χ_C Measurement in PHENIX: the Present and the Future.

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Motivation

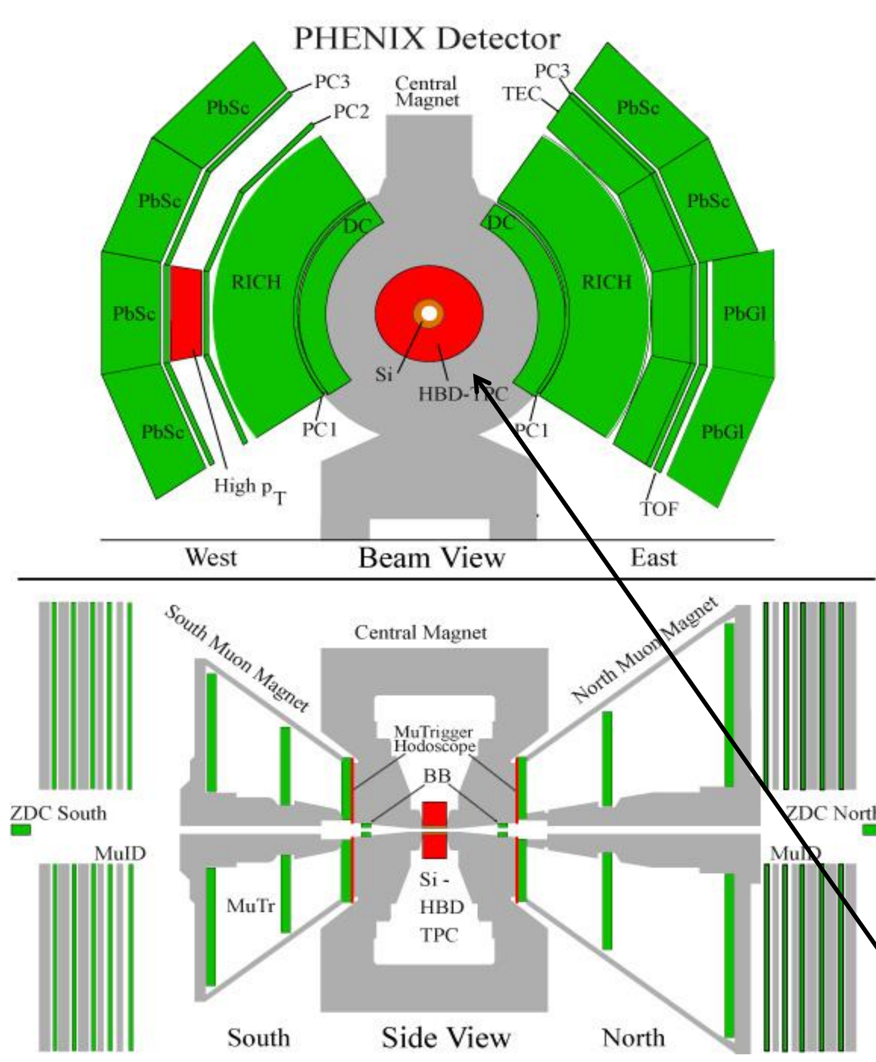
Measurement of different quarkonia states is a well known tool for study of hot and dense matter produced in heavy ion collisions.

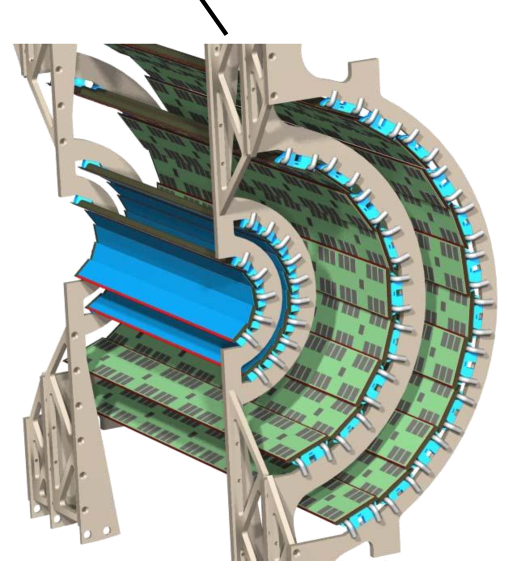
The PHENIX (**P**ioneering **H**igh **E**nergy **N**uclear **I**nteraction e**X**periment) at RHIC have successfully measured χ_C production in p+p and d+Au collisions at 200 GeV. The χ_C were reconstructed through their decays to $J/\psi + \gamma$ in PHENIX Central Arms.

The accuracy and p_T reach of these measurements potentially can be improved, if one uses conversions of soft photons from χ_C decays to e^+e^- pairs. These pairs can be then detected by the recently installed Silicon Vertex Detector (VTX). Since VTX detector covers much larger acceptance than PHENIX Central Arms, and momentum resolution of VTX at low p_T is reasonably good, such measurement can improve existing results.

Introduction

The PHENIX experiment is one of the two large experiments at the Relativistic Heavy Ion Collider (RHIC) located at the Brookhaven National Laboratory (BNL) on Long Island, New York.



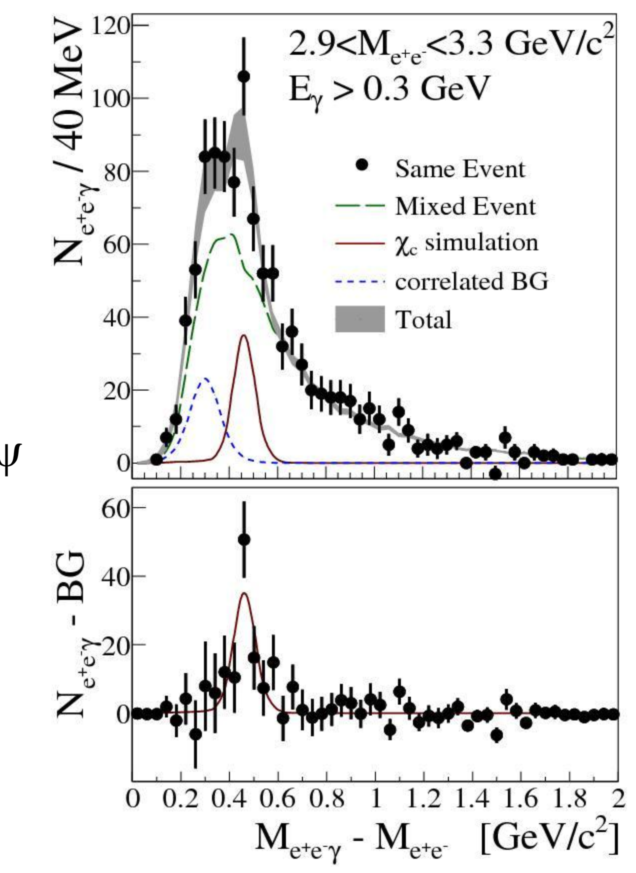


The Slicon Vertex Detector Upgrade (VTX) to the PHENIX detector was installed in PHENIX at the end of 2010, and commissioned during 500 GeV p + p in 2011. It took data during 200 GeV Au+Au in 2011, and 200 GeV p+p in 2012.

VTX detector consists of two layers of silicon pixels surrounded by two layers of silicon stripixels, and covers $|\eta| < 1$ in pseudo-rapidity, and $\Delta\phi$ of 80% of 2π in azimuth. The main purpose of the VTX is to identify the displaced vertices of D and B meson decays, allowing separate identification of open charm and open beauty.
VTX also provides large solid angle stand-alone tracking with modest momentum resolution ($\Delta p/p$ = 5% +10%p). This helps to improve jet and flow measurements in PHENIX. In Au+Au collisions
VTX detector provides accurate measurement of the event vertex, with few tens of microns precision.

The Present: 2006 and 2009 χ_C measurements

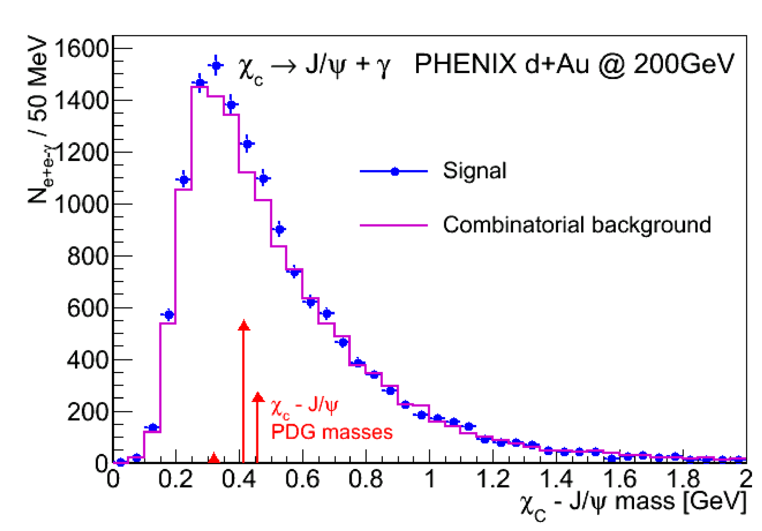
The PHENIX experiment measured χ_C production in p+p and d+Au collisions at 200*AGeV* before the VTX detector was installed. The χ_C decays were reconstructed through their decays to $J/\psi + \gamma$. The main problem of χ_C measurement is that the photon from χ_C decay has very low energy (typically 0.3-0.6*GeV*). As a result, there is very large combinatorial background. Another problem is the presence of correlated background from processes that have a J/ψ and a γ in the final state, like $\psi' \to J/\psi + \pi^0 + \pi^0$

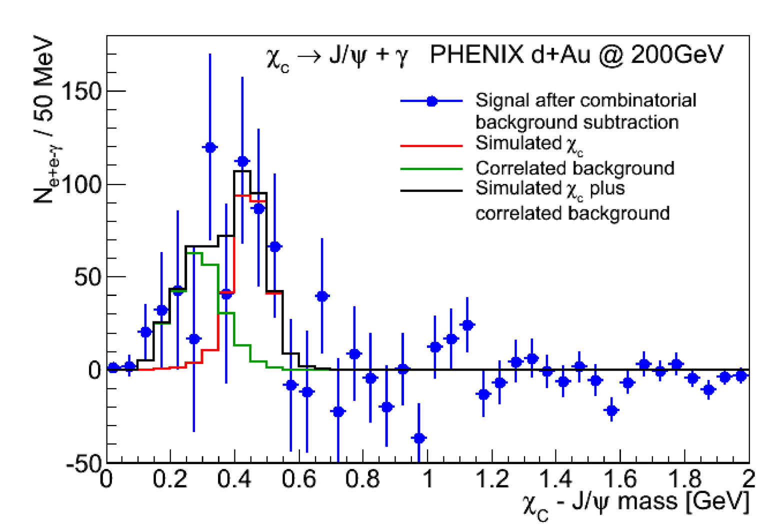


χ_C measurement in p+p collisions is shown at right. By comparing this result to J/ψ measurement we can determine that $0.32 \pm 0.08(stat) \pm 0.03(sys)$ fraction of J/ψ comes from χ_C decays in p+p collisions at 200*GeV*.

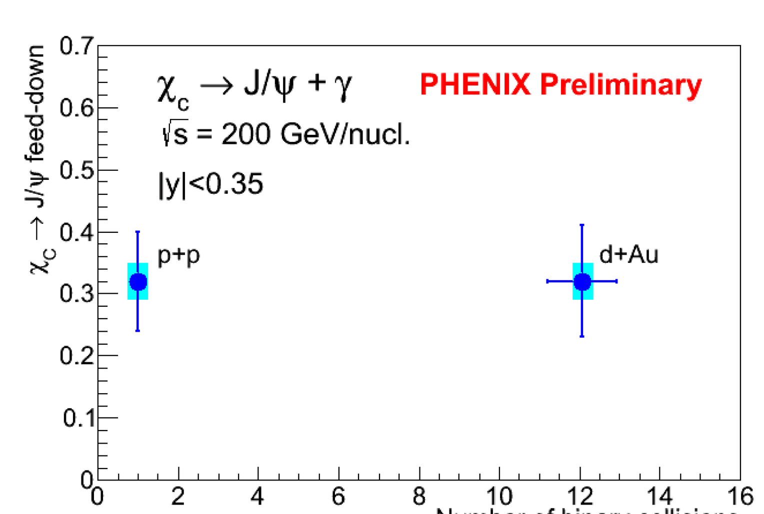
χ_C measurement in d+Au collisions is even more challenging due to higher photon multiplicity. Careful combinatorial background calculation using event mixing method with very fine centrality and event vertex binning was necessary in order to make the measurement. We also made thorough study of correlated background using simulation in order to reproduce the measured J/ψ-gamma invariant mass distribution.

The results of χ_C measurement in d+Au collisions at 200*AGeV* are shown below. The left plot shows measured J/ψ-gamma invariant mass distribution (minus J/ψ mass) and combinatorial background calculated using mixed events method. The right plot shows invariant mass distribution after subtraction of combinatorial background. Correlated background is also shown as green histogram.





χ_C to J/ψ feed-down in d+Au collisions at 200*AGeV* was was found to be $0.32 \pm 0.09(stat) \pm 0.03(sys)$. By comparing this result to p+p measurement, we can calculate that nuclear modification factor in dAu collisions $R_{AA} = 1.0 \pm 0.53(stat) \pm 0.14(sys)$.



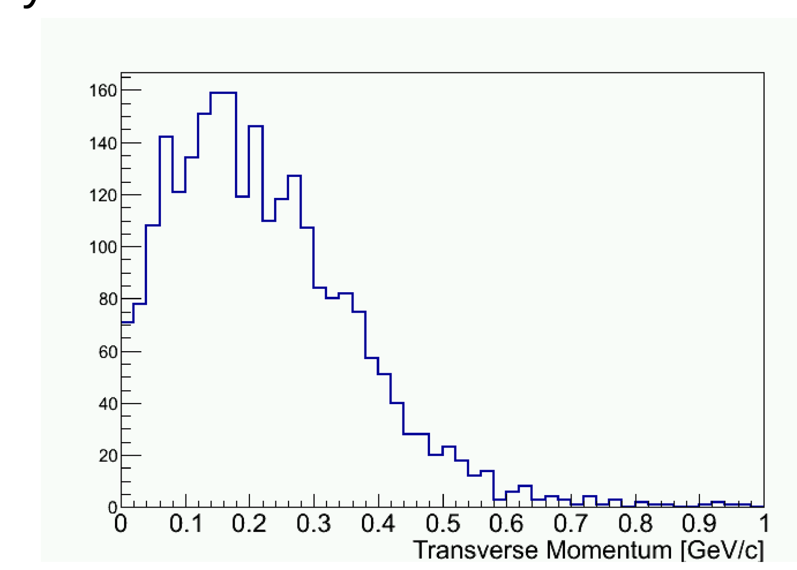
χ_C to J/ψ feed-down as a function of number of binary collisions is shown at left. Number of binary collisions in d+Au was calculated using Glauber model.

The Future: Using VTX to Measure χ_C

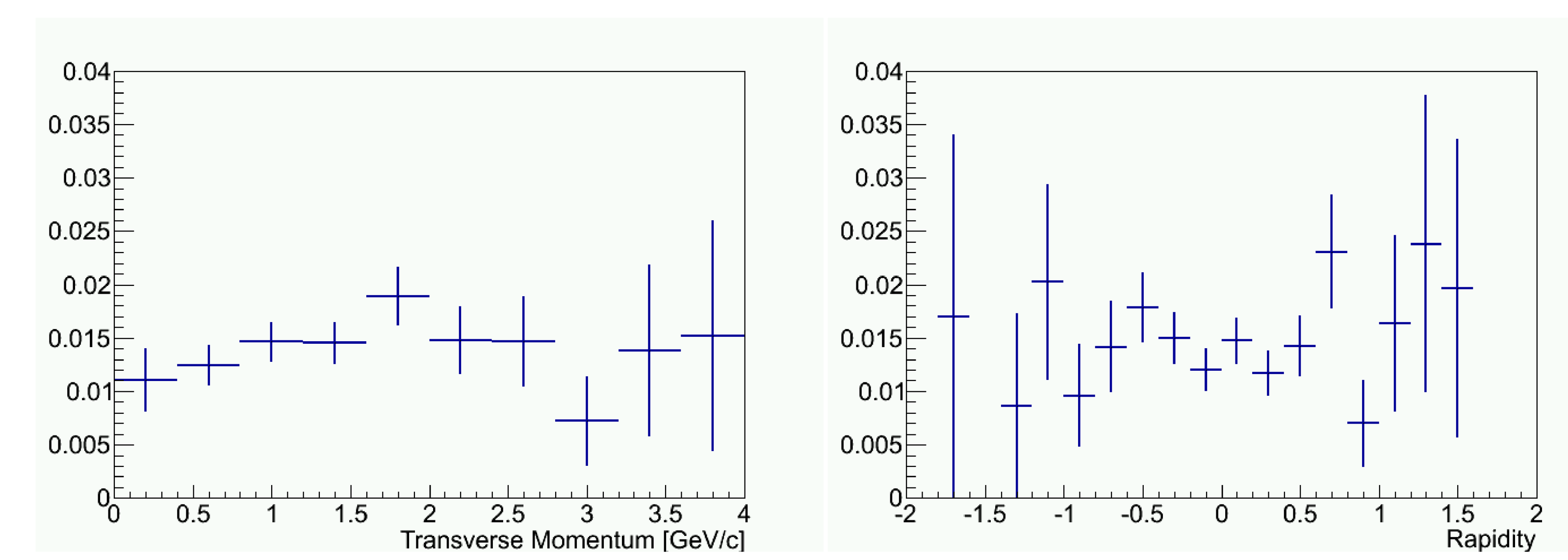
In order to estimate how χ_C measurement can be improved by using photon conversions in the VTX detector, we performed this simulation study. We used PYTHIA to generate single χ_C using "*msel 61*" option.

Those χ_C were processed through GEANT3-based detector response simulation package for PHENIX (PISA) and reconstructed using the same code as was used for the data analysis.

p_T distribution of conversion electrons/positrons is shown at right.

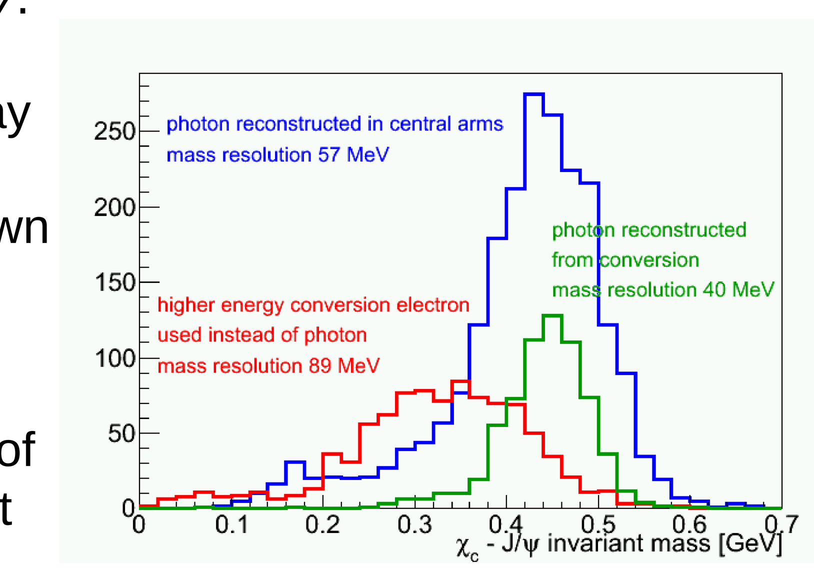


Relative χ_C / J/ψ acceptance was calculated for conversions taking place in the beam pipe and two inner (pixel) VTX layers. We required J/ψ to be fully reconstructed in the PHENIX Central Arms, and required both conversion electron and positron to have transverse momentum of at least 50MeV. Transverse momentum and rapidity dependence of this relative acceptance is shown in the plots below.



Integrated over p_T and rapidity relative acceptance is 1.44% for 50*MeV* conversion electron p_T cut. This value should be compared to the relative acceptance times efficiency for the standard χ_C measurement where photon from χ_C decay is detected in the PHENIX Central Arms, which is 12.1% for photon energy cut 0.3*GeV*.

Reconstructing photon from χ_C decay using conversions can actually improve χ_C mass resolution, as shown in the plot at right. Acceptance and reconstruction efficiency potentially can be improved if one uses higher energy conversion electron instead of the photon in calculating χ_C invariant mass. Mass resolution becomes worse, but there is no need to reconstruct the second conversion electron.



Conclusions and Outlook

PHENIX experiment successfully measured χ_C production in p+p and d+Au collisions at 200 GeV.

This simulation study shows that acceptance for χ_C measurement via conversions in the VTX is rather small. Further study is necessary in order to make final conclusion.