Review of the sPHENIX pixel vertex detector, MVTX

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1. Executive summary

The MVTX is a pixel detector that, as the innermost detector, is intended to provide vertex and tracking information for the sPHENIX experiment. It relies on two important developments from the ALICE experiment, staves and Readout Units. The MVTX intends to obtain these components from the ALICE production.

This committee has been tasked with determining whether the maturity of the design of the sPHENIX tracking system and readout is sufficiently understood to permit the purchase of these components. A number of specific charges to the committee are listed below. The MVTX team gave a number of presentations to address the charges, and provided a presentation that addressed a number of questions the committee raised.

The committee was impressed with the presentations and their organization and found that, with some minor caveats, the MVTX has successfully addressed the charges. We believe the MVTX can proceed with the purchase of the Readout Units, and that upper management should endeavor to find the necessary funding so that the MVTX can combine their order with that of ALICE to achieve significant savings.

We expect the MVTX project should and will proceed with the purchase of the staves. However, as noted in the final general recommendation, there are a few tasks to complete before making the final decision on whether to initiate the purchase. The general recommendation derives from concerns about possible interference between the space envelopes of the MVTX and the Intermediate Silicon Tracker that surrounds it. These tasks should be completed by early September.

2. Answer to charge questions

1. Does the current design demonstrate that the MVTX Staves and Readout Units will be compliant with its specifications?

   A complete list of specifications were not presented. To the degree that the specifications were presented, the Staves and Readout Units meet specifications.

2. Can the data from MVTX staves be extracted, readout and integrated into sPHENIX Data Acquisition System?

   Yes.

3. Are the electrical interfaces of the Staves and Readout Units to other sPHENIX components at a proper level of understanding?

   Yes

4. Has the responsibility for fabrication, tests and acceptance for the Staves and Readout Units been defined?

   Yes

5. Has a QA plan and acceptance tests for the Staves and Readout Units been clearly defined and documented?

   Yes

6. Has the inspection/test records archive plan been clearly defined and is the information easily accessible?

   Yes, as long as sPHENIX makes the ALICE database available in downloaded form to the sPHENIX team in real time (or at least once every few days a download should be done).

7. Is the design of the Staves and Readout Units final?

   Yes, with two minor caveats:

- A stave with the longer power cable has not yet been produced.
- There is a slight possibility a version 2.1 RU will be needed with very minor fixes to version 2.0.

8. Are the Staves and Readout Units ready for procurement?

   The RU are ready for procurement.
   The staves will be ready following the team's addressing the final general recommendation (presented below) concerning the interferences between the

INTT and MVTX envelopes. The committee believes however a solution will be found.

9. Status of the simulation to optimize the MVTX and INTT for tracking in sPHENIX and timescale for its completion

   A plan was presented; See comments below.

10. Status of the mechanical integration between the MVTX, INTT and other sPHENIX components and timescale for a final design

    A plan was presented; See comments below.

3. Staves

Andrei Nomerotski, David Lynn

Findings

- MVTX will use ALICE staves with ALPIDE monolithic sensors.
- The production of the 84 staves should take about 6 months.
- The stave power cables will need modification to extend them by ~20cm to reach the MVTX patch panel.
- Irradiation of the ALPIDE sensors to the required 1 Mrad has not yet been done. Extrapolation of results of irradiations up to 500 krad imply it is likely the sensors will continue to operate satisfactorily at 1 Mrad.
- The mitigation strategy of replacing the inner two layers should the sensors only operate up to 500 krad was presented; it is to replace the inner two layers from the pool of 75% spare staves they intend to purchase.

Comments

- The ALPIDE based staves represent a state-of-the-art solution to tracking in a heavy ion environment. It is a good and cost effective decision by the sPHENIX team to take advantage of years of ALICE development.

- It is important that the team conducts, as they intend, the irradiation of 1Mrad in the next few months which corresponds to the beginning of the sPHENIX stave production. This is so that in the event the ALPIDE sensors prove not to be radiation hard to 1 Mrad, a mitigation strategy of purchasing more staves (for additional cost) can be considered in light of this information.
- We suggest sPHENIX also consider having some discussions about having a joint inventory of spare ALICE staves. Should sPHENIX need these spares, they could be easily retrofitted with the longer sPHENIX power cables.

Recommendation

- Procure longer power cables, test and confirm any production issues with CERN team as soon as possible.

4. Readout Units

Andrei Nomerotski, David Lynn

Findings

- RU is interfacing the stave to FELIX. It is connected to the stave with a Firefly cable and to FELIX readout via a long GBT optical link.
- MVTX will use ALICE RUs without modifications.
- RU was used in the Fermilab beamtest.
- Planning to order 58 RUs which include 20% spares.
- ALICE is about to place order for the RU production with an option to include additional quantities for MVTX.

Comments

- This is a good approach, which takes advantage of ALICE R&D on the boards and saves money if the ALICE and MVTX production order is placed together.
- Better understanding of radiation maps, in particular for neutrons, would be beneficial to verify the projected radiation levels for RUs.

Recommendation

- Order RUs together with ALICE to save money. Note, this is a recommendation to BNL management.

5. Mechanical Interfaces

Connor Miraval, David Lynn

Findings

- With a larger beam-pipe than ALICE RUN 3, sPHENIX required an increase in the three layers of MVTX by 1.25mm, radially, to maintain the required 2mm clearance.
  - Staves were repositioned, after increase in radius, to maintain proper sensor coverage.
- After a mechanical conflict between MVTX and INTT was found, efforts to reduce the local radial footprint of MVTX began.
  - Decreased radial length of patch-panels and large barrel to allow for more room to fit the assembly within the INTT.
  - Increased length of power flex circuit cables to stagger the power and signal connection points reducing radius of the cable interface area.
  - A 46.9mm decrease of the original outer shell OD was determined (154 to 107.1mm) after the design of the reduced patch-panels and removal of the shell's aluminum flange.
- MVTX will be installed around the beam-line in a "clamshell" manner. Changes to the INTT installation procedure will now have it installed via support rails and bearing blocks mounted to the INTT shell, sliding in as one piece.

Comments

- The redesign of the patch-panel with the large slots was resourceful, as the original design with individual apertures per cable seemed encumbering. This reduced the OD by 6.5mm.
- The new installation method of the INTT utilizing support rails and mounted bearing blocks seems more natural, given the tight fit between the MVTX and INTT.
- A 3D physical model/prototype (interference region only!) should soon be produced that accurately represents the interaction between MVTX and INTT to determine if a collision is still occuring.

Recommendations

6. Electrical Interfaces

Andrei Nomerotski, David Lynn

Findings

- Stave is connected to RU with a Firefly cable.
- ALICE cable is 5m long, estimate of the MVTX cable length is 6-10m.
- The testbeam at Fermilab was done with a 5m long cable.
- Longer cables have been tested for signal propagation and with stave readout.

Comments

- The electrical interfaces seem to be in good shape

Recommendations

7. Simulation

Dmitri Tsybyshev, Andrei Nomerotski

Findings

- Simulation, digitization, clustering, track reconstruction software chain necessary to optimize the MVTX and INTT for tracking exists.
- The full software chain was exercised to obtain preliminary results to assess impact on physics due to addition of MVTX.
- sPHENIX relies on ALICE experiment to provide the detailed MVTX stave geometry description, but description of the detector layout and support services is specific to sPHENIX and is done by collaboration.
- A task force was created by the sPHENIX collaboration to study optimization of the MVTX and INTT configurations and impact on tracking using full GEANT based detector simulation.
- Task force comprises 4-5 FTE.
- The task force is active and is able to do necessary geometry modifications, particle and event simulation, track reconstruction and performance studies to

access the impact due to changes in detector configuration on a reasonable time scale.

Comments

- Include fake track rate as figure of merit to assess layouts

- Present b-tagging ROC curves as light jets efficiency or rejection vs b-jet efficiency to avoid theoretical model dependencies

Recommendations

- Create a prioritized list of the tracker layout configurations to consider creating additional space for MVTX integration with INTT, by changing number of layers in INTT. Provide realistic time scale for selection of the final layout.

General recommendation to be done before the commitment to purchase staves in September;

The primary concern emerging from this review is whether there is an unavoidable interference between the MVTX and INTT envelopes in the services region. The preferred solution is to move the MVTX power patch panel to a location further out in the Z direction from the signal patch panels. However, it is not certain this will work. Other possible strategies to free up space from the INTT envelope might be to decrease the number of INTT layers or move them further out toward the TPC.

We recommend all of these approaches be quickly considered by mid September. A quick mockup of both the INTT and MVTX in the interference region only should be made. Fast simulations of the INTT with either 3 or 4 layers, or INTT with larger radii should be made to consider the impact on the physics. And finally modeling of what can be gained in the interference region by either decreasing the number of INTT layers to 3 or moving the layers further out in radius should be done.

Results of all of these should be summarized and presented to upper management for consideration before the commitment to purchase the Alice staves.