

# recent SRF cavity R&D @ DESY

## about heat treatments and different furnaces

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on behalf of the complete SRF team

TTC Meeting CERN

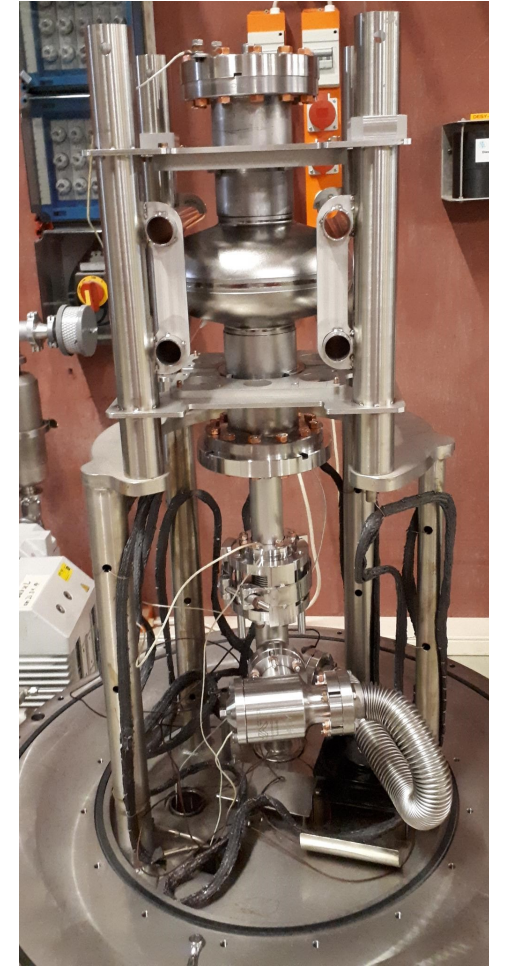
4<sup>th</sup> of February 2020

# DESY low T bake procedure

4h@75°C + 24h@130°C

- > result of statistical analysis → new DESY recipe
  - 4h@75°C + 24h@130°C
  - applied since end 2018
- > standard low temperature “furnace”
  - heating bands
  - T-sensors
- > 4 single-cell cavities treated and tested
  - all got a **cold EP**
  - **DESY low T bake**
  - compared to earlier low T heat treatments (baselines typically 48h@120°C)
- > 3 nine-cells already presented at SRF '19

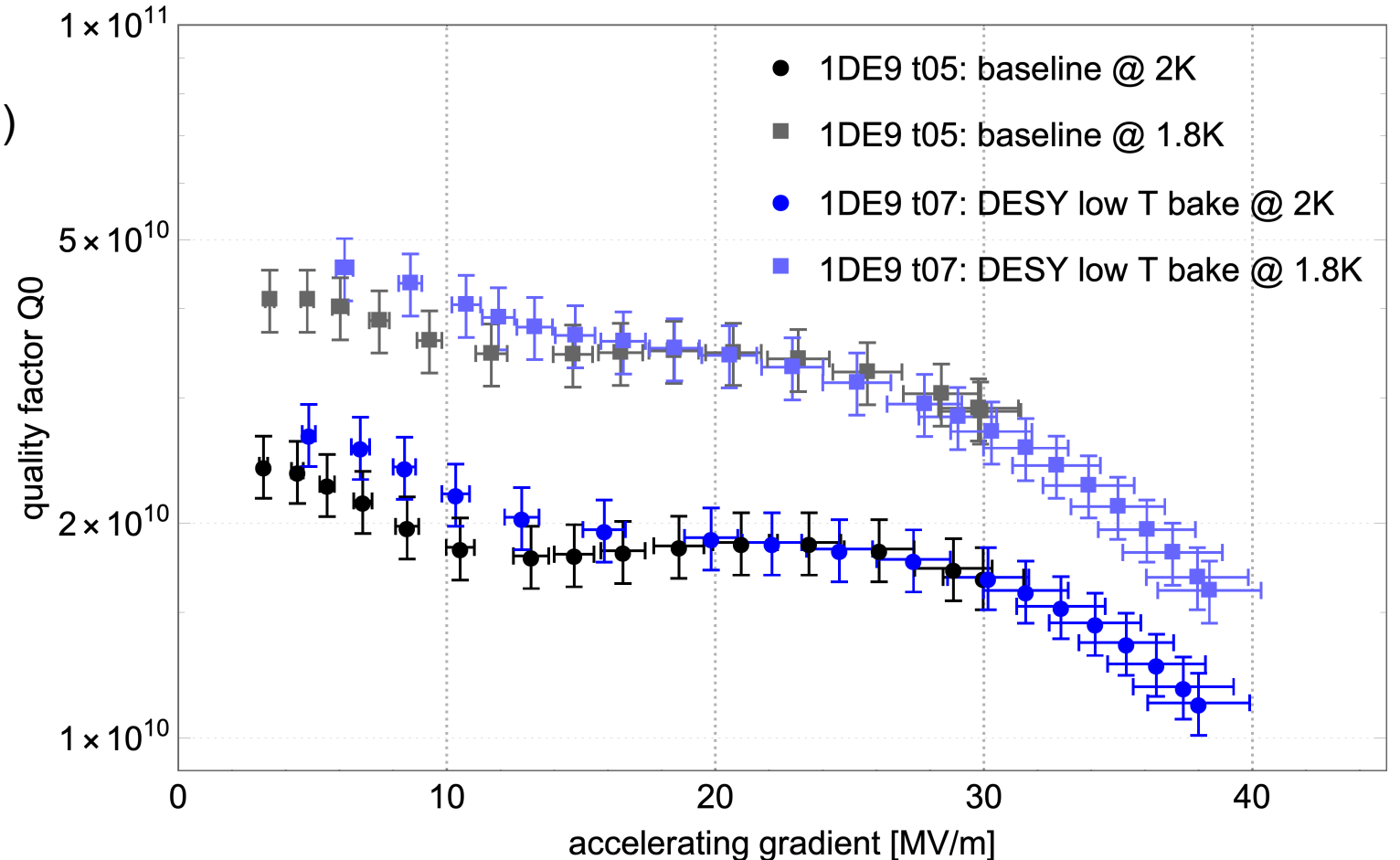
[*Statistical Analysis of the 120°C Bake Procedure of Superconducting Radio Frequency Cavities*, Lea Steder, Proceedings of SRF2019, Dresden]



# gradient improves

## 1DE9 DESY low T bake results

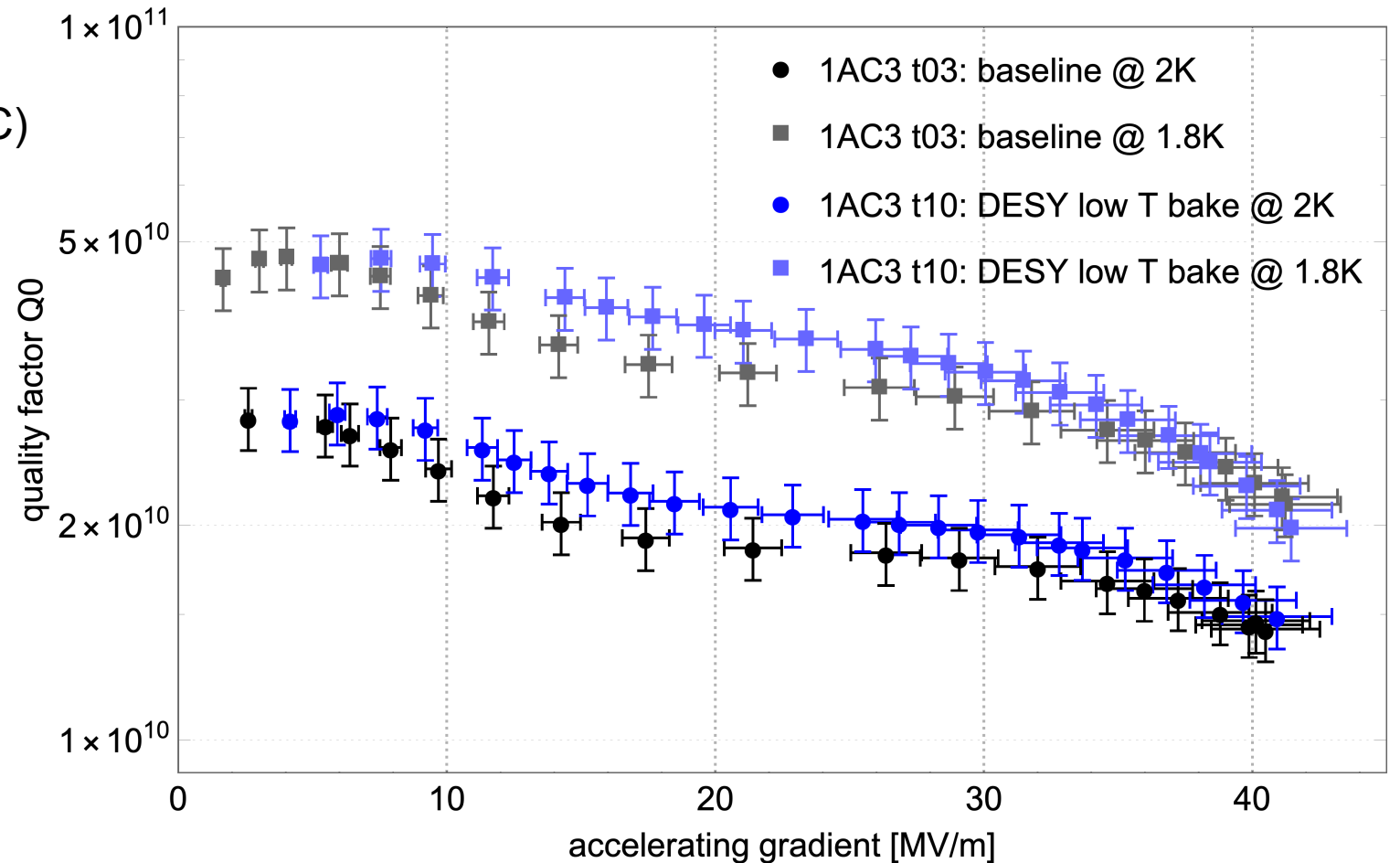
- > 1DE9: Heraeus FG material
- > last treatment: 40  $\mu\text{m}$  EP (14V / 13°C)
- > DESY low T bake:  
4h@75°C + 24h@130°C
- > **significant better acc. gradient**
  - 30 MV/m  $\rightarrow$  38 MV/m: 27% gain
- > (little) better low-field  $Q_0$ 
  - 2 K: about 30% @ 8.5 MV/m
  - 1.8 K: completely contained in uncertainty bands



# unchanged performance

## 1AC3 DESY low T bake results

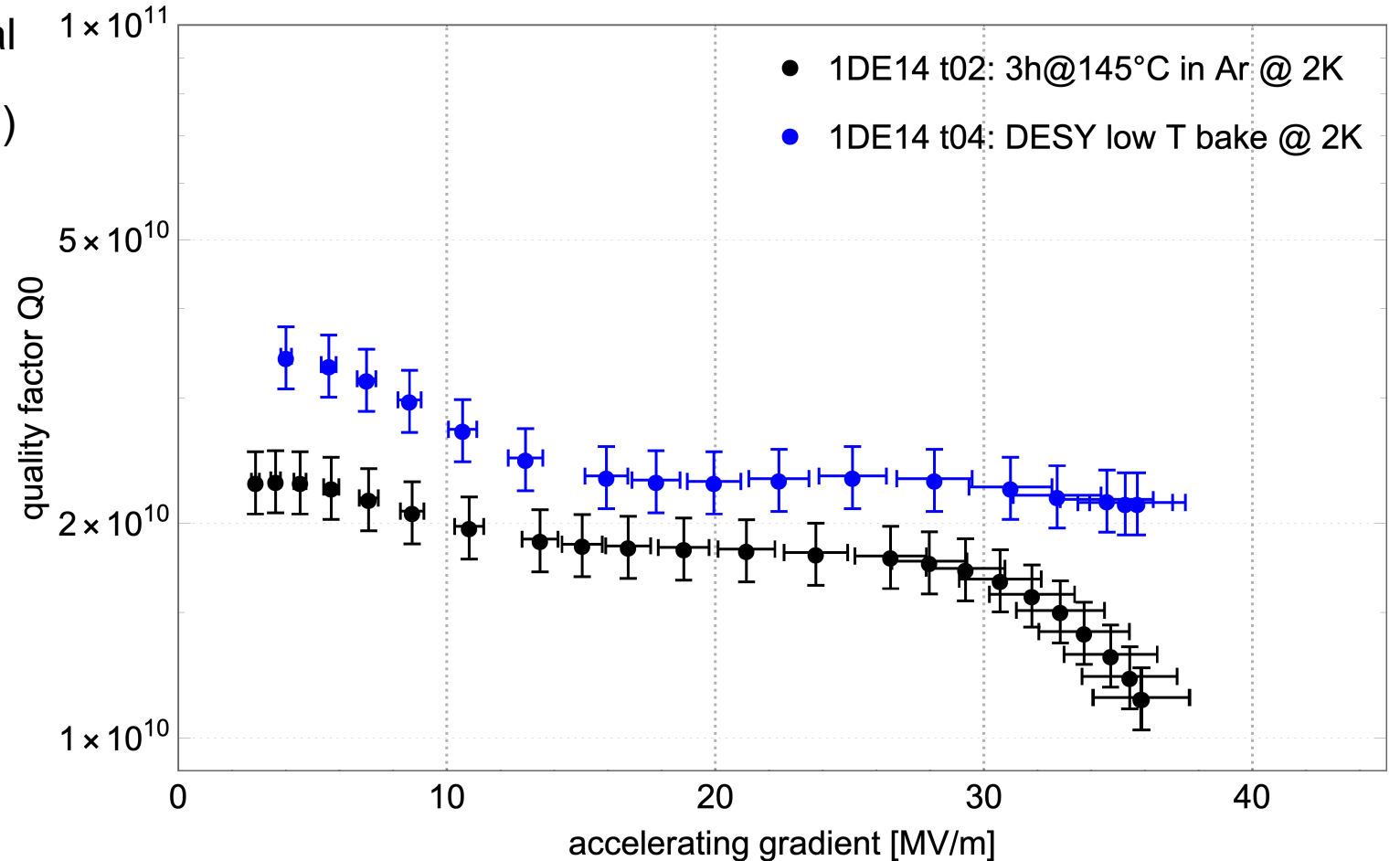
- > 1AC3: Heraeus LG material
- > last treatment: 120  $\mu\text{m}$  EP (14V /17°C)
- > DESY low T bake:  
4h@75°C + 24h@130°C
- > **same** accelerating gradient
- > slightly better mid-field  $Q_0$ 
  - $Q_0$  gain below 20%
  - still **within uncertainty** level



# quality factor improves significantly

## 1DE14 DESY low T bake results

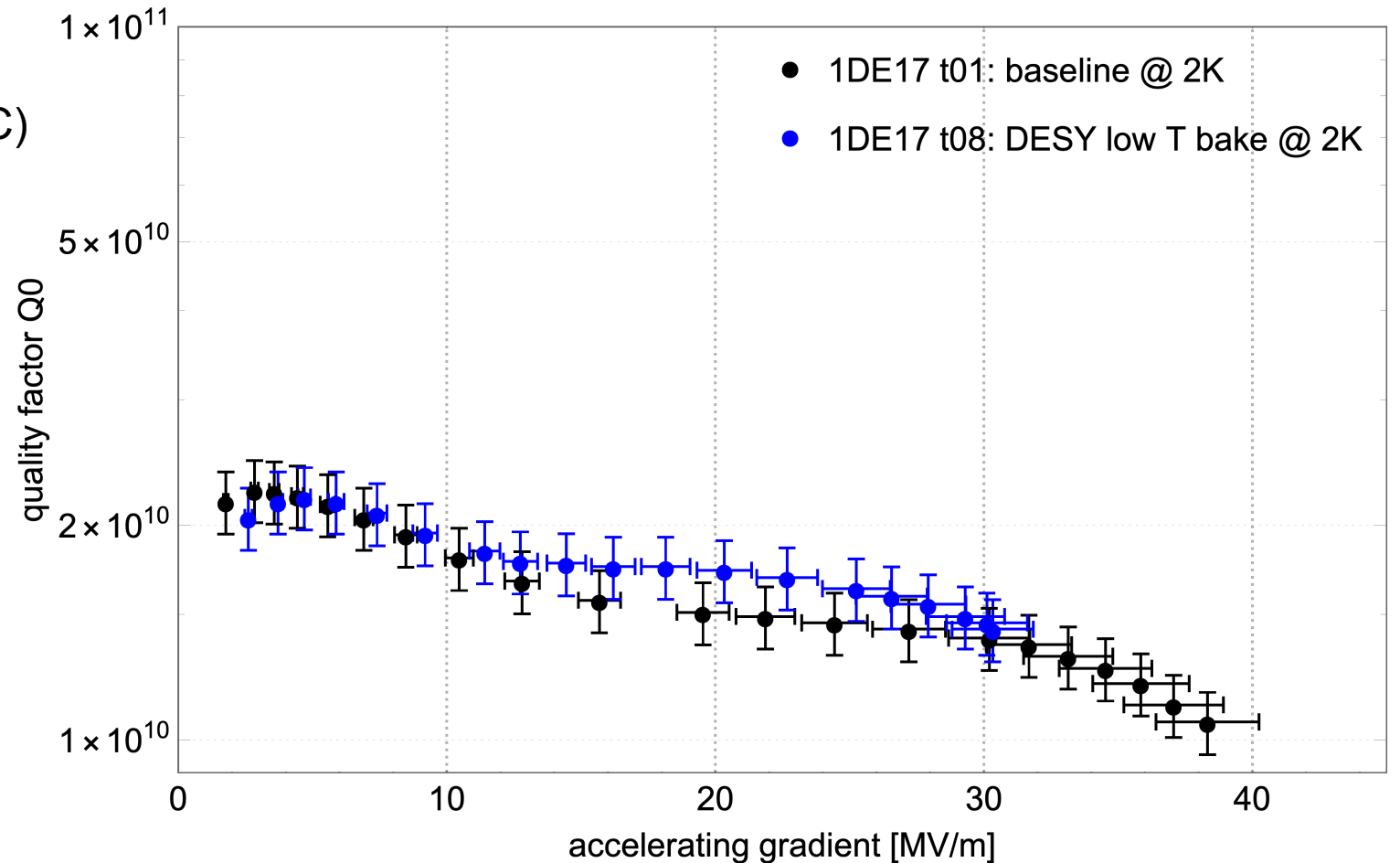
- > 1DE14: Plansee/Heraeus FG material
- > last treatment: 40  $\mu\text{m}$  EP (14V / 13°C)
- > DESY low T bake:  
4h@75°C + 24h@130°C
  - comparison to 3h@145°C in Argon atmosphere (Saclay 2007)
- > same acc. gradient & **better  $Q_0$** 
  - **exceptional good** performance
  - $3.3 \times 10^{10}$  @ 5 MV/m
  - $Q_0$  gain @ low gradients: 40%
  - $Q_0$  gain @ mid-field: 25%
  - HFQS removed



# constant performance

## 1DE17 DESY low T bake results

- > 1DE17: Ningxia FG material
- > last treatment: 120  $\mu\text{m}$  EP (14V /17°C)
- > DESY low T bake:  
4h@75°C + 24h@130°C
- > test 2007, storage, test 2016
  - gradient loss : 38 MV/m  $\rightarrow$  31 MV/m
  - storage problem?
- > slightly larger mid-field  $Q_0$ 
  - $Q_0$  gain below 15%
  - **contained in uncertainty**



# different low T treatment approach

## 120°C in Argon atmosphere

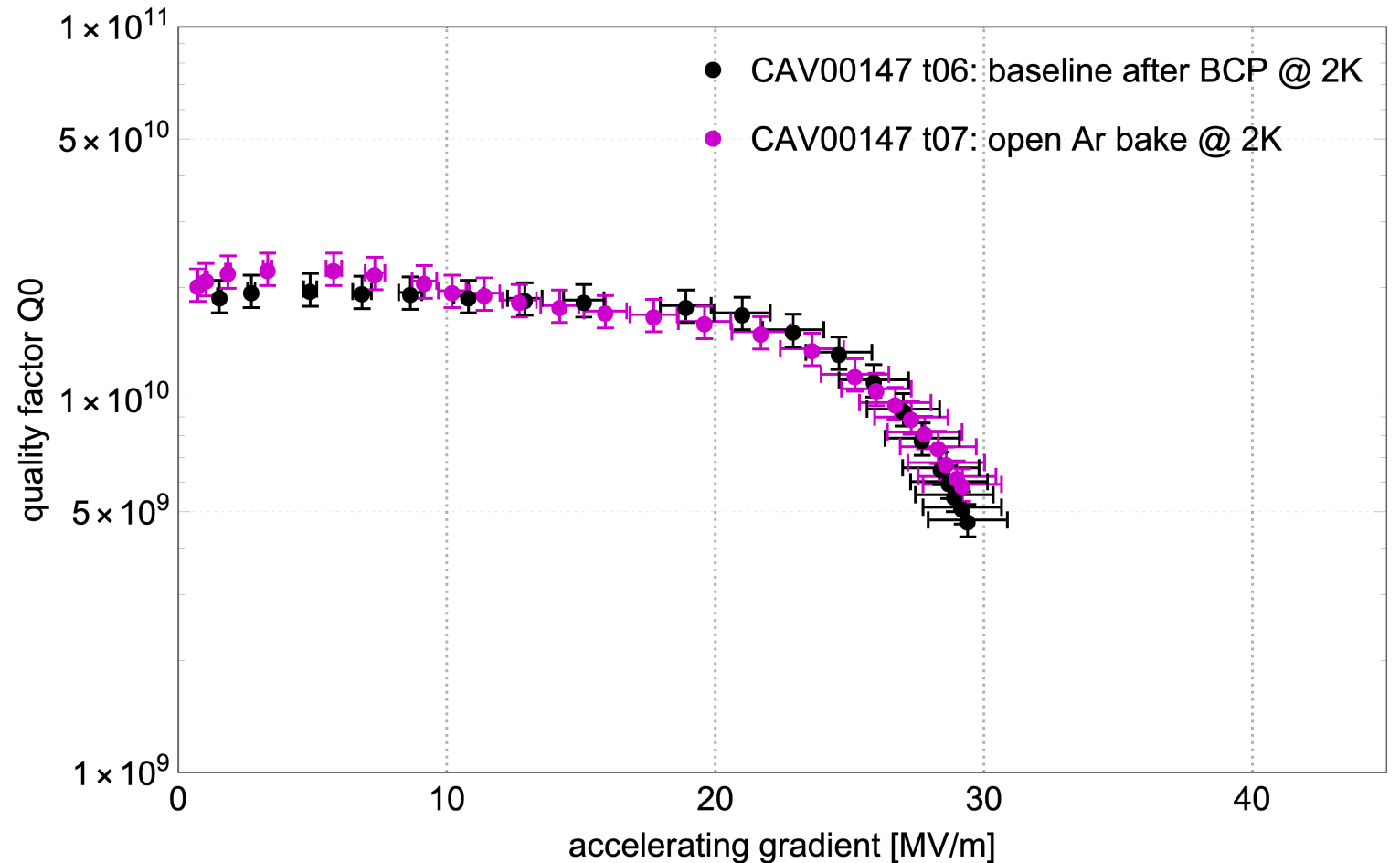
- > bake **open cavity in Argon** atmosphere
- > revival of old idea
  - 2008 – 2010: promising results with 4 single-cells
  - 24h@120°C
  - drying cabinet in “gray” area
- > “new” bake cabinet for nine-cell cavities
  - enough space for nine-cells
  - attached to ISO 4 clean room
  - temperatures up to 120°C
  - twice pump and purge with Argon
  - process in 1 atm Argon



# no effect visible

## CAV00147 low T Argon treatment results

- > HiGrade CAV00147
- > last treatment: 20  $\mu\text{m}$  BCP
- > reference test 6 unbaked after BCP
- > treatment in bake cabinet  
4h@75°C + 24h@120°C
- > performance **unchanged**
  - treatment **does not spoil** cavity
  - BCP surface?
  - too short bake?
- > more cavities will be treated
  - EP surface
  - longer duration





# still infusion related studies

## further tests with DESY furnace

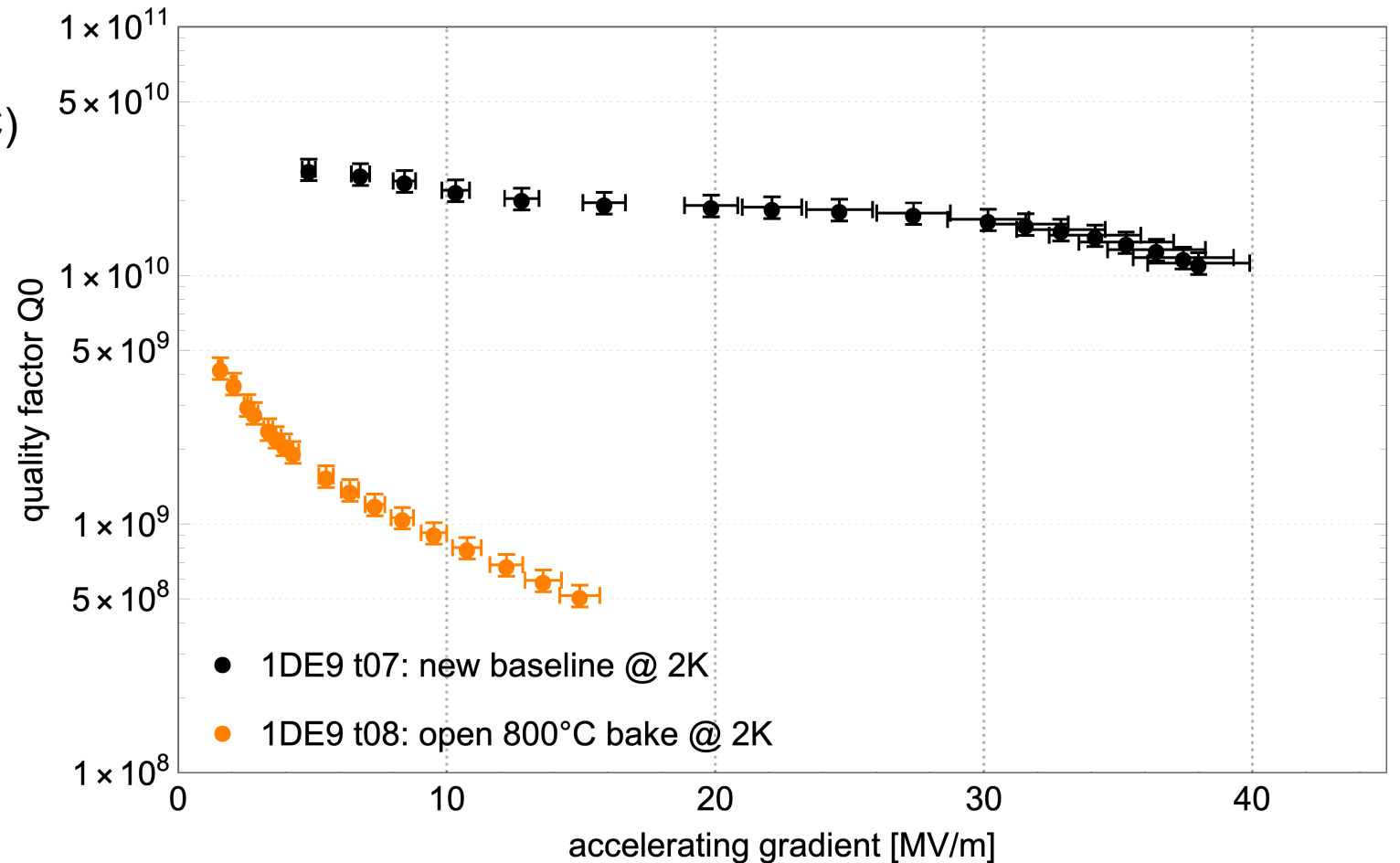
- > 800°C open cavity, no Nitrogen: 1DE9
  - after many infusion attempts
  - check of furnace usability
- > 650°C with caps, no Nitrogen: 1DE10
  - one blind flange
  - one cap with center hole ( $\varnothing$  7.8 mm)
  - suppress Nb-Carbides at lower temperature
  - better pressure @  $T_{\max}$
- > refurbishment plan (3<sup>rd</sup> quarter 2020)
  - new oil-free pre-pumps
  - oil-sealed pumps then only as pre-pump for TMP
  - upgrade of controls



# open bake yields strong degradation

## 1DE9 DESY furnace results

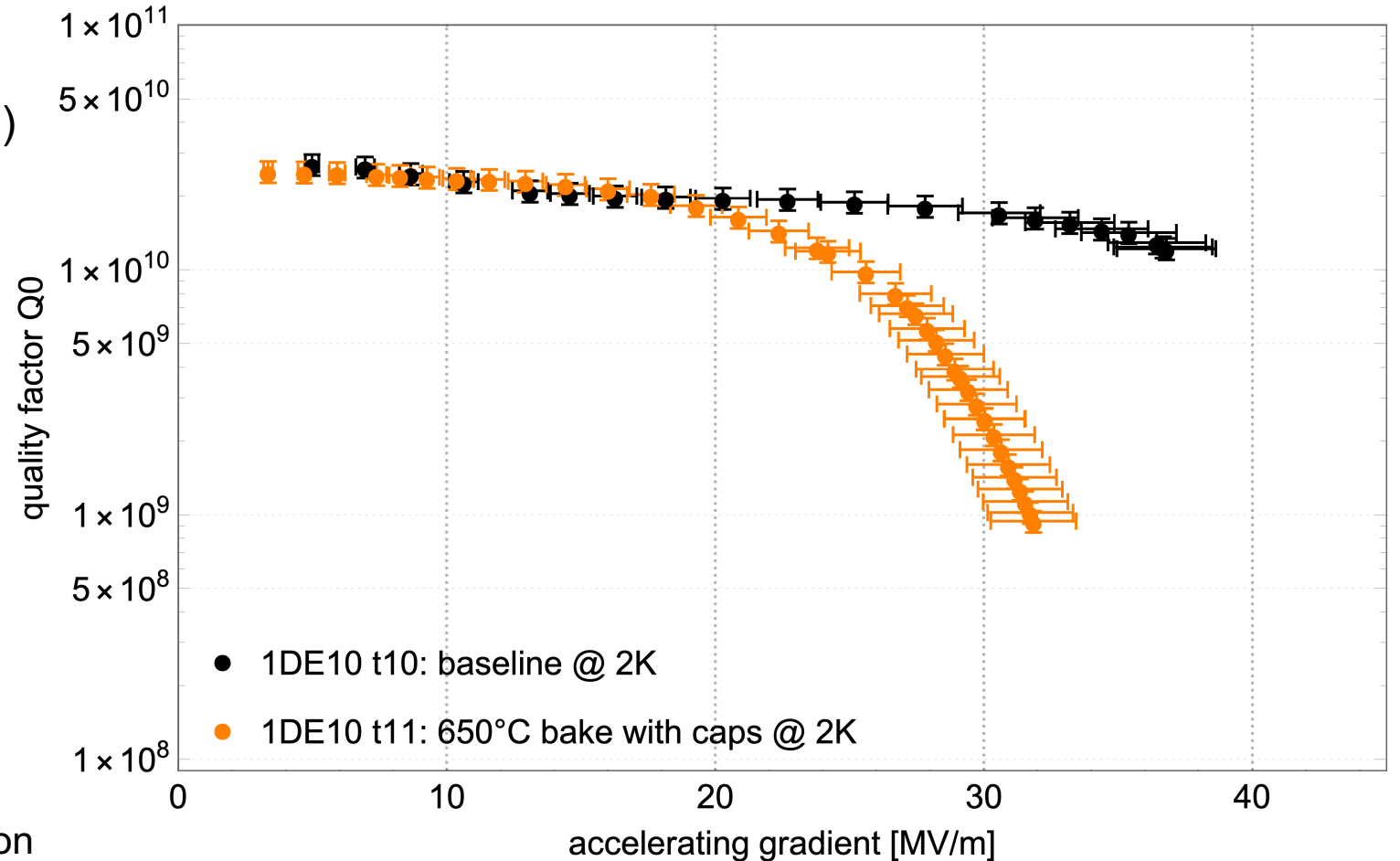
- > 1DE9: Heraeus FG material
- > last chemistry: 40  $\mu\text{m}$  EP (14V / 13°C)
- > DESY low T bake (black baseline)
- > 800°C heat treatment
  - no pre-heating @ 300°C
  - 3h@800°C
  - $1.1 \times 10^{-5}$  mbar @  $T_{\text{max}}$
  - **open** cavity
- > complete **degradation** of cavity
  - very low  $Q_0$
  - EP for reset necessary



# caps and / or lower temperatures help

## 1DE10 DESY furnace results

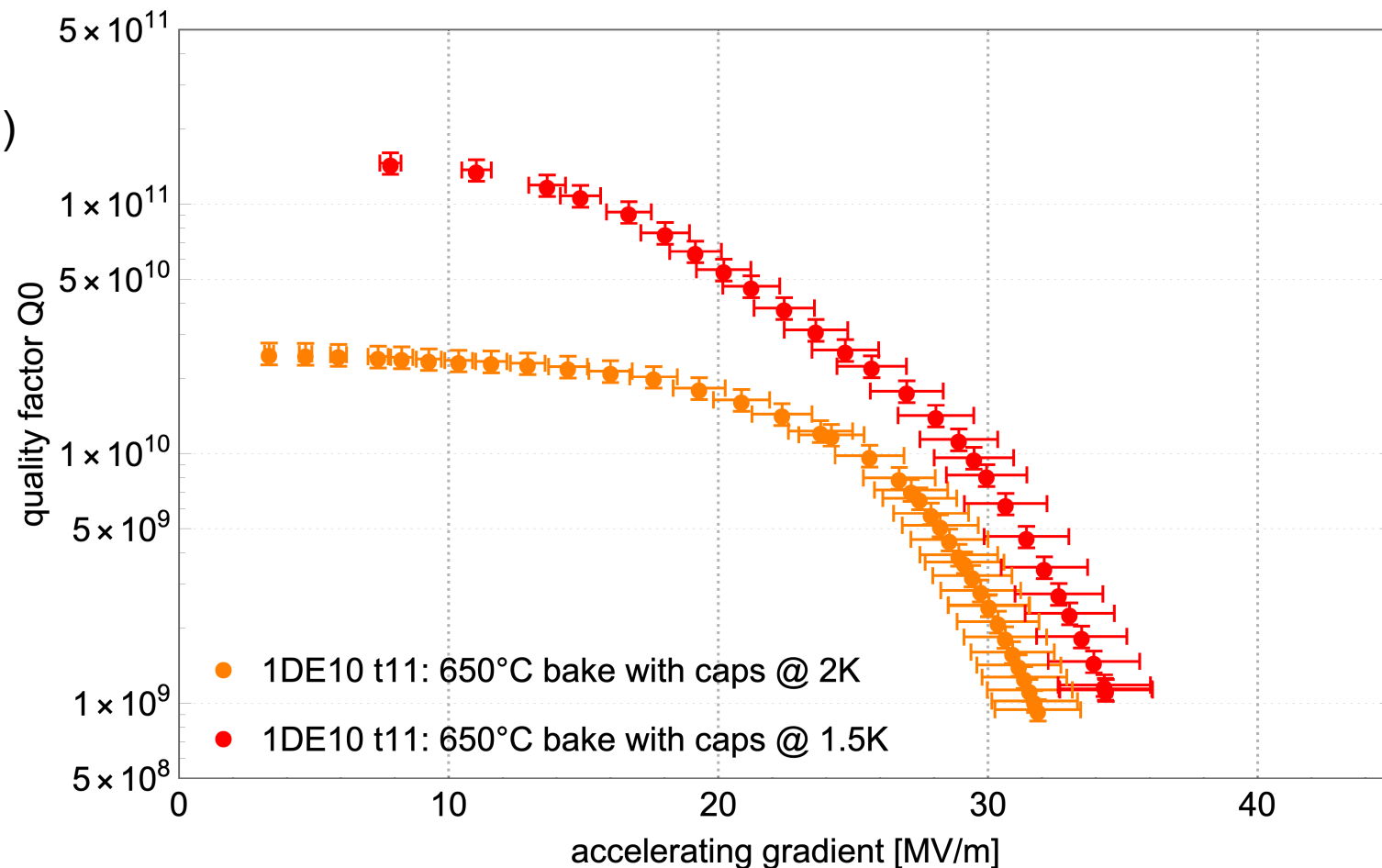
- > 1DE10: Heraeus FG material
- > last chemistry: 40  $\mu\text{m}$  EP (14V / 13°C)
- > 650°C heat treatment
  - 72h@300°C + 6h@650°C
  - $2.1 \times 10^{-6}$  mbar @  $T_{\text{max}}$
  - **cap** with small hole
- > **strong HFQS**
  - starting @ 20 MV/m
  - DESY low T bake in preparation
- > cap cutout reviewed by SEM
  - strong pollution due to manual extraction
  - few star-shaped Carbides on inner and outer surface



# caps and / or lower temperatures help

## 1DE10 DESY furnace results

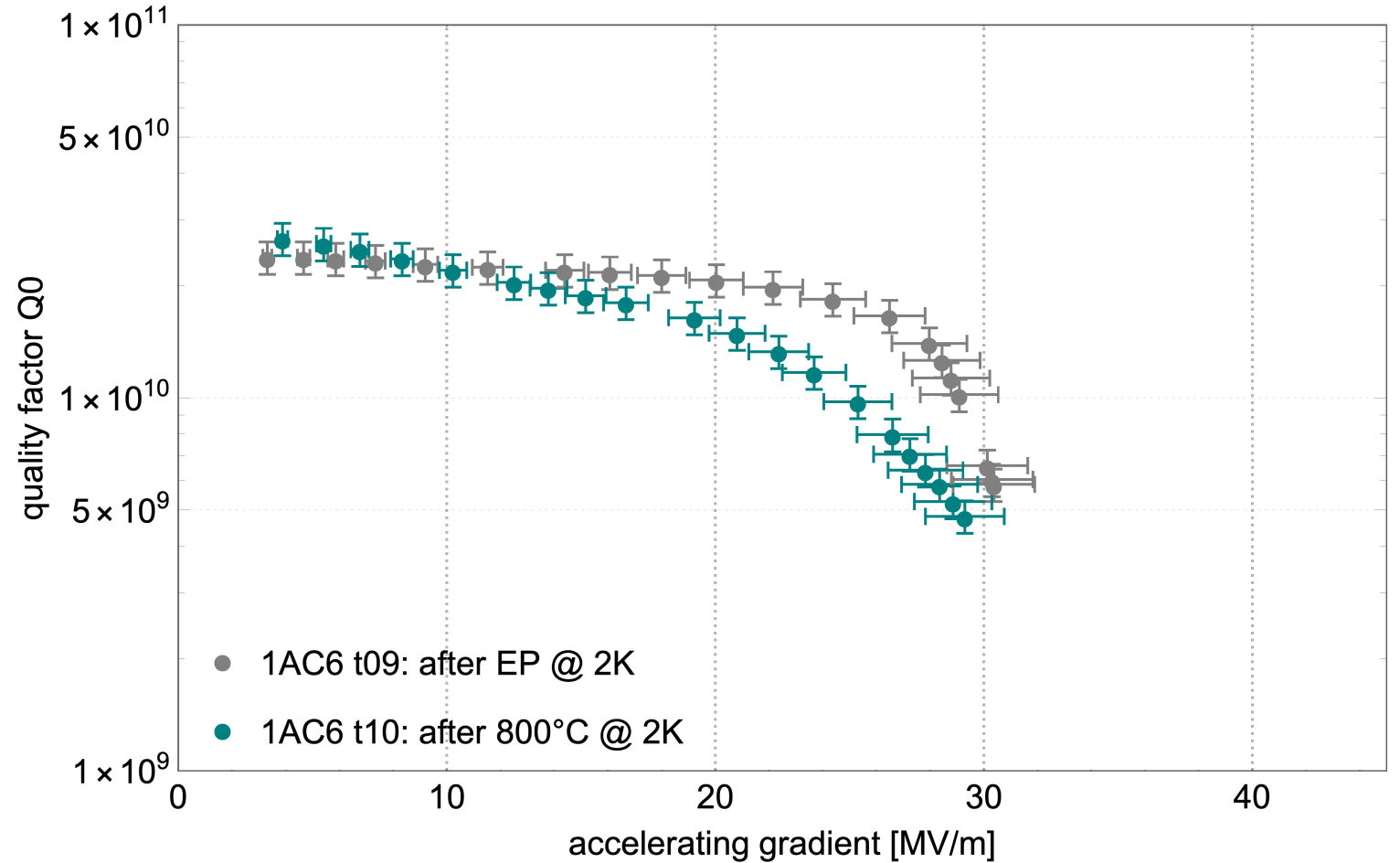
- > 1DE10: Heraeus FG material
- > last chemistry: 40  $\mu\text{m}$  EP (14V / 13°C)
- > 650°C heat treatment
  - 72h@300°C + 6h@650°C
  - $1.1 \times 10^{-5}$  mbar @  $T_{\text{max}}$
  - **cap** with small hole
- > **strong HFQS**
  - starting @ 20 MV/m
  - DESY low T bake in preparation
- > 1.5 K curve: additional unclear **loss mechanism** ~ 15 MV/m



# Zanon furnace qualified

## 1AC6 Zanon furnace results

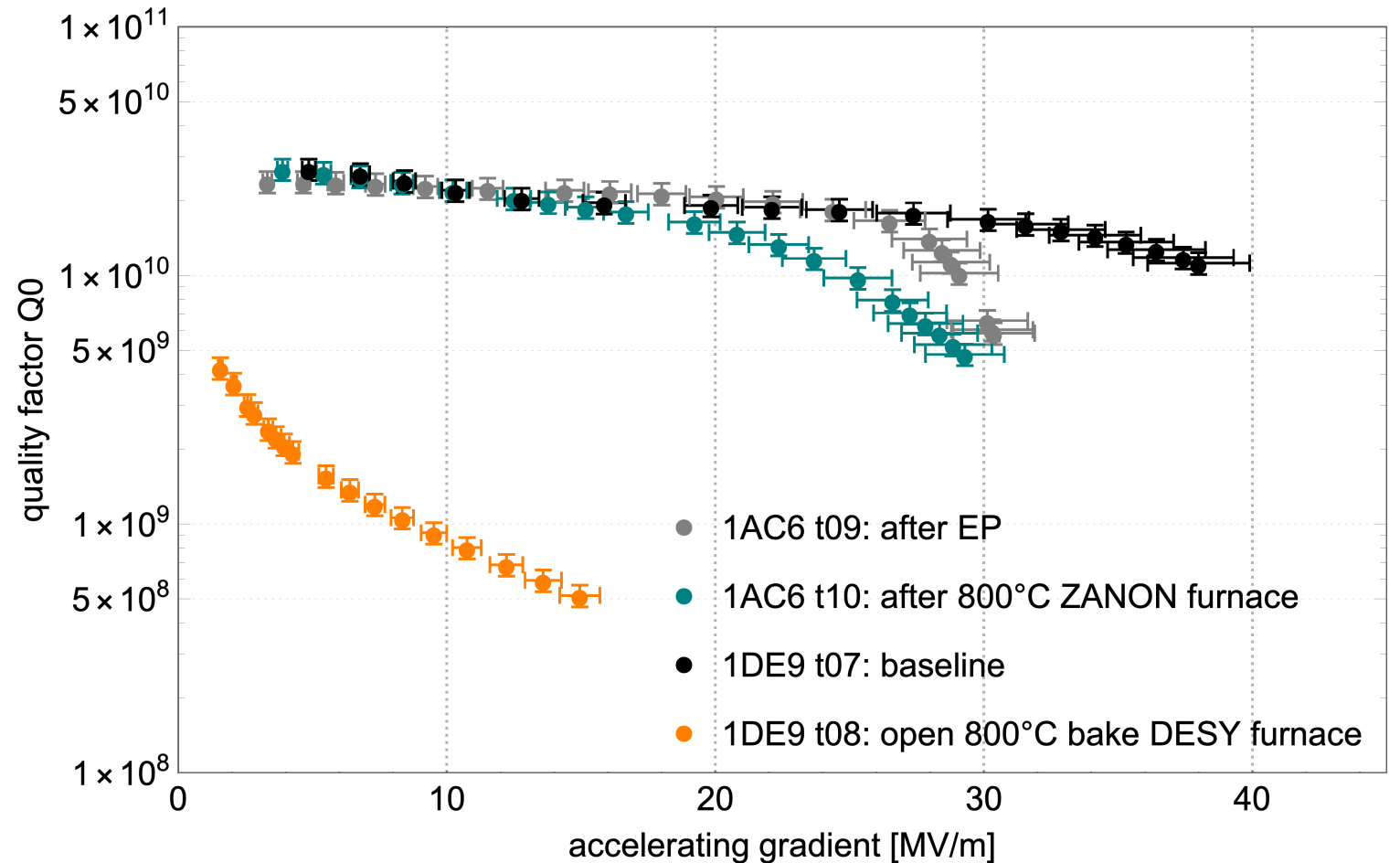
- > 1AC6: CBMM single crystal material
- > 20  $\mu\text{m}$  EP @ Zanon (14 V / 14°C)
- > 800°C heat treatment
  - 1h@600°C
  - 2h@800°C
  - $3.1 \times 10^{-6}$  mbar @  $T_{\text{max}}$
  - open cavity
- > vertical test
  - radiation onset ~ 22 MV/m
- > next: HPR and DESY low T bake



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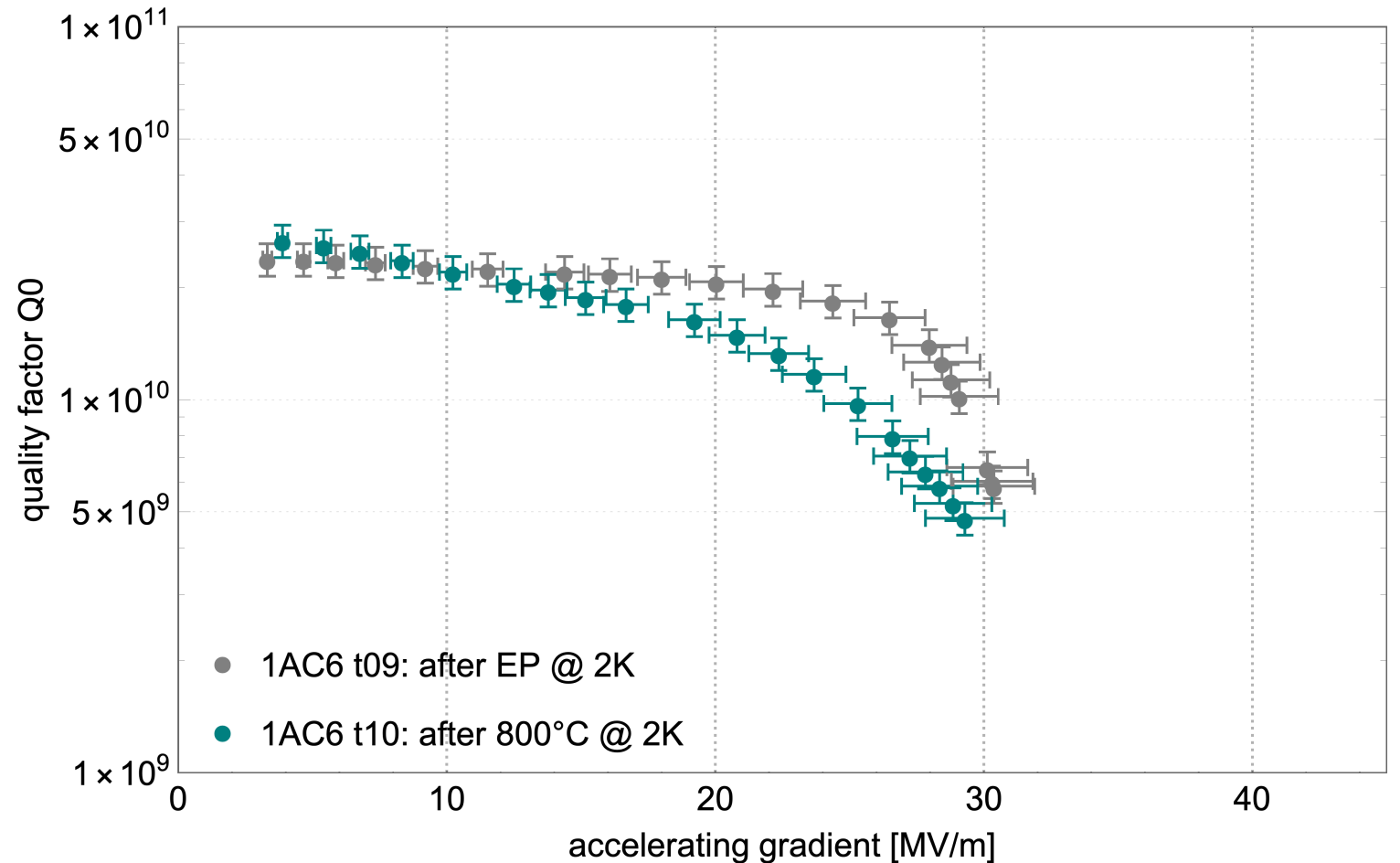
- > 1AC6: CBMM single crystal material
- > 20  $\mu\text{m}$  EP @ Zanon (14 V / 14°C)
- > 800°C heat treatment
  - 1h@600°C
  - 2h@800°C
  - $3.1 \times 10^{-6}$  mbar @  $T_{\text{max}}$
  - open cavity
- > comparison to DESY furnace
  - much **better performance**



# Zanon furnace qualified

## 1AC6 Zanon furnace results

- > 1AC6: CBMM single crystal material
- > 20  $\mu\text{m}$  EP @ Zanon (14 V / 14°C)
- > 800°C heat treatment
  - 1h@600°C
  - 2h@800°C
  - $3.1 \times 10^{-6}$  mbar @  $T_{\text{max}}$
  - open cavity
- > 1DE19: Ningxia FG material
  - 140  $\mu\text{m}$  EP @ Zanon (14 V / 14°C)
  - first test ever performed @ DESY
  - heat treatment done  $\rightarrow$  VT @ DESY



# lessons learned...

## ...about successful recipes and a problematic furnace

- > DESY low T bake
  - **no** significant stable **gain in  $E_{acc}$  and  $Q_0$**  observed
  - (slight) enhancement of performance
    - once gradient, once  $Q_0$ , twice unchanged
  - **removes HFQS** if existent
  - still **more statistics** to be collected
    - 4 cavities treated & waiting for test



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### > open bake in Argon

- treatment does no harm
- **bake cabinet applicable**
- more studies will follow

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### > Zanon furnace

- better than large DESY furnace
- **qualified** for further cavity treatments
- one cavity to be tested

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### > DESY furnace

- **open bake** does **spoil** cavities
- infusion experiments stopped
  - additional test @ 650°C with open cavity
- **furnace refurbishment** in preparation