Establishing beam for physics
Run Group C

Version 1.0

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Run gruop C will be using polarized target. It requires beam to be rastered over th target area. This document [?] describe basic operation of the raster system.

Establishing production quality electron beam for experiments of Run Group C 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]:

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

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 be energized while beam tune is in progress)

- raster FSD masked

- raster is OFF

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 $\sigma_{x,y} \leq 200$ μm, while at 2C24 (tagger) harp $\sigma_{x,y} \leq 500 - 600$ μm. In general it is a good practice to check newly measured beam parameters against last good/acceptable tune.

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

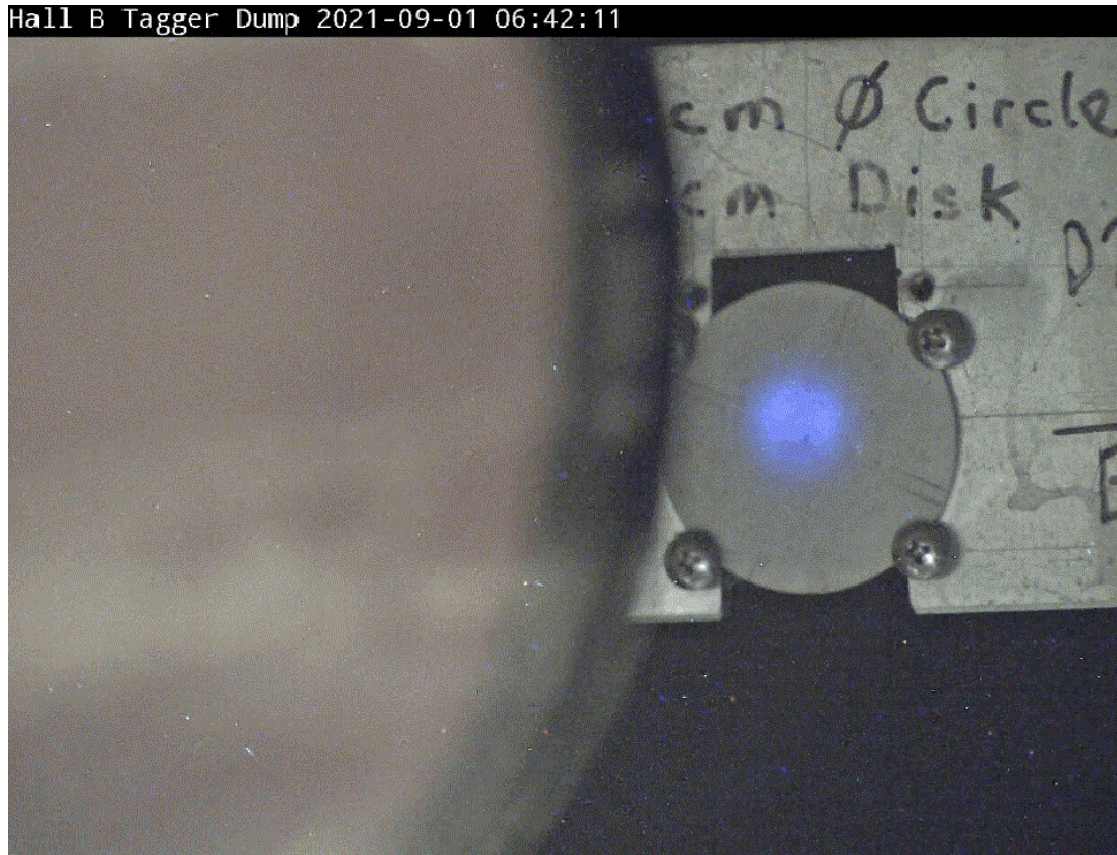Figure 1: Bemaline elements from the green shield wall to Faraday cup dump.

Figure 2: Beam spot on the tagger dump viwer.

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.

This following steps are applicable only for initial beam and raster tunning. If $NH_3 or ND_3$ target cell are installed. The raster must be always ON and in this step you only verify that beam goes to the Faraday cup. All FSD must be unmasked before you request beam to the Faraday cup.

- verify that beam goes to the dump

    a. make sure beam is clearly visible on the downstream viewer, use Chromox screen[1]. 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 then few %)

If the beam passes cleanly to the Faraday cup proceed to production running. and verify the raster pattern on RasterMon [?]

3   Beam to Faraday cup initial tuning

For this step the target should be empty or have RGC alignment cell installed.
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

- Ask MCC to mask Raster FSD

- raster must be OFF

- 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

- verify that beam goes to the dump

    a. make sure beam is clearly visible on the downstream viewer, use Chromox screen[2]. 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 then few %)
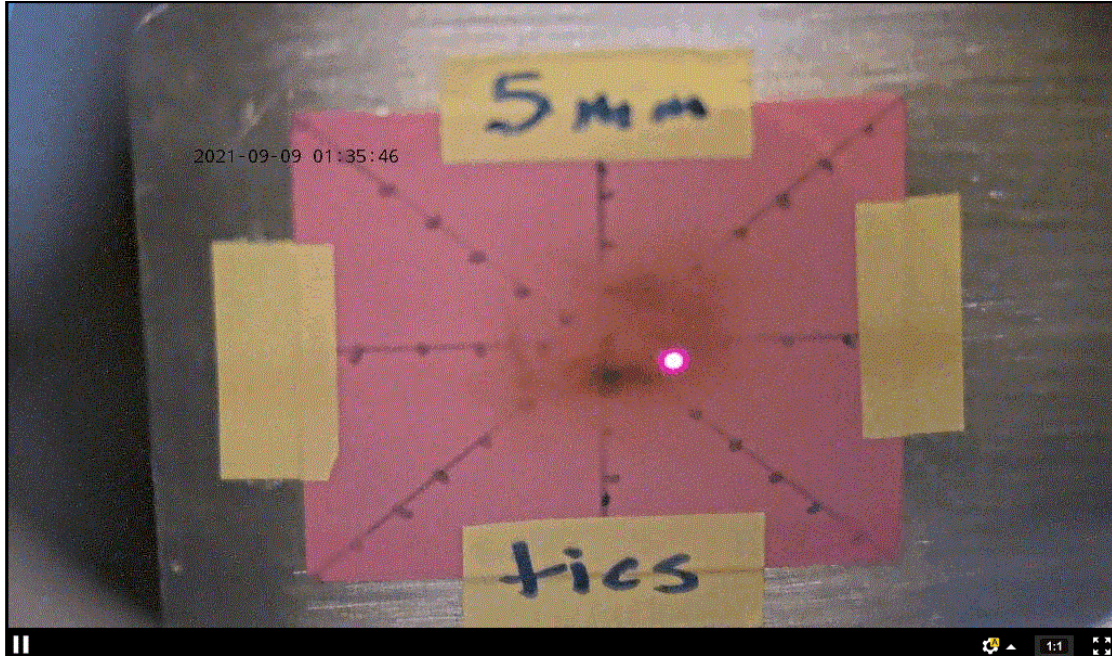
Figure 3: Beam spot on the Faraday cup viewer.

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 ($\sim$ 10m upstream) and will be used to focus beam at the target location to achieve required size (preferably $<$ 200 μm). The profile and position of the beam on the CLAS12 target will be checked using a 3-wire harp 2H01A mounted about $\sim$ 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 proceed to the next step, centering beam on target.

3.1   Procedure for adjusting the beam on the RGC alignment target

To center the beam on RGC target and tuning the raster a special alignment target with cross wires is used. It is shown in Figure 4. It has pair of vertical and pair of horizontal 50 μm thick tungsten wires. The wires are spaced by 10 mm.

Procedure for adjusting the beam on the 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 downstream halo counters 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

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[1]At low energies beam spot may not be clearly visible at 5 nA
[2]At low energies beam spot may not be clearly visible at 5 nA
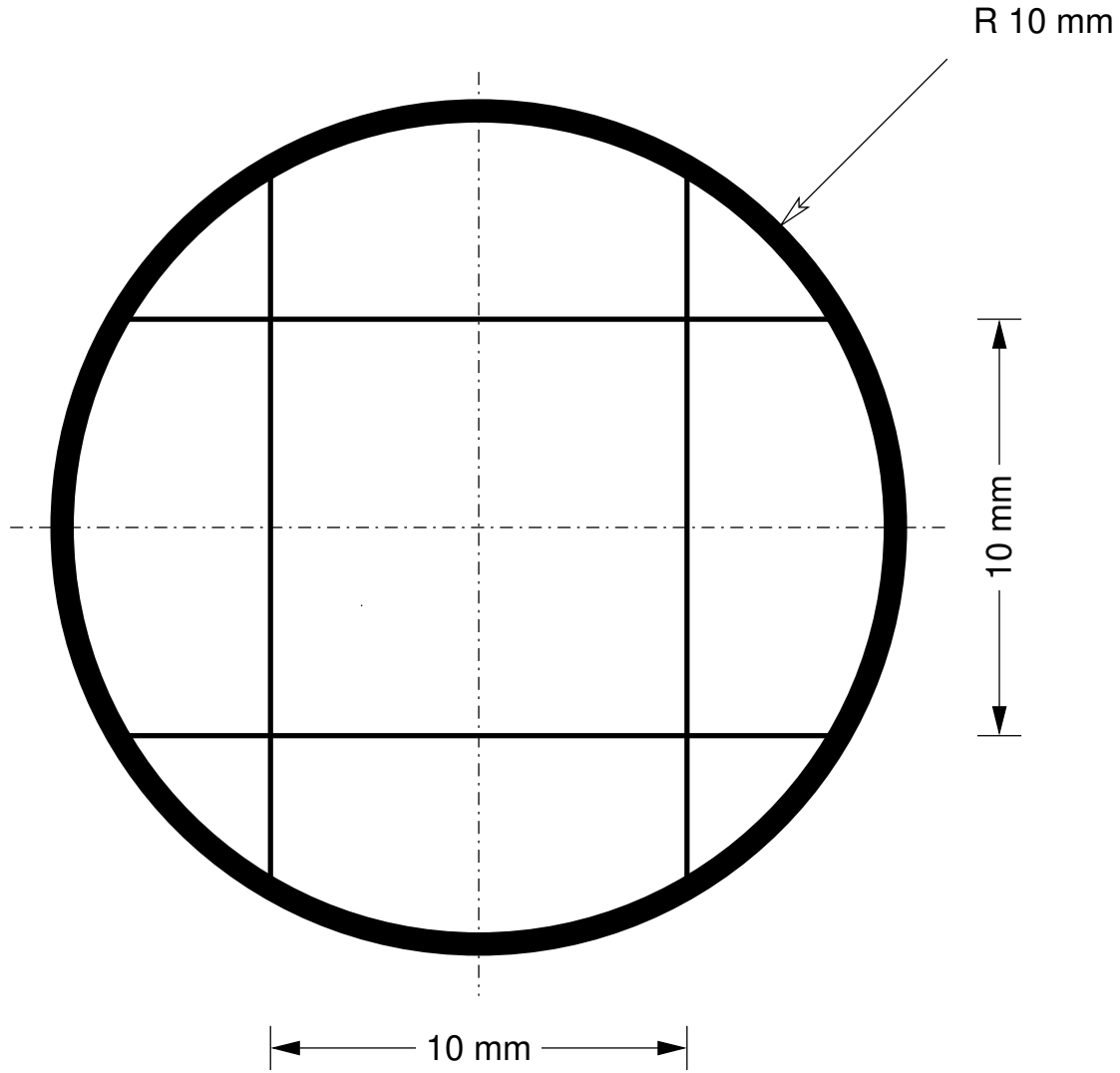
R 10 mm

10 mm

10 mm

Figure 4: RGC alignment target

- set orbit lock using found vertical and horizontal positions on 2H01

The spacing between the wires of the alignment cell is 10 mm which constrains the scan rang to about 5 mm in any direction. Once the center point between all wires is found record all BPM readings and proceed to the next step, tuning the raster.

3.2   Tuning the raster

Based on the magnetic field measurements of the raster magnet by th magnet group the initial raster calibration parameters are as follows. @10.6 GeV — ∼10 A/mm — ∼0.23 V/mm
@2.2 GeV — ∼2 A/mm — ∼0.046 V/mm
Where V is control voltage on the power supply. Th range of the power supply is +/-200 A. Corresponding control volatge range is +/- 5V
Wires are at +/- 5mm
For 2.2 GeV beam the shift by 5 mm corresponds to V=0.23 V. To set the raster pattern size to 5mm radius will be Vpp=0.46 V on the raster driver control. At 10.6 GeV it will be V=1.15 V and Vpp=2.3 V

The first thing is to fined relation of the raster voltage sign with direction of beam deflection.

- Set raster driver mode to DC for both X and Y. Set both offsets to 0 V. Turn bout outputs ON.

- Start changing X offset in positive direction towards the wire. Watch motion of the beam spot on the downstream viewer. Record in the log book if "+" moves beam to the left or right. Also watch 2H01 BPM X-position. Continue changing offset with small steps until the beam hits the wire and downstream halo rate goes up. Record the raster offset.

- Do the same in the negative direction until you find the other wire. Record the raster offset.

- Calculate the offset for the mid point between two wires and set this X offset. T

- Repeat the same procedure for the Y offset.

- Once this procedure is complete calculate conversion constant from voltage to mm using formula: $\frac{V_+ - V_-}{10}$ Do it for both X and Y.

At this point turn raster driver off and change driver mode to ARB and load waveform configuration file.

- Verify the period is set to 5 seconds and offsets are set to the values determined in previous step.

- With scale factors determined in previous step set amplitudes corresponding to the radius of 6 mm.

- Turn raster ON. Verify that is running on the scope.

- Start DAQ production configuration with electron trigger.

- Start RasterMon. You should see 4 wires on the RasterMon [?]. Verify that the raster pattern center is centered. on the wires.

- Note ADC channels corresponding to each wire. Set raster amplitude to 0V. RasterMon will show a single spot which corresponds to the target center. Record ADC channels.

- Calculate parameters for conversion of ADC to beam position.

3.3 Final steps

After high quality beam was established and properly aligned, the beam orbit lock system should be engaged. The final step in establishing the production running conditions is setting limits on the halo counter 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 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(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. The halo counter FSD setting should be approved by the beamline expert.

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).

[4] https://useerweb.jlab,org/ kuhn/RasterManual.pdf

[5] https://github.com/JeffersonLab/RasterMon/wiki