

# High gradient multi-cell R&D in 2003/2004

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MPY

21.1.2004

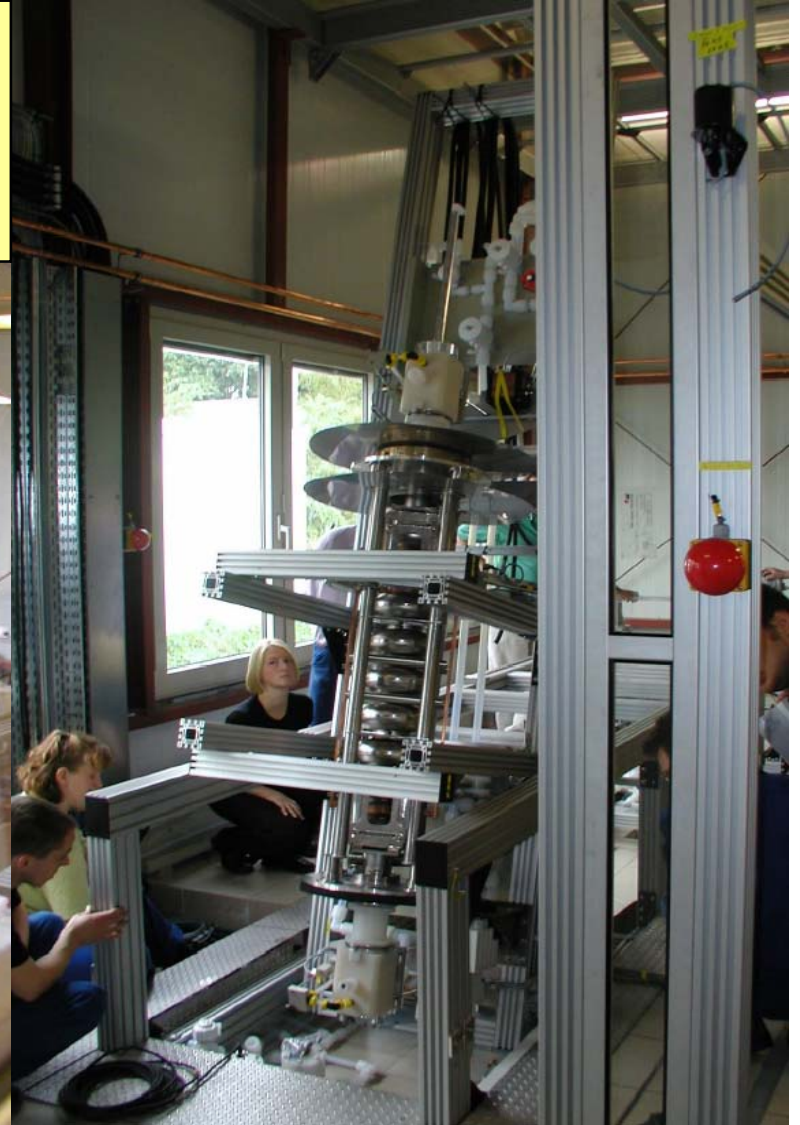
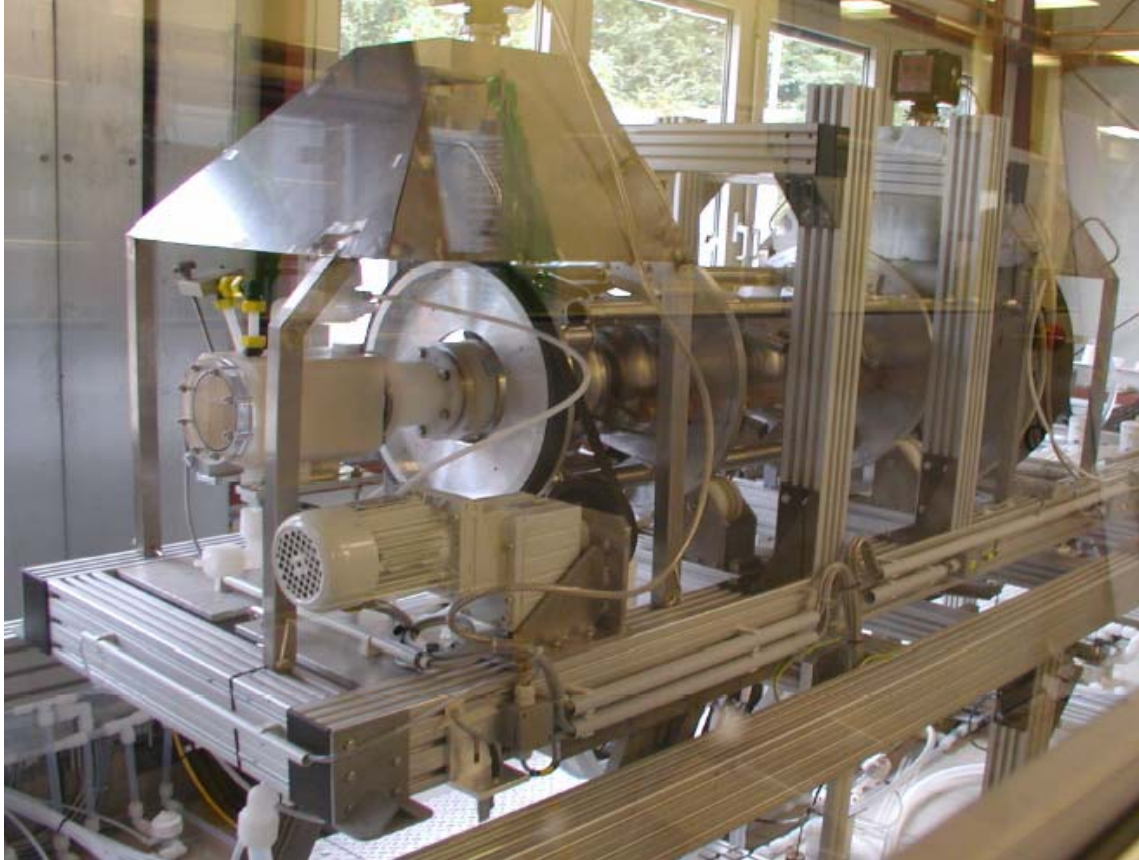
- EP setup at DESY commissioned
- First DESY EP cavity: 39 MV/m at 2K
- Overview on EP statistics
- 2 cavities with KEK EP at 35 MV/m in high power test (AC72,AC73)
- Proposal for future work
  - EP
  - CHECHIA tests

# 35 MV/m for 800 GeV c.m.

## Electrolytic Polishing at DESY

Infrastructure for 9-cell cavities was commissioned with single cell cavities.

9-cell cavities will follow soon.

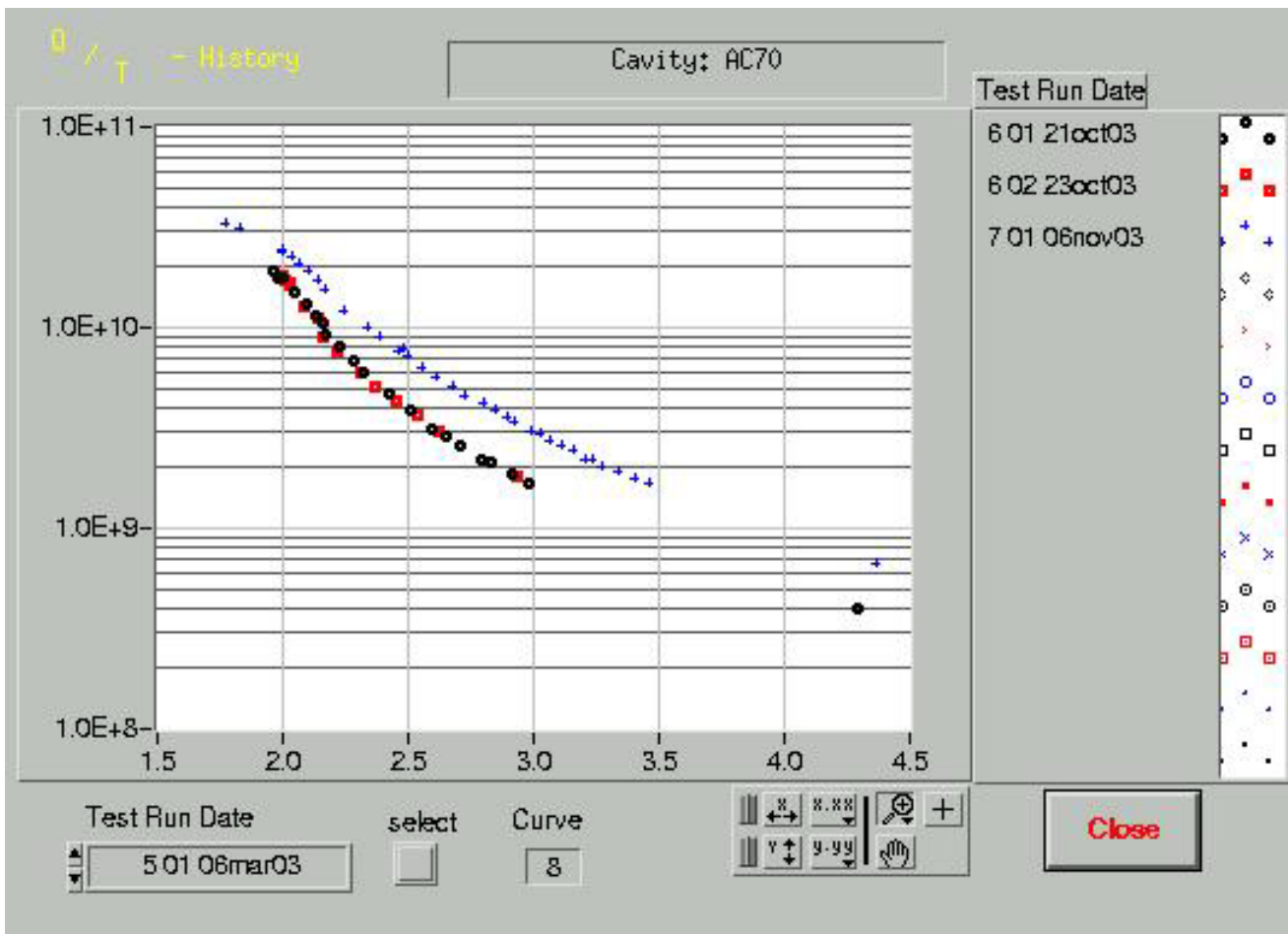


# Recent test DESY EP cavity

- EP system is working
- Fine-tuning has started
- First two cavity tests were only partially successful
  - **defect** not fully removed (AC78)
  - **Q-disease** due to unclear history (P-1)

# History on AC70

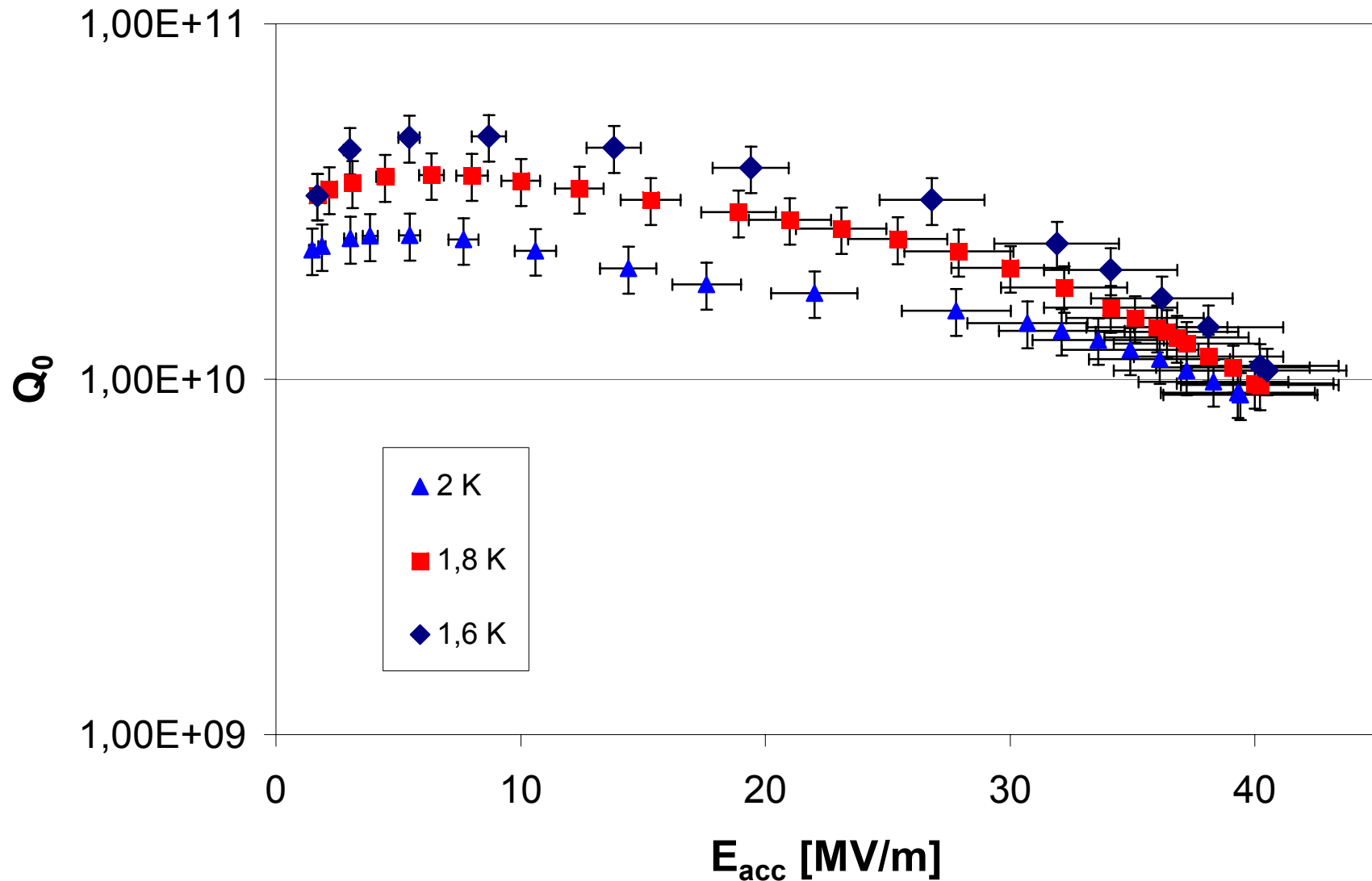
- Only 800°C firing
- EP at KEK/Nomura (100+50um): **Strong field emission (FE)**
- BCP (8+10um) to try to remove FE: not successful
- EP@DESY (~40um) : **30 MV/m with Q-slope**
- Baking



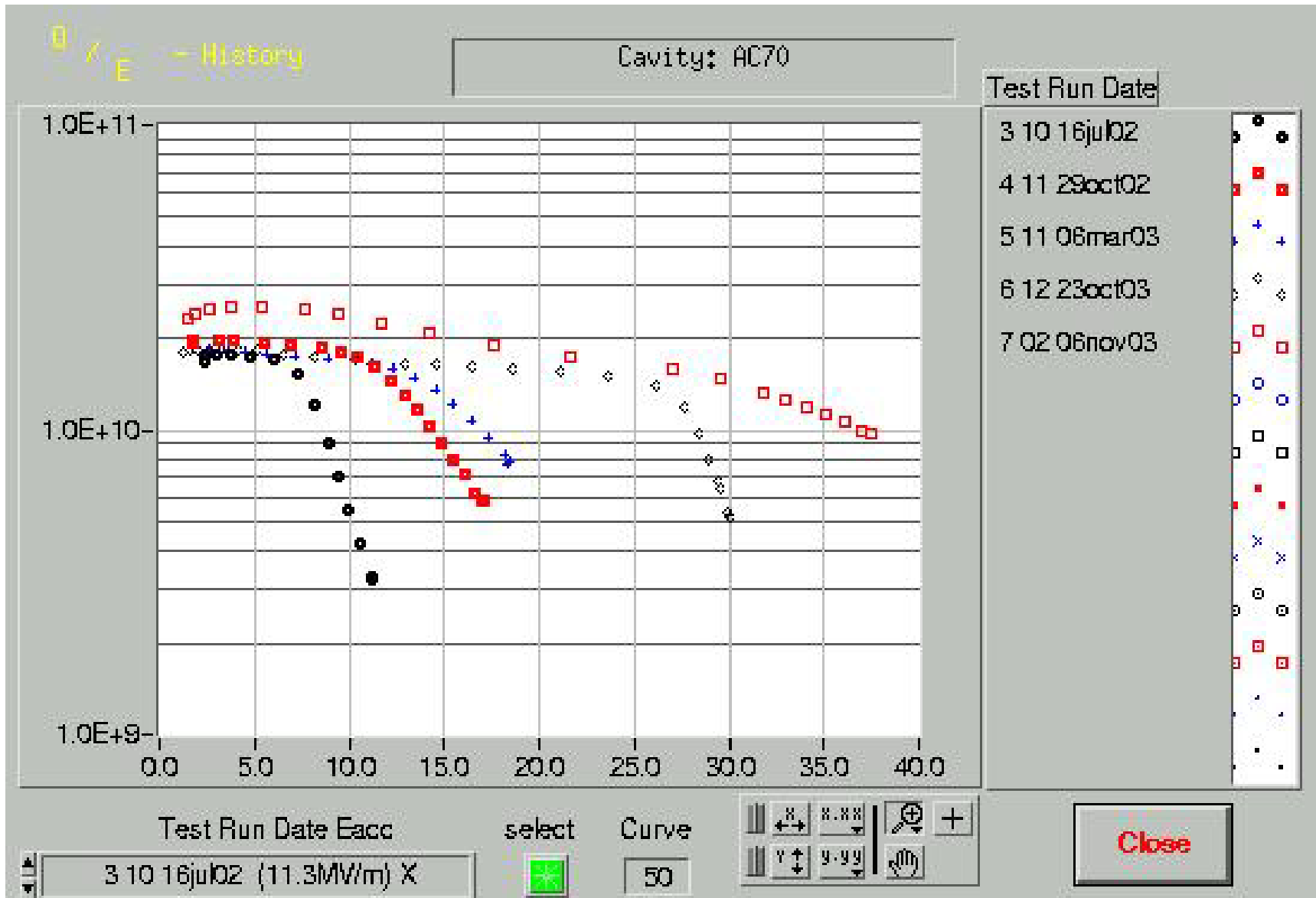
Q vs T

- Typical behaviour after 124°C bake

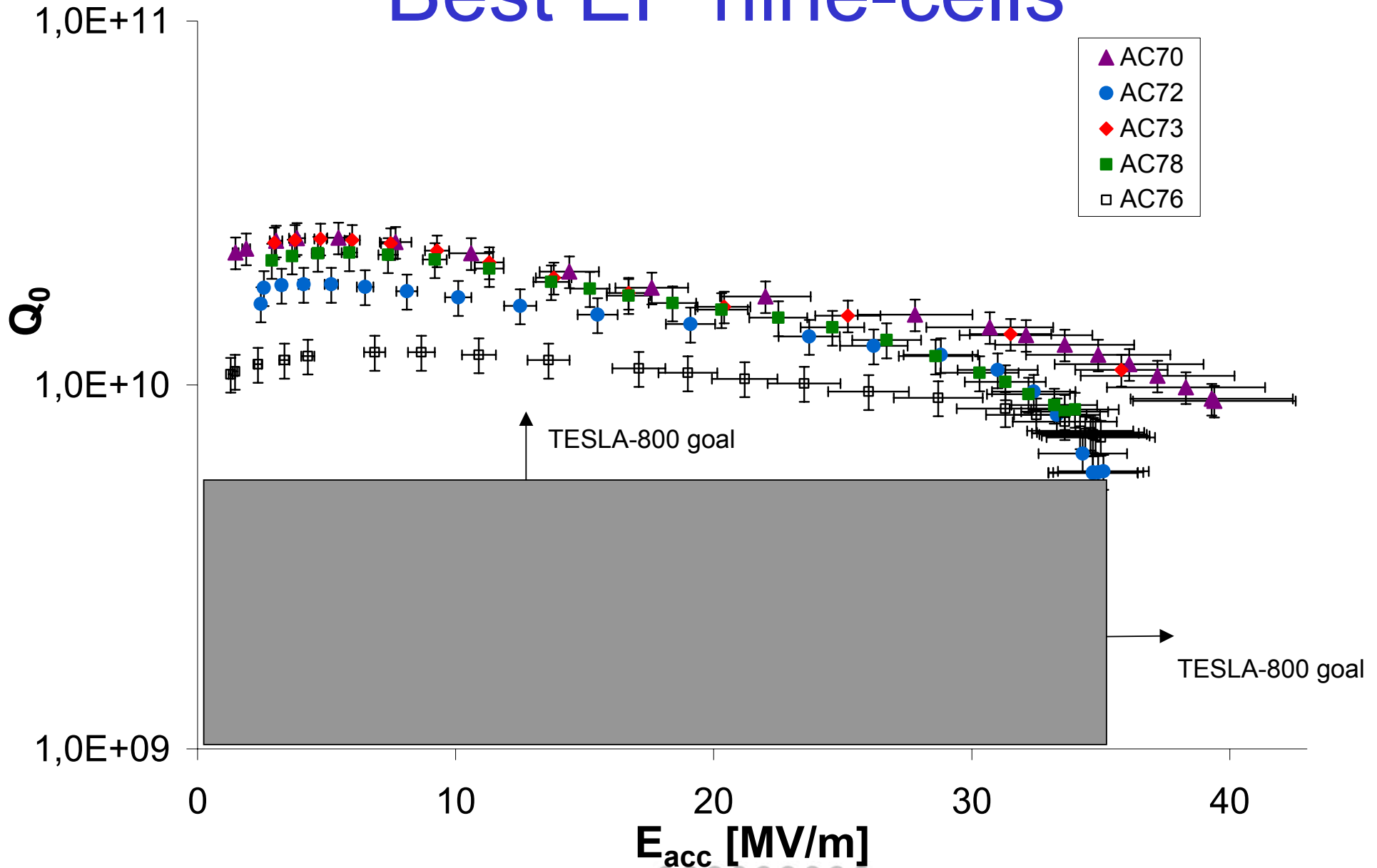
# AC70: EP at DESY



# AC70: History

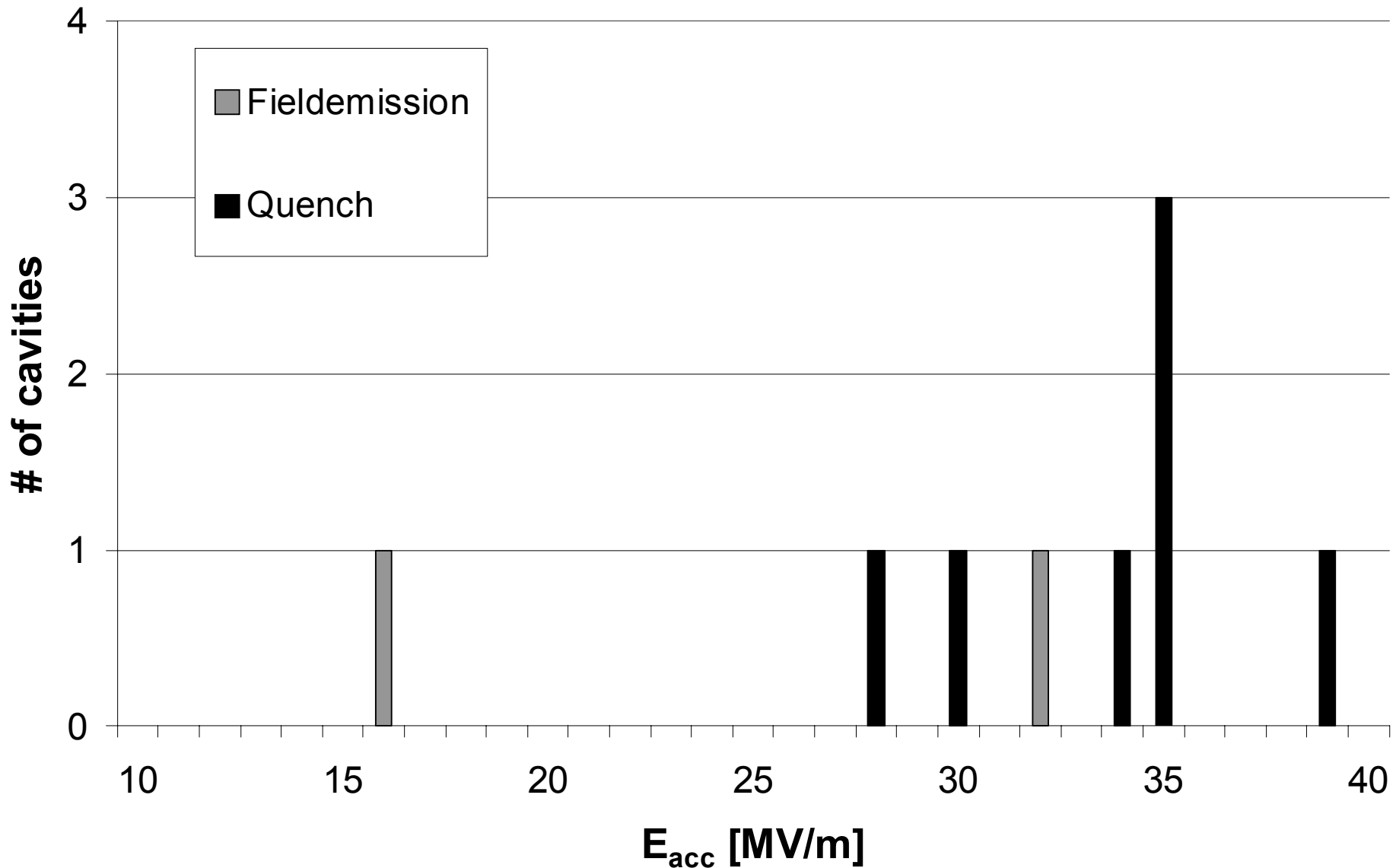


# Best EP nine-cells

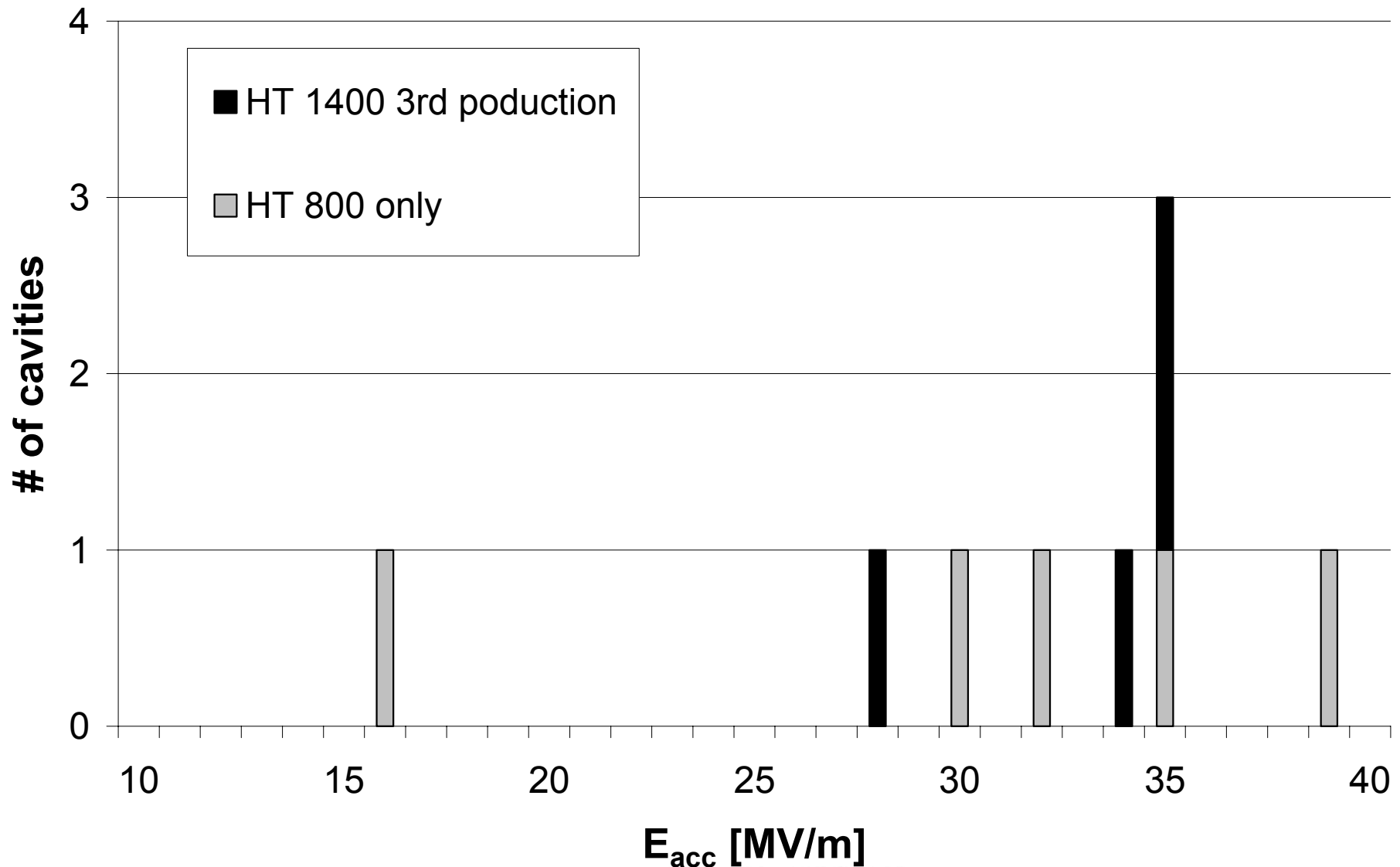




# Limitation of EP nine-cells



# Comparison of heat treatments in EP cavities



# EP and heat treatments

| Batch of cavities                             | 800°C          | 1400°C         |
|-----------------------------------------------|----------------|----------------|
| single-cells                                  | $35.4 \pm 5.3$ | $34.7 \pm 2.5$ |
| nine-cells                                    | $34.0 \pm 3.9$ | $33.0 \pm 3.3$ |
| single cell analysis of<br>nine-cell cavities | $35.6 \pm 2.8$ | $35.6 \pm 1.7$ |

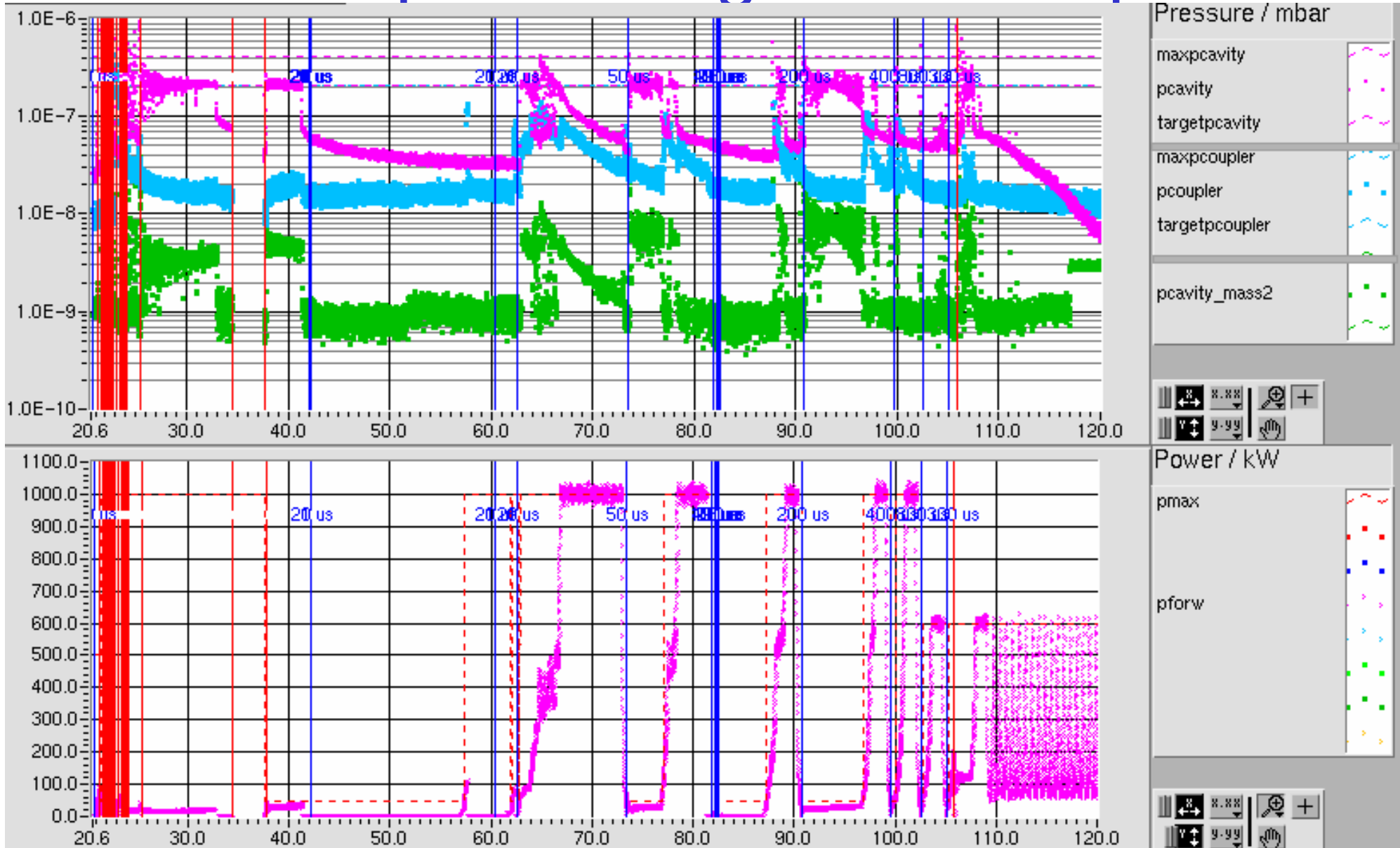
# High-power Test of Cavities AC72 and AC73 in CHECHIA (Horizontal cryostat)



# Coupler processing in High Power tests

- Coupler and cavity processing went smoothly
  - RF on time for full warm conditioning <90 hours
  - coupler heating to 150°C
  - full warm and cold processing

# Warm processing of the coupler

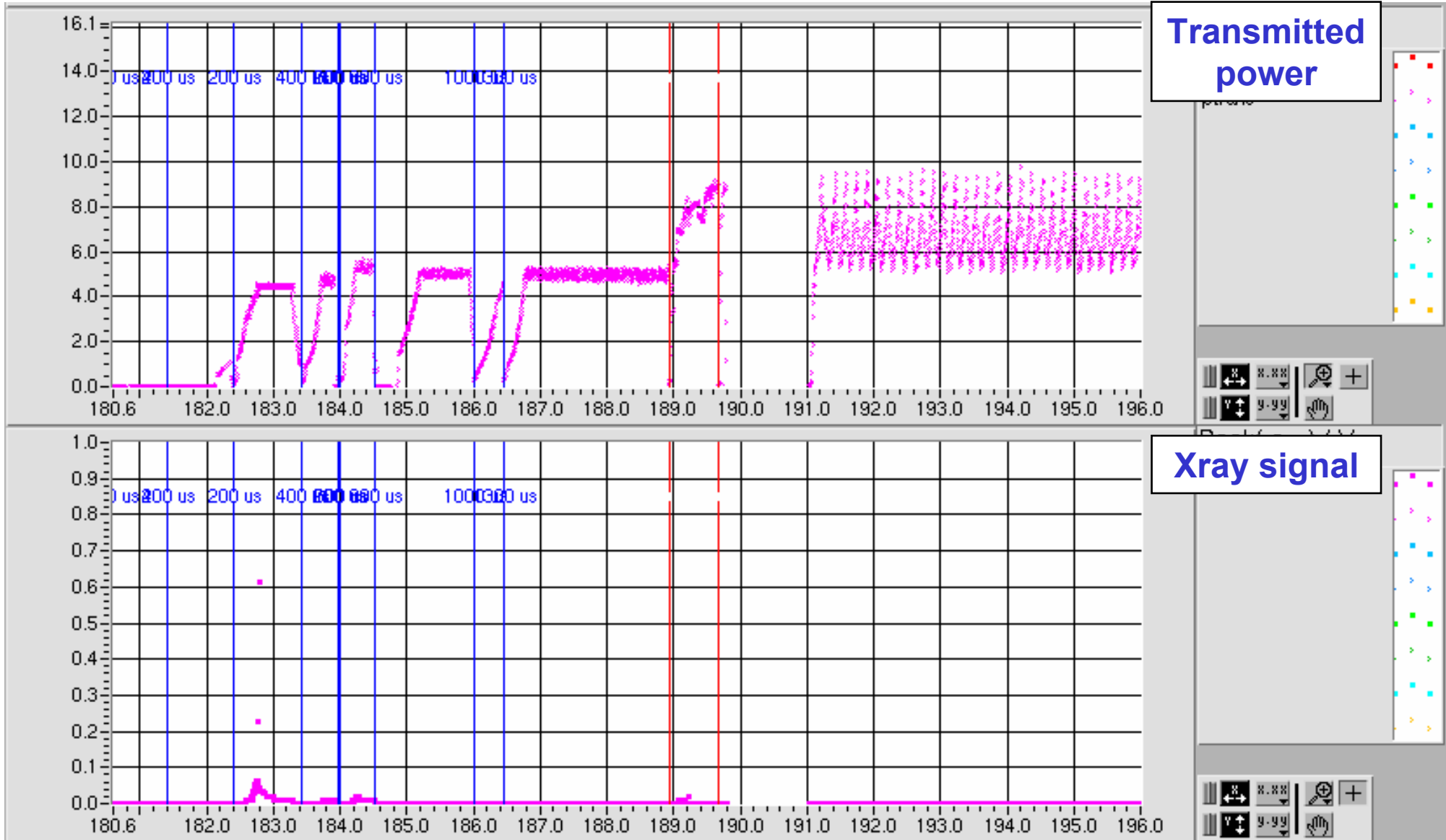




# Multipacting

- Cavity AC72 has shown **multipacting similar to AC73**
- resonant electron emission results in an avalanche
- Xray emission at power levels corresponding to 20 MV/m disappeared after processing for a few hours (see below)
- **barrier is soft:**
  - when the cavity is kept below 100 K no new processing necessary
  - after warmup very short processing is needed (some minutes)

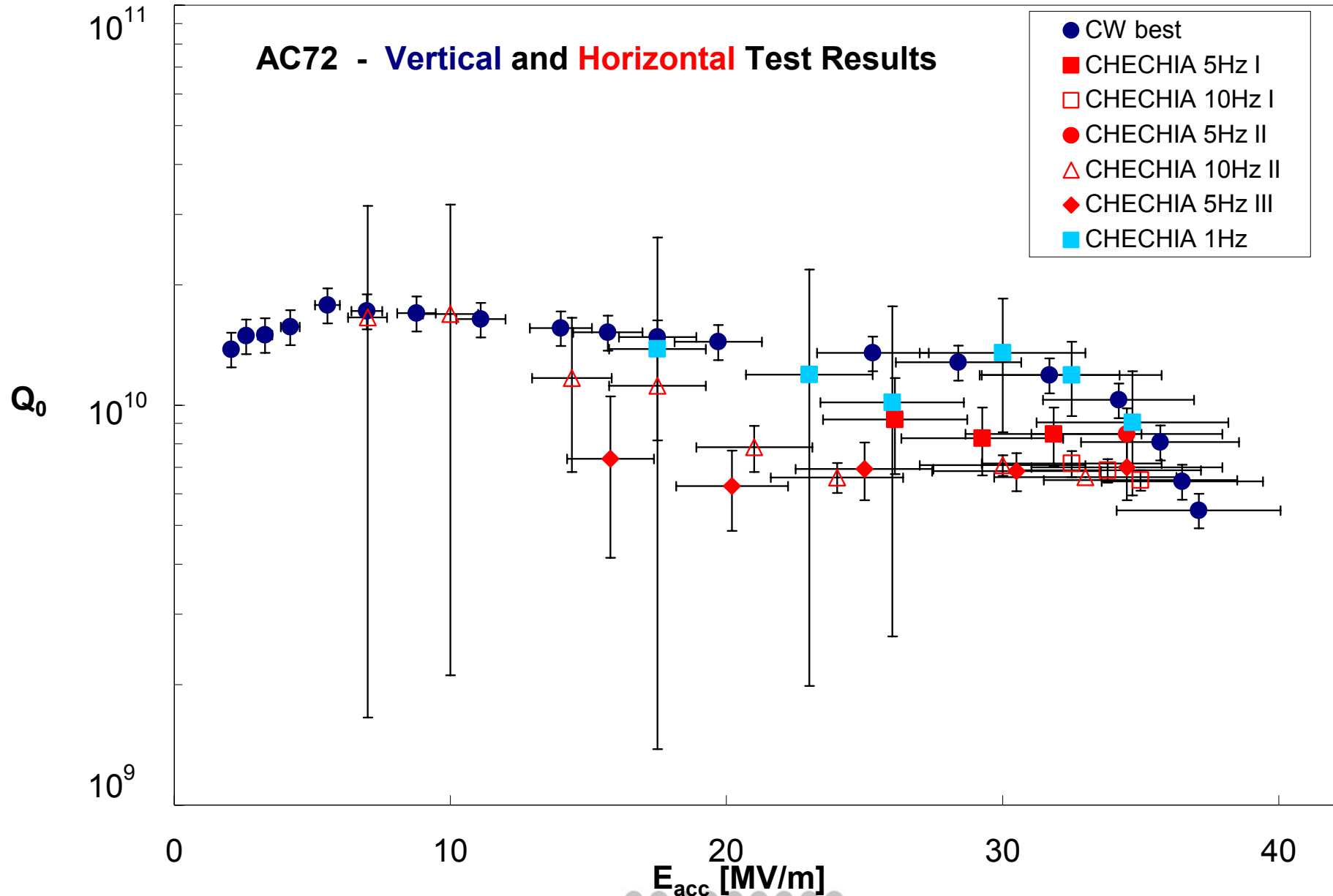
# Multipacting also in AC72?







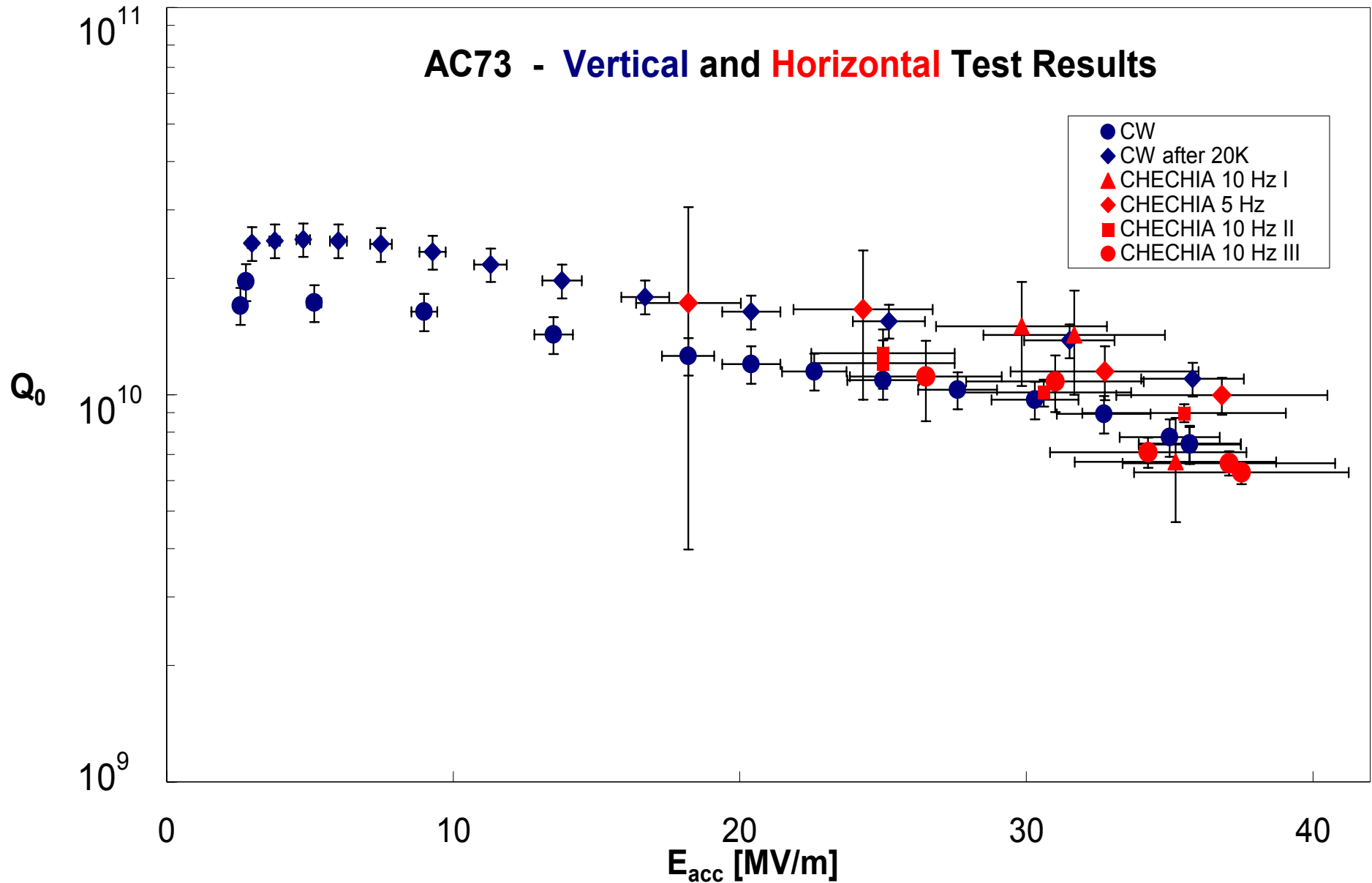
# High Power Test of AC72



# Cavity AC72 performance measurements

- 35 MV/m at  $\sim 6,5 \cdot 10^9$  (10 Hz)
- 34,7 MV/m at  $\sim 9 \cdot 10^9$  (1 Hz)
- Problems with HOM #2
  - no Piezo compensation
  - no LLRF feedback, but
    - much lower noise on LLRF signals (as compared with AC73 test)
    - LLRF for lower gradient o.k (adaptive feedforward)

# High Power Test of AC73

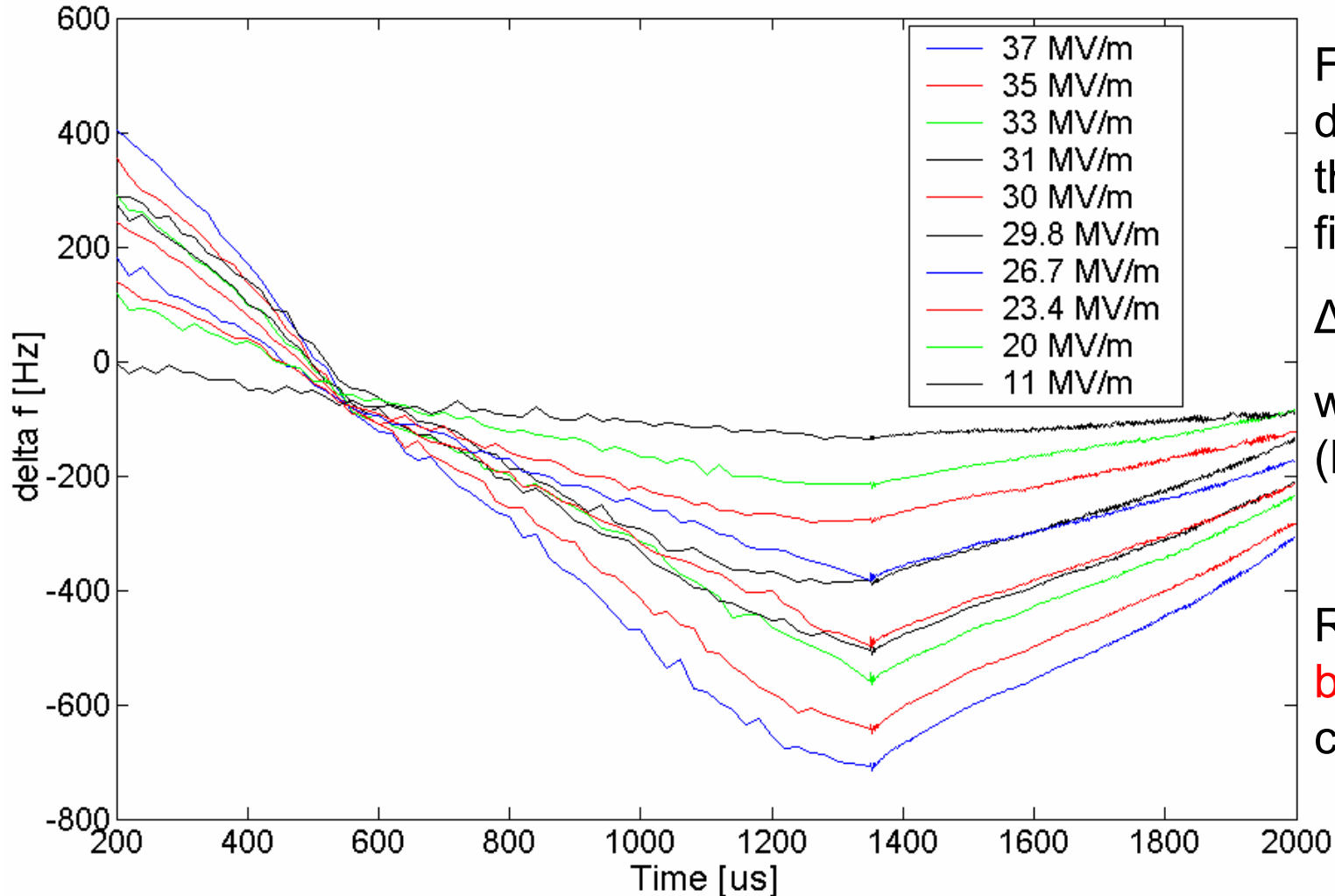


# Some statistics on the test

- Test running 7.3.2003 – 14.8.2003
  - test took about 160 days (exact 3848 hours)
  - Scheduled cryo shutdown about 600 hours
  - warm-ups: 2x300 K, 4-5 times around 100 K
- Processing took about 165 hours
  - coupler 130 hours
  - cavity 35 hours
- RF operation of the coupler
  - cavity off-resonance and not at 2 K
  - power between 150 – 600 kW
  - 5 Hz operation very smooth
  - 10 Hz causes heating of the warm ceramics
  - **Total time RF on ~ 2400 hours**
- RF operation of the cavity
  - **1100 hours at around 35 +/-1 MV/m**
    - ~110 hours without interruption
    - 57 hours at 36 MV/m +
  - most of this is feed-forward operation
- Piezo compensation
  - **about 700 hours**

# Frequency detuning during RF pulse

← Beam on →



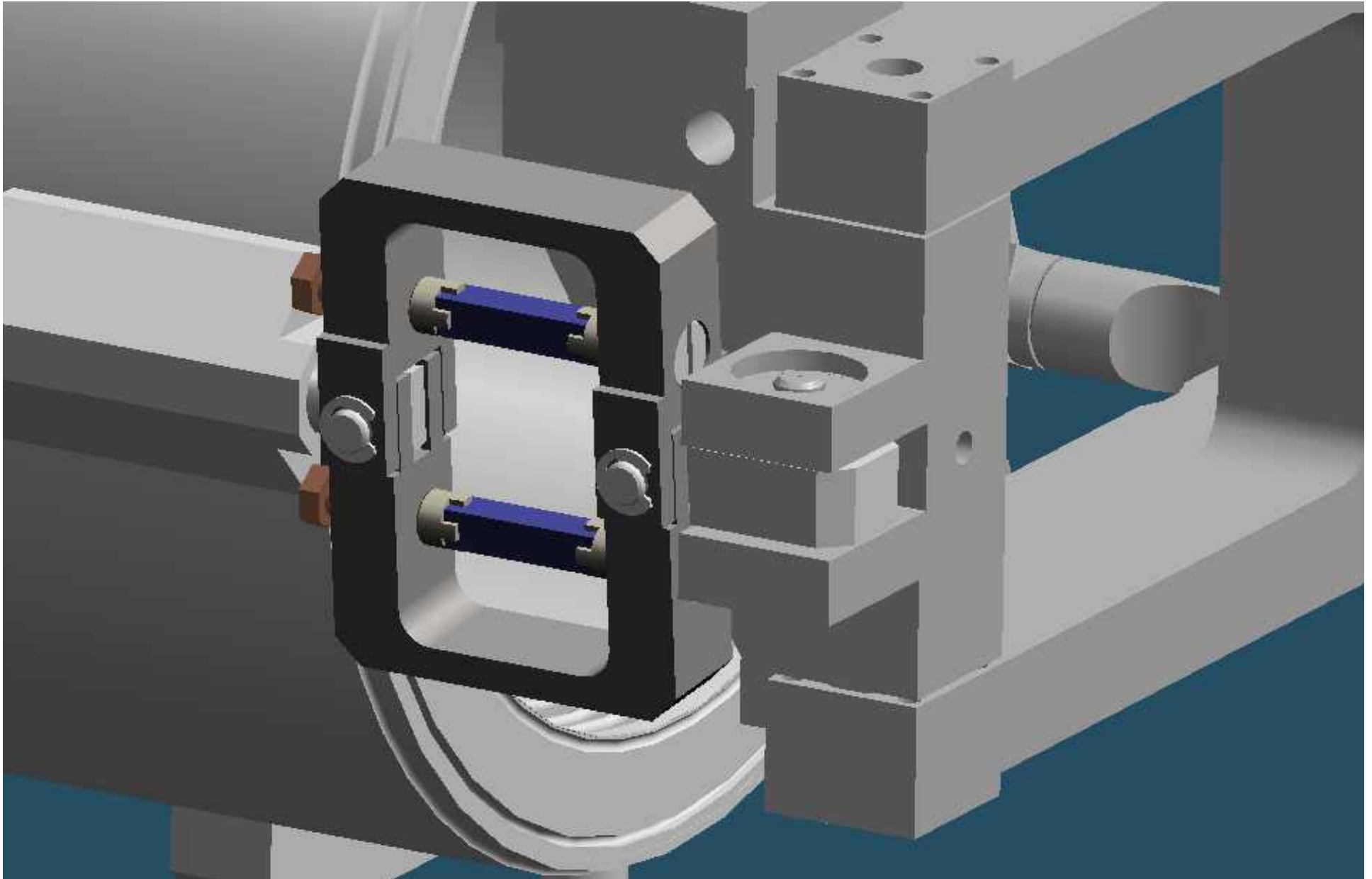
Frequency detuning due Lorentz forces of the electromagnetic field in the cavities:

$$\Delta f = K \cdot E_{\text{acc}}^2$$

where  $K \approx 1 \text{ Hz} / (\text{MV/m})^2$

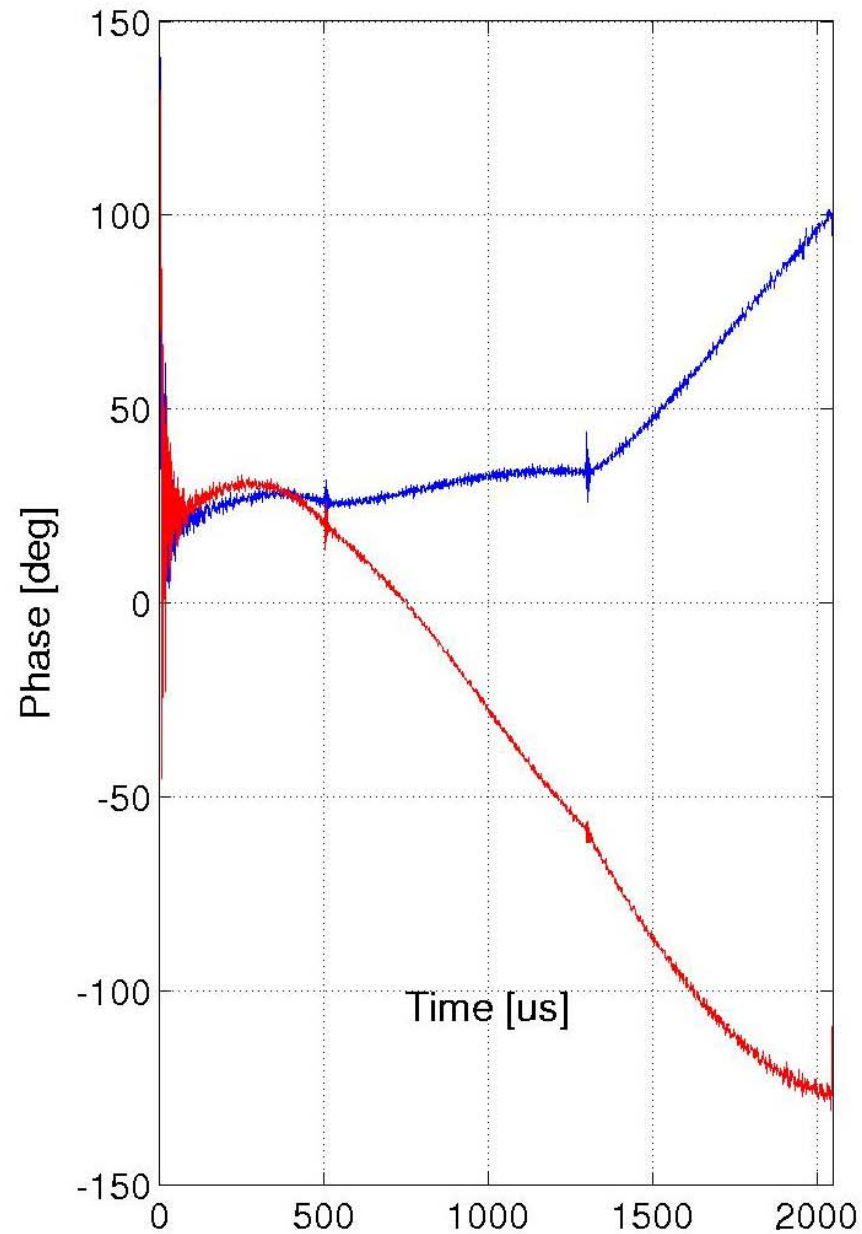
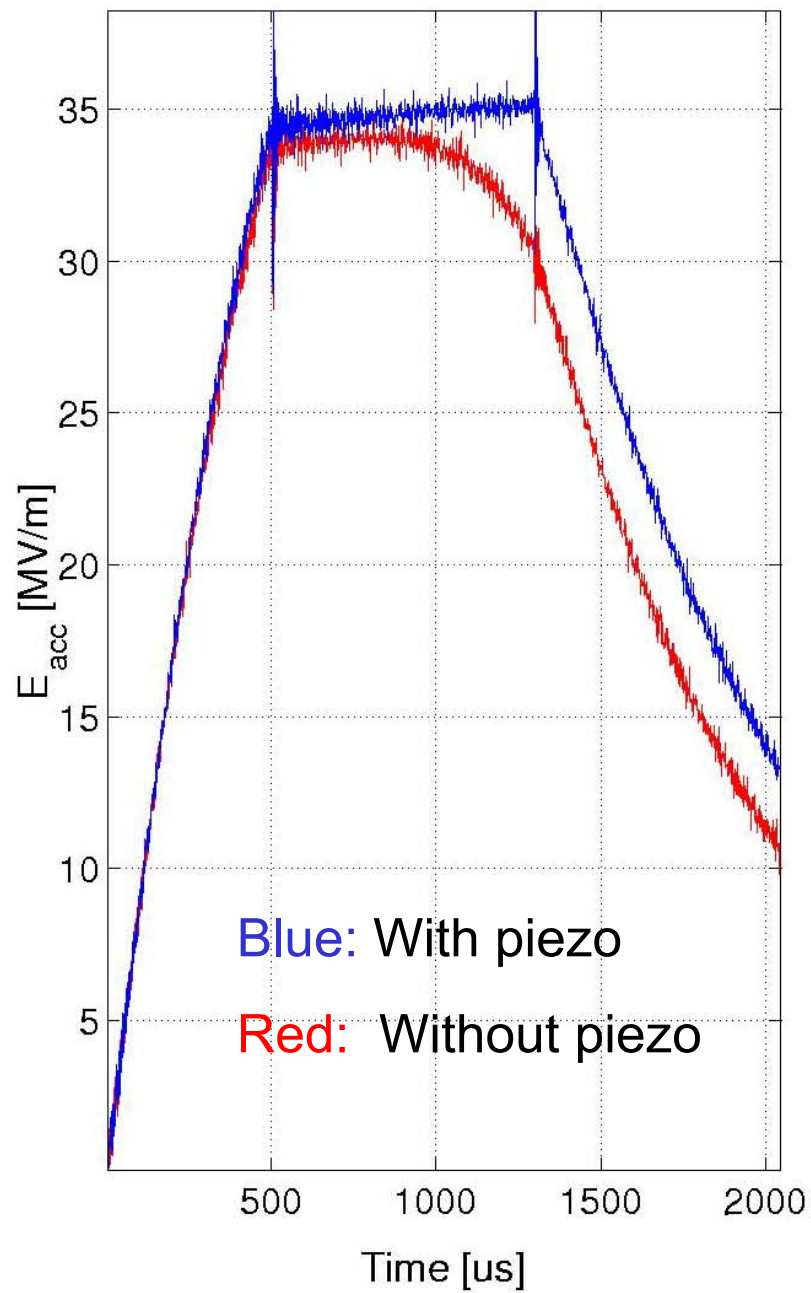
Remember: **Cavity bandwidth** with main coupler is  **$\approx 300 \text{ Hz}$**

# Drawing of current setup (H.-B. Peters)





# RF signals at 35 MV/m



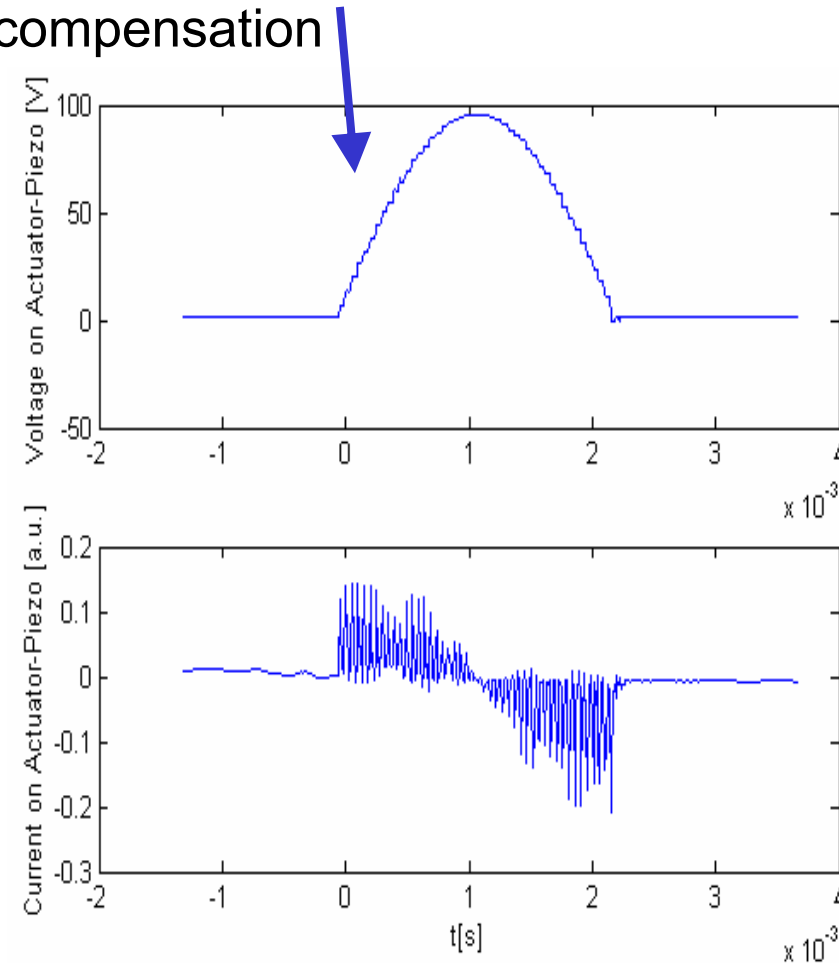
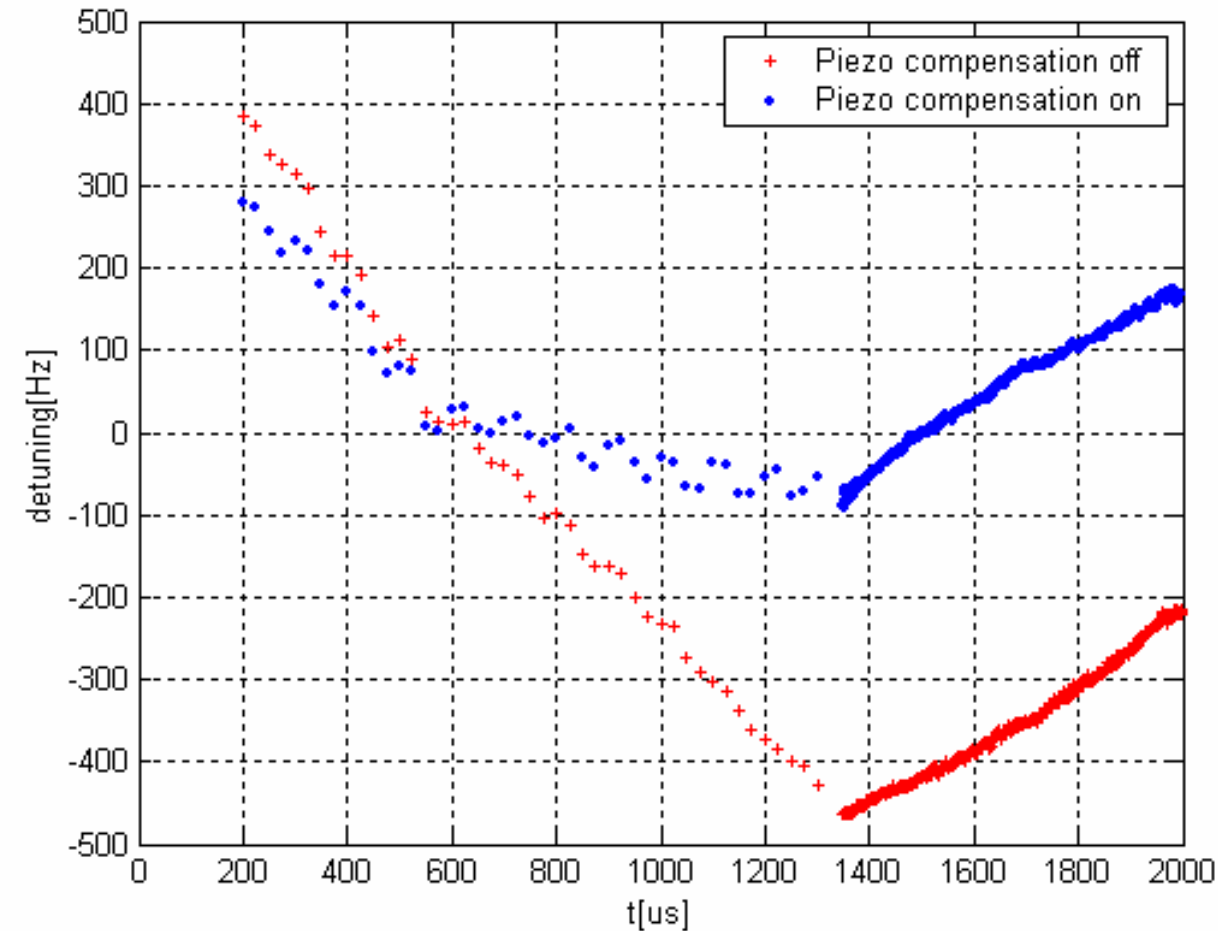


# Frequency stabilization during RF pulse using a piezoelectric tuner

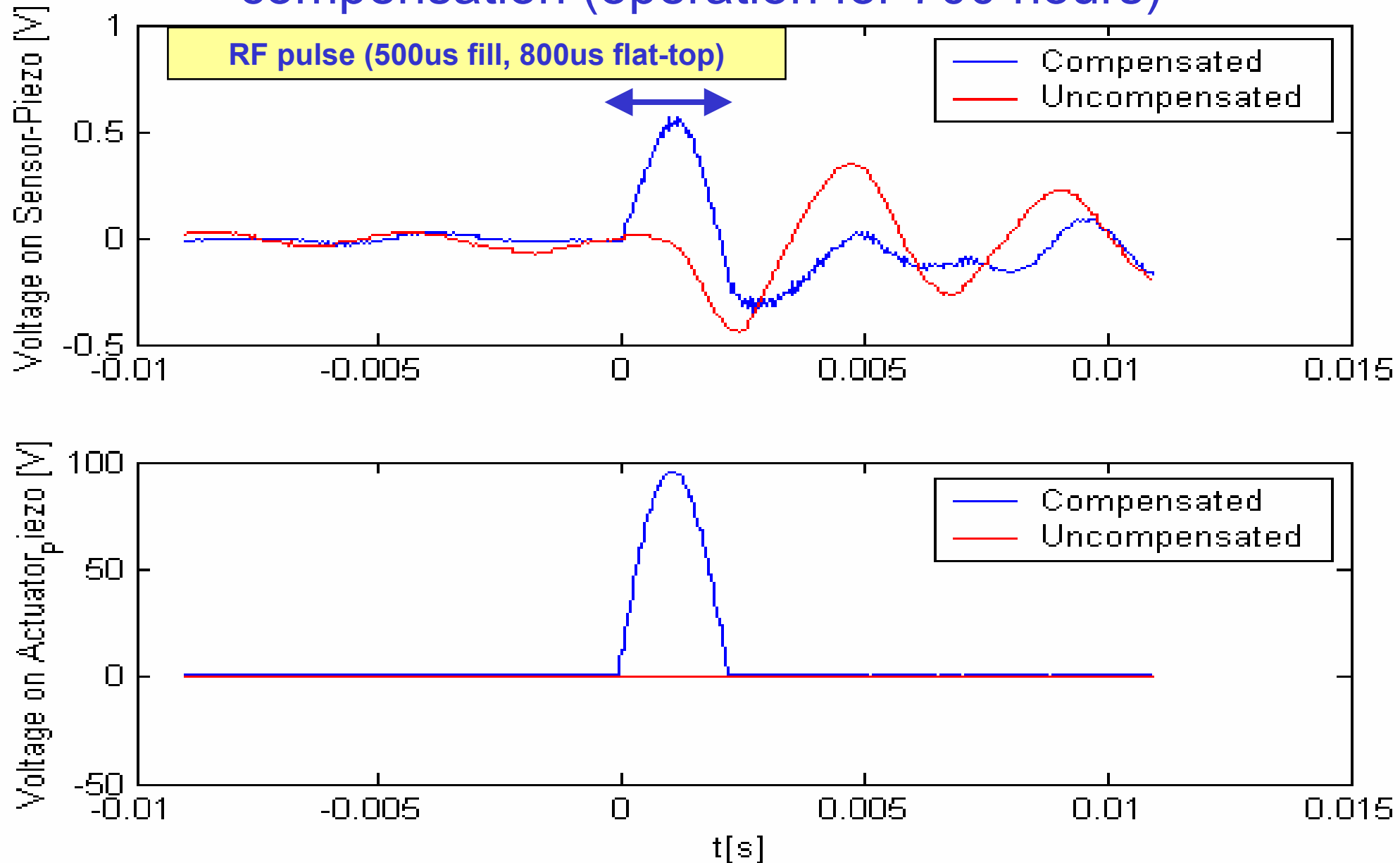
Blue: With piezo

Red: Without piezo

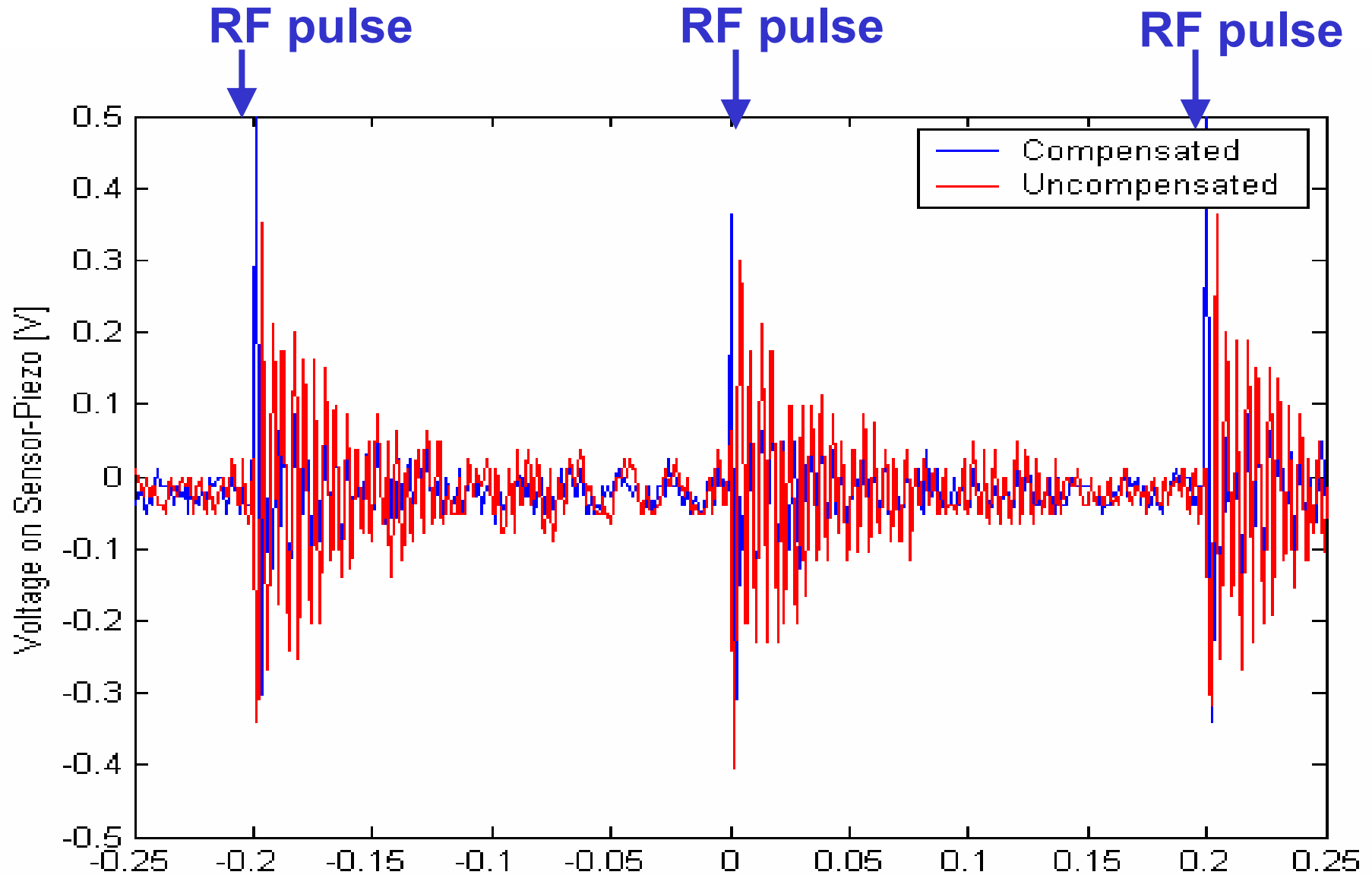
Frequency detuning of 500 Hz compensated voltage pulse (~100 V) on the piezo. No resonant compensation



# Piezo excitation of the cavity for frequency compensation (operation for 700 hours)



# Damping of the ringing between pulses (5Hz operation)



# Plans for 2004

- Cavities
  - Rework (Re-EP) the existing cavities from the AC series, then continue with ZANON production
    - Accumulate as much experience as possible with EP
    - First 10 ZANON cavities will not get 1400°C
    - Should be possible to get around 8 cavities for a module by september this year
    - Look at possible promising cavities from older productions: A16
  - Further CHECHIA tests
    - AC70,...
    - More experience on assembly of tank and high power coupler
    - Piezo tuner needs engineering design and tests
    - Try to get about 8 CHECHIA tests until the end of the year

# Plans for 2004

- Assembly of the Module of type II
  - Should aim at 35 MV/m
  - Can serve as a spare module
  - This could use AC73 as Cavity #1 (Fermilab option!?)
- Options for module type I spare
  - Rework old cavities from module 2
    - Need flange modification (Nb->NbTi)
    - Only etch is possible (nobody has tried EP on cavities with tank)
    - Block the infrastructure for a significant time (No EP, no preparation for CHEHCIA)
  - Continue EP on ZANON series
    - built new tanks of the old type
    - Needs check with schedule, available manpower
    - Requires money for tank preparation and welding

# Options for module tests

- Difficult to guess
- According to today's planning
  - LINAC
    - Installation not before 2005
    - Cooldown not before 2006
  - Module test stand
    - When money becomes available, ~1 1/2 year later first test

# Conclusion

- DESY EP cavity reaches 39 MV/m at 2K
- Not a big difference between 800°C and 1400°C firing
- Two electropolished nine-cell cavities have performed at very high gradients and sufficiently high Q fulfilling TESLA-800 specification in high power test
- Couplers performed very well, no problems
- The piezo proof-of-principle at 35 MV/m exists