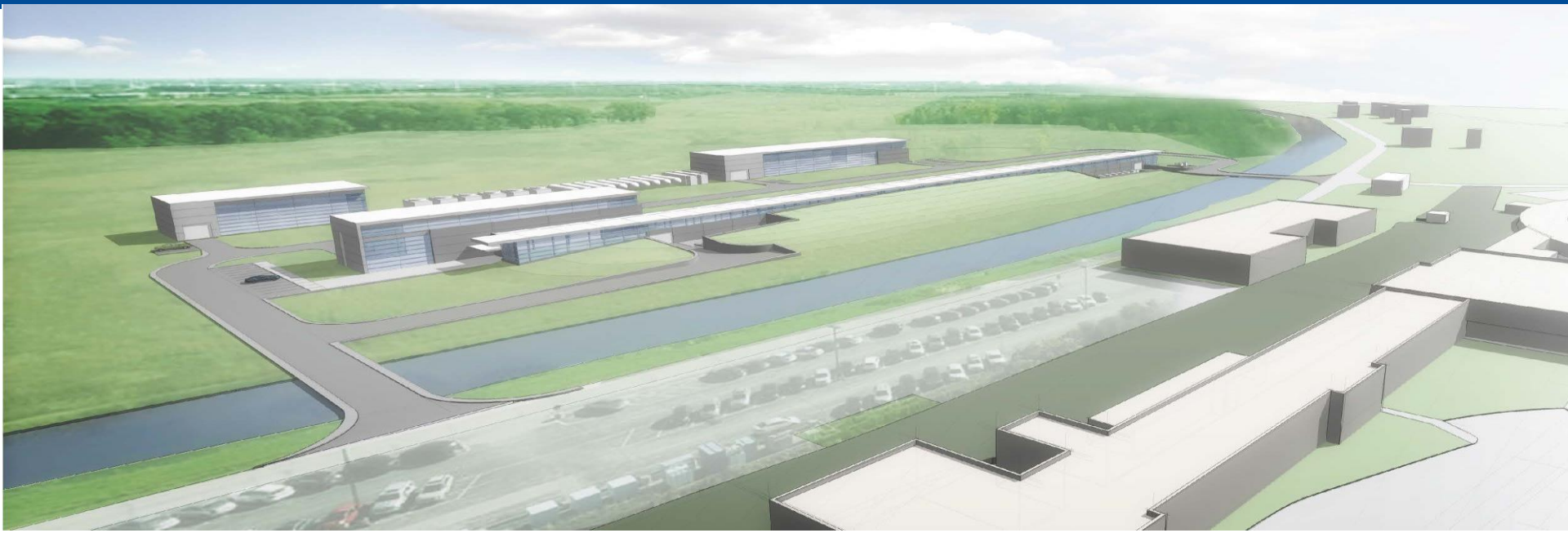

PIP-II Top Risks and Mitigation Plan from L2 and L3

Shekhar Mishra (Editor)

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In partnership with:
India/DAE
Italy/INFN
UK/STFC
France/CEA/Irfu, CNRS/IN2P3

Risk: PIP-II Project Risk

- Resonance control and field regulation
- Technical Issues with International Deliverables
- Pulsed and CW cryomodule operating modes cause cryogenic or mechanical instabilities
- Machine performance problems during commissioning
- SSR1/SSR2/LB650/HB650 CM (1) Performance at PIP2IT does not meet technical requirements
- IIFC LLRF/RFPI hardware/software does not meet acceptance criteria
- MEBT kickers performance is unsatisfactory
- SSR1 Cryomodule design modifications identified late in design cycle
- SRF Pre-Production Input Coupler Failure
- Unable to maintain proper vacuum between MEBT absorber and SRF

Title	Technical Impact	P * Impact (k$)	P * Impact (month	Probability
Resonance control and field regulation	3 (H) - extremely substandard or	700	6.0	40.00%
Technical Issues with International Deliverables	2 (M) - significantly substandard	2,542	2.5	25.00%
Pulsed and CW cryomodule operating modes cause cryogenic or mechanical instabilities	2 (M) - significantly substandard	688	3.3	50.00%
Machine performance problems during commissioning	2 (M) - significantly substandard	508	2.4	25.00%
SSR1/SSR2/HB650/LB650 CM (1) Performance at PIP2IT does not meet technical requirements	2 (M) - significantly substandard	433	2.8	40.00%
IIFC LLRF/RFPI hardware/software does not meet acceptance criteria	2 (M) - significantly substandard	400	3.8	50.00%
MEBT kickers performance is unsatisfactory	2 (M) - significantly substandard	250	1.5	25.00%
SSR1 Cryomodule design modifications identified late in design cycle	2 (M) - significantly substandard	217	1.6	20.00%
SRF Pre-Production Input Coupler Failure	2 (M) - significantly substandard	140	3.1	50.00%
Unable to maintain proper vacuum between MEBT absorber and SRF	2 (M) - significantly substandard	108	1.6	25.00%

Risk: PIP-II Enterprise (DOE/Fermilab) Risk

- Failure of SRF cavity processing equipment
- SRF Test Infrastructure Cryogenic Plant Failure
- Delay in access to SRF testing and fabrication infrastructure
- Delay in formalizing international in-kind contributions
- Major Accident/Incident on Fermilab Site

Title	Technical Impact	P * Impact (k$)	P * Impact (month	Probability
Failure of SRF cavity processing equipment	2 (M) - significantly substandard	20	0.4	10.00%
SRF Test Infrastructure Cryogenic Plant Failure	1 (L) - somewhat substandard	0	0.9	15.00%
Delay in access to SRF testing and fabrication infrastructure	0 (N) - negligible technical impact	150	1.8	50.00%
Delay in formalizing international in-kind contributions	0 (N) - negligible technical impact	0	1.5	25.00%
Major Accident/Incident on Fermilab Site (PHA-1,3-6,8-15)	0 (N) - negligible technical impact	0	0.1	10.00%

Risk: PIP-II Project Office Risks

- Technical Issues with International Deliverables
- Insufficient Scientific, engineering and technical human resources including Contractor
  - Inability to assign qualified individuals to key Project positions
- Insufficient International Deliverable Documentation
- Assumed R&D funding profile not achieved
- Non-jurisdictional Wetlands application denied
- Project Assumption of Operating fund with laboratory not implemented

Title	Technical Impact	P * Impact (k$)	P * Impact (month	Probability
Technical Issues with International Deliverables	2 (M) - significantly substandard	2,542	2.5	25.00%
Insufficient Scientific, engineering and technical human resources including Contractor	1 (L) - somewhat substandard	1,500	4.8	50.00%
Insufficient International Deliverable Documentation	1 (L) - somewhat substandard	15	0.4	25.00%
Inability to assign qualified individuals to key Project positions	1 (L) - somewhat substandard	0	1.4	15.00%
Assumed R&D funding profile not achieved	1 (L) - somewhat substandard	0	1.2	15.00%
Non-jurisdictional Wetlands application denied	0 (N) - negligible technical	1,035	0.9	30.00%
Project Assumption of Operating fund with laboratory not implemented	0 (N) - negligible technical	1,000	0.0	50.00%

Risk: PIP-II Project International Risks

- Technical Issues with International Deliverables
- IIFC LLRF/RFPI hardware/software does not meet acceptance criteria
- LB650 CMs (1-11) Performance at CMTS does not meet technical requirements
- Niobium quality assurance
- Technical Issues with RF Power Amps
- RF interlocks fail to protect SSA-Coupler-Cavity
- Insufficient International Deliverable Documentation

Title	Technical Impact	P * Impact (k$)	P * Impact (months)	Probability
Technical Issues with International Deliverables	2 (M) - significantly substandard	2,542	2.5	25.00%
IIFC LLRF/RFPI hardware/software does not meet acceptance criteria	2 (M) - significantly substandard	400	3.8	50.00%
LB650 CMs (1-11) Performance at CMTS does not meet technical requirements	2 (M) - significantly substandard	188	1.8	25.00%
Niobium quality assurance	2 (M) - significantly substandard	100	1.2	20.00%
Technical Issues with RF Power Amps	1 (L) - somewhat substandard	142	6.0	50.00%
RF interlocks fail to protect SSA-Coupler-Cavity	1 (L) - somewhat substandard	23	0.4	10.00%
Insufficient International Deliverable Documentation	1 (L) - somewhat substandard	15	0.4	25.00%

Risk Mitigation Plan: Technical Issues with International Deliverables

- Risk Mitigation Strategy (PIP-II-Doc-1201)
  - Jointly agreed upon Requirements and Specifications
  - Development and Demonstration
    - International partners' capabilities
      - Prototype
      - Production
  - Design Validations
    - Formalized review processes
  - Project Quality Assurance Program
    - Integration of international partners into Fermilab
  - Coordination at all level
    - Technical managers communication

Risk: Cavity, CM and Cryogenics

- Pulsed and CW cryomodule operating modes cause cryogenic or mechanical instabilities
- SSR1/SSR2/LB650/HB650 CM (1) Performance at PIP2IT does not meet technical requirements
- SSR1 Cryomodule design modifications identified late in design cycle
- SRF Pre-Production Input Coupler Failure
- Niobium quality assurance

Title	Technical Impact	P * Impact (k$)	P * Impact (months)	Probability
Pulsed and CW cryomodule operating modes cause cryogenic or mechanical instabilities	2 (M) - significantly substandard	688	3.3	50.00%
SSR1/SSR2/LB650/HB650 CM (1) Performance at PIP2IT does not meet technical	2 (M) - significantly substandard	433	2.8	40.00%
SSR1 Cryomodule design modifications identified late in design cycle	2 (M) - significantly substandard	217	1.6	20.00%
SRF Pre-Production Input Coupler Failure	2 (M) - significantly substandard	140	3.1	50.00%
Niobium quality assurance	2 (M) - significantly substandard	100	1.2	20.00%

Risk Mitigation: Pulsed and CW cryomodule operating modes cause cryogenic or mechanical instabilities

- Lessons learned from LCLS-II CW cryomodule testing will be implemented to the extent possible on PIP-II CM designs.
- Passive mitigation first line of defense.
- Extended CW and pulsed testing will occur both for CMs and dressed cavity systems for the purpose of characterizing resonance responses and sensitivities as well as identify possible design improvements.
- Active compensation required, so robust plans in place with LLRF (RF-INT) WBS to carry forward resonance control development.

Risk: RF, Controls and Instrumentation

- Resonance control and field regulation
- IIFC LLRF/RFPI hardware/software does not meet acceptance criteria
- Choice of laser profiling technology
- Machine Protection System Fails (Allows Beam Event)
- Technical Issues with RF Power Amps

Title	Technical Impact	P * Impact (k$)	P * Impact (months)	Probability
Resonance control and field regulation	3 (H) - extremely substandard or	700	6.0	40.00%
IIFC LLRF/RFPI hardware/software does not meet acceptance criteria	2 (M) - significantly substandard	400	3.8	50.00%
Choice of laser profiling technology	2 (M) - significantly substandard	50	1.5	25.00%
Machine Protection System Fails (Allows Beam Event)	1 (L) - somewhat substandard	254	0.8	25.00%
Technical Issues with RF Power Amps	1 (L) - somewhat substandard	142	6.0	50.00%

Risk Mitigation: RF System Test

- PIP2IT/CMTF are the key Risk Mitigation development program.
  - It is addressing many PIP-II Risks including Resonance control and field regulation
- SSR1 and HWR cryomodule cavities will be RF commissioned: HWR with CW RF and SSR1 with pulsed and CW RF.
- Both cryomodules will be commissioned with pulsed beam with sufficient intensities to satisfy KPPs.
- Entire 162.5 MHz and 325 MHz RF systems will be exercised during commissioning.
  - Resonant control system will be debugged and verified on both cryomodules.
  - DAE LLRF system, RF protection interlock (RFPI) system, and 325 MHz 7kW RF power amplifiers will be verified on SSR1 cryomodule.
- Instrumentation and controls systems will be commissioned for pulsed beam and sufficient to test MPS system for cryomodules.

Risk: Linac Support System, Installation and Commissioning

- Machine performance problems during commissioning
- MEBT kickers performance is unsatisfactory
- Unable to maintain proper vacuum between MEBT absorber and SRF
- MEBT Absorber does not meet performance requirement
- LCW system does not achieve temperature stability requirements

Title	Technical Impact	P * Impact (k$)	P * Impact (months)	Probability
Machine performance problems during commissioning	2 (M) - significantly substandard	508	2.4	25.00%
MEBT kickers performance is unsatisfactory	2 (M) - significantly substandard	250	1.5	25.00%
Unable to maintain proper vacuum between MEBT absorber and SRF	2 (M) - significantly substandard	108	1.6	25.00%
MEBT Absorber does not meet performance requirement	2 (M) - significantly substandard	45	1.2	10.00%
LCW system does not achieve temperature stability requirements	2 (M) - significantly substandard	30	0.4	10.00%

Risk Mitigation: Machine performance problems during commissioning

- This is a technical risk with a high impact to schedule & cost
- Development plan (FY16-FY22) is planned to minimize the impact
  - PIP2IT and CMTS1 will enable a variety of system-level tests to be performed on many critical systems providing opportunity for the majority of the issues to be identified and addressed long before the accelerator components are installed in PIP-II tunnel
  - Perform cold RF-cryomodule test on all cryomodules
  - Verification of RF power systems before and after installation
  - Machine protection system is being developed and tested at PIP2IT
  - First two cryomodules (HWR and one SSR1 cryomodule) will be tested with beam at PIP2IT before moving to PIP-II enclosure

Risk: Conventional Facility

- Subproject Changes Impact Conventional Facilities
- Construction Bids Exceed Estimates
- RF LCW Temperature Delta Too Low
- Unclear/Incomplete Delineation Between Construction Packages
- Design Complexity
- Poor Interface Definition

Title	Technical Impact	P * Impact (k$)	P * Impact (months)	Probability
Subproject Changes Impact Conventional Facilities	1 (L) - somewhat substandard	285	2.0	30.00%
Construction Bids Exceed Estimates	1 (L) - somewhat substandard	68	0.2	15.00%
RF LCW Temperature Delta Too Low	1 (L) - somewhat substandard	63	0.9	20.00%
Unclear/Incomplete Delineation Between Construction Packages	1 (L) - somewhat substandard	58	0.3	25.00%
Design Complexity	1 (L) - somewhat substandard	43	0.0	15.00%
Poor Interface Definition	1 (L) - somewhat substandard	40	1.3	25.00%

Risk Mitigation: Subproject Changes Impact CF

- Summary

  If the subproject requirements changes then the design of the conventional facilities will need to be modified jeopardizing the cost and schedule objectives

- Cause/Trigger

  Changes to the subproject requirements

- Mitigation
  - Include subproject managers in design meetings;
  - Include subproject managers in formal design reviews;
  - Management control of changes through a change/configuration control process;

Risk: HWR Cryomodule

- HWR Cryomodule does not meet technical performance requirements

WBS / Ops Lab Activity	RI-ID	Title	Technical Impact	P * Impact (k$)	P * Impact (months)	Probability
121.03 Linac	RT-121-03-06-001	HWR Cryomodule does not meet technical performance	1 (L) - somewhat substandard	217	2.4	20.00%

Risk Mitigation: HWR Cryomodule does not meet the technical performance requirement

- All HWRs are tested off-line prior to installation in the cryomodule.
  - Performance testing:
    - All HWRs are tested while fully dressed: high-power coupler with bias-tee, slow tuner, pick-up probes, vacuum pumping.
  - Solenoid field operation:
    - Two HWRs have been tested with a cryomodule solenoid oriented in the same manner as in the cryomodule. No performance limitations found, see slide 12.
- All components are tested in a real cryomodule environment prior to installation in the cryomodule.
- The cryomodule is fully tested in PIP2IT prior to use in PIP-II.

Risk: SSR Cavity and CM

- SSR1 CM (1) Performance at PIP2IT does not meet technical requirements
- SSR2 CM (1) Performance at PIP2IT does not meet technical requirements
- SSR1 Cryomodule design modifications identified late in design cycle

Title	Technical Impact	P * Impact (k$)	P * Impact (months)	Probability
SSR1 CM (1) Performance at PIP2IT does not meet technical	2 (M) - significantly substandard	433	2.8	40.00%
SSR2 CM (1) Performance at PIP2IT does not meet technical	2 (M) - significantly substandard	333	2.8	40.00%
SSR1 Cryomodule design modifications identified late in design cycle	2 (M) - significantly substandard	217	1.6	20.00%

Risk Mitigation: SSR1 CM (1) Performance at PIP2IT does not meet technical requirements

- SSR1 CM (1) designed to meet/exceed specifications
  - Structural, thermal and multiphysics finite element analyses
  - Dressed cavities with very low df/dp
  - Piping systems and pressure vessels designed to comply the ASME codes
  - Features to mitigate thermal acoustic oscillations and mechanical instabilities
- Pre-qualification of of key-components
  - Cold testing fully integrated cavities with coupler and tuner
    - RF and structural/cryogenic performance
    - Resonance control studies
    - Assessment of field emission, multipacting, magnetic field, and other limiting factors
  - Testing solenoids, BPMs
  - QA/QC inspections at each critical step from manufacturing to final installation
- Integration of lessons learned about low beta cavities
  - Processing of cavity surfaces and cleanroom procedures
  - Handling of cavity string assembly, coldmass, cryomodule

Risk: 650 Cavity and CM

- Pulsed and CW cryomodule operating modes cause cryogenic or mechanical instabilities
- HB650 CM (1) Performance at CMTF does not meet technical requirements
- LB650 CMs (1-11) Performance at CMTS does not meet technical requirements

Title	Technical Impact	P * Impact (k$)	P * Impact (months)	Probability
Pulsed and CW cryomodule operating modes cause cryogenic or	2 (M) - significantly substandard	688	3.3	50.00%
HB650 CM (1) Performance at CMTF does not meet technical	2 (M) - significantly substandard	333	2.8	40.00%
LB650 CMs (1-11) Performance at CMTS does not meet technical	2 (M) - significantly substandard	188	1.8	25.00%

Risk Mitigation: HB650 CM (1) Performance at CMTF does not meet technical requirements

- CM Performance risk areas + Mitigation
  - Resonance control
    - Slow and Fast Tuner response, integration with LLRF
    - Design verification testing of dressed cavities in both CW and pulsed ops.
  - Integrated Cavity String Performance
    - Performance degradation from VTS/STC to integrated CM
    - LCLS-II lessons learned integrated into prep&test protocols, tailored to larger cavities
      - Field Emission - surface prep recipe, cleanroom skills proficiency
      - Q0 retention – magnetic hygiene, CM cooling regimen, shielding design
    - CM design features to mitigate thermal acoustic oscillations, string mechanical instabilities.
      - specifics
  - Cryomodule Final Design Loop

Risk: Cryogenics

- Cryogenic system specification changes
- Insufficient Cryogenic system vendor manufacturing capacity and priority

Title	Technical Impact	P * Impact (k$)	P * Impact (months)	Probability
Cryogenic system specification changes	1 (L) - somewhat substandard	15	0.1	1.00%
Insufficient Cryogenic system vendor manufacturing capacity and	0 (N) - negligible technical	500	3.5	50.00%

Risk Mitigation: Cryogenic system specification changes

- Hybrid compression cycle was chosen for reference design to allow efficient capacity adjustment
- Cryogenic plant reference design has options to increase cavity circuit cryogenic plant capacity by adjusting shields capacity
- Cryogenic system design has provisions to use warm pumping system and a shield refrigerator
- Cryogenic system Technical Specifications have or will have options for vendors to adjust requirements up to and including Production Readiness Review
- Cryogenic system specifications/requirements are documented and controlled. Changes to the specifications are coordinated and controlled.

Risk: RF Power

- Technical Issues with RF Power Amps
- Failure of 650 MHz IOT Amplifiers
- 162.5 MHz, 7 kW RF amplifier procurement delayed
- Failure of High Power Circulator

Title	Technical Impact	P * Impact (k$)	P * Impact (months)	Probability
Technical Issues with RF Power Amps	1 (L) - somewhat substandard	142	6.0	50.00%
Failure of 650 MHz IOT Amplifiers	1 (L) - somewhat substandard	15	3.5	50.00%
162.5 MHz, 7 kW RF amplifier procurement delayed	0 (N) - negligible technical	19	1.5	25.00%
Failure of High Power Circulator	0 (N) - negligible technical	15	3.0	50.00%

Risk Mitigation: Technical Issues with RF Power Amps

- The PIP-II RF Power Amplifier development phase with International partners have been broken into two steps
  - 1st Unit for 325 and 650 MHz
  - Prototype
- Plan is to verify and certify the RF Power Amps after 1st units that have been fabricated at the partner location
- Full prototype RF Power Amplifier integrated system test will be done at PIP2IT and CMTS
  - Experience in PIP2IT and CMTS will allow us to mitigate the technical issues of 325 MHz, and 650 MHz amplifiers during the development phase.
- This experience and any improvements will be communicated to partners before construction of PIP-II final amplifiers begins.

Risk: RF Integration

- Resonance control and field regulation
- IIFC LLRF/RFPI hardware/software does not meet acceptance criteria
- RF interlocks fail to protect SSA-Coupler-Cavity

Title	Technical Impact	P * Impact (k$)	P * Impact (months)	Probability
Resonance control and field regulation	3 (H) - extremely substandard or	700	6.0	40.00%
IIFC LLRF/RFPI hardware/software does not meet	2 (M) - significantly substandard	400	3.8	50.00%
RF interlocks fail to protect SSA-Coupler-Cavity	1 (L) - somewhat substandard	23	0.4	10.00%

Risk Mitigation: Resonance control and field regulation

- Is a Risk in the pulse mode of PIP-II operation due to microphonics and Lorentz force detuning.
  - Which is the default operating mode for the LBNF/DUNE
- Is a much smaller Risk in the CW mode of PIP-II operation as Lorentz force detuning does not come into play
  - PIP-II is being built as a CW capable SRF Linac
  - Additional operating cost in CW mode will be ~850k/yr
- Workable solution may fall between pure pulsed and CW
- Planned Development (FY18-FY23) is to mitigate these Risks
  - Risk Mitigation Plan (PIP-II DocDb 1272)

IIFC LLRF/RFPI hardware/software does not meet acceptance criteria

- Using Fermilab QA guidelines and collaboration acceptance criteria
- PIP2IT and CMTS will allow us to mitigate this risk by testing and further develop prototypes delivered from DAE in these facilities
- Areas to address:
  - Field and resonance control
  - Software compatibility with FNAL Timing, Controls, MPS
  - Reliability and build quality

Risk: Controls

- Machine Protection System Fails (Allows Beam Event)
- Controls interface to existing complex
- Internal interfaces to control system

Title	Technical Impact	P * Impact (k$)	P * Impact (months)	Probability
Machine Protection System Fails (Allows Beam Event)	1 (L) - somewhat substandard	254	0.8	25.00%
Controls interface to existing complex	1 (L) - somewhat substandard	3	0.2	10.00%
Internal interfaces to control system	1 (L) - somewhat substandard	0	0.2	10.00%

Risk Mitigation: Machine Protection System Fails (Allows Beam Event)

- Mitigated by testing at PIP2IT
- Currently being commissioned and debugged on warm front-end, where damage probability and cost is very low.
- Will be verified with HWR and SSR1 cryomodule systems and interlocks with low duty, pulsed beam.
- All aspects of the system will be tested at PIP2IT except for scaling to PIP-II device quantities and the interface to the rings complex.

Risk: Instrumentation

- Choice of laser profiling technology (Transverse Profile)
- Integration of instrumentation into MPS

Title	Technical Impact	P * Impact (k$)	P * Impact (months)	Probability
Choice of laser profiling technology	2 (M) - significantly substandard	50	1.5	25.00%
Integration of instrumentation into MPS	1 (L) - somewhat substandard	25	1.5	25.00%

Risk Mitigation: Choice of laser profiling technology (Transverse Profile)

- Two options for laser profiling: (1) low-power lasers or (2) high-power lasers
- Low-power laser option is preferred but needs beam measurements as proof of operation
- High-power laser option has been demonstrated at SNS but is more complicated and has risk of damage from laser
- Plan to test low-power option at PIP2IT
- If unsuccessful then fall back to high-power option
- Laser profiling PIP-II infrastructure allows for possibility of either laser option as final choice

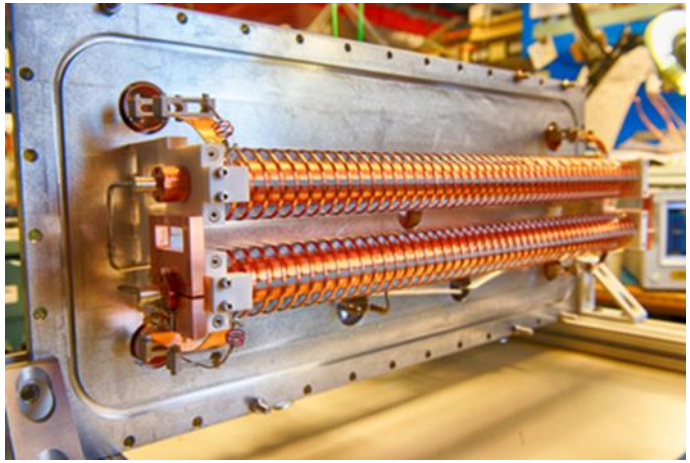
Risk: Warm Front End

- MEBT kickers performance is unsatisfactory
- Unable to maintain proper vacuum between MEBT absorber and SRF
- MEBT Absorber does not meet performance requirement

Title	Technical Impact	P * Impact (k$)	P * Impact (months)	Probability
MEBT kickers performance is unsatisfactory	2 (M) - significantly substandard	250	1.5	25.00%
Unable to maintain proper vacuum between MEBT absorber	2 (M) - significantly substandard	108	1.6	25.00%
MEBT Absorber does not meet performance requirement	2 (M) - significantly substandard	45	1.2	10.00%

Risk Mitigation: MEBT kickers performance is unsatisfactory

- Developed 2 concepts for the MEBT kickers
  - "50-Ohm" and "200-Ohm"
- One prototype of each kind has been fabricated and installed at PIP2IT
  - Tests with beam have started



"200-Ohm" kicker helical structure

"50-Ohm" kicker electrode

Risk: Power Supply

- Quench calculations indicate inadequate QPM system
- Quench analysis shows SSR1 protection is insufficient
- Cold magnet power supply procurement delay

Title	Technical Impact	P * Impact (k$)	P * Impact (months)	Probability
Quench calculations indicate inadaquate QPM system	2 (M) - significantly substandard	20	1.5	50.00%
Quench analysis shows SSR1 protection is insufficient	1 (L) - somewhat substandard	2	0.4	10.00%
Cold magnet power supply procurement delay	0 (N) - negligible technical	1	0.2	20.00%

Risk Mitigation: Quench calculations indicate inadequate QPM system

- Quench calculations are currently being performed on SSR1 magnets and results are being compared with quench data from Magnet Test Facility.
- QPM systems are being designed and built for superconducting Solenoids for the HWR and SSR1 cryomodule #1
  - Total of 8 QPMs will interface with 44 power supplies
- PIP-II during the Development Phase will test these fully integrated CMs with RF and beam
- Quench data will be obtained and analyzed and compared with calculations
  - Any necessary improvement and/or design changes will be implemented in the PIP-II Quench protection system.

Risk: General Support Services

- LCW system does not achieve temperature stability requirements
- Requirements or interface definition for LCW LTA

Title	Technical Impact	P * Impact (k$)	P * Impact (months)	Probability
LCW system does not achieve temperature stability	2 (M) - significantly substandard	30	0.4	10.00%
Requirements or interface definition for LCW LTA	1 (L) - somewhat substandard	53	1.0	50.00%

Risk Mitigation: LCW system does not achieve temperature stability requirements

- Interface documentation to be created and reviewed to ensure system capabilities match customer needs
- Requirements review
  - Draft FRS ED0006218 Rev-, in review currently
- PIP2IT/CMTF/CMTS1 experience
  - "Modern" LCW system with similar architecture installed in CMTF, servicing PIP2IT and CMTS1
    - Currently meets all requirements for PIP2 LCW system
  - Most critical customer systems (e.g. RF amps) must be operated at PIP2IT or CMTS1 prior to PIP2, allowing for early detection of component-specific problems with cooling
    - Unexpectedly-stringent cooling needs have already been identified in one RF component at PIP2IT – this drove the selection of a more robust component for PIP-II

Risk: Installation and Commissioning

- Machine performance problems during commissioning
- Subsystem or component problem discovered after installation
- Late subsystem delivery makes installation less efficient
- Mismatch between subsystem delivery and installation schedule creates need for storage

Title	Technical Impact	P * Impact (k$)	P * Impact (months)	Probability
Machine performance problems during commissioning	2 (M) - significantly substandard	508	2.4	25.00%
Subsystem or component problem discovered after installation	2 (M) - significantly substandard	8	0.7	10.00%
Late subsystem delivery makes installation less efficient	0 (N) - negligible technical	55	1.0	50.00%
Mismatch between sybsystem delivery and installation schedule	0 (N) - negligible technical	13	0.0	25.00%

Risk Mitigation: Subsystem or component problem discovered after installation

- PIP-II development plan includes testing of all subsystems before it is delivered for installation.
  - Minimizing this risk
- Primary mitigations
  - Test critical systems at PIP2IT/CMTS1
    - Entire Warm Front End
    - Cryomodules and RF
- Adhere to the project QA plan
- Communication and team continuity
    - We are creating experts with PIP2IT and CMTS1 testing
    - Same experts to commission PIP2

Risk: Booster/Main Injector/Recycler

- MR RF System upgrade

Title	Technical Impact	P * Impact (k$)	P * Impact (months)	Probability
MI RF System Upgrade	1 (L) - somewhat substandard	1,500	0.5	25.00%

Risk Mitigation: MR RF System upgrade

- MR RF System Upgrade Development program is perusing two options using the existing RF cavities
  - Two tubes side by side
  - Single tube.
- The two tubes solution is the default option, it cost less

4CW250,000B next to presently used Y567B on right.