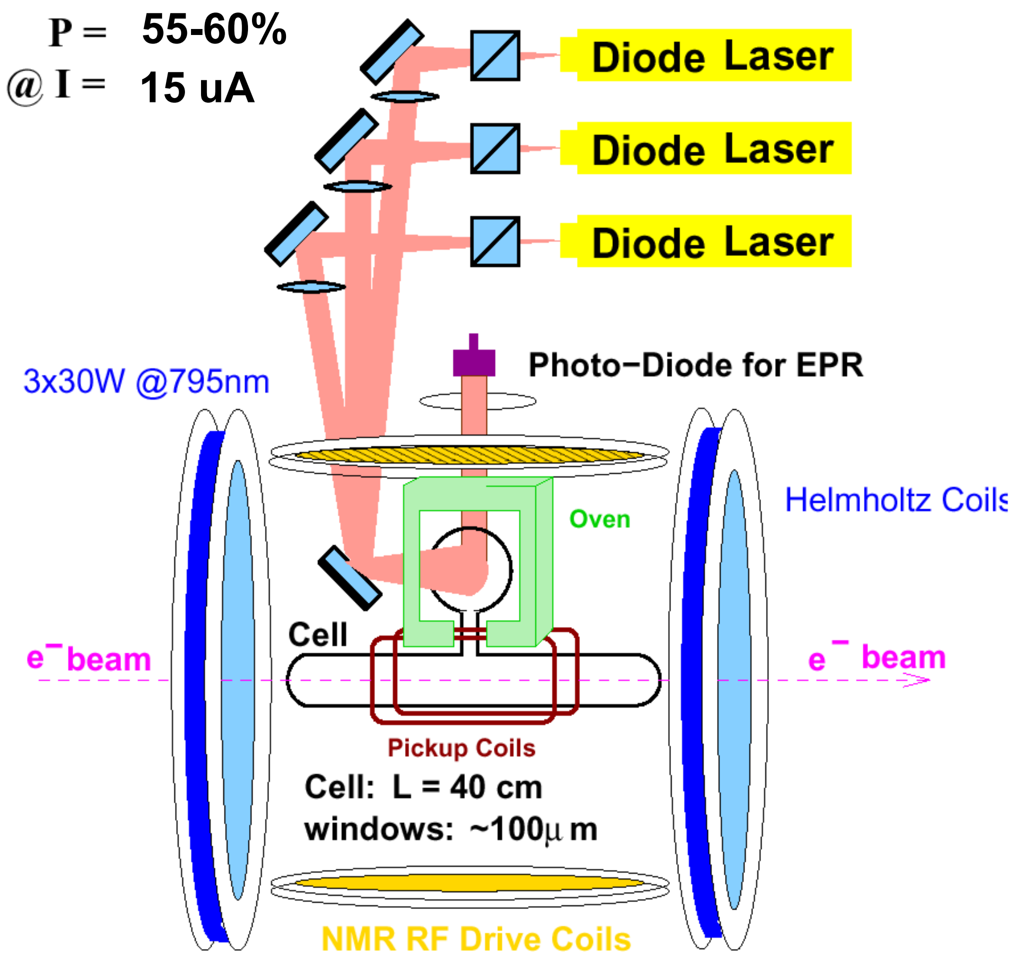
Polarized ^{3}He Target for A1n/d2n in Hall C

Jian-ping Chen, Jefferson Lab

Experimental Readiness Review, March 19, 2018

- Polarized ^{3}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}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}He Performance for 6 GeV Experiments

- luminosity: 10^{36} with 15 uA on 40 cm cell, ~10 amg ^{3}He
- polarization:

✓ < 40% in 1998

✓ with K-Rb hybrid pumping and narrow-width lasers

improved to > 70% (no beam) in 2008

~ 60% (with beam/flip)

~ 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 ~ 5%

    diffusion (2-3%), κ_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 ~ 2.2×10^{36} $cm^{-2}s^{-1}$
- 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.

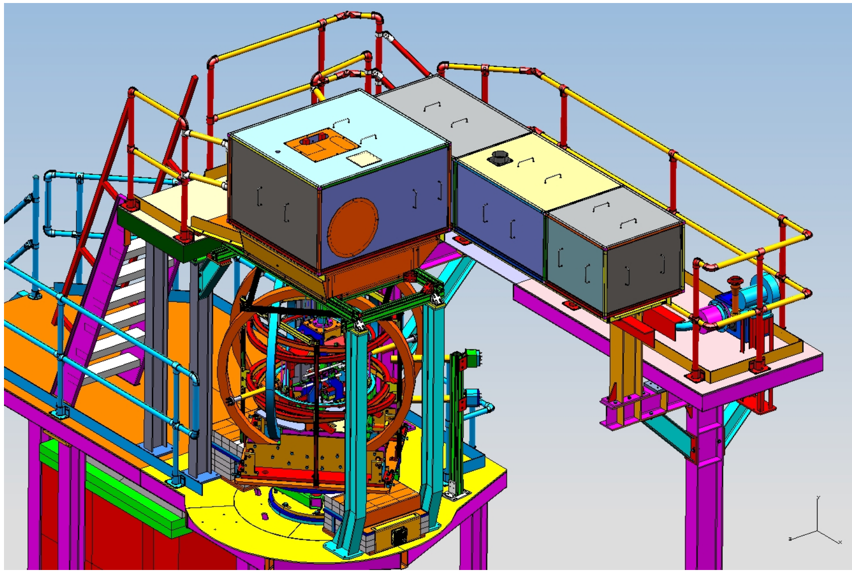
Started preparation for hall installation (Walter Kellner’s talk)

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:

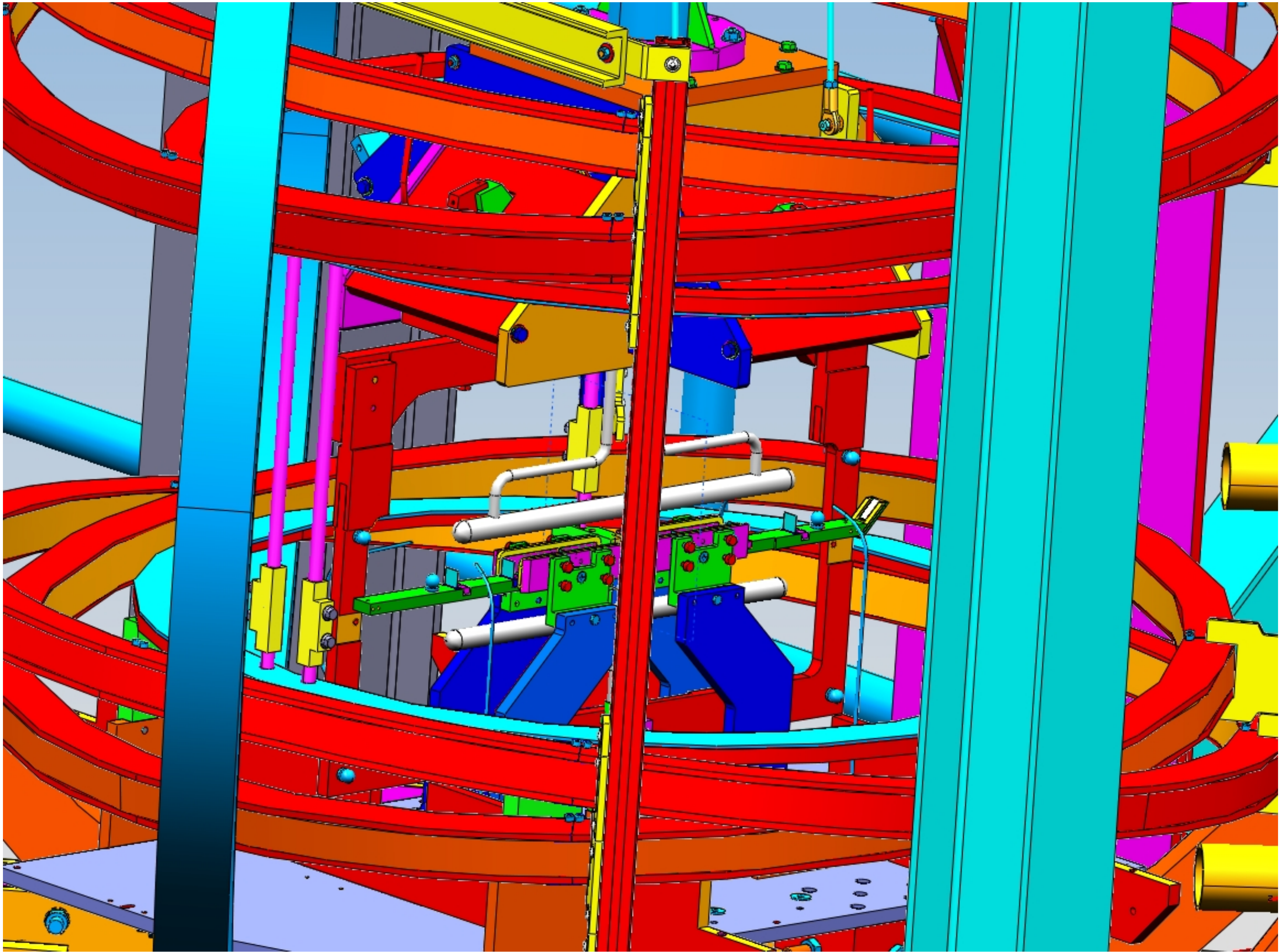
- New parts ordered
- Target ladder manufactured
- Pivot area modified (poster cut)
- Existing parts (in storage) checked
  - will test in advance

Field gradients at target area:

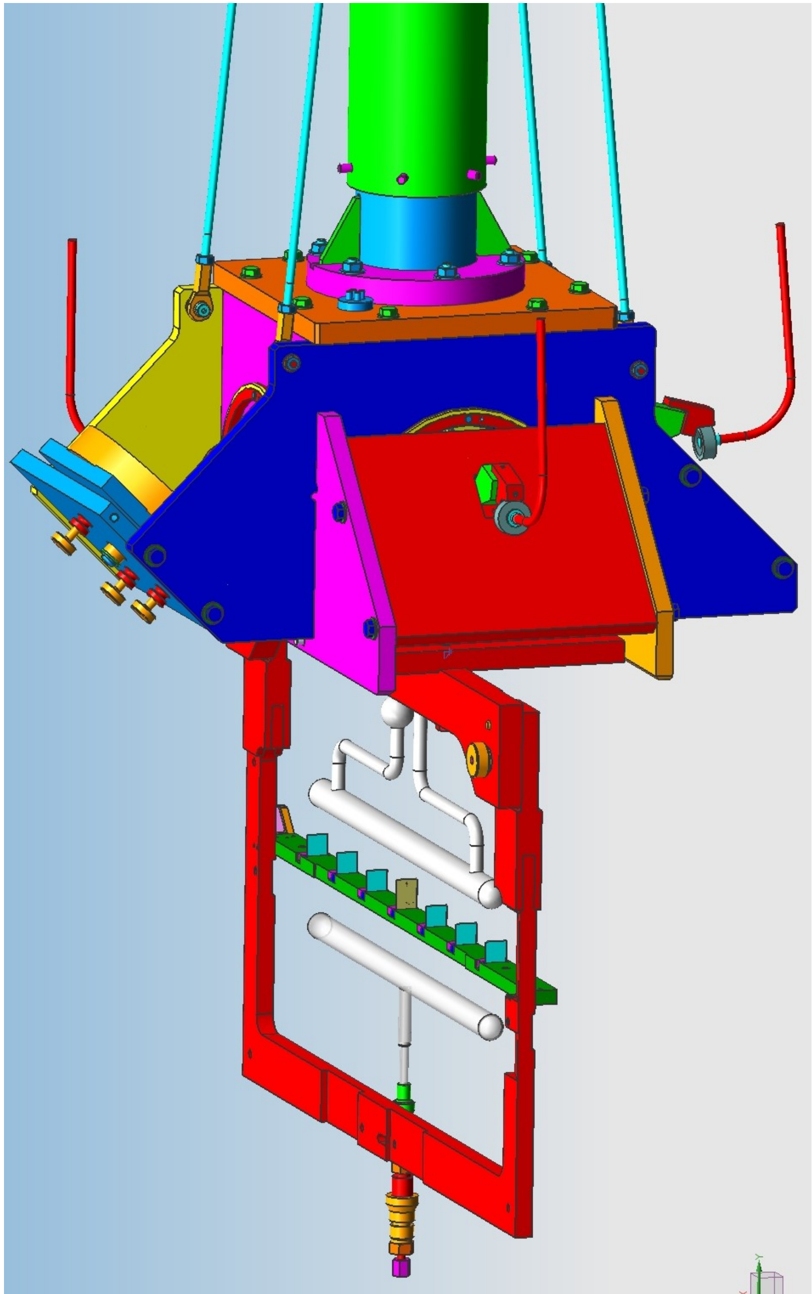
- Study bender field at and magnetic material near the target region
- Correct field gradients with correction coils

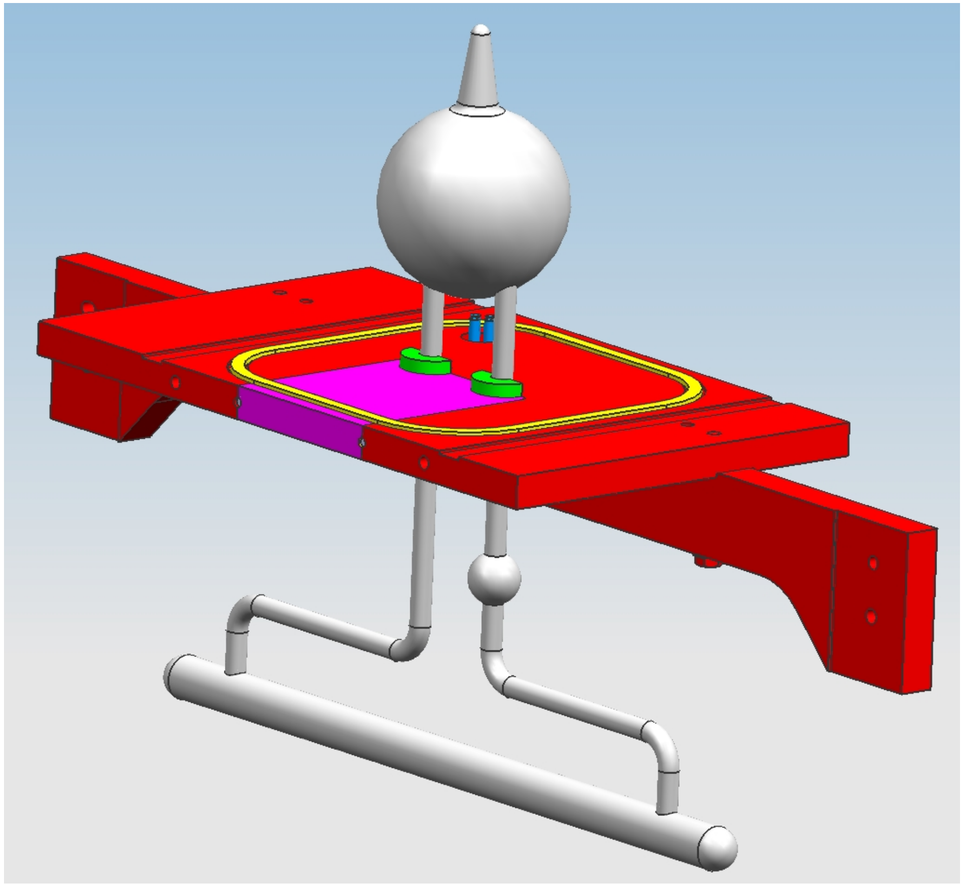
(talk by Lassiter/Cates)

Target System in Hall C



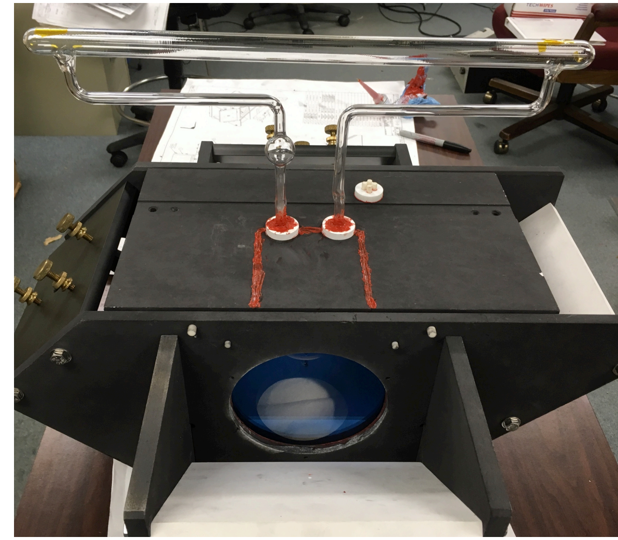
Target Oven, Ladder and Cell





Progress Summary (cont.)

- New oven manufactured/installed/tested



- Target cells

✓ prototyping convection cell extensively tested,

✓ cell production started

1st 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.

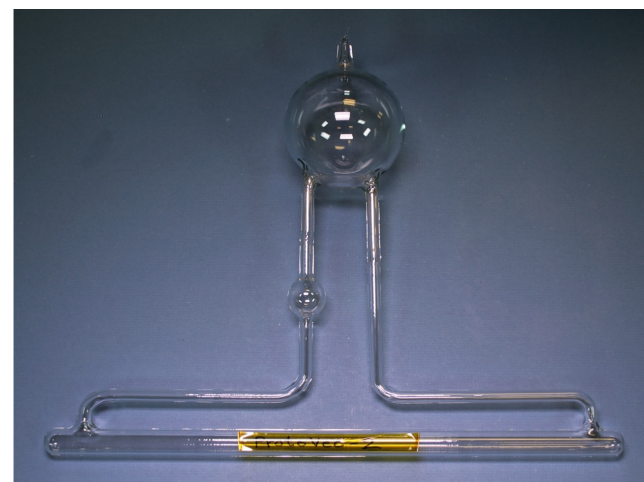
- Lasers/long optical fibers:

✓ five new lasers delivered/tested
more will be ordered as spares and for future

✓ long fibers delivered, tested, conduit installed

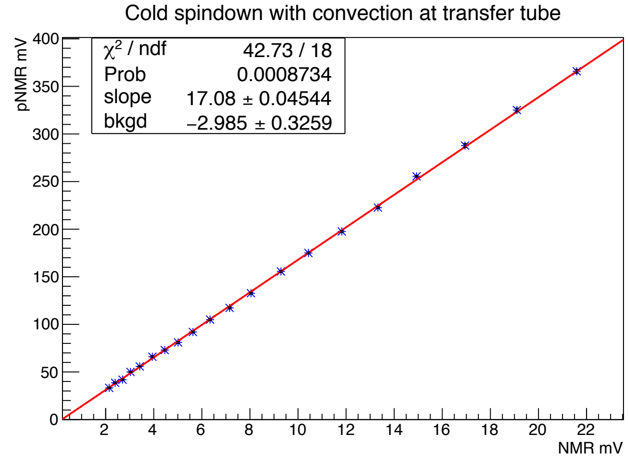
✓ 4-1 combiners ordered, prototype tested

✓ polarization compensation study complete

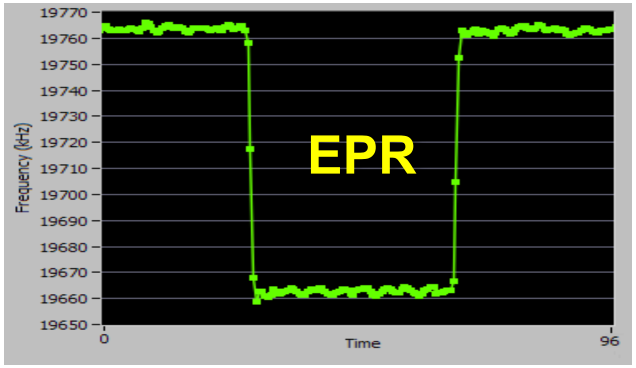


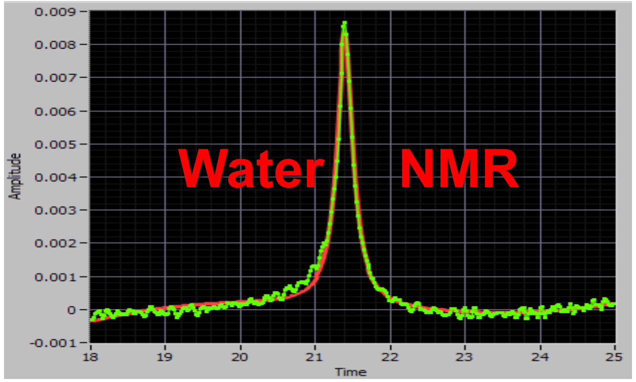
Progress Summary (cont.)

- **Polarimetry:**
  - ✓ pulse NMR systematic study/calibration (Nguyen Ton)
  - ✓ EPR study (Kai Jin)
  - ✓ κ_0 measurement (W&M/UVa) in progress (Averett/Cates)

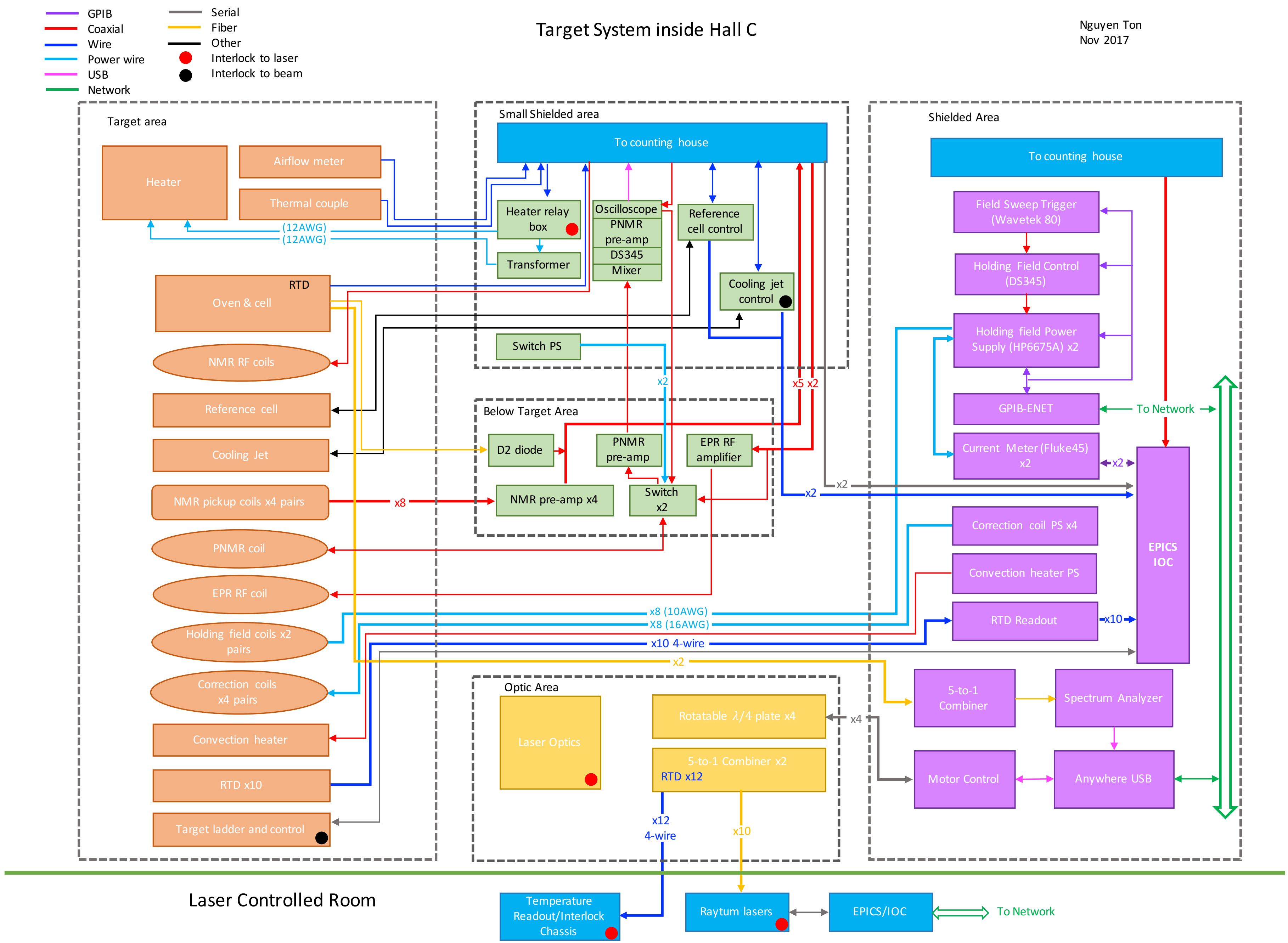


- **Cell characterization:**
  - ✓ Density measurement (August Williams)
  - ✓ Wall and window thickness measurements
  - ✓ Maximum polarization
  - ✓ Spin up
  - ✓ Spin down/ AFP loss study





Target Control System Layout/Electronics/Cables



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	16	37	8main field+ 8correction field
(9&16 AWG)	16	7	8 main field + 8correction field
Power cable	2	21	2 heater
(12AWG)	2	7	2 heater
GPIB	12		5(in Hall)+7(counting house)

Peoplepower/User Contributions

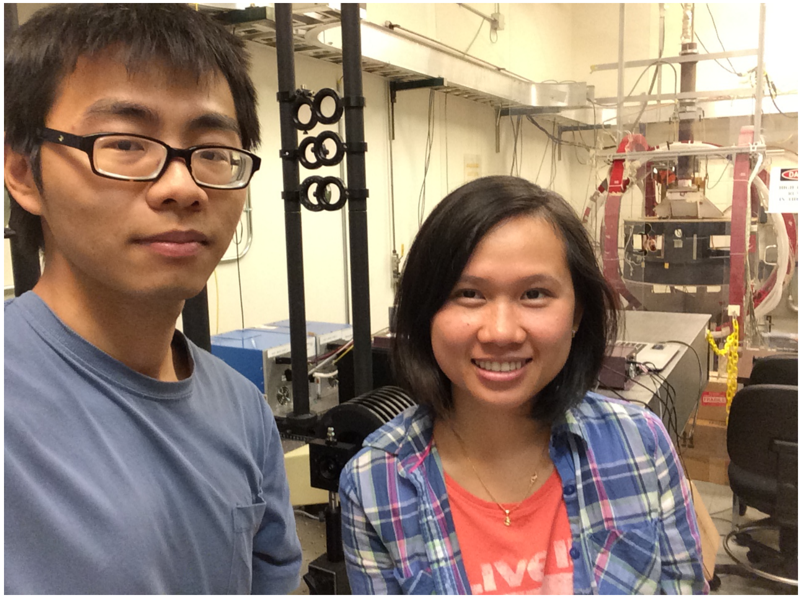
At JLab: students + engineer/designer + JP (supervisor/coordinator)

- 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
  - κ0 measurement
- W&M (Todd Averett)
  - κ0 measurement
  - Reference cell system/cooling jets
- Kentucky (Wolfgang Korsch)
  - field direction measurement



Working at JLab polarized 3He 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):

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
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
   6 GeV time: 200-300 um beam size with ~ 2-4 mm diameter raster size
4) used cooling jets and slow beam ramping rate

For A1n/d2n, 30 uA,

<300 um (sigma) beam size, raster 5 mm diameter circular raster

Summary

- Polarized 3He target reliably used for many 6 GeV experiments in Hall A

- Upgrade (double luminosity) and make it work in Hall C

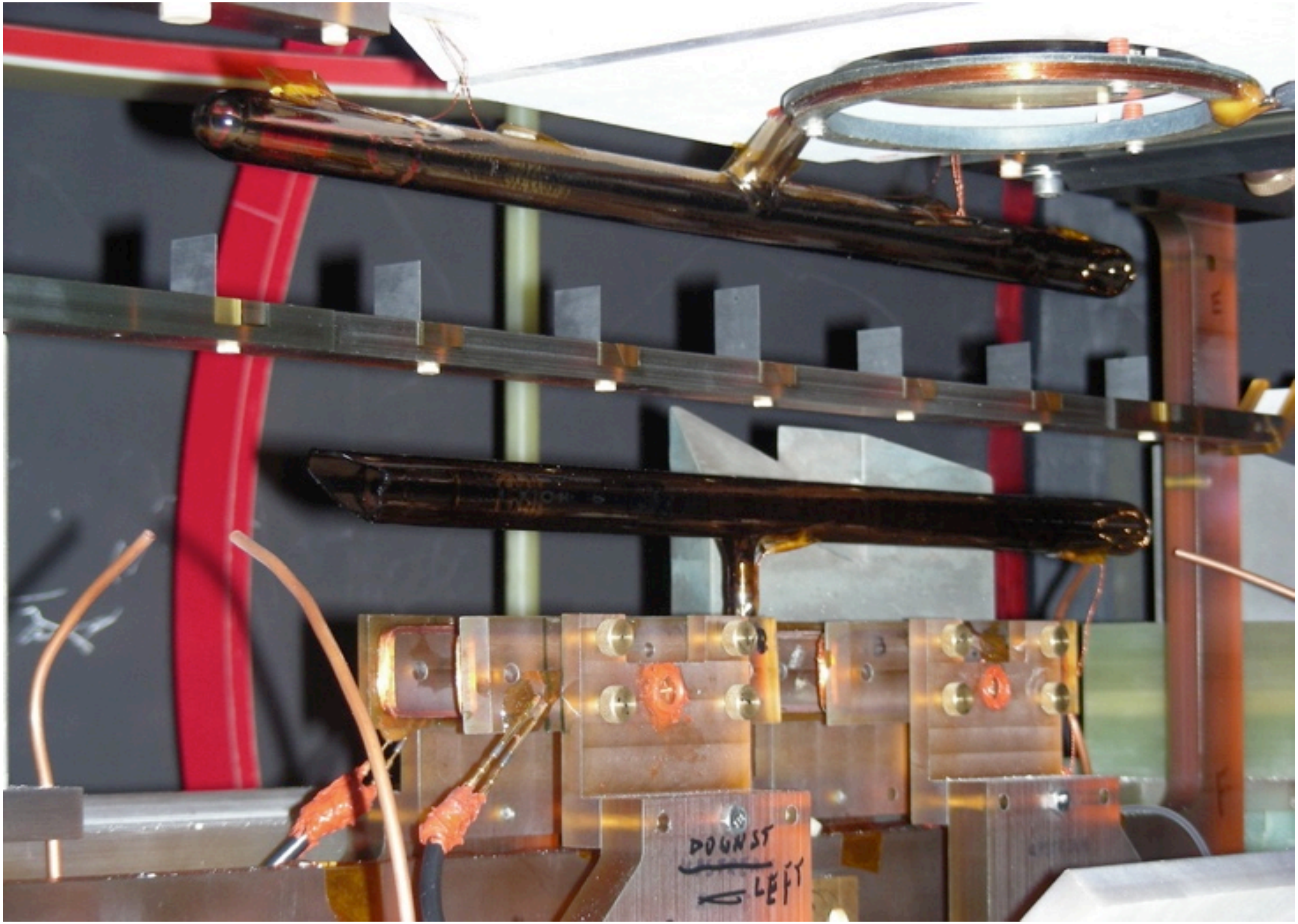
- Progresses:
  - Engineering/Design complete, parts fabricated
  - Hall C pivot area work complete
  - New oven tested, convection cell extensively tested.
  - pulsed NMR established, reached 1% precision in cross calibration
  - New lasers, new optical fiber cables
  - Cell production started

- Installation design mostly complete, preparation started, plan discussed (Walter Kellner's talk)

- Field gradient study/correction coils design (Lassiter/Cates talk)

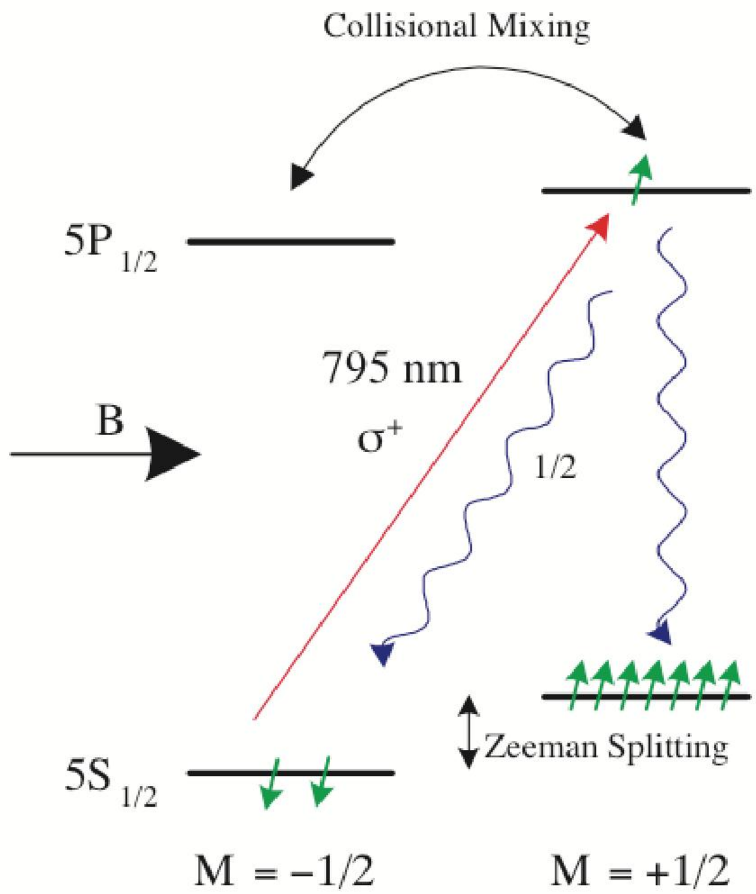
- OSP/LSOP draft ready

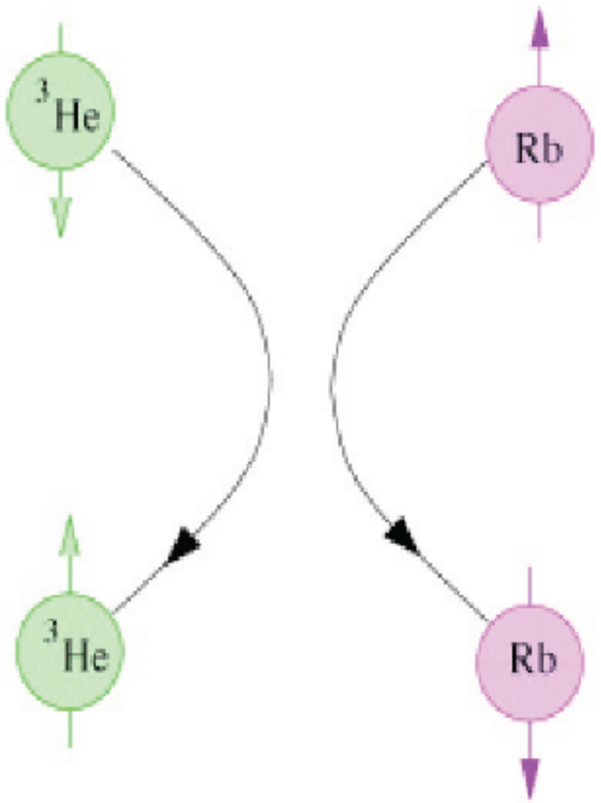
Reference Cell Broken During Transversity



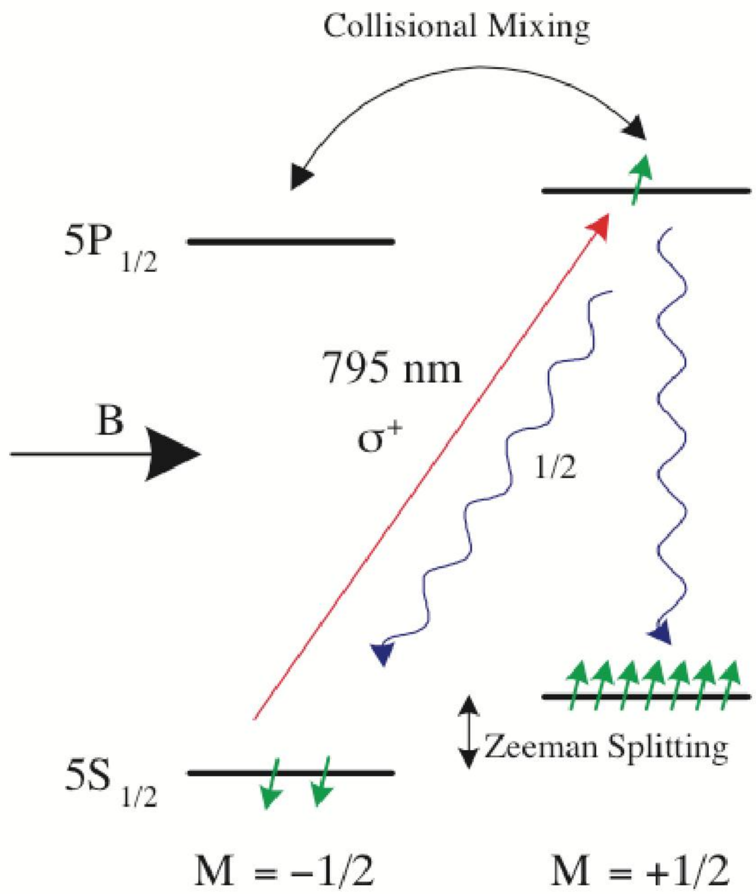
Backup

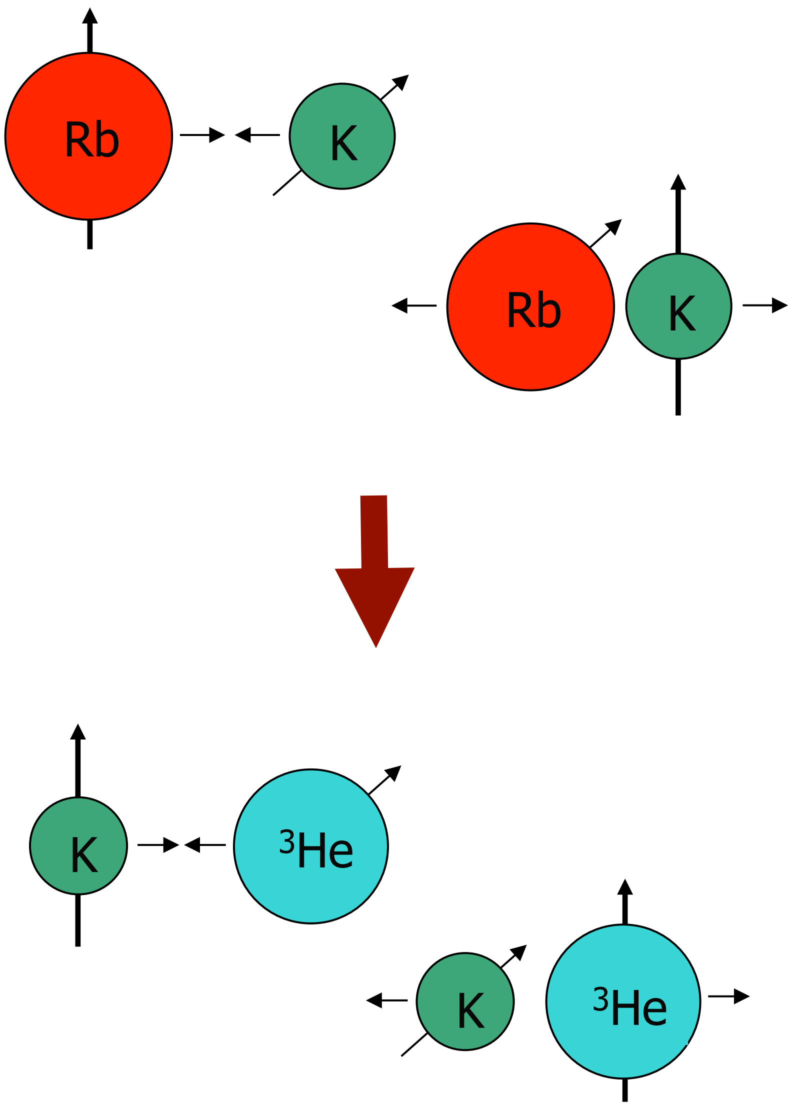
Spin exchange Optical Pumping for ^3He



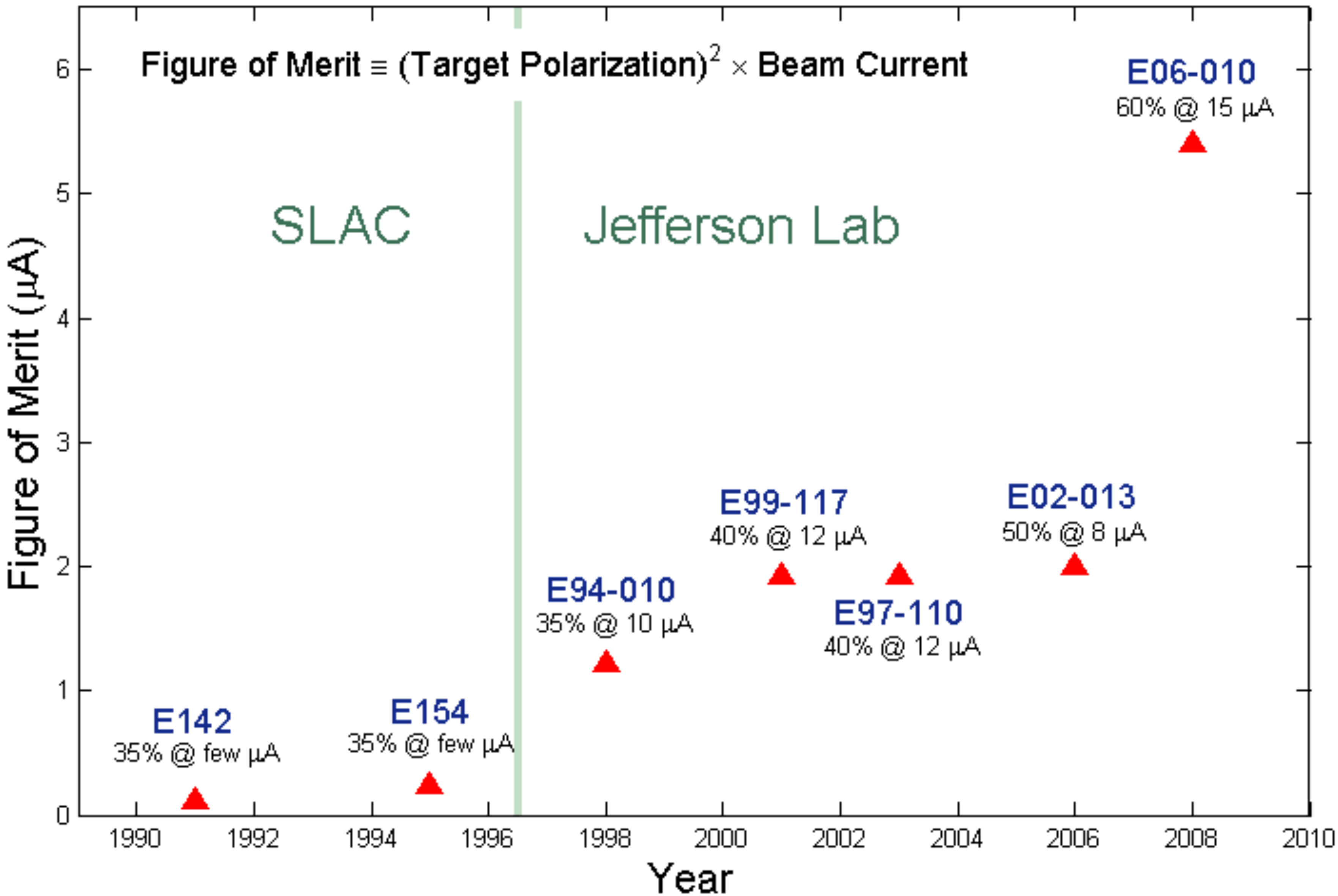


Rb-K Hybrid Optical Pumping Spin Exchange

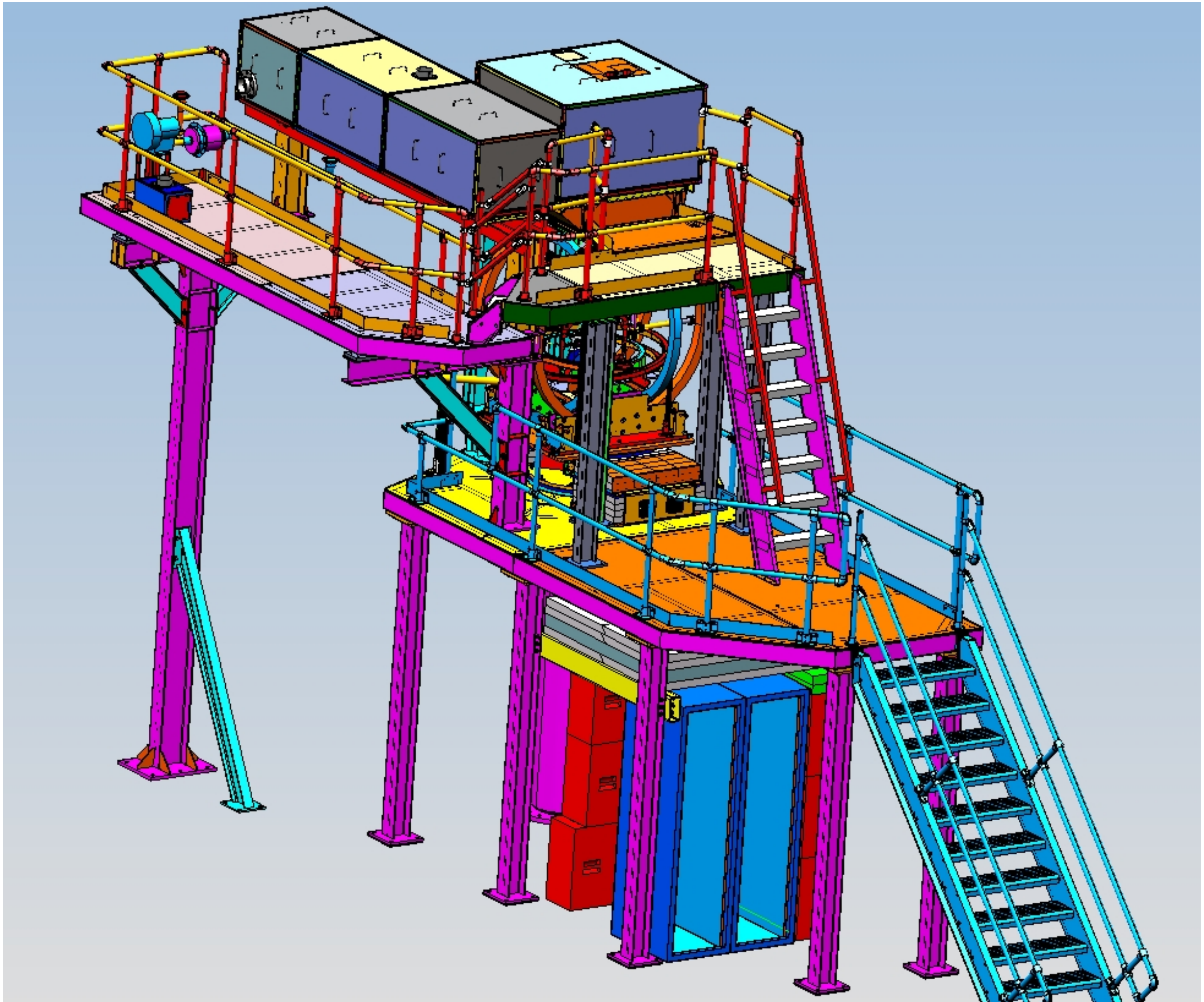




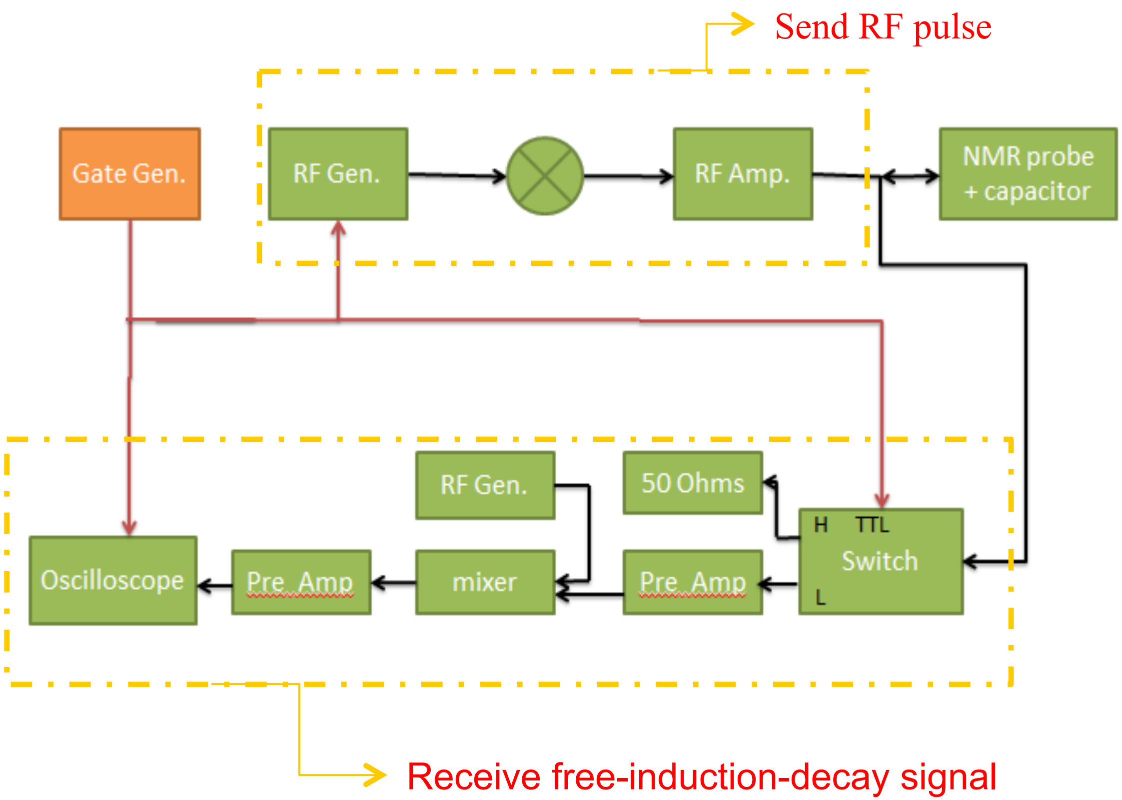
Performance History for High Luminosity Polarized ^{3}He



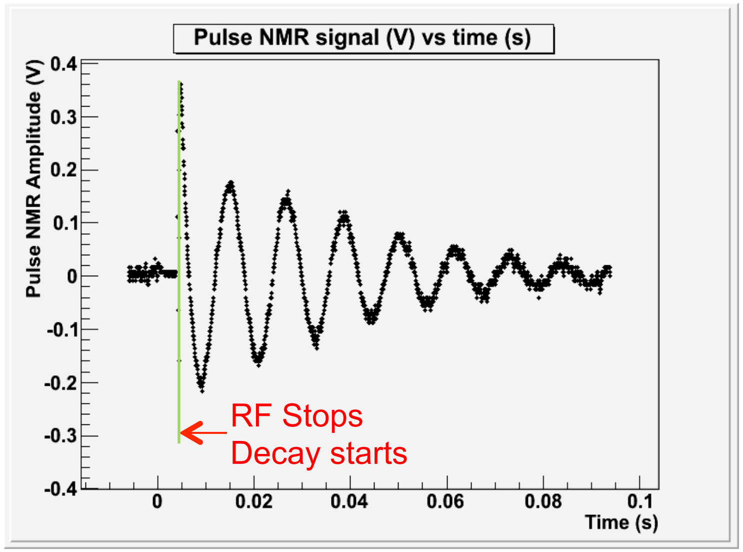
Instrumentation locations in the hall



Pulse NMR



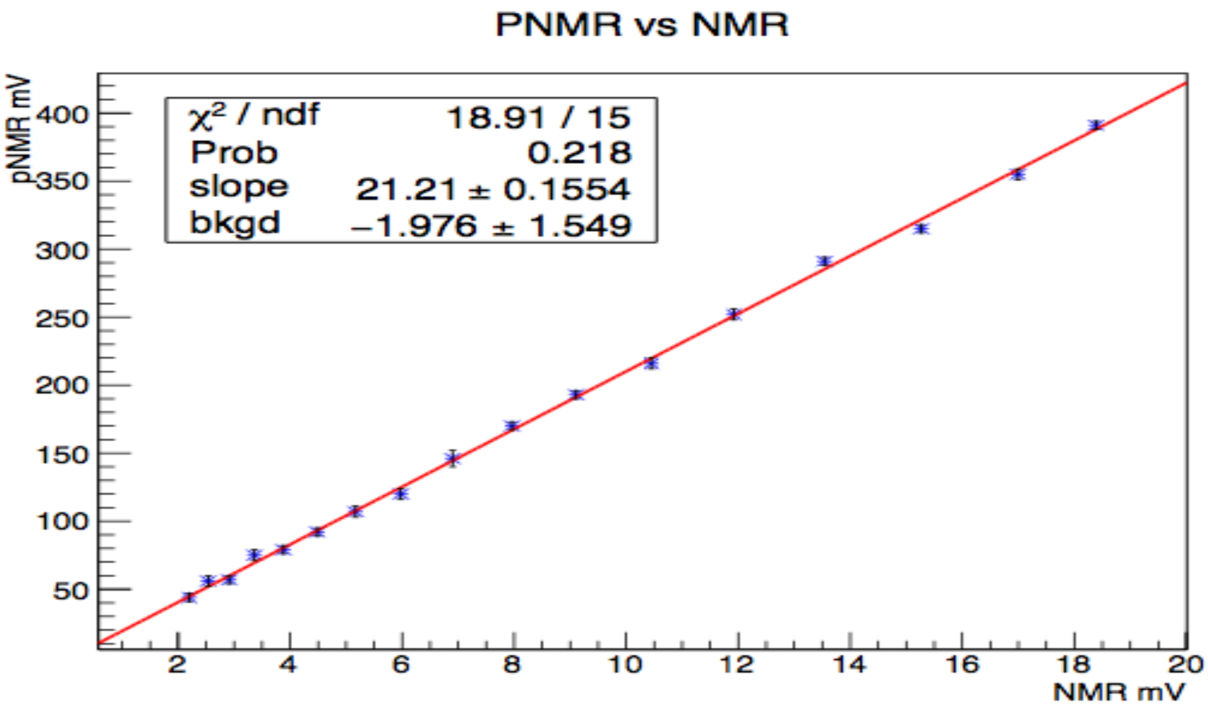
Pulse NMR signal vs time



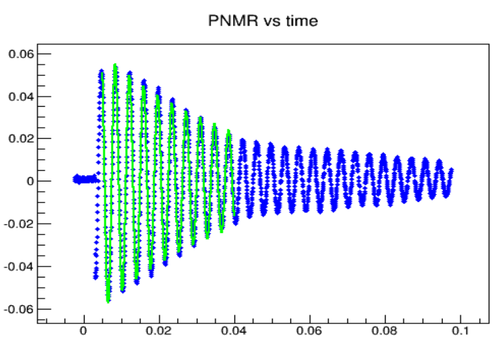
Challenge: to improve signal to noise ratio

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

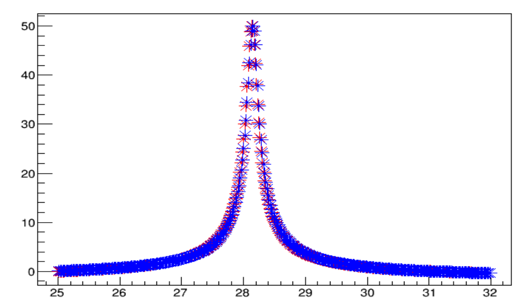
PNMR(mV)



NMR(mV)



Target Chamber



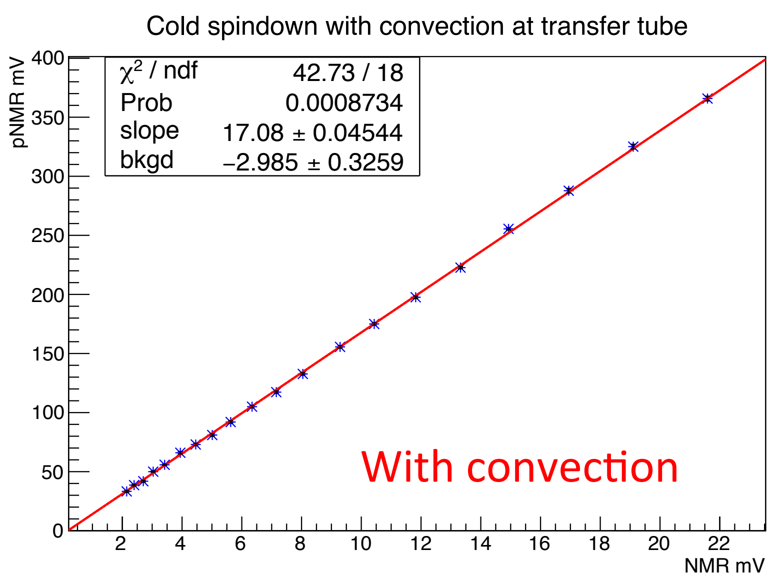
Spinup time, AFP loss and lifetime for protovec-1

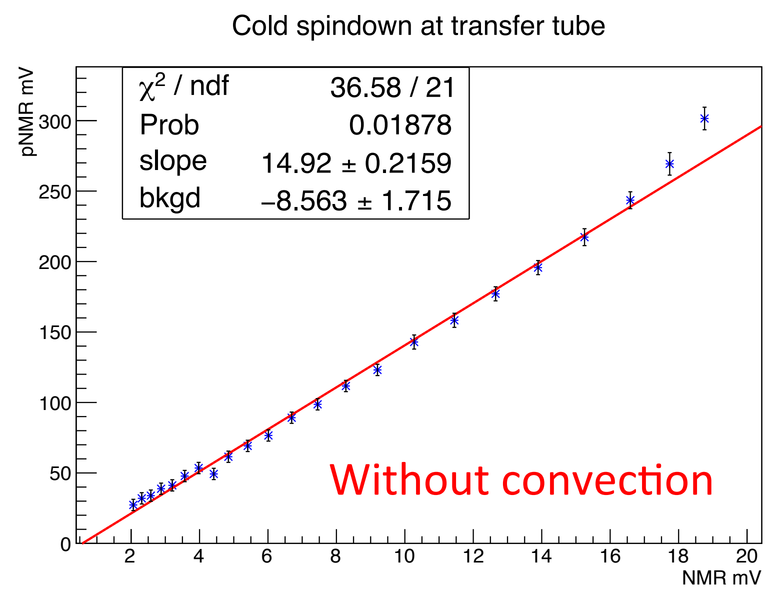
AFP loss	Pumping chamber(%)	Target chamber(%)
Cool without convection	1.18	0.21
Hot without convection	0.95	0.37
Hot with convection	1.43	1.44

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.

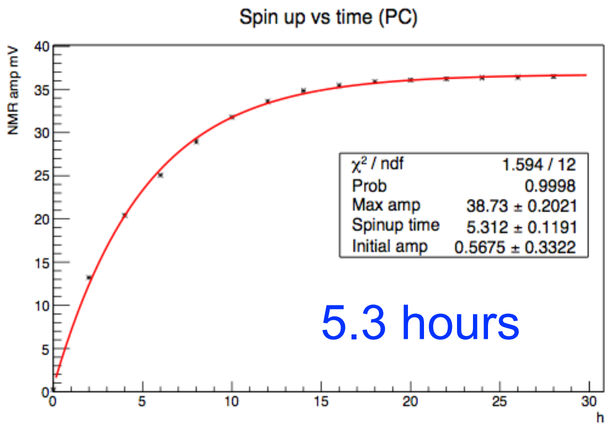
Systematic uncertainty study is in progress. Several tests were done without convection and it showed a strong contribution from diffusion.
From diffusion study for hot spindown, the diffusion constant (between pumping and target chamber) d_{pc} = 0.091 (~11 hours) and d_{tc} = 0.065 (~16 hours).

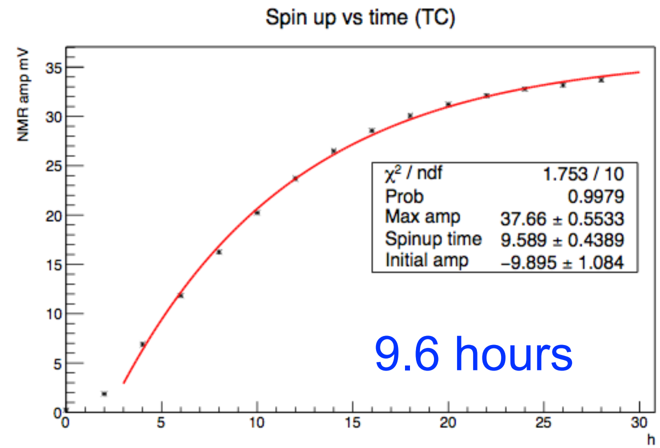
Cell Characterization (Protovec I)

Pumping Chamber

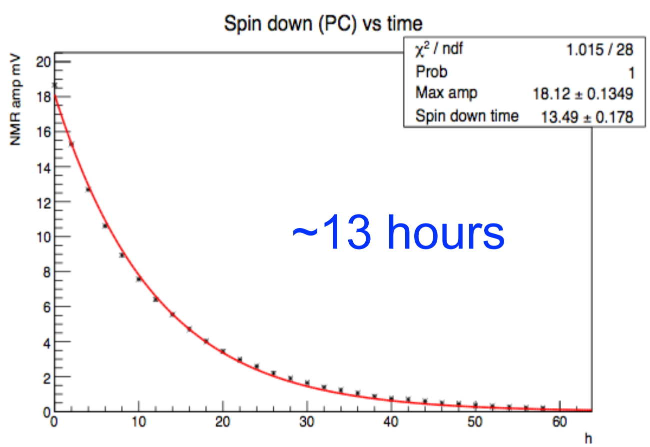
Target Chamber

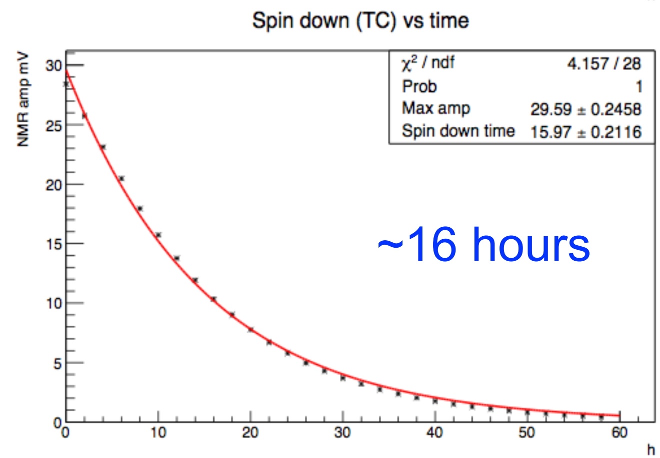
Spin up





Hot Spin down

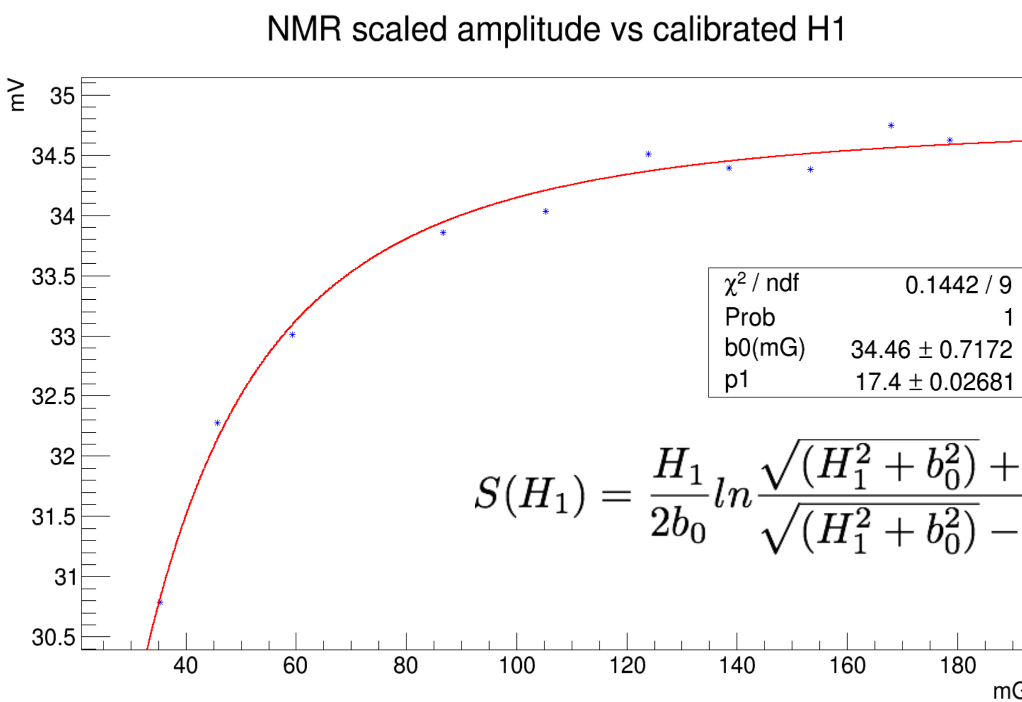




Both PNMR and NMR

Field gradient

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



$$S(H_1) = \frac{H_1}{2b_0} ln \frac{\sqrt{(H_1^2 + b_0^2)} + b_0}{\sqrt{(H_1^2 + b_0^2)} - b_0}$$

~6 mG/cm

- Gaussmeter:

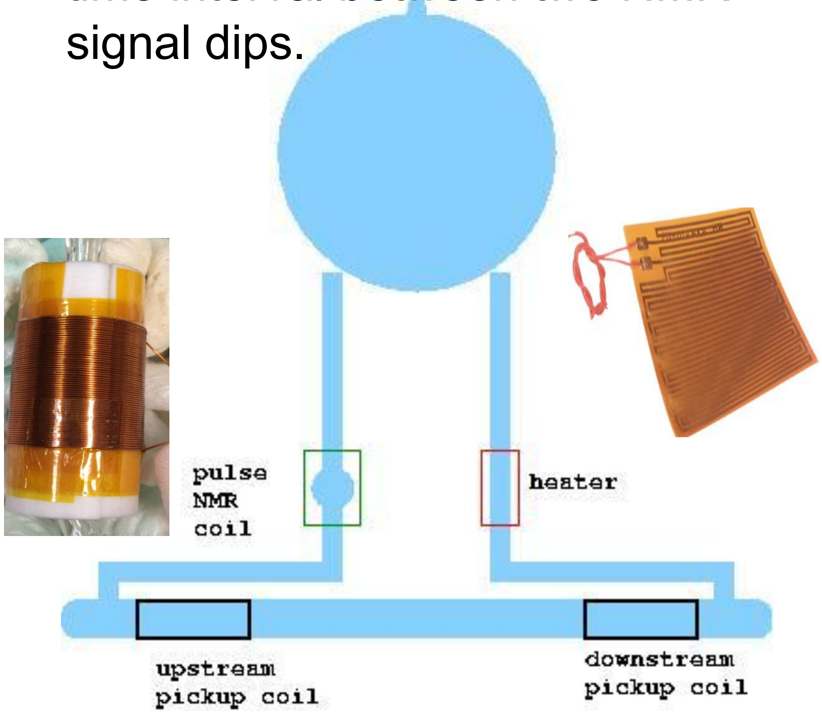
$$5 \text{ mG} < \frac{\partial B_z}{\partial z} < 10 \text{ mG}$$

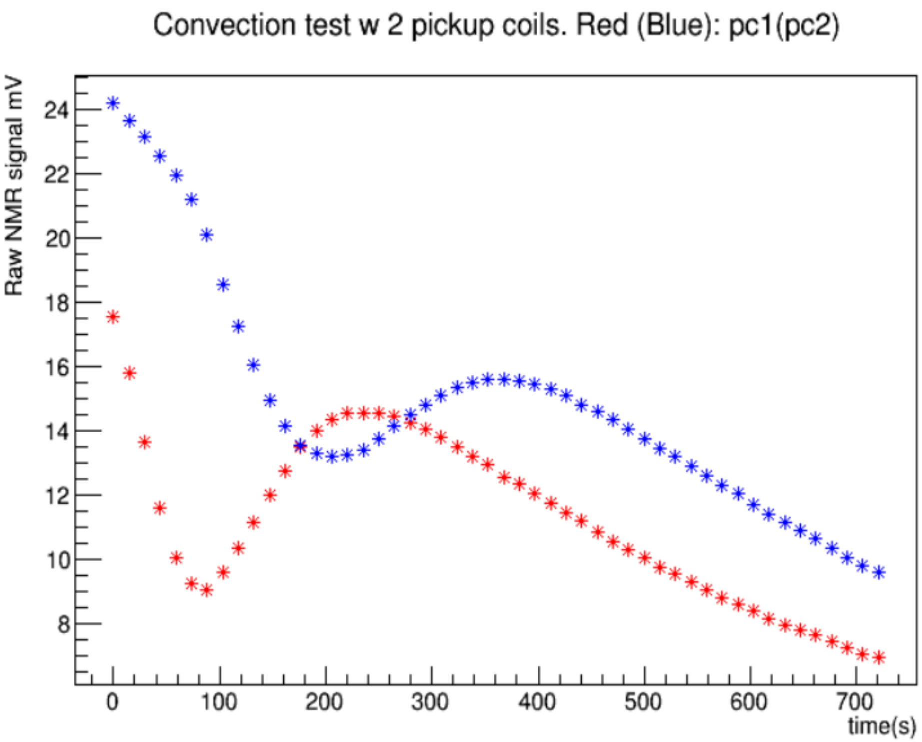
At Hall C pivot: SHMS Bender, one order of magnitude higher

being modeled and studied, correction coils needed

Convection speed measurement

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





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