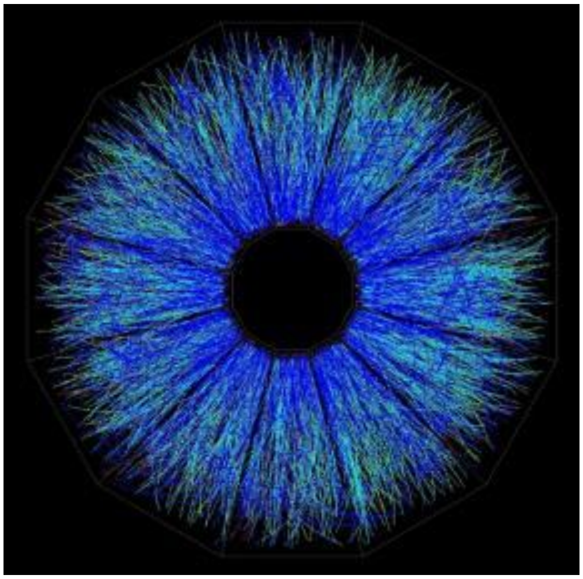
Risk Assessment for Future TPC Operations and the iTPC Upgrade

The STAR Collaboration



November 30th, 2015

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Introduction

The STAR TPC has been running since 2000. It has sustained a RHIC luminosity increase of two orders of magnitude compared to its design luminosity, and benefited from several STAR detector upgrades including a TPC electronics upgrade (DAQ1000) in 2009. The RHIC facility has also undergone significant changes; from the beginning when four experiments were running to the present day with only the large experiments running (STAR and PHENIX). It is anticipated that STAR will be the only experiment running at RHIC for the proposed Beam Energy Scan Phase II (BES-II) in 2019-2020.

TPC operations have gone smoothly since the day that STAR recorded the first beam-beam collisions at RHIC. There were some hiccups when STAR and RHIC/CAD were learning how to take pp-500 beams without damaging the TPC and other detectors, however, pp500 operations at STAR are now routine. This goal was achieved by developing better tuned beams in the accelerator, installing shielding in the tunnel, and adjustments to the TPC.

In a separate document, we have proposed an upgrade to the STAR TPC which will extend the rapidity coverage of the TPC from 1.0 to 1.5 units. We call this the iTPC upgrade because the primary purpose for the upgrade is to replace the inner sector readout with improved sectors which have hermetic coverage over the entire inner sector padplane.

There are technical, schedule and budgetary risks associated with the iTPC upgrade project. The risks associated with the future operation of the TPC and iTPC are discussed in this document. The iTPC Risk Management Plan (RMP) is attached as Appendix II. The RMP takes a broad view of the iTPC project to identify and address specific risks that require assessment, mitigation and tracking. Risk assessment will be an ongoing process throughout the project life cycle.

In Section 1 we discuss the current TPC operations and the risks associated with the continued operation of the TPC, without upgrade, through the BES-II program in 2020. In section 2 we discuss the unique risks associated with the iTPC upgrade.

In sections 3, 4, and 5 we discuss TPC operation since the last TPC review in 2009, recommended equipment upgrades for BES-II operations, and personnel issues, respectively. Three appendices are attached which include the Charge to the STAR Collaboration from the Associate Director’s Office, the iTPC Risk Management Plan, and the Report of the 2009 TPC Review Committee.

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1 The STAR TPC – Current Operations

The text in this chapter is meant to detail the possible risks that could prevent the STAR collaboration from being able to operate the STAR TPC from now through the BES-II running program. As currently planned, the BES-II running will finish at the end of the FY2020 RHIC Run.

Between now and June 2020 the RHIC running plan is to run 200 GeV AuAu for the bulk of Run 16, followed by about five weeks of d-Au at various energies. Run 17 will utilize 500 GeV polarized pp beams, but with the peak luminosity restricted such that the ZDC coincidence rates don't go above 65 kHz. There is no run planned for FY 2018, followed by AuAu running in FY 2019 and 2020 at energies below $\sqrt{s_{NN}} = 20$ GeV.

Risks and Mitigations

1.) **Electronics**

Description:

This topic includes the FEE and RDO board, as well as the RORC cards and the DAQ computers dedicated to the TPC readout. The entire electronics system was upgraded prior to the FY 2009 run.

Risk:

The risk would be if the failure rate for these components, and the availability of replacement parts, prevents us from keeping the TPC fully instrumented and operational.

Mitigation:

The failure rate for both the FEE cards and the RDO boards has been very low for the upgraded TPC electronics. We built and have on hand sufficient spares for these two components to keep the detector fully populated with electronics. The RORC cards are commercial products. We have a supply of spares, and are confident that if we need additional boards they will be available, either from the original vendor or from other experiments that use these devices. The computers used to readout the TPC are commercially available. We don't anticipate any issue with procuring replacement computers as/if necessary.

2.) **Gated Grid system**

Description:

This is the fast switching, ±75 volt, system that opens and closes the TPC gated grid structure.

Risk:

The risk would be if failures of the existing modules, designed and built back in the 1990's by a person no longer in the field, prevented us from being able to operate the TPC sub system.

Mitigation:

We've mitigated this risk in two ways. The first mitigation was to have our electronics support personnel study and understand the design of the current system, so that they have the expertise necessary to repair the current system. The second mitigation was to have our electronics support group design a modern gated grid driver system, which is inherently simpler, but will deliver as good, if not better, performance. A prototype GG driver board has been built, and will be tested when beam operations start in January. We plan to start phasing in this new system starting with the FY 16 RHIC run.

3.) HV Systems

Description:

The TPC has two HV systems. One of these systems supplies the 28 kV potential that we apply to the TPC central cathode. The second system provides the 178 channels of HV in the range of 1100 to 1400 V used on the anode gain wire structures of the TPC.

Risk:

The main risk here is on the operational efficiency of the TPC system. The cathode HV system has been very robust and stable for the life of the STAR program to date. However, the anode HV system is quite old, a 1990s era LeCroy system that is no longer produced. This system also has a problematic network interface, which can cause delays in getting the STAR TPC online for data taking at the start of RHIC stores. The number of spare modules for this system is quite limited, and no more can be purchased.

Mitigation:

We have a spare Cathode HV supply. For the anode HV supply we plan to procure a new modern system using capital equipment funds as soon as possible.

4.) Lasers

Description:

There are Lasers located on both ends of the STAR detector structure which are used to measure distortions in the TPC drift volume, and to measure the electron drift velocity in the TPC gas. The Laser system is comprised of two lasers, and the optical components that reside in the Laser boxes, as well as a series of pipes and mirrors that distribute the laser beams around the outer TPC circumference on both the East and West TPC faces.

Risk:

The risks are that the Laser tubes reach their end of life, and need to be replaced, and that various optical components degrade over time with use, and have to be replaced.

Mitigation:

The Laser system takes annual maintenance, and periodic tuning during the data runs. To date we've had sufficient funds to procure the various replacement parts we need as we need them. Laser and optical components are standard commercial products, Assuming continuing levels of operational support funding for STAR this risk is mitigated.

5.) TPC Sectors

Description:

There are a total of 24 inner and 24 outer TPC sectors in the TPC sub system. These sectors contain the three wire planes (Ground, Gated Grid, and anode), the pad plane, the aluminum strongback, and all of the feed-throughs and connectors that allow for the passage of the analog pulses from the pads out to the FEE cards.

Risk:

The primary risks for the sectors are associated with the integrated charge on the anode wires (aging of the wire planes) and stray beams from the accelerator.

Aging of the wires and stray beams can lead to sparking from the anode wires to the ground plane. Experience has shown that approximately 100 trips (sparks) on an anode wire leads to permanent damage and sometimes to broken wires.

We have a total of four partially damaged sectors. On each of these sectors, we have 4 HV sections and one HV section is damaged on each. (Outer Sector 7 Section 7, Outer Sector 13 Section 6, Outer Sector 20 Section 5, and Inner Sector 15 Section 11). On these specific sectors, we have applied a reduced voltage to the bad sections which makes them useless for tracking. At nominal voltage, these sections will suffer trips, preventing normal data taking.

Mitigation:

A primary mitigating factors for the sectors was the extensive R&D that preceded their fabrication, and the stringent QA as they were built. A further mitigating factor is that there we have two spare inner, and two spare outer sectors that were fabricated in the initial construction of the TPC. They were not tested after arrival from LBL at 1997, but have been constantly under N2 flow. To date we haven’t employed any of these spare sectors due to the lack of an appropriate insertion tool. The mitigation that the spare sectors provide can only be applied however if one has the necessary installation tooling that allows one to replace one of the TPC sectors. Such a tool was fabricated for the initial installation of the sectors prior to the installation of the TPC into the STAR Magnet. This existing tool cannot be used to replace the sectors when the TPC is inside the STAR magnet, so we need to design and fabricate new TPC sector installation tooling. We have completed the design for this new tool, and plan to use capital equipment funds to procure the parts and fabricate the tool in FY 16.

For the sectors with issues, we have set the working high voltage of those four sections at (1250, 1200, 700 and 1030V) in comparison to nominal 1390 V at outer sectors and 1170 at inner sectors. The iTPC project will provide new inner sectors for replacement and also the facility and recovered knowledge for replacing bad sectors. The plan is to replace all the inner sectors with all new iTPC sectors and replace the bad outer sectors before BES-II operation.

We have also increased the amount of shielding in the RHIC tunnel to reduce the background from the accelerator. This has worked well and made pp-500 operations much more reliable. See Section 3.

6.) Field Cages

Description:

The TPC has two field cage structures, one on the outer circumference of the TPC active gas volume and one on the inner circumference of the TPC active gas volume. These field cages are cylinders made out of a honeycombed material, and have circular strips of conductive material (Aluminum for the inner and copper for the outer) on a Kapton insulating sheet. These strips reside on both sides (gas side and air side) of the field cage structure. They are connected along the length of the cylinders, from the center to both ends, by a chain of resistors. The actual current path through the series of strips goes successively from the inner to the outer sides of the field cage using vias through the honeycomb structure that are soldered electrically connected to the strips.

Risks:

There are both electrical and mechanical risks associated with the Field Cage structures. The electrical risks are that a short develops between successive strips on the inner or outer surfaces of the cage structure, which can give a discontinuity in the electrical potential along the field cage, and impact the precision of the TPC position resolution. We’ve had some of these shorts appear in the TPC, and if we can’t find the offending material making the connection and remove it, we deal with it by making it a hard short (i.e. making a firm electrical connection between the affected strips) so that it is stable, and then we correct for its effect by calibration with mathematical modeling. The vias can become disconnected, which has the effect of leaving an inner (on gas side) strip free to float in potential. If we can’t fix these, we adjust the resistance between the adjacent strips so we can maintain the voltage gradient down the chain, but leave the strip floating. The mechanical risks for the field cage are associated with failures due to aging of the structure, or to damage resulting from impacts with other objects. An example here would be a sector being installed into the TPC, which accidentally impacts the field cage structure.

Mitigation:

To mitigate the risk of shorts developing in the TPC field cages we minimize any chance for the introduction of dust, fibers, or foreign material into the TPC gas volume. This is accomplished through filters in the gas system, and minimizing the number of times that the gas volume is opened to the atmosphere. To mitigate the probability of shorts developing for the inner field cage we filter the air that flows through the inner field cage region with HEPA filters, and try to keep avenues for foreign material to enter this region closed. Once we have a sector installation tool that allows us to replace sectors of the TPC some of the risks associated with shorts and open connections could be repaired by allowing us access into the gas volume of the TPC.

The risk of mechanical damage to the TPC has, to date, been mitigated by careful study of the effect of any changes we make that could affect the field cage structures. An example is the study that was done prior to changing out the lighter Central Trigger Barrel modules with the heavier Time of Flight modules, which get supported by the outer TPC gas vessel. To mitigate the risk of replacing sectors in the TPC we rely on engineering/design of the installation tooling to minimize this risk, as well as practicing the sector installation procedure with a mock up of the TPC to ensure we can avoid unwanted movement of the sectors during the process.

7.) Gas System

Description:

The TPC has a volume of 50,000 liters. When we run the system we use a gas mixture of 90% Argon and 10% Methane. The recirculation rate for the gas is about 500 lpm, with a refresh gas rate of about 15 lpm. The gas system was designed, fabricated, and instrumented with computer controls by two Russian colleagues in STAR, Leonid Kotchenda and Peter Kravtsov. Leonid worked on the design and mechanical construction of the system and Peter worked on the computer controls. The system is operated primarily by a BNL staff member, Alexei Lebedev, with assistance/backup by Jim Thomas from LBNL. Alexei has acquired substantial knowledge concerning the operation and maintenance of the system, as has Jim. See Section 5.

Risks:

The primary risk associated with the Gas system is to maintain the necessary expertise to keep the system functional and to operate the system. There are a number of components of the system that age and must be replaced, must get recalibrated periodically, and the Software aspects take maintenance as operating systems evolve over the years. See Section 4.

Mitigation:

The mitigation of this risk is to share knowledge associated with the maintenance and operation of the system, which primarily is done by maintaining access to the individuals in STAR that possess this knowledge. At this point we expect all four of the individuals involved in this effort to maintain their presence in the STAR Collaboration. A key person, in this respect, is Dr. Kotchenda, who due to health concerns, will be limiting or completely stopping his annual visits to BNL to work on the system. We believe that with the continued active participation by the other three individuals, and access to Dr. Kotchenda’s knowledge via phone and E-mail consultation, that we can mitigate the risk through the end of the STAR Operational lifetime.

8.) Personnel

Description:

Similar to the discussion of the gas system above, the maintenance and operation of the other aspects of the TPC sub system (Controls, HV, electronics, Laser system, cooling system, etc.) requires personnel that possess the knowledge necessary. See Section 5.

Risk:

The primary risk is that the personnel with the necessary knowledge become unavailable to the STAR effort.

Mitigation:

The personnel in question here contain those listed for the gas system above, with the addition of Tonko Ljubicic who looks after the electronics and readout systems for the TPC. Tonko is a staff member of the STAR group at BNL. For the operational knowledge for the TPC the primary person is Alexei Lebedev, who is the sub system manager, and a staff member of the STAR group at BNL. His main backup on these aspects is Jim Thomas from LBNL. We believe that this is mitigated because the key personnel are expected to stay with the STAR effort through the remainder of its operational lifetime. If we become aware of reason to believe that this might not be the case, the mitigation is to identify other individuals to be trained in the necessary skills.

2 The STAR TPC – Risks associated with the iTPC upgrade

The iTPC upgrade will improve the coverage of the STAR inner sectors and provide modern high speed electronics and readout system. The iTPC will significantly enhance our ability to do physics in the BES II era. The proposals for iTPC and BES II have been presented several times over the last couple of years and the physics program has been deemed must-do in the LRP.

1. **Strongback detailed design and final drawings**

   Description:

   The original 2D TPC Engineering drawings exist (circa 1995). To fabricate new strongbacks using modern machine shop techniques, 3D models with their associated 2D drawings are needed.

   Risk:

   Delay production and increase costs.

   Mitigation:

   Significant effort has gone into generating 3D drawings and checking the validity of these drawings against the existing sectors and as-built drawings. At this point about 60 hours of design time is needed to have final drawings in hand for production.

2. **Padplane**

   Description:

   The pad plane is a critical component in an inner sector assembly. It must be produced accurately and on time.

   Risk:

   There is a possibility that the material used for the pad plane does not meet requirements in terms of tolerance and/or material specifications.

   Mitigation:

   The design has been undergoing multiple iterations, and one prototype. The specification has been cross checked to ensure that the mechanics are OK. The material selected will be certified Bromine free. A rigorous QA program will be established and followed, including survey and certified inspection of the final parts.

3. **Joining of padplane and strongback**

   Description:

   The assembly of the padplane with the strongback is a high precision task that must be kept within tight tolerances. The proper tooling and procedures must be employed, requiring effort in engineering, design and training.

   Risk:

   This is a technical risk. If the task is not done with high precision the performance of the TPC could be compromised; particularly in regard to uniformity of gain and the quality of dE/dx measurements.

Mitigation:

It is envisioned that this work will be done in the LBNL shops since they have the technical capabilities to perform the task. Nearly all procedures have been recovered from the original design documents and oral histories collected from the retired technicians. The technical capabilities at LBNL include access to CMM, survey tools and large milling machines in workshop.

4. **Wire mounting of MWPC planes**

Description:

The task involves wire winding, and mounting the wire planes to the strongbacks. There is a requirement for high precision to achieve proper parameters in terms of wire tension, distance between wires and wire planes to padplane.

Risk:

If the prescribed accuracy is not reached the performance of the TPC may be compromised. It is very likely that it will function, but the calibration task to get optimal dE/dx resolution will be much more difficult.

Mitigation:

This task will be done by our collaborators at Shandong University through a project funded by the NSFC in 2015. As part of this activity, they are developing procedures and making measurement on prototype MWPC planes. A number of tools, fixtures, and apparatuses were designed to check and maintain the required precision. For example a laser based wire tension measurement system has been designed to measure the wire tension for each wire and can also check the wire pitch. It is envisioned that one more round of prototyping will be done. The extensive prototyping work at Shandong reduces the risk involved in this task.

5. **Electronics**

Description:

The electronics has been developed in an R&D phase by the BNL STAR electronics group, and most components have low risk at this point. The electronics is based on the SAMPA chip being developed for the ALICE TPC upgrade.

Risk:

Even though the iTPC group is involved in the regular meeting on the SAMPA chip, we cannot control the schedule thus leading to a high risk for schedule of delivery of the chips. There is also a risk in terms of having funds available for procurement in a timely fashion. Manpower levels for the electronics engineering effort are sufficient at this time, but a loss of future manpower would be a serious problem for the project. See Section 5.

Mitigation:

The first prototype SAMPA chip, with all 32 channels and sufficient functionality for STAR, is about to be submitted and should be available in April 2016. STAR does not need all the functionality that ALICE requires, and the risk can be mitigated by negotiating with ALICE that a relatively small production run gets agreed upon, early, and before the main production run for the ALICE TPC upgrade.

6. **Insertion tooling**

Description:

The insertion tool is needed for the extraction of the old sectors and the insertion of the upgraded inner sectors into the TPC. It is also needed for the replacement of damaged outer sectors with spares.

Risk 1:

There is schedule and design risk if the installation tool is not working in the desired way, or not able to provide enough range of motion or degrees of freedom for sector installation with the required precision.

Mitigation:

This will be mitigated by testing the installation tool, on a mockup of the TPC, well in advance of the iTPC installation schedule. The tool will be required to complete the sector installation procedure on the mockup multiple times before proceeding with work on the face of the STAR TPC. This mitigation strategy requires early funding.

Risk 2:

There is a risk to the project if a sector hits the TPC inner field cage (IFC) or an adjacent sector causing damage during installation. The clearance from the adjacent sectors is about 3.5 mm during installation. A great deal of caution is required during the installation to avoid damaging adjacent sectors and/or the IFC. Deflection of tool components and vibrations or oscillations during tool operation can make this problem worse.

Mitigation:

The risk will be mitigated by installing the sectors in such a way that we can use gravity to our advantage by sequencing sector installation so that we install the sector hanging highest before a sector hanging lower. Ideally the installation sequence will be 12, 11 and 1, 10 and 2, 9 and 3, 8 and 4, 7 and 5, then 6 O’clock. Also, the mockup for testing the insertion tool will include features that simulate the IFC and adjacent sector walls to make sure that tool chattering or vibrations are not going to become a problem during actual installation.

Risk 3:

There is a risk if the installation tool fails during sector insertion and causes a sector to fall into the TPC or to get stuck in a non-retrievable position.

Mitigation:

To mitigate this risk, components will be designed with a large safety factor for material strengths. All moving components will be hand cranked to achieve the desired motion under the watchful eye of technicians who have rehearsed the procedure on the mockup. Testing will be done multiple times in all challenging orientations to make sure the tool can achieve the desired goals.

7. **Sector Insertion**

Description:

The new sectors and the inside of the TPC must be kept in a clean environment during installation. The assembly will be with STAR rolled out of the IR into the assembly hall.

Risk:

If the inside of the TPC field cage is contaminated during the installation with debris, or dust, then there is a risk for reduced performance of the TPC and possibly not being able to hold full voltage on the Cathode Plane or degraded tracking performance due to electrons lost or attenuated by contaminated gas.

Mitigation:

The risk will be mitigated through engineering controls and design of a clean enclosure around the end caps during installation, thorough cleaning of the assembly area, and administrative procedures for access to the work area.

8. **Schedule**

Description:

The goal is to have the inner sectors tested, installed, and ready for roll-in at the STAR detector in July 2018. One critical path item is the mechanical construction and testing of the inner sectors. Another critical path item is a fully tested and functioning sector insertion tool.

Risk:

The production schedule will slip if the mechanical production of the strongbacks does not start on time. There must be sufficient time for the joining of the pad plane, and assembly of the MPWCs, as well as survey, testing and QA.

Mitigation:

The construction drawings and 3D CAD models will be ready soon and construction should start immediately. These steps require funding from BNL, and funding is needed in a timely fashion. Our goal is to maintain two months of float in the schedule as a contingency. Without significant funding in early FY16, the schedule float will disappear and the project is not viable.

9. **Quality Assurance of fabricated and assembled parts**

Description:

The task is to insure that the quality of components comprising the assembled iTPC sectors conforms to specifications in the engineering models and drawings.

Risk:

If proper communication and accounting for QA procedures is not maintained at each step over the entire production chain for the iTPC sectors then significant delays in schedule may occur and increased costs incurred to fix the problems.

Mitigation:

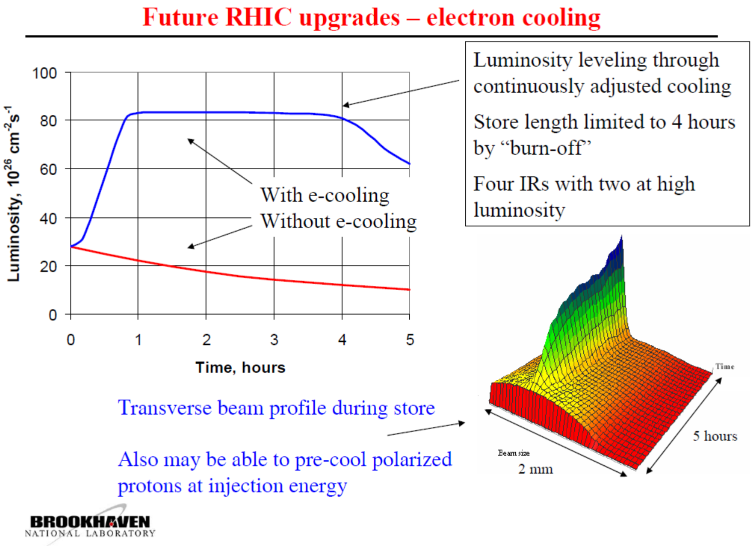
The concept of “traveler" documents from the original TPC project have been adopted and updated. A traveler will be attached to each iTPC sector and revised at each step of the production chain to assist in communicating QA of the assembled sector until it is installed in STAR. The QA plan and drawing tree from the original project (circa 1995) are available and a similar plan will be followed for the iTPC upgrade.

3 Comments regarding TPC operation since the 2009 STAR TPC Review

In June 2000, the STAR TPC observed the first collisions at RHIC. It has been running well since that time. None-the-less, out of an abundance of caution, TPC operations were reviewed carefully in 2006 and 2009. (See Appendix III: Report of the 2009 TPC Review Committee, and references therein.) Many issues were identified in these reviews that could affect the future performance of the TPC. Most of the issues have been addressed through scholarly research, and other items on the list have proven to be less important than we had imagined. However, some issues continue to be a concern. For example, the list of key participants is essentially the same as in 2006 and 2009. We expect that most of these key participants will be available through 2020 but, due to unforeseen events, we cannot guarantee that everyone will be available. Recruiting young people to work on the TPC team is still a high priority for STAR.

Accumulated charge on the inner sector anode wires was a key concern in 2009. As recognized by the committee, the total accumulated charge on the inner sector wires is not unusually high and is not expected to reach unusually high levels during the lifetime of STAR.

Arcing and HV breakdown from the anodes wires to the ground plane was another area of concern in 2009. It was significant during pp-500 operations. We thought the problem might be ‘wire aging’ due to the accumulating charge on the anode wires. But with the benefit of hindsight, most of the breakdown problems seem to have been related to poorly tuned beams in the machine, and lack of shielding, rather than due to wire aging. STAR has added shielding in the tunnel to help diminish parasitic muon beams, and other stray beams, that come down the tunnel. We have also requested that RHIC/CAD flattop the beam by using electron cooling to level the luminosity throughout the fill. See Figure 1. These strategies have helped and they continue to be a good strategies for the future.



Future RHIC upgrades – electron cooling

Luminosity leveling through continuously adjusted cooling

Store length limited to 4 hours by “burn-off”

Four IRs with two at high luminosity

Transverse beam profile during store

Also may be able to pre-cool polarized protons at injection energy

Figure 1: A slide from a talk given by Thomas Roser at MIT in 2004. The key point is that electron cooling can be used to eliminate the high luminosity peak at the start of a fill and save it for later use. Luminosity leveling is thus a very clever way to maximize the useable luminosity of the beam and minimize damage (trips and sparks) in the STAR TPC.

We have also reduced the gain on the inner sector anode wires to 40% of their design values. This was initially done in 2009 as a knee jerk response to the pp-500 performance of the TPC (before shielding). But after a great deal of simulation and data analysis, we have confirmed that continued operation at the 40% level is perfectly acceptable for tracking and gives excellent dE/dx performance. Recent simulations have also confirmed that we can raise the threshold for "found" clusters. This will reduce the amount of data sent by the TPC and will help relieve bottlenecks in the DAQ bandwidth. Overall, as of 2015, TPC performance is good.

We believe that through the use of Luminosity leveling, and keeping the gain low on the anode wires, that the TPC will perform as expected in the two additional high-luminosity RHIC runs before BES-II (Au+Au collisions at 200GeV in run 16 and p+p collisions at 510 GeV in run 17).

It is worth noting that the iTPC upgrade will help this situation. New wires and pad planes will reset the aging problem (if there is one). Also, the iTPC will have larger pads and thus higher gain since larger pads collect more charge from the avalanche. As a result, the iTPC will have improved S/N. These factors mean that we can lower the iTPC anode voltage settings the same amount as in 2009 and actually achieve higher S/N than before.

Two recommendations from the 2009 review remain untouched:

Manpower and key TPC personnel continue to be a concern. See Section 5.

And, for lack of an insertion tool, we have not replaced the bad inner and outer sectors as was recommended.

4 Recommended Equipment Upgrades for BES II Operations

The following equipment upgrades are recommended for efficient beam use and operation of the STAR TPC. These upgrades are independent of the iTPC upgrade.

High Voltage supplies	50K (direct costs, only)
Gated Grid Drivers	36K (direct costs, only)
Gas System	20K (estimated)
EPICS Slow Controls upgrade	Contributed labor

Justification:

A new set of HV supplies for the inner and outer sectors will minimize operational failures and minimize downtime.

A new set of Gated Grid drivers will allow the TPC to run at higher data acquisition rates, and maximize the productive use of the beam.

The TPC gas system is an active system that is continuously consuming materials and supplies. Valves, pumps, sensors and electronics equipment must be continuously replaced in order to ensure reliable operations.

The EPICS Slow Controls system will have to be upgraded to accommodate the new hardware (HV supplies, GG drivers, etc.) It is always a good idea to continue improving the EPICS interface because it generally leads to higher efficiency and high productivity from the control room shift crews.

5 Key Personnel

TPC Operations	Alexei Lebedev (BNL)	Available through 2020
	Jim Thomas (LBNL)	Available through 2020
TPC Calibrations	Gene Van Buren (BNL)	Available through 2020
	Yuri Fisyak (BNL)	Available through 2020
	Richard Witt (USNA)	Available through 2020
	Post Doc (STAR)	Contributed labor
	Student (STAR)	Contributed labor
TPC Gas System	Leonid Kotchenda (PNPI)	Retired consultant
	Peter Kravtsov (PNPI)	Consultant
Tracking Software	Victor Perevoztchikov(BNL)	Available through 2020
	Spiros Margetis (Kent State)	Available through 2020
	Jerome Lauret (BNL)	Available through 2020
	Jason Webb (BNL)	Available through 2020
Electronics	Tonko Ljubicic (BNL)	Available through 2020
	Bob Scheetz (BNL)	Available for a few more years
	John Hammond (BNL)	Available through 2020
	Tim Carmarda (BNL)	Available through 2020
STAR Operations	Bill Christie (BNL)	Available through 2020
	Rahul Sharma (BNL)	Available through 2020
	Bob Soja (BNL)	Available through 2020

Gas system experts Leonid Kotchenda and Peter Kravtsov are from PNPI, Gatchina Russia. They are also the gas system experts for the PHENIX collaboration. They are happy to continue consulting on the STAR gas systems, but obviously Leonid's availability is a concern and may require STAR (and perhaps sPHENIX) to develop a new expert.

The electronics engineering team is very productive and efficient, but it is not large. Similarly, the Calibrations and Tracking groups are not large. The loss of personnel in these categories would have a critical impact on the project.

The team of TPC experts is not large and is aging. The introduction of new scientific capabilities which will be enabled by the iTPC upgrade will be very beneficial in terms of attracting younger collaborators to the team.

Appendix I: Charge to the Collaboration from the Associate Director

Dear Zhangbu,

[…] I am requesting a comprehensive assessment of the performance risks of the STAR TPC during the Beam Energy Scan 2 runs, currently planned for 2019 and 2020. The report, which should be submitted to me no later than December 1, 2015, should analyze and assess the risks associated with

(1) operating the STAR TPC in its current state through 2020;

(2) upgrading the STAR TPC as described in the iTPC proposal, including the risk of an upgrade schedule slip that might delay the run planned for 2019.

It would be useful if the report would briefly review the performance of the STAR TPC since 2010 in the light of the 2009 TPC Performance Review.

The report should describe necessary repairs or other precautionary steps that should be taken to ensure smooth and efficient operation of the TPC during the Beam Energy Scan 2 runs and estimate their cost.

The report should also review the risks associated with personnel devoted to the operation of the TPC.

Thank you in advance.
Berndt

Appendix II: iTPC Risk Management Plan

Introduction

Project risk is a measure of the potential inability to achieve project objectives within defined scope, cost, schedule, and technical constraints. Project risk management entails the systematic process of identifying, quantifying, handling, tracking, and reporting risk events. Risk events are defined as individual occurrences or situations that are determined to have potential negative or positive impacts to a project. Project risk management includes maximizing the probability and consequences of positive events and minimizing the probability and consequences of adverse effects to a project.

The iTPC project team is committed to managing project risk effectively by employing a comprehensive strategy that emphasizes risk identification and prevention or mitigation. The overall objectives of the Risk Management Plan (RMP) are to prevent or minimize unnecessary project costs and/or schedule delays, while achieving the project scope. *This Risk Management Plan (RMP) describes the overall philosophy and process for risk management.*

Risk Assessment for the iTPC Project

The Risk Management Plan takes a broad view of the iTPC project to identify and address specific risks that require assessment, mitigation and tracking. While the initial risk assessment will be focused on the establishment of a valid baseline, risk assessment will be an ongoing process throughout the project life cycle. In addition, the following assumptions will serve to guide/bound the risk assessment:

- The project will be executed in accordance with RHIC/STAR and Brookhaven National Laboratory Policies and Procedures.
- The project scope will be limited to the scope of the Memorandum of Understanding (MOU) between STAR and the BNL Associate Directors Office.
- The installation, integration, commissioning and operation of the project will be executed in accordance with RHIC/CAD and STAR Policies and Procedures.
- The project will be carried out by the STAR Collaboration and will be dependent on the STAR/RHIC operations schedule.

1. Risk Registry and Strategic Risk Management

Strategic project planning is based on a top-down Risk Analysis that identifies all significant technical, cost and schedule risks, which are tabulated in the formal Risk Registry. For risks not yet retired, mitigation strategies are developed that are taken into account when making decisions about R&D efforts, design and purchasing strategies, production methodologies and schedules, and other significant aspects of project management and execution.

Informal risk analysis and assessment are implicit in the day-to-day operation of the project, as the project management team responds to new vendor quotes, further experience with detector production, and so on. The Project Management Team will in addition carry out more formal reviews of project risks, updating the Risk Registry as needed. Prior to the start of each significant new sub-project, a focused risk assessment will be performed to ensure that significant new risks are identified and the appropriate risk handling measures are incorporated into project planning.

Risk Analysis and Monitoring

Individual risks are tabulated in the project Risk Registry. A single risk owner is assigned to monitor each risk and to develop avoidance or mitigation strategies, with ownership assigned by the Project Management Team.

The Project Manager is responsible for overseeing the development and maintenance of the Risk Registry and for coordinating the risk management process along with the Level 2 Managers. Experience within the project has shown that joint ownership of the Risk Registry by the Level 2's and the Project Manager is advantageous, since a wide range of experience is required to cover all areas of project risk.

Project risks are assessed for likelihood of occurrence and for potential consequences to the project cost and schedule.

Risk monitoring is required throughout the life of the project. The objectives of risk monitoring are to:

- monitor the appropriateness and validity of mitigation strategies.
- ensure that risk mitigation measures have been implemented as planned.
- evaluate the effectiveness of the risk mitigation measures.
- identify previously unanticipated risks.
- retire risks.

Risk monitoring and assessment will include reviews by the Project Management Team, facilitated jointly by the Project Manager and the Level 2 Subsystem Managers. These reviews may lead to reevaluation of the technical performance of a sub-project, additional or modified risk mitigation measures, scope change requests, reallocation of resources, revised probability/consequence and expected value estimates, adjustment of contingency, or retirement of risks. Work plans and mitigation strategies will be adjusted continuously to take advantage of lessons learned and to maximize the probability for successful project completion.

Appendix III: Report of the 2009 TPC Review Committee

A review of the STAR TPC operations and projected lifetime was held on June 4-5, 2009 at BNL. The Committee was chaired by Dr. Ron Settles of the Max Planck Institute, Munich.

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

This report, all presentations, and additional material for the review can be found on the web at: https://indico.mpp.mpg.de/conferenceDisplay.py?confId=494

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

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