Status of the Single Cell Cavity R&D at DESY

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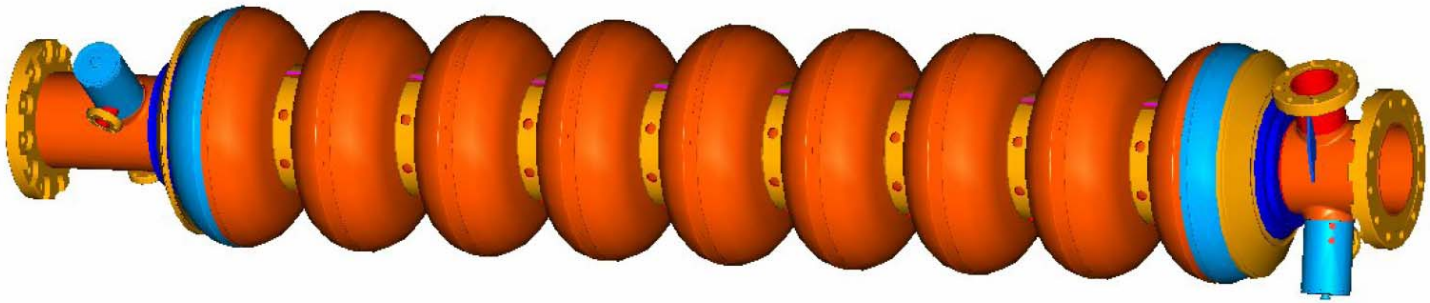
for the DESY team

Motivation

- XFEL will be based on today's nine-cell cavities
  (no super-structure, no major modifications of inter-cavity connection,.)



- Specification for cavity fabrication: **2007**

=> Qualification of modified fabrication parameters is urgent

=> Qualification of further/alternative Nb vendors

=> large-crystal Nb for series nine-cell production ?

Object of the program

- Qualification of further niobium vendors:
  - Heraeus stopped fabrication of Nb sheets; only ingots available
  => sheets by Plansee Co. need to be qualified urgently
  - check of chinese Ningxia niobium
  - check of Cabot niobium, but RRR spec not met
  - check of russian Giredmet niobium with high RRR + low tantalum
  => availability of large quantities??

- Large grain & single crystal niobium:
  - application of “large grain” (cm-size) niobium disks cut from ingot (instead of forged and rolled sheets with grain size of ~ 100µm)
  => ingots from Hereaus, Ningxia, CBMM

  - test of mono-crystal niobium (two cavities)

Object of the program (ctd.)

- Comparison of EP processes at Henkel + Saclay + DESY
  - different and complex behavior of electrolytic bath (1 part HF : 9 parts H_2SO_4)
  => study of parameters, electrolyte, set-up

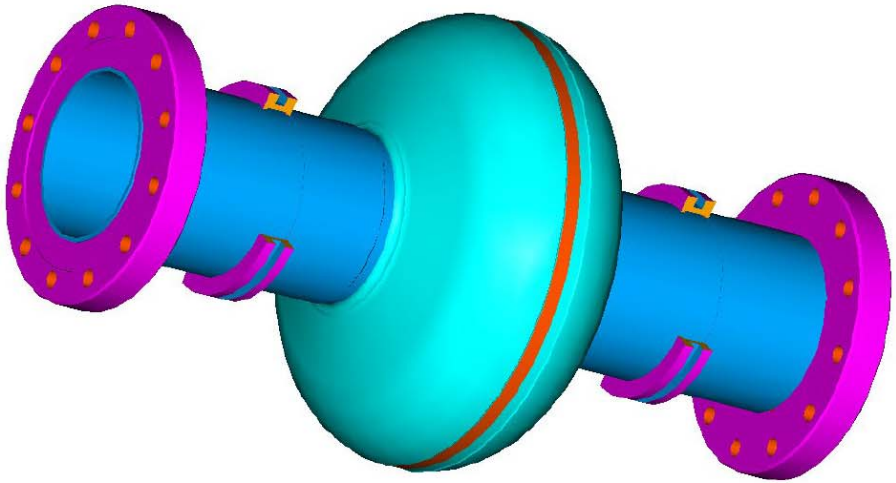
- Development of dry-ice cleaning as additional cleaning process (CARE,..)

- Check + optimisation of “120C-bake” parameters

- Further activities:
  - second s.c. photo cathode gun cavity with 0.6-cells (Jacek Sekutowicz)
  - optional: extension to 1.6-cell s.c. gun cavity
  - prototype of three-cell cavity

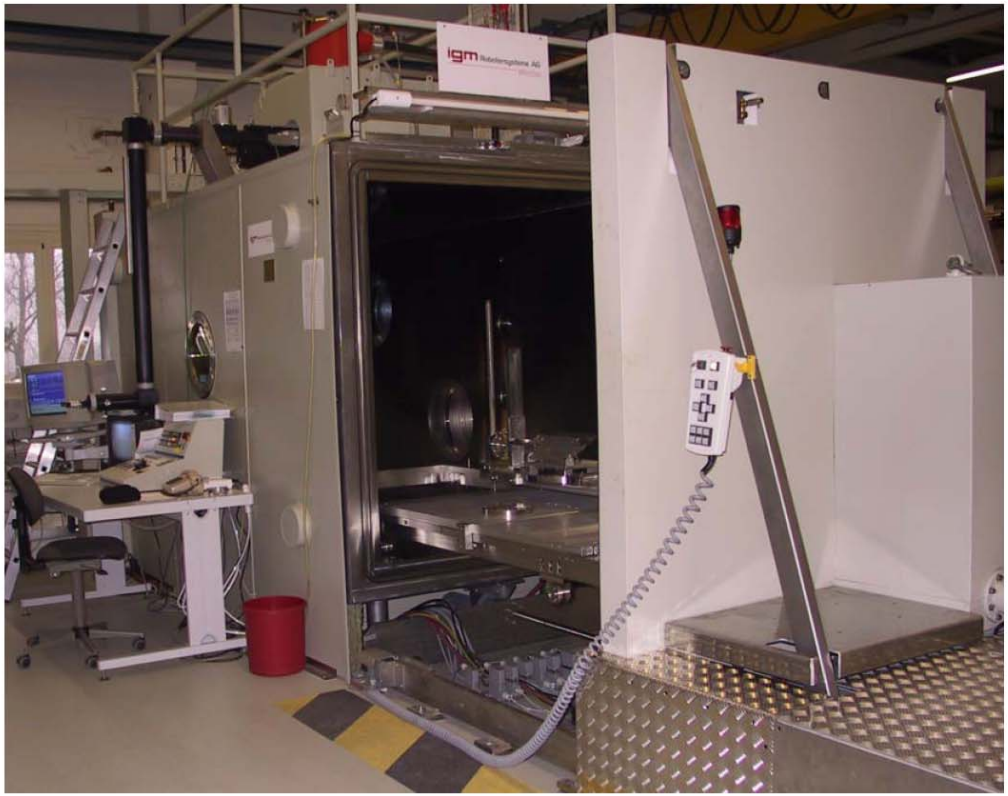
Status and Results

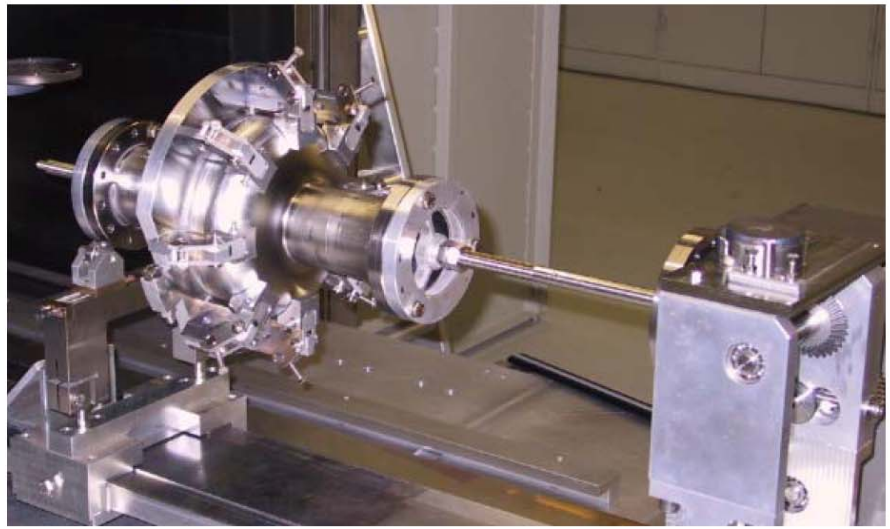
- DESY standard single-cell cavity:

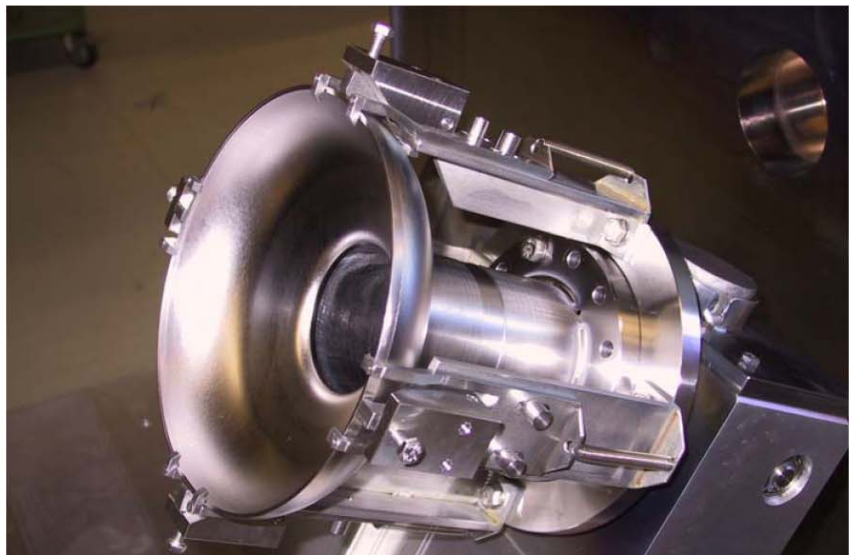


- 21 cavities at DESY completed (19 fine grain, 2 large grain):
  - machining, etching, EB welding + mechanical/optical checks inhouse
  - deep drawing of cups and electropolishing (EP) + etching (BCP) of cavities in industry
- 6 cavities + 1 two-cell at Accel Co. completed (large grain + mono crystal):
  - final mechanical/optical checks at DESY; EP at Henkel Co.; BCP at Accel

Electron beam welding at DESY





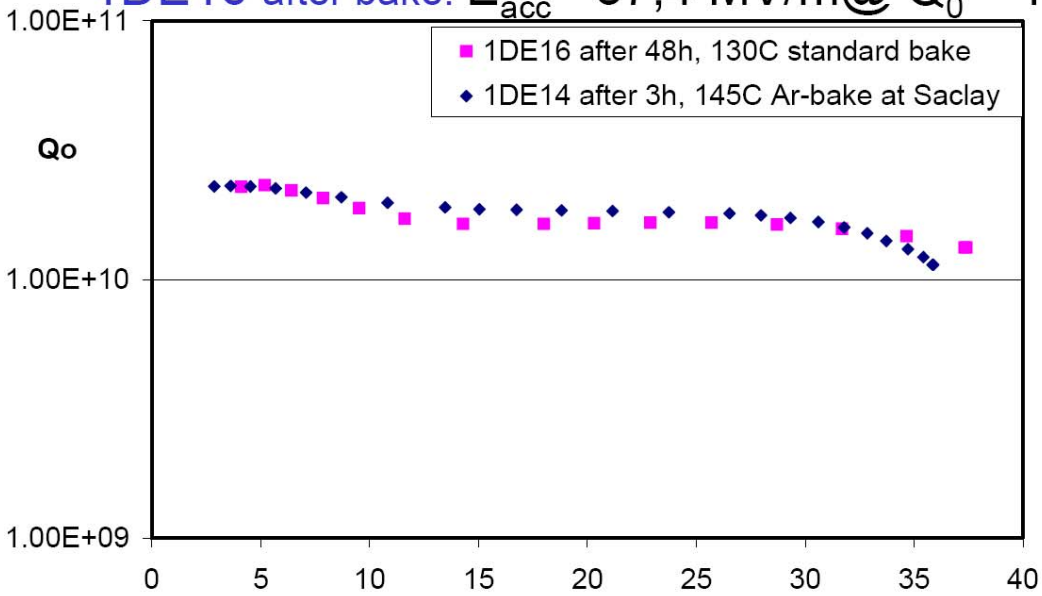


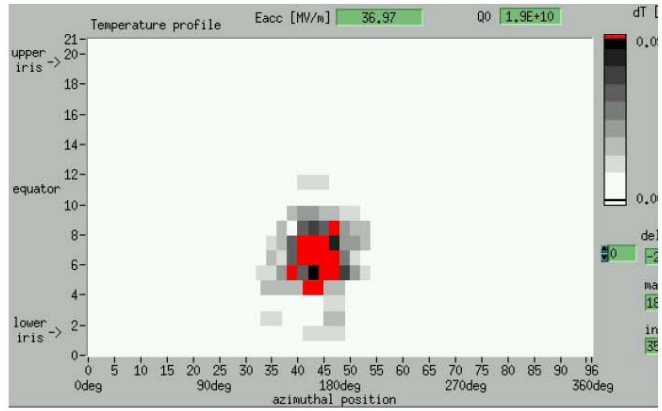
Status + Results: Plansee Nb

- Three cavities fabricated in-house of Heraeus/Plansee Nb with RRR ~ 300
- Preparation: >80µm BCP, 800C firing, 100µm EP, HPR, (bake, HPR)
- 1DE14 after bake: bake under argon atmosphere 145C/ 3h at Saclay =>
  E_{acc}= 35,5 MV/m@ Q_0 = 1,1 ·10^{10}; lim. by BD, few FE (>31/-)

  1DE15 before bake: strong FE in first test due to corroded HPR waterpipe

  1DE16 after bake: E_{acc}= 37,4 MV/m@ Q_0 = 1,3 ·10^{10}; lim. by BD; no FE





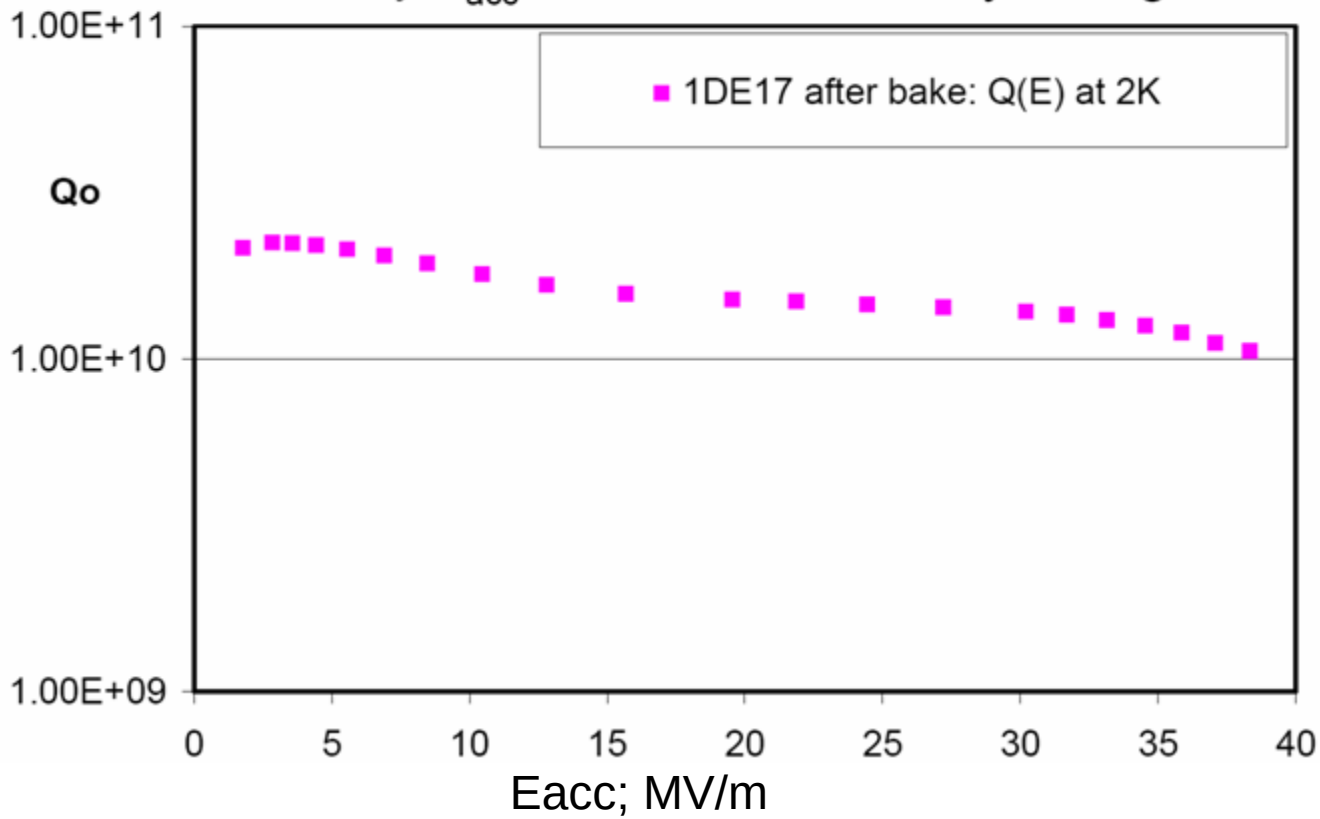
T-map of 1DE16 after bake

Status and Results: Ningxia Nb

- Three cavities fabricated in-house of fine-grain Ningxia Nb with RRR of 330
- Preparation: >80µm BCP, 800C, >100µm EP, HPR, bake, HPR

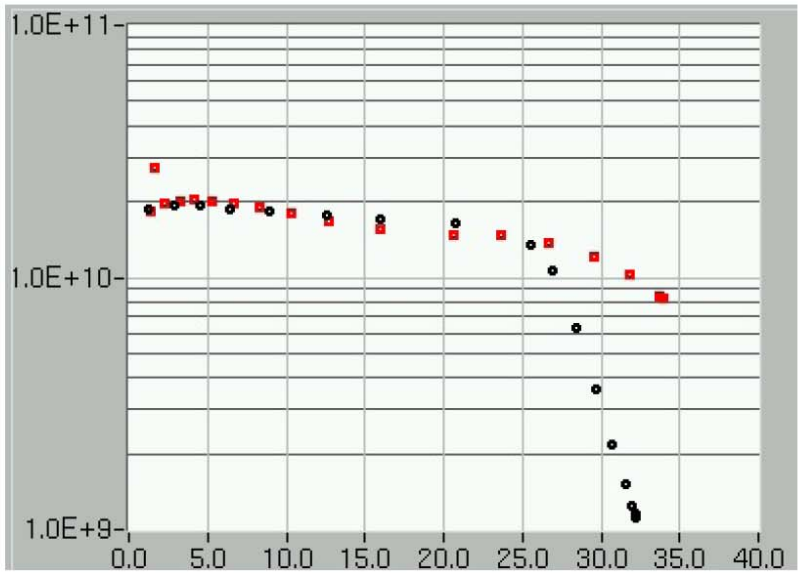
  1DE17 after bake: E_{acc}= 38,3 MV/m@ Q_0 = 1,1 ·10^{10}; lim. by BD; few FE

  1DE18 after bake: only E_{acc}= 25 MV/m limited by strong FE => new test

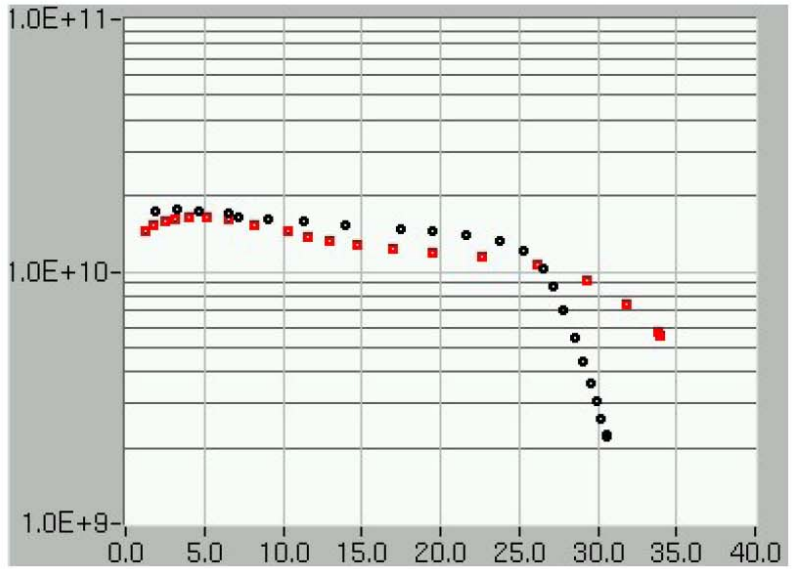


Done: Qualification of Giredmet Nb

- Three cavities fabricated in-house of russian Giredmet Nb with RRR > 600 (2x completed)
- Preparation: 150µm EP, 800C firing, 40µm EP, HPR, (add. HPR or add. 130C/136C bake)
- Qualification successful !!



Q(E)-curves of 1DE4 before and after bake (some FE present before and after bake)



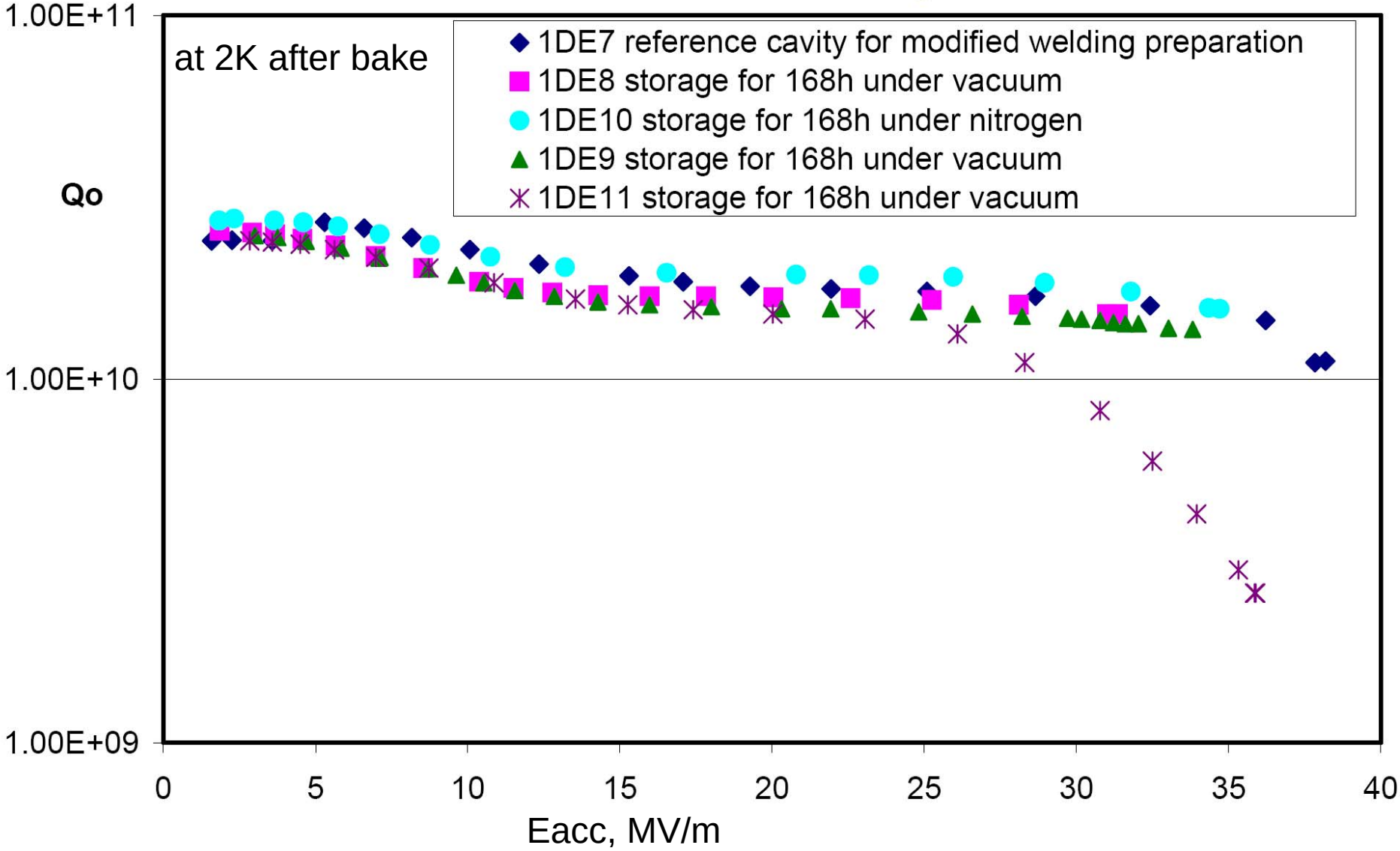
Q(E)-curves of 1DE5 before and after bake (some FE present before and after bake

Done: Modification of welding preparation

- Modification of present spec for welding preparation during cavity fabrication:
  - 1x reference cavity: max 8h between final etching of weld area and EB welding; (tested)
  - 2x cavities with 168h storage under vacuum of components after final etch of weld area; (2x tested)
  - 2x cavities with 168h storage under nitrogen atmosphere of components after final etch of weld area; (2x tested)

- Good cavity performance with gradients between 31MV/m and 38 MV/m!!
- Modified welding preparation is accepted !!

Done: Modification of welding preparation II

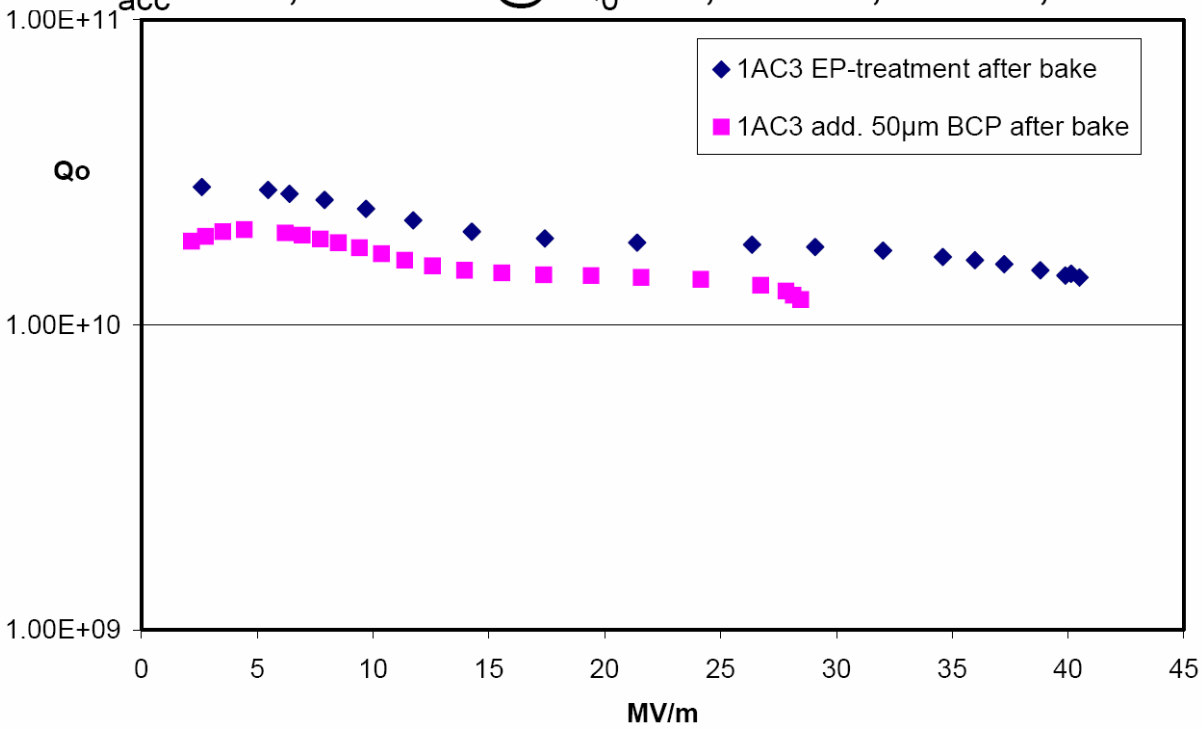


Large grain cavity 1AC3: EP vs. BCP

- large grain Heraeus Nb RRR 500 cut from ingot; fabrication at Accel Co.

EP: 150µm EP@Henkel, 800C, 40µm EP, HPR, 120C bake, HPR (T-maps):
E_{acc} = 41 MV/m @ Q_0 = 1,4 ·10^{10}; no FE ; limited by bd

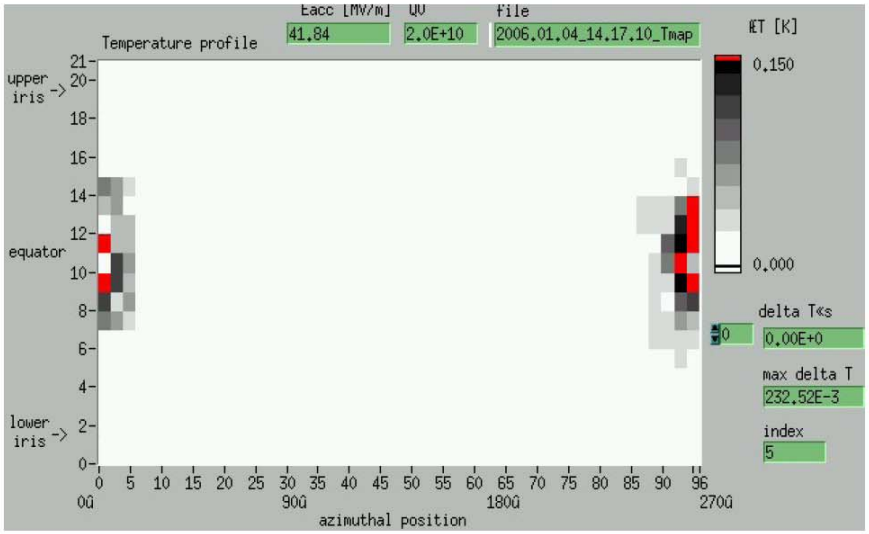
BCP: 42 µm BCP, grinding of beam tubes, 10µm BCP, HPR, 133C bake (T-maps)
E_{acc} = 28,5 MV/m @ Q_0 = 1,2 ·10^{10}; no FE; limited by quench

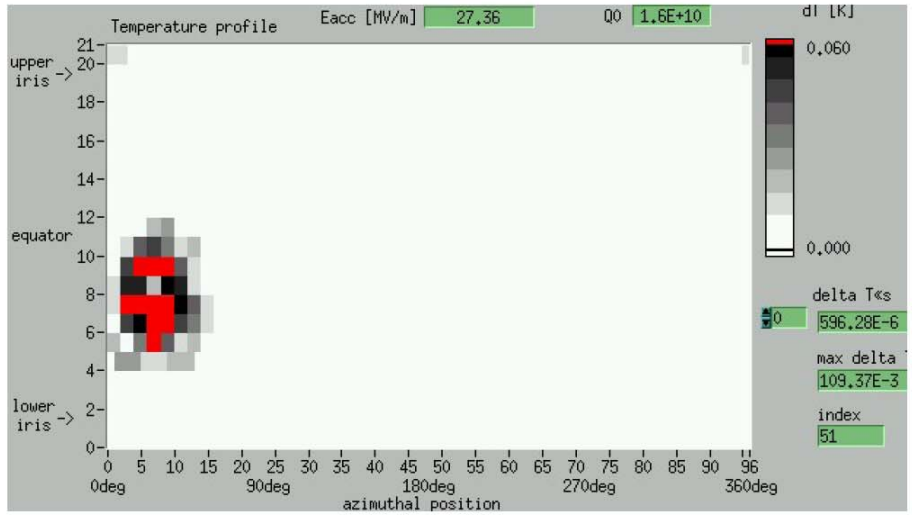


Eacc reduced by 10 MV/m after BCP compared to EP

1AC3 comparison of T-maps after EP vs. BCP

- Comparison of T-Maps during quench after EP (test 3) and BCP (test 5):





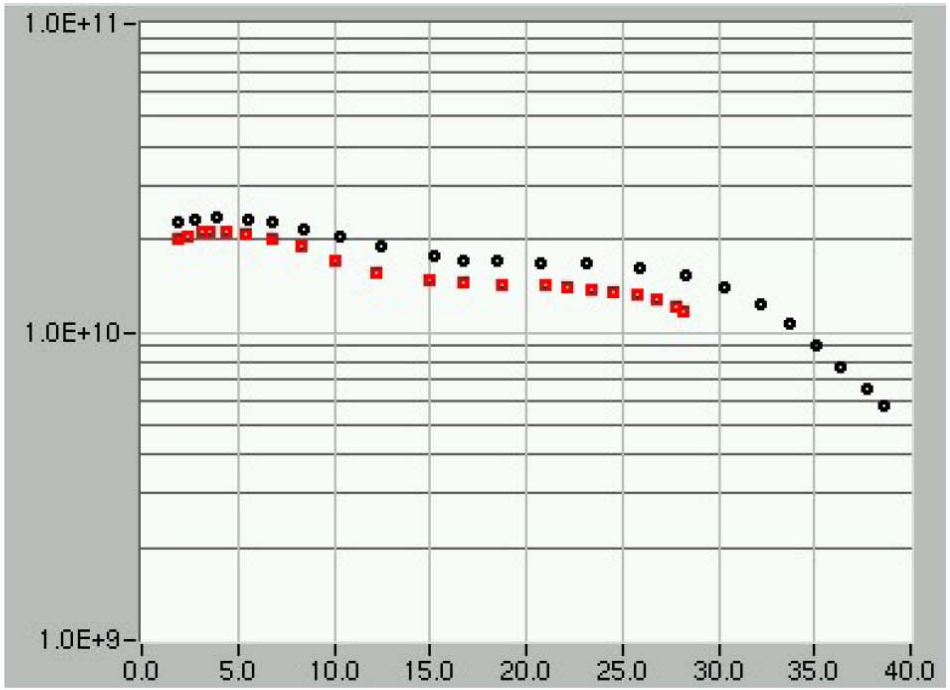
EP: E_{acc} = 41 MV/m @ Q_0 = 2 ·10¹⁰; no FE

BCP: E_{acc} = 28,5 MV/m @ Q_0 = 1,2 ·10¹⁰; no FE

- Changed quench location after BCP !!!

Large grain cavity 1AC4: EP vs. BCP

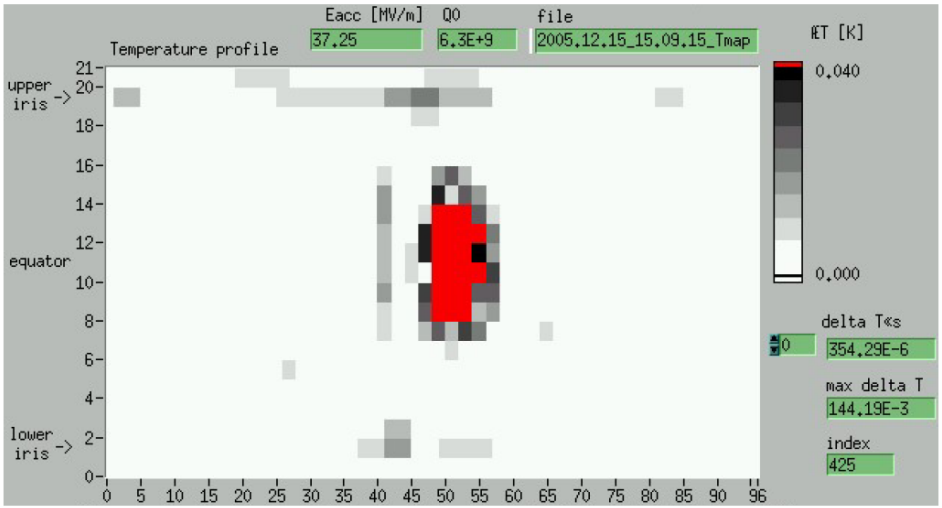
- EP-treatment successful with E_{acc} = 38,5 MV/m @ $Q_0 = 5{,}8 \cdot 10^9$ limited by quench (some FE present)
- Add. 41 µm BCP (after bake) results in 10 MV/m loss in gradient !!!

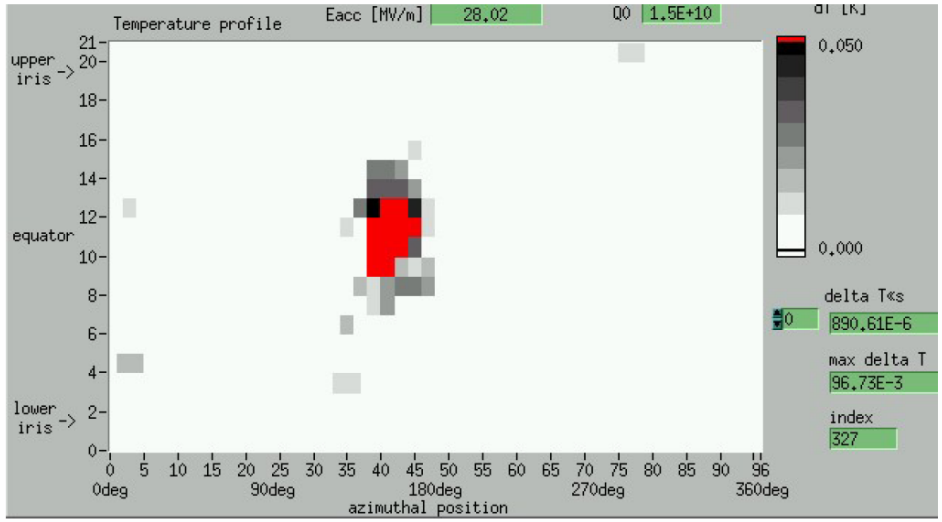


Q(E) - curves at 2K of test 3 (**EP**) and test 8 (**BCP**), both after bake

1AC4: Comparison of T-maps after EP + BCP

- Comparison of T-Maps during quench after EP (left) and BCP (right):

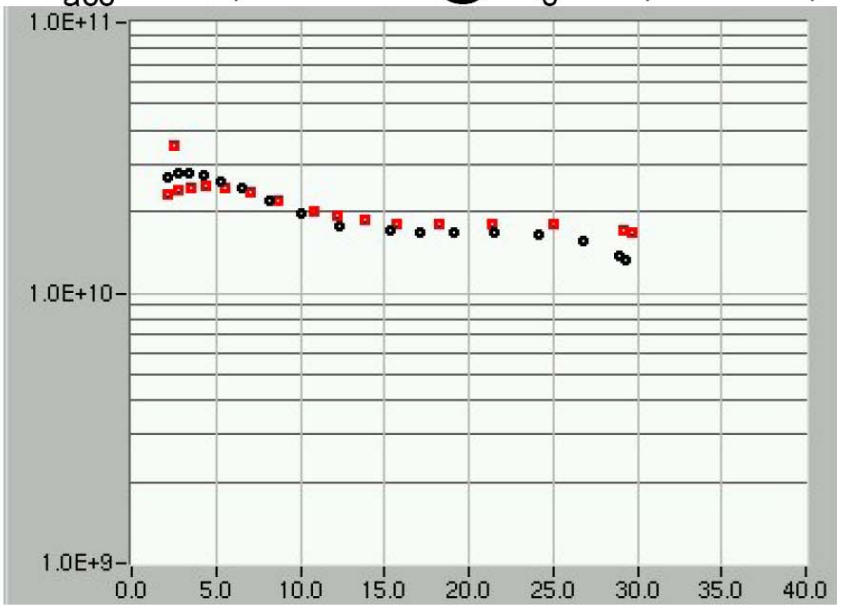




- Quench location changed or assembly problem??

Large grain cavity 1AC5: BCP vs. EP

- Large grain Heraeus Nb cut from ingot; fabrication at Accel: spun cups; EP at Henkel Co.
- EP: 150µm EP, 800C, 40µm EP, HPR, 135C bake, HPR (T-Maps):
  E_{acc} = 29,3 MV/m @ Q_0 = 1,3 ·10^{10}; few FE (>28 / -), no MP, lim. by Quench
- BCP: add. (63+22) µm BCP@Accel, HPR, bake at 127C/109h
  (=> failure of bake control, no T-Maps);
  E_{acc} = 29,7 MV/m @ Q_0 = 1,7 ·10^{10}; limited by BD; no FE



=> unchanged Q(E)-performance after EP and BCP

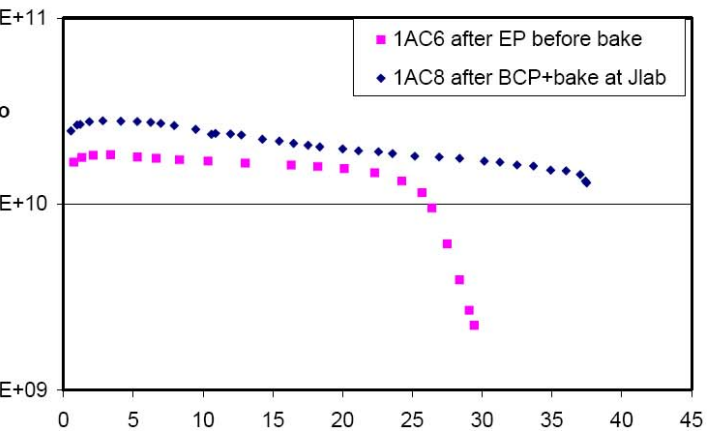
Q(E) – curves after EP (black) and after BCP (red) at 2K

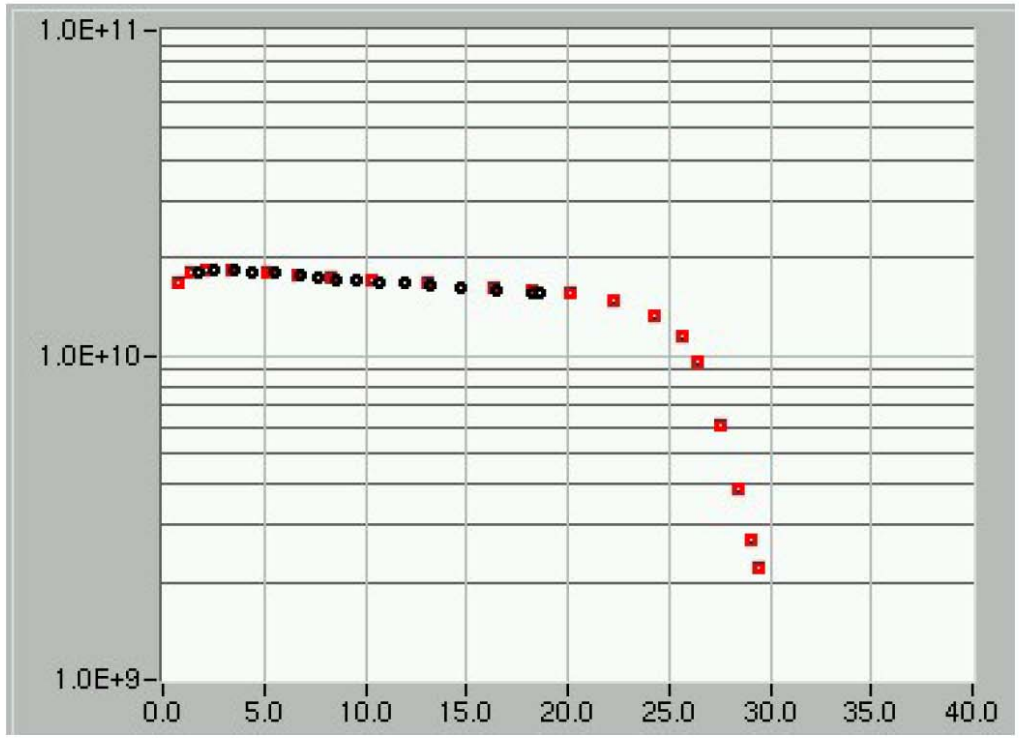
1AC6: Comparison after add. EP

- Test 4: 100 µm EP@Henkel,HPR:
  E_{acc} = 29,4 MV/m @ Q_0 = 2,2 ·10^9; limited by power, few FE (24,5/ -), no MP
  no Q-disease; remark: first power run showed early FE and processing around 12MV/m

=> Gain of 10 MV/m after EP!

=> Tests after bake showed strong FE due HPR problems (not shown) => new rinse necessary !!





Q(E) - curves at 2K of test 3 (BCP) and test 4 (add. EP, red)

XFEL test cavities: Large grain single-cells

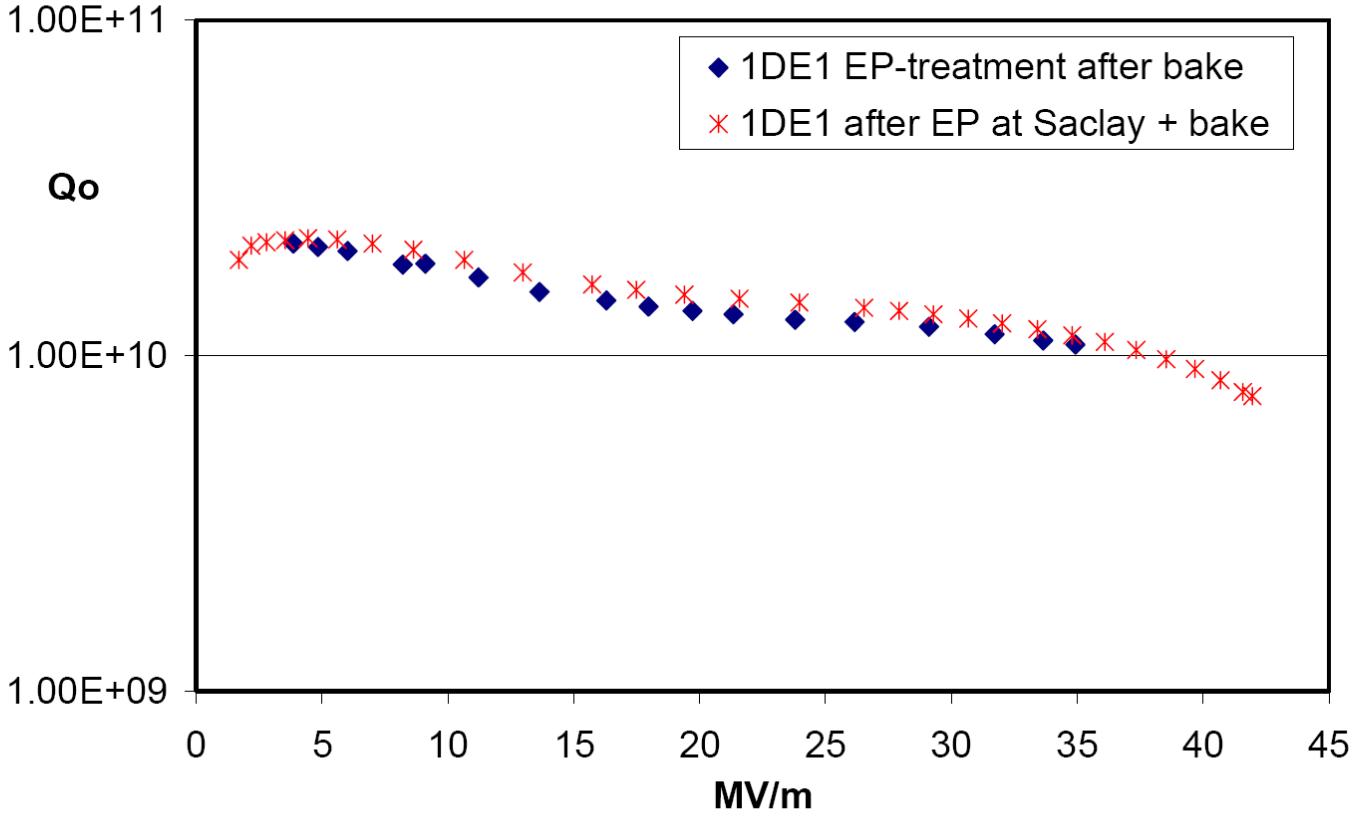
		1AC3	1AC4	1AC5 spun cup	1AC7	1AC6 mc	1AC8 mc (JLab)
EP before bake	Eacc	28,4 (FE)	29 (pwr)	-	-	-	-
	Qo	3e9	3e9	-	-	-	-
+ bake		34,4 (FE)	37,2 (BD)	29,3 (BD)	-	-	-
		4e9	6,3e9	1,3e10	-	-	-
+ re-HPR		41 (BD)	Dry-ice	-	-	-	-
		1,4e10		-	-	-	-
+ BCP(40-50um or only BCP)		30,5 (pwr)	30 (pwr)		25,2 (BD)	21,5 (BD)	37,5 (BD)
+ HPR		2,2e9	2,2e9		1,5e10	1,8e10	
+ bake		28,5 (BD)	28,2 (BD)		-	-	
		1,2e10	1,2e10		-	-	
+ BCP (40 μm)		next test		29,6 (BD)			
+ HPR				4,8e9			
+bake				29,7 (BD)			
				1,7e10			
+ EP (100μm)					20,2 (FE)	29,4 (pwr)	
+ HPR					1,2e9	2,2e9	

Comparison of EP parameters (ctd.)

B) Comparison of new EP system at Saclay to Henkel EP

=> 1 cavity up to now !

=> reproduction and detailed check of parameters necessary!!!

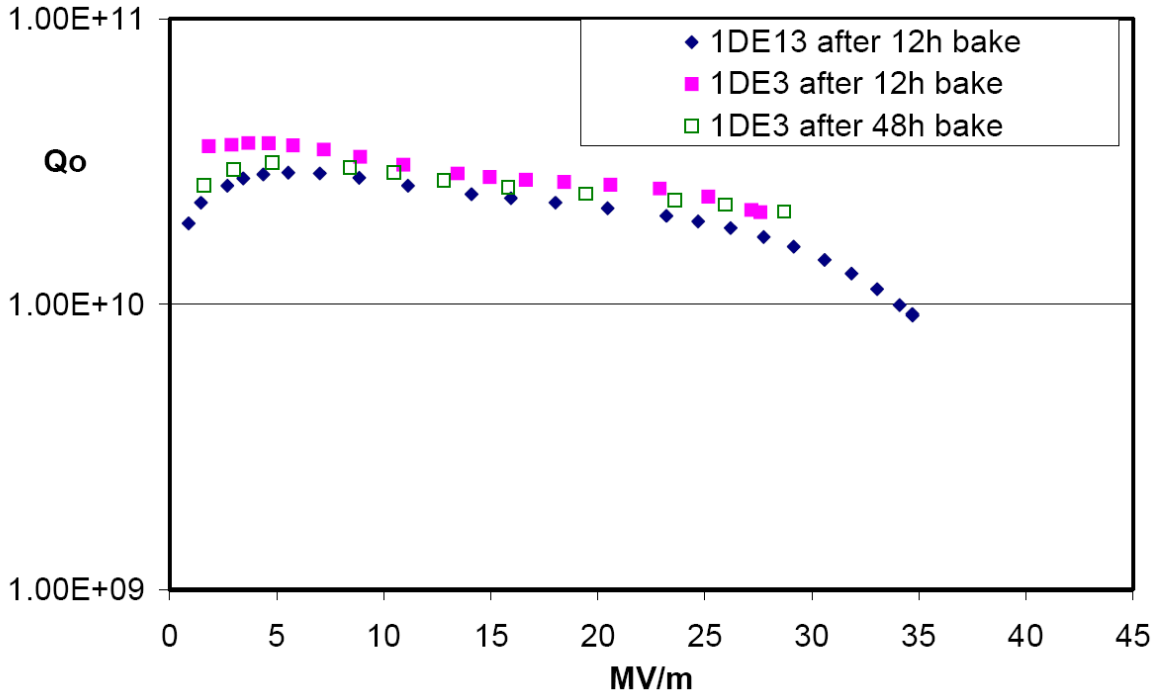


Q(E)-curves at 2K after EP + bake at Henkel and Saclay

Bake parameters

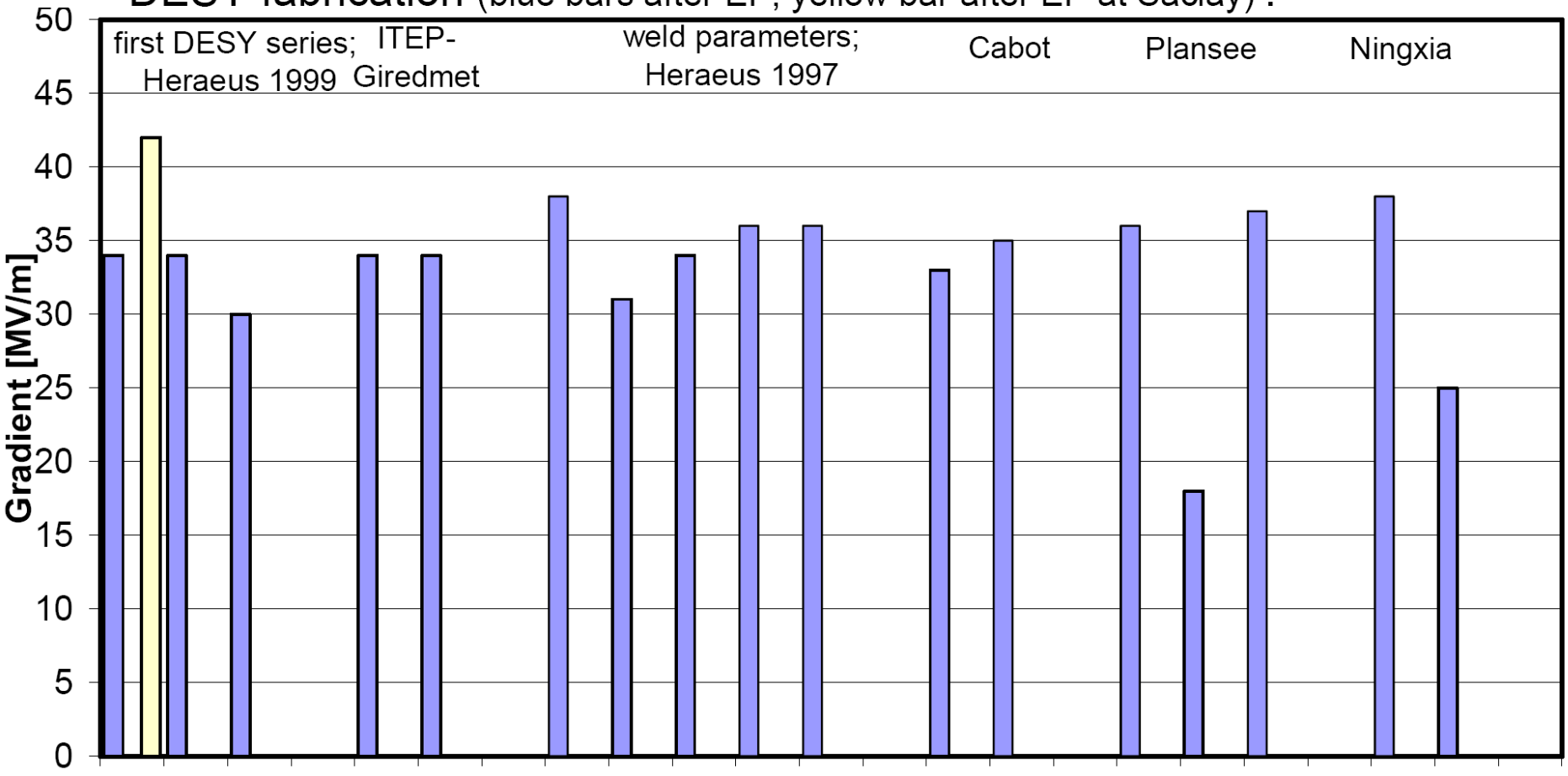
- Bake at (120 - 135)C for 48h gives high Q-values at $E_{acc,max}$
  => separate overview under preparation

- Bake at (135 – 140)C for 12h tested on several cavities with good result
  => more tests under preparation



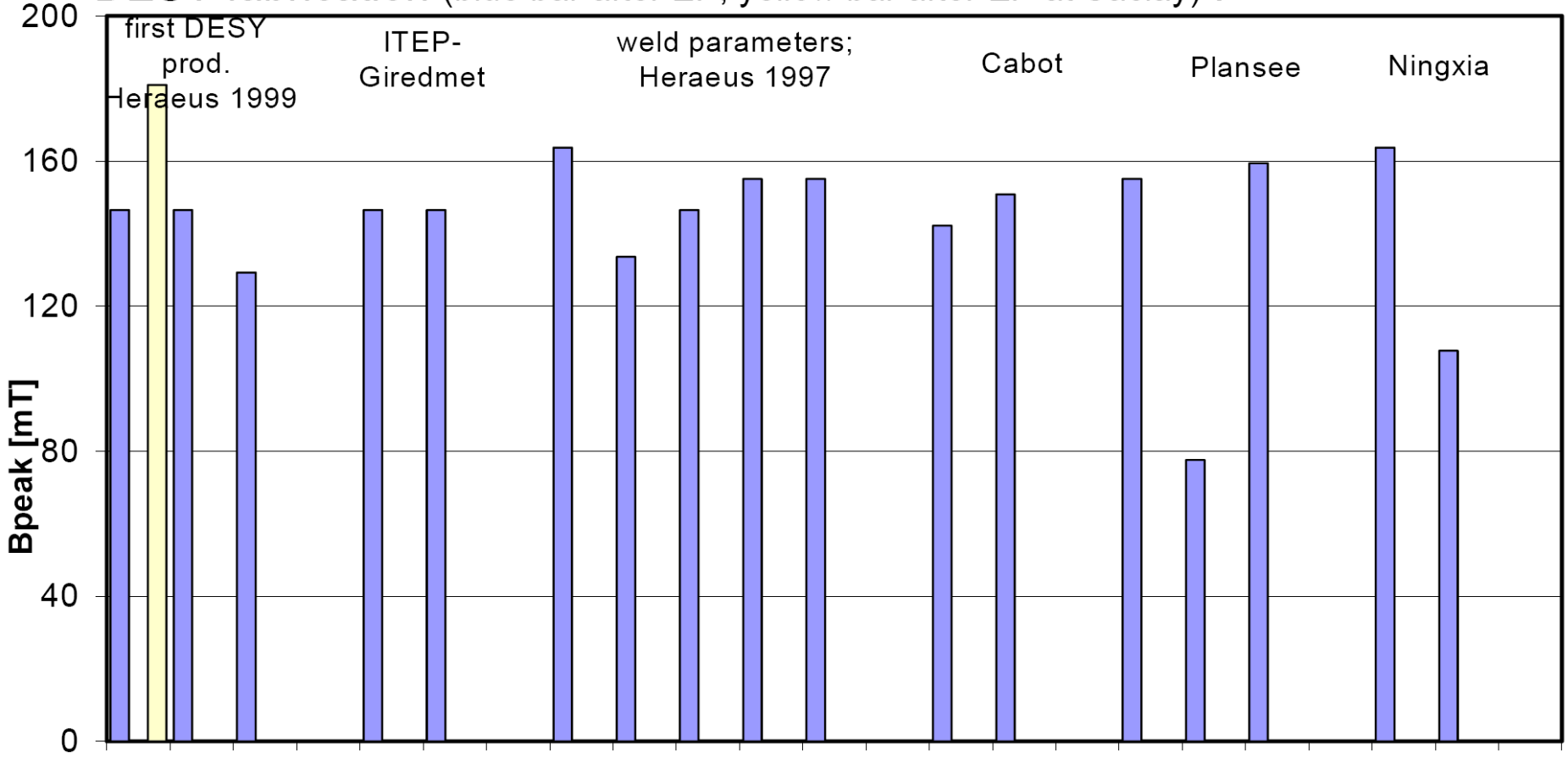
Maximum fields E_{acc}

- DESY fabrication (blue bars after EP; yellow bar after EP at Saclay) :



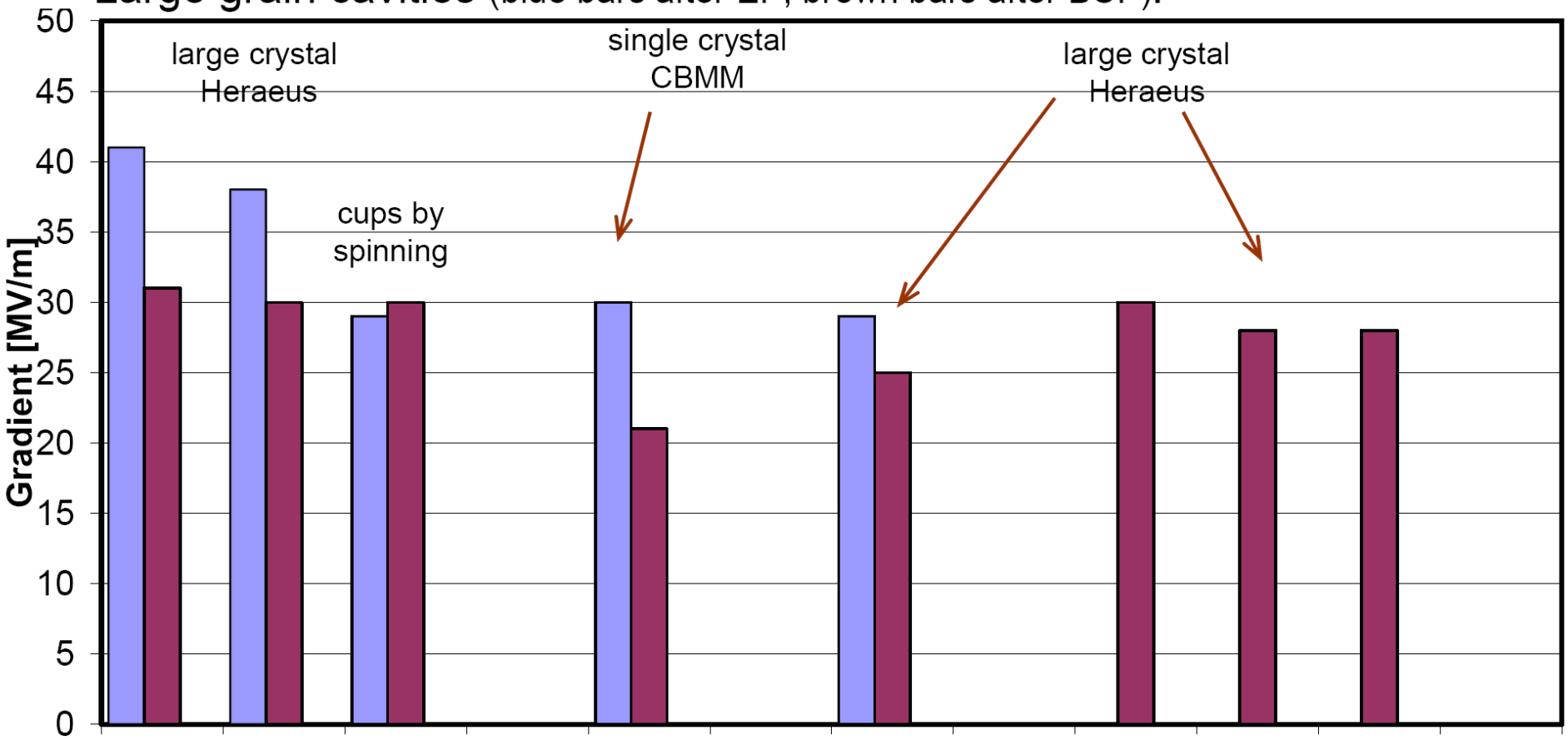
Maximum fields B_{peak}

- DESY fabrication (blue bar after EP; yellow bar after EP at Saclay) :



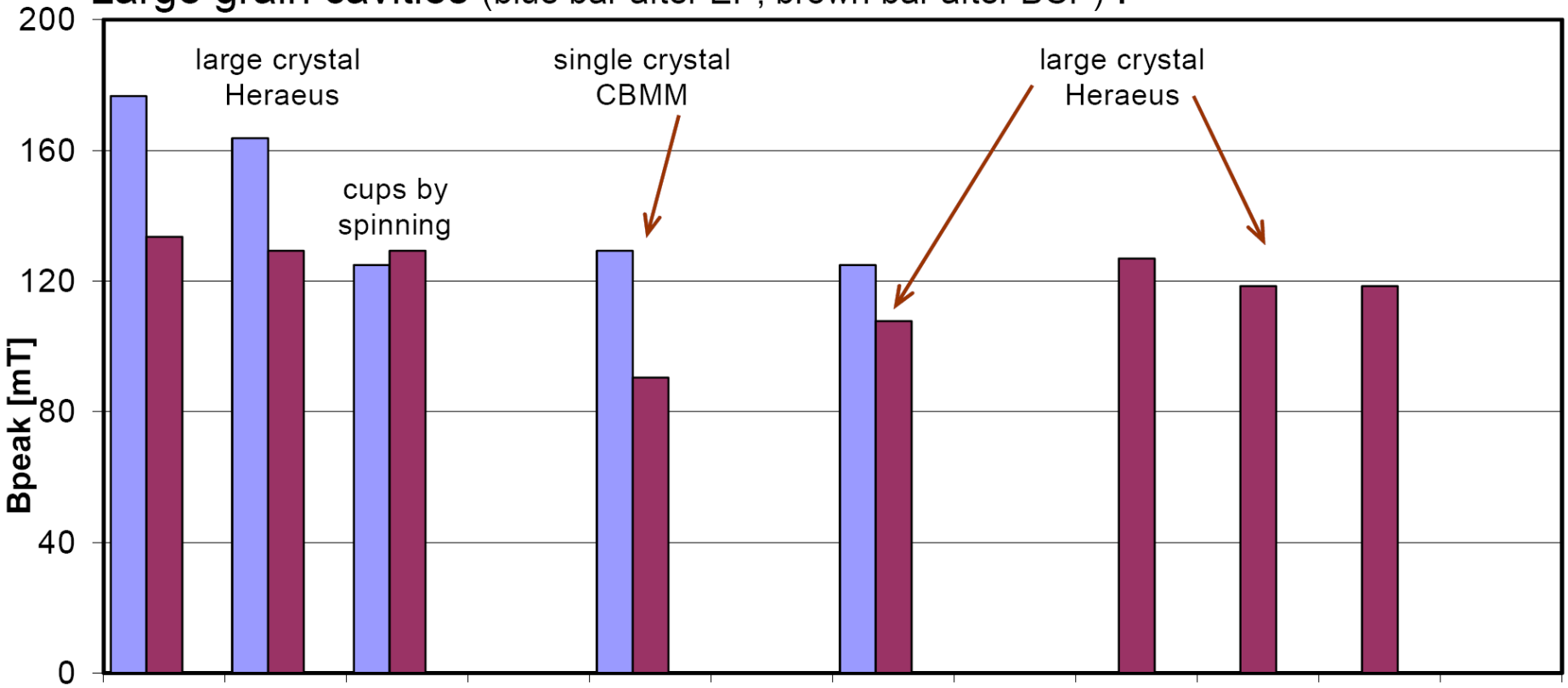
Maximum fields E_{acc}

- Large grain cavities (blue bars after EP; brown bars after BCP):



Maximum fields B_{peak}

- Large grain cavities (blue bar after EP; brown bar after BCP) :



Quench locations

- Table of quench locations of DESY fabrication:

Cavity	Gradient	Quench location	Preparation + remark
1DE1	34	lower cup, close to iris	EP; no FE
1DE1	42	equator area or little above ???	EP at Saclay, nearly no FE
1DE2	31	equator area	EP; no FE
1DE3	28	above equator; not clear	EP; no FE
1DE3	28	below equator, but different positiion !!!	Add. 50 µm EP + 8µm BCP
1DE7	33	lower cup; mid equator – iris	EP; probably FE-induced
1DE8	31	equator area; little above	EP; no FE
1DE9	34	lower cup; between equator – iris	EP; no FE(?)
1DE10	35	equator area, little above	EP; nearly no FE
1DE11	36	Equator area	EP; no FE
1DE13	33	equator area, little above	EP, some FE
1DE16	37	lower cup, between equator – iris	EP, no FE
1DE17	38	Upper cup, between equator – iris	EP, few FE

Quench locations ctd.

- Table of quench locations of large-grain cavities:

Cavity	Gradient	Quench location	Preparation + remark
1AC3	41	equator area, little above	EP; no FE
1AC3	29	lower cup, between equator – iris	**BCP**; no FE; 30 degree changed to EP
1AC4	37	equator area	EP; some FE; 30 degree off FE
1AC4	28	equator area	**BCP**, no FE
1AC5	29	upper cup; mid equator – iris	EP;
1AC6	19	equator area, little below	**BCP,** no FE
1AC7	27	equator area	EP; after strong processing of FE !
AC113	28	Cell 1; equator area	**BCP,** some FE
AC114	28	cell2, upper cup, mid equator –iris	**BCP,** strong FE => FE induced ?

Summary + Outlook

- First Plansee niobium cavities give good results => nine-cell fabrication !!
- Cabot + Giredmet niobium cavities give good results => ???
- First Ningxia niobium cavity gives good result

- "Large-grain" show excellent results after EP
  => ongoing comparison between BCP and EP on "large grain" Nb material
- New EP preparation of mono-crystal cavity 1AC6
  1AC8 will at JLab; return to DESY
- Fabrication, preparation and test of "large grain" niobium cavities at DESY (spring 07)

Summary + Outlook

- Complex behavior of electolytic bath of the EP process
  => study about electrolyte management (Henkel Co., DESY)
  => Henkel vs. Honeywell electrolyt gives comparable result
  => EP system at Saclay starts operation successfully => tests continued

- Dry-ice cleaning => Upcoming presentation
- Analysis of “120C bake” procedure => Upcoming presentation

- Done: Qualification of DESY in-house cavity fabrication successful
- Done: Modified welding preparation gives good results
  => application to next single-cells for more statistics

Thanks:

- D. Reschke, J. Iversen (Coordinators)

- Colleagues of DESY groups –MVP-, MVA-, -MKS-, -MHF-sl-, -MPL-, -ZM-, -V4- +all others

- S. Bauer (ACCEL), Ch. Hartmann, B. Henkel (Henkel), F. Eozenou, B.Visentin (CEA Saclay)

1DE1 details of test 4 (EP at Saclay)

- Main parameters of EP at Saclay:
  constant voltage operation; T < 30°C, new bath 1 vol HF 40% - 9 vol H_2SO_4 95%, ethanol rinse 26 min
- additional description by F. Eozenou, Oct. 06:
  "We polished yesterday 1DE1 cavity during about 1h30. 17 Volts, 1 tr/min, T about 30°C. About 55g of niobium were dissolved. The cavity is very shiny. Shininess has been improved. It has undergone an ethanol rinse and a HPR."
- Removal rate is 42 µm for 1,3 g/µm.

- HPR at hall 3 and test done:
  => no Q-disease
  => Quench at 30MV/m ; needs to be confirmed by test after bake
  => improved Q-value at 2K
  => RRR measured during cooldown with average value 287