Athmospheric Surface Treatments for improving 6Ghz Niobium cavities

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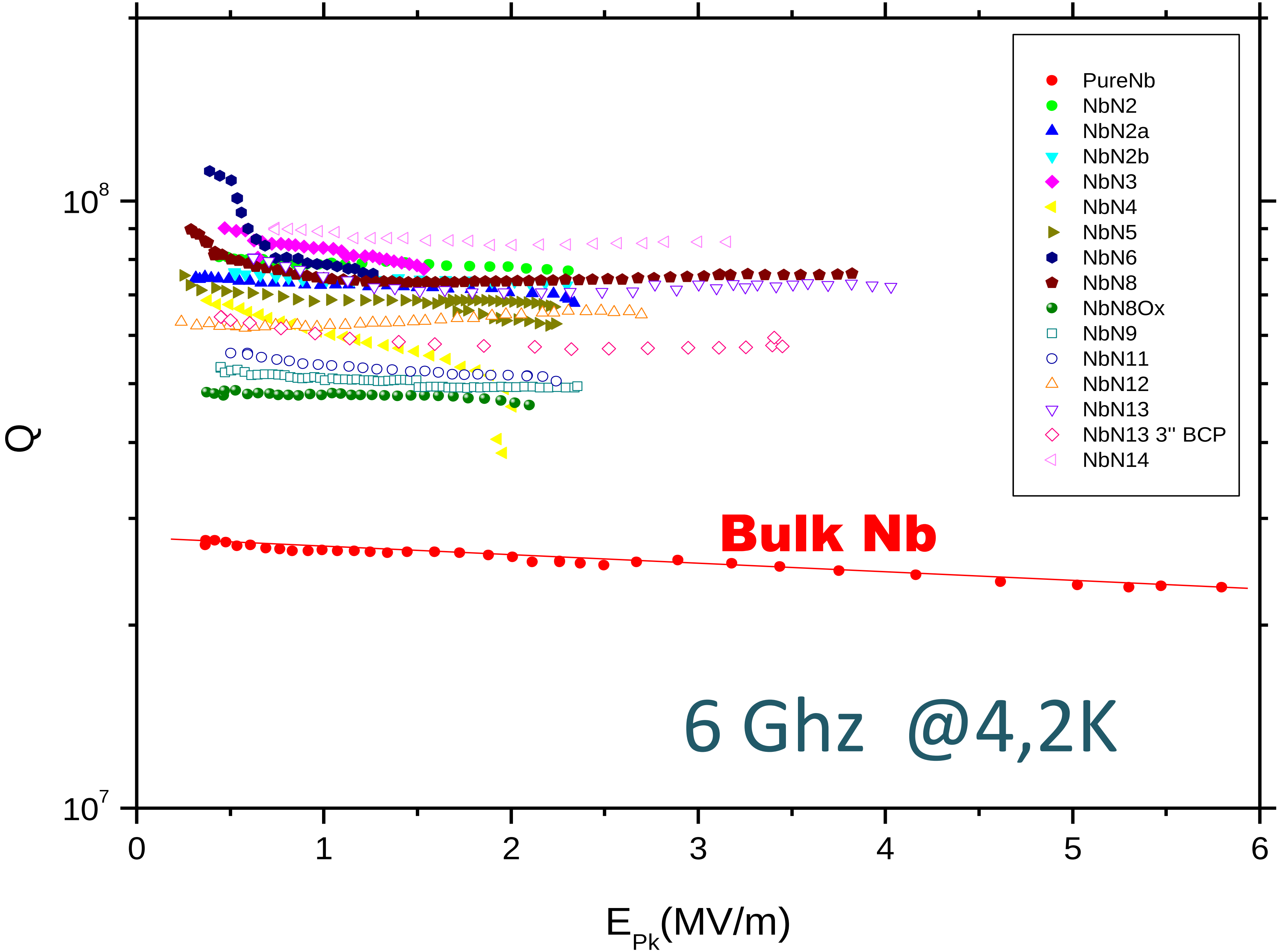
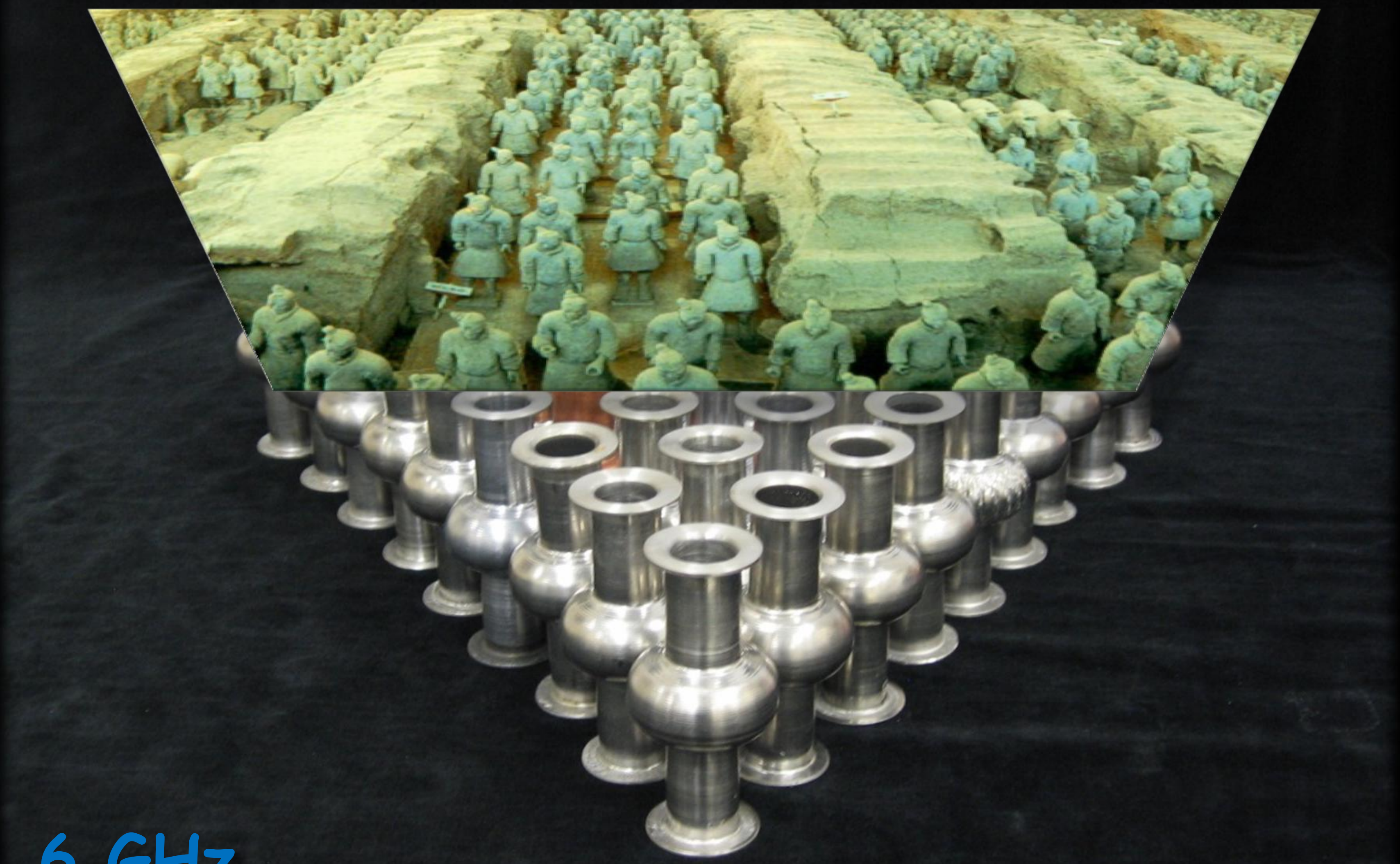


PureNb
NbN2
NbN2a
NbN2b
NbN3
NbN4
NbN5
NbN6
NbN8
NbN8Ox
NbN9
NbN11
NbN12
NbN13
NbN13 3'' BCP
NbN14
Bulk Nb
6 Ghz @4,2K
Q
10^8
10^7
0
1
2
3
4
5
6
E_{Pk}(MV/m)

Low research budget → Large amount of cavities



6 GHz

Samples	Pillbox cavities, etc	Real cavities
Resistive	Calorimetric methods	6 GHz cavities
Inductive	R_S Differential measurements	1,5 /1,3 GHz monocells
H_{c1} Measurement	Microstrip Resonators	1,3 GHz 3-cell cavity
		1,3 GHz 9-cell cavities

R.F. CHARACTERIZATION OF SMALL SCALE CAVITIES

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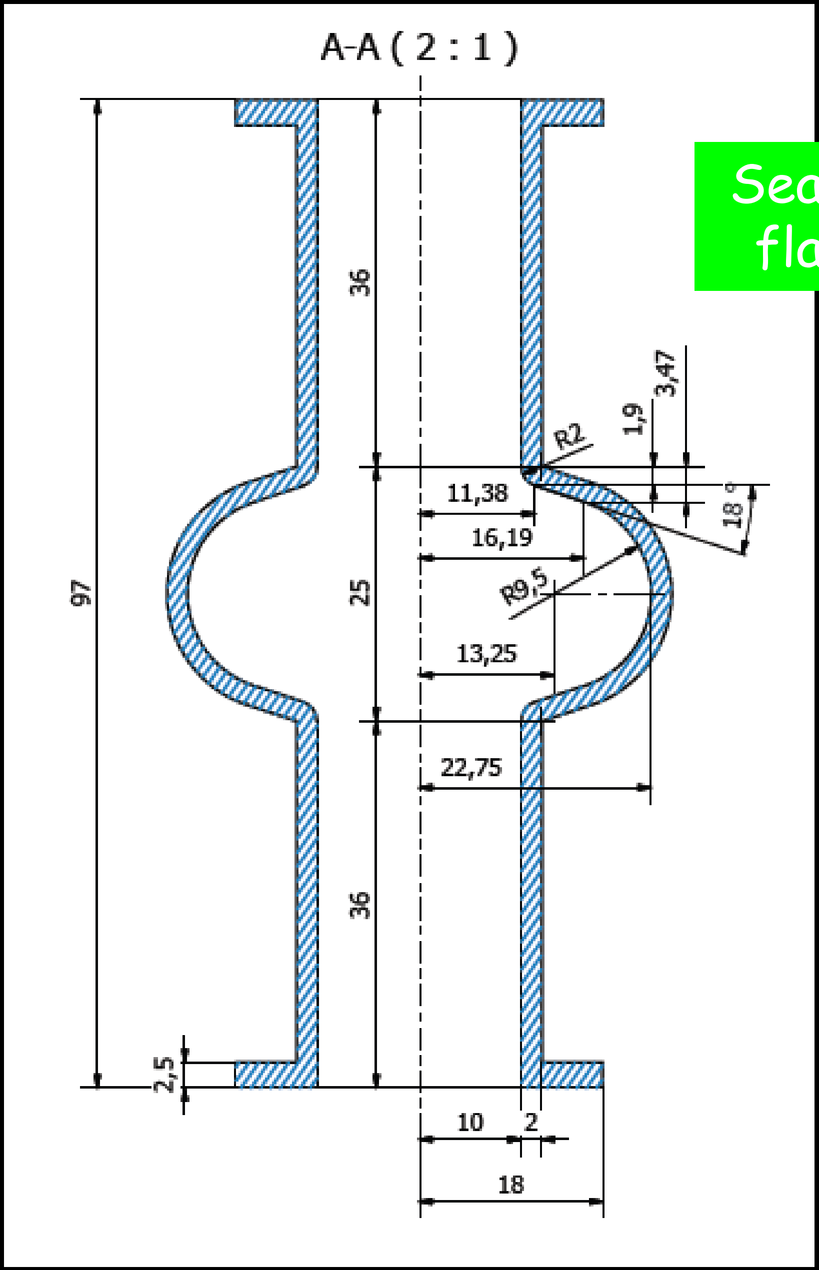
Abstract — The R.F. characterization of samples is an useful diagnostic tool to accurately investigate local properties of superconducting materials. However the most common limitation of systems used for this, consists often in the difficulty of scaling the measured results to the real resonator. The most direct way for measuring material R.F. properties would be the use of micro-cavities completely equal in shape to the real scale model. Using the spinning technique, it becomes feasible to produce small scale resonators in little time, negligible cost and in large quantity. Therefore we provided 6 GHz cavities and developed a suitable R.F. test "plug and measure" bench. The emphasis is placed on the cryogenic and R.F. facilities as well as the first results obtained on bulk Niobium spun cavities.

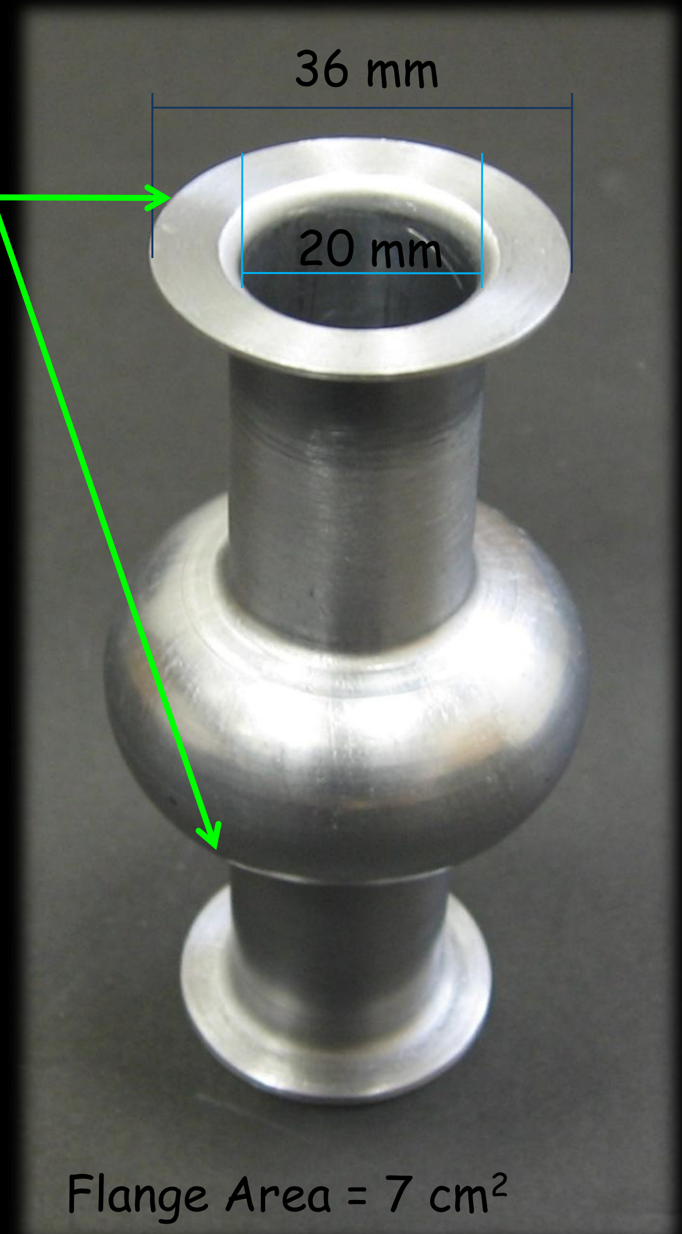

Antonio$_3$ Rossi

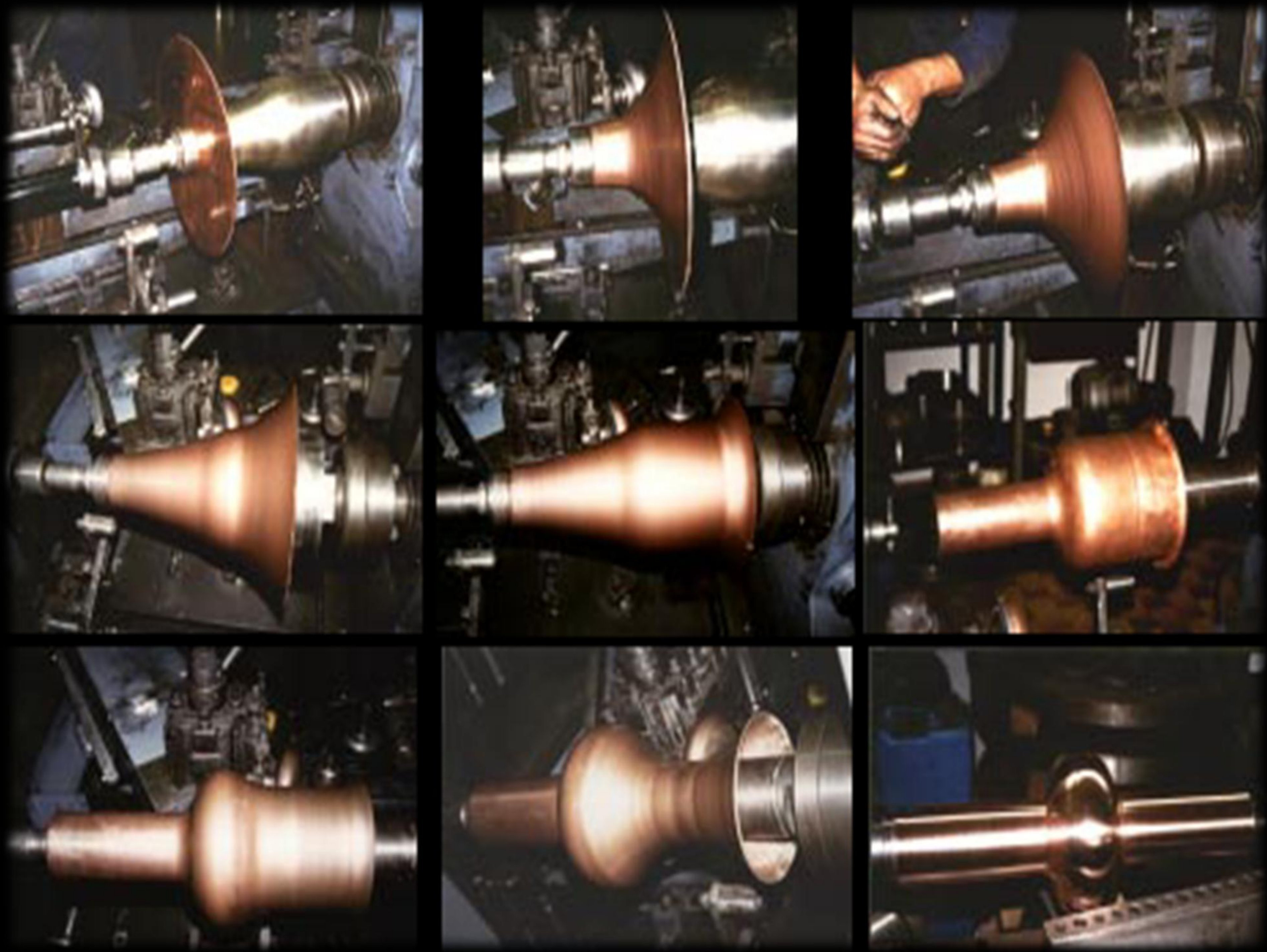
6 GHz CAVITY MINILAB

- No electron beam welding, neither for flanges
- Obtained by spinning from Nb scraps
  - Short fabrication time
  - Fast and low cost BCP and EP treatments
  - Inexpensive Cryogenics
    - Quick RF Measurements

6 Ghz Cavity Geometry

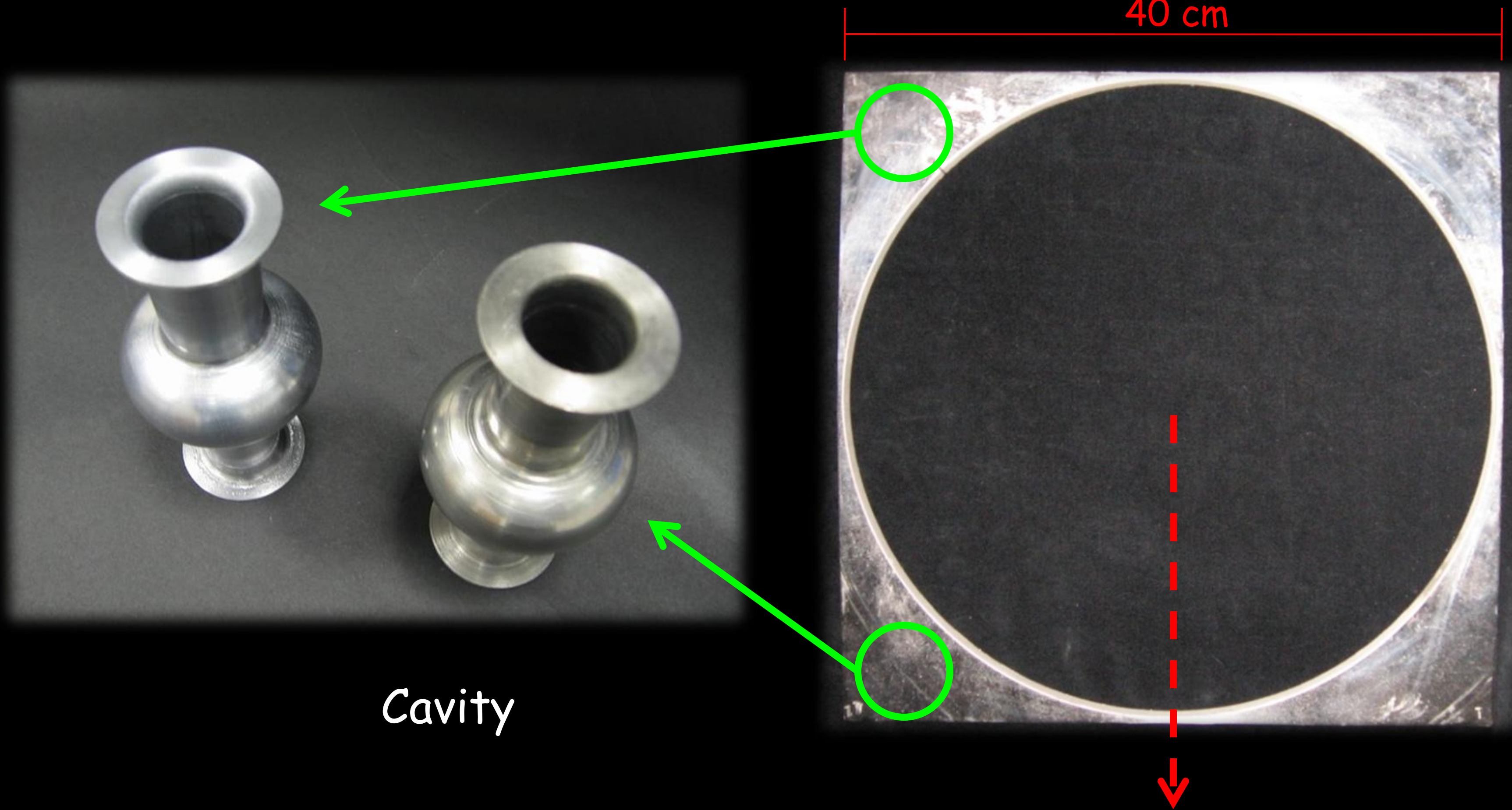






Cavity fabrication

- By Spinning from

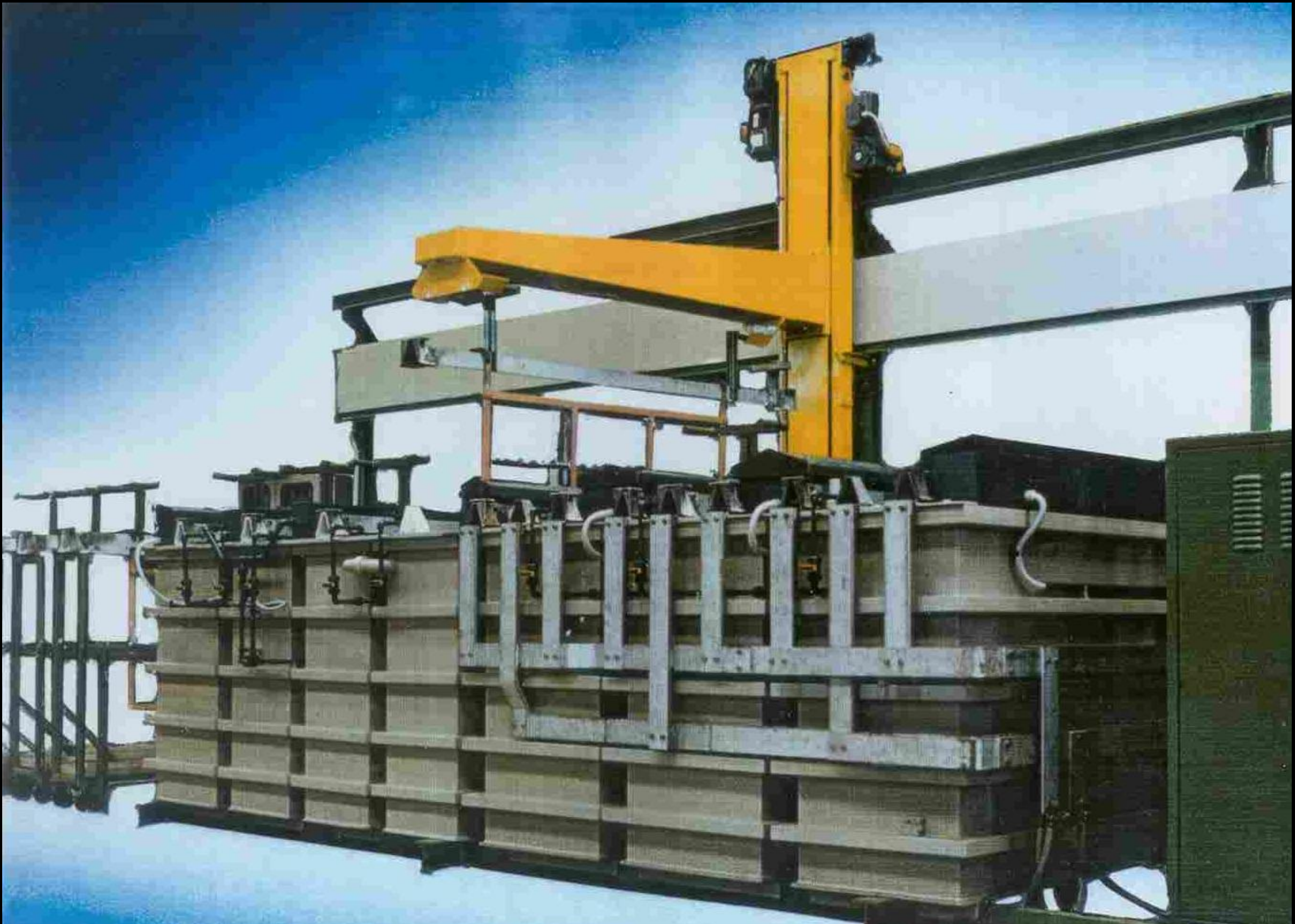


Cavity

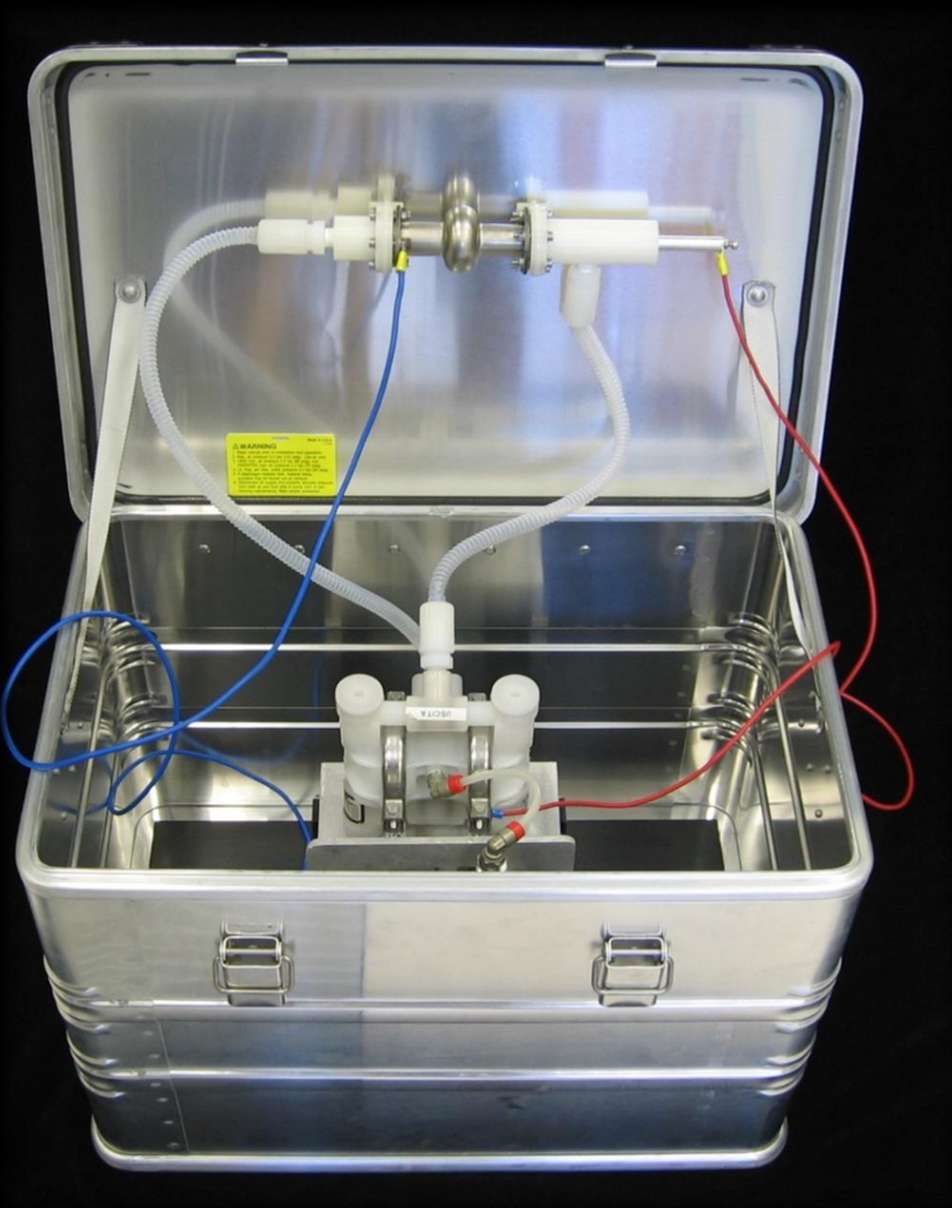
Cavity

Mini Mechanical Tumbling

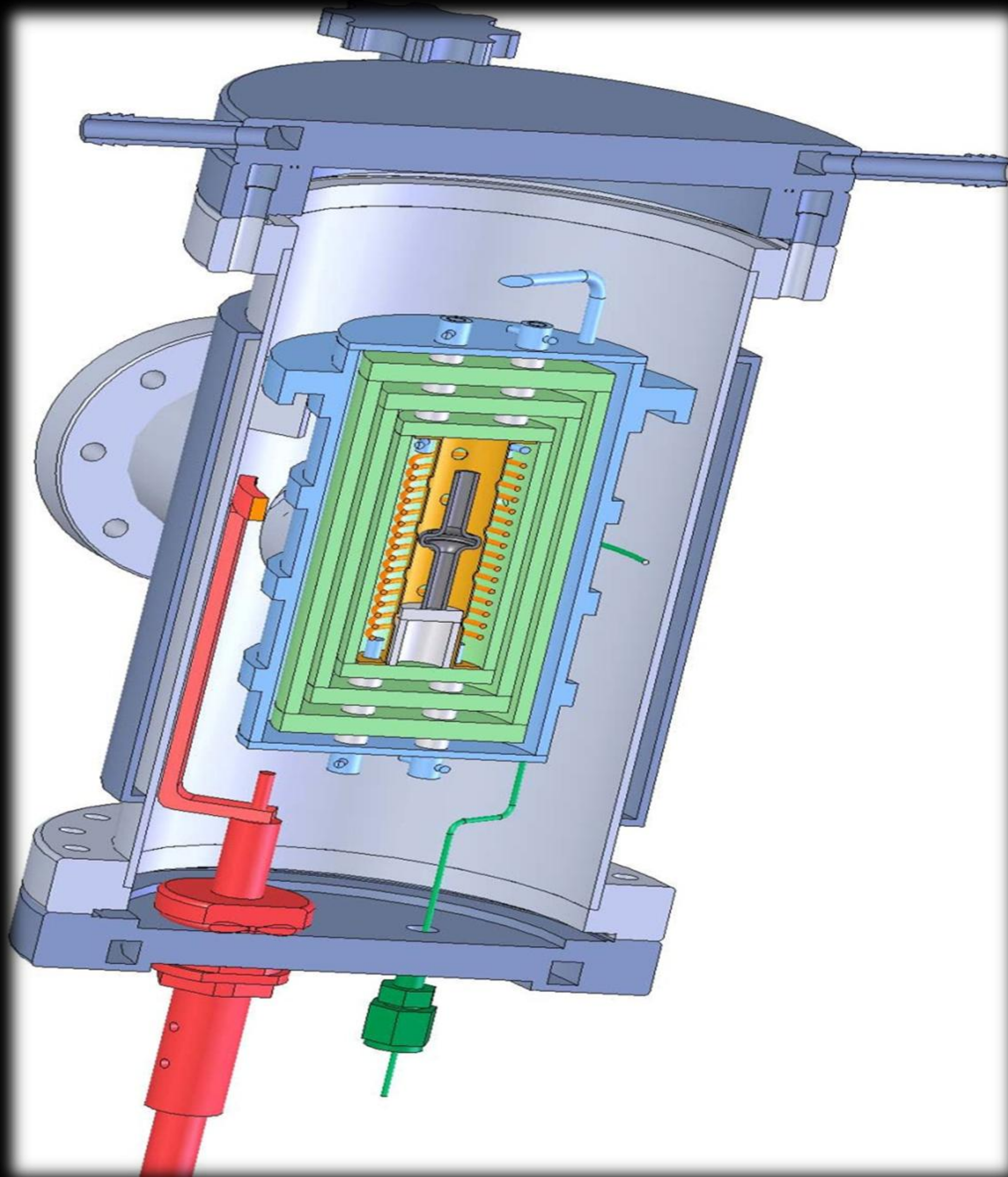
Mini EP



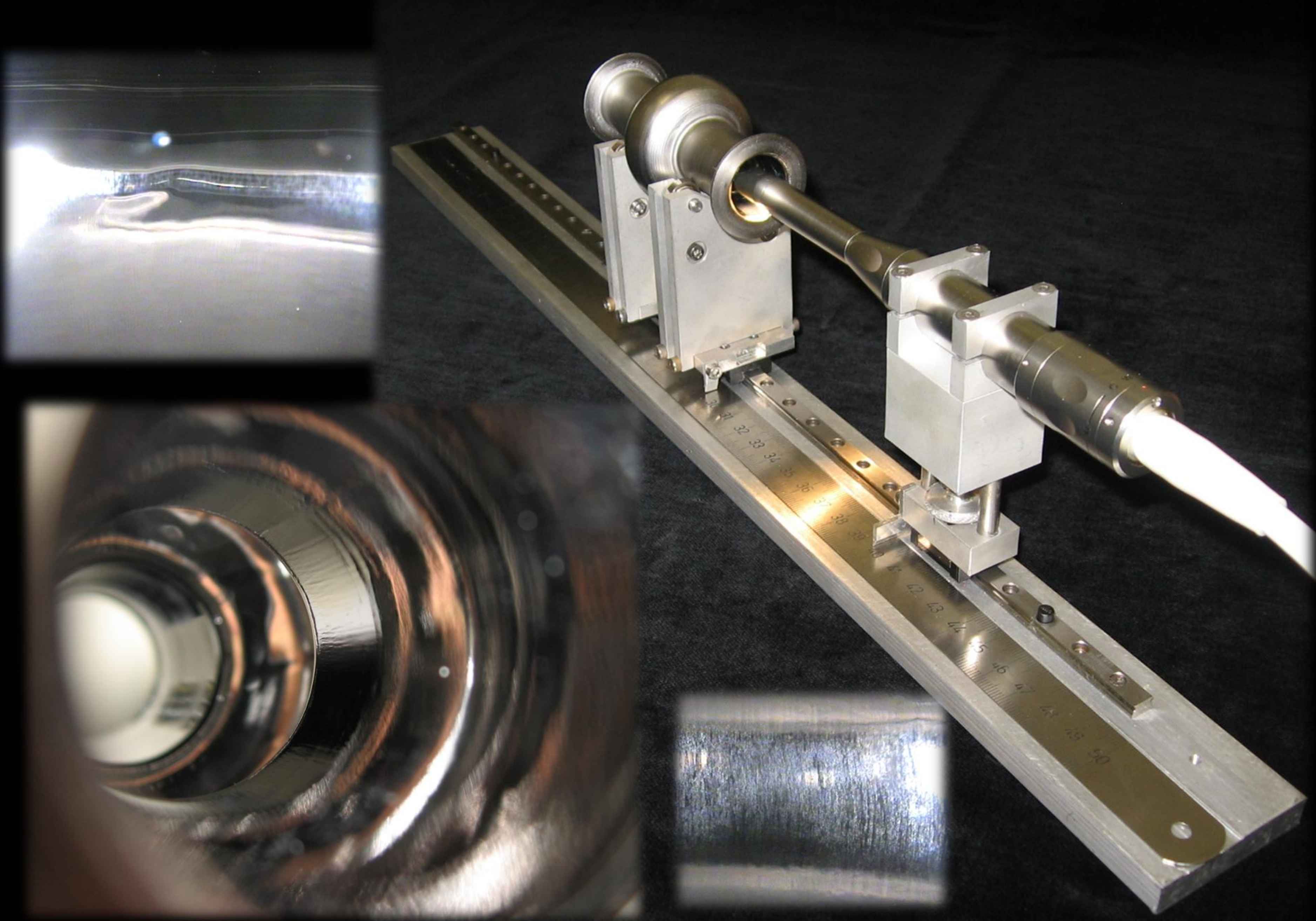
A Mini – BCP / EP Lab



6 GHz CAVITY MINI-furnace



6 GHz CAVITY MINI-Camera



Ready for the RF measurement

6 GHz CAVITY: MINI-Kapton gasket

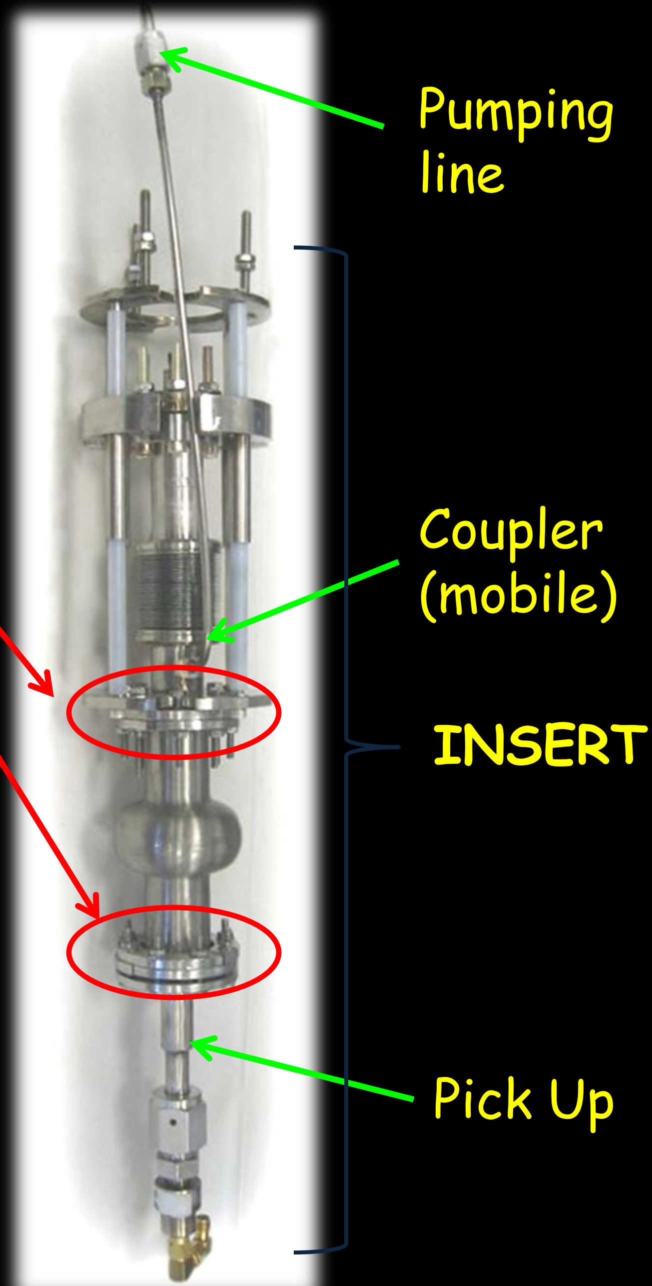
Cryogenic infrastructure

Easy RF Measurement system:

Vacuum seals:
(Two kinds)

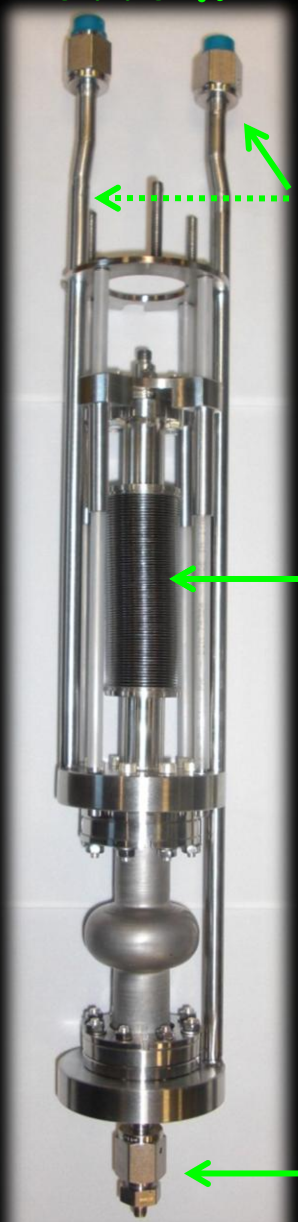
Kapton® disc

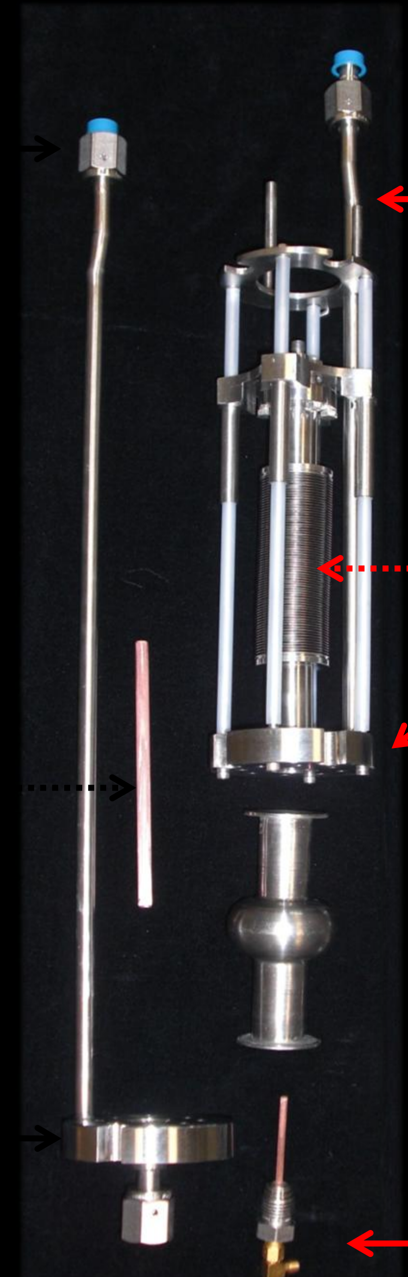
Indium wire



Cryogenic infrastructure: The Bottom Part

Bottom Part





Cryogenic infrastructure: Triple Stand

cavity

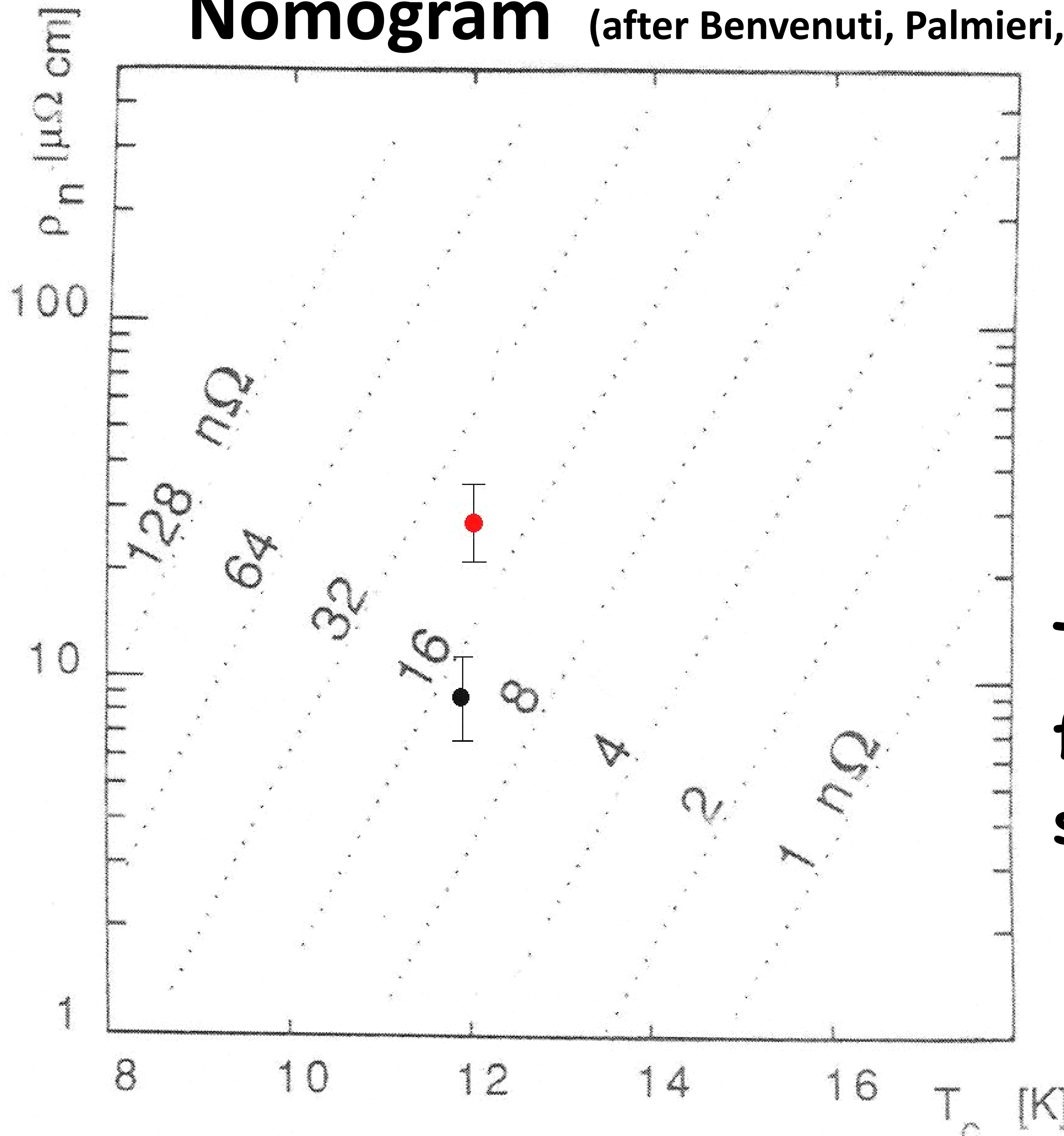
Quick RF Measurements

LIST OF DOGMAS

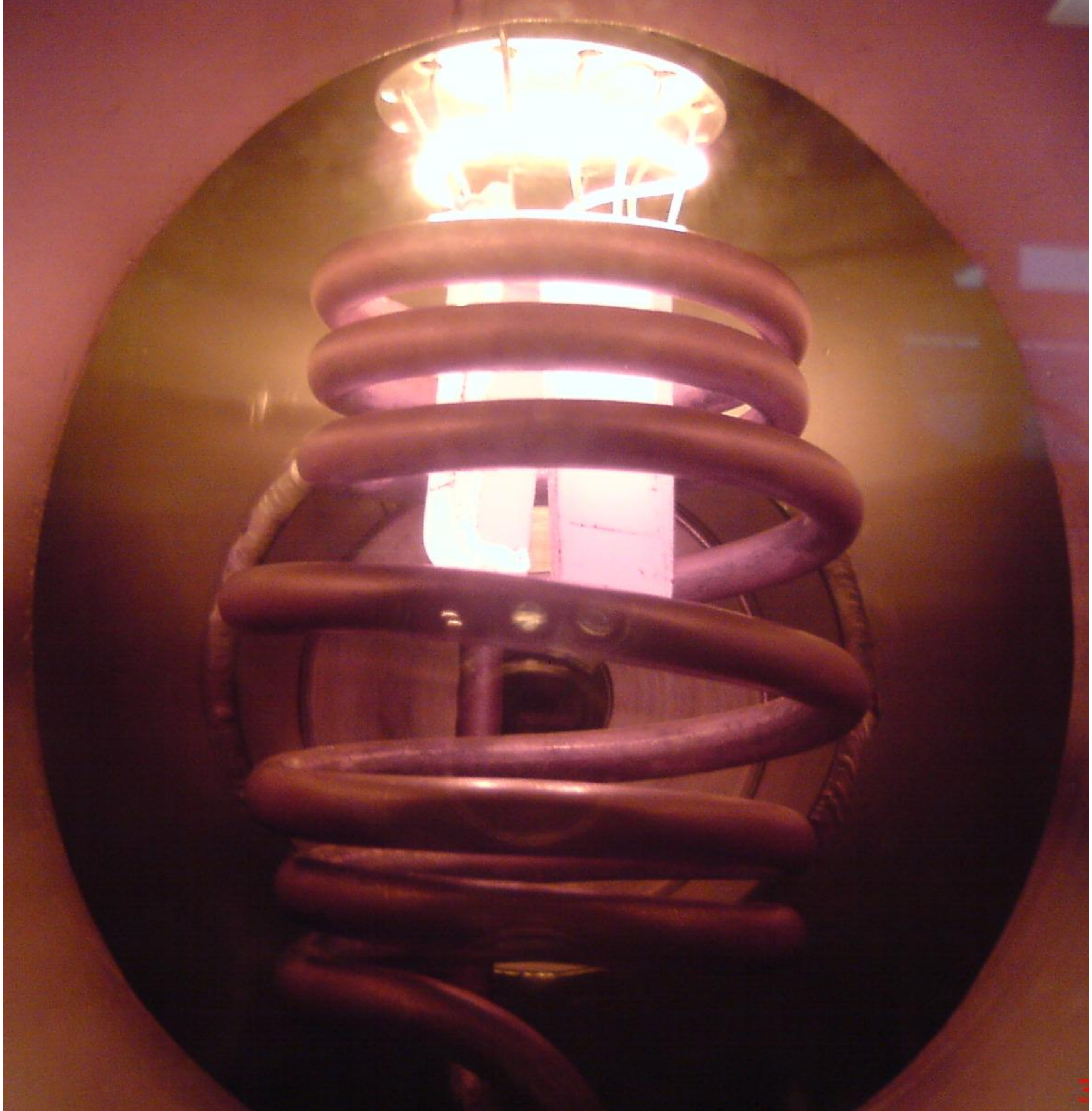
- **6 GHz cavities are not representative**
- **Any other flange, that is not Nb-Ti, is not reliable**
- **Kapton joints will not work**

  … and even if they work, they will not be used!

Nomogram (after Benvenuti, Palmieri, Vaglio)



T = 4.2 K
f = 500 MHz,
s = 4



LIST OF DOGMAS

- 2000° C is a too high temperature

- Over 1000°C you've contamination from crucibles and you will loose the dimensional control

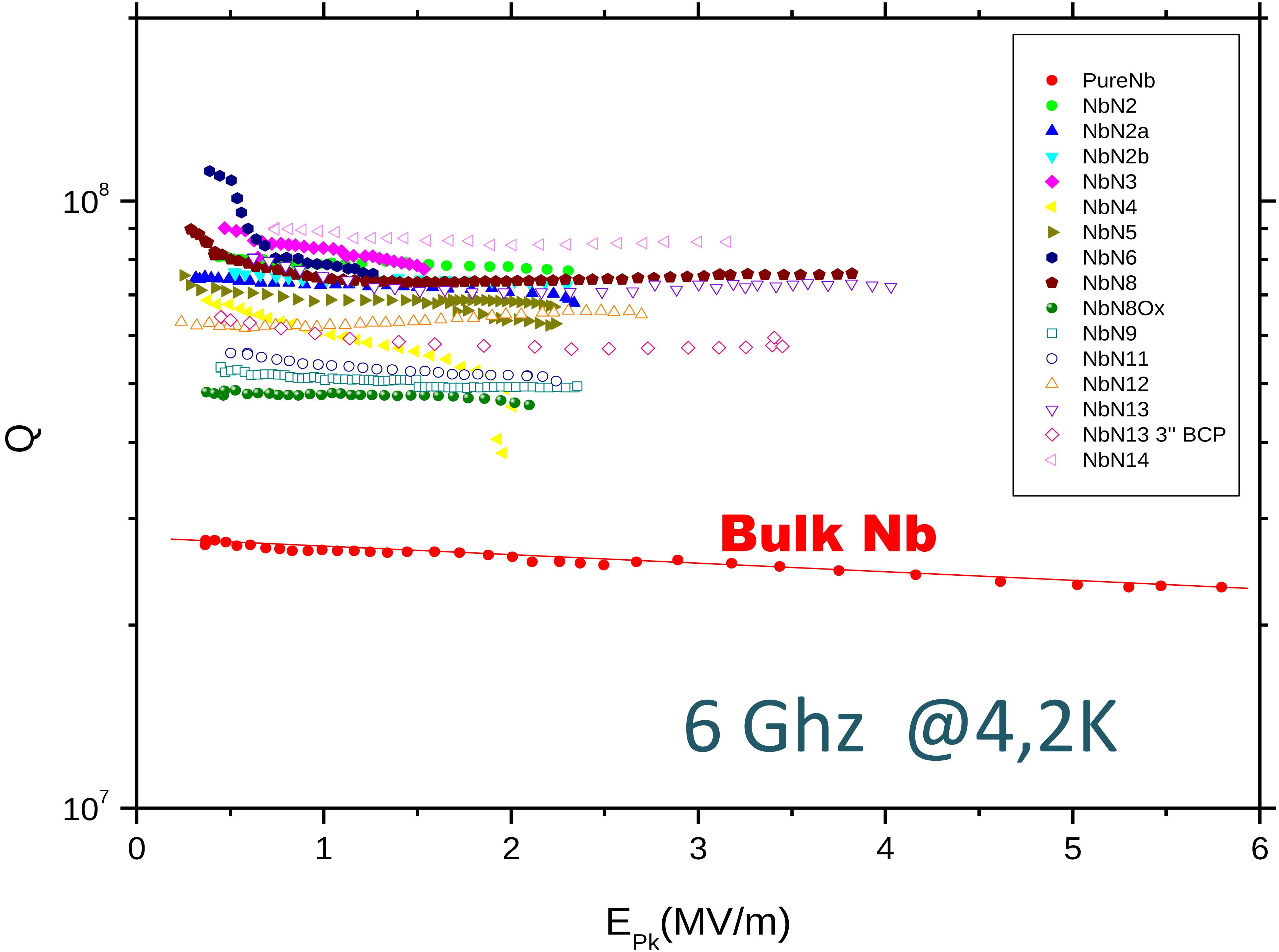
- You can't work around melting point of Niobium

High Temperature Rapid Metathesis

(Nitriding in Mushy State)

The Process is:

- **Fast** (takes only few sec)
- **Cheap** (Vacuum Technology Free)
- **Simple** (No need of special expertise)



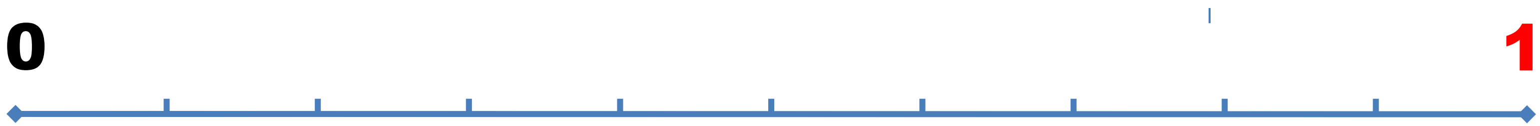
PureNb
NbN2
NbN2a
NbN2b
NbN3
NbN4
NbN5
NbN6
NbN8
NbN8Ox
NbN9
NbN11
NbN12
NbN13
NbN13 3'' BCP
NbN14
Bulk Nb
6 Ghz @4,2K
Q
10^8
10^7
0
1
2
3
4
5
6
E_{Pk}(MV/m)

LIST OF DOGMAS

- You necessarily need good vacuum
- You must limit yourself to select only those A15 that can be prepared at T around 900°C
- In any case B1 and A15 materials will never work

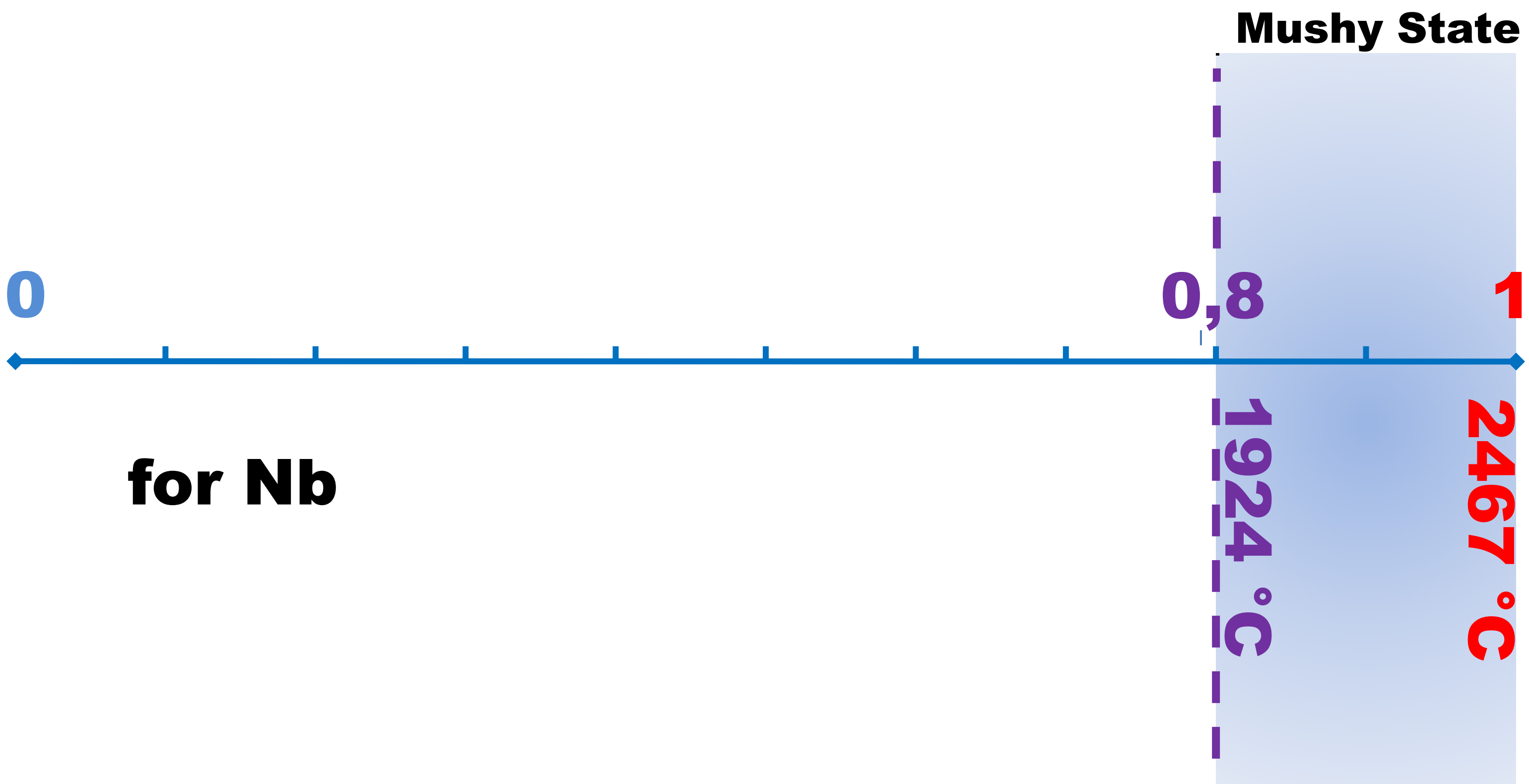
The Homologous Temperature

$$\theta = \frac{T\ [K]}{T_m\ [K]}$$

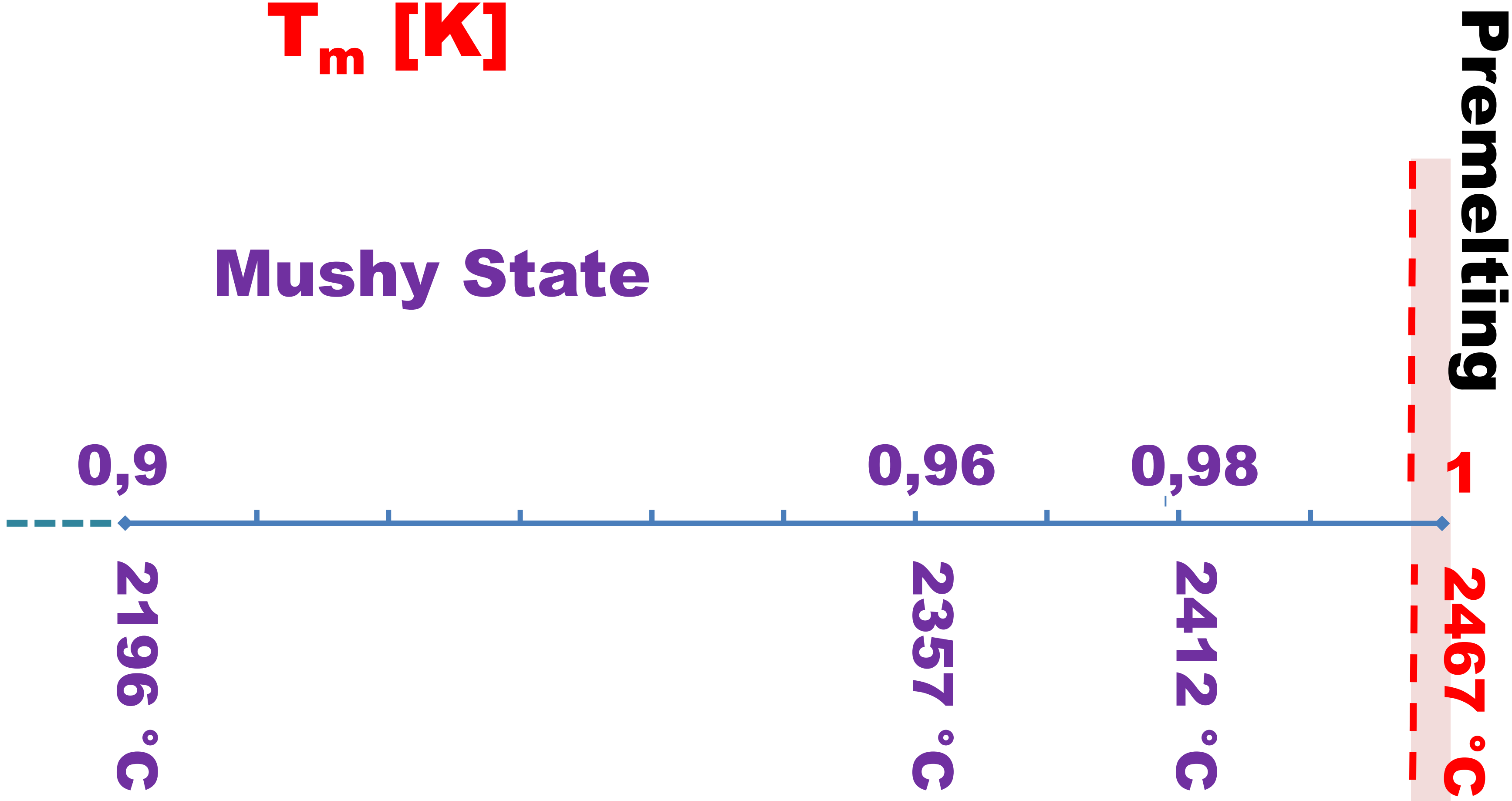


for Nb 2467 °C

$$\theta = \frac{T\ [K]}{T_m\ [K]}$$



$$\theta = \frac{T\,[K]}{T_m\,[K]}$$



Premelting
(also Surface melting)

Even below its melting point (T_m),

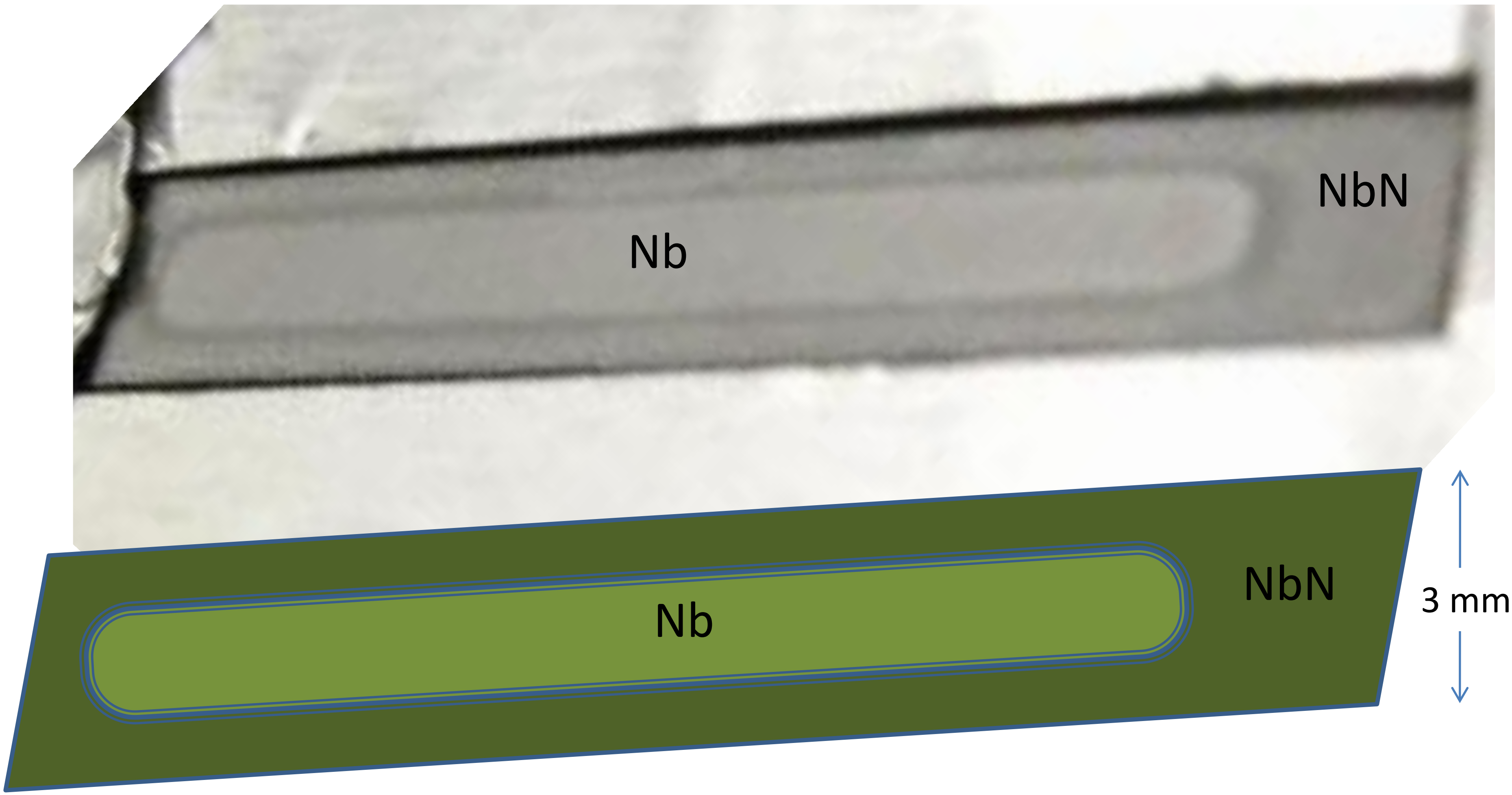
quasi-liquid films can be

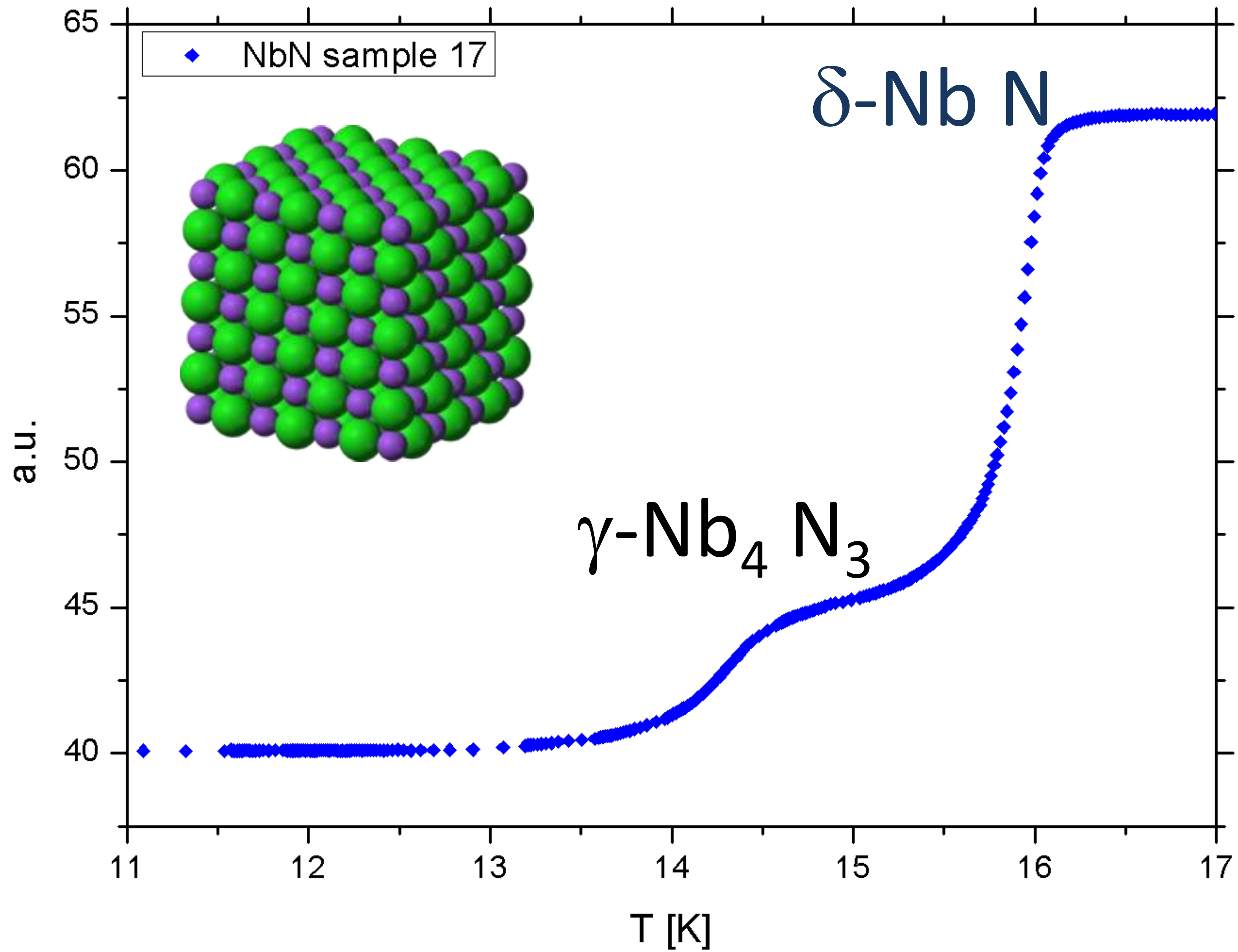
observed on crystalline surfaces

Premelting
(also Surface melting)

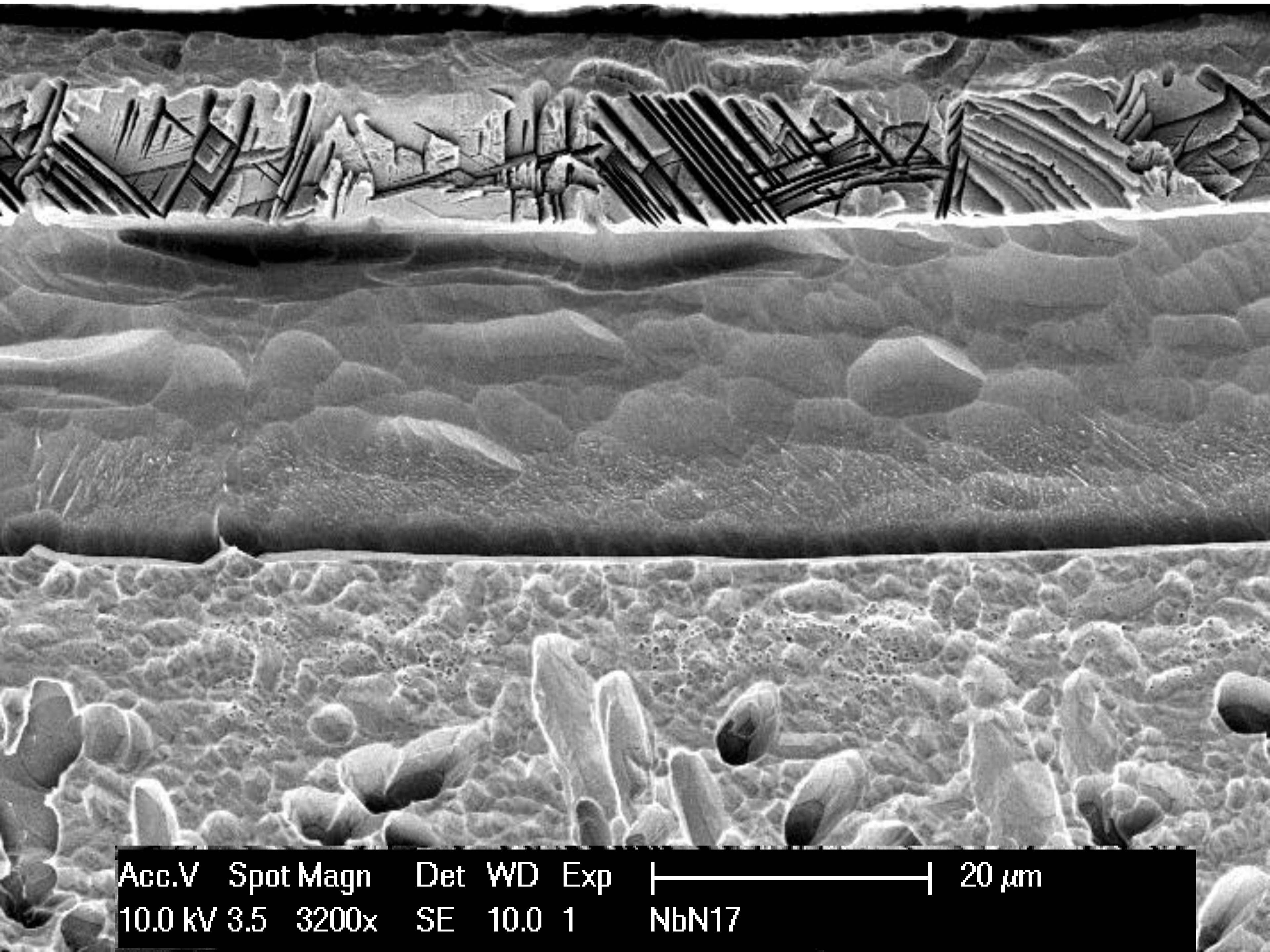
The thickness of the quasi-liquid film is *T* - dependent

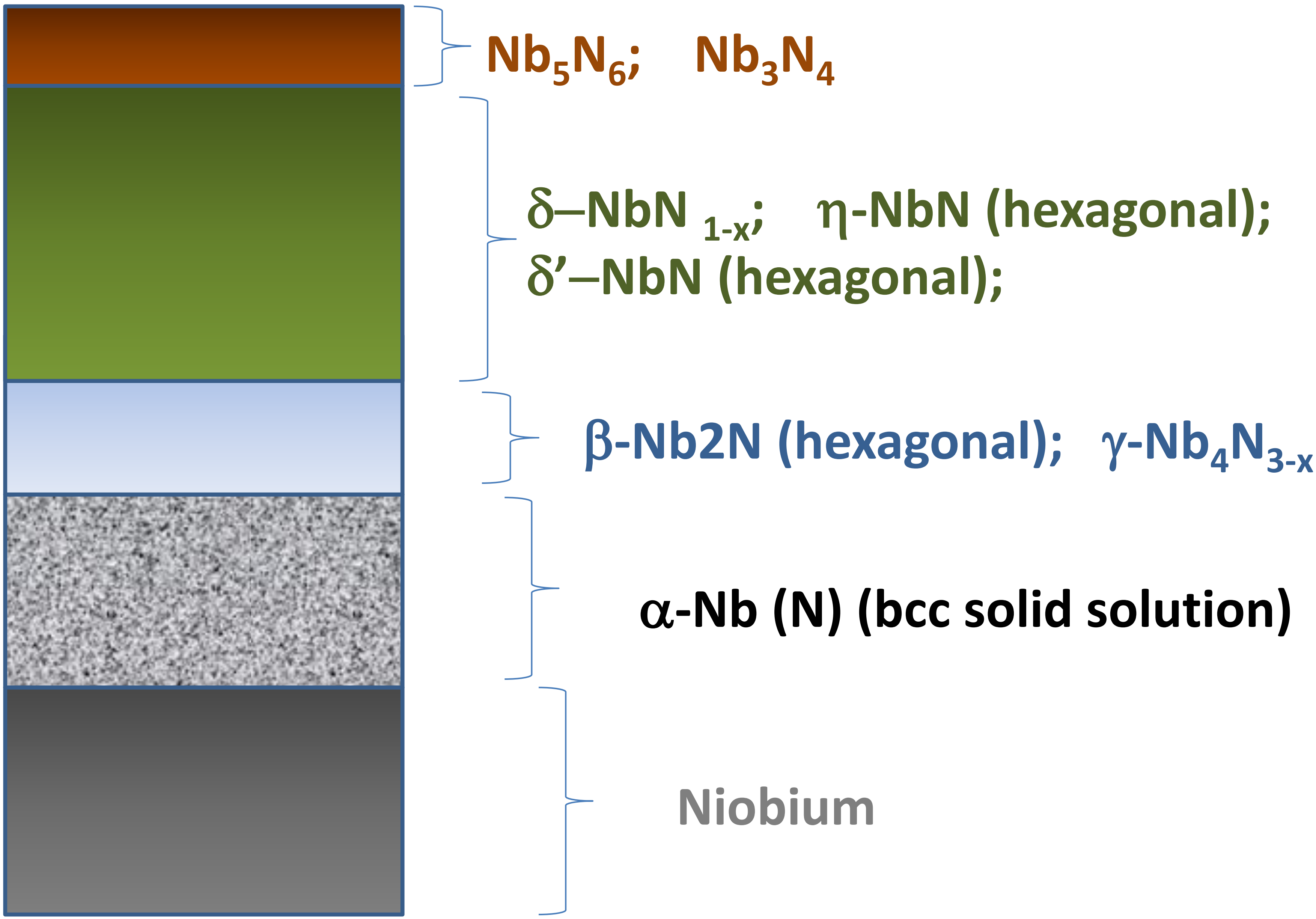
This effect is common for all crystalline materials


NbN
Nb
NbN
Nb
3 mm

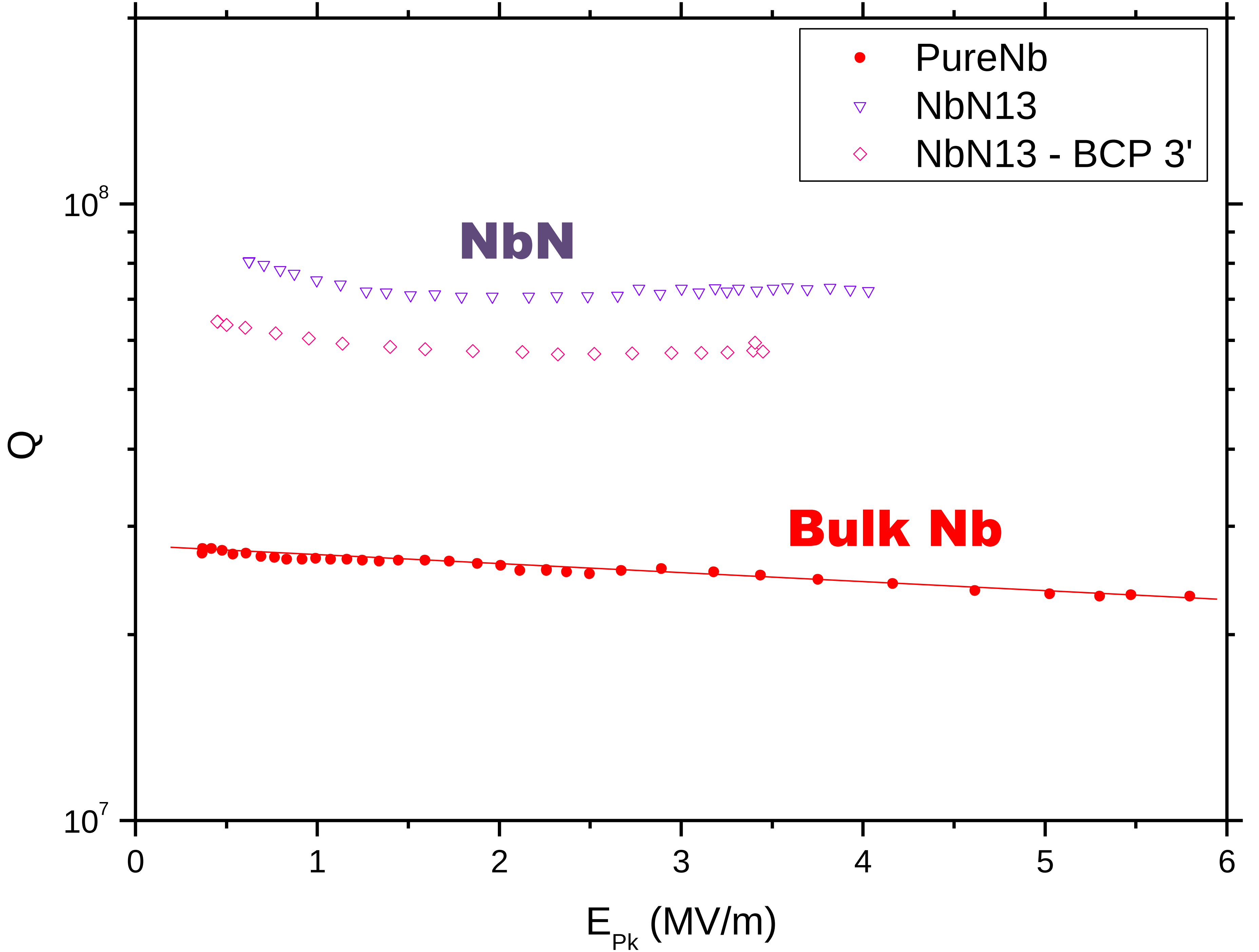


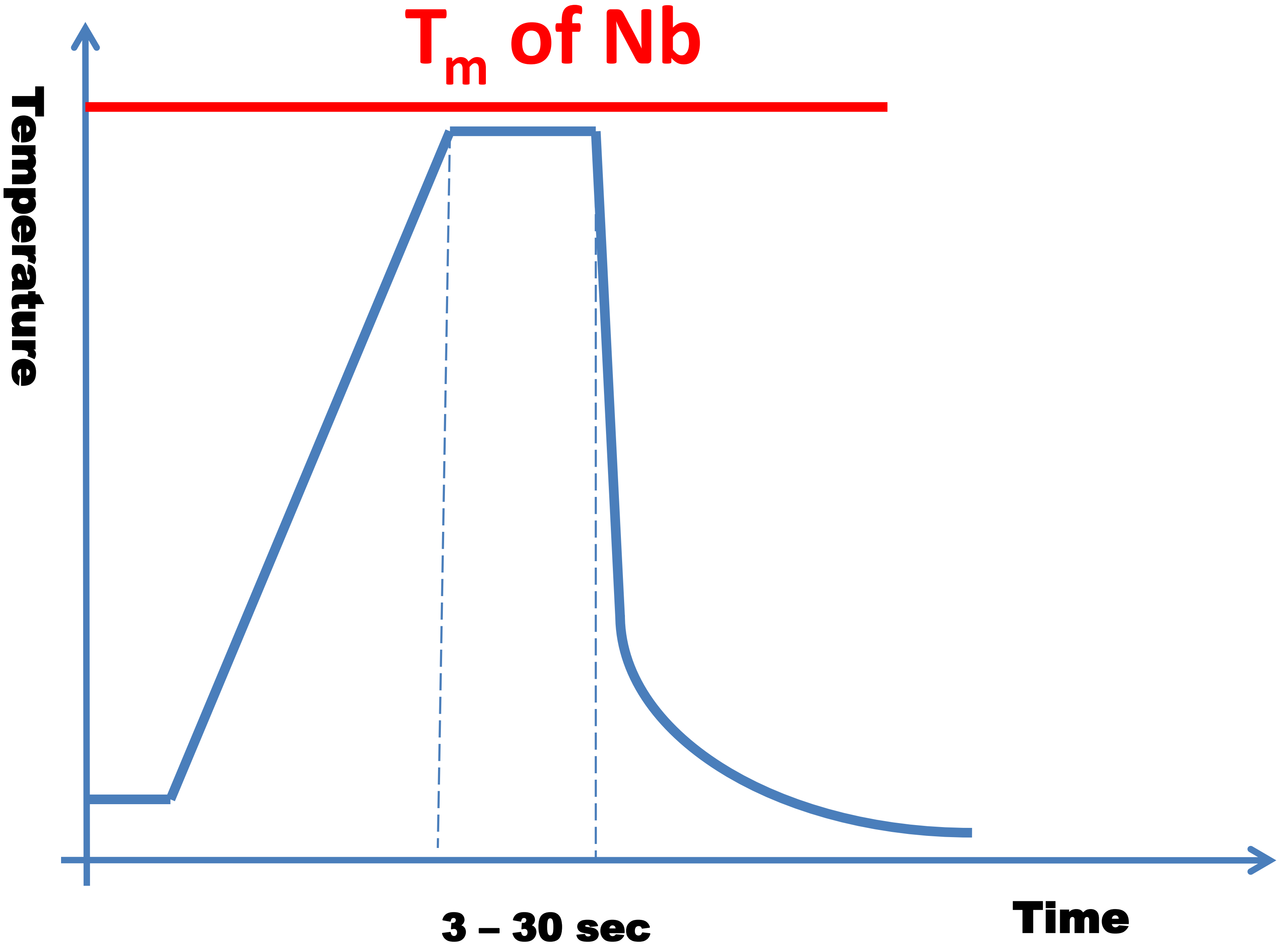
NbN sample 17
δ-Nb N
γ-Nb4 N3
a.u.
T [K]
65
60
55
50
45
40
11
12
13
14
15
16
17


Acc.V Spot Magn Det WD Exp
10.0 kV 3.5 3200x SE 10.0 1
20 μm
NbN17



Nb5N6; Nb3N4
δ–NbN 1-x; η-NbN (hexagonal);
δ'–NbN (hexagonal);
β-Nb2N (hexagonal); γ-Nb4N3-x
α-Nb (N) (bcc solid solution)
Niobium


PureNb
NbN13
NbN13 - BCP 3'
NbN
Bulk Nb
Q
10^8
10^7
0
1
2
3
4
5
6
E_{Pk} (MV/m)



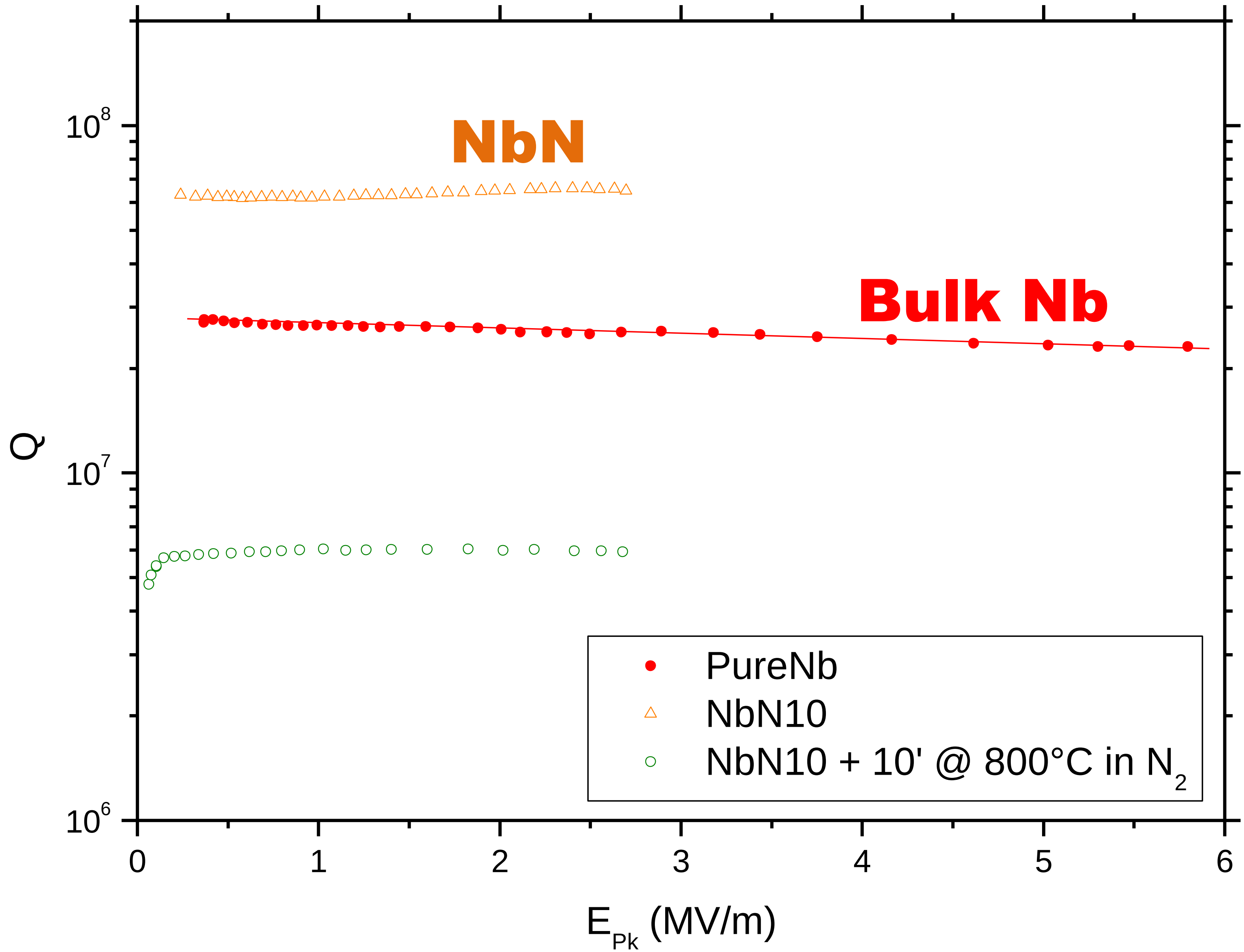
T_m of Nb
Temperature
3 – 30 sec
Time

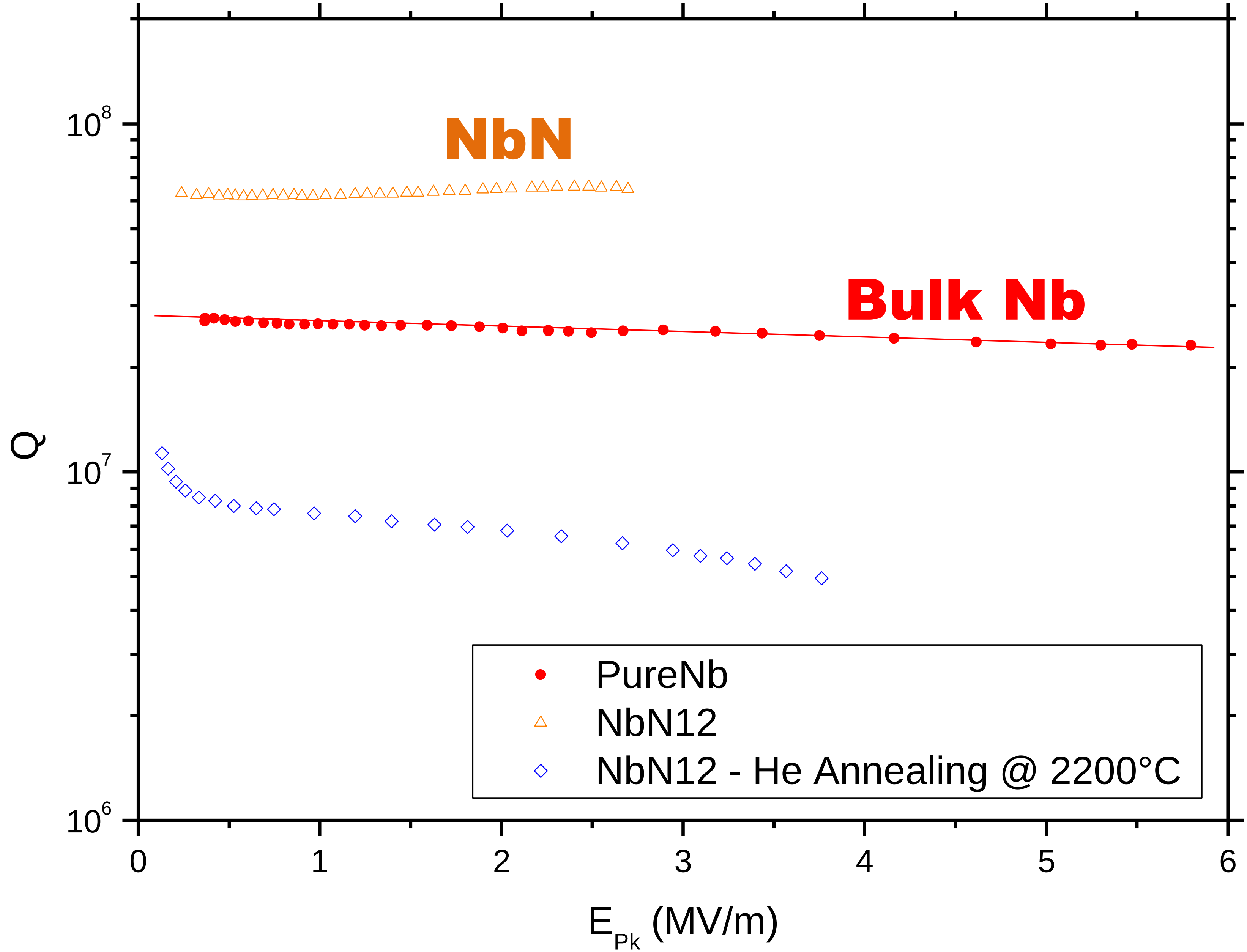
As the δ-NbN $\rightarrow$ γ-Nb_4N_{3-x} phase transformation is a very fast, quasi-continuous Transition,

it cannot be avoided by quenching

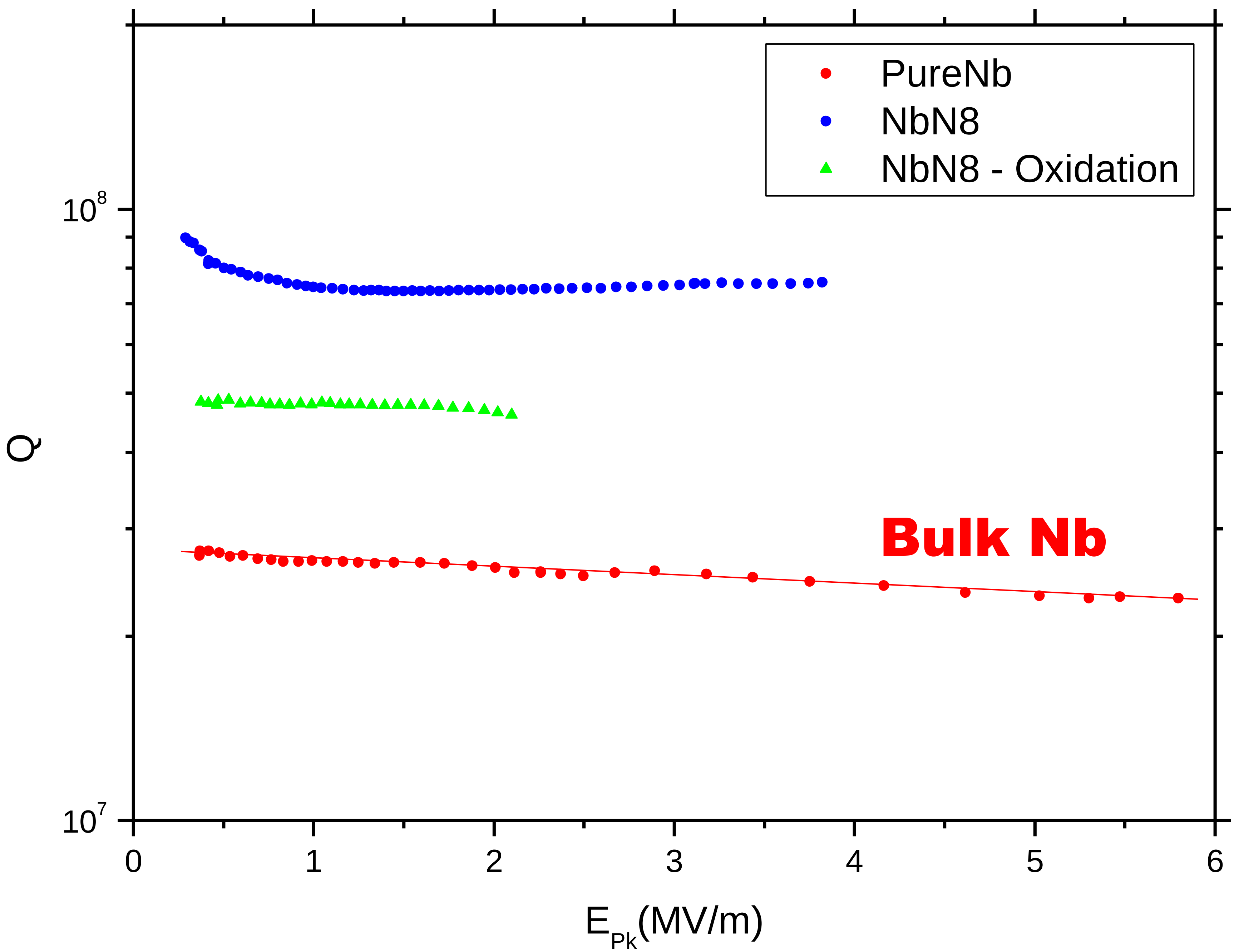
Annealing

doesn’t work


NbN
Bulk Nb
Q
10^8
10^7
10^6
0
1
2
3
4
5
6
E_{Pk} (MV/m)
PureNb
NbN10
NbN10 + 10' @ 800°C in N_2



NbN
Bulk Nb
Q
10^8
10^7
10^6
0
1
2
3
4
5
6
E_{Pk} (MV/m)
PureNb
NbN12
NbN12 - He Annealing @ 2200°C

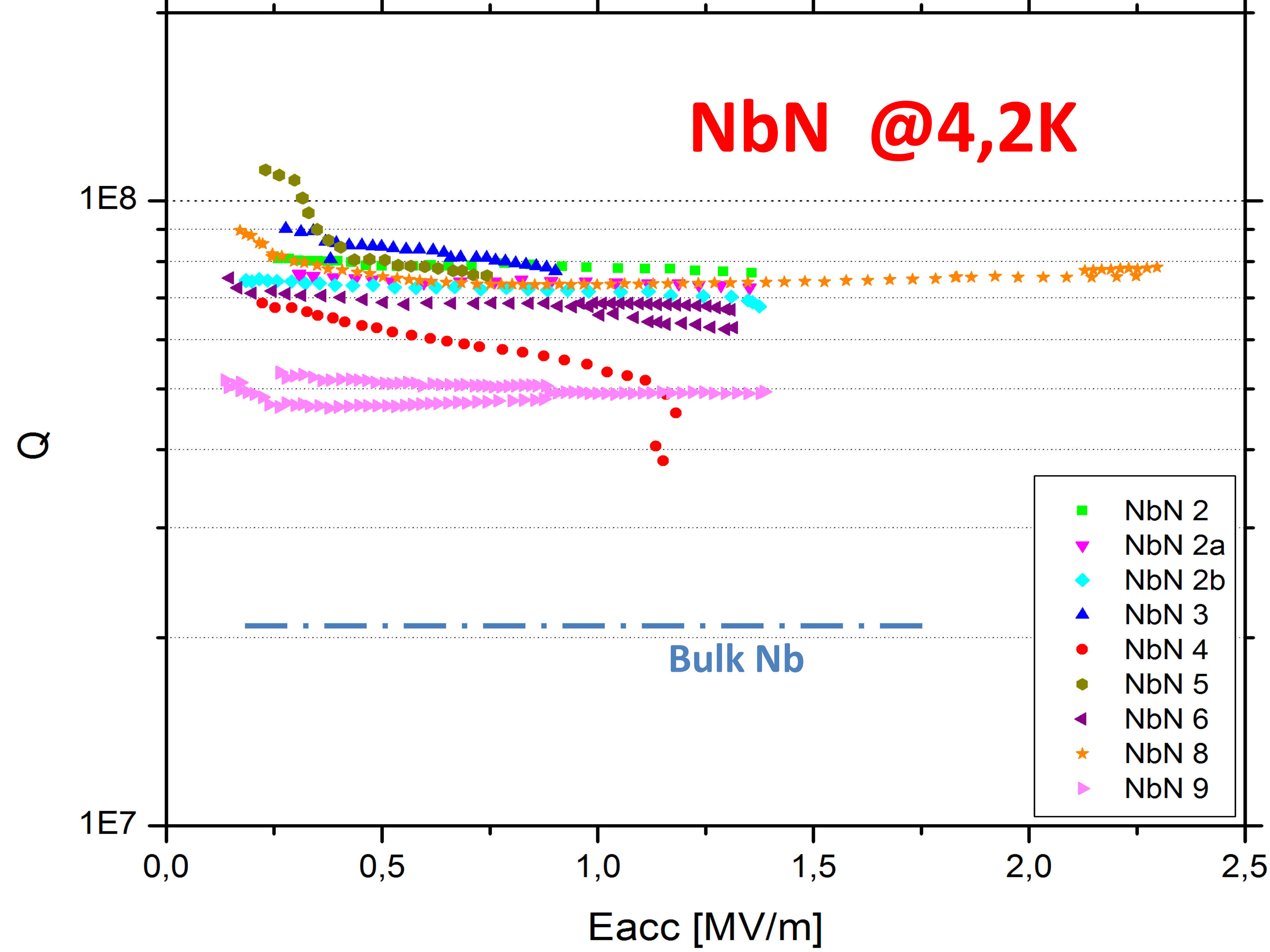

PureNb
NbN8
NbN8 - Oxidation
Bulk Nb
Q
10^8
10^7
0
1
2
3
4
5
6
E_{Pk}(MV/m)

Nb_2O_5

Melting point	**1512 °C**
Evaporation temperature	**1700-1900 °C**

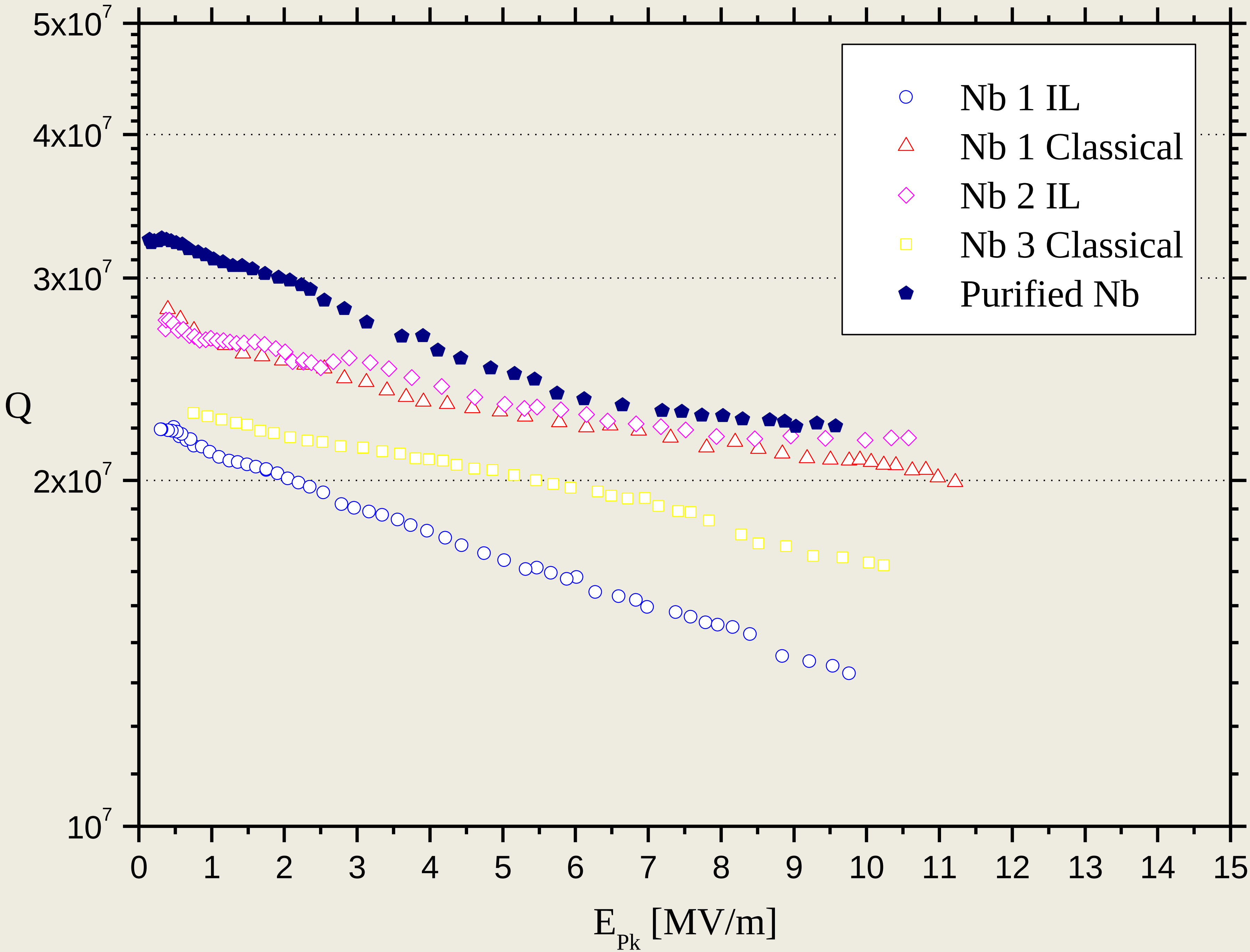
When the N/Nb ratio > 0.84, the δ-phase can be retained by quenching

At N/Nb ratio < 0.8 it transforms in γ-Nb_4 N_3

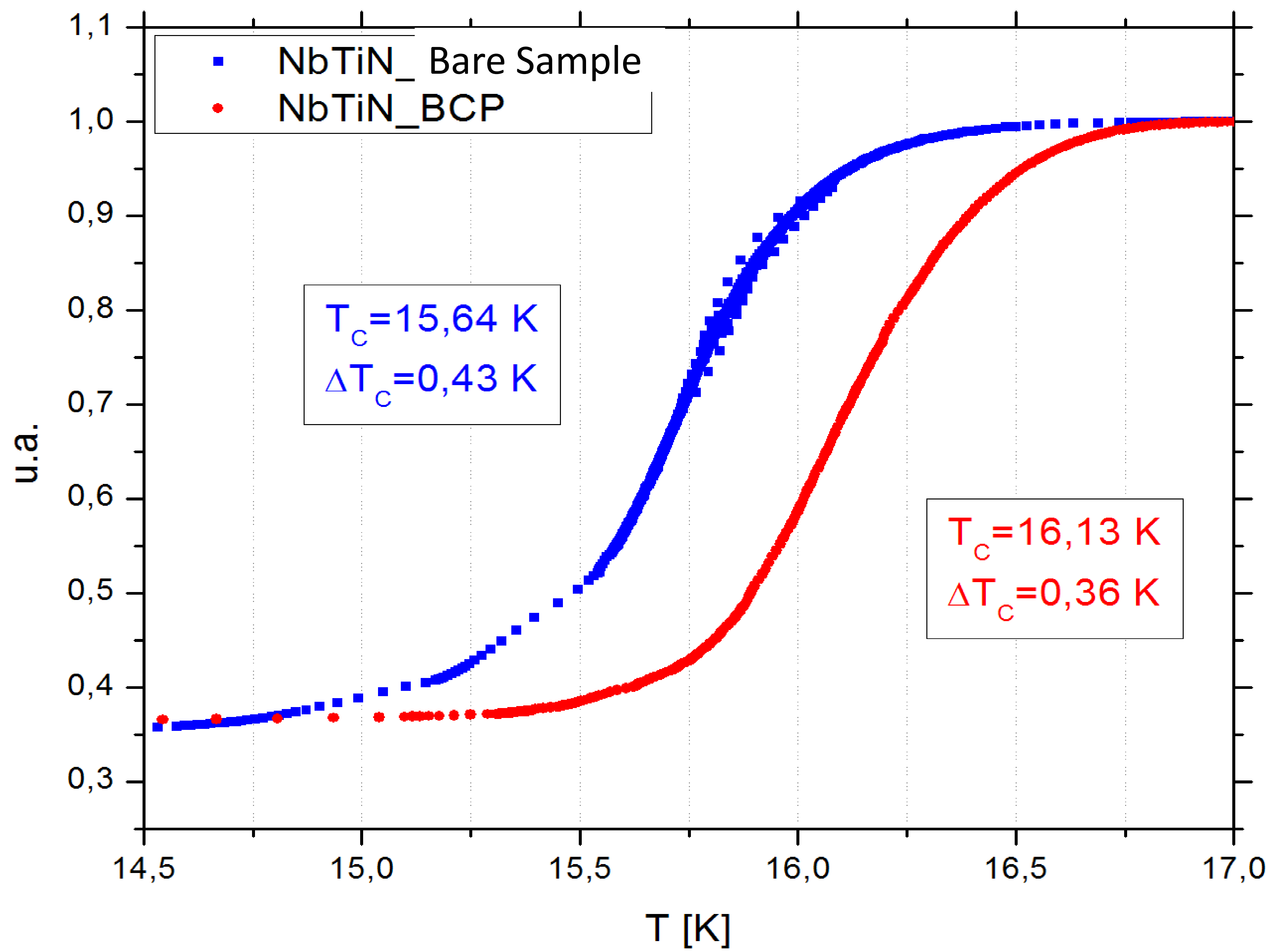

NbN @4,2K
1E8
1E7
Q
0,0
0,5
1,0
1,5
2,0
2,5
Eacc [MV/m]
Bulk Nb
NbN 2
NbN 2a
NbN 2b
NbN 3
NbN 4
NbN 5
NbN 6
NbN 8
NbN 9

High Temperatures for

Nb Purification

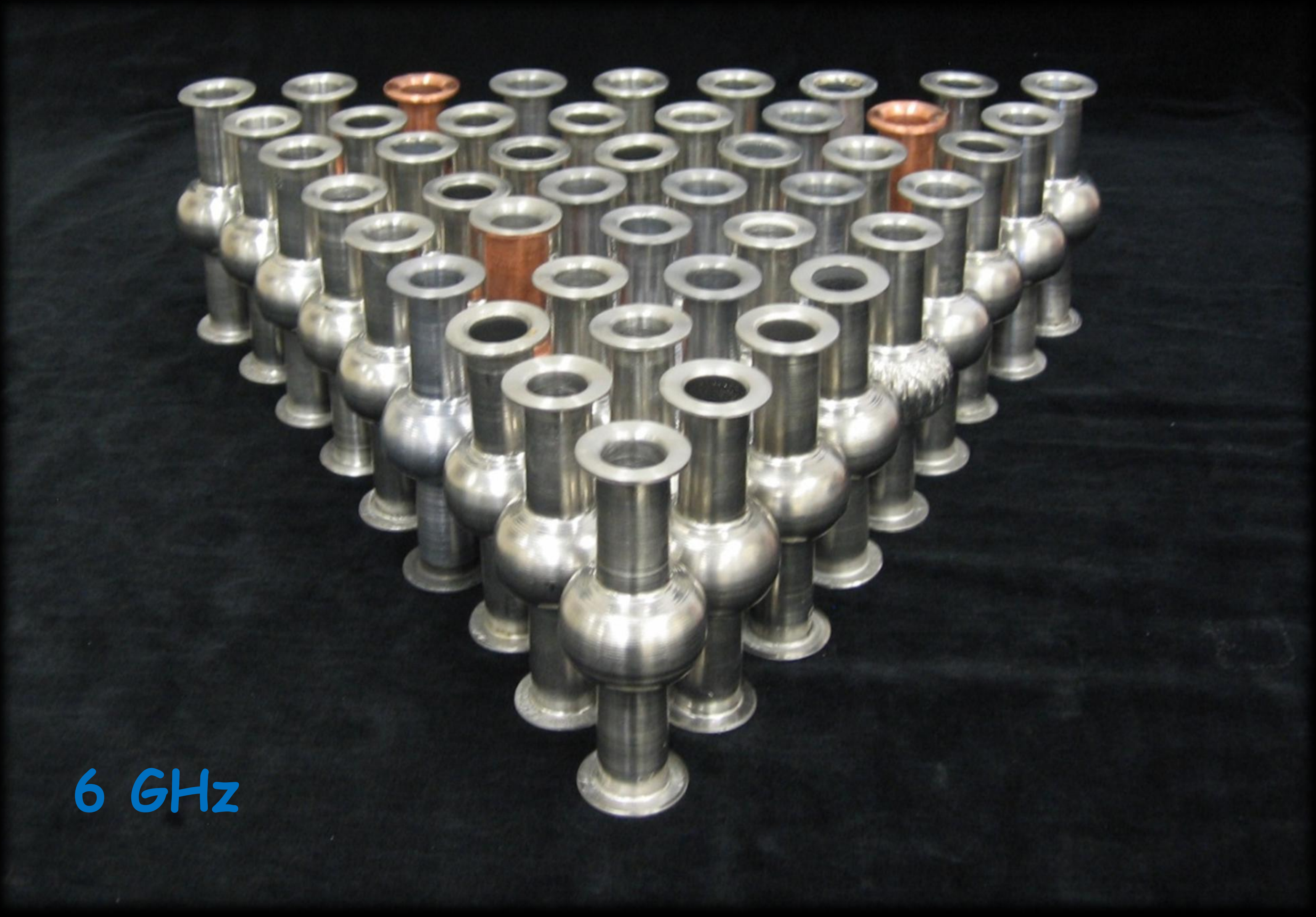


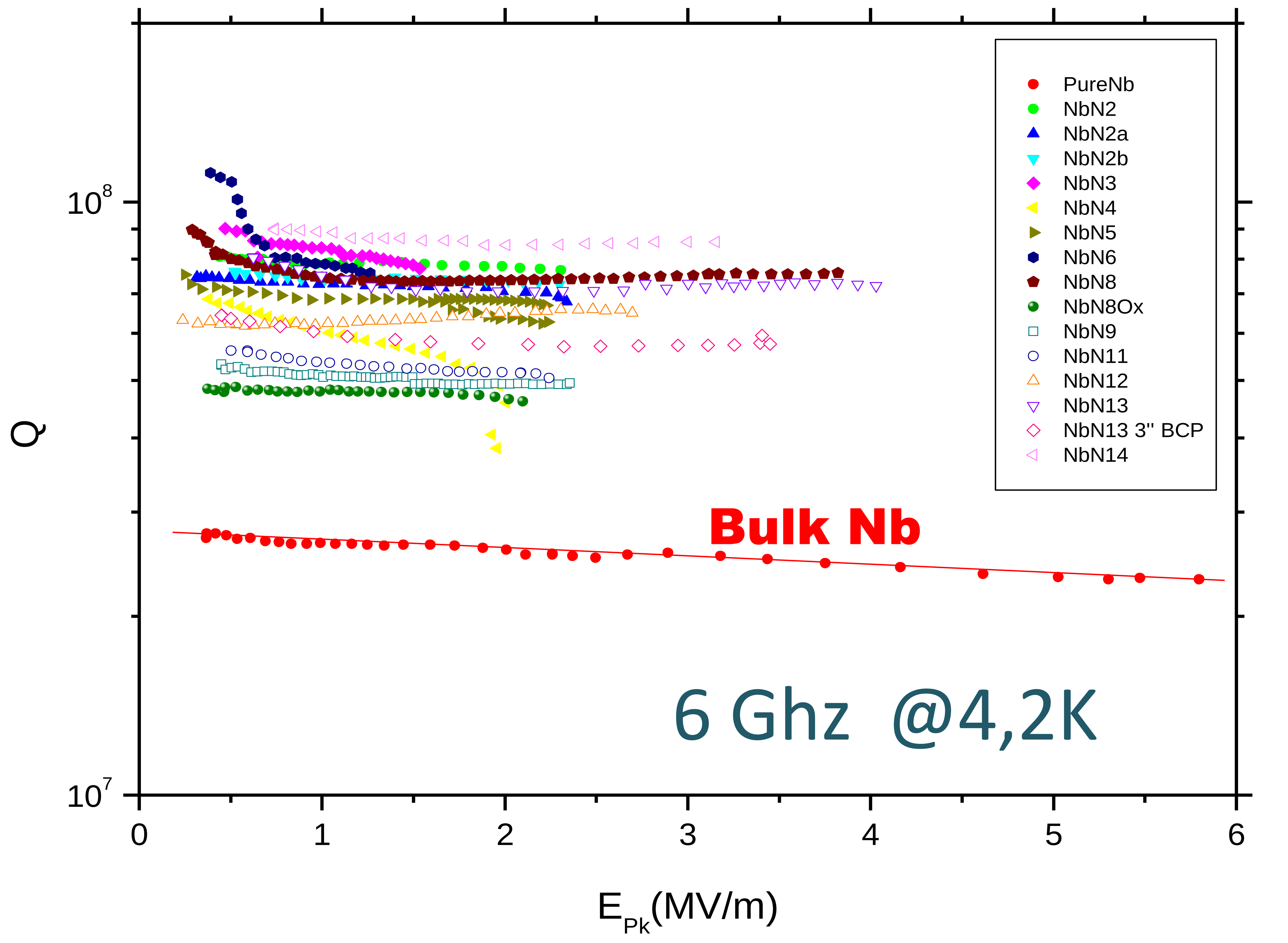
Nb 1 IL
Nb 1 Classical
Nb 2 IL
Nb 3 Classical
Purified Nb
Q
$5x10^7$
$4x10^7$
$3x10^7$
$2x10^7$
10^7
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
E_{Pk} [MV/m]


NbTiN_ Bare Sample
NbTiN_BCP
T_C=15,64 K
ΔT_C=0,43 K
T_C=16,13 K
ΔT_C=0,36 K
u.a.
T [K]
1,1
1,0
0,9
0,8
0,7
0,6
0,5
0,4
0,3
14,5
15,0
15,5
16,0
16,5
17,0

Conclusions

- **6 Ghz cavities** allow a fast and dense statistics
- At **4,2 K the Q-value at low field** increases of even a factor 5
- The important parameters are given by the **3-T rule**


6 GHz



PureNb
NbN2
NbN2a
NbN2b
NbN3
NbN4
NbN5
NbN6
NbN8
NbN8Ox
NbN9
NbN11
NbN12
NbN13
NbN13 3'' BCP
NbN14
Bulk Nb
6 Ghz @4,2K
Q
10^8
10^7
0
1
2
3
4
5
6
E_{Pk}(MV/m)