Relevant information from the Preliminary PEP modified to reflect recommendation from red-team review.

:

## Technical scope

The HFT project scope comprises designing, building and assembling the three sub-detectors that constitutes the system. The technical scope is defined in Table 3-1: Key performance parameters for the HFT instrument to achieve Critical Decision (CD-4) and in Table 3-2: Deliverables for CD-4.

### CD-4 KEY PERFORMANCE PARAMETERS

### Although the high-level key performance parameters (KPPs) cannot be directly measured without beam, the capability to achieve these parameters will be demonstrated at CD-4 through the measurement of the low-level KPPs plus full system simulation studies. The achievement of the low-level KPPs will be proven through bench tests, survey measurements and the meeting of design specifications. Appendix A provides further details on the KPPs.

**High-level CD-4 key performance parameters: instrument must be capable of:**

|  |  |  |
| --- | --- | --- |
| Pointing resolution of HFT system  (750 MeV/c kaons) | ≤60 μm in the r-phi plane | ≤40 μm in the r-phi plane |
| Single-track efficiency for HFT system , requiring PXL hits on both layers.  (1 GeV/c pions) | ≥ 60% | ≥ 70% |
| Compatible with STAR DAQ-1000 system | <10% additional system dead time at 5ooHz | 9% at 1,000 kHz |

**Low-level CD-4 key performance parameters: experimentally demonstrated at Project Completion:**

*The following table is not what will go in PEP since we have added for our internal discussion what the goal is; the goals are given in the TDR.*

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | CD-4 parameter | HFT Goals |
| 1 | Transverse thickness of first PXL layer | < 0.65% X0 | < 0.40% X0 |
| 2 | Internal alignment of sensors on a ladder of PXL. | < 30 μm | < 20 μm |
| 3 | Internal stability of PXL sector | < 30 μm |  |
| 4 | Relative Stability of ISD and SSD relative to PXL layer | < 300 μm | < 100 μm |
| 5 | PXL integration time | < 200 μs |  |
| 6 | Detector hit efficiency and pixel noise- PXL | > 95% sensor efficiency and noise from all sources < 10-4 | 99% sensor efficiency and noise from all sources < 10-4 |
| 7 | Detector hit efficiency and purity - IST | > 95% with 95% purity | > 96% with 97% purity (what is real achievement . Looks like this is what is possible, not relaxed) |
| 8 | Live channels for PXL and IST | > 85% | > 95% |
| 9 | PXL and IST Readout speed and dead time | <5% additional dead time @ 500 Hz average trigger rate and simulated occupancy | <5% additional dead time @ 1000 Hz average trigger rate and simulated occupancy |
| 10 | SSD dead time | < 10% at 500 Hz | < 5% at 500 Hz |

Table 3-1 HFT Key Technical Performance Parameters

These were further justified in the appendix:

# Appendix A - HFT CD-4 Key Performance Parameters

This appendix describes in detail the CD-4 key performance parameters, justification and verification methods.

## HIGH-LEVEL PARAMETERS

The instrument must be capable of a pointing resolution of better than 60 μm for kaons of 750 MeV/c which is the mean momentum of the decay kaons from D0 mesons of 1 GeV/c transverse momentum, the expected mean of the D meson distribution. The pointing resolution in r-phi can be calculated with detector simulations based on the design parameters, as-built dimensions, and from the results of surveys of the sensor ladders. The resolution in z can be up sqrt(2) larger than the r-phi resolution.

The instrument must also be capable of a single-track reconstruction efficiency of better than 60% for pions at 1 GeV/c in an Au+Au environment that are emitted from the center of the detector within a rapidity of ± 1. The 1 GeV/c pion is representative of the momentum distribution. This efficiency is defined as the fraction of TPC tracks that have correct association to PIXEL hits on both layers. The single-track efficiency can/will be calculated from full system simulations with input taken from the design parameters and as-built dimensions.

## Low-level parameters

Low-level parameters 1-9 in Table 3-1 support the high-level key performance parameters. It has to be shown by detailed simulations that fulfilling these parameters results in the anticipated performance given above.

The required pointing resolution can be achieved if performance requirements 1-3 in Table 3-1 are fulfilled.

The required single-track efficiency can be achieved if in addition to requirements 1-3, the performance requirements 4-7 are fulfilled.

The requirements 8-9 will allow the HFT system to acquire data in excess of 500M Au+Au collisions for a typical RHIC running period (10 weeks).

Specific justifications are given in the following with the requirement number given in the heading.

### 1.) Multiple Scattering in the Inner Layers

The precision with which the detector can point to the interaction vertex is determined by the position resolution of the PXL detector layers and by the effects of multiple scattering in the material the particles have to traverse. The beam pipe and the first PXL layer are the two elements that have the most profound effect upon the pointing resolution. The pointing resolution

The new beam pipe has a radius of 2 cm with a wall thickness of 750 μm, equivalent to 0.21% of a radiation length. The two PXL layers will be at a radius of 2.5 cm and 8 cm, respectively.

The total transverse thickness of the first PXL layer must be smaller than 0.65% of a radiation length. In a small solid angle area the walls of the sectors will contribute to a considerable larger radiation length; this area is in order few percent and can be excluded in the analysis. The radiation lengths of the two innermost structures, the beam pipe and the first PXL layer, are verifiable design parameters.

### 2,3,4.) Internal Alignment and Stability

The PXL sensor positions need to be known and need to be stable over the course of a run in order not to have a negative effect on the pointing resolution. The alignment between PXL layers 1 and 2 , within one sector needs to be better than 30 μm . The stability for a sector needs to be better than 30 μm (envelope).

The relative positions of the pixels within a sector will be measured with a coordinate measuring machine (CMM) with an anticipated envelope accuracy of <30 microns. Stability against thermal expansion induced changes will be measured with TV holography and a capacitive probe. Stability against cooling-air induced vibration will be measured in the final PXL assembly with a capacitive probe.

The internal placement and stability of the IST and SSD relative to the PXL should be determined to better than 300 μm (envelope). This refers to hardware limitations and requirements and not e.g. to off-line software relative alignment efforts.

Those parameters can be determined from system parameters and cosmic ray measurements. Relative internal alignment of the IST components and internal alignment of the SSD components will be mapped with a CMM with typical errors of a couple of tens of microns. Final alignment of detector system to detector system will be determined from cosmic ray measurements and off-line alignment analysis.

The relative stability of SSD and IST to pixel is verifiable by mechanical modeling of the Inner detector Support structure. The mechanical construction will be built to such specs that guarantees the SSD and IST ladder position will be known to such initial accuracy.

### 5) PXL Integration Time

The PXL is a “slow” device with a long integration time. All events that occur during the integration or lifetime of the PXL will be recorded and may contribute to pile-up. Pile-up will not limit the physics capability of the HFT if the integration time of the PXL detector is smaller than 200 μs. The PXL integration time is a verifiable design parameter.

### 5.) PXL efficiency and noise

The hit efficiency of the PXL detectors is essential for good detection efficiency. In the case of secondary decay reconstruction, the hit inefficiency of each detector layer enters into the total inefficiency with the power of the number of reconstructed decay particles into the total inefficiency.

The PXL detector sensors are designed to have an operating threshold point such that they will be more than 95% efficient for Minimum Ionizing Particles with a sensor noise hit rate of < 10-4 for the active area and live columns. This can be verified by measurements of complete readout chain on bench and with test beam.

### 6.) IST Detector Hit Efficiency

High hit efficiency for the IST detector is essential for good detection efficiency for tracks. In order to keep the inefficiency low, we require that the active strips of each of the detector ladders has a hit efficiency of better than 95% with a purity of > 95%. The hit efficiency of each detector layer can be measured on the bench before installation. A signal to noise ratio of 10:1 is known from experience with Si-sensors to ensure a hit purity of 97% or better with an efficiency of 99%.

### 7.) Live Channels

Dead channels in the PXL and IST will cause missing hits on tracks and thus lead to inefficiencies in the reconstruction of decay tracks. Therefore, the number of dead channels needs to be as low as possible. The impact of dead channels on the overall performance will be small and affect the overall acceptance, not pointing resolution. if more than 85% of all channels are alive at any time. The number of dead channels can be determined immediately after installation of the detectors on the mounting cone structures. The value is set to reflect typical performance of newly installed detector system as evaluated from historical data.

### 8,9.) Readout Speed and Dead Time

In the absence of a good trigger for D mesons it is imperative for the measurement of rare processes to record as many events as possible and as required by the physics processes. In order not to add significant dead-time to DAQ, the PXL and IST readout speed needs to be compatible with that of DAQ-1000 and the dead-time such that at a readout rate with the Time Projection Chamber at 500 Hz additional dead time is no more than 5% for the PXL, IST and 10% for the SSD. The SSD dead time varies linearly with rate constrained by the existing non-replaceable components on the detector ladders.

Readout speed and dead time are verifiable design parameters.

## Other functional requirements

|  |  |  |
| --- | --- | --- |
| A | Active sensor length of PXL layer 1 & 2 | ≥ 20 cm |
| B | Active sensor length for IST | ≥ 46 cm |
| C | Pseudo-rapidity coverage for SSD | |η| < 1.15 |
| D | PXL RDO data path integrity | BER < 10-10 |

The active sensors length requirements for PXL and IST are to ensure rapidity coverage in -1<η< 1 for all detector systems in the vertex range from -5 cm to +5 cm.

The total length of the PXL detector silicon sensors is designed to be 21.7 cm. The active tracking silicon in this length is 21.19 cm.

The total active silicon length of the IST should be 46 cm or greater at a maximum radius of 15cm to be able to cover -1< η <+1.

The length of the SSD ladders is fixed. The requirement C is consistent with a radius of 22 cm and 2π azimuthal coverage.

The PXL readout data path is expected to have a data transfer rate of ~ 200 MB/s (with a trigger rate of 1 kHz). In order to preserve the data integrity we will validate the data path to have a bit error rate (BER) of < 10-10.

|  |  |
| --- | --- |
| **Sub-system** | **Deliverable** |
| **PXL** |  |
|  | PXL insertion structure |
|  | PXL insertion tool |
|  | Ready to install PXL assembly: with two clam shells populated with 10 sectors with each sector consisting of :  One ladder at a radius of 2.5cm and 3 ladders at 8.0 cm.  Each ladder contains: 10 silicon detector elements, one readout board  40 ladders total |
|  | 3 DAQ receiver Personnel Computers |
|  | Two spare clamshells, with five sectors integrated and aligned on each clamshell, installed on pixel insertion tool. |
|  | Forty additional tested ladders to serve as spares and replacement components to allow for any needed repairs to the existing sectors of the PXL detectors |
|  | Low Voltage Supplies , Cabling, and Cooling Services |
|  | A PC-based control and monitoring system |
| **IST** |  |
|  | 27 (24+3 spares) ladders with six sensors per ladder |
|  | 24 IST ladders installed on the Middle Support Cylinder |
|  | Silicon bias voltage system for 24 ladders |
|  | Readout system for 24 ladders |
|  | Cabling and Cooling Services |
| **SSD** |  |
|  | 20 of the existing SSD ladders instrumented with new readout electronics compatible with the readout requirements for the Time Projection Chamber |
|  | SSD installed on the Outer Support Cylinder (OSC) |
|  | Cabling and cooling services compatible with the IDS structure and the Forward GEM Tracker (FGT) |
| **IDS** |  |
|  | The east support cone, and the middle support cylinders for the SSD, IST and the beam pipe support. |
| **Software** |  |
|  | Online control software verification |