

# JLAB POLARIZED $^3\text{He}$ TARGET STATUS

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*On Behalf of the Polarized  $^3\text{He}$  Target Group*

*Hall A Collaboration Meeting*

*June 13, 2013*

# Outline

- Introduction
- 12 GeV Upgrade Plan
- 12 GeV System Progress
- Summary

# $^3\text{He}$ Target Introduction

## ➤ How to polarize $^3\text{He}$ Target

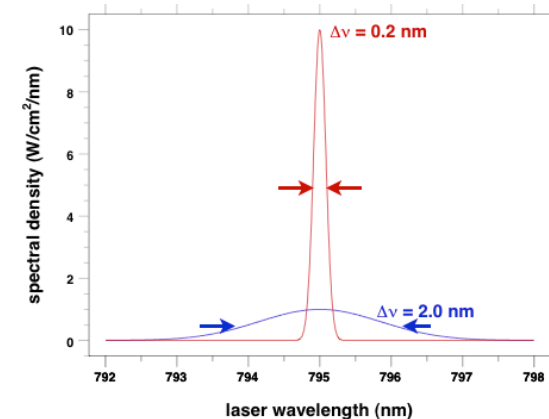
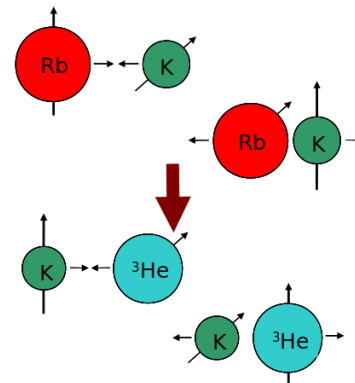
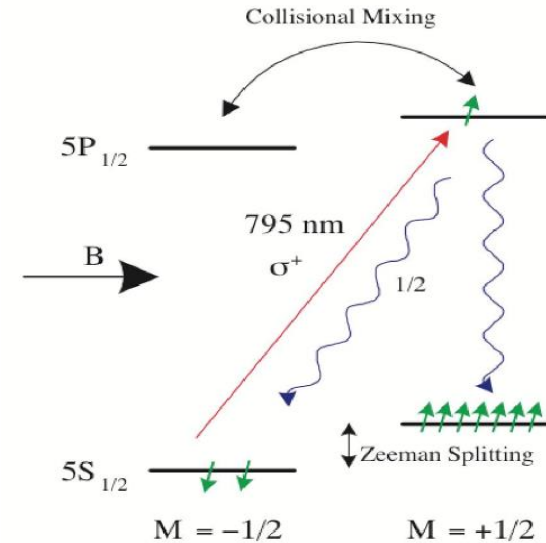
- Spin-exchange optical pumping (SEOP),
  - Polarize the alkali metal atoms
  - Exchange spin with  $^3\text{He}$

## ➤ Improvements in the SEOP:

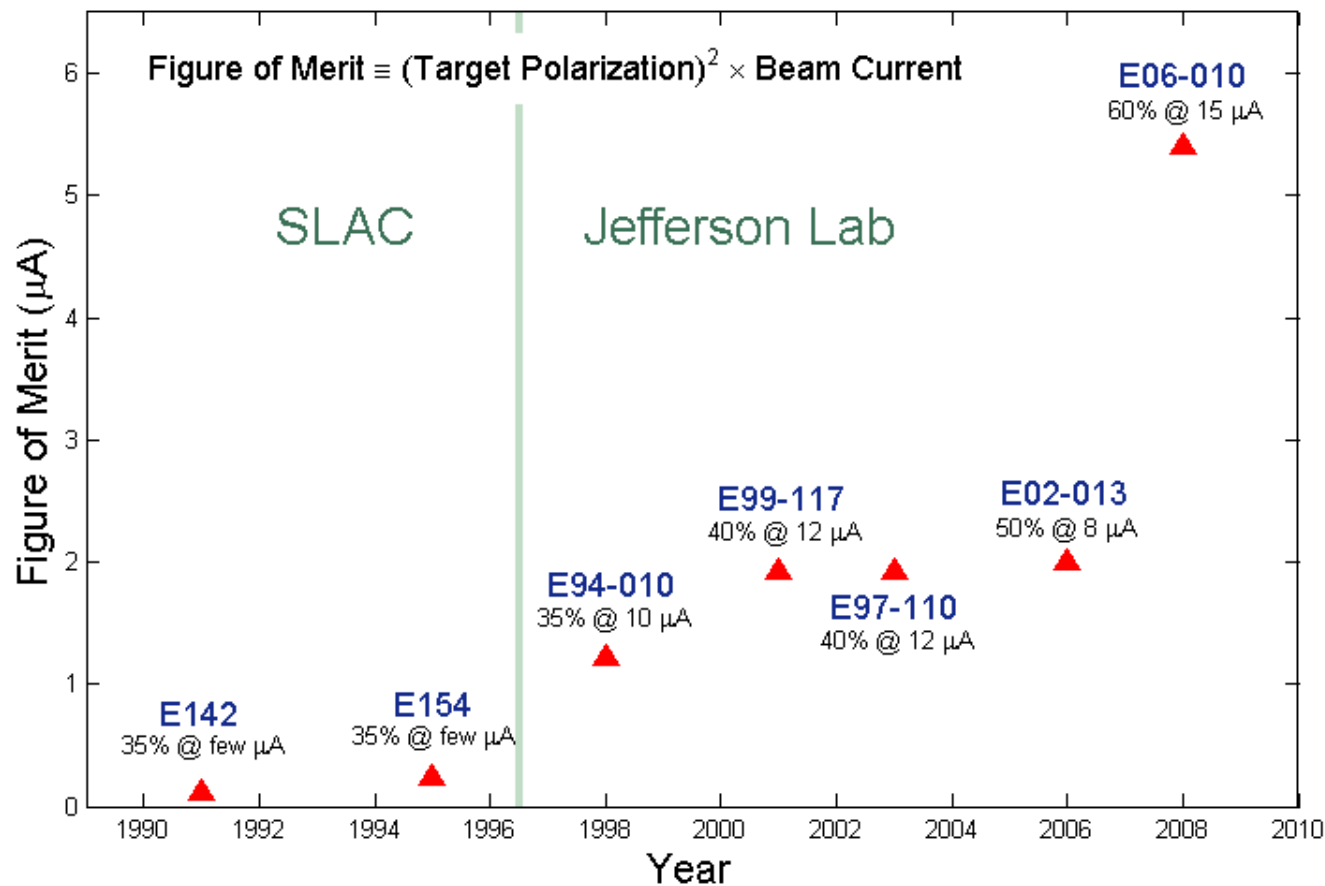
- The change from Rb to Rb-K mixture (hybrid cell)
- The use of spectrally-narrowed diode lasers

## ➤ Performance

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



## Figure-of-Merit history for high luminosity polarized $^3\text{He}$ Target



# 12 GeV $^3\text{He}$ Target Requirement

Experiment	Density	Length	Pol.	Current	Lumi	Polarimetry
<b>A1n-A:</b> 23 days, A-, BigBite, thin window/collimation, BB field shield/compensation						
proposed	10 amg	60 cm	65%	30 uA	$3 \times 10^{36}$	3%
should	10 amg	40 cm	55%	30 uA	$2 \times 10^{36}$	3%
acceptable	10 amg	40 cm	55%	15 uA	$1 \times 10^{36}$	3%
<b>GENII-A:</b> 50 days, A-, BigBite/SBS, thin window/coll., BB/SBS field shield/comp.						
proposed	10 amg	60 cm	65%	60 uA	$6 \times 10^{36}$	3%
acceptable	5/8 FOM					
<b>SIDIS-A:</b> 64 days, A-, BigBite/SBS, vertical polarization and fast spin flip (2 min)						
proposed	10 amg	60 cm	65%	40 uA	$4 \times 10^{36}$	3%
acceptable	5/8 FOM					
<b>d2n-C:</b> 29 days, A-, HMS/SHMS						
proposed	10 amg	60 cm	55%	30 uA	$3 \times 10^{36}$	3%
acceptable	10 amg	40 cm	55%	15 uA	$1 \times 10^{36}$	3%
<b>A1n-C:</b> 36 days, A, HMS/SHMS						
proposed	10 amg	60 cm	60%	60 uA	$6 \times 10^{36}$	3%
acceptable	10 amg	60 cm	60%	40 uA	$4 \times 10^{36}$	3%

Note: Another two approved experiment E12-10-006 and E12-11-007 (both related to SOLIDS), requirements for  $^3\text{He}$  Target already achieved in 6 GeV era.

# $^3\text{He}$ Target Upgrade Plan

## ➤ Two steps:

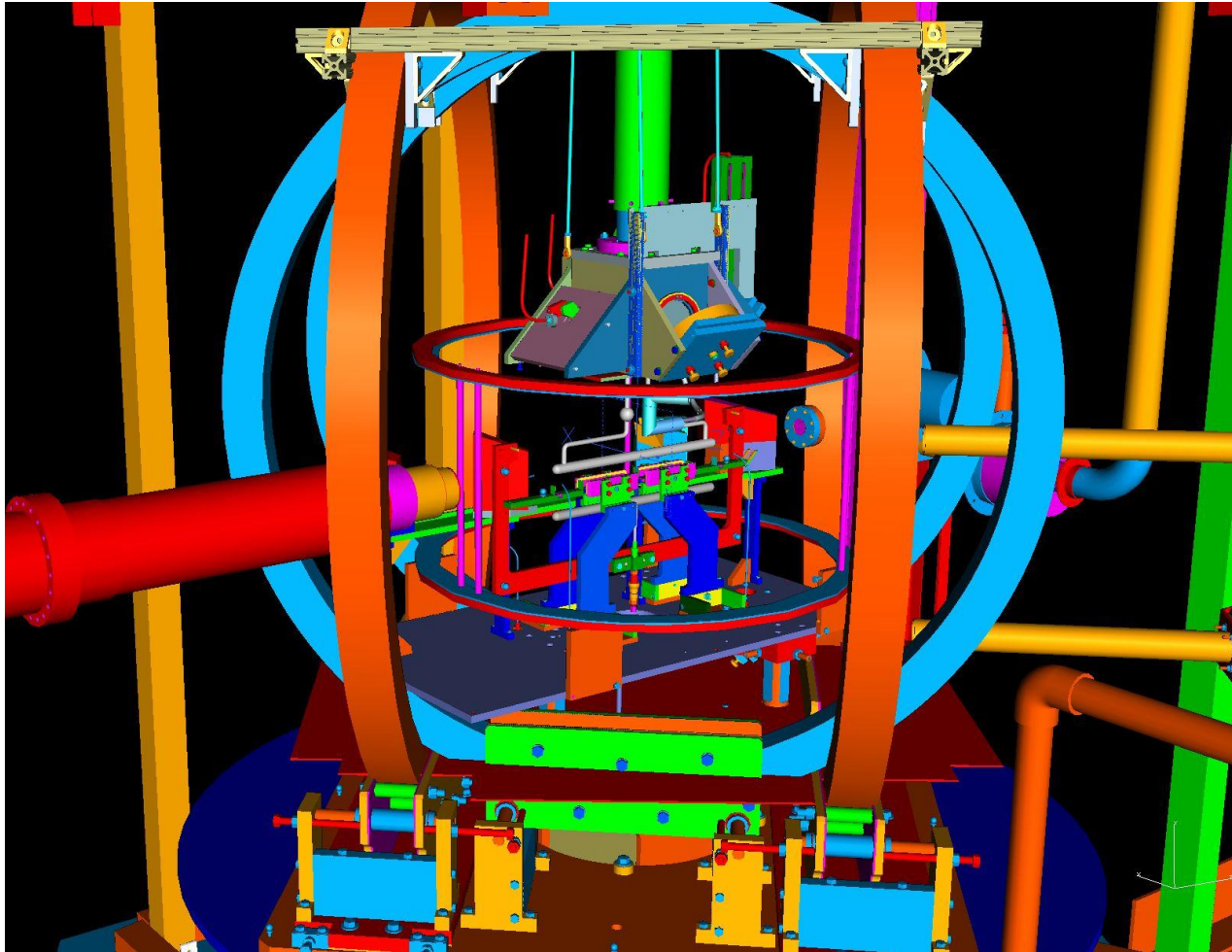
### ❖ Firstly upgrade to a 40cm target with 30uA beam current and reaching ~60% polarization

- *Most parts will be used from Transversity experiment*
- *Using cells with convection flow*
- *Using a single pumping chamber with 3.5" diameter sphere*
- *Shielding pumping chambers from radiation damage*
- *Using pulsed NMR, calibrated with EPR and water NMR*
- *Necessary to measure EPR calibration constant  $k_0$  to higher temperature range covering the hybrid cell operation temperature (user responsibility)*
- *Metal end-windows desirable (optional for 30 uA, must for higher current).*

### ▪ First running of polarized $^3\text{He}$ experiment is expected to be in 2016

### ❖ Secondly upgrade to meet the need for $A_1^n$ in Hall C and GENII in Hall A

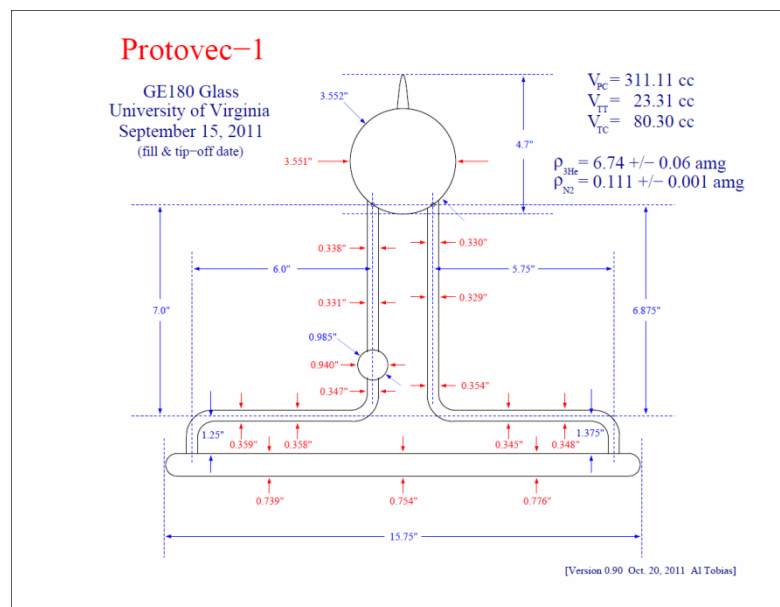
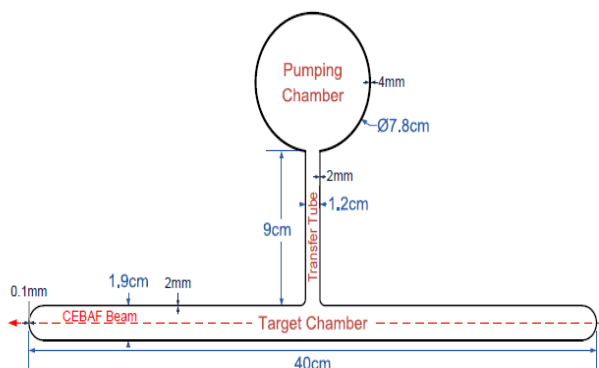
## Mechanical Design



# 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





# $^3\text{He}$ Target Polarimetry

## ➤ Adiabatic Fast Passage (AFP) - NMR

- AFP-NMR will be only used for calibration
- If use hybrid glass/metal cells
- Work for both  $^3\text{He}$  and water

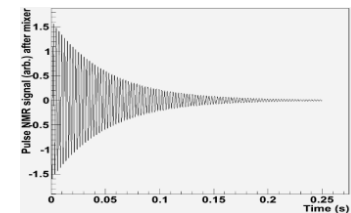
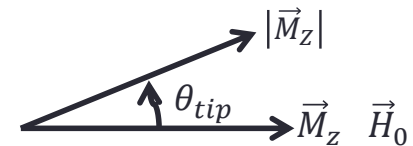
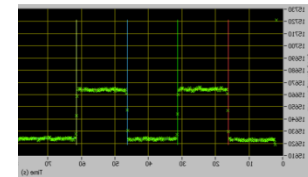
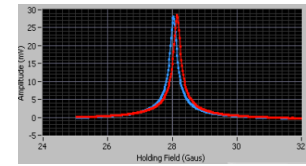
## ➤ Electron Paramagnetic Resonance (EPR)

- EPR will still work

## ➤ Pulse NMR

- Send a pulse tuned at Larmor Frequency
- Spin precesses 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  $\propto M_Z \sin(\theta_{tip})$

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

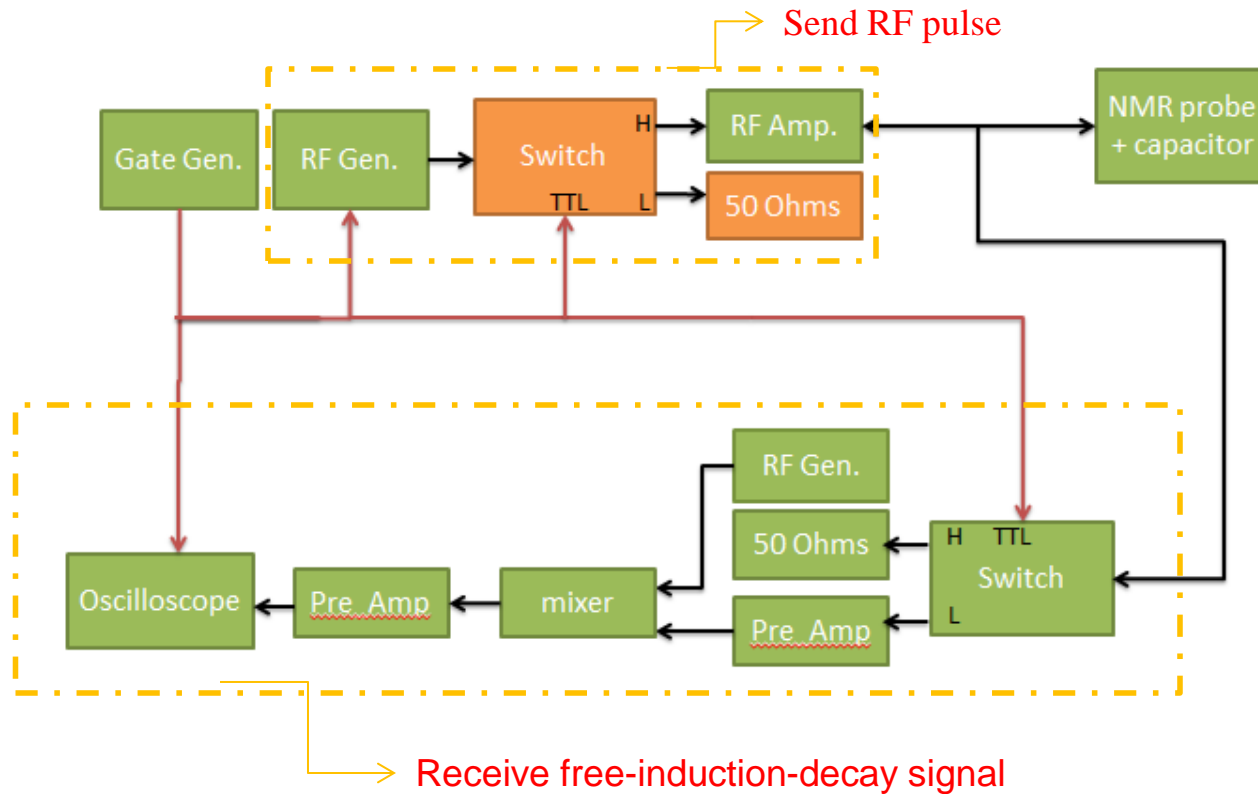


Theory:

$$S \propto M_Z \sin(\theta_{tip}) e^{-t/T_2} \sin(\omega t)$$

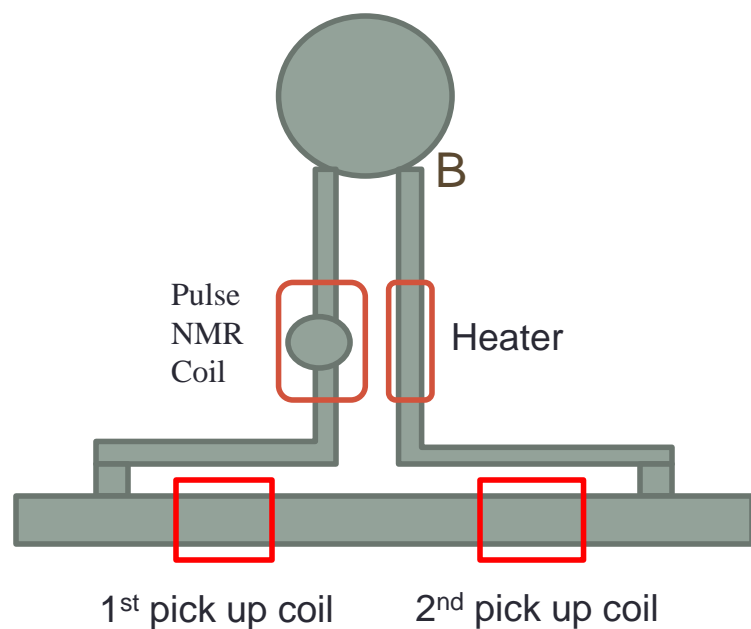
# Pulse NMR @JLab

- Add another switch to isolate the noise from RF-sent-wire after RF turned off



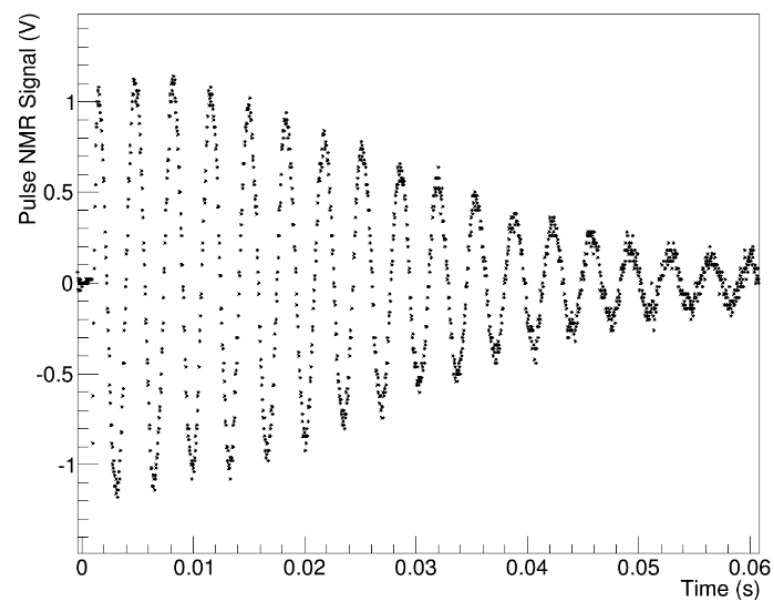
## Pulse NMR Update

### ➤ Pulse NMR on convection cell



Pulse NMR monitor polarization locally around the 1-inch bulb

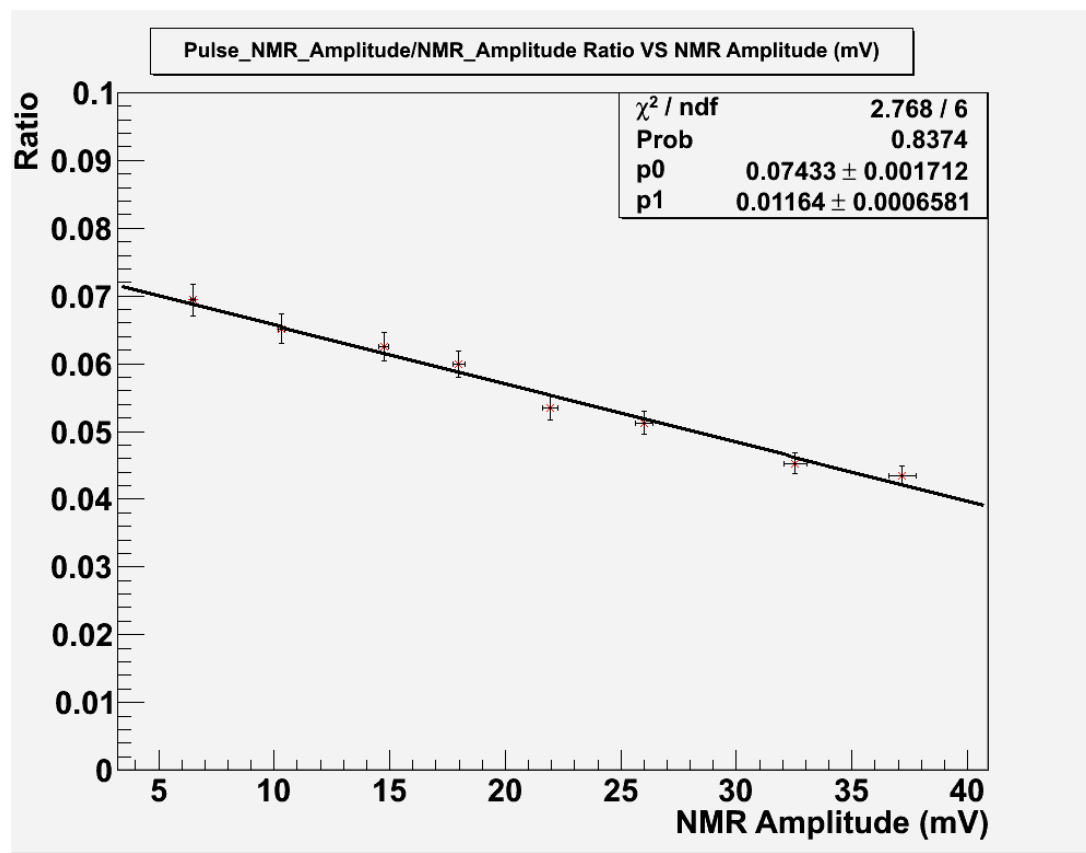
Pulse NMR oscilloscope signal (V) vs time (s)



Challenge: to improve S/N

# Pulse NMR

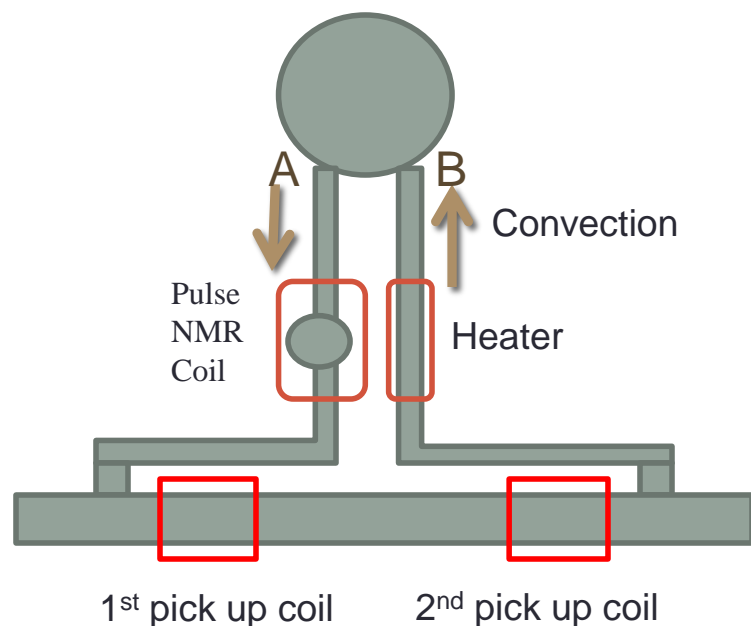
## ➤ Pulse NMR compared with regular NMR



Systematic study continuing

## $^3\text{He}$ 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:**

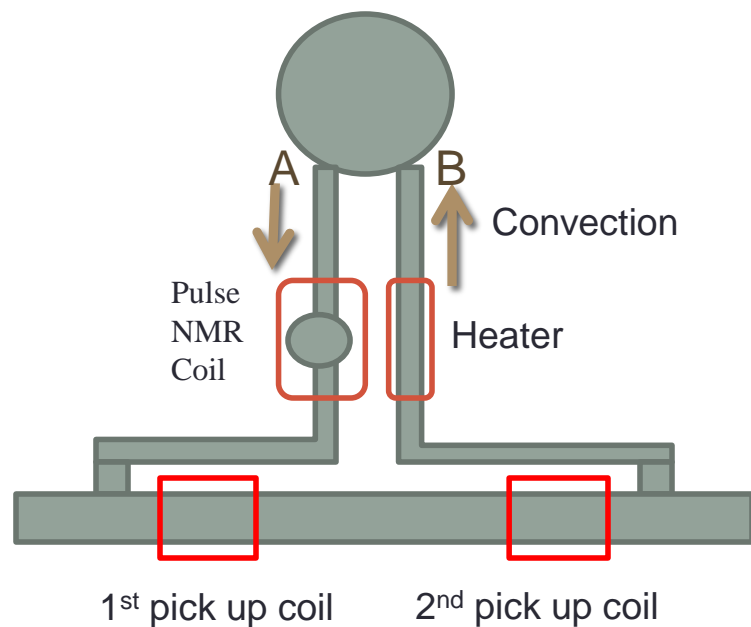
Reduce oven design labor

More convenient to replace cell...

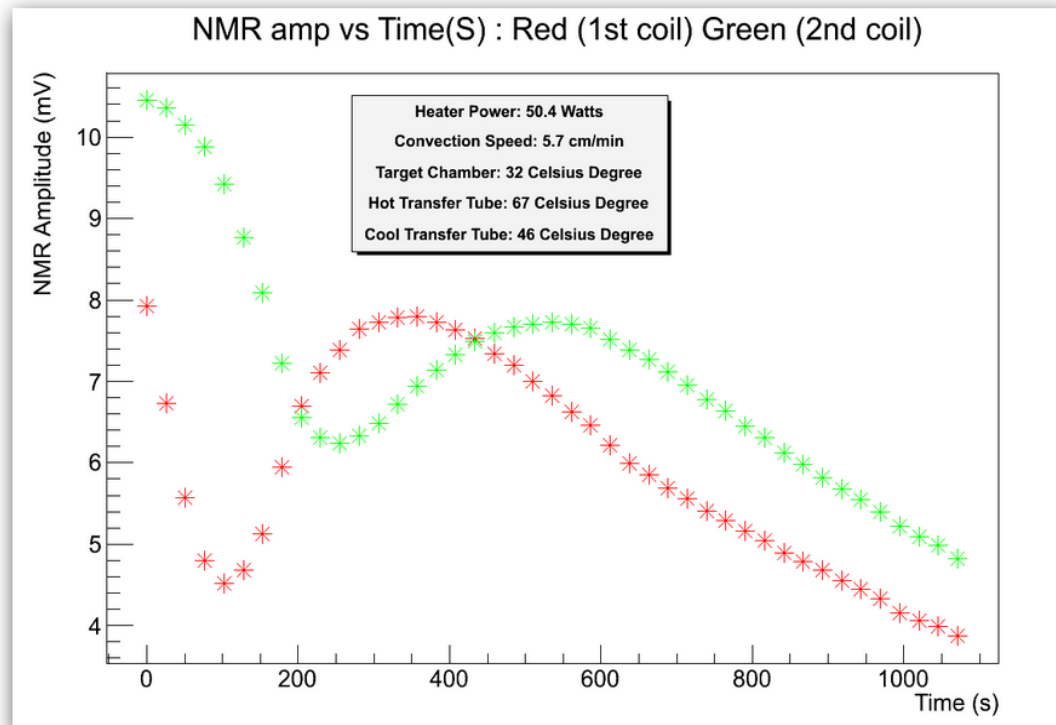
**Problem:** Affect AFP?

## $^3\text{He}$ Convection Speed Test

- Convection can be much faster than diffusion ( $\sim 40\text{min}$ )

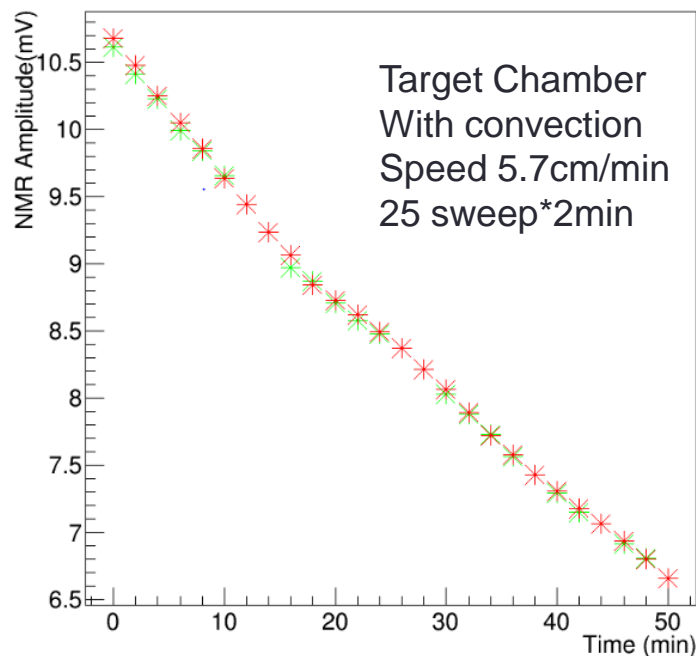


Convection from pumping chamber A to B: **8 mins**

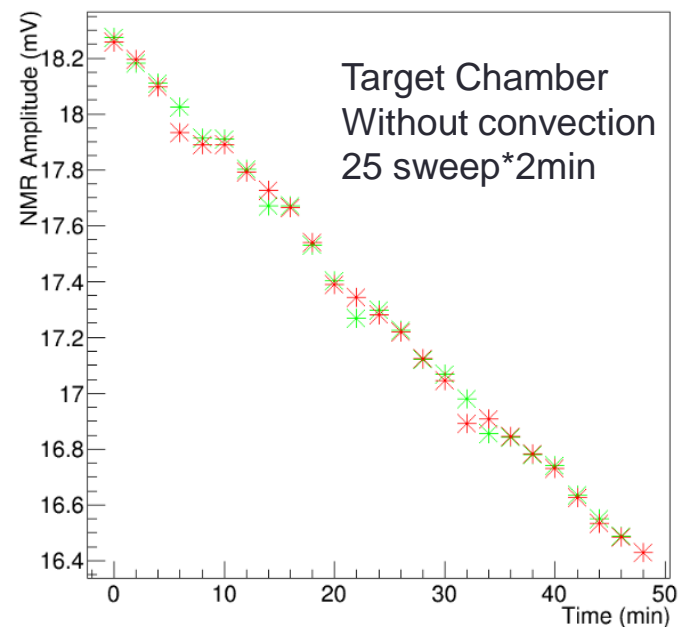


# AFP Lost Study

NMR Amplitude Versus Time: Red (up) Green (down)



NMR Amplitude Versus Time: Red (up) Green (down)

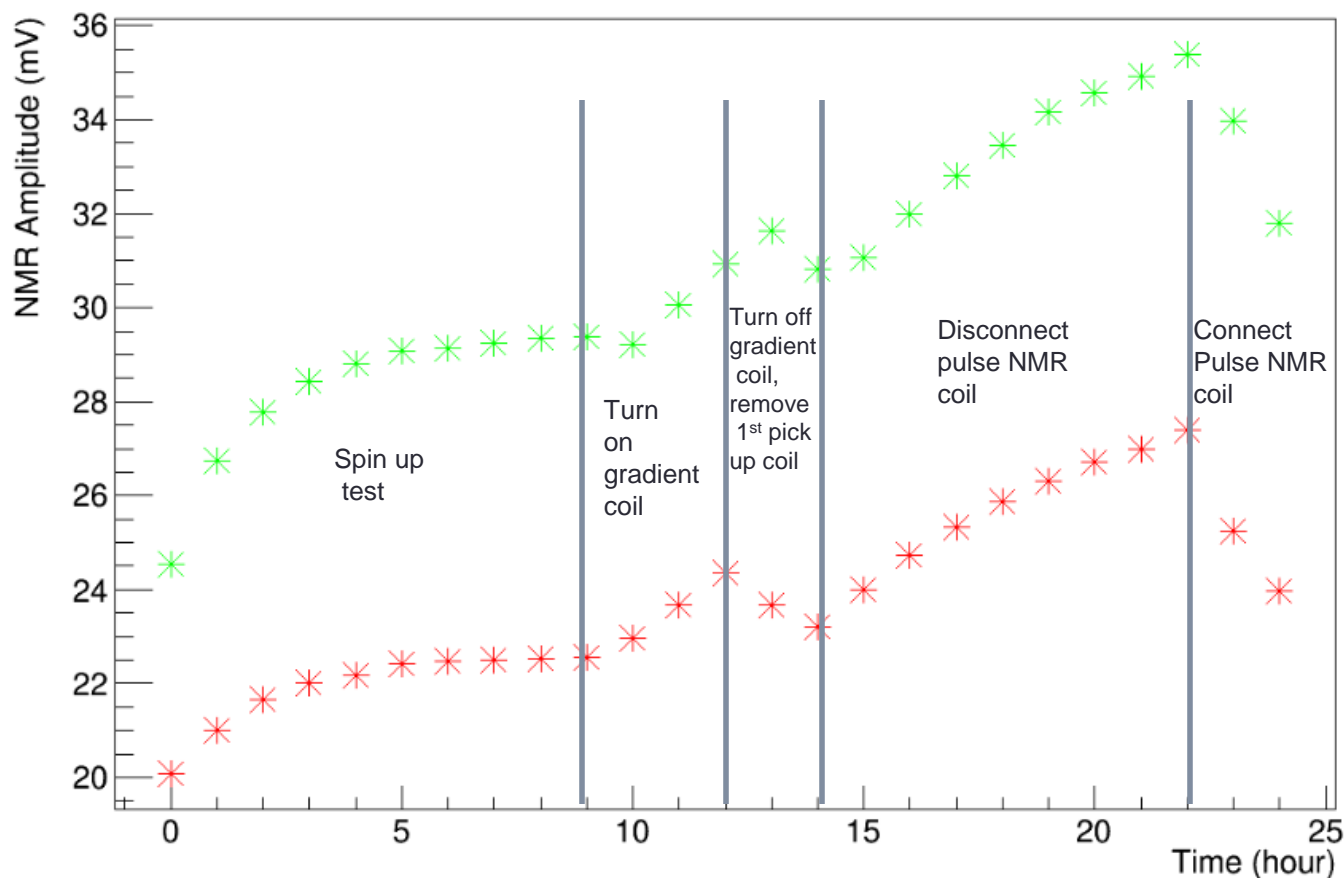


AFP lost per sweep	Target Chamber (%)	Pumping Chamber (%)
AFP Without Convection	0.16%	0.72%
AFP With Convection	0.85%	0.87%

# Masing Effect

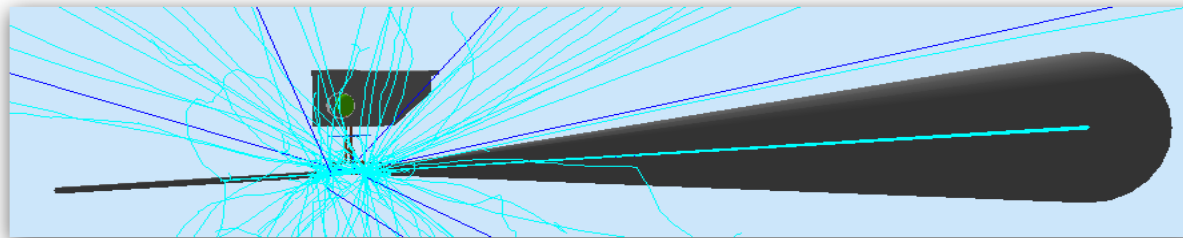
➤ **Masing Effect:** non-linear coupling between pick-up coil and spin

NMR amp vs Time(S) : Red (Pumping chamber) Green (Target Chamber)

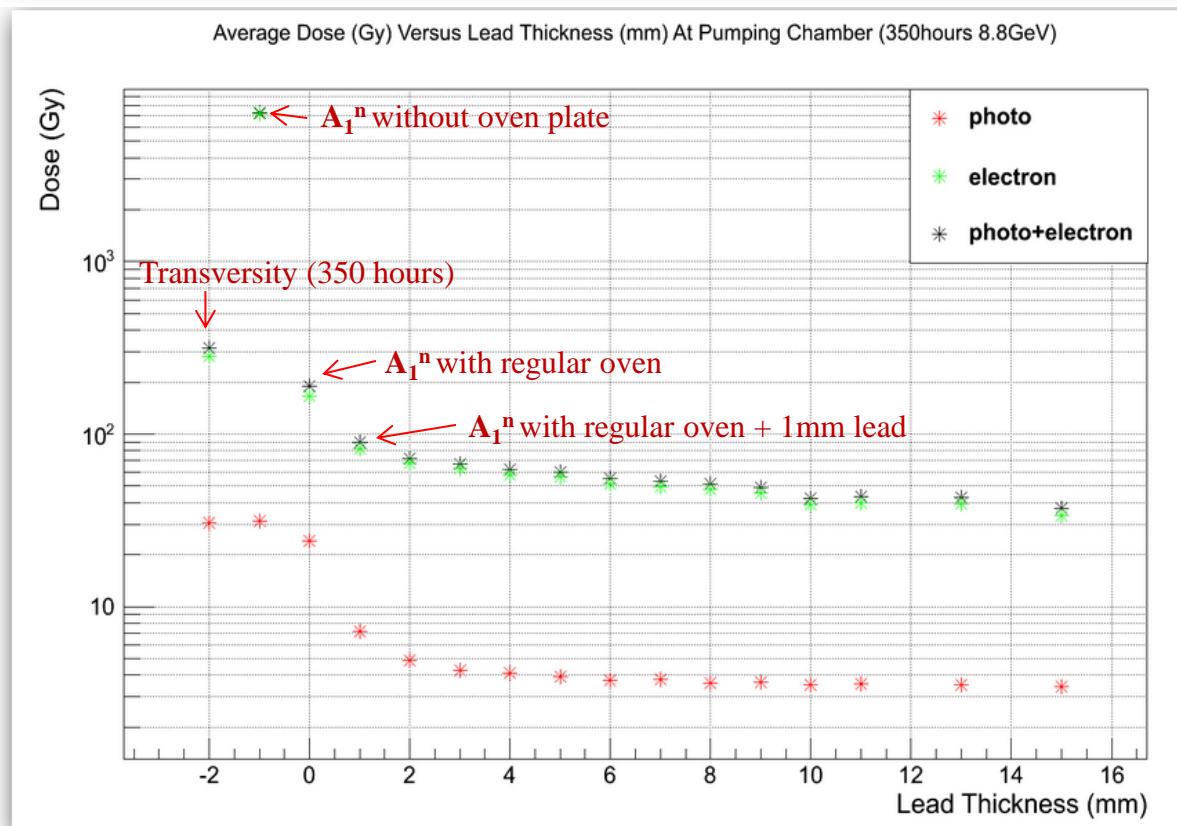




# $^3\text{He}$ Target Radiation Shielding Study



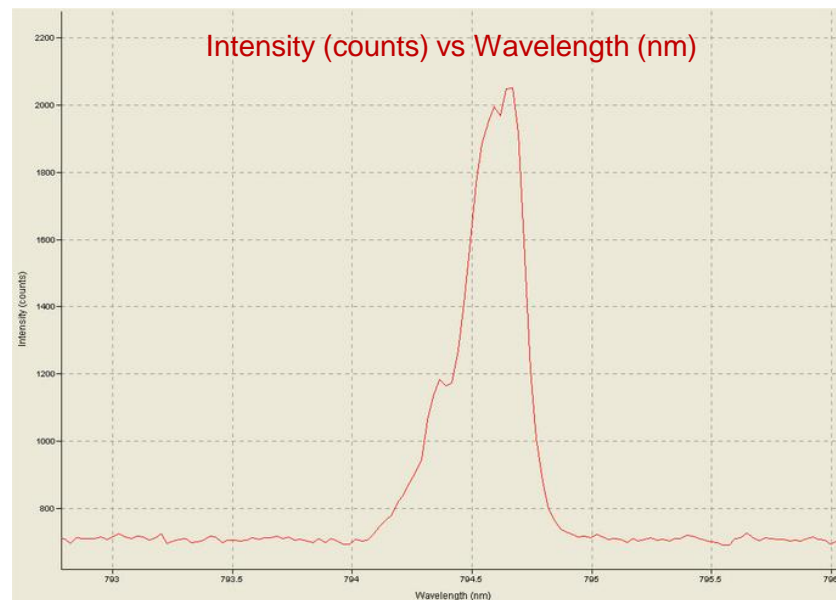
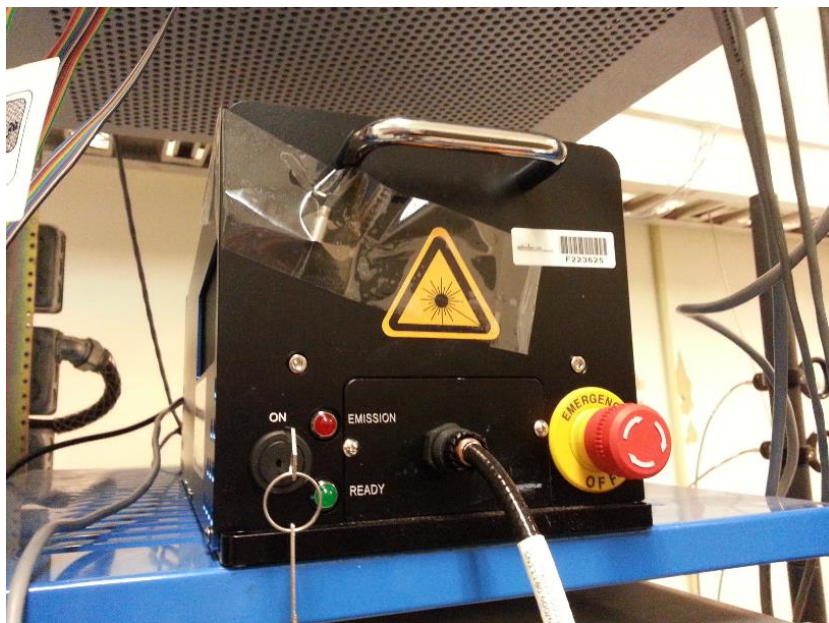
- Study the background shielding from pumping chamber to radiation damage
- Most of the radiation shielded by the oven
- $A_1^n$  will not bring radiation to pumping chamber as much as Transversity



# Lasers

## ➤ New lasers

- The Comet laser (25W, 0.2nm width) production was discontinued
- Purchased one QPC Laser (Hall C, 25W, 0.27nm width) and doing test now
- Possibly upgrade Coherent lasers by Raytum



# User Activity at University Polarized $^3\text{He}$ Target Labs

## ➤ User Activity:

### ❖ University of Virginia (Gordon Cates's group )

- Cell designs
- Convection cell test
- Pulse NMR
- Magnetic field studies
- R&D metal end-windows test and others

### ❖ College of William and Mary (Todd Averett's group)

- QPC laser test and others

### ❖ Other groups (Temple U., U. of Kentucky, Duke U., Lanzhou U. ...)

# Summary

- **12 GeV requirements and plan are set**
- **12 GeV R&D in progress**
- **Future Plan**
  - **Near term- summer:**
    - Jie Liu and two summer students (Stacy Karthas and Joseph Newton) now
    - More will be here in July-August
    - Complete convection cell/heating/polarization loss study
    - Pulsed NMR systematic study
    -
  - **Longer term: ~6 month**
    - Full polarization test
  - **Goal by 2016: full system ready for A1n-A experiment**

# Thanks!

## ➤ People @ Jlab

- **Zhiwen Zhao** (postdoc, UVa) part time
- 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...**)