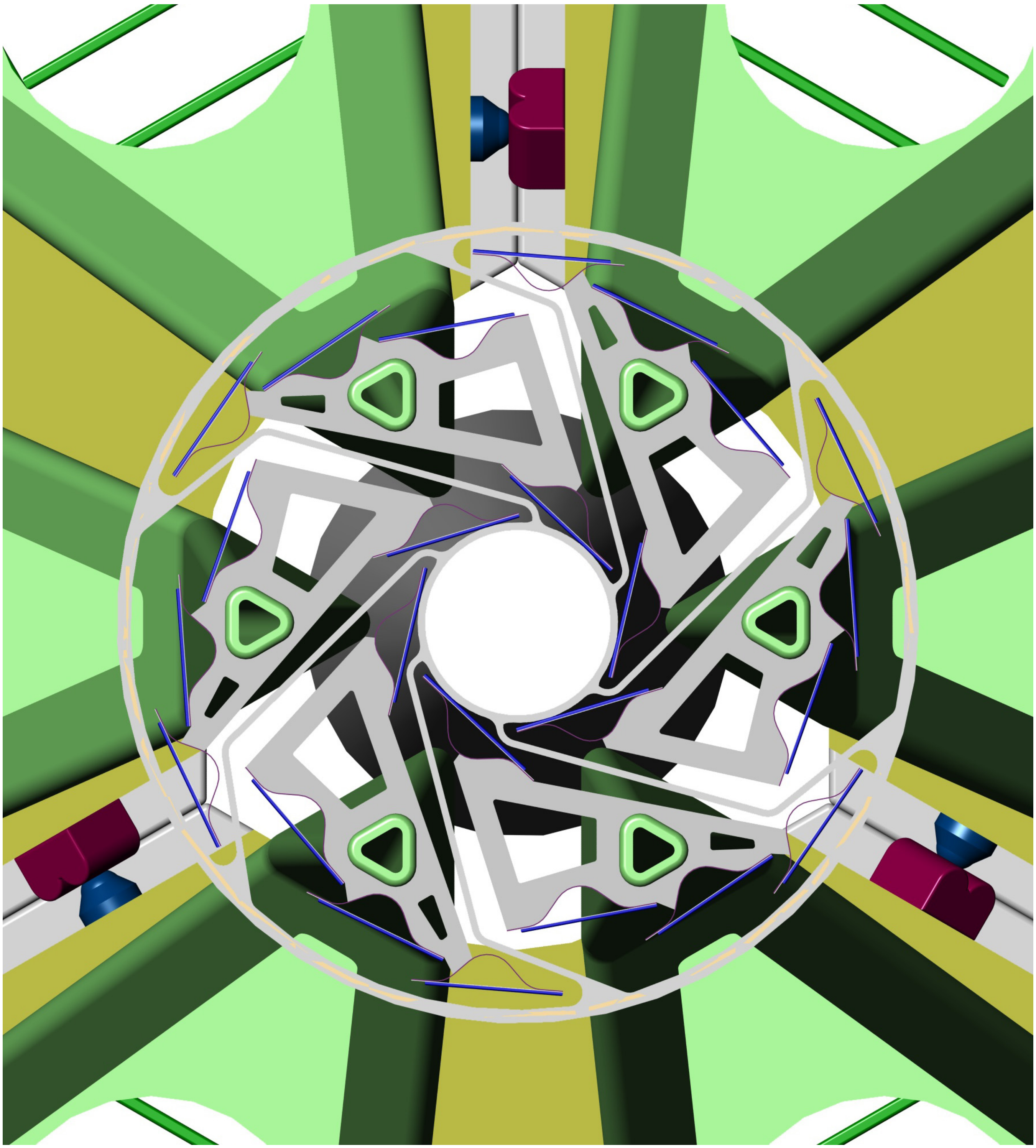
Proposal for FY06 R&D Aimed at Developing A Heavy Flavor Tracker for STAR



Proposal for FY06 R&D Aimed at Developing A Heavy Flavor Tracker for STAR

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on behalf of the HFT development team

Summary: We propose to develop a Heavy Flavor Tracker for STAR. The HFT is a new and innovative detector concept that will enable STAR to do the direct topological reconstruction of open charm hadrons. The detector technology is based on CMOS pixel arrays, code named MIMOSA, that are being developed at the IPHC laboratory in Strasbourg, France. The STAR silicon pixel arrays are based on 5^{th} generation MIMOSA chips and the STAR prototypes are named MIMOSTAR I, II, and III.

We propose to put MIMOSTAR II chips in STAR for run VII. The chips will be mounted on a ladder and installed as close to the STAR IR as possible. We will do this with an electronics package that is fully compatible with the STAR DAQ and readout system. We will also contribute to the development and testing of MimoSTAR III chips, including fabrication in France, testing of the chips at the LBL Light Source, and at the Tandem Van de Graaf laboratory at BNL. Finally, in FY06, we will begin the preliminary engineering design of the beam pipe and carbon fiber kinematic mounts for the final detector.

Scientific Motivation: The primary motivation for the HFT is to extend STAR's capability to measure heavy flavor production by the measurement of displaced vertices. This is a key measurement for the continuing heavy ion and spin physics programs at RHIC. Heavy quark measurements will facilitate the heavy ion program as it moves from the discovery phase to the systematic study of the dense medium created in heavy ion collisions as well as the nucleon spin structure in polarized p + p collisions. The primary physics topics to be addressed by the HFT include open charm measurements, thermalization, flow, and heavy quark energy loss.

One of the most exciting prospective measurement with the pixel detector is to perform a measurement of the elliptic flow of D mesons down to very low p_T values. It is a generally accepted fact that elliptic flow is established in the partonic phase. If charm quarks, with a mass much larger than the temperature of the system, undergo elliptic flow then it has to arise from many collisions with the abundant light quarks. Thus, flow of charm quarks can be taken as a probe for frequent re-scatterings of light quarks and is an indication of thermalization that may be reached in the early stages of heavy ion collisions at RHIC. We believe that proof of thermalization constitutes the last step towards the establishment of the QGP at RHIC and this measurement requires a very thin detector.

Detector Concept: The proposed HFT detector will reside inside the STAR TPC and it will surround the interaction vertex. It will exploit all of STAR's unique features including full azimuthal coverage and tracking from the lowest to the highest p_T. The HFT has two tracking layers composed of monolithic CMOS pixel detectors using 30 μm × 30 μm square pixels. These critical innermost tracking layers lie at radii of 1.5 cm and 5.0 cm, respectively, and these layers are active over 20 cm in Z and have ~ 100 million pixels. The HFT will provide tracking information for decaying particles that are displaced by a hundred microns, or less, from the primary vertex. In this respect, the STAR HFT is unique. No other silicon detector at RHIC combines this kind of extreme pointing accuracy and effectively measures all particles down to 150 MeV/c; it is these feature that enables the HFT to do the direct topological reconstruction of open charm hadrons. The silicon chips for the detector will be thinned to 50 μm and will be mounted on low mass carbon fiber structures to minimize pointing errors generated by multiple Coulomb scattering.

Scope of Work: The scope of work for this R&D project is broken down in detail in Table 1.

One of the primary activities to be accomplished with this R&D project is to build, test, and install a pair of back to back ladders with 2 MIMOSTARII chips per ladder in the STAR detector at RHIC. We will place the ladders as close as possible to the actual location proposed for the HFT in STAR and we propose to take data with it during RHIC run VII.

This will constitute a full test of the active pixel sensor technology to be used by the HFT because the MIMOSTAR II chips are nearly identical to the proposed final chips for STAR except for size. The MIMOSTAR II chips are fabricated with a 128x128 array of pixels while the final chip (MIMOSTAR IV) will have a 640x640 array of pixels.

The beam test will allow us to test the background environment at STAR, it will enable us to sample the luminosity, with limited tracking in a high multiplicity environment. The tests will be done with prototype electronics that are proposed to be used in the final HFT and we expect them to be fully compatible with the unmodified STAR DAQ and readout chain.

Another major activity associated with this R&D project will be to continue developing and testing the MIMOSTAR III chip. This work will be done in collaboration with IPHC Strasbourg and we will share the expense of this fabrication run. The primary difference between MIMOSTAR II and III is that MIMOSTAR II is only a 128x128 array of pixels. MIMOSTAR III will be a full ½ size chip with a 320x640 array of pixels. The new chip will also have two 50 MHz readout buses (instead of one) and it will utilize state of the art radiation-hard diodes. MIMOSTAR II had two kinds of diodes, both rad-hard and non-rad-hard, and our tests showed that the rad-hard diodes are satisfactory for our purposes and therefore the non-rad-hard diodes can be removed from the design. Thus MIMOSTAR III is actually a less complex design, in some respects, than MIMOSTAR II.

We will conduct tests on the chips produced in the MIMOSTAR III fabrication run to measure the basic performance parameters for the chips: charge deposition, dE/dx, and other parameters. These tests will be done at the LBL ALS as well as at the BNL Tandem Van de Graaf accelerator.

Finally, we will begin the preliminary engineering design for two major components of the HFT; the beampipe and the carbon fiber supporting arms to support the detector ladders.

The beampipe for the HFT must be very thin because the HFT is an extremely high resolution detector and therefore it is multiple coulomb scattering limited in most respects. The detector must be thin and anything that comes before it must be thin; so we propose to use a Beryllium beampipe that is only ½ millimeter thick. Such a thin beam pipe is very delicate and will not be easy to handle. We imagine that an exo-skeleton will be required around the thin portion of the beampipe and this requires careful engineering to make it compatible with the HFT. We will specify the parameters for the beampipe in FY06 and work with at least one vendor (Brush-Wellman) to ensure that our design can be built at a reasonable cost. Hopefully, a fully bone-fide quotation can be obtained from the vendor as the end product of this effort.

The mechanical apparatus to support a Si pixel ladder is a very delicate device. It must be mechanically articulated in such a way that it can collapse down around the beam pipe and insert the ladders into and inside the exo-skeleton for the beam pipe. It must also be very stiff because we are trying to hold the detectors to within 10 or 20 microns of their nominal location. We anticipate that the mechanical apparatus will be made of carbon fiber in order to meet the stiffness requirement. Carbon fiber composite engineering is a highly specialized field and therefore we must begin the specification and preliminary engineering design of this apparatus as soon as possible. The selection of a qualified carbon composite engineer will be critical to the success of this phase of the project. We have allocated 4 man months to this part of the project in FY06.

Cost: The costs associated with the work on this project are shown in Table 2. The bottom line is $394K; and does not include contributed labor from IPHC nor the labor of the physicists on the project.

1	support arm	▪ Carbon arm connecting kinematic support to ladders, ▪ should include the ladder support termination structures ▪ fixturing
2	beam test ladder	▪ Carbon ladder supporting the flex pc with chips ▪ fixturing
3	beam test mounting in star	▪ Support of ladder pair next to the beam line ▪ Wiring/power ▪ Safety reviews ▪ DAQ receiver PC ▪ Clock and Trigger in TCD crate with cabling ▪ DDL/SIU
4	chip test	▪ MIMOSTAR2 Mezzanine ▪ APS5 Mezzanine ▪ Readout VHDL ▪ MIMOSA5 thinning studies ▪ MARTEST1 (Battaglia) ▪ MARTEST2 (Battaglia) ▪ APEC ▪ DEPFET (Battaglia)
5	MIMOSTAR3 foundry	▪ Foundry cost, half of a half reticule, engineering run
6	software tools	▪ 2 SolidWorks renewal ▪ 1 Cosmos renewal ▪ IPs for ALTERA (cores) ▪ Chip scope (Xilinx) ▪ 2 Virtex 4 evaluation kits ▪ additional kits
7	beam test mother board	▪ Interface between daughters and Microtronix Stratix kit ▪ PC board ▪ Connectors, standard and high density ▪ Power with Latchup protection ▪ Connection cables
8	beam test flex pc board	▪ Aluminum flex PC that supports APS chips
9	beam pipe	▪ 500 micron beryllium pipe with exoskeleton ▪ Specification for bidding process
10	beam pipe handling	▪ Installation mechanics and procedures
11	UC Program	▪ Support UC Irvine chip development

Table 1: Scope of work for the FY06 HFT R&D project. The breakdown includes specific activities as well as the supplies (such as software tools) required in order to make the activities possible.

	hourly rate	Institution multiplier	burden multipier	overhead multiplier	IBO tot Mult	HRWBOH amount	contingency multiplier	Total hour rate	Monthly rate k$
LBNL Eng	65.625	1.206	1.42	1.175	2.012211	132.0513	1	$132/hr	23.24
LBNL Tech	43.75	1.206	1.42	1.175	2.012211	88.03423	1	$88/hr	15.49
		1.206	1.42	1.175	2.012211	0	1	$/hr	0.00
BNL Eng	65.625	1.206	1.42	1.175	2.012211	132.0513	1	$132/hr	23.24
BNL Tech	43.75	1.206	1.42	1.175	2.012211	88.03423	1	$88/hr	15.49

	task	start date month	duration months	Tech %	ID	Eng %	ID	Scientist %	ID	labor k$	Purchase k$
1	support arm	may	4			1	NH			93	10
2	beam test ladder	april	4	0.3		0.25	LG			42	7
3	beam test mounting in star	april	3			0.3	RB,LG			21	6
4	chip test	oct	12			0.1	LG			28	4
5	MIMOSTAR3 foundry	sept								0	30
6	software tools									0	10
7	beam test mother	dec	5			0.3	LG			35	2
8	beam test flex pc	april				0.25	LG			0	10
9	beam pipe	may	2			0.5	RHIC			23	
10	beam pipe handling	may	5			0.2	UNK			23	
11	UC Program										50
12										265	129
13											
14											
15								Grand Total			394

Table 2: Cost breakdown for the proposed FY06 HFT R&D activities.