PIP-II Beam Instrumentation (BI) Preliminary Design Review Report

Document number: ED00014582

Document Approval

Name: Org: Contact: Role: Committee Member	Date:
Name: Org: Contact: Role: Committee Member	
Name: Org: Contact: Role: Committee Member	
Name: Org: Contact: Role: Committee Member	
Name: Org: Contact: Role: Committee Chair	

Revision History

Revision	Date Release	Originator: Role:	Description of Change

Revision control is managed via Fermilab Teamcenter Workflows.

Table of Contents

1. Introduction

The Introduction provides a brief narrative of the following:

- Overview statements that include the Review Title, summary of the Review Charge, goals and anticipated outcomes, context of the review
- Brief description of the Project area under review (descriptions of the System, Sub-system, and device or requirement under review)
- Brief summary of the thoroughness, effectiveness, and general summarized committee thoughts of the review itself.

Various beam instrumentation and diagnostics systems are needed to characterize and monitor beam parameters for the operation of the PIP-II accelerator performance, from the warm front end through the Beam Transport Line (BTL). In addition, beam instrumentation must support startup and initial beam commissioning. Beam instruments are required to observe:

- Beam position and phase
- Beam losses
- Beam profiles
- Beam current and intensity
- Beam emittance
- Bunch-by-bunch chopping efficiency

The required measurements are facilitated by the following beam instrumentation systems:

- Beam Current Monitor (BCM) system
- Beam Position Monitor (BPM) system
- Beam Loss Monitor (BLM) system
- Beam Profile Monitor (BProM) system

The scope of this review is to determine if the preliminary design of all the beam instrumentation systems align with the functional and technical requirements.

2. Review Agenda

This section shows the details of a typical review agenda which can be tailored to suit the review being held. Changes should be indicated if different from the Review Charge.

Agenda Example:

LLRF Preliminary Design Review Agenda

Location: Day 1:
https://fnal.zoom.us/j/91605592914?pwd=cTJNbnpCamRHSnZycUxCdGVPLys2dz09
Meeting ID: 916 0559 2914
Passcode: 878534
Day 2:
https://fnal.zoom.us/j/95639571730?pwd=NU5VVktueXV4QW0wcXFFRElHTkxudz09
Meeting ID: 956 3957 1730
Passcode: 739669

Date: 21-22 September 2021

Time: 0830 CDT

Indico Site: https://indico.fnal.gov/event/50474/

Participants:

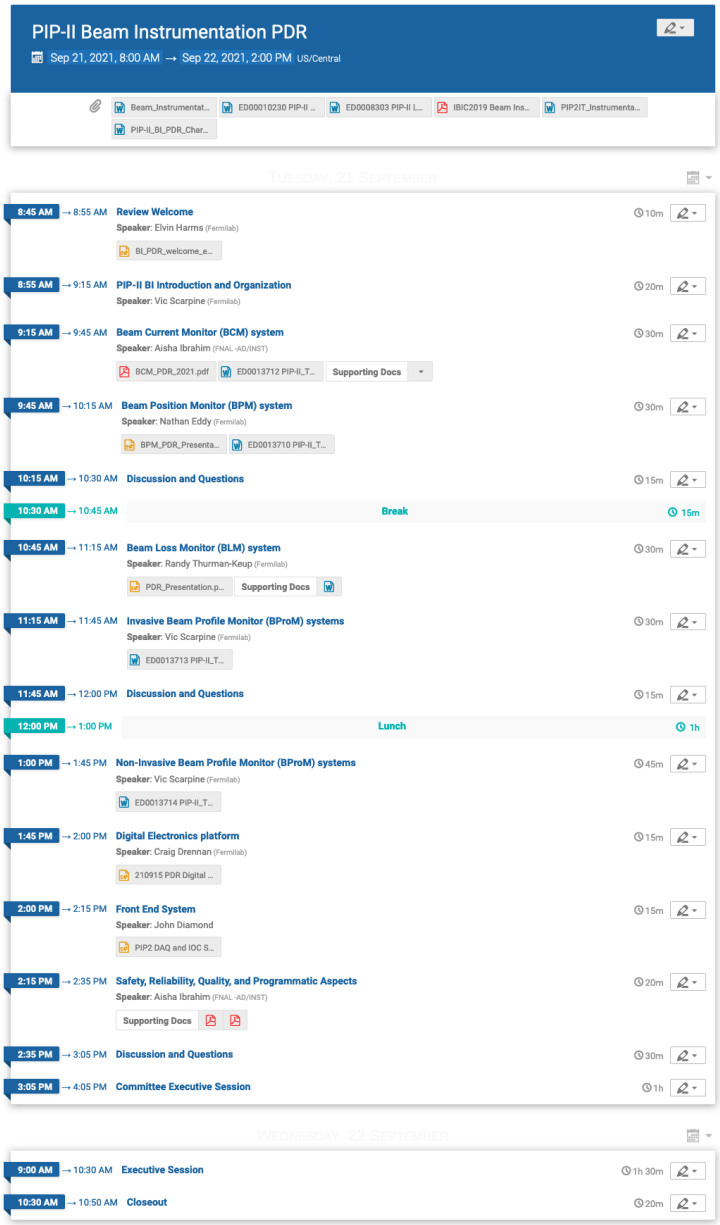
Participant's Name and Contact Information	Organization	Role:
Vic Scarpine scarpine@fnal.gov	Fermilab	Role: Coordinator
Mandy Kiburg rominsky@fnal.gov	Fermilab	Role: Review Chair
Sasha Aleksandrov sasha@ornl.gov	SNS	Role: Reviewer
Jenna Crisp jenna@jcrisp.net	FRIB	Role: Reviewer
Yun Liu	SNS	Role: Reviewer

Liuy2@ornl.gov		
Elvin Harms harms@fnal.gov	Fermilab	Role: Presenter
Vic Scarpine scarpine@fnal.gov	Fermilab	Role: Presenter
Aisha Ibrahim cadornaa@fnal.gov	Fermilab	Role: Presenter
Nathan Eddy eddy@fnal.gov	Fermilab	Role: Presenter
Randy Thurman-Keup keup@fnal.gov	Fermilab	Role: Presenter
Craig Drennan cdrennan@fnal.gov	Fermilab	Role: Presenter
John Diamond jdiamond@fnal.gov	Fermilab	Role: Presenter

Agenda details:

Table 1 – Preliminary Design Review Agenda

Agenda


PIP-II Beam Instrumentation PDR
Sep 21, 2021, 8:00 AM → Sep 22, 2021, 2:00 PM US/Central
Beam_Instrumentat...
ED0010230 PIP-II ...
ED0008303 PIP-II L...
IBIC2019 Beam Ins...
PIP2IT_Instrumenta...
PIP-II_BI_PDR_Char...
Tuesday, 21 September
8:45 AM → 8:55 AM Review Welcome 10m
Speaker: Elvin Harms (Fermilab)
BI_PDR_welcome_e...
8:55 AM → 9:15 AM PIP-II BI Introduction and Organization 20m
Speaker: Vic Scarpine (Fermilab)
9:15 AM → 9:45 AM Beam Current Monitor (BCM) system 30m
Speaker: Aisha Ibrahim (FNAL -AD/INST)
BCM_PDR_2021.pdf
ED0013712 PIP-II_T...
Supporting Docs
9:45 AM → 10:15 AM Beam Position Monitor (BPM) system 30m
Speaker: Nathan Eddy (Fermilab)
BPM_PDR_Presenta...
ED0013710 PIP-II_T...
10:15 AM → 10:30 AM Discussion and Questions 15m
10:30 AM → 10:45 AM Break 15m
10:45 AM → 11:15 AM Beam Loss Monitor (BLM) system 30m
Speaker: Randy Thurman-Keup (Fermilab)
PDR_Presentation.p...
Supporting Docs
11:15 AM → 11:45 AM Invasive Beam Profile Monitor (BProM) systems 30m
Speaker: Vic Scarpine (Fermilab)
ED0013713 PIP-II_T...
11:45 AM → 12:00 PM Discussion and Questions 15m
12:00 PM → 1:00 PM Lunch 1h
1:00 PM → 1:45 PM Non-Invasive Beam Profile Monitor (BProM) systems 45m
Speaker: Vic Scarpine (Fermilab)
ED0013714 PIP-II_T...
1:45 PM → 2:00 PM Digital Electronics platform 15m
Speaker: Craig Drennan (Fermilab)
210915 PDR Digital ...
2:00 PM → 2:15 PM Front End System 15m
Speaker: John Diamond
PIP2 DAQ and IOC S...
2:15 PM → 2:35 PM Safety, Reliability, Quality, and Programmatic Aspects 20m
Speaker: Aisha Ibrahim (FNAL -AD/INST)
Supporting Docs
2:35 PM → 3:05 PM Discussion and Questions 30m
3:05 PM → 4:05 PM Committee Executive Session 1h
Wednesday, 22 September
9:00 AM → 10:30 AM Executive Session 1h 30m
10:30 AM → 10:50 AM Closeout 20m

I. Introduction: Review Coordinator
   a. [To replace tip text (such as this) with your own, just select a paragraph and start typing.]
   b. [For best results when selecting text to replace, don't include space to the left or right of the characters in your selection.]

II. Presentation XYZ: Presenter Name
   a. [Primary Review Content Overview. E.g. organization, requirements, cost & schedule, etc.]

III. Presentation XYZ: Presenter Name
   a. [Technical Content]

IV. Presentation XYZ: Presenter Name
   a. [Technical Content]

V. Presentation XYZ: Presenter Name
   a. [Safety, QA, Risk Analysis, etc.]

VI. Closeout – Review Chair
   a. [Summary Statement]
   b. [Preliminary Findings]
   c. [Preliminary Comments]
   d. [Preliminary Recommendations]

3. Review Charge Statement

The reviewers are asked to perform a Preliminary Design Review of the all the beam instrumentation systems needed for PIP-II.

The technical scope to be reviewed includes:

- Overall soundness of technical designs,
- Alignment of preliminary designs with functional and technical requirements.

Specifically, the panel is asked to answer the following charge questions:

- Are the design requirements clearly stated and reasonable?
- Are the proposed system architectures and chosen technologies sound and viable?
- Are the designs' maturities at the preliminary design level (60%)

- Are the available technical drawings and documentation consistent with this level of design maturity?
- Are project risks and interfaces sufficiently identified?
- Has ESH, especially Prevention through Design, and Quality Control been properly and thoroughly addressed for this level of design?
- Is the cost and schedule presented generally reasonable and consistent with the technical scope presented?
- Does the committee recommend approval of the designs under review and endorse proceeding to Final Design?

4. Attendance List

List review attendees here, including committee, speakers, and prominent audience members. Remote attendees should be included and noted as remotely attending.

Name	Organization

5. Reference Documents

The documents listed below establish the framework for all technical reviews held during the PIP-II Project Lifecycle.

1	PIP-II Technical Review Plan – TC ED0008163
2	PIP-II Quality Assurance Plan DocDB # 142
3	PIP-II Systems Engineering Management Plan – TC ED0008164
4	PIP-II IESH Management Plan DocDB # 141
5	121.02 SRF and Cryo Systems Design Plan DocDB # 2605
6	121.03 Accelerator Systems Design Plan DocDB # 2599
7	121.04 Linac Installation and Commissioning Design Plan DocDB # 2581
8	121.05 Accelerator Complex Upgrades Design Plan DocDB # 2593
9	121.06 Conventional Facilities Design Plan DocDB # 2587
10	PIP-II Value Engineering Plan DocDB # 2830

The review coordinator should populate this following table with the document list for this review from their SDP.

Table 1 - Document Deliverables for this review from the System Design Plan

	Document Title	Status (preliminary, final, released)	Comments
1	PIP-II BI PRD	Final	
2	PIP-II BI FRS	Final	
3	BPM TRS		
4	BCM TRS		
5	BLM TRS		
6	Invasive BProM TRS		
7	Non-Invasive BProM TRS		
8	PIP-II BI Quality Control	Preliminary	
9	PIP2IT BI Final Report	Final	
10	PIP-II Master ICD		
11	PIP-II Parameters PRD	Final	
12	PIP-II Global Requirements Document	Final	
13	Design Basis		Not a document per se but the basis for these designs should be presented, preferably embedded in each presentation

6. Reviewed Document List

This section indicates which documents the committee reviewed as part of this review. The document list provided should match the documents identified in the relevant WBS L2 System Design Plan referenced above.

Table 2 - Documents presented at this Review

	Document Title	Status (preliminary, final, released)	Comments
1			

2			
3			
4			
5			
6			
7			
8			

Committee comments should note any of the following:

- Documents that were expected but not presented.
- Documents that were in a state not commensurate with the review in question (e.g. conceptual design documents at a final design review).
- Standard documentation that, in the committee's expert opinion, should have been in the SDP and presented but was not included.

7. Findings

Beam Current Monitor

NPCT's (DCCT's) and ACCT's are well understood commercial products and the instrumentation department has significant experience using them. Block diagrams presented of the system interfaces looked reasonable. ACCT droop compenstation is well understood.

Invasive BCM systems intercept all or part of the beam current and are ~~generally~~ biased to suppress secondary emission. Signal conditioning and biasing electronics has been demonstrated in PIP2IT. Given the similarities, the invasive BCM's may be able to use the same uTCA interface as the BLM system. ~~The 350kHz bandwidth requirement (**T-ED0013712-A011**) may be limited by detector and cable capacitance and input impedance. No information was presented on beam power limitations.~~ Two RWCM will be installed, one in the WFE and one at the end of the SCL. In the WFE, low beta will limit time resolution to ~0.563 $R/c\beta\gamma$ or 840ps for a 30mm aperture. This should be sufficient for bunch intensity but not bunch shape. ~~**(F-121.3.09-A014).**~~

Beam Position Monitor

The BPM receivers demonstrated in PIP2IT and presented here represent state of the art and should satisfy requirements as configured. These digital receivers can easily meet requirements for 0.1 deg absolute phase measurement. Phase measurement will be limited by the quality/stability of the RF reference signal and its distribution.
Switching to uTCA crates and using rear transition modules is a good choice. Given the success of the PIP2IT bpm's this interface has little risk.

Beam Loss Monitor

The BLM system consists of 235 radiation detectors and data acquisition electronics in 6 MTCA crates. Three types of radiation detectors are planned to use: ionization chamber (IC), PMT + scintillator (PMT), and neutron detectors (ND). A combination of IC, PMT and ND will be used at every location in SCL. Only ICs will be used in BTL.

CERN version is considered as the primary candidate for the IC. FRIB version is considered for the ND. A modified version of the Fermilab design is considered for the PMT. No vendor quotation is available for any of the detectors.

One ND loaned from FRIB, one Fermilab PMT and one Fermilab IC were tested at PIP2IT. None of the detectors showed any response to 2.1MeV beam. The ND and PMT detectors, but not the IC, showed good response to 25MeV beam. No x-ray background from the low beta cryomodule was detected.

A diagram of possible analog electronics design was presented. No real board has been built and tested.

No MPS interface and timing system interface was presented.

Invasive Beam Profile Monitor

Invasive beam profile monitors include 6 Allison type transverse emittance scanners, 26 2-wire scanners and 1 Feschenko type longitudinal profile monitor. No invasive devices are used in the SCL.

The low energy and medium energy Allison scanners were tested at PIP2IT and demonstrated good performance. The wire scanners were tested as well. Some cross-talk between the wires and opposite polarity background were observed, which is not uncommon for the MEBT conditions.

A standard Feschenko style device is considered but no vendor quote has been obtained.

Non-Invasive Beam Profile Monitor

Laser wire-based profile monitor systems were proposed for PIP-II since they cause no risk on superconducting cavities and the measurement can be conducted on the operational beam.

The proposed laser wire systems include 13 transverse profile monitors (1 at WFE, 11 along superconducting linac, 1 at the end of linac) and possibly one more longitudinal profile monitor at the WFE if it is not using the same light source as the transverse profile monitor. It is almost straightforward to also perform longitudinal profile measurement at all laser wire stations using the proposed pulsed light source. A successful completion of the project would realize the world's largest-scale laser-based non-invasive profile monitor system in an accelerator facility.

Preliminary studies of laser wire measurement have been carried out during the PIPII-IT project. Modeling/simulation of laser wire magnetic field and photo-detached electron detection are well conducted and this will benefit other groups of the field. A prototype laser wire setup has been developed and installed in MEBT and the proof-of-principle measurement results have been achieved.

While the overall technical approach and the preliminary designs are aligned with functional and technical requirements, the system scalability and signal-to-noise ratio based on the proposed laser

should be looked into more closely.

- Some Physics Requirements such as the "Longitudinal resolution 20ps/40ps" in Slide #8 seem to be too large

Digital Electronics

The MTCA standard is chosen for all beam instrumentation digital electronics. A minimum set is purchased to get experience with real hardware and formulate requirements for the digital cards. The digital cards design will be outsourced.

Comments

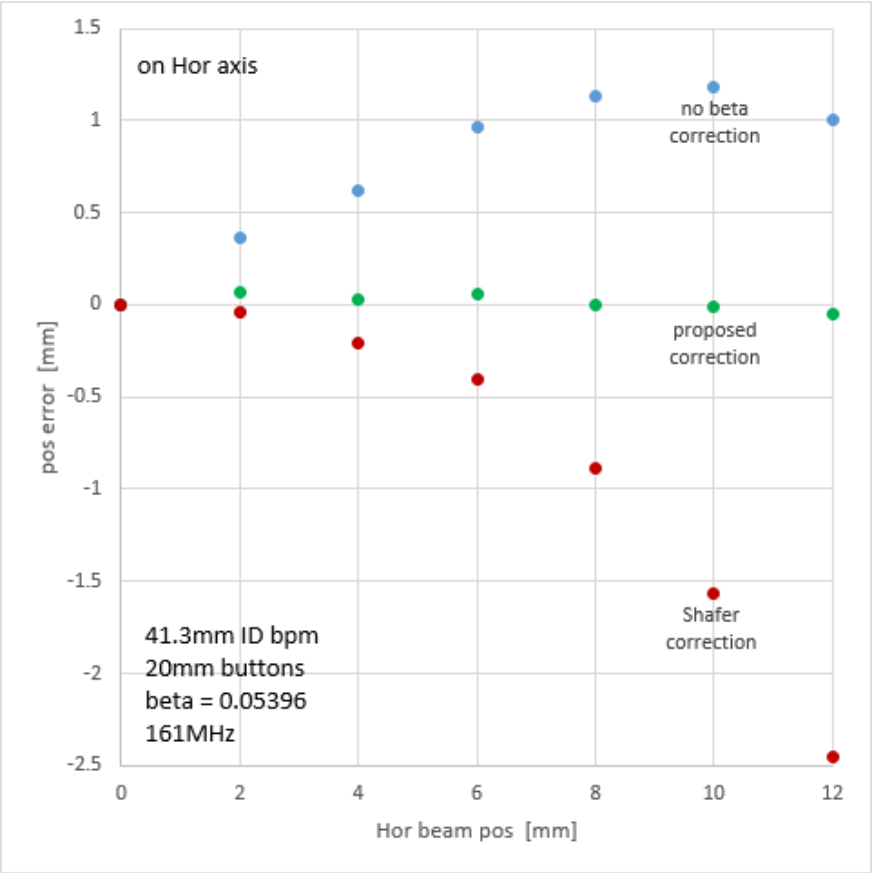
Beam Current Monitor

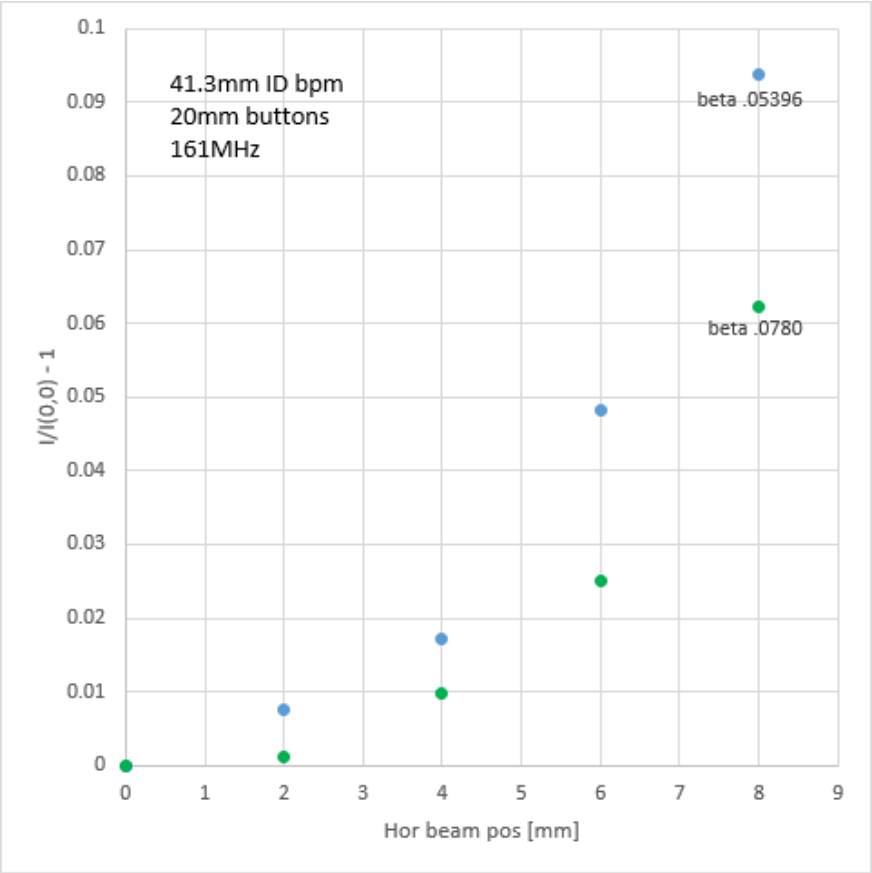
- It is assumed the percentage intensity accuracy requirement is of full scale.
- ACCT calibration and signal port polarity as well as correct labeling should be verified prior to installation.
- Using a separate raw analog signal for MPS may prove problematic. Generally, signal processing in the DSP is done to improve signal to noise ratio as well as properly scale signals to standard units. With separate pathways, both MPS and control system values will need separate

calibrations. Operators will be required to scale MPS thresholds to match numbers presented by the control system.
- The 350kHz bandwidth requirement for invasive BCM's (**T-ED0013712-A011**) may be limited by cable capacitance and detector input impedance.
- For the invasive BCM's, the review committee wants to confirm that only instantaneous beam loss is sufficient. (**F-121.3.09-A013**)
- No information was presented on invasive BCM beam power limitations.
- The RWCM, made in house, is adequate for measuring bunch intensities and thereby chopper efficiency using a sufficiently fast oscilloscope. In the WFE, low beta will limit time resolution to ~0.563 R/cβγ or 842ps for a 30mm aperture. This should be sufficient for bunch intensity but not bunch length. (**F-121.3.09-A014**) An EPICS application would facilitate processing and presenting information from the oscilloscope.

Beam Position Monitor

- Electromagnetic coupling between the high power rf distribution and high sensitivity BPM receivers could be problematic, particularly when both use the same frequency. Some problems where noted in PIP2IT. Evanescent coupling between cavities and BPM's through the vacuum pipe can also corrupt measurements.
- It's difficult to evaluate the Physics requirements as not all of the information was provided. Assuming position resolution is the rms variation in measurements with 2mA beam current averaged over a 10us window, that this average includes any effect of bunch patterns, and that the position and harmonic intensity accuracy is applicable over a sufficiently limited range of positions centered in the detector, then the BPM system should meet or exceed PRD requirements.
- Accounting for beta over the working aperture of a bpm may require more attention. For example, at beta = 0.054 in a 40mm bpm, the 1% amplitude requirement will be exceeded for beam positions greater than about 3mm. Using the Shafer beta correction for position, the 0.1mm position requirement will also be exceeded. See plots below showing position and intensity error versus beam position obtained from a CST Microwave Studio model:


on Hor axis
no beta correction
proposed correction
Shafer correction
41.3mm ID bpm
20mm buttons
beta = 0.05396
161MHz
pos error [mm]
Hor beam pos [mm]
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
0
2
4
6
8
10
12



- It is not clear that measuring both the 1st and 3rd harmonics in all bpm's will provide useful bunch length information. For example at 2.1MeV, the image current for a point charge on a 30mm aperture will be 840ps rms. In addition, it would require 750ps for the beam to travel the length of a 15mm diameter button. In the MEBT, bunches are expected to be 15° rms or 256ps. Bunches become shorter and BPM's larger moving down the linac. Measuring both harmonics at a few locations at higher energy (>100MeV) may make more sense. A 1st harmonic receiver could be modified to measure the 3rd harmonic and used in parallel for this purpose. This would provide a significant simplification in both hardware and software.

  An alternate approach for measuring bunch length is described in this paper:
  Shishlo, Aleksandrov, Liu, and Wang; "Measuring Longitudinal Beam Parameters in the Low Energy Section of the Oak Ridge Spallation Neutron Source Accelerator"; Phys. Rev. Accel. Beams; Vol. 21, Iss. 9, pg. 092803; 2018.
- Phase resolution in radians (with centered beam) can be estimated from the position resolution divided by the radius of the aperture. (30mm aperture and 10um resolution corresponds to 0.04 deg phase resolution)
  The bpm digital receivers can easily satisfy requirements for 0.1° absolute phase measurement. The measurement will be limited by the quality of the rf reference signal and its distribution. Using good quality identical type and length cables for the reference and bpm signals will reduce

errors from temperature and aging. This would require a reference distribution in the tunnel. Tolerance and stability of the bpm receiver input impedance is equally important.

- Requirements for the RF reference should be developed to insure total phase stability and noise is sufficiently low to allow bpm's to meet bpm requirements. In order to conserve the SNR of the ADC, the reference clock jitter must be less than:

$$t_{jitter} < \frac{1}{2\pi f_{sig}} \frac{1}{2^{ENOB}\sqrt{\frac{3}{2}}}$$ = 0.2ps for 12 bit ENOB at 162.5MHz

LDF2-50 cable (3/8") has the best temperature stability of all heliax sizes. Near room temperature it ranges over ±2 ppm/C. For the 220m length of the linac, that becomes ±0.1deg/C at 162.5MHz. The entire phase accuracy would be used up with a 1deg temperature change. Some labs have proposed two parallel cables to allow measurement and compensation for the round trip delay. Careful attention must be paid to terminating impedances and the effect of tapping the signal as well as physical stability and integrity

- The bunch by bunch position measurement using a fast oscilloscope looks useful for establishing and maintaining optimum kicker performance. The RWCM could perhaps share this dedicated oscilloscope. Both would benefit from an EPICS interface.
- Although not mentioned in the physics requirements, the 1us waveform data should prove useful.
- I'm not sure if calibration ports are useful for that purpose. However, they can provide a means of verifying bpm cables and connections by driving one port and measuring coupling between buttons.

Beam Loss Monitors

- The choice of the radiation detector types does not seemed to be well justified. Number of neutron detectors seems to be rather large. They are certainly useful at low energy but do not give any significant advantage at >100MeV energy. Consider reducing number of NDs in favor of IC to reduce cost.
- The same can be true for the PMT based detectors. It is likely that the minimum detectable losses will be determined by the x-ray background from the high gradient RF cavities but not by the detector sensitivity. At least this is the case for SNS. Consider replacing most of the PMTs with ICs.
- There is no plan how on to deal with the x-ray background. The PIP2IT experience of low background is not a good argument as the low beta cavities typically have low gradient.
- It can be dangerous to rely on using the timing system gates for MPS related BLM functions, especially in the case of PIP-II CW RF and ion source. Beam pulse can be triggered when not expected by the BLM system if the chopper timing system fails. The protection logic should be carefully thought out and reviewed.

- We were told at a separate meeting that the differential beam current measurements are planned as the primary mechanism for protection from the beam spill. This is not consistent with <1W/m beam spill requirements and typical BCM resolution of >1%. This must be clarified.

- The detectors and vendors selection should be done ASAP as the cost and lead time can be a big surprise.

Invasive Beam Profile Monitor

- A possibility of adding a diagonal wire to several BTL wire scanners is considered to facilitate x-y coupling measurements. This requires significant modification of the mechanical hardware design to add one more vacuum feedthrough and adding additional DAQ channels. Considering the large number of wire scanners in the BTL, a possible compromise solution is to preserve 2-wire design but replace the horizontal or vertical wires with diagonal on some of them. Several x-d, y-d sets should be sufficient to measure the coupling. There is no physics reason to measure all three x-y-d at the same location.
- Consider vendors other than the Institute of Nuclear Physics for the Bunch Shape Monitor. For example, a domestic company Radiabeam is developing a design capable of measuring the longitudinal emittance if it can be installed at a position with sufficiently large dispersion function.

Non-Invasive Beam Profile Monitor

- As observed in the prototype laser wire system, the small laser peak power (<1 kW) leads to a very low photo-detachment efficiency (< 10^{-5}), which was the major cause for a noisy FC output. Even with the lock-in detection scheme, the achievable dynamic range was lower than 10. A drawback of the lock-in detection system is its long measurement time. A light source with more than two orders of magnitude higher peak power might be needed to produce a reasonable measurement quality.
- A comparison between fiber-based and free space systems should be made on the system complexity, cost, measurement performance, and operation procedure. In particular, the option of diode-pumped solid-state macro-pulse laser amplifier scheme should be investigated as it provides necessary laser power and pulse structure for the PIP-II BI requirement. Such laser amplifier systems might be commercially available.
- In Slide #12, the statement "The free-space optics at each laserwire station shall keep the maximum average optical power density on the vacuum viewports to less than 3 W/cm^2" should not apply in the current case. For 10 ps pulsed lasers, the laser induced damage threshold on the fused-silica optical windows is >100 mJ/cm^2 (or > 10 GW/cm^2) at a wavelength of ~ 1 um.
- Having multiple optical lenses around the measurement station such as the optical setup in Slide #18, could accidently form in a focused spot on the vacuum windows. When a more powerful light source is to be used, there should be only one lens in the scanning box.

Digital Electronics

- The microTCA crates seem to be a good choice and the reviewers are happy to see the team working on these.
- EPICS seems to be an appropriate choice of controls system.

8. Recommendations

Items that require formal action and closure in writing prior to receiving approval to move into the next phase of the project, or items that require formal action and closure in writing prior the next review.

- Beam Current Monitor
  - No recommendations
- Beam Position Monitor
  - Specify beam conditions and assumptions for the requirements presented.
  - Requirements for the RF reference need to be written out.
- Beam Loss Monitor
  - Develop a document describing operation of the BLM system protection function including the MPS interface, timing diagram, and X-ray background discrimination.
- Invasive Beam Profile Monitor
  - No recommendations
- Non-Invasive Beam Profile Monitor

  - Need to resolve issue with the noisy signal (lower dynamic range due to lower laser power).
  - Do a performance and cost comparison between fiber transport line and the free space transport line. This could help make the decision between the 2 systems.
- Digital Electronics
  - No recommendations

9. Response to Charge Questions

If the charge is written in the form of questions, duplicate them and directly respond to them here. These responses should reference the relevant recommendations/comments/findings as appropriate.

1. Are the design requirements clearly stated and reasonable?
   a. Beam Current Monitor - Yes
   b. Beam Position Monitor – Yes~~, but see recommendation.~~
   c. Beam Loss Monitor - Yes
   d. Invasive Beam Profile Monitor - Yes
   e. Non Invasive Beam Profile Monitor - Yes
   f. Digital Electronics – Yes
   g. Front End system - Yes
   h. Safety, Reliability, Quality, programmatic aspects – N/A

2. Are the proposed system architectures and chosen technologies sound and viable?
   a. Beam Current Monitor – Yes
   b. Beam Position Monitor – Yes
   c. Beam Loss Monitor - Yes, see recommendation
   d. Invasive Beam Profile Monitor - Yes
   e. Non Invasive Beam Profile Monitor - Yes, see recommendation
   f. Digital Electronics – Yes
   g. Front End system - Yes

3. Are the designs' maturities at the preliminary design level (60%)
   a. Beam Current Monitor - Yes
   b. Beam Position Monitor – Yes
   c. Beam Loss Monitor – No, see recommendation
   d. Invasive Beam Profile Monitor - ~~yes~~ Yes
   e. Non Invasive Beam Profile Monitor - Yes, see recommendation
   f. Digital Electronics – Yes
   g. Front End system - Yes
   h. Safety, Reliability, Quality, programmatic aspects – n/a

4. Are the available technical drawings and documentation consistent with this level of design maturity?
   a. Beam Current Monitor - Yes
   b. Beam Position Monitor – Yes

c. Beam Loss Monitor – No, see recommendation
d. Invasive Beam Profile Monitor - Yes
e. Non Invasive Beam Profile Monitor - Yes, see recommendation
f. Digital Electronics – Yes
g. Front End system - Yes
h. Safety, Reliability, Quality, programmatic aspects – na

5. Are project risks and interfaces sufficiently identified?
    a. Beam Current Monitor - Yes
    b. Beam Position Monitor – Yes
    c. Beam Loss Monitor – Yes, see recommendation
    d. Invasive Beam Profile Monitor - Yes
    e. Non Invasive Beam Profile Monitor - Yes, see recommendation
    f. Digital Electronics – Yes
    g. Front End system - Yes
    h. Safety, Reliability, Quality, programmatic aspects – Yes

6. Has ESH, especially Prevention through Design, and Quality Control been properly and thoroughly addressed for this level of design?
    a. Beam Current Monitor - Yes
    b. Beam Position Monitor – Yes
    c. Beam Loss Monitor - Yes
    d. Invasive Beam Profile Monitor - Yes
    e. Non Invasive Beam Profile Monitor - Yes
    f. Digital Electronics – Yes
    g. Front End system - Yes
    h. Safety, Reliability, Quality, programmatic aspects – Yes

    i.

7. Is the cost and schedule presented generally reasonable and consistent with the technical scope presented?
    a. Beam Current Monitor - Yes
    b. Beam Position Monitor – Yes
    c. Beam Loss Monitor – Yes, see recommendations.
    d. Invasive Beam Profile Monitor - Yes
    e. Non Invasive Beam Profile Monitor - Yes
    f. Digital Electronics – Yes
    g. Front End system - Yes
    h. Safety, Reliability, Quality, programmatic aspects – na

8. Does the committee recommend approval of the designs under review and endorse proceeding to Final Design?
    a. Beam Current Monitor – Yes, but see recommendations
    b. Beam Position Monitor – Yes

c. Beam Loss Monitor – Yes, but see recommendations
d. Invasive Beam Profile Monitor - Yes
e. Non Invasive Beam Profile Monitor - Yes, but see recommendations.
f. Digital Electronics – Yes
g. Front End system – Yes
h. Safety, Reliability, Quality, programmatic aspects – Yes

10. Value Engineering Opportunities

Value Engineering (VE) opportunities are often discovered during conceptual and preliminary design reviews. The Review Committee will consider Value Engineering in their assessment of the reviewed materials proposed design and provide a list of suggested opportunities below. The PIP-II Project established a *PIP-II Value Engineering Plan* to support this effort [10]. VE opportunities are not intended to be recommendations. Recommendations are captured in Section 9 above. If no VE opportunities are identified, please indicate.