Module Evolution from TTF to ILC

Bernd.Petersen@desy.de
DESY –MKS-
Lutz.Lilje@desy.de
DESY -MPY-

Overview

- Summarize the technical changes which are going to be implemented for the next cryomodules:
  - TTF III plus
- Summarize the design options needed to be implemented for the ILC
- Try to show how one can make a smooth transition without sacrificing too much of the synergy XFEL-ILC

XFEL and ILC modules

- Cryogenic layout fulfills specification
- Cross section likely to be the same
  - Standard diameter piping is desirable
- Cavity support system works o.k.
  - Cavity position will be kept nearly fixed with the help of an invar rod
  - Alignment is o.k., further tests desirable
- Technical improvements from TTF III modules for XFEL known today
  - Cavity HOMs modified
    - Mirrored HOM
    - Larger Pickup-port
  - Quadrupole package
    - supported like cavities (sliding fixtures)
    - 2K operation
  - Position of vacuum coupler pumpline changes
  - Modules suspended from the ceiling

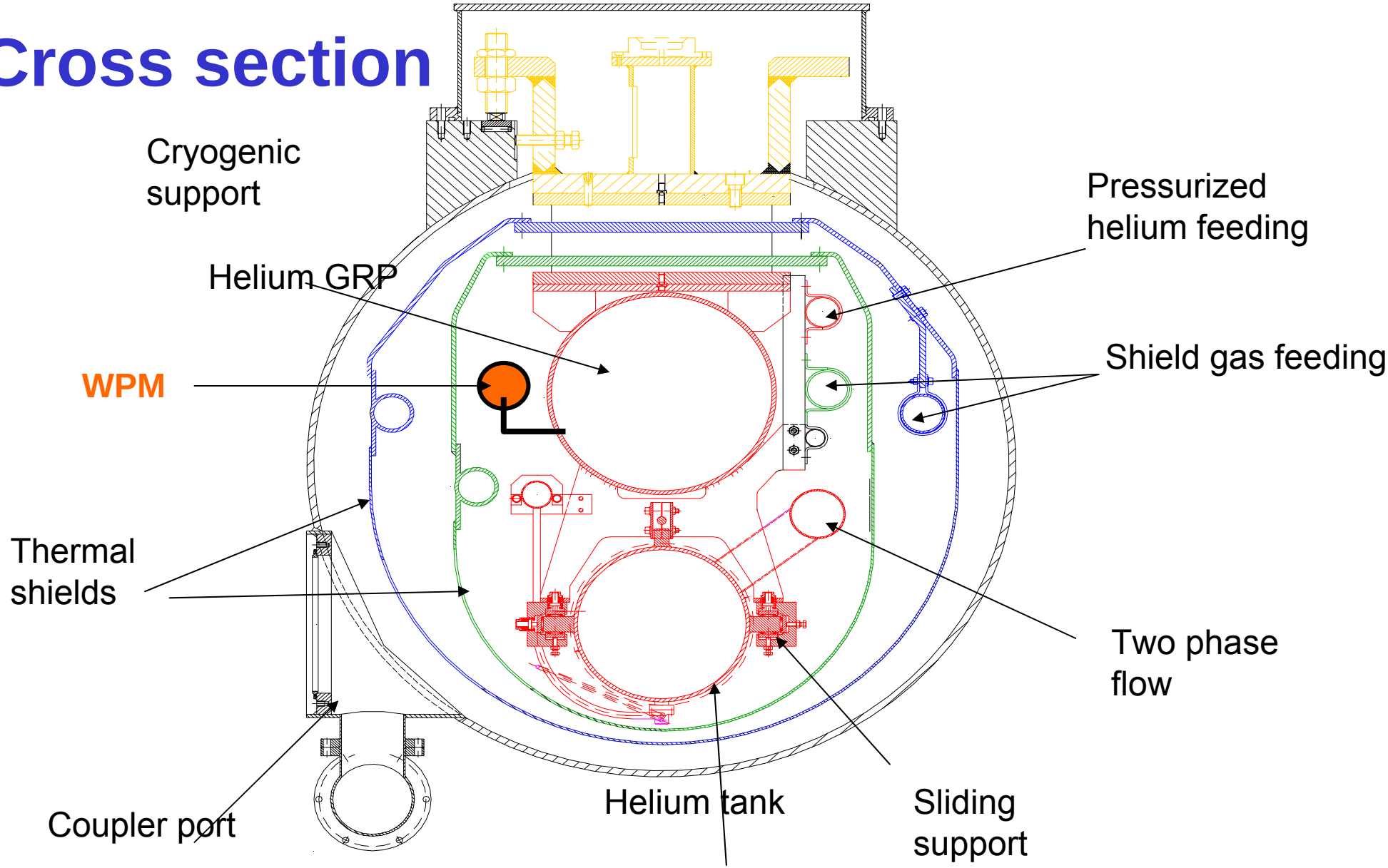
XFEL and ILC modules II

- Technical issues that need work
  - Transport issue needs to be solved
  - O-ring sealings should be replaced
    - All metal gaskets on the cryostat
    - Welding instead of sealings
  - Tuners
    - Can be the same (if a compact design becomes available soon enough for the XFEL)
    - Piezo tuner needs engineering design
  - Vibration measurements
    - Underway, need more work
  - Coupler processing
    - Studies at LAL Orsay underway

XFEL ≠ ILC

- Cavity spacing
  - XFEL: N times lambda distances needed
    - Minor change on TTF cryostat
  - ILC: As compact as possible
    - Cavity design not fixed yet
    - Proposal:
      - » For the first iterations use existing cavity design and evolve cryostat design
      - » Other components (like the tuner) can be made fit already now even with a more spacious cryostat
- 12 m ≠ 17 m
- Quadrupole position might be different

Cross section



Module Length TTF-Type 3 and XFEL Modules

- **Lamda: 230,6 mm**
  - **module length: n x lambda/2**
  - **n x module length within a few millimeters (linac installation!!)**

- **TTF type 3** **12 200 mm, but 53 x lambda = 12 221,8 mm**
  ➔ TTF type 3 is to short by 21,8 mm

- **XFEL type** **Goal: Shorten module length by 230,6 mm**
  ➔ depends on space needed for magnet, BPM and HOM-absorber (detailed design underway)

Differences for Magnet / BPM longitudinal movement

- **Because:**
  - **XFEL magnet will be cooled at 2K (like the cavities)**
  - **XFEL magnet vessel will be made of Titanium**
  - **And most important:**
    - **XFEL magnet/BPM will be supported like cavities!!!**
    - **This means, longitudinal movement will be reduced drastically.**

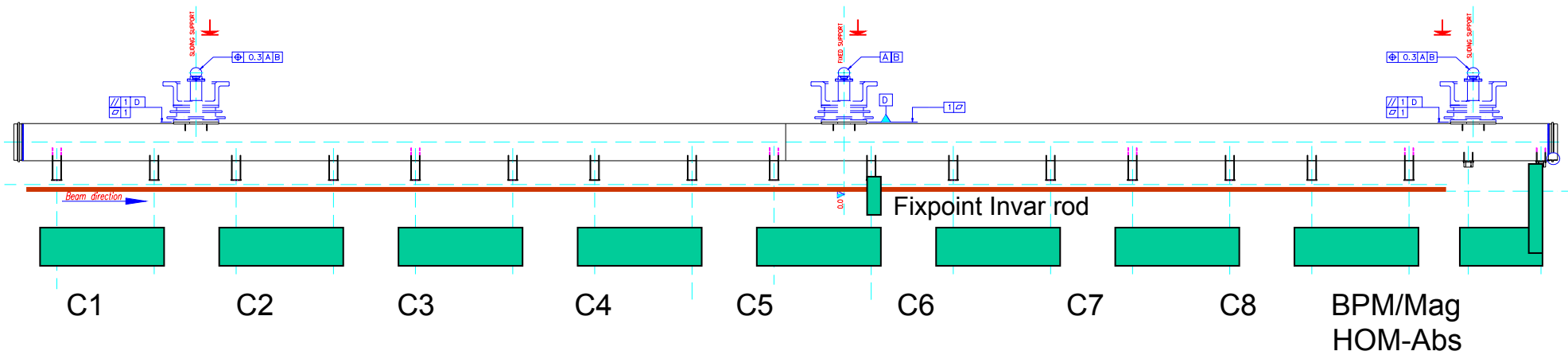
- **Rough comparison for longitudinal movements at the end of the of beam line in direction module center:**
  - **TTF type 3 ~17 mm**
  - **XFEL type ~ 4 mm**

- **➔Impact for beam line bellows…**

Helium GRP/Posts

logitudinal movement posts during cool down <u>module type TTF III</u>

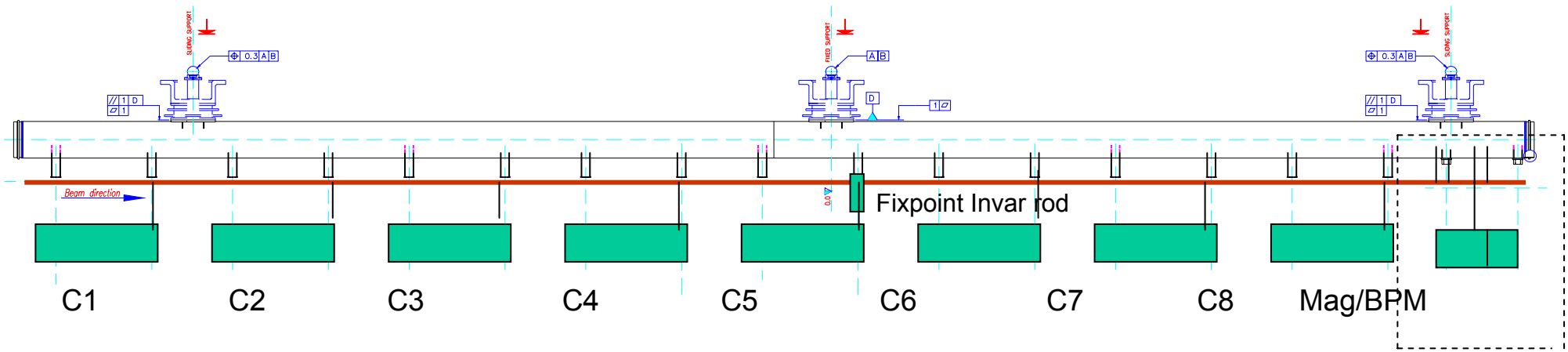
-->sliding fixed ←sliding



Helium GRP/Posts

longitudinal movement posts during cool down **module type TTF III plus (XFEL)**

-->sliding fixed ←sliding

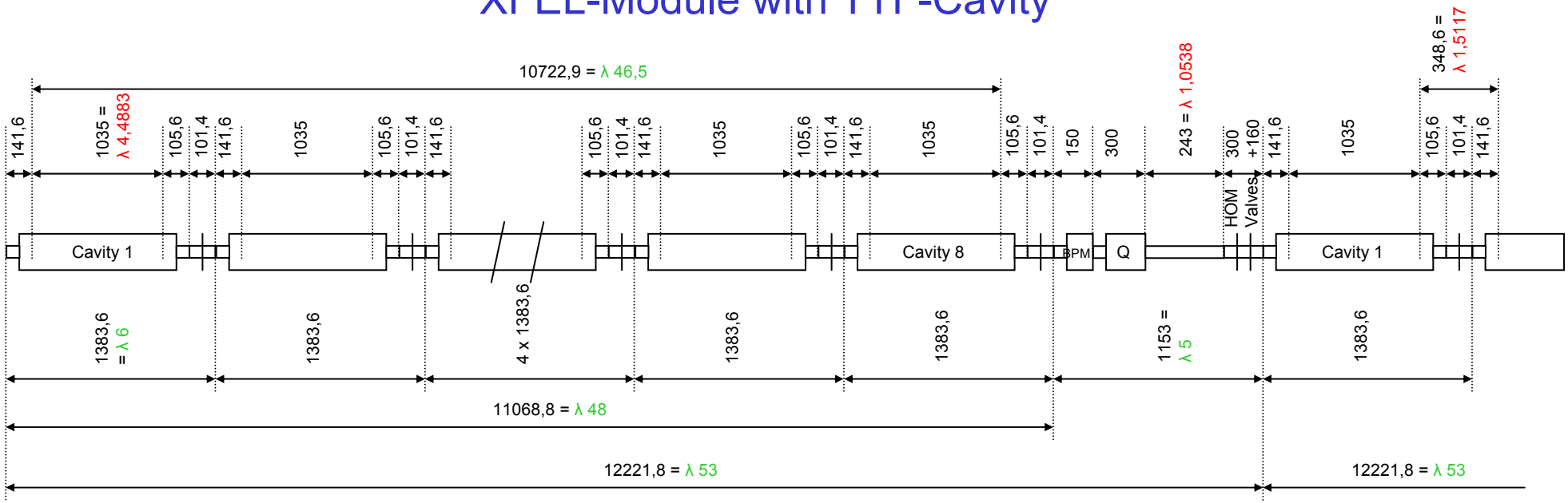


HOM-Absorber

Between Modules

XFEL-Option

XFEL-Module with TTF-Cavity



- New Cold mass design
  - -Minor modification on coupler distance
- Correct lambda cavity-unit and module

- Available spacing for magnet, BPM and HOM absorber :
  - For 12221.8mm module length: 1153
  - For 12221.8 minus lambda/2: 1038
  - For 12221.8 minus lamda: 923

Quadrupole, BPM, HOM absorber package

Estimated length of the components	L [mm]	Known accuracy to date	Comments
2 valves	160		Fixed
Magnet	300	maximum	Design request.
BPM	150	10 mm	Needs confirmation for French BPM version
HOM with pump connection	300	10 mm	
Estimate:	**910**		

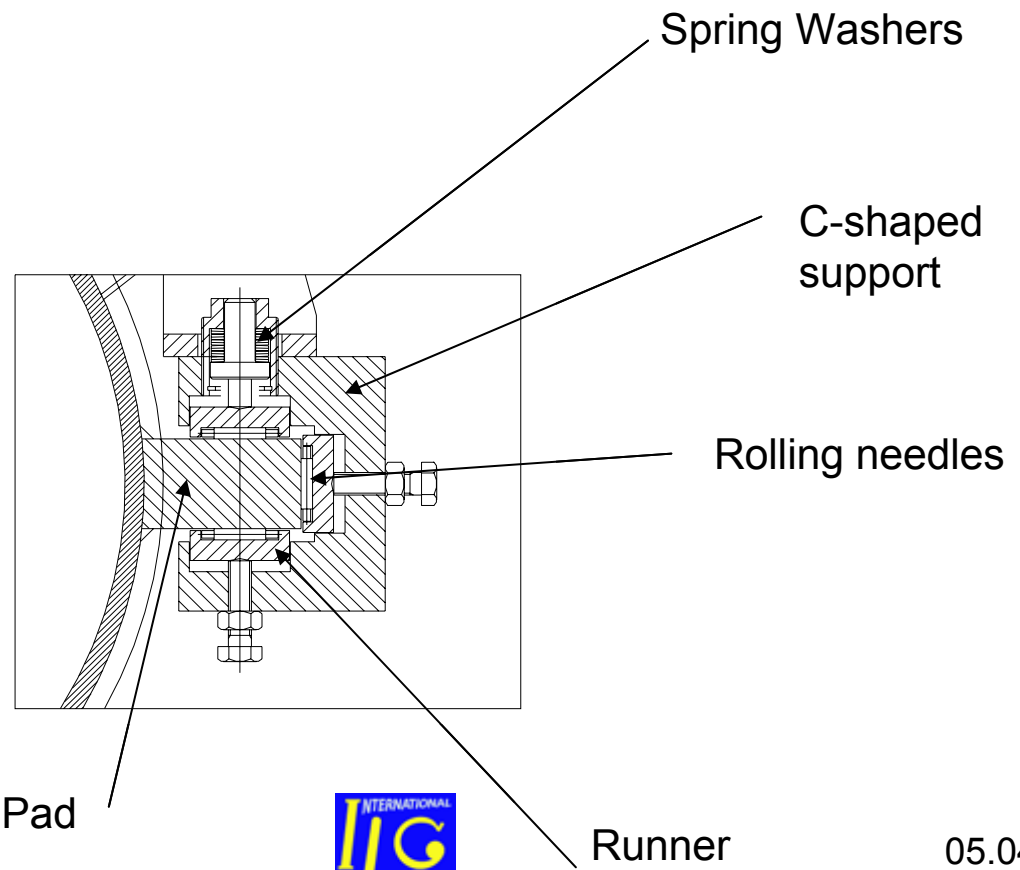
– Reminder: For 12221.8 minus lamda: 923mm

Alignment Modules in Linac Cavity/Magnet-Axes

- Verified new concept in module type 3:
  - Cavity position fixed with invar rods
    - z-position with x-ray at coupler ports/antenna
    - x/y-position with WPM-system
      - Continuous online measurements
      - But finally test with beam needed using HOMs (underway)

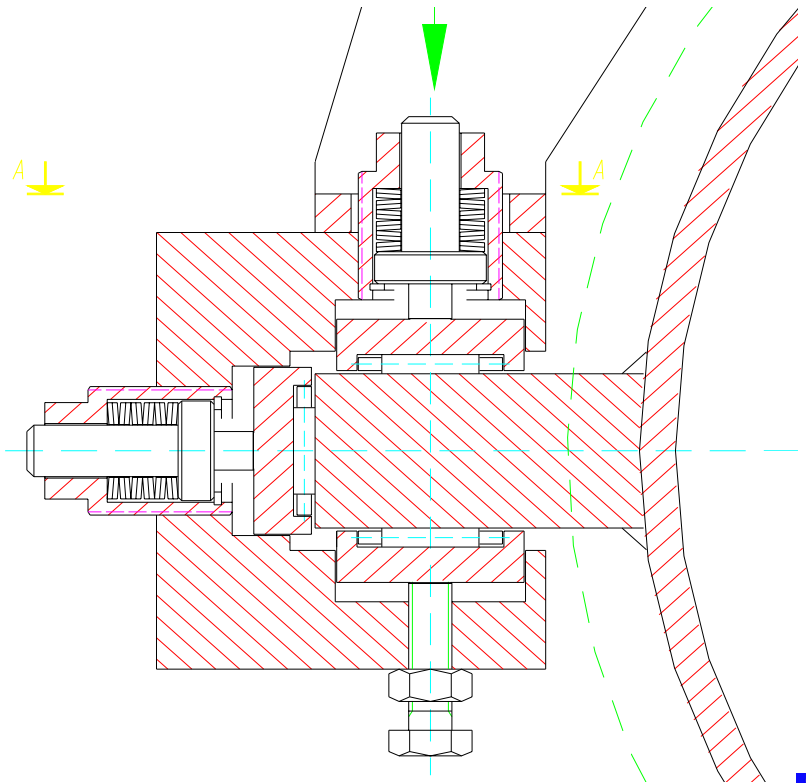
Cavity supports principle

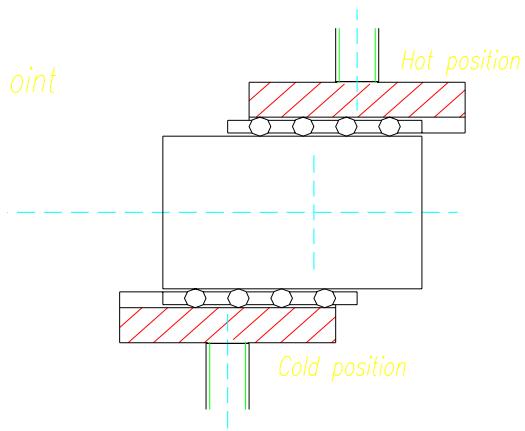
- Four C-shaped stainless steel elements clamp a titanium pad welded to the helium tank.
- Rolling needles reduce drastically the longitudinal friction
- Cavities are independent from the elongation and contraction of the HeGRP.
- Lateral and vertical position are defined by reference screws
- Longitudinal position can be fixed by the use of an Invar rod



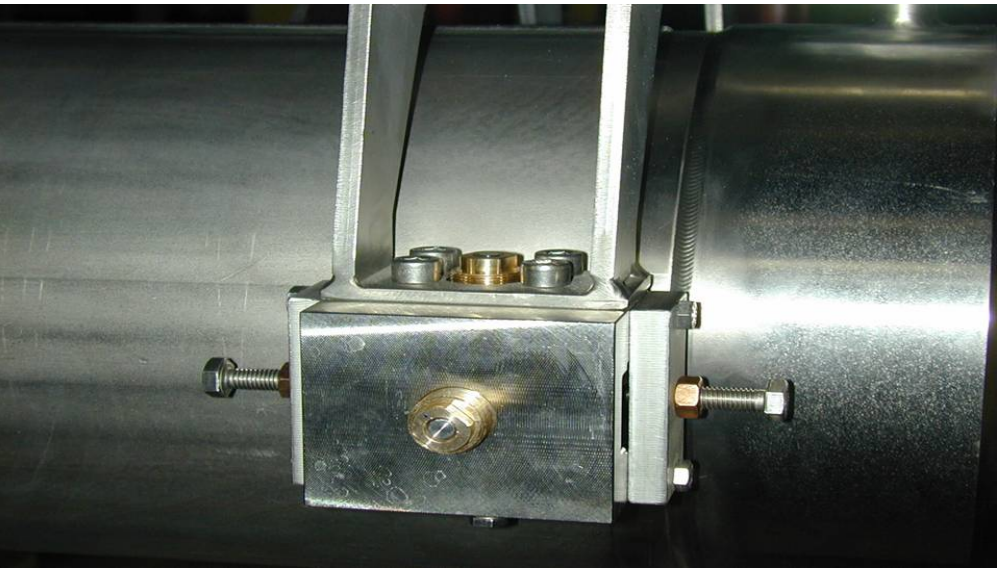
Cavity supports

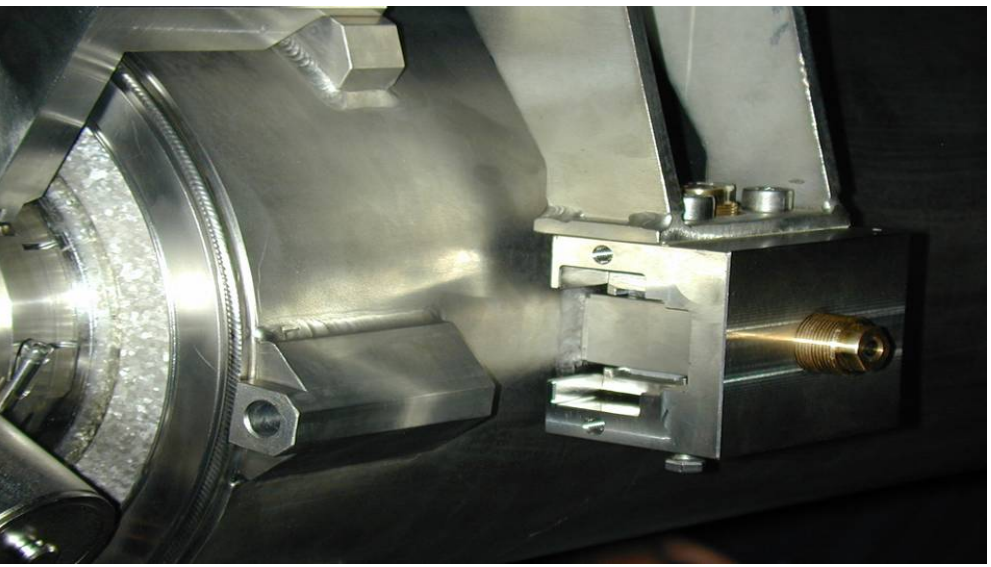
Sliding Fixtures

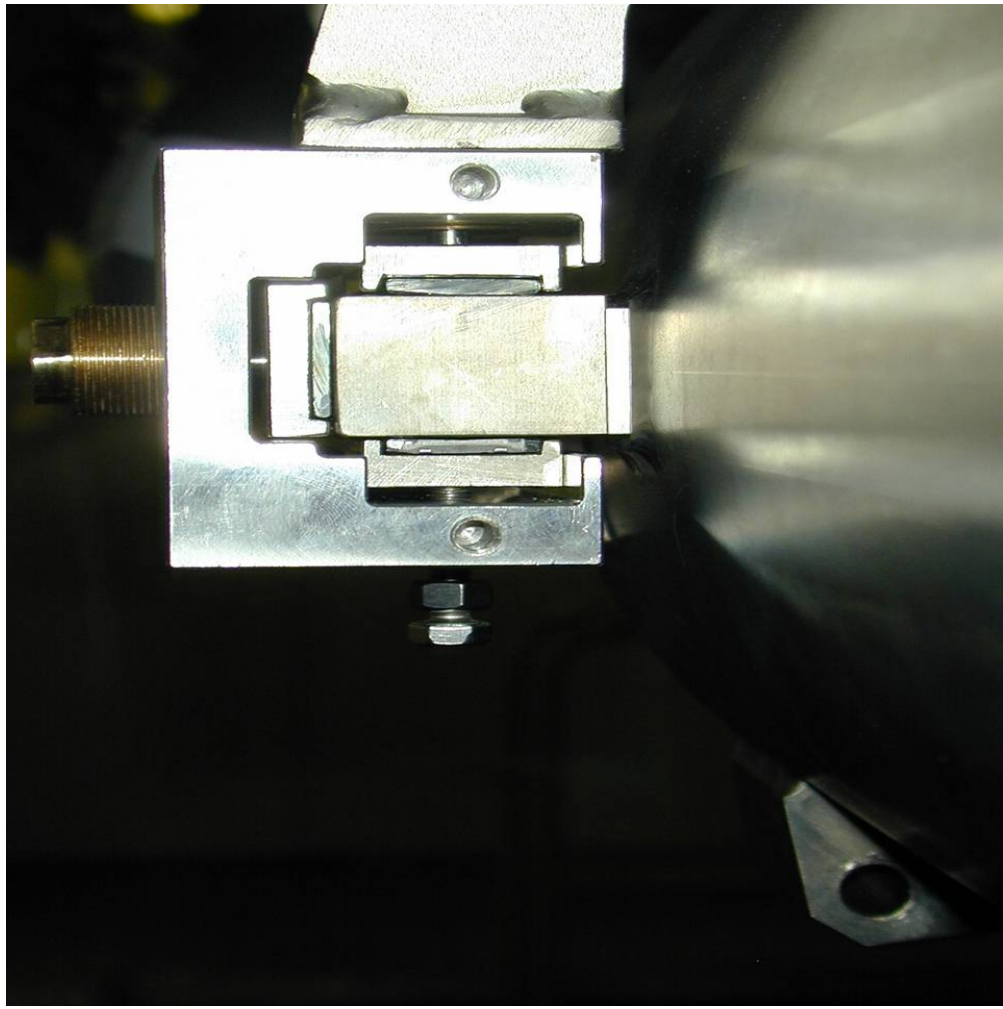




Cavity supports pictures



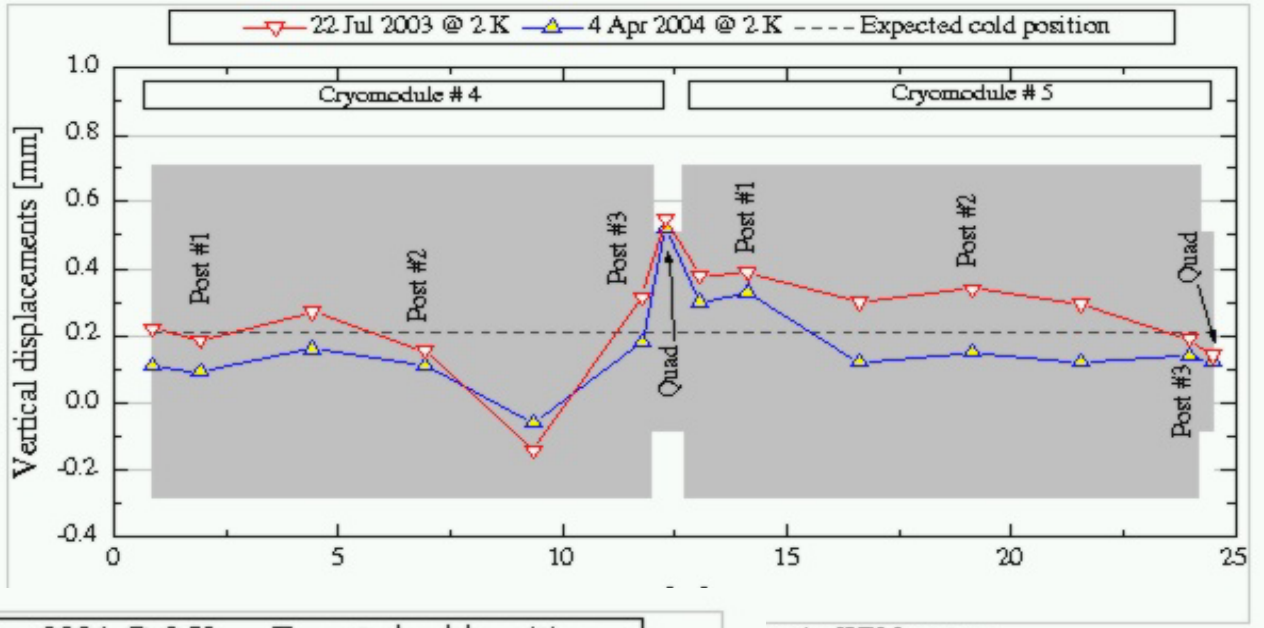




WPMs M4, M5 at 2K

Table 1: Result Summary.

TDR Specifications (rms)		
Cavities	x/y	± 0.5 mm
Quadrupoles	x/y	± 0.3 mm
WPM results (peak)		
Cavities	x	+ 0.35/- 0.27 mm
	y	+ 0.18/- 0.35 mm
Quadrupoles	x	+ 0.2/- 0.1 mm
	y	+ 0.35/- 0.1 mm



by the WPM system.

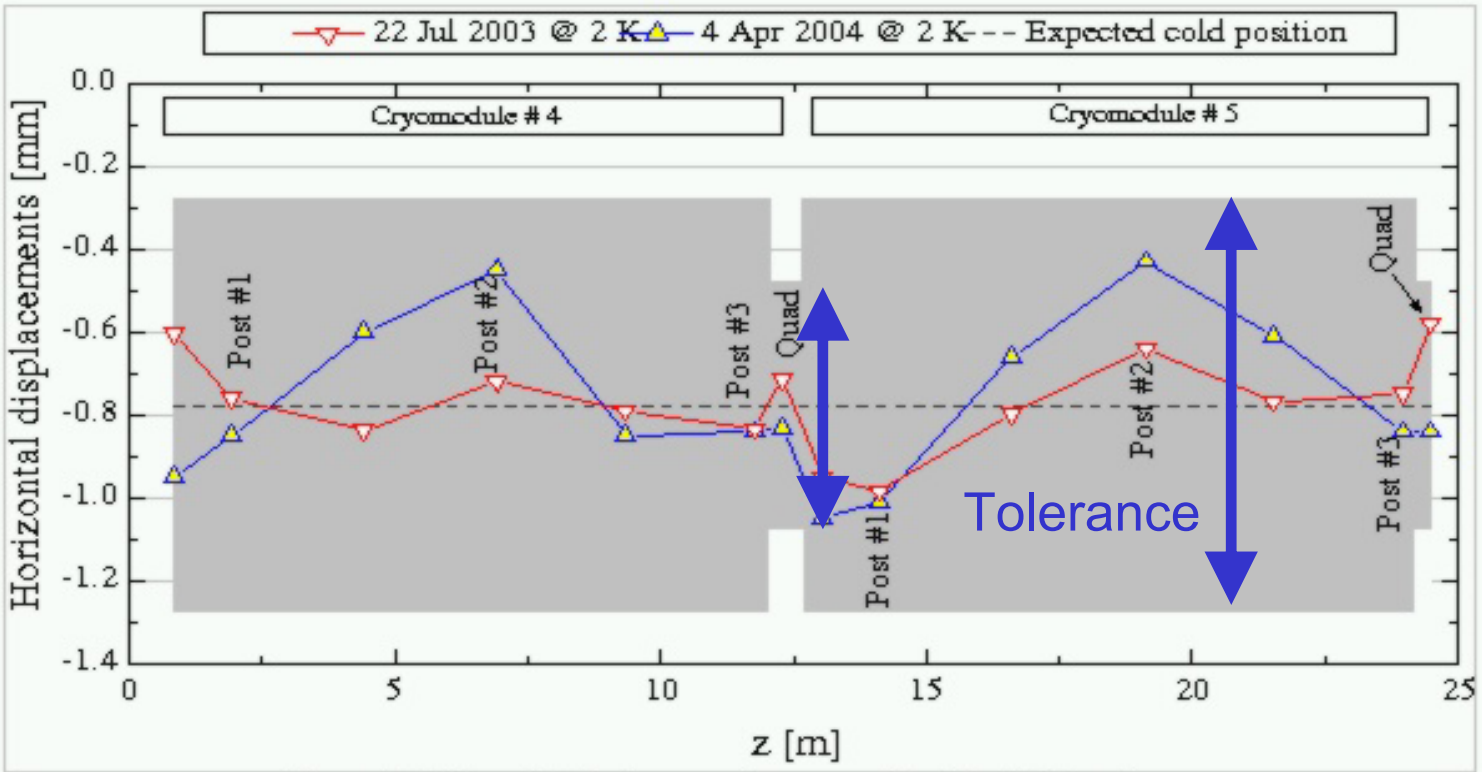
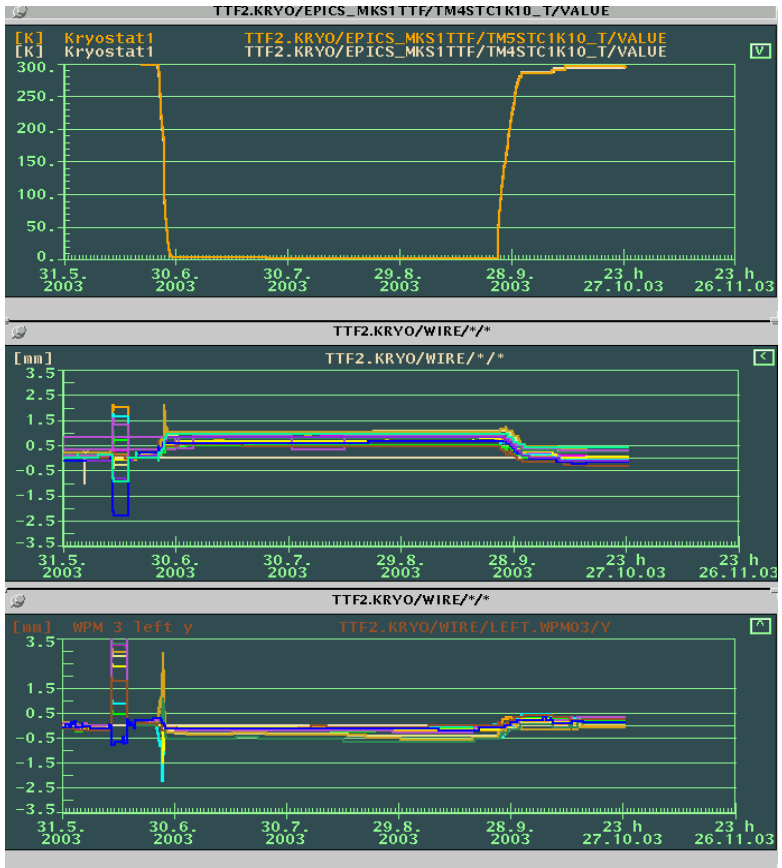


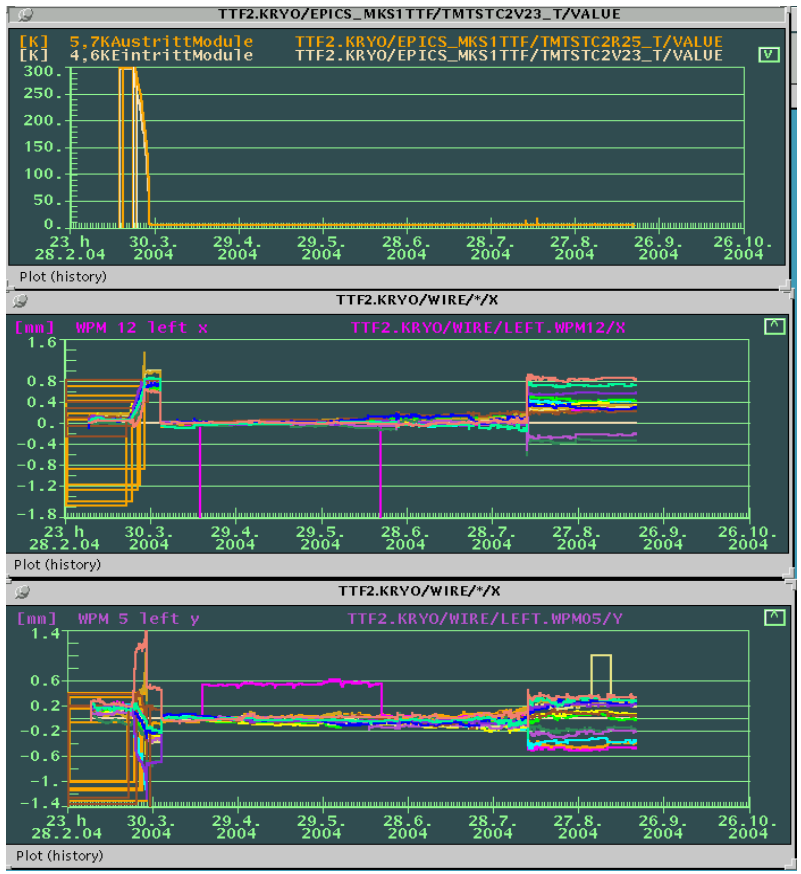
Figure 4: Horizontal displacements measured by the WPM system.

Wire position monitors in Modules 4 and 5

2003 2004

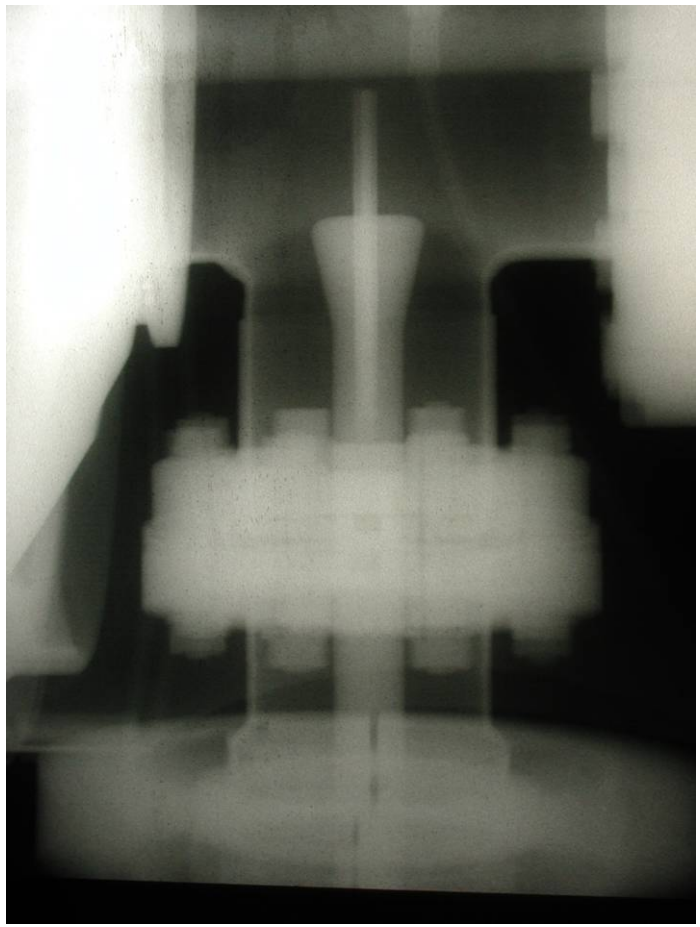
See readjustment 9-Aug-04 refered to beamline



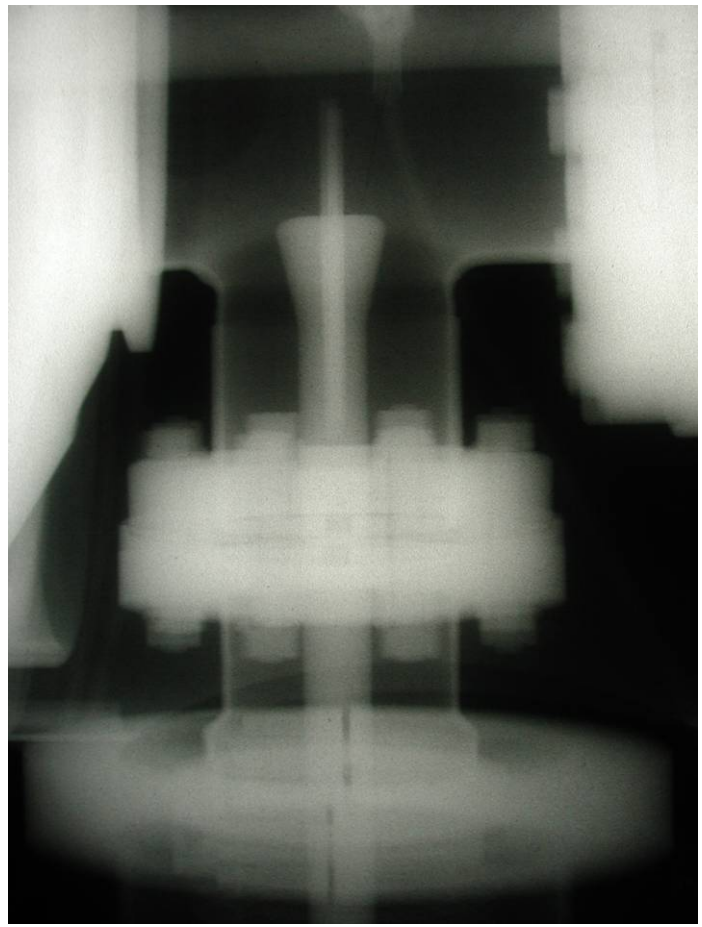


Koppler 2K/300K

2 K



290 K



Quadrupole package

- XFEL magnet package
  - Super ferric design
  - Field simulations finished
  - Mechanical design started
  - About a factor of 2 shorter than TTF design
  - Steering coils
    - Fit in quad aperture
    - investigation for lower current solution (smaller power supplies)

Design of XFEL Magnets

Requirements

	Quadrupole	Inner dipole	Outer dipole
Strength	5.6 T	0.006 T·m	0.006 T·m
Current	50 A	50 A	50 A
Temperature	2 K	2 K	2 K
Aperture	112 mm	100 mm	105 mm
Field quality	$\|b_6\| < 10$ units	-	-
Gradient/Field	35 T/m	0.04 T	0.04 T
Length	200 mm	250 mm	250 mm
Operation	DC	DC	DC

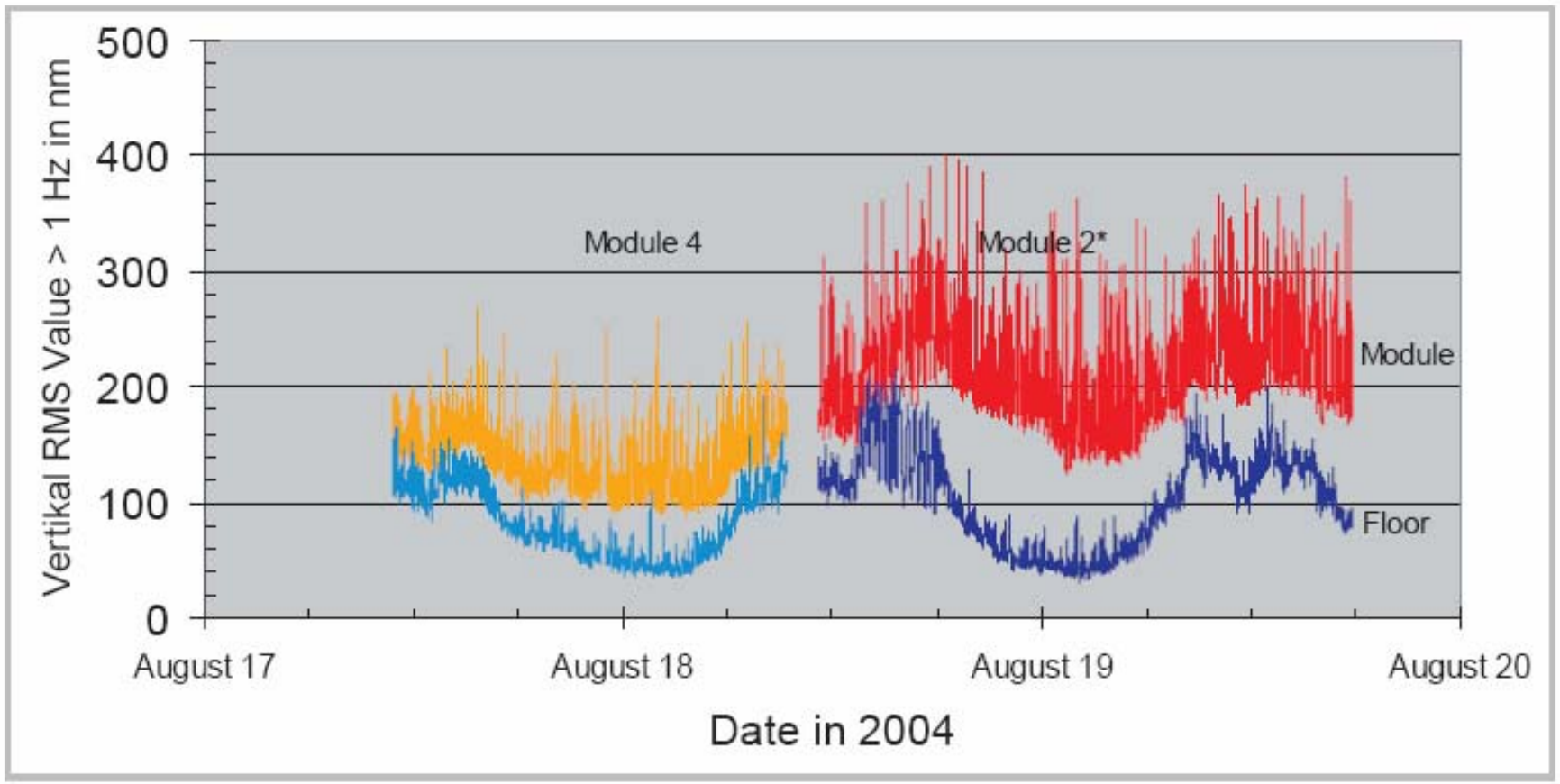
Design of a superferric quadrupole-dipole package – p. 2/21

Work done by Julio Lucas

Ciemat CEDEX DESY

Vibration measurements

- Accelerometers
- Geophones / Seismic sensors
- Results
  - Experimental setups working
  - Cultural noise can be identified
  - Pumpstands for isolation vacuum identified as a noise source
    - Decoupling of mechanical vibrations tested and achieved
  - Amplitude on quadrupole 2-3 times higher than on the ground
  - Seismic sensors show larger amplitudes
- Experiments need to be continued on TTF
- Module test stand or TTF
  - Excite mechanical modes with an external vibration source

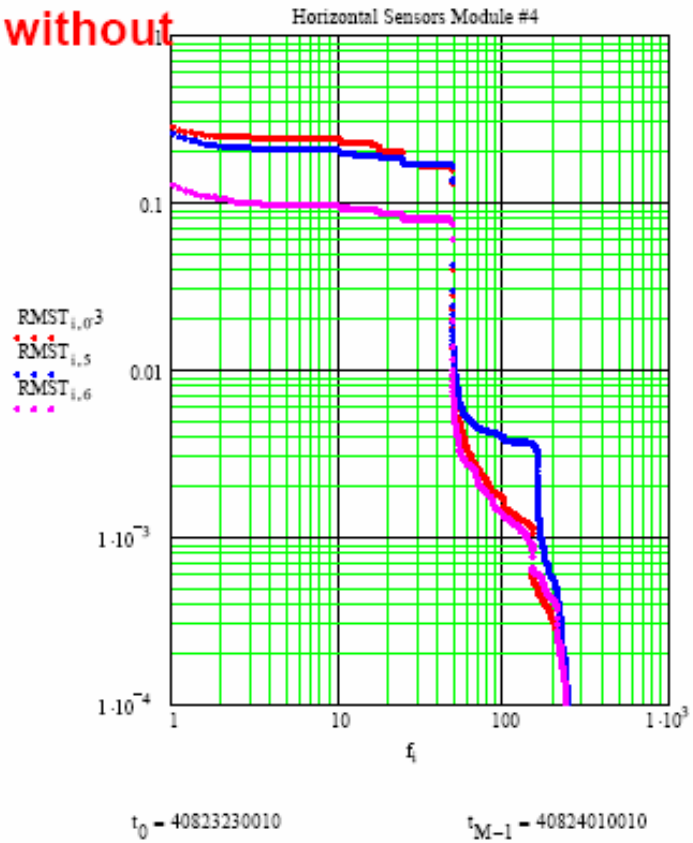


Comparisation between the vertical vibration on the floor and on the module 4 and 2*.

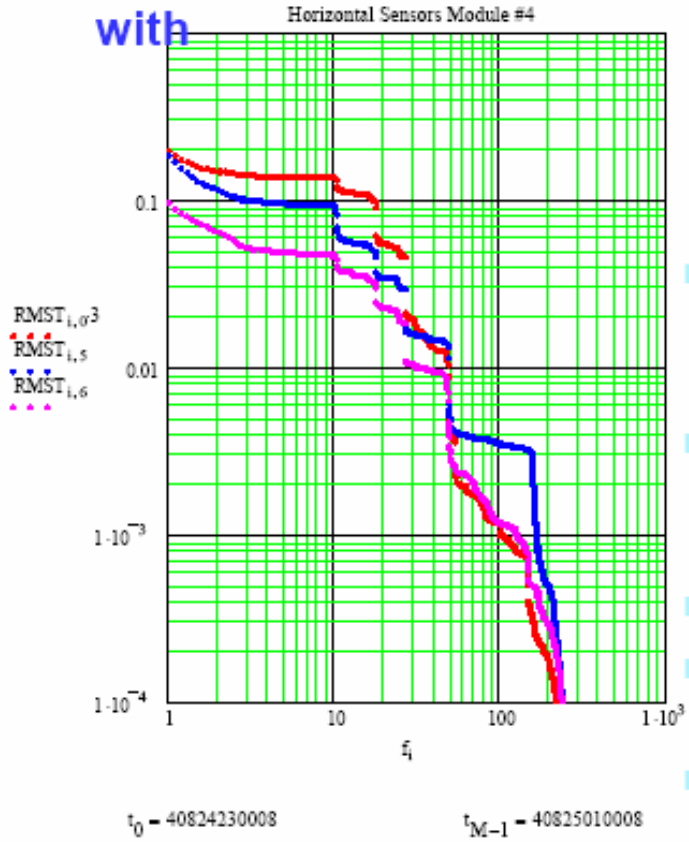
Pump stand without/with modifications
Horizontal Sensors (2 different days)

RMS average, midnight ± 1 hour

without



with



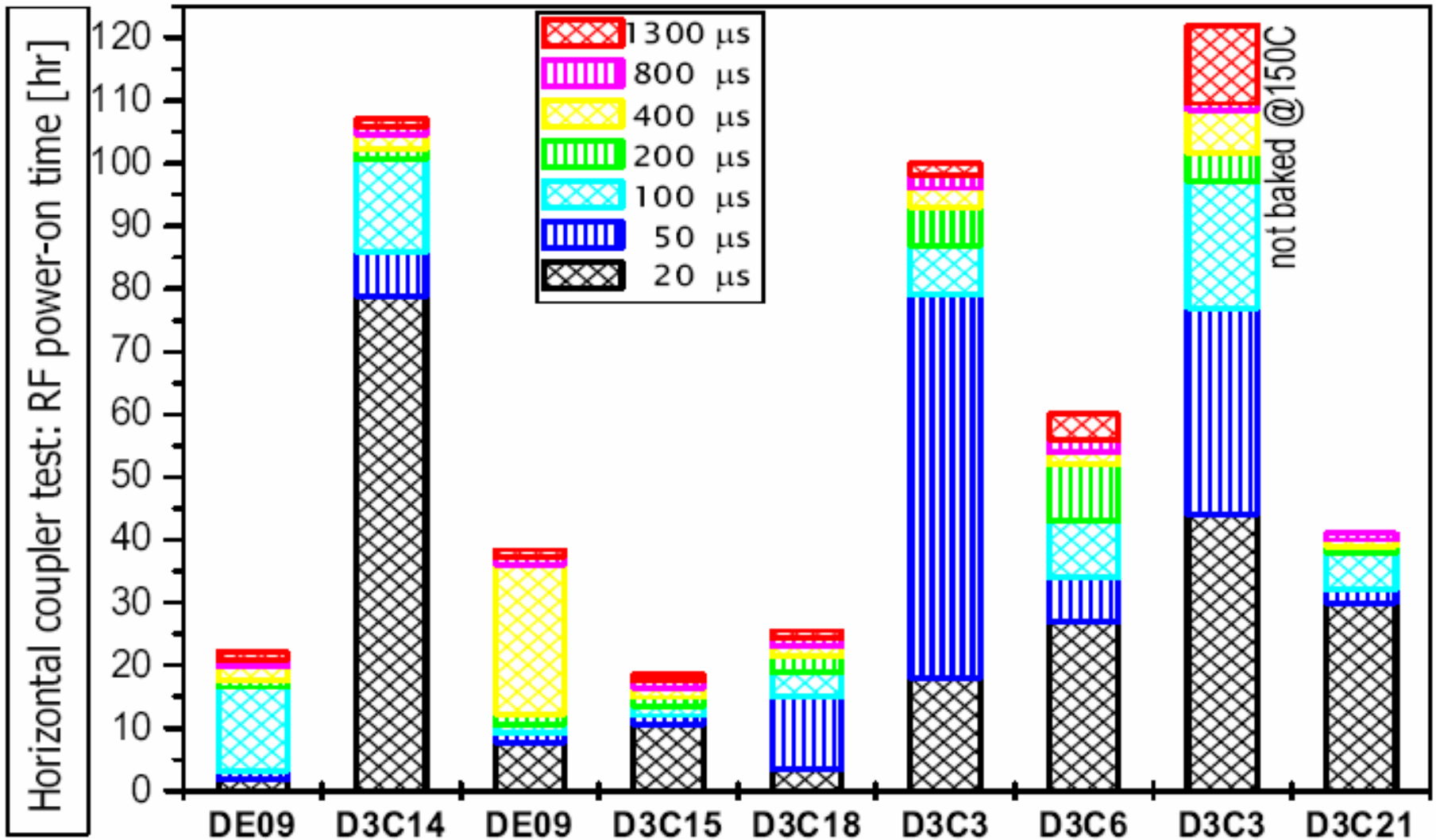
Sensors:
Cold
Top
Socket

- Different days
  - Mon "without"
  - Tue "with"
- Horizontal vibrations much larger
- Cold Signal *3
- Some reduction below 25 Hz
- Large reduction between 25 and 50 Hz

High Power Coupler

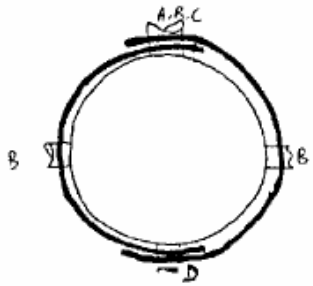
- Reference design is TTF3
- Processing of couplers
  - Test stand: 50-130 hours (pair)
  - CHECHIA: 20-120 hours (single coupler + cavity)
  - Module: 41 days
    - together with TTF2 couplers
    - Never limited by a TTF3 coupler
- Improvement of the coupler handling
  - Storage under dry nitrogen as long as possible
  - More data needed (coupler test stand/ CHECHIA)
- Test on CHECHIA showed that processing after exposure to clean air for 24 hours increases processing time by roughly 20 %
  - Limited in the cold part which was not exposed to air
- Further testing (LAL Orsay, CHECHIA)
- Thermal switch to facilitate ‘In-situ’ bake of the coupler will be tested

TTF3 conditioning time on Chechia



Magnetic Shielding

- Superconducting niobium cavities need to be shielded from the earth magnetic shielding
- Flux frozen into the material during cooldown leads to increased surface losses ~3-5 nOhm/μT
- For $Q_0 > 10^{10}$:
  - Acceptable magnetic field: B< 2 μT
- Use a cryoperm layer



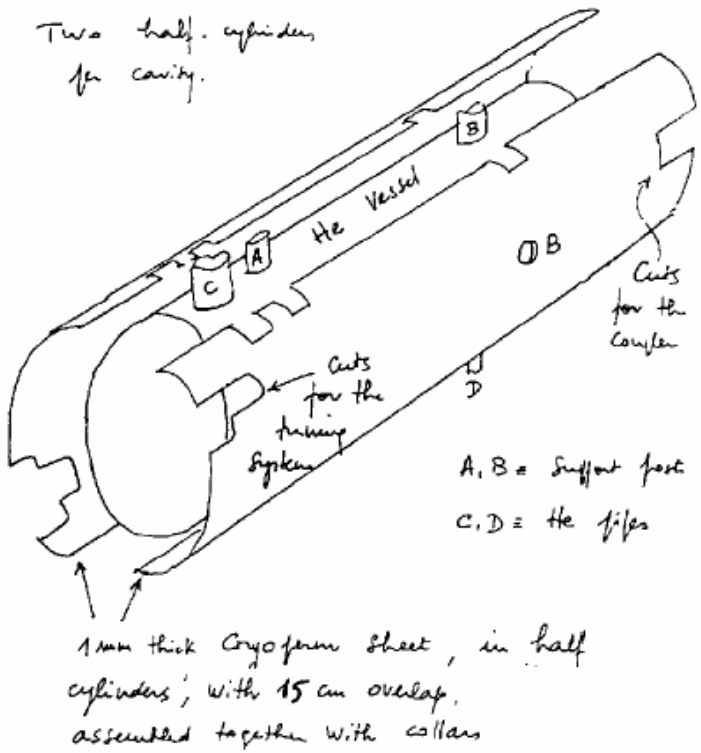


Figure 4.31: The Cryoperm shield around the helium vessel.

Demagnetization

- Mu-metal shield (Cryoperm) needed
  - Less than 2 μT at the cavity, $Q_0 > 10^{10}$
- Demagnetization of the cryostat vessel
  - Might be avoided
  - Test in CHECHIA with Helmholtz coils proposed to test efficiency of cryoperm shielding

Frequency Tuner

- Tuner consists of 2 parts
  - Slow tuner
    - Allow for different thermal shrinkage
    - Correct slow drifts e.g. He pressure
    - Specification:
      - Range: 820 kHz
      - Resolution: 1 Hz /step
    - 2 basic types have been tested
      - Lateral (Saclay)
      - Coaxial (INFN, DESY)
  - Fast tuner
    - Compensate Lorentz-forces
      - df <= 1 kHz in 1 m
    - Piezoelectric

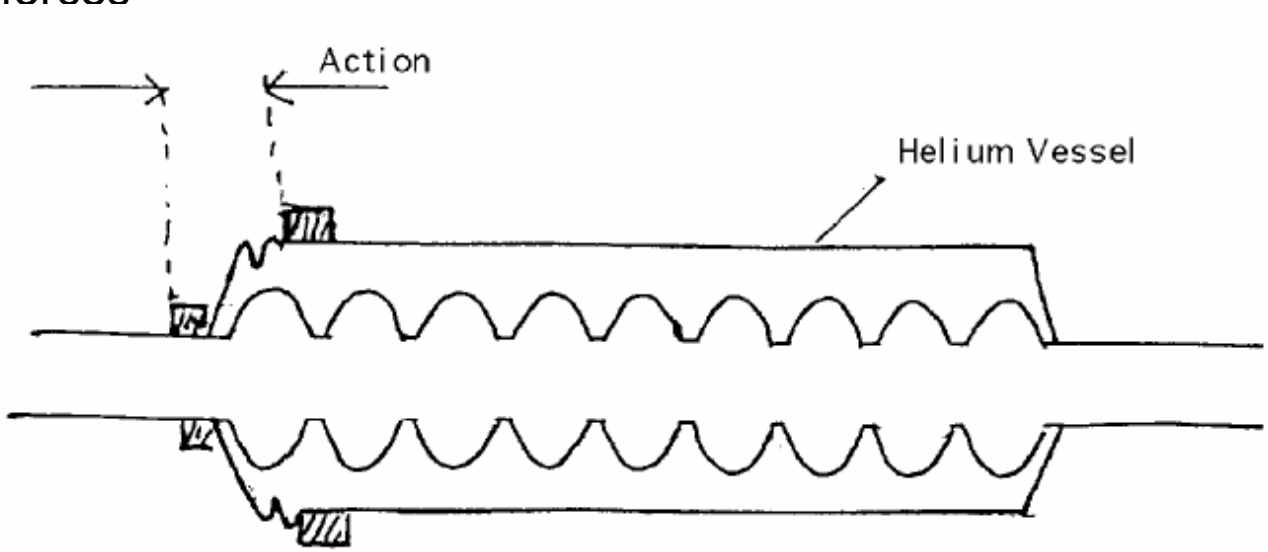
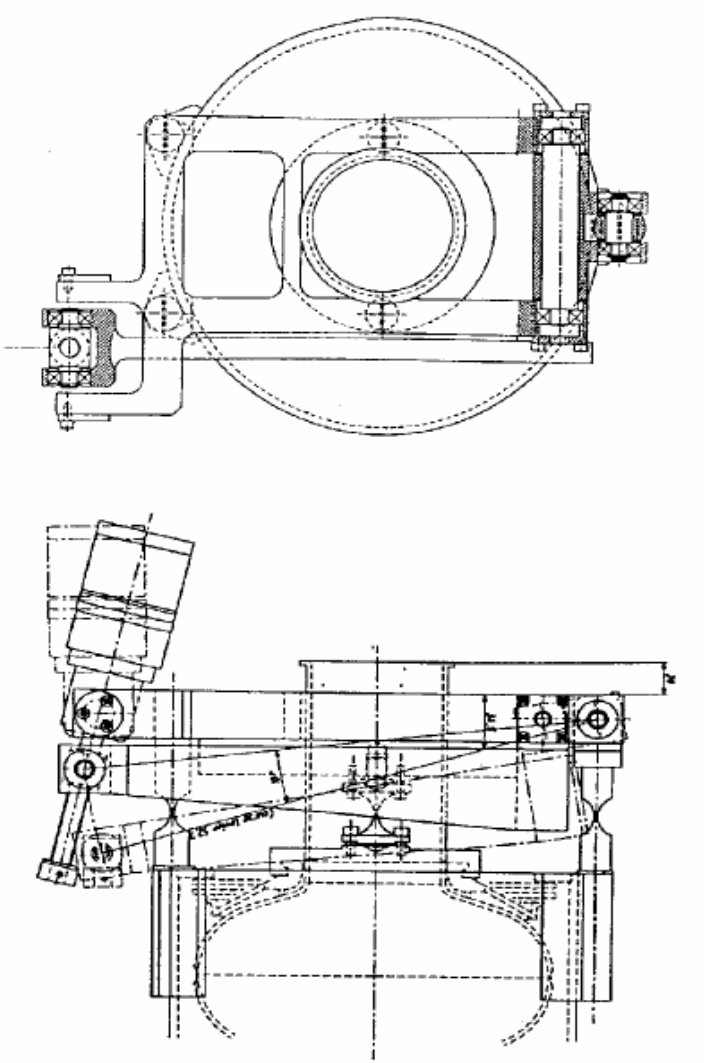
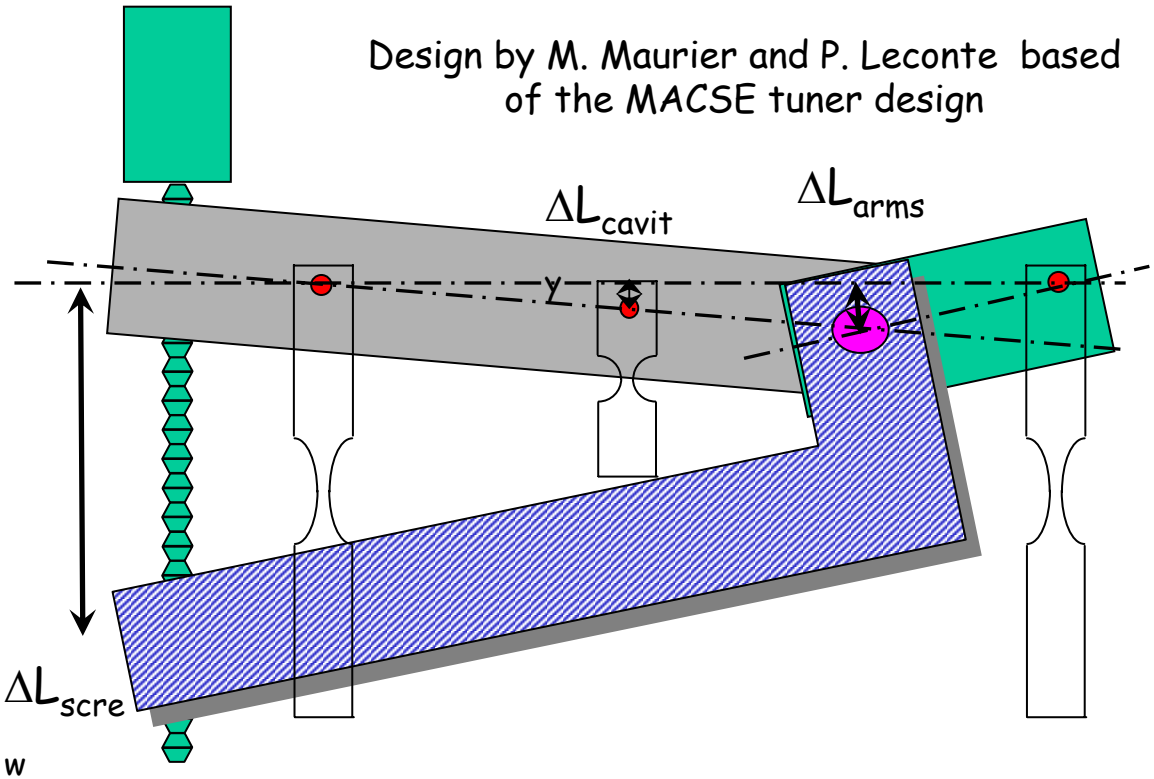


Figure 4.21: How the CTS is acting on the cavity length.

Lateral Tuner (Saclay)

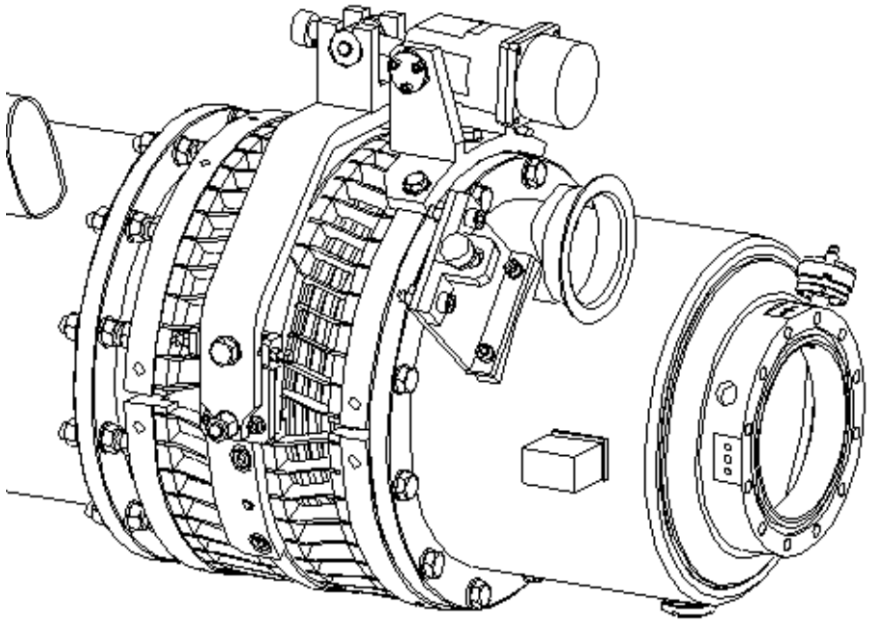


Design by M. Maurier and P. Leconte based of the MACSE tuner design



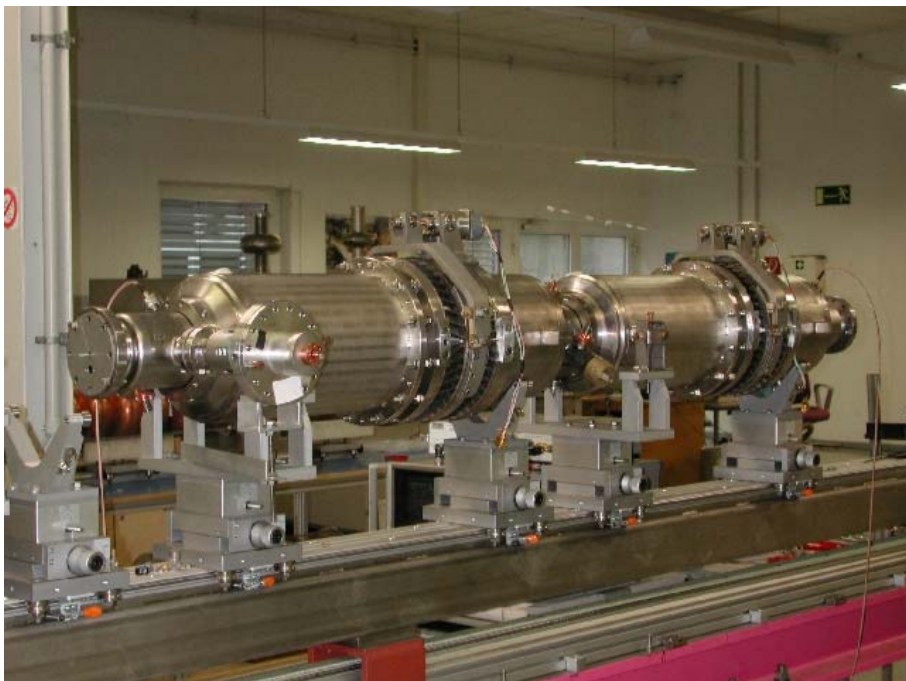
- Used in TTF
  - Double lever system: ratio ~ 1/17
  - Stepping motor with Harmonic Drive gear box
  - Screw – nut system
- Needs space between cavities
- Interferes with HOM couplers
- More compact design seems feasible

Coaxial Tuner (INFN, DESY)



- On the He vessel
- Tested on the superstructure in TTF (4 units)
- Magnetic shielding more difficult
- 2nd design exists
  - Test in CHECHIA done

	Standard	New Tuner
Tuning range [mm]	1.9	1
Tuning range [kHz]	820	440
Sensitivity [Hz/step]	0.74	0.38

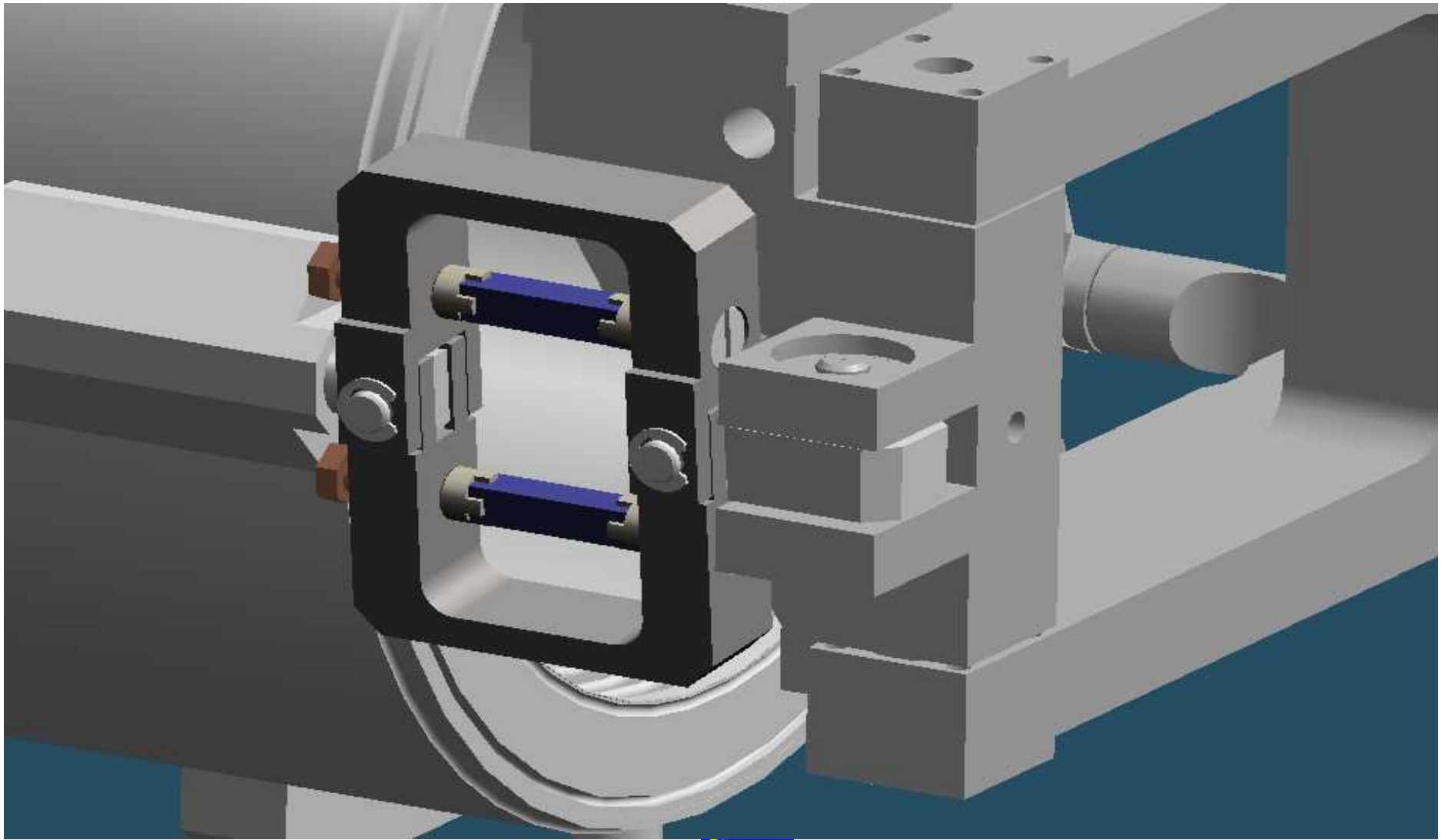


Active Tuner

- Actively compensate the detuning of the cavity during the RF pulse by mechanical means to reduce power consumption
- Piezoelectric elements are suitable for this application (heavily used for fuel injection in car industry)

- Proof-of-principle done
- A lot of engineering needed
  - Choice of tuner
  - Choice of Actuator
  - …

Drawing of Piezoelectric Elements in the Tuning Mechanism



Safety issues, AfA/TÜV

- First meeting with AfA (Amt für Arbeitsschutz)
  - 2-July-04
  - Druckbehälterklassifizierung der XFEL-Cryomodule
  - No problems expected
  - But:
    - Niobium is not a qualified material for cold temperature (mechanical properties)
    - This can be mitigated by arguing that the Ti-Vessel and the Cryostat are the safety containers
- First meeting with TÜV-Nord
  - 27-Sep-04
  - Introduction for the TÜV to propose a procedure for approval for
    - CrNi-welding 2K
    - Ti-Vessel weldings
    - ….

Modules

- Improved material specifications are available
- Improved procedures including specification/ work plan for
  - Preparation components
  - Module assembly
  - Linac module installation
- Complete drawings for modules type 3 expected Dec-04

Industrial Studies on Module Assembly

- Prepare a study by industry on the cryomodule assembly
  - Involve industry early
  - Profit of industrial experience
- Results of the study will be published
- Specification of XFEL-Cryomodule Design&Assembly for Industrial Studies

Cavity Spacing

- The cavity spacing for ILC and XFEL is probably different
  - XFEL will have minor changes e.g. coupler ports will move a few mm
  - ILC wants to increase fill factor
    - No ILC structure has been built
      - Shortened nine-cell is considered to be straightforward and should be done
      - 2x7 Superstructures as prototype
      - Other cell shapes
- Many of the components and procedures can be made compatible with ILC, and still be tested in TTF III plus cryomodules
  - Tuners
    - Lateral
    - Coaxial
  - Couplers
  - Assembly procedures including cavity assembly
  - Quadrupole position

Summary

- General cryostat layout o.k.
- Minor changes evolve from TTF-III towards first XFEL prototypes (TTF III plus)
- There are still technical issues that need to be resolved
  - Transport, O-ring vs. metal gaskets, vibrations etc.
- Most of the ILC compatible components can be tested in the TTF III plus cryostats
- Reduction of cavity spacing should run in parallel to cryostat evolution allowing to implement improvements on the cryostat now

Backup

Next:

- Next Meeting
  - Piezo tuner
- Action items
  - Fix module length
  - Tests on coupler baking
  - Test cryoperm shielding with Helmholtz coil
  - Safeguarding module transportation

XFEL-Module length options

MOD-006

3. Comment to the module length (RL)

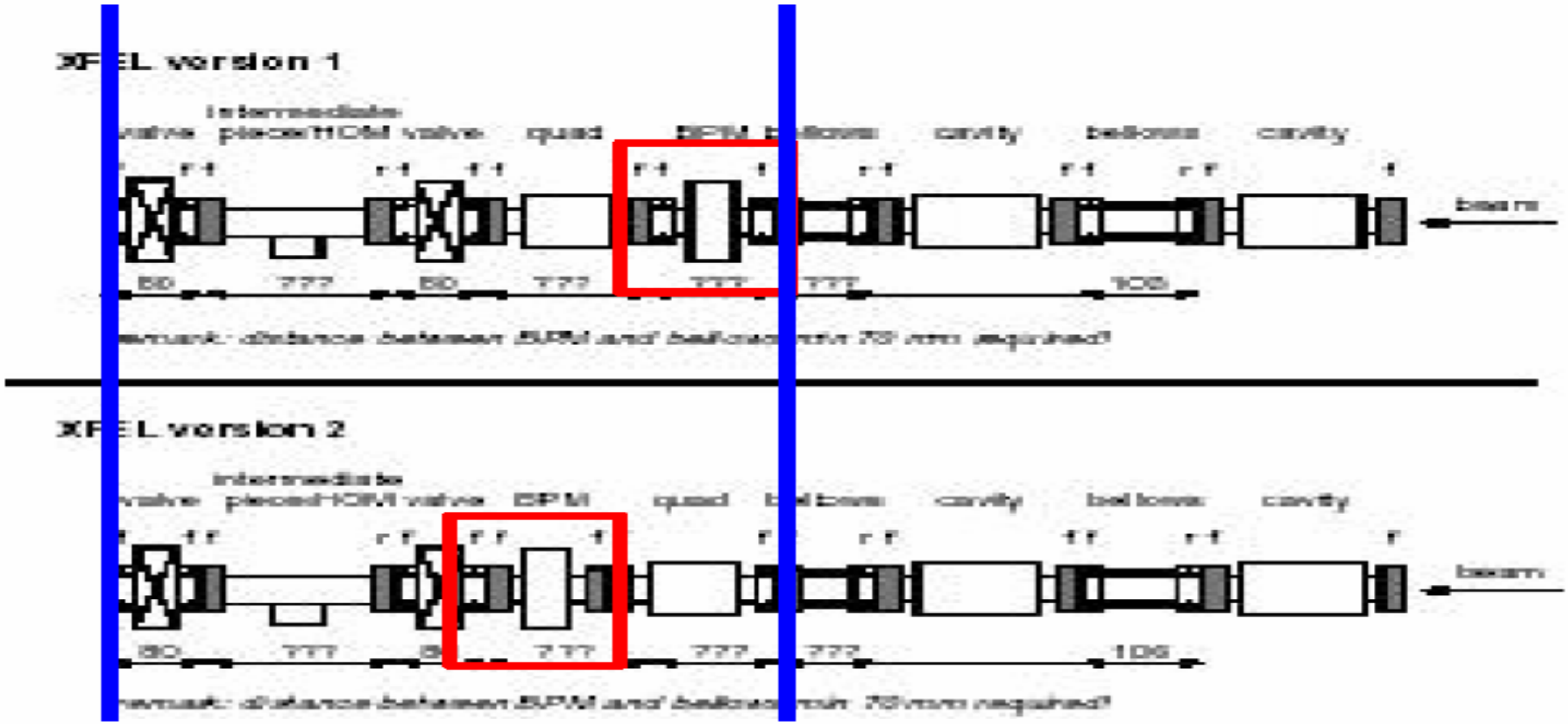


Figure 1: Layout of the XFEL end section (Talk by KiZ).

Modul Typ3 (M4,M5) Laengenangaben(Kalte Pos, Abstaende):

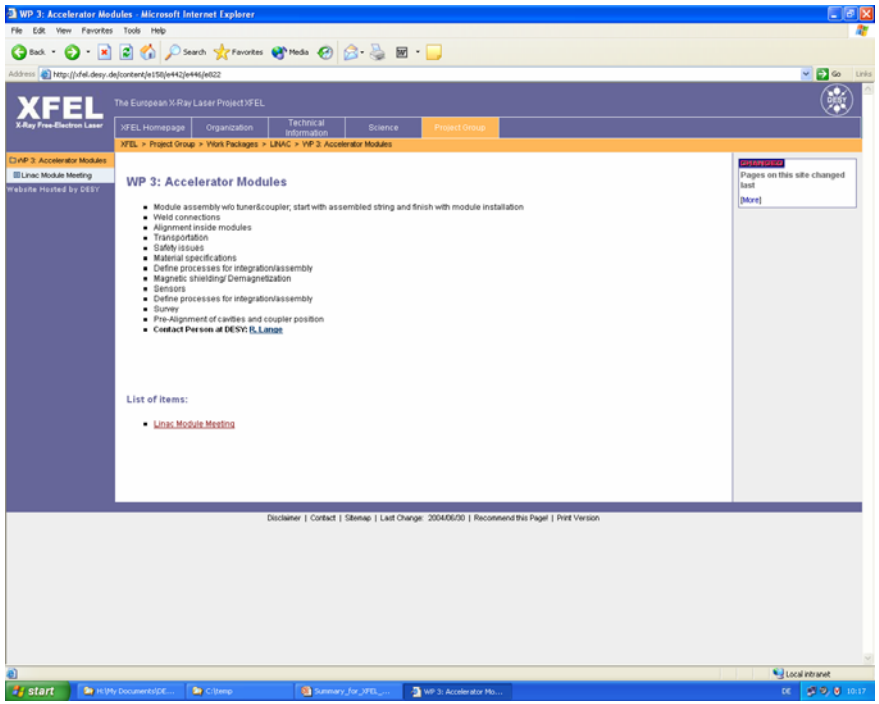
			n x 230mm	n x 230.6mm
Vak-Behaelter	Modul1_Anfang ➔	Modul2_Anfang 12 200 mm	53.04	52.91
Cavity_gesamt	FlanschC1_Anfang ➔	FlanschC2_Anfang 1 380 mm	6.00	5.98
Cavity Zellen	Iris-Zelle1_Anfang ➔	Iris-Zelle9_Ende 1 035 mm	4.50	4.49
Cavity Space	C1-Iris-Zelle8_Ende ➔	C2-Iris-Zelle1_Anfang 345 mm	1.50	1.50
Cavity_String	FlanschC1_Anfang ➔	FlanschC8_Ende 11 040 mm	48.00	47.88
Cavity String Zel	IrisC1-Zelle1_Anf ➔	IrisC8-Zelle9_Ende 10 695 mm	46.50	46.38
Modul1/Modul2	M1_C8-Zelle8_End ➔	M2_C1_Zelle1_Anf 1 505 mm	6.54	6.53

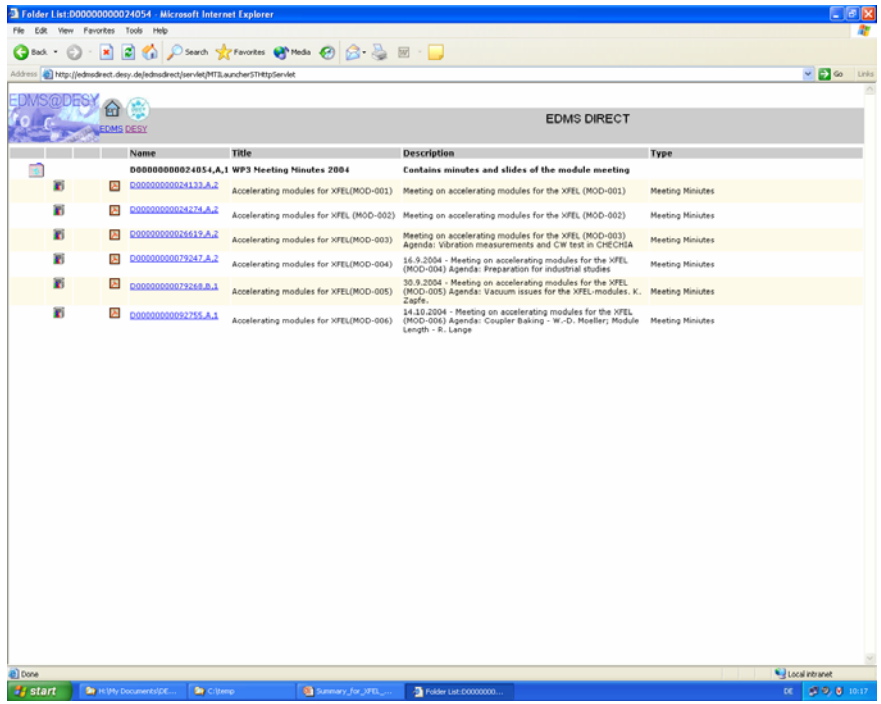
- **Für lambda 230mm**
  - **das Modul ist 10mm zu lang, aber Korrektur über Länge der Schiebemuffe moeglich.**
- **Nachtrag:lambda =230.6mm**
  - **Modul ist 21.8mm zu kurz , aber Korrektur über Länge der Schiebemuffe moeglich.**

14-Okt-04 Jensch/Lange-MKS-

Meeting Minutes available under EDMS and WWW

- EDMS folder: 24054
- http://xfel.desy.de/content/e158/e442/e446/e822





Presentations to date

- Demagnetisation
- Vibration measurements
- Vacuum issues
- High power coupler
- Magnet package
- Alignment Modules in Linac: Cavity/Magnet-Axes
- Safty issues, AfA/TÜV

Vacuum issues

- Position of the BPM
  - Flanged connection to magnet (different from TTF)
    - Mechanical precision of the connection under investigation
    - Downstream of the magnet is the preferred position
- ‘In-Situ‘ bake for couplers (see below)
- Position of the pumpline for the high power couplers needs change
- Replace o-ring seals with metal gaskets
  - at least for the cryostat vessel interconnection
- Overall length of the module needs to be determined
  - Will be close to existing length, if not shorter

Beam Vacuum

- **Industrial study**
  - fix position of BPM
- **XFEL module**
  - fix interface BPM/quadrupole
  - fix length of BPM
  - fix length of quadrupole

➔ **fix total length of cavity string**

➔ **fix total length of intermediate piece**

When do we need final length?