Cavity Work Packages

Lutz Lilje
GDE

Outline

- Request form PM
  - **Progress and finding from KOM,**
  - **Component/system and the interfaces design parameters,**
  - **Work packages,**
  - **Summary of discussions in the parallel session**

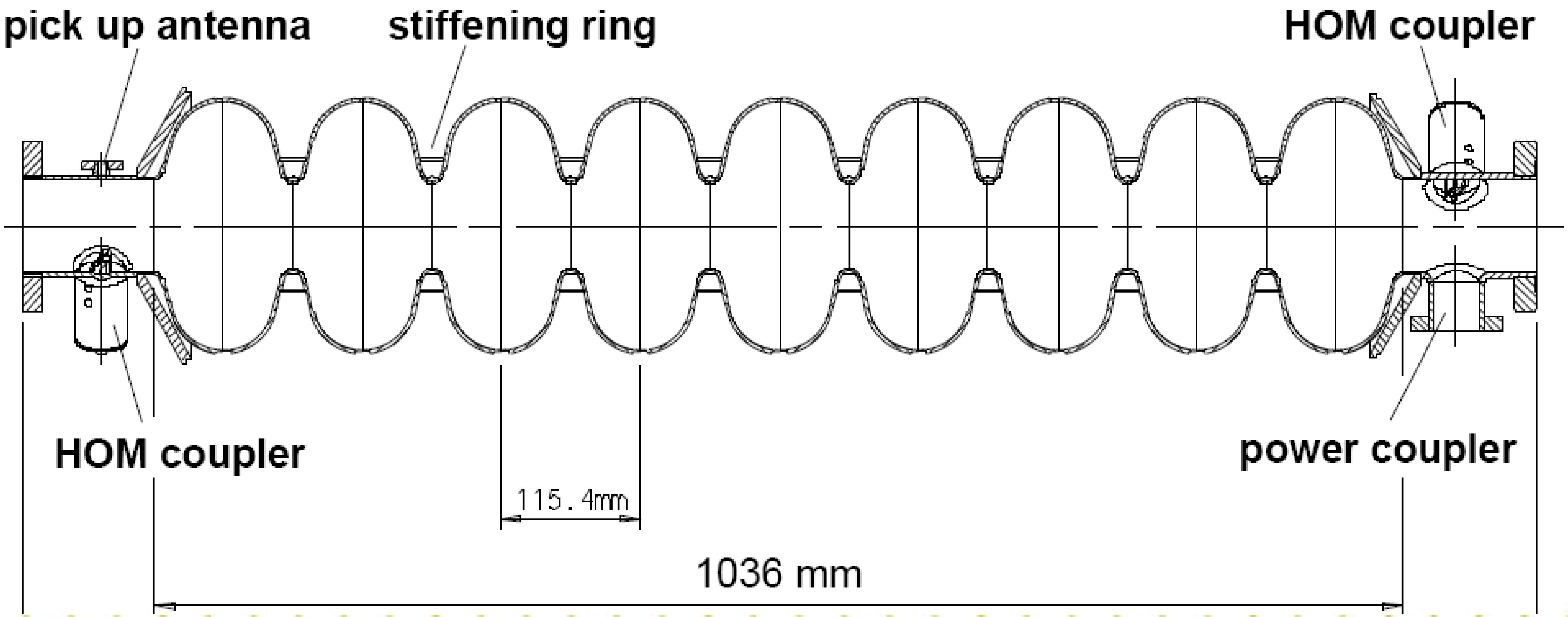
- will discuss this along the talk for Cavity
  - **Performance, Design, Manufacturing**
  - **Cavity systems (coupler, tuner etc.) see next talk by H. Hayano**

Cavity KOM Findings

- Integration and Plug-compatibility
  - **Definition of interface**
    - Fixing outer envelope of cavity allows flexibility for RF design
      - Flange system needs technical evaluation
- Gradient performance
  - **New results available available for ‘S0‘**
    - Field emission is being reduced with specific surface preparation addressing sulphur contamination
    - Thermal breakdowns are now limitation causing still a significant spread in performance
      - Especially for new vendor cavities but also at last DESY production
        - » Diagnostics tools (temperature mapping) essential
  - **Setting up new infrastructures will require effort**
- Organizational
  - **Down-selection for alternatives**
  - **Cost optimization**
  - **Integration of new R&D initiatives**
- Industrialization
  - **XFEL experience**
    - new developments for module integration

Assumptions for Plug Compatibility

- Outer dimensions
  - **Critical for cavity package and module groups**
- RF Specification
  - **When the cavity stays within its mechanical bounds possibly less critical for the interfaces to other systems**
  - **Likely exception: Iris diameter is beam dynamics issue**

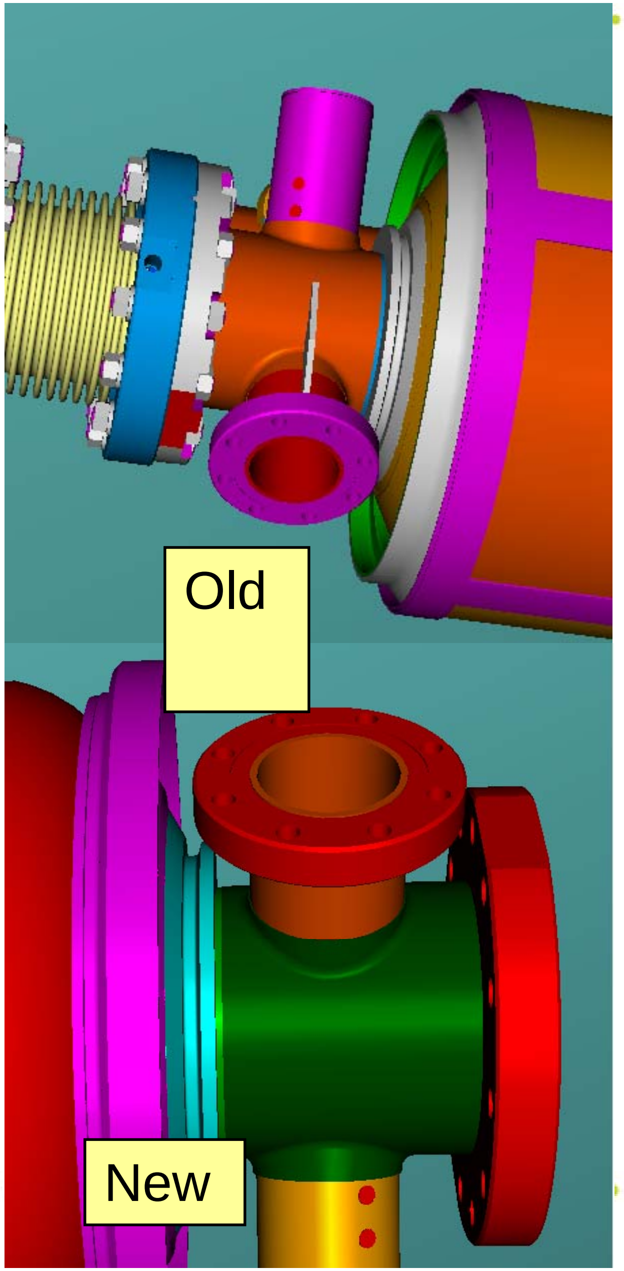


ILC Cavity RF Parameters – Fixed and Changeable

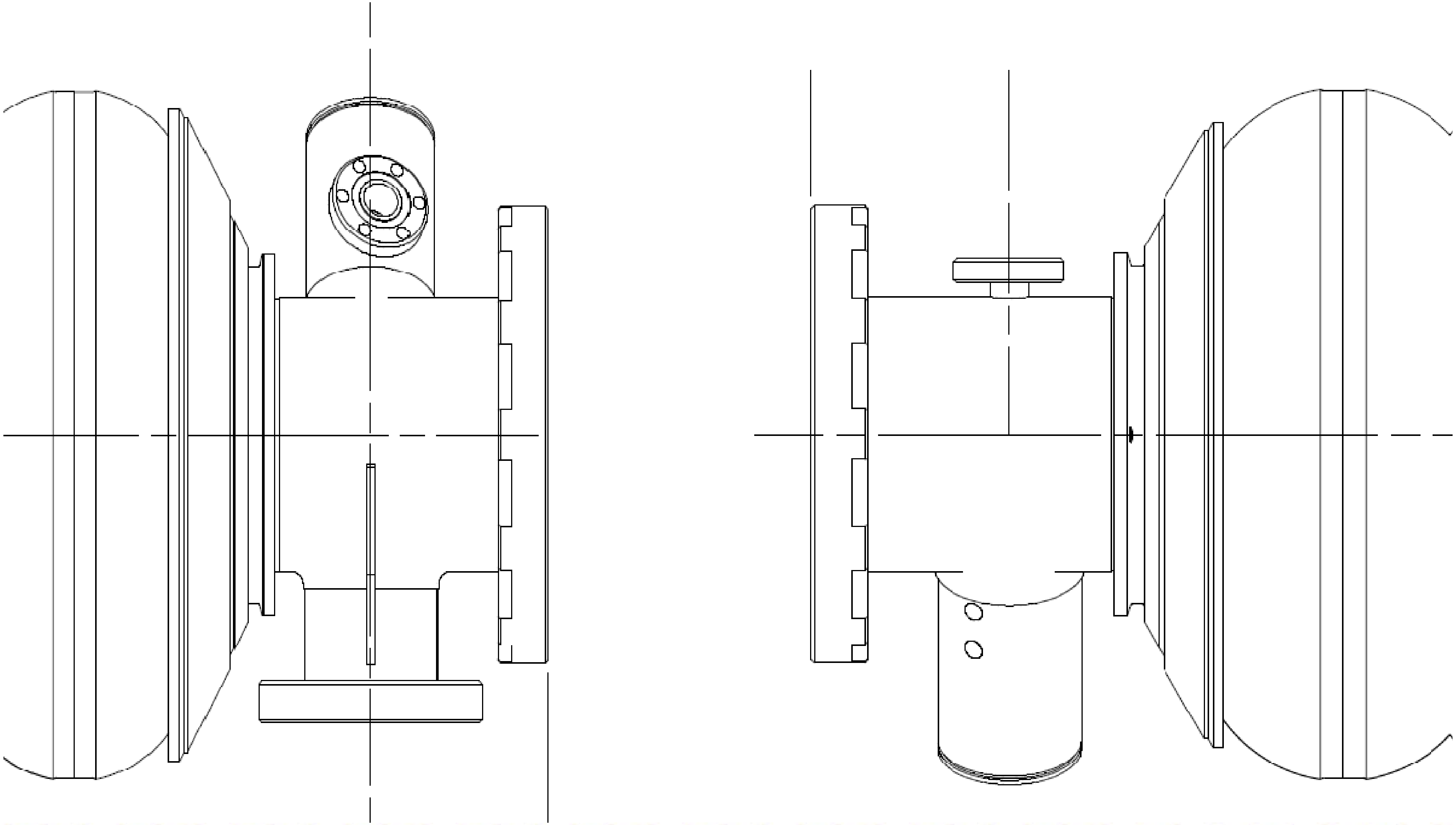
Parameter	Value
Type of accelerating structure	Standing Wave
Accelerating Mode	TM_{010}, π mode
Fundamental Frequency	1.300 GHz
Average installed gradient	31.5 MV/m
Qualification gradient	35.0 MV/m
Installed quality factor	$\geq 1 \times 10^{10}$
Quality factor during qualification	$\geq 0.8 \times 10^{10}$
Active length	1.038 m
Number of cells	9
Cell to cell coupling	1.87%
Iris diameter	70 mm
R/Q	1036 Ω
Geometry factor	270 Ω
E_{peak}/E_{acc}	2.0
B_{peak}/E_{acc}	4.26 $mT\ MV^{-1}m^{-1}$
Tuning range	±300 kHz
$\Delta f/\Delta L$	315 kHz/mm
Number of HOM couplers	2

Cavity length, Diameter, Beam tube and Flange Design

- Length: 1247 mm
  - **Will define a slot length with cryomodule group**
- Maximum Outer Diameter:
  - **Cells: 210 mm**
  - **HOM coupler: 232 mm**
- Beamtube
  - **'Tesla short' diameter: 78 mm**
- Flange system
  - **6 flanges total**
    - see XFEL example
  - **Several sealing systems available**
    - Choice should take into account
      - Reliability
      - Potential re-assembly for re-test
  - **Need WP to make a proposal**
- Interconnecting bellow
  - **after definition of flange system into module group's responsibility**

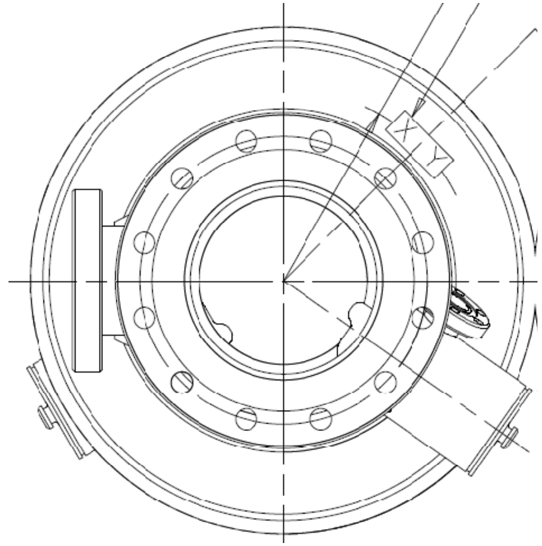


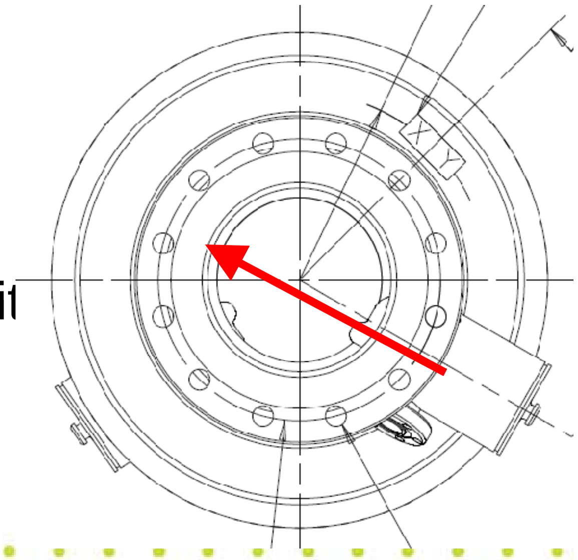
Coupler Port Location



Coupler Port Location

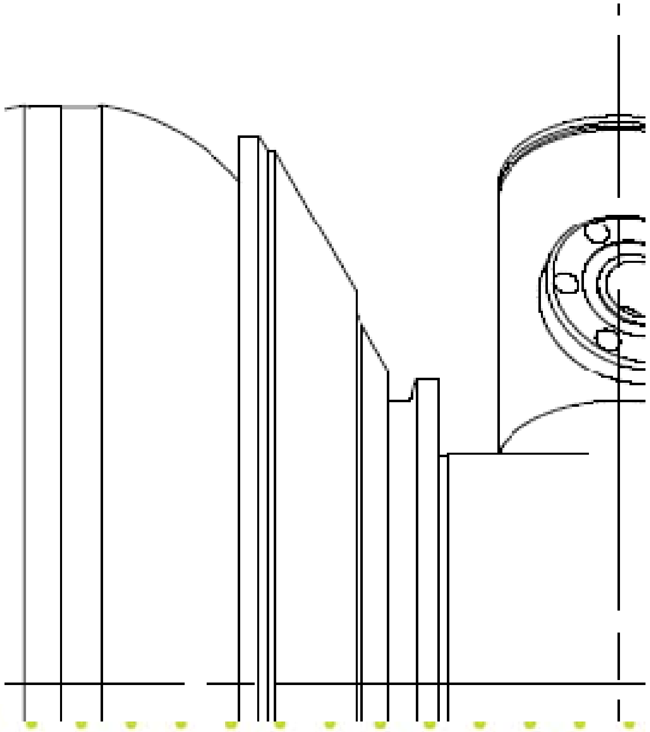
- Issues
  - **Wake-potential needs further look**
    - rotating one end group by 180° is likely solution
  - **Port position**
    - Depends on thickness of conical disk and Magnetic shielding position
  - **Port size**
    - Do we need larger power capability?
  - **Cabling**
    - With tuner not at extreme position this is a bit more relaxed





Definition of Weld Position for He Tank

- Tank welding after performance test
  - **Conical disks part of the bare cavity**
  - **Tank material need be welded to disk**
  - **Magnetic shield position**
- Technical evaluation of options needed



Other Topics

- Alignment tolerance: 300 um
- Referencing the Cavities
  - **'Refererence ring' is one of the more expensive parts in the fabrications**
    - are there better options than this?
    - Cavity supports are attaching to reference ring
- Magnetic shielding: 20 mG at Cavity for $Q=10^{10}$
- Maximum allowed pressure
  - **High pressure vessel codes need discussion**
    - Some harmonization between US and EU, Japan more difficult
  - **TBD:**
    - 4 bar He vessel
      - cold, vacuum inside
        - » agreed
    - 2 bar (1.3 bar KEK number)
      - warm, vacuum inside ?
        - » not clear !!!
  - **Action item:**
    - compile list for different conditions
    - CHECHIA test cooldown conditions

‘S‘-issues: Overview

- S0
  - **Achieve 35 MV/m in 9-cell cavity in vertical dewar tests (low-power) with a sufficient yield**
  - **Staged approach with intermediate goals to track progress**
- S1
  - **Achieve 31.5 operational as specified in the BCD in more than one accelerating module**
  - **… and enough overhead as described in the BCD.**
- S2
  - **a string of N modules with full xyz...by date ...**
  - **Need for a linac ?**
  - **Endurance testing**

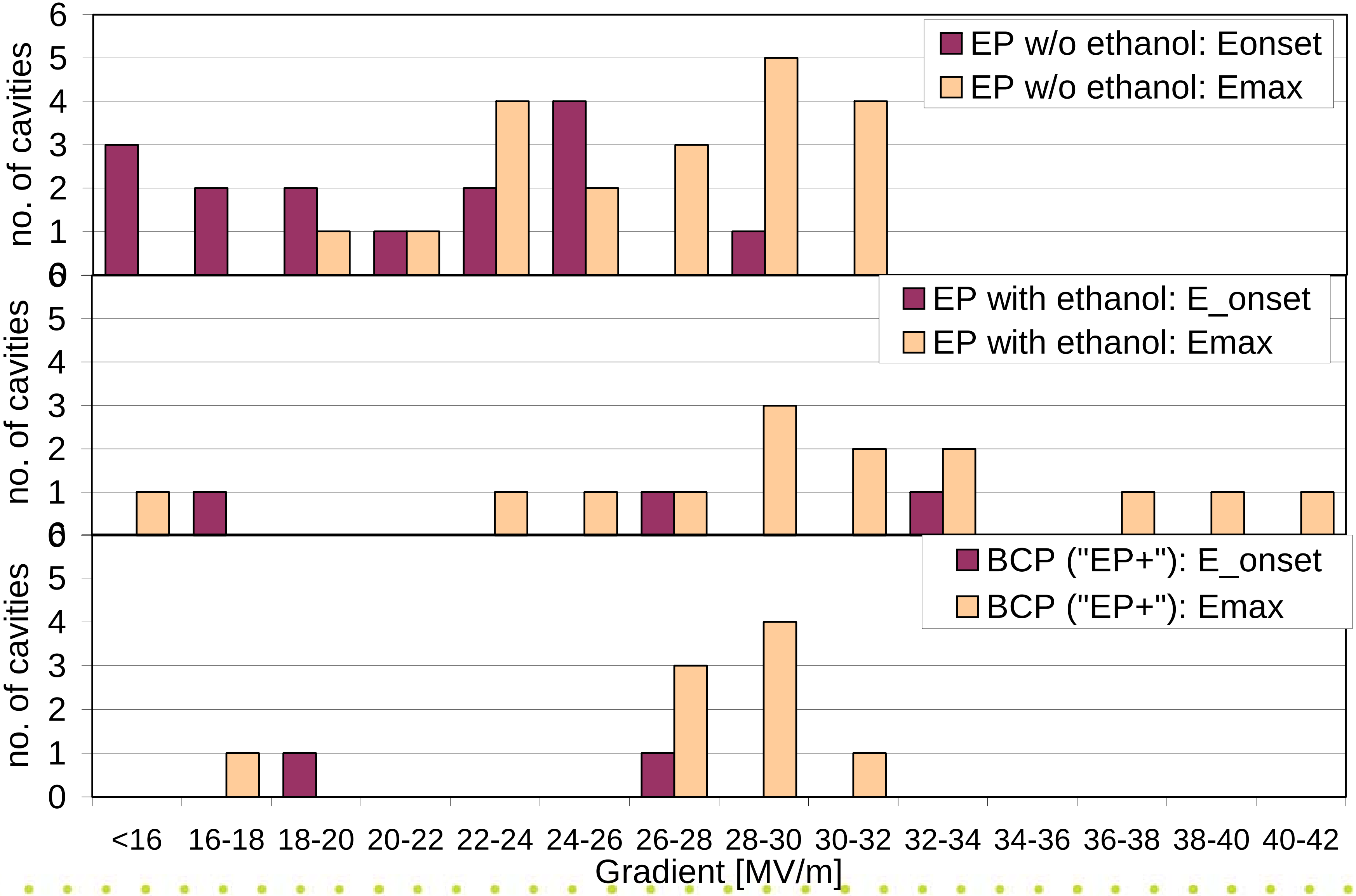
S0 Plan

- Three main activities which are closely coupled and partially progressing in parallel
  - **This is needed to separate cavity preparation and production issues**
- Single-cell R&D
  - **Establishing more reliable final preparation parameters**
    - Focus on the final rinse after EP before HPR:
      - E.g. Ultrasound, Short EP (or HF rinse), Ethanol, H2O2
- Tight-loop
  - **International multi-cell cavity exchange**
    - 1st round
      - Includes repeated processing in the same institute
        - » Consistency of preparation needs check
      - Comparison of regional differences in preparation and testing
    - 2nd round
      - Use single-cell results and implement on multi-cells
- Production-like effort
  - **Monitor ongoing productions**
    - Esp. XFEL preparation
    - Use qualified and new vendors
  - **Use improved preparation process for an ultimate batch of cavities**
- A lot of data will be (is already) available by the time for the EDR writing

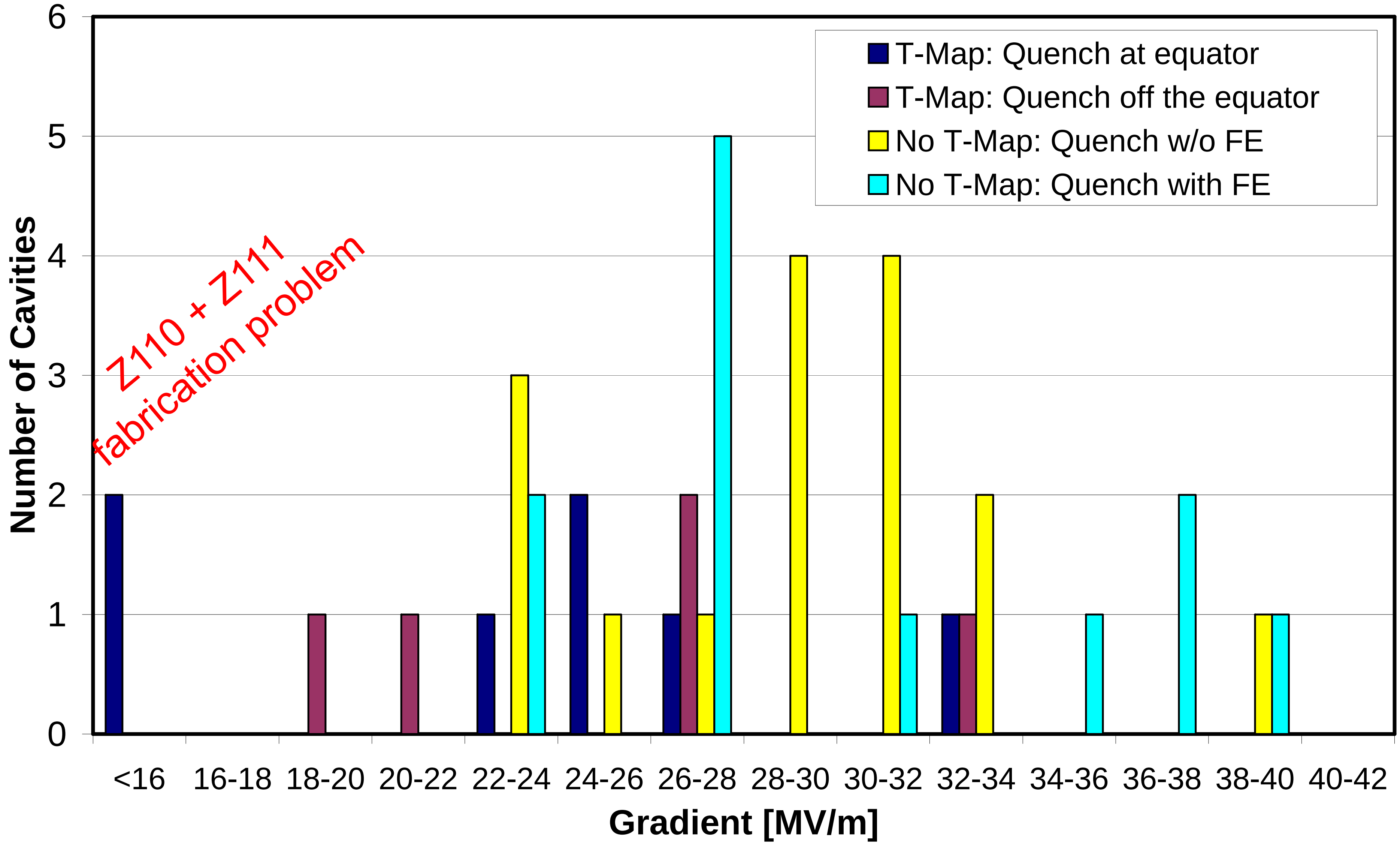
S0 Plan: Where are we?

- Three main activities which are closely coupled and partially progressing in parallel
  - This is needed to separate cavity preparation and production issues
  - *Qualification of new vendors is difficult*
    - *Multi-cell results in Japan and US are only partially promising*
      - *Several cavities limited to gradients below 20 MV/m*
    - *This needs considerable resources for preparation and tests*
  - *Infrastructure not available*
    - *New installations no yet fully operational*
      - *KEK and ANL/FNAL*
      - *DESY sometimes*
    - *Infrastructure blocked*
      - *DESY progresses e.g. with module assembly for industry training*
    - *Missing redundancy in infrastructures is an issue*

DESY 4th: Field Emission Analysis



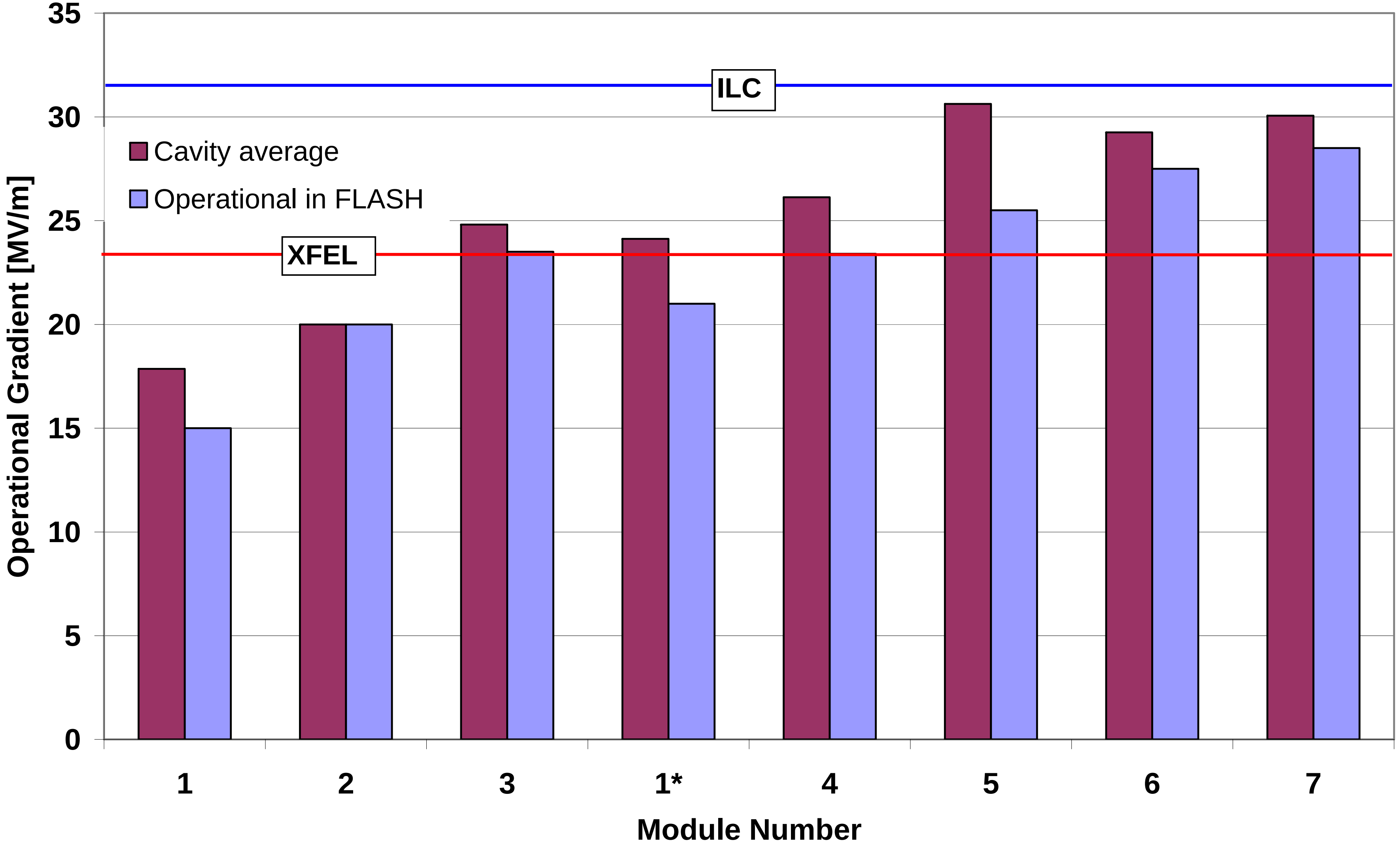
Analysis of Quenches 4th Production



Cavity Performance Limits

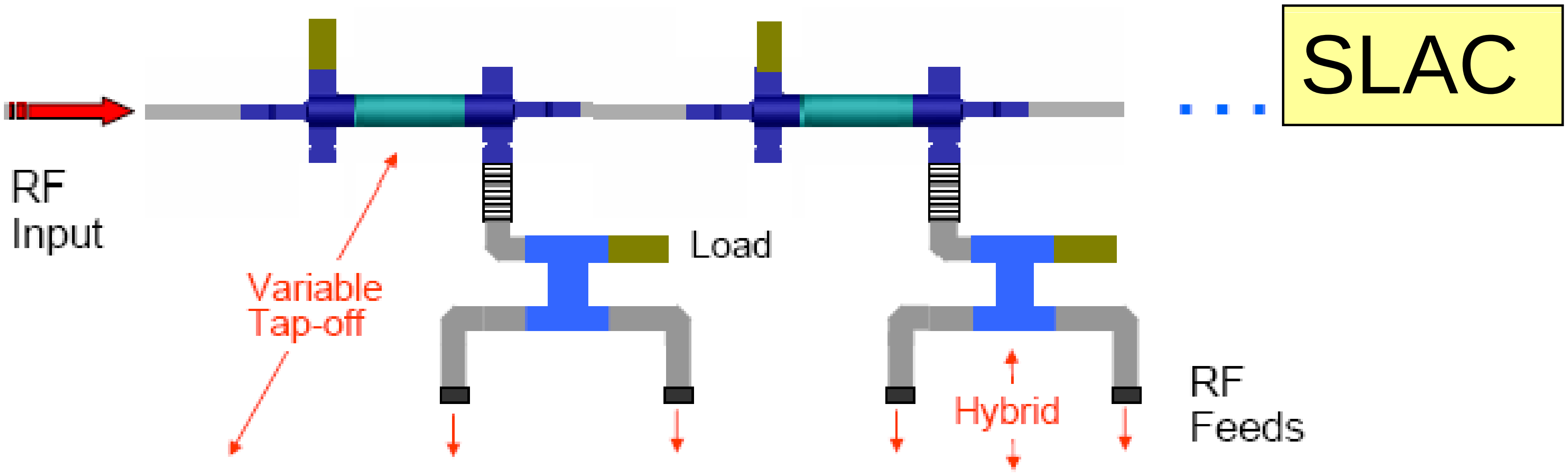
- Field emission
  - **New rinses seem successful**
    - Simplest ones are possibly degrease and ethanol
    - Short EP is more effort, depends on implementation on multi-cells
  - **Field emission was, is and will be an uphill battle**
    - Need confirm results of new rinses across regions
      - Original idea was to use the cavity exchange for this
  - **Quality control needs to be further improved**
    - Better understanding of the HPR systems
      - Comparison underway (TTC)
- Thermal breakdowns (Quenches)
  - **Especially with new vendors**
    - Need to make sure that the cleaning steps including the etch before welding are done
    - Need to be able to distinguish whether quench is in equator or elsewhere: Temperature-mapping
  - **Quality control needs further improvement**
    - DESY 4th production last batch of 4 has two bad cavities
    - Several of the lower performing cavities show quenches in the equator weld
  - **Analysis of quench locations could be the next step**
    - Possibly destructive….
  - **Could try to involve TTC again**
    - Was successful for rinsing parameters

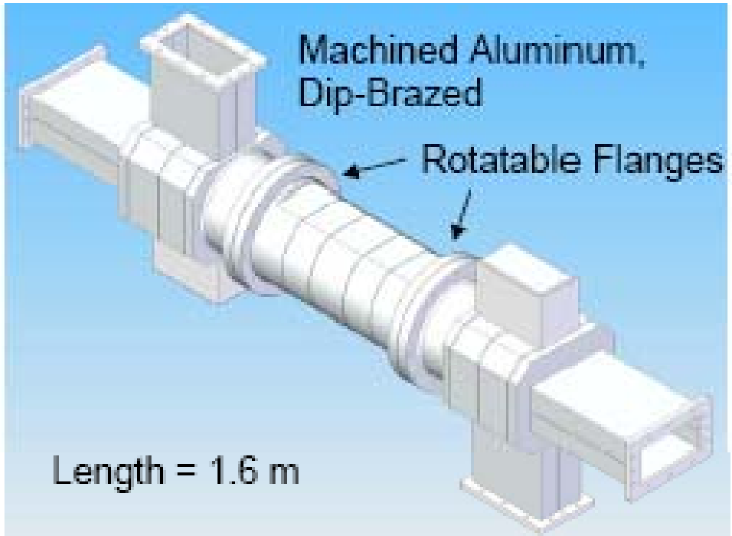
Side remark: S1 Data from DESY

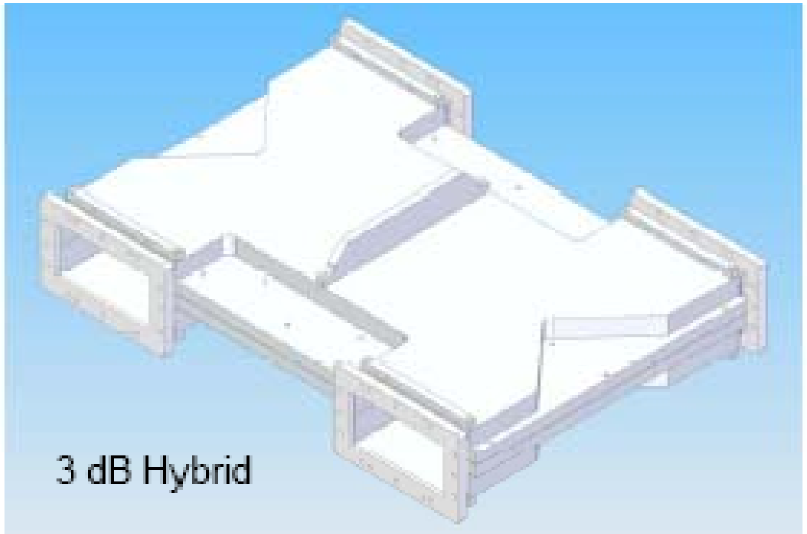


Cavity average will be usable with alternative RF distributions (SLAC, XFEL)

RF Distribution System without Circulators but with Variable Tap-offs (VTOs)







Work packages

- The work packages have to account for some of the ongoing R&D as well as for the design and industrialization issues
- Main R&D packages are related to
  - **Continuing 'S0'**
    - e.g. Re-evaluation of low-power acceptance test specification in light of variable tab-offs in RF distribution
  - **Most promising alternatives**
    - Cavity shapes
    - Large-grain material
- Industrialization and cost optimization WP still need one more iteration on the scope
  - **Integration of cost cutting proposals and related R&D initiatives**

WP C1: Gradient Performance

- 1.1 Tight-loop effort
  - **1.1.1 Finalize the tight-loop process.**
- 1.2 Production-like effort
  - **1.2.1 Treat 30 cavities with EP + ethanol process.**
  - **1.2.2 Treat 20-30 cavities with EP, Degrease.**
  - **1.2.3 Treat 10-20 cavities with fresh EP.**
- 1.3 Preparation for ultimate cavity batch
  - **1.3.1 Evaluate data from tight-loop and production data**
  - **1.3.2 Treat 30 cavities with ILC process**
- 1.4 Single-cell program
- 1.5 Common performance evaluation
  - **1.5.1 Database setup**
  - **1.5.2 Data evaluation between laboratories**
- 1.6 Gradient proposal for the EDR
  - **1.6.1 Definition of vertical test gradient specification for ILC**
  - **1.6.2 Final proposal for ILC gradient**

WP-C2. Fabrication

- 2.1 Material
  - **2.1.1 Material specification**
- 2.2 Alternative materials
  - **2.2.1 Large grain cost evaluation**
  - **2.2.2 Large grain multi-cell cavity development and testing**
- 2.3 Fabrication method
  - **2.3.1 Analysis of EBW performance**
  - **2.3.2 EBW specification**
- 2.4 High Pressure Vessel regulation

WP-C3. Preparation

- 3.1 Baseline Process
  - **3.1.1 Process Specification**
- 3.2 Alternatives
  - **3.2.1 Dry-ice**
  - **....**

4 WP-C4. Cavity Design

- 4.1 Specification of outer envelope
  - **4.1.1 Outer diameter, length**
  - **4.1.2 Sealing technology**
  - **4.1.3 Input port diameter**
- 4.2 Preparation for the cavity shape decision
  - **4.2.1 Definition of tests**
  - **4.2.2 Testing of cavity shape alternatives**
- 4.3 Lorentz detuning concept
  - **4.3.1 Evaluation of tests**
- 4.4 Beam dynamics
  - **4.4.1 HOM Concept**
  - **4.4.2 Wakefields**
  - **4.4.3 Alignment**
  - **4.4.4 Straightness**

WP-C5 Cost Optimization and Industrialisation

- Under discussion still!

- 5.1 Evaluation of Cost-cutting proposals

- 5.2. Industrialisation Issues
  - **5.2.1 Review of XFEL Industrialisation plan**
  - **5.2.2. Models for Industrialisation in the regions**

Example: ACD Down-select and Testing

- Testing of alternate Cavities requires (according to Rich Stanek's list)
  - **Cavity shape:**
    - 24-30 cavities in 3 modules with beam including
      - Low-power performance test
      - High-power test (individual or full module)
      - HOM testing with beam
  - **Cavity material:**
    - Cost-benefit analysis
    - 30 cavities in bench tests (low-power and high-power),
      - Performance test
      - Getting experience with pulsed operation
      - no module or beam test needed
  - **Cavity 'Design For Manufacturing' (similar to XFEL)**
    - Minor design changes for easier welding, simpler machining etc.
    - Few cavities in bench tests, if at all
  - **For other changes**
    - Needs discussion

Summary

- Work packages defined
  - **includes an estimate on resources needed**
- R&D WPs
  - **Gradient performance**
    - Encouraging results (also for the modules) but still significant amount of work to do
      - Program needs to make sure that sufficient diagnostic capacity is available
      - Focus need address new vendors and QC issues in weld preparation
  - **Most promising ACDs are included**
    - Cavity shape and material
- Design and Cost optimization
  - **Develop ‚plug-compatible concept further**
    - some things are straight-forward, others need technical evaluation
      - Outer envelope being defined
  - **New R&D initiatives have to be evaluated for their cost cutting/performance improvement first**