Update on the Longitudinally Polarized Target

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(w/ James Brock, Chris Carlin, James Maxwell & Victoria Lagerquist)

CLAS12 Polarized Target: run group C

A new dynamically polarized target is under construction for multiple experiments in CLAS12 (240 days total)

Run Group C NH_3/ND_3

E12-06-109: *Longitudinal spin structure of the nucleon*
E12-15-109a: *DVCS on the neutron with a longitudinally polarized deuterium target*
E12-06-119: *DVCS on a longitudinally polarized proton target with CLAS at 12 GeV*
E12-07-107: *Spin-orbit correlations with a longitudinally polarized target*
E12-09-107b: *Study of partonic distributions using SIDIS K production*
E12-09-009: *Spin-orbit correlations in kaon electroproduction with polarized targets*

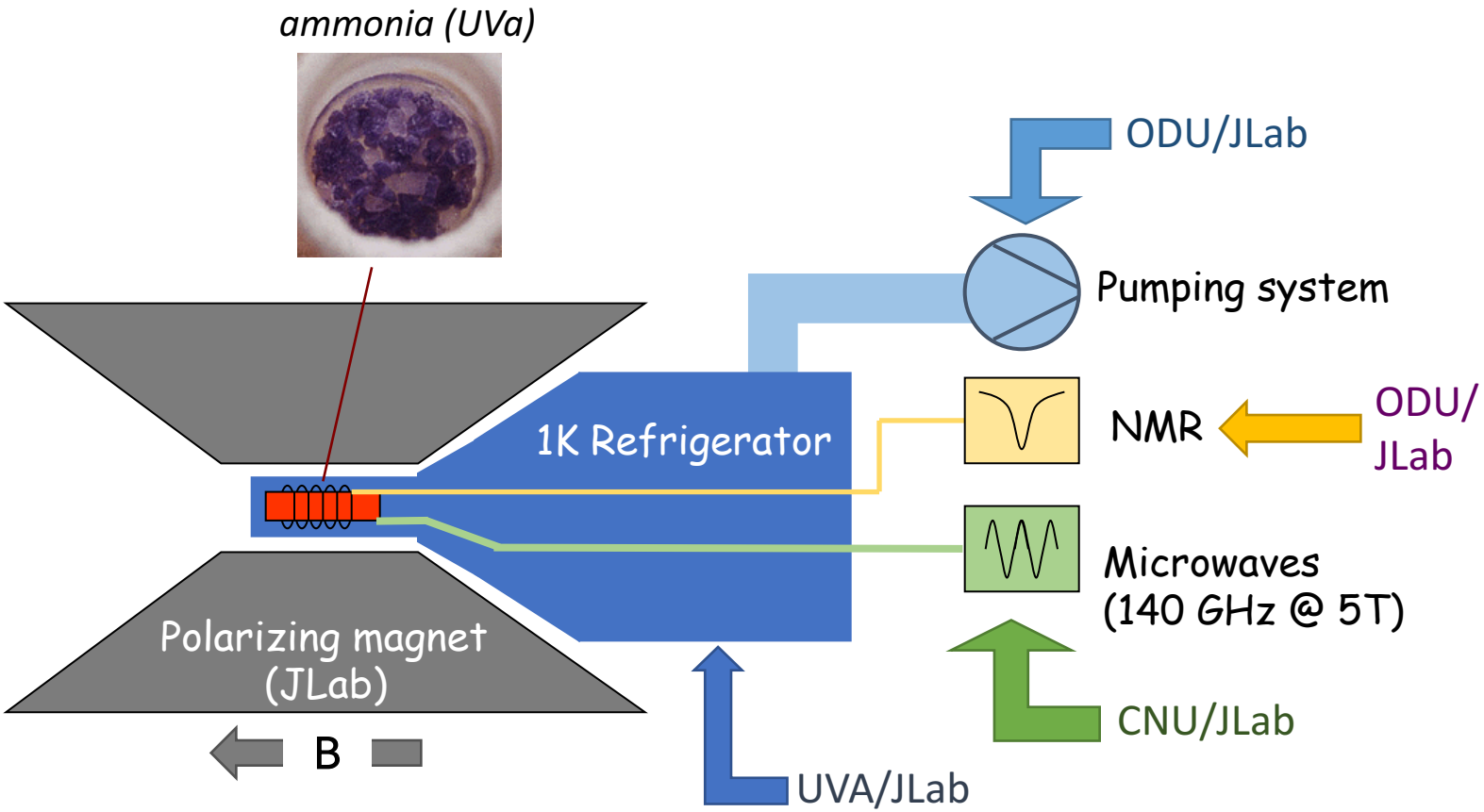
E12-12-001: *EMC effect in spin structure functions (^{6}LiH & ^{7}LiD)*

Run Group C hopes for installation in Summer 2020

- ERR for Run Group C: June 21, 2018

CLAS12 Polarized Target: instrumentation

Target development & construction is a collaborative effort between ODU, CNU, UVa & JLab



CLAS12 Polarized Target: vacuum pumps

ODU's 6000 m^3/hr pumping set is now installed and tested at JLab

Cooling power of evaporation:

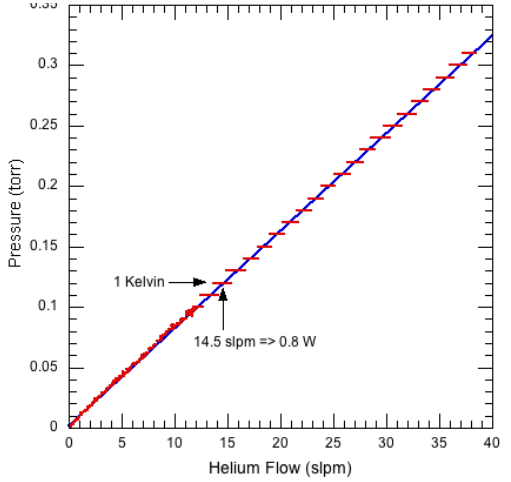
- Rate of vaporization: (mol/s)
- Latent heat of vaporization (J/mol)

Helium-4: 80 J/mol @ 1 K

- 1 Watt = 12.5 mmol/s = 16.8 slpm

To maintain a vapor pressure of 0.12 torr (1 K) at a 1 Watt evaporation rate requires a pumping speed of 6500 m^3/hr

Data courtesy of Chris Carlin, Target Group



Cooling Requirements:

Beam: ~1.2 mW/cm/nA

- 10 nA, 4 cm = 50 mW

Microwaves: ~20 mW/g

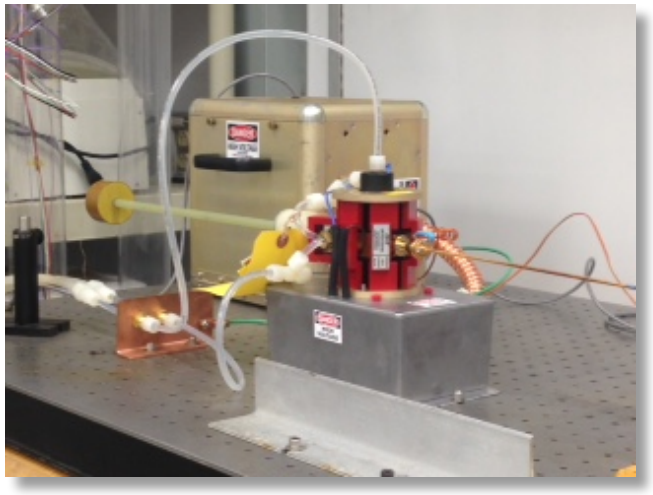
- 8 g = 160 mW

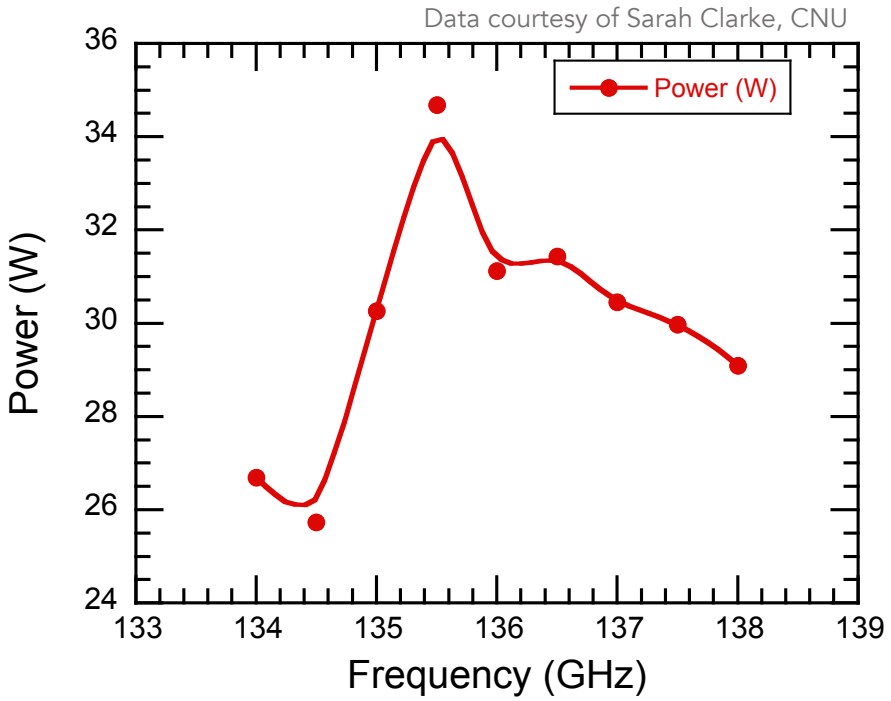
Total: ~ 200 mW

CLAS12 Polarized Target: microwaves

CNU's 135 GHz microwave tube tested at JLab

- optimized for 136 GHz (4.8 T)
- JLab has two, spare 140 GHz tubes

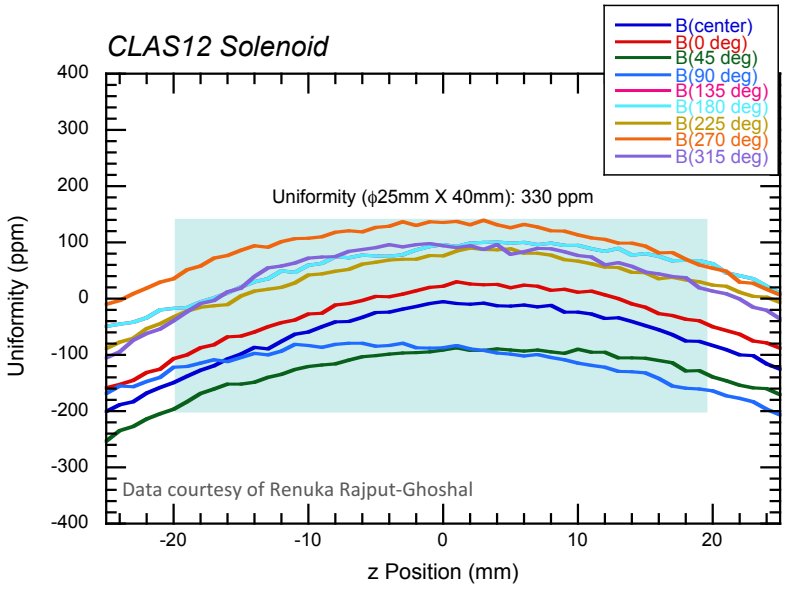


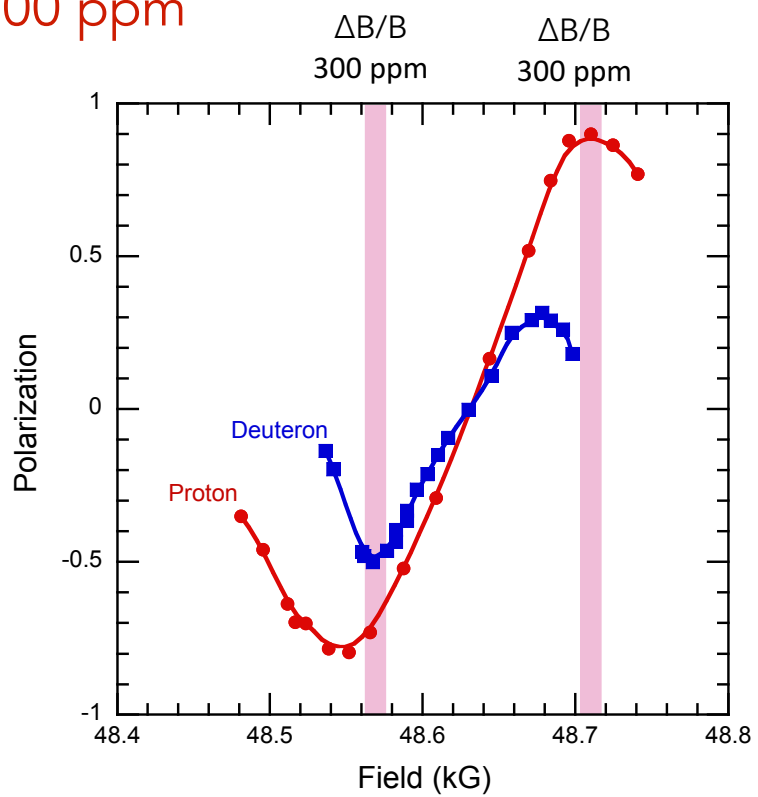


CLAS12 Polarized Target: polarizing magnet

The CLAS12 solenoid was specified to have a uniform field region of $\Delta B/B = 10^{-4}$ (100 ppm) over a target volume ⌀25 x 40 mm

The preliminary field map indicates ~300 ppm





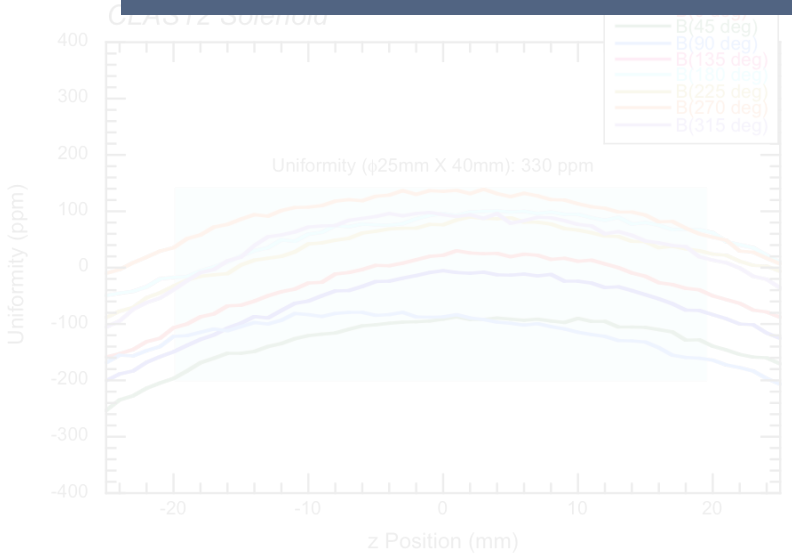
Polarization data: Mike Seely, Yale 1982

- Tolerable effect on NH3 polarization.
- ND3 polarization could suffer 10-20% (rel).

CLAS12 Polarized Target: polarizing magnet

NOTE:

The positive & negative polarizations are separated by only about 160 gauss



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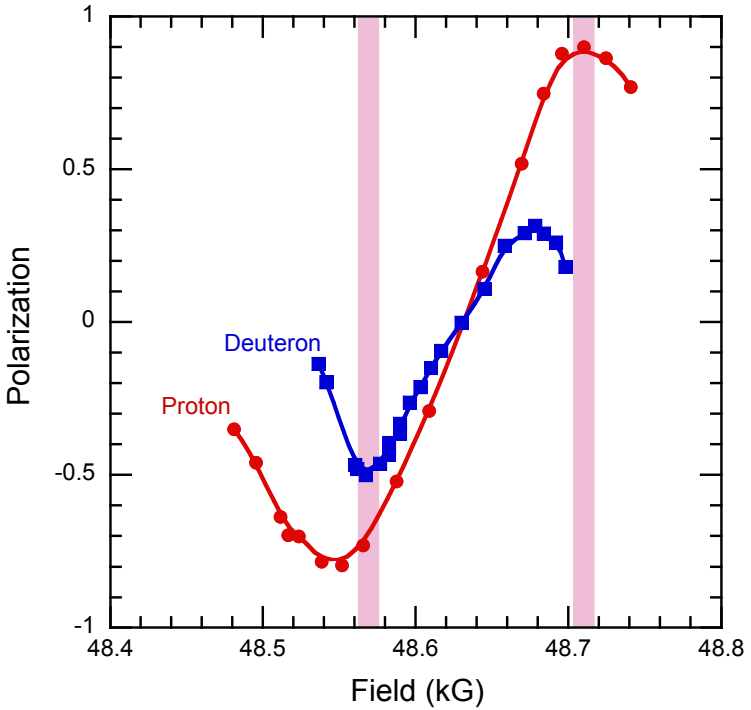
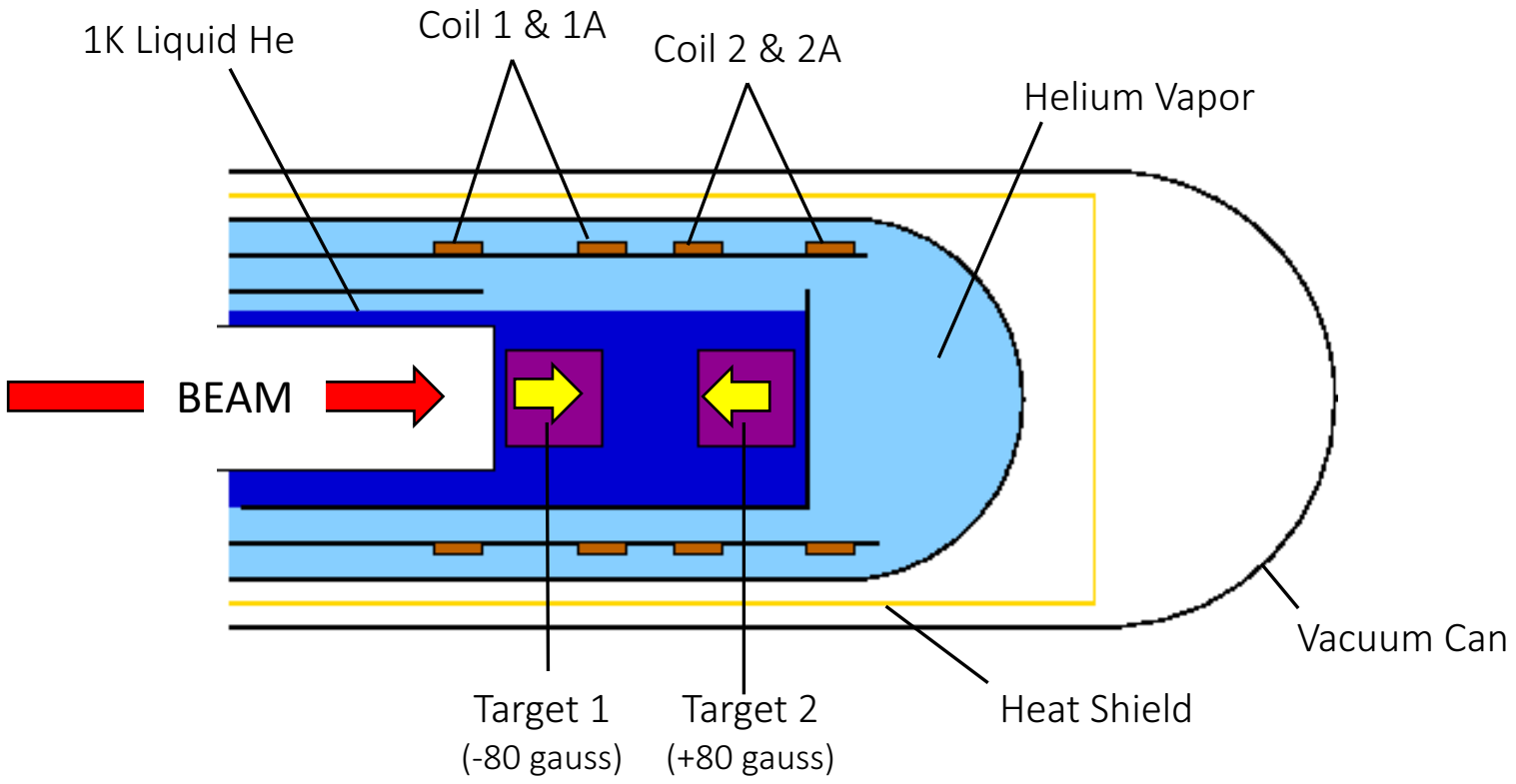


Polarization data: M.L. Seely, Yale 1982

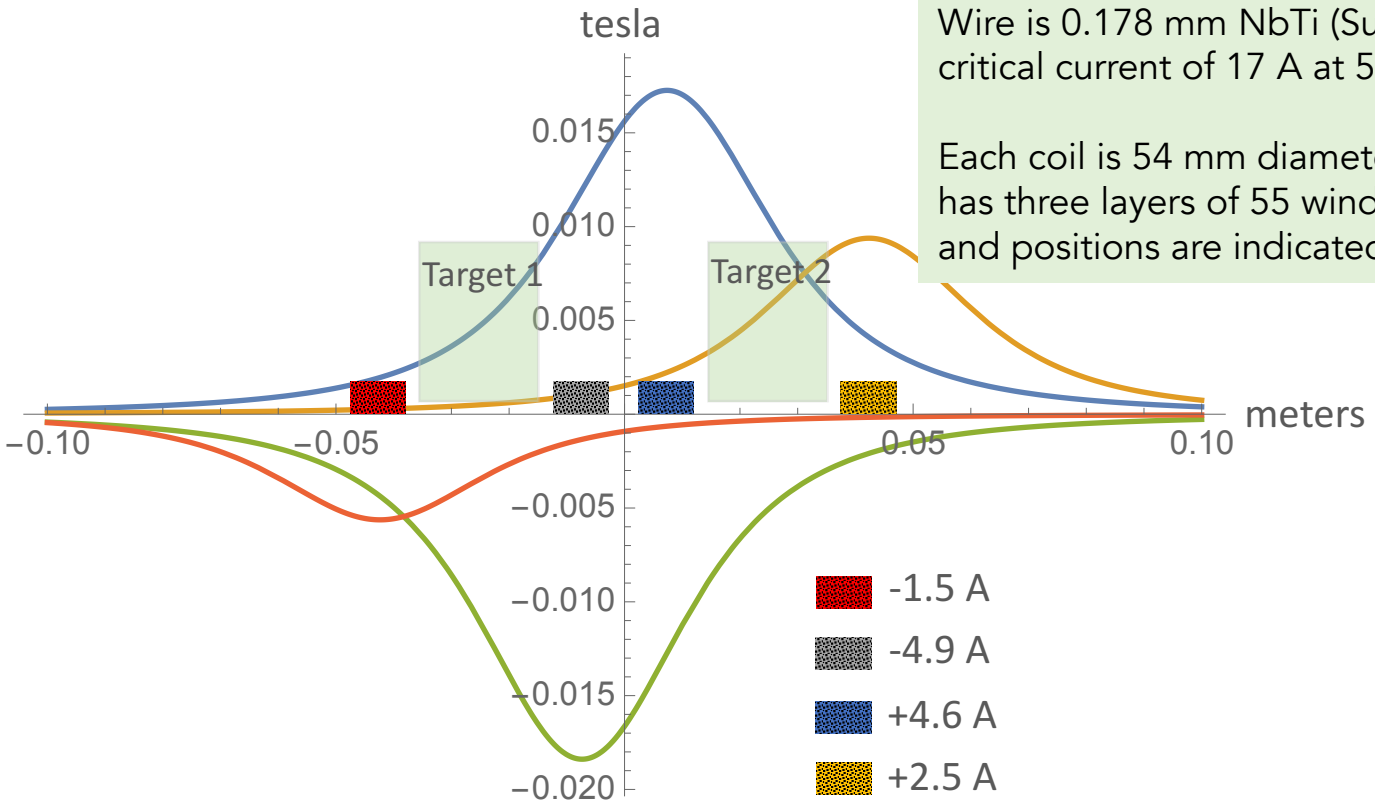
CLAS12 Polarized Target: two target cells

We can adjust the CLAS12 field with ± 80 gauss shim coils and simultaneously polarize two samples in opposite directions.



CLAS12 Polarized Target: shim coils

Preliminary models using the solenoid field map indicate that the ±100 gauss fields can be generated with 3 layers of superconductor at <5 amps.



Wire is 0.178 mm NbTi (SuperCon 54S43), with a critical current of 17 A at 5 T.

Each coil is 54 mm diameter, 12 mm long and has three layers of 55 windings. The currents and positions are indicated.

CLAS12 Polarized Target: shim coils

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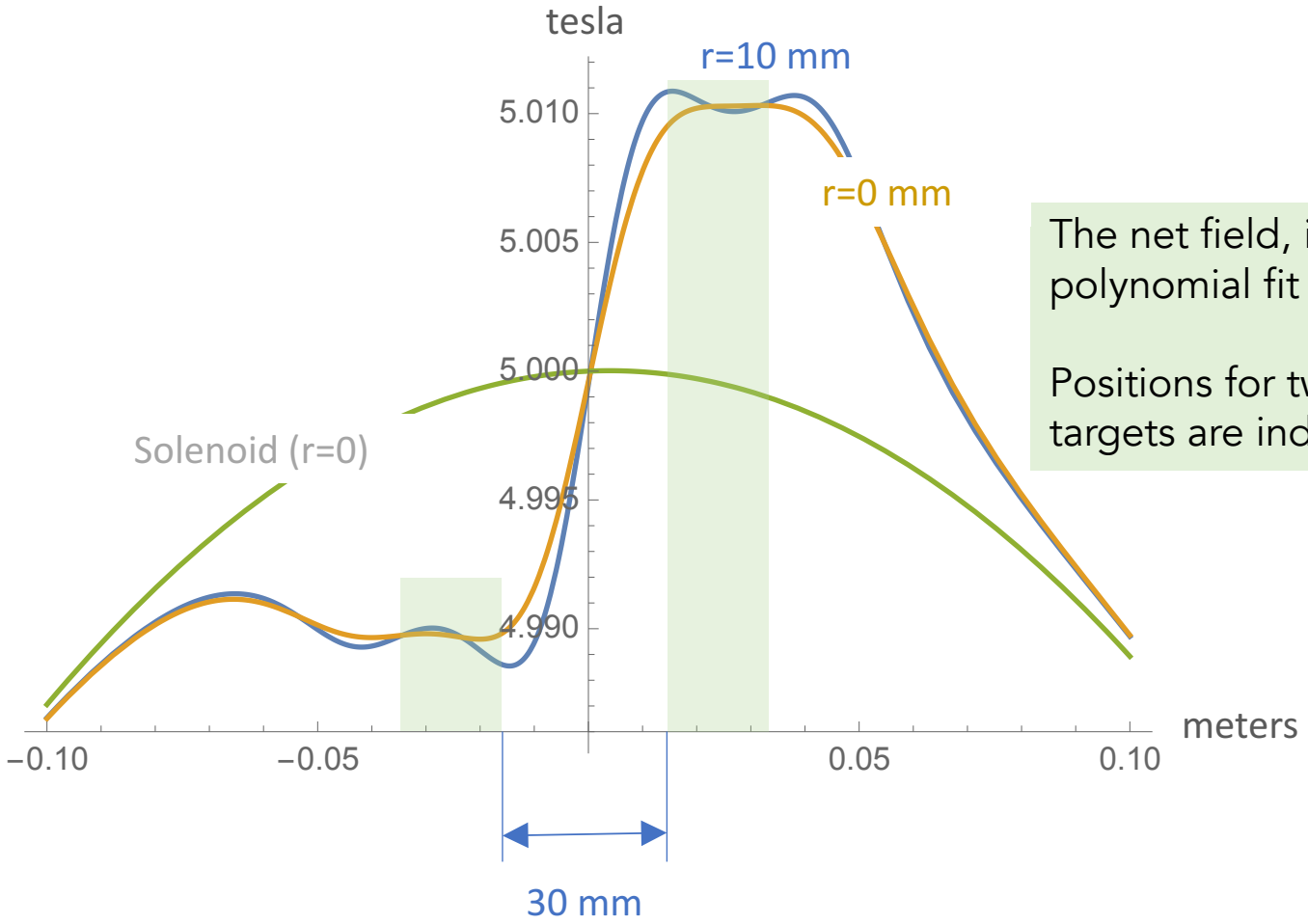
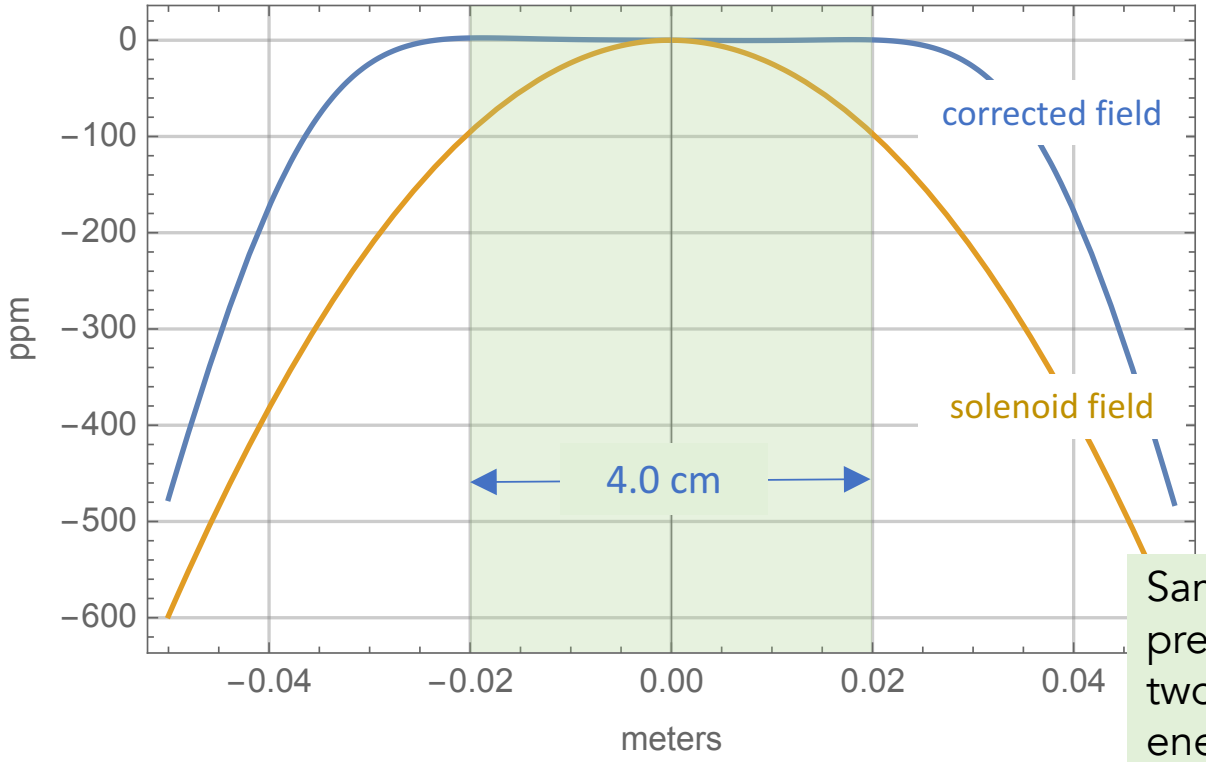


The net field, included with a polynomial fit to the solenoid.

Positions for two, 20 mm long targets are indicated.

CLAS12 Polarized Target: shim coils

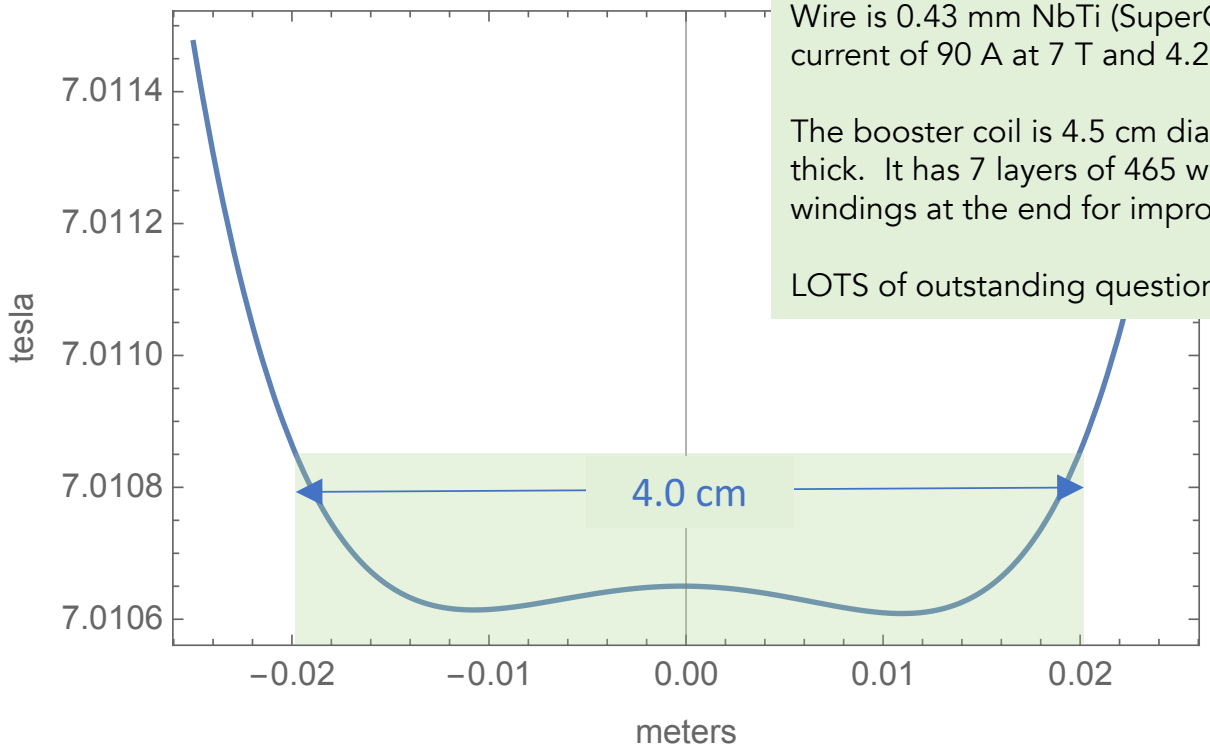
Alternatively, the same coils can be used to make the 5 T solenoid field more uniform for a single 4 cm long target.



Same coil design as previous. Only outer two windings are energized, 0.55 A.

CLAS12 Polarized Target: 2 T booster coil

Or, a much thicker coil could be used to "boost" the solenoid's field to 7 T, and increase the ND_3 polarization to 60 – 70%.



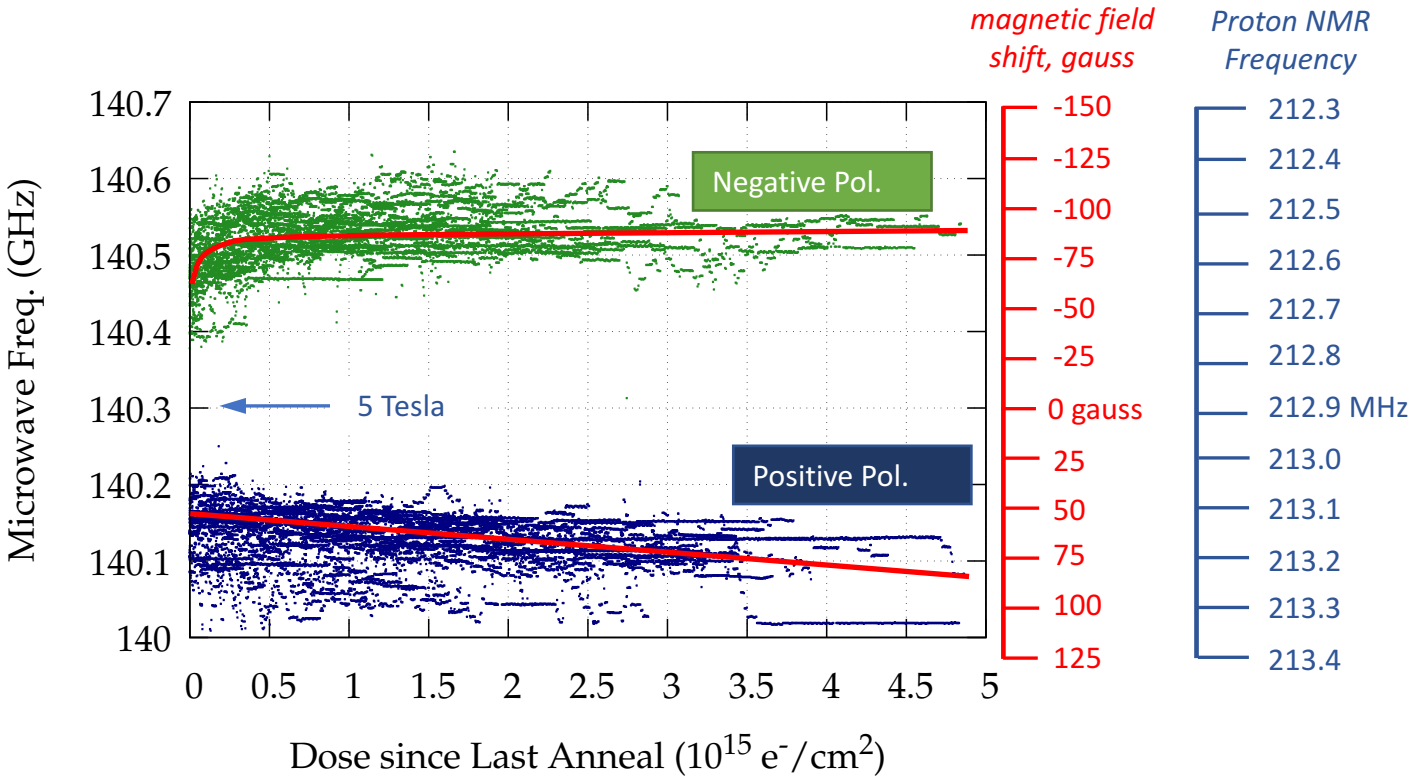
Wire is 0.43 mm NbTi (SuperCon 54S43), with a critical current of 90 A at 7 T and 4.2 K. Required current is 100 A.

The booster coil is 4.5 cm diameter, 20 cm long, and 0.3 cm thick. It has 7 layers of 465 windings, with additional windings at the end for improved field uniformity.

LOTS of outstanding questions…

CLAS12 Polarized Target: two target cells

Utilizing two cells at different fields will necessitate changes to our NMR polarimetry.



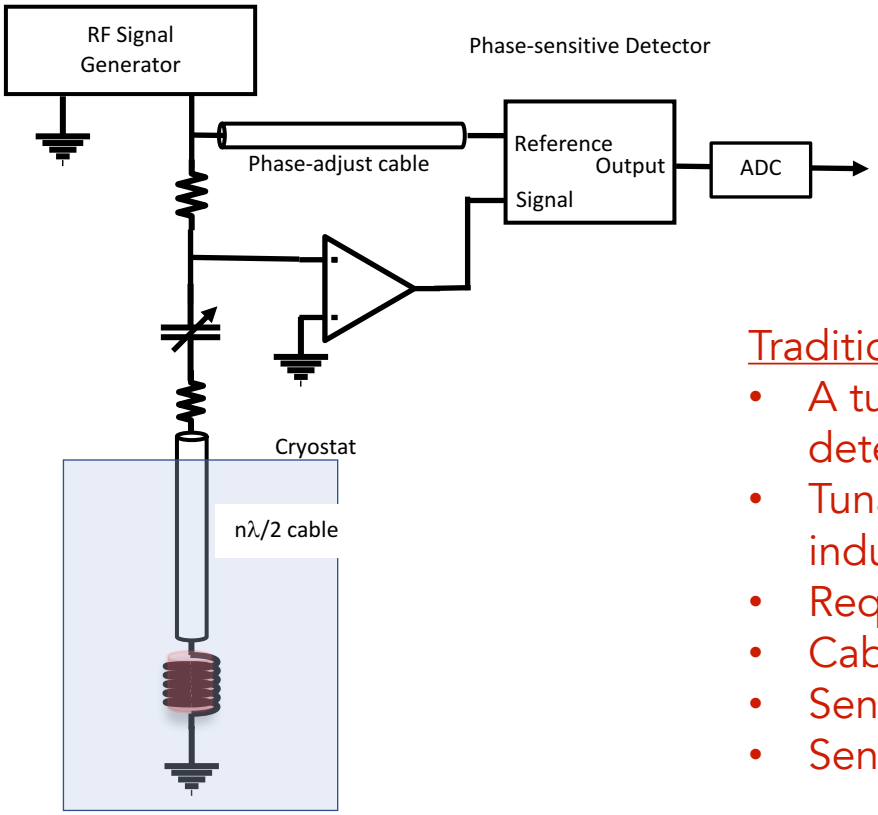
SANE microwave frequency versus dose.

data courtesy of J. Maxwell

CLAS12 Polarized Target: nmr

James Maxwell (Target Group) is leading an effort to improve upon our 40-year old Liverpool Q-meter NMR system

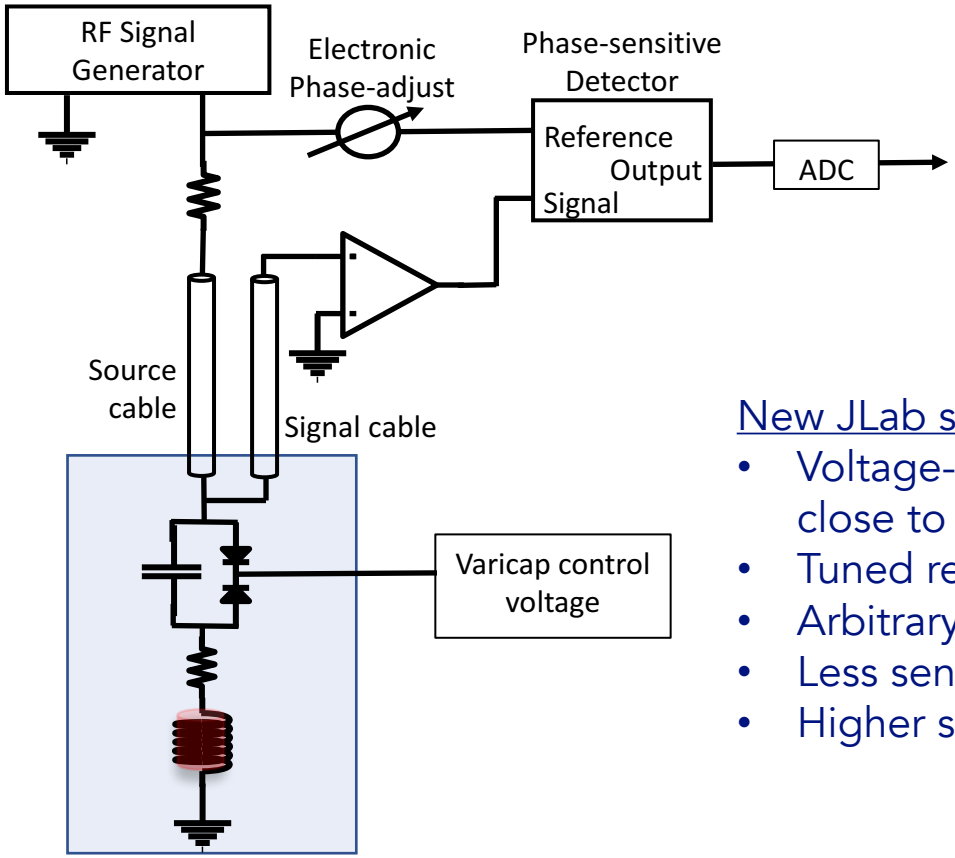
Working with Hai Dong & Jeff Wilson, JLab Fast Electronics Group



Traditional Q-meter system

- A tuned LC circuit w/ phase sensitive detection
- Tunable capacitor at room temperature, inductor (NMR coil) at low temperature
- Requires access to hall for tuning
- Cable length is critical
- Sensitive to thermal drifts
- Sensitivity is often hampered by noise

CLAS12 Polarized Target: nmr

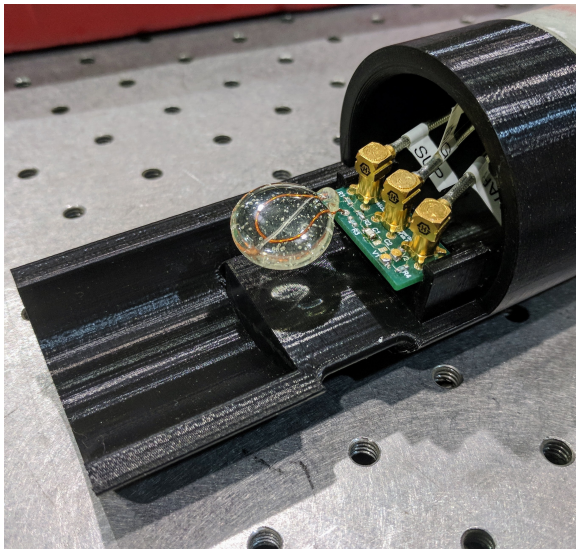


New JLab system

- Voltage-tuned capacitor moved close to NMR
- Tuned remotely
- Arbitrary cable length
- Less sensitive to thermal drifts
- Higher signal-to-noise

CLAS12 Polarized Target: nmr

Tested at 77K using 5T FROST solenoid



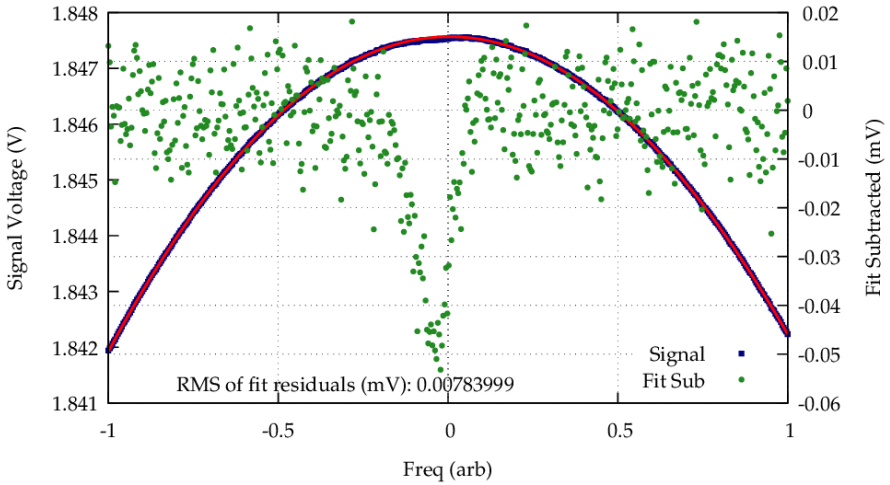
NMR sample is 5-minute epoxy

Images courtesy of James Maxwell, Target Group

CLAS12 Polarized Target: nmr

Tested at 77K using 5T FROST solenoid

Thermal Equil. Polarization = 7 x 10^{-5}



Output of Q-meter (Q-curve + proton signal)

Fit to Q-curve

Proton signal

Traditional circuit @ 77 K, 5 T

Images courtesy of James Maxwell, Target Group

CLAS12 Polarized Target: nmr

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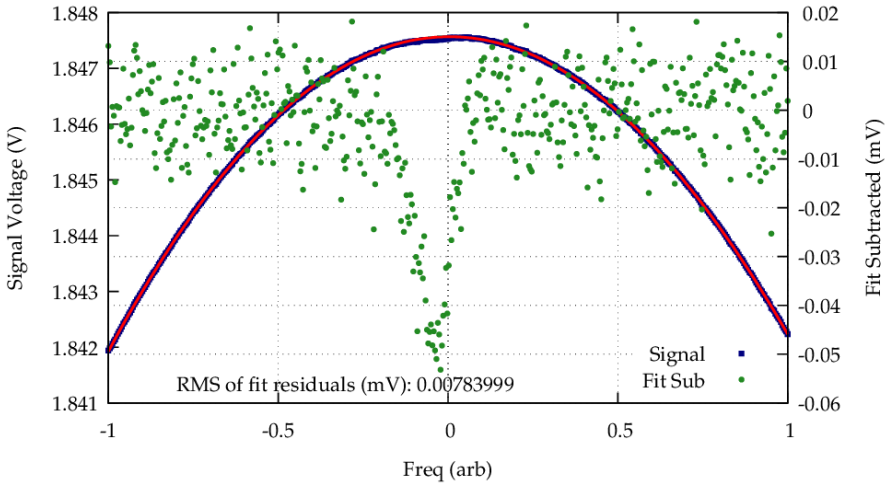
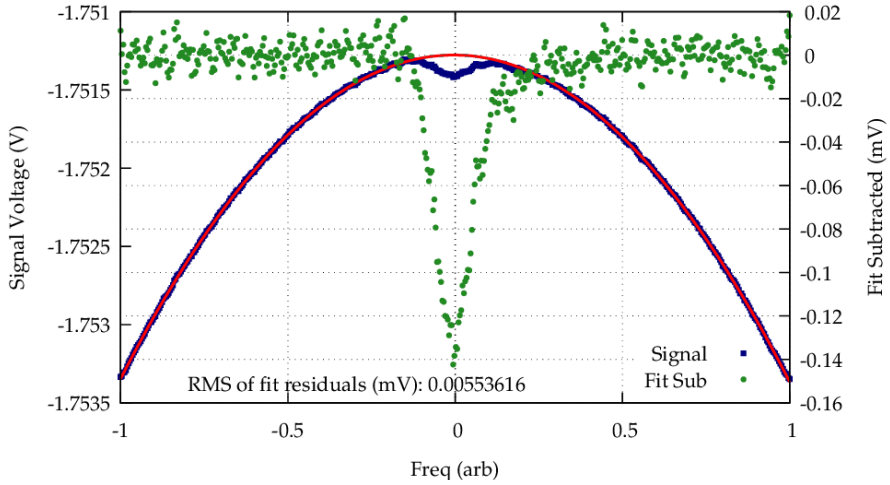


Traditional circuit @ 77 K, 5 T



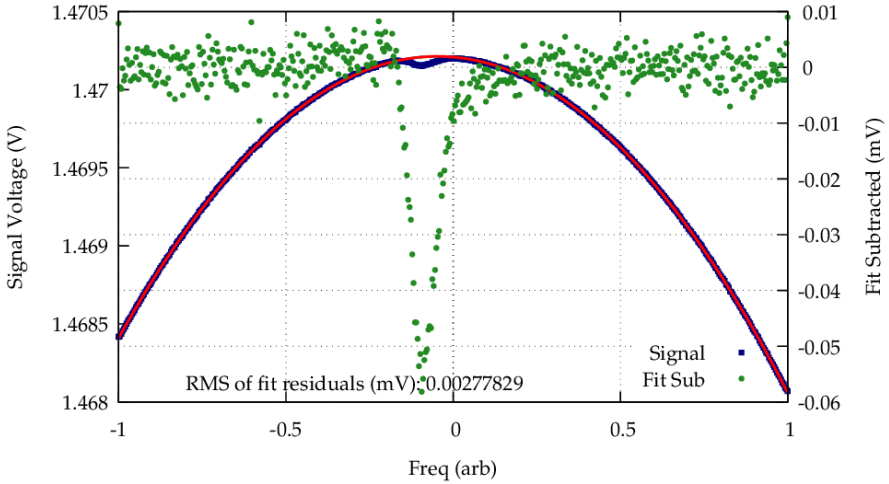
New circuit @ 77 K, 5 T

Images courtesy of James Maxwell, Target Group

CLAS12 Polarized Target: nmr

Tested at ROOM TEMPERATURE using 5T FROST solenoid

Polarization = 2 x 10^{-5}



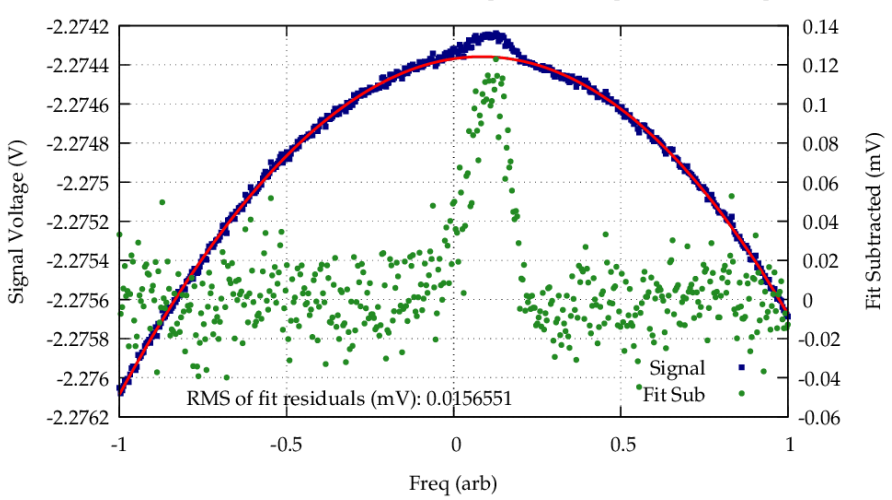
New circuit @ 290 K, 5 T

Images courtesy of James Maxwell, Target Group

CLAS12 Polarized Target: nmr

Dynamic Polarization at 77 K and 5 T

Polarization ≈ -10^{-4}



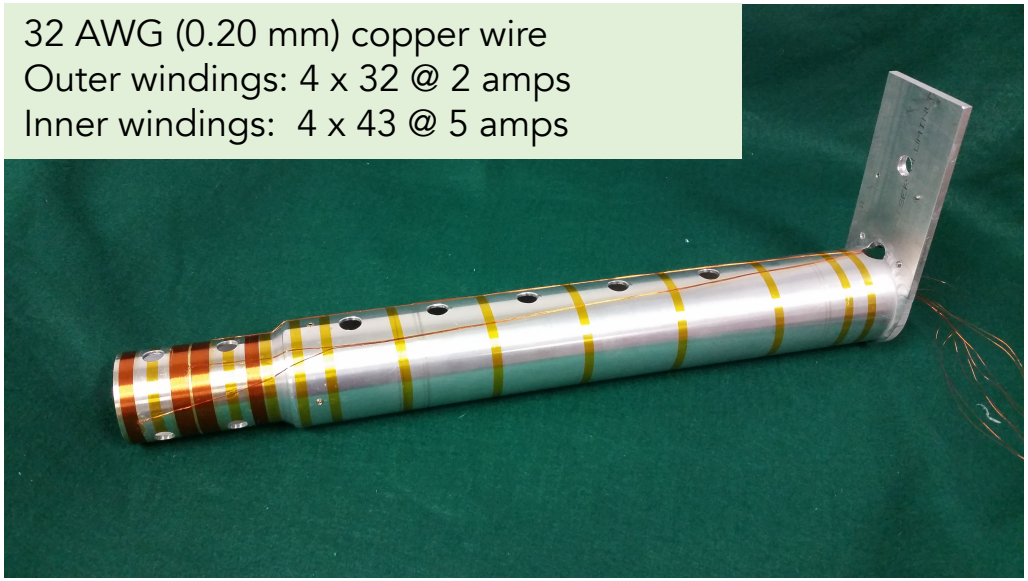
Negative polarization @ 77 K, 5 T

Images courtesy of James Maxwell, Target Group

CLAS12 Polarized Target: nmr

New 77 K tests of NMR with ± 80 gauss shim coils are taking place now, in the EEL

32 AWG (0.20 mm) copper wire
Outer windings: 4 x 32 @ 2 amps
Inner windings: 4 x 43 @ 5 amps



Images courtesy of Victoria Lagerquist, ODU

CLAS12 Polarized Target: target samples

In previous 1 K targets at JLab, the ammonia beads were poured into cups that were rigidly attached to a target insert that included microwaves, NMR etc.

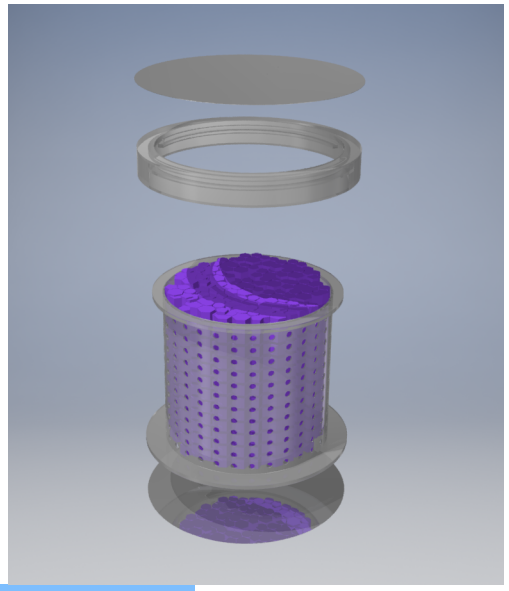
The insert was loaded *vertically* into the refrigerator, and did not disturb the electron beam line.

A similar, *horizontal* insert for CLAS12 insert would be over 3 meters long, and would require dismantling a substantial portion of the beam line.

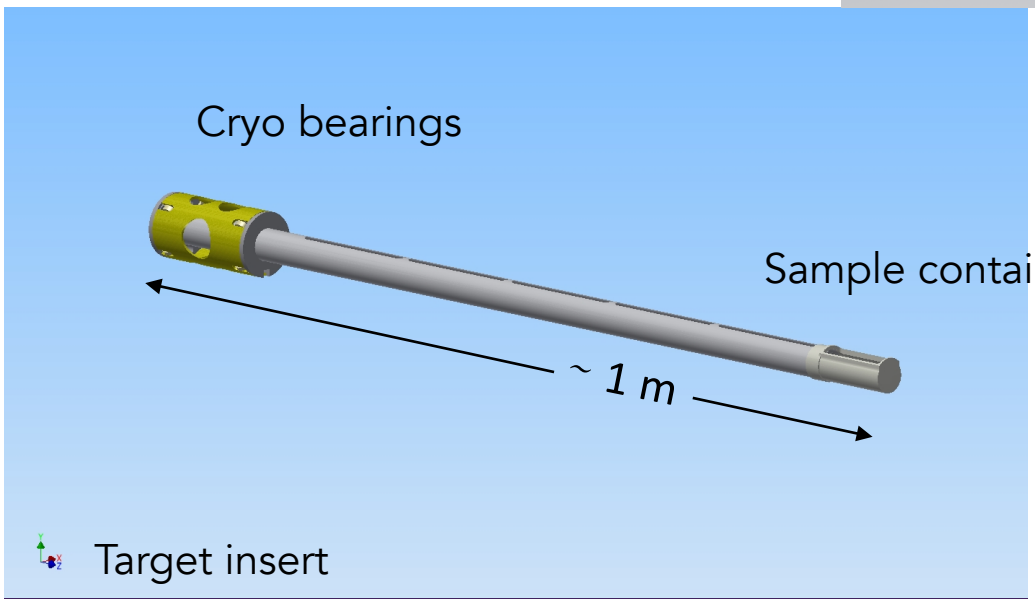
Our design goal is an insert that always *stays inside the target cryostat*.

CLAS12 Polarized Target: target sample & insert

Ammonia samples will be loaded into Kel-F containers and stored under liquid nitrogen prior to the experiment.

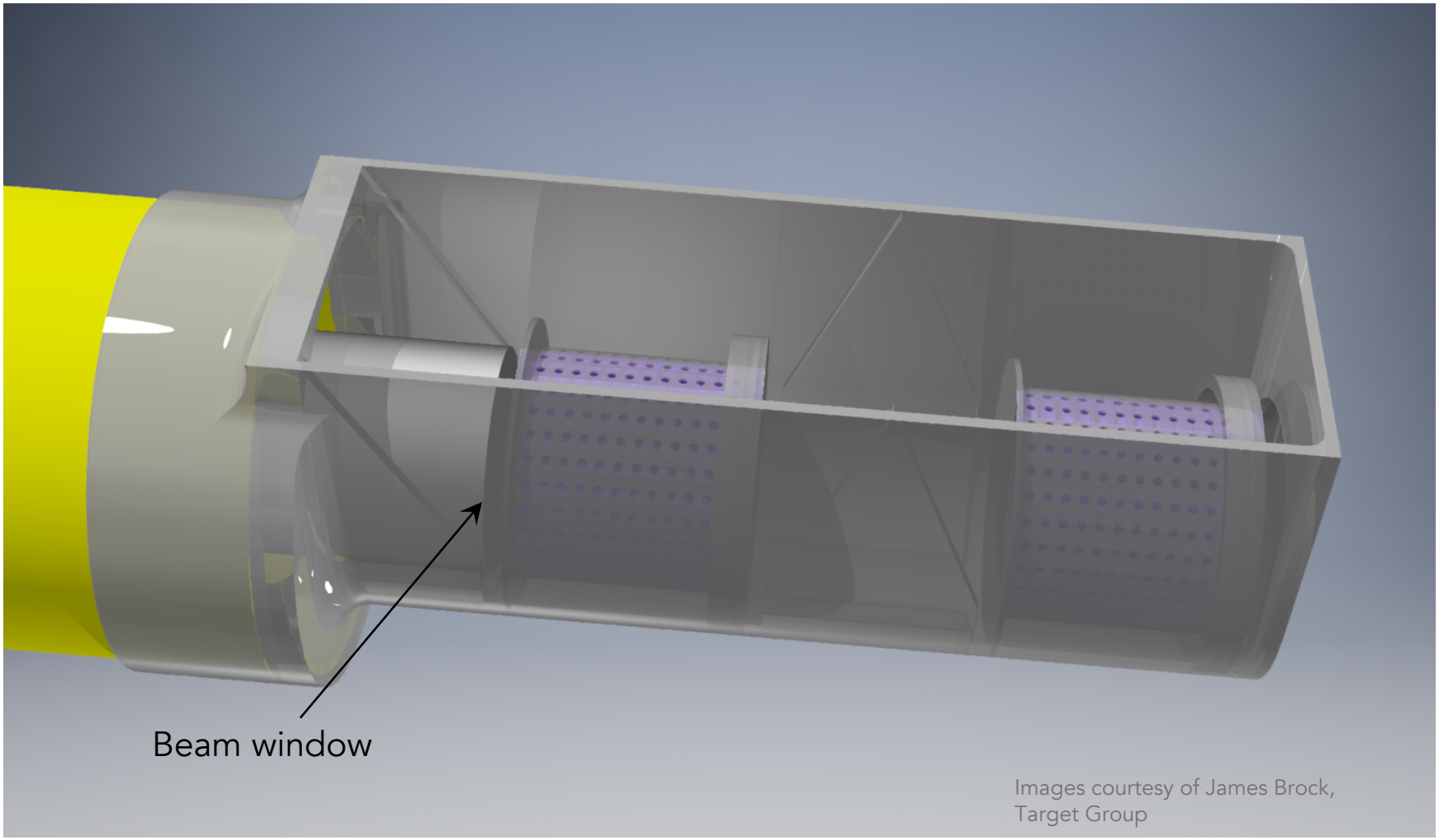


Target sample



Images courtesy of James Brock, Target Group

CLAS12 Polarized Target: target sample & insert



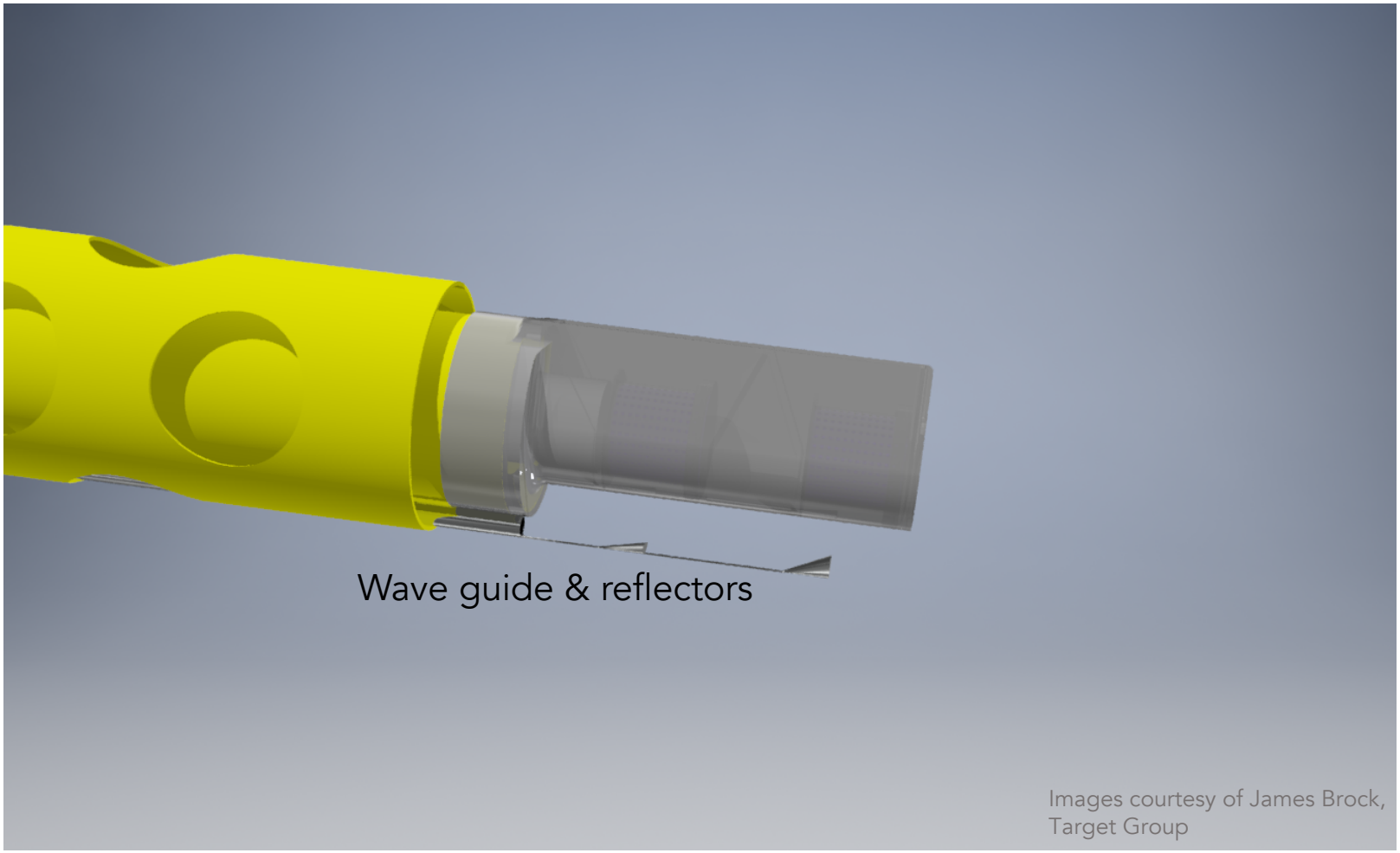
Images courtesy of James Brock, Target Group

CLAS12 Polarized Target: nmr & microwave insert

The insert slides through the center of a cabon-fiber structure that holds the microwave waveguide, NMR coils and cables, and the shim coils.

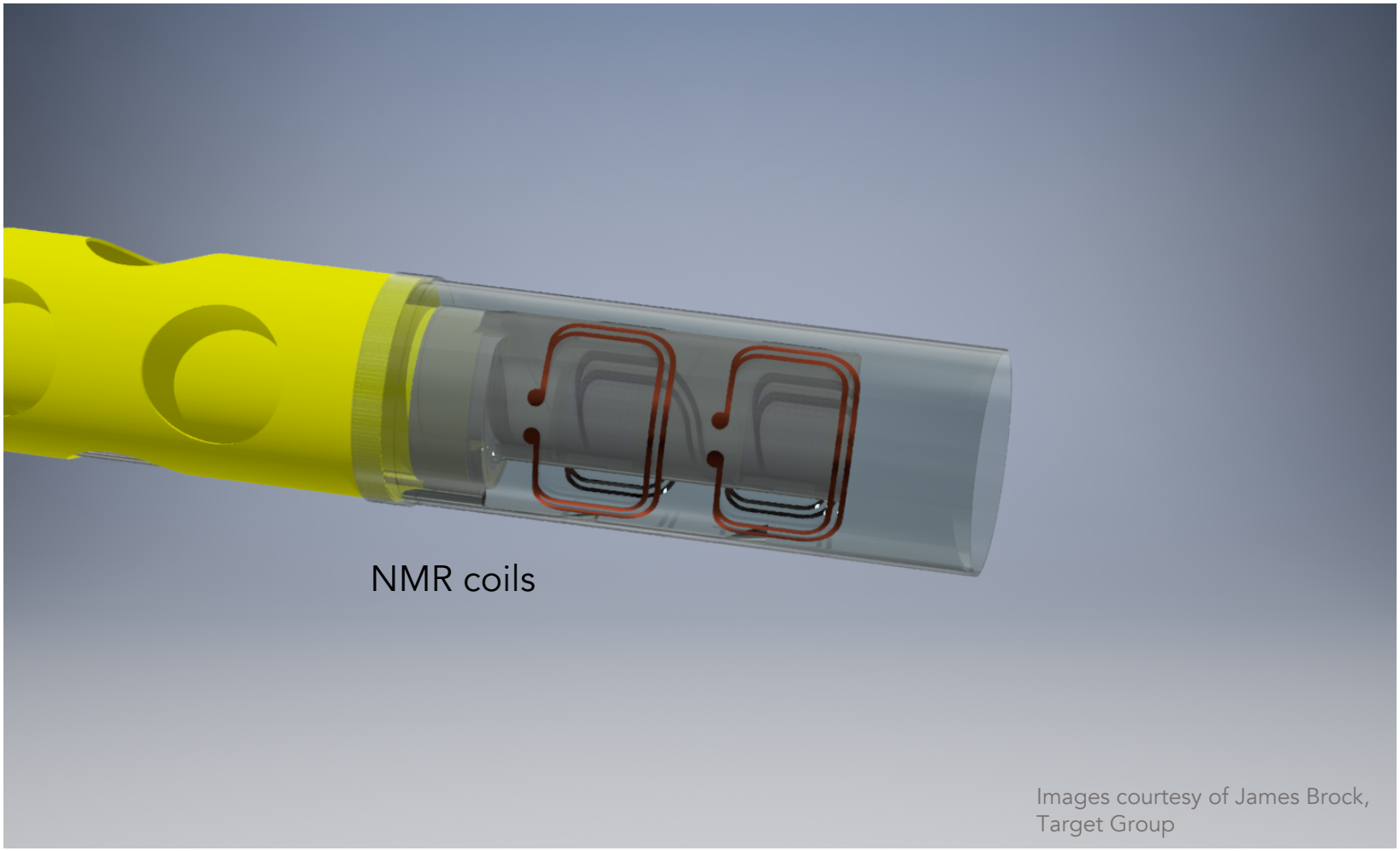
Images courtesy of James Brock, Target Group

CLAS12 Polarized Target: nmr & microwave insert



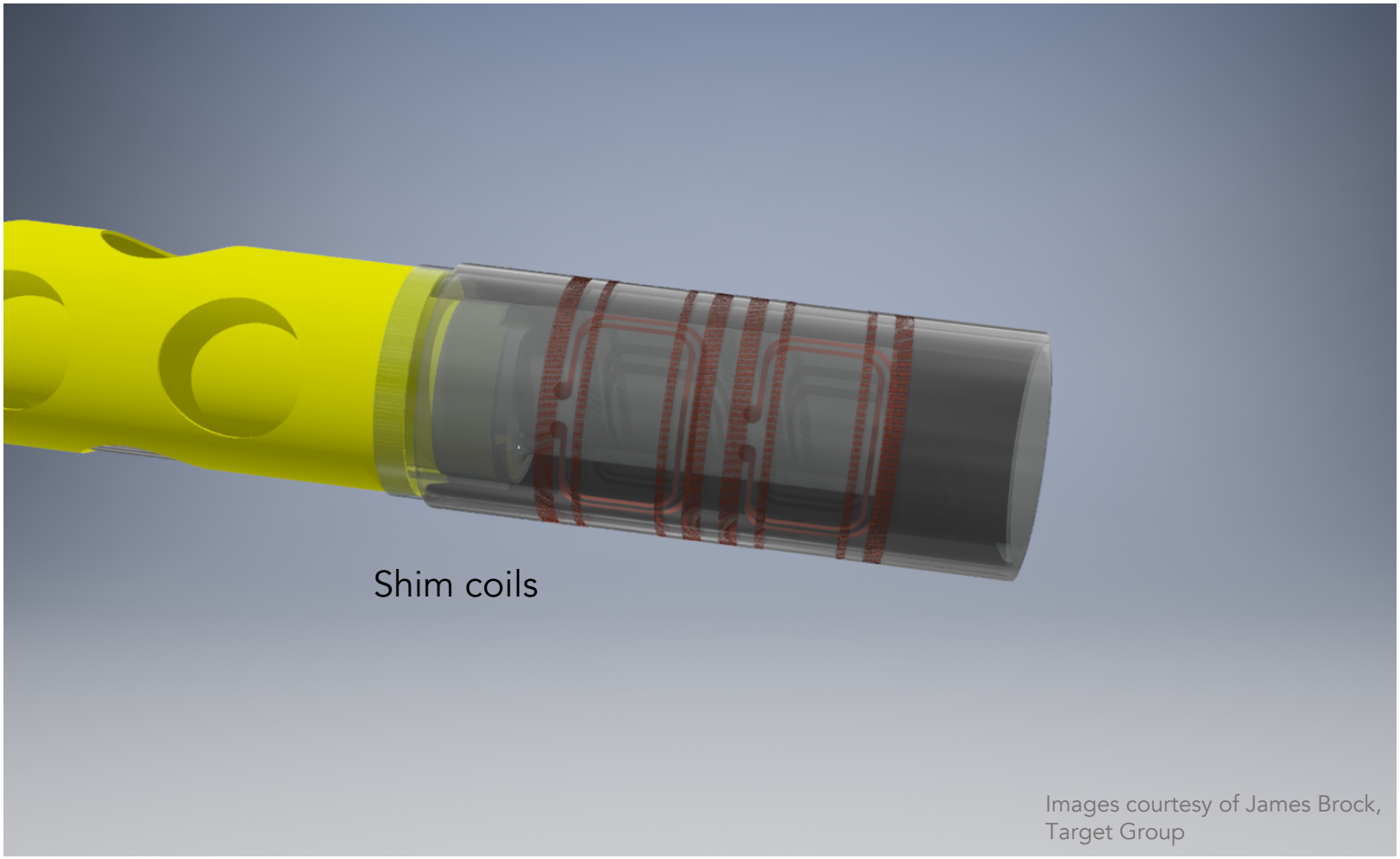
Images courtesy of James Brock, Target Group

CLAS12 Polarized Target: nmr & microwave insert



Images courtesy of James Brock, Target Group

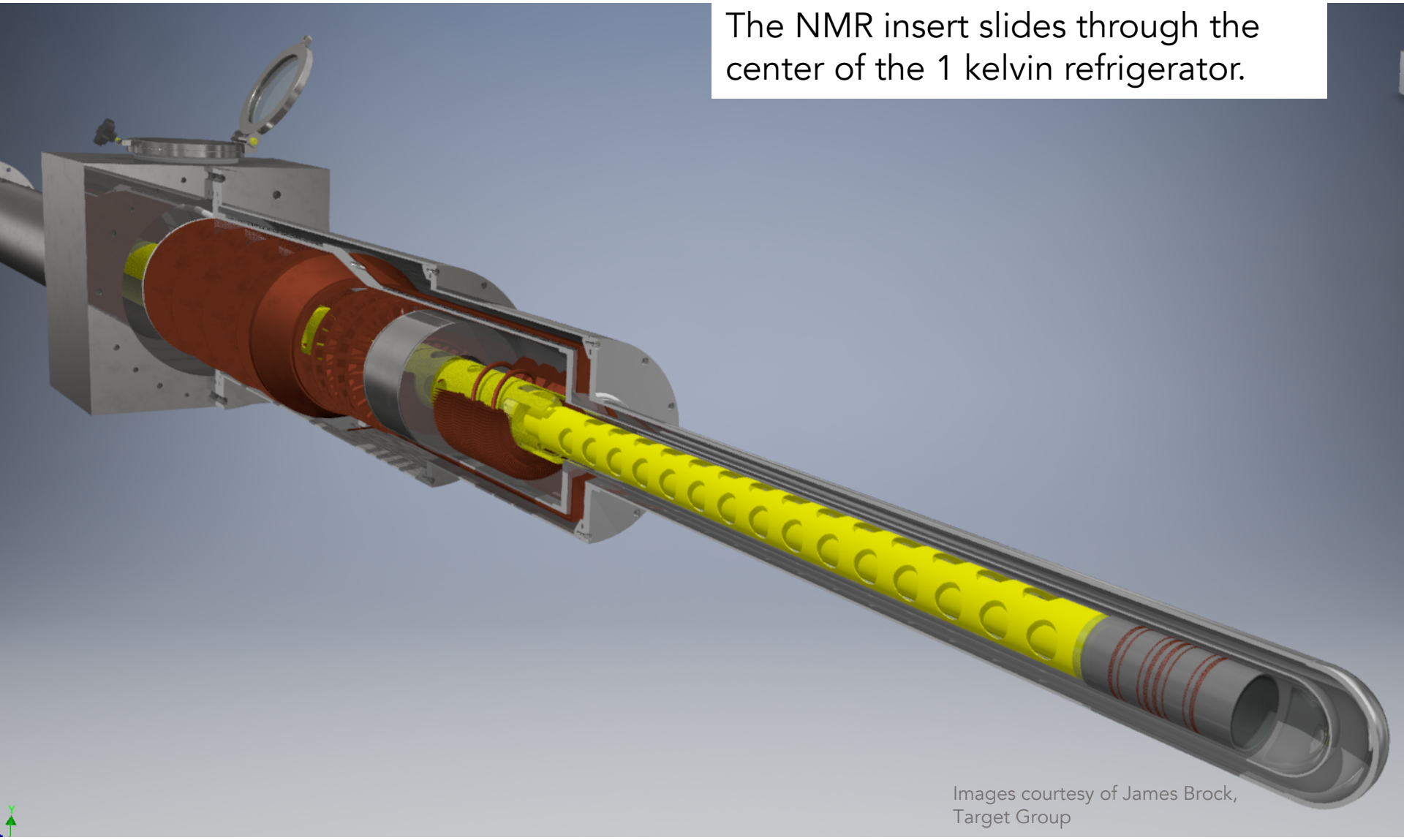
CLAS12 Polarized Target: nmr & microwave insert



Images courtesy of James Brock, Target Group

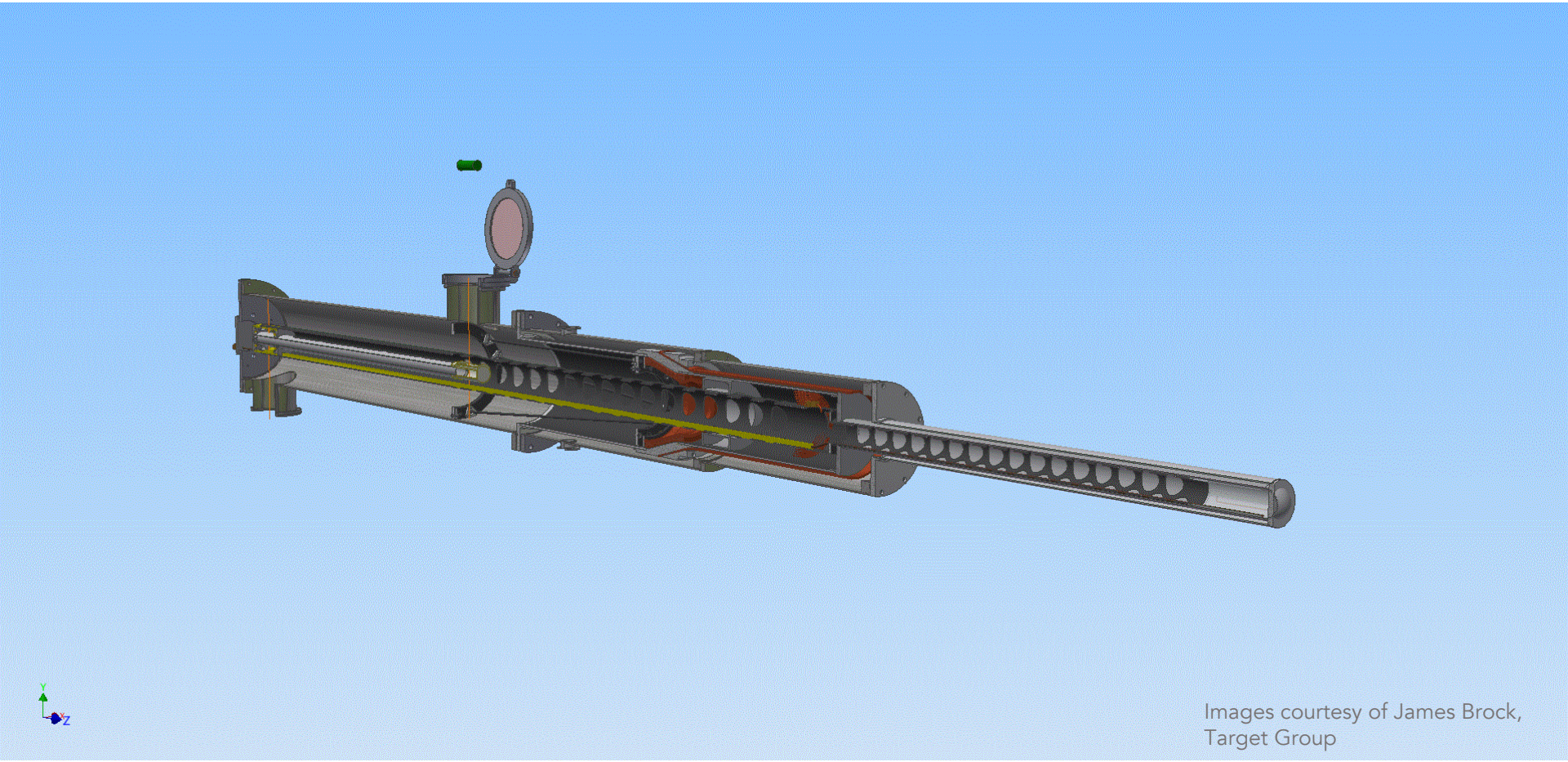
CLAS12 Polarized Target: 1 kelvin refrigerator

The NMR insert slides through the center of the 1 kelvin refrigerator.



Images courtesy of James Brock, Target Group

CLAS12 Polarized Target: loading the target



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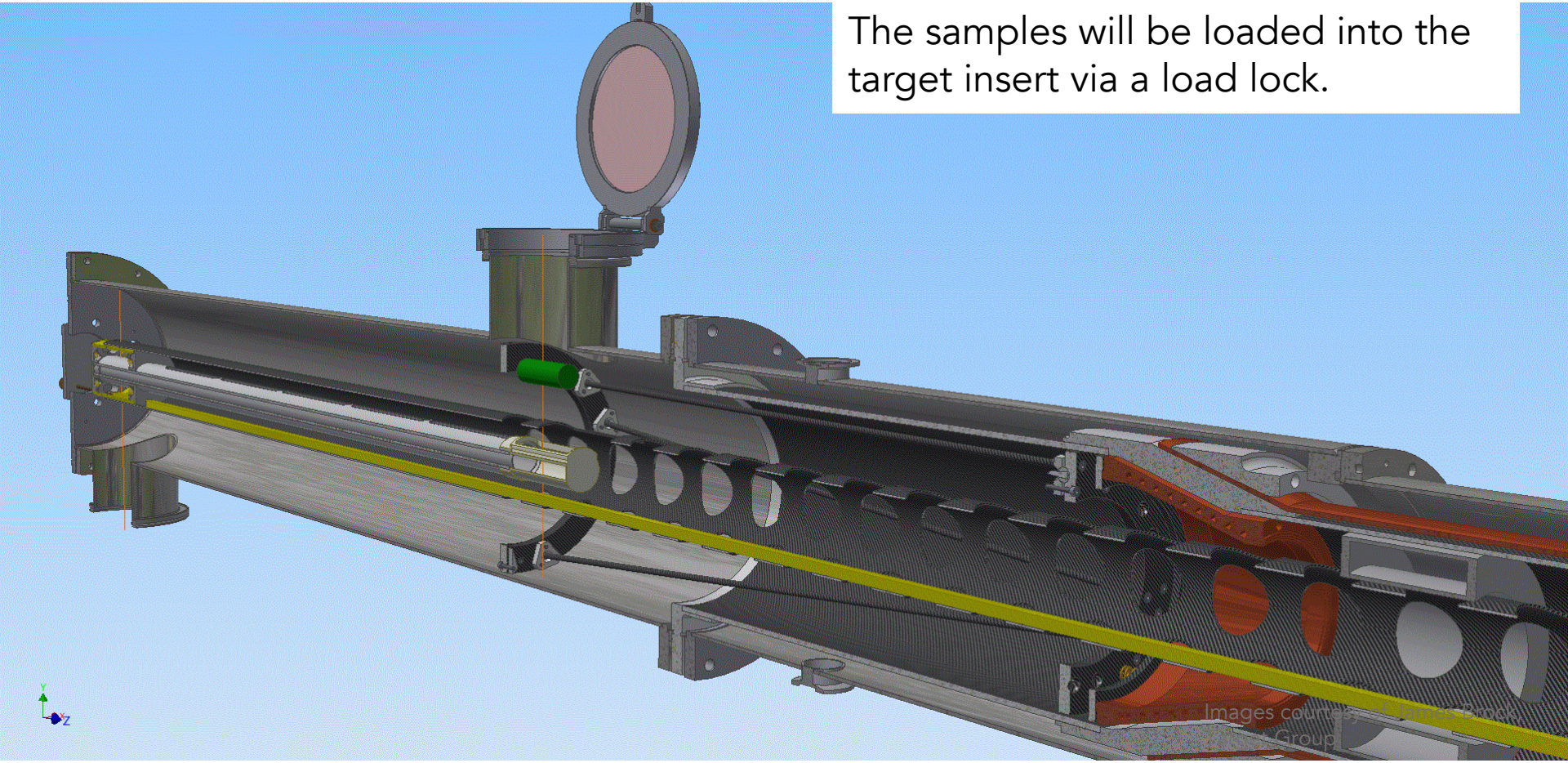

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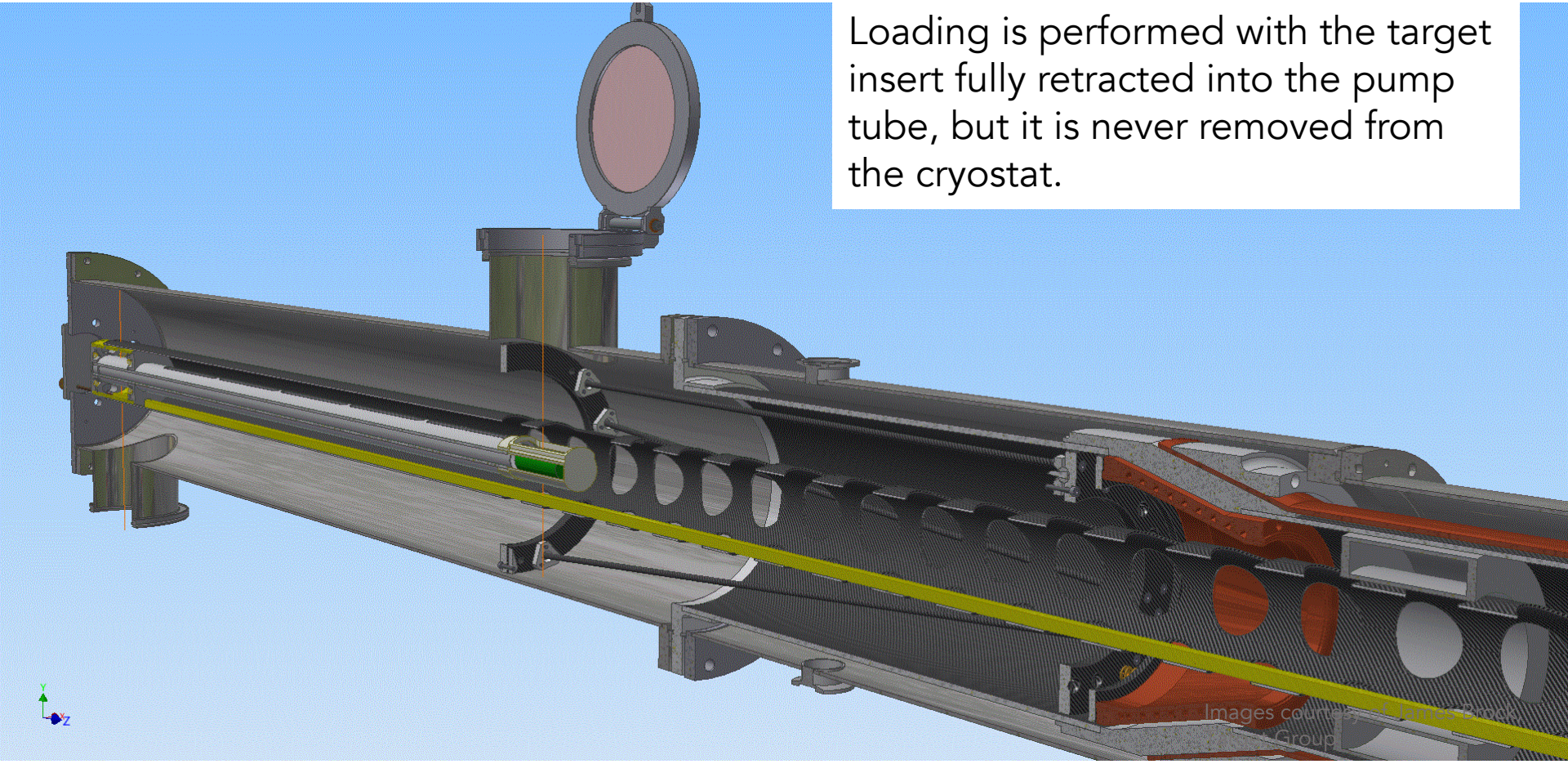

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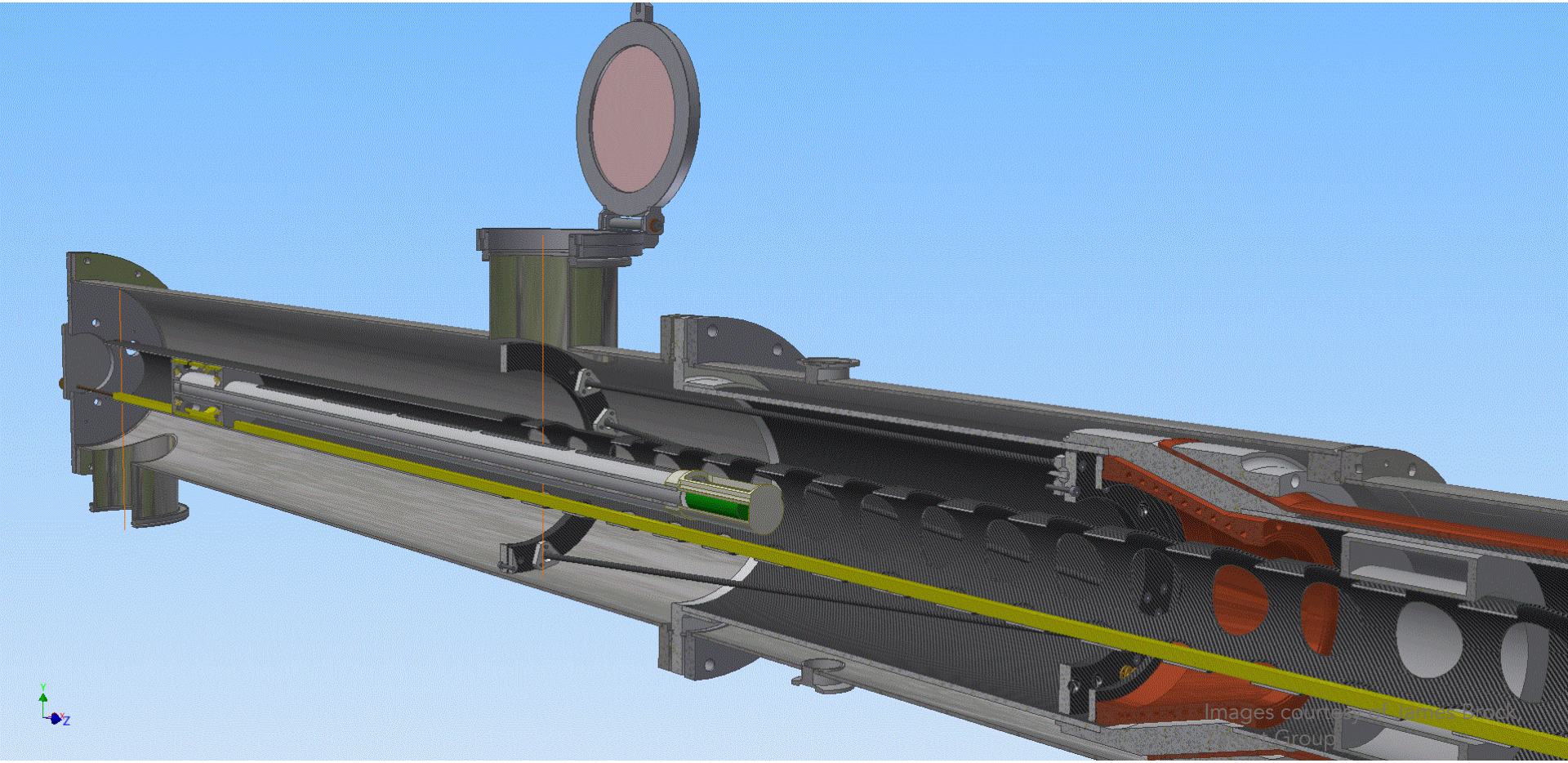
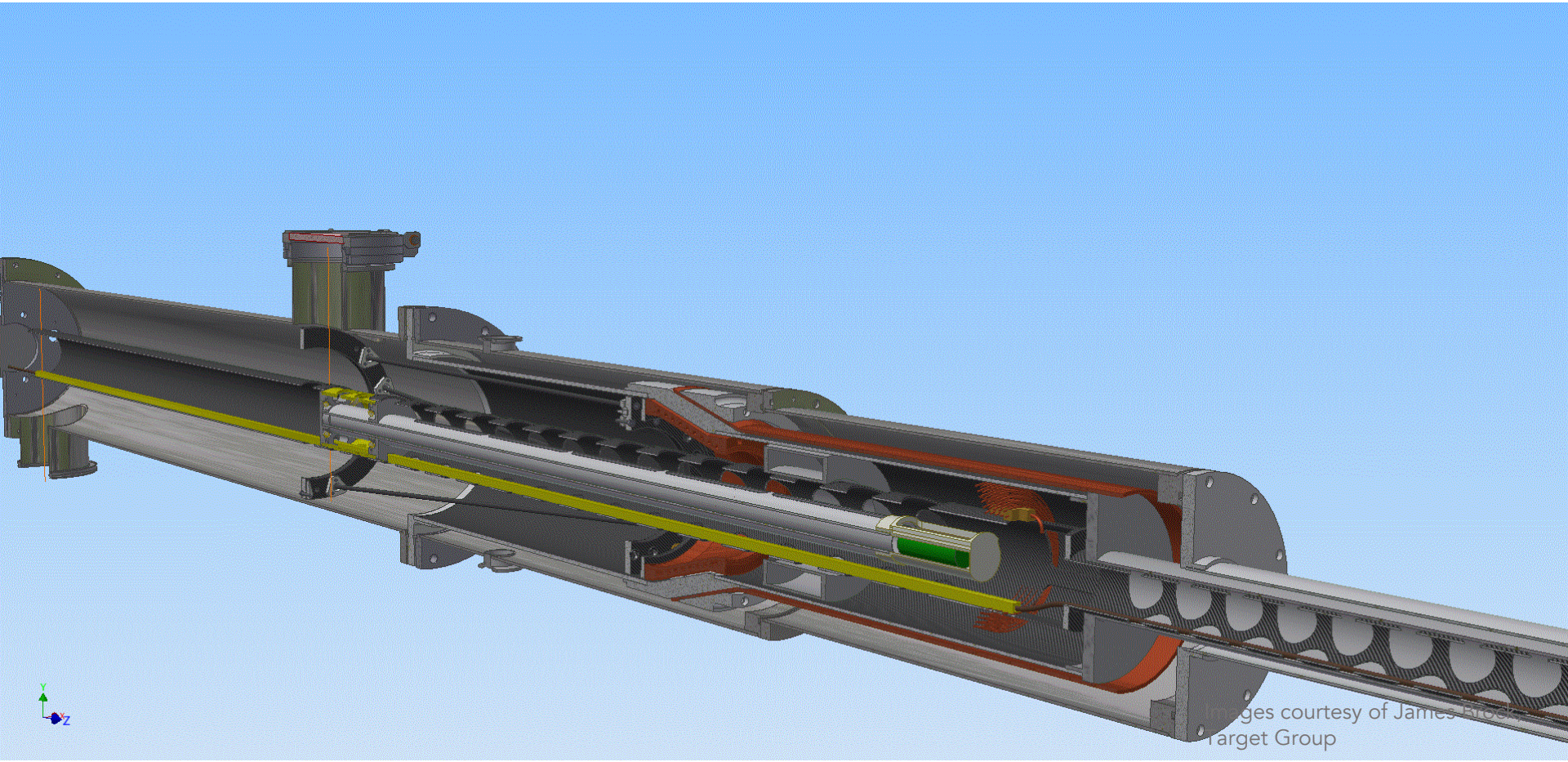
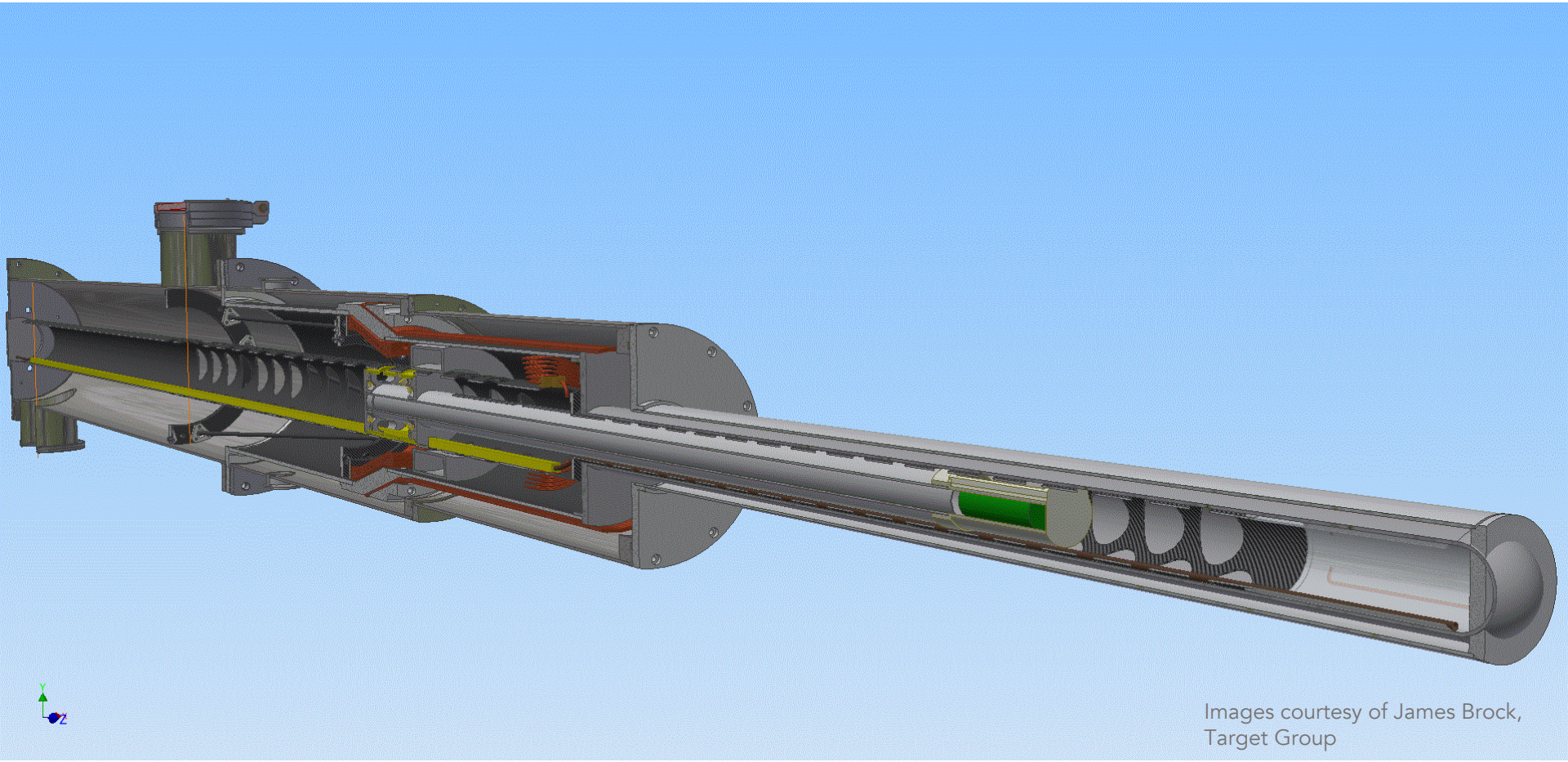


CLAS12 Polarized Target: loading the target



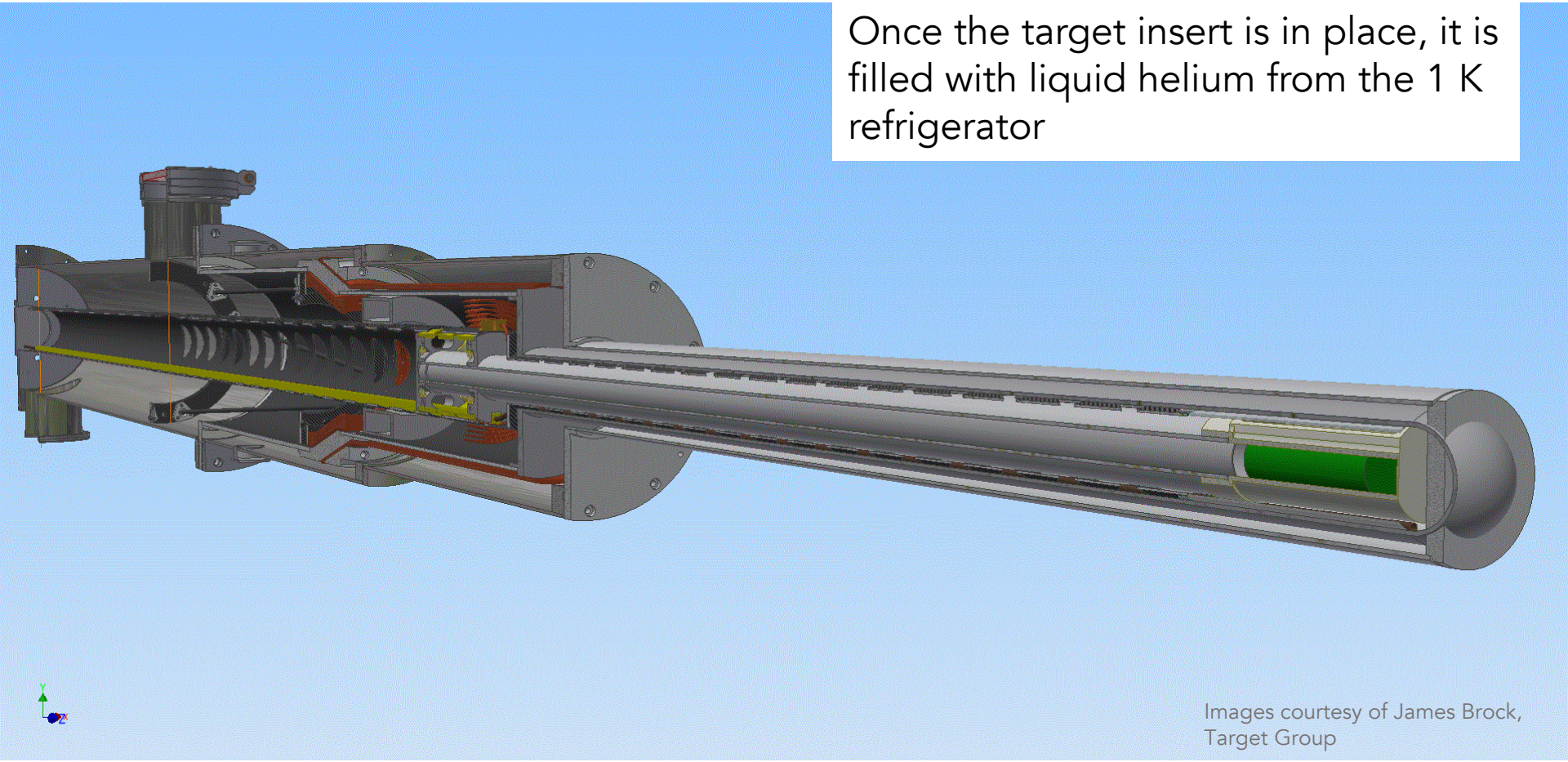
CLAS12 Polarized Target: loading the target



Images courtesy of James Brock, Target Group

CLAS12 Polarized Target: loading the target

Once the target insert is in place, it is filled with liquid helium from the 1 K refrigerator



Images courtesy of James Brock, Target Group

CLAS12 Polarized Target: loading the target

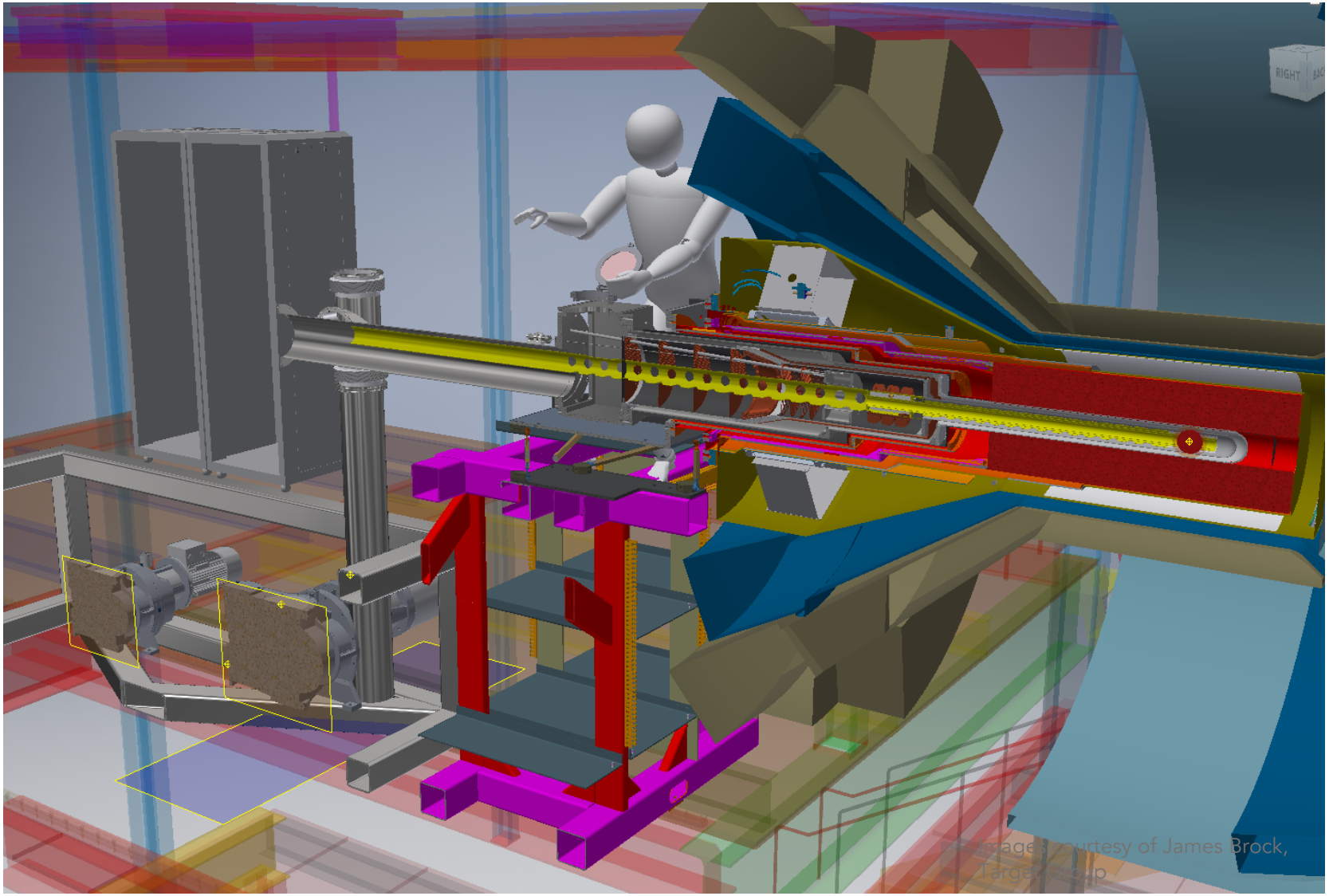


Image courtesy of James Brock, Target Group

CLAS12 Polarized Target: summary & outlook

- Polarized NH3/ND3 target under construction for Run Group C
- Most instrumentation is in hand (already at JLab)
- One major component is currently under construction: 1 K refrigerator
- R&D activities for double-cell targets is underway

- ERR: June 21, 2018
- Refrigerator completion date: Aug, 2018
- Refrigeration tests: Aug. – Dec., 2018
- Single-cell DNP tests: Jan. – May, 2019
- Double-cell DNP tests: July – Dec., 2019
- Full system tests: Jan. – April, 2020
- Ready for installation: May, 2020