The INFN research program on MgB_2

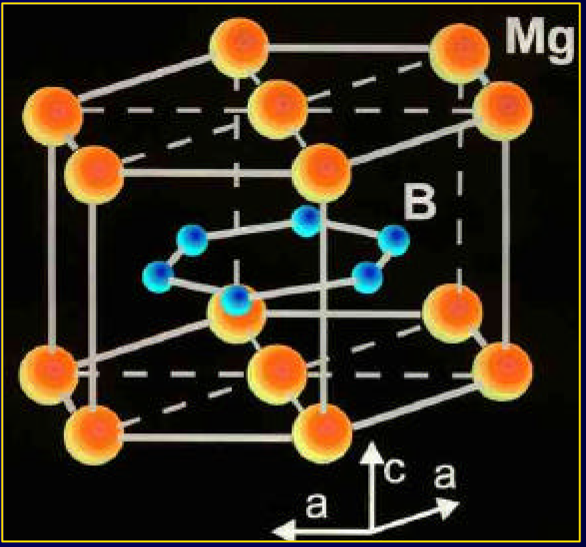
Application of magnesium diboride to particle physics

Riccardo Musenich

Istituto Nazionale di Fisica Nucleare

Genova, Italy

MgB_2



T_c = 39 K

J.Nagamatsu, N.Nakagawa, T.Muranaka, Y.Zenitani, J.Akimitsu

Nature 410 63 (2001)

The material characteristics seems favourable for technological applications:

- high critical temperature (39 K)
- $B_{c2} > 15$ T
- no weak links
- low anisotropy
- high critical current density ($J_c \approx 5 \cdot 10^9 A/m^2$ a 20 K e 0 T)
- low cost

Possible applications

Bulk MgB_2 ⇓ Magnets

Thin MgB_2 films ⇓

- Resonant cavities
- SQUIDs
- Detectors

Thanks to the know-how and the technologies developed for the production of HTCS conductors, few month after the discovery of the superconducting properties of MgB_2, wires and tapes became available in several meter lengths.

production technique of magnesium diboride conductors:

Powder in tubes (PIT) $\left\{ \begin{array}{l} \text{in situ} \\ \\ \text{ex situ} \end{array} \right.$

Like Nb_3Sn, MgB_2 requires a high temperature heat treatment to achieve good transport properties. Two routes can be followed to construct a magnet:

REACT & WIND

WIND & REACT

Thin films can be deposited using several techniques:

- Sputtering
  - from MgB_2 cathode
  - from precursor cathodes
  - reactive sputtering
- Evaporation
- Laser ablation
- CVD

MgB_2

Research programs on MgB_2 in Italy

Research (mainly fundamental) with ordinary funds (CNR, INFM, Universities)

Industrial R&D (Ansaldo Superconduttori, Columbus Superconductors, Edison, Europa Metalli, Pirelli)

INFN (Ma-Bo project) 2002-2004

MIUR funded project 2004-2006

Ma-Bo

the INFN program (2002-2004) on magnesium diboride applications to nuclear and particle physics

Genova

Frascati National Laboratories

Legnaro National Laboratories

Milano

Napoli

Torino

30 people involved (about 10 FTE).

Ma-Bo is in collabotation with:

ENEA

INFM

Ansaldo Superconduttori

Columbus Superconductors

Ma-Bo

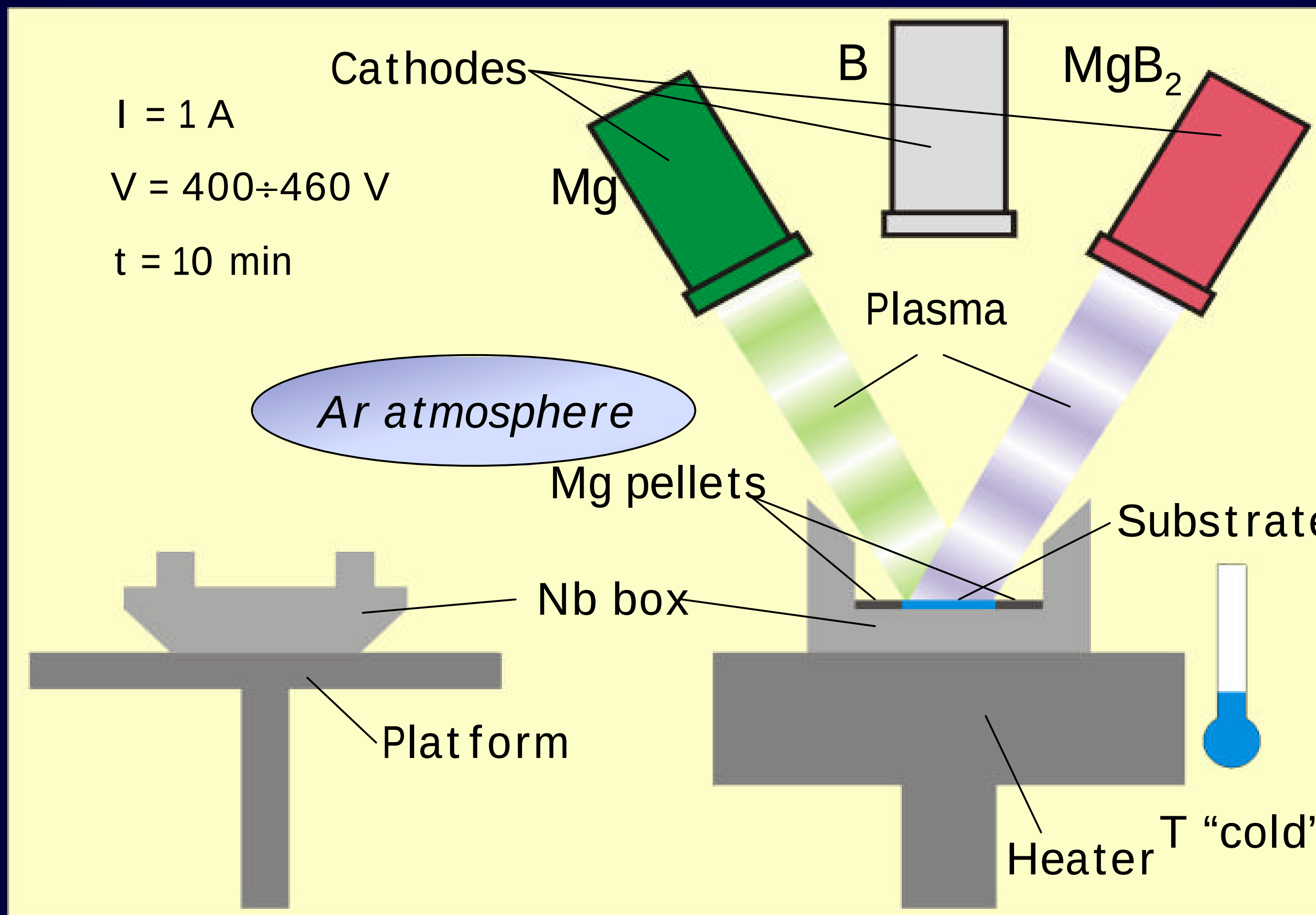
The research project Ma-Bo aims to understand if magnesium diboride could be used for particle physics applications. The research activities are related to:

Magnets

Thin films for cavities

Thin films for detectors and other devices

Thin films

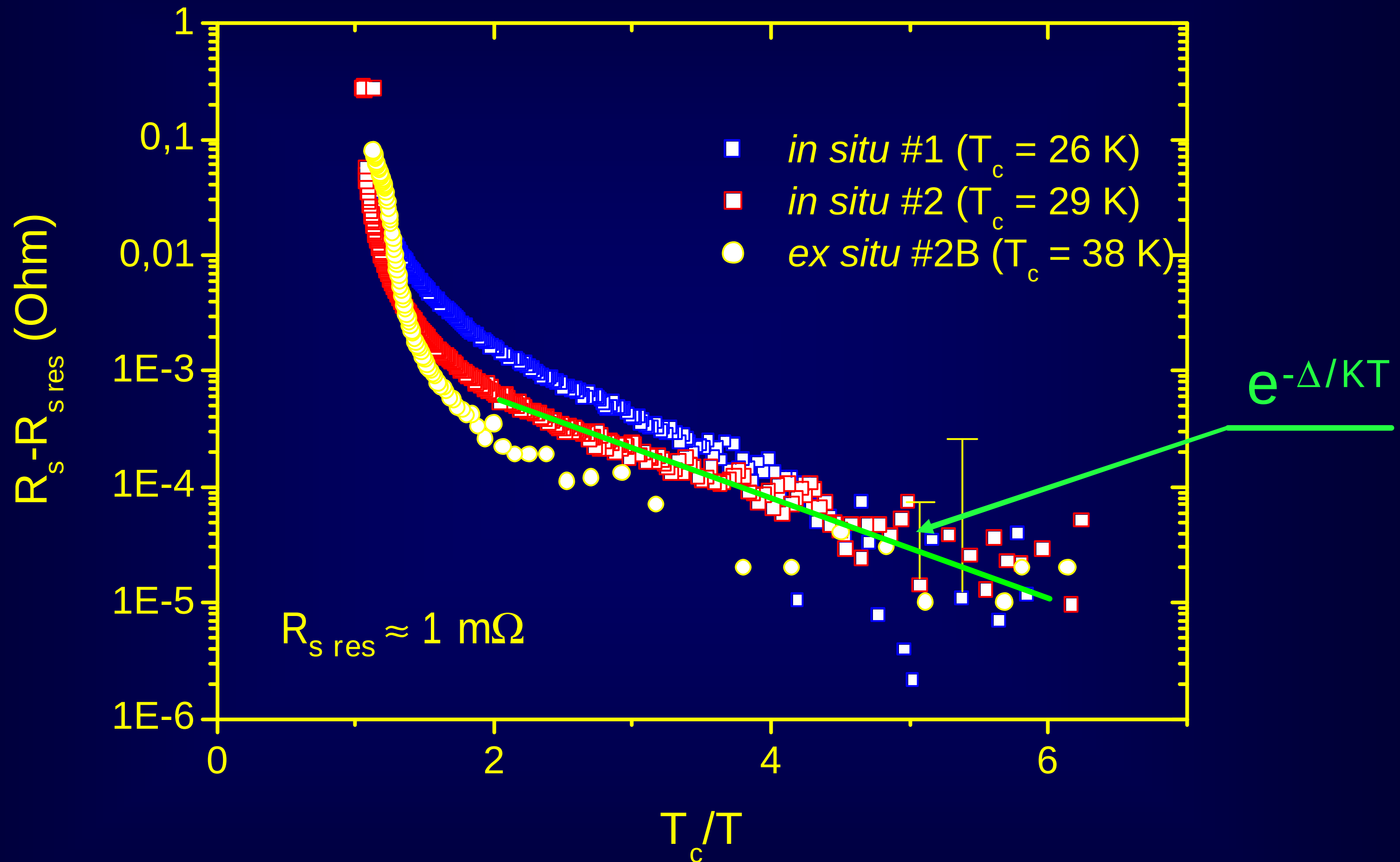

Cathodes
B
MgB_2
I = 1 A
V = 400÷460 V
t = 10 min
Mg
Plasma
Ar atmosphere
Mg pellets
Substrate
Nb box
Platform
T "cold"
Heater

Problems in using MgB_2 for rf resonant cavities:

- MgB_2 is a double gap superconductor
- A homogeneous, pure (single phase) film must be deposited onto large area substrates
- The material is chemically instable (exposed to the atmosphere)

radio-frequency applications

f = 20 GHz



R.Vaglio, INFN and University of Naples

radio-frequency applications

$R_S = R_{BCS} + R_{RES}$

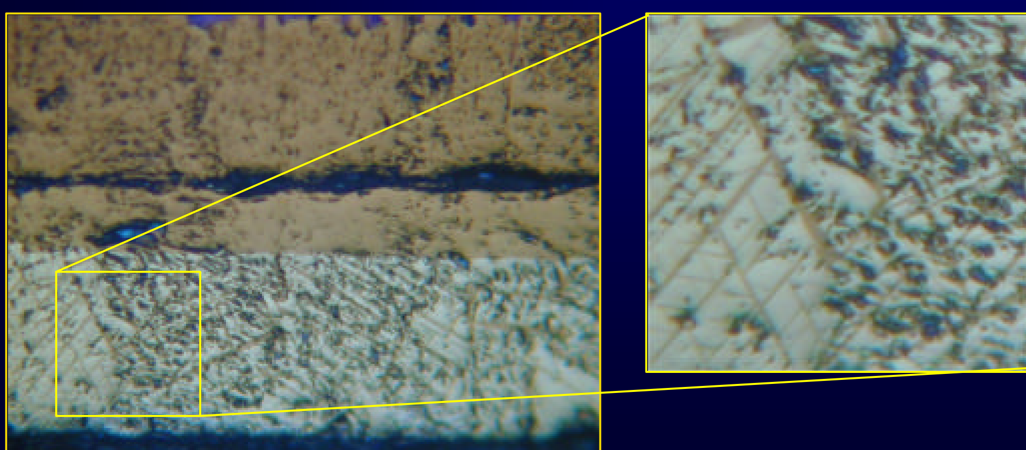
$$R_{BCS} \propto \frac{\sqrt{r_n}}{T} e^{-\frac{\Delta}{k_B T_C}\frac{T_C}{T}}$$

Pb

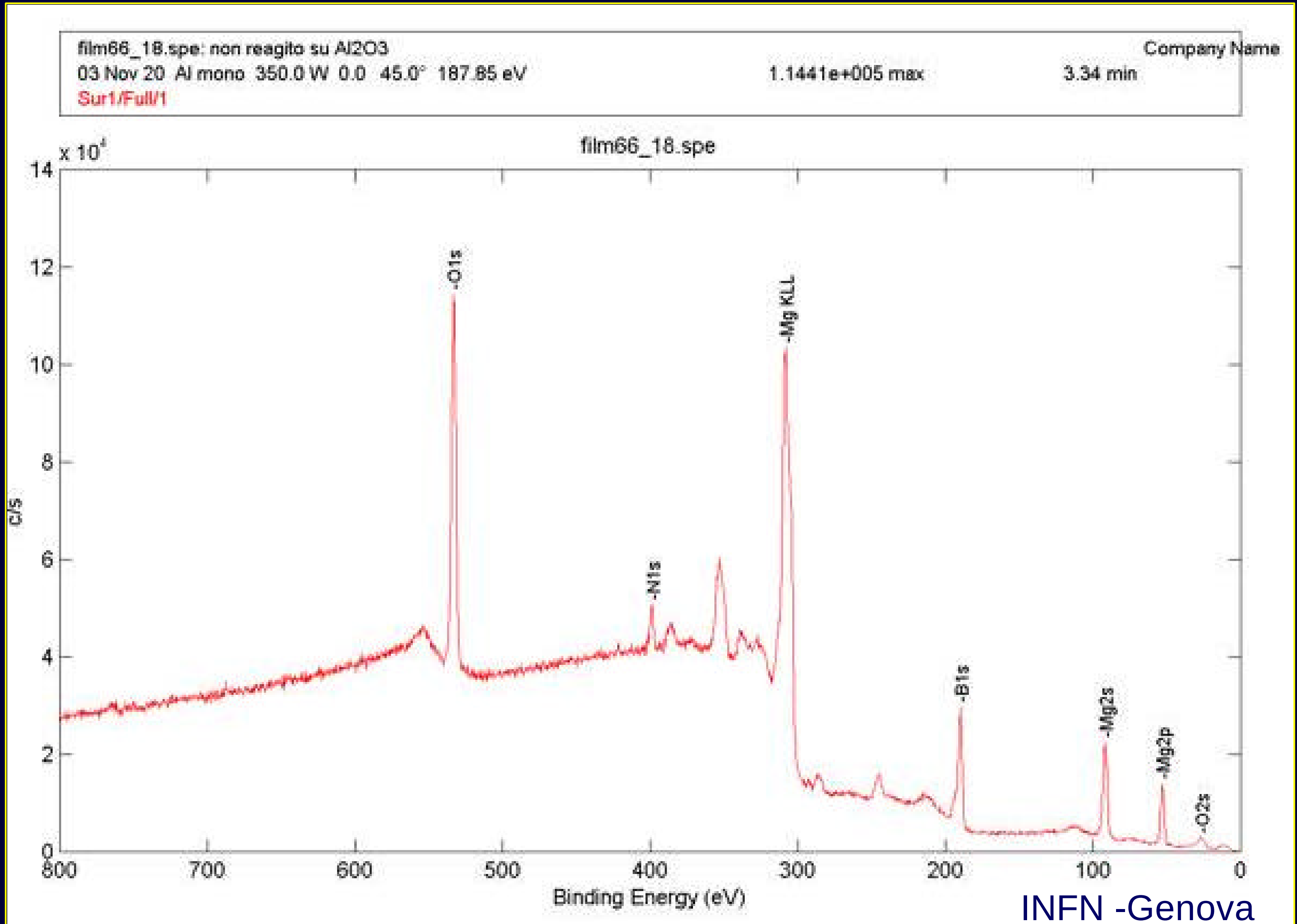
Nb

other material

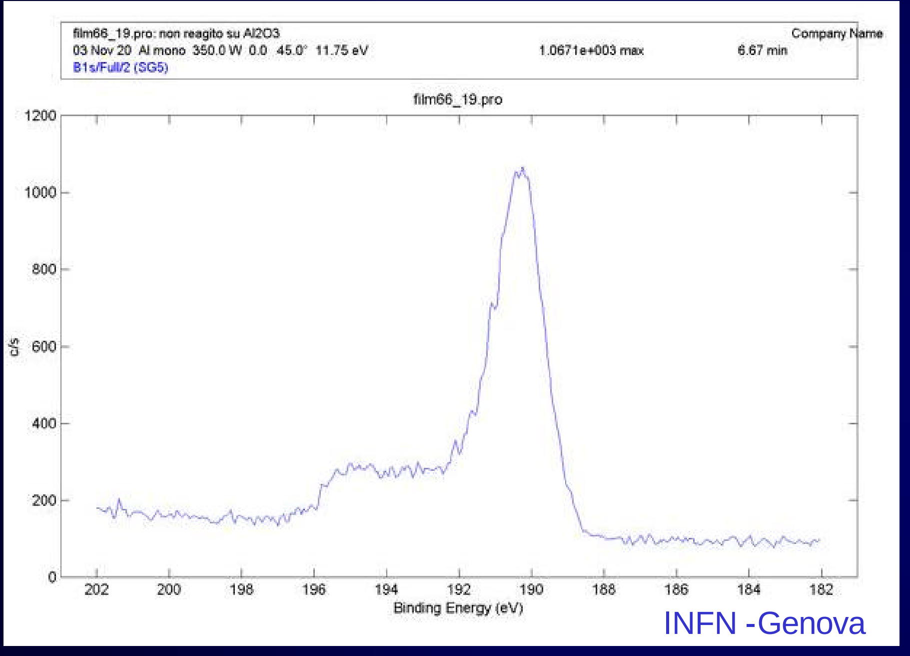
(NbN, Nb_3Sn ...)

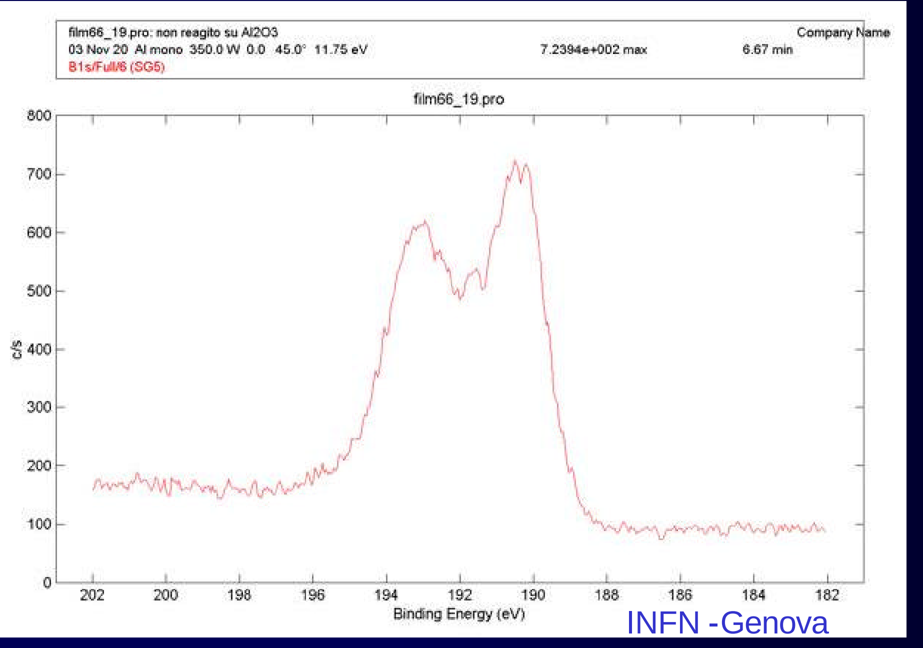


Niobium nitride

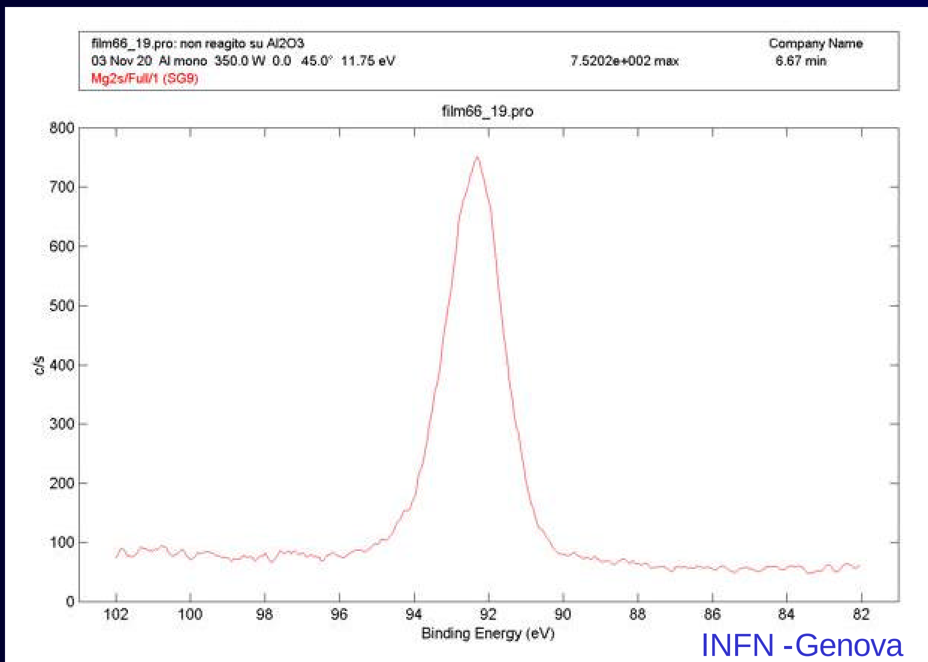


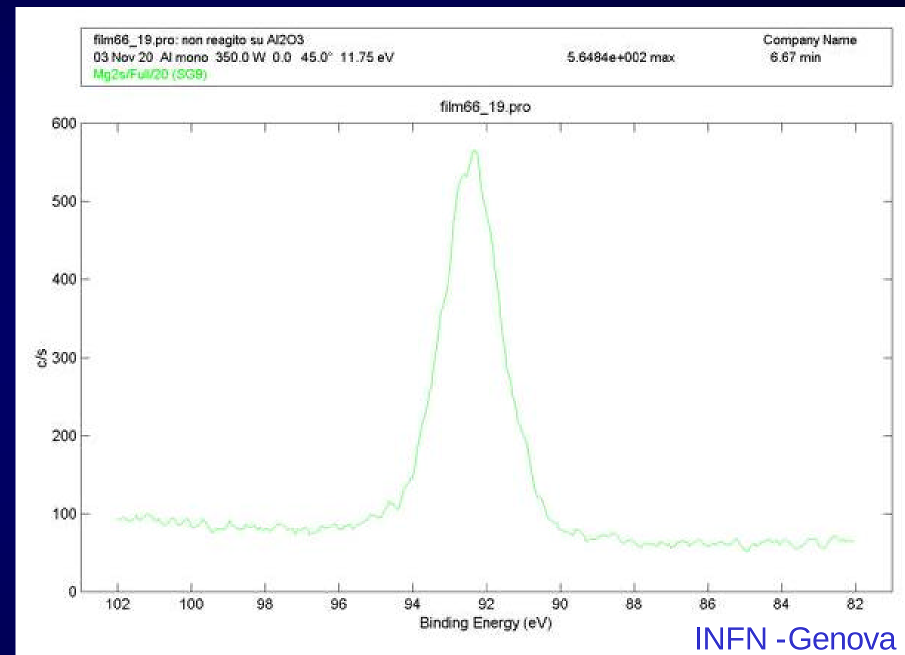
XPS spectrum of a MgB_2 film





XPS spectrum of a MgB_2 film (B 1s)





XPS spectrum of a MgB_2 film (Mg 2s)

MgB_2 as particle detector

Low activation energy

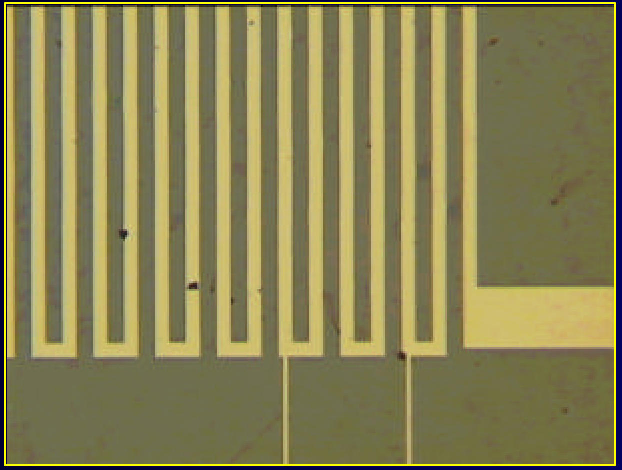
Good radiation hardness

High thermal conductivity

short recovery time (~ps)

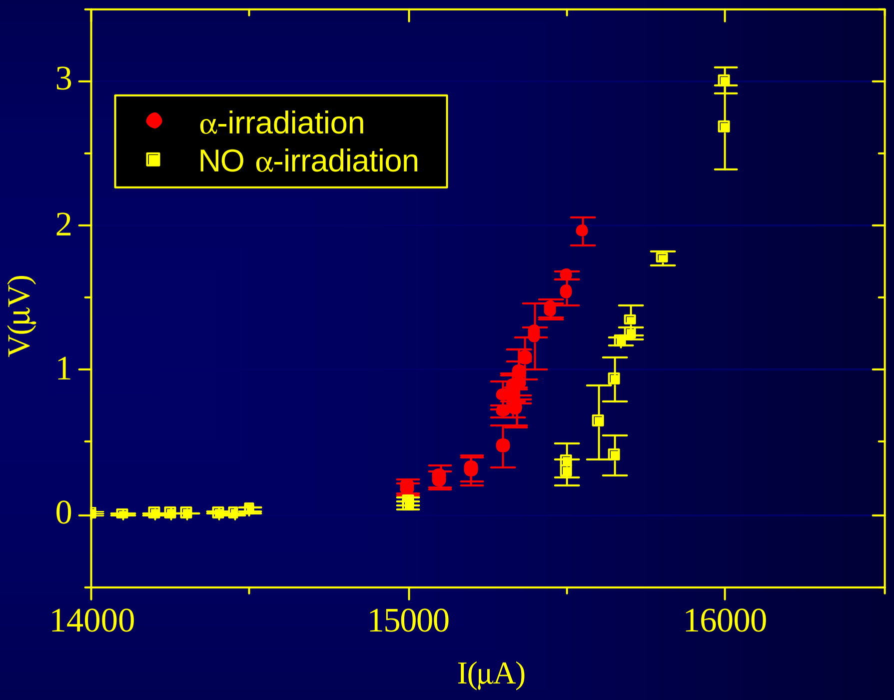
Possible use as neutron detector

Microstrip detectors



$W_{strip} = 20\ \mu m$

Sample 2 - T=23.0 K



Critical radius ≈ 3 μm

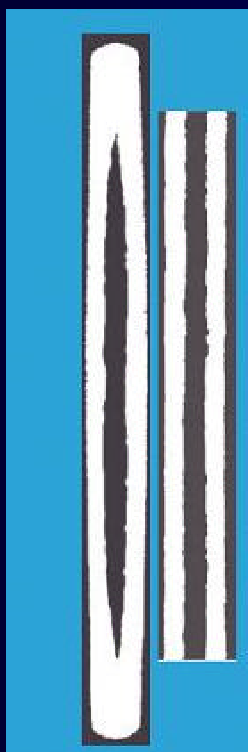
$T_c = 25.2$ K

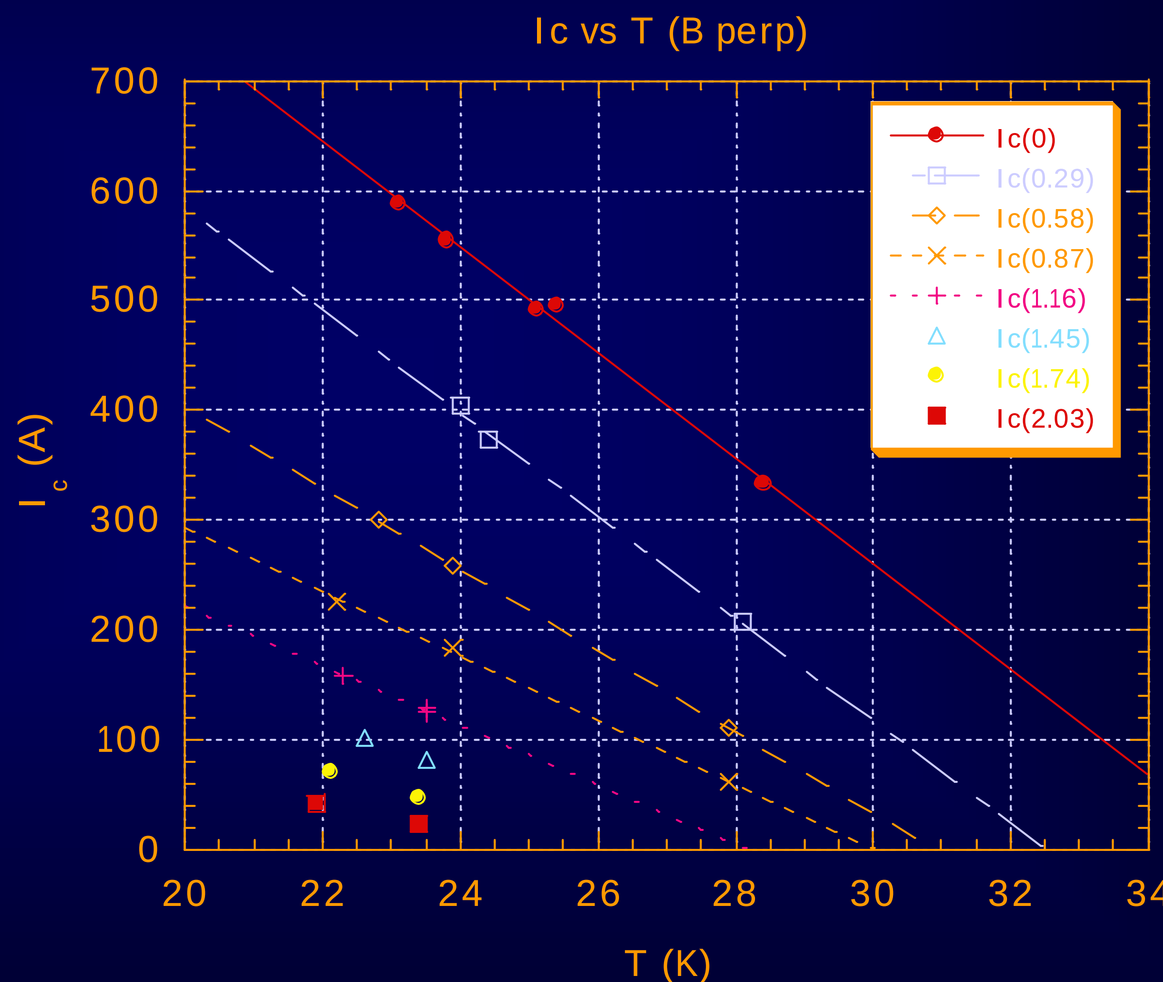
E.Monticone, INFN and IEN Turin

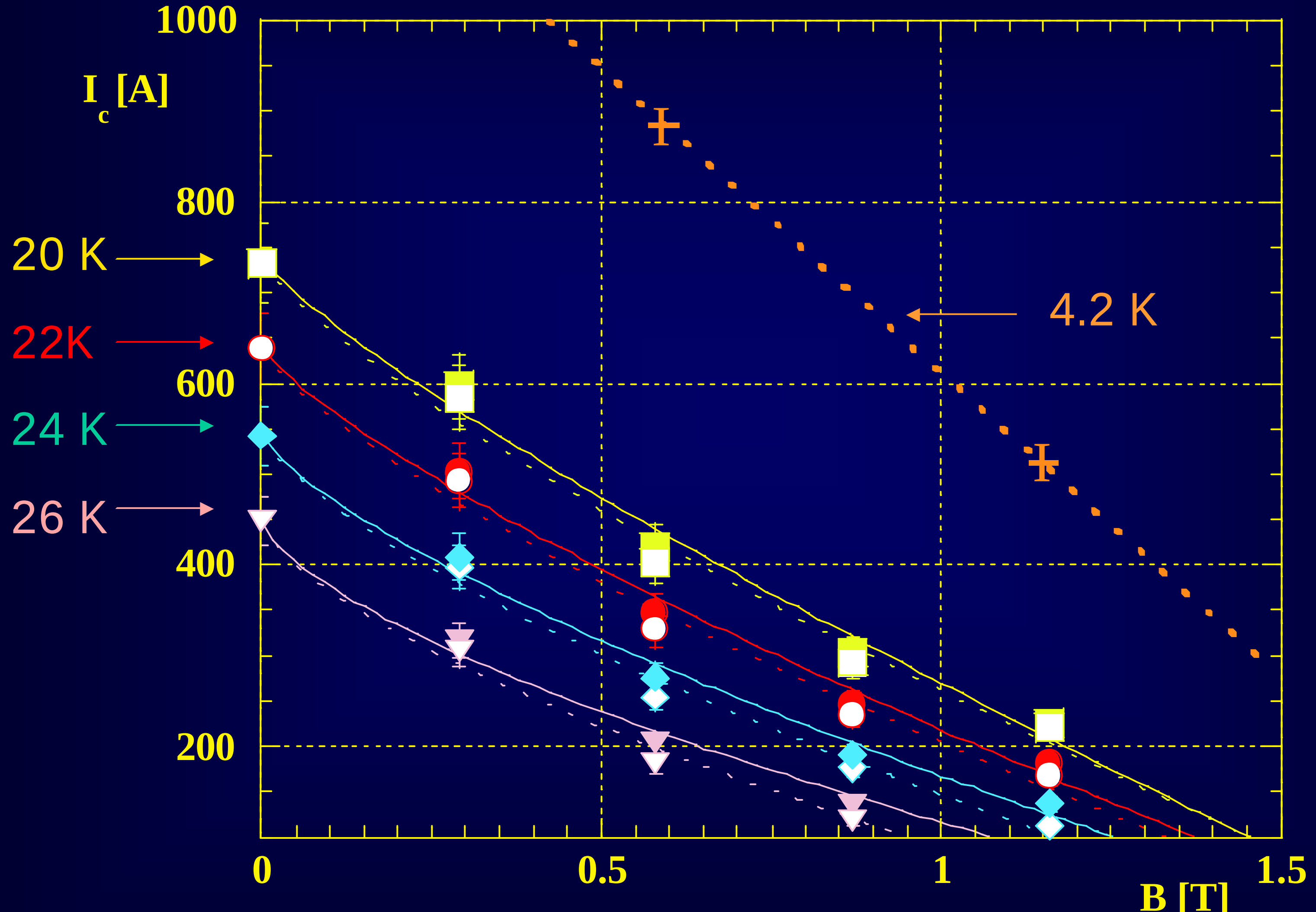
M.Truccato, INFN and University of Turin

Conductors for magnets

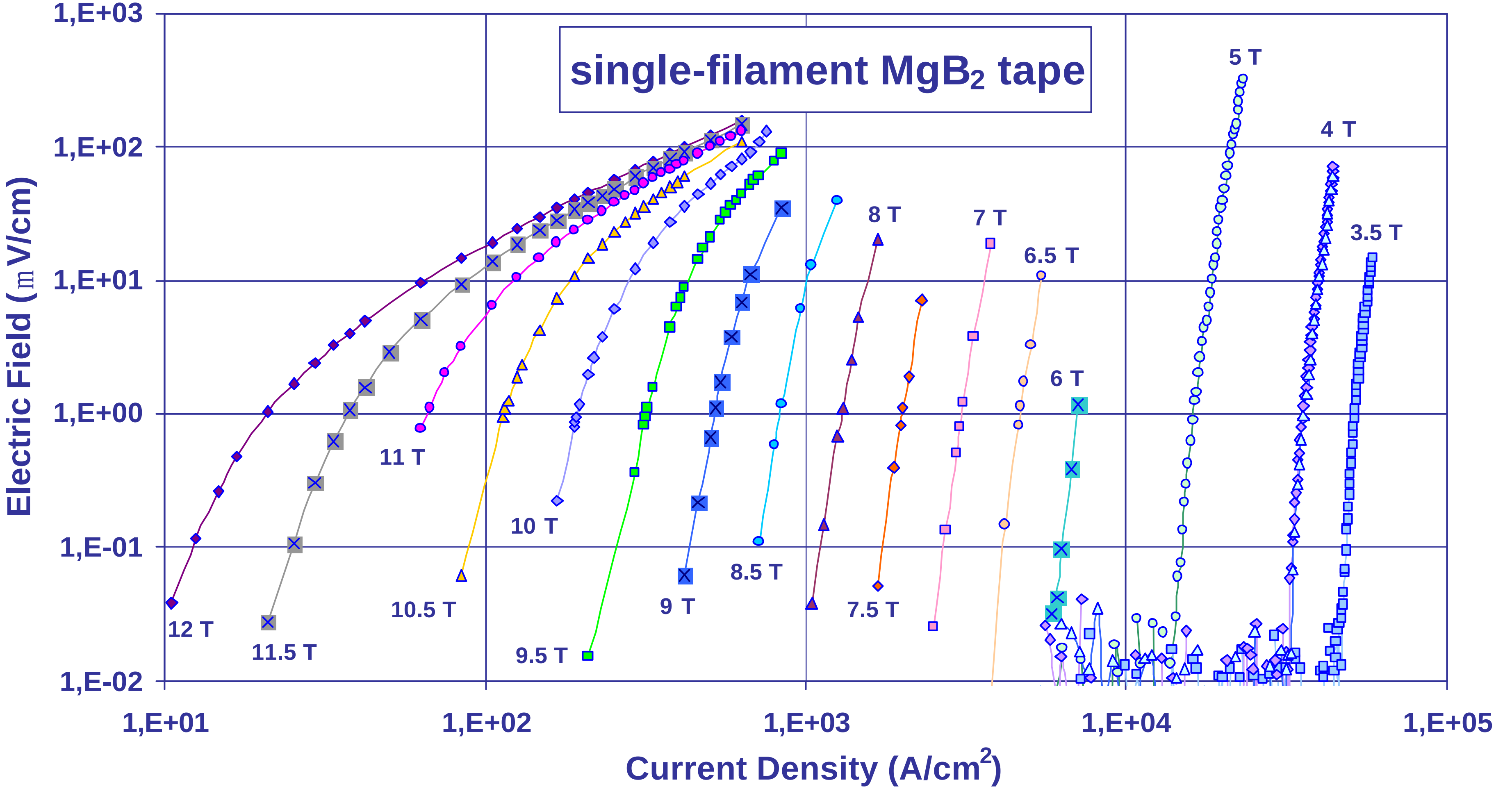
3.5 mm x 0.3 mm
SC fill factor
15-20%







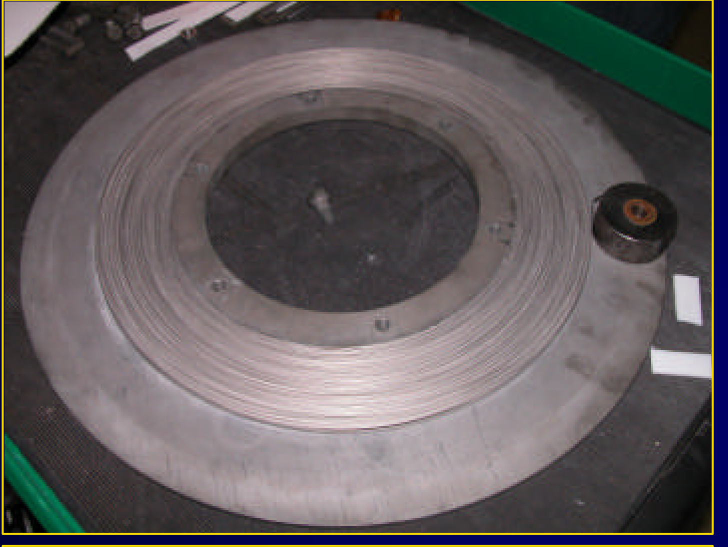
1000
800
600
400
200
I_c [A]
20 K
22K
24 K
26 K
4.2 K
0
0.5
1
1.5
B [T]



INFN Milano lab. LASA

Chiara Bracco, Danilo Pedrini, Valentina Previtali, Giovanni Volpini

MgB_2 “React&Wind” solenoid wound by Ansaldo Superconduttori with 80 m long INFM/Columbus tape



React & wind technique

6 layers

27 turns/layer

Diameter = 15 cm

B = 1.35 mT/A,

(coil center)

B = 2.15 mT/A

(B_{MAX} at the conductor)

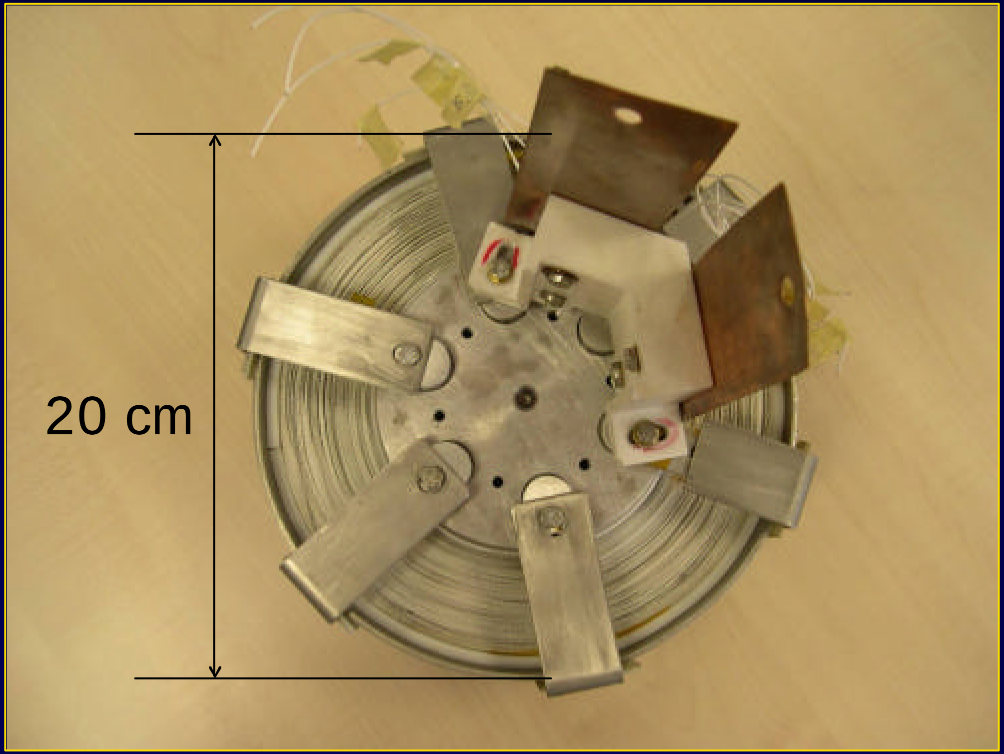
Solenoid test in liquid helium bath

Superconducting for most of the length

No resistance observed at the layer joggle

Localized dissipation at the inner electrical exit

Despite the localizad dissipation (4 W at 47 A) the solenoid was able to carry 53 A before quenching (11 mT at the conductor, 6 mT at coil center)



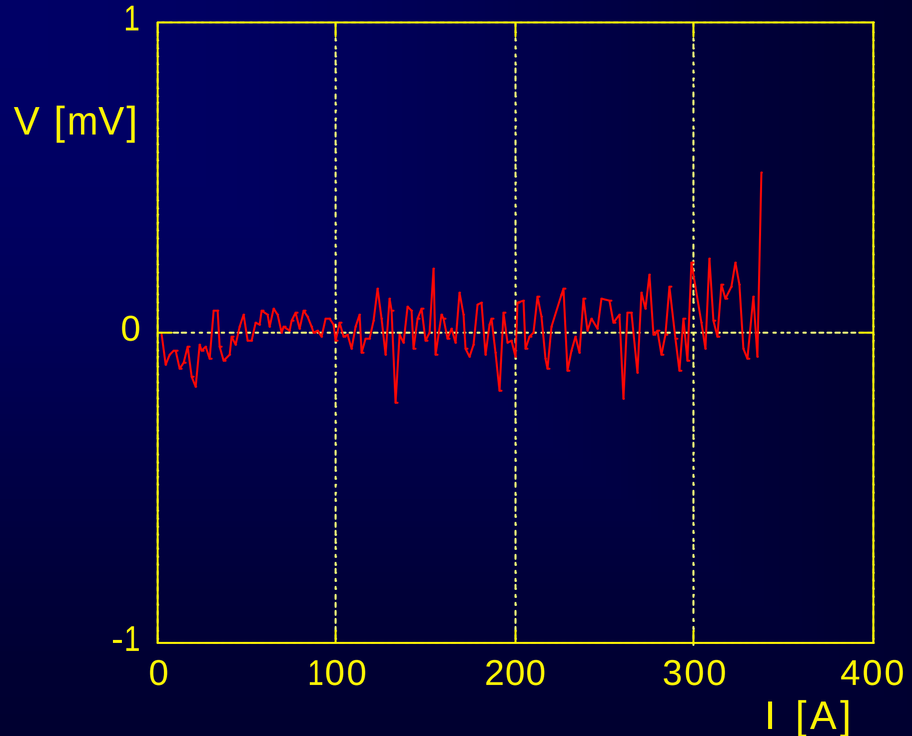
Pancake coil wound by Ansaldo Superconduttori with 40 m tape (INFM/Columbus Superconductors)

Test of the pancake coils
in liquid helium bath

With the exclusion of #5 and #6, the pancakes were fully superconducting. The higher current was reached by #8:

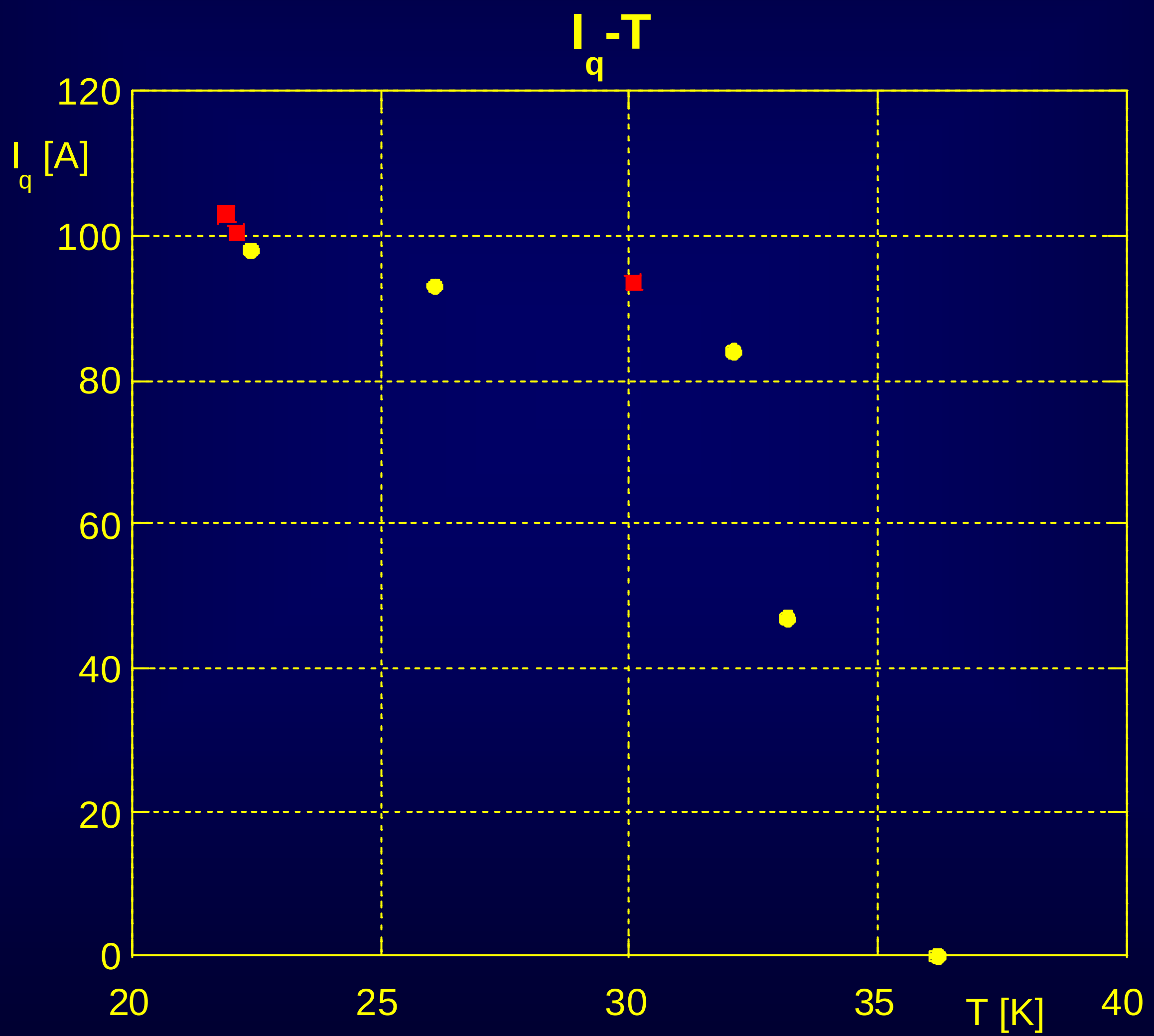
I_q=343 A

(B_{MAX}=0.76 T, B_C= 0.21 T)



Test of pancake coil #10

with cryocoolers



Several problems must be solved but

the feasibility of MgB_2 magnets

is clearly demonstrated

CONCLUSIONS

(Perspective for MgB_2 in nuclear and subnuclear physics)

☹ Till now, neither MgB_2 nor other superconducting materials can compete with niobium for application in accelerating cavities.

😐 Magnesium diboride seems a possible candidate as material for radiation microstrip detectors.

☺ Magnesium diboride is a promising material for the construction of accelerator magnets.