

Charmed Meson Reconstruction using Silicon Trackers in STAR Experiment at RHIC

- Motivation
- STAR Detector
- Microvertexing
- Results
- Summary and Future



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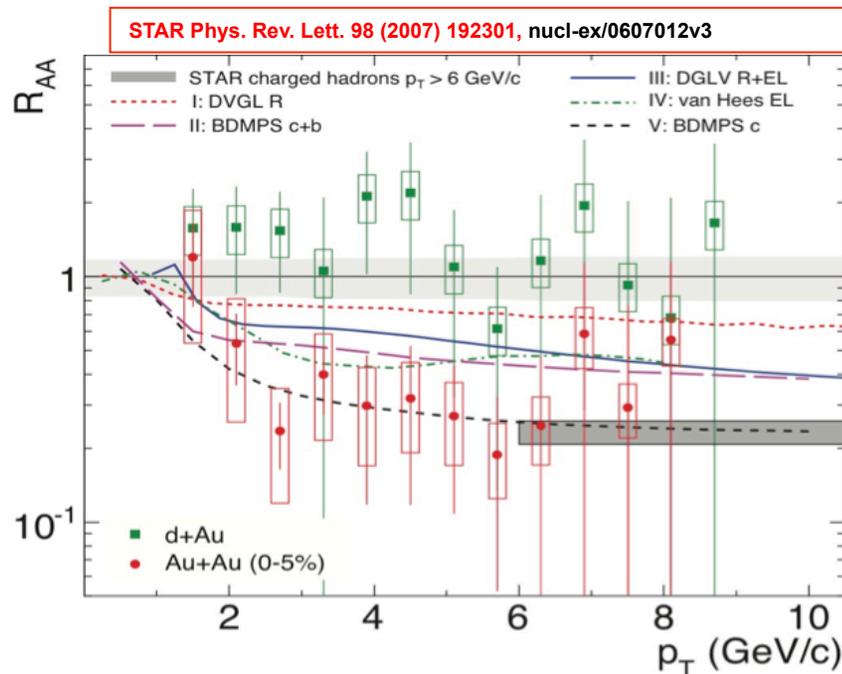


Why Charm Mesons?

□ Heavy quarks are produced during the early stages of collision mainly through gluon fusion.

- They are unaffected by chiral symmetry restoration
- Their production cross-section scales with binary collisions

Heavy quarks are ideal to probe the medium created in HI collisions.



□ Their measurement through semi-leptonic decay channel shows suppression levels comparable to light quarks at $p_T \geq 6$ GeV[1]

$$R_{AA}(n.p.e.) \sim R_{AA}(h^\pm)!$$

□ This contradicts theoretical predictions

- Dead-cone effect[2]

□ A measurement of charm elliptic flow, v_2 can tell us if thermalization is reached during early stages of collision.

Need to understand the mechanism of parton energy loss and Thermalization

[1] B. I. Abelev et al (STAR Collaboration), *Phys.Rev.Lett.*98:192301,2007; *Erratum-ibid.*106:159902,2011
 Adare A et al. (PHENIX Collaboration) 2010 *arXiv:1005.1627*
 [2] Dokshitzer, Yuri L. and Kharzeev, D. E., *Phys. Lett. B*519

Measurement through Indirect & Direct Methods

Indirect measurement through Semi-leptonic decay channels:

- $D^0 \rightarrow e^+ + X$ (BR : 6.9 %)
- $D^{+/-} \rightarrow e^{+/-} + X$ (BR : 17.2%)

- ✓ Large p_T range.
- ✓ Relative contribution of electrons from B and D mesons are unknown.

Direct measurement through Hadronic decay channels

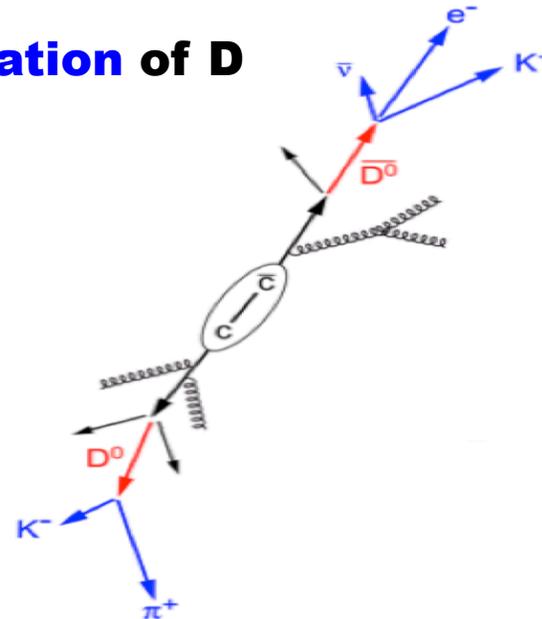
- $D^0(\bar{D}^0) \rightarrow K^-\pi^+(K^+\pi^-)$ (BR : 3.8 %)
- $D^{+/-} \rightarrow K\pi\pi$ (BR : 9.2%)

- ✓ Limited to low momentum range.
- ✓ C and B contributions separated.
- ✓ Challenging for charm mesons due to small decay length

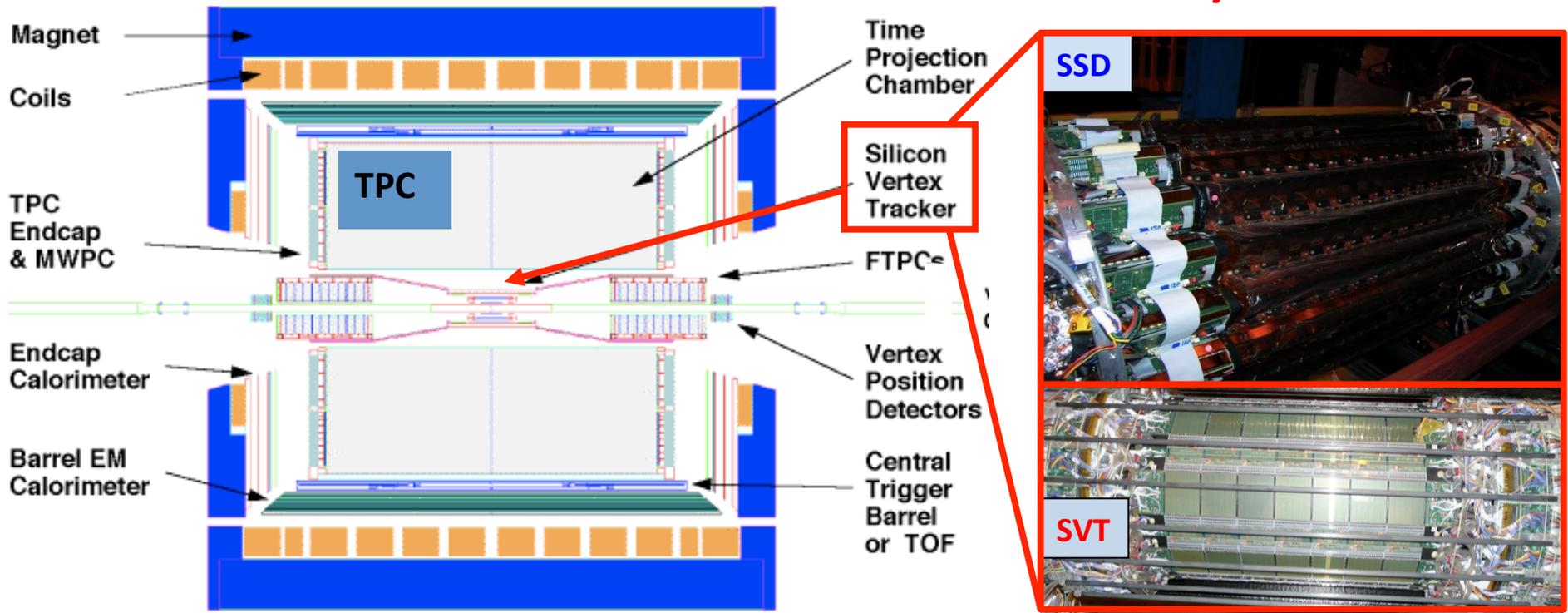
Measurement using azimuthal correlation of D mesons with e^-

Azimuthal correlation of open charm mesons with non-photonic Electron can be utilized to disentangle the charm and bottom contributions[3]

- ✓ Triggers on high p_T electrons



STAR detector (in 2007)



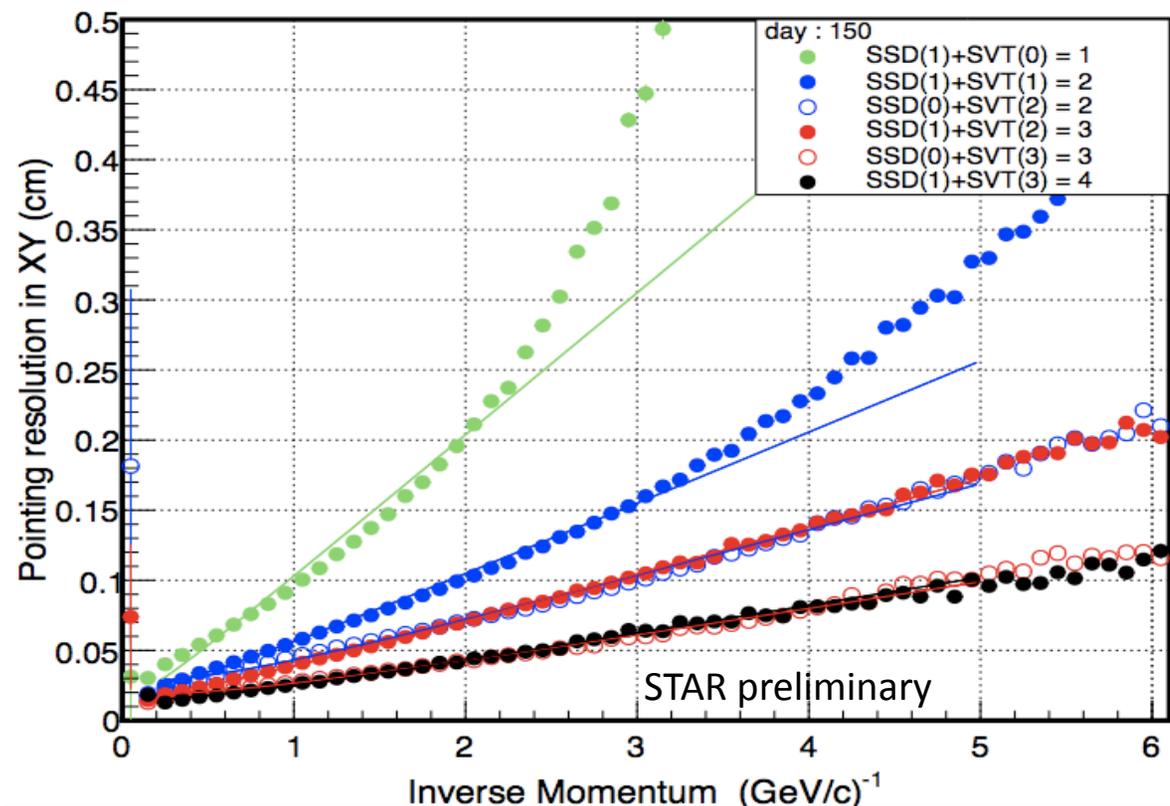
The tracking system consisted of :

- **TPC** : provides momentum, particle identification
- Silicon detectors :
 - 1 layer of silicon **strip** detectors (**SSD**) and 3 layers of silicon **drift** detectors (**SVT**).
 - **high spatial resolution** : pointing resolution of **250 μ m** in transverse direction (at 1GeV) was achieved[*] (next slide).
 - was not designed (thickness, geometry) for charm measurement.

[*] Fisyak Y V et al. 2008 J. Phys. Conf. Ser. 119 032017

Distance of Closest Approach resolution

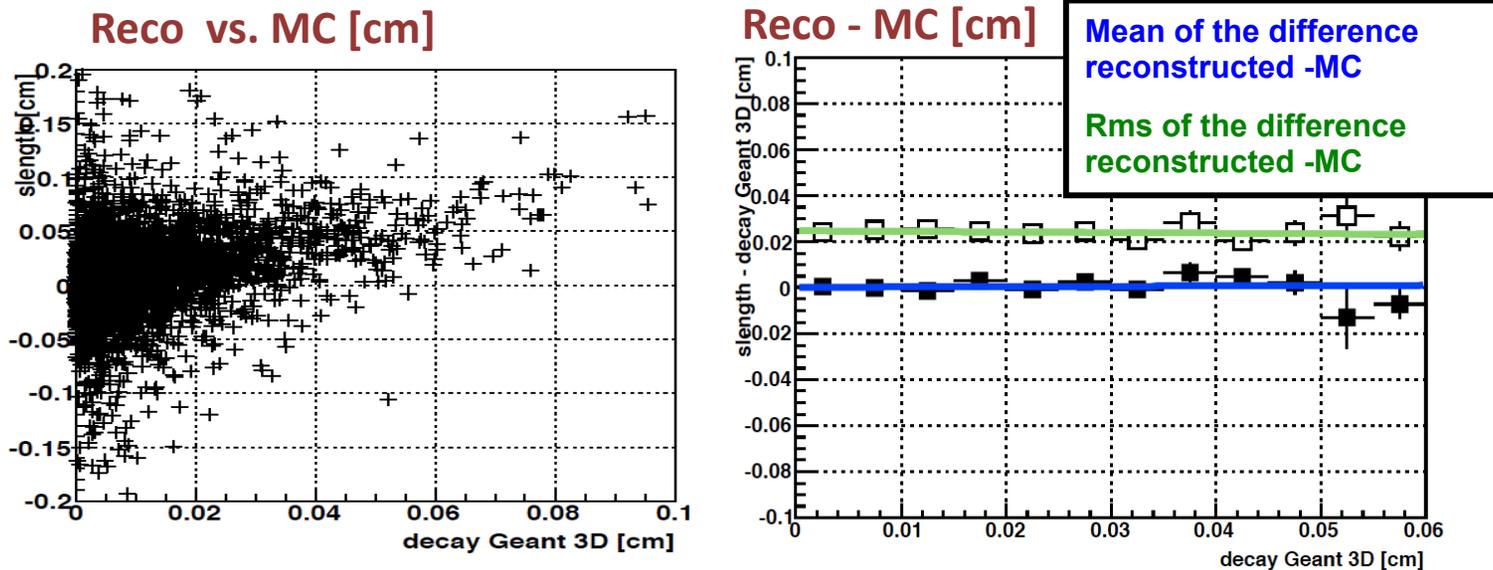
- run 7 Au+Au@200GeV (MinBias trigger).
- DCA resolution as a function of inverse momentum.
- Reflect the resolution and Multiple Coulomb Scattering.



- ➔ Including the silicon detectors in the tracking improves the pointing resolution.
- ➔ with 4 silicon hits, the pointing resolution to the interaction point $\sim 250 \mu\text{m}$ at $P = 1\text{GeV}/c$.

Microvertexing using STAR Silicon Detectors

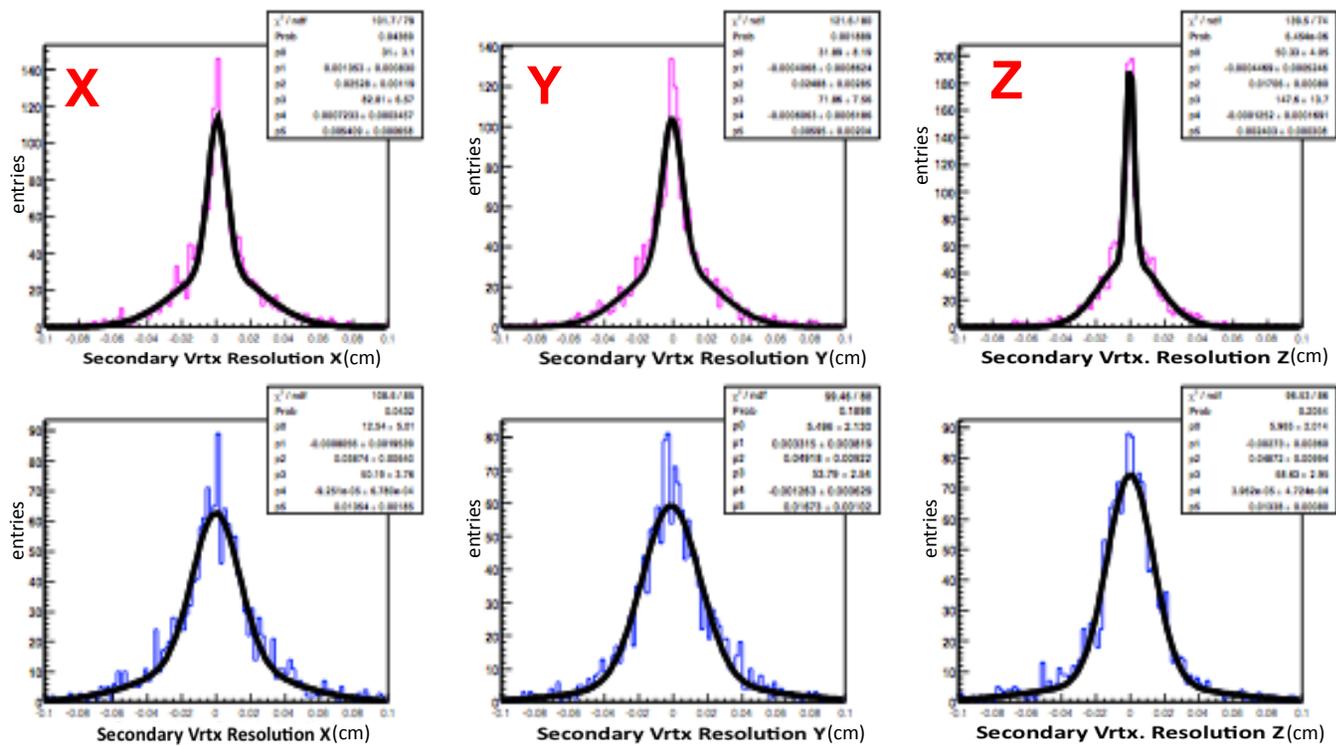
- ✧ We tried a **full topological reconstruction** of the charm decay. The method uses a constrained fit for decay vertex reconstruction[*]
- ✧ The code uses full track/error information.



- There is **no systematic shift** in reconstructed quantities.
- The **standard deviation** of the distribution is flat at $\sim 250 \mu\text{m}$, which is of the order of the resolution of (SSD+SVT).

[*] Decay Chain Fitting with a Kalman Filter, W. D. Hulsbergen (arxiv:physics,0503191)

Secondary Vertex Resolution Plots (x,y,z)



Fit Method
(central region)
 $\sigma_{XY} \sim 55\mu\text{m}$
 $\sigma_z \sim 25\mu\text{m}$

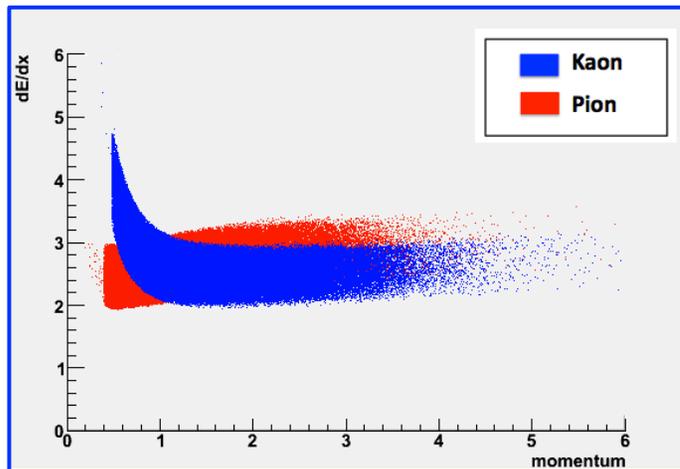
Helix Swimming Method
(central region)
 $\sigma_{XY} \sim 150\mu\text{m}$
 $\sigma_z \sim 135\mu\text{m}$

Simulation results shows that a factor of two was gained in secondary vertex Resolution

D⁰/D⁰bar Cross-feed

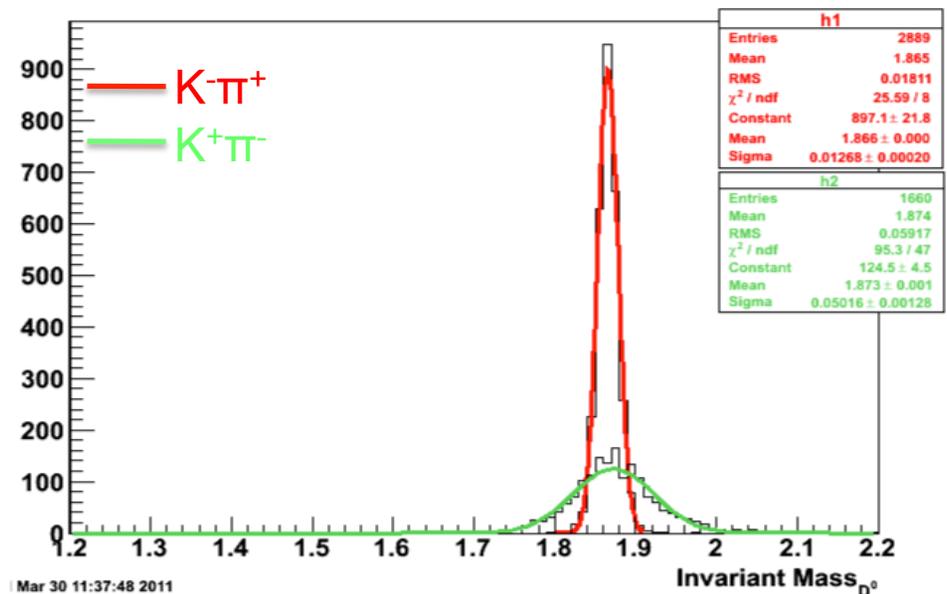
(Monte Carlo using power law $p_T D^0$)

- The D⁰ candidates are built by combining a K⁻ and π⁺ track (D⁰ → K⁻π⁺)
- Because of the overlapping dE/dx bands of Kaon and Pion tracks, at intermediate momenta



- ➔ a K⁻ can be identified as π⁻
- ➔ a π⁺ can be identified as a K⁺
- ➔ Therefore, K⁻π⁺ → K⁺π⁻ and can contribute to the the D⁰bar mass window and a **pseudo-enhancement**.

- The X-feed is reduced
 - with a tighter cut on $|\eta\sigma|$ (better PID)
 - with increase in p_T
- X-feed has a strong dependence on the Kaon opening angle, $\text{Cos}(\theta^*)$



The estimated overall X-feed (Ratio of reconstructed pairs with wrong signs to all pairs) ~ 35%

Data Production

Initial analysis of the Au-Au dataset (34 Million Events) is complete. Although the cuts used were not optimized, we got preliminary results from this production (next slides). A new production of run-7 data using the microvertexing code was just completed. Analysis is in progress.

Highlights of this new production/analysis set-up:

- ✓ We calculate the flow parameter, v_2
- ✓ All charge combinations (D^0 , $D^0\text{bar}$, $++$, $--$) are included for study of systematics
- ✓ Optimized cuts

New Cuts

Event Level: Primary vertex position along the beam axis : $|\mathbf{zvertex}| < 10 \text{ cm}$
Resolution of the primary vertex position along the beam axis: $|\sigma_{\mathbf{zvertex}}| < 200\mu\text{m}$

Track: **Ratio TPC hits Fitted/Possible > 0.51**

Pseudo-rapidity : $|\eta| < 1.2$

dEdxTrackLength > 40 cm

Silicon Hits: **SiHit > 1**, radius of 1st Hit < 9cm if SiHit = 2
else, radius of 1st Hit < 13cm
DCA to Primary vertex (transverse), **DCA_{xy} < .2 cm**

Track momenta: **$p_K + p_\pi > 1.5\text{GeV}$**

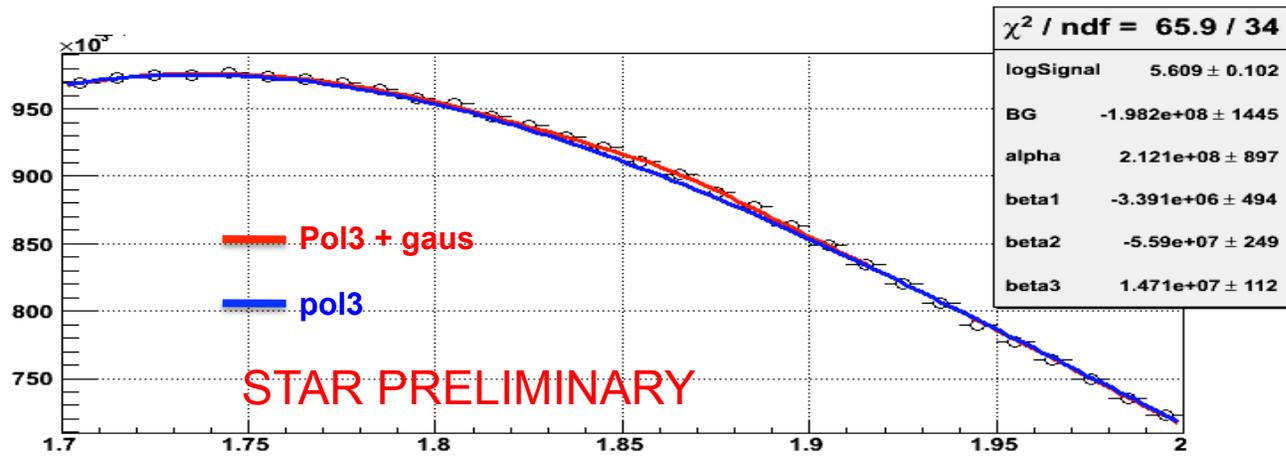
Particle ID: **$|\mathbf{n}\sigma_K| < 2.5$, $|\mathbf{n}\sigma_\pi| < 2.5$**

D^0 candidate: **$|\mathbf{y}(D^0)| < 1$, $|\cos(\theta^*)| < 0.8$**

DECAY FIT level: **Probability of fit > 0.01 && $|\mathbf{sLength}| < .1\text{cm}$**

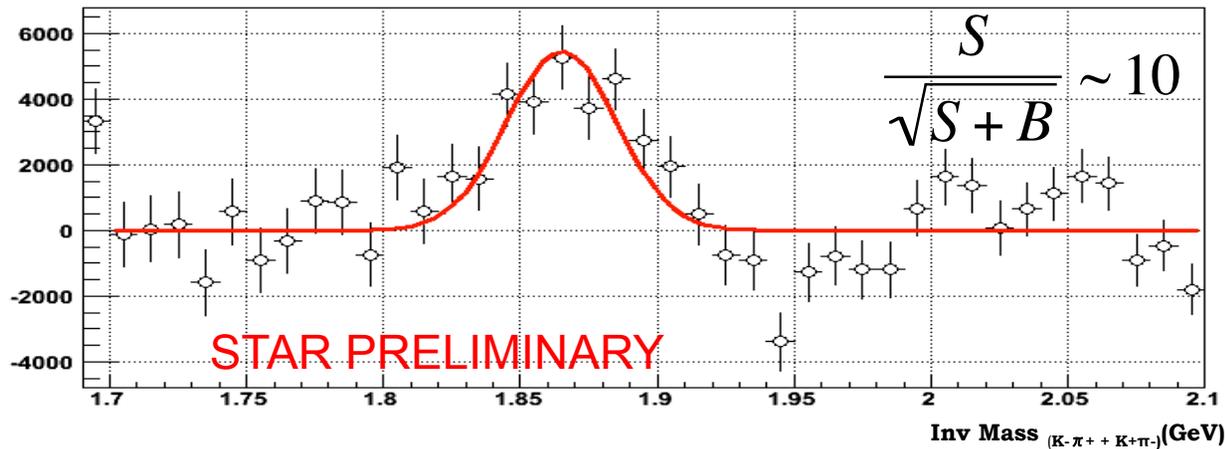
D⁰+D⁰bar signal

in 2007 Data (MinBias Files)



◆ 34 Million Events used for this analysis.

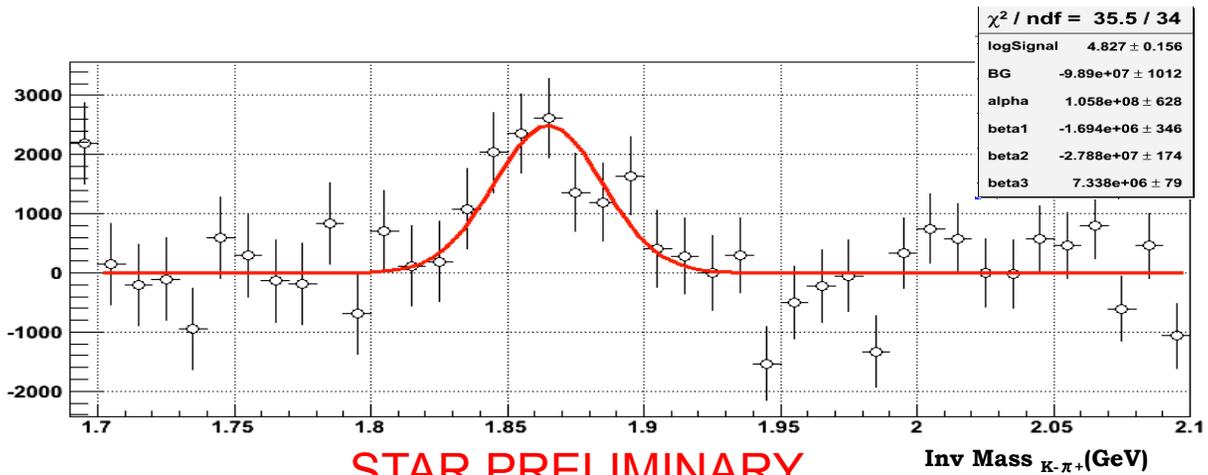
◆ Kinematic fit yields an improved significance of 10σ for combined D⁰+D⁰bar.



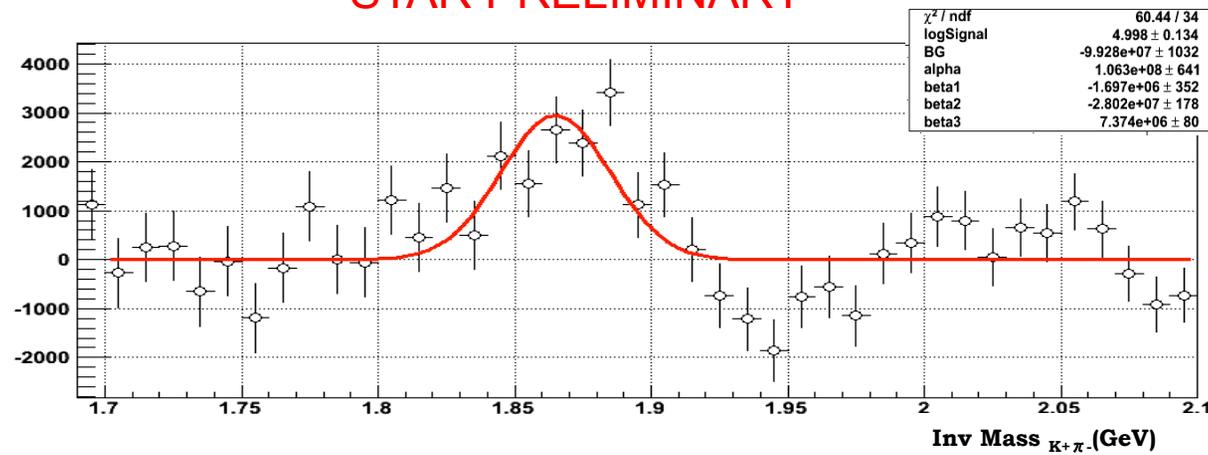
◆ The signal is somewhat sensitive to the degree of the pol. Fit.

◆ Need a robust backgr. estimation method (new production)

D^0 and $D^0\bar{\text{bar}}$ separately



STAR PRELIMINARY



Preliminary $D^0\bar{\text{bar}}/D^0$ ratio $\sim 1.05 \pm 0.19(\text{stat.})$

Summary

- We present progress on a method for full Topological reconstruction of open charm mesons.
- Ongoing efforts to measure cross-section (with smaller errors) and some D^0 flow(v_2)
- Method developed is baseline for analyses involving the future upgrade of STAR – Heavy Flavor Tracker (HFT), which will provide unambiguous measurement of charm.

Thank you

Back-Up

2007 Production MinBias

- cut changed
- new cut

Cuts from Previous Production

EVENT level

triggerId : 200001, 200003, 200013
Primary vertex position along the beam axis :
 $|z_{\text{vertex}}| < 10 \text{ cm}$
Resolution of the primary vertex position along the beam axis:
 $|\sigma_{z_{\text{vertex}}}| < 200 \mu\text{m}$

TRACKS level

Number of hits in the vertex detectors :
SiliconHits > 2 (tracks with sufficient DCA resolution)
Transverse Momentum of tracks:
 $p_T > .5 \text{ GeV}/c$
Momentum of tracks:
 $p > .5 \text{ GeV}/c$
Number of fitted:
TPC hits > 20
Pseudo-rapidity : **$|\eta| < 1$** (SSD acceptance)
dEdxTrackLength > 40 cm
DCA to Primary vertex (transverse),
 $\text{DCA}_{xy} < .1 \text{ cm}$

Cuts in New Production

EVENT level

triggerId : 200001, 200003, 200013
Primary vertex position along the beam axis :
 $|z_{\text{vertex}}| < 10 \text{ cm}$
Resolution of the primary vertex position along the beam axis:
 $|\sigma_{z_{\text{vertex}}}| < 200 \mu\text{m}$

TRACKS level

Number of hits in the vertex detectors:
SiliconHits > 1
Transverse Momentum of tracks:
 $p_T > .5 \text{ GeV}/c$
Momentum of tracks
 $pK + pPi > 1.5 \text{ GeV}/c$
Ratio TPC hits Fitted/Possible > 0.51
Pseudo-rapidity : **$|\eta| < 1.2$**
dEdxTrackLength > 40 cm
DCA to Primary vertex (transverse),
 $\text{DCA}_{xy} < .2 \text{ cm}$
Radius of first hit on track :
 $< 9 \text{ cm}$ if number of silicon hits = 2
 $< 13 \text{ cm}$ else

Continued..

Cuts from Previous production

Cuts in New Production

DECAY FIT level

Probability of fit >0.1 && $|sLength| < .1\text{cm}$

Particle ID : ndEdx : **$|n\sigma_K| < 2$, $|n\sigma_\pi| < 2$**

D⁰ candidate

**$|y(D^0)| < 1$
 $|\cos(\theta^*)| < 0.8$**

DECAY FIT level

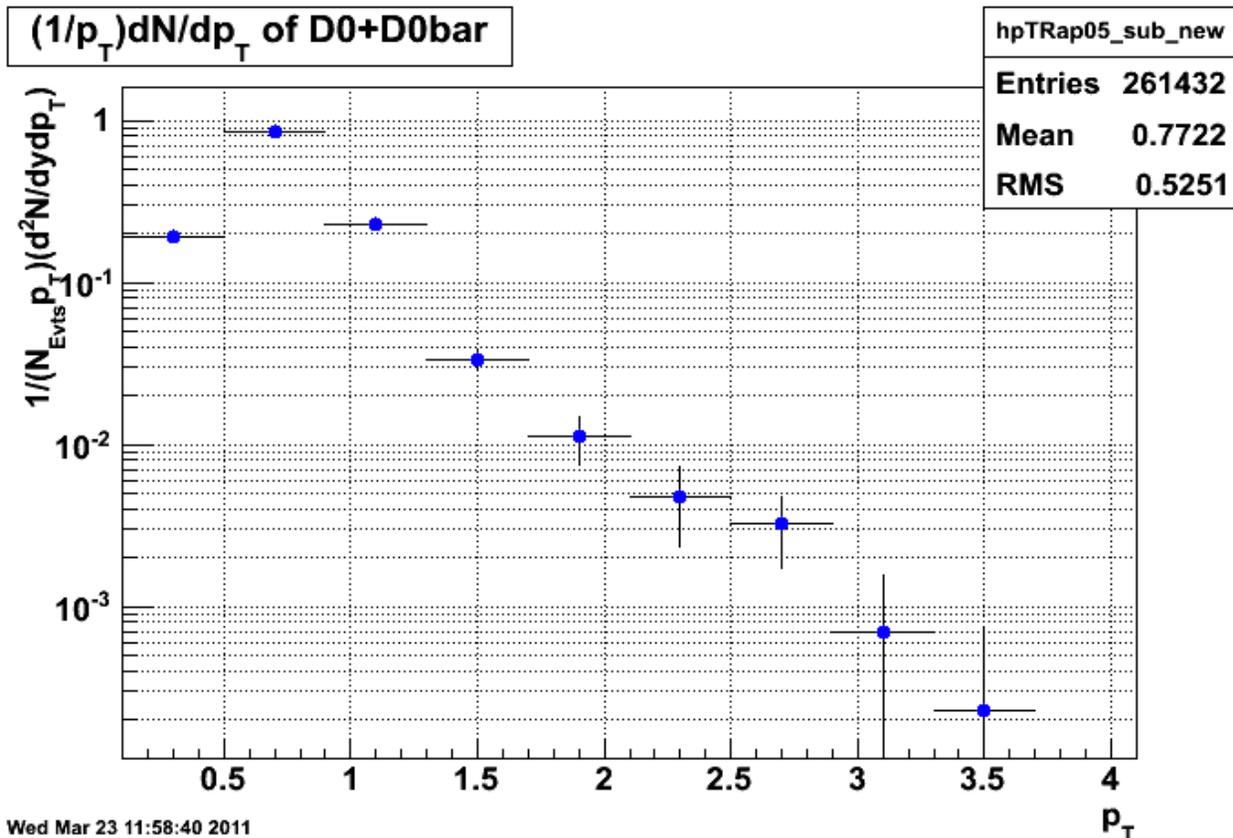
Probability of fit >0.01 && $|sLength| < .1\text{cm}$

Particle ID : ndEdx : **$|n\sigma_K| < 2.5$, $|n\sigma_\pi| < 2.5$**

In both productions we made a pico file for further analysis.

D⁰ –p_T distribution

$$\frac{1}{N_{Events} p_T} \frac{d^2 N}{dy dp_T}$$

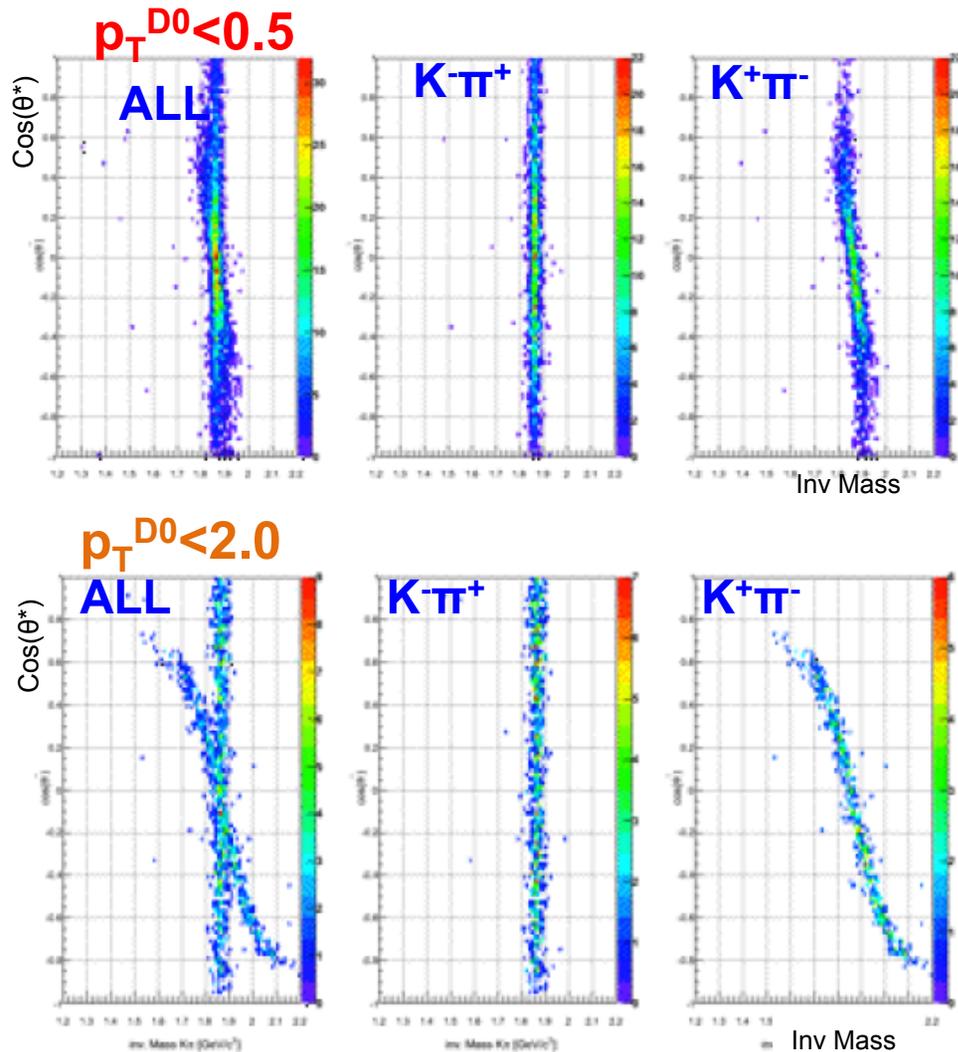


Uncorrected
p_T spectra for
D⁰+D⁰bar

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D⁰ p_T is done by subtracting from the central mass peak the normalized sum of the side bands.

Cross-feed Vs Kaon Opening Angle in the CM frame



For Low $p_T^{D^0}$:

Both true pairs and misidentified pairs have the distribution going from -1 to 1

For High $p_T^{D^0}$:

The true pairs have the same distribution (-1,1)
Misidentified pairs have shortened tails (-0.8,0.8)

The Cut* $|\text{Cos}(\theta^*)| < 0.6$, can be limited to the low $p_T^{D^0}$ s.

* The cut $|\text{Cos}(\theta^*)| < 0.6$ removes the poorly reconstructed soft tracks.