Update on the SBS G_E^n polarized ^{3}He target

- Comments on milestones
- Progress on engineering
- Progress on κ_0 measurement and lessons learned
- Progress on cell development and production
  - Status of metal-window development.
  - Record polarization achieved using dual-direction optical pumping.
  - Polarization test of Stage-I (3 liter) target cell
  - Preparations for production of Stage-II target cell.

G. Cates - UVa
SBS Polarized ^{3}He target update
May 24, 2017

Progress on target milestones and updates

As presented at November review → **Target milestones**

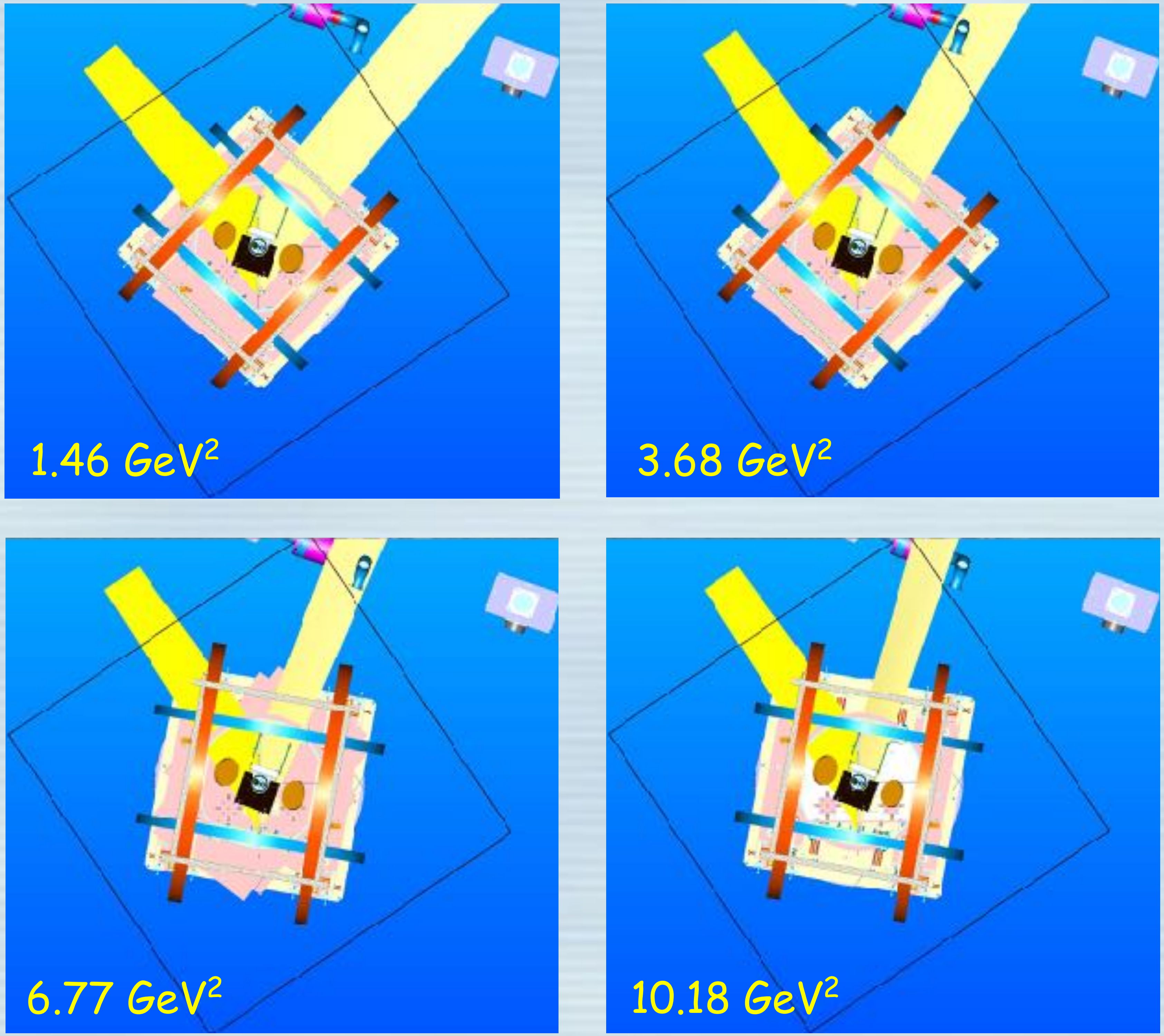
*** Selection of target cell design	Nov 2014	(Complete)
Conceptual design document complete	January 2016	(Complete)
Conceptual design review	March 2016	(Complete)
Start bench test of 3 liter glass conv. target	April 2016	(Complete)
Conceptual design frozen	June 2016	(Complete)
Test of glass/metal technology complete	June 2016	(Complete)
Begin engineering and design	July 2016	(Complete)
Bench test of 3 liter glass/metal target	January 2017	→ Nov. 2017
*** Simulated beam test (bench test) (full scale 6 liter cell)	September 2017	→ July 2018
Begin production of full-scale cells	November 2017	→ Aug. 2018
End of engineering	January 2018	
*** Design complete of target hardware and Instrumentation	June 2018	
*** Target is ready	January 2019	→ Mtg. this afternoon to determine. Probably March 2019?

Cell production complete June 2019

Mtg. this afternoon to determine
Probably March 2019?

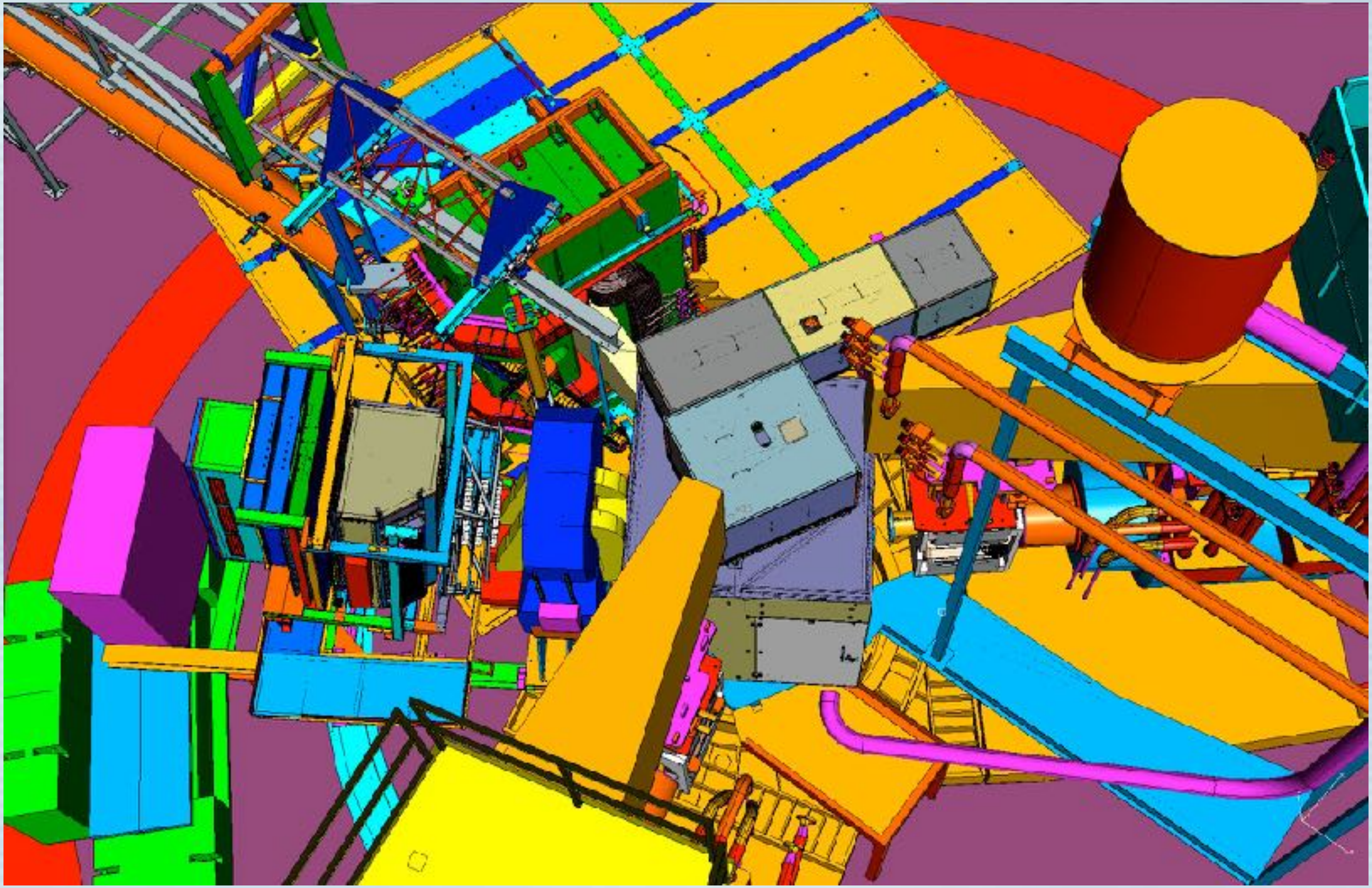
Engineering

Kinematic settings for SBS G_E^n target



Design accommodates the acceptance for all kinematic points.

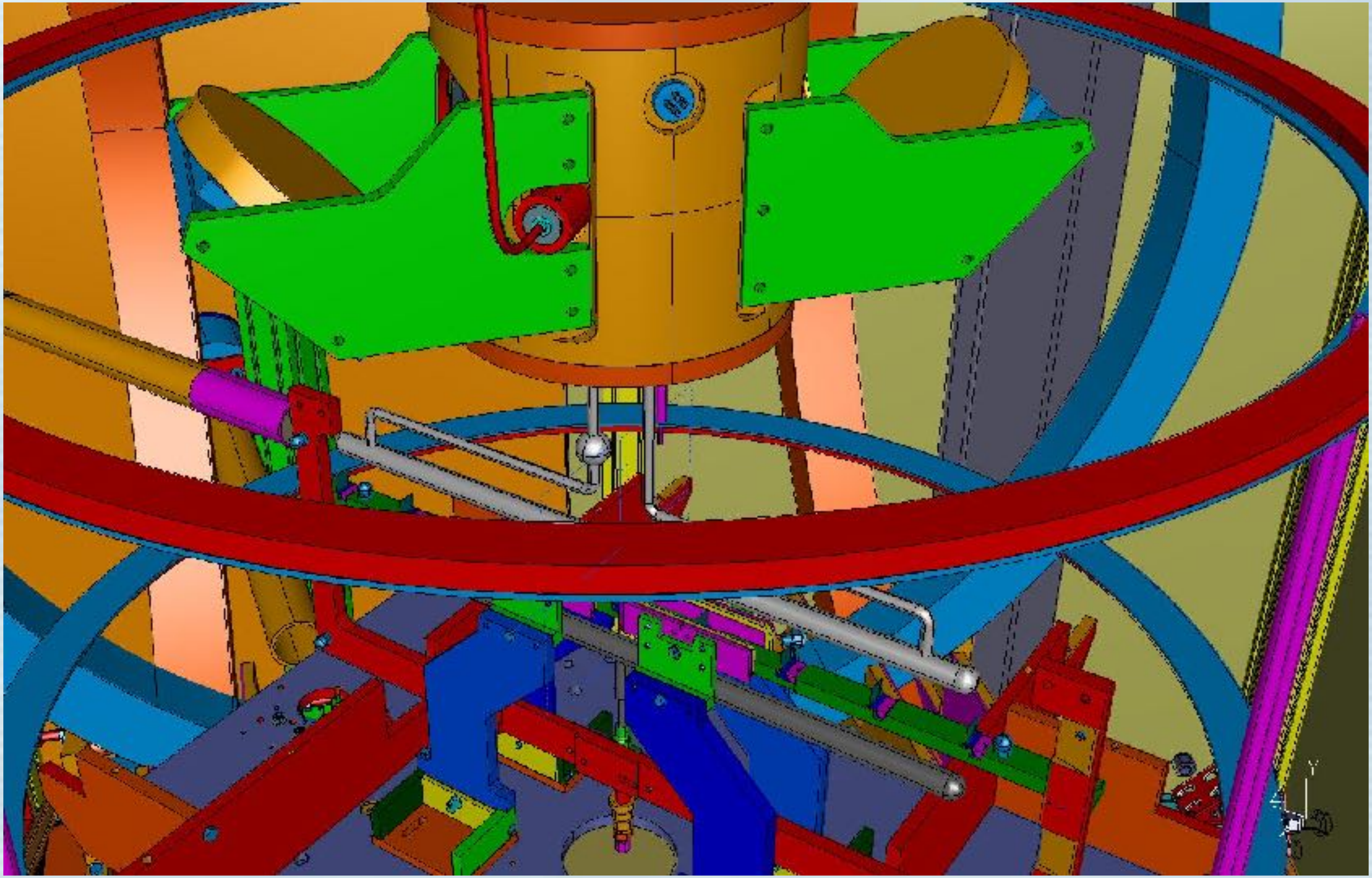
Current state of the engineering design



Overview of GEn target on the pivot.

New since
Nov. review

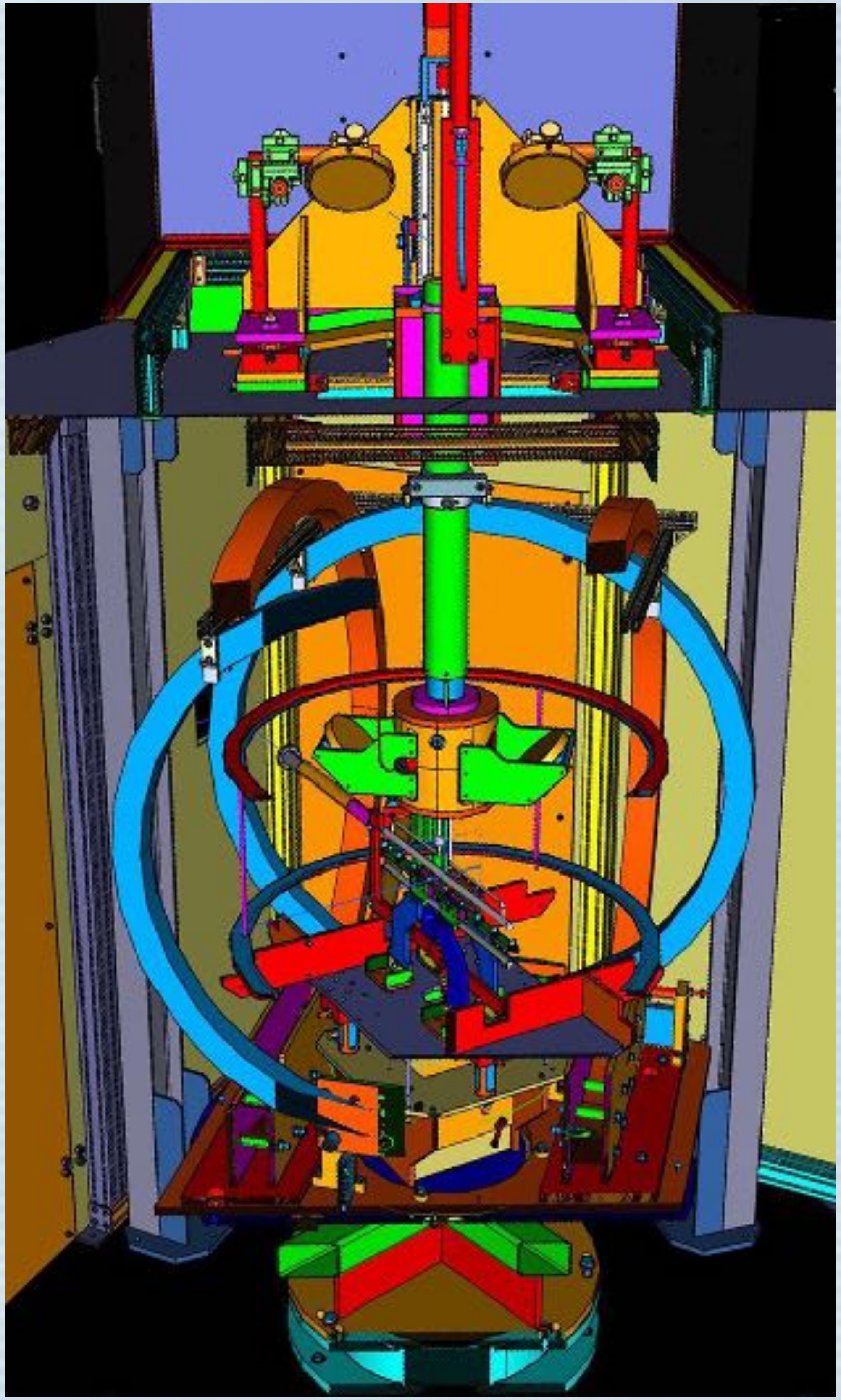
Current state of the engineering design



Closeup emphasizing area around target cell.

New since Nov. review

Current state of the engineering design

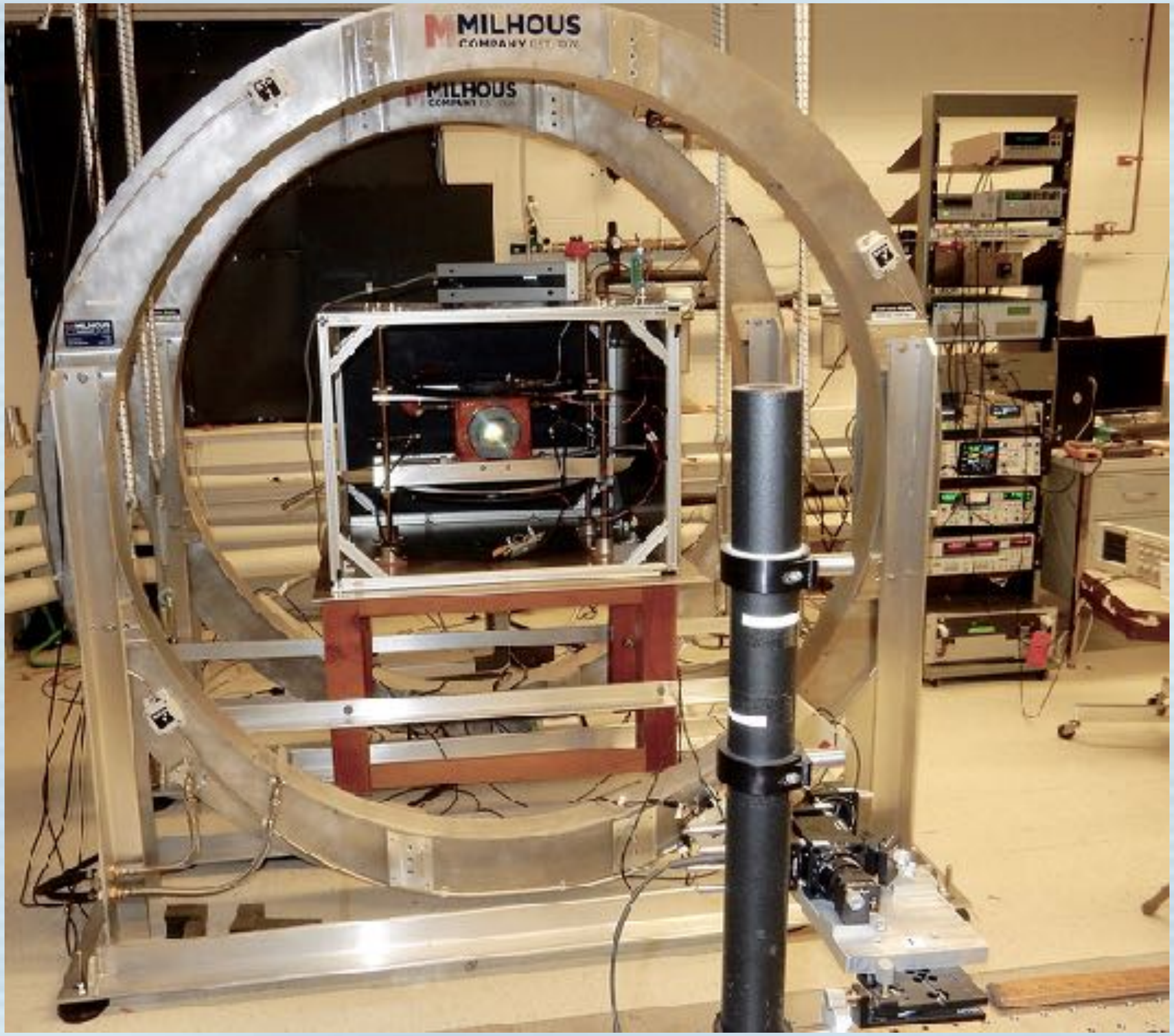


Closeup emphasizing target ladder.

New since Nov. review

Progress on κ_0 measurement and lessons learned

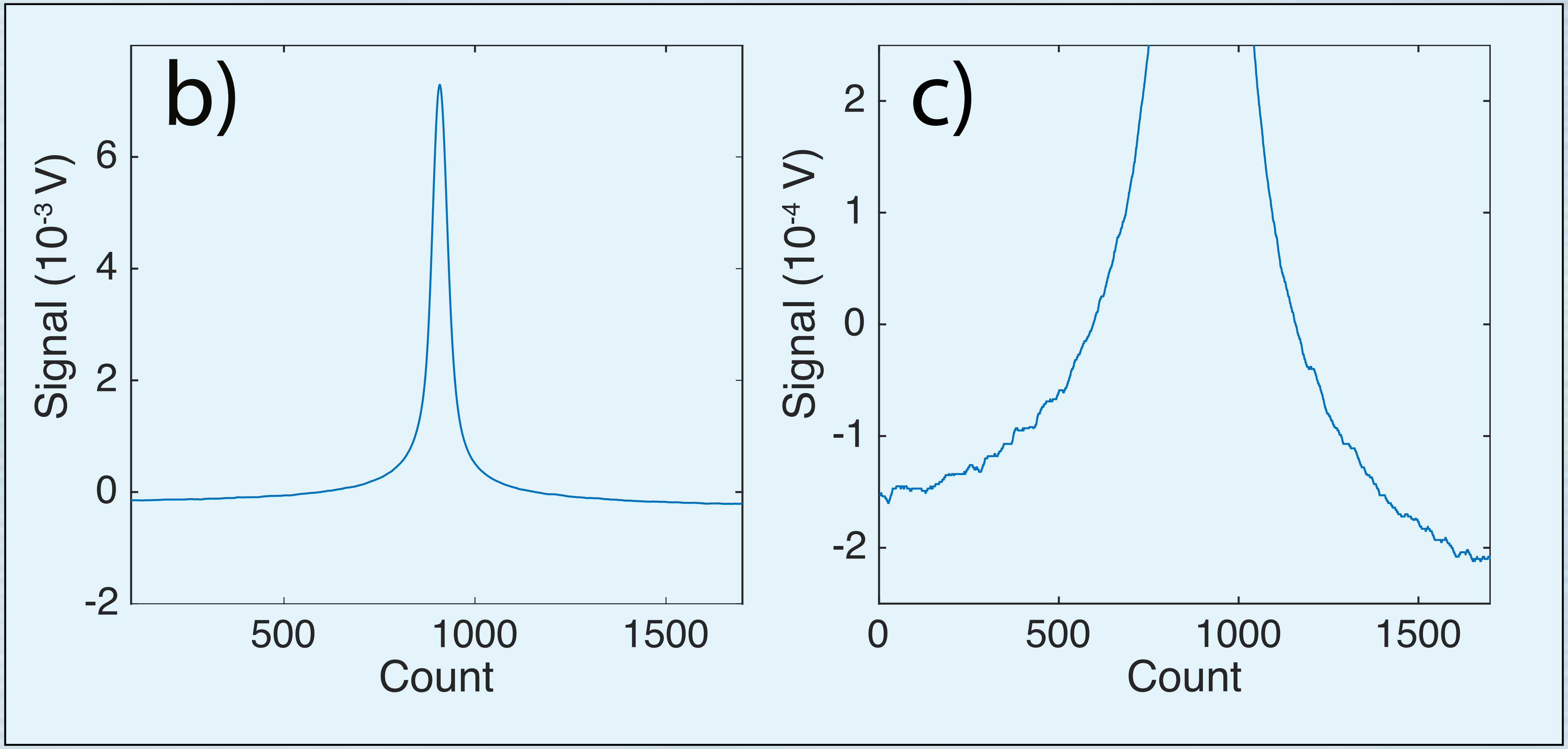
Apparatus for κ_0 measurement



- Apparatus significantly more complete since November review
- Apparatus is suspended by bungee cords to suppress microphonic-induced noise.
- Aluminum shielding suppresses electromagnetic noise.
- Wonderful signal:noise ratio achieved.
- Unfortunately, when fully shielded, excessive AFP losses occur.

New since Nov. review

S/N ratio approaching 1000 achieved
(and the system is not yet fully optimized)



Design is working well for noise suppression.

New since Nov. review

Relaxation due to inhomogeneous magnetic fields during resonance conditions

This paper, the usual reference for AFP losses, neglects the effects of inhomogeneous RF fields.

PHYSICAL REVIEW A VOLUME 38, NUMBER 10 NOVEMBER 15, 1988

Spin relaxation in gases due to inhomogeneous static and oscillating magnetic fields

G. D. Cates, D. J. White, Ting-Ray Chien, S. R. Schaefer, and W. Happer
Department of Physics, Princeton University, Princeton, New Jersey 08544
(Received 27 June 1988)

We have extended a recent theory of spin relaxation in gases due to static magnetic field inhomogeneities to include the effects of oscillating magnetic fields. We use this theory to show how magnetic field inhomogeneities cause spin relaxation under magnetic resonance conditions. We have confirmed some of the main theoretical predictions by experimental observations. Spin relaxation in inhomogeneous magnetic fields can be used as a convenient new way to measure diffusion constants in gases.

Recent studies of the effects for earlier target work at JLab seemed to describe things nicely.

$$\frac{1}{T_{1\rho}} = \frac{|\vec{\nabla} B_z|^2}{B_1^2} D$$

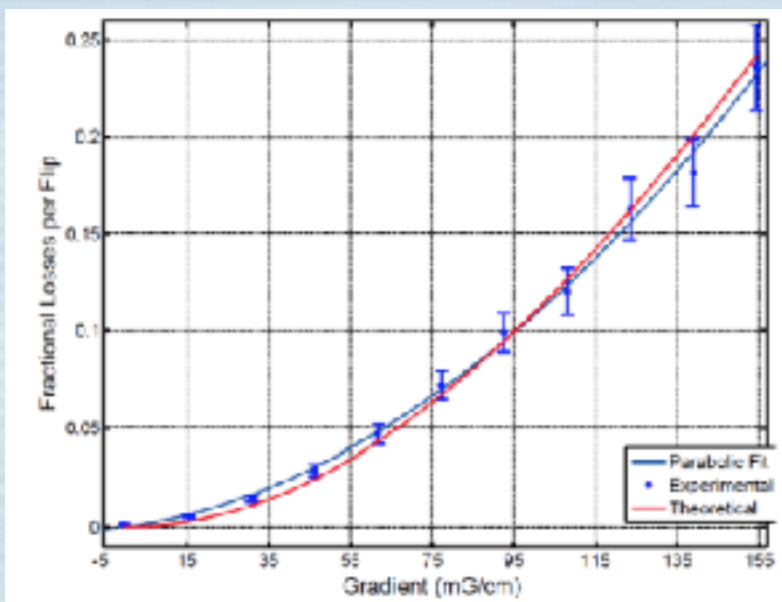


Figure 3.4: Fractional AFP loss (single flip) as a function of field gradient.

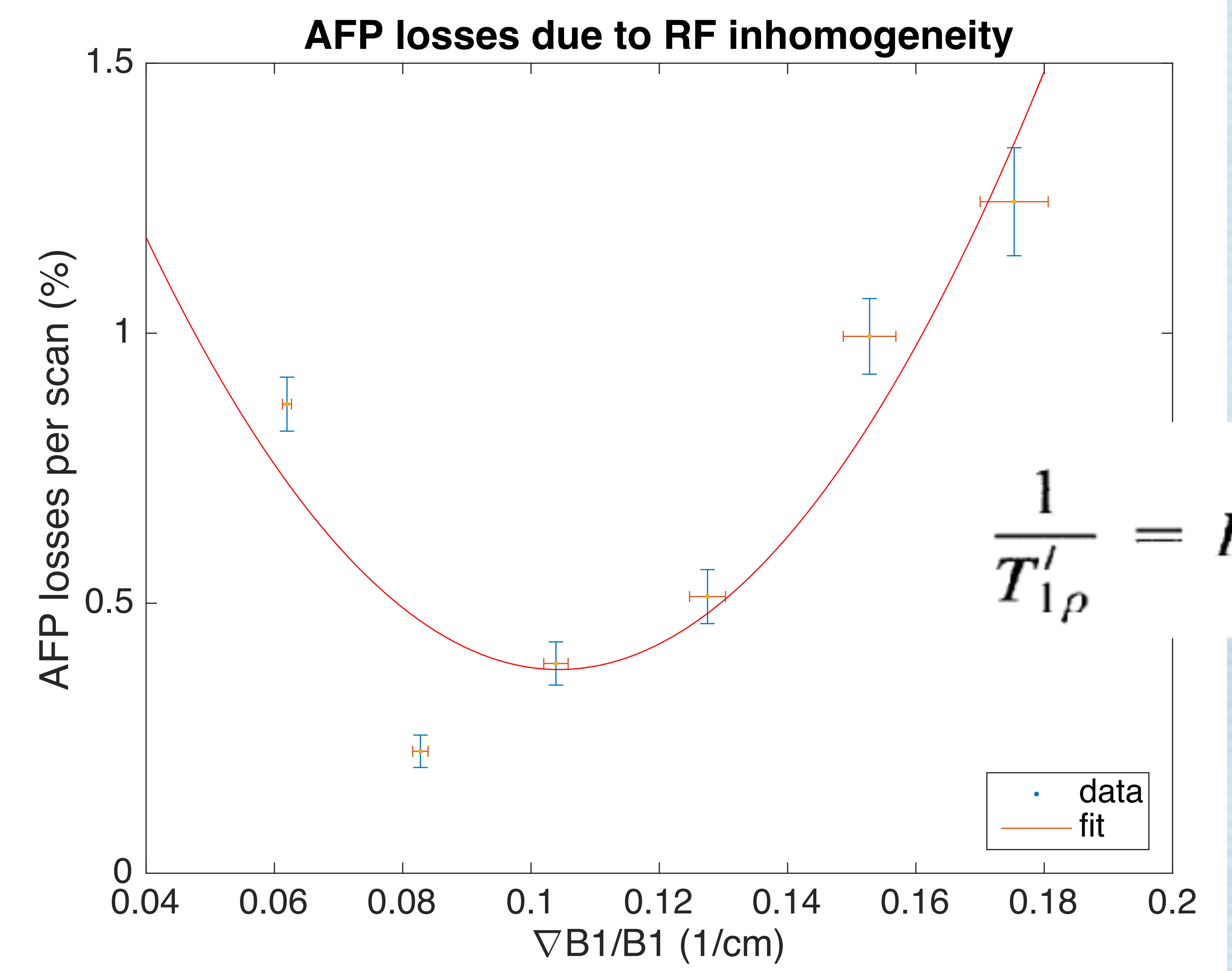
However, a later paper by Driehuys, Cates and Happer considered conditions where the RF inhomogeneities needed to be included:

PRL 74, 4943 (1995)

$$\frac{1}{T'_{1\rho}} = D\left[\frac{|\nabla H_{0z}|^2}{H_{1I}^2} + \frac{|\nabla H_{1I}|^2}{H_{1I}^2}\right]$$

New since Nov. review

We were led to study the AFP losses due to RF inhomogeneities



PRL 74, 4943 (1995)

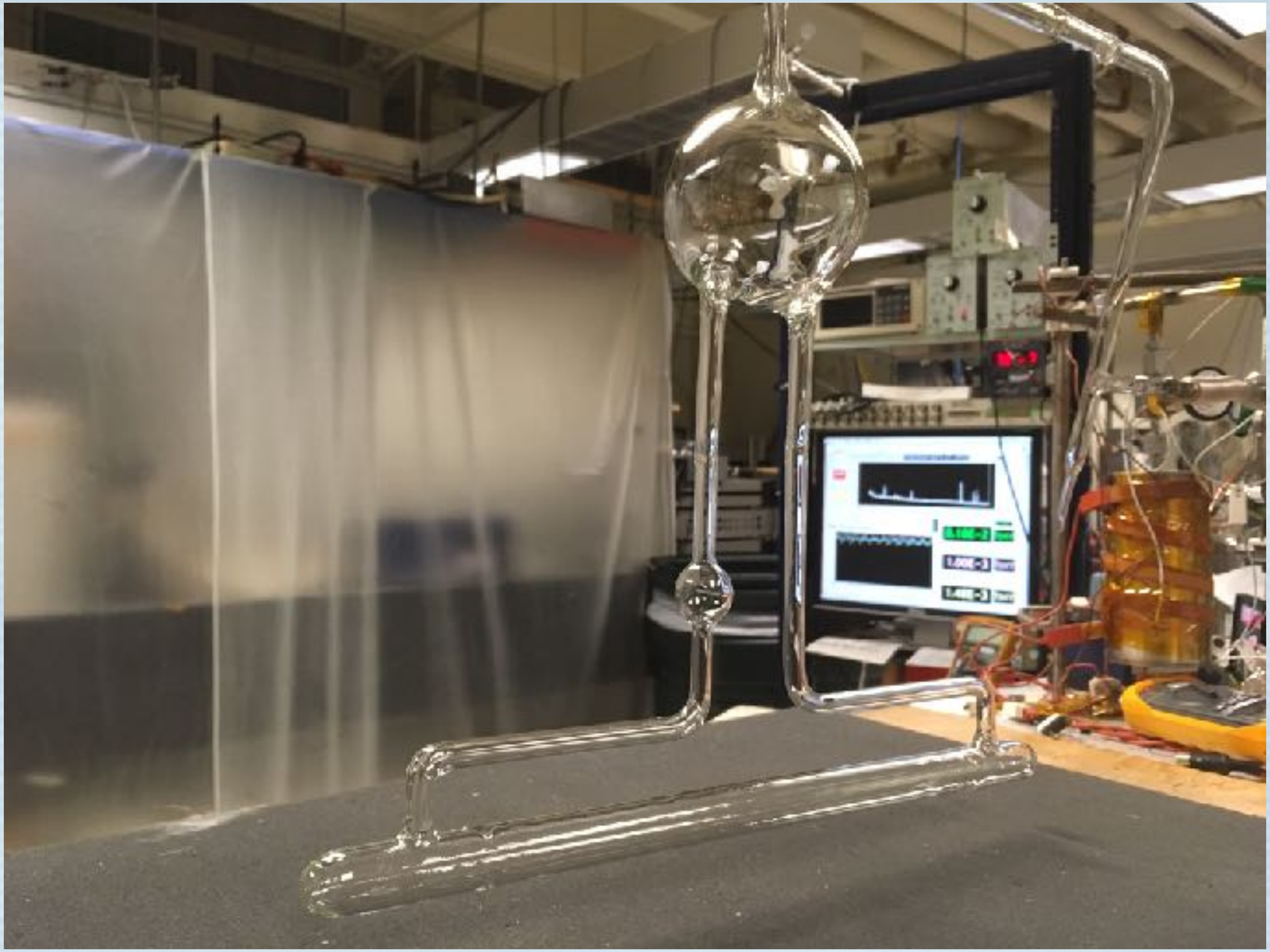
$$\frac{1}{T'_{1\rho}} = D\left[\frac{|\nabla H_{0z}|^2}{H_{1I}^2} + \frac{|\nabla H_{1I}|^2}{H_{1I}^2}\right]$$

This term previously neglected

New since Nov. review

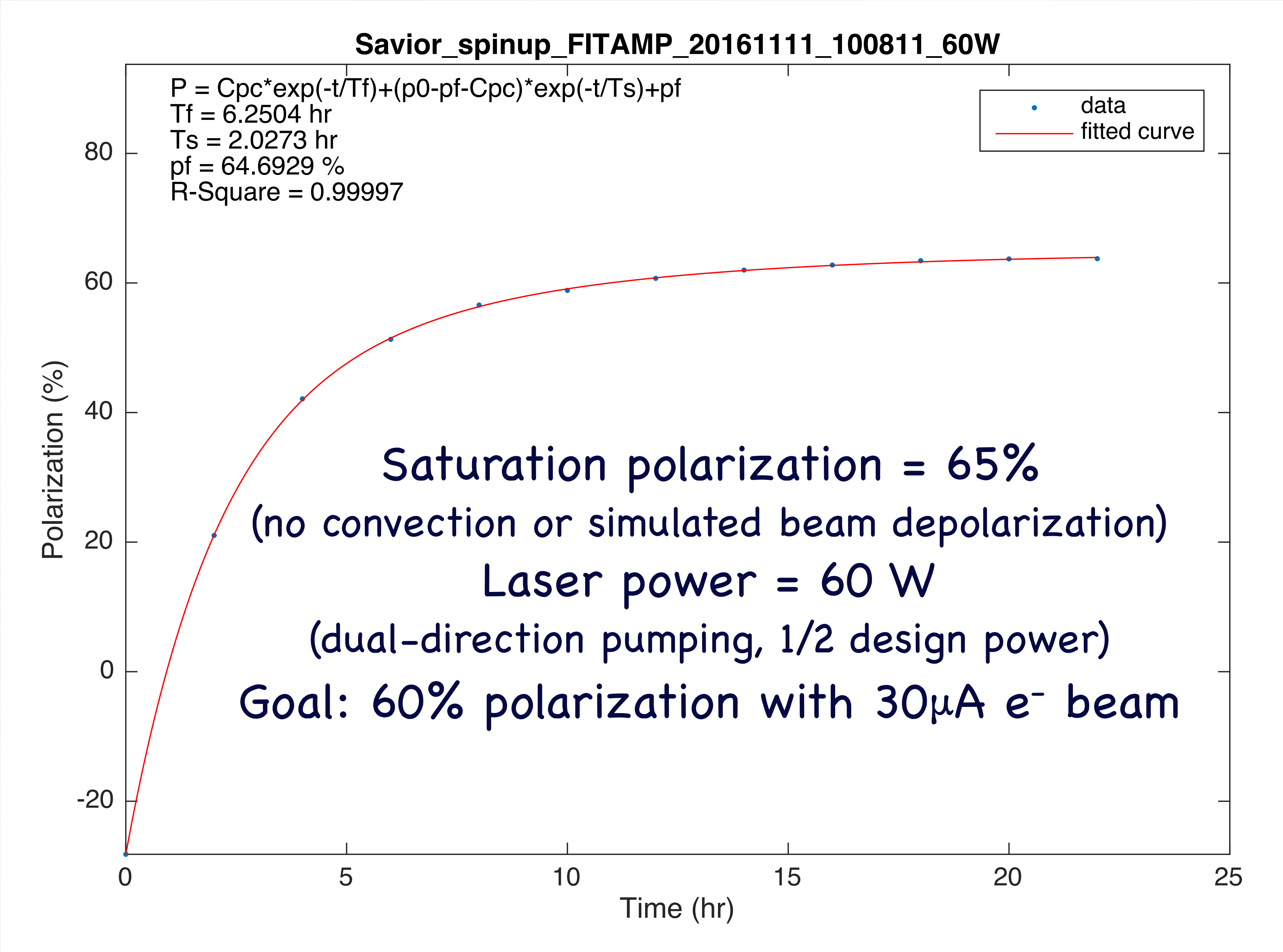
Progress on cell development and production

Stage I target production underway



Shown is the Stage-I (3-liter) target cell "Savior"on the UVa gas-handling system prior to being filled.

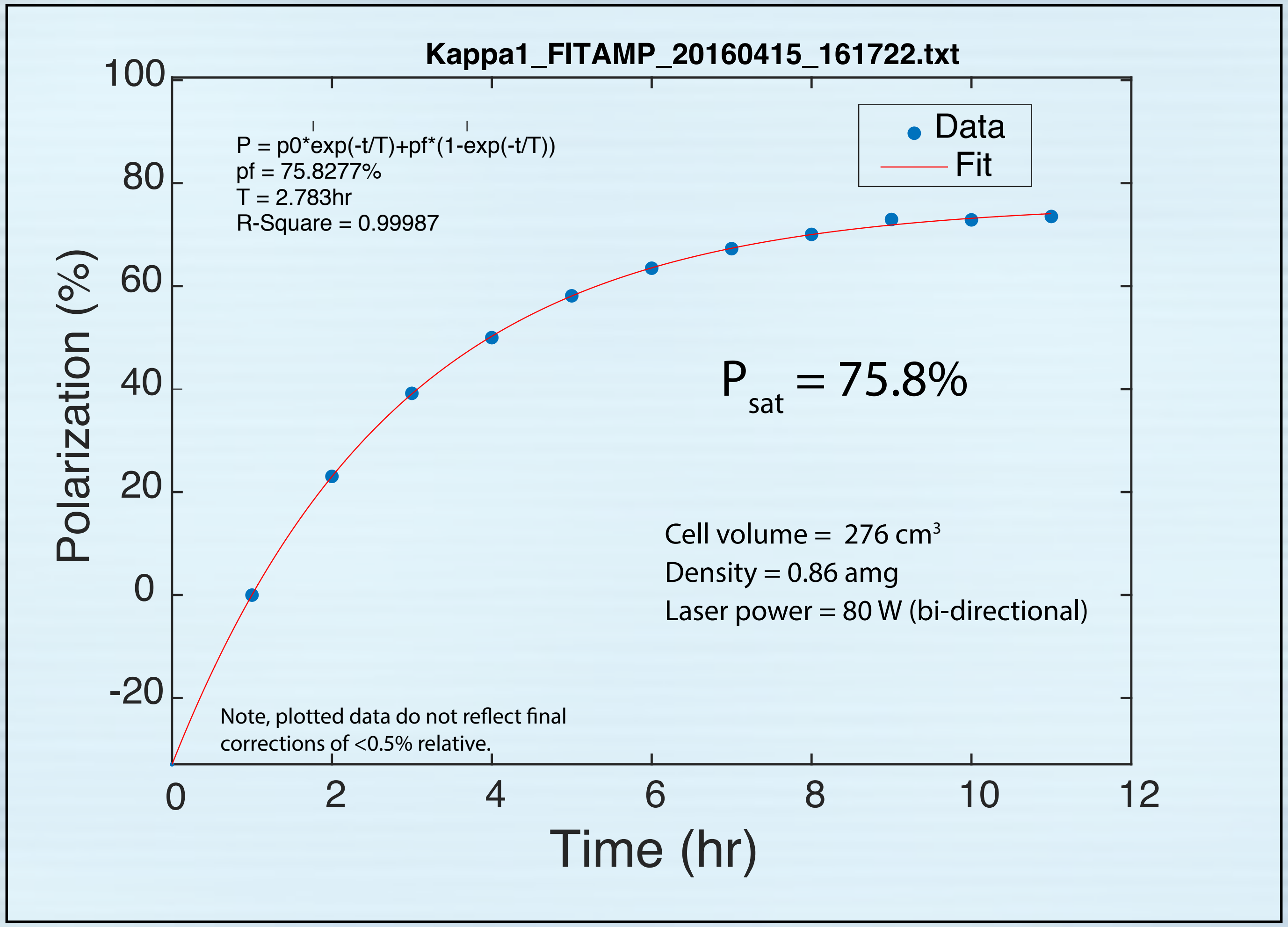
Stage-I polarization test of Savior

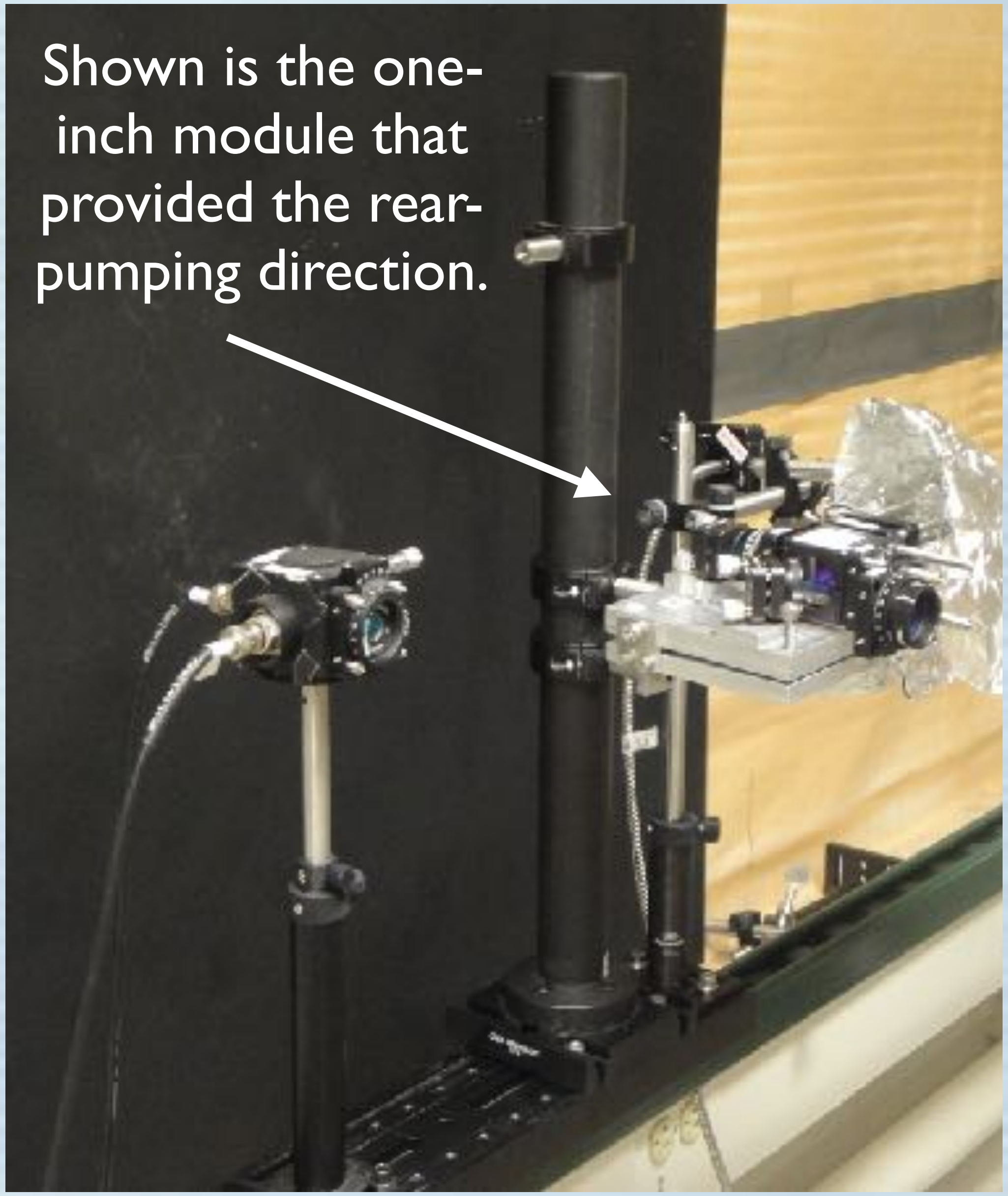


While not yet conclusive, test is very encouraging regarding the ultimate performance that is required.

New since Nov. review

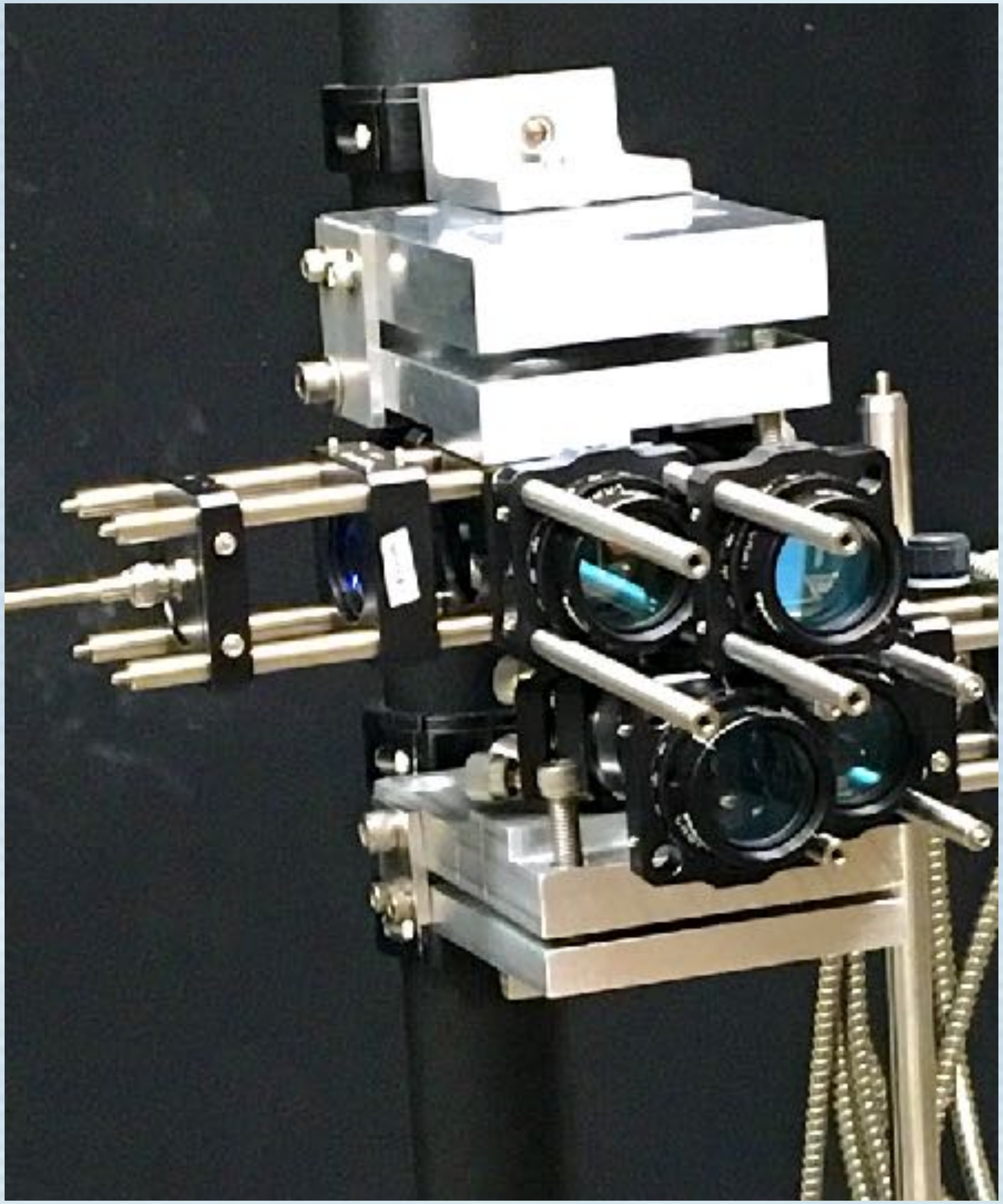
First test of dual-direction pumping





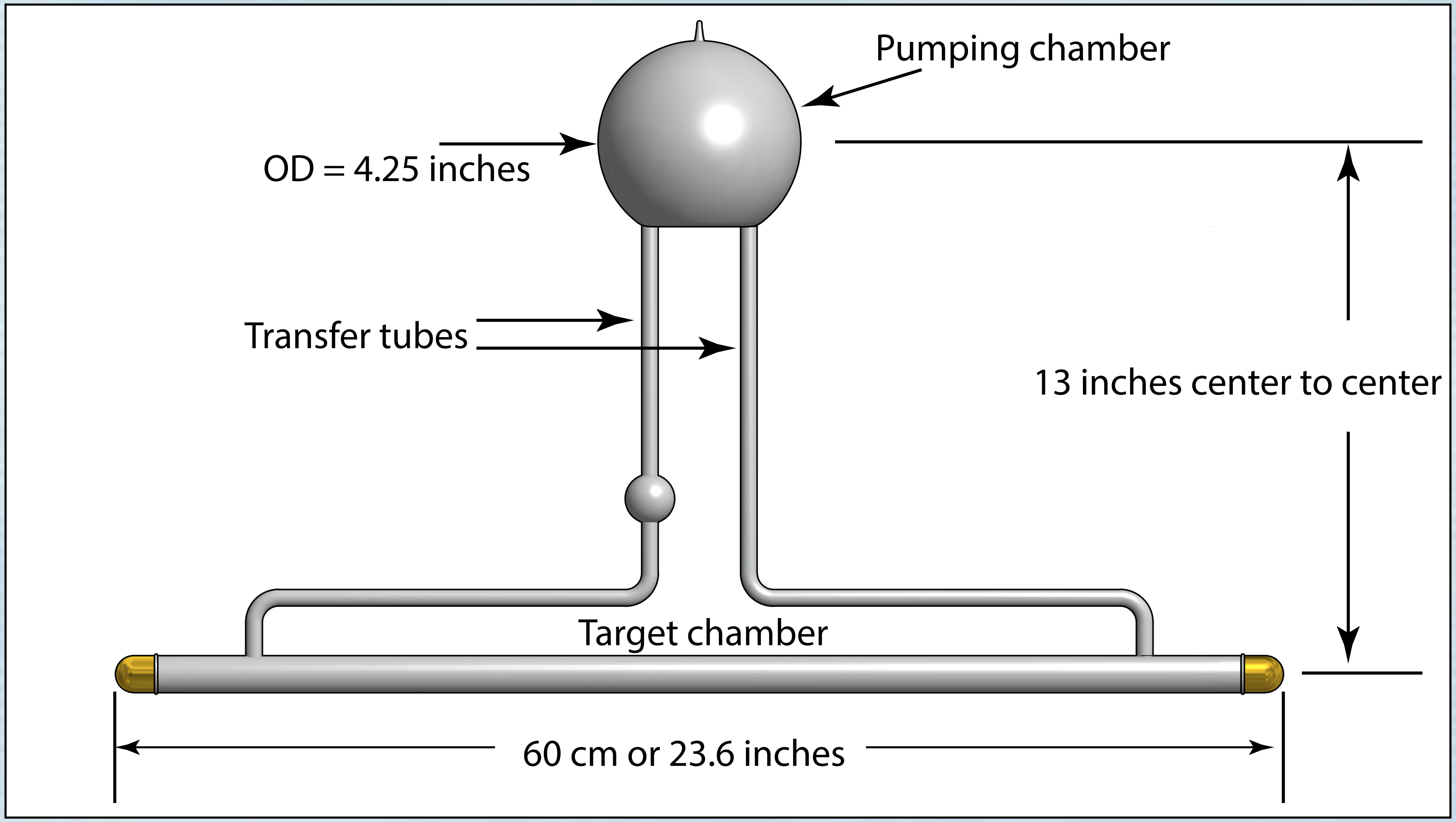
- Spherical cell, 3.25 inches outside diameter.
- Pressure just under one atmosphere.
- 40 Watts from three lasers combined with five-to-one combiner from the "front" pumping direction.
- 40 Watts from single one-inch module from the "back" pumping direction.

More recent setup with two sets of optics stacked vertically



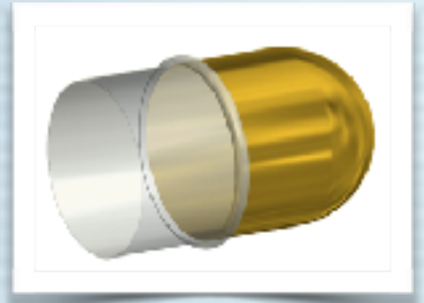
New since Nov. review

G_E^n style (Stage II) target cell design



Shown is the GEn target-cell design as it appears in the Target Conceptual Design Report

Window properties

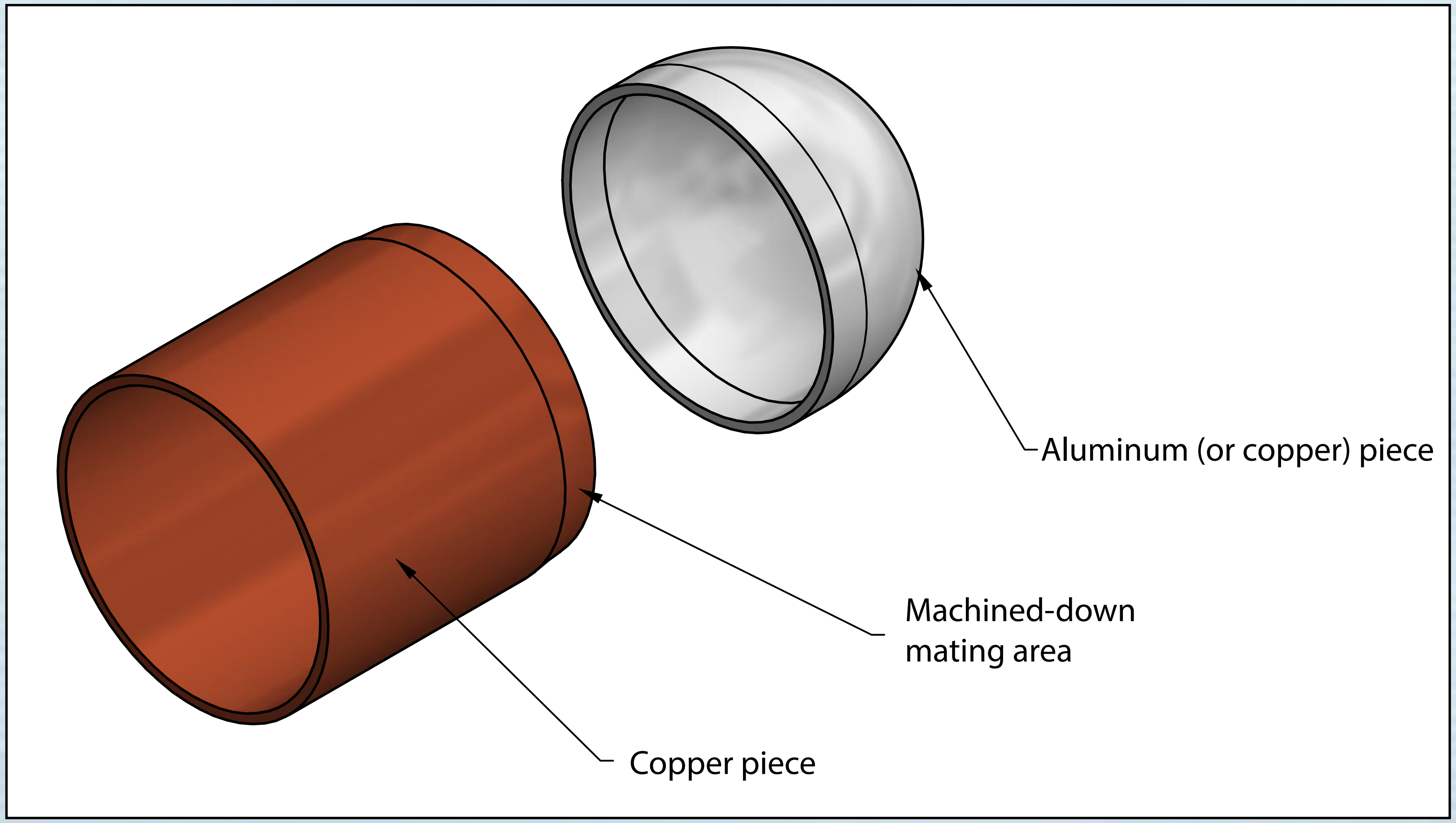


For several materials, the window thickness such that the "yield point" occurs at pressure 50% greater than the operating point. Existing GE-180 glass windows included for comparison.

Material	Density (g/cm^3)	Melting Point (^0C)	Yield Strength (MPa)	Min. Thickness Needed (um)	Min. Thickness Needed (mg/cm^2)	Radiation Length (mg/cm^2)	Number of radiation lengths
OFHC	8.9	1065	49	172.09	153.16	$1.247*10^4$	0.0123
Cartridge Brass	8.53	916	441	19.12	16.31	$9.439*10^3$	0.0017
Glidcop Al-60	8.81	1083	413	20.42	17.99	$9.693*10^3$	0.0019
GE 180	2.76	1015		139.7 (thickness used)	38.56 (thickness used)	$1.388*10^4$	0.0028
Al	2.7	~ 600	55	153	41.40	$1.591*10^4$	0.0026

If spin-relaxation properties are acceptable, aluminum is the preferred solution.

Thin window development



- Aluminum is an attractive material for the end windows, but gold-coated aluminum has not yet been tested for its spin-relaxation properties.
- We are in conversation with Epner about the best way to attach and coat the aluminum "end cap".
- Hope to construct and study test cells with aluminum end caps within one or two months.
- A successful test could lead to a target cell with metal end windows within one to two months after successful test (3-4 months out).

Summary of progress on Stage-II target cell production

- Stage-I production is leading naturally to the production of the larger Stage-II target cells.
- Recently re-vamped our pressure broadening oven to accommodate the larger target cells, both Stage-I and Stage-II.
- Successful metal end-window tests will lead quickly to producing a Stage-I target cell with metal end windows.
- Once a viable Stage-I target is produced with metal end windows, we will move to the (even larger) Stage-II target cell production.

Overall summary

- We are essentially ready to begin full-scale production of Stage-I target (to be used in, for example, A_1^n).
- The only remaining obvious technical challenge or Stage-II production is the successful test of a viable end cap.
- Engineering is almost on track (which, unfortunately, puts us well ahead of any likely dates for scheduling).
- Metal end window work was somewhat delayed while we studied the problems associated with RF inhomogeneities (which is relevant to the engineering design).
- Bench tests, while not yet conclusive, support the Conceptual Design as viable for the required performance.