C. Pira, V. Garcia, L. Zanotto, E. Chyhyrynets,
F. Stivanello, O. Azzolini, G. Keppel, R. Vaglio,
A. Cassinese, S. Aliasghari, R. Valizadeh, V. Palmieri

Legnaro Thick Films

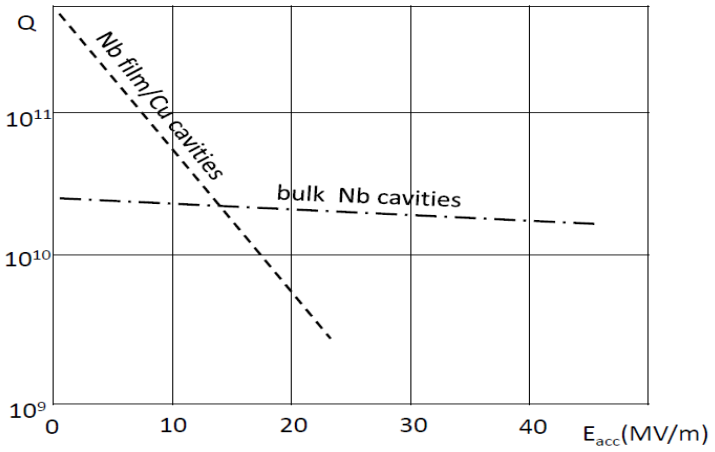
TTC 2020, CERN 5 February 2020

Work supported by the INFN V group experiment TEFEN
and performed under the CERN-INFN-STFC Agreement N. KE2722/BE/FCC

EASITrain – European Advanced Superconductivity Innovation and Training. This Marie Sklodowska-Curie Action (MSCA) Innovative Training Networks (ITN) has received funding from the European Union's H2020 Framework Programme under Grant Agreement no. 764879

Motivation (1)

Q slope, a problem since 80's



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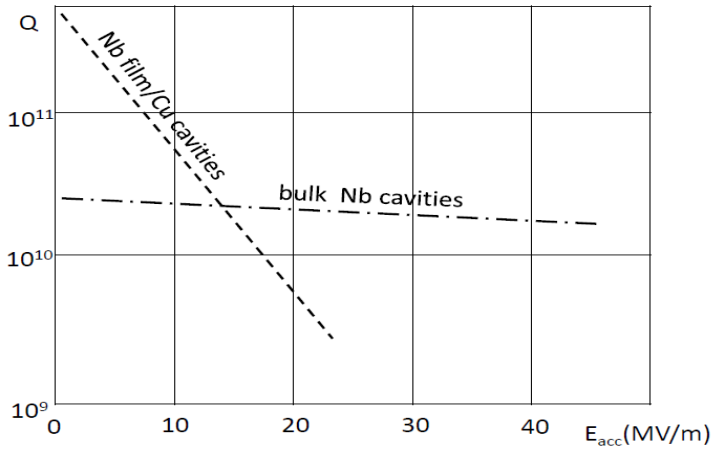
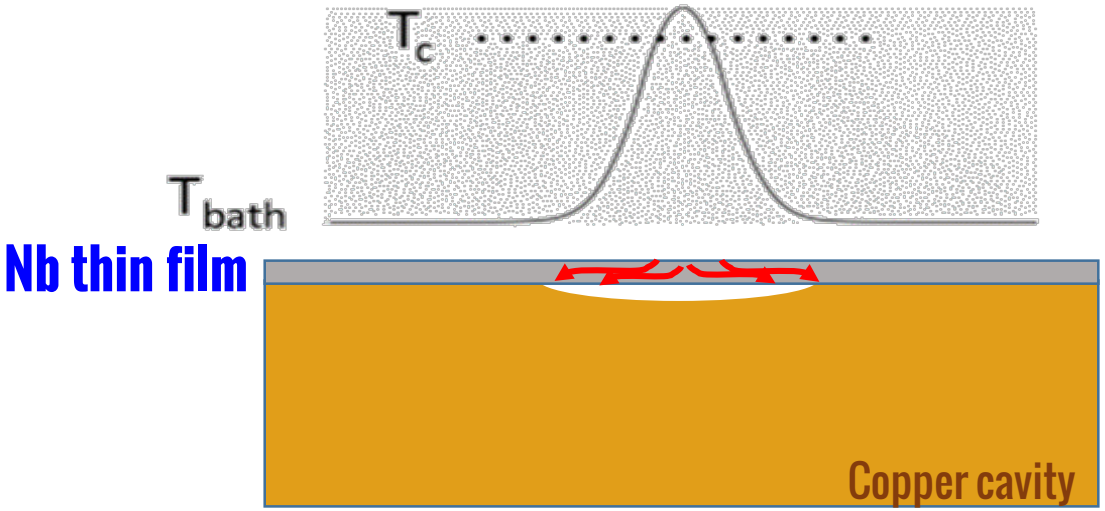




- **Theoretical model from Vaglio and Palmieri**

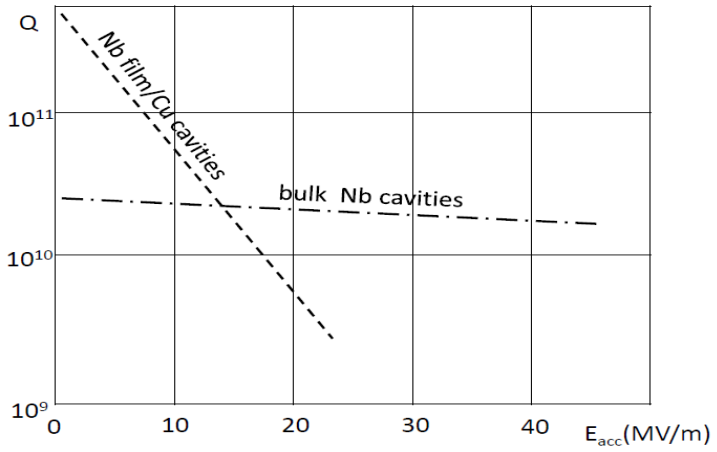
Q-slope is related to local enhancement of the **thermal boundary resistance at the Nb/Cu interface**, due to poor thermal contact between film and substrate

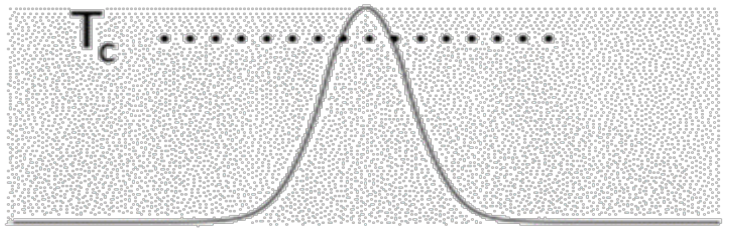
V. Palmieri and R. Vaglio, Supercond. Sci. Technol, Jan. 2016

- **Thick Film for hard coatings depeloped at LNL**

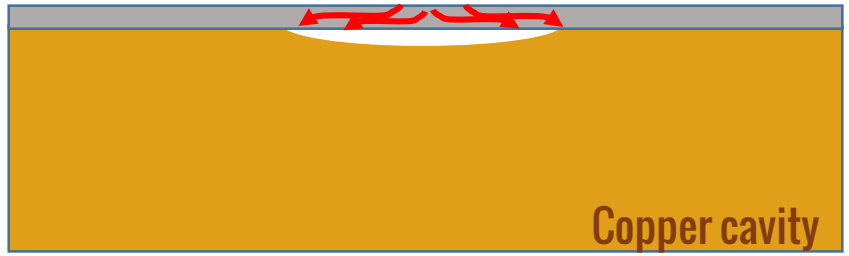
Motivation (1)

Q slope, a problem since 80's





Nb thin film



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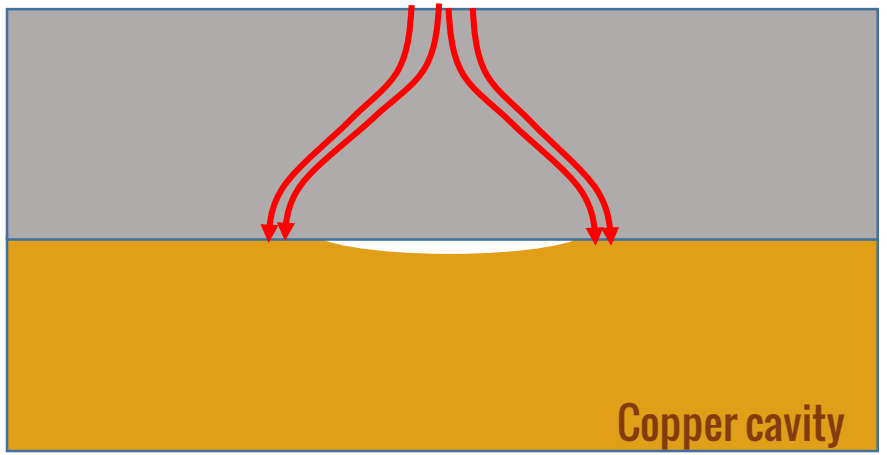


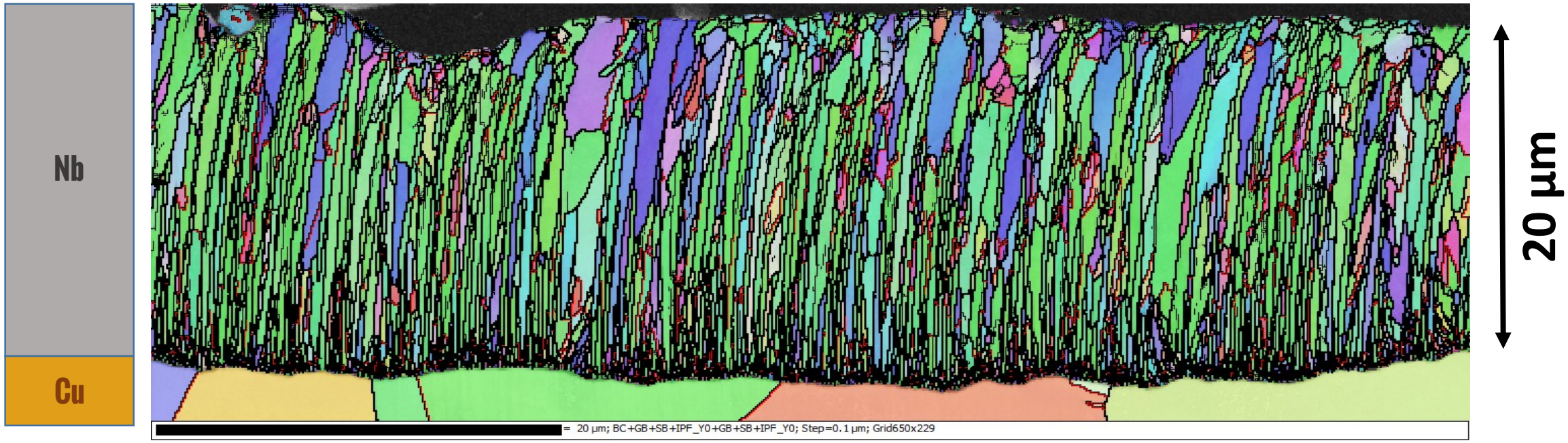
LNL IDEA

Increasing the thickness

Thermal dissipation could by-pass the thermal defect

Motivation (2)

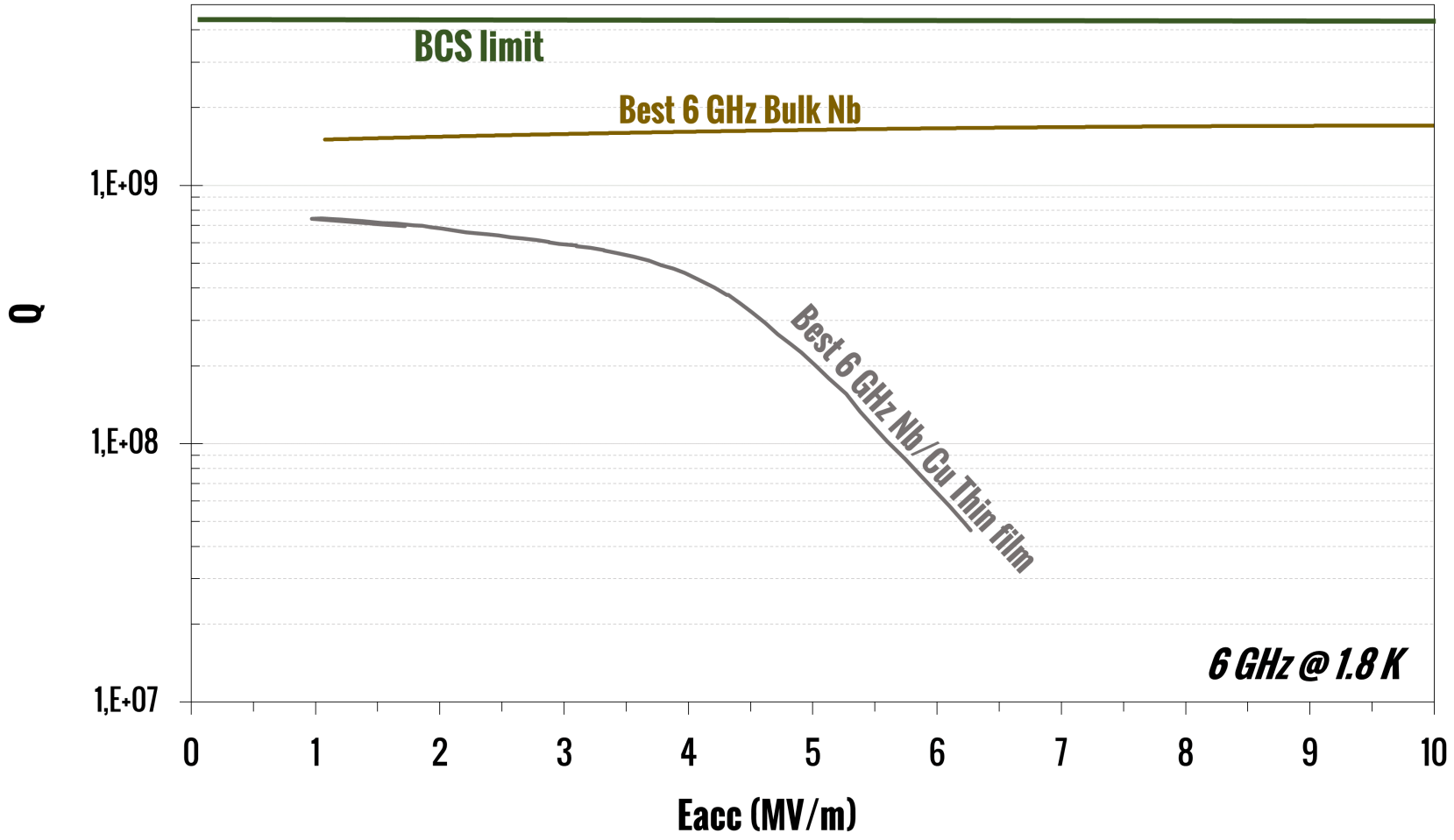
BULK LIKE PROPERTIES ON A FILM → Thick films increase grain dimensions and RRR



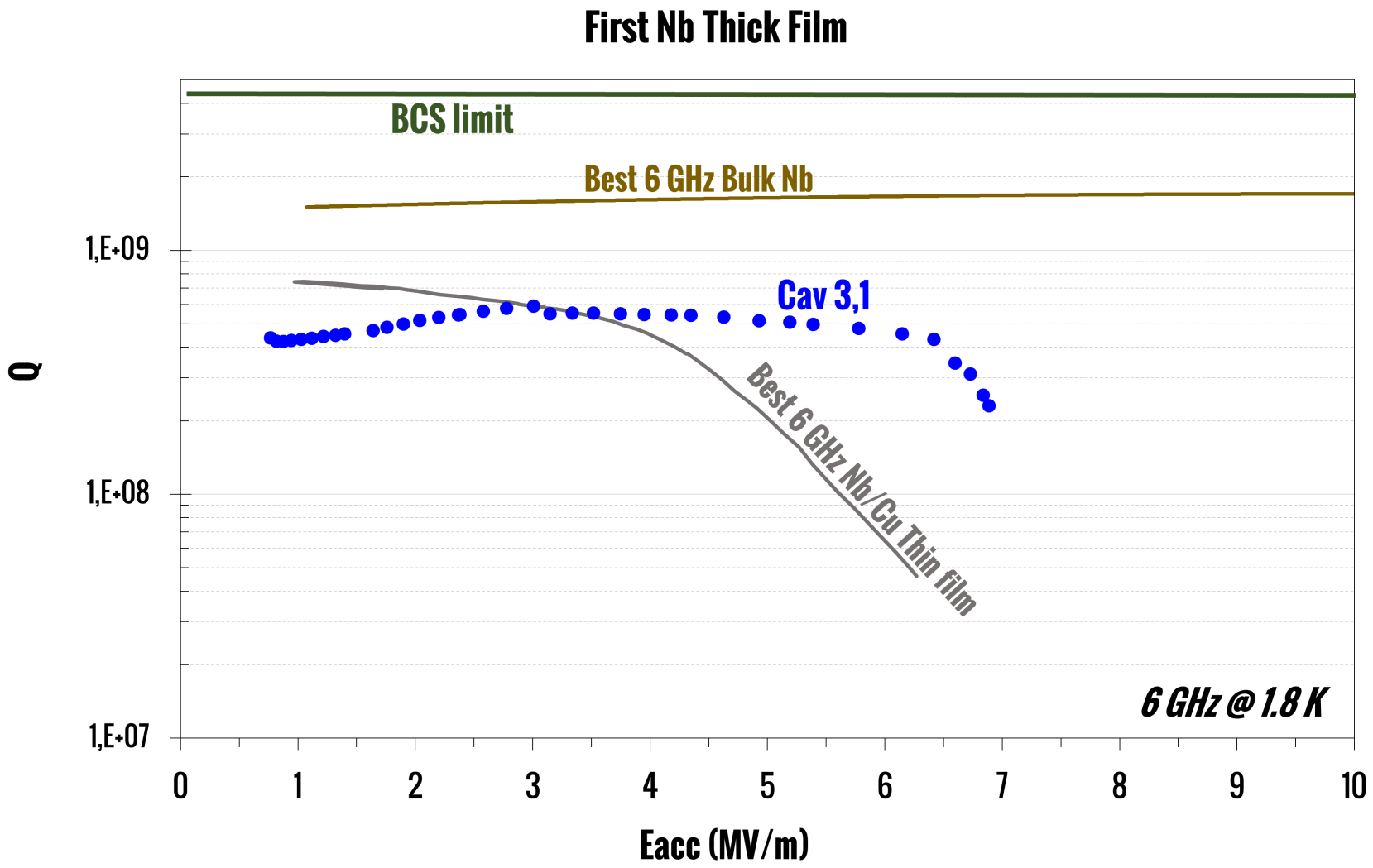
EBSD Micrograph of cavity #4, Courtesy of Reza Valizadeh (STFC)

- Grain dimension > 1 µm
- RRR > 60

6 GHz Base line



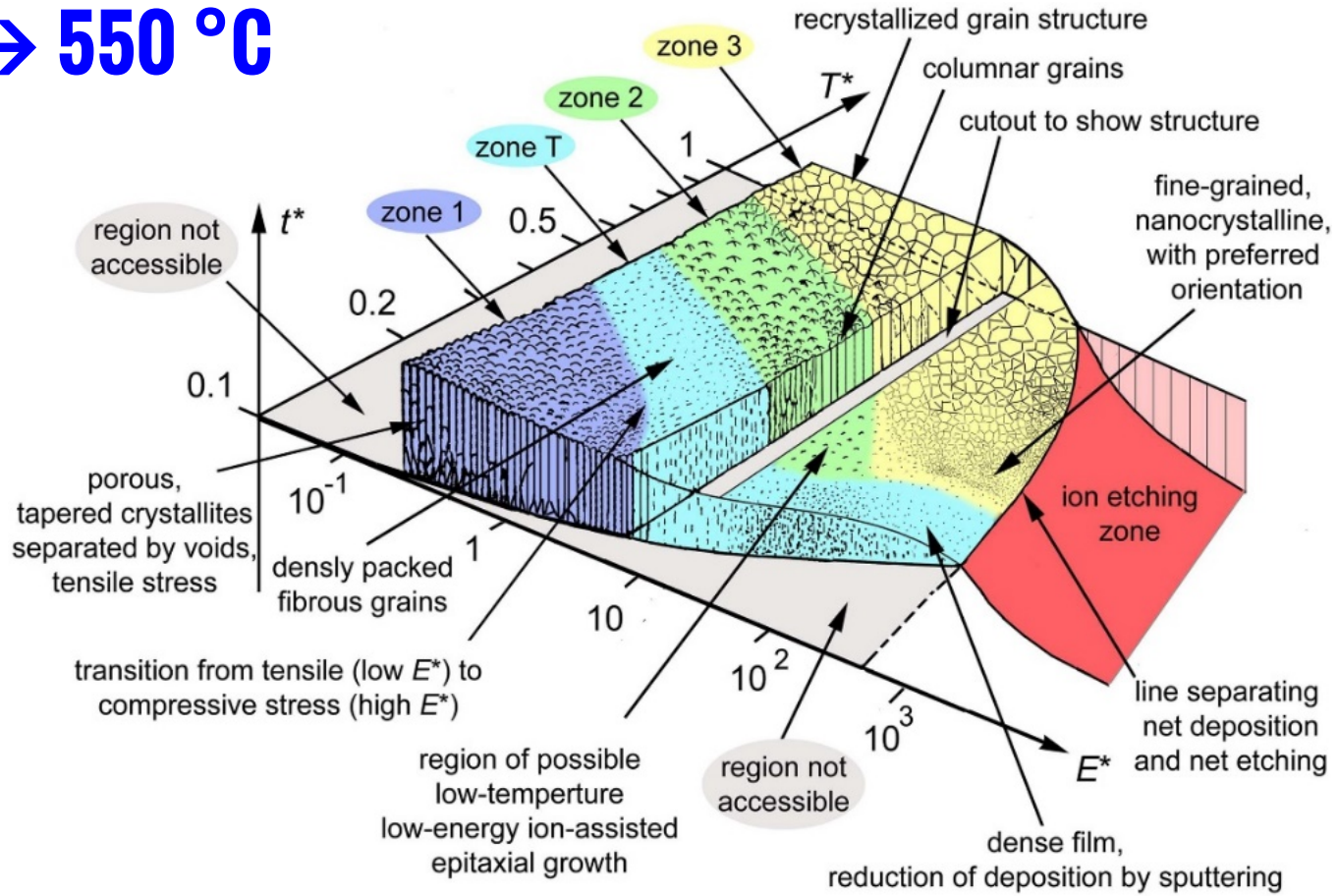
First result



How to avoid peeling/increase film quality? (1)

HIGH SUBSTRATE TEMPERATURE → 550 °C (limited by Cu)

- **Magnetron sputtering** allows to play with **T**
- **Limited** access to exploration of the **E axis**
- **Simple configuration**
  compared to energetic condensation configurations
  (HiPIMS, ECR, …)



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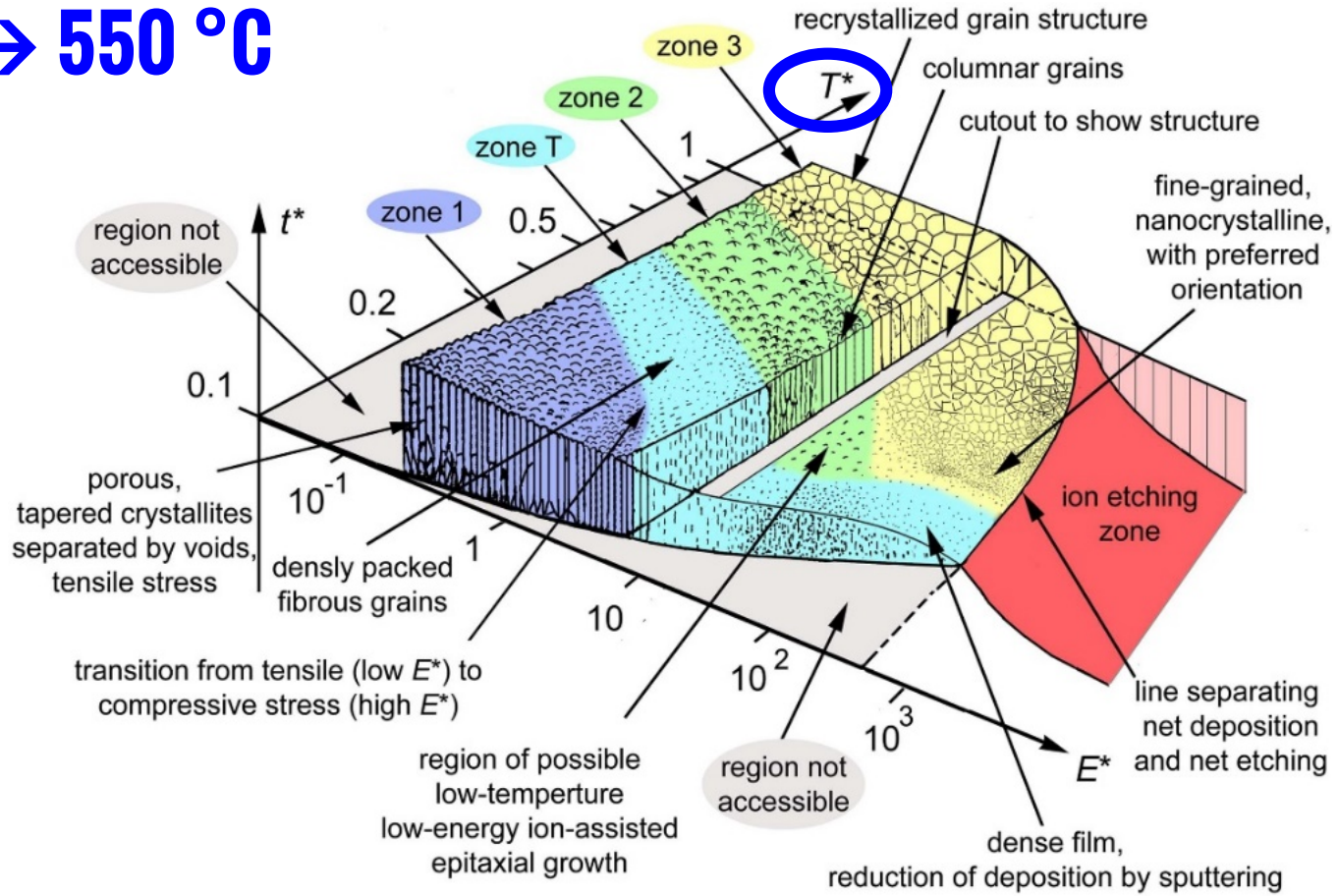

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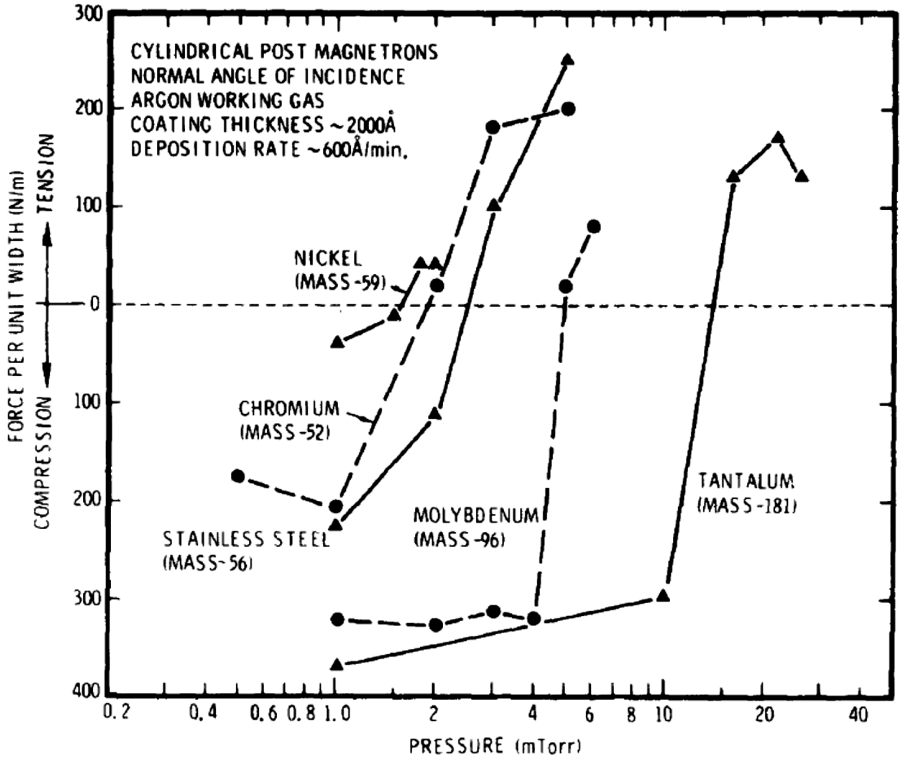
How to avoid peeling/increase film quality? (2)

ZERO STRESS PRESSURE



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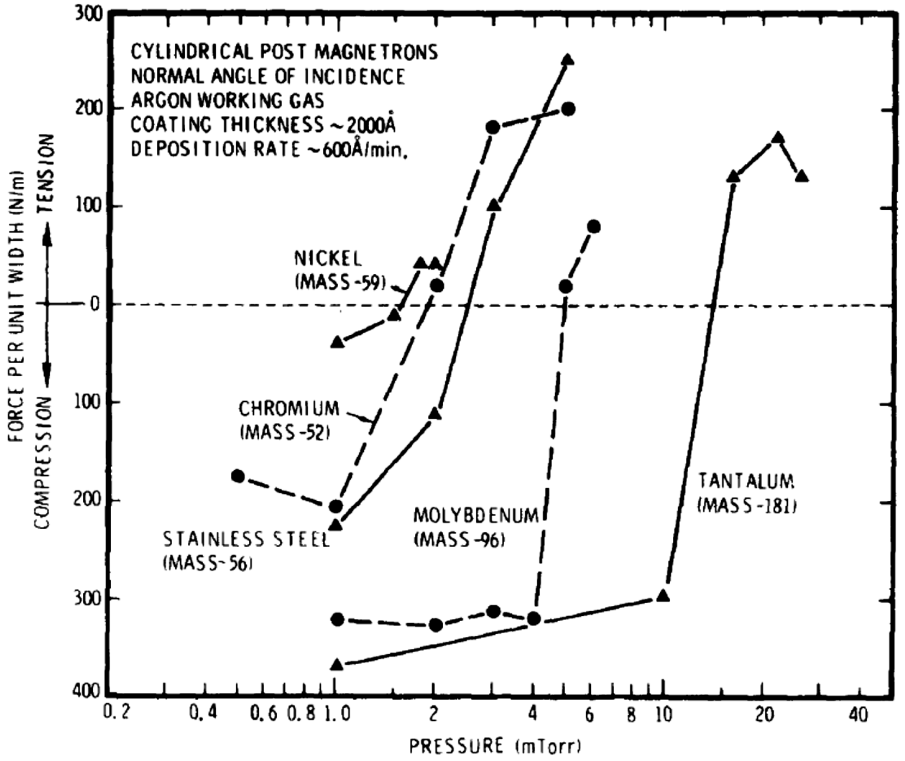

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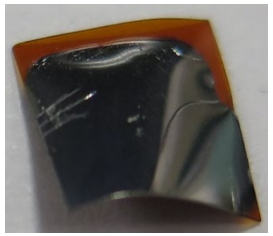
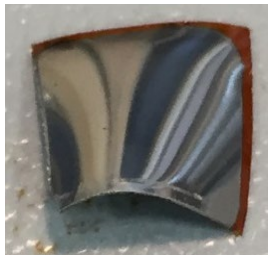
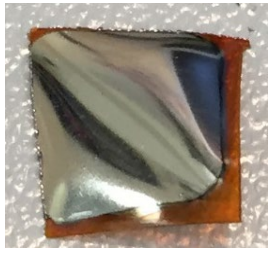


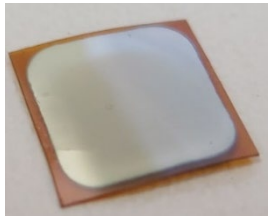
$7 \cdot 10^{-3}$ mbar



$9 \cdot 10^{-3}$ mbar



$2 \cdot 10^{-2}$ mbar

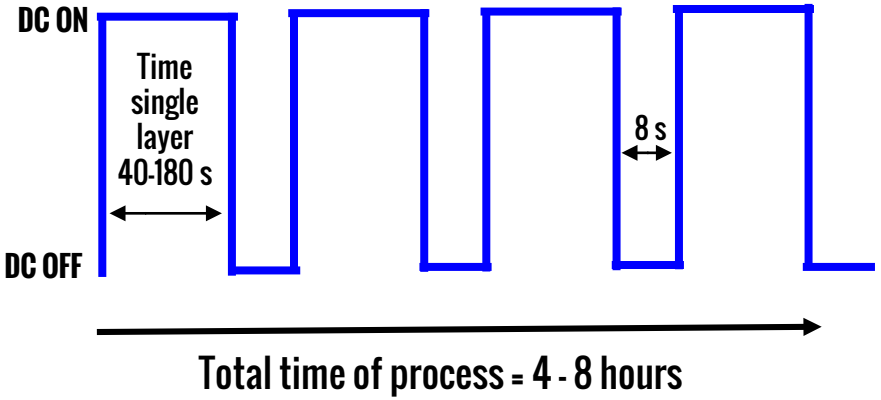


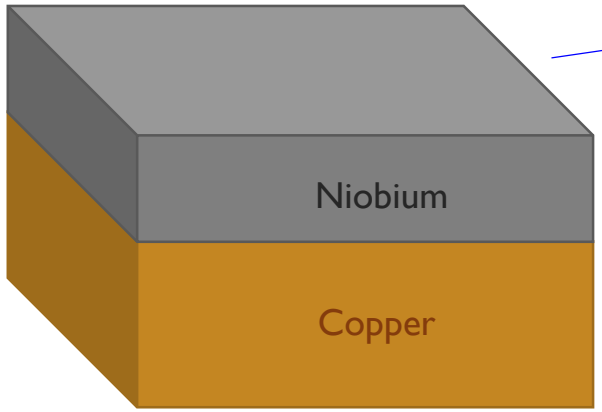
$5 \cdot 10^{-2}$ mbar

How to avoid peeling/increase film quality? (3)

LONG PULSE DEPOSITION MODE

(borrowed from QWR coating procedure)





40 - 70 µm

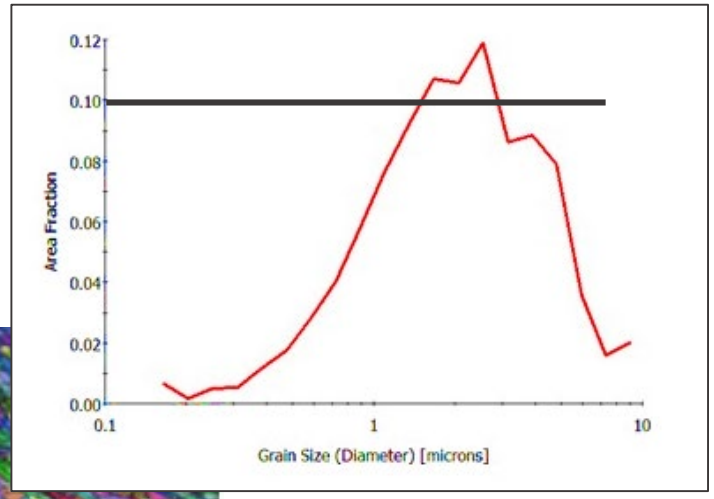
Total Thickness

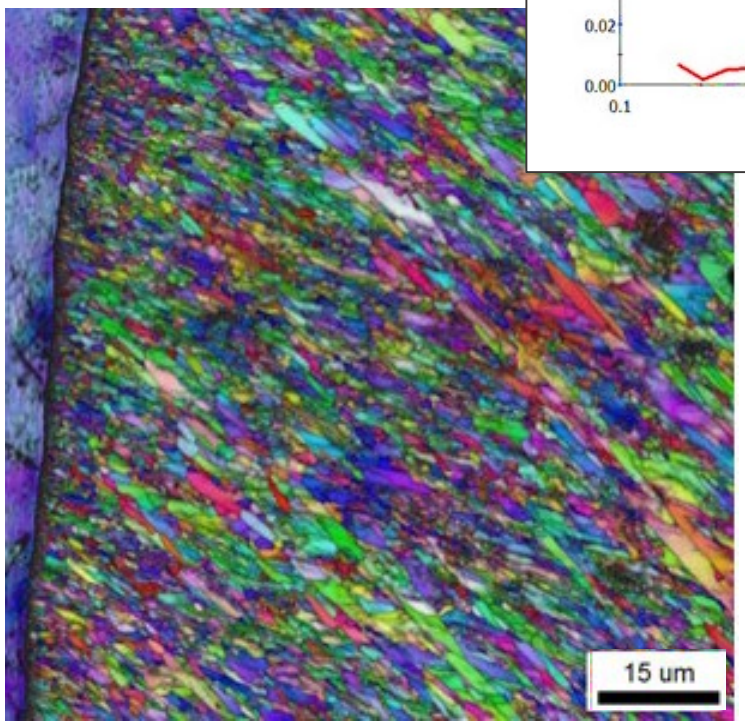
100 - 500 nm

Single Layer Thickness

How to avoid peeling/increase film quality? (3)

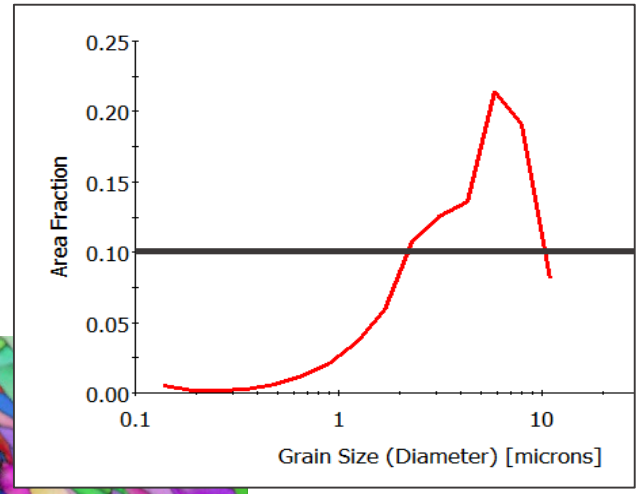
one shot deposition

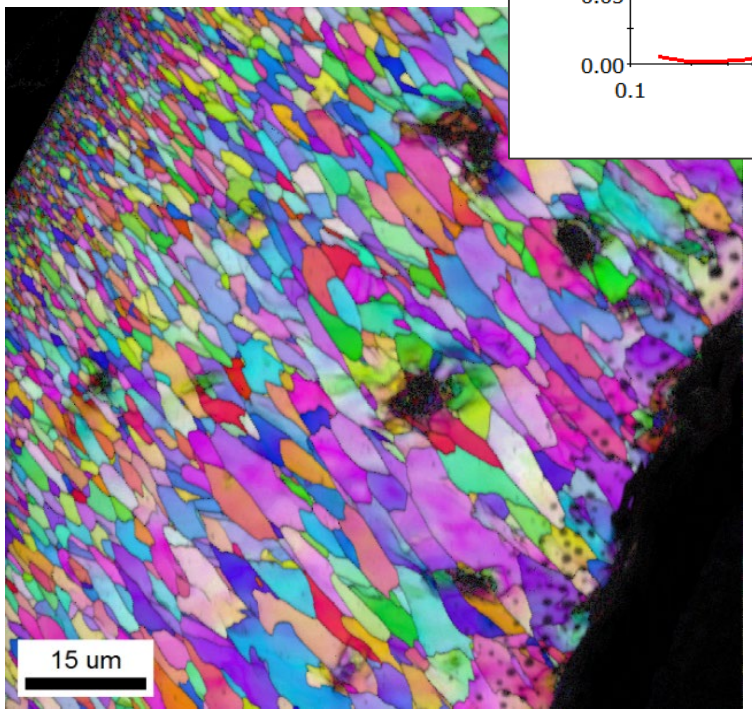




Cav 7, 100 µm single shot

long pulse deposition

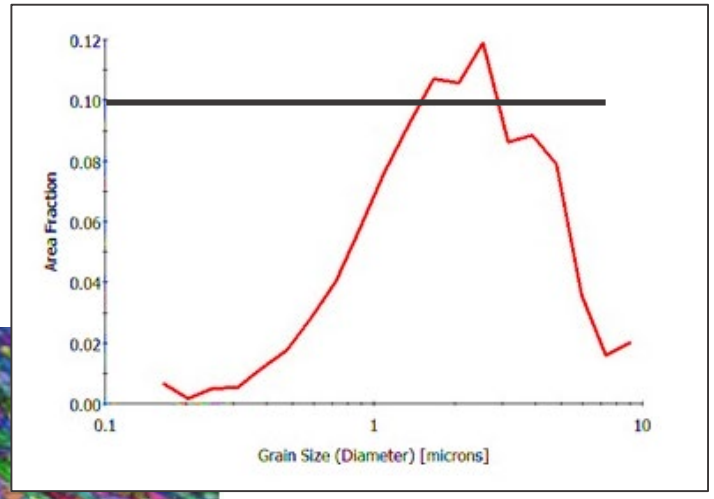


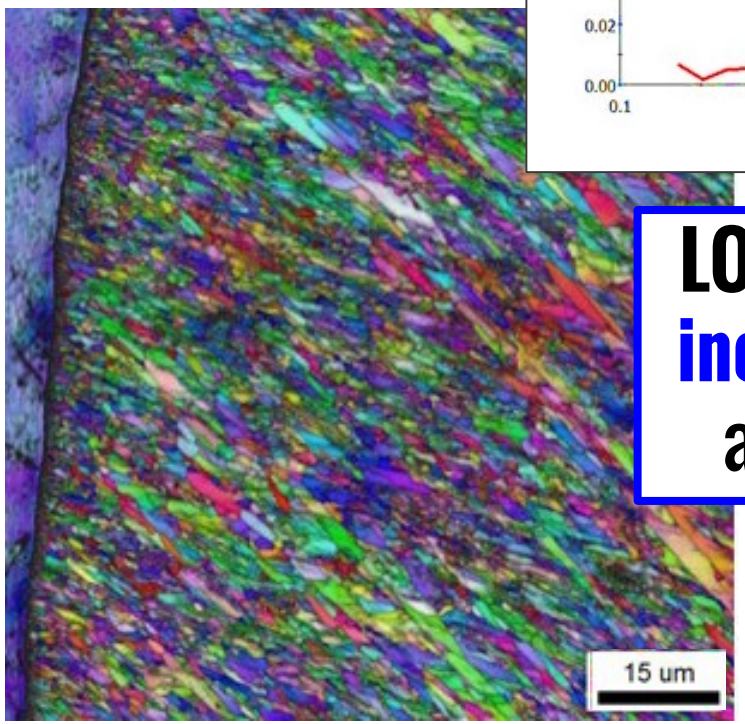


Cav 16, 75 µm thick, 500nm single pulse layer thickness

How to avoid peeling/increase film quality? (3)

one shot deposition

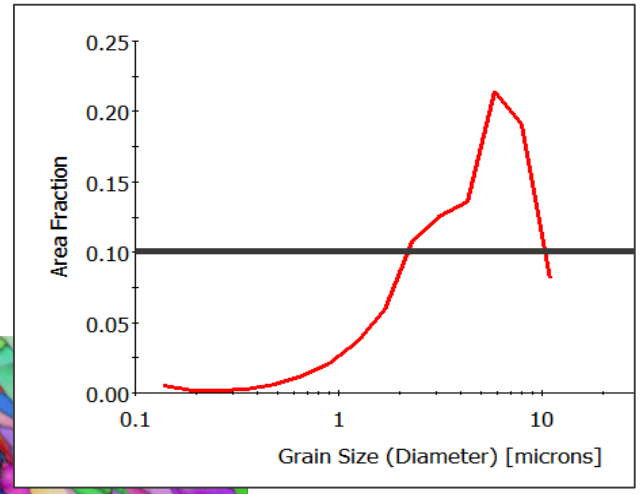


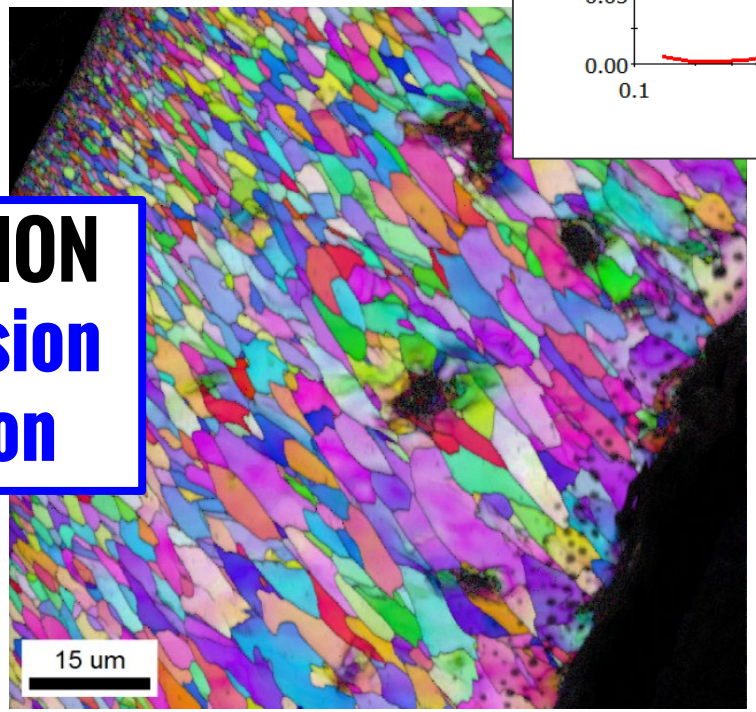


Cav 7, 100 µm single shot

LONG PULSE DEPOSITION
increase grain dimension
and **reduce dispersion**

long pulse deposition





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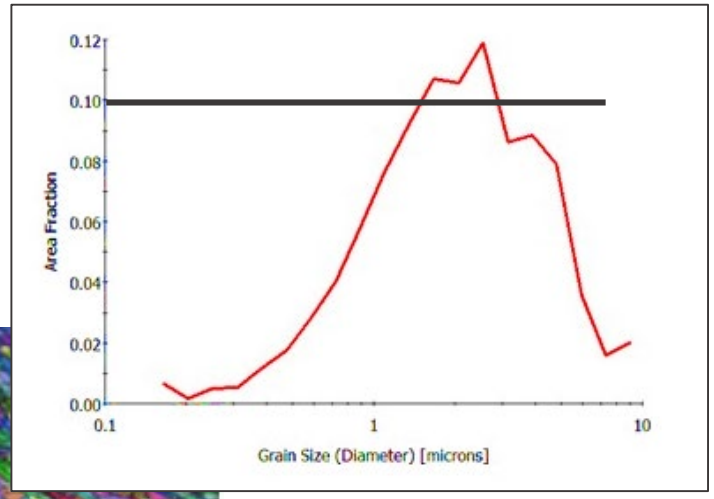

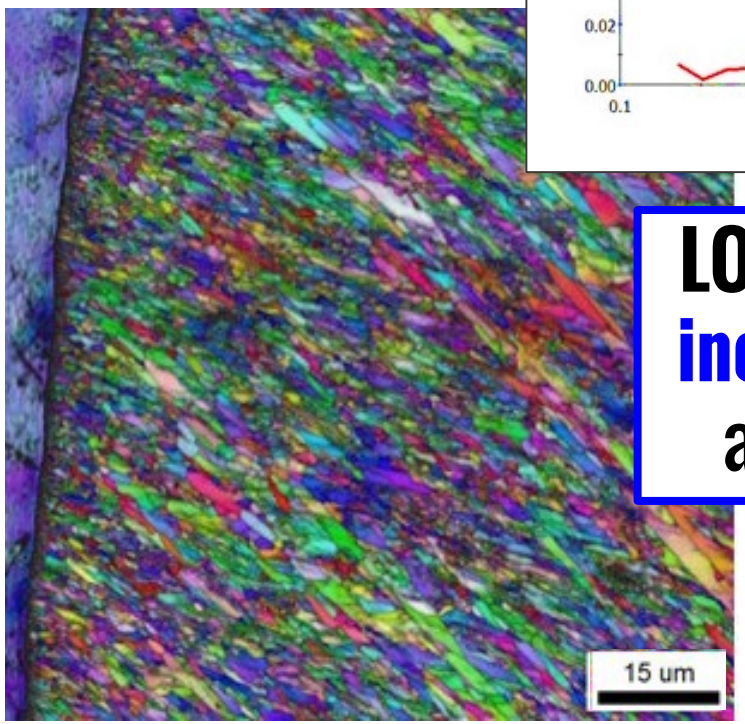

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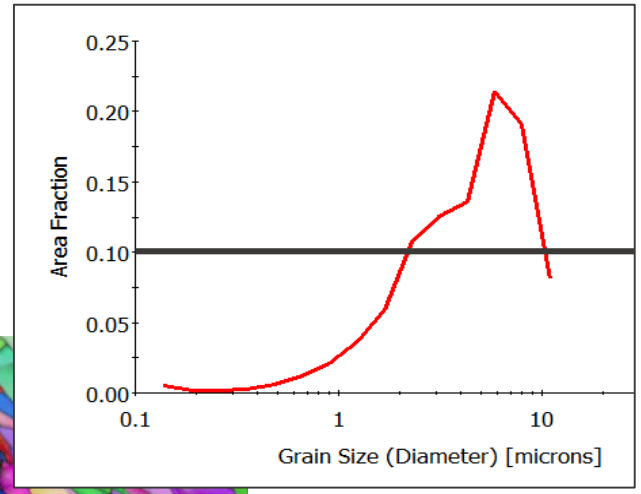
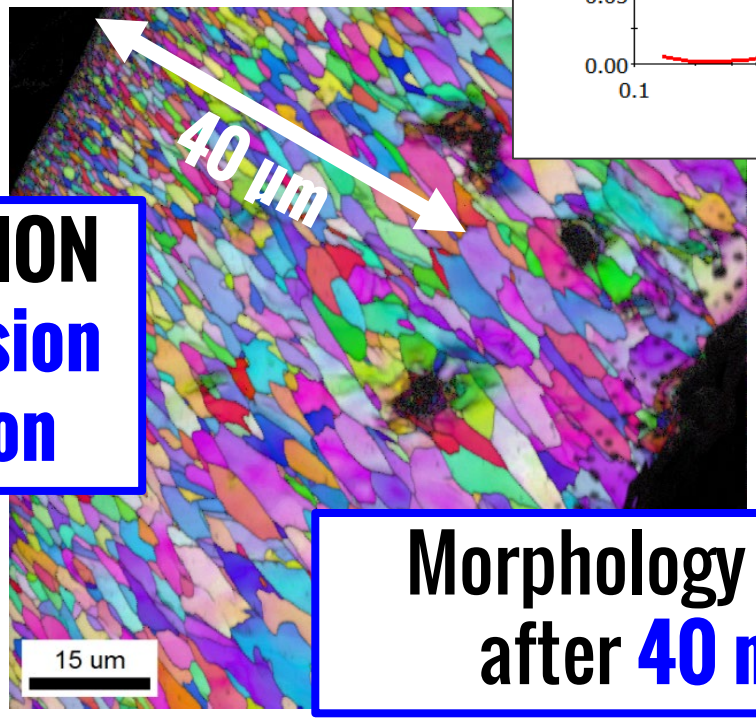


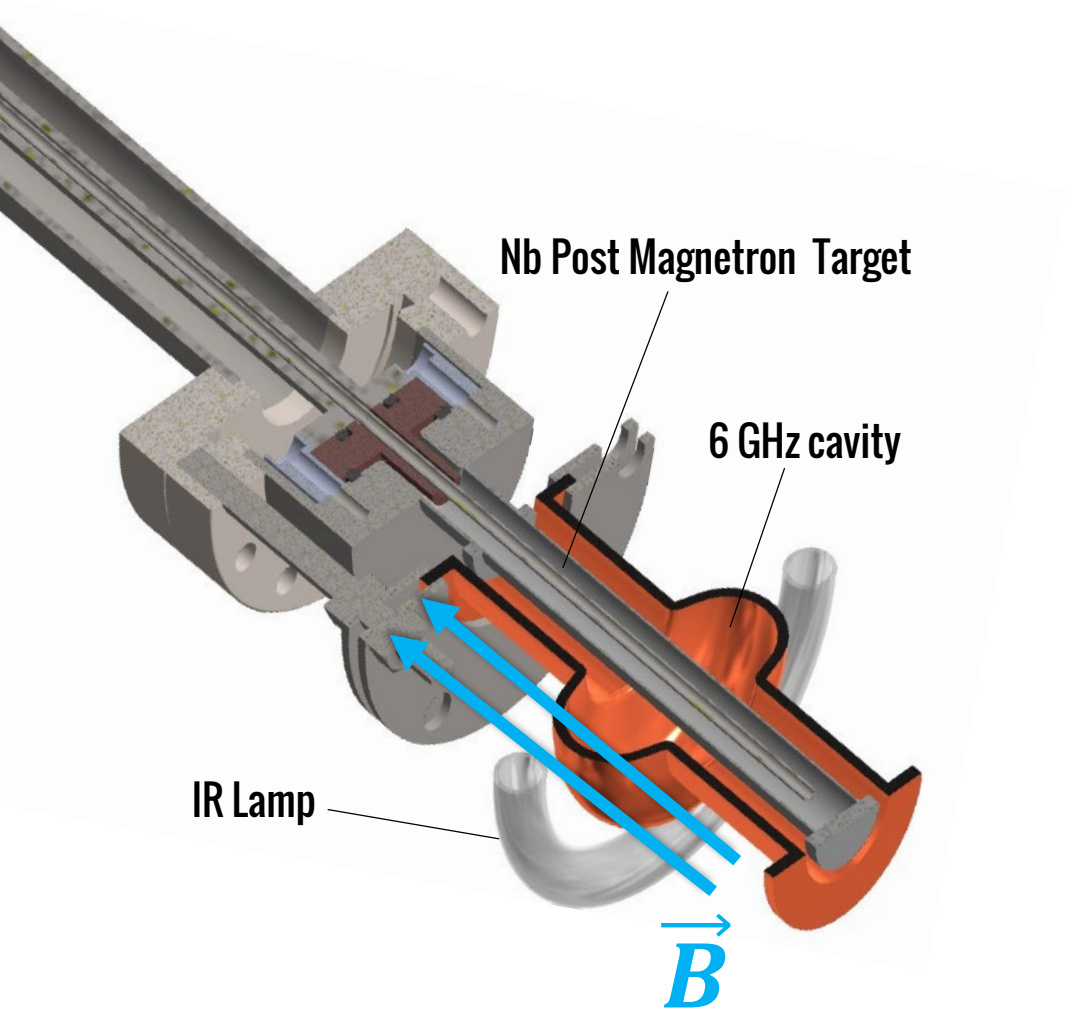


Cav 16, 75 µm thick, 500nm single pulse layer thickness

LONG PULSE DEPOSITION
increase grain dimension
and **reduce dispersion**

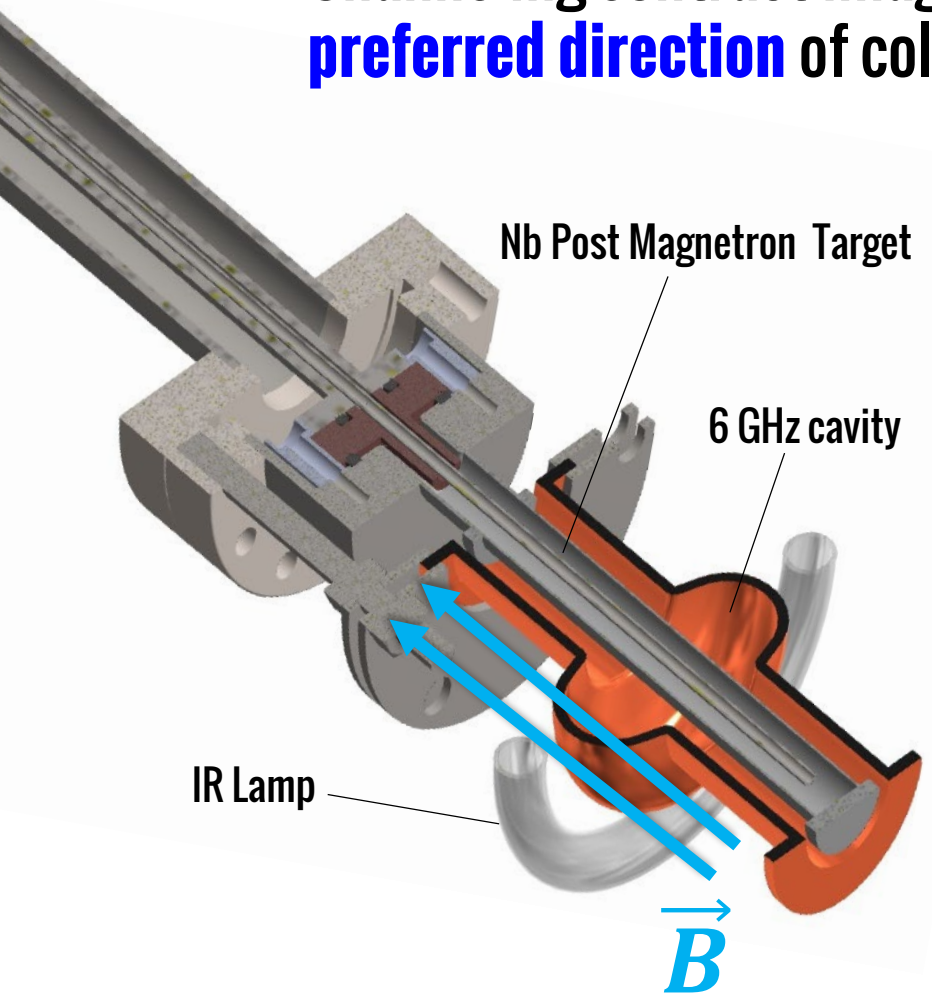
Morphology stabilizes after 40 microns

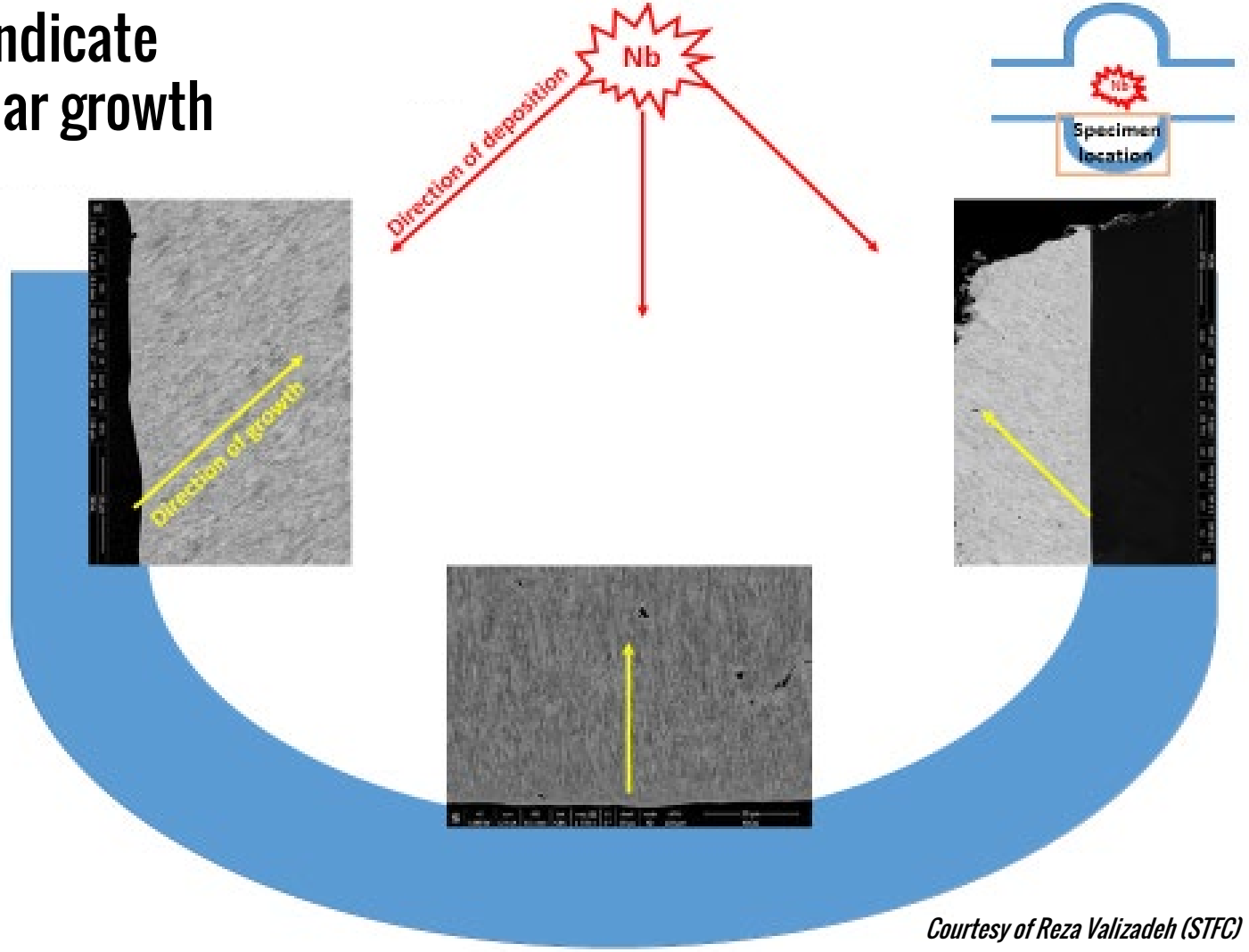
Thick Films Morphology



Thick Films Morphology

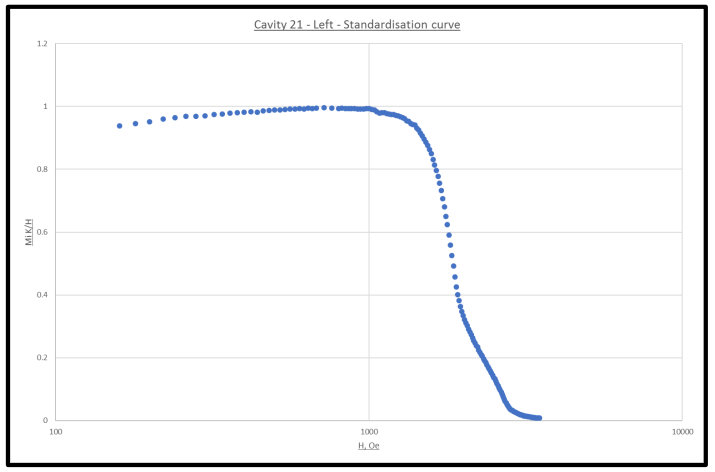
Channeling contrast images indicate **preferred direction** of columnar growth

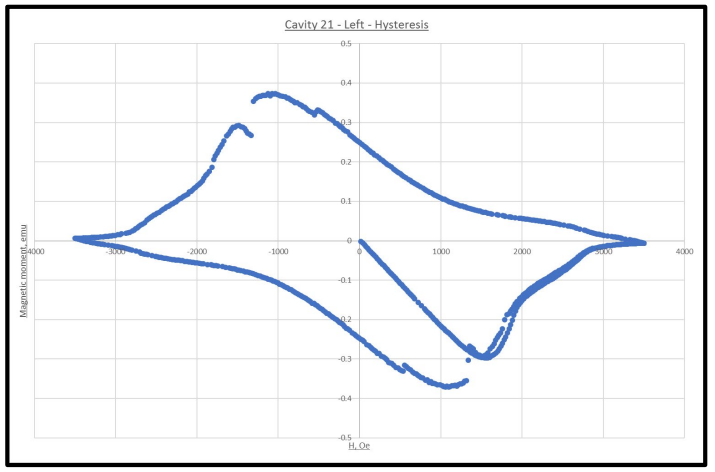


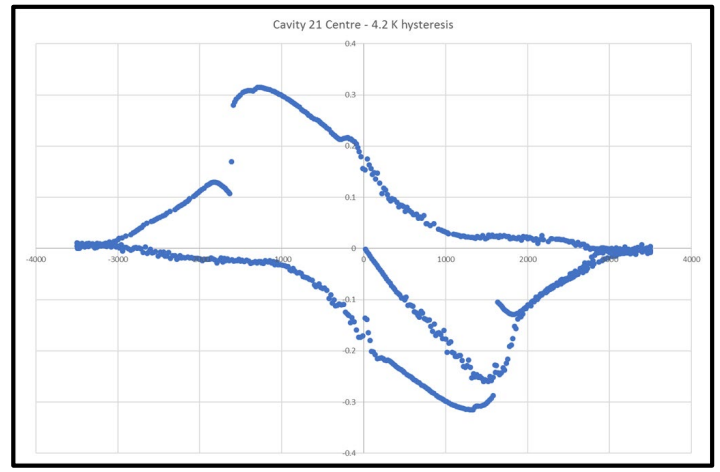


Courtesy of Reza Valizadeh (STFC)

Thick Films DC Properties







4 cavities characterized. All measurements was done on **stripped Nb film** on Kapton tape **@ 4,2 K**

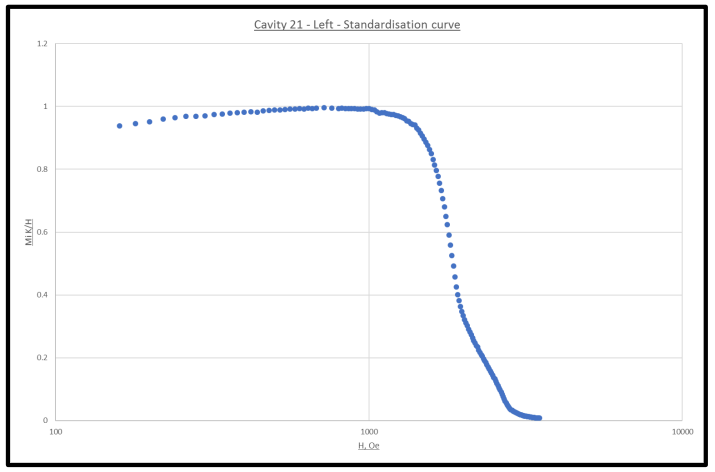
Courtesy of Reza Valizadeh (STFC)

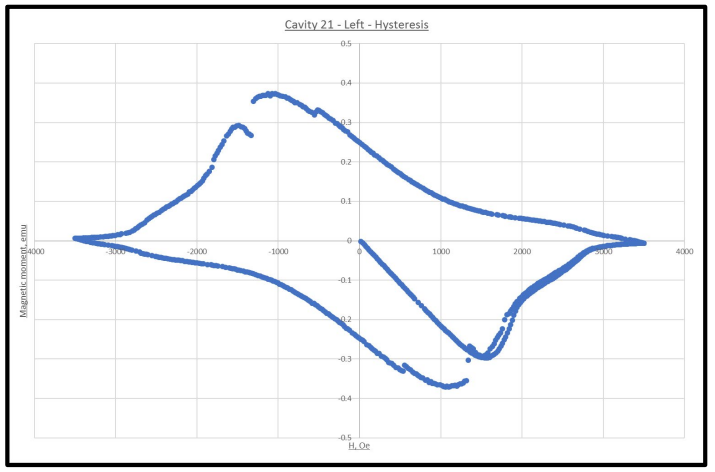
	Nb thin films (ARIES samples)
H_{fp}	12-20 mT
H_{c2}	280-300 mT

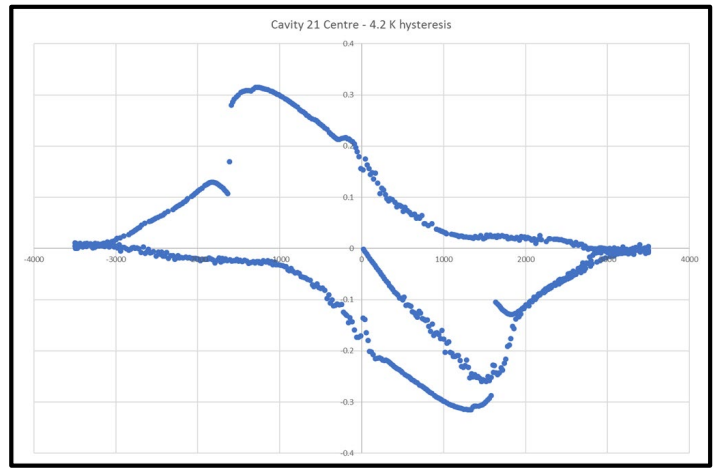
Courtesy of Eugen Seiler (IEE Bratislava)

	Nb thick films
H_{fp}	140-155 mT
H_{c2}	320-350 mT

Thick Films DC Properties







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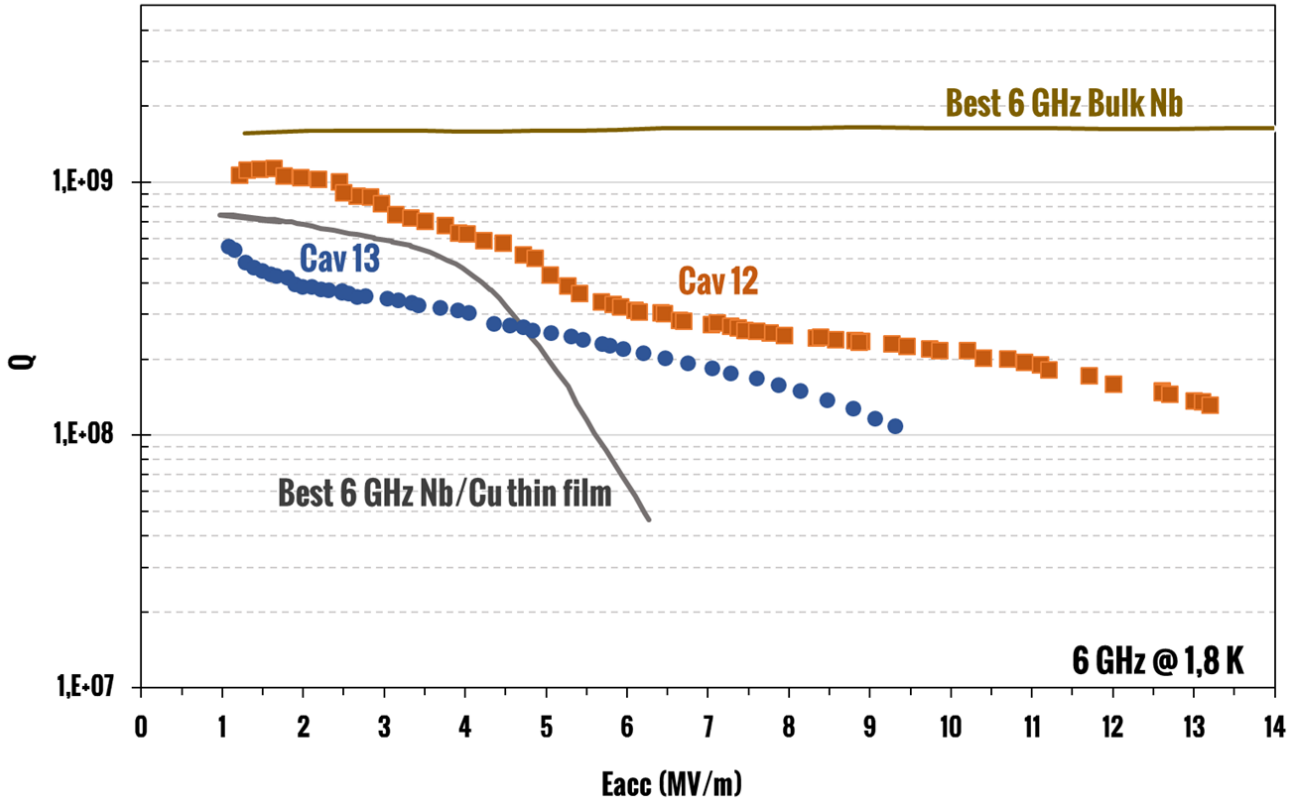
	Nb thick films
H_{fp}	140-155 mT
H_{c2}	320-350 mT

- **High H_{fp} value** between (140-155 mT)
- All films shown almost identical superconducting behavior in DC magnetometer @ 4.2 K → **No correlation with RF behavior**

Thick Films RF Results

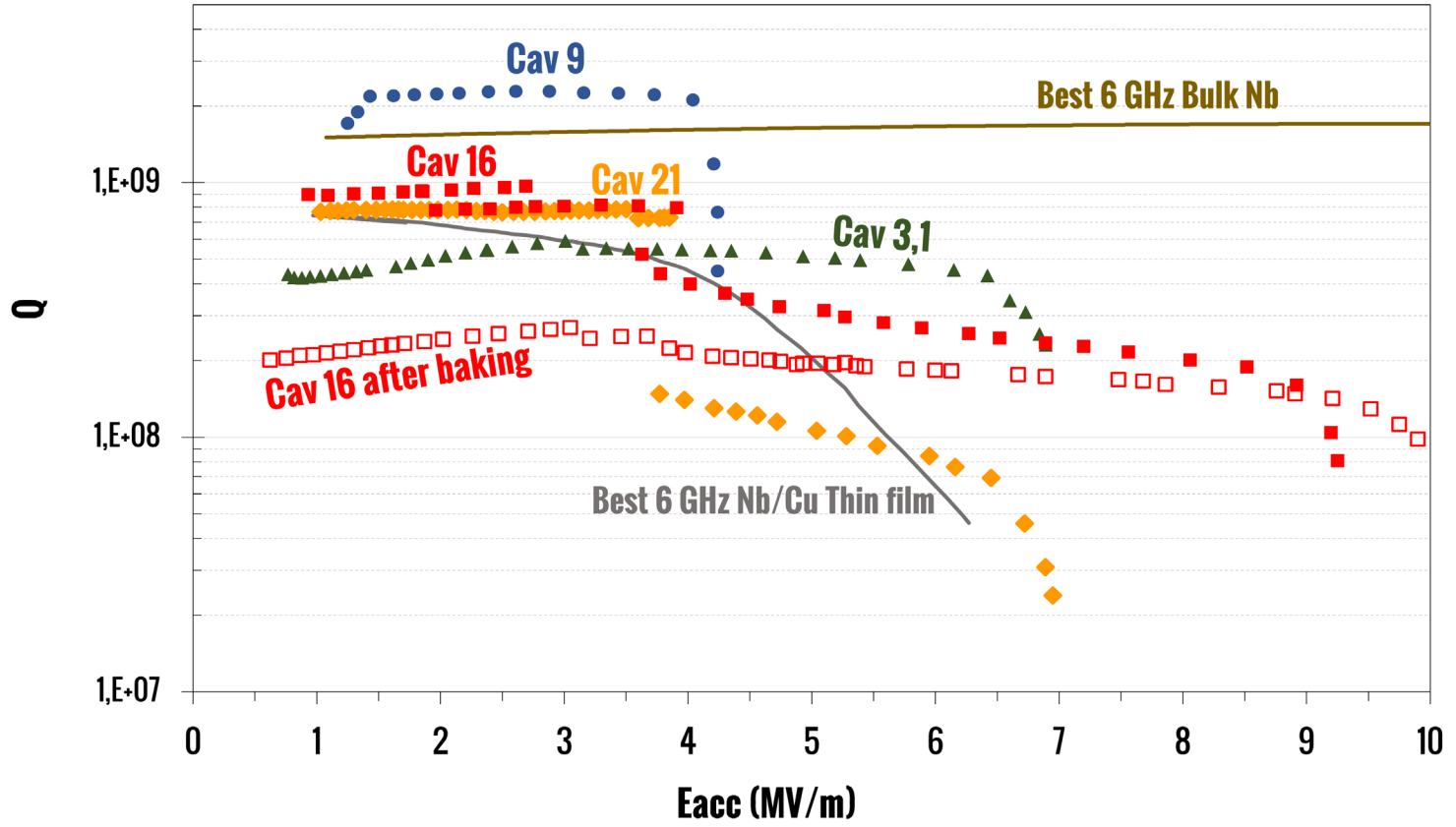
- 30 cavities coated with thick films exploring different parameters

- Q-slope still remain in many cavities…



Thick Films RF Results

- 30 cavities coated with thick films exploring different parameters
- Q-slope still remain in many cavities…
- …but not in all!

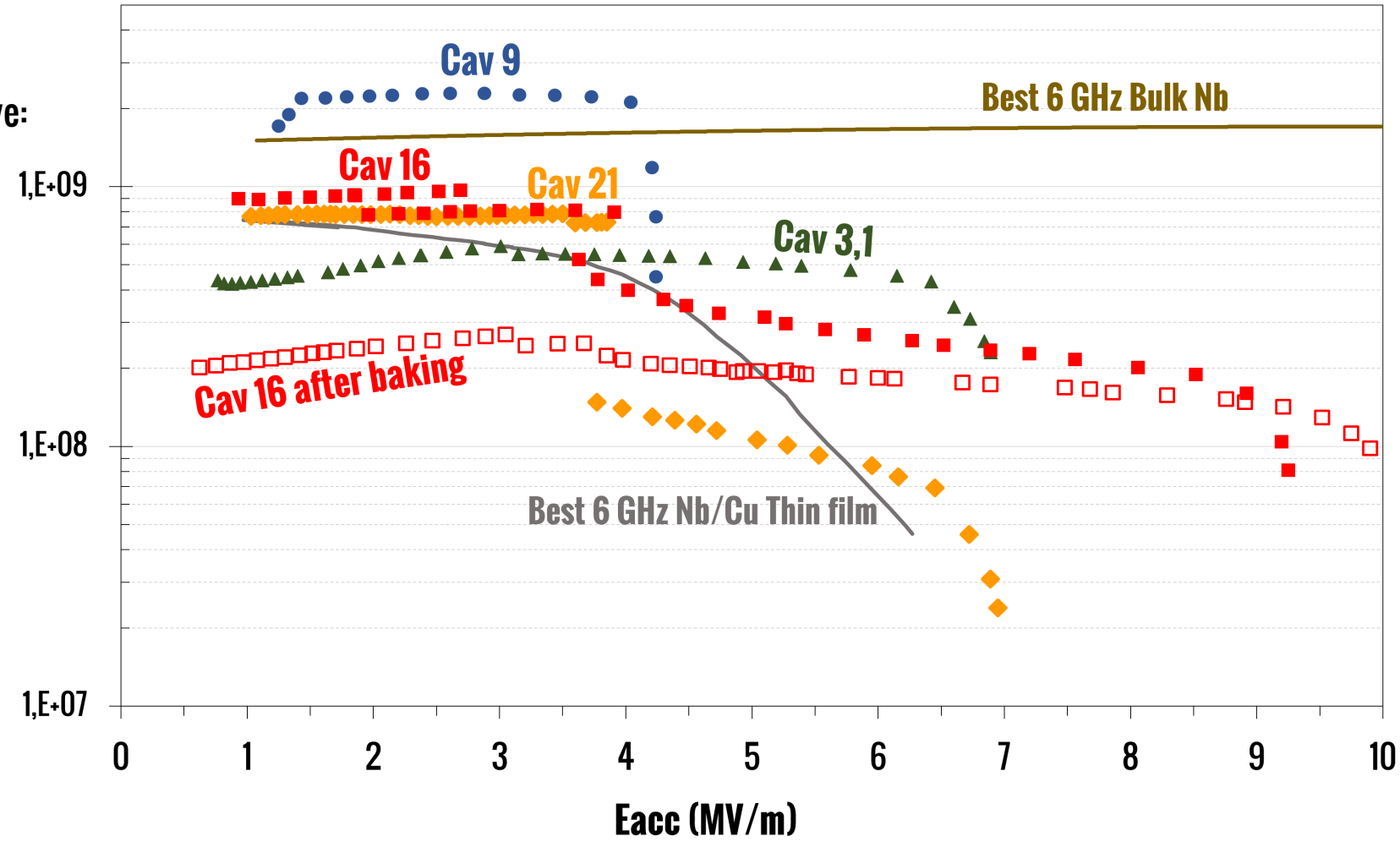


Thick Films RF Results

- **Great results**

  but still remain to understand and solve:

- **Reproducibility** issue
- **Q-switch @ 4 MV/m**



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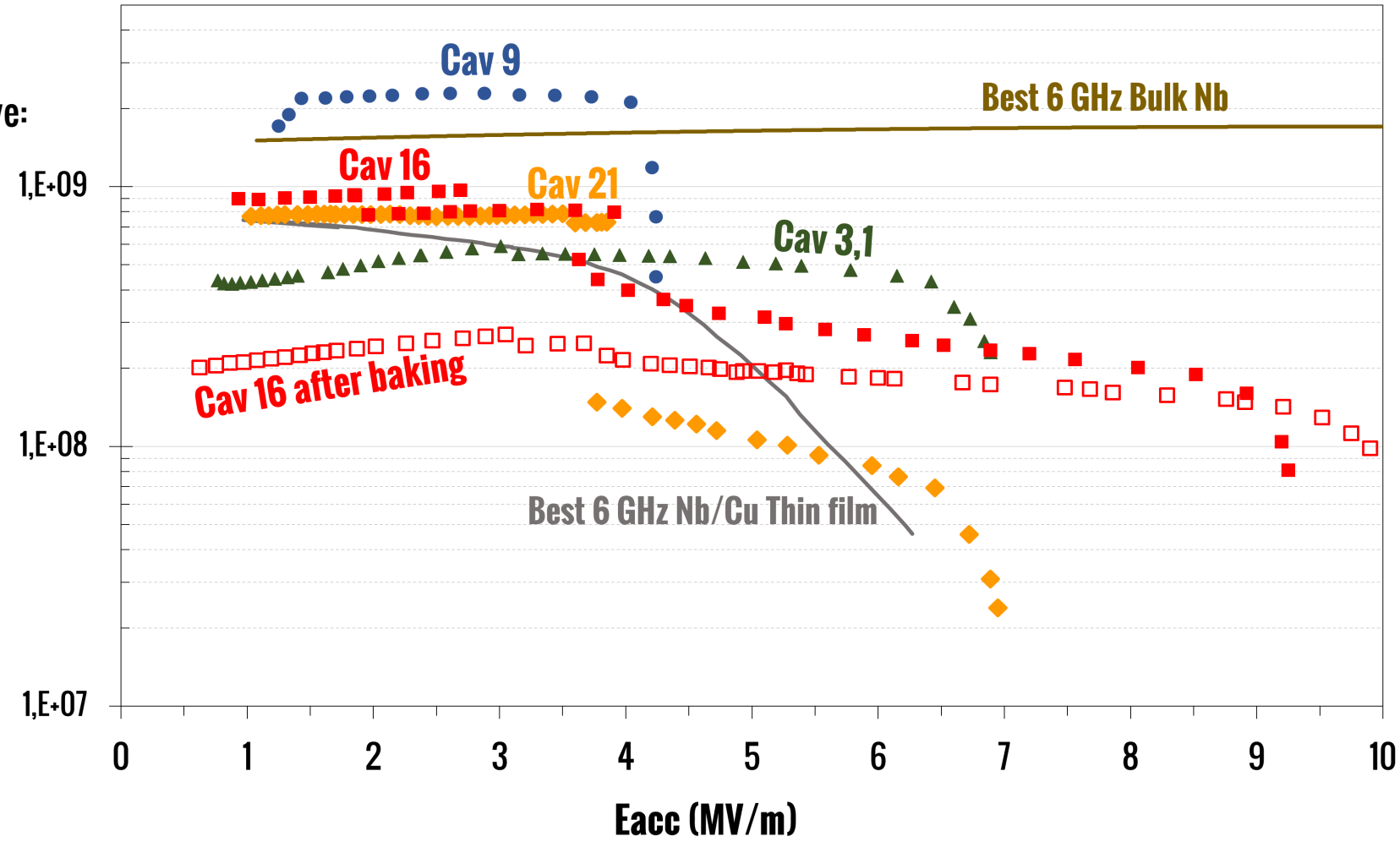
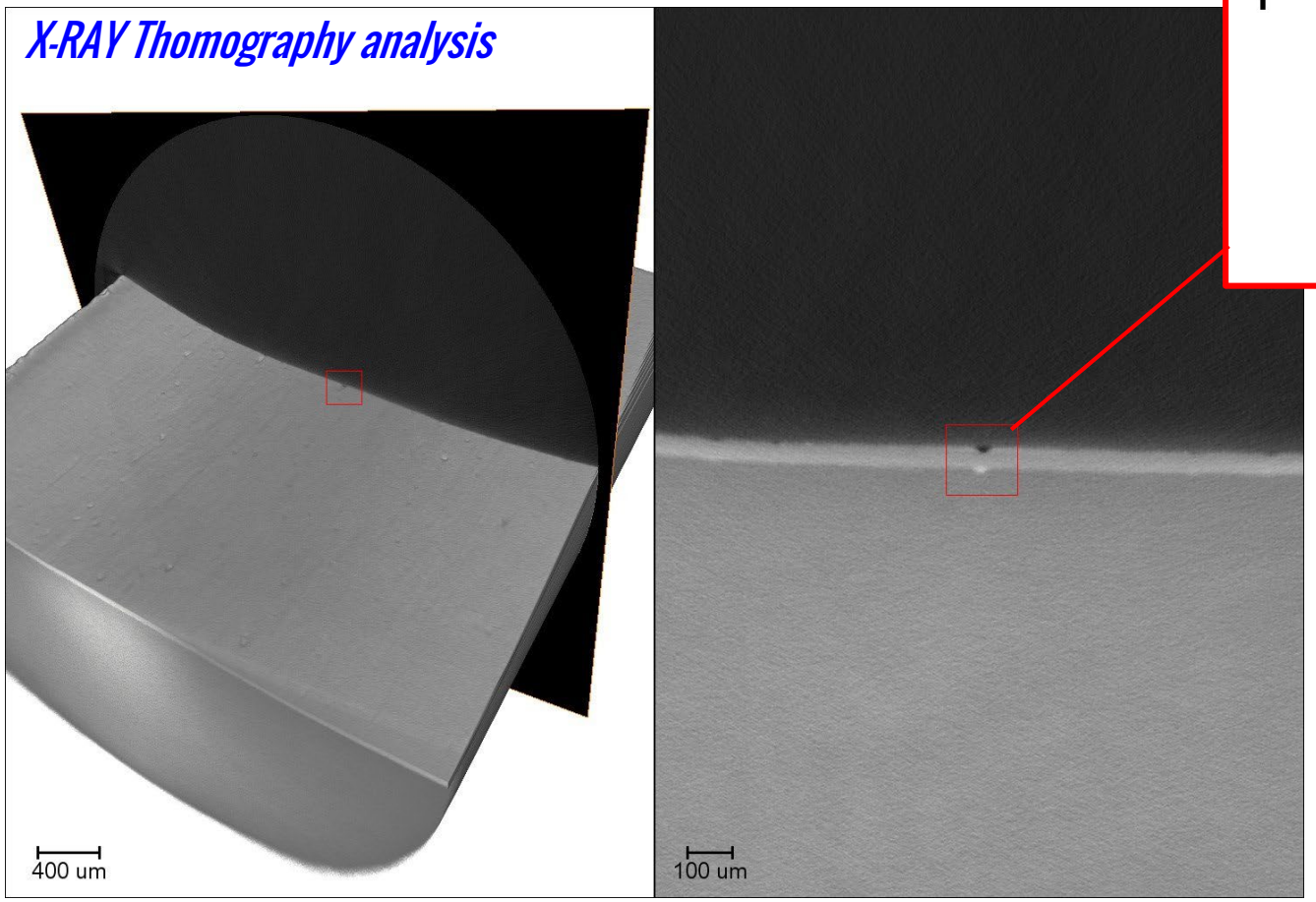
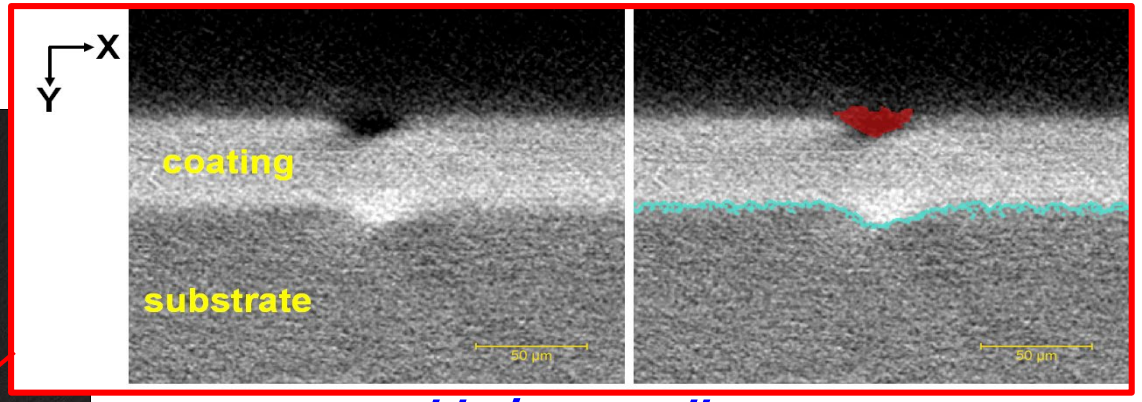


- **Substrate effect?**

Possible explanation low reproduciblity → Substrate defects

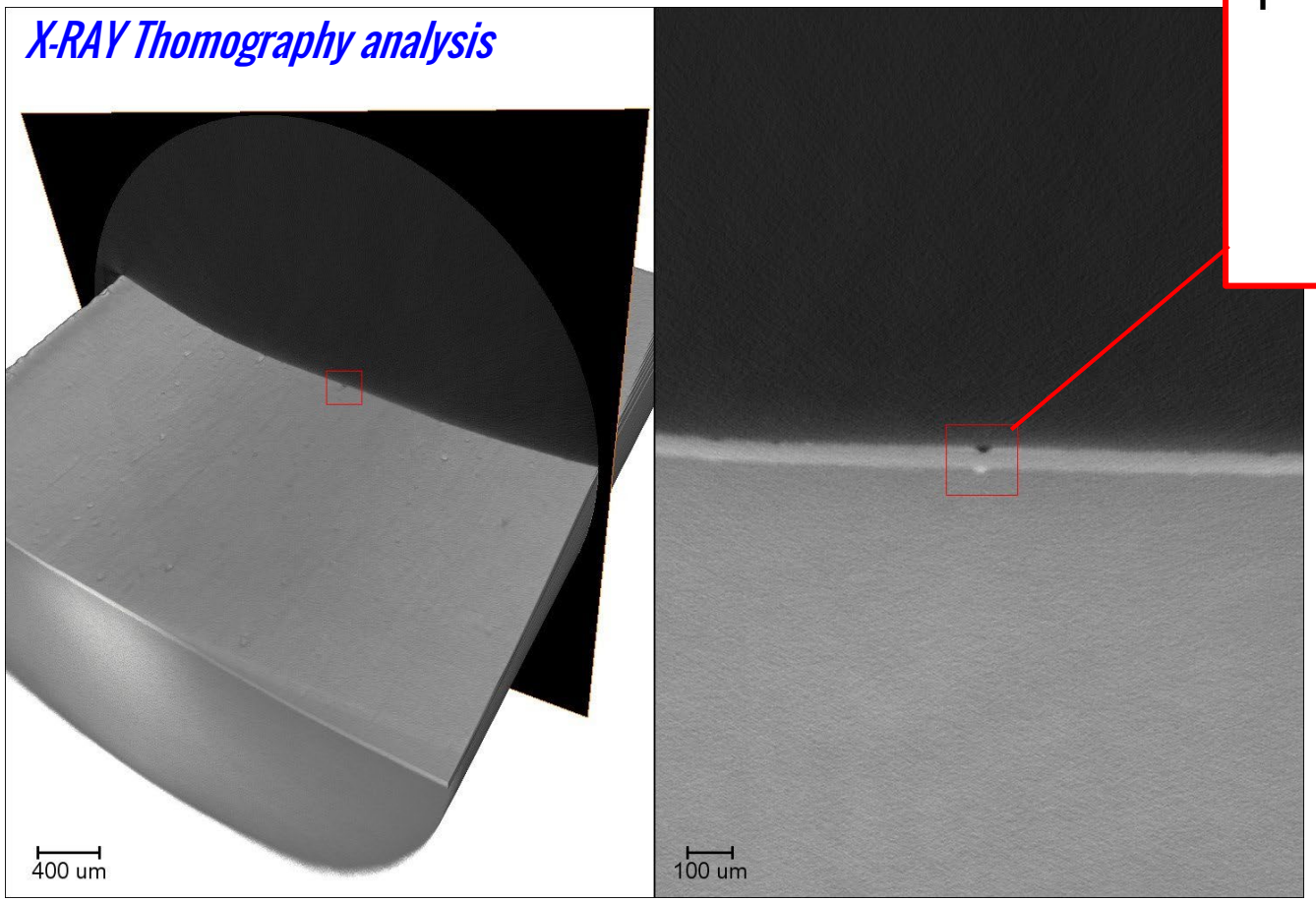


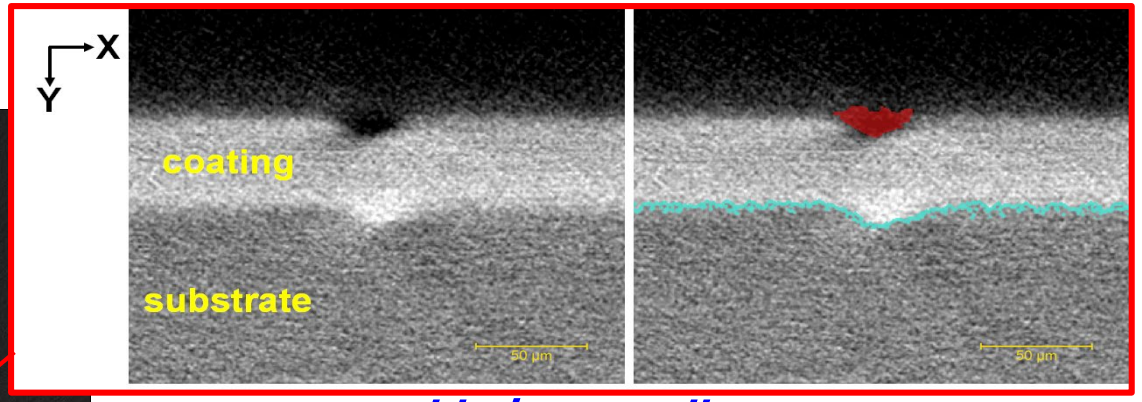


X-RAY Thomography **virtual cross-section**

Paper submitted, courtesy of Sepideh Aliasghari (University of Manchester)

Possible explanation low reproduciblity → Substrate defects





X-RAY Thomography **virtual cross-section**

EDS of a FIB cross-section sample

Paper submitted, courtesy of Sepideh Aliasghari (University of Manchester)

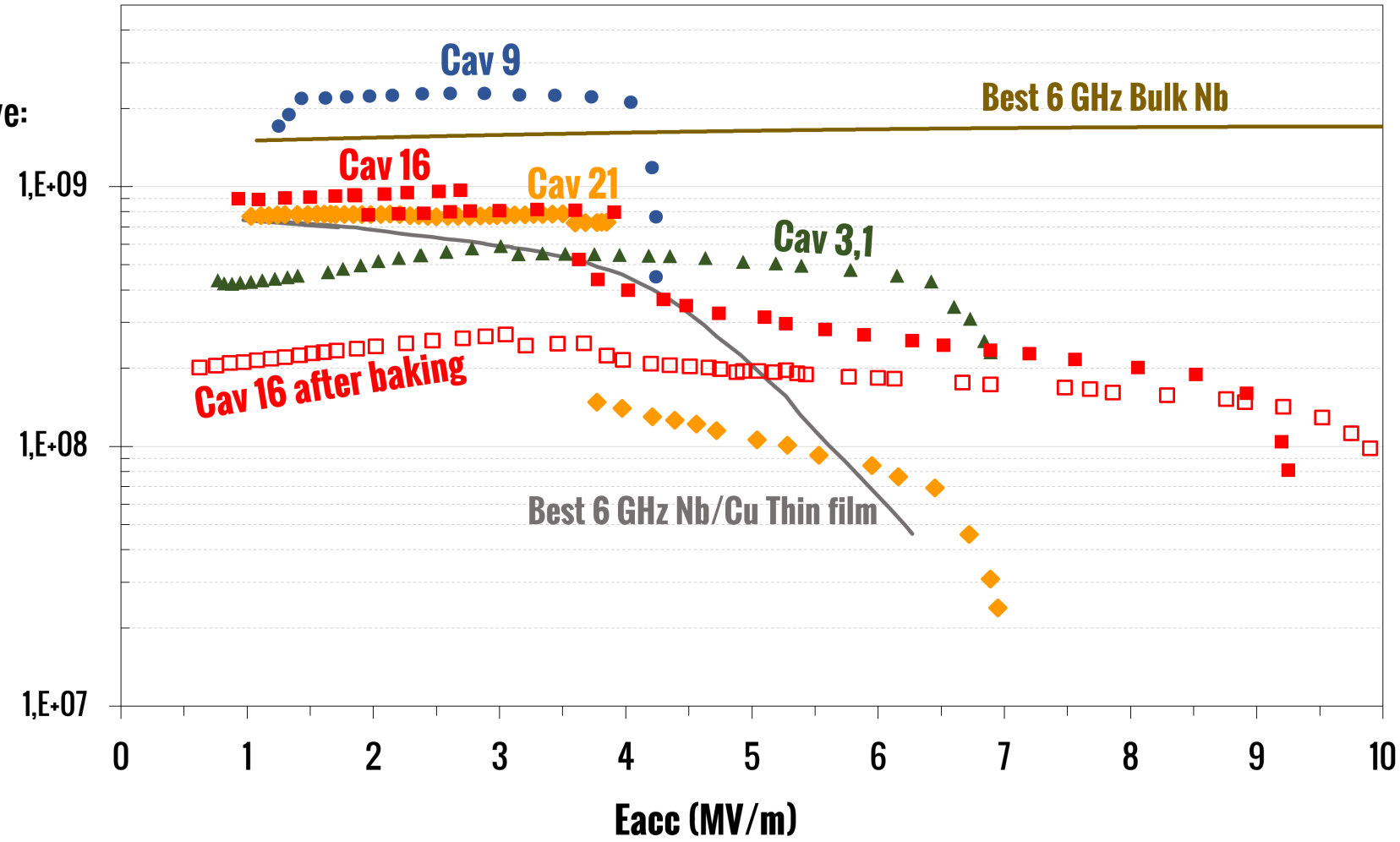
Thick Films RF Results

- **Great results**

  but still remain to understand and solve:

- **Reproducibility** issue
- **Q-switch @ 4 MV/m**

- Substrate effect?
- **Hot leaks (< 10^{-11} mbar*l/s)**

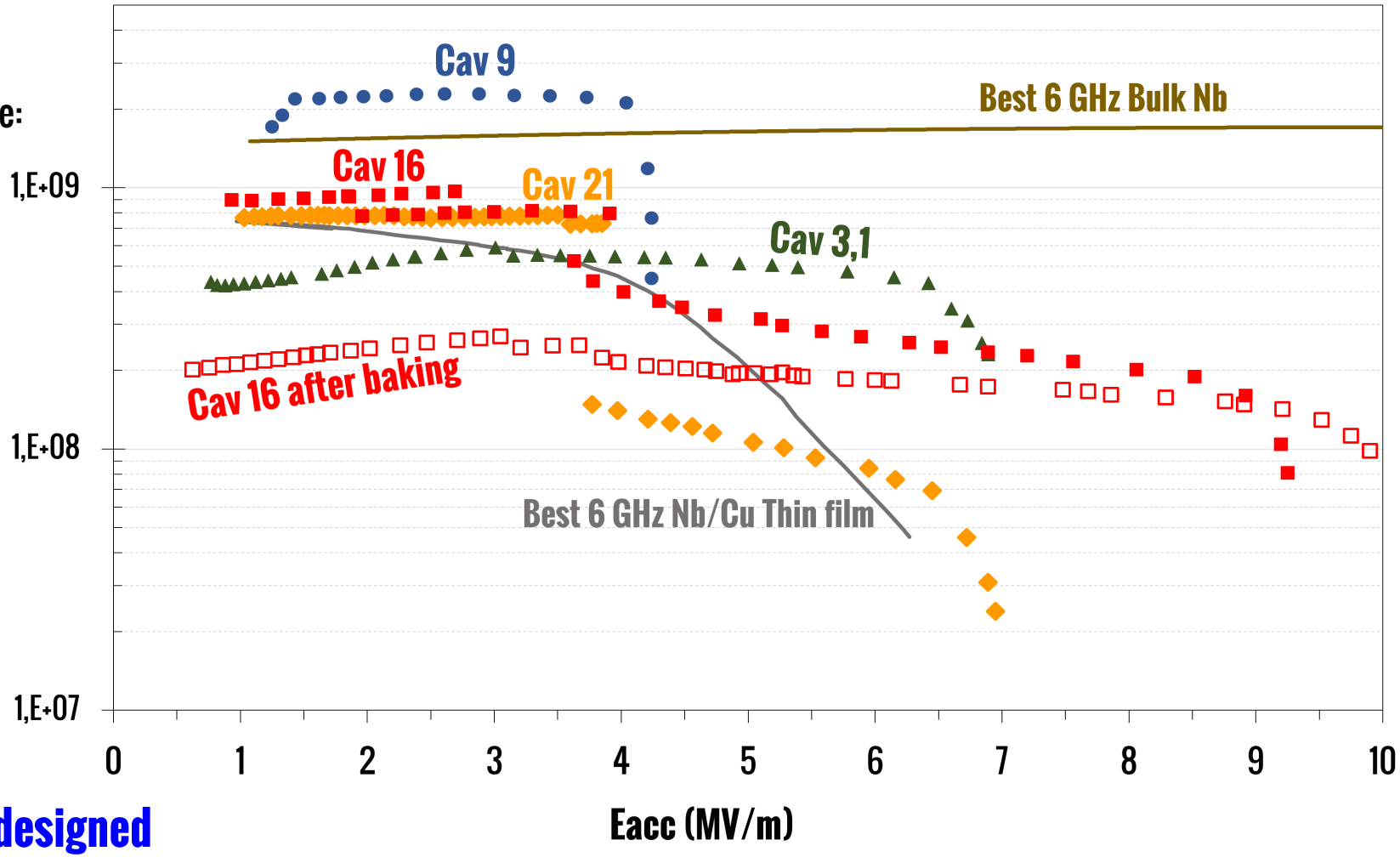


Thick Films RF Results

- **Great results**

  but still remain to understand and solve:

- **Reproducibility** issue
- **Q-switch @ 4 MV/m**



- Substrate effect?
- **Hot leaks (< 10^{-11} mbar*l/s)**

Magnetron source completely re-designed

Conclusions

- **Q-slope mitigation possible with thick films**
- **Low reproducibility and low accelerating gradient**
  - Substrate defects → Vibrotumbling (see TTC2019)
  - Hot leaks → magnetron source re-designed
- **New results soon**

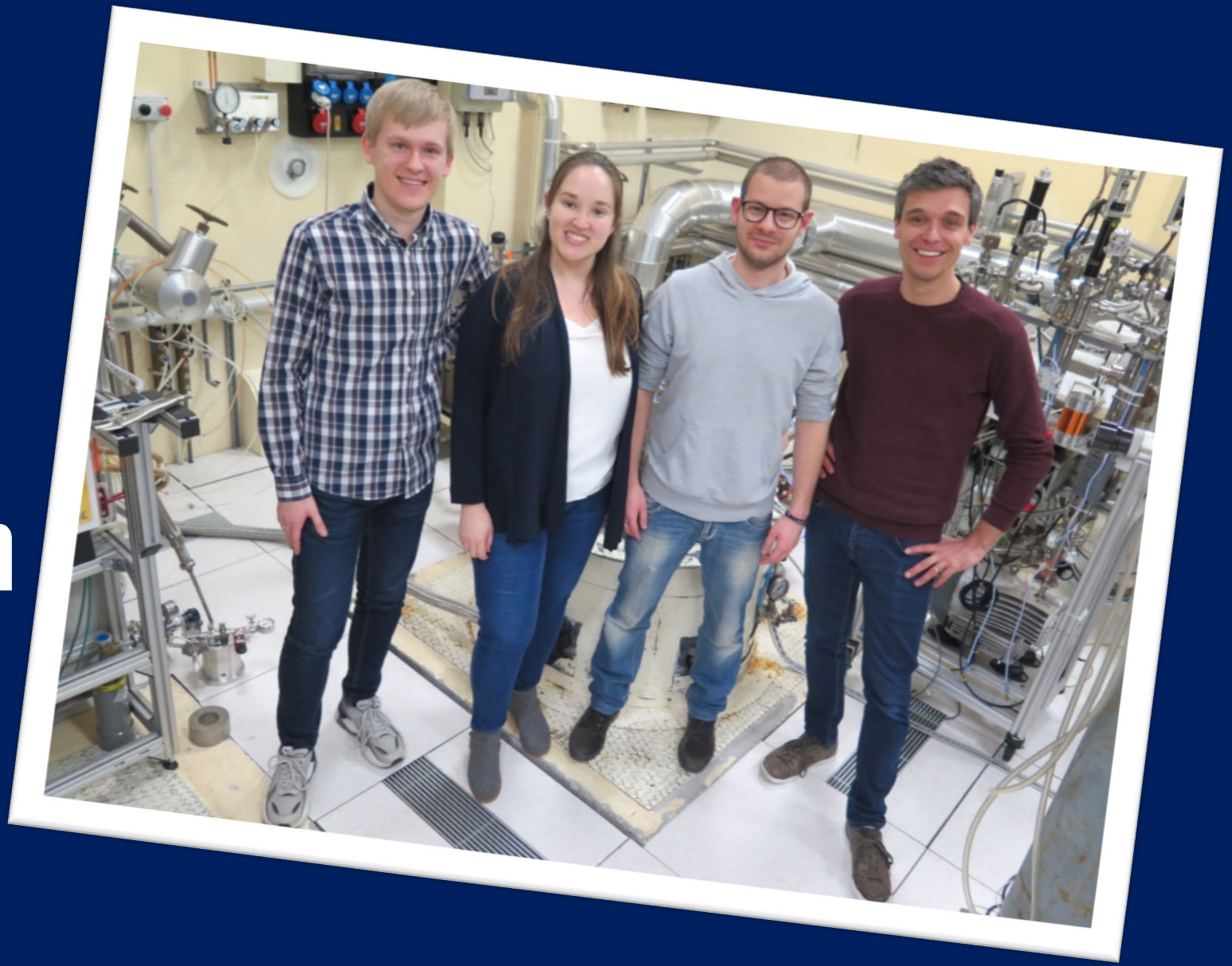
Conclusions

- **Q-slope mitigation possible with thick films**
- **Low reproducibility and low accelerating gradient**
  - Substrate defects → Vibrotumbling (see TTC2019)
  - Hot leaks → magnetron source re-designed
- **New results soon**

and future work

- Continue study on 6 GHz
- QPR samples
- 6 GHz → 1.3 GHz

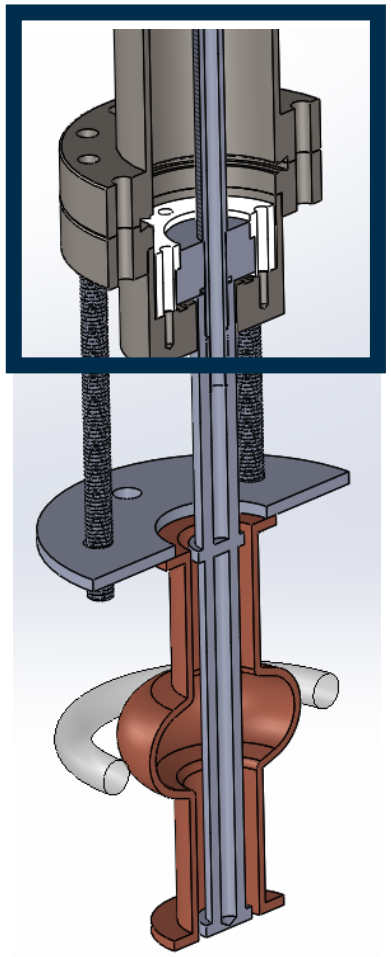
Thank you
for your attention

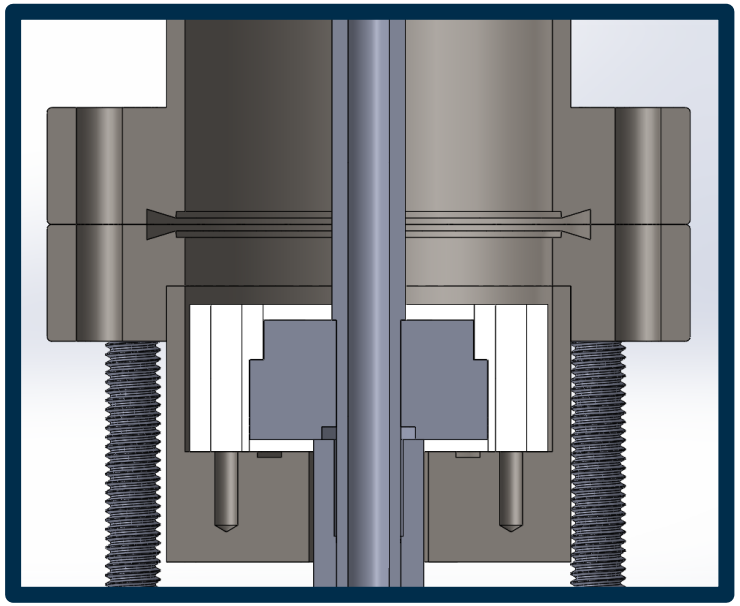


cristian.pira@lnl.infn.it

New magnetron configuration

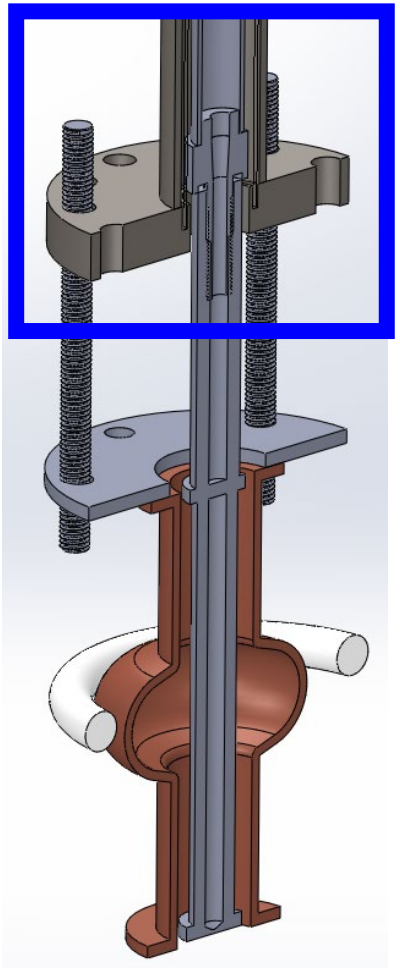
Old

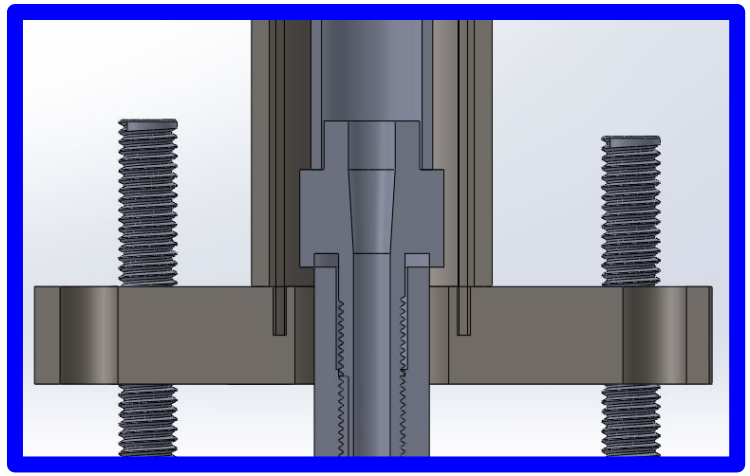




1 Copper gasket
2 Viton o-rings

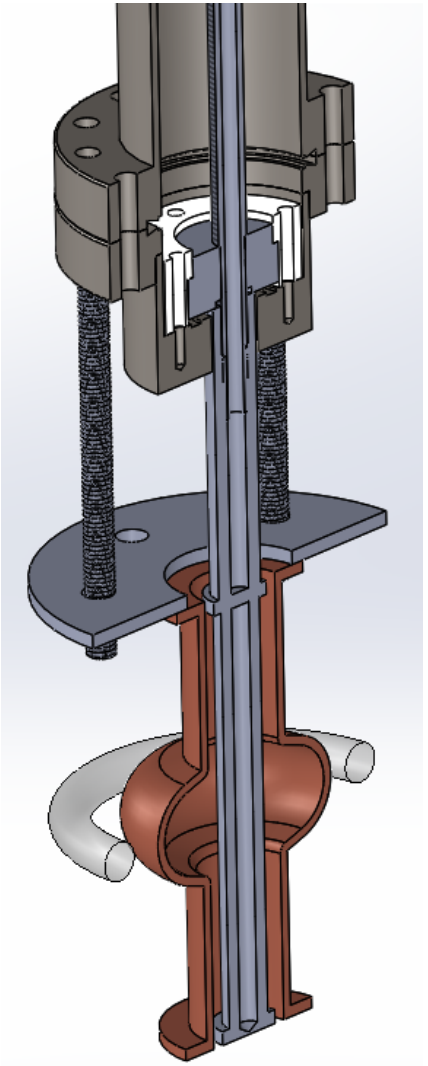
New



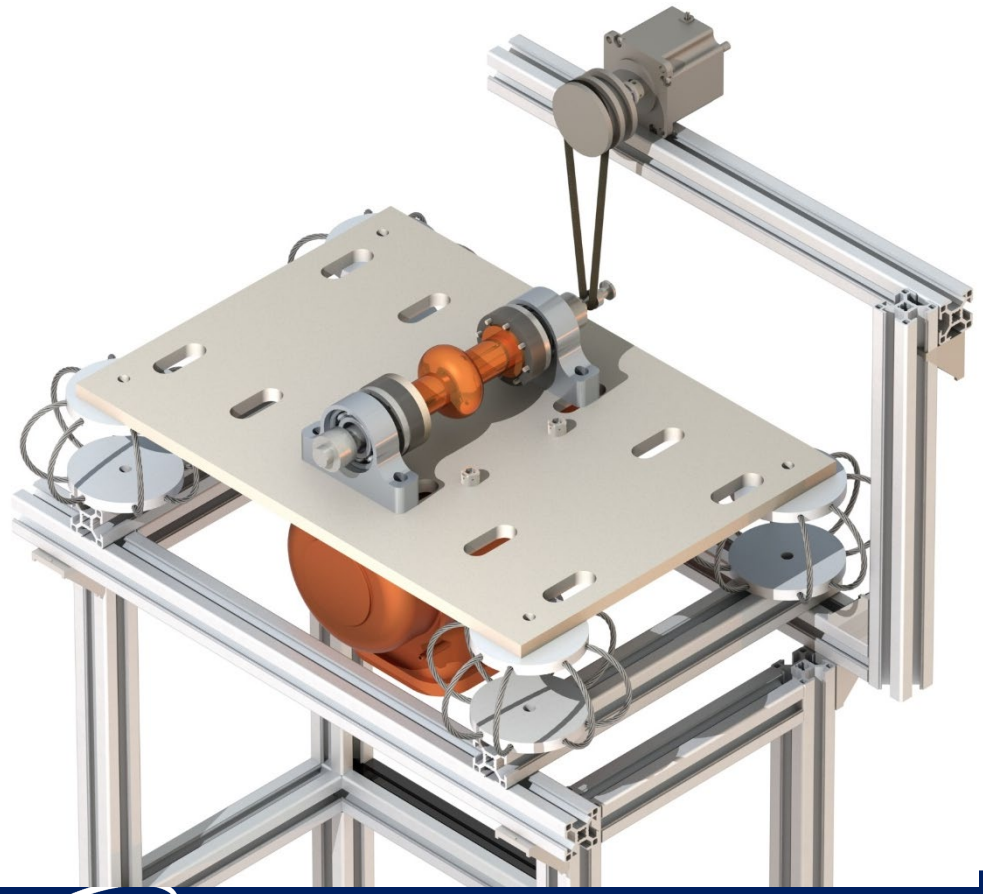


1 Viton o-ring

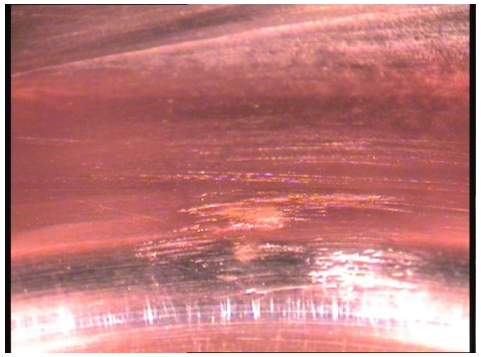
Coating Set-up



Vibrotumbling



Initial surface



Step 1

Al_2O_3

8h

0,3 g/h
3,6 µm/h

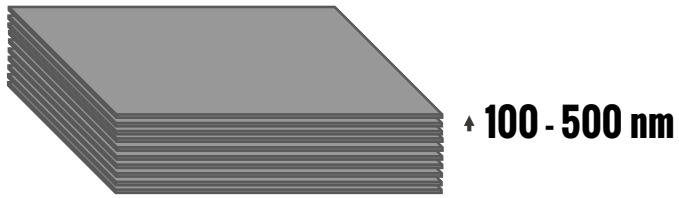
Step 2

Coconut

4h

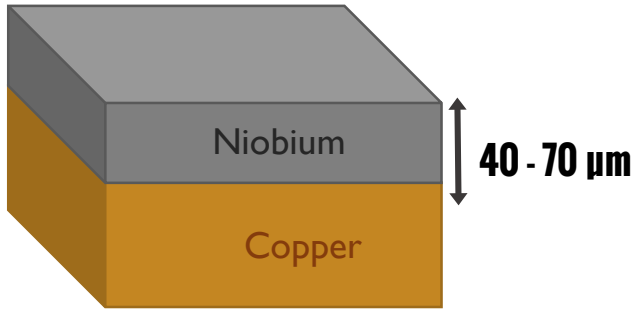
0,01 g/h
0,1 µm/h

Single Layer Thickness effect

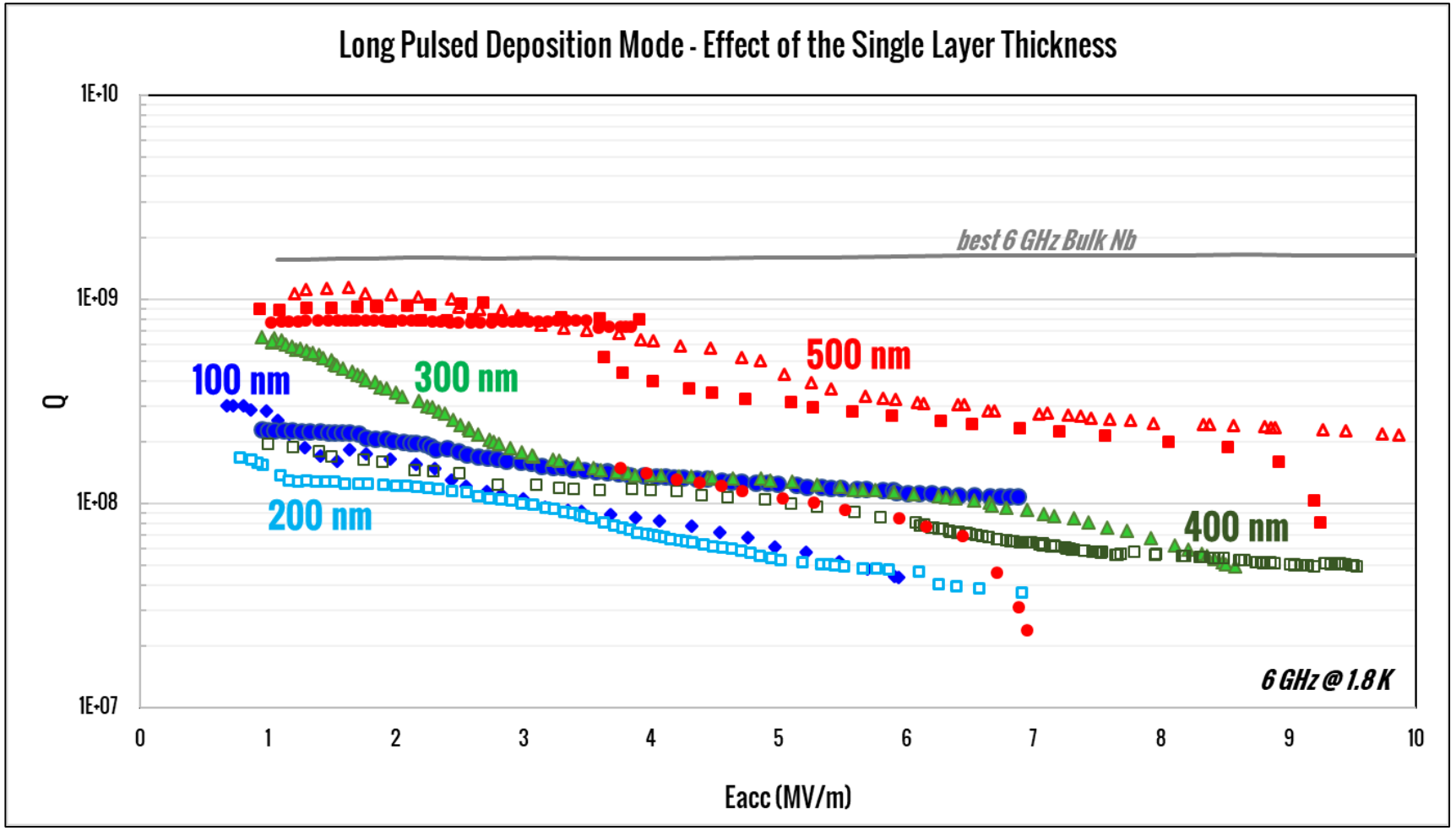


100 - 500 nm

Single Layer Thickness



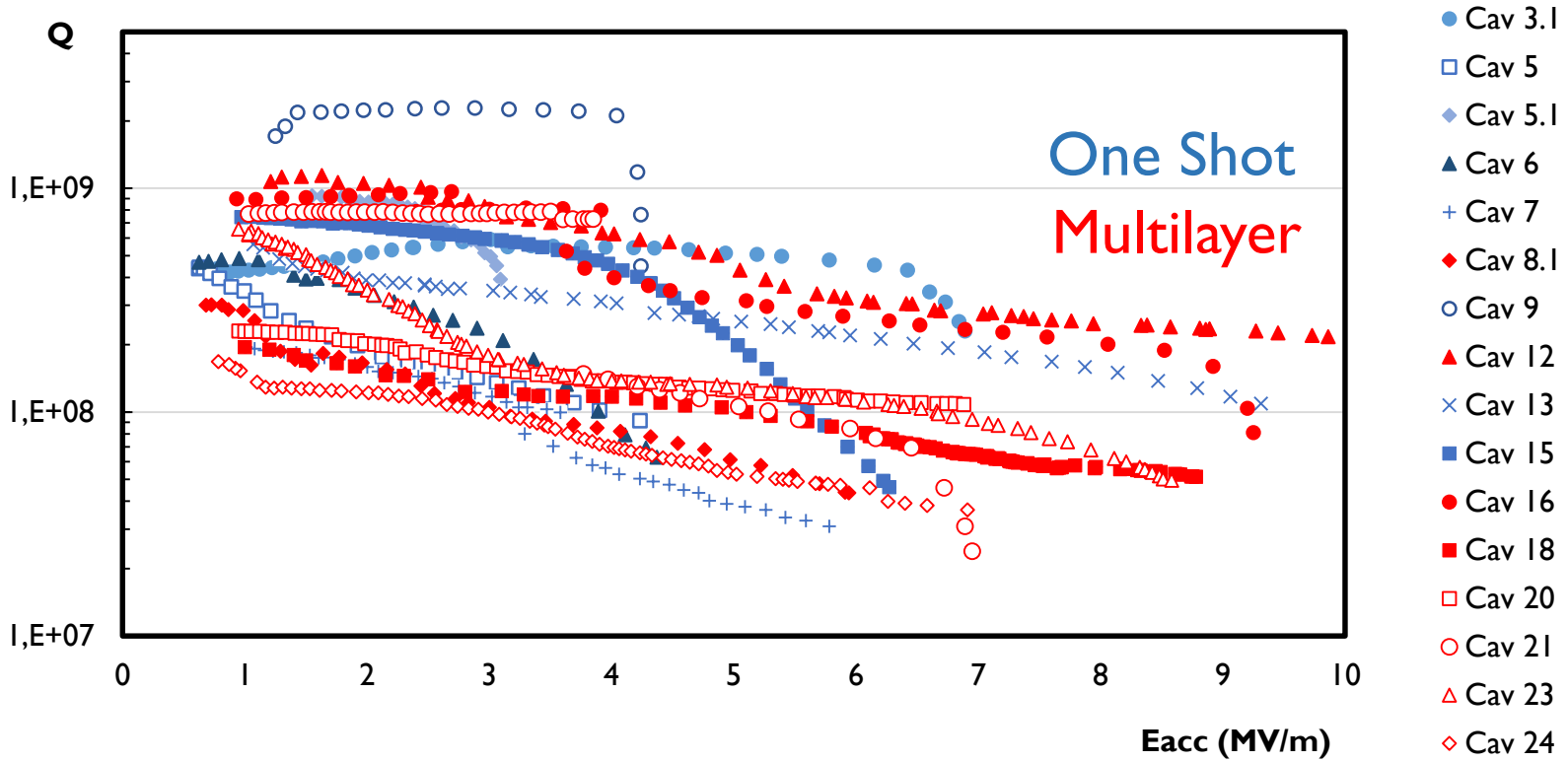
Total Thickness



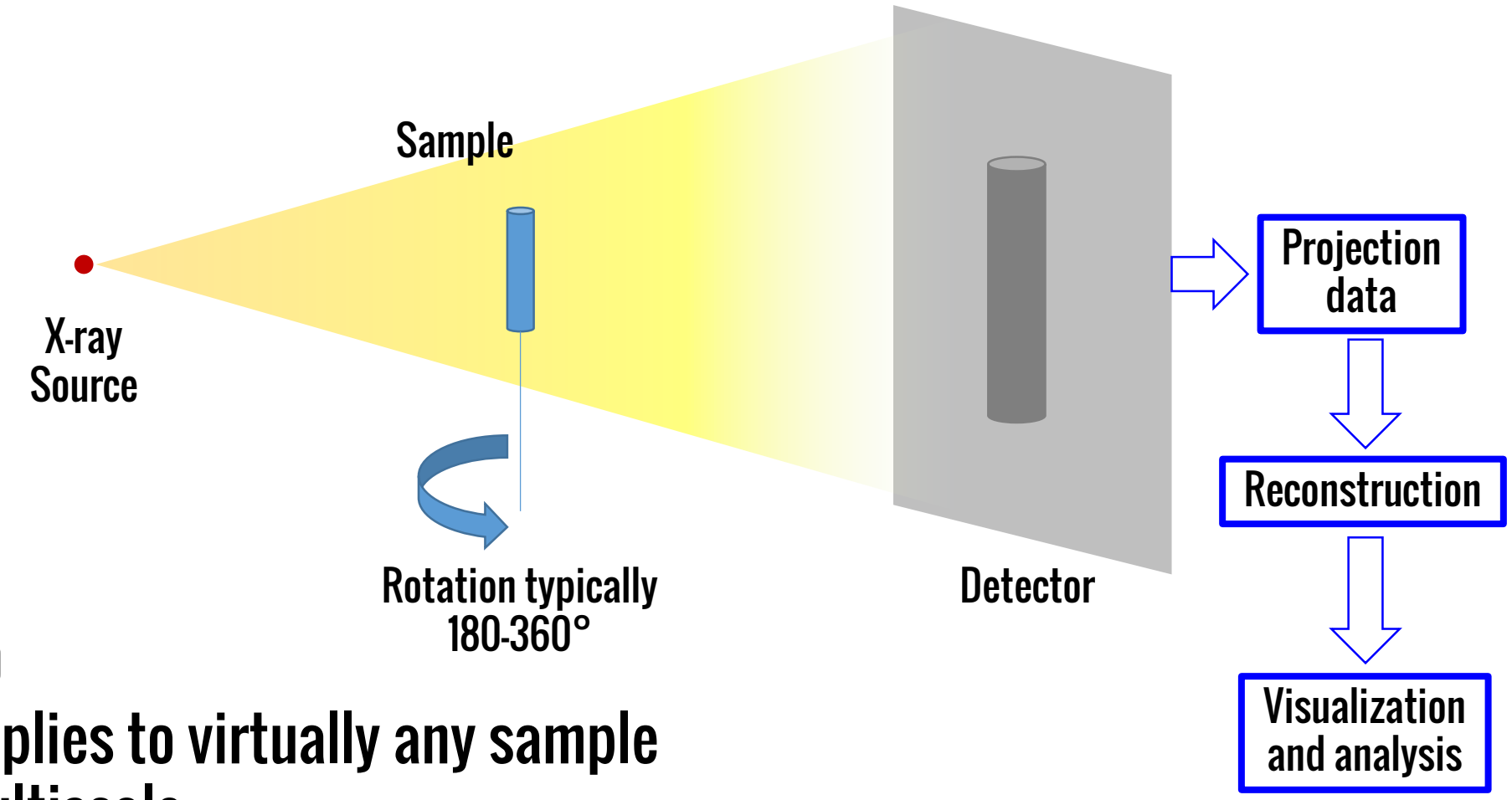
How to avoid peeling/increase film quality? (3)

LONG PULSE DEPOSITION MODE

- reduce **peeling risk**
- may contribute to **increase E_{acc}**



X-ray Computed Tomography



- 3D
- Applies to virtually any sample
- Multiscale
- Non-destructive

X-ray Computed Tomography