SRF R&D at DESY

Nitrogen Treatment Research

Marc Wenskat (on behalf of many!)
LCWS 2016
Morioka, 7.12.2016

HELMHOLTZ GEMEINSCHAFT

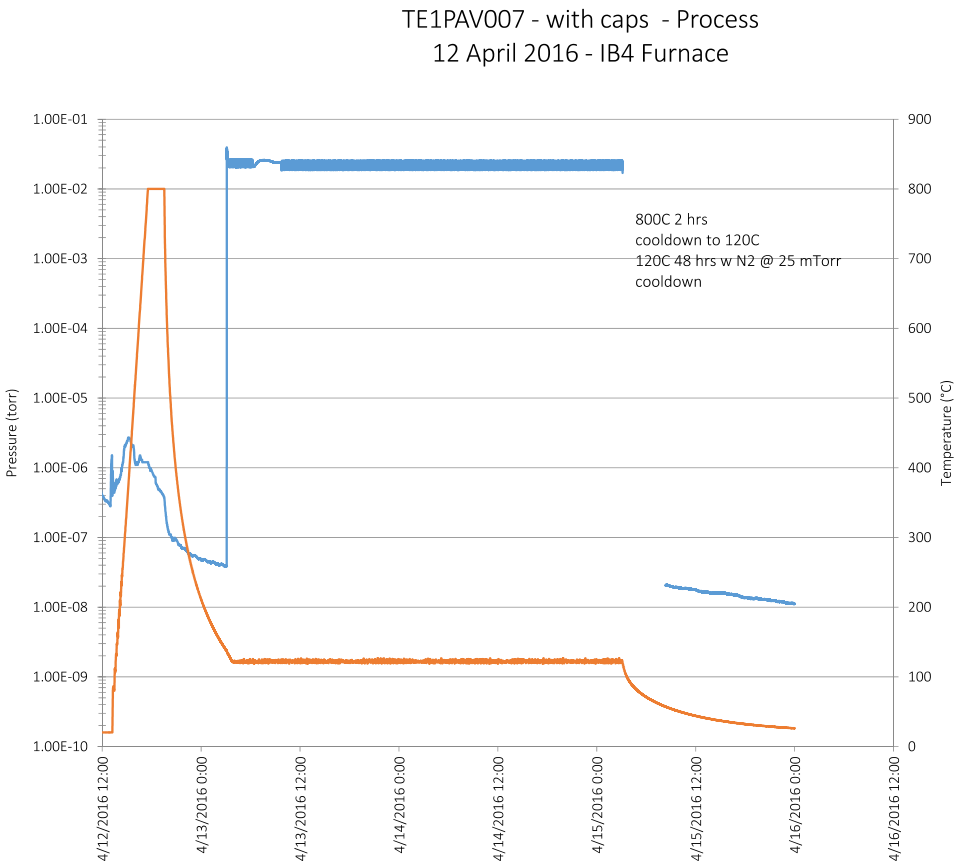
DESY

Outline

- Reminder nitrogen infusion
- Single cells for nitrogen infusion
- Furnace @ DESY
- Nanolab – preliminary results

Nitrogen Infusion – Fermilabs discovery

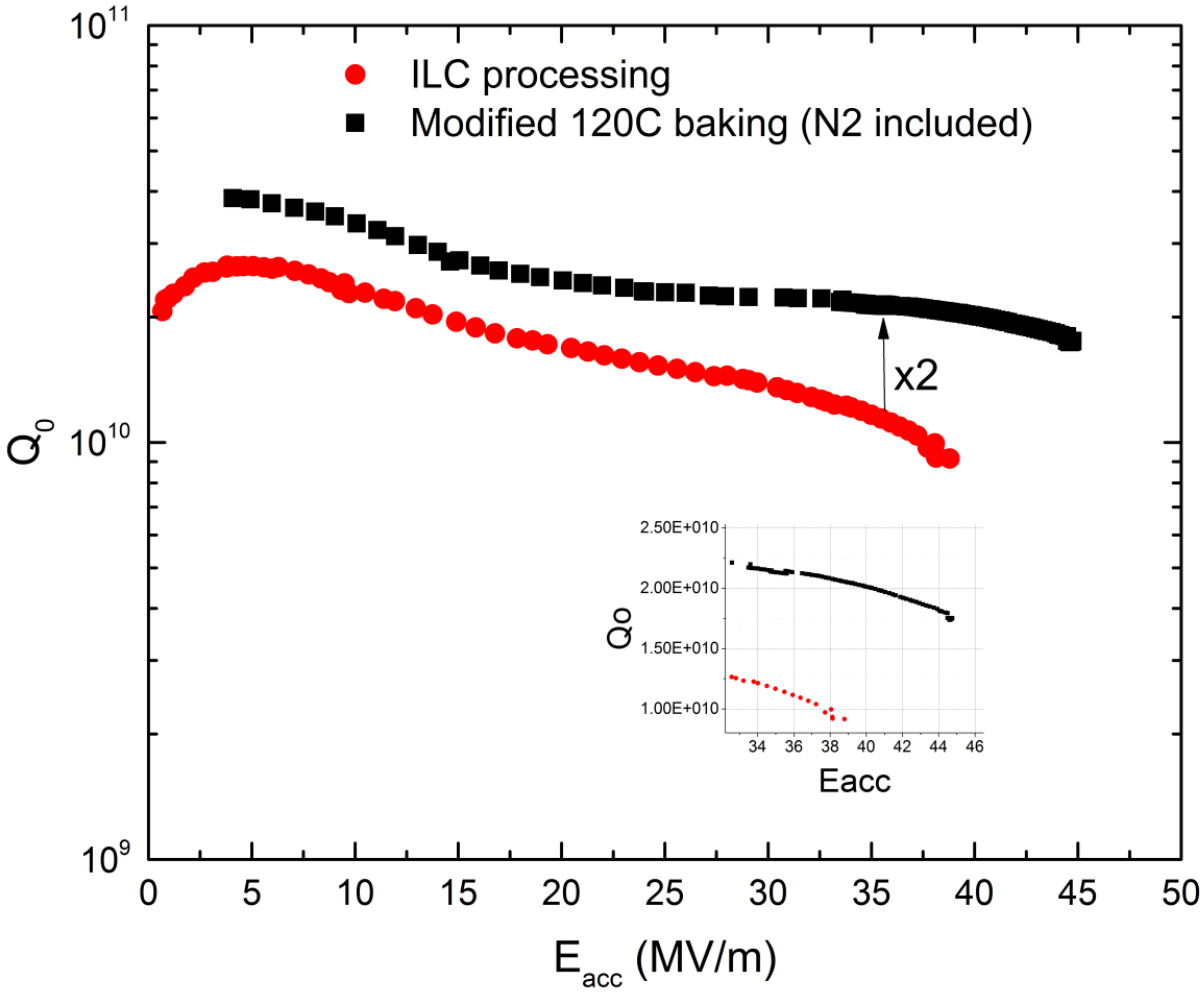
- Presented at ECFA2016 in Santander & TTC2016 in Saclay



- 800°C
  - 3h
  - O(p) ~ 10^{-6} mbar
- Cool down to 120°C
  - 48h
  - Inject N_2
  - O(p) ~ 10^{-2} mbar

[A.Grassellino, S. Aderhold - TTC Saclay 2016]

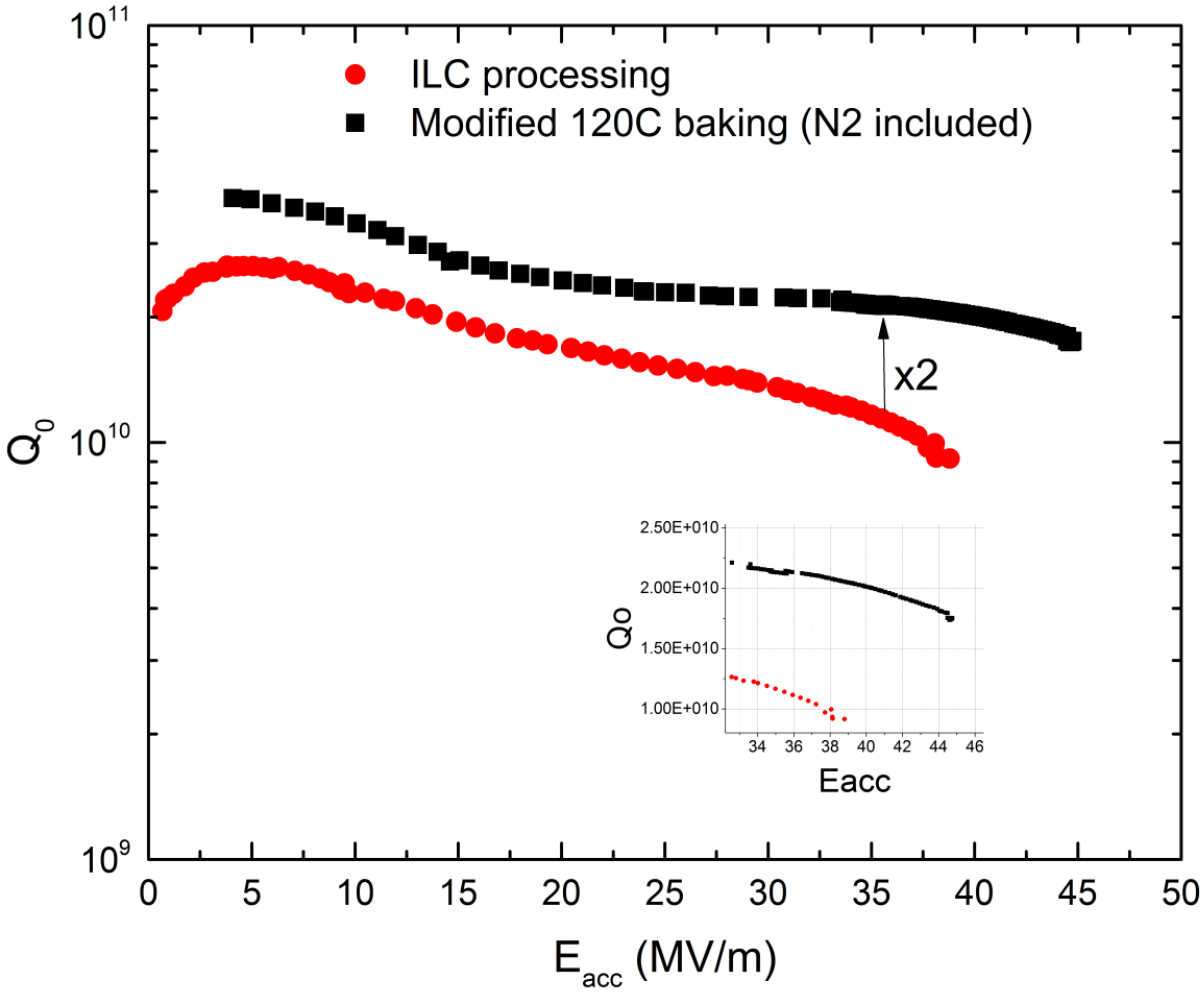
Nitrogen Infusion – Fermilabs discovery



- Achieved 45 MV/m@2x10^{10}
- Shown on other single cells as well

[A.Grassellino, S. Aderhold - TTC Saclay 2016]

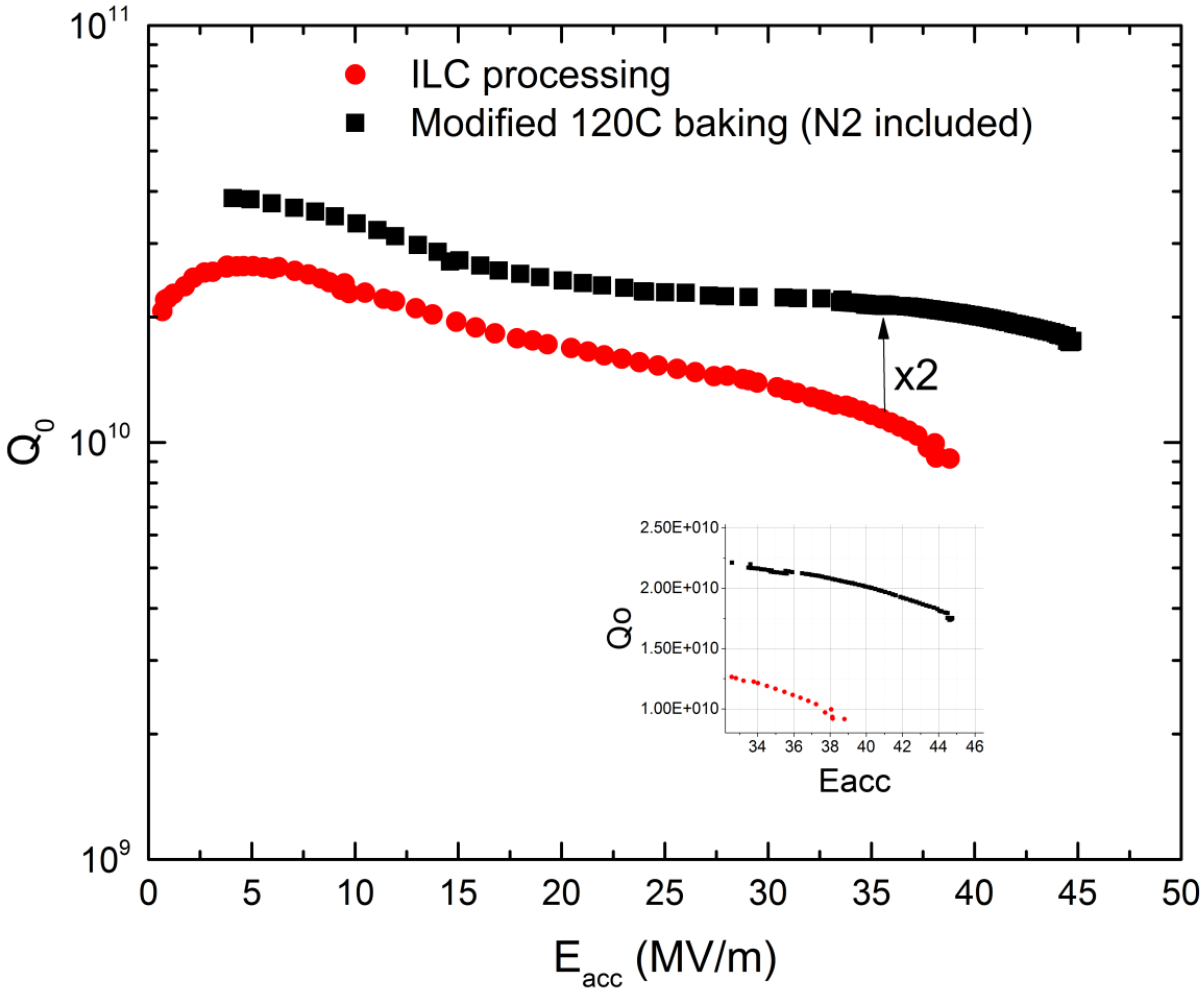
Nitrogen Infusion – Fermilabs discovery



[A.Grassellino, S. Aderhold - TTC Saclay 2016]

- Achieved 45 MV/m@2x10^{10}
- Shown on other single cells as well
- Interesting for cw machines or cost reduction of high gradient machines

Nitrogen Infusion – Fermilabs discovery



[A.Grassellino, S. Aderhold - TTC Saclay 2016]

- Achieved 45 MV/m@2x10^{10}
- Shown on other single cells as well
- Interesting for cw machines or cost reduction of high gradient machines
- DESY will do infusion, not doping

Single Cells

- Three single cell cavities

Single Cells

- Three single cell cavities
  - 1DE17 FG Ningxia – t2 (2007): E_{acc}= 38.3 MV/m@ Q_0 = 1,1 ·10^{10}; lim. by BD, few FE

Single Cells

- Three single cell cavities
  - 1DE17 FG Ningxia – t2 (2007): E_{acc}= 38.3 MV/m@ Q_0 = 1,1 ·10^{10}; lim. by BD, few FE
  - 1DE18 FG Ningxia – t3 (2007): E_{acc}= 39.5 MV/m@ Q_0 = 1,2 ·10^{10}; lim. by BD, no FE

Single Cells

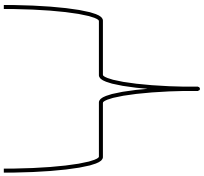
- Three single cell cavities
  - 1DE17 FG Ningxia – t2 (2007): E_{acc}= 38.3 MV/m@ Q_0 = 1,1 ·10^{10}; lim. by BD, few FE
  - 1DE18 FG Ningxia – t3 (2007): E_{acc}= 39.5 MV/m@ Q_0 = 1,2 ·10^{10}; lim. by BD, no FE
  - 1DE21 LG Heraeus – t2 (2008): E_{acc}= 39 MV/m@ Q_0 = 1,1 ·10^{10}; lim. by BD; low FE

Single Cells

- Three single cell cavities
  - 1DE17 FG Ningxia – t2 (2007): E_{acc}= 38.3 MV/m@ Q_0 = 1,1 ·10^{10}; lim. by BD, few FE
  - 1DE18 FG Ningxia – t3 (2007): E_{acc}= 39.5 MV/m@ Q_0 = 1,2 ·10^{10}; lim. by BD, no FE
  - 1DE21 LG Heraeus – t2 (2008): E_{acc}= 39 MV/m@ Q_0 = 1,1 ·10^{10}; lim. by BD; low FE
- Retested 2016
  - Q vs. T
  - Q vs. E at different T

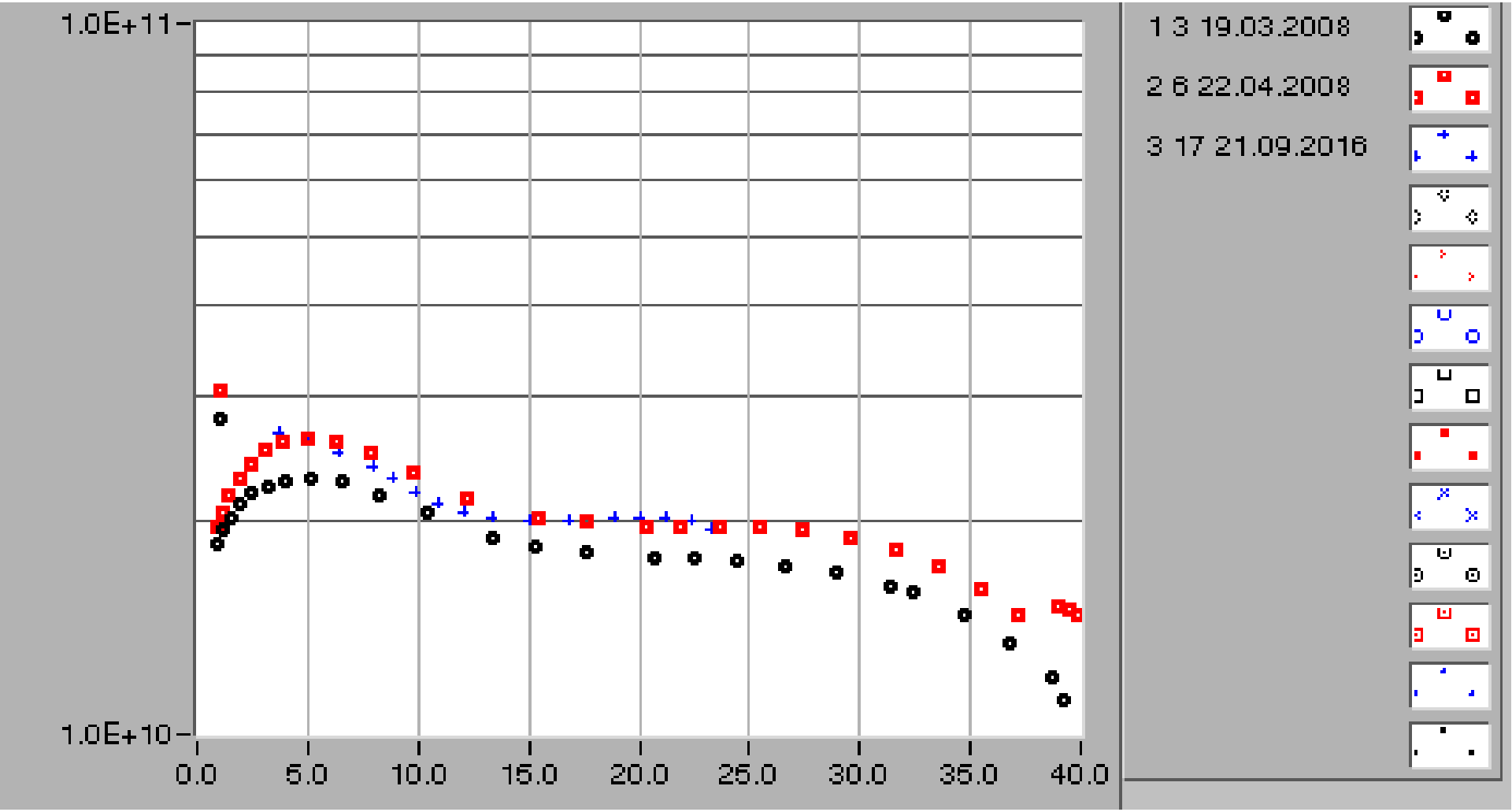
Single Cells

- Three single cell cavities
  - 1DE17 FG Ningxia – t2 (2007): E_{acc}= 38.3 MV/m@ Q_0 = 1,1 ·10^{10}; lim. by BD, few FE
  - 1DE18 FG Ningxia – t3 (2007): E_{acc}= 39.5 MV/m@ Q_0 = 1,2 ·10^{10}; lim. by BD, no FE
  - 1DE21 LG Heraeus – t2 (2008): E_{acc}= 39 MV/m@ Q_0 = 1,1 ·10^{10}; lim. by BD; low FE
- Retested 2016
  - Q vs. T
  - Q vs. E at different T



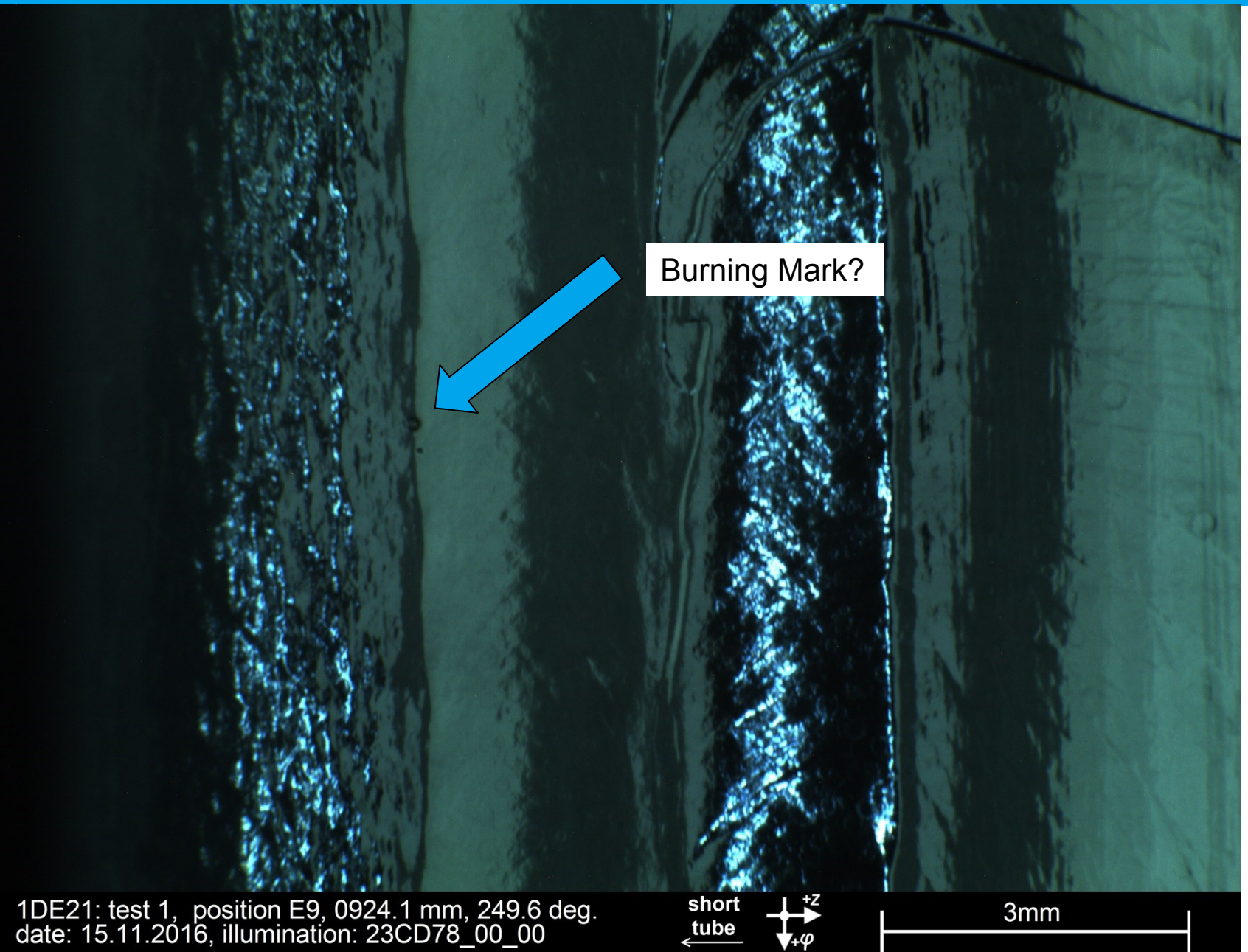
Baseline for N_2 treatment
& commissioning of HPR after maintenance

Single Cells – 1DE21 – Q vs. E History

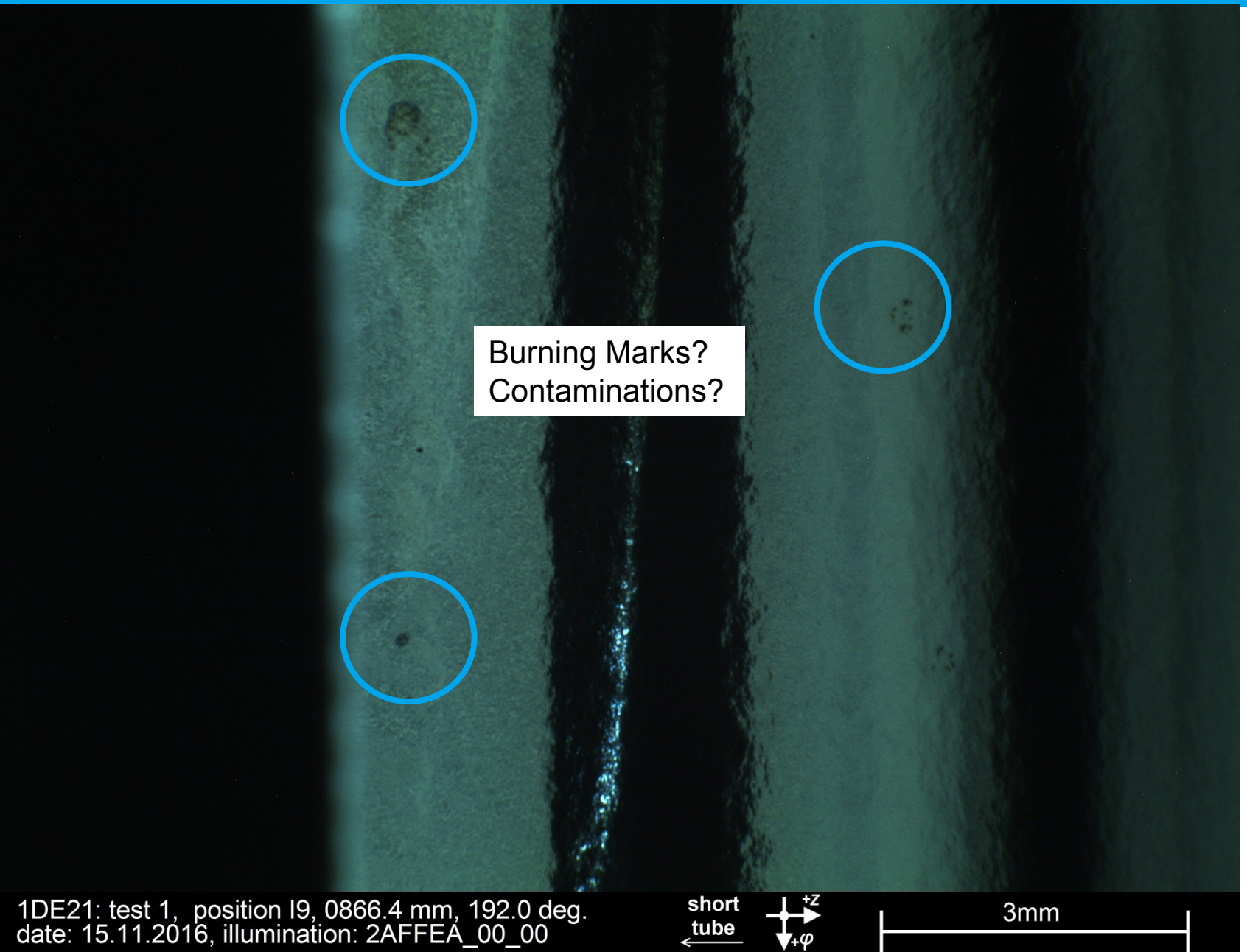


Test 3: E_{acc}= 23 MV/m@ Q_0 = 1,9 ·10^{10}; lim. by BD; no FE

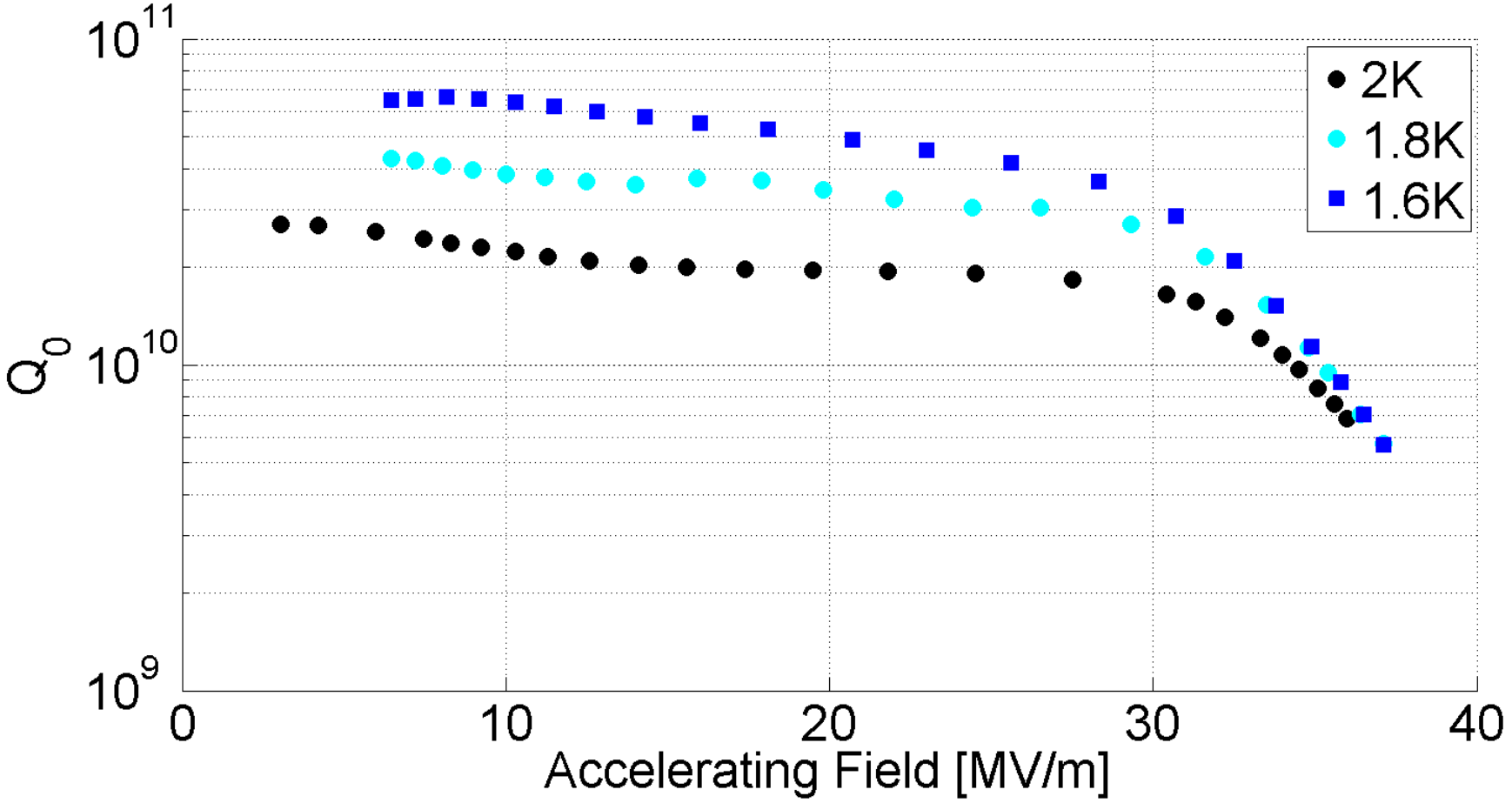
Single Cells – 1DE21 – OBACHT



Single Cells – 1DE21 – OBACHT

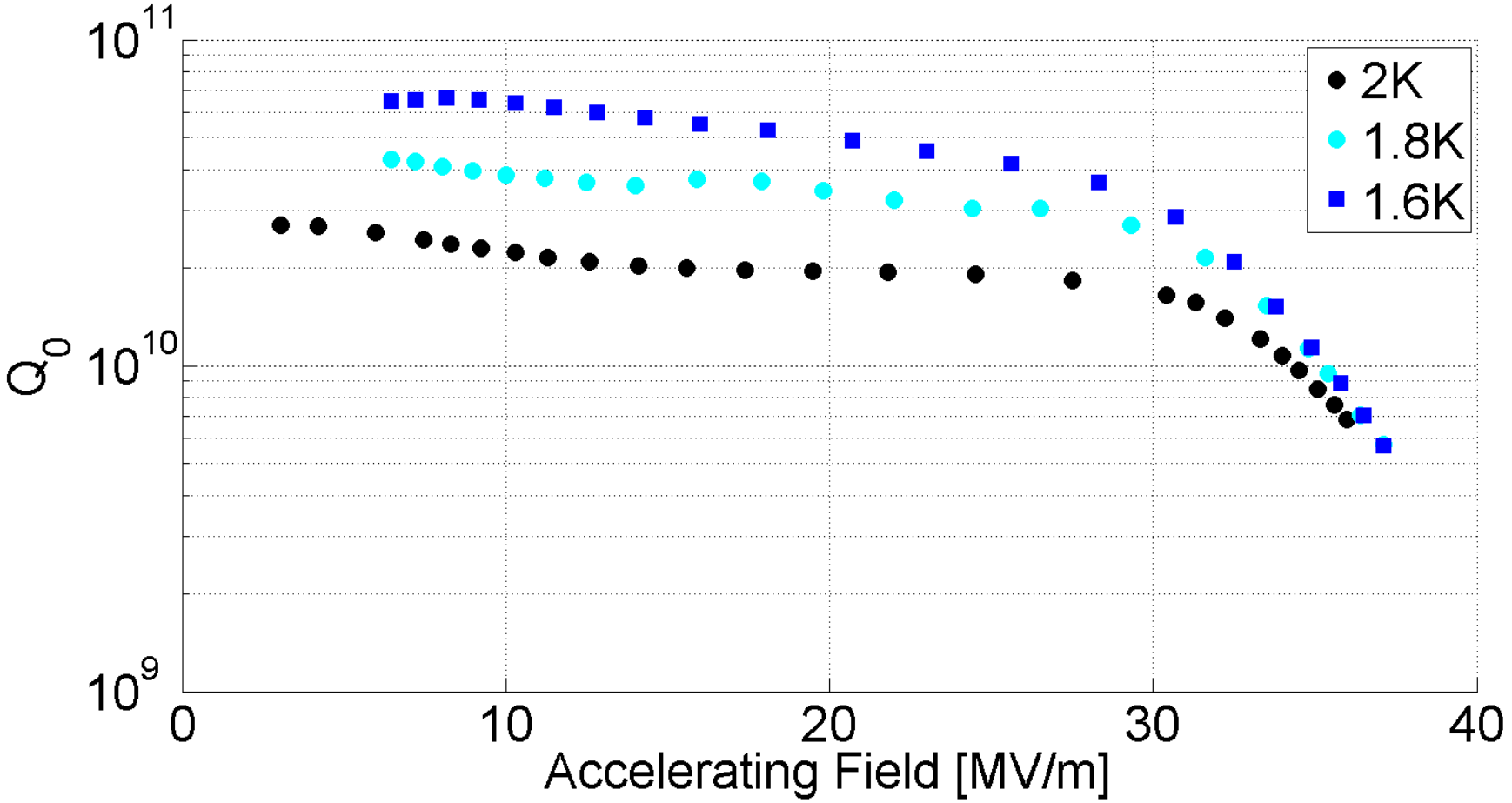


Single Cells – 1DE18 – Q vs. E – different T



Test 4 (2016): E_{acc}= 36 MV/m@ Q_0 = 6,8 ·10^9; lim. by PWR, some FE

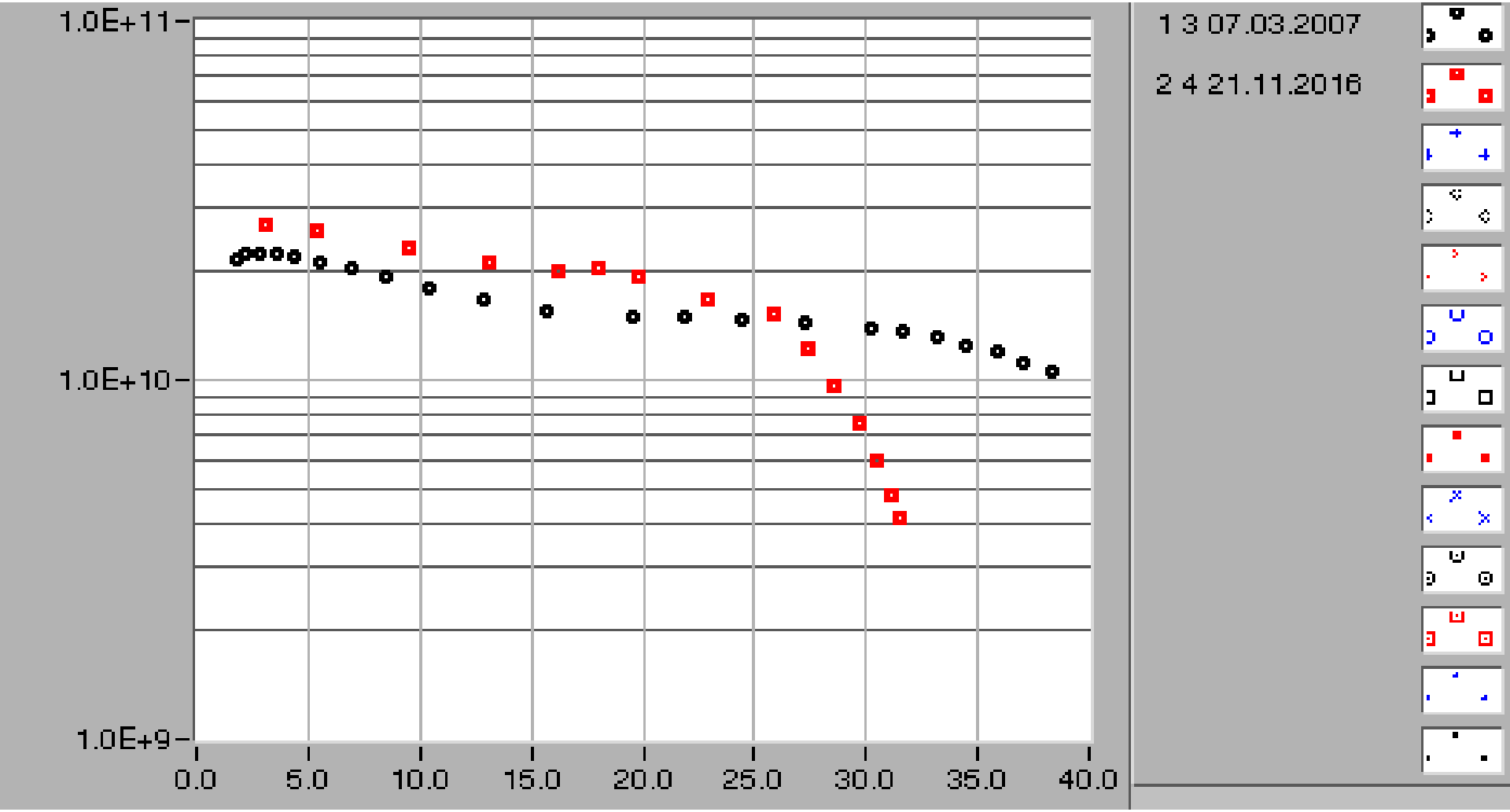
Single Cells – 1DE18 – Q vs. E – different T



Test 4 (2016): E_{acc}= 36 MV/m@ Q_0 = 6,8 ·10^9; lim. by PWR, some FE

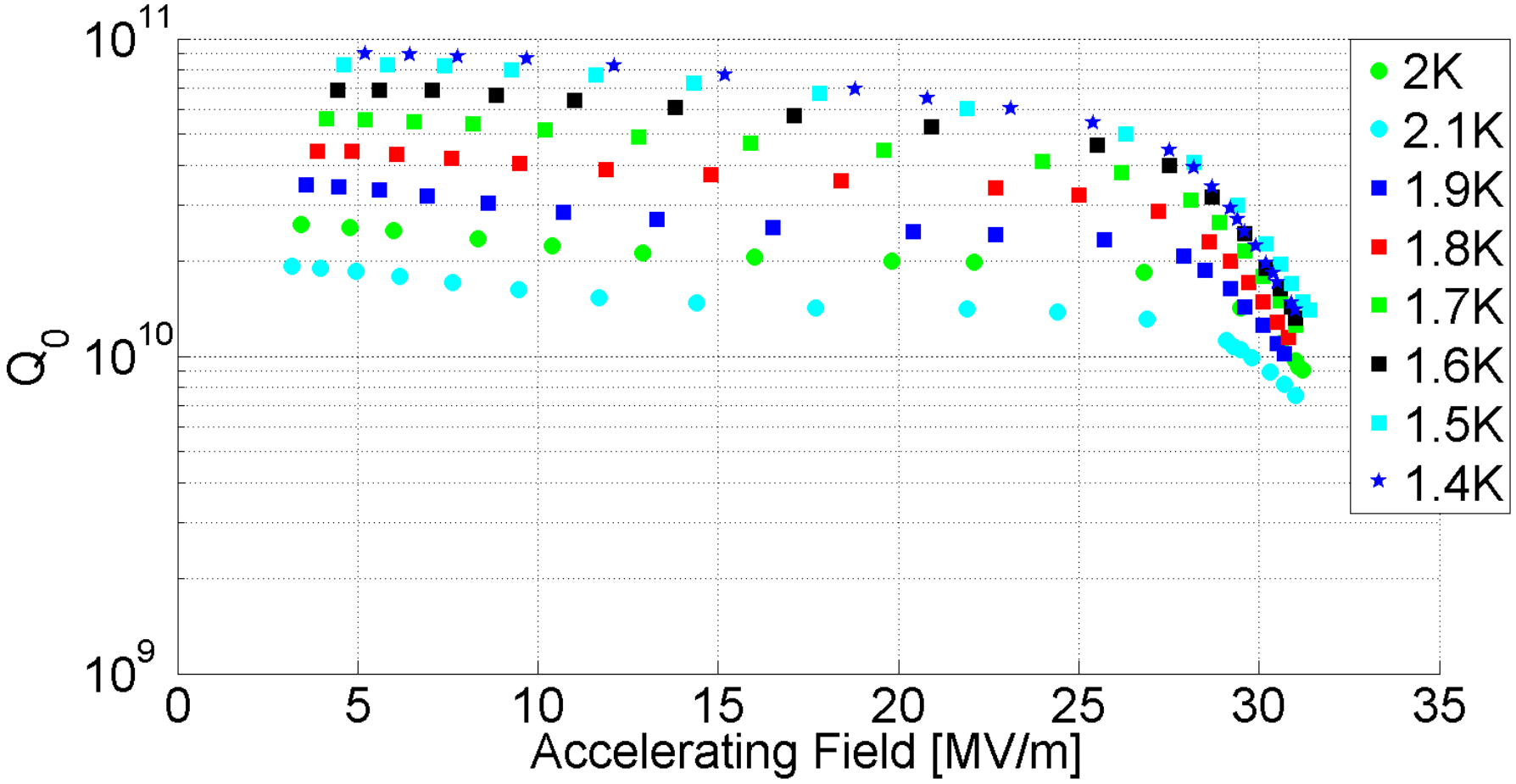
Test 3 (2007): E_{acc}= 39,5 MV/m@ Q_0 = 1,2 ·10^{10}; lim. by BD, no FE

Single Cells – 1DE17 – Q vs. E History



strong FE after 21MV/m - processing (2h) at last point → improved performance

Single Cells – 1DE17 – Q vs. E – different T



Test 3: E_{acc}= 31 MV/m@ Q_0 = 9 ·10^9; lim. by BD, some FE

Next steps

Next steps

- 1DE18
  - In the furnace now

Next steps

- 1DE18
  - In the furnace now
- 1DE21
  - Will undergo chemistry in next cycle (next year)
  - Replace with other LG single cell?

Next steps

- 1DE18
  - In the furnace now
- 1DE21
  - Will undergo chemistry in next cycle (next year)
  - Replace with other LG single cell?
- 1DE17
  - Now back in clean room
  - In preparation for N_2 infusion

Next steps

- 1DE18
  - In the furnace now
- 1DE21
  - Will undergo chemistry in next cycle (next year)
  - Replace with other LG single cell?
- 1DE17
  - Now back in clean room
  - In preparation for N_2 infusion
- HiGrade cavities (9-cell) for N_2 infusion

Next steps

- 1DE18
  - In the furnace now
- 1DE21
  - Will undergo chemistry in next cycle (next year)
  - Replace with other LG single cell?
- 1DE17
  - Now back in clean room
  - In preparation for N_2 infusion
- HiGrade cavities (9-cell) for N_2 infusion
  - Decide on which cavity
  - HPR & assembly
  - Base line measurement

Furnace

- 2 turbo molecular pumps (Varian, 6000 l/s each , max. intake pressure ~ 10^{-2} mbar)
- T_{max} ~ 1320°C
- V = 1800 x 625 x 660 mm³

Furnace

- Test run two weeks ago

Furnace

- Test run two weeks ago
  - 400°C instead 800°C for 2h (time saving)

Furnace

- Test run two weeks ago
  - 400°C instead 800°C for 2h (time saving)
  - Important part was cool down and stabilize at 120°C and

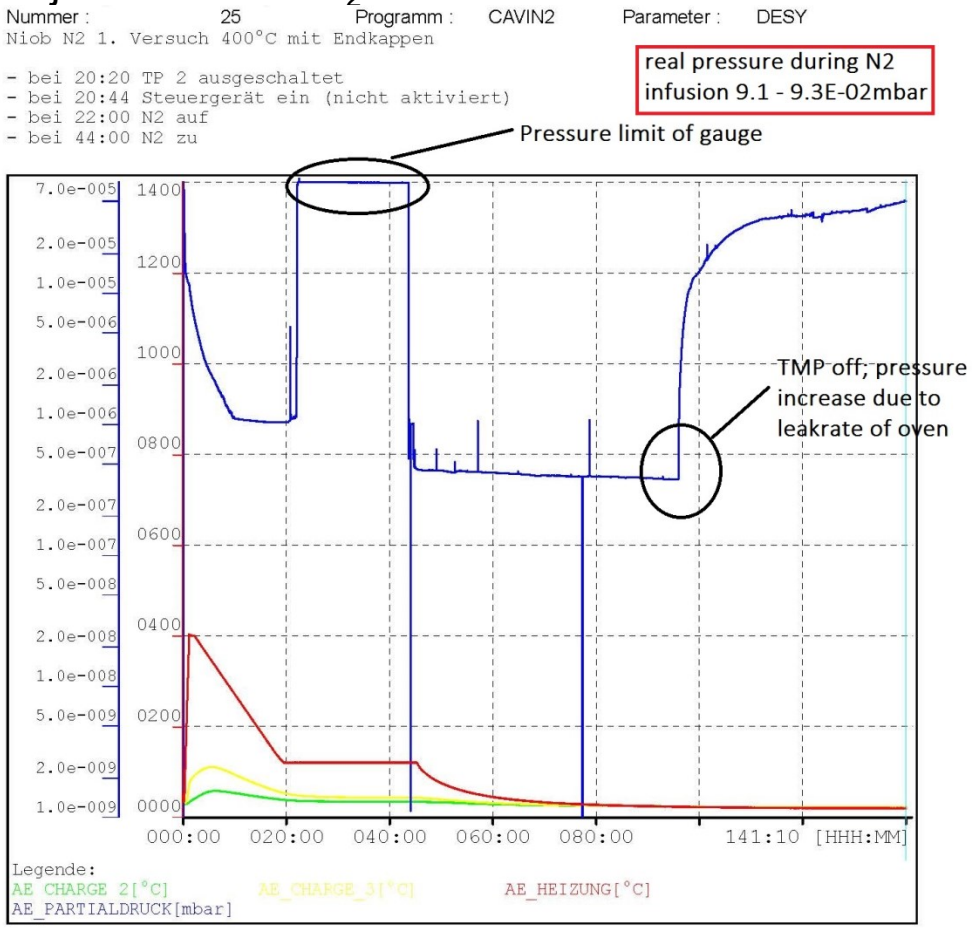
DESY

Furnace

- Test run two weeks ago
  - 400°C instead 800°C for 2h (time saving)
  - Important part was cool down and stabilize at 120°C and
  - Inject 25 mTorr N_2 at 120°C to check for overheating of pumps

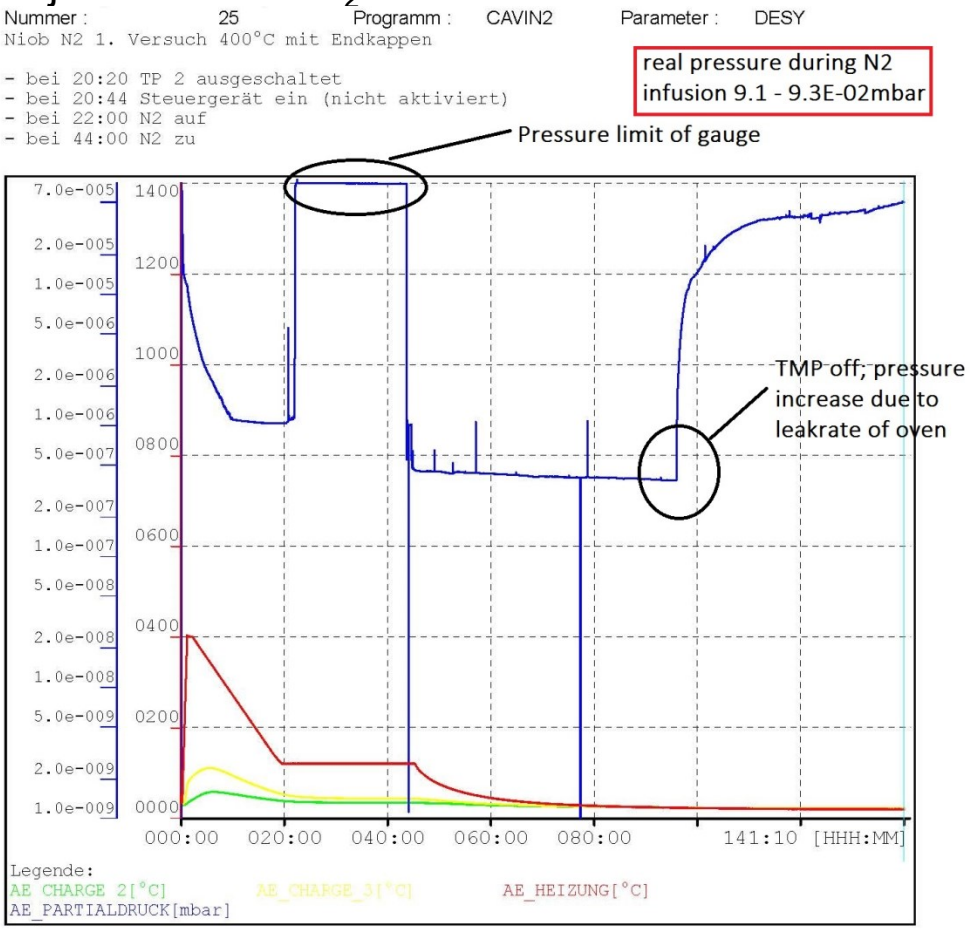
Furnace

- Test run two weeks ago
  - 400°C instead 800°C for 2h (time saving)
  - Important part was cool down and stabilize at 120°C and
  - Inject 25 mTorr N_2 at 120°C to check for overheating of pumps



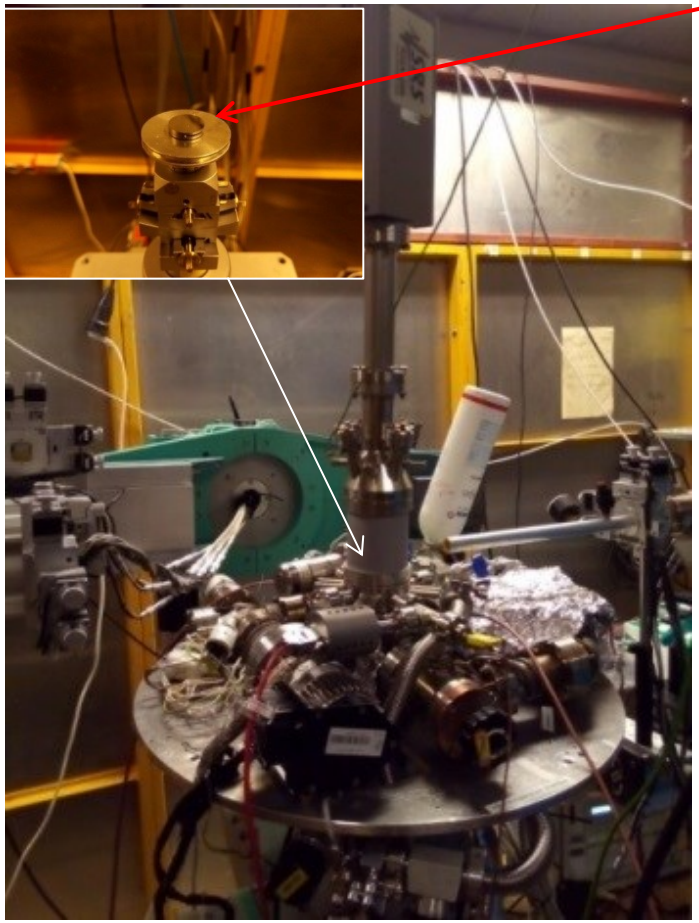
Furnace

- Test run two weeks ago
  - 400°C instead 800°C for 2h (time saving)
  - Important part was cool down and stabilize at 120°C and
  - Inject 25 mTorr N_2 at 120°C to check for overheating of pumps



Fundamental R&D at DESY NanoLab

‘Nitrogen infusion’ experiment on a model sample

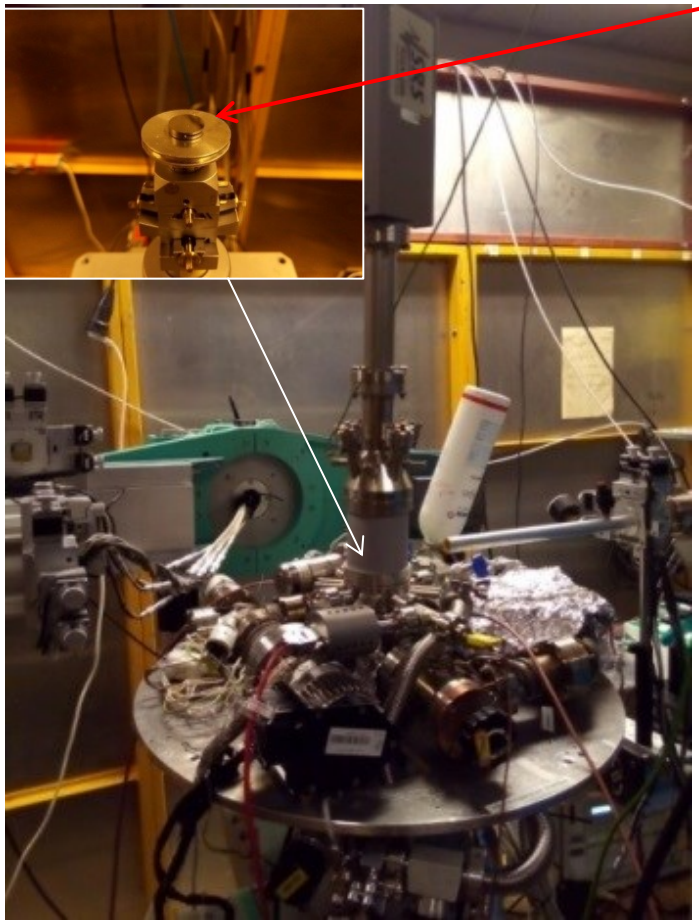


- Nb (100) Single-Crystal
- UHV Mobile Chamber
- Cu Kα source

Arti Dangwal Pandey & Guilherme dalla lana Semione

Fundamental R&D at DESY NanoLab

‘Nitrogen infusion’ experiment on a model sample



- Nb (100) Single-Crystal
- UHV Mobile Chamber
- Cu Kα source

800°C annealing/2 hours

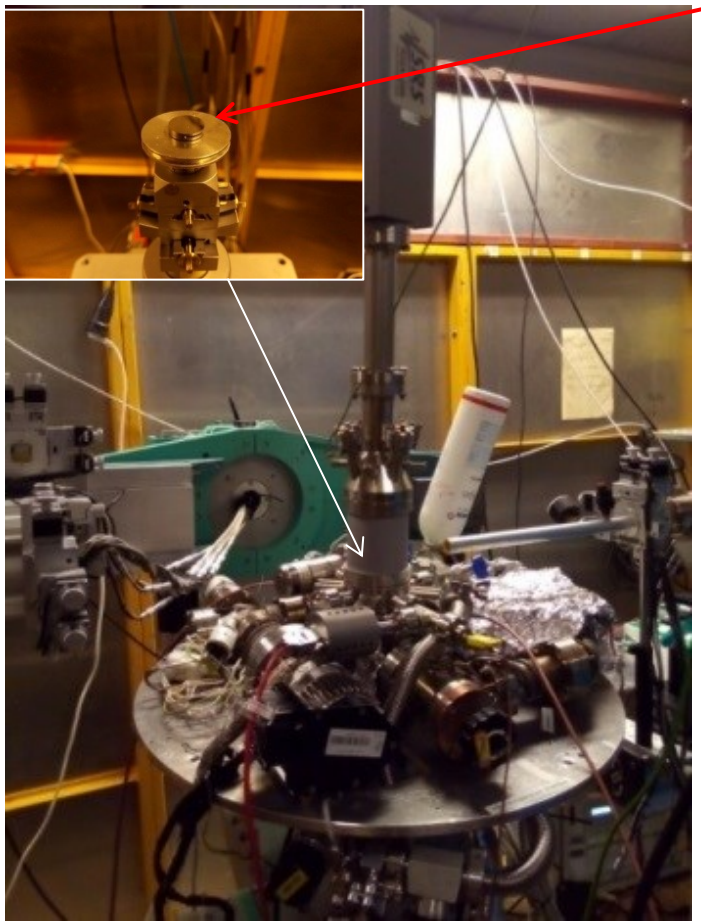
Cooldown to 120°C, insert 25mTorr of N_2

Hold for 23 hours

Arti Dangwal Pandey & Guilherme dalla lana Semione

Fundamental R&D at DESY NanoLab

‘Nitrogen infusion’ experiment on a model sample



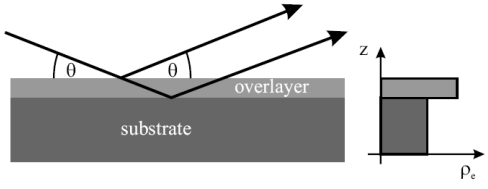
- Nb (100) Single-Crystal
- UHV Mobile Chamber
- Cu Kα source

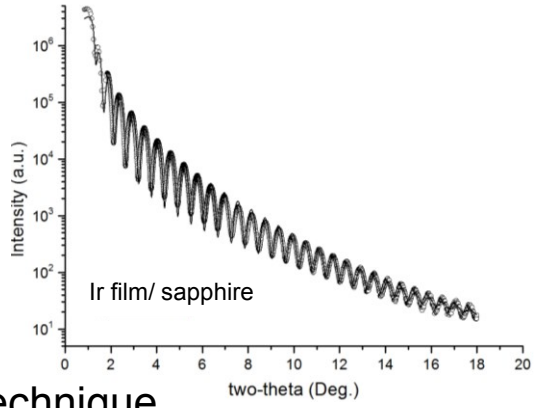
800°C annealing/2 hours

Cooldown to 120°C, insert 25mTorr of N_2

Hold for 23 hours

In-situ x-ray reflectivity (XRR) measurements



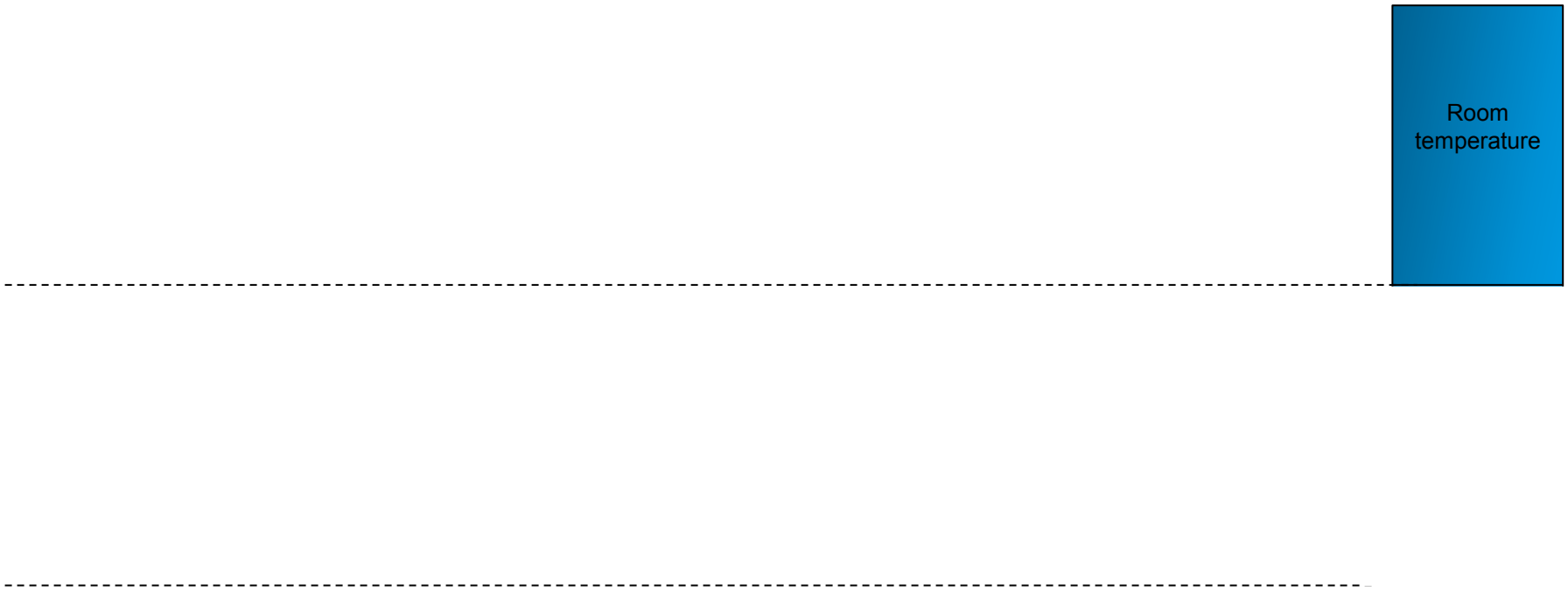


Surface sensitive technique

Arti Dangwal Pandey & Guilherme dalla lana Semione

Fundamental R&D at DESY NanoLab

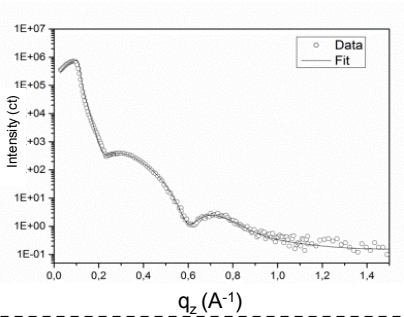
‘Nitrogen infusion’ experiment on Nb(100): preliminary results



Arti Dangwal Pandey & Guilherme dalla lana Semione

Fundamental R&D at DESY NanoLab

‘Nitrogen infusion’ experiment on Nb(100): preliminary results

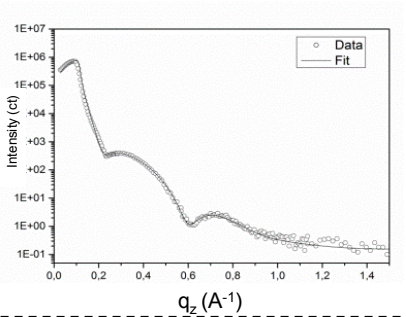


Room temperature

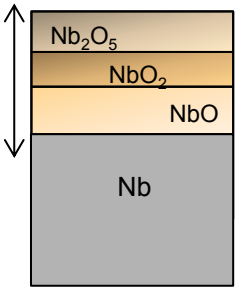
Arti Dangwal Pandey & Guilherme dalla lana Semione

Fundamental R&D at DESY NanoLab

‘Nitrogen infusion’ experiment on Nb(100): preliminary results



4.7 nm



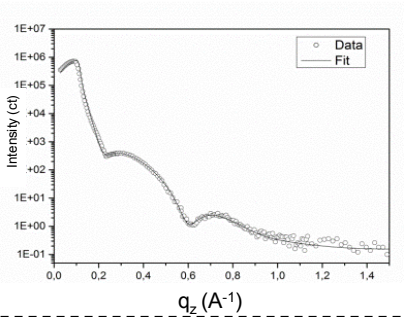
Natural oxide layers

Room temperature

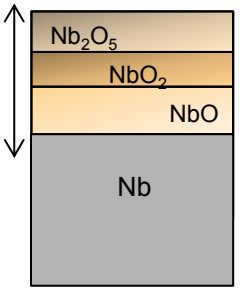
Arti Dangwal Pandey & Guilherme dalla lana Semione

Fundamental R&D at DESY NanoLab

‘Nitrogen infusion’ experiment on Nb(100): preliminary results



4.7 nm



Natural oxide layers

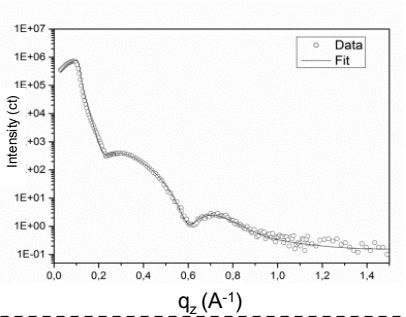
Room temperature

During/After 800°C anneal

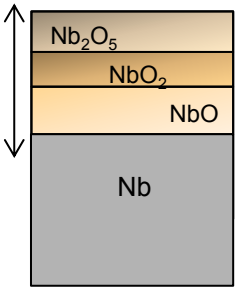
Arti Dangwal Pandey & Guilherme dalla lana Semione

Fundamental R&D at DESY NanoLab

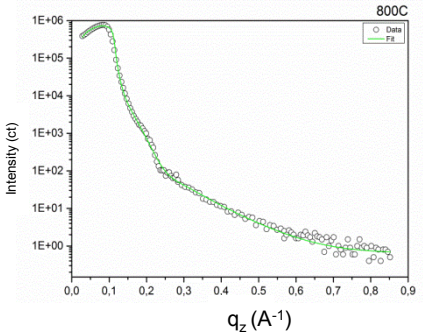
‘Nitrogen infusion’ experiment on Nb(100): preliminary results



4.7 nm



Natural oxide layers



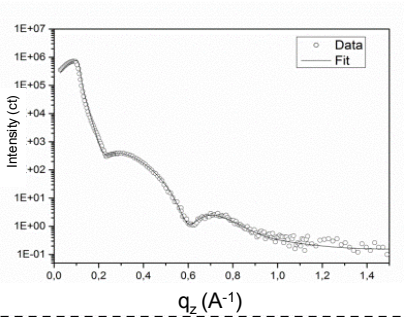
Room temperature

During/After 800°C anneal

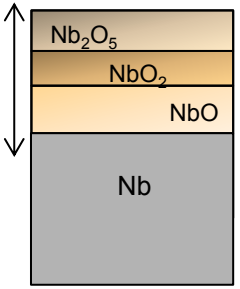
Arti Dangwal Pandey & Guilherme dalla lana Semione

Fundamental R&D at DESY NanoLab

‘Nitrogen infusion’ experiment on Nb(100): preliminary results

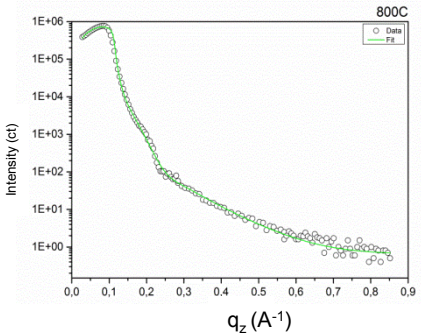


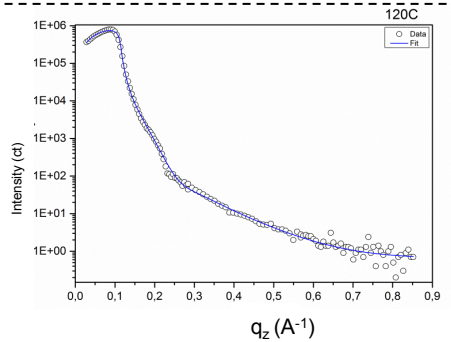
4.7 nm



Natural oxide layers

Room temperature



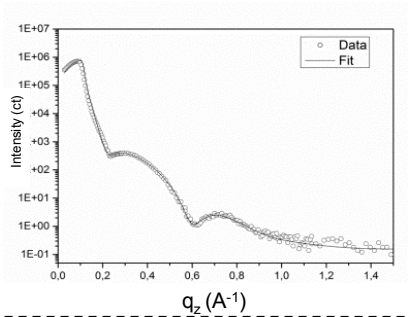


During/After 800°C anneal

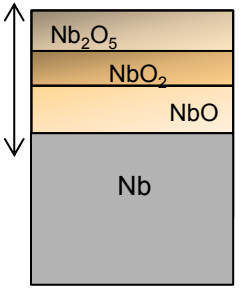
Arti Dangwal Pandey & Guilherme dalla lana Semione

Fundamental R&D at DESY NanoLab

‘Nitrogen infusion’ experiment on Nb(100): preliminary results

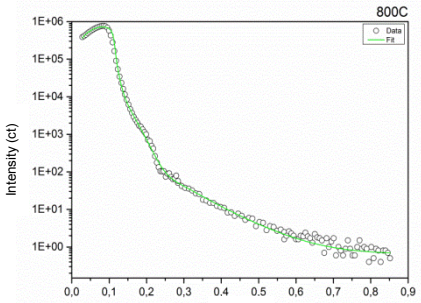


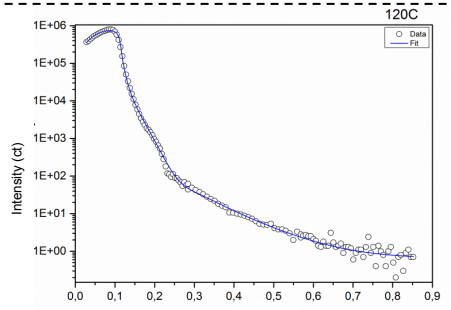
4.7 nm



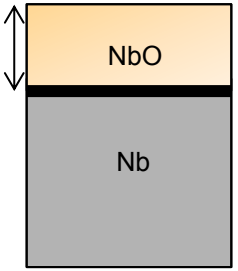
Natural oxide layers

Room temperature





4.2 nm

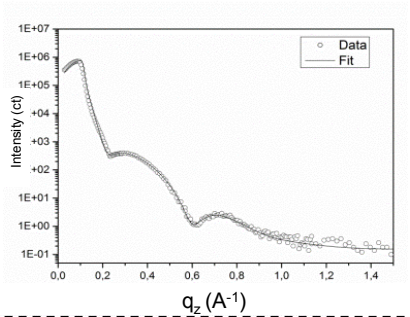


During/After 800°C anneal

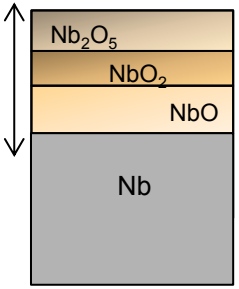
Arti Dangwal Pandey & Guilherme dalla lana Semione

Fundamental R&D at DESY NanoLab

‘Nitrogen infusion’ experiment on Nb(100): preliminary results

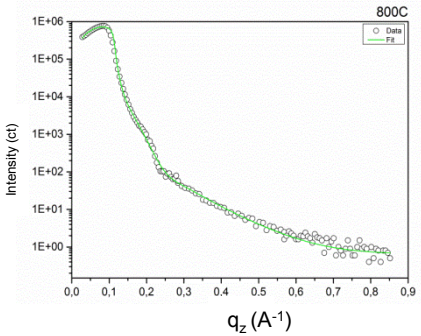


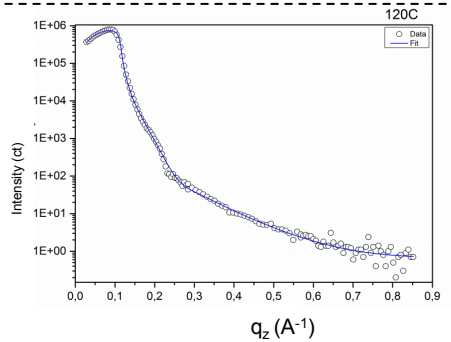
4.7 nm



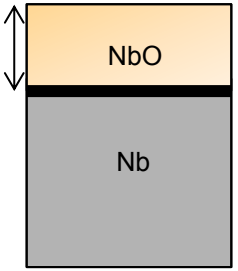
Natural oxide layers

Room temperature





4.2 nm



During/After 800°C anneal

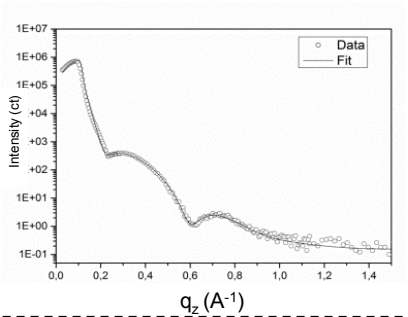
During infusion at 120°C

25mTorr N_2

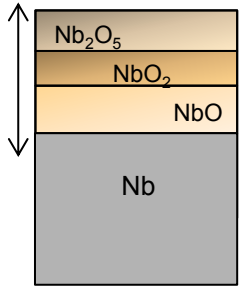
Arti Dangwal Pandey & Guilherme dalla lana Semione

Fundamental R&D at DESY NanoLab

‘Nitrogen infusion’ experiment on Nb(100): preliminary results

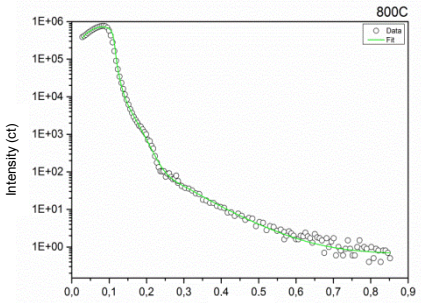


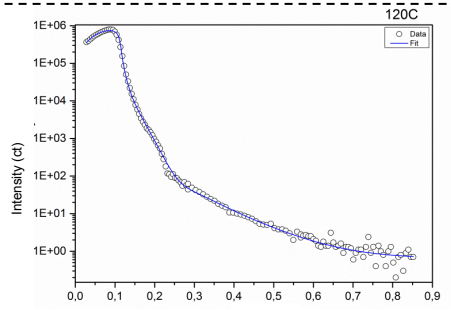
4.7 nm



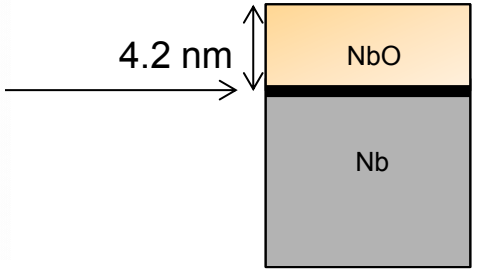
Natural oxide layers

Room temperature

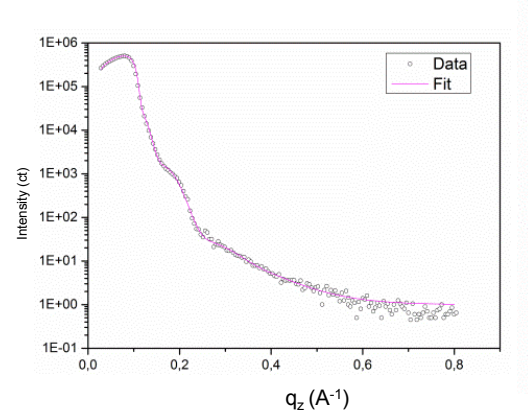




4.2 nm



During/After 800°C anneal



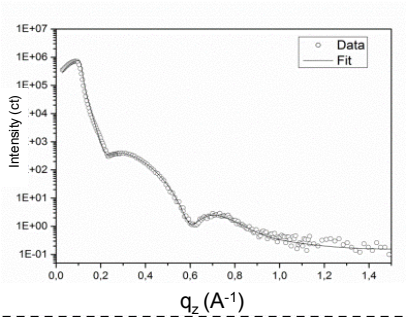
During infusion at 120°C

25mTorr N_2

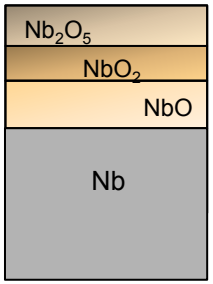
Arti Dangwal Pandey & Guilherme dalla lana Semione

Fundamental R&D at DESY NanoLab

‘Nitrogen infusion’ experiment on Nb(100): preliminary results

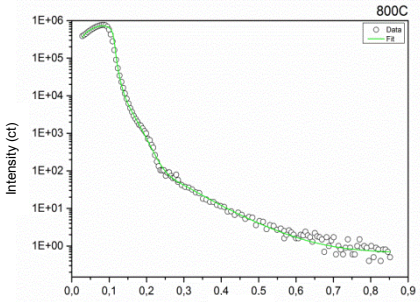


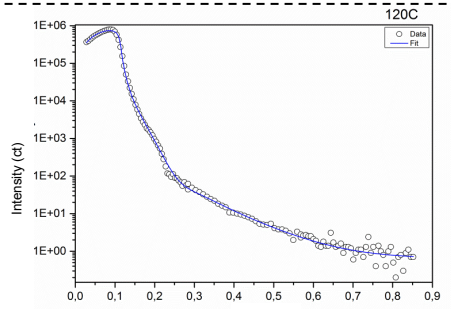
4.7 nm



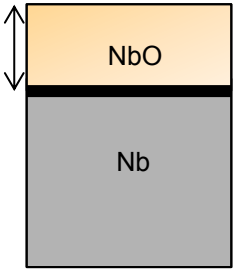
Natural oxide layers

Room temperature

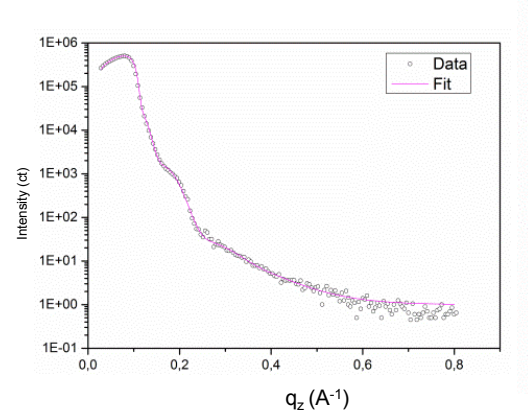




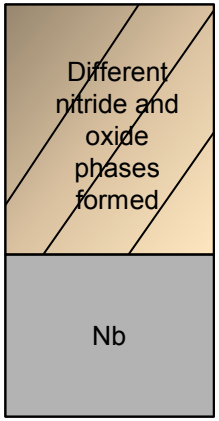
4.2 nm



During/After 800°C anneal



14.5 nm



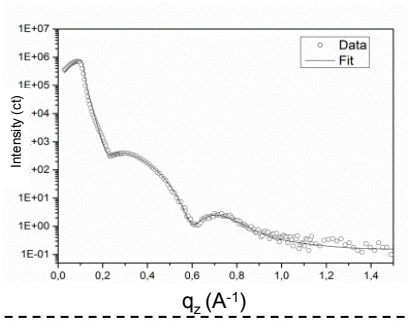
During infusion at 120°C

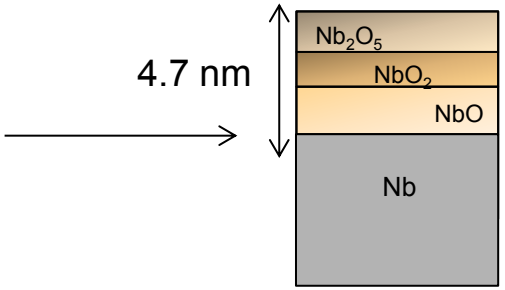
25mTorr N_2

Arti Dangwal Pandey & Guilherme dalla lana Semione

Fundamental R&D at DESY NanoLab

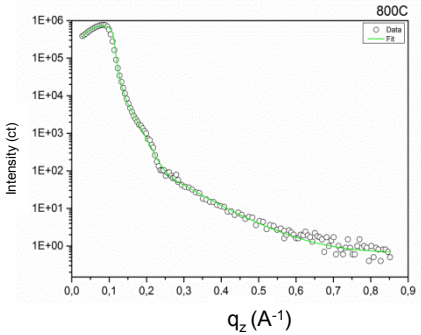
‘Nitrogen infusion’ experiment on Nb(100): preliminary results

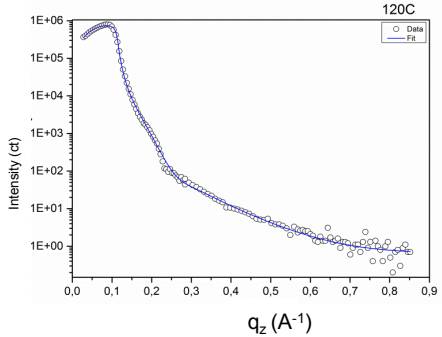


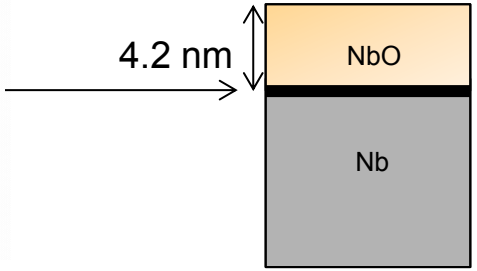


Natural oxide layers

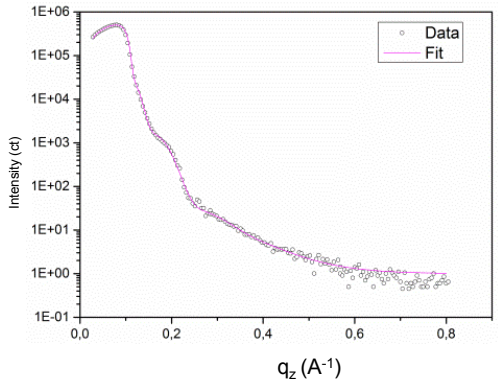
Room temperature

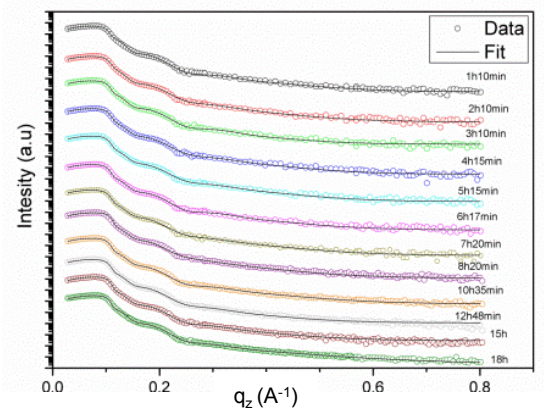


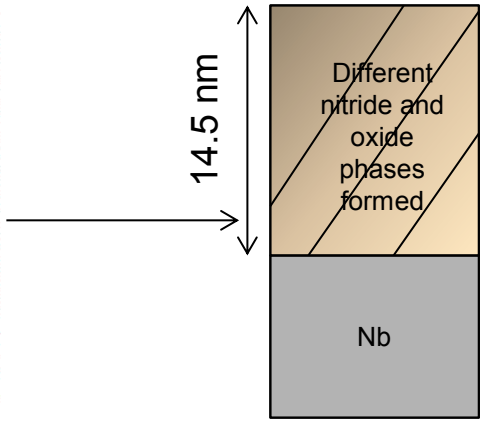




During/After 800°C anneal







During infusion at 120°C

25mTorr N_2

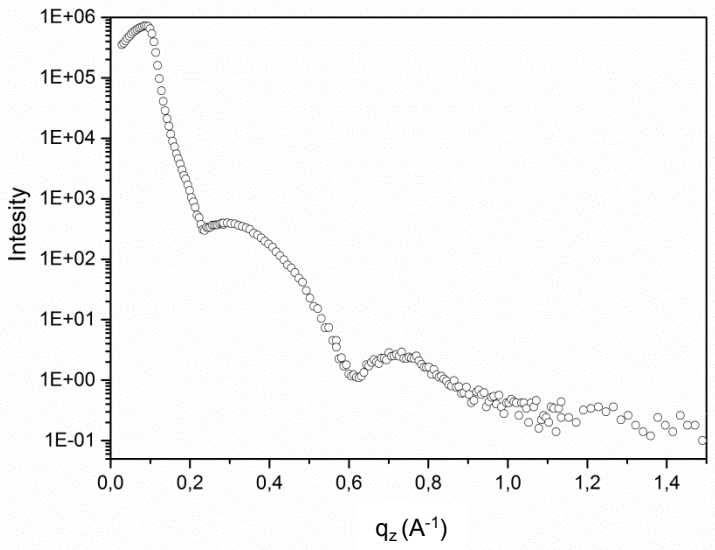
Arti Dangwal Pandey & Guilherme dalla lana Semione

Fundamental R&D at DESY NanoLab

‘Nitrogen infusion’ experiment on Nb(100): preliminary results

- After exposure to air:

  Annealed @ 800°C (UHV)/1h



Natural oxide layer grows again

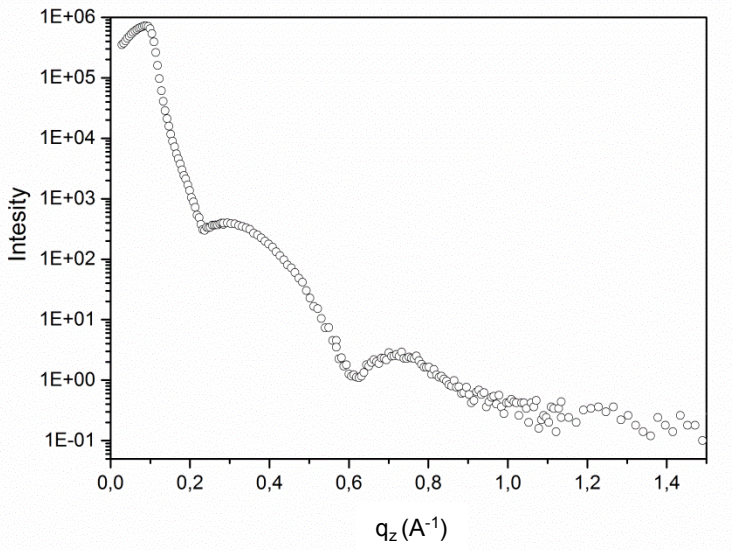
Arti Dangwal Pandey & Guilherme dalla lana Semione

Fundamental R&D at DESY NanoLab

‘Nitrogen infusion’ experiment on Nb(100): preliminary results

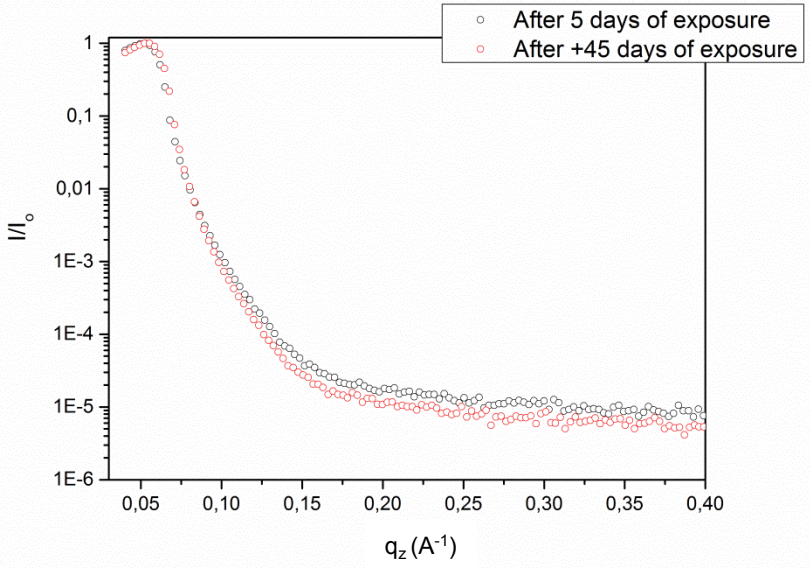
- After exposure to air:

Annealed @ 800°C (UHV)/1h



Natural oxide layer grows again

N_2 infused



Natural oxide layer suppressed

Arti Dangwal Pandey & Guilherme dalla lana Semione

First conclusions

Arti Dangwal Pandey & Guilherme dalla lana Semione

First conclusions

- Oscillations caused by natural oxide layer are not seen in N-infused sample after exposure to air

Arti Dangwal Pandey & Guilherme dalla lana Semione

First conclusions

- Oscillations caused by natural oxide layer are not seen in N-infused sample after exposure to air

- Changes in near surface region of the sample occur within the first hour of N_2 treatment. No significant changes were observed after longer exposure

Arti Dangwal Pandey & Guilherme dalla lana Semione

First conclusions

- Oscillations caused by natural oxide layer are not seen in N-infused sample after exposure to air

- Changes in near surface region of the sample occur within the first hour of N_2 treatment. No significant changes were observed after longer exposure

- N_2 introduction caused an increase in the total layer thickness – possibly different phases are formed

Arti Dangwal Pandey & Guilherme dalla lana Semione

DESY

Summary

On behalf of (imcomplete) :
A. Matheisen / B. van der Horst / D. Reschke / J. Eschke / W.D. Möller / N. Walker / M. Wiencek / J. Schaffran / L. Lijle / D. Liebertz / B. Foster / A. Stierle / A. Pandey / G. Semione

Summary

- Single cells
  - Prepared for first experiments
  - Find replacement for 1DE21
  - HPR not sufficient to re-establish performance (reason unclear)

On behalf of (imcomplete) :
A. Matheisen / B. van der Horst / D. Reschke / J. Eschke / W.D. Möller / N. Walker / M. Wiencek / J. Schaffran / L. Lijle / D. Liebertz / B. Foster / A. Stierle / A. Pandey / G. Semione

DESY

Summary

- Single cells
  - Prepared for first experiments
  - Find replacement for 1DE21
  - HPR not sufficient to re-establish performance (reason unclear)
- Furnace
  - Equipping the furnace took time
  - Test runs successful

On behalf of (imcomplete) :
A. Matheisen / B. van der Horst / D. Reschke / J. Eschke / W.D. Möller / N. Walker / M. Wiencek / J. Schaffran / L. Lijle / D. Liebertz / B. Foster / A. Stierle / A. Pandey / G. Semione

DESY

Summary

- Single cells
  - Prepared for first experiments
  - Find replacement for 1DE21
  - HPR not sufficient to re-establish performance (reason unclear)
- Furnace
  - Equipping the furnace took time
  - Test runs successful
- Nanolab
  - Excellent resources & diagnostic methods
  - Research on samples – first results interesting

On behalf of (imcomplete) :
A. Matheisen / B. van der Horst / D. Reschke / J. Eschke / W.D. Möller / N. Walker / M. Wiencek / J. Schaffran / L. Lijle / D. Liebertz / B. Foster / A. Stierle / A. Pandey / G. Semione