P2MAC Report (preliminary version V1.2)

Hans Weise (for the P2MAC)

PIP-II Machine Advisory Committee Meeting

1-3 June 2021

Logistics

- The 8th meeting of the PIP-II Machine Advisory Committee (P2MAC) took place on June 1- 3, 2021 at Fermilab with the agenda shown in Appendix 1.
- Due to Covid-19 the meeting was organized virtually.

P2MAC members as of June 2021		
Andrew Burrill	SLAC	
Sarah Cousineau	ORNL, SNS	
Frank Gerigk	CERN	
Kazuo Hasegawa	QST	excused
Mats Lindroos	ESS	new
Deepak Raparia	BNL	
Jie Wie	MSU, FRIB	
Hans Weise	DESY	P2MAC Chair
Lydia Young	SLAC	new

Intro

- The Committee was informed about the PIP-II Final Design Report - initial release for the P2MAC together with the request for review and comments. The document was shared with the P2MAC end of April, and the committee was able to provide its feedback until May 27.
- The FDR in its end April version reads already extremely well. It is understood that all recent PIP2IT results will be included as soon as all tests runs are analyzed. Publication of the final version is expected for August 12.
- The P2MAC meeting on June 1 – 3, 2021 is used to
  - highlight the PIP-II project status
  - summarize the PIP2IT run,
  - and to describe redesign status and plans

P2MAC Charge

- The PIP-II Machine Advisory Committee is requested to perform
  - an assessment of the project's technical progress and status,
  - to identify any potential issues,
  - and to offer advice, recommendations, and/or commentary relative to the following specific questions:
    1. Are the demonstrated critical technologies and the results from beam tests at PIP2IT completely and effectively incorporated into PIP-II technical designs?
    2. Is the technical design presented in the FDR sound and provide basis for proceeding to the construction phase with confidence that performance goals can be met?
    3. Are the technical risks appropriately identified, prioritized, and being addressed?
    4. Has the project satisfactorily responded to the recommendations from previous reviews?
- The P2MAC is not limited by these specific charge areas and may delve into other related areas, and offer advice, comments, or recommendations, as it deems appropriate under the general guidance of this charge.

P2MAC Meeting Agenda

PIP-II Machine Advisory Committee 6th Meeting June 1-3, 2021					
CDT					
Start	**Duration**	**End**	**Speaker**	**Topic**	**Notes**
Tuesday, June 1, 2021					
08:00	01:00	09:00	*H. Weise*	*Executive Session*	
				Day 1 - Overview and PIP2IT	**NOTES**
09:00	00:05	09:05	N. Lockyer	Welcome	
09:05	00:30	09:35	L. Merminga	PIP-II Project Status	
09:35	00:05	09:40	A. Klebaner	PIP-II Critical Technologies and PIP2IT goals	Set-up and refresh for Q1
09:40	00:10	09:50		*Coffee Break*	
09:50	00:20	10:10	E. Pozdeyev	PIP2IT Run Overview	Q1p1 - results from beam tests at PIP2IT
10:10	00:10	10:20		Discussion	
10:20	00:15	10:35	J.Ozelis	PI2IT SRF Performance	Q1p1 - results from beam tests at PIP2IT
10:35	00:05	10:40		Discussion	
10:40	00:15	10:55	B.Chase	PIP2IT LLRF Performance	Q1p1 - results from beam tests at PIP2IT
10:55	00:05	11:00		Discussion	
11:00	01:00	12:00	H. Weise	*Discussion*	
Wednesday, June 2, 2021					
				Day 2 - Technical Systems	
08:00	00:30	08:30	C.Boffo	SRF and Cryogenics system design status and plans	Q1p2 - effectively incorporated into PIP-II technical designs
08:30	00:10	08:40		Discussion	
08:40	00:30	09:10	E.Harms	Accelerator Systems design status and plans	Q1p2 - effectively incorporated into PIP-II technical designs
09:10	00:10	09:20		Discussion	
09:20	00:30	09:50	I. Kourbanis	Accelerator Upgrades design status and plans	Q1p2 - effectively incorporated into PIP-II technical designs
09:50	00:10	10:00		Discussion	
10:00	00:10	10:10		*Coffee Break*	
10:10	00:30	10:40	J. Leibfritz	Installation & Commissioning design status and plar	Q1p2 - effectively incorporated into PIP-II technical designs
10:40	00:10	10:50		Discussion	
10:50	00:20	11:10	A. Klebaner	PIP-II Technical risks and challenges	Q3
				Executive Session	
11:10	00:50	12:00	*H. Weise*	Executive Session with PIP-II Management Team	
12:00	01:00	13:00		*reserved*	

P2MAC Meeting Agenda

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10:40	00:10	10:50		Discussion	
10:50	00:20	11:10	A. Klebaner	PIP-II Technical risks and challenges	Q3
Executive Session					
11:10	00:50	12:00	*H. Weise*	Executive Session with PIP-II Management Team	
12:00	01:00	13:00		*reserved*	
Thursday, June 3, 2021					
Day 3 - Executive Session and Closeout					
08:00	01:00	09:00		FDR Discussion - review of the P2MAC comments	Q2
09:00	01:00	10:00		Committee Discussion Time	
10:00	01:30	11:30		Report writing	
11:30	00:30	12:00	*H. Weise*	Executive Session with PIP-II Management Team	
12:00	00:30	12:30	Closeout		
12:30			Adjourn		

P2MAC Tasks

- We request an oral closeout presentation by the P2MAC with Fermilab and PIP-II management, and DOE observer(s), at the end of the meeting.
- A written report is requested to be submitted to the PIP-II Project Director by August 6, 2021.

Reply to Charge Question 1 - Conditional YES

Are the demonstrated critical technologies and the results from beam tests at PIP2IT completely and effectively incorporated into PIP-II technical designs?

- The important and to a large extent successful operation of PIP2IT was extremely useful for finalizing the PIP-II technical design. Lessons were learned wrt. many sub-systems. The Final Design Report can surely include the results or reference the respective publications or technical documents. By doing this, the PIP-II technical designs can completely and effectively incorporate the lessons learned.
- The P2MAC Committee regrets not seeing longer PIP2IT operation. We understood the need to convert the respective area into an accelerator module test facility for PIP-II. But a number of systems tested should have been operated during longer periods to study reliability. We understood that some (many?) technical systems were operated for longer periods but obviously not with beam. The PIP-II team should investigate details of the early commissioning starting after beneficial occupancy of the tunnel. When can the first beam be accelerated and how is the beam time used? Will it be possible to operate a first LB650 module with beam by using a temporary beam dump? Any early operation will be advantageous.

Reply to Charge Question 2 - Conditional YES

Is the technical design presented in the FDR sound and provide basis for proceeding to the construction phase with confidence that performance goals can be met?

- The technical design presented in the FDR is in principle convincing, and many prototype systems were tested at Fermilab. A very good basis for the construction.
- The P2MAC does not have a clear picture how and when exactly the Final Design Review of all essential sub-systems can be finished.
- P2MAC suggests a careful planning of Production Readiness Reviews at all places / institutes taking over the responsibility for series production / procurement / assembly. Production Readiness at partner labs requires the knowledge and technology transfer being completed. Some examples, where prototyping and pre-production items still have to be demonstrated are: LB650 cavities and CM, solid state amplifiers (especially 40 and 70 kW), and RF power couplers (especially LB and HB).
- PRRs should also address the issue of single sources for challenging sub-systems. Entries in the risk register should be accompanied by the respective mitigation plan which often includes a well-thought QA/QC program.

Reply to Charge Question 3 - Conditional YES

Are the technical risks appropriately identified, prioritized, and being addressed?

- The P2MAC learned about technical risks, the respective risk register and the prioritization within that register. Some few examples were discussed (SSA, RF power couplers, …).
- The retirement of technical risks was explained. The basic technology risk / proof of technical principle could surely be retired for a large number of sub-systems tested at PIP2IT. The risk for series production especially at external partners requires discussion in the respective Production Readiness Reviews.

Reply to Charge Question 4 - YES

Has the project satisfactorily responded to the recommendations from previous reviews?

- The PIP-II provided answers to all recommendations from previous reviews. The evolving final design surely includes changes based on PIP2IT, many dedicated expert reviews, and also recommendations from project leaders being member of the P2MAC.
- It is still unclear to the P2MAC to which extent the PIP-II project scope includes the improvement and upgrade of Booster, Main Injector and Recycler. Several important components seem to be part of the project, the overall strategy and its follow up does not seem to be reflected in the PIP-II organization.

PIP-II Project Status – Lia Merminga

Findings

- 16 April 2021: beam testing at PIP2IT successfully completed, critical technologies demonstrated.
- Preparing for CD3, (start of execution)
- 1st big US accelerator project with significant international collaboration from world leading experts
- 3 measures to get to 1.2 MW on LBNF target: increase number of protons per Booster pulse, reduce main injector cycle 1.33 to 1.2 s, increase rep rate, 15 – 20 Hz.
- Besides overall front-end test, PIP2IT emphasized essential first tests of LLRF and resonance control, EPICS early development, instrumentation, etc.
- MEBT chopper is fully operational.
- Cryoplant building to be completed in 2021.
- Project cost: 978 M$ + 310 M$ in-kind.
- Warm front-end tunnel installation in May 2024, available until 2026 for testing, beam commissioning starts in 2027.

PIP-II Project Status – Lia Merminga

Comments

- The very visible project progress is commended. The successful PIP2IT operation is an excellent basis for the upcoming years. It is somewhat unfortunate that the commissioning phase now ended. Some systems could profit from longer running periods.
- The close team work on all project levels is key to success. There are the L2/L3 Mgmt. obligations as defined in the D.O.E. system. The direct communication of experts at all levels should supplement the more formal relations as defined in the project organigram.
- Being a large and challenging project PIP-II will see surprises. Entries in the project risk register try to cover this which is appreciated. Staying agile remains important in the for the first time picked in-kind scenario. Having the mentioned very experienced key-experts on board seems promising.
- The success of the ring upgrade projects is critical to ultimate performance goal of delivering >1 MW for neutrino production. The committee advises that the ring beam physics program be reviewed as part of the P2MAC meetings.

Recommendations

- Integrate beam physics presentations in the sub-sequent P2MAC meetings.
- See individual presentations

PIP-II Critical Technologies and PIP2IT Goals – Arkadiy Klebaner

Findings

- Technology roadmap guides the technical risk management process, strategy and priorities
- Critical technologies are HWR, SSR1, SSR2, LB650, HB650 cryomodules and cavities. There are partly in-house built prototypes, and partly items received from collaborators.
- The HWR module will go into the machine. SSR1 is a prototype module.
- The SSR2 module will be delivered as assembly kit from India.
- There is an entry in the risk register to account for risks related to the testing of pre-production modules and the impact of potential repairs/improvements that need to be made.
- Technology demonstration at partners is vital to ensure that technology transfer from prototyping to production is successful.

PIP-II Critical Technologies and PIP2IT Goals – Arkadiy Klebaner

Comments

- What is the mitigation in case tests go wrong? It is foreseen to have a design adaptation phase after the tests. Not clear where this appears in the planning.
- The risk register items with the highest risks should be added to the technology roadmap. LLRF is present in both but power couplers and amplifiers should be added as well to make clear at which point in time it is planned to resolve the issues.
- For the 40 kW 325 MHz amplifiers a clear timeline should be established to go from the presently achieved 32 kW to the nominal 40 kW.
- It is worrying that the amplifiers are so far installed in (soon obsolete) VME racks and that control systems are used, which do not conform to the foreseen EPICS standard. Organising a workshop to discuss outstanding technical issues is a good way forward.
- Some critical technologies of certain components have been tested but the complete systems are not yet ready for series production: 650 MHz LB cavities and CM, power couplers, SS amplifiers.

Recommendations

- Make sure that the institute, which produces cavities or CMs for the series, does a full qualification with a pre-production cavity or module. This has to be done even if the technology has been tested and qualified with FNAL produced/assembled cavities/CMs.

PIP2IT Run Overview – Eduard Pozdeyev

Findings

- The PIP2IT commissioning consists of ion source, LEBT, RFQ, MEBT, HWR, SSR1, and HEBT/dump. The design proton beam output energy is 22 MeV. The technical scope of phase 2 commissioning includes HWR and SSR1 cryomodules, RF, PS, MPS, controls, vacuum, instrumentation, and cryogenics.
- Some equipment arrived late and was installed for testing as it became available.
- 3 of 8 of the HWR cavities could not be used to accelerate beam, but did demonstrate they met gradient
- Proton beam was accelerated to 16 MeV (2 mA current, 550 us pulse length, 20 Hz rep rate) chopped with Booster pattern. The lower-than-design energy was largely due to missing the first 3 HWR cavities.
- The total duration of beam commissioning was short with about 2 hours of full intensity operation. The shorter-than-planned duration was largely due to delivery and installation delays.
- Main commissioning goals including system integration, technical demonstration, team training and lessons learning were achieved.
- The test facility is to be dismantled to allow subsequent project activities in the area. The next opportunity of PIP-II beam test is around 2024.

PIP2IT Run Overview – Eduard Pozdeyev

Comments

- PIP2IT commissioning is an important milestone demonstrating technical integration of selected PIP-II linac systems, namely the first two types of cryomodules, cryogenics, RF and low-level RF control, machine protection, hardware controls, and instrumentation. It is an important test bed for design integration, collaboration coordination, installation, integrated tests, interlock and safety validation, and beam commissioning.
- The PIP-II team is commended for pursuing the PIP2IT commissioning despite unresolved issues with three half-wave resonators with the HWR cryomodule and thermal issues with the SSR1 cryomodule. The commissioning provided valuable experience and early indicators pointing to the challenges in multi-institutional collaboration and technical complexities. The PIP-II team is again commended for focusing on lessons learned.
- Short beam commissioning time with two hours of full-intensity operation is insufficient to conduct systematic studies, to expose potential stability and endurance issues, and to identify problems in addition to what was found. Given the heavy investment and the long duration before the next opportunity to test PIP-II - type beams, every efforts should be made to extend the PIP2IT beam studies. Efforts should also be made to resume beam tests as soon as building beneficial occupancy is granted around 2024.
- Reaching the design high power performance of the PIP-II complex requires challenging upgrades of the legacy Booster and Main Injector rings whose performance are intensity limited, and close interface with the newly designed PIP-II linac. Accelerator physics integration and seamless interfacing is essential not only at the conceptual and preliminary design stages but throughout the life cycle of the project continuously deepening beam dynamics understanding (e.g. electron cloud studies at SNS and PSR), optimizing designs (e.g. ring extraction kicker and pulse forming network impedance minimization R&D at SNS and J-PARC), resolving construction deviations and mitigate performance limiting issues, guiding, integrating and interfacing various technical systems towards commissioning and operations.

PIP2IT Run Overview – Eduard Pozdeyev

Recommendations

- Consider to extend PIP2IT commissioning to deepen understanding and lessons learned prior to dismantling the facility and converting it to a cryomodule test facility. Plan to resume beam tests as soon as building beneficial occupancy is granted around 2024.
- Demonstrate that all 8 HWR cavities can be brought to resonance to accelerate beam before installation in the accelerator housing.
- Present accelerator physics integration and system interfacing at the next PIP2 MAC review.

PIP2IT SRF Performance – Joe Ozelis

Findings

- HWR: all cavities reached max allowed gradient without quenching (apart cav3 with coupler bias problem). No FE problem observed.
- SSR1: 16 hours to condition through MP barriers at 4 – 7.5 MV/m, cavity 3,4 had FE onsets at lower fields and strong FE, no rad in 5,6, mild radiation in the others. Lower Q 5x10^9 instead of 7/8x10^9,
- Dynamic heat load 65% higher than spec. probably due to trapped flux. CM will be demagnetized and cooled in the next weeks. If this remains for all other modules, it may be a problem for the cryo-system.
- SSR1 had issues with the insulating vacuum and thermal shield temperature due to a leak in the current lead connection opening during cooldown.

Comments

- Cavities 1 and 2 in the HWR were prototype cavities and behaved differently when cooled down and could not be brought on resonance. Care should be taken in other CM styles when cavities manufactured from different vendors, material or institutions are mixed and could potentially behave differently and may not be usable for beam acceleration.
- If nitrogen doping is planned for the 650 LB and HB CM's rolling out the doping processes across multiple partners and vendors may be a challenge
- Changing the magnet design seems like a significant change to the cryomodule and would benefit from a re-test.
- The flux trapping in the cryomodules needs further investigation
- Having the same components (cavities, magnets etc.) coming from multiple vendors and partners for integration into a single CM will require very careful coordination to ensure successful operation.

PIP2IT SRF Performance – Joe Ozelis

Recommendations

- Re-test of HWR module after repair and before installation into its final position in the PIP-II tunnel.

PIP2IT LLRF Performance – Brian Chase

Findings

- Cavity and phase variation limit: 6E-4,
- -+ 20 Hz peak detuning
- Chopper timing control with 38 ps resolution, was demonstrated.
- HWR amp and phase regulation met requirements (5 min measurement without beam).
- SSR same as above, one cavity slightly exceeded the -+20 Hz, can be compensated with power overhead.
- Profiting a lot from LCLS2 experience

Comments

- The presented tests of LLRF on HWR and SSR appear to fulfill specifications but they were of very short duration. Longer testing of the LLRF field and phase regulation with beam is highly advised.
- The schedule for accelerator module testing should give the LLRF team sufficient time, based on a sufficiently elaborated and detailed request; in all LLRF project phases.
- The final technology choices (electronic board design / chip selection) will be made in the next roughly two years. The full suite of electronic boards needs to be decided, and work sharing with in-kind partners is to be agreed on at a detailed level.
- Buncher performance limited by sparking is a concern

Recommendations

- none

SRF and Cryogenics System Design Status and Plans – Cristian Boffo

Findings

- Beam passed at nearly full transmission at the first shot. Alignment and energy gain are as expected.
- One cavity from India in SSR1 performed as good as the best FNAL cavities.
- Overall reduced Q in SSR1 suspected to be caused by magnetization. Module will be demagnetized.
- LB650 cavity design by INFN. More cavities by Zanon to come. MSU 644 MHz cavities (directly scaled) reached performance goals (Q=2.4 x 10^10) **otherwise no actual prototype has been tested even though the cavity has been on hand since May 2020.**
- HB650 undergo N-doping, jacketed testing ongoing. Q=3.3 x 10^10
- Q values can be reached without doping but with doping there is more margin and challenges.
- HPR issues as cavities are bigger than 1.3 GHz. Being investigated.
- LB650 CM, design lead by CEA with input from UKRI. HB650 design FDR completed. Series will be assembled in UK.
- The same FNAL team has design authority for all CMs. A dedicated group looks at overseas transport.

SRF and Cryogenics System Design Status and Plans – Cristian Boffo

Comments

- The procedure to move from prototype cryomodule designs to pre-production or series design appears sound. However a number of key components are not yet in a state for production to be launched: the 650 MHz low-beta cavity, LB and HB power couplers, new magnet design for SSR CMs.
- The high pressure rinsing required for 650 MHz cavities needs to be well developed before asking partner labs and vendors to carry out this work. The failure of the nozzle in Lab2 points to a quality control issue that needs to be addressed as more HPR is not likely to remove imbedded material from the cavity surface.

Recommendations

- Develop a clear plan for demonstration of each technology prior to the FDR and production readiness.

Accelerator Systems Design Status – Elvin Harms

Findings

- 17 MeV beam was accelerated and transported to the HEBT absorber
- MPS high level functional requirements were achieved
- RF amplifier control had two separated path; PLC and ethernet
- EPICS was used for HWR and SSR1 amplifier control
- Overall RFPI reliability was quite good, except Incase of coupler #3
- MagPS worked well, no changes required for PIPII MagPS system
- PIP2IT mostly used Fermilab control system (ACNET) and bridge to EPICS for LLRF and HPRF
- Most of the beam instruments performed well

Accelerator Systems Design Status – Elvin Harms

Comments

- The P2MAC committee appreciates the detailed mentioning and description of issues and also failures during the PIP2IT operation. Discussing the lessons learned is the right way to do.
- Discuss what will be missed by not testing LB650 and HB650 modules with beam.
- Field emission caused radiation will be measured with a network of monitors, during module testing. Please check to which extent captured electrons from FE can be transported and become a risk for local front-end electronics. Is the use of a flexible monitoring system meaningful? (see MARVIN at E-XFEL).
- For mor robust MPS system, two beam inhibit devices could be used
- Use of single diamond crystal as beam loss monitor for lower energies is nice
- Review QA for DAE-ECIL SS amplifiers systems
- Lesson learned at PIPIT should improve PIPII reliability

Accelerator Systems Design Status – Elvin Harms

Recommendations

- All lesson learned should be documented
- Review QA for DAE-ECIL SS amplifiers systems

Accelerator Upgrades Design Status and Plans – Ioanis Kourbanis

Findings

- New components in the transfer line to the booster will include a movable low energy absorber and a fixed high energy absorber (collimator). Low energy absorber is under design and high energy absorber has completed FDR.
- Extensive scope of upgrades in the Booster includes a new 800 MeV injection system, 20Hz upgrade for pulsed systems, new longitudinal and transverse dampers, and a 2 stage collimator.
- Booster upgrades are at various levels of maturity from conceptual to final.
- Booster gradient magnets are considered a technical risk due to short length requirement (0.5m) and lack of experience in building these for many years.
- MIRR upgrade scope is focused on upgrading the RF systems. This includes higher RF power to accomodate higher intensity, upgrades for 20 Hz operation, larger aperture in some systems, and upgrades for CW slip stacking.
- Booster large aperture cavity for 20Hz is being tested in the Booster at lower repitition rate.
- The accelerator physics program was not presented or formally reviewed. Information was provided in the form of slides sent to the committee by email.
- A Joint Booster Intensity Studies Team was Established in 2019 as part of the PIP-II scope. The committee has continued to progress the beam physics basis for the ring upgrades required to deliver >1MW from the MI.
- End-end-simulations of the linac have been completed.
- Simulations of several critical aspects of the upgraded ring configurations have been completed, including the new injection painting scheme, space charge effects in the Booster at low energy, and slip stacking.

Accelerator Upgrades Design Status and Plans – Ioanis Kourbanis

Comments

- Excellent progress has been made on the hardware design for system upgrades for the BSTR, Booster, MI, and MRR.
- The integration and testing of systems early prototypes is commended.
- The committee endorses the plan to test all new 20Hz Booster magnets on the spare girder in the E4R building.
- Two of the main performance drivers for a high intensity facility are beam losses and impedances. It is advisable to develop both a beam loss budget and an impedance budget to help drive critical design decisions.
- Transport of the stripped, unstripped, and partially stripped beam in the injection region is quite complex and can lead to performance limitations if issues are encountered after installation. Consider performing single particle trajectory simulations with the 3D magnet fields through entire injection region including waste tracking.
- The beam physics effort should be a foundational effort that informs the design basis of the hardware and provides a feedback cycle between hardware modifications and simulation predictions. Robust simulations that integrate proposed hardware modifications including collimation, dampers, and impedances, should be performed to validate designs.
- The possibility of an electron-cloud instability requires a more rigorous analysis that includes an assessment of cloud-generating mechanisms, scaling with intensity, and mitigation techniques.
- The vast majority of linacs do not come online with all hardware operational and matched beam conditions. As a next step in linac simulations, consider simulating these off-nominal configurations.

Recommendations none

Accelerator Upgrades Design Status and Plans – Ioanis Kourbanis

Recommendations

- Develop beam loss budget and impedance budget for the Booster and Main Injector, respectively, to help drive critical design decisions.
- Conduct electron cloud analysis that includes an assessment of cloud-generating mechanisms, scaling with intensity, and mitigation techniques.

Installation & Commissioning Design Status and Plans – Curtis Baffes

Findings

- Presentation limited to 3 WBS (Test Infrastructure, Building Infrastucture, Linac Installation)
- Install/Commissioning for Warm Front End and Beam Commissioning in Pozdeyev's presentation
- PIP2IT Test Area is being reconfigured to make room for CM Test Stand
- PIP2IT has been used as a testbed for WFE, HWR and SSR1 - integrated system with beam. Verified many key components and technologies
- Installation WBS includes: Infrastructure/utilities: fluids/electrical systems, Accelerator components, Beam commissioning, Disassembly
- Goal to start preparations for the 650MHz Test Stand in June 2021.
- Lessons learned for both construction, operation, and disassembly of PIP2IT Infrastructure - cooling, coupler air cooling, ion source chiller, dissolved oxygen removal technology, cable database. The Installation team was part of PIP2IT installation. Lessons feed forward to development/practices for PIP-II acceptance, verification/validation/, travelers
- An overview of the 650 Test Stand was presented.

Installation & Commissioning Design Status and Plans – Curtis Baffes

Findings

- An overview of the Building Infrastructure efforts were described.
  - Electrical (racks, cables, power delivery from CF interface to equipment). The Cable database developed for PIP2IT will support for overall installation
  - Mechanical (fluids) - partnering with CF. Most of the various systems (water, cooling, air, nitrogen) are just past PDR. Lessons learned from PIP2IT are being applied to RFQ LCW cooling system and ion source chiller (proof of operation)
- The elements of planning for Linac Installation were presented.
  - Developing and applying Integrated CAD Model that pulls together CF, Alignment network and the beam systems (warm, CMs) plus support. Used also for Booster tunnel planning,.
  - Processes to support Installation planning and details:
    - Framework for hardware acceptance (IRR)
    - Storyboarding to develop install sequences
    - Framework for travelers: There is a matrix to identify and track the needed travelers.
    - Framework for Verification and Validation
  - There are warm sections between each CM

Installation & Commissioning Design Status and Plans – Curtis Baffes

Comments

- The Installation/Commissioning team seems to have adopted a number of quality/Systems best practices that should enable management of a complex installation.
  - The use of an integrated model to encourage communications amongst the project design engineers, Conventional Facilities, and the Alignment team is an excellent best practice.
  - Storyboarding for development of procedures is a very good best practice. The technicians who will be performing the work should be part of the story development.
  - The requirement for IRRs is a necessary step in quality/systems management. The project is advise to be rigorous in the requirement for all subsystems, assemblies including CF systems.
- Installation of warm sections between cryomodules and installation of the cryomodules has been practiced during PIP2IT operation but also in other FNAL projects. It is important that a core team comprised of qualified mechanical and vacuum technicians be assigned and maintained as best possible for the duration of the Install. Qualification criteria for each role should be developed and implemented.
- The PIP-II Commissioning strategy was not explicitly provided by either C. Baffes or E. Pozdeyev at this review. Though the IRRs along with V/V procedures should catch many hardware issues at the assembly/subsystem levels, the strategy for verifying/validating of the integrated system was not presented. Perhaps this will be captured by an Accelerator Readiness Review?

Recommendations

- (non yet)

PIP-II Technical Risks and Challenges – Arkadiy Klebaner

Findings

- The Fermilab PIP-II management presented a solid risk management plan and risk register for the PIP-II project.
- The risk register follows the lab's strategy for risk management and includes a total of 88 open risks (14 high rank, 47 medium rank and 27 low rank).
- The PIP-technical risks includes 7 high rank (CMs transportation, Coupler performance, Resonance control and RF amplifiers), 38 medium rank and 23 low rank.
- The Fermilab risk management strategy includes regular reviews and updates of the risk register.
- Effective risk mitigation and response plans are in place and are being utilized
- The lab works actively with in-kind partners to assure that the in-kind partners develop risk registers and that there is a good understanding between Fermilab and the in-kind partners on the ownership of the risks.
- Following DOE rules, the lab has included a risk contingency for in-kind contributions with a contingency for the possible re-work or "take over" cost for Fermilab.
- There are frequent meetings between Fermilab management and in-kind partners to discuss risks.

PIP-II Technical Risks and Challenges – Arkadiy Klebaner

Comments

- The risks due to COVID for all on-going projects in big science need to be continuously reviewed. The impact of potentially losing key people, having funding re-directed from science into more urgent areas and possible new COVID mutation for which the vaccines are less effective are example of factors which must be closely followed.
- Risk registers must be continuously reviewed to assure that development risks are retired when the development is validated with e.g. a prototype test and that new risks related to the actual progress of manufacturing including in-kind work
- The risk related to transfer of know-how to an in-kind partner who performs e.g. assembly of a Fermilab designed and prototyped CM is by experience larger than projects tend to estimate. The learning curve is long when the development and prototyping hasn’t been done locally at the final producer.
- When manufacturing is moved due to in-kind partners requesting to use local and regional companies, there is an additional risk regarding quality and validation of components.
- When setting the higher limit for cost and schedule impact for transport risks, one should include the risk of total loss of equipment due to a serious accident.
- The in-kind model is based on a partnership and not on a sub-contractor relationship. It is important to remember this and continuously develop this partnership with e.g. visibility in the organigrams of the project.

PIP-II Technical Risks and Challenges – Arkadiy Klebaner

Recommendations

- Continue the pro-active work on continuously reviewing and updating the risks at Fermilab associated with in-kind and the in-kind partners' own risk registers. Experience shows that the effort spent on this is well invested and can avoid major issues.
- Assure that quality work at in-kind partners are given high-priority with an industrial-standard QA/QC budget and effort.

Thank you!