PIP-II BTLBA Collimators Final Design Review Report

Document number: ED000xxxx

Document Approval

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| Name: Kevin Duel  Org: Fermilab  Contact: kduel@fnal.gov  Role: Committee Member | 25 October 2022 |
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Revision History

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| Revision | Date Release | Originator:  Role: | Description of Change |
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*Revision control is managed via Fermilab Teamcenter Workflows.*

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# Introduction

PIP-II Beam Transfer Line and Beam Absorber (BTLBA) will deliver a Horizontal and a Vertical beamline collimator each capable of removing up to 1% of the beam tail. The transport will reflect these edges as cuts in the H & V plane of the distribution at the injection foil location for Booster injection. Figure 1 gives the base of the horizontal and vertical collimator respectively. The collimators will be fabricated and assembled at Fermilab.

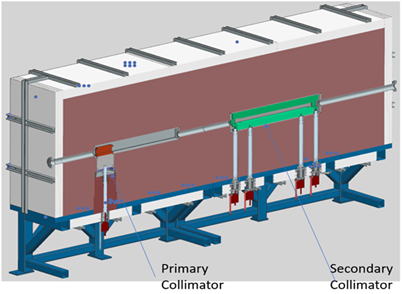
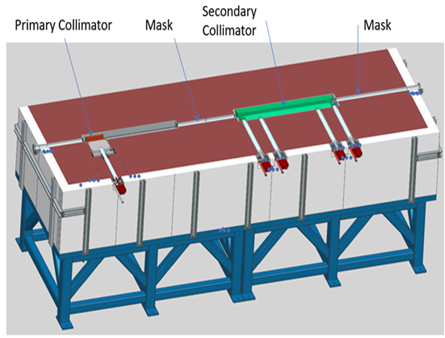


Fig. 1: Models of the BTLBA Collimators. Horizontal collimator on the left and vertical collimator on the right.

# Review Agenda

| BTLBA Collimators FDR Review Agenda |
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| --- | --- |
| Location: | Zoom only |
| Date: | 4-October 2022 |
| Time:  Indico Site: | 09:00-16:00  https://indico.fnal.gov/event/24090/ |

Participants:

|  |  |  |  |
| --- | --- | --- | --- |
| Ioanis Kourbanis | Fermilab | ioanis@fnal.gov | Role: L2 Manager |
| Meiqin Xiao | Fermilab | meiqin@fnal.gov | Role:Coordinator/L3 manager/Presenter |
| Chris Becker | Fermilab | csbecker@fnal.gov | Role: Presenter |
| Bruce Brown | Fermilab (SE) | bcbrown@fnal.gov | Role: Review Chair |
| Kevin Duel | Fermilab | kduel@fnal.gov | Role: Reviewer |
| William S. Higgins | Fermilab | higgins@fnal.gov | Role: Reviewer |
| Dave Johnson | Fermilab | dej@fnal.gov | Role: Presenter |
| Raul Campos | Fermilab | rcampos@fnal.gov | Role: Presenter |
| Vladimir Sidorov | Fermilab | sidorov@fnal.gov | Role: Presenter |
| Dali Georgobiani | Fermilab | dgeorgob@fnal.gov | Role: Presenter |
| Jean-Francois Ostiguy | Fermilab | ostiguy@fnal.gov | Role: Presenter |
| Denton Morris | Fermilab | dmorris@fnal.gov | Role: Presenter |

Agenda details:

1. PIP II Review Introduction (Chris Becker) - 10 min
2. AccU-BTLBA the BTL CollimatorsIntroduction (Meiqin Xiao) - 10 min
3. Collimation Requirements (David Johnson) - 20 min
4. Placement of collimators (Jean-Francois Ostiguy) - 15 min
5. Mechanical design-3-D model (Vladimir Sidorov) - 35 min
6. MARS Calculations (Dali Georgobiani) - 25 min
7. ANSYS Calculations (Raul Campos) - 25 min
8. Assembly Procedure (Vladimir Sidorov) - 25 min
9. Installation Plan (Denton Morris) - 15 min

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# Review Charge Statement

The reviewers are asked to perform a Final Design Review of the BTLBA Colimators.

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

1. Are the requirements documented, clear, complete, and appropriate?
2. Is the proposed design for the BTLBA Collimators likely to meet requirements? Explain any deficiencies or concerns.
3. Are there any features present (or absent) that threaten the intended function and performance of this design?
4. Are the connections and interfaces of the collimators well understood?
5. Have safety and environmental aspects been appropriately considered?
6. Have quality aspects been appropriately considered?

The intended outcome of the review:

* Collect and document findings, comments, and recommendations necessary to proceed to the construction of the BTLBA Collimators.

# Attendance List

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

|  |  |
| --- | --- |
| Name | Organization |
| Bruce C. Brown | Fermilab (Scientist Emeritus) |
| Kevin Duel | Fermilab |
| William S. Higgins | Fermilab |
| Chris Becker | Fermilab |
| Lidija Kokoska | Fermilab |
| Thomas Digrazia | Fermilab |
| Ioanis Kourbanis | Fermilab |
| Meiqin Xiao | Fermilab |
| Dave Johnson | Fermilab |
| Jean-Francois Ostiguy | Fermilab |
| Vladimir Sidorov | Fermilab |
| Dali Georgobiani | Fermilab |
| Raul Campos | Fermilab |
| Denton Morris | Fermilab |
| Zuxin Chen | Fermilab |
| Michael Geelhoed | Fermilab |

# 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](https://pip2-docdb.fnal.gov/cgi-bin/private/ShowDocument?docid=142) |
| 3 | PIP-II Systems Engineering Management Plan – TC ED0008164 |
| 4 | PIP-II IESH Management Plan DocDB # [141](https://pip2-docdb.fnal.gov/cgi-bin/private/ShowDocument?docid=141) |
| 5 | 121.02 SRF and Cryo Systems Design Plan DocDB # [2605](https://pip2-docdb.fnal.gov/cgi-bin/private/ShowDocument?docid=2605) |
| 6 | 121.03 Accelerator Systems Design Plan DocDB # [2599](https://pip2-docdb.fnal.gov/cgi-bin/private/ShowDocument?docid=2599) |
| 7 | 121.04 Linac Installation and Commissioning Design Plan DocDB # [2581](https://pip2-docdb.fnal.gov/cgi-bin/private/ShowDocument?docid=2581) |
| 8 | 121.05 Accelerator Complex Upgrades Design Plan DocDB # [2593](https://pip2-docdb.fnal.gov/cgi-bin/private/ShowDocument?docid=2593) |
| 9 | 121.06 Conventional Facilities Design Plan DocDB # [2587](https://pip2-docdb.fnal.gov/cgi-bin/private/ShowDocument?docid=2587) |
| 10 | PIP-II Value Engineering Plan DocDB # [2830](https://pip2-docdb.fnal.gov/cgi-bin/private/ShowDocument?docid=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 |
| BTLBA Collimators FRS | Final |  |
| BTLBA Collimators TRS | Final |  |
| BTLBA Collimators ISD | Final |  |
| Prevention through Design | Final |  |
| BTLBA Collimators FMEA |  |  |
| BTLBA Collimators Risk Assessment | Final |  |
| 3-D BTLBA Collimators model |  | Talk |
| BTLBA Collimators ANSYS calculations |  | Talk |
| BTLBA Collimators MARS Calculations |  | Talk |
| BTLBA Collimators Assembly Plan |  | Talk |
| BTLBA Collimators Installation Plan |  | Talk |
| BTLBA Collimators QA Plan | Final |  |

# 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 |
| BTLBA Collimators FRS | Final |  |
| BTLBA Collimators TRS | Final |  |
| BTLBA Collimators ISD | Final |  |
| Prevention through Design | Final |  |
| BTLBA Collimators FMEA |  |  |
| BTLBA Collimators Risk Assessment | Final |  |
| 3-D BTLBA Collimators model |  | Talk |
| BTLBA Collimators ANSYS calculations |  | Talk |
| BTLBA Collimators MARS Calculations |  | Talk |
| BTLBA Collimators Assembly Plan |  | Talk |
| BTLBA Collimators Installation Plan |  | Talk |
| BTLBA Collimators QA Plan | Final |  |

# Findings

General, factual observations about material presented which require no response.

A design for the BTLBA Collimators was presented which is designed to optimize the 800 MeV H- beam for stripping at the carbon stripping foil in the Booster. Larger emittance tails of the beam from one horizontal and one vertical side will be removed such that of up to 1% of the beam power will be scraped in each of the two collimators. Using a phase trombone, the phase from the collimator to the stripping foil will be adjusted to align the collimated edges with the open edges of the foil.

Regarding the design of vacuum parts::

* The presentation slides were updated with thermal FEA results for the primary vacuum chamber, which receives nearly the same amount of power as the secondary jaws. No issues with temperatures and thermal expansion are noted.
* Alignment of the plunger ports on the vacuum chambers during welding was noted as critical during the review. Misalignment could result in interference, binding, or additional friction with the plungers and guides. Fixtures to aid with alignment during the fabrication process are planned to be made.

The plan for installing the top shielding pieces was discussed during the review. Tapped holes for lifting eyes will be added to those pieces and a more detailed installation plan will be developed as the design work is finalized and the installation date approaches.

The thermal analysis used as input the MARS energy deposition with a 250 W beam loss to conservatively cover a design loss of 170 W. The MARS calculation showed that about 18% of the power of the beam lost in the collimator was not captured in the collimator to deliver heat to the collimator material. The thermal analysis conservatively added back that 18% by scaling up the MARS results. The steady state results are based on free convection from the external faces of the collimators.

# Comments

Observations with value judgments, or “soft” recommendations that require action by the design/engineering team, but where a formal written response is not requirement.

By designing the collimators to have interactions take place well inside the shield, one can minimize the external radiation.  By providing collimator jaws which are parallel to the beam envelope at the design emittance fraction, rather than parallel to the beam centerline, one can enhance the fraction of beam which interacts at the design interaction point near the upstream end of the collimator while minimizing possible out-scatter.  This may be less important for the primary collimator in this design since it is so short, and less important for the secondary since it will only see secondary (or highly scattered primary) beam.  Nevertheless, we comment that this should be considered since it adds no significant cost.

Dali Georgobiani's presentation "MARS Calculations" documents the effects of air activation due to the operation of the BTL collimators, which contribute about 14% of the air activity produced by the PIP-II/BTL complex. These estimates used assumptions about parameters that affect radionuclide activity in released air, such as volume of air in the enclosure, transit time, and air release rate.  As the BTL enclosure is constructed and the collimators are installed, care should be taken to check that these assumptions remain valid for the system as built. Or, if as-built parameters differ, estimates of activity must be updated to reflect changes.

It is suggested to update the FRS section 7 with FESHM Chapter 5100 Structural Safety in the list of FESHM requirements.

Based on prior collimator installation experience it is suggested to use generously oversized holes in the floor plates to allow for misalignment of the stands with respect to the concrete anchors. This is particularly important if the anchors are installed prior to the stand being set and aligned. The collimator stand design calls for the stands to set on one-inch shim plates, which allows for floor height uncertainty.

Spherical balls and Belleville spring washers will be used to provide contact between the vertical collimator jaws and the vacuum chamber wall which is important for transferring heat from the jaws. Use of this design feature should also be considered for the horizontal jaws instead of relying only on gravity to provide thermal contact.

# 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.

Prior to the PRR, document the structural analysis and calculations in an engineering note and have peer reviewed per the FESHM Chapter 5100 Structural Safety. The note shall include calculations and analysis of parts where a failure presents a hazard to people or equipment.

Communicate to Conventional Facilities the load from the collimators that will be distributed on the concrete floor structure and obtain approval that the stand and floor design are adequate.

Consult with Conventional Facilities about whether the tunnel enclosure will settle and change its elevation. The tunnel enclosure may settle for some time after it is installed and possibly seasonally. This area may also experience additional settling due to the weight of the collimators after they are installed. If settling is considered a concern, document a plan to monitor and adjust for the settling during installation. Explore with CF whether the tunnel structural design or ground preparation beneath the tunnel can be improved to alleviate settling issues.

Perform vacuum calculations to confirm the design will meet the vacuum requirements given the space available for pumping. Take into consideration additional outgassing that may occur due to heating. Vacuum requirements were not included in the documentation provided or presented, and it is assumed the requirements are documented in the vacuum subsystem WBS.

The secondary jaw plunger blind tapped holes need to be vented for vacuum. All parts inside the vacuum chambers should be checked for potential virtual vacuum leaks and addressed prior to approving and releasing the drawings.

The interface between the collimators and neighboring devices such as magnets, instrumentation, and vacuum components is unclear. The insertion length of the collimators should be clearly stated in the Interface Specification Document (ISD) and any space envelope needed to make up vacuum connections and insert vacuum flange bolts should be included.

This new PIP II Linac is a completely new type of accelerator.  Instrumentation to measure beam halo is an art still in development.  These collimators will provide a unique tool to study the beam halo out to very low (but important) levels.  We recommend that this capability be reviewed so that any required mechanical features or instrumentation requirements can be included at the design stage. The response to this recommendation will perhaps require updating the requirements documents. See perhaps FERMILAB-CONF-07-262-AD.

Include in the quality control plan a test to demonstrate the design features meant to act as a hard stop for the jaws in the event of limit switch or control system failure will function as intended.

# Response to Charge Questions

1. Are the requirements documented, clear, complete, and appropriate?

Since the beam line and the collimators are within the same WBS, the documentation of special concern for the vacuum features of the collimators might not be required in the existing plans but we note that this part of the vacuum is different than that along the beam transport sections.

As noted above, we recommend that the value of these collimators as devices to study beam tails should be included in the requirements for this system. If the project accepts this the requirement documents should reflect that decision.

1. Is the proposed design for the BTLBA Collimators likely to meet requirements? Explain any deficiencies or concerns.

We believe that the requirements can be met when the comments and recommendations noted above are addressed.

1. Are there any features present (or absent) that threaten the intended function and performance of this design?

We have not identified any concerns that threaten the intended function.

1. Are the connections and interfaces of the collimators well understood?

We have identified issues with the connections and interfaces, as noted in our comments and recommendations.

1. Have safety and environmental aspects been appropriately considered?

Safety concerns (such as lifting bolt holes) and environmental requirements (such as radiation issues) have been addressed.

1. Have quality aspects been appropriately considered?

The Quality Control Plan documentation was provided and is a work in progress. The QA and QC plans shall be finalized prior to the Procurement Readiness Review. There are significant quality issues to be addressed during assembly.

# 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.

We have no suggestions for value engineering.