JLAB POLARIZED ^{3}He TARGET

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

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Outline

- Introduction
- Upgrade Plan
- R&D Progress
- Summary

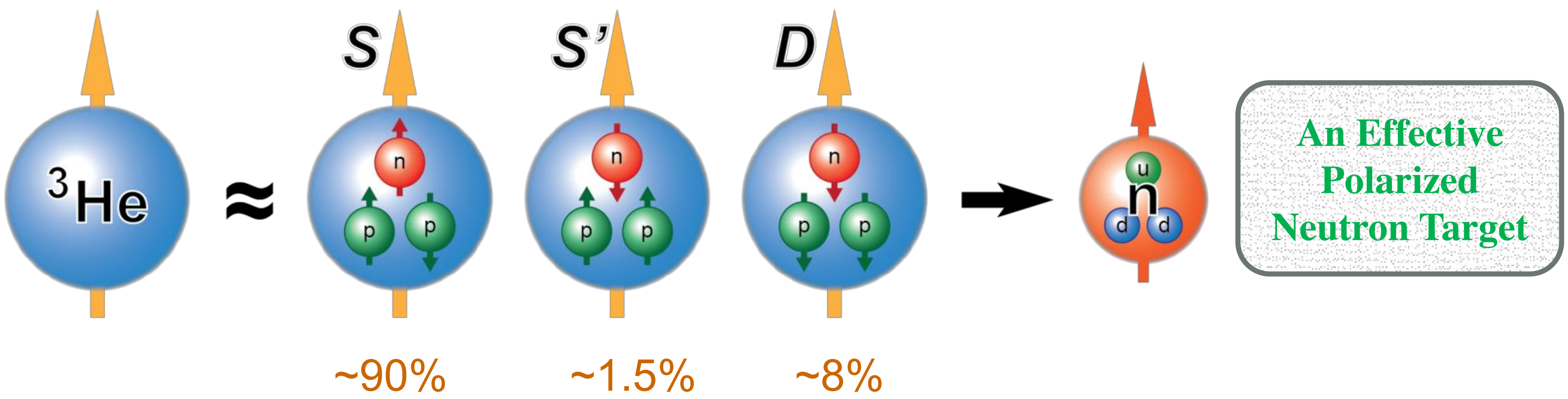
Introduction

➢ Why Polarized ^{3}He Target

- Polarized targets essential for nucleon spin structure study

- Free neutrons, short lifetime < 15 minutes

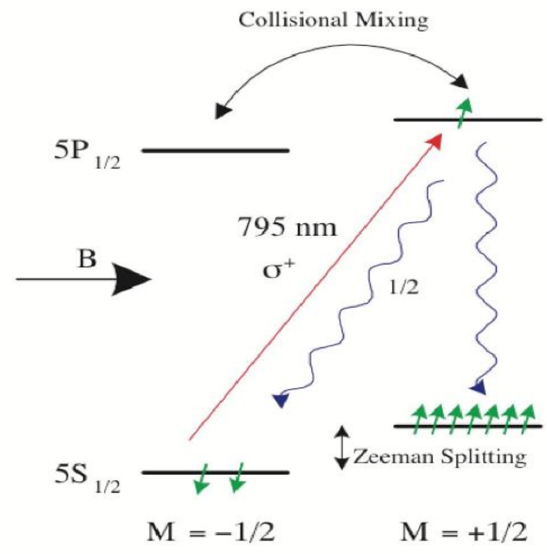
- ^{3}He and deuteron are two good candidates for an effective neutron target.



Introduction

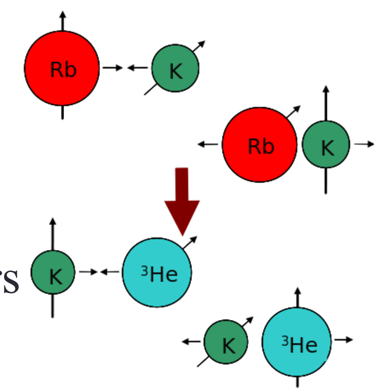
➢ How to polarize ^{3}He Target

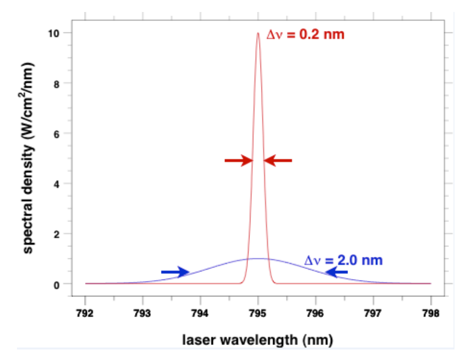
- Spin-exchange optical pumping (**SEOP**)
  - Polarize the alkali metal atoms
  - Exchange spin with ^{3}He



➢ Recent improvements in the SEOP:

- The change from Rb to Rb-K mixture (hybrid cell)
- The use of spectrally-narrowed diode lasers

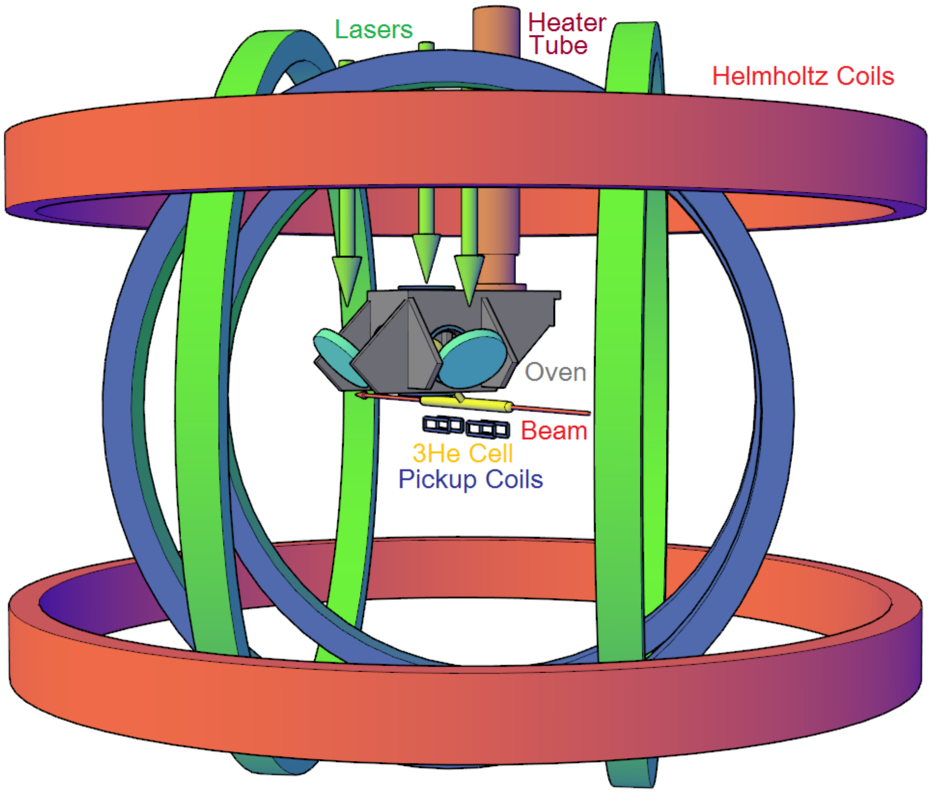




➢ Progress

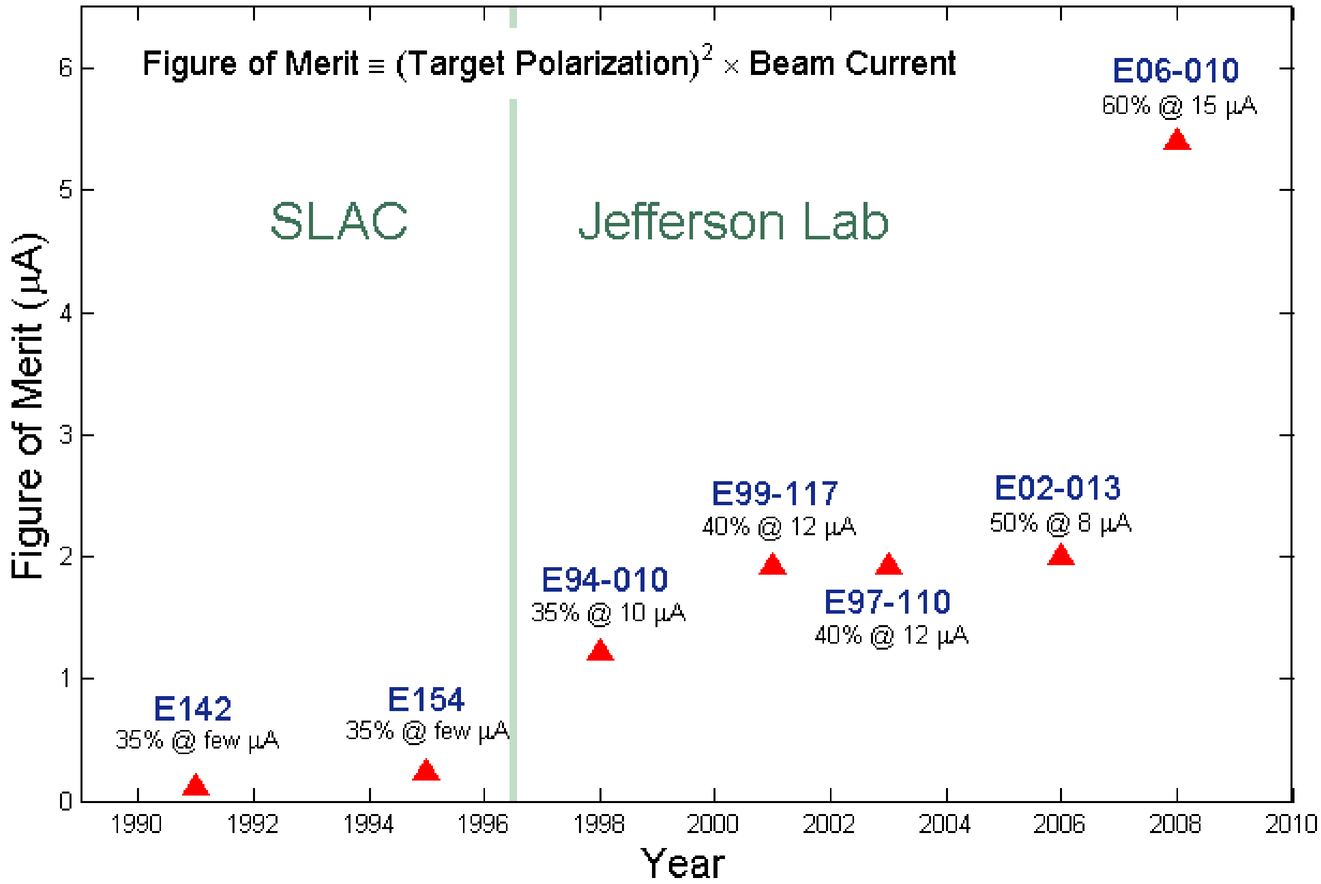
- Spin up time shorten: 10 hours ➔ about 5 hours
- In-beam target polarization:
  40% ➔ 50% (GEN) ➔ 60% (Transversity)

JLab Polarized ^{3}He Target Overview



- ✓longitudinal, transverse and vertical
- ✓Luminosity=10^{36} ($1/cm^2$/s) (highest in the world)
- ✓High in-beam polarization 55-60%, maximum reached over 70% without beam
- ✓Polarimetry: NMR/water +EPR total uncertainty 3~5%
- ✓Effective polarized neutron target
- ✓13 completed experiments 7 approved with JLab 12 GeV

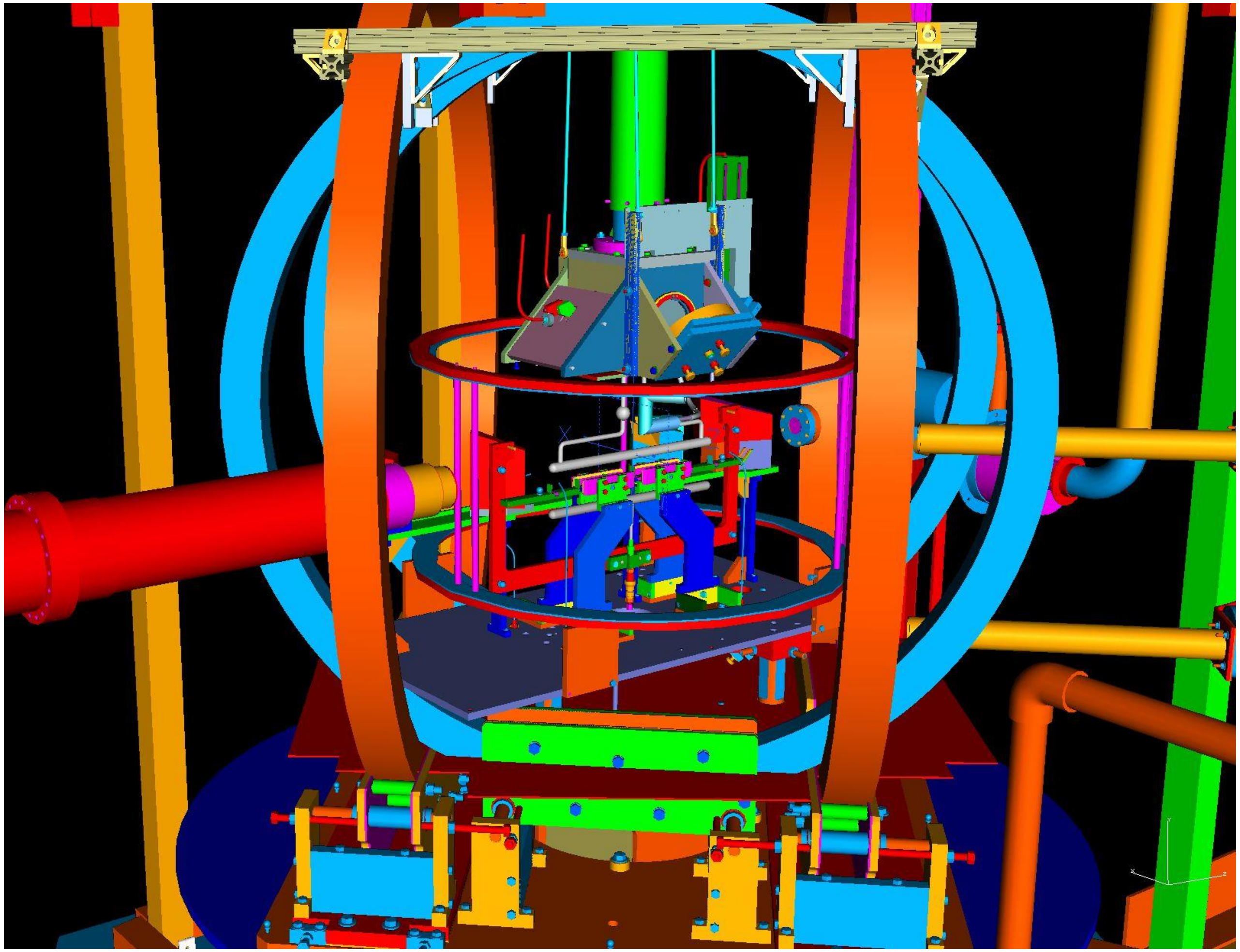
Figure-of-Merit History for High Luminosity Polarized ^{3}He Target



^{3}He Target Upgrade Plan

- **Upgrade the target with a factor of 2~3 in FOM of the best achieved**
- **To satisfy A_1^n -A requirements/plan:**
  - **30 uA on 40 cm convection cell, 60% in beam, 3% polarimetry**
  - **Use transversity setup with convection cell**
    - **Uniform polarization between target and pumping chambers**
    - **→ 60% achievable**
    - **→ Eliminate diffusion uncertainty**
  - **Pulsed NMR, calibrated with EPR and AFP NMR/water ,**
  - **κ_0 measurements (users)**
- **R&D progress:**
  - **Mechanical design**
  - **Diffusion model test**
  - **Convection cell tests/transfer heater design**
  - **Polarization loss study (field gradient, new material, …)**
  - **Pulsed NMR setup and systematic study**
  - **Laser system study**
  - **Higher current study: shielding needs?**

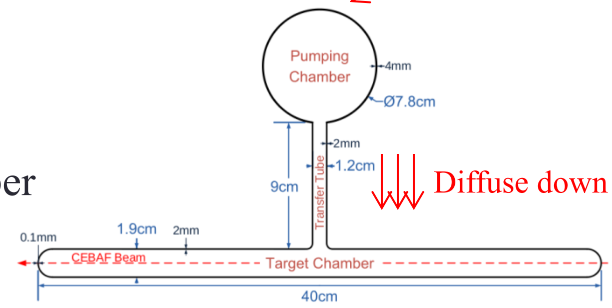
Mechanical Design

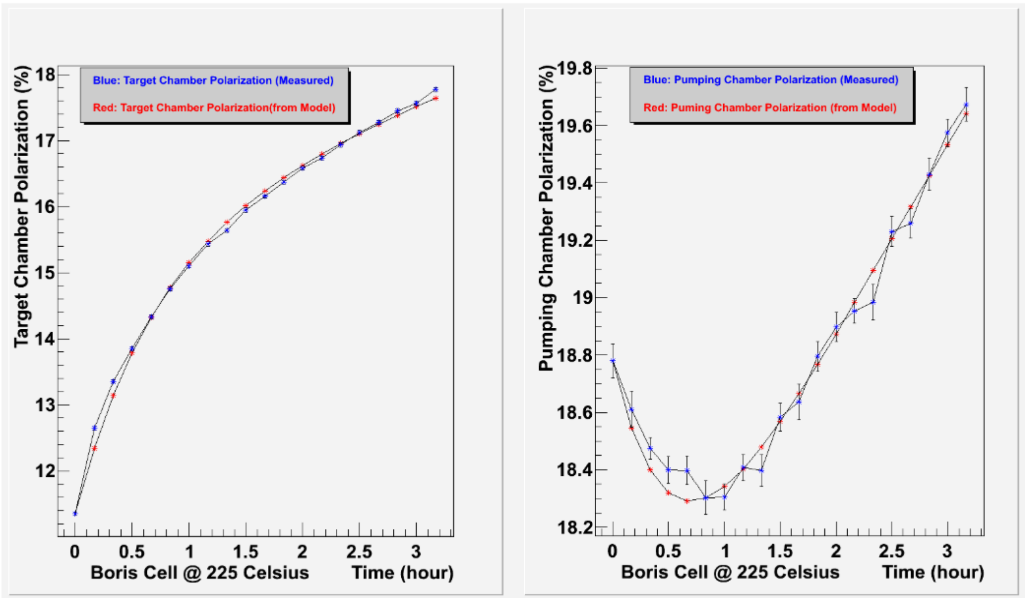


Diffusion Model Test

➢ Diffusion Model Test:

- Pump up to high polarization
- Destroy spin polarization along target chamber
  Keep pumping chamber polarization as high as possible
- Record the dynamics of polarization progress in two chamber
- Water NMR calibrate the target chamber NMR signal
- EPR calibrate the pumping chamber NMR signal





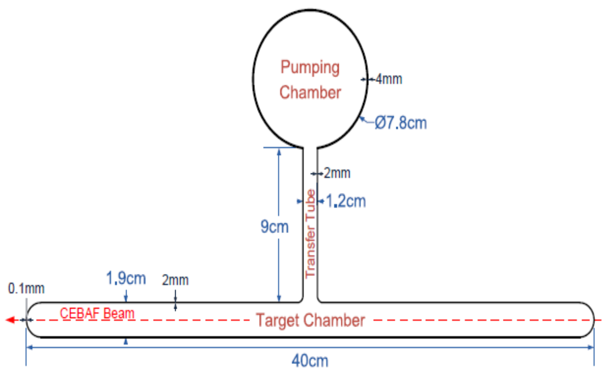
➢ Preliminary Result:

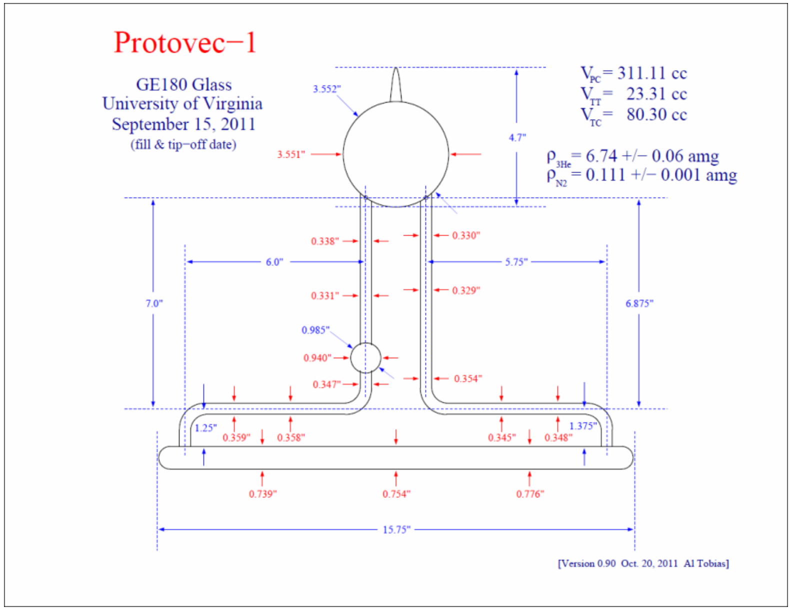
Diffusion time ~ 40 mins

Diffusion Cell to Convection Cell

➢ New convection style cell (single pumping chamber)

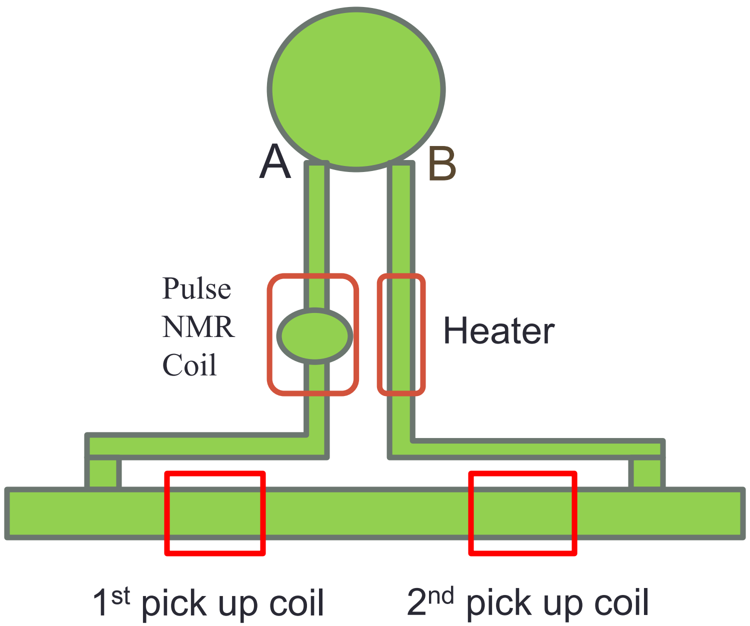
- “Protovec-I” tested at UVa, transferred to JLab a few months ago
- 3D measurement of the cell, CAD model
- Made customized mount and oven bottom piece
- Testing ongoing at JLab now





^{3}He Convection Heater

- **Heater choice and effects study**



Silicone Rubber Encapsulated Heating Tape

Kapton (polyimide film) heater
Excellent radiation resistance

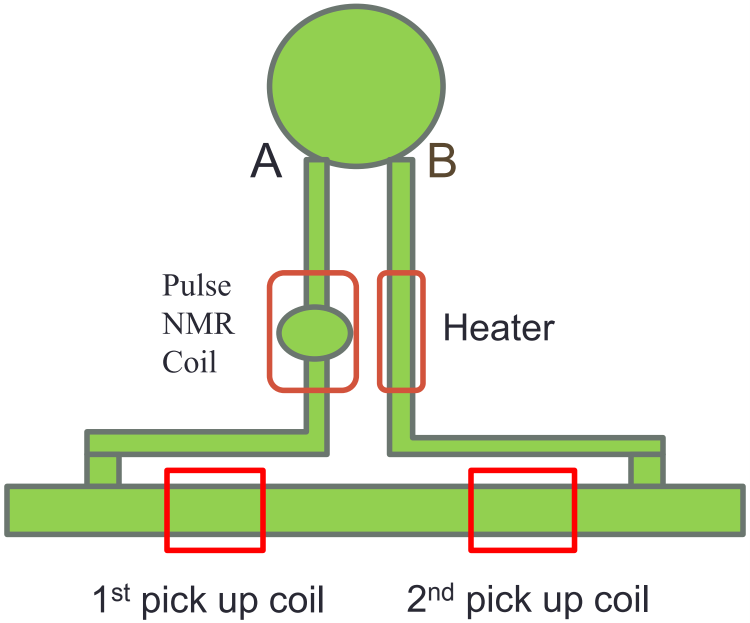
Heater instead of convection oven?

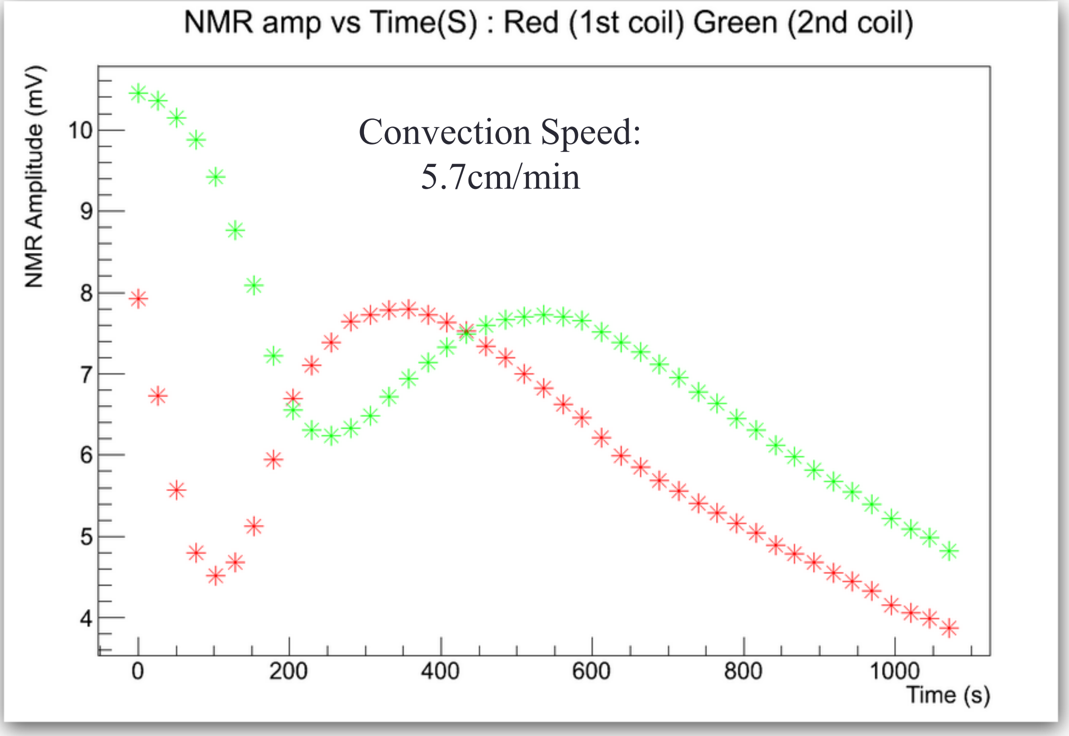
Advantage:
Reduce oven design labor
More convenient to replace cell…

Problem: Affect AFP?

^{3}He Convection Speed Test

- Convection can be much fast than diffusion (~40mins)

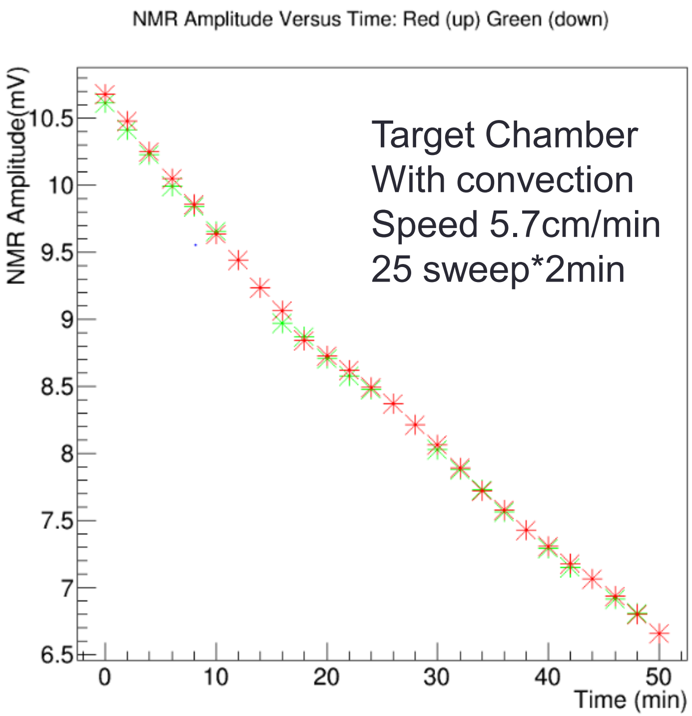


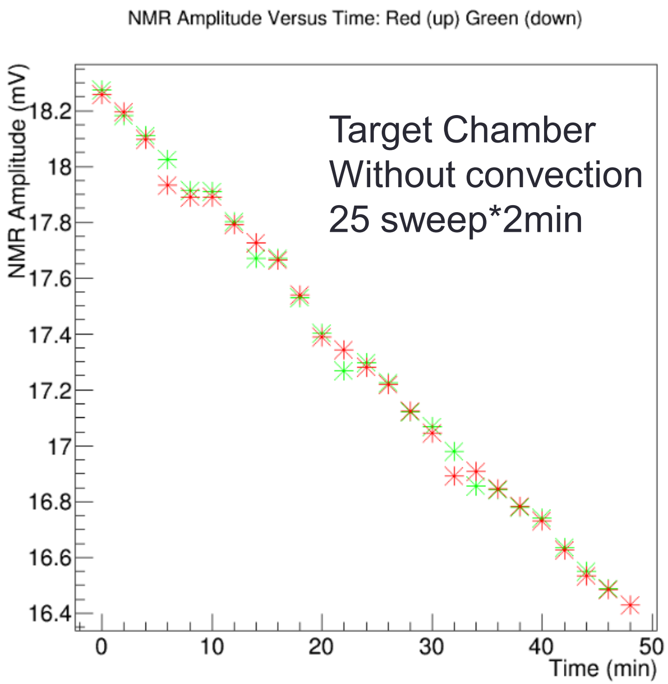


Convection from pumping chamber A to target chamber: ~1 min

Convection from pumping chamber A, through target chamber, back to B: ~8 mins

AFP Loss Study

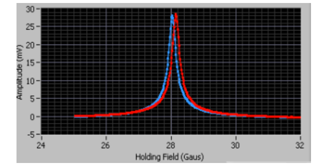




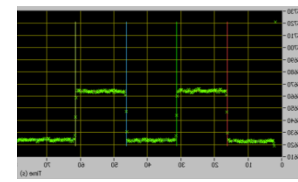
AFP Loss Per Sweep	Target Chamber	Pumping Chamber
AFP Without Convection	0.16%	0.72%
AFP With Convection	0.85%	0.87%

^{3}He Target Polarimetry

➢ Adiabatic Fast Passage (AFP) - NMR

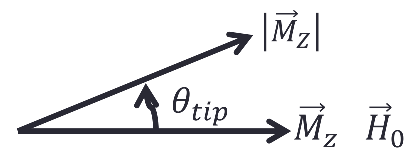


- AFP-NMR works for both 3He and water
- AFP loss significant for longer/larger cell due to field gradient
- Will not work for metal target chambers or hybrid glass/metal cells



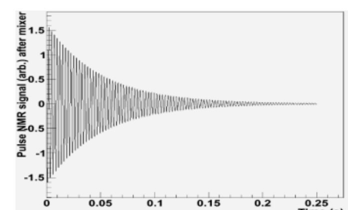
➢ Electron Paramagnetic Resonance (EPR)

- EPR will still work



➢ Pulsed NMR

- Send a pulse tuned at Larmor Frequency
- Spin presses tipping from holding field
- $\theta_{tip} = \frac{1}{2}\gamma H_1 t_{pulse}$
- Spin components orthogonal to holding field,
- Have free-induction-decay, Amplitude∝ $M_z \sin(\theta_{tip})$

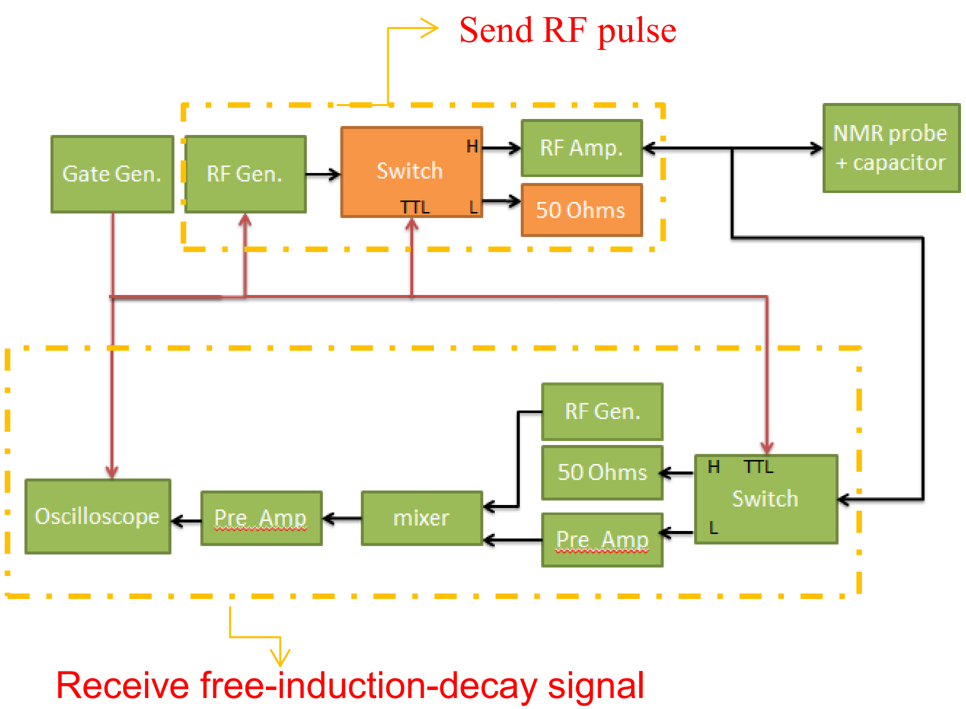


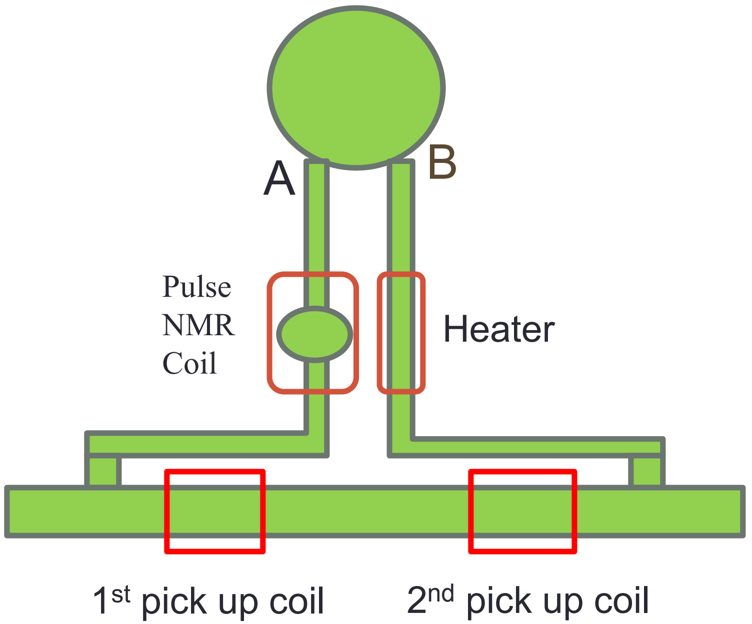
Theory:
S∝ $M_z \sin(\theta_{tip}) e^{-t/T_2} \sin(wt)$

AFP-NMR will not be suitable for measurement on target chamber of glass/metal cell. Pulsed NMR can work on transfer tube

Pulsed NMR @JLab

➢ Pulsed NMR Set Up

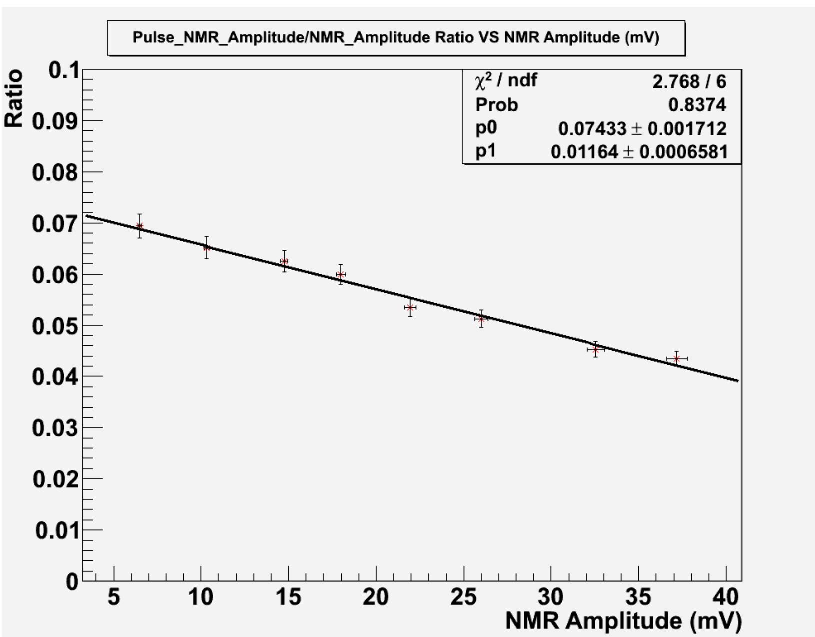


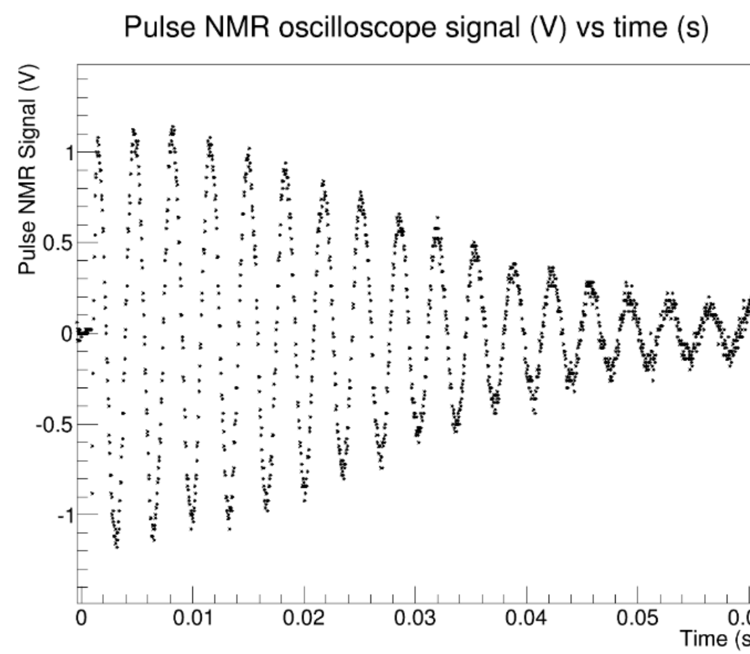


Pulsed NMR monitor polarization locally around the 1-inch bulb

Pulsed NMR

- **Pulsed NMR compared with regular NMR**





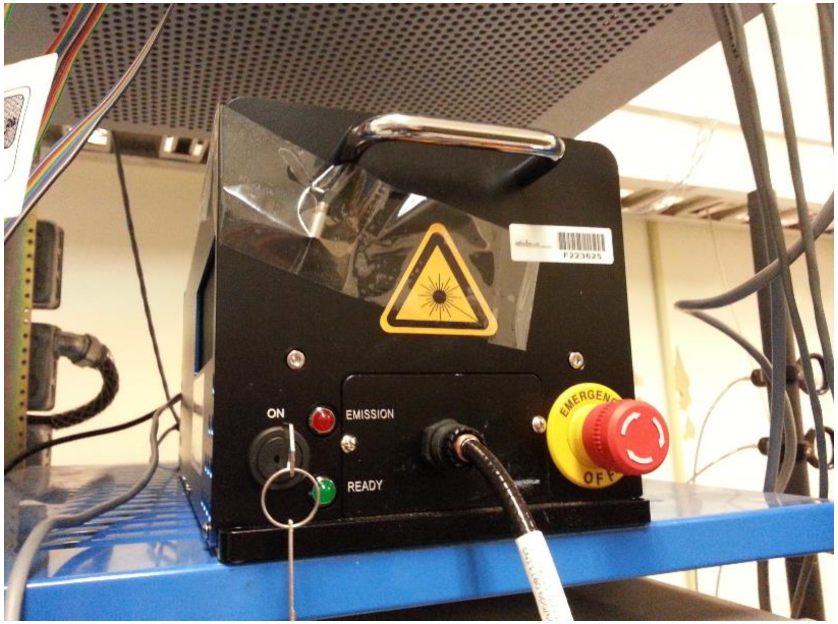
Systematic study continuing

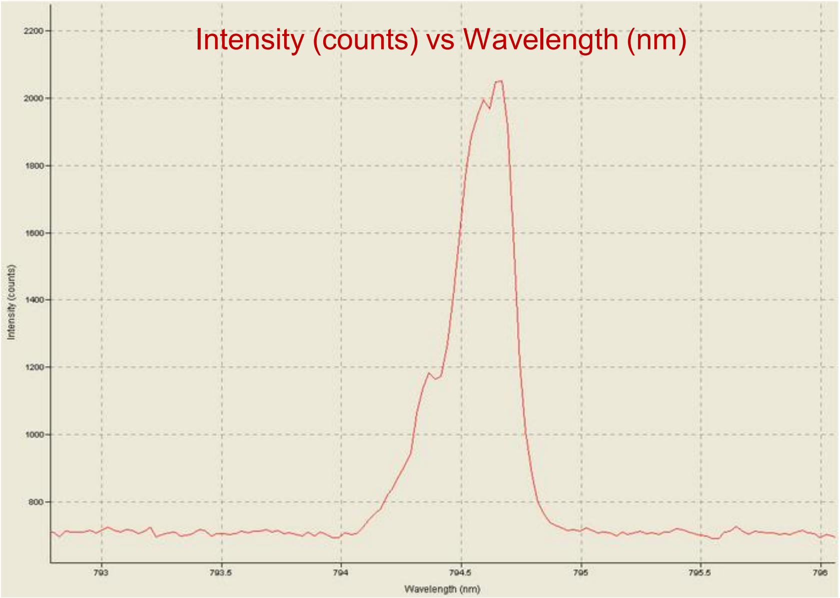
Challenge: to improve S/N

Lasers

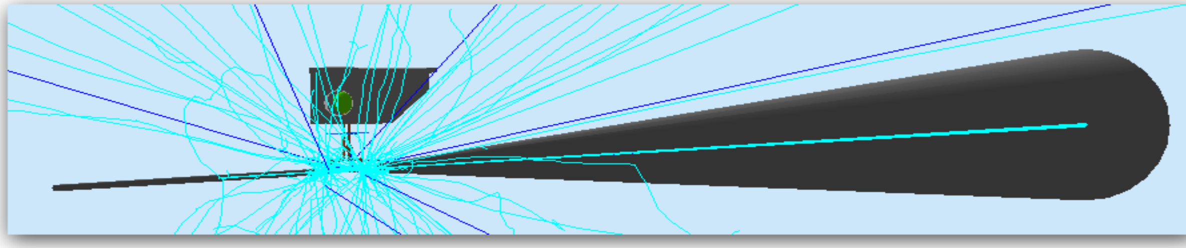
➢New lasers

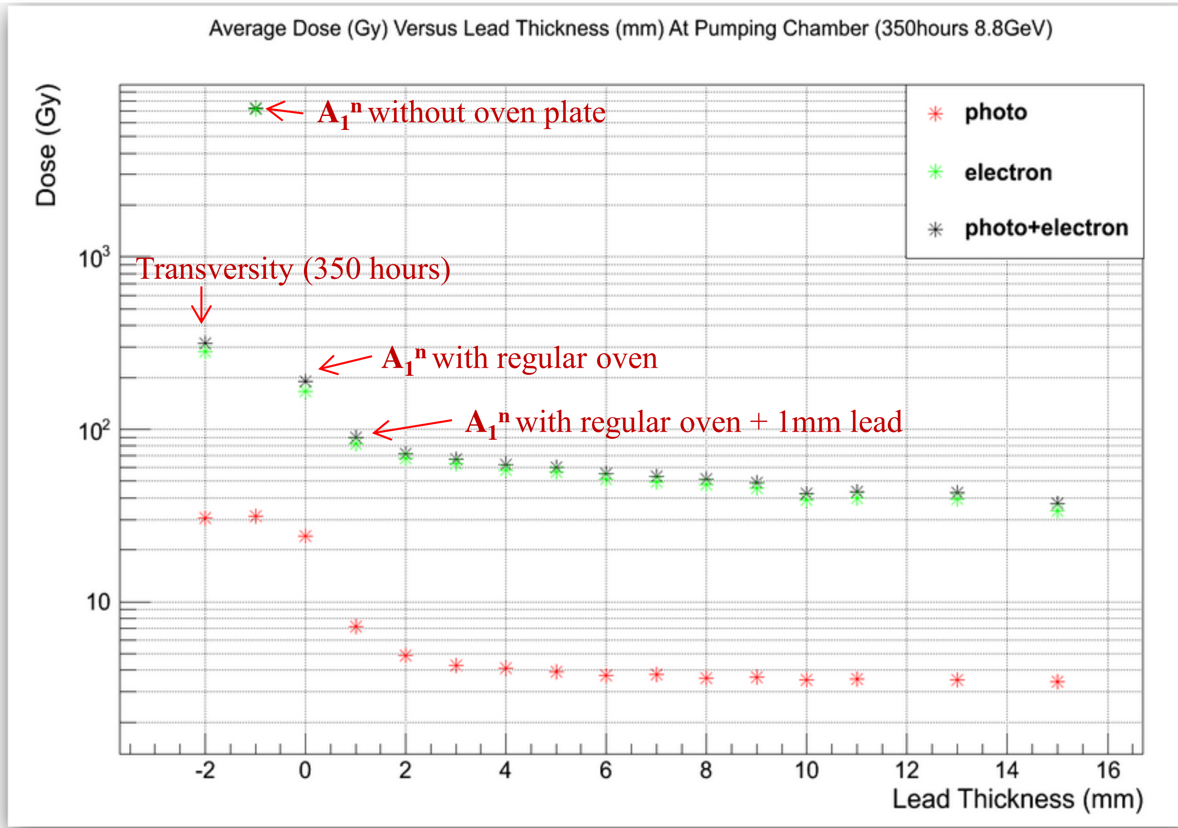
- The Comet laser (25W, 0.2nm width) production was discontinued
- Purchased one QPC Laser (Hall C, 25W, 0.27nm width)
- Upgrade one Coherent laser by Raytum (can be adjusted 794.6nm~795nm, 0.22nm width)
- Both in test now





^{3}He Target Radiation Shielding Study

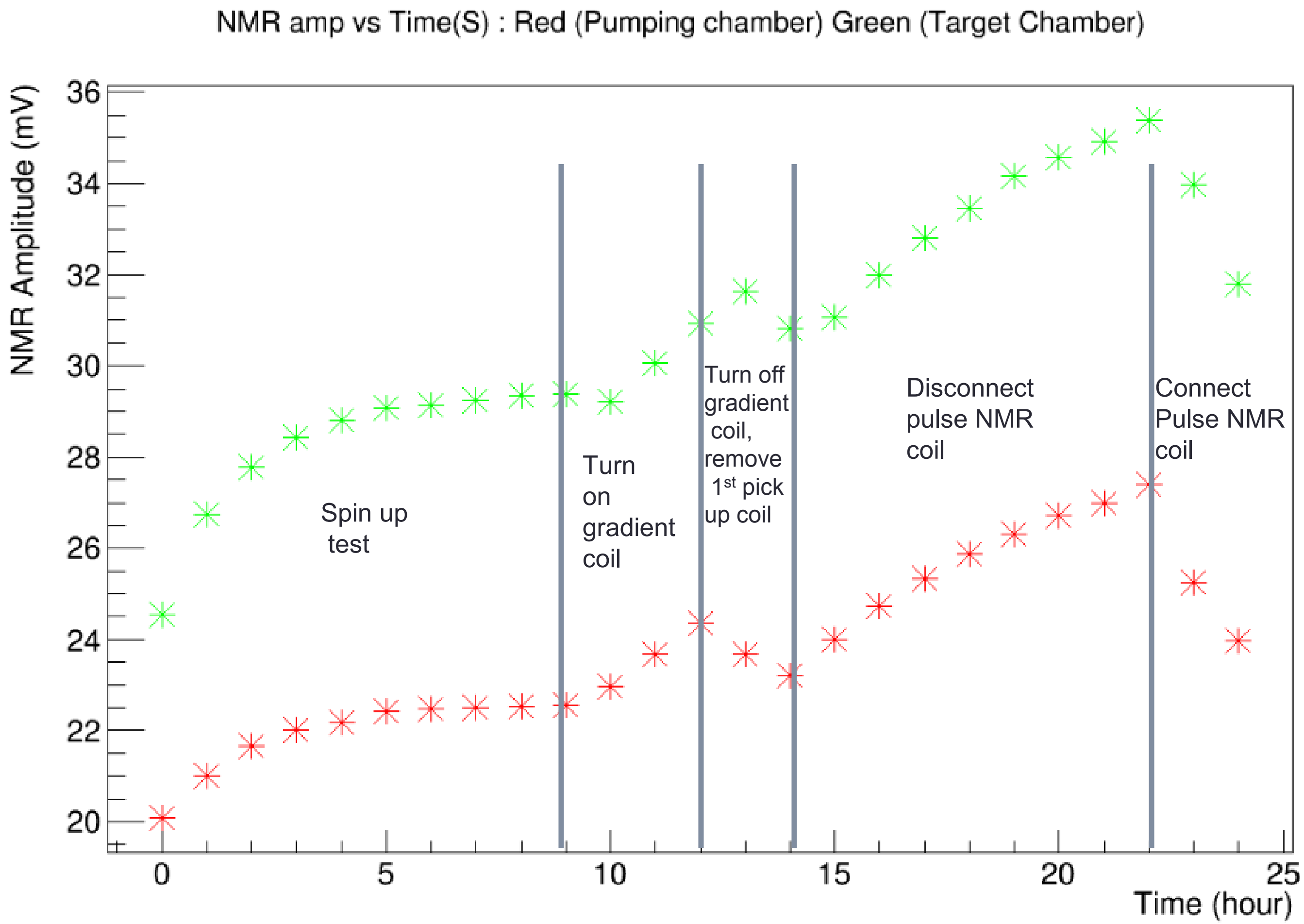




- Study shielding of pumping chamber from radiation damage
- Most of the radiation shielded by the oven
- A_1^n will not bring radiation to pumping chamber as much as Transversity

Masing Effect

- **Masing Effect:** non-linear coupling between coil/closed loop and spin



Summary

- Polarized 3He target world-record performance for 6 GeV experiments
- 12 GeV R&D in progress
- Future Plan

- **Near term: ~6 month**
  - Pulsed NMR systematic study
  - Full polarization test
- **Goal by 2016: full system ready for A_1^n -A exepriment**

Thanks!

➢People @ Jlab

- **Jie Liu** (Graduate Student, UVa)
- **Zhiwen Zhao** (postdoc, UVa)
- Supervision: **J.P. Chen and Patricia Solvignon**
- Help from: **Yi Qiang, Jin Huang, Yi Zhang, Yawei Zhang, Chunhua Chen, Vincent Sulkosky …**

➢Collaborators @ University

- University of Virginia (**Gordon Cates's group**)
- College of William and Mary (**Todd Averett's group**)
- Other groups (**Temple U., U. of Kentucky, Duke U., Lanzhou U...**)