ILC European Regional Meeting and ILC-BDIR

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Cryomodule Issues

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On leave from University of Milano

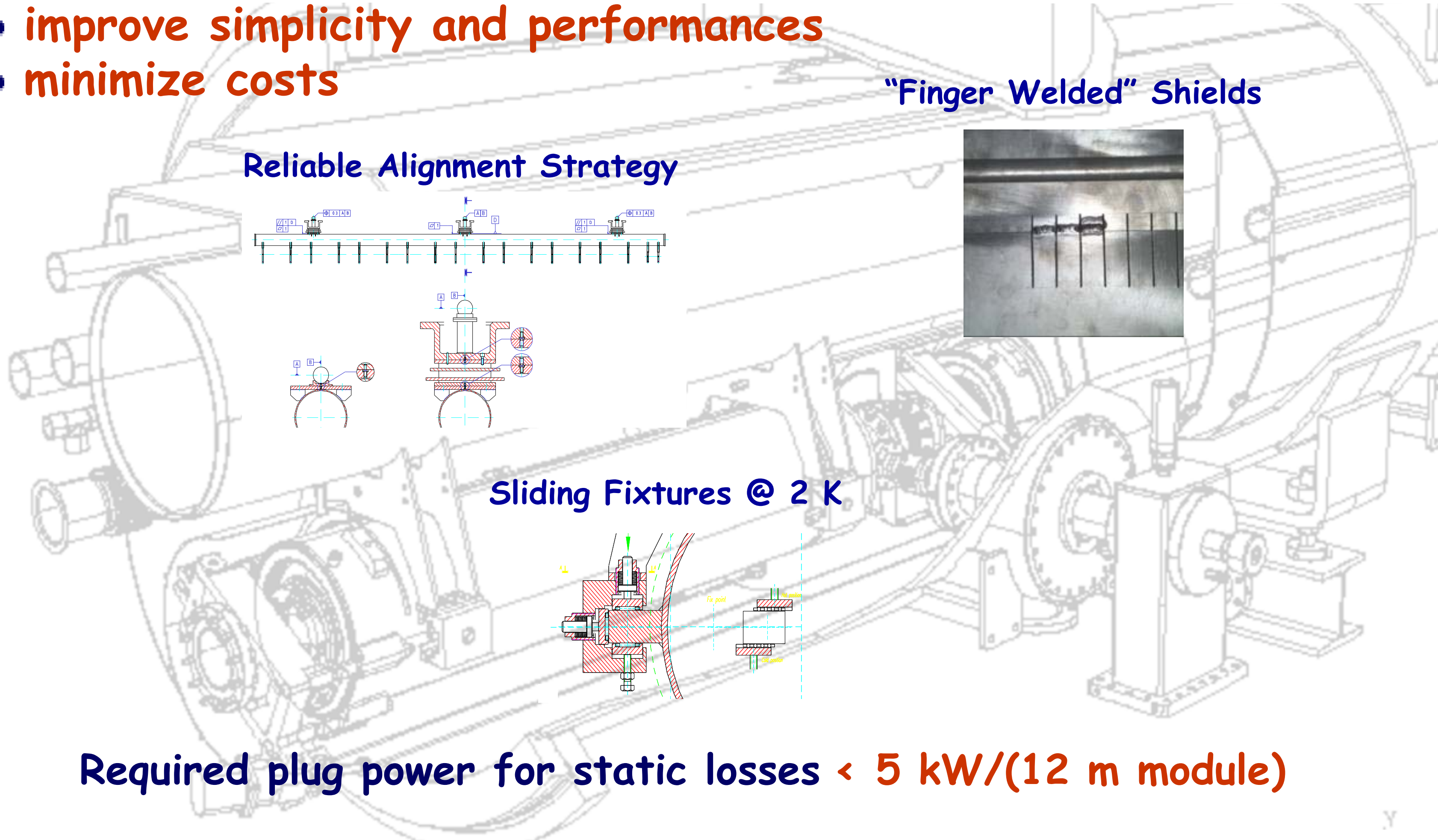
TESLA Cryomodule Design Rationales

- High Performance Cryomodule was central for the TESLA Mission
  - More then one order of magnitude was to be gained in term of capital and operational cost
- High filling factor: to maximize real estate gradient
  - Long sub-units with many cavities (and quad): cryomodules
  - Sub-units connected in longer strings
  - Cooling and return pipes integrated into a unique cryomodule
- Low cost per meter: to be compatible with a long TeV Collider
  - Cryomodule used also for feeding and return pipes
  - Minimize the number of cold to warm connections for static losses
  - Minimize the use of special components and materials
  - Modular design using the simplest possible solution
- Easy to be alligned and stable: to fullfil beam requirements

Performing Cryomodules

Three cryomodule generations to:

- improve simplicity and performances
- minimize costs



"Finger Welded" Shields

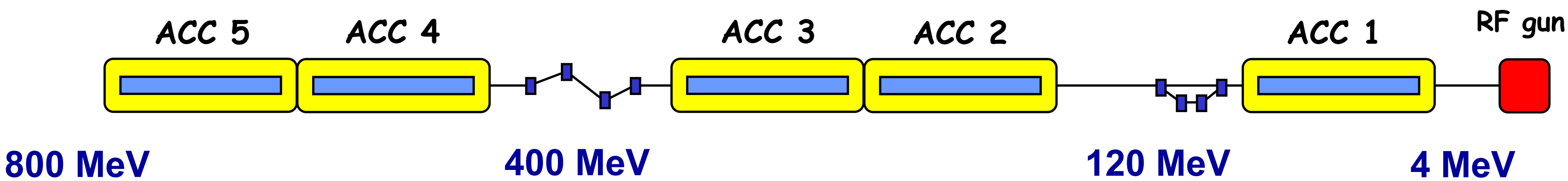
Reliable Alignment Strategy

Sliding Fixtures @ 2 K

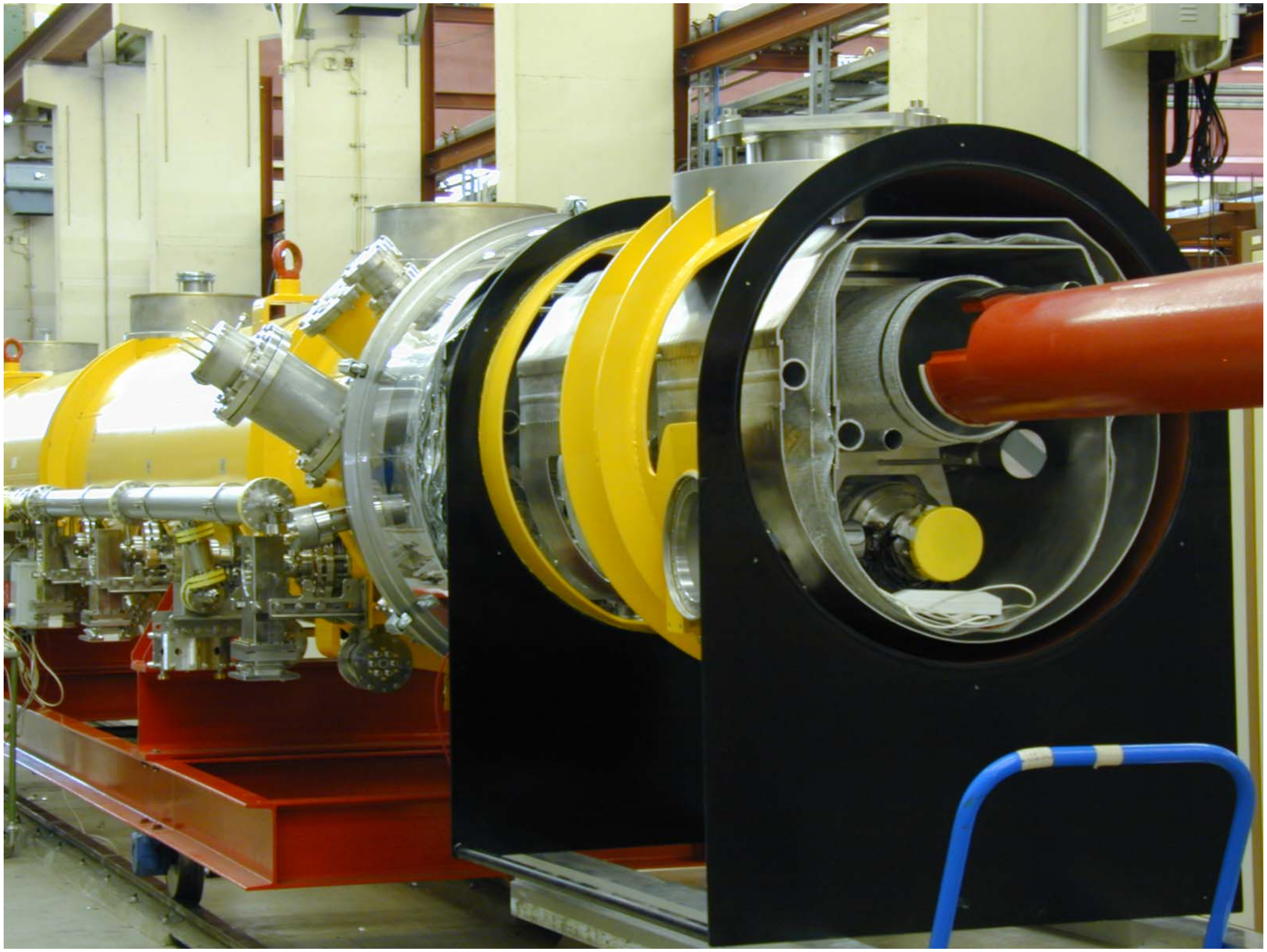
Required plug power for static losses < 5 kW/(12 m module)

Cryoodules installed in TTF II

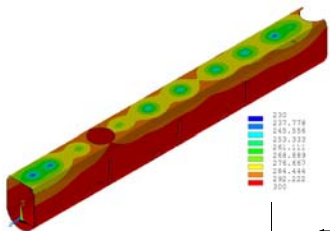


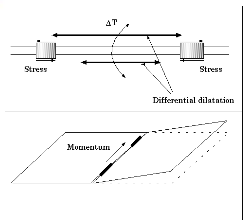



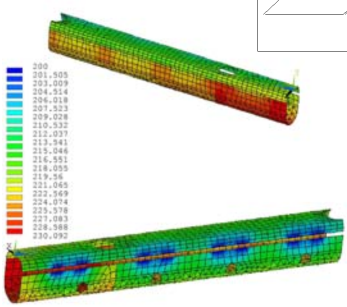
Cry2 to Cry3: Diameter Comparison



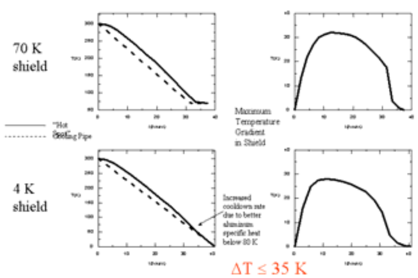
From Prototype to Cry 3

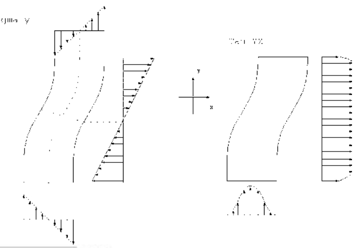


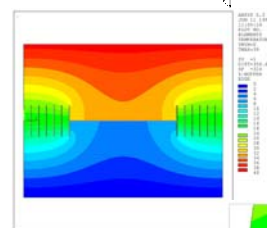


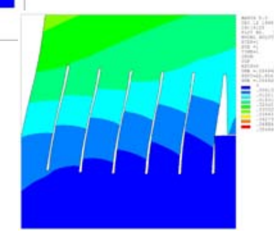


Welded Shields







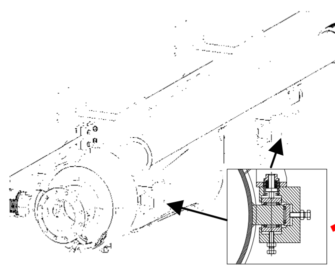


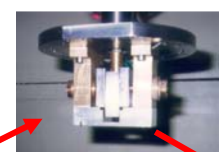
Extensive FEA modeling (ANSYS™) of the entire cryomodule

- Transient thermal analysis during cooldown/warmup cycles,
- Coupled structural/thermal simulations
- Full nonlinear material properties

Detailed sub-modeling of new components and Laboratory tests

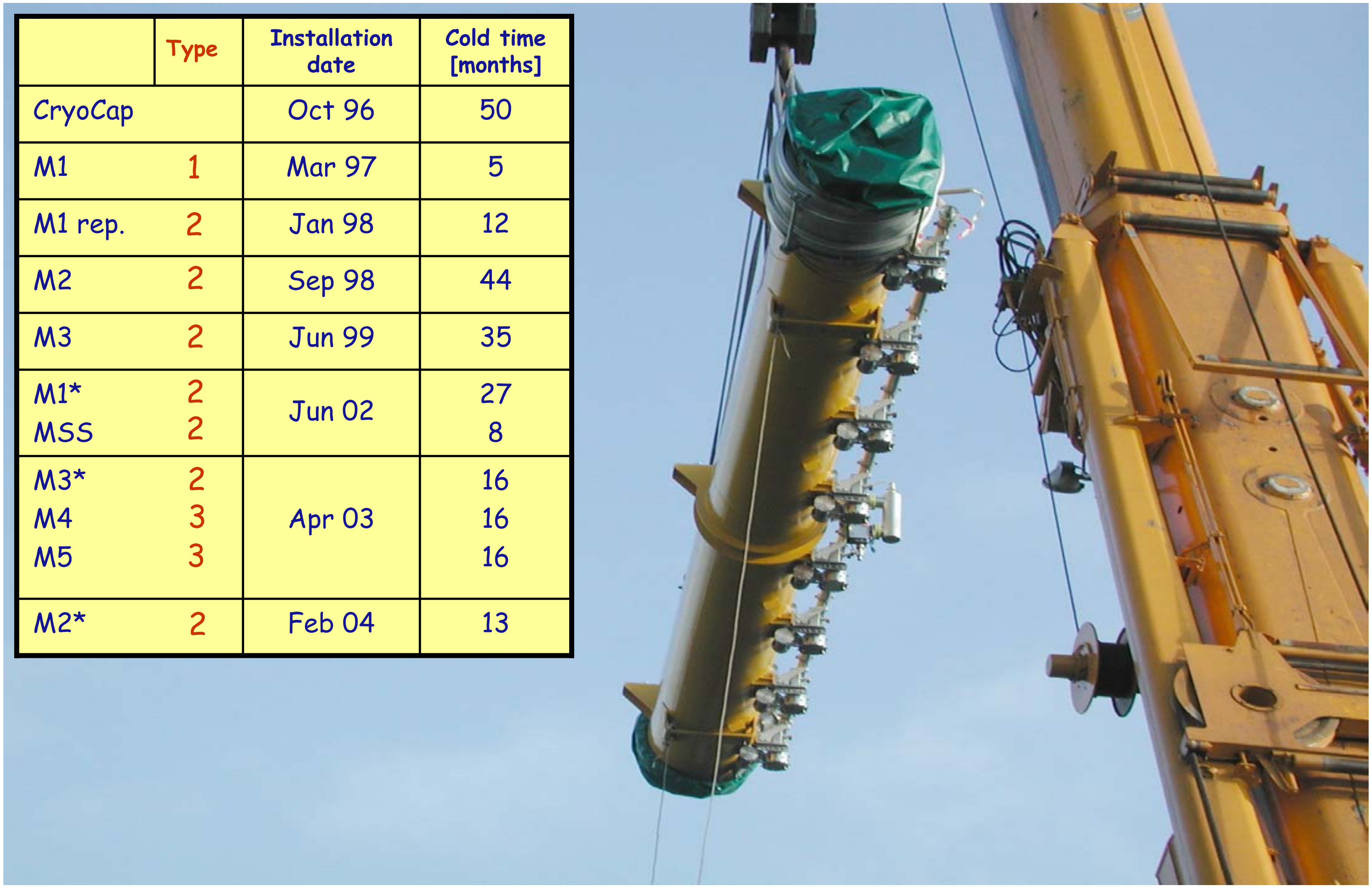
- Finger-welding tests at ZANON
- Cryogenic tests of the sliding supports at INFN-LASA



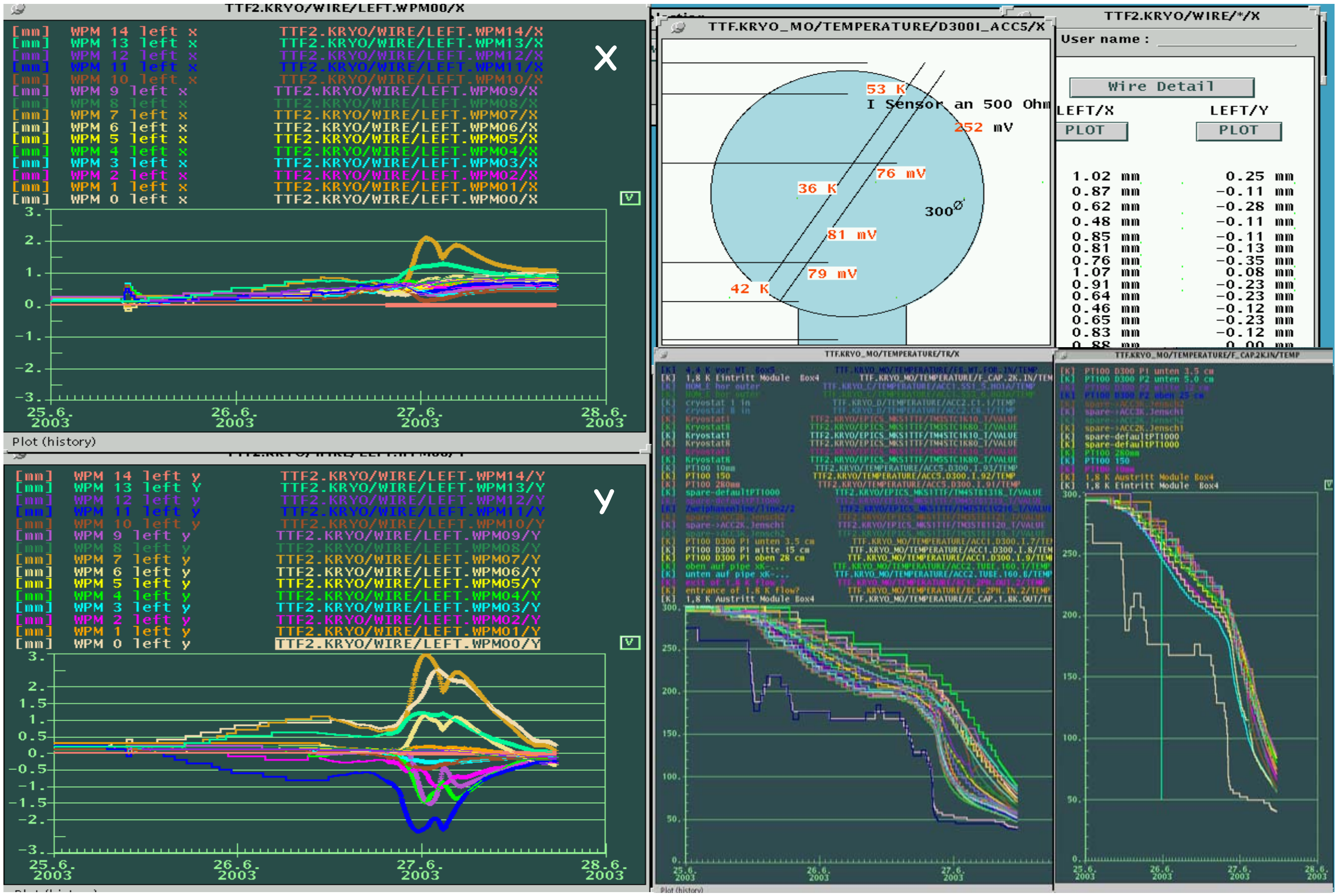


TTF Module Installation

	Type	Installation date	Cold time [months]
CryoCap		Oct 96	50
M1	1	Mar 97	5
M1 rep.	2	Jan 98	12
M2	2	Sep 98	44
M3	2	Jun 99	35
M1* MSS	2 2	Jun 02	27 8
M3* M4 M5	2 3 3	Apr 03	16 16 16
M2*	2	Feb 04	13

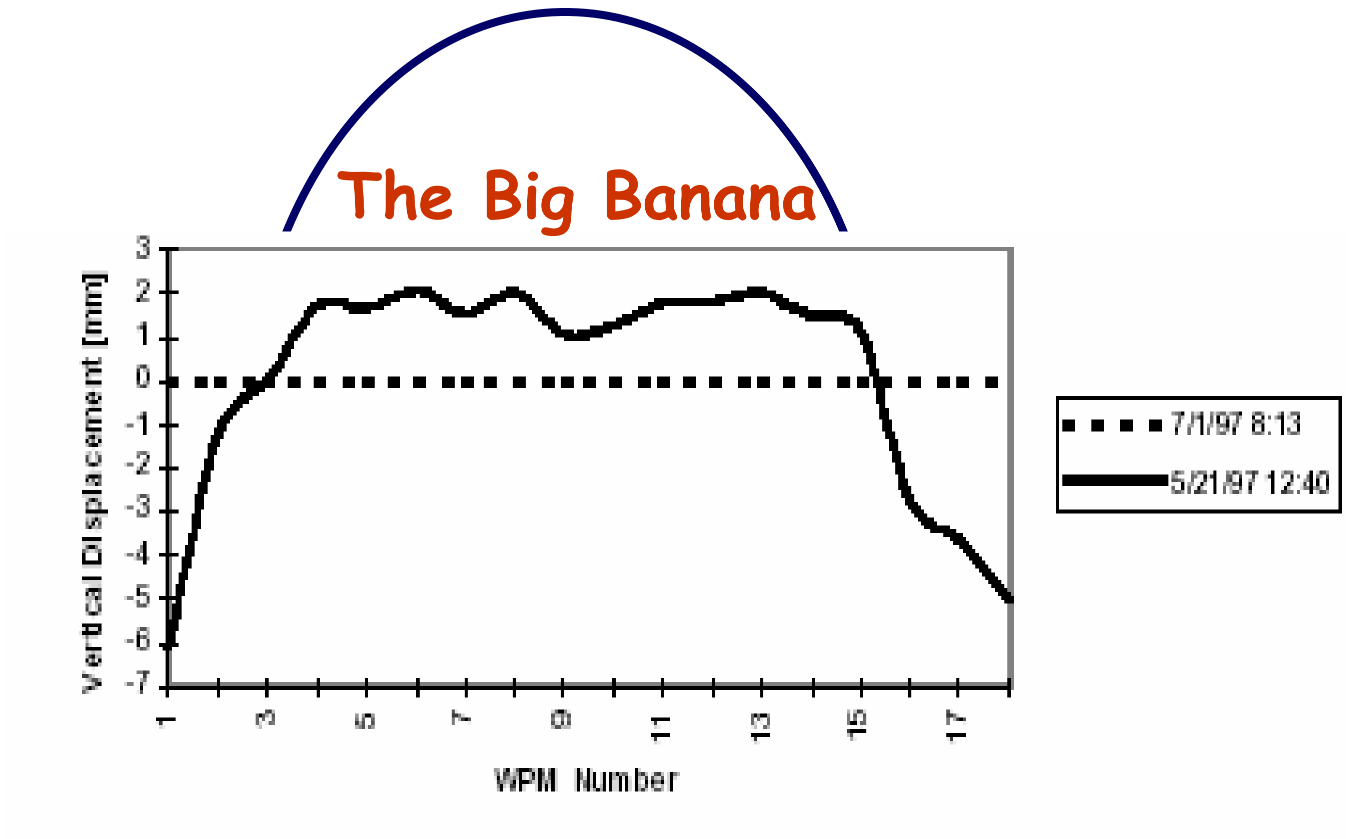


Safe Cooldown of ACC4 and ACC5



Large Bending in First Cooldown

New Cooldown procedure suggested by the WPM's measurements during the first "fast" cooldown



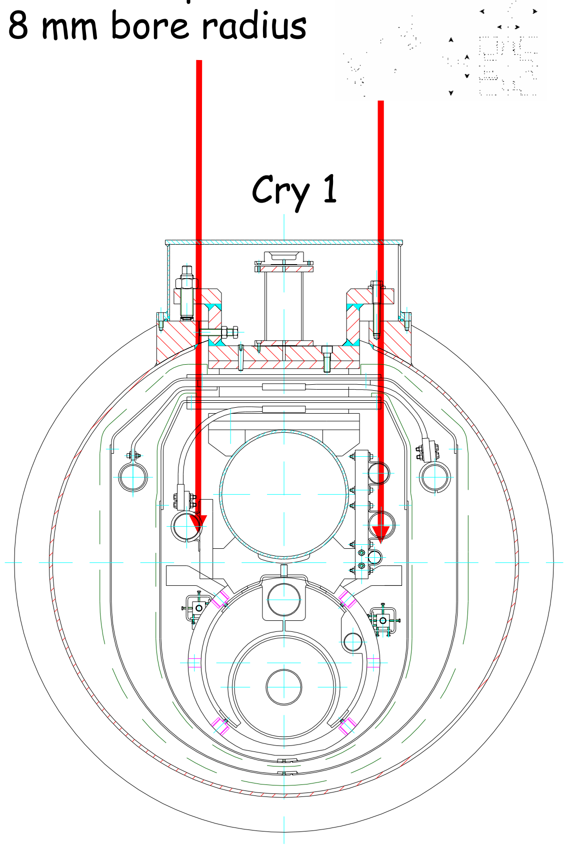
Wire Position Monitors

On line monitoring of cold mass movements during cool-down, warm-up and operation

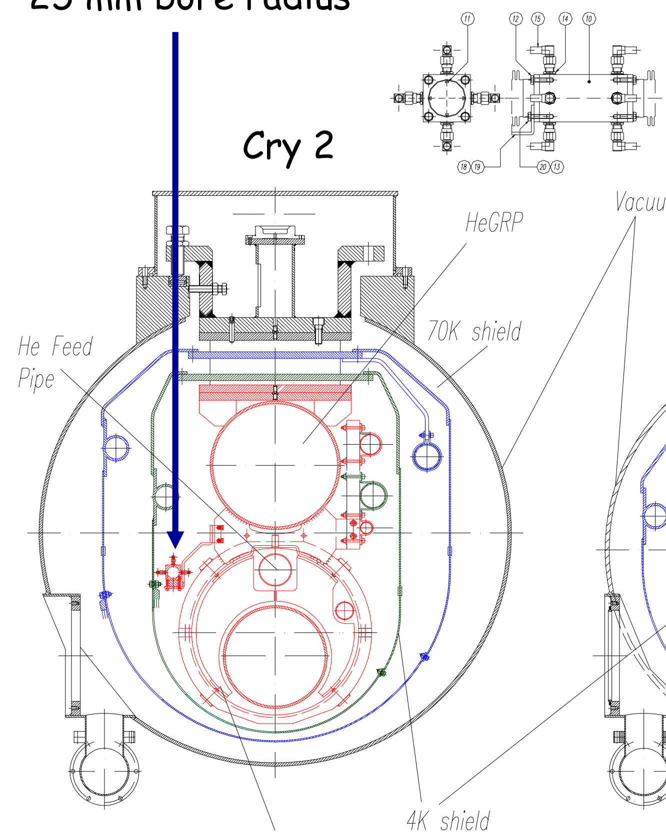
2 WPM lines with 2 x 18 sensors
4 sensors per active element
8 mm bore radius

1 WPM lines
1 sensors per active element
25 mm bore radius

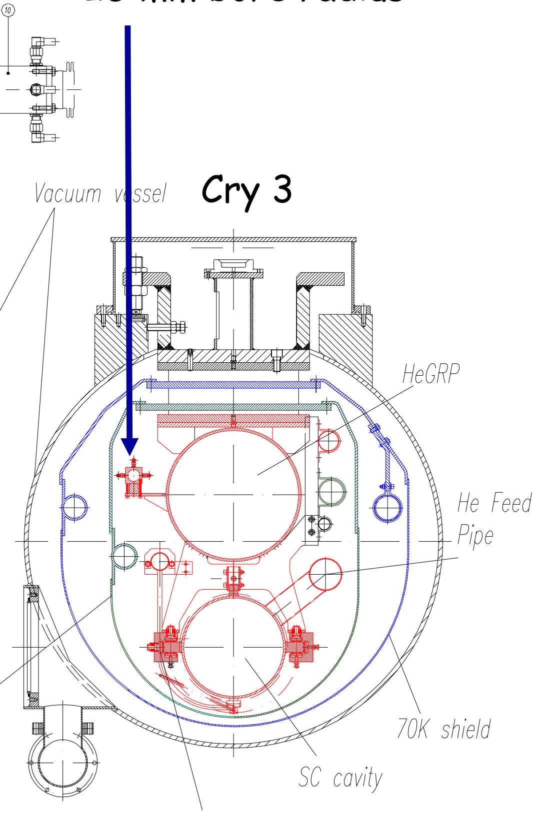
1 WPM line
7 sensors/module
25 mm bore radius



Module 1

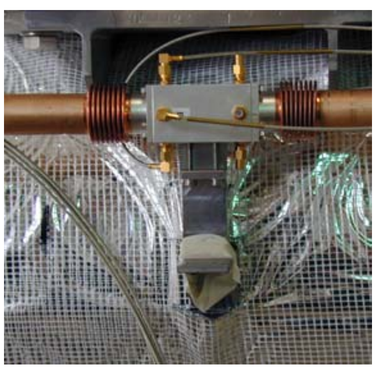


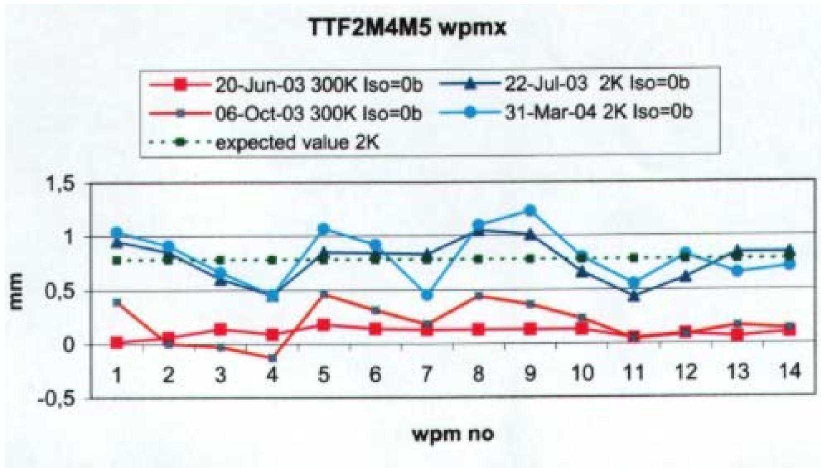
Module 2 & 3

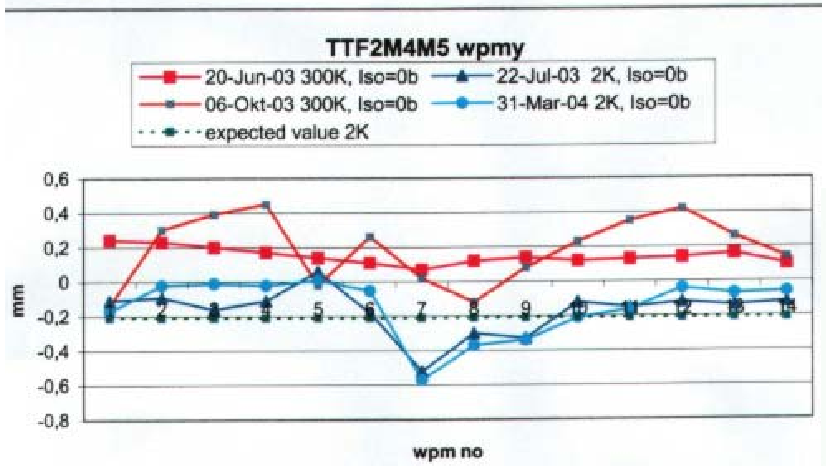


Module 4 & 5

ACC4 & ACC5 Met Specs







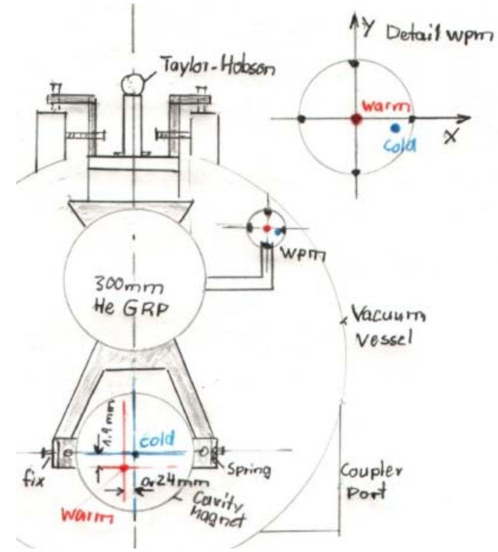


Table 1: Result Summary.

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

- Still some work at the module interconnection
- Cavity axis to be properly defined

Installation and Cold test Overview

Module	Type	Assembly Year	Days	Installation and Test in TTF-Linac		Therm. Cycles cold/warm
Capture	Spec.	Saclay 1996		Oct-96	96-->Sep-03	c/w 13
M1	I	1997	>>	Mar-97	97-->Sep-97	c/w 2
M1 rep.	I	1997/98	>>	Jan-98	98-->Mar-99	c/w 3
M2	II	1998	>>	Sep-98	98-->May-02	c/w 3
M3	II	1999	35+15	Jun-99	99-->May-02	c/w 1
M1*	II	2000	24	Jun-02	02-->	c/w 3 +1
M4	III	2001	18+10	Apr-03	03-->	c/w 1 +1
M5	III	2002	30	Apr-03	03-->	c/w 1 +1
MSS	Spec.	2002	36	Jun-02	02-->Sep-03	c/w 3
M3*	II	2003	18+6	Apr-03	03-->	c/w 1 +1
M2*	II	2004	20	Feb-04	04-->	c/w 1
(M6 EP)	III	(end 2004?)		Modules under test in TTF2-Linac		

Status:15-Sep-04 RLange-MKS-

TTF Cryomodule Performances

Status:15-Sep-04 R.Lange -MKS1-

Designed, estimated and measured static Cryo-Loads TTF-Modules in TTF-Linac

Module	40/80 K [W]			4.3K [W]			2 K [W]			Notes
Name/Type	Design	Estim.	Meas.	Design	Estim.	Meas.	Design	Estim.	Meas.	
Capture			46,8			3,9			5,5	Special
Module 1 I	115.0	76.8	90.0 *	21.0	13,9	23.0 *	4,2	2,8	6,0 *	Open holes in isolation
Modul1 rep. I	115.0	76.8	81,5	21.0	13,9	15,9	4,2	2,8	5,0	2 end-caps
Modul 2 II	115.0	76.8	77,9	21.0	13,9	13.0	4,2	2,8	4,0	2 end-caps
Module 3 II	115.0	76.8	72.0 **	21.0	13,9	48.0 **	4,2	2,8	5,0 *	Iso-vac 1E-04 mb, 2e-caps
Module 1* II	115.0	76.8	73.0	21.0	13,9	13.0	4,2	2,8	<3.5	1 end-cap
Module 4 III	115.0	76.8	74	21.0	13,9	13.5	4,2	2,8	<3.5	1 end-cap
Module 5 III	115.0	76.8	74	21.0	13,9	13.0	4,2	2,8	<3.5	1 end-cap
Module SS	115.0	~76.8	72.0	~21.0	~13.9	12.0	~4.2	>2,8	4,5	Special, 2 end-caps
Module 3* II	115.0	76.8	75	21.0	13,9	14	4,2	2,8	<3.5	1 end-cap
Module 2* II	115.0	76.8	74	21.0	13,9	14,5	4,2	2,8	<4,5	2 end-caps
Module 6 EP	Type III, EP-Cavities Goal:Solution close to XFEL Modules									(Assembly End-04??)
	Design and estimated values by Tom Petersen 1995 -Fermilab-							Modules under Test in TTF2-Linac		

Cold Leaks Experience at TTF

Summary of Vacuum/He Leaks after Cold Tests in TTF/TTF2-Modules

Status:15-Sep-04 R. Lange -MKS-

Module	M1	M2	M3	MSS	M1*	M3*	M4	M5	M2*
Number of leaks Vac	1	6	7	0	1	1	0	0	
Number of cool/warm	3	3	1	3	3 +1	1 +1	1 +1	1 +1	1
He-->insulation	0	0	1 C5 tank weld	0	0	0	0	0	0
			1 C8 bellow w						
Insulation-->coupler	0	0	0	0	0	0	0	0	?
Insulation-->beam pipe	Cav-flange	4 BPM feed-thr	1 BPM feed-th	0	1	1(more?)	0	0	?
		1 C6 e-pickup	2 C2/C8 e-pick						
			1 C7 coup-flan						
Coupler-->beam pipe	0	1 C1 ceram wi		0	0	0	0	0	?
He-->beam pipe	0	0		0	0	0	0	0	0

TESLA Cryomodule Concept Peculiarities

Positive

- Very low static losses
- Very good filling factor: Best real estate gradient
- Low cost per meter in term both of fabrication and assembly

Project Dependent

- Long cavity strings, few warm to cold transitions
- Large gas return pipe inside the cryomodule
- Cavities and Quads position settable at ± 300 μm (rms)
- Reliability and redundancy for longer MTTR (mean time to repair)
- Lateral access and cold window natural for the coupler

Negative ?

- Longer MTTR in case of non scheduled repair
- Moderate (± 1 mm) coupler flexibility required

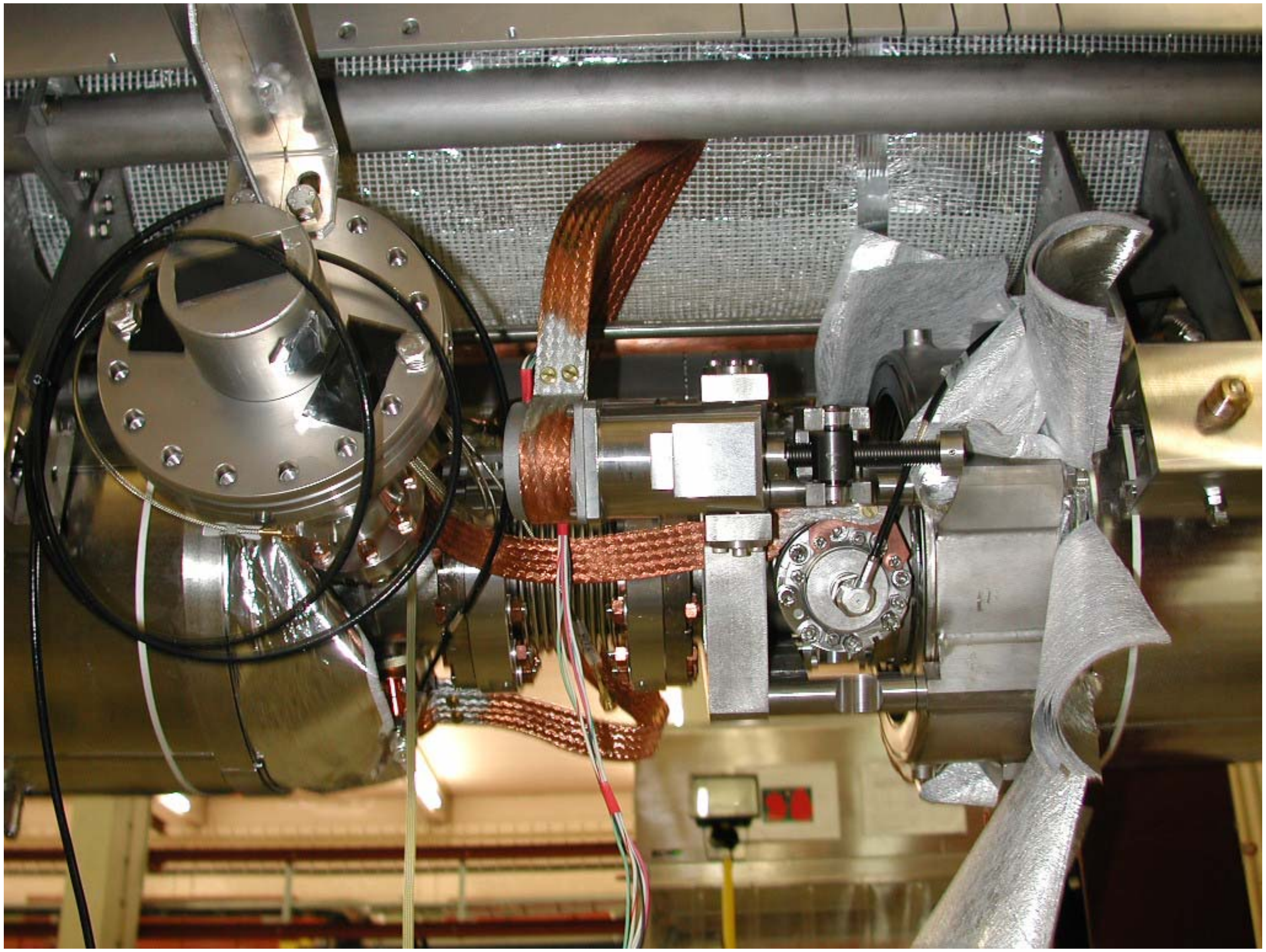
Module assembly picture gallery - 1

String inside the Clean Room

Module assembly picture gallery - 2

String in the assembly area

Module assembly picture gallery - 3



Cavity interconnection detail

Module assembly picture gallery - 4

String hanged to he HeGRP

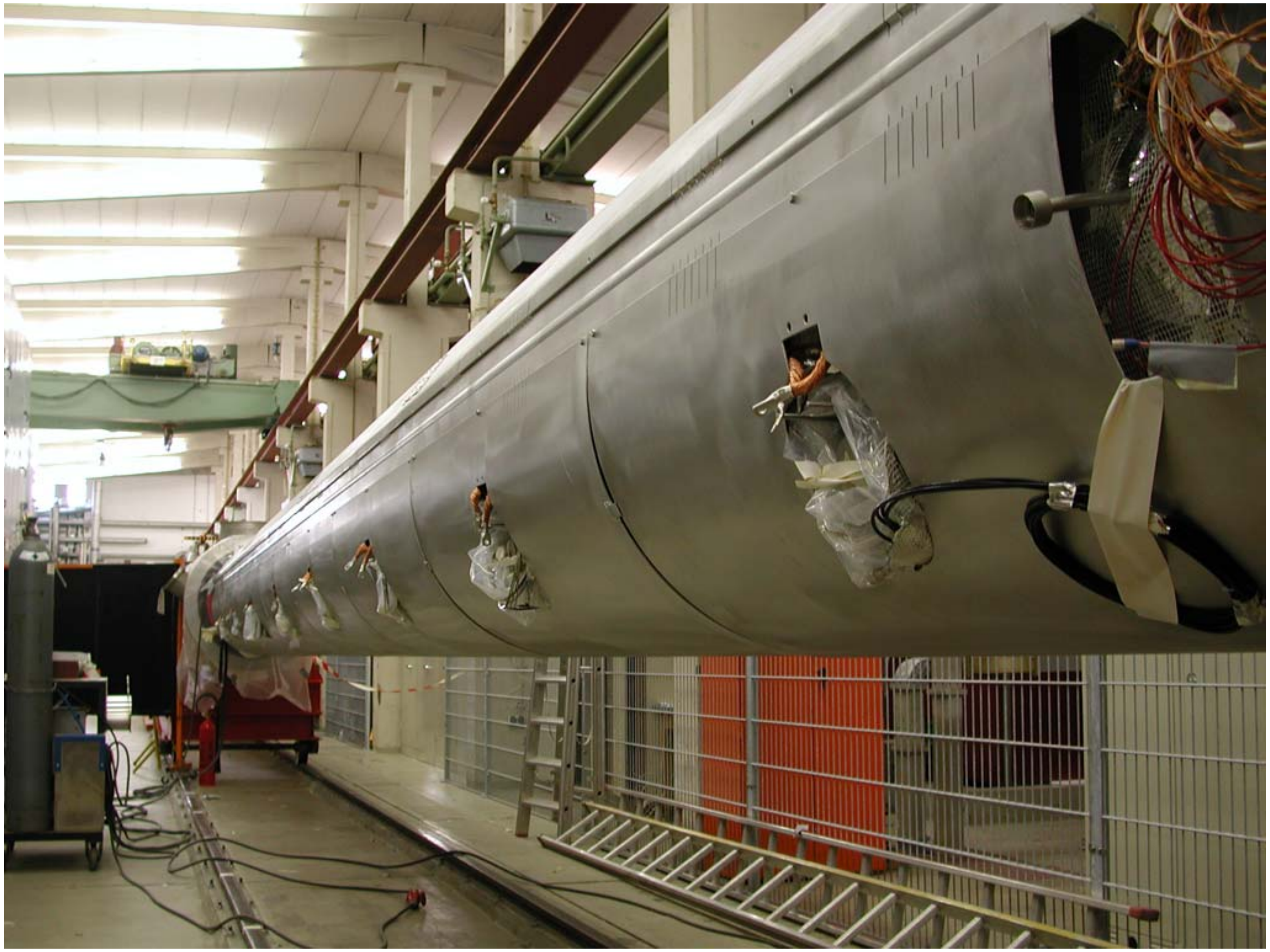
Module assembly picture gallery - 5

String on the cantilevers

Module assembly picture gallery - 6

Close internal shield MLI

Module assembly picture gallery - 7



External shield in place

Module assembly picture gallery - 8

Welding “fingers”

Module assembly picture gallery - 9

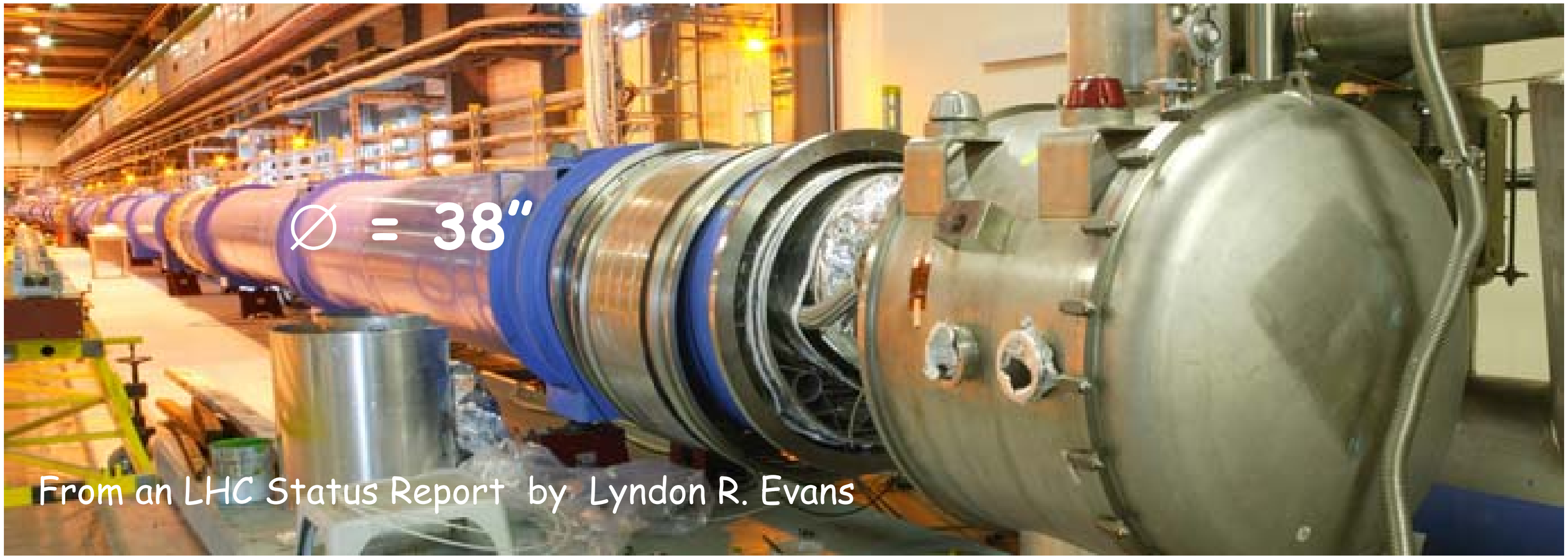
Sliding the Vacuum Vessel

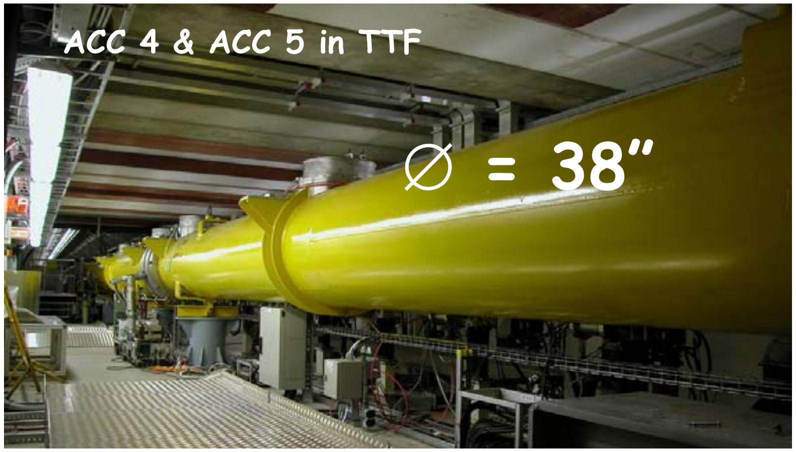
Module assembly picture gallery - 10

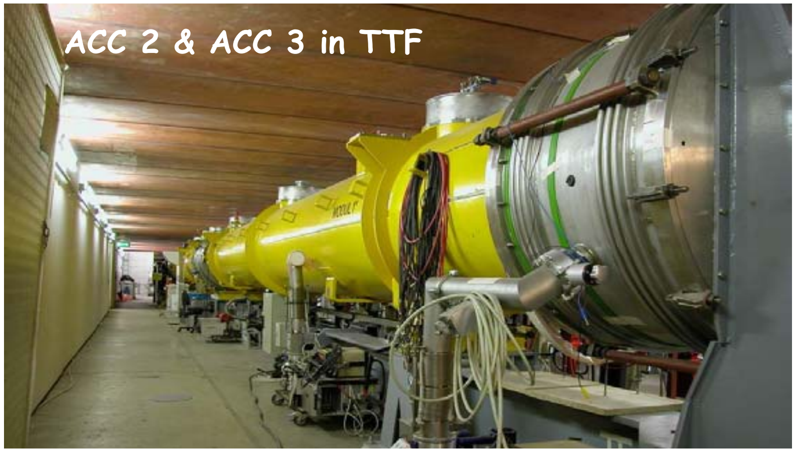
Complete module moved for storage

LCH and TESLA Cryomodule Comparison

A number of design details from the LHC/CERN experience should be considered

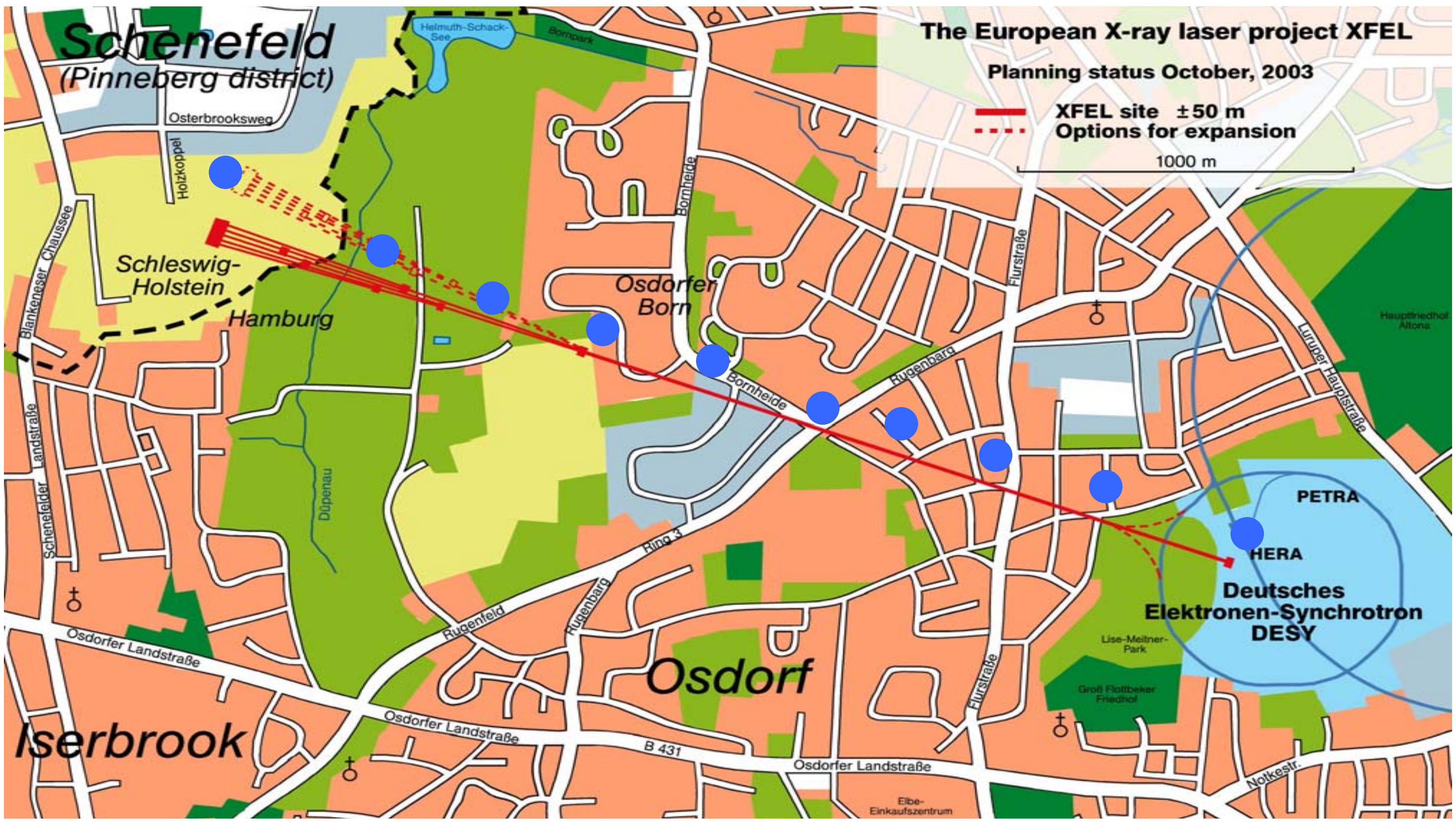






The X-FEL

- 50%-60% funded by the German Government - European consensus established
- **Great opportunity for all TESLA Technology based Projects**
  - Machine reliability according to SRL standards
  - Industrial mass production of cavities (~ 1000) and modules (> 120)



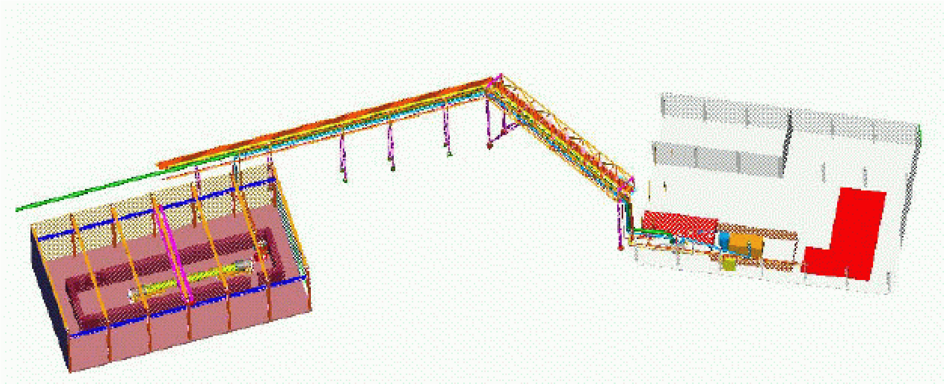
Cry 3 Design and X-FEL Requirements

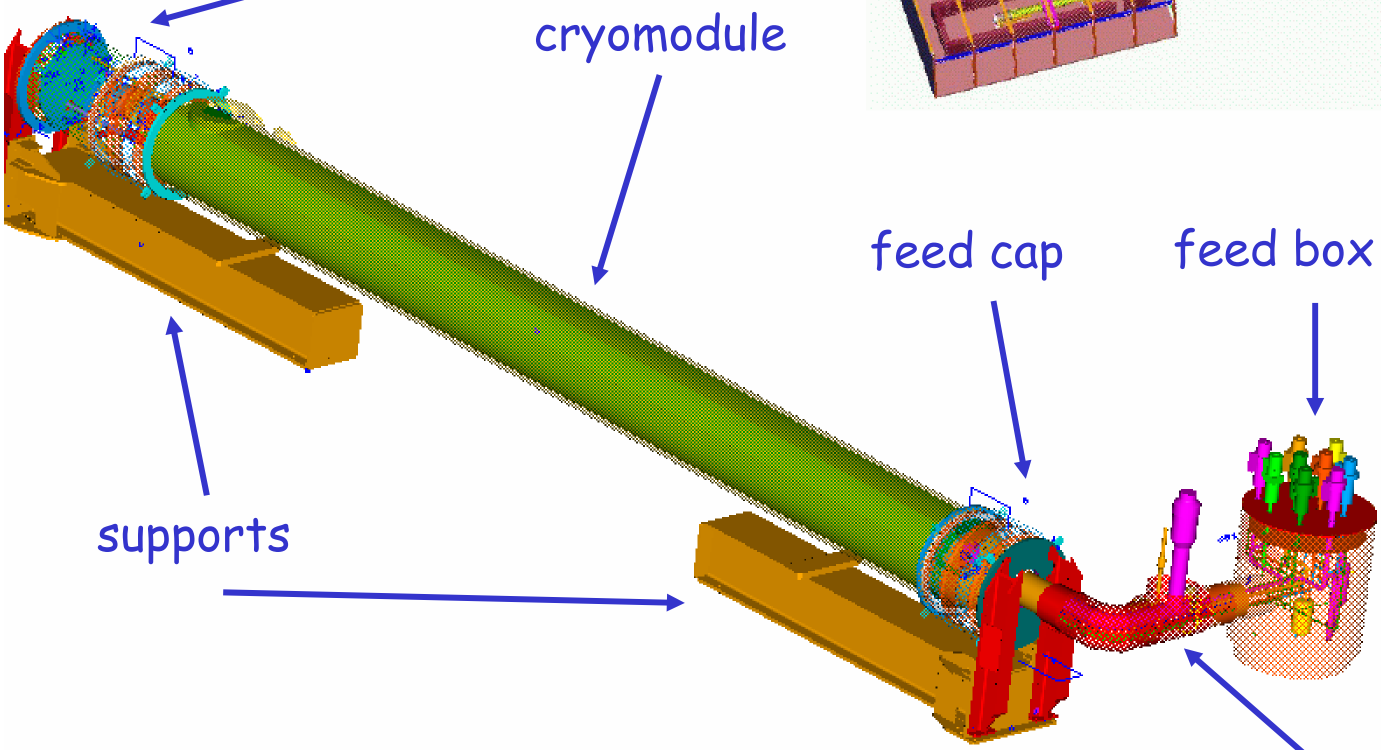
Module performance	Module 4	Module 5	Meet XFEL Requirements	Comment
RF gradient	>23 MV/m	>25 MV/m	yes	
Cryo losses (2K /4K/ 70K)	<3.5 / 13.5 / 74	<3 / 13.5 / 74	yes	
Leaks	no	no	yes	2 cooldown / 1 warmup
Alignment of cavities inside	better +/- 0.5 mm	better +/- 0.5 mm	yes	improvements possible
Component performance				
Coupler	TTF II	TTF III	yes	Options: reduce cost e.g. increase copper layer thickness, simplify assembly
HOM coupler	DESY/Saclay	DESY	yes	Option: Higher duty cycle
Pickups	diverse	diverse	yes	thermal cycling necessary as quality control
Tuner	Saclay	Saclay	yes	Option: Piezo, more compact and stiffer mechanical design
Magnet	DESY	DESY	yes	Option: Smaller size and 2 K operation
BPM	Saclay/ DESY	Saclay/ DESY	no	Prototype in M2* at ACC1 O.K.
HOM absorber	stainless steel beampipe inside the quad	stainless steel beampipe inside the quad	no	Absorber samples installed between ACC2 and ACC3, New design underway, needs test
Magnetic shielding	Cryoperm + demagnetization	Cryoperm + demagnetization	yes	

Rolf Lange/ Lutz Lilje DESY TESLA 1st Module Meeting 17.06.2004

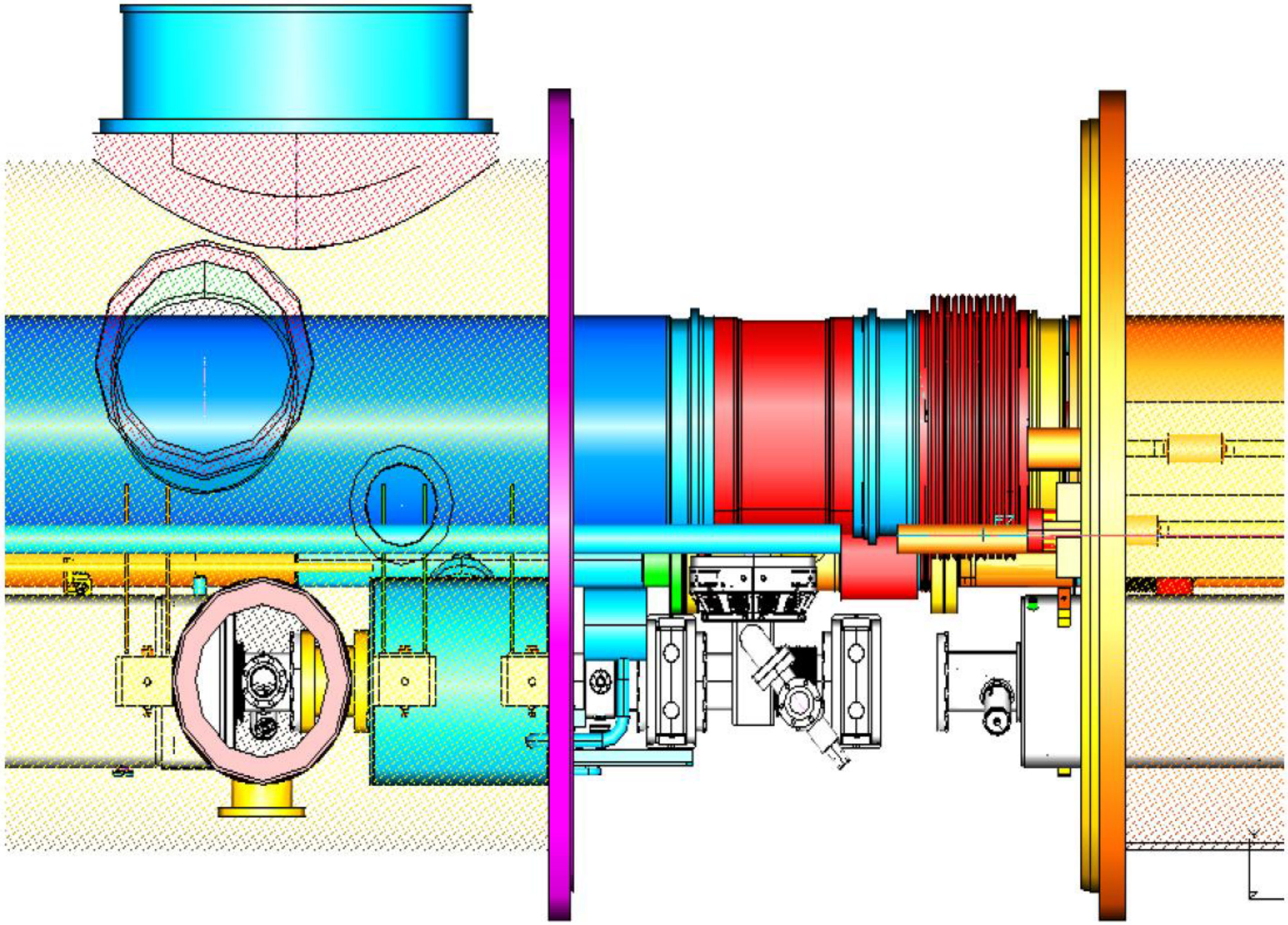
Cryomodule Test Stand @ DESY

- **Under construction**
- **Commissioning 2005/06**

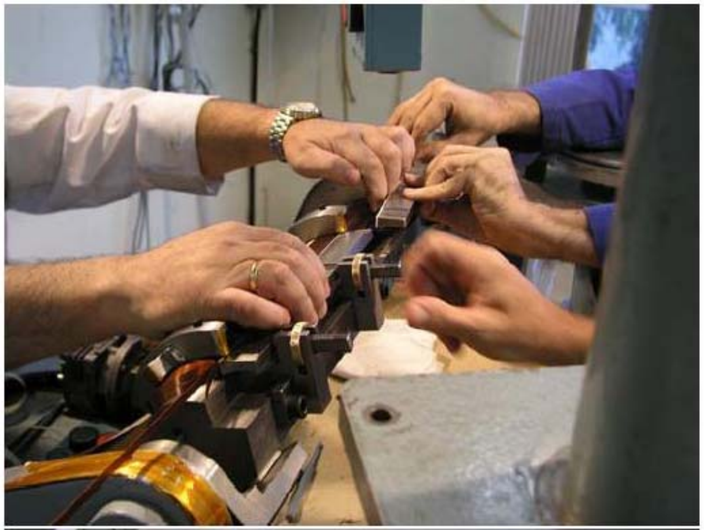
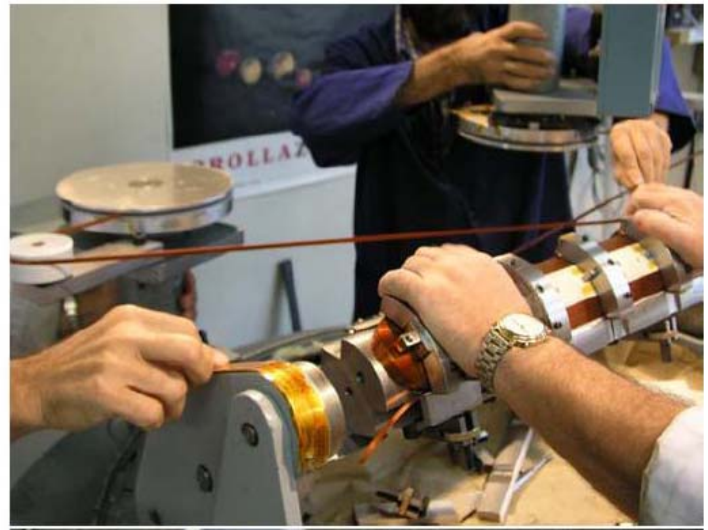


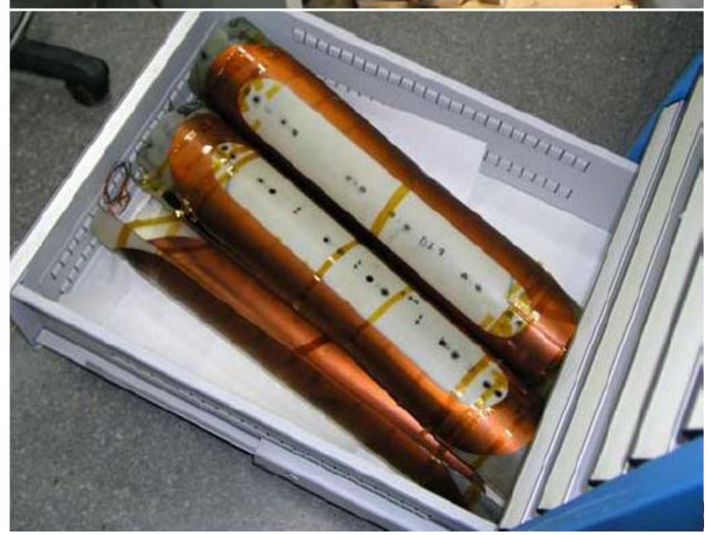


Cry3 adaptation in progress

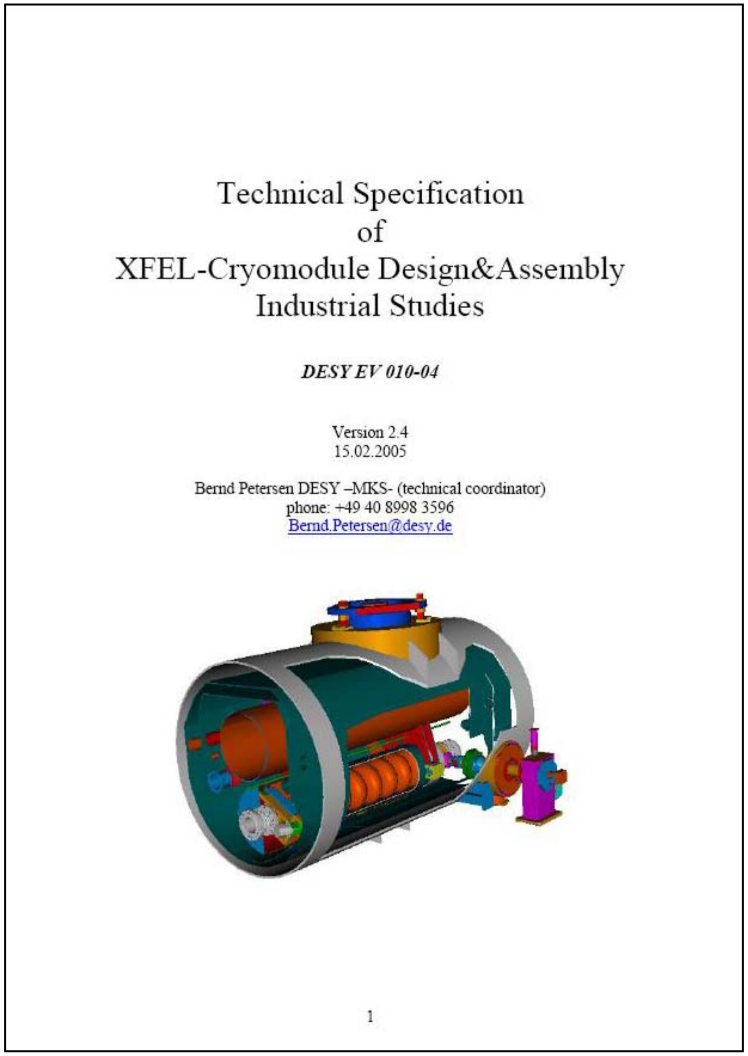


The Ciemat 2K Quadrupole



Industrial Study



Technical Specification
of
XFEL-Cryomodule Design&Assembly
Industrial Studies

DESY EV 010-04

Version 2.4
15.02.2005

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1

- Technology transfer from Research to Industry
- Review with industry of the cryomodule design and assembly to focus:
  - Cost drivers
  - Critical steps of the assembly procedure
- Suggestion based on industrial experience in term of:
  - Similar productions
  - Labor organization
  - Quality control

Proven design, just few details to clean up

Most are useful, but not necessary, for X-FEL

Industrialization foreseen for X-FEL good for ILC too

A few examples

- Quad Fixture (sliding as for cavities) – planned for X-FEL
- Flange connections: Sealing and Fixing
- Various braids for heat sinking (all coupler sinking stile)
- Cables, Cabling, Connectors and Feed-through
- Composite post diameter (and fixture for transportation)
- Warm fixtures of cold mass on Vacuum Vessel (fixed and sliding)
- LMI Blankets for the 50-70 K shield (LHC Style)
- Module interconnection: Vacuum Vessel sealing, pipe welds, etc.
- Coupler provisional fixtures and assembly

Design changes important for ILC

- Move quadrupole to the center
  - Quad/BPM Fiducialization
  - High pressure rinsing and clean room assembly issues
  - Movers for beam based alignment? Why not if really beneficial
- Short cavity design
  - Cutoff tubes length by e.m. not ancillaries (coaxial tuner)
- Cavity inter-connection: Flanges and bellows (coating?)
  - Fast locking system for space and reliability (CARE activity)
  - Bellow waves according to demonstrated tolerances
- Coaxial Tuner with integrated piezo-actuators
  - Parametric "Blade Tuner" successfully operated on superstructures
  - Piezo fast tuner not integrated yet
- Longer module design: 10-12 cavities
  - Length to be based on the overall machine cost optimization

Concluding Remarks

- TTF Operation Experience shows that Cry 3 Modules are close to the optimum in term of performances
- Improvements where conceived at the time of the TESLA TDR, but never developed because of sake of funding and personnel
- X-FEL will use the present design with minimum modifications
- ILC should use the TESLA TDR cryomodule design, very close to the so called Cry 3, as the basis for further improvements
- An international concentrated effort in this direction would have the advantage to have most of the modifications implemented in time for the X-FEL, with the strong support and expertise of DESY and of the European TESLA Collaboration members.
- Synergy with the X-FEL would be much stronger and the benefit for the ILC really great