

# Comments from the Slack Channel

Thanks for all the lively discussions and great posters! I enjoyed this session much more than expected. Cheers!

-Dustin McNulty

I am really getting into this .. the videos are really well done!

-Ciprian Gal

“We found that all the posters were of very high quality and it was difficult to select the top two.”

-Elton Smith

Lots of great videos! The judges have their work cut out for them!

-Lorelei Carlson

# Special thanks to:

---

## OUR JUDGES

Scott Barcus	Sebastian Kuhn
Mark Dalton	Dave Mack
Wouter Deconinck	Chris Monahan
Sean Dobbs	Kostas Orginos
Dave Gaskell	Will Phelps
Keith Griffioen	Julie Roche
Doug Higinbotham	Elton Smith
Yordanka Ilieva	Justin Stevens

## OUR PLANNING COMMITTEE

Amy Schertz  
Lorelei Carlson  
Ed Brash  
Kent Paschke  
Julie Roche  
Yordanka Ilieva  
Susan Schadmand

## ...and our sponsor JSA!

This project is supported by the JSA Initiatives Fund Program (<http://www.jsallc.org/IF/IFProjects.html>), a commitment from the JSA owners, SURA and PAE Applied Technologies. Initiatives Funds support programs, initiatives, and activities that further the scientific outreach, promote the science, education and technology of the Jefferson Lab and benefit the Lab's extended user community in ways that complement the Lab's basic and applied research missions.

# Top 8 Finalists

Pierre Chatagnon

Brandon Clary

Brandon Kriesten

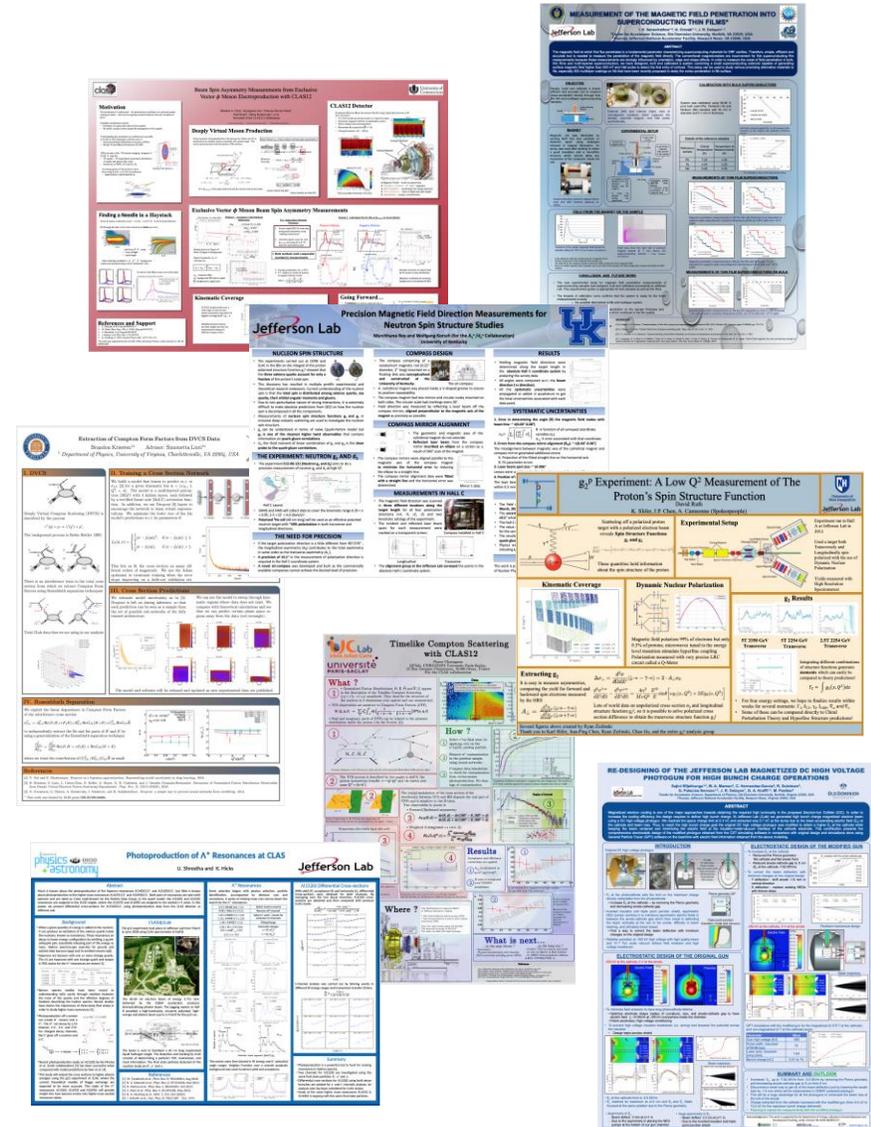
Murchhana Roy

David Ruth

Iresha Harshani Senevirathne

Utsav Shrestha

Sajini Wijethunga





**ABSTRACT**

The magnetic field at which first flux penetrates is a fundamental parameter characterizing superconducting materials for SRF cavities. Therefore, simple, efficient and accurate tool is needed to measure the penetration of the magnetic field directly. The conventional magnetometers are inconvenient for thin superconducting film measurements because these measurements are strongly influenced by orientation, edge and shape effects. In order to measure the onset of field penetration in bulk, in films and multi-layered superconductors, we have designed, built and calibrated a system combining a small superconducting solenoid capable of generating surface magnetic field higher than 500 mT and Hall probe to detect the first entry of vortices. This setup can be used to study various promising alternative materials to Nb, especially SIS multilayer coatings on Nb that have been recently proposed to delay the vortex penetration in Nb surface.

**OBJECTIVE**

Design, build and calibrate a simple, efficient and accurate tool to measure the penetration directly through bulk, film and multilayer superconducting samples.

External (left) and internal (right) view of nonmagnetic container which supports the sample, solenoid magnet, and Hall probe symmetrically.

**MAGNET**

Magnetic coil was fabricated by winding NbTi thin wire carefully on ceramic spool using strategies used in magnet fabrication. An epoxy was used after winding to obtain good insulation and a monolithic structure which cannot allow any movement of the conductor inside the superconducting solenoid magnet before (top) and after (bottom) applying an epoxy.

**EXPERIMENTAL SETUP**

Labels: Finger springs, Current, Cu leads, SC wire, to push the magnet down, to pass high current, to generate a magnetic field parallel to the sample, Sapphire plate, Solenoid magnet, SC sample, Hall probe, Cryogenic probe HHP-NP from Anspec to measure onset penetration of the magnetic field.

- to maintain a fixed distance (0.5 mm) between the sample and the magnet
- to keep the sample rigid during experiment

**FIELD FROM THE MAGNET ON THE SAMPLE**

Variation of the radial magnetic field along the sample radius at 100 A (From Poisson Simulators)

Field lines from the right half of solenoid magnet placed at 1 mm above the superconducting sample (From Poisson Simulators)

**CONCLUSION AND FUTURE WORK**

The new experimental setup for magnetic field penetration measurements of superconducting samples was designed, built and calibrated successfully at Jefferson Lab. This experimental system is appropriate for bulk samples as well as thin films.

The linearity of calibration curve confirms that the system is ready for the future measurements to study

- the possible alternatives to Nb and multilayer system.
- the dependence of field penetration on the sample thickness and different coating parameters which contribute to the film quality.

**CALIBRATION WITH BULK SUPERCONDUCTORS**

System was calibrated using 99.99 % pure bulk Lead (Pb), Tantalum (Ta) and Niobium (Nb) samples with 50 mm in diameter and 0.1 mm in thickness.

Hall Probe response against Pb, Ta, Nb samples while powering up the magnet with gradually increasing current.

Reference sample	Critical Temperature (K)	Temperature at Measurements (K)
Pb	7.20	4.35
Ta	4.50	2.00
Nb	9.25	4.35

The calibration curve of the experimental setup

**MEASUREMENTS OF THIN FILM SUPERCONDUCTORS**

Magnetic penetration measurements on Nb thin film with thickness 2 μm deposited on sapphire plate using Electron Cyclotron Resonance (ECR) at 4.35 K (left) and 1.97 K (right)

Magnetic penetration measurements on Nb<sub>2</sub>Sn thin film with thickness 1.5 μm deposited on sapphire plate using Magnetron Sputtering at 4.35 K (left) and 1.97 K (right)

**MEASUREMENTS OF THIN FILM SUPERCONDUCTORS ON BULK**

Magnetic penetration measurements on Nb thin film deposited on bulk Cu with thickness 1 μm using Electron Cyclotron Resonance (ECR) at 4.35 K (left) and 1.97 K (right)

# Iresha Harshani Senevirathne

## Old Dominion University

### Measurements of the Magnetic Field Penetration into Superconducting Thin Films



# Murchhana Roy

University of Kentucky

## Precision Magnetic Field Direction Measurements for Neutron Spin Structure Studies



**Jefferson Lab**

### Precision Magnetic Field Direction Measurements for Neutron Spin Structure Studies

Murchhana Roy and Wolfgang Korsch (for the  $A_1^n/d_2^n$  Collaboration)  
University of Kentucky



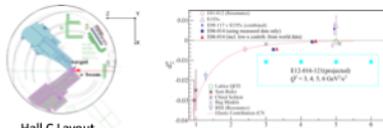
---

#### NUCLEON SPIN STRUCTURE

The experiments carried out at CERN and SLAC in the 80s on the integral of the proton polarized structure function  $g_1^p$  showed that the **three valence quarks account for only a fraction of the proton's total spin**. This discovery has resulted in multiple prolific experimental and theoretical research endeavors. Current understanding of the nucleon spin is that the **total spin is distributed among valence quarks, sea quarks, their orbital angular momenta and gluons**. Due to non-perturbative nature of strong interactions, it is extremely difficult to make absolute predictions from QCD on how the nucleon spin is decomposed in all the components. Measurements of nucleon spin structure functions  $g_1$  and  $g_2$  in inclusive deep inelastic scattering are used to investigate the nucleon spin structure.  $g_1$  can be understood in terms of naive Quark-Parton model but  $g_2$  is **one of the cleanest higher twist observables** that contains information on **quark-gluon correlations**.  $d_2$ , the third moment of linear combination of  $g_1$  and  $g_2$ , is the **clean probe to the quark-gluon correlations**.

#### THE EXPERIMENT: NEUTRON $g_2$ AND $d_2$

The experiment E12-06-121 (Neutron  $g_2$  and  $d_2$ ) aims to do a precision measurement of neutron  $g_2$  and  $d_2$  at high  $Q^2$ .



Hall C Layout

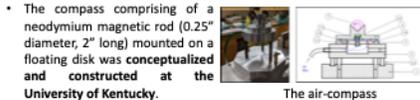
SHMS and HMS will collect data to cover the kinematic range  $0.20 < x < 0.95$ ,  $2.5 < Q^2 < 6.0$  (GeV/c)<sup>2</sup>. Polarized <sup>3</sup>He cell (40 cm long) will be used as an effective polarized neutron target with ~50% polarization in both transverse and longitudinal directions.

#### THE NEED FOR PRECISION

If the target polarization direction is a little different from 90°/270°, the longitudinal asymmetry ( $A_L$ ) contributes to the total asymmetry in same order as the transverse asymmetry ( $A_T$ ). A precision of  $\pm 0.1^\circ$  in the measurement of polarization direction is required in the Hall C coordinate system. A novel **air-compass** was developed and built as the commercially available compasses cannot achieve the desired level of precision.

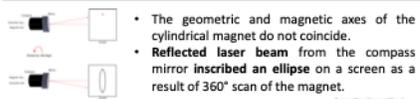
#### COMPASS DESIGN

- The compass comprising of a neodymium magnetic rod (0.25" diameter, 2" long) mounted on a floating disk was **conceptualized and constructed at the University of Kentucky**.
- A cylindrical magnet was placed inside a V-shaped groove to ensure its position repeatability.
- The compass magnet had two mirrors and circular scales mounted on both sides. The circular scale had markings every 30°.
- Field direction was measured by reflecting a laser beam off the compass mirrors, **aligned perpendicular to the magnetic axis of the magnet** as precisely as possible.



The air-compass

#### COMPASS MIRROR ALIGNMENT

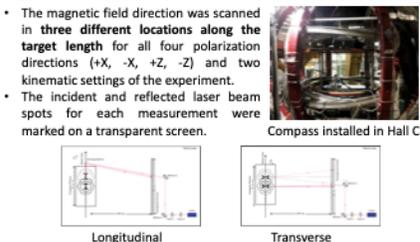


- The geometric and magnetic axes of the cylindrical magnet do not coincide.
- Reflected laser beam from the compass mirror **inscribed an ellipse** on a screen as a result of 360° scan of the magnet.
- The compass mirrors were aligned parallel to the magnetic axis of the compass magnet to **minimize the horizontal error** by reducing the ellipse to a straight line.
- The compass mirror alignment data were **fit with a straight line** and the horizontal error was determined.

Mirror 1 data

#### MEASUREMENTS IN HALL C

- The magnetic field direction was scanned in **three different locations along the target length** for all four polarization directions (+X, -X, +Z, -Z) and two kinematic settings of the experiment.
- The incident and reflected laser beam spots for each measurement were marked on a transparent screen.



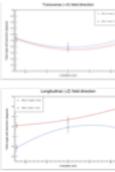
Compass installed in Hall C

Longitudinal
Transverse

- The **alignment group at the Jefferson Lab surveyed** the points in the absolute Hall C coordinate system.

#### RESULTS

- Holding magnetic field directions were determined along the target length in the **absolute Hall C coordinate system** by analyzing the survey data.
- All angles were computed w.r.t. the **beam direction (+z direction)**.
- All the **systematic uncertainties** were propagated or added in quadrature to get the total uncertainties associated with each data point.



#### SYSTEMATIC UNCERTAINTIES

- Error in determining the angle ( $\theta$ ) the magnetic field makes w beam line:  $\sim \pm(0.04^\circ-0.08^\circ)$
- Errors from the compass mirror alignment ( $\theta_{mis}$ ):  $\sim \pm(0.04^\circ-0.06^\circ)$
- Laser beam spot size:  $\sim \pm 0.006^\circ$
- Position of incident laser beam on the compass mirror:  $\sim \pm 0.01^\circ$

The misalignment between magnetic axis of the cylindrical magnet a compass mirror generated additional errors:

- Projection of the fitted straight line on the horizontal axis
- Fit parameter errors

Lenses were used to make the laser beam spot diameter  $\sim 2$  mm.

The laser beam always reflected off the center of the compass mirror within 0.5 mm uncertainty.

#### SUMMARY

- The field direction measurement was **successfully completed 1 March, 2020**.
- The **uncertainty** in the field direction measurement was **limited to  $\pm 0.1^\circ$**  which satisfies requirement for the  $d_2^n$  experiment.
- The Hall C is currently **getting ready for data taking**.
- The value of  $d_2^n$  will be measured at **four truly constant  $Q^2$**  value for the very first time.
- The results will provide **insight on the neutron spin structure** an **quark-gluon correlations**.
- Physics will be explored to test different theoretical predictor including **Lattice QCD**.

#### ACKNOWLEDGEMENT

This work is partially supported by the U.S. Department of Energy Office of Nuclear Physics under Contract No. DEFG02-99ER41101.

