Hall-B Beamline Commissioning Plan for CLAS12

Version 1.0

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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, for where most experiments the targets were located close to the hall center, 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, $\sigma_{x/y} > 400$ 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 will be 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 Ni collimators of 20 mm and 12.5 mm diameter openings) and addition of lead shielding on the photon tagger dipole yoke, right before the collimator. These additions serve the following purposes:

- Collimator will protect the CLAS12 SVT and MVT from direct hit from an errant beam
- Due to limitations of the tagger dipole field strength, beams with energies above 6.12 GeV cannot be dumped in the tagger dump, as has been done during initial beam tune and Möller runs in the past. Instead, the beam will be dumped on the tagger dipole yoke [1] and the additional shielding with a blank collimator block will protect the CLAS12 detectors and electronics from the radiation produced in the tagger dipole yoke dump.

The beam commissioning steps described below are for establishing physics quality, high energy (> 6 GeV) beams for the CLAS12 experiments. Note that all of beamline devices involved, i.e. wire harps, optics elements, BPMs, collimator, viewers, electron dump, see the full list in Figure 3, have been used for HPS and PRad experiments and have been commissioned with low energy (< 2.3 GeV) beams. For high energy beam commissioning, the important aspects of course are the new tagger yoke dump and the transverse size of the beam at the target.

2 Commissioning with High Energy Beams (> 6 GeV)

Establishing production quality electron beam for experiments in Hall B is a two step process. The initial tune is done at low current by deflecting the beam down to an intermediate dump with the Hall B tagged photon spectrometer dipole magnet [2]. Then in the second step establishing the physics quality beam on the target. The procedure on how to establish physics beam for the CLAS12 experiments can be found in the [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. There are two options discussed, with and without the solenoid and the cryo-target. Most of the commissioning steps are the same for both modes of running, only few items are added when solenoid and cryo-target are present.

It is assumed that the Hall is in a “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 deliver mode. Note, the relation of 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 the Hall is closed and is in "Beam Permit", there is no need to wait until MCC is ready to send the beam. It takes 45 minutes to set the magnet.

(b) position the "blank" collimator on the beam

(c) after the tagger magnet is up at the required current ask MCC, if they are ready, to establish 3 pass beam on the tagger yoke dump ($\leq$ 5 nA). (Note for the engineering run in the fall it should be 5 pass beam). Use the ITV2C24 Yag viewer to make sure the beam has a reasonable shape. It will take $\sim$ 1 hour for MCC to setup and cleanly transport beam to the tagger yoke dump,

(d) perform harp scans using the 2C21 harp. Beam widths in 'x' and 'y' directions should be less than 150 μm, with peak/tail $> 10^3$. Ask MCC to retune if needed, repeat the scan. Iterate to get acceptable beam profile. Time for this study $\sim$ 2 hours,

(e) study rates in halo counters and CLAS12 calorimeters (part of PCAL or EC in one sector will be enough, there is no need to turn on whole detector) as a function of tagger magnet current. The above relation, Eq.1, was derived from the existing field map of the tagger dipole and GEANT simulations of the dump and it must be validated. Find the appropriate tagger current where the rates are the lowest. Do not go beyond $\pm$10% of the current calculated by the above formula. Time for these studies $\sim$ 1 hour.

(f) 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 $\sigma_{x/y/45^\circ} < 500 - 700$ μm. Time for this study is $\sim$ 4 hours.

(g) after reasonable profile is established on 2C24 ("tagger") harp, send the beam to Faraday Cup dump (otherwise known as electron dump).

- CLAS12 detectors, solenoid (if in place), and torus (if it is KPP run) are are at 10% of their full field. For the engineering run torus must be ON at the required for the run field,
- 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 the beam (if it is not already)

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

(h) when ready, ask MCC to send 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 the 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 magnetic fields on the beam:

- for the KPP run, ramp the torus up to the desired current. Watch the beam spot on the downstream viewer. Beam deflections on the order of a few mm at the viewer are not a problem (on the Chromox screen tick marks are in 5 mm steps). If the beam moves more than 10 mm call the beamline expert.
- for engineering run, torus should be already up and the solenoid at 10% of max current. Start ramping up the solenoid to the desired current and watch the beam spot on the downstream viewer. Beam deflections of 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 call the beamline expert.

This will take as long as it takes to ramp up the magnets, $\sim$ 4 hours.

(j) position beam on the target:

- for the KPP run, when the solid target in the form of a carbon wire mounted on the 2H01A harp stick is used and the beam vacuum is continuous from upstream to downstream, move beam by ± 1 mm up/down, and left/right on the 2H01 nA BPM and observe rates on the halo counters. If beam is transported cleanly (beam pipes are at least $ID = 1.5$ inches) no rate changes are expected, choose the position on the 2H01 BPM where rates are the lowest and ask MCC to set the Orbit Locks to that position on the 2H01 BPM.
- For engineering run, when the cryo-target is installed, study beam transport through the cryo-target cell. The target cell is a 5 cm long Kapton

cylinder, 20 mm in diameter, with entrance and exit windows that have a thin part 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 parts. Using position readings on 2H01, move beam up/down and left/right and find the sweet spot where rates in the downstream halo counters are the lowest.

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

(k) tune the beam profile using the 2H01A harp. This harp will measure beam width in 'x', 'y', and 45° projections. Acceptable beam profile is $\sigma_{x/y/45^\circ} <$ 300 μm. If needed, use quads on the 2H00 girder to adjust beam width. Time for this study is $\sim$ 4 hours.

(l) fill (if cryo-target is in place) or move in the target. Set FSD based on the halo counter rates. Two things must be set, the trip rate and the trip detection time interval. In order to limit "false positive" trips, the trip limit should be $\sim 5\sigma$ to 6σ above the nominal count rates (N), here $\sigma = \sqrt{(N)}$. The trip detection time interval, $\delta\tau$, must be selected such that $N \times \delta\tau \geq 200$. This can take up to 2 hours.

(m) test 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.

(n) remove (empty) the target. 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:

- if this is the KPP run without solenoid and the carbon wire target (0.5 mm carbon wire mounted on the harp stick), start moving the target into beam, watch the rates on the forward detectors, and occupancies and currents in the DC. Find the position of the target where rates and occupancies are still acceptable for the KPP run and the DC does not trip; consult with the RC if needed.
- if this is the engineering run with the solenoid and cryo-target, fill the target and raise the beam current. Watch the rates on the forward detectors, and occupancies and currents in the DC. Stop at the beam current where rates and occupancies are still acceptable; consult with RC if needed.

This will take ~ 1 hour.

(p) if solenoid is in place, study DC occupancies and detector rates as a function of solenoid field. Will take ~ 2 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.

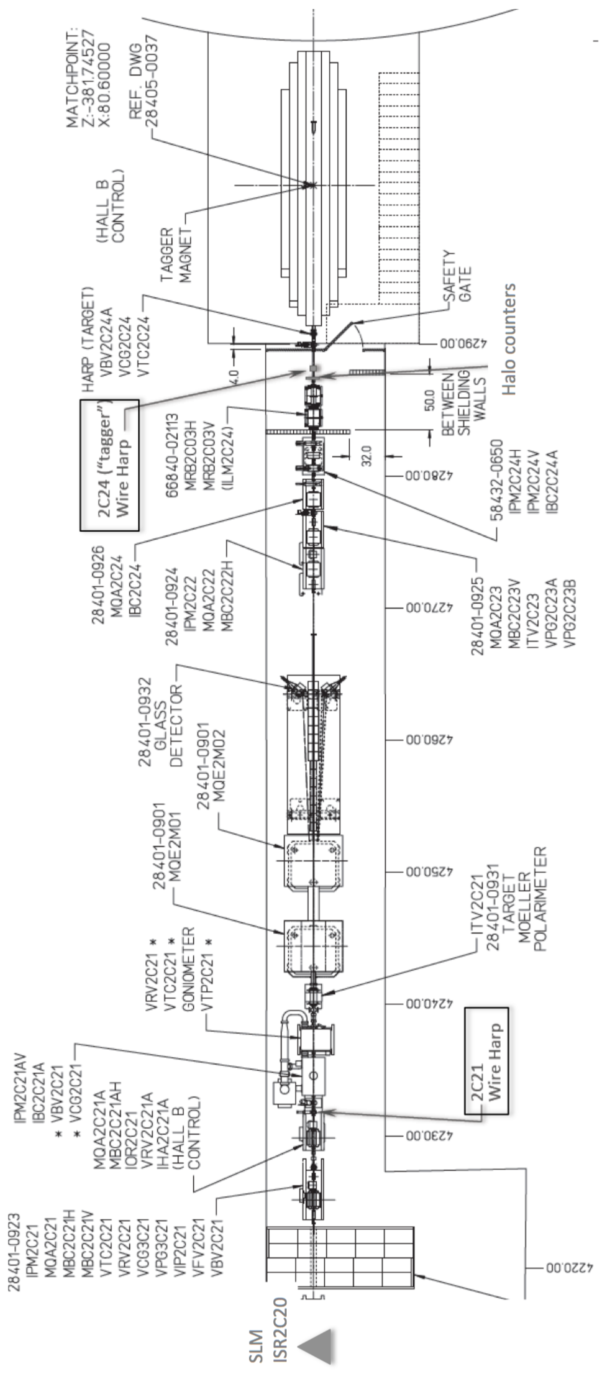

Figure 1: The "2C" line from the green shielding wall to the Hall-B tagged photon spectrometer dipole magnet. This is the part in the upstream tunnel where the beam gets to the hall beamline elevation.

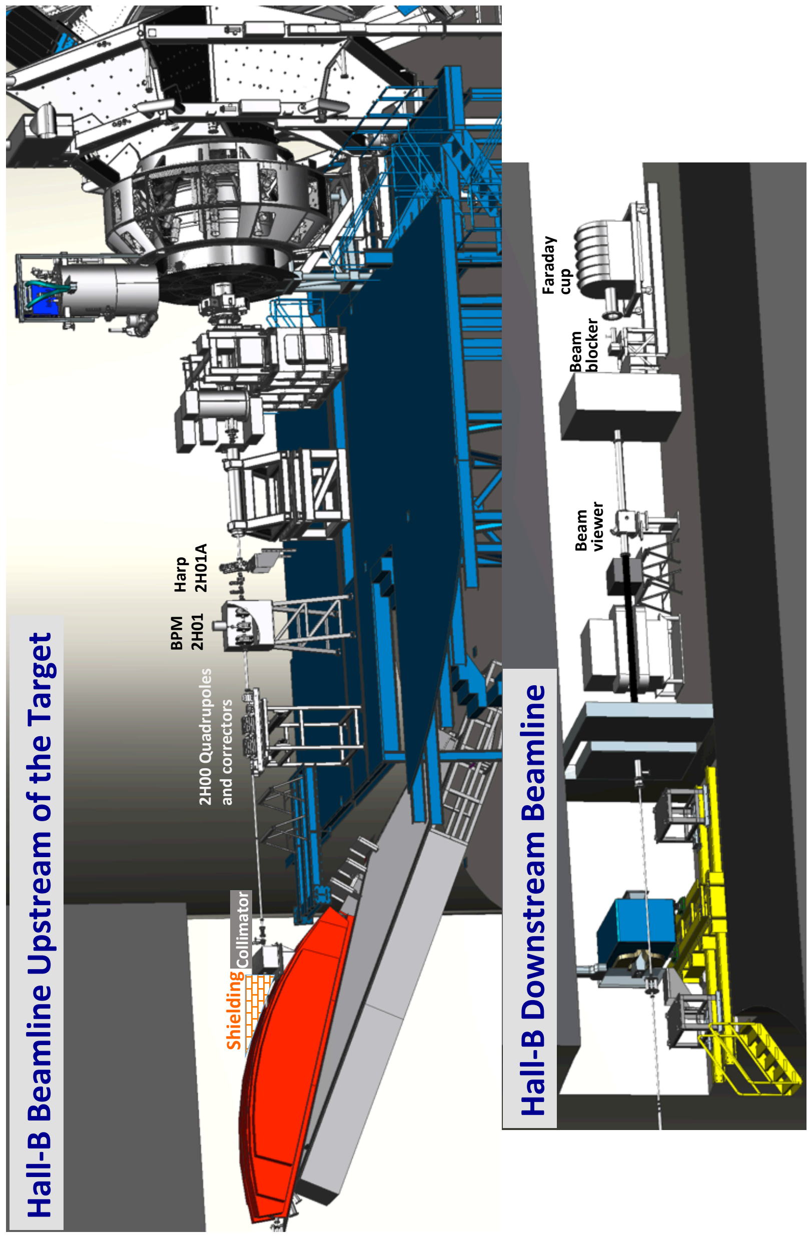

Figure 2: The “2H” line from the Hall-B tagged photon spectrometer dipole magnet to the Faraday cup dump in the downstream tunnel (electron dump).

Moller Pol.

1st Raster Pair

Halo Coun.

Target BOM

HPS

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.