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# ULTIMATE ACCELERATING FIELD AND LOCAL MAGNETOMETRY

EUCARD2 WP12.2 THIN FILMS PROSPECTIVE

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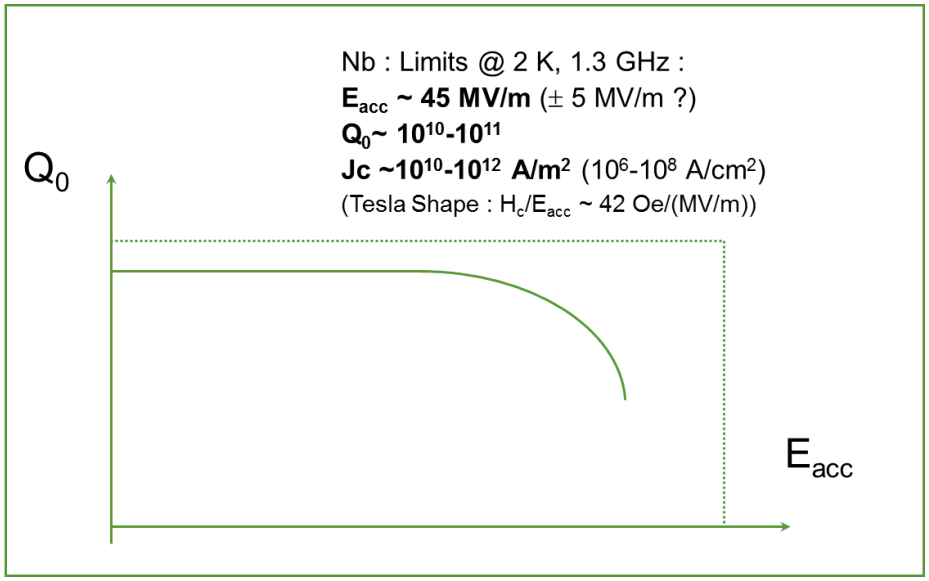
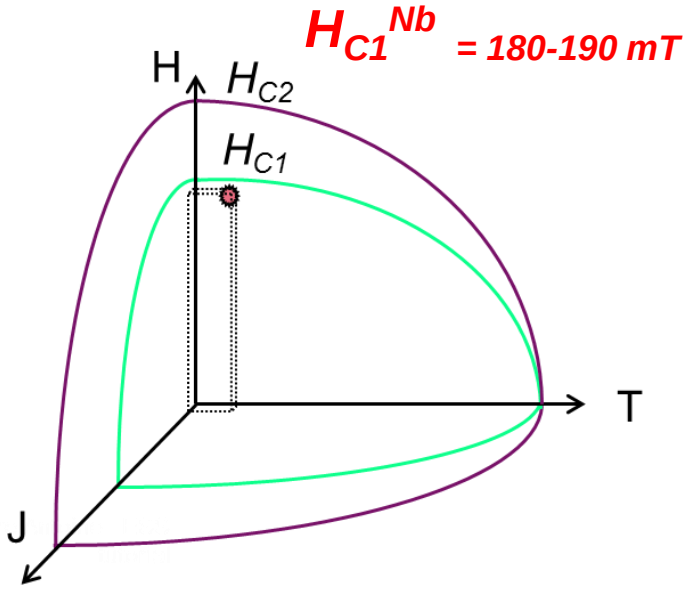
# IN A NUTSHELL

- Limits in superconducting cavities
- Vortex penetration
- $H_{C1}$ measurement using local magnetometry
- Conclusion and perspectives

# SRF LIMITS : BACK TO BASICS

- **$Q_0$ ($\propto$1/Thermal dissipations)**
  - Depends on surface resistance which depends on $T_c$ and $\omega^2$
  - Higher $T_c$ => higher $Q_0$ => lower operation cost
- **Ultimate limit in $E_{acc}$: when the SC becomes dissipative!**
  - Transition : when T and/or B↑
  - Vortices in RF highly dissipative => keep Meissner state
- **At $\omega$< 3 GHz: we are mostly limited by $B^{RF}$!!!**



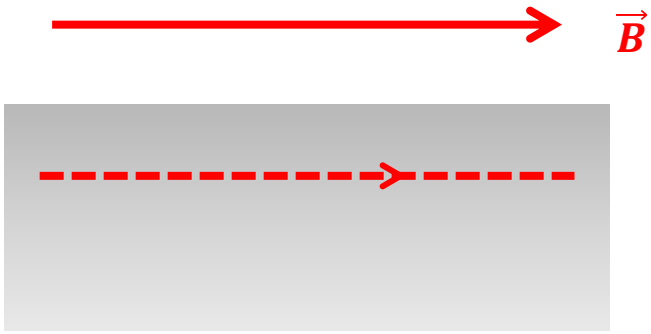




$H_{C1}^{Nb}$ = 180-190 mT

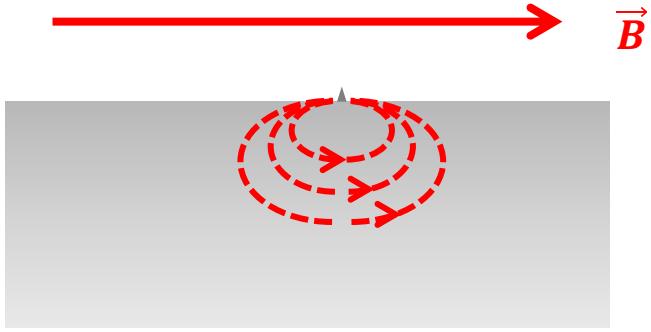
Cavities : Meissner State,
**no vortex** please !!!

# VORTEX PENETRATION

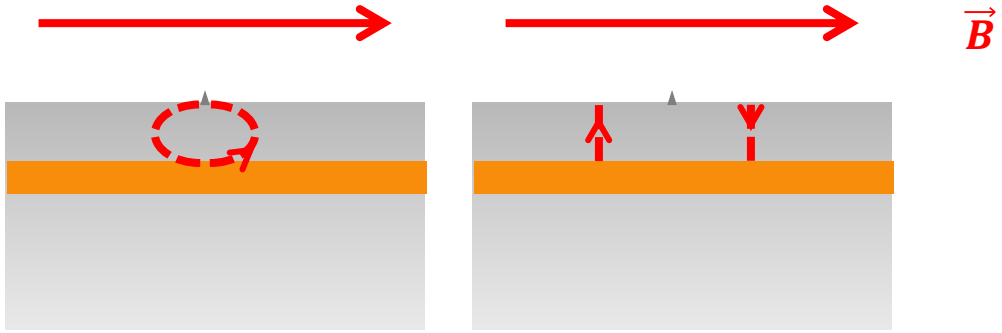
- **Ideal case**
  - field // surface, => surface barrier (Bean Livingston)
  - Vortex // surface start to enter @ $H_{SH}$
  - oscillations in RF → dissipations




- **Defect at surface**
  - Early vortex penetration (bundle) @ $H_{C1}$
  - **Avalanche**
  - Formation of current loops
  - oscillations in RF → dissipations



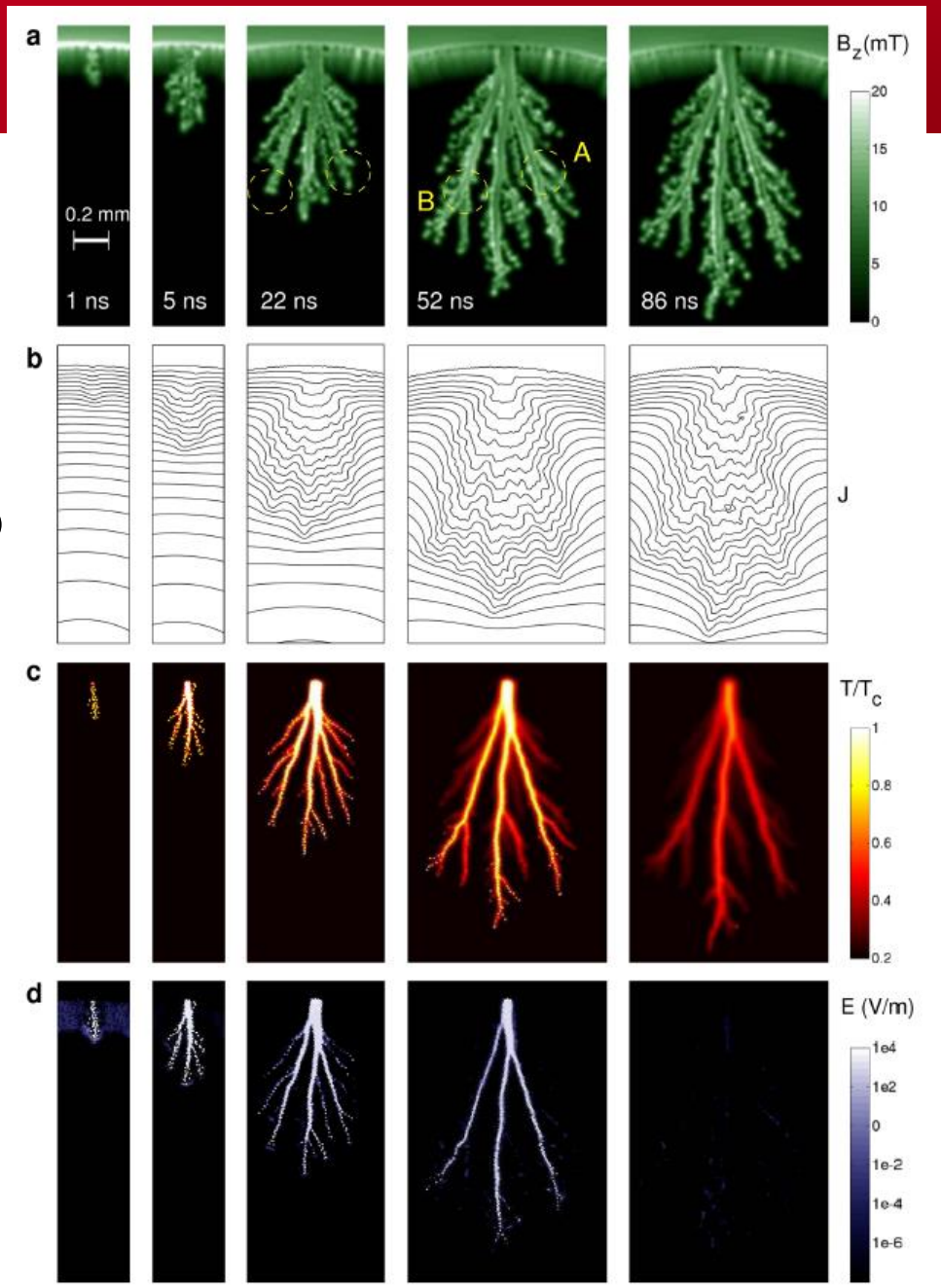

- **Dielectric layer**
  - Small ⊥ vortex (short -> low dissipation)
  - Quickly coalesce (w. RF)
  - Blocks avalanche penetration



# AVALANCHE VORTEX PENETRATION

- Penetration of vortices (~100 µm) within the time of rf period (ns)

This example is of $MgB_2$
http://www.nature.com/srep/2012/121126/srep00886/full/srep00886.html?message-global=remove&WT.ec_id=SREP-20121127




$\vec{B}$

# SC CAVITY : HIGHER PERFORMANCES

## To overcome Nb monopoly

- Need to have samples with low $R_S$ (i.e. Higher $T_C$ ).
- High $H_{SH}$ or critical field enhancement using multilayer.

## When do the vortices enter ?

- Measurement with conventional magnetometer does not hold. (uniform field around the sample, whereas only one side for Cavities)
- Development of **<u>local Magnetometry</u>** necessary to explore other SC at higher fields.

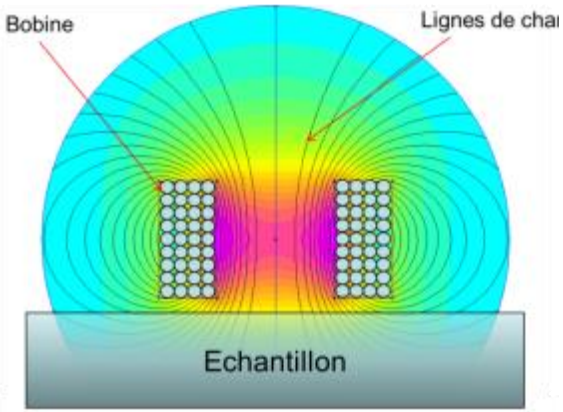
# $H_{C1}$ MEASUREMENT

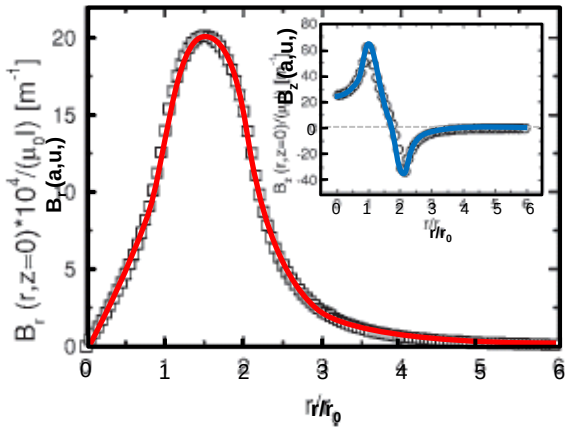
# LOCAL MAGNETOMETRY DEVELOPED @CEA

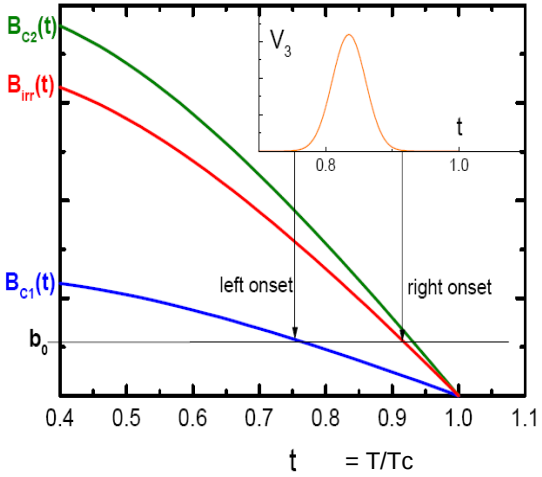
## Measurement of $H_{C1}$ on sample without edge/demagnetization effect

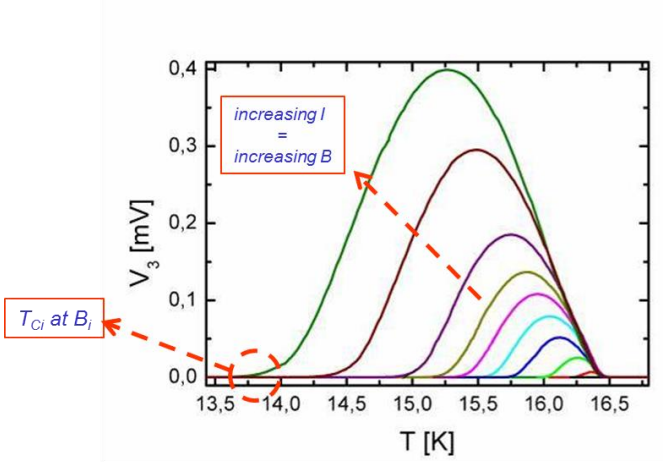
(local measurement: field decreases quickly far from the coil: $r_{coil}$ = 2.5 mm; $r_{sample}$~1 cm ~ $r_{coil}$ x 4 )

- Sample cool down @ H=0
- $I_0 \cos(\omega\tau)$ in the coil => $b_0 \cos(\omega\tau)$ on the sample
- Slow Tp° rise
- When in Meissner state : sample ="perfect magnetic mirror"
- @ $H_{C1}$ : V3 appears (pinned vortices => dragging force => non linear behavior)



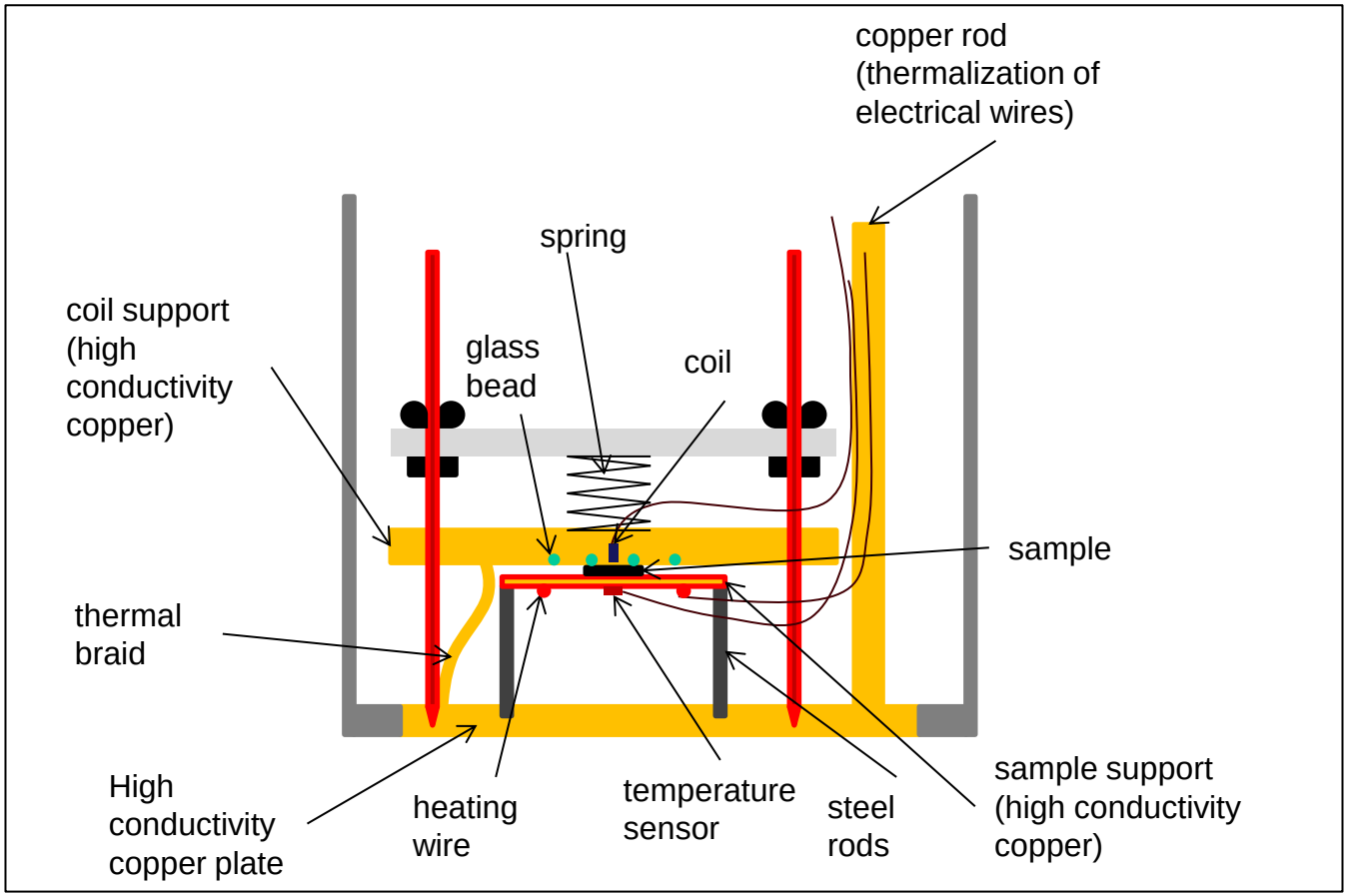



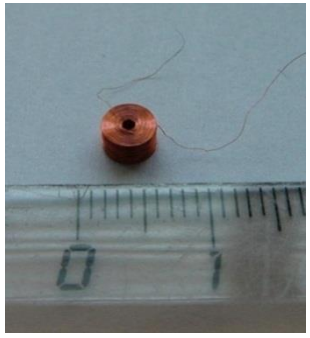

Sample SL : third harmonic signal for various b0

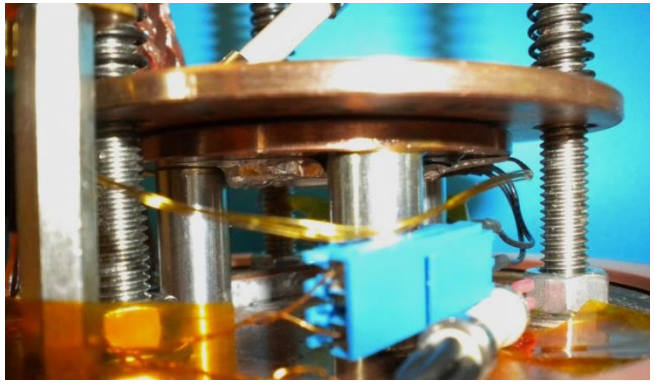
# Schematic of the local magnetometry



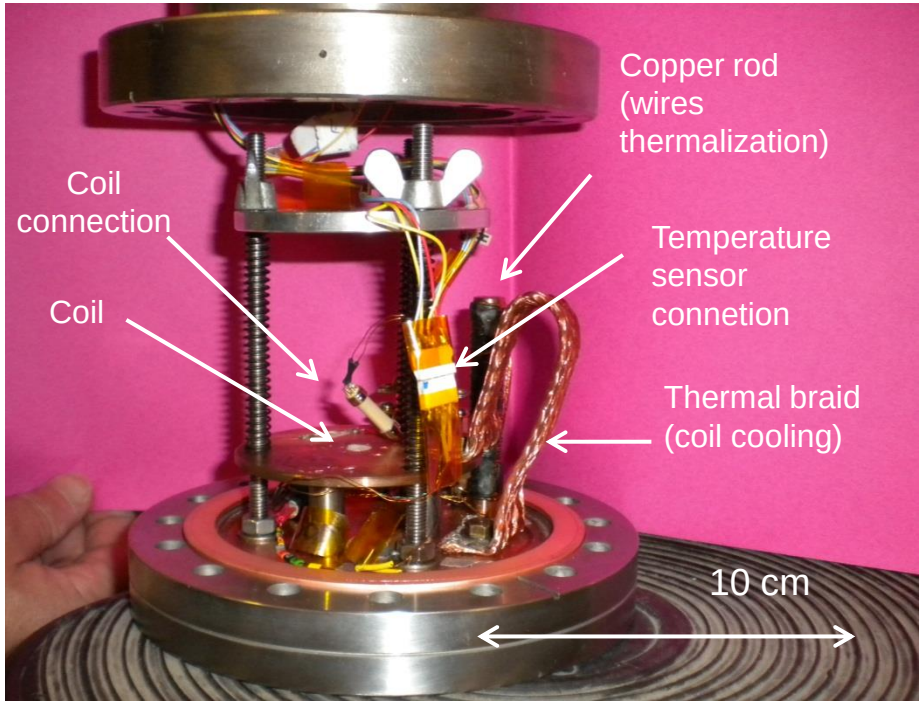
# COMPONENTS OF EXPERIMENT SETUP

**Coil**





**Sample holder details**



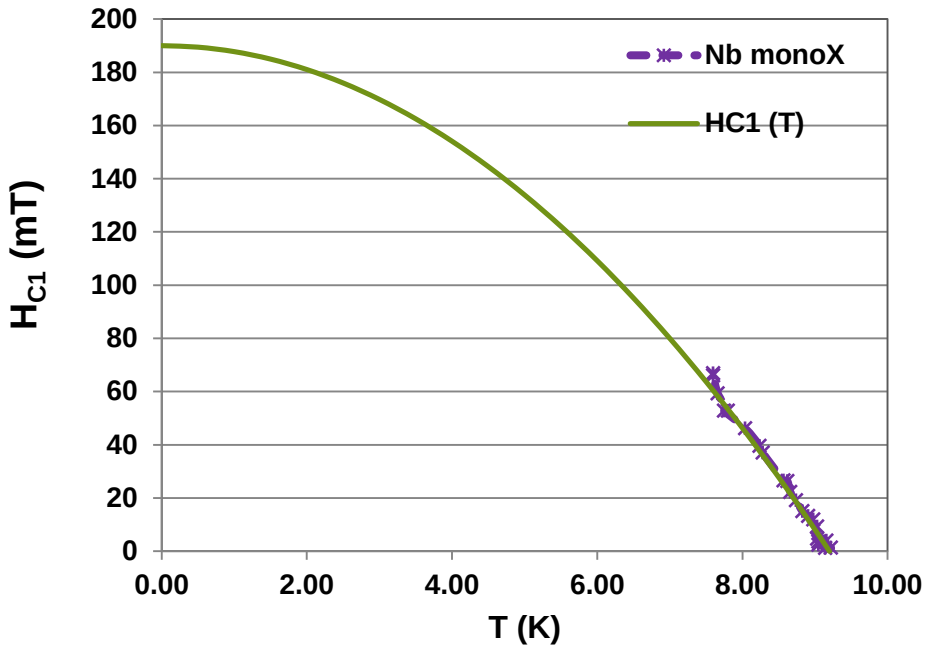

**Vacuum holder**

**Cryostat**

# Calibrating with monocrystalline Nb

$$Hc = H_0\left[1 - \left(\frac{T}{Tc}\right)^2\right]$$

**With $H_{C1}$ = 190 mT, $T_C$ = 9,2 K [Saito, 200]**




- Measurement with Nb monolCrystal
- High field exp. measurements limited (~60mT) by unexpected heating of the system

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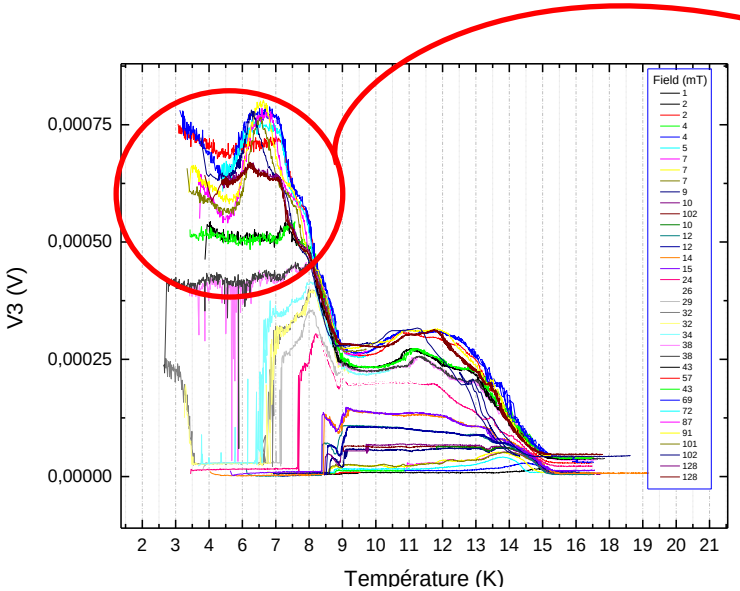
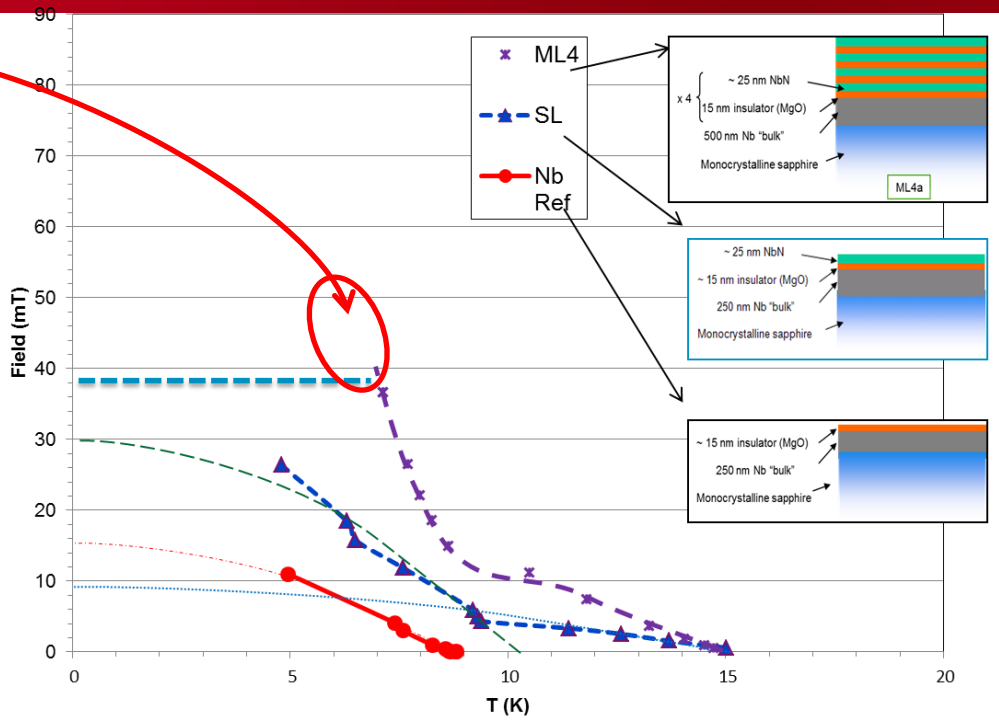
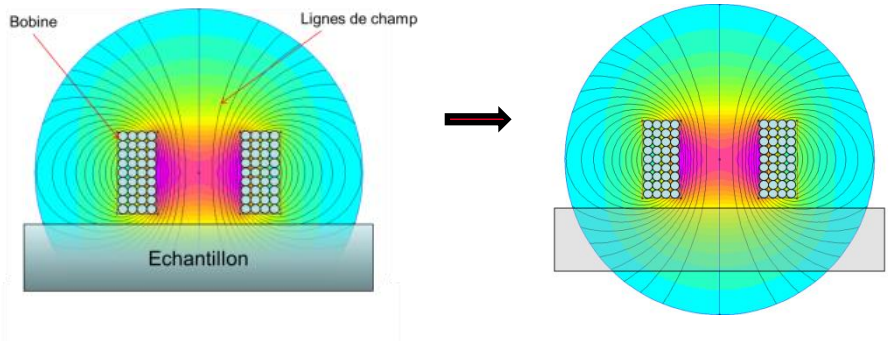
# MAGNETOMETRY (CONTINUED)




- Magnetic screening evident for ML4 up to 38 mT, at T~7K
- Dramatic transition around 38 mT => $r_{coil}$ << $r_{sample}$ not valid anymore ?
- Magnetometer is effective up to 1500 mA (equivalent field 150 mT) Tp° 2-40 K
- Use of larger samples/smaller coil is mandatory.



# CONCLUSION

## Local magnetometry

- Has proven to be effective at measuring vortex penetration in conditions close to cavities operating condition.
- Proved the screening effect of multilayers.
- Recently was hindered by electric parasites (changes in the building).
- Refurbishment (grounding the system, shielded electronics etc.) under process.
- Unfortunately unexpected 6-8 months delay on the schedule.
- In near future, plan is to measure new multilayer/thin film samples (already available) and get new results.

# Thank you!!