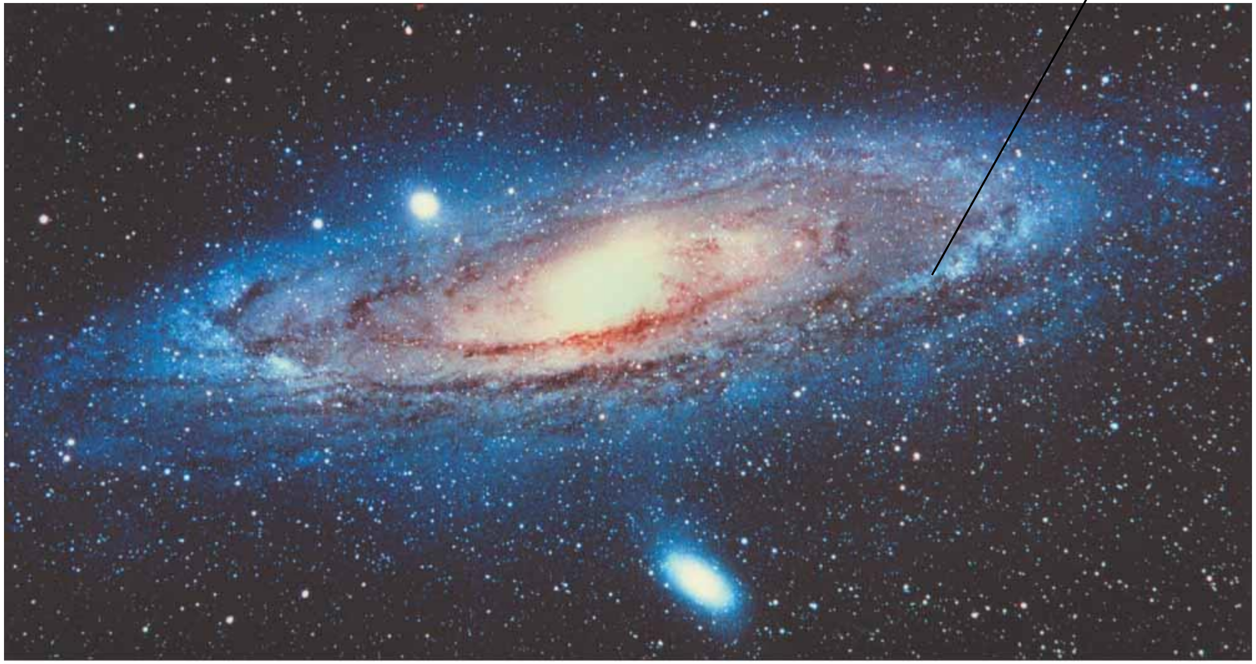
NHMFL
Tallahassee



Magnetic fields available at the
Intergalactic Magnet Lab: 1 nT to 1 GT

Presenter: J. Brooks, Physics Dept. and Mag Lab

NATIONAL HIGH MAGNETIC FIELD LABORATORY

World Comparison: Largest, highest powered magnet lab in the world with one of the broadest science agenda (soft to hard matter)

NHMFL Pulsed Field Facility
Los Alamos National Laboratory

1.43GW Generator

60T controlled Pulse Magnet, 32 mm liq. N_2 bore

High B/T Facility

45 T hybrid, 32 mm bore

Florida State University

11 T, 40 cm warm bore MRI magnet (Magnex)

University of Florida

Tesla = 10^4 Gauss

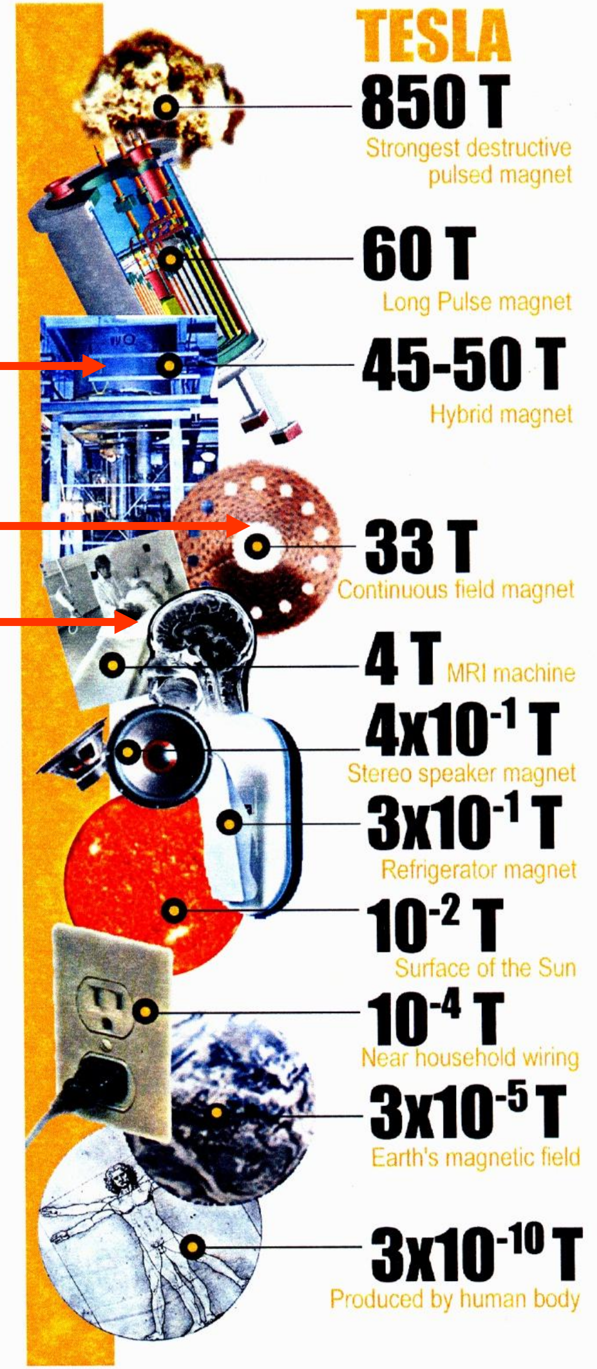
Neutron Star – 10^8 T

White Dwarf – 10^4

Nucleus – 300

Sunspot – 10^{-2}

Intergalactic space – 10^{-12}



"Megagauss"

8.5×10^6 Gauss

600,000

450,000

330,000

40,000

4000

3000

100

1

0.3

3×10^{-6}

"Microgauss"

We are Here

Universal Magnetism

Comes from:

Electrons (moving or spinning)

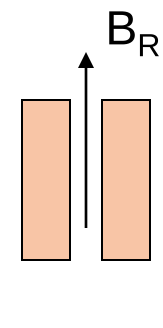
Nuclei

Maxwell's equations

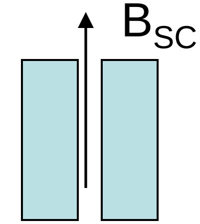
- FOUR TYPES OF MAGNETS USED HERE:

- PERMANENT – to hold notes on our magnetic white boards! 100 gauss

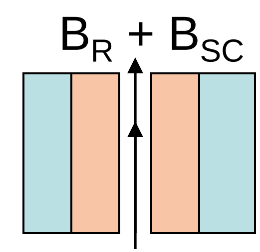
- RESISTIVE ELECTROMAGNETS – to do experiments – 35 T (or 3.5 x 10^5 gauss)



- SUPERCONDUCTING ELECTROMAGNETS – for experiments, medicine – 20 T

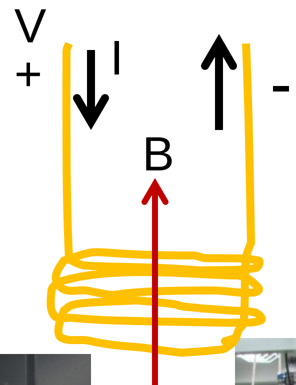


- HYBRID MAGNETS! COMBINATION OF RESISTIVE AND SUPERCONDUCTING MAGNETS – 45 T (or 0.45 megagauss!)

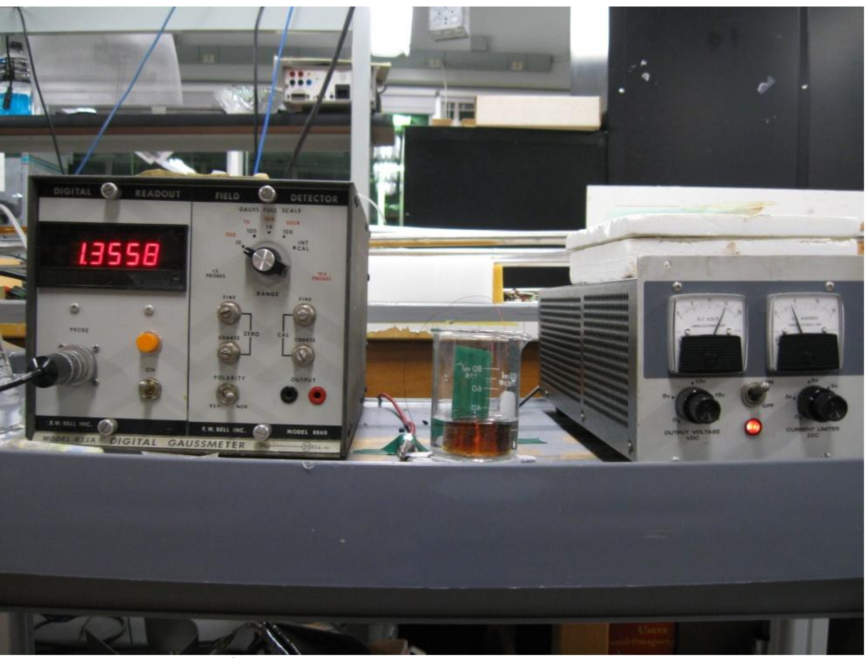


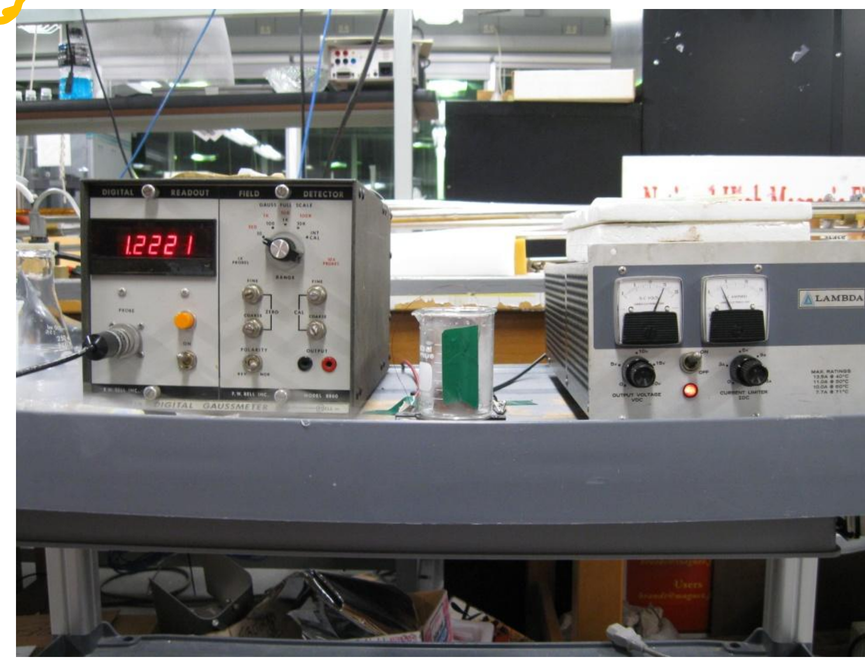
Electromagnets 1.0
(a coil of wire with current)

Copper: has resistance, gets warm when we put current through it.
Need water cooling!



Superconductors: NO resistance as long as we keep the wire cold!
Need liquid helium!





15 V, 0.75 A Warm
R = V/I = 20 Ohms
P= I*V = 11.25 Watts
13.5 Gauss

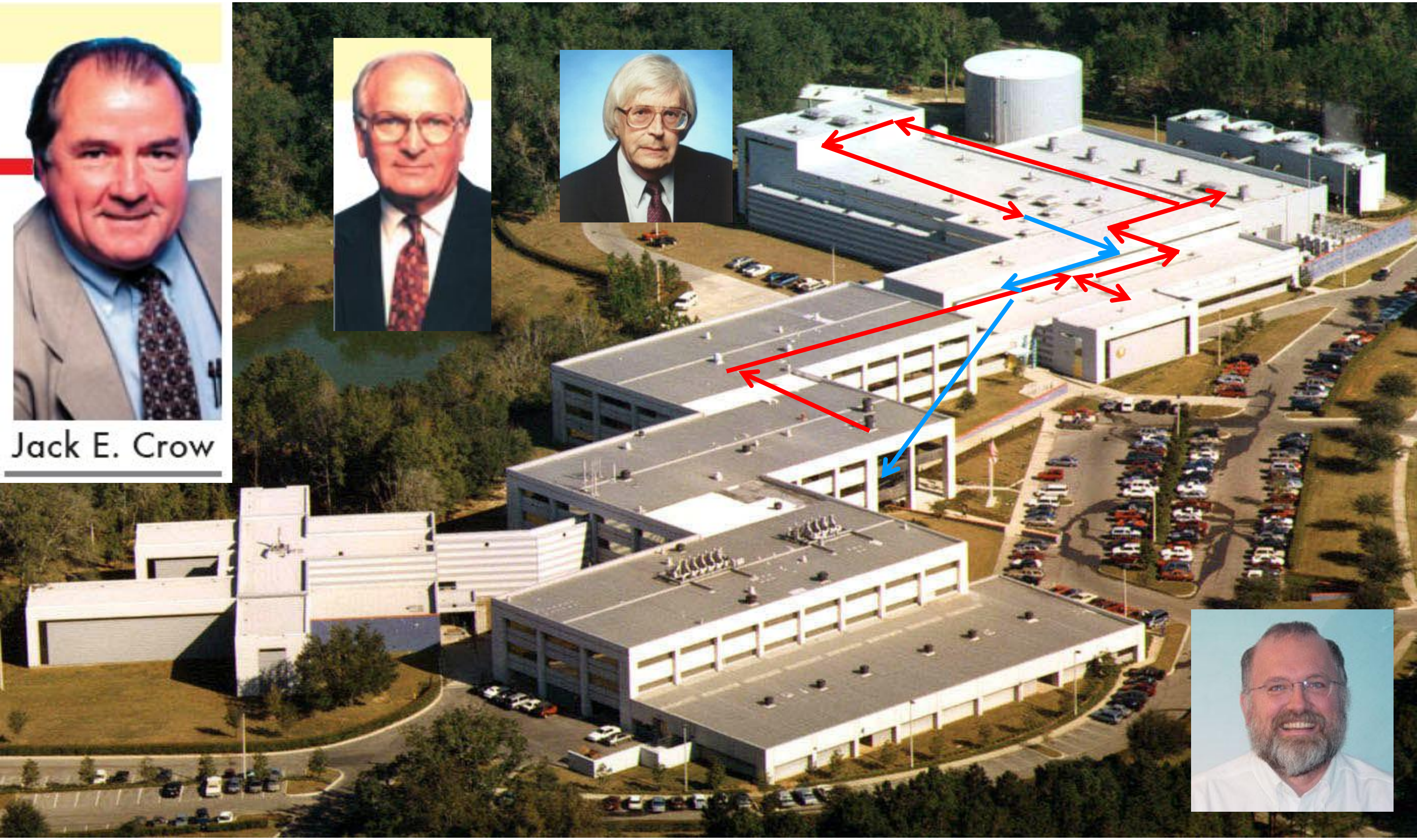
Same magnetic field, same current, but almost 10 times less power!

2.5 V, 0.75 A Cold
R = V/I = 3.3 Ohms
P= I*V = 1.9 Watts
14.4 Gauss

A word about cryogenics:

- Room Temp: 295 K (22 Celsius; 72 Fahrenheit)
- Chilled water in the Resistive Magnets: 283 K
- Water Freezing: 273 K (32 Fahrenheit)
- Liquid Nitrogen: 77 K (-321 Fahrenheit)
- Liquid Helium-4 : 4.2 K -> 1.0 K (pumped) (-457.87 ^{o}F)
- Liquid Helium-3 : 3 K -> 0.3 K (pumped)
- Mix Helium-3 + Helium-4 and pump: 0.003 K
      - » or 3 milliKelvin!
  - – People have reached micro Kelvin by special tricks.

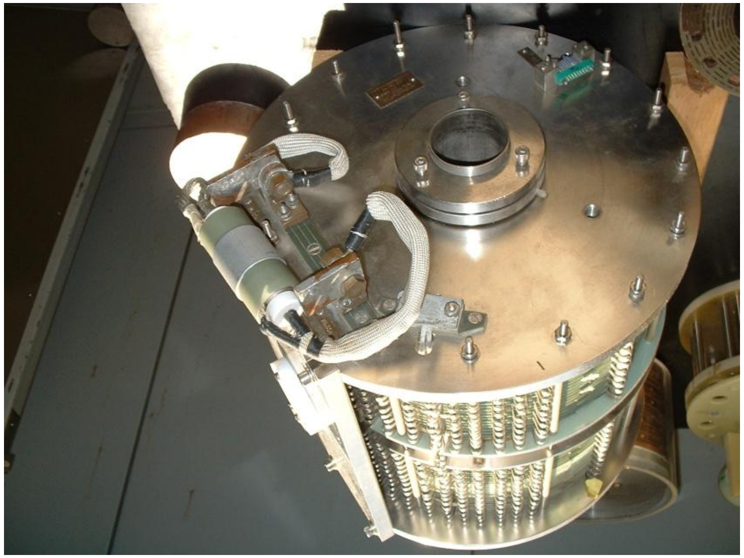
NHMFL- Tallahassee DC, Los Alamos Pulsed, Gainesville - Low T.



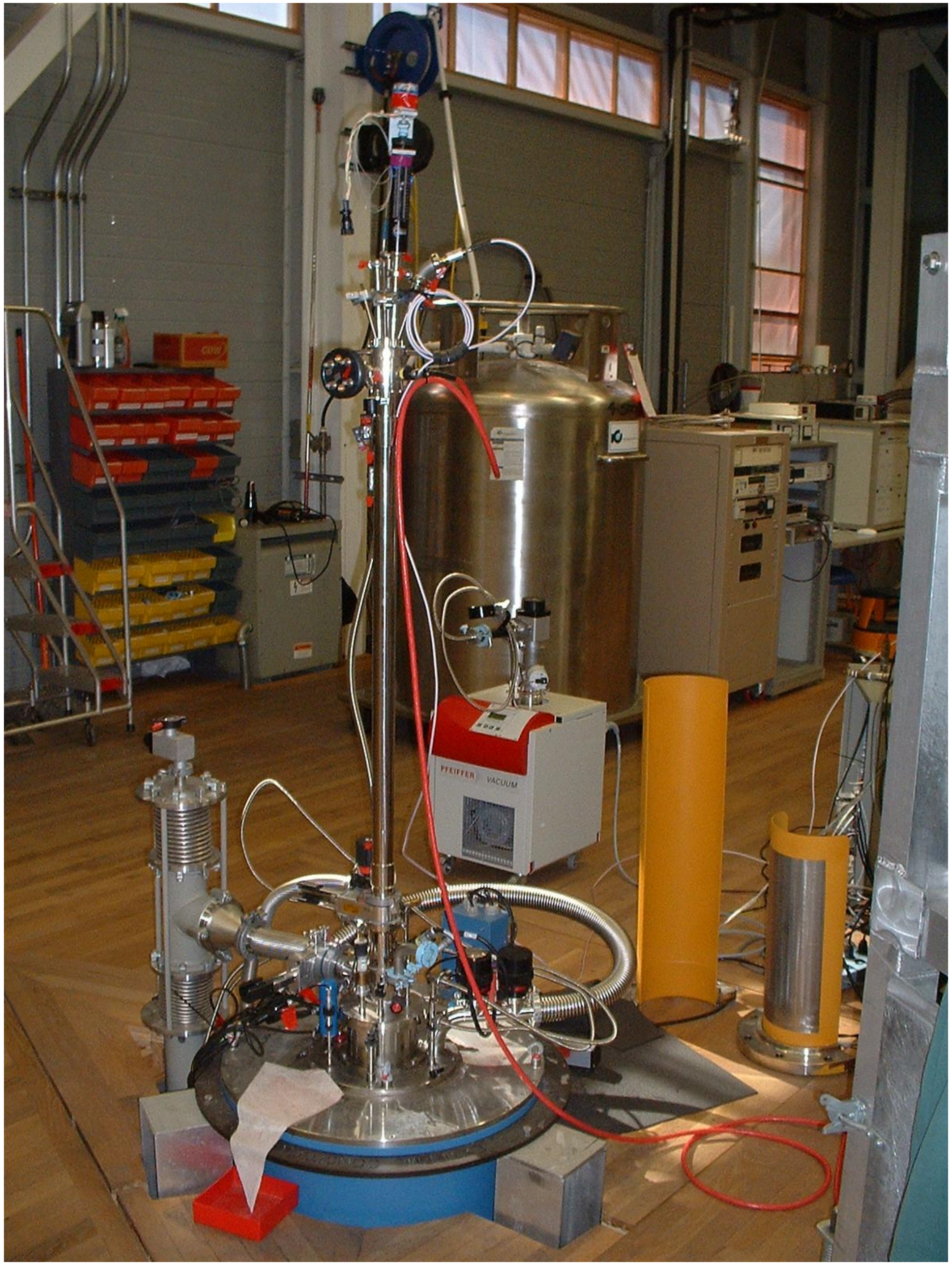
Today’s tour: The logistics!

Here is what you will see on the tour:

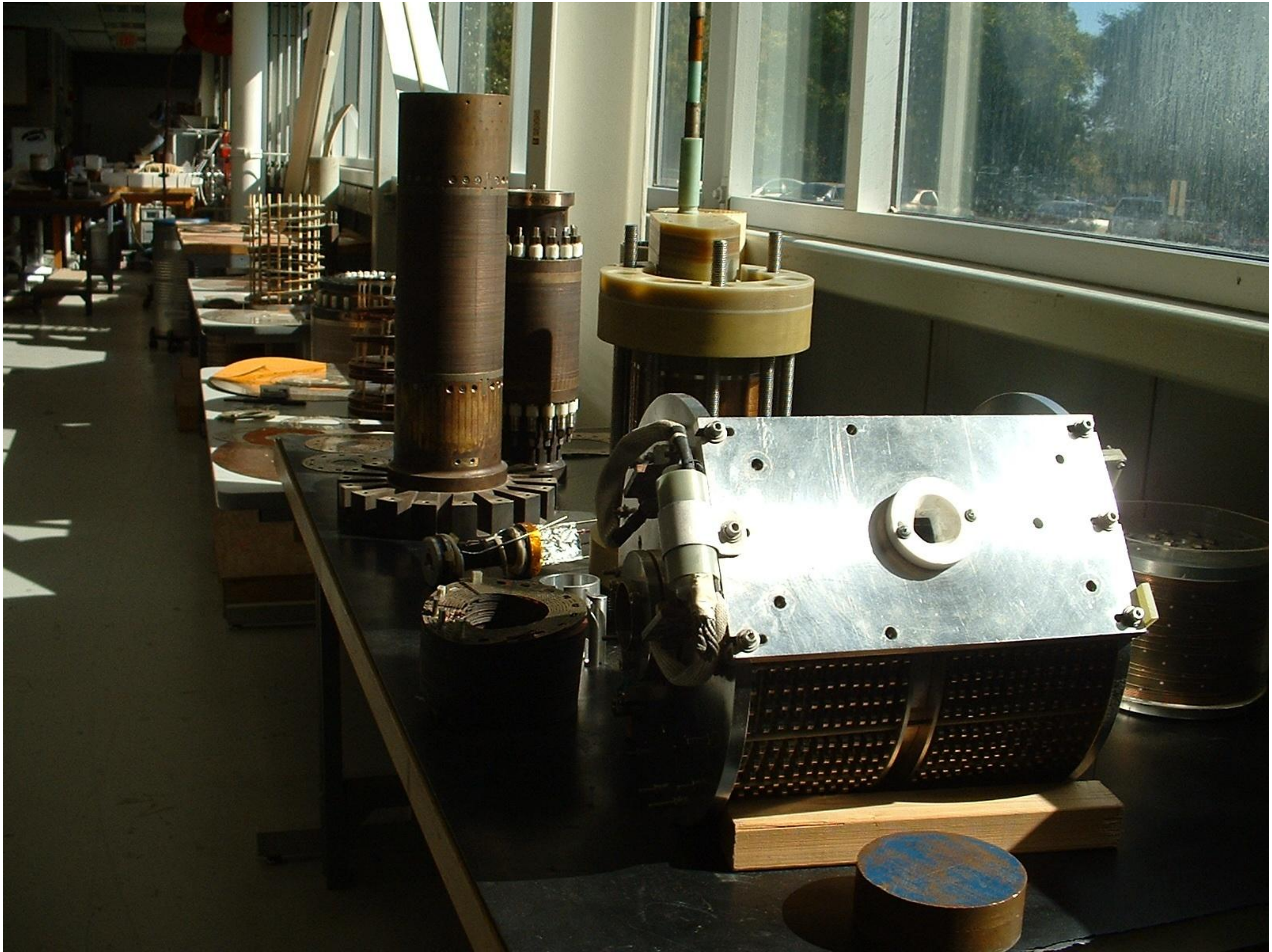
Stop #1: An Experimental Lab with Superconducting Magnets.



Stop #1: An Experimental Lab with Superconducting Magnets.



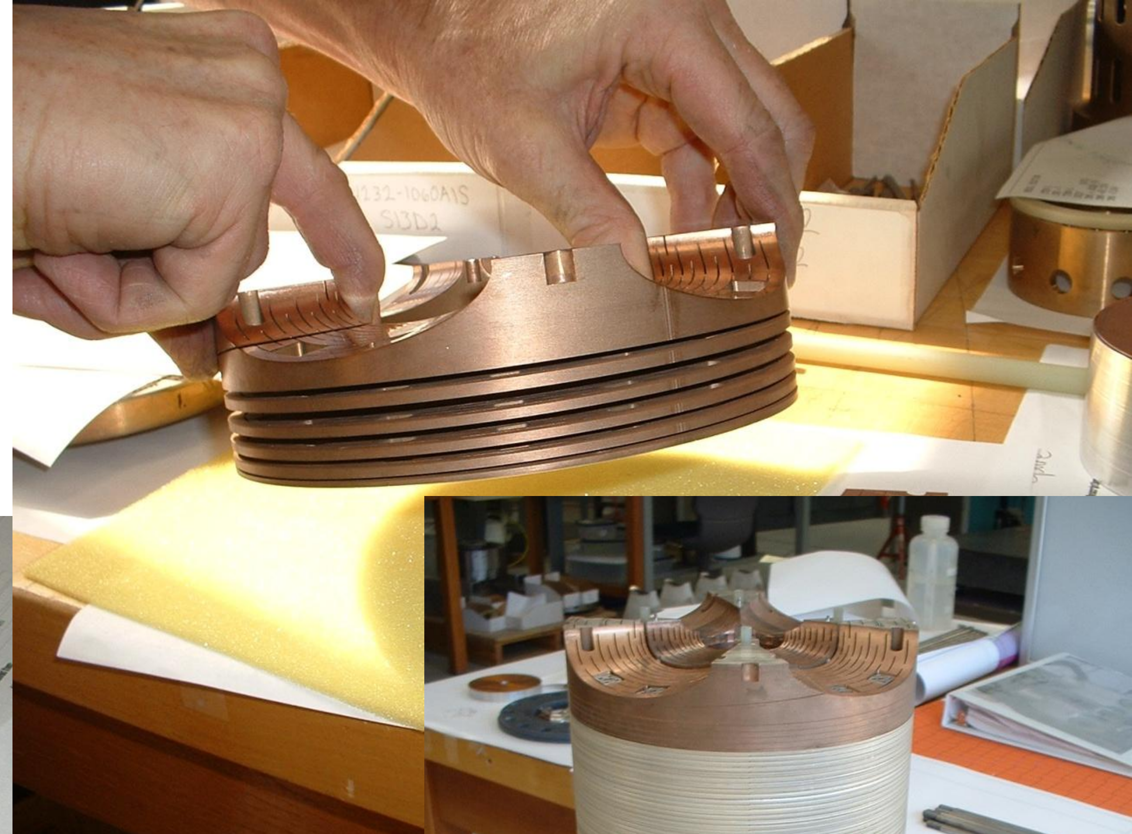
Stop #2: The Magnet Shop – where the big magnets are made

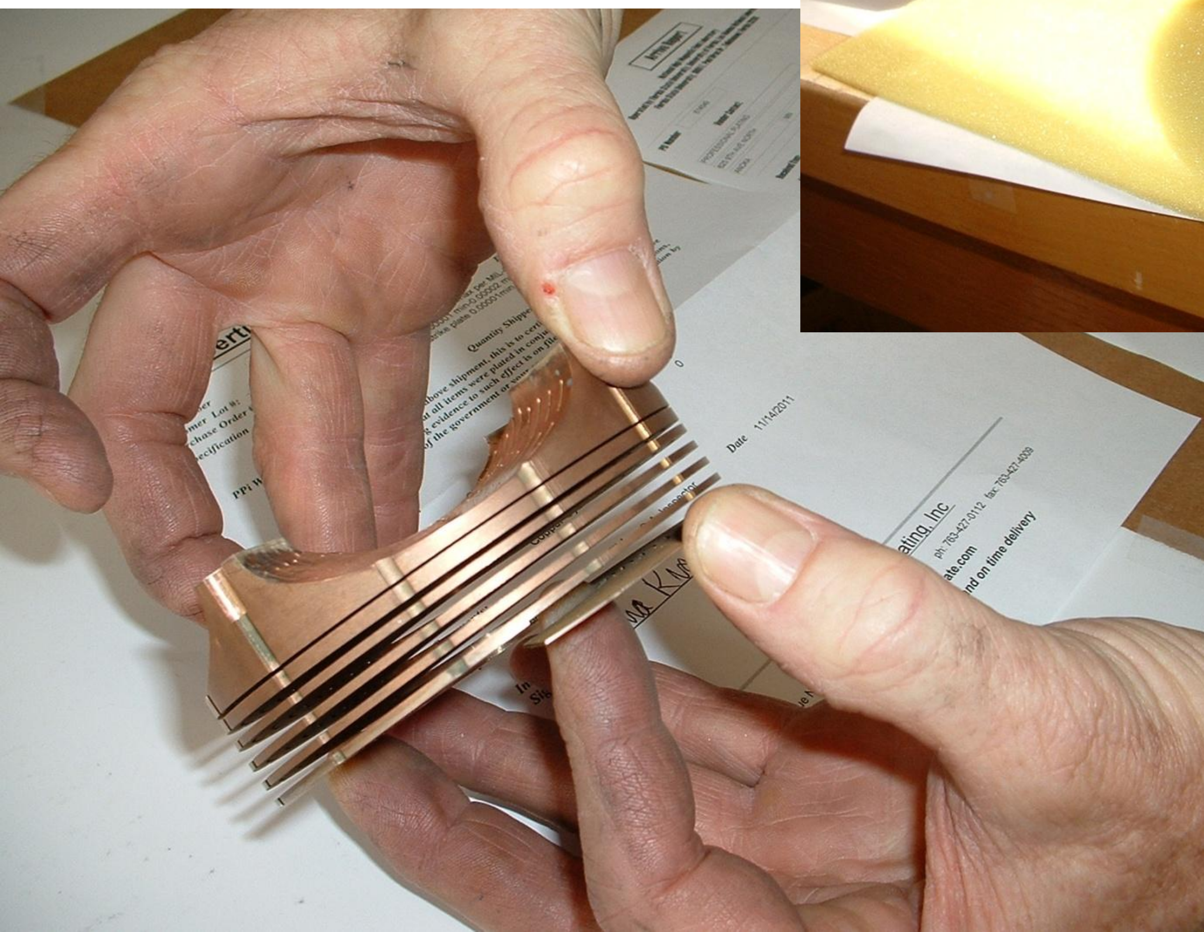


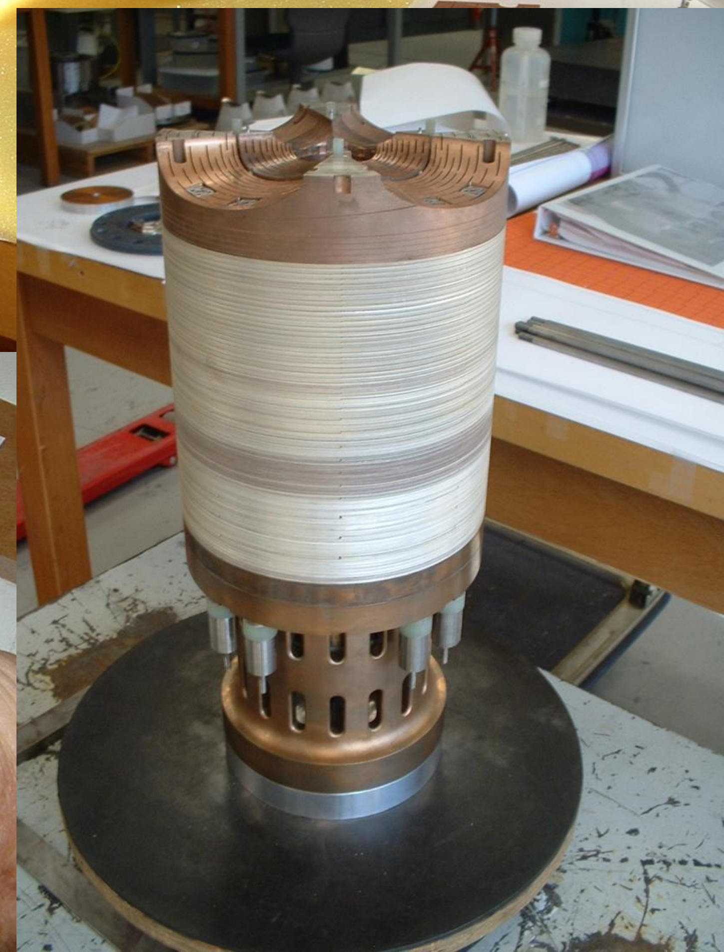
Stop #2: The Magnet Shop

Stop #2: The Magnet Shop

Some coils are really exotic!
This one is called the “Split coil”, machined out of one piece of high strength conductor.





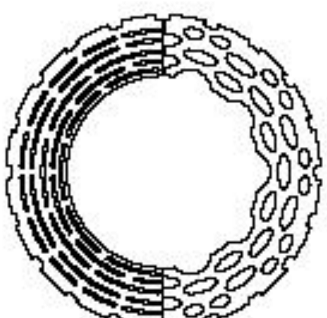


DC Resistive Magnets

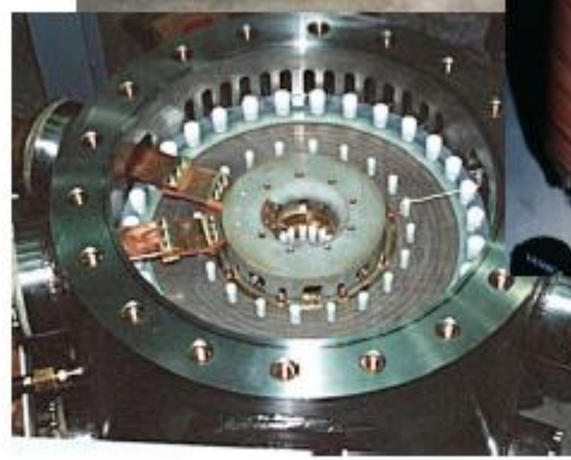
Water cooled DC "Bitter" magnets

- Most DC magnets are 32 mm bore up to 33 T high field systems
- Some with larger bores for special purposes
  - 50 mm bore at 29 T
  - 200 mm bore at 20 T
- A transverse field coil with 32 mm bore and B ≈ 20 T is planned

This technology requires continuous design, development and materials improvement to advance.



Innovative "Florida Bitter" Design



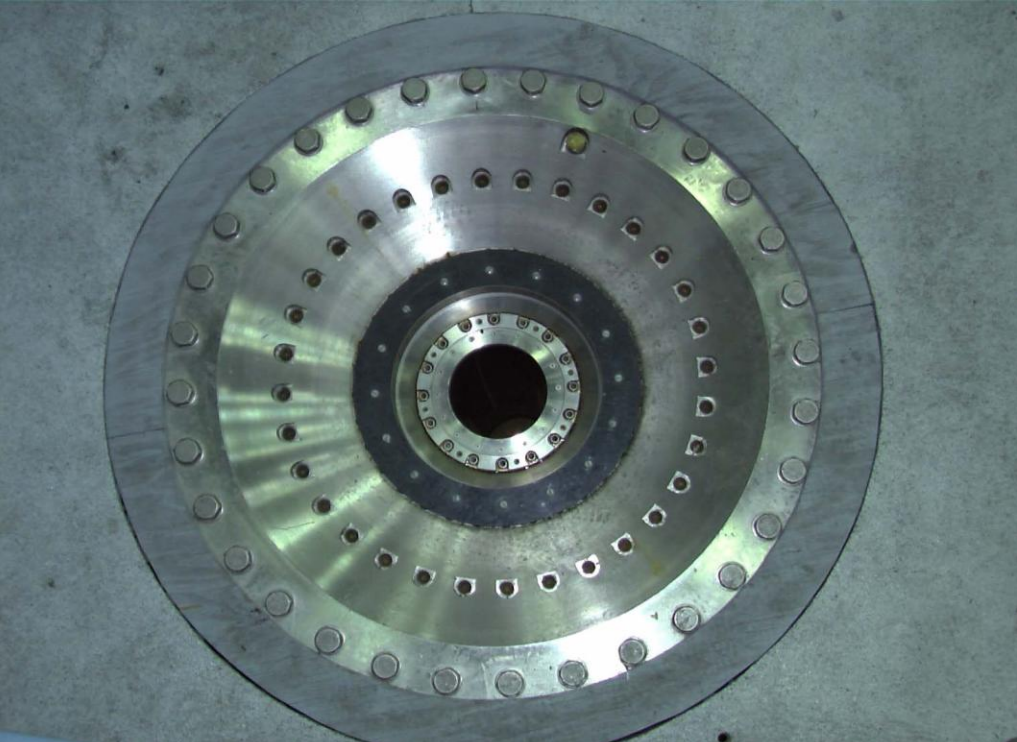
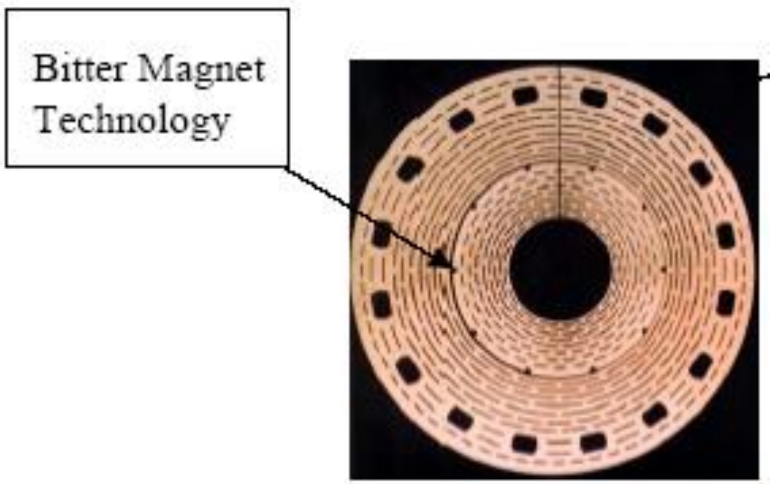


Figure 2. Mid-plane temperature of the new A2 coil.

Figure 3. Mid-plane stress of the new A2 coil.



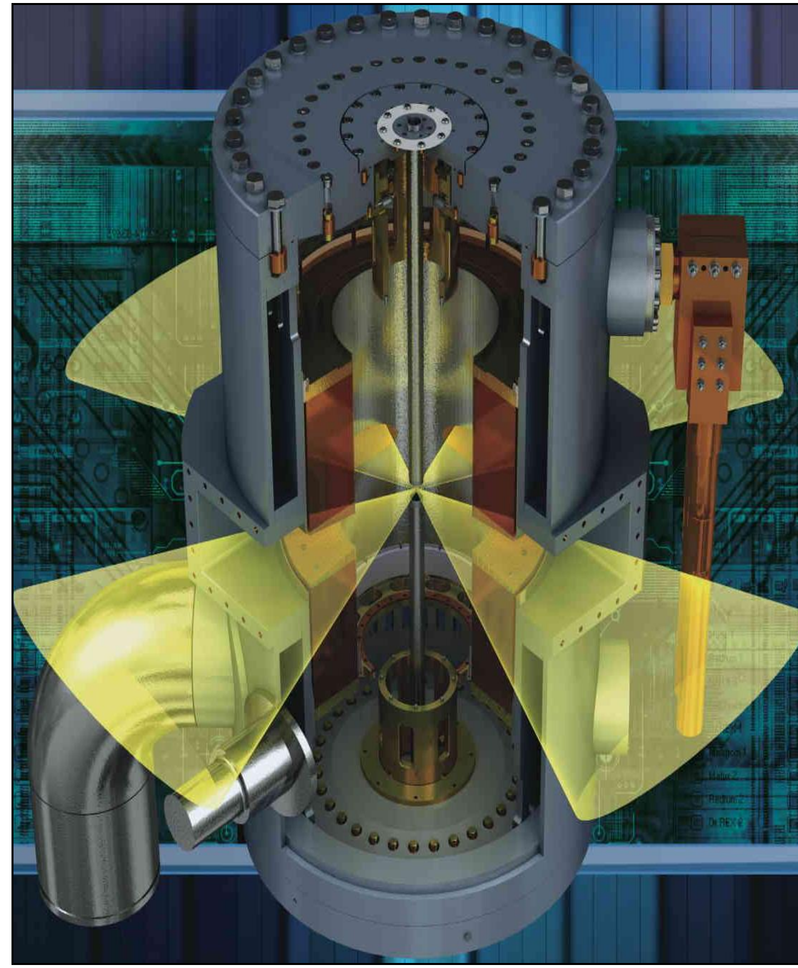
Stop #2 1/2: Where the BIG superconducting magnets are made!
(We may only be able to peek in this room).

Superconducting wire is inside copper wire, and then in bundles inside stainless steel conduit.

The conduit is really stiff, so it is a major effort to wind the magnet.
The magnet then has to be cooked in a huge furnace to complete the Nb_3Sn metallurgy.

Stop #3 The control room – this is where the “water and electricity” for the magnets are managed. It’s a HUGE power station!

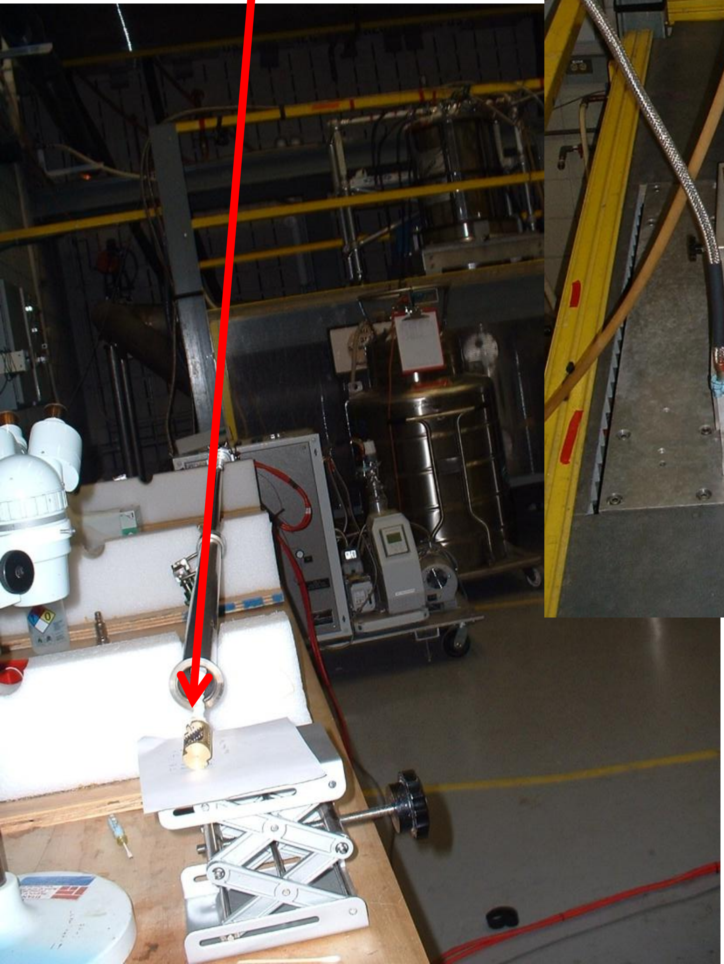
Stop #4 The “spit coil” magnet. Researchers can access the very center of the magnet from the sides! Great for optical experiments.

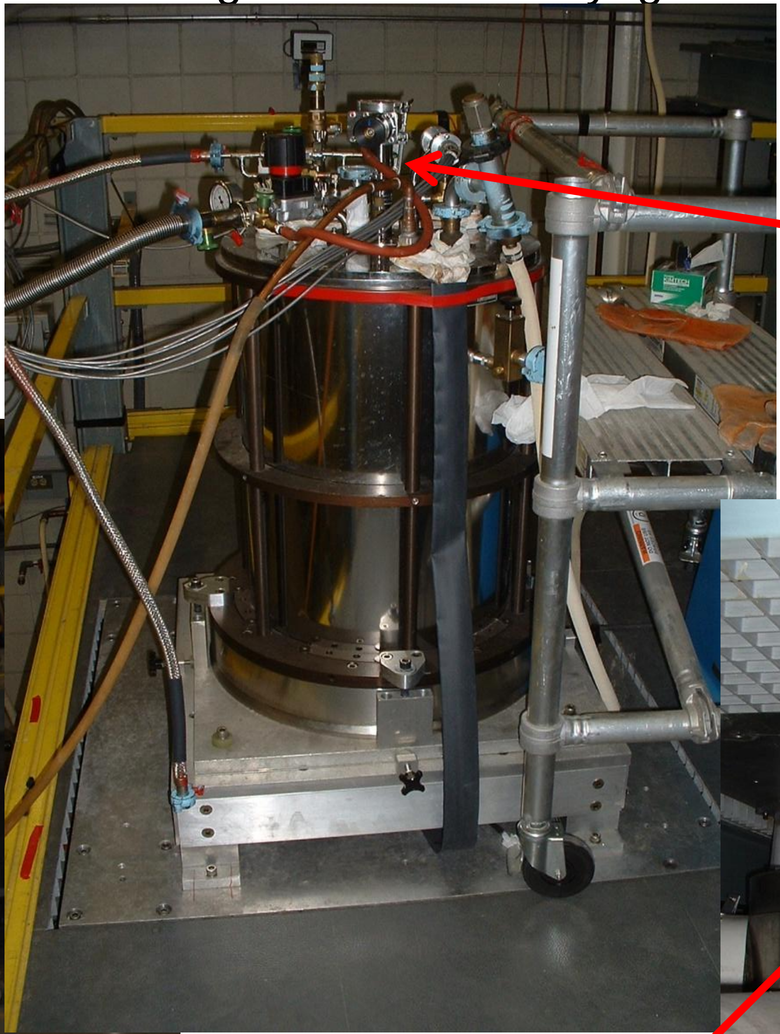


When you visit, make note of the water cooling pipes and the electrical connections!

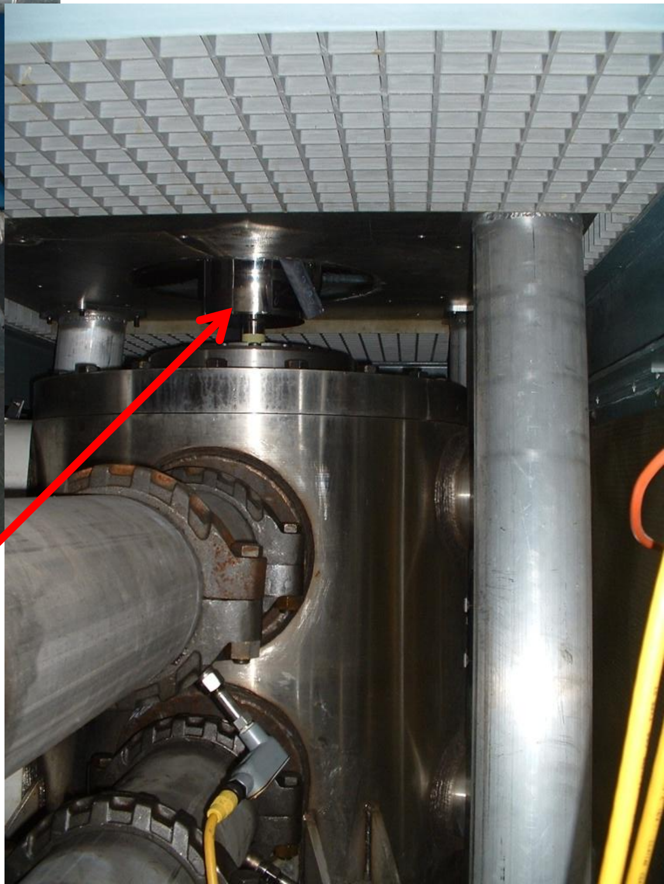
Stop #5 A typical experimental magnet cell with a cryogenic container for experiments.

Your material goes on the probe





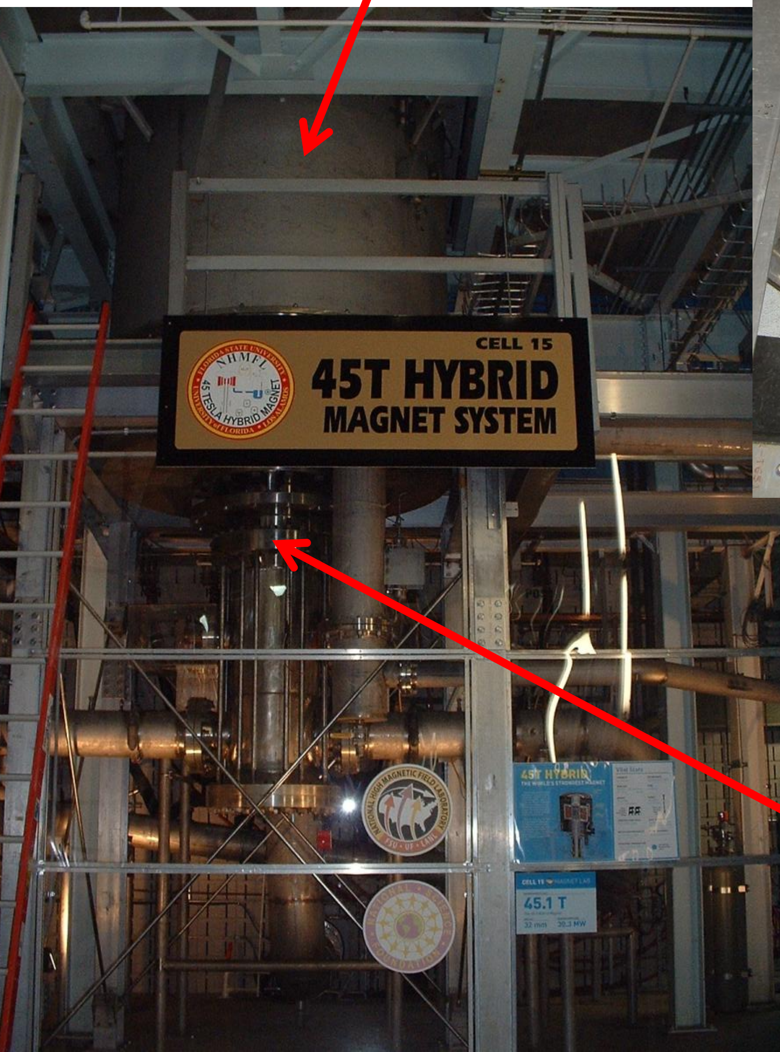
The probe goes in the cryostat



The cryostat goes in the magnet.

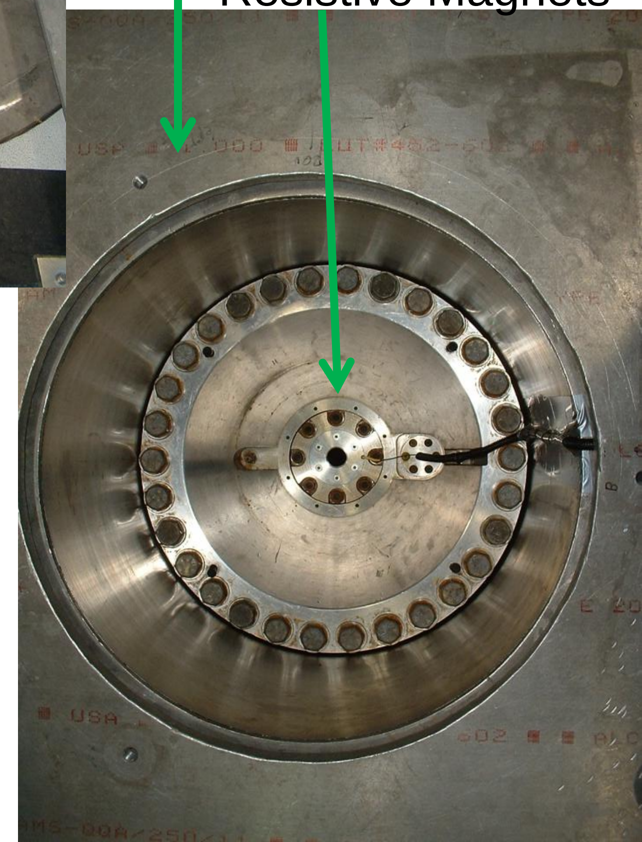
Stop #6 The Worlds Biggest Magnet! This magnet uses both a resistive magnet and a superconducting magnet!

Helium tank with superconducting magnet.

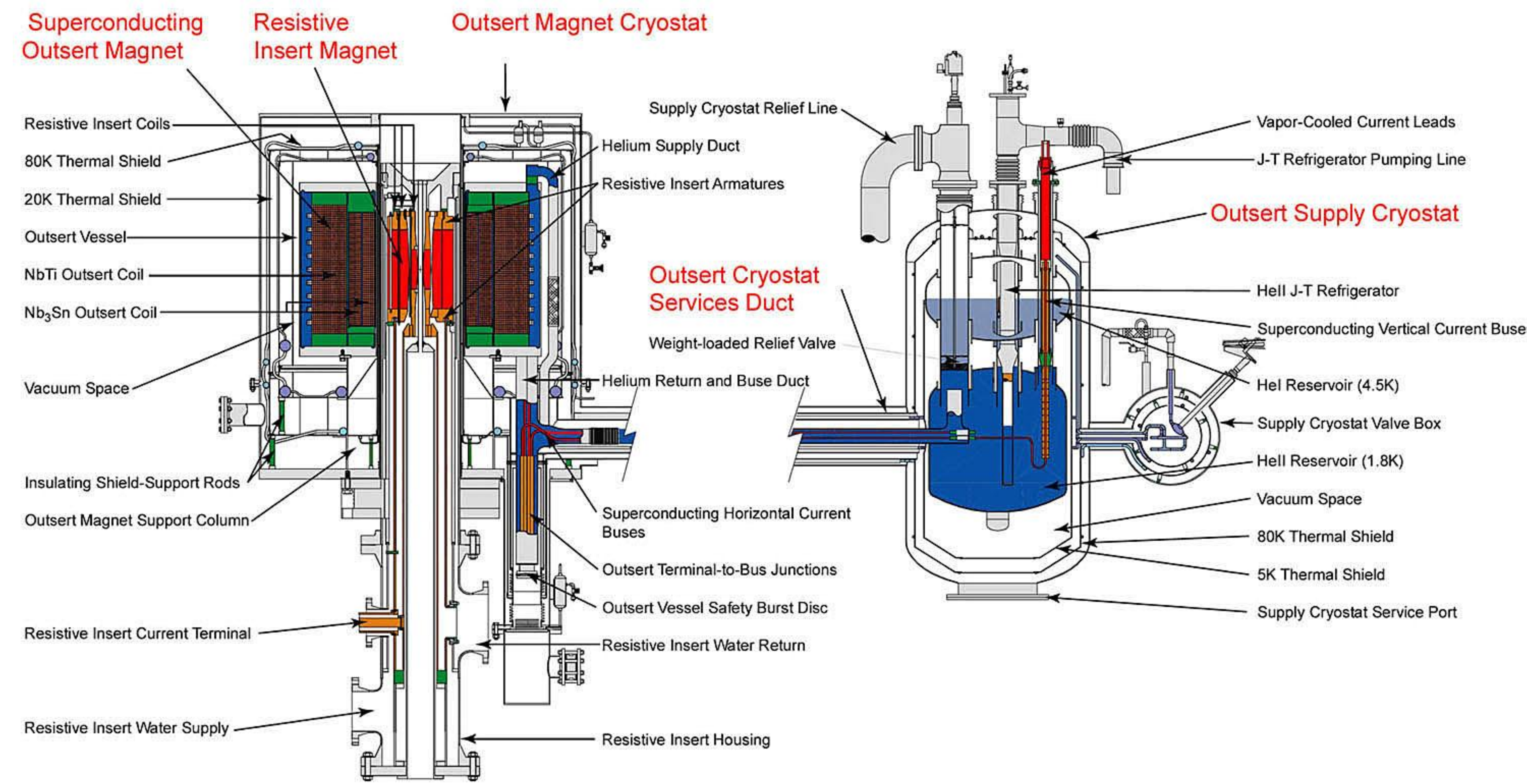


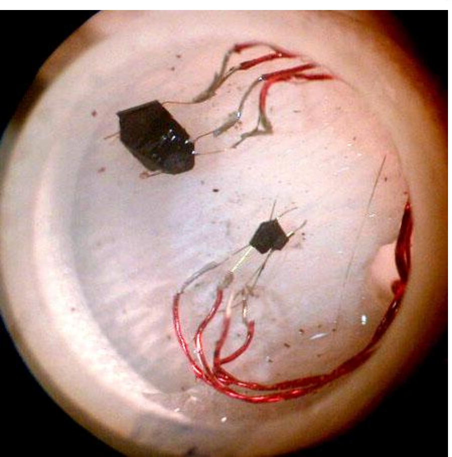
Top of the superconducting magnet.

Top of Superconducting and Resistive Magnets



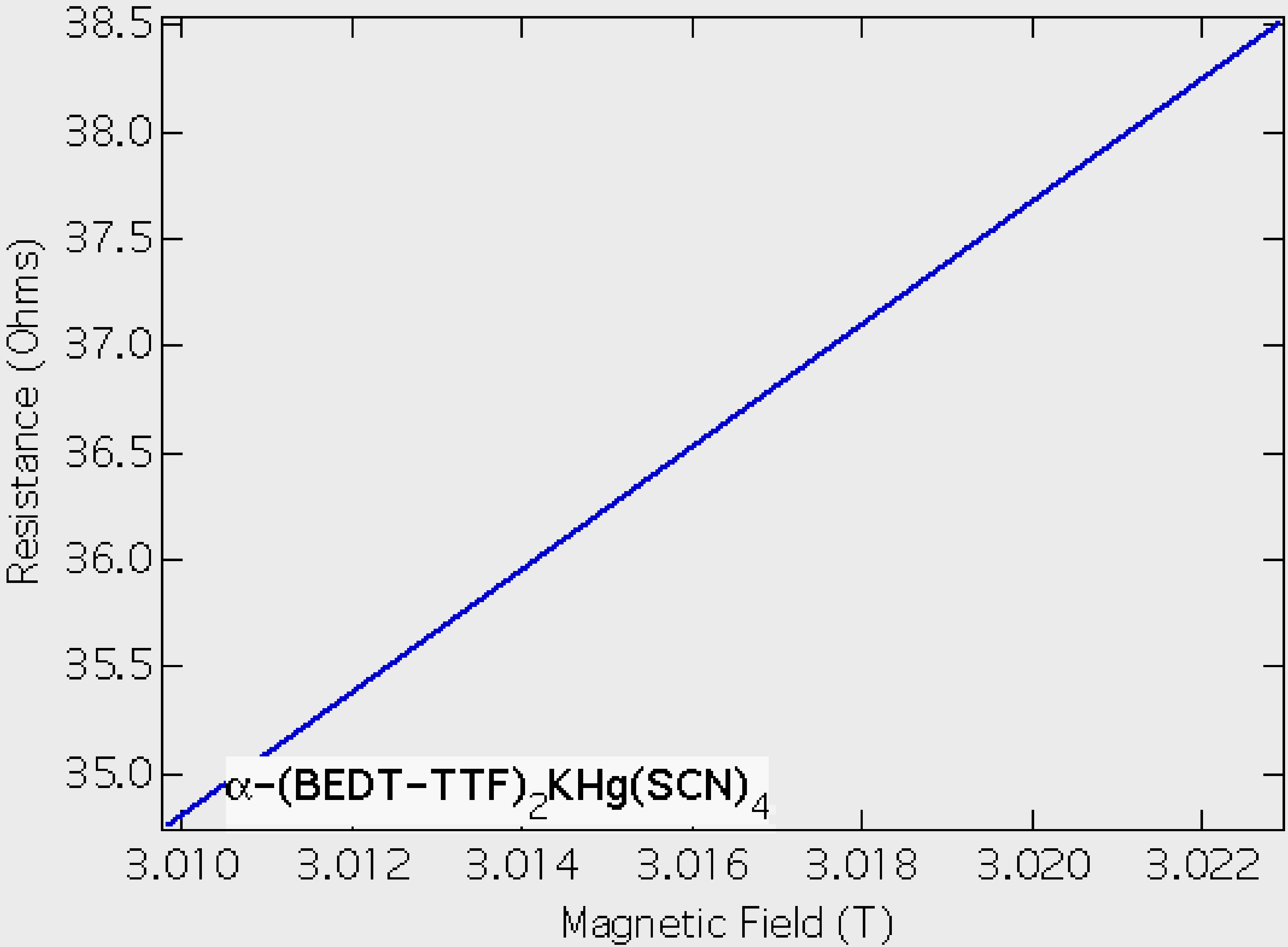
Bottom of the resistive magnet.


Superconducting Outsert Magnet
Resistive Insert Magnet
Outsert Magnet Cryostat
Resistive Insert Coils
80K Thermal Shield
20K Thermal Shield
Outsert Vessel
NbTi Outsert Coil
Nb_3Sn Outsert Coil
Vacuum Space
Insulating Shield-Support Rods
Outsert Magnet Support Column
Resistive Insert Current Terminal
Resistive Insert Water Supply
Helium Supply Duct
Resistive Insert Armatures
Helium Return and Buse Duct
Superconducting Horizontal Current Buses
Outsert Terminal-to-Bus Junctions
Outsert Vessel Safety Burst Disc
Resistive Insert Water Return
Resistive Insert Housing
Supply Cryostat Relief Line
Outsert Cryostat Services Duct
Weight-loaded Relief Valve
Vapor-Cooled Current Leads
J-T Refrigerator Pumping Line
Outsert Supply Cryostat
HeII J-T Refrigerator
Superconducting Vertical Current Buse
HeI Reservoir (4.5K)
Supply Cryostat Valve Box
HeII Reservoir (1.8K)
Vacuum Space
80K Thermal Shield
5K Thermal Shield
Supply Cryostat Service Port




HELIUM
REFRIGERATED
LIQUID
UN-1963

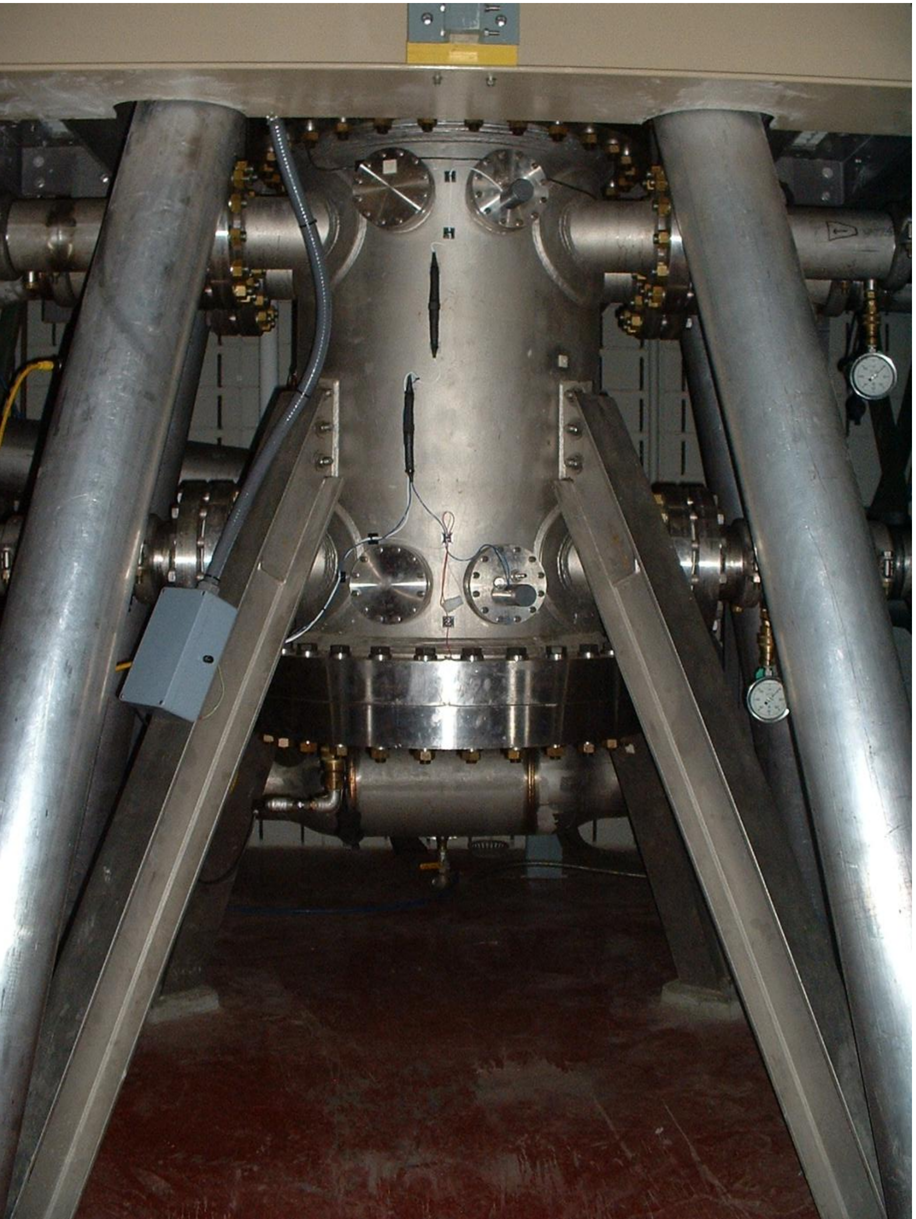

Outsert
Power/Protection
System



What have we learned? New states of matter exists in high magnetic fields. *

Stop #7 SERIOUS CRYOGENICS!   We liquefy our own helium! It is used to cool superconducting magnets and experiments too.

Stop #8 See a magnet up and personal! (Cell 2).



Extremes at Tallahassee Lab:

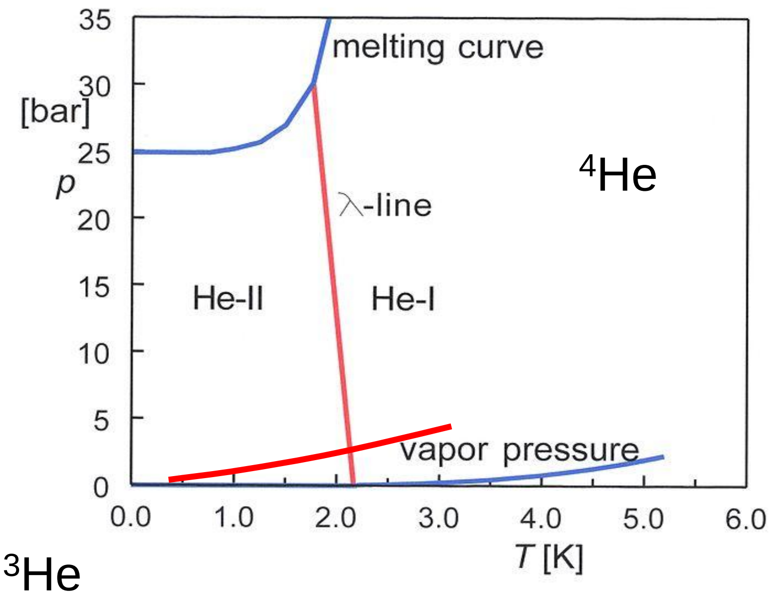
Magnetic field: 45 T

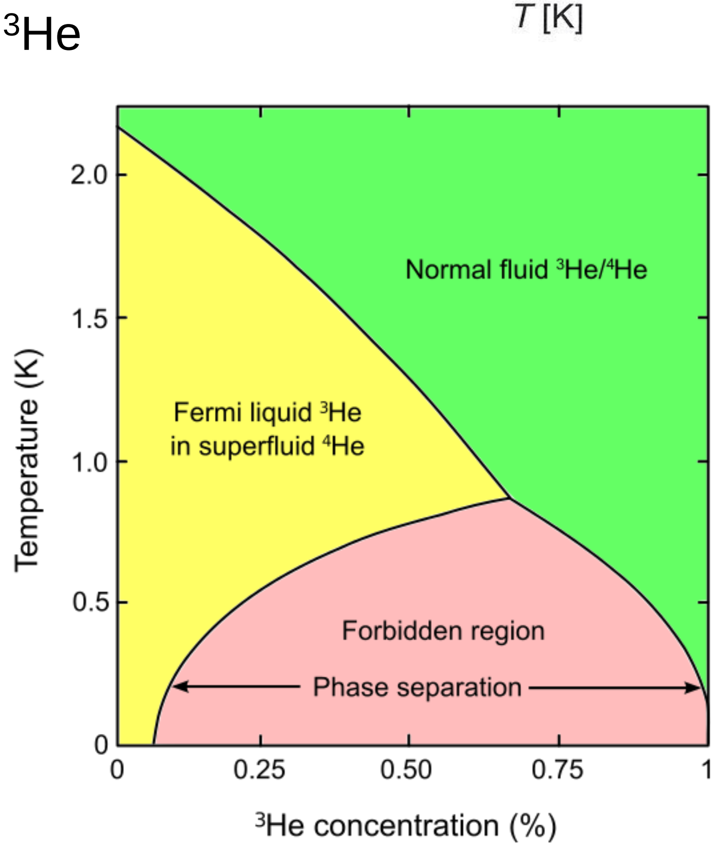
Temperature: 5 mK

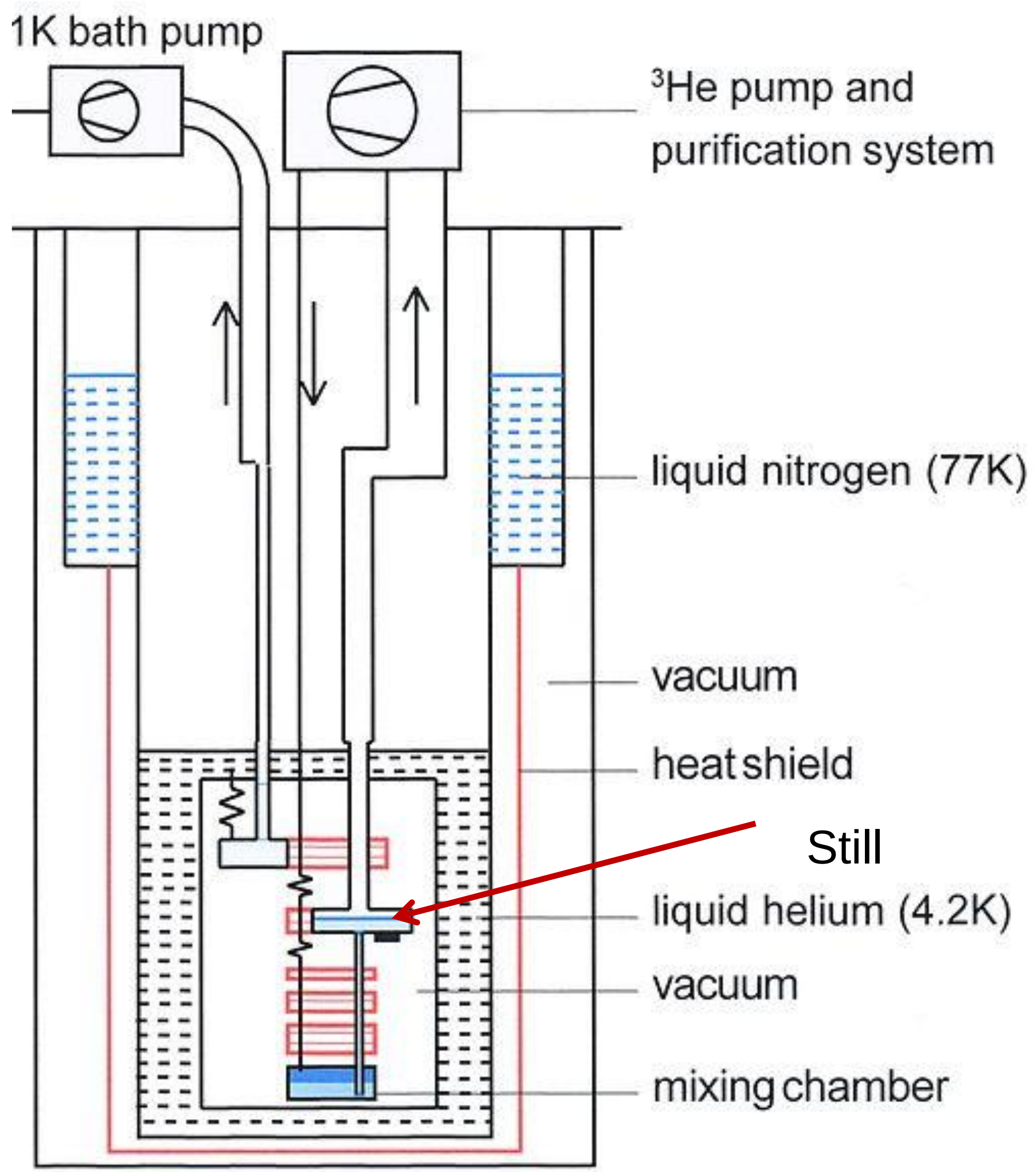
Pressure: 14 GPa (140 Kbar)

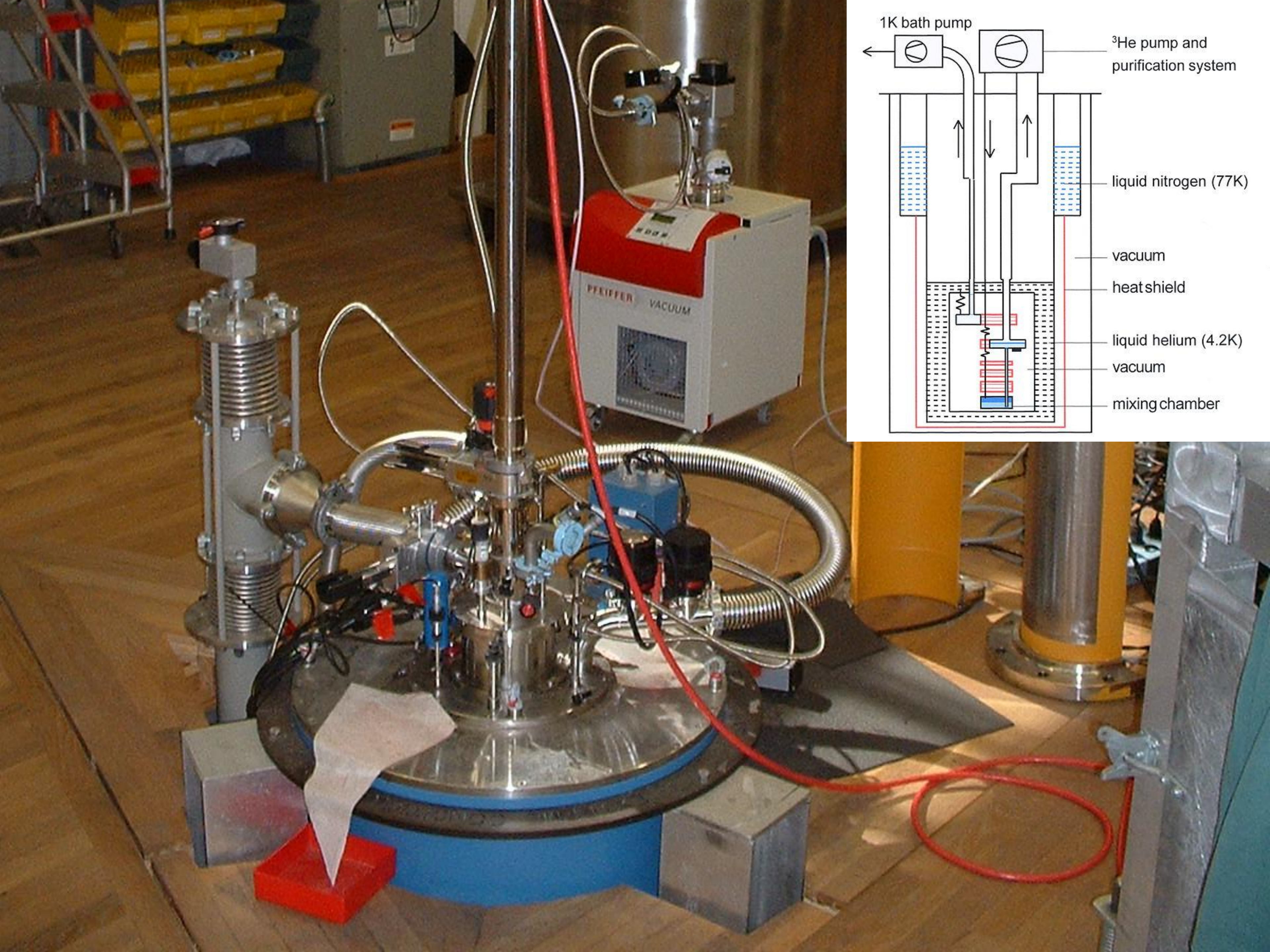
Let’s take a closer look at how you get low T and high P

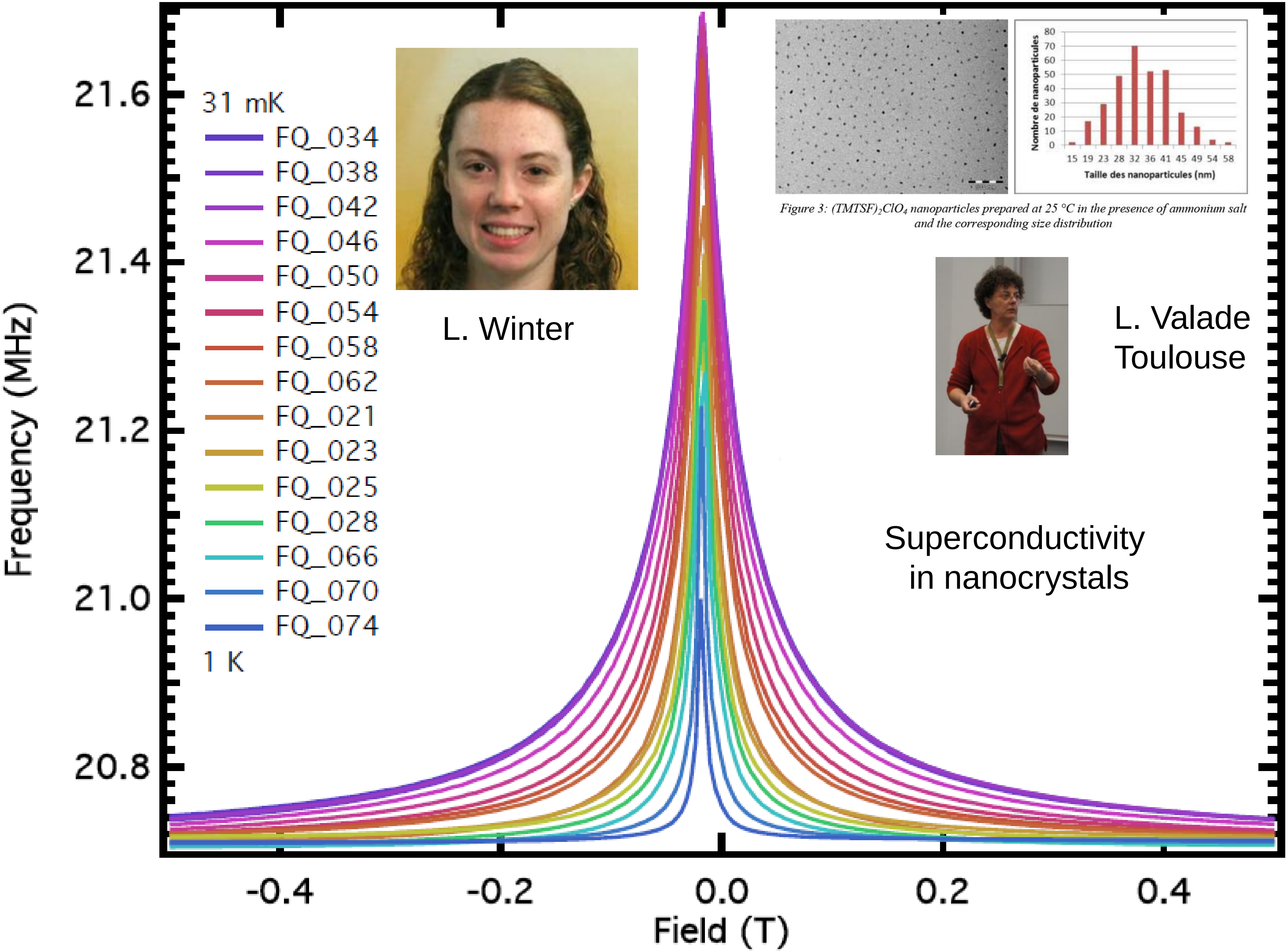
Quest for absolute zero
Games with ^3He and ^4He



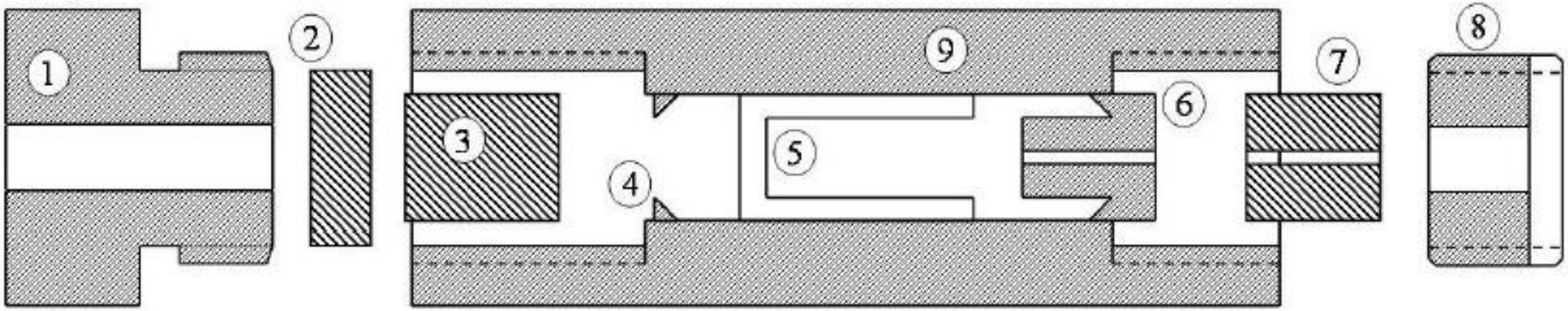




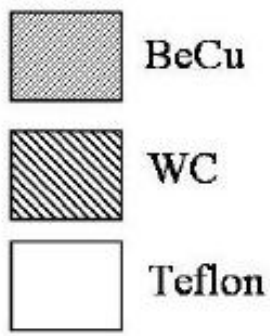

1K bath pump
^{3}He pump and
purification system
liquid nitrogen (77K)
vacuum
heat shield
liquid helium (4.2K)
vacuum
mixing chamber
PFEIFFER VACUUM

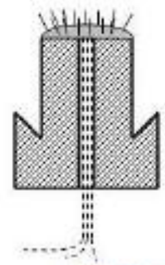

Frequency (MHz)
21.6
21.4
21.2
21.0
20.8
Field (T)
-0.4
-0.2
0.0
0.2
0.4
31 mK
FQ_034
FQ_038
FQ_042
FQ_046
FQ_050
FQ_054
FQ_058
FQ_062
FQ_021
FQ_023
FQ_025
FQ_028
FQ_066
FQ_070
FQ_074
1 K
L. Winter
Nombre de nanoparticules
Taille des nanoparticules (nm)
15 19 23 28 32 36 41 45 49 54 58
Figure 3: (TMTSF)$_2$ClO$_4$ nanoparticles prepared at 25 °C in the presence of ammonium salt and the corresponding size distribution
L. Valade
Toulouse
Superconductivity
in nanocrystals

A few words about High Pressure (and magnetism)



1 – Top clamp
2 – WC disk
3 – WC piston
4 – Centering ring
5 – Teflon cup
6 – Sample stage
7 – WC feedthrough
8 – Bottom clamp
9 – Cell body





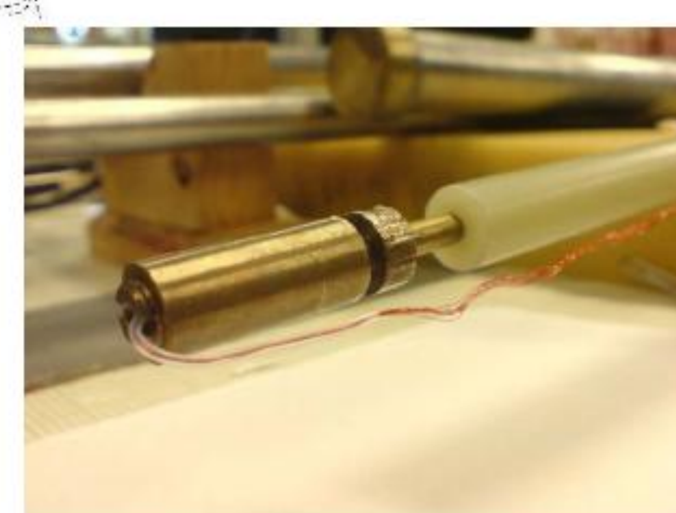
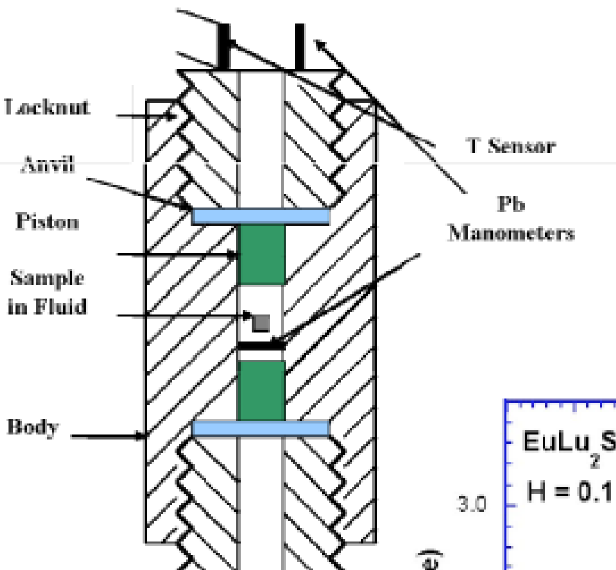
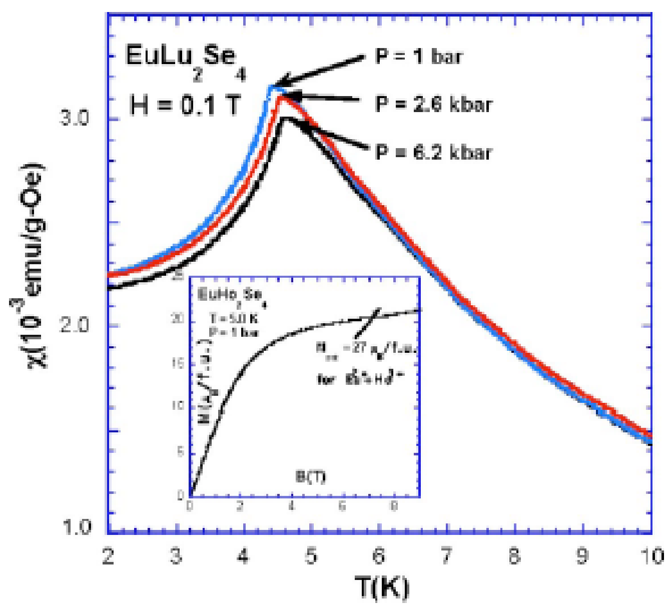


Figure 1a – Dr. Graf, THESIS: *Magnetic Field-Dependent Structures of Low-Dimensional Organic Material. pp35*

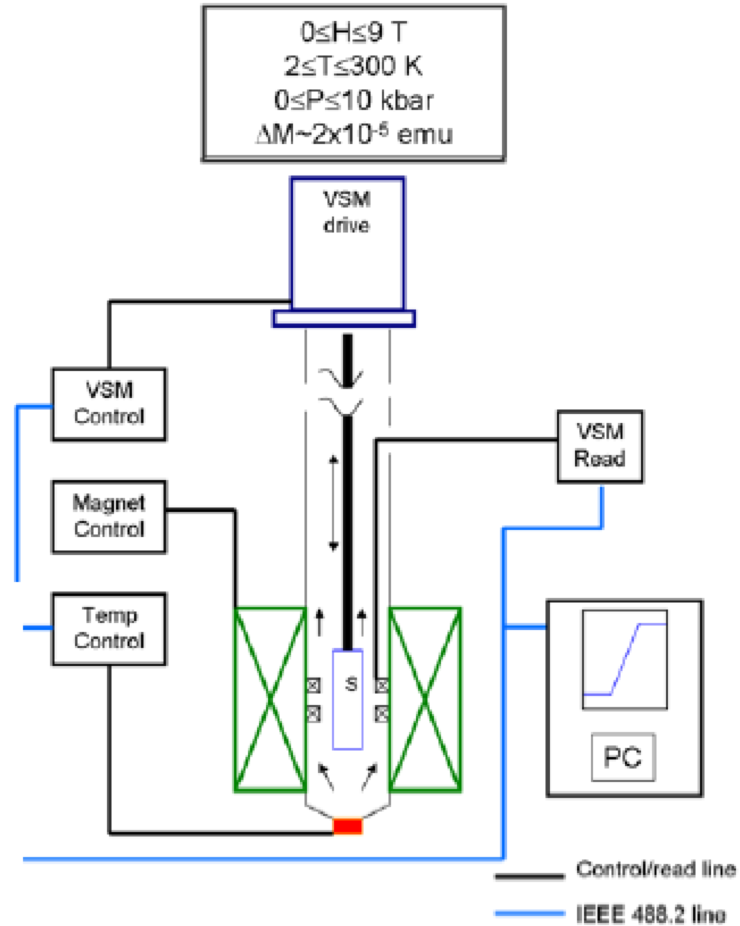
High Pressure Self-Locking Pressure Clamp for VSM Measurements

Material: High Purity (Co-free) BeCu
Sample size: ~ 1 mm^3
Sample mass: < 10^{-2} gm
Clamp mass: ~ 13 gm

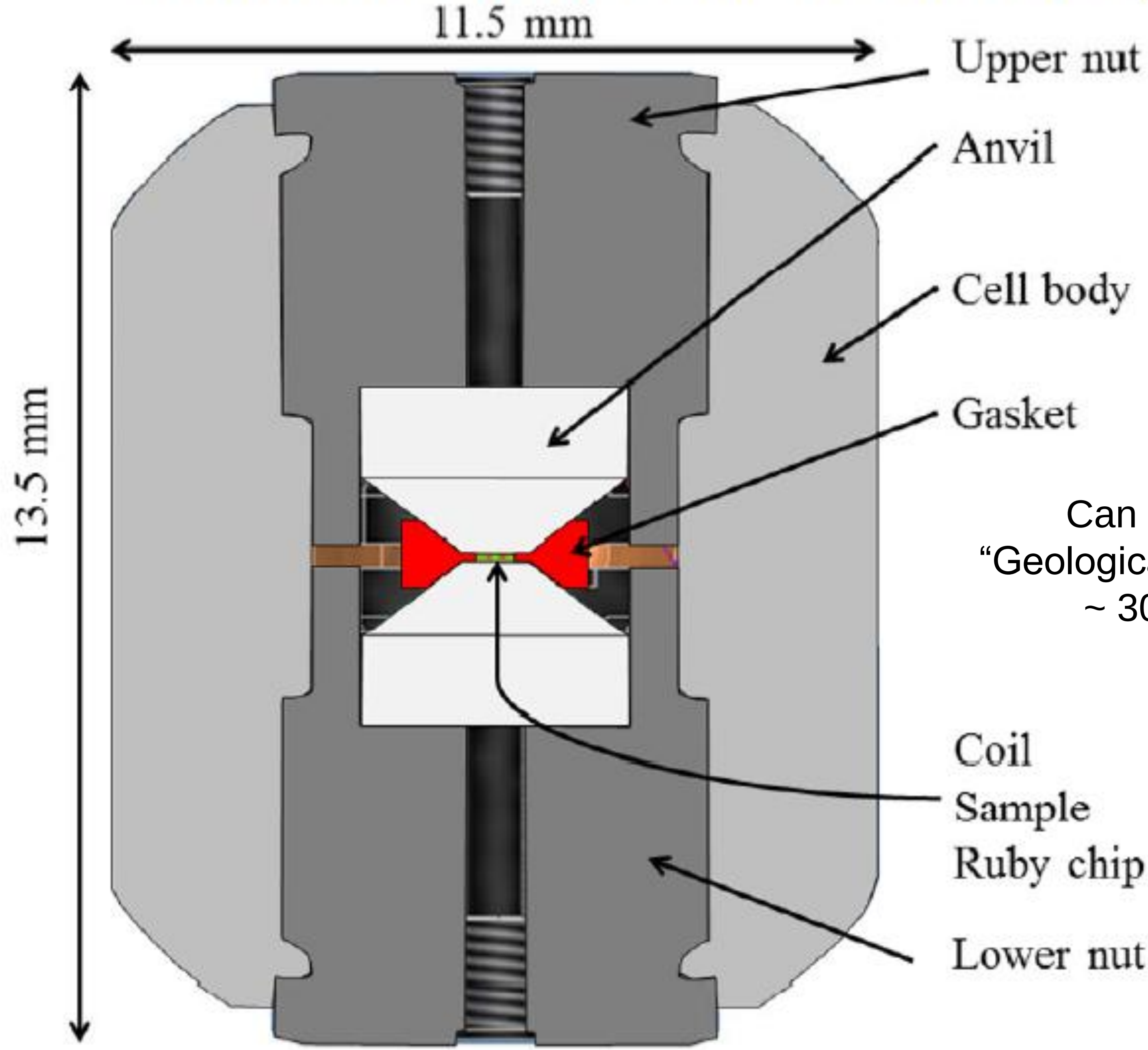




Magnetization Measurements at High Pressure



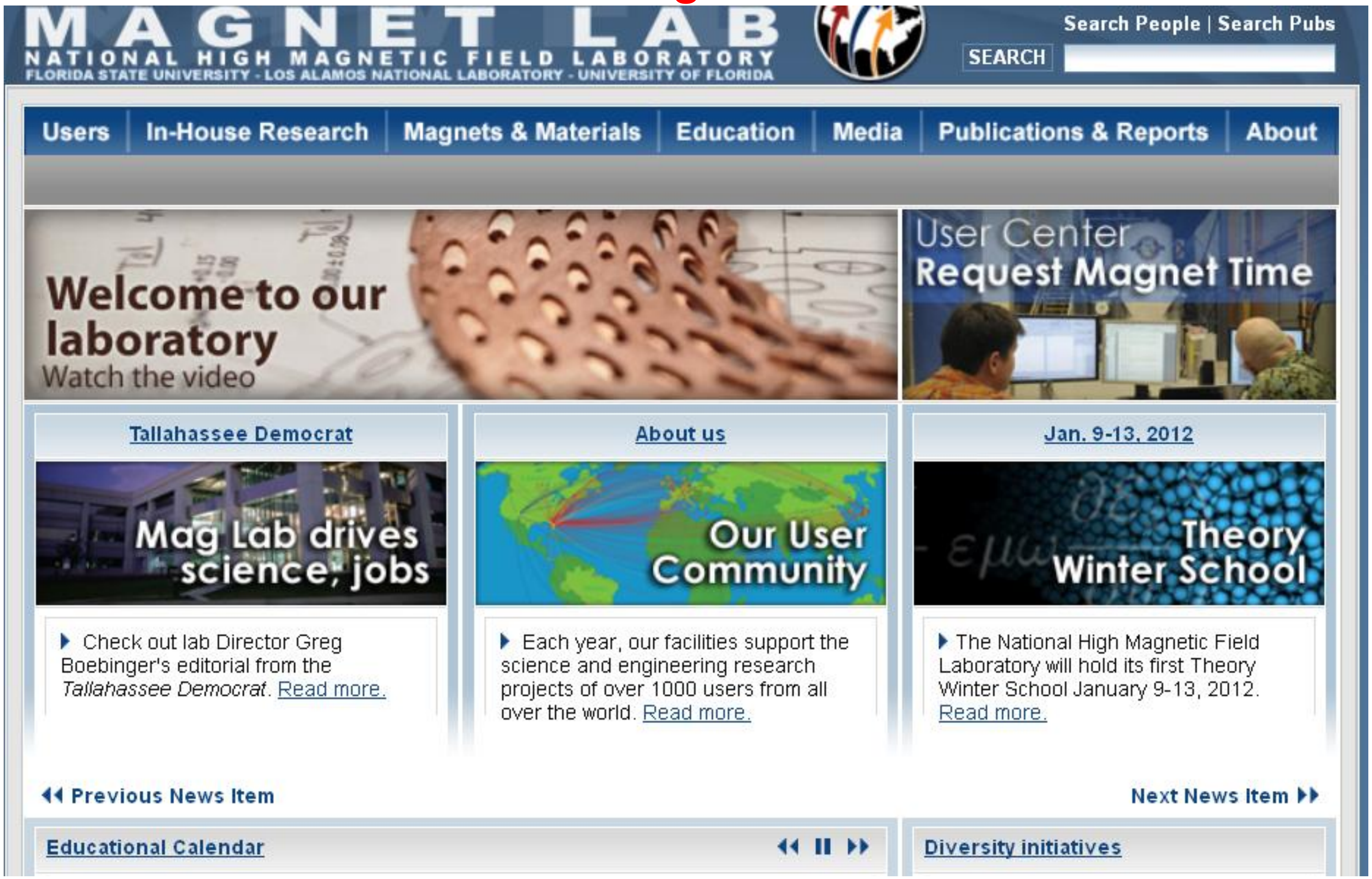
"Diamond Anvil Cell" Tozer Group



Can go up to
"Geological" Pressures
~ 300 GPa

For more information, please visit our website!

www.magnet.fsu.edu



Time for the tour!