Addendum to STAR HFT proposal

January 8, 2008

Introduction

The STAR HFT upgrade proposal was submitted to BNL in the summer of 2007. It describes the configuration and proposed design of the detector as of that time[1]. Since then the simulation work and the R&D effort have continued. In particular, we have improved the design and geometry of the PIXEL detector and we have simplified the IST design and geometry. We have also made substantial improvements to the electronics readout scheme for the PIXEL detector. In part due to these changes, the overall cost of range the proposal has come down.

We have also reviewed our plans for a PIXEL engineering prototype. Instead of planning for a full detector with slow sensors (a different technology than our final sensor) we will now implement a small detector patch with prototype sensors that are a milestone on the path towards a final sensor chip.

This addendum highlights the important changes that have resulted from the work in the past year and it describes the most important consequences for the expected performance of the HFT.

Changes to the PIXEL Detector Geometry

The support and geometry for the pixel sensors have been modified and the new layout is shown in Figure 1. The sensors will be mounted on a trapezoidal 'box beam' (similar to the ALICE and CMS detector designs) and we will no longer use individual ladders to support a row of sensors. Each carrier assembly now has 3 rows of outer sensors for each inner row of sensors. The inner layer of sensors will be located at 2.5 cm radius and the outer layer will sit at an average radius of 8 cm. This is a small increase over the ~7 cm outer radius quoted in the proposal.

We have also changed the way the detector is assembled around the beam pipe. We have adopted a clam shell design rather than a three part assembly (section 4.8.1 page 105) which is easier to design and fabricate.

PIXEL Read-out and Engineering Prototype

Recent changes in the development path for the PIXEL sensors have resulted in a plan which delivers sensors with enhanced capabilities sooner than the ones described in the

[1] The version is labeled "hft_final_submission_version"

original proposal. But with these new capabilities comes a new set of requirements for the readout system.

We intend to approach the completion of the final PIXEL detector for STAR as a two stage development process with the readout system requirements tied to the stages of sensor development effort in France at IPHC. In the new development path, the first available set of prototype sensors will have digital outputs and a 640 μsec integration time. We will use these sensor prototypes to construct a limited engineering prototype detector system for deployment at STAR during the summer of 2010. See Figure 2. The prototype system will employ the same mechanical design planned for the final PIXEL detector as well as a readout system that is designed to be a prototype for the expected final readout system. The final electrical and mechanical systems are expected to be deployed with the final sensors at the end of FY11. Thus a 4 msec sensor will not be deployed at any point and the new development path for the readout and DAQ systems will proceed in a linear way without diversions.

A complete write-up describing the readout and DAQ is attached at the end of this addendum and is also available at:

http://rnc.lbl.gov/hft/hardware/docs/Addendum_rdo_2007_12_26.pdf

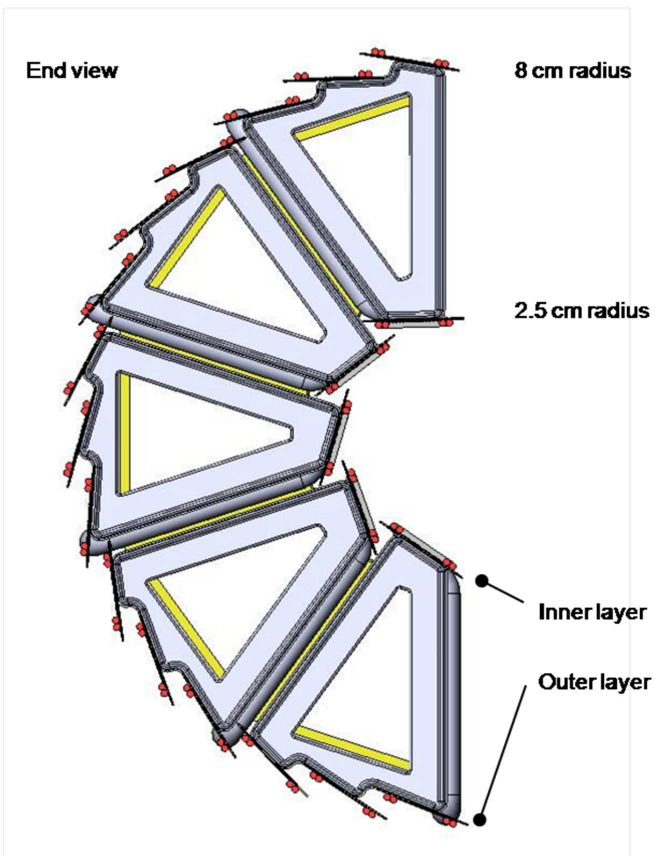

Figure 1: End view of the new PIXEL geometry. The figure shows the inner and outer sensor layers at their new locations of 2.5 cm and 8.0 cm, respectively.

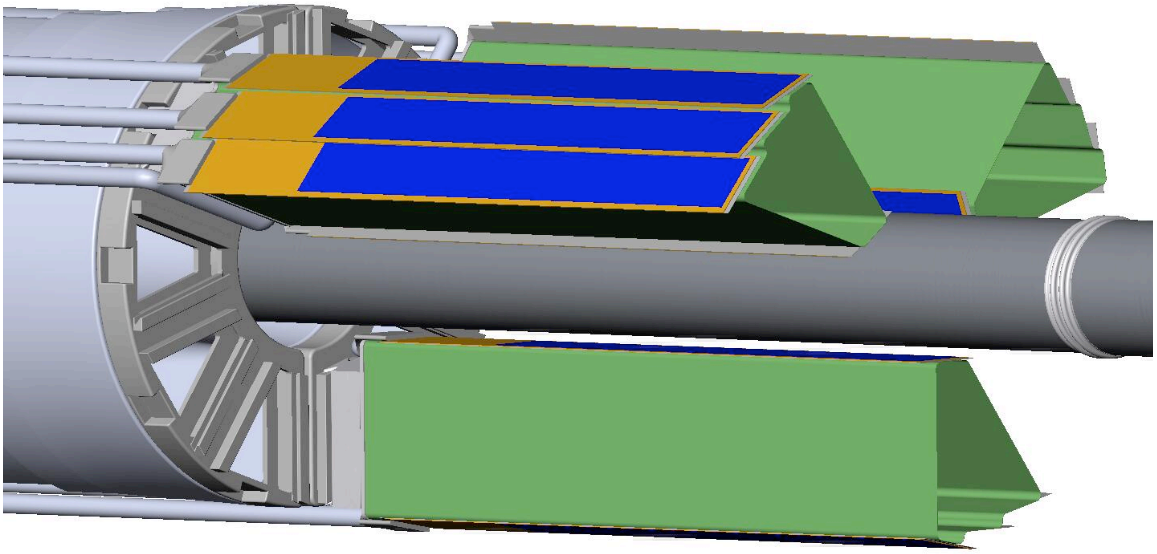

Figure 2: An oblique view of the new detector assembly. Three sensor-assemblies are shown. The detector will be deployed in this configuration for the 'patch' prototype. Putting the detectors in a 120° configuration maximizes their acceptance for catching the charged-daughter particles from a D^0 decay. The final detector configuration will cover the full 2π azimuth.

IST Geometry

The layout of the Intermediate Silicon Tracker has been optimized by investigating a large number of different detector geometries with different numbers of layers at different radii, and with different pad sizes to maximize the single-track efficiency for the system as a whole. Another goal was to ensure redundancy in case of failures of either the SSD or the IST sensors.

The old layout (proposal configuration) had three silicon layers at two radial locations. The new layout employs one layer of silicon at one radial location. This design minimizes the number of silicon layers and thus minimizes the number of channels (number of readout chips) and reduces the cost. The current design consists of a single layer at a radius of 14 cm, with 23 ladders, and has a length of 44 cm with 11 sensor modules per ladder. Each Silicon pad sensor has a double-metal-layer construction, AC coupled and with an overall size of 4 cm by 4 cm. The final structure is still being optimized; but pad dimensions of 400 μm x 1 cm are currently anticipated with 5 APV25-S1 readout chips per module. (Section 5.2 page 129-130).

The new configuration has many fewer sensors and readout chips and results in an overall reduction in heat load on the system; but the new scheme requires the use of the more expensive double-metal sensors. A schematic drawing of the new IST geometry and layout is shown in Figure 3.

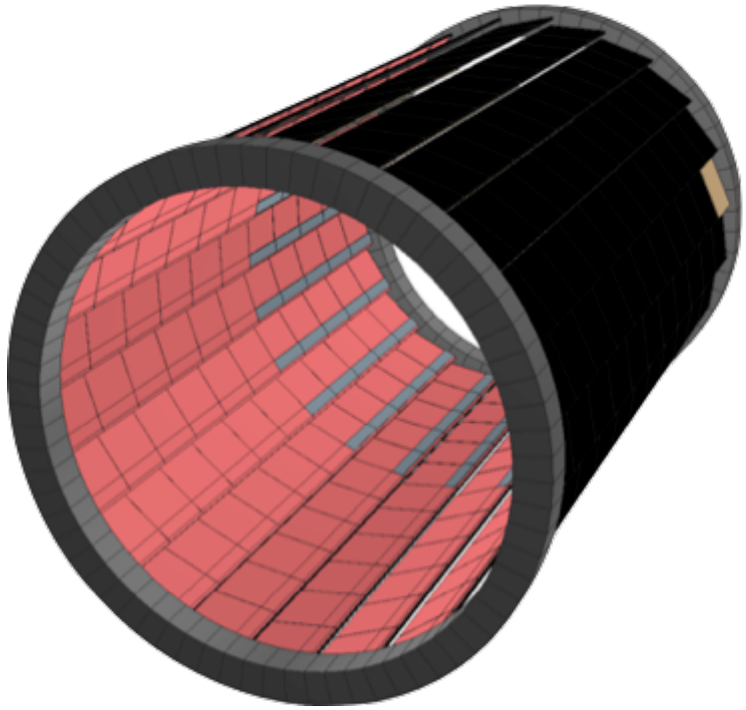

Figure 3: Geometry of the new single layer IST. There are 23 ladders at an average radius of 14 cm; each with 11 Si sensor modules per ladder and 5 APV 25 readout chips per module.

Simulations

We have completed a detailed set of simulations for the HFT at RHIC II luminosities using GEANT and ITTF. The new feature in these simulations is the fact that they include pile-up from overlapping events. The pile-up calculations were not available at the time the proposal was submitted to BNL and so this is a new result. However, due to the slow pace of performing GEANT simulations, we have only been able to do these simulations, with pile-up, for the configuration described in the proposal. We have not yet completed a full set of simulations for the new detector geometry that is described in this addendum to the proposal. Instead, we have investigated the performance of the new geometry with a compact series of 'hand-calculations' and we have found that the new detector's performance will modestly exceed the performance of the old detector.

The simulation chain that is referred to in the previous paragraph is the complete STAR software chain that we are developing for physics analysis with the proposed detector. These simulations include the effects of pile-up in Au-Au collisions and, as a critical figure of merit, we have now shown that even for RHIC-II luminosities we can achieve good efficiencies and reasonable signal to background ratios. See Figure 4.

We have also studied the performance of the old detector configuration and the new configuration using hand-calculations. These calculations are based on a simplified Kalman Filter that is closely related to the tracking algorithm implemented in ITTF.

The calculated efficiency for reconstructing pions and kaons in the HFT using GEANT/ITTF and the hand-calculations is compared in Figure 5.

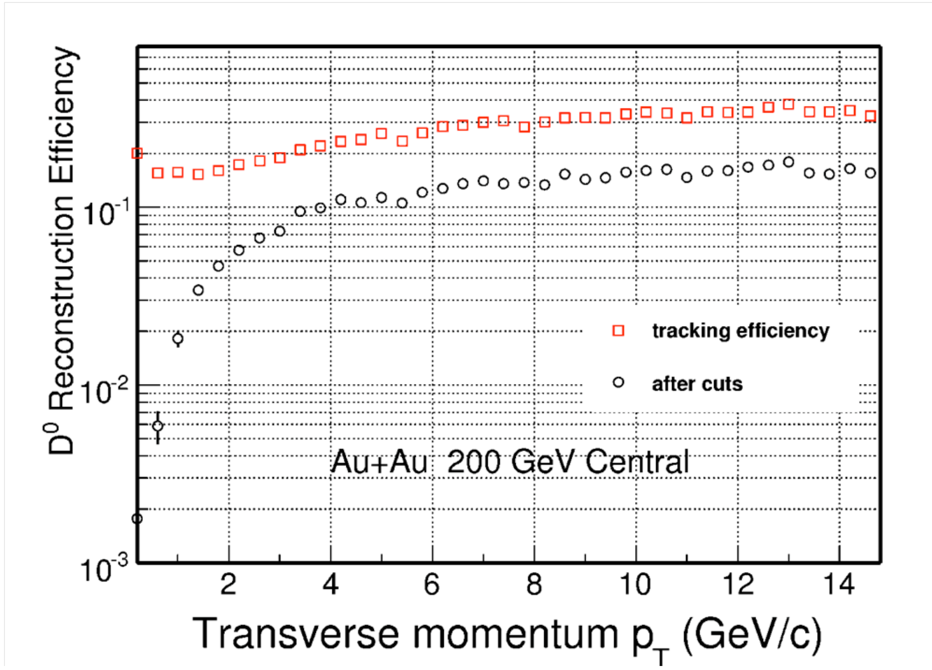

Figure 4: The total efficiency for reconstructing D^0s in the HFT (proposal configuration). These simulations include pileup and were done with GEANT and ITTF and include the finite geometric acceptance of the TPC and SSD. The red squares show the probability that a D^0 is seen by the HFT and the black squares show the absolute efficiency for finding the D^0 after all of the requisite software cuts have been applied to the data. A flat spectrum of D^0s, as a function of p_T, was assumed in the simulation.

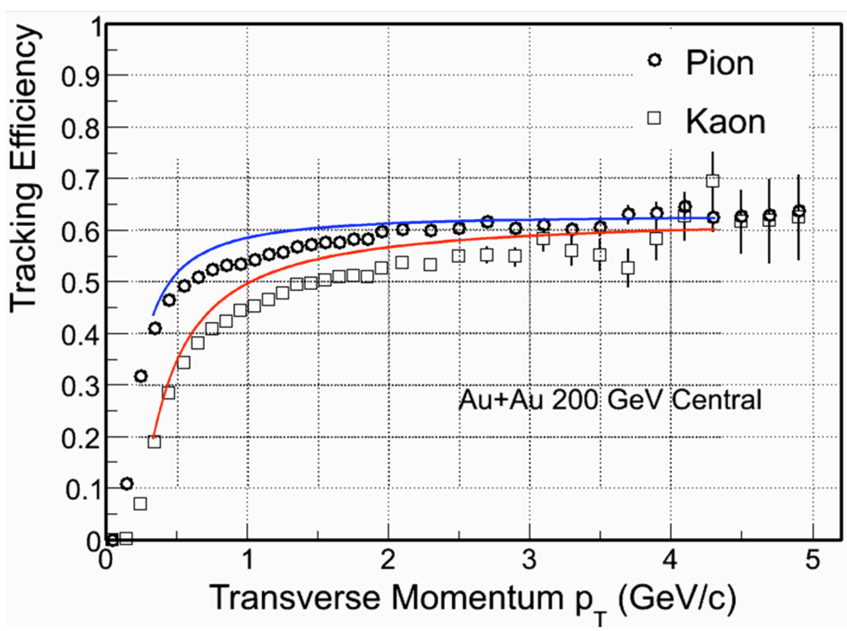

Figure 5: The total efficiency for reconstructing pions and kaons in the HFT (proposal configuration). The simulations include the effects of pileup in the HFT. The data points are from a full GEANT/ITTF simulation that includes the finite acceptance of the TPC and the SSD. The blue and red lines are the result of calculating the same quantities with the hand-calculations. The agreement is surprisingly good in view of the fact that the hand calculations involve a number of simplifications in order to make the calculations tractable with modest tools.

In view of the fact that the hand-calculations agree with the GEANT/ITTF simulations in most critical areas, we are confident that the new detector geometry will also perform well. The results of the hand calculations, for the new geometry, are not substantially different than the results shown in Figure 4.

Cost Estimate

The simplification of the HFT design results in a reduced cost compared to the proposal configuration. The table, below, gives the new cost range and the cost for the sub-systems with an estimate of the contingency for each level two WBS item.

WBS	Task Name	Cost (estimate) in K$	Average % Cont.	Cont. in K$	Lower Range in K$	Upper Range in K$
1.1	Research and Design	1,461	0	0	1,461	1,461
1.2	Pixel	1,985	46	1,125	3,110	4,354
1.3	Strip Detector	2,293	36	859	3,152	4,255
1.4	Integration	1,665	41	946	2,611	3,656
1.5	Software	0	60	0	0	0
1.6	Project Management	785	0	0	785	941
Total		8,189	29	2,930	11,119	14,668