Hall-B Beamline Commissioning Plan for CLAS12

Version 1.4

S. Stepanyan

December 5, 2017

1 Introduction

The beamline for CLAS12 utilizes the existing Hall-B beamline setup with a few modifications and additions. The Hall B beamline is divided into two segments, the so called "2C" line, from the Beam Switch Yard (BSY) to the hall proper, see Figure 1, and the "2H" line from the upstream end of the experimental hall to the beam dump in the downstream tunnel, Figure 2. The "2C" part of the beamline features an achromatic double bend (dogleg) that brings the beam up to the hall's beamline elevation from the BSY. In the past, in 6-GeV era, instrumentation on the "2C" line was sufficient to shape the beam profile and position it. The beamline instrumentation on "2H" line is then used only for monitoring the beam properties. In the 12-GeV era, at higher passes (at 4^{th} and 5^{th} passes) the beam dispersion due to the synchrotron radiation is large and the beam spots at the CLAS12 target with use of only "2C" line optics is expected to be large, $\sigma_{x/y} \simeq 400$ μm. In order to reduce the beam size on the target for high energy beams, a new girder consisting of two corrector dipoles (horizontal and vertical) and two quadrupoles is installed ~ 10 meters upstream of the CLAS12 target. This girder, referred to as "2H00", has already been used for the HPS experiment at approximately the same location on the space frame and is fully tested.

Two other important changes that took place to the "2H" line for high energy running, compared to the past electron beam running, are; use of a collimator (the Hall-B photon collimator box with ~ 30 cm long Ni collimators with 20 mm and 12.5 mm diameter holes) and addition shielding on the photon tagger dipole yoke, lead bricks right upstream and poly. blocks right downstream of the collimator. These additions serve the following purposes:

- Collimator will protect the CLAS12 SVT and MVT from direct hit from an errant beam

- The shielding is necessary to shield CLAS12 detectors and electronics when beam will be dumped in the new dump on the tagger dipole yoke [1]. This dump will play the same role as the Hall-B photon tagger dump in the past, it will be used to terminate beam during the initial beam tune and during the Möller runs. (Due to limitations of the tagger dipole field strength, beams with energies above 6.12 GeV cannot be dumped in the tagger dump). In addition a blank collimator block (Ni block without a hole) will be positioned on the beam line to prevent radiation leakage through the beamline.

The beam commissioning steps described below are for establishing physics quality beams for the CLAS12 experiments. Note that all of beamline devices involved, i.e. wire harps, optics elements, BPMs, collimators, viewers, electron dump, see the full list in Figure 3, have been used for the KPP run, as well as for the HPS and PRad experiments, and have been commissioned.

2 Commissioning with High Energy Beams

Establishing production quality electron beam for experiments in Hall B is a two step process. The initial tune is done at low currents, < 10 nA, by deflecting the beam down to an intermediate dump with the Hall B tagged photon spectrometer dipole magnet [2]. Then in the second step a physics quality beam is established on the target. The procedure on how to establish physics beam for the CLAS12 experiments can be found in [3]. Here we describe additional checks that will be done for beam commissioning for the first time. The total time for the commissioning is ~ 26 hours.

It is assumed that Hall is in "Beam Permit" state. The time allotted for each step assumes beam is available for 50% of the time.

(a) ask MCC to energize the tagger dipole magnet and set the current as needed for dumping the beam in the designated dump on the tagger yoke. MCC will ask you to change (set) the beam delivery mode. Note, the relation between the beam energy and tagger magnet current is:

$$I(A) \ = \ 43.491 \times E(GeV) - 0.076 \tag{1}$$

Energizing the tagger magnet can be done right after Hall is closed and is in "Beam Permit". There is no need to wait until MCC is ready to send the beam and then energize the magnet, it can take up to 45 minutes to set the magnet

(b) position the "blank" collimator on the beam (this is a collimator block, 30 cm long Ni cylinder, without a hole)

(c) when the tagger magnet is at required setting ask MCC if they are ready to deliver beam to the tagger yoke dump ($\leq$ 5 nA). The only available beam viewer in this configuration is ITV2C24 YAG viewer controlled by MCC. It can be used to make sure the beam has a reasonable shape.

It may take $\sim$ 1 hour for MCC to setup and cleanly transport beam to the tagger yoke dump,

(d) perform harp scans using the wire harp at 2C21 girder. Beam width in 'x' and 'y' directions is energy (pass) dependent, should be $\lesssim 150\ \mu$m, with peak/tail $> 10^2$ (this ratio is small due to the background from tagger yoke dump on the upstream halo counters located only 4 m upstream of the dump). Ask MCC to retune if needed (e.g. beam is too wide or asymmetric or has large tails), repeat the scan after every tune. Iterate to get acceptable beam profile.

Time for this study $\sim$ 2 hours,

NOTE: since the "Tagger yoke dump" is used, radiation environment will be high and the rates on some of halo counters will be higher than usual. Call RC and beamline expert if background in all halo counters will be too high to perform harp scans.

(e) continue with beam tune, perform harp scans using the 2C24 ("tagger") wire harp. This harp will measure beam width in 'x', 'y', and 45° projections. Acceptable beam profile is $\sigma_{x/y/45^\circ} < 500 - 700\ \mu$m.

Time for this study is $\sim$ 4 hours.

(f) after reasonable profile is established on 2C24 ("tagger") harp, and before sending the beam to CLAS12 (to Faraday cup dump):

- perform **basic functionality checks for Moller polarimeter, see Section 3.1**.
- study bleedthrough to Hall-B. Since Halls B and D use the same slit, this study cannot be conducted by just closing "B" slit. Ask MCC to first turn OFF B-laser, see if the nA BPMs 2C21 and 2C24 read any current and if halo counters show still significant rates. If no current is on BPMs and no much background rate on halo counters, move forward with the commissioning plan. If rates will be high or BPMs measure current > 0.1

nA perform harp scans with 2C21 and 2C24 harps. If significant beam is present in the hall consult with RC and beam line expert, the situation must be worked out with MCC to lower the bleedthrough.

(g) send the beam to Faraday Cup dump (otherwise known as electron dump).

- CLAS12 detectors should be OFF, the solenoid magnet current is at 10% its max, torus is at the required setting for the run (magnets can be energized as soon hall is in "beam permit")
- ask MCC to degauss and turn the tagger dipole off
- position 20 mm collimator on the beam and move "Chromox" screen of the downstream viewer in beam position (if it is not already)

This will take $\sim$ 2 hours (degaussing of the tagger magnet is a long procedure).

(h) when ready, ask MCC to send a 5 nA beam to the Faraday cup. Closely watch the downstream viewer and the Faraday cup reading. If the beam goes through cleanly you should see a clean beam spot on the viewer and the current as reported by Faraday cup should be within a few % of the BPM readings (2C21 and 2C24).

The clean transport of the beam to the dump can take up to 2 hours.

(i) study effect of the solenoid magnetic field on the beam: torus should be already up to its required field setting, the solenoid is at 10% of max current. Start ramping up the solenoid to the desired current, follow instructions for ramping up the solenoid, and watch the beam spot on the downstream viewer. Beam deflections of a few mm at the viewer is not a problem (on the Chromox screen tick marks are in 5 mm steps). If beam moves more than 10 mm stop the ramp and notify RC. If beam motion is large, additional checks will be needed in the next step to understand relative alignment of the magnetic center of the solenoid and the beam.

This step will take as long as it takes to ramp up the magnets, $\sim$ 2 hours.

(j) position beam on the target: The cryo target cell is a 5 cm long Kapton cylinder, 20 mm in diameter. The entrance and exit windows of the cylinder have a thin area in the center, 30 μm aluminum, 10 mm in diameter. Beam always should pass through the thin part. Outside of that range beam will hit the target support frame. Using position readings on 2H01 BPM, move beam up/down and left/right to find the sweet spot where rates in the downstream halo counters are the lowest. Target should be in "empty" state.

If deflection of the beam in the solenoid field was large (see above) then during this scan recored beam position change on the downstream viewer. Based on the results, solenoid may be aligned to reduce the effect on the beam.

Time for this study is $\sim$ 1 hour.

(k) tune the beam profile using the 2H01A harp. This harp will measure the beam width in 'x', 'y', and 45° projections. Acceptable beam profile is $\sigma_{x/y/45^\circ} <$ 300 μm. If needed ask MCC to use quads on the 2H00 girder to adjust beam width (MCC should consult with Michael Tiefenback).

Time for this study is $\sim$ 4 hours.

(l) repeat (i)

(m) test the halo counter FSD system by running the harp wire through the beam and reading out rates using the Struck scaler system with a 15 μs dwell time.

This will take $\sim$ 4 hours and **must be done with beamline expert**

(n) turn on forward PMT detectors (EC/FTOF/LTCC), make sure rates are reasonable while running $\sim$ 5 nA beam.

Will take $\sim$ 1 hour.

(o) rate studies with the target: fill the cryo target (LH_2), if rates on the PMT detectors are reasonable turn ON DCs. Raise the beam current slowly and watch the rates on the forward detectors, and occupancies and currents in DC. The beam current for luminosity of $L = 10^{35}$ cm^{-2} sec^{-1} is 72.5 nA. Stop raising the beam current if rates, occupancies or DC currents get close to an unacceptable levels; consult with RC.

This will take $\sim$ 1 hour.

(p) study DC occupancies and detector rates as a function of solenoid field.

Will take $\sim$ 2 hours.

3 Commissioning of Möller polarimeter

The commissioning will take place in three steps. We assume counters are installed, aligned, and shielded, connected to the electronics. Quad power supply controls are ready, current settings are programmed. Overall Möller EPICS software is ready. The GUIs to monitor and control charge asymmetry should be ready as well.

3.1 Initial commissioning with a 5-pass beam

The first step will take place after beam is tuned at the tagger yoke dump on day one, after bullet e) of Section 2. MCC should have injector setting such that gives for Hall-B maximum polarization transfer (should be 100% at $\sim 55°$ degree of Wien angle, although at synchrotron radiation will change this old relation). To save time, before degaussing the tagger magnet (it takes ~ 1 hour to degauss), and sending the beam to FC the following will be done (note: CLAS12 is OFF) - overall functionality check with 10 nA beam current:

(a) check singles rates of Möller counters, adjust gains (HV settings) to get rates down to < 10 kHz. If at the HV $\simeq 1500$ V rates are still high, more shielding may be needed around the counters (tagger yoke dump crates a background in upstream tunnel, at 10 kHz per-counter accidental coincidence rate will be ~ 5 Hz). More shielding can be added during the first long down time

(b) turn ON quads and set pre-calculated currents (for 10.6 GeV currents on both PS should be initially set to 3180 A), record change in the singles, and coincidence rates

(c) stop the beam delivery and insert the "right" target foil, Helmholtz coils should be OFF

(d) resume 10 nA beam delivery to the tagger yoke dump. Adjust thresholds on the discriminators to get the ratio of accidental/true coincidences $< 10\%$

(e) adjust quad currents within $\pm 10\%$ of set current to find where the max coincidence rate is, which corresponds to the scattering at $\theta_{CM} = 90°$ for a symmetric detector. The longitudinal asymmetry is maximum at $\theta_{CM} = 90°$, that is where we want to be for beam polarization measurement:

$$A_L(\theta_{CM}) = \frac{(7 + \cos^2\theta_{CM}) \cdot \sin^2\theta_{CM}}{(7 + \cos^2\theta_{CM})^2}$$

(f) run for ~ 30 min with optimal setting of currents, system should record zero polarization, any significant deviation from zero (within measurement errors) will indicate either something wrong with the software that calculates the polarization or presence of a significant charge asymmetry. For latter check charge asymmetry GUI

(g) turn ON Helmholtz coils, watch for any rate change (singles, coincidence, or accidentals) should not be any outside of statistical fluctuations

(h) reset Möller DAQ and continue to run until statistical error on the measured polarization gets to $< 1.5\%$

(i) make a log entry (Möller GUI should allow that by push of a button)

This will end the first step of the commissioning. Above activities will take ~ 4 hours. After this step, changes will be made to the settings of the PMT HVs and the quad currents in the Möller EPICS software in order to have optimal parameters set automatically with push of a button.

3.2 Commissioning with a 3-pass beam

The second step in the Möller polarimeter commissioning is the beam polarization measurement at 6.4 GeV (3-pass beam) after a reasonable beam is established on the tagger yoke dump at the start of the 3-pass run. Again, MCC should setup maximum transmission for Hall-B (100% will be 165°). The commissioning will include:

1. turn off the beam and start Möller run using the GUI. HVs, quad currents, Helmholtz setting and the target will be setup automatically

2. repeat steps (d), (e), (h), and (i) Section 3.1

Time for this is ~ 2 hours.

3.3 Final commissioning with a 5-pass beam

This commissioning step consists of set of normal Möller runs with different settings of Wien angle (single hall spin dance). It will be done after beam is tuned to the tagger yoke dump when we resume running in January. First measurement will be at the nominal setting of the injector to deliver highest beam polarization to Hall-B ($\sim 55°$ according to the old table). This measurement should repeat the measurement done in December. The series of measurements will be done at $+10°$, $+20°$, $-10°$, and $-20°$ settings. To take data for each setting, reset the Möller DAQ after sending previous measurement to logbook. The polarization change at $\pm 20°$ is about 6%. Fit the polarization values as a function of Wien angle, find the angle that corresponds to maximum longitudinal polarization of the beam, and ask MCC to set the angle at that value.

The total duration of this commissioning step is ~ 8 hours.

References

[1] Under "Document" at https://clasweb.jlab.org/wiki/index.php/CLAS12_Beamline, "Proposed tagger yoke dump" and "Simulation of the tagger yoke dump".

[2] D.I. Sober et al., "The Bremsstrahlung Tagged Photon Beam in Hall B at JLab", Nucl. Inst. and Meth. A 440, 263 (2000).

[3] Appendix of the beam line manual or under "Procedure" on the run wiki.

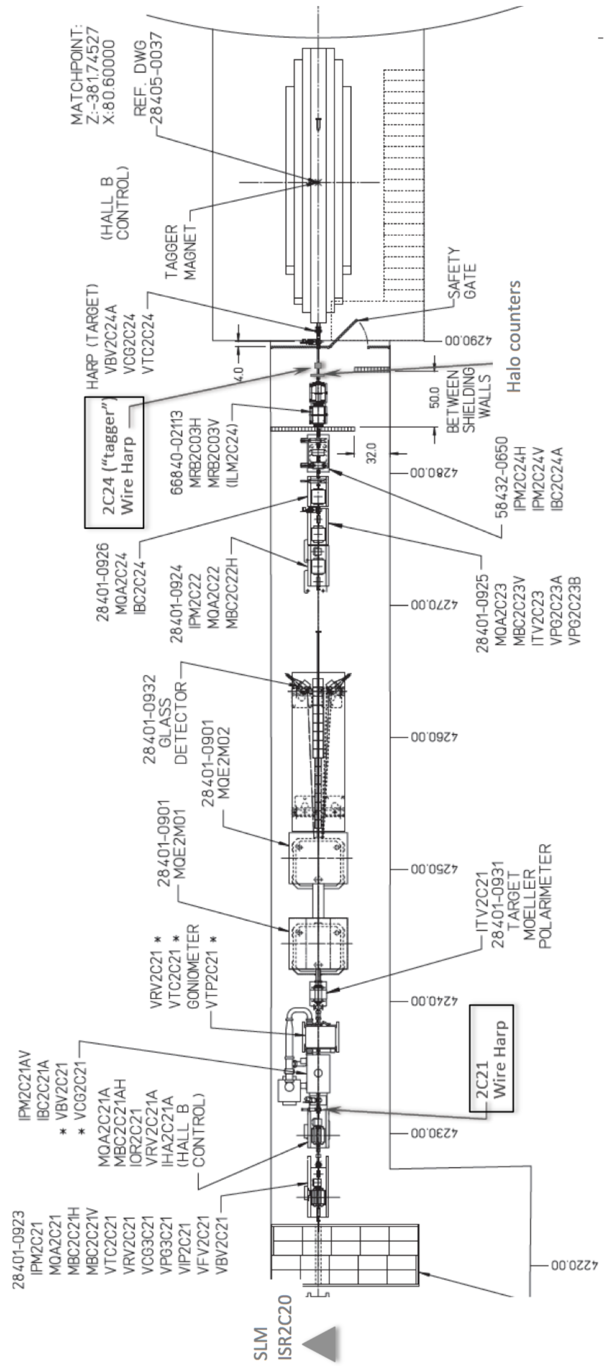


Figure 1: The “2C” line from the green shielding wall to the Hall-B tagged photon spectrometer dipole magnet. This is the part in the upstream tunnel where the beam gets to the hall beamline elevation.

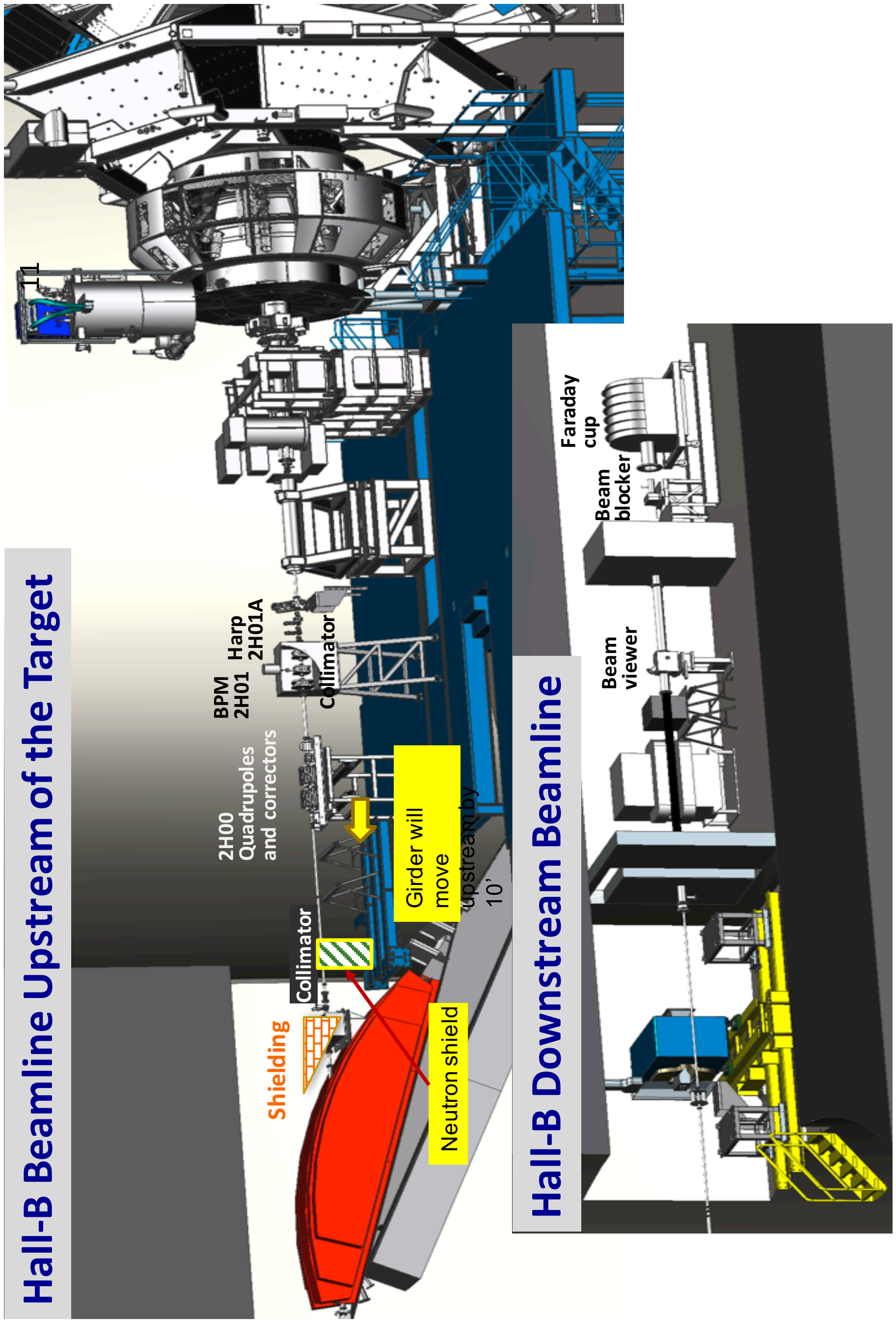
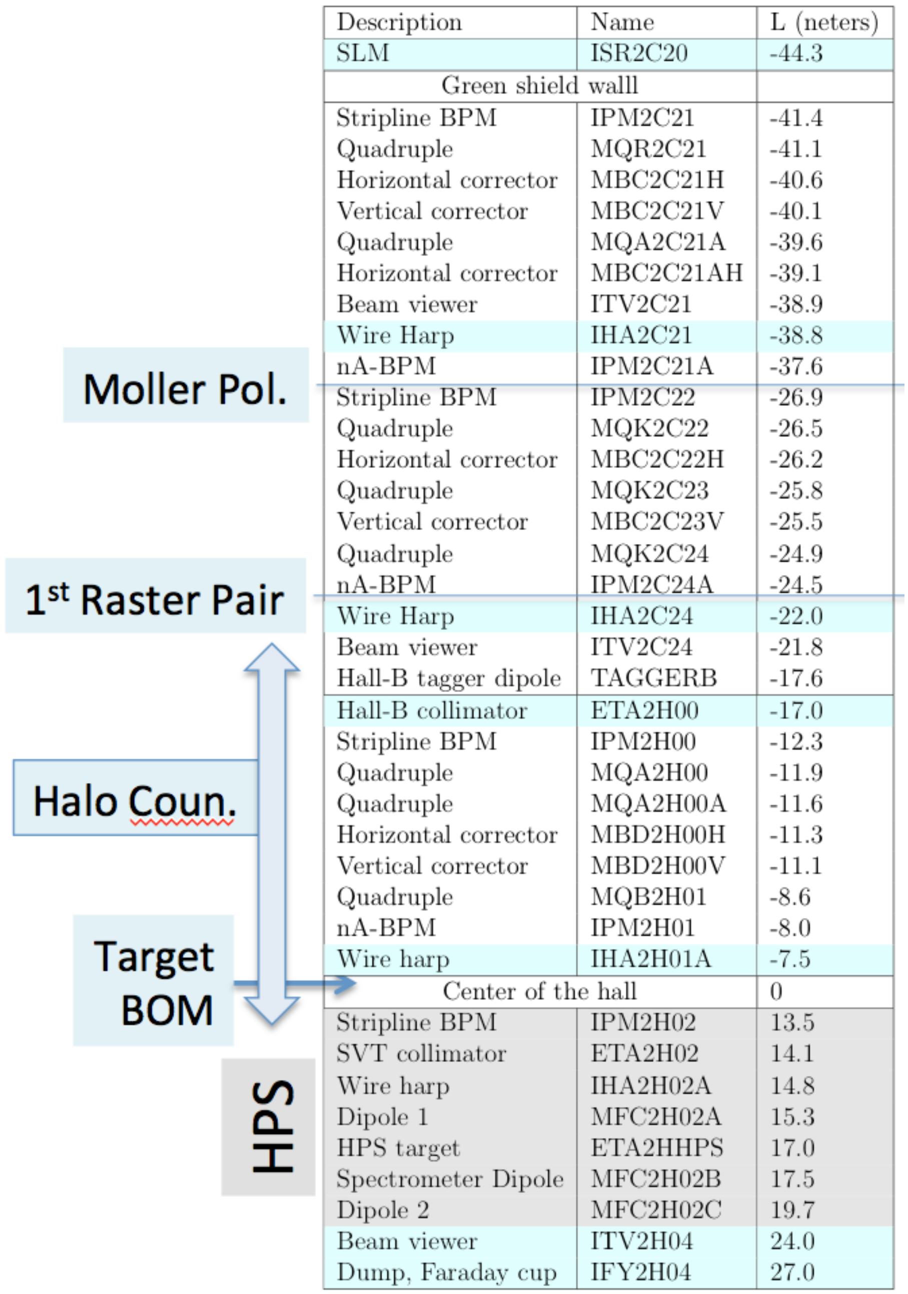


Figure 2: The “2H” line from the Hall-B tagged photon spectrometer dipole magnet to the Faraday cup dump in the downstream tunnel (electron dump).



Description	Name	L (neters)
SLM	ISR2C20	-44.3
Green shield walll		
Stripline BPM	IPM2C21	-41.4
Quadruple	MQR2C21	-41.1
Horizontal corrector	MBC2C21H	-40.6
Vertical corrector	MBC2C21V	-40.1
Quadruple	MQA2C21A	-39.6
Horizontal corrector	MBC2C21AH	-39.1
Beam viewer	ITV2C21	-38.9
Wire Harp	IHA2C21	-38.8
nA-BPM	IPM2C21A	-37.6
Stripline BPM	IPM2C22	-26.9
Quadruple	MQK2C22	-26.5
Horizontal corrector	MBC2C22H	-26.2
Quadruple	MQK2C23	-25.8
Vertical corrector	MBC2C23V	-25.5
Quadruple	MQK2C24	-24.9
nA-BPM	IPM2C24A	-24.5
Wire Harp	IHA2C24	-22.0
Beam viewer	ITV2C24	-21.8
Hall-B tagger dipole	TAGGERB	-17.6
Hall-B collimator	ETA2H00	-17.0
Stripline BPM	IPM2H00	-12.3
Quadruple	MQA2H00	-11.9
Quadruple	MQA2H00A	-11.6
Horizontal corrector	MBD2H00H	-11.3
Vertical corrector	MBD2H00V	-11.1
Quadruple	MQB2H01	-8.6
nA-BPM	IPM2H01	-8.0
Wire harp	IHA2H01A	-7.5
Center of the hall		0
Stripline BPM	IPM2H02	13.5
SVT collimator	ETA2H02	14.1
Wire harp	IHA2H02A	14.8
Dipole 1	MFC2H02A	15.3
HPS target	ETA2HHPS	17.0
Spectrometer Dipole	MFC2H02B	17.5
Dipole 2	MFC2H02C	19.7
Beam viewer	ITV2H04	24.0
Dump, Faraday cup	IFY2H04	27.0

Figure 3: Bemaline elements from the green shield wall to the Faraday cup dump.