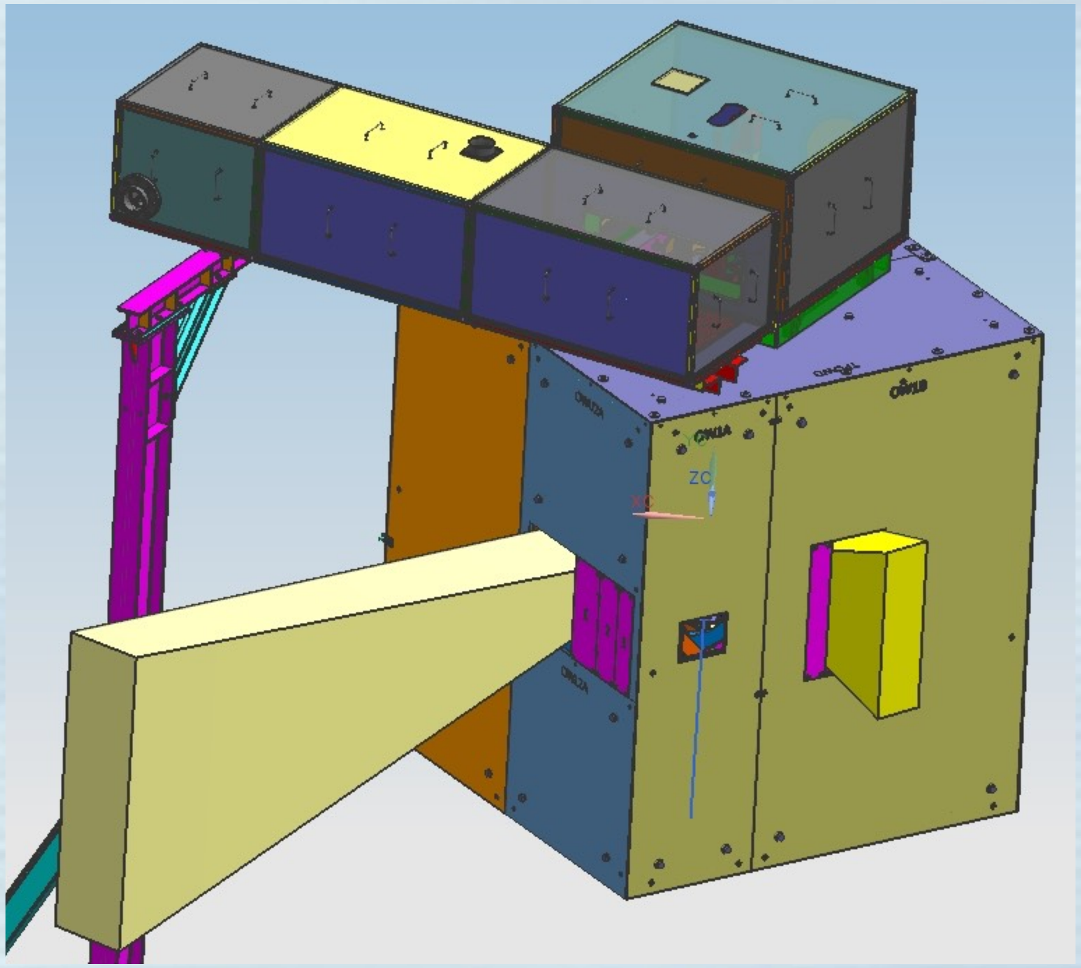
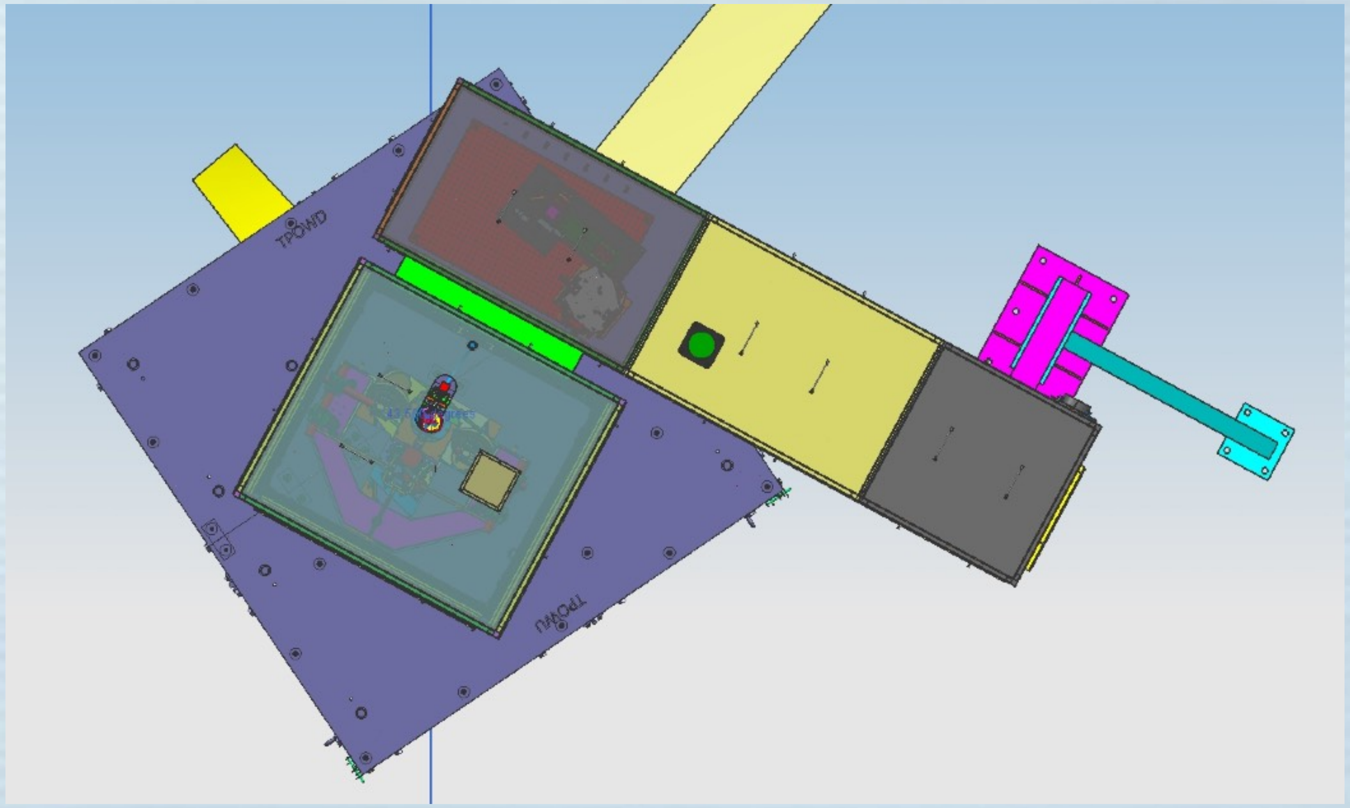
SBS G_E^n Target Update

- Engineering progress is on track. I'll just show a few picture.
- Progress on the SBS GEn target-cell development is described, including updated milestones.
- Progress in our new κ_0 ameasurement is described.
- Magnetic field determination has made breakthrough.

G. Cates - UVa
March 14, 2018

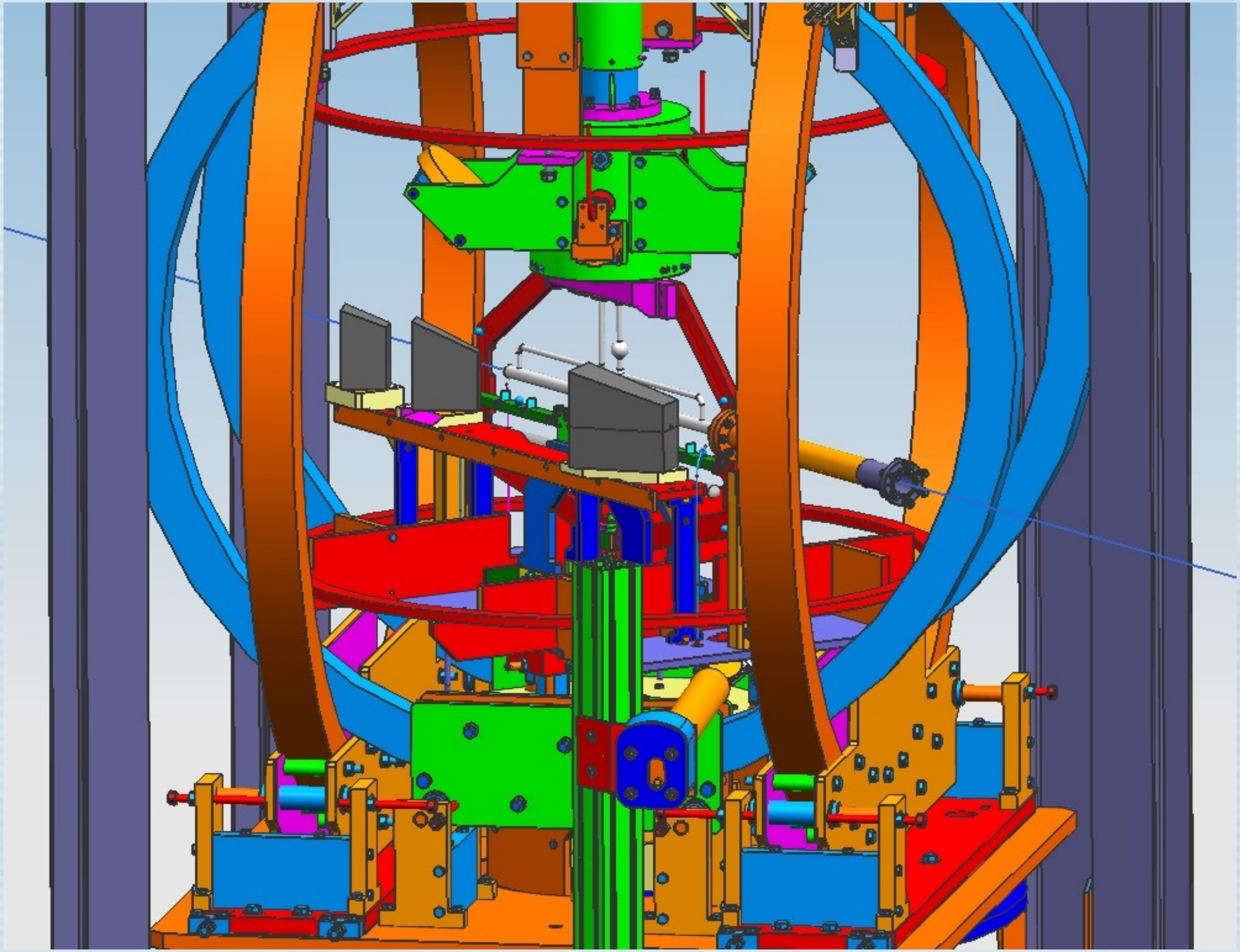
Engineering and design



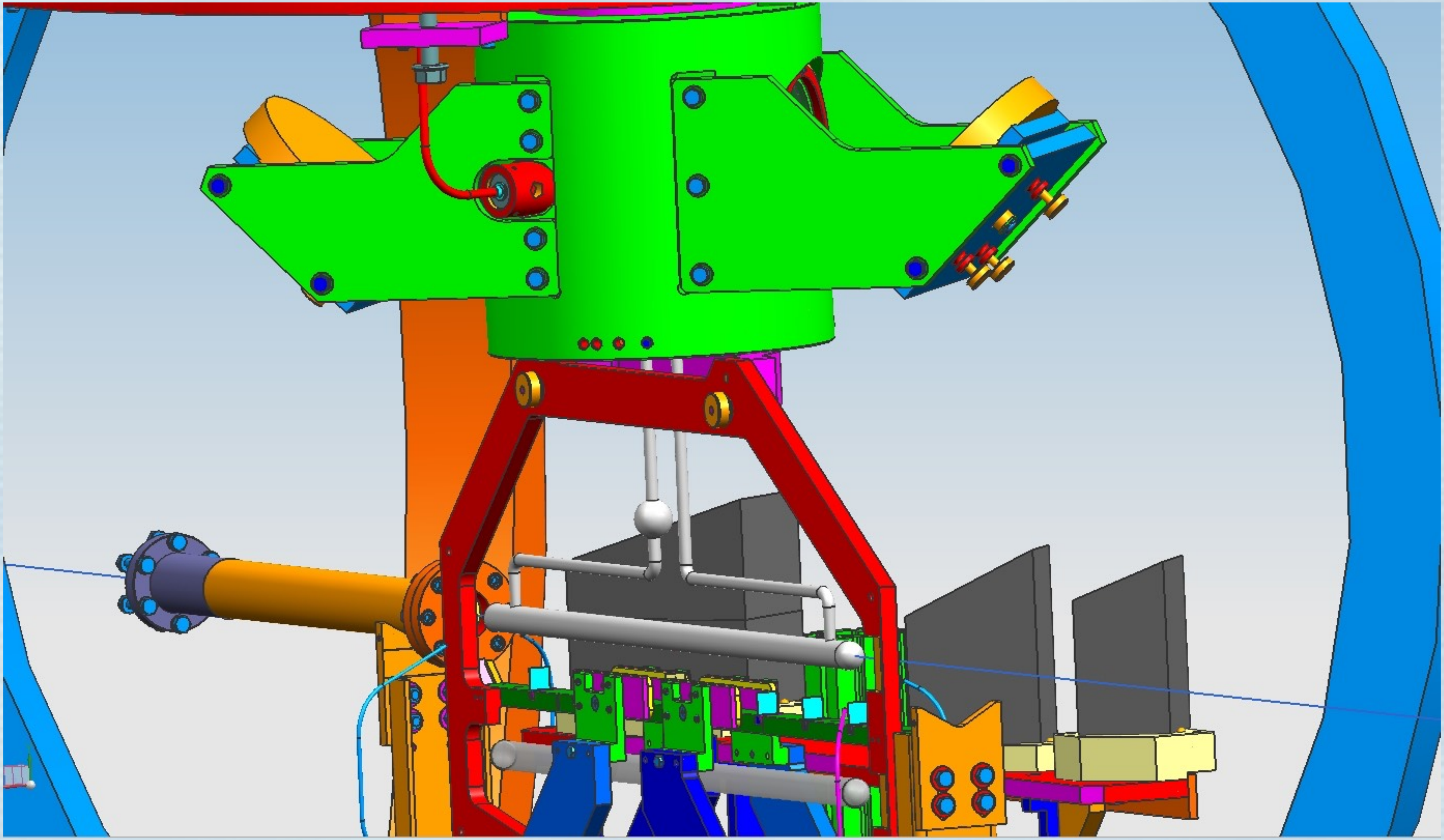


Overview with magnetic shielding in place

Engineering and design



Engineering and design



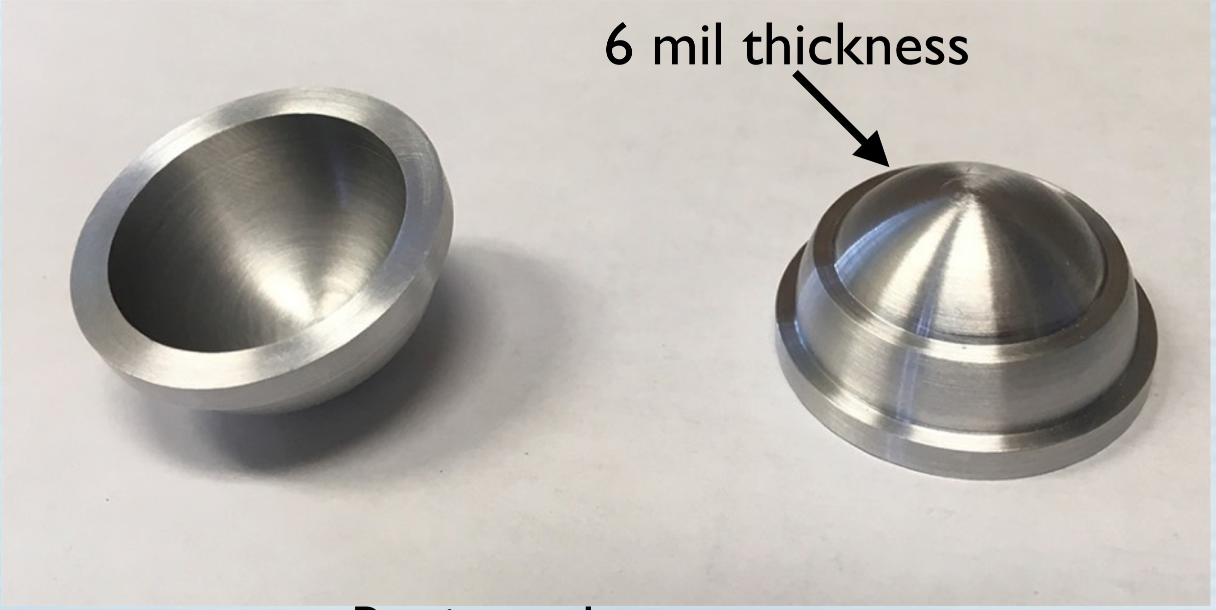
Closeup highlighting cylindrical oven

Cell development and production

Progress metal end-window assemblies since the July collaboration meeting

- As of last July, two prototypes had been constructed, but had not yet been polished, electropolished, joined by electroplating, and plated with gold.
- As of now, three prototypes have been constructed.
  - The first suffered a puncture to its 6 mil window during electroplating.
  - The next two were “finished”, but both had vacuum leaks.
  - Both were “repaired” but still had small leaks.
- The best end-window assembly has been sent to Princeton to be incorporated into a test cell. The very small leaks will be sealed using the same epoxy used by Mainz on the metal end windows of their polarized 3He target.
- Mark-II end-window assemblies now being fabricated. We expect them to be much less likely to leak.

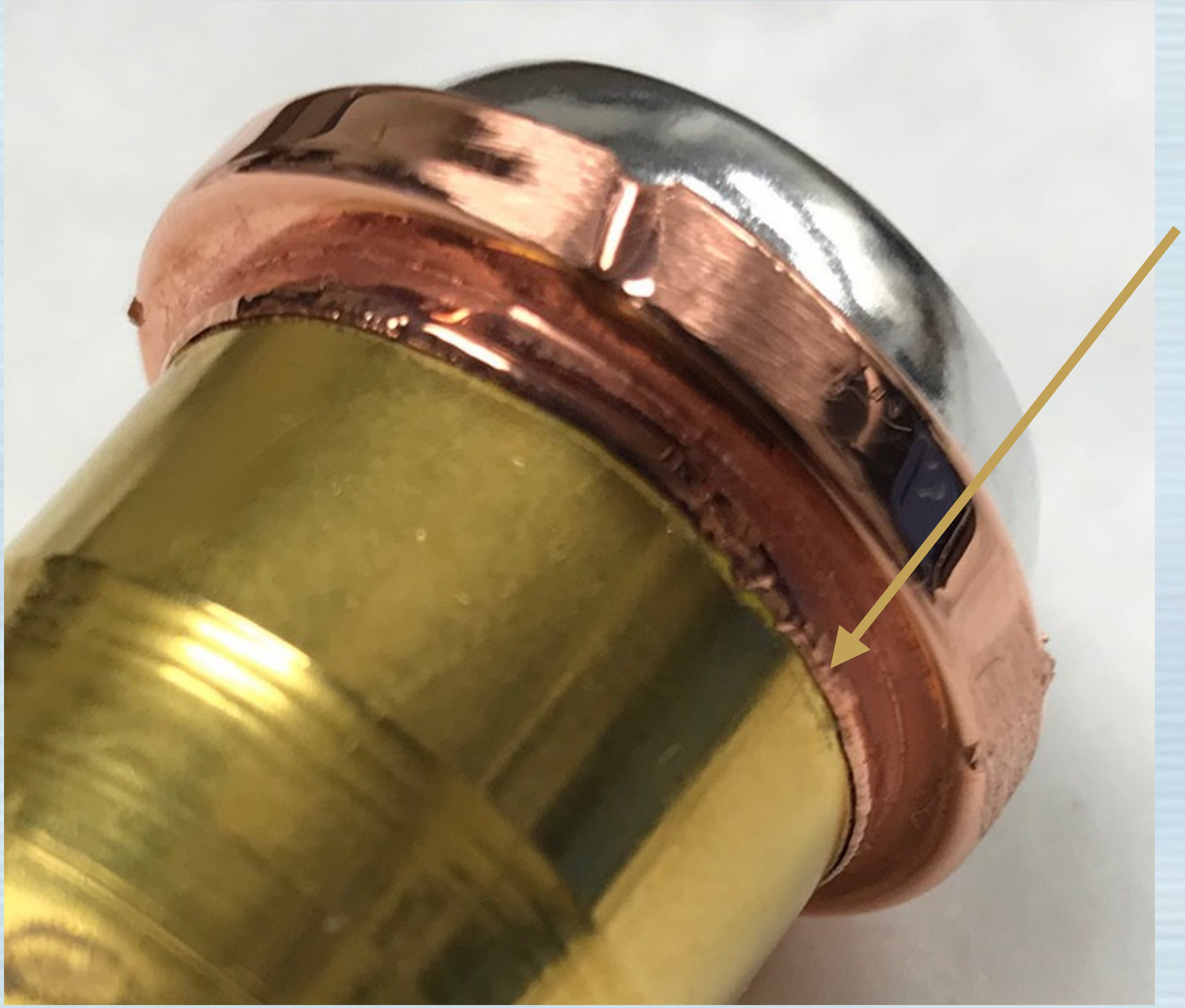
Components for each end-window assembly



Region where copper is deposited to join the two pieces

- The actual end window is an aluminum "end-cap", machined at UVa, in which the central region has a 6 mil thickness and provides a 21 mm diameter clear aperture.
- Each end-cap is attached to a copper tube that provides a transition to glass using a "Housekeeper Seal" (purchased from Larson Glass).
- All surfaces "seen" by the He-3 gas are coated with gold.
- The aluminum end-cap is joined to the copper tube by electroplating copper across the junction. NO HEAT IS REQUIRED FOR THE JOINING PROCESS!!!

The first prototype window assembly



The joint between the aluminum end-cap and the copper tube is accomplished by electroplating copper across the junction.

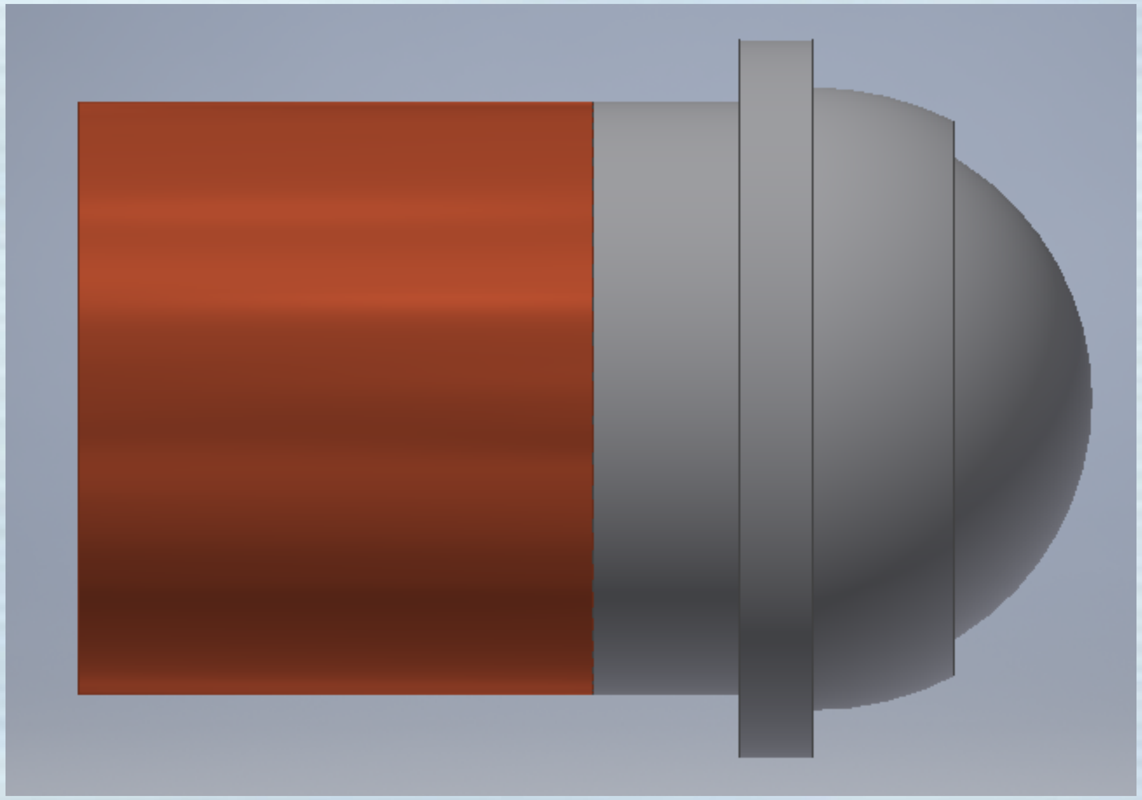
This technique, which requires NO HEAT, was unknown to us before being suggested by David Epner, the founder and president of Epner Inc. that performs the electroplating.

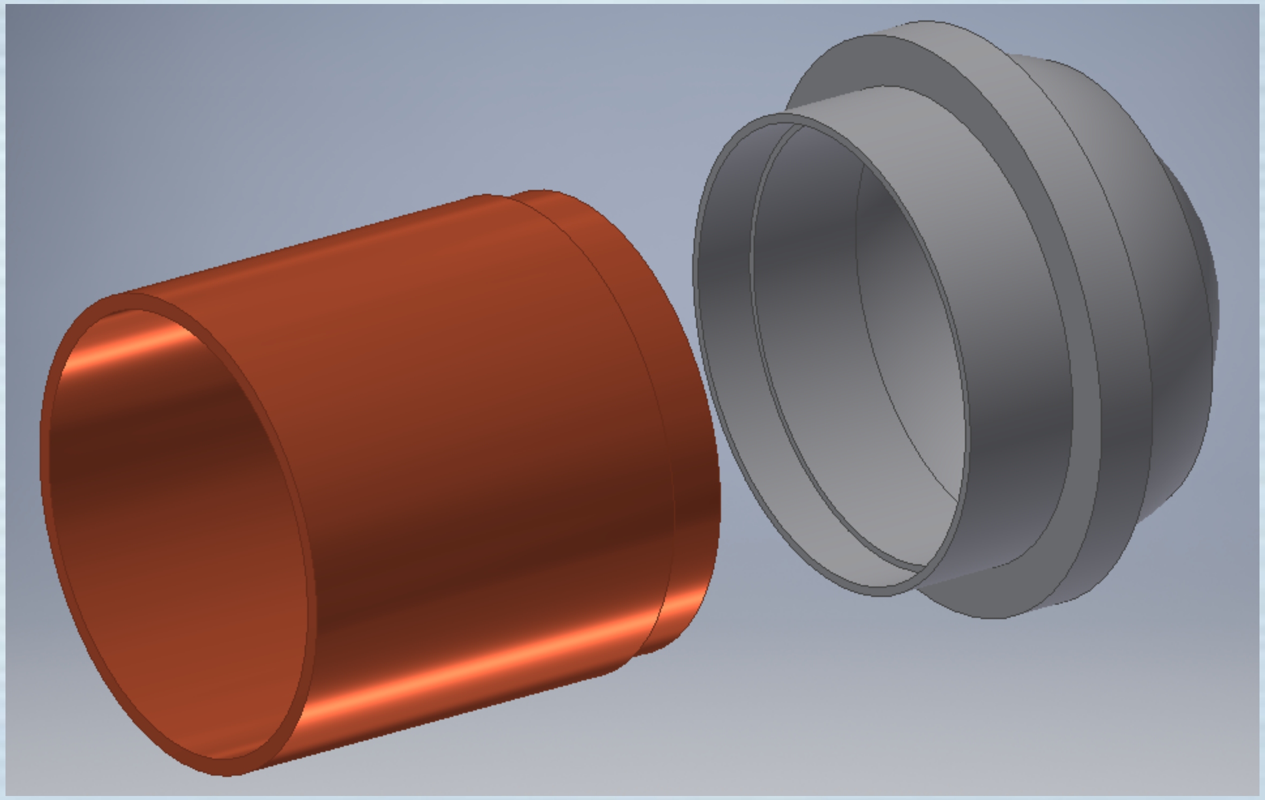
The vacuum integrity of the seal could not be tested because of the hole/tear in the 6 mil window.

The second and third prototype window assemblies

- The second and third prototypes (received at the same time) looked beautiful.
- We were able to establish rough vacuum with these pieces, thus establishing that the thin 6 mil window had sufficient mechanical integrity to NOT collapse when under vacuum (an important test!!!).
- Unfortunately, small pinholes limited us to rough vacuum.
- The areas that were leaking showed visible pinholes upon close inspection, and Epner subsequently attempted to seal them, nearly succeeding on one of the pieces.

Mark-II design for the window assemblies





- The Mark-II design has the important feature that the junction between the copper and aluminum pieces is flat instead of occurring at an inside corner.
- The Mark-II design also has less surface area associated with the aluminum piece, and also better minimizes the amount of metal overall.

Remaining steps to produce usable glass-and-metal target cells

- Spin-relaxation test of first end-window assembly (soon !).
- Fabricate Mark-II versions, which should be less apt to leak.
- Fabricate and characterize additional test cells as needed to finalize the window-assembly technology.
- Construct our first 3-liter ("Stage-1") target cell with metal end windows. The only significant challenge compared our current cell-making techniques involves avoiding cooling the target chamber to cryogenic temperatures as is our current practice.
- Construct our first 6-liter target cell, which will include metal end windows.

Filling glass-and-metal cells to 10 atms

- Our current technique for filling target cells to 10 atms involves chilling the target chamber and some of the transfer tubes to cryogenic temperatures, filling the cell with an appropriate quantity of He-3, and sealing the cell. The cryogenic temperatures insure that the pressure in the cell is always below 1 atm when glass is melted to make the seal.
- With both metal and glass parts in the target chamber, differences in thermal coefficients of expansion preclude cooling any portion of the cell containing metal.
- There are at least four variants of our current techniques that can be used to fill metal-and-glass target cells:
  - ➡ Two “pull-offs” can be used, one for introducing droplets of alkali metal, and one for filling with gas. The gas-filling pull-off would be equipped with a “break seal”, which allows the cell to be removed from and reattached to the gas manifold without losing vacuum. Our group has used this technique previously in a different context.
  - ➡ The cell can be fitted with a valve which permits filling to pressures greater than 1 atm using several different techniques.
  - ➡ The cell can be fitted with a “pinch tube” that is crimped once the cell is filled. The pinch tube eliminates the need to have a pressure less than one atmosphere during the sealing process.
  - ➡ A dewar can be constructed that excludes the window assemblies from the cryogenically cooled areas. We note we have successfully constructed similar (but smaller) custom-shaped dewars in the past.
- Tests to determine the most expedient approach for filling glass-and-metal cells to 10 atms can proceed in parallel with tests of the window assemblies.

Timeline for SBS G_E^n target cells

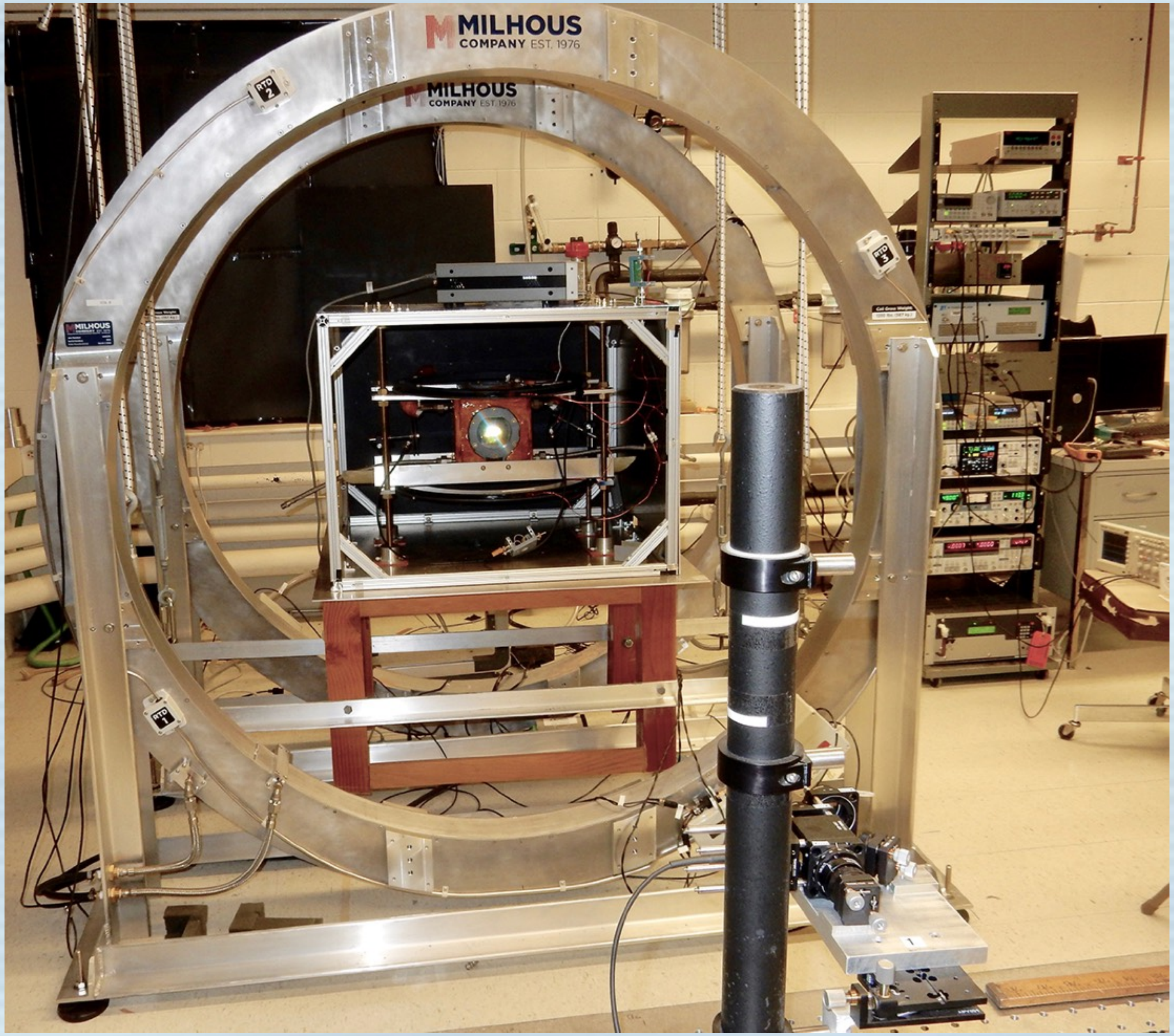
Several factors have contributed to pushing our target-cell milestones further into the future: 1) An earlier decision to use an alloy of copper for the window needed to be abandoned when the JLab target group advised us that regardless of mechanical strength, a sufficiently thin copper window would leak, 2) Epner, our critical partner for electroplating, moved large portions of their operations during the summer of 2017 and were unavailable for producing parts, and 3) the technique of joining two pieces using an "electroplated bridge" has required some fine tuning.

Milestone	Projection as of May 2017	Projection as of January 2018
Fabricate leak-free window assembly	n/a	March 2018
Incorporate window assembly into test cell	n/a	April 2018
Test cells sufficiently characterized	n/a	June 2018
Begin bench tests of 3-liter target cell	January 2017	July 2018
Begin bench tests of 6-liter target cells	July 2018	October 2018
Begin production of 6-liter target cells	August 2018	December 2018
GEn target cell(s) available for use	January 2018	January 2019

Our revised target-cell milestones will still provide one or more usable targets cells by January of 2019. We will thus have a "complete" ^3He target by the established January 2019 date, even if additional target-cell production continues past that date.

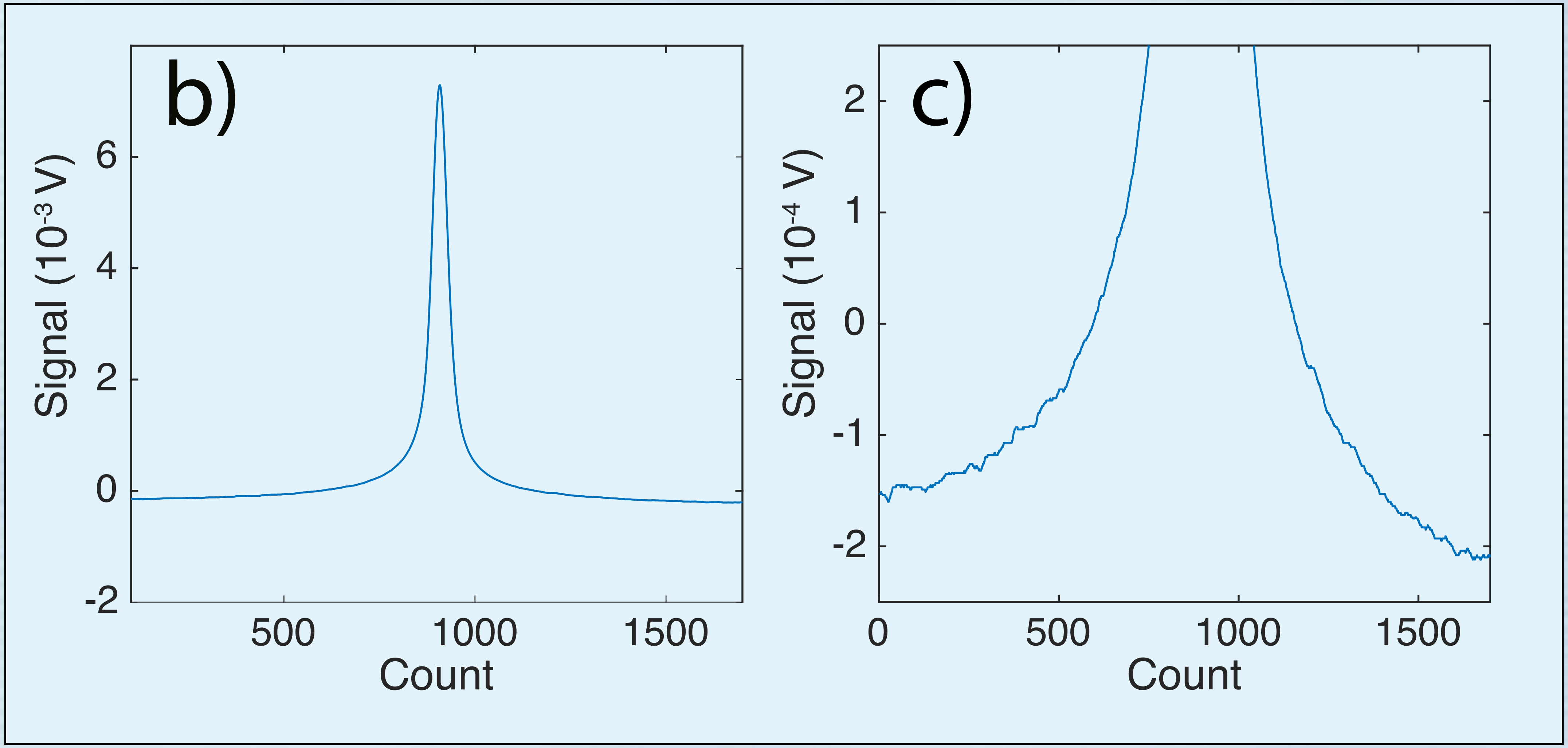
Progress on κ_0 measurement and lessons learned

Apparatus for κ_0 measurement



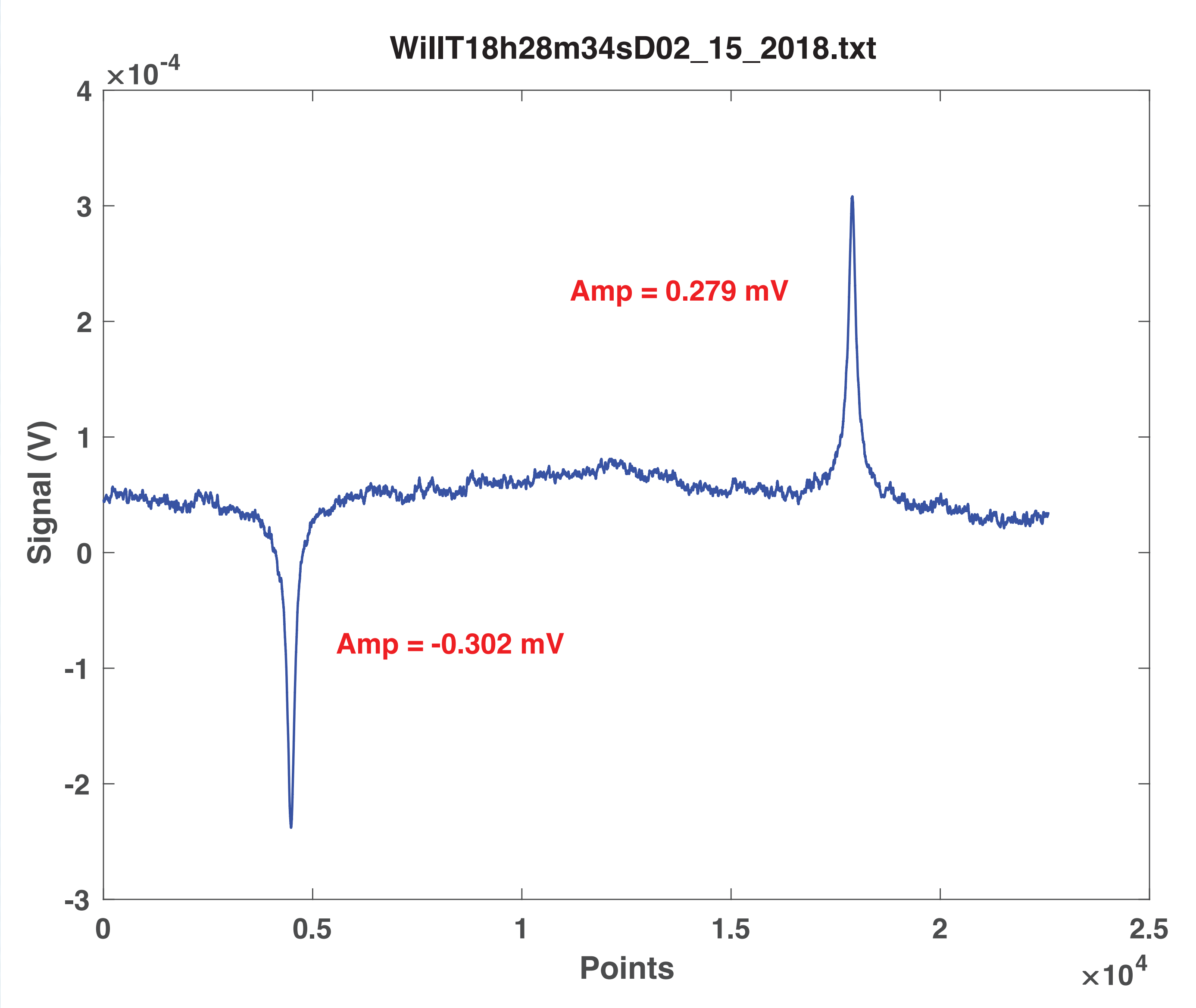
- Apparatus is suspended by bungee cords to suppress microphonic-induced noise.
- Aluminum shielding suppresses electromagnetic noise.
- While we are still optimizing, we have improved S/N of thermal water signals by 2 or more orders of magnitude, thus satisfying one of our most demanding requirements.

S/N ratio approaching 1000 achieved for ^3He signals



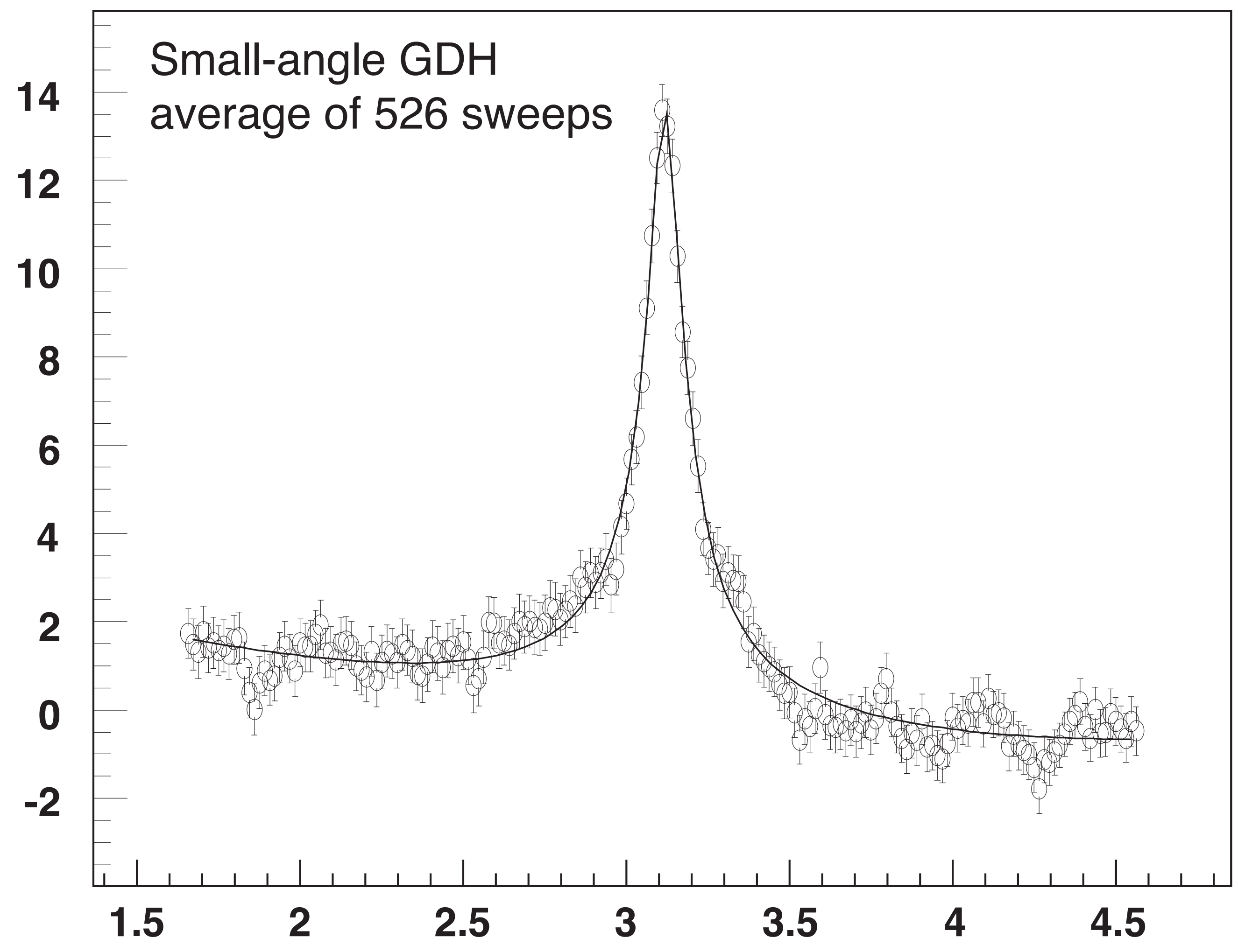
Design is working well for noise suppression!

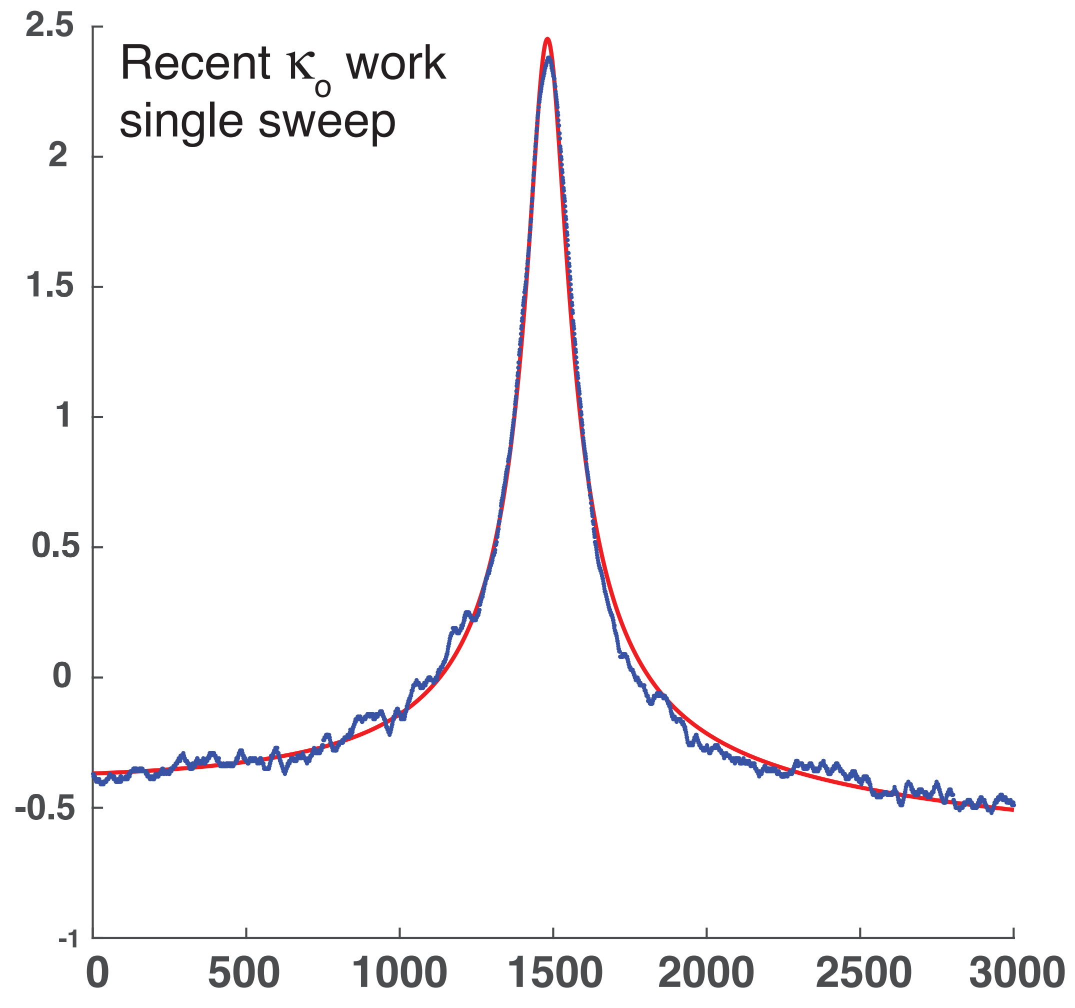
Single-shot thermal water signals



- S/N better than 10:1, the best thermal water signals we have ever achieved.
- System not yet fully optimized.
- Unresolved issues:
  - Need stronger RF amplitude.
  - Need better cancelation of RF leakage within shield.

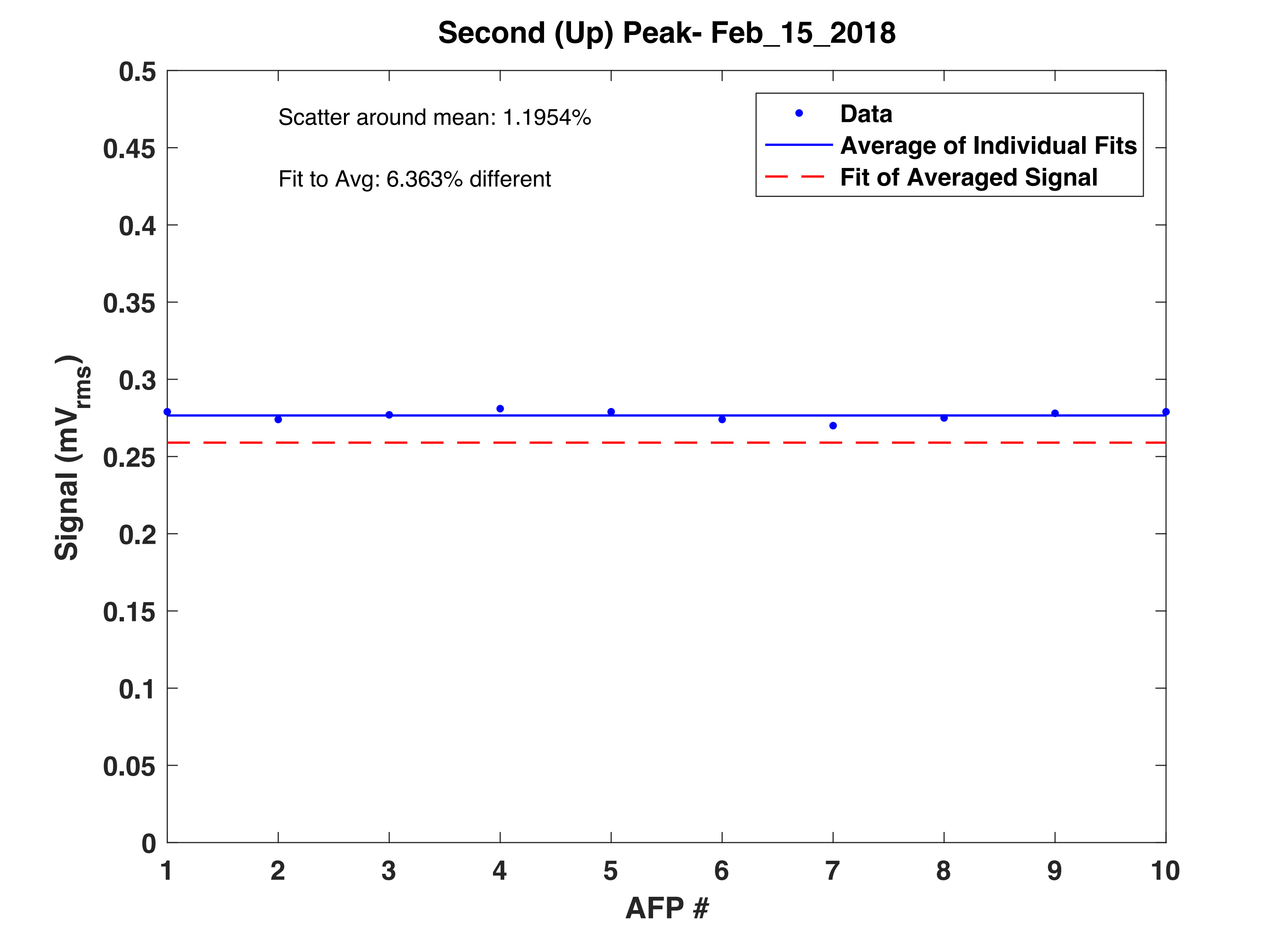
Comparison with previous water signals at JLab





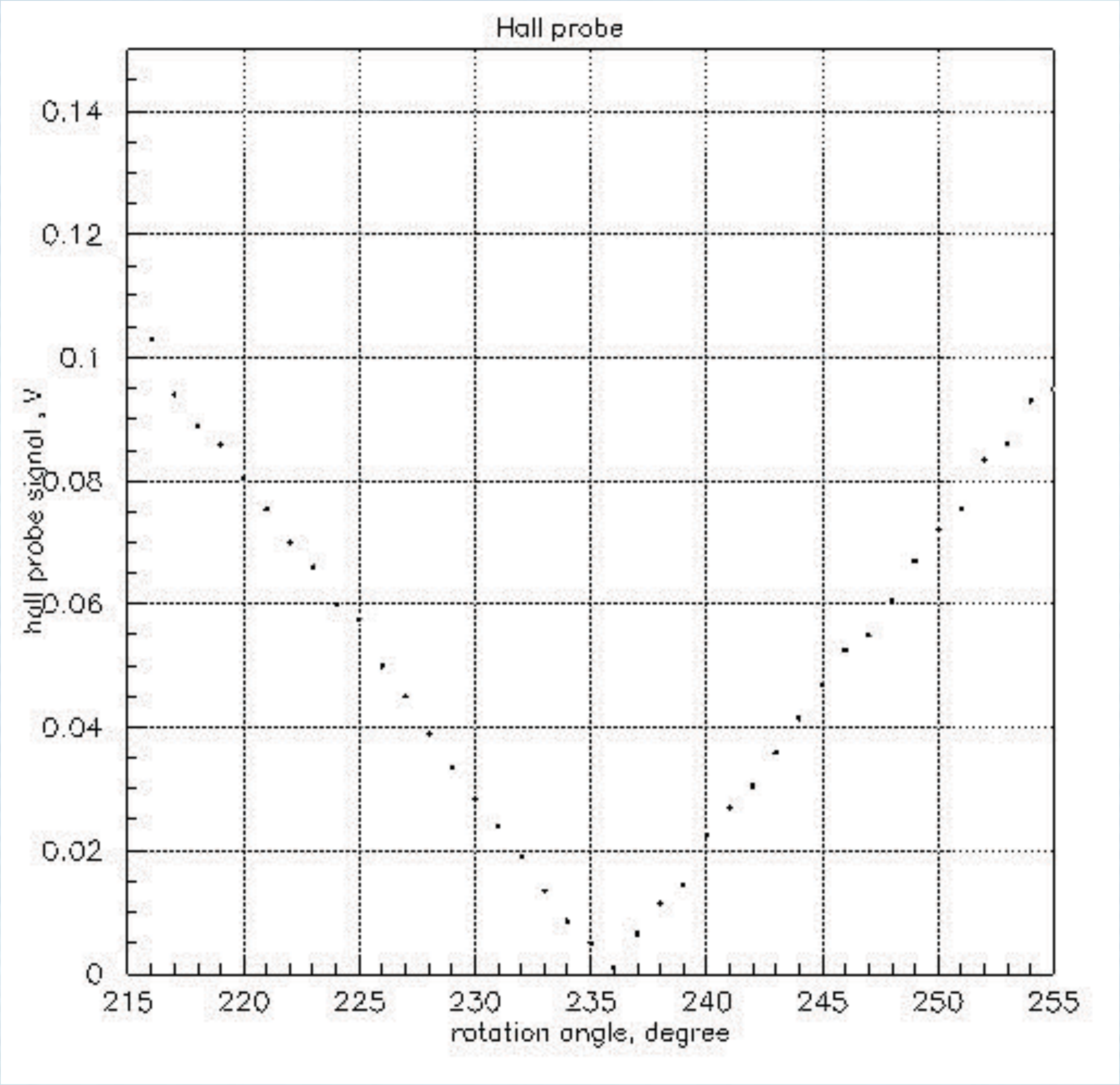
- S/N better than 30:1, the best thermal water signals we have ever achieved.
- The ability to make relatively precise single-shot measurements makes it possible to study a host of systematic effects.

Comparing the average of 10 fits with the fit of the average of 10 signals



Substantial differences have been observed between fits to averaged signals, and the averages of fits to individual signals. We have long suspected this as a systematic problem with NMR calibrations using water, and our recent measurements both confirm this suspicion and provides a path forward that avoids the problem.

Magnetic field direction measurements



Hall probe is extremely good at finding zeroes in the magnetic field and can form the basis for the field-measurement system.

Summary

- Engineering is on track, and we are even beginning fabrication (at UVa) of optical hardware for Hall A.
- The target-cell development, while proving challenging, has steadily progressed, and we anticipate having one or more target cells ready by January 2019.
- The new κ_0 measurement, which required developing very-low-noise thermal water signals has proceeded well beyond initial expectations, and even sheds light on past polarimetry efforts.
- Characterizing target-cells requires a new scannable single-frequency laser. That laser has been purchased, and early tests indicate excellent performance.
- The κ_0 measurement is moving along with unprecedented water signals, and has provided valuable lessons.
- There has been major progress in the metal end-window issue, although the proof will be in the upcoming tests.