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Memo

Date: March 4, 2021

To: Rachid Nouicer, INTT L2 manager

From: Russell Feder, sPHENIX Chief ME and review chair

Subject: INTT Production Readiness Review Panel Recommendations and Notes Memo

A Production Readiness Review (PRR) for INTT components was held March 2nd, 2021 as a virtual meeting. The purpose of the PRR was to assess and approve readiness for fabrication of the INTT stave and ladder parts and assemblies.

The agenda for the INTT review and web meeting link information is posted on INDICO here: *https://indico.bnl.gov/event/10800/*

INTT PRR Panel

- Russell Feder (Chair) – BNL sPHENIX engineering and integration
- Jason Bessuille – MIT Bates MVTX engineering
- David Lynn – BNL ATLAS Detector
- John Haggerty - BNL sPHENIX physics and detectors expert
- Rich Ruggiero - BNL sPHENIX engineering and integration
- Walter Sondheim – LANL MVTX engineering

The review panel commends the INTT team for the obvious hard work and preparation that went into this review. The panel also thanks the far-flung team spread between Japan, Taiwan and New York for their patience and organization and clearly presenting complicated designs and production details via the Zoom virtual platform.

Production of the INTT staves and ladders should move forward at full speed. There is one recommendation and a few clarifications the review panel would like answers to as follow up to this PRR. This is all described below. Recommendations are key aspects of the project that the panel feel were missing or not presented well at the review. Any review recommendation needs to be closed out with the panel before the next INTT review and before the device can be installed in sPHENIX. The clarifications are important additional questions from the panel but do not place any hold on the INTT project progress. In additional there is a compilation of other relevant panel comments and questions provided at the end of this memo.

The ***Production Readiness Review (PRR)*** for the INTT stave and ladder components addressed the following questions and topics. The review panel response is provided under each sest of charge question:

1. **Engineering and Design** – For the items under consideration for fabrication approval are all requirements and interfaces locked and documented? Has the integration of

the parts been carefully checked with other INTT components and surrounding sPHENIX components? Is the design complete, and documented in detailed assembly and parts drawings? Have the drawings been checked?

The INTT stave and ladder assemblies are approved for full fabrication. The panel was very impressed with the thoroughness and attention to detail of the INTT engineering team. Requirements, interfaces and integration of the stave and ladder components has been carefully studied and the design is complete and well documented in drawings. There has been extensive structural and thermal FEA backed and verified by lab testing. There is also a INTT barrel assembly prototype to further verify the fit and performance of the stave-ladder assemblies.

Several "pre-production" stave-ladder assemblies have been produced and checked for quality. This is a very good confirmation of the engineering and detailed drawing accuracy.

2. **Management** - Has the schedule for procurement, including internal signatures and approvals, bid duration, material procurement, and fabrication been correctly estimated? Is the schedule in-line with the sPHENIX construction schedule?

   The INTT project has made significant progress on the design, testing and early production of a complex one-of-a-kind device. The effort is spread across RIKEN, BNL and technical teams in Taiwan and Japan. The INTT project is clearly well managed in keeping all this organized and moving forward. With so much focus on stave and ladder design and fabrication there is a need to catch up and update INTT project management plans with the sPHENIX PM team. The INTT device needs to be completely ready for installation and commissioning in sPHENIX by July 2022.

   Recommendation #1: *The INTT schedule needs to be thoroughly reviewed, updated, and integrated into the sPHENIX project plan. Production of the staves and ladders should proceed in parallel with this important management work. The INTT management team should work closely with the sPHENIX PM team to integrate an updated realistic schedule. Schedule risks and contingencies should also be evaluated and included in the schedule estimate. The updated INTT plan (including BNL and Taiwan facility schedules and contingency) should be updated by May 1st.*

   Response:
   The INTT Team fully agreed to have a review of the INTT schedule in June; just after the Readout Electronic Readiness Production Review. The present FDR/PRR review of the INTT ladder and soon (May 25th, 2021) the Final Design Review of the INTT Barrels Assembly will help the INTT schedule. If necessary, we will increase Manpower for INTT to accommodate the INTT schedule.

3. **Fabrication** – Have potential vendors been identified? Will assembly be required? Who will perform the assembly? What are the acceptance criteria for parts? Is this documented and part of the procurement package? Who will do the acceptance inspection and testing? Is shipping included in the procurement? Where will equipment be stored upon arrival at BNL?

   The INTT team presented fabrication and quality procedures at the BNL and Taiwan production facilities. Several pre-production stave-ladder assemblies have been fabricated and tested proving out the full production life-cycle and QC steps. It was

not clear to the panel what provisions have been made for packaging and shipping the sensitive components from Taiwan to BNL. The panel also did not see information about assembly-lab requirements and provisions in the production facilities.

Clarification #1: *Provide information to the panel to be posted to the PRR INDICO page describing how the staves and ladders are packaged and handled for shipment between facilities. Post this information by April 1st.*

Response:
See at PRR ladder INDICO page for slides

The ladders shipping between Japan (Nara Women's University, and Asuka Company), Taiwan and US (BNL) have been achieved successfully. Several ladders were tested prior shipping and at arrival of destination, and the results were identical; No damage to the ladders were observed due shipping cross the pacific ocean.

*- Stave packaging and shipping **from Asuka co. to BNL** (or Taiwan):*
it was achieved successfully (see slides posted on PRR ladder indico).
*- Ladder shipping **from Taiwan to BNL:**: it was achieved successfully (see slides posted on PRR ladder indico),*

Clarification #2: *Provide information to the panel to be posted to the PRR INDICO page describing required assembly lab conditions and implementation. Provide this information by April 1st.*

Response:
See at PRR ladder INDICO page for slides

The INTT silicon lab assembly in the physics Department at BNL is a new lab dedicated to the sPHENIX silicon detector construction. The temperature and humidity in the silicon lab are automatically controlled and they can be adjusted from the main controle if needed. The temperature setting right now in the lab is 70 degree Fahrenheit and humidity is set to 50 % to avoid any static charges. We have also dry air constantly provided to the lab through valves located on the four sides of the laboratory walls. We also have nitrogen in the lab. The dew point in the desiccators are set to 0.1% F. The conditions of silicon detector construction are under good conditions of temperature and humidity, and they are well adequate. Similar conditions were applied at the silicon lbs in Taiwan.

4. **Quality** - What are the quality assurance requirements for this procurement? Are material certifications required? Are there intermediate inspection steps required during fabrication that will require BNL team involvement?

The INTT team presented fabrication and quality procedures at the BNL and Taiwan production facilities. Several pre-production stave-ladder assemblies have been fabricated and tested proving out the full production life-cycle and QC steps. Stave-ladder assembly quality is checked in several steps that have been practiced. There is an experienced team in Taiwan and BNL that have been trained in these quality steps. It was not clear to the panel how travelers are used to document

production and QC steps and how all this quality data is tied to each specific stave-ladder assembly.

Clarification #3: *Provide information to the panel to be posted to the PRR INDICO page describing how fabrication and quality steps are documented in travelers and databases. Post this information by April 1st.*

Response

We have created an online database to collect all information during production., It contains pre-construction stave testing information, epoxy lot numbers, ID's of HDI's, chips and sensors. In addition, comments are added when necessary for any stave when needed. Example below of the HDI section. Similar information for the sensor section.

	NEW Ladder Number	Barrel Type	Build	START DATE	Ladder Class	Stave I.D.	HDI SOUTH Ladder / Chip Assembly							HDI NORTH Ladder / Chip Assembly					
							Name	HDI I.D.	3M TC-2810	Chip I.D	Loctite 2902	HDI Flatness	HDI Flatness	Name	HDI I.D.	3M TC-2810	Chip I.D	Loctite 2902	HDI Flatness
							Initials		Lot #	Wafer	lot #	Wafer Type R	Wafer Type A	Initials		Lot #	Wafer	Lot #	Type
Count												small (20x2)	Big (16x4)						Big (1
1	PPB1_L1	1	BNL	10/6/2020		205-300-0100-0 S/N 0009	RP & RN	#003	936146	W58752-09F3 #9	IDH:1402586 batch:049LAA4356			RP & RN	#004	936146	W58752-09F3 #9 & #13	IDH:1402586 batch:049LAA4356	
2	PPB2_L2	2	BNL	10/13/2020		205-300-0100-01 S/N 0006	RN & RP	#005	936146	W58752-05e4 #19	IDH:1402586 batch:040EAA8535			RP & RN	#006	936146	W58752-05e4 #20	IDH:1402586 Batch:040eaa8535	
3	PPB2_L3	2	BNL	10/21/2020		205-300-0100-02 S/N 0007	RN & RP	#007	936146	W58752-05A4 #13	IDH:1402586 batch:040EAA8535			RN & RP	#008	936146	W58752-05e4 #13 ,19, 22	IDH:1402586 batch:040EAA8535	
4	PPB2_L4	2	BNL	10/24/2020		205-310-0100-02 S/N 0004	RN & RP	#009	936146	W58752-05A4 #22	IDH:1402586 batch:049LAA4356			RN & RP	#010	936146	W58752-05A4 #14 & 17 (U1-U13)	IDH:1402586 batch:040EAA8535	
5	PPB2_L5	2	BNL	10/29/2020		205-310-0100-02 S/N 0003	RN & RP	#011	936146	W58752-05A4 #13 #13 #2	IDH:1402586 batch:040EAA8535			RN & RP	#012	936146	W58752-05A4 #15	IDH:1402586 batch:040EAA8535	
6	PPB2_L6	2	BNL	11/4/2020		205-310-0100-02 S/N 0002	RN & RP	#013	936146	W58752-05A4 #16	IDH:1402586 batch:049LAA0466			RN & RP	#014	936146	W58752-05A4 #24 #16 #20 #19	IDH:1402586 batch:049LAA0466	
7	PPB1_L7	1	BNL	11/09/2020		205-310-0100-01 S/N 001	RN & RP	#015	936146	W58752-05A4 #16	IDH:1402586 batch:040EAA8535			RN & RP	#016	936146	W58752-05A4 #16 #16	IDH:1402586 batch:040EAA8535	
8	PB2_L001	2	BNL	03/05/21		205-310-0100-02 S/N 0037	SA/RN	#017	936146	W58752-05A4 #4	IDH:1402586 batch:040HAB8312			SA/RN	#018	936146	W58752-05A4 #4 #21	IDH:1402586 batch:040EAA8535	
9	PB2_L002	2	BNL	03/08/21		205-310-0100-02 S/N 0029	RP/RN	#019	936146	W58752-05A4 #3 /11	IDH:1402586 batch:040HAB8312			RP/RN	#020	936146	W58752-05A4 #17 / #3	IDH:1402586 batch:040HAB8312	
10	PB2_L003	2	BNL	03/08/21		205-310-0100-02 S/N 0036	RP/RN	#021	936146	W58752-05A4 #9 #10	IDH:1402586 batch:040HAB8312			RP/RN	#022	936146	W58752-05A4 #9 #10	IDH:1402586 batch:040HAB8312	
11	PB1_L001	1	BNL	03/09/21		205-310-0100-01 S/N 0040	SA/RN	#023	936146	W58752-05A4 #6/12	IDH:1402586 batch:040HAB8312			Sa/RN	#025	936146	W58752-05A4 #6/12	IDH:1402586 batch:040HAB8312	
12	PB2_L004	2	BNL	03/09/21		205-310-0100-02 S/N 0020	SA/RN	#026	936146	W58752-05A4 #15/2	IDH:1402586 batch:040HAB8312			Sa/RN	#027	936146	W58752-05A4 #15/2	IDH:1402586 batch:040HAB8312	
13	PB1_L002	1	BNL	03/10/21		205-310-0100-01 S/N 0022	SA	#028	936146	W58752-05A4 #9/ 11	IDH:1402586 batch:040HAB8312			SA	#029	936146	W58752-05A4 #9/ 11	IDH:1402586 batch:040HAB8312	
14	PB2_L005	2	BNL	03/10/21		205-310-0100-02 S/N 0035	SA	#030	936146	W58752-05A4 #7/2	IDH:1402586 batch:040HAB8312			SA	#031	936146	W58752-05A4 #7/9	IDH:1402586 batch:040HAB8312	
15	PB1_L003	1	BNL	03/15/21		205-310-0100-01 S/N 0041	SA	#032	936146	W58752-05A4 #13/ 2/6	IDH:1402586 batch:040HAB8312			SA	#033	936146	W58752-05A4 #6/2	IDH:1402586 batch:040HAB8312	
16	PB1_L004	1	BNL	2/18/2021		205-310-0100-01 S/N 0038	RN/RP	#34	936146		IDH:1402586 batch:040HAB8312			RN/RP	#35	936146		IDH:1402586 batch:040HAB8312	
17	PB2-L006	2	BNL	04/01/2021		205-310-0100-02 S/N 0014	SA	#36	936146		IDH:1402586 batch:040HAB8312			SA	#37	936146		IDH:1402586 batch:040HAB8312	

Clarification #4: *Provide information to the panel to be posted to the PRR INDICO page describing training and how the procedures and quality controls are passed on to new personnel. Will the same production and quality teams in Taiwan and BNL be in place for the entire INTT project? Post this information by April 1st.*

Response:
See at PRR ladder INDICO page assembly document procedure

We have two teams taking charge of the full ladder mass production of the INTT, one at BNL and second at Taiwan. The full procedure of the ladder assembly was established: staves evaluation such as flatness , pressure tests, and leak tests, HDIs gluing to staves, chips gluing to HDIs, sensors gluing to HDI's and tests in every step. The document is posted on INDICO page.

5. **Safety** – Have all safety requirements for assembly and testing work at BNL been satisfied and closed out? Is there an ESR approval for the INTT assembly and testing areas in building 510?

Several INTT stave-ladder prototype and pre-production units have been produced safely. There is a strong record of safety for the experienced INTT team. BNL INTT

fabrication lab areas in building 510 have been certified for safety with ESR reviews and postings on the doors. All BNL personnel have current safety training.

The following is a compilation of panel comments. There are several insightful and useful observations and suggestions and the INTT team should read this section carefully:

Engineering and Design

Reviewer #1: It was not clear to me what was expected from the sPHENIX infrastructure group for temperature interlocks. Presumably, those temperature sensors need to be aggregated to a PLC or some device that can be used to turn off power, I don't know if that's spelled out in ICD042 and if Joel is aware of it.

Reviewer #1: By design, this review was limited in scope, but whenever a review is limited, one wonders about the other parts of the project, particularly in a silicon detector, which is 90% a solid state electronic device. We will need an electronics review, an installation review, and then the ESRC safety review.

Response:
We are planing to have the INTT electronic in June (or July) 2021. A new hire will be in charge of the INTT Felix boards readout electronics by the end of May 2021.

Reviewer #3: Consider including ladder fiducials needed to help with barrel assembly and insertion, for later installation help.

Response:
During ladder assembly, each sensor is surveyed automatically by the OGP machine relatively to two reference holes located on the Endcaps of the stave, and the data is stored. Now, we need to survey the ladders relative to the barrel to a fixed target on the outer side of the barrel visible to the outside/front view of the TPC. Full survey is on the to-do list of the INTT project, and it is already started by surveying silicon sensors relatively to the ladder.

Reviewer #4: For the thermal model consider studying a half symmetric barrel assembly to get the right convection model. Although heat loads are low, it would be good to see a convection CFD that considers the entire model. Can you shut off a rogue chip that starts to heat up? 3W per ladder is very low but are there any thermal excursion scenarios that need to be looked at?

Response:
We will be running the INTT at approximately room temperature and, should we need to, we will have the ability to control the flow for 16 divisions to compensate for any deviation, so a convection CFD model isn't necessary. In addition, we have the capability to mask a single chip, as it was done in the previous experiment (FVTX), as we are using the same chips.

Reviewer #4: Ensure that 100% of the stave cooling tubes are tested for conductivity. Make sure that good contact is made between the carbon glue and carbon fibers at both ends.

Response:
Yes, we checked the stainless cooling tubes on both sides, they are electrically connected.

Reviewer #4: Small concern about tolerance stack-up of the stave end-caps and end-rings between carbon shells. Are manufacturing tolerances sufficient to avoid interference or

binding (carbon-peek is notoriously difficult to machine)? If not, are the parts flexible enough to take up any misalignment?

Response:
The parts are toleranced such that there is a small clearance up worst case tolerance stackup. The parts have already been mocked up and fit together.

Reviewer #4: Having staves that are structural members may have consequences for assembly onto the barrels - which might need to be supported internally until all the staves are installed and can all bear load simultaneously.

Response:
Although the staves may see some load, this is not until the barrel is fully assembled, and all staves and the service barrel would be loaded simultaneously.

Management

Reviewer #1: Rachid's schedule has the completion of the ladders on 5/22/2021 which is only 80 calendar days from now. Is that realistic? What are the ramifications of being a month late? This question could be absorbed into the updating of the schedule that the committee agreed should be done to be prepared for installation.

Response:
To accommodate this delay due to Covid-19, one month, several tasks were adjusted; some of the tasks are in parallel now, such as ladder mass production and mockup of the barrels' assembly. We also have a six-month contingency time in the INTT project file. The INTT team is very well aware, and we will do many tasks to be ahead of the schedule. If necessary, we will increase Manpower for INTT to accommodate the INTT schedule.

Reviewer #2: The schedule for building 56 ladders by May seems aggressive but appears to be doable. We note that up until this point only BNL has built full-sized working ladder prototypes and that Taiwan may run into unexpected difficulties building their first real ladders. It would be nice to see an assembly and testing schedule with contingency.

Response:
BNL is committed to build 80 ladders (or 100 ladders if needed) independently of the situation of the silicon lab in Taiwan to ensure the INTT needs (56 ladders). However, the Taiwan collaborators are going through the learning curve, and they already built first ladders. We are expecting more ladders from Taiwan's silicon lab to be shipped to BNL.

Reviewer #5: The INTT organization spans between RIKEN, BNL and teams in Taiwan and Japan. Is there an Org Chart for the INTT project that clearly defines decision making roles and responsibilities?

Response:
See management chart posted on the Indico page.

Fabrication, Quality and Safety

Reviewer #2: Bubble leak test immersed in water? Are material or epoxy hygroscopic? Better way to do this? Baked after to dry out? Static water pressure test? Helium leak check for negative pressure?

Response:
Bubble test is only for staves that fail the standard 20 psi leak test. It is used to locate the leak and better understand the condition of the stave. Any stave that is immersed in water, is heated to 120C for 2 hours to draw out any water. These staves are typically rejected because of their static pressure leak test failure. The epoxy and materials are not hygroscopic.