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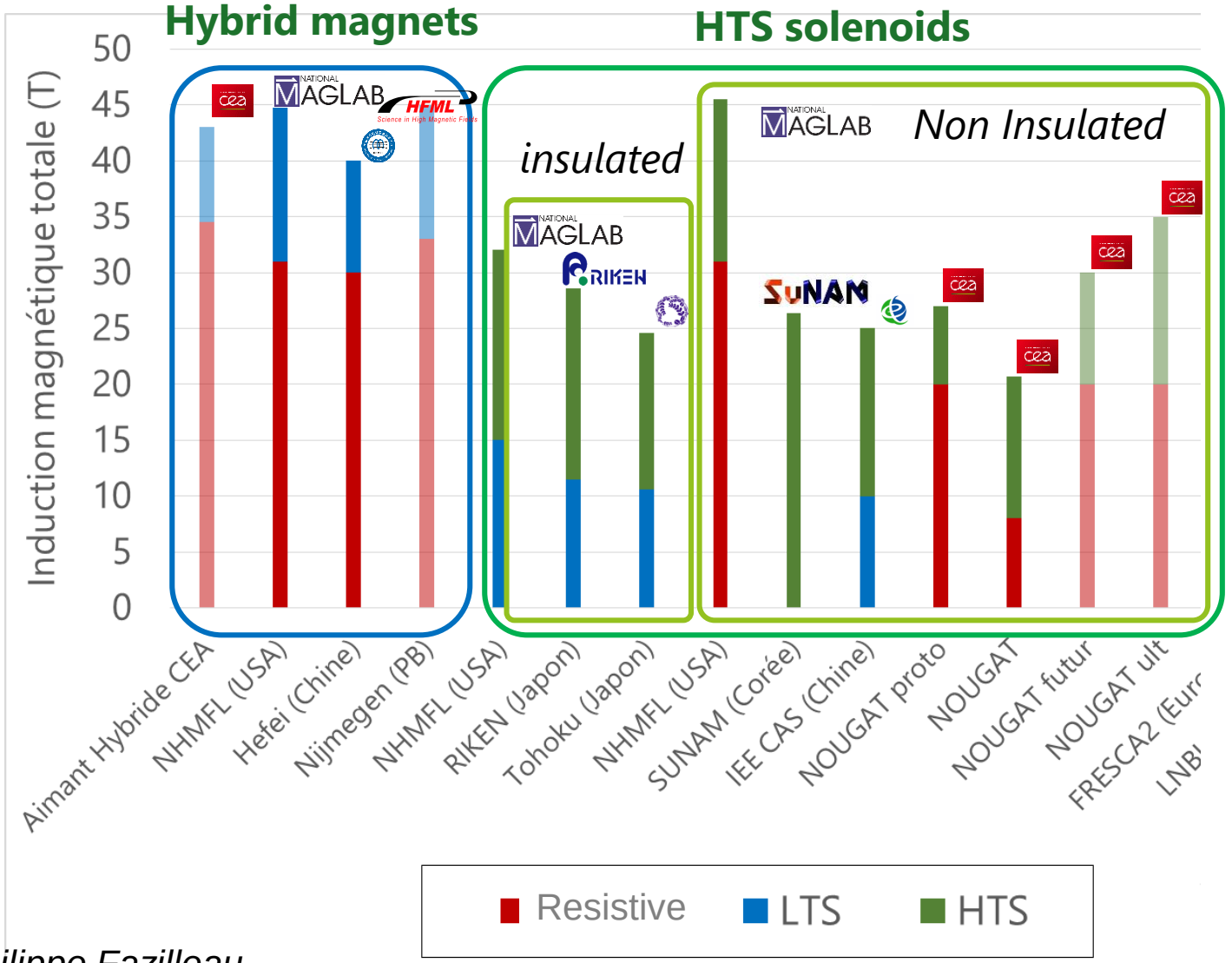
# HIGH FIELD SOLENOIDS

LIONEL QUETTIER

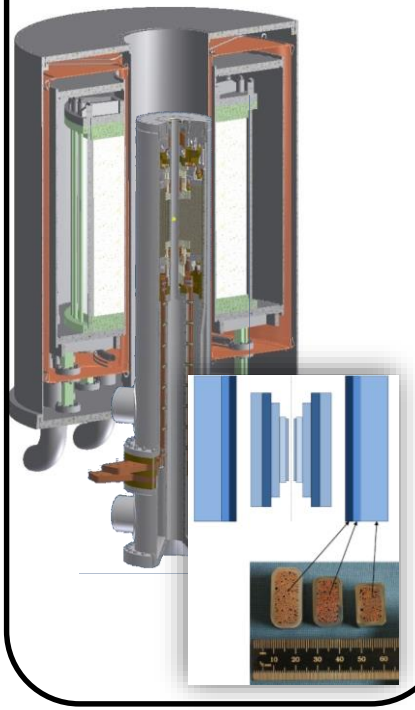
# HIGH FIELD MAGNETS PANEL

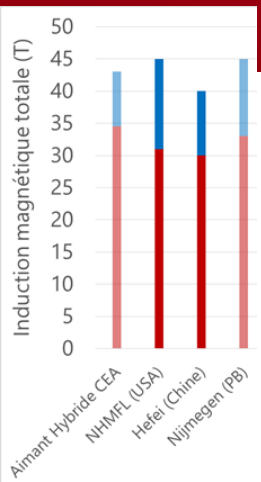


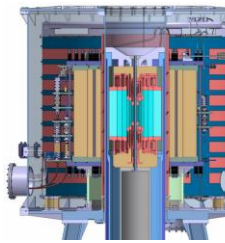

*Courtesy Philippe Fazilleau*

# HYBRID MAGNETS: LTS + RESISTIVE MAGNETS

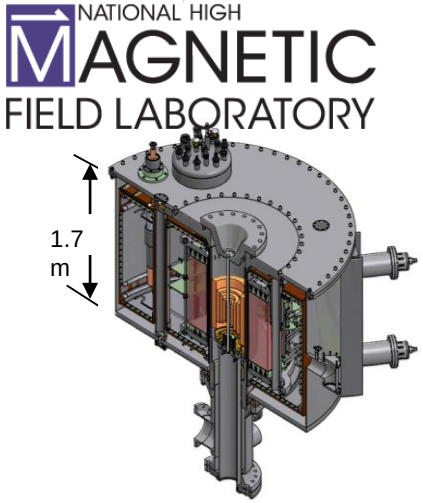
## ‘hybrid LNCMI’





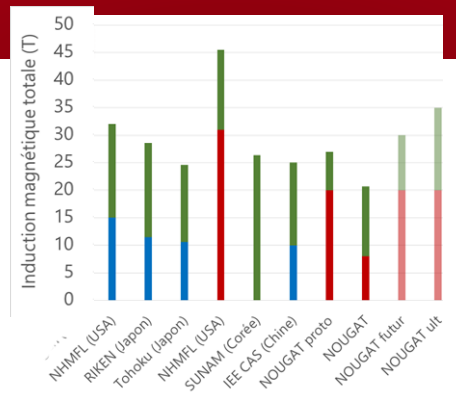



| Grenoble, France | Nijmegen, Netherlands | Hefei, China | Tallahassee, FL |
|---|---|---|---|
| 8.5T LTS + 34.5T Res. | 12T LTS + 33T Res. | 10T LTS + 30T Res. | 11T LTS + 34 Res. |
| **43T** | **45 T** | **40 T** | **45 T** |
| **34 mm**, 24 (30) MW | **32 mm**, 24 MW | **32 mm**, 25.4 MW | **32 mm**, 32 MW |
| RCOCC Nb-Ti, 1.8 K | CICC Nb3-Sn, 4.2 K | CICC Nb3-Sn, 4.2 K | CICC Nb3-Sn, 4.2 K |
| 7.1 kA, 1100/1826 mm dia. | 20 kA, 720/1286 mm dia. | 13.4 kA, 680/1650 mm dia. | 20 kA |

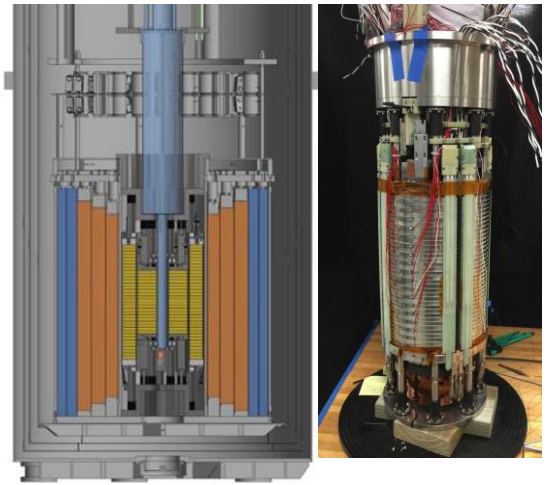
*Courtesy Philippe Fazilleau*

# HTS SOLENOIDS

*Courtesy Philippe Fazilleau*

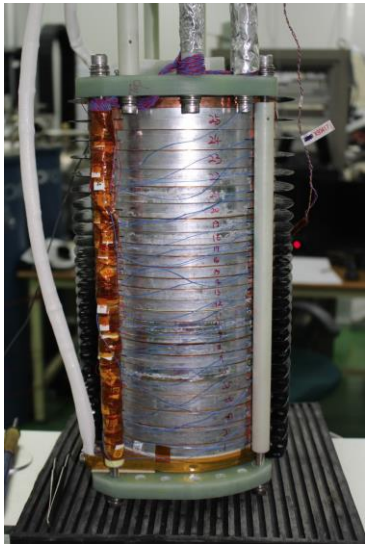



NATIONAL HIGH MAGNETIC FIELD LABORATORY



NATIONAL HIGH MAGNETIC FIELD LABORATORY

SUNAM



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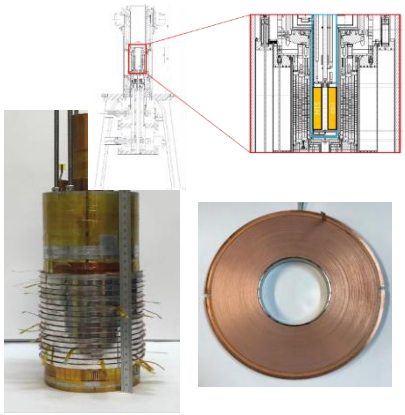
NÉEL institut CNRS

LNCMI

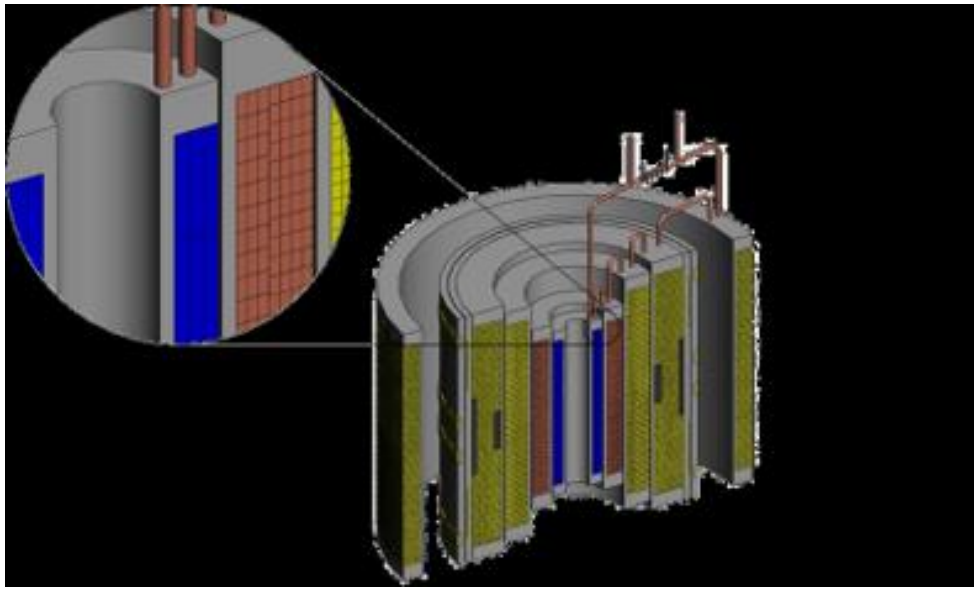


| NHMFL, USA | LBC3, NHMFL, USA | SUNAM, Korea | NOUGAT, CEA, France |
|---|---|---|---|
| 17 T (HTS) + *15 T (LTS)* **32 T** | 14.5 T (HTS) + *31 T (resistive)* **45.5 T** | **26.4 T** (HTS) | 12.5 T (HTS) + *20 T (res)* **32.5T** |
| Insulated magnet | No-Insulation (NI) | No-Insulation (NI) | Metal-as-Insulation (MI) |
| REBCO 4 mm, 4.2 K | REBCO 4 mm, 4.2 K | REBCO 4-8 mm, 4.2 K | REBCO 6 mm, 4.2 K |
| DI 40 mm | DI 14 mm | DI 35 mm | DI 50 mm |

# NMR COMMERCIAL MAGNETS


**Bruker ASCEND 1.2 GHz (28.2T – 54 mm warm bore)**

Strongest commercial NMR



Combination of LTS/HTS materials
Operating temperature of 1.9K

# 11.7T WHOLE BODY MRI MAGNETS



**Magnets manufactured by ASG - Italy**
**delivered at NIH (US) and at NRI (Korea) - On-going commissioning**

**Iseult - On-going commissioning**
**CEA Neurospin - France**

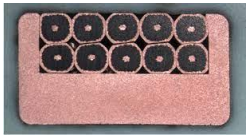
| | NIH/NRI | Iseult |
|---|---|---|
| Conductor | NbTi | NbTi |
| Current | 246A | 1483A |
| Inner diameter | 68 cm | 90 cm |
| OD | 2.6m | 5m |
| Length | 4m | 5m |
| Shielding | Passive | Active |
| Mass | 450 tons (380 tons of iron) | 132 tons |
| Temperature | 2.3K | 1.8K |

**NbTi is still a serious candidate for 1m ID bore / 10T**

# HIGH FIELD SOLENOIDS CHALLENGES

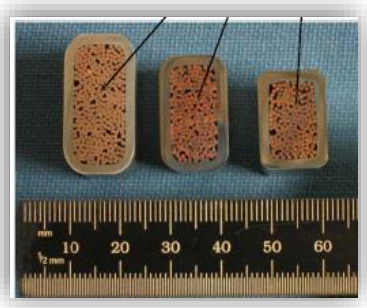
**Challenge #1** : mechanics (Laplace forces proportional to $B^2$)
Designs with B>20T are with a vertical field orientation.
**What about horizontal solenoids?**

- Conductor
  - Need of stabilized/reinforced NbTi/Nb3Sn conductors for large high field solenoids



Iseult WB 11,7T MRI
NbTi RIC

Hybrid magnet 45T
Grenoble
NbTi RCOCC



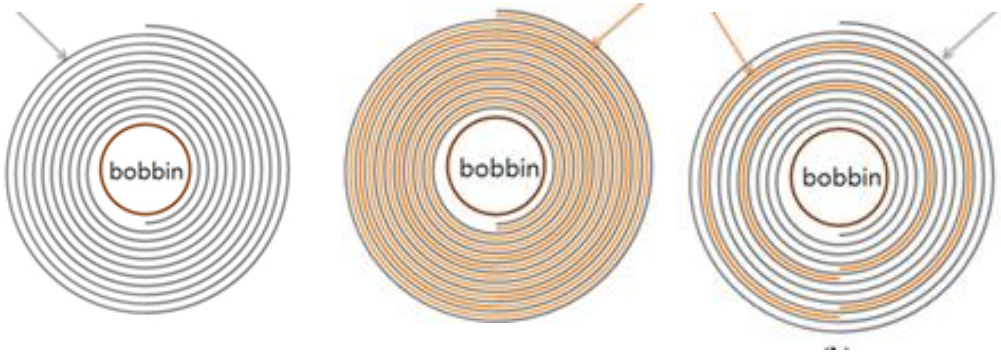

Hybrid magnet 45T
Nijmegen
Nb3Sn/Cu CICC

Hybrid magnet 45T – NHMFL
Nb3Sn/Cu CICC
(typical size 3 x 1.5 cm)

# HIGH FIELD SOLENOIDS CHALLENGES

**HTS Solenoid specific challenges**

- Protection (insulated / NI / MI / PI)

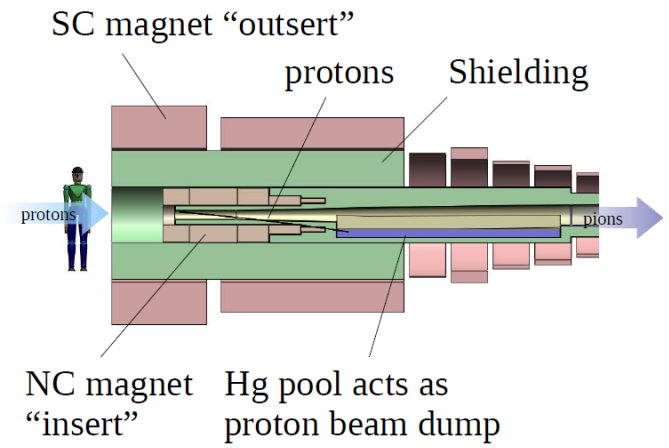



- Field homogeneity due to screening currents (overshoot and vortex shaking technics)

- Cryogenics
  - Cooling of the core part (use of thermal drains…)
  - Less efficient cooling due to the magnetic forces acting on helium (diamagnetism)

# MUON COLLIDER SOLENOIDS

## Target end solenoid



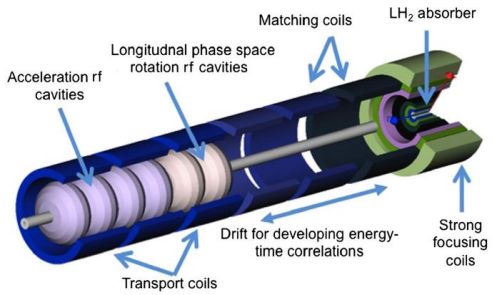

Hybrid design
(superconducting + conventionnal magnets)

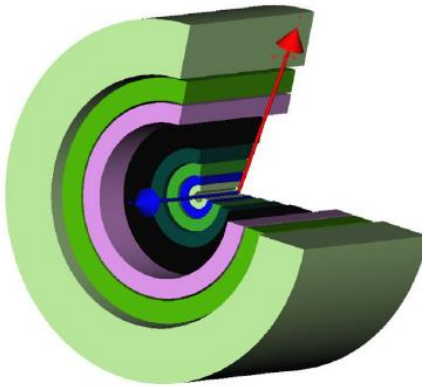
Target field from 15T to 20T, SC coil inner diameter up to 1.2m

## Cooling solenoids

Need of high field and very high field solenoids, as short as possible

>30T, SC coil inner diameter of 50mm for the final cooling



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**Thank you for your attention**