PIP2IT HEBT Final Design Review Charge

Document number: ED0009237

Document Approval

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*Approvals managed via Fermilab Teamcenter Workflows.*

*Non-Teamcenter Users will provide approvals via e-mails recorded in Teamcenter.*

Revision History

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| Revision | Date Release | Originator:  Role: | Description of Change |
| - |  | L. Prost WFE Manager | Initial release |
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*Revision control is managed via Fermilab Teamcenter Workflows.*

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# Introduction

The PIP-II Injector Test facility (PIP2IT) is an integrated system test of the front-end of the PIP-II superconducting linac. The injector includes a Warm Front-End section (WFE) and 2 superconducting RF cryomodules (Half-Wave Resonator (HWR) and prototype Single-Spoke Resonator Type I (protoSSR1)). The WFE, installed at the Cryomodule Test Facility (CMTF), has been extensively studied and has demonstrated that it was capable of delivering a beam with properties consistent with those defined in the Preliminary Design Report (PDR). Meanwhile, the cryomodules’ fabrication is on-going and the PIP2IT cave is being outfitted to receive them.

For assessing the cryomodules’ performance with beam, a High Energy Beam Transfer line (HEBT) is needed downstream to measure the properties of the accelerated beam and safely dispose of it into a high-power dump.

This PIP2IT HEBT Final Design Review (FDR) is intended to evaluate the overall design of the HEBT. This design has been developed in accordance to the HEBT Technical Requirements Specification (TRS) document [1] and within the following constraints and guidelines (which will be discussed in some detail during the review):

* The HEBT is a temporary beam line and will not be part of the PIP-II linac
  + The expected duration of the beam run with the HEBT installed downstream of the two cryomodules is currently 6 months
  + Some of the components (e.g. diagnostics) might be re-used in diagnostics lines at PIP-II, currently assumed to be temporary as well and for use during beam commissioning only
* The HEBT should use as much existing equipment as possible
  + The focusing and steering elements to be used are those destined for the PIP-II MEBT
  + Beam instrumentation used in the MEBT, and not part of its final configuration, should be relocated in the HEBT, if found adequate for measuring the beam properties after acceleration to 20‑25 MeV
  + The HEBT will use the “SNS dump” as its high-power dump
    - The HEBT design has to include a proper radiation shielding assessment and radiation shielding design for the dump, accordingly
    - The HEBT beam optics design should emphasize (passively) preventing tight focusing of the beam at the location of the beam dump
* The HEBT design shall allow conducting the beam measurements listed in Ref. [2]

Thus, the expected outcome of the PIP2IT HEBT FDR is the recommendation to proceed with the fabrication and/or procurement of all the components not currently owned, followed by the installation of the complete beam line at CMTF, allowing cryomodule testing with beam thereafter.

# Review Agenda

| PIP2IT HEBT Final Design Review Agenda |
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| Location: | AD/Huddle |
| Date: | Wednesday, February 13, 2019 |
| Time:  Indico Site:  Participants: | 08:00-12:30  <https://indico.fnal.gov/event/19475/>   |  |  |  | | --- | --- | --- | | Lionel Prost lprost@fnal.gov | AD/ACCEL\_SYS/SCL | Role: Coordinator, Presenter | | Phil Adamson pa@fnal.gov | AD/ACCEL\_SYS/MID/GRP | Role: Chair | | C.Y. Tan cytan@fnal.gov | AD/ACCEL\_SYS/PROTON | Role: Reviewer | | Lucy Nobrega lnobrega@fnal.gov | AD/ENG/MSD | Role: Reviewer | | Leonardo Ristori leoristo@fnal.gov | APS-TD/SRF/DEV/PS | Role: Reviewer | | Alex Chen alexchen@fnal.gov | AD/ENG/MSD/PROJENG | Role: Presenter | | Vic Scarpine scarpine@fnal.gov | AD/ENG/INST/G2 | Role: Presenter | | Rich Andrews andrews@fnal.gov | AD/ACCEL\_SYS/SCL | Role: Presenter | | Alexander Shemyakin shemyakin@fnal.gov | AD/ACCEL\_SYS/SCL | Role: Presenter | | Steve Wesseln wesseln@fnal.gov | AD/ENG/MSD/CAD | Role: CAD Support | |  |  |  | |

Agenda details:

## Introduction (*Lionel Prost*) 25’

### Introduction to PIP-II and PIP-II Injector Test (PIP2IT)

### Charge and Scope of the review

#### Agenda for the review

## HEBT beam line overview (*Sasha Shemyakin*) 45’

### PIP2IT in its final configuration

### HEBT specifications and scheme

### HEBT in operation

### Measurements intended to be carried out

## Vacuum design (*Alex Chen*) 30’

### Configuration

### MolFlow+ simulation

### Vacuum protection test results

## Beam line mechanical design (*Rich Andrews*) 30’

### Particle-free assembly and installation

## Plan for diagnostics (*Vic Scarpine*) 20’

### List of existing diagnostics

### Performance at high-energy

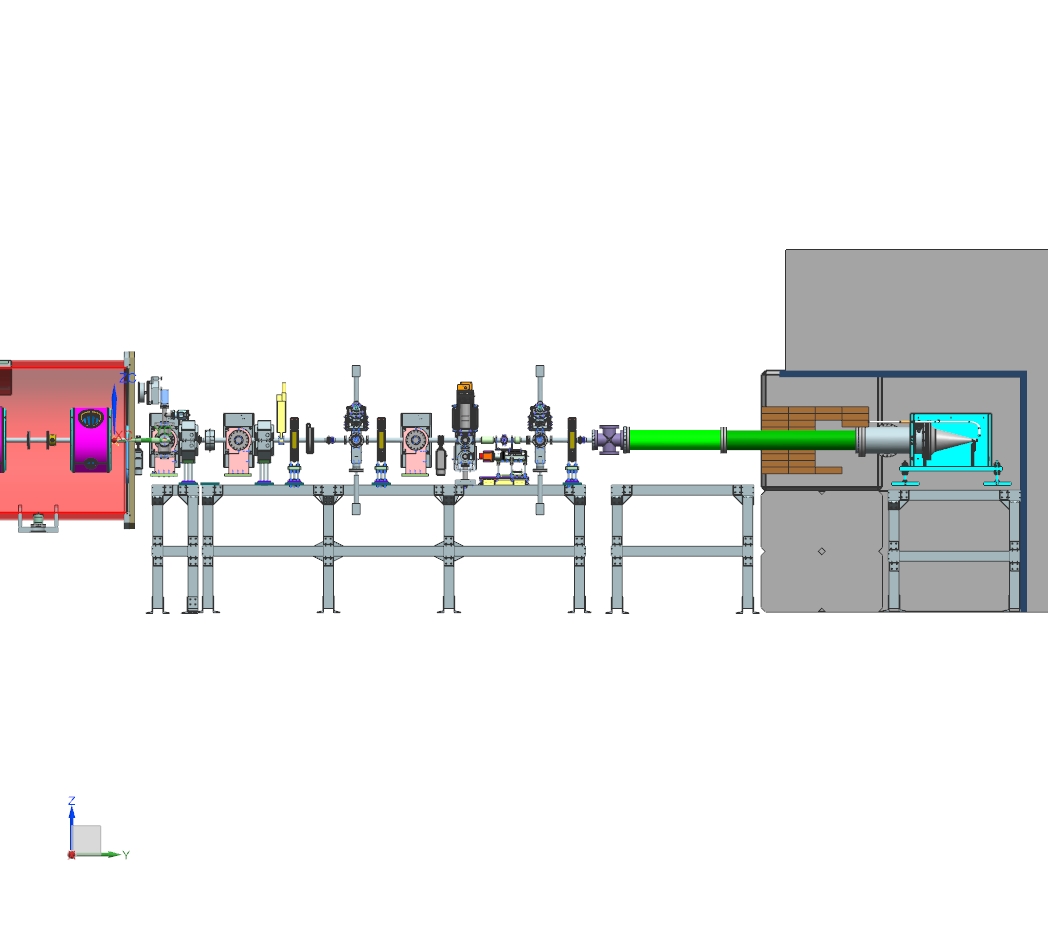
## Closeout (*Phil Adamson – Review Chair*)

### Preliminary Findings, Comments & Recommendations

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# Review Charge Statement

The HEBT design (Figure 1) includes a pair of transverse focusing elements (quadrupoles), dipole correctors (horizontal/vertical steering), a suite of beam diagnostics and a beam dump. There are several vacuum pumping stations (currently 3, with the possibility of adding another one later on the 4-way cross vacuum chamber) along with a couple of vacuum valves (one ‘slow’ and one “Fast Acting Valve”). Beam diagnostics include Beam Position Monitors (BPM), an AC Current Transformer (ACCT), a Time-of-Flight BPM (TOF BPM), a Resistive Wall Current Monitor (RWCM) and a Fast Faraday Cup (FFC). There are a couple of vacuum chambers that may host either wire scanners or a double-slit emittance scanner, or possibly both. Provision is made for the possibility of installing a diamond detector (for beam loss and halo characterization), a laser wire - should a prototype be available - and a Feschenko-style Beam Shape Monitor (BSM).



Pumping station

Quadrupole

ACCT

Fast Acting Valve

RWCM

Dipole correctors

FFC

TOF BMP

Dump shielding (a.k.a. dog house)

High-power dump

Quadrupole

Pumping station

Pumping station

Dipole correctors

Figure 1: 3D Model of the HEBT (not showing the diamond detector assembly nor the BSM). A vacuum cross for a low-power faraday cup is also shown (just downstream of the last dipole correctors, before the large vacuum pipe (in green)).

The committee is requested to review the HEBT as a whole and to comment on the rationale that lead to the proposed beam optics solution. Furthermore, the committee is expected to assess the vacuum design of the beam line, in particular in the vicinity of the cryomodule. We also would like the committee to examine the adequacy of the diagnostics chosen to carry out the measurements listed in Ref. [2], and comment on whether additional *formal* reviews for any of the sub-systems that do not already exist are necessary or not.

Note that the review of the radiation shielding for the PIP2IT cave, including shielding of the beam dump, is not part of this Final Design Review of the HEBT. It is addressed separately, and the proper Radiation Shielding Assessment is being generated accordingly to the procedures established in the Fermilab Radiological Control Manual (FRCM). However, general comments are welcome if deemed necessary by the committee.

More specifically, we would like the committee to consider the following questions:

1. Is the optics design sufficiently mature to satisfy the specifications [1]?
   1. Is the design sufficiently optimized to conduct the measurements listed in Ref. [2]?
      1. Are the diagnostics appropriate, properly located and in enough quantities?
         1. Are the instruments dedicated to protecting the beam line adequate?
      2. Which instruments are absolutely needed to properly carry-out those measurements and are they mature enough to approve the HEBT design?
   2. Does the design appropriately address concerns about controlling the power density deposited into the beam dump (and avoiding damaging the dump)?
2. Is the vacuum design likely to meet the performance expectations?
   1. Is the vacuum protection scheme adequate in order to protect the upstream cryomodules from irreparable damages in case of a failure (e.g. joint failure between the beam tube and the beam dump)?
   2. Are the measures in place to prevent contamination of the superconducting surfaces adequate?
      1. During installation, operation and maintenance
3. Have installation issues been adequately addressed?
   1. Was maintenance/servicing of the HEBT taken into account appropriately?
      1. Was the possibility for residual radiation addressed, in particular for servicing/repairing the beam dump?
4. Are all necessary design specifications and requirements documents complete or near completion?
5. Have the critical documents for the HEBT beam line (e.g. FRS, some key drawings) been reviewed, approved and released?
6. Is the level of maturity of the design and associated drawing packages sufficient to proceed?
7. Are there any other issues that have been identified and need to be addressed?

From this review, we seek from the Review Committee the recommendation to proceed with the fabrication of the HEBT and associated sub-systems.

The Review Committee is kindly asked to submit a Final Design Review Report no later than 2 weeks after the conclusion of the review. A Review Report template will be provided.

# Acronyms

|  |  |
| --- | --- |
| ACCT | AC Current Transformer |
| BPM | Beam Position Monitor |
| BSM | Beam Shape Monitor |
| CMTF | Cryomodule Test Facility |
| EPDM | Engineering Process Data Management |
| FDR | Final Design Review |
| FRCM | Fermilab Radiation Control Manual |
| FRS | Functional Requirement Specification |
| HEBT | High Energy Beam Transport |
| HWR | Half-Wave Resonator |
| MEBT | Medium Energy Beam Transport |
| PDR | Preliminary Design Report |
| PIP-II | Proton Improvement Plan-II |
| PIP2IT | PIP-II Injector Test |
| RF | Radio Frequency |
| RWCM | Resistive Wall Current Monitor |
| SSR1 | Single-Spoke Resonator Type I |
| TC | Teamcenter |
| TOF | Time-of-Flight |
| TRS | Technical Requirements Specification |
| WFE | Warm Front End |

# Reference Documents

Below is a list of documents that serve as references for the review. Additional documents may be added to this list up to 1 week prior to the date of the review.

Note that TC ‘Documents’ are in fact TC “Items”, which may contain more than one document. In particular, the material shown during the review (e.g.: slides), some supporting documentation and the Review Report are all located within the Final Design Review Teamcenter Item # ED0009237 [0].

**Teamcenter Documents**

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| --- | --- |
| 0 | PIP2IT HEBT Final Design Review, TC# ED0009237   * Review charge * Slides of presentations * Selection of drawings for the review (pdf) * Notes on HEBT diagnostics * Draft (advanced) Hazard Analysis Report * Description of the lattice file (and configuration file to run TraceWin) |
| 1 | PIP2IT HEBT Technical Requirements Specification, TC# ED0008220 |
| 2 | Measurements to be conducted in the High Energy Beam Transport (HEBT) line of the  PIP-II Injector Test (PIP2IT), TC# ED0008280 |
| 3 | Producing Very Low-Particulate UHV Components, TC# ED0003571-B |
| 4 | Prototype Particle Safe Vacuum Cart Operation, TC# ED0000373-A |
| 5 | MEBT BPM EPDM, TC# ED0001310 |
| 6 | MEBT BPM FRS, TC# ED0001309/ED0003675 |
| 7 | Wire-scanner FRS, TC# ED0004340 |
| 8 | Slit/Slit emittance scanner FRS, TC# ED0008473 |
| 9 | TOF BPM FRS, TC# ED0004201 |
| 10 | HEBT Risk Analysis, TC# ED0008219 |
| 11 | Fast Faraday Cup FRS, TC# ED0004200 |
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**PIP-II DocDB Documents**

Technical meeting presentations

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| --- | --- |
| 11 | Temporary High Energy Beam Transport line, HEBT-0, PIP-II DocDB# 277 |
| 12 | Proposal for the HEBT design, PIP-II DocDB# 1648 |
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**Drawings (*assembly level*)**

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| F10001768 | HEBT beam line assembly |
| F10015688-A | Vacuum chambers for diagnostics |
| F10042979 | MEBT correctors package |
| F10021417 | MEBT triplet assembly with vacuum chamber and BPM |
| F10021423 | MEBT doublet assembly |
| F10039331 | TOF monitor assembly |
| F10031000 | FFC assembly |
| F10018276 | BPM assembly |
| F00484270-A | RWCM assembly |