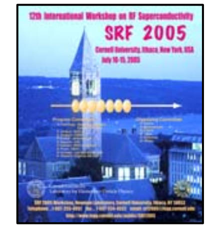
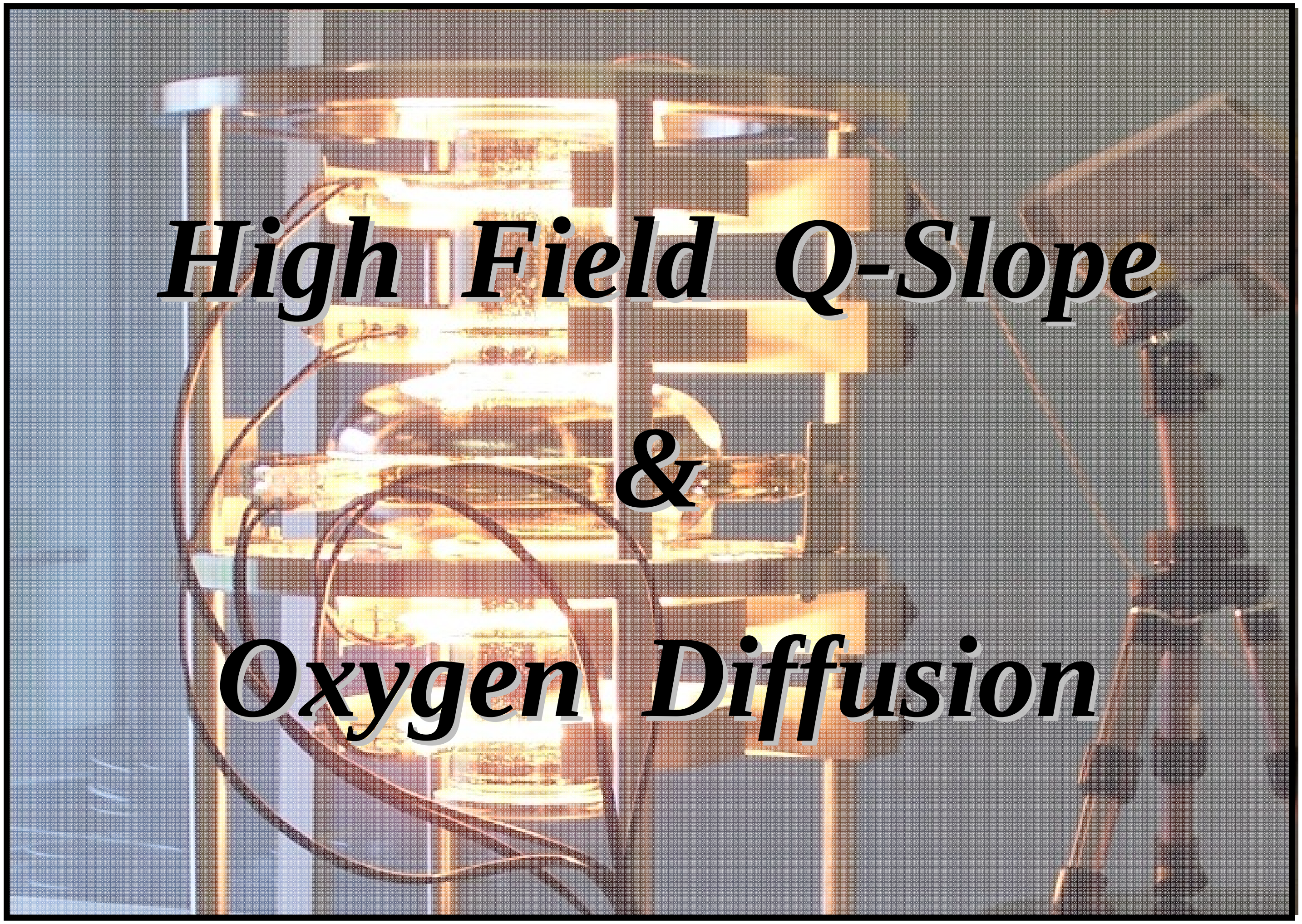
dapnia

cea

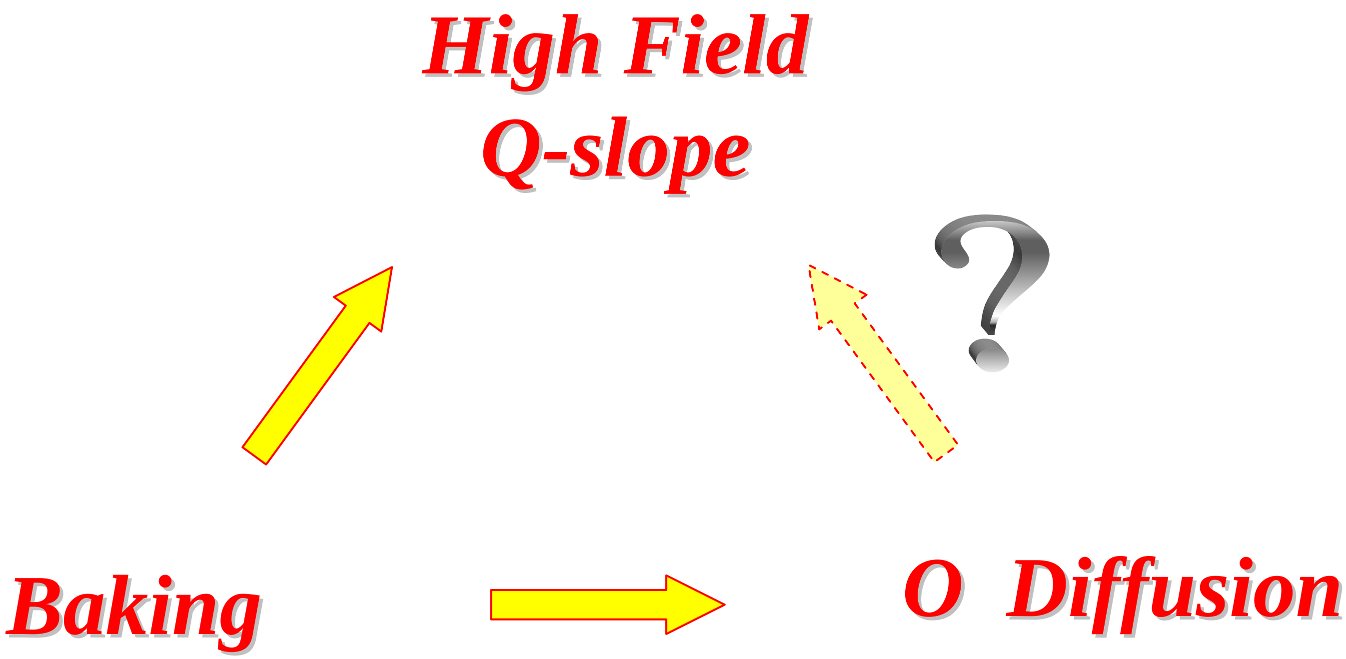
saclay





High Field Q-Slope & Oxygen Diffusion

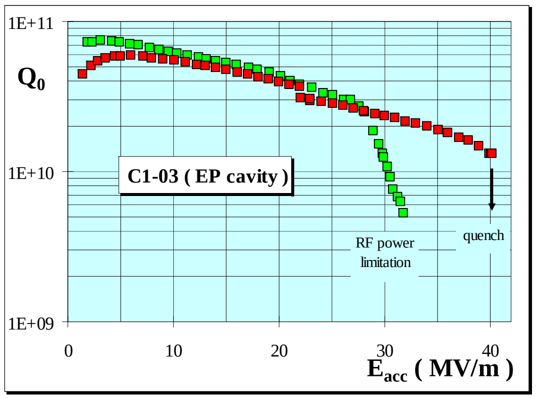
Bernard VISENTIN


High Field
Q-slope
?
Baking
O Diffusion

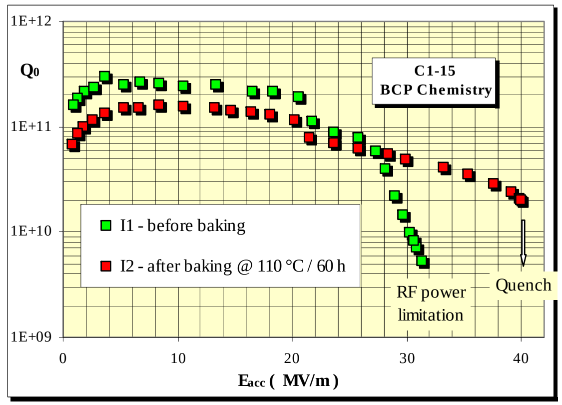
Baking ≡ *Recipe for high gradients*

dapnia
cea
saclay

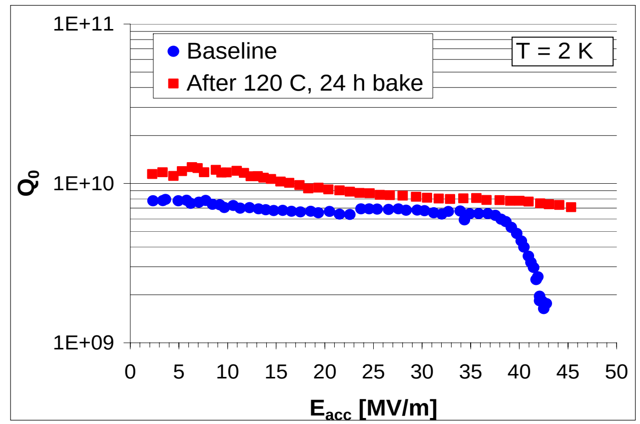
in-situ (UHV)	*T = 110 - 120 °C*	*t = 1 – 2 days*



TTF 1.3 GHz - Saclay / KEK
Polycrystalline
No Thermal Treatment
Electropolishing



TTF 1.3 GHz - Saclay
Polycrystalline
1300°C / Ti
Chemical Etching 1:1:2



LL 2.2 GHz - JLab
Single crystal
800°C – 1250°C / Ti
Chemical Etching 1:1:1

Whatever the niobium structure… (Single or Poly-crystal,)

Whatever the fabrication method…(EB Welding or Hydroforming, bulk Nb or clad Nb/Cu)

Whatever the thermal treatment… (nothing, 800°C, 1300°C/Ti)

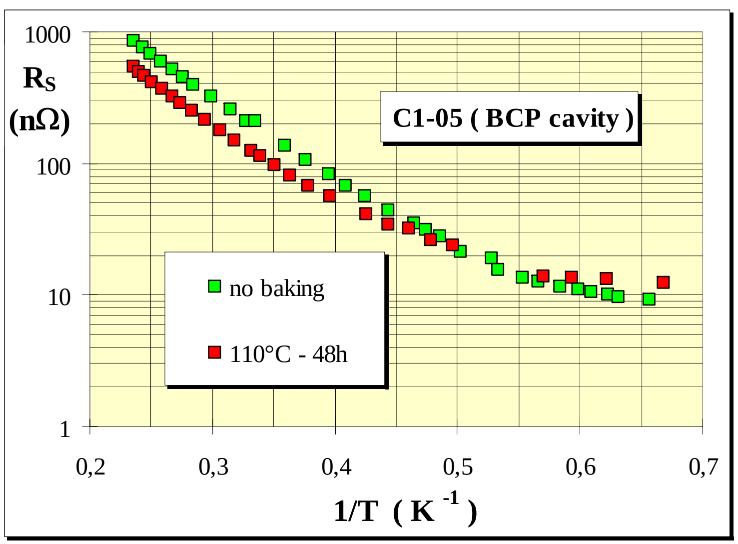
Whatever the chemical treatment… (Electropolishing or B C P)

Baking => O Diffusion

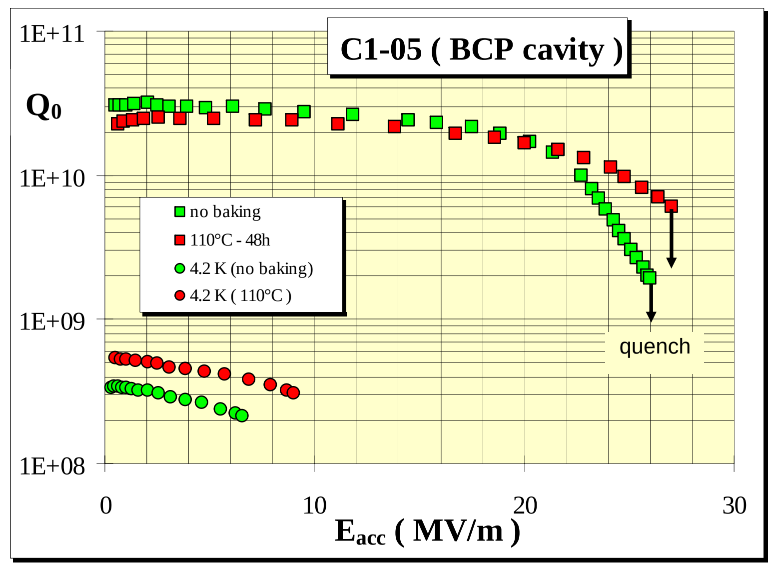
Nb superconductivity is modified
surface resistance R_S is trough $R_{BCS}(\ell)$ & R_{res}

$$R_S = R_{res} + A(\lambda_L, \xi_F, \ell)\frac{\omega^2}{T}e^{-\Delta/kT}$$

High Field Q-slope improvement : O diffusion is it involved too ?



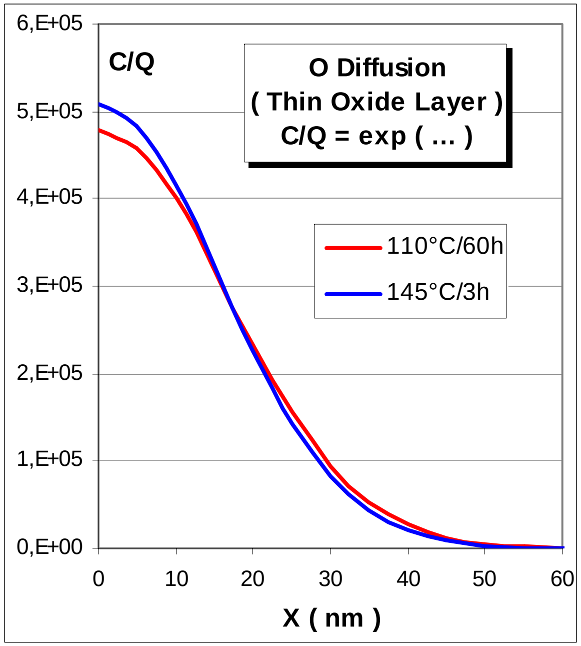
110 °C
60 hours
in-situ
(UHV)



dapnia
cea
saclay

Baking Parameters (T , t) with Unchanged Oxygen Penetration

2nd Fick's law $$\boxed{\frac{\partial C}{\partial t} = D_0\, e^{E_A/RT}\, \frac{\partial^2 C}{\partial x^2}}$$ → analytic solutions

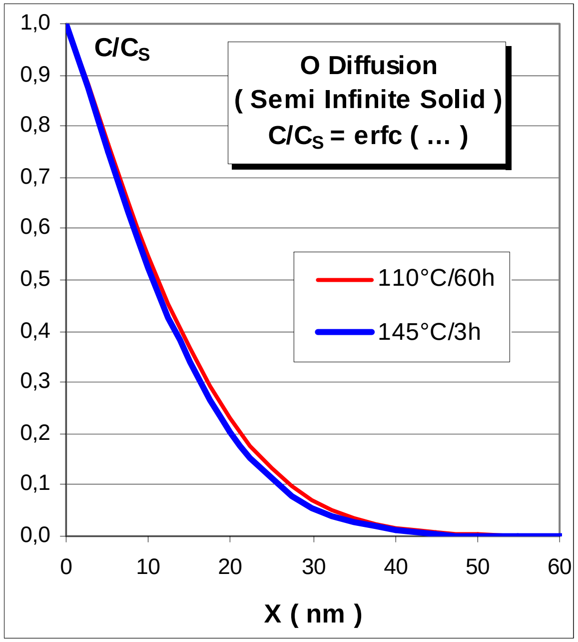


110 °C / 60 hours

equivalence

145 °C / 3 hours

High Field Q-Slope ?



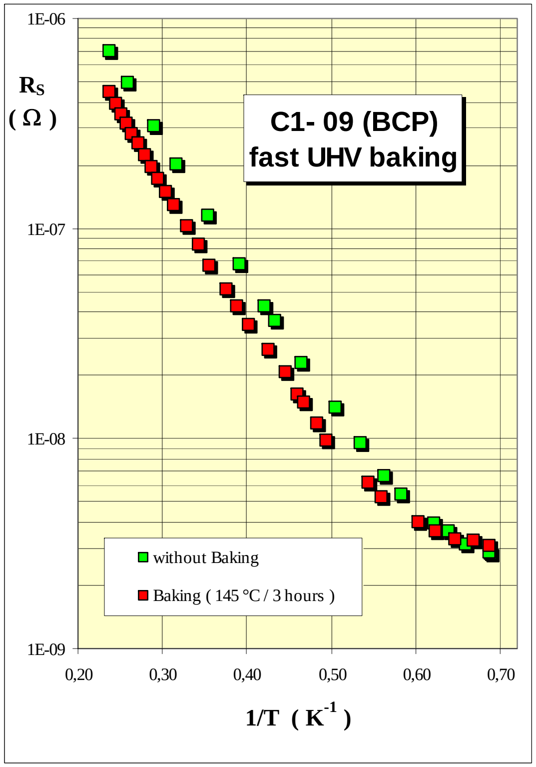
thin oxide layer : $C(x,0) = Q\,\delta(x)$

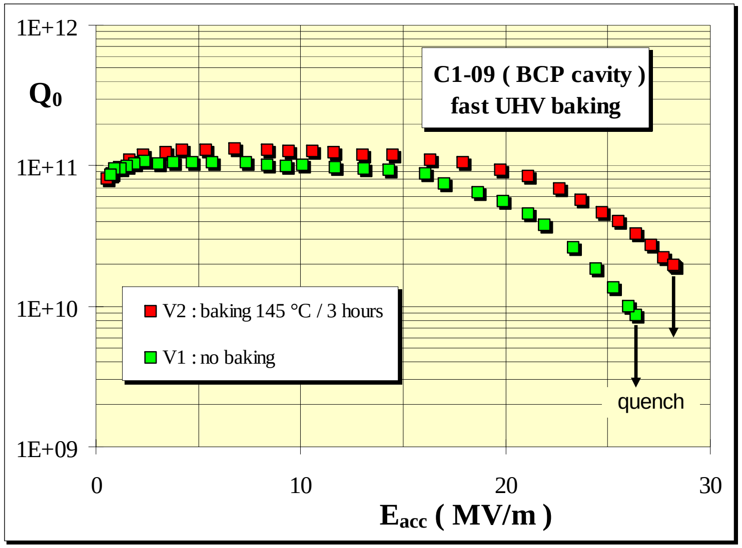
semi infinite solid : $C(0,t) = C_S$

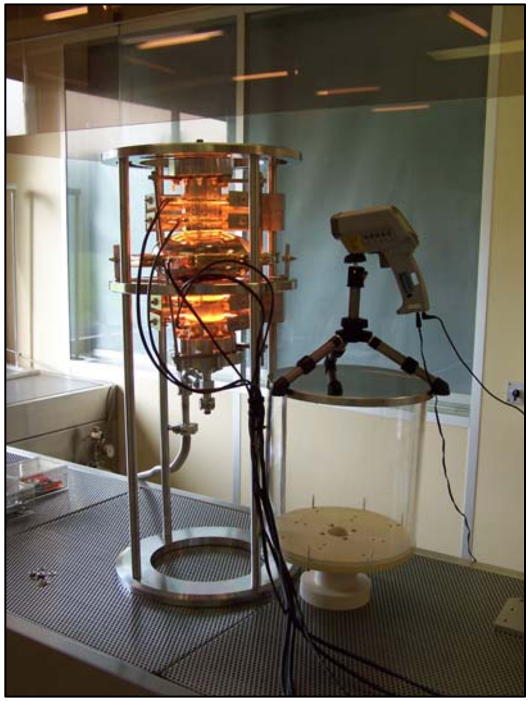
dapnia
cea
saclay

« Fast » Baking (UHV)

- Infra-Red emitters (short T rise time)
- Cavity pumped out (Ultra High Vacuum)







145 °C - 3 hours

Similarities with Standard Baking

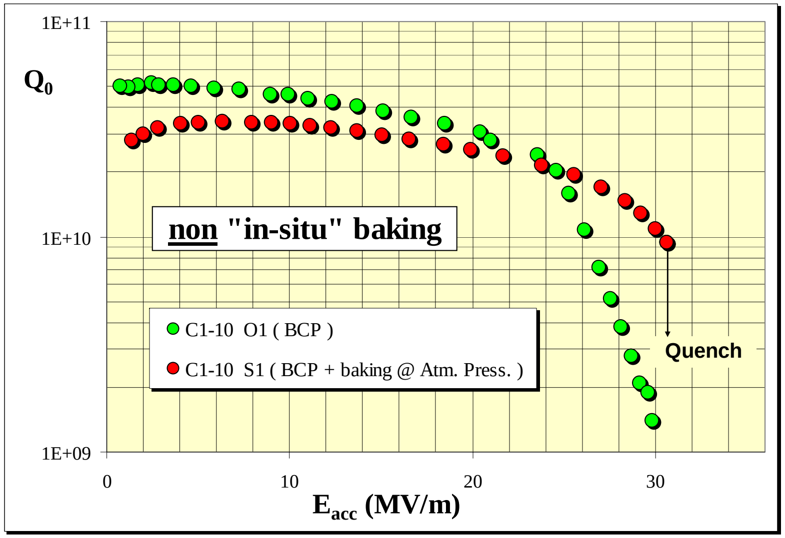
O diffusion → HF Q-slope improvement

dapnia
cea
saclay

« UHV » → « Air - Baking »
Atmosphere - Nb Surface Interaction

Cavity open-ended in Stove
(room atmosphere - atmospheric pressure)

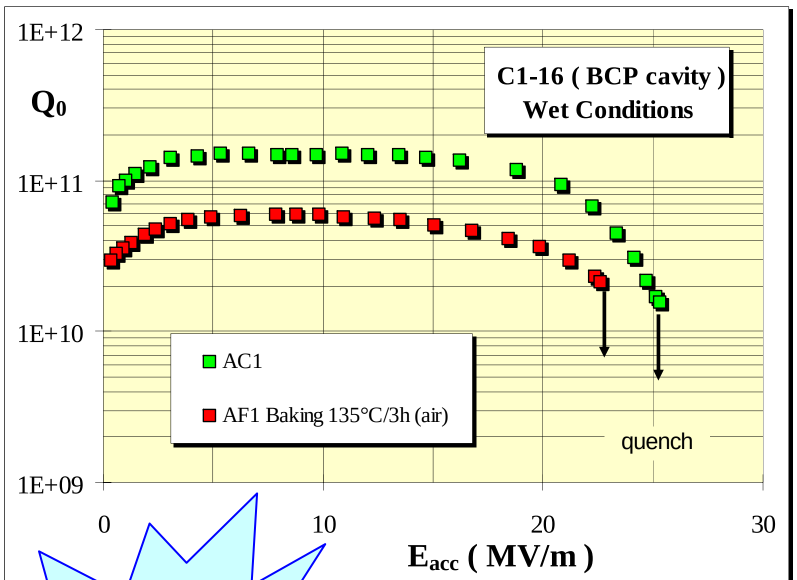
110 °C
60 hours
+ HPR

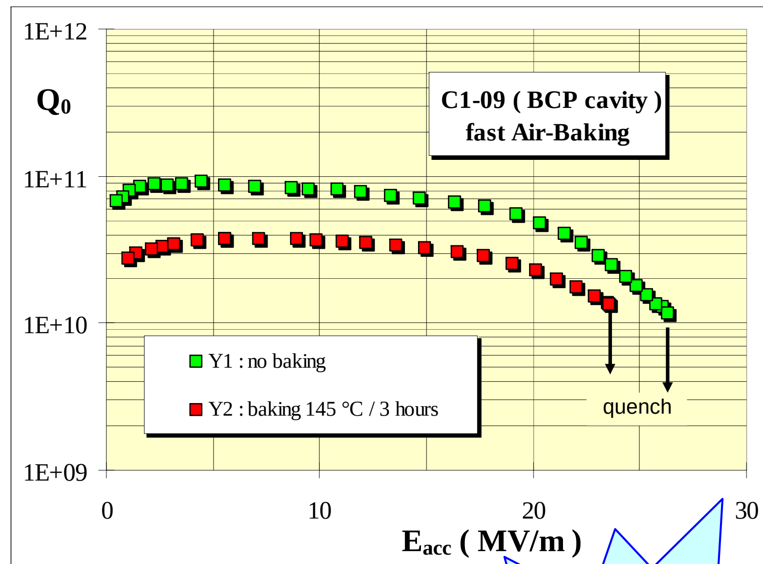


no significant modification due to the atmosphere, but…

Fast Air-Baking

145°C / 3 hours + HPR

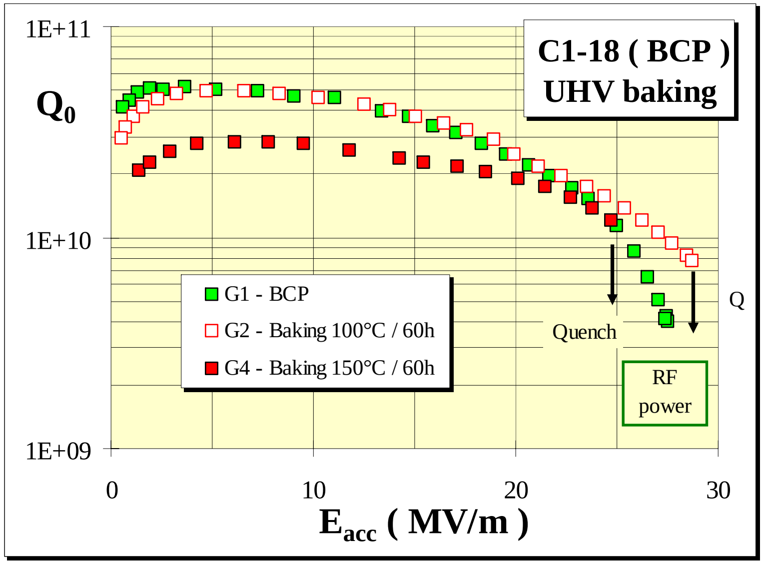




Oven
Wet Cavity
from *HPR*

Bad Results after baking (R_S, quench)
Active interaction between atmosphere and Nb surface (≠ Fast UHV-Baking)

IR heaters
Dry Cavity
CR **hygrometry**
60%



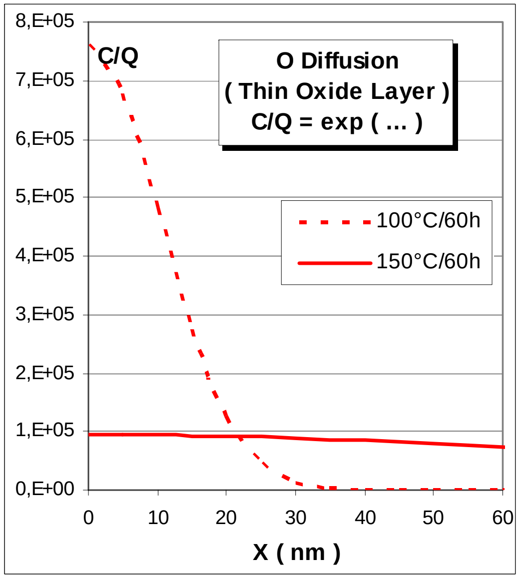
Similarities with
standard in-situ baking (UHV)
150 °C / 60h

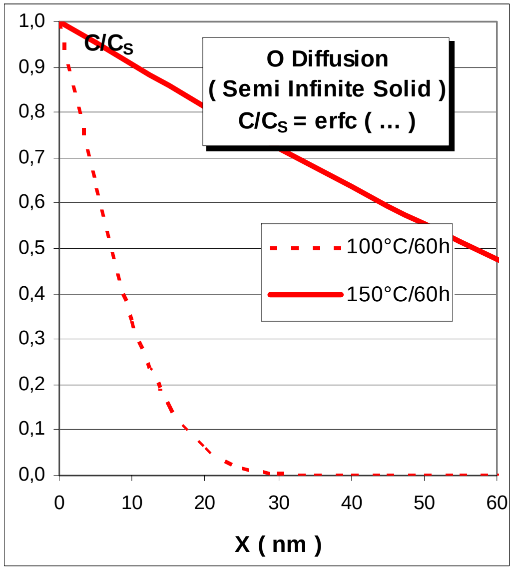
Fast Air-Baking @ 145°C / 3h

O concentration in excess

going from surface
due to wet atmosphere H_2O

3 hours is too long





XPS analysis on Nb Samples :

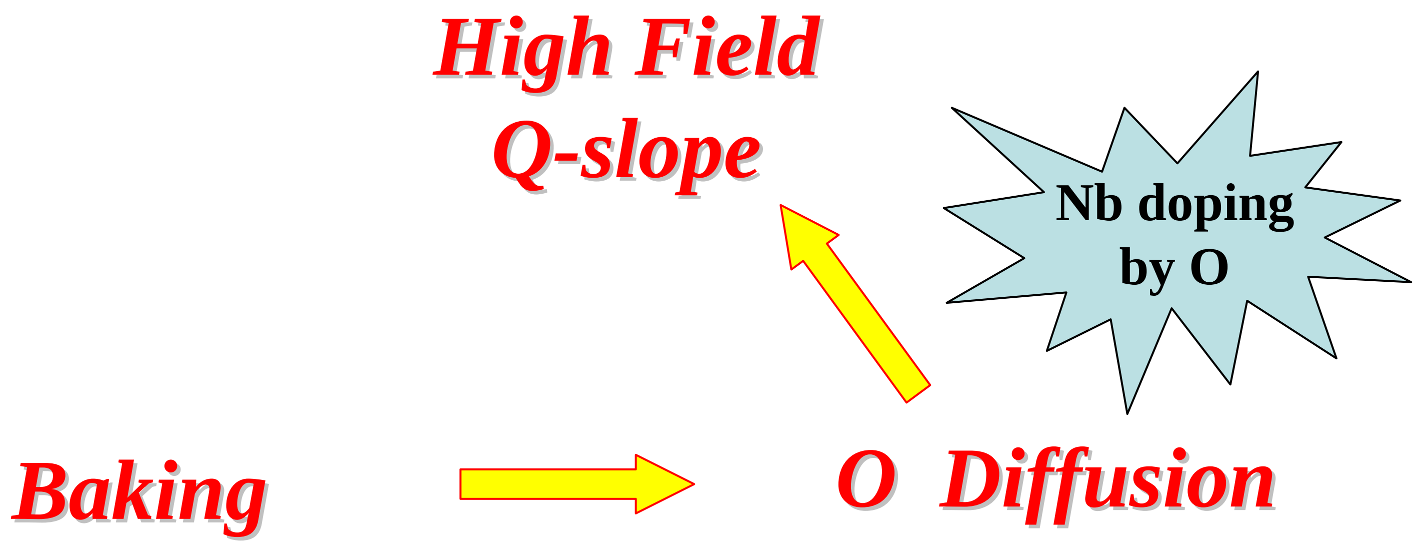
- to confirm this hypothesis
- to fix the right time
for fast air-baking @145°C

O % from NbO_X, NbO_5 →

O % from H_2O on surface ↓

	110 °C 3 h	110 °C 60 h	145 °C 3 h	145 °C 60 h
UHV	=	+	+	-
Air		+	-	

<u>optimum value</u> for O concentration
is needed in the Nb RF layer to suppress the HF Q-Slope…



A key to understand the High Field Q-slope Origin …

But not only …

Practical Consequence :

Fast Baking well adapted to Cavity Mass Production

Clean Room
(Class 100)

High Pressure Rinse - 85 bars (FE)

Air-Drying : **RT - 3 hours**

Assembly + Helium Test

Test Stand
(Vertical Cryostat)

(RF Test)

« in-situ » Baking : **110 °C - ~~2 days~~**

RF Test

save time:

<u>decrease</u> Baking Duration

risk of helium leaks ($\propto$ T)
for final RF test:

Baking <u>before</u> Assembly

save step:

Drying <u>with</u> Baking

Combination of Air-Drying and Baking

Clean Room
(Class 100)

High Pressure Rinse - 85 bars (FE)

Hot Air-Drying : **145°C, t < 3 hours**

Assembly + Helium Test

RF Test

Fast Air-Baking on Wet cavity under Laminar Flow (FE)

OK

t < 3hours

turbulences

dapnia

cea

saclay