Introduction to the Quantum Design systems in the Birck Spintronics Lab

June 2016

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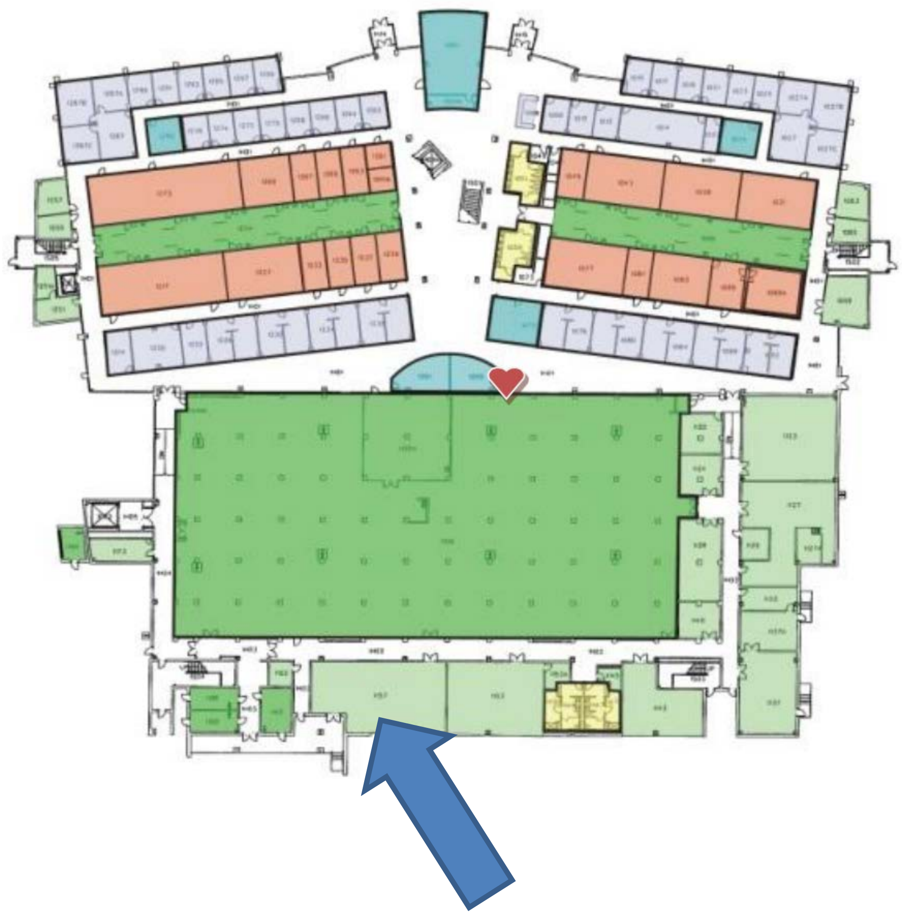
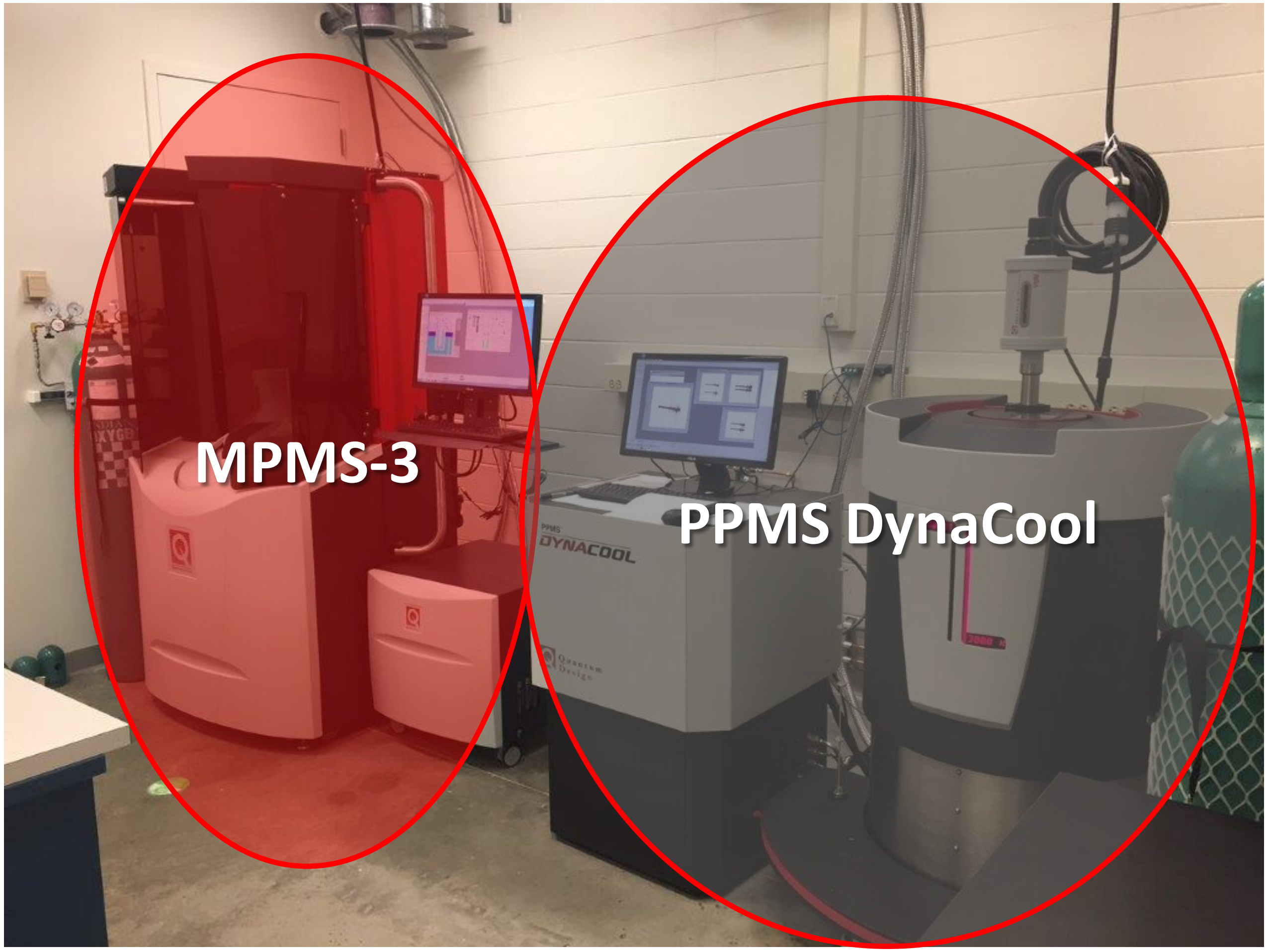
outline

- Where is the lab?
- What is Spintronics?
- Why use Quantum Design equipment?
- Quantum Design family tree
- A look inside the instruments
- Examples of some data taken here at Birck

Where is the Spintronics Lab?



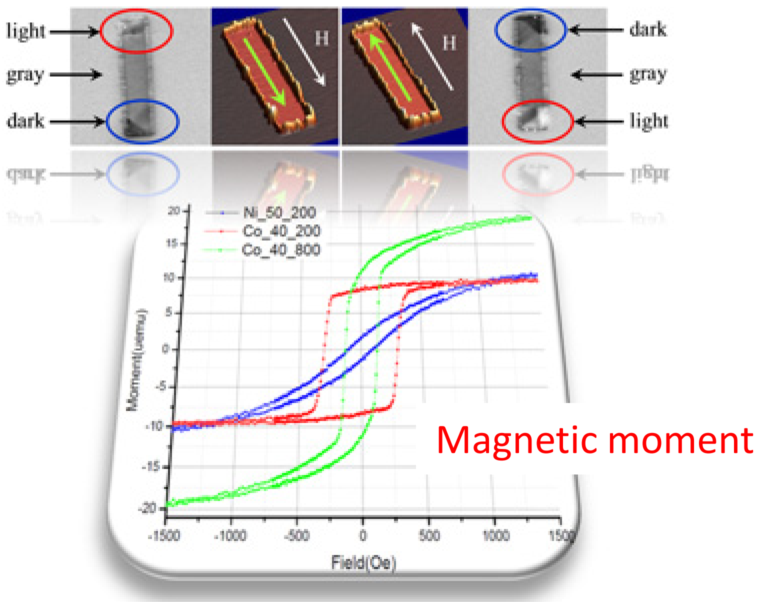
Spintronics Lab: BRK 1157a



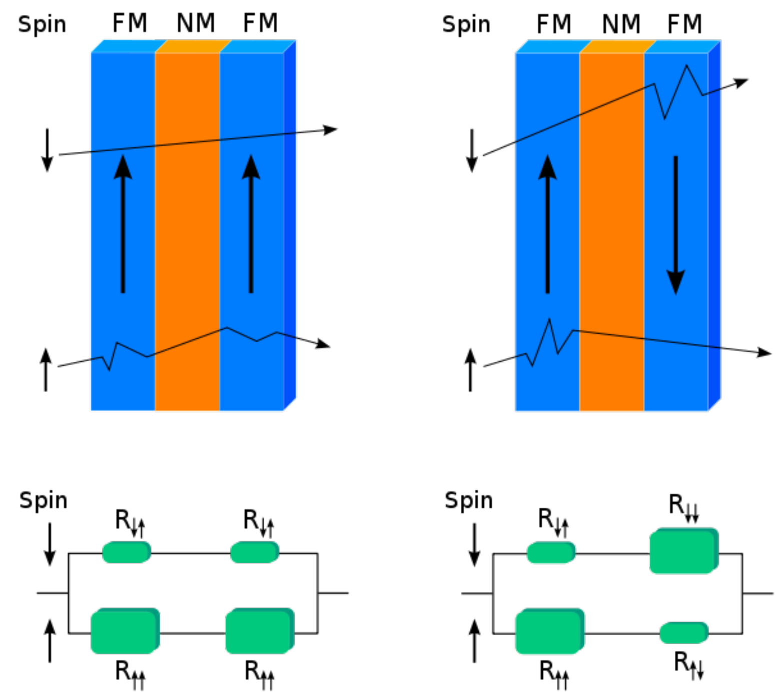
Self-maintaining liquid helium cryostats

What is Spintronics?

- “spin electronics”
- Uses electron SPIN to run circuits, just like we use electron CHARGE now



Ferromagnetic contacts: one way of controlling spin in circuits (Appenzeller group, Birck)



LOW resistance

HIGH resistance

Giant Magneto-Resistance effect (Fert/Grünberg, 1988), sensor used to read magnetic hard drives

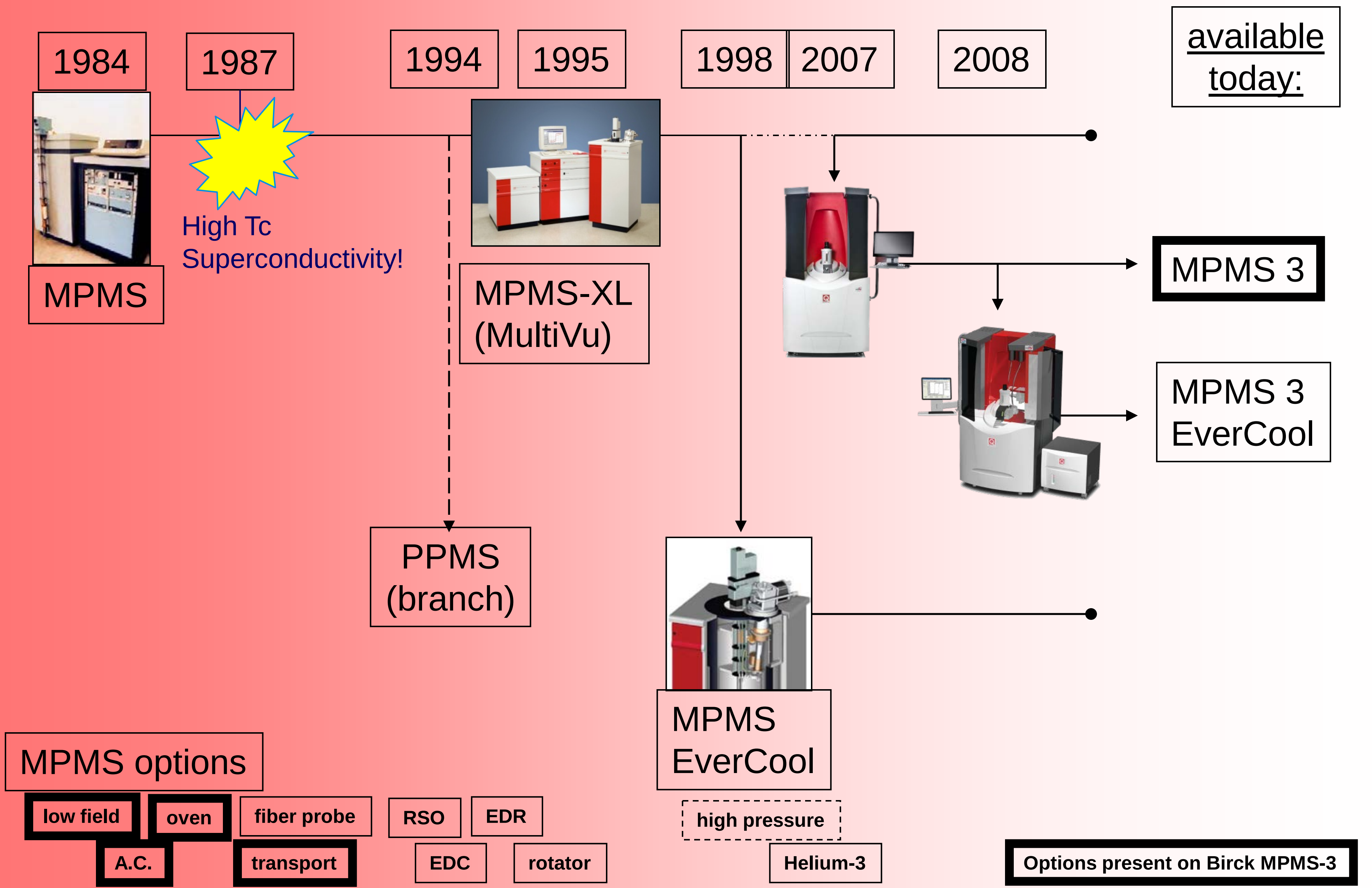
Why use Quantum Design equipment?

- Industry leaders in automated materials properties measurements like…

- Magnetic moment
- Electrical resistance

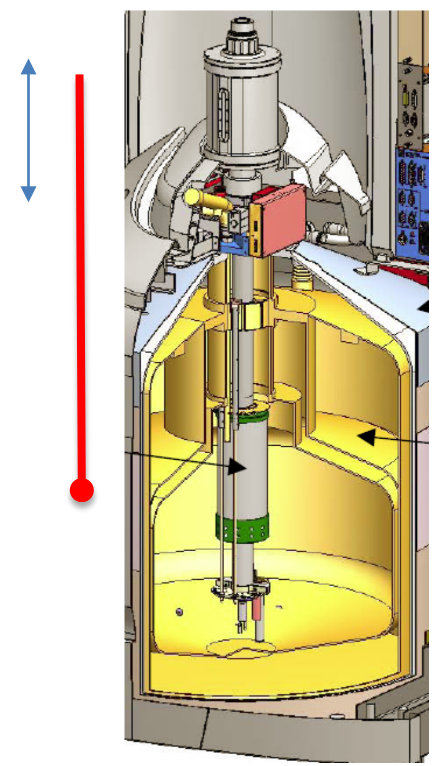
- Machines run all day/night on programs at
  - High magnetic fields (up to 9 tesla)
  - Low temperatures (down to 1.8 K)
- Workhorse for the labs, does routine characterizations
- Potential for many add-on and custom measurements

Quantum Design family tree trunk: SQUIDs

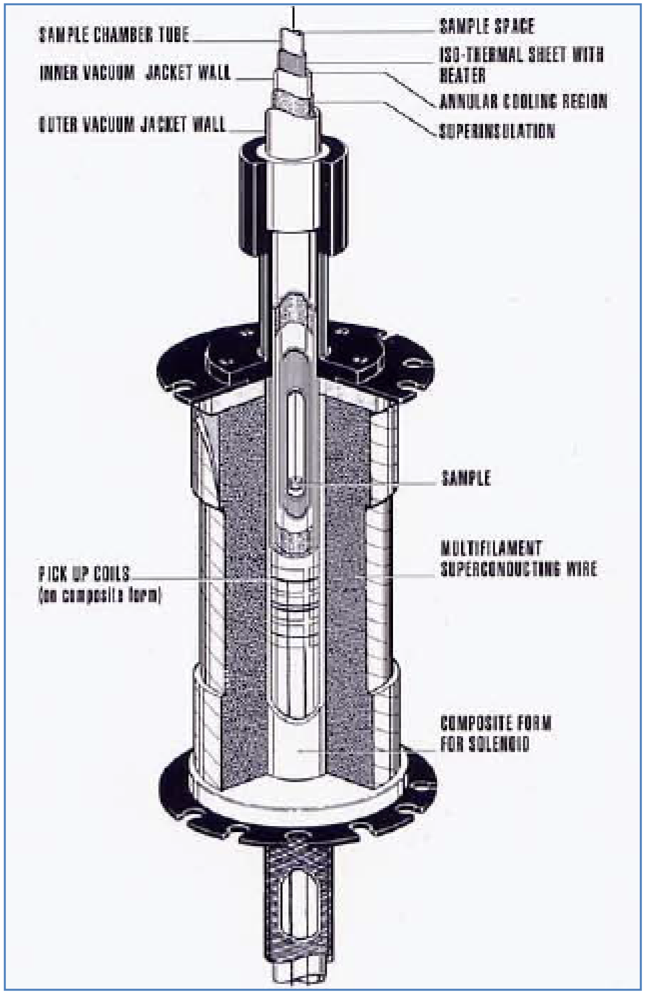


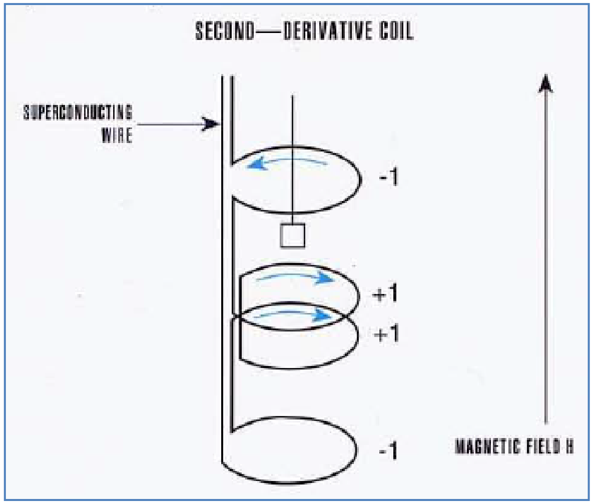
What is going on inside there?

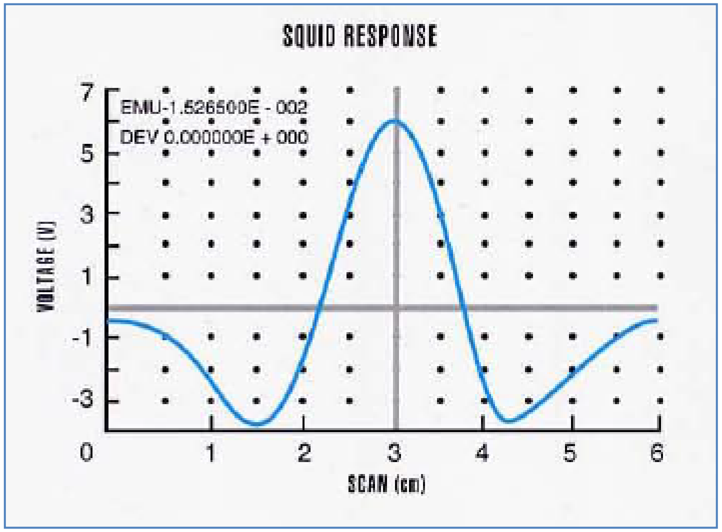
- MPMS-3
  - Magnetic Properties Measurement System
  - Magnetometer (susceptometer)
- Sample (•) typ. 4mm film, powder, crystal…
- Liquid helium in dewar (yellow area)
- Superconducting technology…
  - Electronics (SQUID detects the sample mag. field)
  - Magnet (7 tesla field)
- Similar story in PPMS DynaCool (more later)



MPMS: the Standard



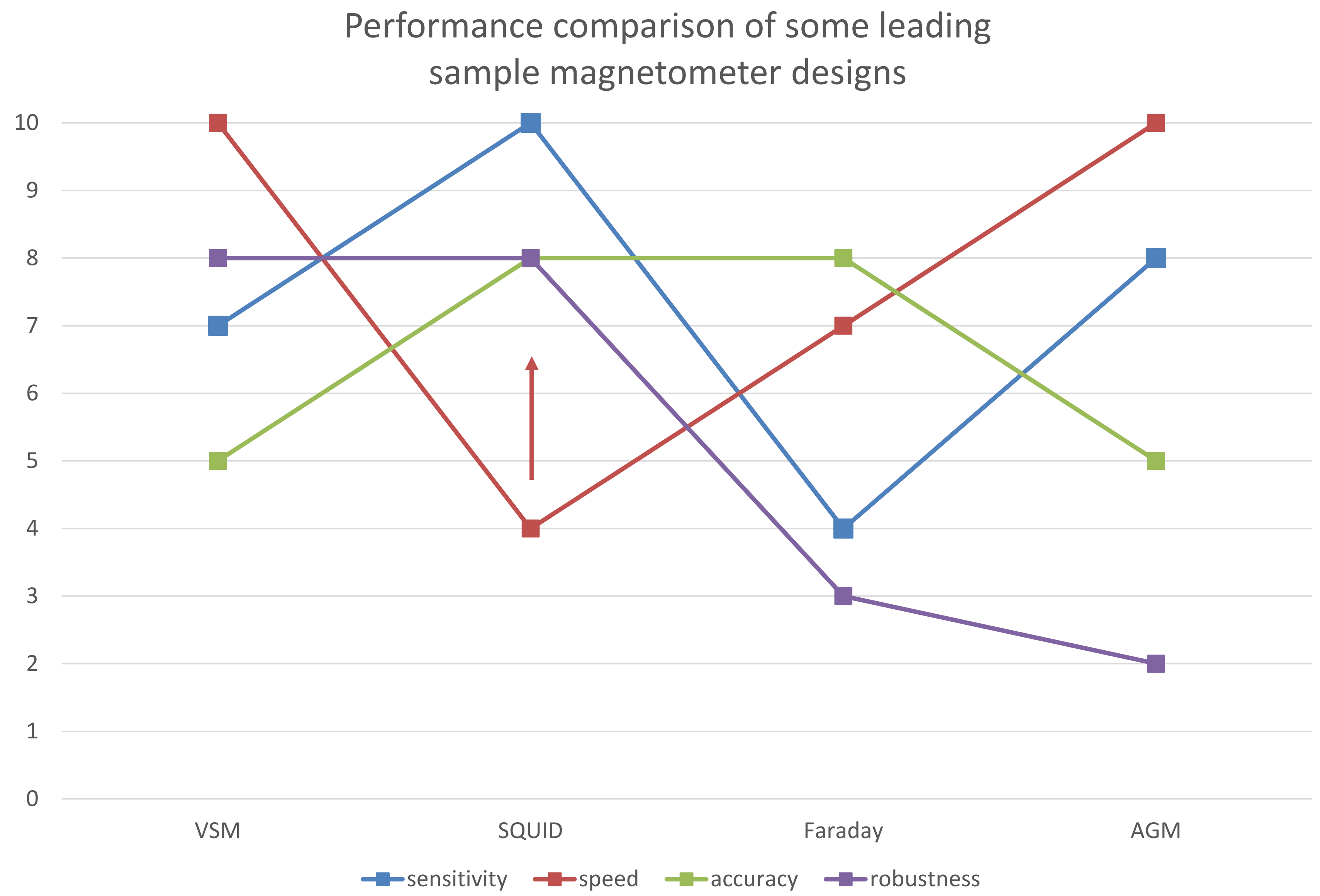




Two Modes

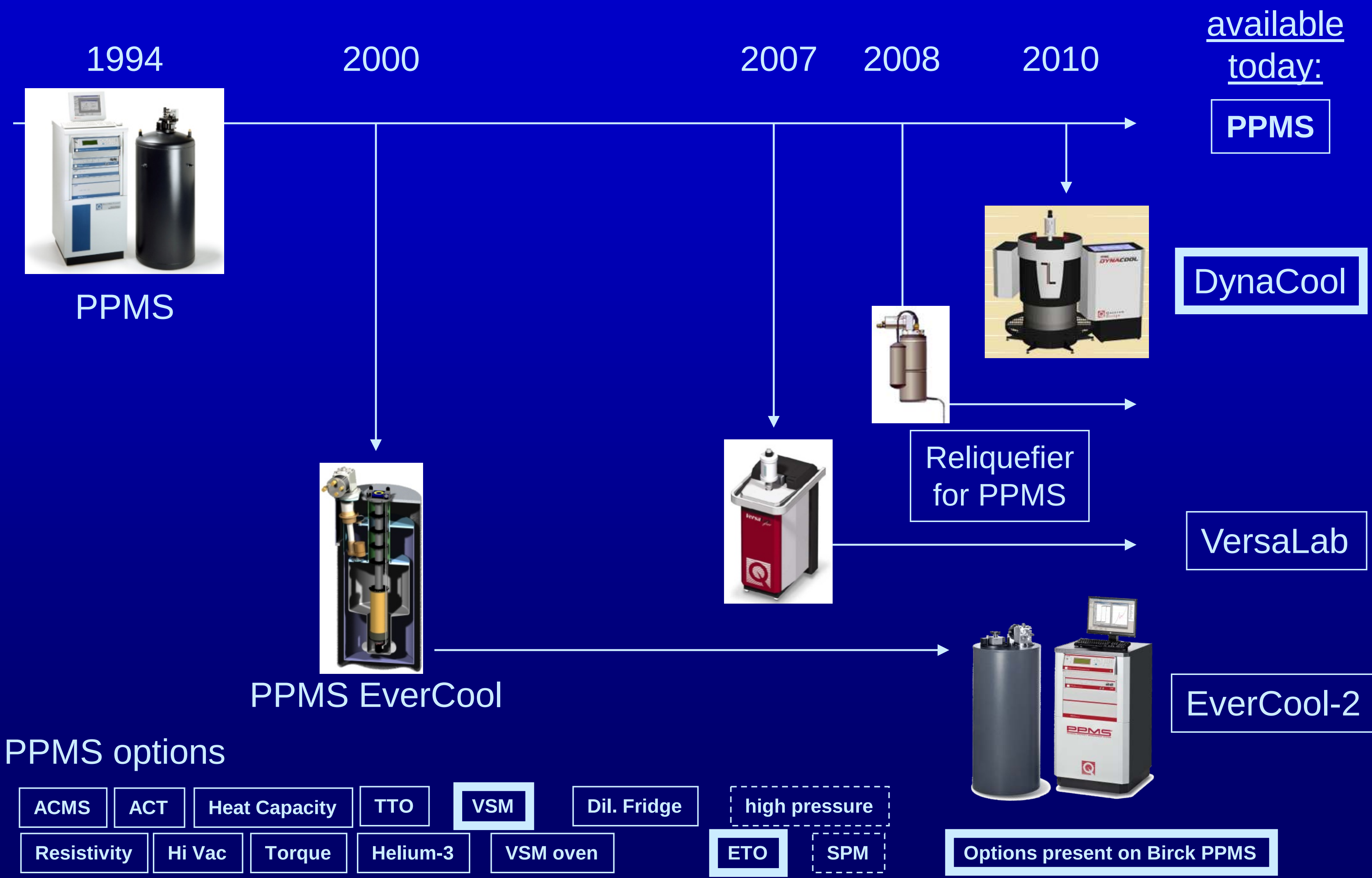
VSM

DC Scan

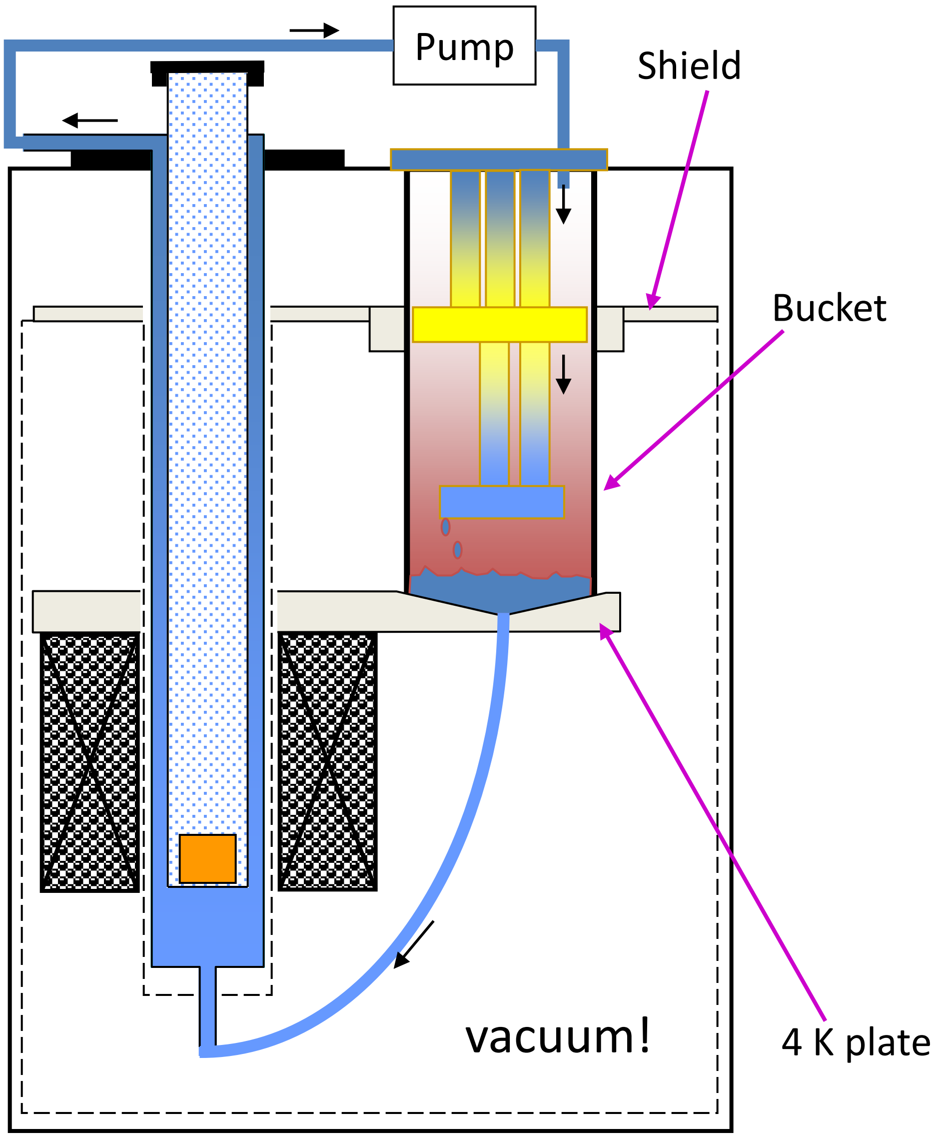


Performance comparison of some leading sample magnetometer designs
10
9
8
7
6
5
4
3
2
1
0
VSM
SQUID
Faraday
AGM
sensitivity
speed
accuracy
robustness

QD family tree branch: non-SQUIDs

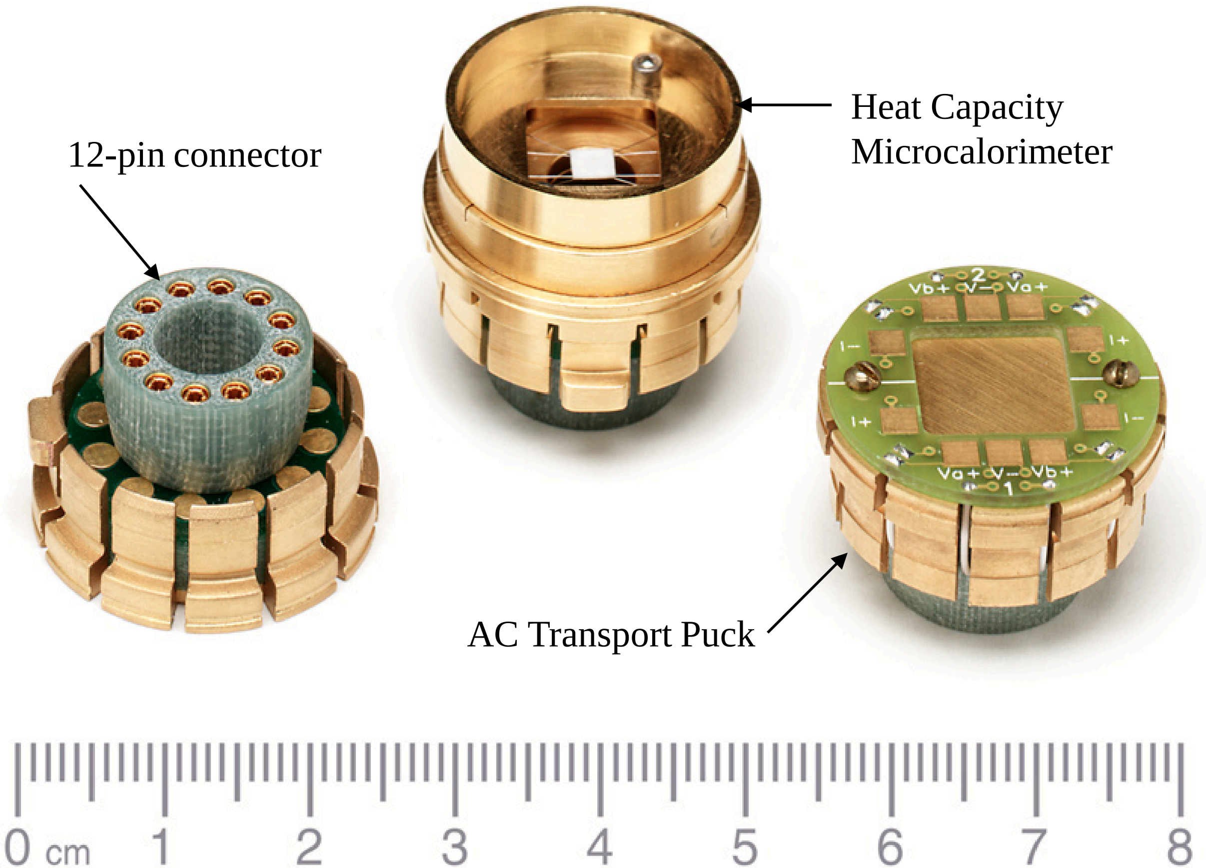


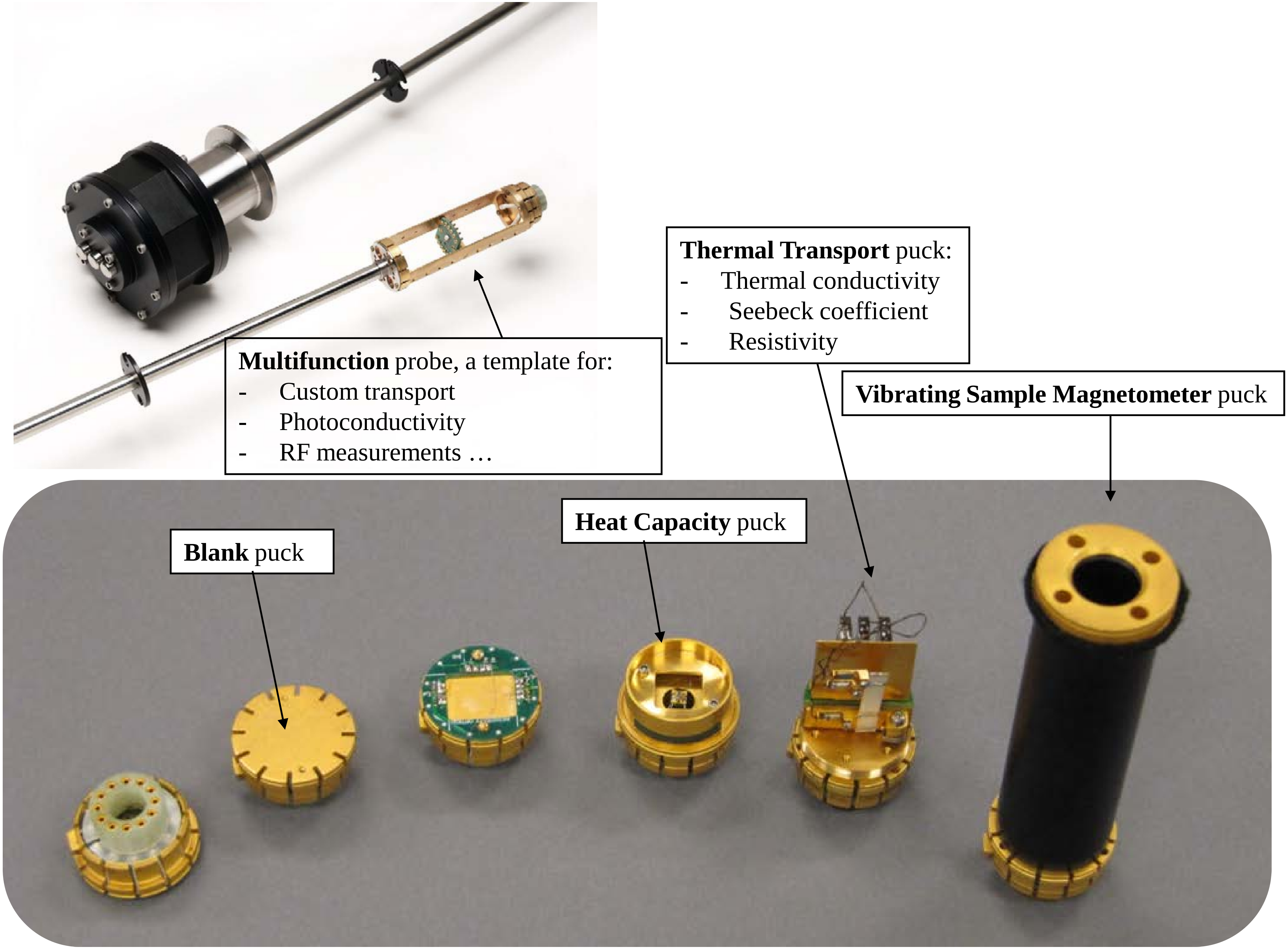
DynaCool inside



- pulse tube Cryocooler in gas
  - Efficient use of available cooling
  - Inherently vibration isolated
- Large, solid copper links to magnet
  - Large A/L, simple
- Helium flow cooled by direct contact with cryocooler
  - Large gas flows without affecting magnet temperature

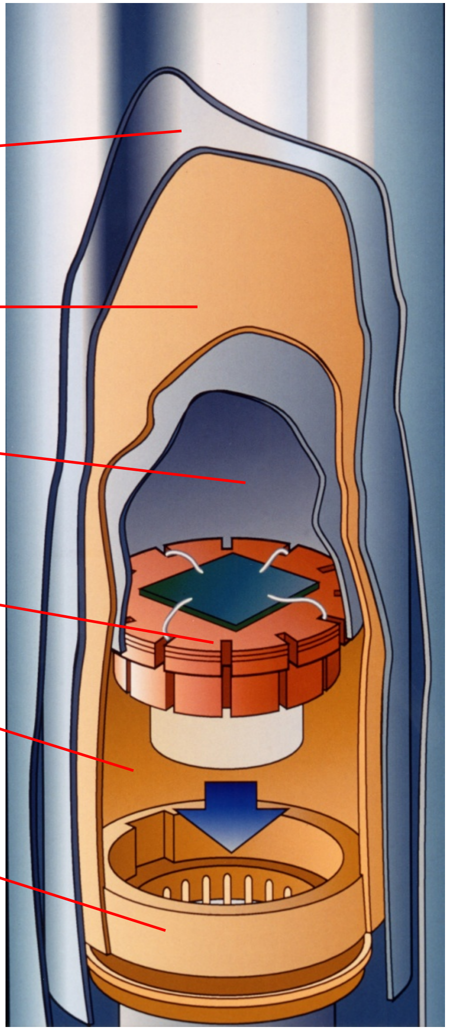
PPMS Sample Puck™: the experiment stage

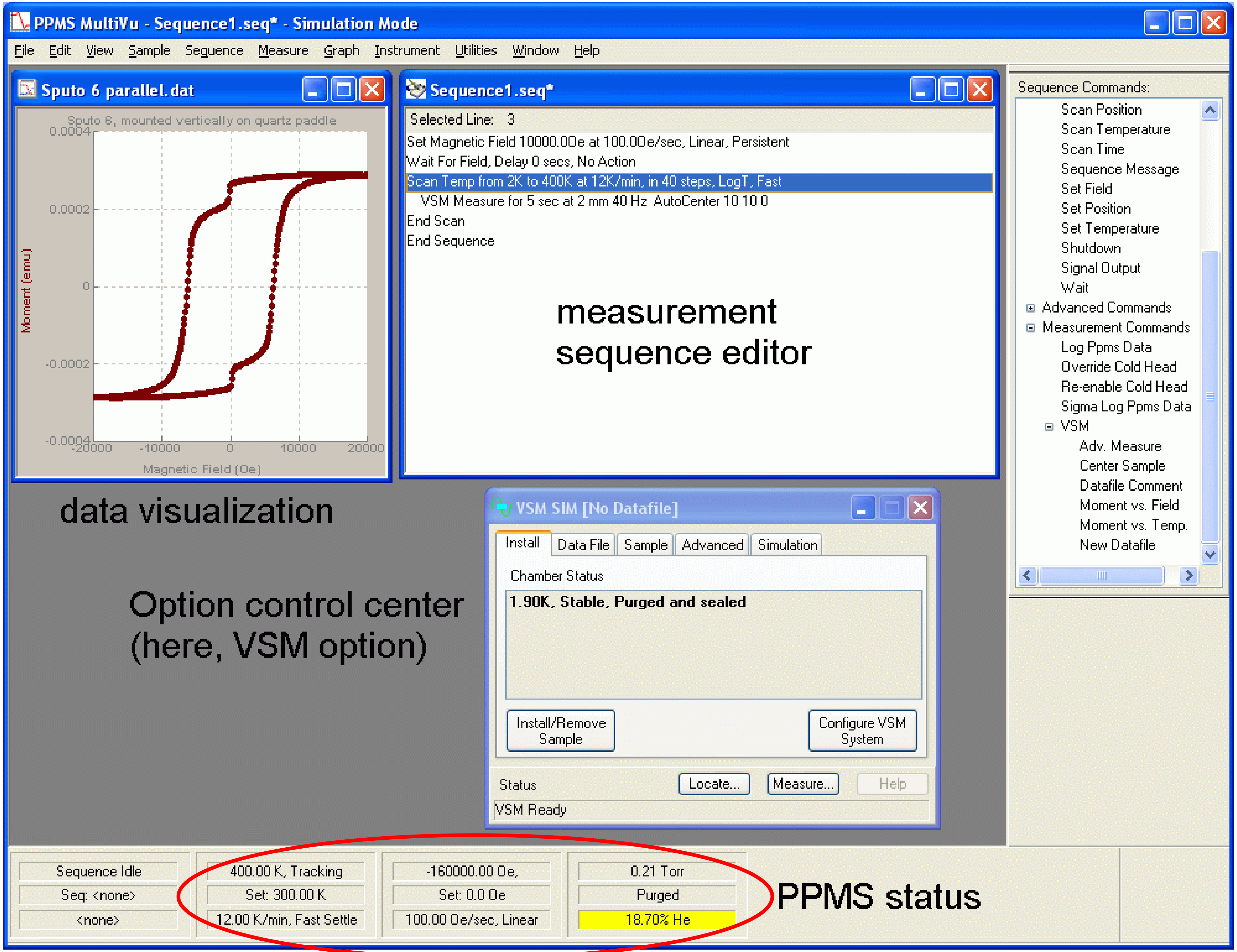



Multifunction probe, a template for:
- Custom transport
- Photoconductivity
- RF measurements …
Thermal Transport puck:
- Thermal conductivity
- Seebeck coefficient
- Resistivity
Vibrating Sample Magnetometer puck
Heat Capacity puck
Blank puck

Unique Cryostat Design

- Vacuum Space
- Cooling Annulus
- Sample Insertion Tool
- Sample "Puck"
- Sealed Sample Chamber
- 12-pin Connector




PPMS MultiVu - Sequence1.seq* - Simulation Mode
File Edit View Sample Sequence Measure Graph Instrument Utilities Window Help
Sputo 6 parallel.dat
Sputo 6, mounted vertically on quartz paddle
0.0004
0.0002
0
-0.0002
-0.0004
Moment (emu)
-20000
-10000
0
10000
20000
Magnetic Field (Oe)
Sequence1.seq*
Selected Line: 3
Set Magnetic Field 10000.0Oe at 100.0Oe/sec, Linear, Persistent
Wait For Field, Delay 0 secs, No Action
Scan Temp from 2K to 400K at 12K/min, in 40 steps, LogT, Fast
VSM Measure for 5 sec at 2 mm 40 Hz AutoCenter 10 10 0
End Scan
End Sequence
measurement sequence editor
Sequence Commands:
Scan Position
Scan Temperature
Scan Time
Sequence Message
Set Field
Set Position
Set Temperature
Shutdown
Signal Output
Wait
Advanced Commands
Measurement Commands
Log Ppms Data
Override Cold Head
Re-enable Cold Head
Sigma Log Ppms Data
VSM
Adv. Measure
Center Sample
Datafile Comment
Moment vs. Field
Moment vs. Temp.
New Datafile
data visualization
Option control center (here, VSM option)
VSM SIM [No Datafile]
Install
Data File
Sample
Advanced
Simulation
Chamber Status
1.90K, Stable, Purged and sealed
Install/Remove Sample
Configure VSM System
Status
Locate...
Measure...
Help
VSM Ready
Sequence Idle
Seq: <none>
<none>
400.00 K, Tracking
Set: 300.00 K
12.00 K/min, Fast Settle
-160000.00 Oe,
Set: 0.0 Oe
100.00 Oe/sec, Linear
0.21 Torr
Purged
18.70% He
PPMS status

wiring on sample chamber

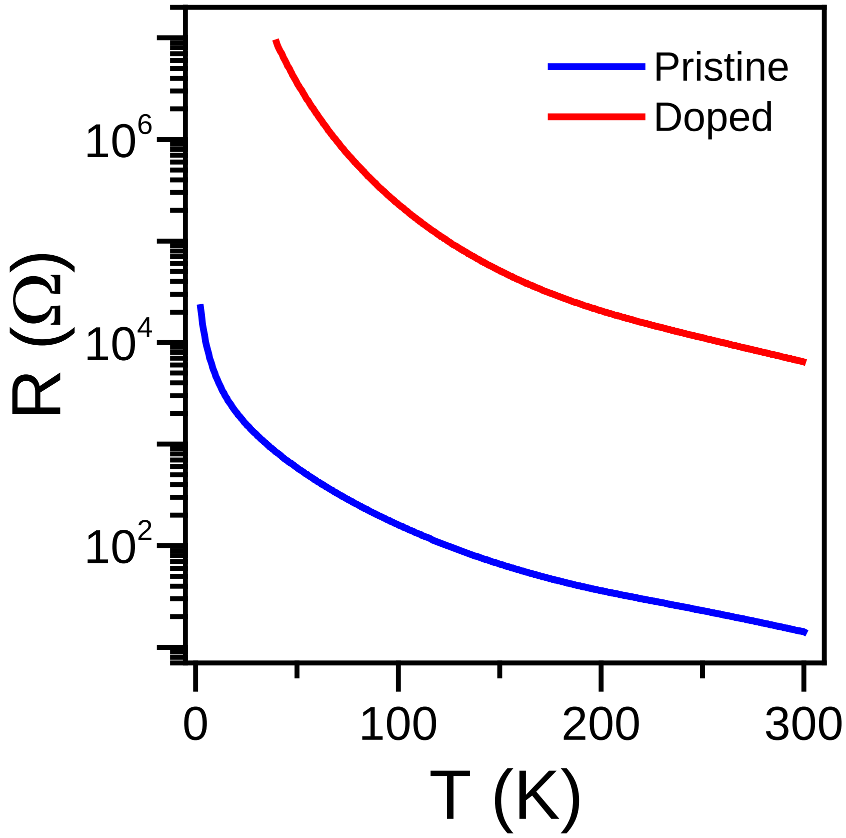
- twisted pairs of low resistance Cu alloy
  - running in annulus → thermal exchange w/ He gas
  - roundtrip resistance from Lemo connector ~1.1 ohm
- each wire
  - 1m of length
  - 0.32mm diameter
  - approx. 100 pF capacitance to ground
- ratings
  - 50 V DC max
  - 500 mA max continuous

- …or make your own probe!

Birck Research Data thus far…

From Koushik Ramadoss (S. Ramanathan, Materials Engineering)

Thin films of SmNiO3 on LaAlO3 – Four wire resistance measurement

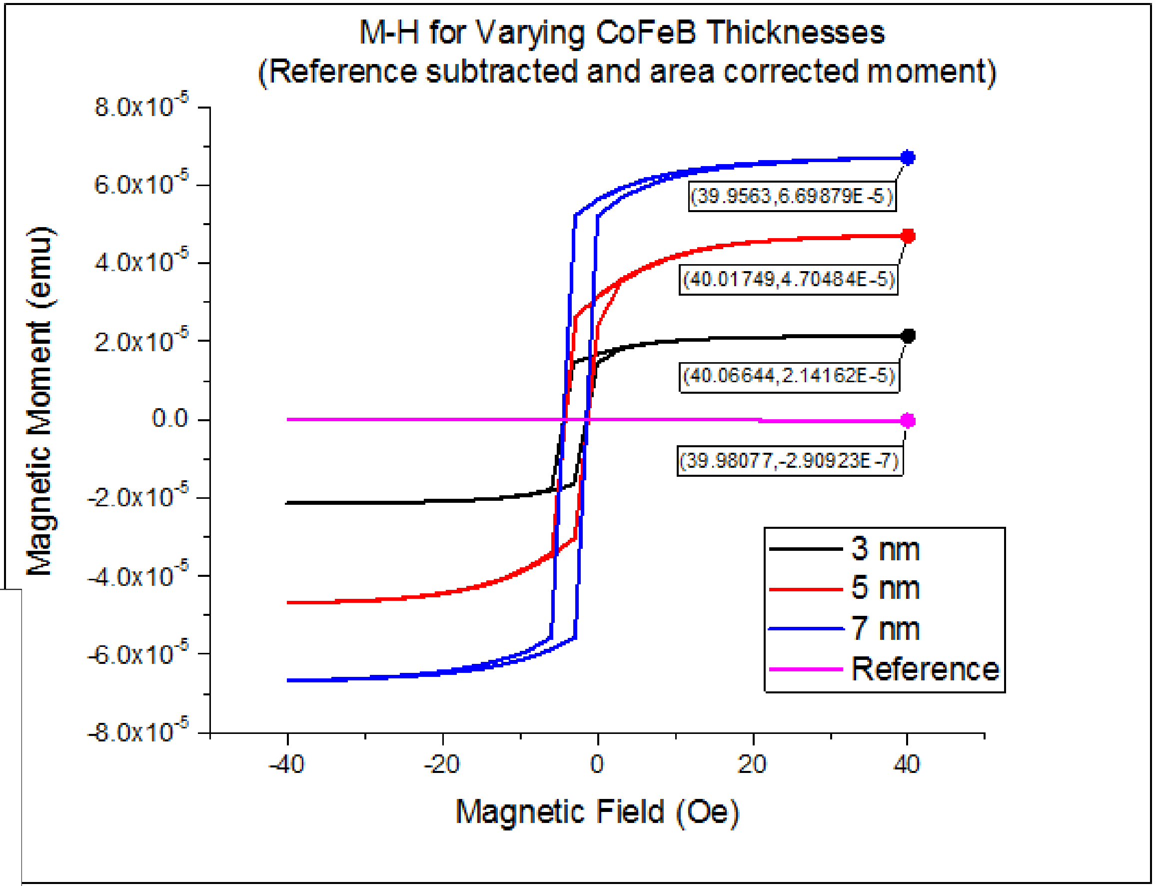


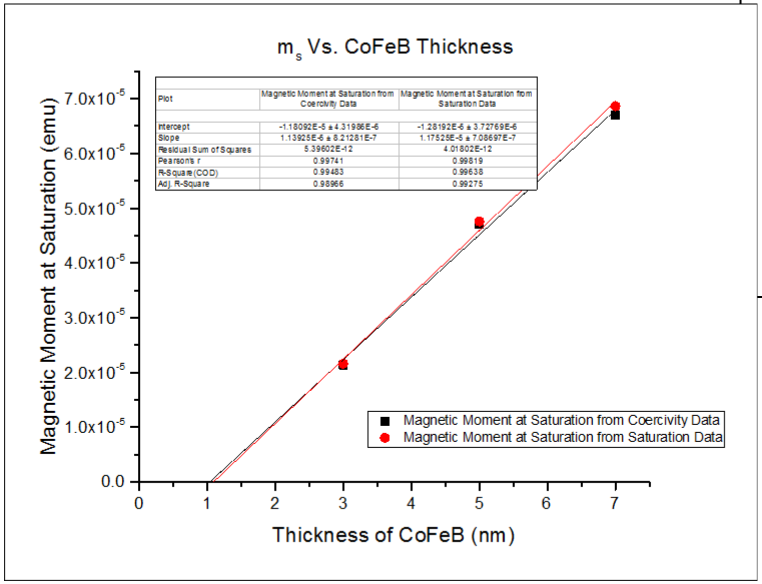
Increase in resistance by 3 orders of magnitude with doping. Data taken at B= 0 T

PPMS: QD transport (ETO)

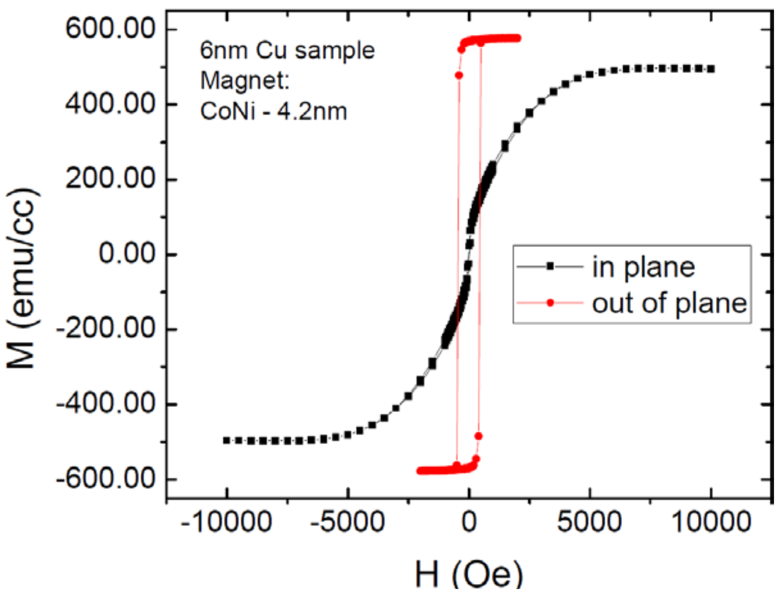
From Bradlee Beauchamp (E. Marinero)

MPMS-3: saturation moment

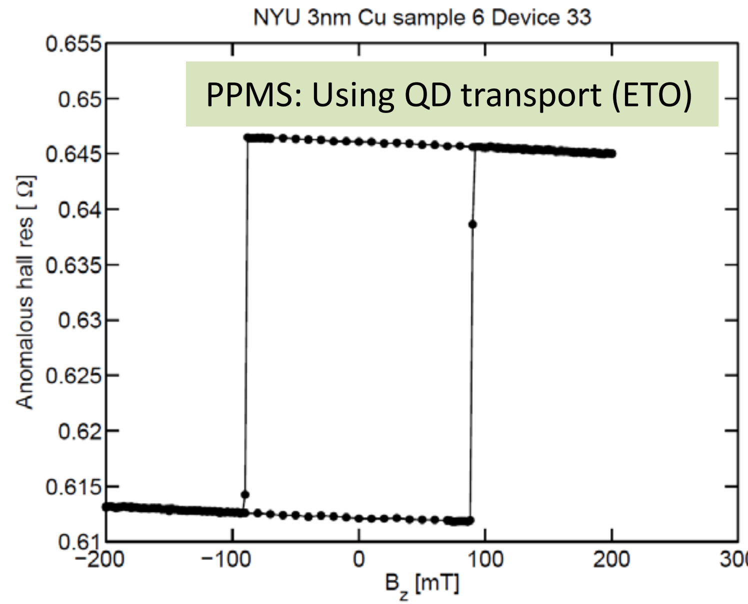




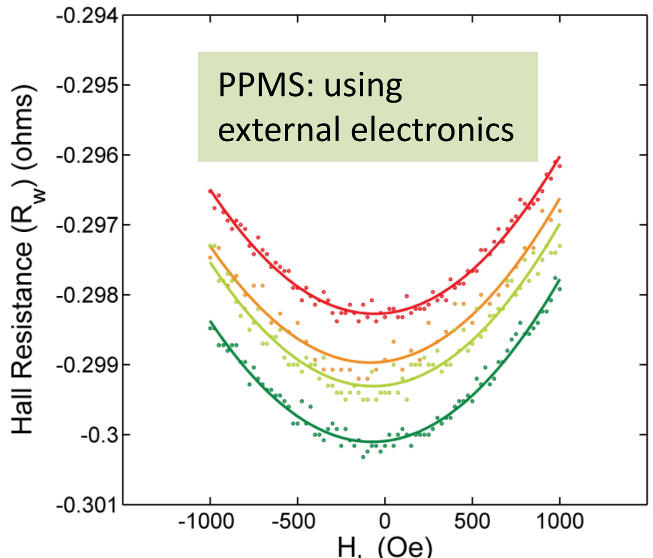
From Ashish Penumatcha (J. Appenzeller)



MPMS-3: anisotropy study

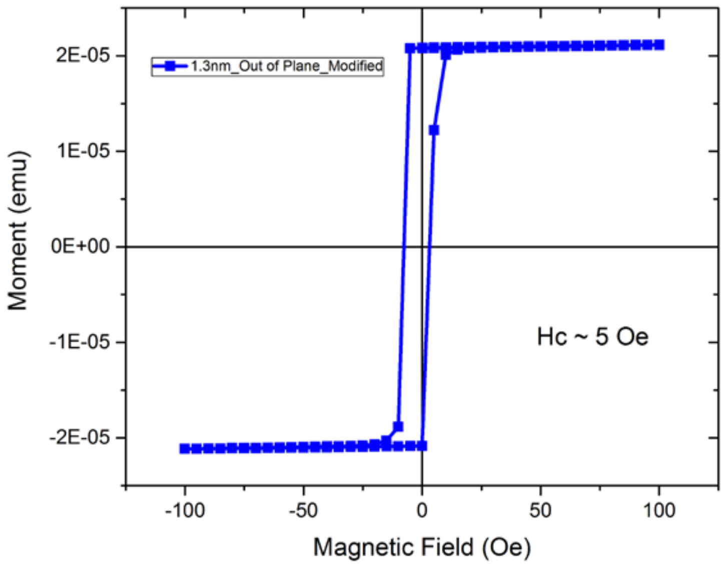


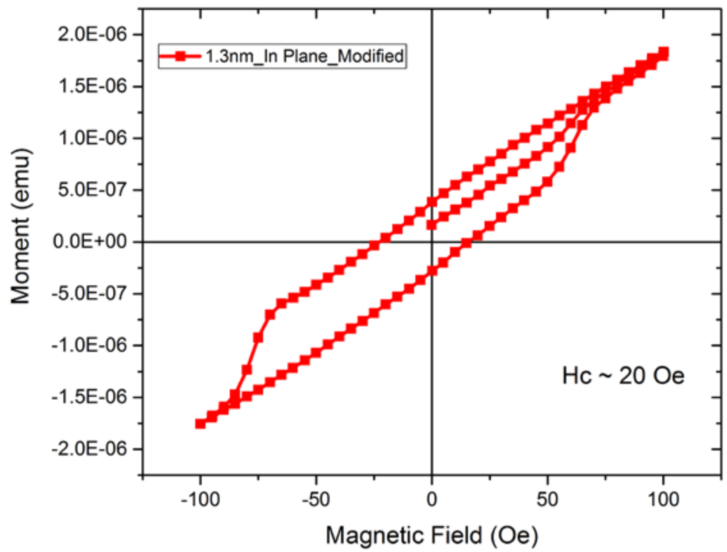
PPMS: Using QD transport (ETO)



PPMS: using external electronics

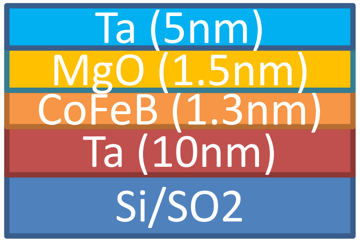
From TingTing Shen (J. Appenzeller)





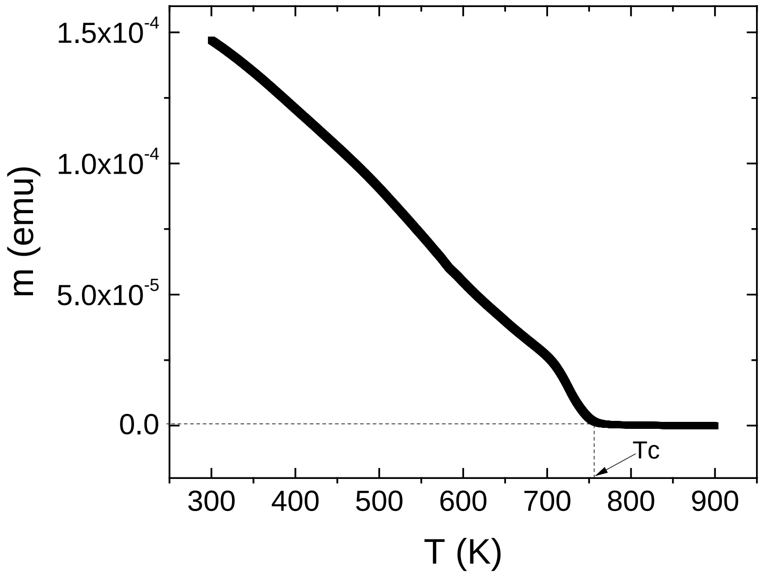
1.3nm CoFeB_PMA!

Saturation magnetization Ms ~ 817 emu/cc

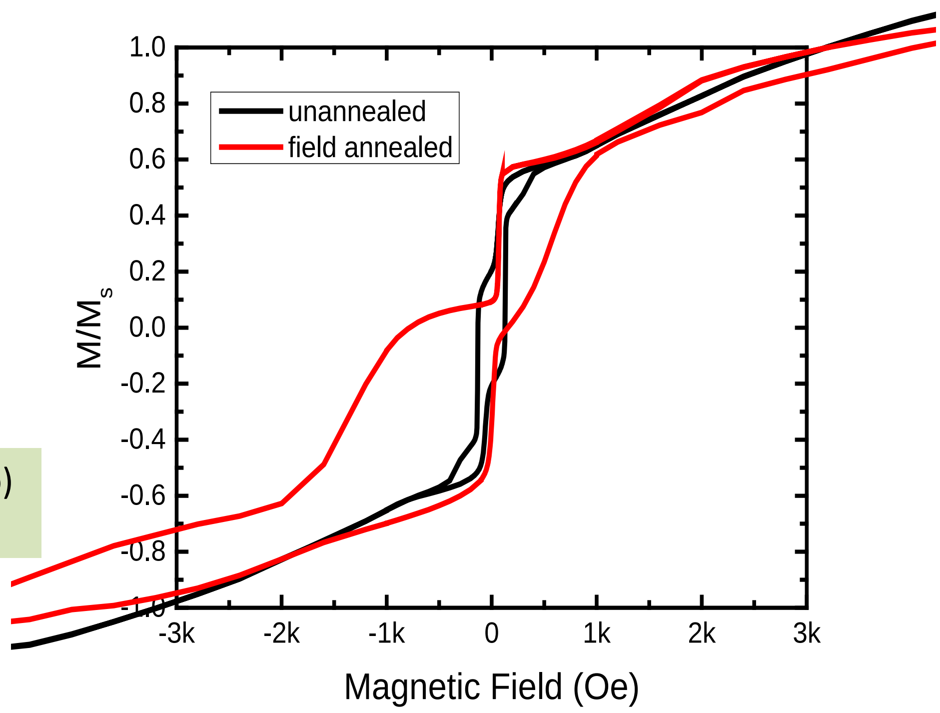


MPMS-3: anisotropy study

From Punyashloka Debashis (Z. Chen)

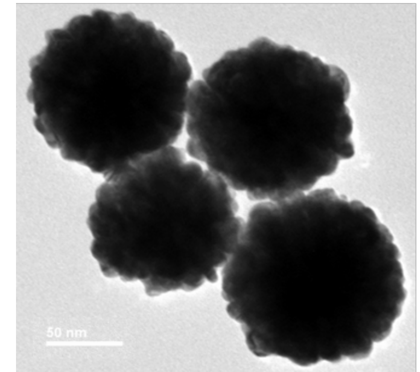


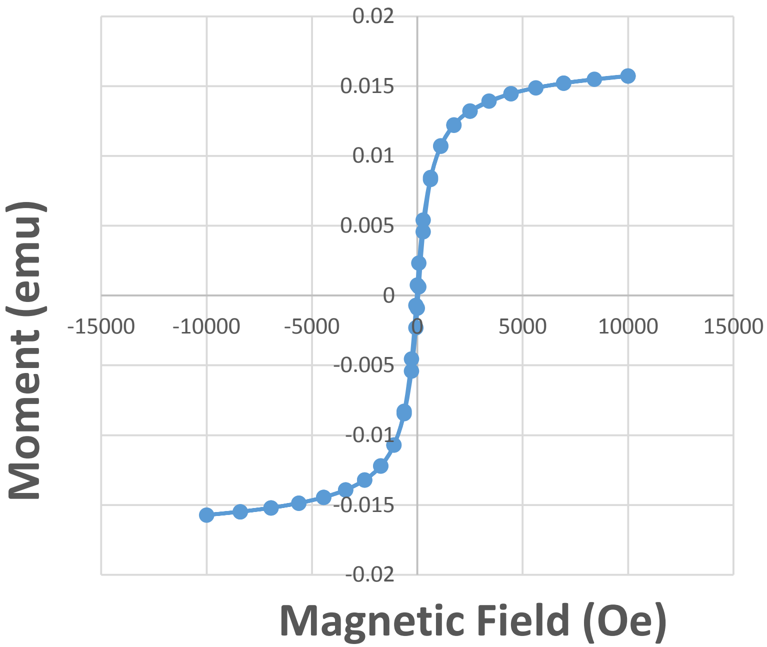
m vs. T at 10 Oe external field for a 25nm thick Permalloy film on Si_3N_4.

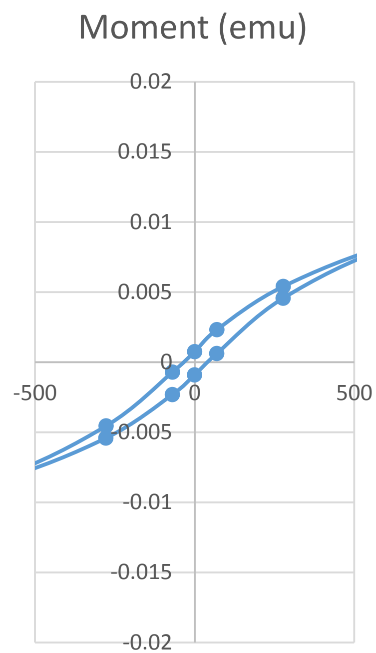


MPMS-3 oven: Curie temperature measurement (top)
In situ annealing in oven (bottom)

From Lu Lin (Alex Wei, Chemistry)







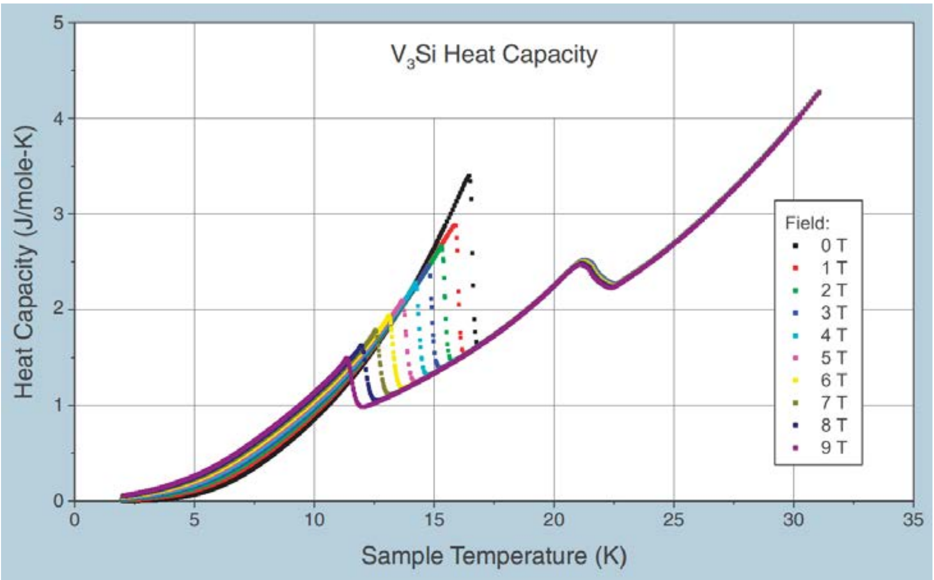
Sample	M_S (emu/g)
LL-140-1	1.6
LL-140-2	3.9
LL-150-1	0.3
LL-150-2	6.0

Sample weights (powder): 0.4 – 2.5 mg
M_S values range from 0.3 – 6.0 emu/g

Magnetic saturation measurements of ~100nm Au-Fe_3O_4 nanoparticles

Further possibilities

Heat Capacity

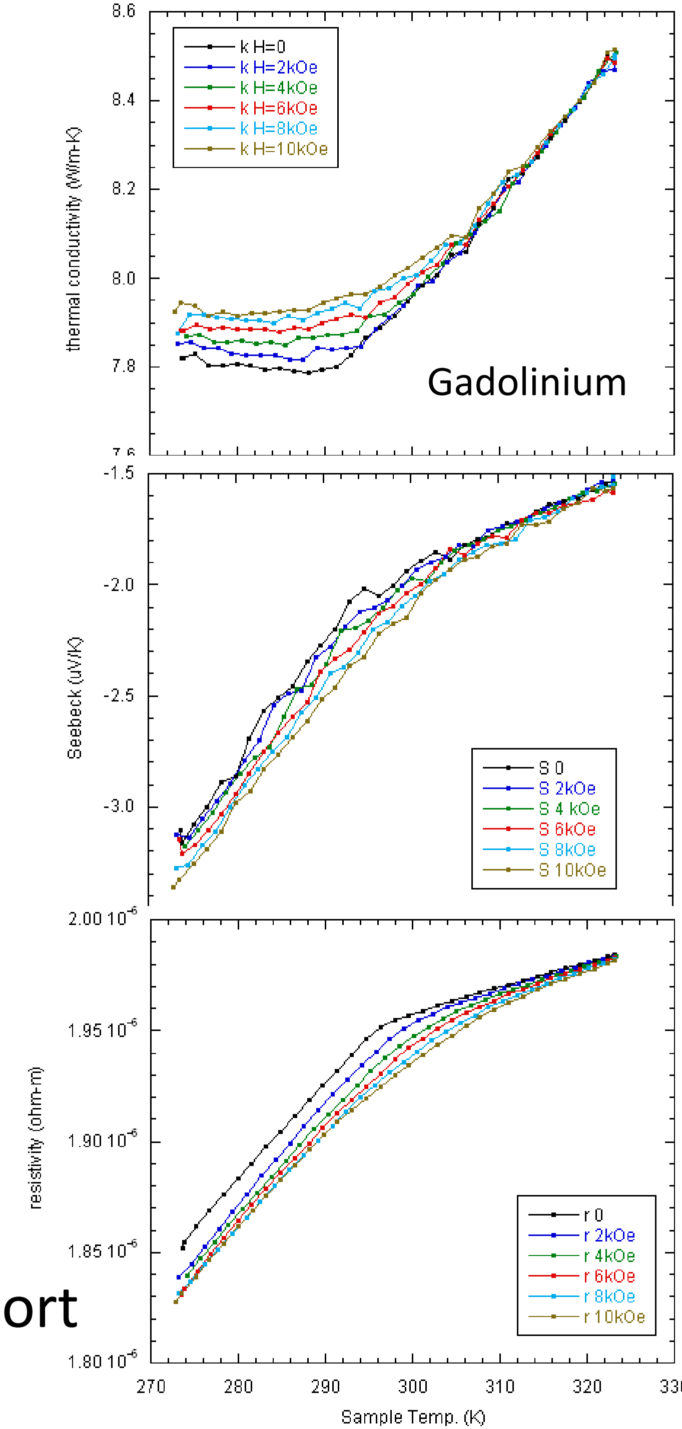


Also…

*Torque Magnetometry

*50 mK Dilution Refrigerator

*custom probes



Thermal Transport