Simulations for Heavy Flavor Tracker–Pixel Detector

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Abstract

The Heavy Flavor Tracker (HFT) is a new state-of-the-art detector installed at the STAR experiment in January 2014. It consists of four layers of silicon detectors divided into three subsystems: A double sided strip detector SSD (Silicon Strip Detector), a silicon pad detector, called IST (Intermediate Silicon Tracker), and finally two layers of pixel detectors, based on the state-of-the-art MAPS (Monolithic Active Pixel Sensors) technology.

The HFT provides excellent primary and secondary vertex position measurement capability (pointing resolution of $\sim 30\ \mu$m) which allows for measurements of hadrons containing heavy flavor, such as D^0 and Λ_c. Moreover, the combined analysis of the identified charm hadrons and the non-photonic electrons will allow the measurement of bottom production and azimuthal anisotropy at RHIC top energy.

A new tool DIGMAPS [4] has been developed for the simulation of the response of the pixel sensors. Results from tuning of DIGMAPS as well as comparison between simulation and recently taken data by the STAR experiment is being presented.

HFT physics

The high energy collisions at RHIC allow us to study nuclear matter at extremely high temperatures. In these conditions a new state of matter, called quark-gluon plasma (QGP), is created.

Heavy flavored quarks are produced during the initial phase of the collision, therefore they are an important tool for study of QGP. However they are also hard to analyze due the large combinatorial background.

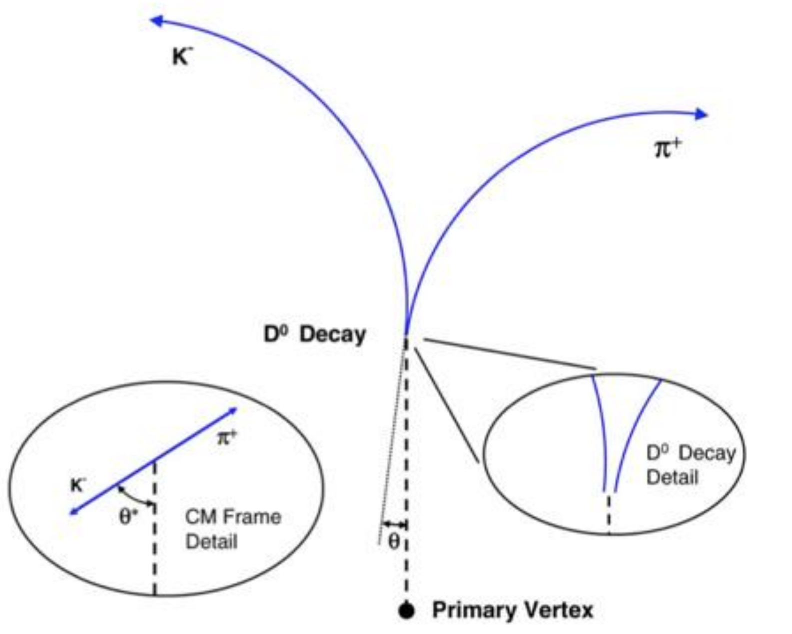

Figure 1: D^0 production and subsequent decay into K^- and π^+.

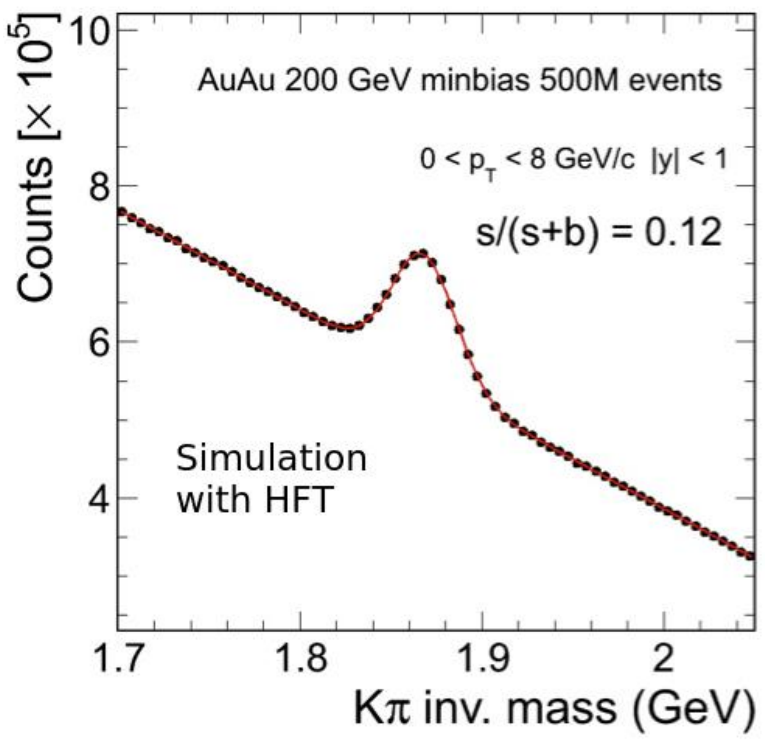

Figure 2: Simulated D^0 peak with HFT used.

HFT can detect heavy flavor particles through precise measurements of displaced vertices. This greatly reduces the combinatorial background. The pointing resolution has to be approximately $30\ \mu$m.

Examples of displaced decay vertices

- $\mathrm{D}^0 \to \mathrm{K}^-\pi^+$ BR = 3.83 % $\quad c\tau \sim 120\ \mu$m
- $\Lambda_c^+ \to \mathrm{p\,K}^-\pi^+$ BR = 5.0 % $\quad c\tau \sim 60\ \mu$m
- B mesons → J/ψ + X or e + X $\quad c\tau \sim 500\ \mu$m

Technical Design

The HFT consists of three subsystems [1]:

- **Silicon Strip Detector (SSD):** One layer of double sided silicon strip detector located 22 cm from the beam axis. This existing detector was refurbished and equipped with new readout electronics.
- **Intermediate Silicon Tracker (IST):** A new single layer silicon pad detector, placed at 14 cm radius. The purpose of the IST and SSD is to guide the particle tracks from the Time Projection Chamber to the PXL layers.

Figure 3: Photograph of the Silicon Pixel Detector.

- **Silicon Pixel Detector (PXL):** The two innermost layers at 8 and 2.8 cm consist of silicon pixel detectors. They are based on the state-of-the-art MAPS technology and have pixel size of $20.7\ \mu\mathrm{m} \times 20.7\ \mu\mathrm{m}$.

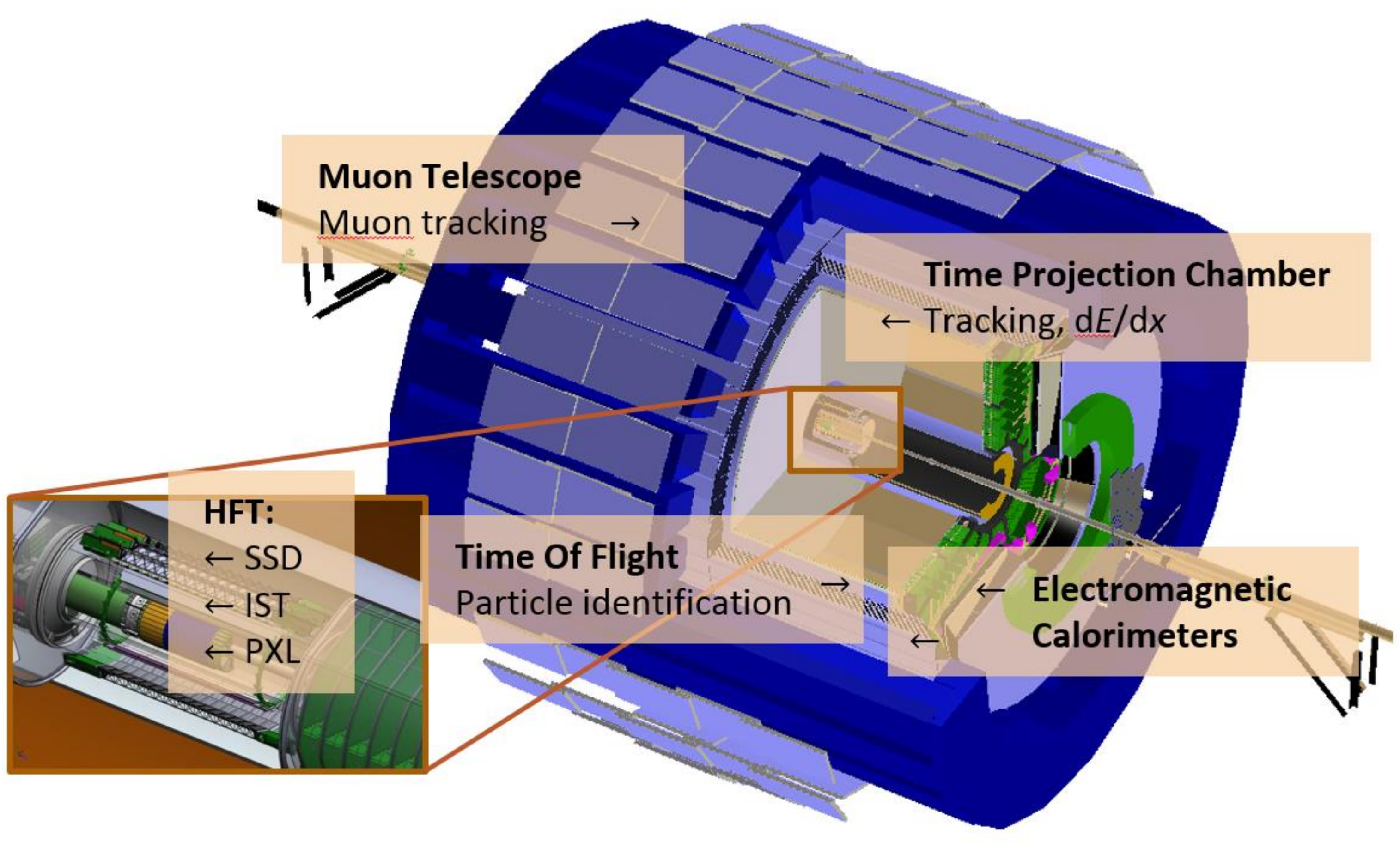

Figure 4: HFT inside the STAR detector; (right) four layers of silicon detectors of the HFT.

In addition, the PXL features a very fast and precise insertion mechanism which allows to quickly access the whole system. Insertion was done in less than 24 hours.

Slow simulator

A part of every analysis is efficiency study. For this purpose a slow simulator is needed. Simulation tool DIGMAPS was developed for the PXL at IPHC – CNRS of Université de Strasbourg [4].

The sensitive area of the pixel sensor is called epitaxial layer (see Fig. 5). As a particle passes through this layer, it creates a cloud of electrons which is then collected by the N-wells. The clouds usually cause that the particles fire more than one pixels and leave a trace in the form of a cluster of pixels.

Simulation consists of the following steps:

- **Energy deposition and creation of electron/hole pairs:** The energy deposition in the epitaxial layer can be translated directly into created electron/hole pairs (3.6 e^-/eV) and is currently implemented as Landau law with MPV of approximately 80 e^-/μm.

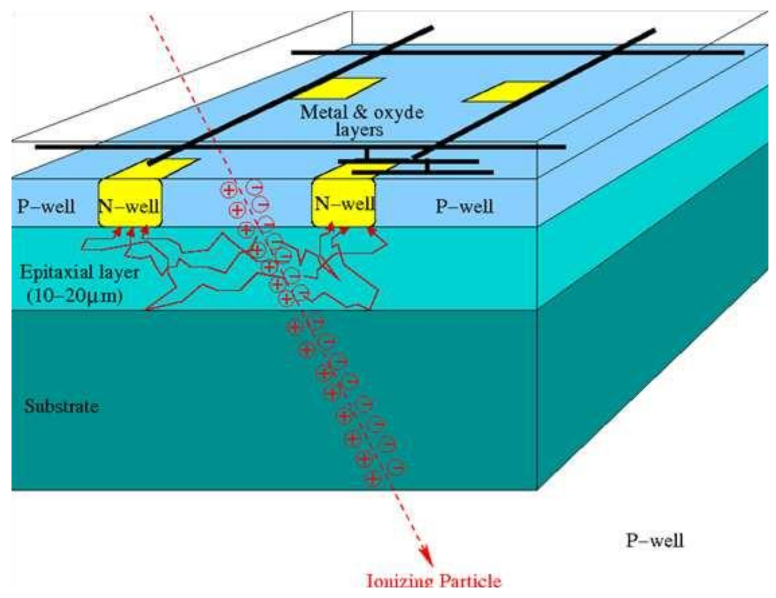

Figure 5: Illustration of a particle, traversing a MAPS sensor.

- **Charge transport:** Ionization electrons transport to and collection by N-wells is emulated by probability distribution functions for charge collection by the nearest and next-to-nearest neighbors N-wells. Studies at IPHC showed that a distribution of a guassian + lorentzian describe the beam test data very well.
- **Digitization:** In the end, noise is added to each channel and an ADC threshold is applied.

Comparison between data and simulations

To evaluate and tune the simulation tool, a comparison between the STAR data and the simulation had to be undertaken. Because the traversing particle usually fires more than one pixel, the best way of comparing the simulation to the measured data is to study the pixel clusters.

The parameters for the charge deposition and collection model were tuned to beam test data at IPHC [4]. At STAR we have to tune the ADC threshold because every pixel column has a different discriminator and therefore a different ADC threshold value.

An analysis of zero field cosmic data was done. In order to reduce the noise in PXL, following steps were taken:

- Only tracks going through all the PXL and IST layers were included (see Fig. 6).
- Hits had to be within 3 mm radius from the track.
- No more than one hit had to be within the radius
- At least one hit with cluster size > 1 was required

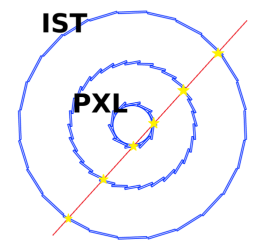

Figure 6: An example of a good zero field cosmic track

Slices for different incident angles were compared to the simulations with different ADC thresholds. The threshold for the simulation was optimized by a Chi^2/NDF comparison.

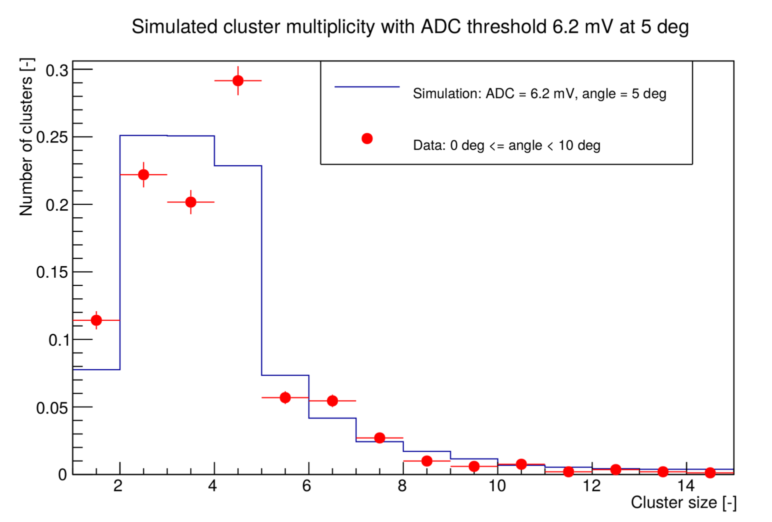

Figure 7: Cluster multiplicity from simulation (blue line) and zero field cosmic data (red dots).

Conclusion and outlook

- The HFT has been successfully installed and is taking data during RHIC 2014 run.
- Accurate simulation is imperative for detector efficiency corrections.
- PXL sensors simulator (DIGMAPS) has been tuned to cosmics data.
- A more thorough comparison to the Au+Au data is currently being carried out.

References

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