Charm and Beauty searches using e–D^0 azimuthal correlations and microvertexing techniques in STAR experiment at RHIC

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Outline

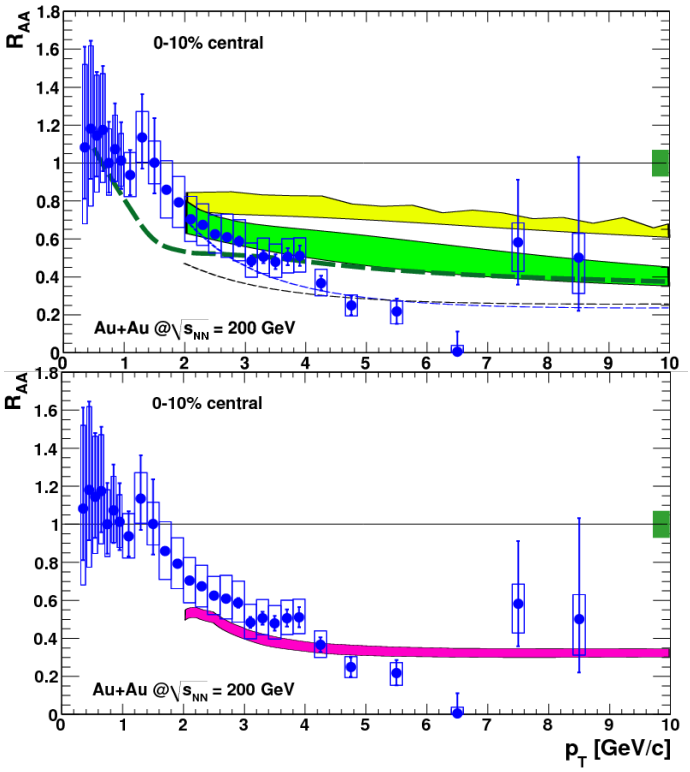
- Motivation
- Experimental Description
- Analysis Methodology
- Results

Motivation

Suppression in non photonic electron yields for B and D mesons decays in central AuAu collision

nuclear modification factor $R_{AA} = \frac{\text{Yield}_{AuAu} / \langle N_{binary} \rangle_{AuAu}}{\text{Yield}_{pp}}$

- **Similar** as observed for the **light quark hadrons**
- **Not expected** (dead cone-effect)
  D.Kharzeev et al. Phys Letter B. 519:1999
- **Theoretical Models** explaining the charm and bottom quark energy loss **are still inconclusive**
- Need for separation of D/B contributions in the spectra of non photonic electrons



MOTIVATION (cont'd)

A novel method of separating Charm and Bottom Contribution

Non photonic electrons are used to *trigger* on C or B quark pairs.

D meson is being reconstructed by its hadronic decay: *probe side*.

$$D^0 \rightarrow K^- \pi^+$$
$$\bar{D}^0 \rightarrow K^+ \pi^-$$

Calculate the Invariant Mass

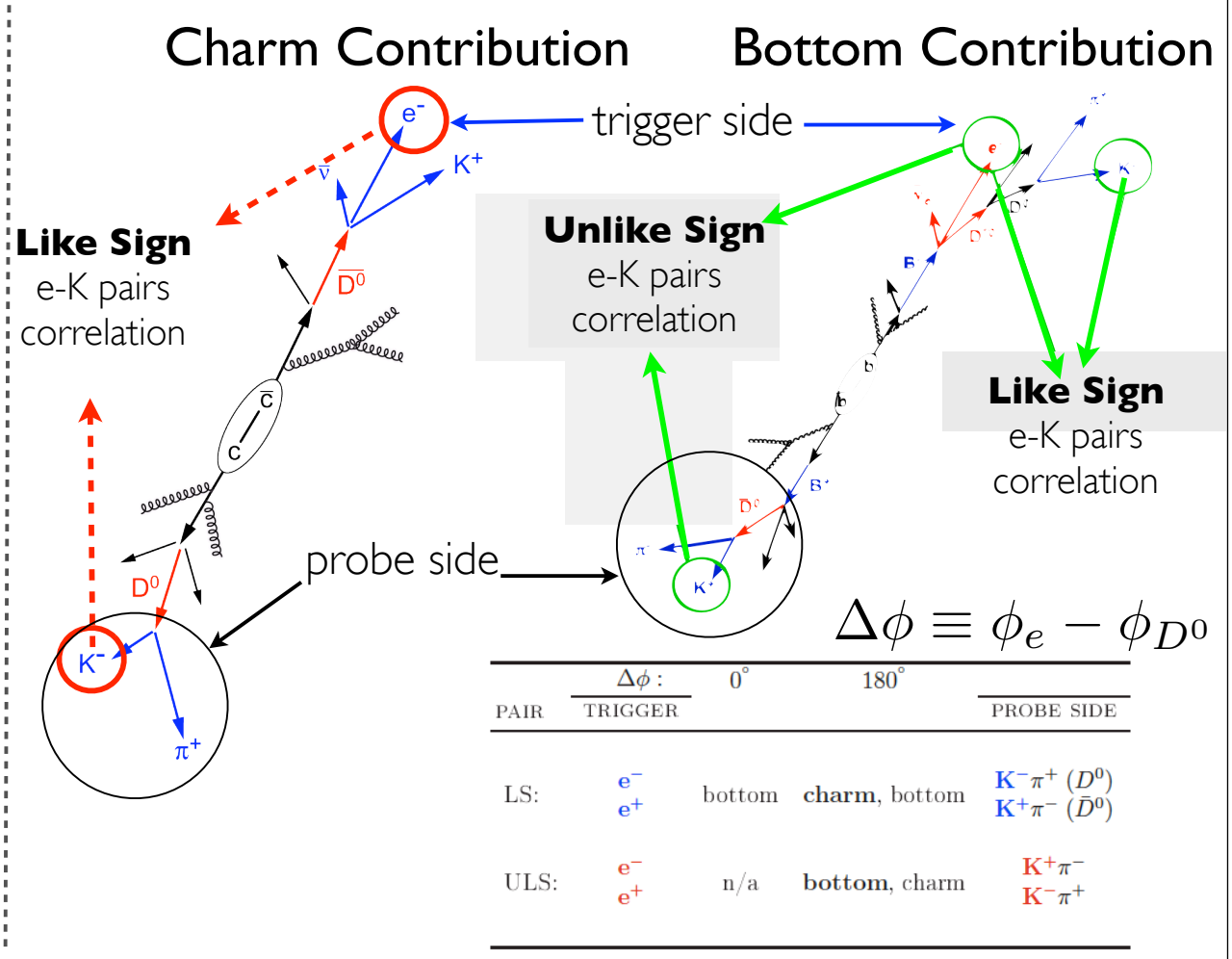
Calculate the Background:

I) Rotational Background

Kaon candidates are rotated by 180 degrees

II)Samesign Background

$$D^0 \not\rightarrow K^- \pi^-$$
$$\bar{D}^0 \not\rightarrow K^+ \pi^+$$



$$\Delta\phi \equiv \phi_e - \phi_{D^0}$$

PAIR	$\Delta\phi$: TRIGGER	0°	180°	PROBE SIDE
LS:	e^- e^+	bottom	**charm**, bottom	$K^-\pi^+$ (D^0) $K^+\pi^-$ ($\bar{D}^0$)
ULS:	e^- e^+	n/a	**bottom**, charm	$K^+\pi^-$ $K^-\pi^+$

STAR Experiment

STAR DETECTOR

Solenoidal Tracker at RHIC

Tracking and PID:

TPC **Magnet:** $\mathrm{B}{=}0.5\ \mathrm{T}$

$|\eta| < 1.5$

$\Delta p/p = 2\text{-}4\%$

$$\frac{\sigma_{dE/dx}}{dE/dx} = 8\%$$

Energy Measurement:

Barrel EMC

$|\eta| < 1.0$

Lead scintillation $(21\ X_0)$

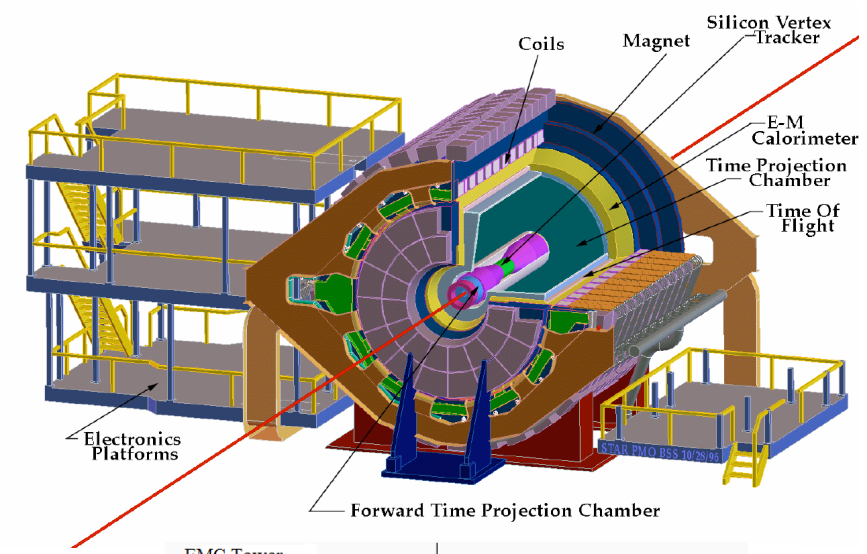
Shower Maximum Detector

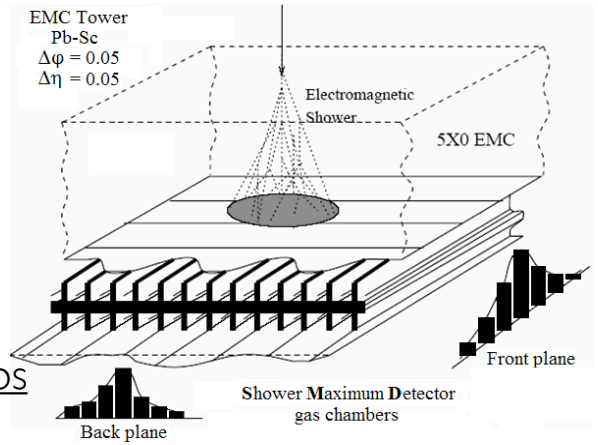
Wire proportional detector with strip readout

Situated at $5\ X_0$

Strip Resolution: $(\Delta\phi, \Delta\eta) = (0.007, 0.007)$

80% of the EM shower energy is being deposited in 2-3 strips

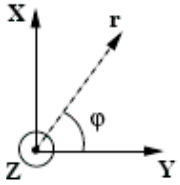




STAR Silicon Detectors

- Silicon Strip Detector

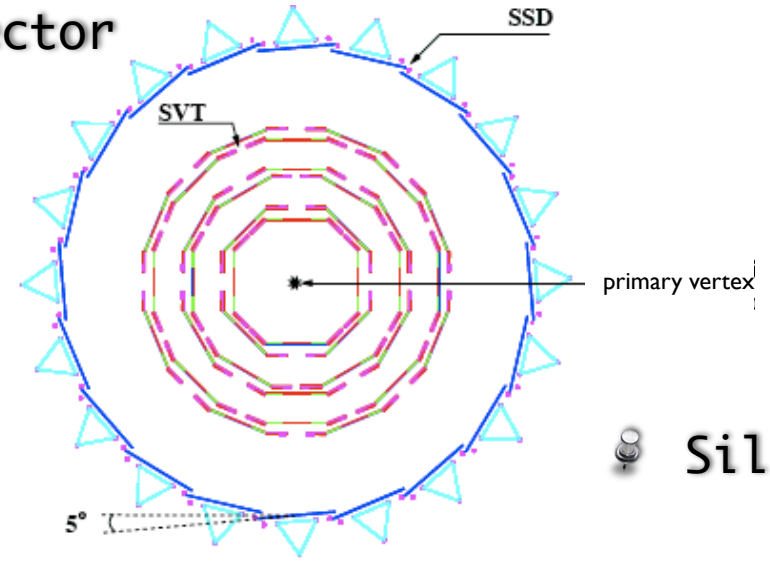
1 layer at 23 cm

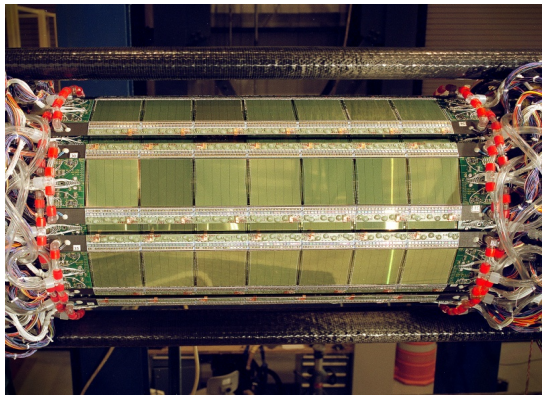


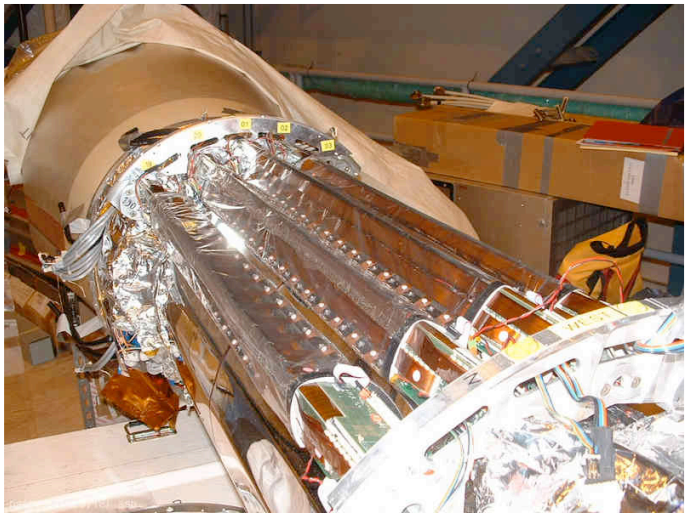
$\sigma_{r\phi} = 30\ \mu m$

$\sigma_Z = 800\ \mu m$

$1\%\ X_0$ per layer



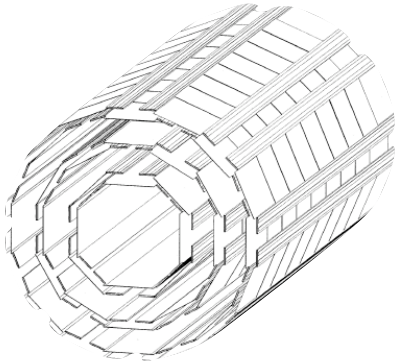




- Silicon Vertex Tracker

3 layers:

6.85 cm
10.80 cm
14.7 cm



$\sigma_Z = \sigma_{r\phi} = 40\ \mu m$

$1.5\%\ X_0$ per layer

ANALYSIS METHODOLOGY

Event and track cuts

Event level:

- Event cuts:|Primary vertex-Z|<20,30 cm
- Demand for a high-pT particle that trigger the BEMC (a.k.a. tower) Et>4.2 GeV (for Au+Au) and Et>5.4 GeV (for p+p 2006)

Particle level:

- Track quality cuts: $|\eta| < 1$ (for hadrons), TPC hits>15 (max:45)
- For electrons $|\eta| < 0.7$ avoiding the edges of the BEMC
  - Energy loss in the TPC expressed in standard deviations (σ) with a prior mass hypothesis: |nSigmaKaon|<a, |nSigmaPion|<b
  - Charge demand between the trigger particle and the kaon candidate (after passing the dE/dx-above cut)
- For the electron identification a more sophisticated set of cuts is applied.

Non-photonic electron (NPE) selection

- Energy loss $3.5 < \frac{dE}{dx} < 5.0(keV/cm)$

$p > 1.5GeV/c$

Extrapolate TPC tracks on the BEMC surface

Check for nearby towers within a distance

- Momentum over Energy of tower

EM showers deposit the whole amount of the particle's energy in the BEMC cells

Electrons p/E distribution is a Gaussian with a mean value p/E~1

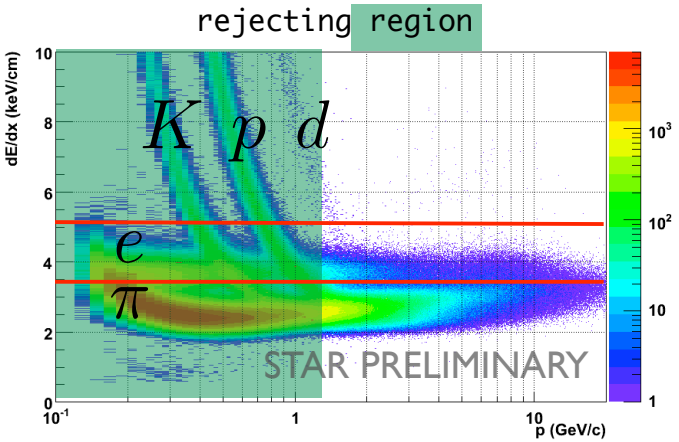
$$0 < \frac{p}{E} < 2$$

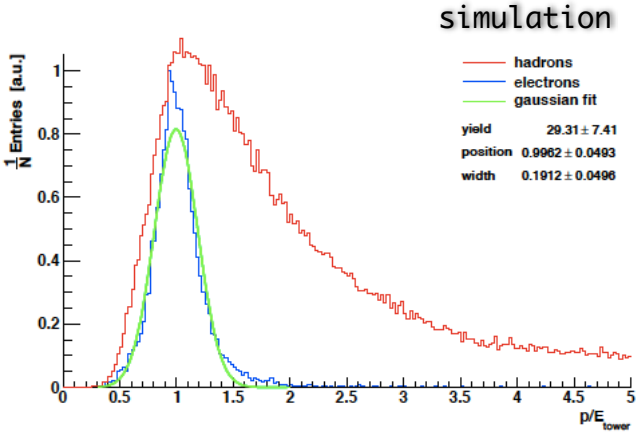
E measured by the BEMC

p measured by the TPC

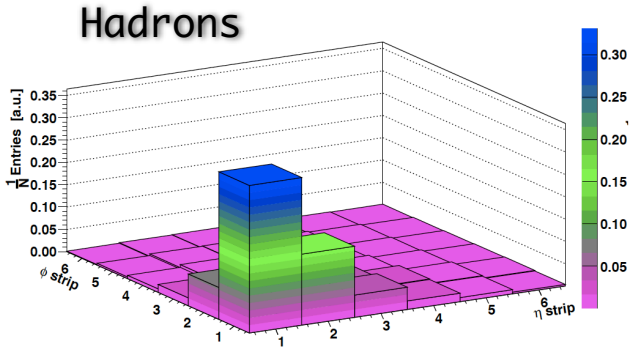
- Cut on the SMD strips-(Shower Maximum Detector)

SMD strips cut: hadron showers' profile develop in single strips as opposed to the electromagnetic ones. ~80% of the EM shower energy is being deposited in 2-3 strips

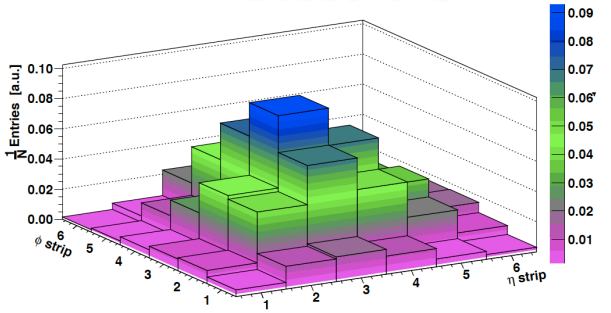




Hadrons



Electrons



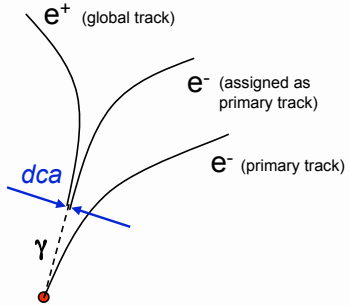
NPE selection

- **Sources of contamination:**

Photon Conversion (inside the material)

Conversion decay $\gamma \rightarrow e^- e^+$

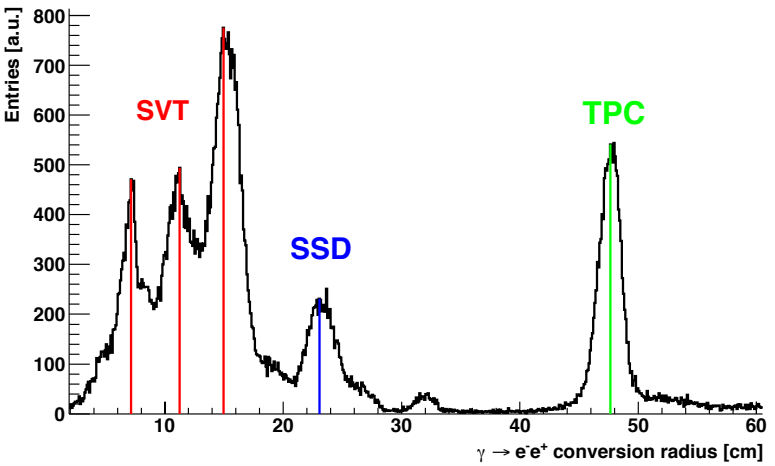
Neutral meson decay π^0, η

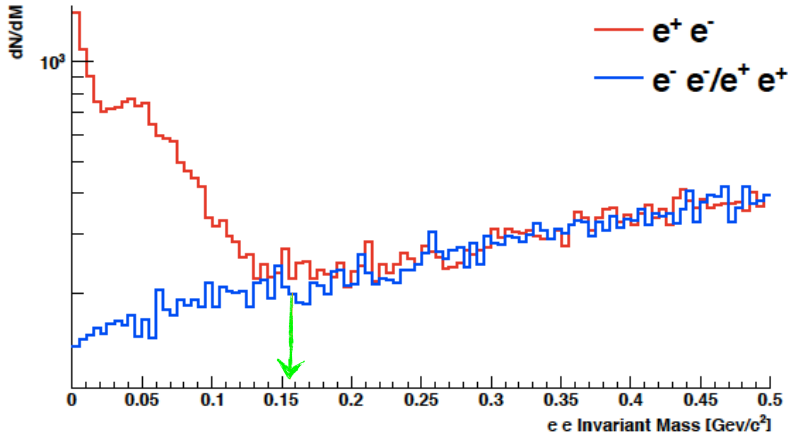


- **Discrimination Method:**

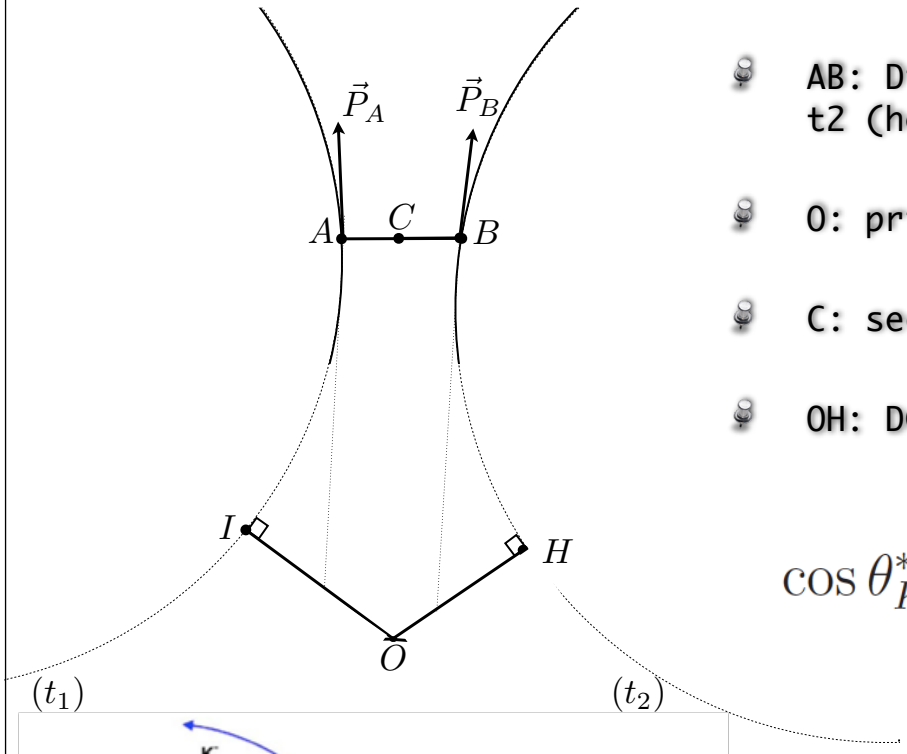
Calculate the invariant mass of every e^+e^- and e^+e^+/e^-e^-

Superimposing both plots indicates the cut at $> 150\,\mathrm{MeV/c^2}$



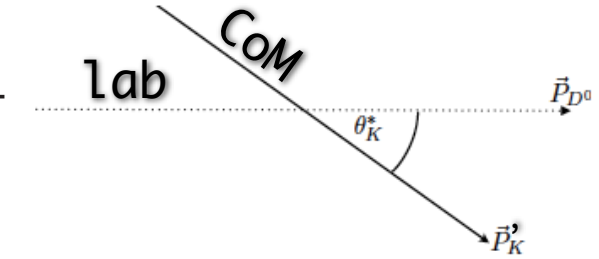


micro-Vertexing Technique

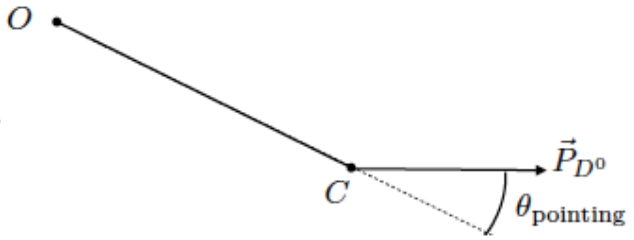


- AB: Distance of closest approach between tracks t1 and t2 (helices)
- O: primary vertex
- C: secondary vertex
- OH: DCA of tracks to primary vertex

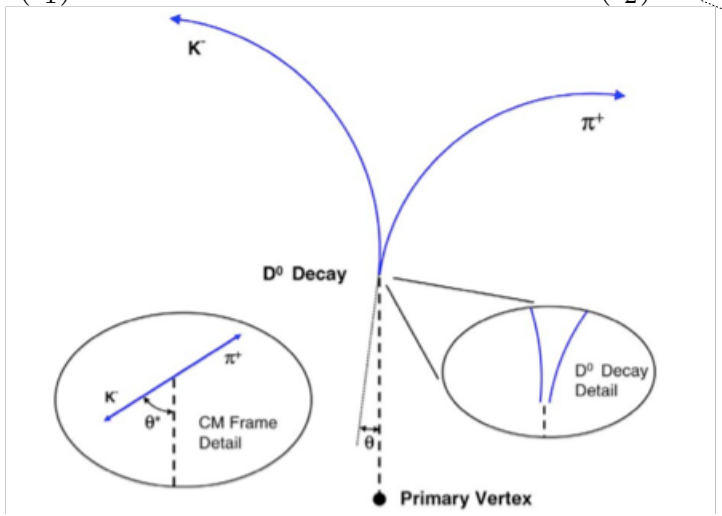
$$\cos\theta^*_K \equiv \frac{\vec{p}\,'_K \cdot \vec{P}_{D^0}}{|\vec{p}\,'_K||\vec{P}_{D^0}|}$$



$$\cos\theta_{\text{POINTING}} = \frac{\vec{OC}\cdot(\vec{P}_A+\vec{P}_B)}{|\vec{OC}|\cdot|\vec{P}_A+\vec{P}_B|}$$



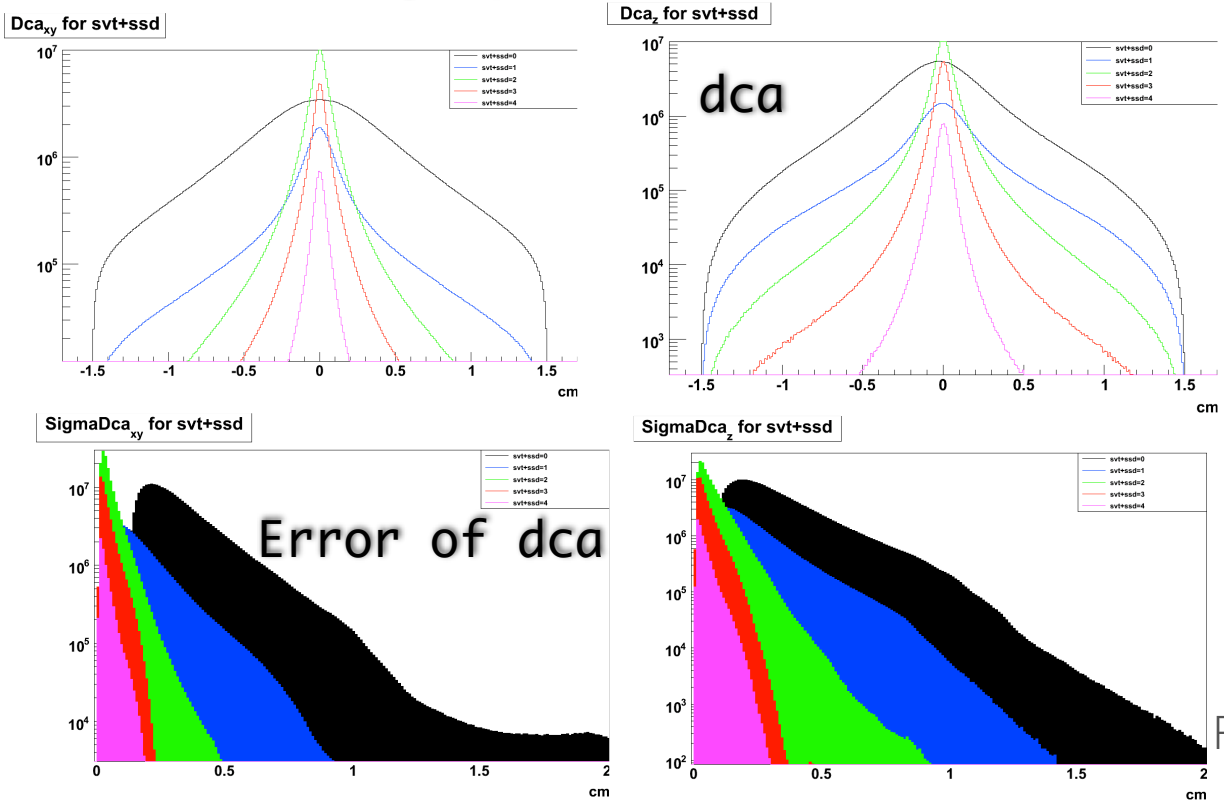
$$\text{DCA}_{D^0} = |\vec{OC}| \cdot \sin\theta_{\text{POINTING}}$$



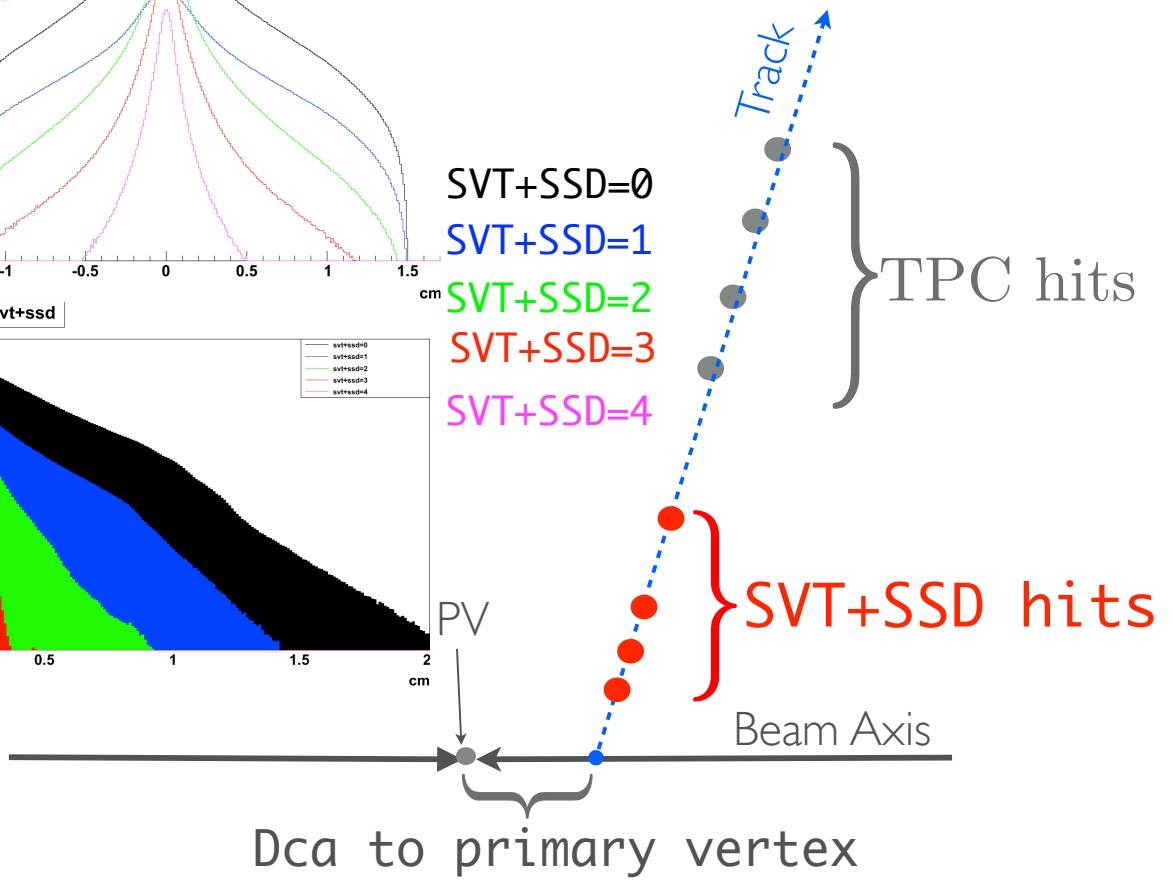
Track Fitting: DCA and error

Transverse (xy) plane

Z-axis



$AuAu@\sqrt{s} = 200\ GeV$

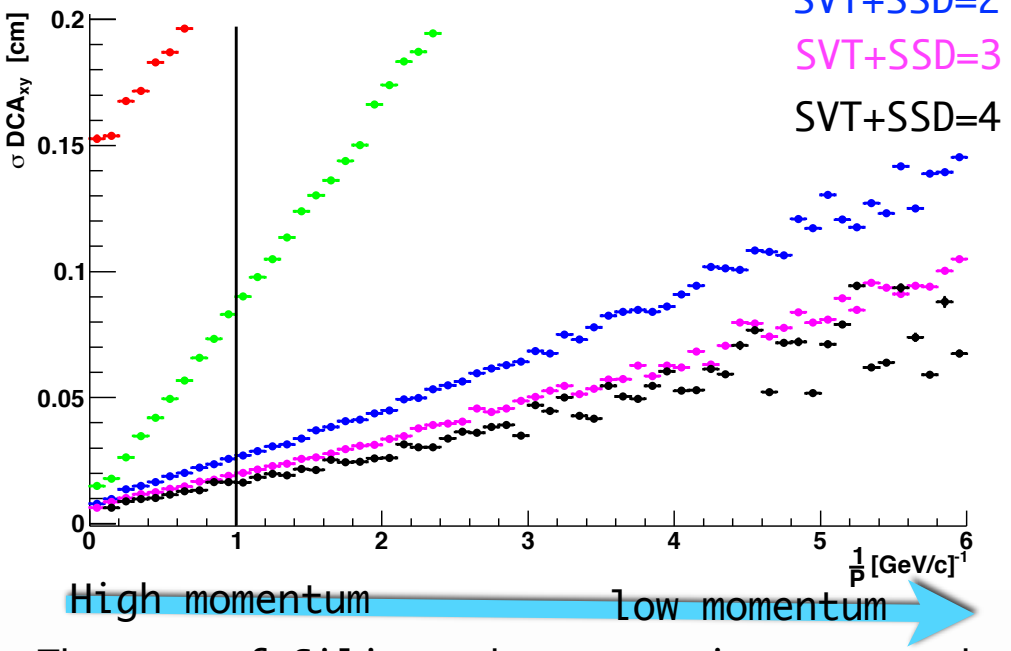


Tracking resolution vs. momentum

Multiple Coulomb Scattering:

Charged particles are deflected by an angle when passing through thin targets

$$\theta_0 = \frac{13.6\ [\mathrm{MeV}]}{\beta cp} z\sqrt{x/X_0}\left(1 + 0.038 \ln \frac{x}{X_0}\right)$$



$$\sigma(p) = \sqrt{a^2 + \frac{b^2}{p^2}}$$

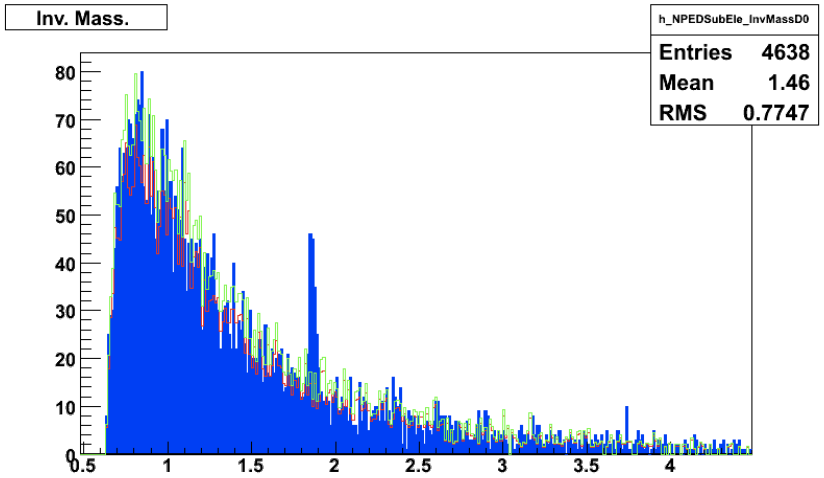
Tracking resolution at 1 GeV/c

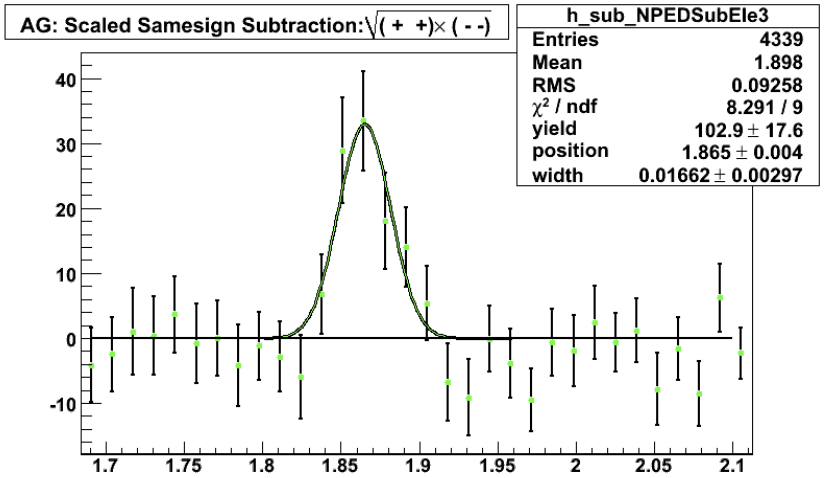
SVT+SSD hits	$\sigma\mathrm{DCA}_{xy}$ [μm]	$\sigma\mathrm{DCA}_{z}$ [μm]
	Au+Au	
0	2248.93 ± 0.96	2117.61 ± 0.68
1	900.66 ± 0.54	1430.63 ± 0.86
2	272.00 ± 0.16	379.71 ± 0.32
3	201.25 ± 0.16	240.00 ± 0.27
4	163.52 ± 0.38	195.11 ± 0.58

The use of Silicon detectors increases the pointing resolution by more than one order of magnitude

RESULTS

SIMULATION-pp2006





Fit results

Peak position m = 1865 ± 4 MeV/c^2

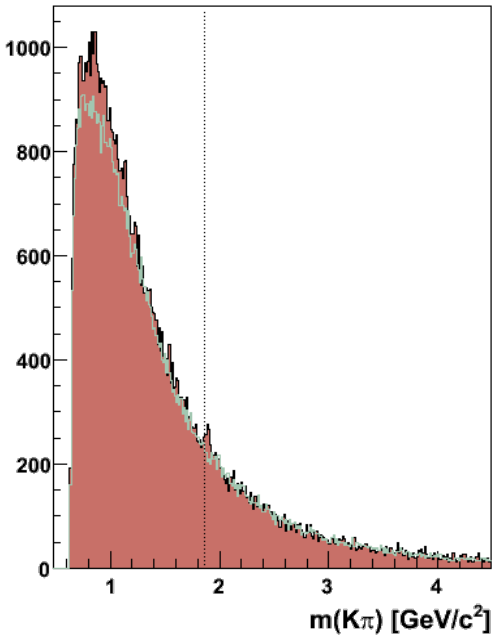
Width of the signal σ_m = 17 ± 3 MeV/c^2

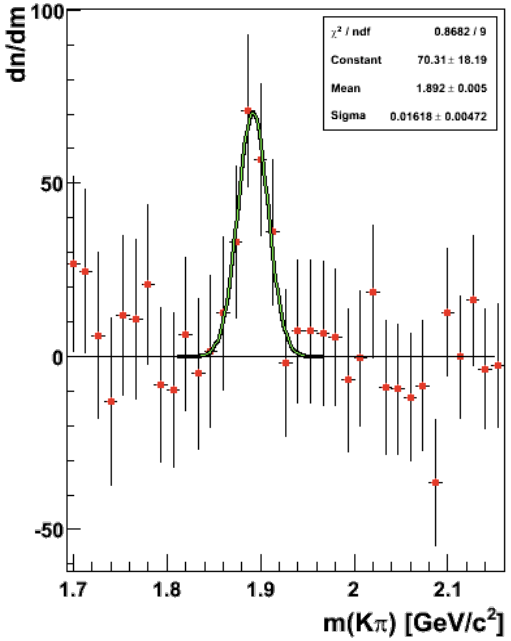
Invariant mass

Samesign invariant mass $\sqrt{K^-\pi^- \otimes K^+\pi^+}$

Rotational invariant mass $\sqrt{E_1E_2 - |\vec{p}_1||\vec{p}_2|\cos(\theta + \theta_{\rm rot})}$

DATA-pp2006 at $\sqrt{s_{\mathrm{NN}}} = 200\,\mathrm{GeV}$





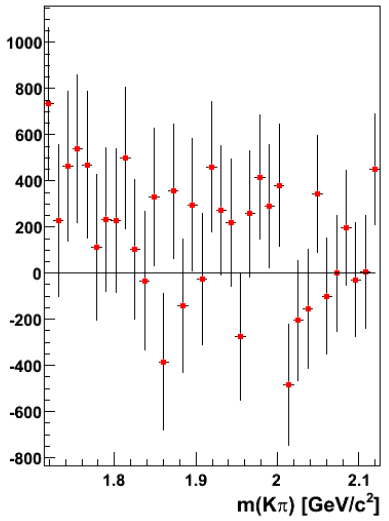
Fit results

Peak position m = 1892±5 MeV/c^2

Width of the signal σ_m = 16±5 MeV/c^2

Signal-to-background ratio ~0.14%

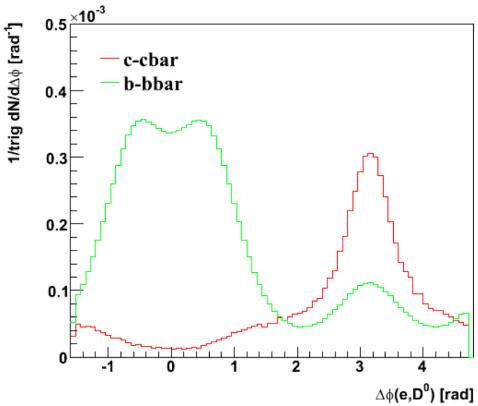
Signal significance ~3.7

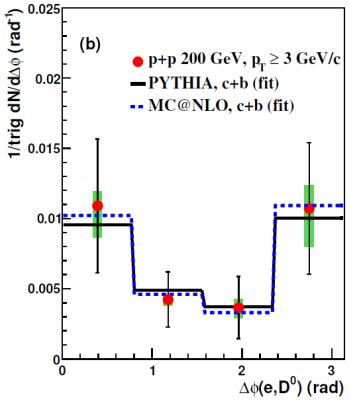


Demand on electron triggered events reduces background **by a factor of 100**

J. Phys. G35, 104117 (2008)

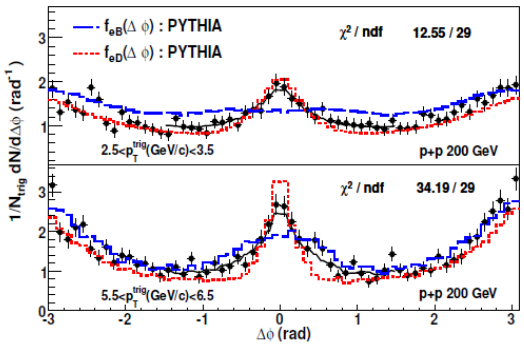
DATA-pp2006





Charm to beauty ratio obtained form the real data is in agreement with PYTHIA simulations

Heavy flavor contribution to non-photonic electrons



B much heavier than D

↓

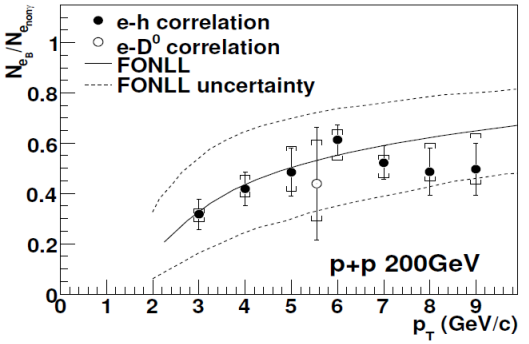
Sub leading electrons get a larger kick from B

↓

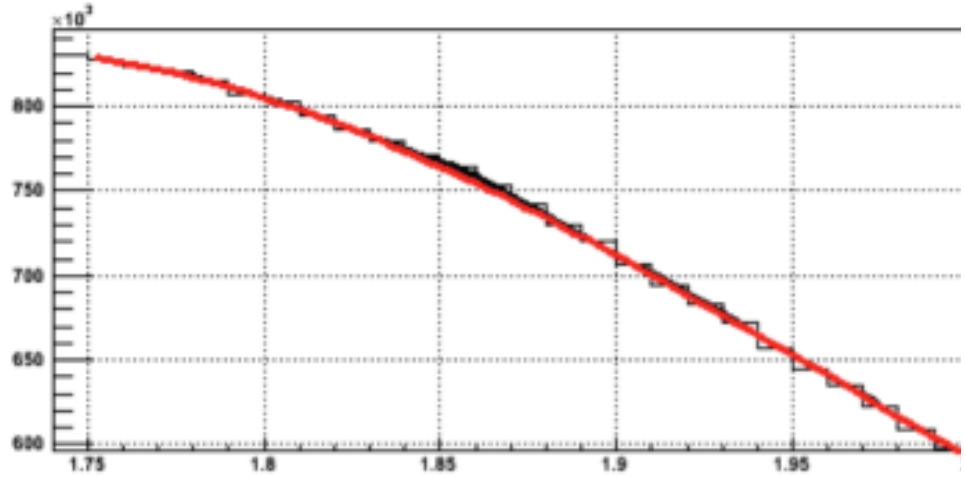
Near side e-h correlation is broadened

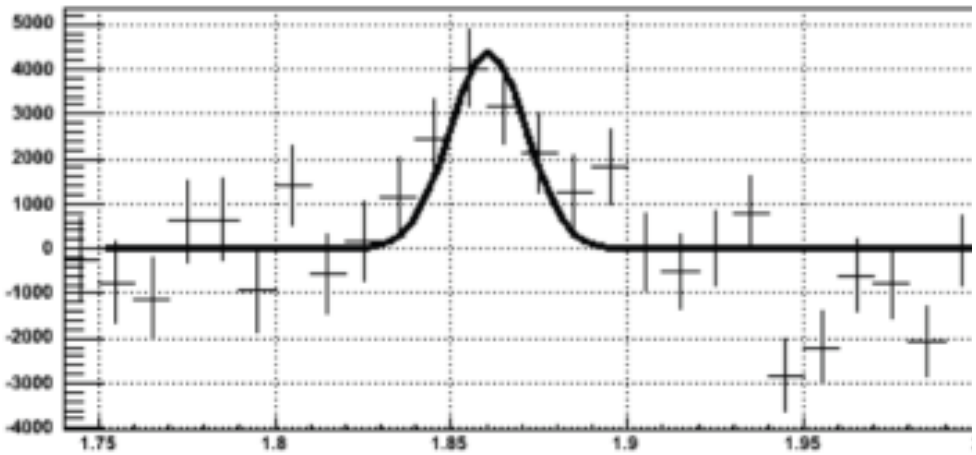
Conclusion from e-h and e-D correlations:

B contribution to non photonic electrons is ~50% at p_T~ 5 GeV/c



AuAu2007 at $\sqrt{s_{\mathrm{NN}}} = 200\,\mathrm{GeV}$





Min Bias

Statistics ~35M
Peak significance ~5.16

Samesign
Background
Subtraction

Summary & Outlook

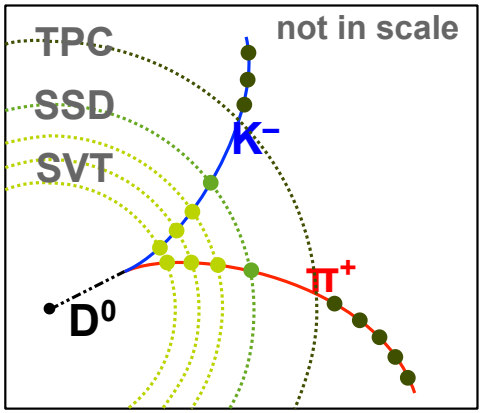
- Studies on e-D0 correlation in p+p collisions have been presented
  - Observed results agrees with the simulation within the errors
  - B contribution to non photonic electrons is ~50% at p_T~ 5 GeV/c
  - e-h and e-D0 correlations are consistent with each other

- Ongoing studies on e-D0 correlation in Au+Au at $\sqrt{s_{\mathrm{NN}}} = 200\,\mathrm{GeV}$
  - MicroVertexing techniques have been developed and successfully applied to the data
  - A peak of D0 has been observed
  - Further analysis are still needed to optimize the cuts
  - A comparison with models is on the way

Reconstruction of the D^0 decay

$D^0 \rightarrow K^-\pi^+$ BR: 3.89%

c_T = 123 μm



D^0 decay

Reconstructed Tracks

Helix of negatively charged particle

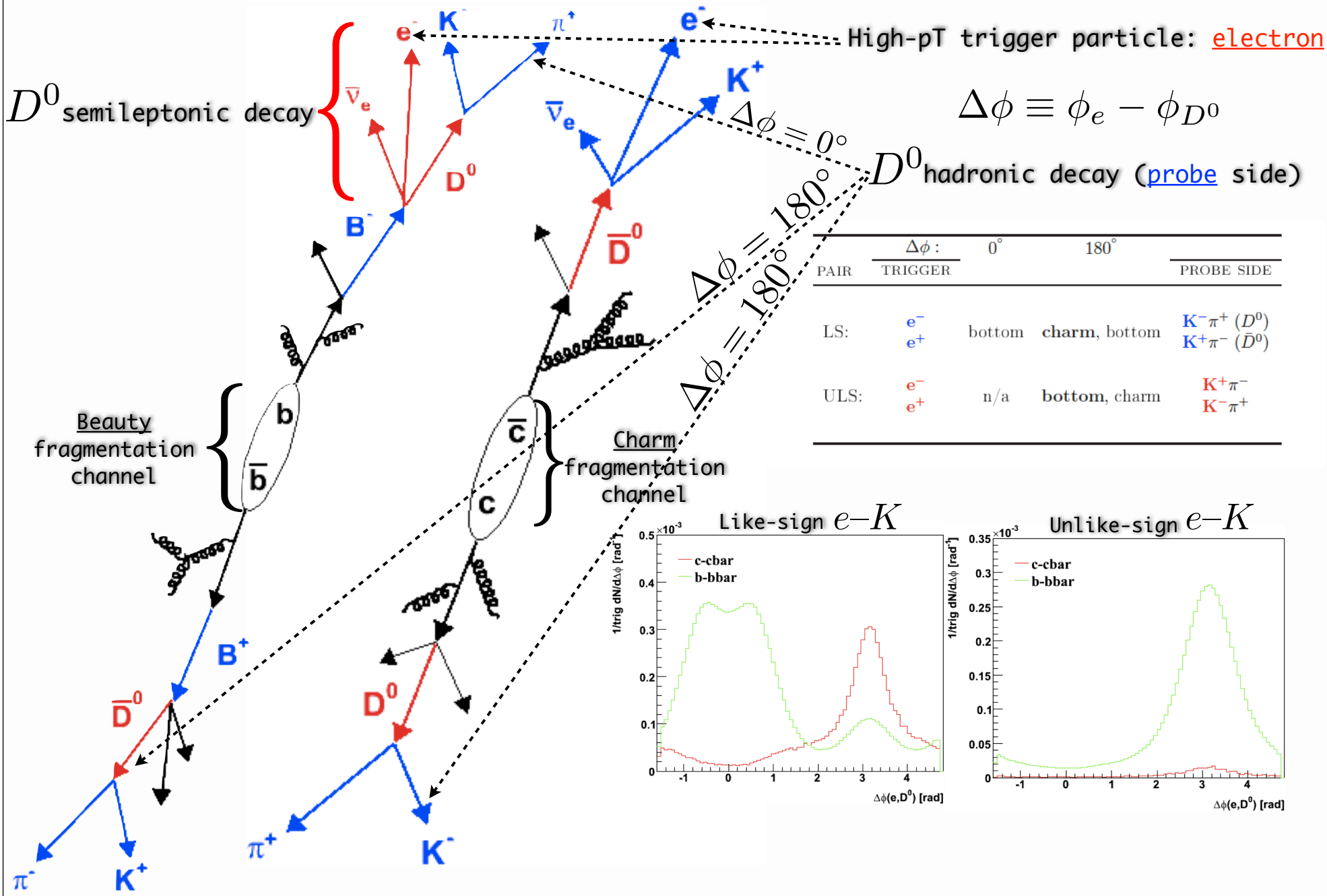
Helix of positively charged particle

Distance of Closest Approach between tracks

Distance of Closest Approach (DCA) to PV

Primary Vertex

e–D^0 Azimuthal Correlation Method



PAIR	$\Delta\phi$: TRIGGER	0°	180°	PROBE SIDE
LS:	e^- e^+	bottom	**charm**, bottom	$K^-\pi^+$ (D^0) $K^+\pi^-$ ($\bar{D}^0$)
ULS:	e^- e^+	n/a	**bottom**, charm	$K^+\pi^-$ $K^-\pi^+$