A_1^n Run Plan

(1-pass commissioning)

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Outline:

1. Pass Change Schedule
2. Elastic ^3He P_bP_t runs
3. Reference Cell elastic runs (^3He, N_2, H_2)
4. Delta transverse Asymmetry
5. Summary of 1-pass commissioning

Pass Change Schedule

- Pass change to 1-pass beam: on day 1 day shift;
- Stay at 1-pass for day1 swing, day2 fullday, and day 3 owl; (total 40 Cal hours)
- Pass change to 5-pass beam during day 3 day shift.

Optics: C_{12}

- For 1-pass beam, we will do dP scan which will take about 7 Cal hours.
- More detail about Optics could be found in Jixie's presentation.

Elastic Kinematics

- For 1-pass (E_b=2.1 GeV) large angle running, the smallest angles of the spectrometers are:

  HMS at 11.7°; SHMS at 8.5°

- The spectrometers could be set at min angle at the same time. Since smaller spectrometer angle will shorten the need beam time, we use HMS at 11.7°,E_p=2.068 GeV; SHMS at 8.5°, E_p=2.083 GeV as elastic kinematics.

- Estimate 35 min to configure the spectrometers into elastic kinematics.

  (30 min to cycle HMS or SHMS dipole + 5 min to change momentum)

Elastic ^{3}He PbPt runs

- For elastic kinematics, the 3He QE/el rate ratio is relatively large when using spectrometers' full acceptance.
- Only turn on 2 SC bars to accept the region around el peak and suppress the QE rate.
- Estimate elastic beam time for $\Delta A_{raw}/A_{raw}$=2% or 3%.
- For 50% Hall C beam availability, need 9 Cal hours to reach $\Delta A_{raw}/A_{raw}$= 3% for SHMS, while HMS will reach $\Delta A_{raw}/A_{raw}$= 2% at the end of 6 Cal hour.

2.1 GeV ^3He Elastic P_bP_t runs with 2SC										
Spec	E_p GeV	θ ($\circ$)	Tot 1μA rate(Hz)	elas 1μA rate(Hz)	I_{sug} (μA)	PS	PS elas ^3He rate (Hz)	$A_{physics}$	Time (2%)(hr)	Time (3%)(hr)
HMS	2.068	11.7	1077.93	157.98	4.175	1	659.51	0.04795	2.995	1.331
SHMS	2.083	8.5	25432.66	4294.69	4.175	24	747.04	0.02503	9.705	4.314
Total Cal Time: 9 Cal hours for longer time SHMS run with $\frac{\Delta A_{raw}}{A_{raw}} = 3\%$										

Table 1: Estimated rate and Beam time for ^3He Elastic P_bP_t runs. $P_b = 85\%$, $P_t = 50\%$, $f_{N_2} = 0.92$.

Reference Cell Pressure Curve

2.1 GeV ^3He Reference cell Elastic runs with 2SC								
Spec	Pressure (atm)	Tot 1μA rate(Hz)	elas 1μA rate(Hz)	I_{sug} (μA)	PS	PS elas rate (Hz)	Elastic Events (#)	Beam Time (min)
HMS	2	572.154	24.442	7.87	1	192.237	10000	0.867
SHMS	2	12017.423	664.458	7.87	22	237.544	10000	0.702
HMS	4	664.728	48.885	6.77	1	330.936	10000	0.504
SHMS	4	14472.877	1328.917	6.77	22	408.925	10000	0.408
HMS	6	757.302	73.327	5.94	1	435.720	10000	0.383
SHMS	6	16928.33	1993.375	5.94	23	514.997	10000	0.324
HMS	8	849.877	97.77	5.29	1	517.681	10000	0.322
SHMS	8	19383.783	2657.834	5.29	23	611.866	10000	0.272
HMS	10	942.451	122.212	4.77	1	583.536	10000	0.286
SHMS	10	21839.237	3322.292	4.77	24	660.968	10000	0.252
Total Cal Time: 25 min for 5min as the minimum data taking time for each run								

Table 2: Estimated rate and Beam time for ^3He reference cell Elastic runs: HMS 11.7°, 2.068GeV/c; SHMS 8.5°, 2.083GeV/c.

- Using same Elastic Kinematics.
- ^{3}He pressure curve, take 5 pressure points at 2,4,6,8,10 atm for calibration of ^{3}He density in production cell.
- Collect 10,000 elastic events for HMS and SHMS.
- The minimum Cal time for each run is set to be 5 min.
- Estimate 10 min*4=40 min for each gas pressure change and 1 hour for changing to N_2 gas for next measurement.

Reference Cell Pressure Curve

2.1 GeV N_2 Reference cell Elastic runs with 2SC								
Spec	Pressure (atm)	Tot 1μA rate(Hz)	elas 1μA rate(Hz)	I_{sug} (μA)	PS	PS elas rate (Hz)	Elastic Events (#)	Beam Time (min)
HMS	2	1333.44	11.003	3.37	1	37.132	10000	4.488
SHMS	2	21611.991	552.814	3.37	17	109.741	10000	1.519
HMS	4	2187.3	22.006	2.06	1	45.274	10000	3.681
SHMS	4	33662.012	1105.627	2.06	16	142.165	10000	1.172
HMS	6	3041.159	33.009	1.48	1	48.843	10000	3.412
SHMS	6	45712.033	1658.441	1.48	16	153.375	10000	1.087
HMS	8	3895.019	44.012	1.16	1	50.848	10000	3.278
SHMS	8	57762.055	2211.255	1.16	15	170.314	10000	0.979
HMS	10	4748.879	55.015	0.95	1	52.132	10000	3.197
SHMS	10	69812.076	2764.068	0.95	15	174.614	10000	0.954
Total Cal Time: 50 min for 10 min Cal time each HMS run								

Table 3: Estimated rate and Beam time for N_2 reference cell Elastic runs: HMS 11.7°, 2.068GeV/c; SHMS 8.5°, 2.083GeV/c.

- Using same Elastic Kinematics.
- N_2 pressure curve, take 5 pressure points at 2,4,6,8,10 atm for calibration of N_2 density in production cell.
- Collect 10,000 elastic events for HMS and SHMS.
- For 50% Hall C beam availability, each HMS run take data for 10 min Cal time.
- Estimate 10 min*4=40 min for each gas pressure change and 1 hour for changing to H_2 gas for next measurement.

Reference Cell Proton Cross Section

2.1 GeV H_2 Reference cell Elastic runs with 2SC								
Spec	Pressure (atm)	Tot 1μA rate(Hz)	elas 1μA rate(Hz)	I_{sug} (μA)	PS	PS elas rate (Hz)	Elastic Events (#)	Beam Time (min)
HMS	10	617.844	138.264	7.28	1	1007.031	10000	0.166
SHMS	10	23252.646	13690.662	7.28	38	2624.065	10000	0.064
Total Cal Time: 5 min for the minimum data taking time.								

Table 4: Estimated rate and Beam time for H_2 reference cell Elastic runs: HMS 11.7°, 2.068GeV/c; SHMS 8.5°, 2.083GeV/c.

- Using same Elastic Kinematics.
- H_2 elastic at 10 atm for calibration of proton cross section.
- Collect 10,000 elastic events for HMS and SHMS.
- The minimum Cal time is set to be 5 min.

Delta Transverse Asymmetry

2.1 GeV ^3He Delta Transverse Asymmetry Full Acceptance										
Spec	E_p GeV	θ ($\circ$)	Q^2 GeV^2	Tot 1μA rate(Hz)	Delta 1μA rate(Hz)	I_{sug} (μA)	PS	PS Delta rate (Hz)	$\frac{A_{raw}}{P_b P_t}$ (%)	Beam Time (min)
HMS	1.682	11.7	0.1468	5380.98	2150.85	0.836	1	1798.710	1.706	4.405
SHMS	1.718	8.5	0.0793	35044.9	5158.5	0.836	7	616.278	1.176	27.044
Total Cal Time:60 min run for longer time SHMS run with $\frac{\Delta A^{\Delta}_{\perp raw}}{A^{\Delta}_{\perp raw}} = 1/5$										

Table 5: Estimated rate and Beam time for ^3He Delta Transverse Asymmetry. $P_b = 85\%$, $P_t = 50\%$.

- Delta transverse kinematics: HMS at 11.7°,E_p=1.682 GeV; SHMS at 8.5°, E_p=1.718 GeV.
- Estimate 35 min to configure the spectrometers into Delta transverse kinematics.

  (30 min to cycle HMS or SHMS dipole + 5 min to change momentum)
- For Delta transverse asymmetry, we use the spectrometers full acceptance.
- From Peter Bosted Xsection, apply W cut (1.1 GeV<W<1.35 GeV) to select Delta resonance peak.
- For 50% Hall C beam availability, need 1 Cal hours to reach $\Delta A^{\Delta}_{\perp raw}/A^{\Delta}_{\perp raw}$=1/5 for SHMS.

Moller Commissioning

- Need total of 16 calendar hours to complete:

  8 calendar hours + 4 PAC hours= 16 Cal hours.

Summary of 1-pass commissioning

1. Calibration runs: Optics C12: 7 Cal hrs.
2. Configure to Elastic kinematics: 35 min
3. ^3He Elastic P_bP_t runs with HMS/SHMS reach $\frac{\Delta A_{raw}}{A_{raw}} = 2\%/3\%$: 9 Cal hrs.
4. Reference Cell Pressure Curve:

- ^3He: pressure change $(4*10=40$ min); Data taking $(5*5=25$ min)
- Change reference cell gas to N_2: 1 Cal hr
- N_2: pressure change $(4*10=40$ min); Data taking $(10*5=50$ min)
- Change reference cell gas to H_2: 1 Cal hr
- H_2: Data taking (5 min)

Subtotal time for Reference Cell Pressure Curve: 80 min+ 200 min over head time=4 hrs and 40 min Calendar time.

5. Configure to Delta transverse Asymmetry: 35 min
6. ^3He Delta Transverse Asymmetry: 60 min
7. Moller: 16 Cal hrs

Thus total time for 1-pass beam is: 38 hrs and 50 mins Calendar time.

Note: We can have shorter elastic ^{3}He P_bP_t runs be 5 Cal hour for HMS/SHMS reach $\Delta A_{raw}/A_{raw}=3\%/4\%$. Then total time for 1-pass is 34 hrs and 50 mins Calendar time.

Backup Slides

Elastic ^{3}He PbPt runs

- The elastic ^{3}He PbPt runs can be shorter with HMS/SHMS reach $\Delta A_{raw}/A_{raw}$=3%/4%.
- For 50% Hall C beam availability, need 5 Cal hours to reach $\Delta A_{raw}/A_{raw}$= 4% for SHMS, while HMS will reach $\Delta A_{raw}/A_{raw}$= 3% at the end of 3 Cal hour.

2.1 GeV ^3He Elastic P_bP_t runs with 2SC										
Spec	E_p GeV	θ ($\circ$)	Tot 1μA rate(Hz)	elas 1μA rate(Hz)	I_{sug} (μA)	PS	PS elas ^3He rate (Hz)	$A_{physics}$	Time (3%)(hr)	Time (4%)(hr)
HMS	2.068	11.7	1077.93	157.98	4.175	1	659.51	0.04795	1.331	0.749
SHMS	2.083	8.5	25432.66	4294.69	4.175	24	747.04	0.02503	4.314	2.426
Total Cal Time: 5 Cal hours for longer time SHMS run with $\frac{\Delta A_{raw}}{A_{raw}} = 4\%$										

Table 2: Estimated rate and Beam time for ^3He Elastic P_bP_t runs. $P_b = 85\%$, $P_t = 50\%$, $f_{N_2} = 0.92$.

^{3}He Elastic P_bP_t

(P_b=85%, P_t=50%, f_{N2}=0.92, $\Delta A_{raw}/A_{raw}$=2% or 3%)

- Since $A_{raw} = A_{physics} P_b P_t f_{N2}$
- From calculated $A_{physics}$ and estimated rate under DAQ limit, the beam time need to reach certain $\Delta A_{raw}/A_{raw}$ level is:

$$t_{beam} = \frac{1}{\left(A_{physics} P_b P_t f_{N2} \frac{\Delta A_{raw}}{A_{raw}}\right)^2 * rate}$$

(use DAQ limit =4.5 kHz, calculate $A_{physics}$ using function “asym_calc3” in “he3_elastic.f”.)

GE180 glass windows elastic (P_bP_t) rates

(E_b=2.1 GeV, I_b=1.0 uA, ^{3}He at 12 amg)

^{3}He elastic (P_bP_t)	Full Rate (QE+el) (Hz)	Pure Elastic Rate (el) (Hz)	Full Acc Rate ratio (QE/el)	2SC Full Rate (QE+el) (Hz)	2SC Pure Elastic Rate (el) (Hz)	2SC Rate ratio (QE/el)
HMS(11.7° ,2.06GeV)	3196.88	157.98	19.236	598.35	157.98	2.788
SHMS(8.5° , 2.08GeV)	20137.55	4294.69	3.689	15870.69	4294.69	2.695

Upstream Window	Full Rate (QE+el) (Hz)	Pure Elastic Rate (el) (Hz)	Full Acc Rate ratio (QE/el)	2SC Full Rate (QE+el) (Hz)	2SC Pure Elastic Rate (el) (Hz)	2SC Rate ratio (QE/el)
HMS(11.7° ,2.06GeV)	1473.96	12.88	113.438	323.90	11.56	27.019
SHMS(8.5° , 2.08GeV)	8476.23	600.42	13.117	5364.06	600.42	7.934

Downstream Window	Full Rate (QE+el) (Hz)	Pure Elastic Rate (el) (Hz)	Full Acc Rate ratio (QE/el)	2SC Full Rate (QE+el) (Hz)	2SC Pure Elastic Rate (el) (Hz)	2SC Rate ratio (QE/el)
HMS(11.7° ,2.06GeV)	860.18	7.16	119.137	155.68	7.16	20.743
SHMS(8.5° , 2.08GeV)	7327.25	201.71	35.326	4197.91	201.71	19.812

- Using bin: $\Delta\cos\theta$=5E-4 rad, $\Delta\varphi$=0.01 rad, $\Delta p/p$=0.2% to get the integrated Xsection.

Delta Transverse Asymmetry

(P_b=85%, P_t=50%, $\Delta A^{\Delta}_{\perp raw}/A^{\Delta}_{\perp raw}$=1/5)

- Since $A^{\Delta}_{\perp raw} = \frac{A^{\Delta}_{\perp raw}}{P_b P_t} * P_b P_t$
- From calculated $\frac{A^{\Delta}_{\perp raw}}{P_b P_t}$ and estimated rate under DAQ limit, the beam time need to reach certain $\Delta A^{\Delta}_{\perp raw}/A^{\Delta}_{\perp raw}$ level is:

$$t_{beam} = \frac{1}{\left(\frac{A^{\Delta}_{\perp raw}}{P_b P_t} P_b P_t \frac{\Delta A^{\Delta}_{\perp raw}}{A^{\Delta}_{\perp raw}}\right)^2 * rate}$$

- Obtain $\frac{A^{\Delta}_{\perp raw}}{P_b P_t}$ value by Linear Interpolation of E94010 data.

$$\text{At } Q^2 = 0.03\, GeV/C^2, \frac{A^{\Delta}_{\perp raw}}{P_b P_t} = 0.79\,\%$$

$$\text{At } Q^2 = 0.16\, GeV/C^2, \frac{A^{\Delta}_{\perp raw}}{P_b P_t} = 1.81\,\%$$

Method for Rate Estimation

$$Rate = \int \frac{\partial^2\sigma(\Omega, E')}{\partial\Omega\partial E'} \cdot \epsilon(\Omega, E') d\Omega dE' \cdot Lumi$$

Acceptance

$$\epsilon(\Omega, E') = \frac{N_{detected}(\Omega, E')}{N_{thrown}(\Omega, E')}$$

- Need acceptance
- Define very fine Omega-E` bins. In each bin, calculate the differential _xs using the bin center.
- Integrate “differential_xs * acceptance” only if the acceptance of this Omega-E` bin > 0.1 over the whole phase space.
- Multiply Luminosity to get rate

Note: For current rate estimation we used the Peter Bosted xs” model to calculate differentia_xs and did not account the radiative correction yet. Need to introduce the radiative correction into our rate estimation.

(radiative correction may only have a small effect on the estimated rate.)

Table for Production Beam Time

(E_{beam}=10.5 GeV)

Kine	Ebeam (GeV)	Spec	p0	θ0	e- production time (hours)	e+ (hours)
1	10.5	HMS	5.7	12.5	12.0	0.0
2	10.5	HMS	6.8	12.5	24.0	0.0
3	10.5	HMS	2.9	30.0	88.0	1.0
4	10.5	HMS	3.5	30.0	511.0	1.0
A	10.5	SHMS	5.8	12.5	36.0	0.0
B	10.5	SHMS	3.4	30.0	511.0	0.0
C	10.5	SHMS	2.4	30.0	88.0	0.0
D	10.5	SHMS	7.5	12.5	96.0	0.9

- From “A1nTalk_Zheng_20181210.pdf”.
- target length=40 cm, I_b=30uA; P_b=85%, P_t=60%, f_{N2}=0.92

Kinematics for ΔA_1^n

(E_{beam}=10.5 GeV, with radiative correction)

Kine	Spec	E_b GeV	E_p GeV	θ ($\circ$)	(e,e') rate(Hz)	π^-/e	e^+/e^-	$x(Q^2$ in $GeV^2)(W^2$ in $GeV^2)$ coverages
DIS								
1	HMS	10.5	5.70	12.5	882.17	<0.4	$<0.1\%$	0.25-0.55 (2.39- 4.07) (2.1- 2.8)
2	HMS	10.5	6.80	12.5	498.26	<0.2	$<0.1\%$	0.25-0.60 (2.24- 4.36) (1.9- 2.8)
3	HMS	10.5	2.90	30.0	3.41	<8.8	$<0.1\%$	0.40-0.77 (6.21-10.14) (2.0- 3.2)
4	HMS	10.5	3.50	30.0	0.94	<2.2	$<0.1\%$	0.50-0.77 (7.28- 9.94) (2.0- 2.9)
A	SHMS	10.5	5.80	12.5	990.36	<0.4	$<0.1\%$	0.25-0.55 (2.45- 3.80) (2.0- 2.9)
B	SHMS	10.5	3.40	30.0	1.57	<4.8	$<0.1\%$	0.45-0.77 (6.83- 9.89) (2.0- 3.0)
C	SHMS	10.5	2.40	30.0	8.24	<45.2	$<0.1\%$	0.30-0.71 (5.07- 9.49) (2.2- 3.6)
Resonances								
D	SHMS	10.5	7.50	12.5	185.14	–	–	0.45-1.00 (2.72- 4.11) (0.9- 2.0)

Table 1: Kinematics for HMS/SHMS in DIS and resonance region

Table for ΔA_1^n

(E_{beam}=10.5 GeV, with radiative correction)

x_{bj}	ΔA_1^n (stat.) Low Q^2	ΔA_1^n(stat.) High Q^2	ΔA_1^n(stat.) two Q^2 combined	ΔA_1^n(syst.)	ΔA_1^n(total.)
0.25	0.0032	0.0000	0.0032	0.0132	0.0136
0.30	0.0033	0.0709	0.0033	0.0130	0.0134
0.35	0.0041	0.0191	0.0040	0.0129	0.0135
0.40	0.0053	0.0154	0.0050	0.0132	0.0141
0.45	0.0070	0.0164	0.0065	0.0137	0.0152
0.50	0.0108	0.0164	0.0090	0.0147	0.0172
0.55	0.0257	0.0138	0.0121	0.0162	0.0202
0.60	0.2667	0.0124	0.0124	0.0182	0.0220
0.65	0.0000	0.0133	0.0133	0.0206	0.0246
0.71	0.0000	0.0156	0.0156	0.0294	0.0333
0.77	0.0000	0.0345	0.0345	0.0379	0.0513

Table 1: Statistical and systematic uncertainties for DIS data at different x and Q^2

x_{bj}	ΔA_1^n (stat.)	ΔA_1^n(syst.)	ΔA_1^n(total.)
0.45	0.1218	0.0138	0.1226
0.50	0.0188	0.0150	0.0240
0.55	0.0126	0.0171	0.0212
0.60	0.0135	0.0191	0.0234
0.65	0.0116	0.0212	0.0242
0.71	0.0207	0.0283	0.0351
0.77	0.0326	0.0365	0.0489
0.83	0.0328	0.0472	0.0575
0.89	0.0309	0.0687	0.0753

Table 2: Statistical and systematic uncertainties for Resonance data at different x and Q^2