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Optics design of the ion beam transport for the GRIFFIN & BIO-BNMR

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Abstract

An ion beam transport section has been designed to transport the extracted beam from the polarizer to the GRIFFIN and BIO-BNMR facilities. In this design note the beam optics, beamline layout, optical element specifications and the required diagnostics are documented.

1 Overview

A new ion beam transport section has been proposed for transporting a polarized RIB from the polarizer to the GRIFFIN and BIO-BNMR experimental facilities. The planned layout of the transport section that connects GRIFFIN and BIO-BNMR facilities with the polarizer is shown in Fig. 1. Here, the position of the GRIFFIN beamline [1] with respect to the polarizer is fixed and BIO-BNMR facility is a new addition to the ISAC LEBT [2]. Required beams through this section have been specified in table 1.

Beam	Polarized RIB beams
Beam energy	10 – 60 keV
Beam intensity	< 10 nA
Beam emittance at 30 keV [4 RMS]	< 12 μm

Table 1: *Summary of basic beam parameters.*

In this design note, beam envelope calculations for transporting beams from the polarizer through the GRIFFIN and BIO-BNMR are presented in Sec. 1.3. The optical elements and the diagnostics in the beamline are listed in table 2, 3 & 4.

1.1 Purpose and scope

The purpose of this document is to give a design specification for the optical elements and describe the functionality of ion beam transport briefly. The scope of this document is limited to the beam optics design of the ion beam transport section that connects the polarizer with the GRIFFIN/BIO-BNMR experimental facilities.

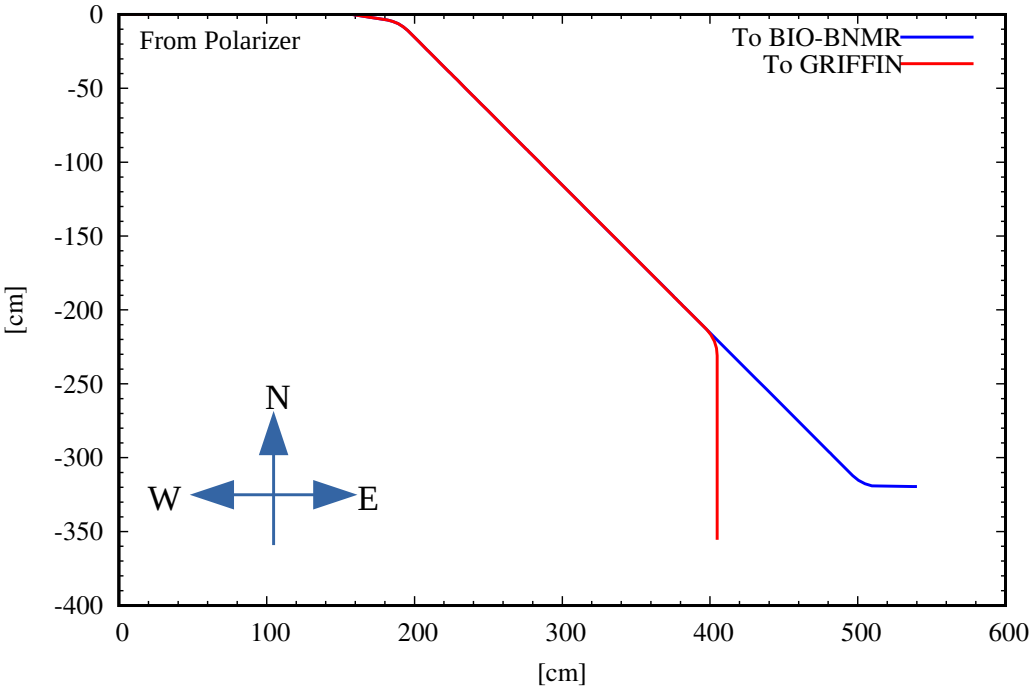

Figure 1: Layout for the ion beam transport section from the polarizer exit to the GRIFFIN and BIO-BNMR facilities at ISAC-1.

1.2 Abbreviations and definitions

- **B:** electrostatic Bender
- **D:** electrostatic Deflector
- **D-quad:** De-focusing quadrupole
- **F-quad:** Focusing quadrupole
- **E–W:** East–West
- **FC:** Faraday Cup
- **LEBT:** Low Energy Beam Transport
- **N–S:** North–South
- **PM:** Profile Monitor
- **Q:** electrostatic Quadrupole
- **RIB:** Radioactive Ion Beam

- **XCB:** X-Correcting Bender
- **YCB:** Y-Correcting Bender

1.3 Beam envelope

The beam transport section consists of electrostatic optical elements such as quadrupoles, steerers, $9°, 36°$ and $45°$ benders. The optical elements and the concept of ion beam transport are similar to the existing transport section from the polarizer to the BNMR/BNQR sections in the ISAC LEBT [2].

The ion beam transport calculations have been performed for the given beamline layout at the GRIFFIN and BIO-BNMR facilities with respect to the existing polarizer in ISAC. Figure 2 shows the calculated beam envelope from the exit of the polarizer through the entrance of the GRIFFIN beamline by using the code TRANSOPTR. Here, the transport section between the ILE2:B21 and ILE1B:Q5 is the new transport section that connects the existing GRIFFIN facility with the existing polarizer in ISAC. Similarly, Fig. 3 shows the calculated beam envelope from the exit of the polarizer through the entrance of the BIO-BNMR beamline. The transport section between the ILE2:B21 and ILE2B:B4 is the new transport section that connects the existing BIO-BNMR facility with the existing polarizer in ISAC. Here, the section between the ILE2:B21 and ILE2B:Q6 is a common transport section between the GRIFFIN and BIO-BNMR facilities. The optical elements in this section can have identical applied voltages for a given beam energy in order to transport the beam either through the GRIFFIN or BIO-BNMR. The required optical elements along with the diagnostics devices are listed in the table 2, 3 & 4. Tolerance for the optical elements are provided in Ref. [3].

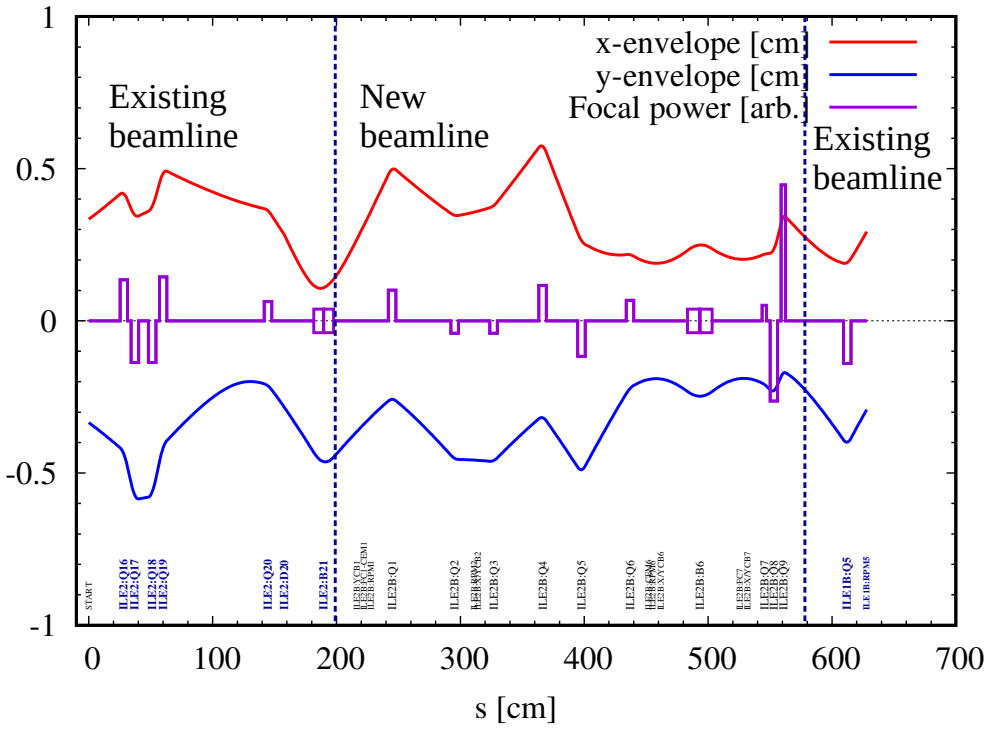

Figure 2: Calculated beam envelope (2RMS, positive for x, negative for y) for a 60 keV ion beam from the exit of the polarizer through the entrance of the GRIFFIN beamline with $\varepsilon_{4\mathrm{rms}} = 10$ μm.

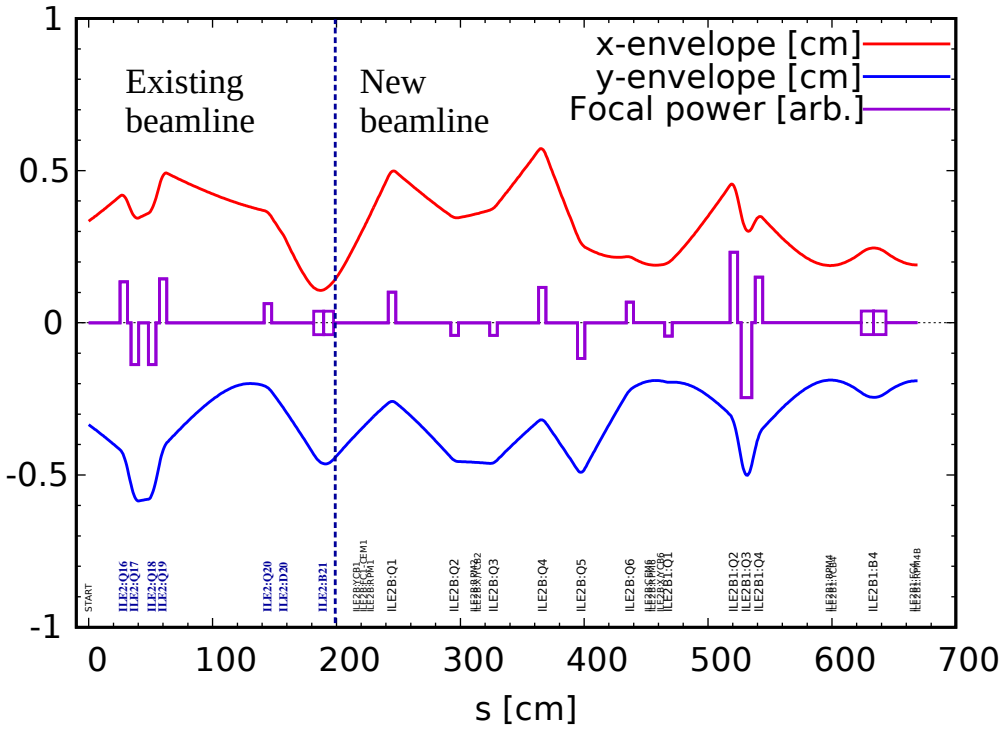

Figure 3: Calculated beam envelope (2RMS, positive for x, negative for y) for a 60 keV ion beam from the exit of the polarizer through the entrance of the BIO-BNMR beamline with $\varepsilon_{4\mathrm{rms}} = 10$ μm.

Elements	**Function**	**V [kV]**	*S* **[cm]**	**E-W [cm]**	**T-B. [cm]**	**N-S [cm]**	**R [cm]**	**L [cm]**
START	–	–	0.0000	-0.0000	0.0000	0.0000	–	–
ILE2:Q16	F-quad	2.085	28.3459	28.3459	0.0000	0.0000	2.54	5.08
ILE2:Q17	D-quad	2.115	37.2359	37.2359	0.0000	0.0000	2.54	5.08
ILE2:Q18	D-quad	2.115	51.2059	51.2059	0.0000	0.0000	2.54	5.08
ILE2:Q19	F-quad	2.238	60.0959	60.0959	0.0000	0.0000	2.54	5.08
ILE2:Q20	F-quad	0.982	144.7279	144.7279	0.0000	0.0000	2.54	5.08
ILE2:D20	–	–	157.8338	157.8338	0.0000	0.0000	–	9°
ILE2:B21	–	–	189.6893	188.9739	0.0000	-6.1907	25.4	36°
ILE2B:YCB1	–	–	216.4219	208.6634	0.0000	-24.1221	–	–
ILE2B:FC1	–	–	222.0289	212.6282	0.0000	-28.0868	–	–
ILE2B:CEM1	–	–	225.0298	214.7502	0.0000	-30.2089	–	–
ILE2B:RPM1	–	–	228.0298	216.8715	0.0000	-32.3302	–	–
ILE2B:Q1	F-quad	1.562	244.9289	228.8210	0.0000	-44.2796	2.54	5.08
ILE2B:Q2	D-quad	0.629	295.4528	264.5468	0.0000	-80.0053	2.54	5.08
ILE2B:XCB2	–	–	308.1509	273.5256	0.0000	-88.9842	–	–
ILE2B:RPM2	–	–	311.1509	275.6469	0.0000	-91.1055	–	–
ILE2B:YCB2	–	–	314.1509	277.7683	0.0000	-93.2268	–	–
ILE2B:Q3	D-quad	0.629	326.8489	286.7471	0.0000	-102.2056	2.54	5.08
ILE2B:Q4	F-quad	1.800	366.4038	314.7165	0.0000	-130.1752	2.54	5.08
ILE2B:Q5	D-quad	1.800	397.8007	336.9173	0.0000	-152.3761	2.54	5.08
ILE2B:Q6	F-quad	1.042	437.0028	364.6377	0.0000	-180.0961	2.54	5.08
ILE2B:CEM6	–	–	452.0058	375.2463	0.0000	-190.7048	–	–
ILE2B:RPM6	–	–	455.0058	377.3677	0.0000	-192.8261	–	–
ILE2B:XCB6	–	–	458.0058	379.4890	0.0000	-194.9475	–	–
ILE2B:YCB6	–	–	461.8159	382.1831	0.0000	-197.6416	–	–

Table 2: *Position of the optical and diagnostics elements in the common transport section between the GRIFFIN and BIO-BNMR. Optical elements colored in blue are the existing elements and rest of the elements are the new ones. The 5th, 6th and 7th column specifies the reference coordinates of the mid-point of each quadrupole in the low beta insertion of the injection beamline. The 2nd column specifies the optical function of the quadrupole. The 3rd column specifies the applied voltage to the quadrupoles for transporting a 60 keV beams. The 4th column (S) is the reference trajectory length. Beamline elevation (T-B) reference to the elevation of the polarizer beamline. The 8th column specifies the aperture radius (R) of the quadrupole and 9th column specifies the length (L) of the quadrupole, whereas for the bender it is bending radius and bending angle.*

Elements	**Function**	**V [kV]**	S **[cm]**	**E-W [cm]**	**T-B. [cm]**	**N-S [cm]**	**R [cm]**	**L [cm]**
ILE2B:B6	–	–	493.3809	402.9554	0.0000	-221.1485	25.4	45°
ILE2B:FC7	–	–	525.7559	404.8888	0.0000	-253.2685	–	–
ILE2B:XCB7	–	–	528.7559	404.8888	0.0000	-256.2685	–	–
ILE2B:YCB7	–	–	531.7559	404.8888	0.0000	-259.2685	–	–
ILE2B:Q7	F-quad	0.787	545.4779	404.8888	0.0000	-272.9910	2.54	2.54
ILE2B:Q8	D-quad	4.077	553.0980	404.8888	0.0000	-280.6109	2.54	5.08
ILE2B:Q9	F-quad	6.914	560.7182	404.8888	0.0000	-288.2309	2.54	2.54
ILE1B:Q5	D-quad	2.163	612.3254	404.8888	0.0000	-339.8381	2.54	5.08
ILE1B:RPM5	–	–	628.0252	404.8888	0.0000	-355.5381	–	–

Table 3: *Position of the optical and diagnostics elements for the beam transport to the GRIFFIN. Optical elements colored in blue are the existing elements and rest of the elements are the new ones. The 5th, 6th and 7th column specifies the reference coordinates of the mid-point of each quadrupole in the low beta insertion of the injection beamline. The 2nd column specifies the optical function of the quadrupole. The 3rd column specifies the applied voltage to the quadrupoles for transporting a 60 keV beams. The 4th column (S) is the reference trajectory length. Beamline elevation (T-B) reference to the elevation of the polarizer beamline. The 8th column specifies the aperture radius (R) of the quadrupole and 9th column specifies the length (L) of the quadrupole, whereas for the bender it is bending radius and bending angle.*

Elements	**Function**	**V [kV]**	S **[cm]**	**E-W [cm]**	**T-B. [cm]**	**N-S [cm]**	**R [cm]**	**L [cm]**
ILE2B1:Q1	D-quad	0.683	467.9656	386.5321	0.0000	-201.9904	2.54	5.08
ILE2B1:Q2	F-quad	3.584	520.8434	423.9223	0.0000	-239.3805	2.54	5.08
ILE2B1:Q3	D-quad	3.806	531.0037	431.1065	0.0000	-246.5646	2.54	7.62
ILE2B1:Q4	F-quad	2.322	541.1640	438.2906	0.0000	-253.7488	2.54	5.08
ILE2B1:RPM4	–	–	598.2650	478.6670	0.0000	-294.1253	–	–
ILE2B1:YCB4	–	–	601.2650	480.7883	0.0000	-296.2466	–	–
ILE2B1:B4	–	–	633.6388	504.8676	0.0000	-317.5916	25.4	45°
ILE2B1:FC4	–	–	666.0137	536.9884	0.0000	-319.5250	–	–
ILE2B1:RPM4B	–	–	669.0137	539.9884	0.0000	-319.5250	–	–

Table 4: *Position of the optical and diagnostics elements for the beam transport to the BIO-BNMR. The 5th, 6th and 7th column specifies the reference coordinates of the mid-point of each quadrupole in the low beta insertion of the injection beamline. The 2nd column specifies the optical function of the quadrupole. The 3rd column specifies the applied voltage to the quadrupoles for transporting a 60 keV beams. The 4th column (S) is the reference trajectory length. Beamline elevation (T-B) reference to the elevation of the polarizer beamline. The 8th column specifies the aperture radius (R) of the quadrupole and 9th column specifies the length (L) of the quadrupole, whereas for the bender it is bending radius and bending angle.*

2 Summary

Beam optics design for the ion beam transport that connects polarizer with the GRIFFIN and BIO-BNMR facilities have been summarized. The required optical, diagnostics elements and its locations are presented.

References

[1] R. Baartman. GRIFFIN Optics. Technical Report TRI-BN-11-01, TRIUMF, 2011.

[2] R. Baartman. ISAC LEBT. Technical Report TRI-BN-12-10, TRIUMF, 2012.

[3] R. Baartman. Tolerances in the LEBT Optics. Technical Report TRI-DN-97-11, TRIUMF, 1997.