1. Introduction

Beamline 2A delivers a 500 MeV proton beam to the targets of the ISAC facility of TRIUMF. This beamline is designed such that beam may be delivered to either of two targets that are located symmetrically about the incident proton beam. At present one, the west target, has been operational for some time; the second, the east target, has recently been commissioned. Each target has its own ion source and its own target material. Consequently, should one target develop a problem, beam could be redirected to the other target while repairs were being made to the faulty target. However, were problems to develop in beamline 2A and/or the cyclotron, no radioactive beam would be available to experimenters until problems associated with the faulty components were addressed.

It has been suggested that in planning for the future, consideration of the provision for an alternate beam delivery system to ISAC should be made. Several options for such a beamline were presented in ref[1)]. The present report presents more detailed studies of one of the options given in that reference. An overview of this study was also presented in a poster session at the 2003 Particle Accelerator Conference[2)] in Portland, Oregon in May of this year.

2. An overview of this report

The scheme reported here involves the use of extraction port 4. As such, this would allow beam delivery to two independent ISAC targets and, consequently, to two different experiments at ISAC. Also, were beamline 2A to have problems, beam to ISAC could still be delivered to one target. However, it does not alleviate the unavailability of beam should the cyclotron itself develop a problem.

In the designs presented in ref[1)] and that given here, an attempt has been made to use as many existing beam-transport elements as possible. We repeat here the assumptions made in ref[1)] in order to accomplish this goal. It is assumed that one or more of the following will occur.

1. Beamline 4B is decommissioned.

This frees one 35° dipole (currently designated 4AB2) and seven standard 4Q14/8 quadrupoles for use in any designs. One additional quadrupole of this type becomes available if its (leaking) coils are replaced.

2. Beamline 4A2 is decommissioned—that is, the Parity experiment will be finished within the next few years. This frees one 12° dipole and three more 4Q14/8 quadrupoles.

3. Beamline 4A may or may not be decommissioned—that is, the existing TISOL facility may or may not be required in the future.

If the TISOL facility will be required in the future, beamline 4A could be maintained as it exists. However, assuming that the new beamline to ISAC is extracted from extraction port 4 as proposed, it is necessary to replace the existing vault dipole 4VB1 with a new switching dipole. Looking in the beam direction this new dipole is required to bend the extracted beam 40° to the left and 35° to the right and, as such, would be relatively expensive.

Alternately, as indicated in ref[1)], the beamline could be reconfigured to run parallel to the east-west wall of the proton area. This would allow the existing beam dump to be used but would require that TISOL be moved to a new location *and* additional optics added at its top end.

If the TISOL facility will *not* be required in the future, an additional 35° dipole and are seven 4Q14/8 quadrupoles become available.

4. The vault dipole.

If it is decided that beamline 4A is *not* to be decommissioned, it will be necessary to replace the existing vault dipole 4VB1 with a switching magnet that is capable of bending a proton beam 40° to the left and 33° to the right, left and right being defined as one is looking in the beam direction. This, of course, will require the design of a new dipole.

On the other hand, should beamline 4A be decommissioned, dipole 4VB1 could simply be flipped over and used as is, and no new dipole is required.

In addition, because it is not possible to tunnel under the remote-handling building, it is taken as given that the existing stores building will be relocated.

Thus a minimum of one 35° dipole, one 12° dipole, and ten 4Q14/8 quadrupoles are expected to become available for reuse because of the decommissioning of beamlines 4B and 4A2. This rises to a total of two 35° dipoles, one 12° dipole, and seventeen 4Q14/8 quadrupoles if beamline 4A is also decommissioned.

3. Beamline BL4N

This report deals with the extraction line labeled beamline 4R in ref[1)]. We shall refer to this beamline as BL4N (for beamline 4 North) in the remainder of this report.

Figure 1 shows this beamline and its location relative to the existing beamline 2A. There is a similarity to BL2A in that there is a long drift length through the berm. Beam is then directed north to two target assemblies, each similar to those that exist on beamline 2A. After extraction, radioactive beam would pass through a mass separator, eventually being brought to grade level as in the existing ISAC facility.

We have also included an additional beamline that would take beam to a new 200 μA beam dump. This dump would be used during beamline tuning as well as during development of high-current extraction tunes for the cyclotron.

When all beamlines are in operation it is anticipated that a total current of 400 μA—150 μA on beamline 1A, 100 μA on beamline 2A, 50 μA on beamline 2A, and 100 μA on beamline 4N—would be extracted from the cyclotron. To reduce activation of the cyclotron because of electric stripping at this intensity of circulating beam, we have (arbitrarily) decided to design the beamline 4N for an extracted energy of 460 MeV. All of the settings of the elements of the beamlines described below have been computed for that energy.

The beamline is designed such that all target locations lie along an east-west line that is located a distance of 57.9 m north of the cyclotron center. This positioning then places the targets under an extension of the existing crane facility of ISAC–1. The east-west locations of the targets has been chosen to be approximately at the positions shown in figure 1.

3.1 An overview of the optics of beamline BL4N

Figure 2 shows BL4N in more detail. As can be seen, the beamline consists of a common section from which emanate beamlines to a beam dump and two target locations. The beam dump is reached through a ∼20° bend in the switching dipole downstream of the point $WST3$, and the two targets are reached through switching magnet settings of ∼40° and ∼60°.

3.2 Optics of the common section of beamline BL4N

This beamline uses the existing vault components of beamline 4. To these a quadrupole doublet is added to complete the vault section of the beamline. These elements are adjusted to produce a dispersed double-waist at the point labeled WST1 at the midpoint of the 16 m drift below the existing berm around the cyclotron vault at grade level. Beam size at this waist is nominally $(x,\, y) = (\pm 0.59$ cm, ± 0.49 cm$)$.

In conjunction, the quadrupole doublet upstream of dipole 4NB2 and another downstream are adjusted to produce a doubly-achromatic ($R_{16} = R_{26} = 0$), double waist at the point WST2 where the nominal beam size is $(x,\, y) = (\pm 0.20$ cm, ± 0.20 cm$)$. There follows a four-quadrupole symmetric section that reproduces the double waist at the point WST3 where, again, the beam size is $(x,\, y) = (\pm 0.20$ cm, ± 0.20 cm$)$.

An enlarged view of this common section of beamline is shown in figure 3(a). Table 1 lists the TRANSPORT input for this common section of beamline. The beam envelopes along this section of beamline are shown in figure 4(a). Note that it is the beam half-widths that are plotted and that the vertical half-widths are plotted as negative values.

Beam sizes and elements of the overall transfer matrices at the points WST1, WST2, and WST3 are given in table 2.

TRANSPORT inputs for downstream sections of the beamlines are given in the sections below. These are to be 'tacked on' following the input listed in table 1.

3.3 Optics of beamline to the east target of BL4N

An enlarged plot of this and the following sections of the beamline are shown in figure 3(b).

TRANSPORT input for this beamline section is given in table 3. We note that in order to complete the beamline, the input from table 3 (less the title line) is to be appended to the data listed in table 1.

Downstream of WST3 beam is transported by a quadrupole doublet to a rectangular dipole that bends through an angle of 61.941° to the right looking in the beam direction). This dipole is followed by two symmetric quadrupole doublets. Another rectangular dipole bends the beam 31.94° to the left (again looking downstream) directs the beam to the east target. A quadrupole doublet follows this last dipole. Because of the dipole bend angles we call this the $+60°-30°$ section of the beamline.

The eight quadrupoles of this section are tuned to produce a singly achromatic ($R_{16} = 0$), double waist at the target where the nominal beam size is $(\pm x, \pm y) = (\pm 2\,\mathrm{mm}, \pm 2\,\mathrm{mm})$.

Author's note: As this report was being written it was realized that the spacings between the two quadrupoles of each doublet between the 61.941° and 31.94° dipoles were unequal—as may be seen in table 3. This was not intended. However, to expedite the preparation of this report it was decided to continue with this configuration in this report.

Beam envelopes along this section of beamline are shown in figure 4(b). Beam parameters and elements of the overall transfer-matrix at the east target are listed in table 6.

3.4 Optics of beamline to the west target of BL4N

TRANSPORT input for this beamline section is given in table 4. Again, to complete the beamline, the input from table 4 (less the title line) is to be appended to the data listed in table 1.

The configuration of this section is the same as that for beam delivery to the east target. However, in this case the first dipole deflects the beam to the right through an angle of 43.214° and the second dipole deflects it to the left through an angle of 13.213°. Again because of the bend angles of the dipoles we term this the $+40°-10°$ section of the beamline.

The quadrupoles of this section are tuned to produce nominal beam parameters at the west target that are identical to those at the east target—that is, $(\pm x, \pm y) = (\pm 2\,\mathrm{mm}, \pm 2\,\mathrm{mm})$ and $R_{16} = 0$. Beam parameters and elements of the overall transfer matrix at the west target are also listed in table 6. The beam envelope along this section of beamline are shown in figure 4(c).

3.5 Optics of beamline to the beam dump on BL4N

We have assumed that the beam dump will be similar to that on beamline 1A. Consequently, the design is such that a beam spot with nominal dimensions of $(\pm x, \pm y) = (\pm 2\,\mathrm{cm}, \pm 2.5\,\mathrm{cm})$ is required at the dump. No other conditions were imposed on the beam.

It was found that only one additional quadrupole downstream of the (nominal) 60° dipole was necessary to produce the required spot at the beam dump. TRANSPORT input for this beamline section is given in table 5; this data (less the title line) is to be appended to the data listed in table 1 to complete this section of beamline.

Table 6 also lists the beam parameters and elements of the overall transfer matrix at the beam dump location. The beam envelopes along this section of the beamline are shown in figure 4(d).

3.6 Discussion of this configuration of BL4N

In the above sections we have presented a slightly modified (relative to ref[1]) and ref[2])) configuration of beamline BL4N. The layout of the beamline is such that the amount of excavation required is minimal, and its operation does meet the design requirements. However, in the opinion of the author there is one major concern regarding this design. This lies in the size of the switching magnet required for the delivery of beam to the targets and the beam dump.

This dipole is required to bend a 460 MeV proton beam through ∼62°. Consequently, the magnet is large and is required to run at a high magnetic field (∼14.2 kG). Further, because the magnet is used as a switching magnet, the pole width at the its exit must also be large. This will result in a magnet that not only is expensive to construct but is also expensive to operate.

The question "Could the MRS dipole be used as a switching magnet?" might be asked. This dipole was designed to bend 500 MeV protons through 60° with a radius of curvature of 2.6 m. The TRIUMF Magnet Index lists its pole width as 24 in. Calculation shows that the sagitta of the trajectory has a height of 0.348 m (13.7 in). To ensure that the beam traveled in the 'good field' region, the dipole normally would be installed such that the trajectory of the particle was symmetric about the radius of curvature, thus lying in a region ±6.85 in. either side of it. Further calculation shows that the exit point of a beam that was deflected through 40° would lie 0.481 m (18.94 in.) above that of a beam deflected 60°. Thus, relative to the centerline of the magnet, the 60° beam would exit the dipole 6.85 in. below the centerline whereas the 40° beam would exit 12.09 in. above it. That is, the beam deflected 40° would be at the edge of the pole when exiting the dipole.

The dipole could be installed such that a beam deflected 60° entered and exited the dipole 9.45 in. below the centerline of the magnet. This implies that a deflected 40° would exit 9.49 in. above the centerline. Thus both of beams would exit the dipole within its pole dimensions. However, the field uniformity would be in question. Further, use of this dipole would preclude using it to direct beam to a beam dump unless, of course, an hole was drilled to allow the exit of such a beam. In addition it is noted that this dipole weighs some 90 tons; this probably would require strengthening of the floor of the tunnel in the region of the magnet.

Because of this we present in the following section two variations on a theme that may result in a less expensive beamline.

4. Beamline BL4N_2 – Version 2 of BL4N

In version 2 of BL4N we replace the large 60° dipole with two 30° dipoles. This version is shown in figure 5; we denote it as BL4N_2. As is observed in figure 5, BL4N_2 is similar to the original version described above in §3; each has a common section, a long drift through the vault berm followed by a dipole and two quadrupole doublets. However, version 2 dispenses with the four-quadrupole between the points labeled WST2 and WST3 in figure 2. Beam delivery to the east target is accomplished with three dipoles, the second of which is used as a switching magnet for beam delivery to the west target. Beam is delivered to the beam dump with the use of a single dipole.

Design parameters for the beam characteristics at the two target locations and at the beam dump were maintained identical to those of the design given in §3 above.

One consequence of the above changes is that the point WST2 is shifted approximately 3.5 m to the west. This, of course, is also true of the north-south portion of the beamline. Whether such a shift is feasible is yet to be determined.

4.1 Optics of the common section of BL4N_2

An enlarged view of this common section of beamline is shown in figure 6(a). Components used in this section are identical to those used in the common section of BL4N.

As in the design of §3, the vault quadrupoles are tuned to produce a double waist at the point labeled WST1 of figure 5. In conjunction, the following two doublets and the dipole are tuned such that in the overall optics a doubly-achromatic double waist is produced at the point WST2 where, again, the nominal beam size is $(x, y) = (\pm 0.20 \text{ cm}, \pm 0.20 \text{ cm})$.

Table 7 lists the TRANSPORT input for this common section of beamline; TRANSPORT inputs for downstream sections of the beamlines are given in the sections below. These are to be 'tacked on' following the input listed in table 7.

Beam envelopes along this section of beamline are shown in figure 7(a), and beam sizes and elements of the overall transfer matrices at the points WST1 and WST2 are given in table 8.

4.2 Beam transport to the east target of BL4N_2

A TRANSPORT listing for beam delivery to the east target of BL4N_2 is given in table 9.

Downstream of WST2 lie a quadrupole doublet, a dipole, two quadrupole doublets, and another dipole and quadrupole doublet. This system is symmetric about the midpoint of the two quadrupole doublets between the two dipoles. Each dipole is rectangular and bends the proton beam through and angle of 30.678°. This system is designed to reproduce at WST3 the doubly-achromatic, double waist at the location WST2. Thus at the WST3 location the nominal beam size is $(x, y) = (\pm 0.20 \text{ cm}, \pm 0.20 \text{ cm})$.

There follow two quadrupole doublets, a dipole, and another quadrupole doublet. Again, the dipole is rectangular and bends the proton beam 31.355° to the left to the east target. This section of beamline is designed to produce a singly-achromatic, double waist at this target where, again, the nominal beam size is $(x, y) = (\pm 0.20 \text{ cm}, \pm 0.20 \text{ cm})$.

Beam envelopes along this section of BL4N_2 are shown in figure 7(b). Table 12 lists the beam sizes and elements of the overall transfer matrix for this and the other sections of this beamline.

4.3 Beam transport to the west target of BL4N_2

A TRANSPORT listing for beam delivery to the west target of BL4N_2 is given in table 10. The first dipole downstream of WST2 again bends the beam through 30.678°. However, to reach the west target the second dipole is tuned to deflect the beam through 8.492°. Although the beam enters this (nominally rectangular) dipole at an angle of 15.339°, it leaves the dipole at an angle of −6.847°. As a consequence of the asymmetry of this system it is not possible to produce an achromatic beam downstream of the second dipole as was described in the above section. Consequently, the beam transport downstream of the second dipole was to produce the desired conditions at the west target.

This was accomplished with the use of two doublets and another dipole. This dipole is adjusted to bend the beam 9.169° to the left (looking downstream). The doublets lie either side of the dipole and are adjusted to produce the desired beam conditions at the west target—singly achromatic and a double waist with a nominal radius of 2 mm.

Beam envelopes along this section of BL4N_2 are shown in figure 7(c). Table 12 lists the Beam sizes and elements of the overall transfer matrix for this section of beamline are also listed in table 12.

4.4 Optics of beamline to the beam dump on BL4N_2

We continue to assume that the beam dump will be similar to that on beamline 1A. Consequently, the design is such that a beam spot with nominal dimensions of $(\pm x, \pm y) = (\pm 2\,\mathrm{cm}, \pm 2.5\,\mathrm{cm})$ is required at the dump; no other conditions were imposed on the beam.

For beam delivery to the beam dump the dipole downstream of WST2 is turned off. Beam drifts to another quadrupole doublet that is tuned to identical settings as the doublet immediately downstream of WST2. Beam is directed to the beam dump by another 30° dipole. An additional quadrupole doublet is used to provide the required beam size at the dump.

Table 12 also lists the beam parameters and elements of the overall transfer matrix at the beam dump location. The beam envelopes along this section of the beamline are shown in figure 7(d).

4.5 Discussion of the configuration of BL4N_2

BL4N_2 was developed to eliminate the requirement for the large switching magnet that was required for BL4N. This has been done. However, a switching magnet is still required, albeit it is smaller. In this sense the design goal has been achieved.

One drawback of this design is that a larger area of excavation is required. Overall construction costs would undoubtedly be greater than those required for installation of BL4N.

5. Beamline BL4N_3 – Version 3 of BL4N

As noted above version 2 of BL4N still requires a switching dipole to direct beam to either the east or west target. A logical extension of the design is to do away altogether with such a dipole. BL4N_3 is one version of such a design. An overall view of this beamline is shown in figure 8. A detail of the common section is shown in figure 9(a) and that of delivery to the targets and beam dump is shown in figure 9(b).

5.1 Optics of the common section of BL4N_3

Because a switching magnet is not required in this version, the common section of BL4N_3 is identical to that of the original BL4N up to and including the WST2 location. Consequently, its transport parameters up to that point are as listed in table 1; the beam properties at its two waists are as given in table 2. The beam envelopes are shown in figure 10(a).

5.2 Beam transport to the east target of BL4N_3

TRANSPORT input for the delivery of beam to the east target of BL4N_3 is listed in table 13. Downstream of WST2 lie a quadrupole doublet, a dipole, and another quadrupole doublet. The quadrupole doublets are tuned to produce a (dispersed) double waist at the location WST3, a distance of 3.5 m downstream of the second doublet. Another doublet pair operating in mirror symmetry lie downstream of WST3. These together with a reverse-bending dipole and an additional quadrupole doublet are used to produce a spatially achromatic, double waist at the target. There the (nominal) beam diameter is 4 mm.

Table 16 lists the beam parameters at the WST3 and east target locations for this section of beamline. Also given are the overall elements of the transfer matrix at those positions. The beam envelopes throughout this section are shown in figure 10(b).

5.3 Beam transport to the west target of BL4N_3

For beam delivery to the west target the 36.6° dipole (for beam delivery to the east target) is turned off and another quadrupole doublet added downstream of it in the north-south section of beamline. A 30° dipole and another quadrupole doublet follow. The two doublets upstream of the dipole are run symmetrically.

These together with the doublet downstream of the dipole are tuned to produce a 4 mm diameter, dispersed double waist at the WST3 location 1.5 m of the last doublet.

Downstream of the WST3 location a pair of quadrupole doublets are operated in mirror symmetry to produce the 4 mm diameter, spatially-achromatic double waist at the target location.

The beam parameters at the WST3 and west target location of this beamline are also listed in table 16. The beam envelopes throughout this section are shown in figure 10(c).

5.4 Optics of beamline to the beam dump on BL4N_3

For beam delivery to the beam dump, both dipoles downstream of the WST2 position and the quadrupole doublet between them on the north-south beamline are turned off. A quadrupole doublet is added downstream of a 30° dipole that directs beam to the west target. This doublet and that immediately downstream of WST2 are operated in a symmetric mode. It was found that with this doublet pair and an additional quadrupole downstream of the dipole it was possible to produce the desired beam size at the beam dump.

TRANSPORT input for this section of beamline is given in table 15. The beam sizes and elements of the overall transfer matrix at the beam dump are given in table 16. Figure 10(d) shows the beam envelopes along this section of beamline.

5.5 Discussion of the configuration of BL4N_3

This version of BL4N has the advantage that no switching magnet is required in any line transporting beam to the targets or the beam dump.

One disadvantage of this configuration, however, is that it would require the largest amount of excavation of any of the configurations discussed here.

6. Discussion

This note has presented one design for a second beamline to the ISAC facility and two variations on that theme. It has been assumed that beam parameters at the targets would be the same as those designed into beamline 2A and that those at the beam dump would be those presently obtained at the beamline 1A beam dump.

The preference of the author would be the BL4N_3 design. However, any of these designs would meet the proposed design requirements. In each of these designs no attempt has been made to optimize the number of quadrupoles that were used.

In reviewing the designs it is noted that there is an inconsistency in the specifications for the dipoles. In particular, the effective lengths of the 30° dipoles need to be rationalized. Any dipole that bends 40° or less could be replaced with a copy of the 35° dipoles that presently are installed on beamlines 4A and 4B.

Some of the designs require additional dipoles that bend through smaller angles. The Parity dipole on beamline 4A2 was designed to bend a 500 MeV beam through 12°. Thus this dipole likely would be appropriate for bend of 12.5° or less.

References

1. G. M. Stinson, *A study of additional proton beamlines to the* ISAC *building*, TRIUMF report TRI-DNA-01-2, March, 2001.
2. Glen Stinson and Pierre Bricault, *A PROPOSAL FOR AN ADDITIONAL BEAMLINE TO THE TRIUMF ISAC FACILITY*, Paper presented at the 2003 Particle Accelerator Conference, Portland, Oregon, May 2003.

Table 1

TRANSPORT listing for the common section of beamline BL4N

’03/09/17 – 460MEV – BL4 REVERSE 33 DEG BEND – COMMON SECTION’

0									
13.		12.00000;							
16.00	’X0 ’	16.00000	9.82964;						
16.00	’Z0 ’	18.00000	−5.31156;						
16.00	’T0 ’	19.00000	155.18701;						
1.00	’BEAM’	0.12700	1.60400	0.56100	0.57500	0.0	0.10000	1.03673;	
12.		0.0	0.0	0.0	0.0	0.0	−0.94900	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0;	
1.00	’FOIL’	0.0	0.27300	0.0	0.27300	0.0	0.0	0.0	0.0;
14.	’ROW1’	−0.04140	0.32970	0.0	0.0	0.0	1.46880	1.00000;	
14.	’ROW2’	−3.11000	0.11160	0.0	0.0	0.0	1.97800	2.00000;	
14.	’ROW3’	0.0	0.0	1.14100	0.65040	0.0	0.0	3.00000;	
14.	’ROW4’	0.0	0.0	0.51000	1.16500	0.0	0.0	4.00000;	
3.0	’4VM1’	0.31440;							
3.0	’Q1IN’	0.16825;							
5.00	’4VQ1’	0.41110	1.66007	5.08000;					
3.0	’Q2IN’	0.62755;							
5.00	’4VQ2’	0.40700	−1.44916	5.08000;					
3.0		0.49970;							
3.0	’Q3IN’	0.50460;							
5.00	’4VQ3’	0.39720	1.13733	5.08000;					
3.0		0.95496;							
19.00	’SOL1’	0.59055	0.00001;						
3.0		0.95037;							
3.0	’B1IN’	−0.04528;							
2.0		16.29675;							
4.000	’4VB1’	1.56290	12.58686	0.00000;					
2.0		16.29675;							
3.0	’B1EX’	0.00001;							
3.0		0.65000;							
5.00	’4VQ4’	0.40640	−1.35063	5.08000;					
3.0	’Q5IN’	0.30480;							
5.00	’4VQ5’	0.40640	1.99927	5.08000;					
3.0	’D1 ’	0.97283;							
3.0	’D2 ’	0.97283;							
3.0	’D3 ’	0.97283;							
3.0	’D4 ’	0.97283;							
3.0	’D5 ’	0.97283;							
3.0	’D6 ’	0.97283;							
3.0	’D7 ’	0.97283;							
3.0	’WST1’	1.00000;							
−10.0	’XWST’	2.00000	1.00000	0.00000	0.00100;				
−10.0	’YWST’	4.00000	3.00000	0.00000	0.00100;				
3.0	’D9 ’	0.97283;							
3.0	’D10 ’	0.97283;							
3.0	’D11 ’	0.97283;							
3.0	’D12 ’	0.97283;							
3.0	’D13 ’	0.97283;							
3.0	’D14 ’	0.97283;							

Table 1 (Continued)

3.0	'D15 '	0.97283;			
3.0	'D16 '	0.97283;			
5.00	'4NQ6'	0.40640	3.22030	5.08000;	
3.0		0.30480;			
5.00	'4NQ7'	0.40640	−2.82512	5.08000;	
3.0	'B2IN'	0.65000;			
2.0		16.29675;			
4.000	'4NB2'	1.56290	12.58686	0.00000;	
2.0		16.29675;			
3.0	'B2EX'	0.00001;			
−10.0	'VR16'	−1.00000	6.00000	0.00000	0.00100;
−10.0	'VR26'	−2.00000	6.00000	0.00000	0.00100;
3.0		1.00000;			
5.00	'4NQ8'	0.40640	4.30583	5.08000;	
3.0		0.30480;			
5.00	'4NQ9'	0.40640	−1.81979	5.08000;	
3.0	'WST2'	2.00000;			
−10.0	'XWW2'	2.00000	1.00000	0.00000	0.00100;
−10.0	'YWW2'	4.00000	3.00000	0.00000	0.00100;
−10.0	'TSW2'	3.00000	3.00000	0.20000	0.01000;
−10.0	'XSW2'	1.00000	1.00000	0.20000	0.01000;
3.0		0.30000;			
3.0		0.30000;			
3.0		0.31984;			
5.00	'NQ10'	0.40640	5.59549	5.08000;	
3.0		0.30480;			
5.00	'NQ11'	0.40640	−5.59549	5.08000;	
3.0		0.30480;			
5.00	'NQ12'	0.40640	5.59549	5.08000;	
3.0		0.30480;			
5.00	'NQ13'	0.40640	−5.59549	5.08000;	
3.0	'WST3'	1.68728;			
−10.0	'XWW3'	2.00000	1.00000	0.00000	0.00100;
−10.0	'YWW3'	4.00000	3.00000	0.00000	0.00100;
−10.0	'YSW3'	3.00000	3.00000	0.20000	0.01000;
−10.0	'XSW3'	1.00000	1.00000	0.20000	0.01000;

Table 2

Beam sizes and elements of the overall transfer-matrix at the waists of the common section of beamline 4NBL N

Parameter	WST1	WST2	WST3
$\pm x$ (cm)	0.585	0.200	0.200
$\pm\theta$ (mr)	0.375	1.055	1.056
$\pm y$ (cm)	0.485	0.200	0.200
$\pm\phi$ (mr)	0.378	0.917	0.916
R_{11} (cm/cm)	0.2536	−1.3770	1.3765
R_{12} (cm/mr)	−0.3489	0.0596	−0.0595
R_{16} (cm/%)	1.3722	0.0000	0.0000
R_{21} (mr/cm)	2.9101	−4.0288	4.0181
R_{21} (mr/mr)	0.0208	−0.5668	0.5680
R_{26} (mr/%)	0.5317	0.0000	0.0000
R_{33} (cm/cm)	1.2715	−0.5614	0.5624
R_{34} (cm/mr)	1.4588	−0.2403	0.2411
R_{43} (mr/cm)	−0.8552	−1.8583	1.8504
R_{44} (mr/mr)	−0.1967	−2.5721	2.5669

Table 3

TRANSPORT listing for the East Target section of beamline BL4N

’03/09/17 – 460MEV – BL4 REVERSE 33 DEG BEND – +60° −30° SECTION’

3.0		1.00000;		
3.0		1.00000;		
3.0		1.00000;		
5.00	’NQ14’	0.40640	3.81335	5.08000;
3.0		0.30480;		
5.00	’NQ15’	0.40640	−1.06196	5.08000;
3.0	’B3IN’	1.00000;		
2.0		30.97050;		
4.000	’4NB3’	2.63248	14.20143	0.00000;
2.0		30.97050;		
3.0	’B3EX’	0.00001;		
3.0		0.50000;		
3.0		0.50000;		
3.0		0.50000;		
3.0		0.50000;		
3.0		0.10336;		
5.00	’NQ16’	0.40640	1.80131	5.08000;
3.0		0.50000;		
3.0		0.50000;		
3.0		0.10336;		
5.00	’NQ17’	0.40640	−2.22336	5.08000;
3.0		0.50000;		
3.0		0.50000;		
3.0		0.10336;		
5.00	’NQ18’	0.40640	1.80131	5.08000;
3.0		0.50000;		
3.0		0.50000;		
3.0		0.50000;		
3.0		0.50000;		
3.0		0.10336;		
5.00	’NQ19’	0.40640	−2.22336	5.08000;
3.0		0.50000;		
3.0		0.50000;		
3.0	’B4IN’	0.60336;		
20.0		180.00000;		
2.0		15.97000;		
4.000	’4NB4’	1.56290	12.33461	0.00000;
2.0		15.97000;		
20.0		−180.00000;		
3.0	’B4EX’	0.00001;		
3.0	’D4 ’	0.50000;		
3.0	’D5 ’	0.25000;		
5.00	’NQ20’	0.40640	2.75535	5.08000;
3.0		0.30480;		
5.00	’NQ21’	0.40640	−2.46342	5.08000;
3.0		0.50000;		
3.0		0.50000;		
3.0		0.50000;		
3.0		0.50000;		

Table 3 (Continued)

3.0		0.50000;			
3.0	'WST4'	0.40000;			
−10.0		−1.00000	6.00000	0.00000	0.00100;
−10.0		8.00000	1.00000	57.90000	0.00100;
−10.0		8.00000	3.00000	−9.16500	0.00100;
−10.0		8.00000	4.00000	60.90000	0.00100;
−10.0		2.00000	1.00000	0.00000	0.00100;
−10.0		4.00000	3.00000	0.00000	0.00100;
−10.0		3.00000	3.00000	0.20000	0.01000;
−10.0		1.00000	1.00000	0.20000	0.01000;
SENTINEL;					
SENTINEL;					

Table 4

TRANSPORT listing for the West Target section of beamline BL4N

’03/09/17 – 460MEV – BL4 REVERSE 33 DEG BEND – +40° −10° SECTION’

3.0		1.00000;			
3.0		1.00000;			
3.0		1.00000;			
5.00	’NQ14’	0.40640	3.85037	5.08000;	
3.0		0.30480;			
5.00	’NQ15’	0.40640	−2.83637	5.08000;	
3.0	’B3IN’	1.00000;			
2.0		30.97050;			
4.000	’4NB3’	2.6 0121	10.02695	0.00000;	
2.0		12.24350;			
3.0	’B3EX’	0.00001;			
3.0		0.50000;			
3.0		0.50000;			
3.0		0.50000;			
3.0		0.10336;			
5.00	’NQ16’	0.40640	3.69452	5.08000;	
3.0		0.30480;			
5.00	’NQ17’	0.40640	−5.50405	5.08000;	
3.0		0.50000;			
3.0		0.09635;			
3.0		0.09635;			
3.0		0.50000;			
5.00	’NQ18’	0.40640	3.97685	5.08000;	
3.0		0.30480;			
5.00	’NQ19’	0.40640	−4.19718	5.08000;	
3.0		0.13035;			
3.0		0.50000;			
3.0		0.50000;			
3.0	’B4IN’	0.50000;			
20.0		180.00000;			
2.0		6.60650;			
4.000	’4NB4’	0.65000	12.26919	0.00000;	
2.0		6.60650;			
20.0		−180.00000;			
3.0	’B4EX’	0.00001;			
3.0	’D4 ’	0.50000;			
3.0	’D5 ’	0.25000;			
5.00	’NQ20’	0.40640	3.97685	5.08000;	
3.0		0.30480;			
5.00	’NQ21’	0.40640	−4.19718	5.08000;	
3.0		0.50000;			
3.0		0.50000;			
3.0		0.50000;			
3.0		0.50000;			
3.0		0.50000;			
3.0	’WST4’	0.40000;			
−10.0		−1.00000	6.00000	0.00000	0.00100;
−10.0		8.00000	1.00000	57.90000	0.00100;
−10.0		8.00000	3.00000	−14.17100	0.00100;

Table 4 (Continued)

−10.0	8.00000	4.00000	60.90000	0.00100;
−10.0	2.00000	1.00000	0.00000	0.00100;
−10.0	4.00000	3.00000	0.00000	0.00100;
−10.0	3.00000	3.00000	0.20000	0.01000;
−10.0	1.00000	1.00000	0.20000	0.01000;

SENTINEL;
SENTINEL;

Table 5

TRANSPORT listing for the Dump section of beamline BL4N

’03/09/17 – 460MEV – BL4 REVERSE 33 DEG BEND – +20° DUMP SECTION’

3.0		1.00000;			
3.0		1.00000;			
3.0		1.00000;			
5.00	’NQ14’	0.40640	3.85037	5.08000;	
3.0		0.30480;			
5.00	’NQ15’	0.40640	−2.83637	5.08000;	
3.0	’B3IN’	1.00000;			
2.0		30.97050;			
4.000	’4NB3’	2.70248	4.32577	0.00000;	
2.0		−11.60150;			
3.0	’B3EX’	0.00001;			
3.0		0.50000;			
3.0		0.50000;			
3.0		0.54396;			
5.00	’NQ16’	0.40640	1.78542	5.08000;	
3.0		0.30480;			
3.0		0.40640;			
3.0		0.50000;			
3.0		0.50000;			
3.0		0.50000;			
3.0		0.50000;			
3.0		0.50000;			
3.0		0.50000;			
3.0		0.50000;			
3.0		0.50000;			
3.0		0.50000;			
3.0		0.50000;			
3.0		0.50000;			
3.0		0.50000;			
3.0		0.50000;			
3.0		0.50000;			
3.0	’DUMP’	0.12685;			
−10.0		−1.00000	6.00000	0.00000	0.00100;
−10.0		8.00000	1.00000	57.90000	0.00100;
−10.0		8.00000	3.00000	−18.75800	0.00100;
−10.0		8.00000	4.00000	60.90000	0.00100;
−10.0		3.00000	3.00000	2.50000	0.01000;
−10.0		1.00000	1.00000	2.00000	0.01000;

SENTINEL;
SENTINEL;

Table 6

Beam sizes and elements of the overall transfer-matrix at the beam dump and the target locations of BL4N

Parameter	East tgt	West tgt	DUMP
$\pm x$ (cm)	0.200	0.200	2.000
$\pm\theta$ (mr)	1.618	1.464	3.967
$\pm y$ (cm)	0.200	0.200	2.500
$\pm\phi$ (mr)	0.915	0.917	2.527
R_{11} (cm/cm)	0.3220	−0.3752	−12.1227
R_{12} (cm/mr)	−0.1203	−0.1194	−0.7844
R_{16} (cm/%)	0.0000	0.0000	0.3161
R_{21} (mr/cm)	8.1299	8.0650	−23.5054
R_{21} (mr/mr)	0.1326	−0.1544	−1.6050
R_{26} (mr/%)	−12.2704	−10.1478	−0.8658
R_{33} (cm/cm)	0.1927	0.6787	1.6223
R_{34} (cm/mr)	−0.1567	0.5752	5.0838
R_{43} (mr/cm)	3.0446	−0.6306	1.3898
R_{44} (mr/mr)	2.7000	0.9355	4.9702

Table 7

TRANSPORT listing for the common section of beamline BL4N_2

'03/09/19 – 460MEV – BL4N VERSION 2 REVERSE 33 DEG BEND – COMMON SECTION'

0									
13.		12.00000;							
16.00	'X0 '	16.00000	9.82964;						
16.00	'Z0 '	18.00000	−5.31156;						
16.00	'T0 '	19.00000	155.18701;						
1.00	'BEAM'	0.12700	1.60400	0.56100	0.57500	0.0	0.10000	1.03673;	
12.		0.0	0.0	0.0	0.0	0.0	−0.94900	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0;	
1.00	'FOIL'	0.0	0.27300	0.0	0.27300	0.0	0.0	0.0	0.0;
14.	'ROW1'	−0.04140	0.32970	0.0	0.0	0.0	1.46880	1.00000;	
14.	'ROW2'	−3.11000	0.11160	0.0	0.0	0.0	1.97800	2.00000;	
14.	'ROW3'	0.0	0.0	1.14100	0.65040	0.0	0.0	3.00000;	
14.	'ROW4'	0.0	0.0	0.51000	1.16500	0.0	0.0	4.00000;	
3.0	'4VM1'	0.31440;							
3.0	'Q1IN'	0.16825;							
5.00	'4VQ1'	0.41110	1.70933	5.08000;					
3.0	'Q2IN'	0.62755;							
5.00	'4VQ2'	0.40700	−1.96906	5.08000;					
3.0		0.49970;							
3.0	'Q3IN'	0.50460;							
5.00	'4VQ3'	0.39720	2.13781	5.08000;					
3.0		0.95496;							
19.00	'SOL1'	0.59055	0.00001;						
3.0		0.95037;							
3.0	'B1IN'	−0.04528;							
2.0		16.29675;							
4.000	'4VB1'	1.56290	12.58686	0.00000;					
2.0		16.29675;							
3.0	'B1EX'	0.00001;							
3.0		0.65000;							
5.00	'4VQ4'	0.40640	−1.57215	5.08000;					
3.0	'Q5IN'	0.30480;							
5.00	'4VQ5'	0.40640	2.07985	5.08000;					
3.0	'D1 '	1.11255;							
3.0	'D2 '	1.11255;							
3.0	'D3 '	1.11255;							
3.0	'D4 '	1.11255;							
3.0	'D5 '	1.11255;							
3.0	'D6 '	1.11255;							
3.0	'D7 '	1.11255;							
3.0	'WST1'	1.11255;							
−10.0	'XWST'	2.00000	1.00000	0.00000	0.00100;				
−10.0	'YWST'	4.00000	3.00000	0.00000	0.00100;				
3.0	'D9 '	1.11255;							
3.0	'D10 '	1.11255;							
3.0	'D11 '	1.11255;							
3.0	'D12 '	1.11255;							
3.0	'D13 '	1.11255;							
3.0	'D14 '	1.11255;							

Table 7 (Continued)

3.0	'D15 '	1.11255;			
3.0	'D16 '	1.11255;			
5.00	'4NQ6'	0.40640	3.54238	5.08000;	
3.0		0.30480;			
5.00	'4NQ7'	0.40640	−3.43822	5.08000;	
3.0	'B2IN'	0.65000;			
2.0		16.29675;			
4.000	'4NB2'	1.56290	12.58686	0.00000;	
2.0		16.29675;			
3.0	'B2EX'	0.00001;			
−10.0	'VR16'	−1.00000	6.00000	0.00000	0.00100;
−10.0	'VR26'	−2.00000	6.00000	0.00000	0.00100;
3.0		1.00000;			
5.00	'4NQ8'	0.40640	5.99847	5.08000;	
3.0		0.30480;			
5.00	'4NQ9'	0.40640	−7.10556	5.08000;	
3.0	'WST2'	2.00000;			
−10.0	'XWW2'	2.00000	1.00000	0.00000	0.00100;
−10.0	'YWW2'	4.00000	3.00000	0.00000	0.00100;
−10.0	'TSW2'	3.00000	3.00000	0.20000	0.01000;
−10.0	'XSW2'	1.00000	1.00000	0.20000	0.01000;

Table 8

Beam sizes and elements of the overall transfer-matrix at the waists of the common section of beamline BL4N_2

Parameter	WST1	WST2
$\pm x$ (cm)	0.794	0.200
$\pm \theta$ (mr)	0.288	1.055
$\pm y$ (cm)	0.440	0.200
$\pm \phi$ (mr)	0.427	0.916
R_{11} (cm/cm)	1.1465	-1.4837
R_{12} (cm/mr)	-0.4774	0.0412
R_{16} (cm/%)	0.7990	-0.0001
R_{21} (mr/cm)	2.0498	-2.7820
R_{21} (mr/mr)	0.0368	-0.6108
R_{26} (mr/%)	1.0763	-0.0003
R_{33} (cm/cm)	0.8525	0.3569
R_{34} (cm/mr)	1.1974	0.0002
R_{43} (mr/cm)	-1.2103	2.7171
R_{44} (mr/mr)	-0.5297	2.7966

Table 9

TRANSPORT listing for the East Target section of beamline BL4N_2

'03/09/19 – 460MEV – VERSION 2 BL4 REVERSE 33 DEG BEND – +30° +30° −30° SECTION'

3.0		1.00000;			
5.00	'NQ10'	0.40640	−5.05100	5.08000;	
3.0		0.30480;			
5.00	'NQ11'	0.40640	4.61175	5.08000;	
3.0	'B3IN'	1.00000;			
2.0		15.33900;			
4.000	'4NB3'	1.50000	12.34394	0.00000;	
2.0		15.33900;			
3.0	'B3EX'	0.00001;			
3.0		1.00000;			
5.00	'NQ12'	0.40640	−4.80590	5.08000;	
3.0		0.30480;			
5.00	'NQ13'	0.40640	3.50249	5.08000;	
3.0	'MID '	0.50000;			
5.00	'NQ14'	0.40640	3.50249	5.08000;	
3.0		0.30480;			
5.00	'NQ15'	0.40640	−4.80590	5.08000;	
3.0		1.00000;			
3.0	'B4IN'	1.00000;			
2.0		15.33900;			
4.000	'4NB4'	1.50000	12.34394	0.00000;	
2.0		15.33900;			
3.0	'B4EX'	0.00001;			
3.0		1.00000;			
5.00	'NQ16'	0.40640	4.61175	5.08000;	
3.0		0.30480;			
5.00	'NQ17'	0.40640	−5.05100	5.08000;	
3.0		0.50000;			
3.0	'WST3'	0.50000;			
−10.0	'3R16'	−1.00000	6.00000	0.00000	0.00100;
−10.0	'3R26'	−2.00000	6.00000	0.00000	0.00100;
−10.0	'XWW3'	2.00000	1.00000	0.00000	0.00100;
−10.0	'YWW3'	4.00000	3.00000	0.00000	0.00100;
−10.0	'TSW3'	3.00000	3.00000	0.20000	0.01000;
−10.0	'XSW3'	1.00000	1.00000	0.20000	0.01000;
3.0		0.30000;			
3.0		0.30000;			
3.0		0.30000;			
3.0		0.21354;			
5.00	'NQ18'	0.40640	−6.98929	5.08000;	
3.0		0.30480;			
5.00	'NQ19'	0.40640	5.24201	5.08000;	
3.0		0.30000;			
3.0		0.30000;			
3.0		0.06667;			
3.0		0.06667;			
3.0		0.30000;			
3.0		0.30000;			
5.00	'NQ20'	0.40640	−6.98929	5.08000;	

Table 9 (Continued)

3.0		0.30480;			
5.00	'NQ21'	0.40640	4.58268	5.08000;	
3.0		0.21354;			
3.0		0.30000;			
3.0		0.30000;			
3.0	'B5IN'	0.30000;			
20.0		180.00000;			
2.0		15.00000;			
4.000	'4NB5'	1.56290	12.10864	0.00000;	
2.0		15.00000;			
20.0		−180.00000;			
3.0	'B5EX'	0.00001;			
3.0	'D4 '	0.50000;			
3.0	'D5 '	0.25000;			
5.00	'NQ22'	0.40640	−4.62646	5.08000;	
3.0		0.30480;			
5.00	'NQ23'	0.40640	5.15337	5.08000;	
3.0		0.50000;			
3.0		0.50000;			
3.0		0.50000;			
3.0		0.50000;			
3.0		0.50000;			
3.0	'WST4'	0.40000;			
−10.0		−1.00000	6.00000	0.00000	0.00100;
−10.0		8.00000	1.00000	57.90000	0.00100;
−10.0		8.00000	3.00000	−9.16500	0.00100;
−10.0		8.00000	4.00000	60.90000	0.00100;
−10.0		2.00000	1.00000	0.00000	0.00100;
−10.0		4.00000	3.00000	0.00000	0.00100;
−10.0		3.00000	3.00000	0.20000	0.01000;
−10.0		1.00000	1.00000	0.20000	0.01000;
SENTINEL;					
SENTINEL;					

Table 10

TRANSPORT listing for the West Target section of beamline BL4N_2

'03/09/19 – 460MEV – VERSION 2 BL4 REVERSE 33 DEG BEND – +30° +10° −10° SECTION'

3.0		1.00000;		
5.00	'NQ10'	0.40640	−3.86188	5.08000;
3.0		0.30480;		
5.00	'NQ11'	0.40640	4.10788	5.08000;
3.0	'B3IN'	1.00000;		
2.0		15.33900;		
4.000	'4NB3'	1.50000	12.34394	0.00000;
2.0		15.33900;		
3.0	'B3EX'	0.00001;		
3.0		1.00000;		
5.00	'NQ12'	0.40640	−4.80590	5.08000;
3.0		0.30480;		
5.00	'NQ13'	0.40640	3.50249	5.08000;
3.0	'MID '	0.50000;		
3.0	' '	0.50000;		
5.00	'NQ14'	0.40640	3.50249	5.08000;
3.0		0.30480;		
5.00	'NQ15'	0.40640	−4.80590	5.08000;
3.0	'B4IN'	1.00000;		
2.0		15.33900;		
4.000	'4NB4'	1.51175	3.39047	0.00000;
2.0		−6.84700;		
3.0	'B4EX'	0.00001;		
3.0		0.30000;		
3.0		0.30000;		
3.0		0.30000;		
3.0		0.30000;		
3.0		0.30000;		
3.0		0.30000;		
3.0		0.30000;		
3.0		0.23264;		
5.00	'NQ16'	0.40640	3.00836	5.08000;
3.0		0.30480;		
5.00	'NQ17'	0.40640	−1.83959	5.08000;
3.0		0.30480;		
3.0		0.30000;		
3.0		0.30000;		
3.0		0.30000;		
3.0		0.30000;		
3.0		0.30000;		
3.0		0.30000;		
3.0	'B5IN'	0.38808;		
20.0		180.00000;		
2.0		4.59450;		
4.000	'4NB5'	0.65000	8.51419	0.00000;
2.0		4.59450;		
20.0		−180.00000;		
3.0	'B5EX'	0.00001;		

Table 10 (Continued)

3.0	'D4 '	0.50000;			
3.0	'D5 '	0.25000;			
5.00	'NQ20'	0.40640	−3.52711	5.08000;	
3.0		0.30480;			
5.00	'NQ21'	0.40640	4.25493	5.08000;	
3.0		0.50000;			
3.0		0.50000;			
3.0		0.50000;			
3.0		0.50000;			
3.0		0.50000;			
3.0	'WST4'	0.40000;			
−10.0		−1.00000	6.00000	0.00000	0.00100;
−10.0		8.00000	1.00000	57.90000	0.00100;
−10.0		8.00000	3.00000	−14.17100	0.00100;
−10.0		8.00000	4.00000	60.90000	0.00100;
−10.0		2.00000	1.00000	0.00000	0.00100;
−10.0		4.00000	3.00000	0.00000	0.00100;
−10.0		3.00000	3.00000	0.20000	0.01000;
−10.0		1.00000	1.00000	0.20000	0.01000;
SENTINEL;					
SENTINEL;					

Table 11

TRANSPORT listing for the Dump section of beamline BL4N_2

'03/09/17 – 460MEV – VERSION 2 BL4 REVERSE 33 DEG BEND – +30° DUMP SECTION'

3.0		1.00000;			
5.00	'NQ10'	0.40640	3.43451	5.08000;	
3.0		0.30480;			
5.00	'NQ11'	0.40640	−3.92269	5.08000;	
3.0		0.42901;			
3.0		1.00000;			
3.0		1.00000;			
3.0		1.00000;			
3.0		1.00000;			
5.00	'NQ12'	0.40640	3.43451	5.08000;	
3.0		0.30480;			
5.00	'NQ13'	0.40640	−3.92269	5.08000;	
3.0		0.50000;			
3.0	'B3IN'	0.50000;			
2.0		15.00000;			
4.000	'4NB3'	1.50000	12.07149	0.00000;	
2.0		15.00000;			
3.0	'B3EX'	0.00001;			
3.0		1.00000;			
3.0		1.00000;			
3.0		1.00000;			
3.0		0.11760;			
5.00	'NQ14'	0.40640	−1.93922	5.08000;	
3.0		0.30480;			
5.00	'NQ15'	0.40640	4.03899	5.08000;	
3.0		0.19098;			
3.0		0.50000;			
3.0		0.50000;			
3.0		1.00000;			
3.0		1.00000;			
3.0		1.00000;			
3.0		1.00000;			
3.0		1.00000;			
3.0		1.00000;			
3.0	'DUMP'	0.50000;			
−10.0		8.00000	1.00000	57.90000	0.00100;
−10.0		8.00000	3.00000	−18.75800	0.00100;
−10.0		8.00000	4.00000	60.90000	0.00100;
−10.0		3.00000	3.00000	2.50000	0.01000;
−10.0		1.00000	1.00000	2.00000	0.01000;
SENTINEL;					
SENTINEL;					

Table 12

Beam sizes and elements of the overall transfer-matrix at the specific locations on BL4N_2

Parameter	+30 +30 −30		+30 +10 −10	+30 to DUMP
	WST3	East tgt	West tgt	DUMP
$\pm x$ (cm)	0.200	0.200	0.200	2.000
$\pm \theta$ (mr)	1.056	1.256	1.205	4.089
$\pm y$ (cm)	0.200	0.200	0.200	2.500
$\pm \phi$ (mr)	0.917	0.917	0.917	3.146
R_{11} (cm/cm)	−0.1623	1.5446	−0.8758	−5.0871
R_{12} (cm/mr)	0.1221	−0.0237	−0.1022	1.1062
R_{16} (cm/%)	−0.0001	0.0000	0.0000	−5.8565
R_{21} (mr/cm)	−8.2688	1.6031	6.9017	−11.1064
R_{22} (mr/mr)	−0.0681	0.6362	−0.3604	2.2145
R_{26} (mr/%)	0.0000	6.8143	5.8268	−13.2102
R_{33} (cm/cm)	0.5311	0.1949	0.4322	−2.5733
R_{34} (cm/mr)	0.6028	0.4488	0.5721	−5.6943
R_{43} (mr/cm)	−2.0387	−3.0465	−2.4803	−2.9945
R_{44} (mr/mr)	−0.4356	−1.8964	−0.9748	−7.0139

Table 13

TRANSPORT listing for the East Target section of beamline BL4N_3

'03/09/19 – 460MEV – VERSION 3 BL4 REVERSE 33 DEG BEND – +36.6° −6.6° SECTION'

3.0		1.00000;			
5.00	'NQ10'	0.40640	−1.46482	5.08000;	
3.0		0.30480;			
5.00	'NQ11'	0.40640	3.14783	5.08000;	
3.0	'B3IN'	1.00000;			
2.0		18.32700;			
4.000	'4NB3'	1.86085;	11.88825	0.00000;	
2.0		18.32700;			
3.0	'B3EX'	0.00001;			
3.0		1.00000;			
5.00	'NQ12'	0.40640	−3.27378	5.08000;	
3.0		0.30480;			
5.00	'NQ13'	0.40640	3.95444	5.08000;	
3.0		1.00000;			
3.0		1.00000;			
3.0		1.00000;			
3.0	'WST3'	0.50000;			
−10.0	'XWW3'	2.00000	1.00000	0.00000	0.00100;
−10.0	'YWW3'	4.00000	3.00000	0.00000	0.00100;
−10.0	'TSW3'	3.00000	3.00000	0.20000	0.01000;
−10.0	'XSW3'	1.00000	1.00000	0.20000	0.01000;
3.0		1.00000;			
3.0		1.00000;			
3.0		0.50000;			
3.0		0.37685;			
5.00	'NQ14'	0.40640	−2.20343	5.08000;	
3.0		0.30480;			
5.00	'NQ15'	0.40640	2.21174	5.08000;	
3.0		1.00000;			
3.0		1.00000;			
3.0		0.49056;			
3.0		1.00000;			
3.0		1.00000;			
5.00	'NQ16'	0.40640	2.21174	5.08000;	
3.0		0.30480;			
5.00	'NQ17'	0.40640	−2.20343	5.08000;	
3.0		0.12864;			
3.0		1.00000;			
3.0		1.00000;			
3.0		1.00000;			
3.0	'B4IN'	0.50000;			
20.0		180.00000;			
2.0		3.32600;			
4.000	'4NB4'	0.50000	8.03006	0.00000;	
2.0		3.32600;			
20.0		−180.00000;			
3.0	'B4EX'	0.00001;			
3.0	'D4 '	0.50000;			
3.0	'D5 '	0.25000;			

Table 13 (Continued)

5.00	'NQ22'	0.40640	−2.55008	5.08000;	
3.0		0.30480;			
5.00	'NQ23'	0.40640	3.56743	5.08000;	
3.0		0.50000;			
3.0		0.50000;			
3.0		0.50000;			
3.0		0.50000;			
3.0		0.50000;			
3.0	'WST4'	0.40000;			
−10.0		−1.00000	6.00000	0.00000	0.00100;
−10.0		8.00000	1.00000	57.90000	0.00100;
−10.0		8.00000	3.00000	−9.16500	0.00100;
−10.0		8.00000	4.00000	60.90000	0.00100;
−10.0		2.00000	1.00000	0.00000	0.00100;
−10.0		4.00000	3.00000	0.00000	0.00100;
−10.0		3.00000	3.00000	0.20000	0.01000;
−10.0		1.00000	1.00000	0.20000	0.01000;
SENTINEL;					
SENTINEL;					

Table 14

TRANSPORT listing for the West Target section of beamline BL4N_3

’03/09/19 – 460MEV – VERSION 3 BL4 REVERSE 33 DEG BEND – +30° SECTION’

3.0		1.00000;			
5.00	’NQ10’	0.40640	−2.68802	5.08000;	
3.0		0.30480;			
5.00	’NQ11’	0.40640	2.84544	5.08000;	
3.0		1.00000;			
3.0		1.00000;			
3.0		1.00000;			
3.0		0.53181;			
5.00	’NQ12’	0.40640	−2.68802	5.08000;	
3.0		0.30480;			
5.00	’NQ13’	0.40640	2.84544	5.08000;	
3.0		0.50000;			
3.0	’B3IN’	0.50000;			
2.0		15.00000;			
4.000	’4NB3’	1.56290	11.58566	0.00000;	
2.0		15.00000;			
3.0	’B3EX’	0.00001;			
3.0		0.50000;			
3.0		0.50000;			
5.00	’NQ14’	0.40640	−2.60470	5.08000;	
3.0		0.30480;			
5.00	’NQ15’	0.40640	3.48601	5.08000;	
3.0		0.50000;			
3.0		0.50000;			
3.0	’WST3’	0.50000;			
−10.0		2.00000	1.00000	0.00000	0.00100;
−10.0		4.00000	3.00000	0.00000	0.00100;
−10.0		3.00000	3.00000	0.20000	0.01000;
−10.0		1.00000	1.00000	0.20000	0.01000;
3.0		0.37500;			
3.0		0.37500;			
3.0		0.37500;			
3.0		0.78347;			
5.00	’NQ16’	0.40640	−2.23289	5.08000;	
3.0		0.30480;			
5.00	’NQ17’	0.40640	2.52974	5.08000;	
3.0		0.37500;			
3.0		0.37500;			
3.0		0.18369;			
5.00	’NQ18’	0.40640	2.52974	5.08000;	
3.0		0.30480;			
5.00	’NQ19’	0.40640	−2.23289	5.08000;	
3.0		0.01638;			
3.0		0.37500;			
3.0		0.37500;			
3.0		0.37500;			
3.0		0.37500;			
3.0		0.37500;			
3.0		0.37500;			

Table 14 (Continued)

3.0		0.37500;			
3.0		0.29246;			
5.00	'NQ20'	0.40640	−3.52711	5.08000;	
3.0		0.30480;			
5.00	'NQ21'	0.40640	4.25493	5.08000;	
3.0		0.50000;			
3.0		0.50000;			
3.0		0.50000;			
3.0		0.50000;			
3.0		0.50000;			
3.0	'WST4'	0.40000;			
−10.0		−1.00000	6.00000	0.00000	0.00100;
−10.0		8.00000	1.00000	57.90000	0.00100;
−10.0		8.00000	3.00000	−14.17100	0.00100;
−10.0		8.00000	4.00000	60.90000	0.00100;
−10.0		2.00000	1.00000	0.00000	0.00100;
−10.0		4.00000	3.00000	0.00000	0.00100;
−10.0		3.00000	3.00000	0.20000	0.01000;
−10.0		1.00000	1.00000	0.20000	0.01000;
SENTINEL;					
SENTINEL;					

Table 15

TRANSPORT listing for the Dump section of beamline BL4N_3

'03/09/17 – 460MEV – VERSION 3 BL4 REVERSE 33 DEG BEND – +30° DUMP SECTION'					
3.0		1.00000;			
5.00	'NQ10'	0.40640	2.90259	5.08000;	
3.0		0.30480;			
5.00	'NQ11'	0.40640	−3.19958	5.08000;	
3.0		1.00000;			
3.0		1.00000;			
3.0		1.00000;			
3.0		1.00000;			
3.0		0.64941;			
3.0		1.00000;			
3.0		1.00000;			
3.0		1.00000;			
3.0		1.00000;			
3.0		0.50000;			
5.00	'NQ12'	0.40640	2.90259	5.08000;	
3.0		0.30480;			
5.00	'NQ13'	0.40640	−3.19958	5.08000;	
3.0		1.00000;			
3.0		1.00000;			
3.0		1.00000;			
3.0	'B3IN'	0.32721;			
2.0		15.00000;			
4.000	'4NB3'	1.56290	11.58566	0.00000;	
2.0		15.00000;			
3.0	'B3EX'	0.00001;			
3.0		1.00000;			
5.00	'NQ14'	0.40640	5.16509	5.08000;	
3.0		0.69118;			
3.0		1.00000;			
3.0		1.00000;			
3.0		1.00000;			
3.0		1.00000;			
3.0	'DUMP'	0.50000;			
−10.0		8.00000	1.00000	57.90000	0.00100;
−10.0		8.00000	3.00000	−18.75800	0.00100;
−10.0		8.00000	4.00000	60.90000	0.00100;
−10.0		3.00000	3.00000	2.50000	0.01000;
−10.0		1.00000	1.00000	2.00000	0.01000;
SENTINEL;					
SENTINEL;					

Table 16

Beam sizes and elements of the overall transfer-matrix at the specific locations on BL4N_3

Parameter	+36 −6		+30 +0		+30 to DUMP
	WST3	East tgt	WST3	West tgt	DUMP
$\pm x$ (cm)	0.194	0.199	0.200	0.200	2.005
$\pm\theta$ (mr)	1.302	1.279	1.453	1.454	4.296
$\pm y$ (cm)	0.203	0.199	0.200	0.200	2.510
$\pm\phi$ (mr)	0.902	0.921	0.917	0.917	4.268
R_{11} (cm/cm)	1.3792	−0.7493	1.1693	−0.6739	−0.2699
R_{12} (cm/mr)	0.0195	−0.1071	−0.0089	−0.1111	1.2238
R_{16} (cm/%)	1.3322	0.0001	0.0000	0.0000	−2.2946
R_{21} (mr/cm)	−0.0160	7.3417	2.8409	7.5053	−1.4099
R_{22} (mr/mr)	0.7399	−0.3131	0.8512	−0.2774	2.6105
R_{26} (mr/%)	−4.9643	7.1192	−2.5292	10.0043	−6.1890
R_{33} (cm/cm)	0.0523	0.2151	0.4355	−0.0256	0.7816
R_{34} (cm/mr)	−0.2789	0.4598	0.0847	0.2947	4.5174
R_{43} (mr/cm)	3.1153	−3.0291	2.4687	−3.1726	1.0770
R_{44} (mr/mr)	2.4605	−1.8374	2.7711	−2.4503	7.5009

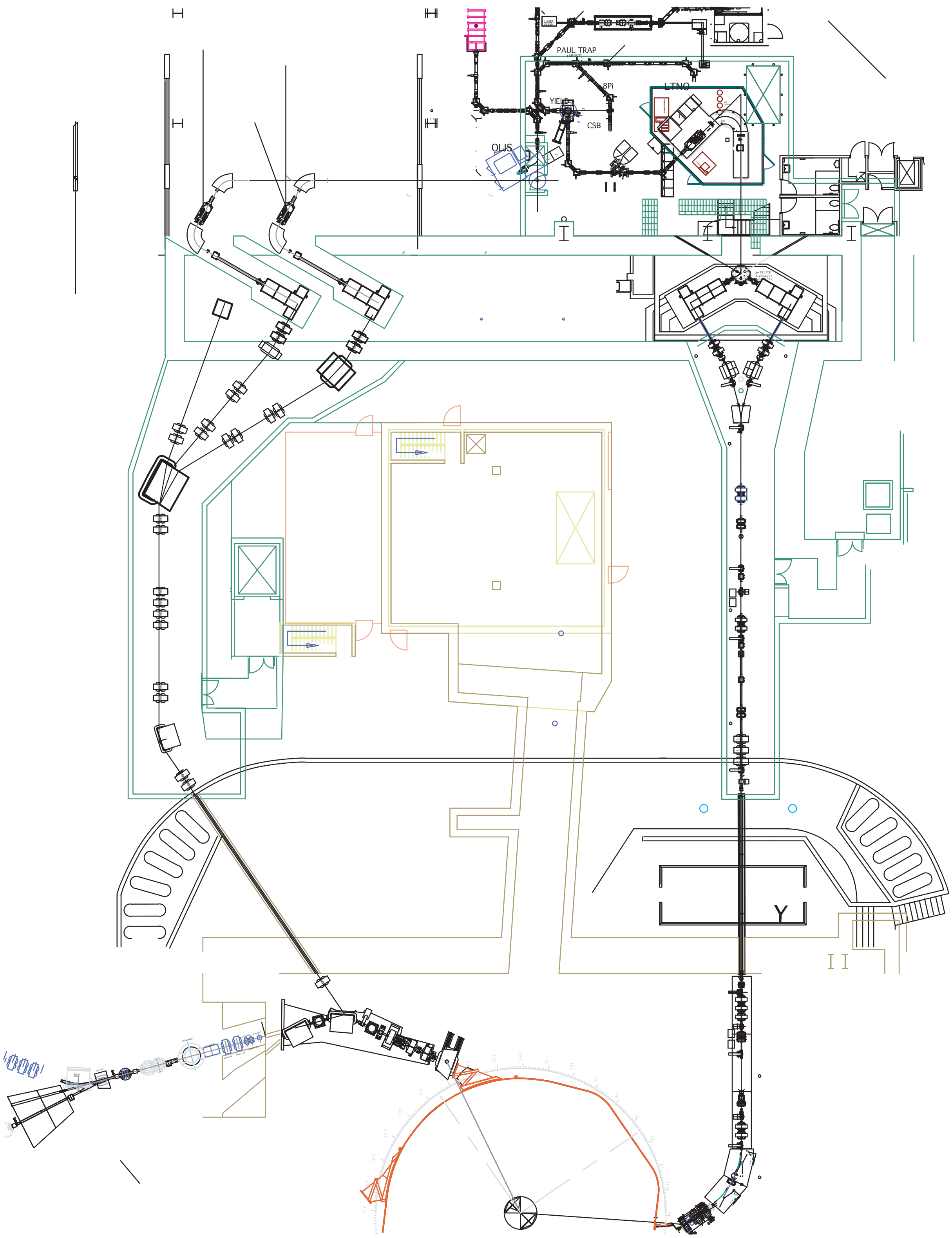

Fig. 1. An overview of the relative locations of BL2A and BL4N.

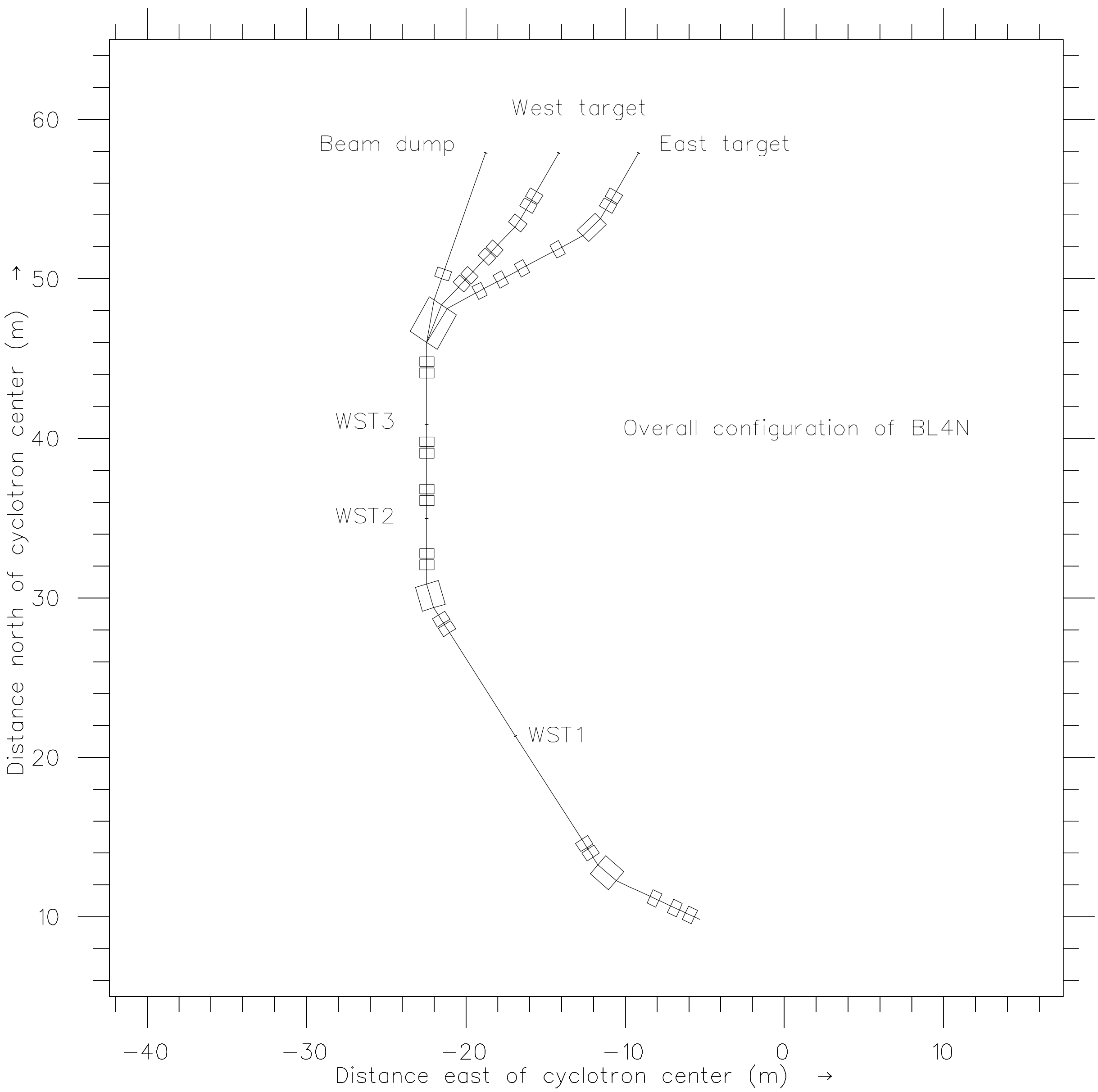

Fig. 2. Detail of the beamline BL4N.

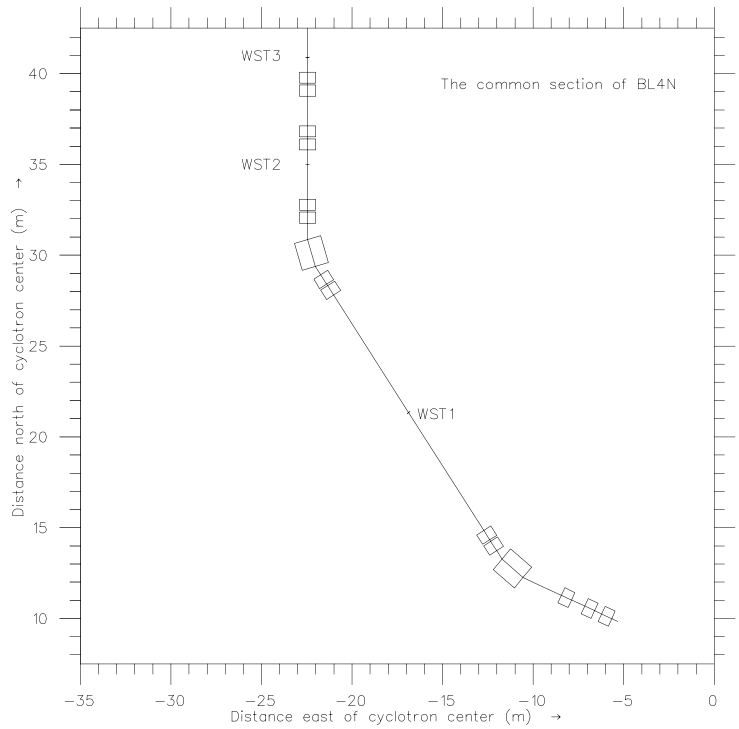

Fig. 3(a). Detail of the common section of BL4N.

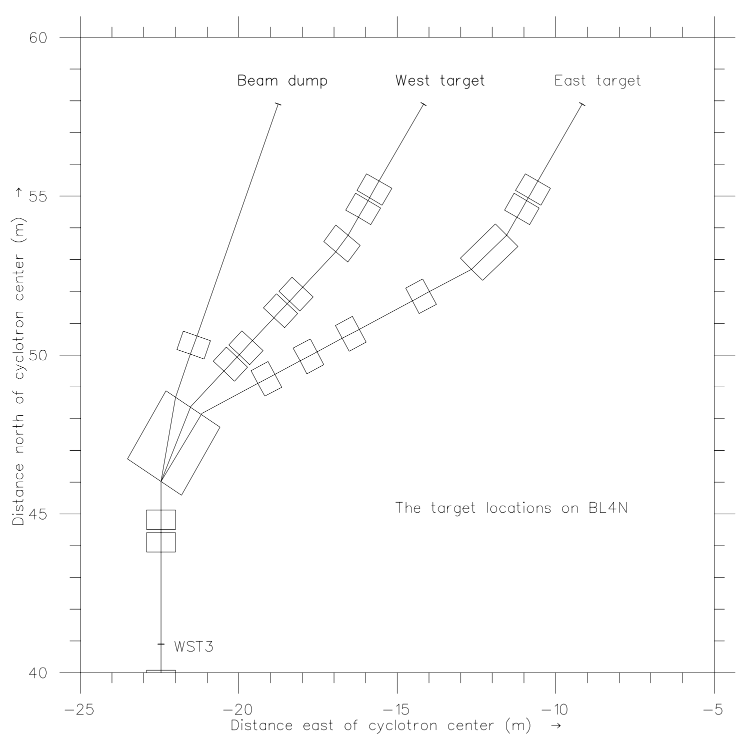

Fig. 3(b). Detail of the target and beam dump sections of BL4N.

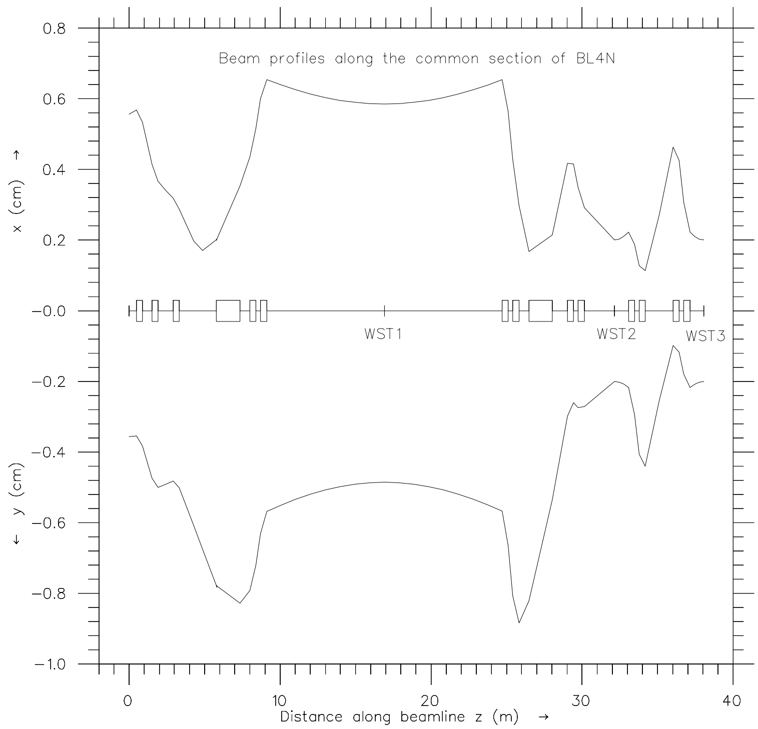

Fig. 4(a). Beam envelopes along the common section of BL4N.

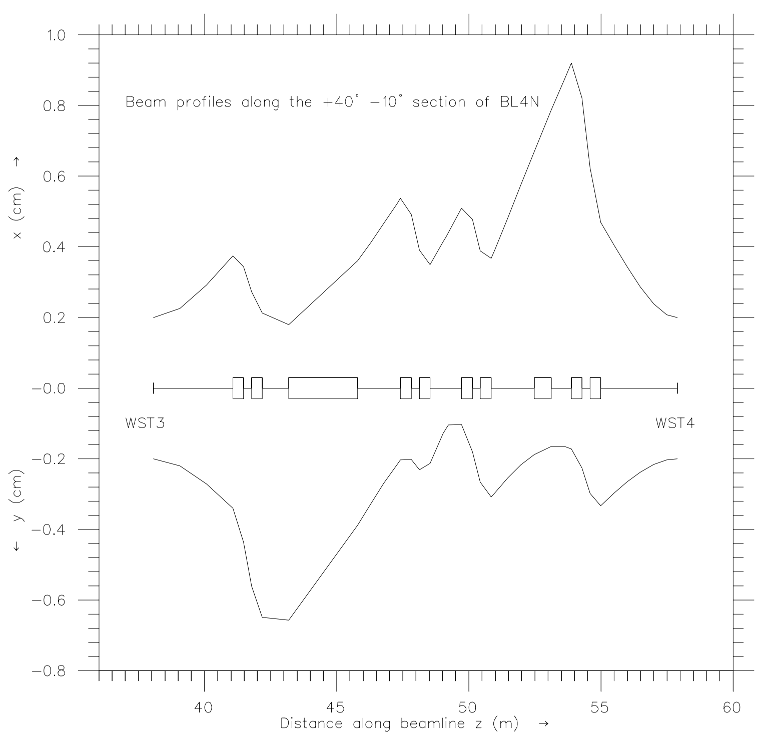

Fig. 4(b). Beam envelopes along the east target section of BL4N.

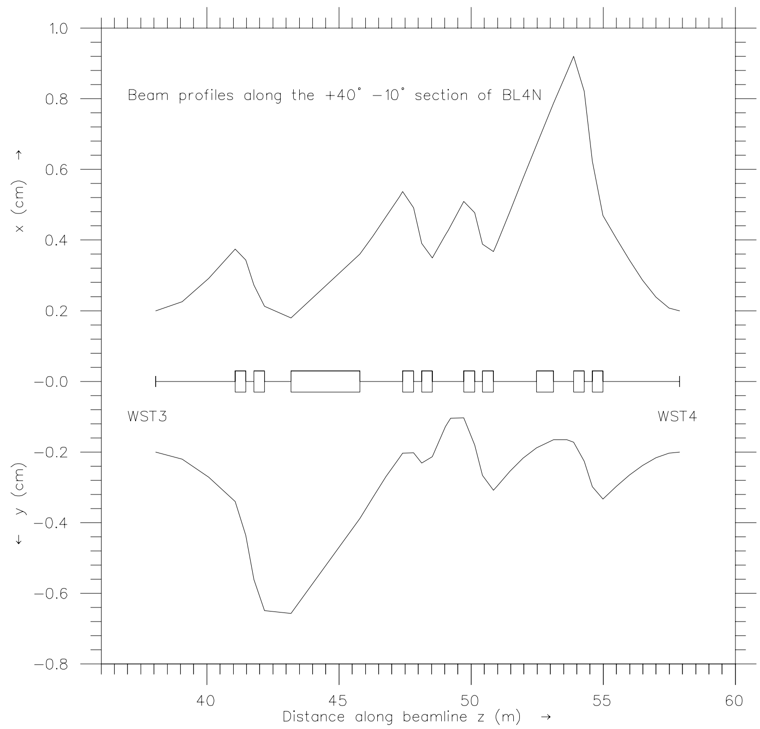

Fig. 4(c). Beam envelopes along the west target section of BL4N.

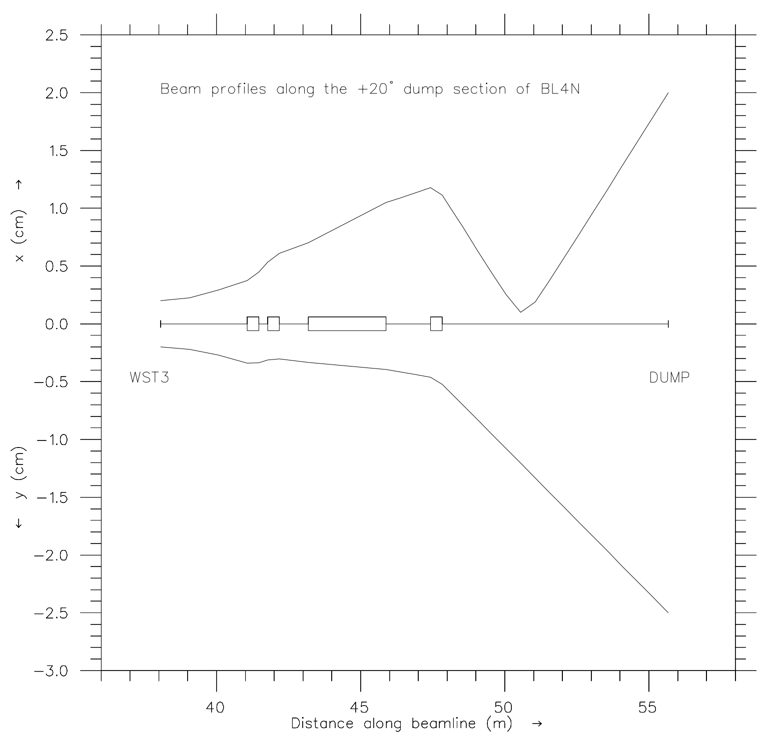

Fig. 4(d). Beam envelopes in the dump section of BL4N.

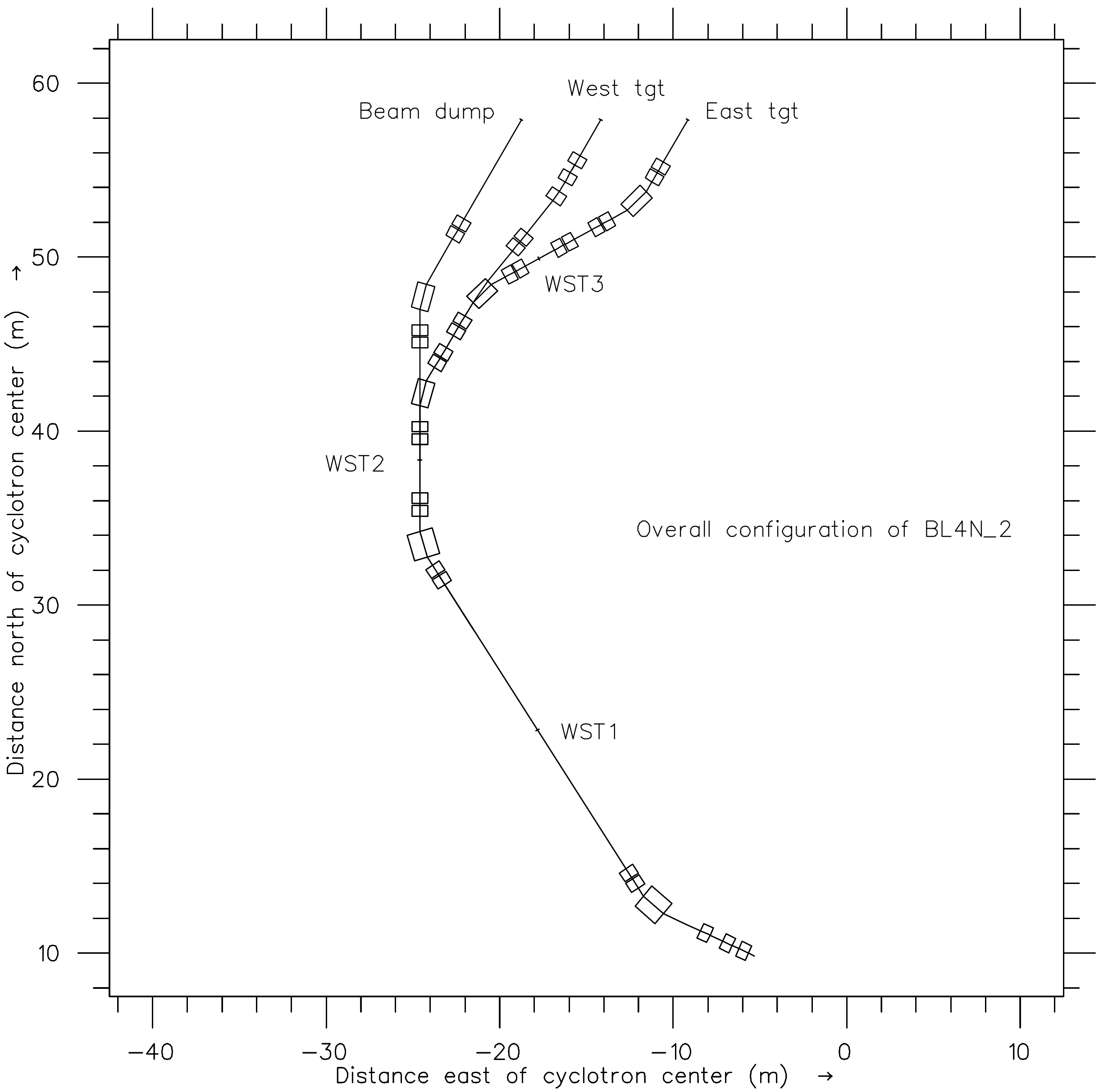

Fig. 5. Detail of the beamline BL4N_2.

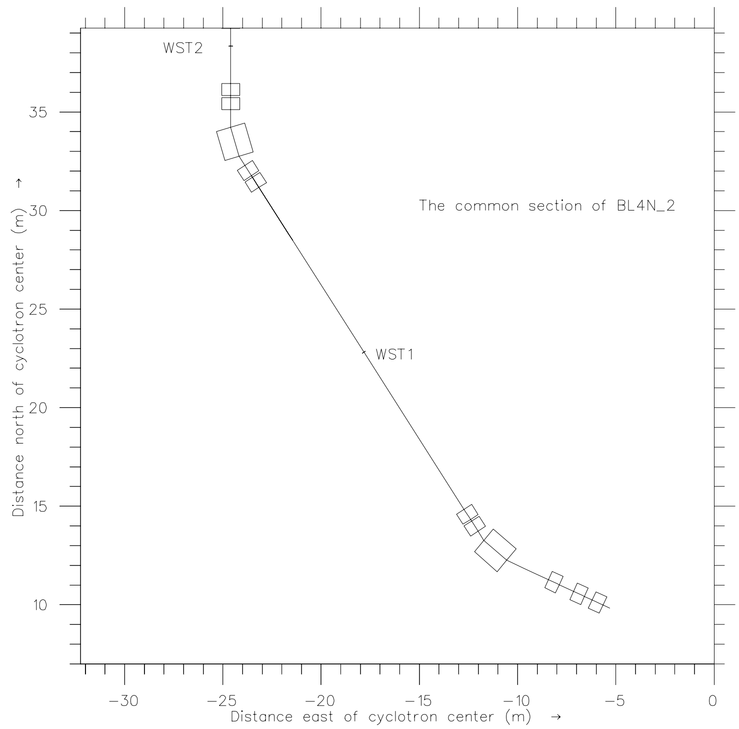

Fig. 6(a). Detail of the common section of BL4N_2.

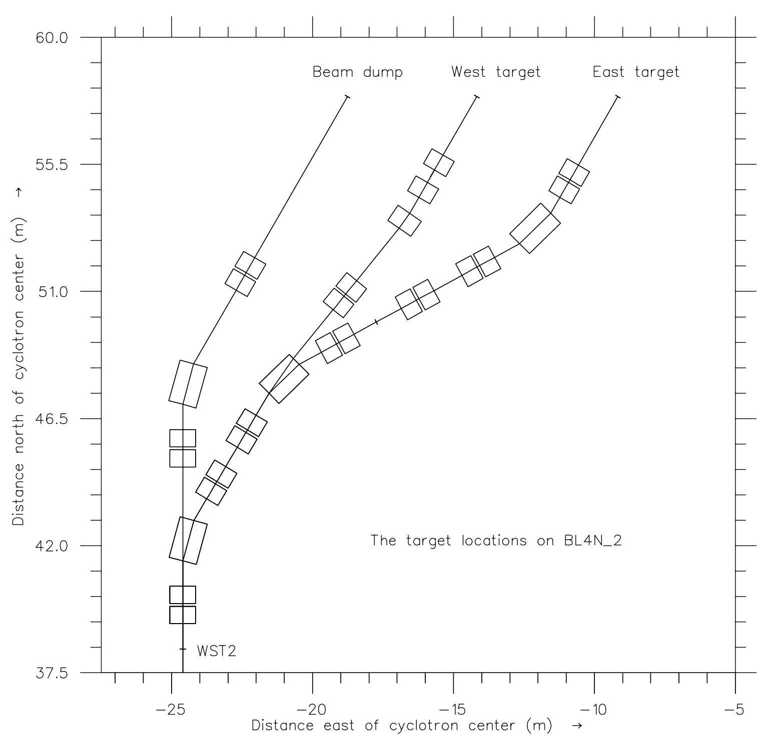

Fig. 6(b). Detail of the target and beam dump sections of BL4N_2.

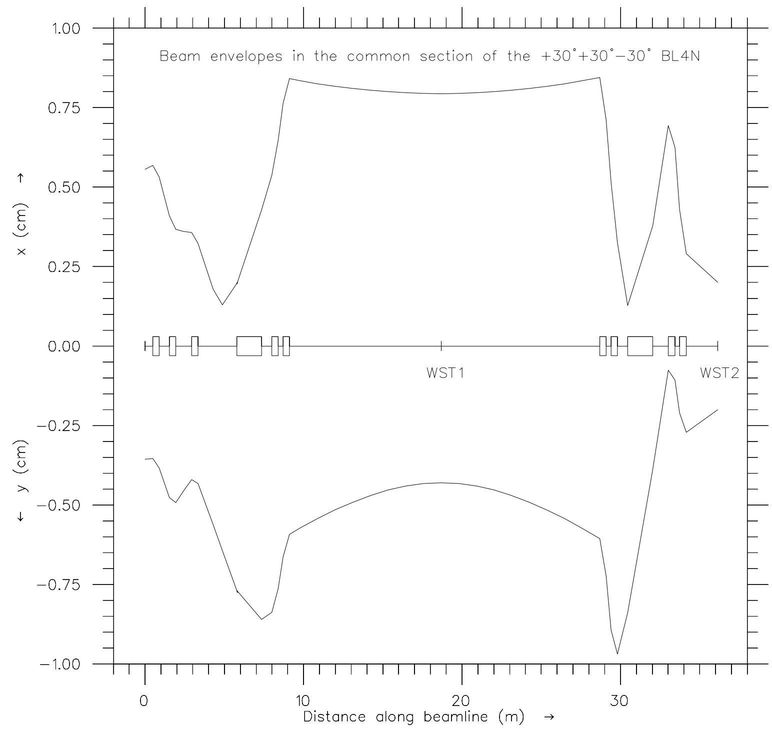

Fig. 7(a). Beam envelopes along the common section of BL4N_2.

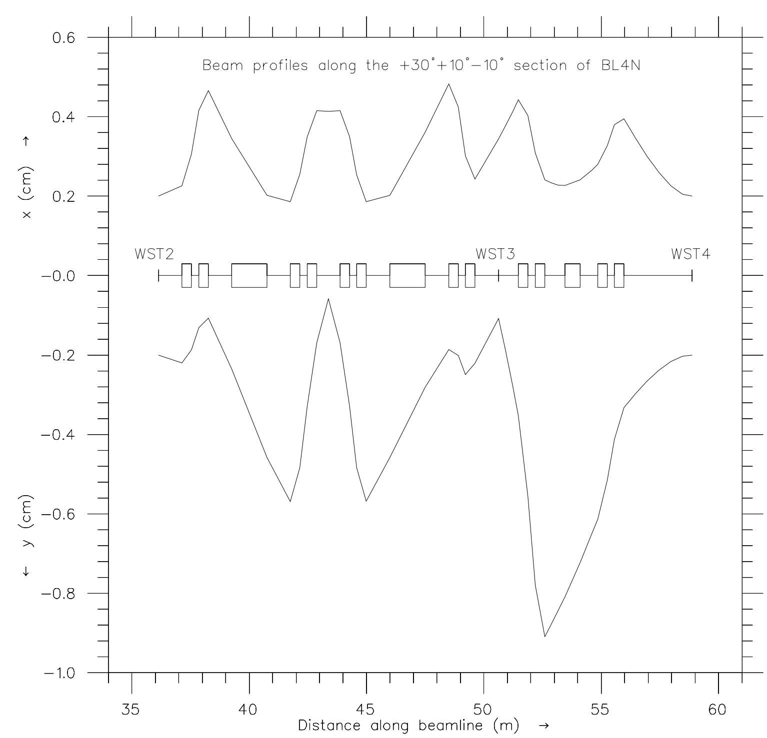

Fig. 7(b). Beam envelopes along the east target section of BL4N_2.

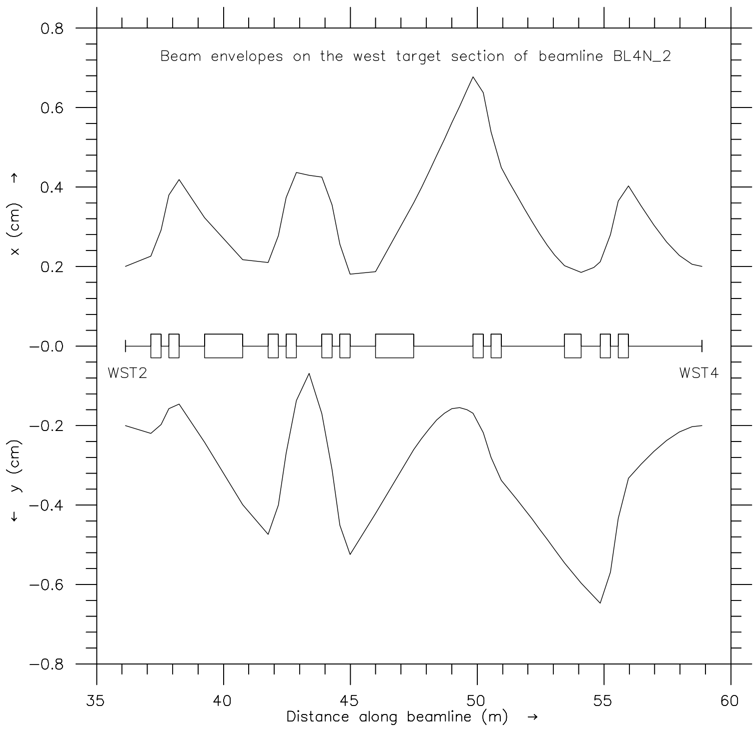

Fig. 7(c). Beam envelopes along the west target section of BL4N_2.

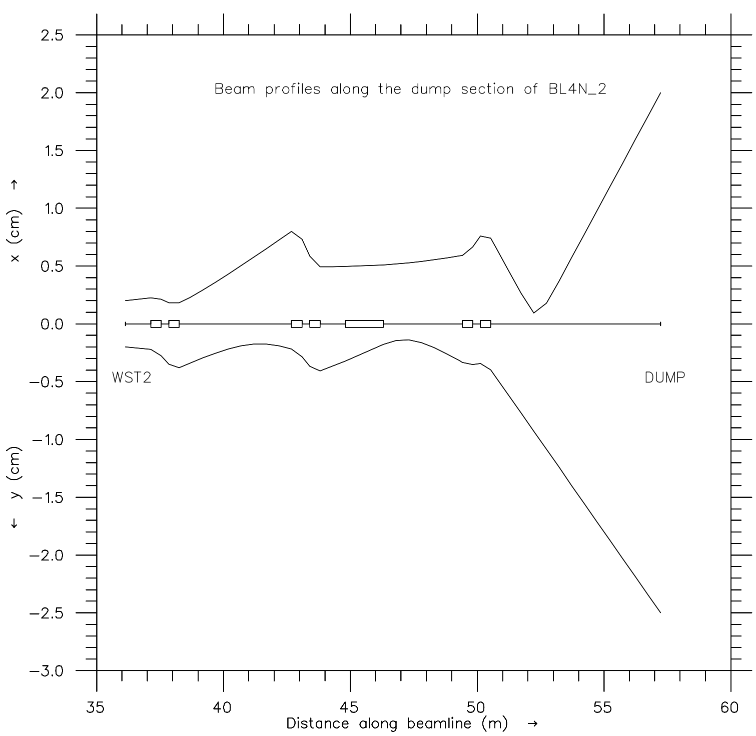

Fig. 7(d). Beam envelopes in the dump section of BL4N_2.

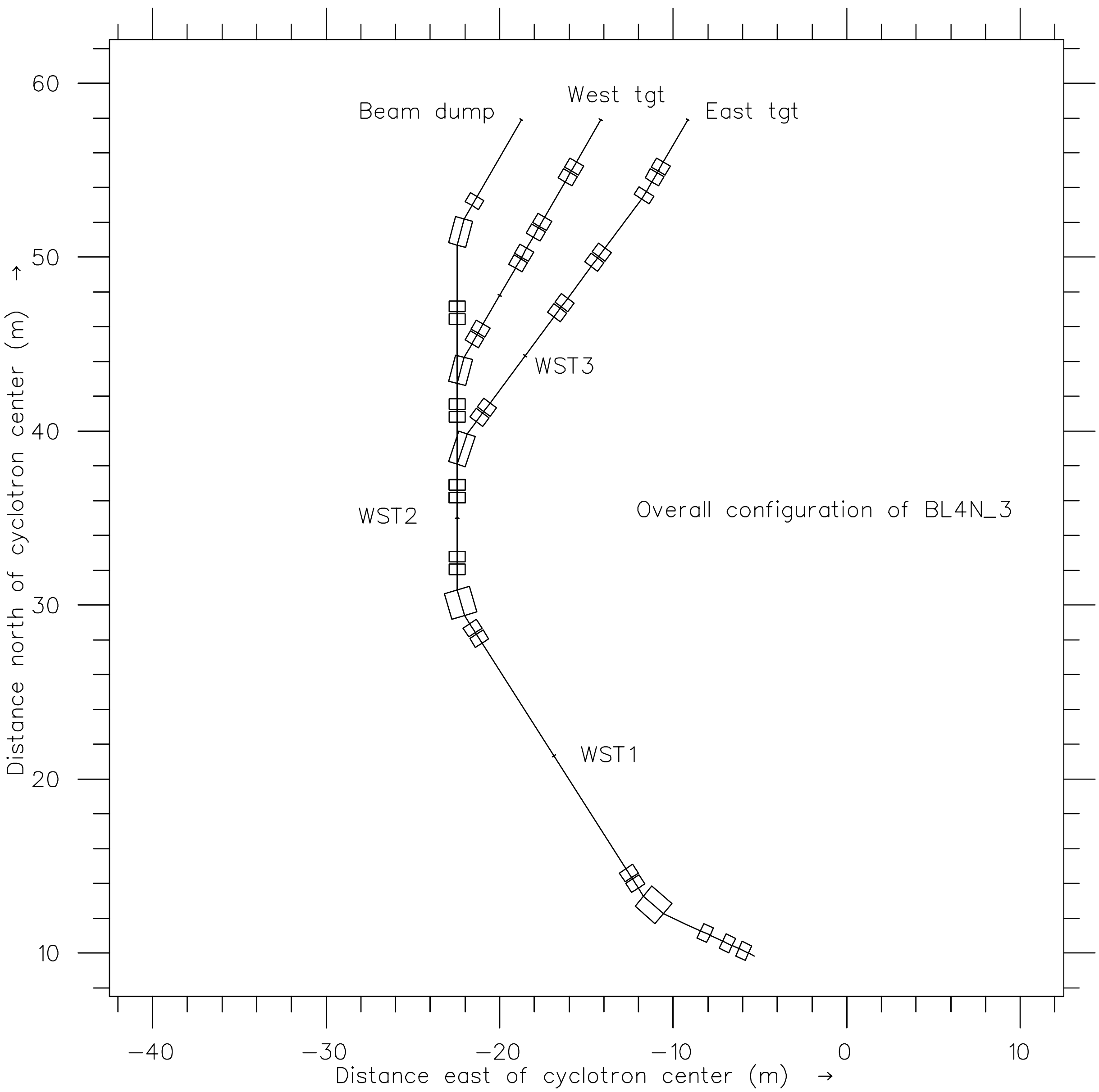

Fig. 8. Detail of the beamline BL4N_3.

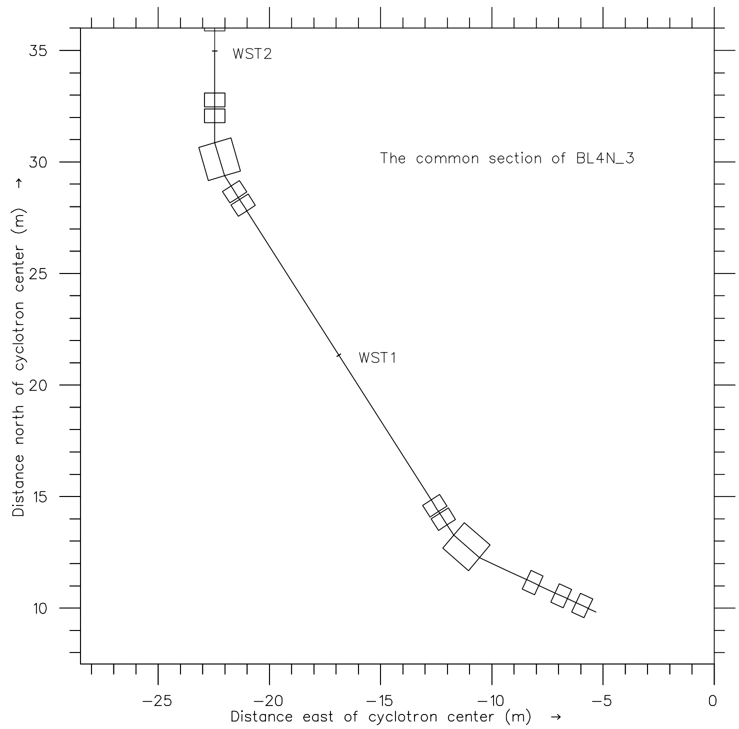

Fig. 9(a). Detail of the common section of BL4N_3.

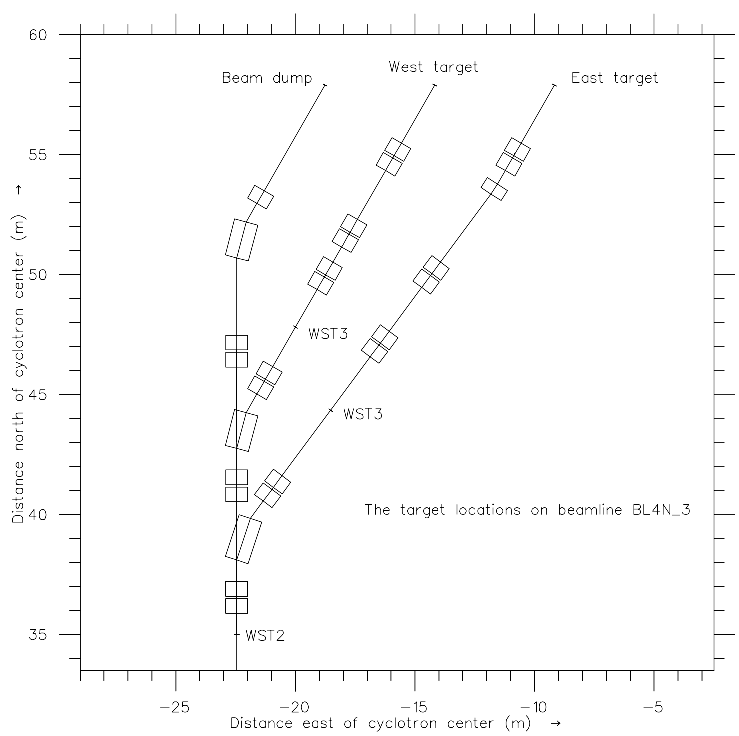

Fig. 9(b). Detail of the target and beam dump sections of BL4N_3.

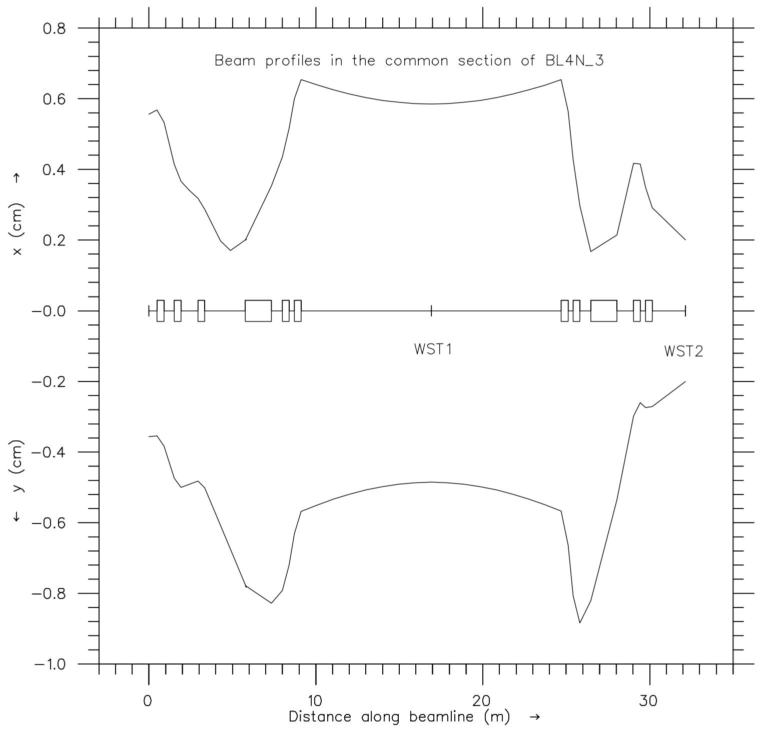

Fig. 10(a). Beam envelopes along the common section of BL4N_3.

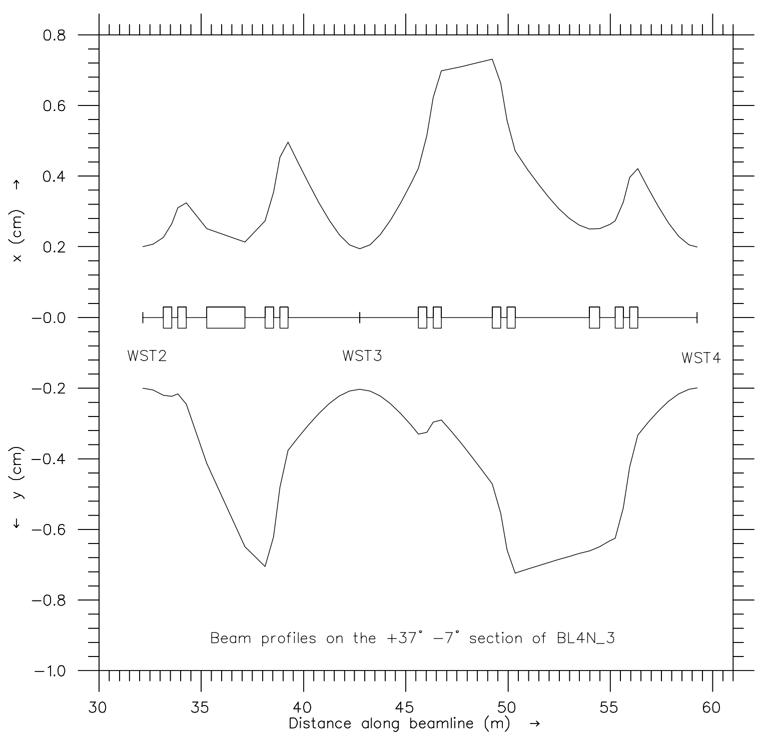

Fig. 10(b). Beam envelopes along the east target section of BL4N_3.

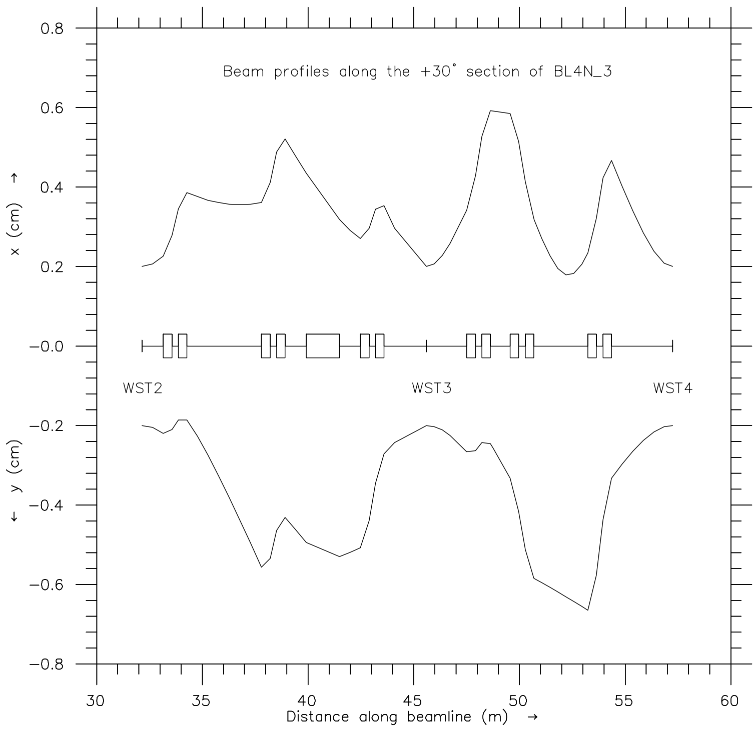

Fig. 10(c). Beam envelopes along the west target section of BL4N_3.

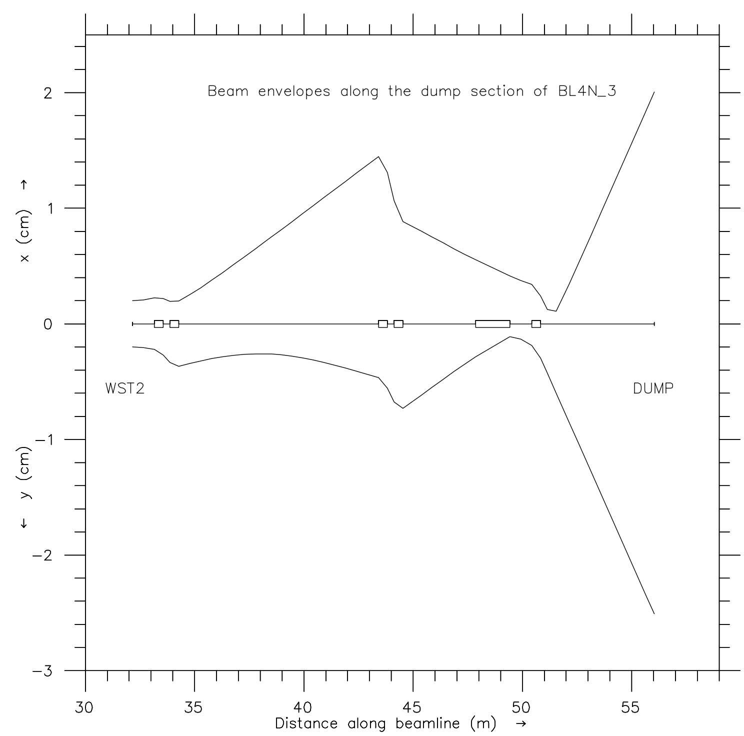

Fig. 10(d). Beam envelopes in the dump section of BL4N_3.