Simulation Studies of the Separation of Heavy Flavor Decays Using the Silicon Vertex Detector Upgrade at PHENIX

Richard Petti

Department of Physics and Astronomy

Stony Brook University

Physics at RHIC

PHENIX (Pioneering High Energy Nuclear Interaction eXperiment) is one of the large experiments taking place at the Relativistic Heavy Ion Collider (RHIC) located at Brookhaven National Lab (BNL) on Long Island, New York.

PHENIX has two major programs, a heavy ion program and a spin program. The former seeks to create and characterize a new state of hot, dense matter (the Quark Gluon Plasma, or QGP), where quarks and gluons are the relevant degrees of freedom in the system. The latter focuses on probing the gluon contribution to the spin of the proton by colliding polarized protons and measuring a spin asymmetry.

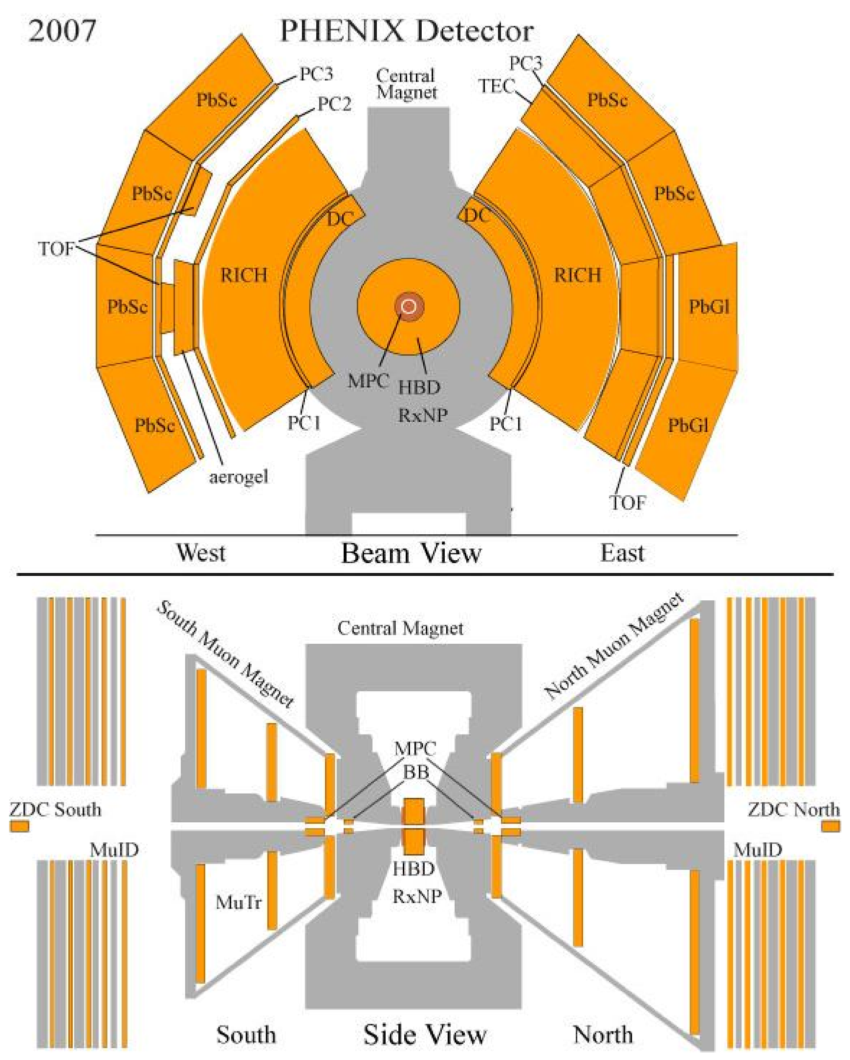


Figure 1: The PHENIX detector, 2007 configuration

Motivation for this Study

Heavy quarks are an important probe in studying heavy ion collisions. Because of their large mass, charm and bottom are only produced in the initial hard scattering and are sensitive to the entire evolution of the collision.

Being able to measure charm and bottom contributions separately will allow us to distinguish between various theoretical models describing the medium, such as energy loss models.

PHENIX has measured a significant heavy flavor azimuthal anisotropy, contrary to theoretical predictions. Being able to measure the v2 separately for charm and bottom will provide us with more information about the medium.

Goals for the VTX Detector

The VTX upgrade will expand the physics observables that PHENIX is able to measure. The detector will also improve the accuracy of previous measurements.

One of the main advantages of the VTX is that the detector will allow us to separate charm and bottom contributions to the electron continuum. This will allow a more precise determination of the charm production cross section and also the transverse momentum spectrum.

The VTX will also be utilized to measure recoil jets in direct photon production, due to the increase in acceptance.

Detector Design

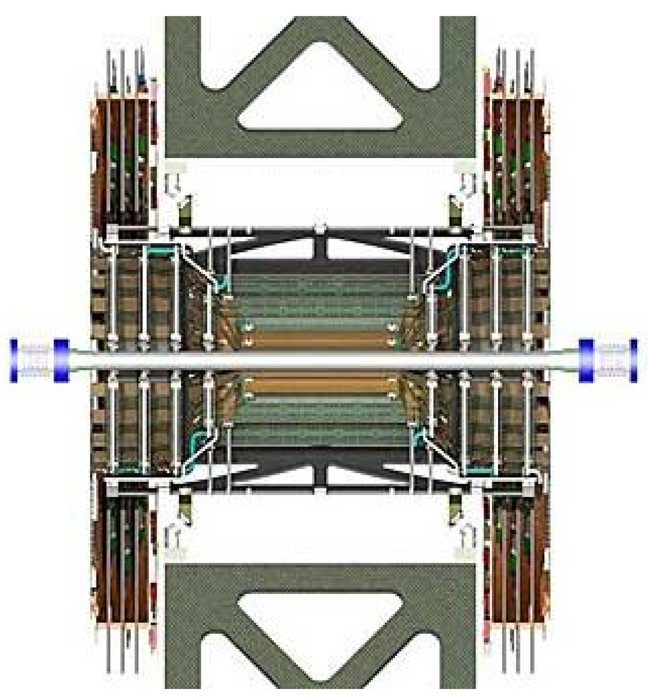


Figure 2: The full VTX upgrade project around the beam pipe

Detector Layout

The barrel portion of the detector consists of four silicon layers.
The inner two layers are made of hybrid pixel sensors which were developed at CERN for ALICE and sit at 2.5cm and 5cm from the center of the beam pipe.
The outermost layers are stripixel layers of a novel design, with sensors developed at BNL and FNAL's readout chips.

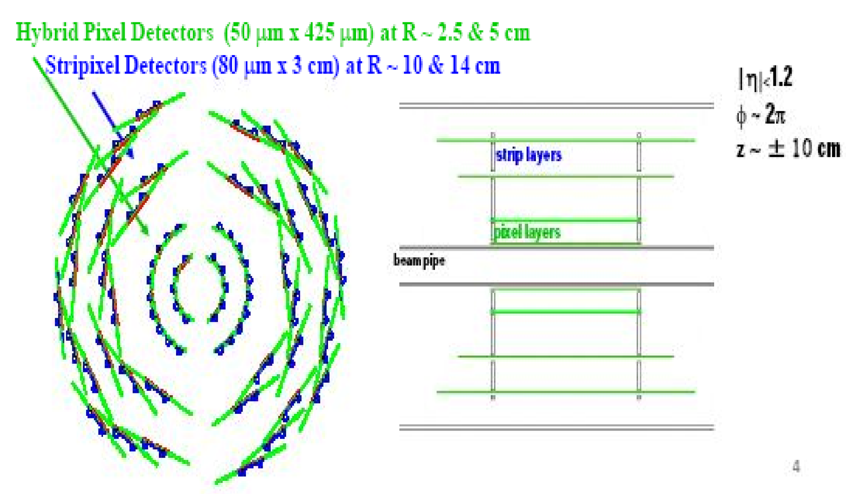


Figure 3: Layering of the VTX detector

The detector will increase the acceptance of PHENIX.
In psuedorapidity, increases to +/- 1.2 units.
Almost a full 2Pi coverage in azimuth.
Along the beam pipe the detector extends to about +/- 10cm.

Specifics of the Simulation

A Monte Carlo simulation study is in progress on the ability of the VTX detector to separate heavy flavor contributions.
Pythia v8.108 is used to produce the physics events.
The simulated events are of p+p collisions at sqrt(s) = 200 GeV. Processes which produce c and b quarks are explicitly turned on (and produced separately).
The heavy mesons produced in these collisions are then allowed to decay. The decay products we are interested in are positrons and electrons.
Only positrons and electrons which have a heavy meson in their lineage are written to file.
Then these decay products are sent through a Monte Carlo simulation of the PHENIX detector and the VTX detector response is modeled.
Then using the cluster positions of hits in the detector layers, the DCA is calculated.
A prompt contribution of electrons and positrons from the event vertex is also studied.

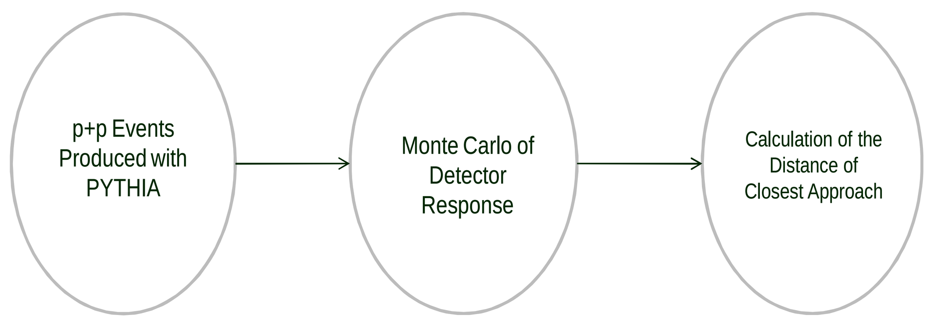


Figure 4: A cartoon of the simulation process

Calculating Distance of Closest Approach (DCA)

The particle trajectory is approximated as a straight track.
The hits in the first two layers of the detector are used to construct the trajectory (see Figure 5 below).
Once the track has been defined, the DCA is calculated.
The track reconstruction algorithm is still in development and is not being tested here.
The position of the hits used is a result of a clustering
algorithm in order to fully model the detector response.

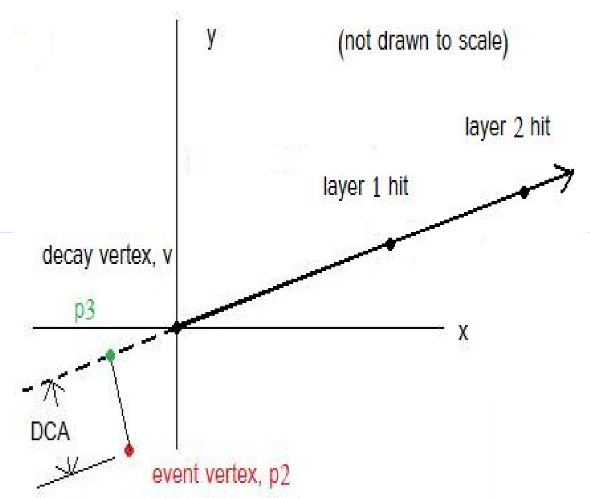
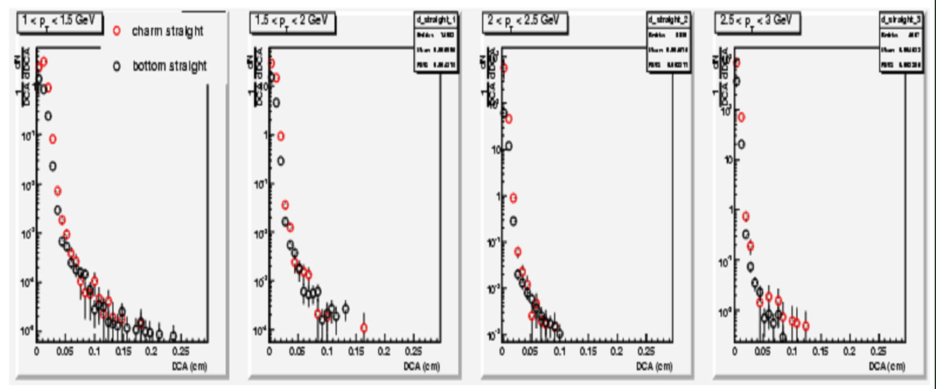


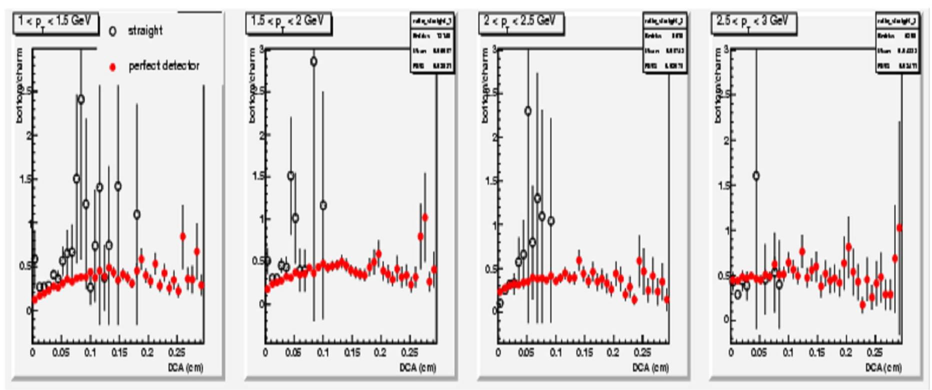
Figure 5: A sketch of the DCA calculation, not drawn to scale.

Results

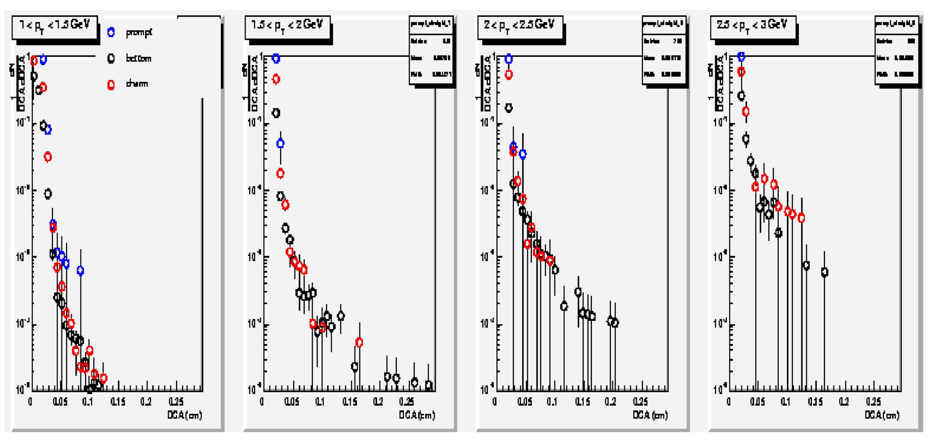
DCA distributions:



Bottom/Charm Ratio:



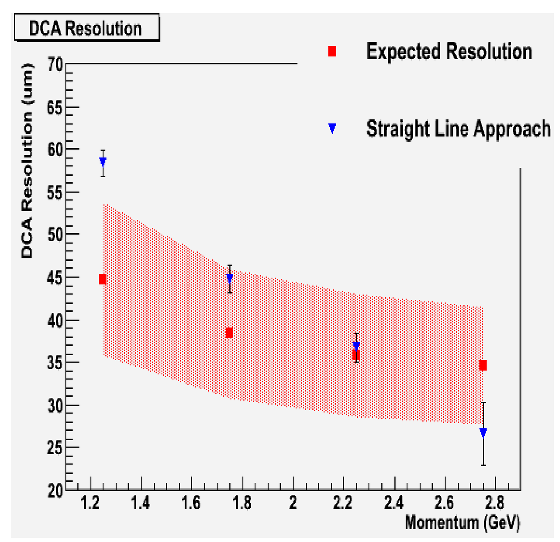
Cocktail:



The relative normalization between charm and bottom contributions is taken from the PYTHIA event generator. The relative contributions from photonic and non-photonic sources of electrons is taken from PHENIX publication, Phys. Rev. Lett. 97 .252002(2006)

DCA Resolution:

$$\sigma^2_{DCA} \approx \frac{(\sigma_1^2 r_2^2 + \sigma_2^2 r_1^2)}{(r_2 - r_1)^2} + \theta^2_{ms} \frac{r_1^2}{\sin^2\theta}$$



Conclusions and Outlook

There is an inherent shape difference in the DCA distributions of charm and bottom decays.
As DCA increases, the ratio of bottom to charm increases.
It should also be possible to cut out prompt contributions at a smaller DCA.
In the future, the study will be refined. There is work on using both decay products to pin down the actual decay vertex, not just the DCA.
There is also a more complicated Kalman filter approach which gives promising results.

For more information on the VTX detector upgrade for PHENIX see posters by Maki Kurosawa and Alexandre Lebedev