The PHENIX Silicon Vertex Upgrade

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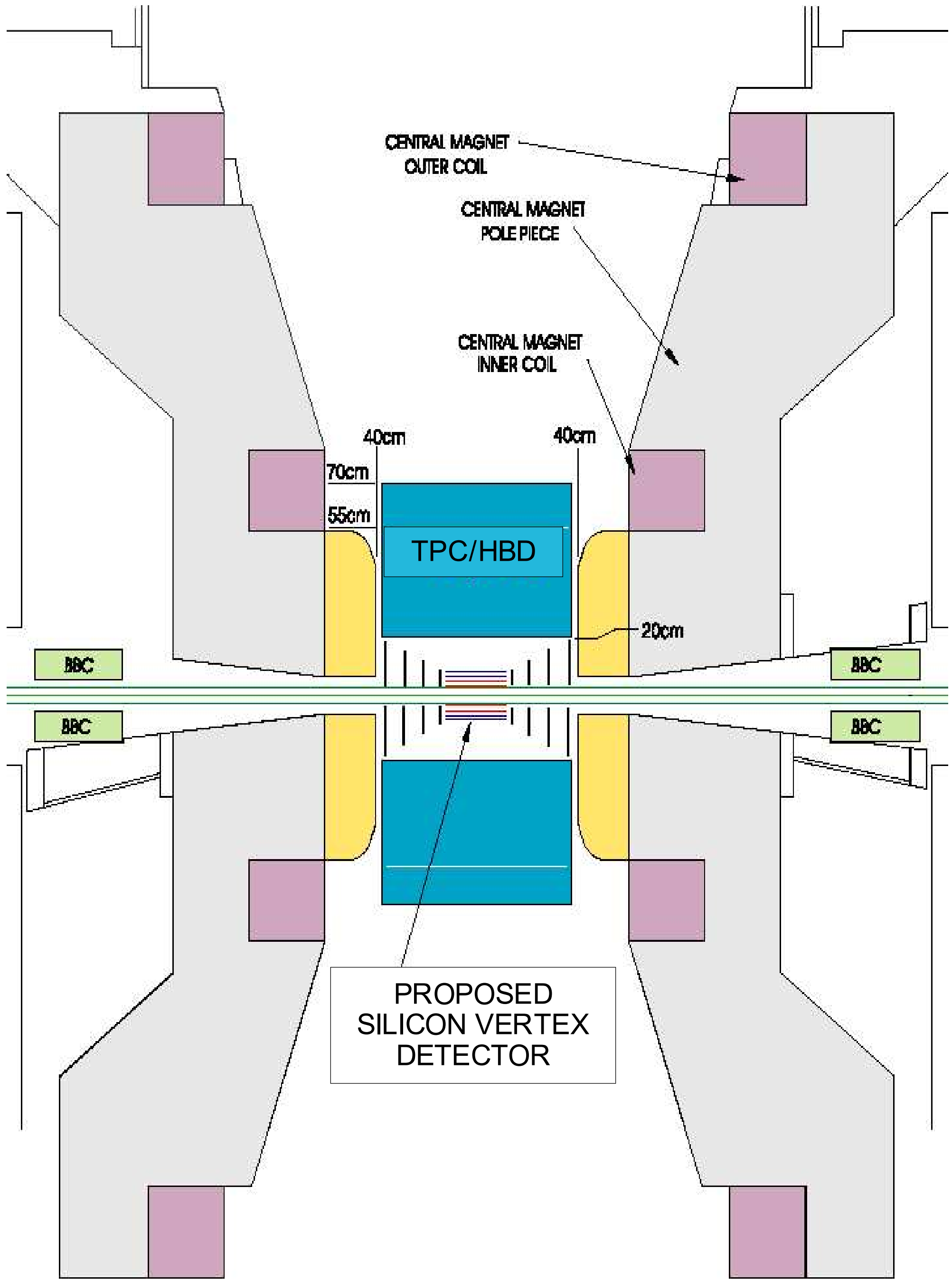
PHENIX

Introduction

The Silicon Vertex Upgrade is part of a package of upgrades to the PHENIX detector that is planned for the near-to-medium term.

Other new detectors are being planned in the central area, such as the TPC/HBD, see poster #89. The proposed Silicon Vertex Detector would sit inside the TPC/HBD (blue), and between the copper nosecones (yellow) of the Central Magnet.



Physics motivation

heavy ion collisions

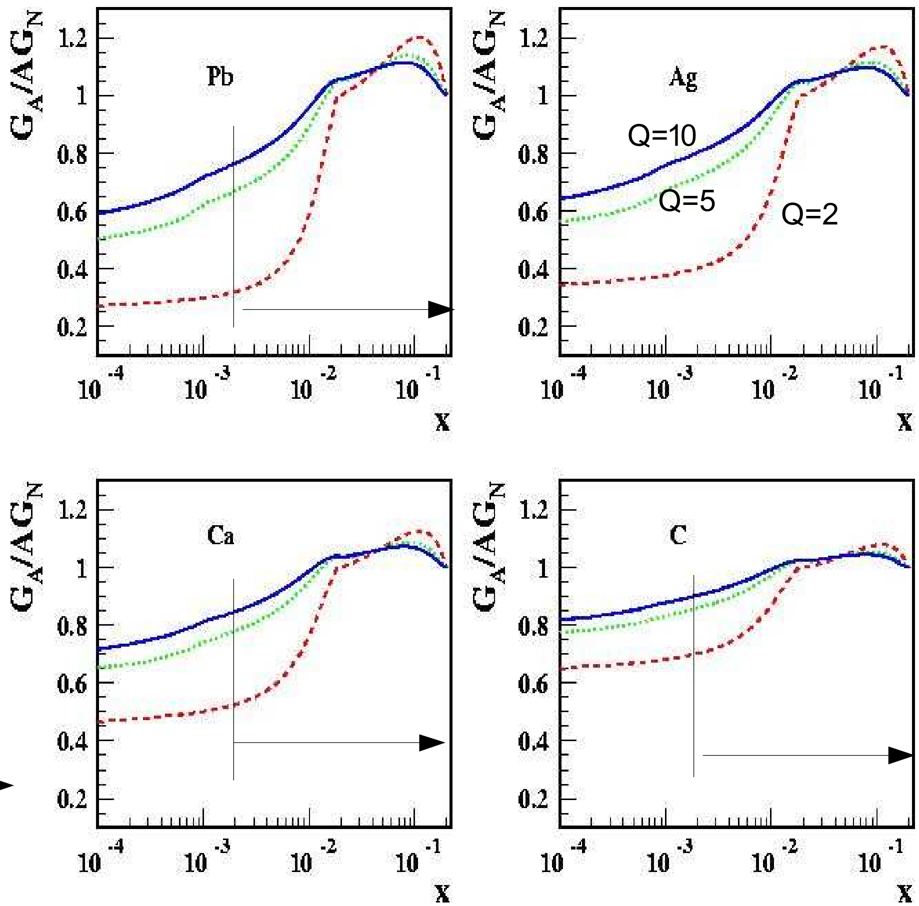
- Energy loss of heavy quarks
  - High-pT partons lose energy in the medium due to gluon radiation and elastic collisions with lower-energy partons. The latter mechanism becomes a smaller effect as the mass of the high-pT parton increases.
  - The Silicon Vertex Detector alows the investigation of energy loss for example via the measurement of open charm via D -> K+π.
- Enhancement of Charm and Beauty
  - The mechanism is the same as for the strangeness enhancement of old (early-stage parton-parton collisions, and gluon fusion), but it is not clouded by late-stage production, as it is in the case of strangeness.
  - Need to measure open charm and open beauty over a wide range of pT in AA, pA and pp

- J/Ψ Suppression
  - Screening in the quark-gluon plasma would suppress J/Ψ yields, as would interactions with semi-hard gluons.
  - Measuring the ratio of J/Ψ to open charm adresses this issue
- Other
  - Multi-strange baryons: Yields of multi-strange baryons are greatly enhanced, and pT spectra are softer than expectations based on thermal production. These are likely signals from the very early stages of the collision.
  - Improve the mass resolution of dimuons and di-electrons leads to the possibility of Upsilon spectroscopy
  - Verifying tracks close to the interaction point will reduce backgrounds in high-pT spectra.
  - Verifying μ-pair tracks close to the interaction point will reduce background from π and K decays.

Motivation (continued)
p-A collisions

- Gluon Structure Functions In Nuclei
  - Not much is known about the modification of the gluon structure functions in the nuclear environment.
  - The vertex upgrade detector can measure the gluon structure functions in nuclei over a broad range in x, 0.002<x<0.4 via the measurement of charm and beauty production.

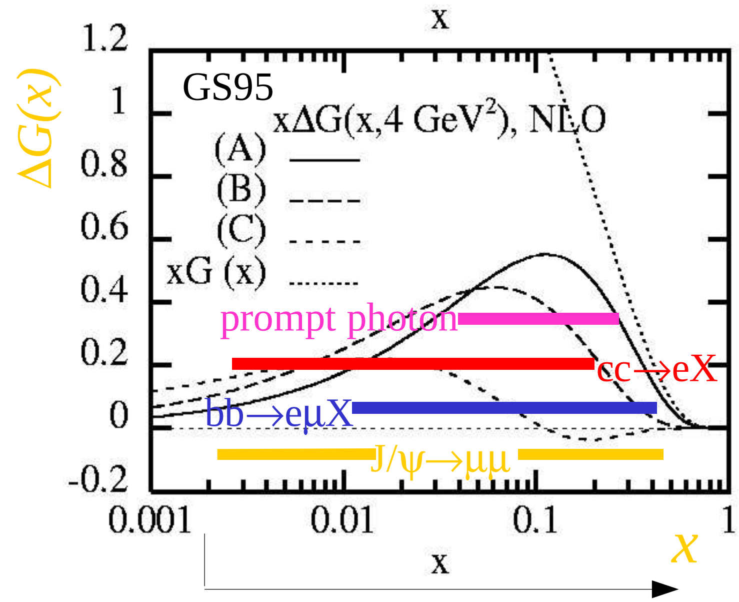
Predictions for the relative gluon structure function for different nuclei, as a function of x.



L. Frankfurt and M. Strikman, Eur. Phys. J. A5, 293 (1996)

Motivation (continued)
polarized p-p

- The measured quark spin-structure functions in the proton sum to less than the required spin-1/2: the 'spin crisis'. One possibility is that the gluons carry the missing spin.
- PHENIX currently has limited existing capability to adress this question for x>0.05, using direct photons approximately opposite a high-pT hadron. This x-range is not broad enough to address the spin crisis.
- The silicon vertex upgrade detector can extend the range to 0.002<x<0.4, measuring the spin asymmetry of open charm and open beauty.



The gluon spin structure function for Q=2GeV for different models

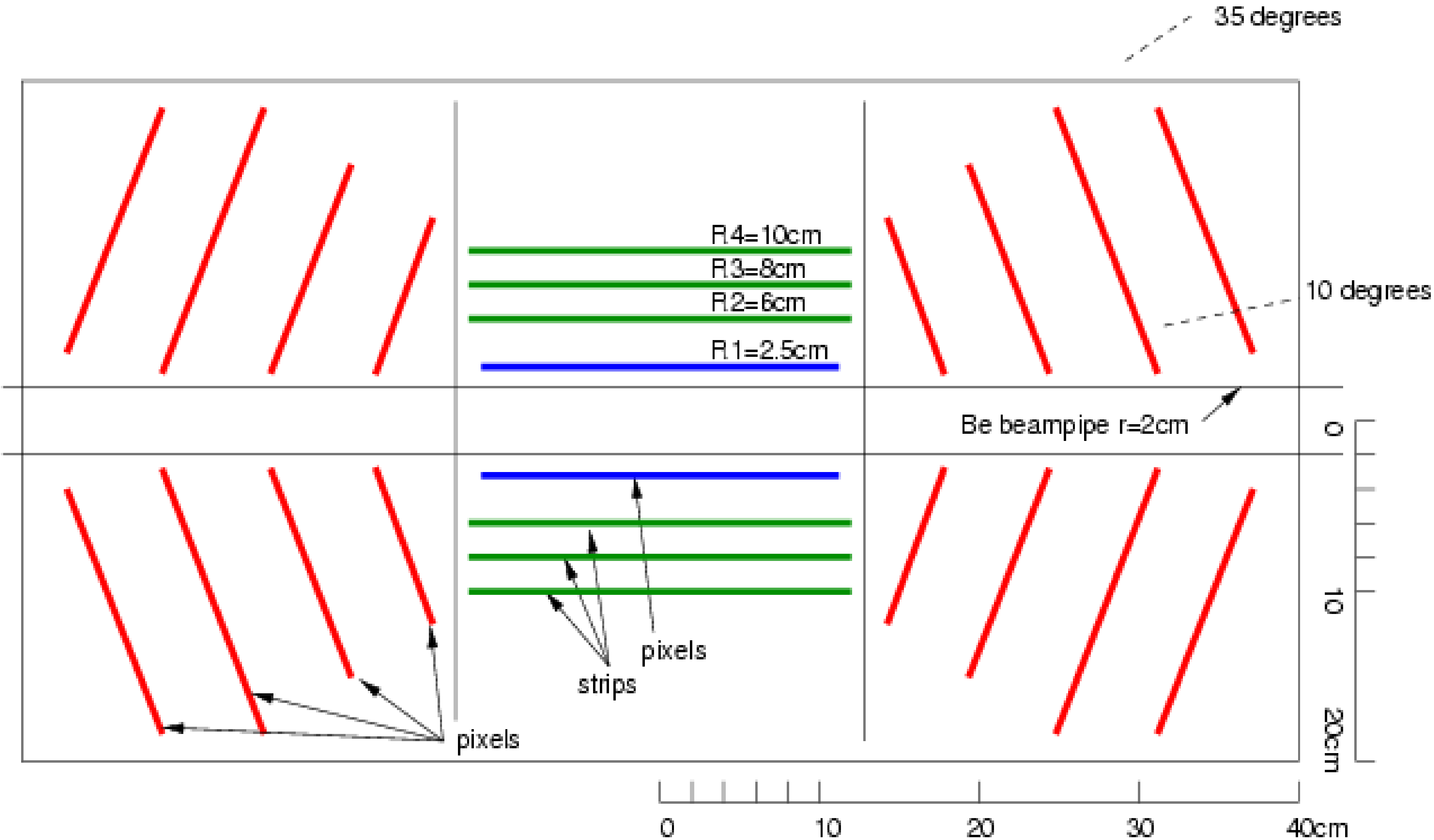
T. Gehrmann and W.J. Sterling, Phys.Rev.D53 6100 (1996)

Detector requirements

- Match tracks from the central arms and the muon arms to hits in multiple layers in the silicon detector
- Position resolution sufficient to resolve secondary vertices of charm and beauty decays, i.e. 30-50 μm
- For mid-rapidity tracks, spatial resolution needs to be predominantly in the r-φ plane, for tracks at forward rapidities, good resolution in z is required.
- The detector must match acceptances of the current and proposed central arm and muon arm detectors.
- The detector should be thin. The desire is to achieve 1% of a radiation length, including electronics, cooling and support structure.

Strawman Design

Based on the the physics criteria, a provisional design is currently under study.
The device consists of a 4-layer barrel section, and 2 4-layer endcaps.



Barrel

The secondary-vertex resolution is determined by the resolution of the inner two silicon layers, and by the multiple scattering. Therefore the beampipe radius is reduced to 2cm (Beryllium), and the first Silicon layer is placed at 2.5 cm. Over a broad range of momenta, multiple scattering is the dominant limiting effect.

The central part (-12<z<12cm) of the detector consists of 4 concentric barrels, the innermost barrel consisting of pixel detectors, the outer 3 of silicon strips.

The pixel detectors may possibly be based on the Alice/NA60 design, and the strips based on a prototype strip detector currently under development at BNL:

Layer	R(cm)	pixel/strip	channels	occupancy
R1	2.5	50μm x 425μm	1.3M	1%
R2	6	80μm x 3cm	37500	11.5%
R3	8	80μm x 3cm	50000	7.2%
R4	10	80μm x 3cm	62000	4.8%

Endcaps

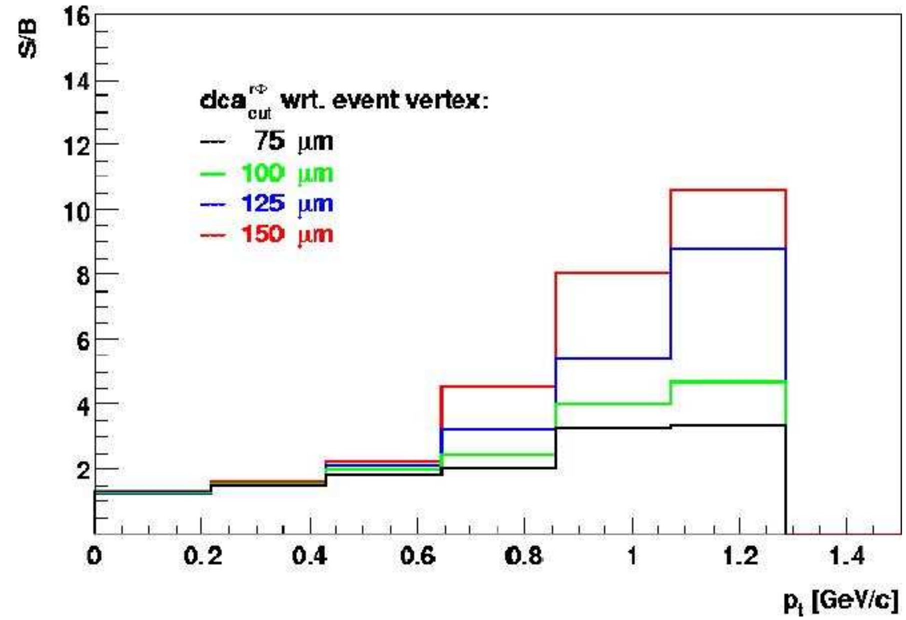
The endcap detectors may also be based on the Alice/NA60 design, though the pixel length can be increased to 4mm to decrease channel count.

With 50μm x 4mm pixels, the total channel count would be 1.7M, and the occupancy in the first disk would be less than 3%, and less in the outer disks.

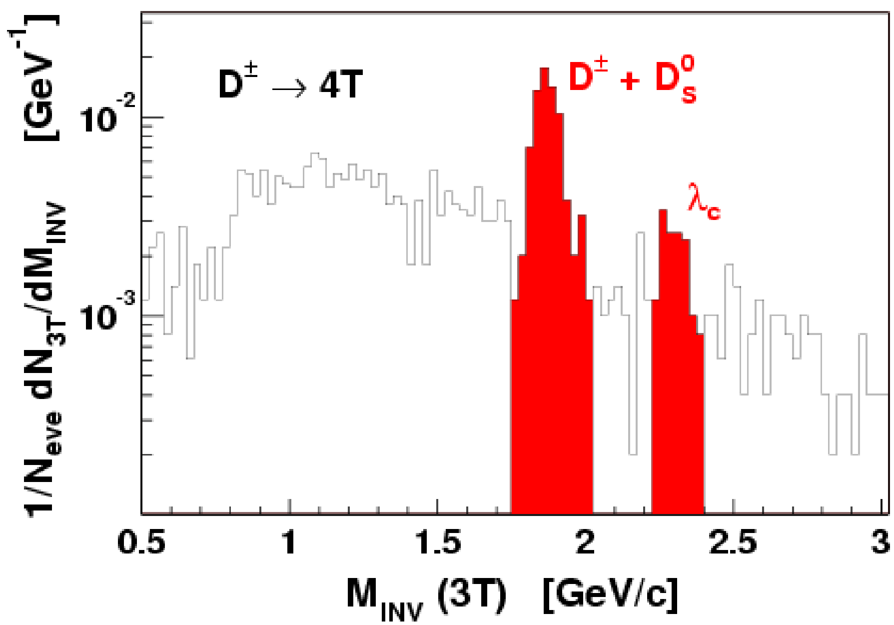
Performance

Open Charm

Signal-to-background ratio of electrons from D->e+X decays, for various cuts on the distance of closest approach of the electron track to the primary vertex. The background is a realistic coctail of other electron sources.
The plot shows that we have good sensitivity to the open charm signal in this channel.

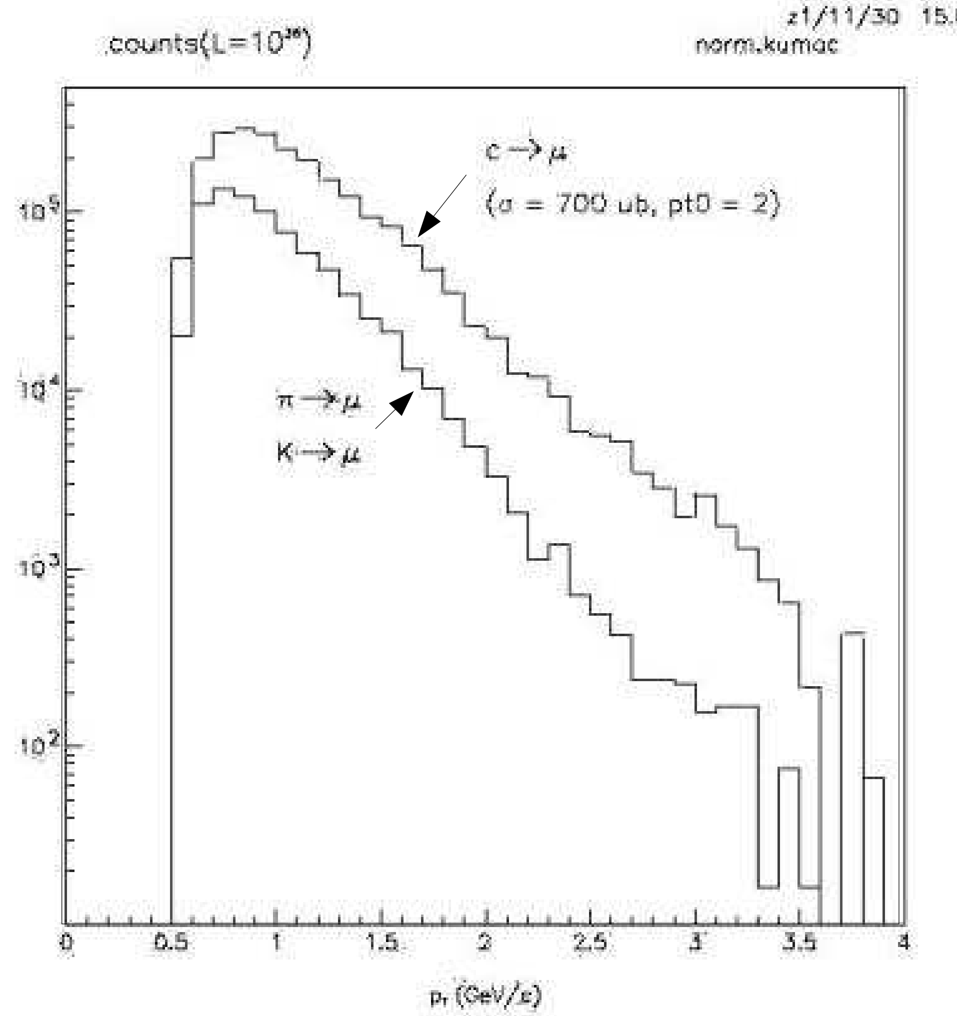


Three-body invariant mass for the decay D->K-π+π+. The displaced-vertex requirement and the strong contraints on 3-body decay produce a clear signal for D's and charmed baryons.



Muons from charm vs muons from π and K decay. Signal-to-noise is better than 2 for pT>800 MeV.

Since charm is produced in pairs, the S/N can be further increased by requiring both (opposite-sign) leptons to be observed. This would work in low-multiplicity events (p-p and p-A collisions)



Open Beauty

Because of their longer lifetimes, It is easier to measur B-meson production, but low rates are the limiting factor. Studies are ongoing, but here are some options:

B-> J/Ψ: the J/Ψ decay distance distribution can be exploited to extract the B yield.

B->μ+X, B->J/Ψ->μ+μ- : estimates show that several hundred per day can be reconstructed.

B-> J/Ψ+K: identify J/Ψ in the muon arms via μ+μ-, and identify K in the central arms.

Technology Options

The relatively short timescale of this project does not allow the development of detectors (pixel, strip) or front-end electronics from scratch. We have to adapt existing designs for our application.

- Pixel Detectors and electronics
  - For the pixel detectors, the likely choice is one of the available hybrid active pixel detectors. The leading candidates are the pixel detectors/readout developed for CERN's Alice experiment, and the FPIX chips for Fermilab's BTEV experiment.
  - PHENIX members are currently involved in experiment NA60 at CERN, which uses the Alice pixel detectors, in order to gain experience with this system.
- Strip Detectors and electronics
  - Leading candidates for the strip detectors are the commercially available detectors for example Hammamatsu, or the detectors currently under development at BNL.
  - For the front-end electronics, there are several candidates: the SCTA chips or the ABCD chips of CERN's ATLAS experiment; Fermilab's SVX4 chips, CMS's APV25 chips, Alice's Pilot chip.

Staged Construction

Because the outer layers of the central barrel use strip technology, which can be implemented before the pixel layers, options for staged construction is under consideration:

- Design and build the infrastructure (support, cooling, signal and power distribution) for the entire device (barrel strips and pixels, and endcap pixels), and mount detectors in stages, starting with barrel strips. The advantage is that it requires only one infrastructure design, the disadvantage is that everything has to be specified very early on.
- Design and build a temporary support structure for the barrel strip layers, and build a new structure when the pixel detectors are ready, transferring the strip detectors. The disadvantage is that the design and construction effort of the support structure is nearly doubled.

More info: http://p25ext.lanl.gov/~hubert/phenix/silicon/index.html
http://www.phenix.bnl.gov/WWW/publish/hubert/qm02_poster/phenix_si_upgrade.html

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