Report of the
BNL Technical Advisory Committee Review of the
STAR Large Area Time of Flight Project (TOF)
August 2-3, 2007

Committee members: *R. Alarcon (Arizona State University), R. Betts (UIC), C.-Y. Chi (Columbia U.), A. Drees (Stony Brook), V. Radeka (BNL)*

Also participating: *P. Bond (BNL), T. Ludlam (BNL, convener), H. Marsiske (DOE), J. Simon-Gillo (DOE)*

Summary
The Committee was asked to provide an assessment of the technical status and progress, as well as the cost, schedule, and management performance of the project. This assessment focused particularly on issues reflected in the Committee's findings at the annual review conducted in the September 2006 regarding the estimated cost to complete the project, and the schedule for design and production of critical electronics components (TDIG and TCPU boards). The Committee's assessment is based on presentations made during the review by the STAR TOF collaboration, and documentation provided prior to the review. The charge letter is given in Appendix 1, and the Review Agenda is shown in Appendix 2.

The Committee heard a presentation of the physics objectives and performance requirements for the TOF detector. The range of physics goals has increased since the project was first proposed. The device is now central to the STAR plans for carrying out a search for the QCD critical point, with a scan through very low collision energies in a special series of RHIC runs. BNL plans to begin carrying out such runs in FY 2010 (Run 10), in anticipation that the TOF detector will be fully operational at that time.

The TOF project managers have taken steps to reduce the costs and bring the contingency funds to an acceptable level. The amount of contingency, as a fraction of the estimated cost-to-complete, has risen from 9% at the last review to 20% currently. This is in part due to savings in labor costs, but is largely due to completion of technical components of the project within the original baseline cost estimate.

Good progress has been made on the electronics since the last review. The design and initial testing of the critical readout boards, TDIG and TCPU, is substantially complete. Near-final prototype boards (useable in the experiment) have been received from the vendor, Blue Sky Electronics, and full-scale production of these boards is expected to begin within the next few months. The production schedule given by Blue Sky calls for completion of the production in less than a year. The production of these boards is starting approximately one year later than anticipated in the initial project schedule.

Excellent progress continues to be made by the Chinese collaboration responsible for the MRPC production at Tsinghua University and at University of Science and Technology of China (USTC). The production is on schedule, with more than 2000 modules

produced to date. The MRPCs have met rigorous QA standards in tests both in China and the U.S. The MRPC production is expected to meet its schedule for completion in 2008.

In order to mitigate the delay in the schedule for electronics delivery the project has re-evaluated the tray assembly schedule at UT Austin. As recommended at the September 2006 review, the tray components were purchased and the assembly begun in advance of the production of readout boards. Assembly of the first few trays demonstrated that a rate of two trays per week is possible, and the revised TOF Project Plan is based on this pace. At this rate of assembly, all trays can be completed in the 2nd quarter of FY 2009, the original milestone date for project completion. A Baseline Change Proposal was presented for the project, with schedule milestones corresponding to the revised Project Plan. The proposed new baseline schedule shows the "Project Complete" milestone in the 4th quarter of FY 2009, giving six months of schedule contingency.

The Committee expressed satisfaction that the all-important goal of achieving the production phase for all elements of the TOF modules appears to be very nearly in hand, and that an overall plan to complete the project in time for full operation in 2010 has been developed, with achievable milestones as well as reasonable cost and schedule contingency. While the project has made good progress since the review last September, many challenges remain. Among its recommendations, given below, the Committee advises that a final electronics review be carried out internally by STAR for the TINO, TDIG, and TCPU boards as soon as possible. A pre-production run of ~100 TDIG boards could proceed prior to this review, in order to meet the goal of having approximately ½ of the full TOF detector in place for the FY 2009 run.

The Committee's detailed comments and recommendations are given in the following sections.

Physics objectives and performance requirements:
It is impressive to see how the physics impact of the TOF detector has expanded with time. As well as for other physics topics, the TOF detector will be crucial in the search for the critical point in the low energy run scheduled for 2010. This search will, in part, focus on measurements of fluctuations and correlations as a function of energy and the PID capabilities afforded by the TOF detector will allow the separate study of K's and π's in the medium and low pT regions. Of particular importance in these studies will be the understanding of the π/K separation as a function of pT, especially as apparently small PID contaminations can produce large effects in the correlation functions. This will require a careful characterization of the detector performance (efficiencies and time resolutions) and incorporation of these performance measures in a detailed simulation package.

Overall, the TOF detector system seems to be well integrated into the STAR experiment and into the STAR collaboration. However, it is now time to start working on the detailed plans and required resources for installation, commissioning and testing. Of course, these

plans will need to be carefully synchronized with both RHIC operations and other STAR activities.

Similarly, the development of the analysis packages for detector characterization and simulation need to be put in place as well as packages for the eventual physics analysis. The TOF group and the STAR collaboration would benefit from early discussions on the pathway from detector operations to physics results especially with a mind to identifying crucial ingredients and potential difficulties when it is still early enough to address and solve them.

One issue will be the operational monitoring of the detector system and the need for devising methods of detecting failure modes and appropriate responses. For example, operating multiple trays from a single distributed high voltage, which is risky in view of the narrow plateaus, will make failure diagnostics and the identification of appropriate solutions quite difficult.

Also of some concern in this sense is the start detector system. There are potential technical difficulties and also matters of principle such as the optimum positioning of this detector in different running conditions. For example, for the lowest energy running, it appears that the TOF start array should be placed as close to the interaction region as possible where it may suffer from the solenoid magnetic field and have impact on other detector systems. Again, early discussions of these issues would be most valuable. The next run, Run 8, in which a small number of the final TOF trays will be in place together with the start array and its final electronics, will provide important input and experience to the discussions of these issues.

Recommendation:

- The TOF group, together with the STAR management should begin to develop a detailed plan for the complete detector performance simulation, and for operational monitoring of the system performance. The issues raised regarding the location and performance of the start detector system should also be addressed.

Electronics:

The electronics design and prototyping has been progressing nicely since the last review. TINO, TDIG, TCPU and THUB have been successfully designed and prototyped. While some final tests need to be completed, these boards are ready for final electronics design review.

Minor revisions are needed on the TDIG, TCPU and THUB boards. The TINO, TDIG and TCPU schedule is critical for starting the tray assembly for Run 9, in FY 2009, at which time approximately ½ of the full detector is expected to be installed in STAR. At the time of last year's review, the TINO board had a production issue related to the board assembly. The issue has been addressed and resolved with the assembler. A second board assembler has been identified.

The 40 MHz clock distribution is critical for the overall system performance. The jitter or variation in the phase of this clock as received at the different TDIG boards will be added to the final timing measurement error. An initial choice of the phase lock loop (PLL) has been found to have a timing problem on power ramp up. A replacement has been found. A study has also been done with and without the PLL in the clock distribution tree. It has been demonstrated that the system performance will be adequate with or without PLL in the clock distribution tree. The decision will be made within a few weeks.

The TDIG board production is expected to start with 48 boards per month followed after three months by a fast ramp up to 160 boards. The production schedule for the TDIG boards is very aggressive. The entire schedule depends critically on the performance of the automated board testing system.

There are roughly 1000 TINO and 1000 TDIG boards in the final system. The major components on these boards are Ball Grid Array chips (BGAs). Since rework on BGAs is difficult and costly, special attention has to be paid to the board assembly quality control and yield.

The final power supply and the power supply in the electronics testing lab may have different power ramp-up curve. This could generate different behavior at the startup.

Recommendation:

- A final electronics design review should be arranged internally within the STAR collaboration as soon as possible on the TINO, TDIG and TCPU boards. This review should be performed taking into account operating constraints as installed with other STAR detector subsystems. A pre-production run of these boards (~100) could proceed before the final design review is completed in order to meet the FY 2009 running plan. The component orders for the full quantity could also proceed before the final design review. The production schedule should be revisited to reflect the experience from the pre- production run. The overall system should be tested with the final power supply.

Detector and Mechanical Subsystems:

The production of multi-gap resistive plate chamber (MRPC) modules is well underway at Tsinghua University and at University of Science and Technology of China (USTC). The production is well on schedule for completion last quarter of 2008; to date 2020 modules where produced, 2% more than scheduled. A total of 1118 modules was shipped to UT Austin, 762 will follow later this month.

Similar QA tests are performed at Tsinghua and USTC, but not all modules are tested for timing performance. Modules are tested with an independent test stand at UT Austin before assembly into trays. QA procedures in China and at UT Austin are different, and due to the limited communication between the U.S. and Chinese groups, results are

difficult to compare. An attempt to make such a comparison during the review led to the inconclusive results, but there seemed to be a lack of correlation between test results in Austin and in China for the same MRPC modules.

All parts required for the assembly of the full 120 trays have been purchased. A total of 9 trays have been assembled with MRPC modules and TINO readout cards. The 9 trays have been tested with gas and high voltage. There are no dead channels, and noise rates and dark current are reasonable.

A detailed and well documented assembly procedure is in place to allow assembly of 2-3 complete trays per week. At this rate the assembly will take roughly one calendar year.

While the assembly procedure is well documented, similar documentation for the testing of fully assembled trays is missing. The assembly team at UT Austin, which will also need to do all QA tests before and after assembly, has limited manpower. Careful planning of all activities will be critical for success.

Recommendations:

- A detailed comparison of MRPC test results from China and UT Austin should be performed. Understanding should reach the level that measurements of noise and timing resolution at the production facilities in China lead to predictable QA results at UT Austin. Due to the large time delay between production and final testing at UT Austin a better understanding of the QA seems critical to detect possible unforeseen quality variations early.

- Production of TOF trays with TINO cards should continue at the level of 2 trays per week. Because manpower is limited careful planning is necessary to sustain production for about a year. In this context a detailed testing procedure should be established and documented.

Management/cost/schedule/proposed new baseline

The collaboration should be commended for acting effectively on the recommendations of the 2006 review concerning management issues. A new baseline has been proposed to bring the US component of the project to completion. The proposed new baseline schedule shows the Project Complete milestone in the 4th quarter of FY09. The current project budget is at the original Total Project Cost, with a reasonable 20% contingency. The Project Management Structure now includes a Steering Committee chaired by Tom Ludlam, representing BNL management, and includes key members of the STAR TOF collaboration. The Steering Committee meets monthly, and the subsystem managers meet on a weekly basis.

There is a significant improvement in the communication between Blue Sky Electronics and the collaboration management. This will become even more critical now that the

mass production phase is about to begin. Management has to insure the cash flow to Blue Sky does not present a problem that could impact the project schedule.

The tray mechanical assembly is proceeding well at UT Austin and the MRPC production is on schedule. The schedule is doable but tight, and there is no more room for significant delays. The importance of the STAR TOF system for the RHIC 2010 run makes it imperative that the project be complete by the end of FY09.

The committee understands the rationale behind the proposal for a new project baseline and would like to reiterate that this is a very serious matter. This is a Federally funded project that must be finished in FY09. Further changes to the baseline will require a very high level of scrutiny in DOE and Congress. Our reputation as a community rests in large measure with our ability to bring projects to completion on time and on budget.

Recommendation:

- We recommend that the Project Complete milestone be in the 4th quarter of FY09 as proposed.

Appendix 1: Charge Letter

June 4, 2007

To: Technical Advisory Committee for STAR Time of Flight (TOF) Project
R. Alarcon, R. Betts, C-Y Chi, A. Drees, V. Radeka

Dear Committee members,

Thank you again for agreeing to participate in this review, which will take place at Brookhaven, August 2-3. It will begin at 8:30 am on Thursday, Aug. 2, and end by 4:00 pm on Friday, Aug. 3.

The Committee is asked to provide an assessment of the technical status and progress, as well as the cost, schedule, and management performance of the project. This assessment should include any issues that the Committee finds relevant for the successful completion of the project, and should address the adequacy of the budget, schedule, and workforce availability for the completion and implementation of the TOF detector. The Committee should also assess the progress made in addressing the recommendations of the review conducted in September 2006 (a copy of the review report is attached).

As I have indicated in previous correspondence, this review will focus on the main issues raised in the recommendations made by the Committee at last September's review: the estimated cost to complete the project, and the schedule for design and production of critical electronics components (TDIG and TCPU boards). This August should be an appropriate time to review the final electronics design. A proposed new baseline for the project cost and schedule has been prepared, and will be presented at the review.

An agenda for the review, as well as a brief progress report from the Project manager will be distributed by mid-July. Travel costs for the reviewers will be reimbursed by Brookhaven, in accordance with U.S. DOE regulations. Housing will be reserved for the nights of August 1 and 2. Kelly Smith (kellys@bnl.gov) will be happy to assist you with details.

Many thanks again for your willingness to help with this review. We look forward to seeing you at Brookhaven in August.

With best regards,

Tom Ludlam
Assoc. Chair for Nuclear Physics
Physics Dept.

Appendix 2: Review Agenda

STAR Large-area Time-of-Flight (TOF)

Annual Technical, Cost, Schedule, Management Review

Room 2-160, Physics Dept., BNL
August 2-3, 2007
Agenda

Thursday, August 2

8:30	Executive Session	
9:00	The TOF Project: STAR perspective	T. Hallman, BNL (10+5)
9:15	Physics objectives, performance requirements, BUR and installation plan	X. Dong, LBNL (20+10)
9:45	MRPC construction in China: Status and schedule	X. Wang, Tsinghua (20+10)
10:15	*Break*	
10:30	Project status overview, cost, schedule	G. Eppley, Rice (35+15)
11:20	Tray assembly and testing, status and schedule	G. Hoffmann, UT (30+10)
12:00	*Committee Working Lunch*	
1:15	Electronics, status and test results TINO, THUB production plan	J. Schambach, UT (60+15)
2:30	TDIG, TCPU, production plan	L. Bridges, Blue Sky Electronics LLC, (30+15)
3:15	Break	
3:30	Mechanical systems: Start Detector; Gas system, LV, HV, Infrastructure	W.J. Llope, Rice (30+10)
4:10	Re-baseline plan	T. Ludlam, BNL (15+5)
4:30	Executive Session	
7:00	*Committee Dinner*	

Friday, August 3

8:30	Q & A, electronics and other	All
9:30	Executive Session, report writing	
12:00	*Committee Working Lunch*	
1:00	Continued report writing	
3:00	Close-Out	
3:30	Adjourn	