

Establishing beam for physics Run Group M

Version 1.0

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Establishing production quality electron beam for experiments of Run Group M in Hall B is a two step process.

1 Beam to tagger dump

The initial tune is done at low currents, < 10 nA. If the beam energy is below 6.12 GeV it is dumped on the tagger dump located under the hall's floor. If the beam energy is above 6.12 GeV it is dumped on the "tagger-yoke dump", a dump in the tagger dipole magnet yoke, before hall proper. Beam is deflected down to this intermediate dump by the tagger dipole magnet [1]. The tagger dipole power supply set current relates to the beam energy as [2]:

$$I(A) = 43.491 \times E(GeV) - 0.076 \quad (1)$$

In this first step:

- the CLAS12 detectors (especially tracking detectors) must be OFF, BMT HV must be set to a SAFE mode, SVT LV should stay ON (HV OFF)
- all halo counters must be ON
- masked the halo counters (upstream, midstream, BOM and downstream) in beam Fast Shut Down (FSD) system
- the "blank" collimator with no hole is on the beam
- the CLAS12 solenoid and torus magnets are energized (or can be energized while beam tune is in progress)

The beam with required profile and trajectory is established by MCC OPS using correctors and quadrupoles on 2C line, while monitored by Hall-B shift crew using the wire harps and the nanoamp (nA) BPMs [3] at 2C21 and 2C24 girders in the upstream tunnel (see Figure 1). There is a Yag viewer, ITV2C24, upstream of the tagger dipole, controlled by MCC, that may be used by MCC to verify position and profile of the beam. If the beam is tuned to the tagger dump the beam spot can be seen on the tagger dump viewer (see Figure 2). Hall-B shift personnel should work with MCC operator to establish required quality beam. All harp scans must be properly analyzed and logged into logbook.

The beam tune is good when required parameters for the profile (x/y widths) and trajectory (x/y positions on various monitors) are achieved. These parameters will be written on the run wiki and/or on the white board in the counting house. Typically widths at 2C21 harp $\sigma_{x,y} \leq 200 \mu\text{m}$, while at 2C24 (tagger) harp $\sigma_{x,y} \leq 500 - 600 \mu\text{m}$. In general it is a good practice to check newly measured beam parameters against last good/acceptable tune.

Description	Name	L (meters)
SLM	ISR2C20	-44.3
Green shield wall		
Stripline BPM	IPM2C21	-41.4
Quadrupole	MQR2C21	-41.1
Horizontal corrector	MBC2C21H	-40.6
Vertical corrector	MBC2C21V	-40.1
Quadrupole	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
Quadrupole	MQK2C22	-26.5
Horizontal corrector	MBC2C22H	-26.2
Quadrupole	MQK2C23	-25.8
Vertical corrector	MBC2C23V	-25.5
Quadrupole	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
Quadrupole	MQA2H00	-11.9
Quadrupole	MQA2H00A	-11.6
Horizontal corrector	MBD2H00H	-11.3
Vertical corrector	MBD2H00V	-11.1
Quadrupole	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 1: Bernaline elements from the green shield wall to Faraday cup dump.

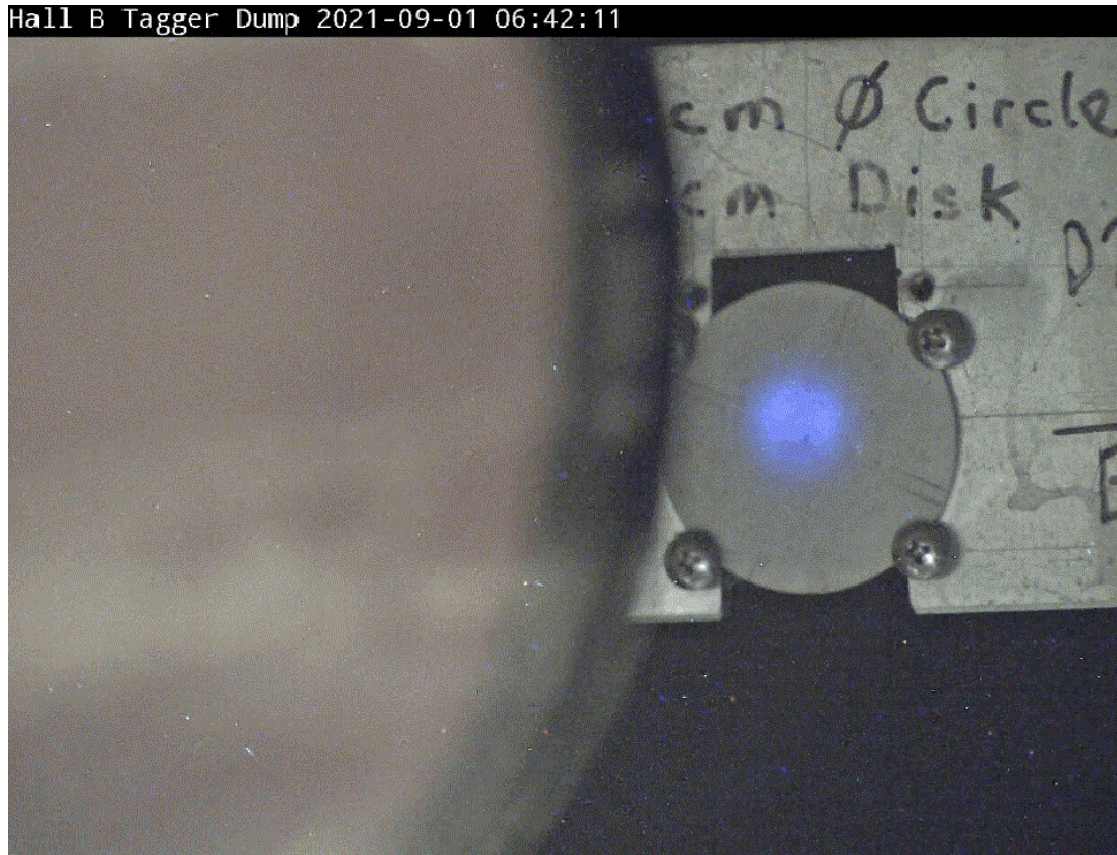


Figure 2: Beam spot on the tagger dump viewer.

2 Beam to Faraday cup

The second step of establishing a physics quality beam starts after acceptable beam parameters have been achieved on the tagger (tagger-yoke) dump. While the tagger magnet is degaussing empty the cryotarget. If movable solid targets are used then move them out of the beam. The following are steps for sending beam to CLAS12:

- tell MCC that beam is acceptable at the tagger
- ask to take the beam away, and degauss and turn OFF the tagger magnet
- position 20 mm diameter collimator on the beam
- take the beam blocker out
- set the halo counter FSD thresholds in to 1 MHz and the integration time interval to 50 milliseconds
- when ready ask MCC to send ~ 5 nA beam straight to the electron dump, at the end of the Hall B beamline where Faraday cup is located
- if target is ^{40}Ca request beam Y position on 2H01 to be moved up from the position previously established for cryo target by 4 mm so it goes through the notch of the Ca disk. See section 2.3
- If the target ^{48}Ca (does not have a notch) there is no “empty” option. Use nominal positions established for cryo target.
- verify that beam goes to the dump
 - a. make sure beam is clearly visible on the downstream viewer, use Chromox screen¹. Beam should be within 10 mm (2-tick marks) around the center (see Figure 3)
 - b. make sure that Faraday cup beam current reading and the beam currents on 2C21 and 2C24 BPMs are consistent (the difference should not be more than few %)
- once it is verified that the beam cleanly goes to the Faraday Cup insert the beam blocker

The beam profile and position adjustments on the target will be done using correctors and quadrupoles on 2C22/2C23/2C24 girders in the upstream tunnel and 2H00 girder in the hall (if needed). The last one is the closest to the target ($\sim 10\text{m}$ upstream) and will be used to focus beam at the target location to achieve required size (preferably $< 200\ \mu\text{m}$). The profile and position of the beam on the CLAS12 target will be checked using a 3-wire harp 2H01A mounted about ~ 7 meters upstream of the CLAS12 target and 2H01 nA BPM (stripline BPM on 2H00 will not work at low currents). The 2H01A harp measures the beam profile and its projected position along x-, y-, and 45° axes. After physics quality beam is established based on the profile, beam position on either the cryo target cell or any of CLAS12 detector component (e.g. FTcal) must be adjusted based on the lowest rates on the downstream halo counters and on BOM or symmetry of rates in the detector.

¹At low energies beam spot may not be clearly visible at 5 nA

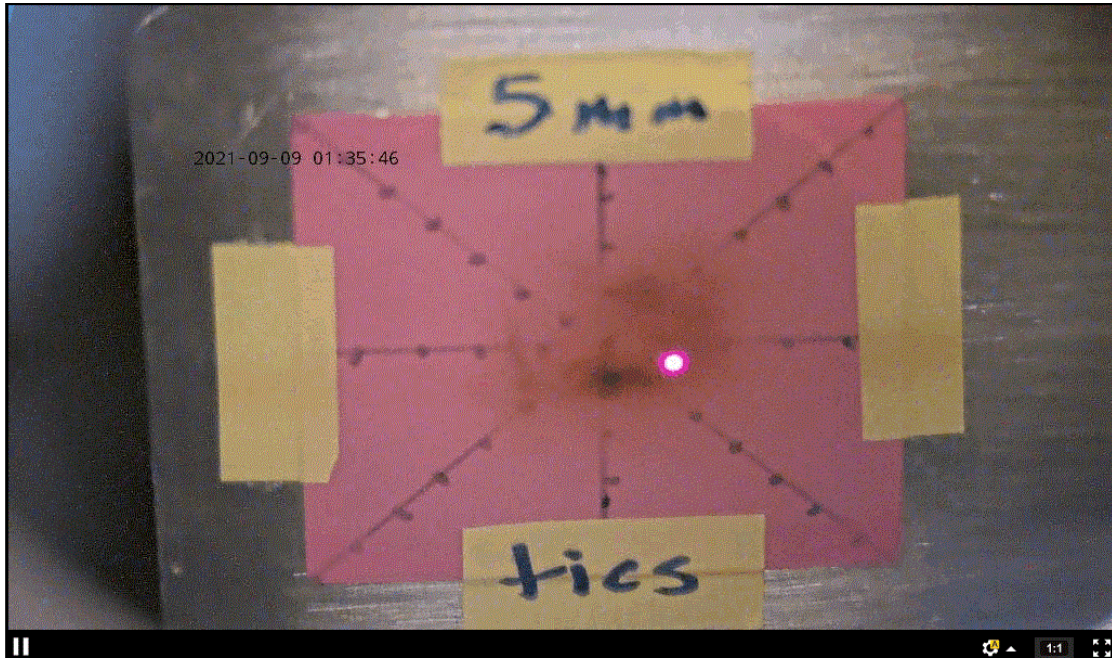


Figure 3: Beam spot on the Faraday cup viewer.

2.1 Procedure for adjusting the beam on the cryo target

Procedure for adjusting the beam on the cryo target is the following:

- ask MCC operator to move beam on 2H01 BPM by 0.1-0.2 mm steps up and down, vertical direction
- record rates on halo counters and on BOM for each step. Stop moving in the given direction when rates go more more than $\times 10$ from where you started
- analyze rates as a function of position, find a position on 2H01 corresponding to the mid point of the two extreme ends where rates were highest. Ask MCC operator to position the beam on that position on 2H01 nA BPM
- repeat everything for horizontal alignment, moving the beam to left and right
- set orbit lock using found vertical and horizontal positions on 2H01

The ID of the BOM is 10 mm which constrains the scan rang to less than 5 mm in any direction.

For adjusting the beam position to get symmetric rates on a detector, e.g. FTcal, move beam with small steps in x- and/or y- on 2H01 nA BPM until desired symmetry is achieved.

Once you are happy with beam position and profile document obtained beam positions on the BPMs in the logbook and proceed to the Final Steps (Section 2.4).

2.2 Procedure for adjusting the beam on the movable solid targets

The solid targets are 4 x 4 m Target motion control GUI is shown in Figure 4. Procedure for adjusting the beam on the movable solid targets is the following:

- With solid targets out (empty position on target control GUI) of the beam request MCC to set initial beam positions on 2H01 previously obtained with cryo target. Make sure it goes cleanly to the Faraday Cup viewer and appears at the same location as with cryo target.
- Insert solid target
- ask MCC operator to move beam on 2H01 BPM by 0.1-0.2 mm steps left and right in horizontal direction
- record rates on downstream halo counters for each step. Stop moving in the given direction when rates drop down more more than $\times 10$ from where you started
- analyze rates as a function of position, find a position on 2H01 corresponding to the mid point of the two extreme ends where rates drop. Ask MCC operator to position the beam on that position on 2H01 nA BPM
- similarly align beam vertically, moving the beam up until the rate drops. This is the top edge of the target
- From this position move beam down by 1.5 mm
- set orbit lock using found vertical and horizontal positions on 2H01

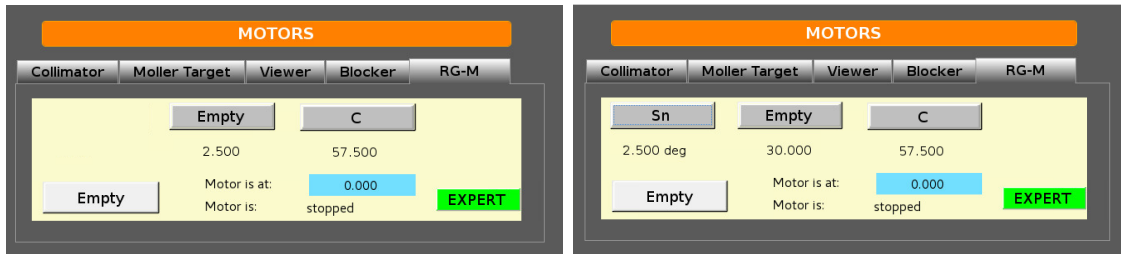


Figure 4: Solid target controls

Once you are happy with beam and target position and profile document obtained beam positions on the BPMs in the logbook and proceed to the Final Steps (Section 2.4).

2.3 Procedure for adjusting the beam on the Ca targets

^{40}Ca target is a disk with a notch on the top as shown in Figure 5 The notch is about 3 mm above the disk center. Moving beam above the notch emulate empty target. ^{48}Ca target does not have a notch therefore there is no “empty” option for it

1 ^{40}Ca target

- Request MCC to move beam to Y position on 2H01 to be moved up from the position previously established for cryotarget by 4 mm so it goes through the notch of the ^{40}Ca disk. Make sure it goes cleanly to the Faraday Cup viewer and appears at the same location as with cryo target.
- keeping horizontal beam position fixed move beam down with steps 0.1-0.2 mm until the rate on the downstream halo counters increases. Note this position: this is the edge of the notch.
- Move beam down by 3 mm from the notch.

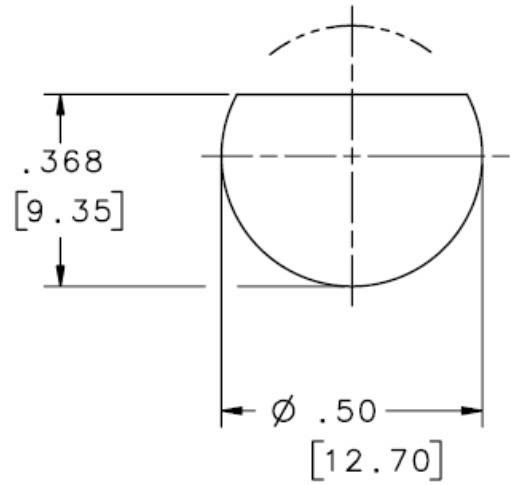


Figure 5: Ca target

- Keeping vertical beam position fixed scan beam horizontally in both directions with steps 0.1-0.2 mm until the rates in BOM and downstream halo counters increases. Find the midpoint and move beam to this location.

Once you are happy with beam position and profile document obtained beam positions on the BPMs in the logbook and proceed to the Final Steps (Section 2.4).

2 ^{48}Ca target

For ^{48}Ca the alignment procedure is similar to the cryo target.

- ask MCC operator to move beam on 2H01 BPM by 0.1-0.2 mm steps up and down, vertical direction
- record rates on halo counters and on BOM for each step. Stop moving in the given direction when rates go more more than $\times 10$ from where you started
- analyze rates as a function of position, find a position on 2H01 corresponding to the mid point of the two extreme ends where rates were highest. Ask MCC operator to position the beam on that position on 2H01 nA BPM
- repeat everything for horizontal alignment, moving the beam to left and right
- set orbit lock using found vertical and horizontal positions on 2H01

Once you are happy with beam position and profile document obtained beam positions on the BPMs in the logbook and proceed to the Final Steps (Section 2.4).

2.4 Final steps

After high quality beam was established and properly aligned, the beam orbit lock system should be engaged. This system incorporates position readings from the BPMs (2H01 and 2H00 if currents are high enough) to regulate currents in the horizontal and vertical corrector dipoles to minimize beam

motion at the target. The final step in establishing the production running conditions is setting limits on the halo counter and BOM rates for FSD system. If beam moves unexpectedly and gets close to an obstacle, e.g. collimator walls or to the thick parts of the target cell, count rates on the beam halo monitors and on the BOM will increase. The appropriate rate limits will depend on actual run conditions and the target, and will be noted on the white board in the counting room and/or on the run wiki. General prescription for setting a limit for FSD input rate of $N(\text{Hz})$ for a trip time interval of δt is:

$$N_{thr} = N + n_{\sigma} \times \sqrt{\frac{N}{\delta t}}$$

where n_{σ} is how far from mean value we want the trip to acquire. For example, for $\delta t = 5$ ms - the recommended value, $n_{\sigma} = 5$. will mean one false tripe every 5 hour. In order to avoid frequent false trips and allow some overhead in average rate and possible smaller time interval, a recommended value is $n_{\sigma} = 6$. Note, when beam is cleanly transported to Faraday cup, "Upstream" and "Midstream" halo counters should count $< 10 - 15$ Hz, for those FSD threshold should be set to 1000. High rates (~ 100 Hz) on these counters will indicate bed beam transport or a bleed-through from other halls and must be corrected.

References

- [1] D. Sober et al., Nucl. Inst. and Meth. A 440, 263 (2000).
- [2] https://clasweb.jlab.org/wiki/images/9/97/Beam_on_tagger.pdf
- [3] M. Piller, et al., JLAB-ACC-99-30 (1998).