NPS-DVCS Run Plan Fall 2023

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Contents

1 Production & Calibration Kinematics

1.1 Production Data Kinematics

Table 1: DVCS Production Kinematics, Commissioning, and Calibrations. Full production details are in the file `DVCS-kin-NPS-2023_v0.xlsx` located at `https://hallcweb.jlab.org/wiki/index.php/NPS_Run_Plan_(2023)`. Expectation to take all data at 30 μAmp. Production run times are 'PAC Days'. Accelerator schedule (Appendix B) has 225 calendar days, but not with proportional mix of 3-, 4-, and 5-pass running.

Name KinC-	x_B	Q^2 GeV^2	E GeV	ϵ	E' GeV	$\theta_{\rm HMS}$ deg	$\theta_{\rm Calo}$ deg	$q'_{\rm Max}$ GeV	$D_{\rm Calo}$ m	H_2 Days	D_2 Days
x25-1	0.24	2.10	6.397	0.470	1.734	25.13	8.68	4.63	6.0	1	1
x25-2	0.24	2.40	8.483	0.629	3.154	17.22	9.69	5.30	4.0	1	1
x25-3'	0.26	2.40	10.558	0.816	5.639	11.52	12.62	4.88	4.0	1	1
x25-4	0.25	3.00	10.558	0.663	4.163	15.01	9.37	6.36	6.0	1	1
x36-1	0.36	3.00	6.397	0.509	1.956	28.34	11.24	4.35	3.0	0.9	1.0
x36-2	0.36	3.00	8.483	0.747	4.042	17.01	14.36	4.35	3.0	0.4	0.5
x36-3	0.36	3.00	10.558	0.849	6.117	12.37	15.96	4.35	3.0	0.25	0.33
x36-4	0.36	4.00	8.483	0.515	2.562	24.77	9.89	5.83	4.0	1.0	1.0
x36-5	0.36	4.00	10.558	0.711	4.637	16.44	12.12	5.83	3.0	0.66	1.0
x36-6	0.36	5.50	10.558	0.402	2.416	26.85	7.40	8.05	4.0	1.66	2.0
x50-0	0.48	3.40	6.397	0.647	2.640	25.93	16.01	3.58	3.0	3.0	3.0
x50-1	0.48	3.40	8.483	0.818	4.726	16.75	18.98	3.58	3.0	1.5	1.5
x50-2	0.48	3.40	10.558	0.890	6.800	12.49	20.58	3.58	3.0	1.25	1.25
x50-3	0.48	4.80	10.558	0.767	5.253	16.92	15.45	5.12	3.0	2.5	2.5
x60-1	0.58	5.10	6.397	0.418	1.717	39.84	12.22	4.364	3.0	10	10
x60-2	0.58	5.10	8.483	0.697	3.803	22.93	16.57	4.364	3.0	7.5	7.5
x60-3	0.58	5.10	10.558	0.818	5.878	16.48	18.72	4.364	3.0	4.5	4.5
x60-4	0.58	6.00	10.558	0.741	5.052	19.31	16.09	5.182	3.0	7.5	7.5
	Subtotals									47.5	48.5
	Subtotal H + D Production									96.0	
	Initial Commissioning									2.5	
	Calorimeter Calibrations (8 × 12hrs)									4.0	
	Moeller Runs (15 × 4hr)									2.5	
	HMS Optics (18 × 4hr)									3	
Total										108	

1.2 Calorimeter Elastic Kinematics (electrons in NPS)

Table 2: Coincidence elastic $H(e, e'_{\text{Calo}} p_{\text{HMS}})$ settings. Count rates and run times assume 30 μAmp beam current.

Beam Energy	Three-Pass 6.397 GeV	Five-Pass 10.558 GeV	Four-Pass 8.483 GeV
HMS Proton Momentum	2.778 GeV	4.036 GeV	3.310 GeV
HMS Central Angle	34.612°	30.145°	32.906°
Nominal Calorimeter Angle	21.00°	16°	17.5°
Calorimeter Distance (front)	8 m	9 m	9 m
Nominal Electron Momentum	4.403 GeV	7.353 GeV	5.981 GeV
Nominal Q^2	3.742 GeV^2	6.015 GeV^2	4.696 GeV^2
NPS Calo angles	19.14°	14.60°	15.60
	20.57°	15.74°	16.99
	22.00°	16.89°	18.39
Count Rate per setting	66/sec	10/sec	29/sec
Total calibration time	7.5 hour	12 hour	9 hour

1.3 HMS Elastic Settings (electrons in HMS)

Table 3: HMS Elastic ep Calibration Settings. Count rate is at a luminisity of $5 \cdot 10^{37}/\text{cm}^2/\text{sec}$ (Beam current 19.8 μAmp).

Setting	1	2	3	4	5
Beam (GeV)	10.558	10.558	10.558	10.558	10.558
k'_{HMS} (GeV)	6.934	6.117	6.028	5.442	5.229
θ_{HMS} (deg)	17.531	20.694	21.058	23.587	24.573
Events (1000/hr)	31.5	6.66	5.67	2.06	1.44

2 Commissioning at 5-Pass Beam

Beam check-out procedures adapted from
https://redmine.jlab.org/attachments/download/1494/10_549_GeV_Runplan.pdf.
Initial configuration of spectrometers: **Setting KinC_x36_5**:

1. HMS angle = 16.435 deg.
2. HMS momentum = −4.637 GeV/c (negative polarity, all magnets cycled).
3. HMS "Large" Collimator.
4. NPS Calorimeter distance 9.5 m. Angle 17 deg.
5. Carbon foil target at $z = 0$, thickness 0.5% radiation length.
6. Trigger Configuration

Trig. 1	(NPS VTP Single-Cluster) ∪ (NPS VTP Two-Cluster) ∪ (Delayed EDTM)
Trig. 2	(NPS LED)∪(NPS Cosmic)
Trig. 3	HMS 3/4 (Scint)
Trig. 4	HMS El-Real:
Trig. 5	(Trig.1) ∩ (Trig.3)
Trig. 6	(Trig.1) ∩ (Trig.4)

All of this trigger logic is performed in Counting House.
HMS triggers are described by Carlos Yero in https://hallcweb.jlab.org/doc-public/ShowDocument?docid=1028.

2.1 Beam & HMS Check-Out

Initial NPS settings: Sweep magnet off, calorimeter at $\geq 20°$. Calorimeter distance 9 m (§2.3). All changes of calorimeter distance must be done during day shift (week-day).

1. BPM Calibration vs. Harp Scan, Beam Centering on Carbon Hole
   https://hallcweb.jlab.org/wiki/index.php/Beam_Checkout_Procedures
   Coordinate with Dave Gaskell.
2. Fix Beam Angle at Target
   Use the gui at: `/home/cdaq/users/gaskelld/target_bpm/target_bpm.py` Adjust 3H07Ax, y to remove slope while keeping 3H07Cx, y fixed. Recheck carbon hole and iterate as necessary.
3. NPS Sweep Magnet Commissioning
   Coordinate with Bogdan Wojtsekhowski and Jay Benesh.
   Verify beam deflection at dump with required magnet current for $\int Bdl = 0.3$ Tm (468 A), and calorimeter central angles $\geq 7.4°$

4. BCM Calibration
   The Run Coordinator will schedule this with the Program Deputy (not crucial until all other commissioning is complete). This requires MCC's ability to reliably deliver 50 μA beam, so this calibration might have to wait at least a few days. The BCM calibration procedure is at
   `https://hallcweb.jlab.org/doc-public/ShowDocument?docid=957`
   Coordinate with Dave Mack, analysis lead Christine Ploen.

5. Beam Energy Calibration
   This should be completed as soon as possible, this is vital to the DVCS Calorimeter calibration. The Run Coordinator will schedule this with the Program Deputy. MCC sets up a clean dispersive tune. Shift Leader must make a full `hclog` entry of the MCC data. Follow the "Hall C Beam Energy Measurement Procedure" at MCC Ops Doc:MCC-PR-06-004.

6. General verification of HMS detectors.
   HMS Single Arm DAQ or Coic DAQ:
   HMS CerMode10, other HMS FADCmode9.

   (a) Defocus Q2 by +20% to fully illuminate focal plane. Use LD_2 target. Set HMS_3/4 prescale to keep event rate below 1000/sec (expect 8 : 1 prescale). All other prescales -1. EDTM rate 100 Hz. Start with a 5 min run, then a 1 hour run, keep data files below 3M events. Keep event rate low enough for near 100% efficiency.
   Analysis lead: Mark Mathison. Verify that all Hodoscope bars are counting and focal plane is illuminated. Check that timing spectra make sense. Contact expert(s) if in doubt. Verify event rate after cuts are close to expectations (Zheng Huang).

   (b) Return HMS-Q2 to nominal setting. Run for 1 hour. Keep prescales same as defocussed setting and record equal sized files.

   (c) PID checkout (HMS e/π). Analysis lead Wassim Hamdi, Mitch Kerver. Verify in previous data electing events HMS_3/4 events in the MIP peak of the shower counter should give a clear single photo-electron peak in the Cherenkov. Take a 20 min run with HMS_El-Real prescale 1 and others -1. Verify HMS_El-Real events provide a clean Poisson distribution (mean $\geq$ 12 photo-electrons) in the Cherenkov withouth inefficience at low Chernkov amplitude.. Setting KinC_x36_5 has an expected $\pi : e$ ratio of 1 : 1. If unsure of PID quality either adjust threshold in HMS_El_Real trigger and/or move spectrometer to a more favorable setting, *e.g.* KinC-x50-2 or -3.

   (d) Take a 10 minute run with all HMS FADC channels in mode10.

7. Initial verification of HMS optics.

   (a) Take a Sieve Slit run (HMS Single Arm) at setting KinC_x36_5 (above).
   HMS_El_Real prescale 1 : 1

HMS 3/4 prescale $\sim 16 : 1$

Single foil $0.5\% X_0 = 0.114$ g/cm^2 carbon target.
NPS Sweep Magnet Off.
Expected average count rate per pinhole 0.46/sec at 30 μAmp.
One hour run, or scaled to beam current.
Details of the HMS Sieve at
`https://hallcweb.jlab.org/DocDB/0011/001104/002/HMS-Sieve.pdf`
Look at the HMS $x_{\rm FP}$ *vs* $y_{\rm FP}$ scatter-plots. Verify most holes have at least 200 events.
Analysis leads Holly Szumila-Vance, Christine Ploen, Joshua Crafts.
General information on HMS optics at
`https://hallcweb.jlab.org/wiki/index.php/12_GeV_HMS_Optics_Data`

(b) Verification of NPS fringe field on HMS optics.
Sieve Slit run at setting KinC_x36_1
NPS angle = 12.12°.
NPS Sweep Magnet On, setting 0.3 Tm (468 A).
Single foil $0.5\% X_0 = 0.114$ g/cm^2 carbon target.
Beam Current 30 μAmp.
One Hour Run (0.108 C)

8. Full HMS optics
If either of the previous two runs show any problems with optics, then repeat with "Optics Target": two thin carbon foils (0.044 g/cm^2 each) at $z = \pm 8cm$.
NPS Sweep Magnet on and off. 1.5 hour runs (0.16C each).

The following items can be moved to after or in-between the calorimeter calibration runs of section § 2.3.

9. HMS Singles DAQ Check
This study, and items 10 and 11 can be deferred to the 'downtime' during Calo elastic calibration analysis and re-calibration.

    (a) Deadtime *vs.* Prescale check, HMS Single-arm DAQ
    Setting KinC_x36_5 (NPS Calo at large angle). Expected HMS DIS single arm rate ($D\delta = \pm 8\%$) at 30μA is 2500/sec, with $\pi : e$ ratio $1 : 1$.
    Take 10 min runs at **15** μA with HMS EL_REAL prescale at $1 : 1$ and HMS_3/4 prescale settings $128 : 1$, $16 : 1$, $4 : 1$, & $1 : 1$ (if rate allows). Quick analysis to test if good electron yield corrected for deadtime is consistent.

    (b) Deadtime *vs.* Rate study, HMS Single-arm DAQ
    Beam Current 15 μA. EL_REAL prescale at $1 : 1$, others -1. Take 15 min runs with EDTM rate 10 Hz, 100 Hz, 1000 Hz.
    Increase beam to 30 μA. Take 15 min runs with HMS EL_Real prescale settings 0, 1, 3, 4 (factors $1 : 1$, $2 : 1$, $5 : 1$, $9 : 1$). Adjust EDTM rate correspondingly to 10, 20, 50, 180 Hz

10. Target Boiling Study, HMS Single-arm DAQ
    Move NPS Calo to $\sim 20°$.
    HMS_3/4 prescale ∞. EDTM 10 Hz. HMS EL_Real prescale 1 : 1.
    Take 10 min runs at beam current 5, 15, 30, and 45 μA.
    Second pass: Keep trigger rate constant. Take 15 min runs at constant rate as follows:

Beam μA	5	10	15	25	45
HMS EL_Real prescale GUI	0	1	2	3	4
EDTM rate (Hz)	10	20	30	50	90

11. Moeller Measurement of Beam Polarization
    Coordinate with experts: Dave Gaskell and William Henry.
    Initial measurement expected to take 4 hours. Follow-up measurements (every 1-2 weeks) expected to take $\sim 1/2$ shift. Precision goal is $\pm 2\%$.

2.2 Coincidence DAQ Commissioning

Setting KinC_x36_5 (above). Expected HMS DIS single arm rate ($D\delta = \pm 8\%$) at 30μA is 2500/sec, $\pi : e$ ratio is 1 : 1. Preferred distance of NPS calorimeter is 3.0 m. *Due to downtime/scheduling issues of moving calorimeter, this can be done with Calo at 9 m. This simply means coincidence rate will be 9 times lower and $\pi^0 \to \gamma\gamma$ efficiency will be reduced.* After an initial check, perhaps some of this could/should be done after the first calorimeter calibration.
Establish H$(e, e'_{\rm HMS}\gamma_{\rm Calo})$ coincidence timing with sweep magnet on.

1. Run with Beam Off (10 min), EDTM at ~ 10 Hz in HMS and set NPS firmware to readout waveforms of entire calorimeter to readout entire calorimeter for electronic baseline/pedestal measurement.
   Coincidence DAQ Prescales:

Trigger	Name	Prescale
1	NPS	$\infty : 1$
2	Cosmic$\cap$LED	$\infty : 1$
3	HMS 3/4	1 : 1
4	HMS El-Real	$\infty : 1$
5	(Trig.1)$\cap$(Trig.3)	$\infty : 1$
6	(Trig.1)$\cap$(Trig.4)	$\infty : 1$

   Extract NPS FADC pedestal values for DC anode current monitor. *Do these values need to be input to firmware or EPICS script?*

2. Start with Hydrogen target, low current run (5 μA) run (20 min) with waveform readout of entire calorimeter.
   Coincidence DAQ Prescales:

Trigger	Name	Prescale
1	NPS	$\infty : 1$
2	Cosmic∩LED	$\infty : 1$
3	HMS 3/4	$\infty : 1$
4	HMS El-Real	$\infty : 1$
5	(Trig.1)∩(Trig.3)	$\infty : 1$
6	(Trig.1)∩(Trig.4)	1 : 1

3. Follow up with 20 min run at 30 μA and VTP trigger
   Verify cluster finding in replay of FADC waveforms with VTP cluster finding.

The remaining items should be completed after Calorimeter Calibration.

4. Set readout window offset and length. Take 15 min runs at 30 and 50 μA with 'Number of Samples After' (NSA) parameter set to 4, 8, 12 to verify double pulse resolution and high rate efficiency.

5. Take 15 min coincidence runs at 30 μA at VTP cluster trigger threshold of 300 MeV, 500 MeV, and 900 MeV. Readout threshold 300 MeV.

6. Take a 15 min run at 30 μA at VTP cluster trigger threshold at 500 MeV and readout threshold 100 MeV. Compare event size with previous ($500 \oplus 300$) run.

7. Verify $\gamma\gamma$ coincidence timing (two-clusters) in analysis, including both random continuum and true coincidence peak. This should be done in production configuration with Calorimeter at 3 m.

2.3 NPS Calorimeter Calibration: 5-Pass

Note that moving the calorimeter longitudinally must be coordinated with the technical staff, and can only be done during regular working hours. This is because it is necessary to use the crane to lift and move cable bundle.

Kinematic settings listed here are specific to 5-pass beam energy = 10.558 GeV. Consult with Charles Hyde for alternate kinematics if beam energy is significantly different.
Switch HMS polarity to protons.
Setting CaloCal 10.56
Table 2 and `https://hallcweb.jlab.org/wiki/images/2/22/NPS_ElasticCalibrations.pdf`

- HMS Angle 30.145 deg;
- HMS Momentum +4.036 GeV;
- HMS Collimator "Large";
- NPS Calo Angles 14.60°, 15.74°, 16.89°
- Calorimeter distance from target: $D_{\text{Calo}} = 9.5$ m;

- Coincidence Trigger setting

Trigger	Name	Prescale	Setting
1	NPS	$\infty : 1$	-1
2	Cosmic$\cup$LED	$\infty : 1$	-1
3	HMS 3/4	$\infty : 1$	-1
4	HMS El-Real	$\infty : 1$	-1
5	(Trig.1)$\cap$(Trig.3)	$1 : 1$	0
6	(Trig.1)$\cap$(Trig.4)	$\infty : 1$	-1

- EDTM rate 10 Hz.
- NPS DAQ configuration: DTP cluster trigger threshold 500 MeV and readout threshold 100 MeV.
- Target: LH_2.

Central electron energy in calorimeter will be 7.4 GeV.
Data taking *nb: HMS angle and momentum settings do not change*:

0. Setting CaloCal-10.56-0
    - NPS angle 14.60° (SHMS 30.87°)
    - NPS Sweep Magnet setting: 200 A, 0.3 Tm (TBD)
      Electrons will be deflected $\sim$ 14 cm vertical from nominal location projected from protons in HMS
    - Beam Current = 30 μAmp.
    - Ensure background rates in Calo are acceptable. Verify DC anode current from integral of FADC signals. Check Calo singles trigger rate
    - 1 hour run (or 0.108 Coulomb).
1. Setting CaloCal-10.56-1
    - NPS angle 14.60°
    - NPS Sweep Magnet **Off** Take 10 min runs at 7, 14, 21, and 30 μAmp.
      Evaluate background levels:
        (a) Anode DC current as measured by FADC integrals (in EPICS events). Acceptable anode current is 30 μAmp. With 1 Volt full scale on 12 bit FADC, least significant bit in one (4 ns) sample is 19.5 fC. Running integral (after subtracting beam-off pedestal) must grow at less than 1.5G counts/sec.
        (b) Mean number of clusters found per event. A 100 MeV background cluster is a 1.4% effect on a 7 GeV electron cluster. Desirable to keep the multiplicity of secondary clusters within 32 nsec triggering less than 2 per event ($\leq$ 1% pileup probability of two 25 block clusters). If readout window is 400 nsec long, then total multiplicity (including primary electron) should be kept below $\sim$ 15/event.

- 4.0 hour run (or 0.43 Coulomb). Expect 120K coincidence events.

2. Setting CaloCal-10.56-2

   - NPS angle 15.74°
   - NPS Sweep Magnet **Off**
   - Same beam current and integrated charge as Setting CaloCal-10.56-1

3. Setting CaloCal-10.56-3

   - SHMS angle 16.89°
   - NPS Sweep Magnet **Off**
   - Same beam current and integrated charge as Setting CaloCal-10.56-1

Total beam time 13 hours (if at 30 μA).

The calibration data must be analyzed as quickly as possible (analysis lead: Hao Huang, Carlos Muñoz Camacho). New High Voltage settings established and then a second calibration set of calibration runs (CalCal-10.59-1 to -3) repeated to verify gain equalization. This second set of runs can be shorter, perhaps. The 'downtime' during calibration analysis should be filled with HMS single arm runs, such as the Deadtime, Target boiling studies, listed above, a Moeller run, or some of the HMS optics runs (for different kinematics) listed below.

3 HMS High-Momentum Optics Calibration

Calibrations needed at $k_{\rm HMS} = -6.117, 5.442$ GeV/c. These correspond to the DVCS settings KinC-x36-3 and KinC-x25-3, respectively. Other high-momentum settings at $k_{\rm HMS} =$ 6.800 GeV (KinC-x50-2) 5.253 GeV (KinC-x50-3) 5.878 GeV (KinC-x60-3) are tuned to previous calibration points from the pionLT experiment.

3.1 Setting KinC-x36-3 HMS Optics.

Full HMS optics calibration required for $k_{\rm HMS} = 6.117$ GeV.

- $(E_{\rm Beam}, x_B, Q^2) = 10.558\ {\rm GeV}, 0.36, 3.00\ {\rm GeV}^2)$
- HMS angle = 12.373°;
- HMS momentum = -6.117 GeV;
- HMS Collimator: "Sieve";
- NPS angle = 15.96°.

- HMS Single Arm DAQ.
  Prescale GUI settings:
  Trig-4 (HMS El-Real) prescale 1 : 1.
  All others ∞ : 1.

1. Optics-6.117-1, Single foil, NPS Sweep Off
   - HMS Sieve Slit;
   - NPS Sweep Magnet Off;
   - Target: C 0.5%, 0.114 g/cm^2.
   - Beam Current 30 μAmp;
   - Expected HMS rate 2.2/sec/hole;
   - Run Time 0.5 hour;
2. Optics-6.117-2
   - HMS Sieve Slit;
   - NPS Sweep Magnet Off;
   - Target: Optics foils $\pm 8cm$.
   - Beam Current 30 μAmp;
   - Expected HMS rate 0.9/sec/hole/foil;
   - Run Time 1 hour;
3. Optics-6.117-3
   - HMS Sieve Slit;
   - NPS Sweep Magnet On: 0.3 Tm;
   - Target: C 0.5%, 0.114 g/cm^2.
   - Prescale GUI settings: Single arm HMS
   - Beam Current 30 μAmp (if higher, move SHMS to 37 deg);
   - Expected HMS rate 2.2/sec/hole;
   - Run Time 1.0 hour;
4. Optics-6.117-4
   - HMS Sieve Slit;
   - NPS Sweep Magnet On: 0.3 Tm;
   - Target: Optics foils $\pm 8cm$.
   - Beam Current 30 μAmp (if higher, move SHMS to 20 deg);
   - Expected HMS rate 0.9/sec/hole/foil;

- Run Time 1 hour;

5. Optics-6.117-5
   - HMS Sieve Slit;
   - NPS Sweep Magnet Off;
   - Target: Optics foils $\pm 3cm$.
   - Prescale GUI settings: Single arm HMS
   - Beam Current 30 μAmp (if higher, move SHMS to 20 deg);
   - Expected HMS rate 0.9/sec/hole/foil;
   - Run Time 1 hour;
6. Optics-6.117-Elastic-0
   - HMS Angle = $20.69°$;
   - HMS Momentum = -6.117 GeV (electrons);
   - NPS Sweep Magnet Off;
   - HMS Collimator: "Large";
   - Target: LH2;
   - Beam Current 30 μAmp. Expected elastic rate 10^4/hour;
   - Time: 0.5 hour
     Repeat with HMS at $19.26°$ and $22.12°$.
7. Optics-6.117-Elastic-1
   - HMS Angle = $20.69°$;
   - HMS Momentum = -6.117 GeV (electrons);
   - NPS Sweep Magnet On;
   - HMS Collimator: "Large";
   - Target: LH2;
   - Beam Current 30 μAmp. Expected elastic rate 10^4/hour;
   - Time: 0.5 hour
     Repeat with HMS at $19.26°$ and $22.12°$.

3.2 Setting KinC-x25-3 HMS Optics.

The HMS energy, angle and NPS angle settings are very sensitive to the exact choice of central Q^2, x_B values chosen for this setting. Both nominal and modified settings are listed in Table 4. The modified setting has the advantage of a slightly large separation angle between the SHMS and HMS carriages.

Repeat same sequence or measurements as for KinC-x36-3 (sec 3.1).

Table 4: Kinematics of setting KinC-x25-3. Setting (1) is nominal, (2) is modified for larger SHMS–HMS separation.

Option	E_b GeV	Q^2 GeV^2	x_B	$k'_{\rm HMS}$ GeV/c	$\theta_{\rm HMS}$ deg	θ_{NPS} deg	θ_{SHMS} deg	$q'_{\rm Max}$ GeV
1	10.558	0.25	2.40	5.442	11.73	11.95	28.25	5.08
2	10.558	0.26	2.40	5.639	11.52	12.62	28.92	4.88

4 Production 5-Pass Beam (Phase 1)

Scheduled for 48 calendar days after 7 days commissioning.
All of these settings have the NPS Calorimeter a distance 3.0 m from target

4.1 Setting KinC-x36-5.

- $(E_{\rm Beam}, x_B, Q^2) = 10.558\ {\rm GeV}, 0.36, 4.00\ {\rm GeV}^2)$
- HMS angle = 16.435°;
- HMS momentum = −4.637 GeV;
- HMS Collimator: "Large";
- NPS Sweep Magnet setting 0.3 Tm;
- Prescale GUI settings:
  NPS ∩ [HMS El-Real] 1 : 1
  All others ∞ : 1
  NPS Calo threshold 500 MeV
  Single or two cluster trigger?
  Other Calo trigger settings TBD
- NPS Calo angle = 12.117°. SHMS = ?;

4.1.1 KinC-x36-5 HMS Optics

Already completed in commissioning. Additional runs as needed

4.1.2 KinC-x36-5 Production

1 day of running each on LH_2 and LD_2 target, including 10% of total beam charge on Dummy Target. No reverse field running required as $\pi : e$ ratio is 1 : 1.

4.2 Setting KinC-x50-2.

4.3 Setting KinC-x50-3.

4.4 Setting KinC-x60-3.

4.4.1 KinC-x36-3 Production

12 hours each on LH2 and LD2 targets.
1 hour on dummy target.
No reverse polarity running.

4.5 Moeller Run

4.6 NPS Calibration at 5 Pass

Only a single set of measurements are required to assess radiation damage. After any adjustments to HV are made, a second calibration will be done next at 4-pass.

5 Production 4-Pass Beam (Phase 1)

Total of 11 calendar days, including pass change starting on 10/30/2023.
Petition PD to move Pass change to 5 pass from Friday 11/10/2023 to Monday 11/13/2023.

5.1 NPS Calorimeter Elastic Calibration at 4 Pass

5.2 Moeller at 4-Pass

One shift for initial measurement.

5.3 Setting KinC-x36-2.

5.4 Setting KinC-x50-1.

5.5 Setting KinC-x60-2.

5.6 Recalibrate Calo Before Small Angle Running

5.7 Setting KinC-x36-4.

5.8 Setting KinC-x25-2.

6 5-Pass Beam (Phase 2)

Scheduled for 38 calendar days Nov 10 – Dec 18 plus 49 days Jan 12 – 39 Feb. Possibility of adding addition higher Q^2 and/or higher x_B setting. Listed kinematics starting with

KinC-x60-4 are small angle settings, requiring 8 PAC days of production, plus two PAC days calibrations (Moeller, Calo, HMS Optics).

6.1 NPS Calorimeter 5-Pass Elastic Calibration

6.2 Moeller

6.3 Setting KinC-x60-4.

6.4 Setting KinC-x36-6.

6.5 Setting KinC-x25-3.

6.6 Setting KinC-x25-4.

6.7 Final Moeller

6.8 Final 5-pass NPS Calorimeter Calibration

7 Production 4-Pass Beam (Phase 2)

These settings will move here if not enough calendar days during 4-Pass (Phase 1).

7.1 Setting KinC-x36-4

7.2 Setting KinC-x25-2

8 Production 3-Pass Beam (Phase 1)

Total projected time is 33 PAC days + Moeller + NPS Calorimeter Calibration time. Setting KinC-36-5 could be split in half, with 10 days moved to phase 2 running.

8.1 Production Setting KinC-x36-1.

- HMS angle = 29.51 deg.
- HMS momentum = 1.840 GeV/c (negative polarity, all magnets cycled).
- HMS “Large” Collimator.
- SHMS angle = 10.96 deg.
- NPS Sweep Magnet Current setting 200 A, 0.3 Tm.
- Prescale GUI settings: TBD.
- Beam Current 30 μAmp.

Run 4 hours LH2, 4 hours LD2 alternating for a total of 2.3 Coulomb each target. Every 8 hours take a 40 min dummy target run. Expected time to completion is 2.0 days.

8.2 Setting KinC-x50-0.

- HMS angle = 25.931 deg.
- HMS momentum = -2.640 GeV/c (negative polarity, all magnets cycled).
- HMS "Large" Collimator.
- SHMS angle = 16.01 deg.
- NPS Sweep Magnet Current setting 0.3 Tm.
- Prescale GUI settings: TBD.
- Beam Current 30 μAmp.

8.2.1 KinC-x50-0 HMS Optics

- HMS Sieve Slit
- Target: Single foil 0.5%X_0 C at $z = 0$
- Single arm HMS trigger
- NPS Sweep Magnet Setting: 0.3 Tm
- Expected NPS rate 0.1/sec/hole.
- Run 1.5 Hours (0.16 C)

If there are problems with optics, repeat with "Optics Target" and run for 2 hours.

8.2.2 KinC-x50-0 Production

Run 4 hours LH2, 4 hours LD2 at for a total of 7.9 Coulomb each target.
Every 8 hours run 40 min on Dummy target.
Predicted π/e ratio = 1.6. Reverse polarity running not required.
Expected time to completion is 7 days.

8.3 Setting KinC-x60-1.

- HMS angle = 39.84 deg.
- HMS momentum = -1.717 GeV/c (negative polarity, all magnets cycled).
- HMS "Large" Collimator.

- SHMS angle = 12.22 deg.
- NPS Sweep Magnet Current setting 0.3 Tm.
- Prescale GUI settings: TBD.
- Beam Current 30 μAmp.

Run 4 hours LH2, 4 hours LD2 at for a total of 25.6 Coulomb per target (51.2 C total).
Every 8 hours run for 40 min Dummy target (0.072 C).
Reverse HMS polarity running desired, $\pi : e = 11 : 1$. After $\sim$ 25 C accumulated charge, reverse polarity of HMS and run for 2.6 C charge (approximately 1 day). Expected time to completion is 23 days.

8.4 Moeller Run

8.5 NPS Calorimeter Elastic Recalibration

Repeat previous 3-pass calibration settings CaloCal-6.28-1, CaloCal-6.28-2, CaloCal-6.28-3. 2.5 hour (0.27 Coulomb) each.

- HMS Angle 34.612 deg;
- HMS Momentum +2.778 GeV;
- HMS Collimator "Large";
- SHMS Angles 19.138°, 20.570°, 21.003°;
- Calorimeter distance from target: $D_{\mathrm{Calo}} = 8$ m;
- NPS Sweep Magnet current = 0.0 Amp or ?
- Coincidence Trigger setting
- Target: LH_2.

One hour run at each angle setting (0.11 Coulomb/setting).

9 3-Pass Beam (Phase 2): Small Angle (Calo)

Estimated time is 18 days production, 1.5 days calibrations (2× Calo, 2× Moller, 3× HMS optics) for a total of 19.5 PAC days

9.1 NPS Calorimeter Elastic Calibration

9.2 Setting KinC-x60-1, Second Half

10 days production

9.3 Setting KinC-x36-4.

2 days production.

9.4 Setting KinC-x36-6.

4 days production.

9.5 Setting KinC-x25-1.

2 days production.

A Electron and Pion Singles Rates

The inclusive HRS rates, estimated by Peter Bosted are listed in Table 5

Table 5: Inclusive e^- and π^- rates in HMS, calculated by Peter Bosted. Note that the kinematics have been tweaked since Peter made this table. *What is the assumed beam current?*

x	Q2 GeV^2	W GeV	E GeV	ϵ	E' GeV	θ_{HMS} deg	$Rate_e$ 1/sec	$Rate_\pi$ 1/sec	π/e
0.20	2.00	2.98	6.4	0.29	1.07	31.3	0.9	226.9	266.8
0.20	2.00	2.98	8.5	0.64	3.17	15.7	11.5	90.6	7.8
0.20	2.00	2.98	10.6	0.78	5.27	10.9	44.5	49.8	1.1
0.20	3.00	3.6	10.6	0.45	2.61	19.0	0.4	18	44
0.36	3.00	2.49	10.6	0.85	6.16	12.3	25.1	3.7	0.1
0.36	3.00	2.49	6.4	0.51	1.96	28.3	1.2	19.5	16.2
0.36	3.00	2.49	8.5	0.75	4.06	17.0	7.9	6.9	0.9
0.36	3.00	2.49	10.6	0.85	6.16	12.3	25.1	3.7	0.1
0.36	4.00	2.83	8.5	0.52	2.58	24.7	1.1	12.1	10.7
0.36	4.00	2.83	10.6	0.71	4.68	16.3	5.2	4.5	0.9
0.36	5.50	3.26	10.6	0.41	2.46	26.6	0.4	12.1	27.0
0.50	3.40	2.07	8.5	0.83	4.88	16.5	7.3	1.1	0.1
0.50	3.40	2.07	6.4	0.67	2.78	25.3	1.6	2.5	1.6
0.50	3.40	2.07	10.6	0.90	6.98	12.3	20.3	0.6	0.0
0.50	4.80	2.38	10.6	0.79	5.48	16.5	3.6	0.5	0.2
0.60	5.10	2.07	6.4	0.46	1.87	38.1	0.1	1.4	10.8
0.60	5.10	2.07	8.5	0.72	3.97	22.4	0.9	0.3	0.4
0.60	5.10	2.07	10.6	0.83	6.07	16.2	2.8	0.1	0.1
0.60	6.00	2.21	10.6	0.76	5.27	18.9	1.1	0.1	0.1

A.1 HMS Cherenkov

In choosing the Cherenkov gas, we want to maximize the Cherenkov efficiency, while also excluding pions in all settings with a high π/e ratio. From Table 5, all of the settings with $pi/e \gg 1$ occur for beam HMS energies < 5 GeV. Even for settings with π/e ratios ≈ 1 the HMS energies are 5.27, 4.88, and 5.27 GeV. CO2 gas at 1 atm pressure (or slightly below) provides a pion threshold of 4.9 GeV/c.

Current gas (from previous run) is C_4F_8O. At pressure 0.45 atm, effective pion threshold is 4.02 GeV. Reported number of photo-electrons at 0.4 atm (absolute) is 11.

B Beam Delivery Schedule

Updated 15 Aug 2023, Further update 16 Aug, not fully implemented.
Pass changes are limited by requirements of Halls A & B and desire for high polarization.

Date	A		B		C			Days
	Name	Pass	Name	Pass	Name	Pass	f (MHz)	cal.
5 September	Install		Install		NPS	5	500	
11 September	GEN-SBS	4	↓		↓	↓	↓	
15 September	↓		RG-D	5	↓	↓	↓	
17 October	Install		↓		↓	↓	↓	
20 October	E12-15-006	3	↓		↓	↓	↓	48+7
30 October	Install		↓		NPS	4	500	
19 November	↓		↓		↓	↓	↓	21
20 November	↓		RG-K	4	NPS	5	500	
17 December	↓		↓		↓	↓	↓	
18 December	End of Beam 07:00 am							28
12 January	Install		RG-K	3	NPS	5	500	
29 February	↓		↓		↓	↓	↓	49
1 March	E12-17-004	2	Install		NPS	4	500	
8 March	↓		RG-E	5	↓	↓	↓	
25 March	Pass Change		↓		↓	↓	↓	24
26 March	E12-20-008	3	↓		No Polarization?			
29 March	↓		↓		↓			
30 March	Install		↓		NPS	4	500	
7 April	↓		↓		↓	↓	↓	9
8 April	↓		↓		NPS	3	500	
19 May	↓		↓		↓	↓	↓	
20 May	End of Beam 07:00 am							42
NPS Summary (Calendar Days)						Pass	Days	
One day deducted for each Pass Change						3	41	
						4	43	
						5	141	