

WBS Dictionary:

The WBS is divided into

1.1 Management

1.2 PXL detector

1.3 IST detector

1.4 SSD detector upgrade

1.5 Inner detector Support and Integration

**1.6 Software**

### Revision History

Revision No.	Description / Pages Affected	Effective Date

## 1.1 Management

Level of effort tasks associated with the daily management, oversight, and assessment of the project.

## 1.2 Pixel

The Pixel System will provide as final deliverables, two copies of the production

### **Sector Mount and Survey (Engineering)**

After D-Tube assemblies are complete, Sectors are mounted to these detector halves, and using the tooling provided above, a survey of sufficient accuracy is performed.

Electrical testing of each sector after it is mounted and it's cables dressed onto the D-Tube is required. The test equipment is provided by the Electronics effort. Labor to complete these QA tests is costed here. Tests are required after mounting and after survey to assure nothing was damaged (e.g. wire bonds) during survey.

Auxiliary labor to replace damaged sectors is included here in contingency. As the installation is serial, if the first Sector is damaged, this represents complete replication of labor and test.

This will be the first qualification of the Survey method, as such, it is desired to have at least 5 sectors available, enough to populate  $\frac{1}{2}$  of the detector to verify the survey procedure for the Production Installation. There are currently 5 such electrically functional sectors costed in base, but argument for additional sectors is warranted. Should scope allow for only 5 sectors, disassembly will be required to populate the other half detector for the engineering run—and associated re-test, re-survey of the final version of the assembled halves.

Final deliverable is 2 surveyed half detectors, 1 with 2 sectors, the second with 1 sector. Each ready to mount onto the hinge structure of the cart and terminate their respective cables to the MTB. Note, Dummy Sectors (w/out functional ladders) may be required to establish proper boundary conditions for cooling air flow.

It is clear that this will at least first occur at LBNL. It is desirable to re-survey after shipment to BNL, thus requiring shipment of the 'Survey Tool' to BNL with the Pixel Engineering System.

Output of Survey is a primary input to 'Alignment' task in Software WBS

### **Sector Mount and Survey**

Two copies of the full detector are required (4 halves). Assembly of the first will use the D-Tube assemblies fabricated for production. The second copy will either use new D-Tubes, or the recovered D-Tubes from the Engineering Run. Advantage of using 'new' D-Tubes is earlier completion of production deliverables rather than waiting for recovery after opening in 2013.

As with the engineering run, all test equipment will have been developed in Electronics for production DAQ/Sensors. Labor here is to mount then test each sector. Survey of each completed half, and labor in contingency to rebuild should damage occur, perhaps for only 2 of the 4 required assemblies. Deliverables are 1 complete detector for Production run sufficiently in advance to allow ~6mo system testing, and lagging a second copy. Note efficiency of completion of both copies simultaneously rather than waiting for recuperated structures from Engineering Run...

### ***1.3 Intermediate Silicon Tracker (IST)***

Efforts related to construction on the IST, including sensors, readout electronics, cooling, and mounting structures.

### ***1.4 Silicon Strip Detector (SSD)***

The RDO boards of the existing Silicon Strip detector (SSD) will be upgraded so its performance matches the requirement of the current STAR DAQ 1000. Upgraded cooling system, as well as mounting structures are provided in this WBS.

### **1.5 Global Supports and Integration**

Primary deliverable is global support structure, and effort to maintain integrated design across all internal sub-detectors and with STAR and the FGT project.

## 1.6 Software

The Software deliverables contain all software modules necessary to produce physics results. The tools are divided into two broad categories: Online and Offline. The modules needed will monitor, calibrate, reconstruct, analyze and evaluate the acquired data samples.

### 1.6.1 Online

The online software primarily ensures the data integrity during data acquisition via appropriate detector monitoring and sample event reconstruction. Online software is detector specific and is a deliverable of the corresponding sub-system.

### 1.6.2 Offline

The offline environment consists of the event reconstruction software packages. This starts with the raw data as input and through proper calibrations it proceeds with detector cluster/hit finding, integrated tracking, event-vertex and secondary-vertex finding and event information writing on DSTs.

### Hit Reconstruction

The Cluster/Hit finder is the first piece of code applied to the pedestal subtracted raw information from the IST and PXL detectors and its task is to deliver reconstructed space points to tracking software. The software modules associated with this task are outlined below (grouped by detector):

**1) SSD:** The SSD is an existing (refurbished) detector in STAR. Its behavior is well understood and there are hit reconstruction modules already in place. The only software tasks left are dead-strip mapping (a calibration/Db issue) and the update/testing of the hit finder routine with the new configuration. We also list here an unfinished/untested single-side hit finder as a prospective hit-finder update provided the manpower to finish it.

1.1 Test/Certify/Update the existing SSD cluster/hit finder with the new configuration. 0.5 FTE for a period of 6(2) months is needed for this task completion.

1.2 Test/Evaluate the single-side hit finder based on the Root function TSpectrum initiated by BNL/Nantes. 0.5 FTE for a period of 6(2) months is needed for this task completion. The deliverable would be a replacement cluster/hit finder for the SSD and perhaps the IST.

Institutions responsible: [KSU, BNL, other]

**2) IST:** The IST hit finder can either be a modified version of the SSD one (since the IST is a single-side version of the SSD), or a STAR adaptation of the PHOBOS hit finder used in similar devices.

2.1 Update/Test/Certify the adapted hit finder. 0.5 FTE for for a period of 6(2) months is needed for this task completion.

Institutions responsible: [MIT, other]

**3) PIXEL:** The hit finding of the PIXEL detector is a more complex task. One major difference is that it is an online task, i.e. only one pixel address number is saved in the raw data, not every fired pixel. This implies that cluster finding and centroid determination is done at the firmware level. Nevertheless, for that to be successful, a slow simulator and extensive studies with real particles (to determine and classify the various cluster shapes and their centroids) are needed. We list those task here but the first one is really an item for the 'Detector Response Simulators' sub-heading.

3.1) Pixel cluster/hit simulator. Estimated needed manpower is 1.0 FTE for 6(4) months. It includes development, testing but not evaluation with data (see next task).

3.2) Evaluation/tuning of cluster/hit finder with data. 0.5 FTE for 4(2) months. This does not include the scheduling and data-taking times.

Institutions responsible: [LBL, Strasburg, other]

### **Tracking**

The tracker module performs pattern recognition at hit level (spanning several detectors) and delivers reconstructed particle trajectories with momentum and directional information. Part of its job is to 'match' segments in different detectors. Integrated tracking is a task the infrastructure of which is taken care by the BNL software group. It is imperative, nevertheless, that the HFT software group has experts in it that will interact with the BNL group for possible improvements, maintenance etc. This was done in the past and greatly improved the performance of the STAR tracking packages. The software tasks associated with the HFT group are:

1.1 Evaluation/tuning/monitoring of current Kalman tracker. 1-2 FTE intermittent over 3 years period. Parts of this task have been done with simulated data but it also needs to be done with real data, as they become available. Parameters to be monitored are momentum resolution (cosmics) and DCA distributions.

1.2 Alternative tracking evaluations. 1-2 FTE intermittent over a 2-3 year period. This task is to evaluate methods that might enhance the performance of the 'standard' tracker. Some work has been done in the past on ideas such as 'momentum ordering' or using the 'event vertex constraint' but detailed, precise performance evaluations are needed before the deployment of such upgrades. Possible deliverables are upgrades of the tracker.

Institutions responsible: [BNL, other]

### **Event Vertex Reconstruction**

The vertex finder module is responsible for using all available tracking and detector information to best estimate the collision point, i.e. the spatial point where the event occurred. Knowledge of the event vertex is a crucial piece of information in associating tracks to it and for secondary decay vertex searches. Several approaches might need to be deployed depending on the environment, e.g. a high multiplicity central Au+Au or a relatively low multiplicity p-p high luminosity event.

Event vertex reconstruction is a task very tightly coupled to tracking and, as in the past, the major part of contributions to developing/testing etc is coming from groups within STAR with special interests. Such a group is the HFT and we need to maintain a core group of experts that will perform these tasks. The following tasks are HFT related:

1.1. Vertex finder for high multiplicity (e.g. AuAu) environment. This refers to Minuit or Kalman based fitter and involves the development/optimization and evaluation of their performance with the HFT in place. The package will need to properly reconstruct multiple vertices and provide a reliable vertex-ranking scheme. 1-2 FTEs ramping up the effort over the course of 2-3 years will be needed for this task. Deliverable is an updated vertex-fitting package in the STAR library.

1.2 Vertex finder for p-p and low multiplicity environments. The special problems of an increased luminosity (especially at higher p-p energies) and low multiplicity need special care as it has been shown in the past. 1 FTE ramping up the effort over the course of 2-3 years will be needed for this task which is closely related to the previous one above. Deliverable is an updated p-p vertex-fitting package in the STAR library.

1.3 R&D. This is for packages, like Kalman vertex fitters, that work closer and are better integrated with the tracker. Thorough testing and evaluation are the main tasks involved here. 0.5-1 FTE spread over the next 2 years is the estimated manpower needed for this task. Deliverable is a new vertex fitter for either (or both) environment above.

Institutions responsible: [BNL, KSU, other]

### ***Secondary/Decay Vertex Reconstruction***

The reconstruction of short-lived particles in a collider environment is an extremely challenging task. The key measurements of HFT involve the reconstruction of D- and B-mesons with typical  $\tau$  in the range of 120 – 500 microns, and  $\Lambda_c$  with a  $\tau$  of 60 microns. These important software modules need to be developed, as they are a key piece of the new software. Their task is to discriminate (separate) the decay points from the primary vertex with good resolution so that the combinatorial background levels are manageable. In order to be compatible with the Kalman-based tracking engine, Kalman packages are thought to be implemented in STAR, like in every major experiment these days.

1.1 Decay vertex fitter. 1.0-2.0 FTEs are needed spread over the next 3-4 years (since the final part of the testing/evaluation will be done with data). Effort on this task has already begun. Deliverable will be one (or more) secondary vertex packages in the STAR library.

Institutions responsible: [BNL, KSU, other]

### ***Databases – Calibration and Alignment***

The accurate monitoring and recording of the state and the position of the detector inside the STAR apparatus is of utmost importance as it directly impacts its performance. Calibration is the online and offline task of monitoring the state of the

detector as well as the set of tasks needed to correct for any disruptive action. The online part (often referred to as slow controls) gathers information of the detector in-situ, usually during running periods. Such information might be temperature or position of elements, pedestal files etc. This information is provided by the detector's slow control system and it is stored in a Database with a timestamp. The offline part of the calibration includes software methods used to check e.g. the position of the detector elements using tracking information. The results of these procedures are stored as updated values in specific bank in the Database and are used in the massive offline physics production reconstruction passes.

**ALIGNMENT** is a special and very demanding task especially for the PXL detector where one would like to perform/know the positioning of the detector elements with offsets and tolerances to within a few microns. There are four distinct steps for the successful completion of this task:

1) **SURVEY** of detector elements: This is the task of determining the relative position of the various detector elements after they are assembled and before they are installed in the experiment. The sub-tasks associated with this problem are:

1.1 Develop software that analyzes the Coordinate Measuring Machine (CMM) data. The manpower needed is 0.5 FTE and the task can be completed in 6 (2) months.

1.2 Test/Certify software. 0.1 FTE is needed and the task duration is 1 (1) months.

1.3 CMM Data analysis. This task will take about 0.5 FTEs to complete and will take 6 (2) months to complete.

The deliverables are the following geometry matrices (for StarDb):

SSD: wafer-to-ladder geometry matrices (g.m.)  
ladder-to-shell g.m.

IST: idem

PXL: [pixel-to-shell] geometry function  $[z=f(x,y)]$   
OR (depending on prototype test results)  
chip-to-ladder g.m.  
ladder-to-sector g.m.  
sector-to-shell g.m.

Institutions responsible: SSD [BNL, KSU, other]  
IST [MIT, BNL, KSU]  
PXL [LBL, BNL, KSU]

The above tasks require skills at the graduate student and/or post-doc level.

Requirements/Pre-requisites:

- a) Detector-element naming-scheme documentation.
- b) CMM operator time to perform the data collection.

2) **GLOBAL** Alignment: This is the task of relative alignment of HFT complex to TPC (and thus the STAR coordinate system) using tracking information. The sub-tasks associated with this problem are:

2.1 Software development. The manpower needed is about 0.5 FTE and the task can be completed in about 3 (1) months (including testing).

2.2 Data analysis. This task takes about 0.5 FTE and about 1 (1) months to complete.

The deliverables are the following geometry matrices (for StarDb):

SSD: Shell-to-STAR (TPC) geometry matrices (6 param.)

IST: idem

PXL: idem

Note: This task needs to be repeated at the beginning of every RHIC run, except in the case of PXL detector where it needs to be repeated every time there is a shell replacement.

Institutions responsible: SSD [BNL, KSU, other]

IST [MIT, BNL, KSU]

PXL [LBL, BNL, KSU]

The above tasks require skills at the graduate student and/or post-doc level.

Requirements/Pre-requisites: Low luminosity data.

3) **SELF** Alignment: This is the task of determining the relative position of SSD, IST and PXL shells using tracking information. The sub-tasks associated with this problem are:

3.1 Software development. The manpower needed is about 1.0 FTE and the task can be completed in about 6 (2) months (including testing).

3.2 Data analysis. This task takes about 0.5 FTE and about 3 (2) months to complete.

The deliverables are the following geometry matrices (for StarDb):

SSD: Shell and/or Ladder-in-Shell (shift) geometry matrices

IST: idem

PXL: idem (but 2<sup>nd</sup> layer only since 1<sup>st</sup> defines the geometry)

Note: 1) Track info can be either collisions or cosmic rays with the detector in situ.

2) This task needs to be repeated at the beginning of every RHIC run, except in the case of PXL detector where it needs to be repeated every time there is a shell replacement.

Institutions responsible: SSD [BNL, KSU, other]

IST [MIT, BNL, KSU]

PXL [LBL, BNL, KSU]

The above tasks require skills at the graduate student and/or post-doc level.

Requirements/Pre-requisites: Low luminosity data.

4) Testing: Use DCA, pulls, physics quantities (like inv. mass resolution) to verify alignment.

4.1 Verification. The manpower needed is about 1.0 FTE and the initial (first time) task can be completed in about 3 (2) months.

Note: Needs to be repeated whenever item 2) or 3) above change, i.e. at least once per RHIC run and before major DST (offline) production.



## Simulation/Evaluation Framework

The tasks, and therefore software modules one needs to develop here are: a) the **detector geometry** definition, b) the **detector response** packages (fast and slow simulators), c) track **embedding** in real/raw events, d) a hit **pileup** handler, e) the Association Maker and structures for **evaluation** purposes, and f) Physics **analysis** code (performance, physics etc) capable of handling and evaluating the resulting information. Our group will have to contribute modules and effort in all these categories. It is worth mentioning here that besides this full and detailed simulation chain the group has developed very useful tools for quick estimates of various detector configurations, resolutions, layouts etc. These tools, sometimes referred to as 'hand calculations' or 'fast Monte Carlo' will keep playing an important role when either a quick turn around is needed or for cross checking purposes.

### Detector Geometry Definition

This task is to include in the GEANT-simulated apparatus of the experiment the latest and most accurate/realistic geometry of HFT (IST and PXL), since this is the only way to ensure reliability of the resulting efficiency numbers. This task also includes the definition of the active areas of the detector, the hit information and the global positioning matrices of the detector.

**1) SSD:** Build/Update the geometry packages of the reconfigured SSD. 0.3 FTE for a period of 3(2) months would be sufficient for the implementation/verification of this task. This task may need one extra iteration before finalizing. The manpower quoted is for a single iteration. Deliverable is a working/accurate geometry package for the detector.

**2) IST:** Build the geometry packages for IST. 0.5 FTE for a period of 3(2) months would be sufficient for the implementation/verification of this task. This task may need one or two iterations before finalizing. The manpower quoted is for a single iteration. Deliverable is a working/accurate geometry package for the detector.

**3) PIXEL:** Build detailed geometry packages for PIXEL. 0.5 FTE for 6(3) months is the estimated needs for implementation/verification of this task. This task may need one extra iteration before finalizing. The manpower quoted is for a single iteration. Deliverable is a working/accurate geometry package for the detector.

Institutions responsible: [LBL, MIT, BNL, KSU, other]

Note: This effort doesn't include possible infrastructure move to VMC. Additional effort might be needed for such adaptation/move.

### Detector Response Simulators

The detector response simulation packages in STAR reside outside the GEANT framework. They are actually invoked at the event reconstruction step. Typically there are two or three categories of response simulators: a) *Fast simulators*, which smear the hit position coordinates and assign hit uncertainties based on parameterized analytical functions. The fast simulators run extremely fast and are good for quick studies that do not need detailed implementation of the detector. They are also relatively easy to implement; we already have an HFT fast simulator in place for all syb-systems, b) *Slow simulators*, which simulates hits at the ADC level

(usually obtained from sampling parameterized response functions. A slow simulator is a must when accurate acceptance and efficiency numbers are requested in physics analysis. A slow simulator is also used in embedding as discussed below, and c) *Very Slow simulators*, which track individual electrons through the detector body; from their generation to the readout. This is usually very time consuming and one utilizes this method only in small-scale productions in order to determine or verify the functions used in the first two methods.

For this task, which is the detailed breakdown of software modules needed to be in place for the successful operation of the detector, we consider only part b), i.e. the Slow simulators. Fast simulators are already in place and Very Slow Simulators will be done as needed. For these latter tasks, 1.0-1.5 FTE spread over the period of 2 years should be reserved by the responsible institutions for this task.

**1) SSD:** Update the SSD simulators. This is a minor task. 0.3 FTE for 2(1) months should be sufficient for this task.

**2) IST:** Build an IST simulator. This task should profit from previous work done in experiments using this technology (PHOBOS). 0.6 FTE for 6(3) months is the estimated effort needed.

Note: Building a PIXEL slow simulator is considered to be part of the Hit finder effort. PIXELS deliver digital information. Here we just need a parameterization (track angle, ionization) that assigns 'Geant' hit to pixels.

Institutions: [MIT, LBL, BNL, KSU, other]

### **Embedding and Pile-Up**

The embedding of simulated tracks into the raw data stream (which provides the best 'background environment' for track/particle reconstruction and therefore the best way to estimate accurate efficiency numbers for physics analysis) has been around the heavy ion community for about fifteen years. It is the merging, at the raw ADC level, of a pedestal-subtracted event, for a given detector, with a few, slow-simulated hits. The resulting output is then passed through the reconstruction chain and the output is compared to MC input (this step is performed by the so-called Association Maker in STAR experiment). During the merging of real data with simulated hits and tracks one reads the appropriate calibration tables so the dead areas of the detectors are properly excluded. This task will require an initial 0.5 FTE effort from the HFT group (working with the embedding/infrastructure group) for verifying the merging mechanism. The deliverable is a successful embedding mechanism in place for all three HFT components (the SSD is already in place). This effort is expected to begin about half a year before the first data taking.

Institutions: [MIT, LBL, BNL, KSU, other]

### **Physics Analysis Framework**

The physics analysis software is the most critical part in signal extraction. When it comes to physics analysis people use a diverse set of tools and methods to extract the physics signals, most of them developed by individuals. Here we will only identify the broad areas of physics interests for the HFT mainly for the purposes of recording the institutional interests, responsibilities and commitments. These areas

are: a) Charm-meson, b) Charm-baryon, c) B-meson reconstruction and d) possible spin-related signals.