The STAR Inner TPC upgrade

Quarterly REPORT

April 2018

BROOKHAVEN
NATIONAL LABORATORY

iTPC QUARTERLY PROGRESS REPORT
Q2FY2018
**Project Status Summary**

The upgrade of the STAR TPC, consisting of the replacement of the 24 inner sectors with full coverage of pad rows and associated electronics, was approved as a BNL capital project on March 18 2016 following the Directors review in January 2016. The project is well into the construction and commissioning phase.

Twenty-two sectors suitable for production have been assembled and shipped to Shandong University (SDU). Due to the number of de-bonded strong backs, additional strong backs and side-mounts have been procured to ensure that 28 sectors are available for wire mounting.

Fabrication of the MWPCs has entered production mode at SDU and to date 17 production modules have been completed, testing is underway, and completed for 12 of those. So far, the sectors pass the local QA procedures.

The pre-production FEE and RDO boards have been completed, tested, commissioned, and a complete set has been mounted on the iTPC sector installed in STAR. The firmware is sufficiently developed such that the iTPC can operate concurrently with the STAR run 18 data-taking.

The installation procedures for the iTPC modules are being updated, and the pre-testing on the installation mockup for all sector position is being practiced.

**WBS 1 Project Management**

Monthly phone calls were held with DOE NP office in January, February, and March.

As the pad-plane bonding has resulted in four unusable sectors for MWPC production at SDU and as it is still unknown if two other failed sectors can be repaired, it was decided to pursue building additional strong backs, pad planes, and side-mounts boards. The LBL engineering group has provided a cost to complete including activities for six more sectors. A request for 215k$ for this activity was made, and it was agreed to transfer those funds to LBNL. This happened in January.

Jim Thomas has stepped down has deputy PM, but is still involved in many technical aspects. Daniel Cebra, from UC Davis, has agreed to take over this position and was appointed. Grazyna Odyniec, LBL, has taken an active role in iTPC oversight at LBNL, along with Howard Wieman, on technical issues.
WBS 2 Pad plane

Pad plane and side-mount production has been completed. A sufficient number of spares has been made so that mishaps at assembly at LBL will not cause delays.

The remaining tasks are to do the burn-in of the ABDB boards and to cover the components with glyptol. This includes the ABDB and LOAB boards that will be installed on the final detector modules. All ABDB boards have been assembled, and final HV testing is underway. No issues have been found so far.

WBS 3 Mechanics

Six additional strong backs were produced at IMT for the phase II of assembling of sectors at LBL. The strong backs were delivered on March 12, and the bonding and assembly process has begun LBL. All the parts needed for side mounts are available there. The production and bonding of six additional sectors at LBNL is expected to be complete by early May.

The grid leaks boards that are to be installed have all been delivered.

MWPC production

I. iTPC MWPC & assembly mass production:

1) The MWPC production & iTPC assembly at SDU went well in this quarter (January-March 2018). In total, seven sectors (SN15, 14, 10, 17, 18, 03, 12) were completed with MWPC mounting and assembly this quarter. Until now, 19 sectors have been assembled with MWPC among 30 articles by the end of this March, as seen in the QA sheet below.
2) Several sectors were found to have an excess epoxy issue with the anode feed through board (SN07, SN08, SN01, SN12, SN05), which made it difficult, or impossible, to plug in the testing card. This issue was solved, although it requires tedious labor, by using acetone to dissolve the excess epoxy.

3) Two sectors were found to have several ADBB pins (3 pins for SN08, 1 pin for SN05) grounded unexpectedly. This will affect the anode wire gain testing, however, it should be fine for physics data taking.

4) Wire winding issue:
It was found that the fluctuations of anode wire tension had became a bit beyond the accepted range (0.5N+0.03N) for anode wire frames. The tension fluctuations are most probably related to the motor of the winding machine, as 0.5N is already on the lower edge of the normal tension range. BNL helped ordering two new motors of same type from the same manufacturer. A new motor was installed in late March, but the resistance of the new motor was found to be too big to get the 0.5N tungsten wire winding started, and the wire get easily broken when the force is close to 0.7~0.8N. The engineer is still investigating this issue. One backup option involves reinstalling the original motor, however, this will require more frames to be wound and tested to find qualified one. Another option is to use a winding machine currently being used by our ATLAS colleagues, however this will require proper coordination.

II. Performance testing:

On detector testing in this quarter, performance tests were done for four sectors: SN11, SN14, SN17, SN19. The tests include HV burn-in, gain uniformity, and high intensity X-ray stability. The anode wire gain uniformity under P10 is <1.5% (better
than the 2% required), the energy resolution is \(~8.5\%\) (in RMS, better than the 10% requirement), and the leakage current remains \(<500\ nA\) under intense X-ray irradiation test without trips or sparks for four hours for each channel. The test results are summarized in the travellers (S-17), which can be found at: https://drupal.star.bnl.gov/STAR/blog/qhxu/itpc-production-travellers

We note that one anode wire was found to have no signal for sector SN17 during wire gain scan. We need to check the anode wire, but first we need to remove the gated wire and shield wire plane. The new tool to remove shield wire plane is still being fabricated. Once the tool is ready, we will check SN0017 and also SN0025, which was reported to have a similar issue in the last quarter report.

**WBS 4 Installation**

As first reported during FY17Q4, a mock-up with the dimensions of the opening that the iTPC sectors are to be inserted was constructed on the floor of STAR wide-angle hall. In FY18Q2, insertion tests have been successfully completed using the installation tool on the lift platform with a prototype iTPC sector at the simulated height for each of the 12 orientations on the STAR detector. The entire procedure was fully documented for reference during actual installation prior to RHIC Run-19. The photo below shows the installation mock-up with the prototype iTPC sector mounted in the 12 o’clock orientation.

Figure 2 Insertion tooling installation mockup in the assembly building.
One of the lessons learned during the installation of the iTPC sector for RHIC Run-18 is that handling of the O-ring proved quite challenging during the removal of the original inner sector. The O-rings have been seated on the originally installed inner sectors for 20 years now, maintaining a tight seal to the TPC end wheel. A special tooling plate was designed by the STAR Technical Support Group (STSG) to facilitate removal of the original inner sectors by applying a more uniform force to push the sector free of TPC end wheel. The pusher plate is shown in orange in the diagram below from the STSG.

![Figure 3 CA drawing of pusher plate.](image)

The annual Operational Readiness Review of the STAR experiment occurred on Feb. 14, 2018, and the final walk-through took place on March 2, 2018 prior to the start of RHIC Run-18. The review included the iTPC sector which was installed on Oct. 5, 2017 and the associated readout electronics which had been previously reviewed on Nov. 28, 2017. No additional action items regarding the iTPC project were generated during the Operational Readiness Review and walk-through.

Progress continues on preparation of an additional clean area in the STAR wide-angle hall for inspection and storage of iTPC sectors. As a reminder, there are three critical tests to be performed at BNL prior to installation of an iTPC sector: (1) vacuum leak test with an Ar sniffer; (2) canary chamber test, and (3) high voltage stability test. Gas lines to provide N₂ for flushing the test chambers and P-10 (90% Ar and 10% Methane) for conducting these tests have been run from the STAR gas-mixing room into the clean area. Optics and electronics for a laser source and a
cosmic-ray trigger are being assembled in the clean area. A dedicated multi-channel analyzer has been purchased for the clean area to operate remotely from the canary chamber in the gas-mixing room.

**WBS 5 Electronics**

**Electronics FY18Q2 Quarterly Report (Jan 1 - Mar 31, 2018.)**

**iRDO**

The super-final version of the iRDO has been manufactured and tested. Both boards work fine. *This completes the last component of the iTPC Electronics Upgrade.* Full production quantities have been ordered and the orders have been dispatched. We are waiting for delivery. These orders include

1) iRDO PCBs  
2) iRDO parts  
3) Specially modified FPGA modules (“Trenz TE0712”)

**iFEE**

The full production quantities have been ordered and the orders have been dispatched to the vendor. We are waiting for delivery. Those orders include:

1) iFEE PCBs  
2) iFEE assembly & parts

**Other parts**

All other parts have been ordered and the orders have been dispatched. We are waiting for delivery. Those orders include:

1) Receiver Boards (“Trenz TEF1001”)  
2) 26 DAQ PCs  
3) Power Supplies
Preparation & scheduling plans have been made for the modification of the existing power supplies at the end of the FY18 run, for the fiber cabling and installation plan, and for the DAQ PC rack installation.

**FY18 Physics Run**

The ITPC has been running successfully in most of the FY18 STAR runs, in concert with the rest of the TPC. Debugging of the firmware and software is ongoing in an iterative fashion. As of the end of Q2 we have the following observations:

1) No components have failed during the ~2 months of running.
2) We observed no particular Single Event Upsets.
3) The real-time (online) cluster-finder has been implemented and is currently being evaluated. Preliminary results look good and as-expected.
4) We have reached a readout rate of ~2.5 kHz with the same deadtime as the current TPC, which completes the DAQ rate requirement.

**SAMPA**

An agreement has been reached with the Brasil Sao Paulo group for the full quantity of the last ordered batch of SAMPA V3s which is about 4000+ pieces. The ASICs are fully cut and packaged in corresponding BGAs but as of yet untested. They are currently at CERN, Geneva.

A preliminary agreement has been made that they will be directly shipped from CERN to Lund, Sweden for final testing before shipment to BNL. Final agreement as well as the final schedule is still pending (the responsible person is on sick leave).

**Commissioning and software**

**iTPC Software**

The software package for simulating, reading, and reconstructing the STAR TPC data consists of parts that are bound to the existing geometry of the detector. Therefore, new design of the iTPC brings challenges that need to be addressed in the software for years 2018 and following.
The existing software has been altered accordingly to accommodate the increased number of padrows, in one case for inner sector 20 for year 2018 and in another case for all inner sectors for all following years accordingly.

Modified software has been used to reconstruct cosmic data taken this year and some of the collision data available for the moment.

Figure 4 Reconstruction of cosmic tracks in sector 20 shows 72 hits for some tracks

Figure 4 shows the distribution of the hits on the reconstructed cosmic rays in sector 20. The distribution demonstrates that we reconstruct tracks that have hits from new inner TPC sector, many of them have all possible 72 hits from all the padrows available in this sector.

Figure 5 Cosmic track in the STAR TPC that traverses sector 20
Figure 5 shows a STAR event display image featuring a cosmic ray track reconstructed in sector 20 using both inner and outer sub-sectors and matched to its counterpart from the sector 1.

The software is still undergoing thorough QA testing for its backwards compatibility and key performance parameters (e.g., reconstruction efficiency). Track reconstruction on collision data shows tracks being reconstructed in sector 20 using hits from both inner and outer sub-sectors.

Figure 6 shows the STAR Event display for collision data for tracks in sector 20 with over 45 (more than possible number of hits in other sectors) hits.

**Milestones**

Milestone date and status changes are discussed in order.

- ABDB burn-in and testing completion is now forecast for 5/1/18
  - The ABDB boards have all been fabricated and HV tested in dry N2. The process of applying and testing with HV applied in P10 gas is underway. This is not a critical milestone.
- MWPC production:
Based on the delayed start and current knowledge of fabrication time, the overall MWPC production schedule with the forecast days for subsequent delivery has been changed. This revised MWPC schedule matches that presented at the review. The revision shows the importance of watching carefully both the padplane assembly at LBL and the actual production time at SDU in order not to impact the overall project schedule. At this point only two fully qualified sectors have been shipped to BNL, although overall 10 have been produced.

- Electronics: FEE (RDO) final design was completed and signed off on 1/28/18(A)
  - A review with non-STAR reviewers was held on 1/28/18
- Installation Safety review for run-19 changed to walk through safety review January 2019.
  - As there is no changes over the installation, chambers and electronics for Run-18 all that is needed is a safety walk through of the experiment.
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<td>FY16 Review</td>
<td>9/30/2016</td>
<td>9/13/16(A)</td>
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<td>FY17 Review</td>
<td>9/30/2017</td>
<td>9/26/17(A)</td>
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<tr>
<td>FY18 Review</td>
<td>9/30/2018</td>
<td></td>
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<tr>
<td>Project Closeout</td>
<td>12/1/2019</td>
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</table>

| Pad planes                    |                           |                   |
| preproduction pad plane complete| 08/17/16(A)              |                   |
| Pad plane material accepted   | 08/29/16(A)               |                   |
| Pad planes Received           | 12/07/16 12/08/16(A)      |                   |
| Delivery of first soldered pad planes | 12/20/16 12/21/16(A) |                   |
| First delivery to LBNL pad plane | 1/9/17 1/14/17(A)  |                   |
| All pad planes completed and tested | 03/30/17 7/16/17(A) |                   |
| Anode side mounts acceptance start | 1/10/17 1/15/17(A) |                   |
| ABDB burn-in and testing complete | 3/31/17 5/1/18(F) |                   |

| Strongback                    |                           |                   |
| Strong back Design Finalized  | 01/28/16(A)               |                   |
| First item preproduction ready| 05/31/16(A)               |                   |
| All strong backs produced    | 08/09/16(A)               |                   |

<p>| MWPC production               |                           |                   |
| MWPC internal production readiness review | 12/3/16 (A) |                   |
| Sector Prototype tested       | 02/16/17 3/15/17(A)      |                   |
| MWPC assembly start           | 02/20/17 6/5/17(A)       |                   |
| First production test results | 04/10/17 7/5/17(A)       |                   |
| First set of modules at BNL   | 08/29/17 9/6/17(A)       |                   |
| Second set modules at BNL     | 12/14/17 4/30/18(F)      |                   |
| Third set modules at BNL      | 03/30/18 6/14/18(F)      |                   |</p>
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<tr>
<th>Event Description</th>
<th>Date</th>
<th>Notes</th>
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<tr>
<td>Last set of modules at BNL</td>
<td>07/20/18</td>
<td>9/20/18(F)</td>
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<tr>
<td>Testing of modules completed</td>
<td>08/31/18</td>
<td>9/31/18(F)</td>
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<td><strong>Electronics</strong></td>
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<tr>
<td>Prototype FEE &amp; RDO ready for test in run-17</td>
<td>12/2/2016 (A)</td>
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<tr>
<td>FEE &amp; RDO pre-production design signoff</td>
<td>6/6/17</td>
<td>5/24/17(A)</td>
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<tr>
<td>FEE Preproduction complete</td>
<td>09/04/17</td>
<td>8/15/17(A)</td>
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<tr>
<td>One full Sector electronics test complete</td>
<td>10/10/17</td>
<td>12/1/17(A)</td>
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<tr>
<td>FEE (RDO) final design complete and signed off</td>
<td>3/29/18</td>
<td>1/28/18(A)</td>
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<tr>
<td>FEEs produced (w/o SAMPA )</td>
<td>7/19/18</td>
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<tr>
<td>FEEs complete with mounting of SAMPA chips</td>
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<td>First FEEs ready for installation</td>
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<td>RDO Prototype complete</td>
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<td>Pre-production RDO produced</td>
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<td>RDO Available for full sector test</td>
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<td>RDO production Complete</td>
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<td>Installation Safety review for run-18</td>
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<td>TPC in assembly building after run-17</td>
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<td>One sector replaced for run-18</td>
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<td>10/3/17(A)</td>
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<td>Ready for roll-in for run-18</td>
<td>12/1/17 *</td>
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<td>Sector installation start for run-19</td>
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<td>East Electronics Installed</td>
<td>10/12/18 **</td>
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<tr>
<td>West Electronics installed</td>
<td>12/15/18 **</td>
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This is an updated schedule for the external milestones for the LBL bonding and shipments. This update was the result of the Cost and Schedule to Complete exercise in November 2017.

<table>
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<th>Padplane joining at LBL</th>
<th>Tooling for pad-plane joining completed</th>
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<td>Joining prototype procedures executed</td>
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<td>First joined sectors ready to ship</td>
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<td>Produce article 19-22</td>
<td>12/18/17</td>
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<td>Produce article 27-30</td>
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<td>Repair articles if feasible</td>
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**Financial Status ($K)**

Note that columns may not up on the last digits due to the rounding to k$ from $.

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**Figure 7 Financial status as of March 31, 2018**

The iTCP project is divided into five main activities. Each of these activities are tied to a project account in the BNL physics department. **Cum actuals** are actual
cumulative expenses. **Req** are outstanding requisitions or commitments. The **Est. Total** is the sum of the cum actuals, the requisitions with the anticipated overhead and the mechanics includes also the transferred funds to LBNL that will cover the pad plane joining.

LBNL is responsible for the assembly of the iTPC strong-backs with the pad planes and wire-mounds which requires a high degree of precision work with custom tools and special procedures. The funds needed to cover the LBNL activities, in amount of k$880 have been transferred to LBNL in 3 installments. The last transfer took place on January 18, 2018.

No request for use of contingency has been done this quarter.
### Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tr>
<td>ABDB</td>
<td>Anode Bias Distribution Board</td>
</tr>
<tr>
<td>BNL</td>
<td>Brookhaven National Laboratory</td>
</tr>
<tr>
<td>C-AD</td>
<td>Collider Accelerator Department</td>
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<tr>
<td>ESRC</td>
<td>Experimental Safety Review Committee</td>
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<td>FEE</td>
<td>Front End Electronics</td>
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<tr>
<td>LOAB</td>
<td>Little Orphan Annie Boards</td>
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<tr>
<td>LBNL</td>
<td>Lawrence Berkeley National Laboratory</td>
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<tr>
<td>LOAB</td>
<td>Little orphan anode board</td>
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<tr>
<td>MCA</td>
<td>Multi Channel Analyzer</td>
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<td>MWPC</td>
<td>Multi Wire Proportional Chamber</td>
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<td>RB</td>
<td>Readout Board</td>
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<td>TPC</td>
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