PHENIX

Muon Workshop 04

d-A Physics Program with Forward Upgrades

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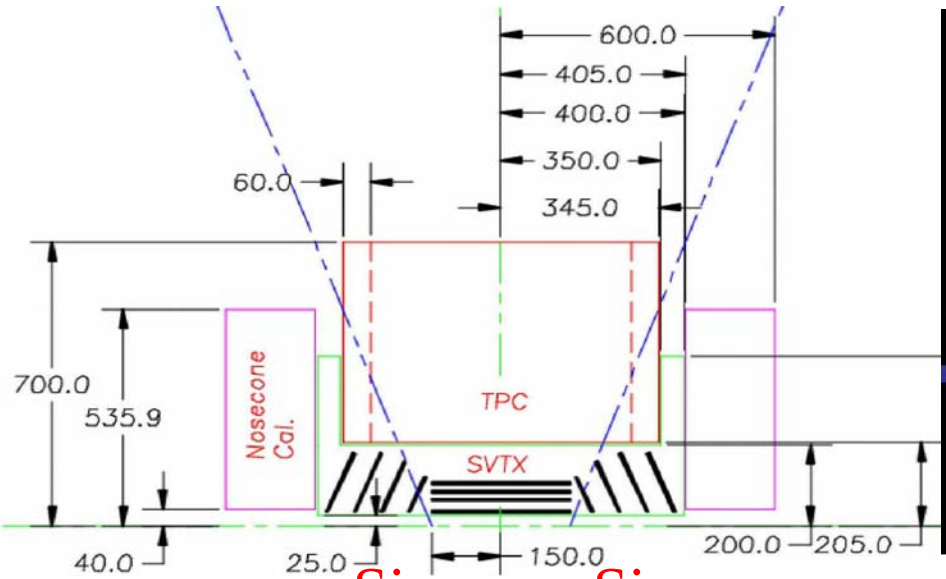
Physics

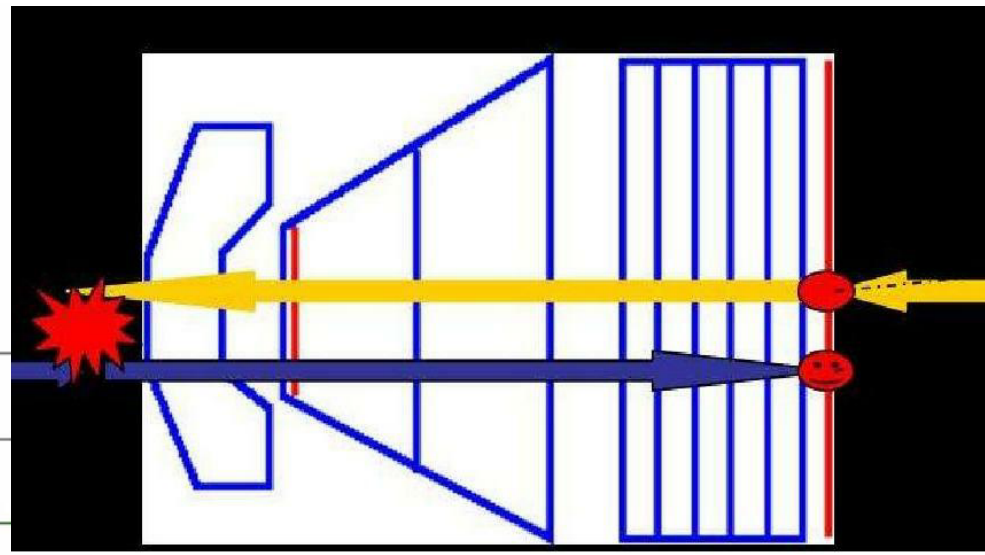
June 23, 2004

Following discussion assumes these Forward Upgrades will exist for RHIC II:

- Endcap Silicon Vertex Detectors
- Nosecone Calorimeters
- High – P_T Muon Trigger

These upgrades are required to exploit existing rare event capabilities of PHENIX. They "complete" the PHENIX forward detectors.





Si Si RPC RPC

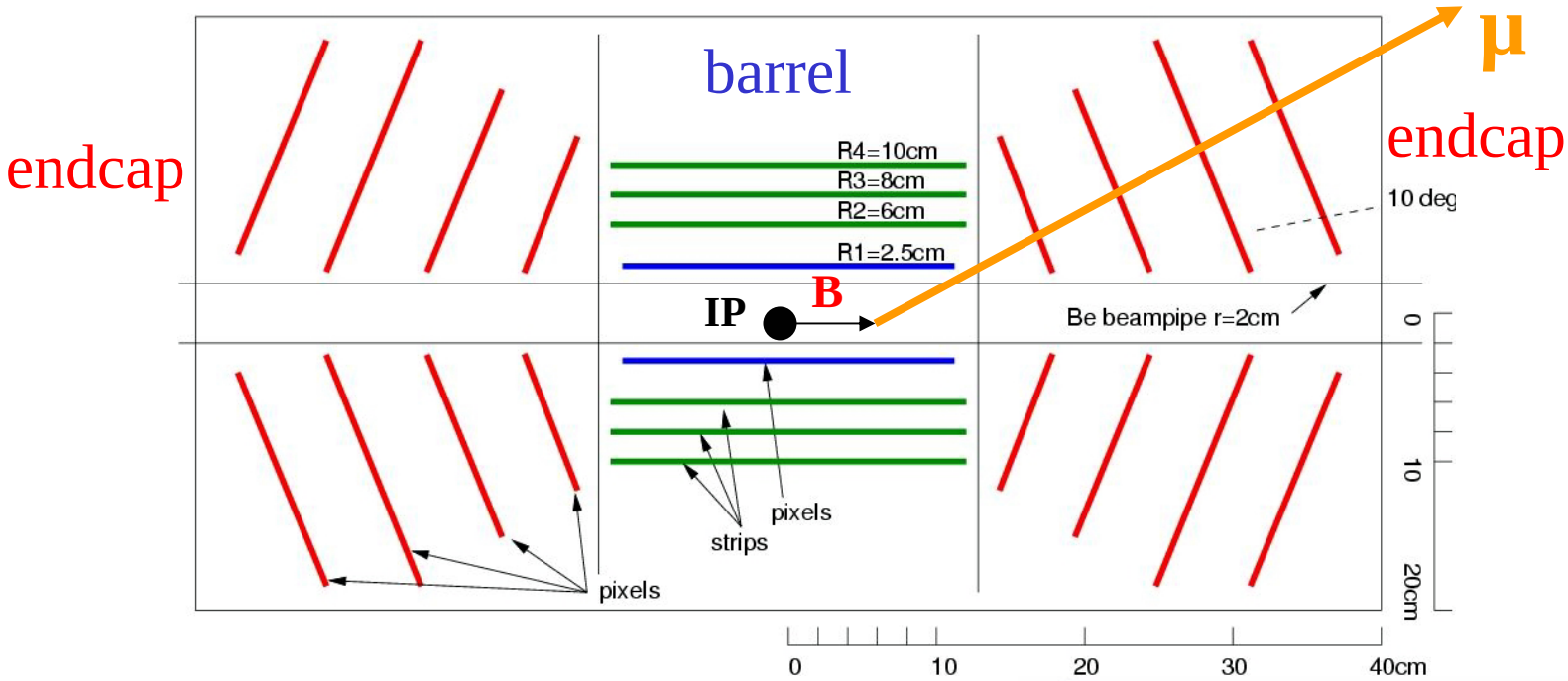
Physics Beyond Reach of PHENIX Baseline

Provide key measurements previously inaccessible or very difficult at PHENIX:

I. Detailed study of Heavy Quark production -

- Direct identification of open charm and beauty via :
  $D \rightarrow \mu + X$, $B \rightarrow \mu + X$, $B \rightarrow J/\psi + X \rightarrow \mu^+ \mu^-$
- Measurement of gluon structure in nuclei – x-dependence of gluon shadowing / Color Glass Condensate.
  $g + g \rightarrow D + \bar{D}$, $B + \bar{B}$
- Energy loss and multiple scattering of charm and beauty in nuclear matter. Separation of initial and final state effects.
  p_T, x_F and centrality dependence of D's and B's
- Improved quarkonium data including chi states and upsilon at y=0. Better mass resolution with improved acceptance for chi.
- Better baseline for A-A collisions. ψ' and χ_C becoming more important as expected temperatures required for screening increase. Open charm needed for interpretation of **J/ψ.**

Silicon Vertex Upgrade (SVT)



Endcaps detect following by displaced vertex of muons :

D → μ + X

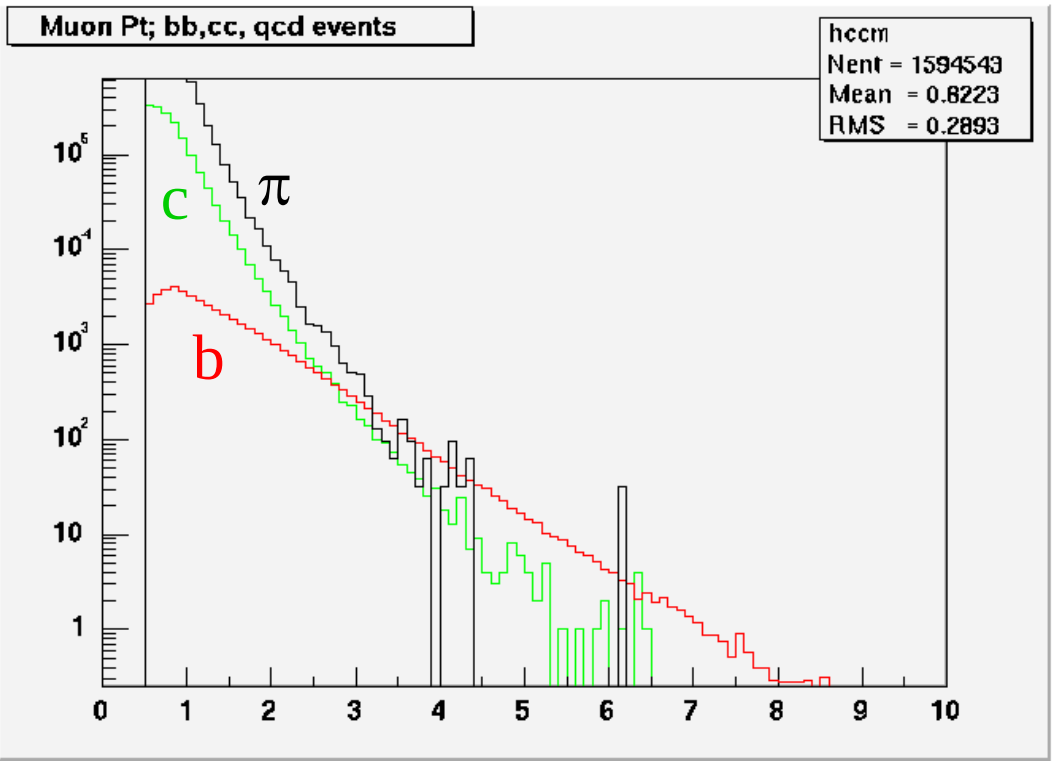
B → μ + X

B → J/ψ + X → $\mu^+ \mu^-$

Secondary vertex resolution ~133 μm (endcap)

Identification of open charm with Endcap SVT (simulations from SVT Proposal)

Without vertex selection

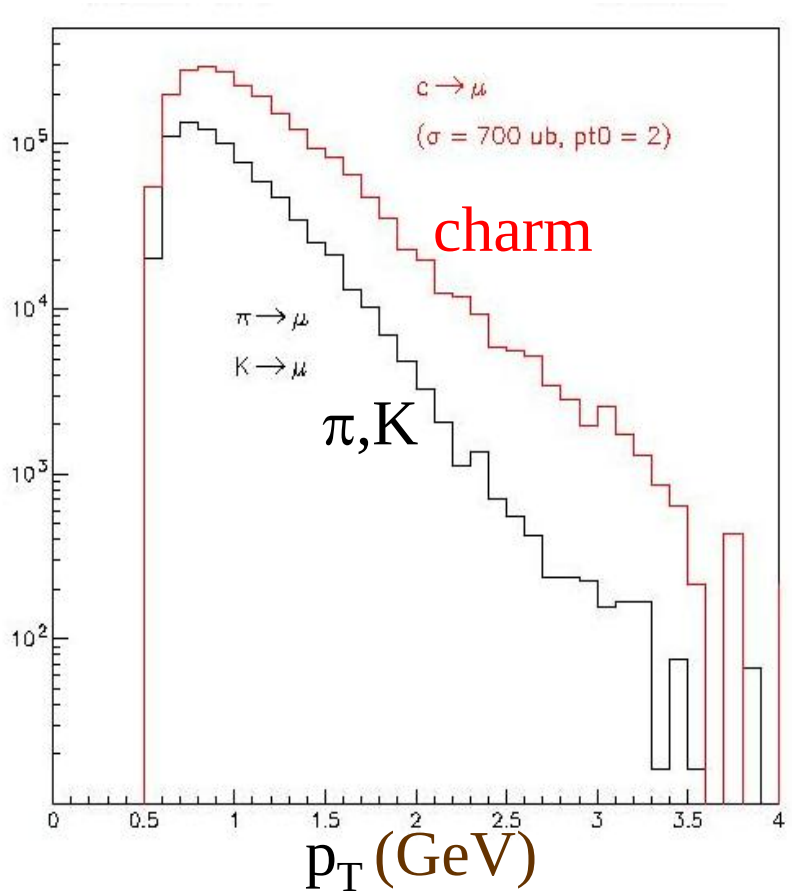


p_T (GeV)

Pions dominate below 3.5 GeV

High p_T part requires muon trigger upgrade

With vertex selection



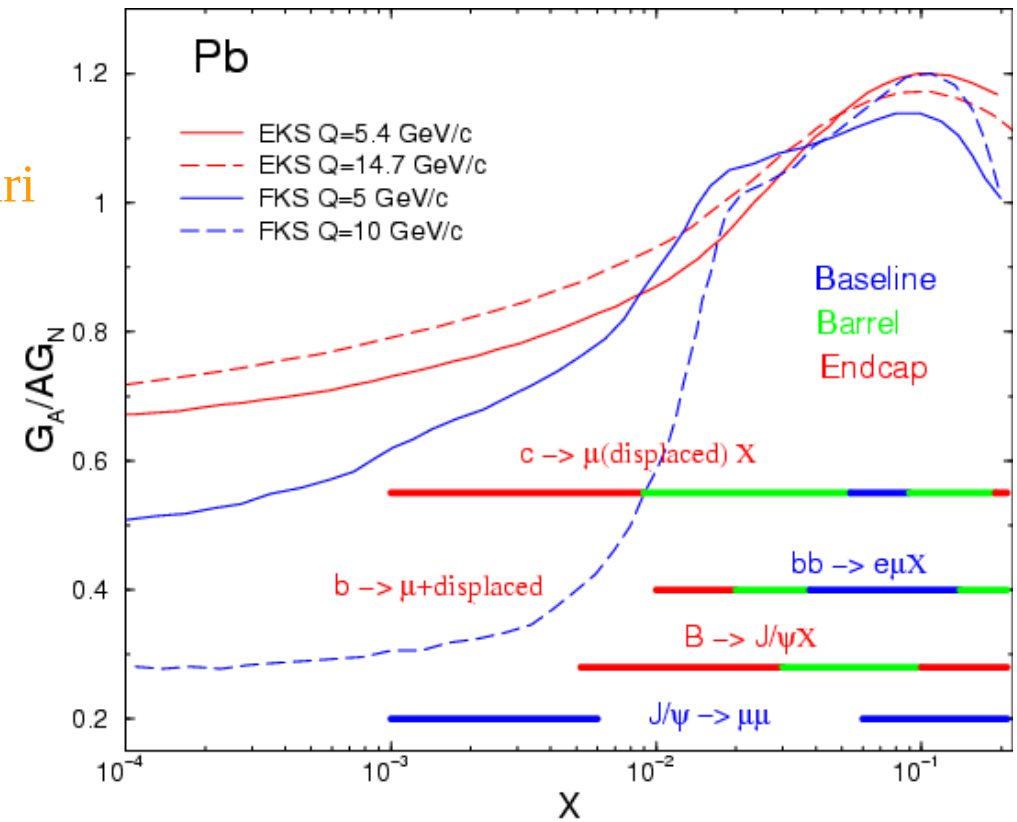
p_T (GeV)

Charm dominates

Measurement of gluon shadowing with SVT

- **Heavy-flavor measurement in p+A**
  - Single lepton and J/Ψ with displaced vertex
- **Extracting gluon structure function in nuclei (shadowing)**
  - Endcap Vertex detector provides broader range in x in the shadowing region (x <= 10^{-2})

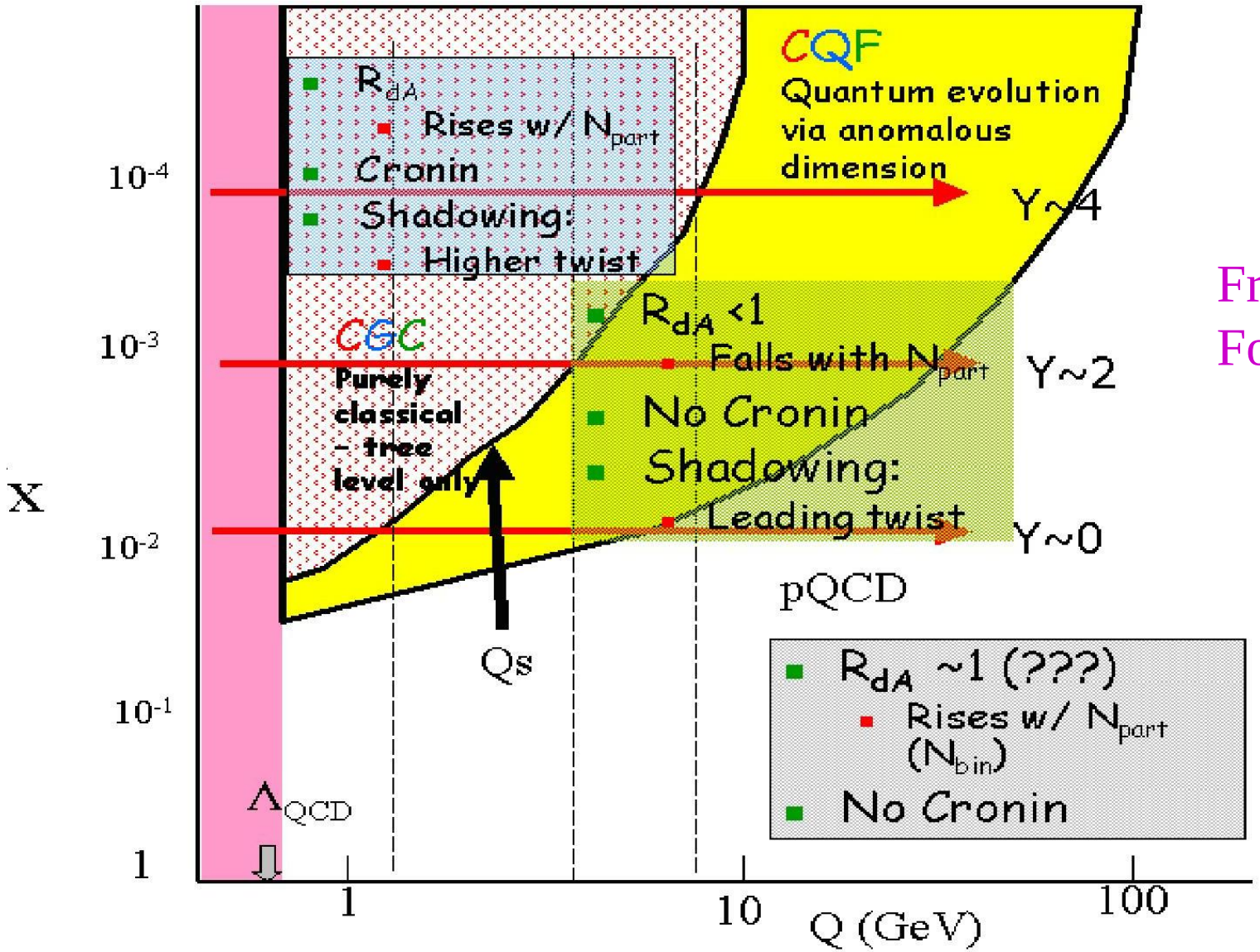
See talk by Yuri Kovchegov on Tues



$g + g \rightarrow Q + \bar{Q}$

From : SVT Proposal

Color Glass Condensate



From : Forward LOI

See QGP and CGC Lectures by L. McLerran

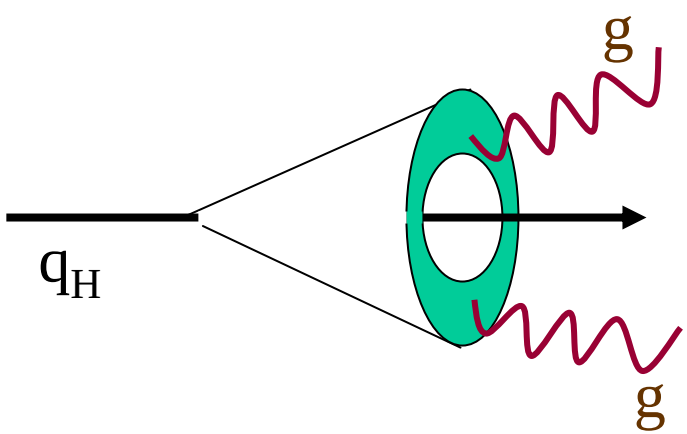
Energy Loss of Heavy Quarks in nuclear matter

"Dead Cone" Effect – Heavy quarks lose less energy than light quarks

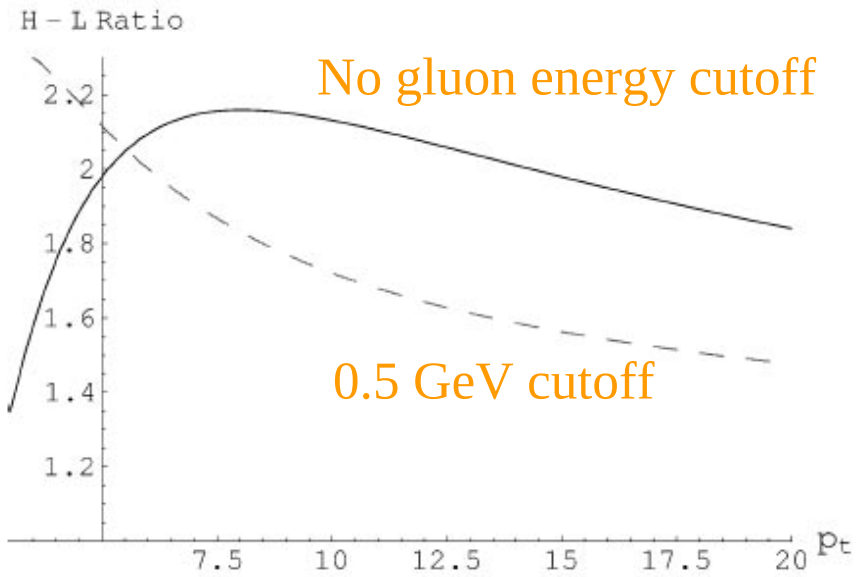
Gluon radiation from a massive parton is suppressed at angles

$\theta < Mq/Eq$ D. Kharzeev et al. Phys.Lett.B 519:1999,2001

See also Monday's talk by M. Djordevic.



Jet quenching factor Q_H/Q_L

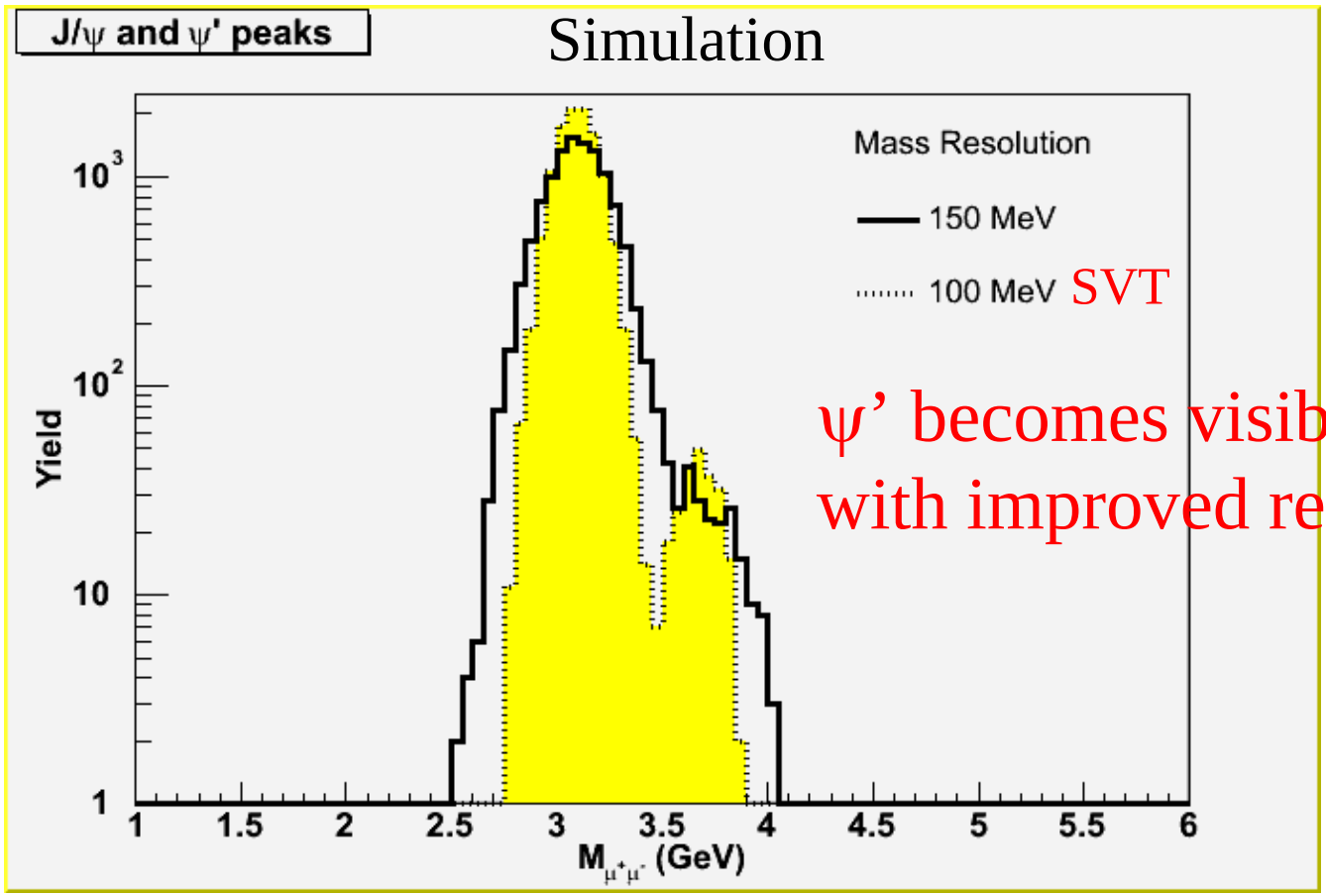


Some other estimates give Smaller quenching factors.

Note the need for high p_T coverage

Improves Separation of J/ψ from ψ' with Endcap SVT

SVT provides opening angle measurement before the nosecone, removing the multiple scattering contribution to the mass resn.



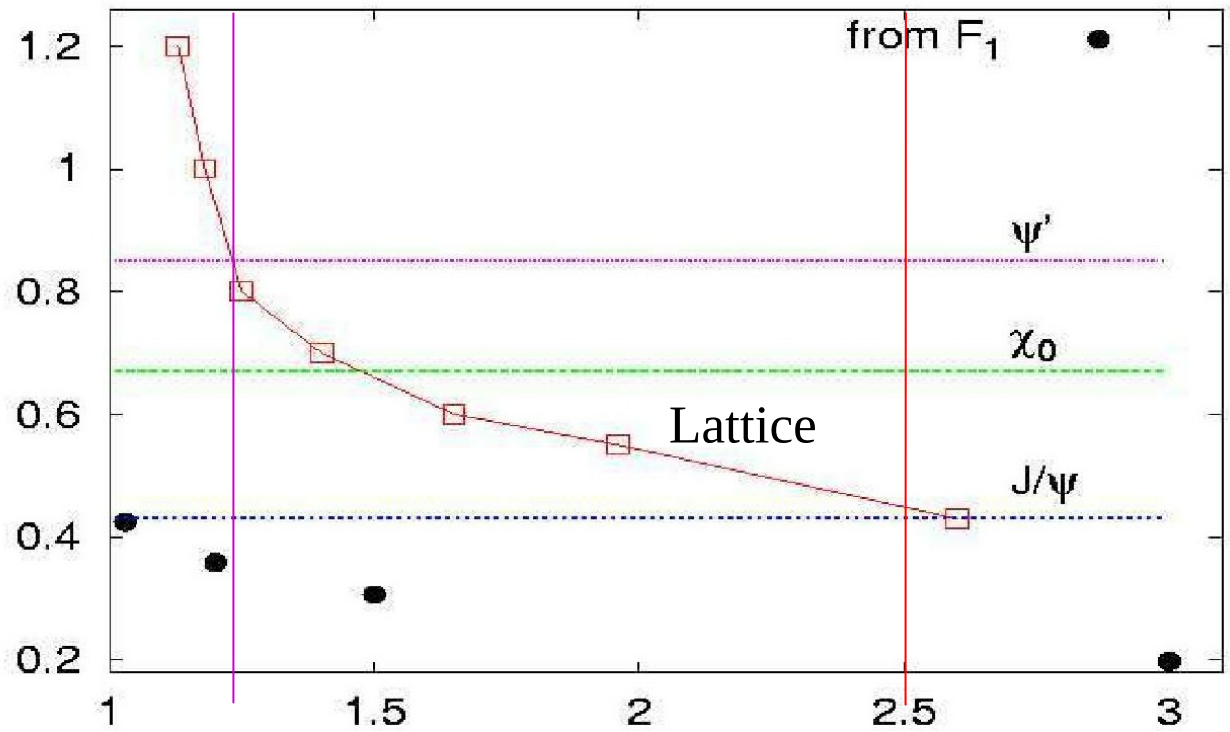
ψ' becomes visible with improved resolution

From : SVT Proposal

Update on Lattice QCD Calculations of Screening Radius versus Plasma Temp.

Quarkonia may survive higher temperatures? ψ' meas. is vital!

Screening Radius (fm)



From : Forward LOI

ψ' melts above 1.2 T_C

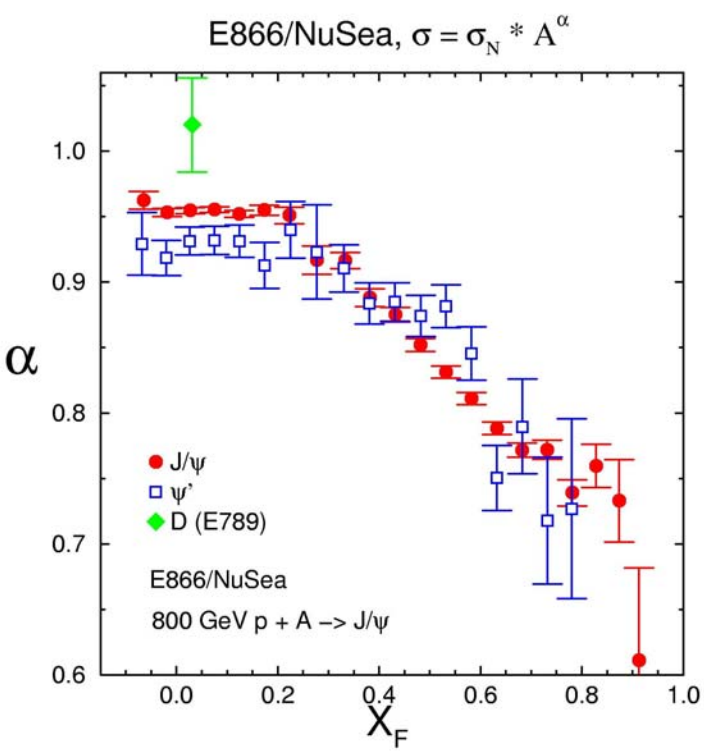
J/ψ melts above 2.5 T_C

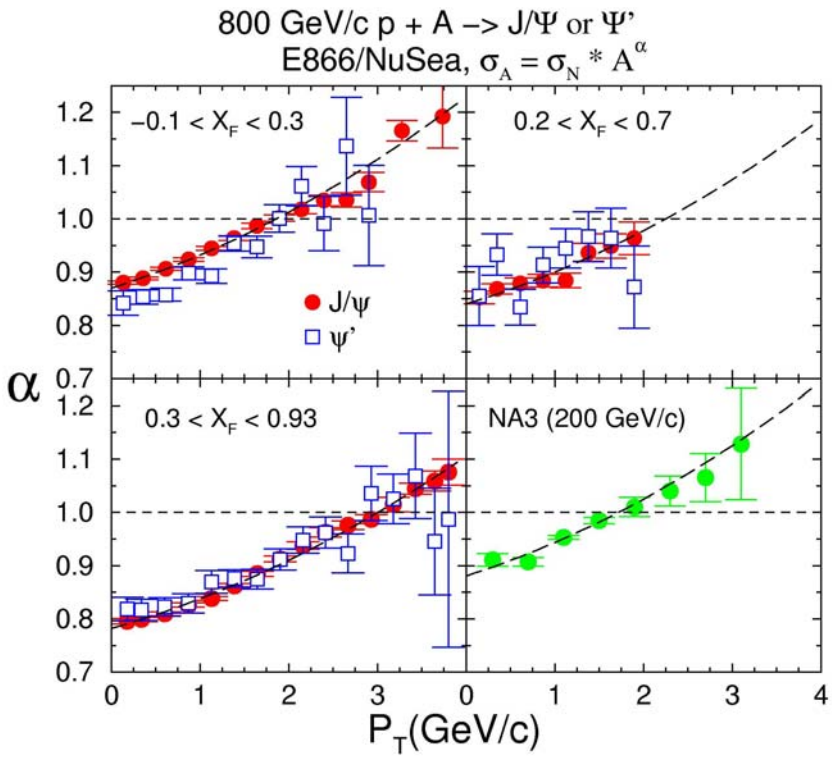
Further complication – Charm recombination?

Nuclear effects on J/ψ, ψ' and open charm

Need to measure all three for QGP baseline in A-A collisions

See Monday's review by M. Leitch



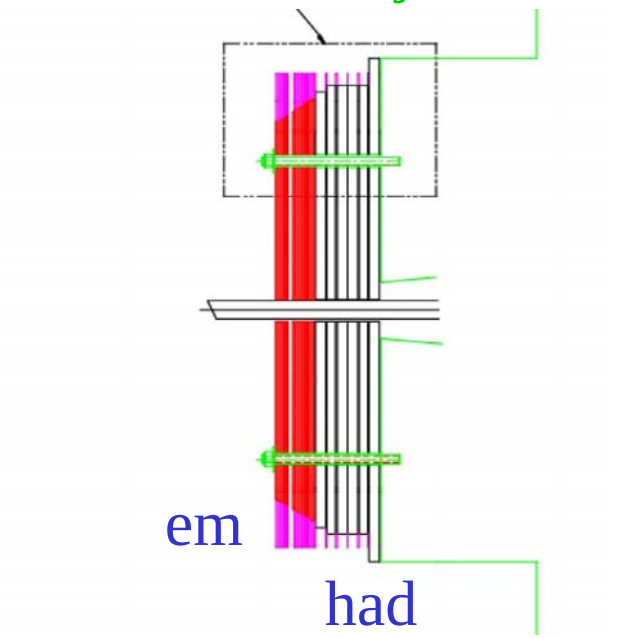


Ψ' is more suppressed than J/Ψ at $x_F \sim 0$

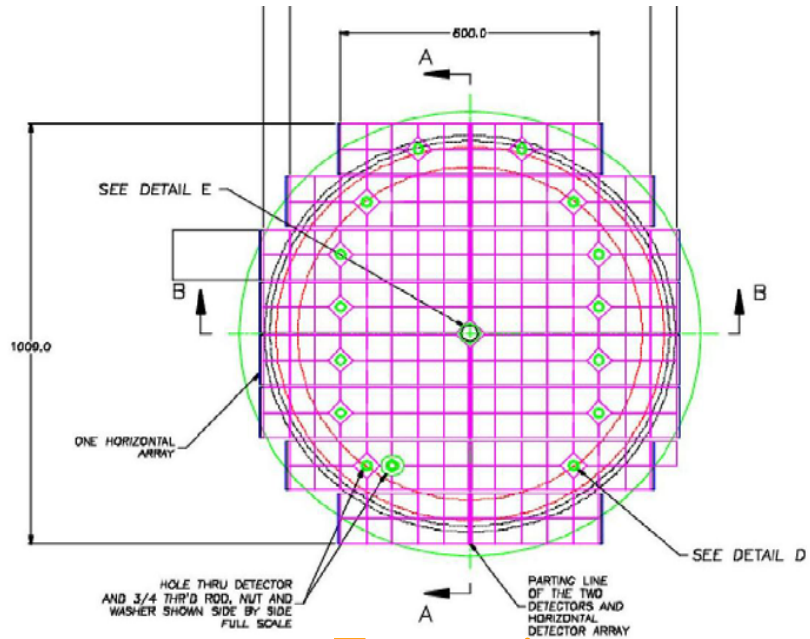
'Universal' behavior for Cronin effect, weak √s dependence

II. Hadron detection at forward / backward rapidity with Nosecone Calorimeters -

- Direct detection of neutral pions ($0.9 < |\eta| < 3.0$) – versus existing low rates of pion decays and punch-thru's.
- Energy loss and multiple scattering of pions at forward / backward rapidity, complementing the central arms and heavy quark data.
- Large acceptance for high P_T pions. Full azimuthal accept.
- Determines jet direction plus a rough energy measurement.



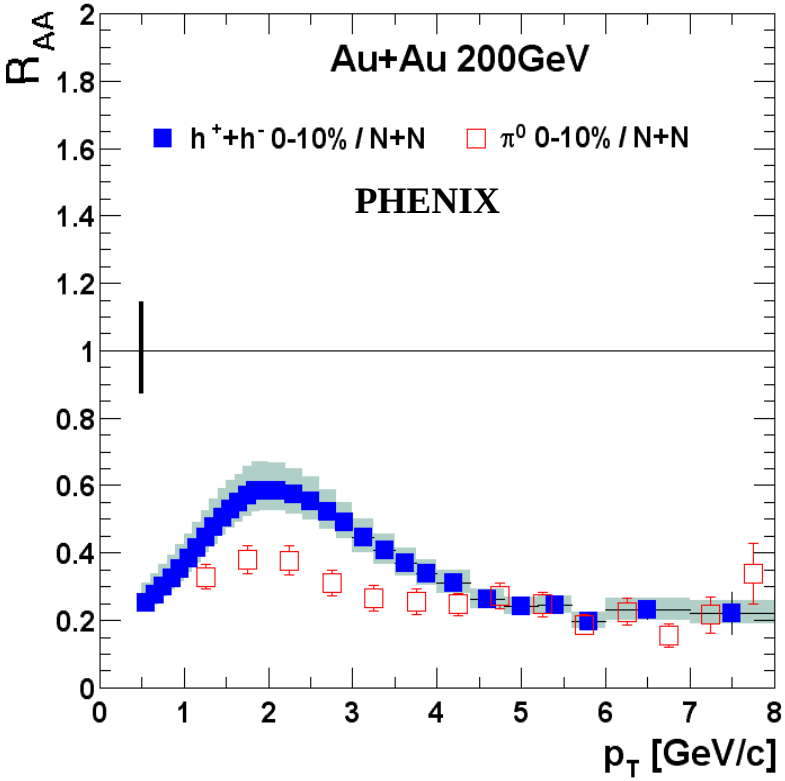
Side view



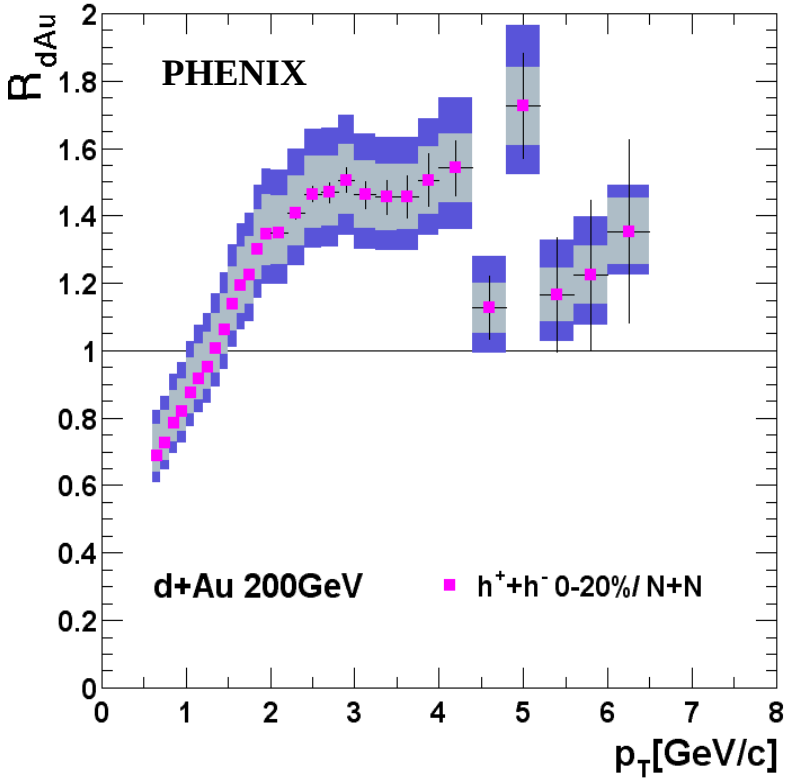
Front view

d+Au is Jet Suppression Control Measurement

Au + Au Experiment



d + Au Control Experiment



Nosecone Calorimeters will provide π^0 measurement, enabling study of jet suppression and Cronin effect over a wide range of rapidity and transverse momentum.

$R_{CP}(y)$: Muons from Light Meson Decays

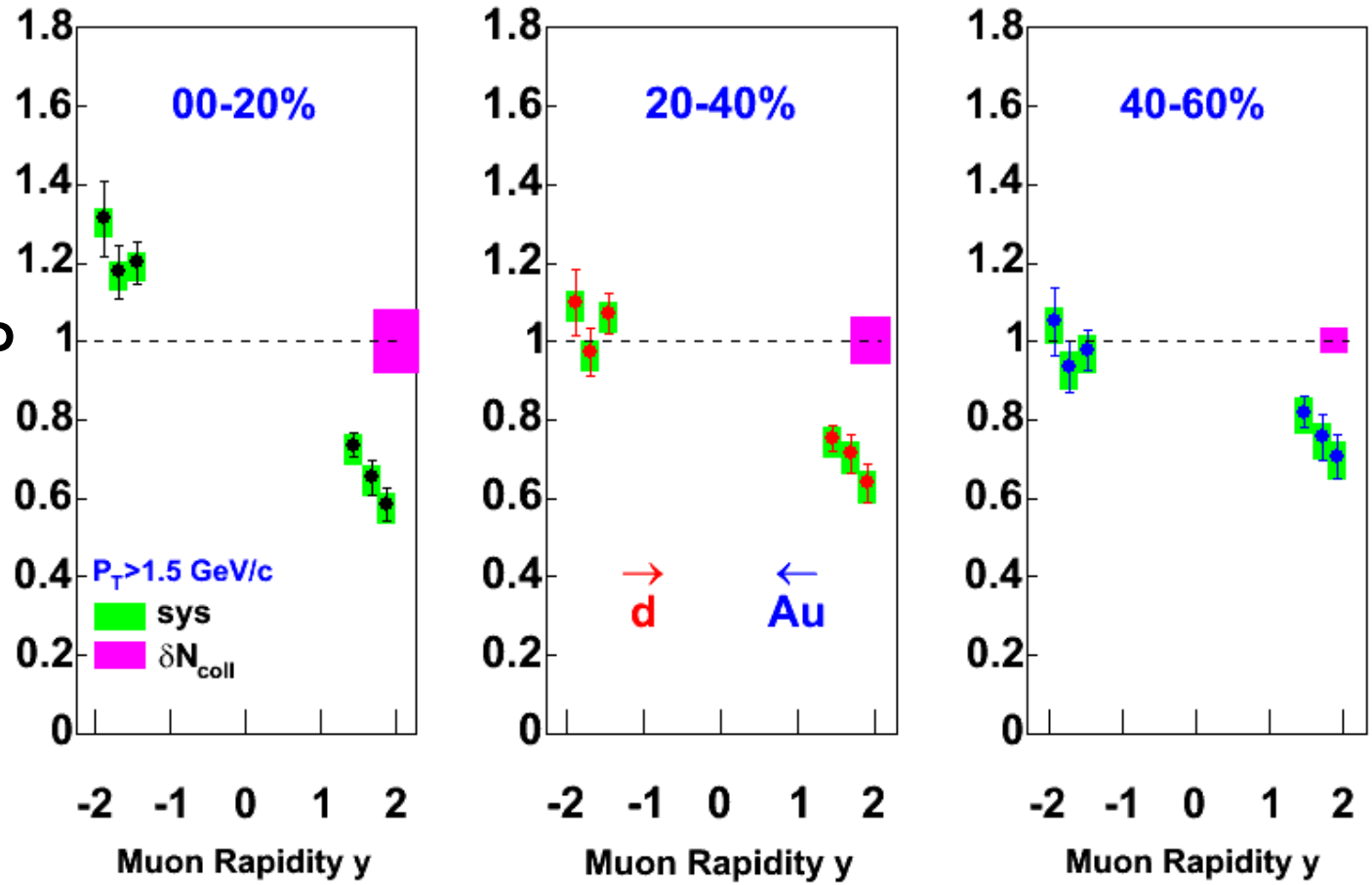
See Tuesday's talks by C. Zhang & M. Liu

PHENIX Preliminary

R_{CP}

$\pi^{\pm} \rightarrow \mu^{\pm} + \nu$

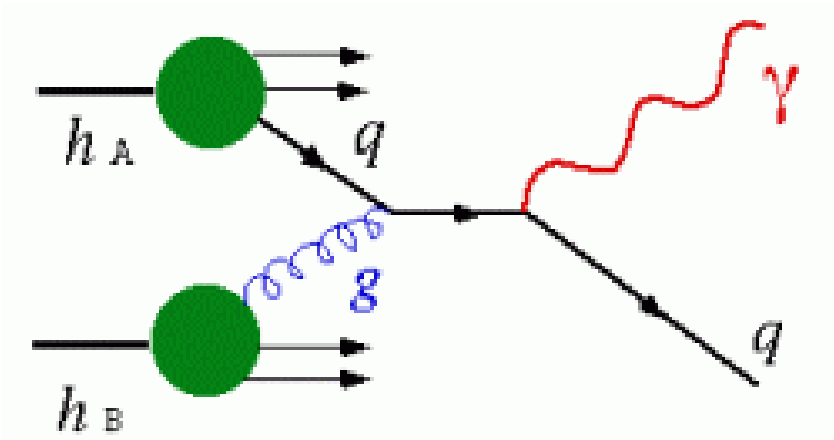
$K^{\pm} \rightarrow \mu^{\pm} + \nu$



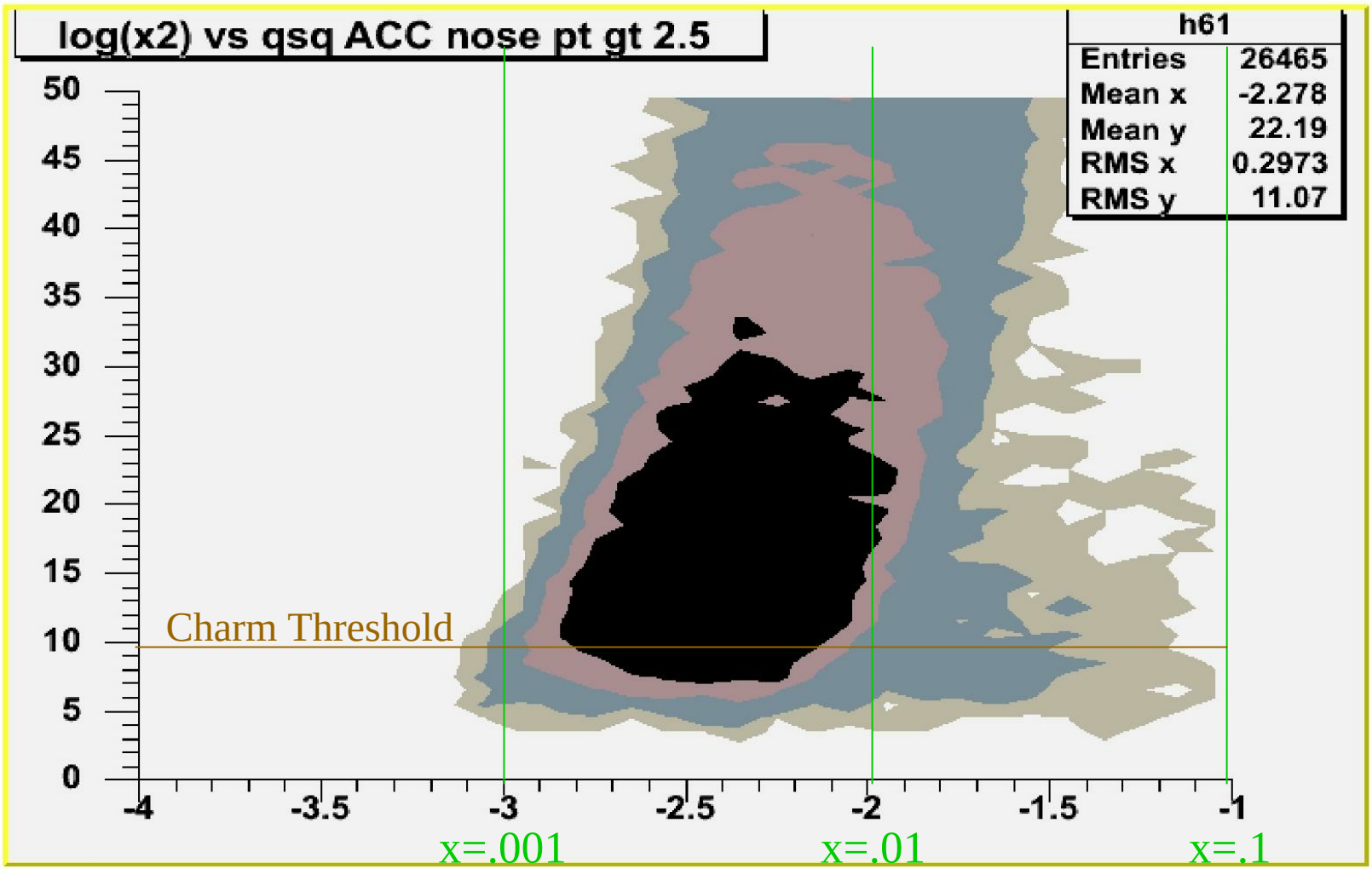
Nosecone calorimeters will provide ~100 X more data, wider rapidity range and select only neutral pion decays.

III. Photon detection at forward /backward rapidity -

- Measurement of gluon structure in nuclei, contrast with heavy quark data.
- Detection of χ_C states via $\chi_C \rightarrow J/\psi + \gamma$. Large acceptance since nosecone calorimeter covers muon arm rapidity range. (Acceptance for photon in central arms is very low.)
  χ_C is a QGP diagnostic plus a contributor to J/ψ yield.
- Can use $q + g \rightarrow \gamma$ + jet for very clean gluon measurement. Should have better x resolution than inclusive channels.
- Large acceptance for γ $(0.9 < |\eta| < 3.0)$
  $\rightarrow$ good for low x shadowing region.



Photon Coverage with Nosecone Calorimeter at √S = 200 GeV



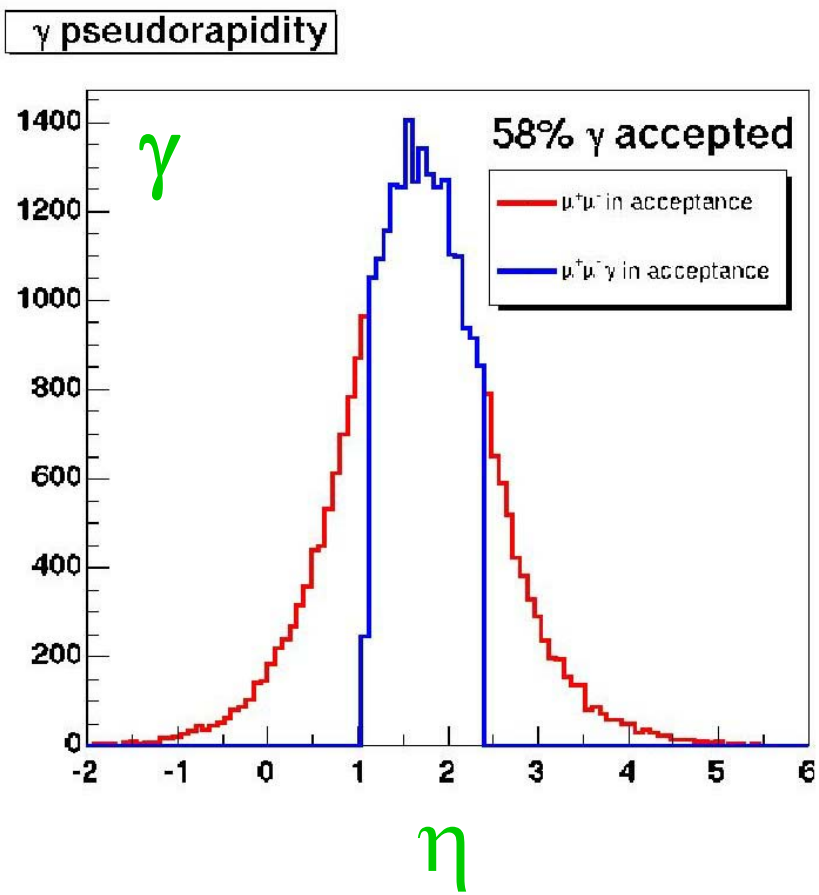
Q^2 GeV

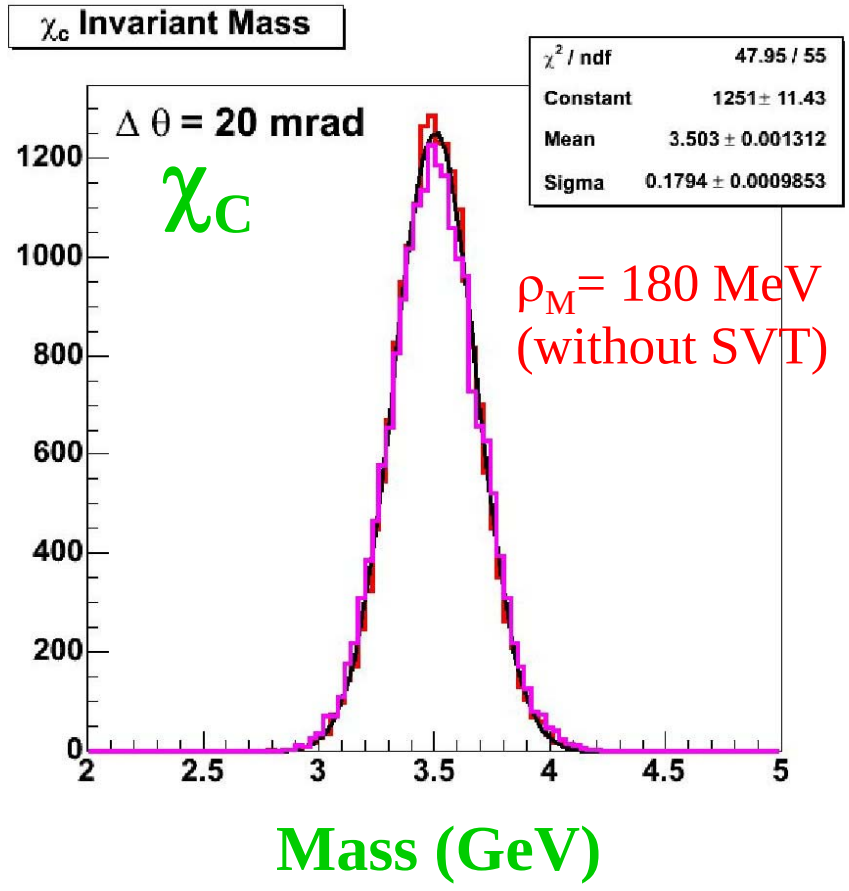
Log (x_2)

From : Forward LOI

Good complement to Charm measurements

χ_C Reconstruction via J/ψ + γ coinc.



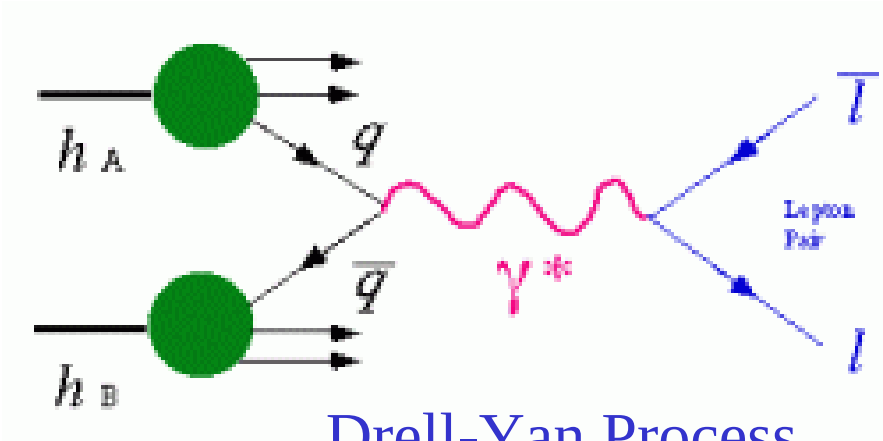


Excellent acceptance and good mass resolution, even without the Endcap SVT detector.

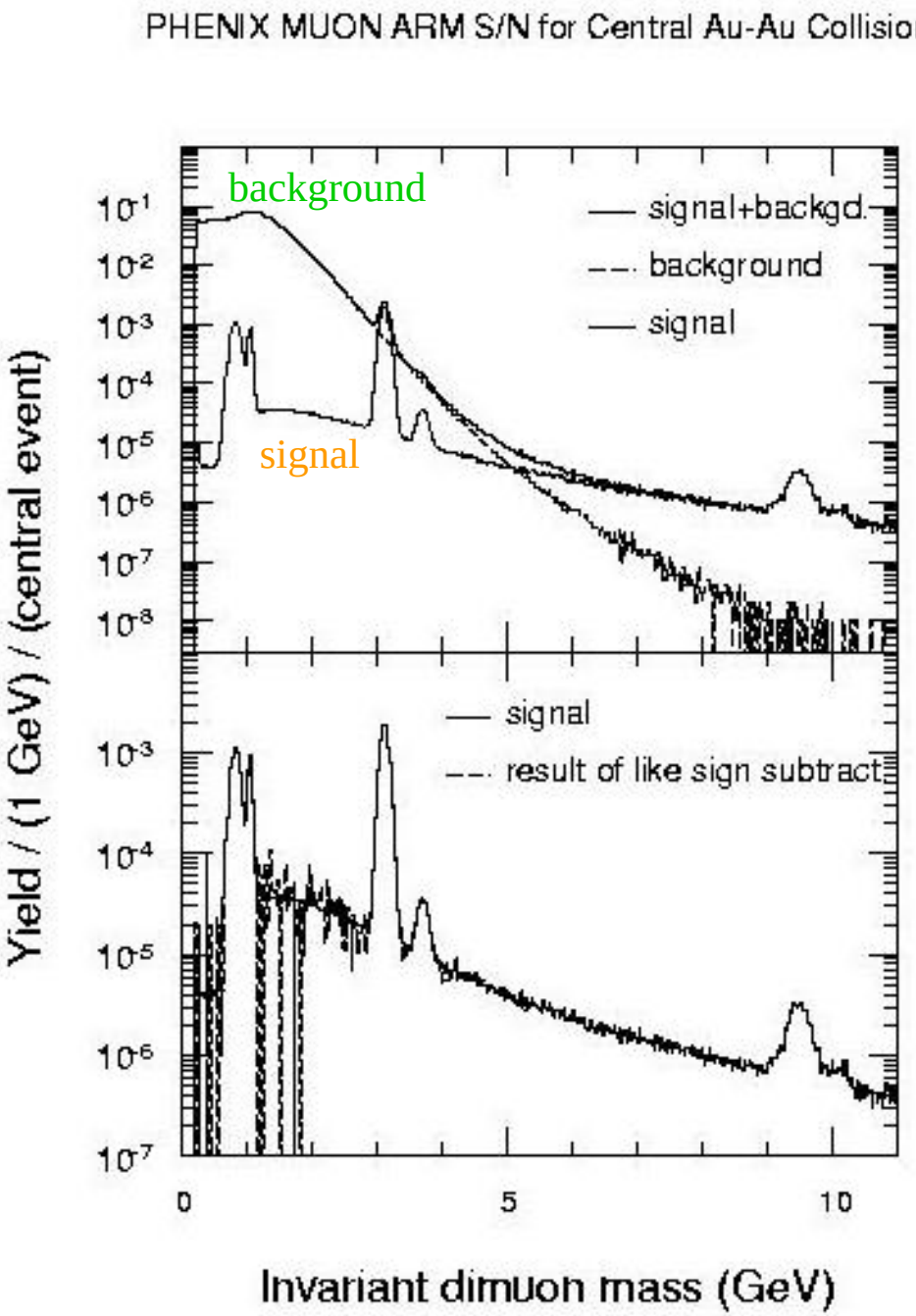
From : Forward LOI

Dimuon, W and Z Measurements –

- Removal of hadron and charm decays from Drell-Yan continuum using endcap SVX. Possible detection of thermal charm between 1 and 3 GeV. D-Y gives direct measure of anti-quark structure in nuclei.
- High p_T single muons from W decays possible with new trigger – provides measurement of flavor dependent anti-quark sea, similar to pp, pd measurements from FNAL E866. High luminosity at $\sqrt{S}$ = 500 GeV and high p_T trigger are required.
- Z^0 with muons in opposite endcaps.



Drell-Yan Process



ORNL dimuon S/N simulation for Au-Au Collisions

Hadron decay backgrounds large below 4 GeV, requiring accurate like sign correction. Φ region has bad S/N!

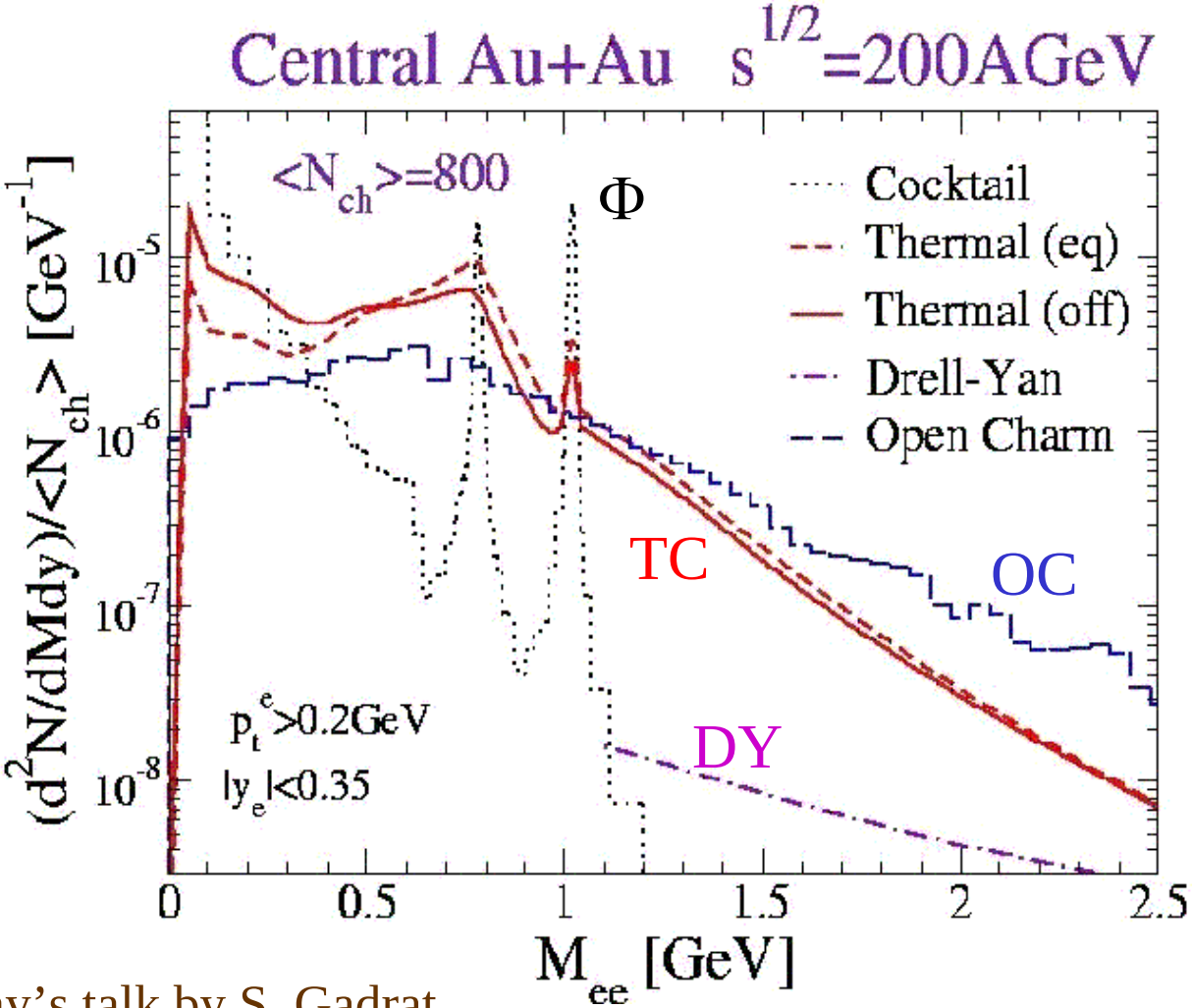
Endcap SVX detector can remove most of these π and K decays. Can also separate charm contribution from DY continuum.

See also Monday's talk by F. Fleuret

From : PHENIX CDR

Simulation of open charm, thermal charm and D-Y at low pair mass

Open charm dominates dilepton spectrum between 1 and 3 GeV.
Once measured we can look for thermal charm in Au+Au.



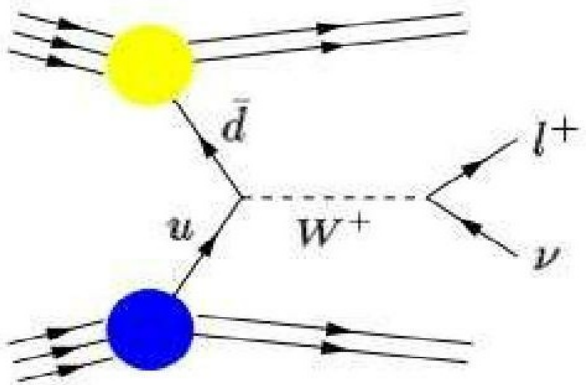
From :
Ralf Rapp

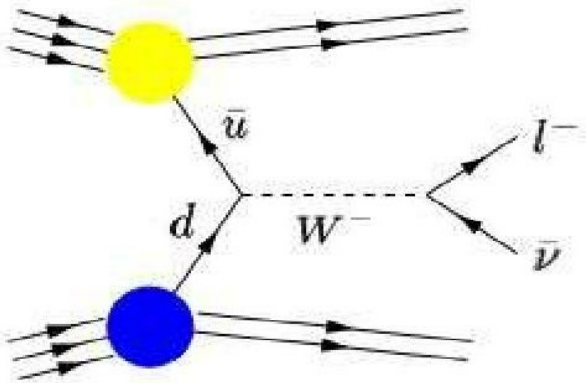
See also Monday's talk by S. Gadrat

W^{+-} measure anti-quark sea for .004 < x <.01

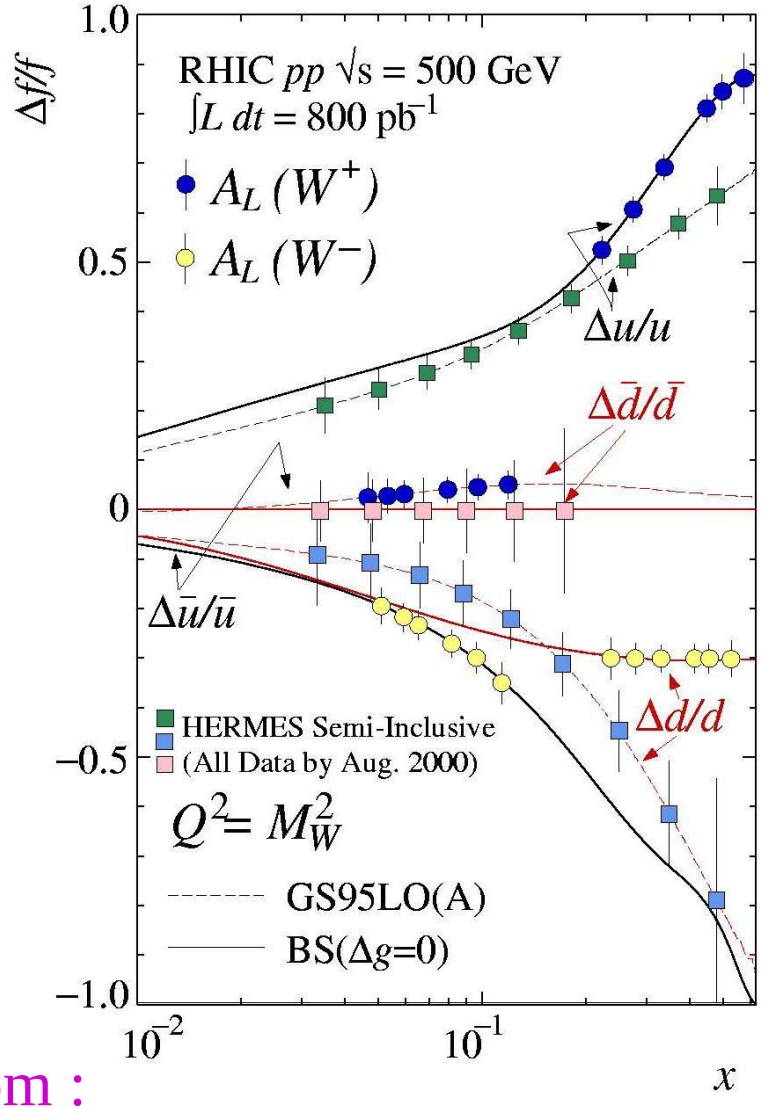
Muon Trigger upgrade and high luminosity are essential!

Yield(W^+) ~ $\bar{d}(x_1)*u(x_2)$





Yield(W^-) ~ $\bar{u}(x_1)*d(x_2)$



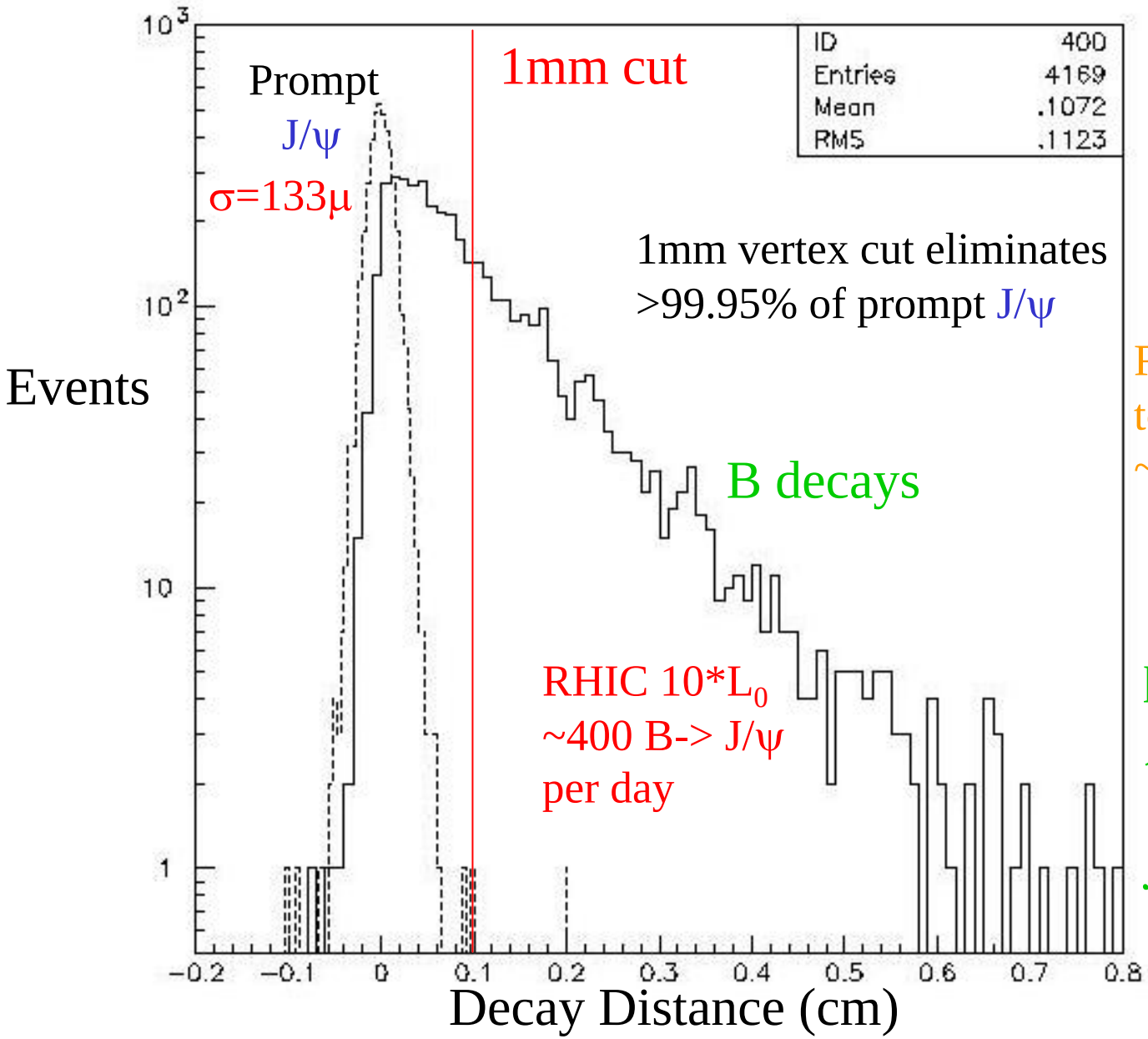
From :
Forward LOI

See Monday's talk by P. Nadolsky

Summary

- With the Endcap SVT, Nosecone Calorimeter and Muon Trigger Upgrades we can :
  - Finally exploit the full rare probe capabilities of PHENIX.
  - Push deep into the shadowing / CGC region.
  - Directly measure heavy quarks.
  - Measure hadrons and photons at forward/backward rapidities.
  - Detect W decays.
- We need to :
  - Push ahead with proposal preparation and submission.
  - Get the necessary R+D funded and underway.
  - Keep these upgrades high on NSAC's and DOE's priority lists.
  - Recognize that these upgrades will take many years and dollars to complete. Let's not get discouraged. (On Monday, the first privately funded manned sub-orbital space flight was completed!)

Simulation of B-> J/ψ -> $\mu^+\mu^-$ with Endcap VTX



Ratio of B decay to prompt J/ψ ~ 1%

p+p

√S=200 GeV

∫L=10^{36}