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Magnetic Shielding Measurements on 2G HTS Coils

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Revolutionary Research . . . Relevant Results

Focus of this talk is on recent variable temperature magnetic shielding measurements on small 2G HTS coils using cryogenic gaseous helium circulation

Significance of Magnetic Shielding

- Future military ships and airplanes will have
  - High power density electrical machinery
  - High power communications equipment
  - Electromagnetic launch systems
  - Pulsed power systems for directed energy weapons
- The high power density electromagnetic systems produce more pronounced magnetic signatures than their conventional counterparts
- Magnetic signatures of the machines have to be addressed to realize their full benefits
- Magnetic shields with enhanced capabilities are needed to address the signatures emanating from future high power density machines
- Magnetic shielding maybe necessary to prevent potential interferences among nearby machines

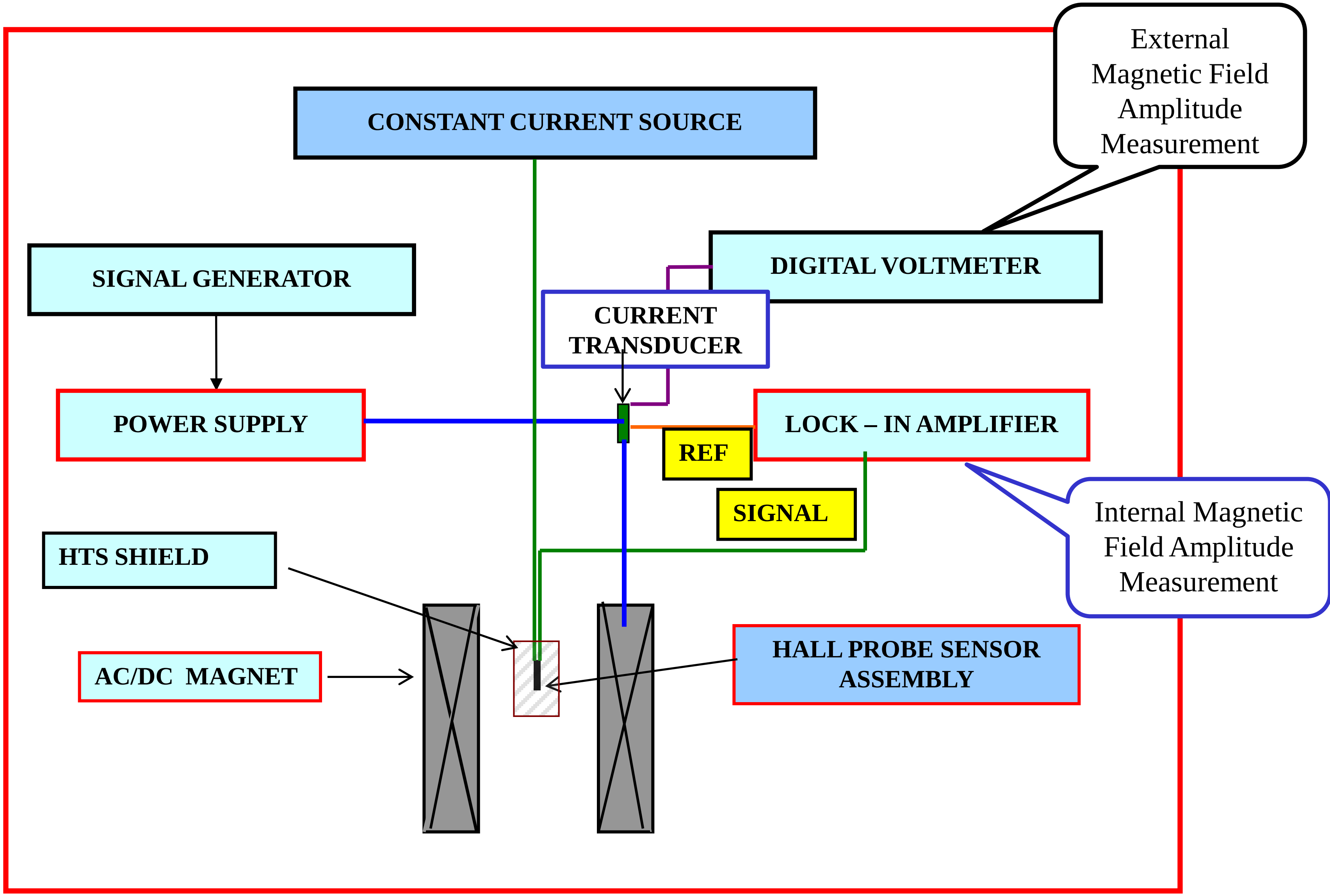
Benefits of High Temperature Superconductors for Shielding Applications

- Significant size and weight reduction
  - Improves fuel efficiency – lower operational costs
  - Frees space for additional weapon systems
- Effective over a wide range of frequencies
- Effective even at large field amplitudes
- Enable fabrication of shields in many geometries
- Can be accommodated in the housing of the electric machines
- Many recent developments in conductor technology
  - Long lengths
  - Wider tapes
  - Improvements in I_c and uniformity

Why Gaseous Helium?

- Earlier attempts with conductive cooling did not yield good data – large copper bars attached to the shields contributed to noise and errors
- Gaseous helium provides a wide temperature range
- Gaseous helium is the cryogen of choice for superconducting applications on ships
- The measurements will give us a realistic idea of AC losses and resulting temperature gradients

Shielding Property Measurement Setup

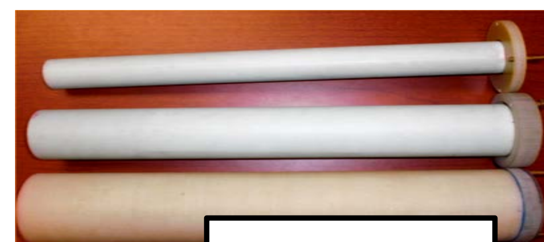


Configuration of 2G HTS Shields

Sheet form

Coil form

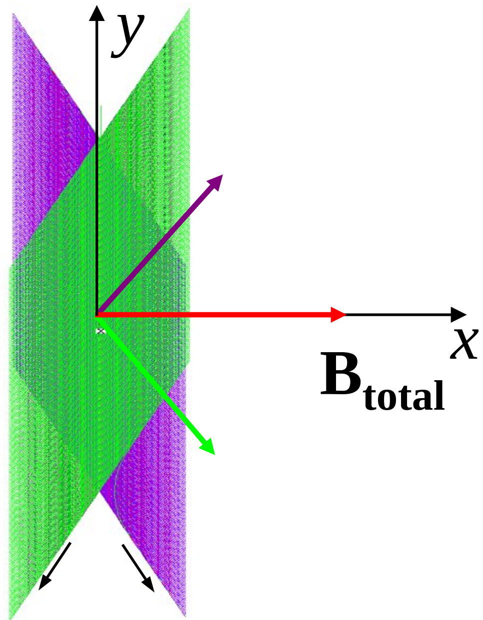
Ring form

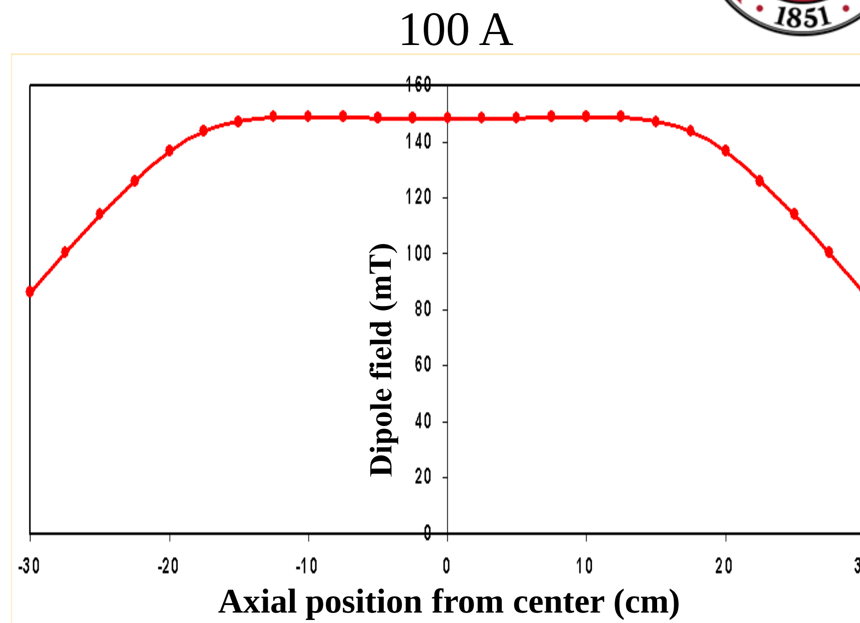


Formers

Inter-turn gap is minimized by placing the successive turns as close to one another as possible without overleaping

Transverse Field Magnet Used In Shielding Experiments



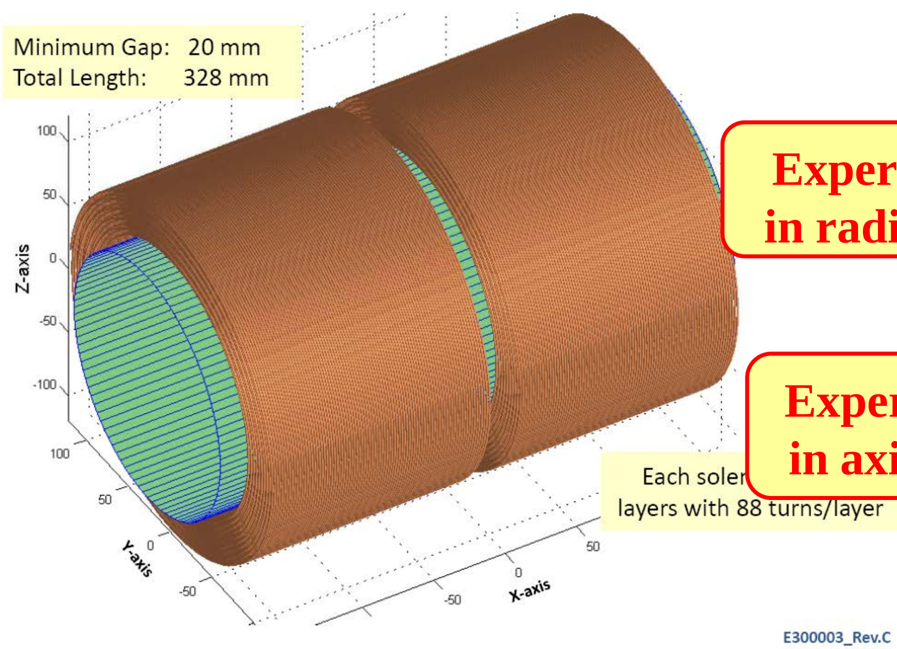


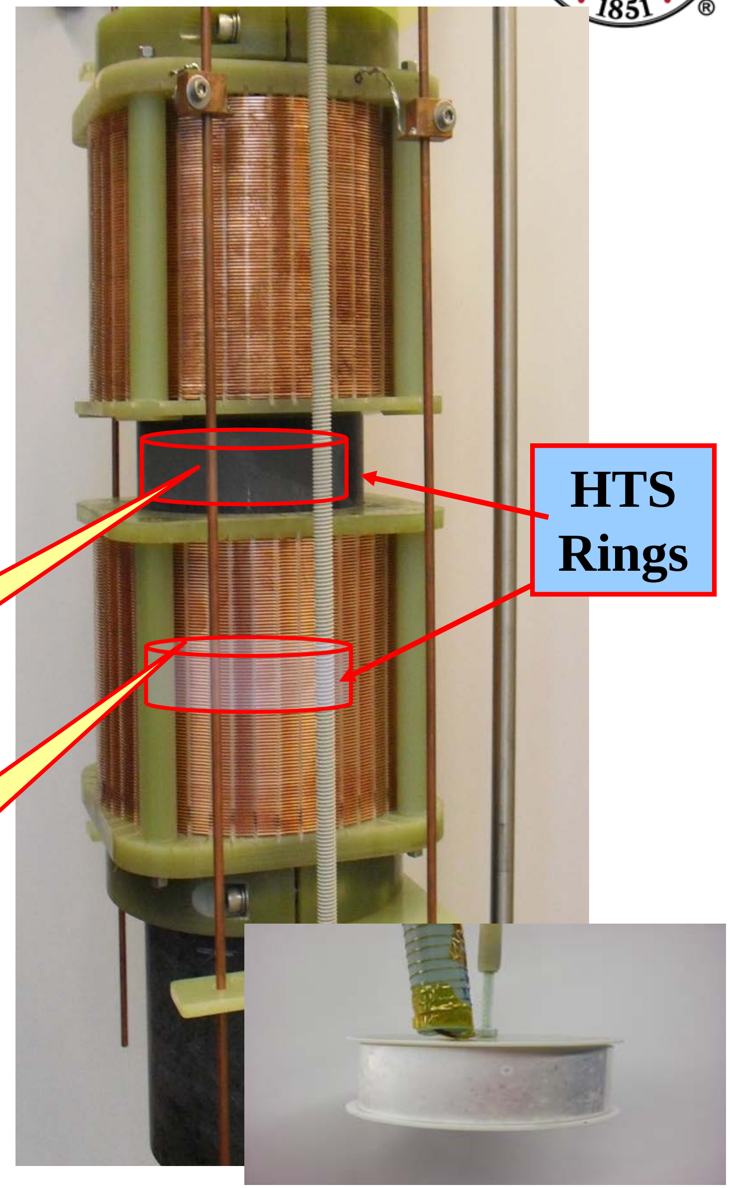
Special double helix magnet:

- Tilted, helically wound coils (6 layers)
- Produce uniform transverse magnetic field => convenient to rotate the sample to study effect of orientation of magnetic field on shielding
- Has 25 cm uniform field ➔ long shields can be characterized

Dual Solenoid Magnet System - Used for Shielding and AC Loss Measurements on Rings and Coils

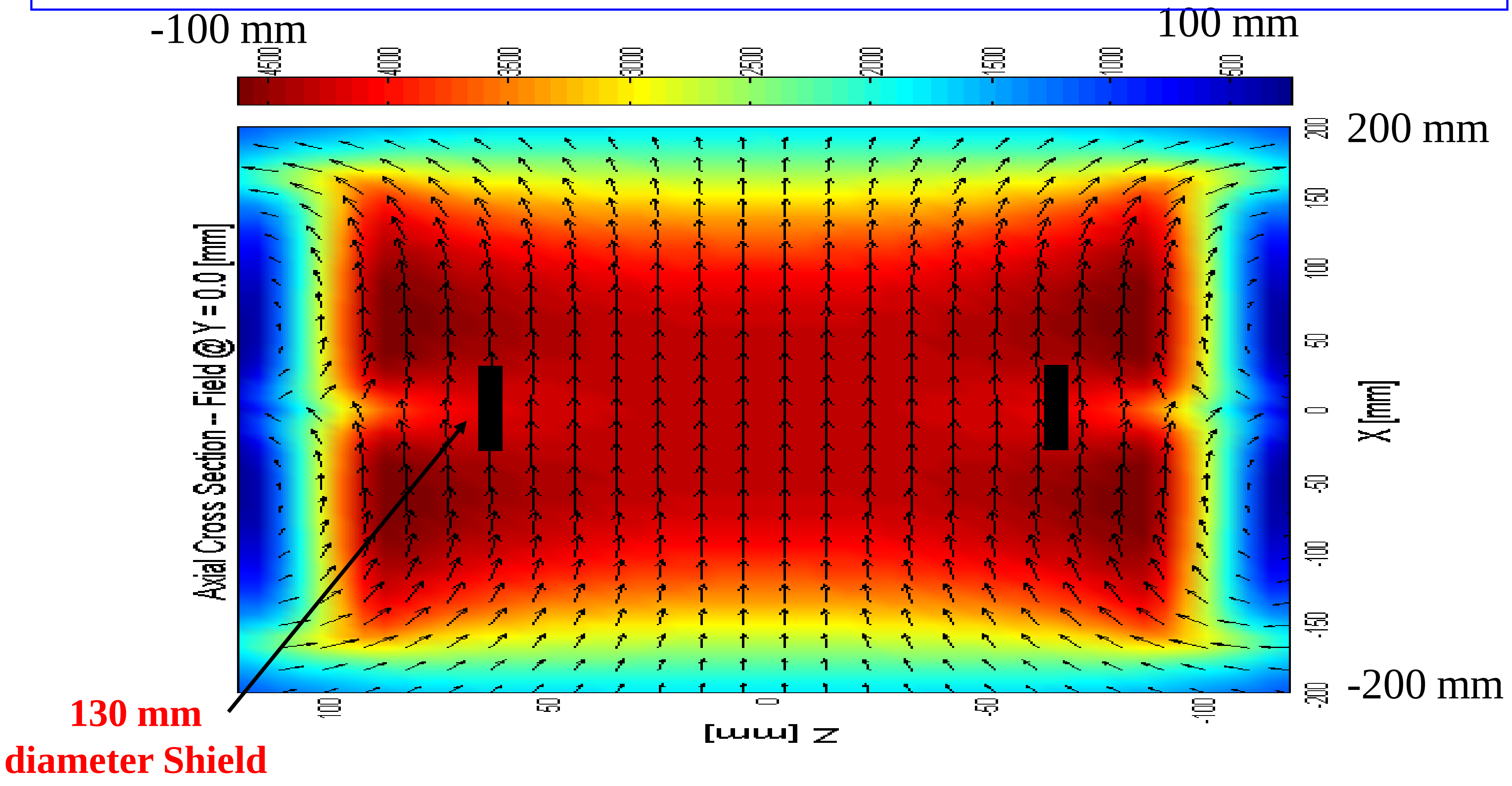
- Squirrel cage technology and adjustable gap between solenoids
- Produce uniform axial or radial magnetic fields
- Open aperture: 165.1 mm ➔ large rings can be characterized





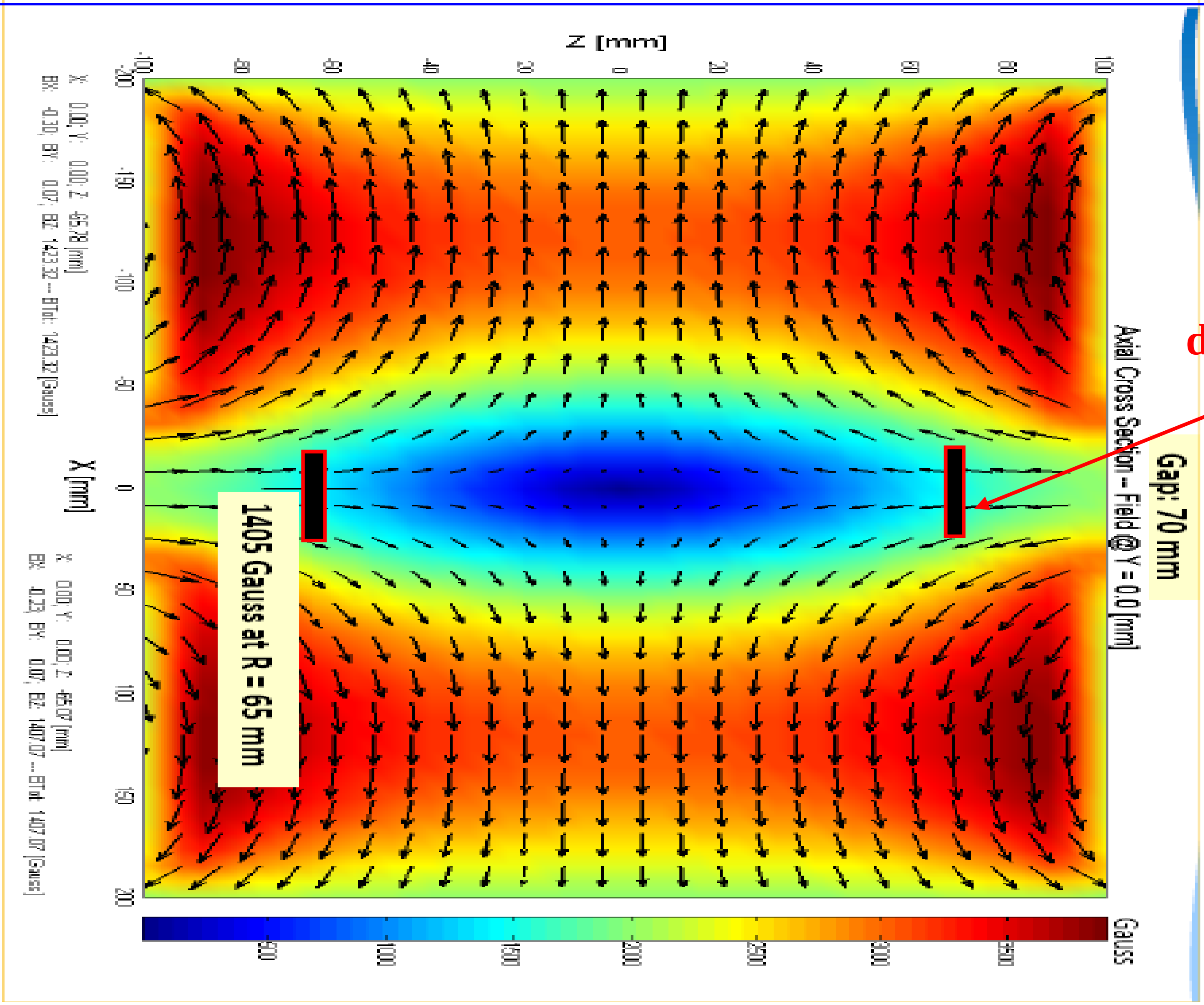
Magnetic Field Profile Axial mode

- Magnetic field is highly uniform -Axial field is uniform over > 200 mm height
- Long shields in cylinder shape can be characterized in axial field orientation



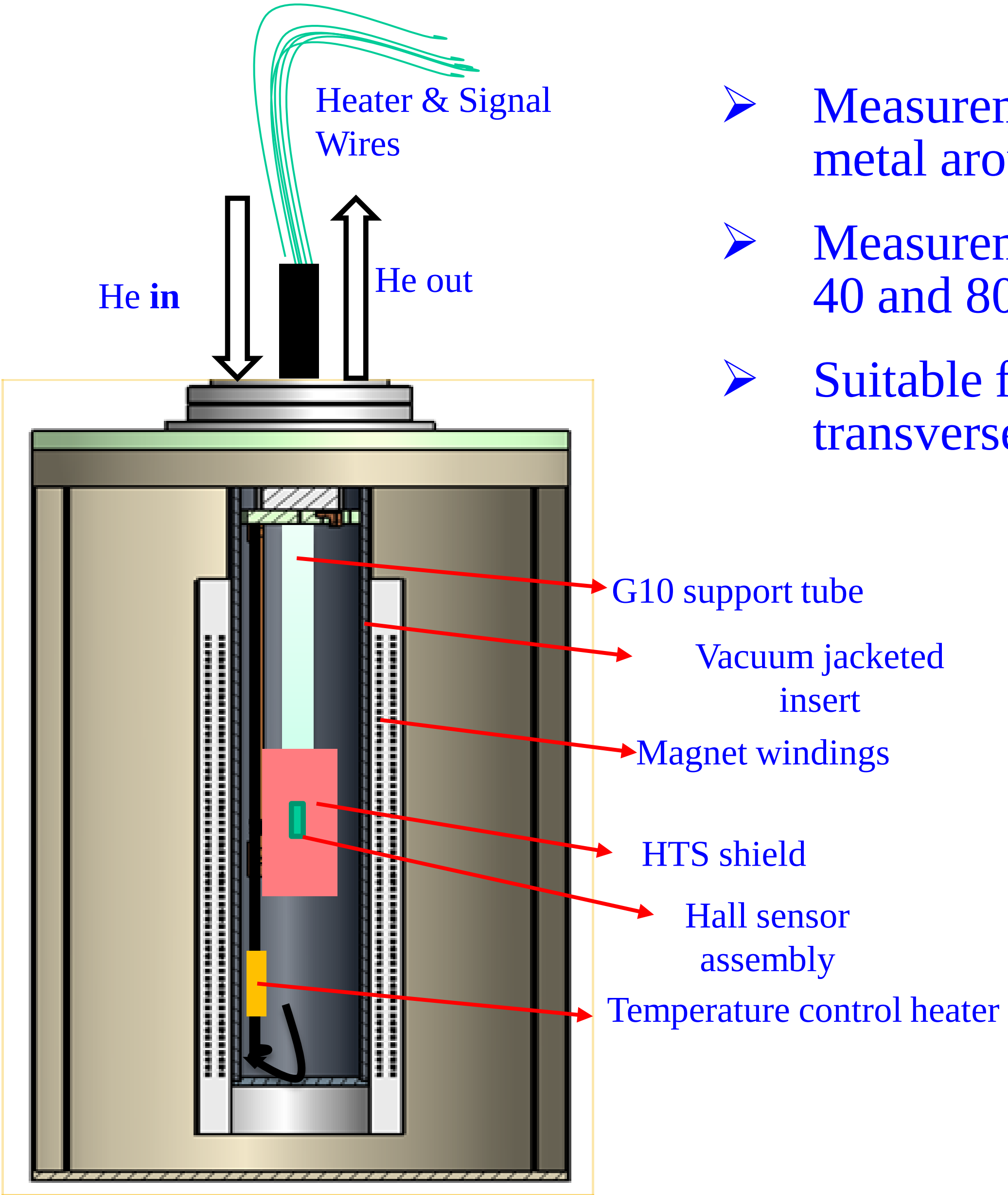
Magnetic Field Profile – Radial Mode

- Field is radial and uniform over 45 mm height of the ring



130 mm diameter Shield

Variable Temperature Shielding Measurements in Helium Gas Circulation



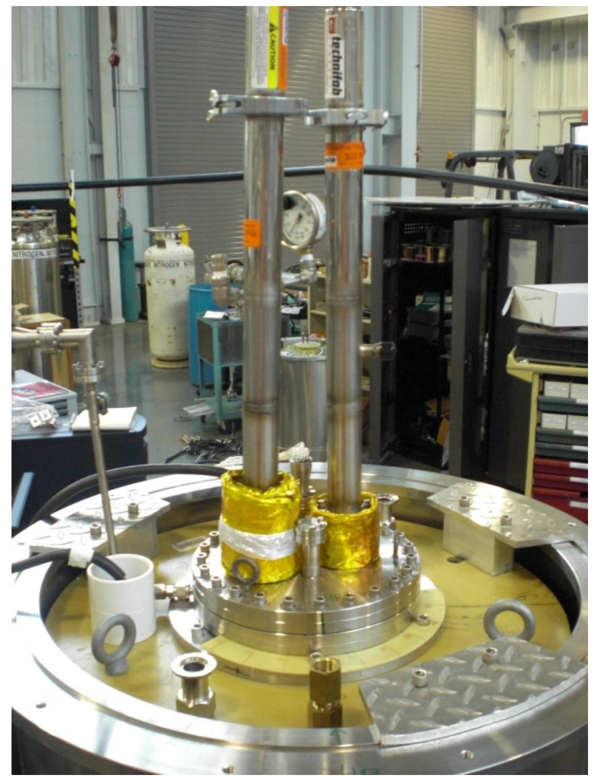
- Measurements are clean, no metal around the shield
- Measurements possible between 40 and 80 K
- Suitable for experiments in axial, transverse, and radial fields

Variable Temperature Shielding Measurements with Gaseous Helium Circulation

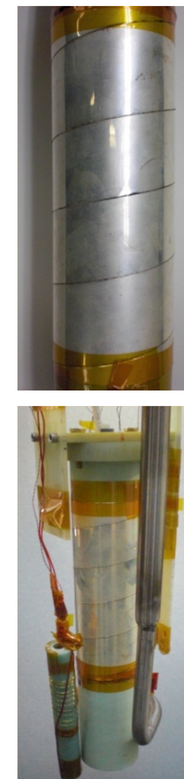
- Shields up to 140 mm in diameter and 200 mm height can be measured
- Temperature between 50 and 80 K can be controlled with ±0.5 K stability
- Suitable for measurements in both DC and AC magnetic fields

He Circulation System

Vacuum Jacketed Insert



Magnet & Measurement Assembly

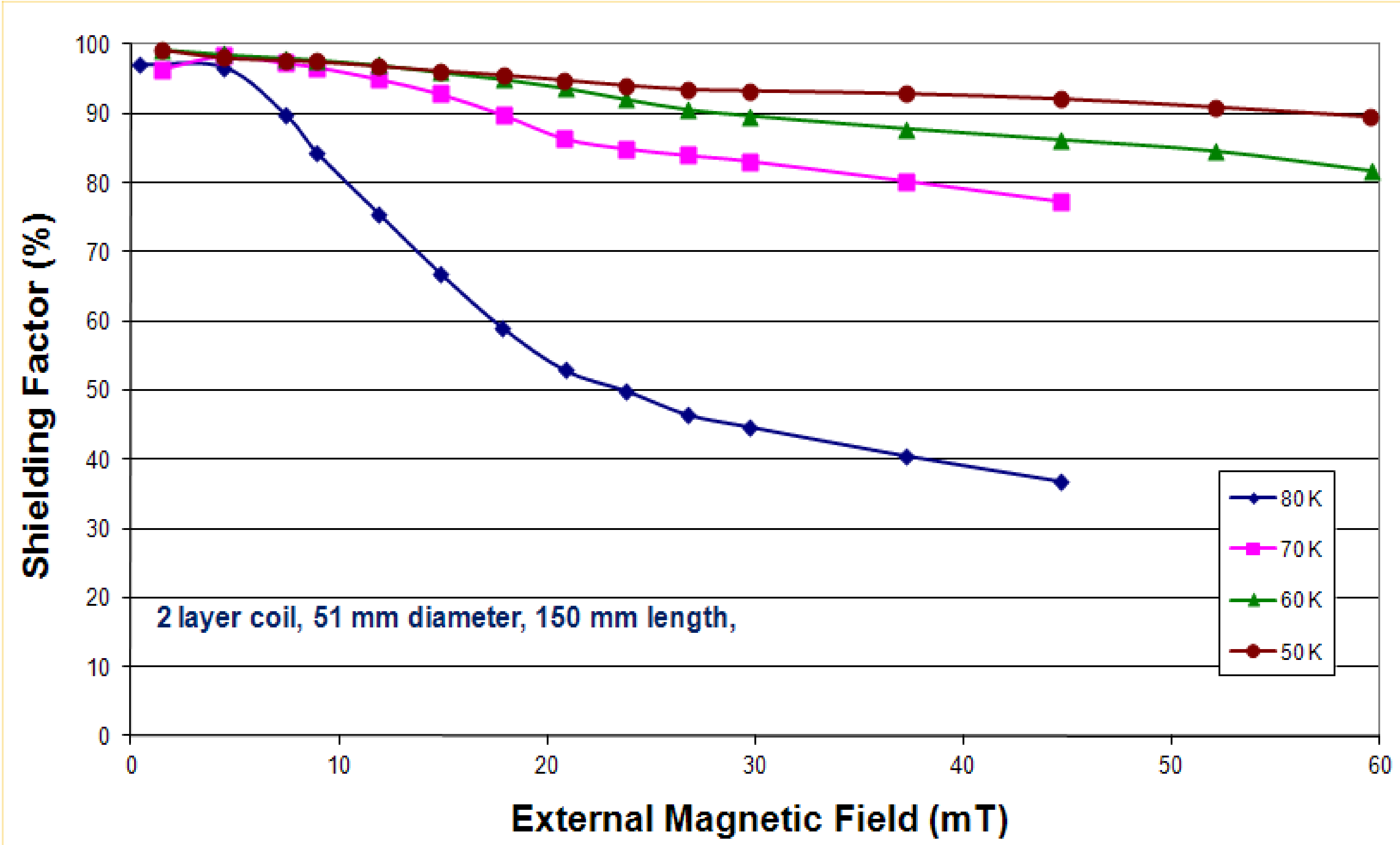


2G Shield

DC Shielding – 2 Layer Coil

- Significant temperature dependence at higher fields
- At 40 mT, the shielding factor doubles from 80 to 70 K

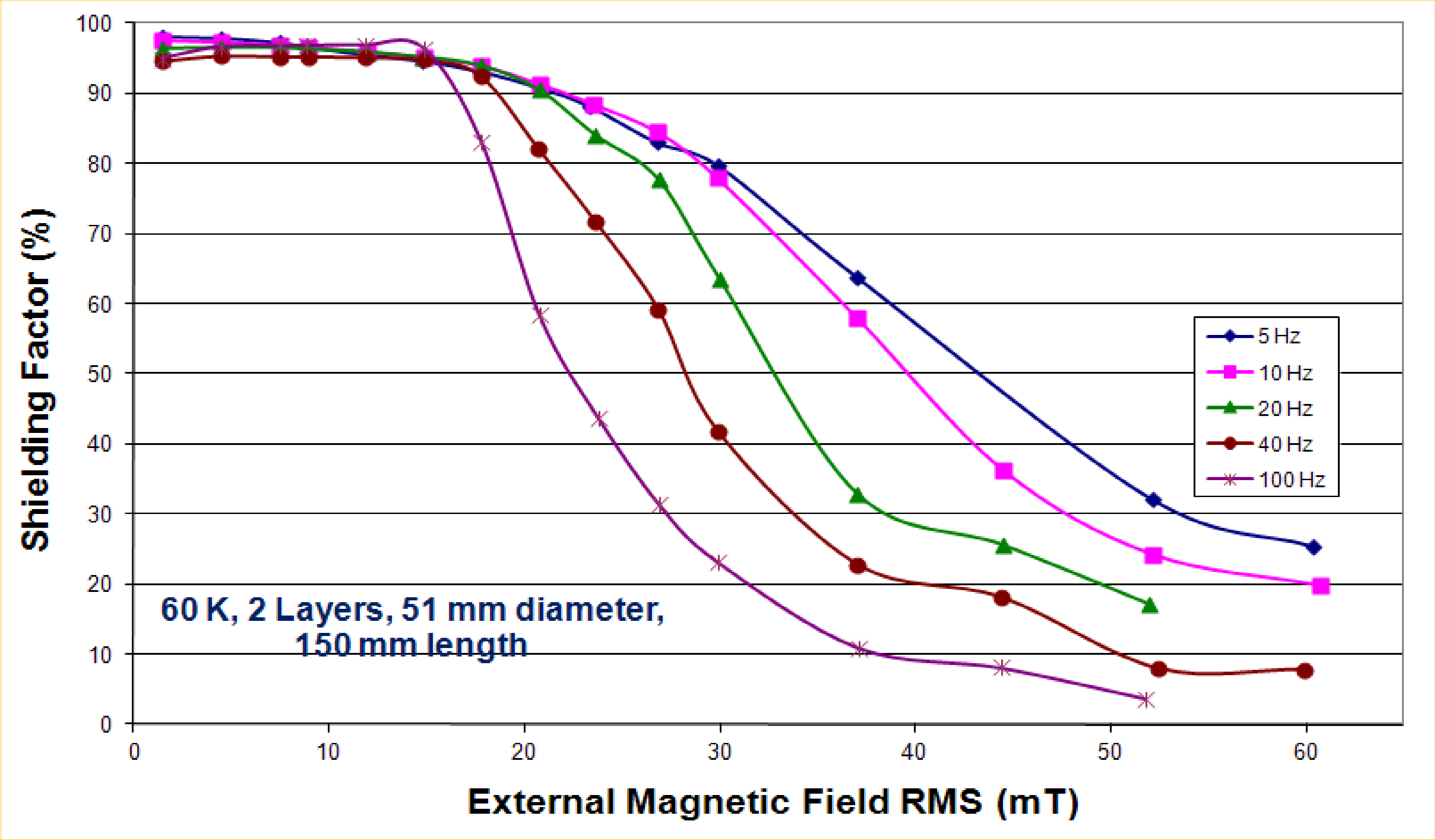
Axial magnetic field



AC Shielding – 2 Layer Coil, 60 K

- Significant temperature dependence at higher fields
- At > 15 mT, there is frequency dependence

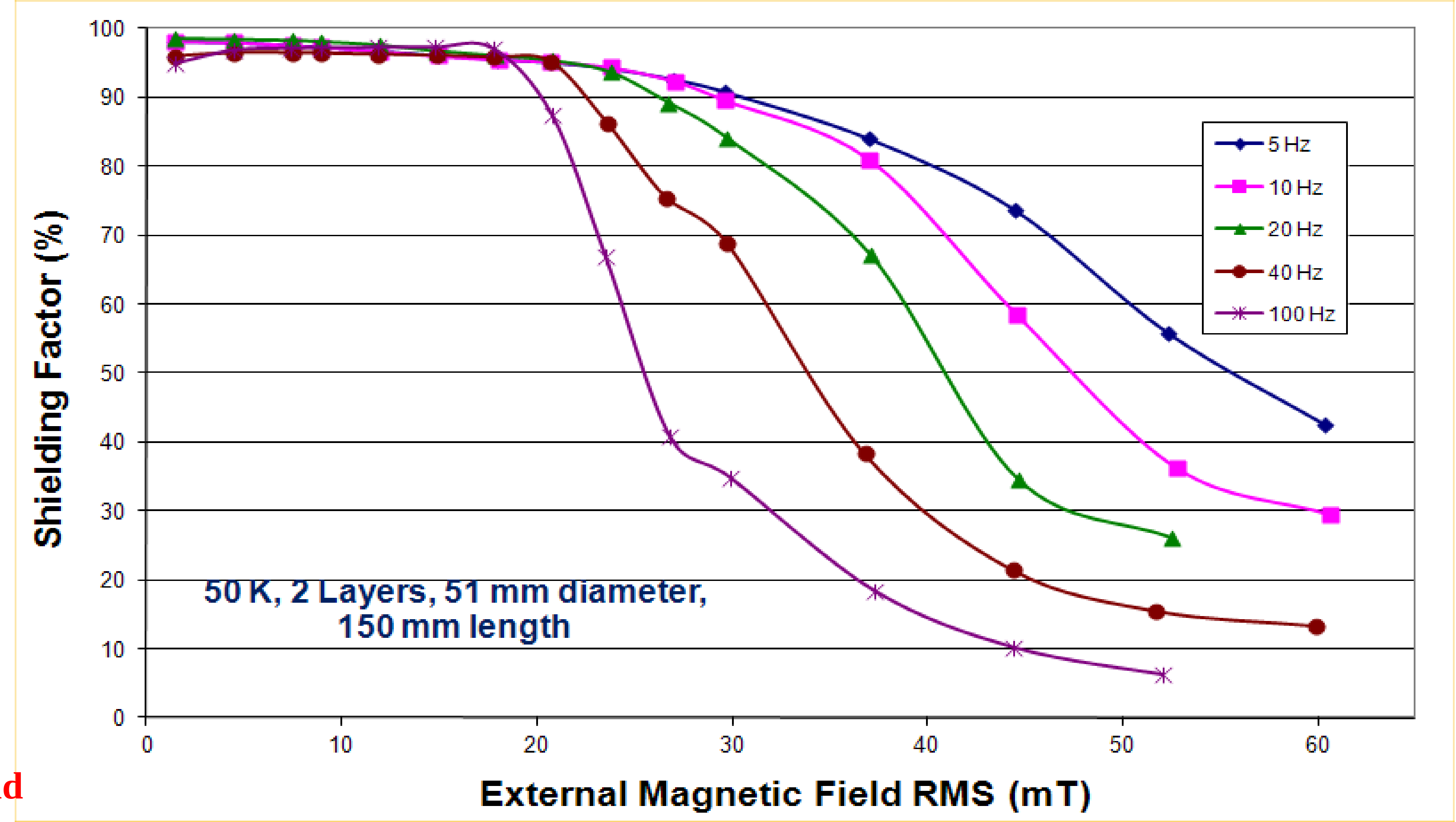
Axial magnetic field



AC Shielding – 2 Layer Coil, 50 K

- As the temperature lowers, frequency dependence starts at higher fields

Axial magnetic field



Conclusions

- Designed and built the apparatus for shielding measurements in cryogenic helium gas
- Shielding measurements performed in axial and radial magnetic fields
- Shielding properties of 2G HTS materials were characterized at several temperatures between 50 and 80 K
- As expected, significant dependence of shielding factors on temperature was observed
- 2-3 layers of superconductor are enough to shield 100% of the field in 30-40 mT region
- The measurements in helium gas showed that AC losses are small up to 200 Hz
- Demonstrated 2G HTS potential for magnetic shielding applications

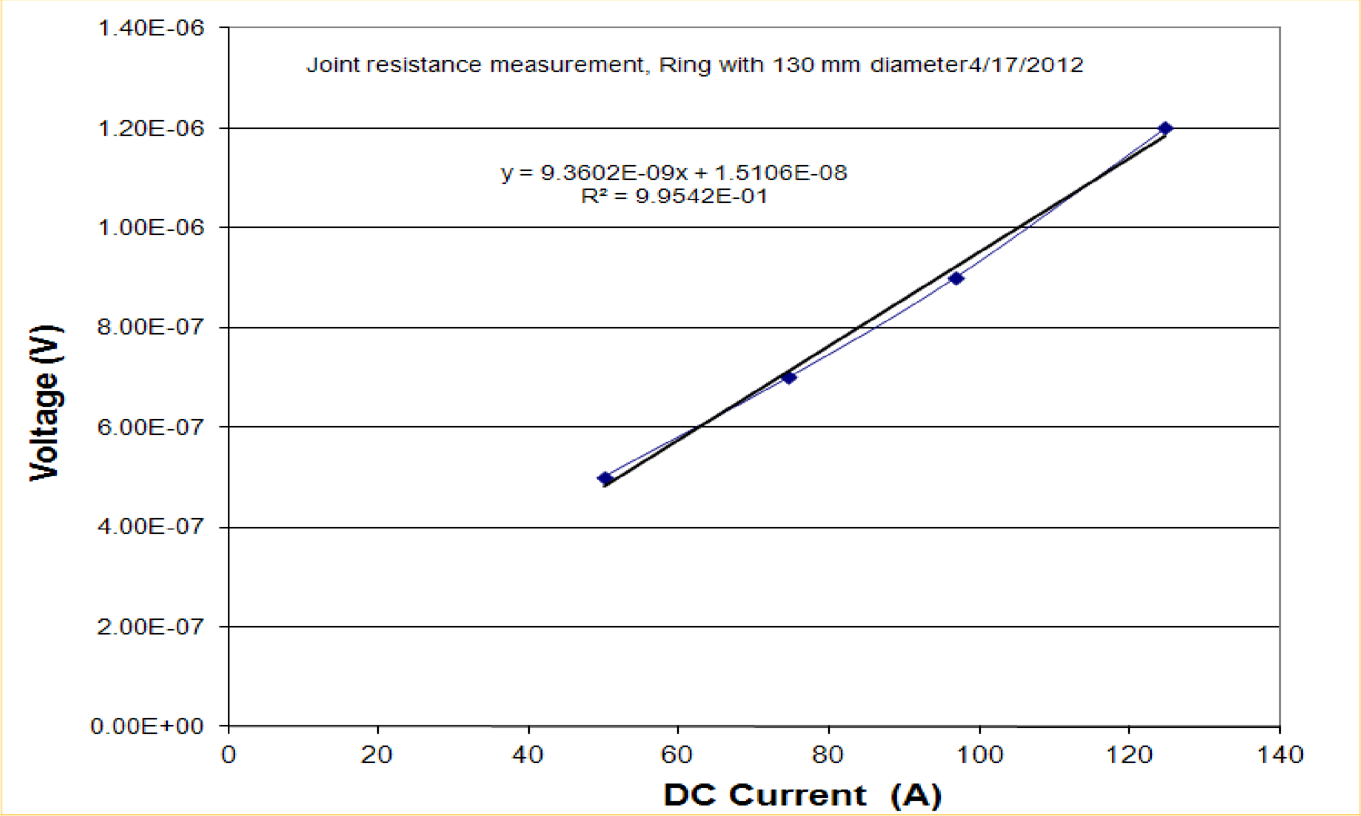
Thank You!

2G Superconductor Rings – Low Resistive Joints

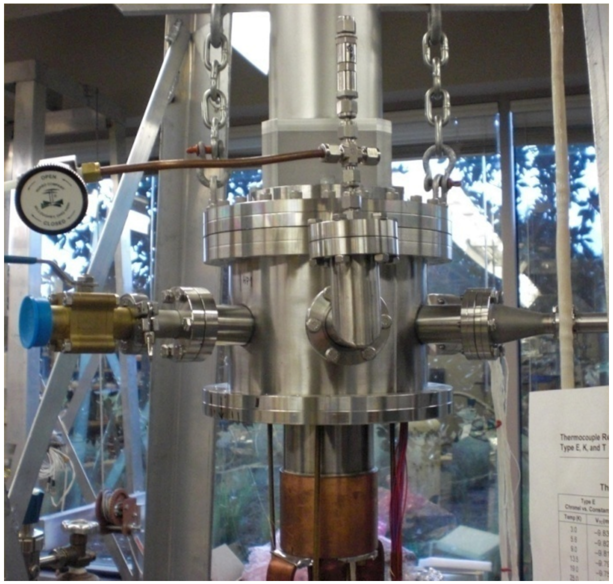
Ic = 1200 A

46 mm

- For axial fields, shielding currents have to cross the resistive joint
- Low restive joints are important to reduce losses
- Joint resistance of a few nano-ohms achieved



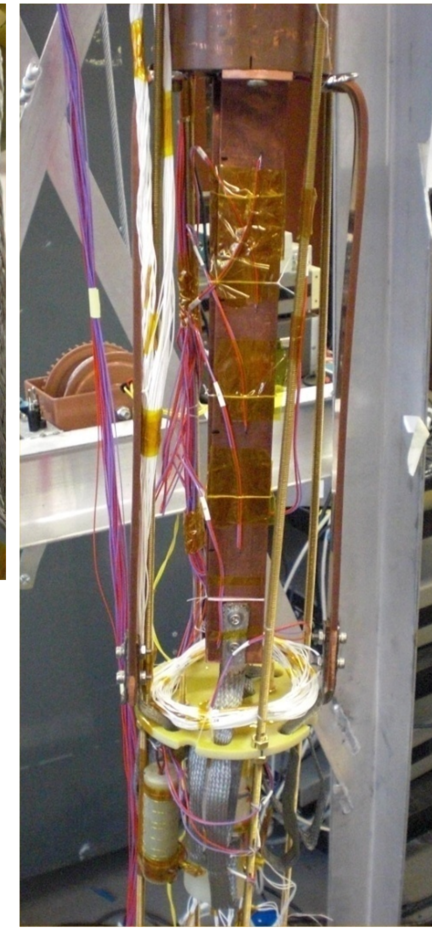
Previous variable temperature shielding measurements – with conductive cooling



Cold Head of a cryocooler

Conductive path for heat transfer

HTS Shield



Assembly

- The assembly is enclosed in a vacuum tight experimental chamber and inserted into the bore of a AC/DC magnet.
- The chamber is evacuated and backfilled with helium
- Temperature stability is achieved using a temperature controller and heater