

Pion-LT Run Plan - Part 2

August 15, 2022

8.487 GeV Beam Plan

Initial beam activities

- While waiting for beam, configure the spectrometers for beam checkout:
 1. **Change HMS and SHMS polarity.** Carefully follow the magnet cycling procedure.
 2. SHMS angle = 12.00 deg (from TV).
 3. SHMS momentum = +2.688 GeV/c (positive polarity and magnets cycled).
 4. HMS angle = 14.55 deg (from TV).
 5. HMS momentum = -6.579 GeV/c (negative polarity and magnets cycled).
 6. Update *standard.kinematics* with the new settings (Reminder: all momenta should be entered as positive quantities).
 7. z= 0 0.5% r.l. carbon target
Current Limit = 80 μ A
 8. Prescale GUI settings:

HMS singles DAQ disabled	all PS=-1
SHMS singles DAQ disabled	all PS=-1
COIN DAQ:	
PS1(SHMS-3/4)	0
PS2(SHMS-ELREAL)	-1
PS3(HMS-3/4)	0
PS4(HMS-ELREAL)	-1
PS5(HMS-ELREAL \times SHMS-3/4)	-1
PS6(HMS-3/4 \times SHMS-3/4)	-1
EDTM Target Prescale Rate	10 Hz
cermode10	ON

- Beam checkout.
Follow the notes at:
https://hallcweb.jlab.org/wiki/index.php/Beam_Checkout_Procedures
including the “Carbon-hole” check to verify beam+target alignment and MCC raster size calibration. **Dave G. will need to be present to determine offsets from harp scans**

- Fix beam angle at target.
Do this step only if MCC is unable to restore the beam positions used at the previous energy.
Use the gui at: `/home/cdaq/users/gaskellld/target_bpm/target_bpm.py`
Adjust 3H07Ax,y to remove slope while keeping 3H07Cx,y fixed
Recheck carbon hole and iterate as necessary.

Items to be done as soon as possible at this energy (time determined by RC).

- BPM calibration (bulls-eye scan).
This is not part of the typical beam checkout procedure. We want this done so that we have reliable absolute beam position information from the BPMs. Follow the procedure at:
https://hallcweb.jlab.org/wiki/index.php/Bull%27s_Eye_Scan
Dave G. will need to be present for this calibration.
- Energy determination with arc.
The Run Co-ordinator will coordinate the timing of this with the Program Deputy. MCC will have to set up a clean dispersive tune. It is important for the Shift Leader to make a full hlog entry of the MCC data. Follow the “Hall C Beam Energy Measurement Procedure” at MCC Ops Doc: MCC-PR-06-004.
- BCM calibrations.
The Run Co-ordinator will coordinate the timing of this with the Program Deputy. This requires MCC’s ability to reliably deliver 70 - 80 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>. Dave Mack will analyze the data later.
- Subsequent BCM calibrations.
Dave Mack states “the BCMS are mostly reliable, but the gains might really drift at the 1% level. E.g., during this run cycle, the outside temperature is going to drop by 40-50°F, which can affect the temperature of the RF cables and even the machine frequency, which is important for the older analog receivers.” **He recommends a second BCM calibration 2 weeks after the first one, then every 2 weeks after that.** If Stephen checks the agreement of the full replay charge every few days, that will help to make educated decisions about the priority of doing more BCM calibrations.

$Q^2=2.45$, $W=3.20$, $x=0.21$, middle ϵ data taking

Nominal $Q^2=2.45$ GeV ² /c ² , $W=3.20$ GeV, $x=0.21$ Kinematics						
E_e	$E_{e'}$	$\theta_{e'}$	ϵ	$ t $	p_π	θ_q
GeV	GeV	deg		(GeV/c) ²	GeV/c	deg
8.487	2.193	20.90	0.461	0.048	6.265	-6.93

1. $p(e, e'\pi^+)n$ LH2 SHMS left ($\theta = 8.93^\circ$) run.

Set up the following configuration:

- (a) Set the SHMS momentum = +6.265 GeV/c (follow the cycling procedure).
- (b) Move the SHMS angle = 8.93 deg (from TV).
- (c) Set HMS momentum = -2.193 GeV/c. Negative polarity.
- (d) Keep HMS angle = 20.90 (from TV). Be sure to record and photograph the actual vernier value to 0.005 degree precision.
- (e) 10 cm LH2 target.
- (f) Update *standard.kinematics* with the new settings.
- (g) **Adjust the beam current to keep the SHMS-3/4 rate below 600 kHz.** We project the current for this run to be about 80 μ A. Do not change PS5=0!
- (h) Set the PS1(SHMS-3/4) and PS4(HMS-ELREAL) target rates to 100 Hz.

For **80 μ A beam** and the projected rates listed below, these prescale factors should give 100 Hz HMS and SHMS singles event rates to disk, and a 565 Hz DAQ rate overall.

Projected prescale GUI settings:	
PS1(SHMS-3/4)	11
PS2(SHMS-ELREAL)	-1
PS3(HMS-3/4)	-1
PS4(HMS-ELREAL)	9
PS5(HMS-ELREAL \times SHMS-3/4)	0
PS6(HMS-3/4 \times SHMS-3/4)	-1
EDTM Target Prescale Rate	10 Hz
cermode10	ON

HMS e^- rate	HMS π^- rate	SHMS π^+ rate	SHMS K rate	SHMS p rate	Random coinc. $(e^- + \frac{\pi^-}{5}) \cdot (\pi + K + p)$	Real coinc. $e^- \cdot \pi$
7 kHz	144 kHz	71 kHz	31 kHz	29 kHz	290 Hz	5.5 Hz

- (i) **fadcmode10 Run:** Start by taking a 2 minute fadcmode10 run. Be sure to mark this clearly on the Run Sheet. After the run, it is extremely important to **unclick the fadcmode10 setting button.**

- (j) **HMS-3/4 trigger run:** Since the HMS momentum is fairly low, take a 20 minute run with HMS-3/4 triggers enabled instead of hELREAL (i.e. PS6 instead of PS5, and PS3 instead of PS4). This is to monitor the ELREAL threshold and will count as part of the physics run total. If the PS3 trigger rate is excessive, adjust PS3 to a higher level to compensate.
- (k) **Take data for 0.9 hours (at 100% efficiency) at 80 μA to get about 17,850 $p(e, e'\pi^+)n$ coincidences.** Use the physics replay to keep track of the event total. **LH2 and LD2 replays have different cuts enabled. Make sure the correct target is inputted into the physics replay.** The first run should be ~ 25 minutes (at 100% data taking efficiency), and should be immediately analyzed to get an indication of the pion rate. Use this to calculate how long to run to get the desired statistics.

2. $\boxed{\text{Al}(e, e'\pi^+)X}$ Thick Dummy target SHMS left ($\theta = 8.93^\circ$) run.

Now put in the “thick” dummy target (± 5 cm) and initially set prescale factors to the same as the LH2 run.

If the HMS and SHMS singles event rates to disk are significantly less than 100 Hz each, the PS1,4 factors can be decreased accordingly.

Current limit: 40 μA .

DO NOT modify *standard.kinematics* for this run (i.e. keep as for LH2 target).

Take data for 0.2 hour (100% efficiency) at 40 μA .

3. $p(e, e'\pi^+)n$ LH2 SHMS center ($\theta = 6.93^\circ$) run.

- (a) Move the SHMS to 6.93 deg (from TV). **This rotation can be done remotely with expert oversight, provided the angle rotation GUI was set to be in agreement with the floor angle during the 8.16 deg setting. The Run Co-ordinator will need to arrange in advance which expert personnel (e.g. Amy Comer, Steve Lassiter) need to monitor remotely.** Be sure to record and photograph the actual vernier value to 0.005 degree precision.
- (b) Put in the LH2 target. Leave the spectrometer magnet settings unchanged.
- (c) Update *standard.kinematics* with the new settings.
- (d) **Adjust the beam current to keep the SHMS-3/4 rate below 600 kHz.** We project the current for this run to be about 80 μA . Do not change PS5=0!
- (e) Set the PS1(SHMS-3/4) and PS4(HMS-ELREAL) target rates to 100 Hz.

For **80 μA beam** and the projected rates listed below, these prescale factors should give 100 Hz HMS and SHMS singles event rates to disk, and a 1259 Hz DAQ rate overall.

Projected prescale GUI settings:	
PS1(SHMS-3/4)	13
PS2(SHMS-ELREAL)	-1
PS3(HMS-3/4)	-1
PS4(HMS-ELREAL)	9
PS5(HMS-ELREAL \times SHMS-3/4)	0
PS6(HMS-3/4 \times SHMS-3/4)	-1
EDTM Target Prescale Rate	10 Hz
cermode10	ON

HMS e^- rate	HMS π^- rate	SHMS π^+ rate	SHMS K rate	SHMS p rate	Random coinc. $(e^- + \frac{\pi^-}{5}) \cdot (\pi + K + p)$	Real coinc. $e^- \cdot \pi$
7 kHz	144 kHz	267 kHz	104 kHz	77 kHz	1002 Hz	5.5 Hz

- (f) **fadcmode10 Run:** Start by taking a 2 minute fadcmode10 run. Be sure to mark this clearly on the Run Sheet. After the run, it is extremely important to **unclick the fadcmode10 setting button.**
- (g) **HMS-3/4 trigger run:** Since the HMS momentum is fairly low, take a 20 minute run with HMS-3/4 triggers enabled instead of hELREAL (i.e. PS6 instead of PS5, and PS3 instead of PS4). This is to monitor the ELREAL threshold and will count as part of the physics run total. If the PS3 trigger rate is excessive, adjust PS3 to a higher level to compensate.
- (h) **Take data for 1.0 hours (100% efficiency) at 80 μA to get 19,850 $p(e, e'\pi^+)n$ coincidences.** Use the physics replay to keep track of the event total. The first run should be ~ 30 minutes (at 100% data taking efficiency), and should be immediately analyzed to get an indication of the pion rate. Use this to calculate how long to run to get the desired statistics.

4. $\boxed{\text{Al}(e, e'\pi^+)X}$ Thick Dummy target SHMS center ($\theta = 6.93^\circ$) run.

Now put in the “thick” dummy target (± 5 cm) and initially set prescale factors to the same as the LH2 run.

If the HMS and SHMS singles event rates to disk are significantly less than 100 Hz each, the PS1,4 factors can be decreased accordingly.

Current limit: 40 μA .

DO NOT modify *standard.kinematics* for this run (i.e. keep as for LH2 target).

Take data for 0.2 hours (100% efficiency) at 40 μA .

5. $p(e, e'\pi^+)n$ LH2 SHMS right ($\theta = 5.50^\circ$) run.

Set up the following configuration:

- (a) Keep the SHMS momentum = +6.265 GeV/c (follow the cycling procedure).
- (b) Move the SHMS angle = 5.50 deg (from TV). **This requires a hall access. The Run Co-ordinator will need to arrange in advance which expert personnel (e.g. Amy Comer, Steve Lassiter) need to be present.**
- (c) Keep HMS momentum = -2.193 GeV/c. Negative polarity.
- (d) keep HMS angle = 20.90 (from TV).
- (e) Put in the LH2 target. Leave the spectrometer magnet settings unchanged.
- (f) Update *standard.kinematics* with the new settings.
- (g) **Adjust the beam current to keep the SHMS-3/4 rate below 600 kHz.** We project the current for this run to be about 50 μA . Do not change PS5=0!
- (h) Set the PS1(SHMS-3/4) and PS4(HMS-ELREAL) target rates to 100 Hz.

For **50 μA beam** and the projected rates listed below, these prescale factors should give 100 Hz HMS and SHMS singles event rates to disk, and a 1154 Hz DAQ rate overall.

Projected prescale GUI settings:	
PS1(SHMS-3/4)	13
PS2(SHMS-ELREAL)	-1
PS3(HMS-3/4)	-1
PS4(HMS-ELREAL)	9
PS5(HMS-ELREAL \times SHMS-3/4)	0
PS6(HMS-3/4 \times SHMS-3/4)	-1
EDTM Target Prescale Rate	10 Hz
cermode10	ON

HMS e^- rate	HMS π^- rate	SHMS π^+ rate	SHMS K rate	SHMS p rate	Random coinc. $(e^- + \frac{\pi^-}{5}) \cdot (\pi + K + p)$	Real coinc. $e^- \cdot \pi$
4 kHz	90 kHz	414 kHz	144 kHz	88 kHz	903 Hz	3.44 Hz

- (i) **fadcmode10 Run:** Start by taking a 2 minute fadcmode10 run. Be sure to mark this clearly on the Run Sheet. After the run, it is extremely important to **unclick the fadcmode10 setting button.**
- (j) **HMS-3/4 trigger run:** Since the HMS momentum is fairly low, take a 20 minute run with HMS-3/4 triggers enabled instead of hELREAL (i.e. PS6 instead of PS5, and PS3 instead of PS4). This is to monitor the ELREAL threshold and will count as part of the physics run total. If the PS3 trigger rate is excessive, adjust PS3 to a higher level to compensate.
- (k) **Take data for 1.4 hours (100% efficiency) at 50 μA to get 17,450 $p(e, e'\pi^+)n$ coincidences.** Use the physics replay to keep track of the event total. **LH2 and LD2 replays have different cuts enabled. Make sure the correct target is inputted**

into the physics replay. The first run should be ~ 25 minutes (at 100% data taking efficiency), and should be immediately analyzed to get an indication of the pion rate. Use this to calculate how long to run to get the desired statistics.

6. $\boxed{\text{Al}(e, e'\pi^+)X}$ Thick Dummy target SHMS right ($\theta = 5.50^\circ$) run.

Now put in the “thick” dummy target (± 5 cm) and initially set prescale factors to the same as the LH2 run.

If the HMS and SHMS singles event rates to disk are significantly less than 100 Hz each, the PS1,4 factors can be decreased accordingly.

Current limit: 40 μA .

DO NOT modify *standard.kinematics* for this run (i.e. keep as for LH2 target).

Take data for 0.3 hours (100% efficiency) at 40 μA .

$Q^2=3.85$, $W=3.07$, $x=0.31$, low ϵ data taking

Nominal $Q^2=3.85$ GeV $^2/c^2$, $W=3.07$ GeV, $x=0.31$ Kinematics						
E_e	$E_{e'}$	$\theta_{e'}$	ϵ	$ t $	p_π	θ_q
GeV	GeV	deg		(GeV/c) 2	GeV/c	deg
8.487	1.882	28.42	0.387	0.120	6.538	-7.47

1. $p(e, e'\pi^+)n$ LH2 SHMS right ($\theta = 5.50^\circ$) run.

Set up the following configuration:

- (a) Set the SHMS momentum = +6.538 GeV/c (follow the cycling procedure).
- (b) Do not move SHMS. Just keep the SHMS to 5.50 deg.
- (c) Set HMS momentum = -1.882 GeV/c. Negative polarity.
- (d) Move HMS angle = 28.42 (from TV). Be sure to record and photograph the actual vernier value to 0.005 degree precision.
- (e) 10 cm LH2 target.
- (f) Update *standard.kinematics* with the new settings.
- (g) **Adjust the beam current to keep the SHMS-3/4 rate below 600 kHz.** We project the current for this run to be about 60 μ A. Do not change PS5=0!
- (h) Set the PS1(SHMS-3/4) and PS4(HMS-ELREAL) target rates to 100 Hz.

For **60 μ A beam** and the projected rates listed below, these prescale factors should give 100 Hz HMS and SHMS singles event rates to disk, and a 550 Hz DAQ rate overall.

Projected prescale GUI settings:	
PS1(SHMS-3/4)	13
PS2(SHMS-ELREAL)	-1
PS3(HMS-3/4)	-1
PS4(HMS-ELREAL)	7
PS5(HMS-ELREAL \times SHMS-3/4)	0
PS6(HMS-3/4 \times SHMS-3/4)	-1
EDTM Target Prescale Rate	10 Hz
cermode10	ON

HMS e^- rate	HMS π^- rate	SHMS π^+ rate	SHMS K rate	SHMS p rate	Random coinc. $(e^- + \frac{\pi^-}{5}) \cdot (\pi + K + p)$	Real coinc. $e^- \cdot \pi$
1.2 kHz	33 kHz	368 kHz	137 kHz	82 kHz	283 Hz	0.86 Hz

- (i) **fadcmode10 Run:** Start by taking a 2 minute fadcmode10 run. Be sure to mark this clearly on the Run Sheet. After the run, it is extremely important to **unclick the fadcmode10 setting button.**

- (j) **HMS-3/4 trigger run:** Since the HMS momentum is fairly low, take a 20 minute run with HMS-3/4 triggers enabled instead of hELREAL (i.e. PS6 instead of PS5, and PS3 instead of PS4). This is to monitor the ELREAL threshold and will count as part of the physics run total. If the PS3 trigger rate is excessive, adjust PS3 to a higher level to compensate.
- (k) **Take data for 5.2 hours (at 100% efficiency) at 60 μA to get about 16,050 $\text{p}(e, e'\pi^+)\text{n}$ coincidences.** Use the physics replay to keep track of the event total. **LH2 and LD2 replays have different cuts enabled. Make sure the correct target is inputted into the physics replay.** The first run should be ~ 15 minutes (at 100% data taking efficiency), and should be immediately analyzed to get an indication of the pion rate. Use this to calculate how long to run to get the desired statistics.

2. $\boxed{\text{Al}(e, e'\pi^+)X}$ Thick Dummy target SHMS right ($\theta = 5.50^\circ$) run.

Now put in the “thick” dummy target (± 5 cm) and initially set prescale factors to the same as the LH2 run.

If the HMS and SHMS singles event rates to disk are significantly less than 100 Hz each, the PS1,4 factors can be decreased accordingly.

Current limit: 40 μA .

DO NOT modify *standard.kinematics* for this run (i.e. keep as for LH2 target).

Take data for 1 hour (100% efficiency) at 40 μA .

3. $p(e, e'\pi^+)n$ LH2 SHMS center ($\theta = 7.47^\circ$) run.

- (a) Move the SHMS angle = 7.47 deg (from TV). Be sure to record and photograph the actual vernier value to 0.005 degree precision.
- (b) Put in the LH2 target. Leave the spectrometer magnet settings unchanged.
- (c) Update *standard.kinematics* with the new settings.
- (d) **Adjust the beam current to keep the SHMS-3/4 rate below 600 kHz.** We project the current for this run to be about 80 μA . Do not change PS5=0!
- (e) Set the PS1(SHMS-3/4) and PS4(HMS-ELREAL) target rates to 100 Hz.

For **80 μA beam** and the projected rates listed below, these prescale factors should give 100 Hz HMS and SHMS singles event rates to disk, and a 344 Hz DAQ rate overall.

Projected prescale GUI settings:	
PS1(SHMS-3/4)	12
PS2(SHMS-ELREAL)	-1
PS3(HMS-3/4)	-1
PS4(HMS-ELREAL)	8
PS5(HMS-ELREAL \times SHMS-3/4)	0
PS6(HMS-3/4 \times SHMS-3/4)	-1
EDTM Target Prescale Rate	10 Hz
cermode10	ON

HMS e^- rate	HMS π^- rate	SHMS π^+ rate	SHMS K rate	SHMS p rate	Random coinc. $(e^- + \frac{\pi^-}{5}) \cdot (\pi + K + p)$	Real coinc. $e^- \cdot \pi$
1.6 kHz	43 kHz	130 kHz	56 kHz	44 kHz	148 Hz	1.14 Hz

- (f) **fadcmode10 Run:** Start by taking a 2 minute fadcmode10 run. Be sure to mark this clearly on the Run Sheet. After the run, it is extremely important to **unclick the fadcmode10 setting button.**
- (g) **HMS-3/4 trigger run:** Since the HMS momentum is fairly low, take a 20 minute run with HMS-3/4 triggers enabled instead of hELREAL (i.e. PS6 instead of PS5, and PS3 instead of PS4). This is to monitor the ELREAL threshold and will count as part of the physics run total. If the PS3 trigger rate is excessive, adjust PS3 to a higher level to compensate.
- (h) **Take data for 4.0 hours (100% efficiency) at 80 μA to get 16,500 $p(e, e'\pi^+)n$ coincidences.** Use the physics replay to keep track of the event total. **LH2 and LD2 replays have different cuts enabled. Make sure the correct target is inputted into the physics replay.** The first run should be ~ 30 minutes (at 100% data taking efficiency), and should be immediately analyzed to get an indication of the pion rate. Use this to calculate how long to run to get the desired statistics.

4. $\boxed{\text{Al}(e, e'\pi^+)X}$ Thick Dummy target SHMS center ($\theta = 7.47^\circ$) run.

Now put in the “thick” dummy target (± 5 cm) and initially set prescale factors to the same as the LH2 run.

If the HMS and SHMS singles event rates to disk are significantly less than 100 Hz each, the PS1,4 factors can be decreased accordingly.

Current limit: 40 μA .

DO NOT modify *standard.kinematics* for this run (i.e. keep as for LH2 target).

Take data for 0.8 hours (100% efficiency) at 40 μA .

5. $p(e, e'\pi^+)n$ LH2 SHMS left ($\theta = 9.47^\circ$) run.

- (a) Move the SHMS angle = 9.47 deg (from TV). Be sure to record and photograph the actual vernier value to 0.005 degree precision.
- (b) Put in the LH2 target. Leave the spectrometer magnet settings unchanged.
- (c) Update *standard.kinematics* with the new settings.
- (d) **Adjust the beam current to keep the SHMS-3/4 rate below 600 kHz.** We project the current for this run to be about 80 μA . Do not change PS5=0!
- (e) Set the PS1(SHMS-3/4) and PS4(HMS-ELREAL) target rates to 100 Hz.

For **80 μA beam** and the projected rates listed below, these prescale factors should give 100 Hz HMS and SHMS singles event rates to disk, and a 243 Hz DAQ rate overall.

Projected prescale GUI settings:	
PS1(SHMS-3/4)	10
PS2(SHMS-ELREAL)	-1
PS3(HMS-3/4)	-1
PS4(HMS-ELREAL)	8
PS5(HMS-ELREAL \times SHMS-3/4)	0
PS6(HMS-3/4 \times SHMS-3/4)	-1
EDTM Target Prescale Rate	10 Hz
cermode10	ON

HMS e^- rate	HMS π^- rate	SHMS π^+ rate	SHMS K rate	SHMS p rate	Random coinc. $(e^- + \frac{\pi^-}{5}) \cdot (\pi + K + p)$	Real coinc. $e^- \cdot \pi$
1.6 kHz	43 kHz	32 kHz	15 kHz	15 kHz	39 Hz	1.14 Hz

- (f) **fadcmode10 Run:** Start by taking a 2 minute fadcmode10 run. Be sure to mark this clearly on the Run Sheet. After the run, it is extremely important to **unclick the fadcmode10 setting button**.
- (g) **HMS-3/4 trigger run:** Since the HMS momentum is fairly low, take a 20 minute run with HMS-3/4 triggers enabled instead of hELREAL (i.e. PS6 instead of PS5, and PS3 instead of PS4). This is to monitor the ELREAL threshold and will count as part of the physics run total. If the PS3 trigger rate is excessive, adjust PS3 to a higher level to compensate.
- (h) **Take data for 4.0 hours (100% efficiency) at 80 μA to get 16,500 $p(e, e'\pi^+)n$ coincidences.** Use the physics replay to keep track of the event total. **LH2 and LD2 replays have different cuts enabled. Make sure the correct target is inputted into the physics replay.** The first run should be ~ 30 minutes (at 100% data taking efficiency), and should be immediately analyzed to get an indication of the pion rate. Use this to calculate how long to run to get the desired statistics.

6. $\boxed{\text{Al}(e, e'\pi^+)X}$ Thick Dummy target SHMS left ($\theta = 9.47^\circ$) run.

Now put in the “thick” dummy target (± 5 cm) and initially set prescale factors to the same as the LH2 run.

If the HMS and SHMS singles event rates to disk are significantly less than 100 Hz each, the PS1,4 factors can be decreased accordingly.

Current limit: 40 μA .

DO NOT modify *standard.kinematics* for this run (i.e. keep as for LH2 target).

Take data for 0.8 hours (100% efficiency) at 40 μA .

Heep-check coincidence run

1. $p(e, e'p)$ setting for both spectrometer angles and momenta

8.487 GeV Heep-check coincidence run

θ_{HMS}	P_{HMS}	θ_{SHMS}	P_{SHMS}	$Rate_{HMS}$	$Rate_{DAQ}$	Time
19.55	5.587	30.021	3.731	2.86 Hz	264 Hz	1 hr

Set up the following configuration:

- (a) Set the SHMS momentum = +3.731 GeV/c.
- (b) Move the SHMS angle = 30.021 deg (from TV). Beam off while approaching the beam line. Be sure to record and photograph the actual achieved vernier value to 0.005 degree precision.
- (c) Set HMS momentum = -5.587 GeV/c (follow the magnet cycling procedure).
- (d) Move HMS angle = 19.55 (from TV). Be sure to record and photograph the actual vernier value to 0.005 degree precision.
- (e) 10 cm LH2 target.
- (f) Update *standard.kinematics* with the new settings.
- (g) Set the PS1(SHMS-3/4) and PS4(HMS-ELREAL) target rates to 100 Hz.
For **80 μ A beam** and the projected rates listed below, these prescale factors should give 100 Hz HMS and SHMS singles event rates to disk, and a 264 Hz DAQ rate overall.

Projected prescale GUI settings:	
PS1(SHMS-3/4)	4
PS2(SHMS-ELREAL)	-1
PS3(HMS-3/4)	-1
PS4(HMS-ELREAL)	0
PS5(HMS-ELREAL \times SHMS-3/4)	0
PS6(HMS-3/4 \times SHMS-3/4)	-1
EDTM Target Prescale Rate	10 Hz
cermode10	ON

- (h) HMS large and SHMS collimators.
- (i) Stable 80 μ A beam with 2×2 raster on.

Take two runs with a combined total of 10,200 $e + p$ elastic scattering coincidences. The first run should be 30 minutes (at 100% data taking efficiency), and should be immediately analyzed, checking E_{miss} and p_{miss} , while taking the second run.

Estimated Running Time: 1 hour at 100% efficiency.

2. $\text{Al}(e, e'p)X$ Thick Dummy target run for Heep-check.

Insert the "thick" dummy target (± 5 cm) and **run for 10 minutes at 40 μA** (assuming 100% efficiency).

DO NOT modify *standard.kinematics* for this run (i.e. keep as for LH2 target).

3. $p(e, e'p)$ setting for both spectrometer angles and momenta

8.487 GeV Heep-check coincidence run

θ_{HMS}	P_{HMS}	θ_{SHMS}	P_{SHMS}	$Rate_{HMS}$	$Rate_{DAQ}$	Time
20.90	5.321	28.358	3.996	1.96 Hz	273 Hz	1.5 hr

Set up the following configuration:

- Set the SHMS momentum = +3.996 GeV/c.
- Move the SHMS angle = 28.358 deg (from TV). Beam off while approaching the beam line. Be sure to record and photograph the actual achieved vernier value to 0.005 degree precision.
- Set HMS momentum = -5.321 GeV/c (follow the magnet cycling procedure).
- Move HMS angle = 20.90 (from TV). Be sure to record and photograph the actual vernier value to 0.005 degree precision.
- 10 cm LH2 target.
- Update *standard.kinematics* with the new settings.
- Set the PS1(SHMS-3/4) and PS4(HMS-ELREAL) target rates to 100 Hz.

For **80 μ A beam** and the projected rates listed below, these prescale factors should give 100 Hz HMS and SHMS singles event rates to disk, and a 273 Hz DAQ rate overall.

Projected prescale GUI settings:	
PS1(SHMS-3/4)	3
PS2(SHMS-ELREAL)	-1
PS3(HMS-3/4)	-1
PS4(HMS-ELREAL)	0
PS5(HMS-ELREAL \times SHMS-3/4)	0
PS6(HMS-3/4 \times SHMS-3/4)	-1
EDTM Target Prescale Rate	10 Hz
cermode10	ON

- HMS large and SHMS collimators.
- Stable 80 μ A beam with 2×2 raster on.

Take two runs with a combined total of 10,500 $e + p$ elastic scattering coincidences. The first run should be 30 minutes (at 100% data taking efficiency), and should be immediately analyzed, checking E_{miss} and p_{miss} , while taking the second run.

Estimated Running Time: 1.5 hour at 100% efficiency.

4. $\boxed{\text{Al}(e, e'p)X}$ Thick Dummy target run for Heep-check.

Insert the "thick" dummy target (± 5 cm) and **run for 10 minutes at 40 μA** (assuming 100% efficiency).

DO NOT modify *standard.kinematics* for this run (i.e. keep as for LH2 target).

$Q^2=2.12$, $W=2.05$, $x=0.39$, high ϵ data taking

Nominal $Q^2=2.12$ GeV $^2/c^2$, $W=2.06$ GeV, $x=0.39$ Kinematics						
E_e	$E_{e'}$	$\theta_{e'}$	ϵ	$ t $	p_π	θ_q
GeV	GeV	deg		(GeV/c) 2	GeV/c	deg
8.487	5.587	12.14	0.899	0.195	2.792	-21.22

1. $p(e, e'\pi^+)n$ LH2 SHMS right ($\theta = 19.22^\circ$) run.

Before moving to this setting, we have to change the aerogel tray in SHMS detector (from $n=1.011$ to $n=1.015$). Please contact RC to make the arrangements in advance.

Set up the following configuration:

- (a) Set the SHMS momentum = +2.792 GeV/c (follow the cycling procedure).
- (b) Move the SHMS angle = 19.22 deg (from TV). Beam off while approaching the beam line. Be sure to record and photograph the actual achieved vernier value to 0.005 degree precision.
- (c) HMS momentum = -5.587 GeV/c. Negative polarity (follow the cycling procedure).
- (d) HMS angle = 12.14 (from TV). Be sure to record and photograph the actual vernier value to 0.005 degree precision.
- (e) 10 cm LH2 target.
- (f) Update *standard.kinematics* with the new settings.
- (g) **Adjust the beam current to keep the SHMS-3/4 rate below 600 kHz.** We project the current for this run to be about 80 μ A. Do not change PS5=0!
- (h) Set the PS1(SHMS-3/4) and PS4(HMS-ELREAL) target rates to 100 Hz.

For **80 μ A beam** and the projected rates listed below, these prescale factors should give 100 Hz HMS and SHMS singles event rates to disk, and a 3140 Hz DAQ rate overall.

Projected prescale GUI settings:	
PS1(SHMS-3/4)	13
PS2(SHMS-ELREAL)	-1
PS3(HMS-3/4)	-1
PS4(HMS-ELREAL)	11
PS5(HMS-ELREAL \times SHMS-3/4)	0
PS6(HMS-3/4 \times SHMS-3/4)	-1
EDTM Target Prescale Rate	10 Hz
cermode10	ON

HMS	HMS	SHMS	SHMS	SHMS	Random coinc.	Real coinc.
e^- rate	π^- rate	π^+ rate	K rate	p rate	$(e^- + \frac{\pi^-}{5}) \cdot (\pi + K + p)$	$e^- \cdot \pi$
143 kHz	6.6 kHz	163 kHz	39 kHz	133 kHz	2901 Hz	74.7 Hz

- (i) **fadcmode10 Run:** Start by taking a 2 minute fadcmode10 run. Be sure to mark this clearly on the Run Sheet. After the run, it is extremely important to **unclick the fadcmode10 setting button.**
- (j) **HMS-3/4 trigger run:** Since the HMS momentum is fairly low, take a 20 minute run with HMS-3/4 triggers enabled instead of hELREAL (i.e. PS6 instead of PS5, and PS3 instead of PS4). This is to monitor the ELREAL threshold and will count as part of the physics run total. If the PS3 trigger rate is excessive, adjust PS3 to a higher level to compensate.
- (k) **Take data for 1.0 hours (at 100% efficiency) at 80 μA to get about 134,500 $p(e, e'\pi^+)$ n coincidences.** Use the physics replay to keep track of the event total. **LH2 and LD2 replays have different cuts enabled. Make sure the correct target is inputted into the physics replay.** The first run should be ~ 30 minutes (at 100% data taking efficiency), and should be immediately analyzed to get an indication of the pion rate. Use this to calculate how long to run to get the desired statistics.

2. $\boxed{\text{Al}(e, e'\pi^+)X}$ Thick Dummy target SHMS right ($\theta = 19.22^\circ$) run.

Now put in the “thick” dummy target (± 5 cm) and initially set prescale factors to the same as the LH2 run.

If the HMS and SHMS singles event rates to disk are significantly less than 100 Hz each, the PS1,4 factors can be decreased accordingly.

Current limit: 40 μA .

DO NOT modify *standard.kinematics* for this run (i.e. keep as for LH2 target).

Take data for 0.1 hour (100% efficiency) at 40 μA .

3. $p(e, e'\pi^+)n$ LH2 SHMS center ($\theta = 21.22^\circ$) run.

- (a) Move the SHMS to 21.22 deg (from TV). Be sure to record and photograph the actual vernier value to 0.005 degree precision.
- (b) Put in the LH2 target. Leave the spectrometer magnet settings unchanged.
- (c) Update *standard.kinematics* with the new settings.
- (d) **Adjust the beam current to keep the SHMS-3/4 rate below 600 kHz.** We project the current for this run to be about 80 μA . Do not change PS5=0!
- (e) Set the PS1(SHMS-3/4) and PS4(HMS-ELREAL) target rates to 100 Hz.

For **80 μA beam** and the projected rates listed below, these prescale factors should give 100 Hz HMS and SHMS singles event rates to disk, and a 1846 Hz DAQ rate overall.

Projected prescale GUI settings:	
PS1(SHMS-3/4)	12
PS2(SHMS-ELREAL)	-1
PS3(HMS-3/4)	-1
PS4(HMS-ELREAL)	11
PS5(HMS-ELREAL \times SHMS-3/4)	0
PS6(HMS-3/4 \times SHMS-3/4)	-1
EDTM Target Prescale Rate	10 Hz
cermode10	ON

HMS e^- rate	HMS π^- rate	SHMS π^+ rate	SHMS K rate	SHMS p rate	Random coinc. $(e^- + \frac{\pi^-}{5}) \cdot (\pi + K + p)$	Real coinc. $e^- \cdot \pi$
143 kHz	6.6 kHz	82 kHz	21 kHz	82 kHz	1598 Hz	74.7 Hz

- (f) **fadcmode10 Run:** Start by taking a 2 minute fadcmode10 run. Be sure to mark this clearly on the Run Sheet. After the run, it is extremely important to **unclick the fadcmode10 setting button.**
- (g) **HMS-3/4 trigger run:** Since the HMS momentum is fairly low, take a 20 minute run with HMS-3/4 triggers enabled instead of hELREAL (i.e. PS6 instead of PS5, and PS3 instead of PS4). This is to monitor the ELREAL threshold and will count as part of the physics run total. If the PS3 trigger rate is excessive, adjust PS3 to a higher level to compensate.
- (h) **Take data for 1.0 hours (100% efficiency) at 80 μA to get 134,500 $p(e, e'\pi^+)n$ coincidences.** Use the physics replay to keep track of the event total. **LH2 and LD2 replays have different cuts enabled. Make sure the correct target is inputted into the physics replay.** The first run should be ~ 30 minutes (at 100% data taking efficiency), and should be immediately analyzed to get an indication of the pion rate. Use this to calculate how long to run to get the desired statistics.

4. $p(e, e'\pi^+)n$ coincidences fADC deadtime study

- (a) Do not change any HMS and SHMS settings.
- (b) 10 cm LH2 target.
- (c) Projected prescale GUI settings:

HMS singles DAQ disabled	all PS=-1
SHMS singles DAQ disabled	all PS=-1
COIN DAQ:	
PS1(SHMS-3/4)	see table
PS2(SHMS-ELREAL)	-1
PS3(HMS-3/4)	-1
PS4(HMS-ELREAL)	see table
PS5(HMS-ELREAL×SHMS-3/4)	0
PS6(HMS-3/4×SHMS-3/4)	-1
EDTM Target Prescale Rate	10 Hz
cermode10	ON

- (d) Make sure the raster is on (2×2), and take coincidences at 65, 50, 30, 20, 12 μ A. Start at the highest current and take LH2 target data. Then go down in current and repeat. **The goal is 10k prompt $p(e, e'\pi^+)n$ coincidences per setting.**

8.487 GeV $p(e, e'\pi^+)n$ fADC Deadtime Study							
$Q^2=2.12$ GeV ² , $W=2.05$ GeV, $\epsilon=0.899$ central angle							
$\theta_{HMS} = 12.14$, $P_{HMS}=-5.587$ GeV/c, $\theta_{SHMS} = 21.22$, $P_{SHMS}=+2.792$ GeV/c							
μ A	Targets	$\frac{Rate_{SHMS}}{LHrun}$	$\frac{PS1}{SHMS}$	$\frac{Rate_{HMS}}{LHrun}$	$\frac{PS4}{HMS}$	Rate _{DAQ}	Time
65	LH2	150 kHz	11	122 kHz	11	5.2 kHz*	0.2 hr
* If the CODA deadtime is excessive (>20%), consider PS5=1							
50	LH2	115 kHz	11	94 kHz	11	3.4 kHz	0.2 hr
30	LH2, Dummy	69 kHz	10	56 kHz	10	2.1 kHz	0.3 hr
20	LH2	46 kHz	10	38 kHz	9	1.1 kHz	0.4 hr
12	LH2	28 kHz	9	23 kHz	9	0.5 kHz	0.7 hr
Total Time (including overhead): 3.33 hrs							

5. $\boxed{\text{Al}(e, e'\pi^+)X}$ Thick Dummy target SHMS center ($\theta = 21.22^\circ$) run.

Now put in the “thick” dummy target (± 5 cm) and initially set prescale factors to the same as the LH2 run.

If the HMS and SHMS singles event rates to disk are significantly less than 100 Hz each, the PS1,4 factors can be decreased accordingly.

Current limit: 40 μA .

DO NOT modify *standard.kinematics* for this run (i.e. keep as for LH2 target).

Take data for 0.1 hours (100% efficiency) at 40 μA .

6. $p(e, e'\pi^+)n$ LH2 SHMS left ($\theta = 23.22^\circ$) run.

- (a) Move the SHMS to 23.22 deg (from TV). Be sure to record and photograph the actual vernier value to 0.005 degree precision.
- (b) Put in the LH2 target. Leave the spectrometer magnet settings unchanged.
- (c) Update *standard.kinematics* with the new settings.
- (d) **Adjust the beam current to keep the SHMS-3/4 rate below 600 kHz.** We project the current for this run to be about 80 μA . Do not change PS5=0!
- (e) Set the PS1(SHMS-3/4) and PS4(HMS-ELREAL) target rates to 100 Hz.

For **80 μA beam** and the projected rates listed below, these prescale factors should give 100 Hz HMS and SHMS singles event rates to disk, and a 1128 Hz DAQ rate overall.

Projected prescale GUI settings:	
PS1(SHMS-3/4)	11
PS2(SHMS-ELREAL)	-1
PS3(HMS-3/4)	-1
PS4(HMS-ELREAL)	11
PS5(HMS-ELREAL \times SHMS-3/4)	0
PS6(HMS-3/4 \times SHMS-3/4)	-1
EDTM Target Prescale Rate	10 Hz
cermode10	ON

HMS e^- rate	HMS π^- rate	SHMS π^+ rate	SHMS K rate	SHMS p rate	Random coinc. $(e^- + \frac{\pi^-}{5}) \cdot (\pi + K + p)$	Real coinc. $e^- \cdot \pi$
143 kHz	6.6 kHz	41 kHz	11 kHz	49 kHz	872 Hz	74.7 Hz

- (f) **fadcmode10 Run:** Start by taking a 2 minute fadcmode10 run. Be sure to mark this clearly on the Run Sheet. After the run, it is extremely important to **unclick the fadcmode10 setting button.**
- (g) **HMS-3/4 trigger run:** Since the HMS momentum is fairly low, take a 20 minute run with HMS-3/4 triggers enabled instead of hELREAL (i.e. PS6 instead of PS5, and PS3 instead of PS4). This is to monitor the ELREAL threshold and will count as part of the physics run total. If the PS3 trigger rate is excessive, adjust PS3 to a higher level to compensate.
- (h) **Take data for 1.0 hours (100% efficiency) at 80 μA to get 134,500 $p(e, e'\pi^+)n$ coincidences.** Use the physics replay to keep track of the event total. **LH2 and LD2 replays have different cuts enabled. Make sure the correct target is inputted into the physics replay.** The first run should be ~ 30 minutes (at 100% data taking efficiency), and should be immediately analyzed to get an indication of the pion rate. Use this to calculate how long to run to get the desired statistics.

7. $\boxed{\text{Al}(e, e'\pi^+)X}$ Thick Dummy target SHMS left ($\theta = 23.22^\circ$) run.

Now put in the “thick” dummy target (± 5 cm) and initially set prescale factors to the same as the LH2 run.

If the HMS and SHMS singles event rates to disk are significantly less than 100 Hz each, the PS1,4 factors can be decreased accordingly.

Current limit: 40 μA .

DO NOT modify *standard.kinematics* for this run (i.e. keep as for LH2 target).

Take data for 0.1 hours (100% efficiency) at 40 μA .

Calibration runs with SHMS at negative polarity

1. $p(e, e')p$ Hydrogen elastic singles, and associated Dummy target runs.

For HEEP singles, please follow Jacob's runplan.

Set up the following configuration:

- (a) HMS and SHMS angles and momenta as specified in the tables below. Both spectrometers should be at negative polarity, and will have to be cycled initially.
- (b) Record all TV angle values on run sheets and hclog. Update *standard.kinematics* with the new settings.
- (c) 10 cm LH2 and "thick" dummy target data should be taken with the HMS large and SHMS collimators.

LH2 target runs:

- Set the PS2 and PS4 target rates to 1000 Hz, all others disabled (i.e. -1). As a guide, projected rates and PS factors are given in the table below.
- Projected beam currents are listed below, we desire to keep the SHMS-3/4 rate below 600 kHz so adjust accordingly. Stable beam with 2×2 **raster on**.
- We want at least 10,000 elastics in the SHMS for each setting, which typically requires at least 60,000 total electron events (times are only a guide). The total event estimate in right-most column includes inelastics.

Thick Dummy target runs:

One run for each angle and momentum setting, current limit: $40 \mu\text{A}$.

To be efficient, please minimize target changes and do LH2, Dummy for first setting, followed by Dummy, LH2 for second setting, etc.

8.487 GeV Heep-check singles runs

θ_{HMS}	P_{HMS}	θ_{SHMS}	P_{SHMS}	Current	$Rate_{HMS}$	$\frac{PS4}{HMS}$	$Rate_{SHMS}$	$\frac{PS2}{SHMS}$	$\frac{Time}{LH2run}$	$\frac{Time}{ALrun}$	Evt_{SHMS}
15.050	-6.477	9.45	-7.559	10 μ A	0.98 kHz	0	57.6 kHz	8	10 min	6 min	266k
15.630	-5.878	11.90	-7.106	25 μ A	4.55 kHz	3	28.6 kHz	7	10 min	6 min	261k
17.970	-5.878	13.85	-6.720	80 μ A	1.80 kHz	0	30.5 kHz	7	12 min	6 min	334k
20.385	-5.878	14.75	-6.538	80 μ A	0.13 kHz	0	18.6 kHz	6	12 min	6 min	400k
* Beam current may need to be lowered if deadtime >15%											
17.24	-5.587	16.10	-6.265	80 μ A	6.80 kHz	3	9.90 kHz	5	12 min	6 min	412k
19.505	-5.587	19.20	-5.646	80 μ A	0.90 kHz	0	2.63 kHz	3	18 min	6 min	554k
21.875	-5.587	23.20	-4.902	80 μ A	0.07 kHz	0	0.65 kHz	0	30 min	6 min	738k

Total Time (including overhead): 8.1 hrs

Lumi Scans

2. First Luminosity scans on LH2, LD2 and $z = 0$ Carbon targets.

This scan relies on MCC's ability to deliver stable high beam currents.

- (a) Set the HMS momentum to -4.570 GeV/c, and the SHMS momentum to -5.370 GeV/c, both negative polarity.
- (b) Rotate the HMS to 12.50 degrees, and the SHMS to 9.50 degrees. Record the TV camera angles on the runsheet to 0.005 degree accuracy.
- (c) ELREAL trigger in both arms. Set the PS2, PS4 target DAQ rates to 1 kHz, to give a total rate to disk of about 2 kHz.
- (d) Make sure the raster is on (2×2), and take HMS and SHMS runs at 80, 60, 40, 25, 18, 12, 8, 5, 2.5, 1 μ A on LH2 target. Start at the highest current, then go down in current and repeat.
- (e) **Try to get runs with a minimum of beam trips (if possible).**
- (f) Take one Thick Dummy target run at 40 μ A about 0.3 hour. During this run, the Target Operator should park the LH2 target and prepare for LD2 data taking.
- (g) Repeat the scans with LD2 target at 40, 25, 18, 12, 8 μ A. (80, 60 μ A rates on LD2 are too high and can be excluded.)
- (h) An expert (Jacob) should do a sanity-check of the EDTM (and any other hardware deadtime measurement system) by comparing runs over a range of detector rates but with low software deadtimes.

8.487 GeV Luminosity Scans								
μ A	Targets	$\frac{Rate_{SHMS}}{LHrun}$	$\frac{PS2}{SHMS}$	$\frac{Rate_{HMS}}{LHrun}$	$\frac{PS4}{HMS}$	DAQ _{SHMS}	DAQ _{HMS}	$\frac{Time}{run}$
$\theta_{HMS} = 12.50, P_{HMS} = -4.570$ GeV/c, $\theta_{SHMS} = 9.50, P_{SHMS} = -5.370$ GeV/c								
80	LH2, C	699 kHz	13	149 kHz	8	1 kHz	1 kHz	10 min
60	LH2, C	524 kHz	13	112 kHz	7	1 kHz	1 kHz	10 min
40	LH2, Dummy, LD2, C	349 kHz	12	74.4 kHz	7	1 kHz	1 kHz	10 min
25	LH2, LD2, C	218 kHz	12	46.5 kHz	6	1 kHz	1 kHz	10 min
18	LH2, LD2, C	157 kHz	11	33.5 kHz	5	1 kHz	1 kHz	10 min
12	LH2, LD2, C	105 kHz	11	22.3 kHz	5	1 kHz	1 kHz	10 min
8	LH2, LD2, C	69.9 kHz	10	14.9 kHz	4	1 kHz	1 kHz	10 min
5	LH2, C	4.37 kHz	9	9.3 kHz	3	1 kHz	1 kHz	10 min
2.5	LH2, C	2.18 kHz	8	4.65 kHz	2	1 kHz	1 kHz	10 min
1	LH2, C	8.7 kHz	7	1.86 kHz	4	0 kHz	1 kHz	10 min
Total Time (including overhead): 9.6 hrs								

3. Second Luminosity scans on LH2, LD2 and $z = 0$ Carbon targets.

This scan relies on MCC's ability to deliver stable high beam currents. If they can not, then RC will instruct whether to defer the luminosity scan later in the experiment.

- (a) Keep the HMS momentum to -4.570 GeV/c, and the SHMS momentum to -5.370 GeV/c, both negative polarity.
- (b) Rotate the HMS to 13.00 degrees, and the SHMS to 10.50 degrees. Record the TV camera angles on the runsheet to 0.005 degree accuracy.
- (c) ELREAL trigger in both arms. Set the PS2, PS4 target DAQ rates to 1 kHz, to give a total rate to disk of about 2 kHz.
- (d) **Change the EDTM target rate from 10 Hz to 25 Hz.**
- (e) Make sure the raster is on (2×2), and take HMS and SHMS runs at 80, 60, 40, 25, 18, 12, 8 μA on LH2 target. Start at the highest current, then go down in current and repeat.
- (f) **Try to get runs with a minimum of beam trips (if possible).**
- (g) Take one Thick Dummy target run at 40 μA about 0.3 hour. During this run, the Target Operator should park the LH2 target and prepare for LD2 data taking.
- (h) Repeat the scans with LD2 target at 40, 25, 18, 12, 8 μA . (80, 60 μA rates on LD2 are too high and can be excluded.)
- (i) An expert (Jacob) should do a sanity-check of the EDTM (and any other hardware deadtime measurement system) by comparing runs over a range of detector rates but with low software deadtimes.

8.487 GeV Luminosity Scans								
μA	Targets	$\frac{Rate_{SHMS}}{LHrun}$	$\frac{PS2}{SHMS}$	$\frac{Rate_{HMS}}{LHrun}$	$\frac{PS4}{HMS}$	DAQ_{SHMS}	DAQ_{HMS}	$\frac{Time}{run}$
$\theta_{HMS} = 13.00, P_{HMS} = -4.570 \text{ GeV}/c, \theta_{SHMS} = 10.50, P_{SHMS} = -5.370 \text{ GeV}/c$								
80	LH2, C	430 kHz	13	120 kHz	7	1 kHz	1 kHz	10 min
60	LH2, C	322 kHz	12	90.2 kHz	7	1 kHz	1 kHz	10 min
40	LH2, Dummy, LD2, C	215 kHz	12	60.2 kHz	6	1 kHz	1 kHz	10 min
25	LH2, LD2, C	134 kHz	11	37.6 kHz	6	1 kHz	1 kHz	10 min
18	LH2, LD2, C	96.7 kHz	11	27.1 kHz	5	1 kHz	1 kHz	10 min
12	LH2, LD2, C	64.5 kHz	10	18 kHz	5	1 kHz	1 kHz	10 min
8	LH2, LD2, C	43.0 kHz	9	12 kHz	4	1 kHz	1 kHz	10 min
5	LH2, C	26.9 kHz	9	7.5 kHz	3	1 kHz	1 kHz	10 min
2.5	LH2, C	13.4 kHz	8	3.76 kHz	2	1 kHz	1 kHz	10 min
1	LH2, C	5.37 kHz	6	1.5 kHz	0	1 kHz	1 kHz	10 min
Total Time (including overhead): 13.7 hrs								