Fermilab | U.S. DEPARTMENT OF ENERGY | Office of Science

Technical Integration

Arkadiy Klebaner

PIP-II Independent Project Review

4-6 December 2018

In partnership with:

India/DAE
Italy/INFN
UK/STFC
France/CEA/Irfu, CNRS/IN2P3

Outline

- Organization
- Systems Engineering
  - SEMP, Requirements, Interfaces, and Design Plan
- Quality Management
- Technical Progress
- Design Maturity
- Top Risks and Technology Roadmap
- Responses to CD-1 recommendations
- Next Step and Summary

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About Me:

- Role on the PIP-II:
  - Project Technical Director

- Relevant experience:
  - Engineer by training
  - 30+ years engineering and management experience
  - Fermilab Applied Physics and Superconducting Technology Division (APS TD) Associate Division Head
  - Fermilab APS TD Cryogenic Sector Head

Organization

TECHNICAL INTEGRATION

Technical Director - A. Klebaner

PROJECT ENGINEER	**Allan Rowe**
DEPUTY PROJ ENGINEER	**Jim Steimel**
INTEGRATION COORDINATOR	**Alex Martinez**
SRF COORDINATOR	**Jeremiah Holzbauer**
QUALITY ASSURANCE MGR	**J. Adetunji (acting)**
Senior Quality Engineer	TBD
Quality Engineer (SRF)	TBD


Allan Rowe


James Steimel


Alex Martinez


Jeremiah Holzbauer


Jemila Adetunji


Andrew Dalesandro*

- **Technical Integration** team is responsible for facilitating the implementation the Systems Engineering and Quality Management throughout the PIP-II Project;
- Motivated, highly qualified, and ready to deliver team.

* - Andrew is a member of APS-TD; leading effort of consolidating, review, and control of the interfaces

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Systems Engineering

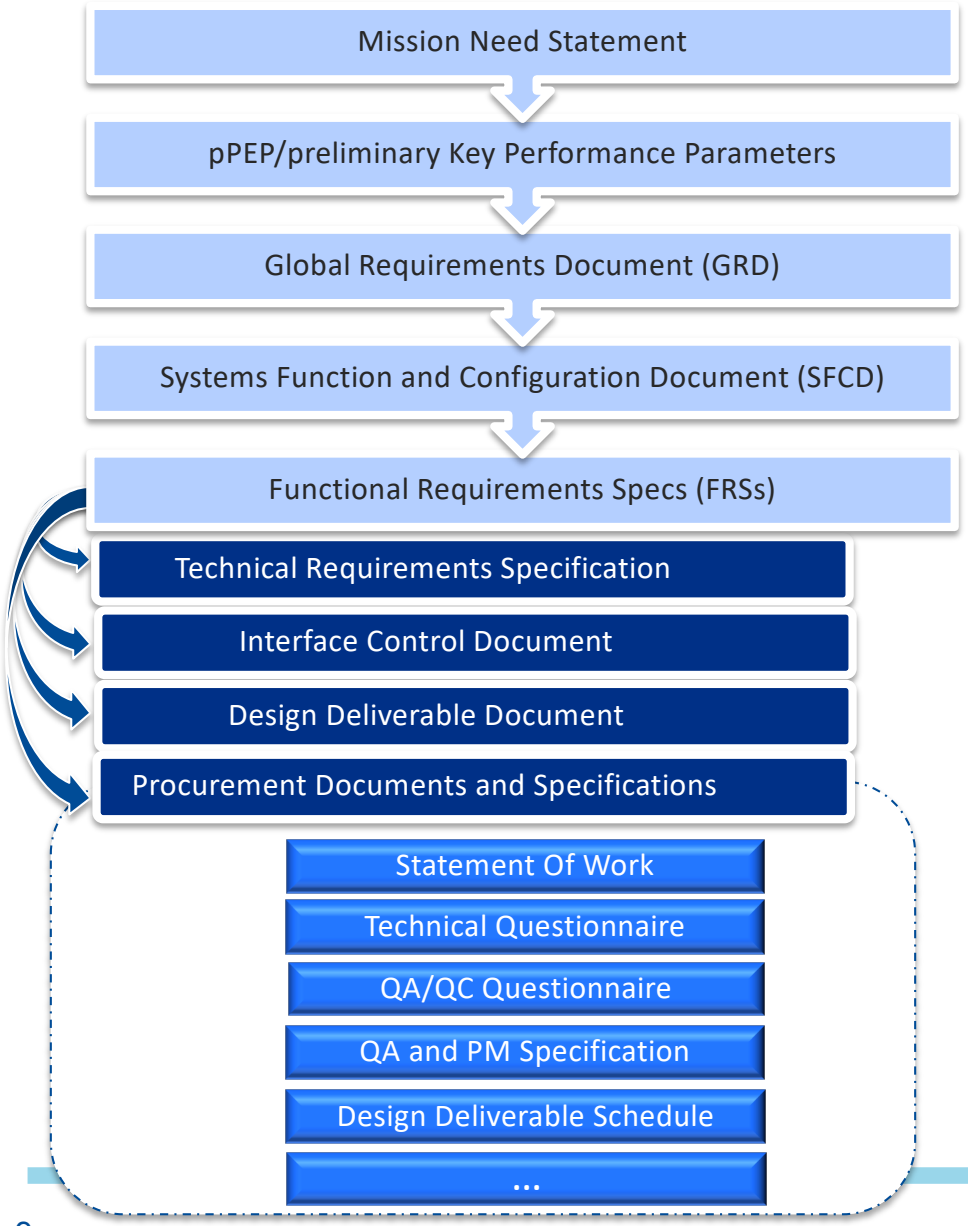
- PIP-II Systems Engineering Management Plan (SEMP) is a formal engineering processes which:
  - Complementary to the Fermilab Engineering Manual
  - Defines roles and responsibilities within the framework established by the PIP-II Project Management Plan (PMP);
  - Defines single set of processes: technical requirements and interfaces, design deliverables, reviews, integration through all systems, design baseline control, value engineering, QA requirements, ES&H and safety-by-design, and traceability to project scientific requirements; Establishes engineering design verification and review methodology;
  - Documented in ➔ PIP-II SEMP, pip2-doc-2480;
- The SEMP was extensively discussed with Partners;
- It will be updated to have strong alignment with Partners standard processes while assuring that the quality of the work on the PIP-II Project will meet technical requirements and project goals;

Design reviews - design verification process is documented

- PIP-II has a Design Review Plan (DRP)
  ➔ pip2-doc-2483;
- The plan establishes design review framework;
- Defines:
  - ✓ Review classes
  - ✓ Roles and responsibilities
  - ✓ Procedure to execute and closeout reviews
  - ✓ Guides design deliverables

Design Review and SEMP plans have been reviewed and commented by colleagues from Fermilab, FRIB, SLAC, and SNS.

Requirements flowdown

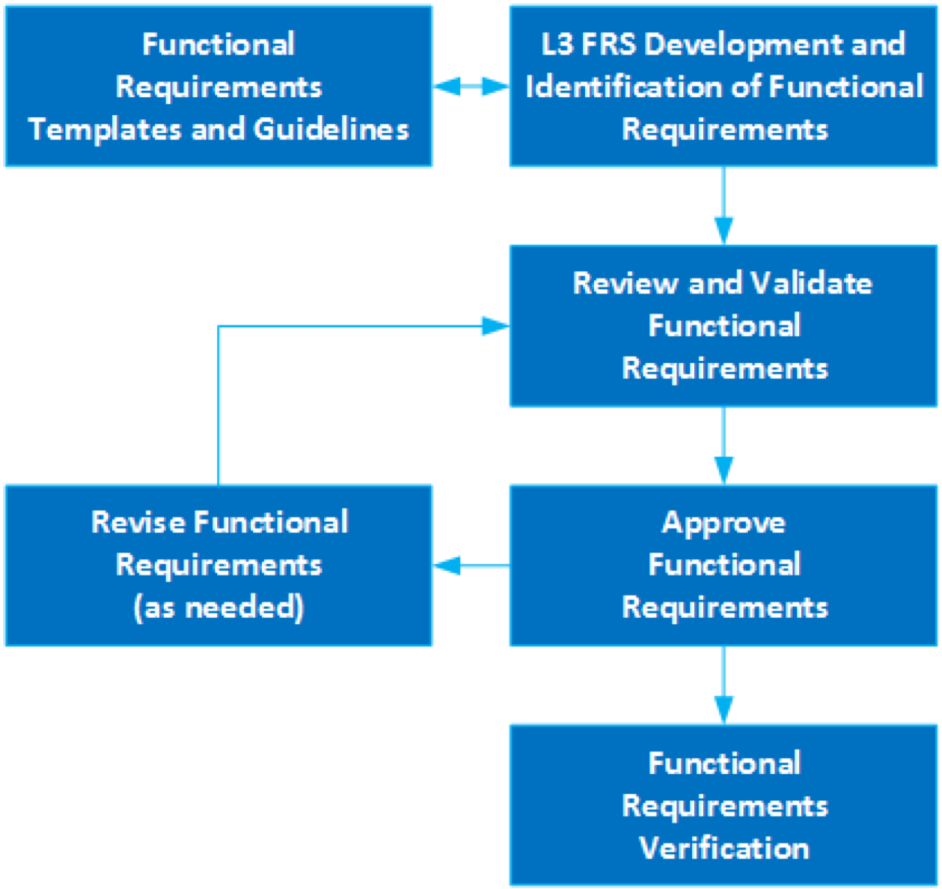


- SFCD exist for each technical system;
- FRSs and ICDs exist for each L3 or below systems;
- Technical documents reside in Teamcenter® and managed via its workflow process;
- Each L3 has unique Engineering Process Document Management (EPDM) check list;
- Non – technical documents are stored in PIP-II DocDb.

Requirements verification - formalized requirements verification process is functional

Charge #1

- Integration Team works with L2s, L3s and Partners to create FRSs;
- Verification and approval ➔ L2s, Partners, Integration Team, SME's as needed; Teamcenter© workflow;
- All functional requirements are placed in a single database ➔ FRS Master List ➔ allows for tracking and sorting;
- Requirements management follows the **Functional Requirements Management Plan** (ED0008235)



Interface definitions - L3 ICDs are documented

- All interfaces are documented in the *PIP-II Master L3 Interface Control Document*

  ➔ Teamcenter® ED0008546;

- Document captures all interfaces, at or below, level 3;

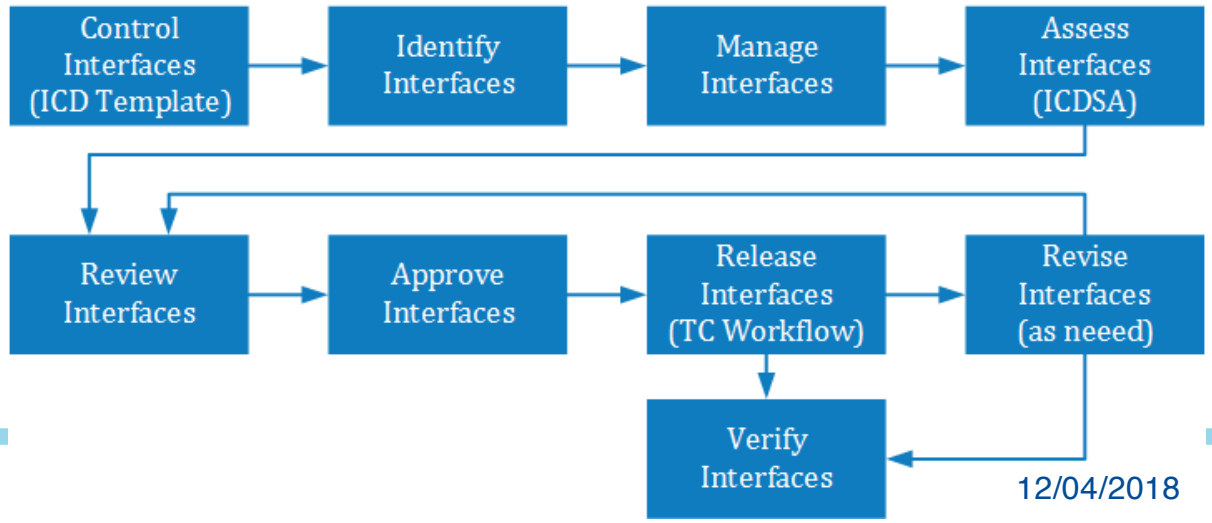
- Technical Interfaces exist between each L3 systems:

  – Mechanical connections, electrical connections, mass or energy (e.g. fluids or current), Space Allocations, digital/analog signals, data, etc.;

- Global interface management system is being considered (e.g. DOORS NG®).

Interface management - process is documented

- PIP-II L2Ms and Partners ➔ identify, review, approve, revise, and verify technical interfaces to their respective systems;
- PIP-II Technical Integration Team ➔ control, manage, assess, and release project L3 technical interfaces;
- PIP-II Project Engineer ➔ reviews technical interfaces monthly;
- Process is documented in the **PIP-II Interface Management Plan - ED0007942.**



Preliminary design plan - design progress tracking

- PIP-II Preliminary Design Plan documented (pip2–doc-2315);
- The plan is developed by L2 and L3 managers in partnership with Technical Integration and is integrated in the Project Resource Loaded Schedule(RLS);
- It defines key design elements, design deliverables with associated weight factors, and preliminary design review milestones;
- The plan is being reviewed by the Technical Integration team and is subject to approval by the Technical Director.

Design – PIP-II CDS design deliverables example

Engineering Process Document Management			
Doc Name	CRYOGENIC DISTRIBUTION SYSTEM (CDS), EPDM	Eng Work Procedure Policy	
Doc #	ED0003563		
Does this task require a design?	☑ Requires a Design		
Standard Documentation			
☐ Required	**Supporting Documentation**		
Requirement	**Document Type**	**Justification for "Not Required"**	**TC Item #**
+	**Requirements and Specifications**		
+	**Engineering Risk Assessment**		
+	**Requirements and Specifications Review**		
–	**System Design**		
	PIP-II - CDS - CDS Piping and Instrument Diagrams (PID)		ED0008572
	PIP-II - CDS - CDS Valve, Instrument, Equipment List (VIE)		ED0008559
	PIP-II - CDS - CDS Heat Leak Analysis		ED0008554
	PIP-II - CDS - CDS Pressure Drop Analysis		ED0008555
	PIP-II - CDS - CDS Relief Analysis		ED0008556
	PIP-II - CDS - CDS Vacuum Relief Analysis		ED0008562
	PIP-II - CDS - CDS Design and Layout Drawings		ED0008564
	PIP-II - CDS - CDS Cooldown Analysis		ED0008557
	PIP-II - CDS - CDS Flexibility Analysis		ED0008558
	PIP-II - CDS - CDS Failure Mode and Effect Analysis (FMEA)		ED0008560
	PIP-II - CDS - Integrated Cryogenic Control System Analysis		ED0008563
	PIP-II - CDS - What If Analysis		ED0008565
	PIP-II - CDS - TL Internal Supports Analysis		ED0008566
	PIP-II - CDS - External Supports and Anchors Analysis		ED0008567
	PIP-II - CDS - TL Vacuum Break Analysis		ED0008568
+	**Engineering Design Review**		
+	**Procurement and Implementation**		
+	**Testing and Validation**		
+	**Release to Operations**		
+	**Final Documentation**		

Engineering documents are captured Teamcenter®

EPDMs capture design documents for each L3

DESIGN- system specific documents

Design – PIP-II CDS % complete example

Preliminary Design Review Plan			
CDS Preliminary Design Review			
REVIEW DELIVERABLES LIST	**Teamcenter ID**	**STATUS**	**WEIGHT FACTOR**
Requirements			
Interfaces			
Risk & Safety			
Project Documents			
Design			
Preliminary Piping and Instrument Diagrams (PID)	ED0008572	50%	30%
Preliminary Valve, Instrument, Equipment List (VIE)	ED0008559	Not Started	5%
Preliminary Heat Load Analysis	ED0008554	25%	10%
Preliminary Pressure Drop Analysis	ED0008555	25%	25%
Preliminary CDS Relief Analysis	ED0008556	25%	15%
Preliminary CDS Vacuum Relief Analysis	ED0008562	Not Started	5%
Preliminary Design and Layout Drawings	ED0008564	Not Started	10%
Procurement/Production/Installation			
		Preliminary Design complete	7%

- Technical weight factor assigned by L3s, L2Ms and SMEs
- Example: CDS Design ➔ 37% (30% CDR + 7 % PDR)

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Quality Management

- The Fermilab Quality Assurance Manual and the PIP-II Quality Assurance Plan (QAP) provide guidance to assure that work on the project meets DOE goals and requirements;
- PIP-II QAP is currently being revised. CD1 version can be found at ➔ pip2-doc-142 ;
- The PIP-II QAP will have strong alignment with Partners standard quality management processes while assuring that the quality of the work on the PIP-II Project will meet technical requirements and project goals;
- Partner's QA Plans approved by both Partner and Fermilab.

Quality Management - essential elements

- PIP-II QAP include:
  - Graded Approach;
  - An effective systems engineering process;
  - Procurement management and assurance;
  - Trained and qualified Project personnel at Fermilab, Partners, Subcontractors, and Vendors
  - Partner/Subcontractor/Vendor oversight plans;
  - Quality Control Plans ➔ Test Plans, and Manufacturing and Inspection Plans, etc.;
  - Risk, Change and Issues management;
  - Effective communication and collaboration.

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Charge #1,2

Technical progress to date - work is progressing well

- The PIP-II configuration is stable; no major changes since the last review;
- The PIP-II Preliminary Design Report (now in draft) is under review by the P2MAC. Plan to publish in February 2019;
- Several technical systems' designs have been completed;
  - Warm Front End is operational;
  - ProtoSSR1 and HWR cryomodules are being assembled.
- Design to support long-lead procurements is well advanced.

WBS 121.02 SRF & Cryogenics

- **Half Wave Resonator cryomodule** ➔is being assembled;
- **SSR cryomodules** ➔ProtoSSR1 is being assembled:
  - 9 cavities with coupler and tuner are qualified;
  - String assembly has started;
  - Lessons learned from SSR1 are applied to SSR2;
  - SSR2 coupler design is ongoing.
- **650 Cryomodules** ➔ HB650 CM design is being advanced.
- **Cryogenic plant** ➔ Procurement in process at DAE;
- **Cryogenic Distribution System** ➔ Leveraging LCLS-II and ESS experience.

WBS 121.03 Accelerator Systems

- **HPRF and LLRF ➔** 4 operating systems at PIP2IT (RFQ, buncher cavities); Commissioning IOT amplifier and RF distribution for 650 MHz coupler tests;
- **Magnets and Power Supplies ➔** QPM system prototyped and tested on a cold SSR1 solenoid at IB1;
- **Beam Instrumentation ➔** Operational at PIP2IT; prototyping low-power laser profile monitor;
- **Controls ➔** Prototyping Machine Protection System at PIP2IT
- **Vacuum system➔** Warm-to-cold transition vacuum protection demonstrated at PIP2IT;

WBS 121.04 LINAC Installation and Commissioning

- Stable operation of the PIP-II Warm Front End at PIP2IT;
- Demonstrated RFQ CW operation, MEBT bunch-by-bunch chopping with arbitrary beam pattern at PIP2IT
- Completed many Final Designs :
  - *Ion source, the LEBT switching dipole, the LEBT solenoid, RFQ couplers, RFQ, the MEBT kicker mechanical structures, the MEBT bunching cavities;*
- Finalizing cryomodule stands design;
- Installing PIP2IT Cryogenic Distribution System.

WBS 121.05 Accelerator Complex Upgrades

- Modified spared Main Injector RF station to drive with 2 power amplifiers;
- Completed preliminary designs of 5 kW and 30 kW absorbers;
- Advancing design of the new 53 MHz Recycler cavity and tuner.

WBS 121.06 Conventional Facilities

- Received favorable wetland determination from the US ACOE;
- Site Preparation design is ~90% complete;
- Site Clearing construction is authorized;
  - Groundbreaking ➔ March 15, 2019;
- Advancing cryogenic plant building design;
- Conventional facilities design is based on similar construction techniques implemented at Fermilab.

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Design Maturity - estimate method

- PIP-II design maturity estimate is based on cost-weighted average at L3 as a sum of credits for:
  - completion of design reviews
  - progress against pre-defined design documents
- Preliminary Design Plan has six categories of design deliverables ➔ requirements, interfaces, risk and safety, updated project documents, system ***design*** documents, and procurement/production/installation;
- Each design document has an associated technical weight factor assigned by L3, L2Ms and SMEs;
- Total system ***design*** documents' percent complete counted as a credit toward completion of a Design (design maturity) at the time of assessment;

Design Maturity

- Metrics:
  - Conceptual Design Review complete ➔ 30% maturity;
  - Preliminary Design Review complete ➔ 60% maturity
  - Final Design Review complete ➔ 90% maturity
- Progress on Partner's work and design-build contracts is not included in the design maturity calculations ➔ they are covering design risk of their own scope;
- By June 2019 ➔ PIP-II project cost-weighted average Design Maturity is planned to exceed 50%;

Design Maturity – expectations by June 2019

WBS	System name	Approx. DM by June 2019
121.2	SRF and Cryogenics	64%
121.3	Accelerator Systems	44%
121.4	Linac Installation and Commissioning	55%
121.5	Accelerator Complex Upgrades	58%
121.6	Conventional Facilities	33%

- Highest priority is on designs associated with critical and advanced technologies (SRF, RF, etc.) ➔ retire major technical risks early;
- Designs of conventional systems (buildings, utilities, “off-the-shelf”, etc.) are prioritized to support long-lead procurements;
- Design plan supports development of credible baseline project cost and schedule estimates.

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Top Technical Risks

RISK ID	RISK DESCRIPTION
RT-121-02-003	Underestimated resources for design optimization of SSR1 CM
RT-121-02-003-B	Underestimated resources for design optimization of HB650 CM
RT-121-02-003-C	Underestimated resources for design optimization of SSR2 CM
RT-121-02-004	SRF pre-production input couplers are unreliable
RT-121-03-002	RF Power Amplifiers have technical issues

- PIP-II technology roadmap guides the technical risk management process, CD3 strategy, and priorities;
- The core of this approach is a **Critical Technology Element** (CTE).

Charge # 2

Technology roadmap ➔ CTEs

Critical Technology Elements
Half Wave Resonator
Single Spoke Resonator - 1
Single Spoke Resonator - 2
650 MHz Low Beta
650 MHz High Beta
Resonance Control
Low-power Laser Profile Monitor

- PIP-II has identified a total of 7 CTEs
- The list is a result of the July 2018 Risk Workshop discussions where each L2 presented CTEs for their respective system using the following definition:

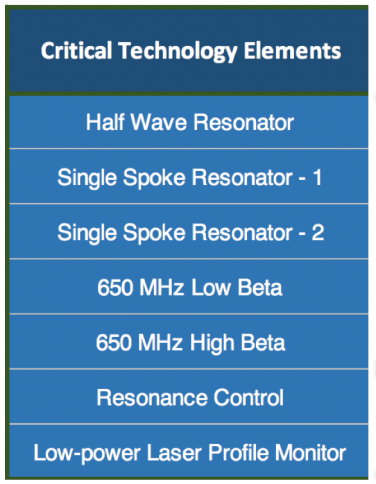
CTE - a technology element is "critical" if this technology is either new or poses major risk

- *Does the component/technology directly impact a functional requirement of the system?*
- *Does the component/technology achieve a performance beyond existing state-of-the art?*
- *Are there uncertainties in the definition of the requirements for this component/technology?*
- *Do the limitations in the understanding of the technology/component non-performance result in a potential:*
  - *cost overrun (> $500k)*
  - *schedule delay (> 4 months)*
- *Is the component/technology expected to operate under new conditions?*

CTEs by systems ➔ WBS 121.02 - SRF and Cryogenics (5)
WBS 121.05 - Accelerator Systems (2)

Charge # 2

Technology demonstration definitions



One of each integrated cavity system* tested in a horizontal test cryostat AND one cryomodule style** RF tested at PIP2IT

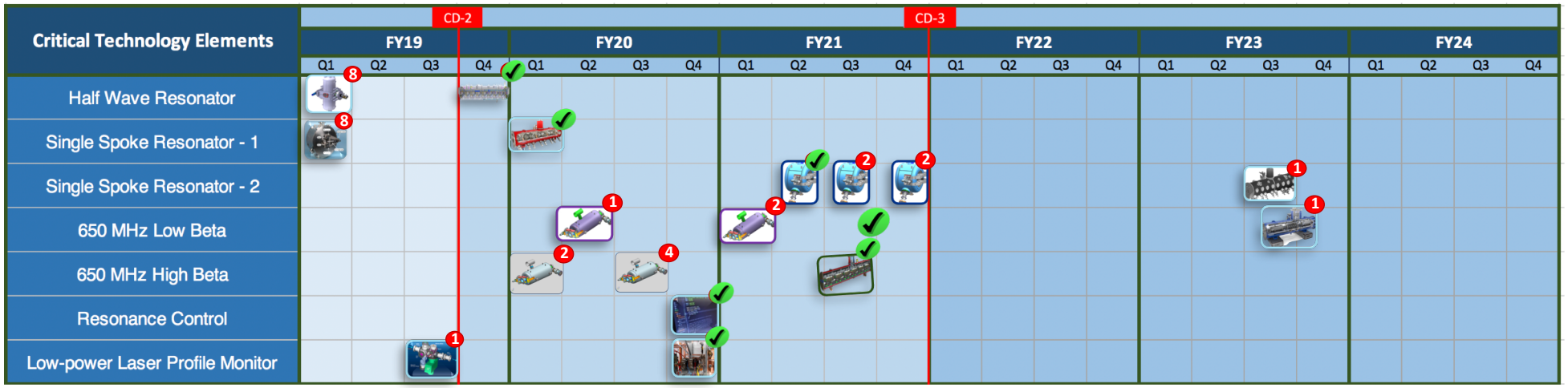
Prototype tested at PIP2IT

Each type of cryomodule will have a prototype validation phase.

* - integrated cavity system is defined as combination of cavity, tuner, and high power coupler
** - cryomodule style is defined based on cavity support structures, e.g. strong back, etc.

Charge # 2

PIP-II Technology Roadmap



HWR Cavity with coupler and tuner HTS tested

HWR cryomodule RF tested at PIP2IT

SSR1 Cavity with coupler and tuner STC tested

ProtoSSR1 cryomodule RF tested at PIP2IT

SSR2 Cavity with coupler and tuner STC tested

ProtoSSR2 cryomodule RF tested at PIP2IT

LB650 Cavity with coupler and tuner STC tested

Proto LB650 cryomodule RF tested at PIP2IT

HB650 Cavity with coupler and tuner STC tested

Proto HB650 cryomodule RF tested at PIP2IT

Laser Profile Monitor tested w/o beam

PIP2IT tests

Software tested at PIP2IT

Number of components

Demonstrated

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Charge # 8

Response to Recommendations (2)

PIP-II P2MAC Review Recommendation No.0a

Status: Closed

Planned Date Closed: 08/16/2018

System	Technical Integration
Owner	A. Klebaner
Recommendation	Ensure full alignment of specifications with PIP-II global requirements
Project Response	PIP-II Functional Requirements Management Plan (ED0008235) defines validation and review process against project global requirement. Requirements are periodically reviewed.

Charge # 8

Response to Recommendations (3)

PIP-II P2MAC Review Recommendation No.4

Status: Ongoing

Planned Date Closed: 12/31/2018

System	Technical Integration
Owner	A. Klebaner
Recommendation	Strive to enforce common engineering design software
Project Response	PIP-II QA Plan is being updated to include Software Quality Assurance elements. A working group to address an issue of common engineering design software and engineering units is being formed. The group will include representatives from CEA, Fermilab, IIFC, INFN,IPNO, and STFC

Charge # 8

Response to Recommendations

PIP-II DOE CD-1 Review Recommendation No.7

Status: Ongoing

Planned Date Closed: 01/31/2019

System	Technical Integration
Owner	A. Klebaner
Recommendation	Spares: Before CD-2, prepare a spares strategy plan document detailing what spares are needed, how this determination is made, what spares are included in project scope, and what spares are deferred for operations
Project Response	We have started development of the PIP-II spare plan. The plan will outline the spares strategy and prioritization approach for the spares developed by the SMEs. The plan also will ensure that spares are reasonable and justifiable and that sufficient spares for commissioning, start-up, and operations of PIP-II are available.

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Charge #5

Next Steps toward CD-2/3a

- Implement SEMP and QAP project-wide ➔ Release design plans, technical requirements specifications and interface control documents;
- Continue to ensure technical, safety and quality requirements are understood and integrated across the project;
- Advance systems technical design ➔ reach > 50% average cost-weighted design maturity by June 2019;
- Continue coordinating space allocation for PIP-II equipment and technical change management process;
- Publish Preliminary Design Report.

Summary

- SEMP is in place; requirements and interfaces are defined; Quality management processes are being implemented;
- Significant technical progress has been demonstrated since last review. The remaining design work is understood;
- Technical risks are understood and a roadmap to retire these risks is in place;
- Technical Integration team is motivated, highly qualified, and ready to deliver;
- PIP-II project is on track to have a design and technology sufficient to baseline the project by June 2019.

END

Thank you!

Acknowledgments:

Information presented here is a summary of collaborative work of many people. Special thanks to the PIP-II Integration Team: ***Jemila Adetunji, Andrew Dalesandro, Jeremiah Holzbauer, Alex Martinez, Allan Rowe, and James Steimel***