Polarized ^{3}He Target Status

On Behalf of the JLab Polarized ^{3}He Target Group

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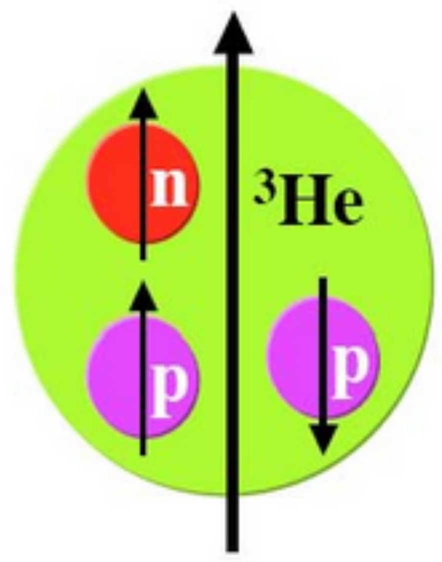
WILLIAM & MARY
CHARTERED 1693

Why Polarized ^{3}He

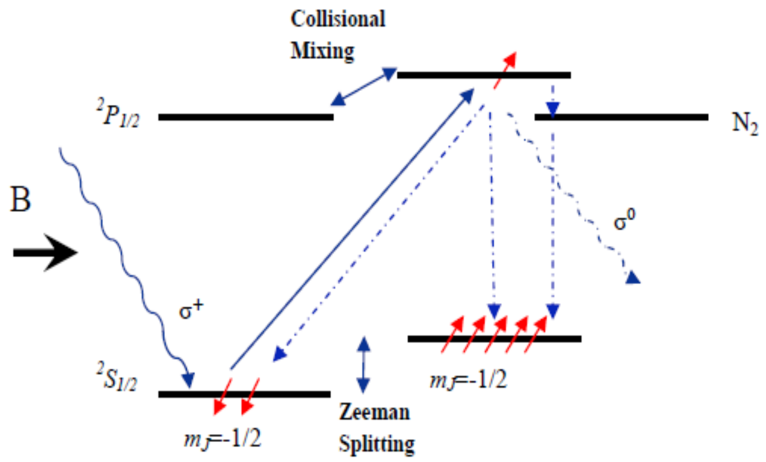
- No free neutron target: life time too short ~ 880.2 s
- Pol. ^{3}He is an effective polarized neutron target:

  neutron carries the majority of the ^{3}He nucleus polarization

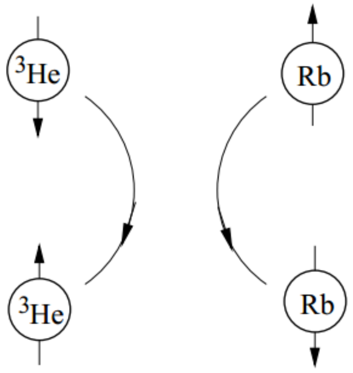


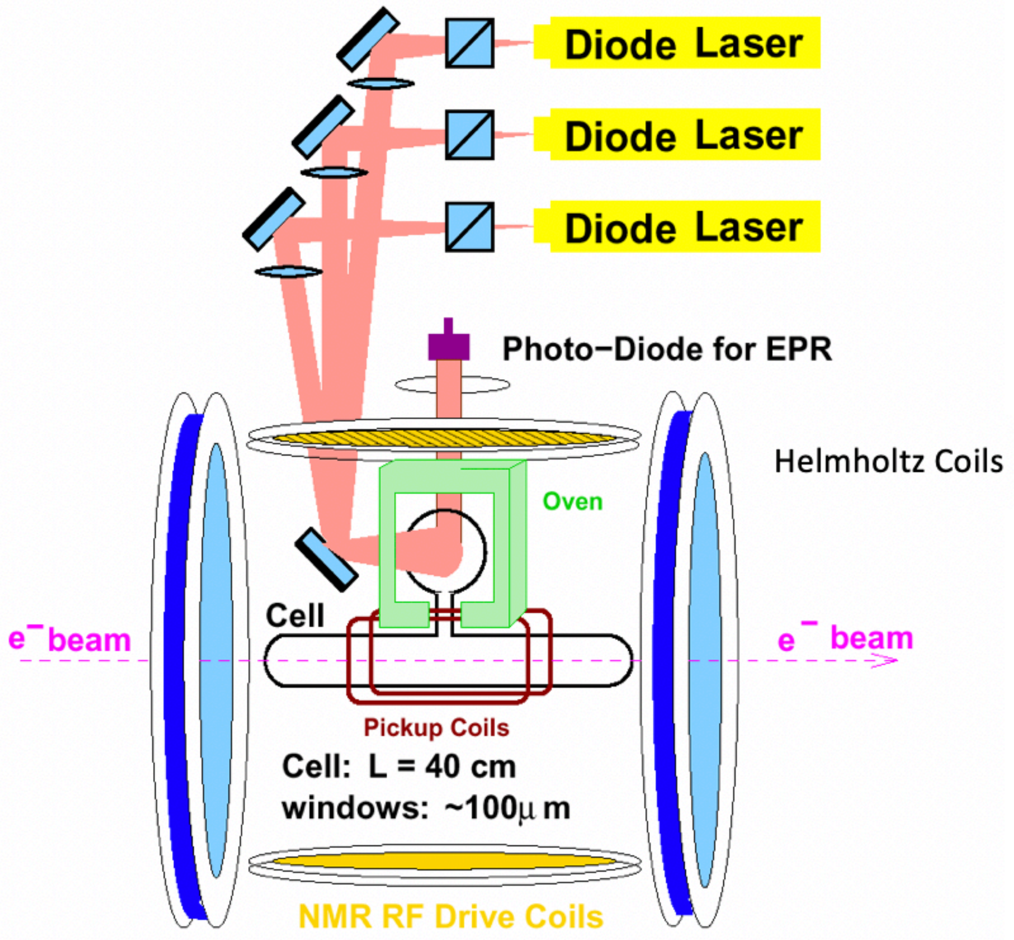
Polarization Method: SEOP
(Spin Exchange Optical Pumping)

1. Optical Pumping



2. Spin Exchange

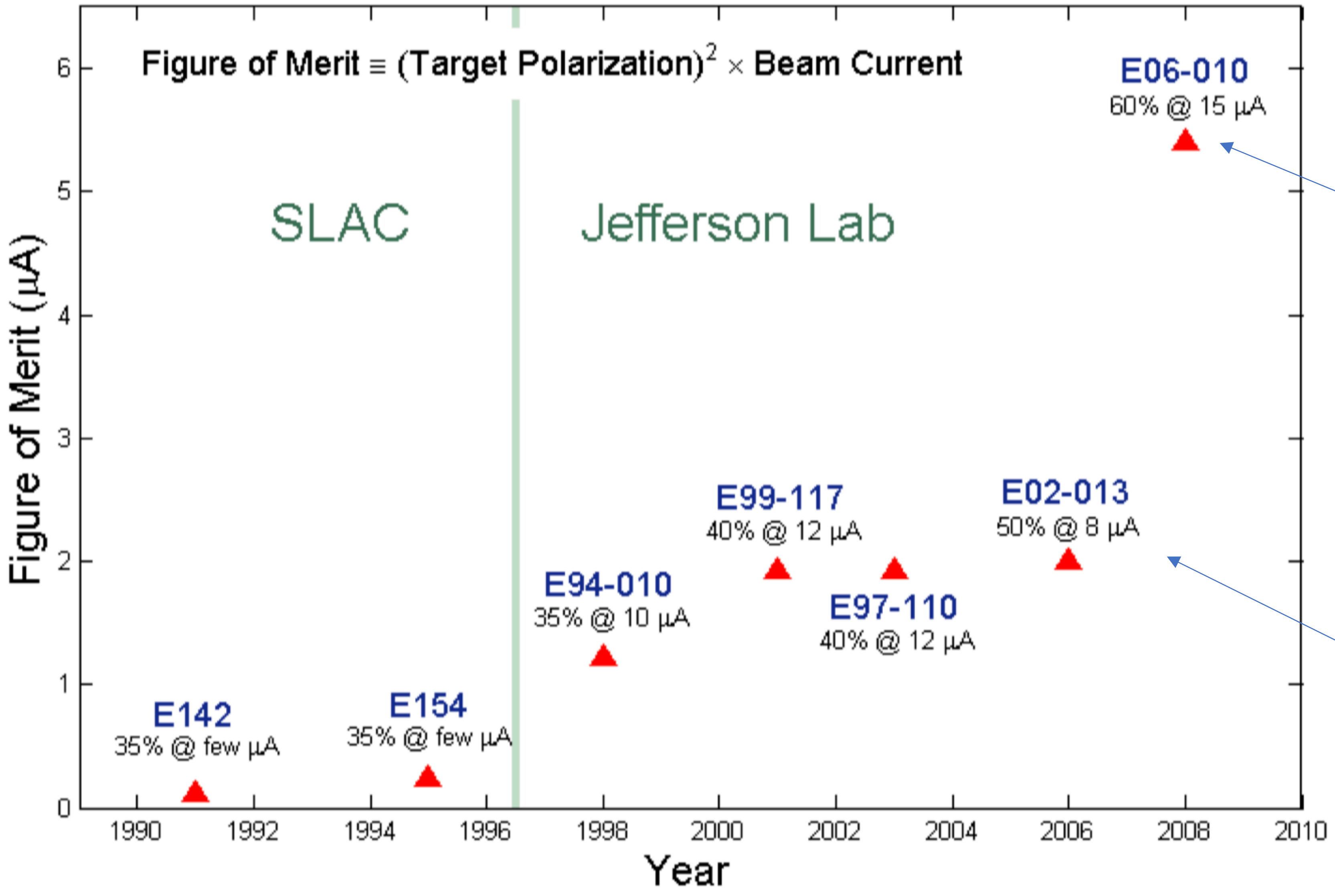




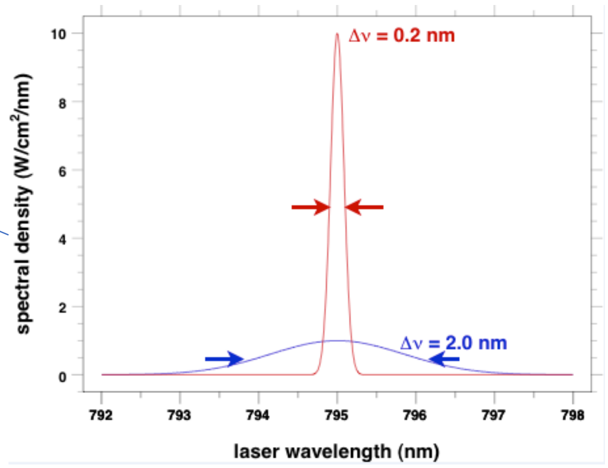
^{3}He Polarimetry Methods

- Adiabatic Fast Passage Nuclear Magnetic Resonance (AFP NMR)
  - Magnetic resonance of ^{3}He nucleus
  - AFP: flip the nucleus spin direction with minimum loss
- Pulse NMR
  - Instead of flipping the spin direction, tilts the nucleus spin to a certain angle
- Electron Paramagnetic Resonance (EPR)
  - Magnetic resonance of the alkali atoms in external field
  - Resonance frequency shifted due to polarized ^{3}He, get ^{3}He polarization through the frequency shift

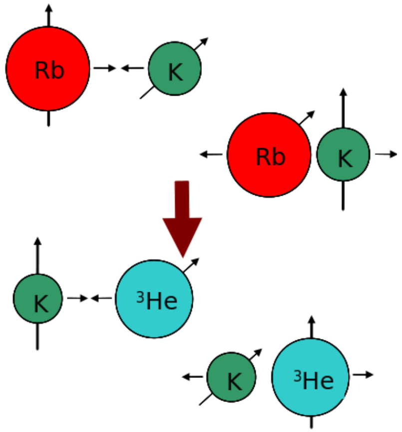
Polarized ^{3}He Performance for 6 GeV Experiments



1. Use narrow band laser



2. Use Rb/K hybrid alkali cell



Polarized ^{3}He Upgrade

6 GeV Era Performance

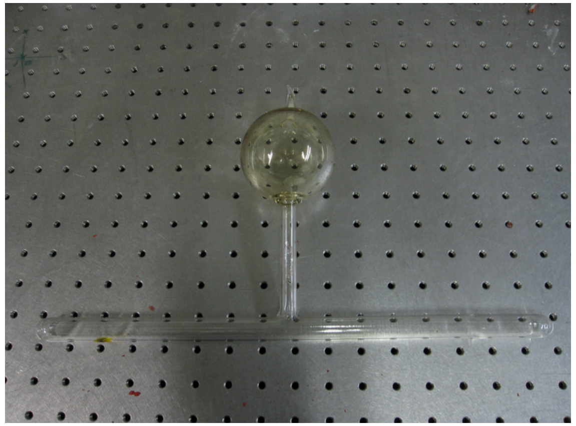
- Beam Current: 15 uA
- Luminosity: 10^{36} cm^{-2}s^{-1}
- Polarimetry: 3% for Rb only
  5% for hybrid

12 GeV (A1nd2n) requirements

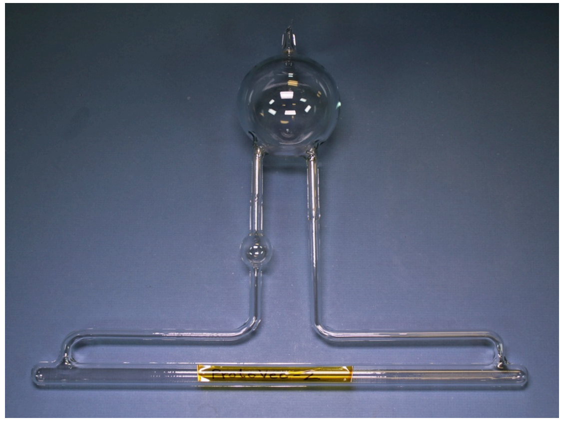
- Beam Current: 30 uA
- Luminosity: ~ 2x10^{36} cm^{-2}s^{-1}
- Polarimetry: 3% for hybrid

Approaches

- Diffusion Cell
- 3” pumping chamber
- 50-80 W laser power



- Convection Cell
- Larger (3.5”) pumping chamber
- More (~ 100 W) laser power



Target Activities at JLab

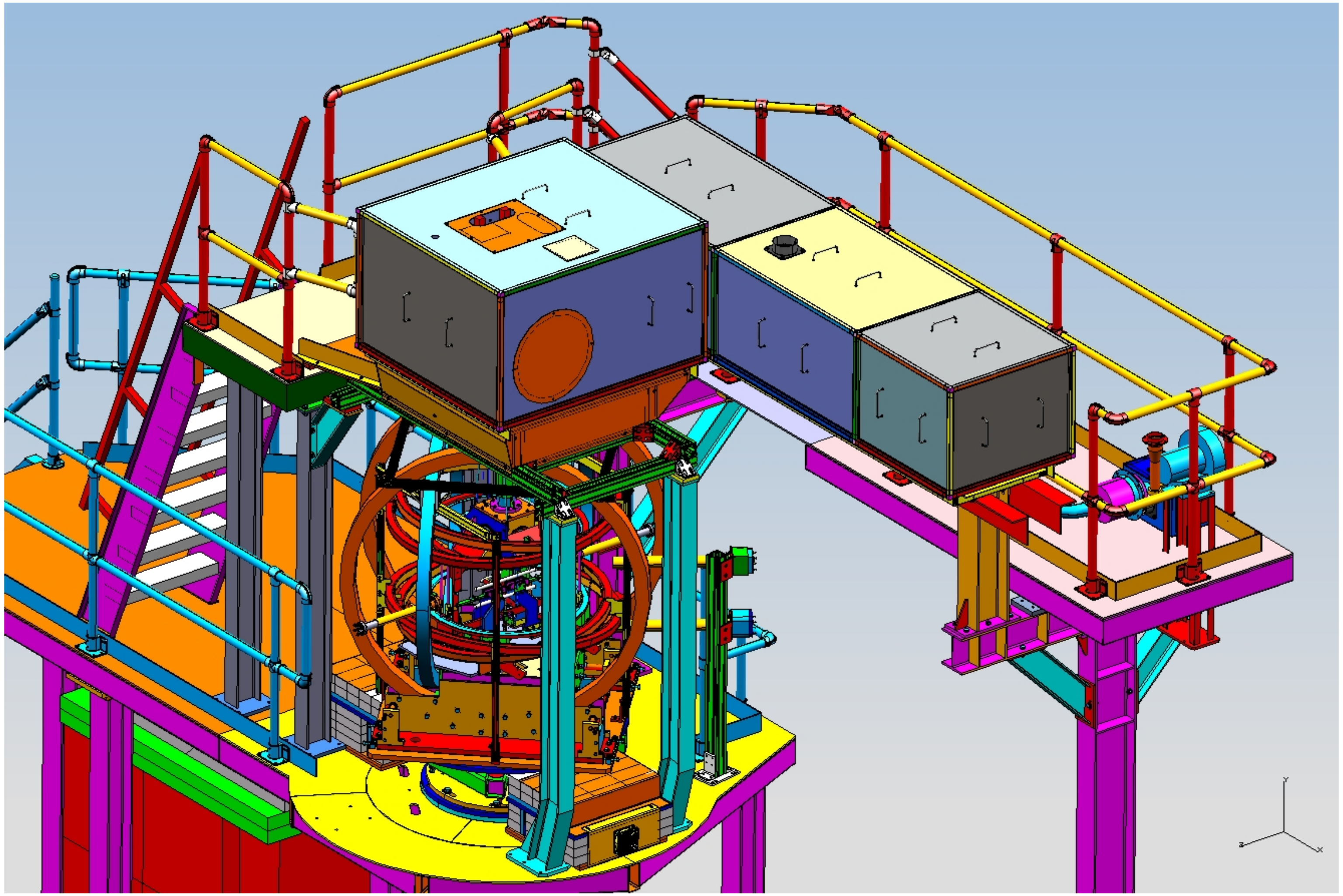
Manpower at JLab:

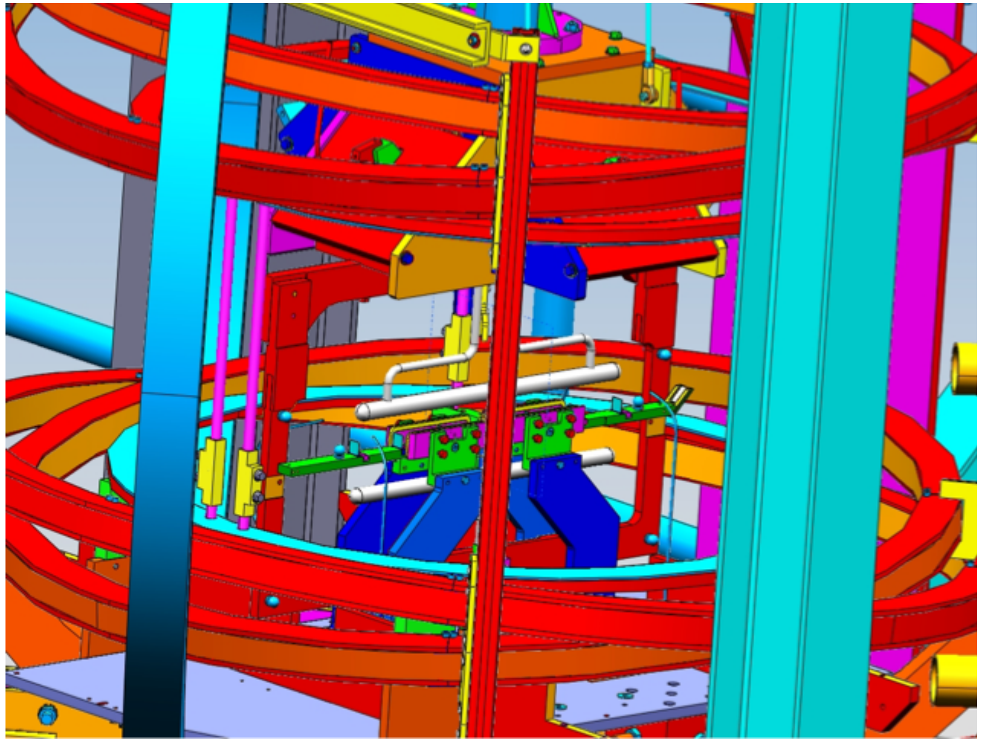
- PhD students: Junhao Chen (W&M, Todd Averett), Mingyu Chen (UVa, Xiaochao Zheng), Murchhana Roy (University of Kentucky, Wolfgang Korsch), Melanie Rehfuss (Temple, Zein-Eddine Meziani)
- Postdoc: Arun Tadepalli, William Henry, Jixie Zhang
- Engineers/Designer (Bert Metzger)
- Installation (Walter Kellner, Hall C technicians)
- Supervisor/coordinator (Jian-ping Chen)

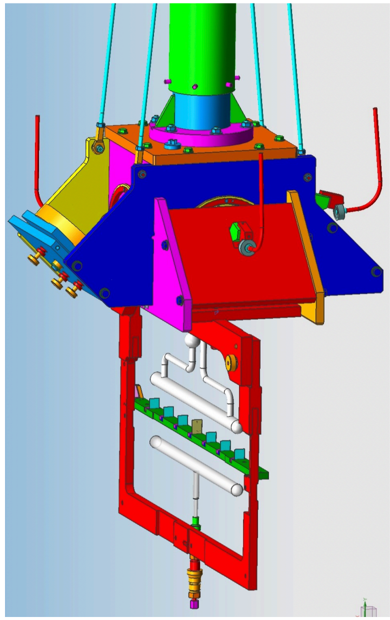
Overview of Activities:

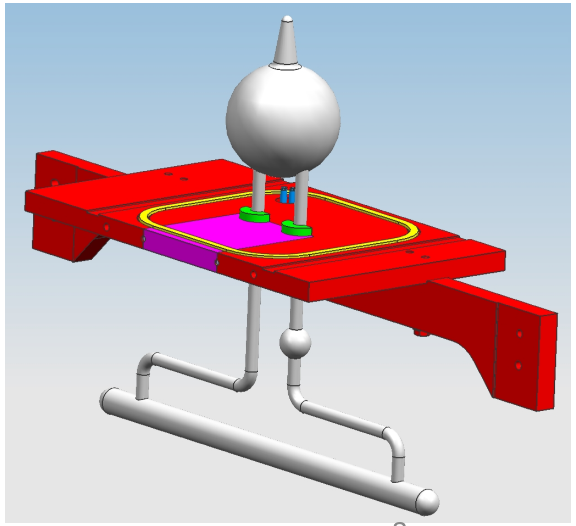
- Design to fit the polarized ^{3}He into Hall C (first time), construction (Bert)
- Develop pulse NMR (Mingyu)
- Upgrade and commissioning EPR (Melanie, Todd, Junhao, Sumudu Katugampola from Uva)
- Commissioning NMR (Junhao, William)
- Field mapping (Jixie et al.)
- Field direction measurement (Murchhana, Arun)
- Reference cell and cooling jets (Todd)
- Target ladder alignment (Alignment group, Bert, Arun)
- Installation (Walter Kellner, Hall C technicians, Bert, alignment group et al.)
- Slow control system (Brad Sawatzky, Ethan Becker, Junhao, Arun, William, Mahlon Long, Mark Taylor, Chris Carlin, Mindy Leffel)

Updated Design and Installation Design Fit into Hall C (Bert Metzger)









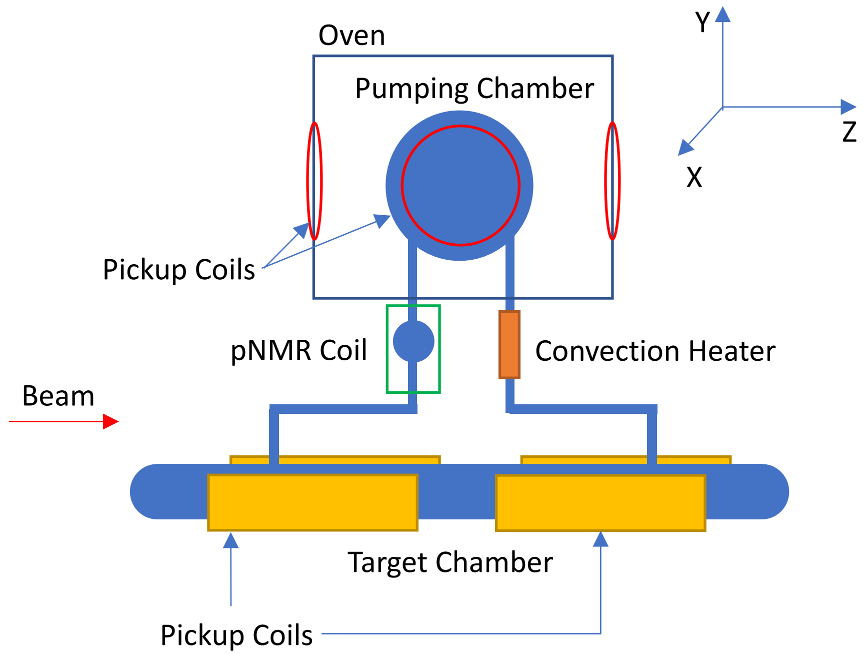
NMR
(Junhao Chen, William Henry)

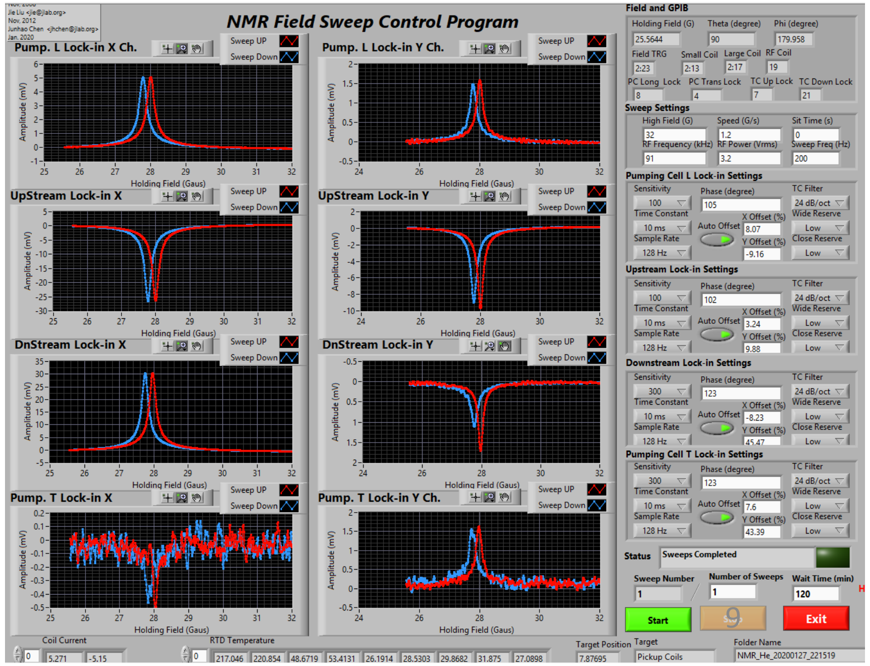
- Two pairs of pumping chamber pickup coils, one in longitudinal direction, another one in transverse direction

- Two pair of target chamber pickup coils: upstream and downstream

- The system is working properly

- Target chamber pickup coils are also used to study convection speed

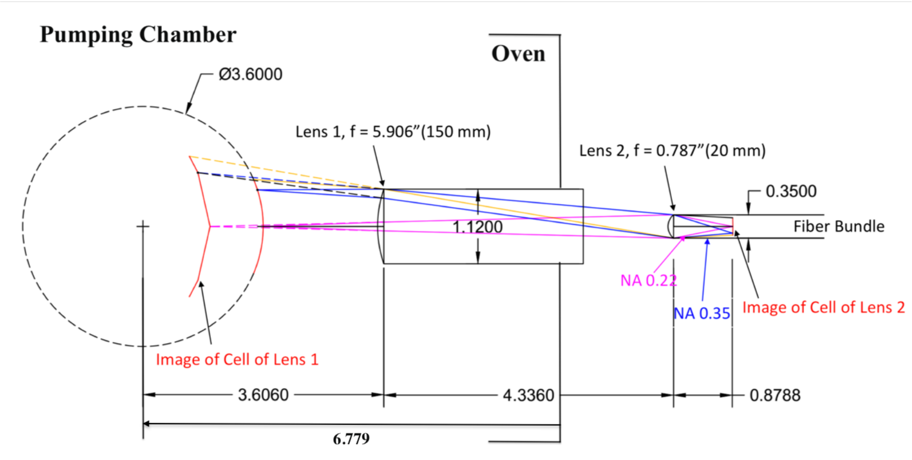




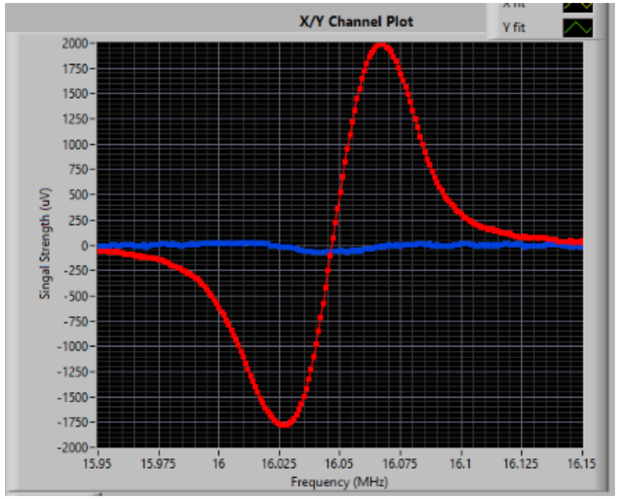
EPR System

(Melanie Rehfuss, Junhao Chen, Murchhana Roy, Todd Averett)

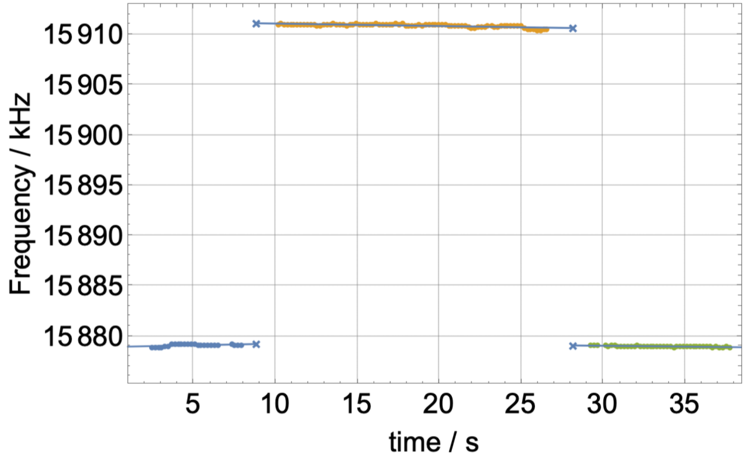
- EPR provides absolute polarimetry.
- EPR polarimetry worked, provided initial calibrations to NMR system.
- D2 fiber bundle not working properly recently. The D2 light is too weak.
- New fiber bundle ordered and will arrive tomorrow.



D2 Fiber Bundle Optics Design



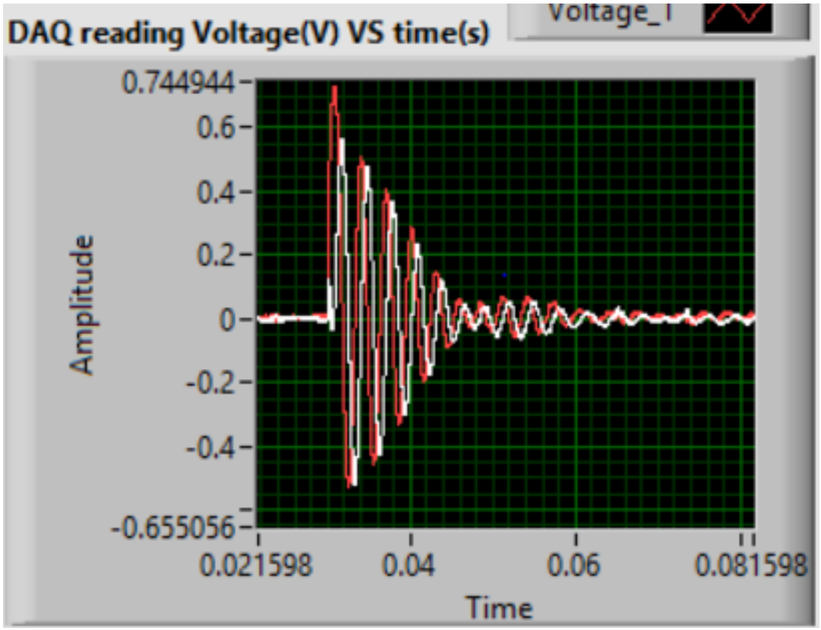
EPR FM Sweep



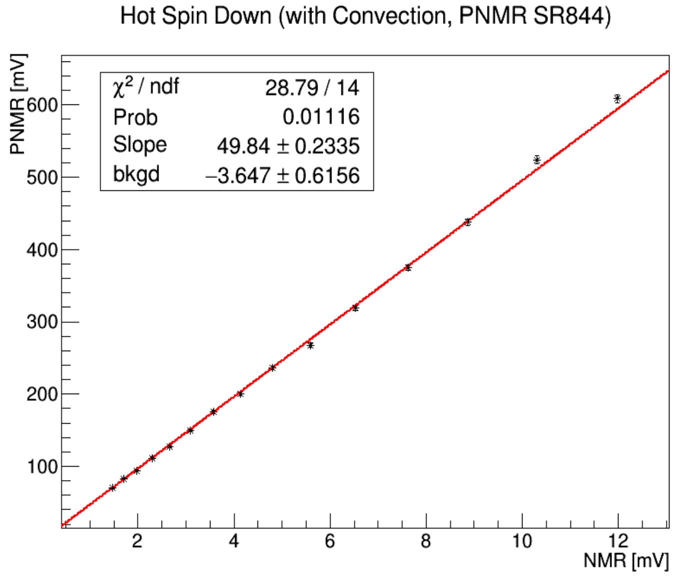
EPR AFP

Pulse NMR (Mingyu Chen)

- Advantage: takes less time to complete than NMR-AFP → less depolarization
- Correlation between NMR-AFP and pNMR signal reached 1% level in target lab
- System has been upgraded with a Lock-in Amplifier and DAQ system
- Pulse NMR system is working but not stable due to field instability.
- New power supply is ordered to improve field stability(Bill).



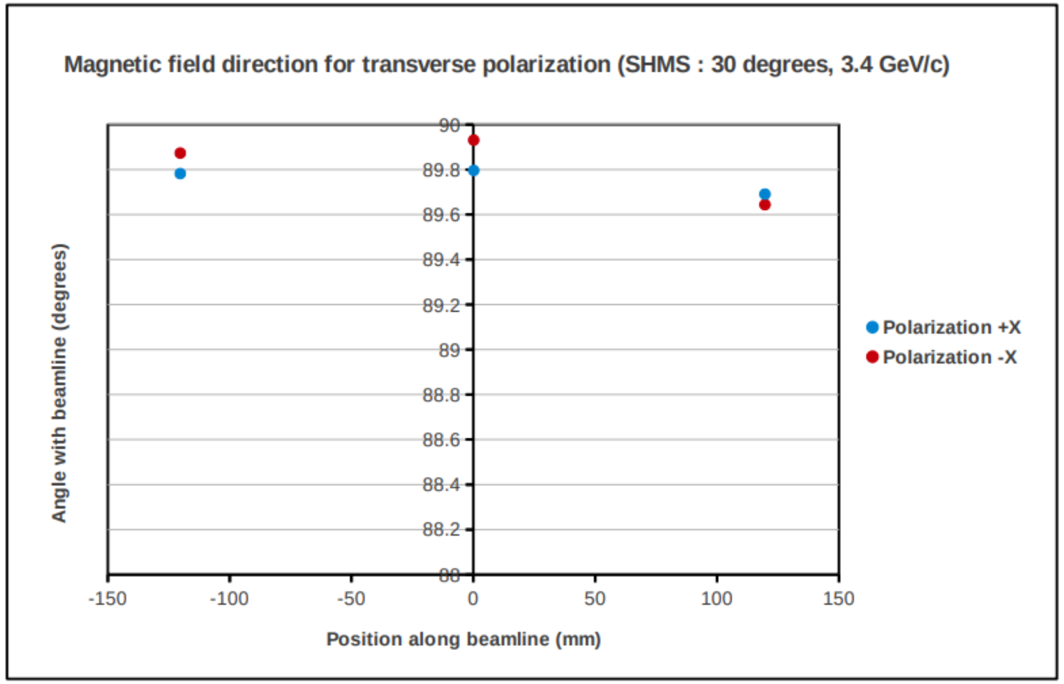
pNMR Signal in Hall C

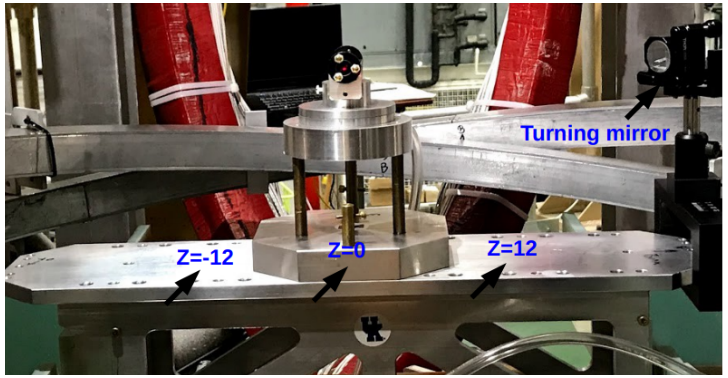


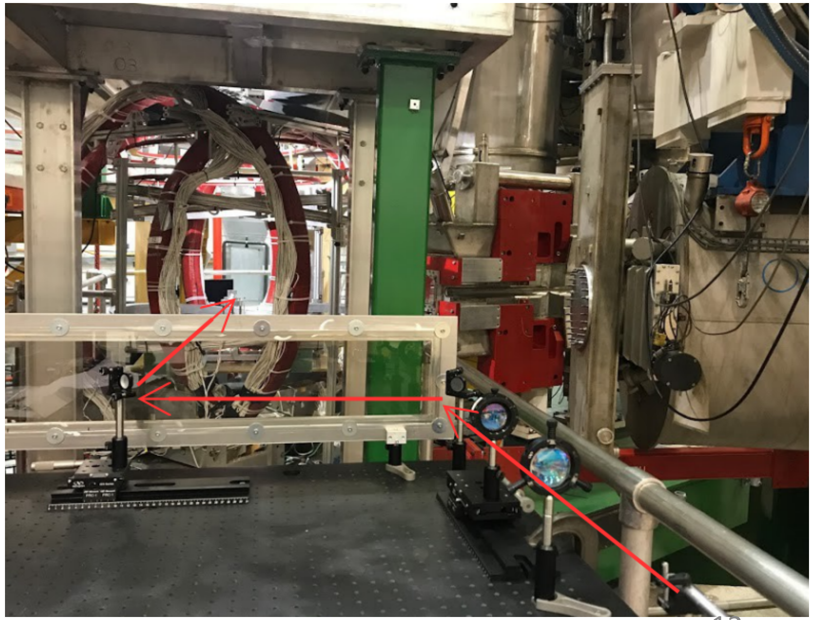
pNMR - NMR Calibration done in target lab

Magnetic Field Direction Measurement
(Murchhana Roy, Arun Tadepalli)

- Measurements done at different target field directions with SHMS at different angles and momentum settings.
- The uncertainty in the angle measurements was <u>less than 0.1 degrees</u>.

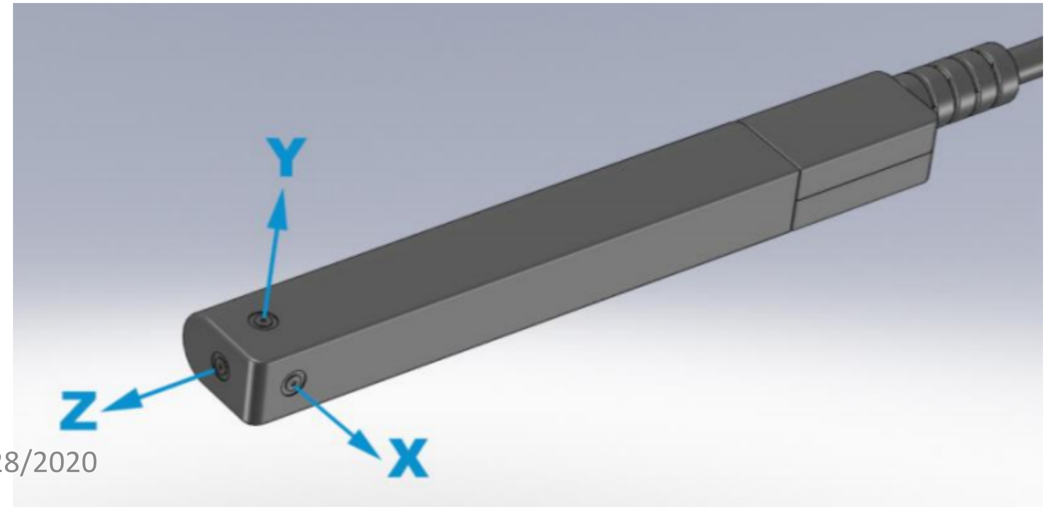


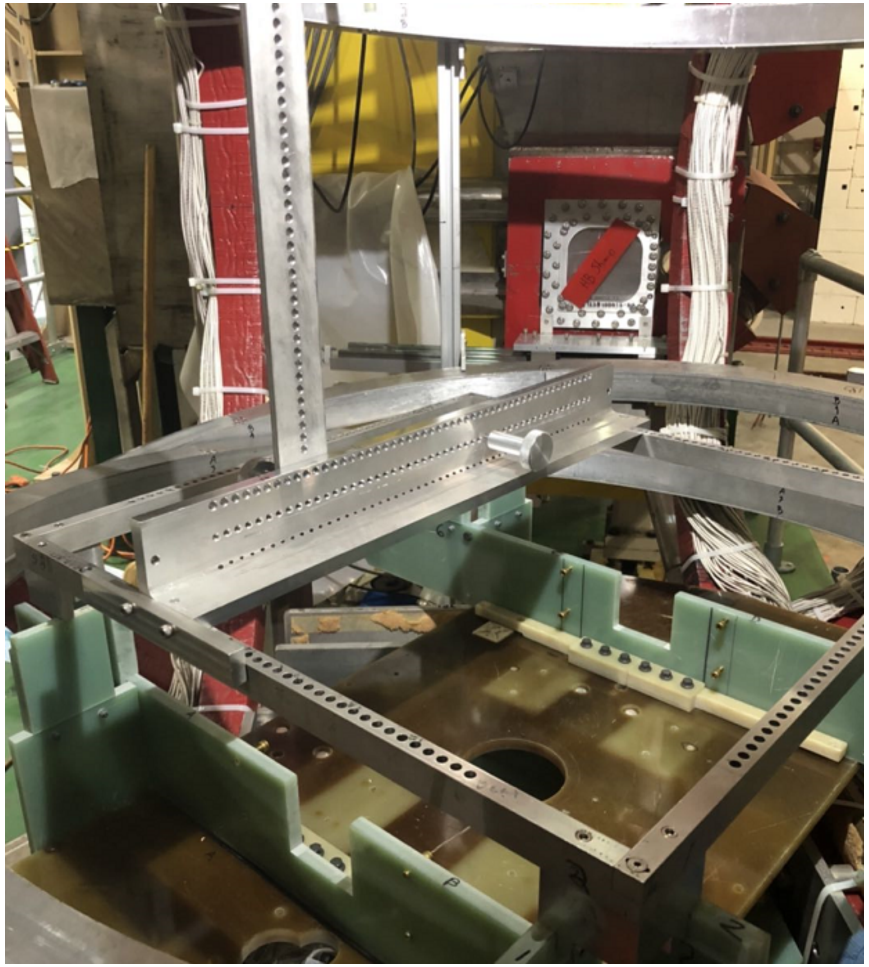




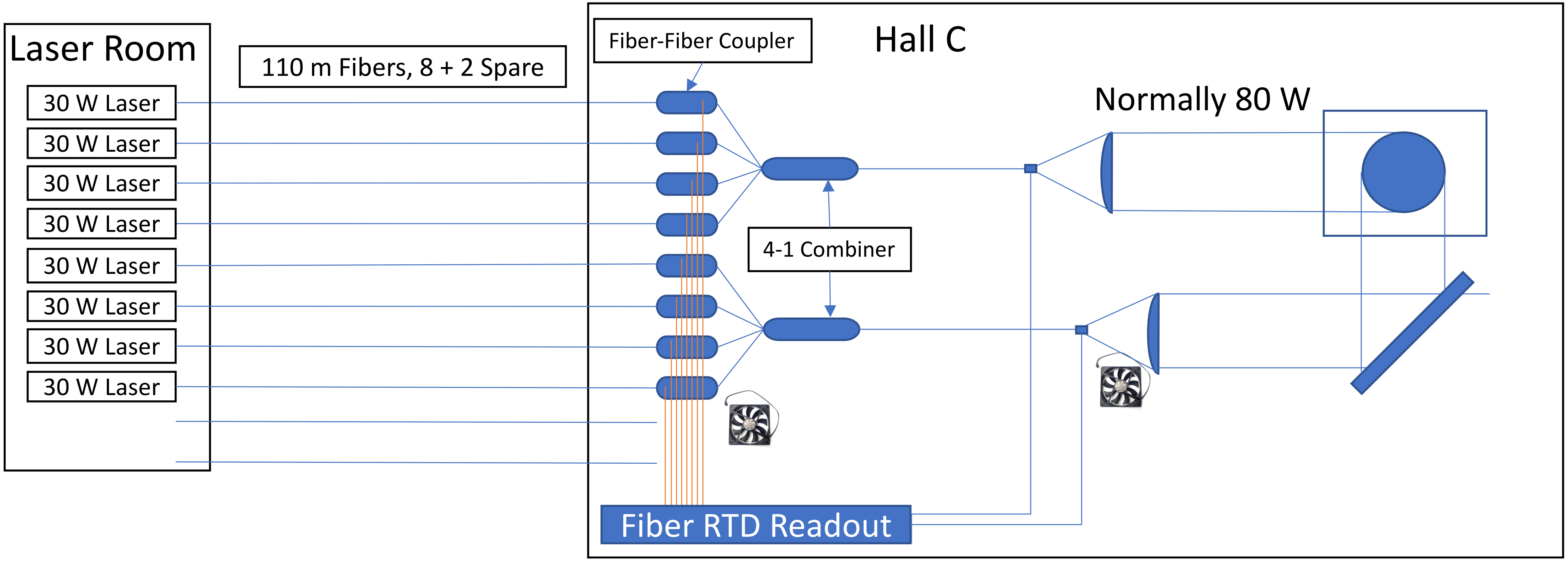
Field Mapping (Jixie Zhang)

- Measure and correct the field gradient and vertical field components caused by the magnetic structures surrounding the target and fringe field of SHMS HB.
- Use a 3-axis Hall probe (Steve Lassiter) mounted on a 3-axis movable slotted rack .





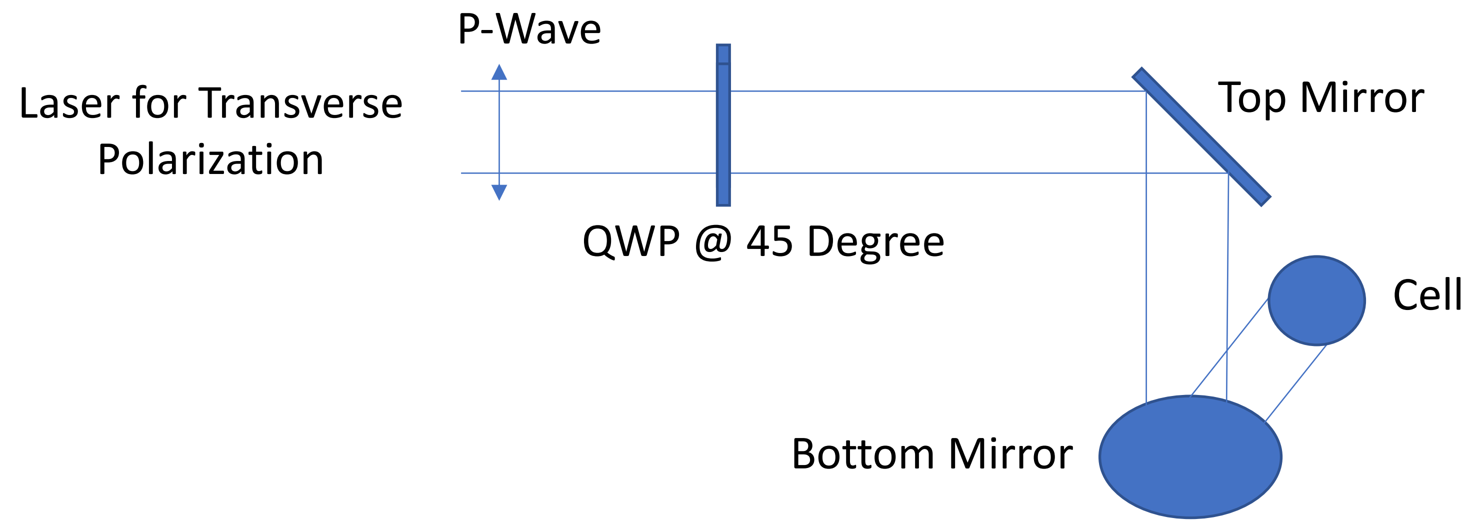
Laser Power Delivery

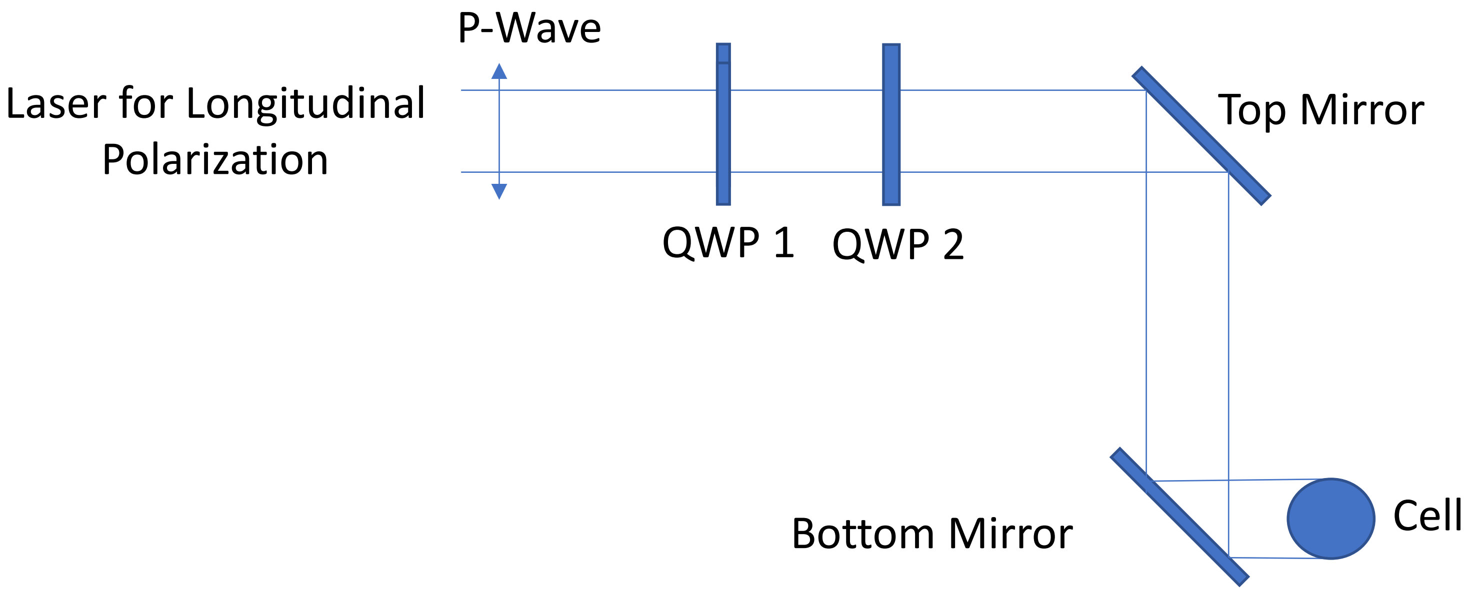


- Eight 30 W narrow band lasers in laser room of counting house for both longitudinal and transverse polarization, 4 for each direction. Also two as spares.
- The laser power coming out of long fibers are combined by a 4-1 fiber combiner for each direction.
- In order to prevent temperature rise of the fiber to fiber coupler and fiber output from damaging the fiber ends, the temperature at these locations are monitored and interlocked to laser system.
- Fiber tip dimensions and fiber con-centricities are measured to ensure fiber to fiber coupling.

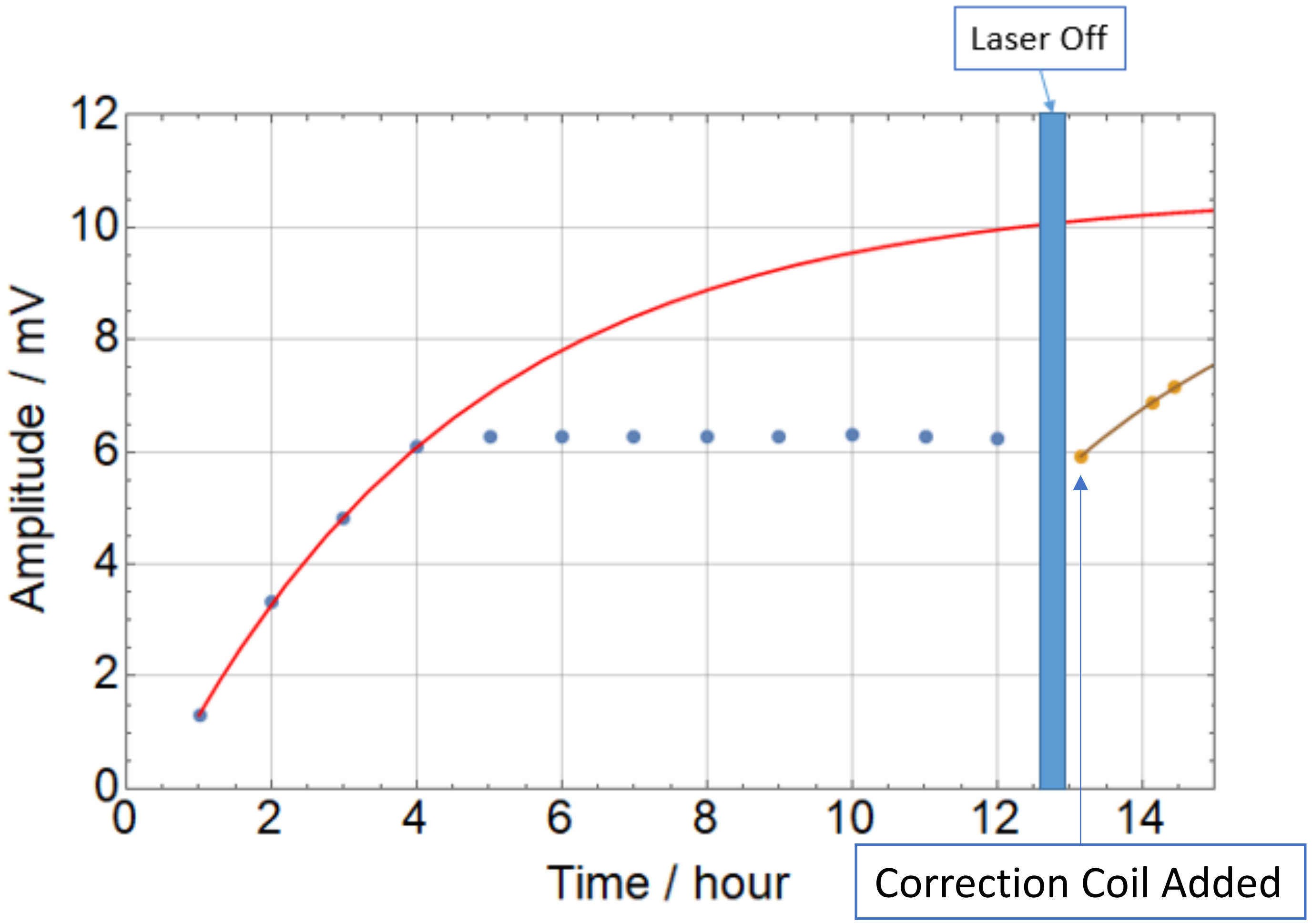
Laser Polarization

- Dielectric mirror has phase shift for S and P wave
- For transverse pumping, the phase shifts from top and bottom mirrors are canceled
- For longitudinal pumping the phase shifts from top and bottom mirrors add up
- For longitudinal pumping, we use two QWPs before the mirrors to compensate the phase shift
- Improper QWPs' settings caused initial low polarizations





Target Polarization: Masing



- After corrected laser polarization, we see clear masing effect for Dutch in the transverse polarization with the SHMS HB off.
- After we added correction coil, the polarization clearly exceeded the masing saturation value.

Log entry:
https://logbooks.jlab.org/entry/3761083

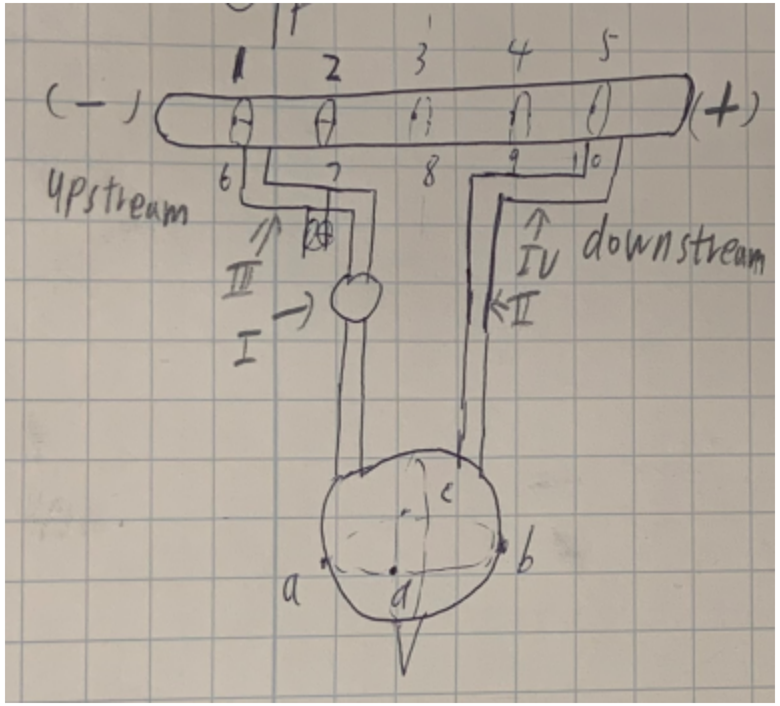
Target Polarization: Dutch

- Without beam, maximum transverse polarization reached mid 60%.
- With 30 μA beam, maximum transverse polarization is around mid 50%.
- Without beam, maximum longitudinal polarization is higher than 60% Initially.
- Now with 30 μA beam, polarization is around mid 40%.

- Current run pattern: we take 5 hour of transverse production data for the target to reach maximum polarization in transverse direction, then rotate polarization to longitudinal direction and take 7 hour of longitudinal production data

Target Cell Glass Thickness Measurement

- Used ultrasonic thickness gauge to measure the wall thickness of target chamber. (Mingyu Chen)
- Used laser interference pattern to measure the window thickness of target chamber. (Christopher Jantz from UVa)



Production Cell "Dutch" Wall Thickness

	Measurement location	Position away from center (along Z) [cm]	Ultrasonic thickness gauge [mm]
TC front	#1	-12.5±0.16	1.323±0.01
	#2	-6.25±0.16	1.295±0.01
	#3	0.0±0.16	1.275±0.01
	#4	+6.25±0.16	1.286±0.01
	#5	+12.5±0.16	1.267±0.01
TC rear	#6	-12.5±0.16	1.341±0.01
	#7	-6.25±0.16	1.342±0.01
	#8	0.0±0.16	1.334±0.01
	#9	+6.25±0.16	1.339±0.01
	#10	+12.5±0.16	1.361±0.01

Cell Production

Credit by Gordon Cates

Cell name	fill date	cold spin down lifetime (hrs)	Max polarization	Expected in-beam polarization	Current status
Big Brother (UVa)	10/24/2019?	26	60% (UVa)	~55%	Ready for experiment
Brianna (UVa)	3/27/2019	12	?	53%	Ready for experiment
Dutch (UVa)	8/22/2019	29.4 (UVa)	54% (UVa)	53%	Ready for experiment
Fulla (UVa)	9/7/2018	17 (UVa); 15 (JLab)	53% (UVa); 54% (JLab)	50%	Ready for experiment
Tommy (W&M)	9/11/2019	15.2 (UVa)	54% (UVa)	49%	Ready for experiment
Austin (UVa)	11/7/19	20 (UVa)	52% (UVa)	N/A	Testing at UVa
Savior (UVa)	10/27/2016	42 (UVa, 2016); 12-28 (JLab); 14.3 (UVa 2019 w convection)	65% (UVa); 38% (JLab); 40% (UVa 2019)	60% (2016) $\rightarrow$??	laser damage, not a good backup cell
Florence (UVa)	9/28/2018	11 (UVa)	45% (UVa)	44%	backup cell
Zhou (W&M)	9/27/2019	9-10 (UVa)	~40% (UVa)	?	backup cell

Other cells made in 2019 but not good: **Noah** (3/07), **Elle** (3/29), **Sandy-II** (5/28), **Phoenix** (6/3), **Zoe** (Aug), **Yeti** (Aug, broke), **Wayne** (Aug/Sept), **Columbus** (Oct);

Target Activities at User Institutions

- Cell fabrication and testing: UVa (Gordon Cates), W&M (Todd Averett)
- κ_0 measurement: W&M (Todd Averett), UVa

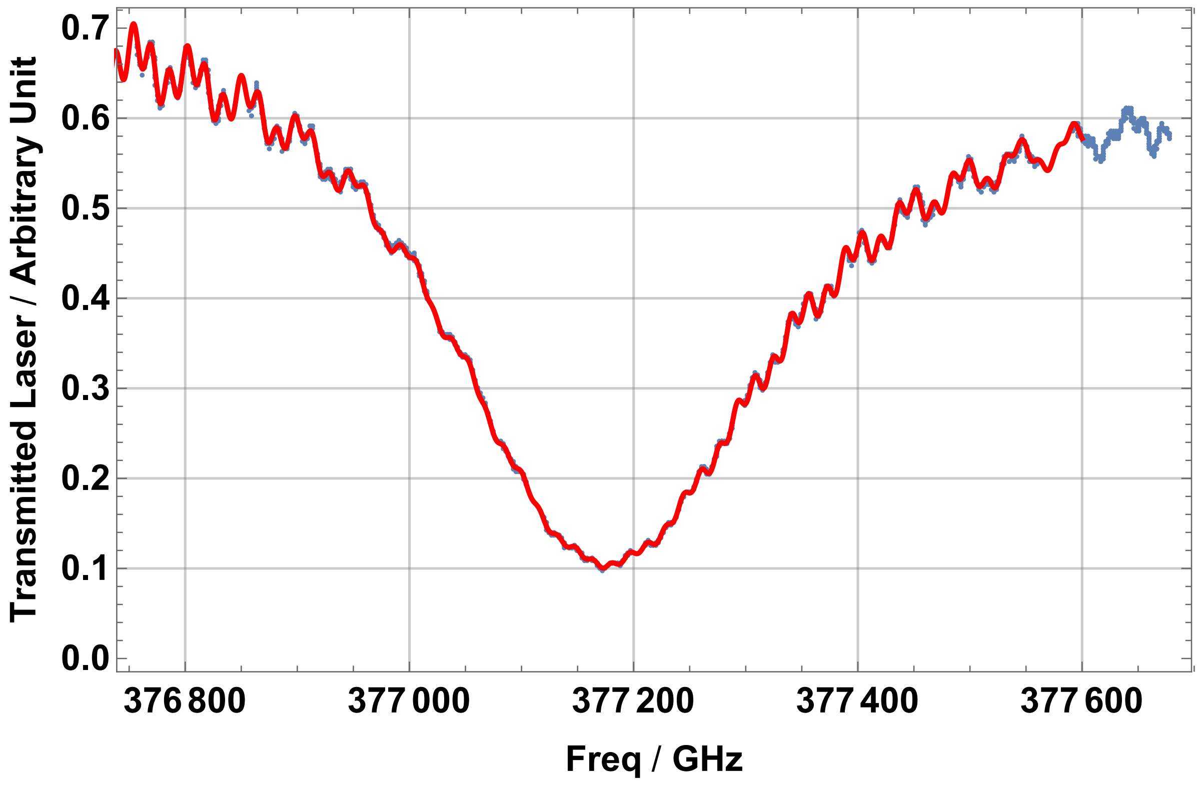
Summary

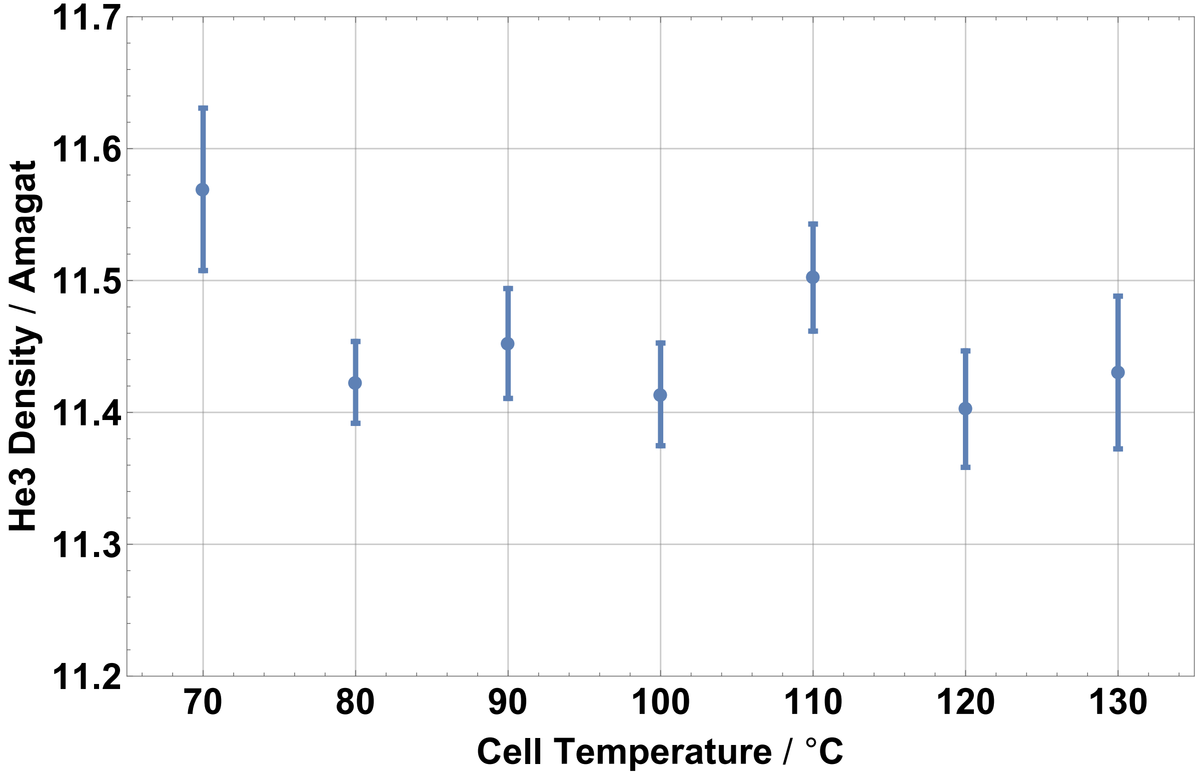
- After overcoming all the challenges, we are taking overall 55% polarization production

Backup Slides

Density Measurement
Pressure Broadening

Rb D1 absorption profile at 100 ℃

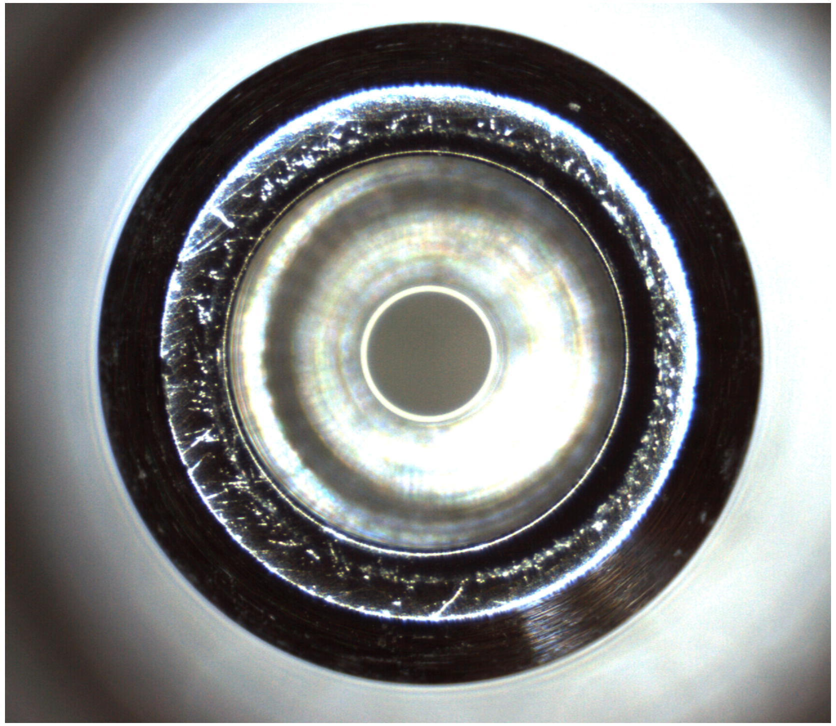




Averaged Density: 11.45 ± 0.02 (Stat.) ± 0.18 (Sys.) amg

Fiber Dimension and Fiber Concentricity

SMA Length Gauge



Microscope Image of Fiber End

Convection Speed Test