STAR TPC Review 2009
June 4, Brookhaven National Laboratory
Room 2-84, Building 510, Physics Department

Report 2009

I) Introduction

The charge to the committee and the agenda of the meeting are reproduced below at the end of the report, followed by the report of the 2006 review for reference.

The very rich future program of physics for STAR with the RHIC luminosity upgrade is envisaged to last another 10 years. This report following our review on June 4 will make recommendations to ensure the continued operability of the TPC for this span of time.

A crucial test of the TPC took place during a four-week test period earlier this year during which running with roughly one-quarter of the maximum luminosity foreseen for the 500 GeV polarized proton (pp500) mode was carried out. Hardware and software aspects of the experiment were pushed to new limits, much experience was gained, and the detector and analysis successfully cleared this hurdle for which the collaboration is heartily congratulated. Many of the recommendations pertain to the pp500 program, since the four-fold luminosity increase will be the most demanding task for the TPC and the whole detector in future years.

An overall observation is that manpower is barely adequate to keep the detector running, and the collaboration should make every effort to increase the critical mass of subdetector, DAQ and software experts. Considering the 10-year program, the manpower should be strengthened to prevent possible problems due to loss of qualified staff. It should, however, be noted that several young people have already been added to the team. This is an excellent step in the right direction. The collaboration should be commended for this positive development, and it is urged to continue along that path.

II) Status and potential problems

Successful pp500 running/analysis found no show-stoppers up to now. The hardware/software experts will be making further improvements as the luminosity increases, and new techniques are being explored which will help maintain the present level of distortion-correction and its adequacy for the physics requirements.

However, problems related to aging can arise. Aging can be factorized into two types: slow aging and fast aging.

a) Before going into their differences, some general recommendations can be made which should mitigate both types of aging:
   i) Up to 10% of the available beam time should be used to make R&D measurements that would lead to possible improvements in operating conditions of the detectors and reduced aging.
   ii) Determine empirically the lowest possible gas gain that will still give adequate tracking efficiency, point resolution and dE/dx resolution. Run at that gain for as much time as the STAR physics program will allow.
   iii) Ramp the voltage on the sense wires (V_sense) down by few hundred volts between DAQ runs during a fill. This action will roughly compensate for the extra charge collected on the anodes due to the recently adopted strategy of extending the opening time of the gating grid.
   iv) Exchange the inner sector with the most problems with one of the existing spare modules. This would require fabricating a special tool to remove and reinstall the inner sectors. Inspect the problematic module for wire aging, detector aging or other sources of tripping. "Open and take a look" is often a good way to understand the cause of symptoms.

b) Slow aging is characterized by a build-up of deposits on anode/cathode wires, is a smooth function of the integrated charge, and is reasonably predictable. The value quoted by many groups has been 0.1C/cm as a guideline for the onset of slow-aging problems in P10 gas, which is used by the STAR TPC. To date, STAR has accumulated .3-.5mC/cm on the inner sectors. This amount of charge is small compared to 0.1C/cm and has not been a problem for the physics analyses to date. In future running, it could increase to several mC/cm, which could result in a decrease in gain of ca. 20%, which would probably not

be a problem for the physics. (NB 0.1C/cm would result in 60% gain decrease.)

c) Fast aging is characterized by discharges or trips, and are often due to high backgrounds, beam-loss, Malter discharges or similar effects. These are highly non-linear and unpredictable. The recommendations in IIa) above should reduce the probability of such discharges.

The onset of aging problems given above in IIb) (0.1C/cm) is not valid in this case, and one possibility is that Malter breakdown currents could appear in the innermost wires after about two years of pp500 operation. The addition of some water vapor to the gas might alleviate this problem. The possible reduction of resistance between field cage strips is a question that would need to be addressed if water is added.

The feasibility of reducing the amount of energy stored in the capacitance of a sector should also be investigated, since this would reduce the intensity of any sparks. On the inner sector, this can be accomplished easily for a large fraction of the wires by removing the ground connection on the wire grounding card for wires that do not pass over the readout pads. This causes the stored energy on the capacitor to be dissipated in a large resistance instead of in the discharge itself. The ground must be maintained on the wires that pass over pads to reduce cross-talk.

It is suggested that an improved diagnostic tool be developed to study the inner sector tripping problem that was observed with the pp500 operation. A multichannel preamp shaper system that would allow a continuous view of selected wire signals during beam operation could shed light on the nature of the tripping problem. This would be a non-intrusive measurement since the sectors are designed with wire output connections for this purpose. The system could be used to monitor micro-discharges and other relevant effects. This is a standard way of studying wire chambers and was used in the original qualification of the TPC sectors.

During the high luminosity running of pp500 there was an increased number of anode power supply trips and one HV subunit would no longer hold voltage. The unit that failed is on the inner sector, but it is not the inner most section. There also appears to be a small drop in gain of ~ 2.5% (inner most pad row), although it is difficult to be sure of the magnitude of such a small change. In light of these developments, operational control limits should be put in place

and followed to limit degradation of the TPC during future running. Initially, the limits should be set on the anode currents and trip rate frequency. In the future, as more sensitive diagnostics are developed, they can be added to the controls. The controls would be reviewed and modified regularly as new information on the wire chamber performance becomes available. Hopefully, the new operating modes, such as reduced gain operation and other proposed means of reducing the rate of charge accumulation, will result in tolerable trip rates during future pp500 running, and the operation control limits will not compromise the pp500 physics measurements.

In addition, one should prepare several plans of action in case trips become too frequent:

i) Plan A: The V_sense supply is divided into 24 x 8 = 192 subunits. A subunit should be disabled if it trips so often that it makes the DAQ too inefficient. The software team should estimate how many subunits can be turned off while still retaining the physics capabilities of the detector. If this number is exceeded, plan B should be activated.

ii) Plan B: Rewire the anode and cathode wire grids of the relevant inner sectors. To limit the ion leakage into the drift volume, the possibility of installing at this point a ground slab at the ends of these chambers, at the depth of the cathode wires, could be explored. This would be a major operation and could not be completed during a normal annual shutdown period. Even though this would require a longer shutdown, given the 10-year time scale for the long term physics program, a one time longer pause in the schedule would not be catastrophic. Preparation for this eventuality will need a long lead-time for understanding the details. We therefore recommend that an initial investigation be started as soon as possible to produce a realistic time, cost and manpower estimate for rewiring all of the inner sectors, including a determination of the status of the wire winding machine in the BNL Physics Department and its suitability for this project.

iii) Plan C: Investigate the possibility of changing from MWPC technology to GEM technology in the inner sectors. GEM detectors are less prone to aging in some gases, but long term operation in P10 needs investigation. GEMs have less ion feedback than wire chambers, but they would probably still require a gating grid. This option would require a much longer lead-time and also a significant amount of R&D. Although such a scenario may seem rather

aggressive, one should thoroughly explore this option now in order to understand if this is a realistic possibility for the future.

iv) Other plans may come to light as the situation evolves.

III) Final comments

a) Given the manpower and field cage situation, changing the gas mixture does not seem to be a realistic option.
b) Find and implement a solution to the problem that causes trips to the magnet power supply that have resulted in field cage shorts, even if it would mean purchasing a new power supply..
c) A subsequent review of the STAR TPC and its operation should be scheduled in approximately two years.

Presentations and Acknowledgements

All presentations for this review are available at
http://indico.mppmu.mpg.de/indico/conferenceDisplay.py?confId=494

Many thanks to Jim Thomas for organizing the talks and to Nu Xu, Flemming Videbaek, Tonko Ljubicic, Jim Thomas, Alexei Lebedev, Yuri Fisyak, Richard Witt, Gene Van Buren, Joe Seele, and Chilo Garabatos for their hard work in preparing excellent presentations.

Charge to the 2009 STAR TPC Review Committee

The STAR Collaboration has recently upgraded the Time Projection Chamber readout electronics so the TPC can take data at ~1 kHz rates. The collaboration is also planning to install several new detectors whose installation will coincide, in time, with a significant increase in the luminosity of the beams at RHIC. These upgrades will allow the collaboration to continue to do compelling physics for many more years but the usefulness of these new detectors will depend on excellent performance from the TPC. Therefore, it is important to know if the TPC can meet the requirements of the experimental program in the high luminosity era at RHIC and if there are intrinsic lifetime or aging issues for the TPC that might affect how, or how long, it can run.

The committee is requested to assess the performance of the TPC in the high luminosity environment which will be encountered at RHIC II, for both pp and HI collisions. The benchmark values of the luminosity for 2013, and beyond, are:

Au-Au (200 GeV/N)	$L_{avg} = 80 \times 10^{26}$ cm^{-2} sec^{-1}
pp (200 GeV)	$L_{avg} = 6 \times 10^{31}$ cm^{-2} sec^{-1}
pp (500 GeV)	$L_{avg} = 15 \times 10^{31}$ cm^{-2} sec^{-1}

The committee should also review the manpower commitments that are devoted to the operation of the TPC.

Questions:

Under the above conditions, the specific questions to be discussed in the review are:

(1) The measure (seriousness) of the aging problem: Is it possible to anticipate problems and predict the future performance of the TPC

(2) The impact on the physics programs, including pp and HI collisions

(3) Possible ways to mitigate the problem or restore prior performance

Committee members:

Howard Wieman (LBNL, STAR), Ron Settlles (MPI, chair), Craig Woody (BNL, PHENIX), Veljko Radeka (BNL), Dick Majka (Yale, STAR), Chilo Garbatsos (GSI)

Report of the STAR TPC Review Committee

(November 2, 2006)

Dedicated to the memory of Michael T. Ronan in appreciation of his contributions to our field of research and to this review and report in particular.

Executive Summary

On October 6 – 7, 2006 a review was held at Brookhaven National Laboratory to assess the capabilities of the STAR TPC in the high luminosity era of RHIC. The review panel consisted of external reviewers and STAR collaborators. The members of the review panel were P.Seyboth (chair, STAR, Max-Planck-Institut für Physik, Munich), R.Majka (STAR, Yale University), M.Ronan (LBL), R.Settles (Max-Planck-Institut für Physik, Munich), G.Smith (BNL), B.Stringfellow (STAR, Purdue University), W.Wiedenmann (University of Wisconsin) and ex officio members C.Gagliardi, J.Lauret and H.-G.Ritter. This written report was unanimously approved. The charge to the panel is contained in Appendix I.

A series of presentations were given on the physics goals of STAR in the coming years, the planned luminosity increases of RHIC, the past and projected performance of the STAR TPC and the issues of maintenance, detector improvements and analysis software of the TPC.

The members of the committee were impressed by the excellent performance and the outstanding physics results obtained from the STAR TPC. It will clearly remain the main tracking detector in STAR for the foreseeable future. The committee notes that RHIC has achieved continued luminosity improvements to within about a factor five of the maximum instantaneous luminosity ultimately envisioned for RHIC II. The STAR TPC has been able to cope with this successfully due to the efforts of an enthusiastic and competent team.

Due to a vigorous effort mainly by G. Van Buren and J. Thomas the considerable distortion effects from the space charge in the TPC drift volume have been successfully corrected to the 100-200 μm level and there appears to be no problem in principle of attaining a similar precision at the higher luminosities. The committee recommends that information from the Si inner detectors and the laser system be used in addition to constrain and validate the corrections. Moreover, efficient procedures have been developed by J. Balewski and M. van Leeuwen to tackle the problem of event pileup in the TPC. These appear likely to be successful also at the higher luminosities. It is of high importance that the manpower devoted to the TPC software be at least maintained at the present level and that timely replacements for departures are found.

The committee recommends that interaction with collider operations be further intensified. More diagnostic measurements should be made available by STAR to diagnose and minimize time

dependent and localized backgrounds which can affect the accuracy of distortion corrections. The limiting aperture of RHIC should be moved away from the STAR interaction region if possible.

The TPC has been operated conservatively and reliably thanks to the efforts of B.Stringfellow and A.Lebedev. Minor hardware problems, which are usual for large experiments, have been solved efficiently. A growing shortage of readout electronics spares requires the replacement of the old electronics by an ALICE-type readout system in the context of the DAQ1000 upgrade. An R&D program of hardware improvements should be pursued for possible reduction of the gated grid leakage, for alternative gas mixtures and for fixes of the field cage imperfections. Such improvements could be implemented in case the software corrections turn out not to be fully satisfactory. The manpower and the know-how for the operation and maintenance of the TPC hardware must be maintained. In particular, a replacement with longer term commitment must be found for B.Stringfellow with sufficient overlap time. Finally, the possible use of a SF_6 admixture in the gas of the MRPC TOF system is strongly discouraged by the committee because small traces at the ppb level diffusing into the TPC gas would seriously compromise the TPC performance.

In summary, the committee believes that the TPC can be operated and produce excellent physics results at the projected higher luminosities. Solving the problems of distortions and pileup continue to pose a challenge, but there appear to be no problems in principle to prevent success.

Detailed assessment and recommendations

In the following more details are given on the results of the discussions of the items of the charge to the committee and the ensuing recommendations.

Distortions:

The peak luminosities in Au+Au operation of RHIC reached $1.5 \cdot 10^{27}$ in 2004, are expected to increase another factor of 2 in 2007 and reach $9 \cdot 10^{27}$ with electron cooling in the RHIC II era. It was demonstrated that correction methods for space charge distortions (as well as the imperfections in the field cages) based on analytical models were implemented which reduced the effect to the 100-200 μm level. The quality of the corrections has been evaluated via the sDCA technique. The development of additional probes based e.g. on track residuals should be considered. The present procedure follows the time dependence of space charge and uses azimuthal symmetry. A database needs to be implemented for recording distortion relevant parameters during the data taking runs in order to automate the procedure.

The committee recommends that the interaction with collider operations be further improved and additional diagnostic measurements be considered and supplied by STAR in order to check and minimize localized and fluctuating backgrounds. It may be possible to use the individual readout sector currents, or prompt TPC end-plane signals, as sensitive background monitors to be fed back to the RHIC operators. At present, the limiting aperture of RHIC is located near the STAR interaction region. In addition to the shielding already put in place, efforts should be made to move it further away in order to reduce backgrounds in STAR.

Gated grid leak at the sector boundaries has been identified to contribute about one third of the space charge distortion. STAR should therefore investigate if it would be possible to run the TPC at somewhat lower gain without significantly deteriorating tracking precision and dE/dx resolution. Moreover, R&D is encouraged to develop hardware modifications to prevent gated grid leak that could be implemented if the need arose.

Information from the Si tracking detectors has not yet been used. These were found to be very useful in constraining and validating the corrections for the ALEPH TPC. The committee recommends their use in STAR and understands that this is planned for the coming 2007 data taking period. The committee moreover recommends assessing how the laser system could be used to track the space charge distortions also during data taking.

An alternative gas mixture offering higher ion drift velocity to reduce space charge, and at the same time preserving the quality of dE/dx measurement, has not been identified. A discussed replacement of the CH_4 quencher by CF_4 may result in a stronger electron attachment and thus compromise the dE/dx measurement. Although distortion corrections are projected to be possible also at higher luminosity with the present gas mixture, R&D with the aim of searching for alternatives is encouraged.

Event Pileup

Effective methods to deal with pileup have been developed both for p+p and Cu+Cu collisions and have allowed STAR to obtain clean physics results. The methods are based on the use of signals from the fast detectors, i.e. CTB and ECAL, in addition to criteria of track quality and continuity across the central TPC membrane. The future availability of fast Si strip detectors and of the finely pixelled MRPC TOF system should further improve the efficiency of pileup rejection.

Detector Aging

Up to now no indications of wire aging have been detected. Projections of H.Wieman, based on published aging studies and projected integrated luminosity, suggest that none are to be expected for some years. No breakage of wires has occurred throughout operation of the TPC although numerous sector HV trips have occurred, especially in the inner sectors. Since it is known that the original sector insertion/extraction tool can no longer be used with the TPC in the STAR magnet, the committee urges that some re-engineering or redesign of this tooling be done now, before it becomes necessary to use it.

There have been a number of local field cage shorts, mostly caused by extraneous stray objects that fell into the inner field cage. Most of these were found and removed successfully in the past. There remains one unstable short in the Inner Field Cage East that is thought to be caused by some stray epoxy in a region that was worked on in 2005. It is felt that this problem can be fixed when the SVT cone is removed in 2007. Until then a combination of external resistors and offline distortion corrections can be used to restore full precision. There is also a bistable current fluctuation in the Outer Field Cage West that first appeared in March, 2005. The origin of this fluctuation is unknown, as is its location. So far the data have not been corrected for this fluctuation since it is relatively small and the position in z is unknown. The committee concurs

that it is best at this time to not open the windows into the outer field cage because of the risk of contamination, but that some R & D should be done on the tooling necessary to hunt for this short if it becomes worse.

Most of the infrastructure maintenance and repair is covered by BNL and external group commitments. Replacements for failing readout electronics components are becoming scarce. This problem will be solved in the context of the DAQ1000 upgrade by the replacement of the present electronics by a new ALICE-type system which is under construction.

R&D

Except for the readout electronics no serious need for changes in the present hardware were identified. However, studies on reducing the grid leak and search for gas mixtures with faster ion drift velocity are encouraged. Tests should be performed in dedicated setups and not in the STAR TPC itself.

Software

As already stated above, and as far as the committee can judge, the calibration and tracking software will be able to cope with the increased luminosities. It was noted that after the DAQ1000 upgrade the dE/dx determination will have to be re-optimized. Also, the Monte Carlo simulation chain needs to be updated to incorporate the residual track distortions and the updated dE/dx determination with DAQ1000. With the expected sizable track distortions Monte Carlo simulation is a valuable tool to understand and develop fixes for possible problems of track pattern recognition potentially caused by the distortions. As the new data comes in new challenges will arise and sufficient manpower will be needed to deal with them. The present dedicated software manpower level of 1.5 FTE is considered rather low. A filling of the now vacant position of TPC software coordinator is urgently required. The STAR core software team also wishes to shift back more of the burden of calibration and corrections to collaborating institutions.

Support for Operations

The present support manpower is estimated at about 1.5 FTE and for most subsystems only a single expert is available. Present TPC system support: subsystem manager (Purdue, will retire in July 2008), gas system (MEPHI), electronics (BNL), TPC interlock system (LBNL), calibration software (LBNL, BNL), laser system (BNL). The committee suggests that BNL find in addition a local gas expert that could help during the coming runs. Continuation of the longer term support commitments are essential and a successor for the present subsystem manager must be found soon in order to ensure the transfer of the accumulated know how.

One final comment: the system – hardware, software and physics – has worked well to date because a general conservative approach has been followed. This conservatism should continue and also apply to manpower, namely adequate effort on each aspect of the TPC system.

The committee wishes to thank D. Majka, J. Dunlop, M. Miller, J. Thomas, Y. Fisyak, G.VanBuren, M.van Leeuwen, J. Balewski, H. Wieman, B. Stringfellow, J. Landgraf, J. Lauret and W. Christie for the preparation and presentation of their concise and informative reports.

Appendix I

Charge for STAR TPC Review Panel:

The STAR Collaboration is planning a number of compelling physics measurements in p+p, p+A, and A+A interactions that will extend well into the era when planned upgrades of the RHIC accelerator will increase the average luminosities for heavy ion and p+p interactions significantly over those achieved to date.

The review panel is asked to assess the ability of the STAR Time Projection Chamber, including planned upgrades of its front end electronics and readout, to meet the physics driven requirements of the experimental program in the high luminosity era at RHIC.

Specifically, the panel is asked to asses the following issues:

Distortions:
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a Given the expected luminosities and projected TPC performance based on experience to date, will it continue to be possible to correct distortions at a level sufficient to meet the needs of the physics program?

b. If the answer to a) is yes or yes possibly with additional instrumentation or a change in the TPCs operational envelope (e.g. use of a faster gas) what changes and/or additional instrumentation/monitoring may be needed?

Event pile up:
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For heavy ions, light ions, and p+p collisions is the pileup in the TPC manageable?

a. Are the current and planned detectors which surround the TPC adequate?

b. Is further software development required?

Detector Aging:

Is aging of the detector and its infrastructure – especially with higher trigger rates-- a "show stopping" concern? What level of concern exists for:

a. Wire aging

b. Field cages, membrane

c. Aging of infrastructure (GG drivers, power supplies, controls, monitoring electronics, gas system, cooling system, lasers). Will the systems continue to operate and are there adequate spares?

R&D:

What if any plans exist for R&D on improved performance and/or diagnostic tools?

Software:
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a. Is the current set of QA, calibration and tracking software adequate for the expected higher luminosities?

b. Is there adequate manpower for continued operation and any new software development that may be required?

Support for Operations:

Is the projected level of manpower available to support the operation of the TPC adequate manpower for its:

a. Operation

b. Maintenance

c. Calibration and analysis software