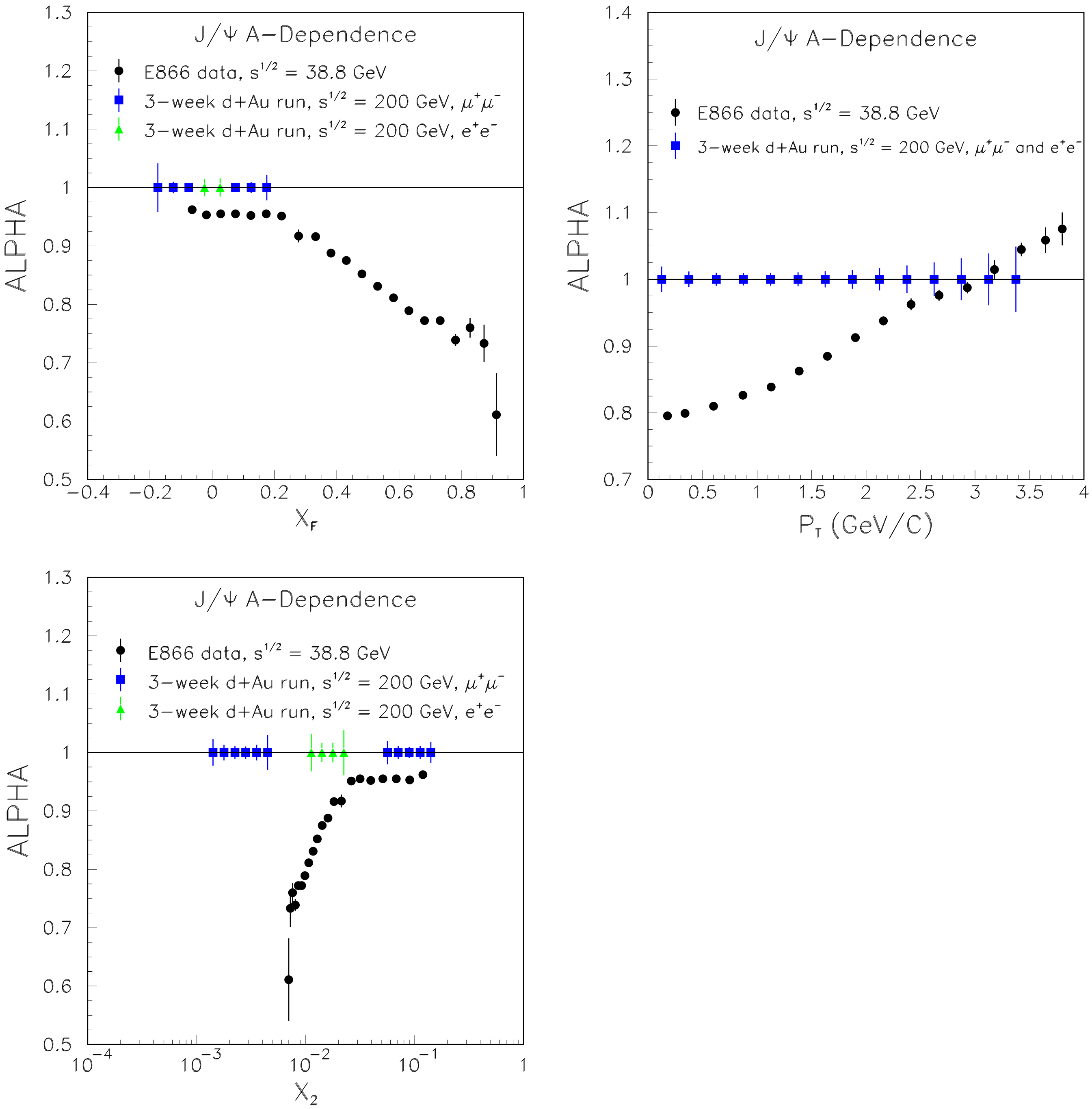

Figure 4: Expected statistical accuracy for measuring the nuclear dependence parameter α from a three-week d+Au run at PHENIX. Data from a fixed-target experiment [8] at $\sqrt{s} = 38.8$ GeV are also shown.