Associate Laboratory Director's Cost & Schedule Review of the TPC Outer Tracker (TPOT) September 2-3, 2021

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Executive Summary

The TPC Outer Tracker will be a valuable addition to determine space charge corrections in near real time and speed up sPHENIX analysis as also noted by the BNL PAC in June. The committee has some concerns about the high occupancy in more central collisions that only the more detailed studies planned later this year can resolve.

The overall schedule is very tight. The production plan for the modules, electronics and services is clear. The schedule calls for installation of 8 modules before the first sPHENIX run and the remaining 18 before the second run. The engineering and design of support structures is on the critical path and that resource has not yet been identified.

The committee recommends that at this point in time the installation for the second year should not be executed due to a high risk for sPHENIX, but that efforts to have a maximal number of modules available for the summer 2022 installation should be made.

It is important if the TPOT moves forward that it does not impact the sPHENIX schedule and cost. It is also important to assemble an experienced mechanical design team within a month to maintain the schedule.

The committee recommends that NPP management and sPHENIX discuss if such a plan is feasible and decide on the TPOT project.

Answer to charge questions

Are the merit and significance of the TPOT upgrade well justified and the conceptual design technically sound to meet the performance expectations?

- Yes, The upgrade will provide for near real time space charge corrections for the TPC and enable faster processing of sPHENIX data. The design for modules and electronics is nearly complete.
- No, The mechanical support structure and installation is pre-conceptual, and not well developed.

Are the costs of the project sufficiently well understood, and are the resource needs required to complete the project fully identified?

Partially, The costs for module production, electronics are well understood and resources identified. The support structure not so. The cost for engineering and design is for 6 months including schedule contingency but may be underestimated. Engineering resources have not yet been identified and may compete with current sPHENIX needs.

Is the schedule of the project sufficiently well understood and matched to the plan for installation in sPHENIX?

In part. The module production presently allows for only installation of 8 out of 26 modules before the TPC installation. The engineering and design of support structure is at a pre-conceptual stage and not well understood. The installation of 8 modules before TPC installation is very tight in the current schedule and would require the remaining 18 modules to be installed before the second sPHENIX run.

Are the risks introduced by the TPOT upgrade into the successful operation of sPHENIX well understood, and are there sufficient plans to mitigate these risks in place?

Mostly yes. The risk of the staged installation to sPHENIX operation is judged by the committee to be high.

Are the interfaces and integration with sPHENIX and RHIC well understood?

Yes. The DAQ and services integration is well understood.
No. Integration and services routing is in the very preliminary phase.

Is the management and ES&H structure effective and are the institutional responsibilities well defined?
This is work in progress. Some institutional responsibilities still must be identified.

Merit and significance

Findings

The TPOT team presented a series of clear presentations. A strong case was presented for the inclusion of this detector in sPHENIX.

The design of the modules (i.e. the detectors) is advanced. The Saclay team responsible for the modules is very experienced.

The front and back end electronics rely on previous developments and are well understood.

The mechanical support and installation are very preliminary and are not yet at the conceptual stage.

Comments:

TPOT detectors in sPHENIX is a good idea, any additional information to correct TPC space charge distortions (SChD) will be useful.

The option, to use two independent chambers (rϕ, Z), is not the optimal one, but was selected on the base of a lot of experiences and reasonable simplicity.

The TPC track and MMG cluster(s) matching with good probability was not justified, especially for a high occupancy and taking into account Lorentz angle. It needs more simulation to be done. Perhaps a third layer at 45 degrees might help? It seems there is space for that and perhaps it might be worthwhile considering such an option.

The alignment procedure was not discussed. As a first step it needs a reasonable long cosmic run with B-field ON/OFF. The possibility to get a trigger from MMG chambers will be very useful.

Recommendation:

- Concentrate maximum efforts to prepare and install more than 8 MMG TPOT chambers before Run-1, taking into account the non-zero possibility that there will not be a chance to install more chambers for Run-2.

TPOT Electronics

Findings

The front end of the TPOT readout is based on an existing ASIC, the SAMPA, which is also used in the readout of the TPC. The SAMPA ASIC includes 32 channels of charge integrating amplifiers followed by semi-gaussian shapers, tail cancellation digital filters, and 10-bit successive approximation ADCs. The same chip is being used for the ALICE TPC upgrade and its function and performance is well understood.
The back end includes data aggregator modules based on the FELIX PCIe board developed by the ATLAS experiment at CERN, also well understood. Each of the 26 2,1D micromegas detectors of the TPOT system is read out by 2 front end (FEE) boards with 256 channels each for a total of ~13,000 channels. Two aggregator boards receive, via optical fibers, the output of 26 FEE each.

Comments

The availability of the front end ASIC, already in use by the collaboration and the use of existing back-end boards makes the production of the TPOT readout reliable, with very low risk while keeping the production cost low. The active components (SAMPA ASIC and FPGA) are already available from the TPC production overage. The total cost is estimated to ~$52K which seems quite reasonable. The schedule, driven mainly by the FEE and aggregator board production is also reasonable with low risk of delays.

Recommendations

None

Integration and installation

Findings

Mechanical design of detector modules is well understood.

Only a pre-conceptual mechanical and installation design was presented. There does however appear to be sufficient space between the TPC and the EMCAL for the modules and their services.

Comments

If there is a second TPOT installation phase where the remaining 18 modules are installed, a more detailed choreography is needed.

If there is a second TPOT installation phase, rails or installation structures need to be in place in Phase #1 and an installation mock up should be developed to test this scheme as part of the Phase #1 design process.

Engineering effort needed to finish the work is underestimated and switching engineers/designers during the project will cause further delays.

Procurement and manufacturing delays should also be accounted for and enough float should be built in schedule to accommodate them.

As TPC outer field cage membrane is very thin and can be damaged easily. Special attention should be paid in the design to the cables, cooling lines and gas lines are dressed in a way that there is no chance of them dangling or scraping on the OFC surface.

A separate independent design review is needed after 3D design is close to completion to make sure that all the design issues are addressed.

Work with the sPHENIX infrastructure team to update ICD-42. This document is used to assign rack space and cable routing requirements for the sPHENIX detectors.

Recommendations

- Structural evaluation of TPC supports, EMCAL support frames, and TPC detector structure with included conservative TPOT loads should be done as soon as possible to show basic feasibility or to identify additional supports design scope.
- A more detailed integration assessment is needed. The interfaces with TPC and EMCAL should be understood and STAY CLEAR ENVELOPES should be generated in 3D model. Cables, Cooling Lines and Gas Lines should also be 3D modeled to better understand the cable and line dressing during installation. This will help identify scope and increase the accuracy of estimates.
- An assessment of the scope and cost of including IsoButane use in the sPHENIX project to support TPOT is needed. There are existing distribution and safety systems that may or may not be functional and sPHENIX interlock and control designs need to be updated.

Schedule

Findings

The schedule assumes that the TPOT project can start on October 1 2021 and that funds are available to setup contracts with CEA Saclay and start design of structures.

The design of support structures and installation has built in float the doubles the estimated time.

The module production time is conservative based on experience with prototype and several other micromegas at CEA Saclay.

Comments

The proposed schedule envisions an initial installation of 8 modules in 2022 and the remaining 18 modules in 2023. The schedule appears reasonable for the modules and electronics, but is extremely tight for the mechanical support. We note that under this schedule the installation design for 2023 needs to be understood so that any mechanical support components needed for such an installation would need to be installed on the TPC at this time.

The module construction schedule is well justified and based on experience of constructing similar modules as well as the prototype. The first 8 modules will be available and tested at

BNL end of May 22. They are planned to be installed on the support structure on 7/26/22, which requires all support structures completed.

The WBS has activities that are at least confusing. There are activities following the installation at the end of July that reads like access to installed modules are required, which is not the case once the TPC is inserted.

Recommendations

none

Risks, impact on sPHENIX

Findings

The methodology for estimating risk, cost, and schedule impact used is based upon the sPHENIX risk management plan. From this an overall impact score for various tasks is calculated. Possible impact scores are “Low”, “Moderate”, and “High”.

No task was given a “High” impact score; a number of tasks were given a “Moderate” score.

Comments

We do not believe the risk assessment for installation in the staged approach is properly judged. It will require re-evaluation of the current TPC support design, and additional FEA with the added weight is needed. This could delay the installation of the TPC. Installation after Run 23 looks very difficult and high risk for sPHENIX. There are several reasons

- Most likely several services will have to be removed, and reconnected.
- The TPC field cage is lightweight and fragile, any damage to it at this point is of dire consequences to the sPHENIX program and RHIC.
- A better strategy would be to install as much as possible for run-22 and drop the subsequent installation

Recommendations

- Assessment of impacts to the sPHENIX construction schedule should be revised. The impact scores presented are underestimated with regards to delays in the design, fabrication and deployment of TPOT supports.

- At this point in time the installation for the second year should not be executed due to a high risk for sPHENIX, but that efforts to have a maximal number of modules available for the summer 2022 installation should be made.

Management, ES&H responsibilities

Findings

This is the first detector in sPHENIX using flammable gas, so they will need to have flammable gas detection inside the solenoid and in the Gas Mixing House. It requires repurposing of PHENIX equipment and additional ESCR reviews.

A management org chart was presented with the caveat that discussion is still ongoing.

Comments

It is important to complete the distribution of responsibilities, particular since not all institutions are on board at this point.

Recommendations

None

Cost, resource needs

Findings

The module production cost is 748k$. This is planned to be funded by a sub-contract between BNL and Sacaly. Saclay will provide contributed engineering.

Contingency was evaluated using a similar methodology as for MVTX.

The cost for the electronics is 211k$, or 258k$ with 20% contingency.

The cost for the global mechanical support is 455k$, or 728k$ with 60% contingency.

The total cost of the TPOT project as presented is $2.15M, $2.8M with contingency

It is assumed that funds from BNL as needed

Comments

Costs associated with the modules and electronics appear well understood. The costs associated with the mechanics and installation are less well understood; the TPOT team understands this and assigns a 60% contingency with the costs. However, as there is not yet any understanding of how to do the year 2 installation these costs may be underestimated even with contingency.

Follow through with recommendations in the Integration/Installation section. Resolution of these recommendations could lead to increased scope and increased costs.

Recommendations

none