Draft Bubble Chamber Run Plan

May 1, 2018

1 Pre Beam

1.1 Bubble Chamber Operation

- No beam
- Place neutron source about 1 m from chamber
  - Enable bubble chamber and count for 30 min
- Place neutron source about 2 m from chamber
  - Enable bubble chamber and count for 30 min
- Counts should be about factor 4 different

1.2 Background Rates

Background rates need to be established to $\delta R \sim 0.25$ counts/hour to be a perturbation on the statistical error for the lowest point. For a background rate of 4 counts/hour, this will require **40-60 hours**. 10 hours is sufficient for the highest four points.

- No beam
- Enable bubble chamber and count

2 Commissioning

High rate checkout beam is $T = 5.25$ MeV, 1 μA. This should produce a rate of 1 event per 5 seconds ($\sim$ 240/hour with 10 s recovery time).

- Beam width is $\sigma_{x,y} = 1\ mm$
- Beam is centered on radiator
- Beam energy width is $\sim$3 keV
- Beam energy is 5.250 ± 0.005 MeV
- Bubble chamber recovery time 10 s

2.1 Establish Fiducial Region

- Bubble chamber active
- Establish high rate checkout beam for 20 min
- Adjust chamber height so fiducial region is in center of glass

2.2 Inactivity Test

- Bubble chamber set inactive
- Establish high rate checkout beam for 30 min
- No events should be observed on CCD

2.3 Establish Rate and Variation with Position

- Bubble chamber active
- Establish high rate checkout beam for 1 hour
- Move beam 3 mm in one direction
- Establish high rate checkout beam for 1 hour
- Rate should be nominally 10-15% lower

2.4 Width (also divergence) scan? TBD

- Bubble chamber active
- Increase width to $\sigma_{x,y} = 2$ mm
- Establish high rate checkout beam for 1 hour
- Rate should be nominally 30% lower

2.5 Recovery Time Scan

- Recovery time set to 8 s
- Bubble chamber active
- Establish high rate checkout beam for 1 hour
  - Normalized rate should be the same as initial rate
- Recovery time set to 10 s
- Establish high rate checkout beam for 1 hour
  - Normalized rate should be the same as initial rate

2.6 Current Scan

- Bubble chamber active
- Establish 5.25 MeV, 2 μA beam for 1 hour
  - Normalized rate should be the same as initial rate
- Establish 5.25 MeV, 1 μA beam for 2 hours
  - Normalized yield should be the same as initial rate

3 Running

- Start with 5.25, 5.15, 5.05 MeV
- Spend shift on 4.75 MeV to see if signal can be identified
- If not revert to 5 point plan

3.1 6 Point Plan

Shift	Energy	Current	Time
May 10 Swing	Commissioning		8
May 11 Swing	Commissioning		16
May 12 Day	5.25	1.5	3
	5.15	4.0	3
May 12 Swing	5.05	8.0	6
	4.75	19.0	8+
May 13 Day	4.95	19.0	16
May 14 Owl	4.85	50	48+
May 16 Day	4.75	50	24

4 Run Statistical Objectives

T_e	$\bar{E}_\gamma$	I [μA]	t [h]	Yield	Back	$\delta\sigma/\sigma$[%]	Y [/hr]
4.75	4.65	50.0	31.0	558.9	120.1	4.7	18.1
4.85	4.75	50.0	40.3	1517.9	135.1	9.5	37.7
4.95	4.85	19.3	12.7	730.4	46.3	5.6	57.7
5.05	4.95	8.0	5.8	682.0	19.2	5.2	118.3
5.15	5.05	3.4	3.0	708.8	8.2	5.0	233.6
5.25	5.15	0.6	3.0	762.5	3.2	4.5	256.8
			95.7				

or

T_e	$\bar{E}_\gamma$	I [μA]	t [h]	Yield	Back	$\delta\sigma/\sigma$[%]	Y [/hr]
4.85	4.75	50.0	44.1	1659.8	166.2	2.6	37.6
4.95	4.85	28.1	26.4	2141.3	93.3	3.4	81.1
5.05	4.95	10.7	11.3	1687.5	35.5	3.3	149.9
5.15	5.05	3.9	6.9	1757.7	15.1	3.1	256.4
5.25	5.15	0.6	7.4	1891.9	6.0	2.9	256.9
			96.0				

5 Deconvolution, Relative Rates, and Uncertainties

The deconvolution matrix to reconstruct cross sections from normalized yields has for the first three terms

$$\sigma_i \propto \frac{Y_i}{L_i t_i} - 1.25\frac{Y_{i-1}}{L_{i-1}t_{i-1}} + 0.125\frac{Y_{i-2}}{L_{i-2}t_{i-2}} \tag{1}$$

where Y_i is the bubble yield for the ith point, L_i is the luminosity, and t_i is the time spent. Terms without data are assumed to be zero, the lowest energy run has a poorly reconstructed cross section from a single yield, and the first two points are the most relevant.

T [MeV]	R [s^{-1}]	R_i/R_{i-1}
4.75	1.0×10^{-3}	
4.85	2.2×10^{-3}	2.1
4.95	9.1×10^{-3}	4.1
5.05	5.0×10^{-2}	5.5
5.15	2.8×10^{-1}	5.7
5.25	1.9×10^{-0}	6.8

Table 1: Rate for 10 μA

The approximate uncertainty for a point is

$$\delta\sigma \quad \propto \quad \sqrt{\frac{R_i}{L_i t_i} + \frac{3}{2}\frac{R_{i-1}}{L_{i-1}t_{i-1}}} \tag{2}$$

$$\delta\sigma/\sigma \quad = \quad \frac{\sqrt{R_i/(L_i t_i) + \frac{3}{2}R_{i-1}/(L_{i-1}t_{i-1})}}{R_i - 1.25R_{i-1}} \tag{3}$$

For the lowest two energy points, the relationship from this formula is

$$\frac{\delta\sigma_1}{\sigma_1} \approx \frac{4}{3}\frac{\delta\sigma_0}{\sigma_0}\sqrt{2\frac{L_0 t_0}{L_1 t_1} + \frac{3}{2}} \tag{4}$$

Without background, the lowest point uncertainty $\delta\sigma_1/\sigma_1$ is limited to $1.6 \times \delta\sigma_0/\sigma_0$ in the situation where the integrated luminosity is infinite. This is a consequence of the fact that the relative rates for the lowest two points are only a factor of 2 different.