HPS 2021 run

July 27, 2021

The Heavy Photon Search (HPS) experiment in Hall-B will be on the floor for 57 days from August 23 to October 16. HPS will take production data using the 3.74 GeV electron beam of up to 300 nA incident on a tungsten target. Experiment exploits resonance and displaced vertex signatures to search for heavy photons over a wide range of couplings, $\epsilon^2 > 10^{-10}$, and masses, 20 MeV/$c^2 < m_{A'} <$ 220 MeV/c^2, see the latest update to JLAB PAC [1] for details. With this run, we expect to explore a new, uncharted territory of mass and coupling using a displaced vertex search method.

HPS detector and requirements to the beam parameters

The 2021 setup of the HPS experiment and hence the requirements for the beam quality is the same as in 2019. The HPS setup, Fig.1, is composed of a three-magnet chicane with the middle 18D36 dipole as an analyzing magnet. The electron beam passes through the system in the vacuum all way to the dump. The HPS detector is a compact, large-acceptance forward spectrometer consisting of a silicon micro-strip vertex tracker (SVT), a scintillation hodoscope (SH), and a $PbWO_4$ electromagnetic calorimeter (ECal). The target, SVT, and SH are installed inside the vacuum chamber in the dipole bore. The ECal is mounted downstream of the magnet. The detector system is split into the top and bottom halves to allow a "sheet of flame" electromagnetic background to pass through. The first layers of the silicon tracker is located 5 cm downstream of the tungsten target. The distance between the edge of the first layers of the silicon and the beam plane in the production data taking configuration is only 500 μm. The proximity of the

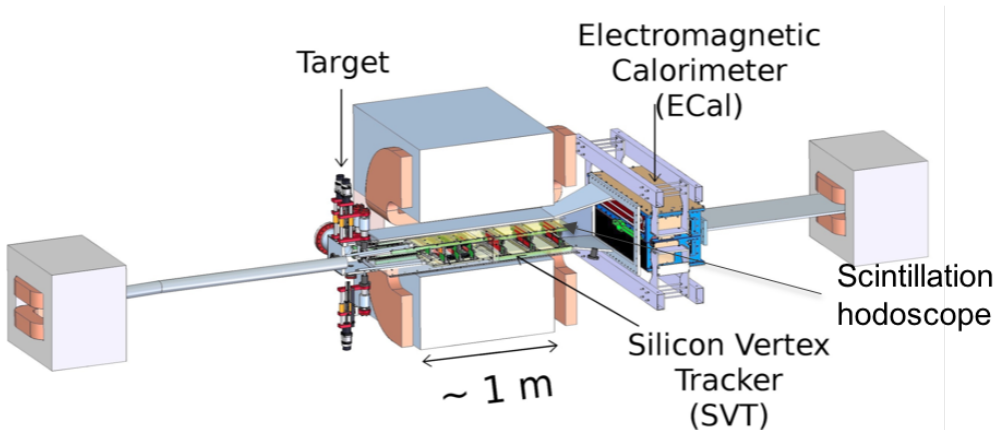

Figure 1: .

tracking detectors to the beam plane and the target derives the requirements to the beam profile and stability listed in Table 1.

A small size beam with superb position stability and a low beam halo as requested in Table 1 is crucial for the success of the experiment. Beams of such quality have been delivered to HPS in the past, during the 2015 and 2016 engineering runs and for the first physics run in 2019. In Fig.2, a typical beam profile during the 2019 run measured with the wire harp located about 3 meters upstream of the HPS target is shown. Widths of the (x,y) profile of the beam and the beam halo rates are well within the specifications. The long-term stability of the beam position, measured on 2H02 BPM (about 3.5 meters upstream of the HPS target), also was within specifications as shown in Fig.3. We expect that the beam quality for the 2021 run at 3.74 GeV will be as good as it was for the 2019 4.5 GeV run.

The other requirements in the table, the beam current stability, and the bunch charge uniformity requirements are related to the data quality. The 120 kHz beam charge modulation, first observed during the 2019 HPS run[1], is a serious issue for HPS. When present, it crates unsustainably high accidental rates and large dead time due to huge event sizes, making the segments of data useless for physics analysis. The beam bunch charge modulation will be monitored using the EPICS application created in 2020. In Fig.4 measured

[1]The same issue surfaced few times during the CLAS12 RG-F run in the summer of 2020

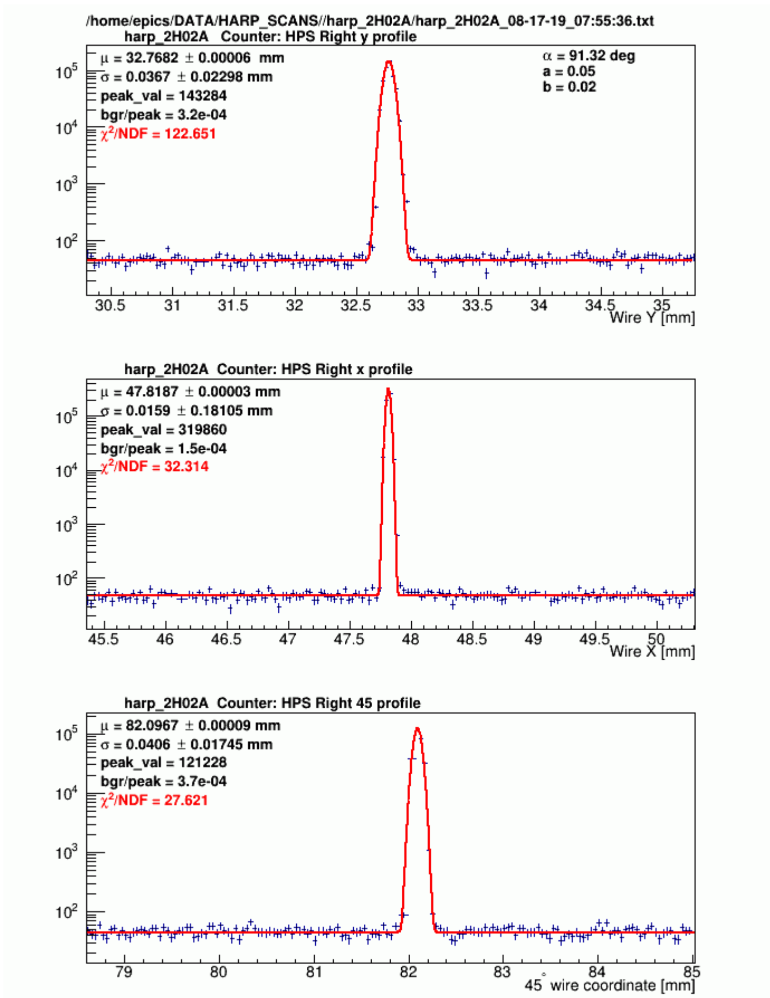

Figure 2: Measured beam profile using the 3-wire harp at the location of 2H02 girder.

Parameter	Requirement	Comments
Energy (GeV)	3.74	May run with 1.92 GeV (1-pass) beam for calibration
δp/p	$\sim 2 \times 10^{-4}$	
Current (nA)	≤ 300	The production running with 20 μm W-target will use $\sim$ 120 nA
σ_{xy} (μm)	< 30	As measured by 2H02A wire harp
Position stability (μm)	< 30	On 2H02 and 2H00 ($>$ 30nA) BPMs with feedback
Divergence (μrad)	< 100	
Beam Halo ($> \pm 5\sigma$)	$< 10^{-5}$	As measured by 2H02A wire harp
Long term current stability	< 5 %	For $>$ 30 nA, integrated over minutes
Short term bean intensity stability (60 Hz harmonics)	$< 10\%$	of the total power, measured with SLM and halo rates
Bunch charge fluctuations	< 10 %	Measured with DAQ

Table 1: Required beam parameters for 2021 HPS run.

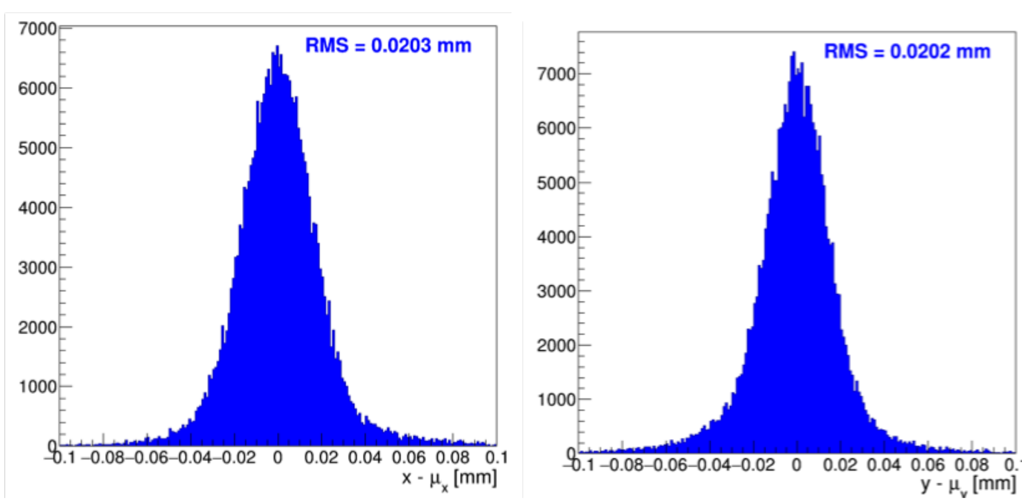

Figure 3: Beam position stability as measured by 2H02A BPM over many hours of running.

Figure 4: Beam time structure with 120 kHz modulation present (top) and when it is suppressed (bottom).

beam time structure is shown for two cases when 120 kHz modulation is present (top) and when it is suppressed (bottom).

Beam setup

The beam setup and delivery for the experiment will be similar to the 2019 run. After a long down or a machine configuration change beam will be established first upstream of the Hall-B tagger magnet using the beam dump at the end of the tunnel inserted into the floor of Hall B. When desired beam

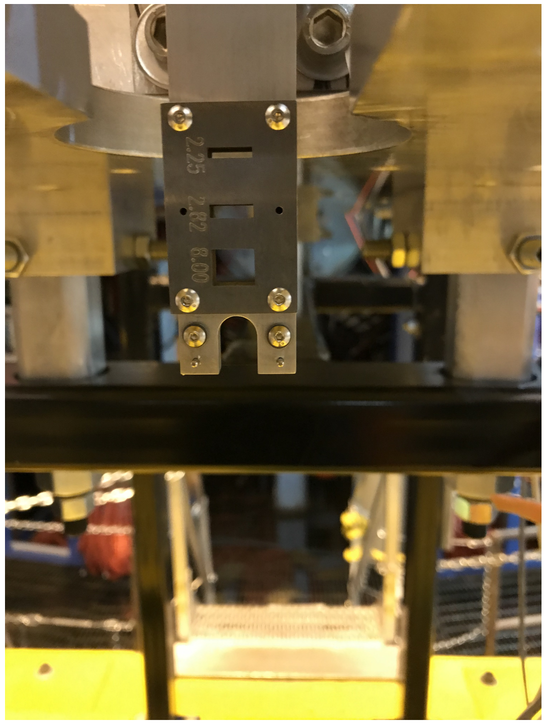

Figure 5: New collimator assembly with 8 mm hole.

parameters are achieved on the tagger dump, the beam will be delivered to the Faraday cup dump and tuned on the HPS target.

When the beam goes to the Faraday cup, it must pass through the HPS SVT protection collimator. The collimator, a tungsten block with holes of various sizes, must always be on the beam, even when SVT is retracted for the beam tuning. In 2019 one of the main issues to establish a good beam for HPS was getting through the collimator hole (10 mm $\times$4 mm). Frequent changes in the injector and the machine setup for the parity experiment prevented reproducible beam delivery for the experiment. After every change, it was hard to get through the hall and the HPS detector system to the dump.

For the upcoming run, two changes will be made to aid the beam setup through HPS. First, there is a new collimator with the hole height of 8 mm instead of 4 mm[2], see Fig.5. The collimator position is fiducialized on the beamline (to the centerline of the 2H02 girder) and the large hole collimator

[2] When retracted, the gap between top and bottom SVT halves is about 10 mm.

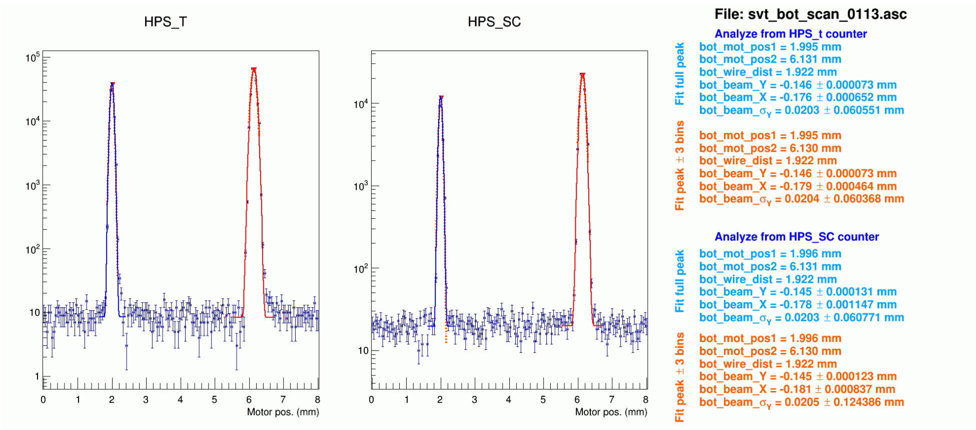

Figure 6: SVT wire profile from 2019 run.

will be on the beam every time beam is tuned to the Faraday cup..

Second, the alignment procedure from the last summer's Bonus run will be used to set up the correct trajectory of the beam through the detector[3]. After the beam is established for HPS for the first time, the beam (x, y) positions on 2C24A BPM and at the "tagger harp" (2C24-harp) will be recorded. These two devices are about 2 meters apart and will define beam trajectory suitable for the experiment. This trajectory, beam positions on 2C24A, and the "tagger harp", will be restored every time when establishing the beam on the tagger. This procedure will ensure that the starting trajectory of the beam to the Faraday cup is close to one from the previous successful setup.

The rest of the procedures to establish a small size beam on the HPS target using quads at 2H00 and 2H02 (if needed) will remain the same. The beam profile at the target will be measured using the HPS SVT wire profiles, see Fig.6.

More details on the establishing physics quality beam for HPS can be found at [2]. MCC should use their procedures for establishing beam to Hall-B using the Hall-B tagger beam dump (current procedures at [3]. must be replaced with the ones used in 2019).

[3]The Bonus experiment used a 6 mm diameter 50 cm long straw target and had a difficult time to get the beam through.

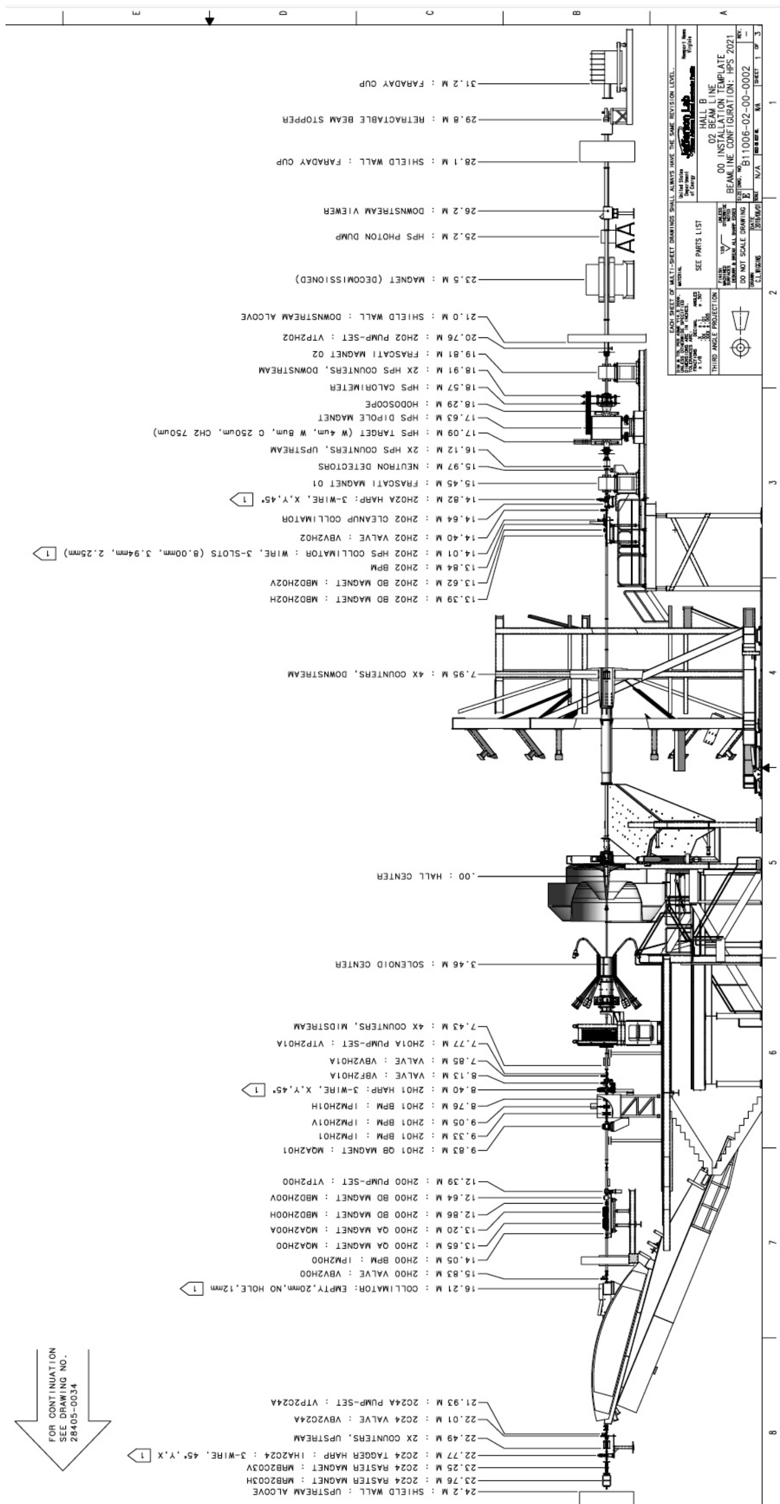

Figure 7: HPS beamline in Hall-B.

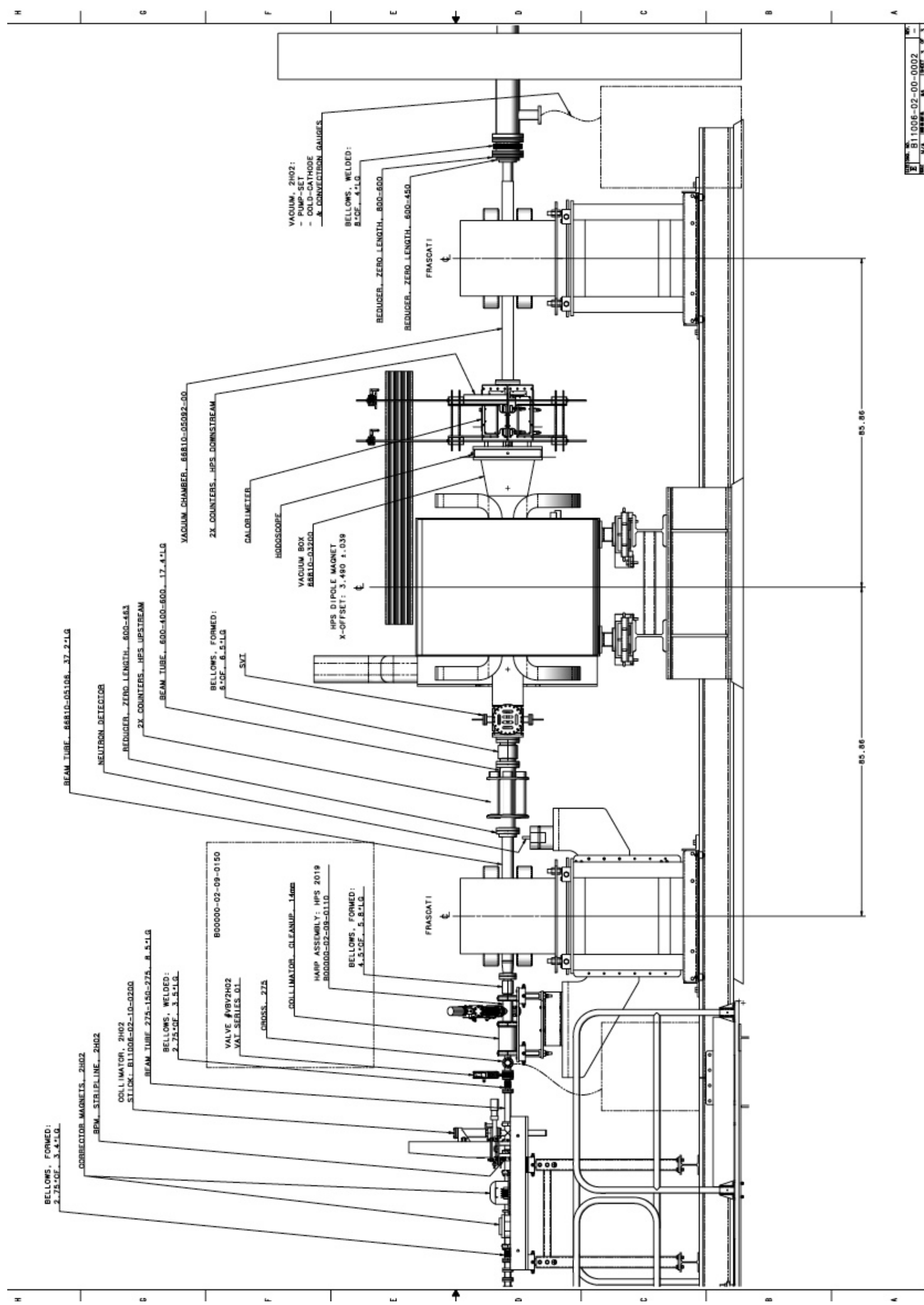

Figure 8: HPS in downstream alcove.

References

[1] M. Holtrop, T.k. Nelson, S. Stepanyan for the HPS collaboration, HPS Update to PAC48 https://www.jlab.org/exp_prog/proposals/20/Jeopardy/HPS_Update.pdf

[2] Establishing physics quality beam for HPS https://wiki.jlab.org/hps-run/images/1/1e/HPS_beam_estab.pdf

[3] MCC Procedures http://opsntsrv.acc.jlab.org/ops_docs/MCC_web_interface/interface_pages/operating_procedures.asp