INDIANA UNIVERSITY BLOOMINGTON

NOPTREX: Polarized ^{3}He Neutron Spin Filter and Polarized Xenon Pseudomagnetic Precession

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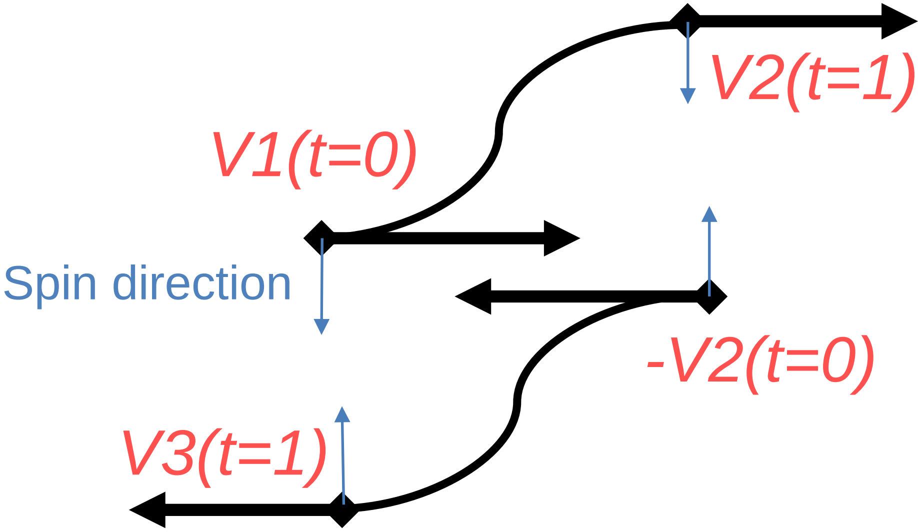
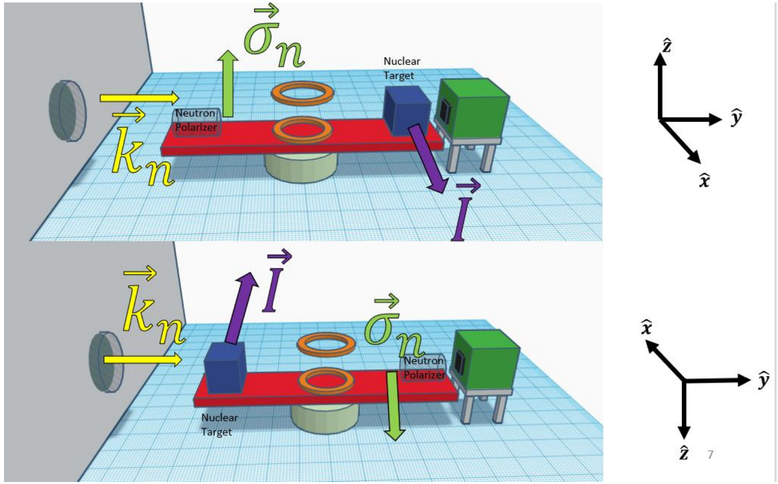
SECTION 1

NOPTREX Overview

NOPTREX

- Neutron OPtics Time Reversal Experiments
- Search for time reversal violation in polarized neutron transmission through polarized heavy nuclei
- Realize Time Reversal by using Motion Reversal





NOPTREX Components

- Parity violation measurements
  - Unpolarized targets: ^{139}La, ^{81}Br, ^{131}Xe
  - Polarized neutron source: ^{3}He spin filter
- Kappa measurements
- Time and parity violation measurements
  - Polarized targets
  - Spin-dependent pseudomagnetic precession

$$\Delta\sigma_{TP} = \kappa(J)\frac{w}{v}\Delta\sigma_P$$

PT violation — P violation

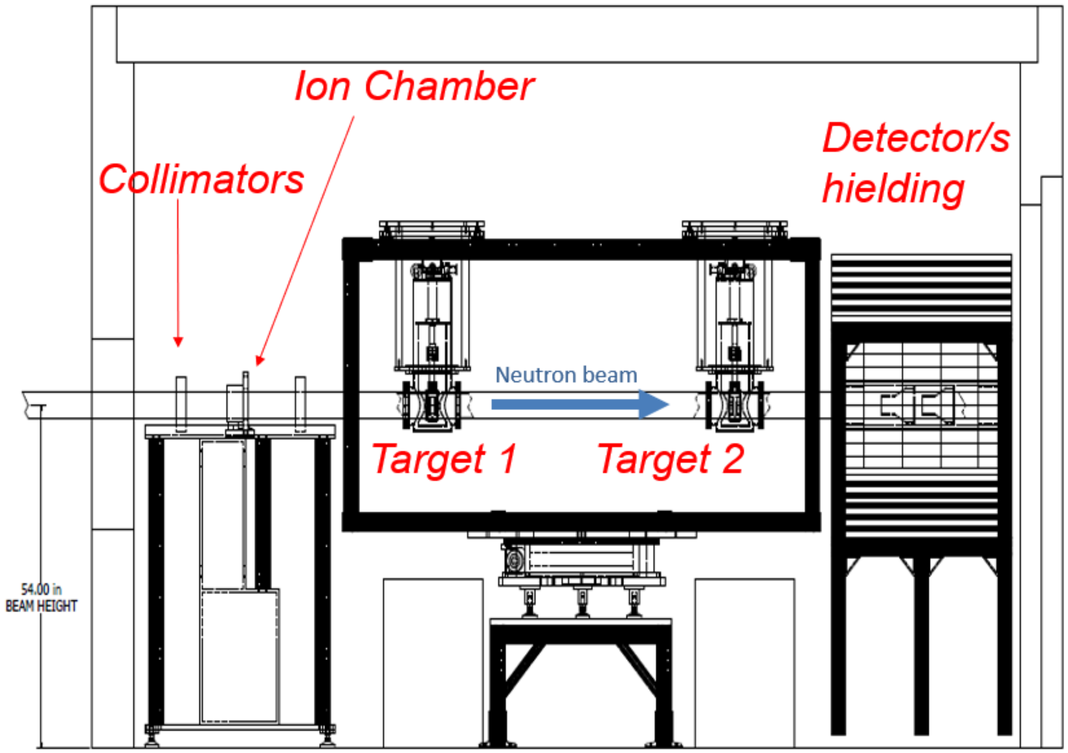
$$f = f_0 + f_1\vec{\sigma_n}\cdot\vec{I} + f_2\vec{\sigma_n}\cdot k_n + f_3\vec{\sigma_n}\cdot(\vec{k_n}\times\vec{I})$$

P-even, T-even — P-odd — P-odd, T-odd

SECTION 2

Polarized ^{3}He Neutron Spin Filter

Double ^{139}La Setup

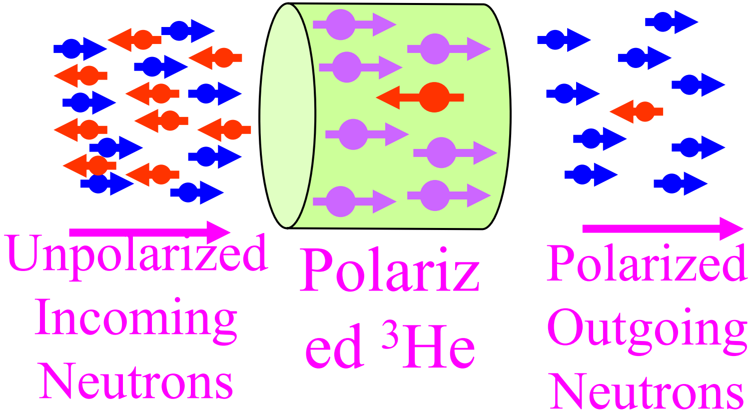


^{3}He neutron spin filter

- Both P-odd and P-odd, T-odd measurements need polarized neutrons
- Strong spin-dependent neutron-3He reaction polarizes neutron beam

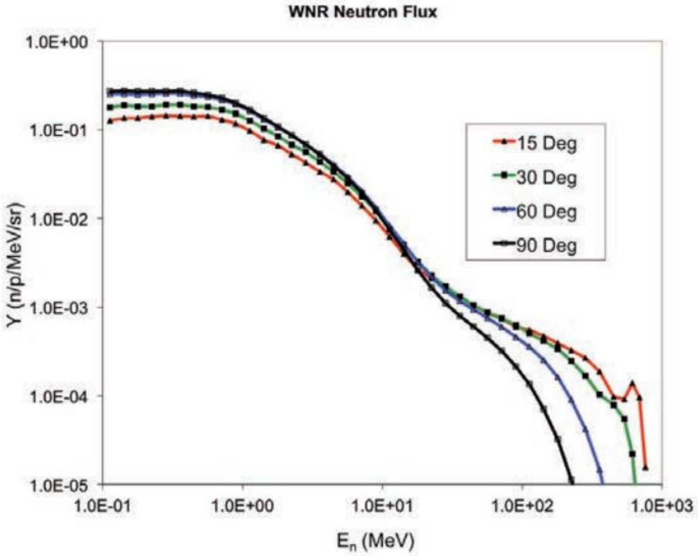
$$\Delta\sigma_{TP} = \kappa(J)\frac{w}{v}\Delta\sigma_P$$

PT violation   P violation



Neutron Energy

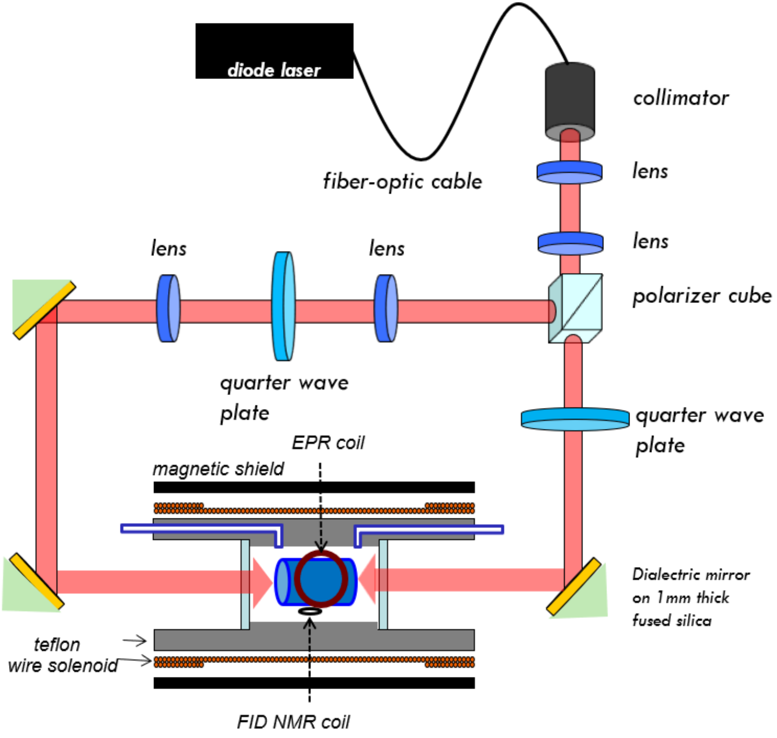
- Resonances of interest as well as neutron energy spectrum determine that we would like to polarize neutrons of a few eV
- ^{139}La
    - P~9.6% at 0.734 eV (Yuan et.al 1991)
- ^{81}Br
    - P~1.77% at 0.88 eV (Frankle et.al 1992)
- ^{131}Xe
    - P~4.3% at 3.2 eV (Szymanski et.al 1996)



Suzanne F. Nowicki et,al. 2016

Spin-Exchange Optical Pumping

- ^3He gas is polarized using SEOP method
- Laser polarizes alkali-metal vapor (Rb, K)
- Rb electrons spin-exchange with 3He thus polarizing 3He



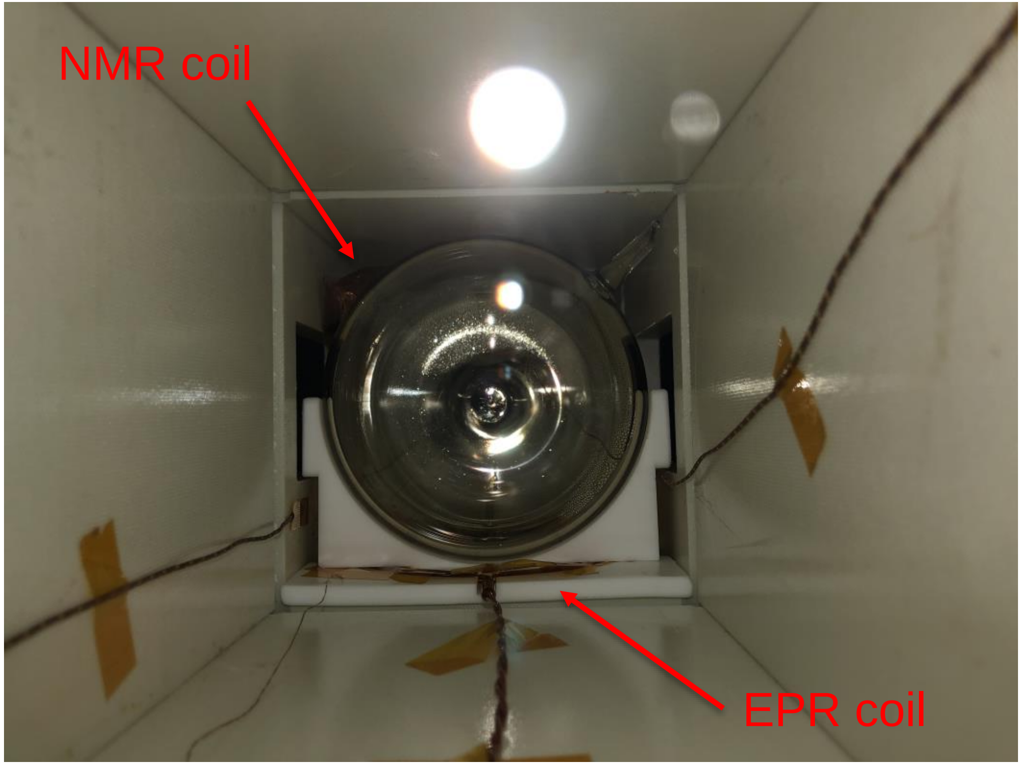
^{3}He Cell

- In order to achieve as high ^{3}He polarization as possible, we generally need higher ^{3}He pressure, longer cell length and larger cross-section
- But longer cell also means less neutron transmission
- $P_{neutron}(\lambda)=\tanh(A\lambda P_{3He})$
- $T_{neutron}(\lambda)=T_0\exp(-A\lambda)\cosh(A\lambda P_{3He})$
- $A=n\sigma_0 l$

^{3}He cell received from ORNL

^{3}He Polarizer Components

- ^{3}He cell
- Oven
- Laser and Optics
- Light-tight box
- Mu-metal shielded solenoid



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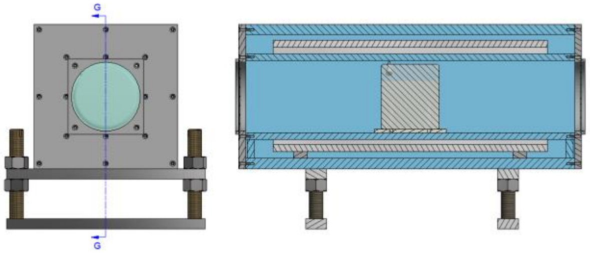

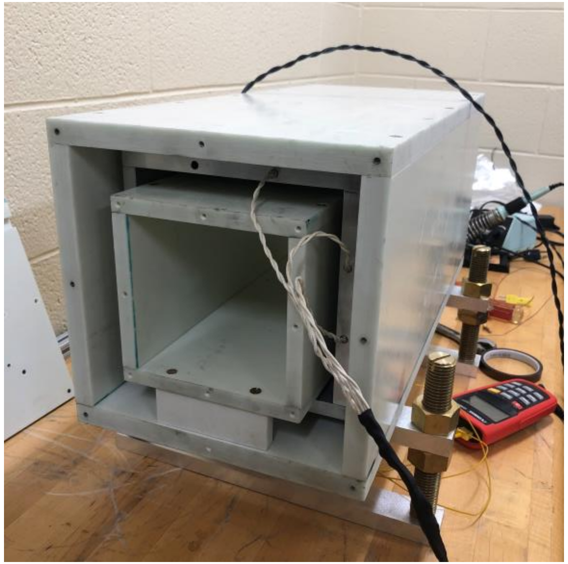

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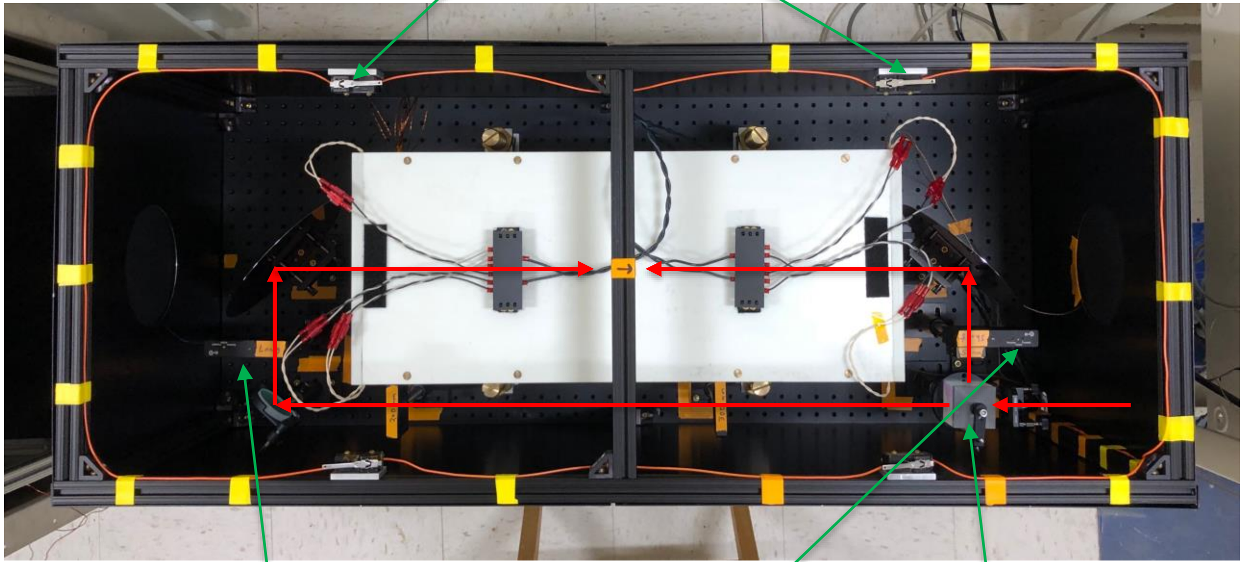

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SECTION 3

^{131}Xe Pseudomagnetic Precession

Pseudomagnetic Precession

- Motivations
  - Systematic error produced by spin-dependent neutron-nucleus strong interaction
  - Input in the global neutron-nucleus scattering length database, which helps quantitative description of nuclei
  - Need to measure spin-dependent scattering lengths for ^{131}Xe and ^{129}Xe

$$f = f_0 + f_1 \vec{\sigma_n} \cdot \vec{I} + f_2 \vec{\sigma_n} \cdot k_n + f_3 \vec{\sigma_n} \cdot (\vec{k_n} \times \vec{I})$$

P-even, T-even P-odd P-odd, T-odd

Pseudomagnetic Precession

- Polarized neutrons experience Fermi pseudo-potential when interacting with polarized nucleus (O. Zimmer et.al, EPJdirect A1, 1-28, 2002)

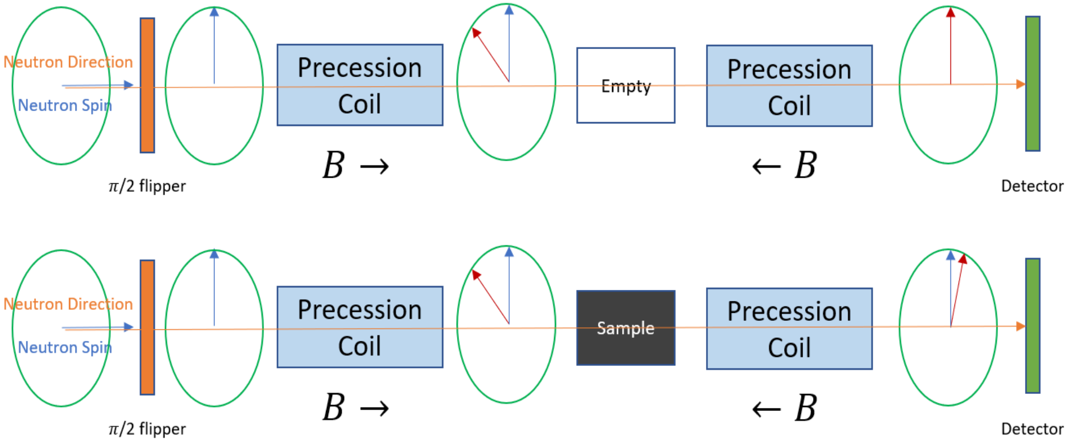
$$V_F = \frac{2\pi\hbar^2}{m} N b'_c + \frac{4\pi\hbar^2}{m} N b'_i \sqrt{\frac{I}{I+1}} \mathbf{s} \cdot \mathbf{P} - \boldsymbol{\mu} \cdot \mathbf{B}.$$

$$V_{F,pm} = -\boldsymbol{\mu} \cdot \left[-\frac{4\pi\hbar}{m\gamma} N b'_i \sqrt{\frac{I}{I+1}} \mathbf{P} \right] =: -\boldsymbol{\mu} \cdot \mathbf{H}^* \ ,$$

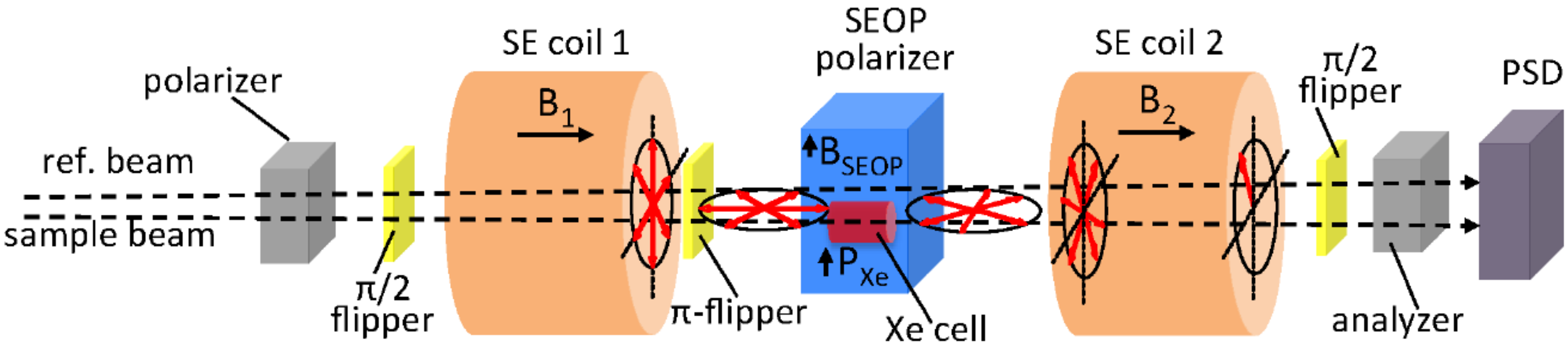
$$\varphi^* = \gamma H^* t = 2\sqrt{\frac{I}{I+1}} \lambda P N d \, b'_i \ .$$

Neutron Spin Echo

- A very precise technique to measure tiny neutron energy change
  - Total rotation angle: $\varphi + 2\pi N$
  - Fractional error: $\Delta\varphi / 2\pi N$
- Modified to reflect pseudomagnetic precession

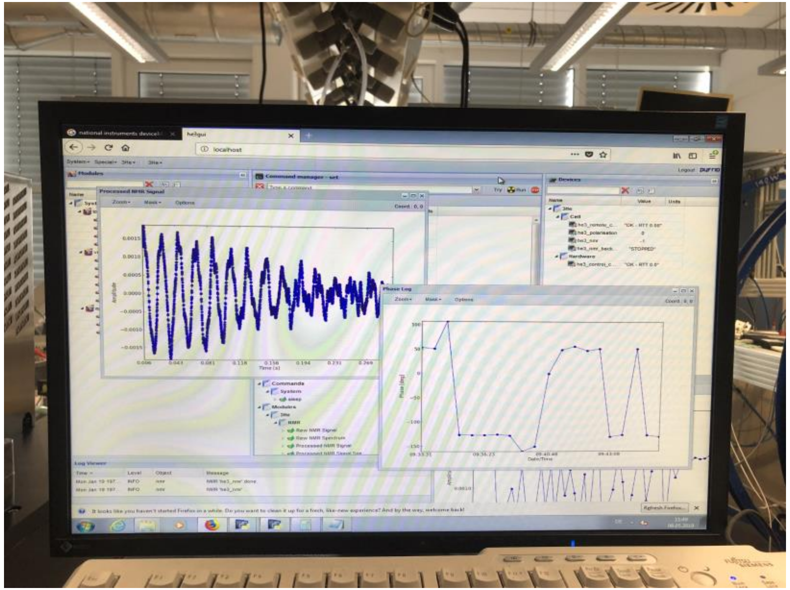


Experiment Setup



Experiment Status

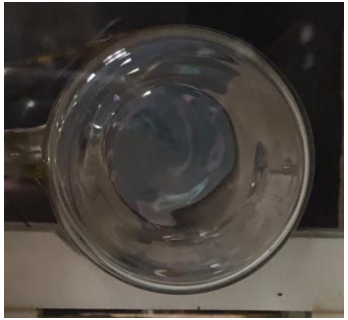
- Successfully polarized Xe using a high performance in-situ SEOP polarizer

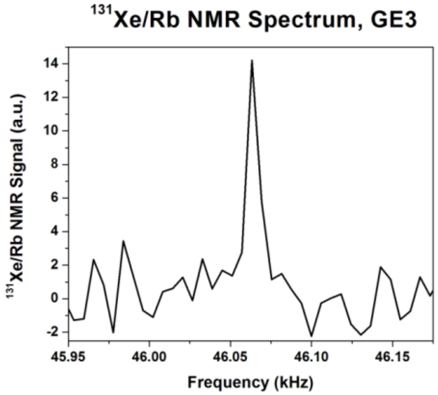


^{129}Xe NMR Signal and AFP phase log

Experiment Status

- Successfully polarized Xe using a high performance in-situ SEOP polarizer
- A long GE180 Xe cell has been made at SIU
- Originally scheduled at FRM II, JCNS, MLZ
- Now consider transferring beam time to SNS at ORNL





First 131Xe spectrum from a GE180 Cell (150 torr 131Xe, 150 torr N2)

Thank You!