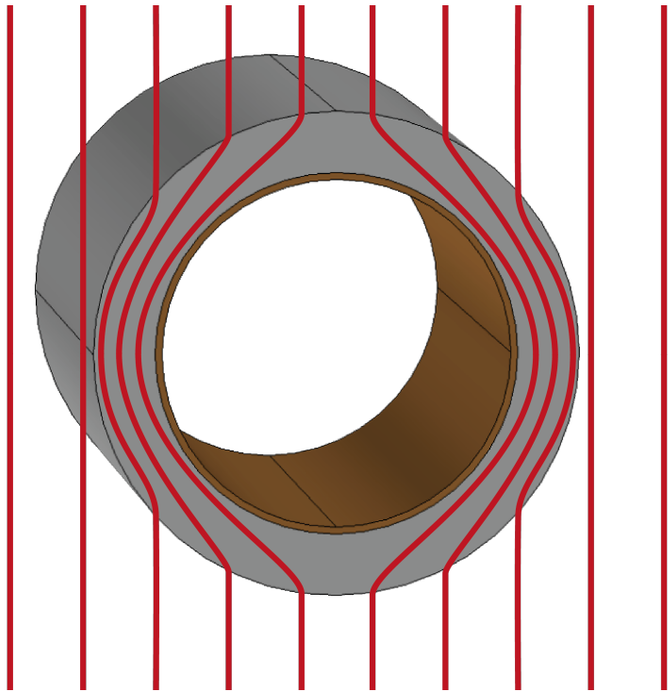
Stony Brook University

Magnetic Field Cloaking Device

eRD2 Progress Report and Proposal



Abhay Deshpande, Nils Feege

EIC R&D Advisory Committee Meeting
Argonne National Laboratory, July 6, 2016

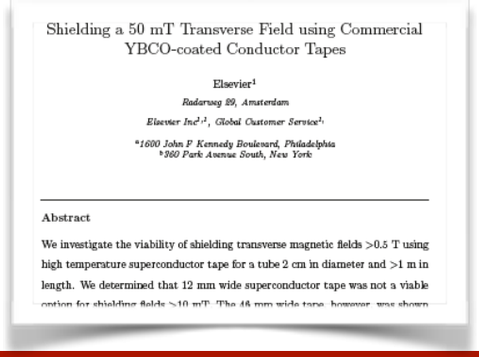
Planned measurements

1. Shield a **charged particle beam** from a transverse magnetic field with a **1.3 m** superconductor cylinder at **liquid nitrogen** temperature.

2. Shield a **0.5 T** magnetic field with a **10 cm** superconductor cylinder at **liquid nitrogen** temperature.

3. Shield a **0.5 T** magnetic field with a **10 cm** superconductor cylinder at **liquid helium** temperature.

Publication



Shielding a 50 mT Transverse Field using Commercial YBCO-coated Conductor Tapes

Elsevier[1]

Radarweg 29, Amsterdam

Elsevier Inc[a,1], Global Customer Service[b,1]

[a]1600 John F Kennedy Boulevard, Philadelphia
[b]360 Park Avenue South, New York

Abstract

We investigate the viability of shielding transverse magnetic fields >0.5 T using high temperature superconductor tape for a tube 2 cm in diameter and >1 m in length. We determined that 12 mm wide superconductor tape was not a viable

Planned measurements

1

Shield a **charged particle beam** from a transverse magnetic field with a **1.3 m** superconductor cylinder at **liquid nitrogen** temperature.

2

Shield a **0.5 T** magnetic field with a **10 cm** superconductor cylinder at **liquid nitrogen** temperature.

3

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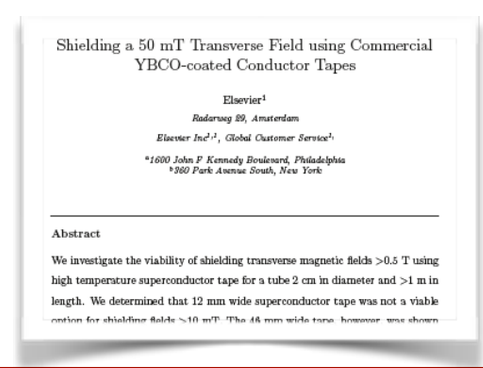
Publication



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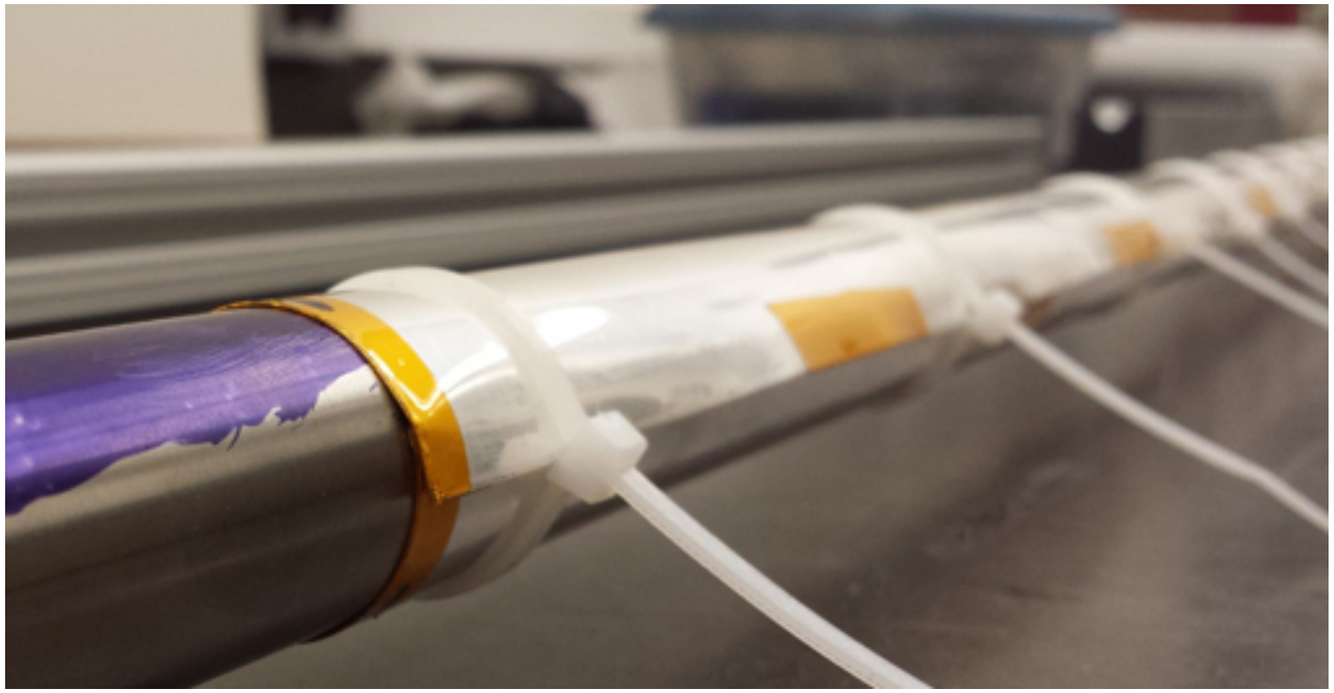
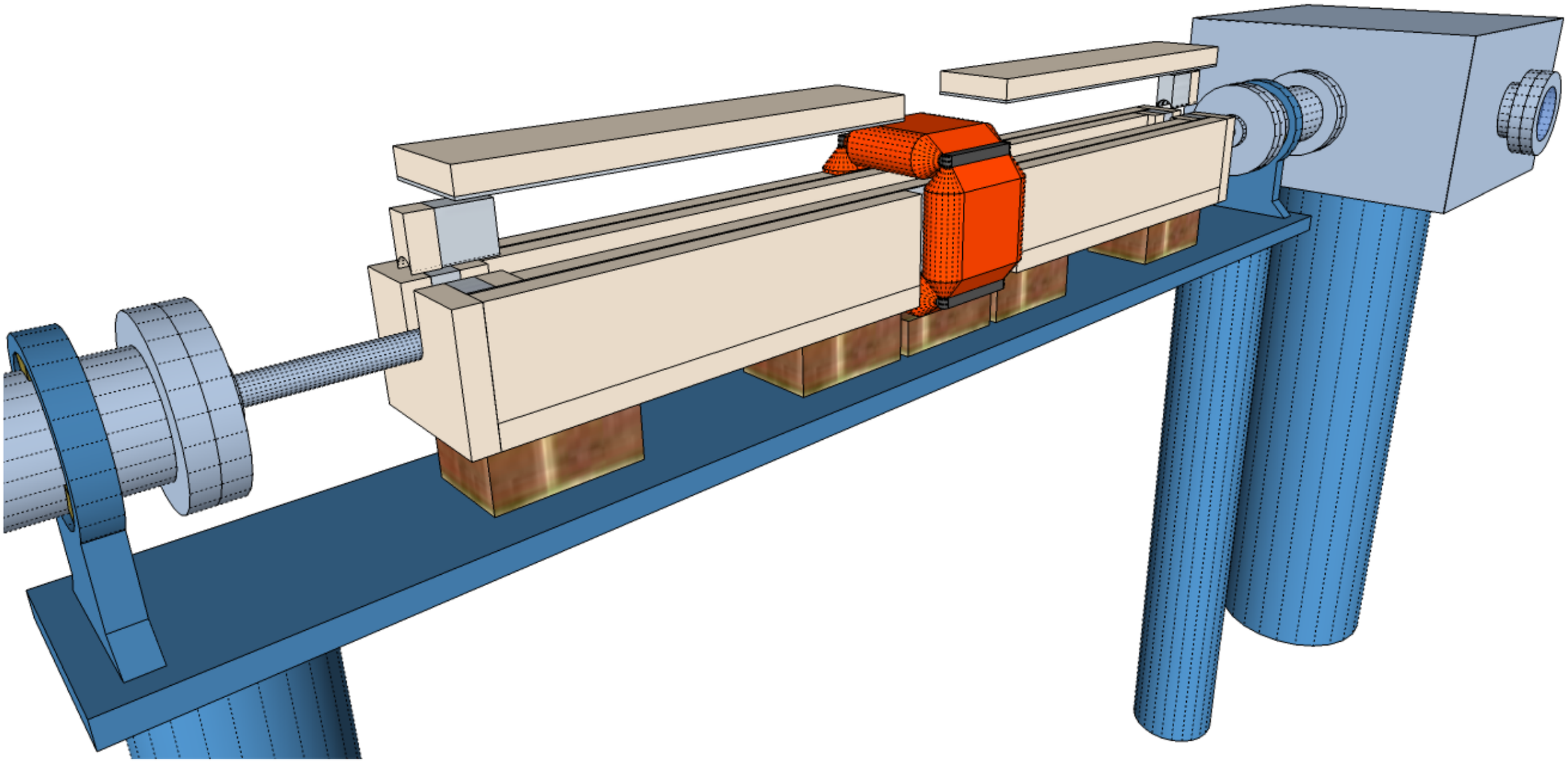
Improved prototype for beam test



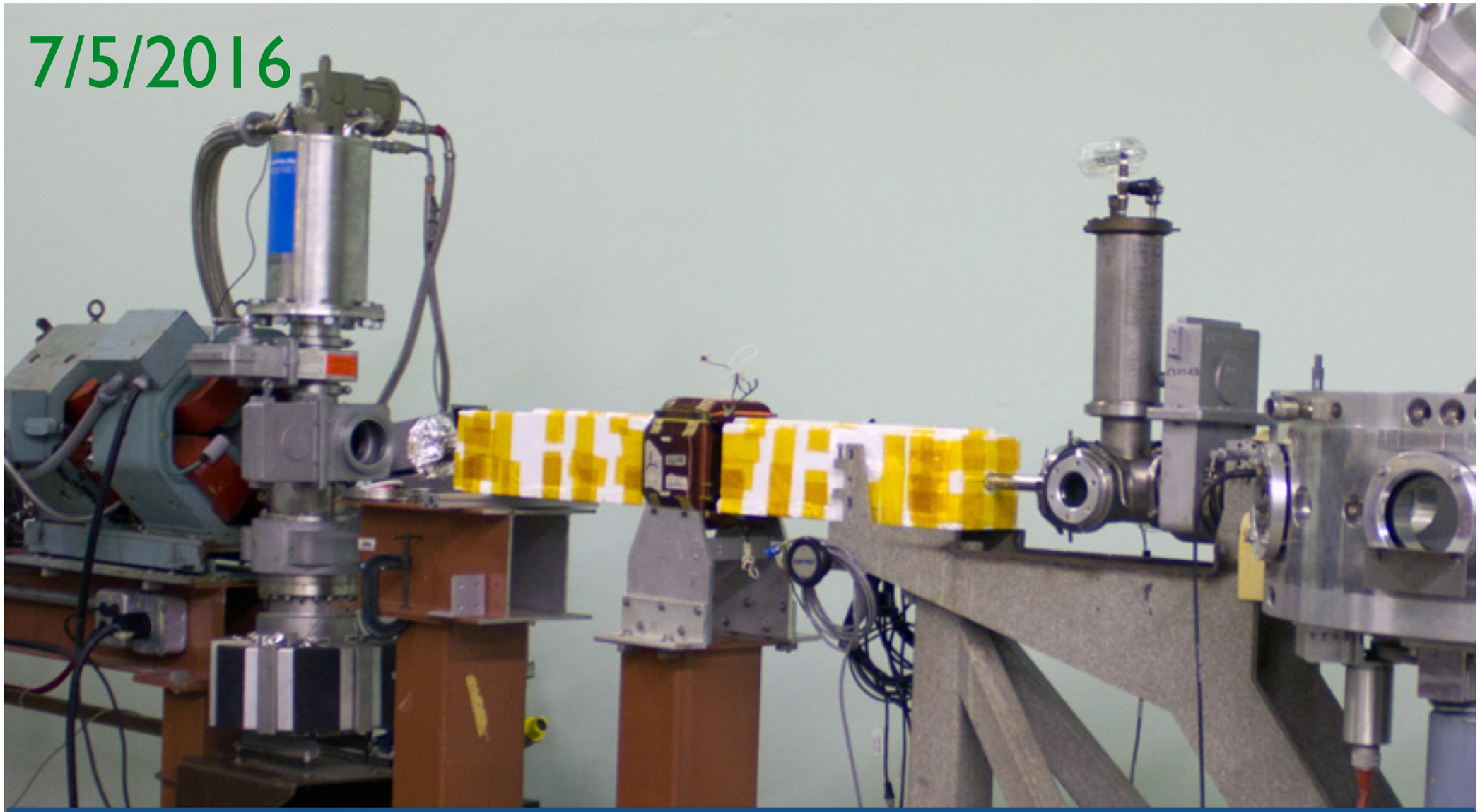
Re-design

- superconductor layers
- liquid nitrogen cooling

Beam test setup designed for BNL Van de Graaff beam line

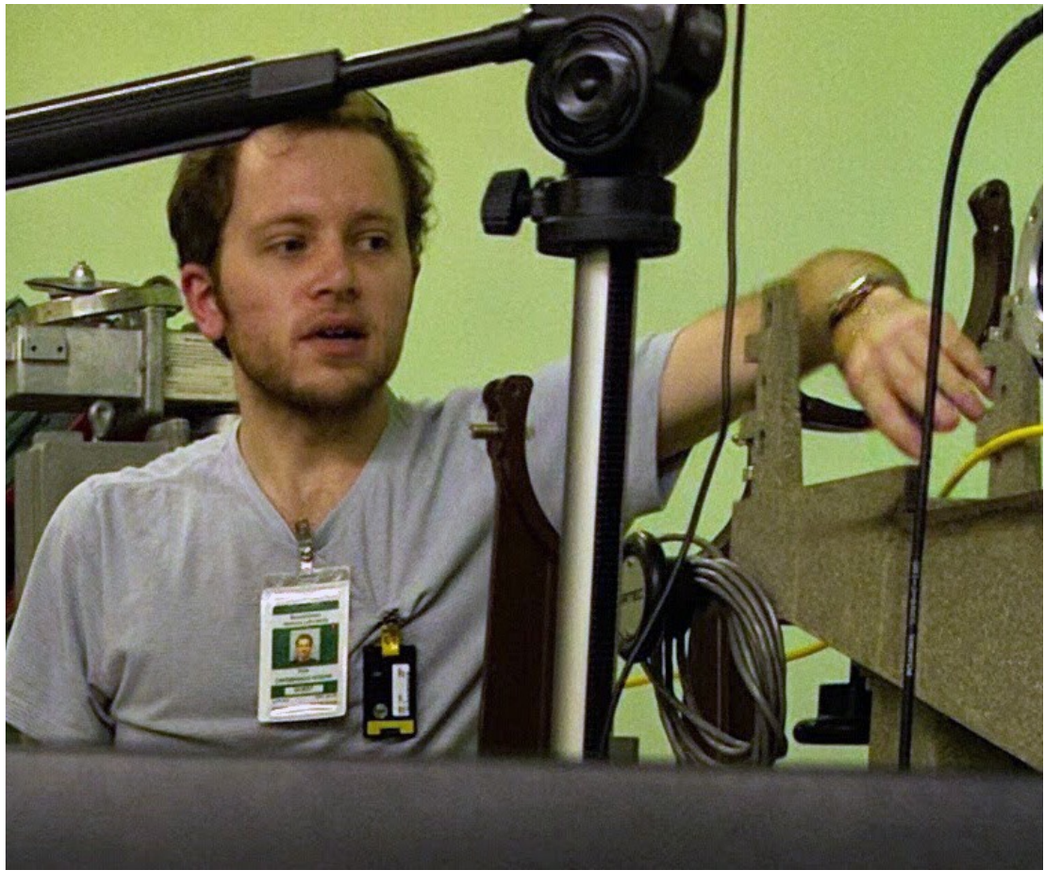


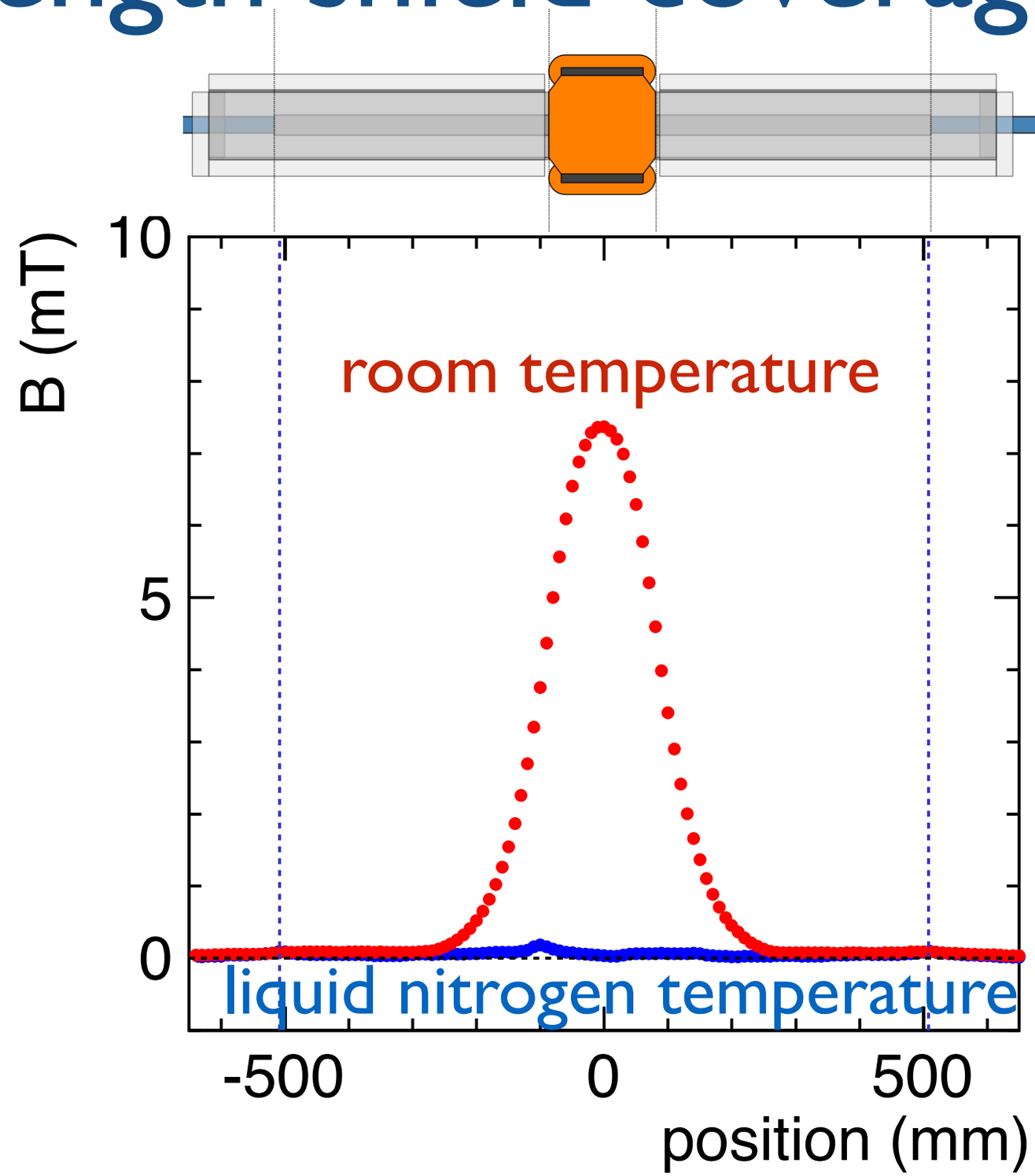
Installation and commissioning at BNL completed- Waiting for beam!



Thanks to the BNL Van de Graaff staff for their support

Confirmed full length shield coverage

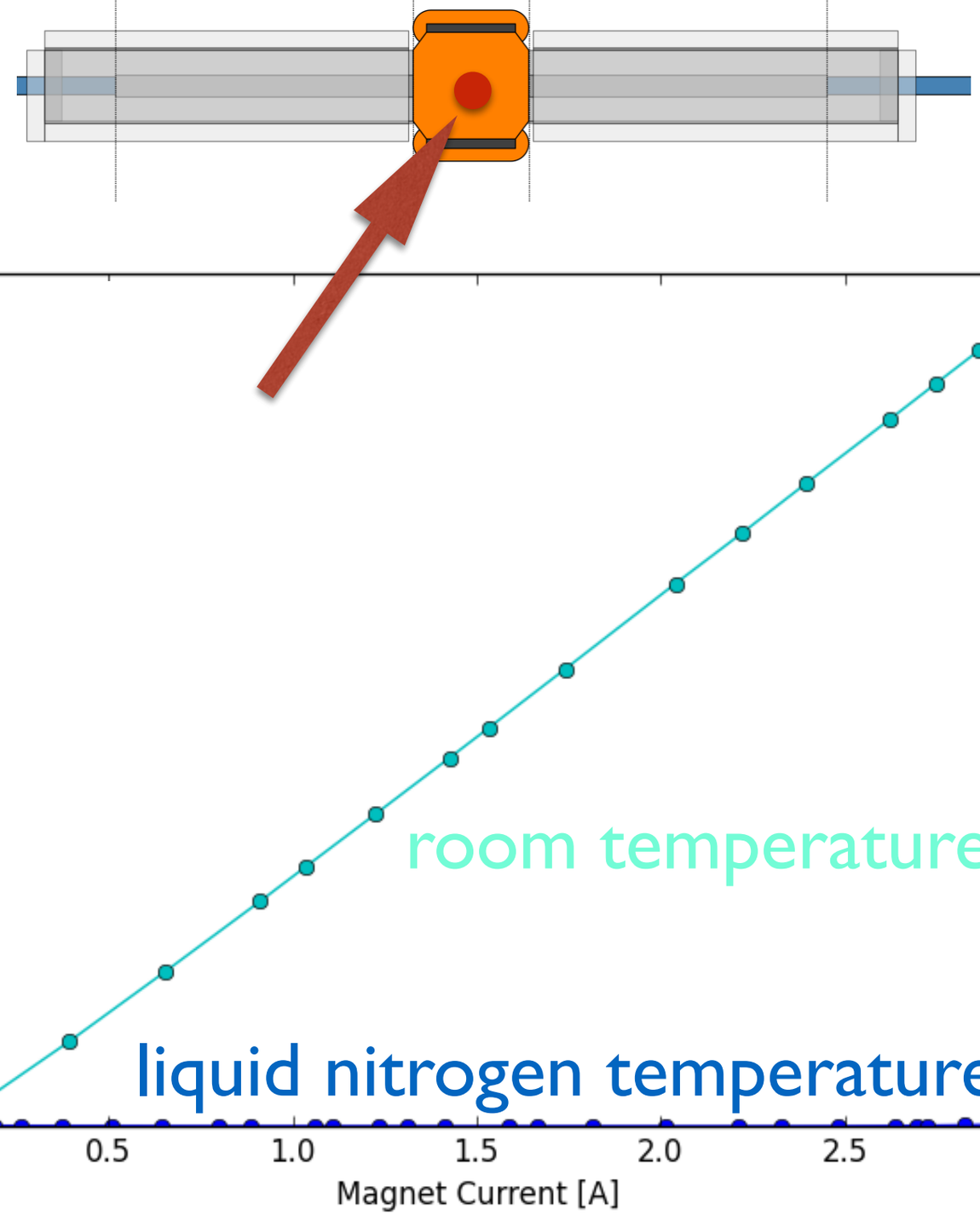




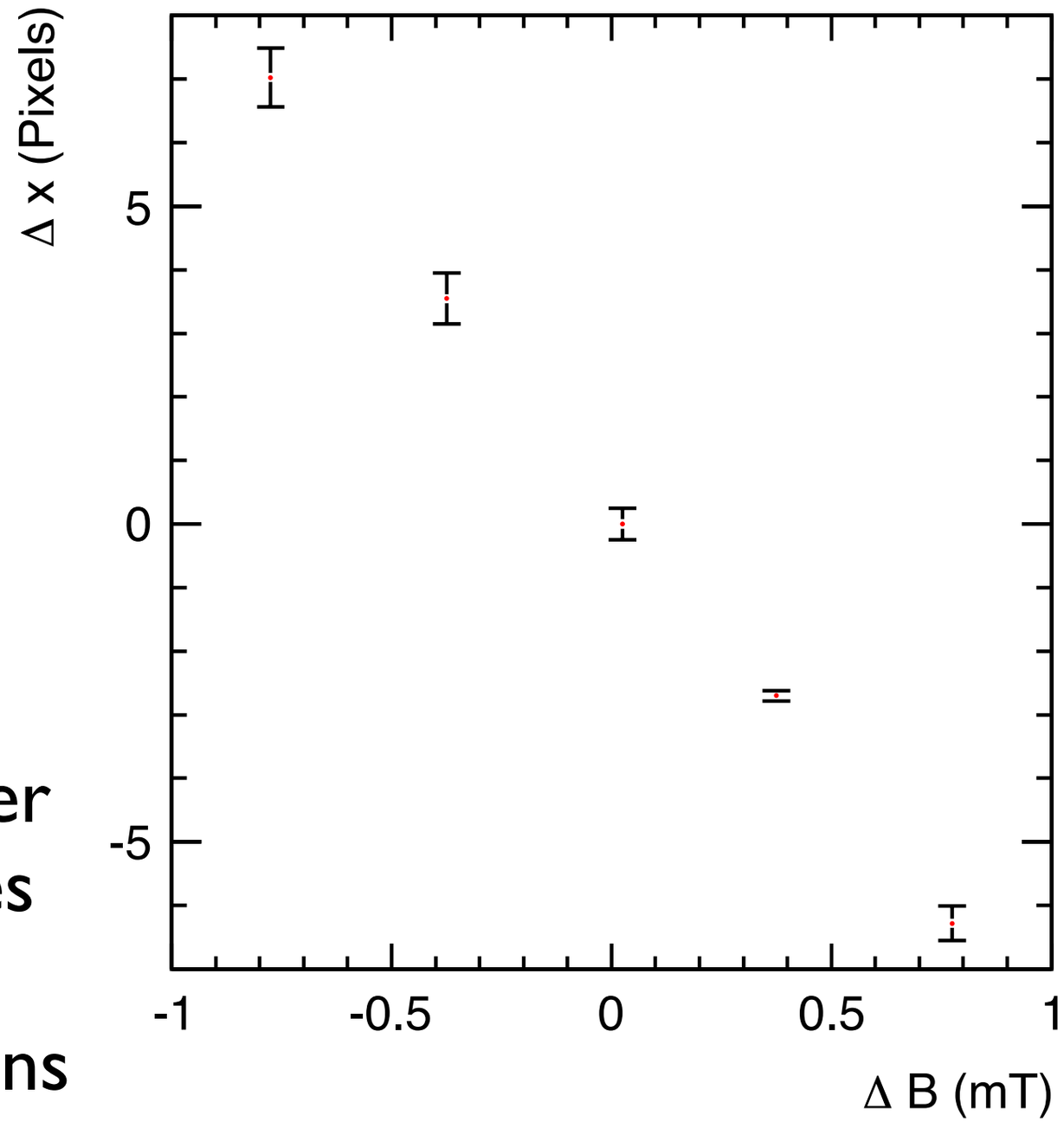
Hall sensor measurement

Confirmed shielding up to ~25 mT

Hall sensor measurement



How can we measure the beam position?



- Developed code to locate center of beam spot on webcam images
- ~ 10 pixel / mm resolution
- Prepared new zinc sulfide screens

Planned measurements

1

Shield a **charged particle beam** from a transverse magnetic field with a **1.3 m** superconductor cylinder at **liquid nitrogen** temperature.

2

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3

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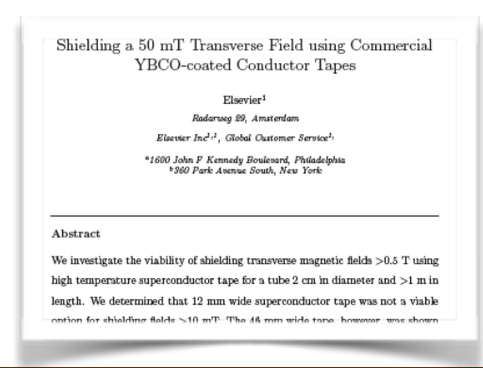

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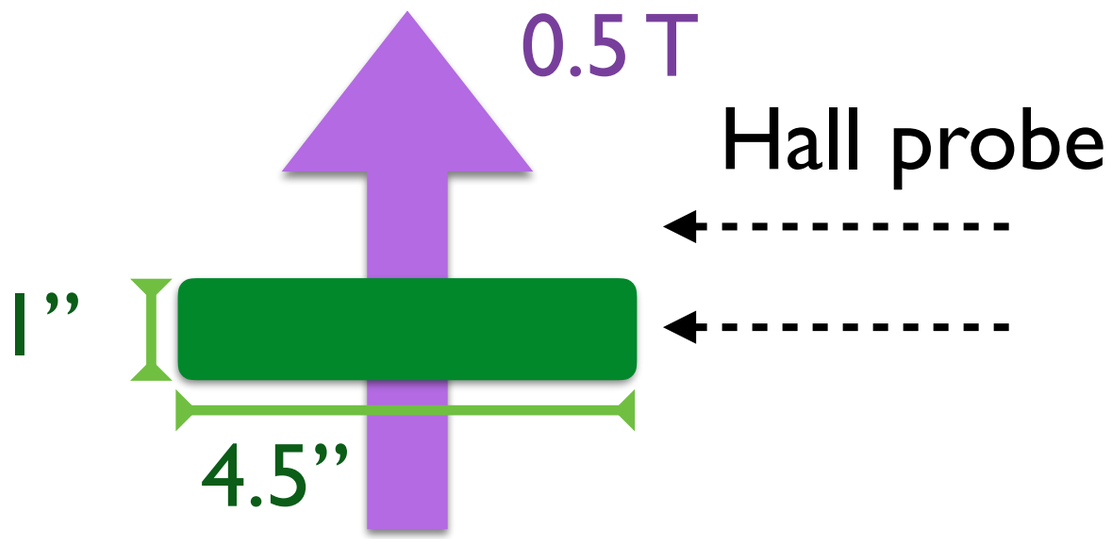
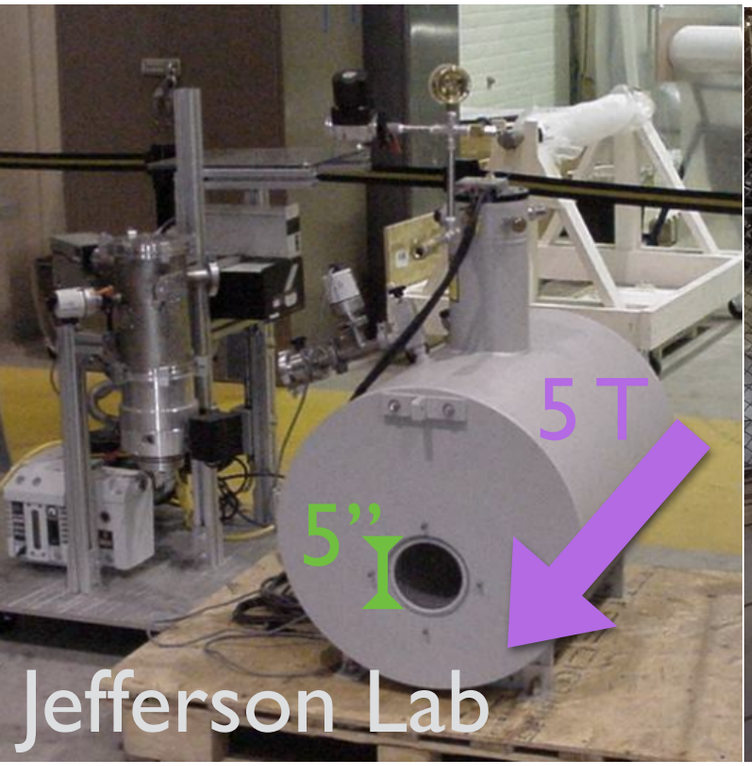
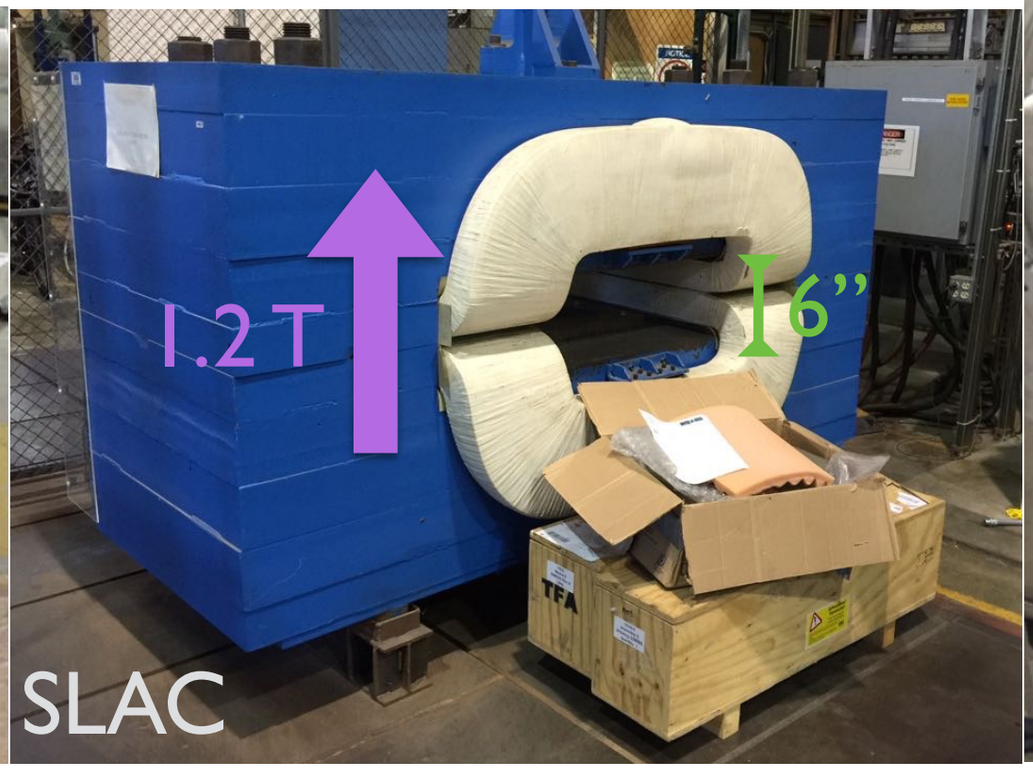
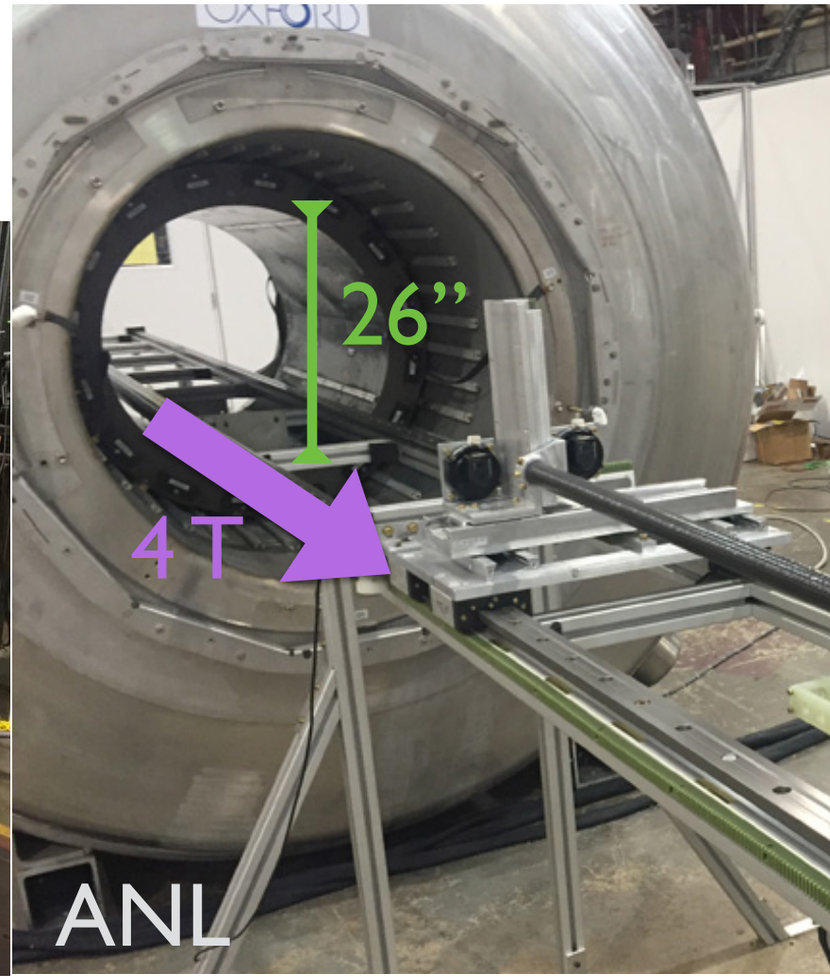
Finding a suitable 0.5 T magnet

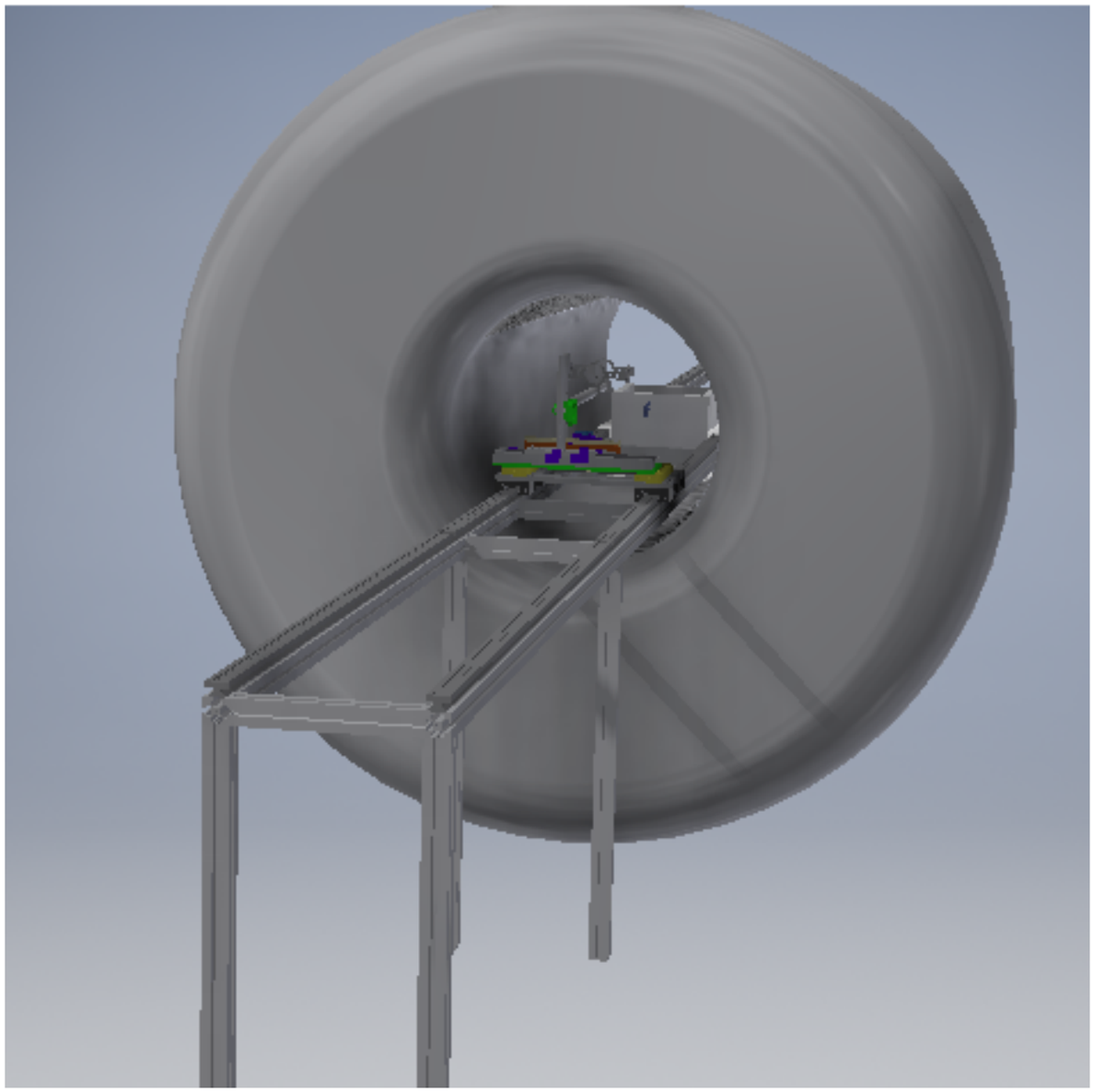


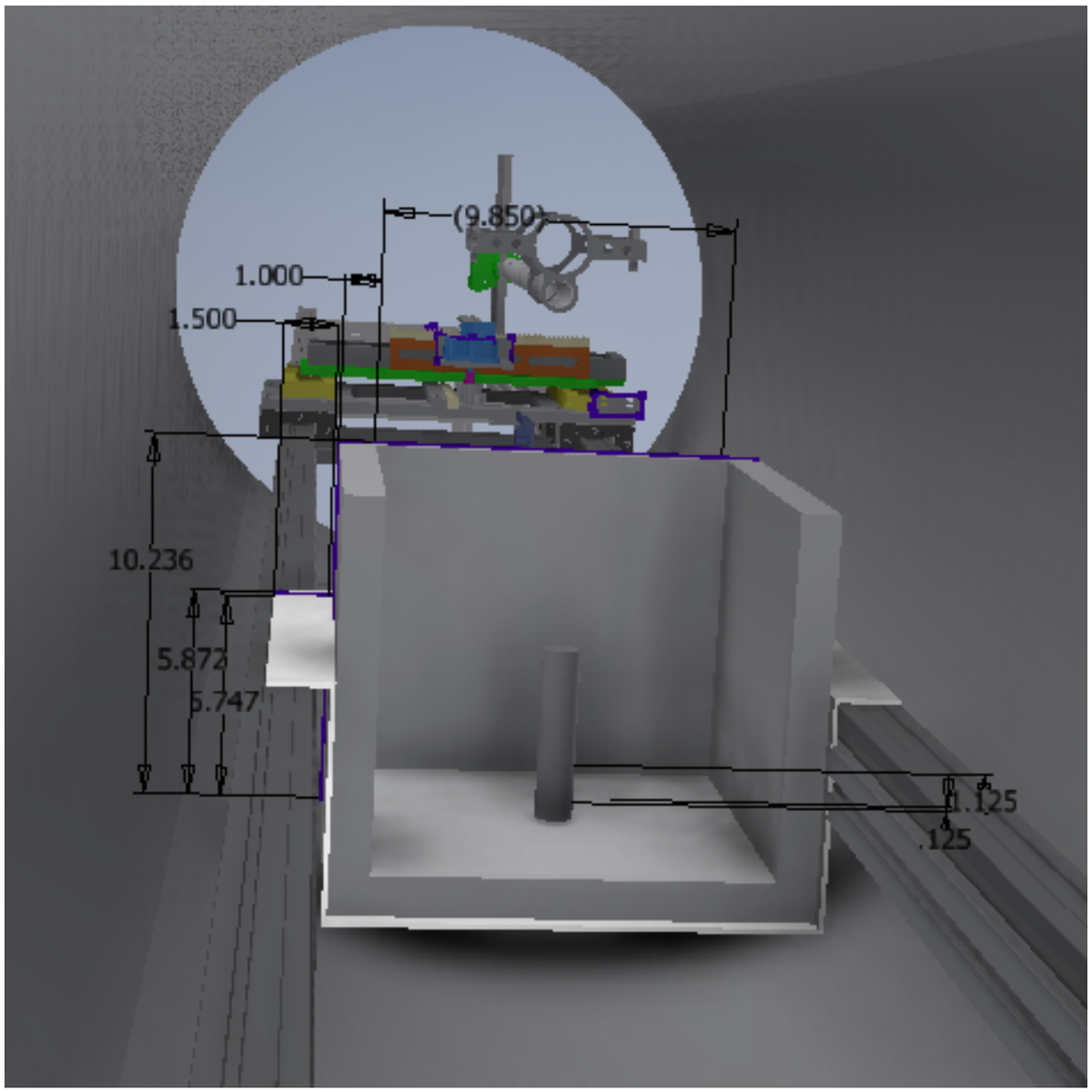






First design of high-field shielding test with MRI magnet at ANL

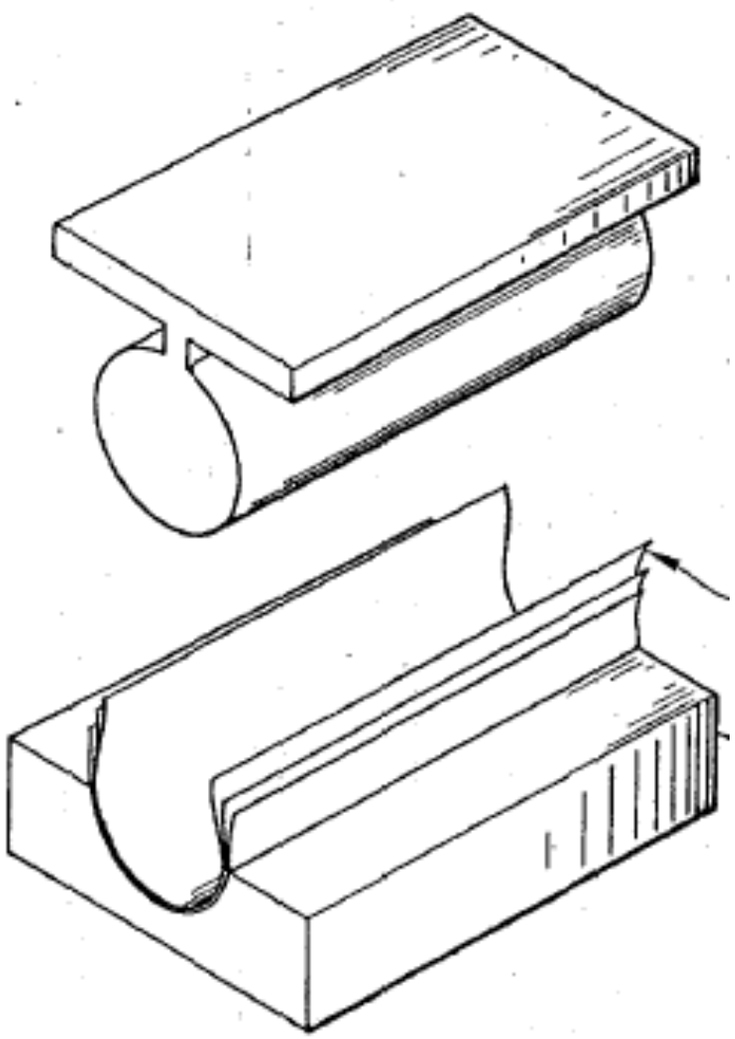




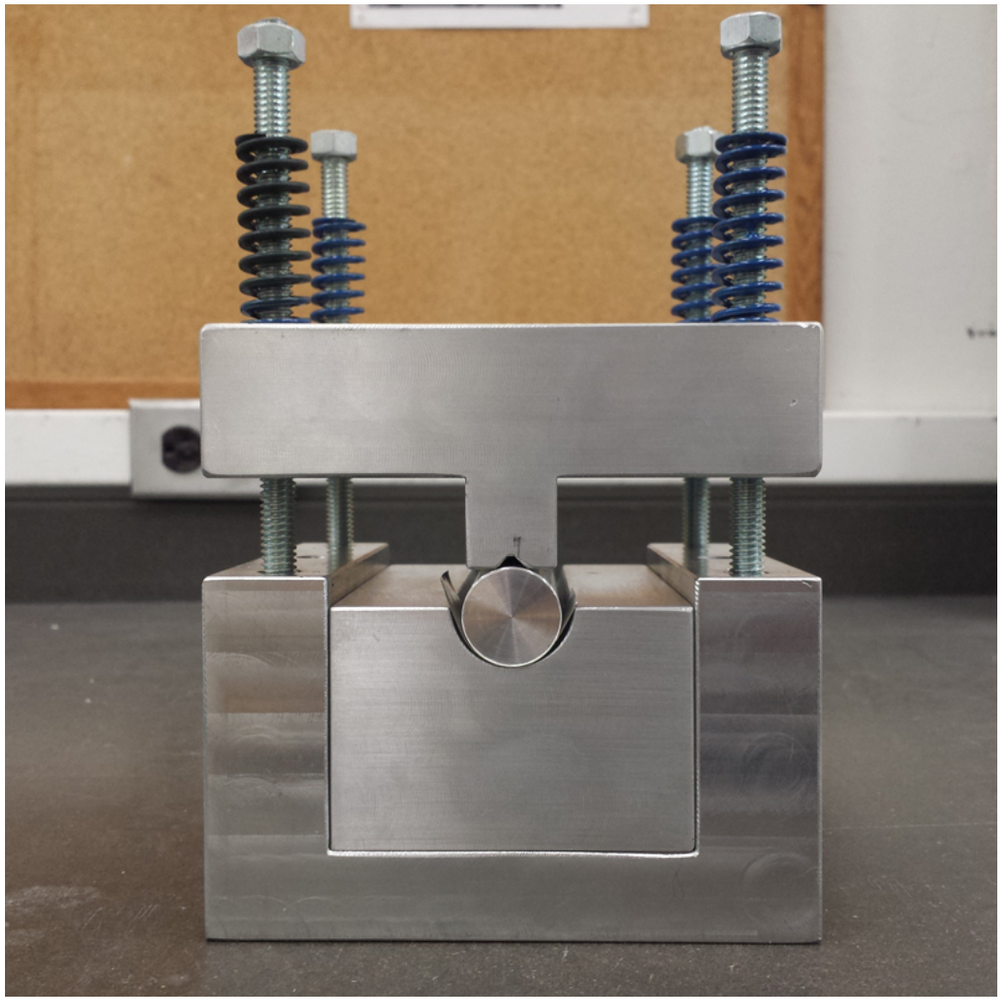
CAD model courtesy P. Winter, ANL

How to make a multi-layer shield?

F. Martin et al.
SLAC-PUB-1040 (1972)

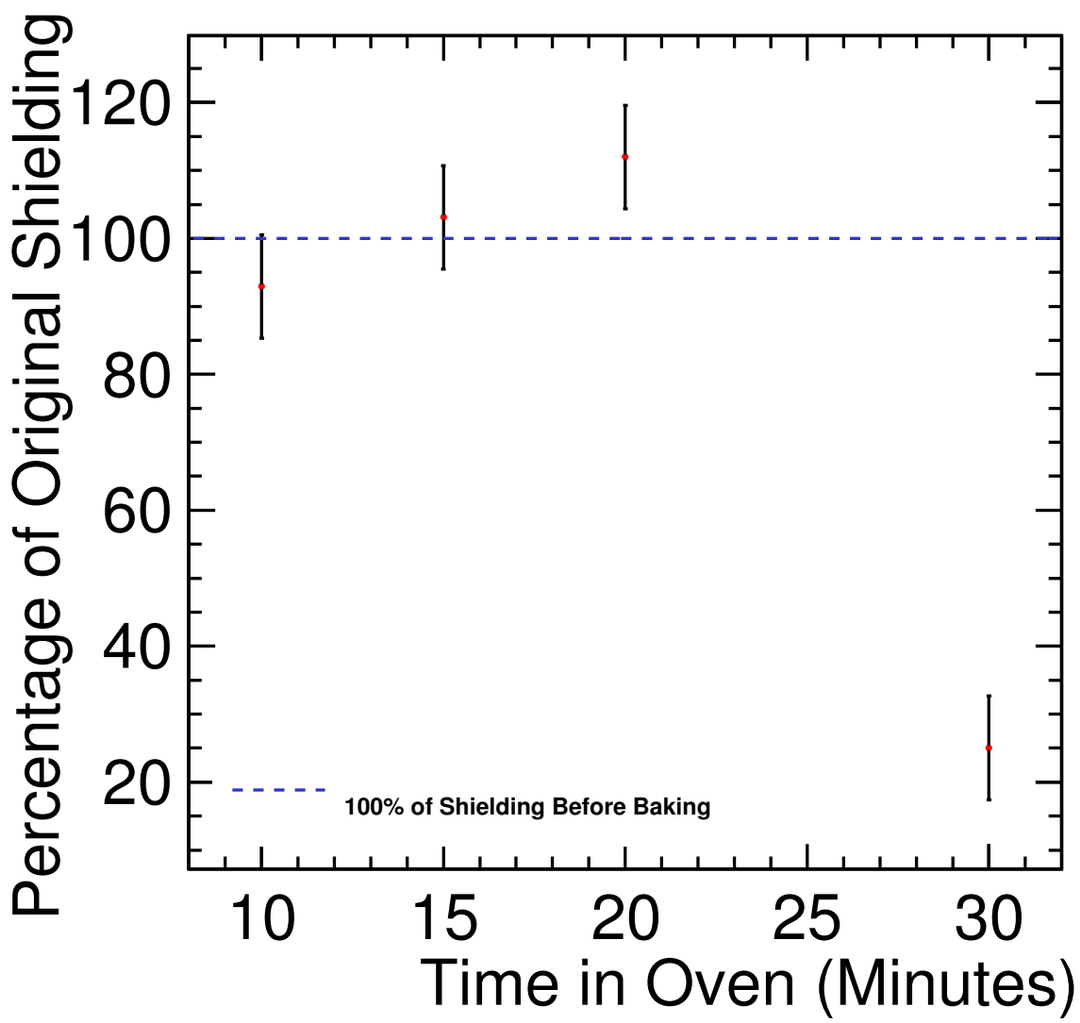


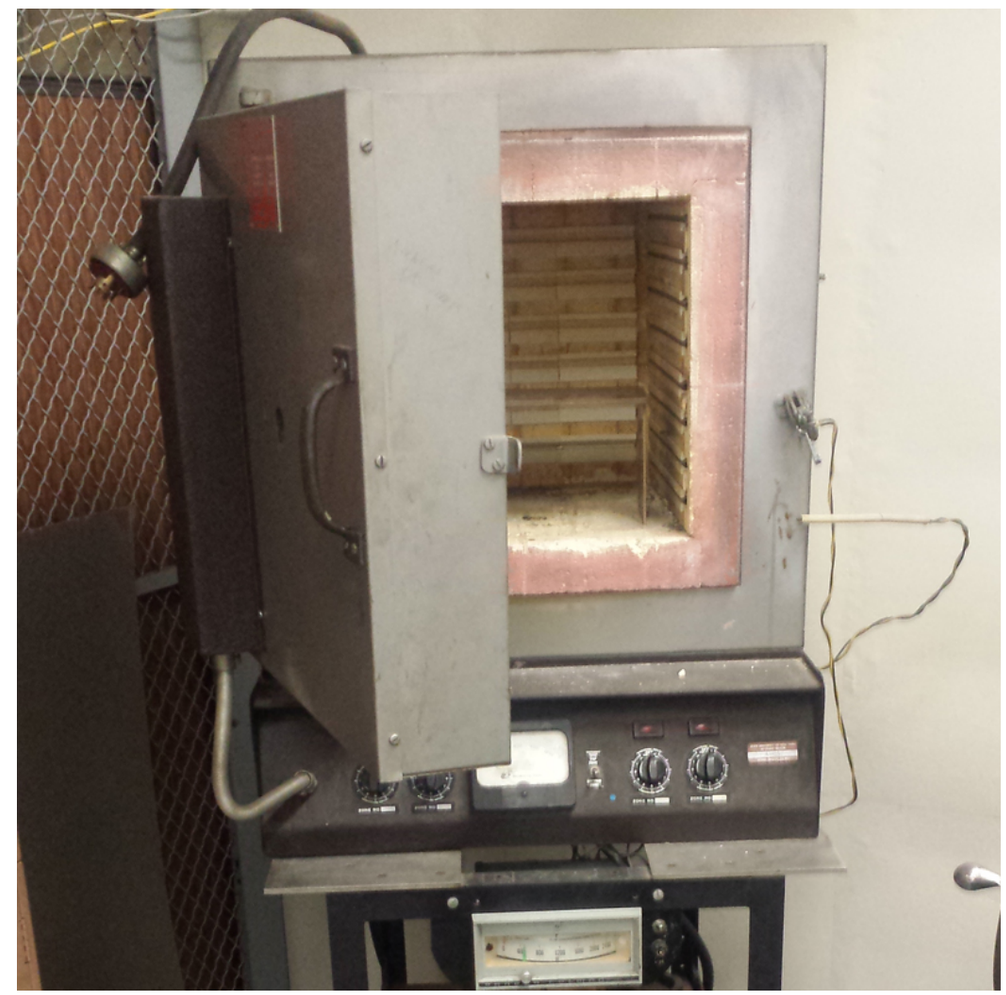
Our realization of die and mandrel for shield fabrication



Shield: 1” diameter, 4.5” length

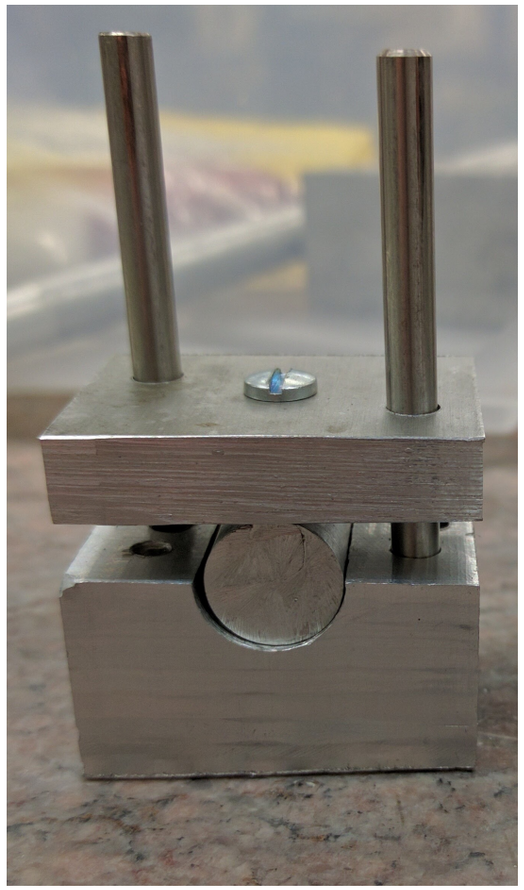
Superconductor shielding stable after less than 20 minutes baking at 200°C



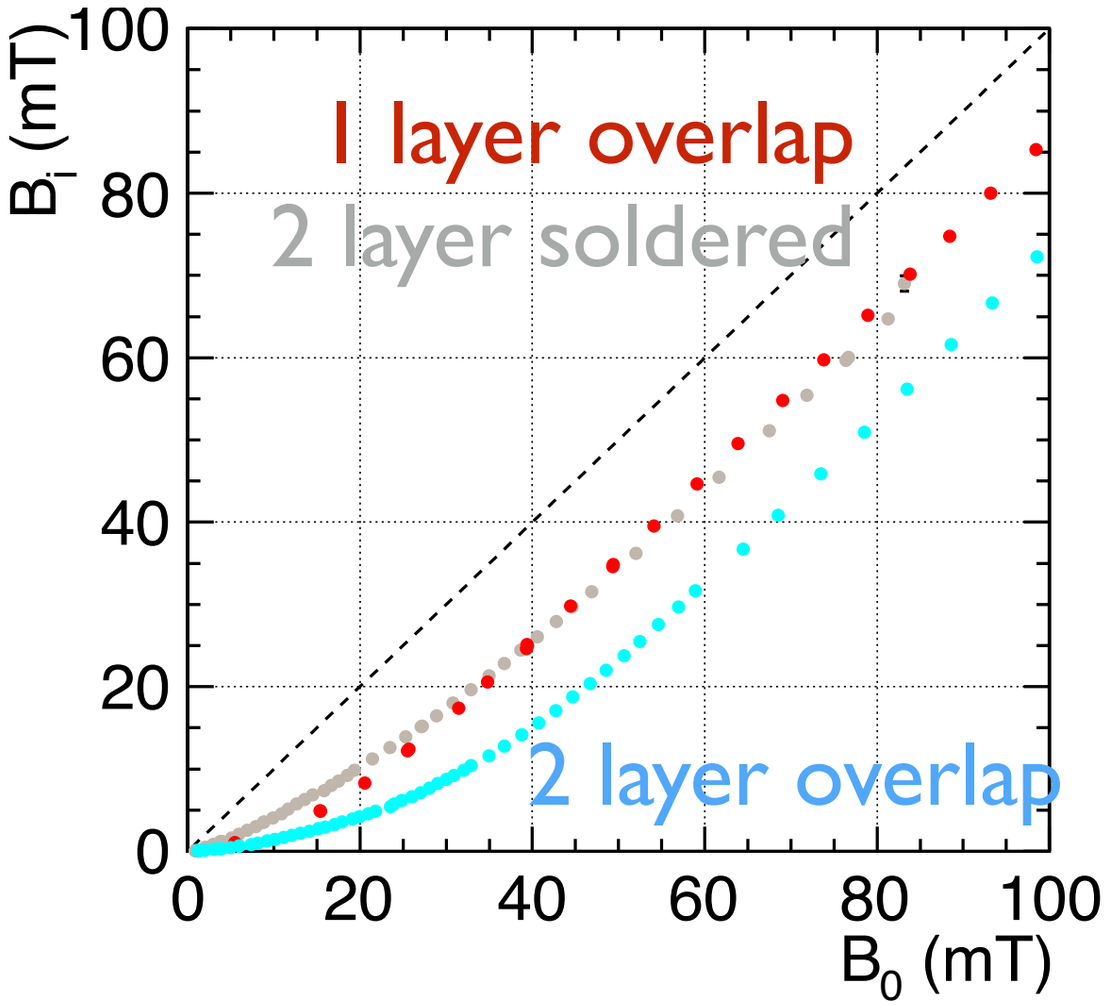


Oven at Stony Brook

First soldering and performance test with miniature version of shield



0.5“ diameter, 1.08” length



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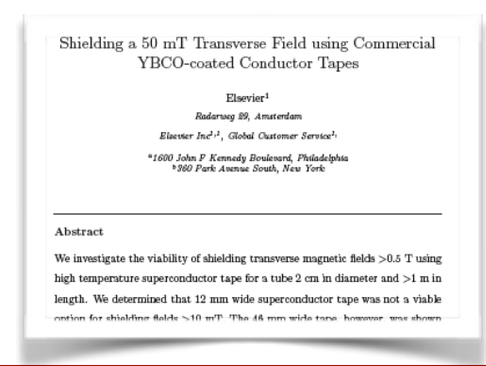
Publication



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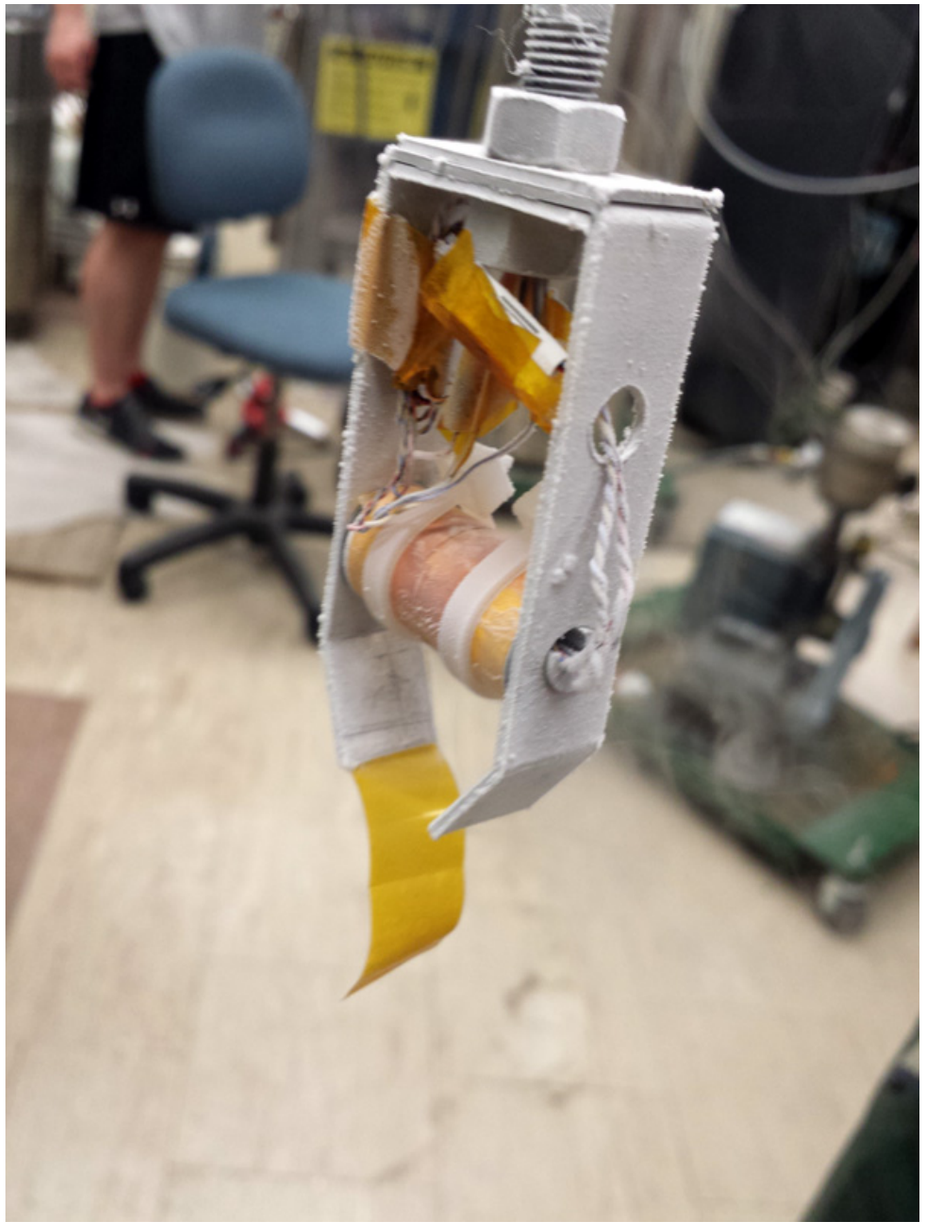
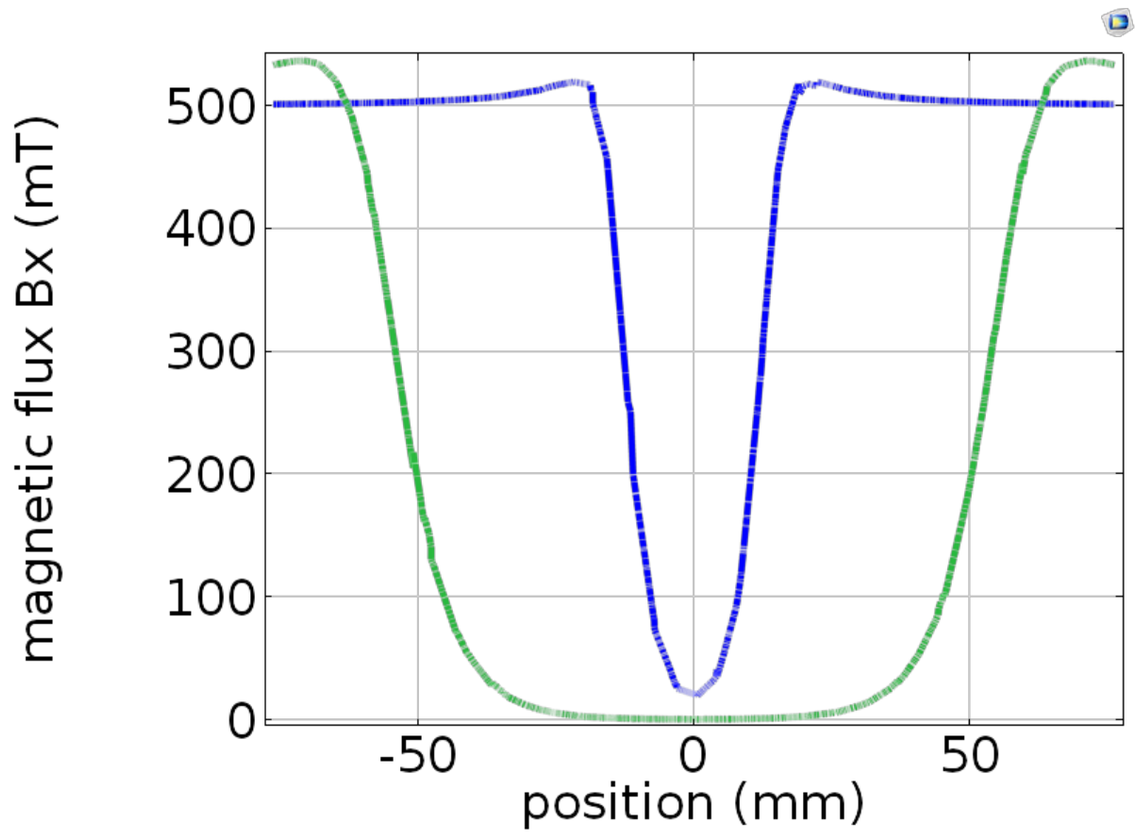
We investigate the viability of shielding transverse magnetic fields >0.5 T using high temperature superconductor tape for a tube 2 cm in diameter and >1 m in length. We determined that 12 mm wide superconductor tape was not a viable

Designed and built a micro-cloak for tests with liquid helium cooling

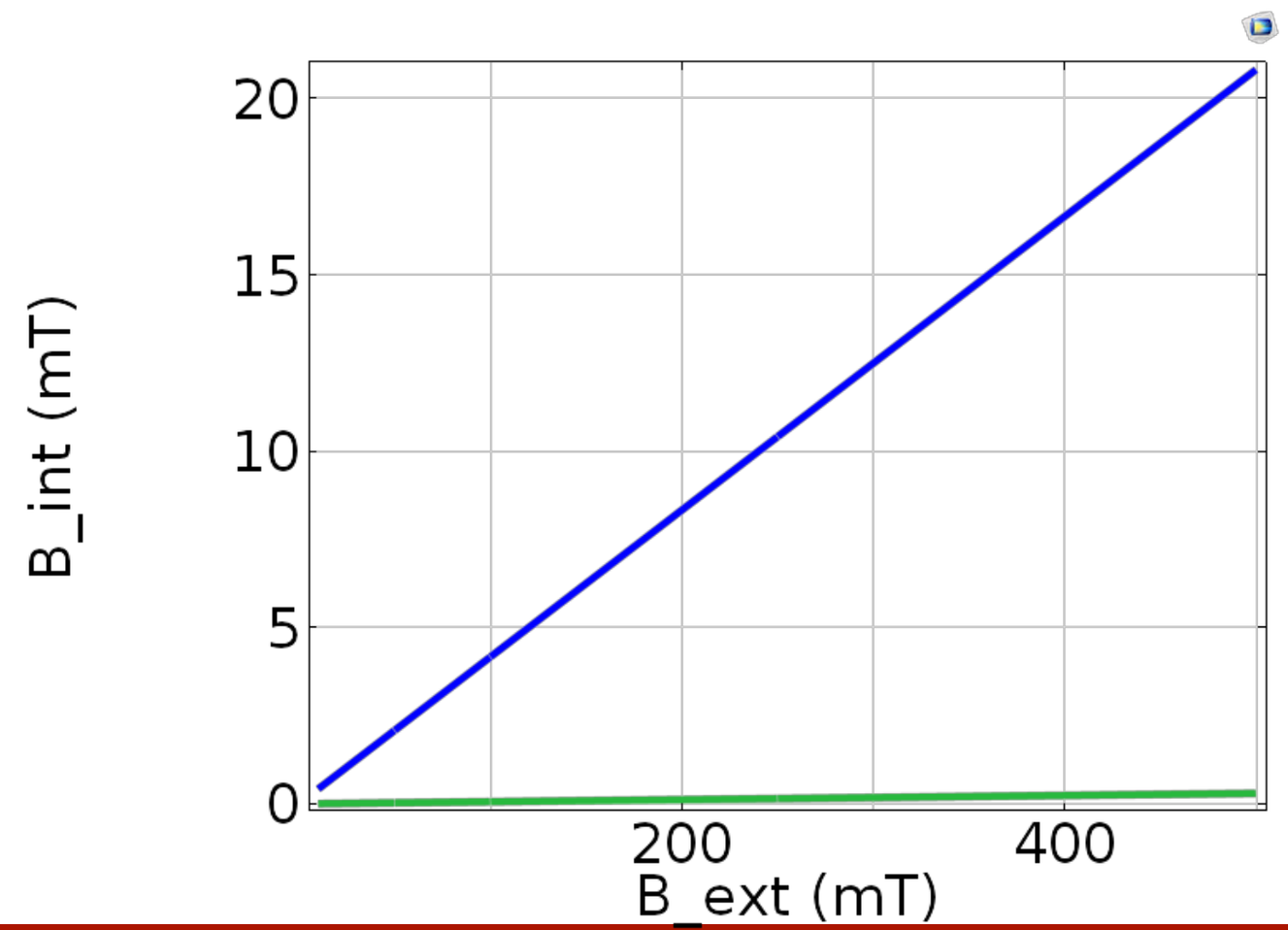


0.5“ diameter
1.08” length

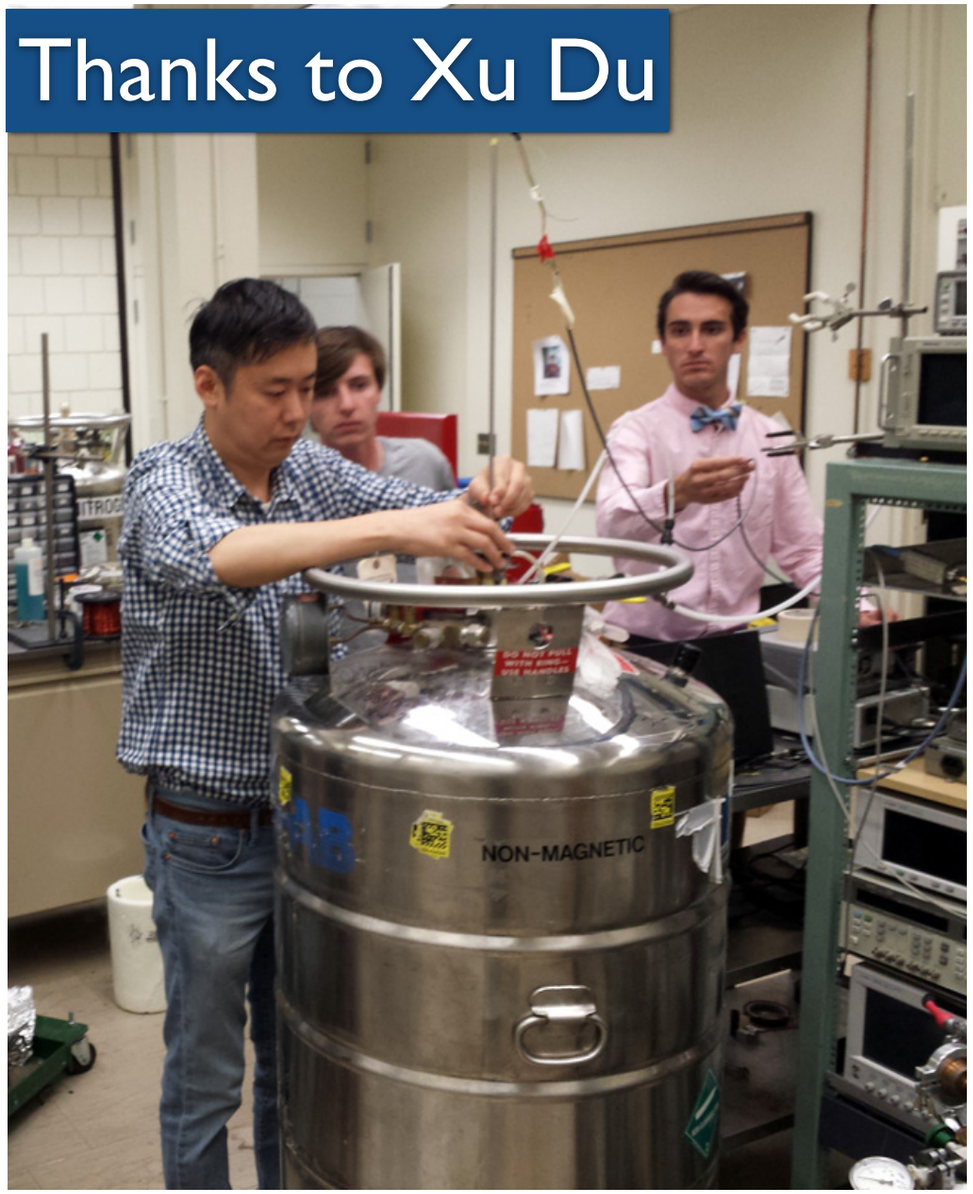
COMSOL: Expecting less shielding due to micro-cloak length / diameter

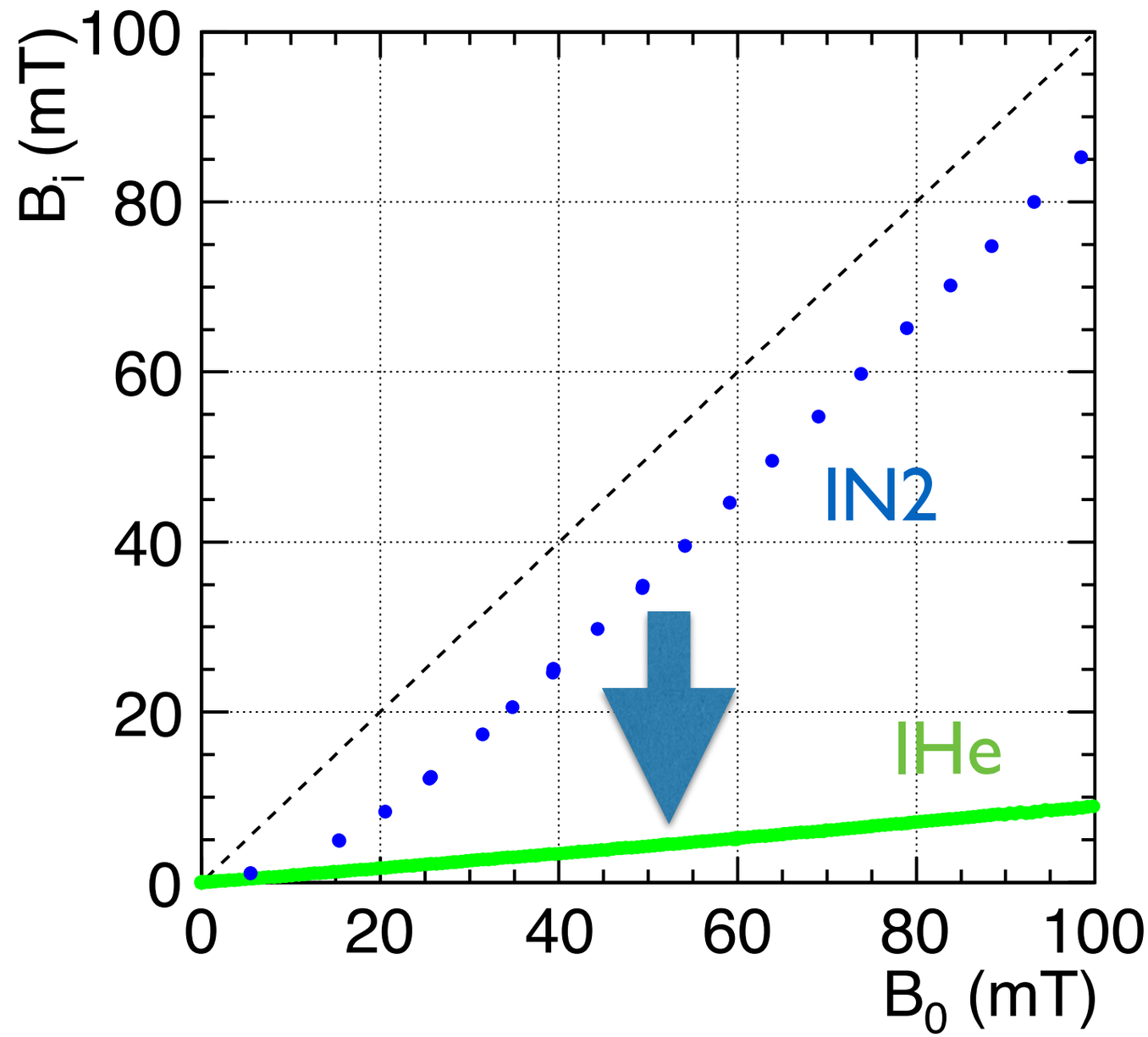


micro-cloak

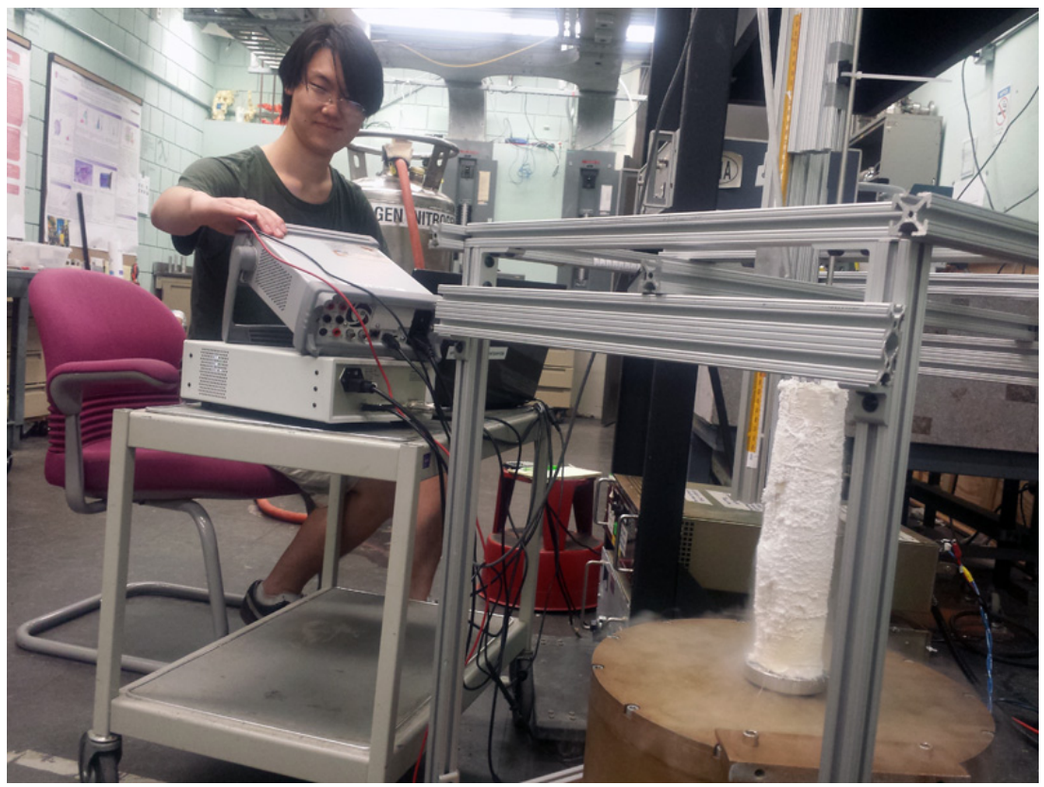


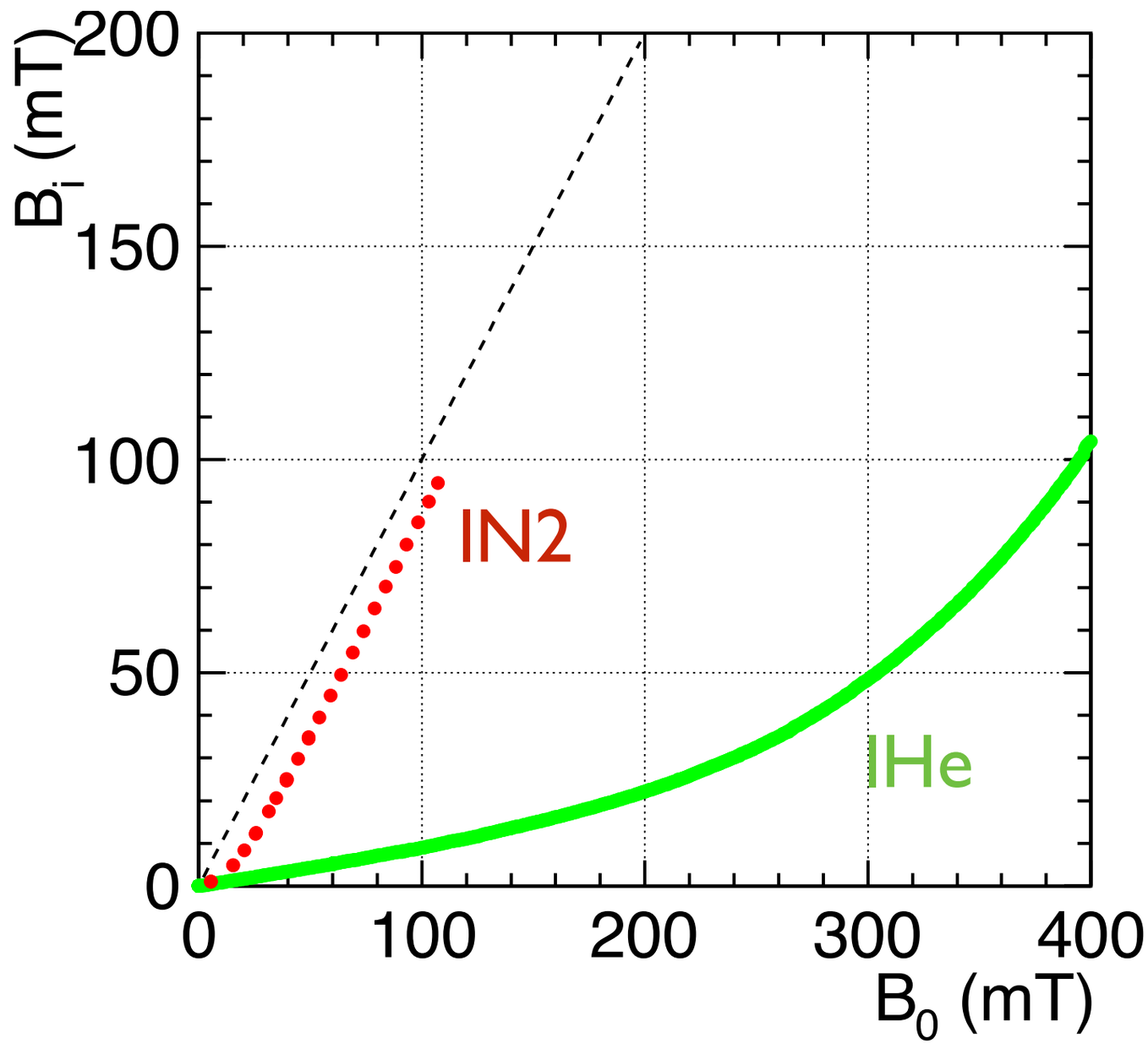
Single YBCO layer shielding at liquid nitrogen and helium temperatures



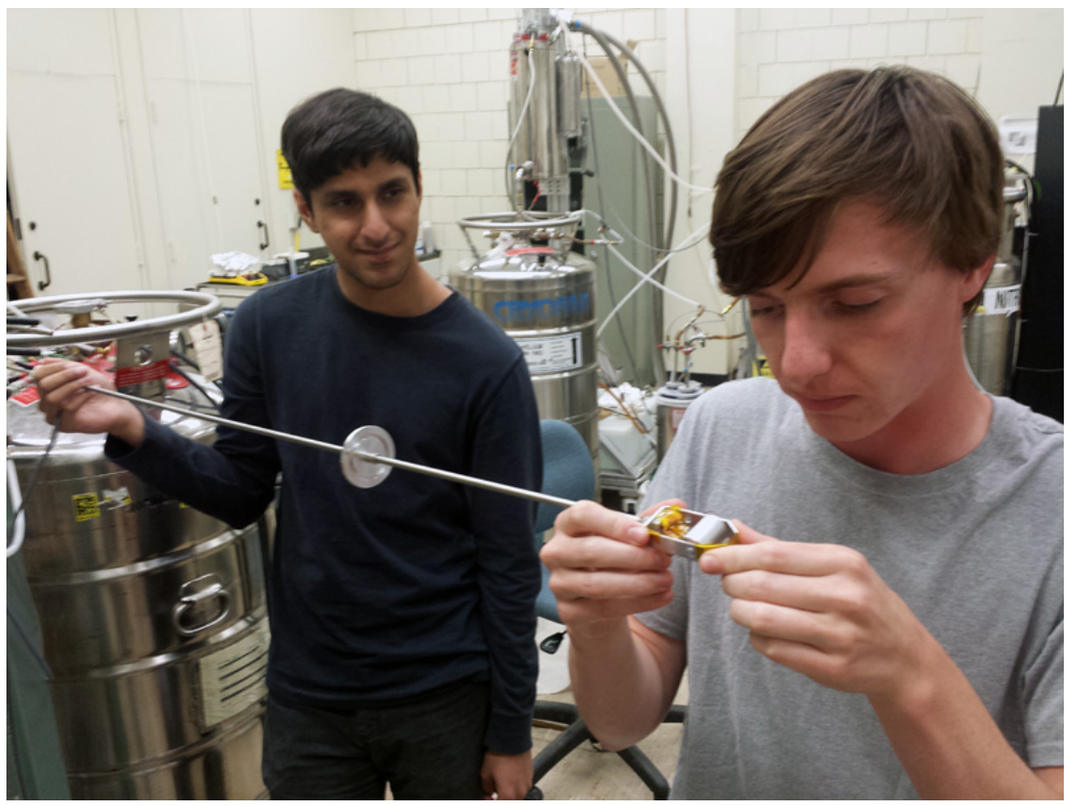


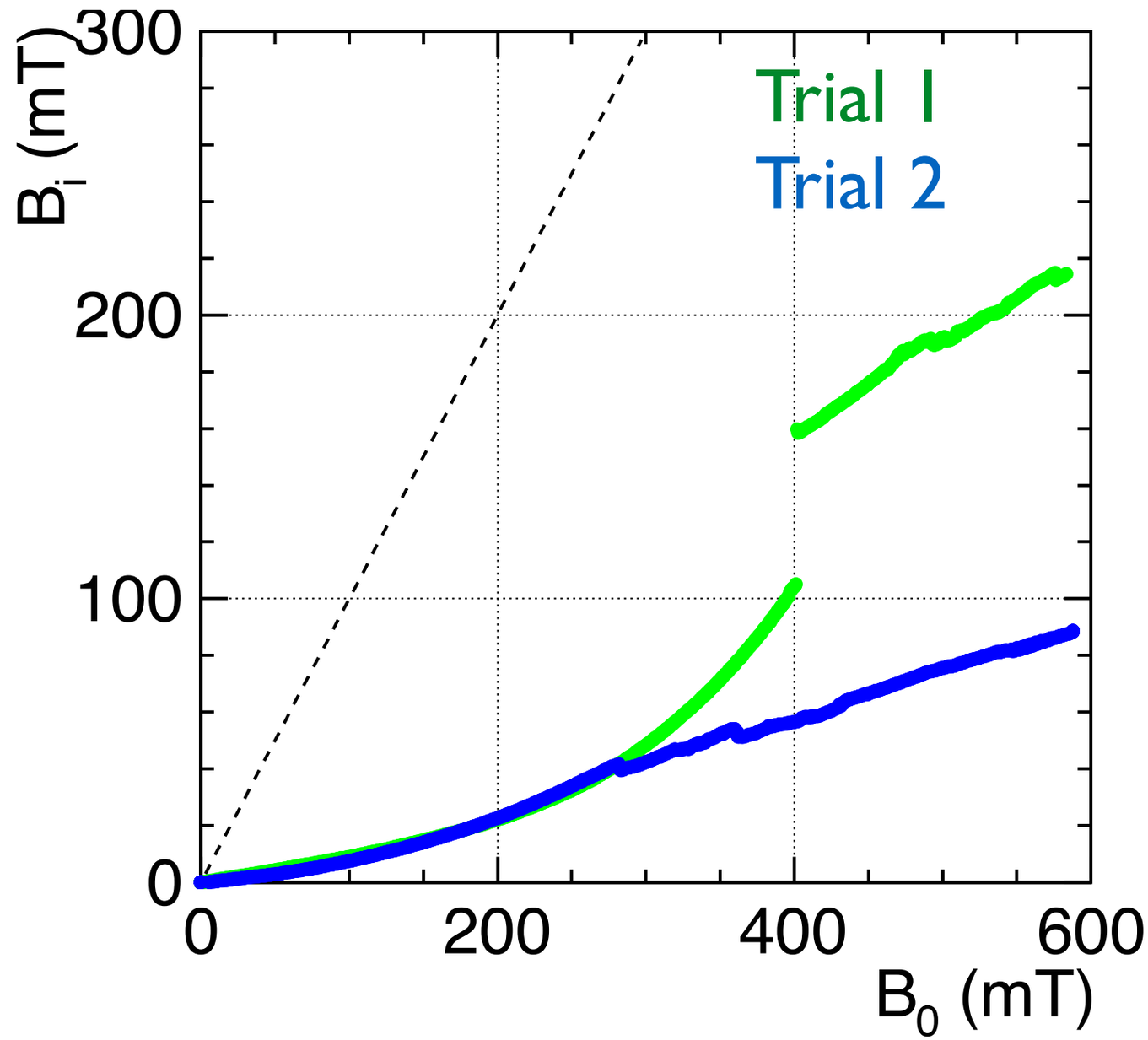
Single YBCO layer shielding of high fields at liquid helium temperatures



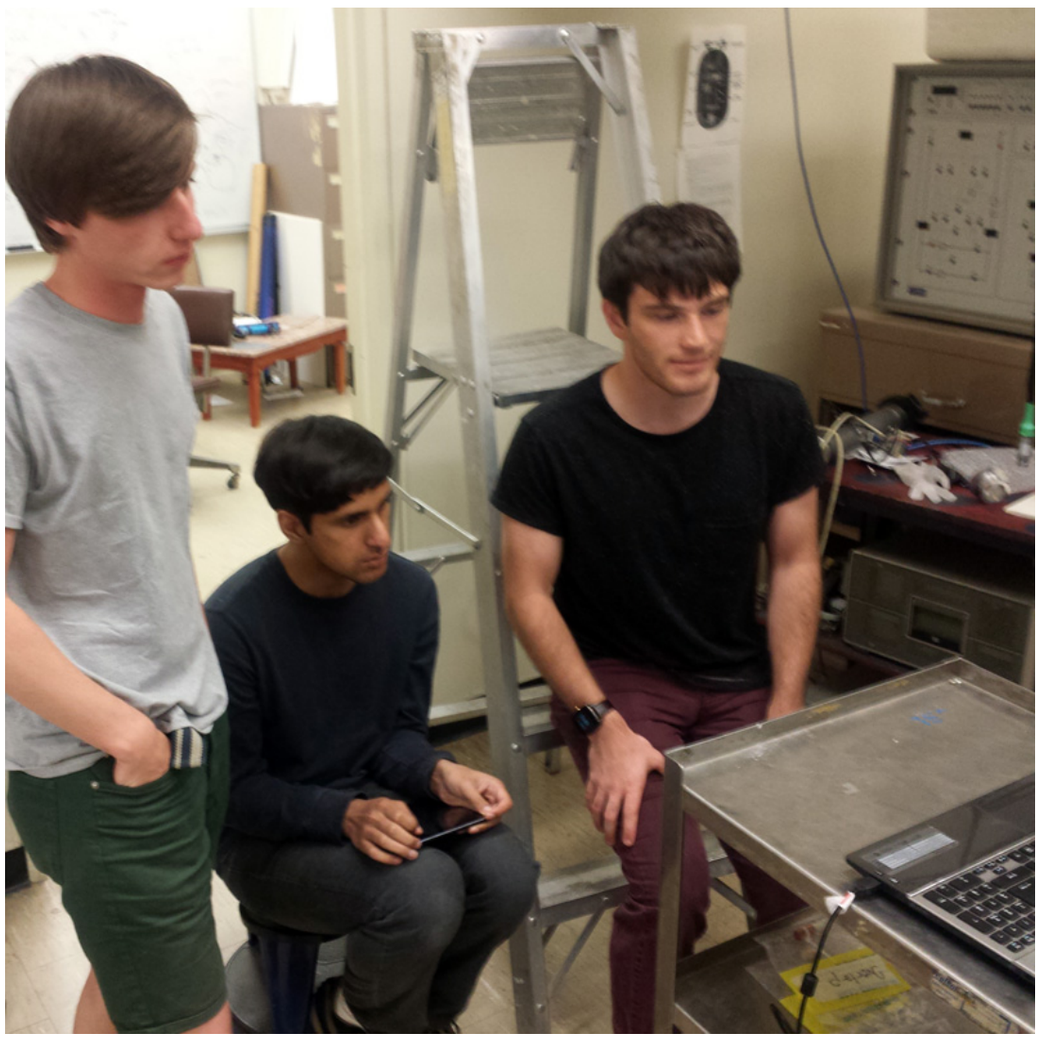


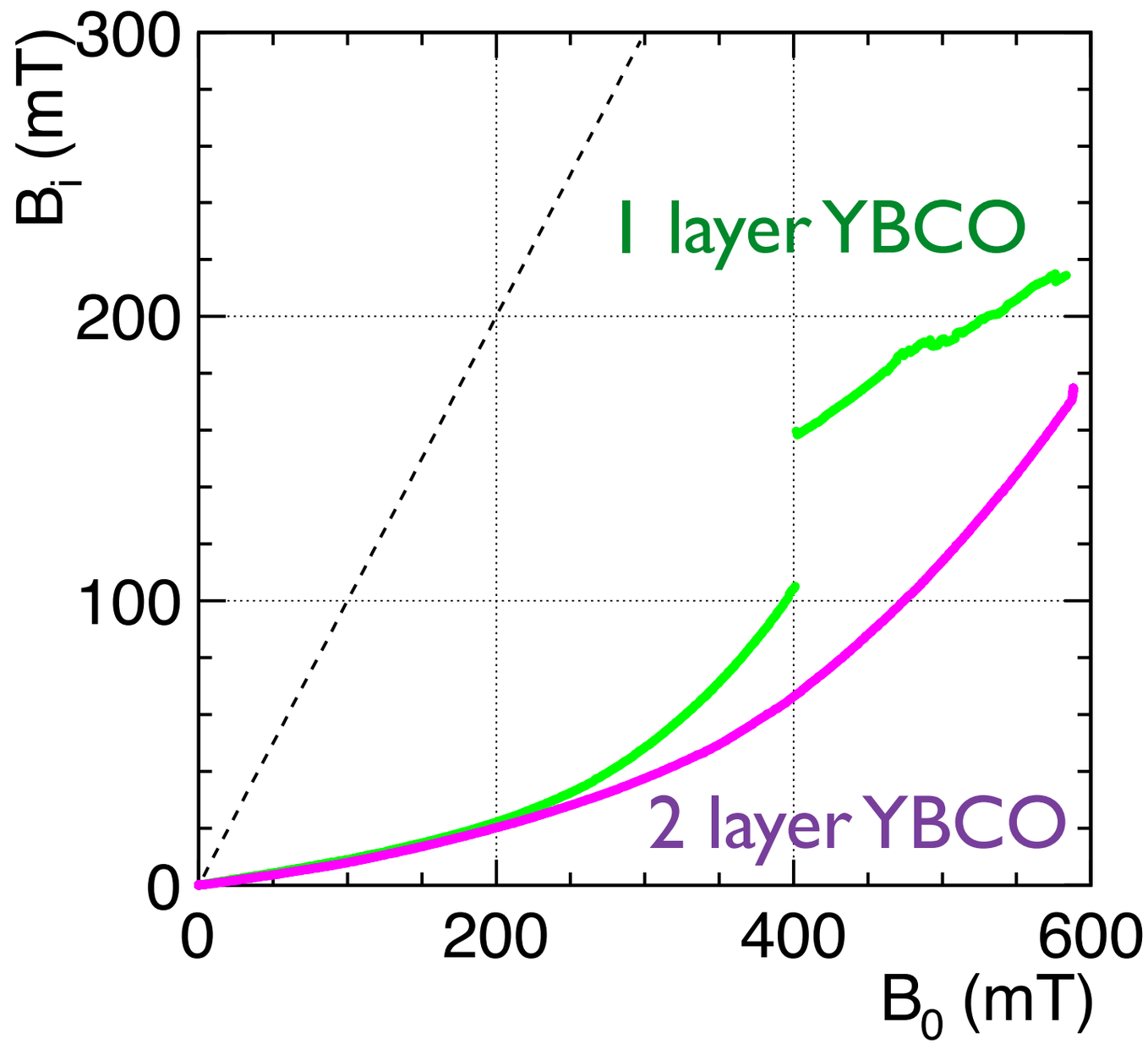
Single YBCO layer (liquid helium) shows shielding instabilities > 300 mT



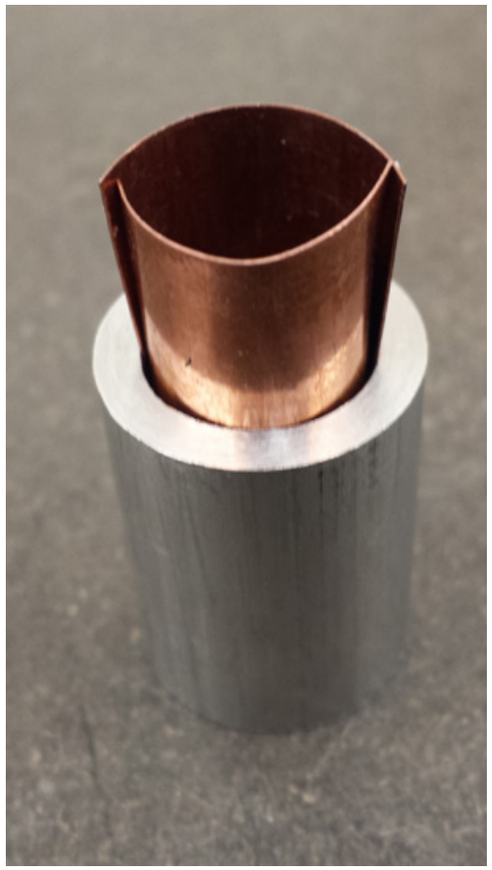


Double YBCO layer (with overlap) shows improved shielding

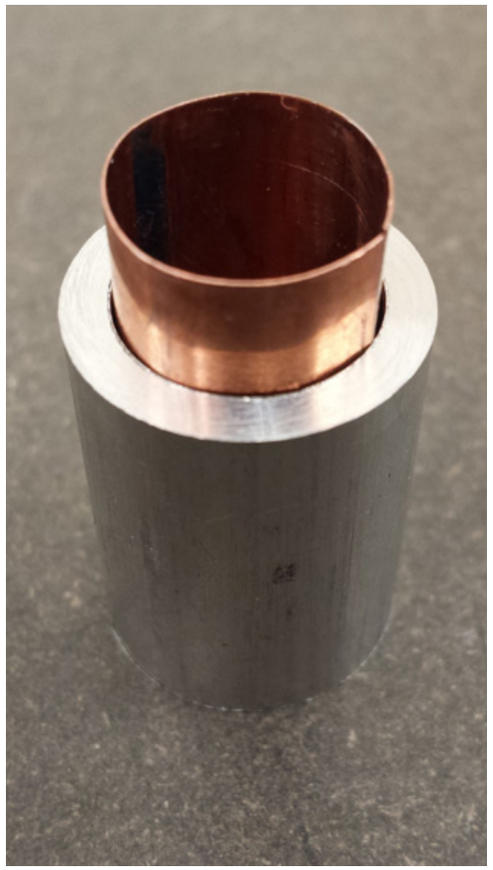




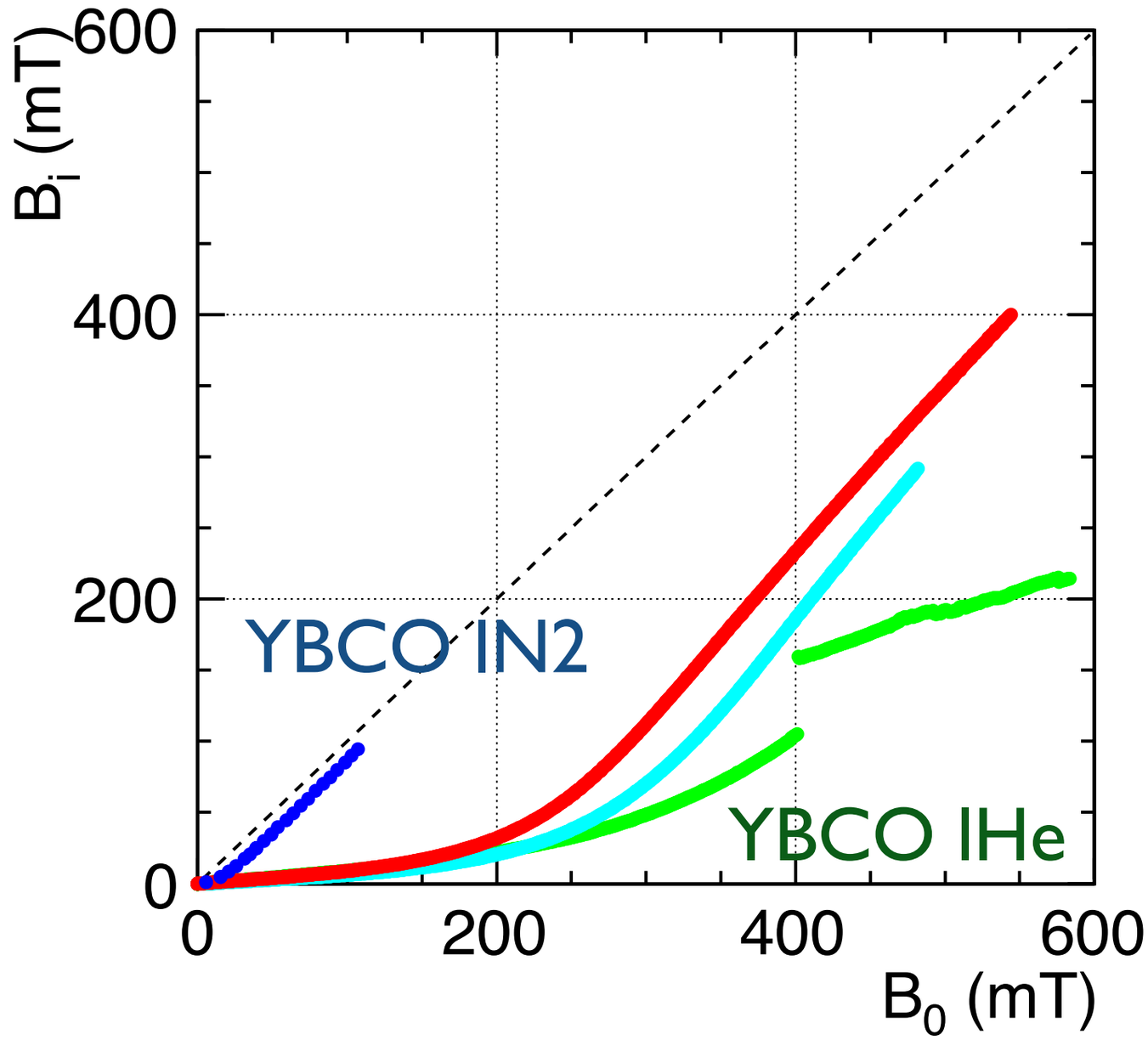
First tests of NbTi sheets at liquid helium temperatures



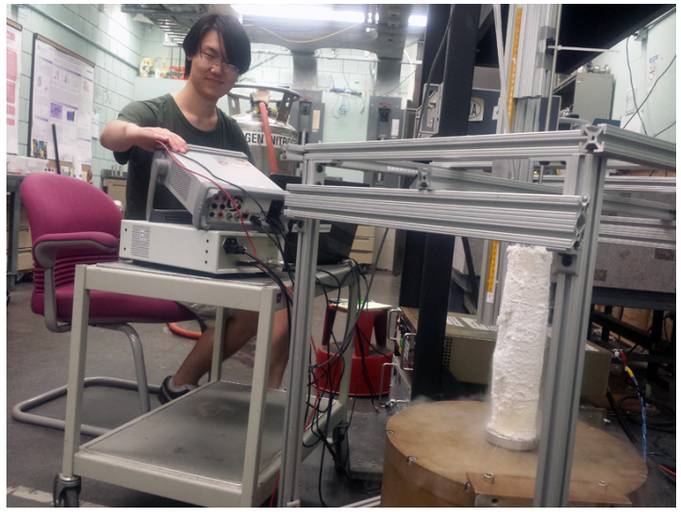
NbTi shells

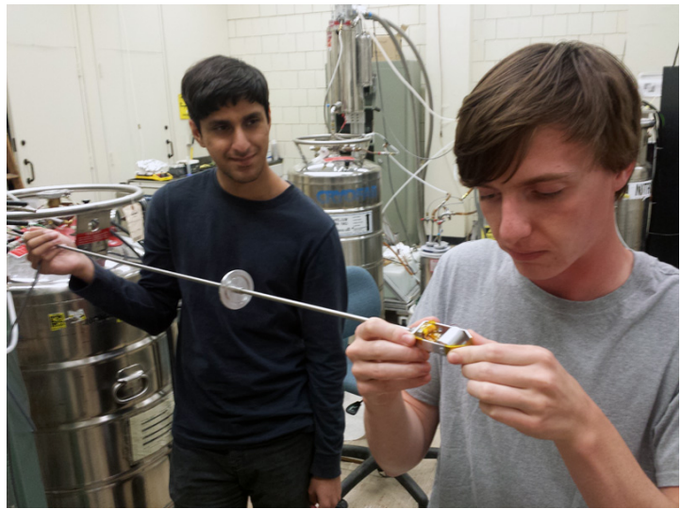


NbTi no-overlap



Credits





Advisors

BNL: R. Gupta, B. Parker, V. Ptitsyn

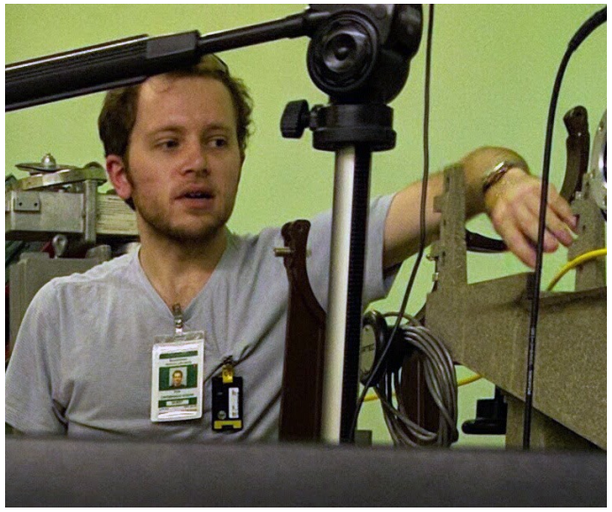
SBU: X. Du

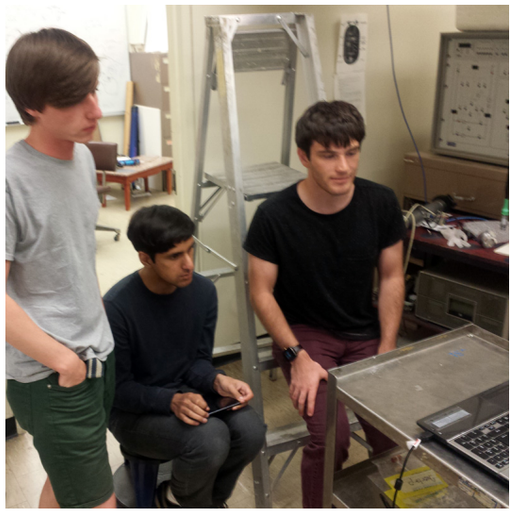
RIKEN

Y. Goto, I. Nakagawa

Stony Brook University (SUNY)

A. Adhyatman, G. Arrowsmith-Kron, D. Bhatti, K. Capobianco-Hogan, R. Cervantes, K. Dehmelt, A. Deshpande, N. Feege, T. K. Hemmick, E. Jiang, T. Krahulik, J. LaBounty, T. LaByer, R. Lefferts, A. Lipski, A. Oliveira, H. Powers, A. Quadri, R. Sekelsky, H. VanNieuwenhuizen, N. Ward

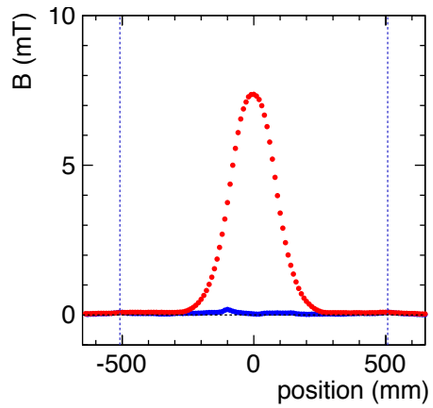


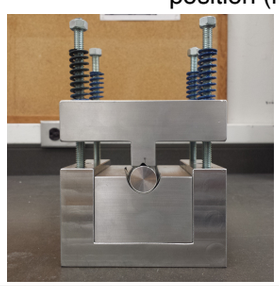


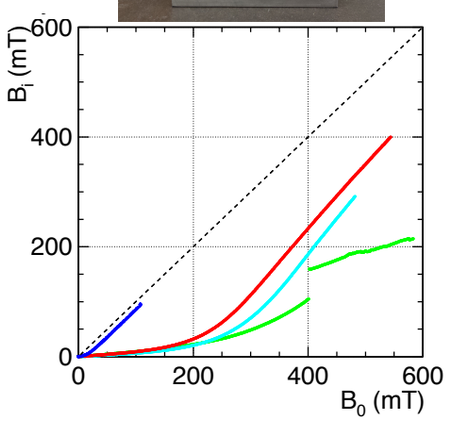
Budget Request for FY 2017

Item	**Cost [$]**
Travel	
Shielding tests with MRI magnet at Argonne National Lab (2 students and 2 PI's for one week)	7,500
Supplies	
Liquid nitrogen	1,000
Laboratory supplies	2,000
Other	
Miscellaneous machine shop services at Stony Brook	2,000
Total Direct Cost	12,500
Total Indirect Cost (Overhead)	7,250
Total Request	**20,000**

Progress towards a cloak for EIC







Commissioned 1.3 m superconductor shield at BNL Van de Graaff; waiting for beam this week.

Improved procedure to fabricate 10-40 layer superconductor shield and found option for 0.5 T test.

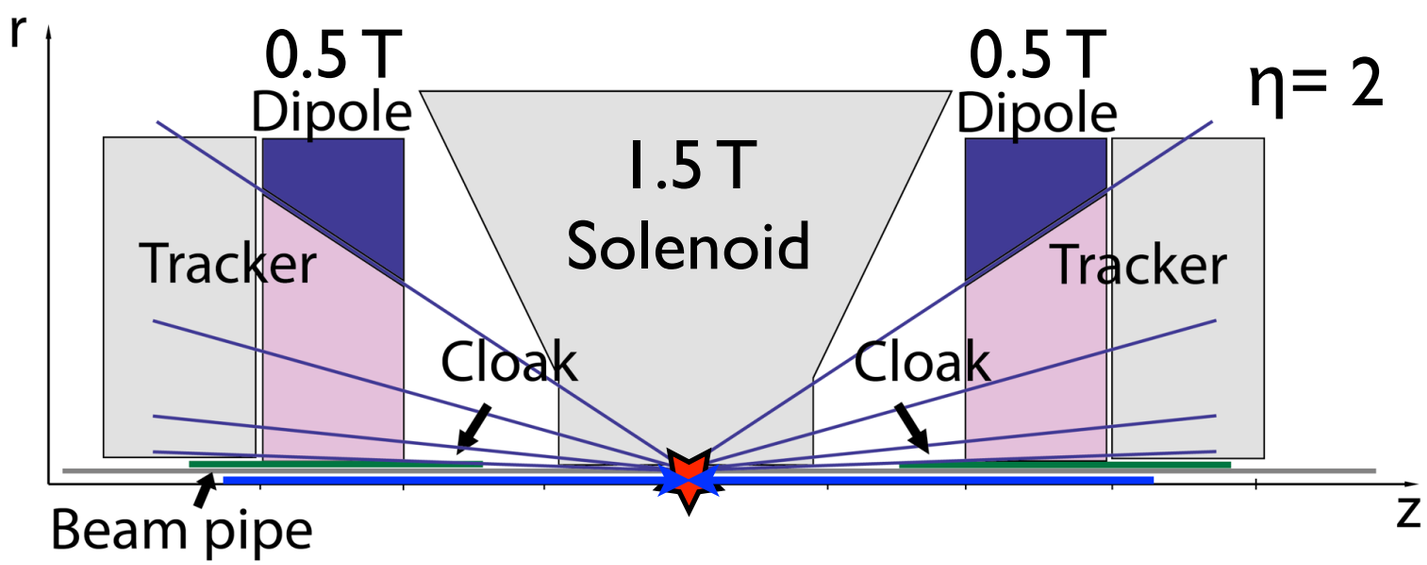
Completed initial shielding tests with micro-cloak at liquid helium temperatures (YBCO and NbTi).

→ **Publication**

We think we understand the design parameters and limitations for a magnetic field cloak for EIC.

ADDITIONAL SLIDES

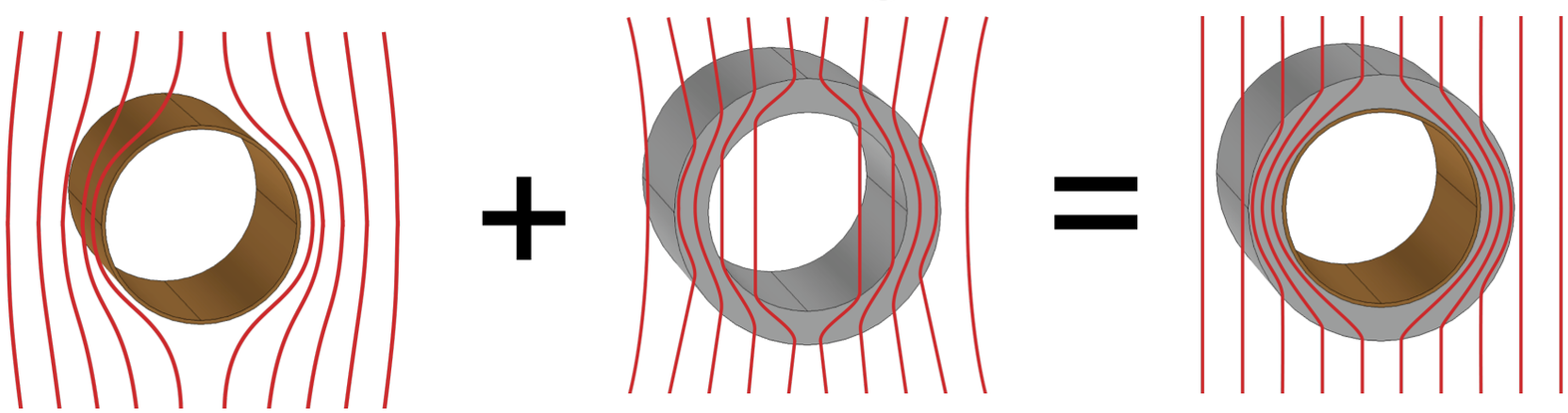
Can we extend good momentum resolution closer to the beam pipe?



Magnetic Cloak:

- Shield fields up to 0.5 T
- No outside field disturbances
- Thin, > 1 m long

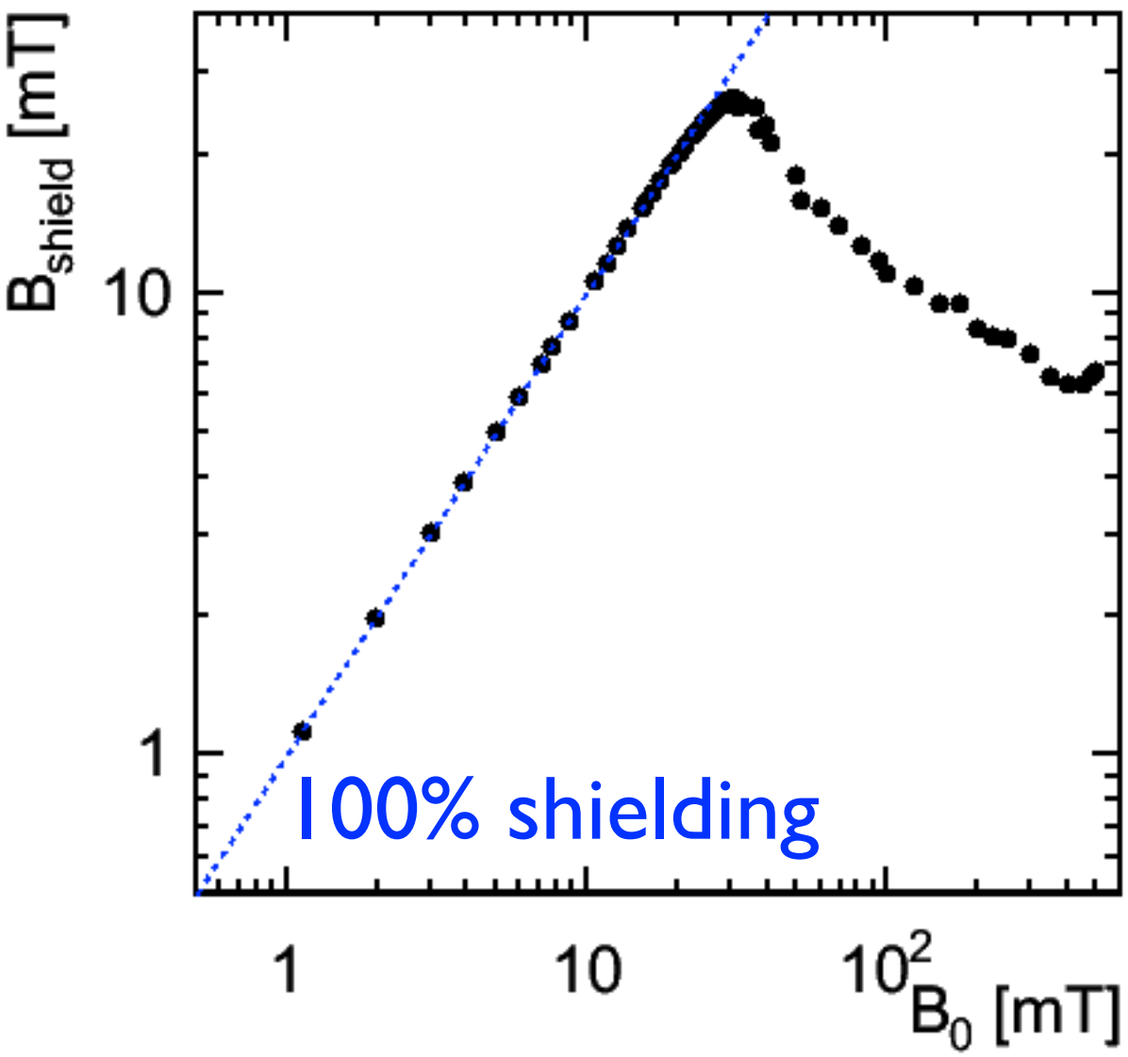
superconductor ferromagnet cloak

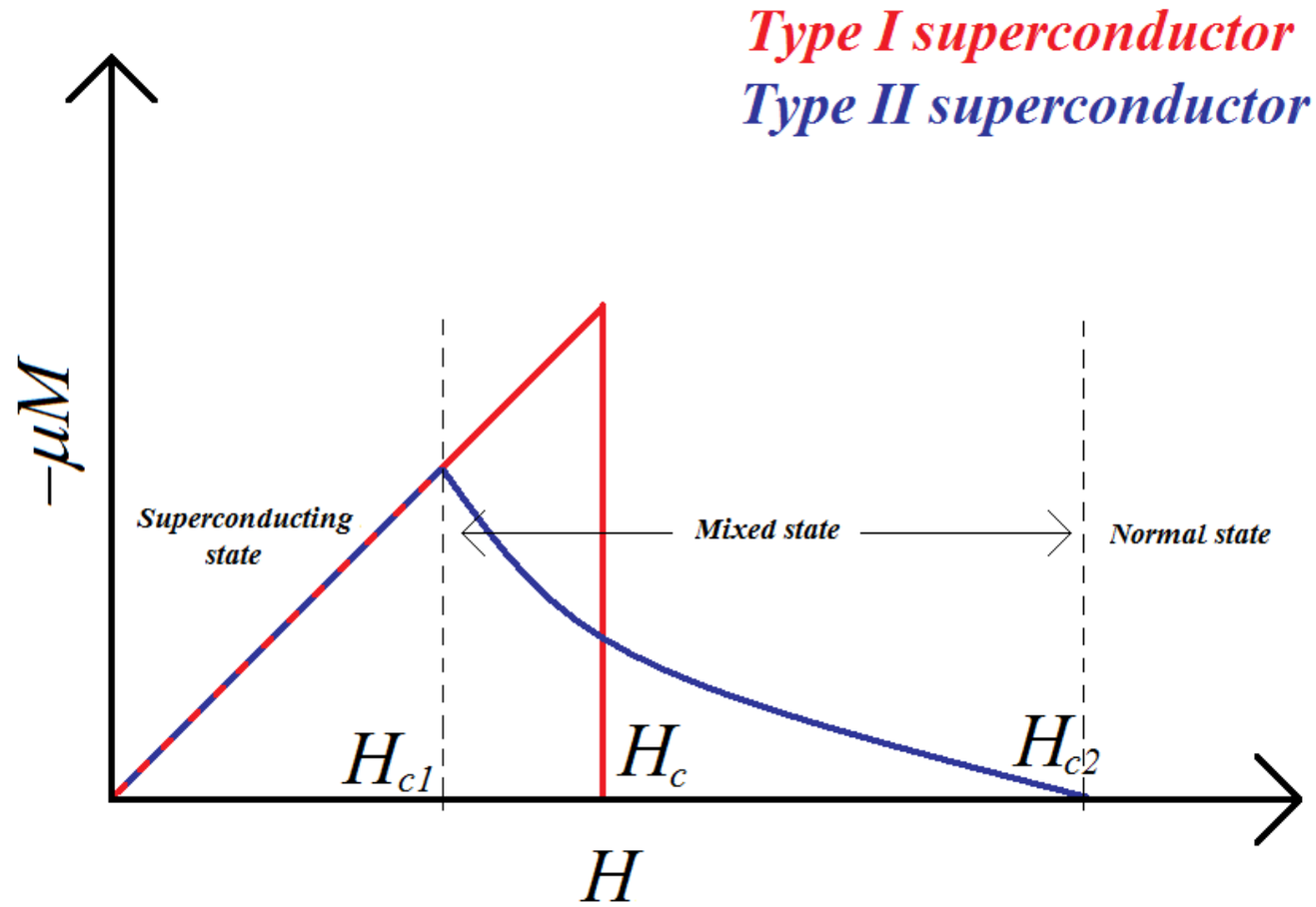


$$\mu_2 = \frac{R_2^2 + R_1^2}{R_2^2 - R_1^2}$$

Fedor Gömöry et al.
DOI: 10.1126/science.1218316

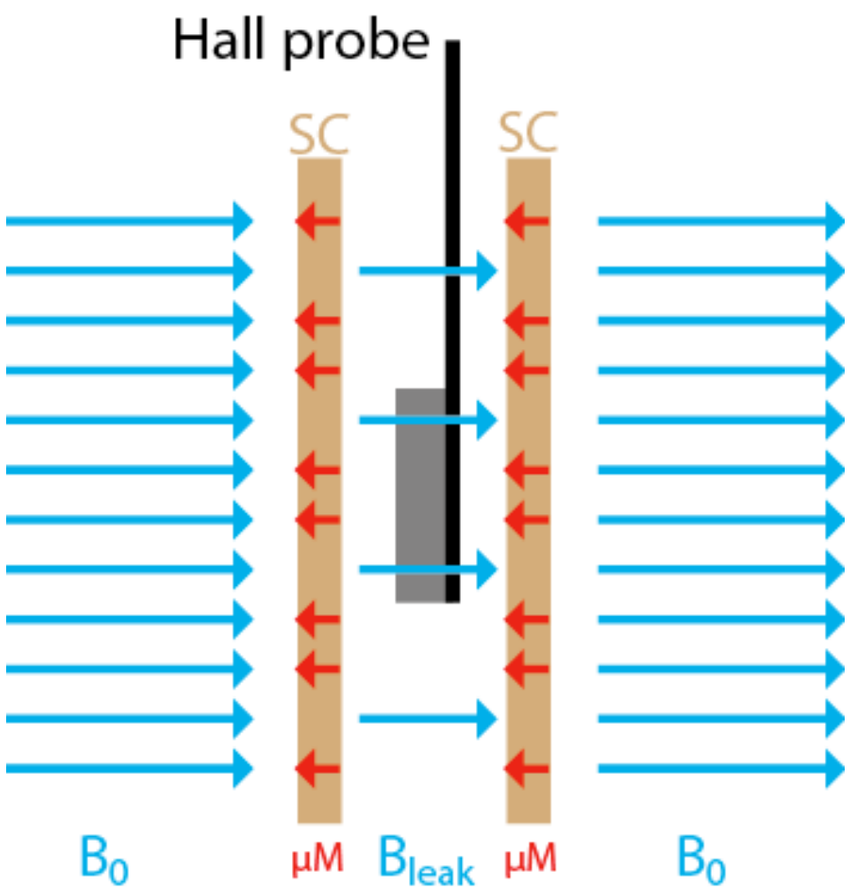
SC tape performance at high fields

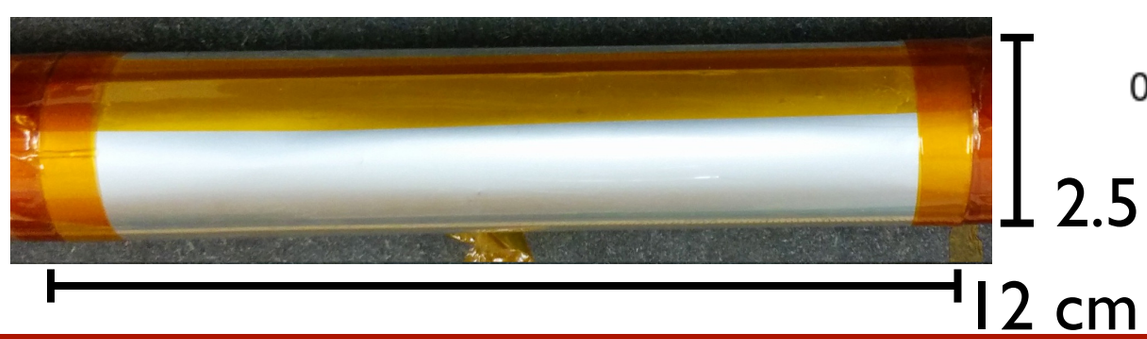


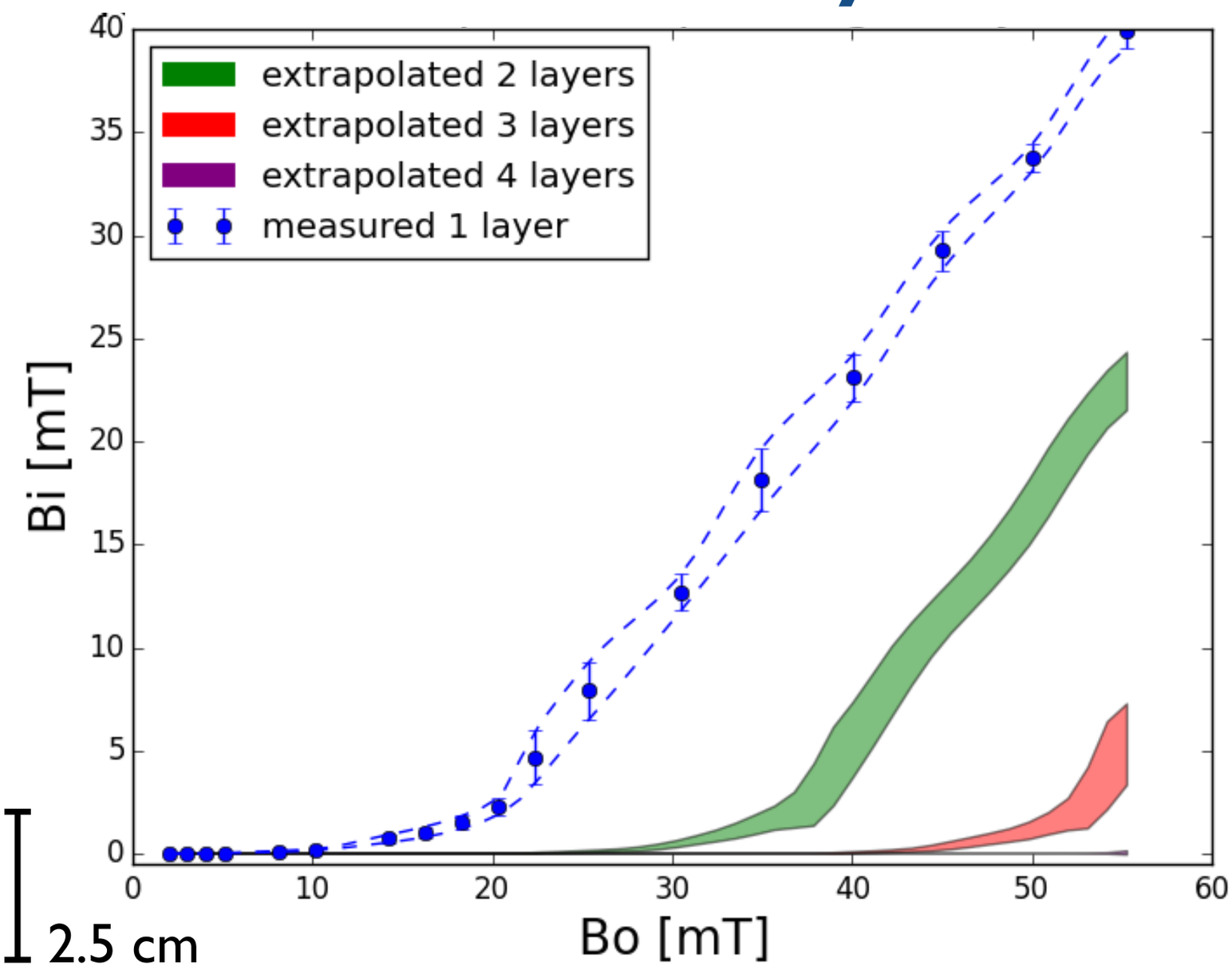


B_{C1} ~ 20 mT
B_{C2} > 500 mT

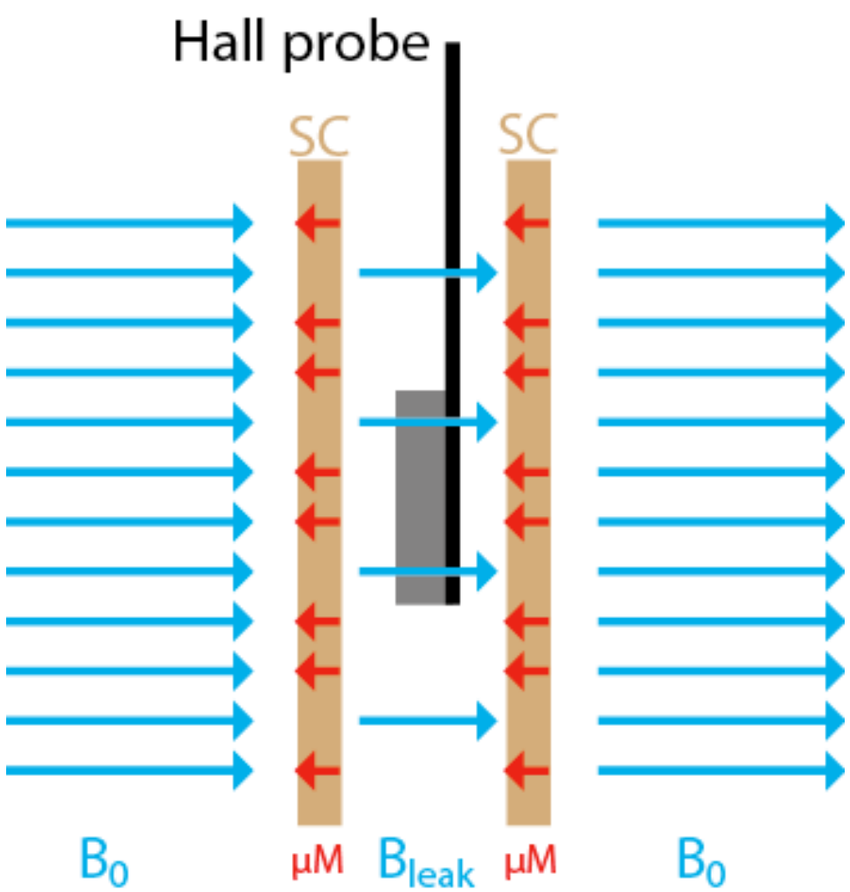
Established method to extrapolate shielding performance of SC cylinder

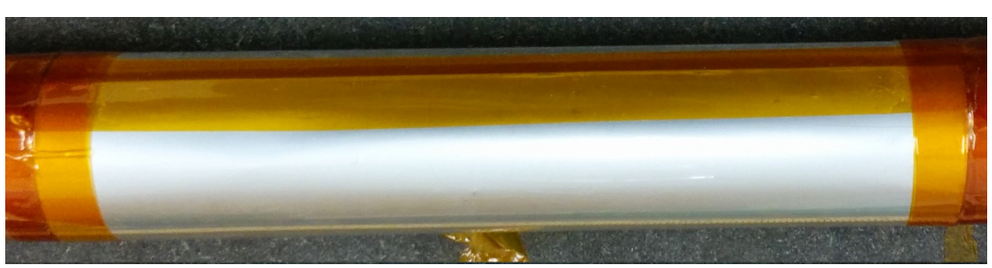




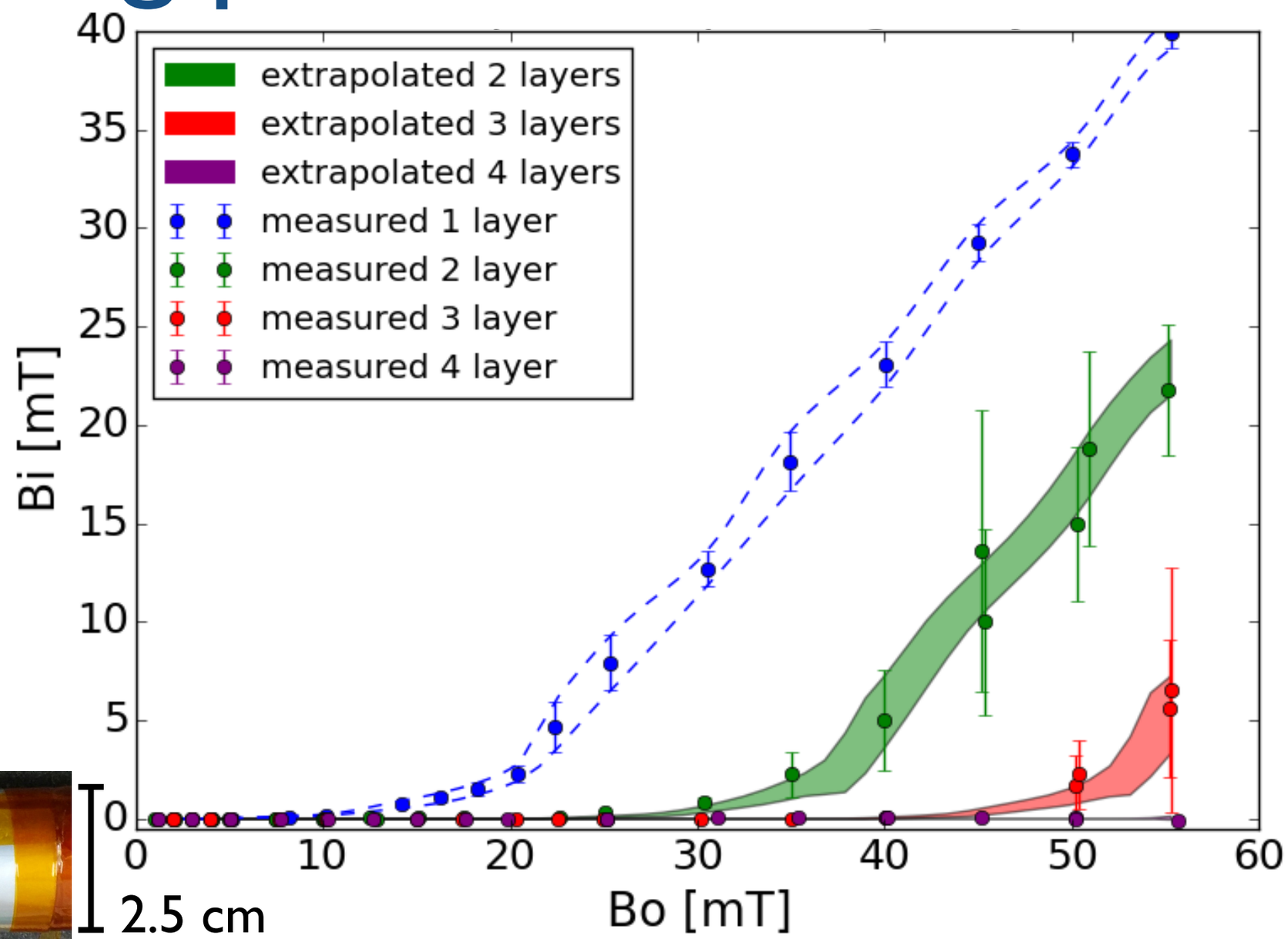


Measurements validate extrapolated shielding performance

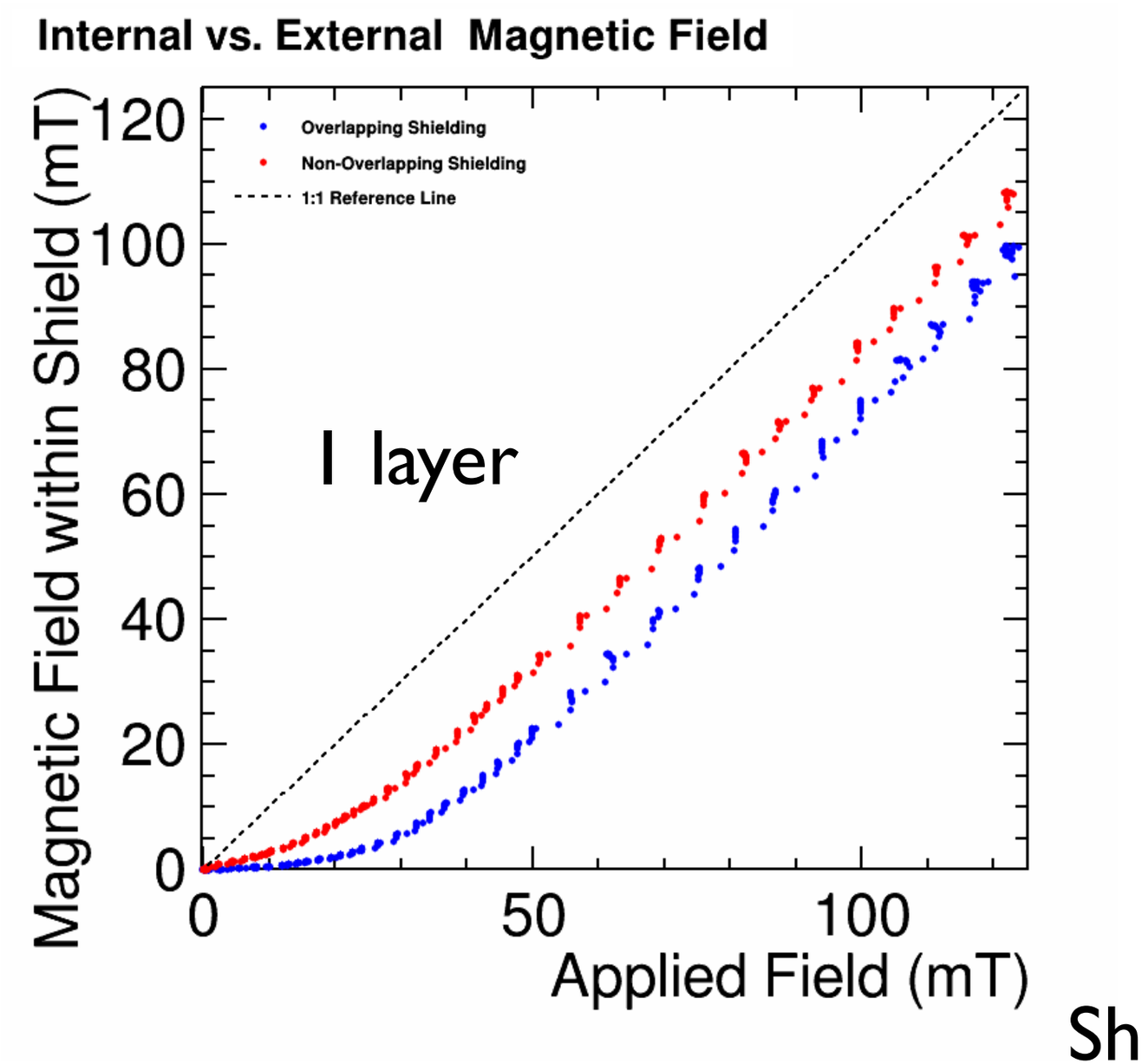




12 cm



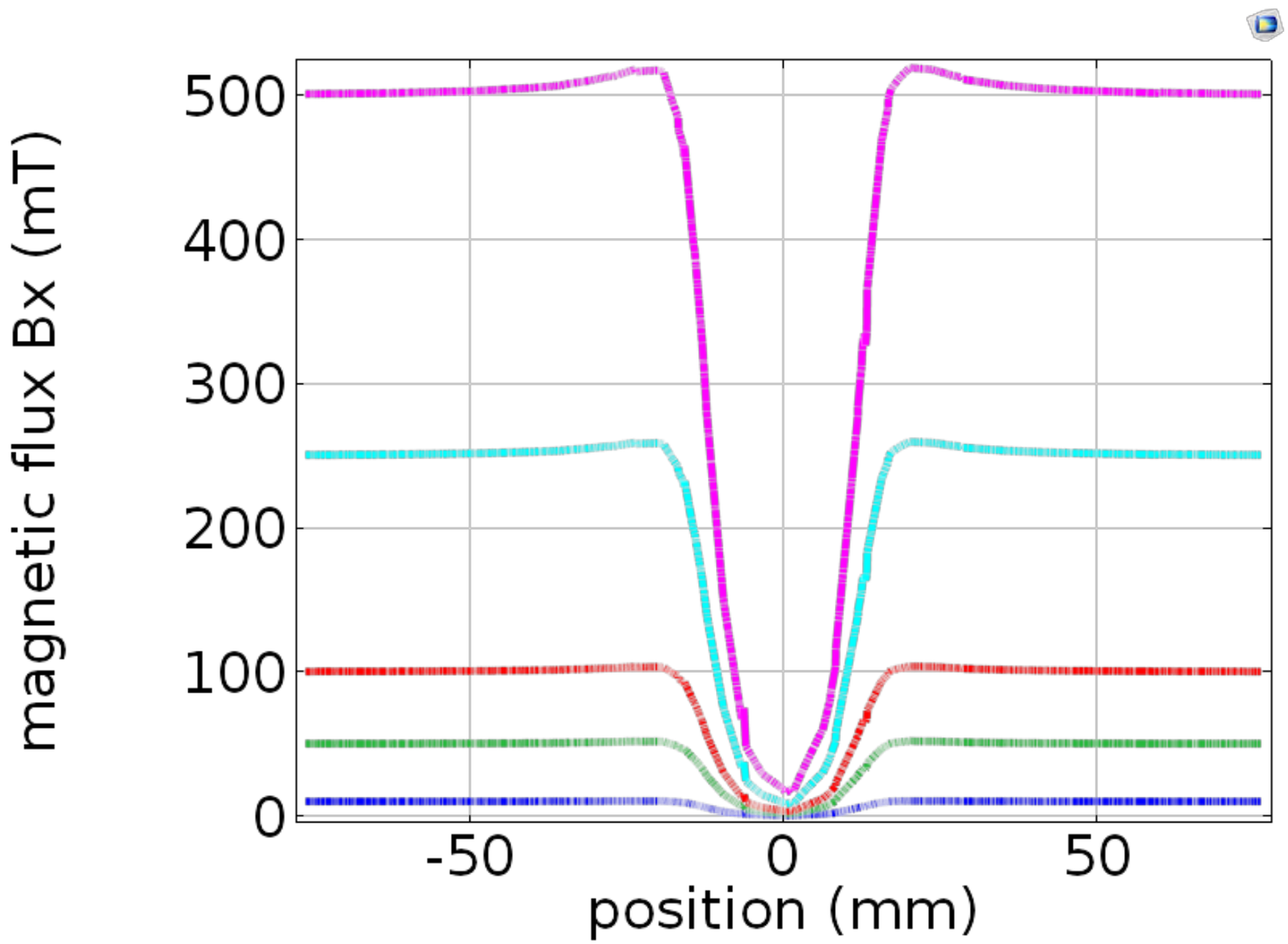
Non-overlapping geometry performs worse than overlapping geometry



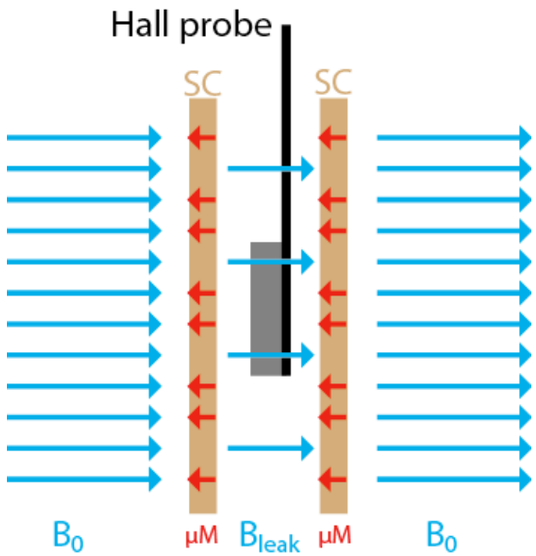
Overlap
No Overlap

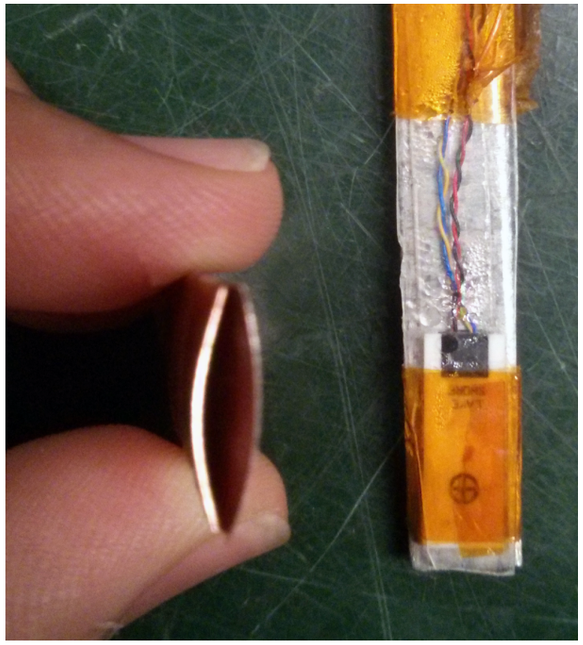
Shield: 1" diameter, 4.5" length

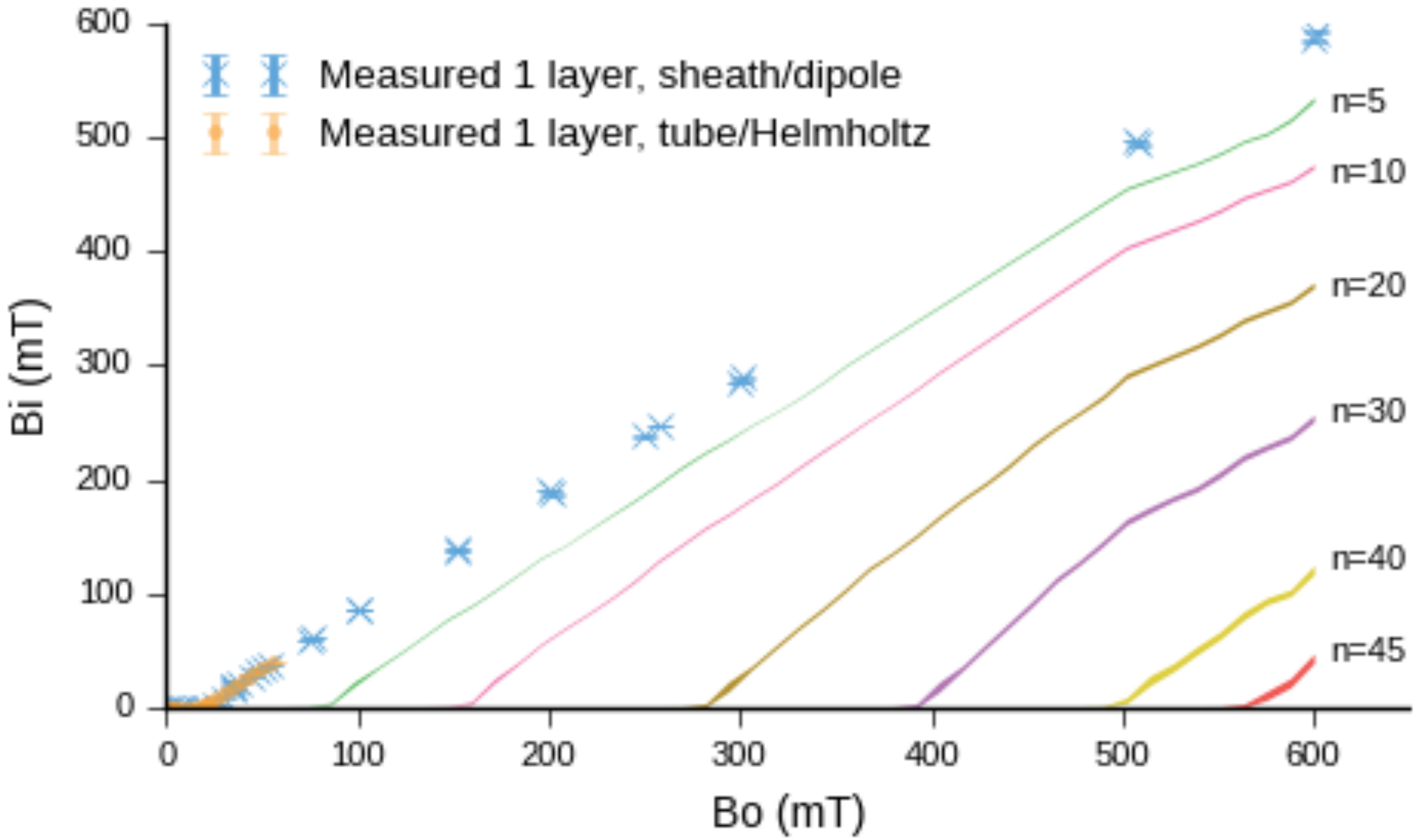
COMSOL Flux Vs Bext for 0.5 inch x 1.08 inch cylinder



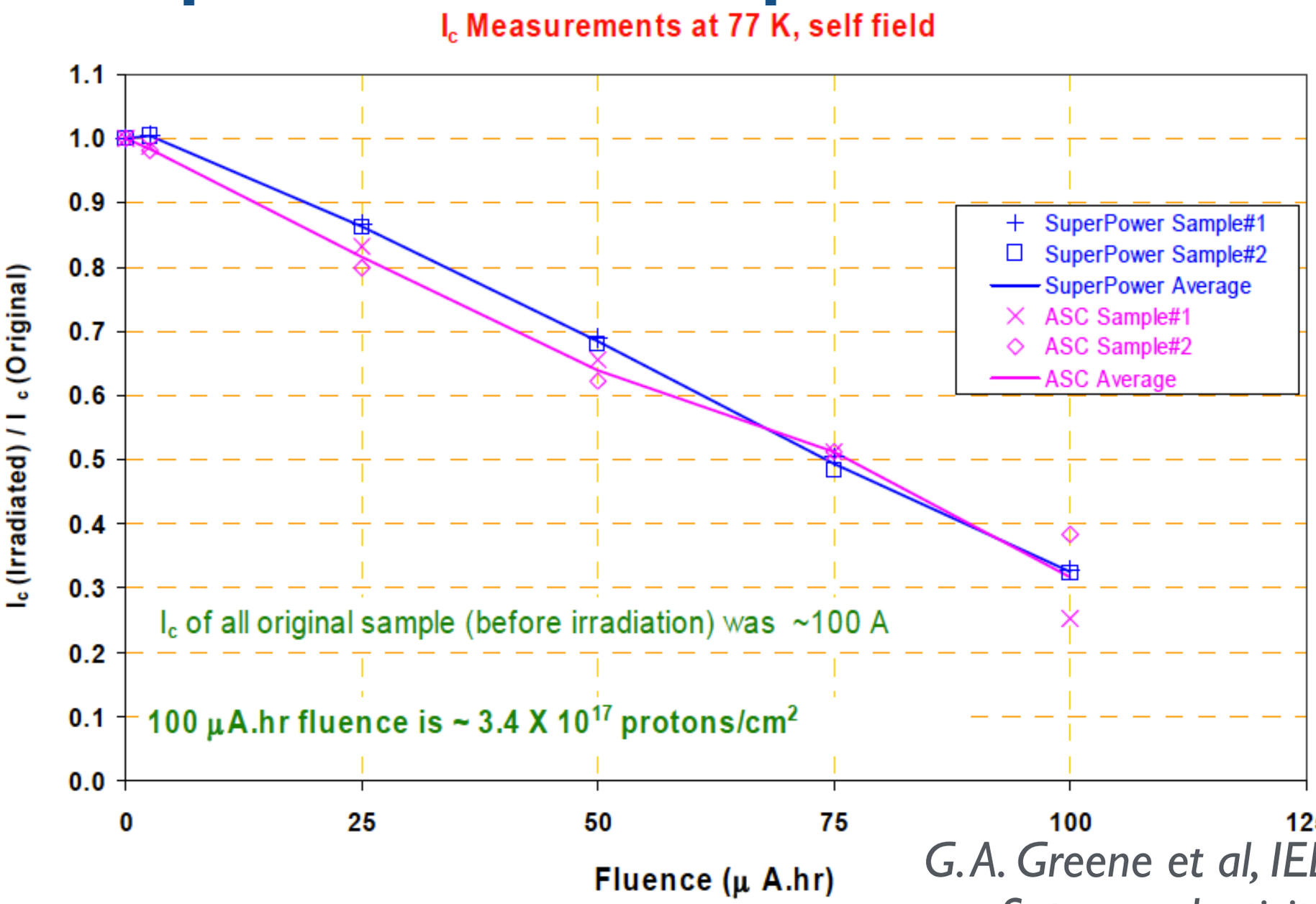
Superconductor test up to 0.5 T and extrapolation to multiple layers







Radiation hardness of commercially produced superconductor wire



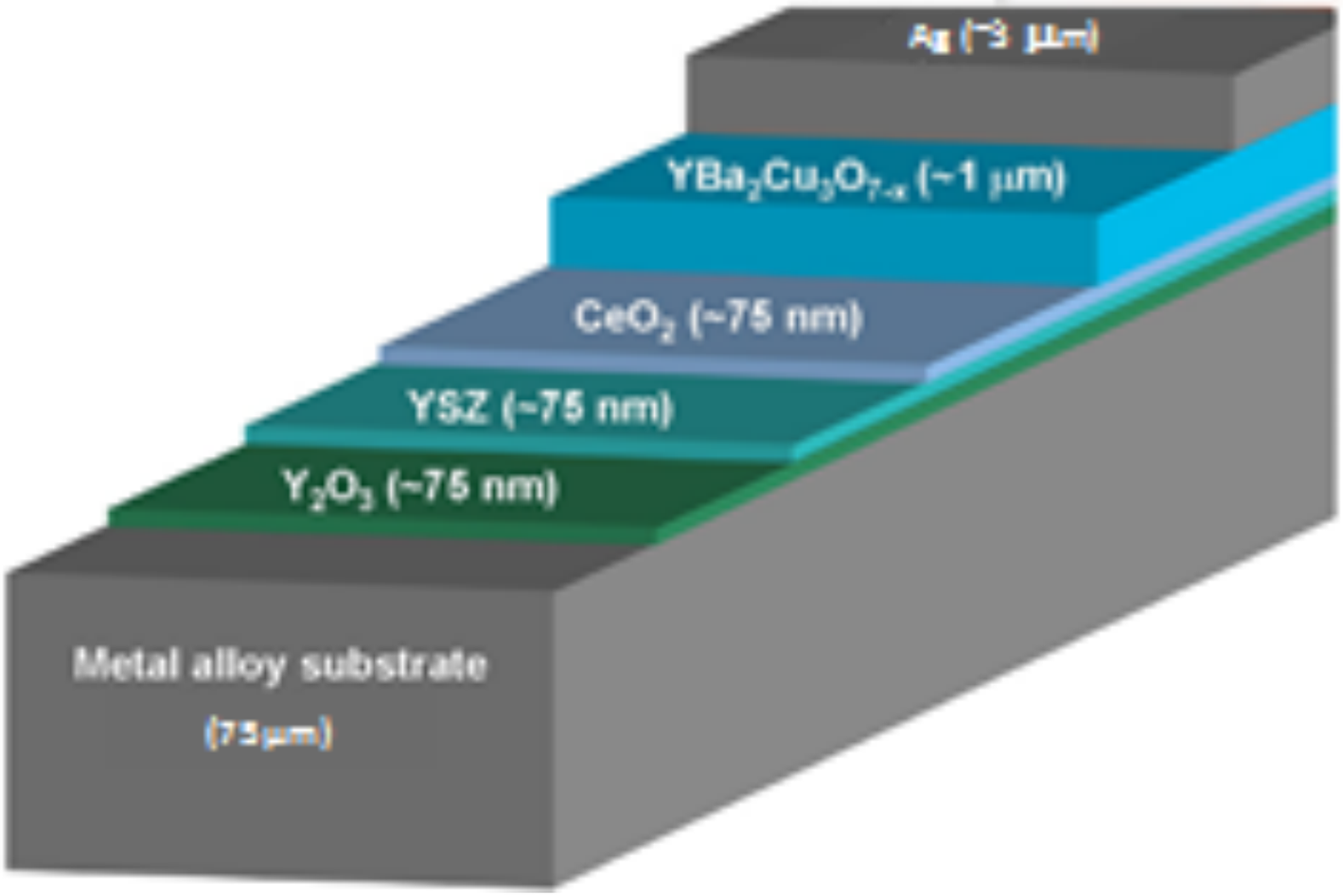
Noticeable effects only above ~10^{16} protons / cm^2

G. A. Greene et al, IEEE Transactions On Applied Superconductivity, Vol. 19, No. 3, June 2009

AMSC 2G Technology

Based on low-cost RABITS™/MOD Architecture

- **Substrate: Ni-5W alloy**
  - Deformation texturing
- **Buffer stack: Y_2O_3/YSZ/CeO_2**
  - High rate reactive sputtering
- **YBCO, the HTS part**
  - Metal Organic Deposition of TFA-based precursors
- **Ag**
  - DC sputtering



46 mm wide wire

NbTi/Nb/Cu sheets quoted to shield up to 0.8 T with single layer

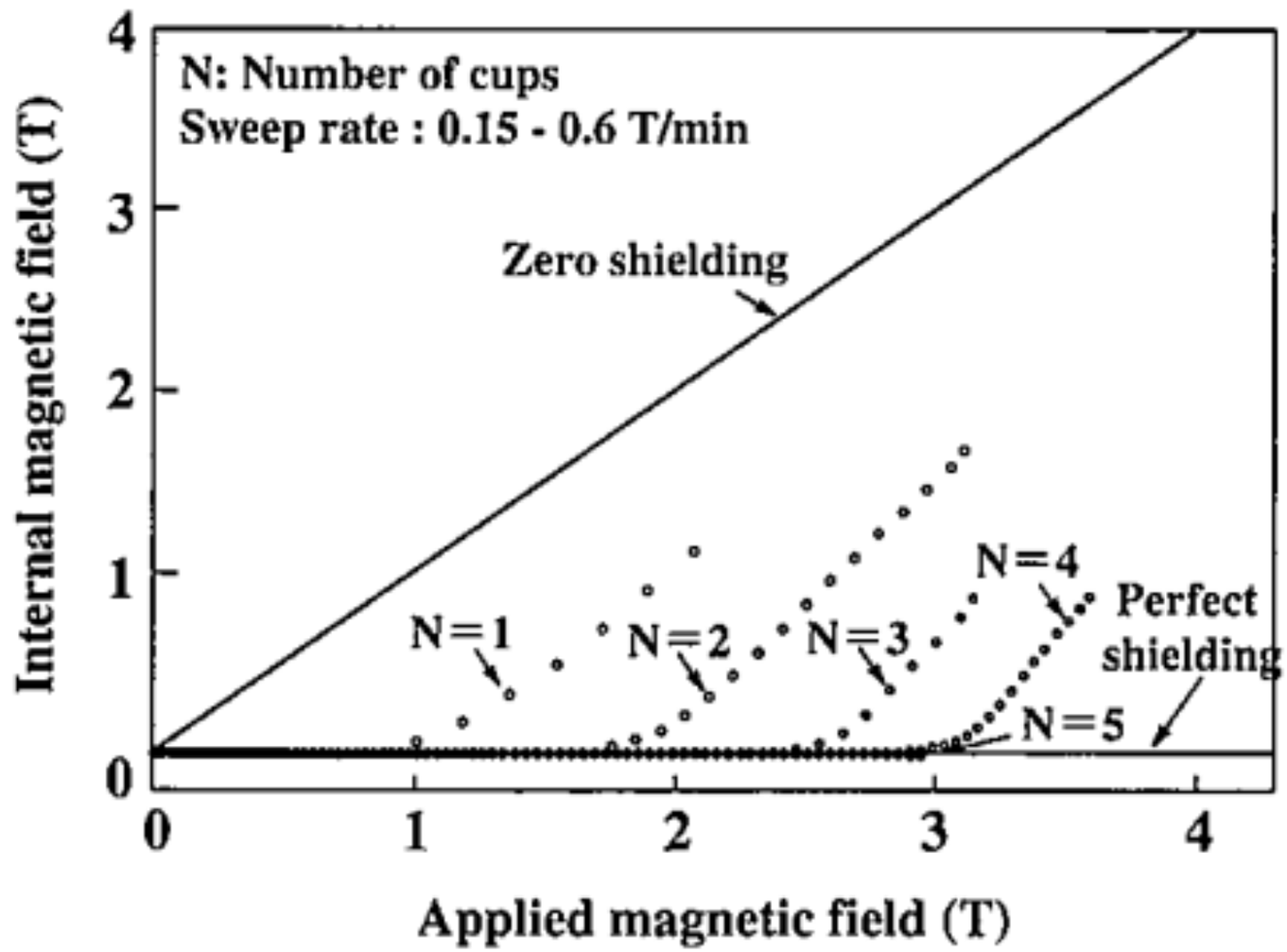


Fig. 5 Dependence of shielding properties of concentrically stacked cups on their stacked number N

Nippon Steel Technical Report No 85, January 2002

Approved eRD2 Budget Overview

	FY 2014	FY2014-2	FY2015	FY2016
TOTAL	**$72,220**	**$65,000**	**$39,500**	**$35,000**
Personnel	$23,700	$42,800	$0	$19,600
Supplies / Equipment	$33,300	0	$24,500	$2,550