Document-134361

Requirement Specifications for BL4N Magnets Stray Field Measurements

Document Type: Specification

Release: 1 **Release Date:** 2017-09-20

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History of Changes

Release Number	Date	Description of Changes	Author(s)
1	2017-09-20	Initial Release	Y.-N. Rao

Keywords: list of keywords: P179,Requirement Specification,BL4N,Magnets,Stray, Field, Measurements,Specification

Distribution List: list of names

1 Abstract

We expect to recuperate suitable TRIUMF surplus magnets and reuse them for the BL4N. We shall lay out these magnets in the BL4N in terms of (1) their apertures and integrated field strengths which are achievable to meet the requirements of optics, and (2) their envelope dimensions that are permissible to avoid mechanical conflicts with the electron line (EHBT) elements throughout the North-South tunnel. Because the BL4N shall be sitting above the electron line by $3'$, one of the major concerns is the interferences of stray magnetic fields of the BL4N magnets with the EHBT, which might cause electron beam orbit distortions. We require any displacement of the electron beam from its axis due to ambient field be less than the beam size [1]. This means that we shall have to get the stray field down to 100 milliGauss level. This is perhaps achievable by for instance using mu-metal magnetic shielding wrapped around the exposed beam pipe sections. In order to quantitatively characterize the stray field strengths and distribution and therefore provide a guideline and strategy for the field shielding, computer modeling of these magnets have been performed with OPERA. In addition to that, actual measurements of the stray fields are needed for some of the magnets. The requirements are spec'ed in this document for the field measurements.

2 Objective

Some of the TRIUMF surplus magnets shall be repurposed for the BL4N. In order to verify the OPERA modelled results, actual field measurements are necessary for some of these magnets. This shall concern particularly the stray fields of the BL4N magnets, which might interfere with the electron beamline and cause electron beam orbit distortions. This document describes the requirement specifications for the stray field measurements, aiming to provide a guideline and strategy for the field shielding.

3 Specific Requirements

RS1. The BL4N shall reuse appropriate TRIUMF surplus magnets in terms of their integrated field strengths that are achievable to meet the optics requirements [2]. The magnets shall be populated to avoid mechanical conflicts with the EHBT elements, and also to retain reasonable clearance from the west wall in the tunnel north end to allow easy installation of and access to both beamlines. After a couple of times iterations with Design Office [3], we reconciled placements of these magnets on the drawing [3] of the beamline layout with minimized envelope interferences. Tables 1 and 2 give the designation list for the quadrupole and dipole magnets respectively.

Table 1: Designation of suplus quadrupole magnets for minimized envelope interferences with EHBT elements.

Quad EPICS Name	Integrated Strength Req'ed (T)	Designated Quad Type	Full Aperture (inch)	Max. Int. Strength (T)	Eff. Length (cm)	Insertion Length (cm)	Max. I (A)
4VQ1	3.88	4Q14/8	4.06	7.2	41.4	60.96	500
4VQ2	5.92	4Q14/8	4.06	7.2	41.4	60.96	500
4VQ3	8.21	4Q19/8	4.06	9.3	52.6	71.12	500
4VQ4	4.65	4Q14/8	4.06	7.2	41.4	60.96	500
4VQ5	3.90	4Q14/8	4.06	7.2	41.4	60.96	500
4VQ6	4.14	4Q14/8	4.06	7.2	41.4	60.96	500
4NQ1	1.05	4Q14/8	4.06	7.2	41.4	60.96	500
4NQ2	2.20	4Q14/8	4.06	7.2	41.4	60.96	500
4NQ3	0.91	4Q14/8	4.06	7.2	41.4	60.96	500
4NQ4	1.80	4Q14/8	4.06	7.2	41.4	60.96	500
4NQ5	0.03	4Q10/3.6	4.06	1.6	26.0	31.496	100
4NQ6	0.48	4Q10/3.6	4.06	1.6	26.0	31.496	100
4NQ7	1.05	4Q14/8	4.06	7.2	41.4	60.96	500
4NQ8	1.99	4Q14/8	4.06	7.2	41.4	60.96	500
4NQ9	1.99	4Q14/8	4.06	7.2	41.4	60.96	500
4NQ10	1.05	4Q14/8	4.06	7.2	41.4	60.96	500
4NQ11	2.87	4Q8.5/8.5	4.06	4.5	26.1	40.64	310
4NQ12	2.87	4Q8.5/8.5	4.06	4.5	26.1	40.64	310
4NQ13	2.87	4Q8.5/8.5	4.06	4.5	26.1	40.64	310
4NQ14	2.87	4Q8.5/8.5	4.06	4.5	26.1	40.64	310
4NQ15	3.14	KEK QA-I	4.33	4.0	40.0	58.5	500
4NQ16	2.76	KEK QA-I	4.33	4.0	40.0	58.5	500
4NQ17	1.76	DanFysika L5	2.795	6.2	20.5	34.29	200
4NQ18	1.39	DanFysika L5	2.795	6.2	20.5	34.29	200
4NQ19	1.66	DanFysika L5	2.795	6.2	20.5	34.29	200
4NQ20	1.50	DanFysika L5	2.795	6.2	20.5	34.29	200
4NQ21	1.37	TUDA-S	3.346	4.3	29.6	48.75	250
4NQ22	2.49	TUDA-S	3.346	4.3	29.6	48.75	250
4NQ23	2.80	TUDA-S	3.346	4.3	29.6	48.75	250
4NQ24	3.10	TUDA-S	3.346	4.3	29.6	48.75	250
4NQ25	3.10	TUDA-S	3.346	4.3	29.6	48.75	250
4NQ26	2.80	TUDA-S	3.346	4.3	29.6	48.75	250
4NQ27	2.42	4Q8.5/8.5	4.06	4.5	26.1	40.64	310
4NQ28	4.03	4Q12/6	4.06	5.0	35.7	50.8	300
4NQ29	2.89	4Q12/6	4.06	5.0	35.7	50.8	300
4NQ30	2.96	4Q12/6	4.06	5.0	35.7	50.8	300

Table 2: Designation of surplus dipole magnets. Note that the bender 4BVB2 was bending 25° in the old BL4B [4]; the bender 4A3B2 was bending 35.5° in the old BL4A3; while the bender 4VB1 was bending 40° in the old BL4V. All these 3 magnets have an identical design[5] of a nominal bend angle of 35°. The designation below is hoping to reuse the old vacuum chamber pertained to the magnet 4BVB2 as it has nearly the same bend angle as that in the BL4N.

Dipole EPICS Name	Bend Angle Req'ed (°)	Designated Dipole Type (old name & bend angle)	Pole Gap (inch)	Max. Field (T)	Eff. Length (cm)	Total Length (cm)
4VMB4	24.8126	35° bender (4BVB2, 25°)	3.06	1.61	152.4	190.5
4NMB22	34	35° bender (4A3B2, 35.5°)	3.06	1.61	152.4	190.5
4NMB26	34	35° bender (4VB1, 40°)	3.06	1.61	152.4	190.5

Rational: TRIUMF existing primary beamlines 1A, 2A and 2C4 all possess 4″ aperture for the quadrupole magnets throughout. For the BL4N, with collimator to reduce spills in transportation, we can in principle use smaller quadrupoles e.g. Danfysik L5 type (20 cm effective length and 2.795″ aperture) from 4NQ5 (inclusive) onward to the end. Thus, our primary selections are the surplus magnets with apertures larger than 2.795″.

RS2. The field measurements shall be taken for every type of magnets explicitly indicated in the following. This requires to remove the magnet with proper stand to the Proton Hall Extension magnet survey area where the cooling water connection and electricity are available.

Measure 3 components B_x, B_y and B_z of the stray field along a straight line mimicing the EHBT axis which lies 3′ below the median plane of the 45° dipole magnet 4NMB10, as is shown in Fig.1, over a planar distance of about ± 2 m from the dipole's cross-over point R (see Fig.1), in a step of 10 cm. Here the Cartesian frame $x-y-z$ is right-handed and defined such that z is along the EHBT axis, y is vertical and x is horizontal. (This coordinate system remains the same throughout this document.) For this measurement, the dipole magnet shall be excited at a current for making the nominal 45° bend.

RS3. Measure 3 components B_x, B_y and B_z of stray field along a straight line at 3′ below the axis of each quadrupole magnet DanFysika L5, KEK QA-I and 4Q8.5/8.5 separately, over a planar distance of about 1 m upstream and downstream respectively from the quadrupole's centre-line, in a step of 10 cm, as shown in the following segmented drawings Fig.2 to Fig.6. For each measurement, the magnet shall be excited at 200 A (for the DanFysika L5), 400 A (for the KEK QA-I), and 200 A (for the 4Q8.5/8.5) respectively.

Rational: We mainly concern about the stray field on the EHBT axis, which is 3′ below the BL4N axis throughout the tunnel.

RS4. Measure 3 components B_x, B_y and B_z of stray field from the quadrupole 4NQ21 (type TUDA-S) along a straight line at $3'$ below the quadrupole axis as is shown in Fig.7, in a step of 10 cm. The magnet should be excited at 200 A.

RS5. Measure 3 components B_x, B_y and B_z of stray field of the 34° dipole magnet 4NMB22 or 4NMB26 along the EHBT axis as is shown in Fig.8 and Fig.9, in a step of 10 cm. For this measurement, the magnet should be excited under a current of ∼700 A to generate a field of ∼1.35 T for the nominal 34° bend.

Also, the $B - I$ curve shall be measured for either magnet, under excitation from zero up to 800 A in a step of 100 A. (It was excited up to 800 A during the magnet measurements by D. Evans [6].)

RS6. Measure 3 components B_x, B_y and B_z of stray field from quadrupole 4NQ28 (type 4Q12/6) along the EHBT axis as shown in Fig.10, in a step of 10 cm. The magnet should be excited at 250 A.

References

[1] Y.-N. Rao, *TRI-DN-14-04: Optics Design for Electron High Energy Beam Transport (EHBT) in the BL4N Era*, Document-108561, Release 2, 2015-03-18.

[2] Y.-N. Rao, R. Baartman, *TRI-DN-13-13: Beam Line 4 North (BL4N) Optics Design*, Document-91008, Release 5, 2015-07-23.

[3] T. Emmens, Private communications, Jan. 19, 2016; DWG. NO. TEL1814_4.DWG, Apr.6, 2016.

[4] A. Wilson, *PROTON HALL/VAULT/MESON HALL LAYOUT*, DWG. NO. TGN0205E, REV. A, JUNE 2004.

[5] D. Evans, *TRIUMF MAGNET INDEX: DIPOLE MAGNETS IN PRIMARY BEAMLINES*, MAY 2009.

[6] *TRIUMF MAGNET INDEX: Page D3-2*.

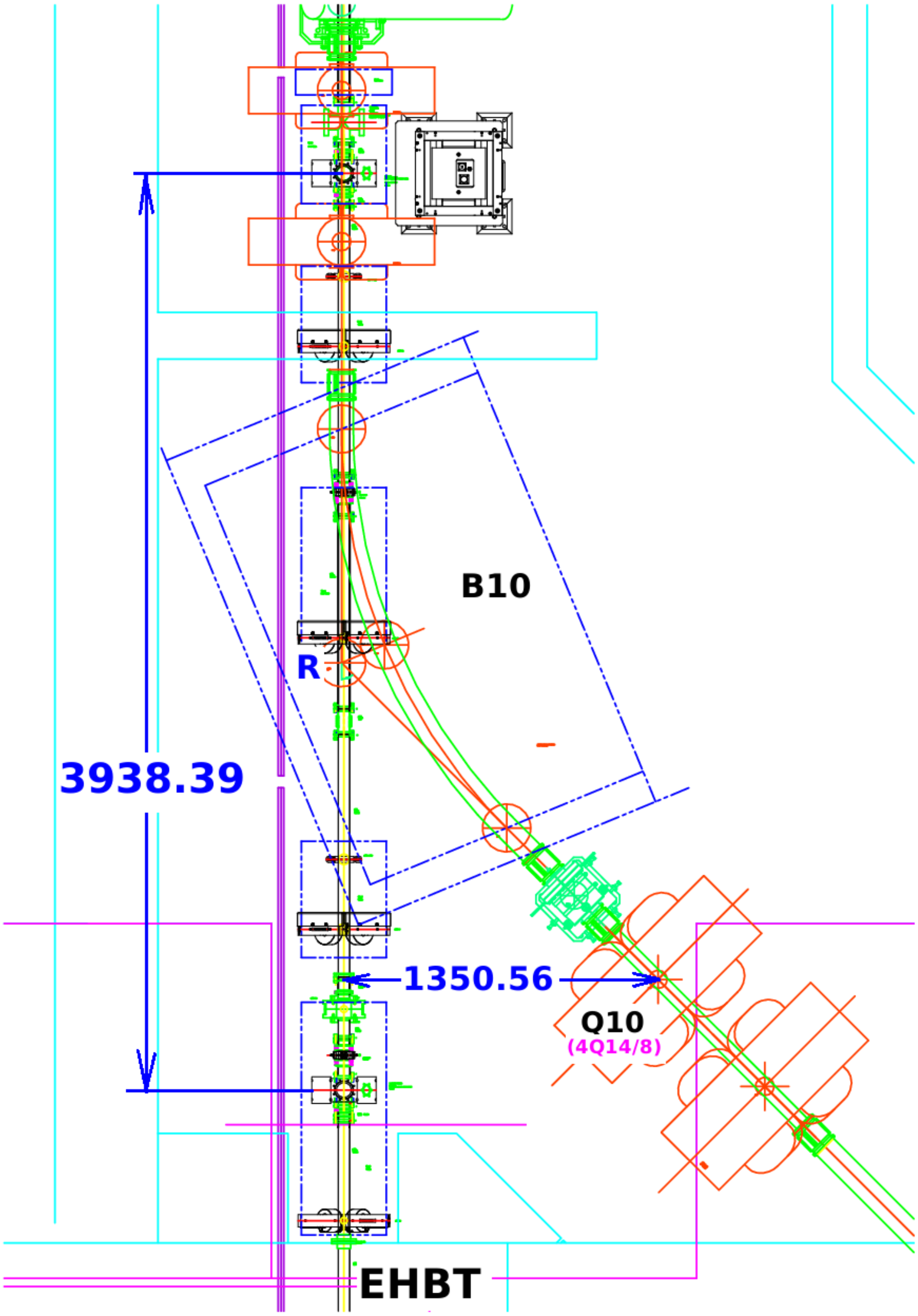

Figure 1: *Plan view of BL4N and EHBT sections around the 45° dipole magnet 4NMB10, sketched in blue rectangles to represent its envelope. The dimensions shown are in mm. The elevation difference is 914.4 mm between the BL4N beam axis (up) and the EHBT beam axis (down). The stray field measurement should be taken along the EHBT axis over a planar distance of about ±2 m from the dipole's cross-over point R, under a current excitation of making the nominal 45° bend.*

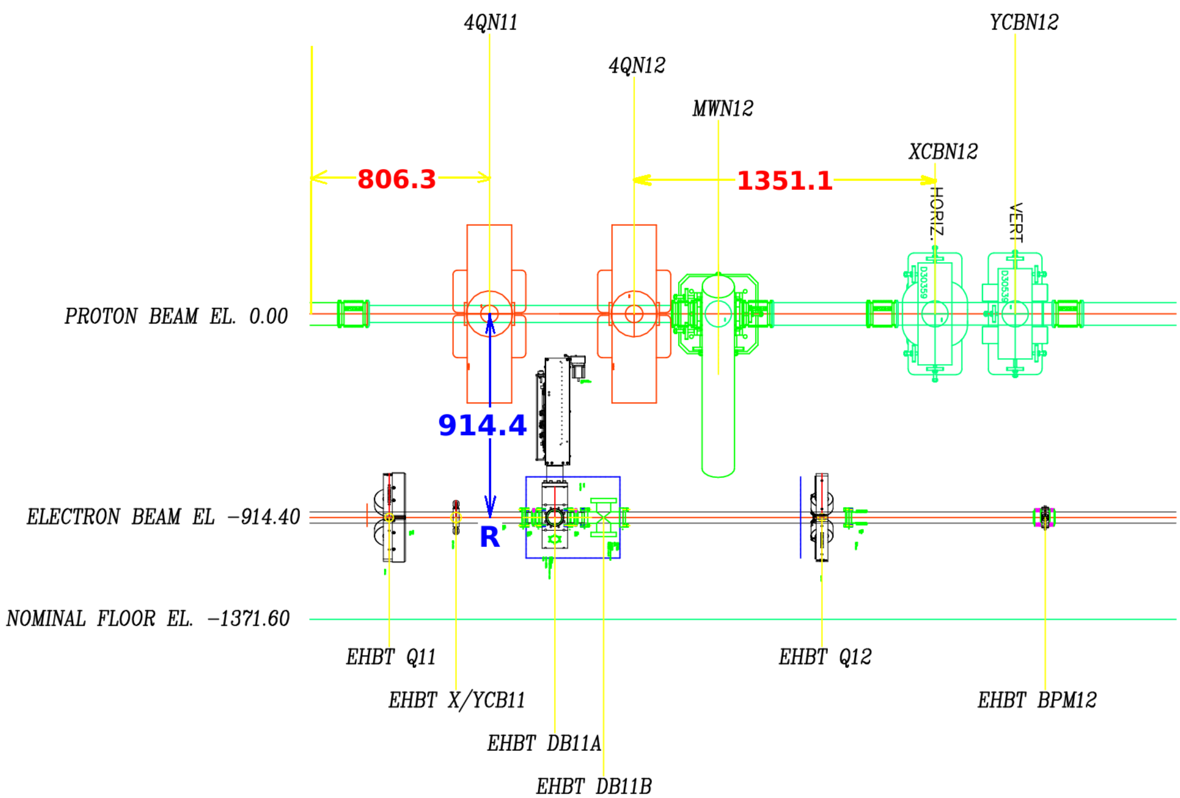

Figure 2: *Side view of BL4N and EHBT sections around the quadrupole doublet 4NQ11 and 4NQ12 of type 4Q8.5/8.5. The dimensions shown are in mm. The stray magnetic field measurement should be taken along the EHBT axis over a planar distance of about* $\pm 1\,m$ *from the reference point R.*

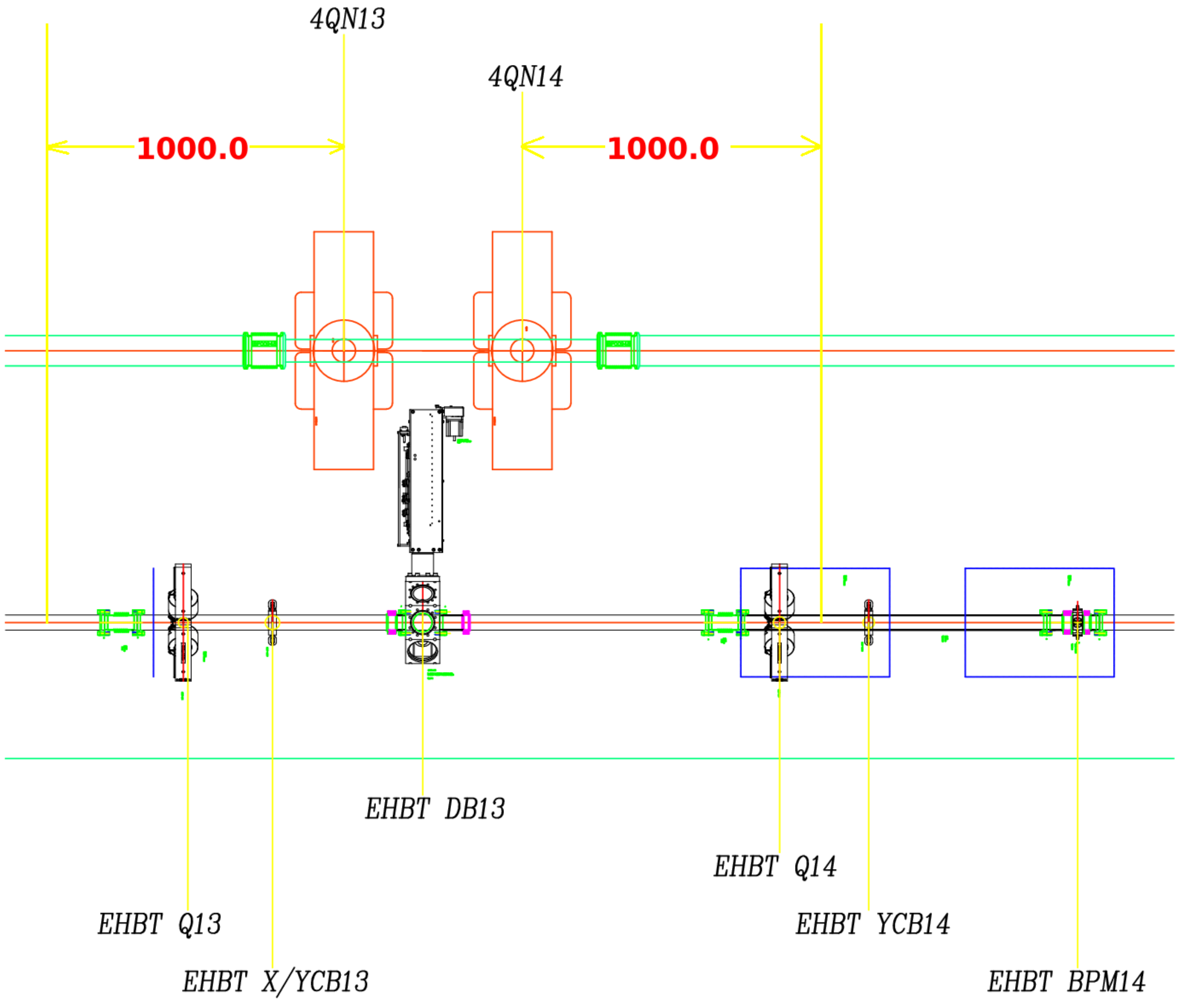

Figure 3: *Side view of BL4N and EHBT sections around the quadrupole doublet 4NQ13 and 4NQ14 of type 4Q8.5/8.5. The dimensions shown are in mm. The elevation difference is 914.4 mm between these 2-beamline's axes.*

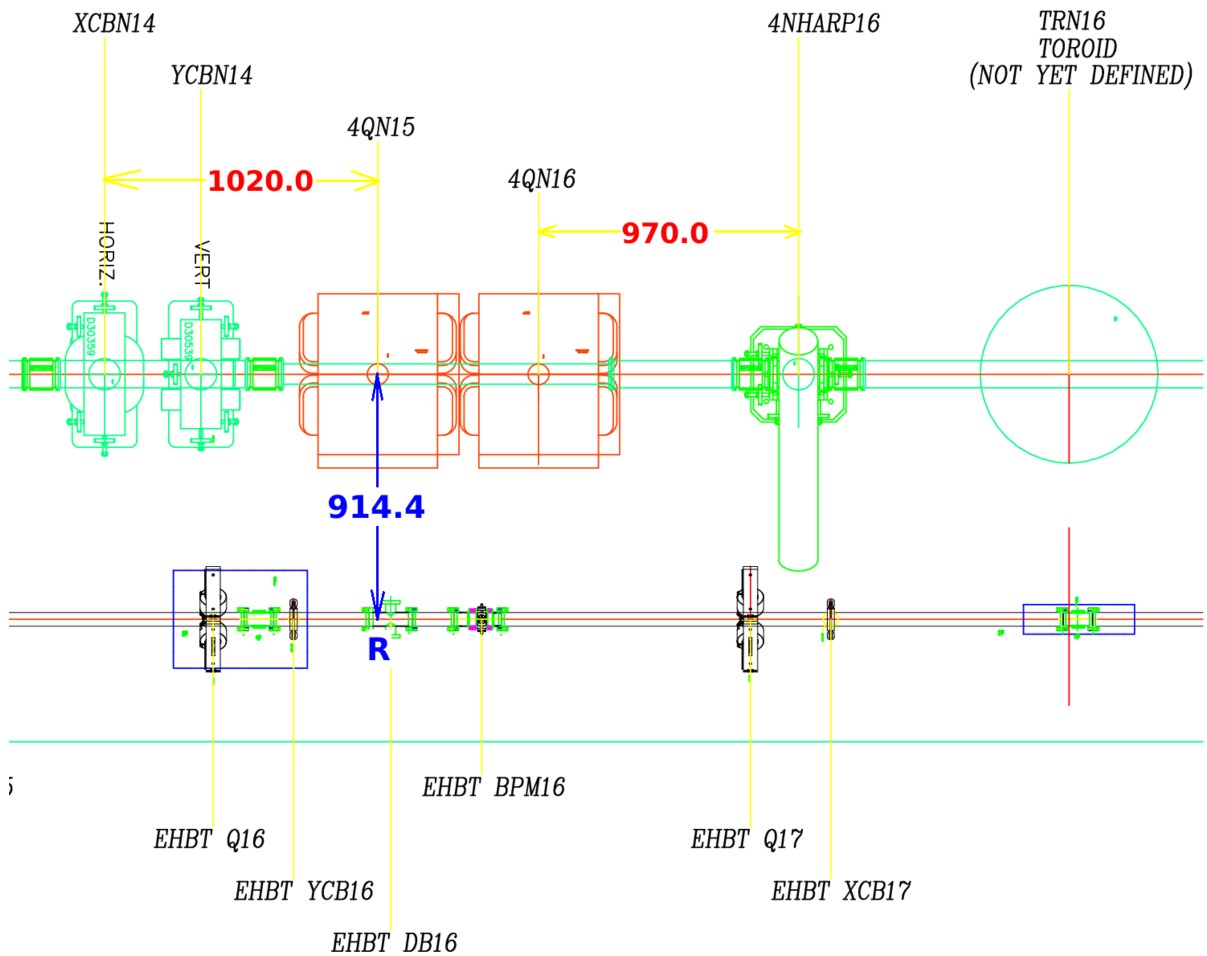

Figure 4: *Side view of BL4N and EHBT sections around the quadrupole doublet 4NQ15 and 4NQ16 of type KEK QA-I. The dimensions shown are in mm. The elevation difference is 914.4 mm between these 2-beamline's axes. The stray magnetic field measurement should be taken along the EHBT axis over a planar distance of about ±1 m from reference point R.*

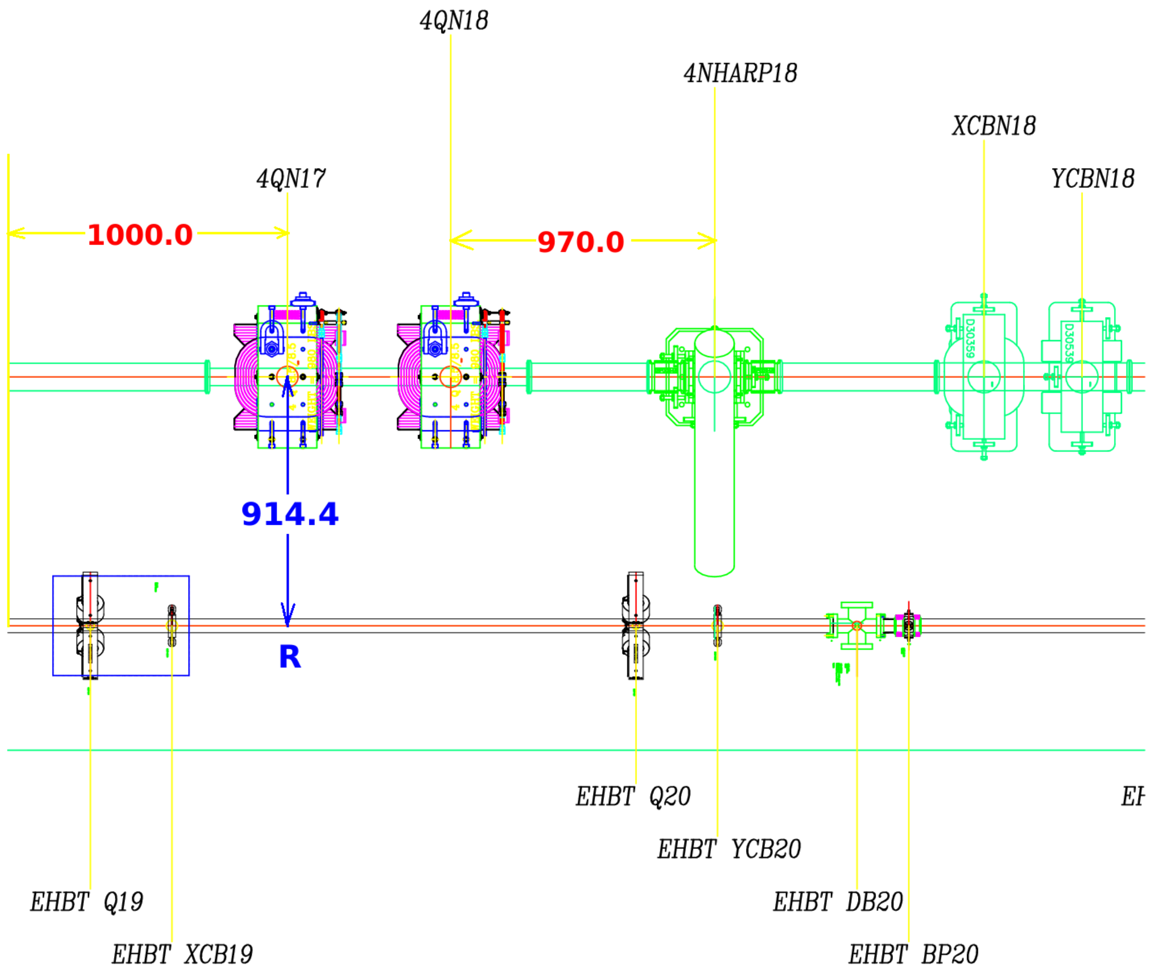

Figure 5: *Side view of BL4N and EHBT sections around the quadrupole doublet 4NQ17 and 4NQ18 of type DanFysika L5. The dimensions shown are in mm. The elevation difference is 914.4 mm between these 2-beamline's axes. The stray magnetic field measurement should be taken along the EHBT axis over a planar distance of about ±1 m from the reference point R.*

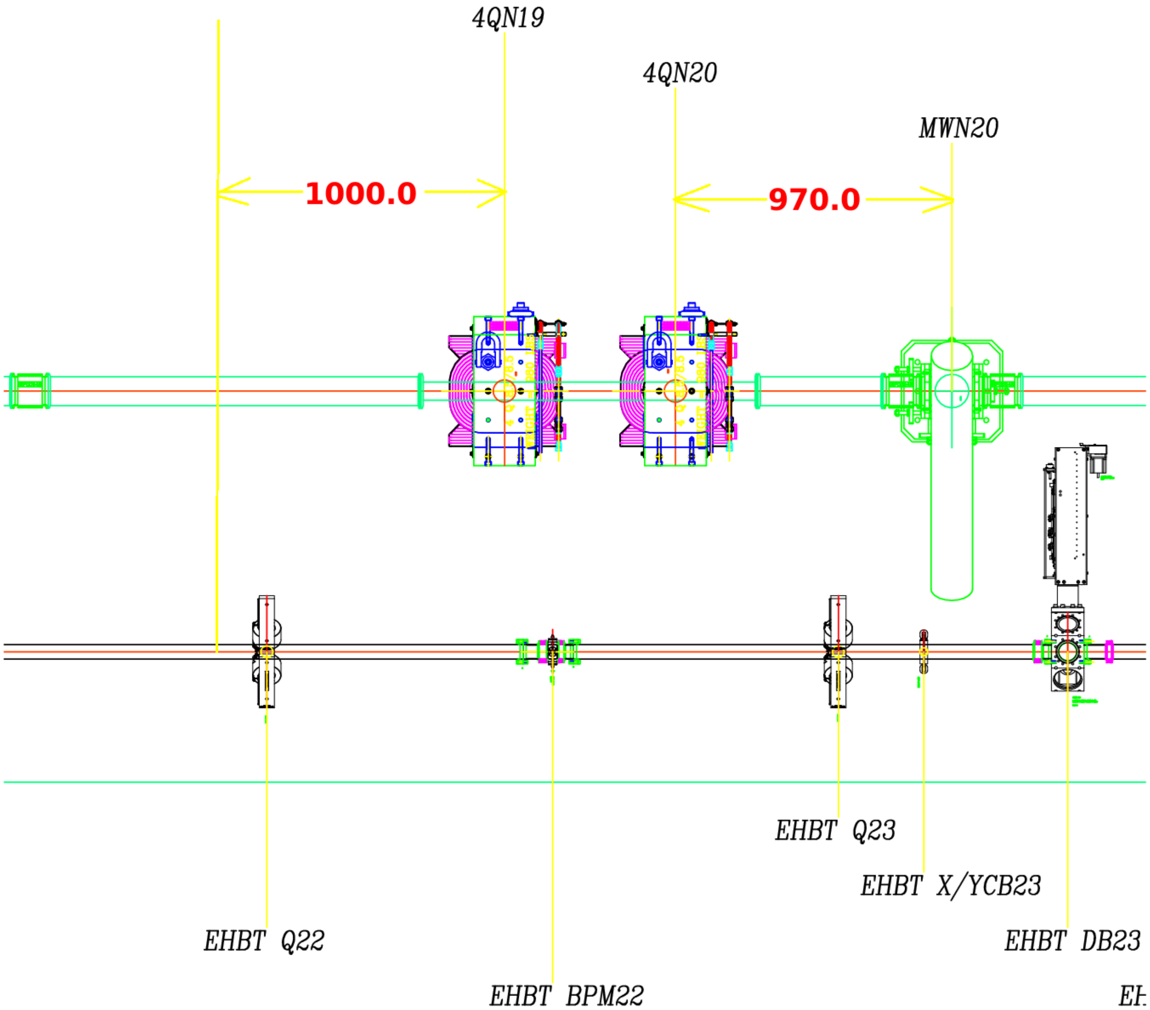

Figure 6: *Side view of BL4N and EHBT sections around the quadrupole doublet 4NQ19 and 4NQ20 of type DanFysika L5. The dimensions shown are in mm. The elevation difference is 914.4 mm between these 2-beamline's axes.*

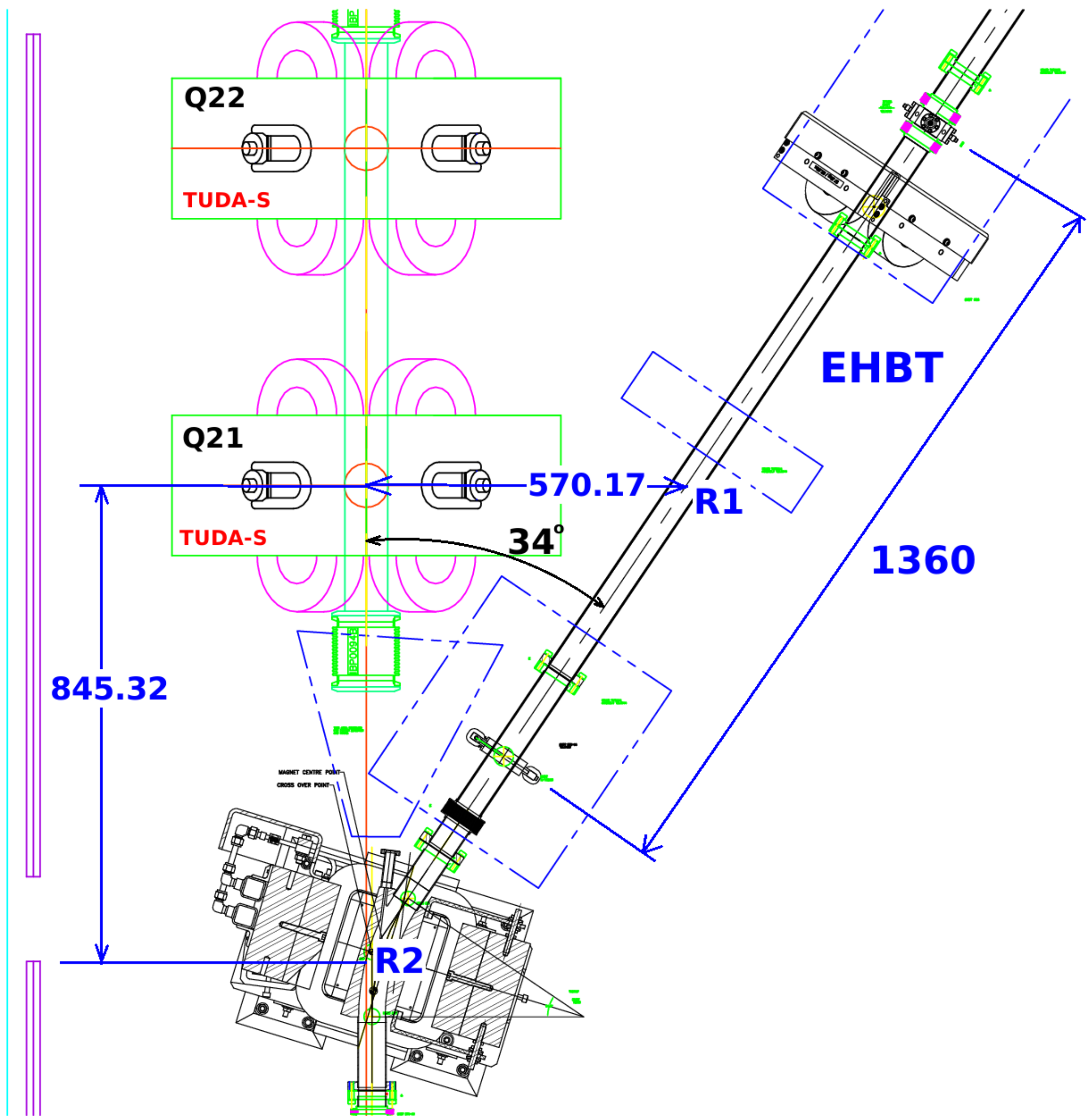

Figure 7: *Plan view of BL4N and EHBT sections around the quadrupole doublet 4NQ21 and 4NQ22 of type TUDA-Short. The dimensions shown are in mm. The elevation difference is 914.4 mm between these 2-beamline's axes. The planar angle is 34° between the 2 axes. The stray magnetic field measurement should be taken along the EHBT axis over a planar distance of about ±1 m from the reference point R1.*

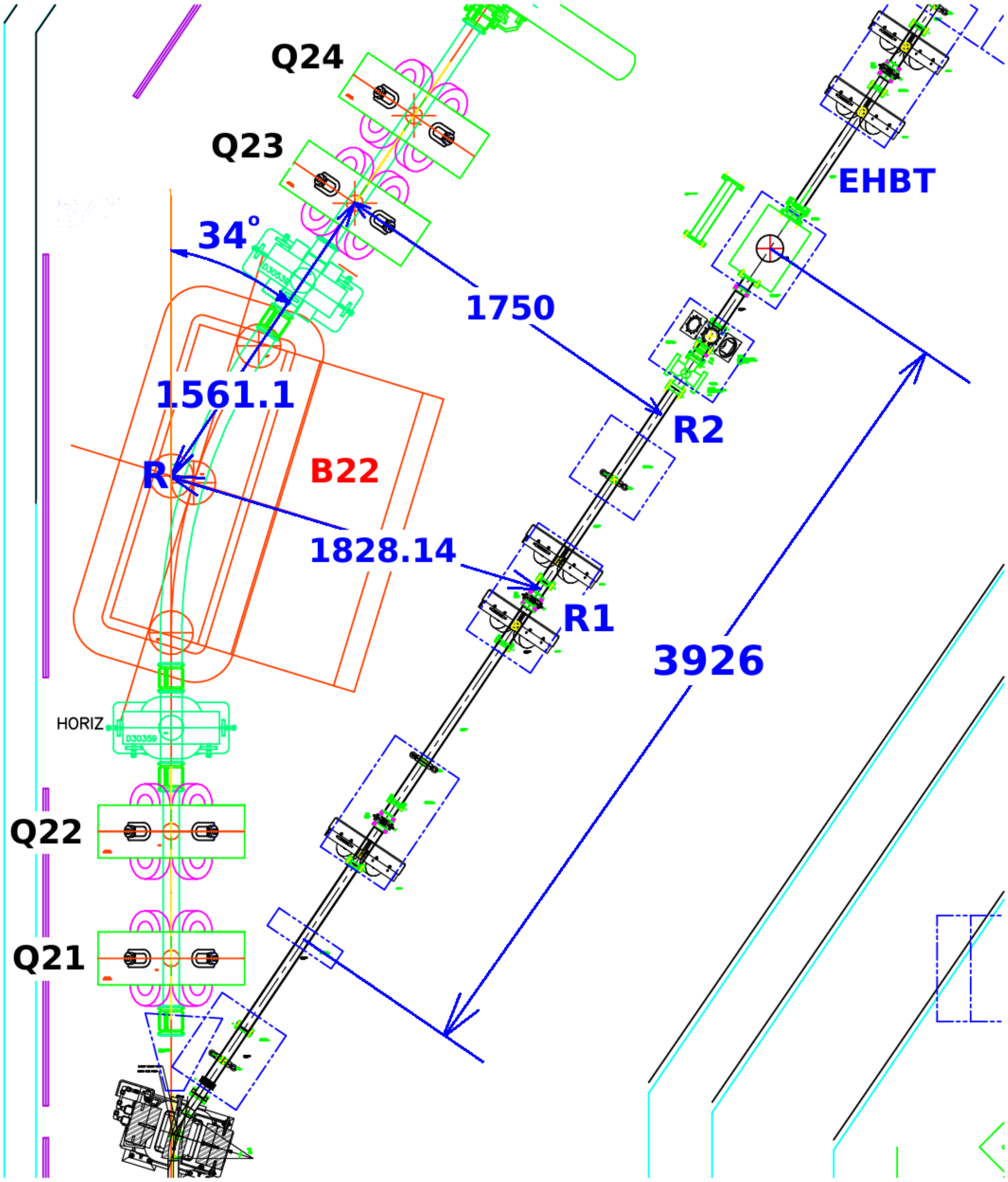

Figure 8: *Plan view of BL4N and EHBT sections around the 34° bending magnet 4NMB22. The dimensions shown are in mm. The 4NMB22 bends symmetrically, and its outgoing axis is parallel with the EHBT axis. The elevation difference is 914.4 mm (3′) between the BL4N axis (up) and the EHBT axis (down). The planar distance from the cross-over point R of 4NMB22* **along its centre-line** *to the EHBT axis (point R1) is 1828.14 mm. The stray magnetic field measurement should be taken along the EHBT axis over a planar distance of about ±2 m from the reference point R1.*

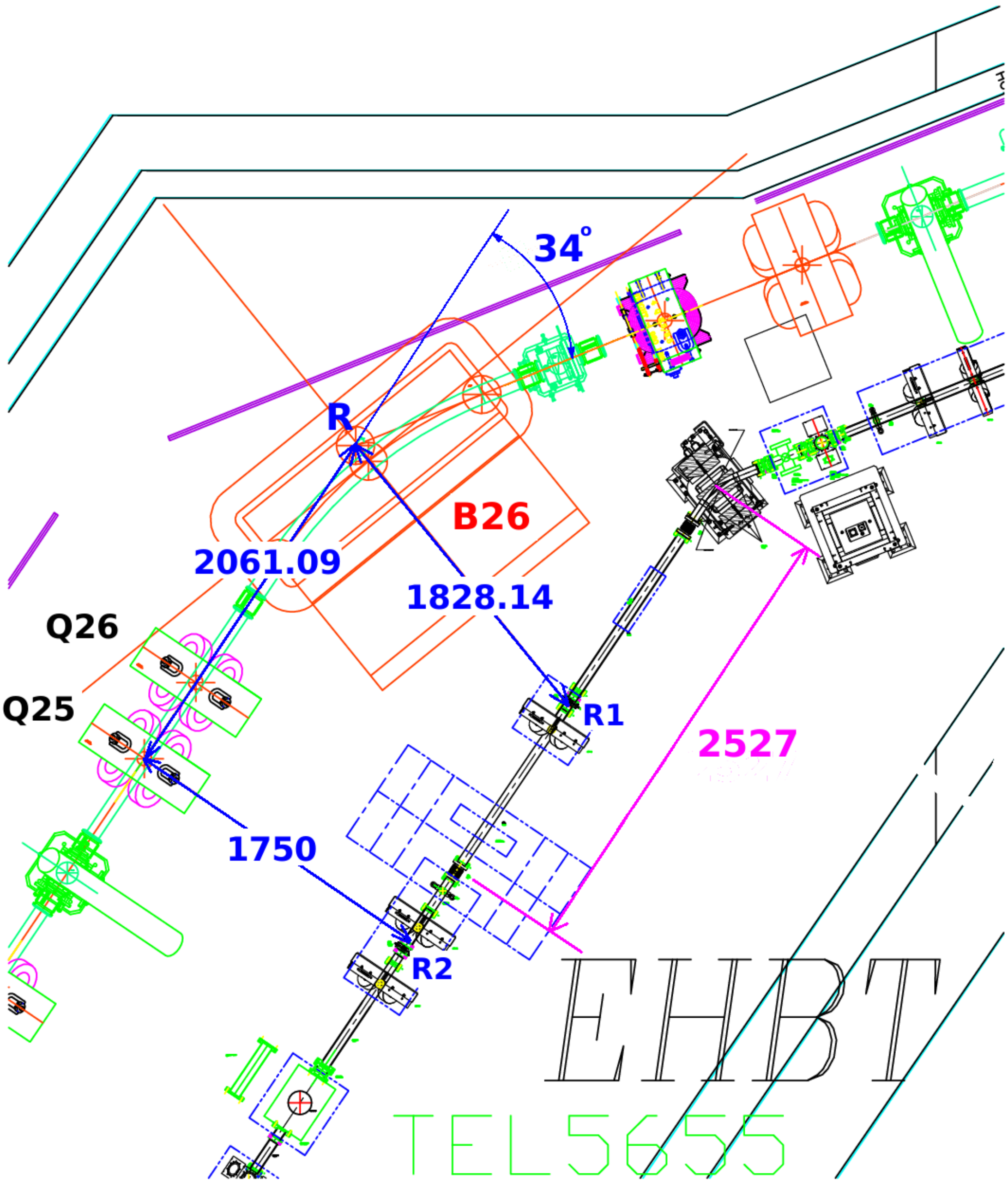

Figure 9: *Plan view of BL4N and EHBT sections around the 34° dipole magnet 4NMB26. The dimensions shown are in mm. The elevation difference is 914.4 mm between these 2-beamline's axes. The planar distance from the cross-over point R of 4NMB26* **along its centre-line** *to the EHBT axis (point R1) is 1828.14 mm.*

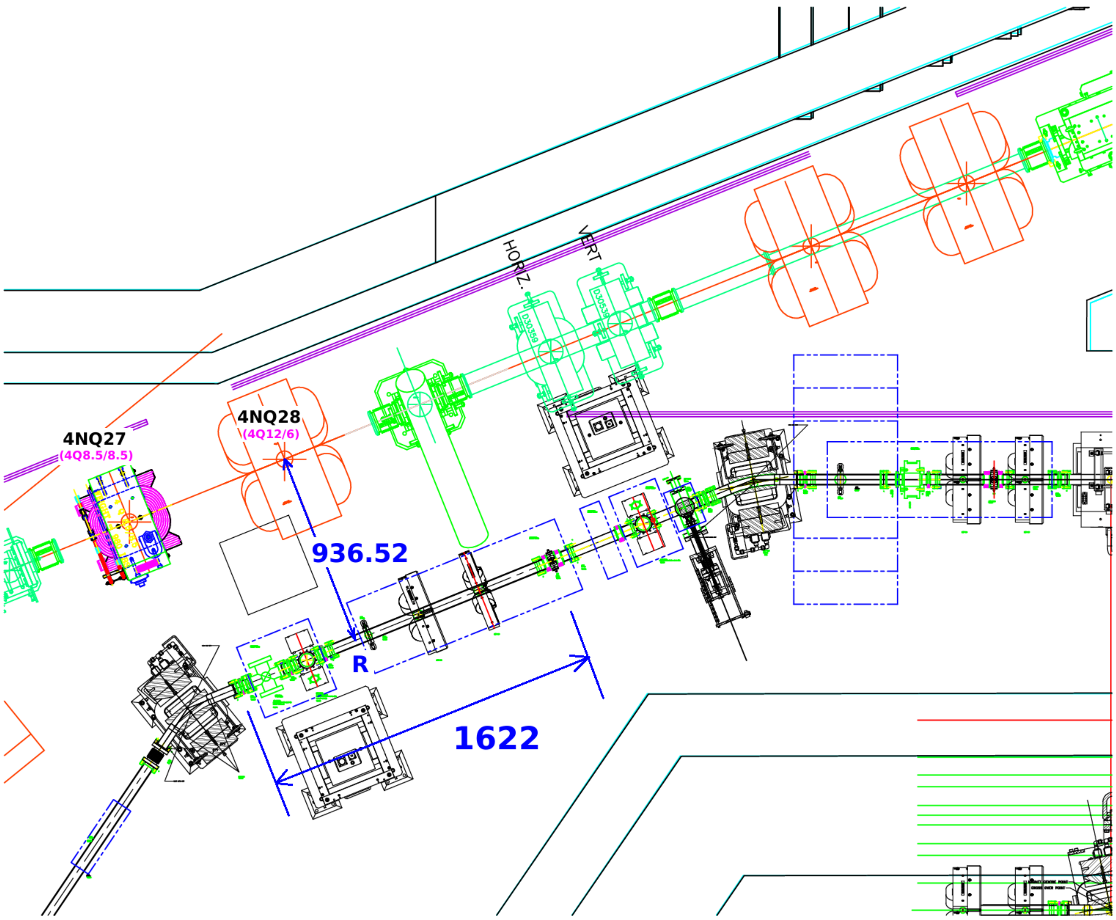

Figure 10: *Plan view of BL4N and EHBT sections around the quadrupole doublet 4NQ27 (of type 4Q8.5/8.5) and 4NQ28 (of type 4Q12/6). The dimensions shown are in mm. The elevation difference is 914.4 mm between these 2-beamline's axes which are parallel. The planar distance from the axis of 4NQ28 to the axis of EHBT is 936.52 mm. The stray magnetic field measurement should be taken along the EHBT axis over a planar distance of about ±1 m from the reference point R.*