Simulated Performance of FVTX

Outline:

- Physics –driven requirements for the FVTX detector
- Simulations that defined detector design and verified performance
  --Detector design and performance
  --FVTX tracks match with muon tracks
- Critical Improvements FVTX provides to physics measurements
  --Single Muon (open heavy flavor) measurement
  --Heavy quarkonium measurement

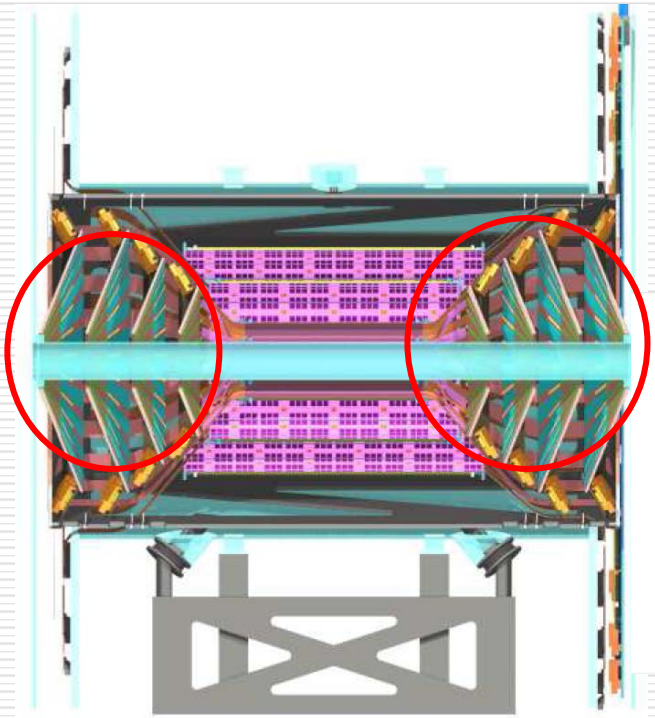
Many contributors: Melynda, Hubert, Dave L., Pat, Xiaorong, Anuj, Joel…

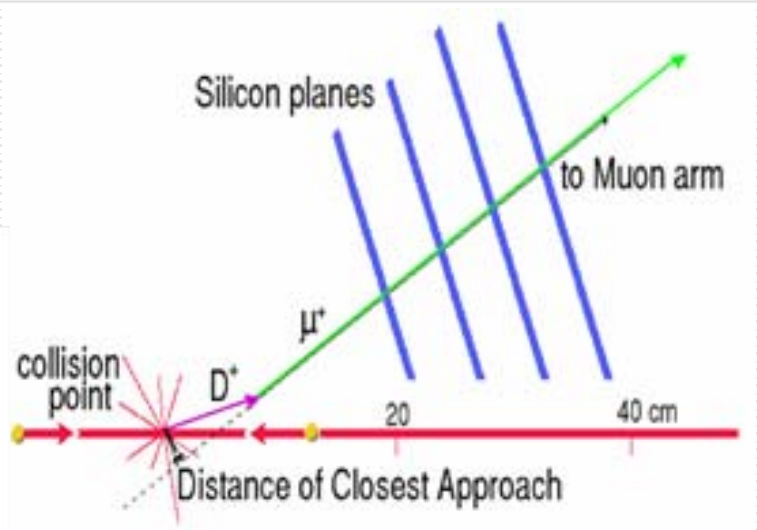
Physics–driven requirements

- DCA resolution to separate prompt, short-lived decays (B,D) and long-lived decay (π and K) from each other
- Ability to separate charm and beauty
- Low enough occupancy and high enough resolution to perform in AuAu environment
- Ability to match tracks from Muon arm to FVTX for all collisions.
- Excellent accuracy for the primary vertex using FVTX and VTX.

Detector design and performance

Detector Design and Performance

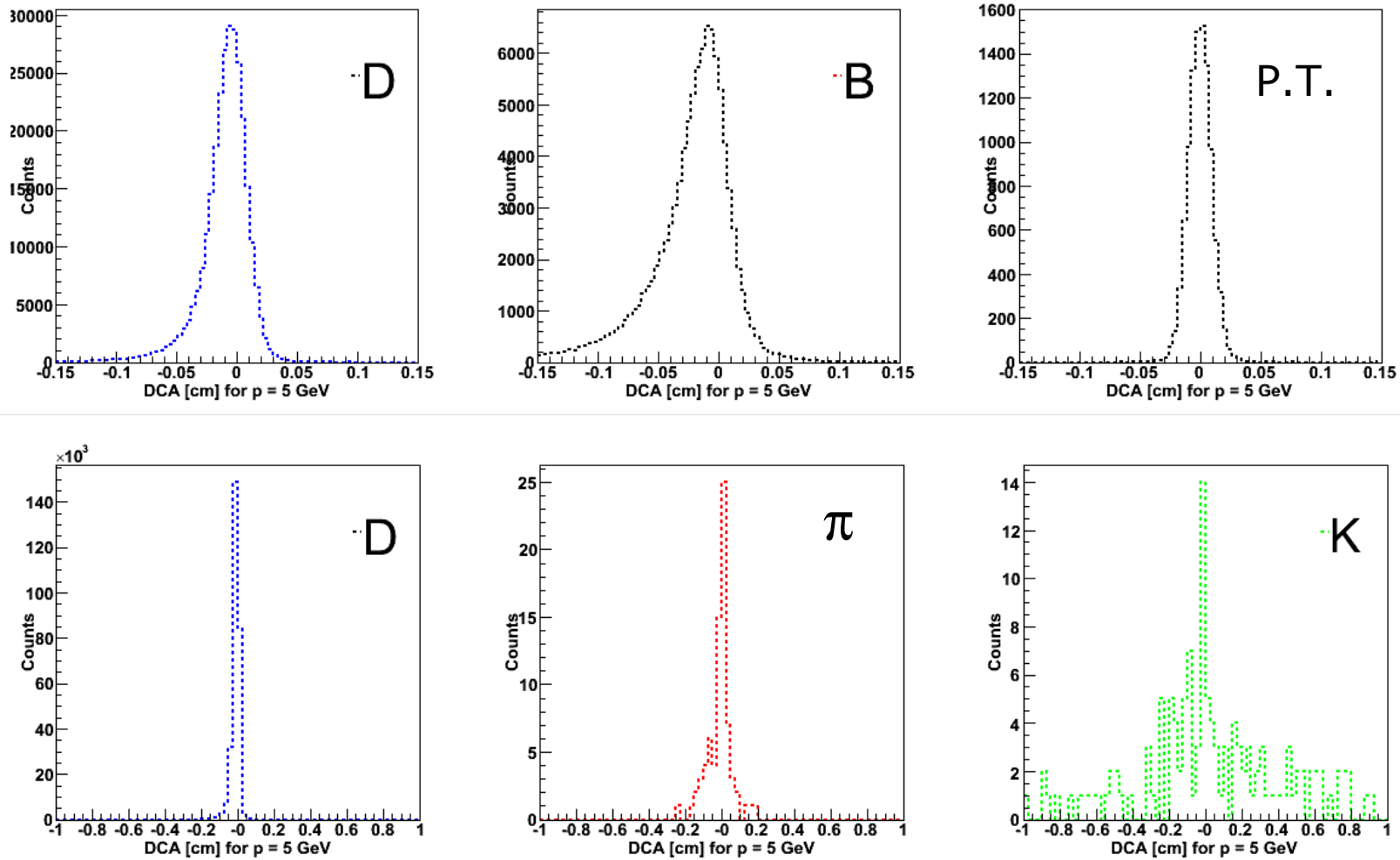




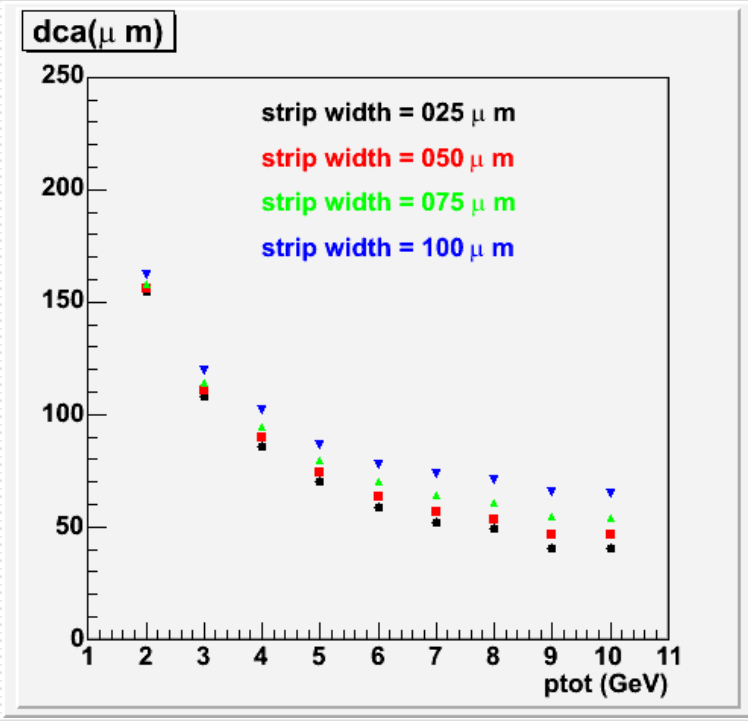
- 4 layers of tracking: to allow at least 3 hits/track
- Radial extents: to allow at least 3 hits/track as much as possible in area of muon coverage, constrained by the detector envelope
- Strips are 50 μm (r segmentation) x 2-13.5 mm (phi segmentation): to allow good DCA measurement in boost direction,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

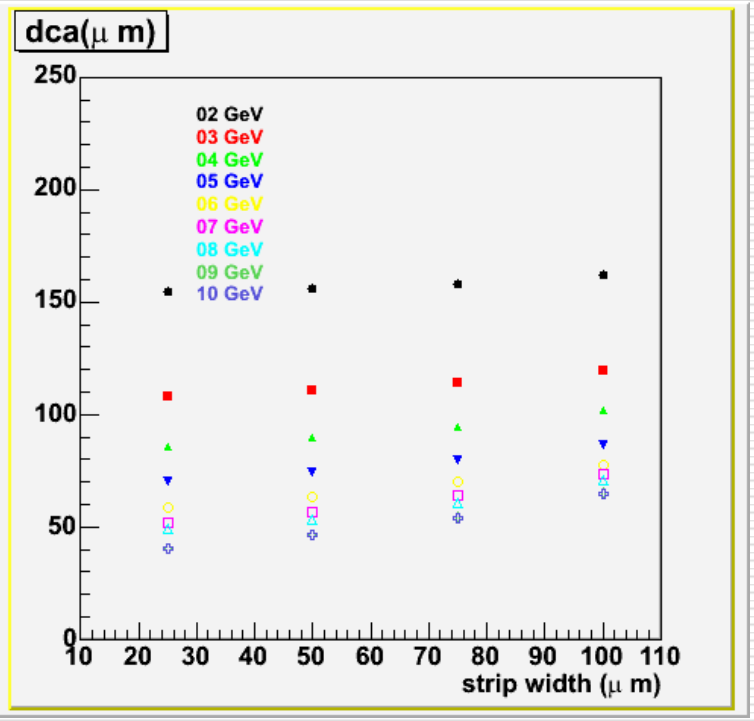
DCA values for different particles

Paticle Type	σ_{DCA}
Hadron punch through	73 μm
Pion	540 μm
Kaon	6924 μm
D	173 μm
B	424 μm



Detector design – Strip width





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

Primary Vertex Determination

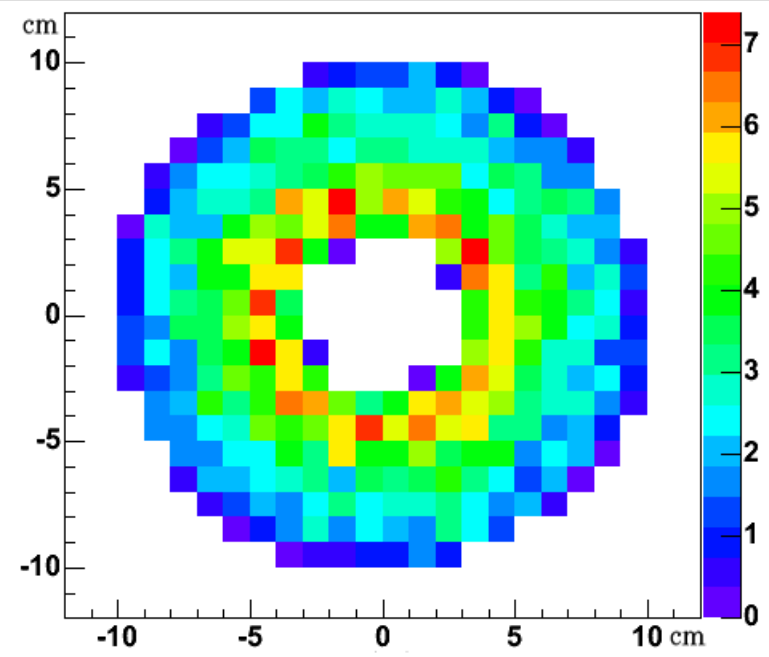
The identification of displaced vertices depends on the accuracy with which the primary vertex can be determined, we are using HIJET together with PISA to determine the primary vertex resolution.

Z vertex resolution:

Collision Species at $\sqrt{s}$= 200 GeV	Number of pions detected in FVTX	Accuracy of primary vertex determination from FVTX alone	Additional pions in VTX	Primary vertex accuracy with FVTX + VTX
p-p min bias	5.8	168 μm	~3	98 μm
p-Au min bias	11.2	120 μm	~6	69 μm
Au-Au central	1730	10 μm	~900	6 μm

Detector occupancy in Central AuAu

Hits/cm^2 per Central AuAu event



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

→average 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

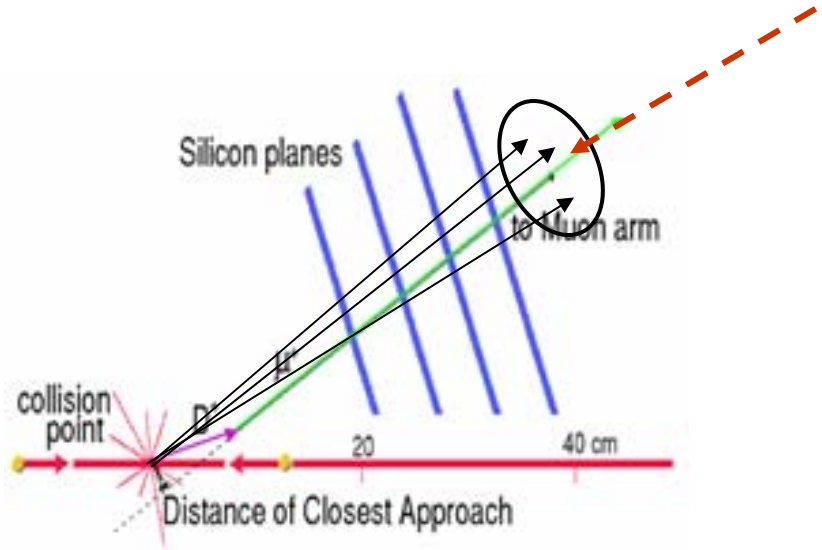
FVTX Track Matching with Muon Track

Matching MuTr and Silicon tracks in Central AuAu (I)

Issue: in Central AuAu events, approximately 3 silicon tracks are found that approximately match each MuTr track

Solutions:

- Look at additional rejection that can be obtained if we use a Kalman-Filter fit to MuTr+Silicon hits and choose best χ^2



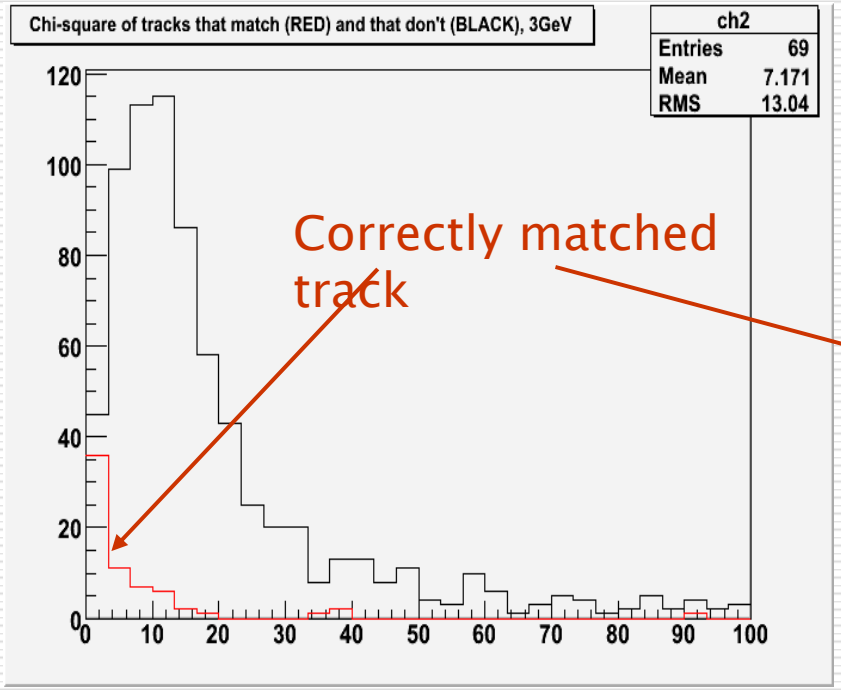
Simulations: Mix Central AuAu events with single muons

- Find MuTr reconstructed track
- Find all silicon stubs that are within a 2-d angular window of this track
- Fit each set of potential silicon hits with the MuTr track and store fit results
- Look at distributions for tracks and check whether they are match
- Select best match (using χ^2)

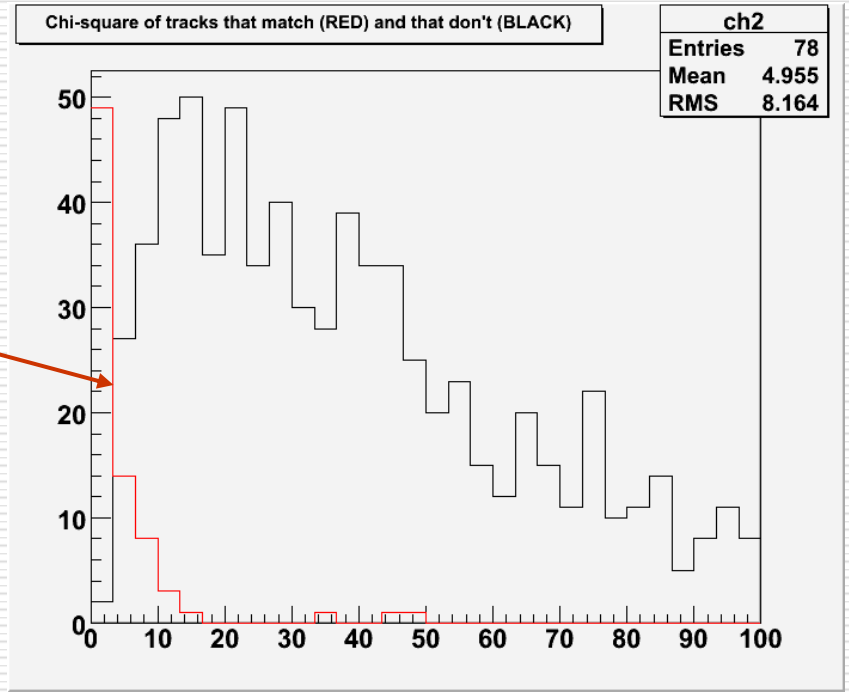
Matching MuTr and Silicon tracks in Central AuAu (II)

Rejection: Pick track with best χ^2: 93%, 83%, 75% of the time the correct match is made for total momentum 9 GeV, 6 GeV, 3 GeV particles

Chi-square (3GeV)

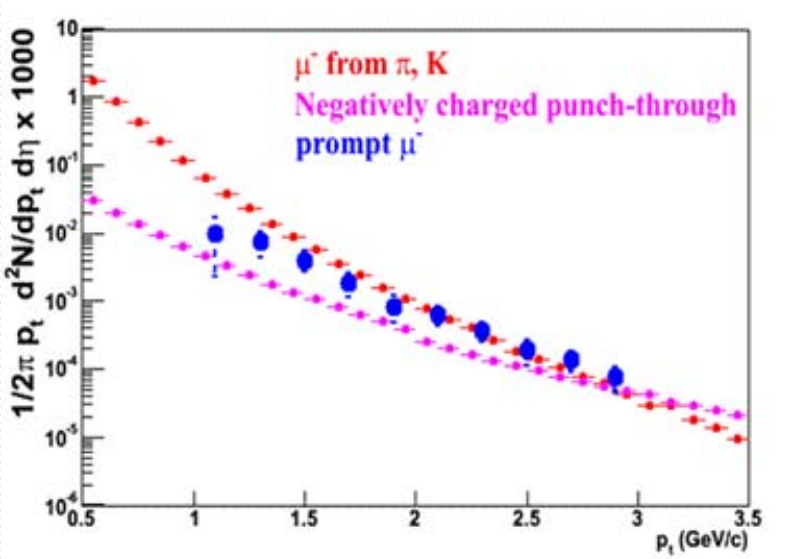


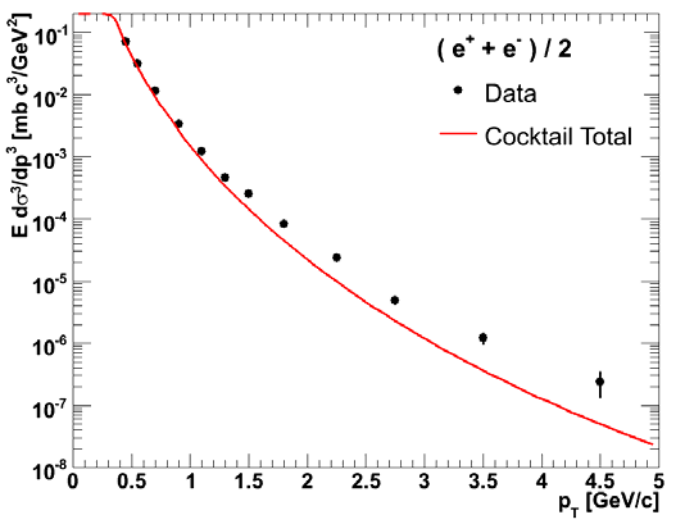
Chi-square (9GeV)

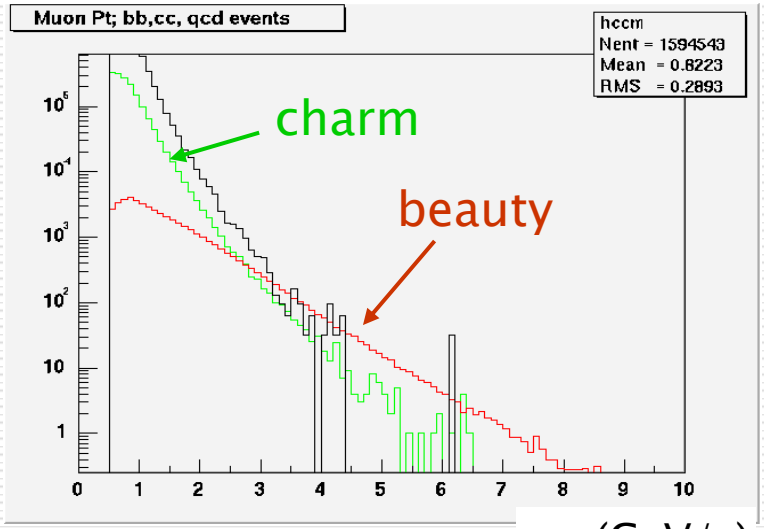


Improvement
for Single Muon Measurement

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 muon and electron measurement can not separate charm and beauty

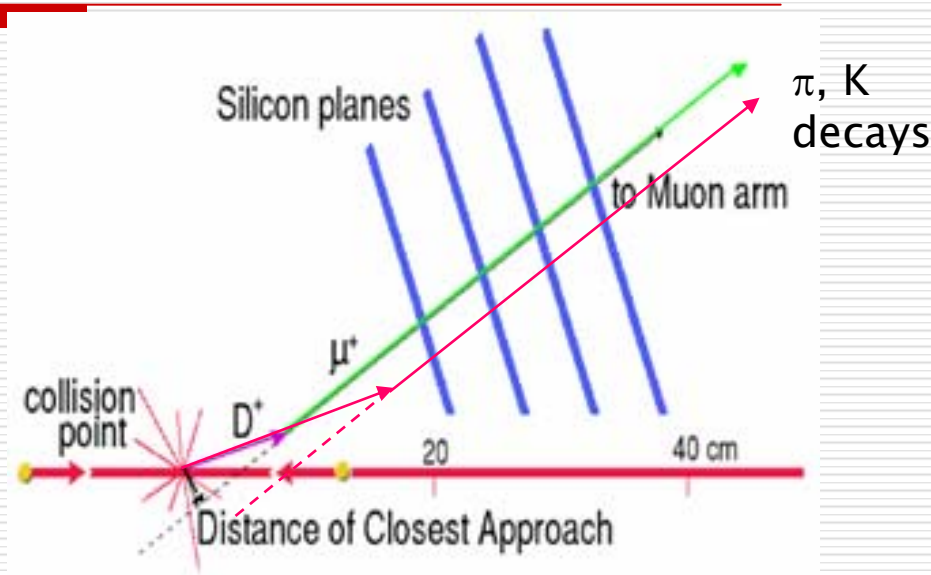
FVTX Contributions—Reduction of long-lived Decay Background

1σ DCA cut at upper end:

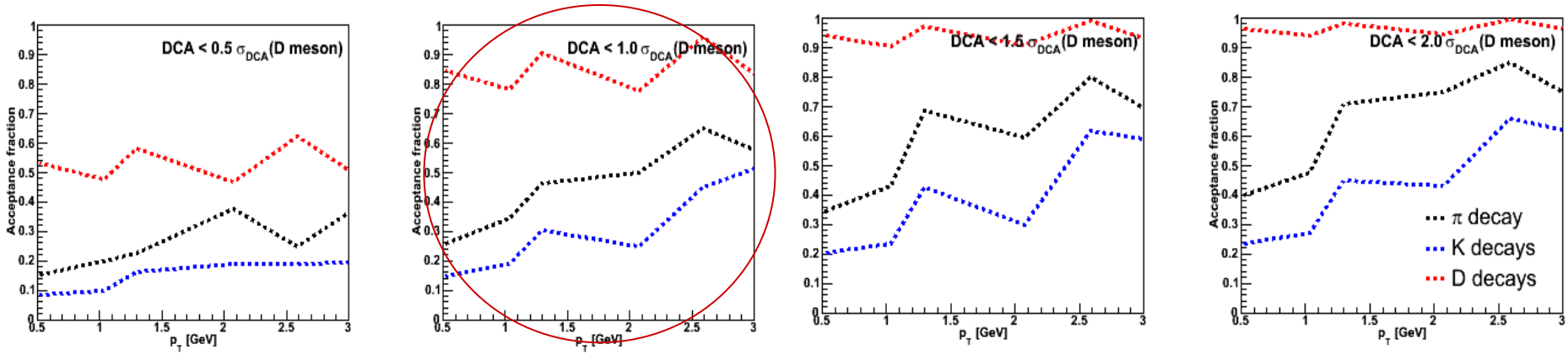
Accept 85% D meson

Accept 25-50% π decay

Accept 15-40% K decay.



Acceptance Fraction vs p_T



- Cutting on DCA<DCA_{max} (upper limit) to remove long-lived π,K decays.
- Especially important at low p_T spectra

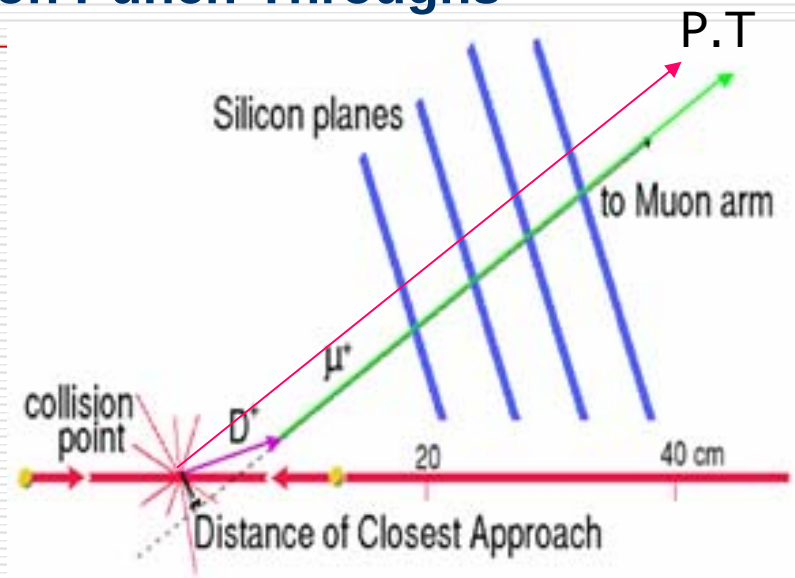
FVTX Contributions—Reduction of hadron Punch-Throughs

1σ DCA cut at low end:

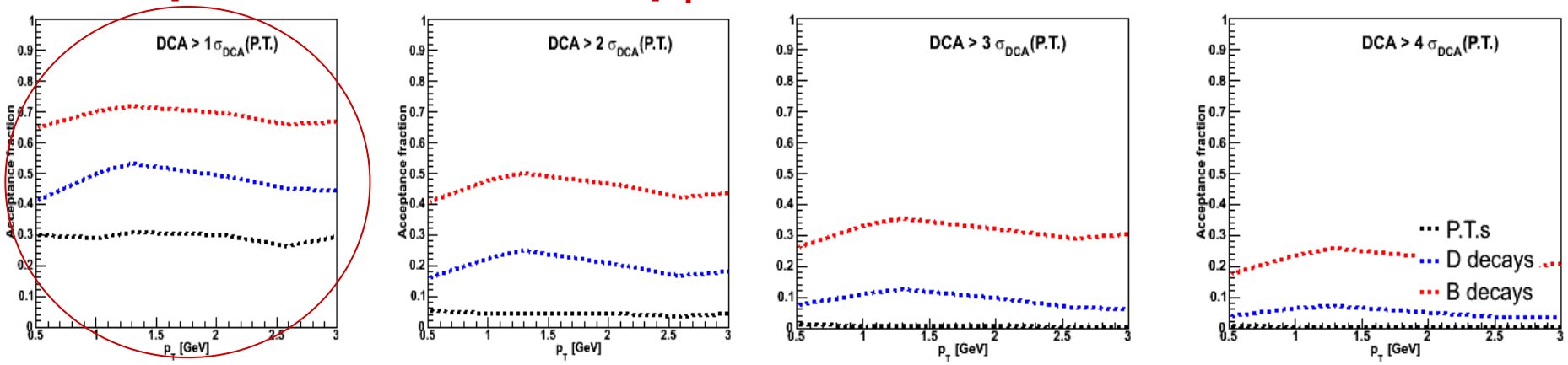
Accept 65% D meson

Accept 45% B meson

Accept 30% Punch Throughs

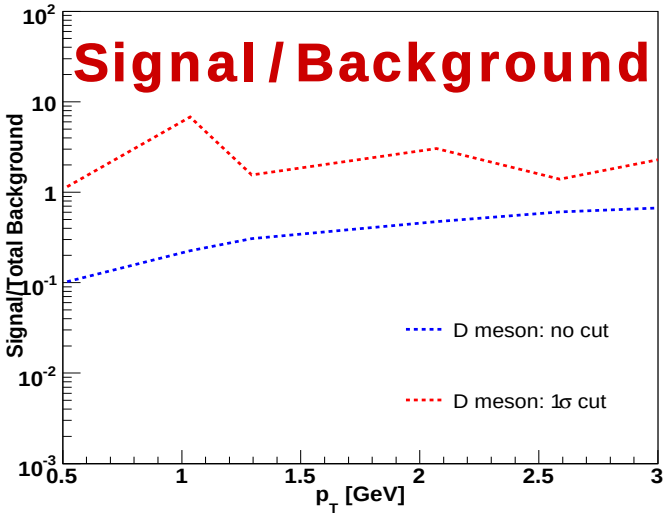


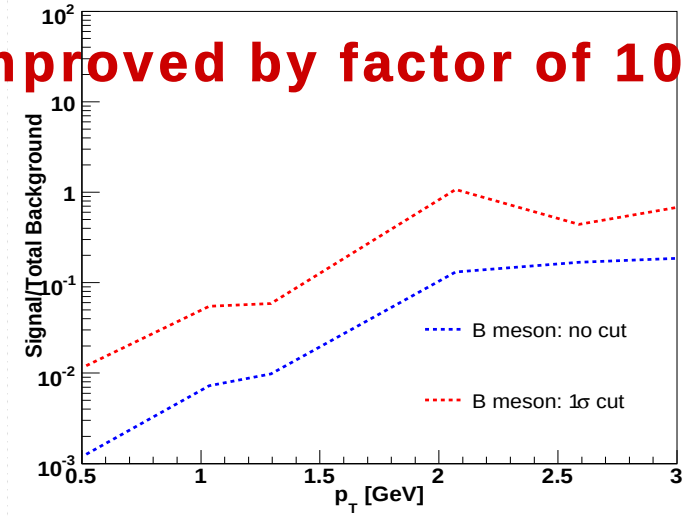
Acceptance Fraction vs p_T

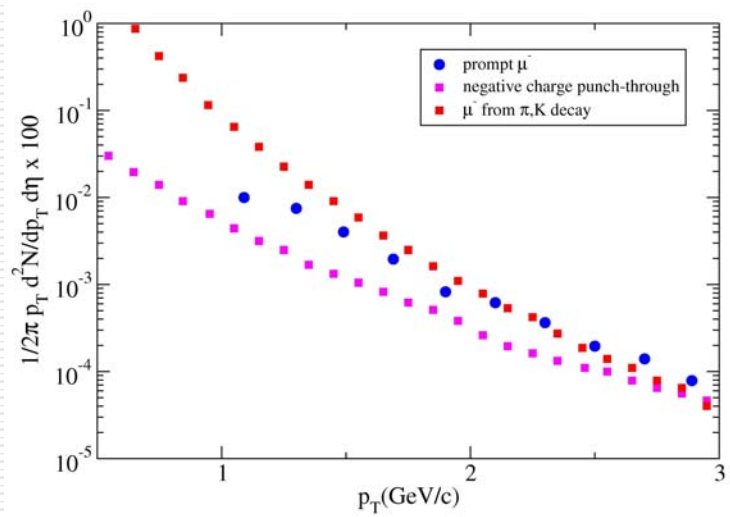


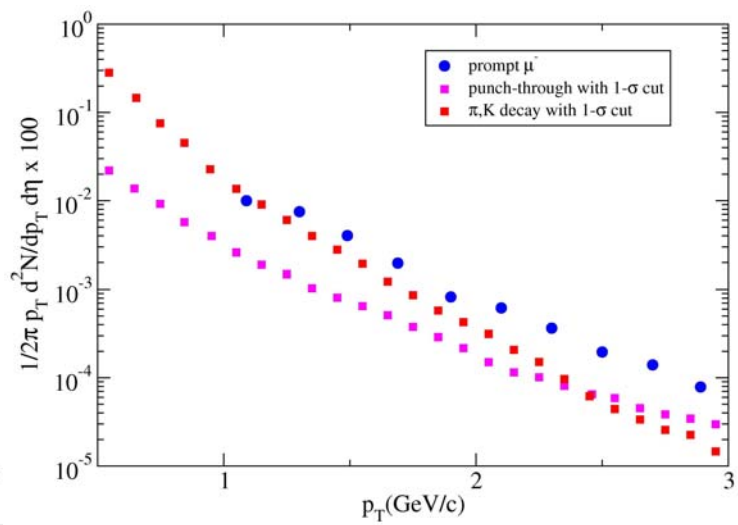
- Cutting on DCA > DCA_{min} (lower limit) to remove punch-through hadrons
- It is important at high p_T spectra

Signal/Background improvement for D,B measurement





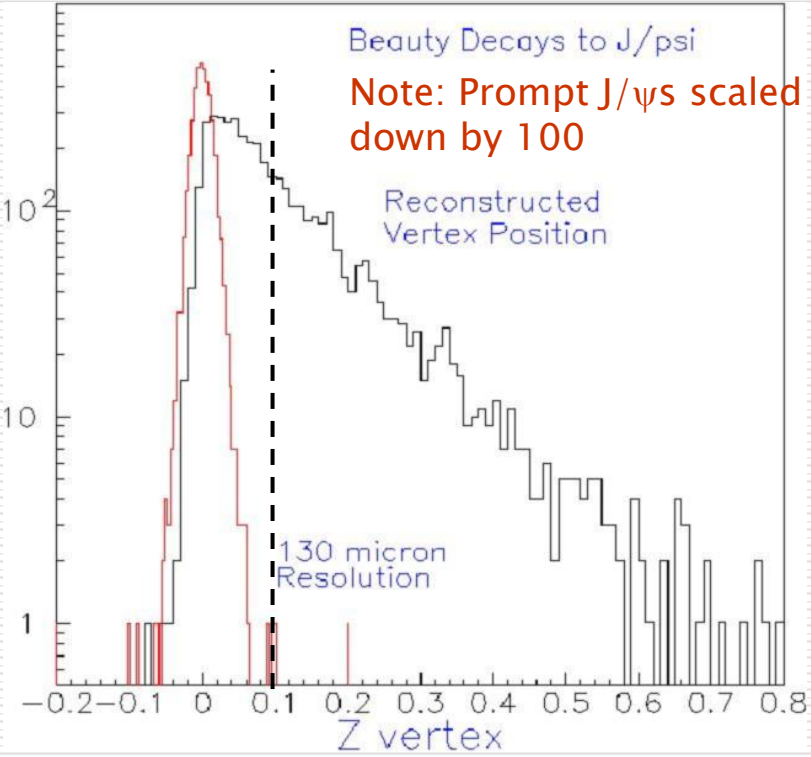




FVTX Contributions—Separation of Charm and Beauty

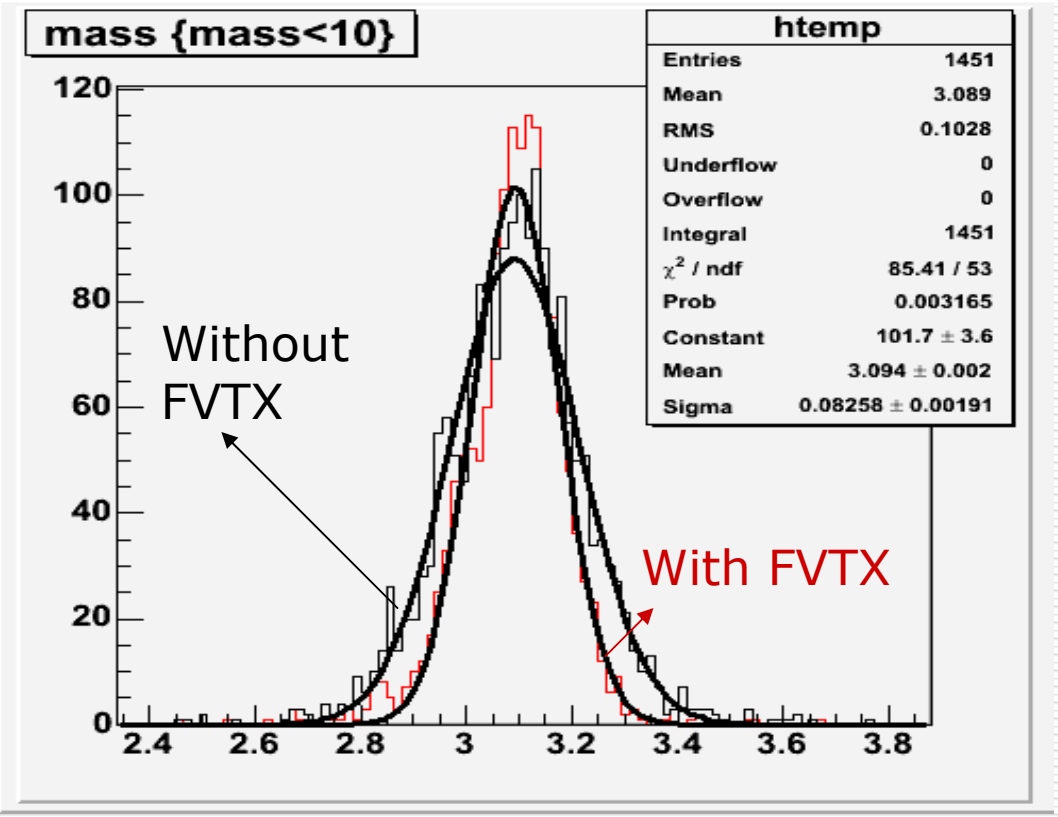
Charm/beauty separation still difficult, but a few possibilities:

- Single muon: Natural separation at high p_T (without FVTX)
- Measure B→J/ψ events and infer beauty differential cross section: cut at 1 mm →10^{-4} rejection of prompt J/ ψ s, 40% acceptance of B→J/ ψ) (clean measurement)
- Take advantage of longer decay length for b compared to c trying to understand whether D's and B's can be separated by using the different life time.



Improvement
for Heavy Quarkonium Measurement

FVTX Contributions —Improvement for J/ψ measurement



- Background removal (60%)
- improvement in J/ψ mass resolution
  120MeV – 80MeV

Note:

Pure J/ψ signal using all silicon hits (barrel and forward).

J/ψ Measurement Improvement with FVTX

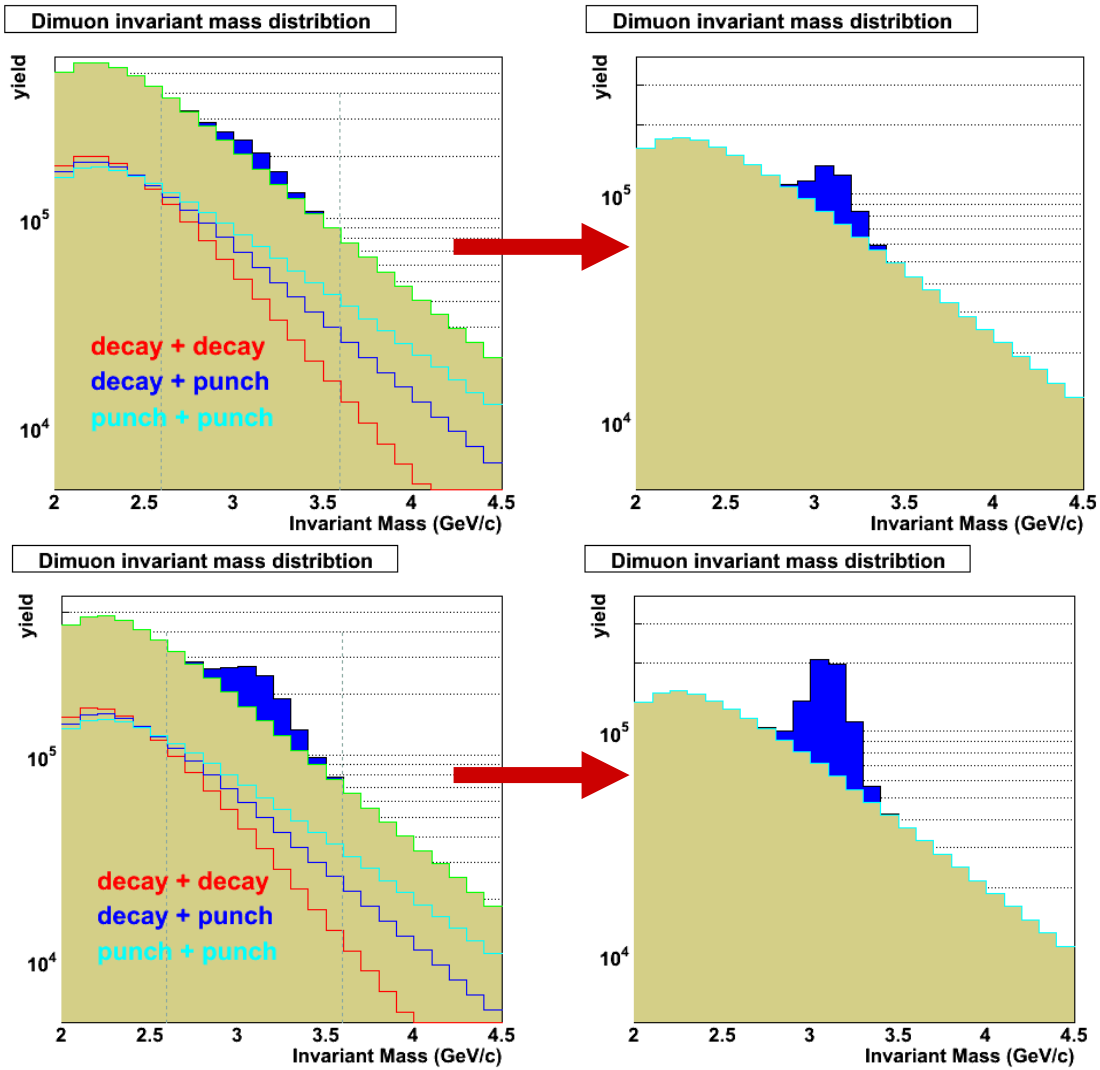
- AuAu Central (upper)
- AuAu MinBias (bottom)

without and with FVTX :

- mass resolution improvement
- background rejection

- Baseline S:B from real data

- Note: similar plots can be made for upsilons

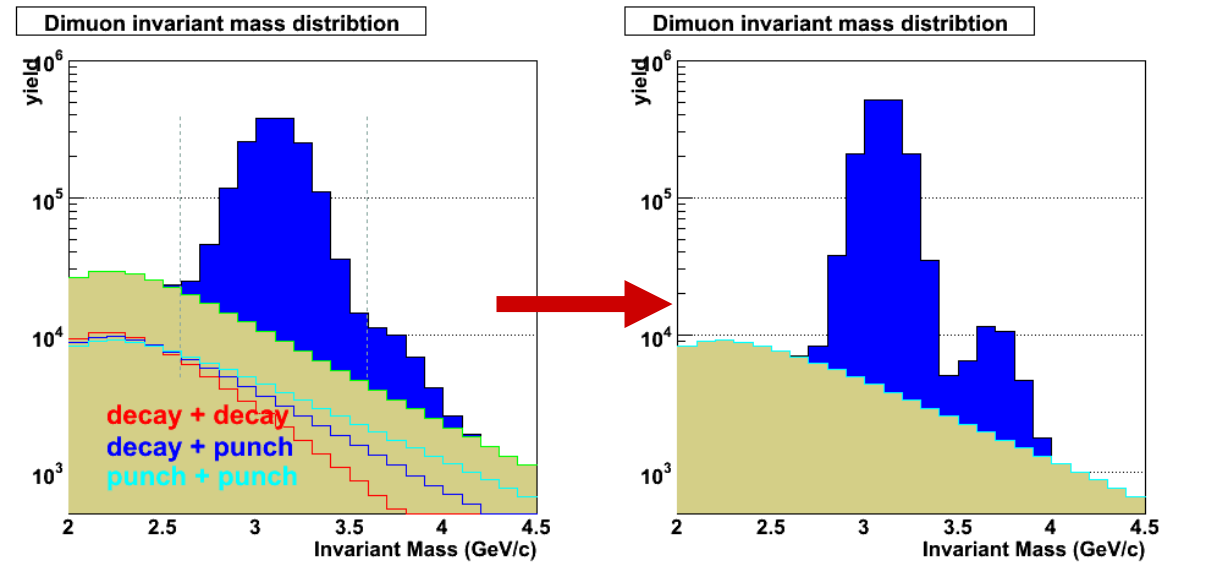


Possibility for ψ' Measurement with FVTX

- pp without and with FVTX

- mass resolution improvement
- background rejection

S/B: run5pp , RHIC II luminosity, 10 Weeks



Expected future simulation work

- Finish optimizing detector geometry with simulations (strip and plane orientation, etc.)
- Incorporate FVTX hits with other upgrade detector (VTX, RPC, NCC) hit to determine performance of to integrated systems:

background rejections, improvement in momentum resolutions…

- More simulation to estimate physics quantities (R_{AA}, flow…)
- More complete study of physics rates with efficiency hits taken into account.

Summary

Detector Performance:

--Geometrical layout gives ≥3 hits per track, most of the time Occupancies ≤1.5%

--50 μm strips give good DCA resolution and desired segregation of prompt tracks, short lived decays, and long-lived decays

--Simulations with expected material retain good DCA resolution

--have sufficient segmentation to achieve clean match from muon track to FVTX in central AuAu collisions.

For single muon measurements:

-- make clear separation of light hadrons and muons from open heavy flavor

-- improve open heavy flavor signal/background by factor of 10

For heavy quarkonium measurements:

-- reduction of backgrounds by at least factor of 2

-- improved mass resolution

-- simulation with RHIC II luminosity already show the possibility to measure other heavy onium state and their resonance.

-- promising to do clean measurement for B->J/ψ.

-- continuum measurement (separate DY and $c\bar{c}$).

Backup

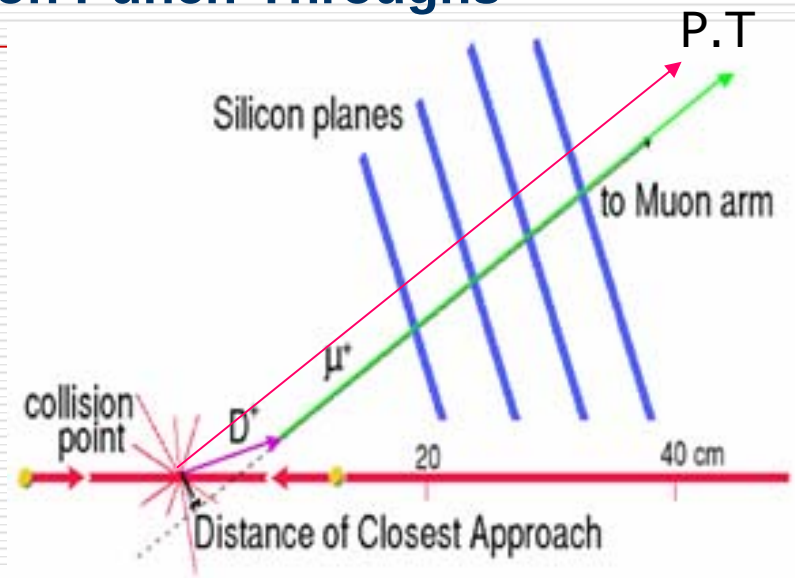
FVTX Contributions—Reduction of hadron Punch-Throughs

1σ DCA cut at low end:

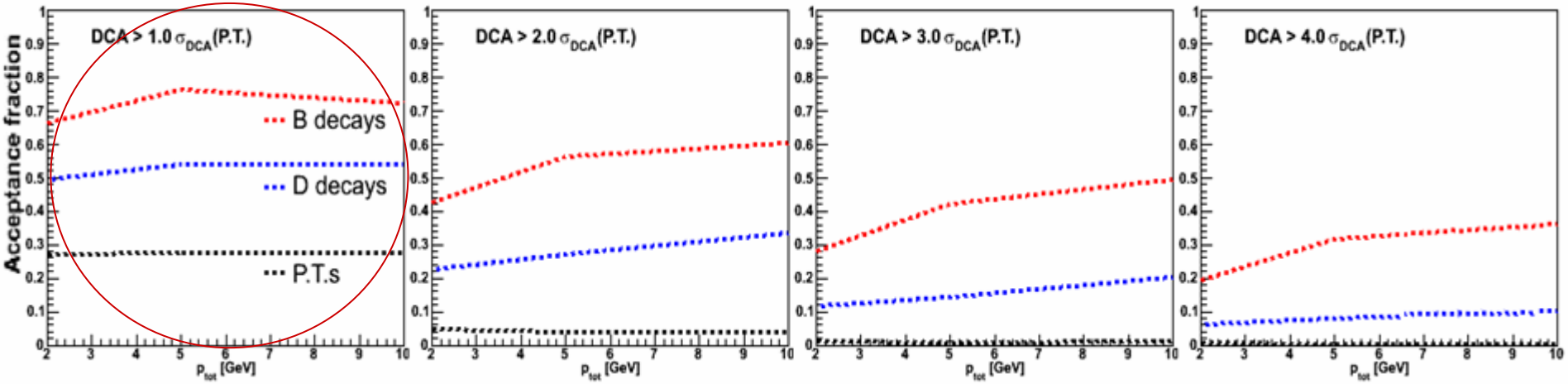
Accept >70% D meson

Accept >50% B meson

Accept <30% Punch Througths



Acceptance Fraction vs p_T



- Cutting on DCA > DCA_{min} (lower limit) to remove punch-through hadrons
- It is important at high p_T spectra

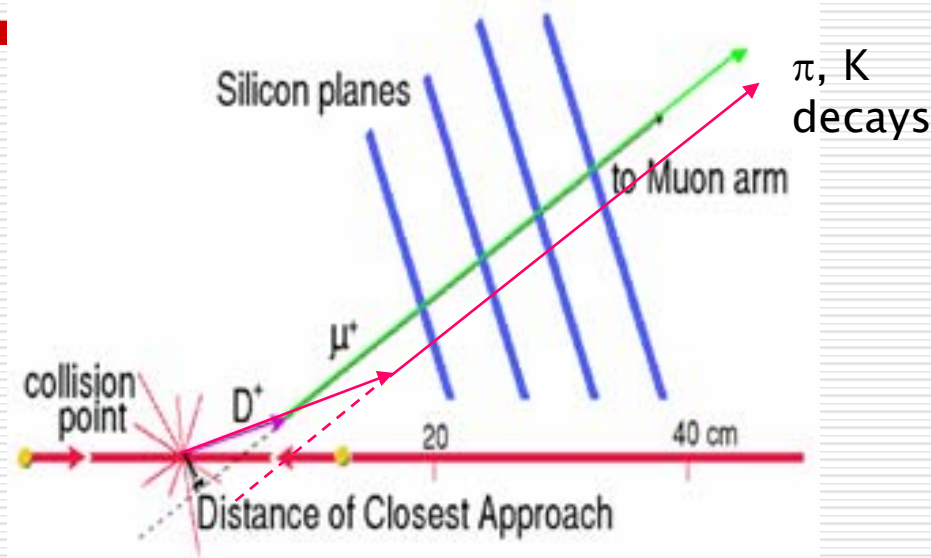
FVTX Contributions—Reduction of long-lived Decay Background

1σ DCA cut at upper end:

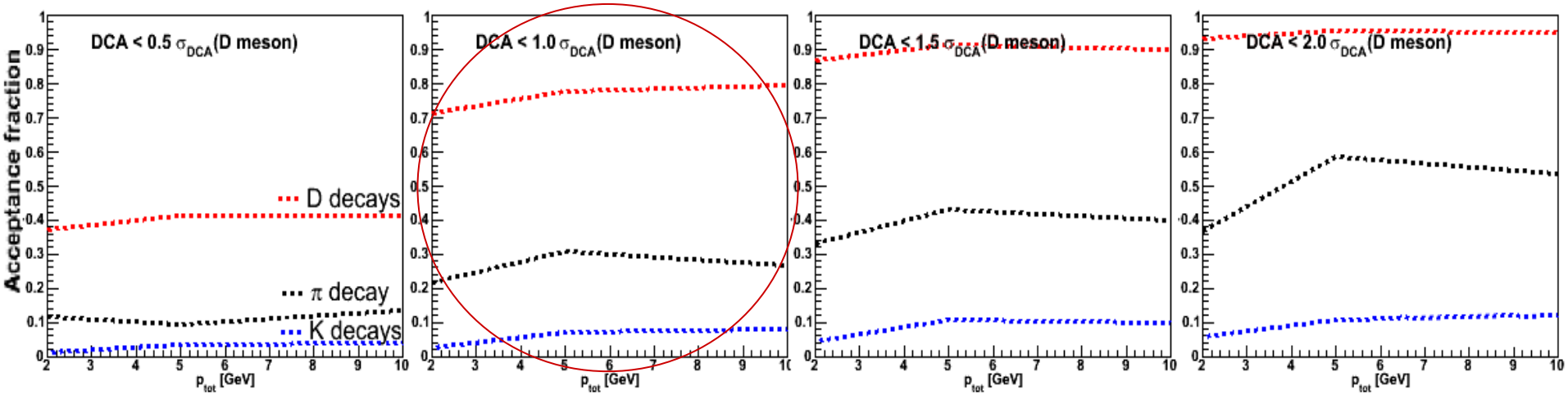
Accept 70-80% D meson

Accept 20-30% π decay

Accept 2-5% K decay



Acceptance Fraction vs p_T



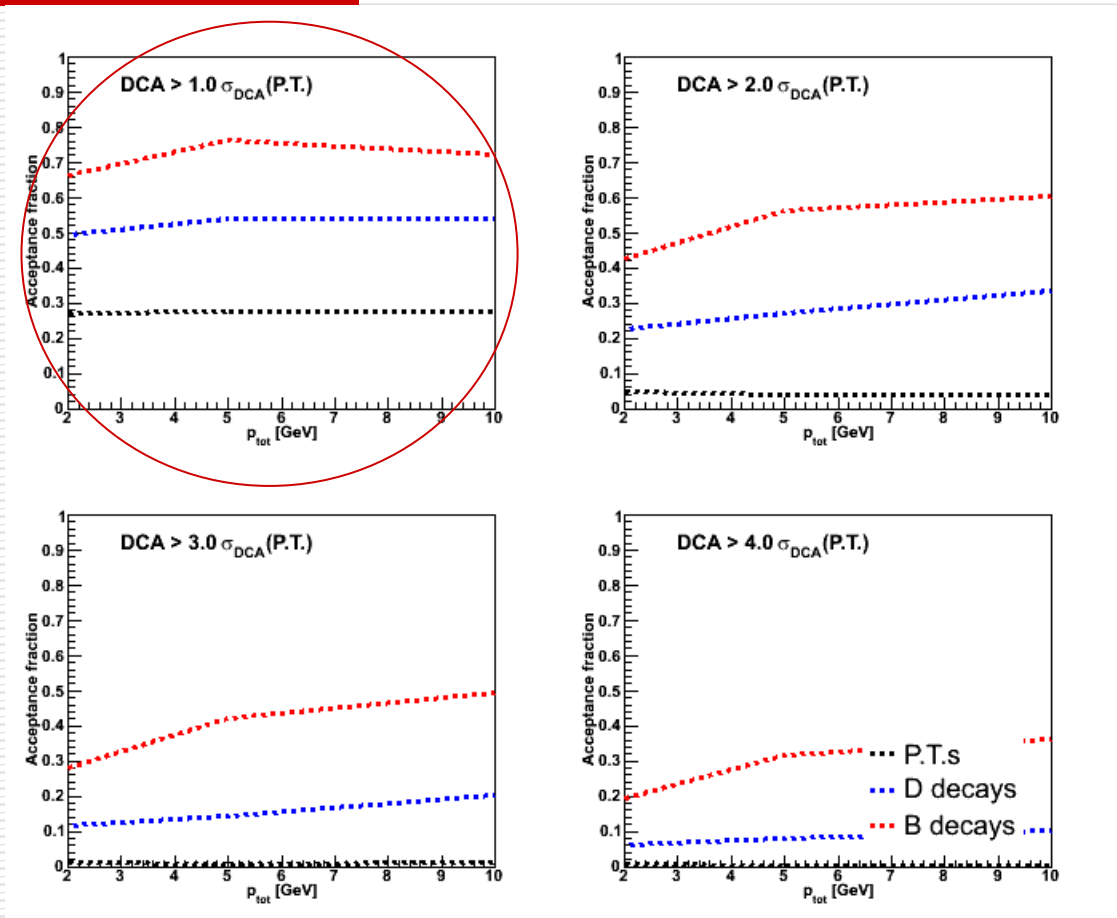
- Cutting on DCA<DCA_{max} (upper limit) to remove long-lived π,K decays.
- Especially important at low p_T spectra

FVTX Contributions—Reduction of hadron Punch-Throughs

To measure D meson:

Acceptance Fraction

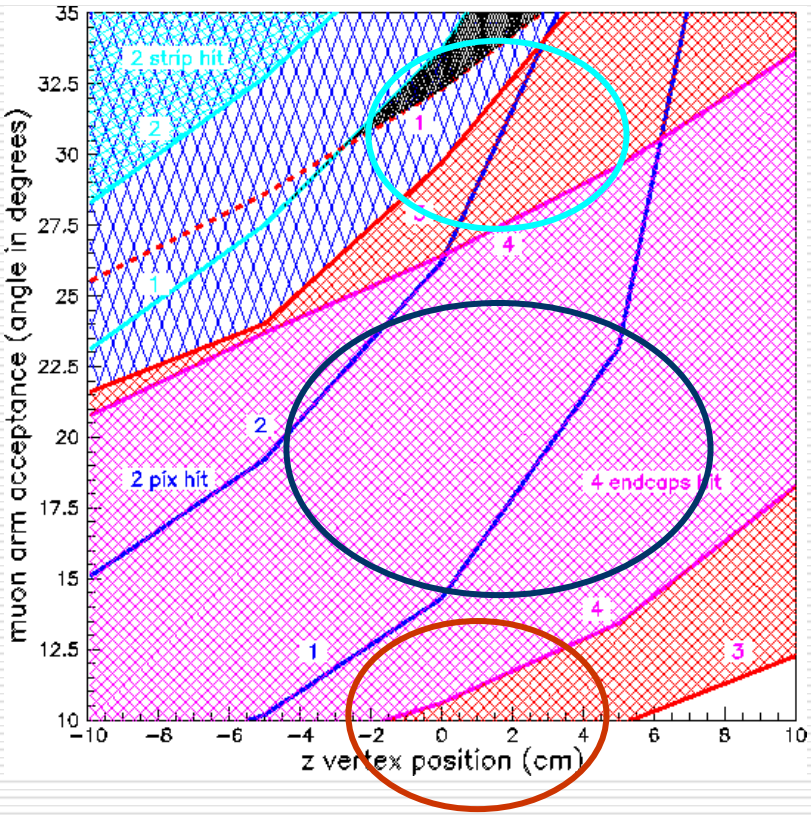
Vs pT

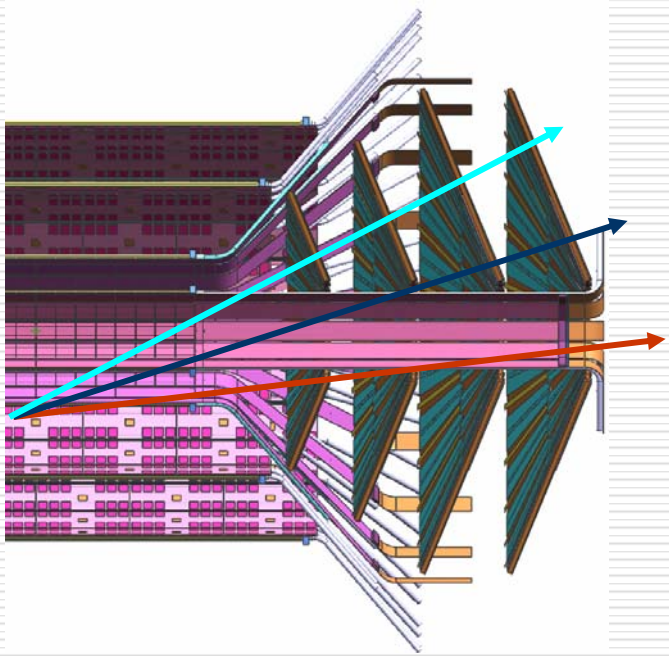


- Cutting on DCA > DCA_{min} (lower limit) to remove punch-through hadrons
- It is important at high p_T spectra

Detector acceptance

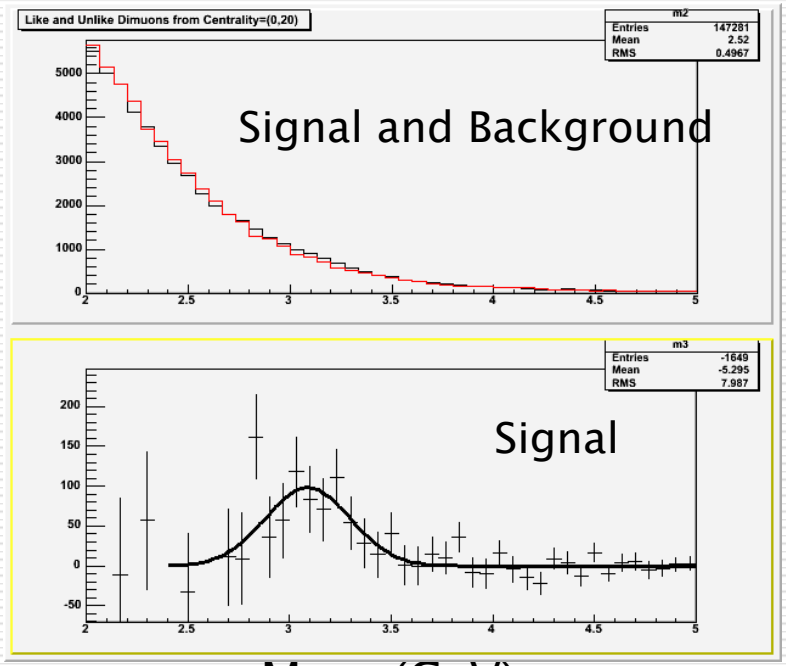
Number of Forward Silicon, Barrel Pixel, and Barrel Strips hit versus theta and z vertex position



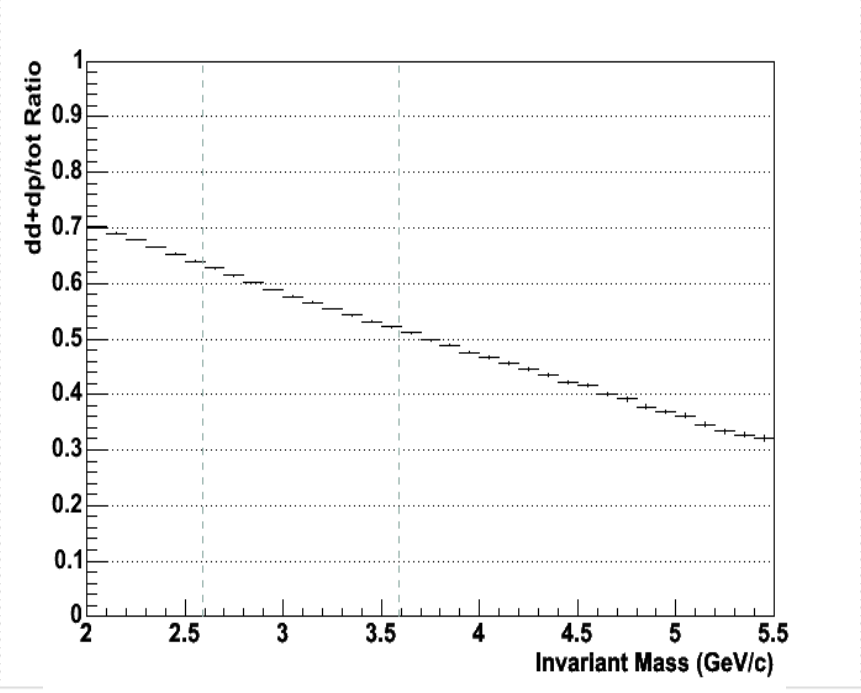


FVTX matches and extend the capability of Muon Arm

FVTX Contributions—Removal of Backgrounds

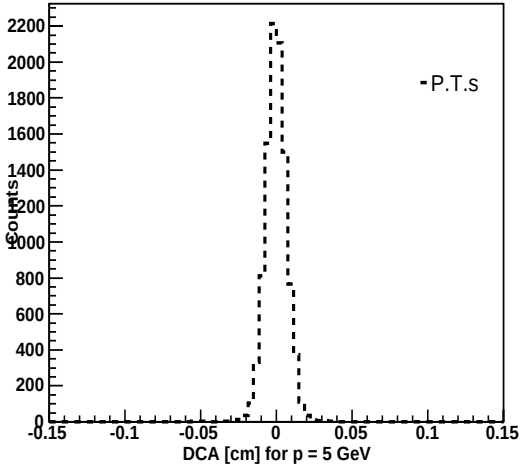


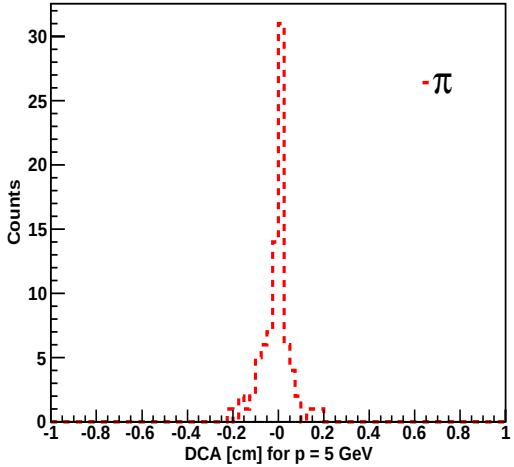
Mass (GeV)

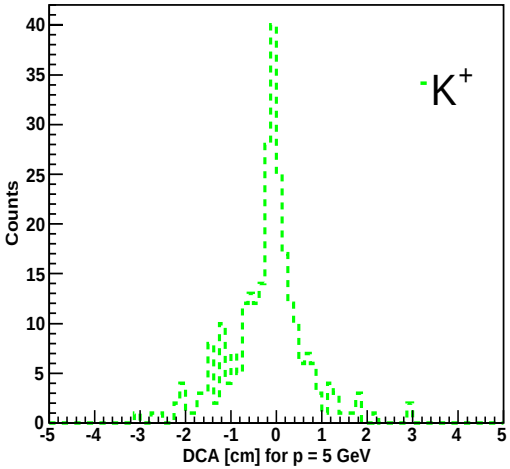


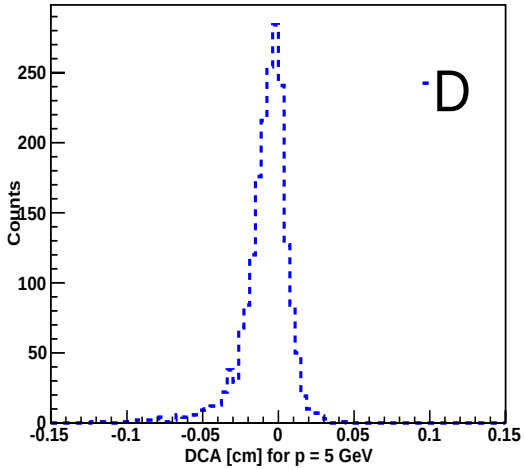
- Signal:Background in central south arm events ~1:20
- Combinatorial background from 3 possible combinations of hadron decay muon and punch-through
- Two combinations which include a decay can potentially be separated from prompt J/ψs: ~60% at J/ψ mass

DCA value for difference particles









Paticle Type	σ_{DCA}
Hadron punch through	73 μm
Pion	540 μm
Kaon	6924 μm
D	173 μm
B	424 μm

For D measurement: (1σ)

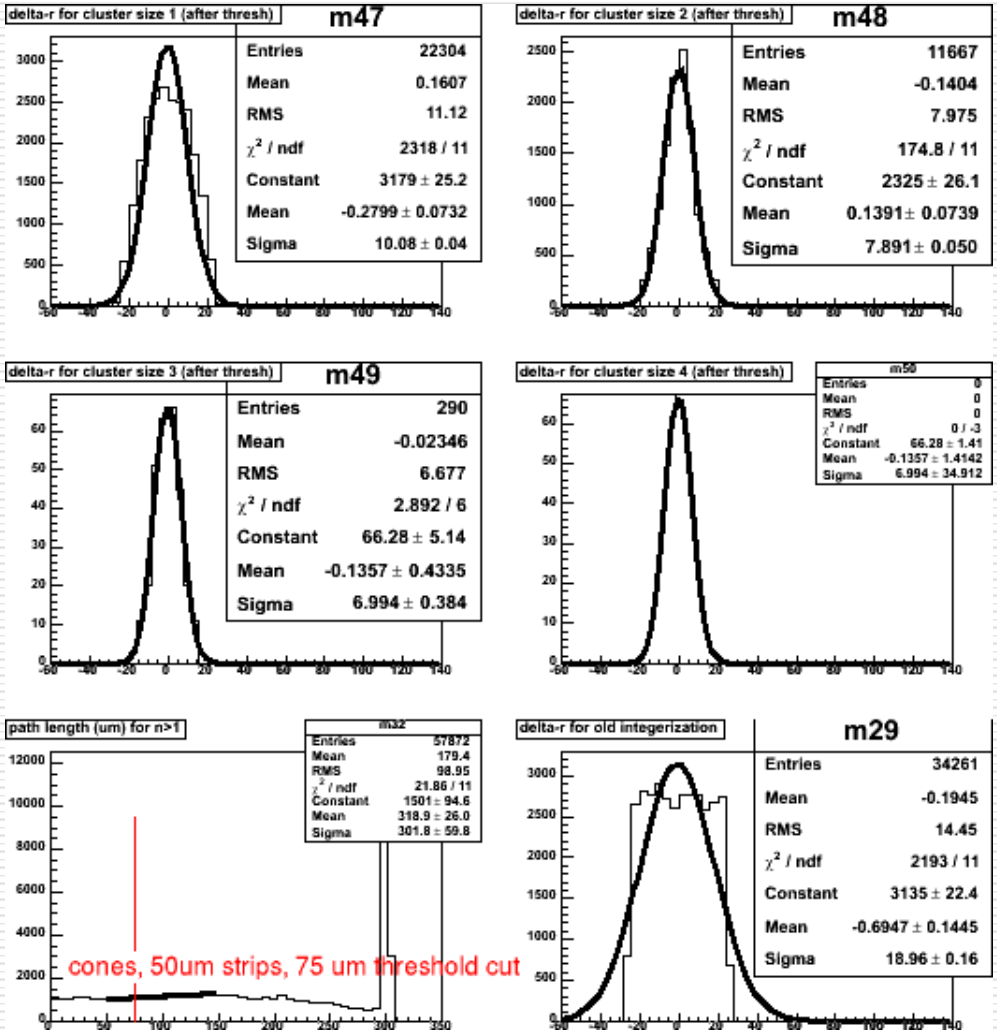
$\sigma_{pt} < DCA < \sigma_D$

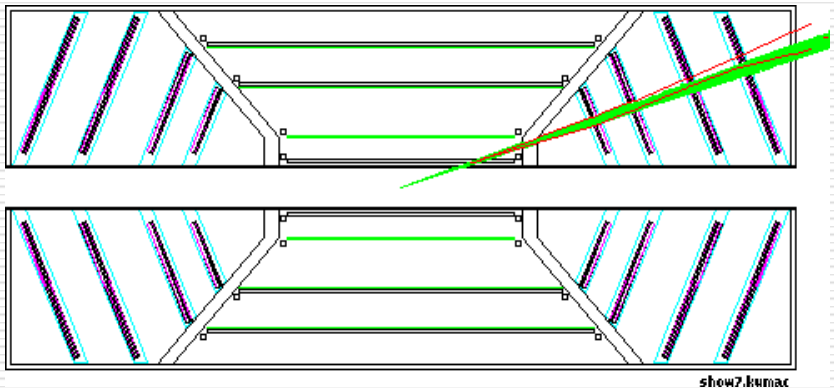
For B measurement: (1σ)

$\sigma_{pt} < DCA < \sigma_B$

Explore performance with different strip orientations

- Strip clustering, strip size and threshold cuts for the cone geometry
- Flat endcap simulaition

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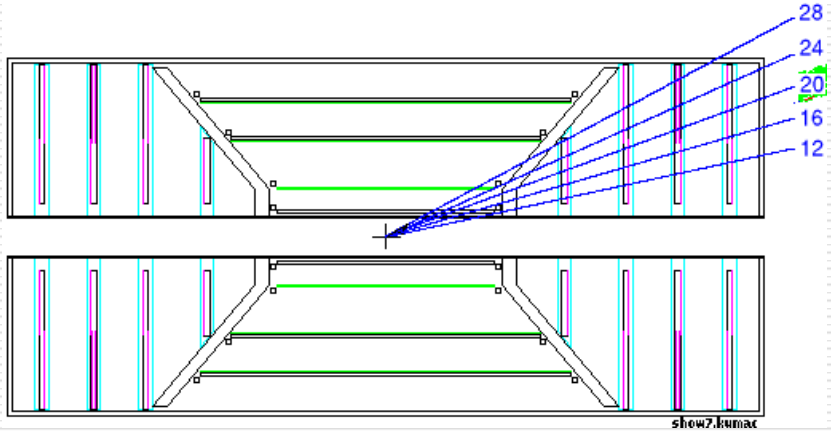
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