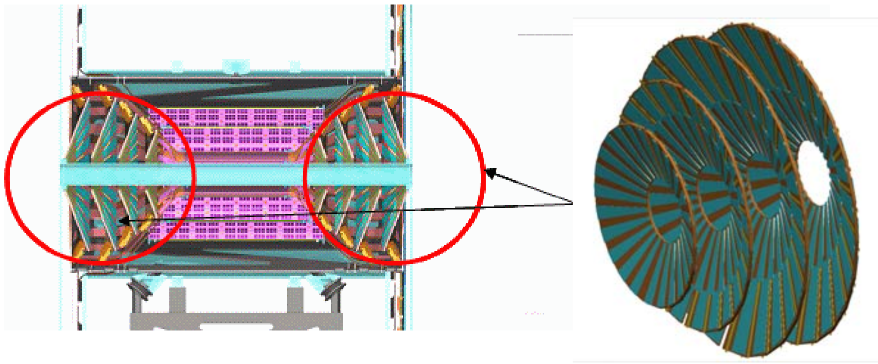
Physics Motivation and Performance

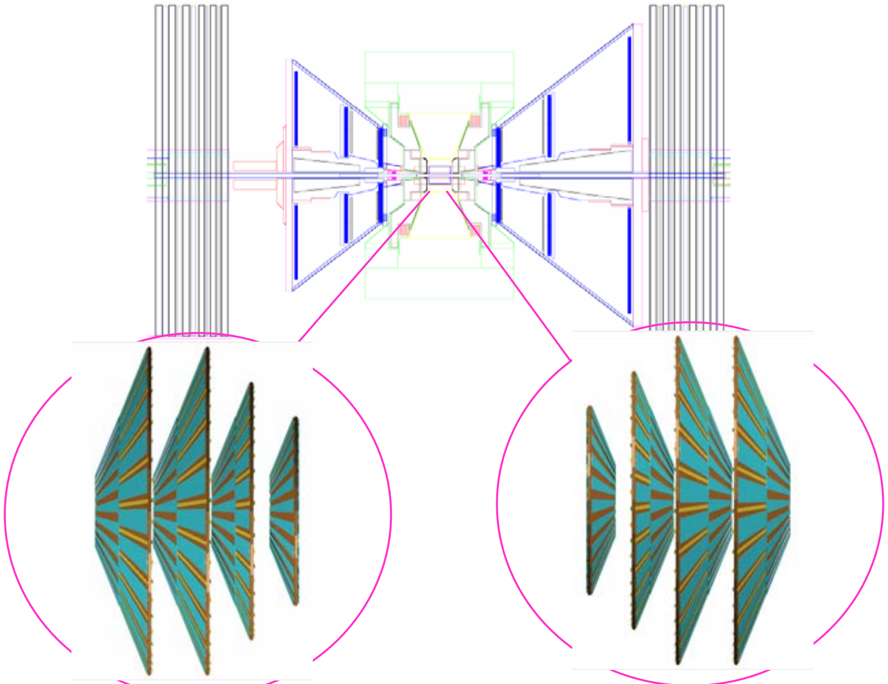


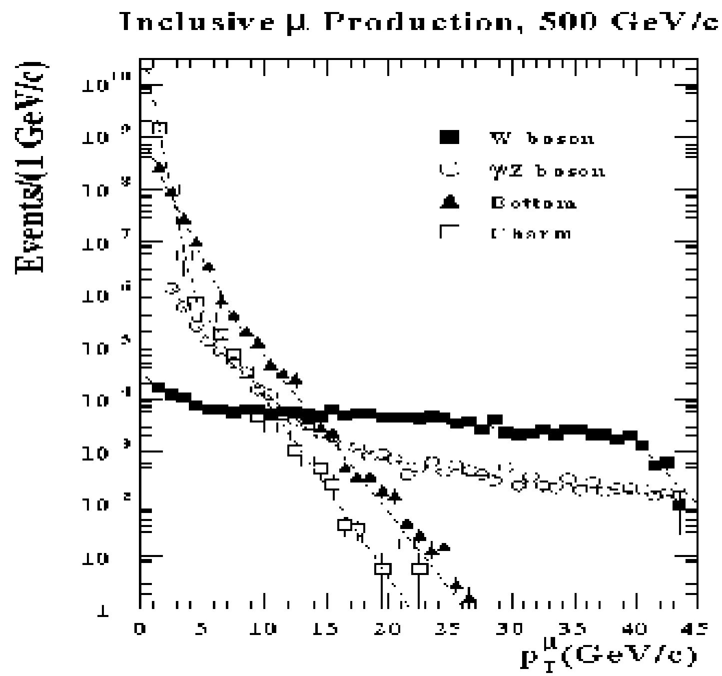
Brief Outline:

- Physics measurements at forward rapidity in PHENIX
- Limitations of measurements with current detector systems
- Critical Improvements FVTX provides
- Simulations that defined detector design and verified performance

Many contributors: Hubert, Dave L., Pat, Xiaorong, Anuj, Joel

Physics Measurements from Forward PHENIX

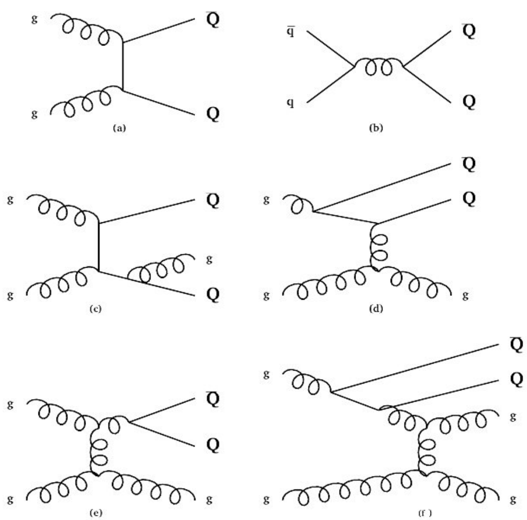


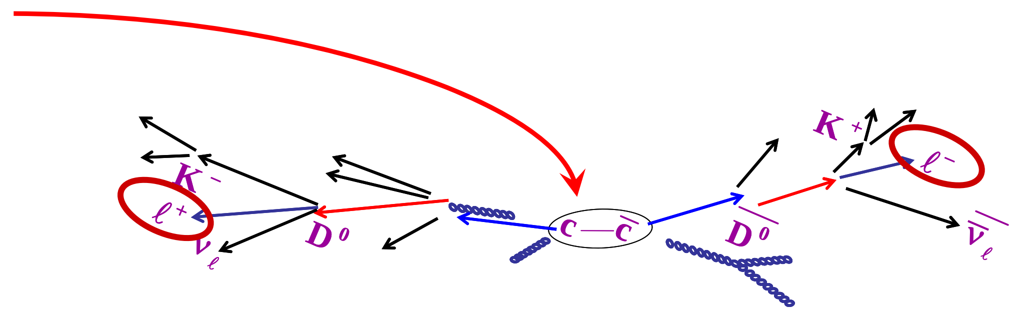


Single/dimuon muon spectra give access to:

- Open heavy flavor via single μ, π/K from decay muons and punch-throughs
- W from single muons at high p_T, 500 GeV
- Vector mesons (J/ψ, ψ', Υ)
- Drell-Yan
- Open heavy flavor from dimuons

Open Heavy Flavor at Forward Rapidity

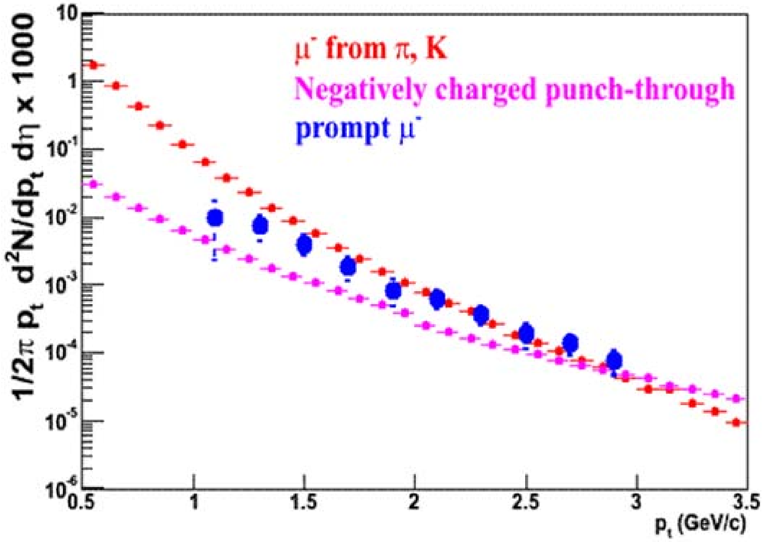


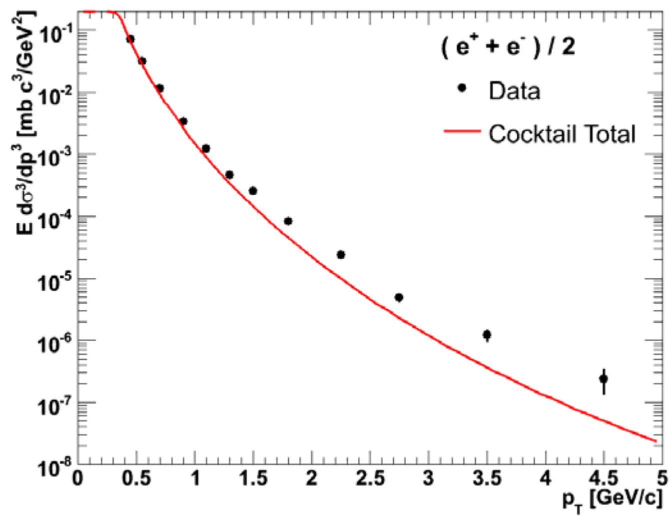


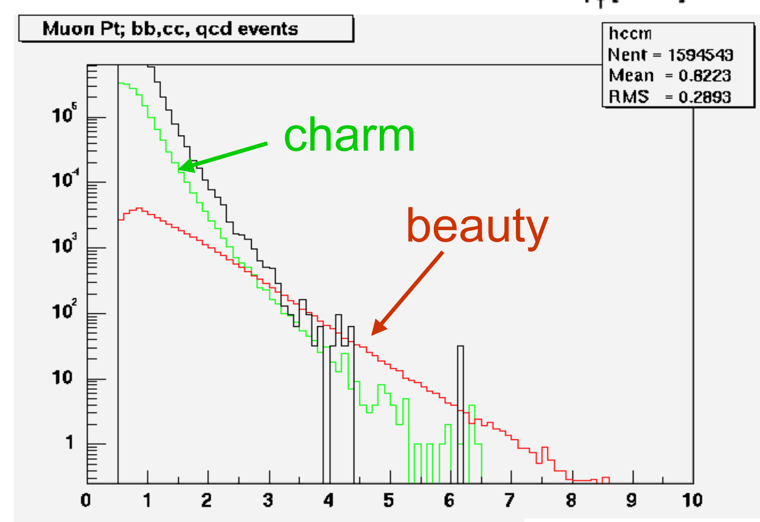
<u>Open Heavy Flavor Physics Interests:</u>

- What is the total cross section for charm/beauty in all collision systems?
- Does asymmetry measurement in polarized pp collisions indicate contribution of gluons to proton spin?
- Is there modification of charm production in cold nuclear matter: gluon saturation,…
- Is there modification of charm production in heavy-ion collisions: energy loss in medium
- Do heavy quarks flow?

Current Limitations on Heavy Quark Measurements



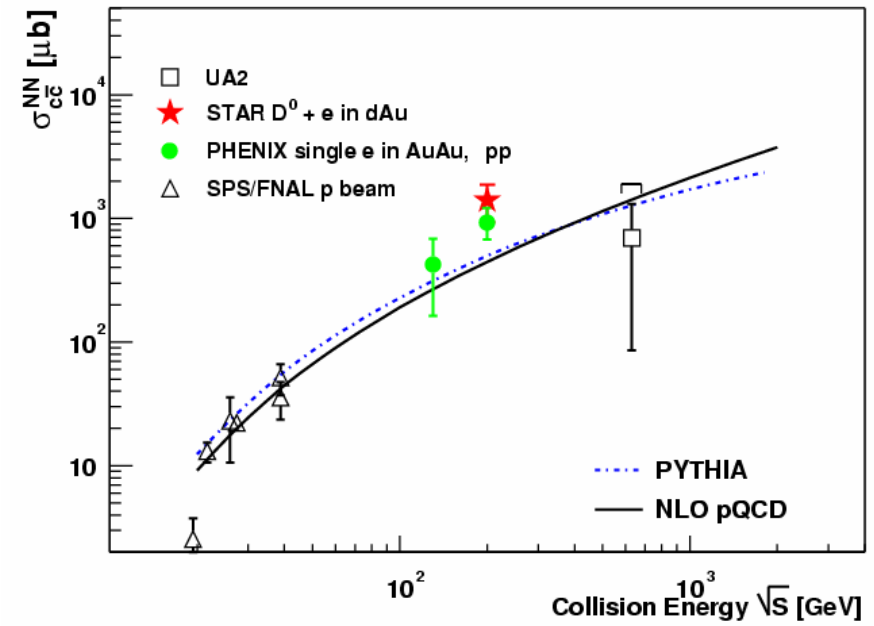


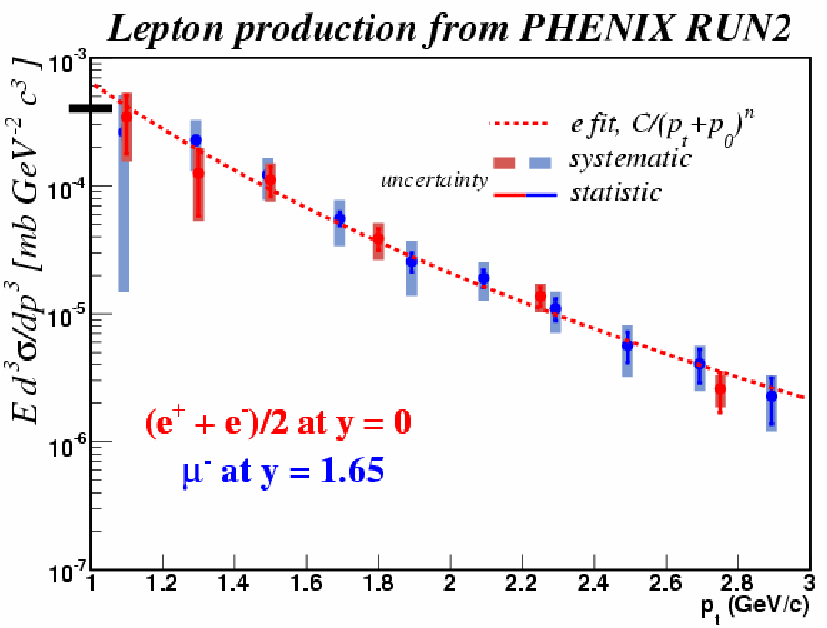


p_T (GeV/c)

- Single muon measurements limited at low p_T by decays and at high p_T by punch-throughs
- Single electrons limited at low p_T by large contribution from π^0, at high p_T by PID capabilities
- Both suffer from not being able to separate charm and beauty

Charm Cross Section Uncertainty

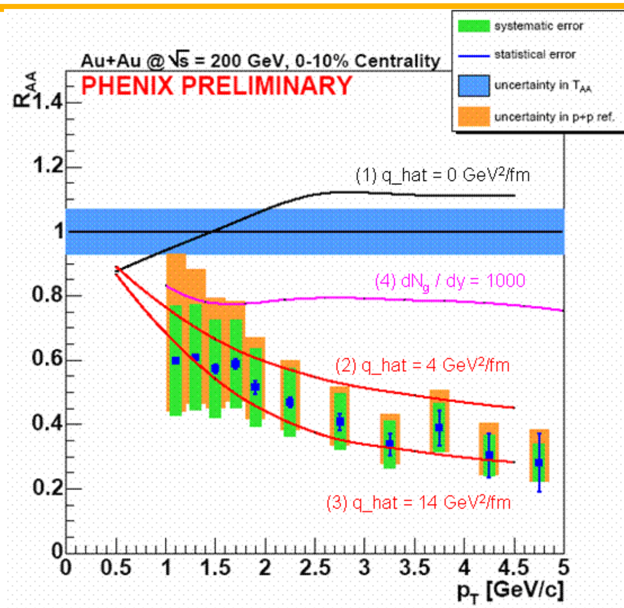


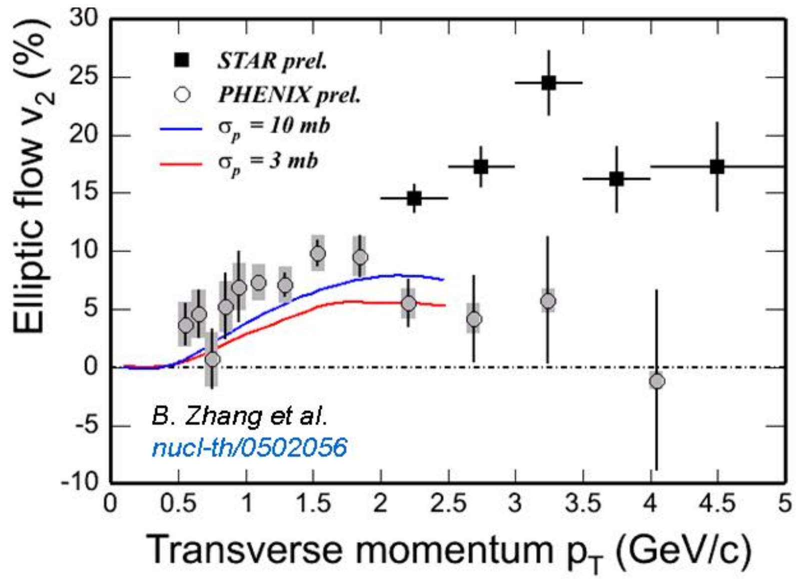


Total cross section is rather uncertain and forward heavy flavor measurements are limited in precision:

- Difficult to measure full p_T range because of large backgrounds
- Rapidity distribution rather uncertain because central and forward rapidity both suffer large (uncorrelated) systematic errors
- No separation of charm and beauty components

Heavy Flavor Suppression and Flow in AuAu

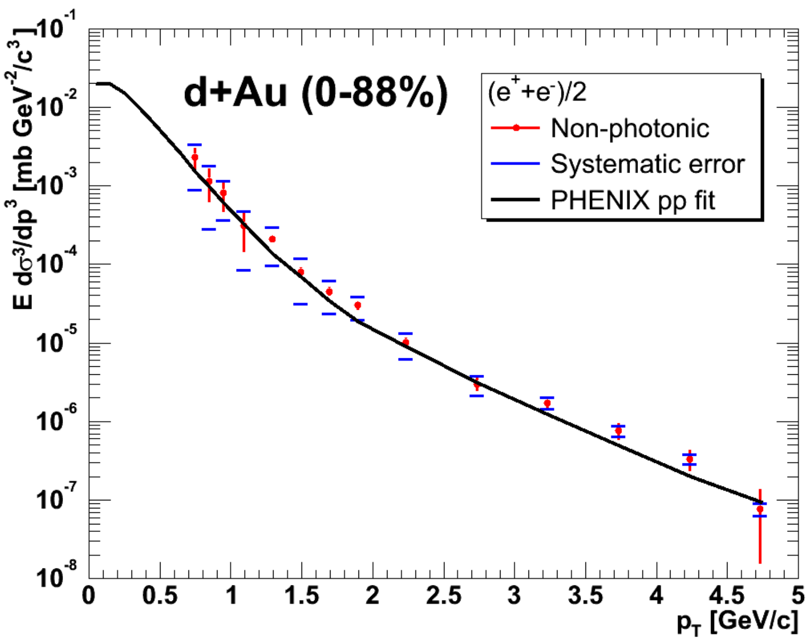


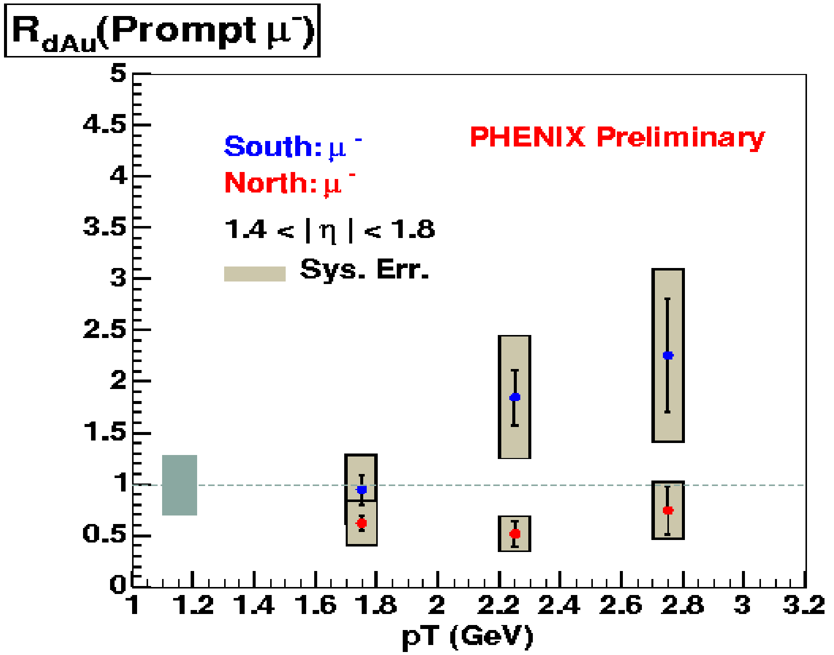


Indications of heavy quark suppression and flow in AuAu collisions at central rapidity from PHENIX/STAR, but

- Systematic errors remain somewhat large because of large backgrounds
- Reaction plane resolution improvement would help
- Separation of charm/beauty would make interpretation of results less ambiguous
- Rapidity and p_T dependence should help separate effects of hot/dense medium, cold-nuclear matter effects

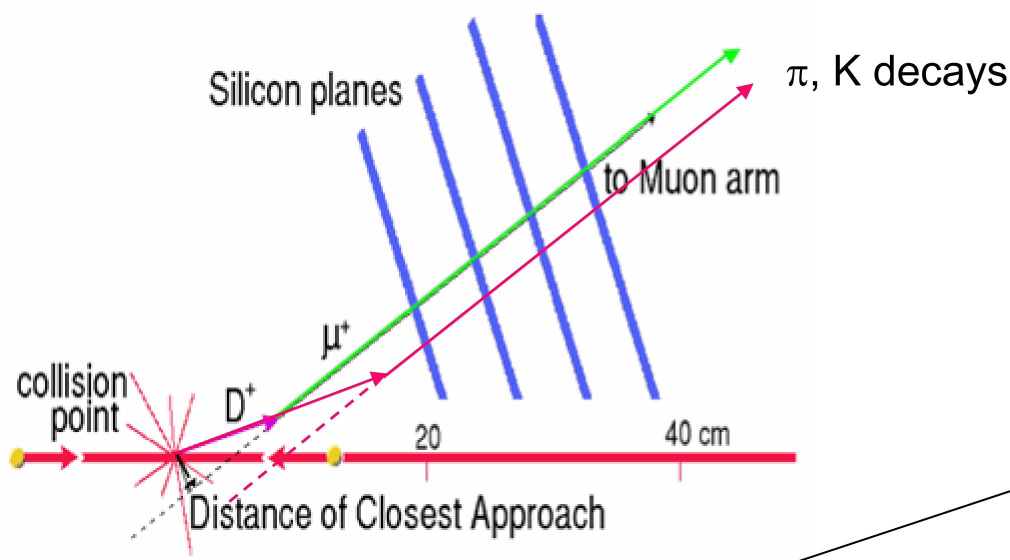
Cold nuclear matter effects from dAu

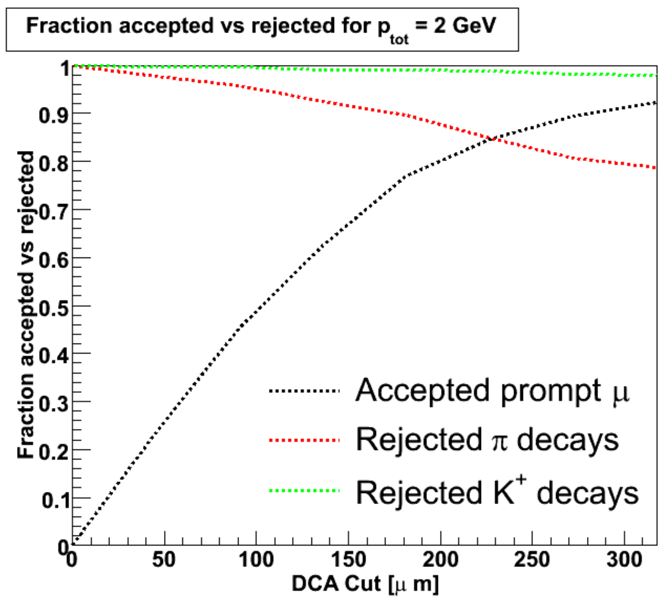


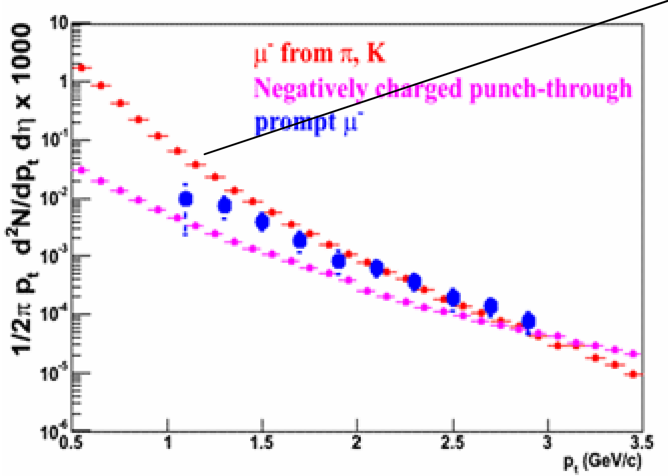


- Central arm shows little change in open heavy flavor in dAu w.r.t pp, but this does not access x region where gluon saturation would be expected to play a role
- Muon arm shows some forward/backward asymmetry, but precision limited for same reasons as stated previously

FVTX Contributions—Reduction of Decay Background

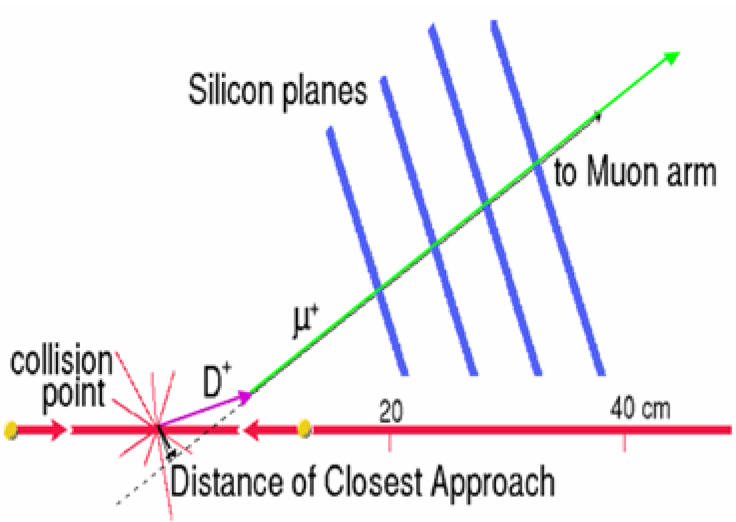


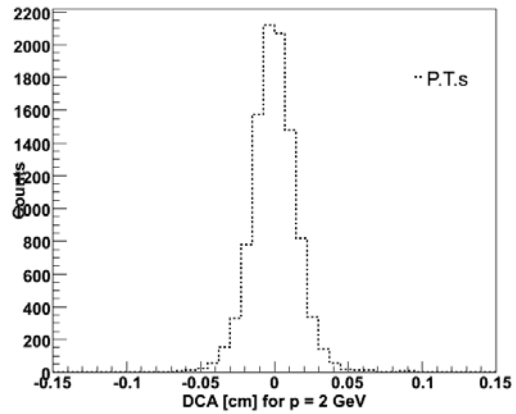


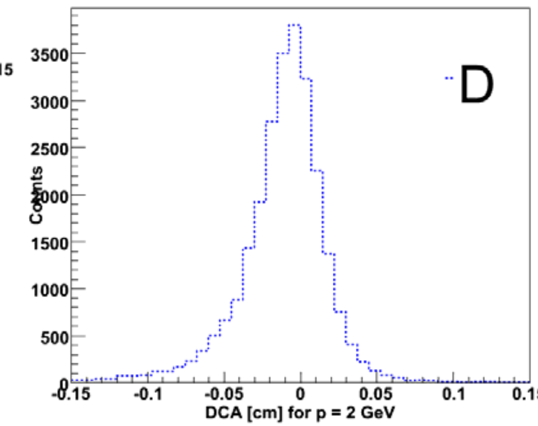


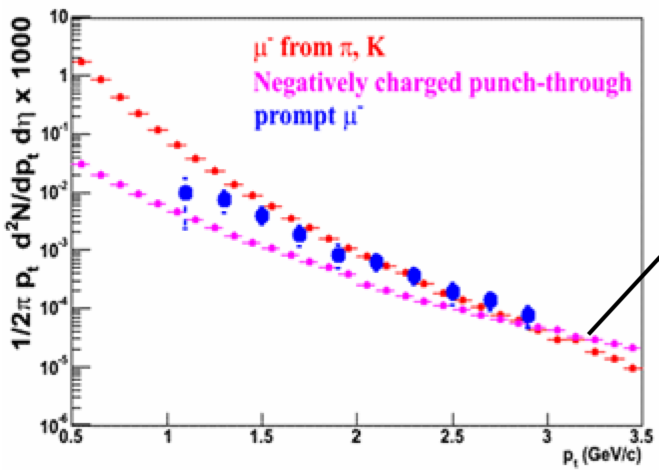
- Cutting on DCA<DCA_{max} allows long-lived π,K decays to be separated from heavy quark decays AND cleaner sample of π,K at forward rapidity
- Especially necessary to access low p_T spectra

FVTX Contributions—Reduction of Punch-Throughs



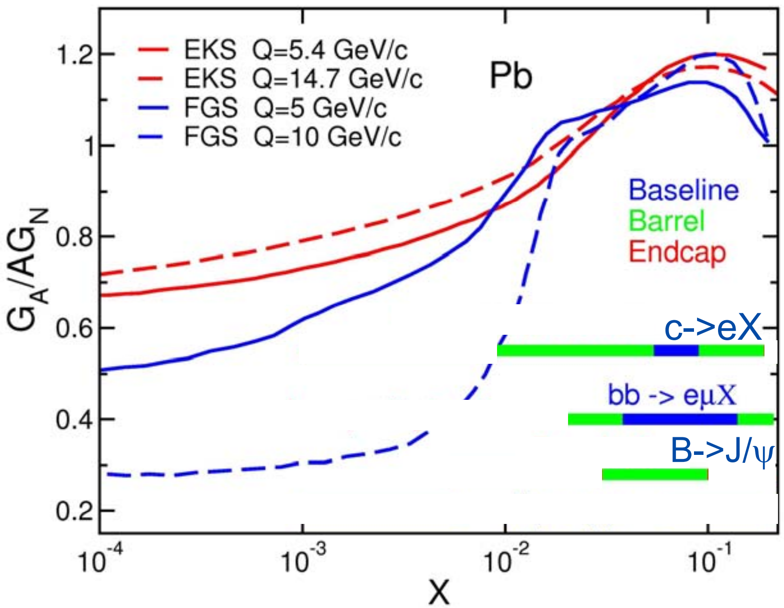


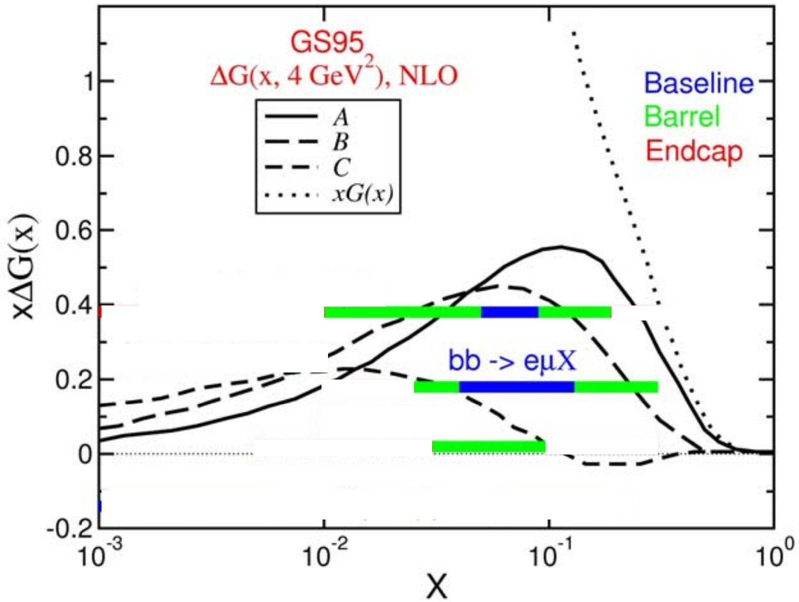




- Cutting on DCA > DCA_{min} allows π,K punch-throughs (prompt) to be separated from open heavy flavor decays
- Especially necessary to access high p_T spectra

FVTX Contributions—Adding forward rapidity coverage

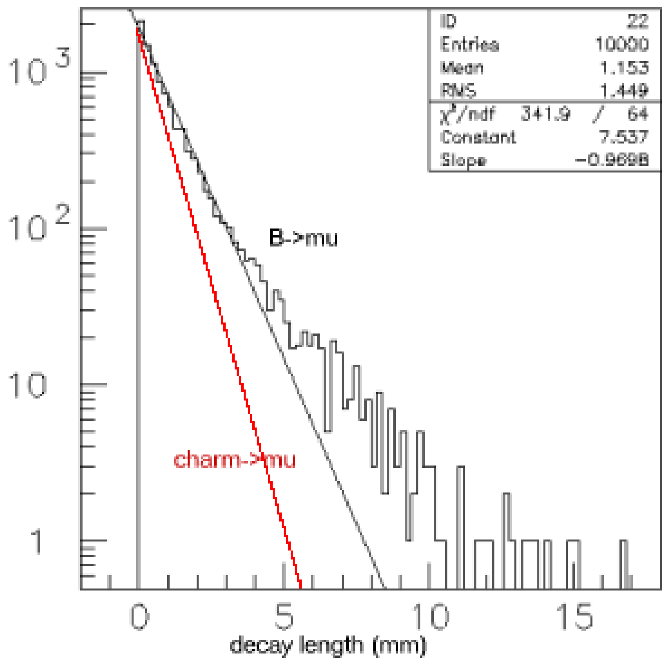


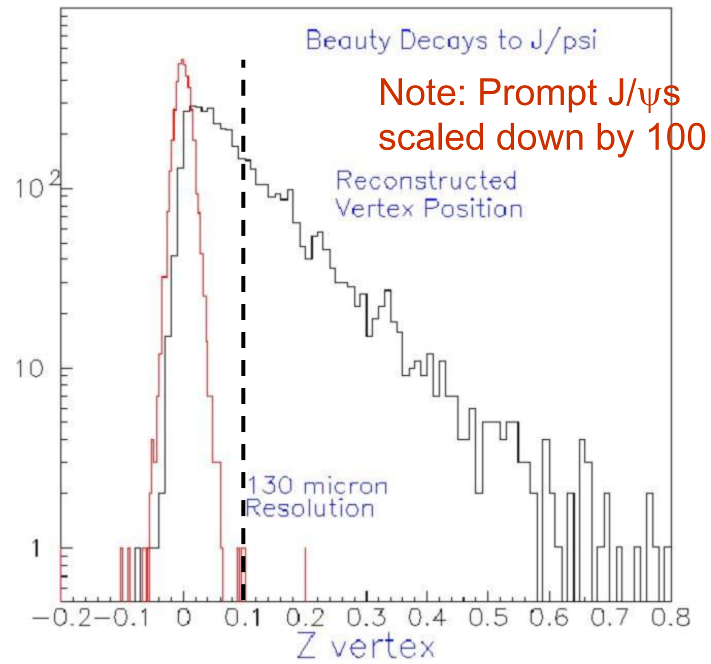


- Forward rapidity critical to map out saturation or not of gluons in cold nuclear matter, over broad x range

- Forward rapidity critical to map out gluon polarization function over broad x range
- Small asymmetries expect (~few percent)→limit to high p_T and/or more precise measurement at low p_T

FVTX Contributions—Separation of Charm and Beauty

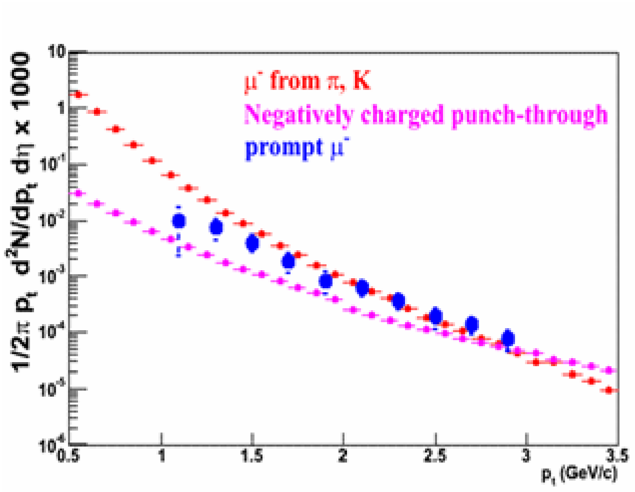


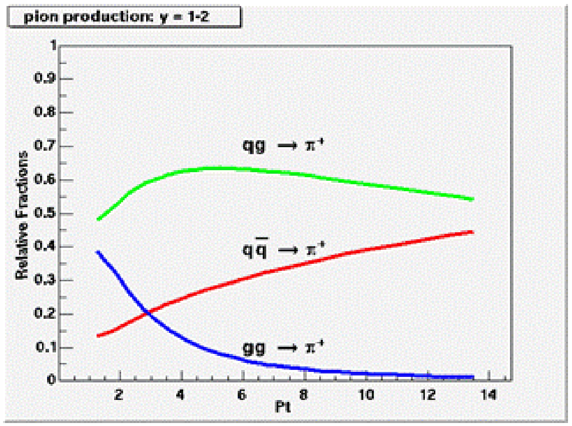


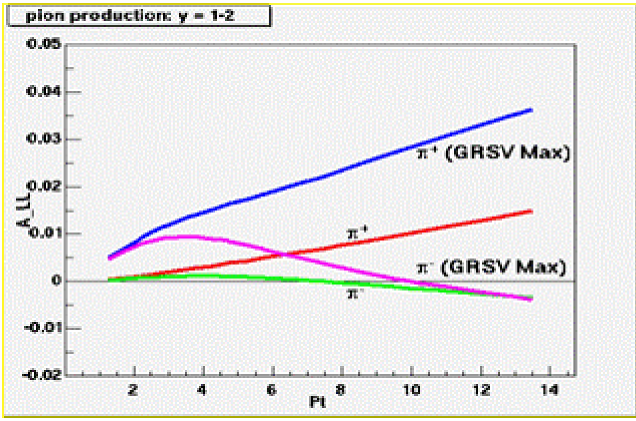
Charm/beauty separation still difficult, but a few possibilities:

- Natural separation at high p_T (doesn't depend on FVTX)
- Take advantage of somewhat longer decay length for b compared to c
- Measure $B \rightarrow J/\psi$ events and infer beauty differential cross section: cut at 1 mm $\rightarrow 10^{-4}$ rejection of prompt J/ψs, 40% acceptance of $B \rightarrow J/\psi$)
- Like-sign dimuons (under study)
- Υ Measurement improved (under study)

Physics Cont'd: Backgrounds can also be signals

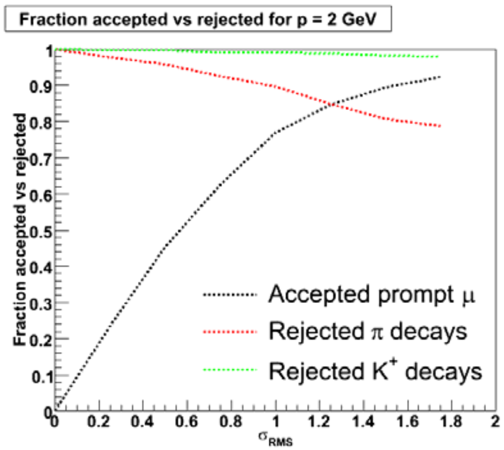




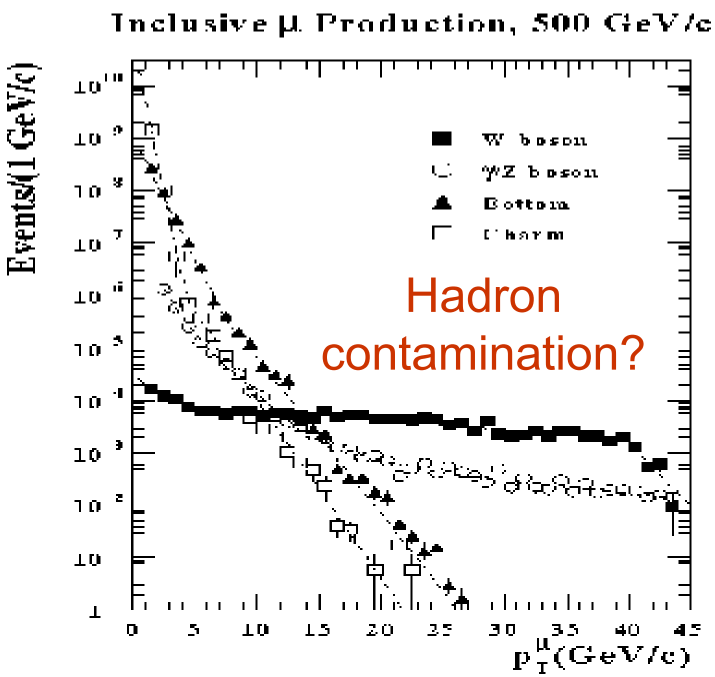


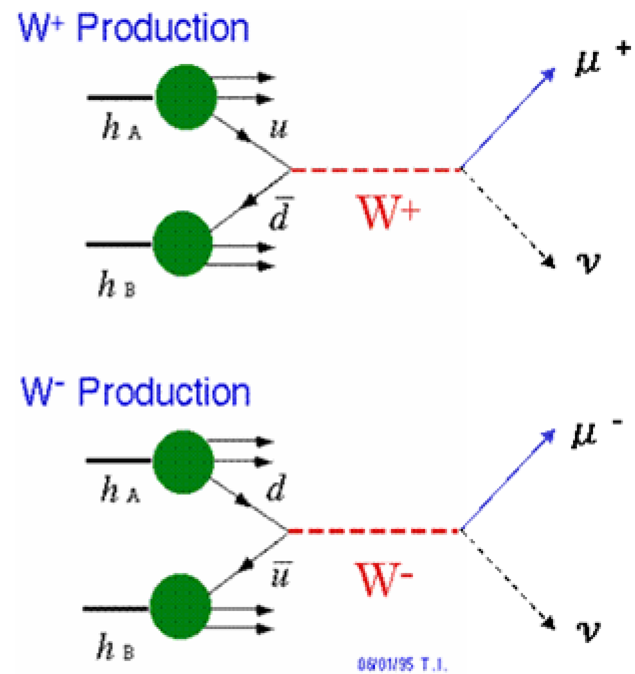
<u>Pion/Kaon production at forward rapidity:</u>

- With FVTX, can have clean pion, kaon identification as well as separation from open charm and prompt muons
- Can also probe gluon contribution to proton spin
- Cold nuclear matter effects at small, large x
- Modification in heavy ion collisions at forward rapidity



Potential to improve W measurement

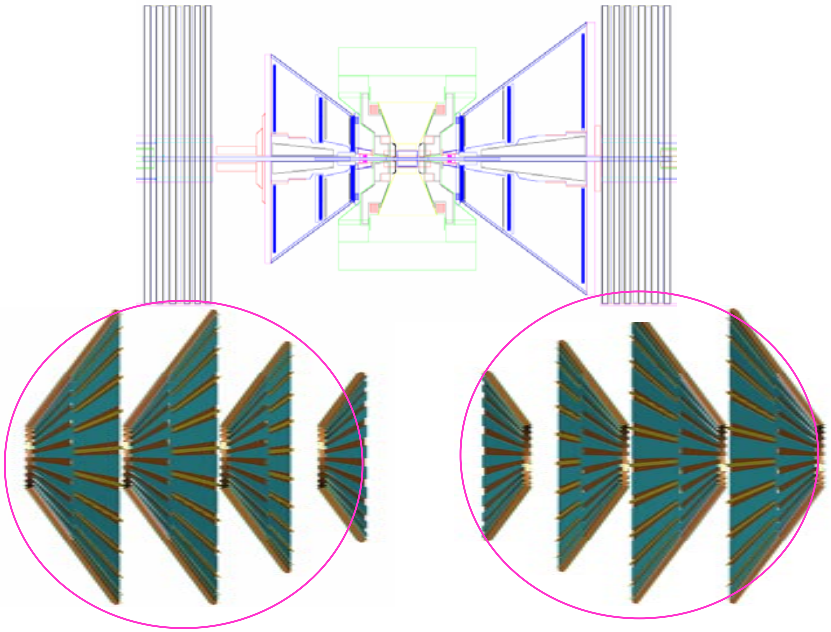


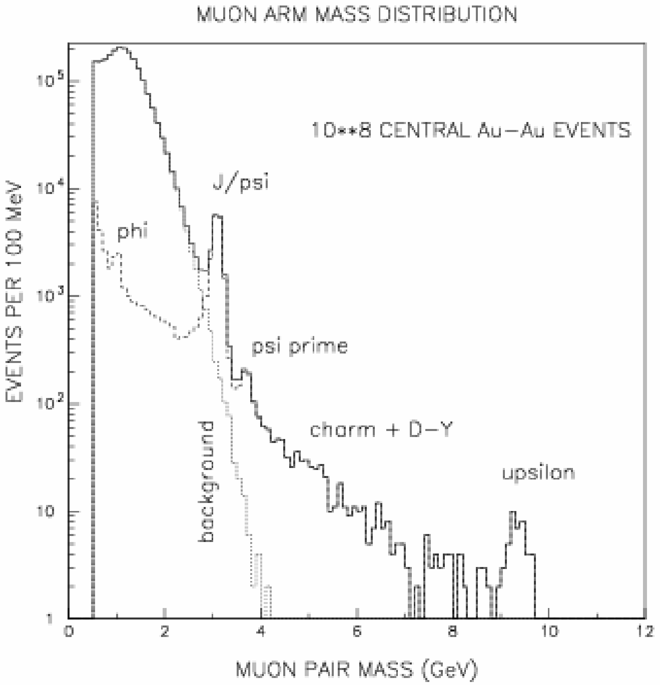


W measurement in polarized pp collisions to get at sea quark contributions to proton spin:

- Isolation cut with FVTX detector could be used to suppress hadron background w.r.t. W signal
- Better tagging of in-flight decays (under study)

Dimuon measurements at forward rapidity

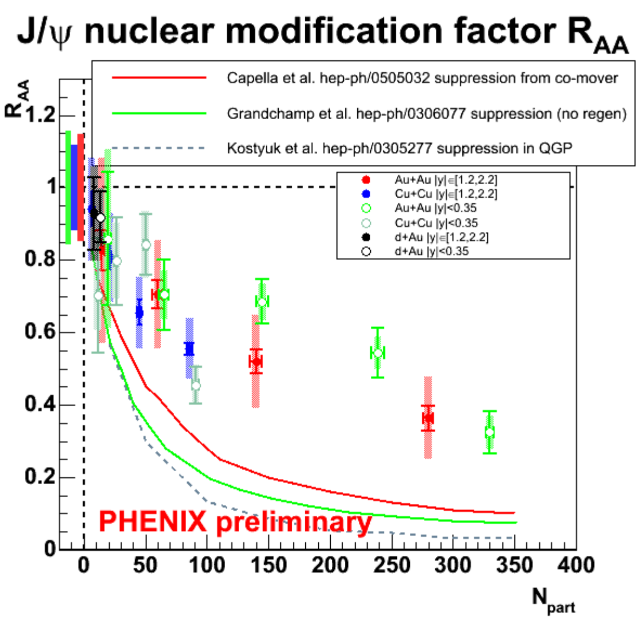


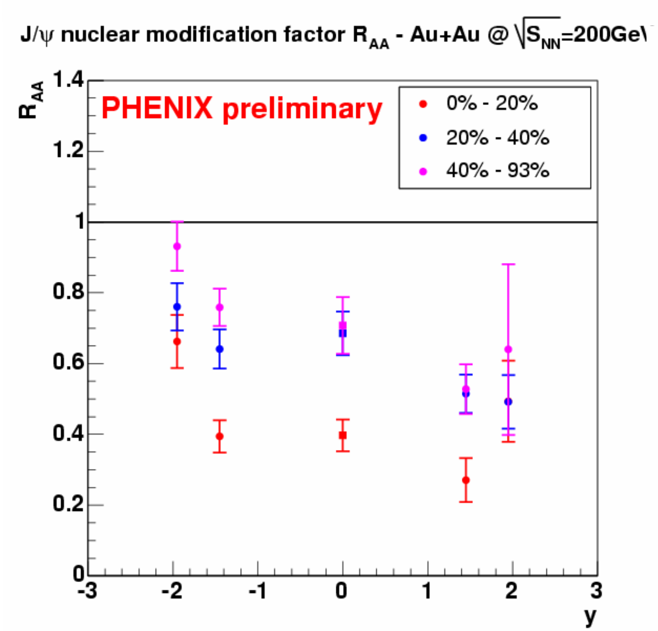


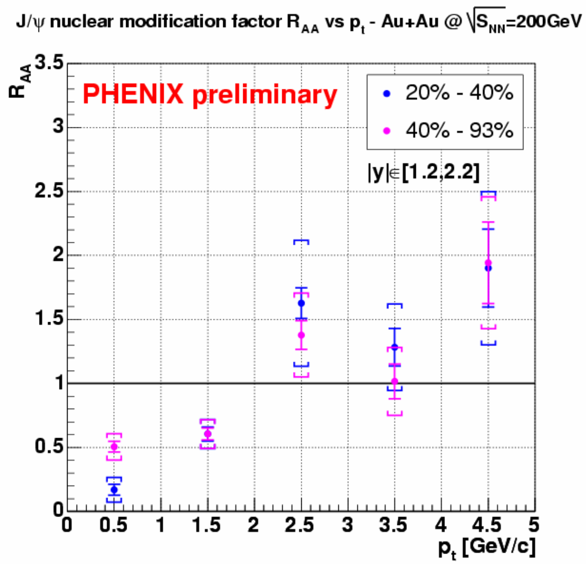
J/ψ measurements of interest to:

- Get information about gluon contribution to proton spin
- Combined with open charm production can disentangle initial-state and final-state modifications to onium production in cold nuclear matter
- Addition of ψ' and Υ measurements will further understanding
- In heavy ion collisions, charm plus J/ψ production can yield: modification of charm production, effect of medium on hadronization, contributions of prompt and recombination to J/ψ production.
- Critical to get precision measurements versus centrality, rapidity, p_T

J/ψ Centrality and Rapidity Dependence and Errors in AuAu

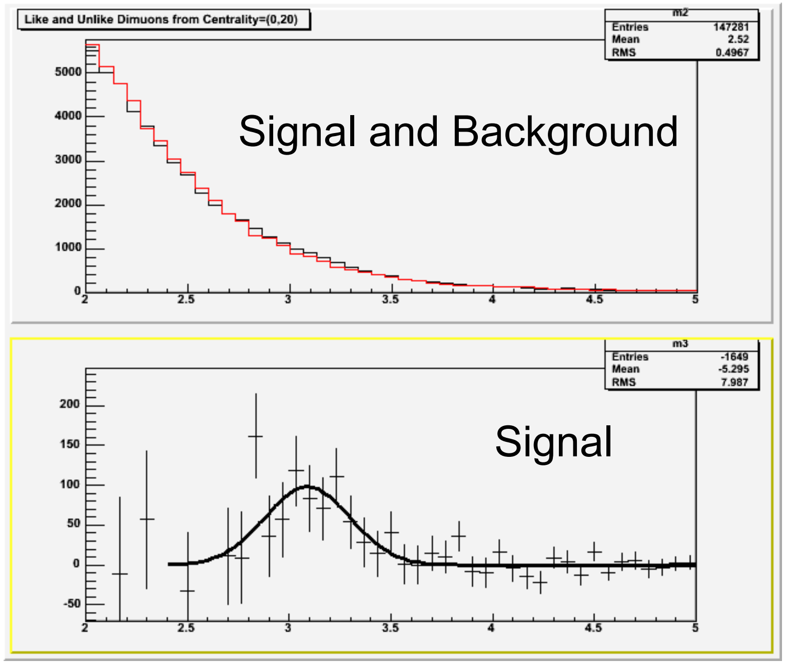




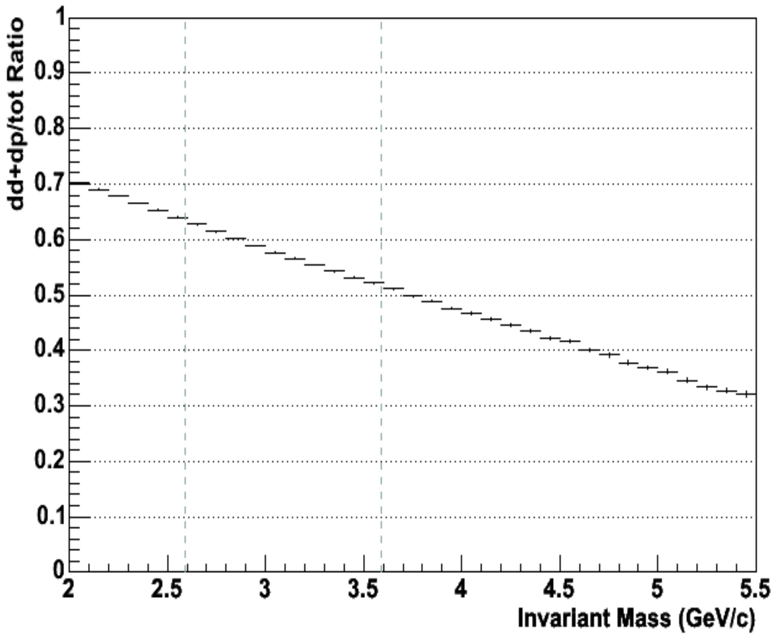


- Most difficult dimuons measurements are in AuAu because of combinatorial background
- Precision on all measurements in AuAu events limited by signal:background

FVTX Contributions—Removal of Backgrounds

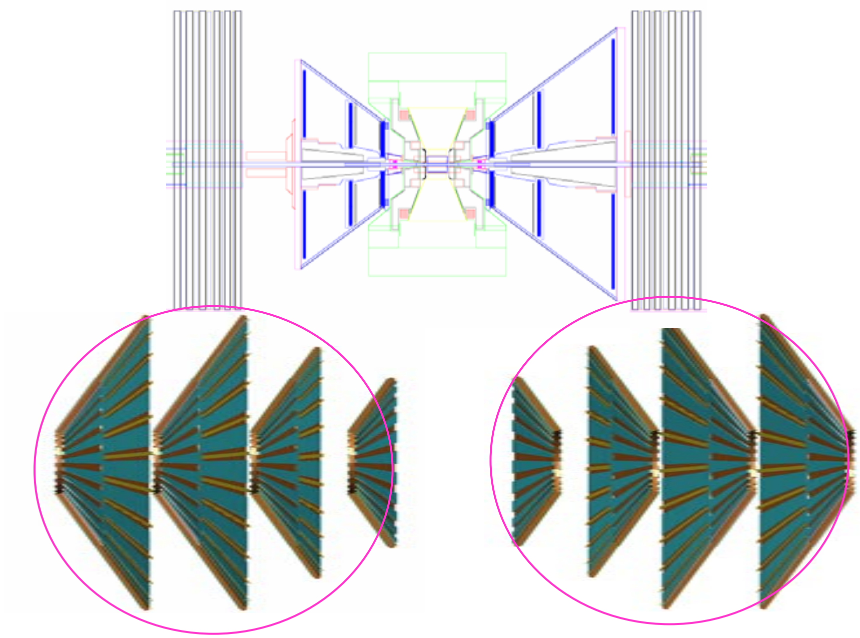


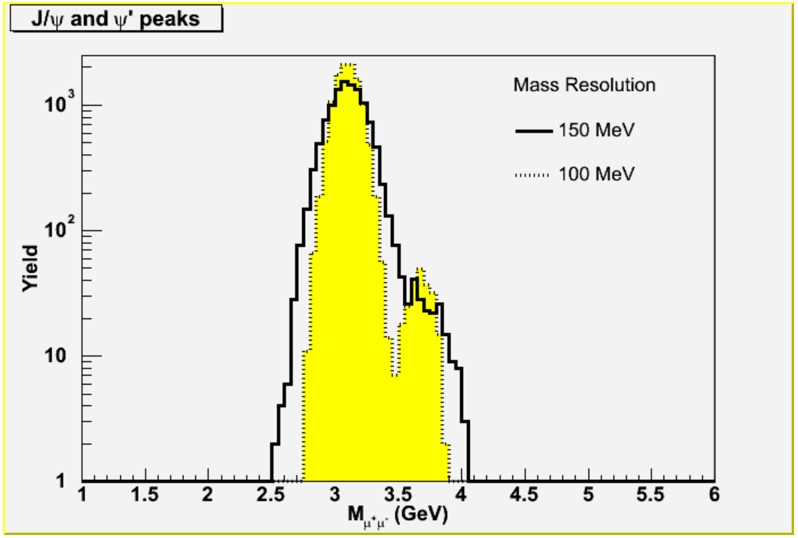
Mass (GeV)



- Signal:Background in central south arm events ~1:20
- Combinatorial background from 3 possible combinations of hadron decay muon and punch-through
- Two combinations which include a decay can potentially be separated from prompt J/ψs: ~60% at J/ψ mass

FVTX Contributions—Improved Mass Resolution

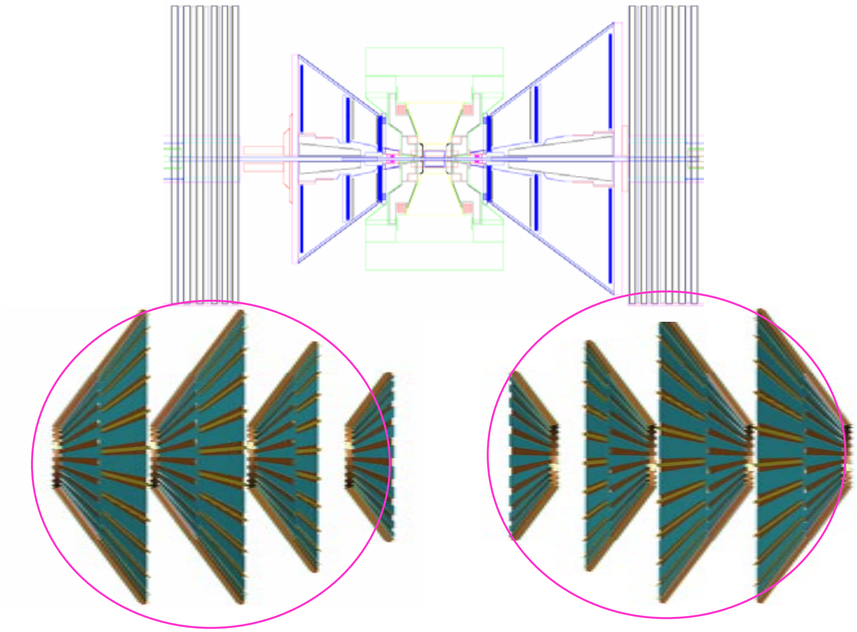


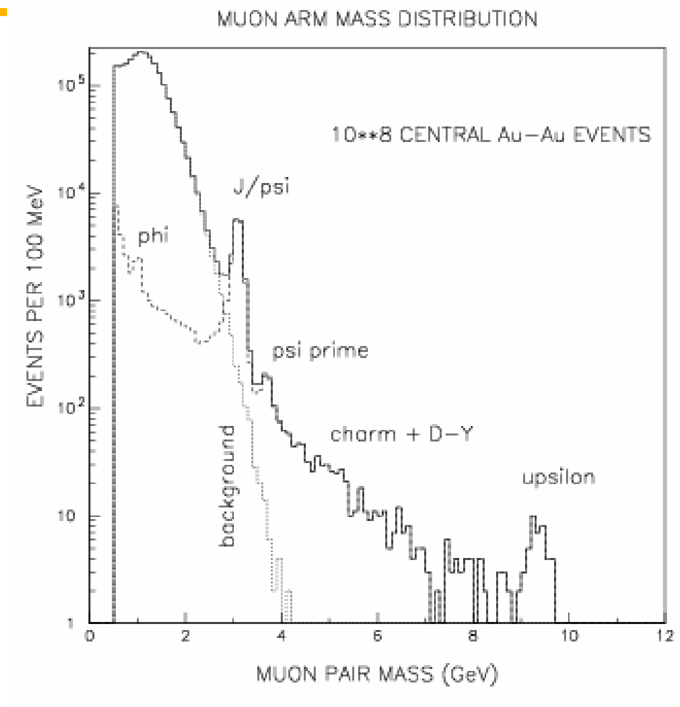


- In addition, mass resolution at J/ψ is dominated by effects of multiple scattering and energy straggling in the absorber material
- Precision angular measurement before the absorber removes the first issue, thus reducing the mass resolution

- This further reduces signal:background as background window will be reduced, and allows for better separation of J/ψ and ψ'

Additional dimuon measurements





Drell-Yan

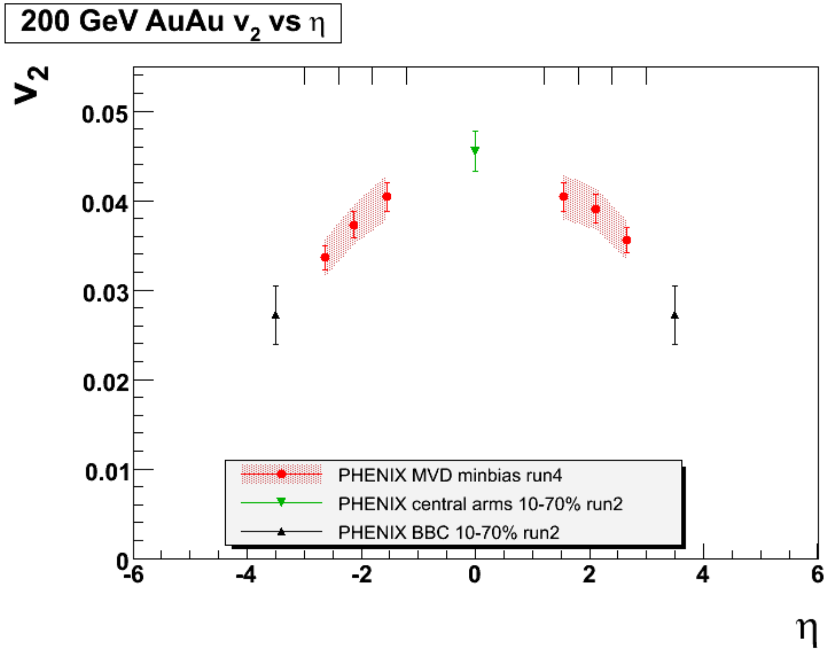
- Sea quark contribution to proton spin
- More information to separate initial-state, final-state effects in cold and hot nuclear matter

Ψ', Υ

- Improved mass resolution allows cleaner separation of ψ from ψ'
- Reduced background improves possibility of Υ at central rapidity

FVTX Bonuses:

- Reaction Plane Improvement
- Future measurements at up to y=3 that can no longer be done by Phobos/Brahms
- Provides e/γ separation capabilities for nosecone calorimeter
- Can provide data to Lvl-1 trigger (which is likely critical in future runs)



Physics Signal Rates

Observable	Counts per RHIC p+p Run 10	Counts per RHIC Au+Au Run 10?
$D \to \mu X$	~$4x10^{8}$	~$1x10^{8}$
$B \to \mu X$	~400 k	~100 k
$B \to J/\Psi X \to \mu^{+}\mu^{-}$	~2000	~600

D->μX

p_T bin	Fraction of accepted
0-1	0.63
1-2	0.35
2-3	0.01
3-4	6E-4

Assumptions:

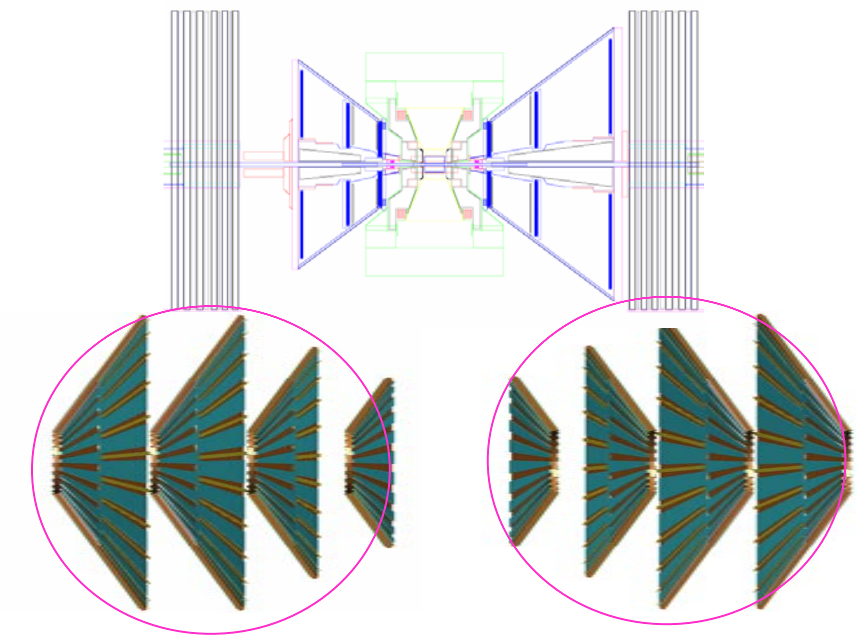
- 50 pb^{-1}
- Acceptance only, no efficiency cuts
- p > 2.5 GeV
- You can trigger

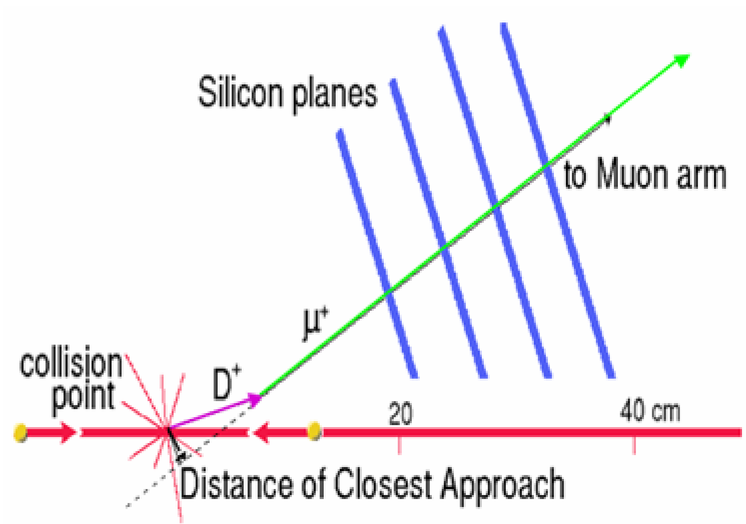
Physics Reach Au+Au (from Craig Ogilvie)

Observable	Trigger	RHIC-I counts/run	RHIC-II counts/run
D =>e pt >1 GeV/c + DCA	e-PID	200K	2M
D =>μ	μ -PID	>10M	>100M
D=>Kπ pt >2 GeV/c + DCA	Min-bias	15K	75K
B =>e pt >2 GeV/c + DCA	e-PID	7K	70K
B =>DCA J/ψ =>μ+μ−	μ -PID	800	8K
Υ =>e+e-	e-PID	16	160
Υ =>μ+μ−	μ -PID	43	430

Detector Design and Performance

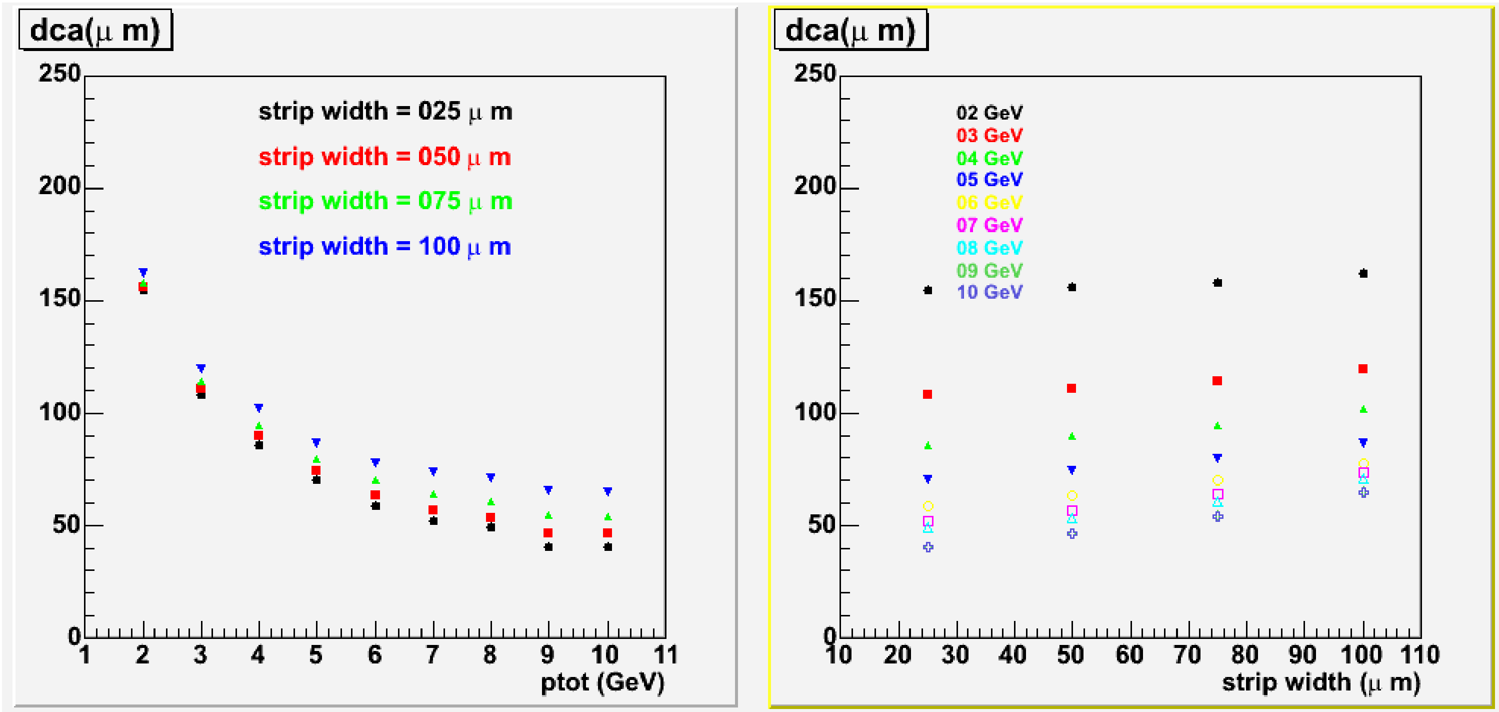
Detector Design and Performance





•4 layers of tracking: to allow at least 3 hits/track
•Radial extents: to allow at least 3 hits/track as much as possible in area of muon coverage, constrained by the detector envelope
•Strips are 50 μm (r segmentation) x 2-13.5 mm (phi segmentation): to allow good DCA measurement in boost direction, limited by multiple scattering rather than detector resolution, and reduce occupancy in AuAu

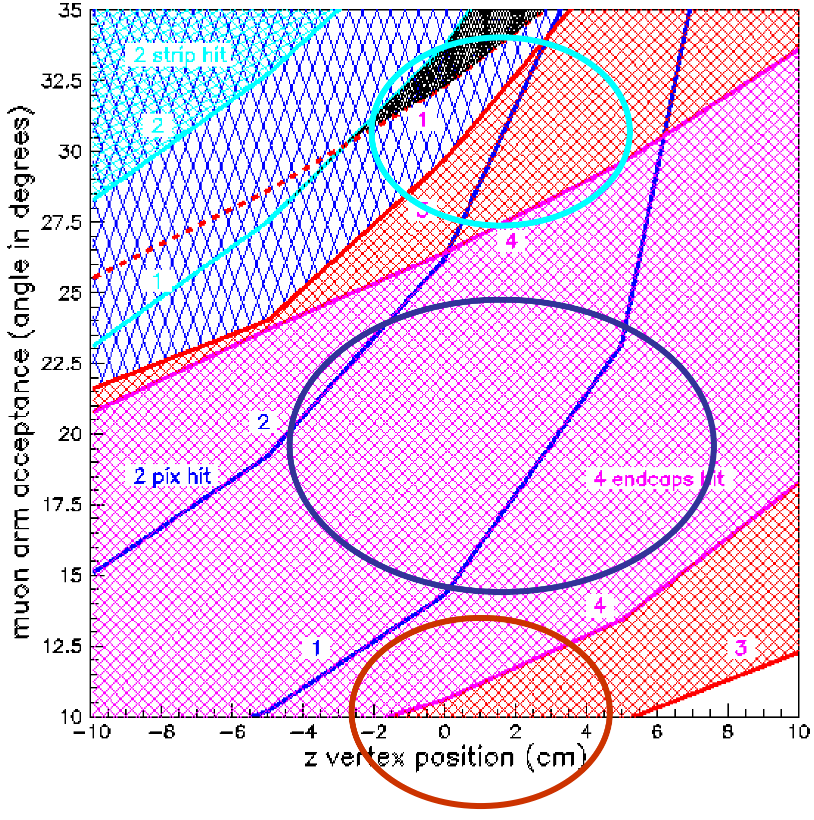
Detector design – Strip width

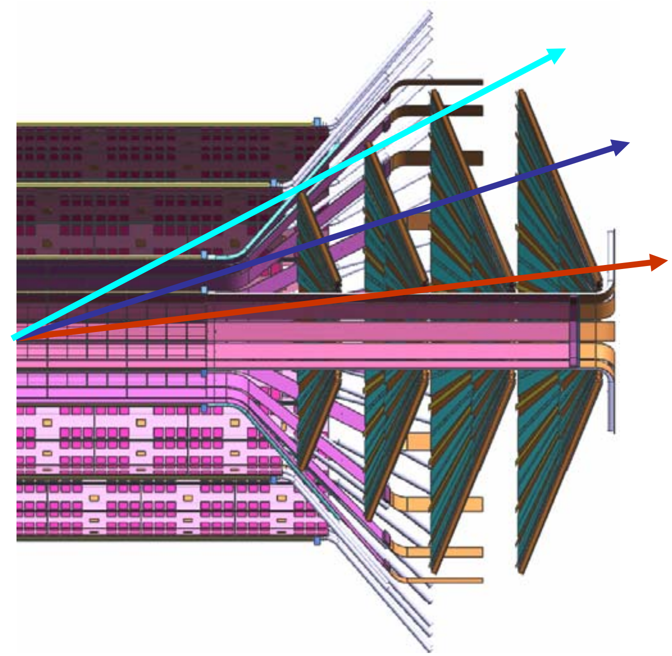


- DCA versus strip width and momentum
- Strip width is chosen to be 50 μm as you start to reach diminishing returns because of multiple scattering contributions

Detector acceptance

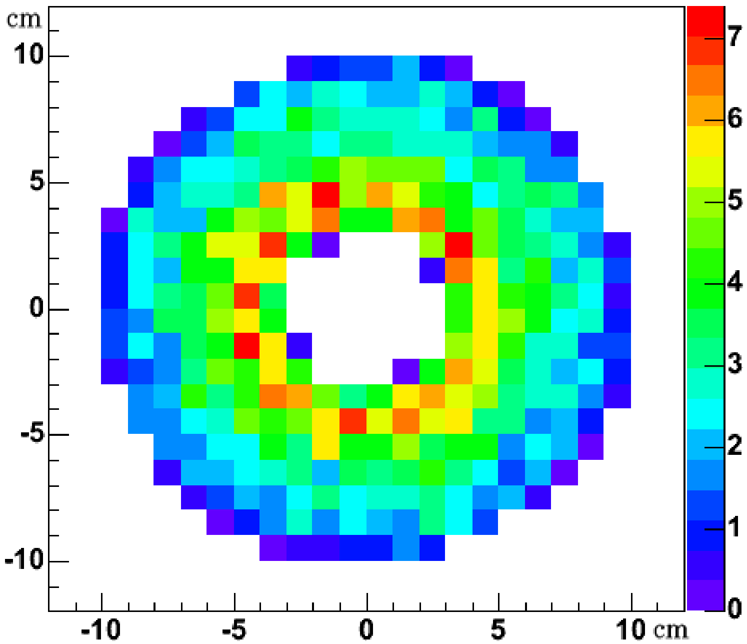
Number of Forward Silicon, Barrel Pixel, and Barrel Strips
hit versus theta and z vertex position





Detector occupancy in Central AuAu

Hits/cm^2



At inner radii, strip size is 0.05 x 2 cm = 0.1 cm^2

→0.7% occupancy in highest occupancy areas

Generally quote 1.5% maximum occupancy to take into account simulation uncertainty

Low enough to expect track finding to be very doable

Expected future simulation work:

- Continue background rejection studies
- Detailed study of matching to MuTr
- Incorporating silicon hits, MuTr, MuID and other upgrade detector hits all together into one track fit to determine performance of integrated systems: background rejections, improvement in momentum resolutions…
- Forward + Barrel silicon performance to be studied
- Explore performance with different strip orientations?
- More complete study of rates with efficiency hits taken into account
- Take into account resolution of, efficiency of finding primary vertex
- Full estimates for physics quantities (R_{AA}, flow…)

Summary

Physics Program Improvements in areas of:

- Open heavy flavor – charm and beauty
- π/K measurements at forward rapidity, including PID
- W
- Vector mesons
- Drell-Yan

via reduction of backgrounds and improvements in mass resolution

Detector Performance:

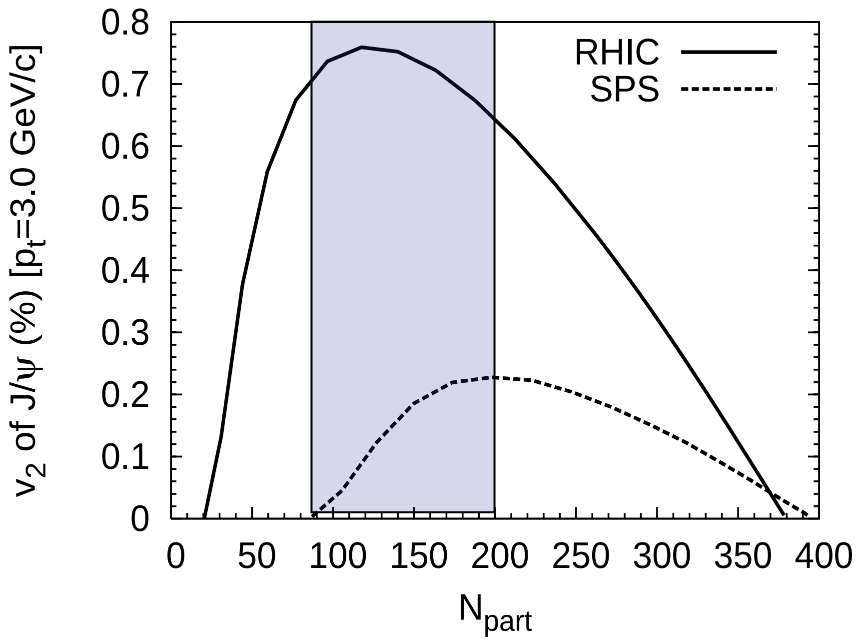
- Geometrical layout gives ≥3 hits per track most of the time
- Occupancies ≤1.5%
- Simulations with expected material retain good DCA resolution
- 50 μm strips give good DCA resolution and desired segregation of prompt tracks, short lived decays, and long-lived decays

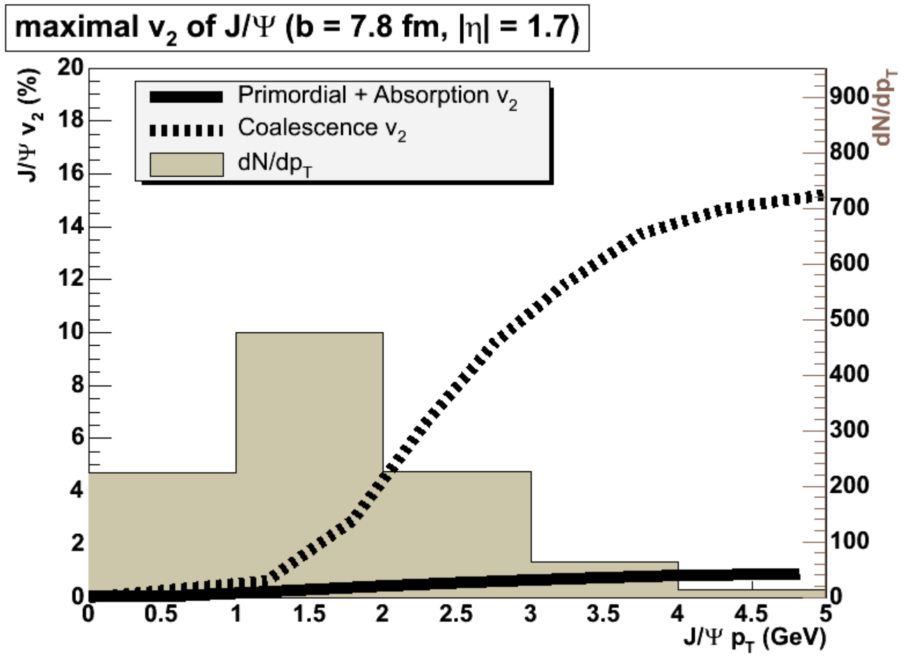
Backups

Backups– Simulation Details

- PISA simulation with beam pipe, barrel silicon, etc.
- 1% of a radiation length/silicon layer

FVTX Improvements—Reaction Plane?



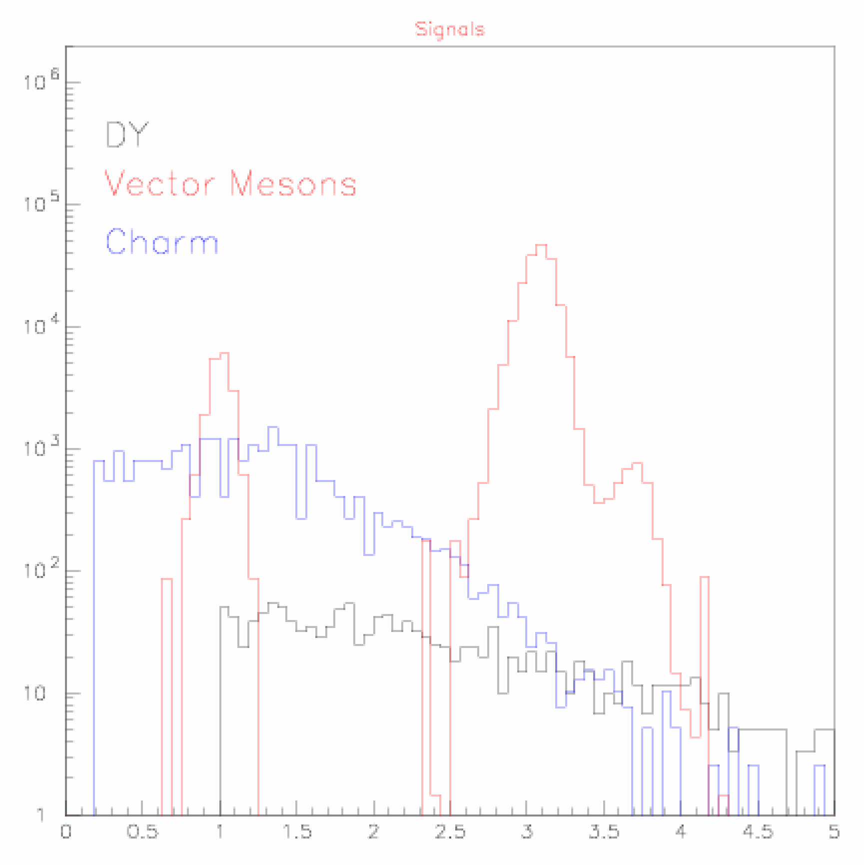


$$N_{J/\psi} = N_{+-} - 2\sqrt{N_{++} \times N_{--}}$$

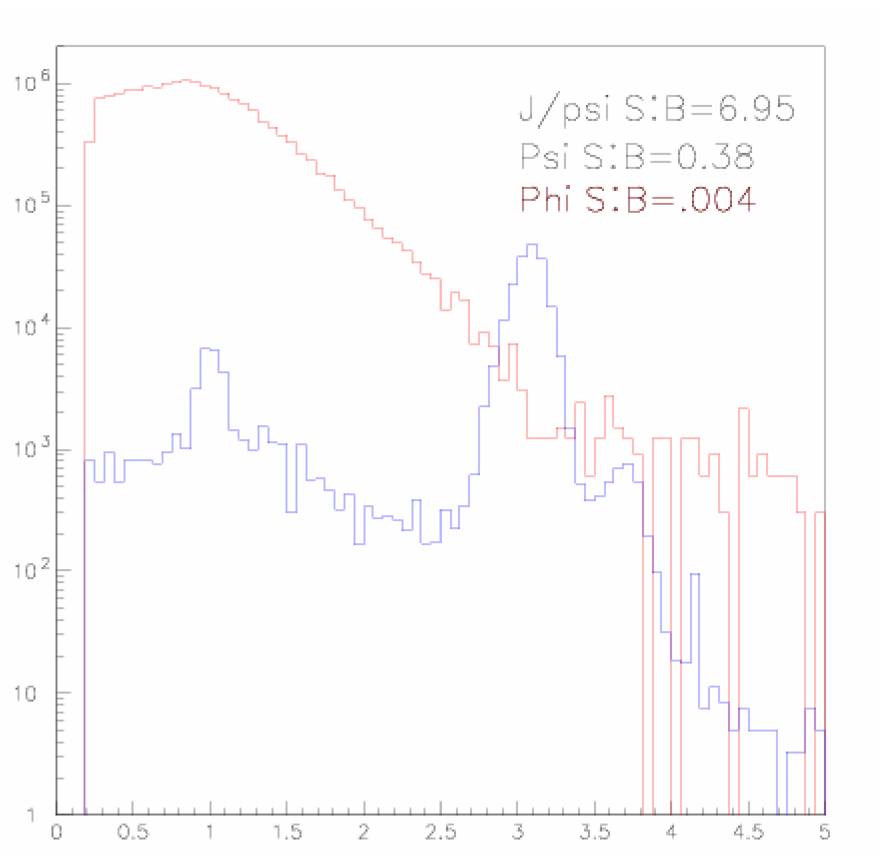
→Improved S/B yield extraction error

→Improved reaction plane measurement would improve measurements w.r.t. reaction plane

Backups



Signals
DY
Vector Mesons
Charm



J/psi S:B=6.95
Psi S:B=0.38
Phi S:B=.004