Vertically pointing transversely polarized target system for the Drell-Yan experiment E1039

M. Yurov,
D. Keller, D. Crabb, D. Day

Solid Polarized Target Group

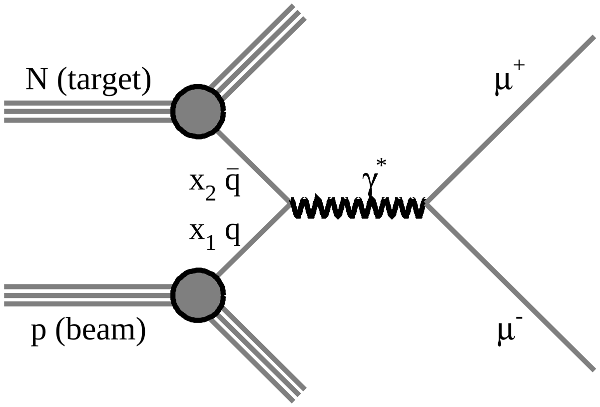
Spin 2016 09/16, Urbana-Champagne, IL

OUTLINE

1. Motivation
2. Subsystems status
3. Full system test
4. Future improvements

POLARIZED TARGET DY E1039

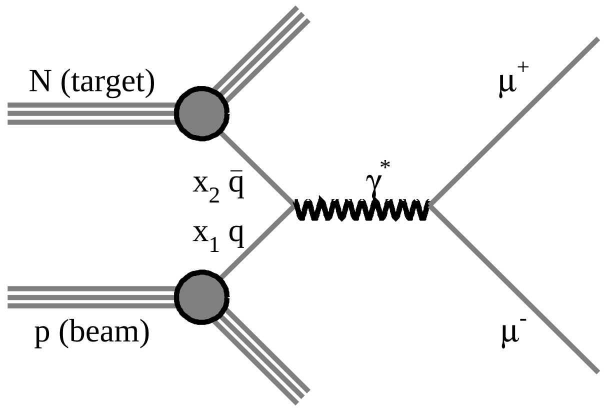
Access the sea quark Sivers function by measuring TSSAs in Drell-Yan production



- unpolarized 120 GeV proton beam from Main Injector at Fermilab
- existing E906/SeaQuest spectrometer to detect muon pair
- fixed polarized target
  - high luminosity
  - transversely polarized
  - high polarization proton/deuteron target

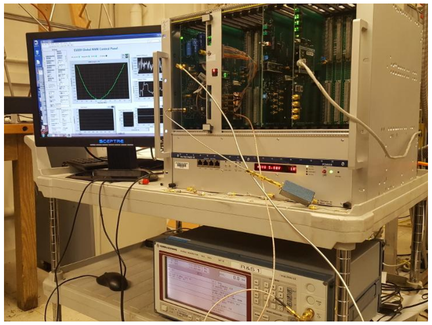
POLARIZED TARGET DY E1039

Access the sea quark Sivers function by measuring TSSAs in Drell-Yan production

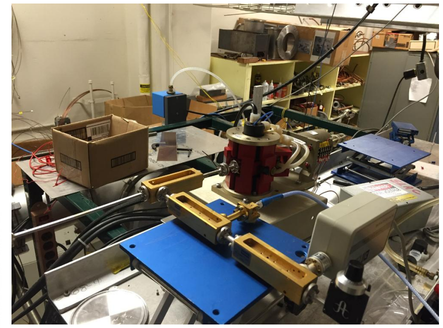


- unpolarized 120 GeV proton beam from Main Injector at Fermilab
- existing E906/SeaQuest spectrometer to detect muon pair
- fixed polarized target
  - solid NH3(ND3) 8 cm long target cell: $1.42 \times 10^{42} (2.11 \times 10^{42}) cm^{-2}$
  - vertically pointing 5T magnetic field
  - polarization: 80%(32%), dilution: 0.176(0.3), packing frac.: 0.6

POLARIZED TARGET DY E1039

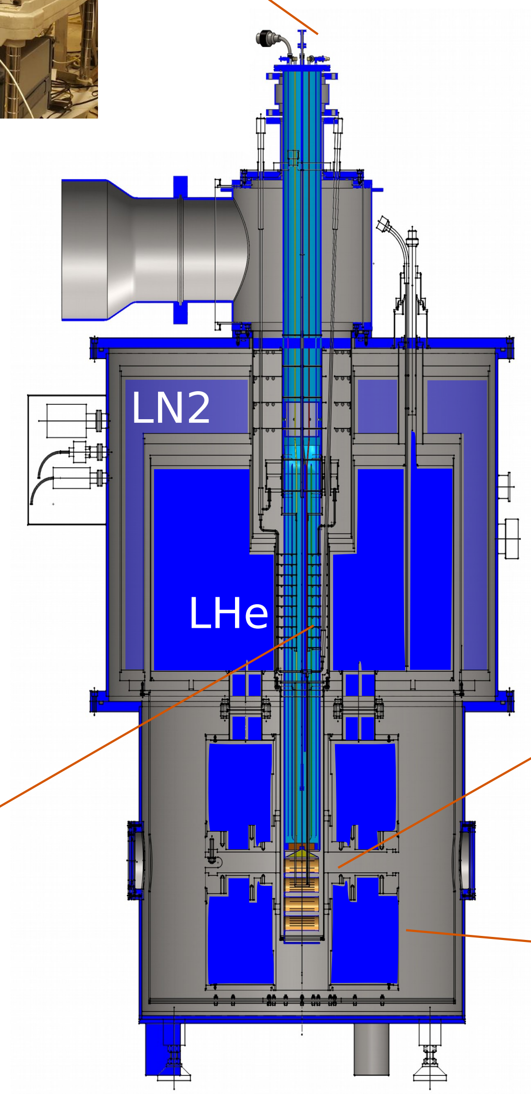


NMR



Microwave

Insert



Pumps

Target material

Fridge

Magnet

POLARIZED TARGET SUBSYSTEMS

Original design by S.Penttila, Oxford Instr.

- kept at LANL storage since ~2000

Feasibility study

- shipped to UVA in 2013
- 1st cooldown 06/2013

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Magnet · Fridge · Insert · NMR · Microwave · Pumps · Target material

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Feasibility study

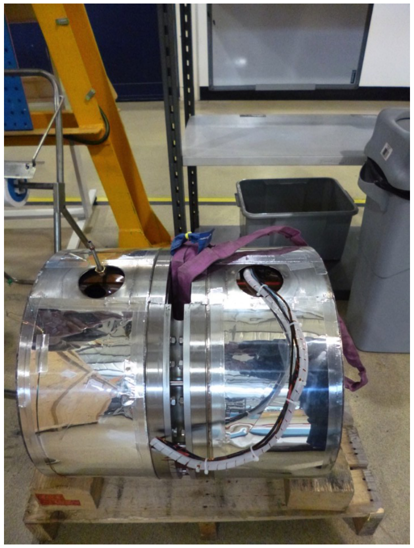
- shipped to UVA in 2013
- 1st cooldown 06/2013

Rotation of the coils

- shipped to Oxford Instruments
- new configuration, 2nd cooldown
- $dB/B < 10^{-4}$ on 3d grid, 5T over 8cm

Back to UVA

- 3rd cooldown, rotated coils test
- magnet is in a very good shape

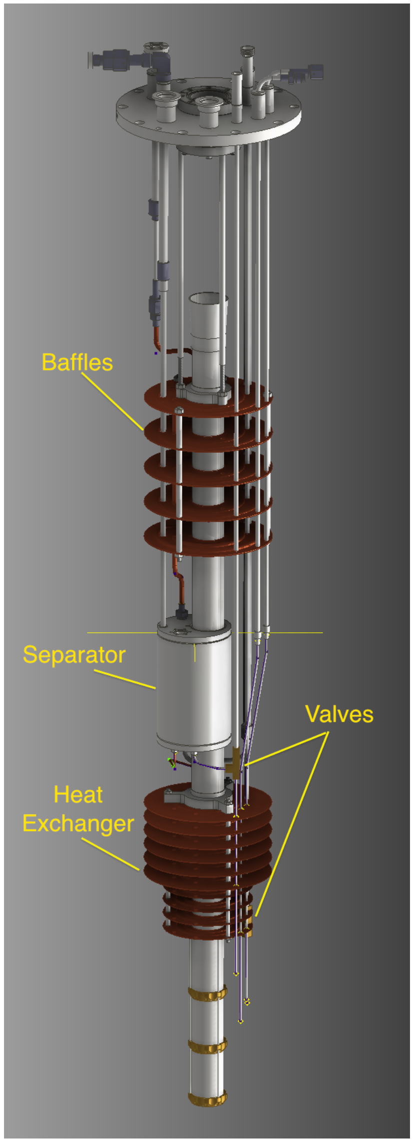


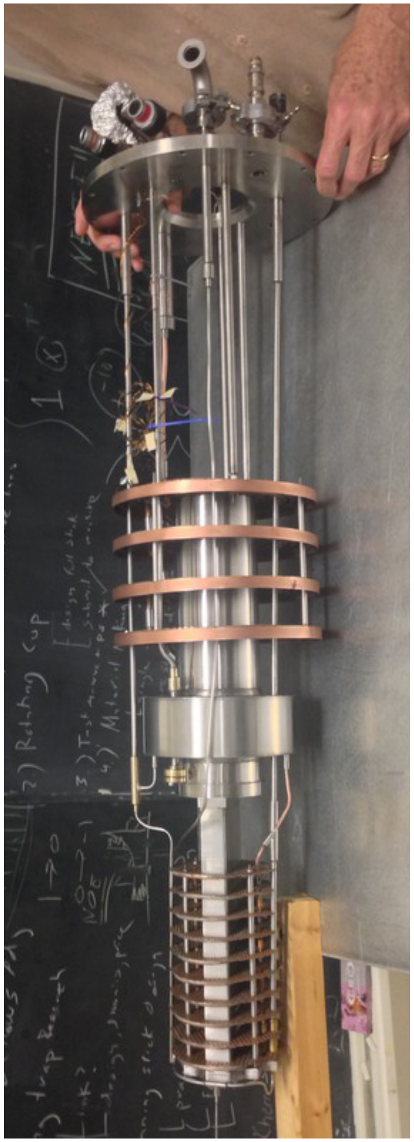

POLARIZED TARGET SUBSYSTEMS

Magnet **Fridge** Insert NMR Microwave Pumps Target material

Fridge modifications

- replaced separator can
- cleaned heat exchangers oxide/corrosion
- leak checked
- refitted run and bypass valves
- installed new LHe channel
- installed 8 temperature sensors
- manufactured new nose, 10mil window





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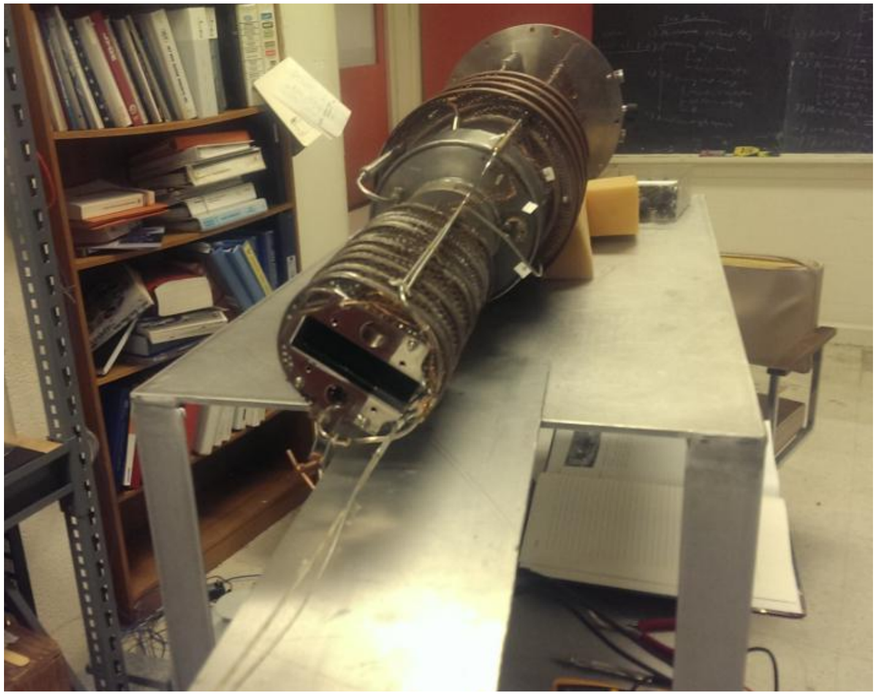

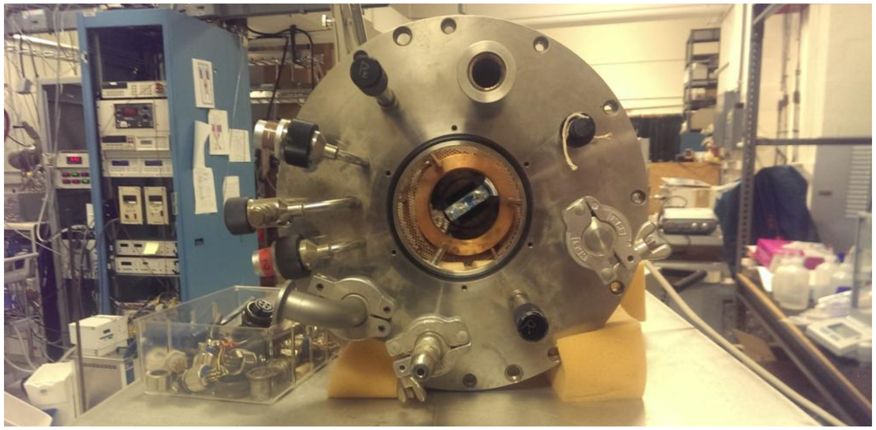

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Fridge alignment
- made laser setup
- shell, fridge, turret and piston rotation
- target insert length

Fridge tests
- 4th and 5th cooldowns
- reached 1K 07/2015

POLARIZED TARGET SUBSYSTEMS

New insert

- four 2.7x2x80mm long target cups
- NH3, C disk, empty
- six NMR channels (3 per cup)
- microwave horn for full cup volume
- temperature sensors
- He3 bulb line
- copper thermal barrier
- carbon fiber enclosure

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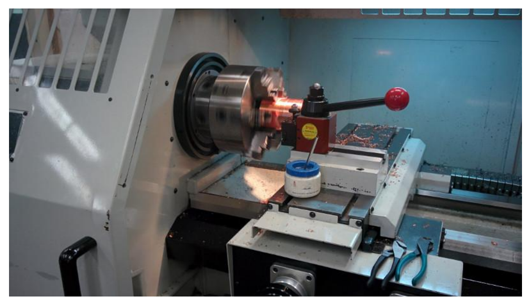
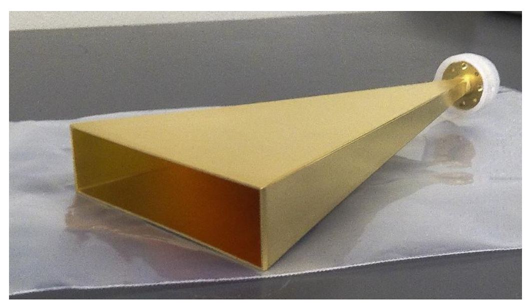
Insert test

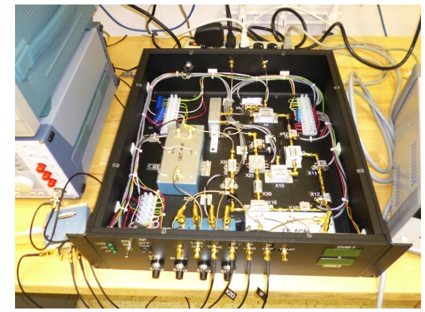
- Warm test is complete
- Load and polarization test





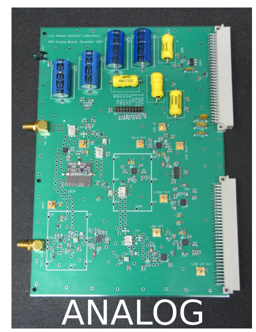
POLARIZED TARGET SUBSYSTEMS

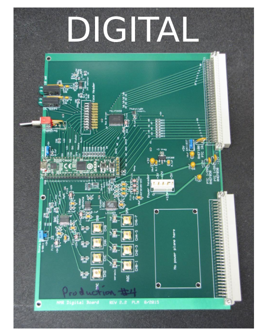
Magnet — Fridge — Insert — **NMR** — Microwave — Pumps — Target material

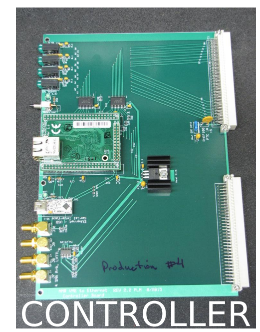


New NMR system developed by LANL

- followed general Liverpool design
- Q-meter as double wide VME module
- 1 analog / 1 digital boards, crate controller
- 16 bit ADCs/DACs, modern RF electronics
- USB/Ethernet interface, LabView based DAQ

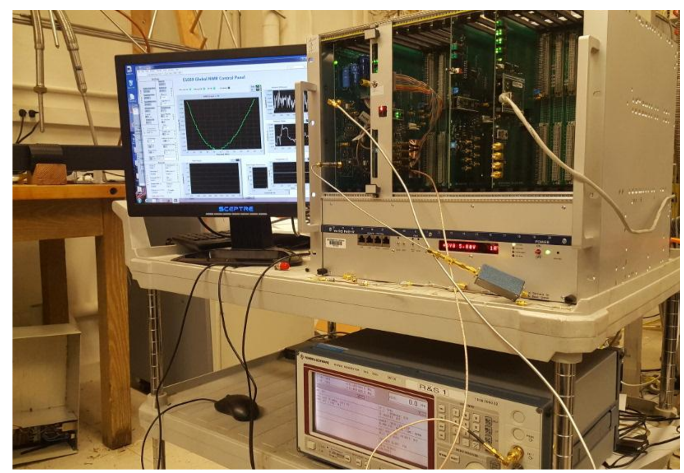






LANL NMR system tests at UVA

- 1st NMR cooldown 2014 (total 3 cold tests)
- 04/2016 full comparison to Liverpool Q-meter
- signal/noise ratio - waiting for results



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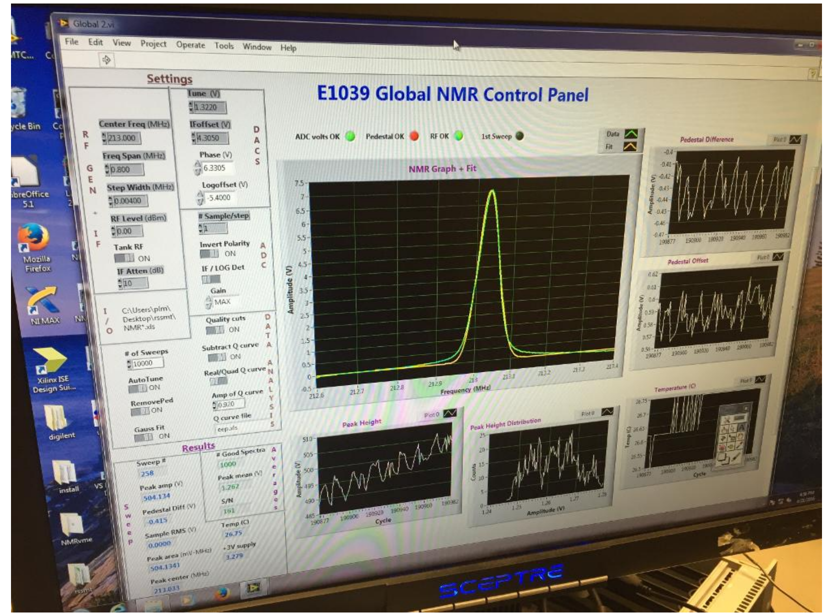

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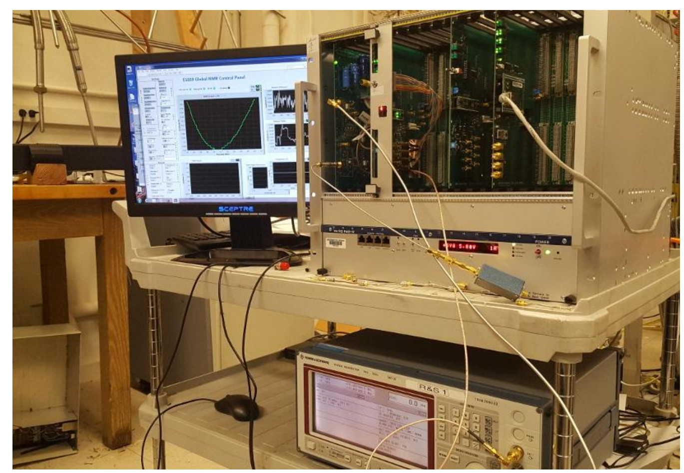
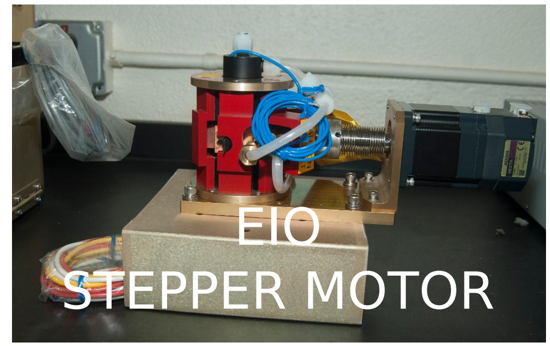


POLARIZED TARGET SUBSYSTEMS

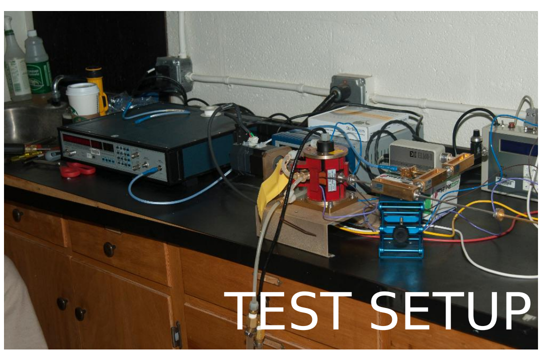
New microwave source

- purchased by LANL
- new EIO tube from CPI, 20W output
- controlled by stepper motor
- new PS with software control UI



Microwave source test

- built setup at UVA in 2015
- checked freq adjustments
- checked cathod HV adjustment



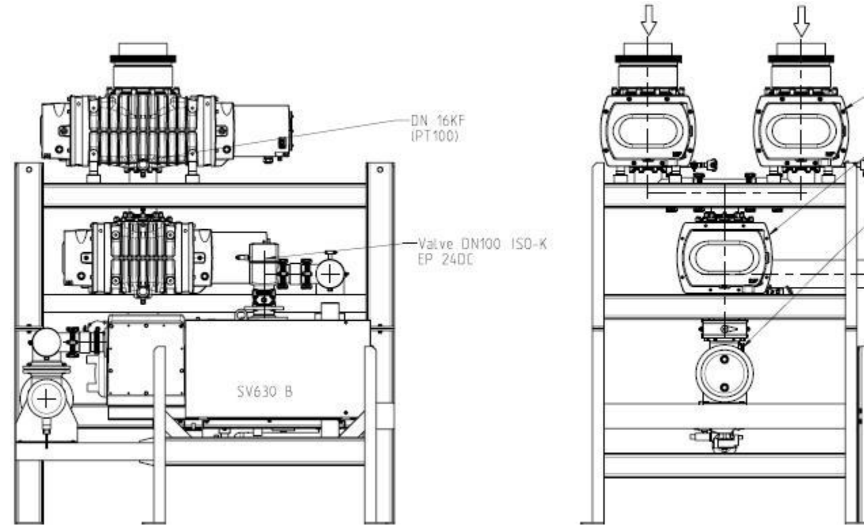
POLARIZED TARGET SUBSYSTEMS

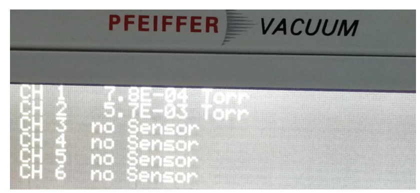
Pumping system

- designed and built by Oerlikon
- target heat load ~1.4W
- μ-wave:~1W, beam:~0.37W
- 3 roots (7000), 1 rotary vane (840)
- requires 100L LHe per day
- 14000 m3/hr pumping capacity

Construction and tests

- first assembly at LANL spring 2015
- tested and shipped to FNAL
- assembled and tested 10/2015





POLARIZED TARGET SUBSYSTEMS

Production

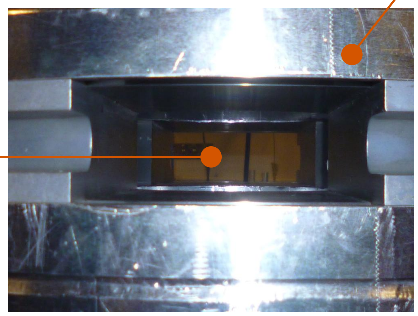
- dedicated setup to produce NH3 beads
- NH3 gas slowly frozen above LN2 bath
- ~1000 g is needed for 2 yr run
- ~450 g currently produced
- purchased three LN2 dewars for storage

Pre-Irradiation

- creates paramagnetic centers for DNP
- 14 MeV electron beam under LAr bath
- routinely done at NIST (Gaithersburg)
- time consuming, trained manpower
- ~100 g irradiated and ready for experiment

Final preparations and run

put vacuum chamber back together

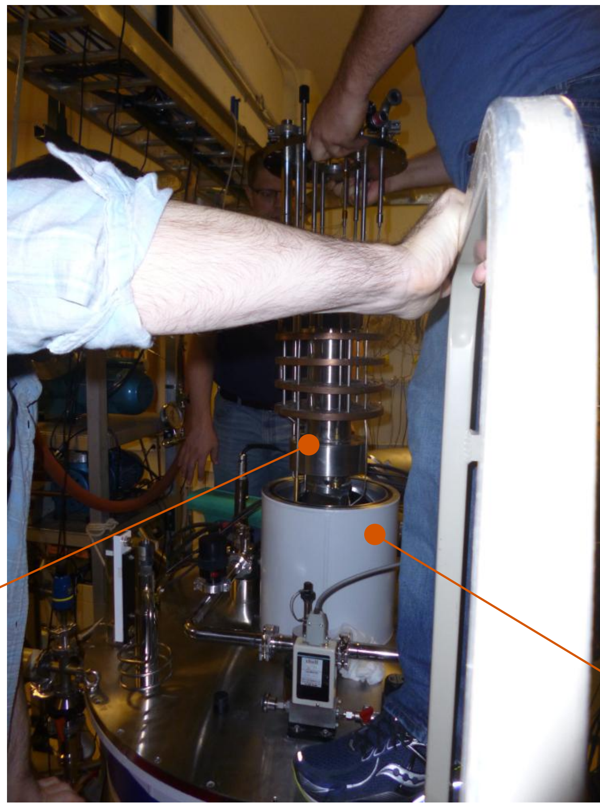


leak checked fridge shell + nose

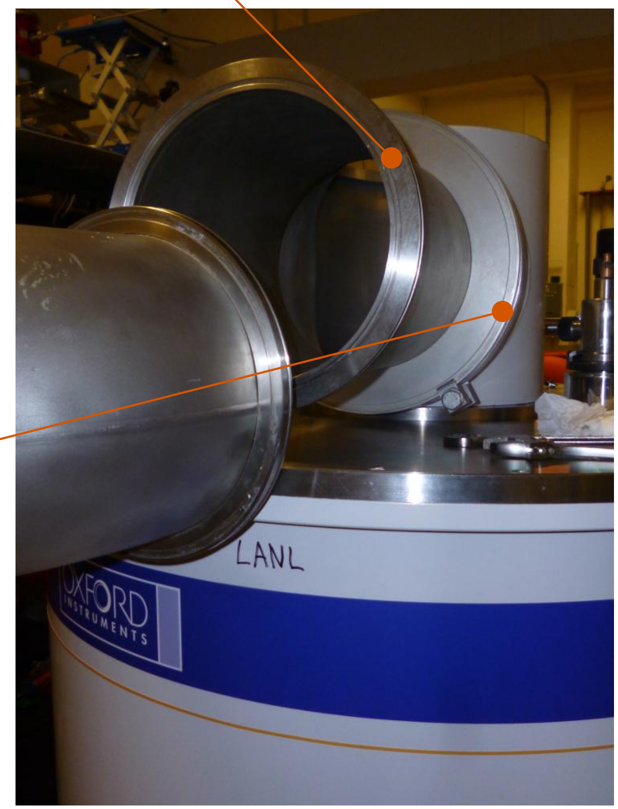
FULL SYSTEM TEST

Final preparations and run

installed fridge



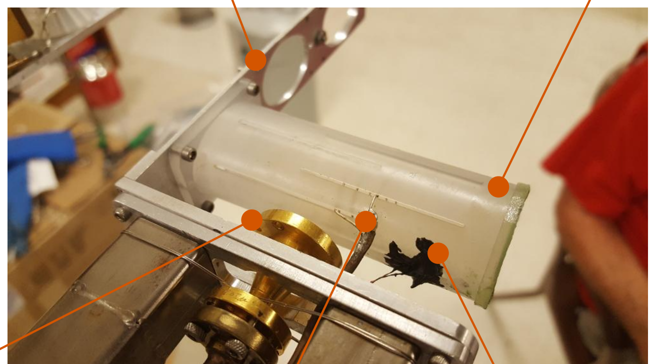
fitted turret to UVA pumping system

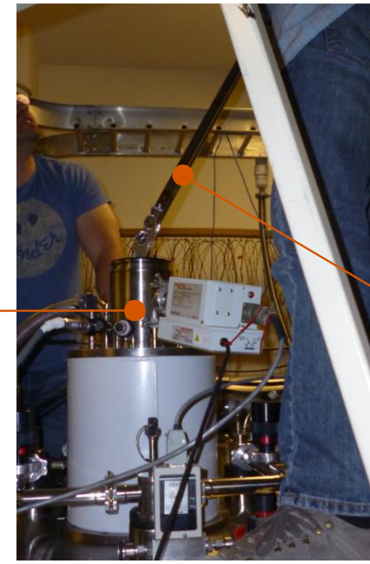


FULL SYSTEM TEST

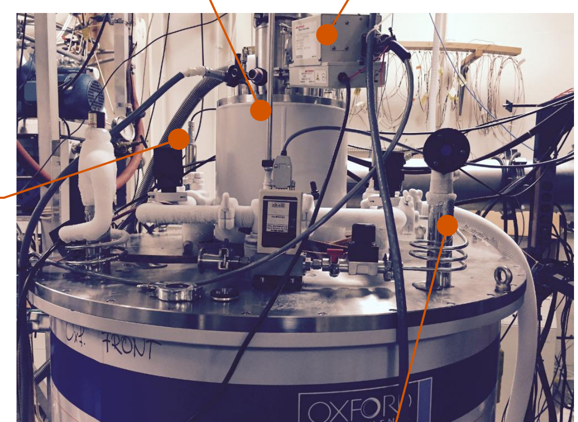
Final preparations and run

made test target insert, practiced installation





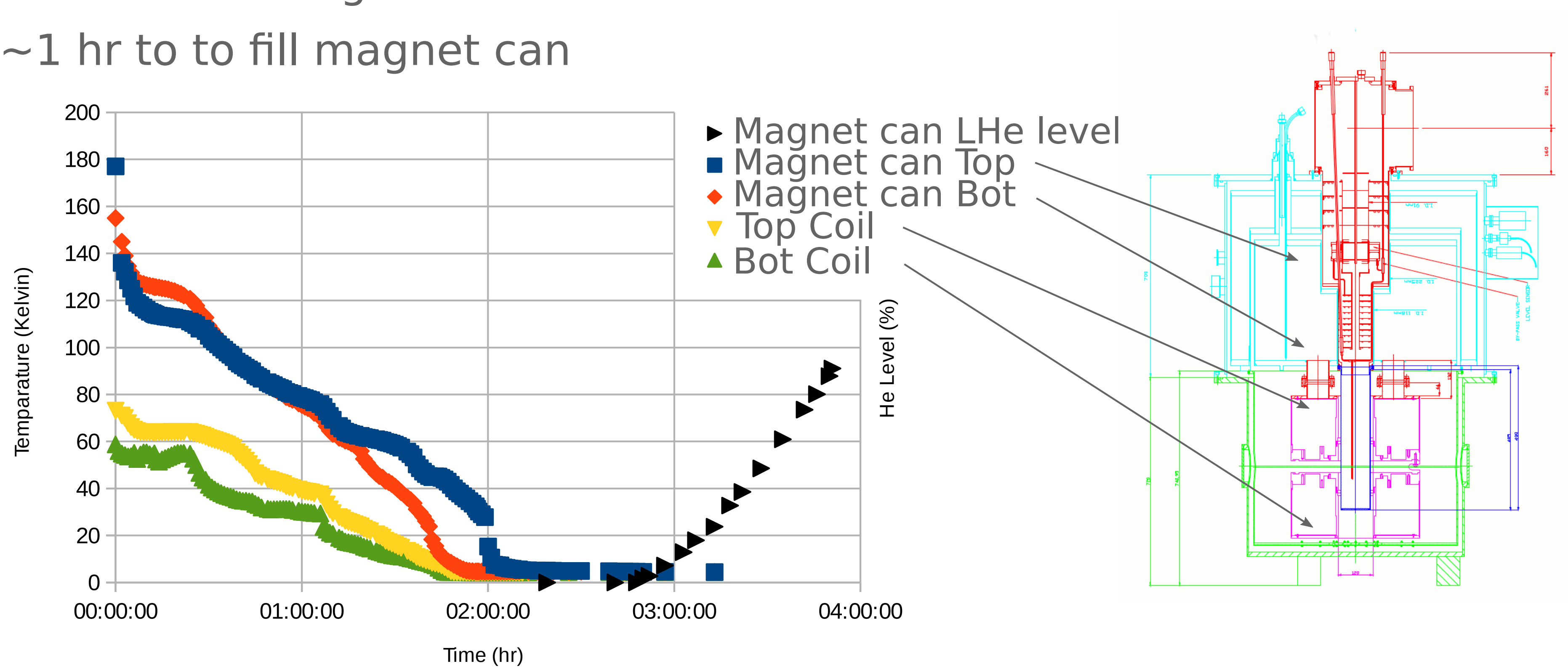
getting cold



Test results

Fridge performance

- magnet fill
- ~2.5 hrs to bring resistors to 4K
- ~1 hr to to fill magnet can



FULL SYSTEM TEST

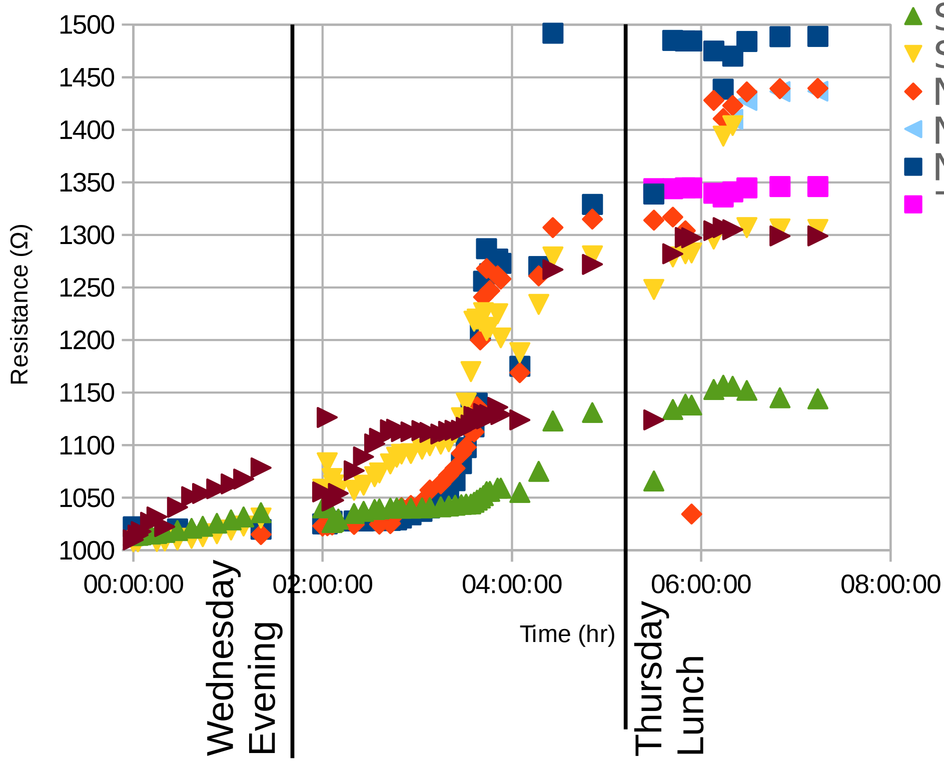
Test results

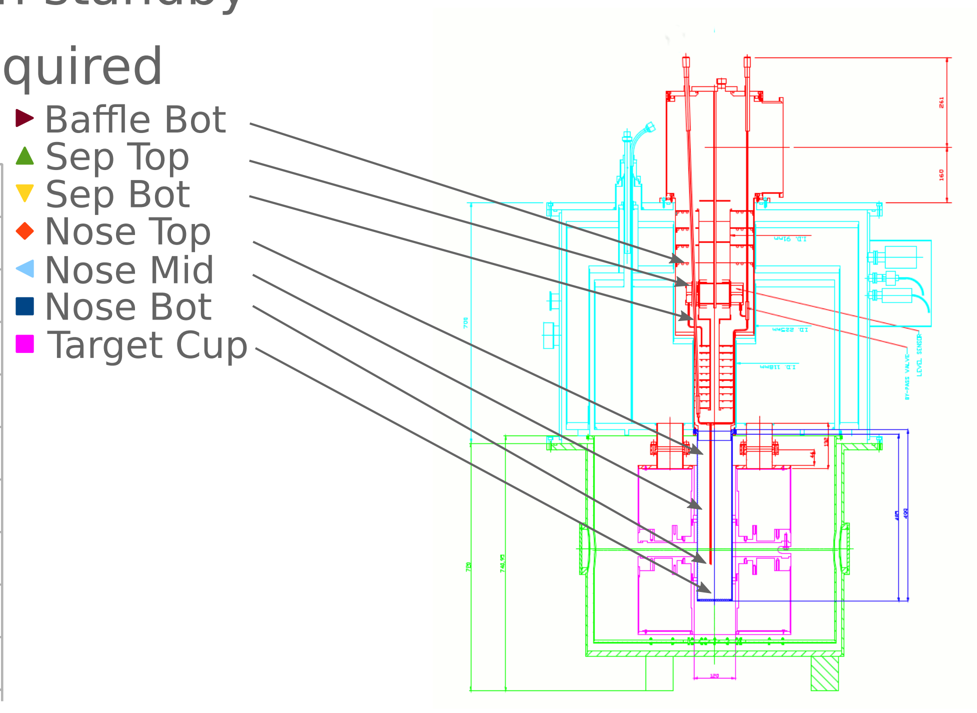
Fridge performance

separator and nose fill

~1hr to fill the nose after a night on standby

very stable, very little attention required



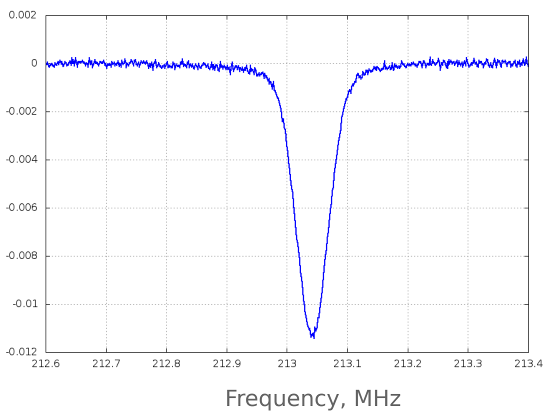


FULL SYSTEM TEST

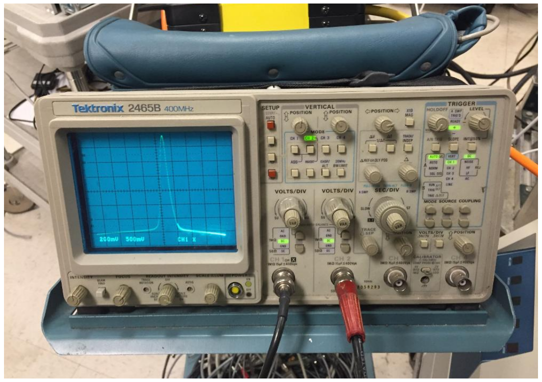
Test results

Polarization

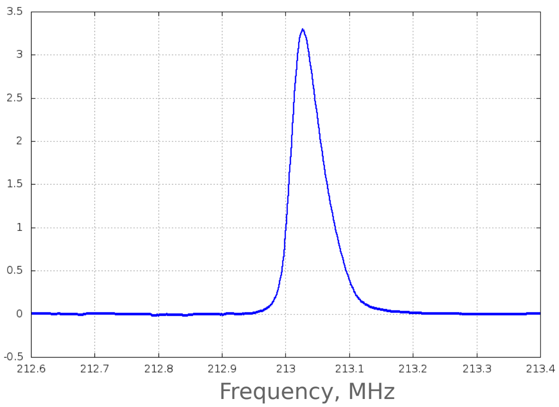
- polarized fresh NH3 both positively and negatively
- took extensive TE measurements
- alternated UVA and new LANL NMR systems



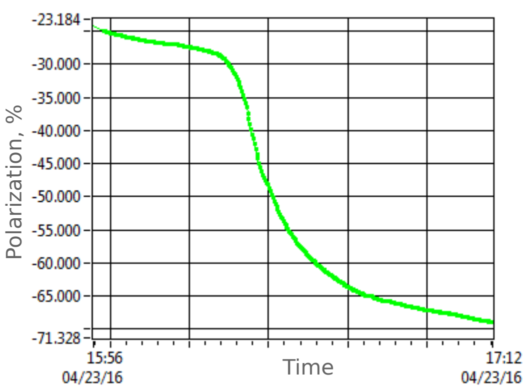
TE signal



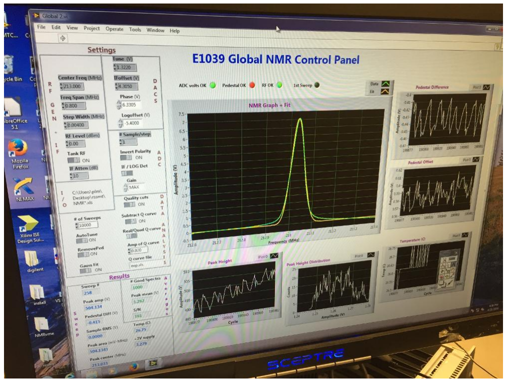
UVA NMR Signal



Enhanced Signal



Polarization Increase



LANL NMR Signal

FUTURE IMPROVEMENTS

Fast target helicity flips through Adiabatic Fast Passage (AFP)

frequent change of target polarizartion is required

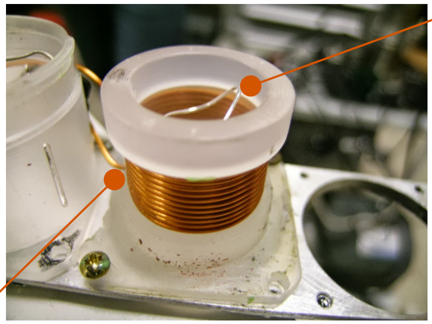
crucial to minimize false assymetry systematic effects

traditionally achieved by microwave frequency change

takes ~1hr (3-4hrs) for proton (deuteron) targets

AFP

- irradiate with RF field $\perp B_0$
- pass through resonance by varying RF field frequency
- under certain RF sweep parameters - reversal of spin direction



FUTURE IMPROVEMENTS

Fast target helicity flips through Adiabatic Fast Passage (AFP)

AFP at UVA

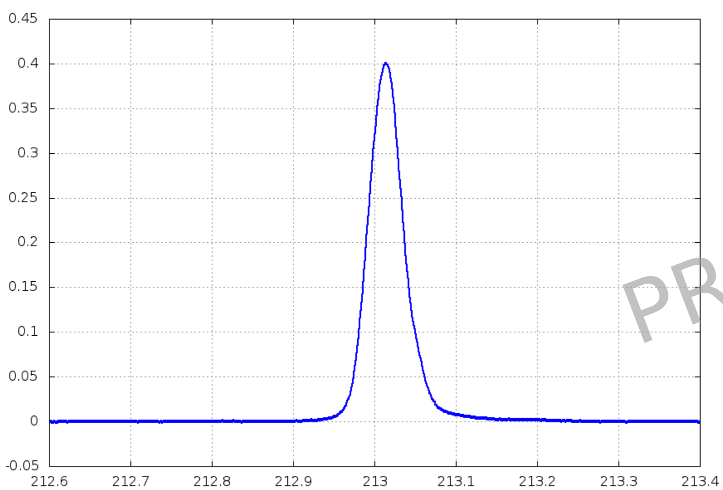
- performed AFP on different materials (5T, 1K)
- 15NH3, D-butanol, butanol+tempo
- preliminary results on flip efficiency

Table 1
Results from AFP experiments with various nuclei in different target materials

Nuclei	Substance dopant	e^- conc. (spins/g)	δP^{max}
^{1}H	1-butanol EHBA-Cr(V)	2.0×10^{19}	-0.76
^{7}Li ^{1}H	^{7}LiH (irradiated)	low	-0.90 -0.90
^{19}F ^{1}H	8-fluoro-1-pentanol TEMPO	1×10^{20}	-0.37 -0.40
^{2}H	1-butanol-d_{10} EHBA-Cr(V)-d_{22}	2.36×10^{19} 6.35×10^{19}	-0.92 -0.90

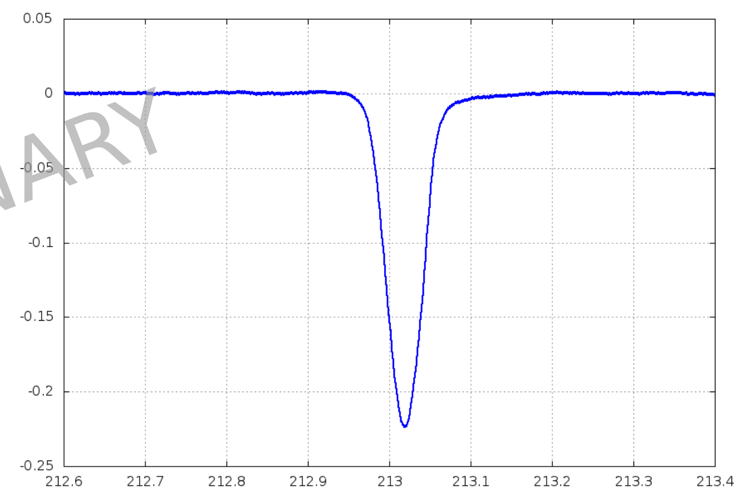
NIM 356 (1995) 108

15NH3



before

flip efficiency
0.55



after

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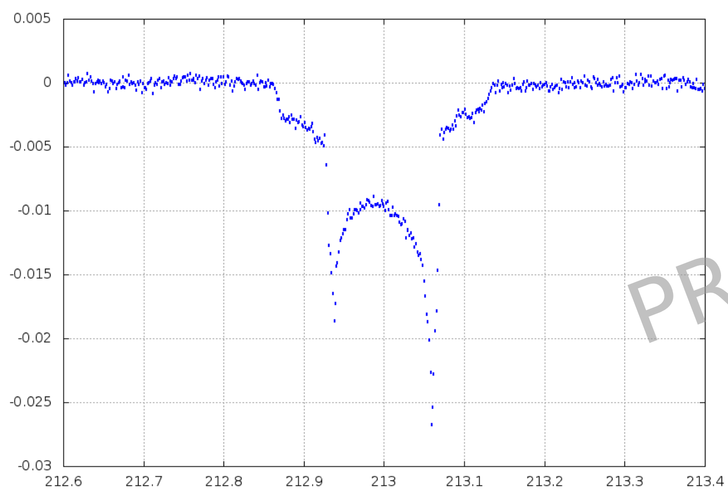
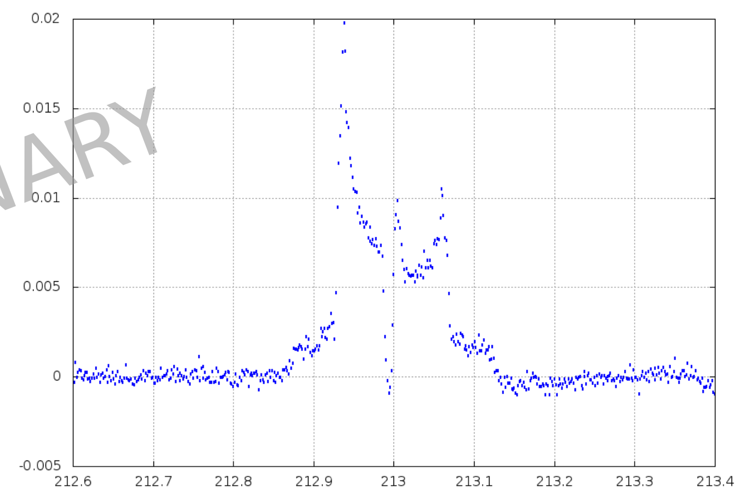
D-Butanol



before

PRELIMINARY



after

flip efficiency >0.8

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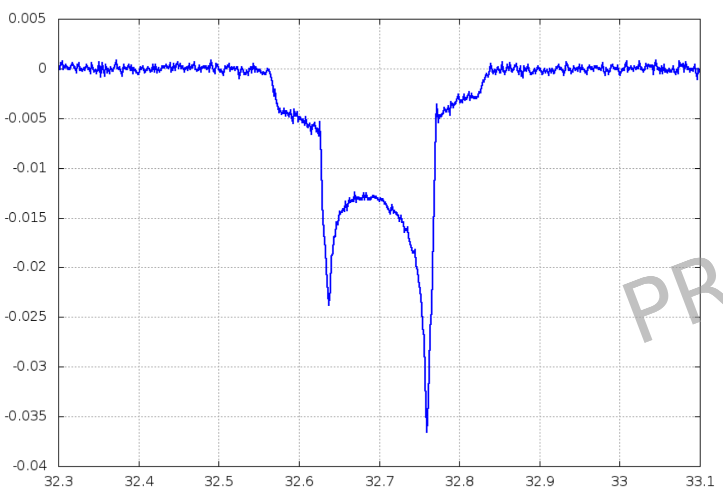
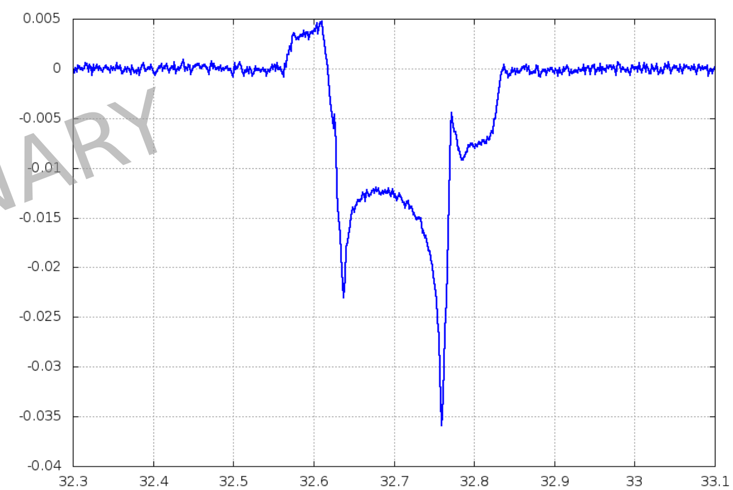
D-Butanol pedestal flip



before

PRELIMINARY



after

FUTURE IMPROVEMENTS

Automated Microwave Frequency Control of DNP Targets

See Darshana-Perera talk later

- μ-wave optimal frequency for maximum polarization changes over time
- function of radiation dose, number of anneals, environment
- has to be adjusted manually by Target Operator during the run

UVA recent developments

- frequency seeking algorithm
- standalone plug & play controller for DC motor driven EIO tubes
- new LabView package to control stepper motor driven EIO tubes
- rates and run evironment MC simulattion

CONCLUSION

Rebuilt vertically polarized target system

- 6 dedicated cooldowns at UVA and at Oxford Instr. during ~3yrs
- 2 parasitic cooldowns at UVA for new LANL NMR system
- over $1M investment in equipment, LHe, and manpower
- LANL LRDR funds and UVA DOE grant

Successfully tested 04/2016

- Very stable performance of the magnet and cryogenics
- Polarized NH3 with test target insert
- Designed and manufactured new target insert
- Comparison of UVA and new LANL NMR systems

New studies

- Successfull NH3 AFP, preliminary flip efficiency results
- Automated Microwave Frequency Control of DNP Targets