

Establishing beam for physics

Version 2.6

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July 19, 2021

Establishing production quality electron beam for experiments in Hall B is a two-step process. First, a beam is delivered and tuned in the Hall-B upstream tunnel, using a special dump before the hall proper. Then it is sent to the downstream electron dump and tuned on physics targets. Both stages require close cooperation between Hall-B shift personnel and MCC OPS.

1 Establishing beam upstream of the Hall-B

This step is necessary when the beam gets restored for the experiment for the first time or after a long downtime¹. The beam with desired parameters will be established upstream of the hall proper by dumping a low current, ≤ 10 nA, beam in the so-called *tagger dump* a designated dump in the floor of the hall before the CLAS detector. The beam is deflected to the dump by the tagger dipole magnet [1]. The tagger dipole power supply is set and controlled by MCC OPS. The magnet current is calculated based on the beam energy.

The following steps must be complete before the beam delivery:

- turn **OFF** HVs on the HPS detectors
- HPS SVT is fully retracted
- the HVs on halo counters (**upstream, tagger, midstream, downstream and HPS**) are **ON**, halo scalers are operational on the main scaler GUI
- halo counters are *masked* in the beam Fast Shut Down (FSD) system
- the *blank* collimator with no hole is on the beam
- the chicane magnets are OFF if this is the first beam delivery at this beam energy. Otherwise chicane can be ON
- ask MCC to energize the tagger dipole magnet. They will ask to switch the beam type to "Photon"

The beam with the required profile and trajectory will be established by MCC OPS using correctors and quadrupoles on the 2C line. Hall-B shift crew must monitor the progress using the wire harps and the nano-Aamp (nA) BPMs [2] at 2C21 and 2C24 girders in the upstream tunnel (see Figure 1). A Yag viewer upstream of the tagger dipole (ITV2C24) may be used by MCC to verify the position and the profile of the beam.

¹Long downtime means more than a shift (8 hours).

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: Beamline elements from the green shield wall to Faraday cup dump.

All harp scans must be properly analyzed and logged into logbook. Use *Upstream*, *Tagger* or *Midstream* halo counters for harp analysis. 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 $\sigma_{x,y} \leq 500 - 600 \mu\text{m}$, see Fig.2. In general it is a good practice to check newly measured beam parameters against last good/acceptable tune. With a decent tune, the beam spot should be visible at the center of the tagger viewer, Fig.3.

1.1 Beam with know trajectory

If the beam with the given machine setup (energy) has already been established for HPS and the beam positions on 2C24A BPM and on the *tagger harp* are known, it is important to restore those positions as close as possible before sending the beam to HPS. The distance between the BPM and the harp is about 2 meters. The distance from the harp to the HPS target is about 20 meters. To restore the beam

trajectory with a couple of mm accuracy at the HPS target, beam positions at the harp and BPM must be restored within $100\text{ }\mu\text{m}$ of the known positions.

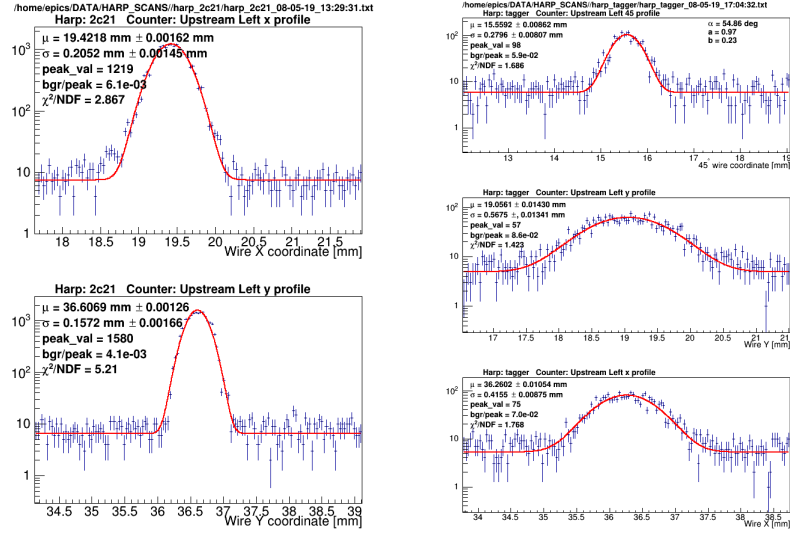


Figure 2: Beam profile as measured with 2C21 (left) and tagger (right) wire harps during the 2019 run.



Figure 3: Beam spot on the tagger dump viewer.

2 Beam to Faraday cup

The second step of establishing a physics quality beam for the experiment starts after acceptable beam parameters have been achieved on the tagger dump. The following are steps for sending beam to HPS:

- HPS detectors are off, SVT retracted
- HPS SVT protection collimator with 8 mm hole is on the beam
- tell MCC that the beam is acceptable at the tagger
- ask to take the beam away, degauss and turn OFF the tagger magnet
- position 20 mm diameter collimator on the beam
- ask MCC to unmask **upstream, tagger, midstream, and downstream** halo counters in FSDs. Set the halo counter FSD thresholds as defined in the run wiki with the integration time interval of 5 milliseconds
- when ready ask MCC to send ~ 10 nA beam straight to the electron dump (downstream end of the Hall B beamline where Faraday cup is located).
Note: Rates on the *Upstream, Tagger, and Midstream* halo counters should not exceed ~ 200 Hz.
- verify that beam goes to the dump cleanly:
 - a. make sure beam is clearly visible on the downstream viewer. Beam should be within 10 mm (2-tick marks) around the center
 - b. make sure that the beam current reading on the Faraday cup and the currents on 2C21 and 2C24 BPMs are consistent (difference should not be more than few %)
If the beam is not visible on the viewer this means, most likely, the beam is not going through the the HPS SVT protection collimator hole. Do not go for *fishing expedition* with moving the beam up and down trying to find the collimator hole or retract the collimator, call the beamline expert!
- check that beam is roughly centered in SVT protection collimator by performing halo rate vs. collimator position scan. This is simply moving the collimator up and down with tiny steps using the *expert GUI* and recording HPS halo counter rates. The collimator motion units are in inches, the step size should not be more than 0.01 inches in the *move rel.* window of the motor expert GUI.

The MCC OPS will adjust the beam profile and position on the target. The most sensitive correctors and quadrupoles are on 2C24A/2C23A (in the upstream tunnel) and the 2H01 (in the hall) girders. The last one is the closest to the target (~ 30 m upstream) and will be used to focus the beam at the target, preferably to < 30 μm width in both x and y directions. Every adjustment requires a check using a 3-wire harp at 2H02A. The harp is mounted about ~ 3 meters upstream of the target. When performing the 2H02A harp scan with the beam on the Faraday cup dump, **the halo counter FSDs for *Upstream, Tagger, and Midstream* must be unmasked, the FSD thresholds should be 1 MHz, and the integration time interval 50 milliseconds. The *Downstream* and HPS halo counters must be masked.**

Before proceeding with the positioning of the beam relative to HPS SVT after the physics quality beam is established with an acceptable profile measured with the 2H02A harp, the following steps must be taken:

- repeat collimator centering procedure
- increase beam current to 50 nA and ask MCC to engage HPS orbit locks
- repeat 2H02A harp scan
- if beam profile is still acceptable, remove the beam and set the 2.82 mm collimator on the beam
- ask for 50 nA beam and check the 2.82 mm collimator centering
- make sure to record changes in the position of the collimator after every centering
- if chicane is OFF:
 - a. remove the beam and energize the chicane magnets
 - b. ask beam back at 50 nA, make sure beam is seen on the downstream viewer, record any position shifts

3 Beam setup relative to SVT

The next step is the aligning the beam relative to SVT. The top and bottom SVT movers have frames with wires upstream of the L1 sensors, Fig.4. The two tungsten wires, a 20 μm horizontal and a 30 μm tilted by about 9° relative to the horizontal are aligned relative to the sensors and will be used to perform beam profile and position measurements. In the fully retracted position of SVT, the beam has to go in between two horizontal wires (see details in SVT the manual [3]). The top wire is about 1.2 mm above the beam. The bottom wire is about 0.7 mm below the beam. Any motion of the SVT movers more than 5-6 mm should result in interaction of the both wires with the beam.

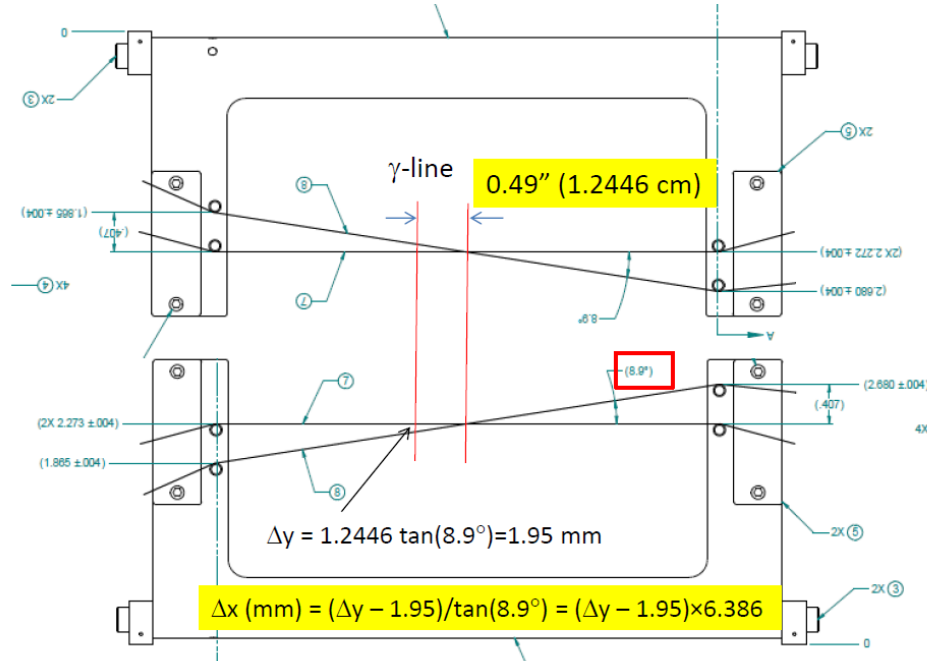


Figure 4: Top and bottom SVT wires.

To perform SVT wire scan, open *SVT Positioners* GUI, then the *SVT BOTTOM Scan* or *SVT TOP Scan* GUIs (one at a time) from the *Experts Screens* button and run the *Scan*. After scan is complete, run *Analyze the data*, see Fig.5.

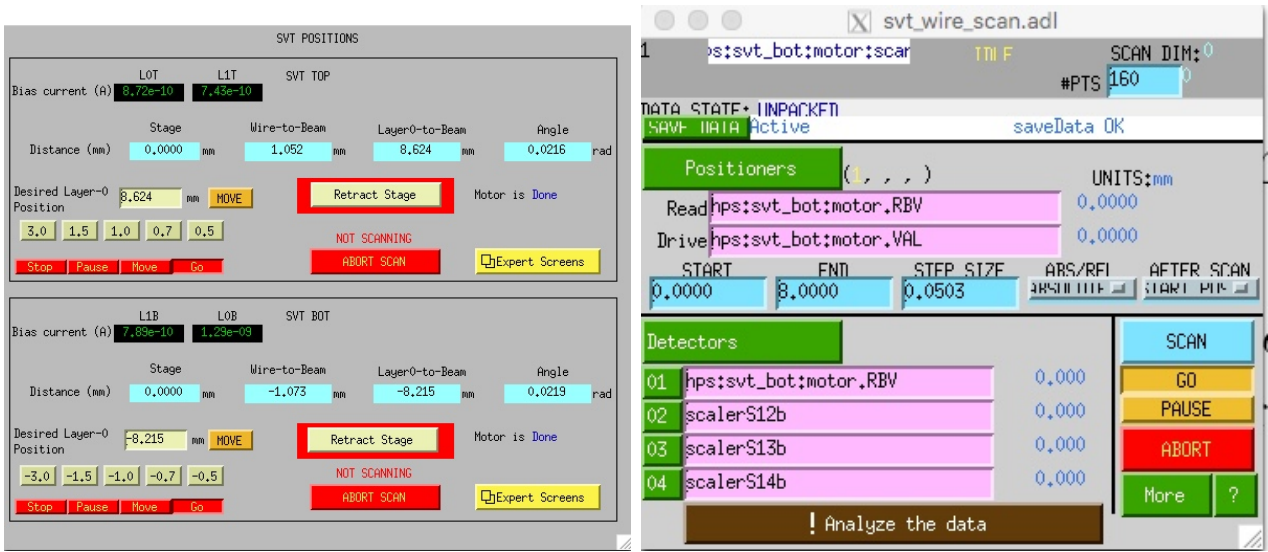


Figure 5: Beam profile as measured with bottom SVT wires during the 2019 run.

The results of one of the scans during the 2019 run are shown in Fig.6. The ideal beam position is when both the $beam_x$ and $beam_y$ are ≈ 0 .

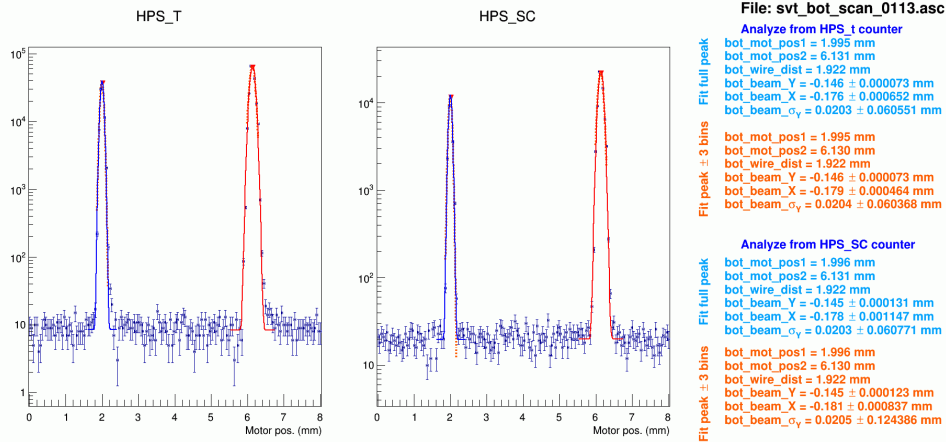


Figure 6: Beam profile as measured with bottom SVT wires during the 2019 run.

Note: if this is the first beam-SVT alignment, the beam may not be in the right place between the two horizontal wires. It is recommended to move top and bottom frames by about 5 mm and observe the passing of both wires through the beam (the HPS halo counter rates will increase). If crossing of the two wires is not observed, contact beamline and SVT experts.

4 Finishing the beam setup

After a high quality beam was established and properly aligned for HPS, the beam orbit lock system should be engaged. This system incorporates position readings from stripline BPMs on 2H00A and 2H02A girders. For proper operations of orbit locks, the beam current must be > 50 nA. After orbit locks are engaged and running for several minutes:

- perform beam profile scans with "tagger" and 2H01 wire harps for the record. **Note the halo**

counter FSDs must be unmasked, the FSD thresholds should be 1 MHz, and the integration time interval 50 milliseconds.

- increase beam current to 100 nA and repeat 2H02A harp scan. Note, beam positions on BPMs may change slightly as their reading is beam-current dependent, however beam position as measured with the harp should not change from the 50 nA scan.

The final step in establishing the production running conditions is setting limits on the halo counter rates for the beam FSD system. If the beam moves unexpectedly and gets close to an obstacle, e.g. collimator walls, 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 whiteboard in the counting room and/or on the run wiki. The integration time for the FSD scalers should be 5 ms. The typical values for *Upstream*, *Midstream* and *Downstream* halo counter rates in 2019 were ~ 100 Hz and the FSD thresholds ~ 10000 Hz.

References

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