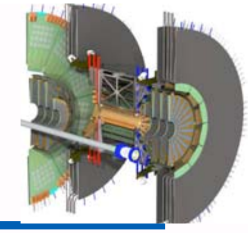
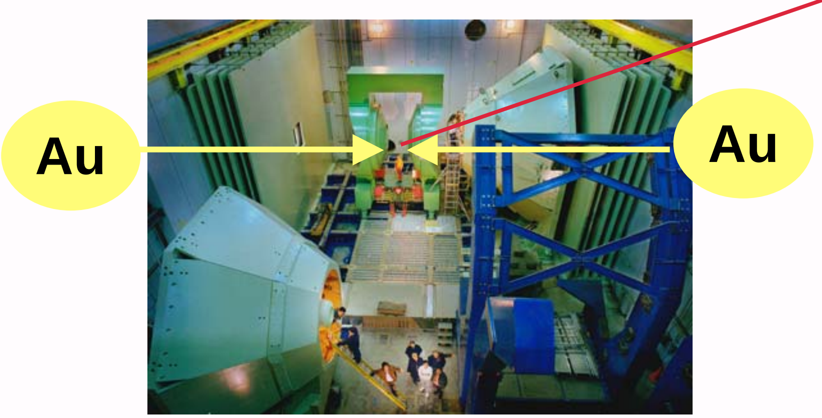
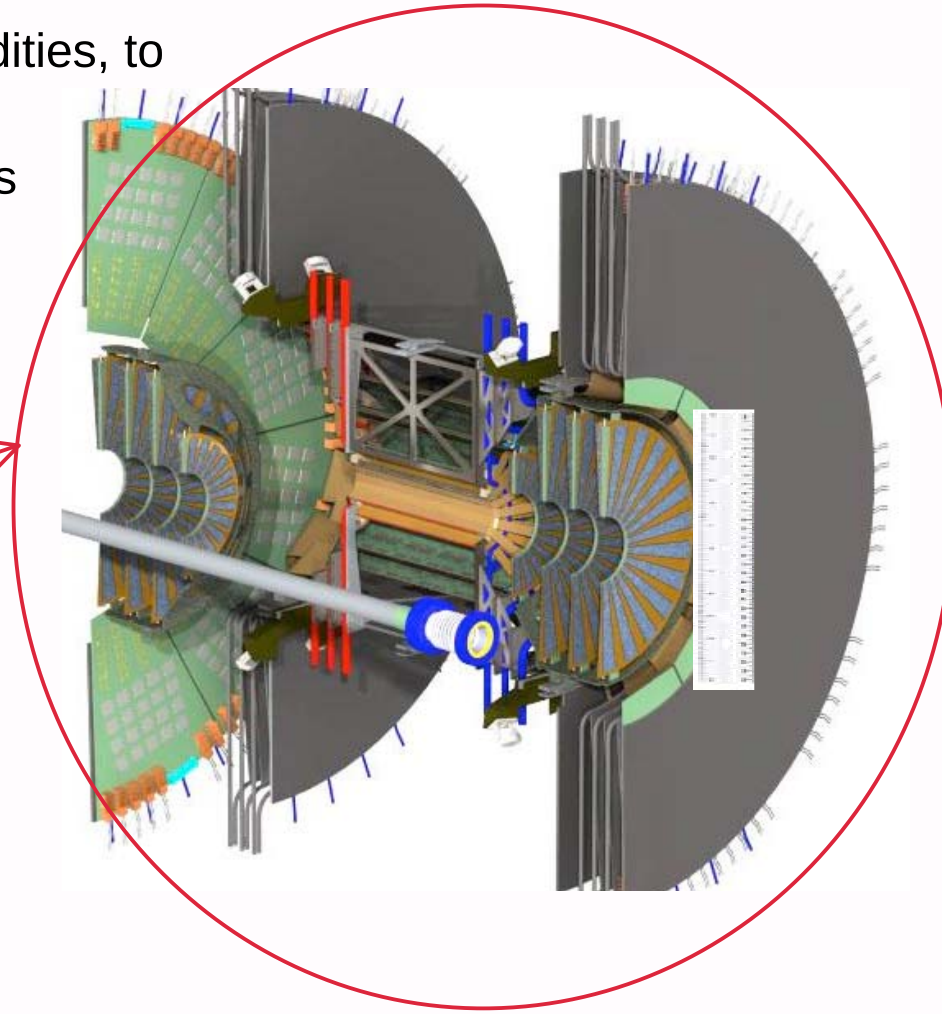
Forward VerTeX Tracking Detector (FVTX)



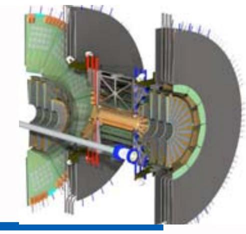
Melynda Brooks, LANL

- Silicon Vertex Tracker at forward rapidities, to enhance Muon Arms physics reach
- Precision Heavy Flavor measurements
- Improved dimuon spectroscopy
- $4.59 M Project (FY07 dollars)
- Installed FY11



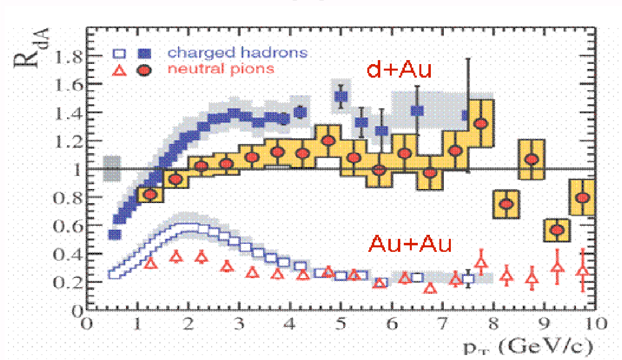


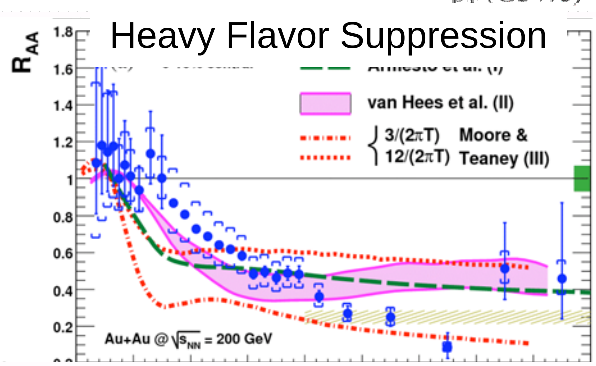
Physics Questions the FVTX can Address



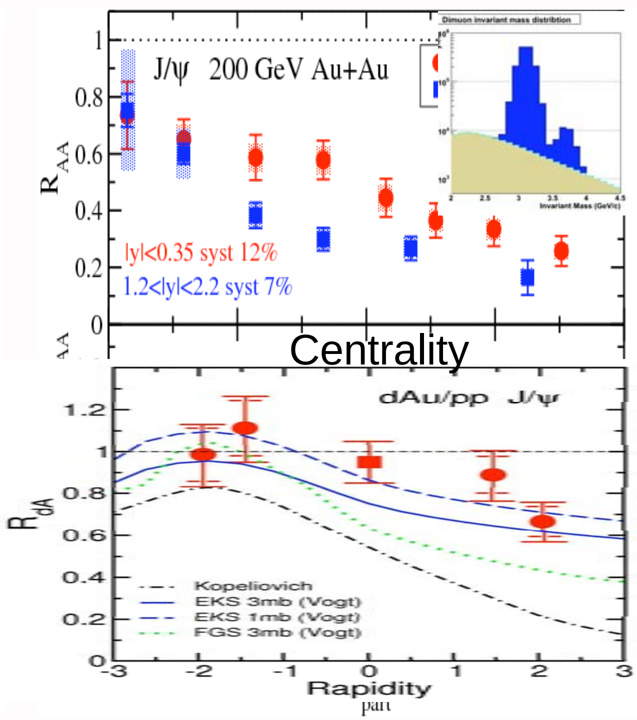
- What are the suppression and flow mechanisms for light and heavy quarks? Are we interpreting the medium's properties correctly?
- What are the production and suppression mechanisms for vector mesons?
- How big a role do cold nuclear matter effects play in HI collisions?
- What are the gluon and sea quark contributions to the proton's spin?

Quark suppression

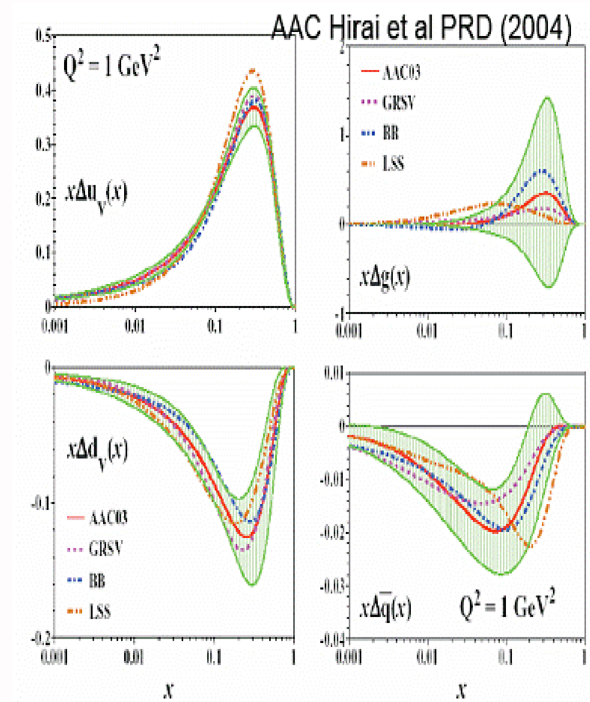




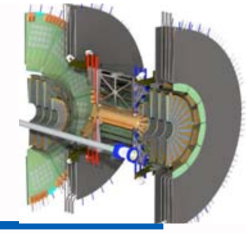
Understanding J/ψ



Proton Spin

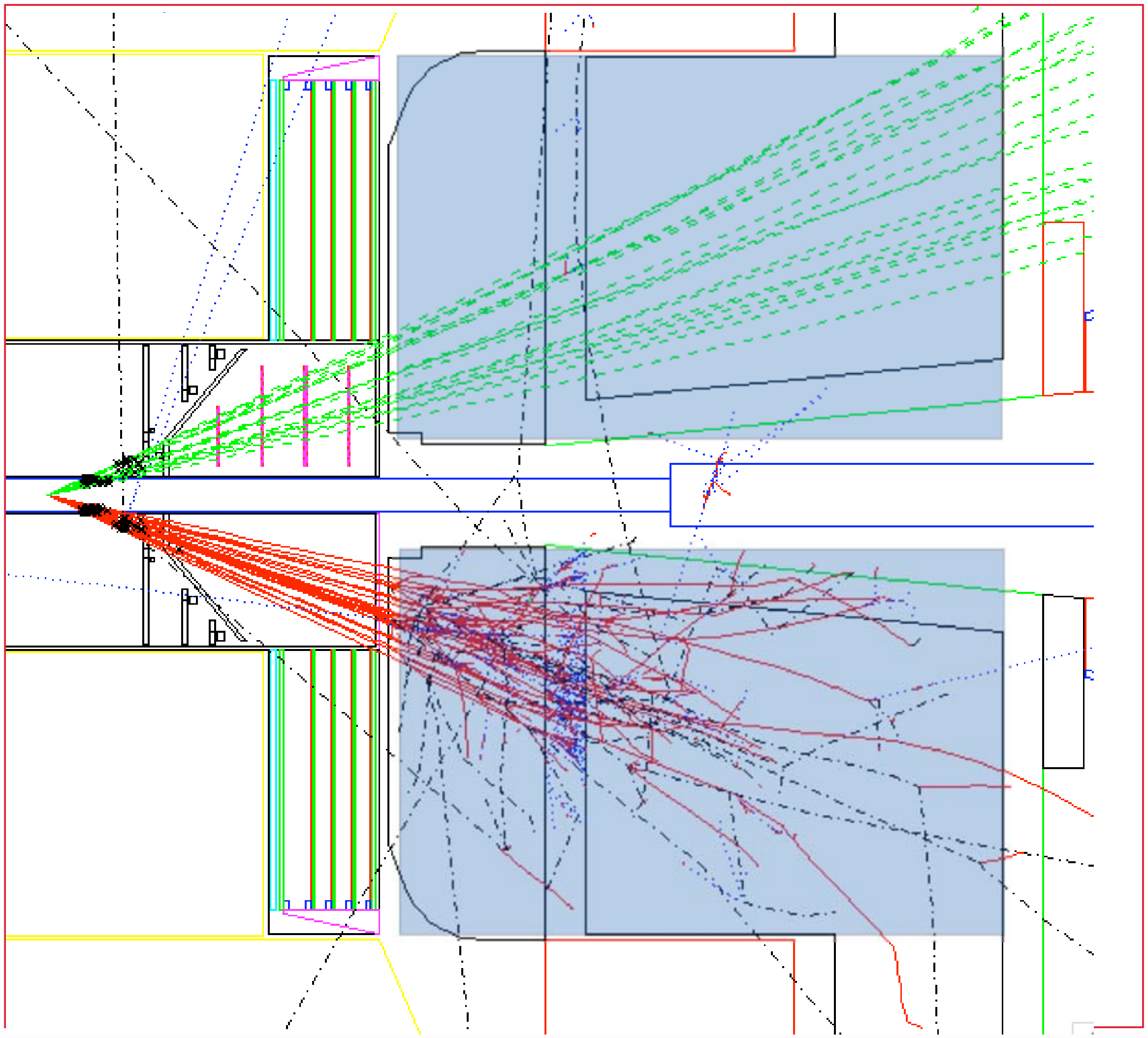


Talk Outline



- ➢Brief Muon Arm Overview
- ➢Physics Added with the FVTX
- ➢FVTX Design
- ➢FVTX Performance

Muon Arm Operation



Muons pass through absorber, tracker and identifier

Pions typically stop in absorber

~1% "punch through"

~1% decay into muon before absorber

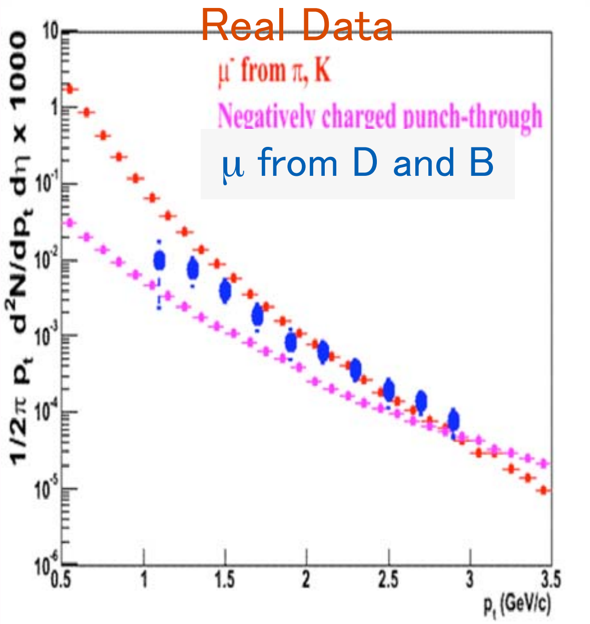
~1%*15% decay after the absorber

Resulting Muon Spectra

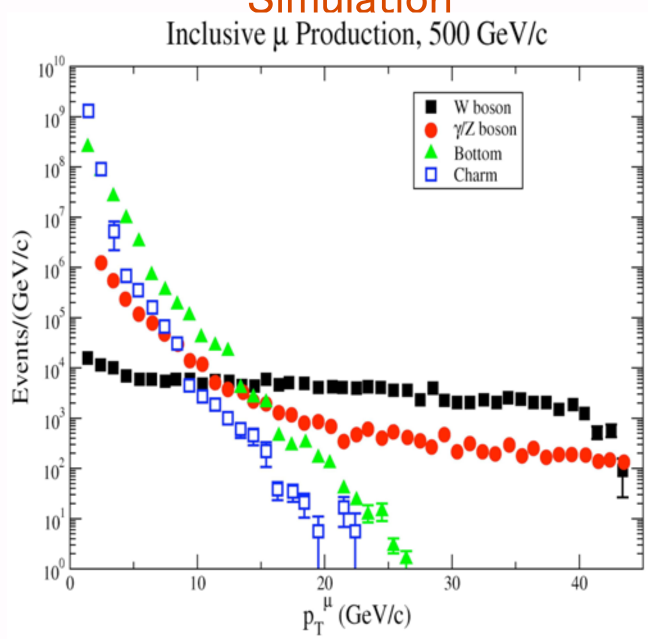
Physics observables with Muon Arms, FVTX:

- Open heavy flavor, hadrons from single particle spectra
- Vector mesons, heavy-flavor correlations, Drell-Yan from dimuons
- W, Z^0 at high p_T

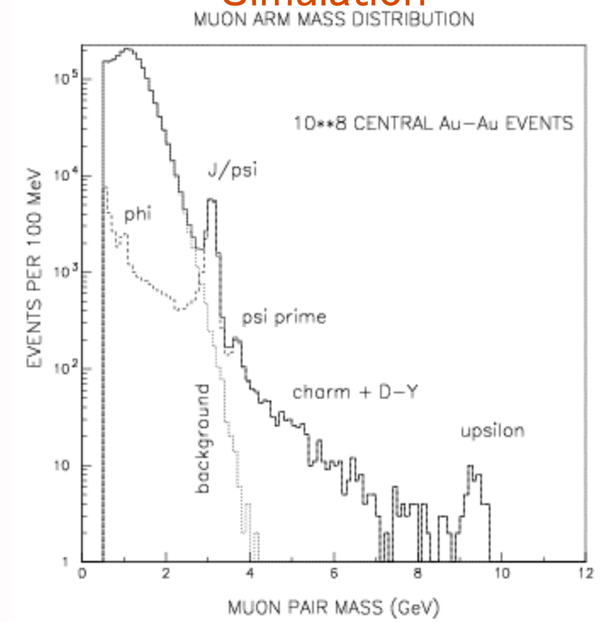
Real Data



Simulation

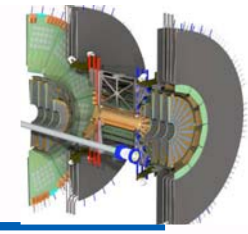


Simulation

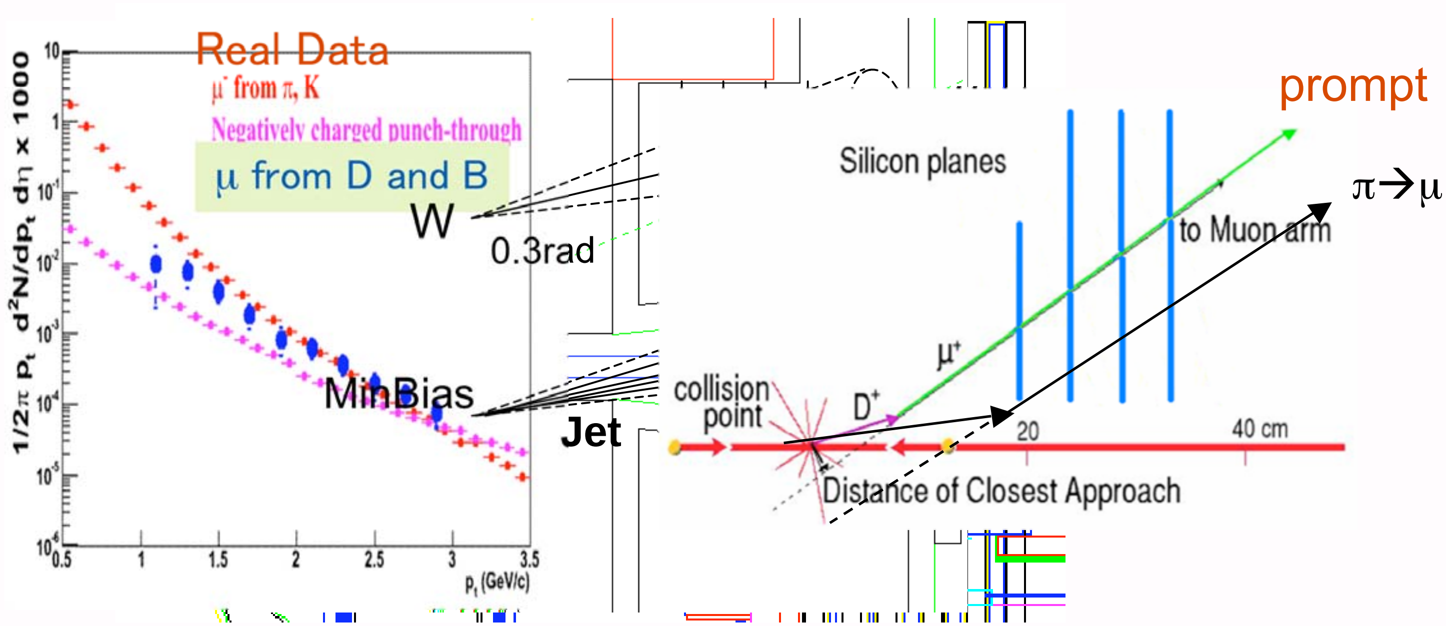


Physics reach at forward rapidities will be significantly advanced by allowing separation of single muon and dimuon components.

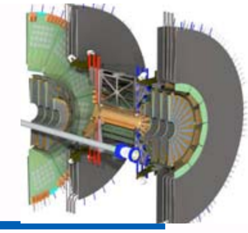
Muon Arm Limitations



- Cannot cleanly identify source of single muons-->measure track origins
- Having most initial particles removed (good for muon tracker) severely limits event information-->measurement of all particles near vertex
- Track resolution limited by multiple scattering and energy loss straggling in absorber-->track hits before absorber material desired
- Minimal track hits in Muon Tracker, difficult to identify mis-reconstructed tracks, hadrons which decay in flight-->More track hits along flight path desired



Physics Programs Accessible With FVTX



Single Muons:

- Precision heavy quark and hadron measurements at forward rapidity
- Separation of charm and beauty
- W background rejection improved

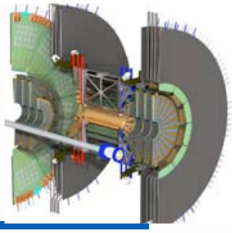
Dimuons:

- First direct bottom measurement via $B \rightarrow J/\psi$
- Separation of J/ψ from ψ' with improved in resolution and S:B
- Drell-Yan separated from continuum
- Direct measurement of c-cbar events via $\mu^+\mu^-$ becomes possible

Physics:

- Advance understanding of energy loss, flow in medium by adding precise heavy quark measurements of R_{AA} and flow.
- First detection of ψ' plus heavy quark allow detailed understanding of vector meson production and modification
- Separation/Understanding of Cold Nuclear Matter and QGP effects with rapidity coverage
- Precise gluon polarization and sea quark measurements over large x range, fundamental tests of Sivers functions possible

FVTX Detector Design and General Performance



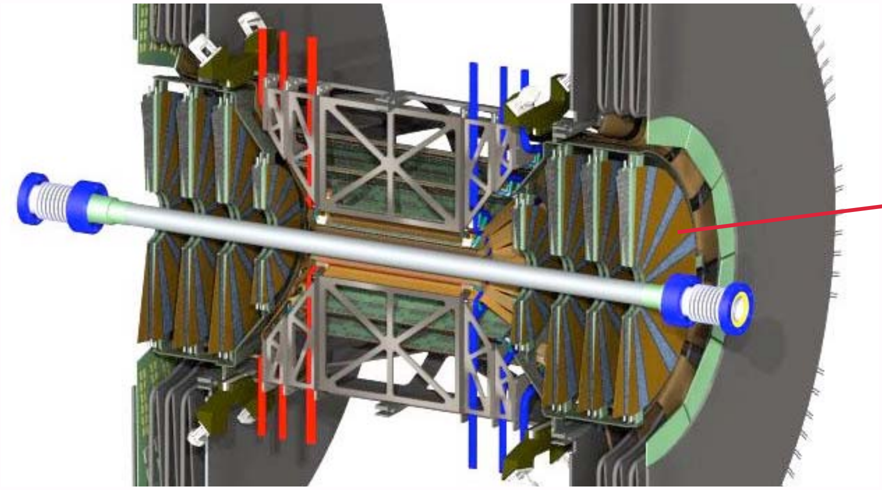
Detector Specifications

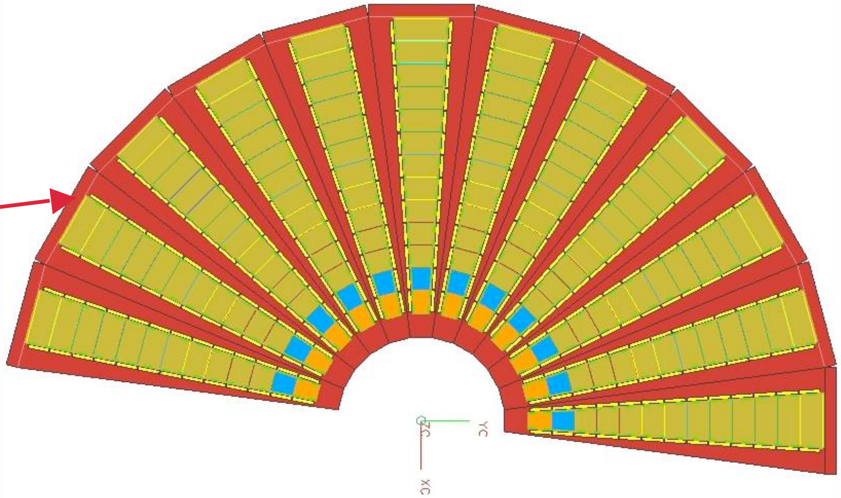
Enough planes to get 3 or more hits on most tracks within the Muon Acceptance --> 4 planes with maximal r/z coverage

Good enough DCA resolution to find primary vertices and separate D, B from prompt and long-lived decays --> 75 μm pitch strips, 3.75° staggered phi strips, z positions of layers

Low enough occupancy in Central AuAu to have efficient track finding -->75μm pitch, with 3.75° phi

Ability to match tracks to muon system tracks --> resolution, hits





Simulation of Performance

Full GEANT simulation to represent known materials

↓

x,y,z → hit silicon strips

↓

Clusters formed and centroid extracted

↓

Full Kalman Filter Fit of tracks

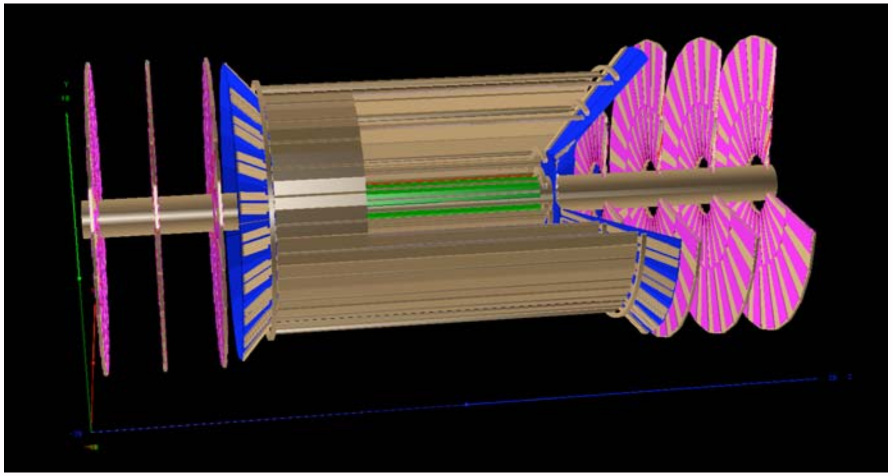
↓

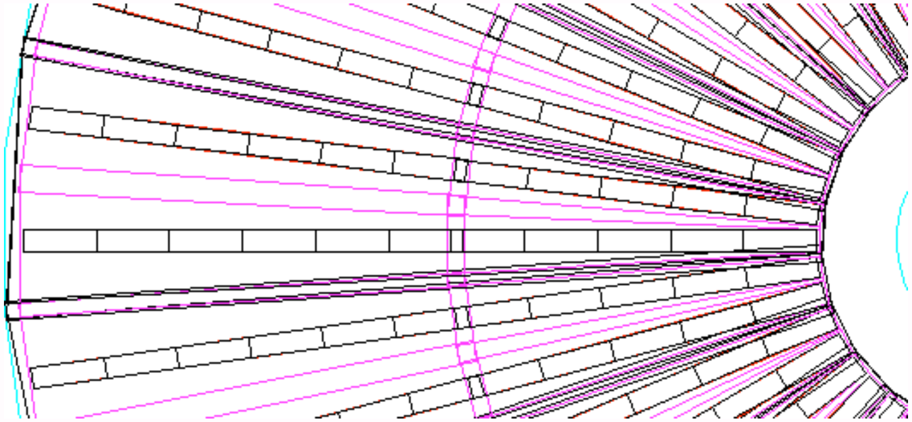
Matching to Muon Track tracks tested with full HIJING event

↓

DCA and other track fit variables extracted

Full PYTHIA events to study signals, HIJING to study occupancy issues



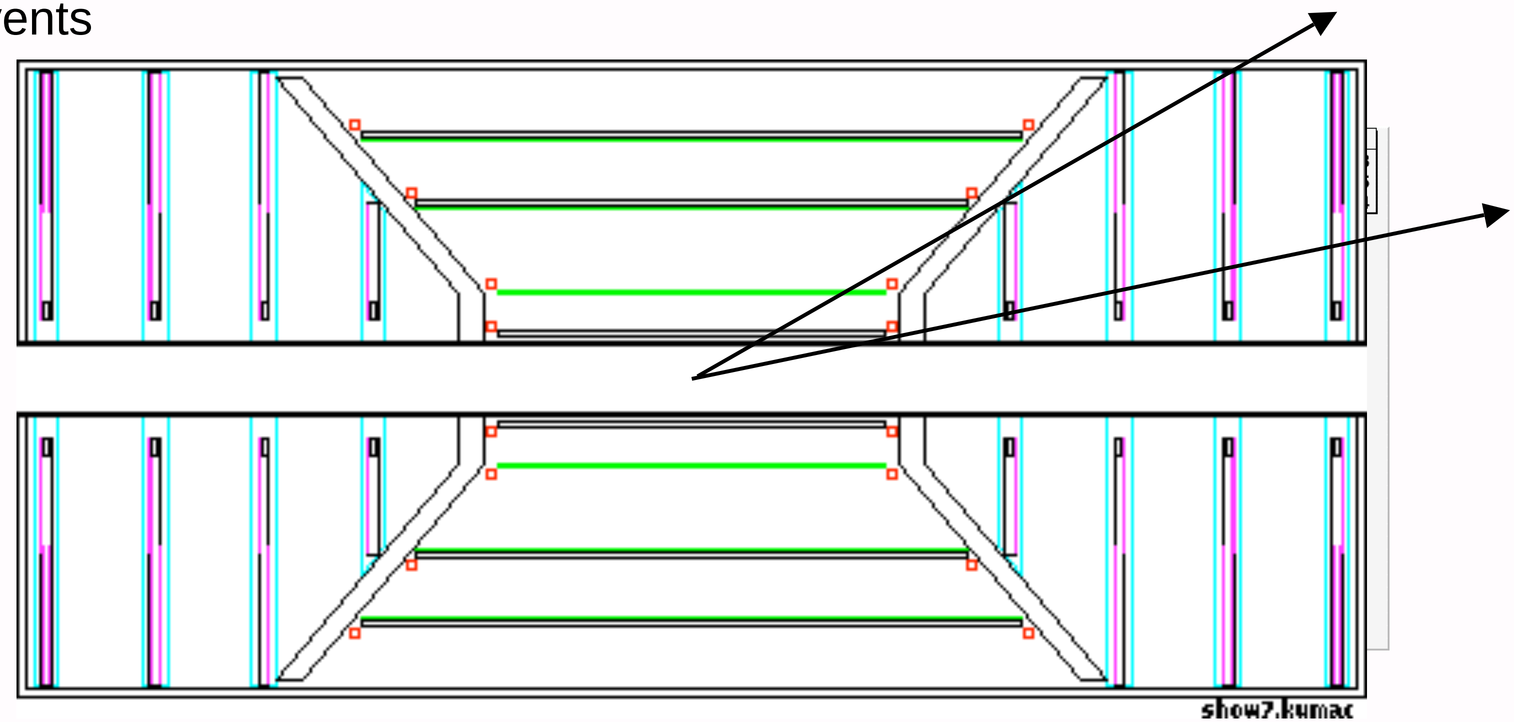


General Detector Performance

3 or more planes hit over most of the acceptance. VTX hits picked up when FVTX disappear retains performance.

Maximum occupancy in central Au+Au events is 2.8% --> track finding should not be an issue

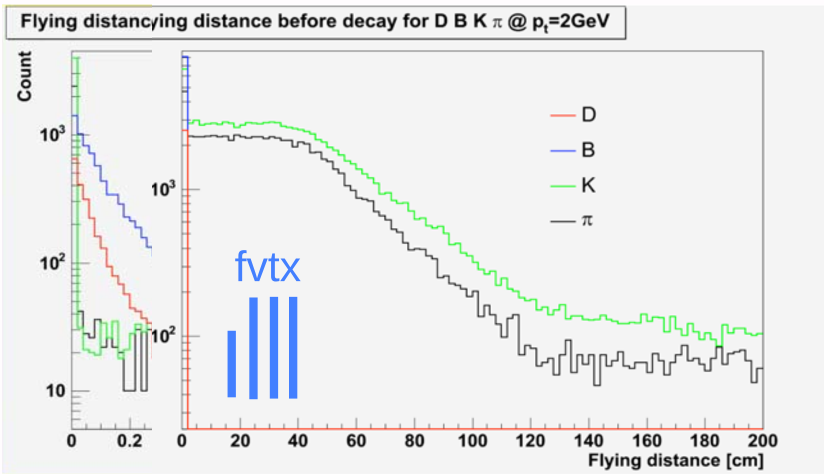
Track matching between FVTX and MuTr good even in central Au+Au events

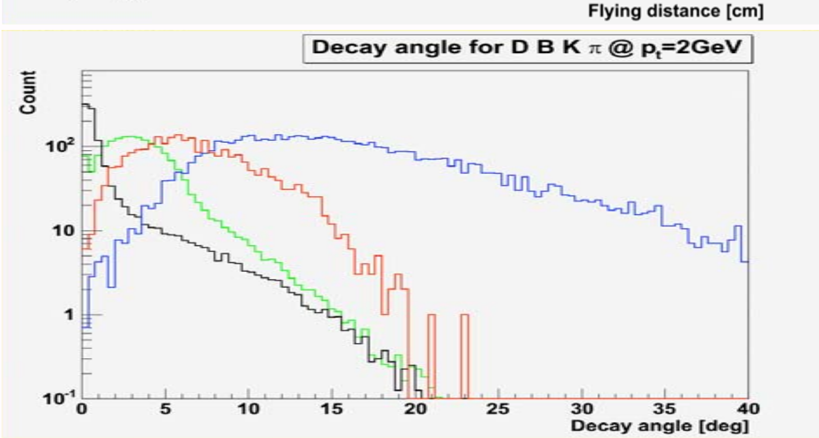


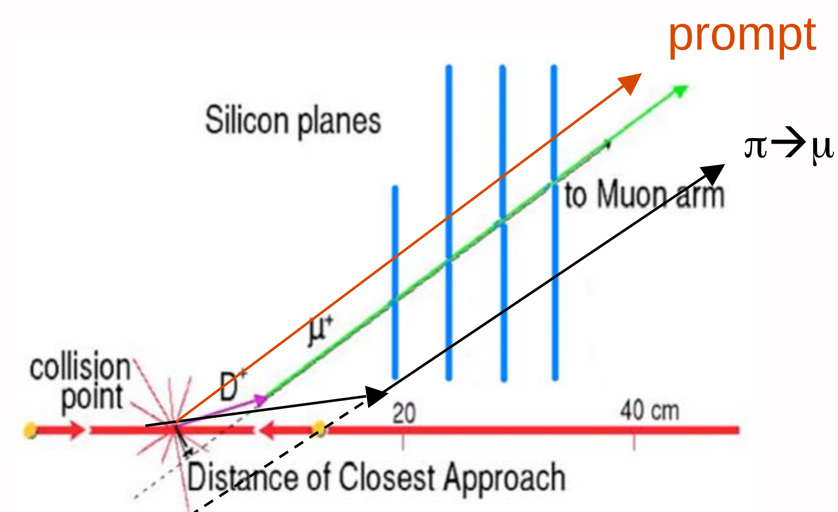
FVTX Track Performance

Identifying Secondary Tracks

- D, B mesons travel ~1 mm (with boost) before semi-leptonic decay to muons
- By measuring DCA to primary vertex, can separate D and B from prompt particles and long-lived decays like π, K

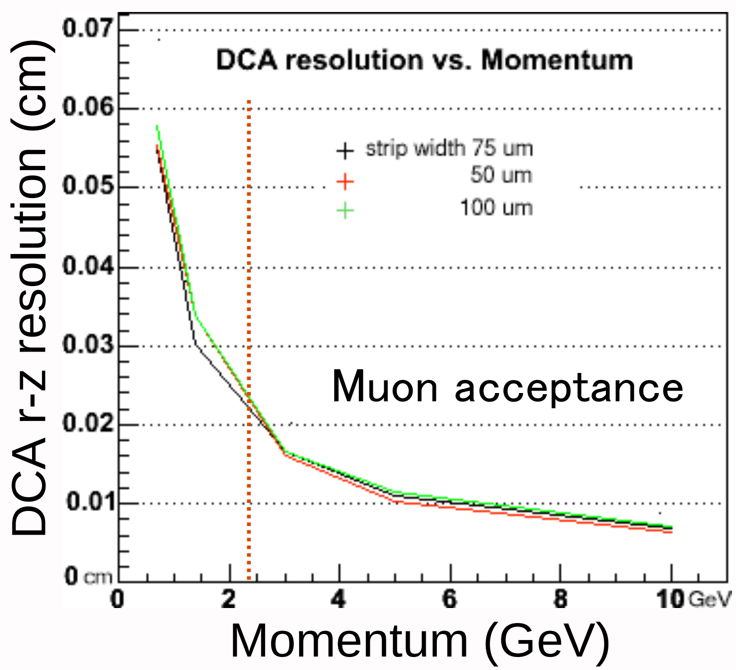


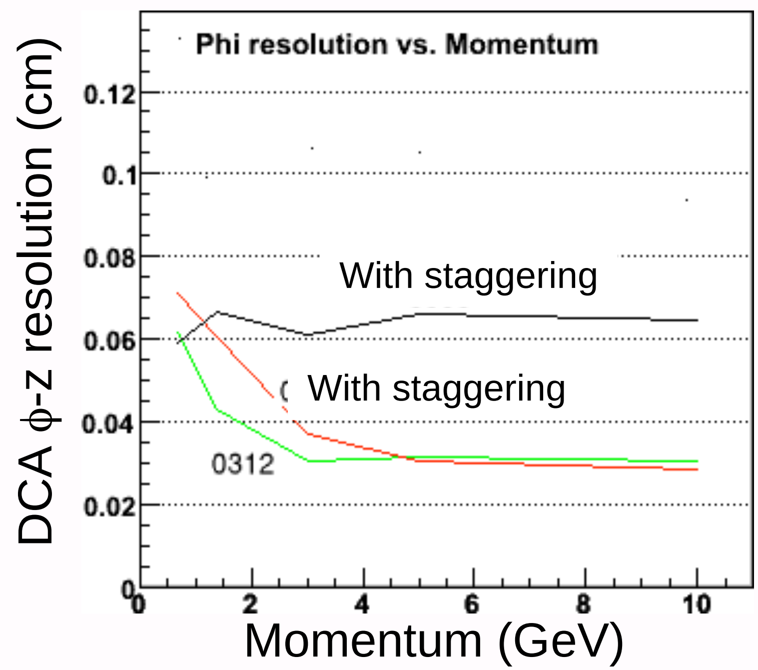




Detector DCA Performance

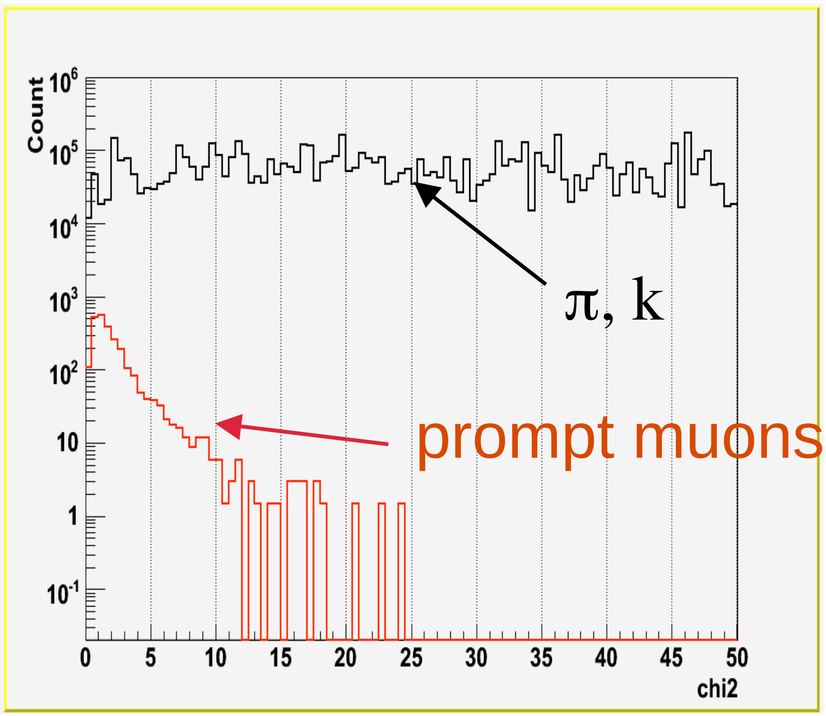
- Use Kalman Filter Fit to fit and project to z_vertex
- Get DCA components in r (good) and phi (less good)
- ~100 μm resolution in r and ~300 μm resolution in phi
- Multiple-scattering dominated resolution
- Sufficient resolution to separate prompt, heavy quark, and light meson decays.

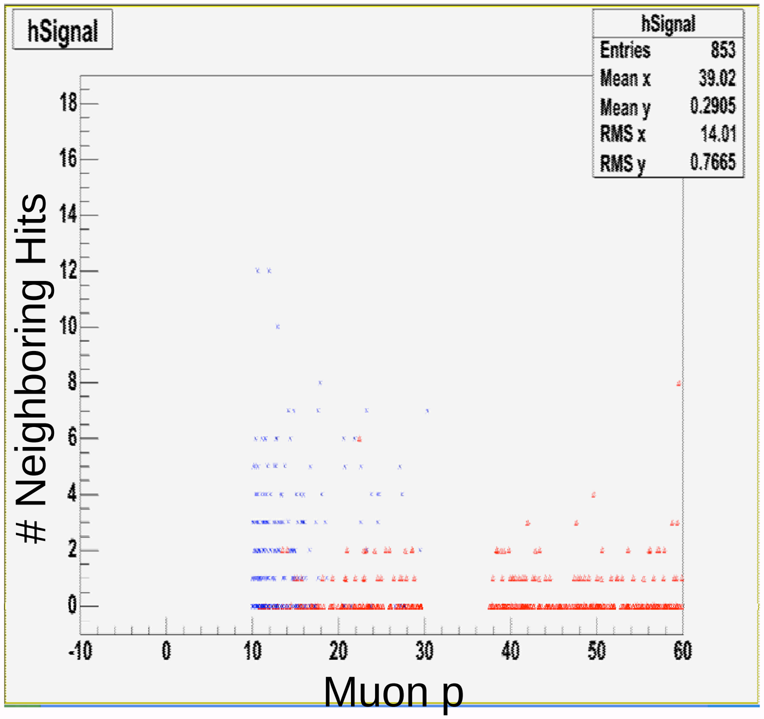




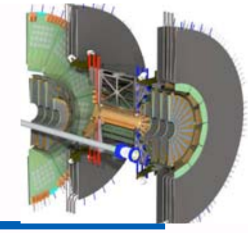
Additional FVTX Track Cuts

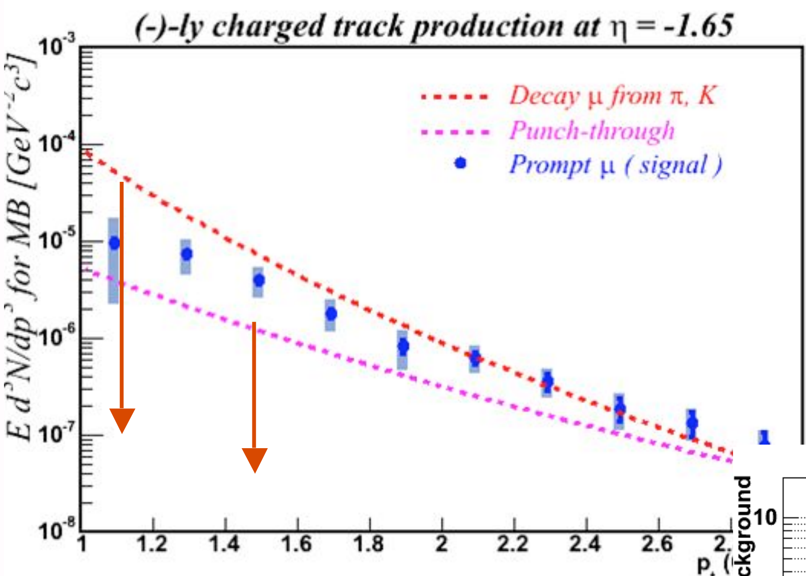
- MuTr + FVTX track fit χ^2 removes particles which change trajectory
- Isolation cut separates hadronic jets from clean muon decays





Heavy Quark Signal Extraction with FVTX

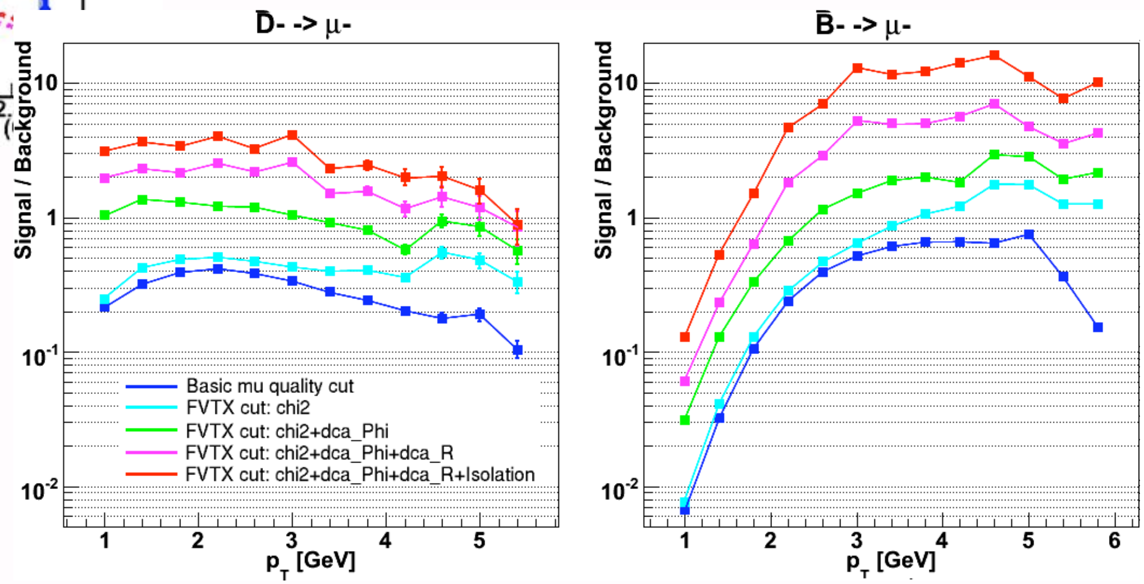




Place cuts :

- $DCA_{min} < DCA < DCA_{max}$,
- χ^2
- isolation cuts

to enhance heavy flavor over background



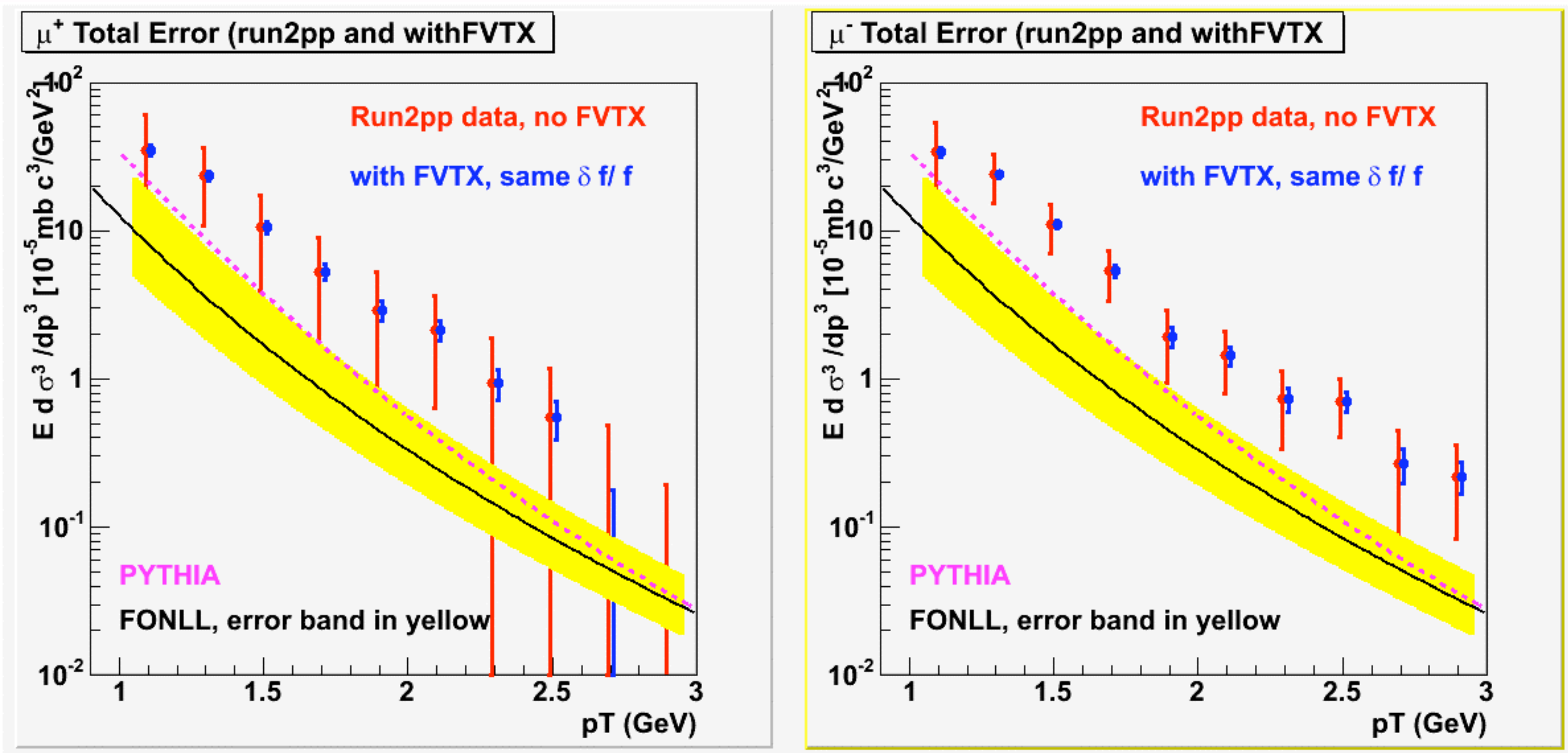
**Plots by Zhengyun You

FVTX Physics Performance

Heavy Quark Signal Extraction with FVTX

- Improved S:B→smaller statistical **and** systematic errors

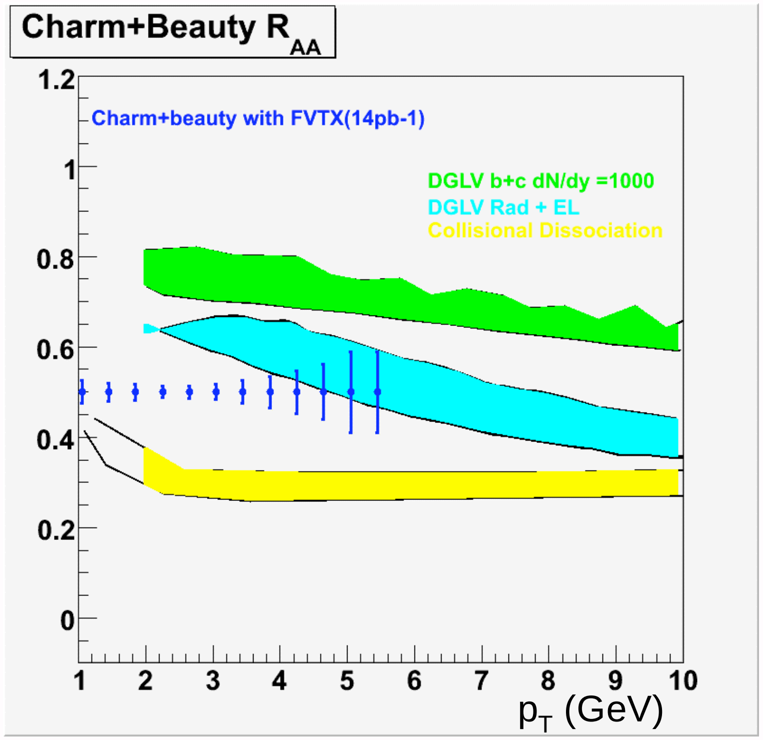
- Heavy quark cross section measurement with and without FVTX, for Run 2 Statistics



*Plots by Xiaorong Wang

Heavy Quark R_{AA} Measurements

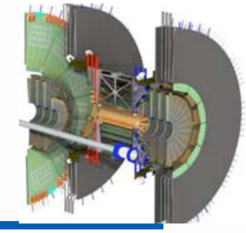
- ➢ R_{AA} for heavy flavor
- ➢ One 2008 RHIC-I Year luminosity assumed
- ➢ Error bars allow distinction among various suppression models



- Does collisional energy loss contribute significantly to light and heavy quark suppression?
- Is dead cone effect in radiative energy loss vastly different between light and heavy quarks or not?
- Does collisional dissociation contribute signficiantly to heavy quark suppression?
- CNM effects better understood with precision heavy flavor, hadrons, DY

- Will these significantly impact extraction of QGP parameters?

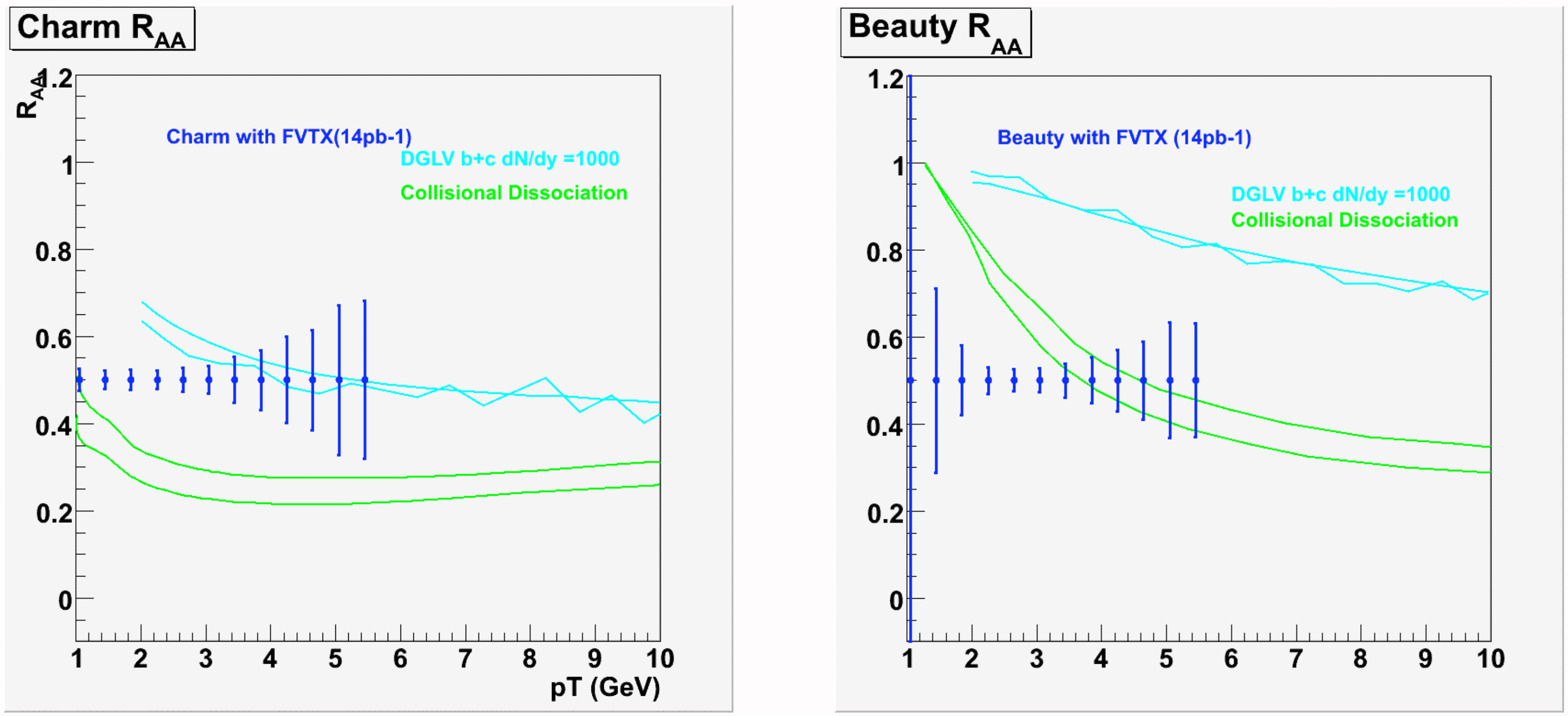
*Plots by Xiaorong Wang



Heavy Quark R_{AA} Measurements

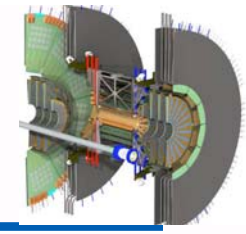
- Charm and Beauty separation allows even clearer distinction among models
- Radiative plus collisional dissociation predicts similar suppressions
- Radiative plus elastic scattering predicts much less beauty suppression than charm, continuing to high p_T

RHIC-I Luminosity



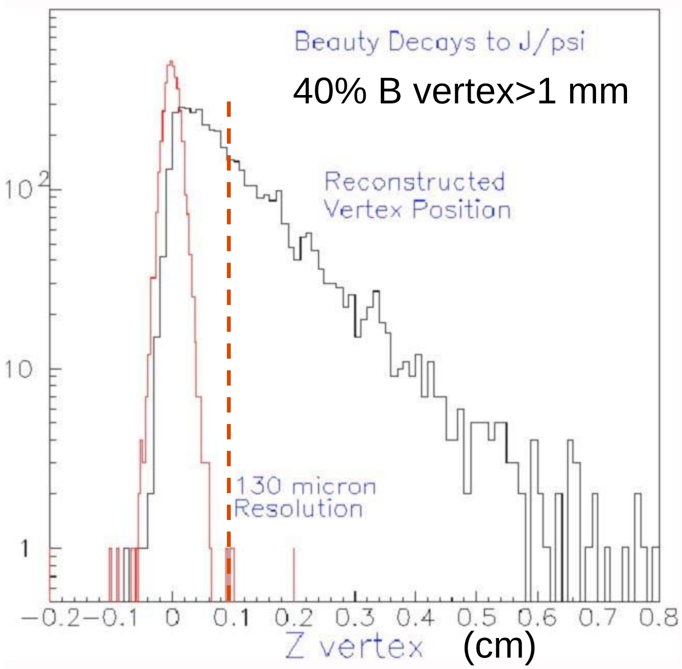
*Plots by Xiaorong Wang

Separating Charm and Beauty

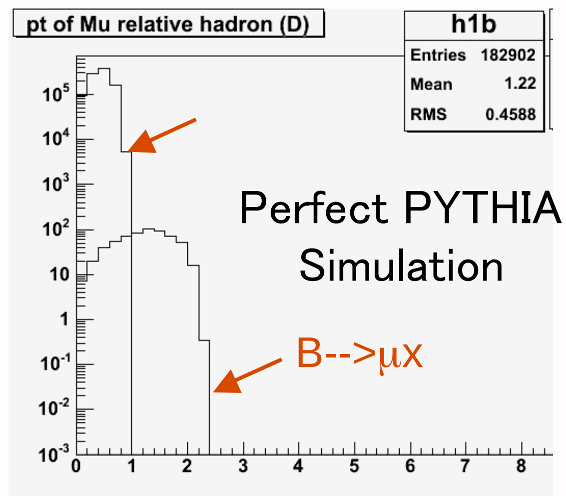


Charm/Beauty Separation by:

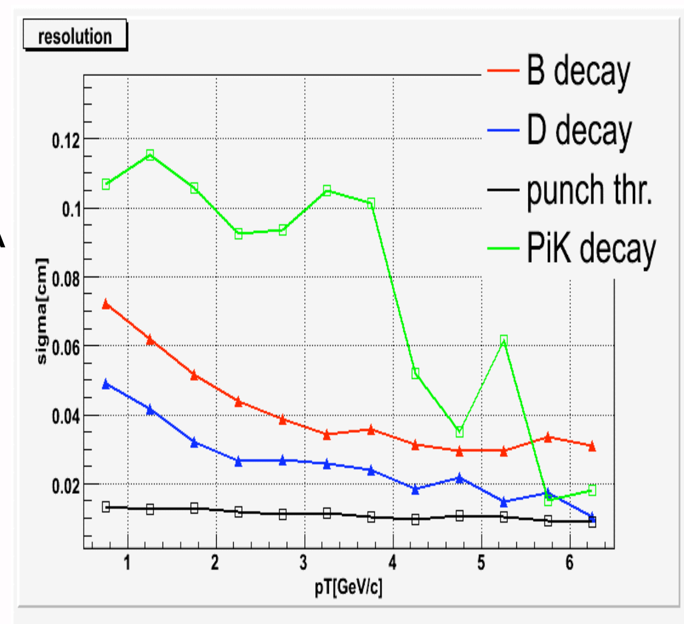
- B→J/ψ measured directly
- D measured directly via Central Arms
- FVTX possibilities to separate components in single muon spectrum:
  - event topology cuts in single muon events
  - kinematic cuts (p_T, DCA fits)



Direct Beauty Measurement

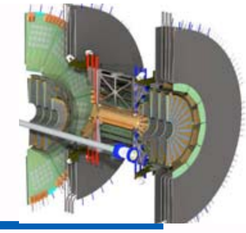


Event Topology

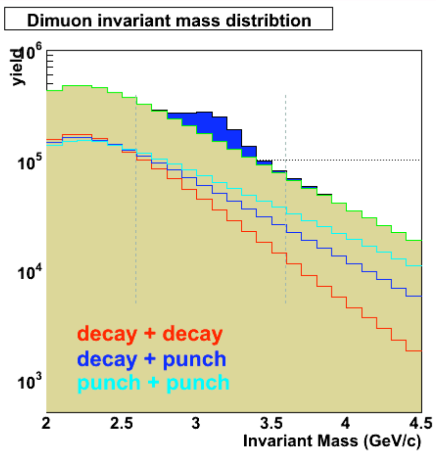


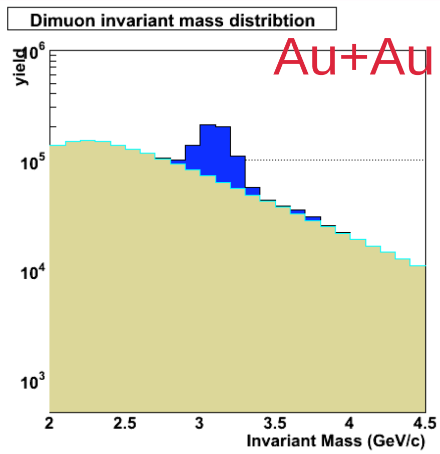
Charm/Beauty DCA, p_T

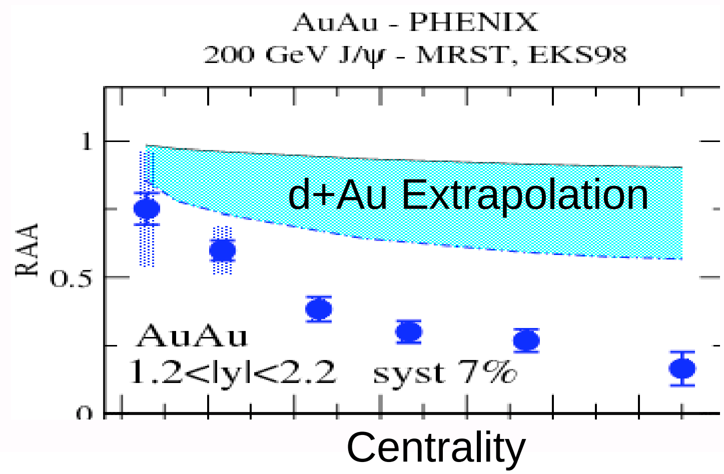
Dimuon Improvements

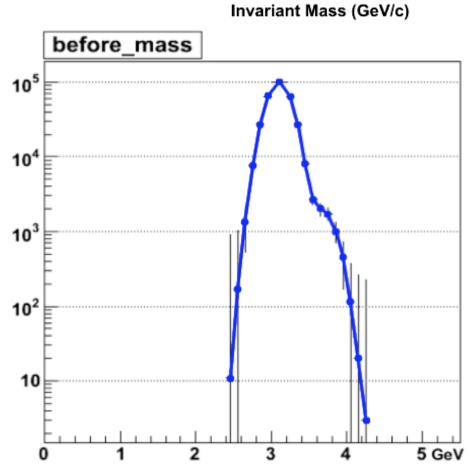


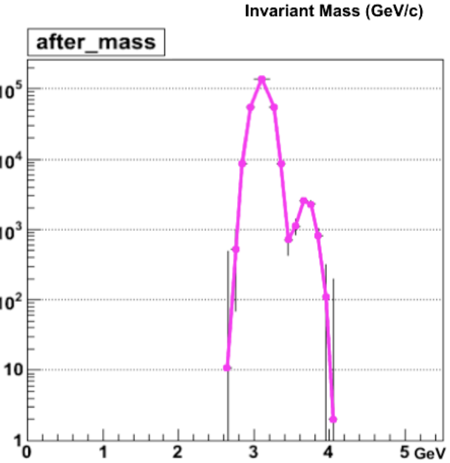
- Mass Resolution and Background Rejection Improvement
- ψ' added to vector meson measurements, J/ψ improved for given run, Υ at central rapidity possible, precision open heavy flavor added (recombination)
- QGP and CNM vector meson production understood

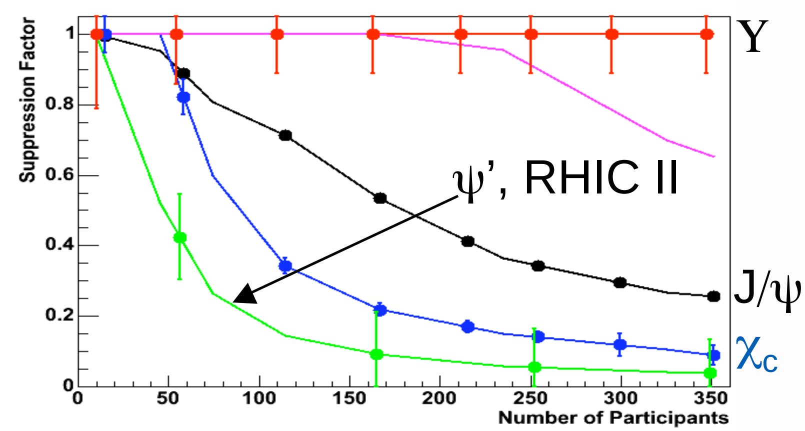




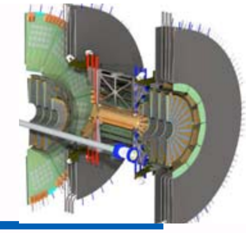






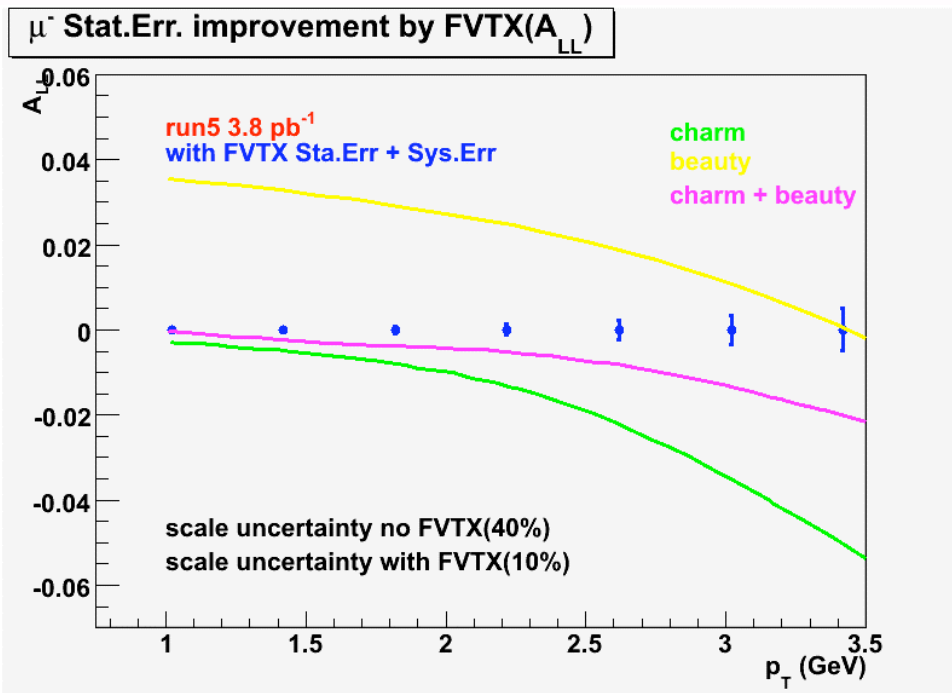


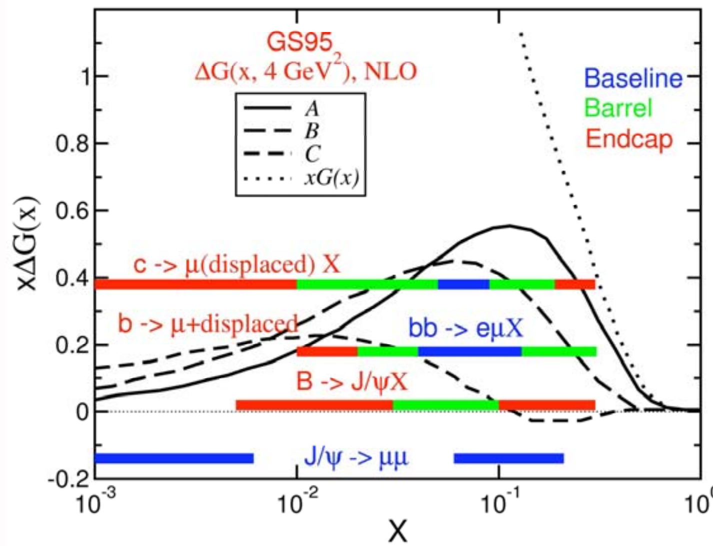
M. Brooks, DOE Review, July 9-10 2007



Heavy Quark Asymmetry Measurements

- Heavy flavor measurement sensitive to ΔG(x)
- Charm and Beauty separation would allow more sensitive measurement





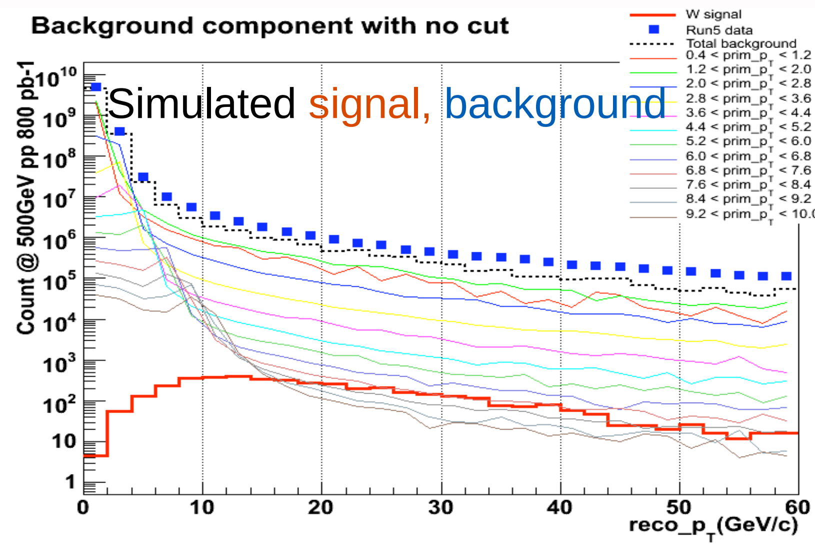
$$A_{LL}(x_1,x_2) = \frac{\Delta G}{G}(x_1)\frac{\Delta G}{G}(x_2) * \bar{a}$$

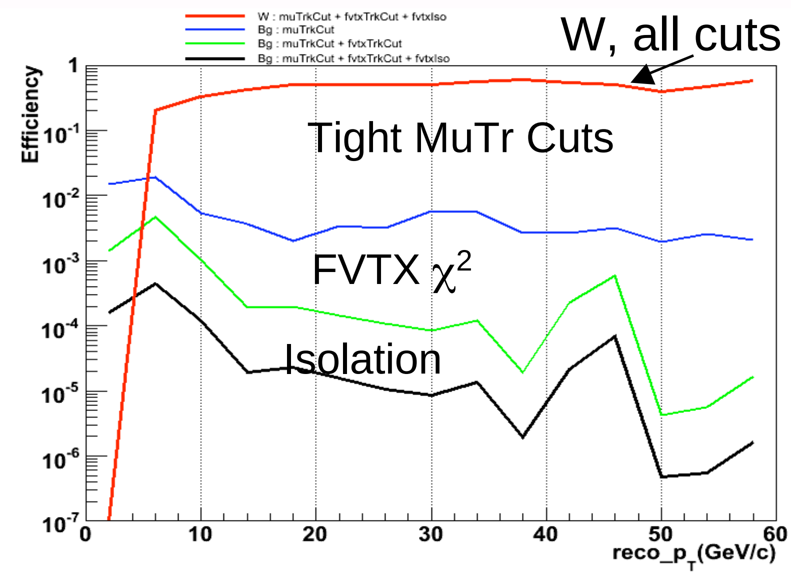
*Plots by Xiaorong Wang

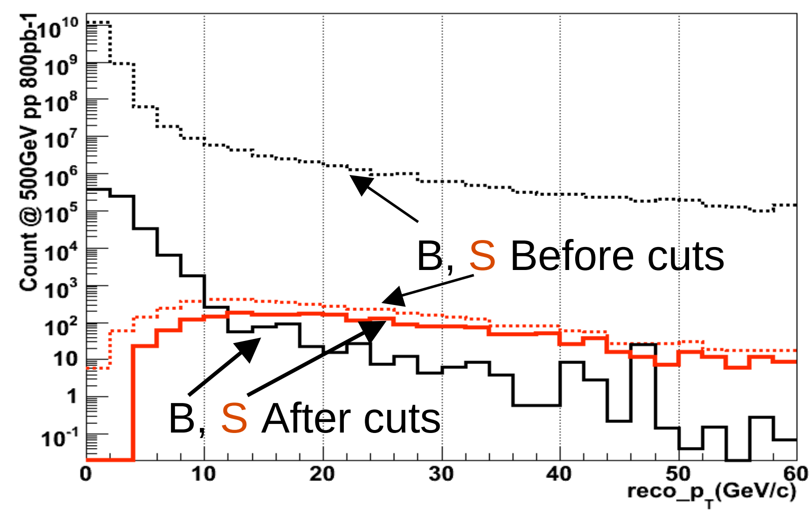
W Background Offline Rejection

Single muon spectrum contributions from:

- W-->μX
- Hadron punch-throughs, decays
- Mis-reconstructed hadrons
- Tight MuTr cuts plus FVTX cuts improve signal:background by ~10^5

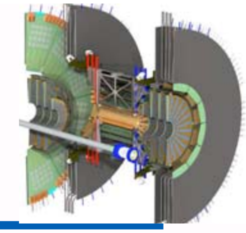






*Plots by Zhengyun You

Summary



Broad Physics Program Attainable with the FVTX

- Suppression mechanisms understood and quantified for light and heavy quarks →extraction of medium's properties
- Vector meson production and suppression understood→screening quantified
- Significantly improved separation of cold nuclear matter and QGP effects
- Significant contributions to ΔG, sea quark and transversity measurements in the spin program

Forward Rapidity Provides Important Kinematic Extension to PHENIX

- Explore larger extent of medium in heavy ion collisions
- Cold nuclear matter effects explored into the shadowing and anti-shadowing regimes, different contributions from E-loss, etc.
- x-coverage for spin measurements significantly extended

Detector Design and Performance

- Standard technology and modest segmentation provides desired performance (to be further established in next talk)

Backups