Polarized 3He Cell Production and Performance in the JLab SBS GEn-II Experiment

H. Presley

PSTP
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Outline

- SBS program and GEn-II
- Fabrication and Production of GEn-II Cells
- Characterization
- Cell performance
- Summary

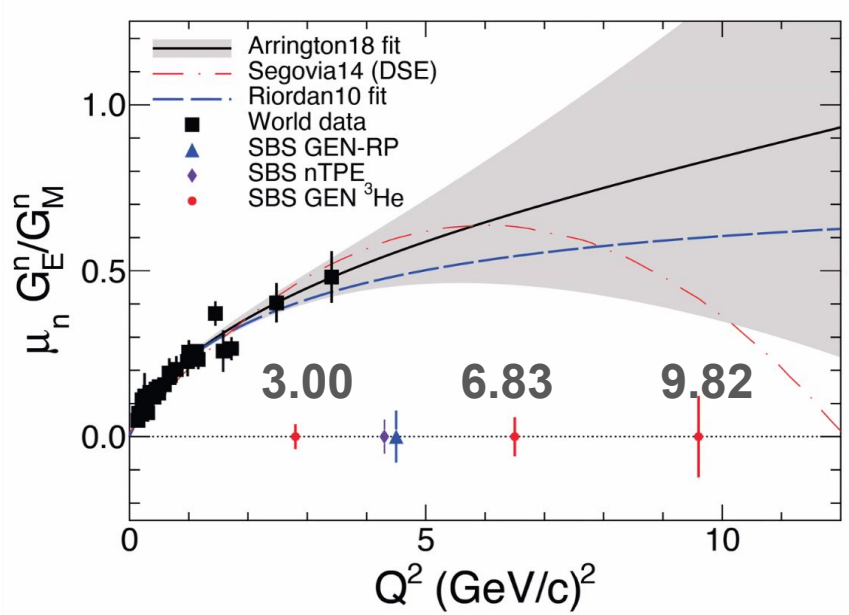
SBS Program at Jefferson Lab

- Goal of SBS - **Determine Sachs Electric and Magnetic Form Factors at high Q^2 values**

- GMn : measure **GMn/GMp** up to Q^2 = **13.5 GeV^2** LD_2 target - **Complete**
- **GEn-II** : measure **GEn/GMn** up to Q^2 = **10 GeV^2** ^{3}He target - **Complete**
- GEn-RP : measure **GEn/GMn** up to Q^2 = **4.5 GeV^2** LD_2 target - **Complete**
- GEp : measure **GEp/GMp** up to Q^2 =**12 GeV^2** LH_2 target - **March 2025?**

SBS GEn-II: Electric Form Factor of the Neutron

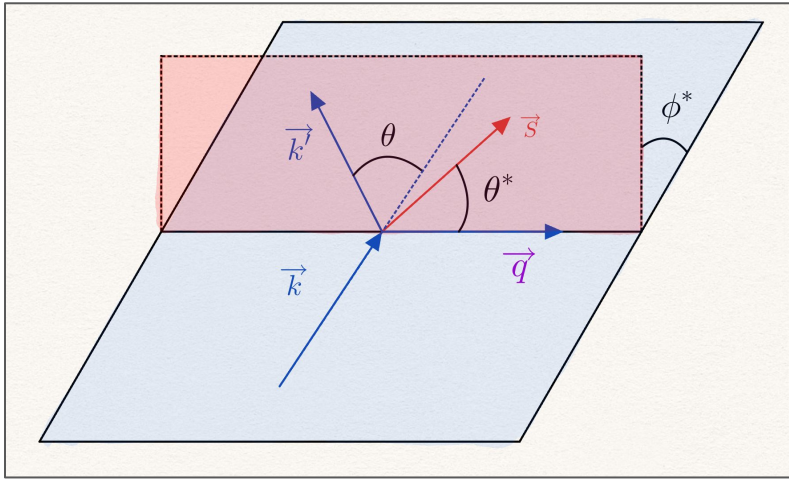
- **Purpose: extract GEn at very high Q^2**
- Proton form factors available up to Q^2 values of ~10 GeV^2
- For neutron, only GMn has been measured up to ~10 GeV^2
- Before this experiment GEn measured up to 3.5 GeV^2
  - Difficult to create high luminosity neutron targets
  - Neutron is neutral - smaller value and harder to isolate from background
- Experimental Runtime - **(09/2022 - 11/2023)**



GEn-II Experimental Technique

- Historically two techniques: Rosenbluth Separation and Double Polarization
- GEn-II utilizes double polarization with asymmetry measurement
- Elastic (e-N) scattering cross section can be written as

$$\sigma_h = \Sigma + h\Delta$$



- Physical Asymmetry is then written as

$$A_N = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-} = \frac{\Delta}{\Sigma}$$

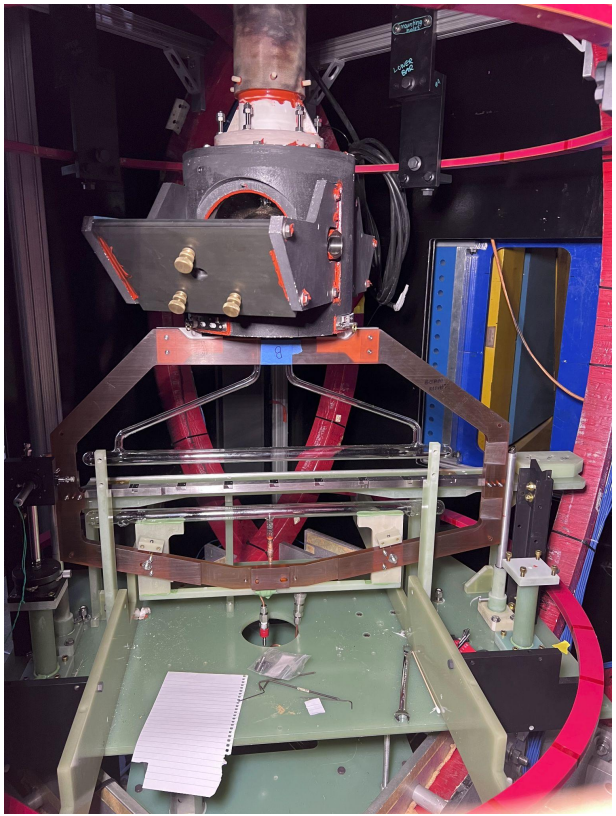
$$A_\perp = -\frac{G_E^n}{G_M^n} \frac{2\sqrt{\tau(\tau+1)}\tan(\theta/2)}{(G_E^n/G_M^n)^2 + (\tau + 2\tau(1+\tau)\tan^2(\theta/2))}$$

Polarized ^{3}He Target

- Many components to polarized 3He target
  - **3He Cell**
  - Oven
  - **Helmholtz Coils**
  - **Laser and Optics system**
  - Soft Iron Shielding
  - RF Coils for NMR and EPR
  - **Target Ladder**

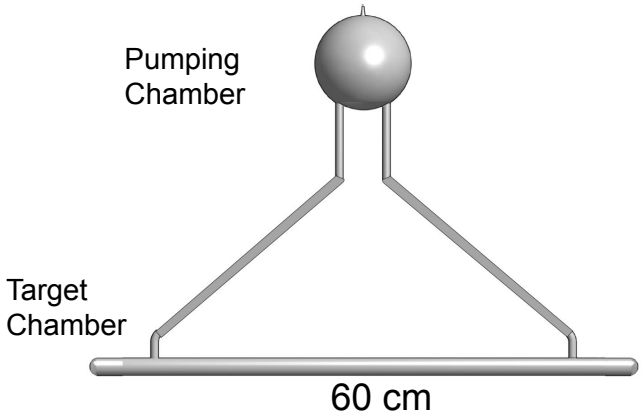
➢ **Jack's talk**

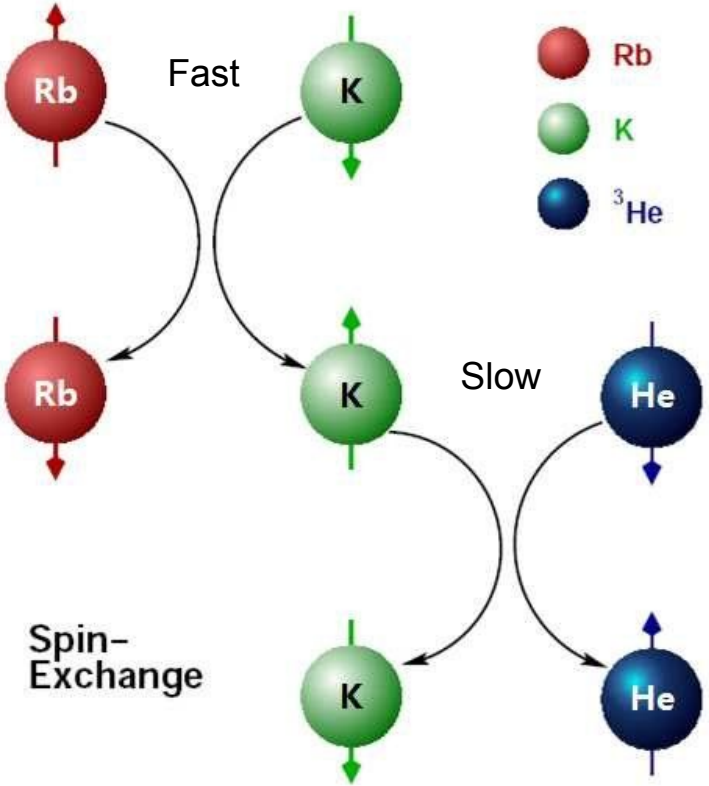
Polarized ^{3}He Target



Spin-Exchange-Optical Pumping (SEOP)

- Optically pumped high density alkali vapor
- Both Rb and K used for increased pumping efficiency
- 3He nuclei polarized through hyperfine interactions during collisions
- Convection used for fast mixing

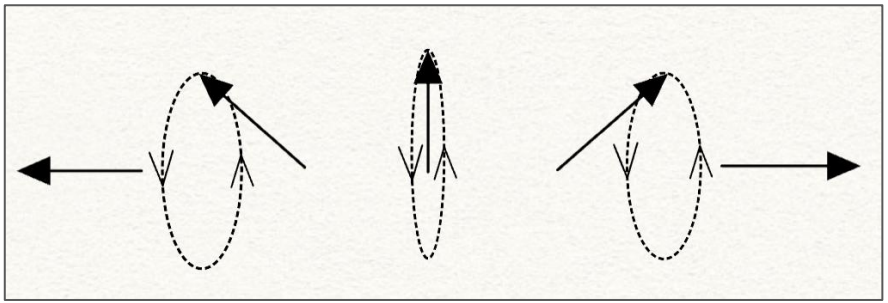




https://www.researchgate.net/figure/Hybrid-approach-of-Spin-Exchange-(

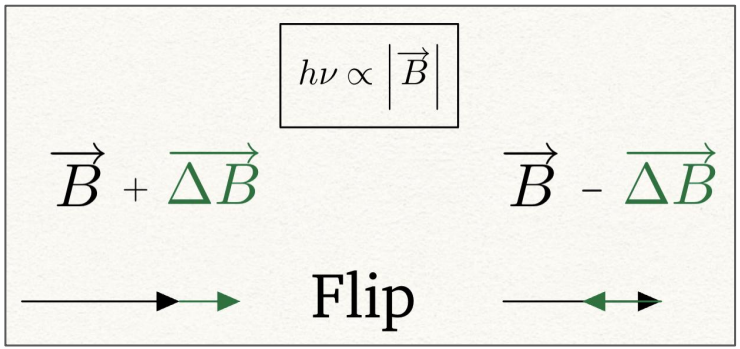
NMR

- Cell in magnetic holding field
- Apply RF (91KHz) field and sweep holding field
- Measure voltage of coils placed near the cell to track polarization signal during sweep
- **Signal in mV**



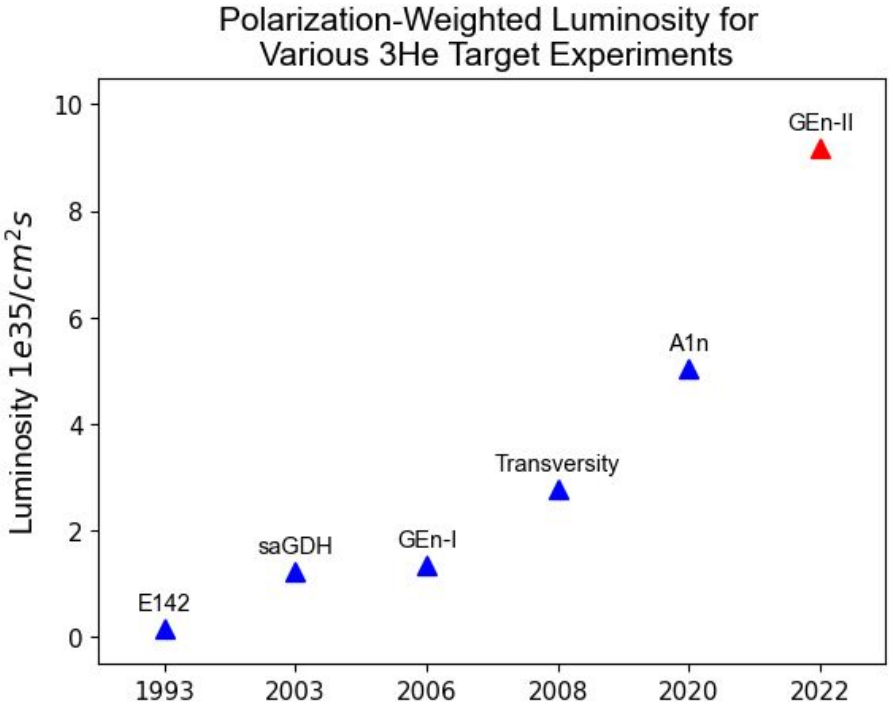
EPR

- Use feedback system to find the frequency at which unpaired electrons in the alkali atoms resonate
- Flip the spins of the 3He
- Find new resonance frequency
- The difference in the frequency is proportional to the 3He polarization
- **Percentage of polarization**



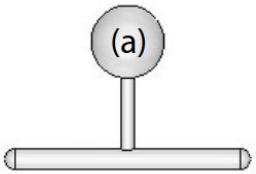
SBS GEn-II Goal: Record Breaking Target Performance

- Polarization-weighted luminosity of previous 3He targets
- Projected performance of GEn-II targets
  - Target chamber length increased to 60 cm
  - Target chamber volume increased by factor of 2
  - Bigger cell -> higher current
    - Limits depolarization effects
  - **Projected goal: 45% at 45uA**



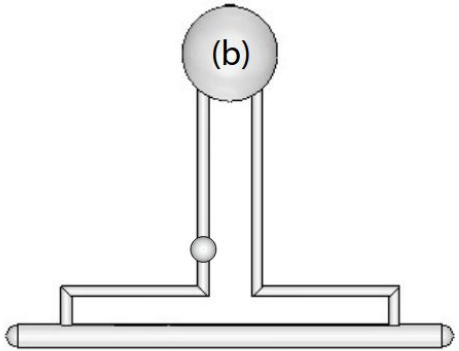
Generations of Cells

Transversity



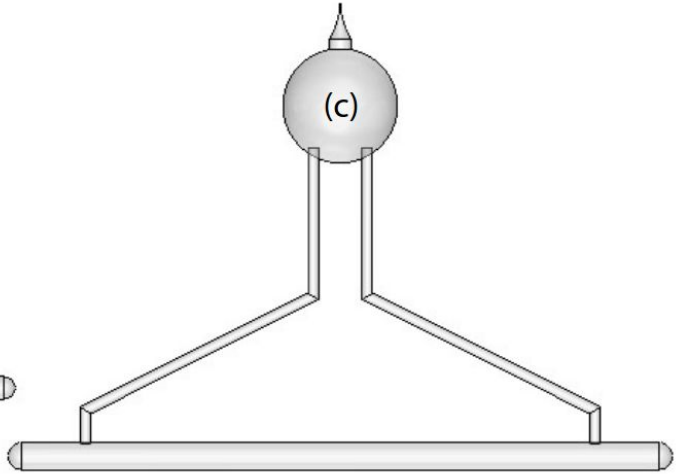
29.1 hrs

Hall C A1n

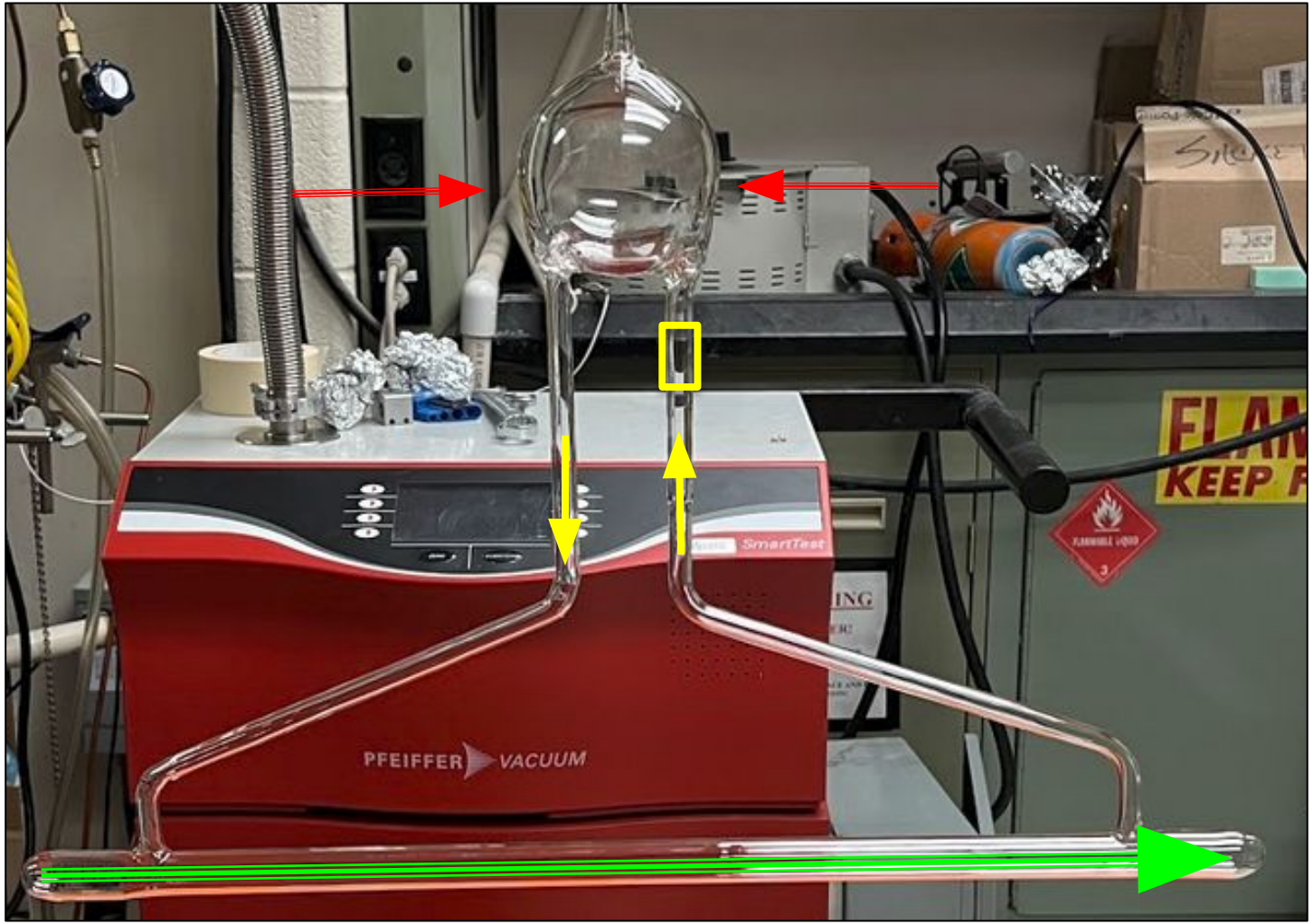


19.6 hrs

GEn-II



15.1 hrs

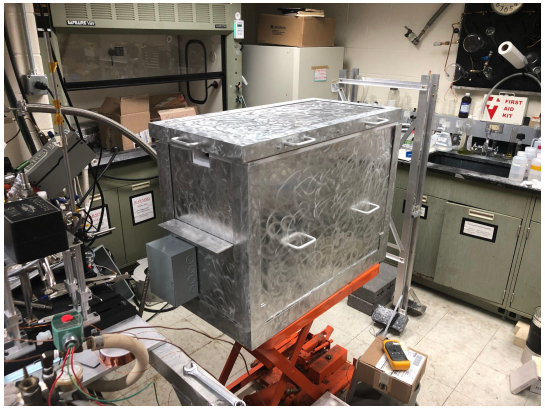

PFEIFFER VACUUM
SmartTest

Fabrication of ^{3}He Cell

- Scientific Glass Blower Mike Souza
- GEn-II specifications set in order to achieve record breaking FOM
- Fabrication separated into two stages
  - Many target windows created and shipped to UVA for pressure testing
  - Best windows are selected and returned to Mike for final process of attaching the windows to the rest of the cell

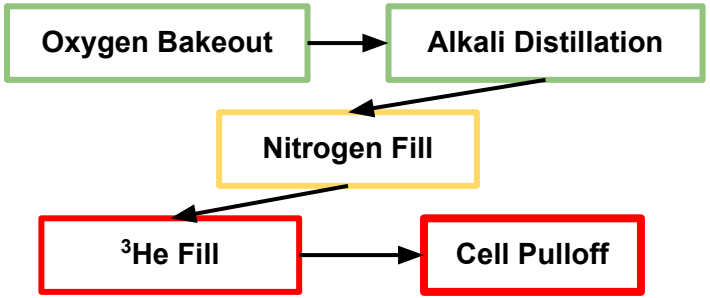
Cell Fill Preparation

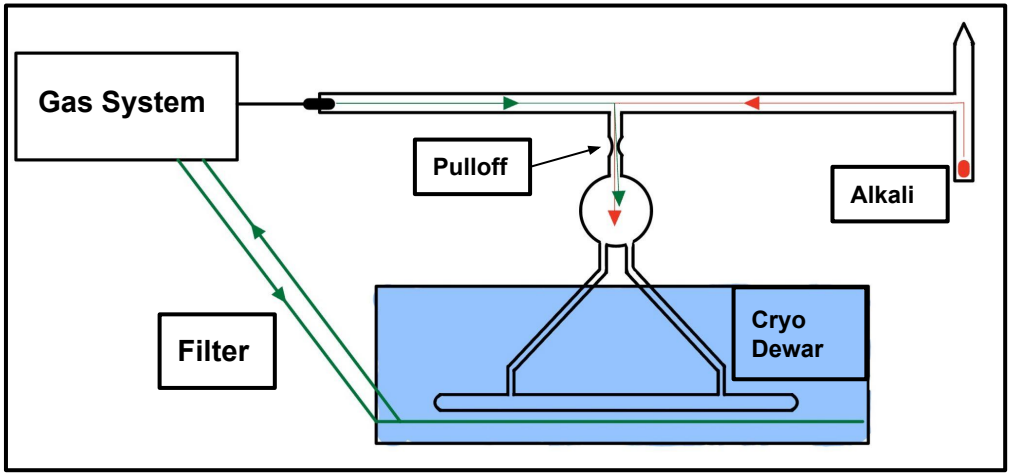
- ~ 1-2 weeks
- Begins with oxygen bake 400°C to remove impurities on the surface
- Ends with alkali distillation



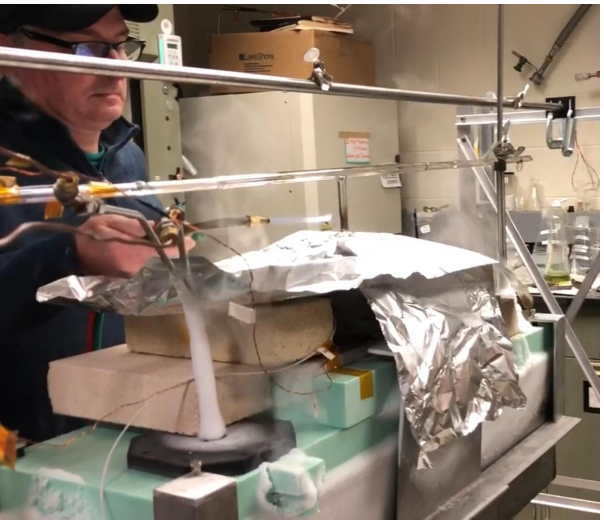
Cell Fill Process

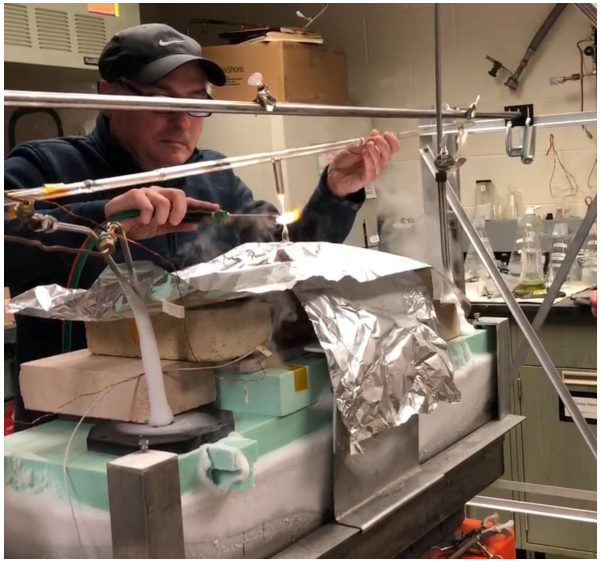
1. Alkali mixture transported into the pumping chamber via distillation
2. Small amount of nitrogen bled into the cell
3. Target chamber submerged in liquid helium
4. ^{3}He fill is done iteratively until ~7 atm pressure at room temp achieved
5. Cell pulloff





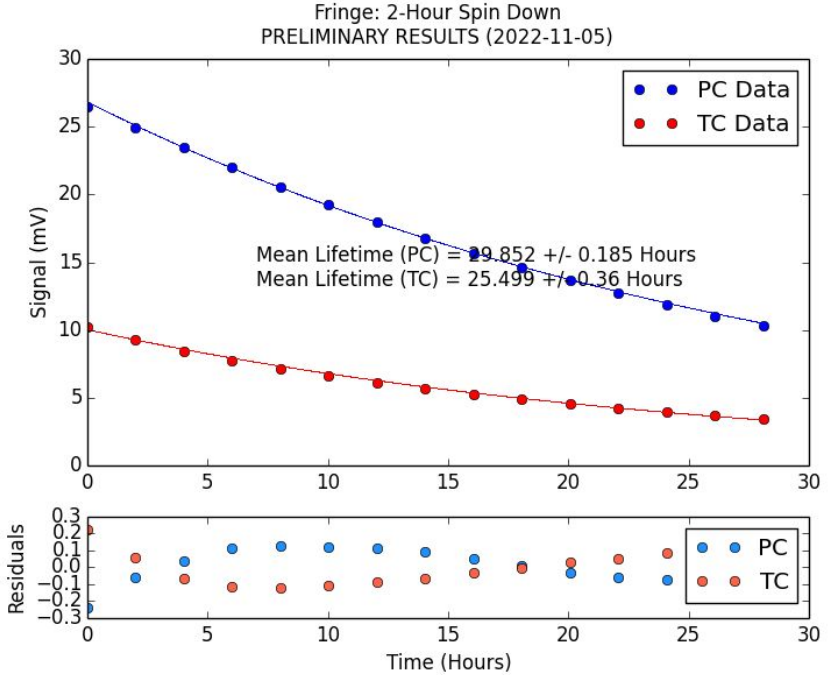
Cell Pulloff



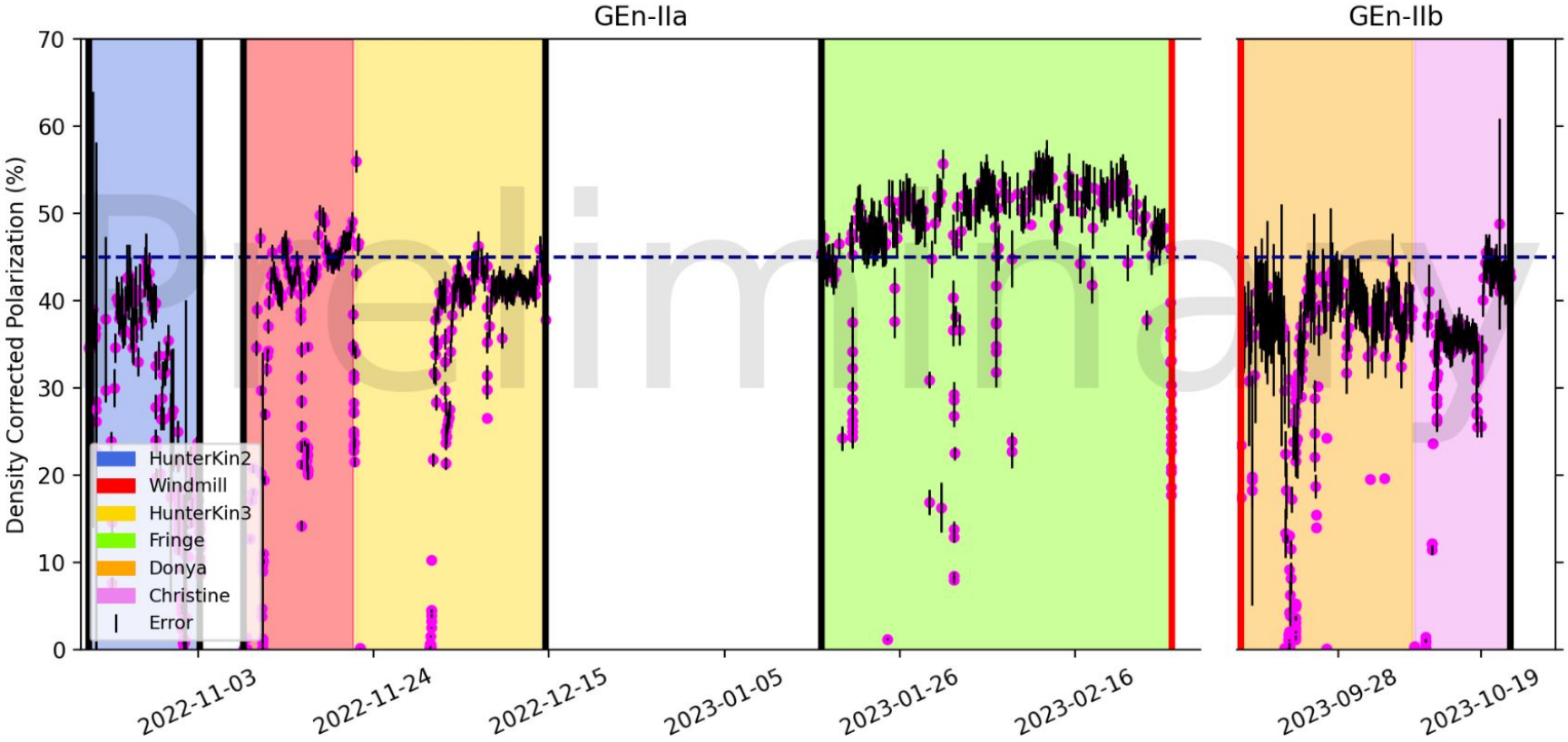


Characterization and Selection

- Cell production continued throughout the majority of the experimental runtime
- At the end of production, **16 target cells** had been successfully filled and characterized at UVA
- Cells with highest lifetime chosen
- **13 cells** fully prepped for installation in Hall A
- **6** were used in production data taking



	Cell Name	Average Polarization	Max Polarization	Duration Installed
Kinematic 2	Hunter	40%	46.08%	20 days
Kinematic 3	Windmill	45%	49.80%	14 days
	Hunter	42%	46.32	24 days
Kinematic 4	Fringe	53%	55.92%	60 days
	Chicago	n/a	43.60%	12 days
	Donya	40%	44.49%	31 days
	Christin	40%	45.57%	20 days



Summary

- GEn-II experiment is **complete**!
- Target program was a success - **45% at 45uA**
- **Six** of the **Sixteen** available ^{3}He cells were used in the production setting
- Specific installation challenges which limited polarization discussed by Jack in the next talk!

Thank you!