The Evolving ILC Project

The Cryomodule from TTF/TESLA to the ILC RDR

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TESLA Cryomodule Design Ratinales

- 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

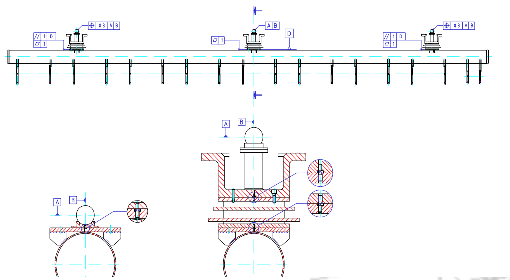
Performing Cryomodules in TTF

Three cryomodule generations to:

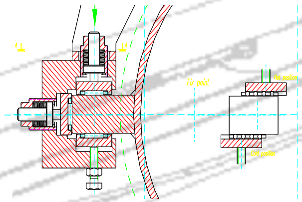
- improve simplicity and performances
- minimize costs

"Finger Welded" Shields

Reliable Alignment Strategy

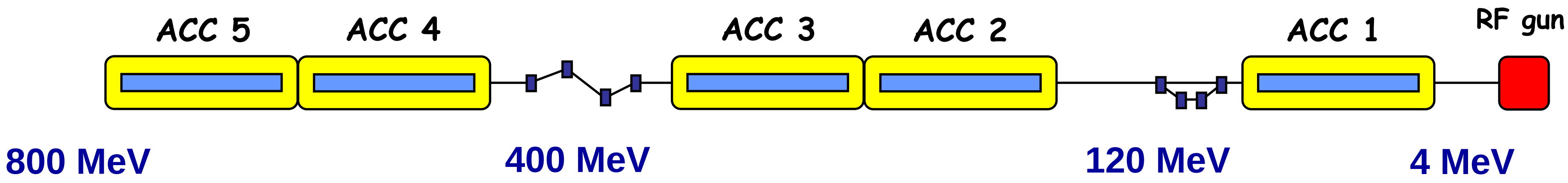


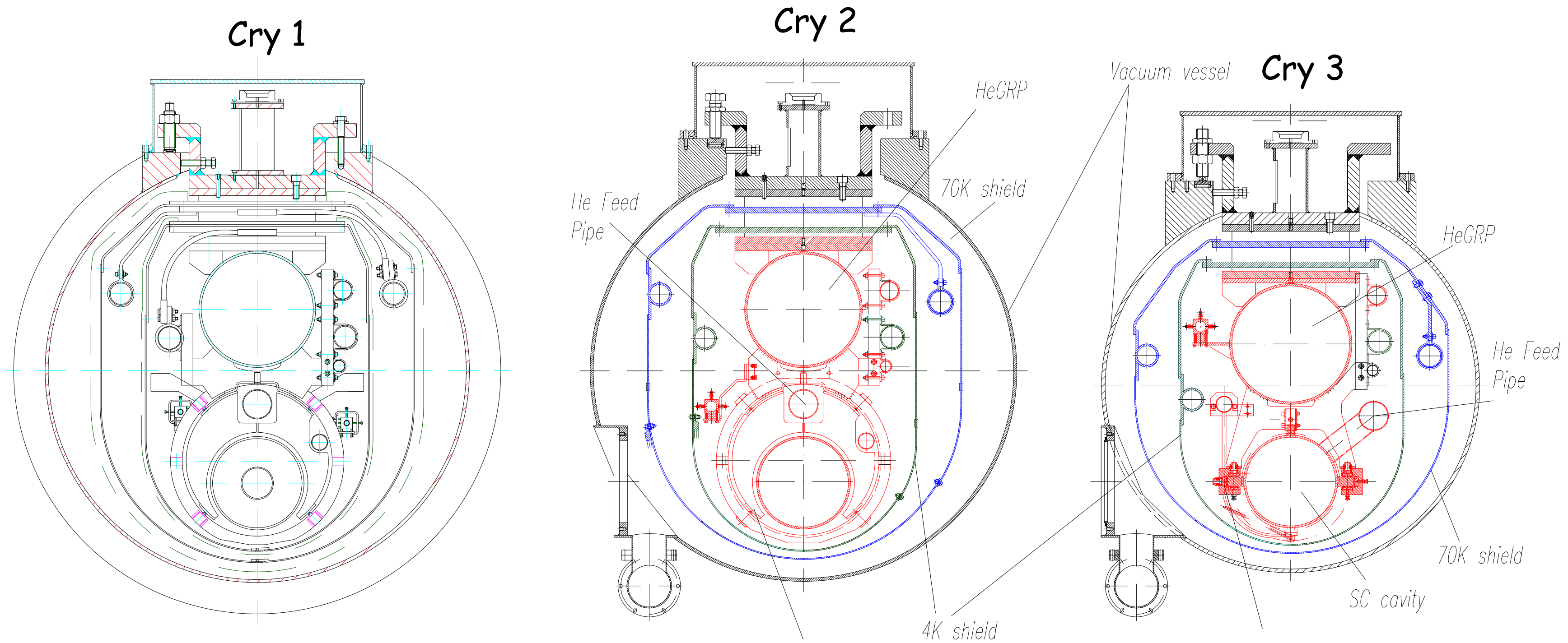
Sliding Fixtures @ 2 K



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

Three Cryomodule Generations in TTF





1st Module in TTF I

Module 1 & 2 in TTF I
Module 1, 2 & 3 in TTF II

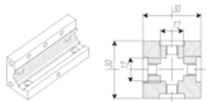
Module 4 & 5 in TTF II

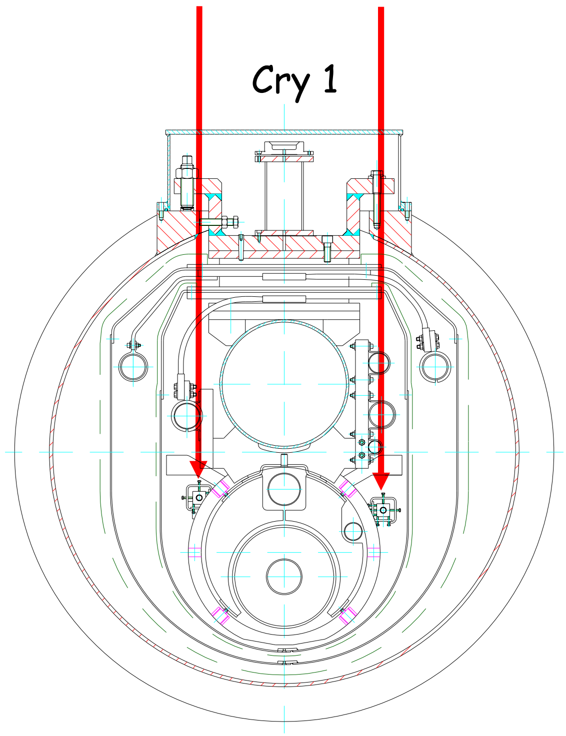
WPMs to qualify alignment strategy

WPM = Wire Position Monitor

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

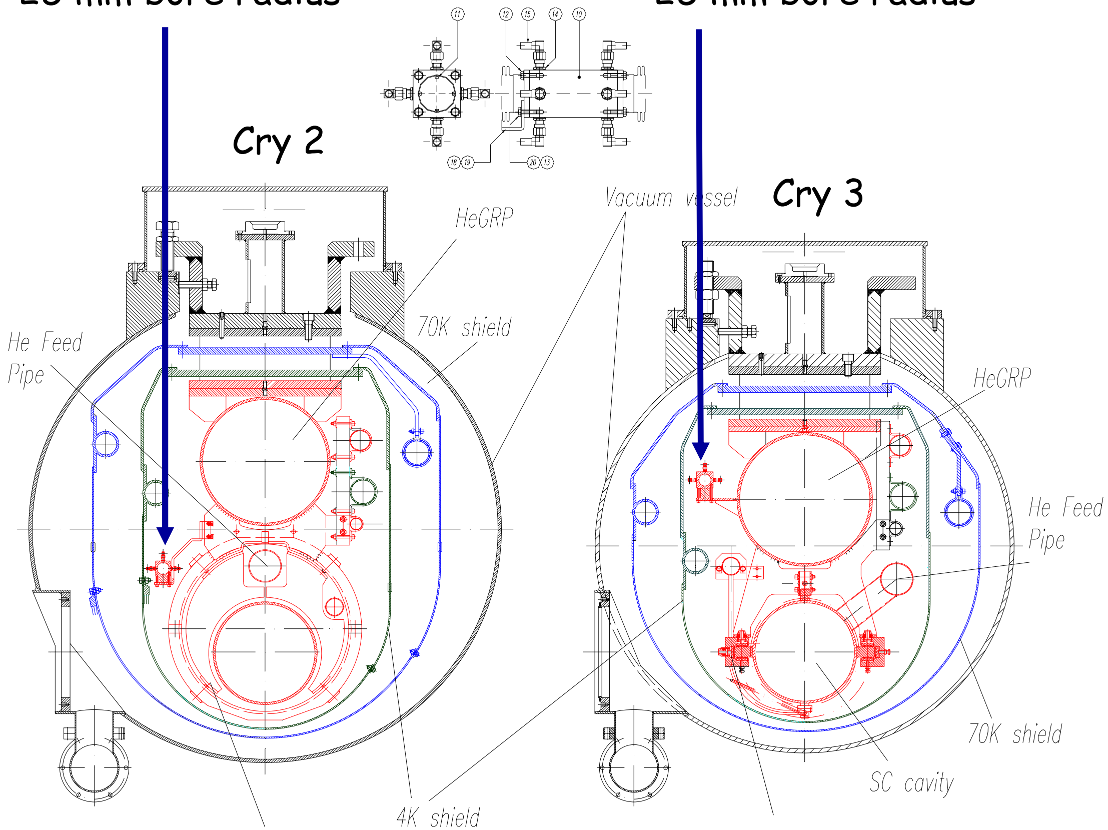
2 WPM lines with 2 x 18 sensors
4 sensors per active element
8 mm bore radius



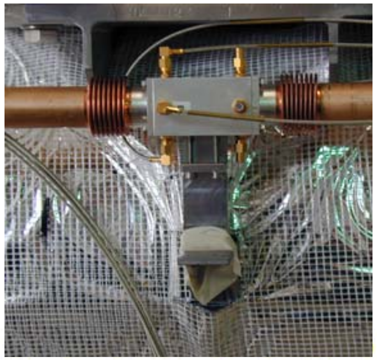


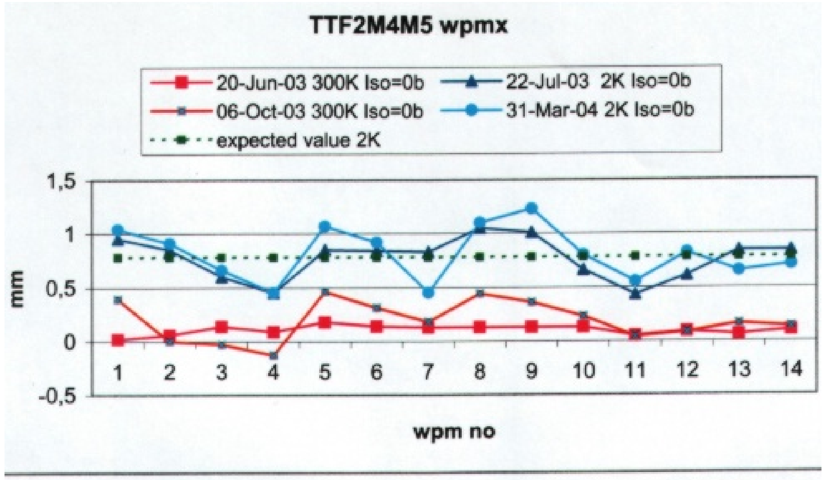
1 WPM lines
1 sensors per active element
25 mm bore radius

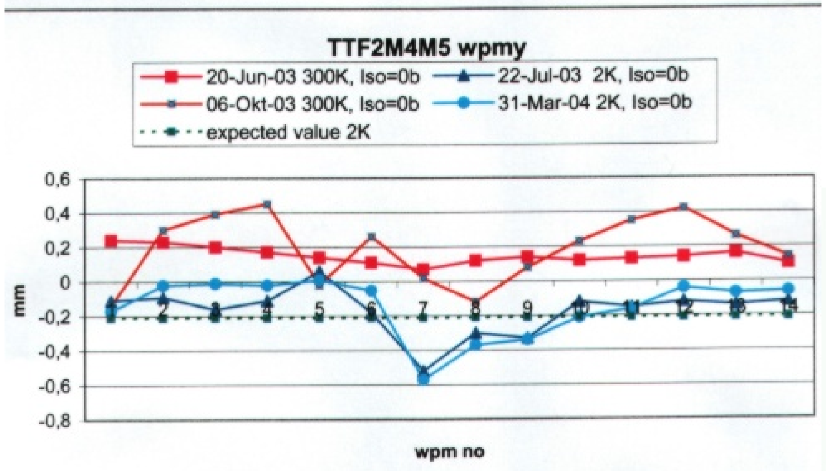
1 WPM line
7 sensors/module
25 mm bore radius



ACC4 & ACC5 Met Specs







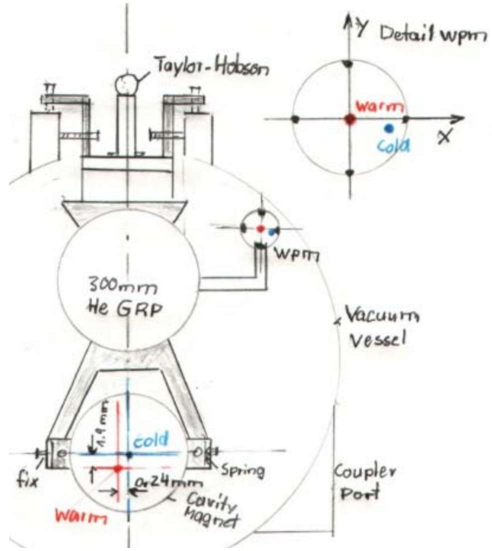
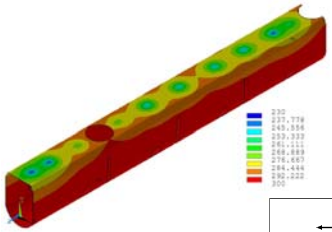


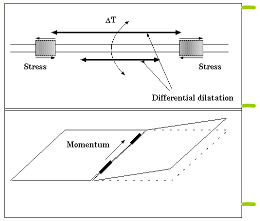
Table 1: Result Summary.

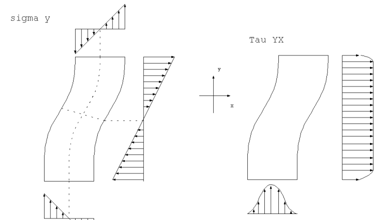
TDR Specifications (rms)		
Cavities	x/y	± 0.5 mm
Quadrupoles	x/y	± 0.3 mm
WPM results (peak)		
Cavities	x	+ 0.35/- 0.27 mm
	y	+ 0.18/- 0.35 mm
Quadrupoles	x	+ 0.2/- 0.1 mm
	y	+ 0.35/- 0.1 mm

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

From Prototype to Cry 3

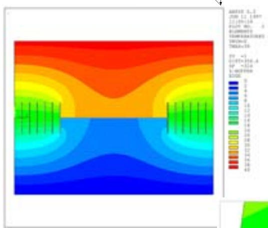


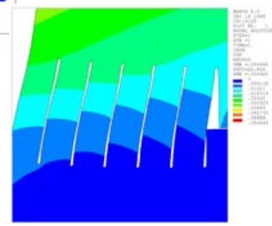


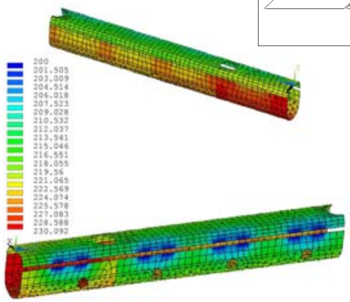


Extensive FEA modeling (ANSYS™) of the entire cryomodule

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



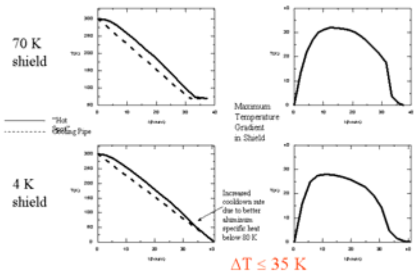


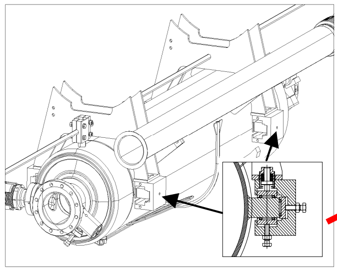


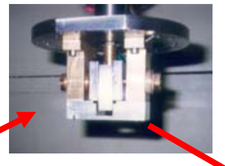
Detailed sub-modeling of new components and Laboratory tests

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

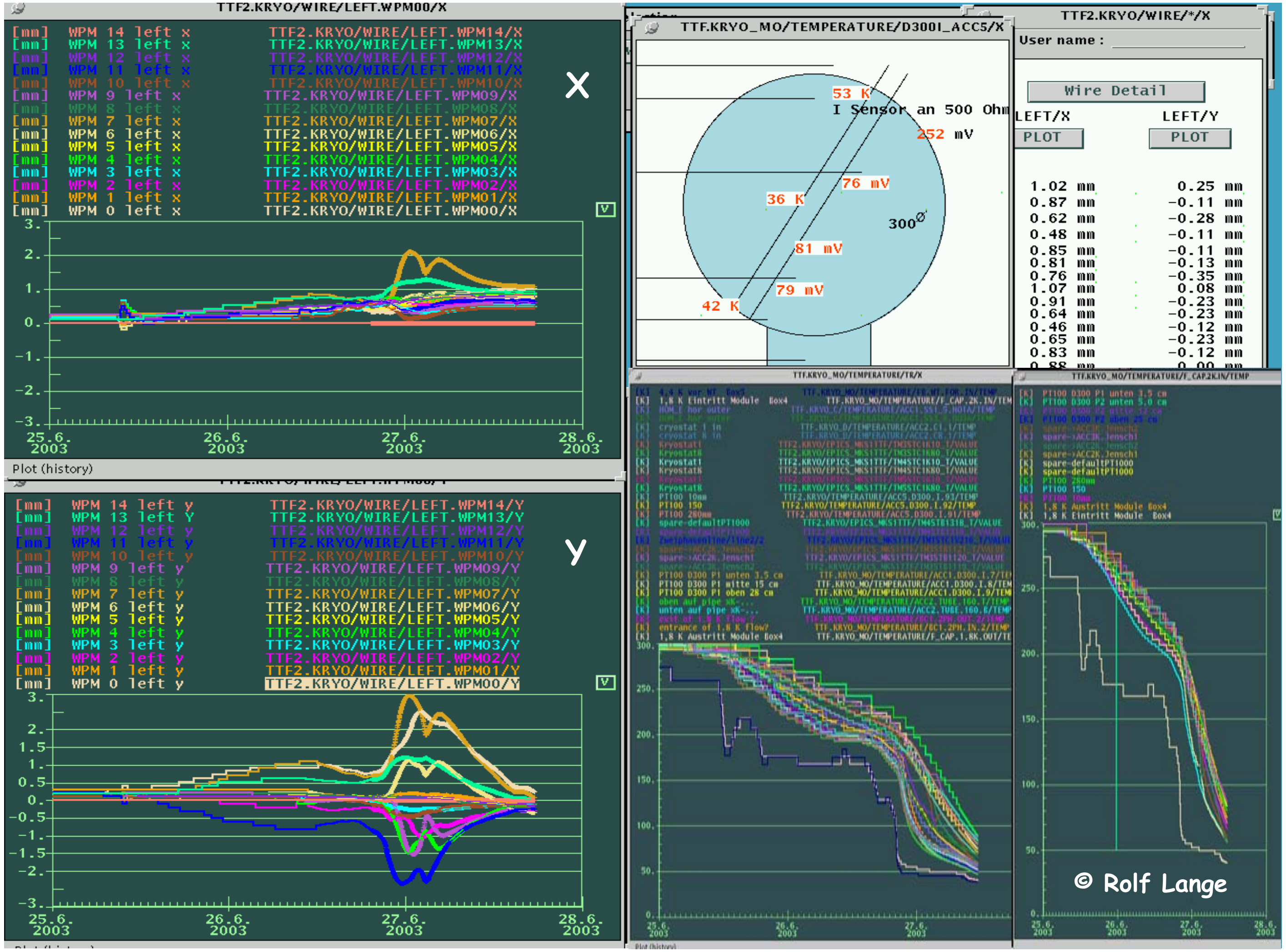
Welded Shields







Safe Cooldown of ACC4 and ACC5



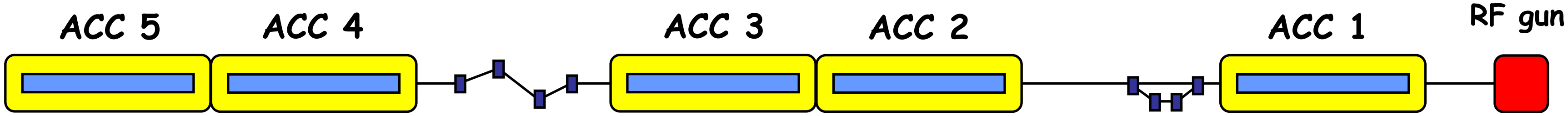
Very Low Static Losses

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			

Cryomodules installed in TTF II



800 MeV 400 MeV 120 MeV 4 MeV

From Type III to TESLA

- Improving quadrupole package stability
  - 2 K quadrupole package
  - Quadrupole placed in the module center
  - Sliding hanging as for cavities

- Improving linac filling factor
  - Inter-cavity spacing reduced to a possible minimum: 283 mm
  - 12 cavities per cryomodule instead of the 8 in TTF
  - Inter-module spacing reviewed, including HOM absorber

- Reviewing cooling pipe size for TESLA 800
  - Conceived inside the available margins
  - Not really studied at the time of the TDR

From Type III to XFEL

- Type III cryomodule is maintained as the reference
  - INFN drawing moved to 3D for modifications
- Some modifications and improvements are in progress:
  - Cavity spacing adapted to be equal to 3/2 λ
  - Module interconnection reviewed
    - Odd integer number of $\lambda/2$ has to be respected
    - HOM absorber integrated, Ti/SS connections reviewed
  - Possible improvements on subcomponents
    - Work mostly independent from ILC
    - Some suggestion from industry is expected
- Two new Type III module fabricated
  - Complete documentation for possible new suppliers
- Industrial Studies for technology transfer and cost saving

From TESLA to ILC (BCD)

Same general criteria than in the TESLA TDR

- Quadrupole package at the module center
- Cavity spacing as for TESLA
- Module interconnection includes HOM absorber

but:

- 8 cavities per cryomodule instead of 12
- Pipe size reviewing for the highest heat load

and:

- Design performed in a full international collaboration
- Specifications consistent with all regional rules
- Subcomponent reviewing for cost reduction still important

From ILC BCD to ILC RDR

- Change request presented to CCB on October 30, 2006:
  - Change of the cryomodule (CM) layout driven by each of the 10MW klystron RF unit. Previously, with two 8-cavity CM without a magnet and one 8-cavity CM with a magnet. Now, with two 9-cavity CM without a magnet and one 8-cavity CM with a magnet.
  - Reduce cryogenic power by 13%
- CCB, after a deep analysis and discussion, on November 28 suggested to EC to not accept this CCR#20.
- Because of its cost saving impact EC represented the same proposal, including a modification of the beam parameters
- CCB is now approving this change proposal, with the exclusion of the reduction of safety margin on cryogenics

Consequences on the Cryomodule

- **No consequences for the cryomodule with quadrupole**

- **Redrawing the cryomodule without quad with 9 cavities**

Note

The two module have now a slightly different length **But**
The two modules could easily have the same length: that's good

3rd T4CM Meeting Goals

- Reviewing the work done so far
- Consider the preparation phase ended
- Redefine the objectives for Type IV cryomodule and prepare a challenging, but also realistic, time schedule
  - Which changes are included in the Type IV ?
  - Which changes are postponed to the ILC prototype ?
- Who is doing what ?
- How stuff are shared and integrated into the EDMS ?
- How the control is done to preserve cost and performances ?
  - 3D general drawing
  - Regional 2D cuts with tolerances
  - Material and fabrication specs