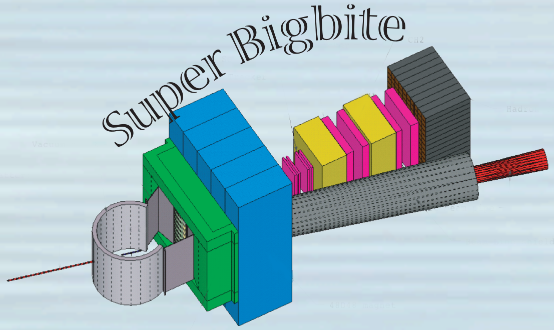
Defining the ^{3}He Target-Design for SBS and A_1^n

- Quick summary of overall approach, and reasons for proceeding in this direction.
- Feasibility of adapting Transversity hardware.
- What is needed to achieve our goals.
- Progress toward metal end windows



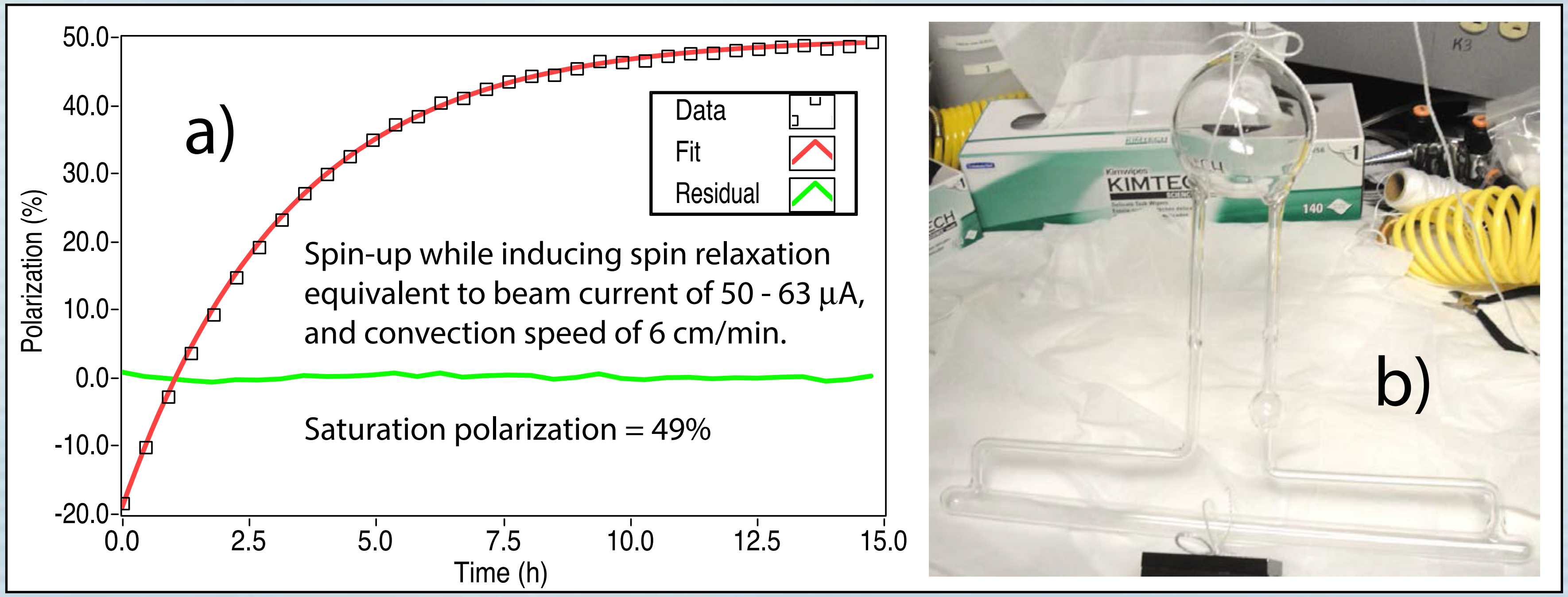
G. Cates, UVa
Sept. 4, 2013

Jefferson Lab
EXPLORING THE NATURE OF MATTER

Intro/Preface

- Ideally, we would build something that would lead directly to the full next-generation target, and approach that might be cheaper in the long run.
- By adapting the Transversity hardware and using a single-pumping-chamber cell, however, we are likely to save money in the short term.
- We need to convince ourselves that this plan is feasible, and understand its limitations.
- We need to define what is required to pursue this approach.

Why are we even having this discussion?



Simulated beam tests suggest that at least 49%, is achievable with 45 μ A on a Protovec style cell.

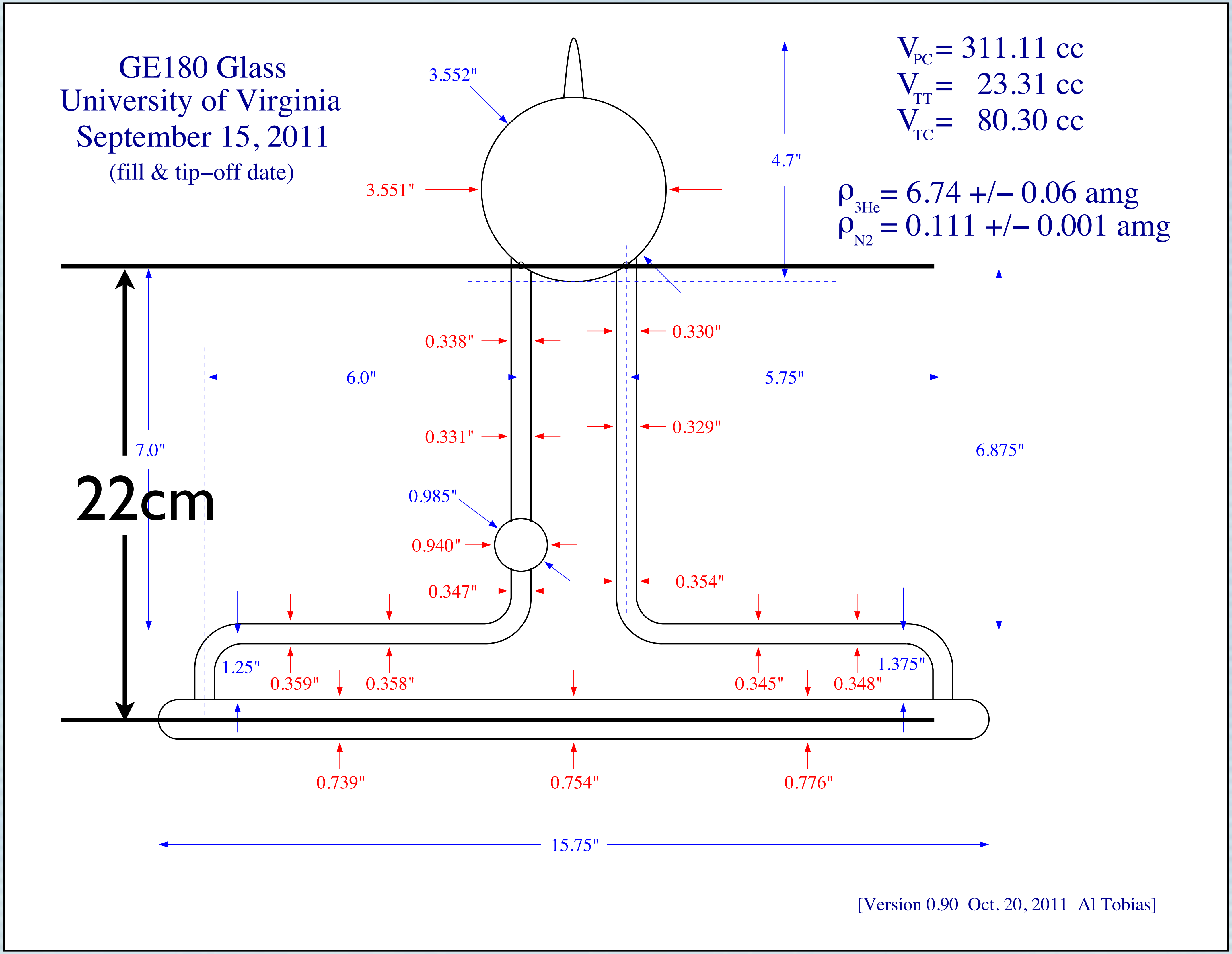
It is likely that 55-60%, should be achievable with 30 μ A of beam on a Protovec-style cell.

Down-graded Performance Requirements for the polarized ^3He system

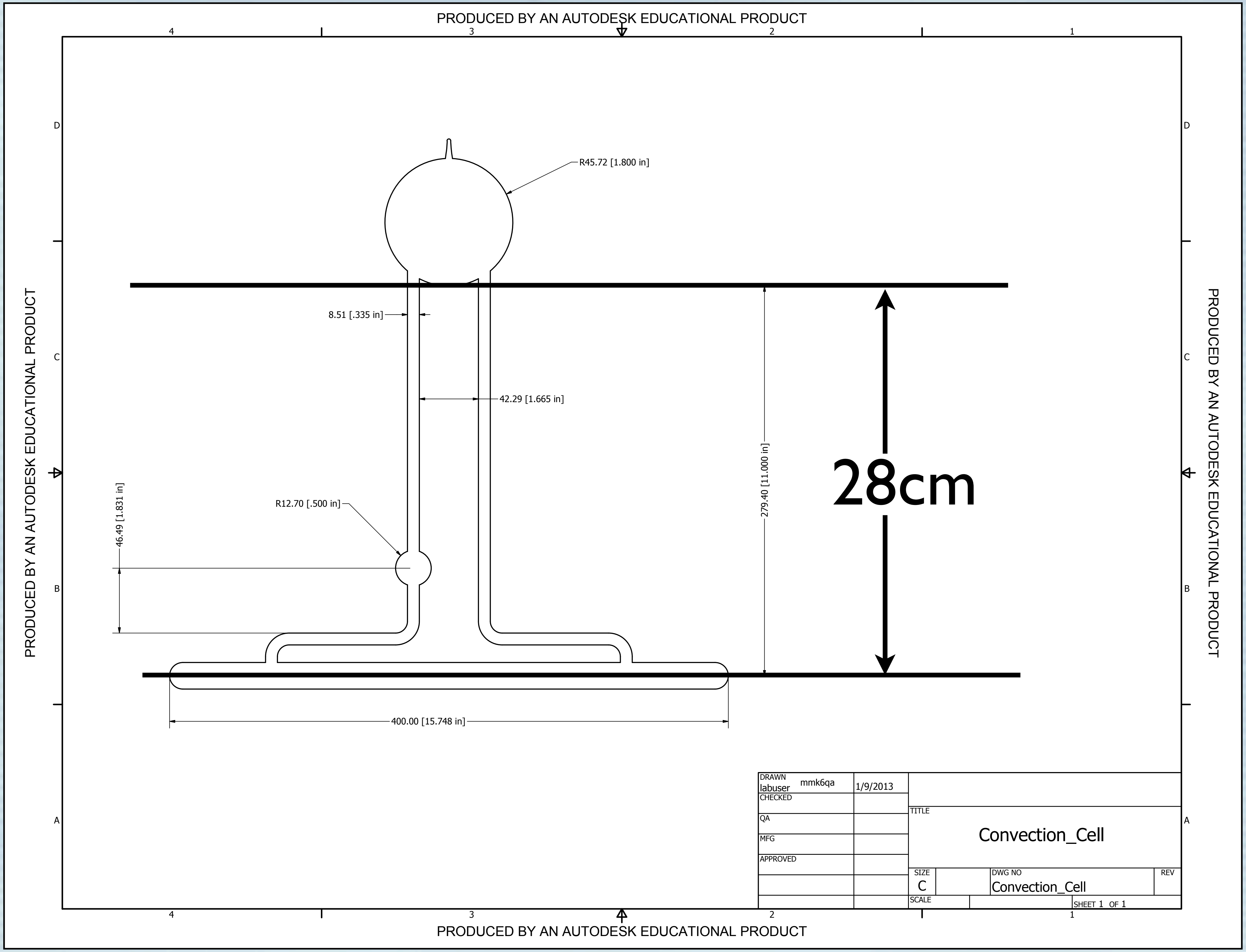
- Achieve 55% polarization (or better) at 30 μA.
- (Unweighted) luminosity 2/3 of original design (40 cm target cell instead of 60 cm.
- Comparable longevity to recent target cells (at least 4 weeks in the beam) despite twice the previous luminosity.
- Non-polarized targets should include:
  - Foils for optics
  - Target empty position
  - Reference cell capable of H_2, N_2, ^3He, or whatever

Can AFP be performed in a reasonable manner while using a modified version of Protovec in a Transversity-based system?

Existing, tested prototype: Protovec I

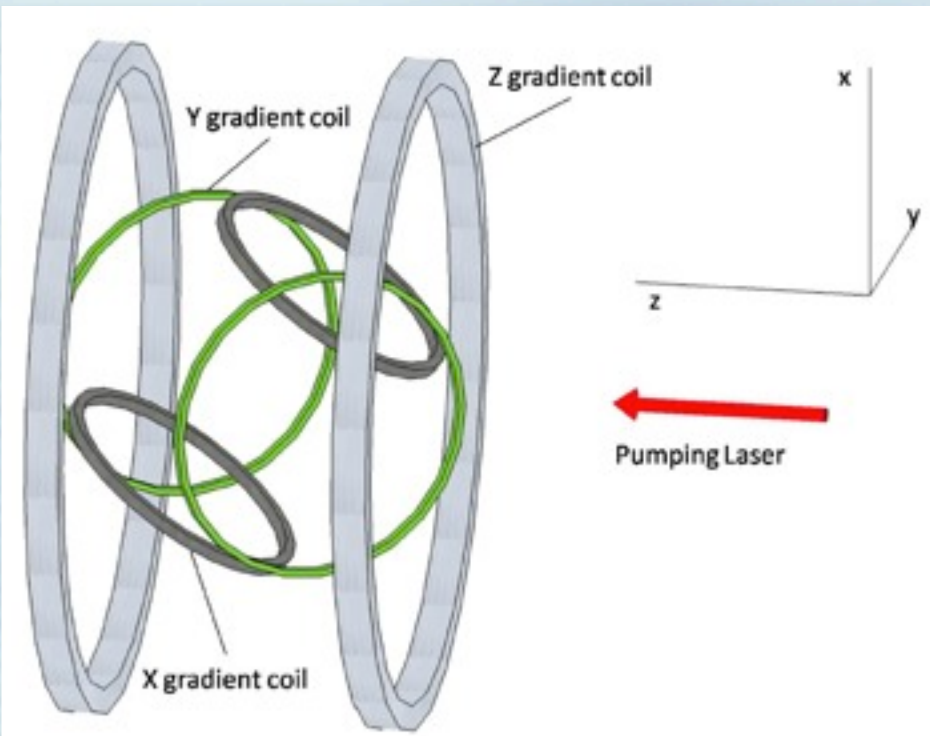


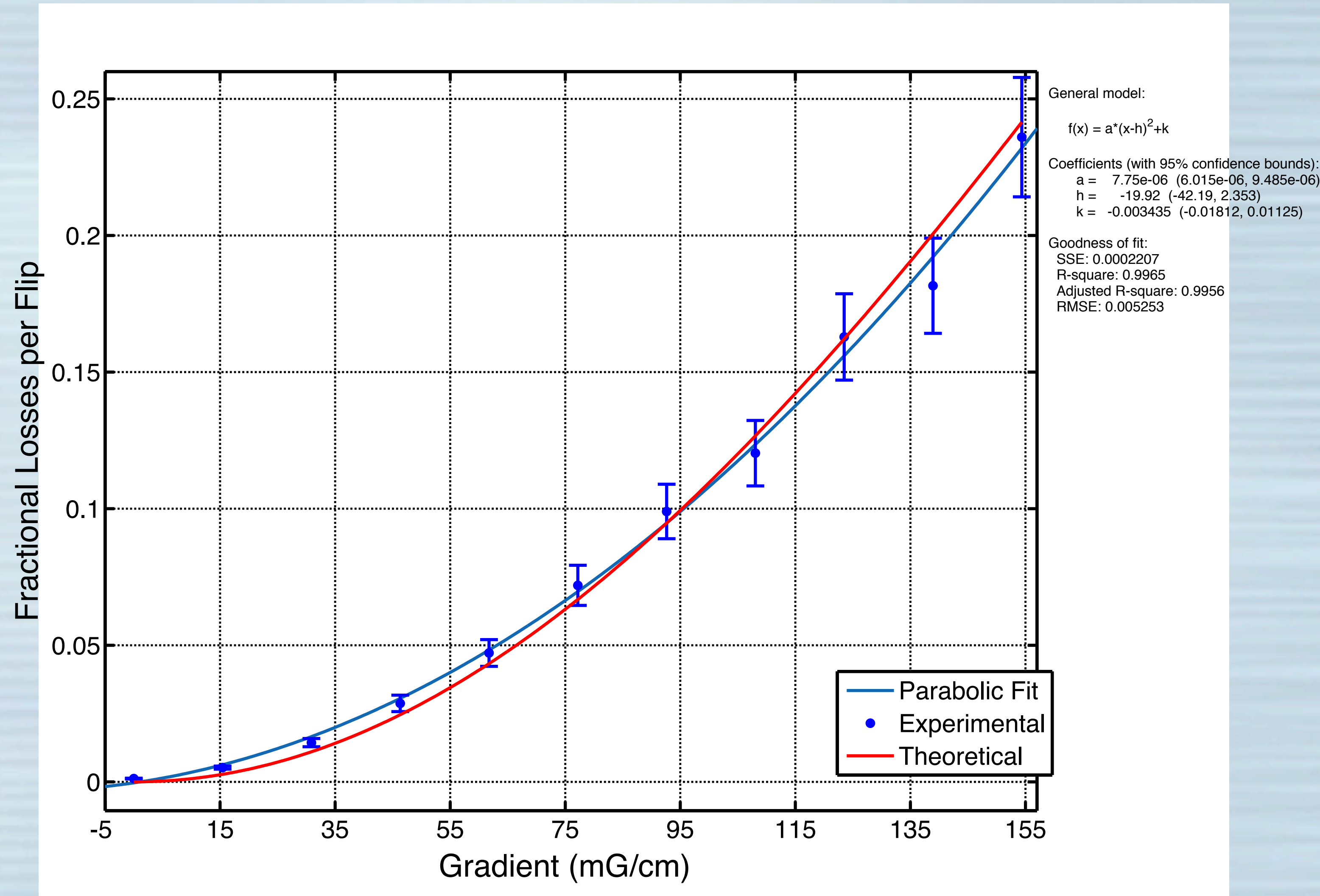
"Option C"



With minor modifications, this design is ready for production for A1n.

We have solid empirical evidence that we understand AFP losses

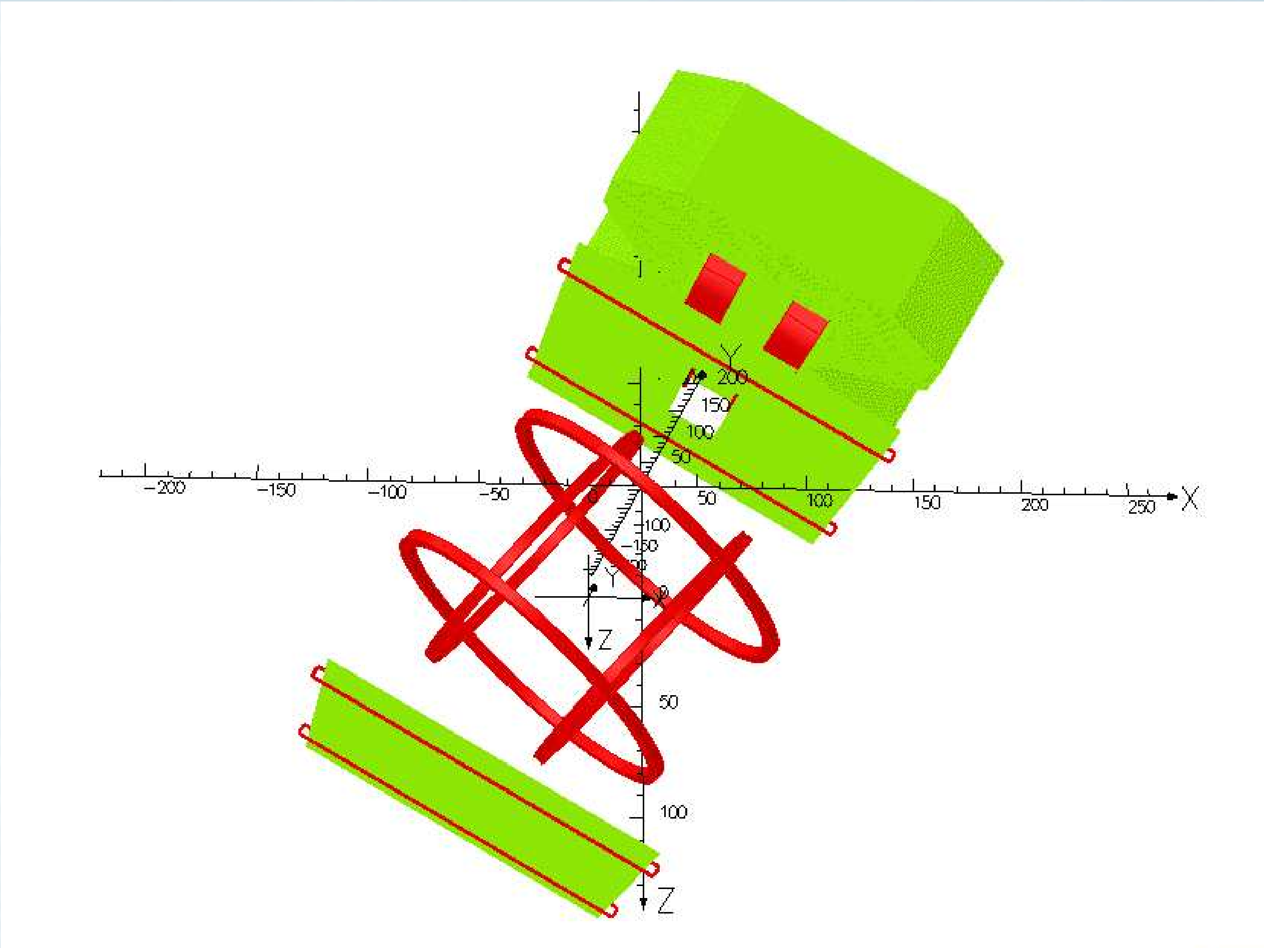




$$\text{fractional relaxation} = \frac{|\vec{\nabla} B_z|^2}{B_1^2} D \, \frac{\pi \, B_1}{2(\partial B_z / \partial t)}$$

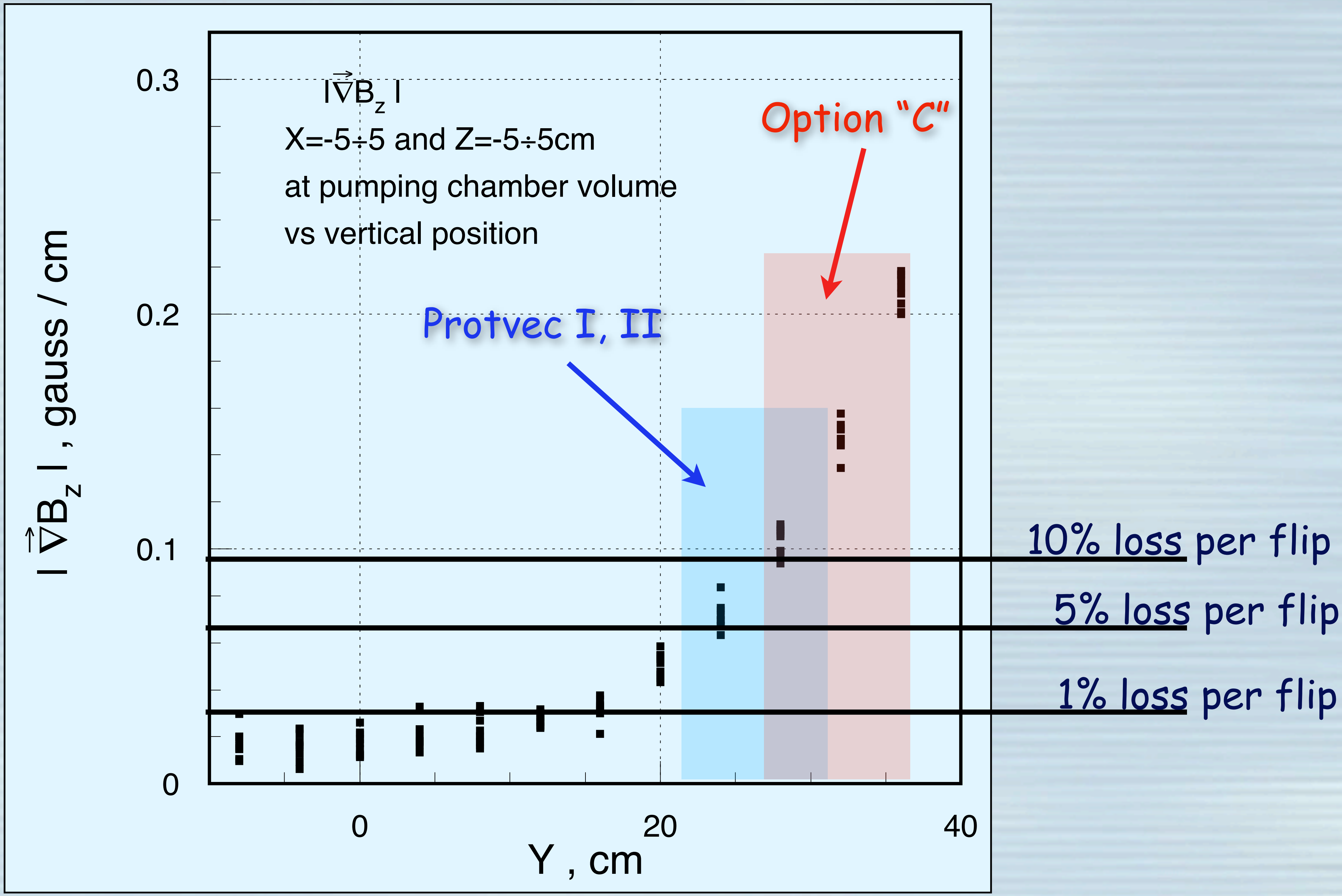
Measurements and theory agree extremely well

What are the magnetic field gradients that would be experienced by a cell such as Protovec or "Option C" ?



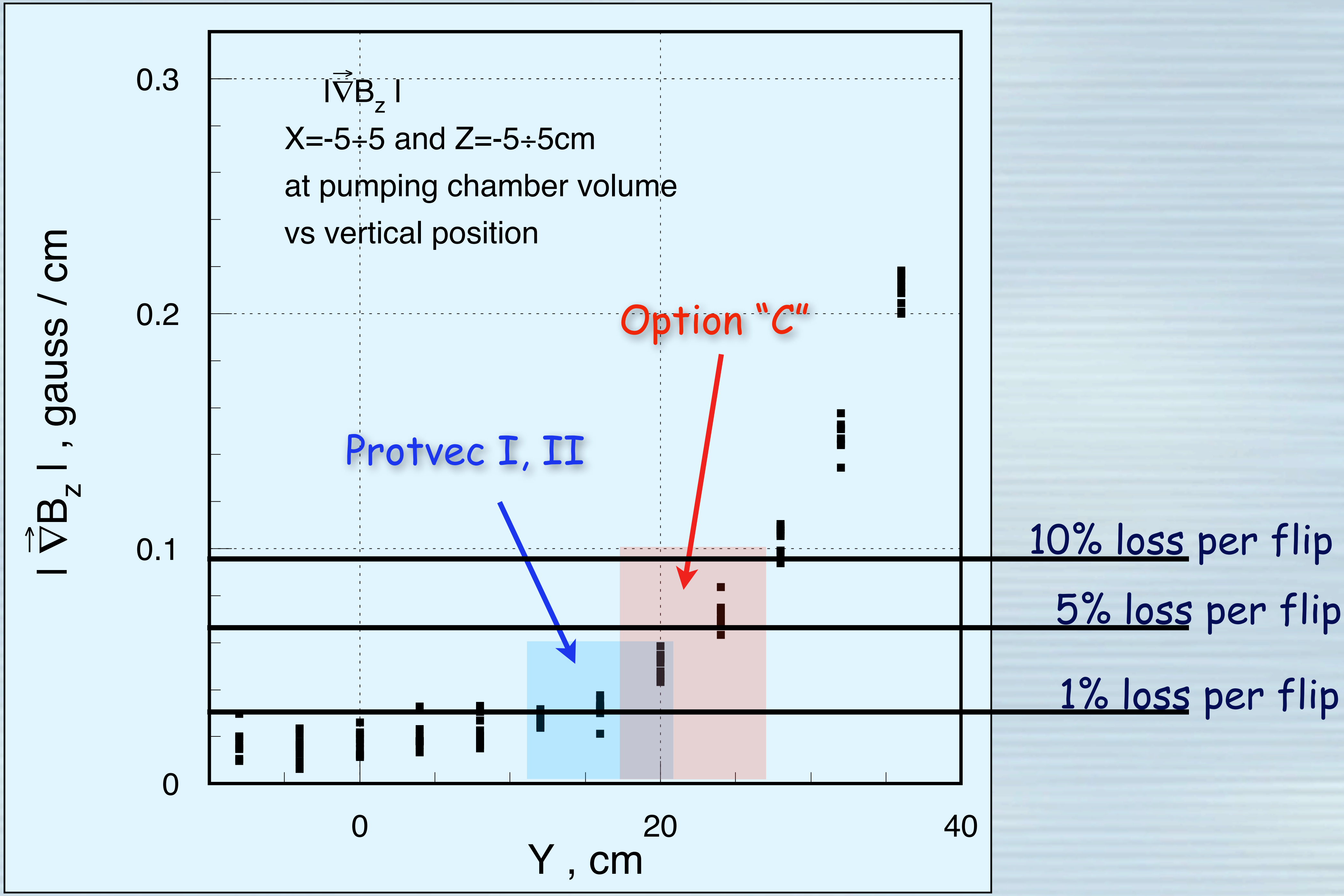
We now have reasonably extensive Tosca calculations that tell us what gradients to expect.

AFP-related inhomogeneities of Transversity Coils with field clamps with target-cell centered on beamline



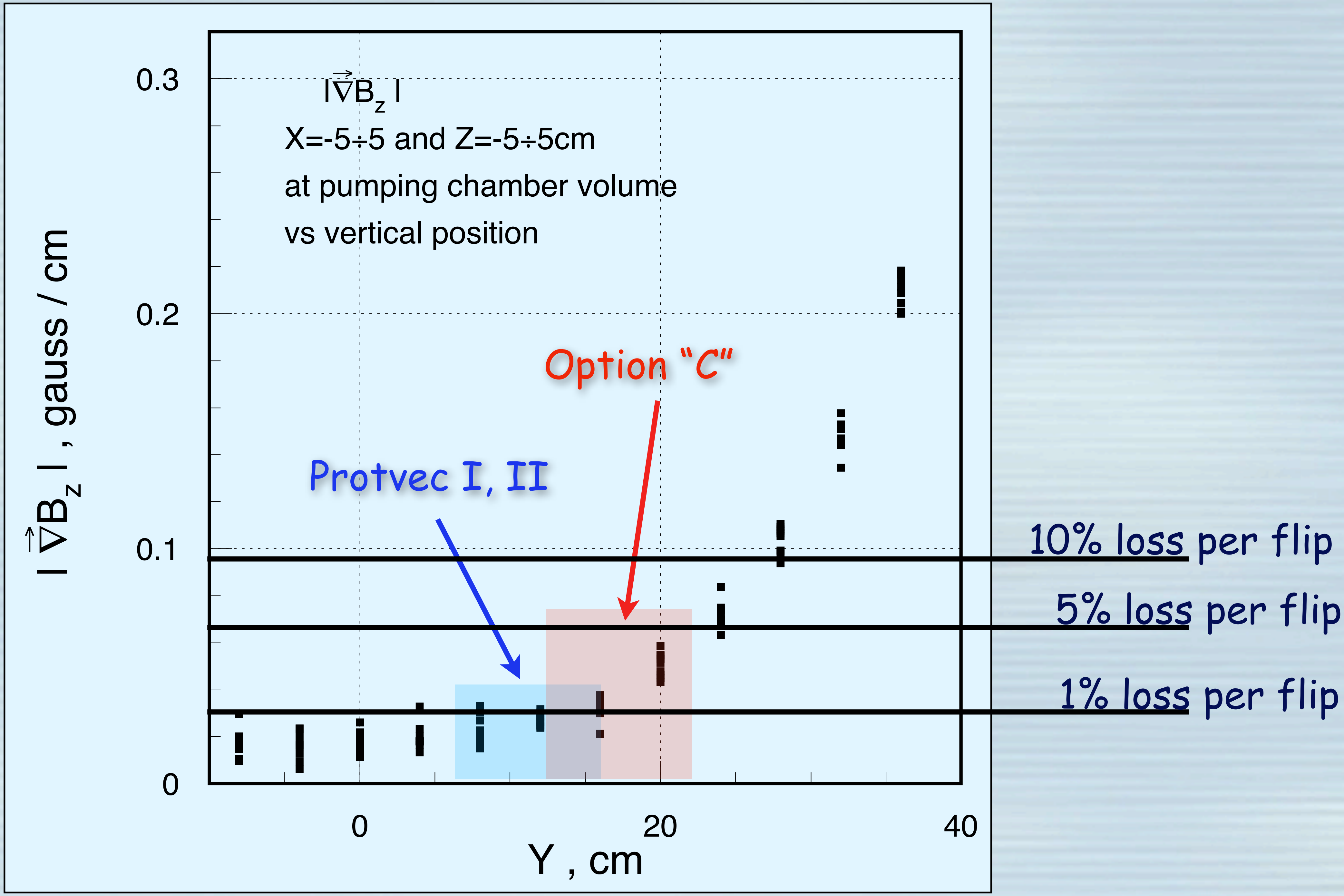
Both Protovec and Option C would have <u>totally unacceptable losses</u>

AFP-related inhomogeneities of Transversity Coils with field clamps with off-set target-cell position



Elevating the Transversity coils by 10 cm might keep losses per AFP < 12% or so.

AFP-related inhomogeneities of Transversity Coils with field clamps with off-set target-cell position



With Tranversity coils elevated by about 15cm, losses might be held to less than 5-7% per AFP measurement. More study is needed to confirm these numbers. Target chamber losses are not included in the above.

What is needed to implement this target?

Polarimetry Requirements

- Absolute accuracy of <3% is stated in the original proposal.
- On-line polarimetry should ideally have precision better than 3%.
- AFP losses need to be low enough for periodic absolute calibration. We have little experience with such a "high-loss" system, but losses lower than 5-10% would seem prudent.
- Need pulse NMR on-line polarimetry (since AFP losses will be prohibitively large).
- Need ability to make relative polarization measurements between the pumping chamber and the target chamber.
- Do not need to measure water at the target-chamber location.

Mechanical/Integration Requirements

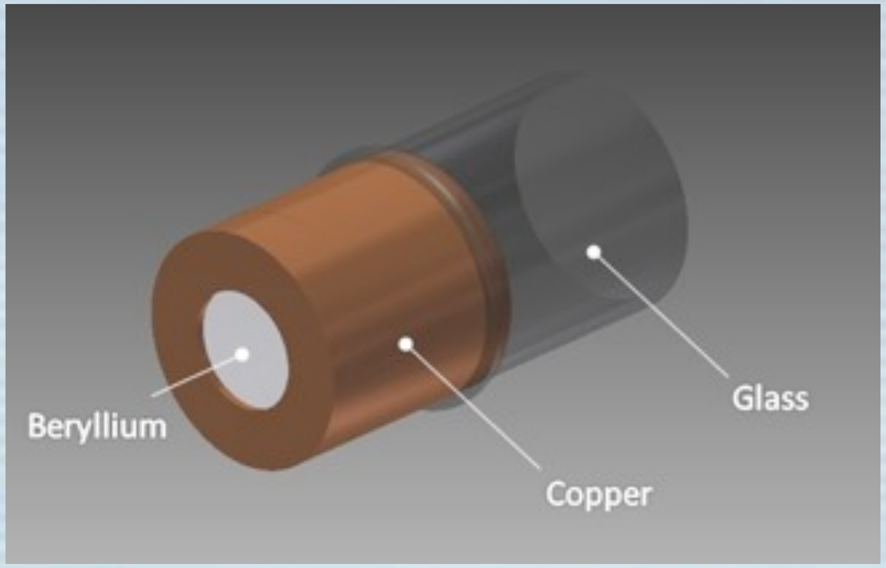
- (Transversity) coils need to be elevated 10-15 cm above old mounting position, which had the coils centered on the beam line.
- Field clamps, probably symmetric, are needed to control inhomogeneities.
- Target chamber pickup coils do not need to surround the cell except during infrequent absolute calibrations.
- Pulse NMR probe needed on spherical volume on transfer tube.
- Need to decide about issues such as having the target in vacuum (presumably not), helium bags, and beam-line window thicknesses.
- Oven needs to accomodate 3.5" pumping chamber and convection style cell.
- Oven should also incorporate a modest amount of shielding (potted Tungesten powder?).
- Convection heater needed, need to decide between forced-hot air, heater tapes, or other options.

Summary for A1n target

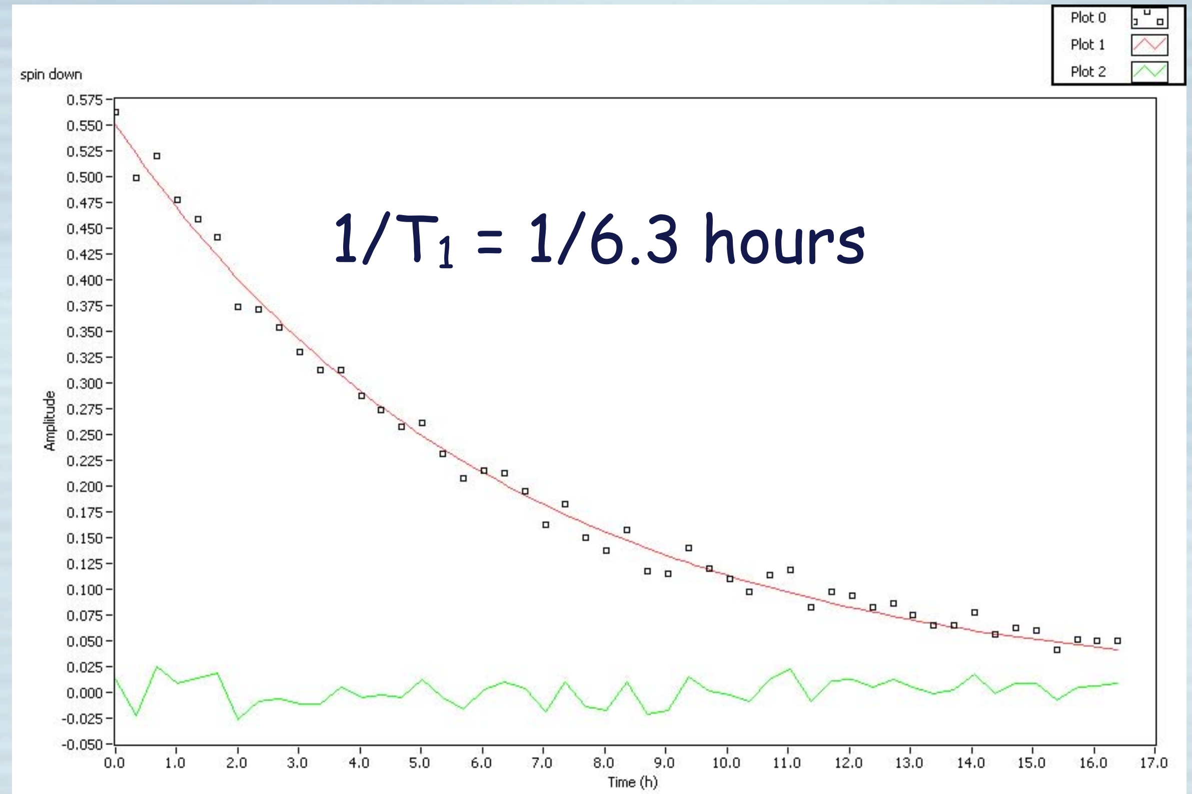
- With down-graded requirements, a solution appears possible utilizing a modified Protovec design and modified Transversity hardware.
- Need to finalize the target requirements that are described in this talk.
- With requirements in hand, we can proceed with true engineering design.

What about going to higher currents?

- At 30μA, we believe that we can use and all-glass cell.
- Above 30μA, we believe it will become increasingly important to use metal end caps.
- Thus, higher luminosity experiments require the development (for the first time) of metal end windows for spin-exchange polarized ^{3}He cells.
- Metal end windows have been used for the Mainz polarized ^{3}He target, which uses metastability-exchange polarized ^{3}He.

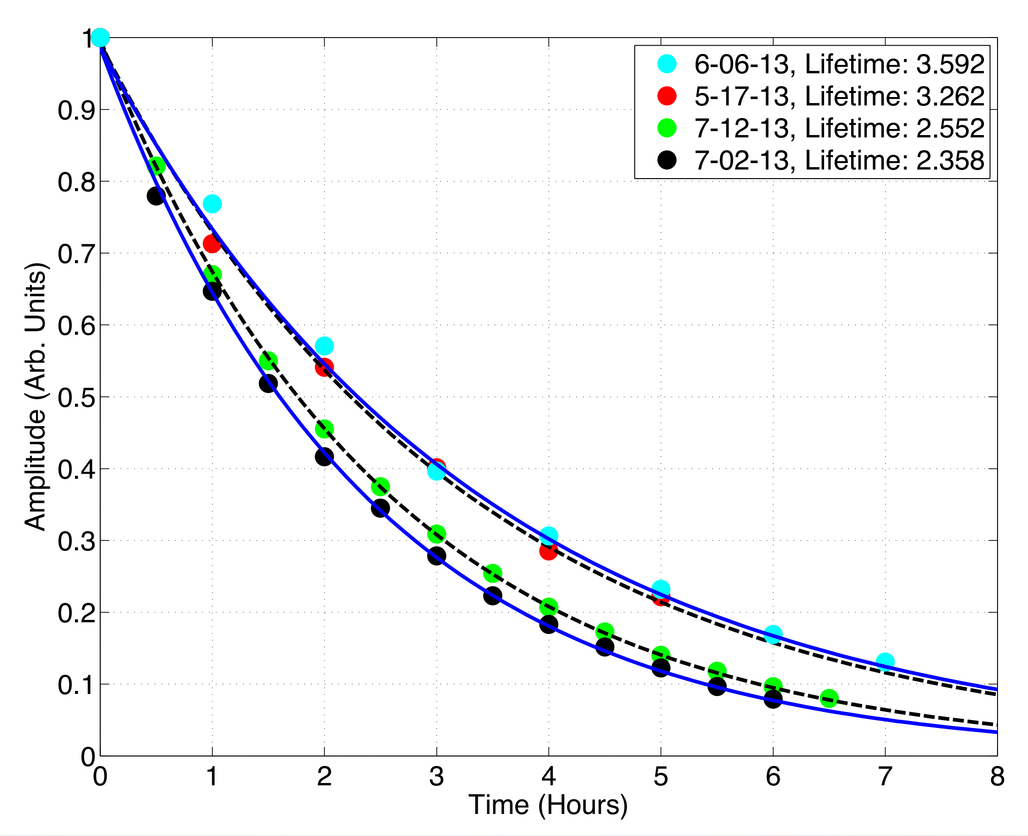


Test of the O-ring cell Gold cell



- Vacuum seals were O-rings.
- Electropolished OFHC copper with electroplated gold.
- Best measured lifetime was 6.3 hours.
- Rb became oxidized with time, which we attributed to leaking through the O-ring.
- I believe (but am not certain) that subsequent lifetime measurements were worse.

Tests of "Goldfinger"

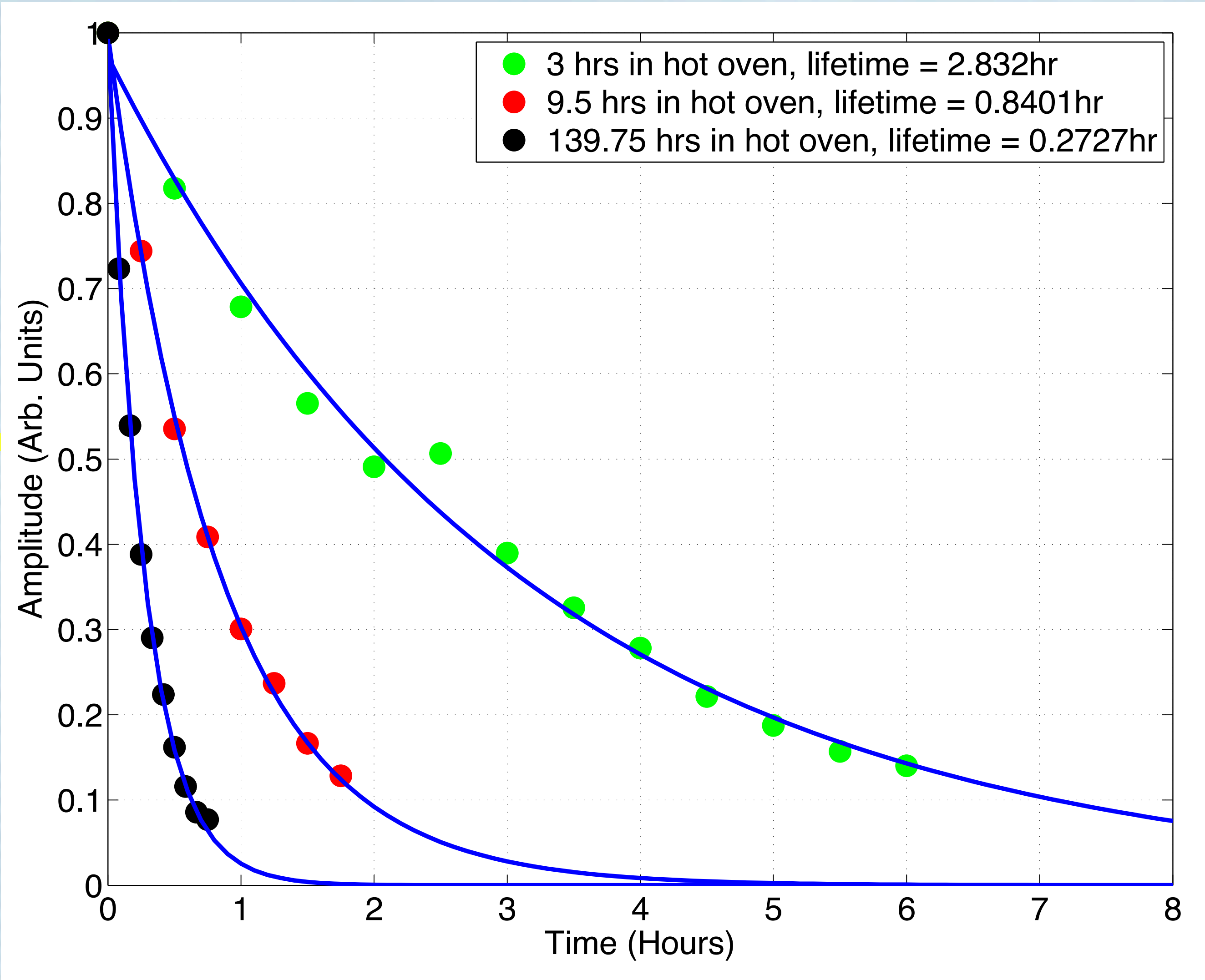


- Glass-to-metal seals with no O-rings.
- Electropolished OFHC copper was electroplated with gold.
- First measured lifetime was 3.6 hours, shorter than O-ring cell's best lifetime.
- Successive measurements showed the lifetime was degrading.
- The cell was heated for a considerable length of time before the lifetime was first measured. There is indirect evidence that the initial lifetime of the cell was significantly longer than 3.6 hours.

Conclusion - Rb and gold don't live together very well?

Tests of "Cupid"

Photo is actually of Goldfinger



- Glass-to-metal seals with no O-rings.
- Electropolished OFHC copper with NO GOLD.
- First measured lifetime was 2.8 hours.
- Successive measurements showed significant degradation of the lifetime with increased exposure to heat and Rb vapor.

Conclusion - Cu starts bad and gets worse with exposure to Rb.

Next test: valved gold-coated cell

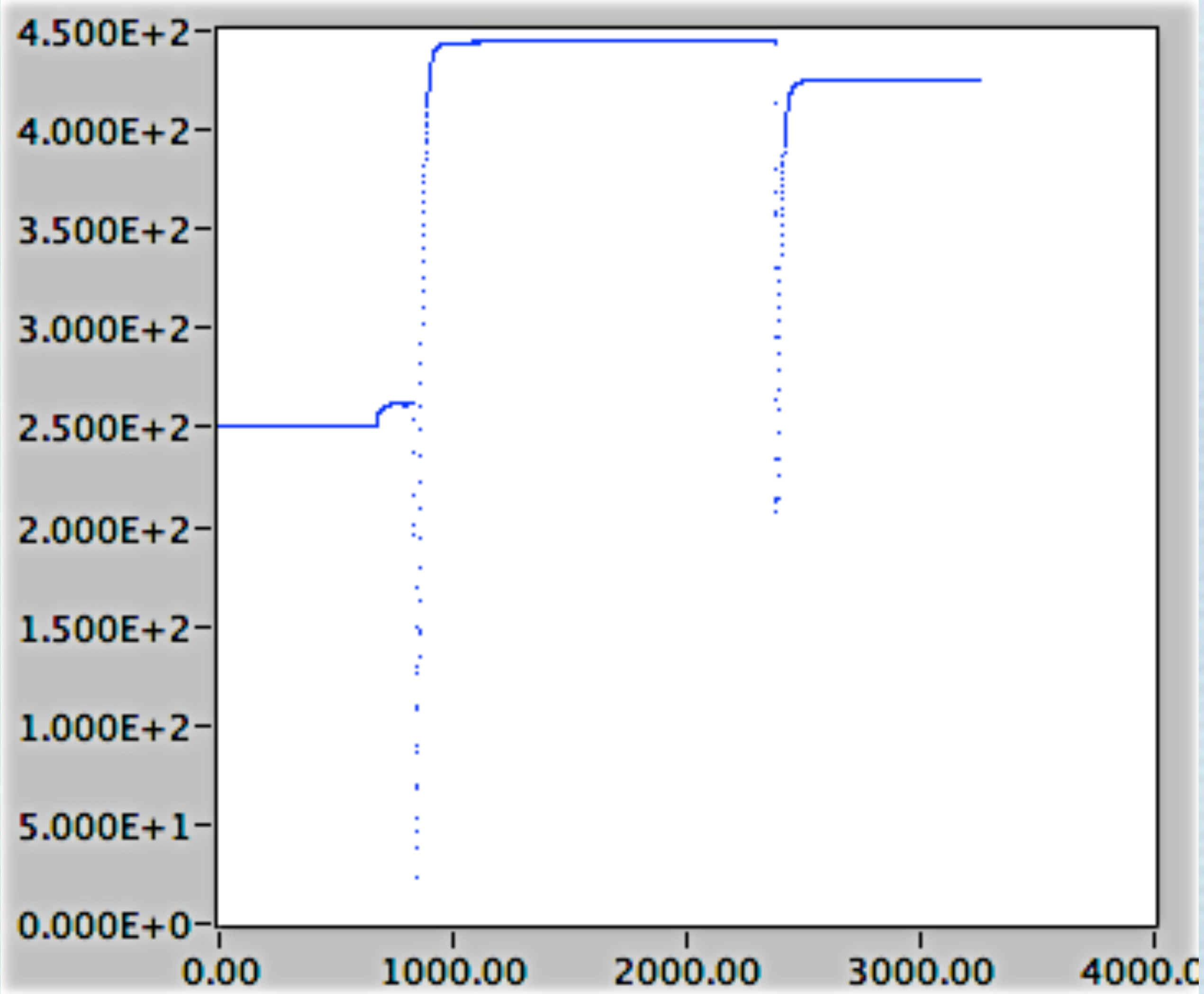
- If gold is a good surface before being exposed to Rb, we should get good lifetimes if we never allow the gold to see any Rb.
- With a valve, we can isolate the gold portion of the cell until the pumping chamber is cold.
- If the results are favorable, we may well be able to design a target in which the Rb reaching the gold is minimized.

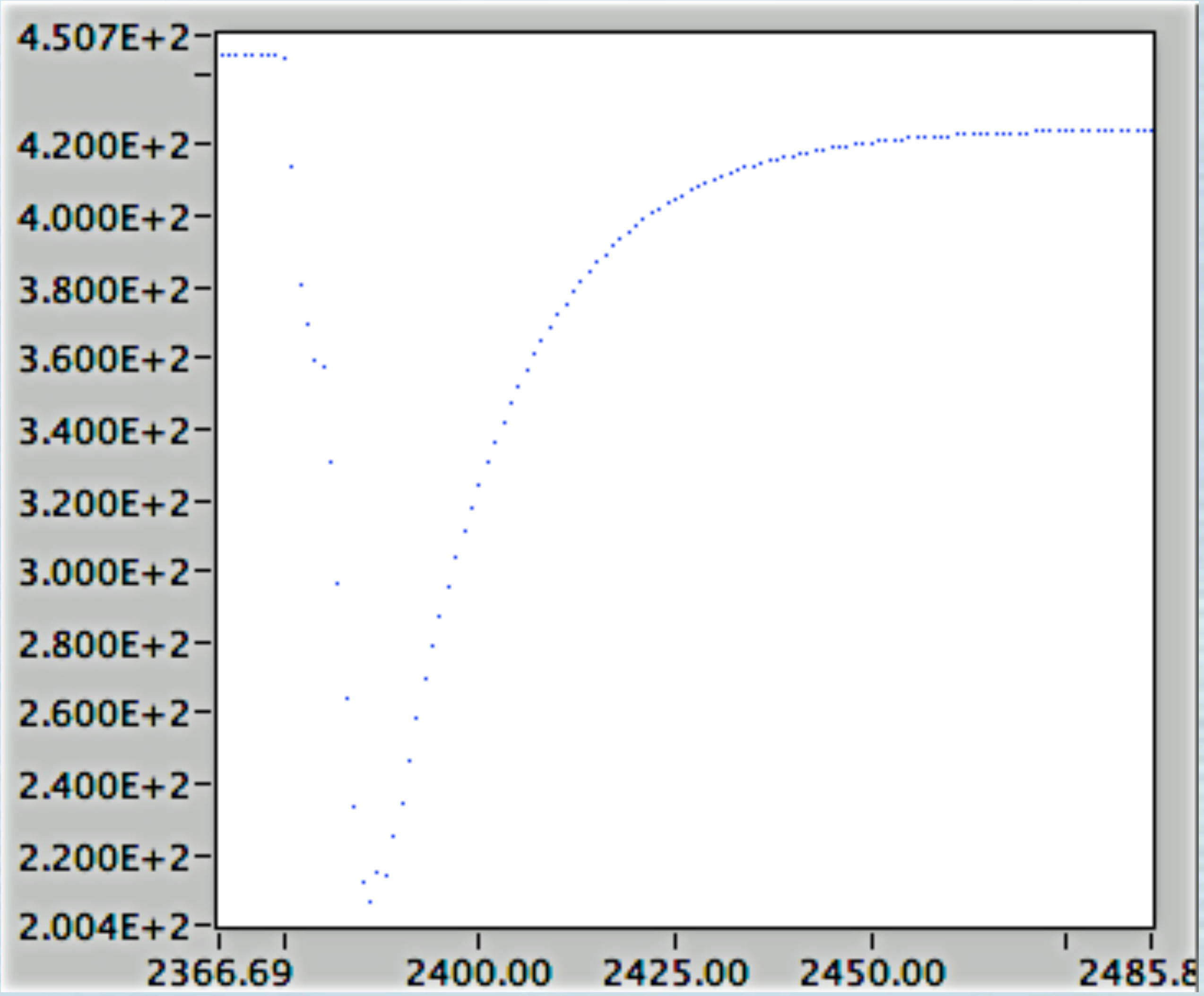
We also have cells in the pipeline with both titanium as well as non-magnetic stainless steel.

AFP Measurement from Goldfinger

Several features to notice in measurement:

- Large shifts in baseline
- Very large apparent losses.
- Asymmetric line shape.
- Regardless of messed-up signal, excellent signal-to-noise. Made us wonder if the cell was better when we first started our tests.



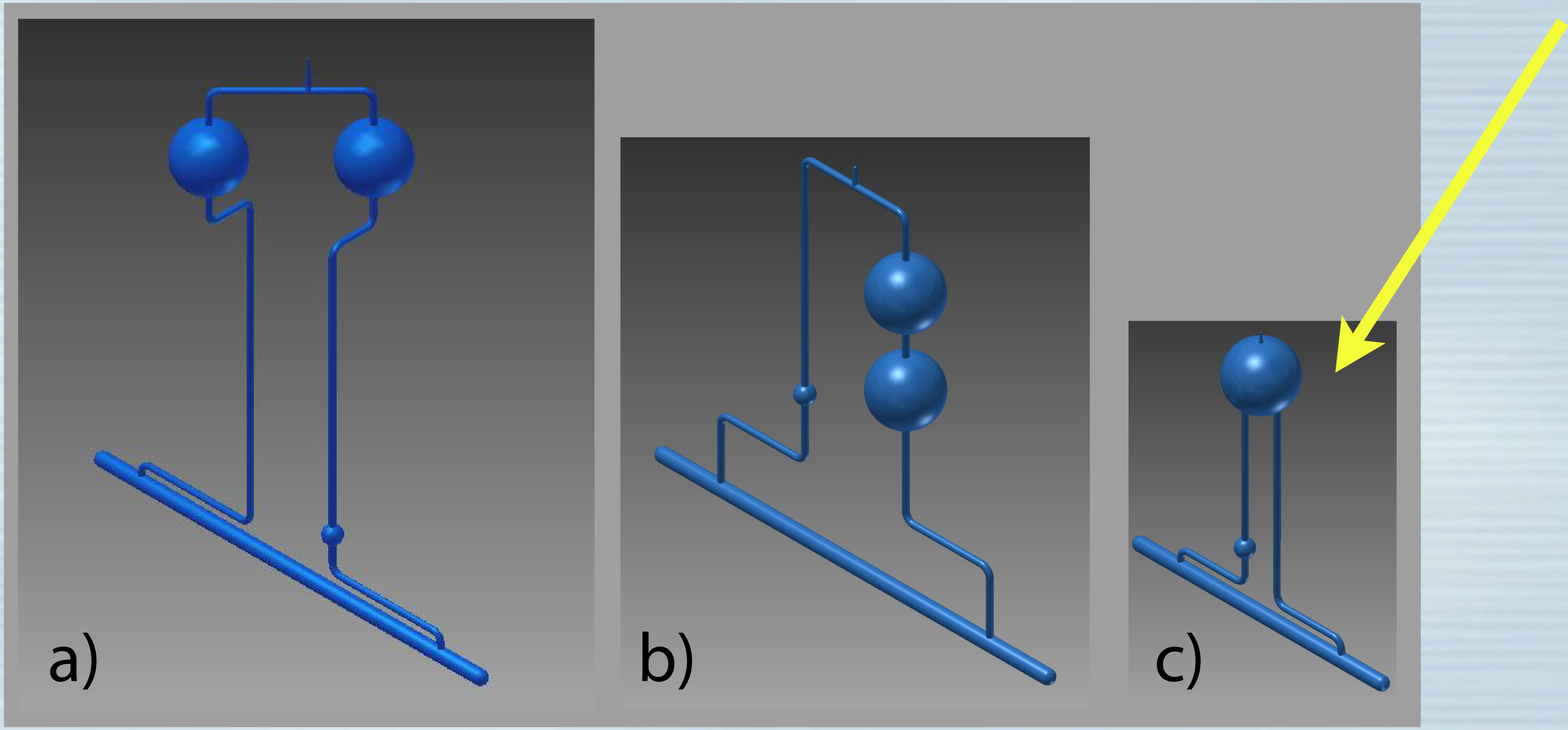


Summary

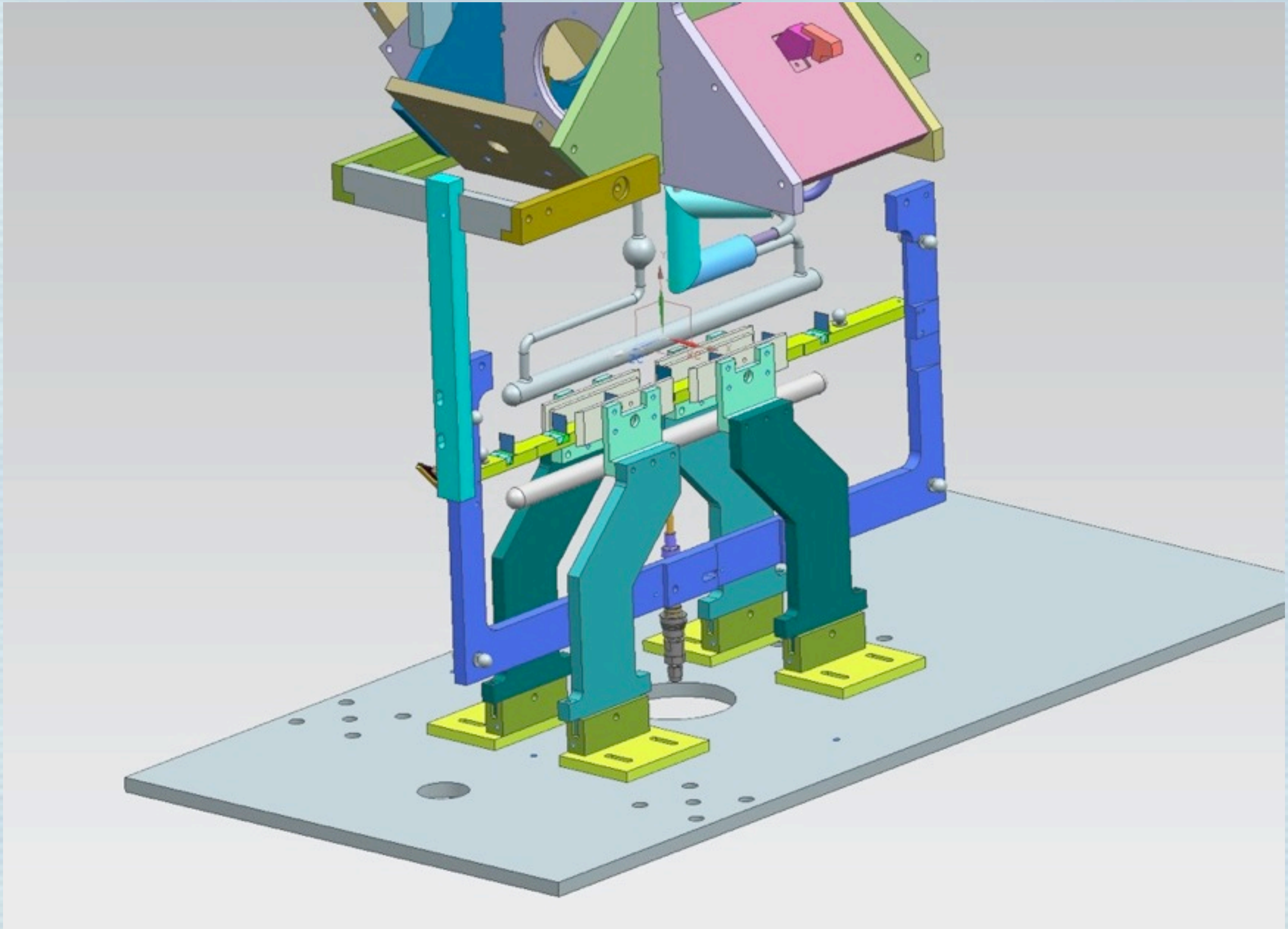
- Gold does not maintain favorable spin-relaxation properties when exposed to Rb.
- Gold may do better if isolated from Rb. This is our next test.
- If Gold does better when isolated from Rb, we may have a path forward for metal end windows.
- Pulse NMR appears critical for polarimetry in future cells that include metal.

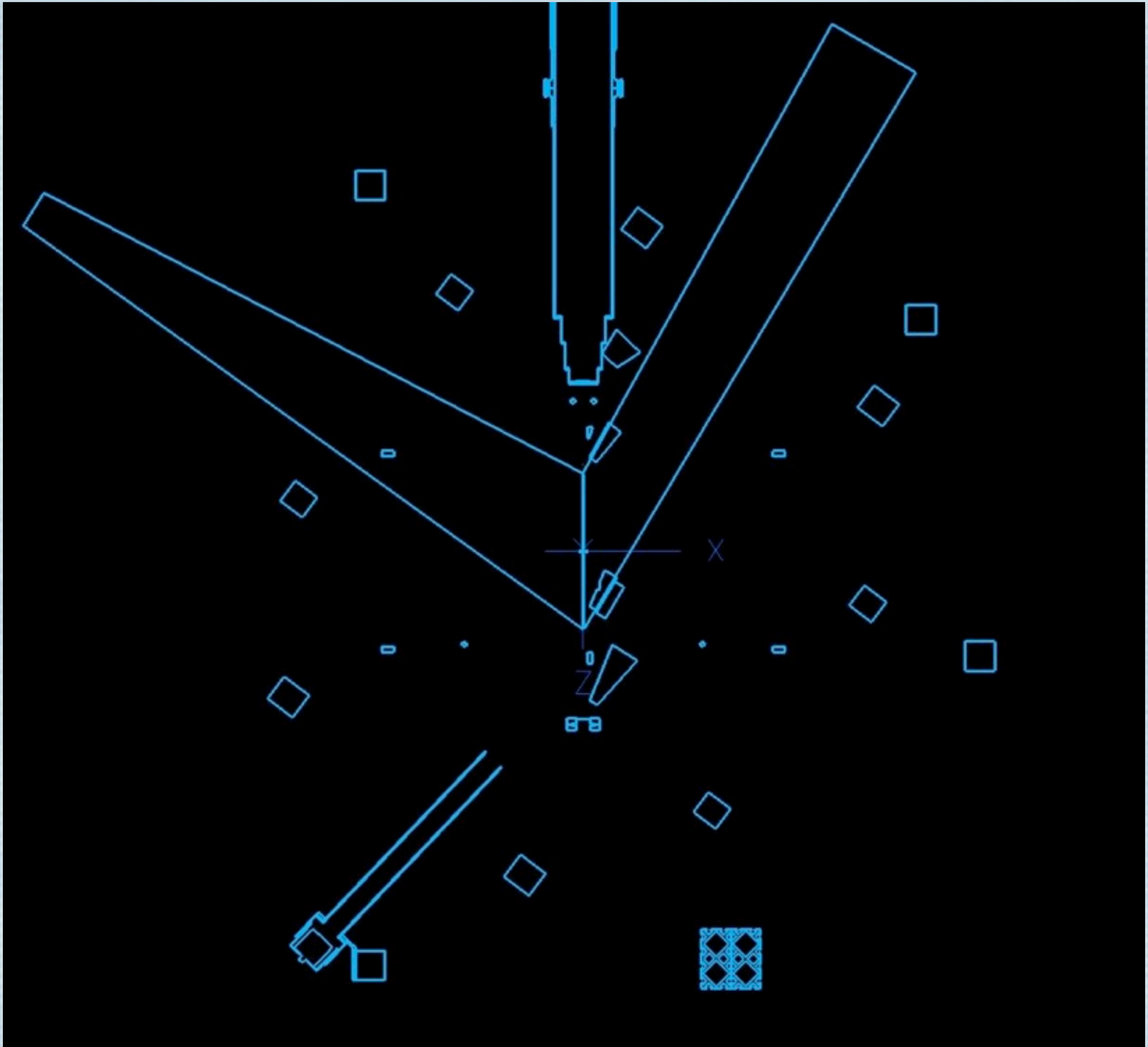
Backup slides

The choice of the cell design



- Currently, our magnetic-field studies are of option a).
- Our design of choice would probably be option b).
- The current plan is option c). This is essentially the design of Protovec-I, which has already been bench tested.

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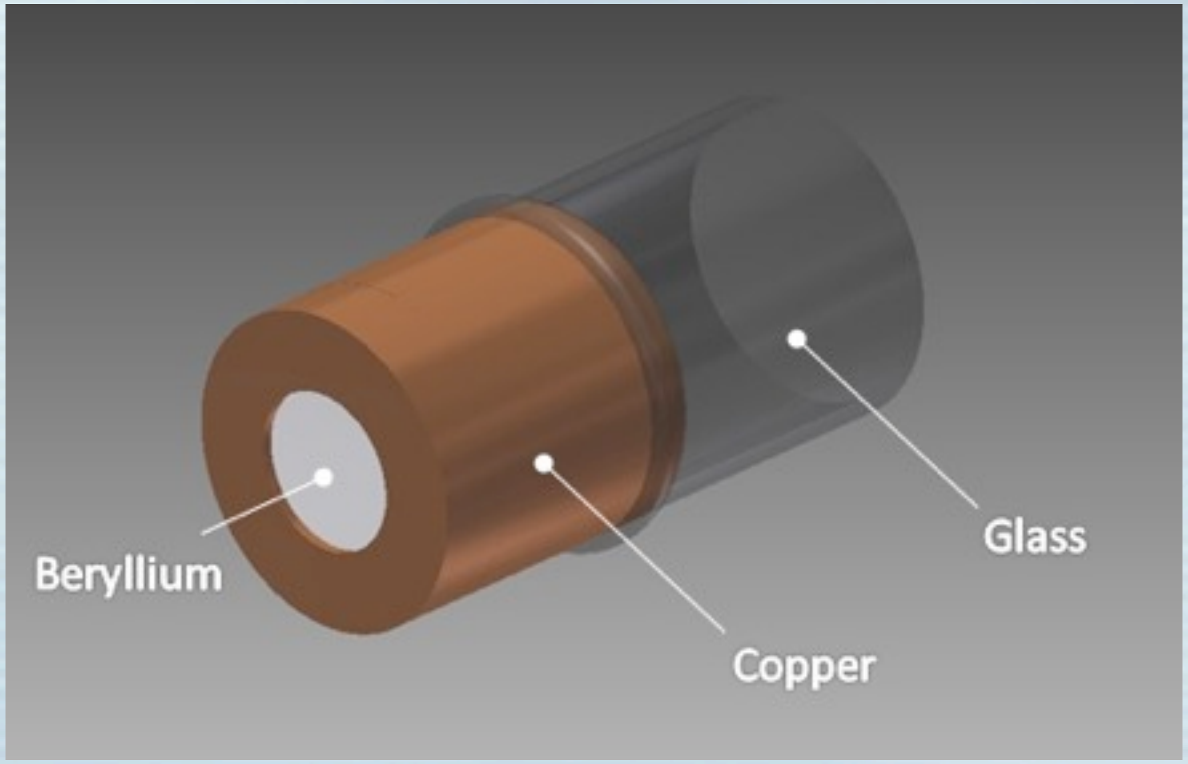
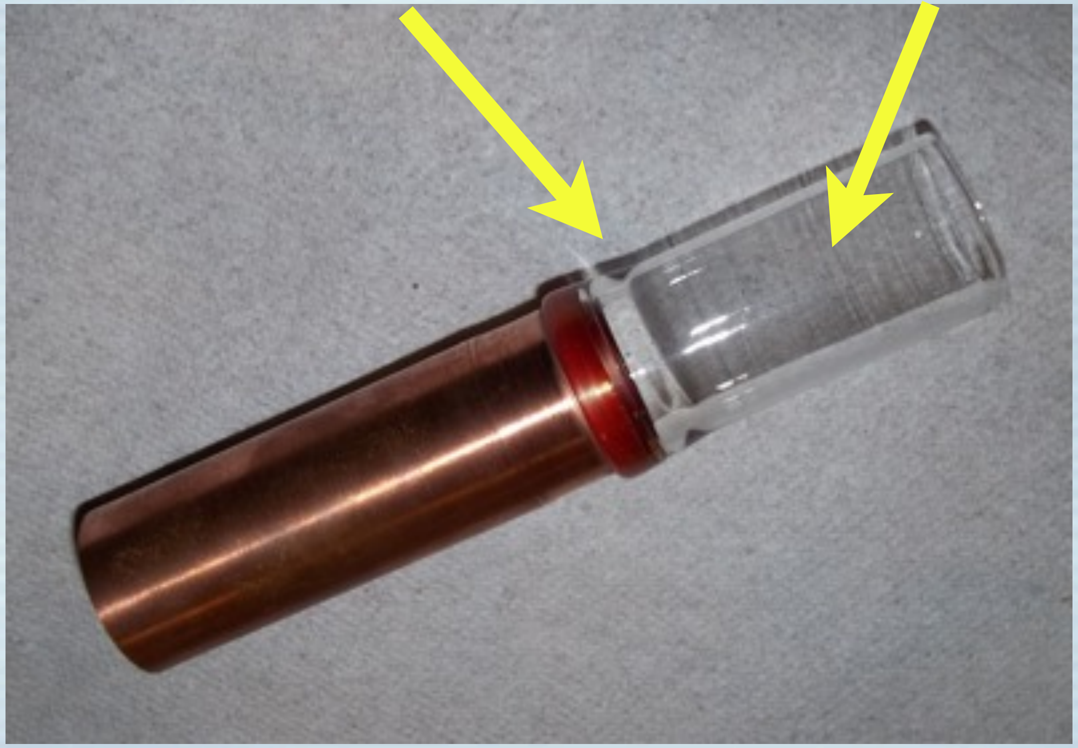
Metal end windows



7052 Transition Glass GE-180



Rather than use an entirely metal target chamber as originally planned, we are planning on beryllium end windows. We are nearly ready to order the first prototypes from Materion.

Custom made for us by Larson Glass, is a GE180 to 7052 Transition glass to copper seal. The GE-180 is resized by Mike Souza at Princeton before being sent to Larson.