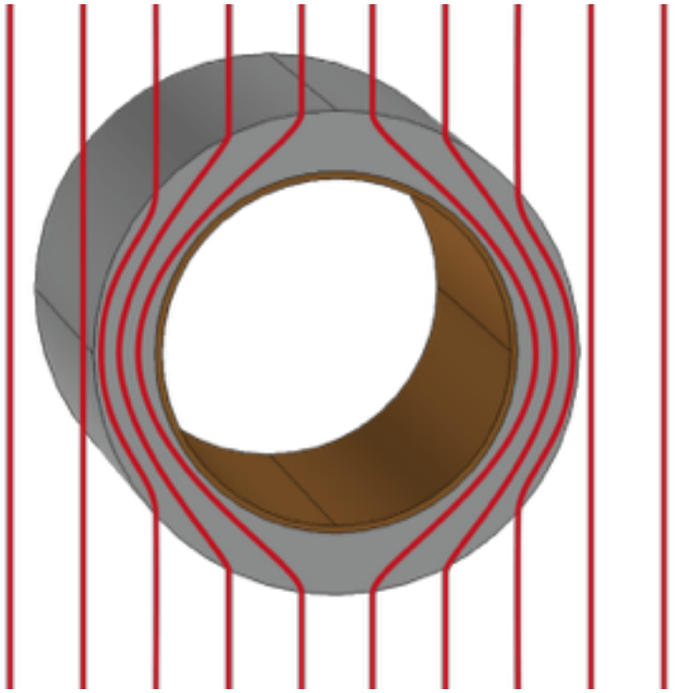
Stony Brook University

Magnetic Field Cloaking Device

eRD2 Progress Report



Abhay Deshpande, Nils Feege

EIC R&D Advisory Committee Meeting
BNL, January 28, 2016

Thanks to all our collaborators!

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

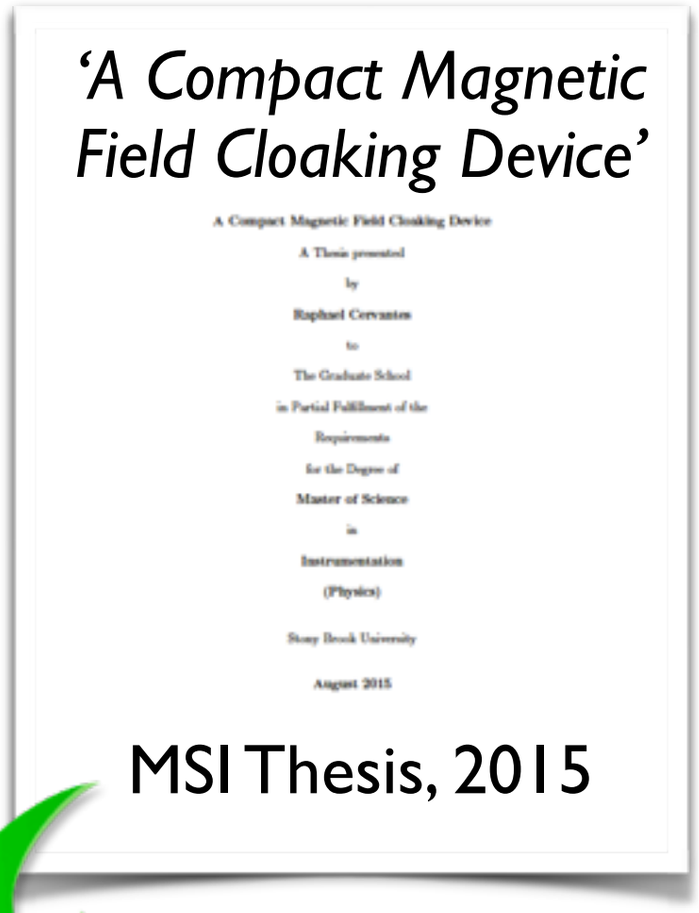
RIKEN: Y. Goto, I. Nakagawa

HS Student: A. Chhugani

Stony Brook University (SUNY): A. Adhyatman, G. Arrowsmith-Kron, G. Bello Portmann, K. Capobianco-Hogan, R. Cervantes, K. Dehmelt, A. Deshpande, N. Feege, T. K. Hemmick, S. Jeffas, T. Krahulik, J. LaBounty, T. LaByer, R. Lefferts, A. Lipski, R. Losacco, S. Mahmud, A. Oliveira, A. Quadri, A. Tishelman-Charny

MSI student funded through EIC R&D graduated in summer 2015

→Now: PhD student at University of Washington, Seattle



'A Compact Magnetic Field Cloaking Device'

A Compact Magnetic Field Cloaking Device

A Thesis presented

by

Raphael Cervantes

to

The Graduate School

in Partial Fulfillment of the

Requirements

for the Degree of

Master of Science

in

Instrumentation

(Physics)

Stony Brook University

August 2015

MSI Thesis, 2015

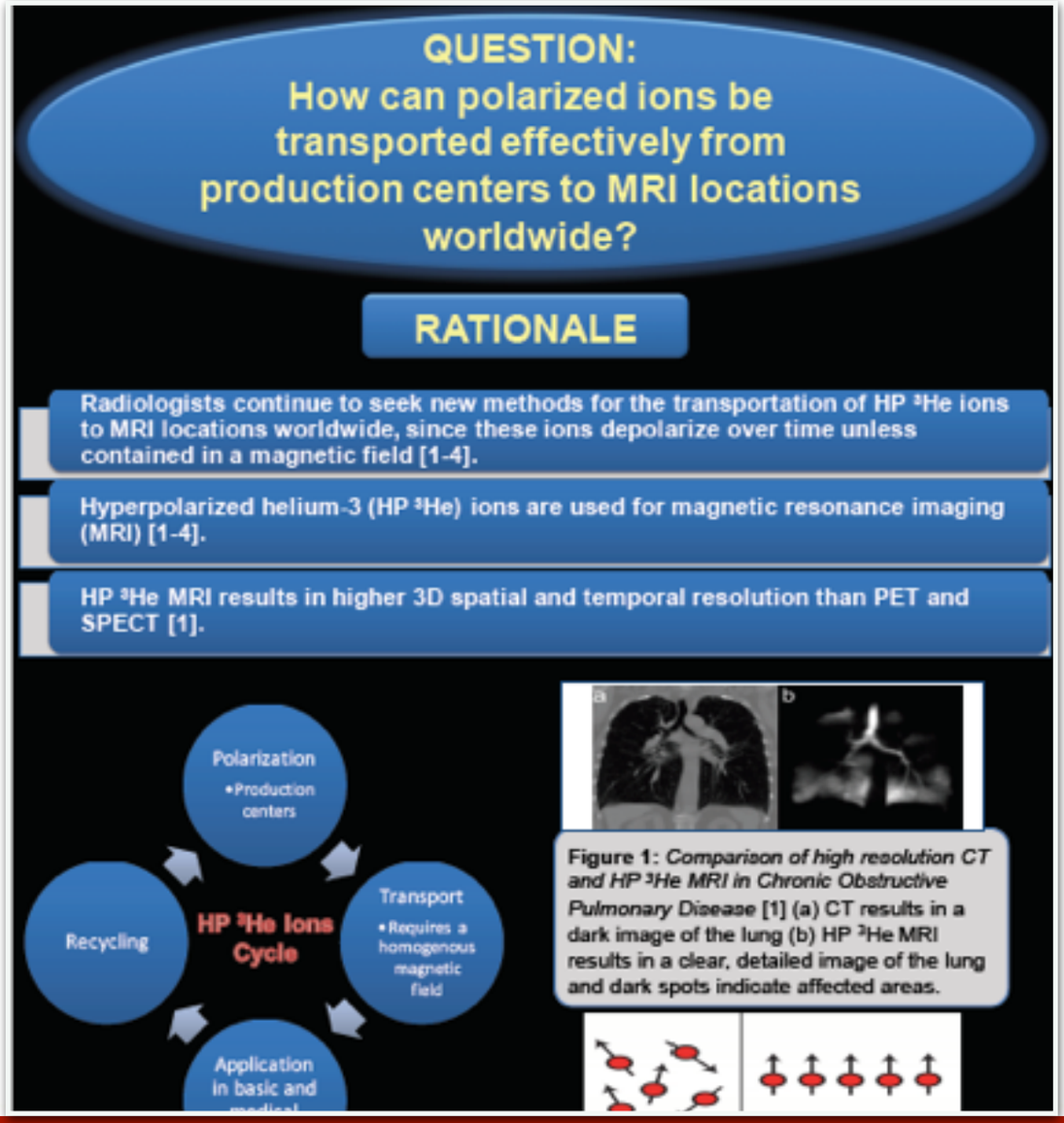
Paper draft!

Raphael Cervantes

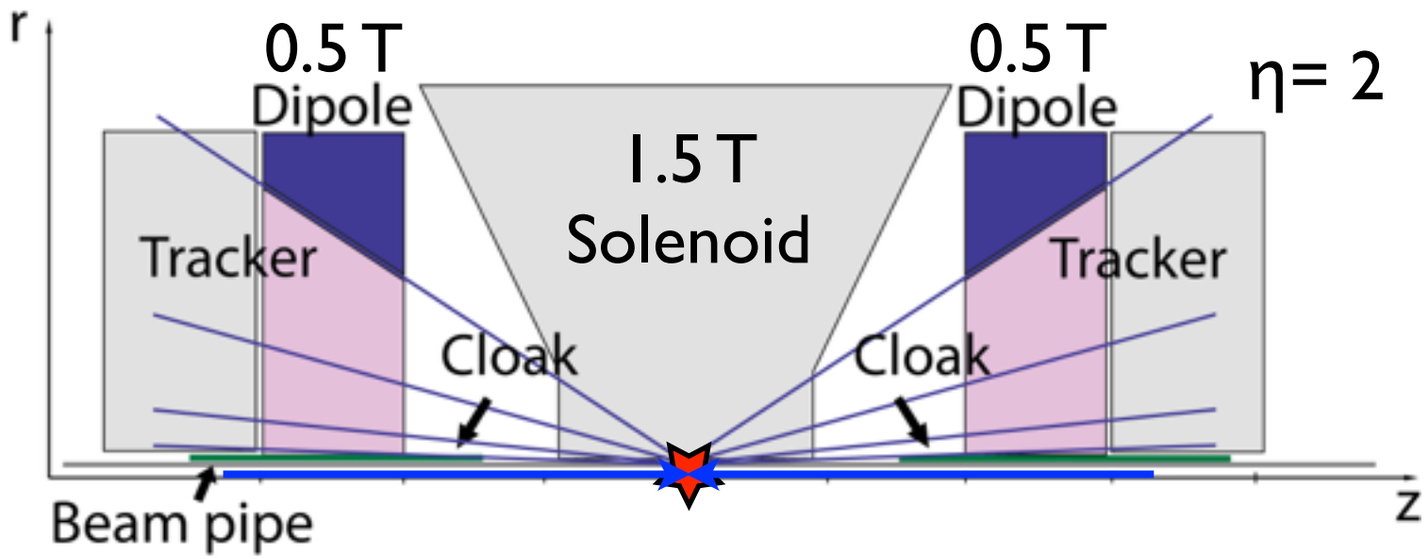
High school student selected semi-finalist in two science competitions

→ Fall 2016: Columbia University- School of Engineering

Ayesha Chhugani



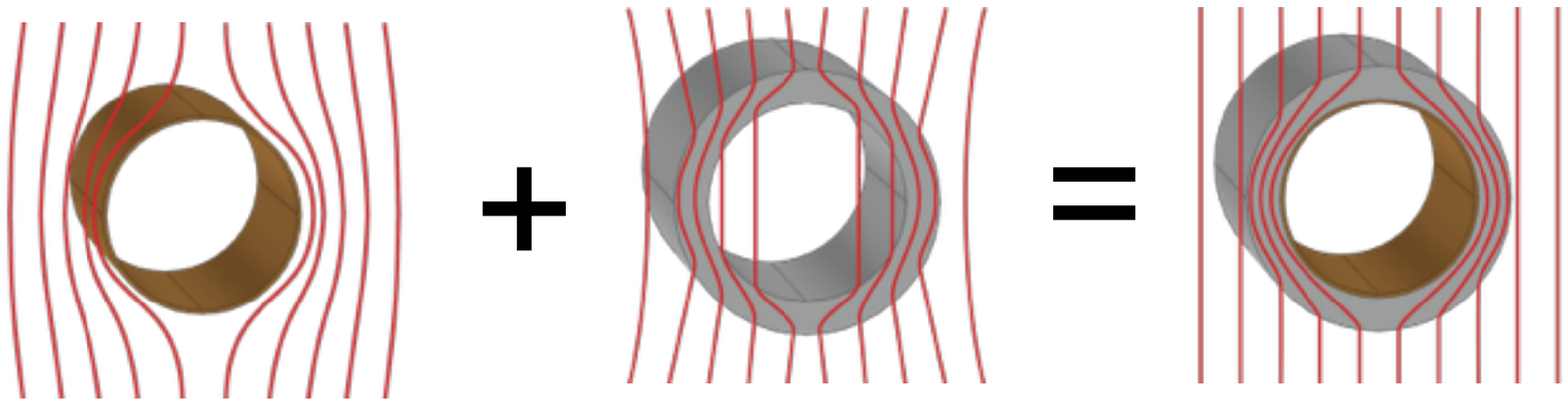
Can we extend good momentum resolution closer to the beam pipe?



Magnetic Cloak:

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

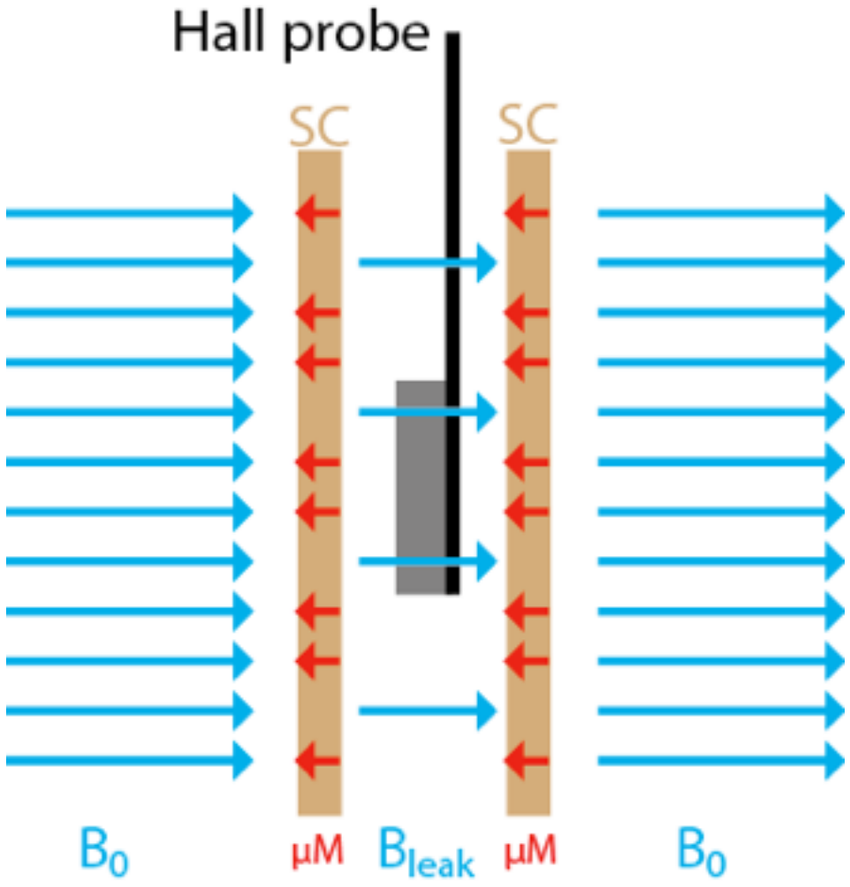
superconductor ferromagnet cloak

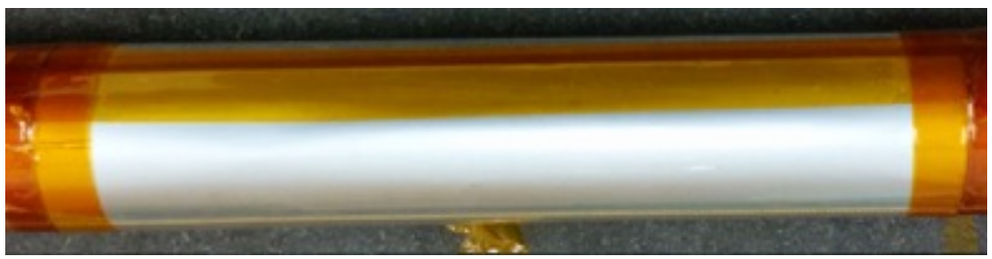


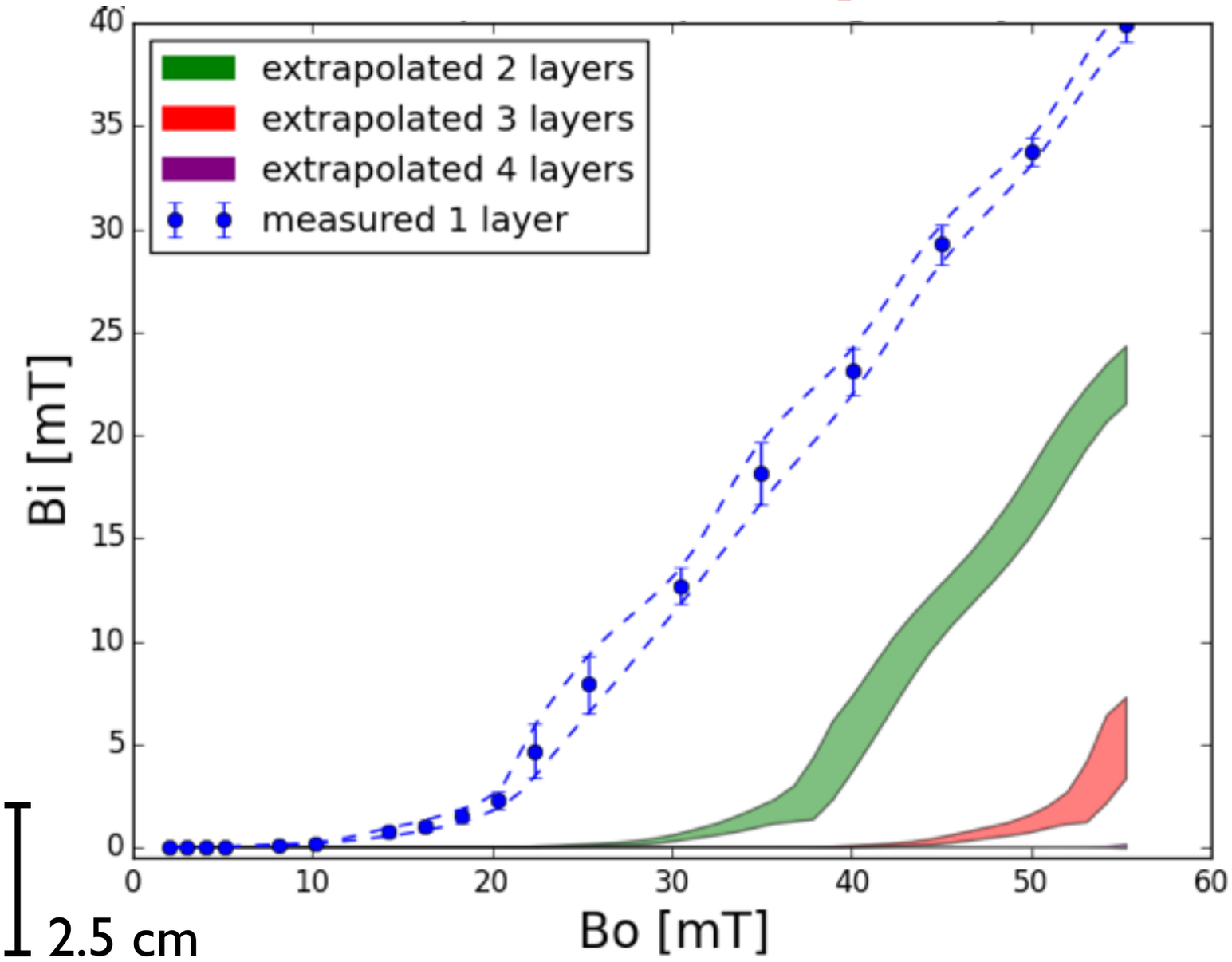
$$\mu_2 = \frac{R_2^2 + R_1^2}{R_2^2 - R_1^2}$$

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

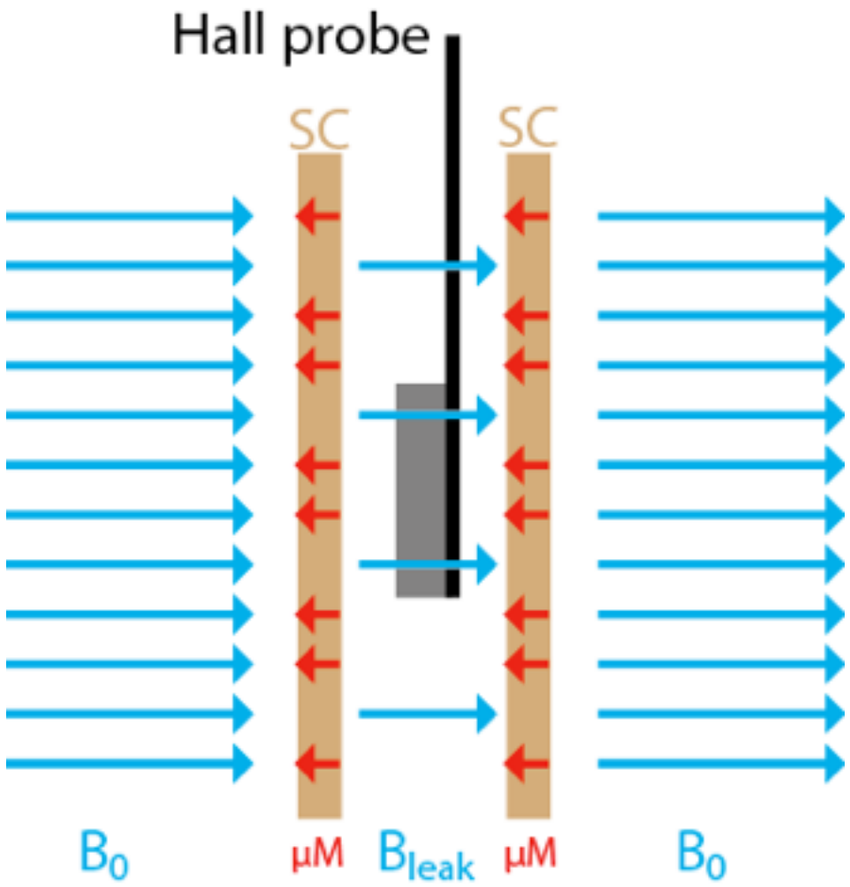
Established method to extrapolate shielding performance of SC cylinder

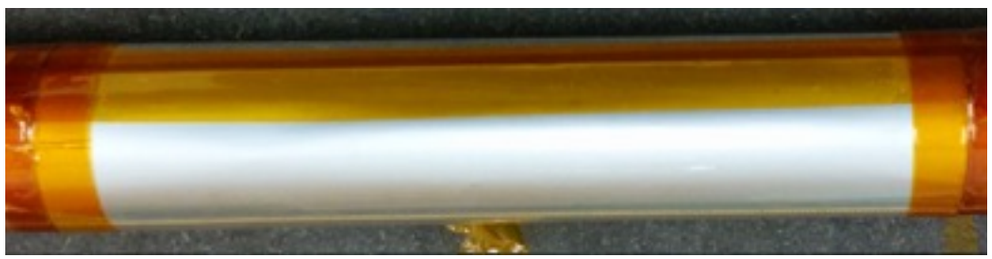






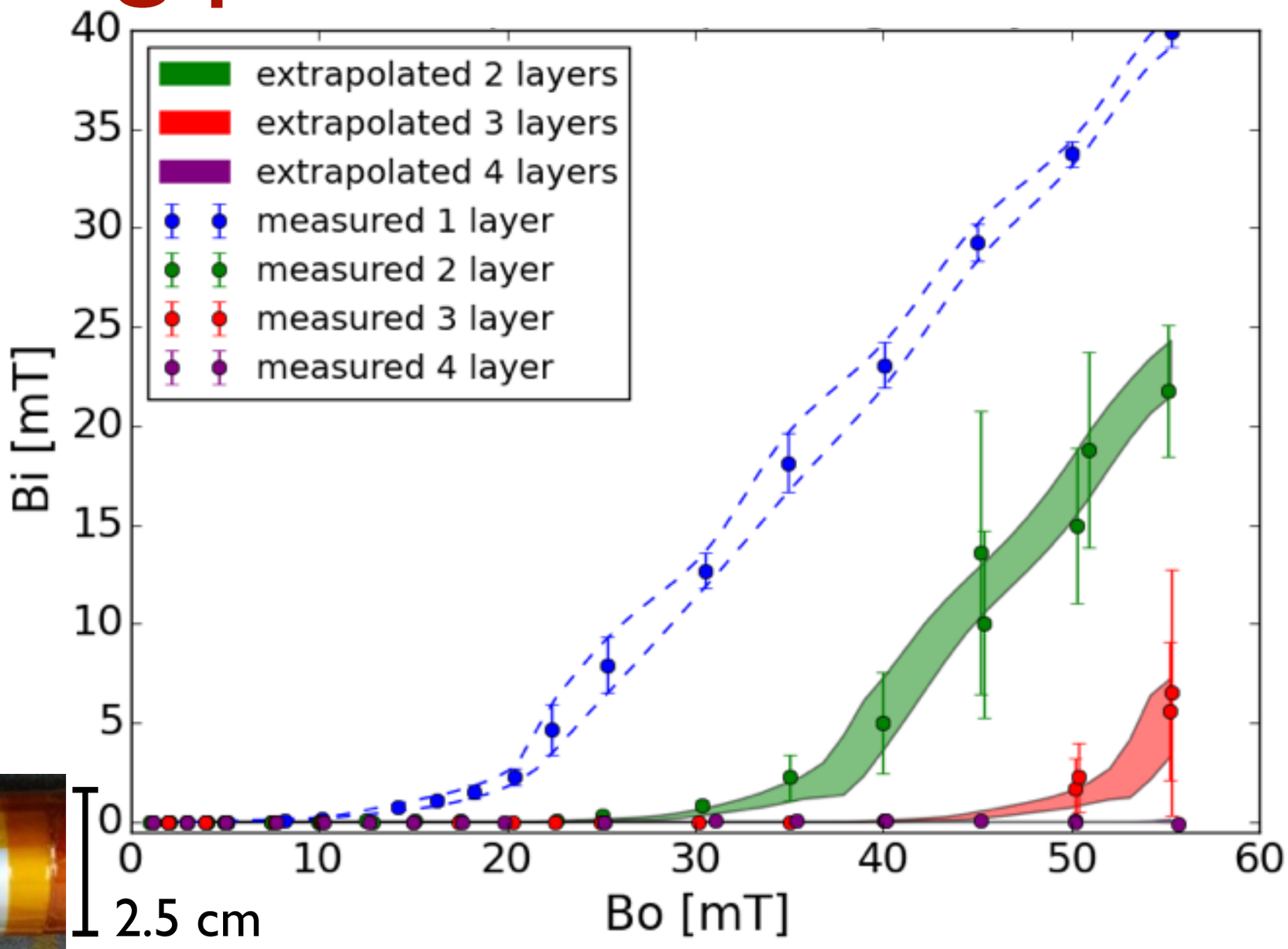
Measurements validate extrapolated shielding performance



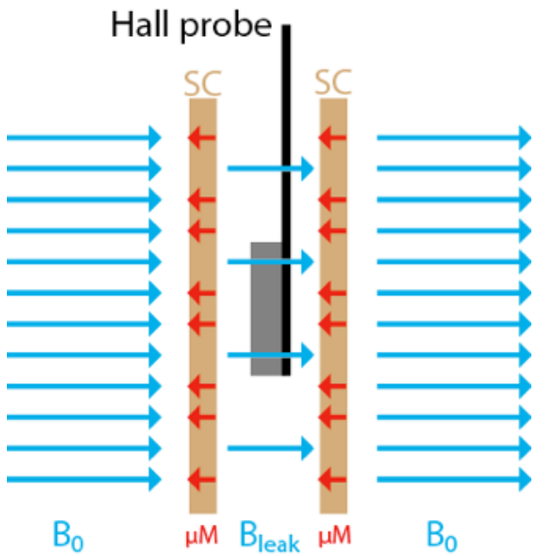


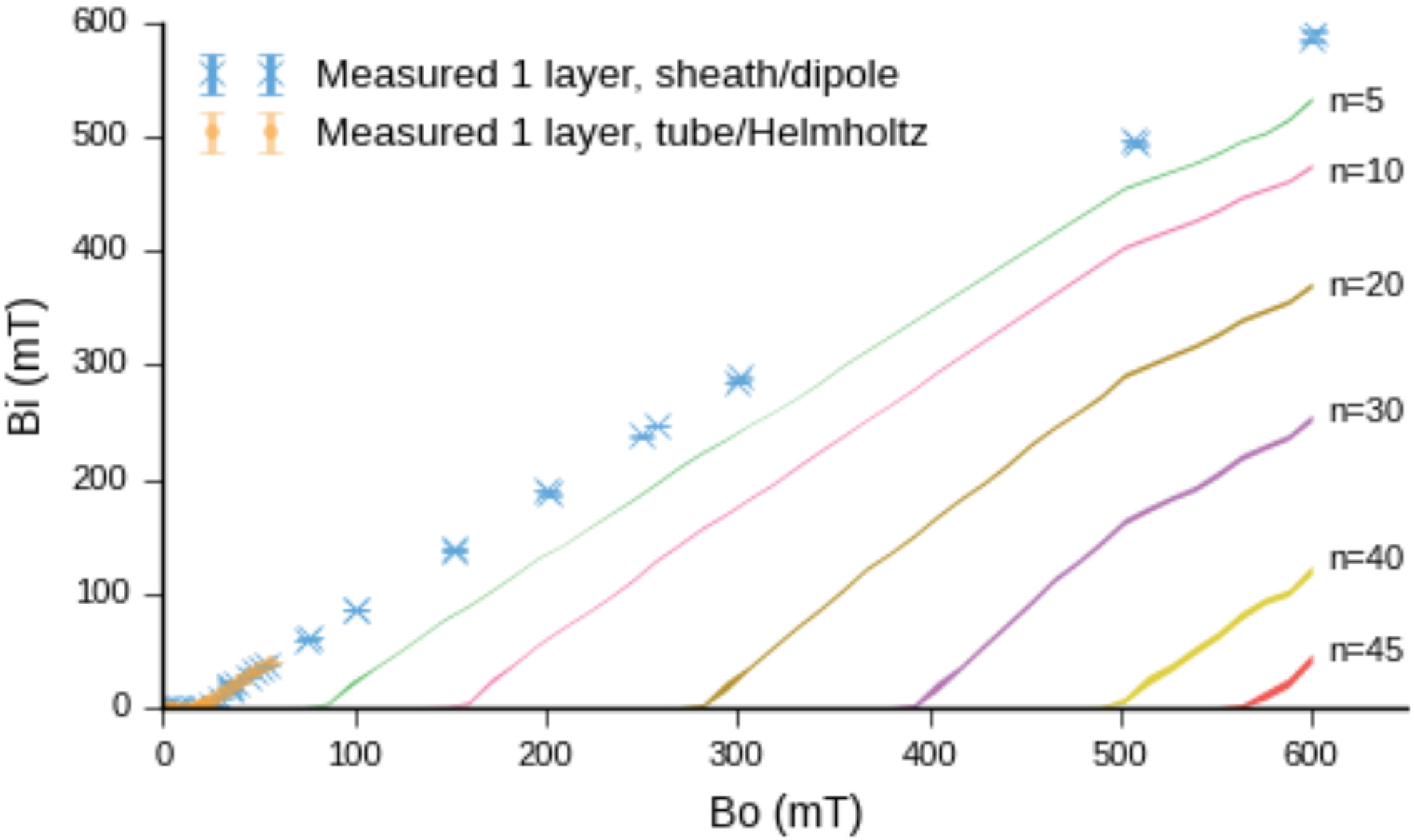
2.5 cm

12 cm

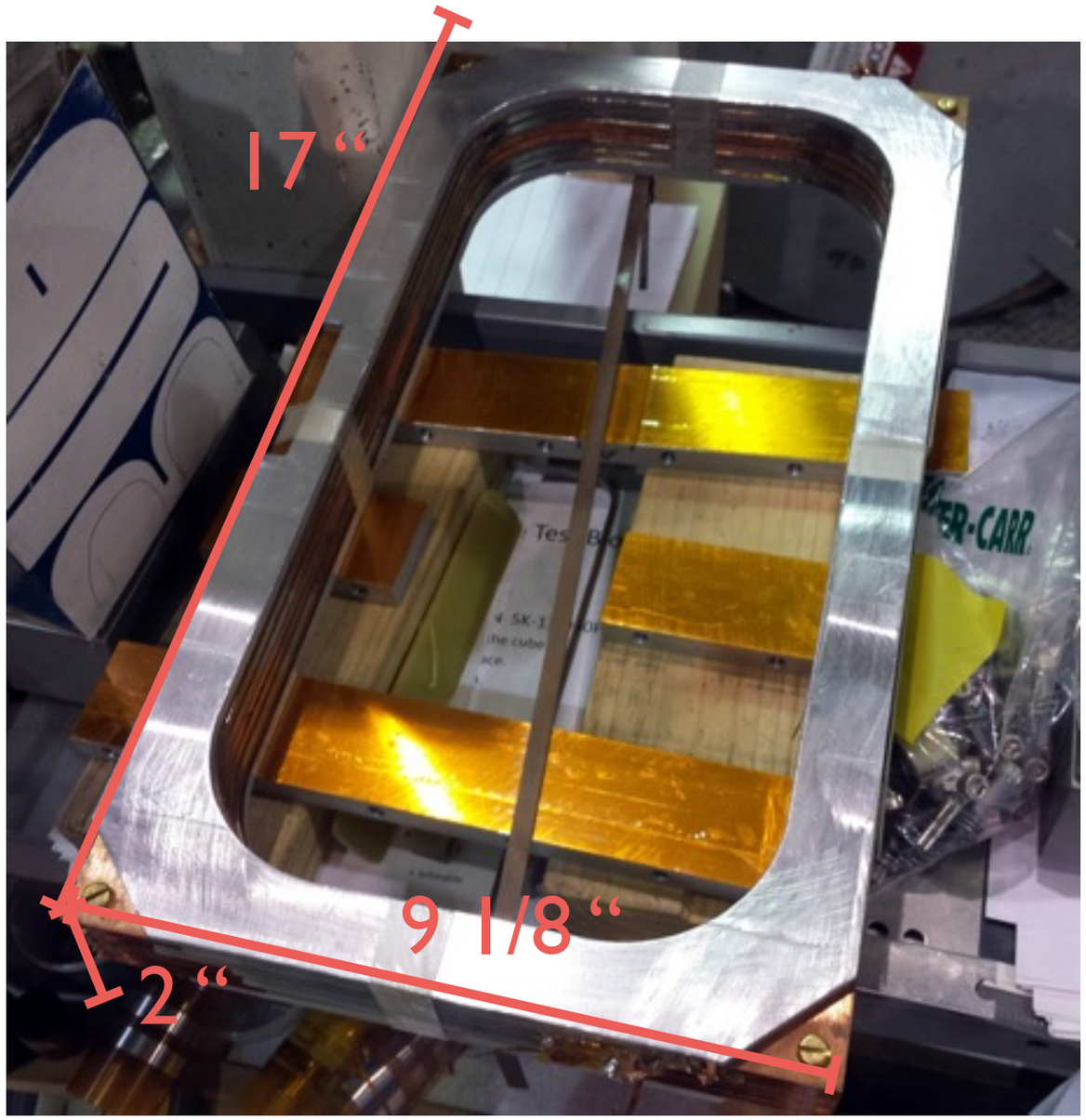


Superconductor test up to 0.5 T and extrapolation to multiple layers





Planned tests with 0.5 T field at BNL



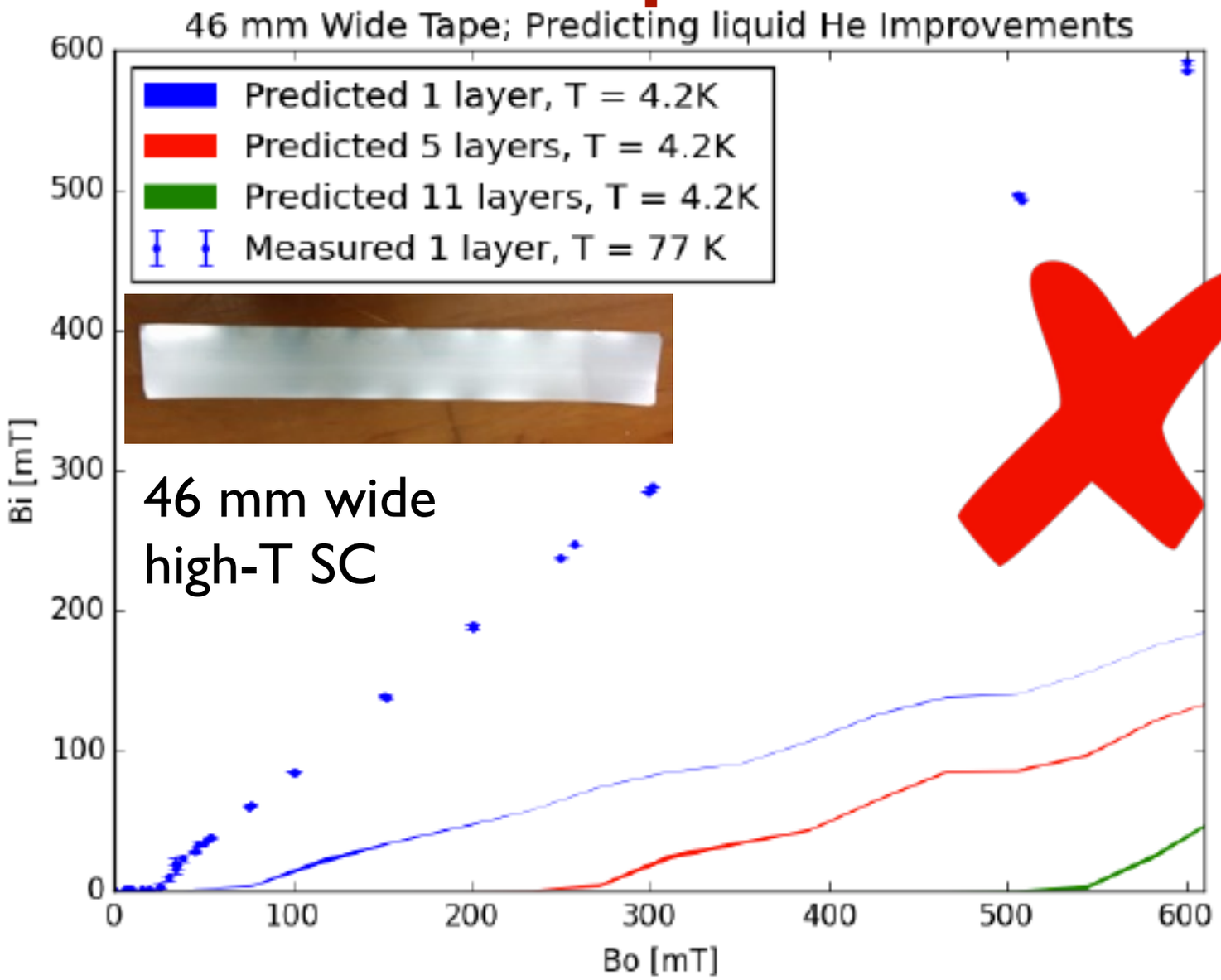
4 m of 46 mm wide high-T SC tape available (16 layers)

High-T SC Coil
(6 x 100 turns at ~ 50 A)
in liquid Nitrogen bath

We need to design and provide our own steel yoke.

Only IN2 tests- **no liquid Helium tests** within our budget

Currently no viable option to do liquid Helium tests

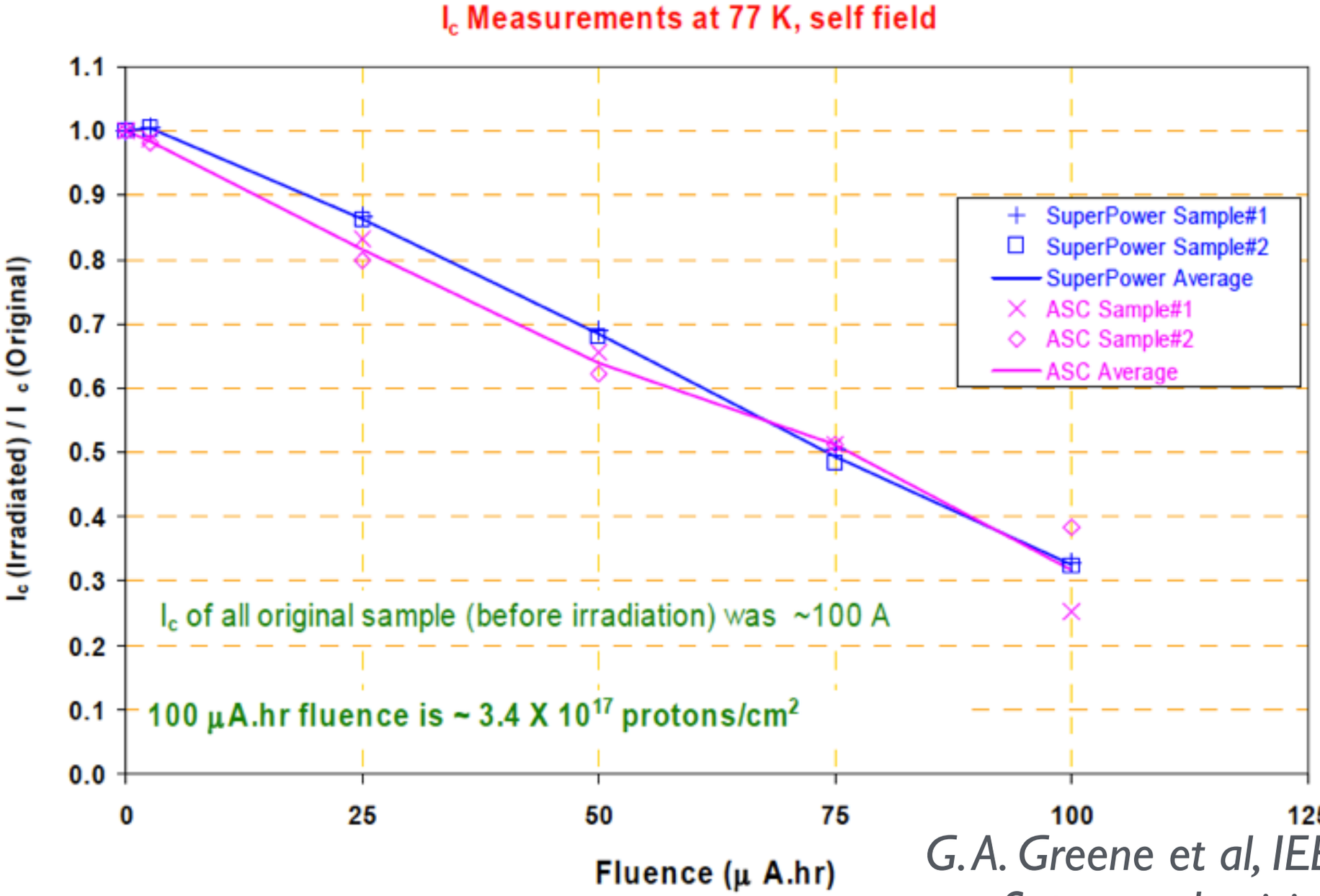


NbTi

$T_c = 10$ K

$$B_i(B_o, T = 4.2K) = B_i(\frac{B_c(T=77K)}{B_c(T=4.2K)} \times B_o, T = 77K).$$

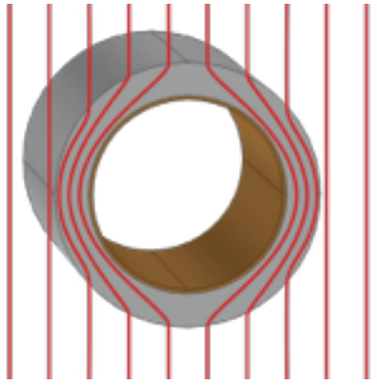
Radiation hardness of commercially produced superconductor wire



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

Fabricating ferromagnetic cylinders with custom size and permeability



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

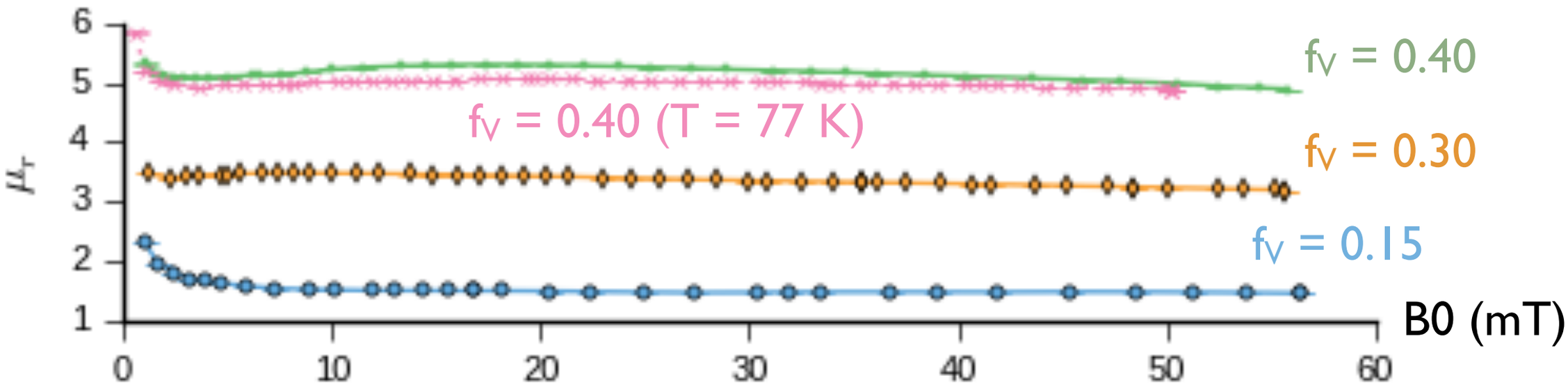
430 Stainless Steel
($\mu_r \sim 500$)

+

Epoxy
($\mu_r = 1$)

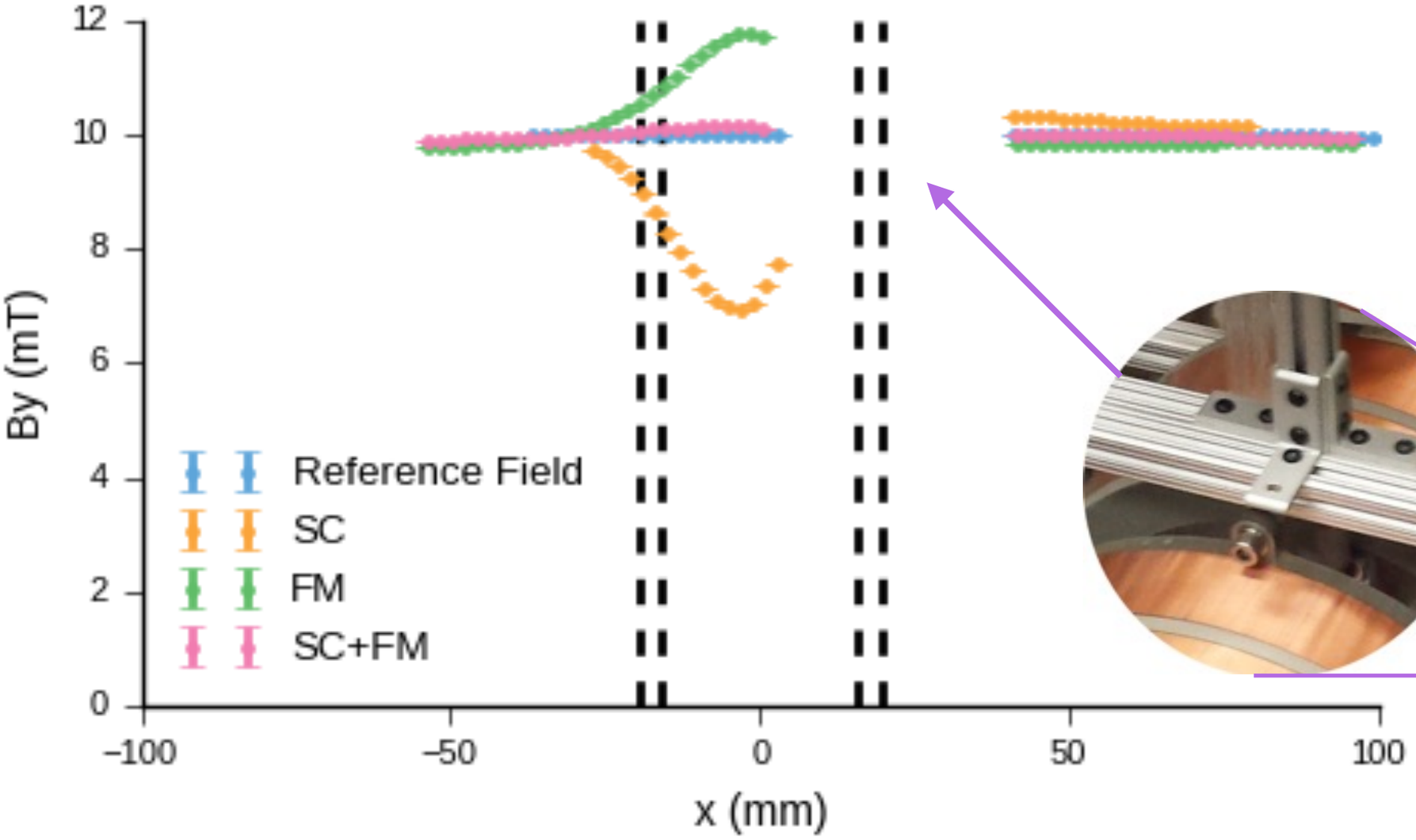
=

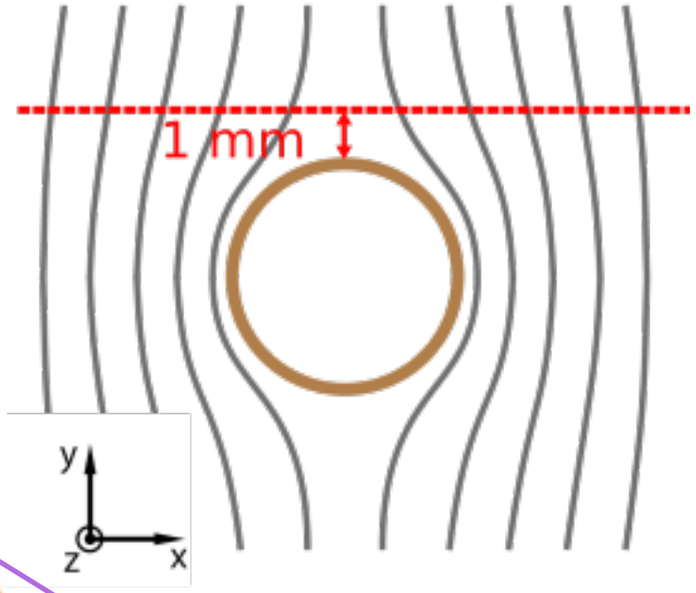
Ferromagnet
($1 < \mu_r < 6$)

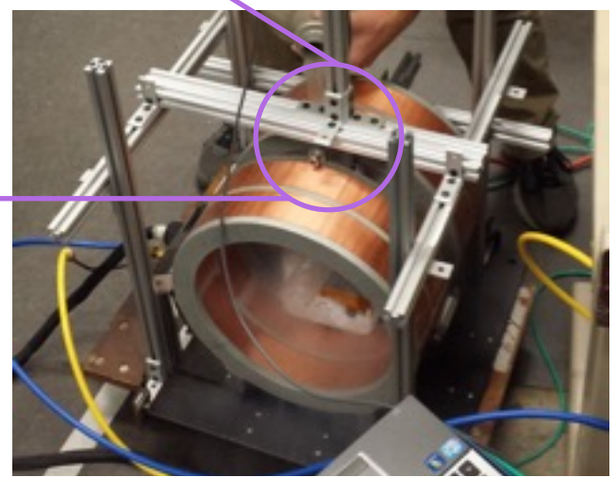


…0.5 T?

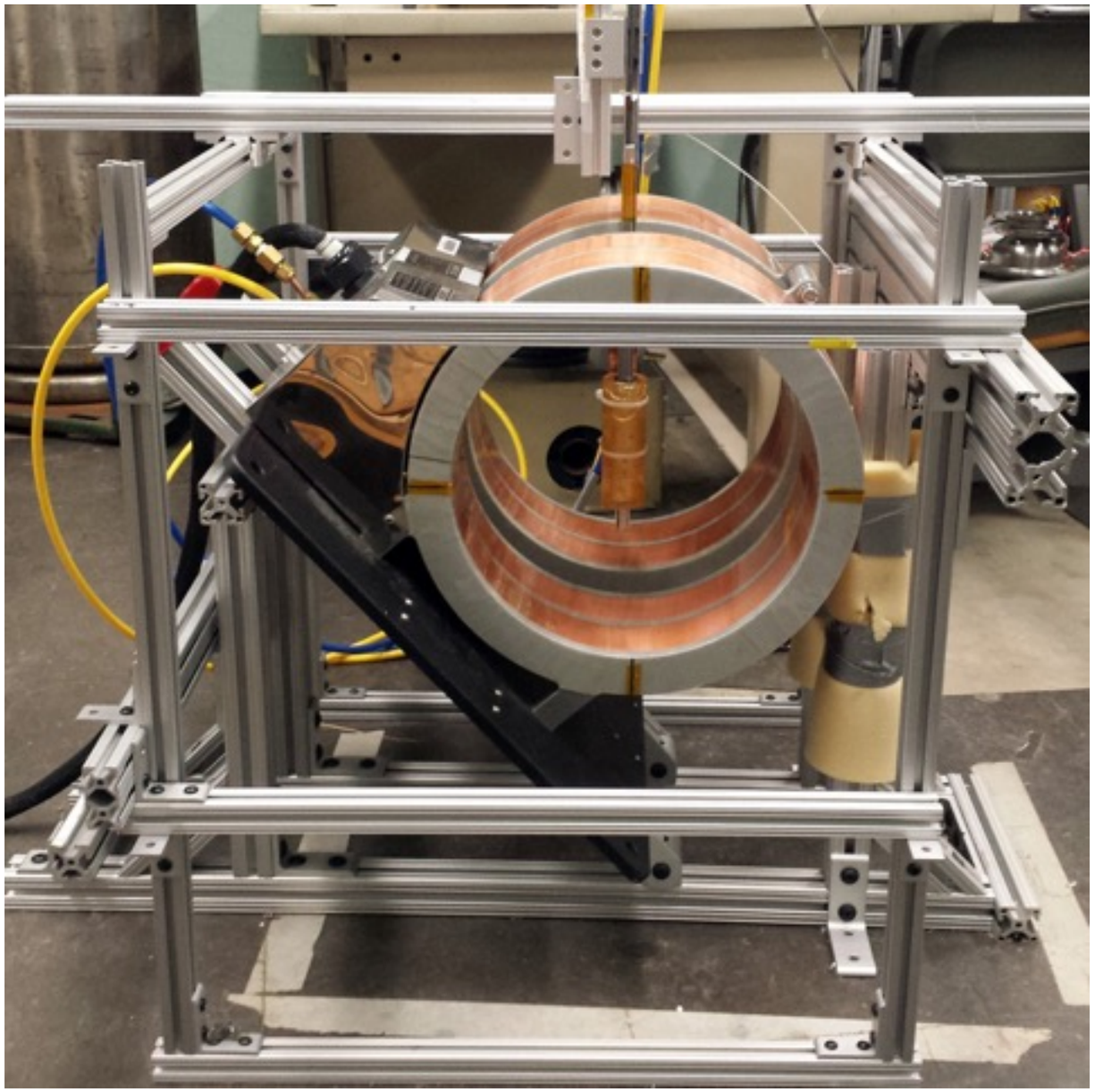
Magnetic field map confirms canceling of field disturbances with cloak

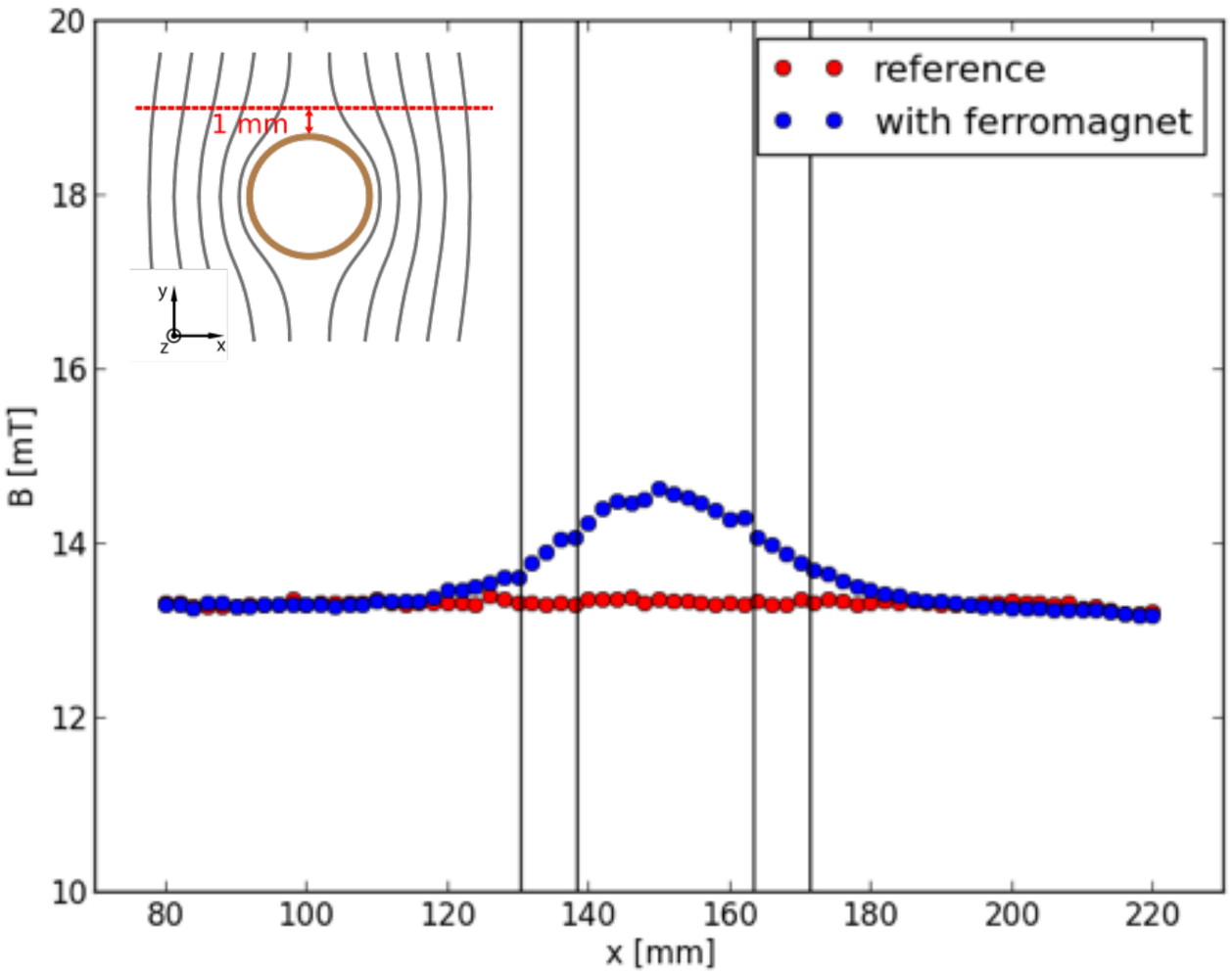






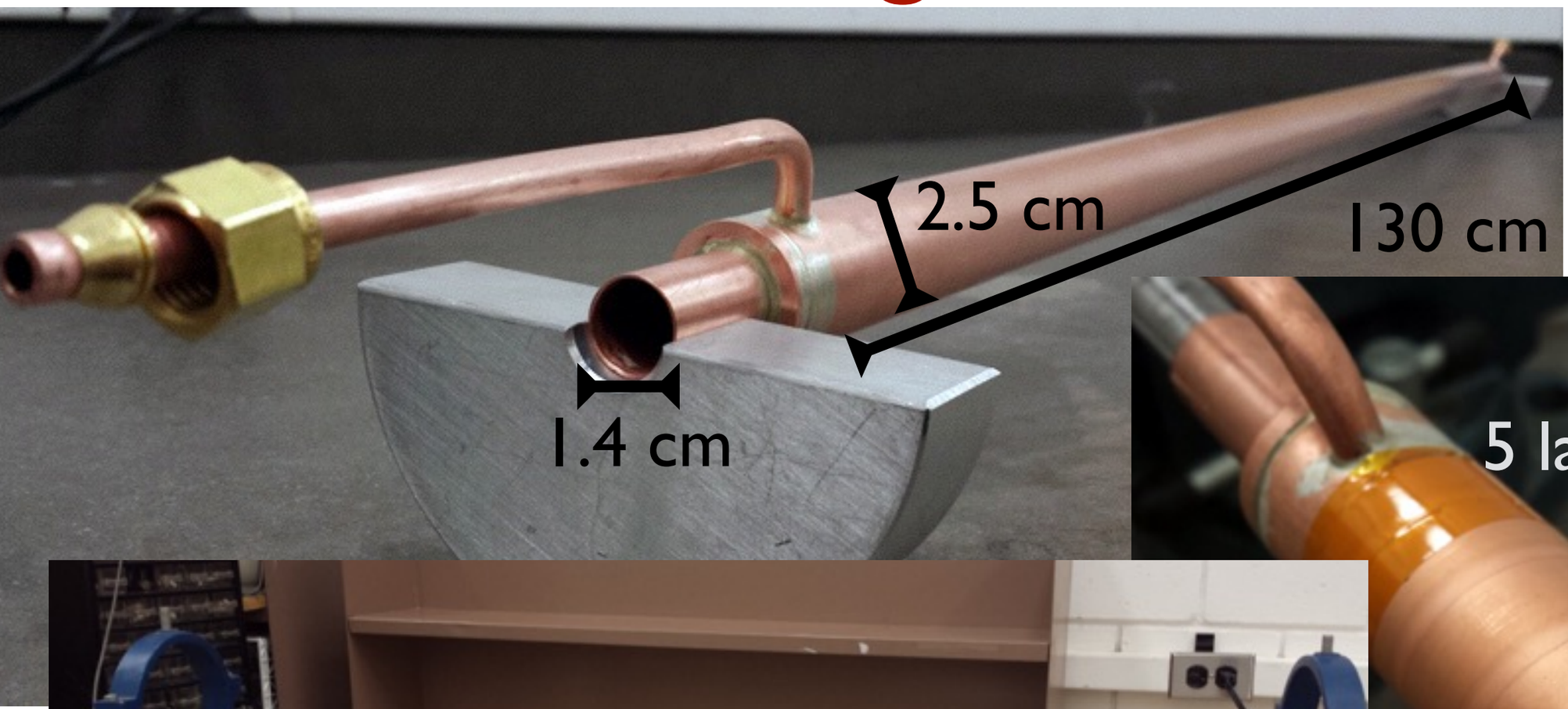
Modified Helmholtz coil setup for improved field map quality

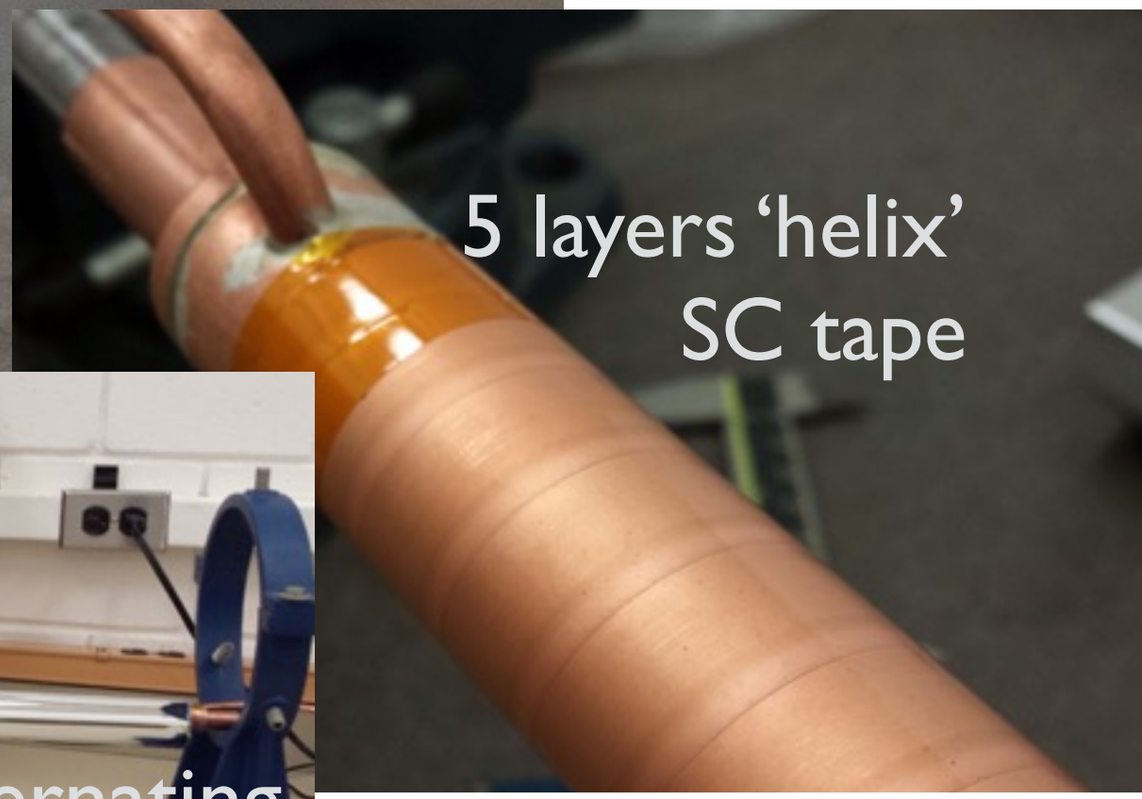




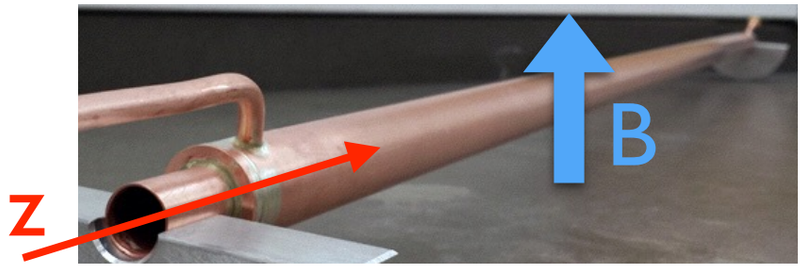
Re-measuring field maps

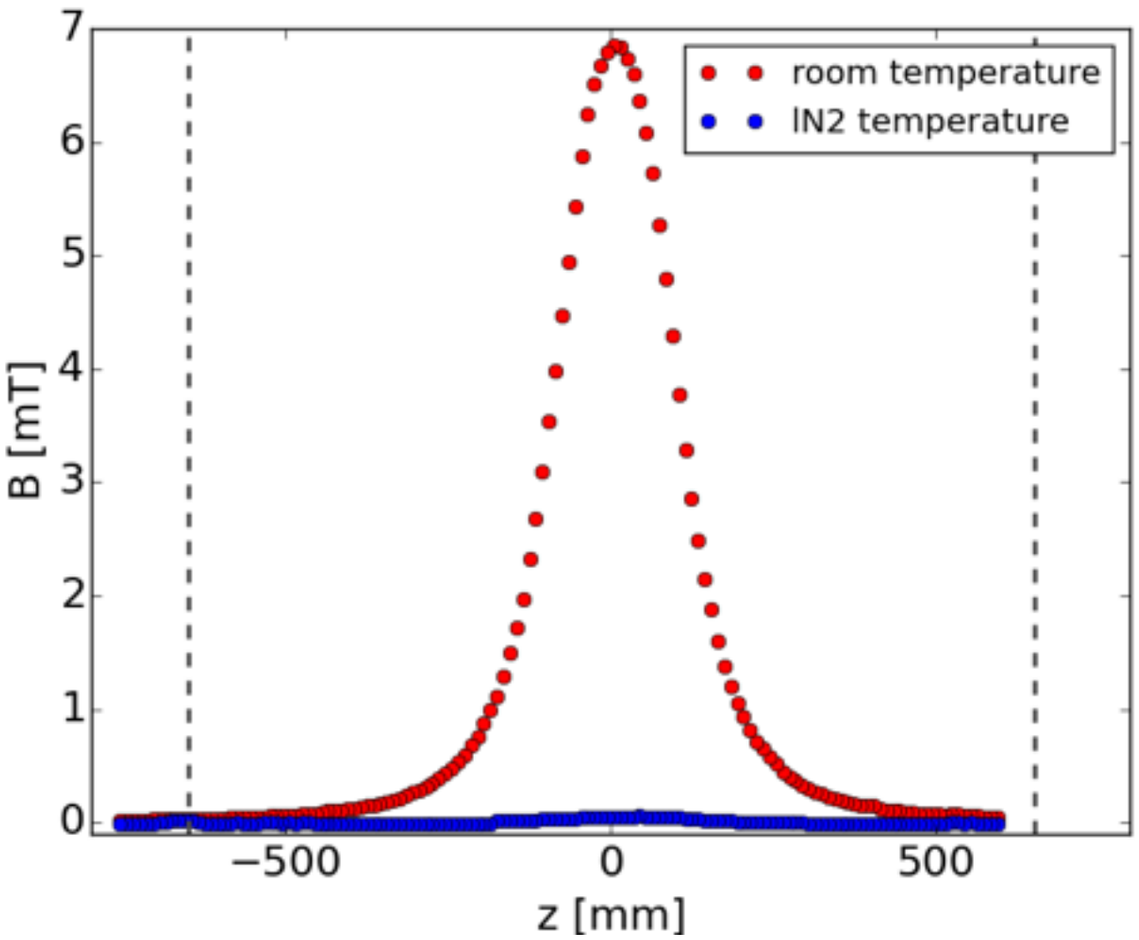
Superconductor cylinder for magnetic field shielding tests with beam

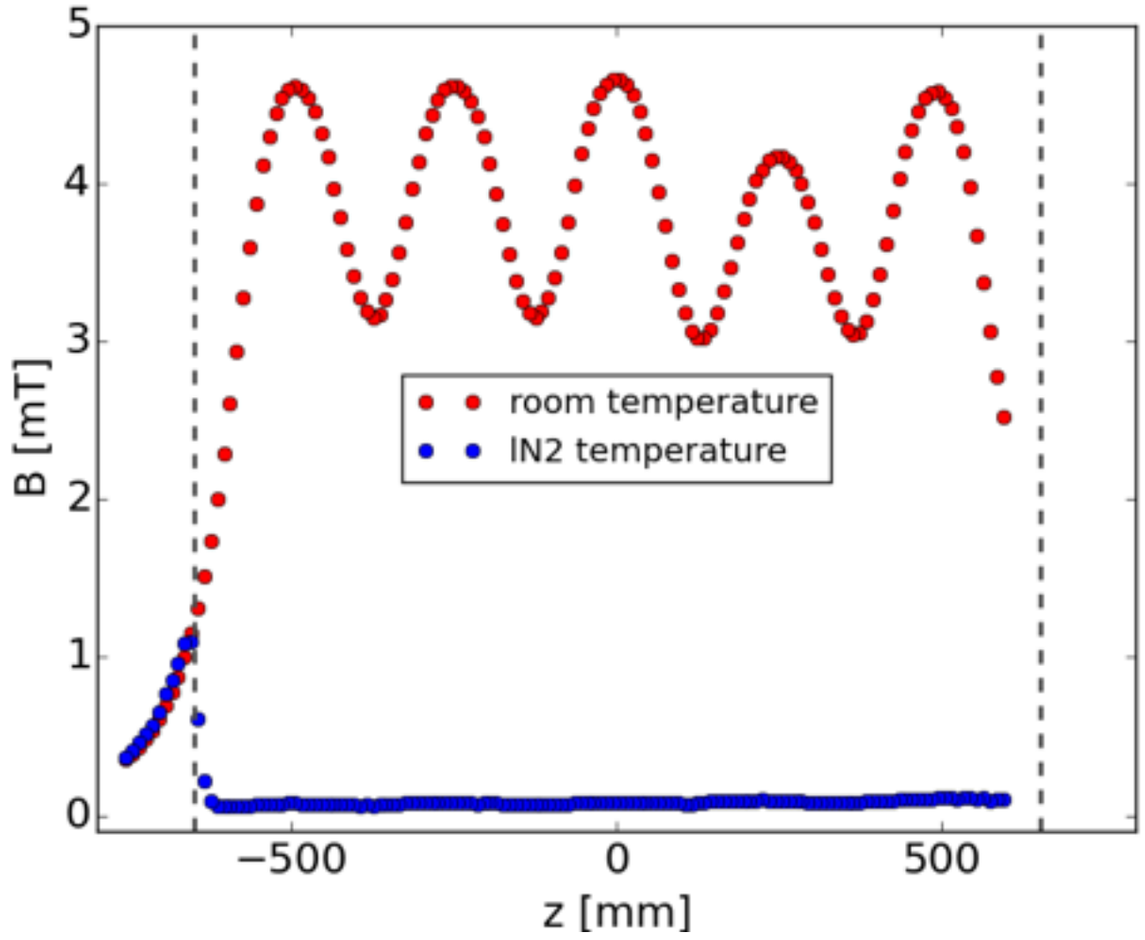




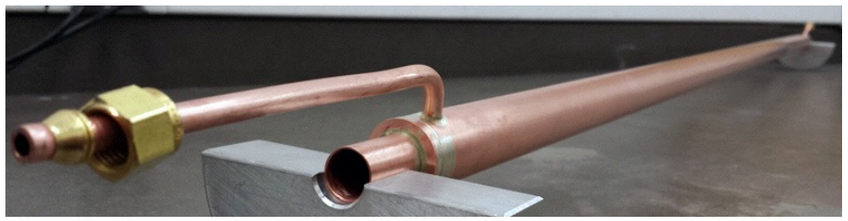
Tests in liquid Nitrogen bath show full length shielding and edge effects

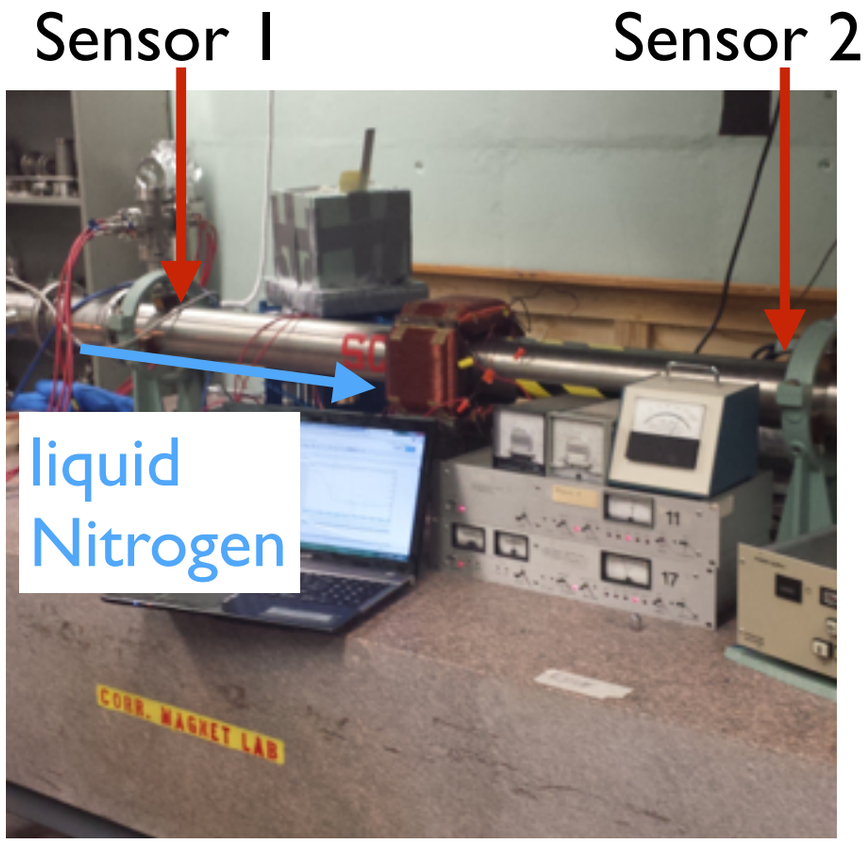


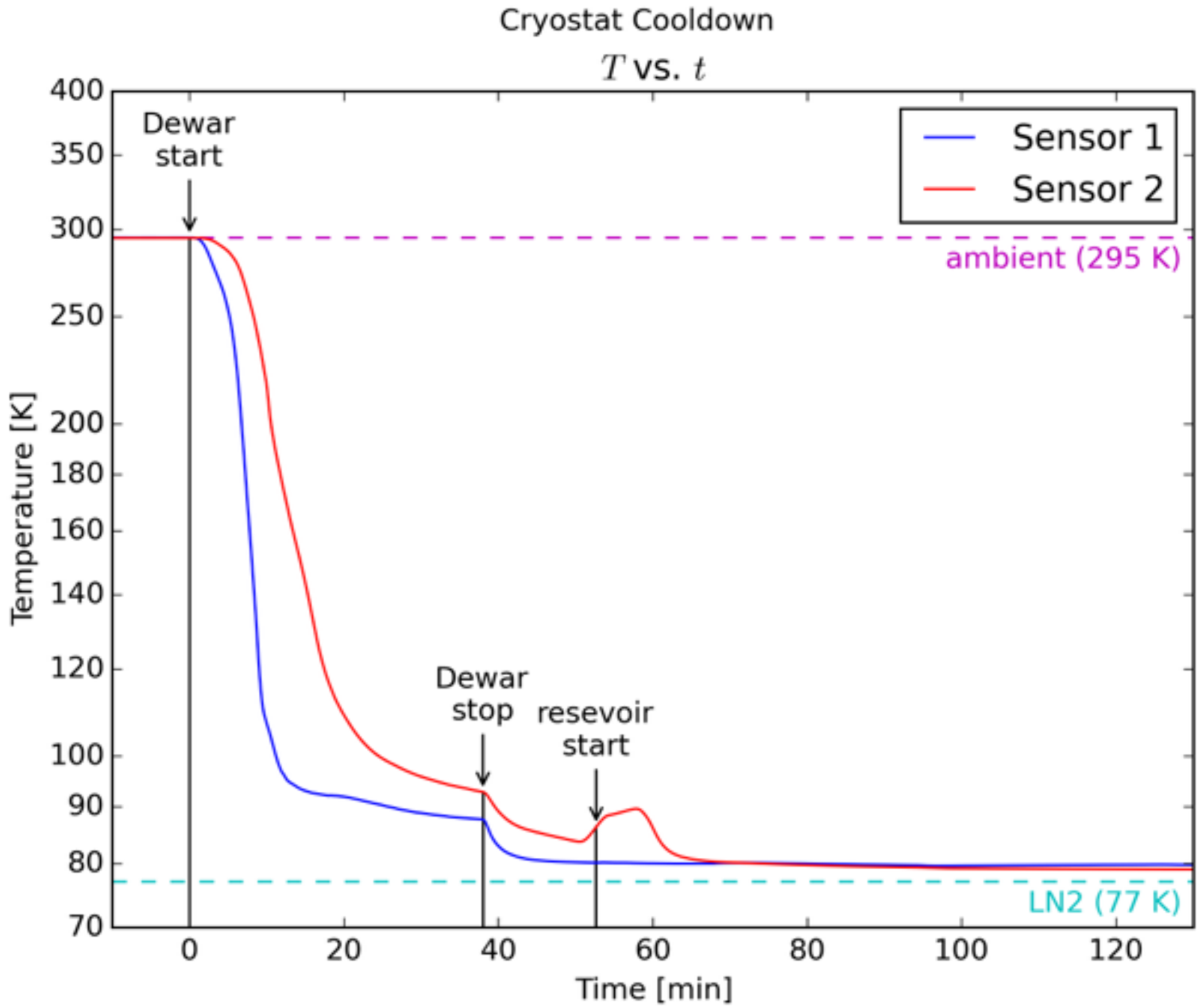




Established efficient cool-down procedure inside beam pipe vacuum







Open Questions

Demonstrate shielding 0.5 T magnetic field with SC cylinder.

Demonstrate shielding with beam.

What is the effect of the end-field on the accelerator performance?

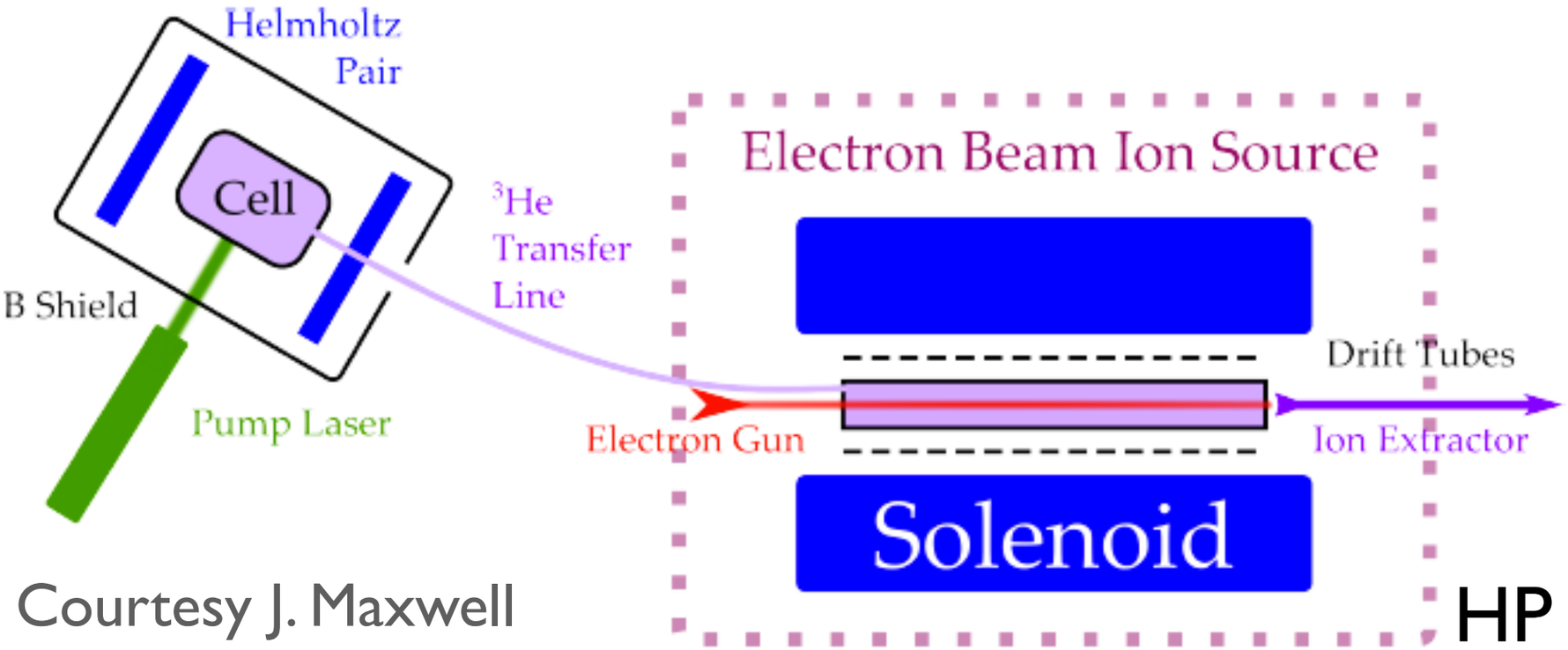
What is the physics benefit (quantitative) for a conceptual forward dipole spectrometer?

What is the radiation hardness of the ferromagnetic and superconducting material?

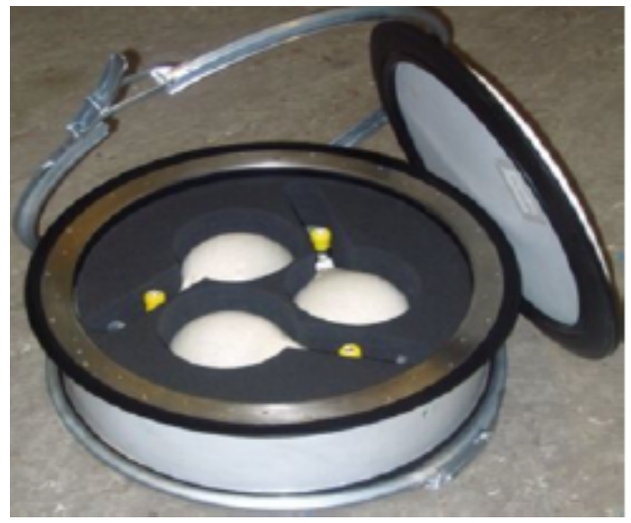
Could thermal effects due to accidental beam dumps damage the structure?

What is the effect of a possible cryostat and its flanges on the detector acceptance and performance at small angles?

Other application: Cloak as a solution for polarized Helium-3 transport?

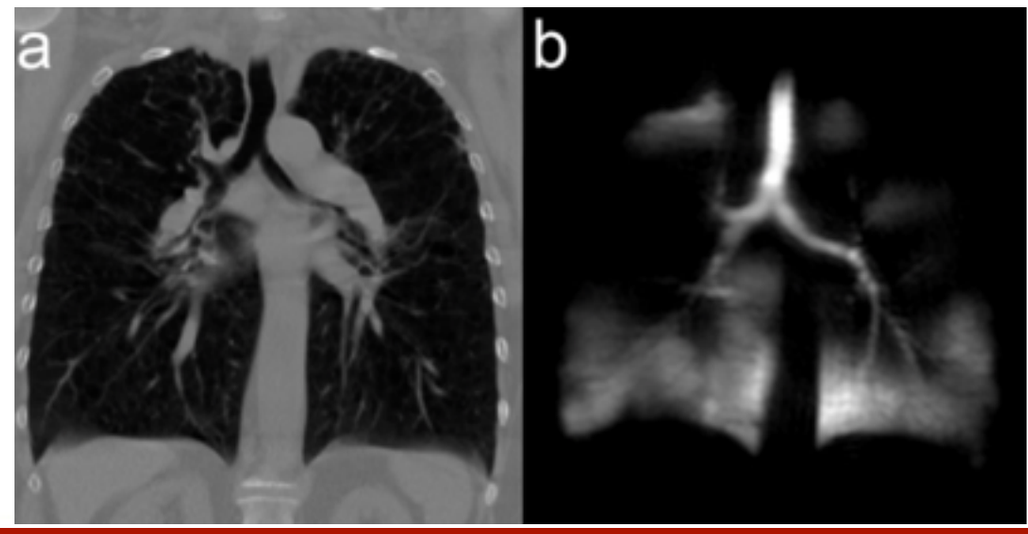


Courtesy J. Maxwell



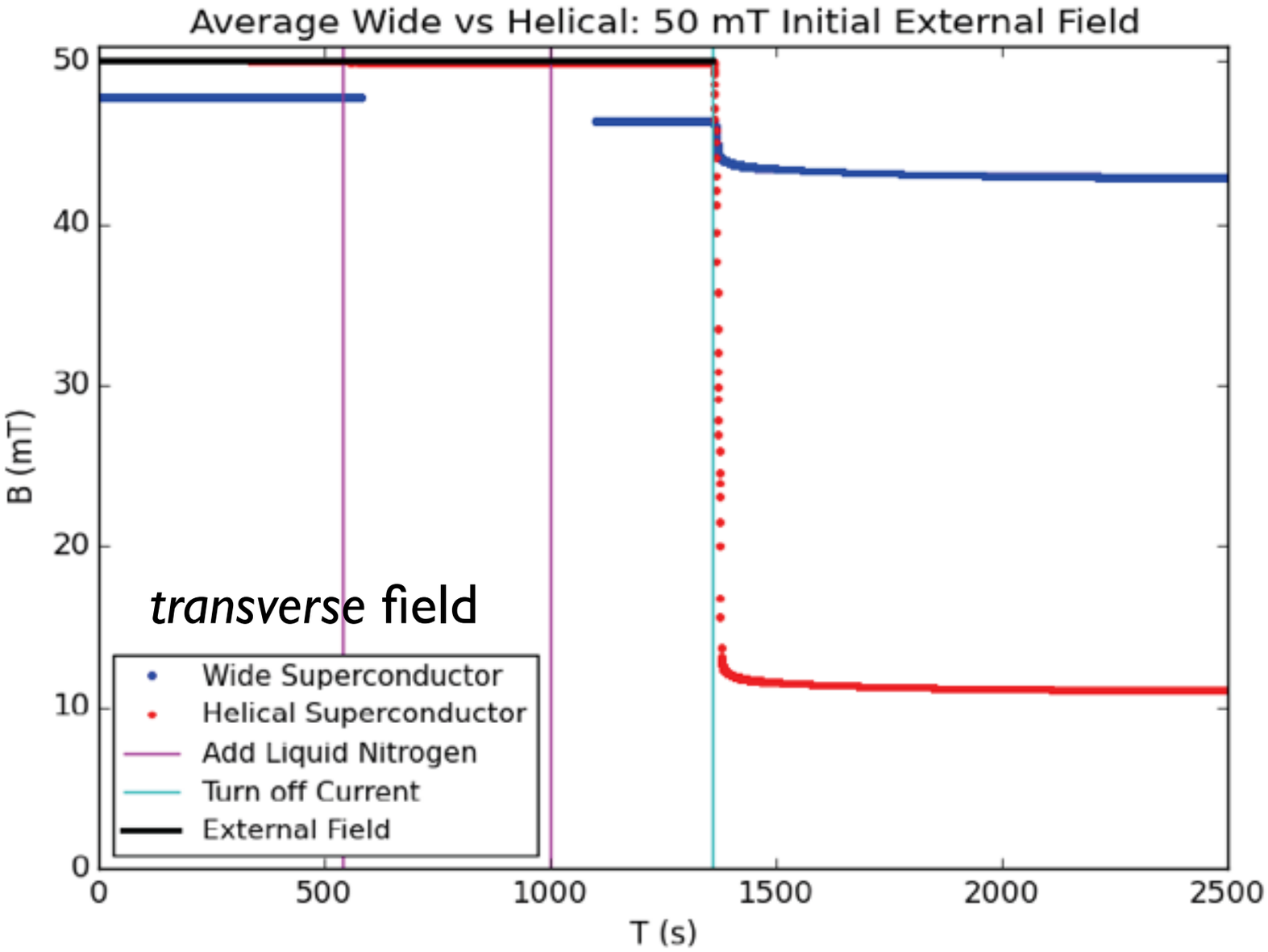
Polarized ^{3}He source at BNL

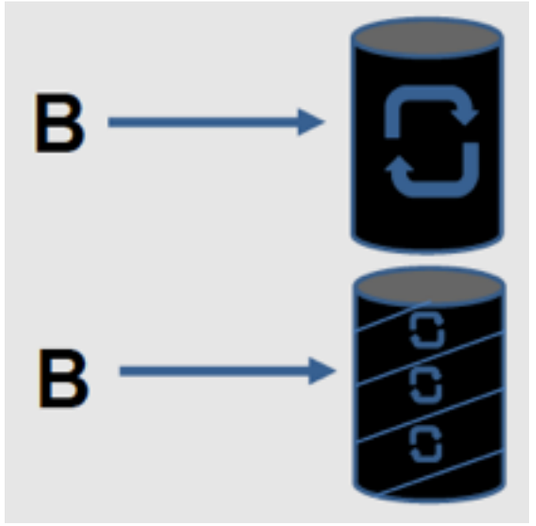
HP ^{3}He MRI CT



- ✓ Tunnel through field gradients
- ✓ Maintain holding field on the inside

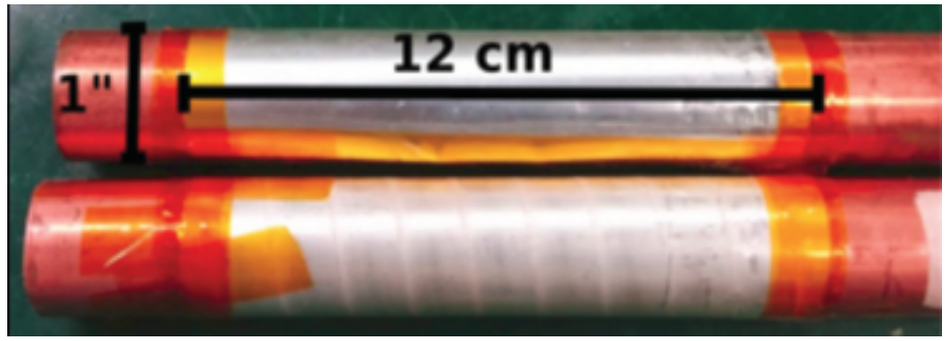
‘Trapping’ a holding field for transfer of polarized Helium-3





Wide SC

Helix

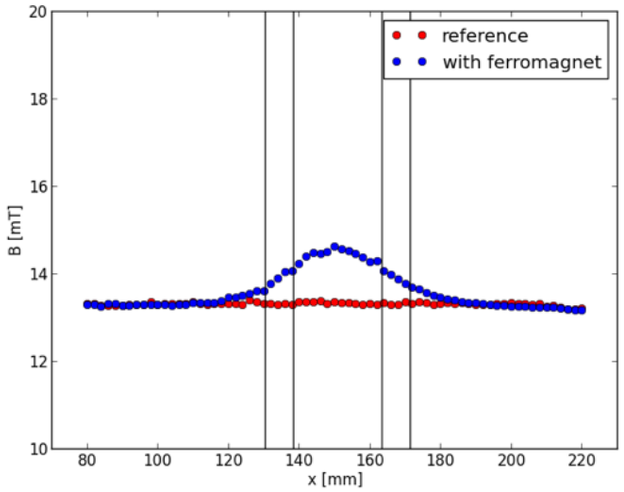


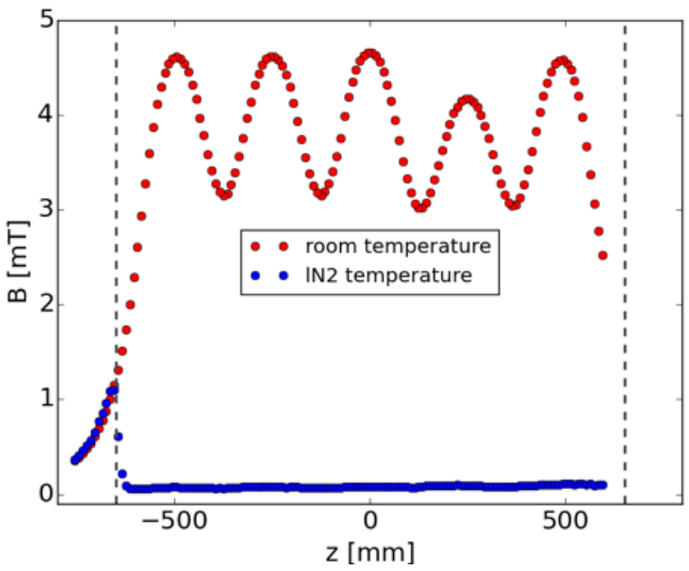
Trapped field not affected by

- Small external field
- Moving the superconductor

Summary

Improved Helmholtz coil field mapping setup for better cloak characterization.





Confirmed full length shielding for long prototype for beam tests.

Started exploring magnetic field trapping for polarized 3He transfer.

Great opportunity for students to collect laboratory experience.

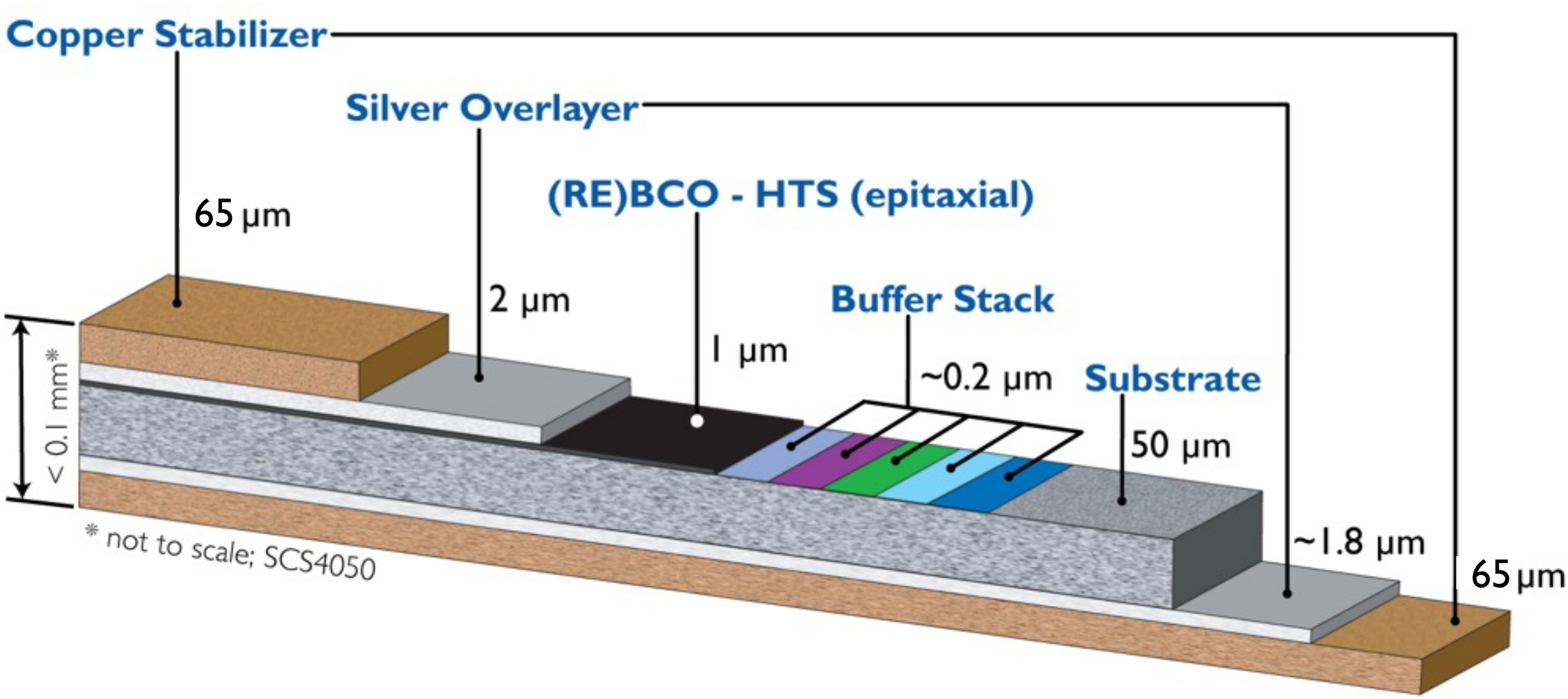
Plan to submit paper soon.

ADDITIONAL SLIDES

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

High-temperature superconductor

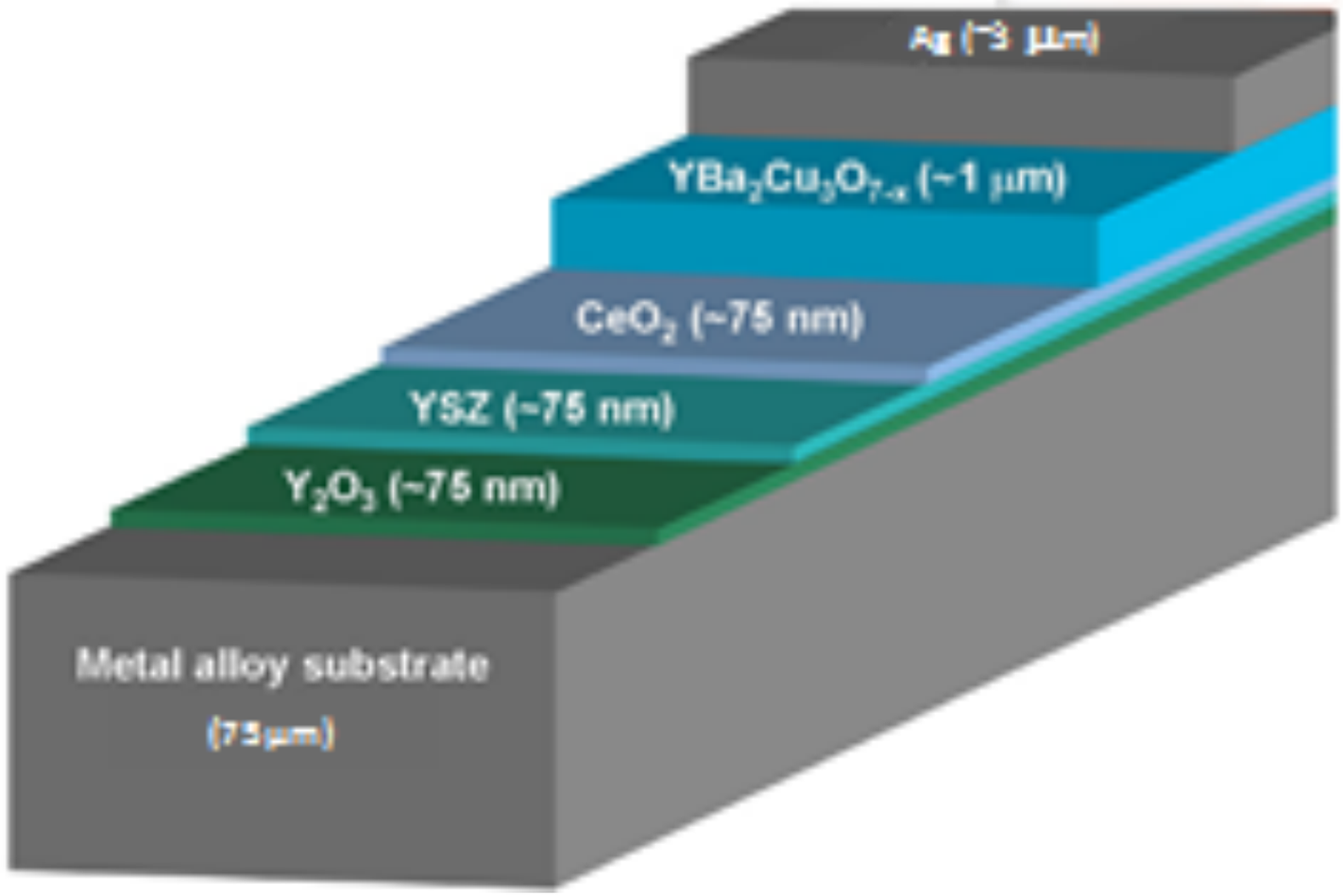


12 mm wide wire

AMSC 2G Technology

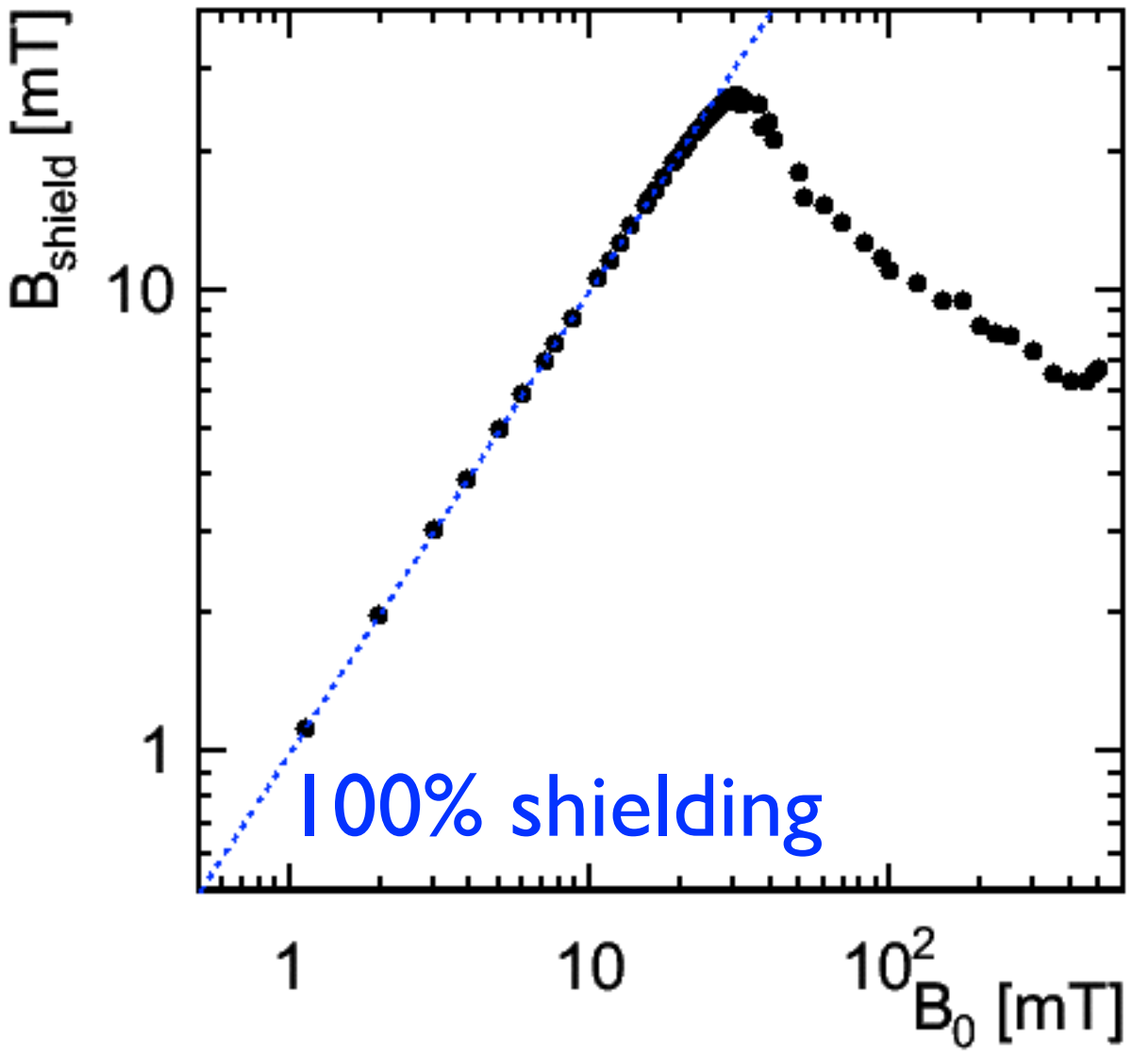
Based on low-cost RABITS™/MOD Architecture

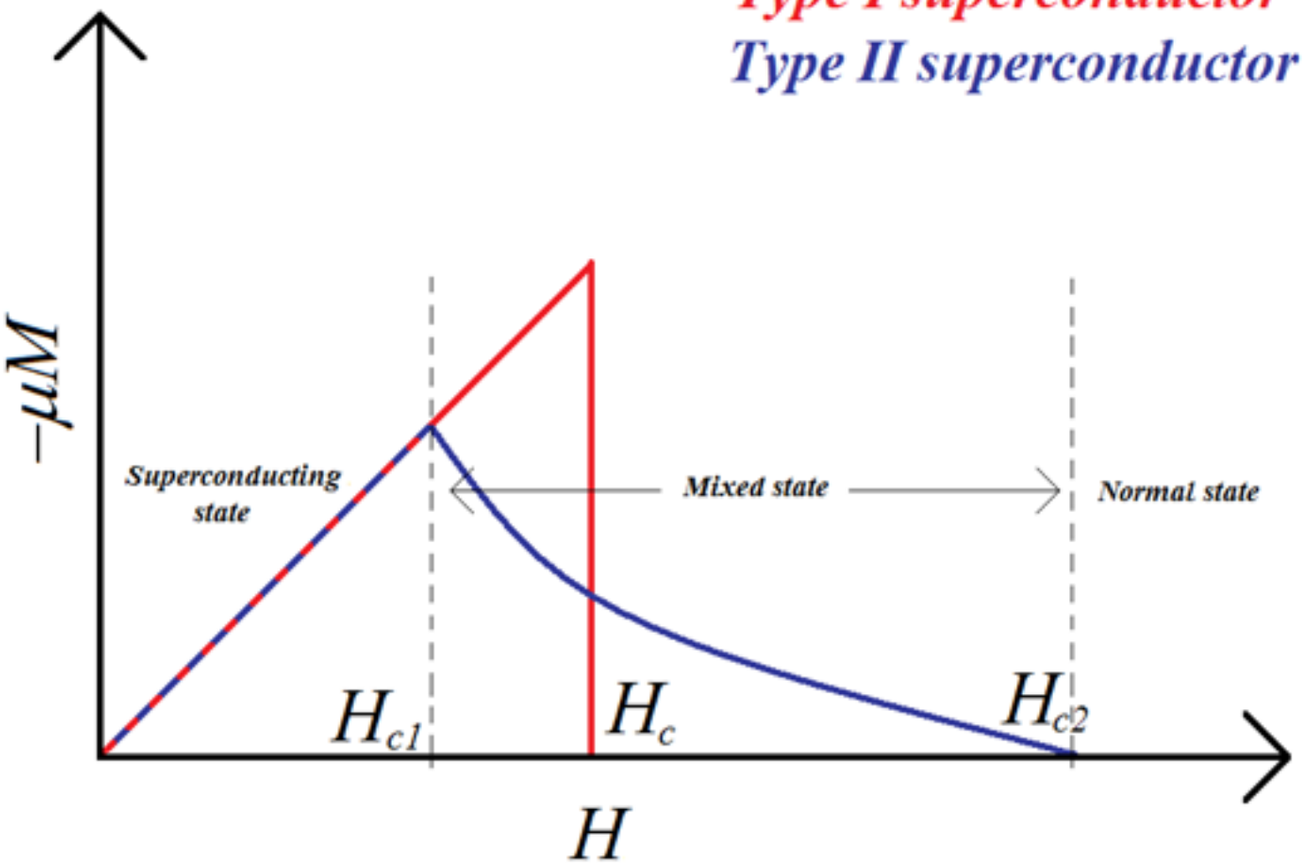
- **Substrate: Ni-5W alloy**
  - Deformation texturing
- **Buffer stack: Y_2O_3/YSZ/CeO_2**
  - High rate reactive sputtering
- **YBCO, the HTS part**
  - Metal Organic Deposition of TFA-based precursors
- **Ag**
  - DC sputtering



46 mm wide wire

SC tape performance at high fields





$B_{C1} \sim 20$ mT

$B_{C2} > 500$ mT

Long prototype commissioning