ACD Down-Select Criteria and Time Scales for Cavity Shapes and Processing

Lutz Lilje

GDE

Outline

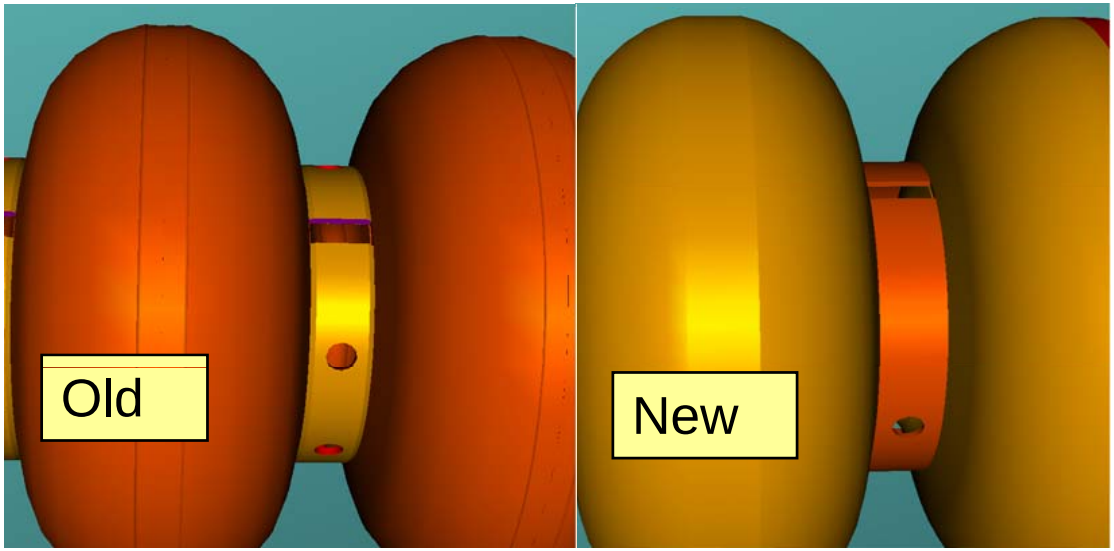
- Short recapitulation on proposed changes for the cavity system
  - **see Cavity KOM talk**
- Development of criteria
  - **Testing needed**
  - **Estimation of minimum time needed to accomplish those**

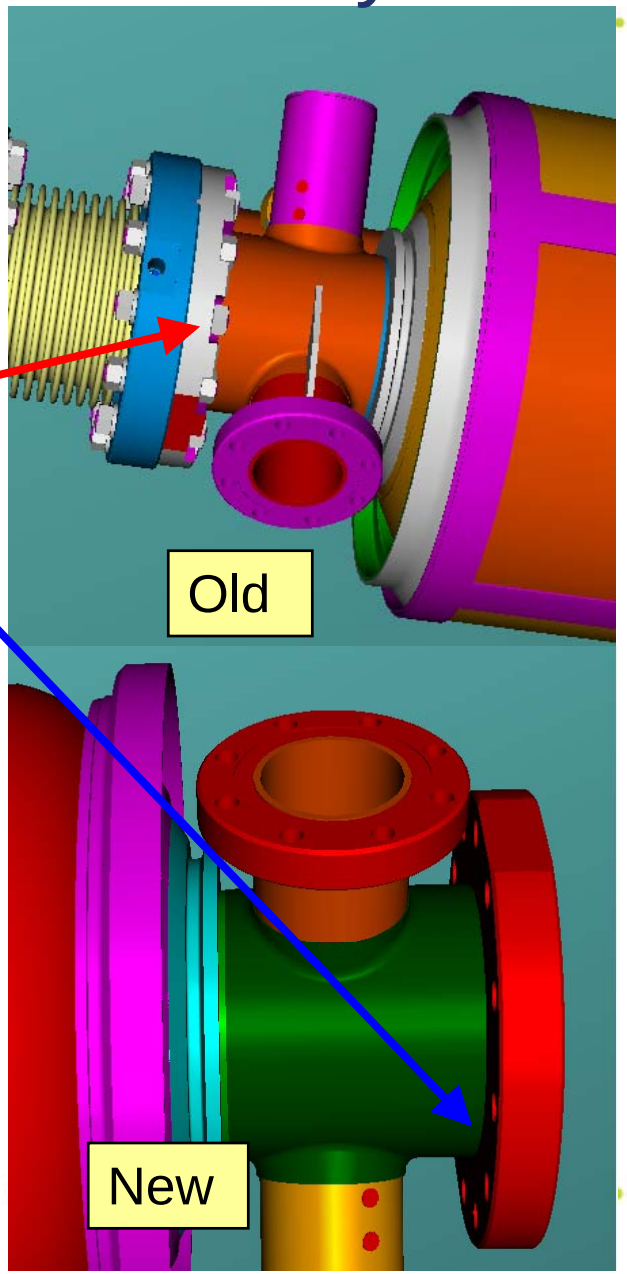
Cavity and cavity system design

- compare XFEL choices with mandatory and potential design changes for the baseline
- Review of RDR work for cavity system,
  - **possible design changes,**
    - fabrication changes for baseline cavity
    - HOM,
    - seal,
    - endgroup welding,
    - thicker endplate,

TTF Cavity Today and XFEL Cavity

- Only minor design changes to reduce cost/simplify manufacturing will be done e.g.
  - **Removal of coupler port stiffener**
  - **Removal of 'pockets' short side**
  - **Removal of outside recess**
  - **Less holes in stiffener ring**
  - **Thinner stiffener ring**
  - **Review tolerances**
    - Loosen where possible e.g. stiffeners rings





Mandatory Changes to Baseline: Cavity

- Cavity Length
  - **Only real necessary change to increase ILC fill factor**
  - **Main issues**
    - Need more compact tuner design
    - XFEL will not change this

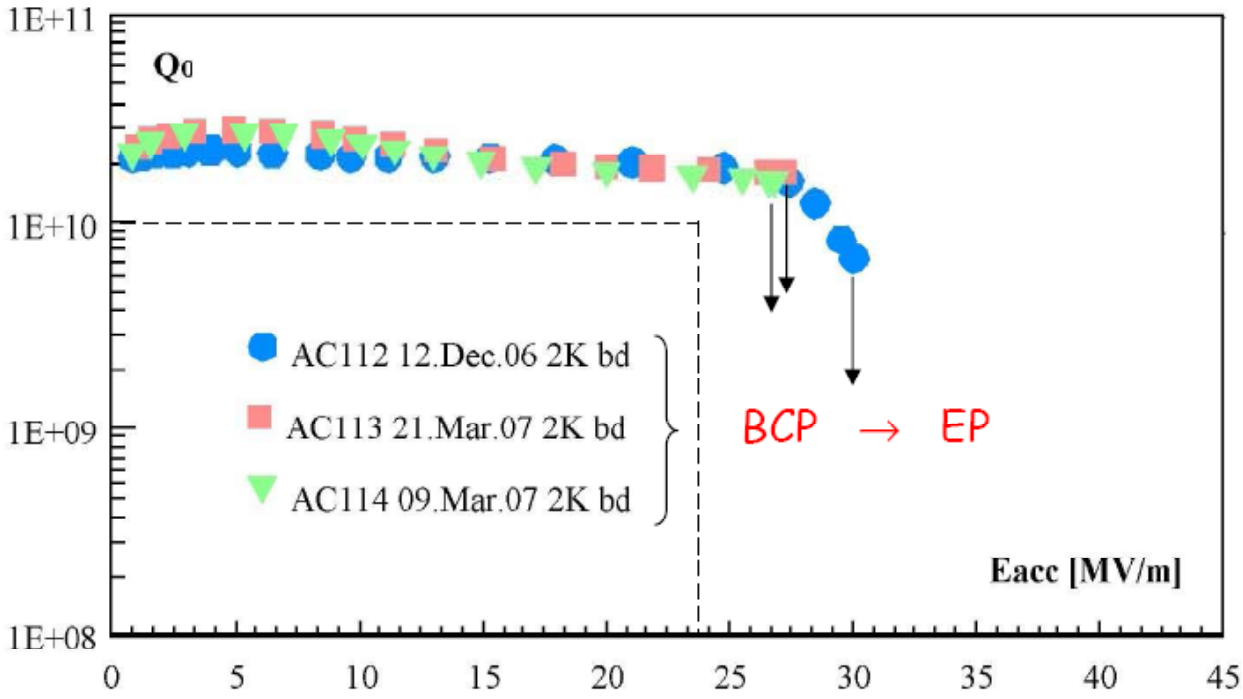
Optional changes: Cavity

- Material
  - **Large-grain**
    - Straight-forward implementation if material available
      - See W. Singer talk
    - Still need thorough analysis of cost-benefit
    - Performance demonstration on multi-cells needed
      - So far only BCP result available
      - EP underway at DESY (stay tuned…)
- HOM design
  - **Coupler kicks**
- Tank material
  - **Cost**
- Thicker endplate
  - **Lorentz-force detuning**
- Seal
- End-group welding

Large Grain Material: Multi-Cells (XFEL option)

Option : Large Grain cavities / BCP

Heraeus /Accel (three cavities)



Less fabrication steps (lower cost)

no forging-rolling

disk from ingot

(less material pollution)

High RRR ~ 500

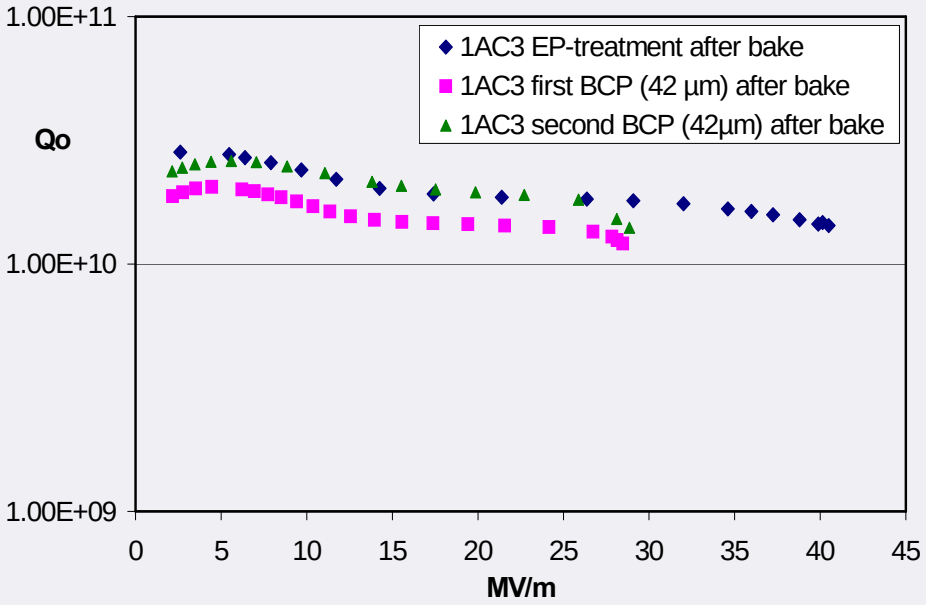
(avoid HT to ↗ κ)

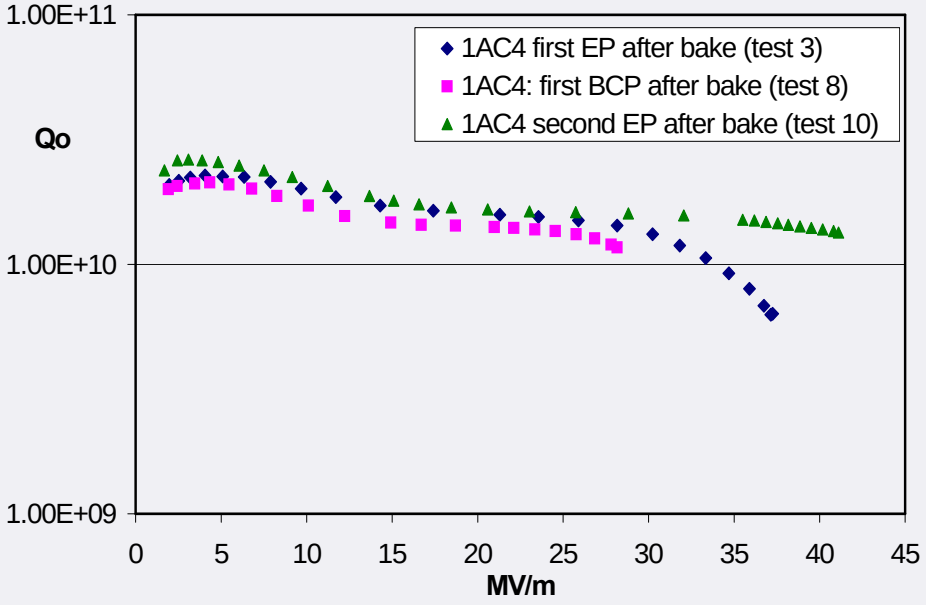
Probably higher gradients after Electropolishing (coming tests)

Large Grain Nb: Comparison of EP vs. BCP

Two cavities (deep drawn cups) of Heraeus Nb with RRR 500;

Reproducible gain of 10 and 13 MV/m after EP compared to BCP





Optional changes: Cavity

- Material
  - **Large-grain**
- HOM design
  - **Coupler kicks**
    - Needs further evaluation
    - Mitigation could be straight-forward
- Thicker endplate
  - **Lorentz-force detuning**
- Tank material
  - **Cost**
- Seal
- End-group welding

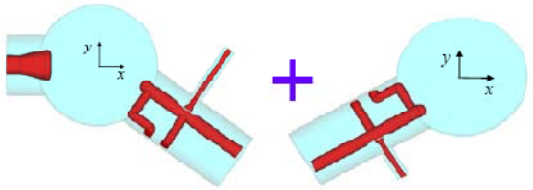
Coupler Kick

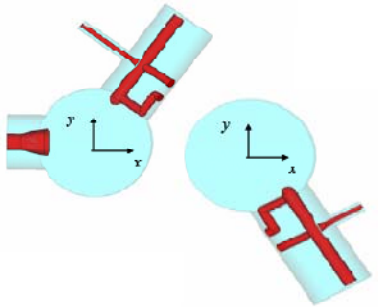
Igor Zagorodnov and Martin Dohlus

ILC Workshop, DESY

31 May, 2007

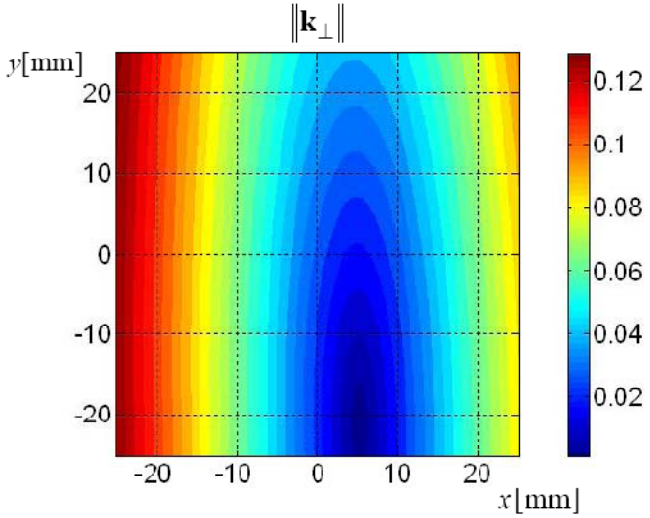
Wake kick for the new orientation

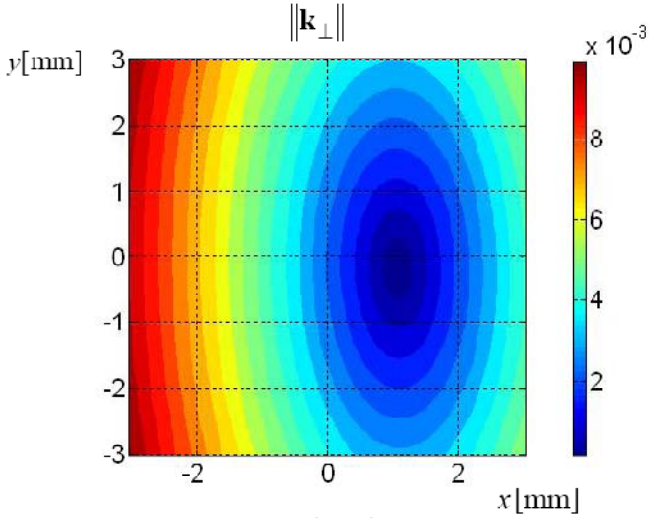




$$\mathbf{k}_\perp(x,y) = \begin{pmatrix} -0.021 \\ -0.019 \end{pmatrix} + \begin{pmatrix} 4.3 & 0.07 \\ 0.03 & -0.9 \end{pmatrix} \begin{pmatrix} x[\mathrm{m}] \\ y[\mathrm{m}] \end{pmatrix} \left[\frac{\mathrm{kV}}{\mathrm{nC}}\right]$$

$$\mathbf{k}_\perp(x,y) = \begin{pmatrix} -0.0025 \\ -0.0002 \end{pmatrix} + \begin{pmatrix} 2.33 & 0.04 \\ -0.02 & 1.1 \end{pmatrix} \begin{pmatrix} x[\mathrm{m}] \\ y[\mathrm{m}] \end{pmatrix} \left[\frac{\mathrm{kV}}{\mathrm{nC}}\right]$$





$$\mathbf{r}_c = \begin{pmatrix} 5.3 \\ -21.3 \end{pmatrix} \mathrm{mm}$$

$$\|\mathbf{k}_\perp\|_{\min} \sim 5e-5 \frac{\mathrm{kV}}{\mathrm{nC}}$$

$$\mathbf{r}_c = \begin{pmatrix} 1.1 \\ 0.2 \end{pmatrix} \mathrm{mm}$$

$$\|\mathbf{k}_\perp\|_{\min} = 8e-5 \frac{\mathrm{kV}}{\mathrm{nC}}$$

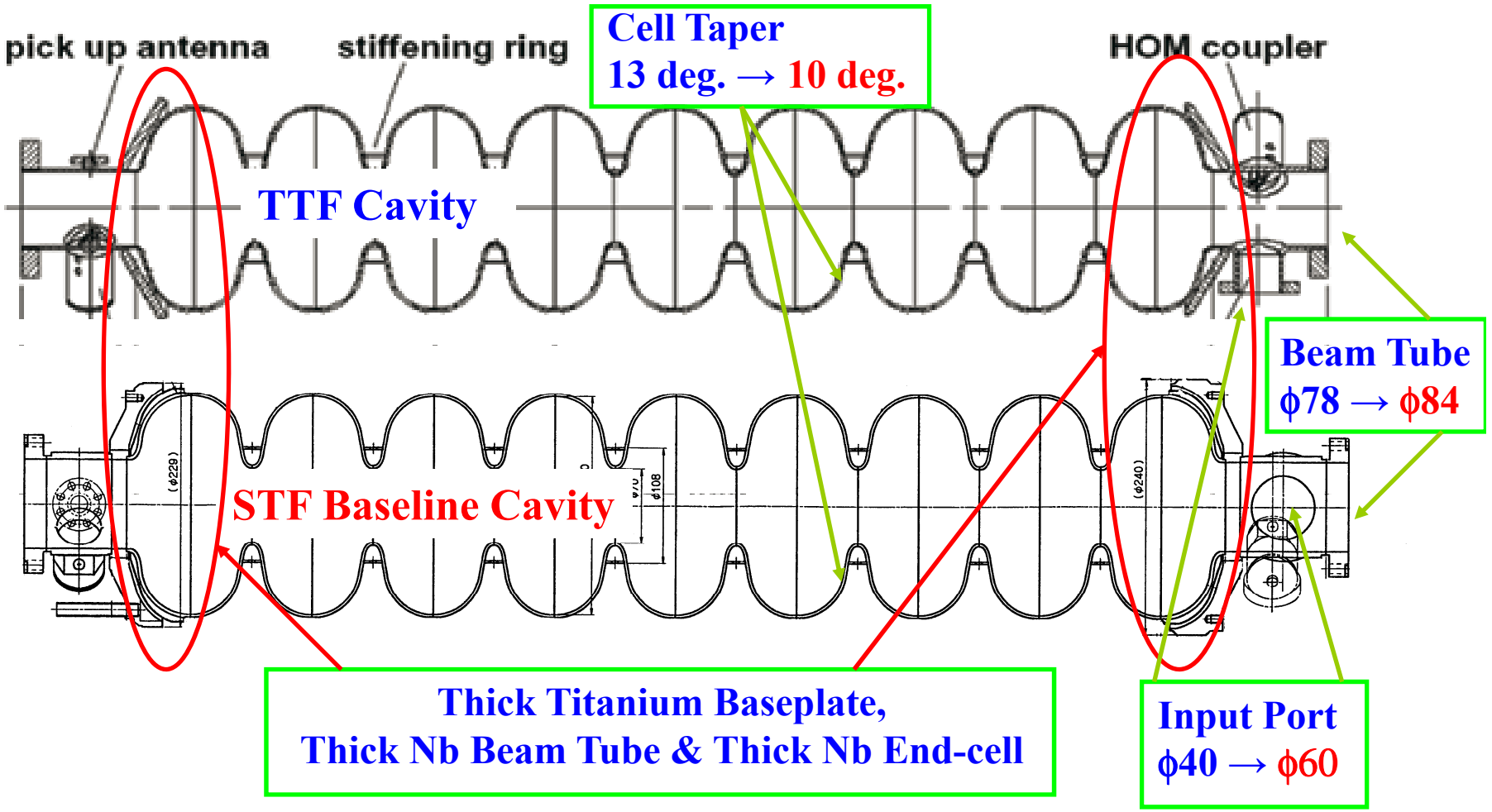
HOM Wake Mitigation Options

- Following Chris Adolphsen there are fixes:
  - **“Igor's solution of rotating the HOM relative the FPC - this reduces the effect by a factor of 10”**
    - Cavity design change
    - Needs beam test
  - **“feeding every other cavity or every other cryomodule from the opposite side (like is done in the SLAC linac).”**
    - Straight-forward solution
    - Is this still feasible from RF unit to RF unit?
      - Possibly simplest way to alter tunnel layout
  - **“reducing the beam pipe diameter to 60 mm so the HOM and FPC antennae are not 'seen' directly by the beam (this is not a problem for the LL cavity for example - note the irises could still be 70 mm diameter, but the wake would still be larger due to the smaller beam pipe size)”**
    - Cavity design change
    - Needs beam test

Optional changes: Cavity

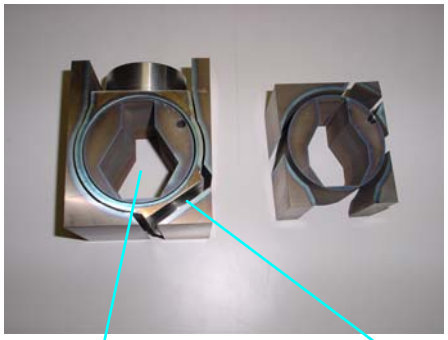
- Material
  - **Large-grain**
- HOM design
  - **Coupler kicks**
- Thicker endplate
  - **Lorentz-force detuning**
    - E.g. TESLA-type cavities at KEK
      - Thicker endplate design necessitated other design changes
    - Need to prove improvement in stiffness reduces Lorentz-force detuning
- Tank material
  - **Cost**
- Seal
- End-group welding

Improvement in the STF Baseline Cavities



	STF Baseline Cavity	TTF Cavity	
Stiffness of Cavity			
Fixing Support	90 kN/mm	13 kN/mm	
Lorentz Detuning	-500 Hz	-900 Hz	(31.5 MV/m)

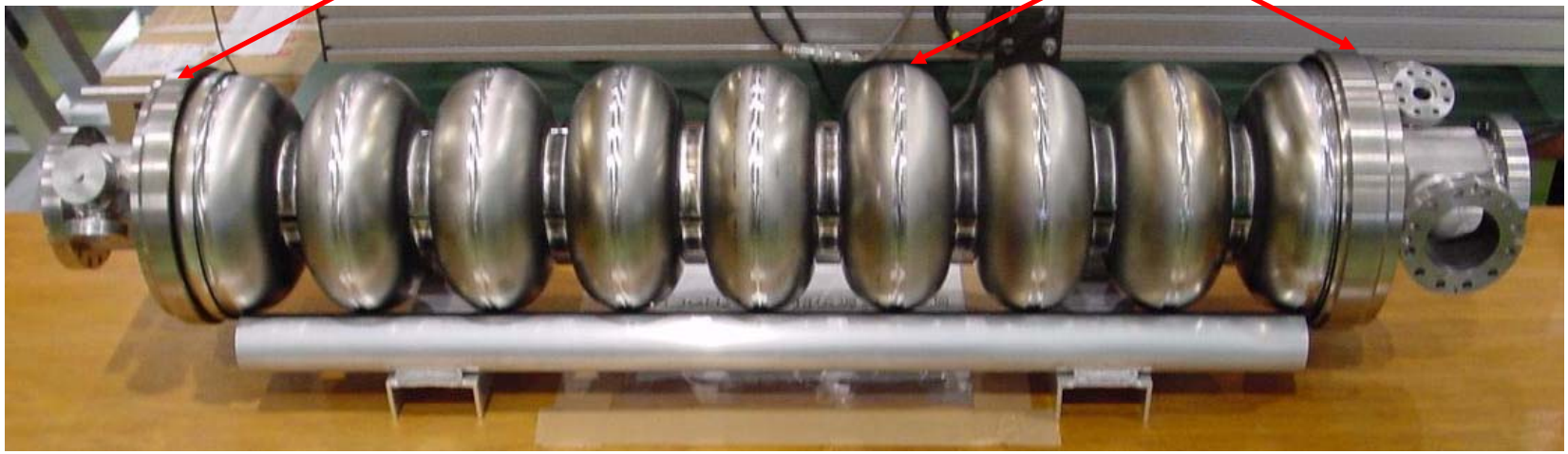
Fabrication of the STF Baseline Cavities



HOM coupler

End-groups

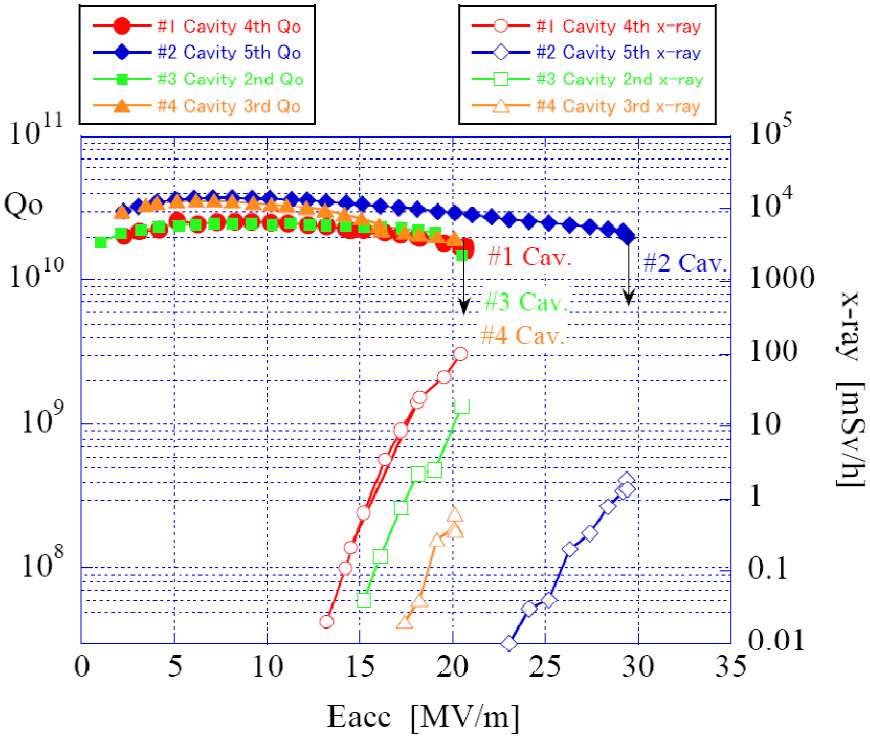
Center-cells



Final Performance in Vertical Tests

KEK TESLA-type Multi-Cells

(Kako, Noguchi)



Eacc,max

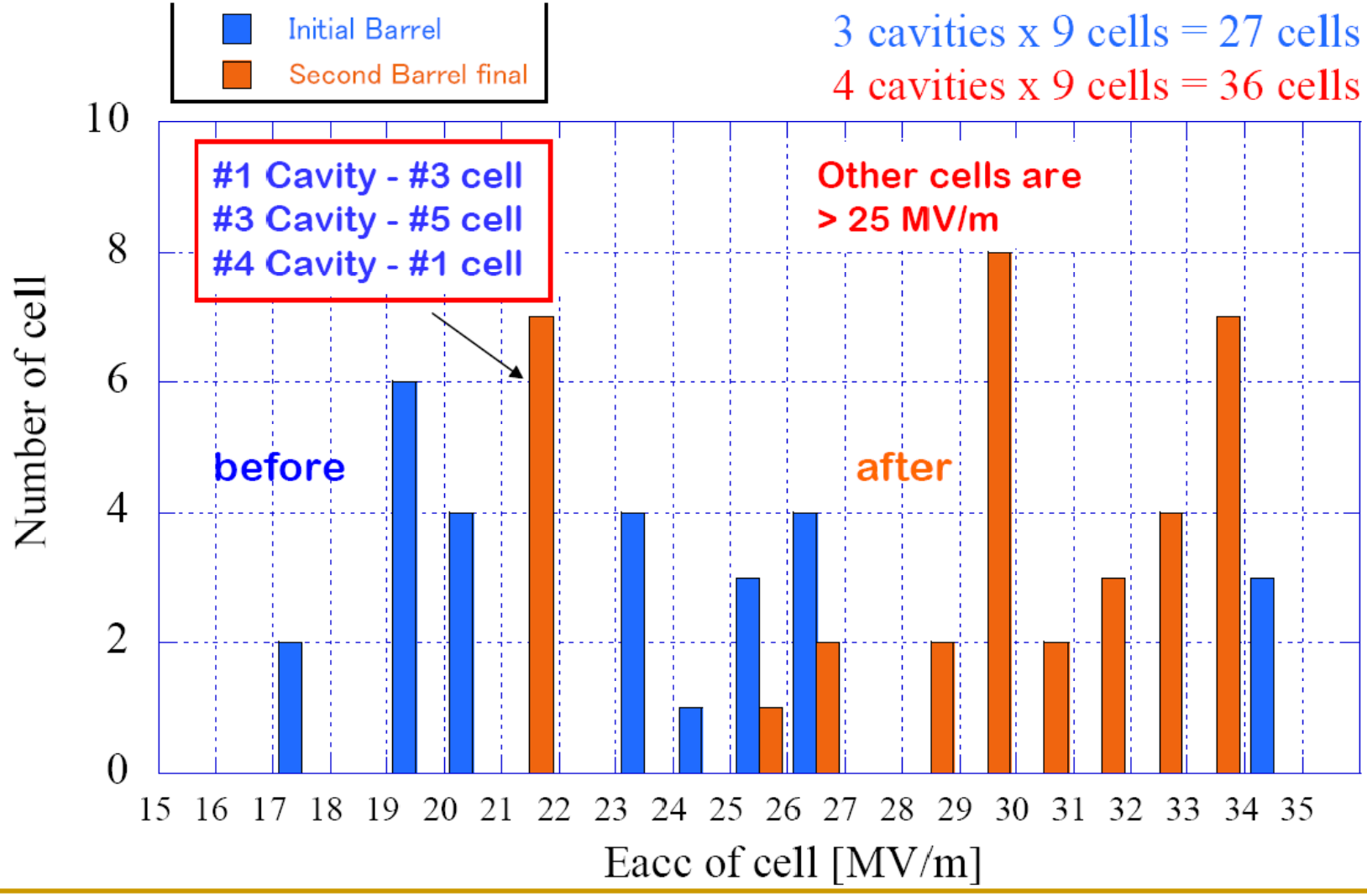
#1 20.8 MV/m
#2 29.4 MV/m
#3 20.5 MV/m
#4 20.2 MV/m

high Qo > 10^{10}

- New cavity vendor
- Surface treatment at 'standard' company
- Field emission in first processing
- Only few cells are limited at low field ~21 MV/m
  - Similar to first 2 production runs at TTF few bad cells, but larger number gaussian distribution at higher gradient
- Best cavity at 29 MV/m!
- Tighter QC for future production runs will be implemented

Vertical Test Results, Eacc of cells

Before (total~250 μm), after 2nd BP (total~500 μm)



Optional changes: Cavity

- Material
  - **Large-grain**
- HOM design
  - **Coupler kicks**
- Thicker endplate
  - **Lorentz-force detuning**
- Tank material
  - **Cost**
    - Need to understand cost differences between regions for Ti as tank material
    - Need to understand technical issues with stainless better
- Seal
  - **Reliability**
    - DESY ‘diamond’-shaped seal choice for XFEL
    - Each lab tends to have its favorite sealing technology
      - Need ‘neutral’ technical analysis on pros and cons
      - Need data on reliability e.g. number of re-assemblies needed
- End-group welding
  - **Cost**
    - Need performance demonstration
    - Need cost-benefit analysis

Criteria for down-select

- Need a fair process
  - **Have to define tests which everybody agrees to**
    - See Rich Staneks survey from the cavity KOM as a starting point
    - As Rich pointed out there was a surprising degree of agreement
- Timeline depends on available funding
  - **as you will see the testing proposed needs a significant effort to prove some ACDs**
  - **this is difficult to judge for me**

Testing Needed for ACDs

	Validation Survey			
2	If you make a change in this →	Cavity Shape LL OR RE	Cavity Material Large/Small Grain	Magr L
3	You validate the change by doing this ↓			
4	Can design change be made without testing?	N	N	
5	Number of components fabricated & tested?	24-30	30	
6	Is bench test only acceptable? (Y/N)	N	Y (V&H)	
7	Hours of bench testing?		1000hrs	
8	Required to be tested in cryomodules? (Y/N)	Y	N	
9	Number of cryomodules?	3		
10	Required to be tested in RF Unit/String test? (Y/N)	Y	N	
11	Number of hours of string testing?	1000hrs	0	

- From Rich Stanek's survey during the Cavity KOM
- Cavity material down-select possible after 30 cavities with High-Power test
- Cavity shape down-select only after 3 modules tested with beam

Cavity ACD Downselect

- During Cavity KOM the discussion was to agree on test procedures needed to validate a design change
- Main Issues
  - **Cavity design**
    - HOM damping concepts need verification
      - Could discuss whether a completely new shape and rotation of HOMs (for wakefield reduction) have identical requirements
    - Beam test seems indispensable
  - **Cavity material**
    - seems to be straight-forward
    - A certain amount (~30 cavities) should have been high-power tested
  - **Cavity preparation**
    - This was not discussed at the KOM in detail
      - Is not really an ACD topic, rather an addition to the baseline
      - Look at S0 planning

Translate the testing requirement to a timescale

- Neglect financial constraints for one slide
- 30 Cavities
  - **Production: 0.5 years minimum**
    - if material available
  - **Preparation and horizontal test: 1 year minimum**
  - **Installation in modules and string setup: 1 year minimum**
- Large-grain material
  - **~2 years to arrive at the proposed tests**
- Alternative shapes
  - **At least 2-3 years**
- Financial constraints mode switched on again

Cavity Preparation Down-select

- Main issue is reproducibility for the baseline
  - **Candidate processes developed until today are very promising**
    - Fresh EP, Degrease, Alcohol rinse
  - **Test requirement (see S0)**
    - Confirm results in more than one lab (tight-loop or variant thereof could be used)
      - Time-scale: 1 year
    - Need to vertically test 30 cavities in a production-like mode with sufficient yield in ultimate experiment
      - Time-scale. 1 year minimum if cavities available, if production needed add 1 year
- Total time-scale is roughly 2 years minimum
  - **Just in time for EDR (getting tighter daily)**
    - Set as a timescale by GDE EC...

Discussion topics

- Are there further ideas ?
  - **Of course I like to collect those as soon as possible**
- Are there further ideas on the testing of components and concepts ?
- How do we keep the process open enough not to miss an important opportunity?
  - **funding limitation needs to be addressed as we are proving the baseline (S0) and work on ACDs simultaneously**
- Time-scales given are optimistic
  - **e.g. assume no breakdowns in infrastructure like high-pressure rinse systems**