Improved ^{3}He Targets for the A_1^n and G_E^n Experiments at JLab

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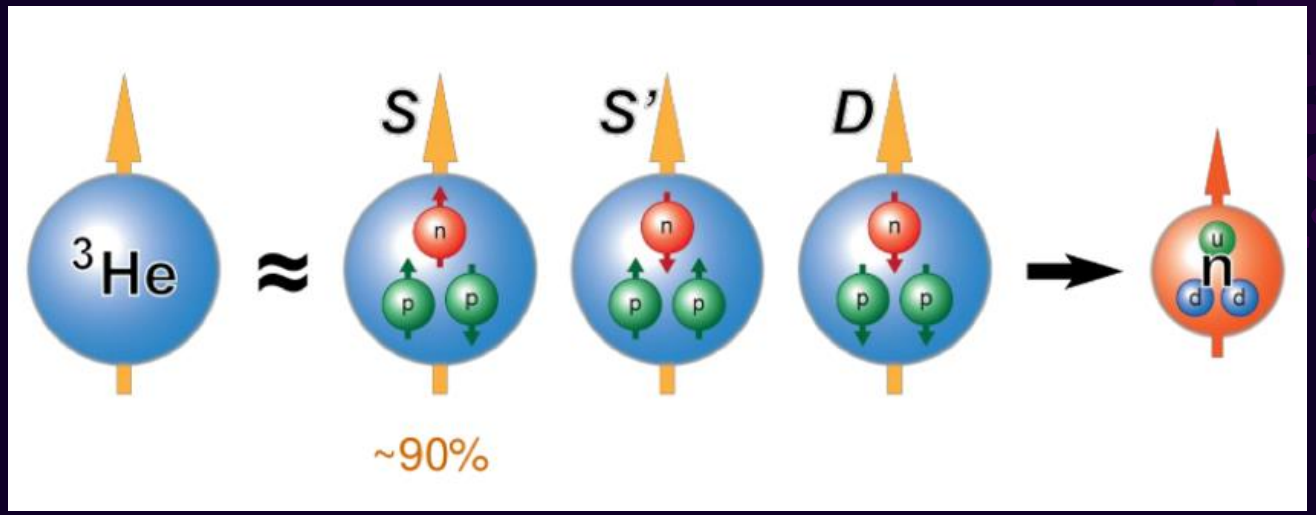
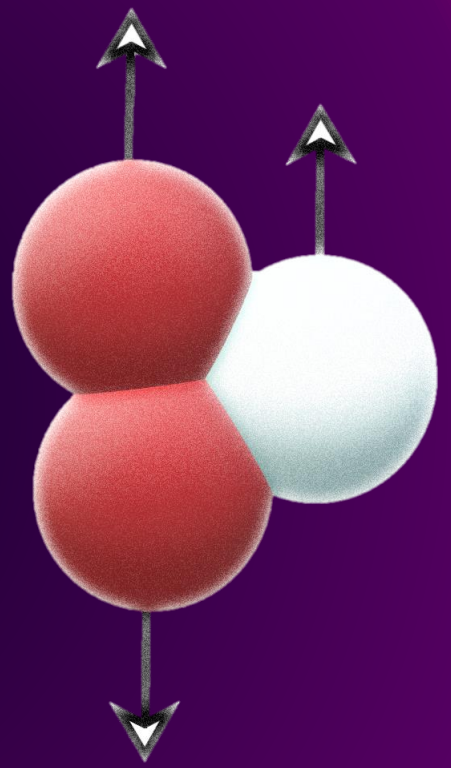
Why do we use ^{3}He?

- ~90% of the time, protons anti-aligned.





The Figure of Merit:

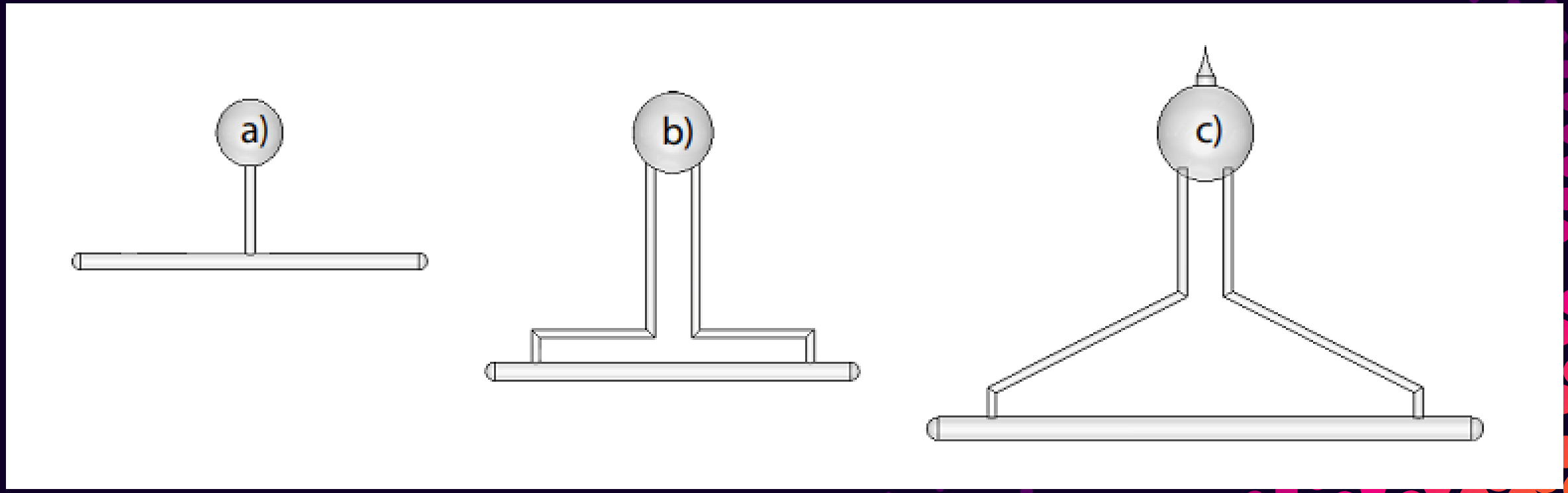
$$\mathcal{L}^{eff} = \mathcal{L}\, P_{He}^2 = I_b \rho_t l_t P_{He}^2$$

$$\mathcal{L} = \left(\frac{1}{\sigma}\right)\left(\frac{dN}{dt}\right)$$

- ⊗ Can't control current, I_b
- ⊗ Maximize other factors to improve target performance

The Figure of Merit:

$$\mathcal{L}^{eff} = \mathcal{L}\, P_{He}^2 = I_b \rho_t l_t P_{He}^2$$



The Figure of Merit:

Target	Kinematic Point	^{3}He Den. (amg)	N_2 Den. (torr)	TC Len. in.	Longest Lifetime Hrs	Max Polarization %	Normalized FOM
Hunter	2, 3	7.387	90.80	23.401	18.098	48.274	2.323
Windmill	3	6.993	90.70	23.750	23.299	46.900	2.291
Fringe	4	6.711	90.13	23.670	16.077	42.334	2.061
Chicago	4	6.890	91.28	23.755	4.590	26.522	1.296

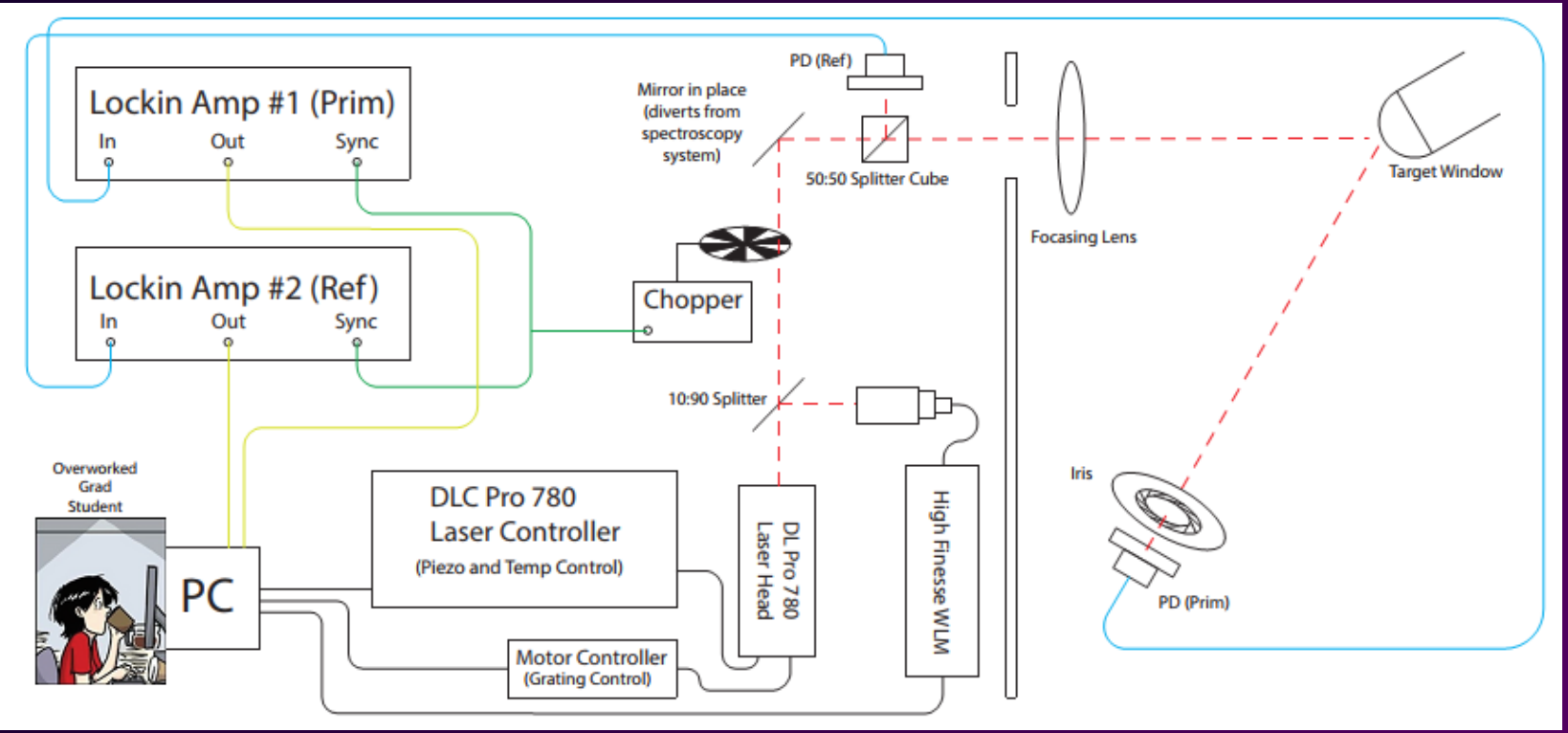
Effective Luminosity for G_E^n Targets, normalized to Big Brother

Target	Experiment	^{3}He Den. (amg)	N_2 Den. (torr)	TC Len. in.	Longest Lifetime Hrs	Max Polarization %	Normalized FOM
Fulla	A1n	6.332	91.70	15.875	26.537	58.452	0.954
Brianna	A1n	6.938	95.93	15.551	19.889	56.122	0.89
Dutch	A1n	7.759	94.69	15.625	20.430	38.239	0.614
Tommy	d2n	7.760		15.748	15.398	52.998	0.858
Big Brother	A1n	6.992	89.52	15.750	23.424	61.748	1.000
Austin	d2n	7.498	93.75	15.686	18.705	56.668	0.914
Butterball	d2n	7.608	93.30	15.611	14.307	56.136	0.901

Effective Luminosity for A_1^n Targets, normalized to Big Brother

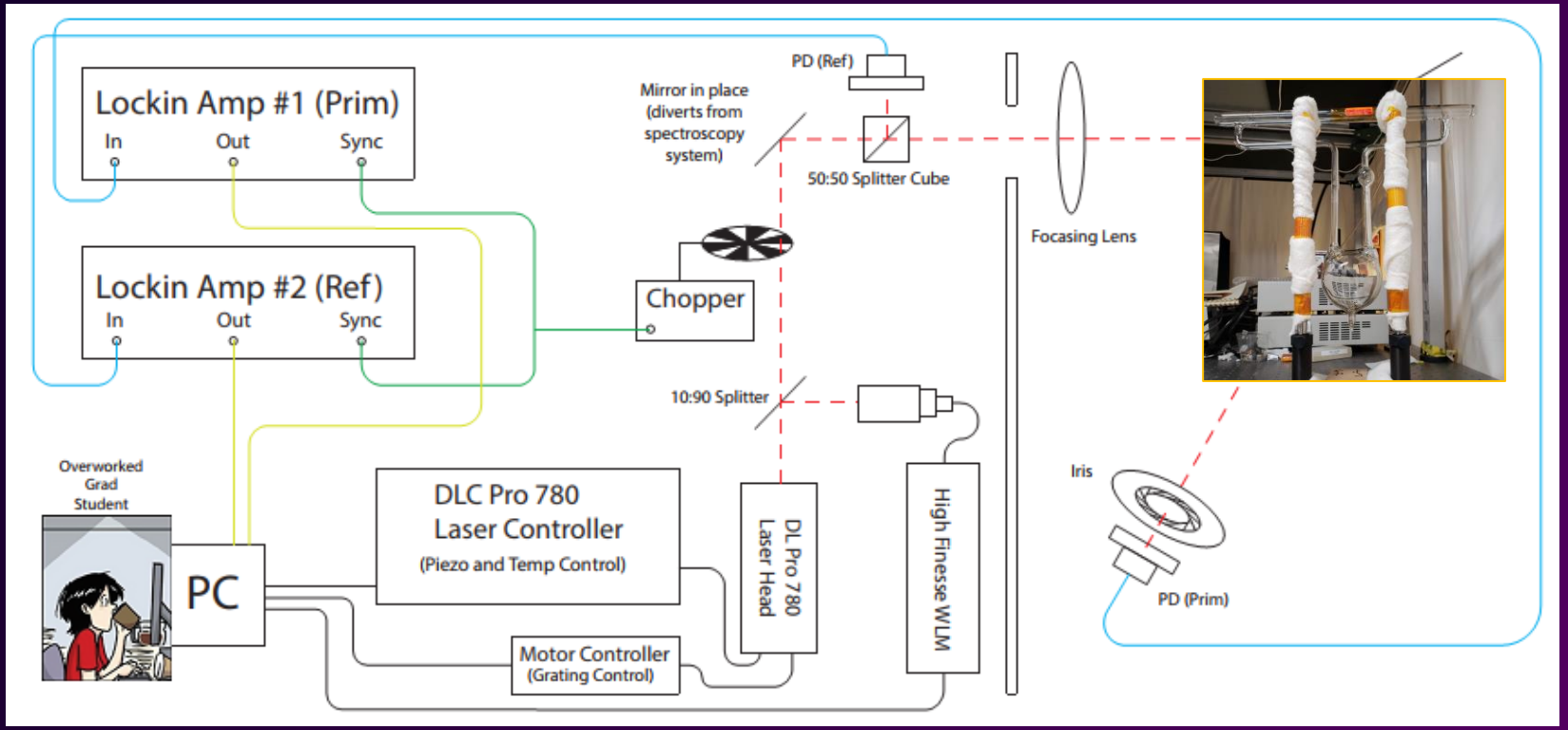
CONSTRUCTING A TARGET: WINDOWS

- Pressure tested



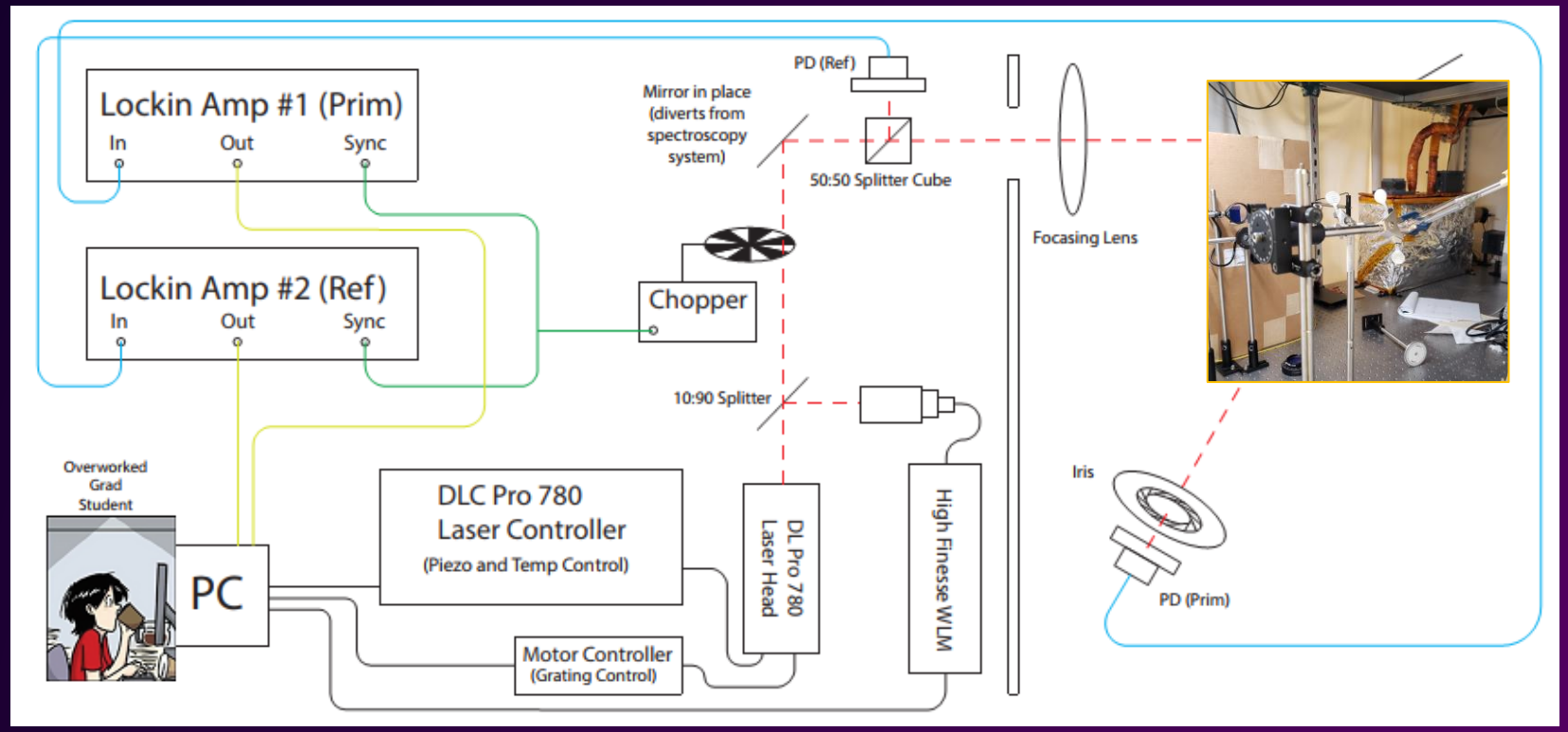
CONSTRUCTING A TARGET: WINDOWS

- Pressure tested
- Measure Window Depth



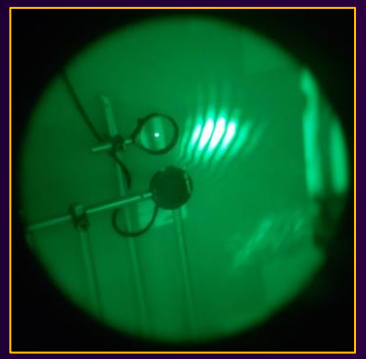
CONSTRUCTING A TARGET: WINDOWS

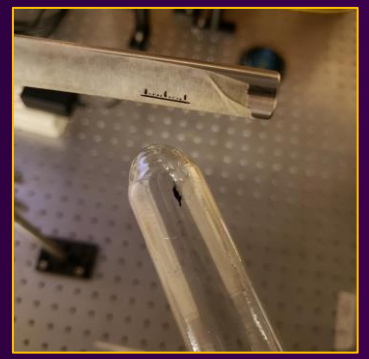
- Pressure tested
- Measure Window Depth
  - A_1^n – Hang Target

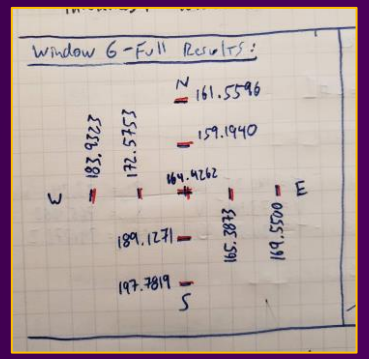


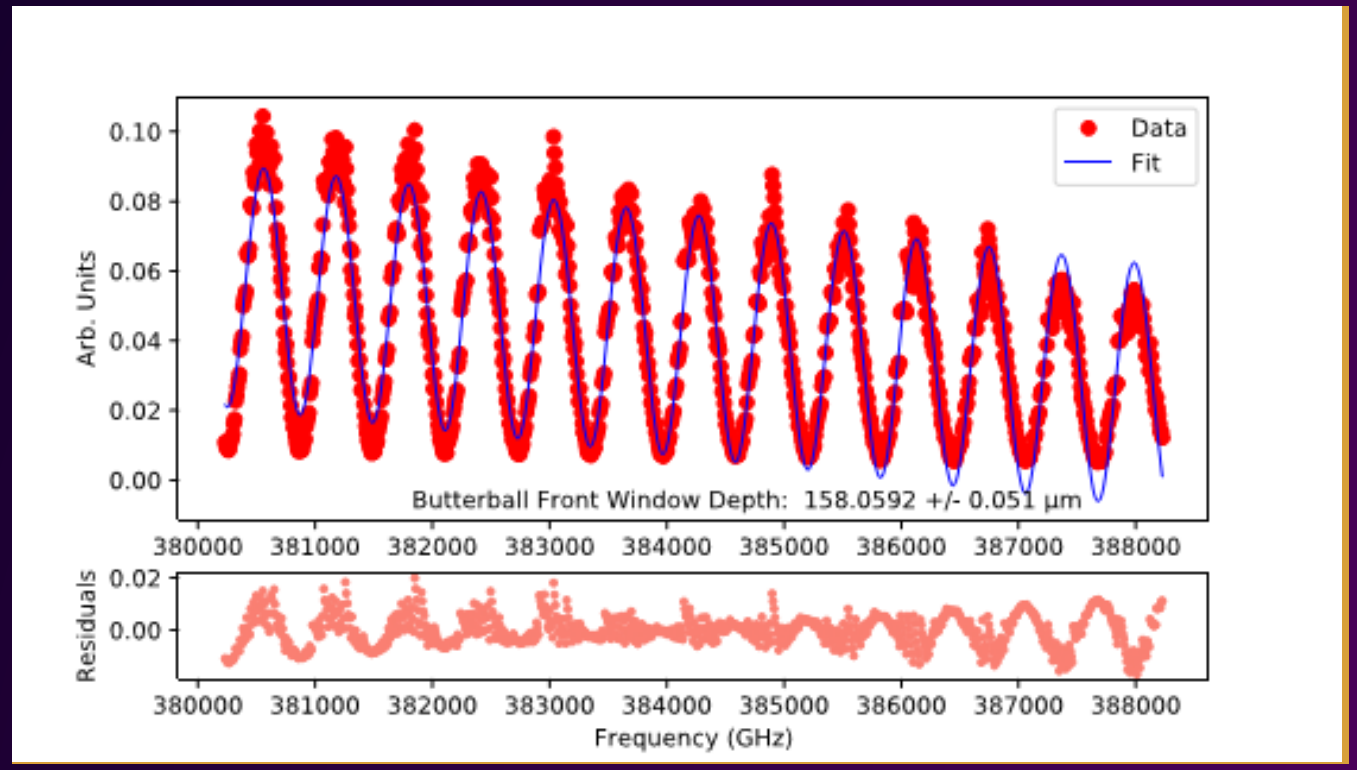
CONSTRUCTING A TARGET: WINDOWS

- Pressure tested
- Measure Window Depth
  - A_1^n – Hang Target
  - G_E^n – Ship separate





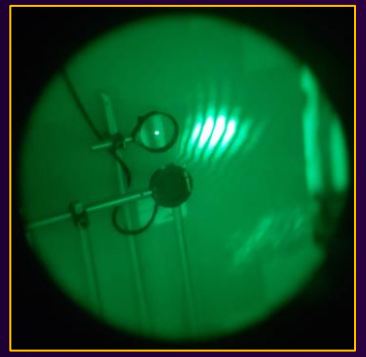


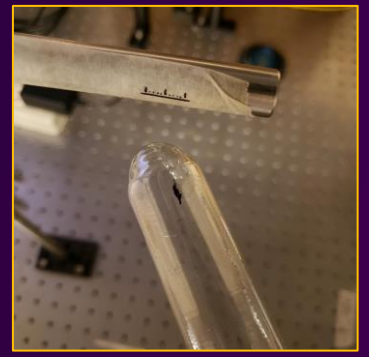


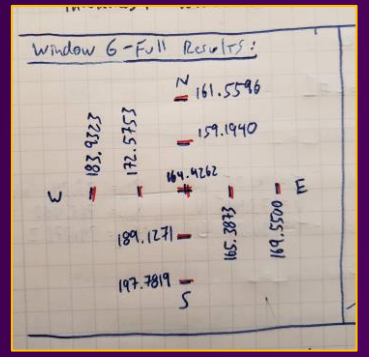
CONSTRUCTING A TARGET: WINDOWS

- Pressure tested
- Measure Window Depth
  - A_1^n – Hang Target
  - G_E^n – Ship separate
- Minimize Angle

$$R = \frac{F \sin^2(\phi/2)}{1 + F \sin^2(\phi/2)}$$







$$\phi = \frac{4\pi f}{c} d \sqrt{n_g^2 - n_a^2 \sin^2(\theta)} + \Delta\phi$$

(Old target on old system – reference only)

CONSTRUCTING A TARGET: THE FILL

- Evacuate

CONSTRUCTING A TARGET: THE FILL

- Evacuate
- Drive Alkali into PC

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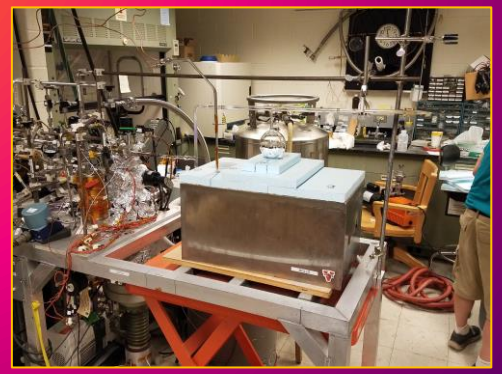
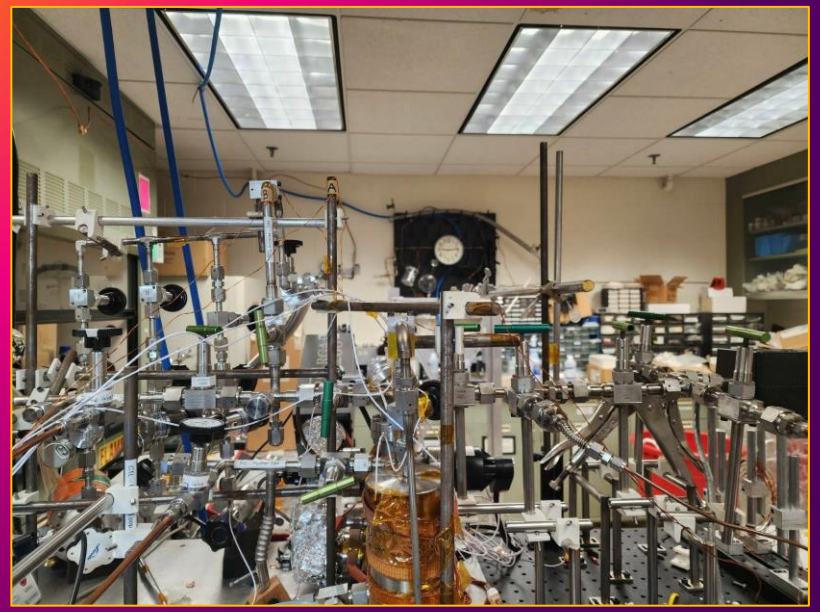


(Old target on old system – reference only)

CONSTRUCTING A TARGET: THE FILL

- Evacuate
- Drive Alkali into PC
- Add N_2
  - ~90 Torr
  - LN_2 Cold Trap
- Add ^3He
  - ~7 amagats
  - Lhe Cold Trap



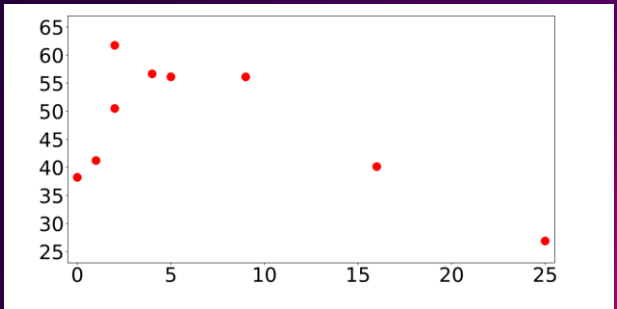
CONSTRUCTING A TARGET: THE FILL

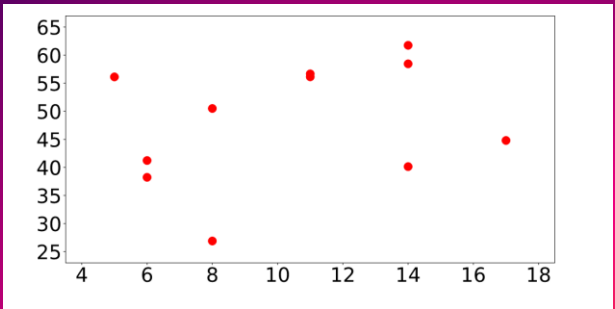
- Evacuate
- Drive Alkali into PC
- Add N_2
  - ~90 Torr
  - LN_2 Cold Trap
- Add ^3He
  - ~7 amagats
  - Lhe Cold Trap
- Pull
- Minimize Contaminants
  - Redesigned by Huong Nguyen
  - Added Bakeout Oven
  - Moved Cold Trap

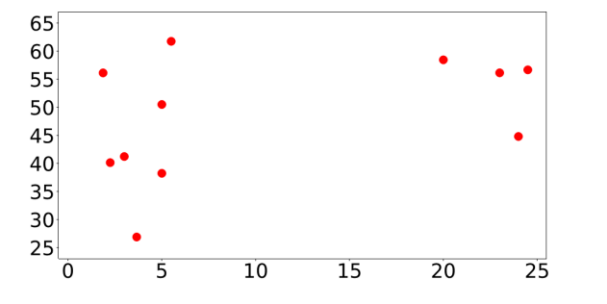
CONSTRUCTING A TARGET: PRODUCTION VARIABLES

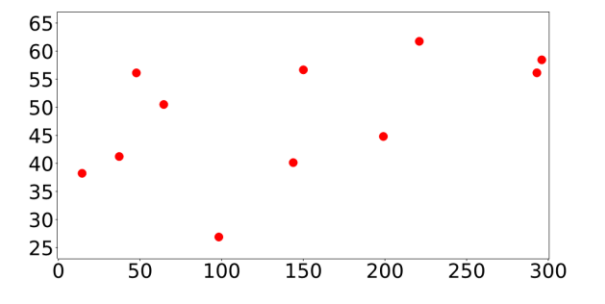
- Receipt to Assembly
- Assembly to Bake
- Bake Time
- Bake Temp
- Number of Flame bakes
- Chase to Fill

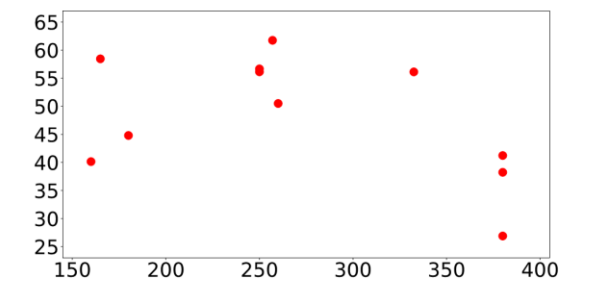
CONSTRUCTING A TARGET: PRODUCTION VARIABLES

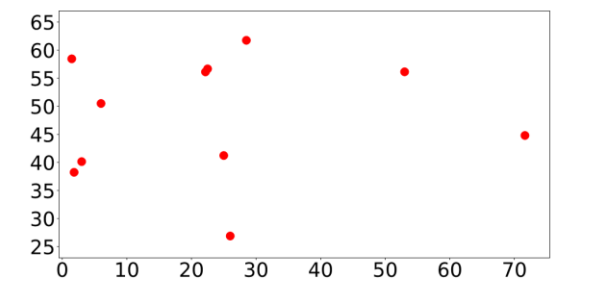




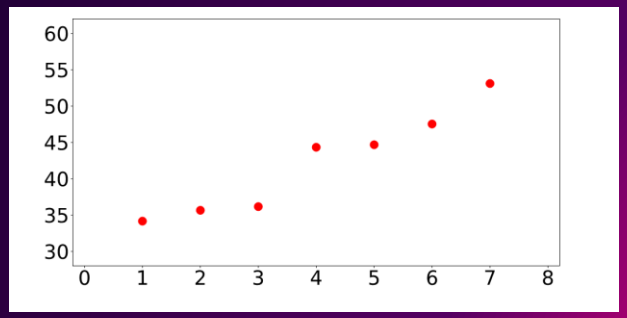


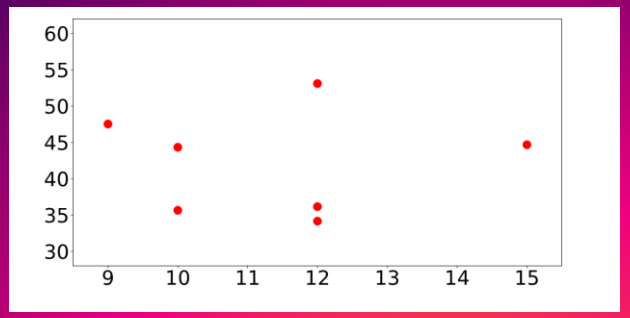


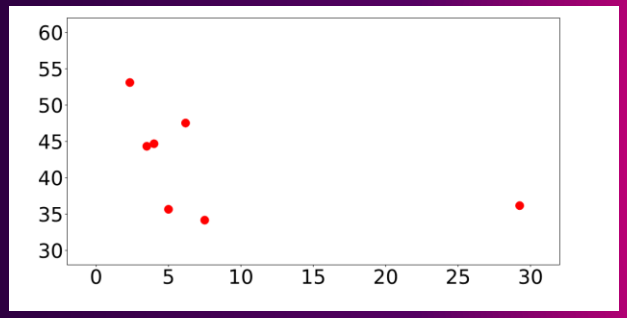


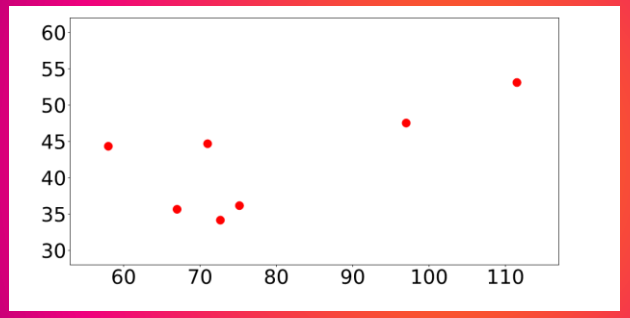


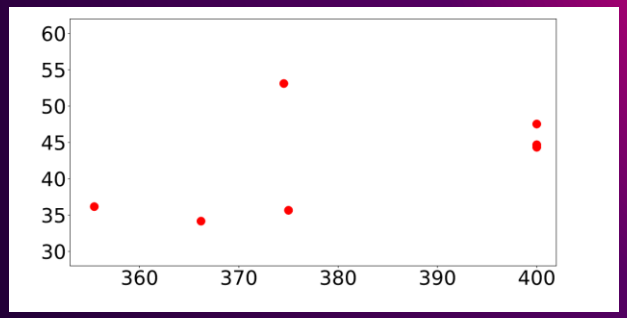
- From Top Left…
  - Receipt to Assembly
  - Assembly to Bake
  - Bake Time
  - Bake Temp
  - Number of Flame bakes
  - Chase to Fill
- For A_1^n / d_2^n Targets…

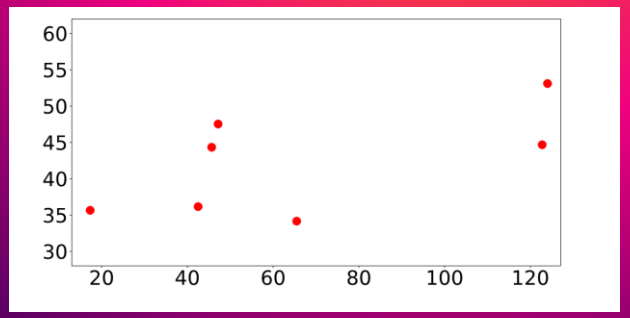








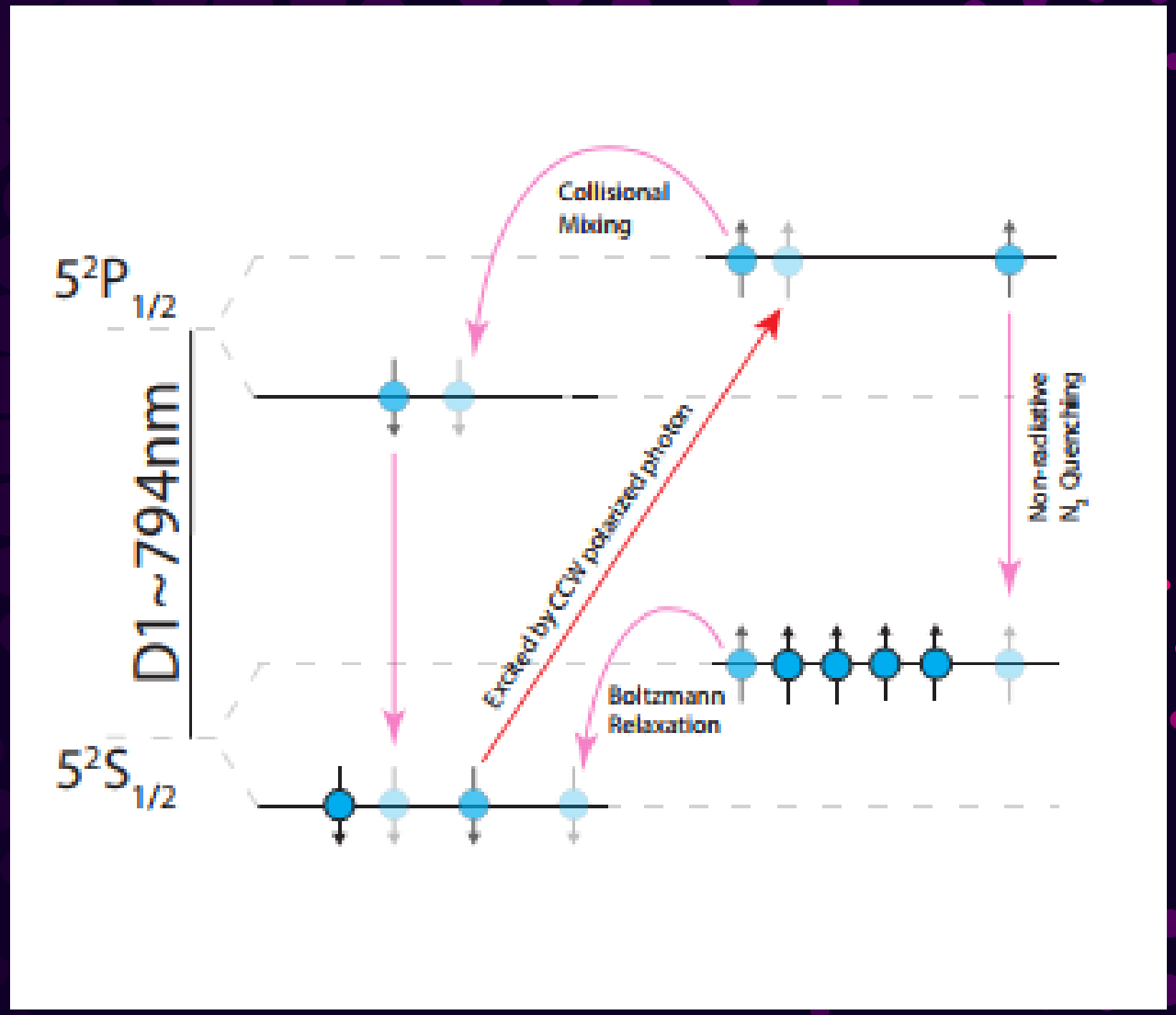


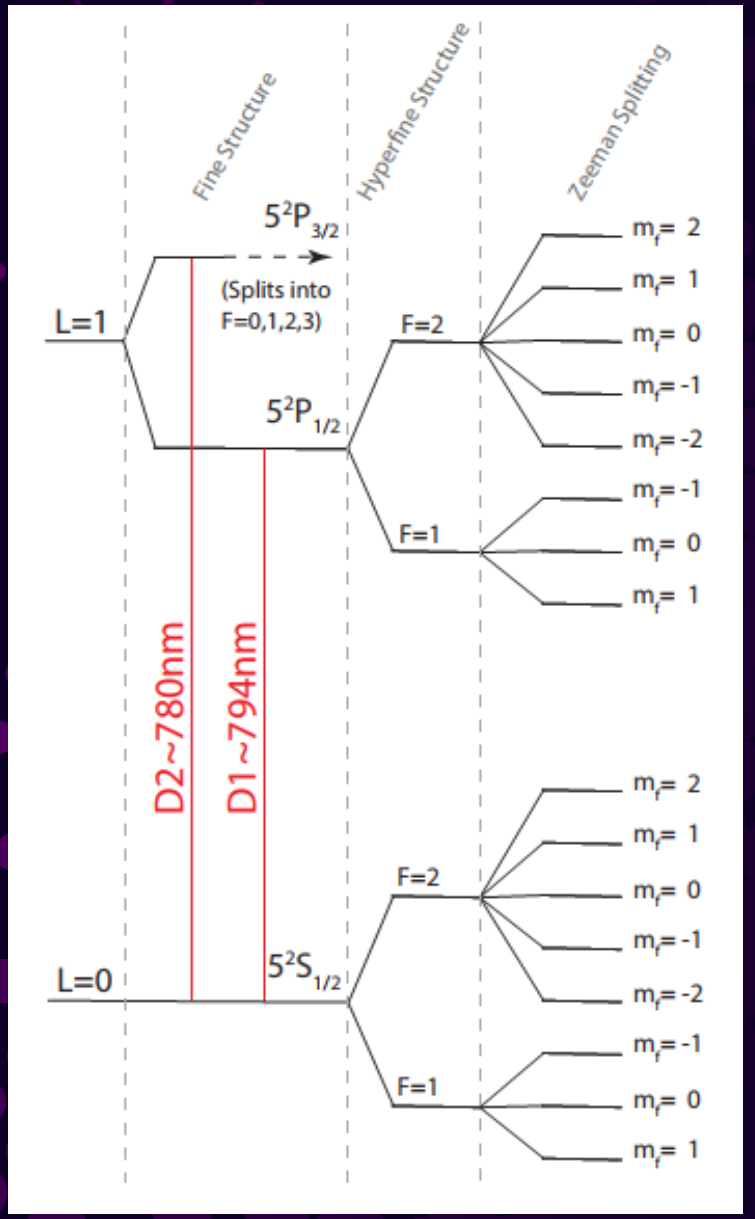


CONSTRUCTING A TARGET: PRODUCTION VARIABLES

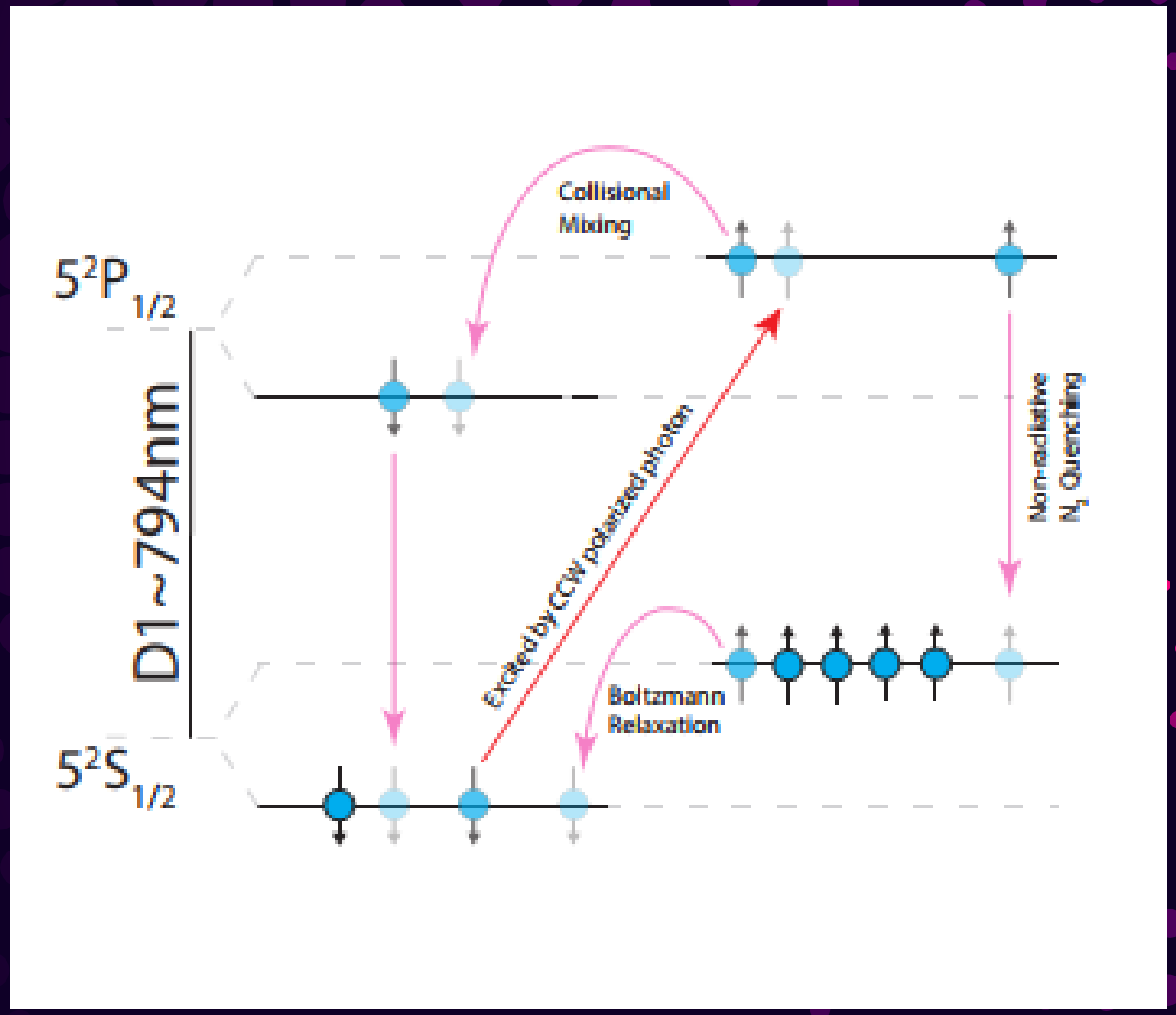
- From Top Left…
  - Receipt to Assembly
  - Assembly to Bake
  - Bake Time
  - Bake Temp
  - Number of Flame bakes
  - Chase to Fill
- For A_1^n / d_2^n Targets…
  - …and G_E^n Targets.
- Limited Data Set

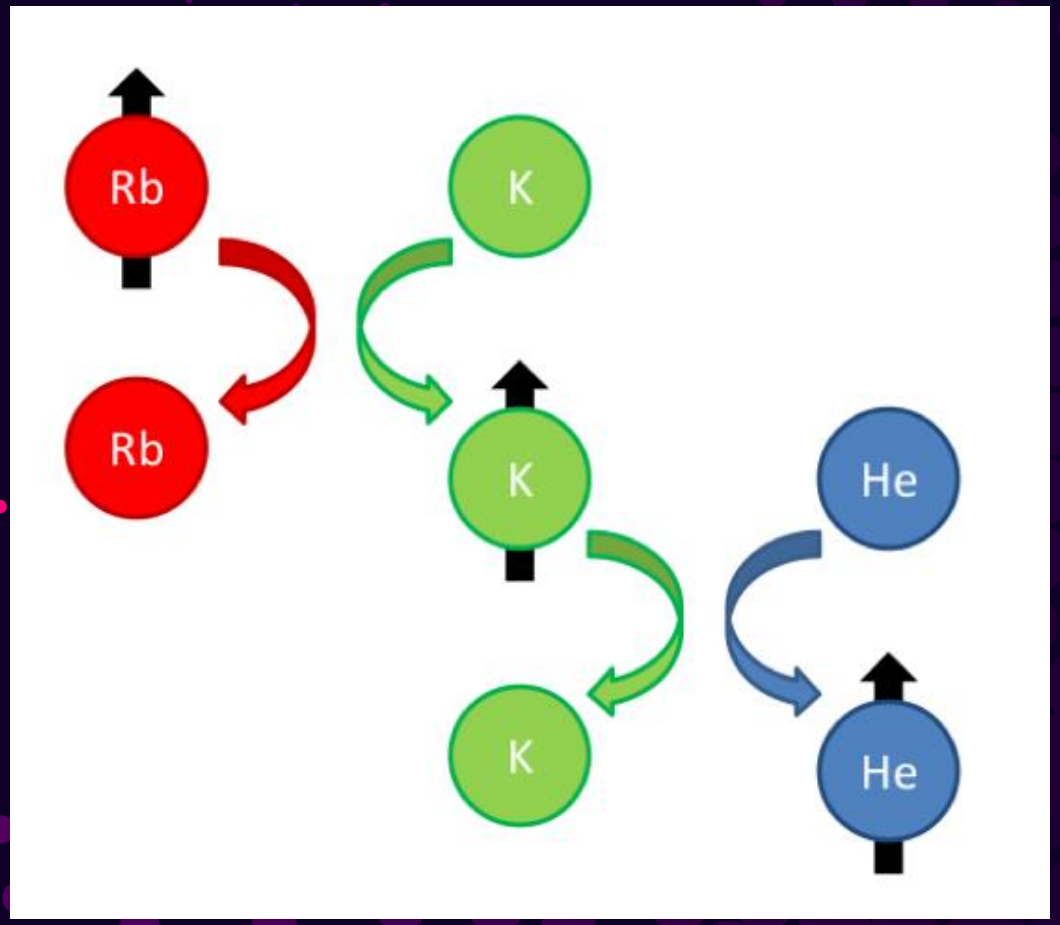
NMR / EPR: (AH)SEOP



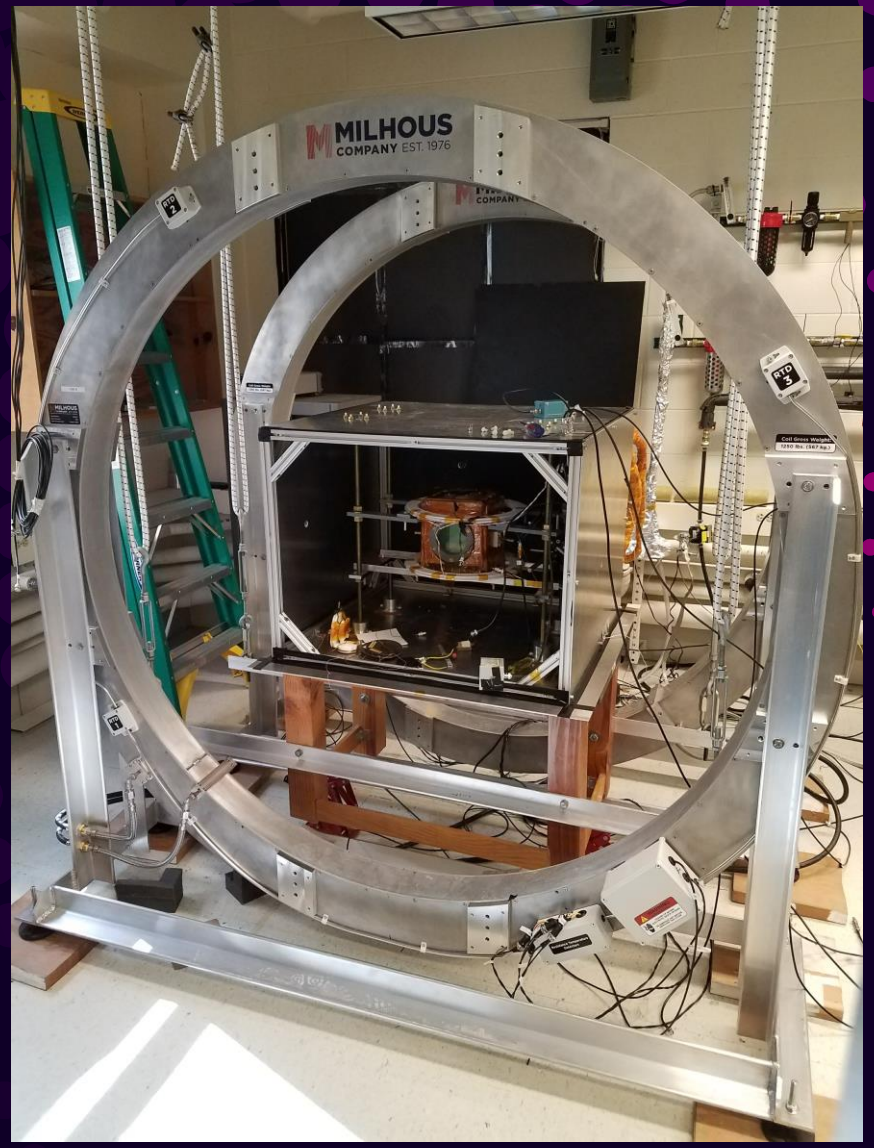


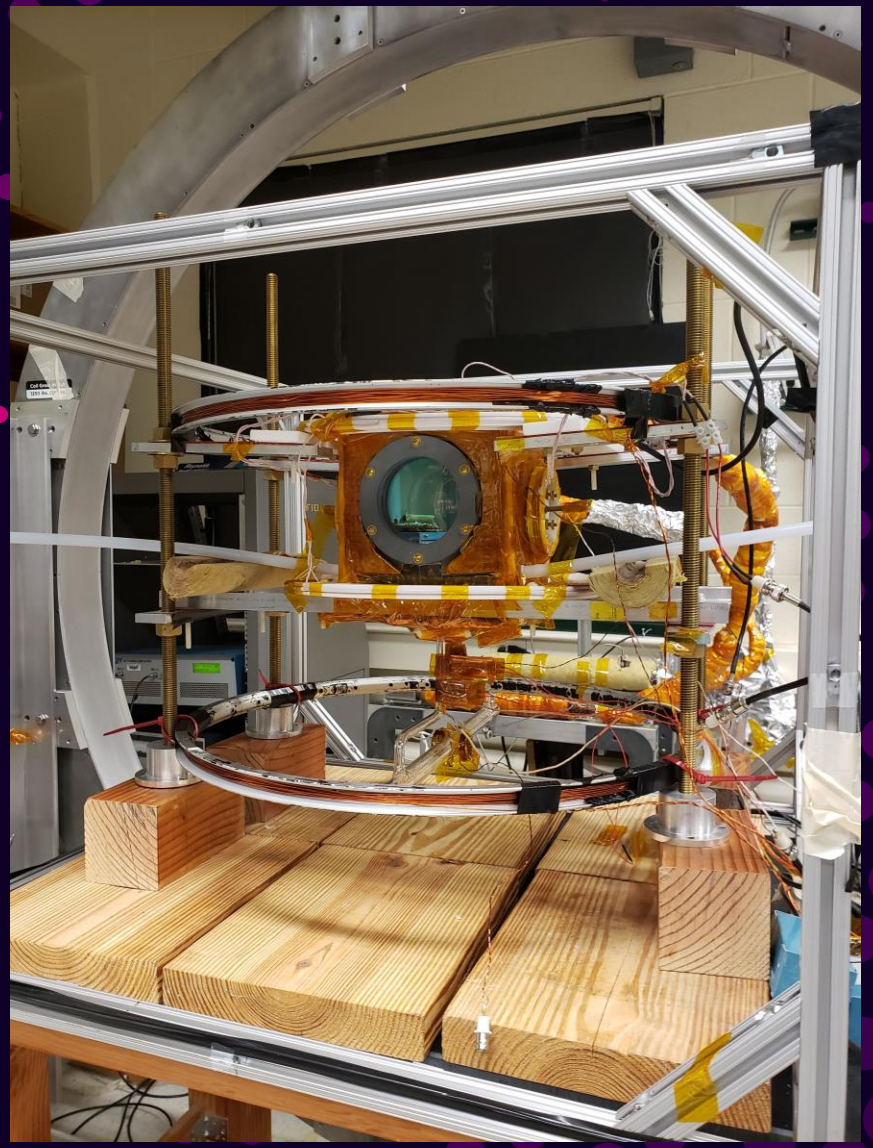
NMR / EPR: (AH)SEOP



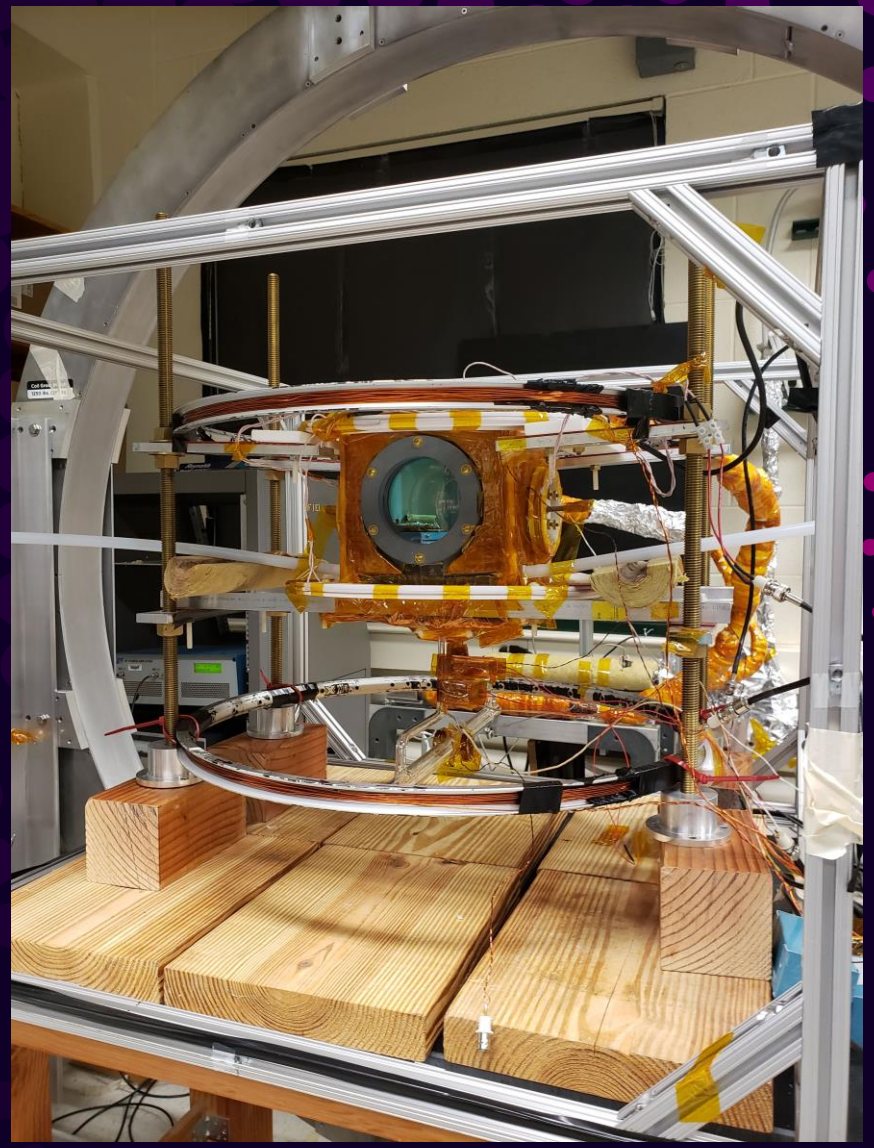


NMR / EPR: Upgrade



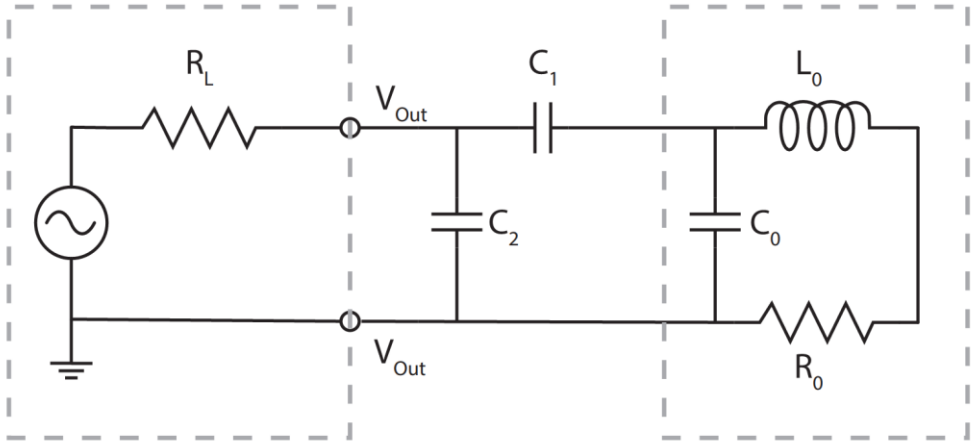


NMR / EPR: Upgrade

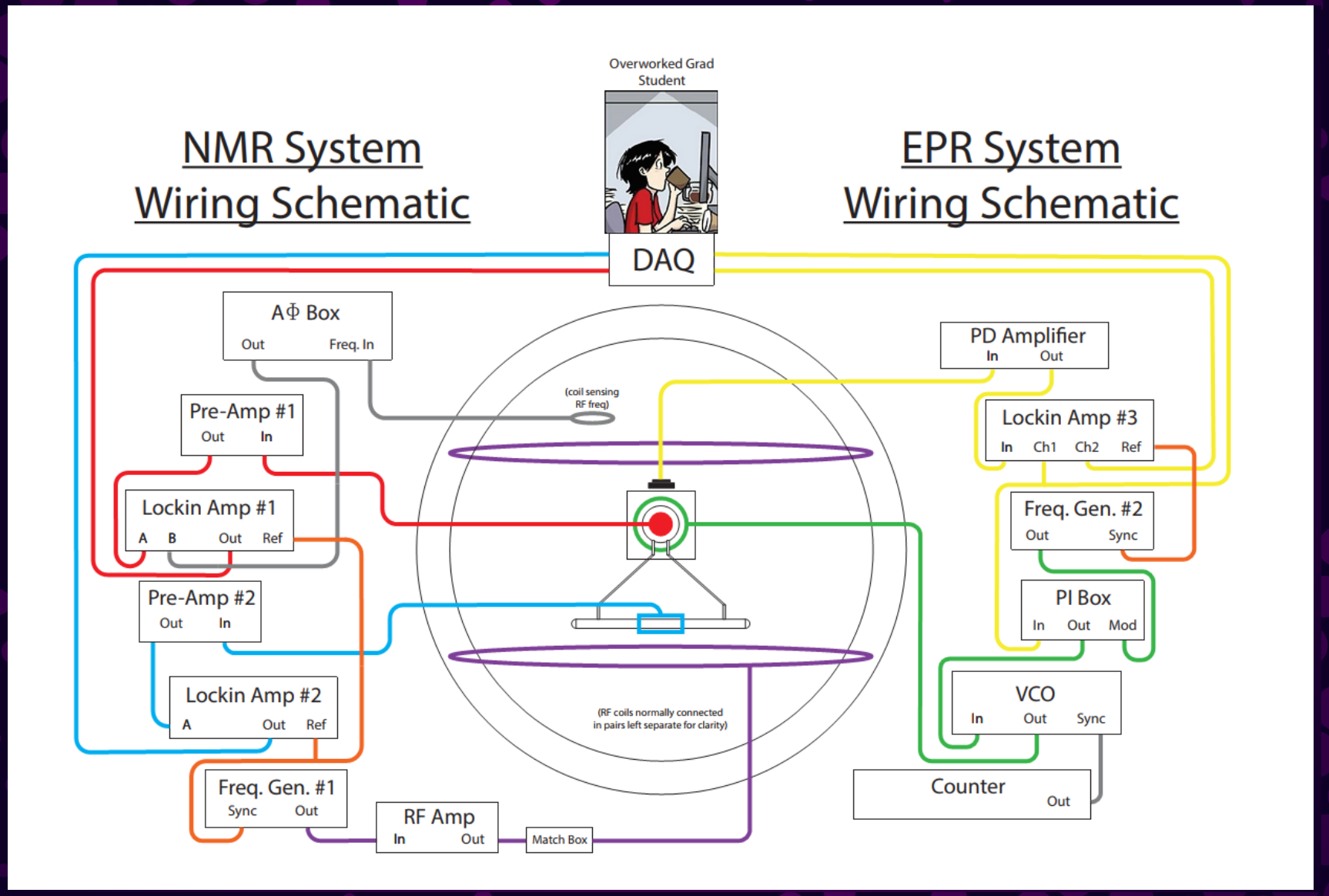


NMR / EPR: Upgrade

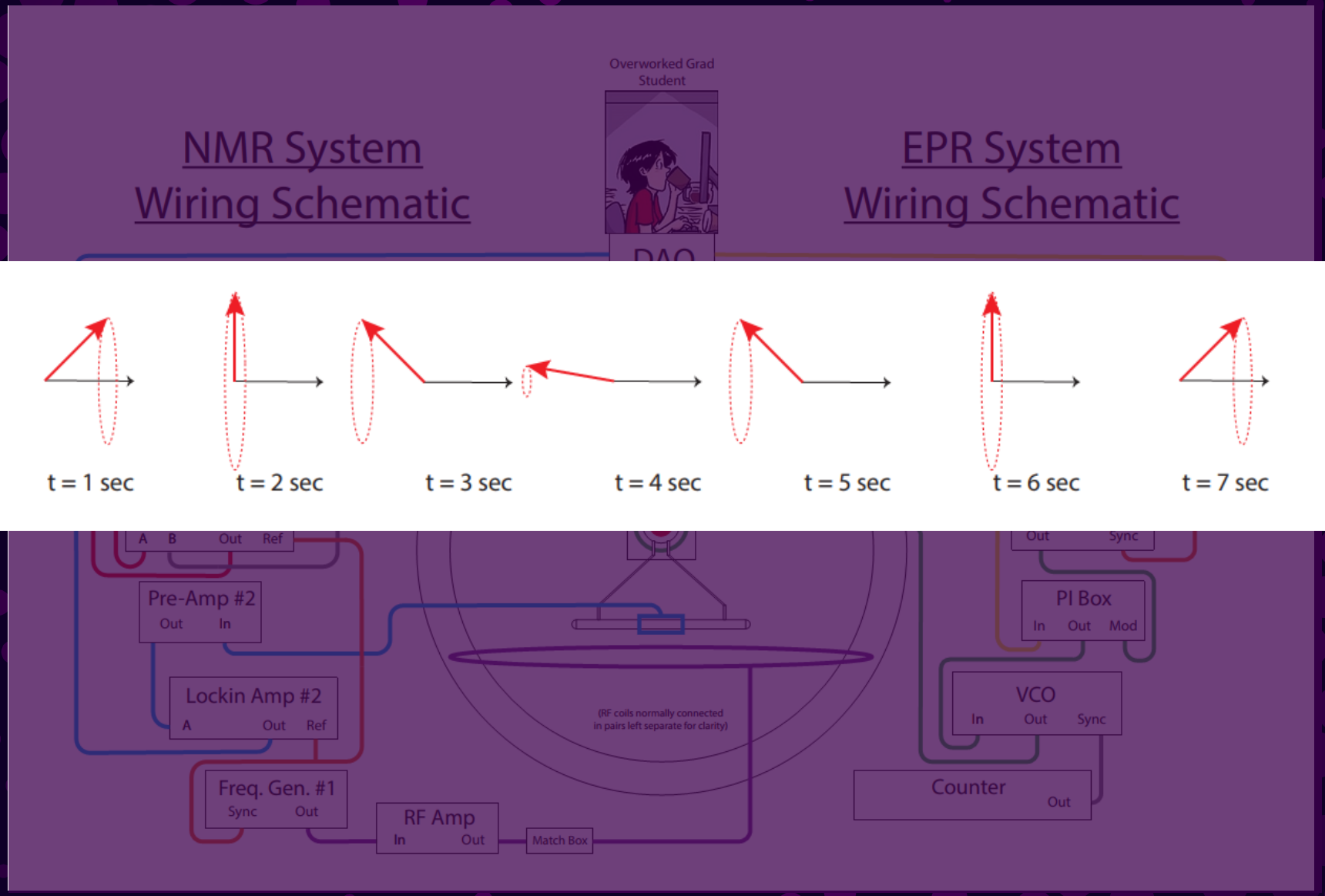
$$\omega_0 = \sqrt{\frac{1}{LC} - \left(\frac{R}{L}\right)^2}$$



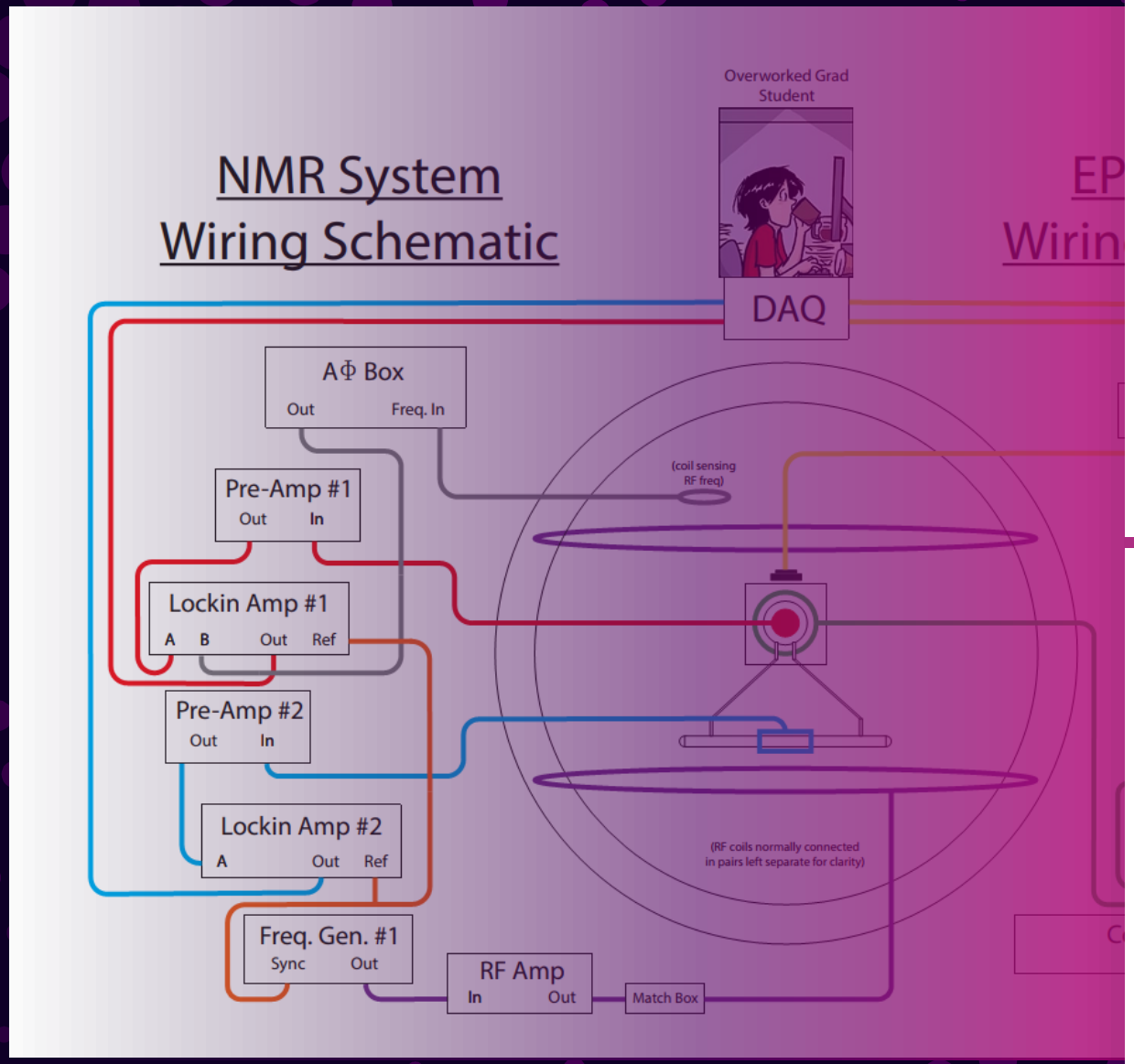
NMR / EPR: System

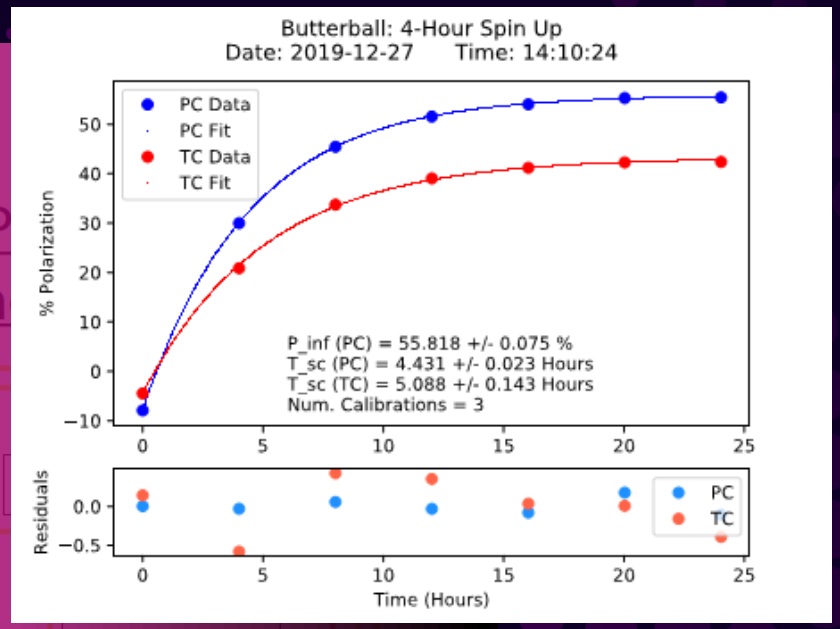


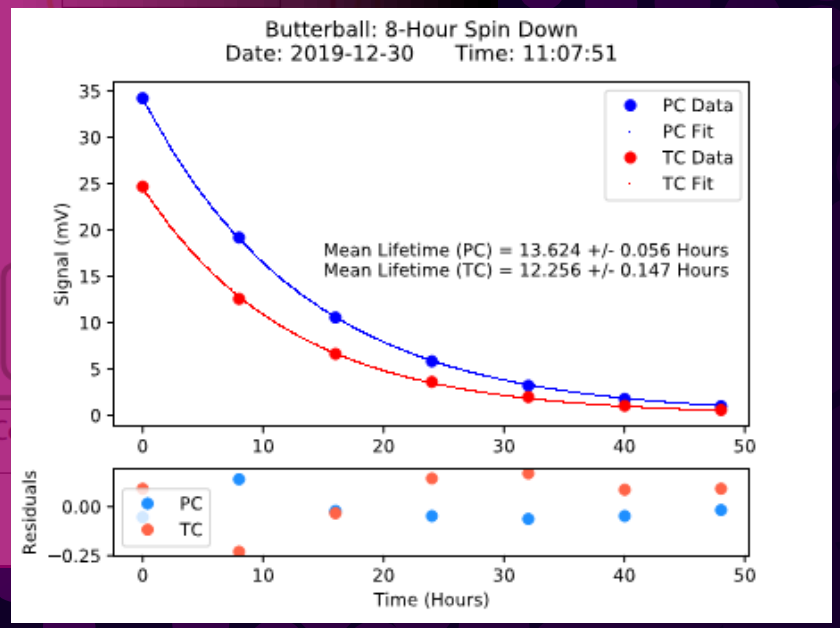
NMR / EPR: Tests



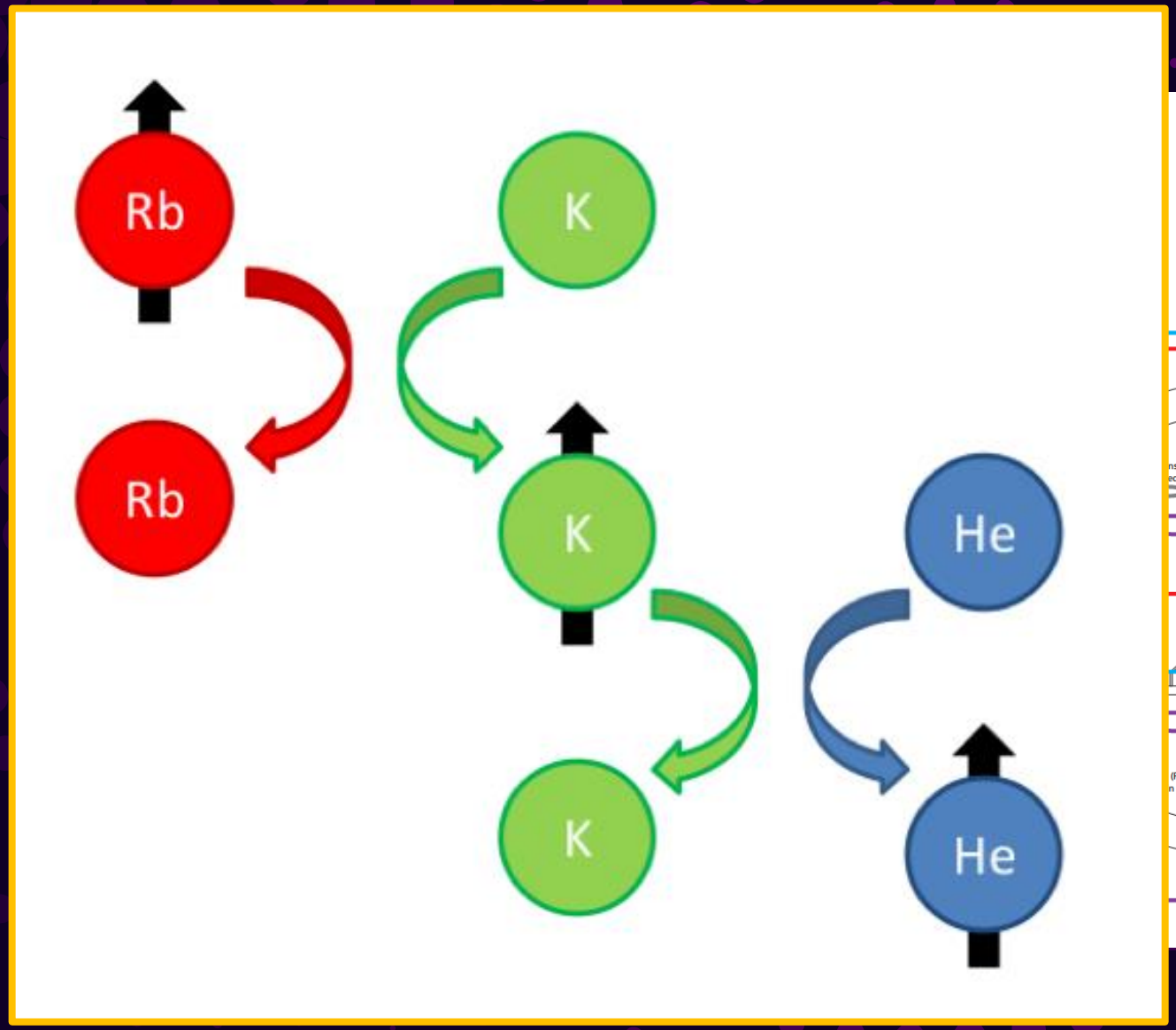
NMR / EPR: Tests

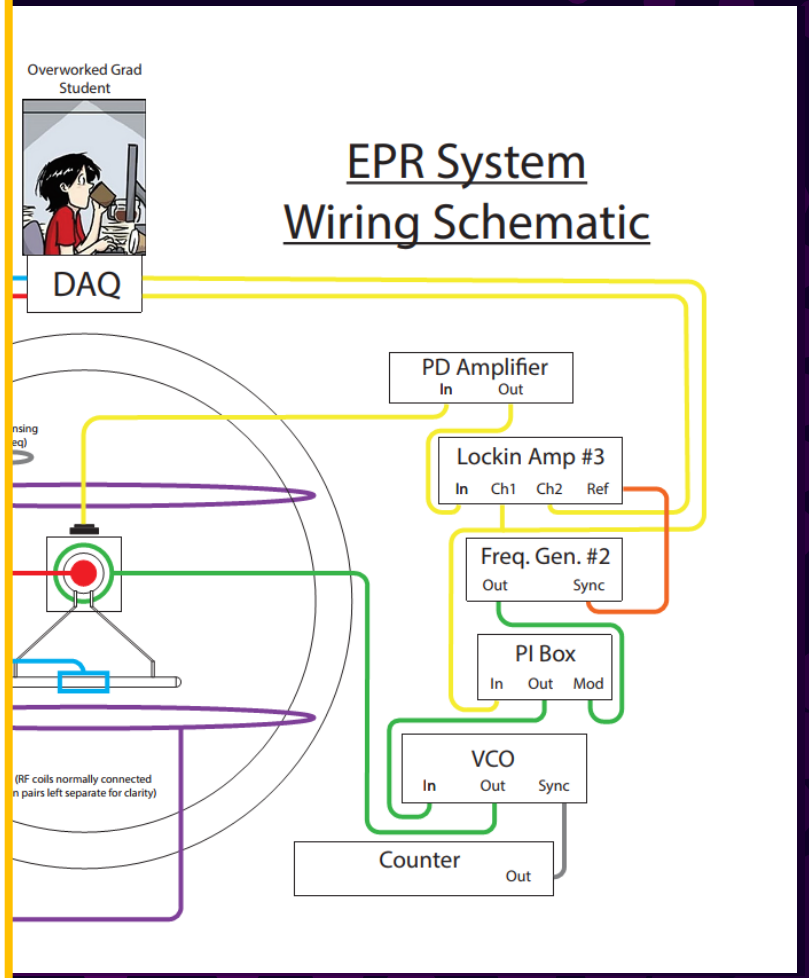




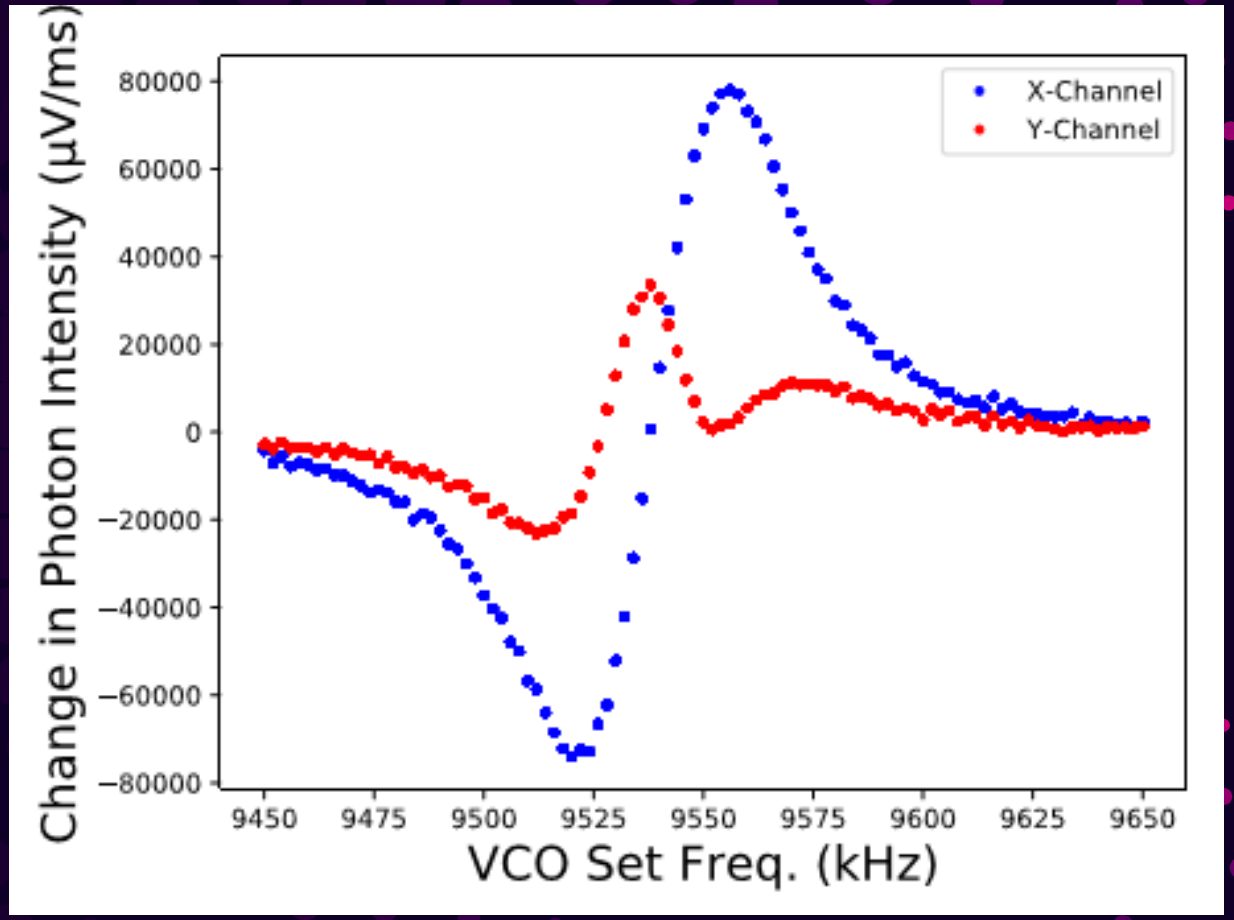


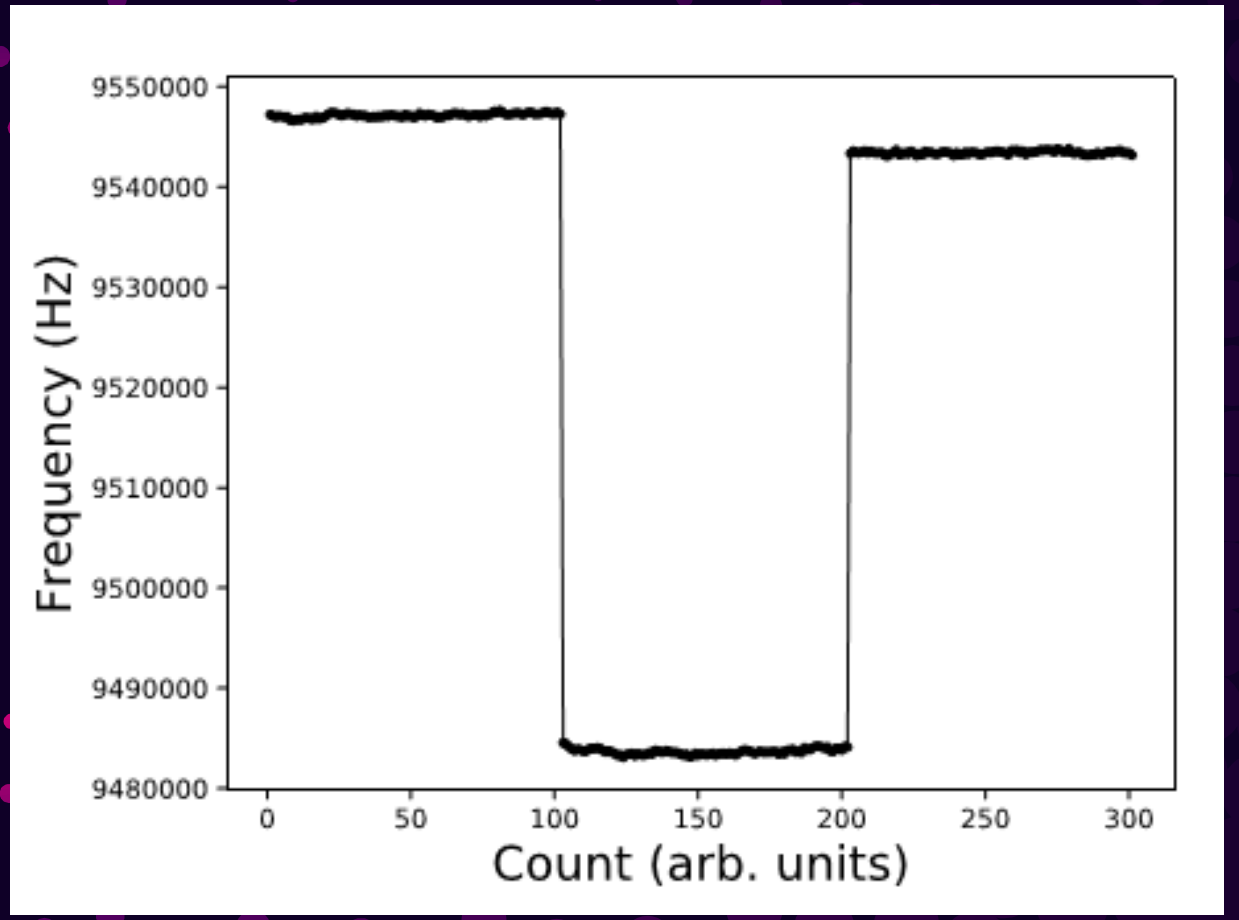
NMR / EPR: Calibration





NMR / EPR: Calibration



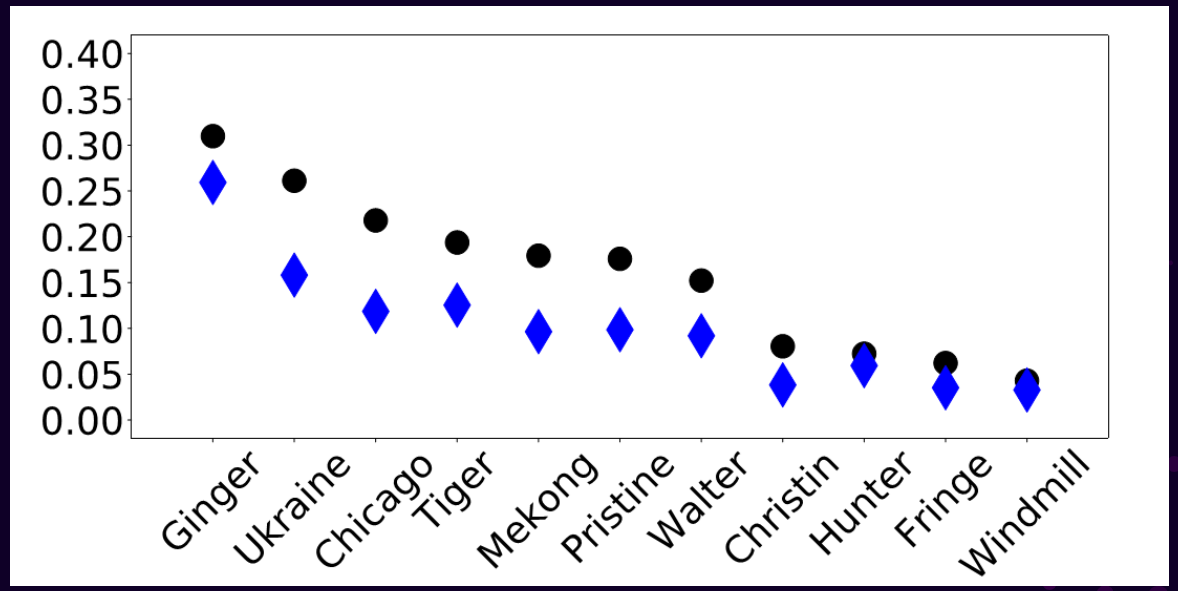


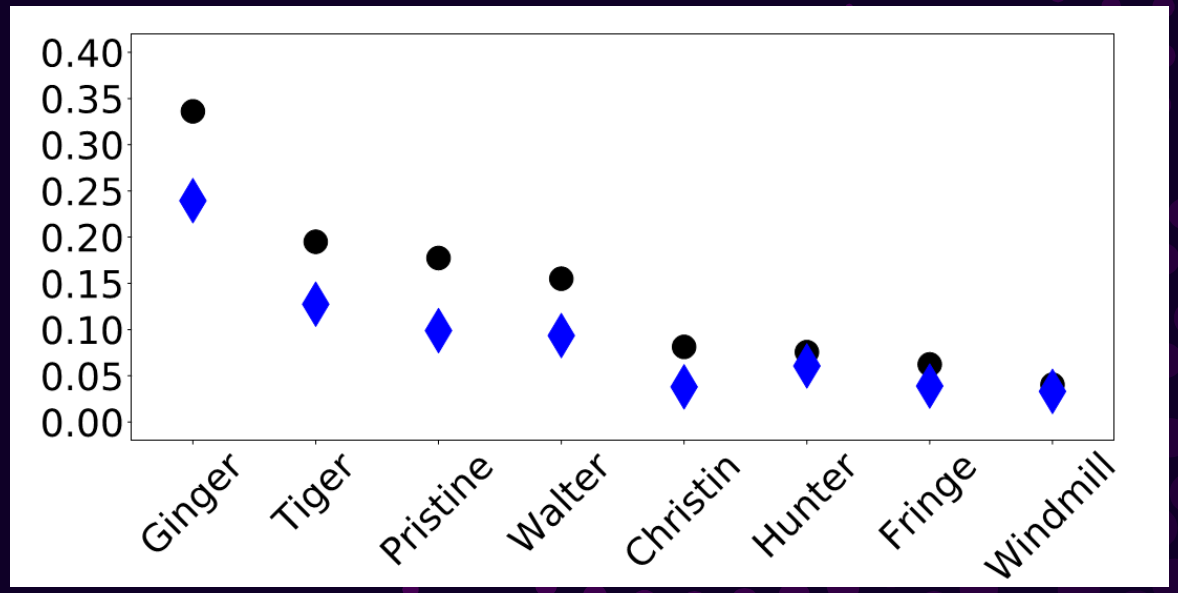
NMR / EPR: Hysteresis

- RF Freq Diff from Jlab
  - UVa – 154 kHz
  - Jlab – 91 kHz
- Otten, et al

NMR / EPR: Hysteresis

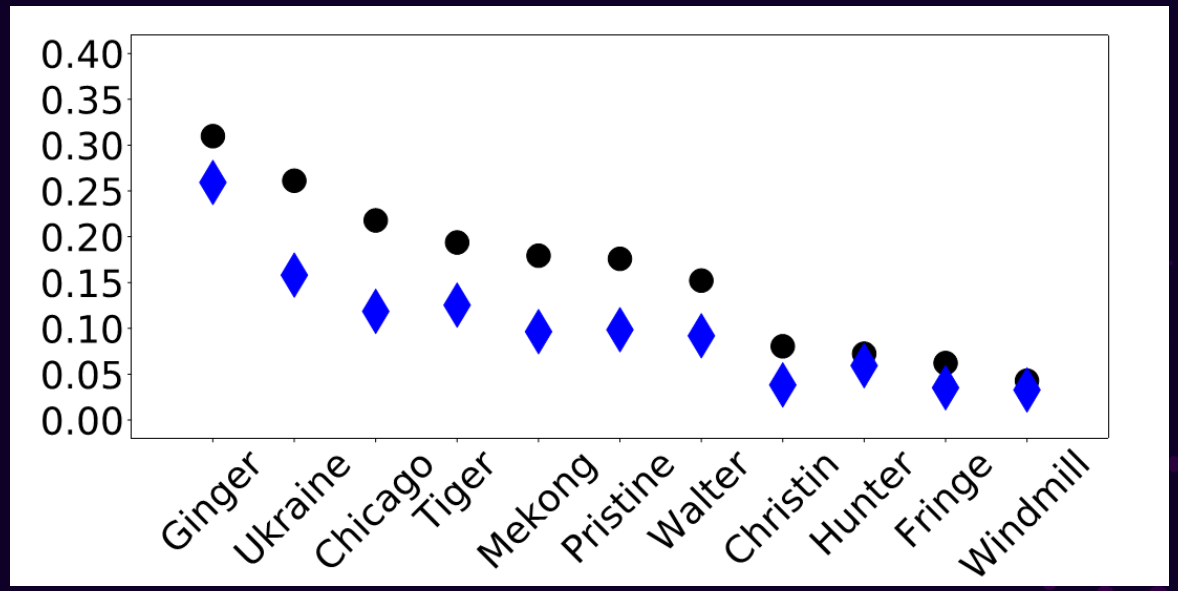
- RF Freq Diff from Jlab
  - UVa – 154 kHz
  - Jlab – 91 kHz
- Otten, et al
- Both Chambers
  - Top – PC
  - Bottom – TC
- Relaxation Rates
  - Black – Initial
  - Blue – Final

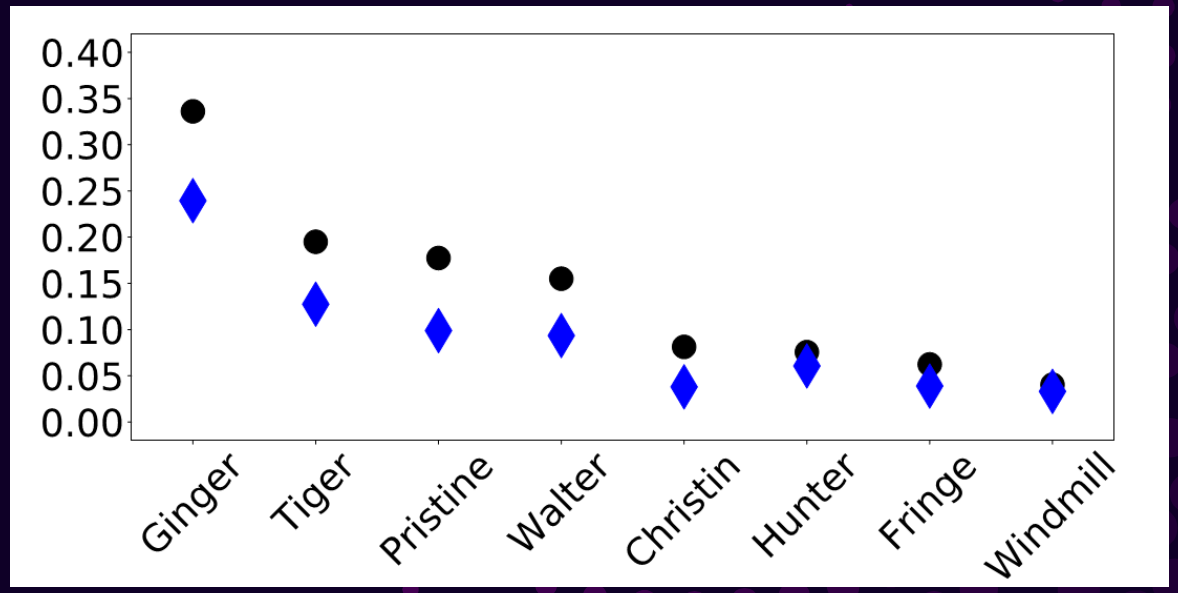




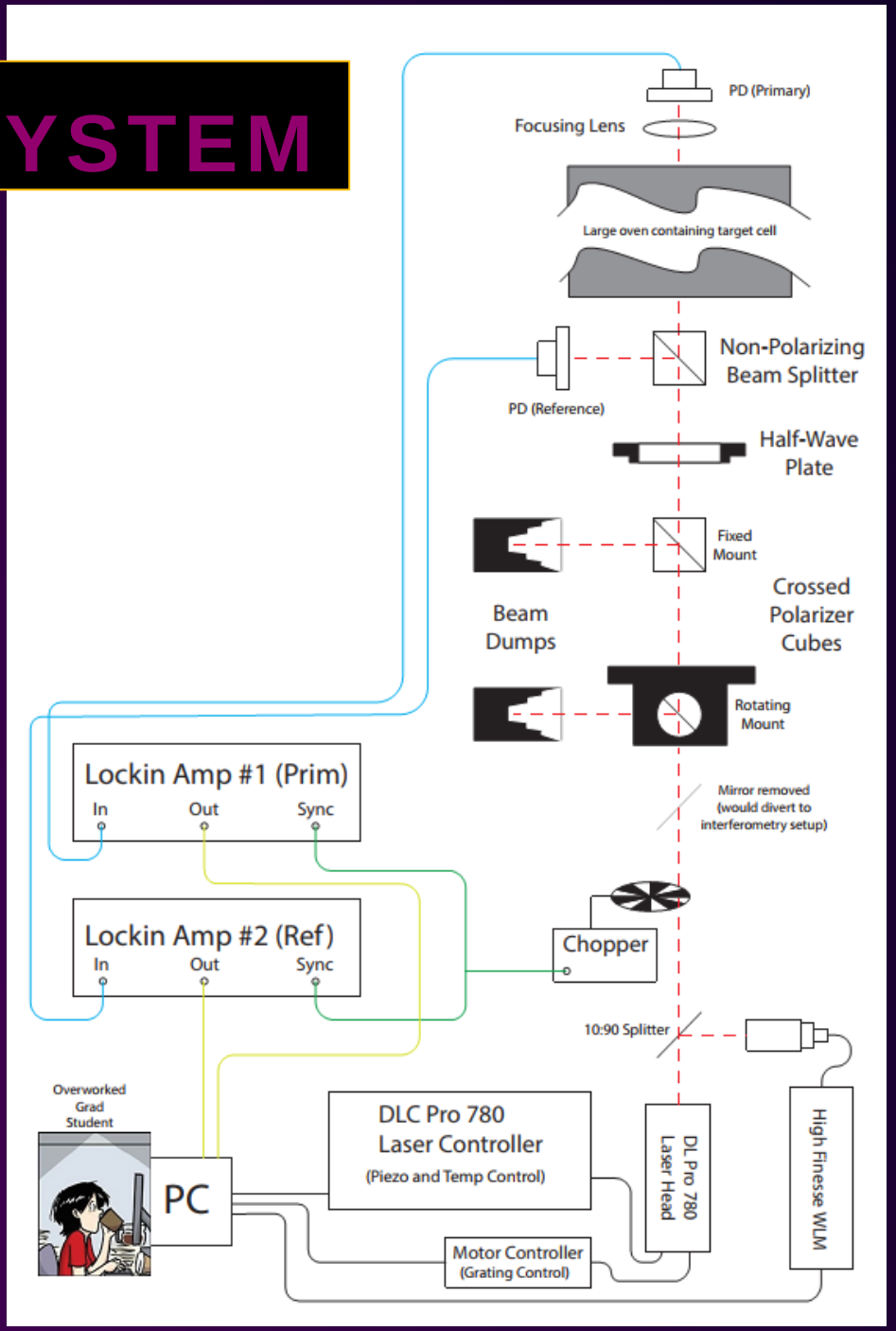
NMR / EPR: Theory

- Stress in glass
  - PC Larger
  - Micro fissures
  - Higher field



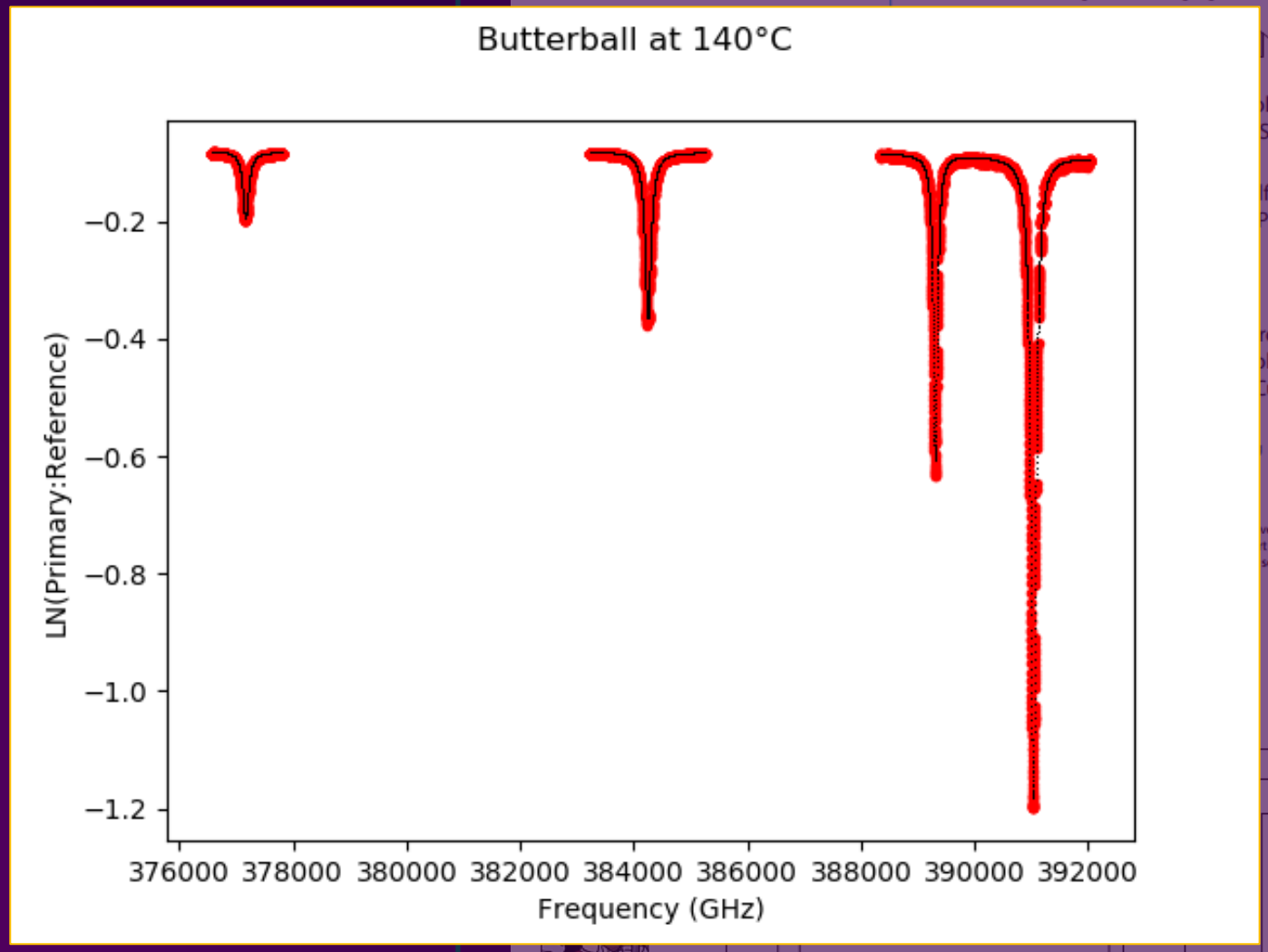


SPECTROSCOPY: SYSTEM



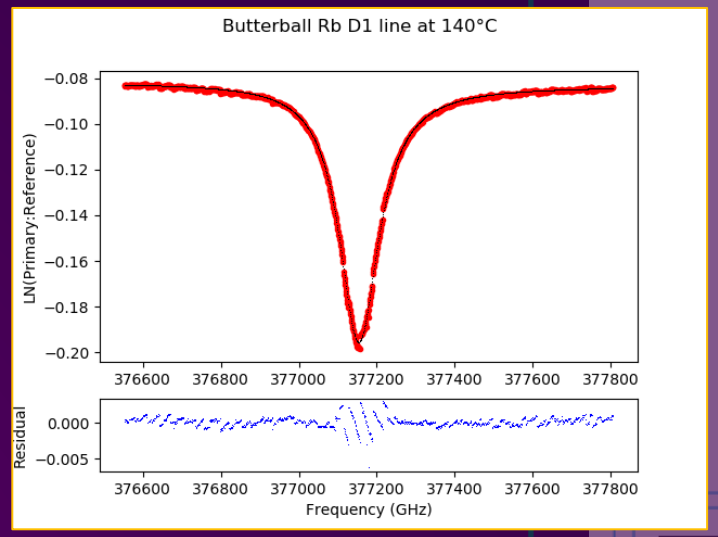
SPECTROSCOPY: SCAN

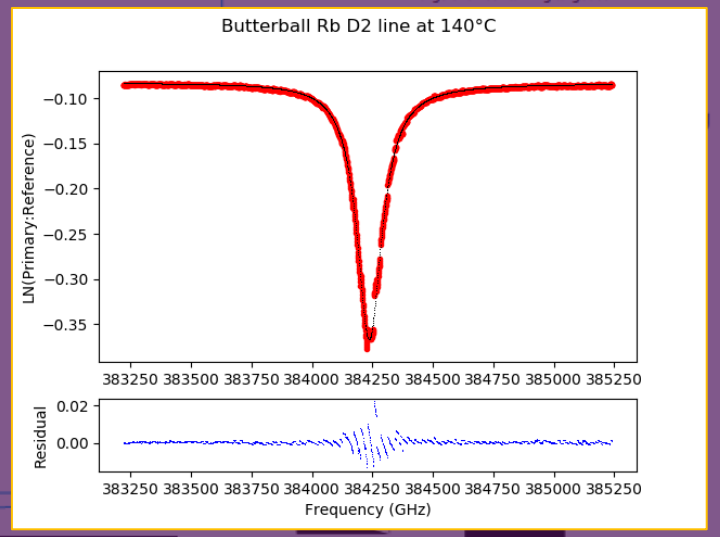
- Set Power
  - P < 25 uW at min
  - P ~ 300 uW at max
- 3 Scans, 4 lines
  - Rb D1
  - Rb D2
  - K D1 and D2 together

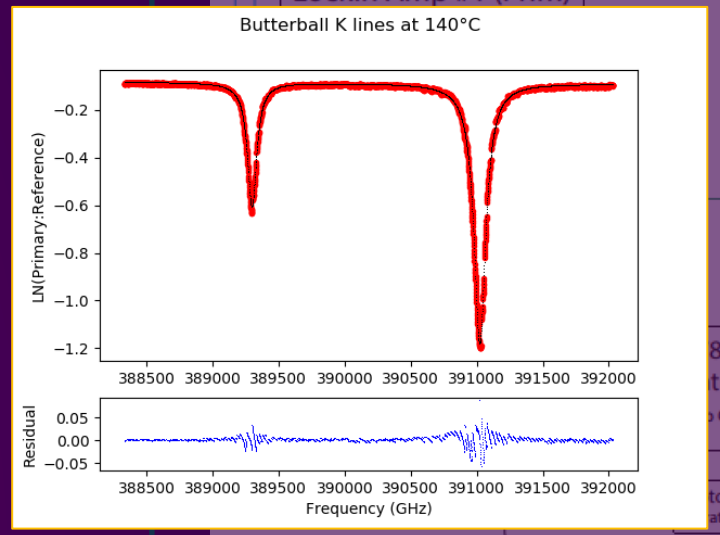


SPECTROSCOPY: SCAN

- Set Power
  - P < 25 uW at min
  - P ~ 300 uW at max
- 3 Scans, 4 lines
  - Rb D1
  - Rb D2
  - K D1 and D2 together







Spectroscopy: ^{3}He Density Analysis

$$\Gamma(\xi) = n v_{\mathrm{th}} 8 \pi R_{\mathrm{th}}^2 I(\xi T_d)$$

Spectroscopy: ^{3}He Density Analysis

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$$\begin{aligned}
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\langle \sigma v \rangle_{\text{pb}} (x(T)) &= 8\pi R_{\text{th}}^2(T) v_{\text{th}}(T) f(x(T)) \\
v_{\text{th}}(T) &= \sqrt{\frac{2kT}{\mu}} \\
R_{\text{th}}(T) &= \sqrt[5]{|C_6| v_{\text{th}}^{-1}} \\
T_d(T) &\equiv \frac{R_{\text{th}}}{v_{\text{th}}} = \sqrt[5]{|C_6| v_{\text{th}}^{-6}}
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$$\Gamma_A = \langle \sigma v \rangle_{A-^3He}[^3He] + \langle \sigma v \rangle_{A-N_2}[N_2]$$

$$\Gamma_A = C\left(\frac{T}{353K}\right)^n [^3He] + D\left(\frac{T}{353K}\right)^m [N_2]$$

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Spectroscopy: The PB Puzzle

- Inconsistent Results for…
  - One Line, Many Temps
  - One Temp, Many Lines
  - Type of Fit

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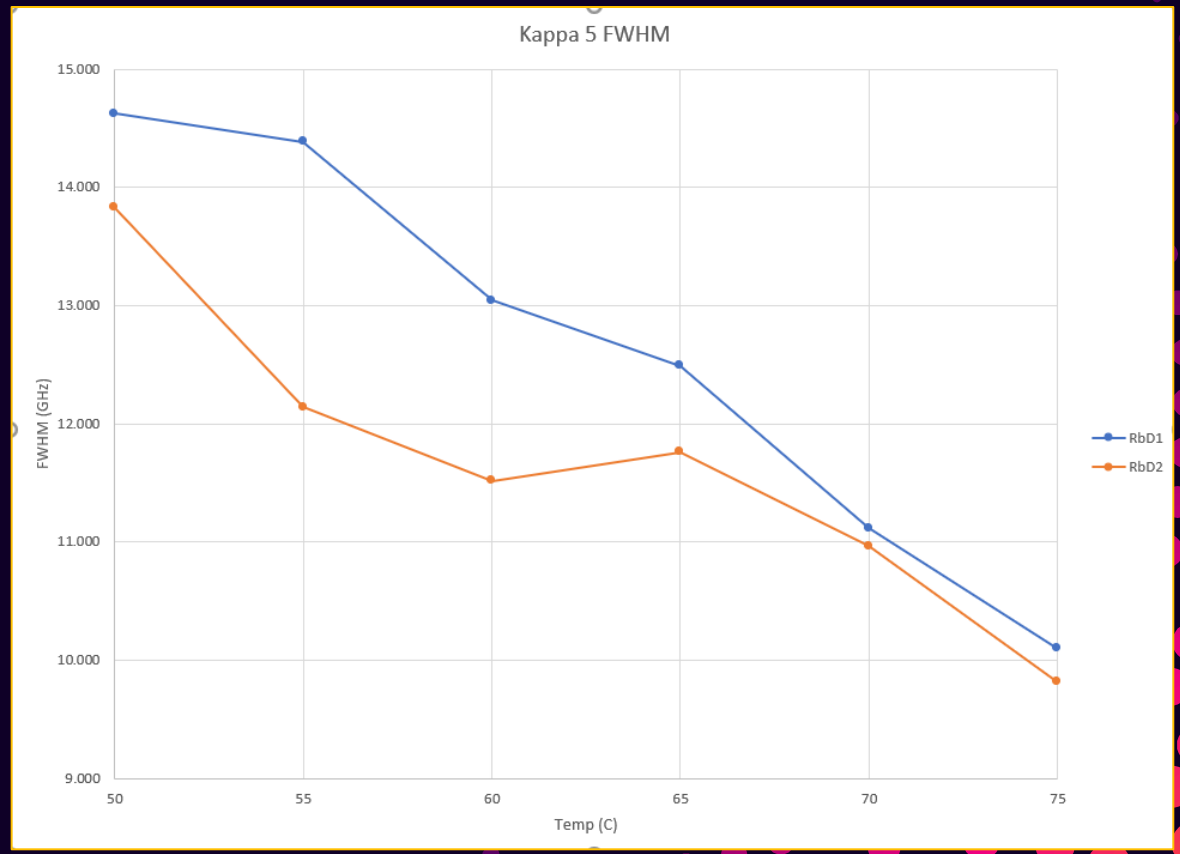

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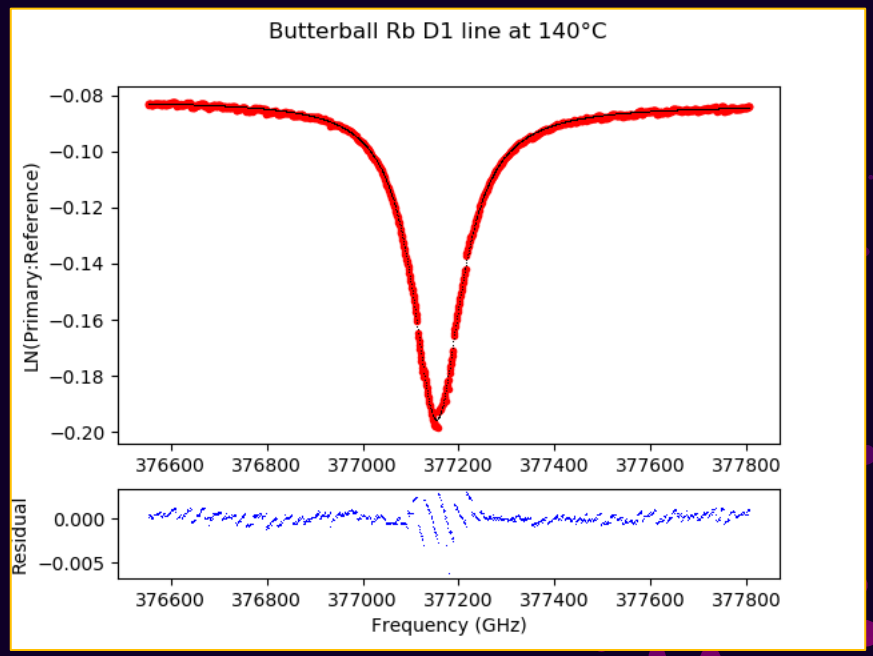

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$$S(\nu) = \frac{AI\left(2\pi T_d(\nu - \nu_c)\right)}{(\nu - \nu_c)^2 + (\gamma/2)^2} + B$$

Spectroscopy: The PB Puzzle

- Inconsistent Results for...
  - One Line, Many Temps
  - One Temp, Many Lines
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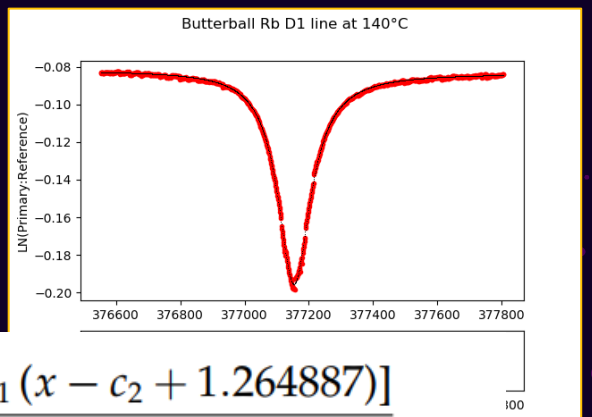
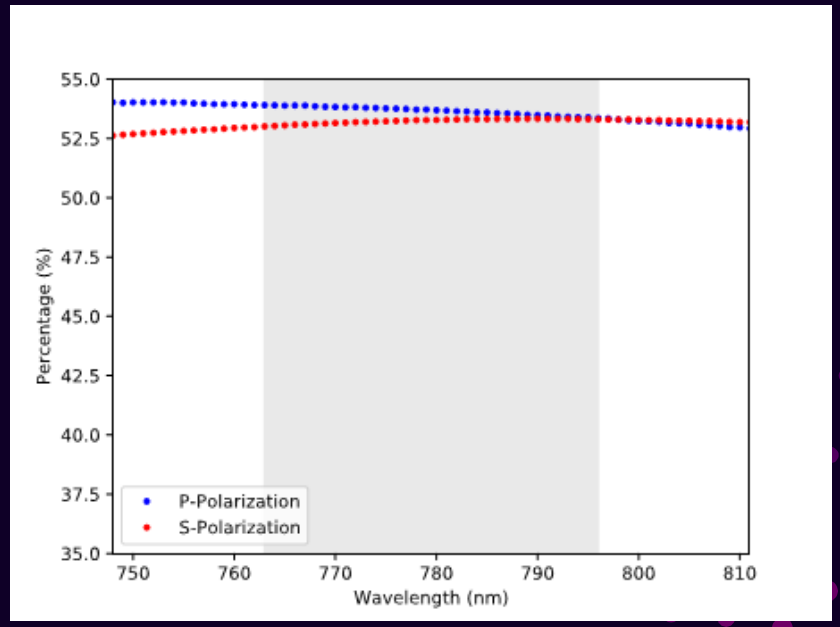


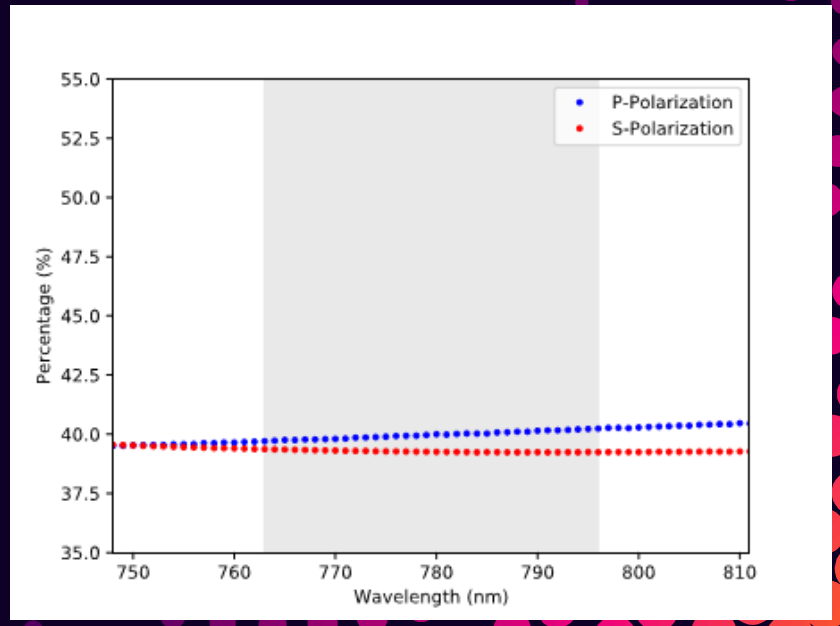
$$
\begin{aligned}
y = {} & 0.7217c_0\left(\left[\frac{7}{12}\right]\frac{[1+0.664\times 2\pi c_1(x-c_2+1.264887)]}{(x-c_2+1.264887)^2+\frac{c_3^2}{4}}\right. \\
& \left.+\left[\frac{5}{12}\right]\frac{[1+0.664\times 2\pi c_1(x-c_2-1.770844)]}{(x-c_2-1.770844)^2+\frac{c_3^2}{4}}\right) \\
& +0.2783c_0\left(\left[\frac{5}{8}\right]\frac{[1+0.664\times 2\pi c_1(x-c_2+2.563005)]}{(x-c_2+2.563005)^2+\frac{c_3^2}{4}}\right. \\
& \left.+\left[\frac{3}{8}\right]\frac{[1+0.664\times 2\pi c_1(x-c_2-4.271676)]}{(x-c_2-4.271676)^2+\frac{c_3^2}{4}}\right)+c_4
\end{aligned}
$$

$$
y = \underbrace{\frac{c_0[1+0.664\times 2\pi c_1(x-c_2)]}{(x-c_2)^2+\frac{c_3^2}{4}}}_{\text{D1}}+\underbrace{\frac{c_5[1+0.664\times 2\pi c_6(x-c_7-1730.32)]}{(x-c_7-1730.32)^2+\frac{c_8^2}{4}}}_{\text{D2}}+c_4
$$

Spectroscopy: The PB Puzzle

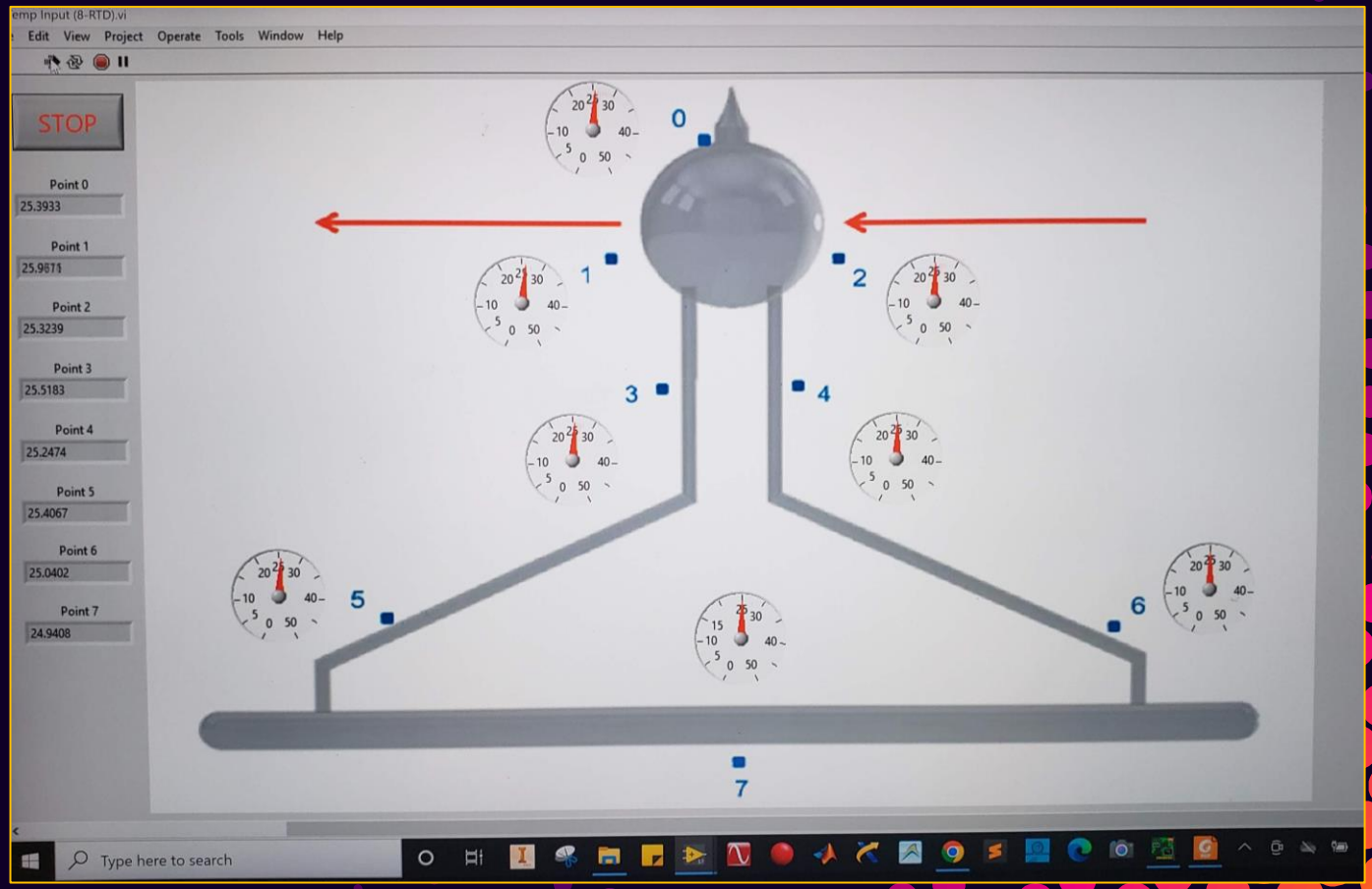
- Inconsistent Results for...
  - One Line, Many Temps
  - One Temp, Many Lines
  - Type of Fit





Spectroscopy: The PB Puzzle

- Inconsistent Results for…
  - One Line, Many Temps
  - One Temp, Many Lines
  - Type of Fit
- Temperature Differentials?



Spectroscopy: The PB Puzzle

- Inconsistent Results for...
  - One Line, Many Temps
  - One Temp, Many Lines
  - Type of Fit
- Temperature Differentials!!!
  - With deflector: dT~32C

Set	0	5	6
110	110.0	118.6	95.9
120	120.0	130.8	104.9
125	125.0	136.1	109.3
130	130.1	140.8	114.0
135	135.0	147.2	118.6
140	139.8	152.2	123.1
145	144.8	157.1	127.4
150	150.0	162.9	132.8
160	160.0	174.1	141.6

Fulla with deflector (°C)

Spectroscopy: The PB Puzzle

- Inconsistent Results for...
  - One Line, Many Temps
  - One Temp, Many Lines
  - Type of Fit
- Temperature Differentials!!!
  - With deflector: dT~32C
  - Without deflector: dT~10-15C

Set	0	5	6
110	109.9	114.3	106.8
120	119.9	124.7	116.1
125	125.0	130.5	121.3
130	130.0	135.8	125.9
135	135.0	140.9	130.6
140	140.0	146.1	133.1
145	145.0	149.4	135.3
150	150.0	154.5	139.4
160	160.0	164.7	148.4

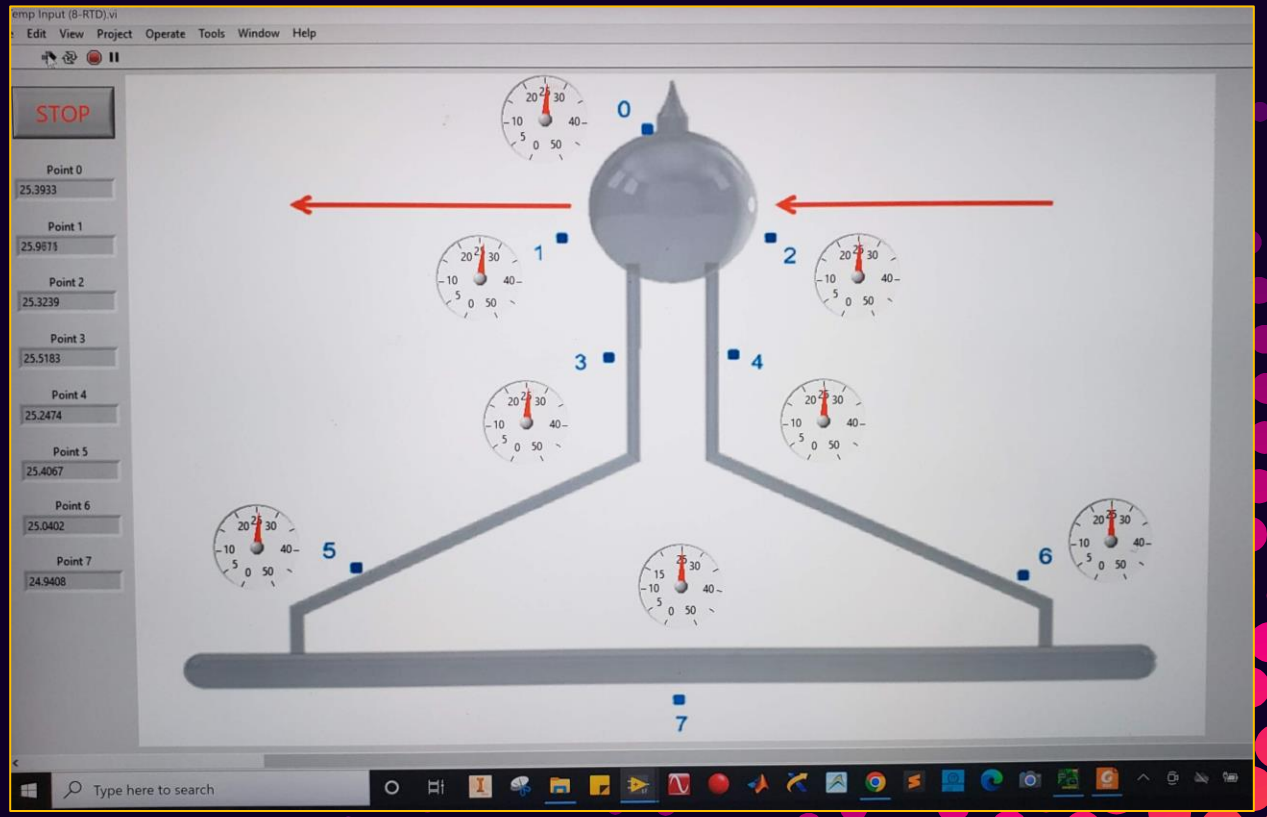
Fulla with no deflector (°C)

Set	0	5	6
110	109.8	116.6	109.7
120	120.1	127.5	120.0
125			
130	130.2	138.2	130.3
135	135.5	143.6	135.5
140	139.8	148.1	139.8
145	145.0	154.3	144.8
150	150.1	159.5	150.0
160	160.0	170.0	159.6

Noah with no deflector (°C)

Spectroscopy: The PB Puzzle

- Inconsistent Results for…
  - One Line, Many Temps
  - One Temp, Many Lines
  - Type of Fit
- Temperature Differentials!!!
  - With deflector: dT~32C
  - Without deflector: dT~10-15C
- New oven / heating scheme



Thank You