

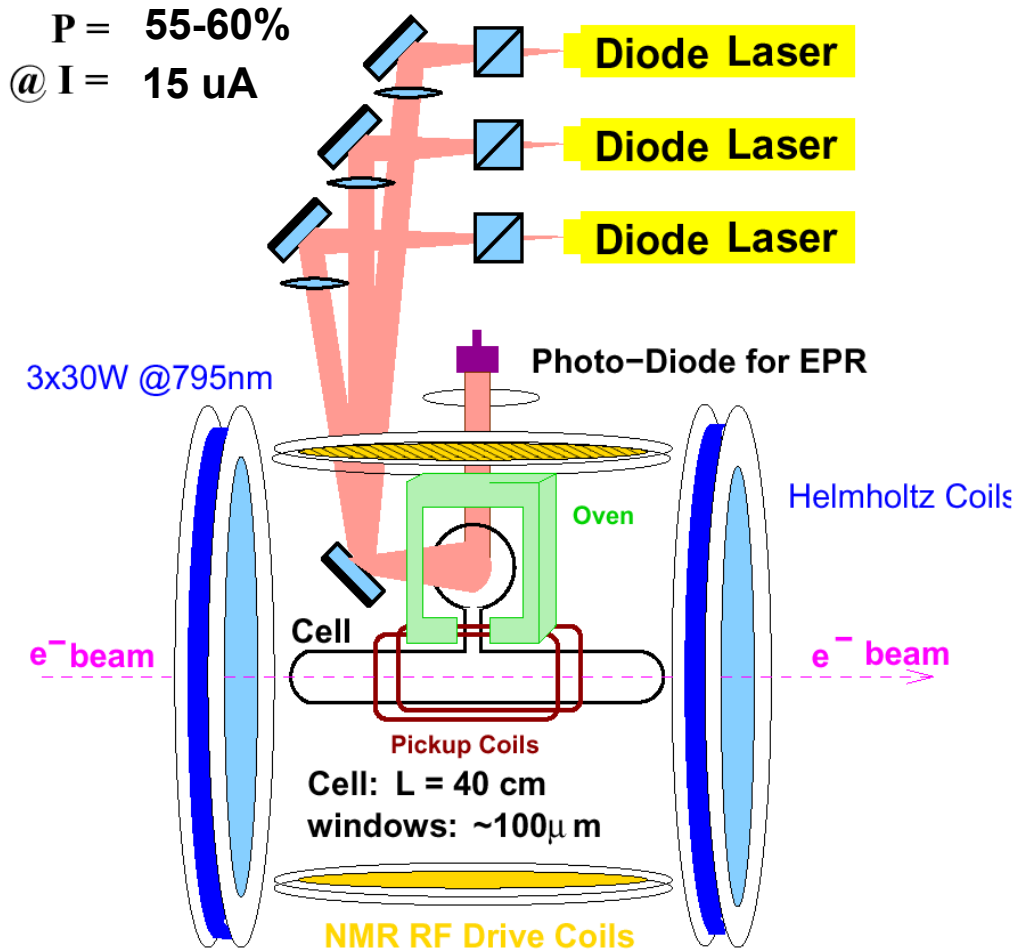
# Polarized $^3\text{He}$ Target for A1n/d2n in Hall C

Jian-ping Chen, Jefferson Lab

Experimental Readiness Review, March 19, 2018

- Polarized  $^3\text{He}$  target: introduction and overview
- Target for A1n/d2n
  - Upgrade
  - Make it work in Hall C
- Current status and plan
  - Engineering/mechanical
  - Target system
- Safety consideration and documents
- Summary

# JLab Polarized $^3\text{He}$ Target



- ✓ Effective pol neutron target
- ✓ longitudinal, transverse  
(and vertical)
- ✓ Luminosity =  $10^{36}$  (1/s)  
(highest in the world)  
upgrade : x2 (stage I)  
additional x3 (stage II)
- ✓ High in-beam polarization  
60% (>70% no beam)
- ✓ 13 completed experiments  
9 approved with 12 GeV (A/C)

# Polarized $^3\text{He}$ Performance for 6 GeV Experiments

- **luminosity:  $10^{36}$  with 15 uA on 40 cm cell,  $\sim 10$  amg  $^3\text{He}$**
- **polarization:**
  - ✓  **$< 40\%$  in 1998**
  - ✓ **with K-Rb hybrid pumping and narrow-width lasers improved to  $> 70\%$  (no beam) in 2008**
    - $\sim 60\%$  (with beam/flip)**
    - $\sim 55\%$  (average for transversity experiment)**
- **polarimetry:**
  - ✓ **NMR-AFP/water +EPR, with Rb only, reached  $3\%$**
  - ✓ **transversity: Rb-K hybrid and longer transfer tube total uncertainty @ target, only reached  $\sim 5\%$** 
    - diffusion (2-3%),  $\kappa_0$  for EPR (2-3%),**

# Polarized He3 Target Upgrade for A1n/d2n

## Hall C A1n/d2n goals:

- 30 uA on 40 cm , ~10 atm,  $L \sim 2.2 \times 10^{36} \text{ cm}^{-2} \text{ s}^{-1}$
- In-beam polarization ~ 55-60%,
- Polarization measurement precision ~ 3%

## Approaches:

- Re-use existing Helmholtz coils and most existing hardware, electronics and optics
- Convection flow
- Target cell, **pumping chamber size 3.5"**, glass cell
- Polarimetry ~ aim for 3%, **Pulse NMR calibrated with AFP NMR**  
**absolute calibration with EPR, AFP-NMR with water optional**
- **Modification to Hall C pivot area and new platform/laser optics line**

**Project mostly complete.**

**Started preparation for hall installation (Walter Kellner's talk)**

**identifying installation requirements: space, shielding, electronics, cables, ...**

# Progress Summary

## Engineering/Design:

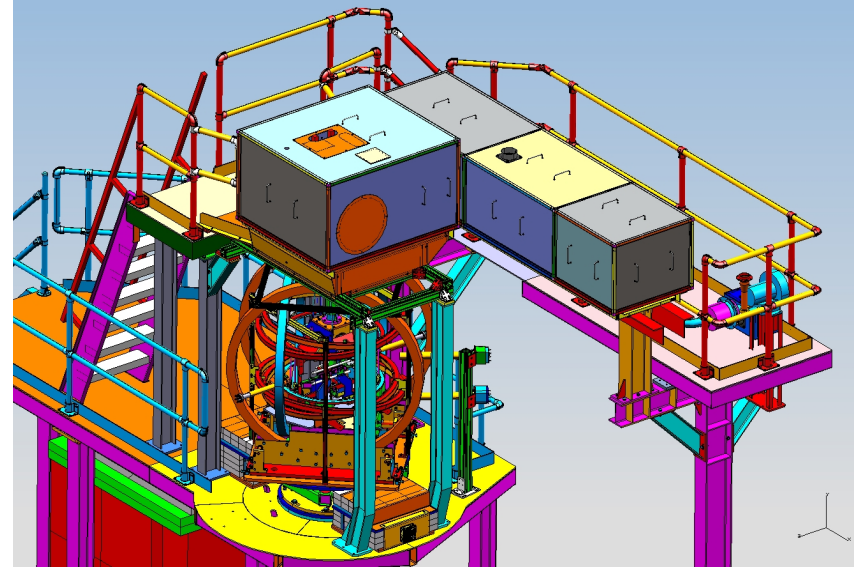
- target design complete:  
oven, ladder, support, optical line,  
enclosure, pivot area, access platform, ...
- installation design mostly complete

## Mechanical:

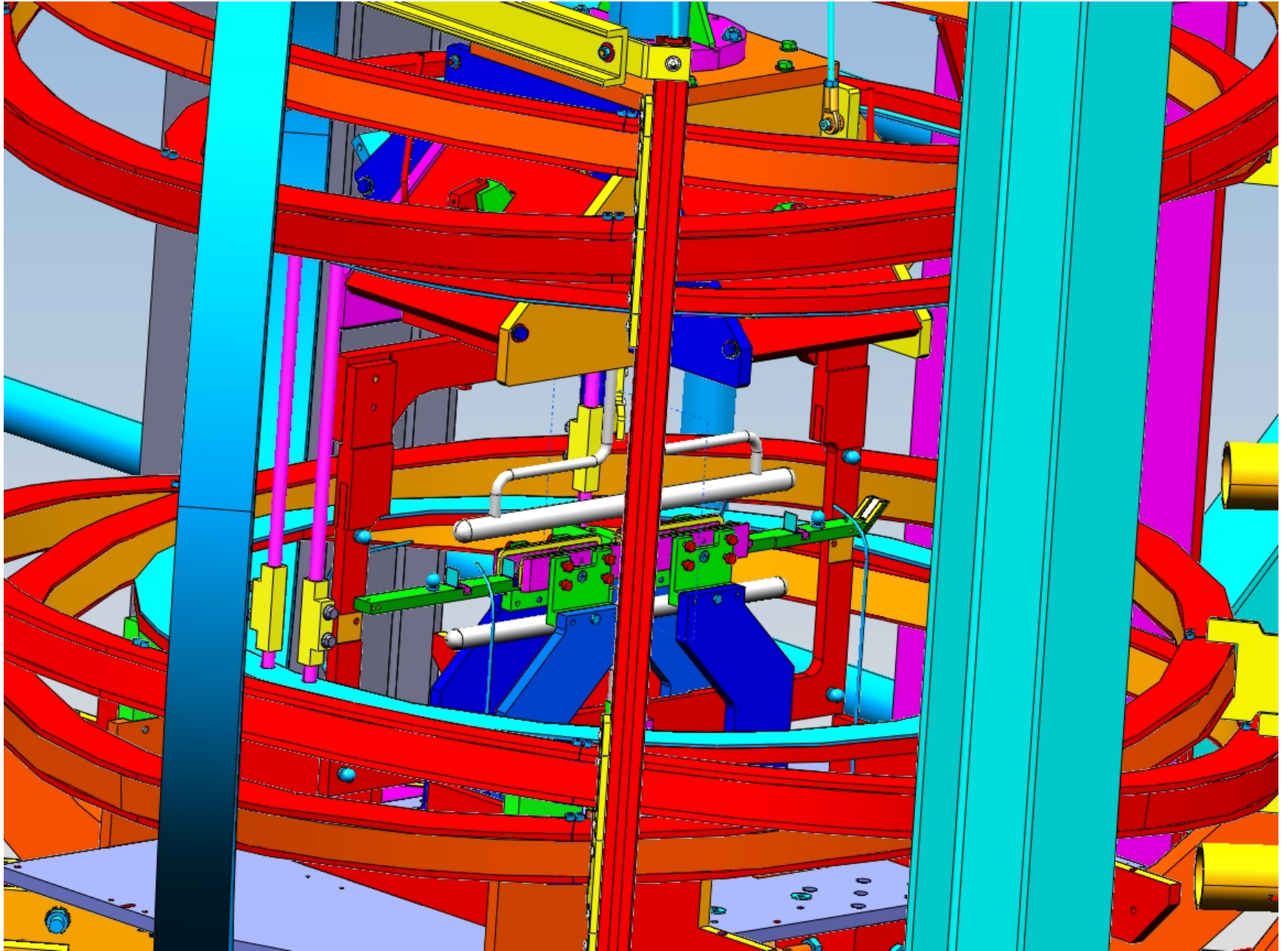
- New parts ordered
- Target ladder manufactured
- Pivot area modified (poster cut)
- Existing parts (in storage) checked  
will test in advance

## Field gradients at target area:

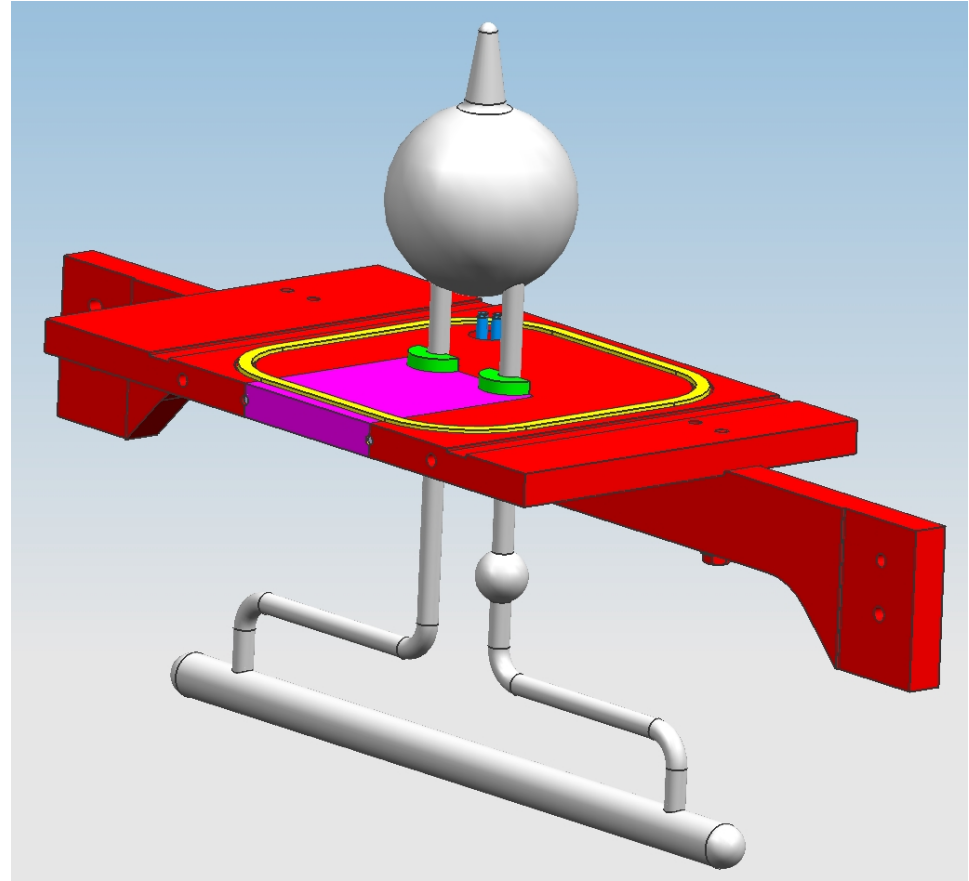
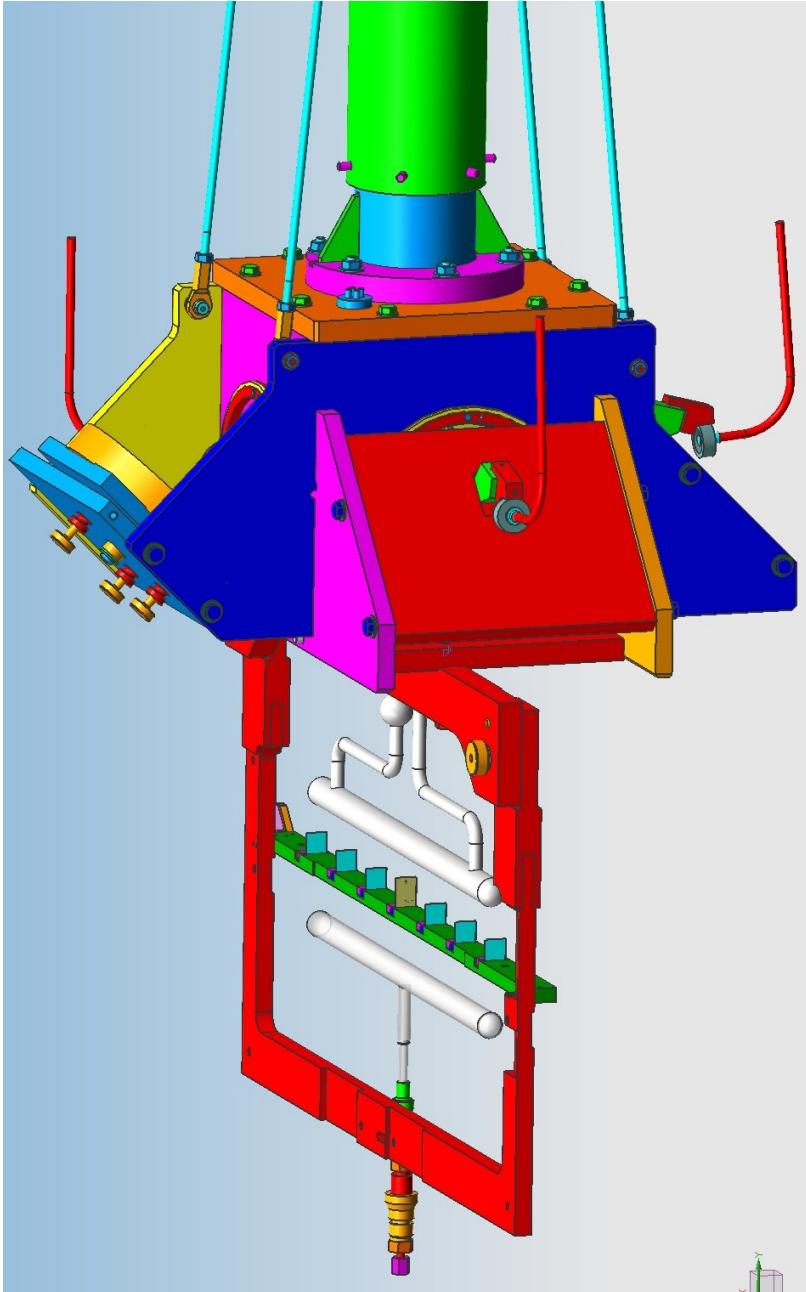
- Study bender field at and magnetic material  
near the target region
- Correct field gradients with correction coils  
(talk by Lassiter/Cates)



# Target System in Hall C

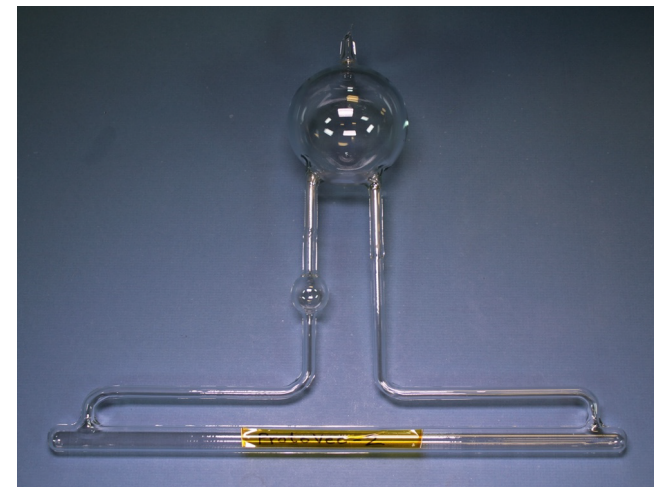
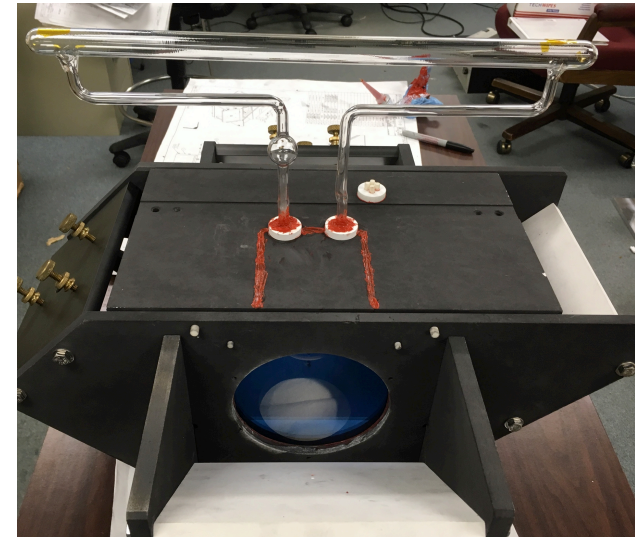


# Target Oven, Ladder and Cell



# Progress Summary (cont.)

- **New oven manufactured/installed/tested**
  - **Target cells**
    - ✓ prototyping convection cell extensively tested,
    - ✓ cell production started
  - 1<sup>st</sup> good cell: lifetime > 48 hours, tested at UVA,  
now at JLab for full characterization
  - five cell production ordered and started
  - five more cell order will be placed in FY18
  - can produce/characterize ~one cell per month.
- 
- **Lasers/long optical fibers:**
    - ✓ five new lasers delivered/tested
    - more will be ordered as spares and for future
    - ✓ long fibers delivered, tested, conduit installed
    - ✓ 4-1 combiners ordered, prototype tested
    - ✓ polarization compensation study complete





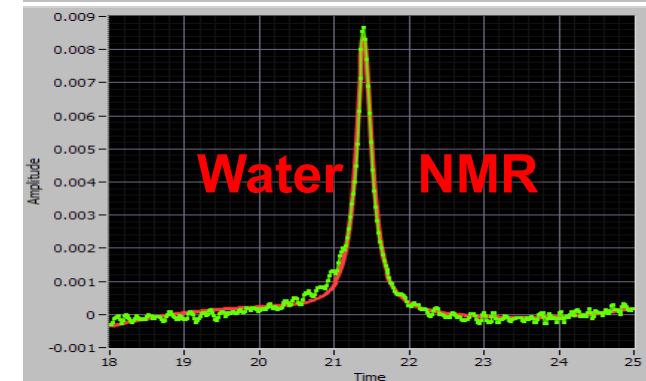
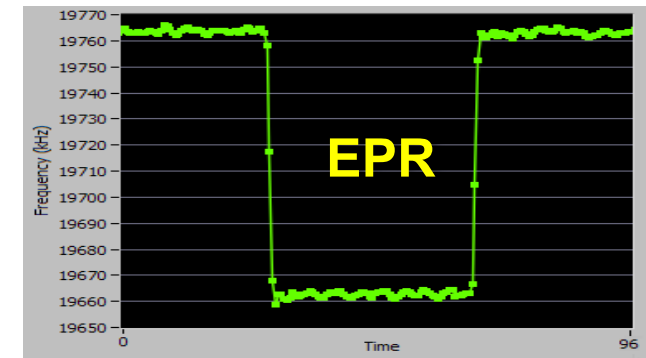
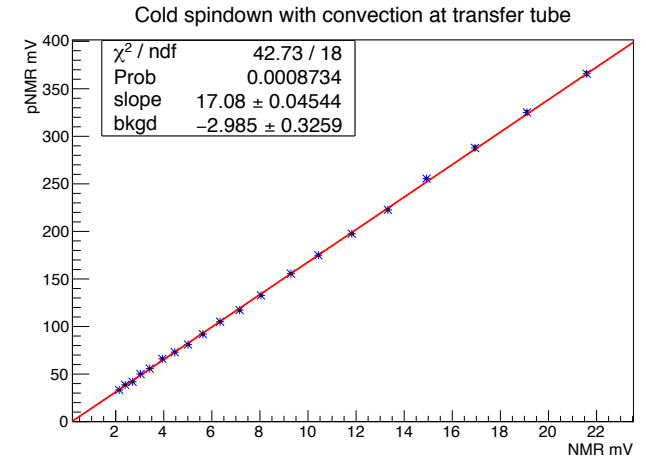
# Progress Summary (cont.)

## Polarimetry:

- ✓ pulse NMR systematic study/calibration (Nguyen Ton)
- ✓ EPR study (Kai Jin)
- ✓  $\kappa_0$  measurement (W&M/UVa) in progress (Averett/Cates)

## Cell characterization:

- ✓ Density measurement (August Williams)
- ✓ Wall and window thickness measurements
- ✓ Maximum polarization
- ✓ Spin up
- ✓ Spin down/ AFP loss study

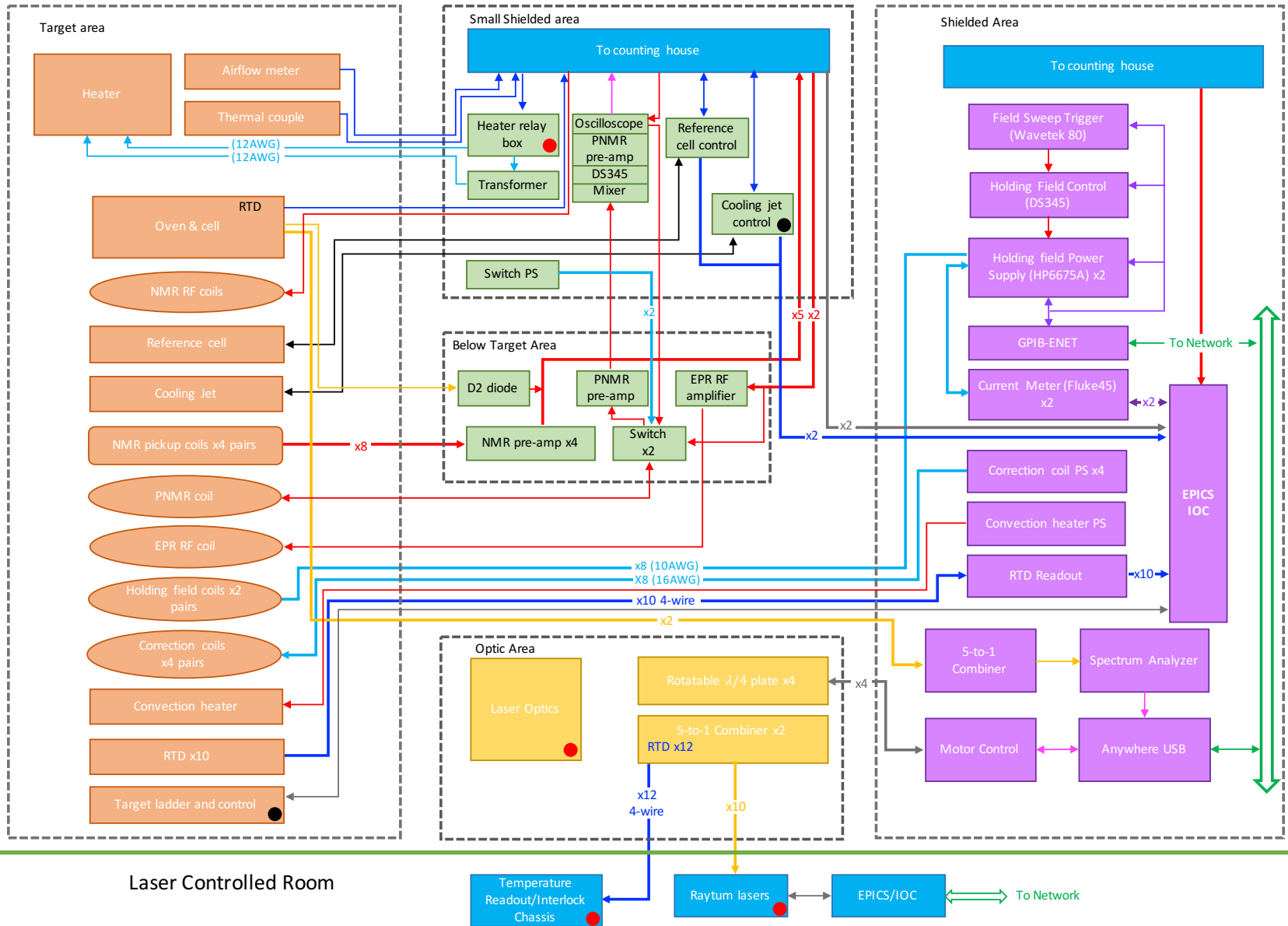


# Target Control System Layout/Electronics/Cables

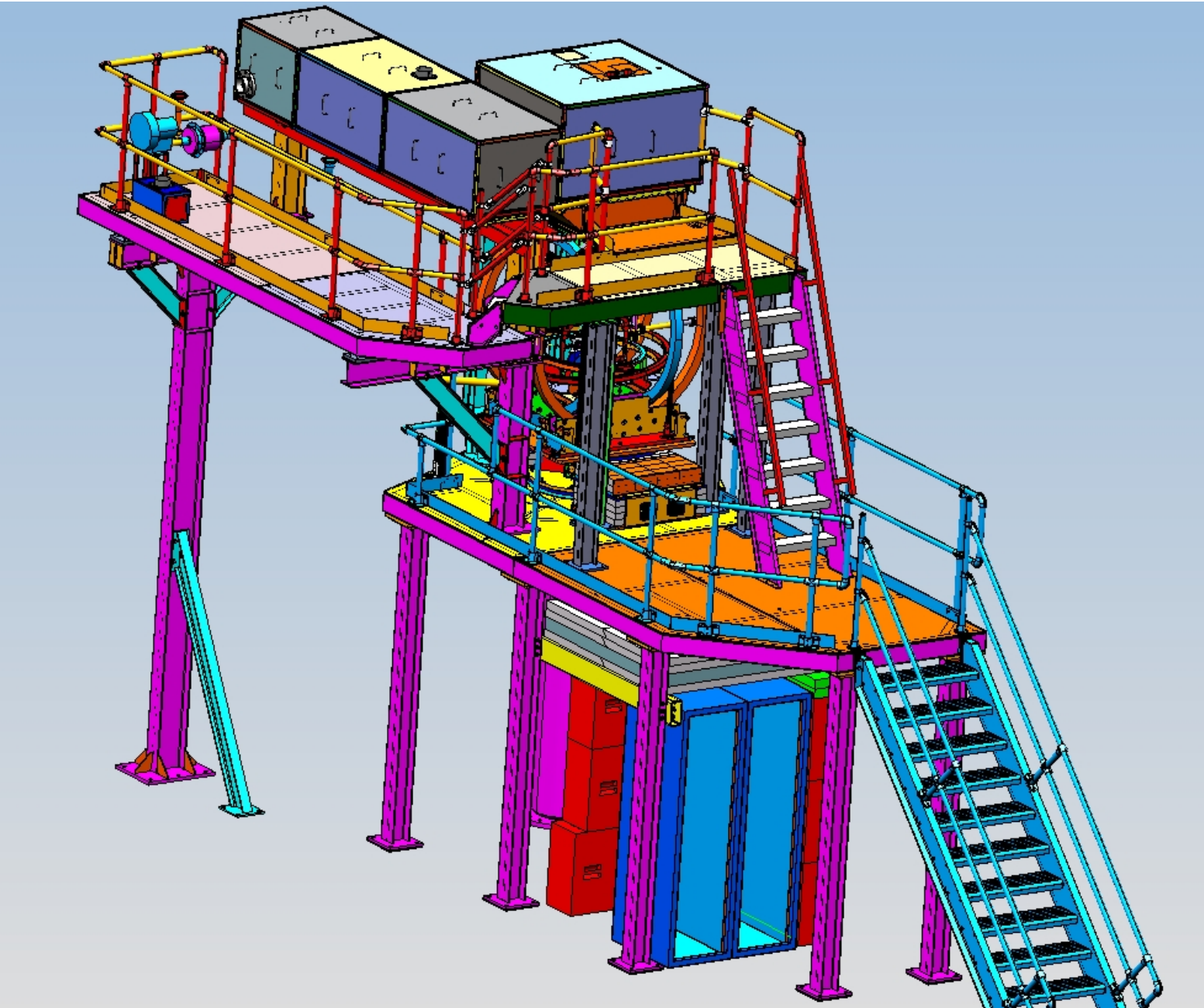
- GPIB
- Coaxial
- Wire
- Power wire
- USB
- Network
- Serial
- Fiber
- Other
- Interlock to laser
- Interlock to beam

Target System inside Hall C

Nguyen Ton  
Nov 2017



# Instrumentation locations in the hall



# Cable lists

X: counting house – patch panel

Y: optic table – further shielded

Z: laser room – optic table

Cable type	Quantity	Length (ft)	Purpose
Series	2	X	2 EPICs
	3	37	2 EPICs+1 ladder and control
	1	7	1 ladder and control
	4	Y	Rotate waveplate
BNC	11	X	5 NMR+2 PNMR+2 EPR+2 EPIC
	2	21	2 PNMR
	2	37	2 EPIC
	18	>7	3 PNMR+ 2 EPR+13 NMR
	20	7	20 (within a rack)
	5	<7	5 (within a rack)
RTD type	6	X	1 ovenRTD+1heater relay+2 reference/cooling(?) +1airflow
TC	1	X	1 thermal couple
RTD	10	37	10 RTD
RTD	5	21	1heater relay+4reference/cooling(2 to counting,2 to target)
RTD	12	7	1ovenRTD+10RTD+1airflow
	2	7	2 reference/cooling (wire type?)
	12	Z	12 RTD for laser monitor
Power wire (9&16 AWG)	16	37	8main field+ 8correction field
	16	7	8 main field + 8correction field
Power cable (12AWG)	2	21	2 heater
	2	7	2 heater
GPIB	12		5(in Hall)+7(counting house)

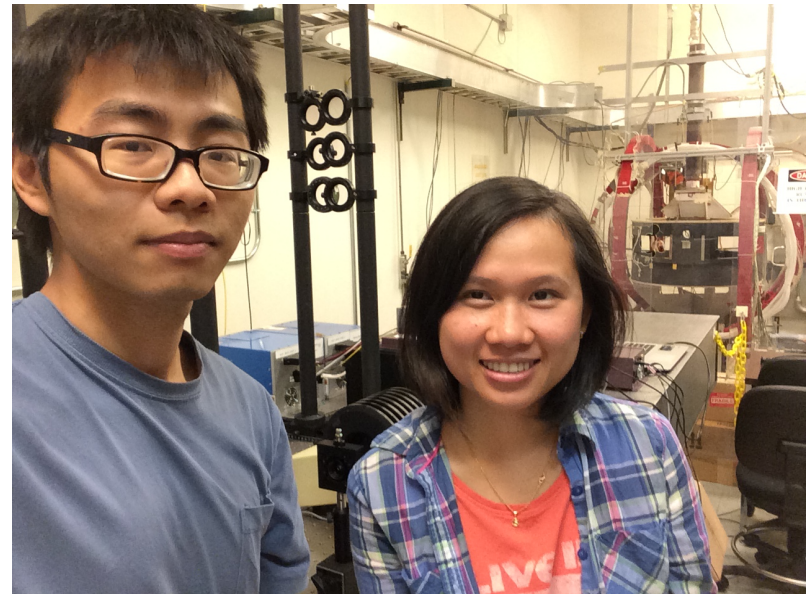
# Peoplepower/User Contributions

**At JLab:** students + engineer/designer + JP (supervisor/coordinator)

- **Engineering/Design:** Bert Metzger and Al Gavalya (work with JP)
- **Magnetic field modelling:** Steve Lassiter (work with UVa group)
- **two graduate students, Kai Jin and Nguyen Ton (UVa, Xiaochao's group) work under JP's supervision**
- ◆ **New students planned to be on site once ERR passed**

**User contributions:**

- **UVa (Gordon Cates):**  
**cell fabrication**  
 **$\kappa_0$  measurement**
- **W&M (Todd Averett)**  
 **$\kappa_0$  measurement**  
**Reference cell system/cooling jets**
- **Kentucky (Wolfgang Korsch)**  
**field direction measurement**



Working at JLab polarized  $^3\text{He}$  target lab  
Kai Jin (UVa), Nguyen Ton (UVa)

# Safety and documents

Laser safety, same as used in Hall A with update

Use CANS system to lock the hall for laser alignment

OSP following what were used in Hall A with update

Main safety issue is the glass cell rupture when handling a cell

Draft OSP and LSOP ready

# Cell rupture and beam conditions

Cell rupture during running, beam line windows materials/thickness as tested

## Minimize cell rupture:

experience from 6 GeV running (12-15 uA on 40 cm, 10 atm glass cell):

- 1) 5 cell rupture during first running period, no more than one since then
- 2) most ruptures from pumping chamber, likely accumulation of radiation damage: cells last ~ 4 weeks for transversity running condition
- 3) direct beam hitting caused two cell rupture:
  - one due to raster turned off (cell ruptured 5-10 minutes unrastered beam)
  - one due to beam hitting inside of the cell wall (joint of window with cell body)
  - beam size limits to not too small, also not too large  
200-300 um (FWHM) beam size with ~ 2-4 mm diameter raster size
- 4) used cooling jets and slow beam ramping rate

For A1n/d2n, 30 uA on 40 cm, 10 atm glass cell

- with longer distance from pumping chamber to beam line, simulation shows accumulated radiation about the same as transversity
- <200-300 um (sigma) beam size, raster 5 mm diameter circular

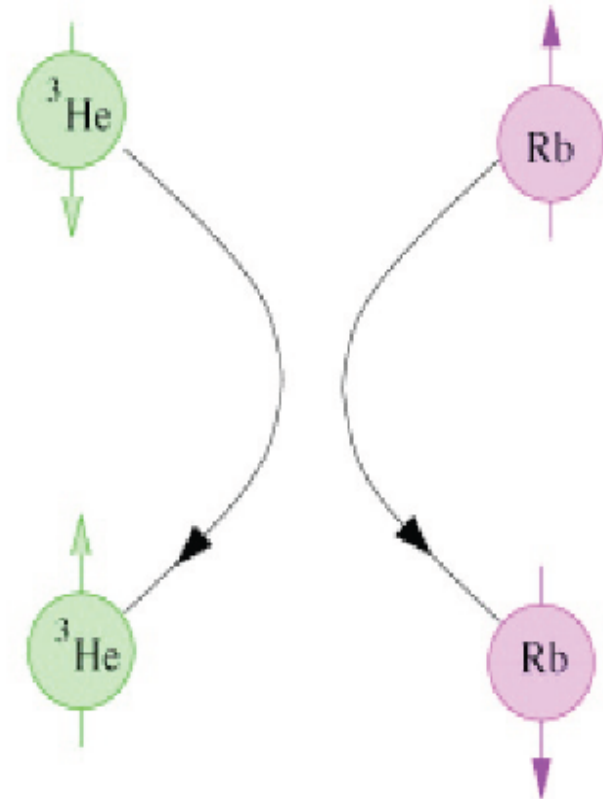
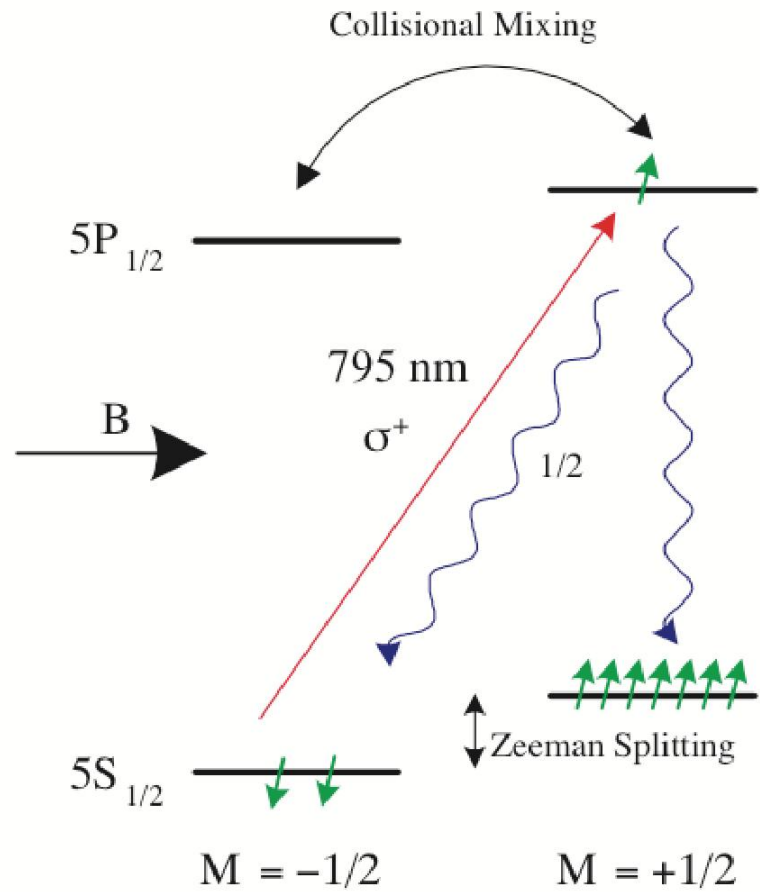
# Summary

- Polarized  $^3\text{He}$  target reliably used for many 6 GeV experiments in Hall A
- Upgrade (double luminosity) and make it work in Hall C
- Progresses:
  - Engineering/Design complete, parts fabricated
  - Hall C pivot area work complete
  - New oven tested, convection cell extensively tested.
  - pulsed NMR established, reached 1% precision in cross calibration
  - New lasers, new optical fiber cables
  - Cell production started
- Installation design mostly complete, preparation started, plan discussed (Walter Kellner's talk)
- Field gradient study/correction coils design (Lassiter/Cates talk)
- OSP/LSOP draft ready

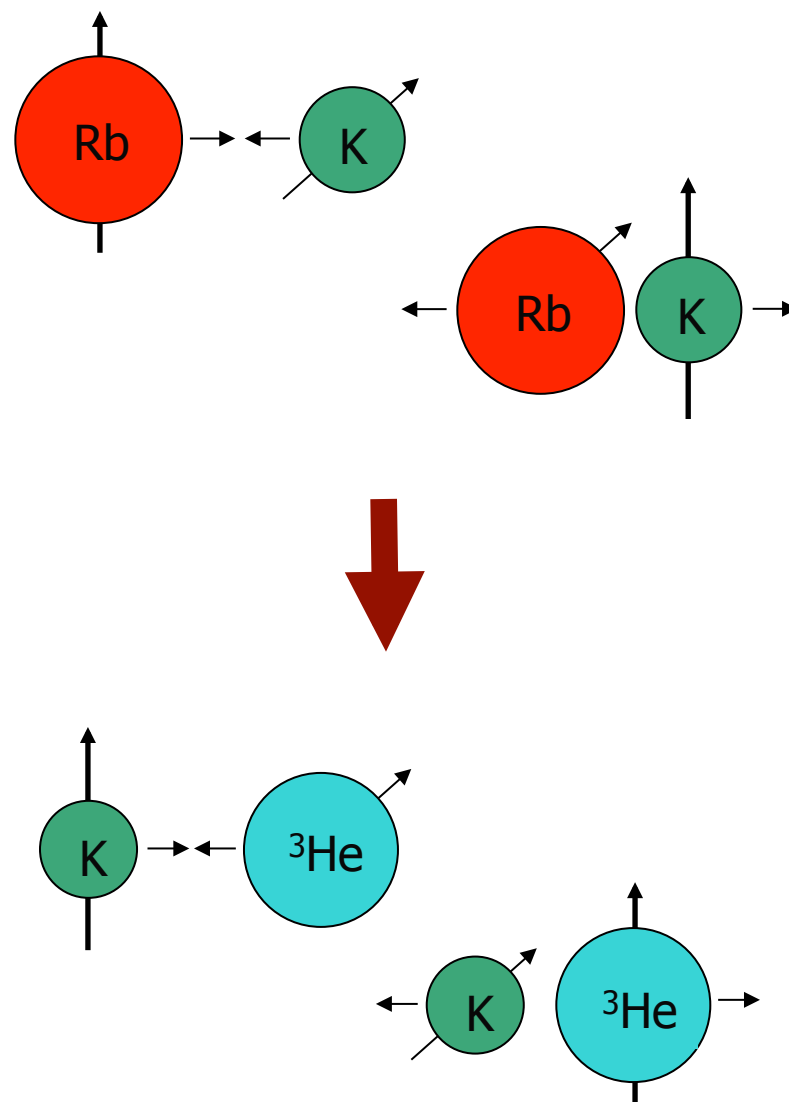
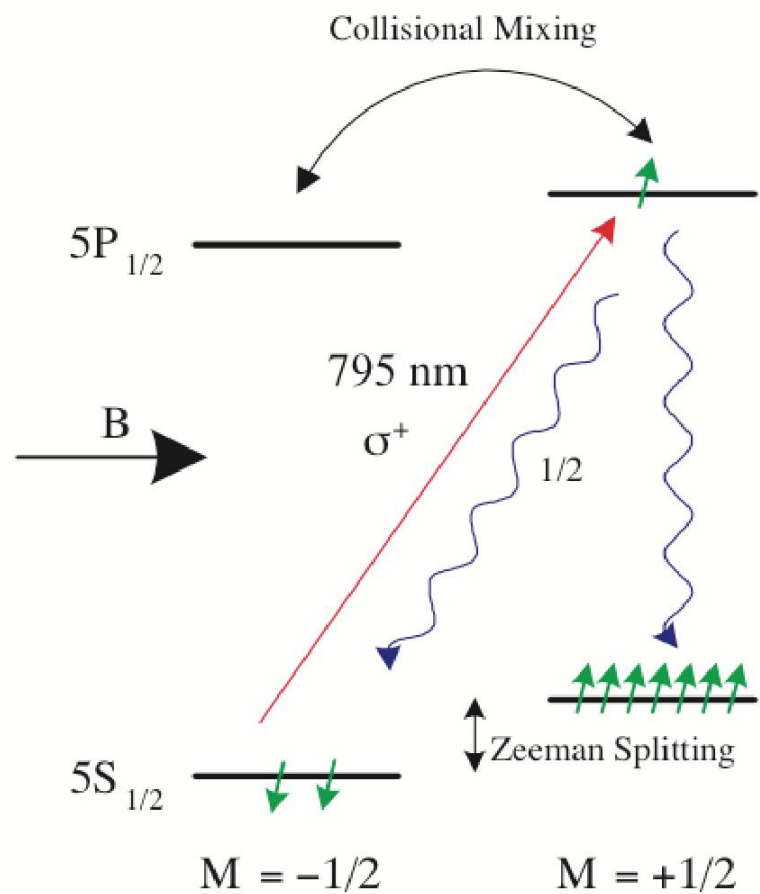


Backup

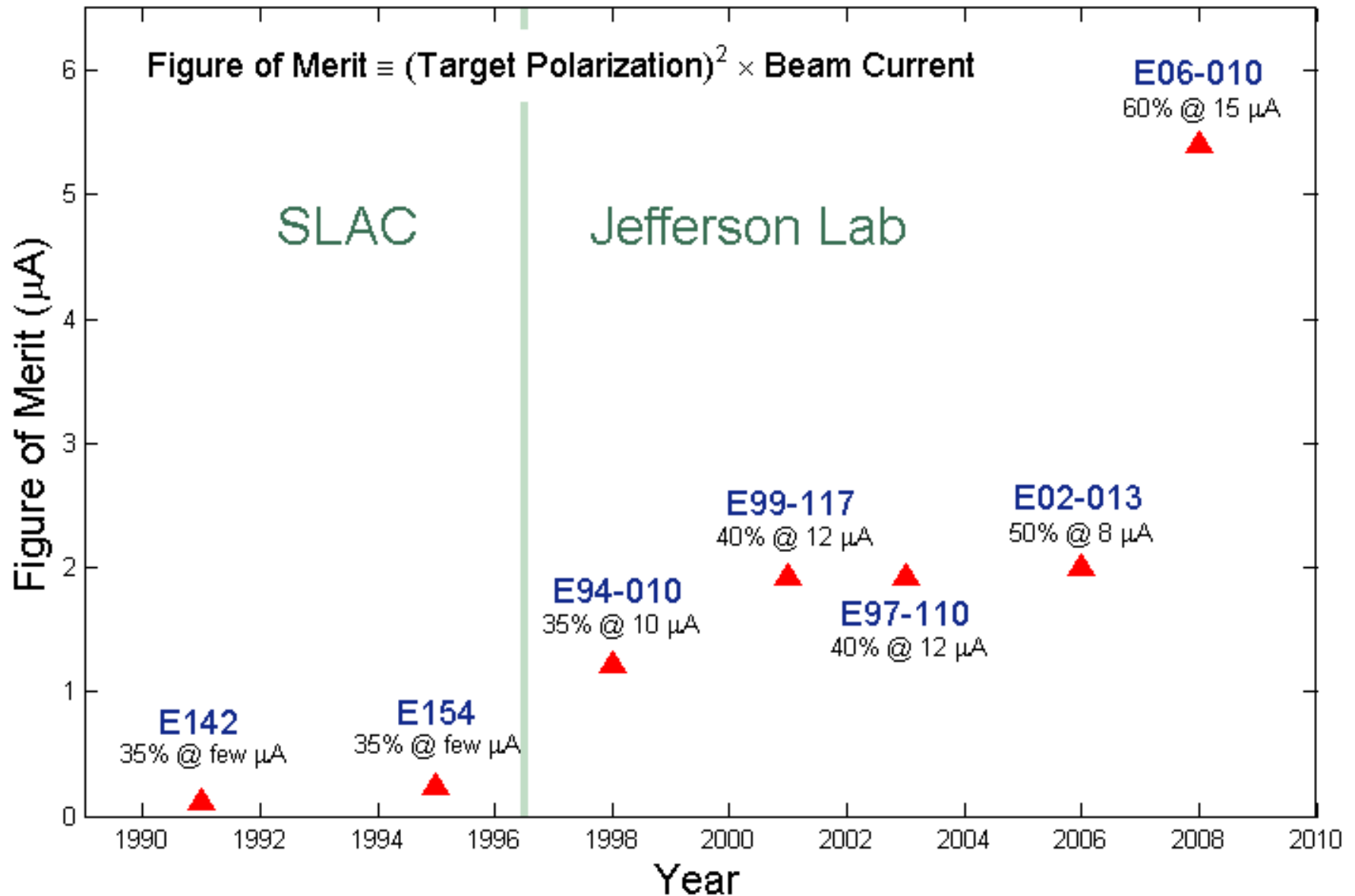
# Spin exchange Optical Pumping for $^3\text{He}$



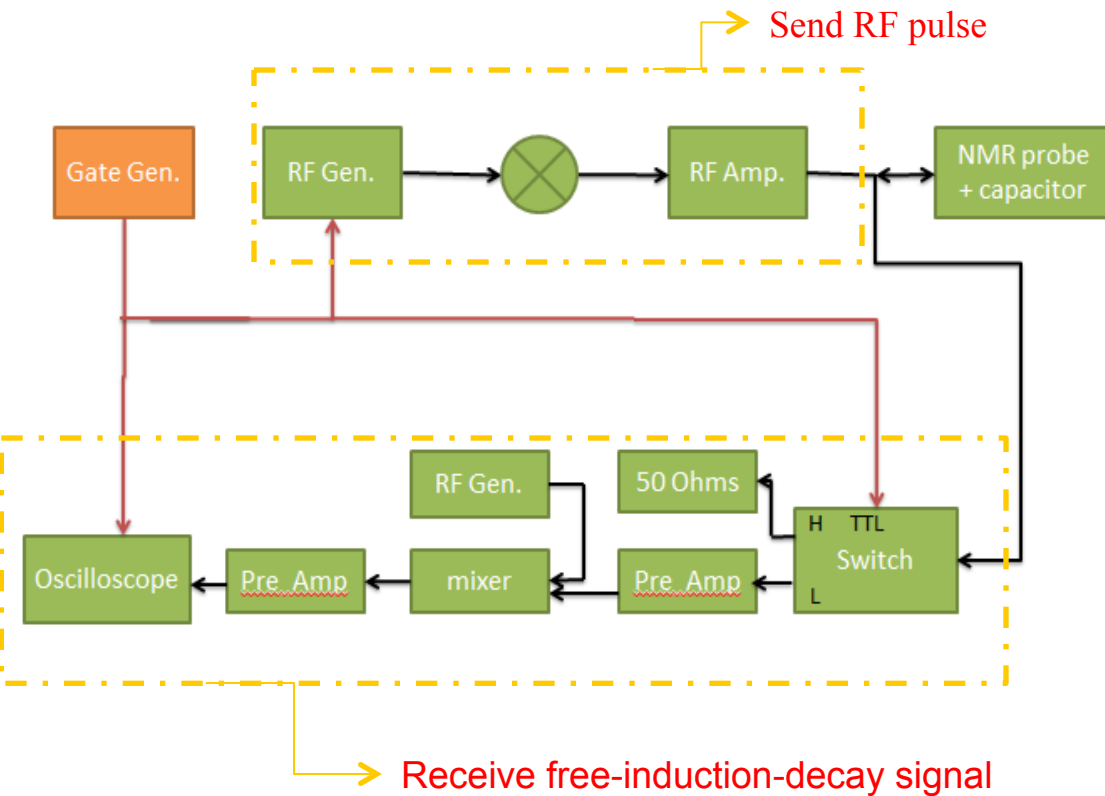
# Rb-K Hybrid Optical Pumping Spin Exchange



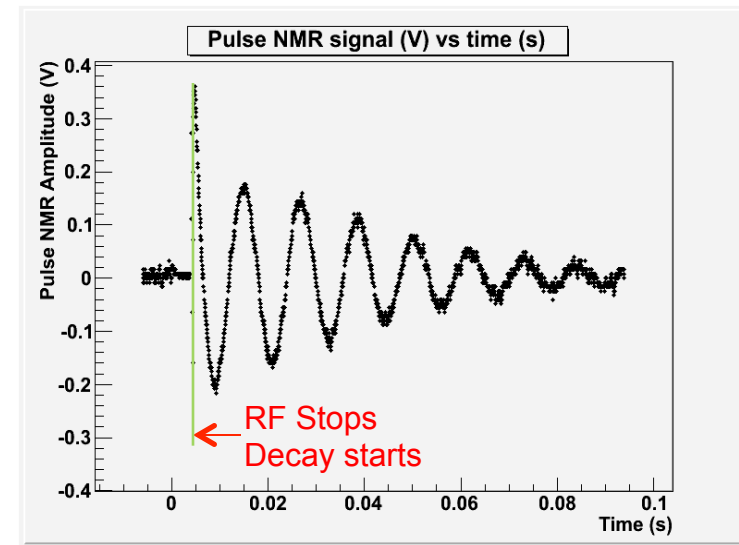
# Performance History for High Luminosity Polarized $^3\text{He}$



# Pulse NMR



## Pulse NMR signal vs time

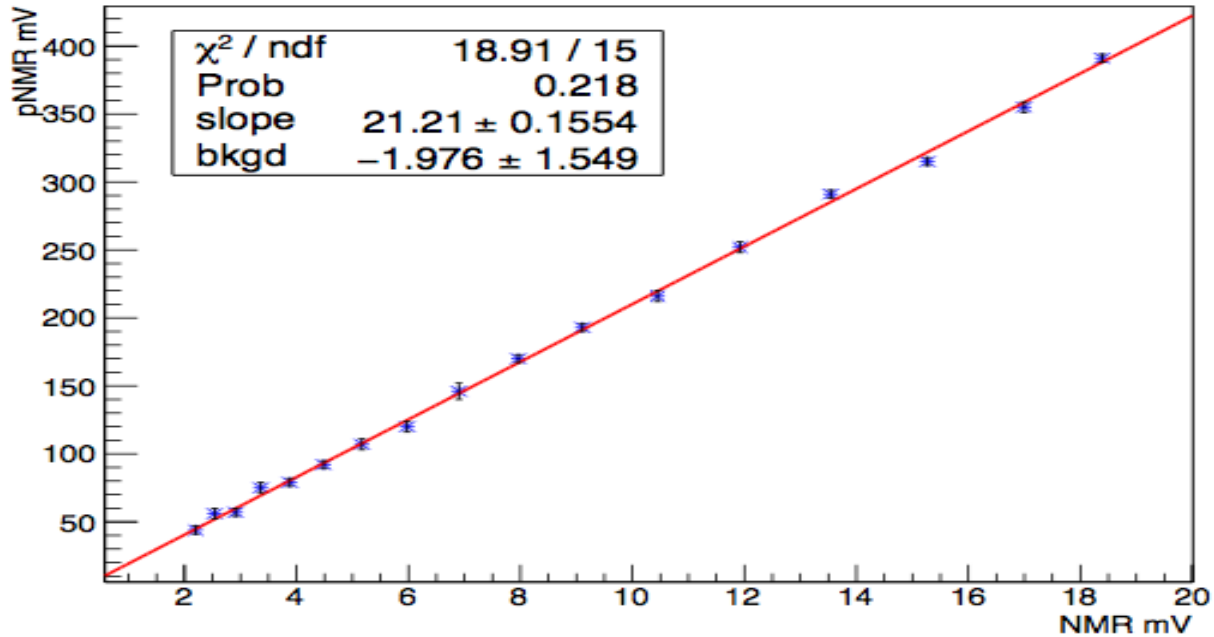


Challenge: to improve signal to noise ratio

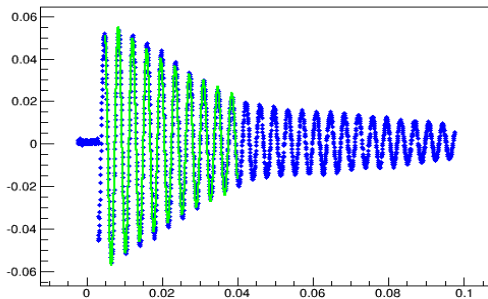
# Pulse-NMR calibrate with AFP-NMR (Spin-Down)

PNMR vs NMR

PNMR(mV)

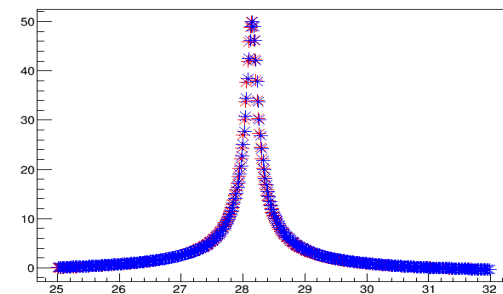


PNMR vs time



Target Chamber

NMR(mV)



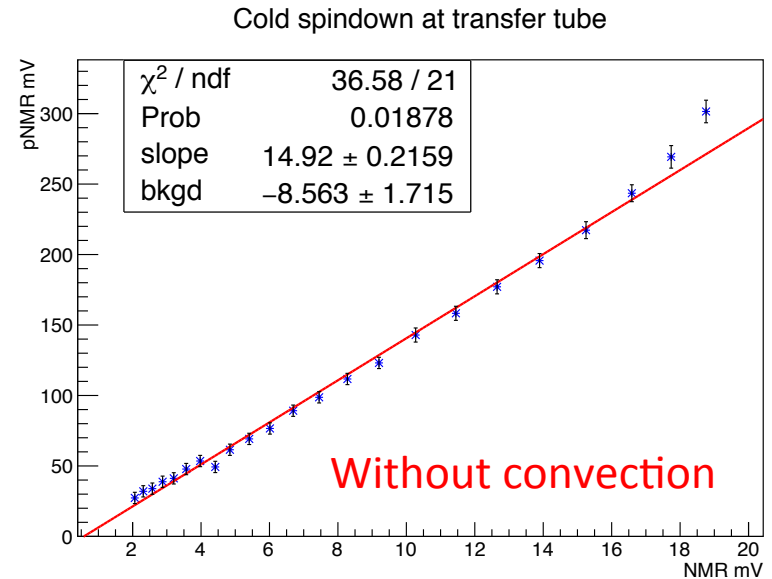
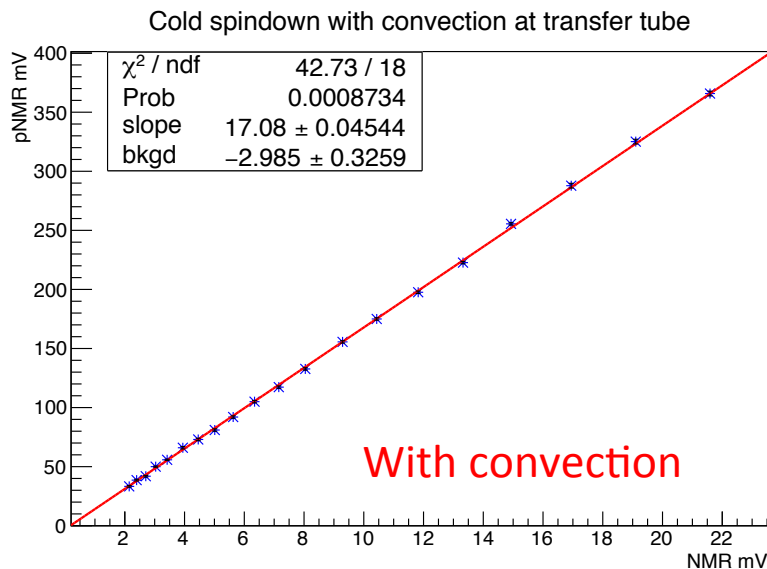
# Spinup time, AFP loss and lifetime for protovec-1

AFP loss	Pumping chamber(%)	Target chamber(%)
Cool without convection	1.18	0.21
Hot without convection	0.95	0.37
Hot with convection	1.43	1.44

Lifetime	Pumping chamber(hr)	Target chamber(hr)
Cool without convection	26.57	23.11
Hot without convection	13.49	15.97
Hot with convection	14.56	14.54

Spinup time	Pumping chamber(hr)	Target chamber(hr)
	5.3	9.6

# Calibrate Pulse NMR at transfer tube versus NMR at target chamber



Measurements were done every 2 hours for each data point.

Systematic uncertainty study is in progress. Several tests were done without convection and it showed a strong contribution from diffusion.

From diffusion study for hot spindown, the diffusion constant (between pumping and target chamber)  $d_{pc} = 0.091$  (~11 hours) and  $d_{tc} = 0.065$  (~16 hours).

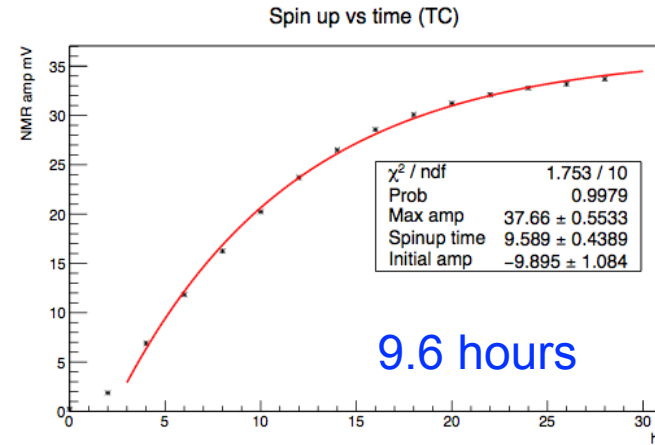
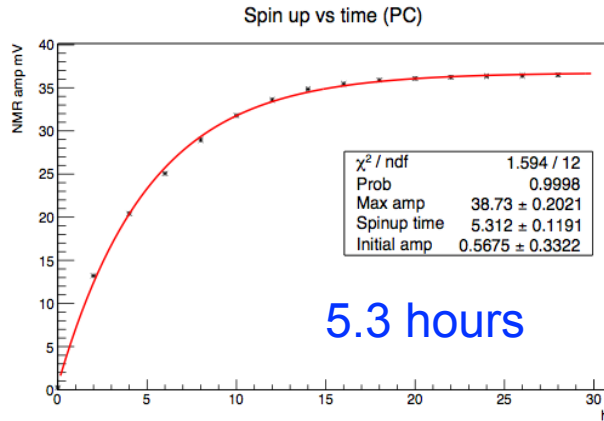


# Cell Characterization (Protovec I)

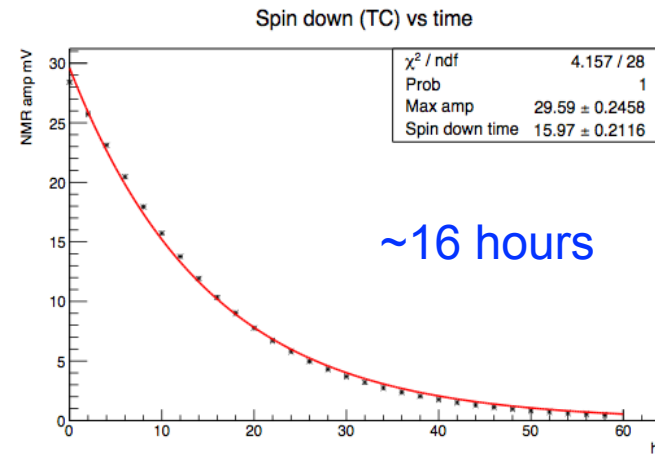
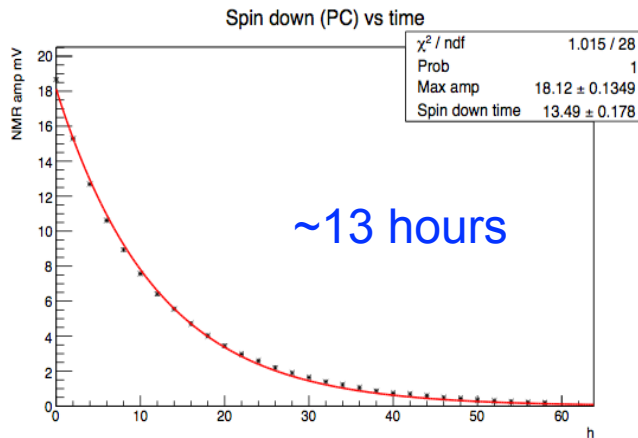
## Pumping Chamber

## Target Chamber

Spin up



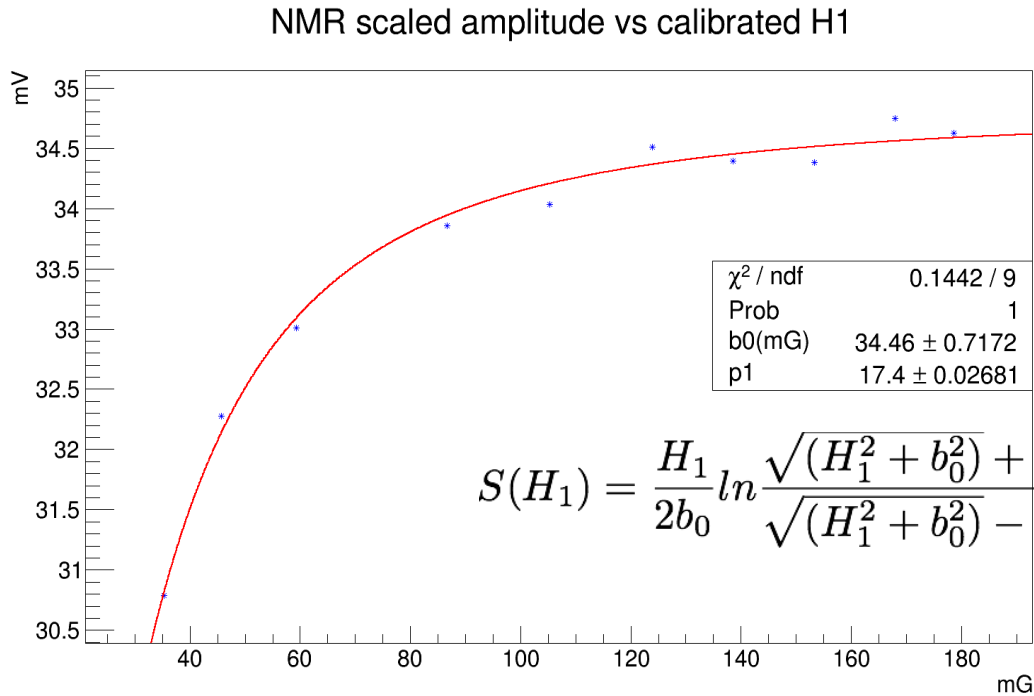
Hot Spin down



Both PNMR and NMR

# Field gradient

- By measuring  $H_1$  as a function of NMR amplitude:



~10 mG/cm

❖ Gaussmeter:

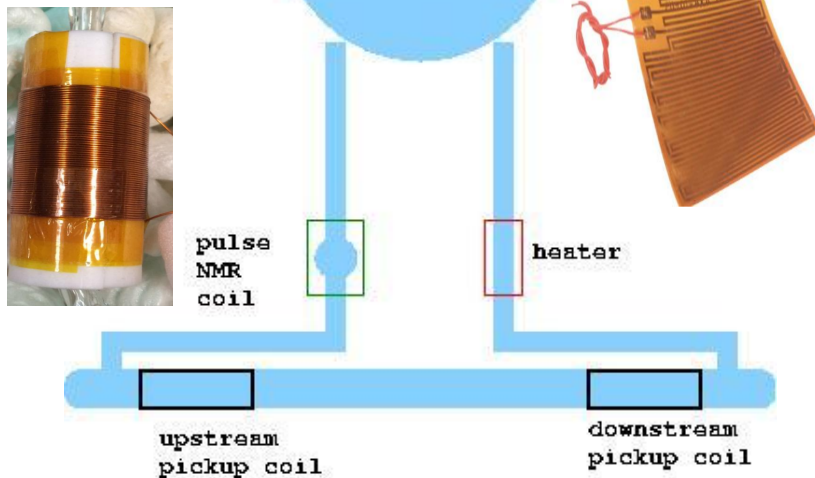
$$5 \text{ mG} < \frac{\partial B_z}{\partial z} < 10 \text{ mG}$$

At Hall C pivot: SHMS Bender, one order of magnitude higher

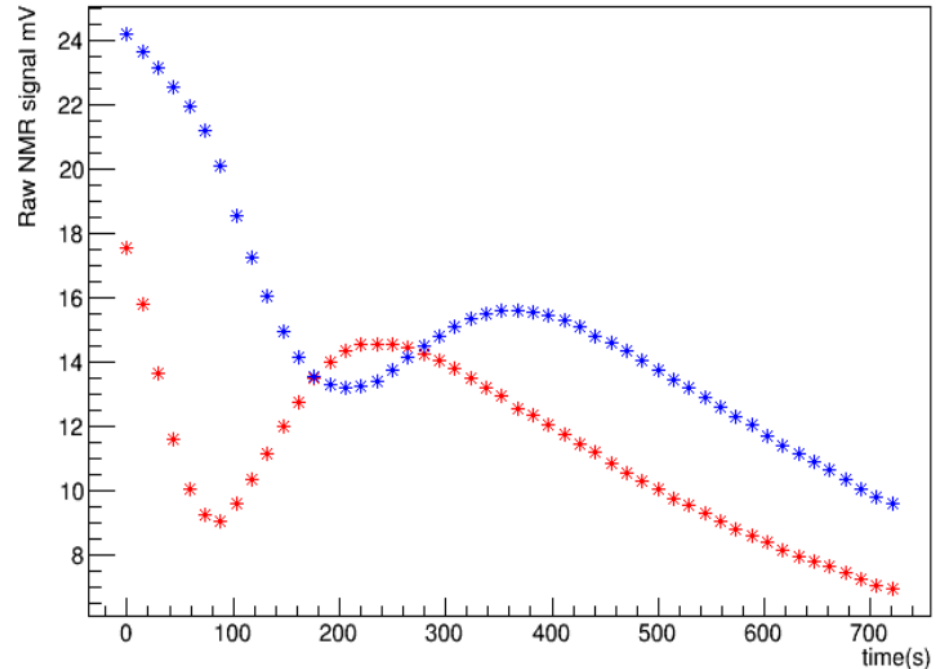
being modeled and studied, correction coils needed

# Convection speed measurement

Use pulse-NMR coil destroy  $^3\text{He}$  polarization in at left transfer tube, and measure the time interval between two NMR signal dips.



Convection test w 2 pickup coils. Red (Blue): pc1(pc2)



convection speed=5.8 cm/s  
From target chamber to pumping chamber : 8 min.  
Compare to diffusion(~40 min),  
convection is faster.

# Reference Cell Broken During Transversity

