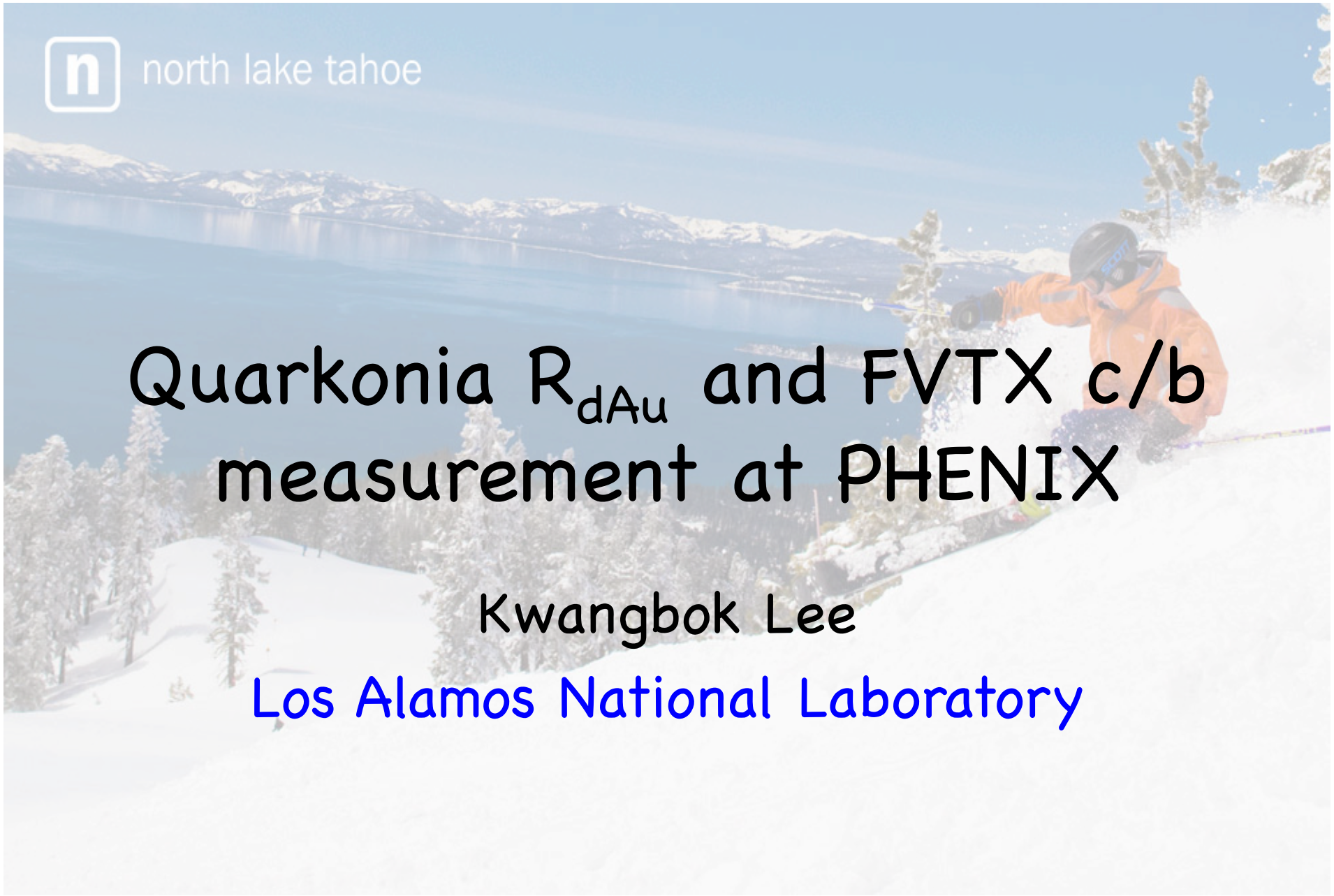


Quarkonia R_{dAu} and FVTX c/b measurement at PHENIX

Kwangbok Lee

Los Alamos National Laboratory

Collision Systems

p + *p* collision 

-> Provide the critical test for pQCD calculations of heavy-quark production.
Serve as baseline for the study of modification of production in HI collision.

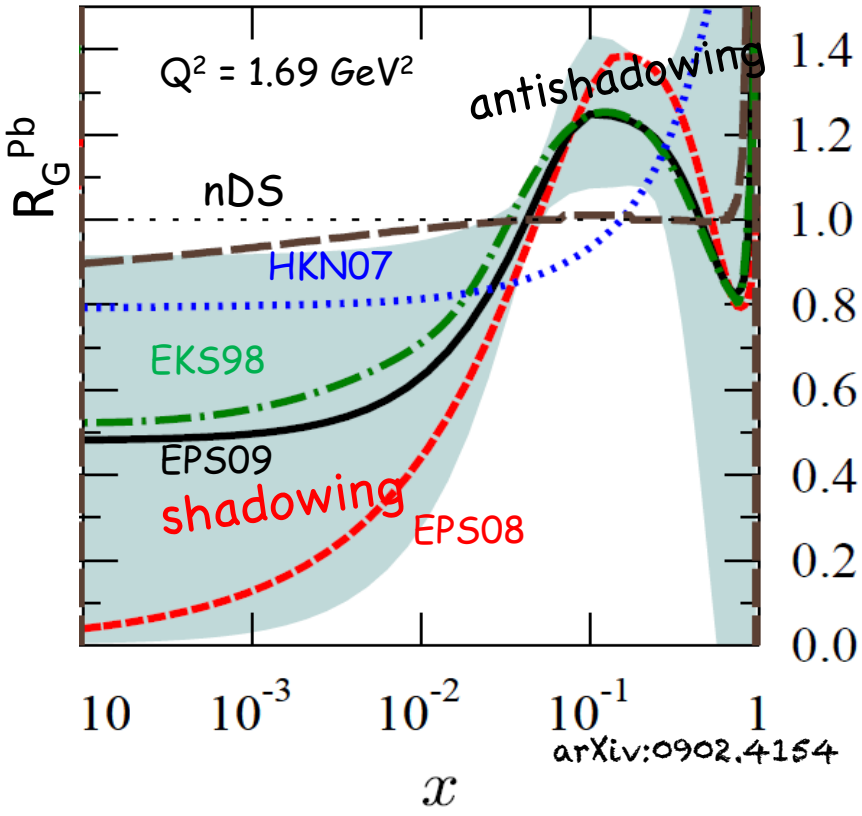
p(*d*) + A collision 

-> Cold nuclear matter (CNM) effects
of parton shadowing, CGC, breakup.
Base measurement to understand hot nuclear matter

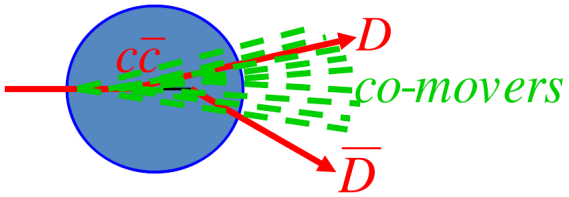
A + A collision

-> Hot nuclear medium effects + CNM effects.

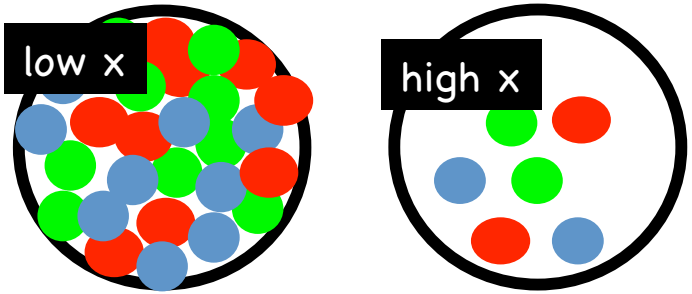
Quarkonia in cold nuclear matter



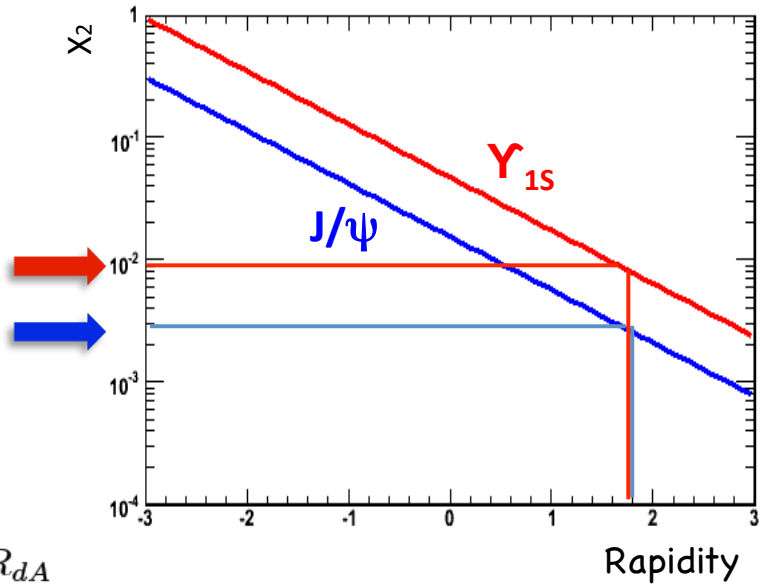
- Modification of gluon distribution in nucleus.
- Nuclear absorption (final)



- Initial state parton energy loss, p_T broadening
- Gluon saturation

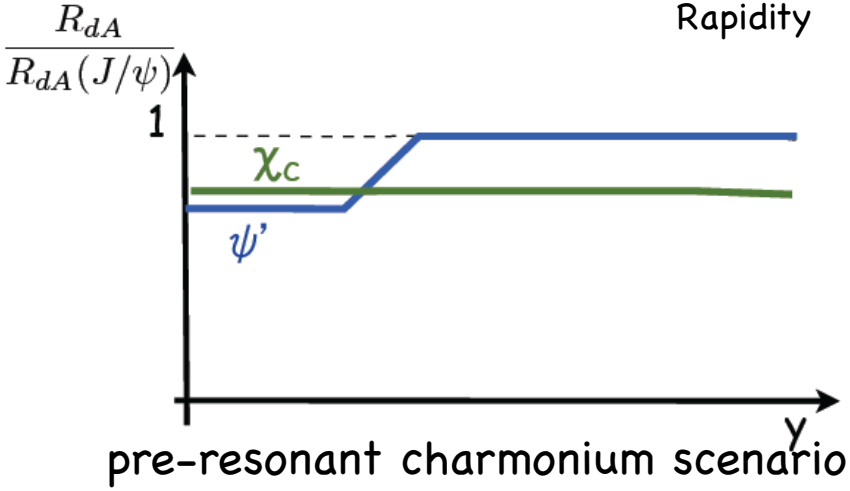


Systematic study on cold nuclear matter with quarkonia



$$x_2 = \frac{m_T e^{-y}}{\sqrt{s}}$$

J/ψ and Υ sample different x
-> Check the x dependence of parton modification



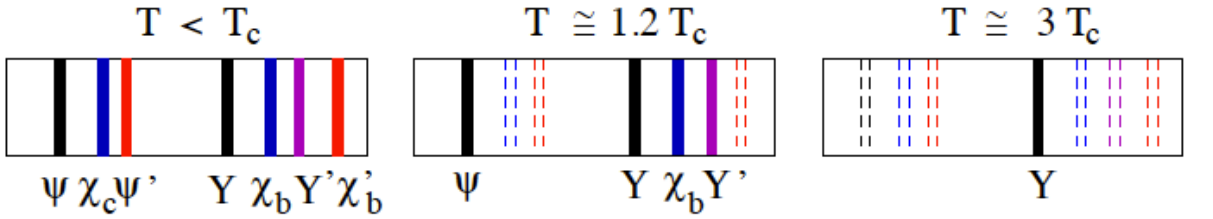
pre-resonant charmonium scenario

J/ψ wave function is formed outside of the nucleus at rapidities y >≈ -2.
[K.Tuchin, D.Kharzeev, Nucl.Phys.A770,40(2006)]

Quarkonia as thermometer in A+A collision

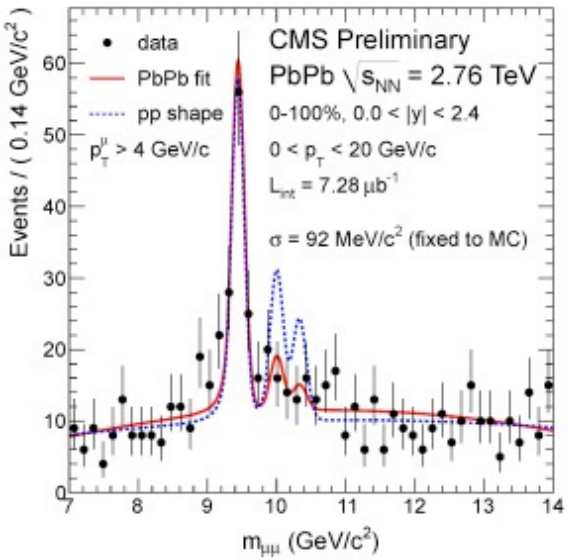
	$c\bar{c}$			$b\bar{b}$		
state	J/ψ (1S)	ψ' (2S)	χ_c (1P)	Υ (1S)	Υ (2S)	Υ (3S)
mass [GeV]	3.10	3.68	3.53	9.46	10.02	10.36
radius [fm]	0.25	0.45	0.36	0.14	0.28	0.39
ΔE [GeV]	0.64	0.05	0.20	1.10	0.54	0.20
T_d/T_c	2.10	1.1	1.16	> 4.0	1.60	1.17

hep-ph/0609197v1 H. Satz



hep-ph/0512217

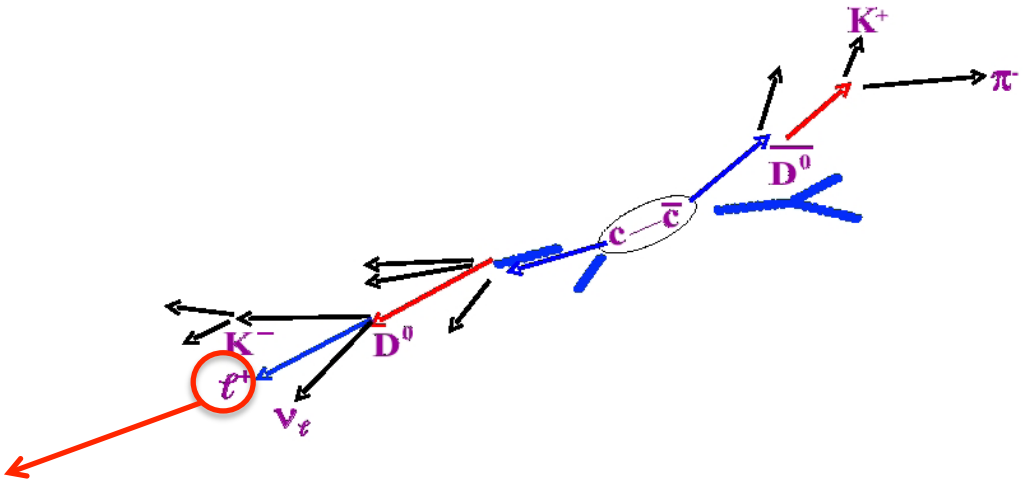
PRL 107, 052302 (2011)



Upsilon at LHC

- J/ψ production can be affected if higher states of charmonia would melt, which would have decayed into J/ψ.

Heavy Quarks and FVTX



Leptons from semi-leptonic decays from heavy flavors (c,b quarks).

- Precise measurement on c/b motivates
  a silicon precision forward vertex (FVTX) detector.
  (continued at following..)

More opportunities with FVTX and VTX detectors…

Single Muons measurements:

- Precision heavy flavor and hadron measurements.
- Separation of c and b in semi-leptonic decays.

-> Get precise energy loss mechanism/p_T broadening in cold nuclear matter.

- Improve W background rejection.

Dimuons measurements:

- Separation of ψ' from J/ψ at forward rapidity.

-> Test dissociation effects dependent on the binding energy and rapidity dependence of production mechanism.

- B→J/ψ+X, golden channel
- First Drell-Yan measurement at RHIC

-> CNM energy loss and parton modification.

-> Access sea quark polarization, test Sivers effect for spin study.

What we have measured and learned so far..

Nuclear modification factors, R_{dAu}, α

$$R_{dAu} = \frac{N_{inv}^{dAu} \Big/ \left\langle N_{coll}^{dAu} \right\rangle}{N_{inv}^{pp}}$$

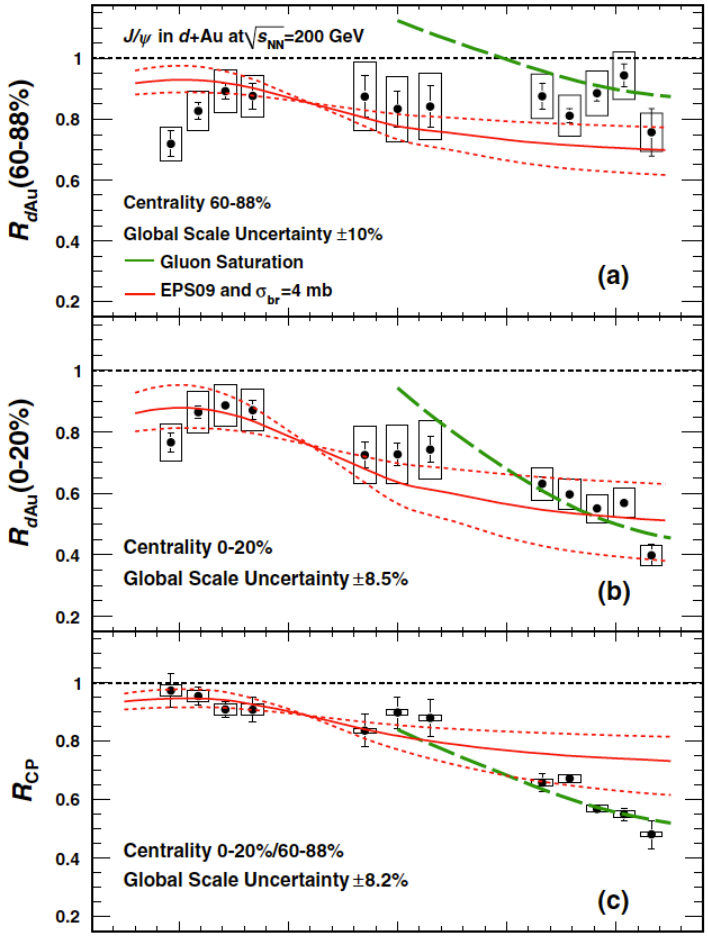
	pp	dAu (all centralities)	dAu (0-20%)	dAu (60-88%)
N_{coll}	1	7.6 ± 0.4	15.1 ± 1.0	3.2 ± 0.2

N_{coll} : number of binary (pp) collisions in one HI collision, calculated by Glauber model and simulation.

$$\sigma_{dAu} = \sigma_{pp} \times (2A_{Au})^{\alpha}$$

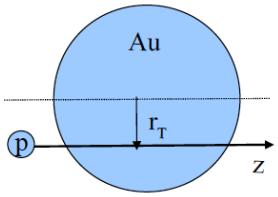
If there is suppression, R_{dAu} , R_{cp}, α < 1

PHENIX J/ψ R_{dAu} and centrality dependence

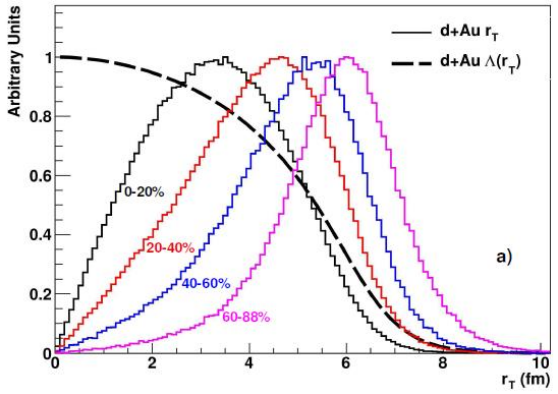


Phys.Rev. Lett. 107, 142301 (2011)

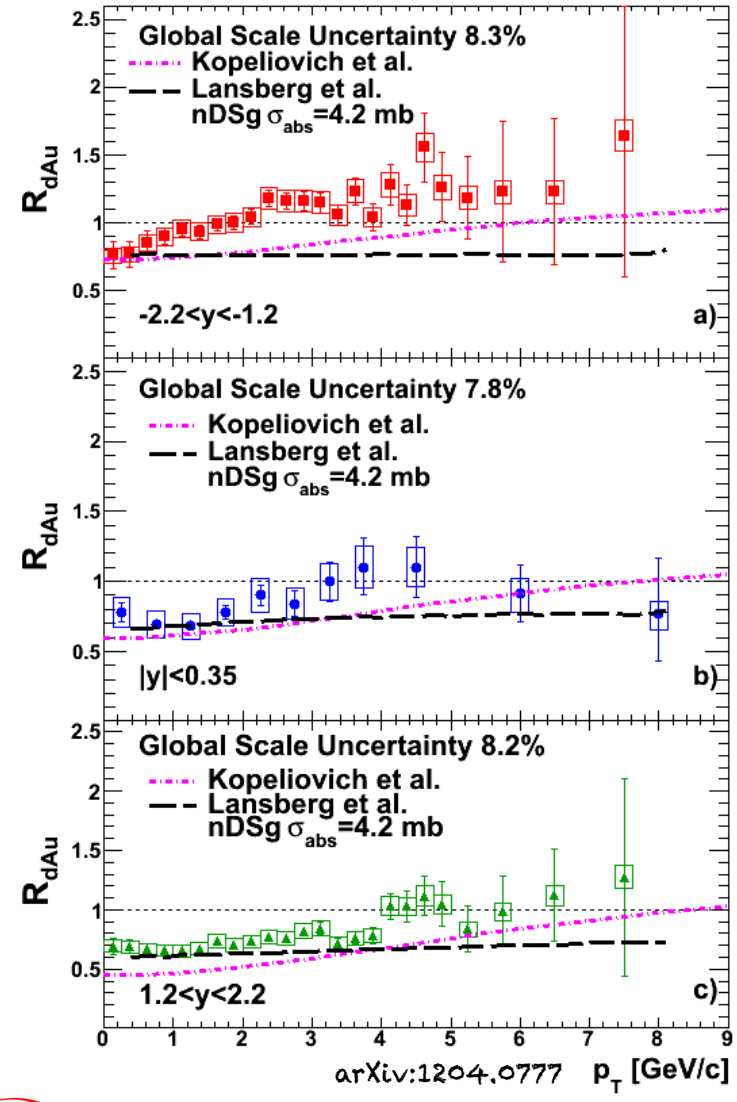
- The centrality dependence compared to nuclear shadowing models that include final-state breakup effects.

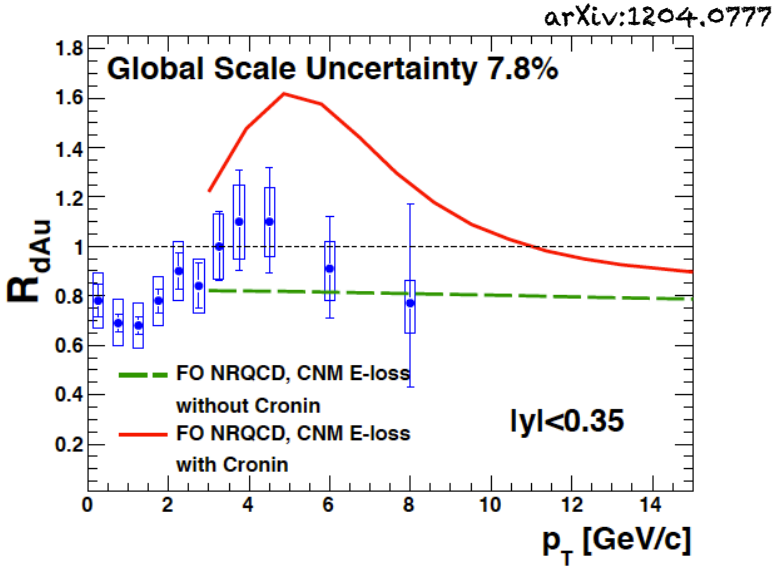


$$\Lambda(r_T) = \frac{1}{\rho_0}\int dz \rho(z, r_T)$$



J/ψ p_T dependence

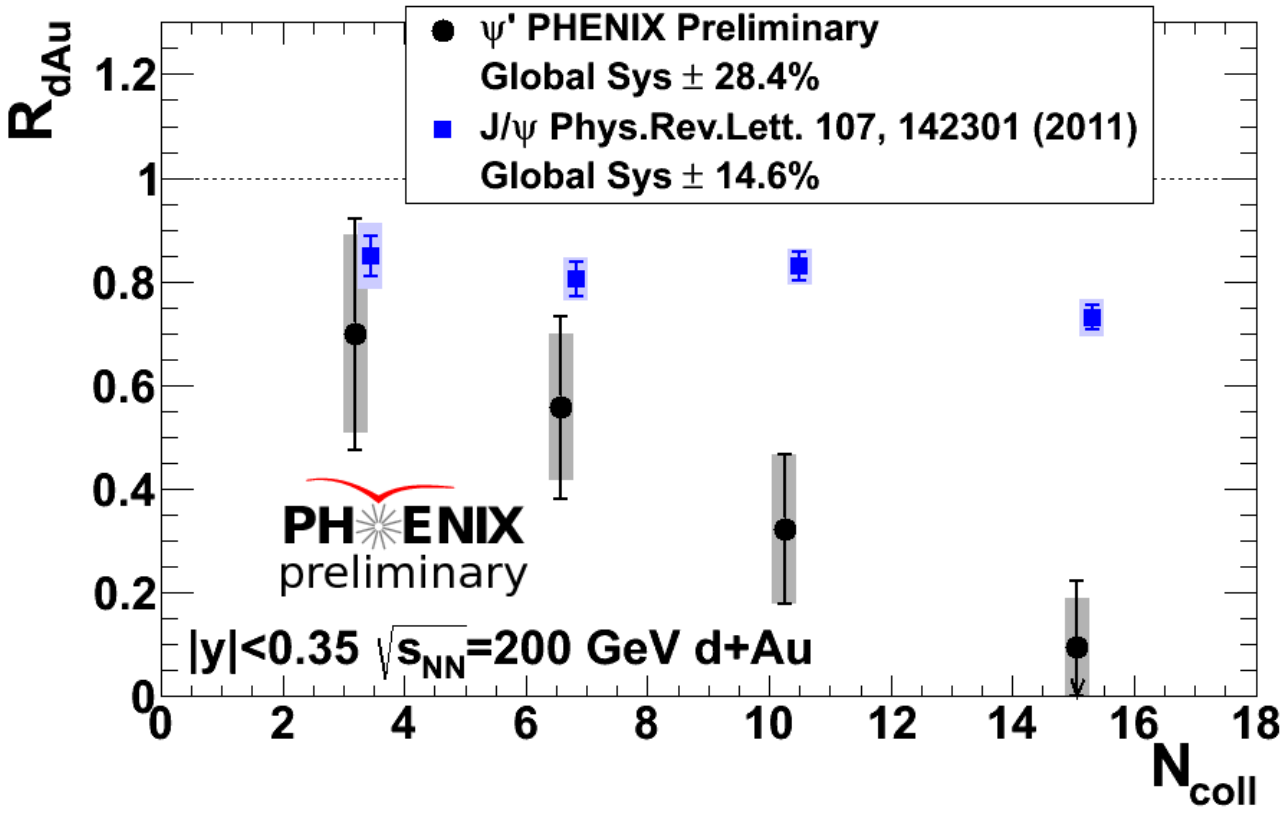




- The calculation including the Cronin effect indicate an R_{dAu} that decreases at higher p_T.

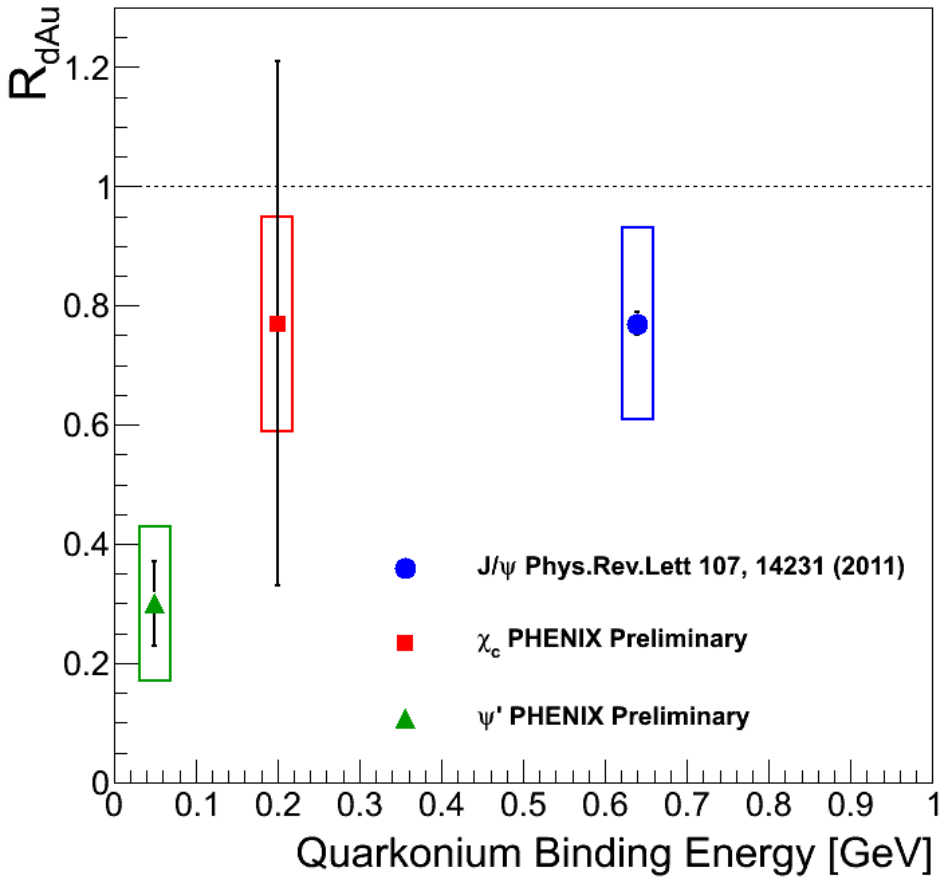
- Models do not do well for backward rapidity.
  -> Final state break up may not be independent of y

ψ' suppression at mid-rapidity



- Same initial-state effects for J/ψ and ψ'
- Stronger suppression of ψ' might be due to weak binding energy of ψ'

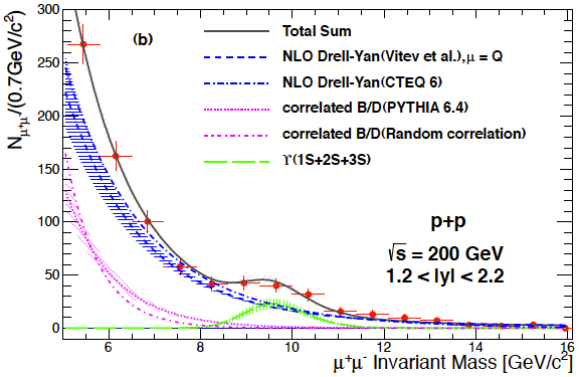
Quarkonia R_{dAu} and binding energy dependence

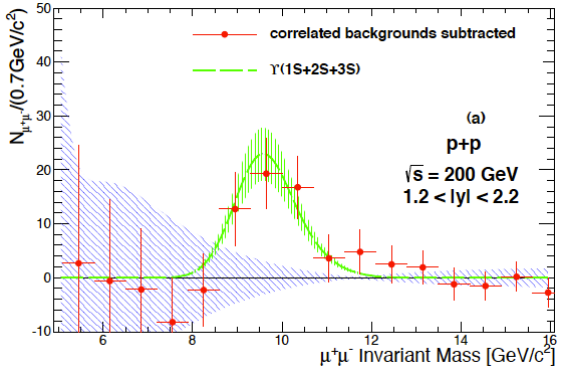


- Charmonium breakup dependence on its binding energy.
- Need ψ' and χ_c at forward rapidity.

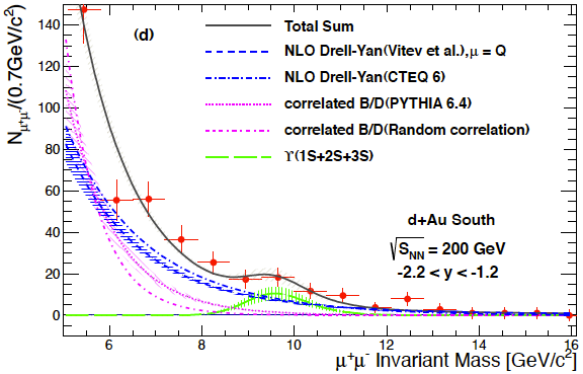
Upsilon at forward rapidity

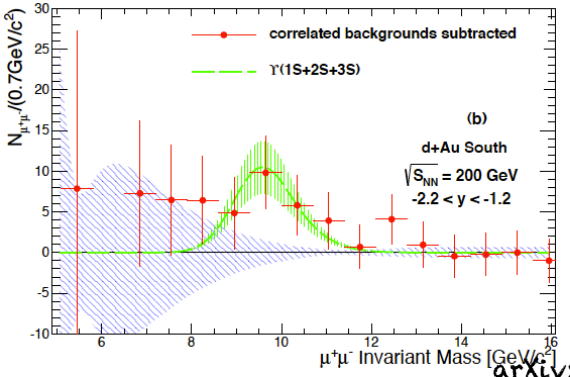
p+p





d+Au





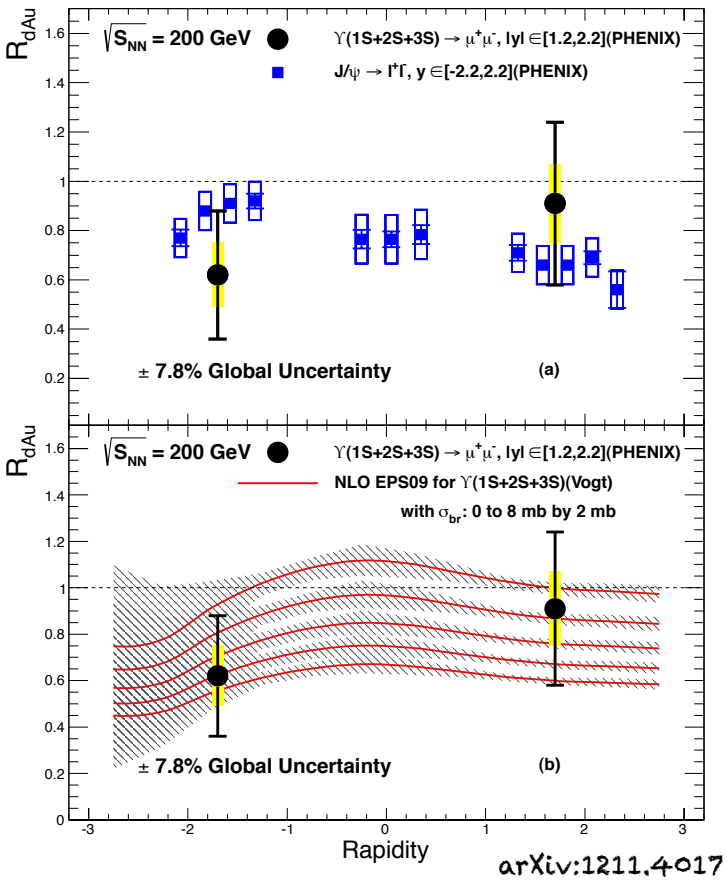
Mass distribution and fitting

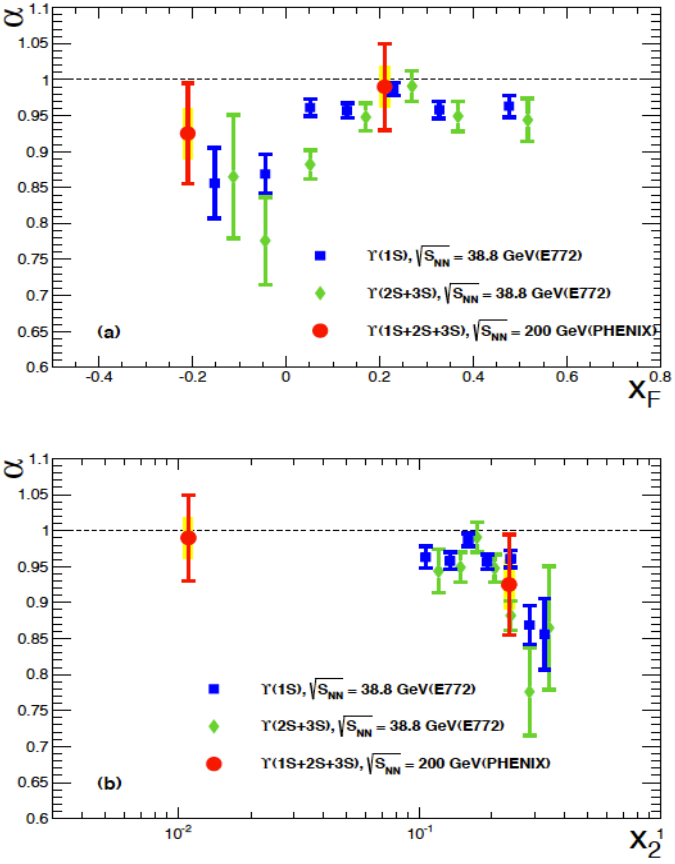
Extracted upsilon signal

arXiv:1211.4017

- First measurement on the Upsilon nuclear effects at $\sqrt{s_{NN}}$ = 200 GeV.
- physical background estimation
  - Drell-Yan process is estimated by NLO calculation(+Iso-spin, energy loss and shadowing).

Upsilon R_{dAu} and comparison



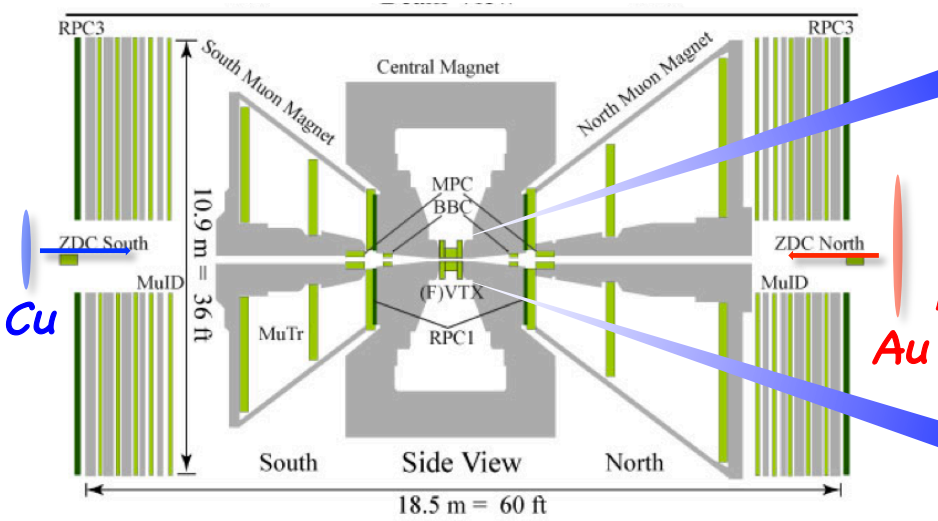


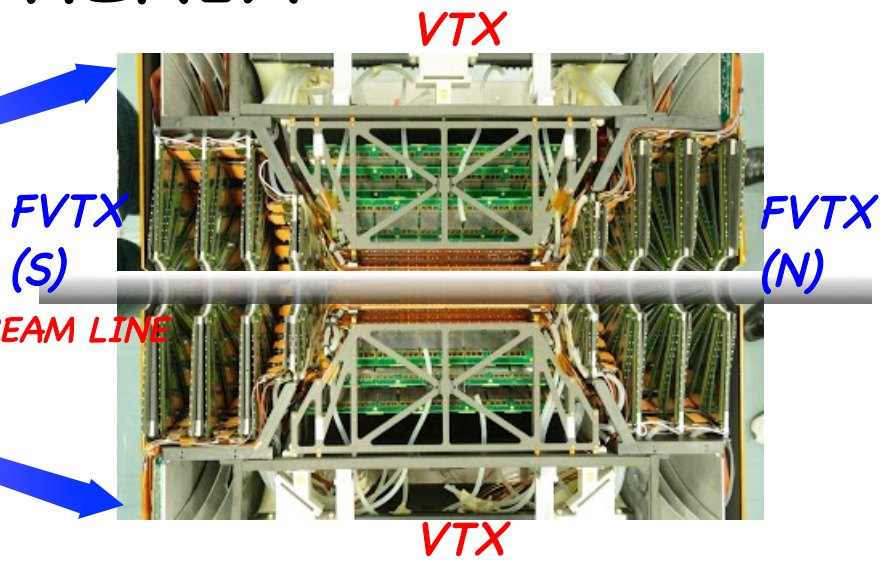
nPDF(EPS09) + breakup σ

Comparison to lower energy pA results(E772)

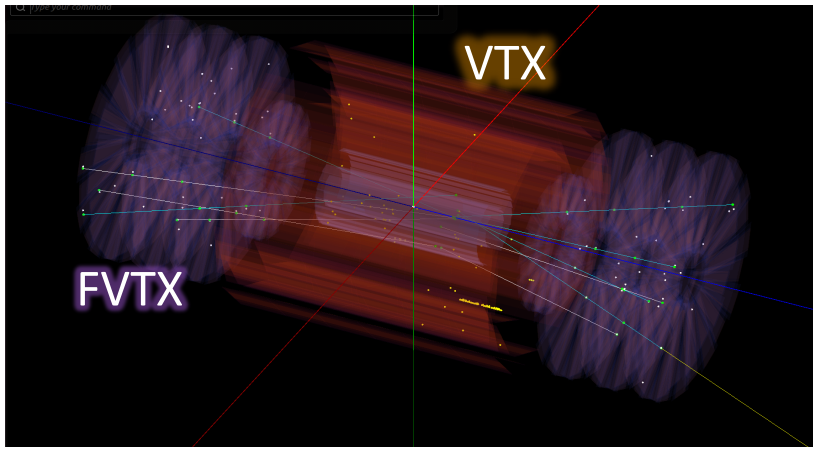
Analysis with FVTX

FVTX in PHENIX



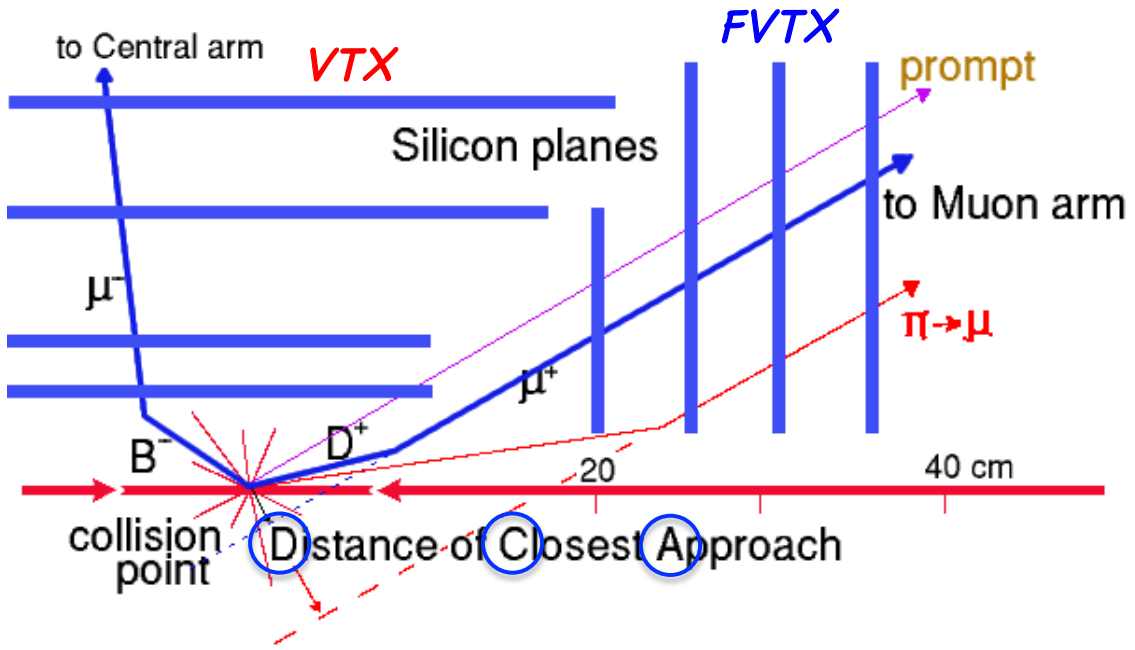


- FVTX Covers
  - same pseudorapidity, $|\eta|$ of 1.2 to 2.2 as Muon arm.
    -> momentum fraction, x_2 of 10^{-3} to 10^{-2} (200 GeV beam).
  - 2π in ϕ
  - 18.5 cm < |z| < 38 cm
- FVTX wedge has design of
  - 75 μm pitch strips in radial direction, *r*
  - 3.75° along Φ direction
    -> most sensitive to *r*-direction



FVTX-VTX Event Display 510GeV p-p

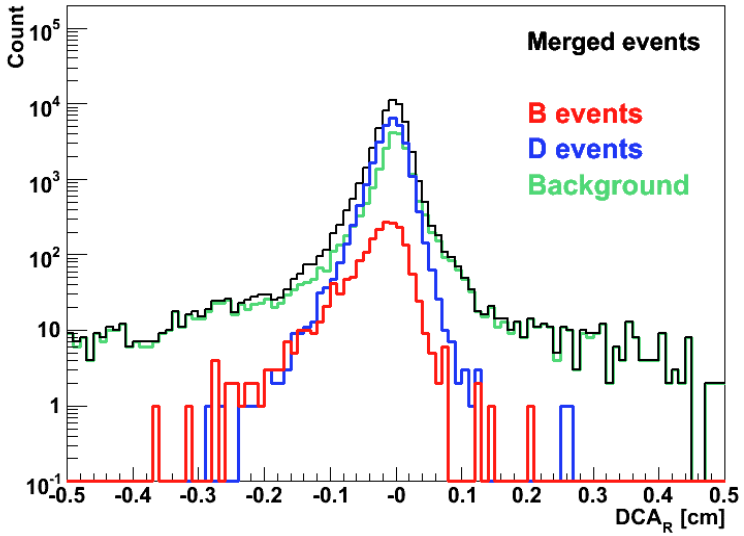
DCA_R measurement



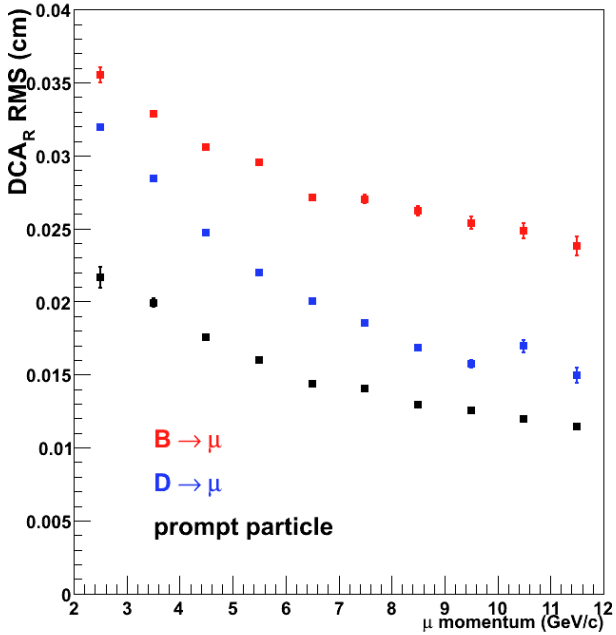
- Measure the primary vertex and secondary decay.

-> Important to extract DCA and distinguish Drell-Yan, c/b decay mesons and W.

DCA_R for c/b separation



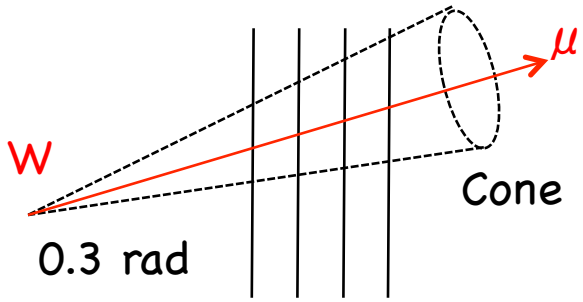
Simulated DCA_R for each process

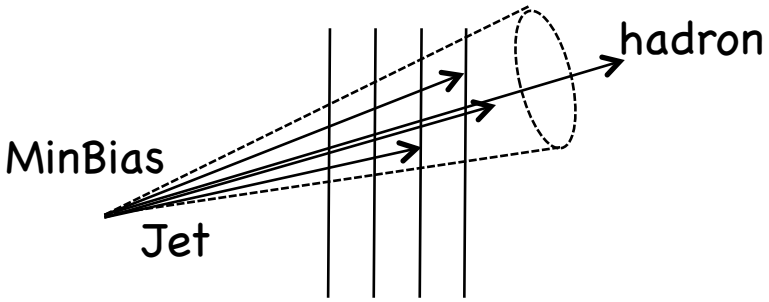


DCA_R vs momentum

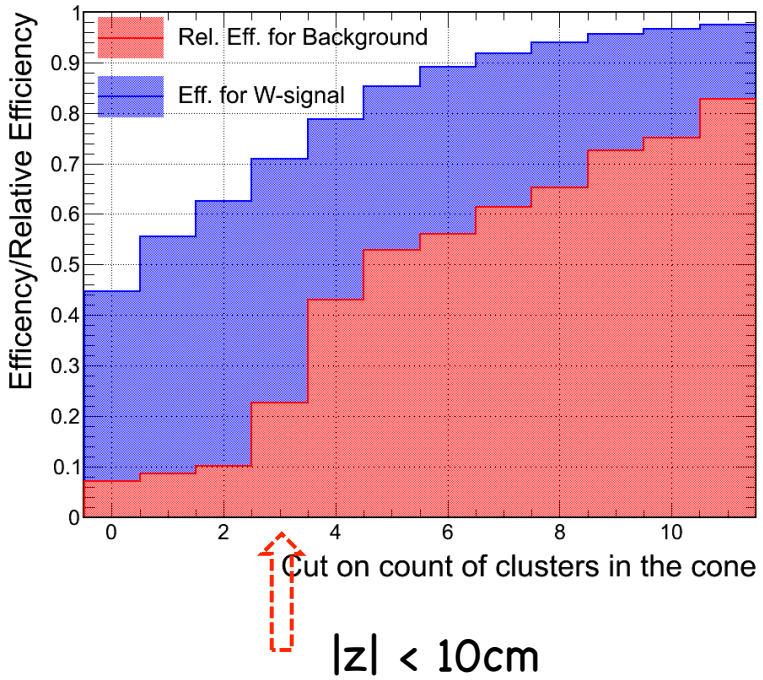
Decay μ s from D, B and hadrons have different DCA_R shapes in a given μ p_T bin.
->Fit the shapes to data or cut out keeping a specific window to reduce background.

Isolation cut for W signal





- Define a cone with $\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2}$.
- Require that a track have limited clusters/hits around it.
  ->Efficient for background rejection from the jet background

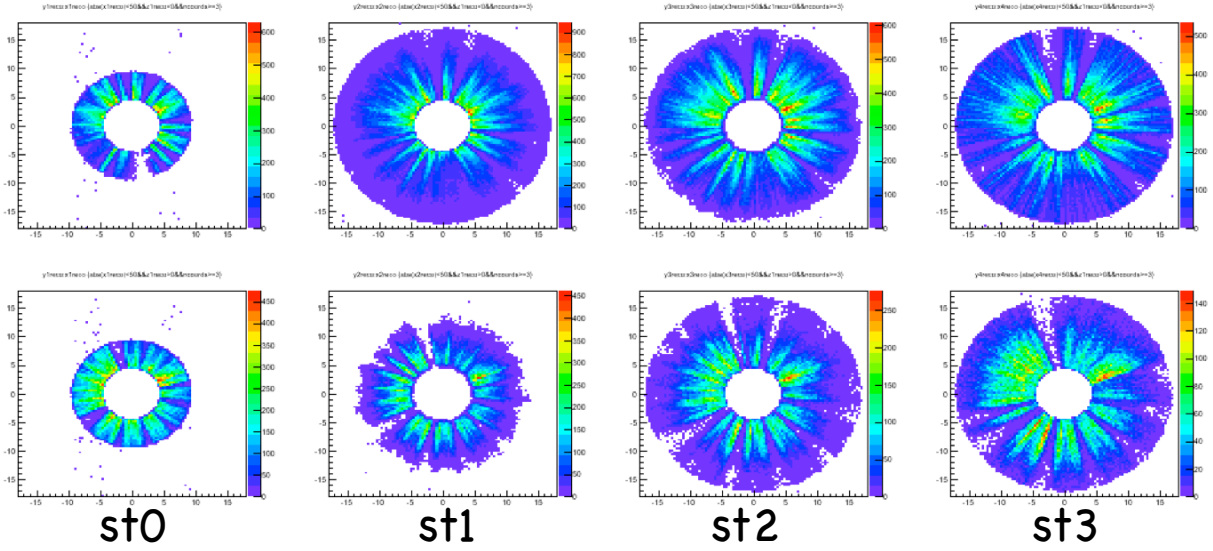


FVTX Status

- Construction completed and detector installed in 2011
- Commissioning during RUN-12 200/500 GeV p+p running

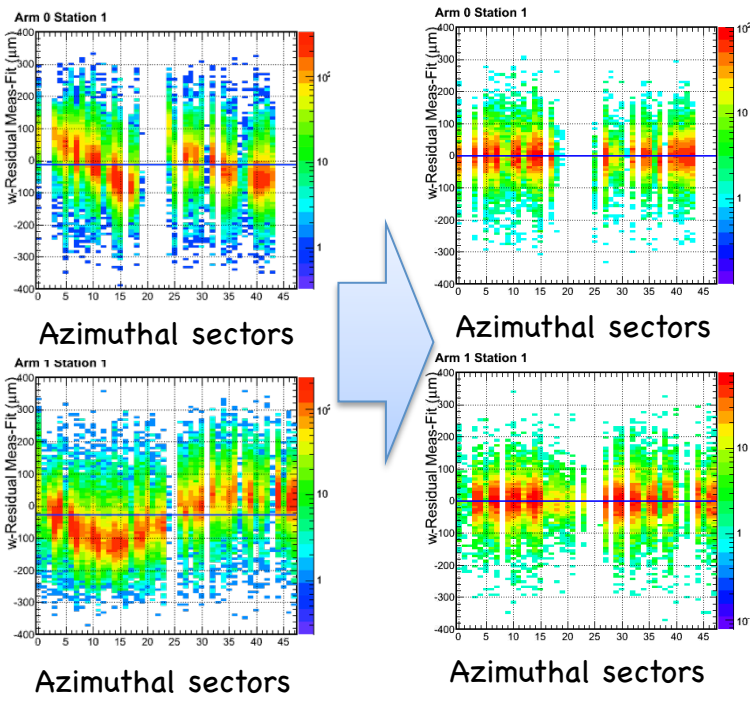
- Took significant data in RUN-12:
  - 200/500 GeV p+p
  - 200 GeV U+U
  - 200 GeV Cu+Au

Stereo plot of hits for each FVTX station, 200 GeV p-p run.

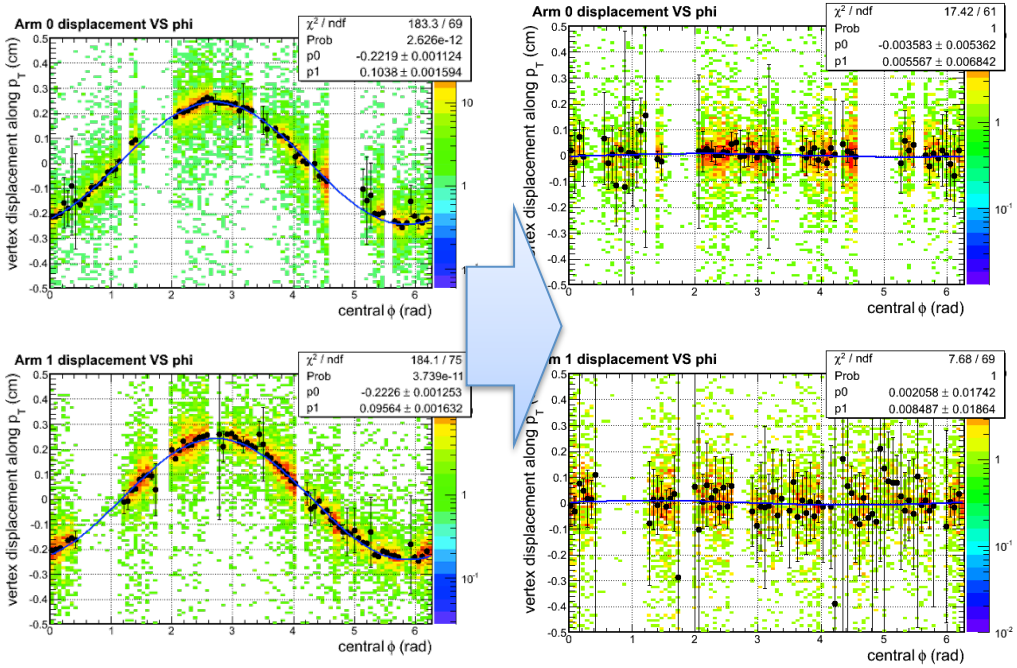


- FVTX hit efficiency is high (>95%, from alive area of run12 data)
- Data analysis is in progress

FVTX alignment



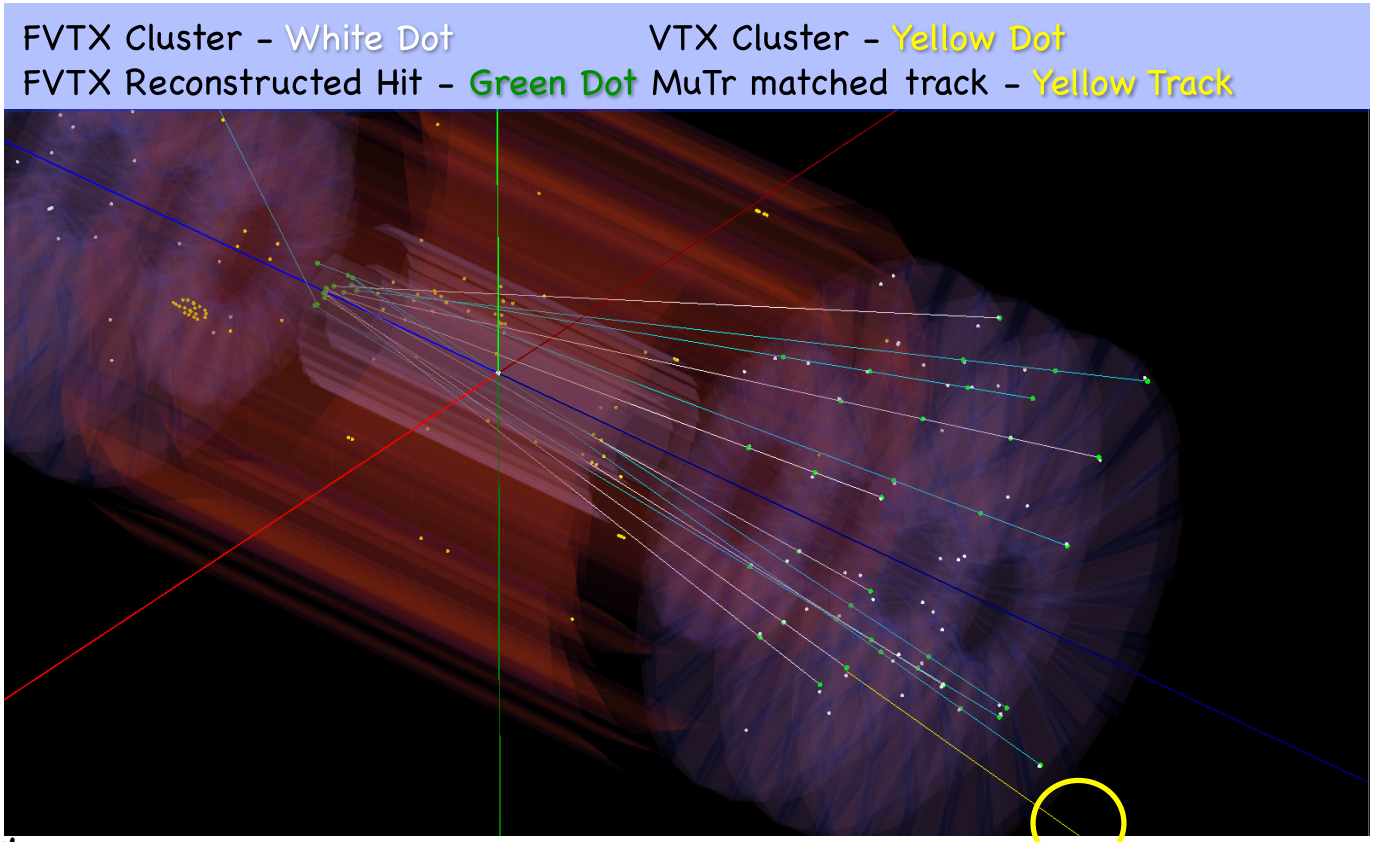
FVTX Residual (μ m)
before and after alignment



VTX – FVTX difference
After assigning corrected average vertex

- Detector self-alignment performed, Global alignment work in progress

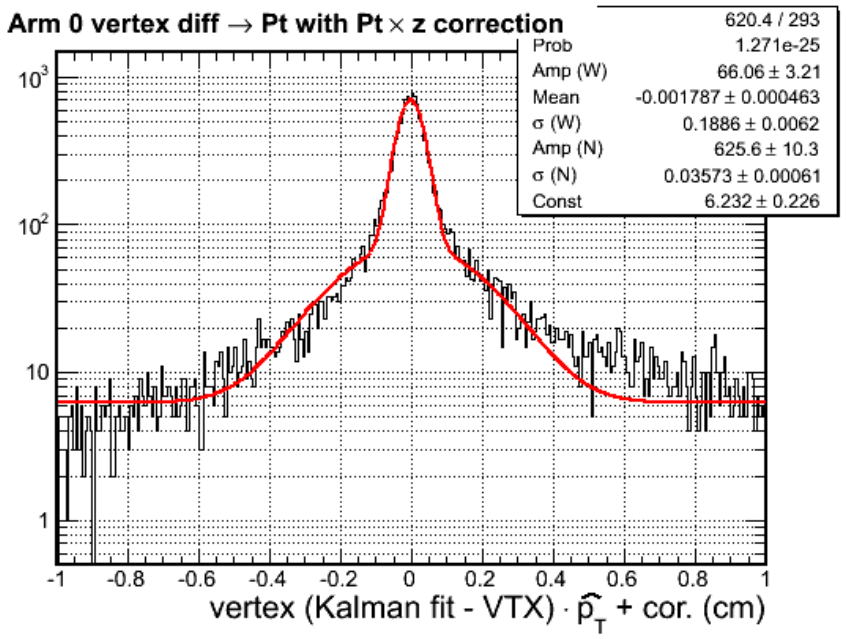
FVTX-Mutr Matching



*510 GeV pp run

- With FVTX track "matches" the MuTr track, get vertex position, angle from vertex obtained, discriminate against decay-in-flight.

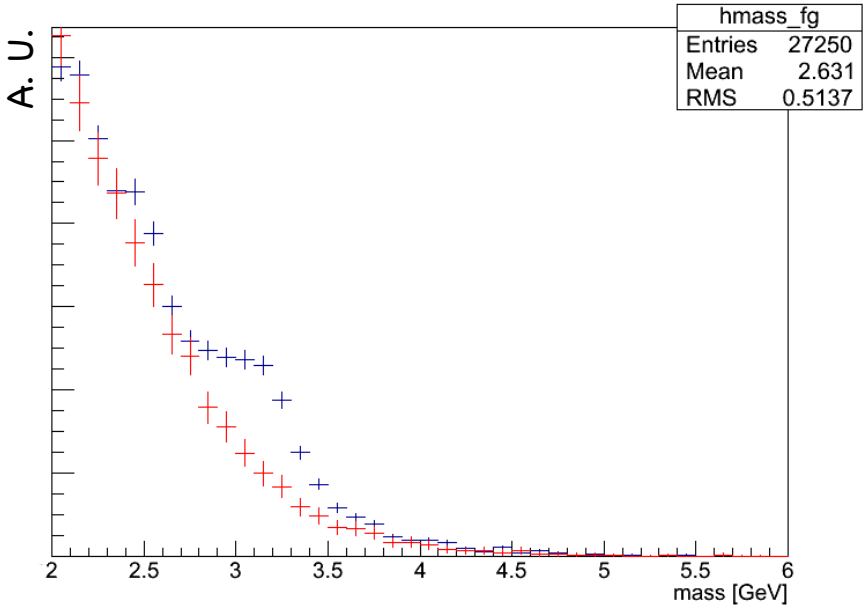
single μ DCA_R in data



510GeV p-p Golden J/ψ sample

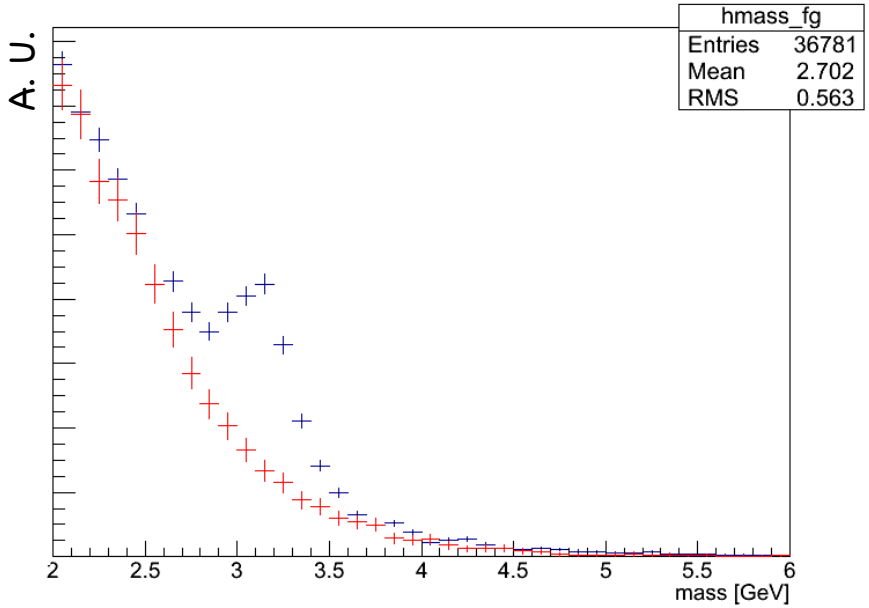
More data is being analyzing for Cu-Au..

Signal to background improvement



Basic muon cut

Add $DCA_R < 2$

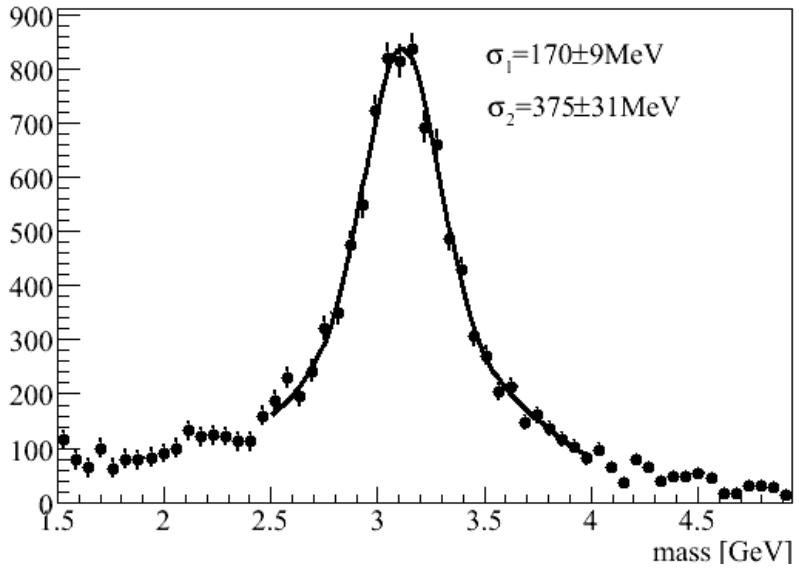


Basic muon cut + $DCA_R < 2$

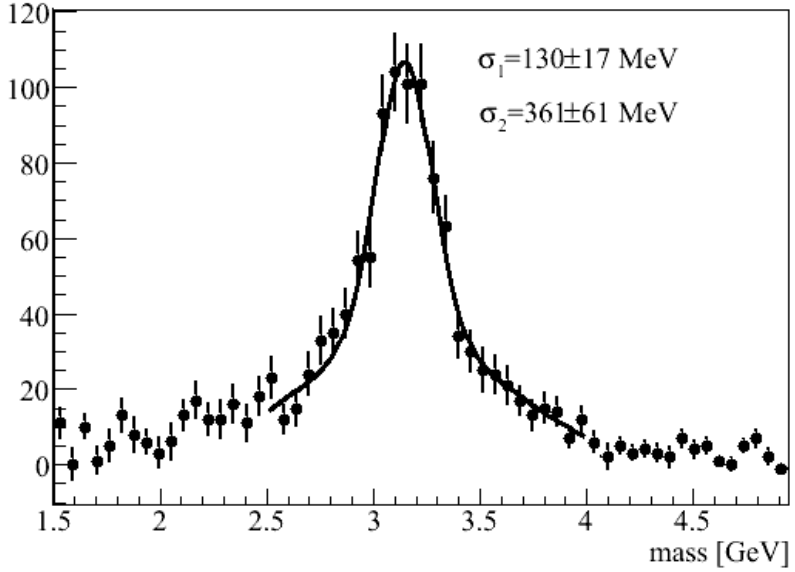
Cu-Au run sample

Signal to background ratio gets improved.

Resolution improvement



All tracks without FVTX info.



Tracks matching FVTX tracks

510 GeV p-p sample - NORTH ARM

Summary and near Future..

Quarkonia:

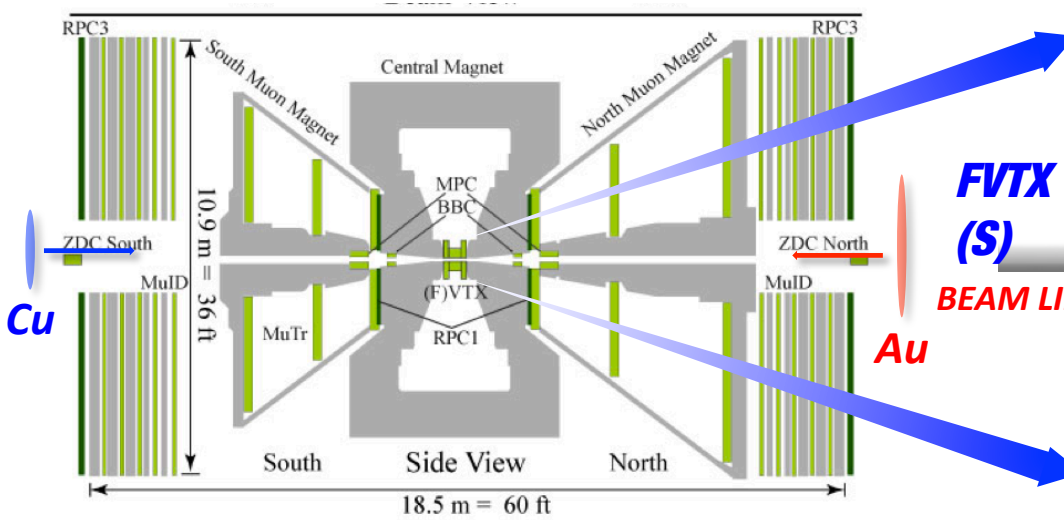
- J/ψ R_{dAu}, R_{CP} are inconsistent with models which has several dependences on nuclear thickness over the full rapidity and centrality.
- Models with nDSg for shadowing do not explain well for backward rapidity at J/ψ R_{dAu} vs P_T.
- Stronger suppression of ψ' shows a dependence of weak binding energy to final state breakup.
- Υ(1S+2S+3S) are compatible with lower energy results and a NLO theoretical calculation. Need more data to constrain on breakup level.

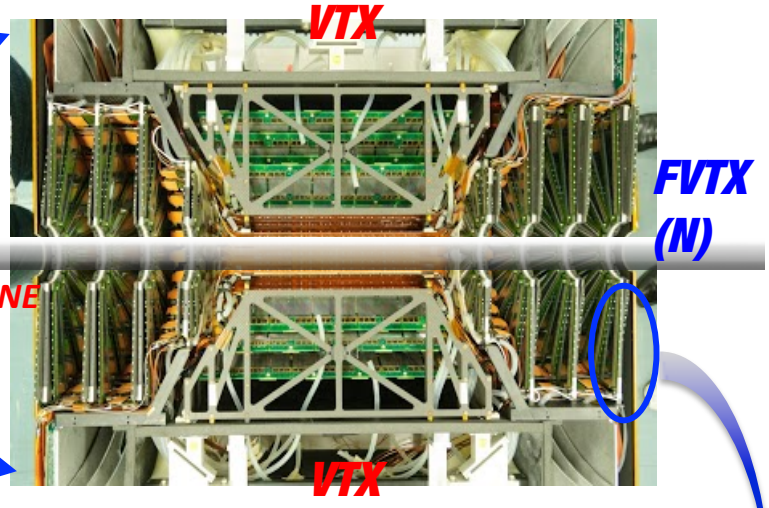
FVTX:

- c/b separation is important for precise energy loss mechanism/ p_T broadening in cold nuclear matter.
- VTX/FVTX would make Drell-Yan, charm/bottom and ψ' measurement possible with improved mass resolution and vertex measurement.
- Alignment and tracking study are in progress.
- Data analysis is in progress.

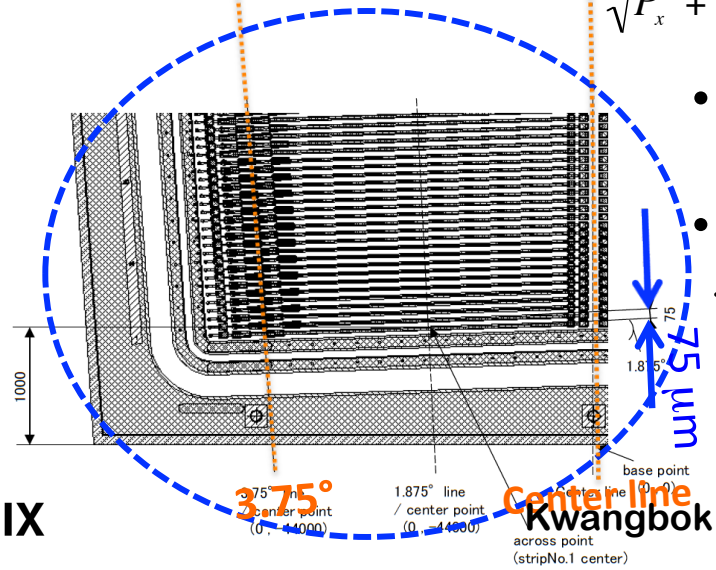
Back up

FVTX in PHENIX



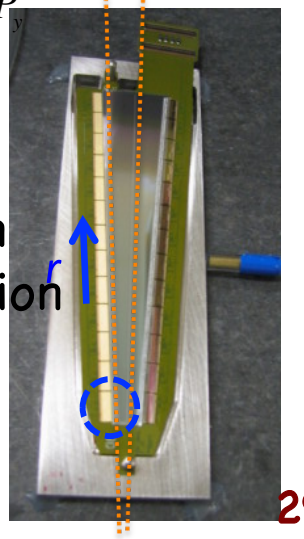


$$DCA_R = (X0_{reco} - Evt\_vtxX)\left(\frac{P_x}{\sqrt{P_x^2 + P_y^2}}\right) + (Y0_{reco} - Evt\_vtxY)\left(\frac{P_y}{\sqrt{P_x^2 + P_y^2}}\right)$$



- 75 μm pitch strips in radial direction, *r*
- 3.75° along Φ direction

-> Sensitive to *r*-direction



C/B separation using single μ dca_r