Athmospheric Surface Treatments of Niobium

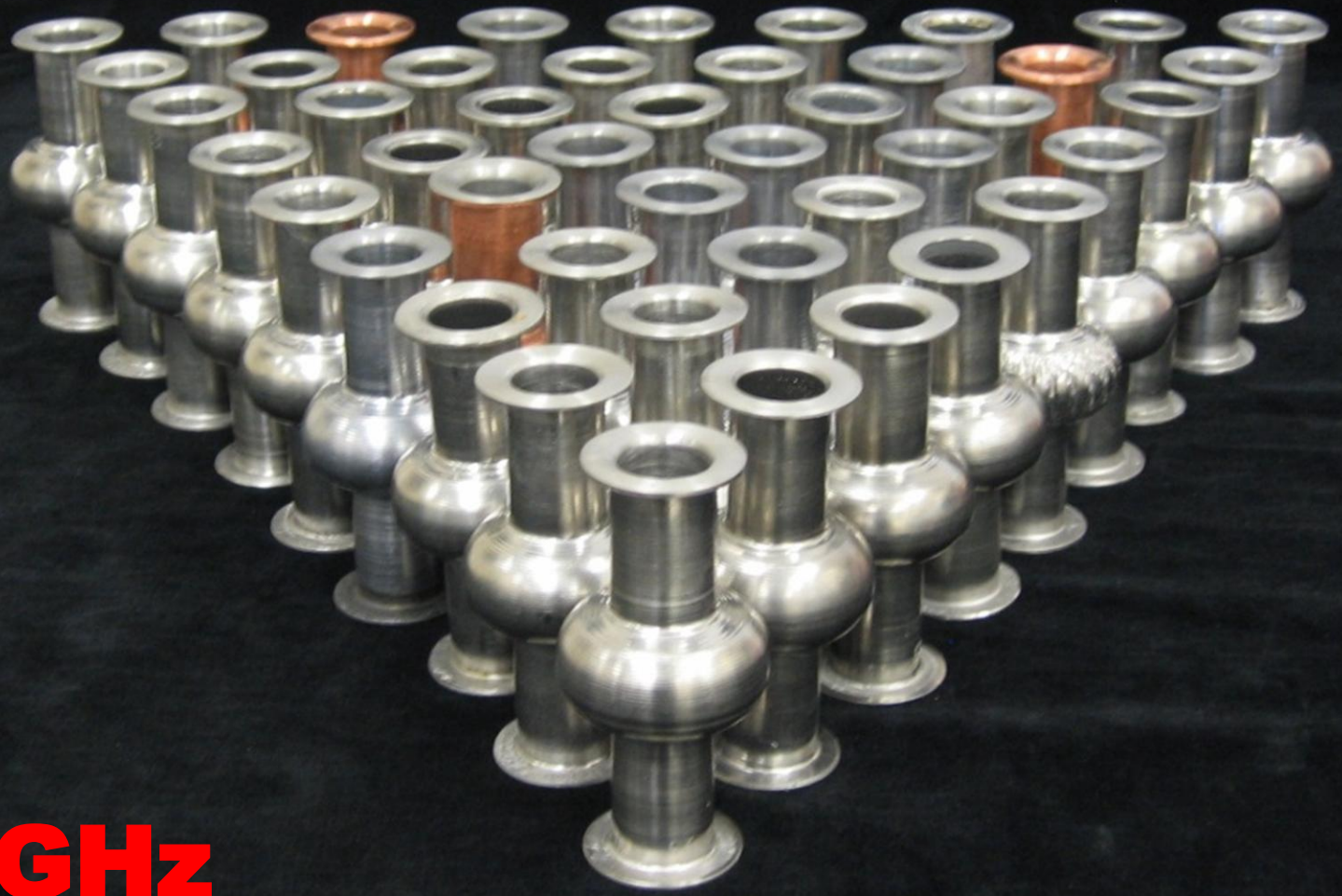
A. Camacho*^, A.A. Rossi* and V. Palmieri*^,

* INFN – Legnaro National Laboratories
^ University of Padua

Samples or Cavities?

Material Study or Cavity construction?

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

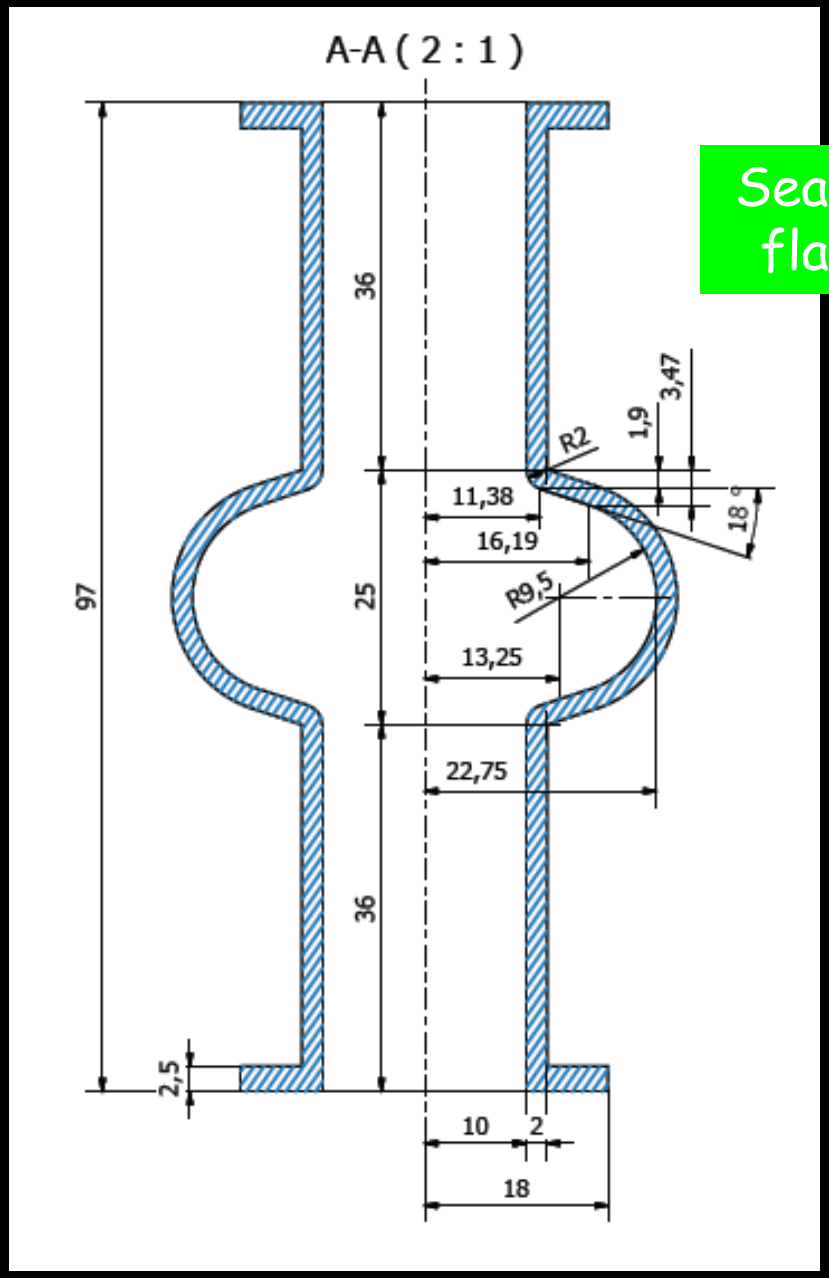
6 GHz CAVITY MINILAB

- No electron beam welding, neither for flanges
- Obtained by spinning from Nb scraps

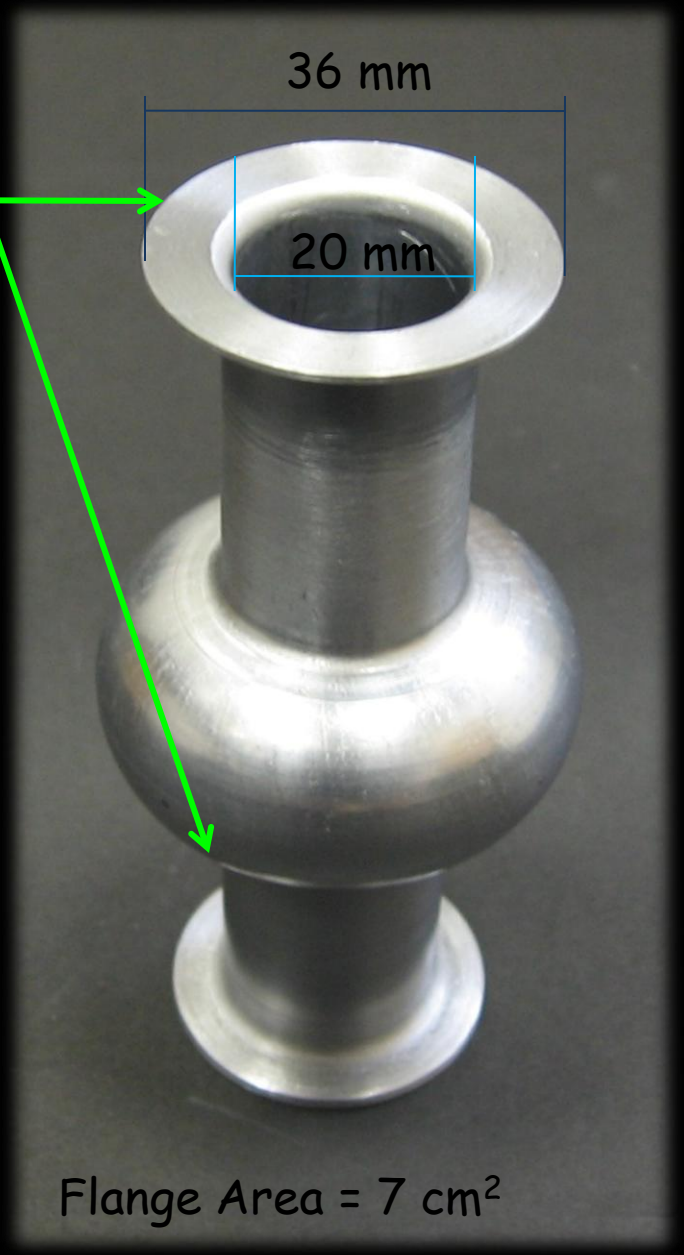
  - Short fabrication time
  - Fast and low cost BCP and EP treatments
  - Inexpensive Cryogenics

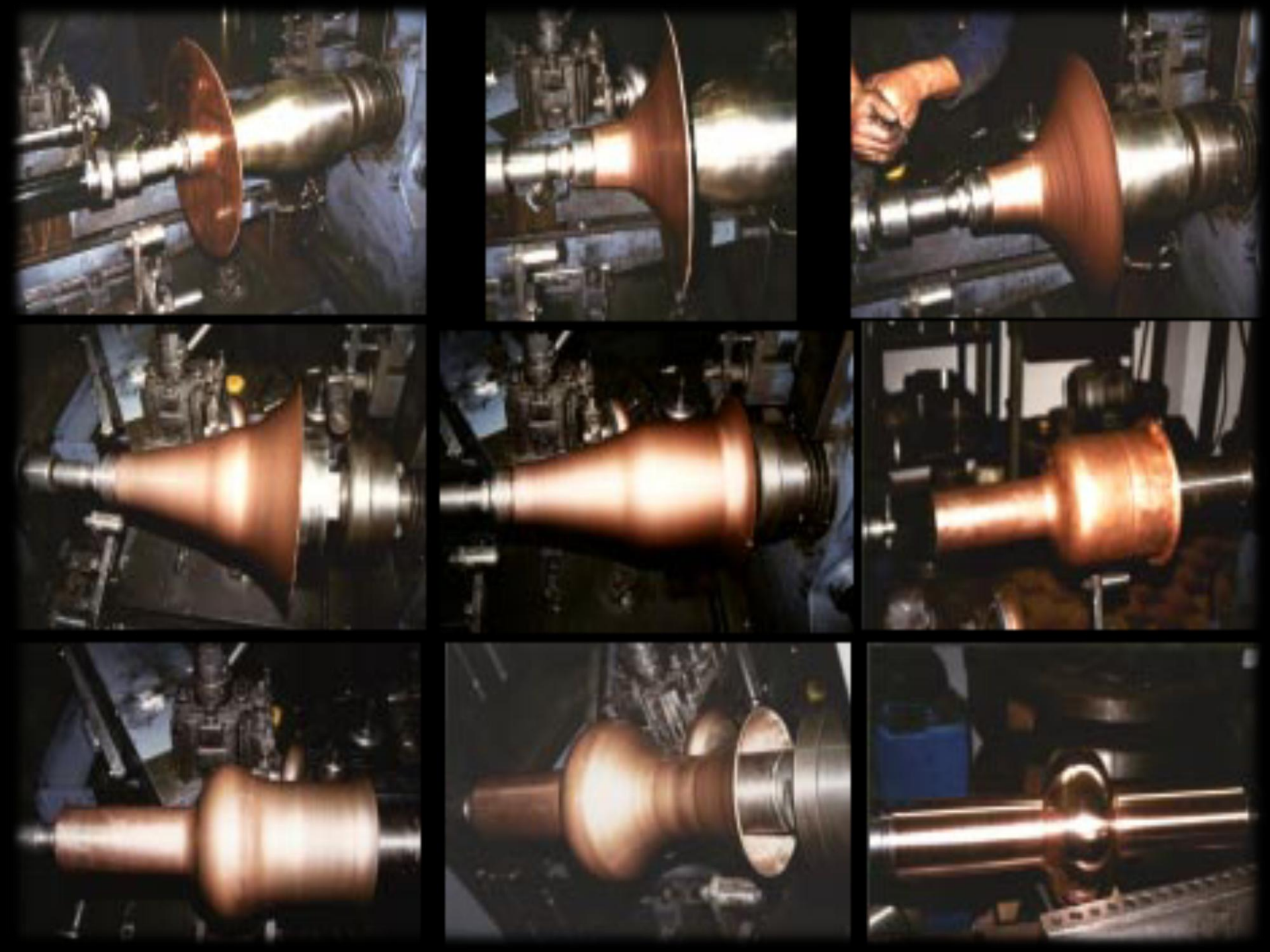
    - Quick RF Measurements

6 Ghz Cavity Geometry



Seamless flanges

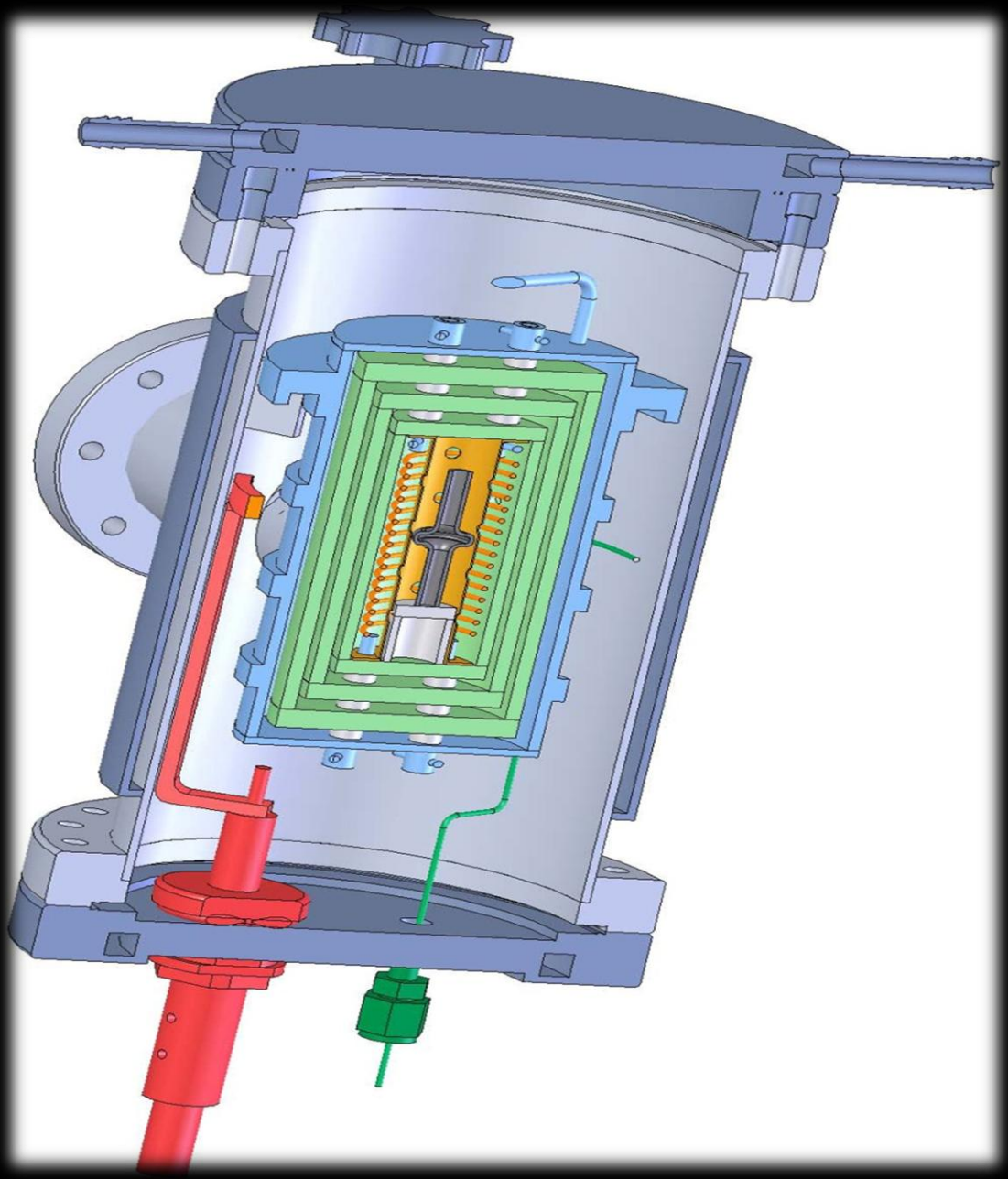




Mini Mechanical Tumbling

Mini EP

6 GHz CAVITY MINI-furnace



6 GHz CAVITY MINI-Camera


Ready for the RF measurement
KONICA MINOLTA

6 GHz CAVITY: MINI-Kapton gasket

Quick RF Measurements

High Temperature Rapid Metathesis

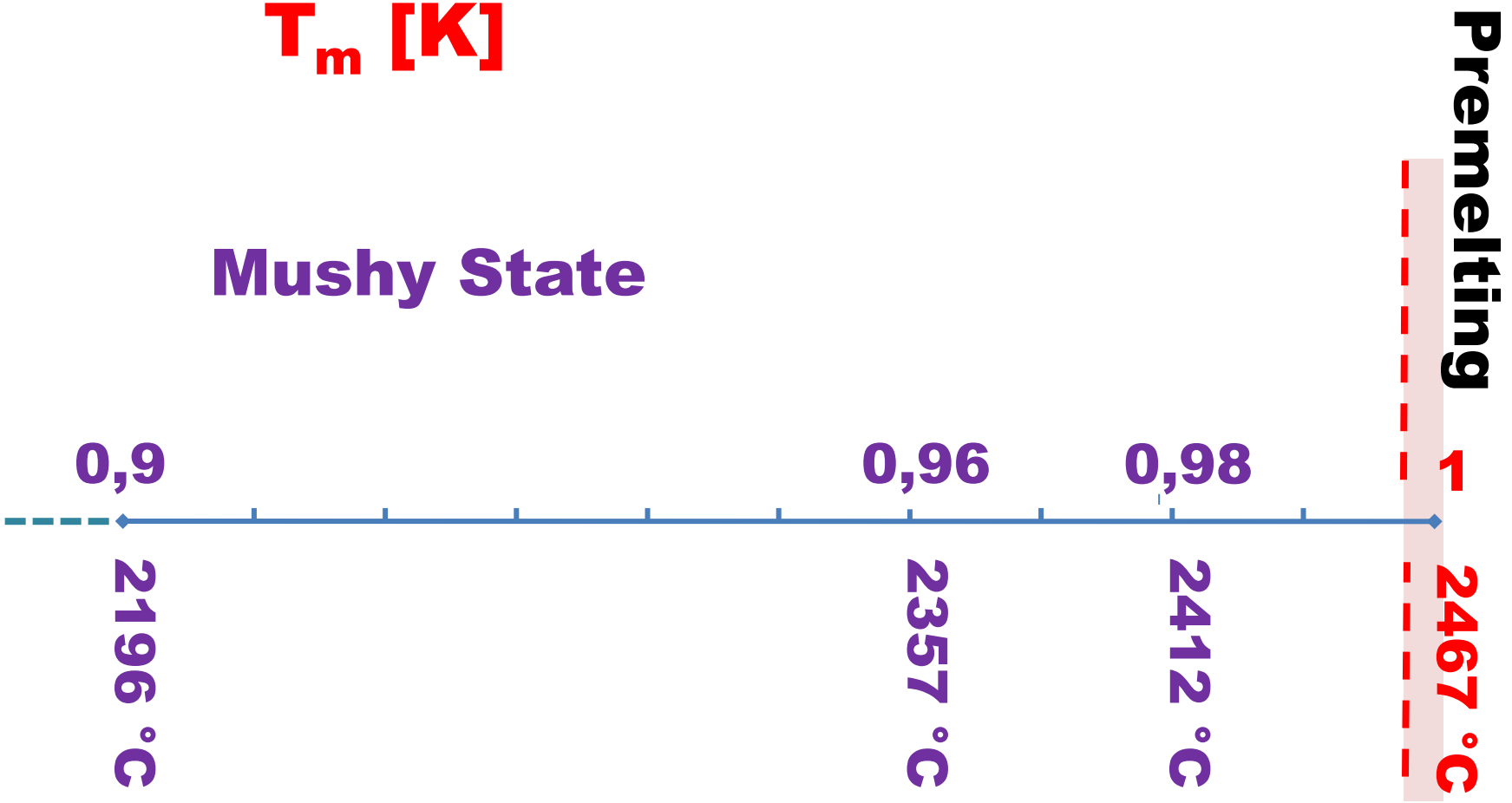
(Nitriding in Mushy State)

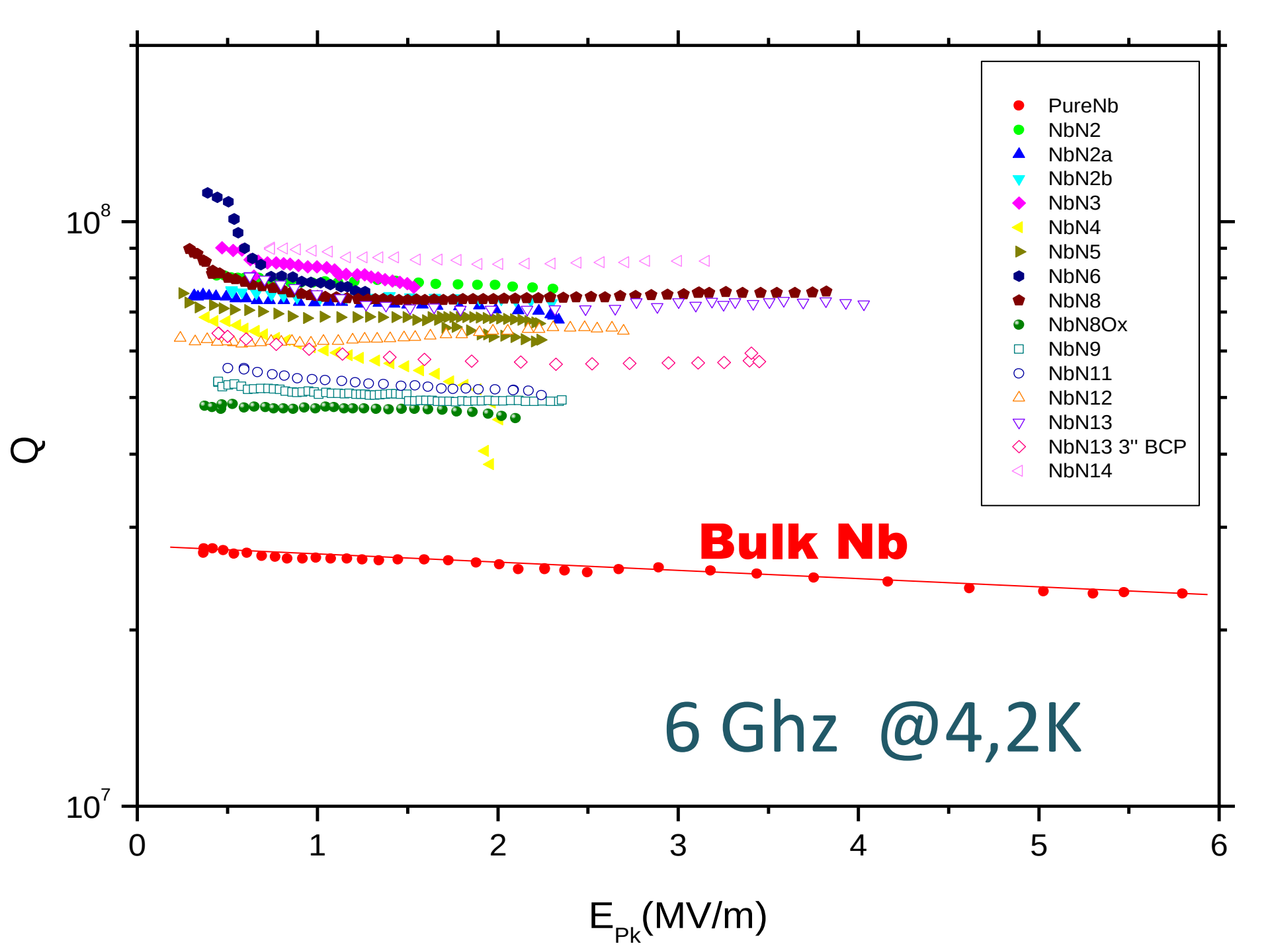
The Homologous Temperature

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

for Nb 2467 °C

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




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)

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)

Premelting
(also Surface melting)

Even below its melting point (T_m),

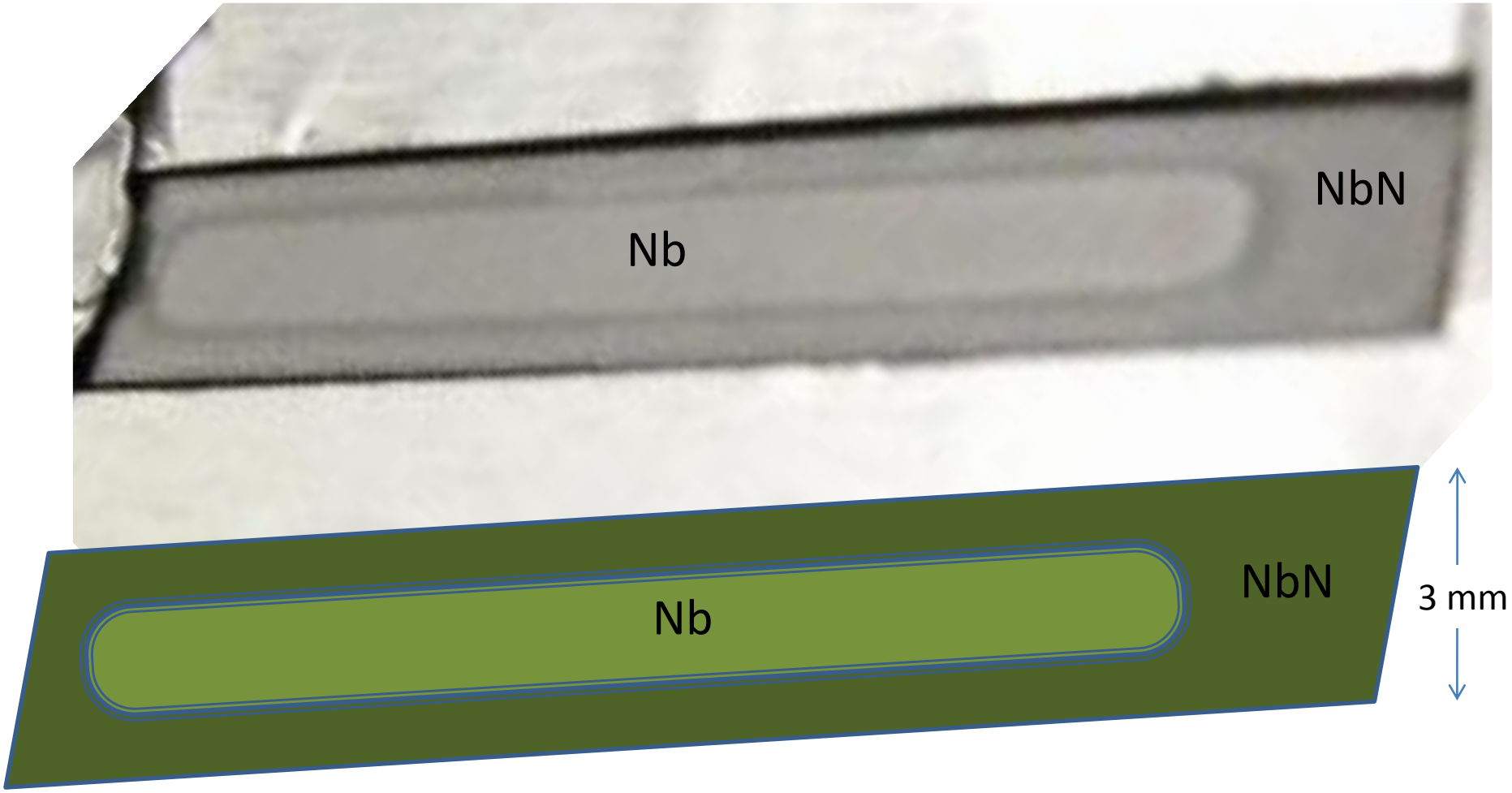
quasi-liquid films can be

observed on crystalline surfaces

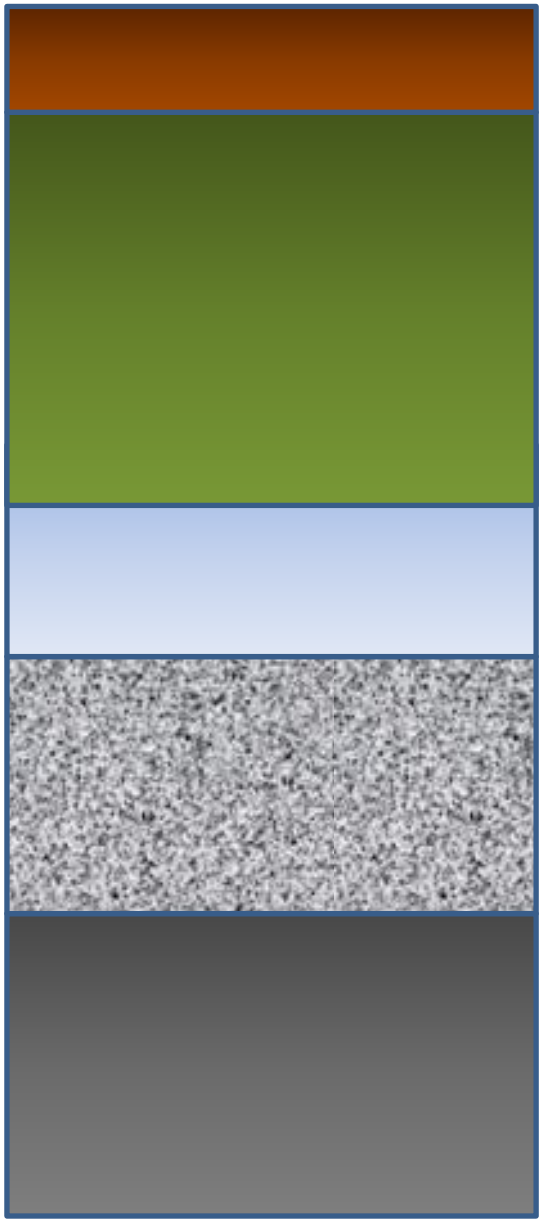
Premelting
(also Surface melting)

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

This effect is common for all crystalline materials


NbN
Nb
NbN
Nb
3 mm

- **Nb_5N_6; N_4N_3** Over-Stoichiometric
- **δ-NbN_{1-x};**
- **γ-Nb_4N_{3-x}** Under-Stoichiometric
- **α-Nb (N)** (bcc solid solution)
- **Niobium**



Nb_5N_6; N_4N_3

δ–NbN_{1-x};

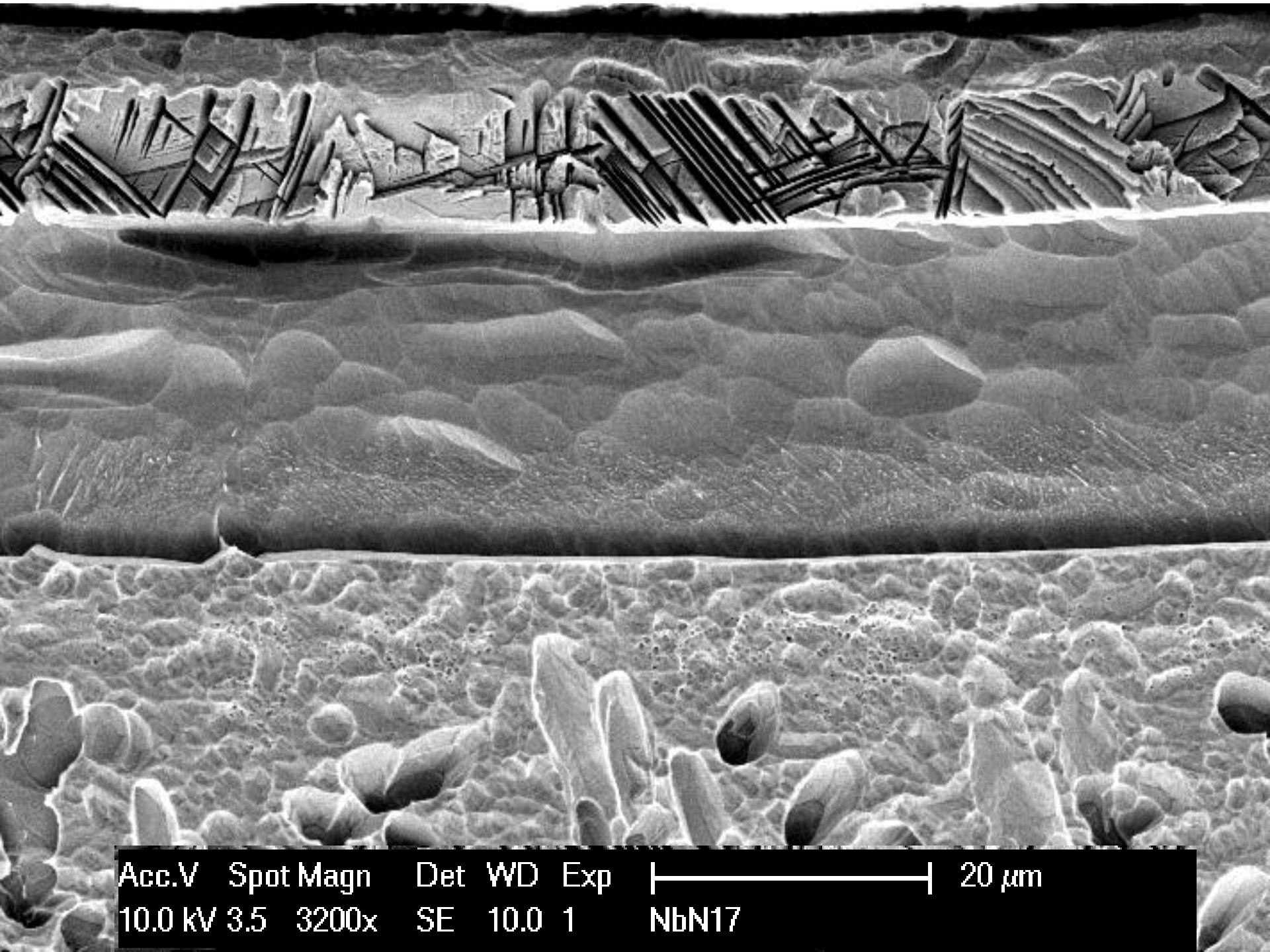
η-NbN (hexagonal);

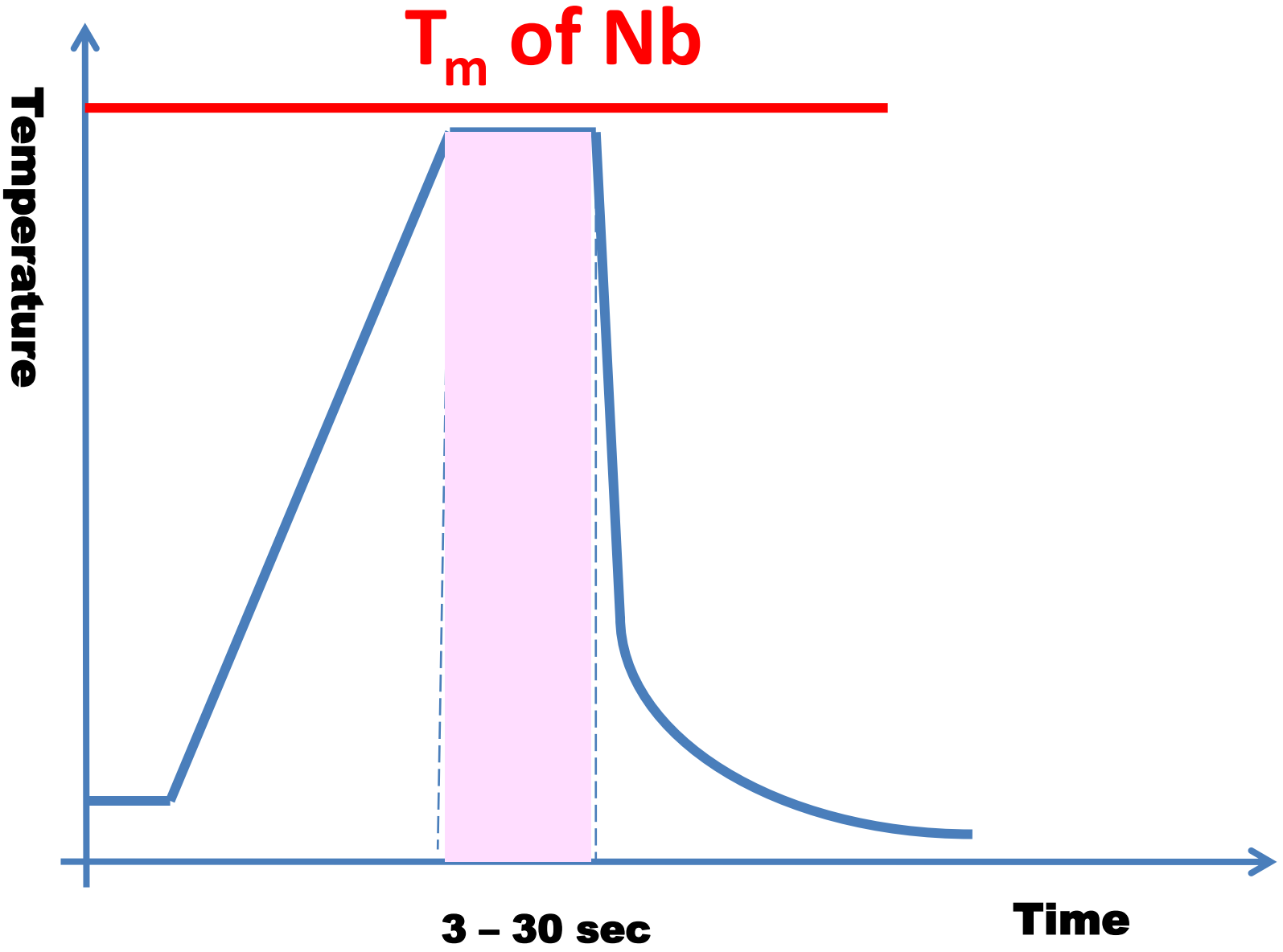
δ'–NbN (hexagonal);

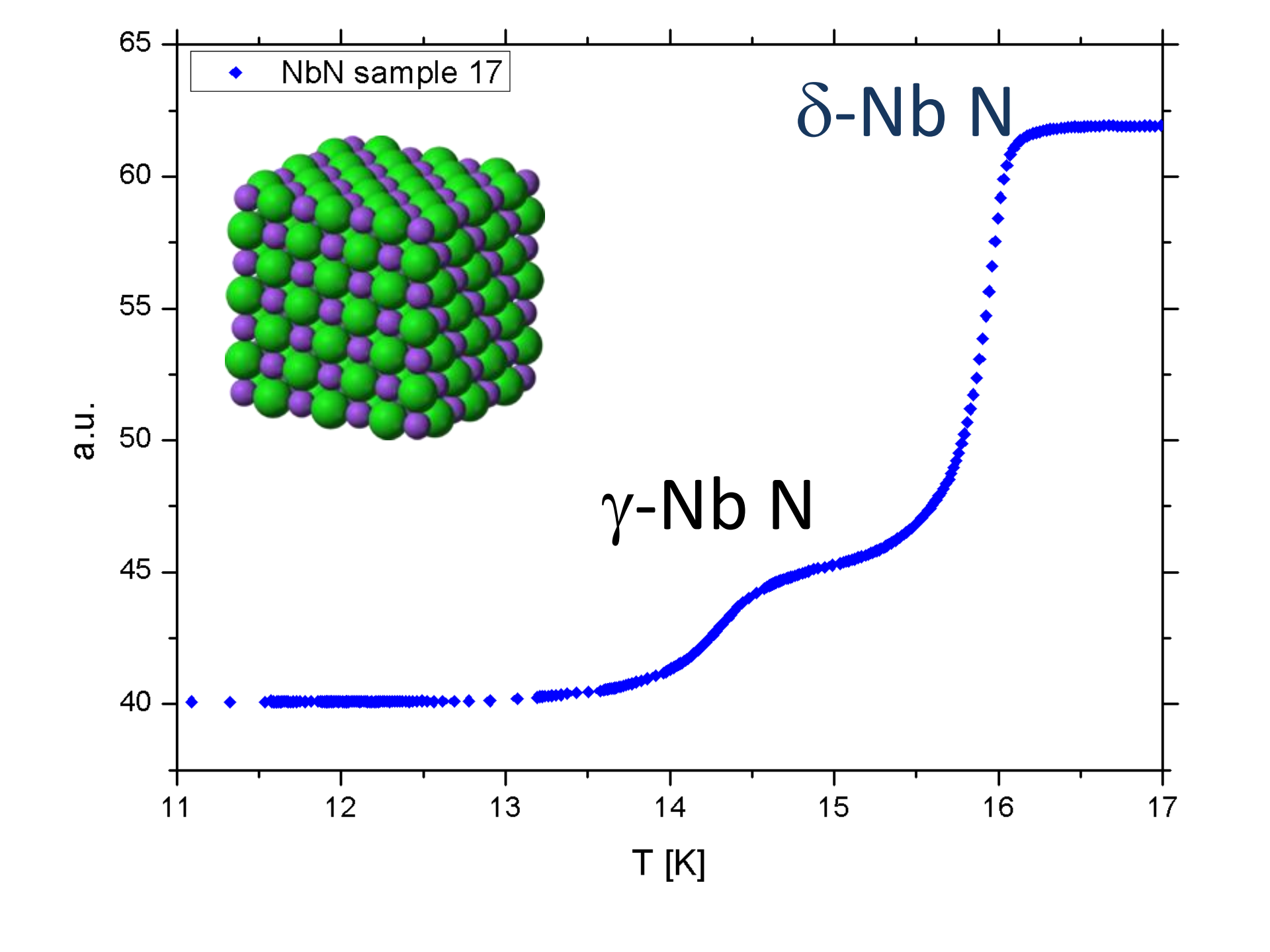
β-Nb2N (hexagonal); γ-Nb_4N_{3-x}

α-Nb (N) (bcc solid solution)

Niobium


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


T_m of Nb
Temperature
3 – 30 sec
Time

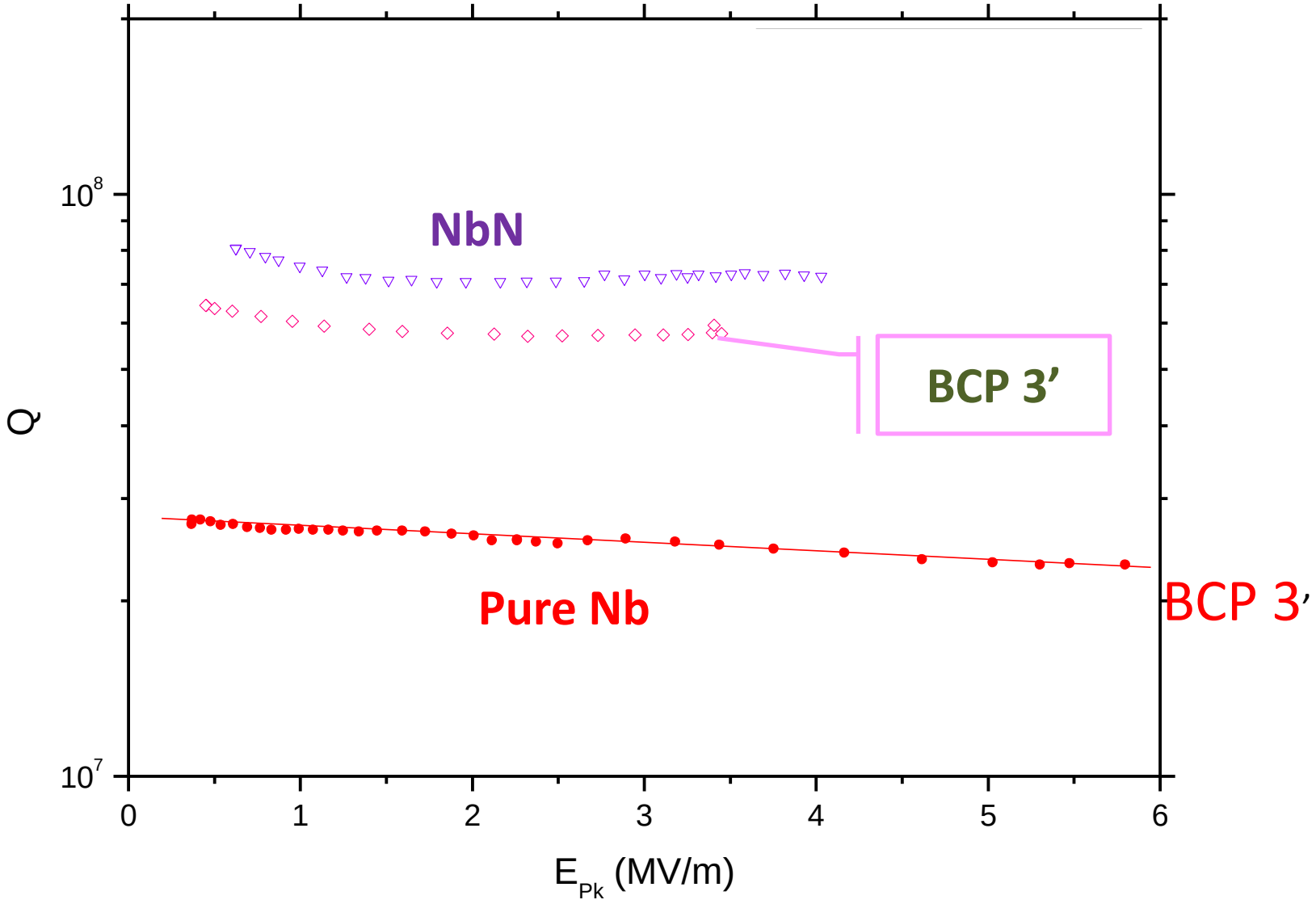

NbN sample 17
δ-Nb N
γ-Nb N
a.u.
T [K]
65
60
55
50
45
40
11
12
13
14
15
16
17

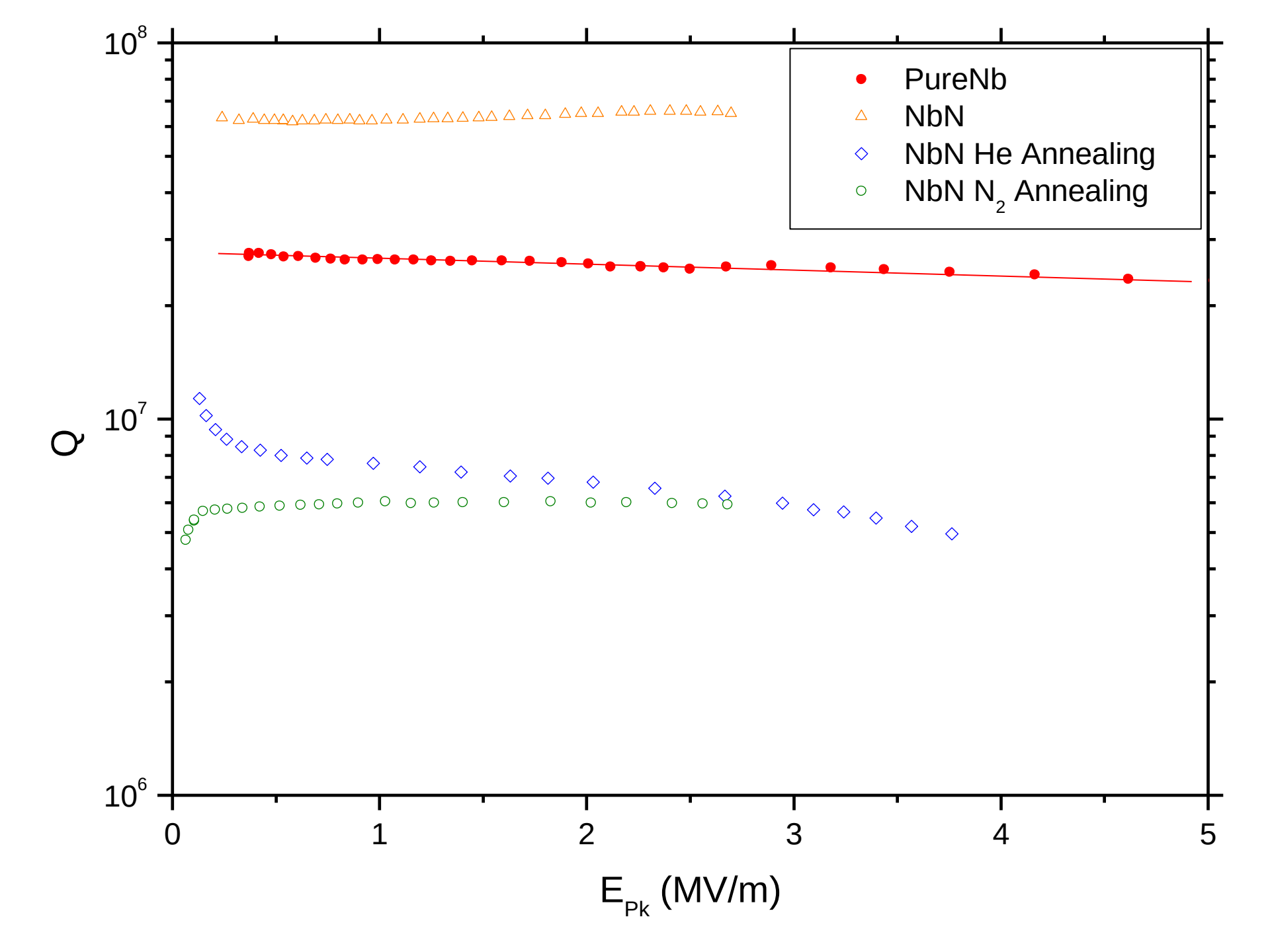
As the δ-NbN $\rightarrow$ γ-Nb_4N_{3-x} phase transformation is a very fast, quasi-continuous Transition,

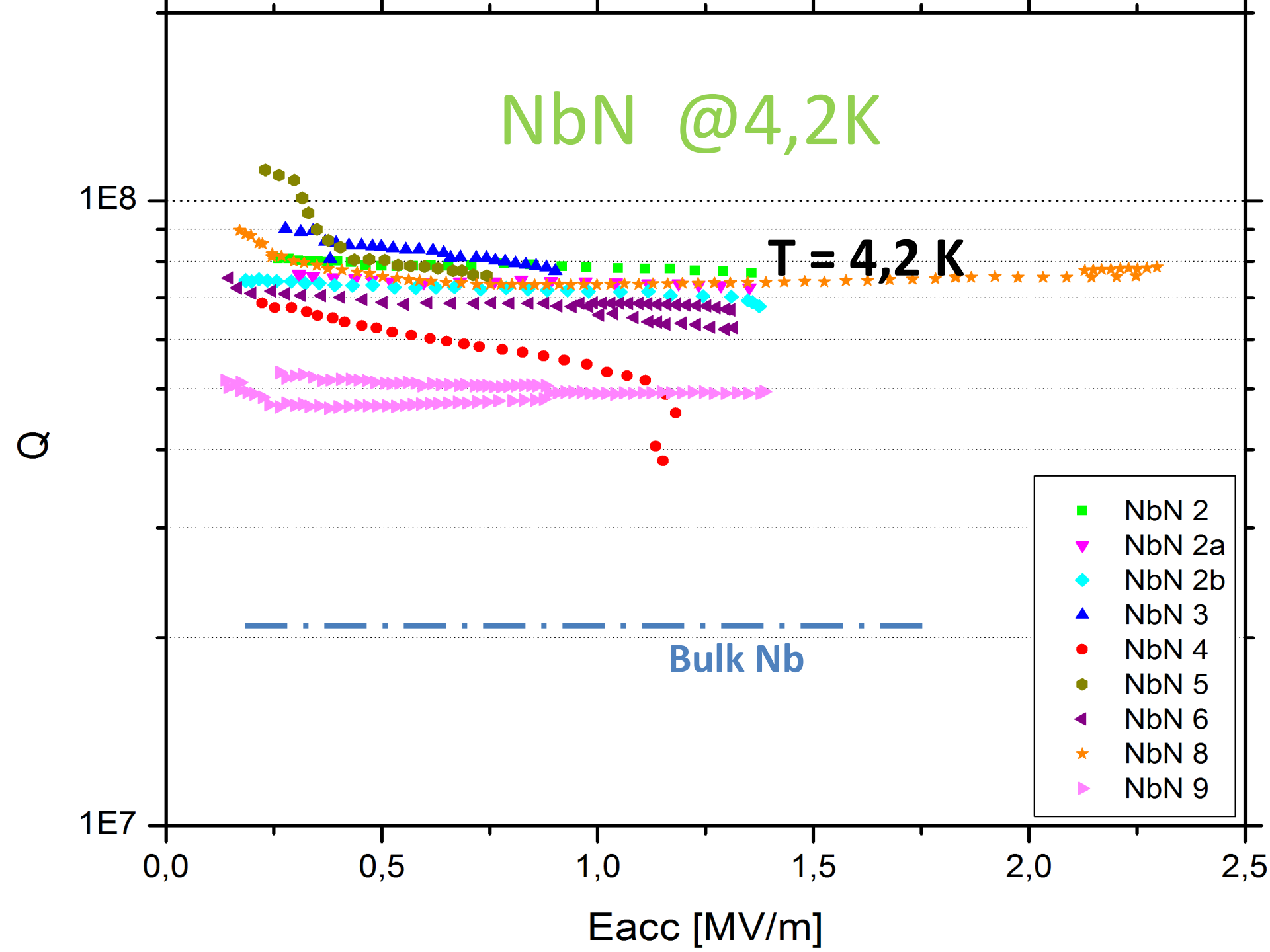
it cannot be avoided by quenching

The good layer is

the most external one

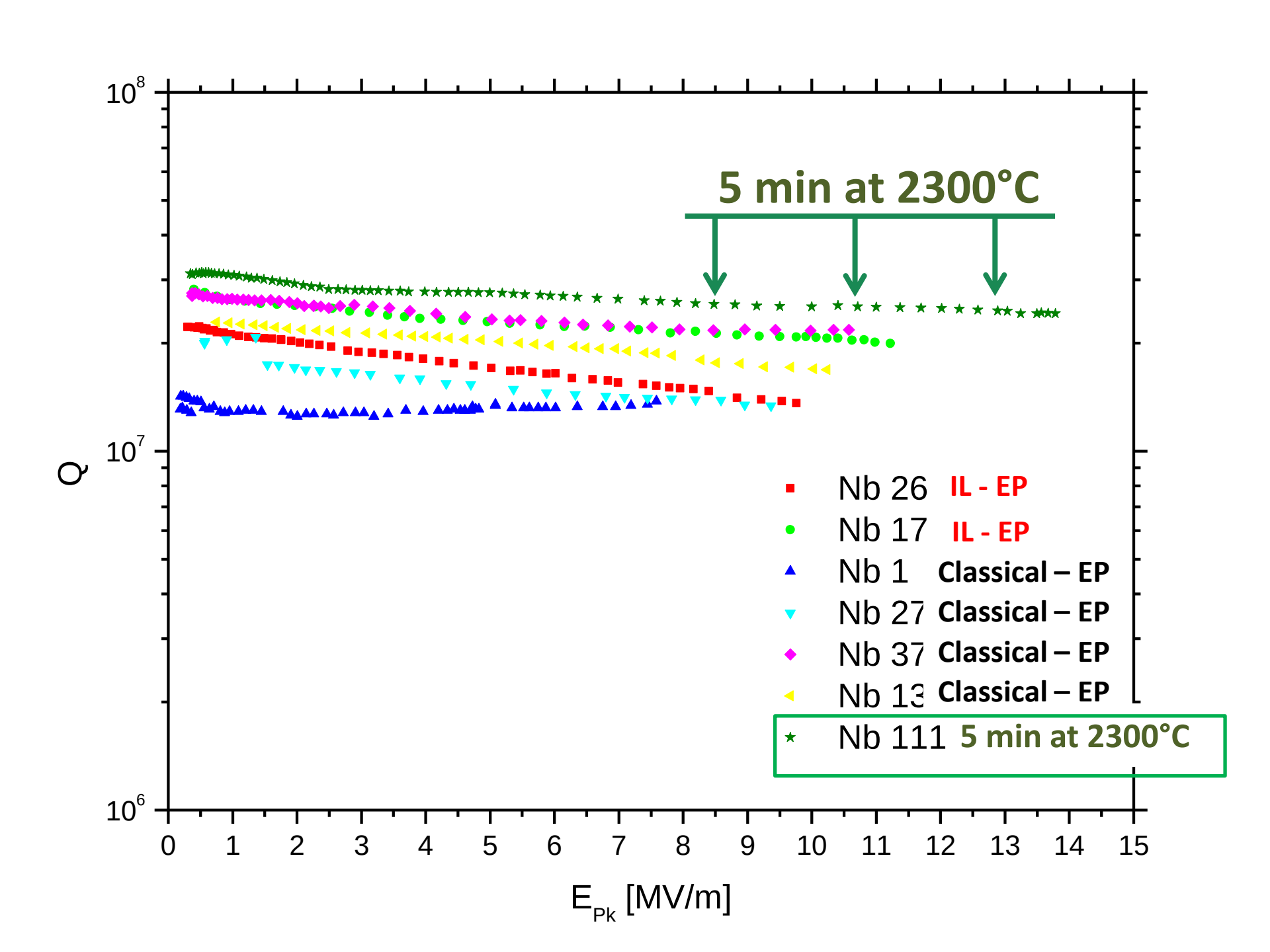

NbN
BCP 3’
Pure Nb
BCP 3’
Q
10^8
10^7
0
1
2
3
4
5
6
E_{Pk} (MV/m)


PureNb
NbN
NbN He Annealing
NbN N2 Annealing
Q
10^8
10^7
10^6
0
1
2
3
4
5
E_Pk (MV/m)


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

High Temperatures for

Nb Purification


5 min at 2300°C
Q
10^8
10^7
10^6
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
E_{Pk} [MV/m]
Nb 26 IL - EP
Nb 17 IL - EP
Nb 1 Classical – EP
Nb 27 Classical – EP
Nb 37 Classical – EP
Nb 13 Classical – EP
Nb 111 5 min at 2300°C

Conclusions 1

- **6 Ghz cavities allow a fast and dense statistics**

Conclusions 2

- **No vacuum required!**
- **5min @ 2300°C seem to purify Nb**
- **Nitriding performed atAtmospheric pressure**
- **At 4,2 K the Q-value at low field increases of even a factor 5**