TESLA Technology Collaboration Meeting

DESY, 30 March - 1 April 2004

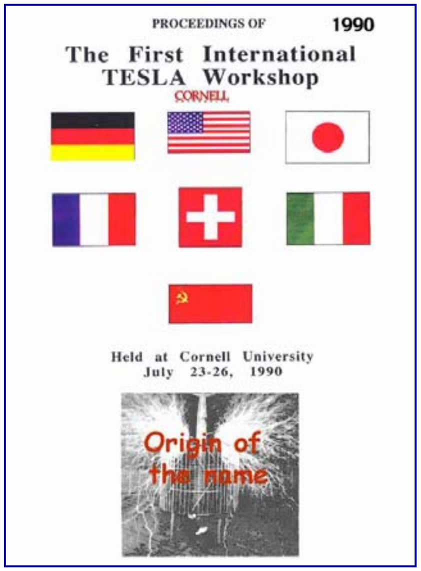
European Overview of TESLA Technology Related Activities

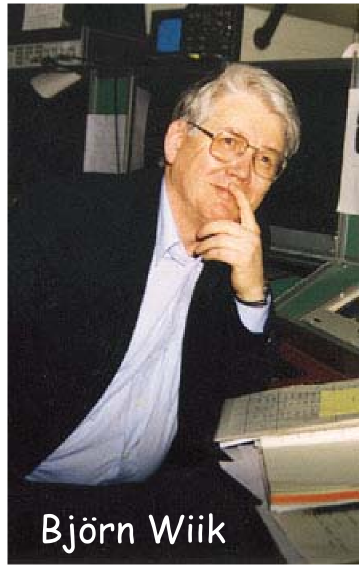
Carlo Pagani

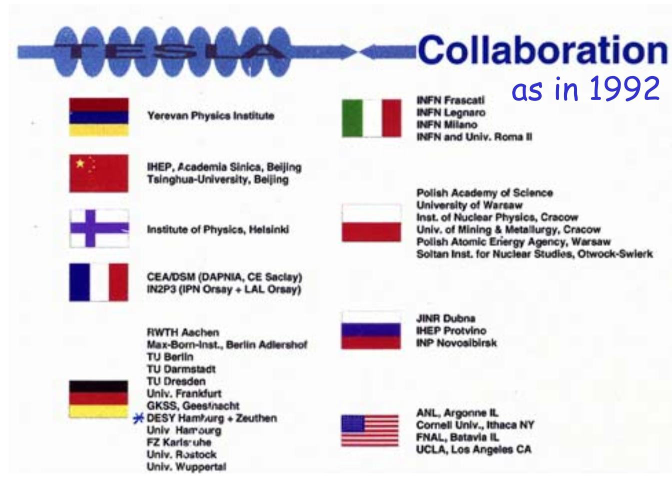
INFN Milano and DESY

On leave from University of Milano

The TESLA Collaboration







Develop SRF for the future TeV Linear Collider

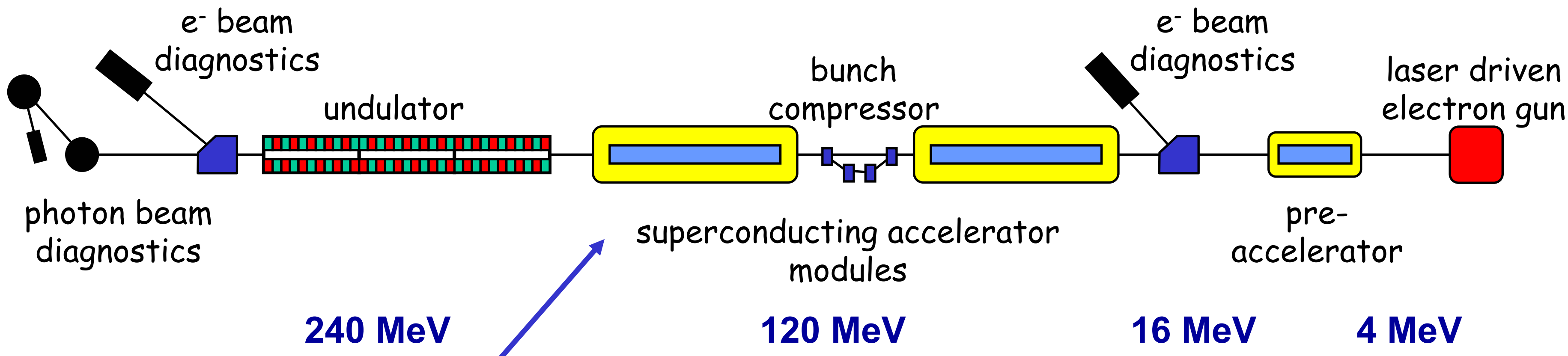
TTF: TESLA Test Facility

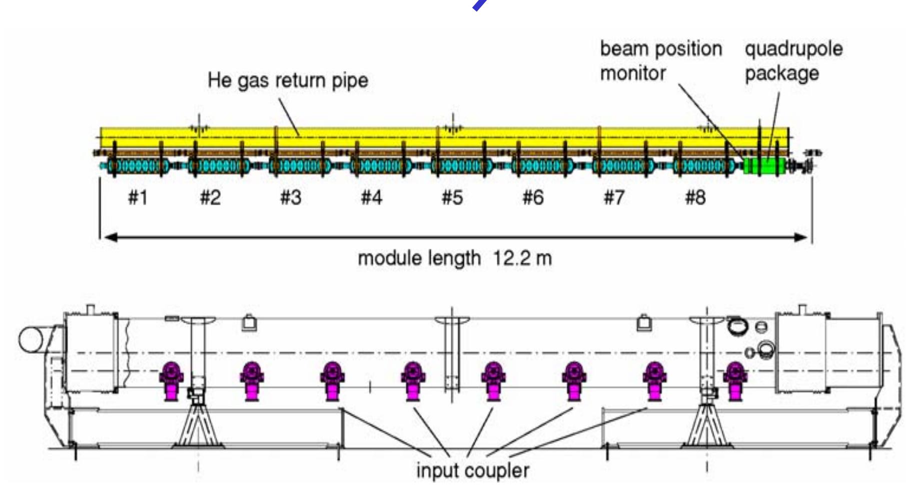
- **Full Prototype of the TESLA Linac:** for component and operation experience
- **Infrastructure**: for cavity development and module assembly

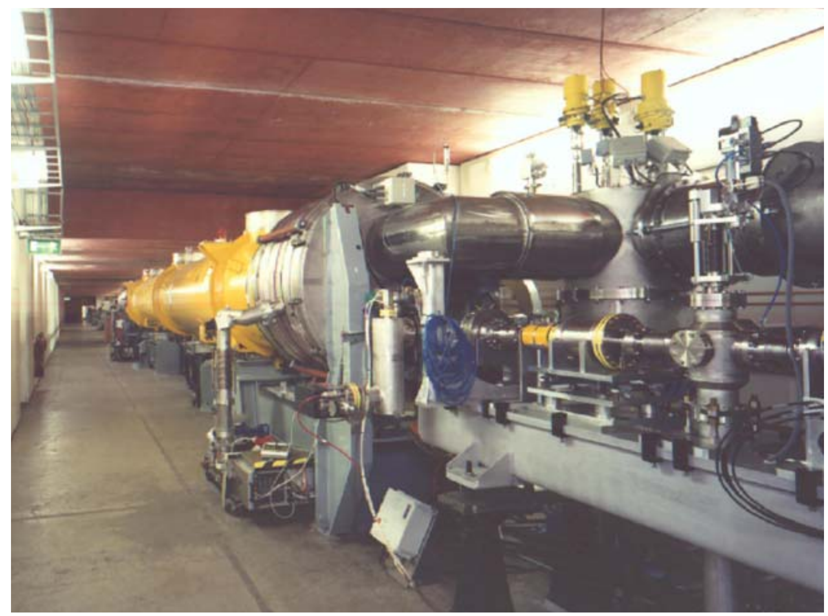
Basic goals

- ***Increase gradient by a factor of 5*** (Physical limit for Nb at ~ 50 MV/m)
- ***Reduce cost per MV by a factor 20*** (New cryomodule concept and Industrialization)
- ***Make possible pulsed operation*** (Combine SRF and mechanical engineering)

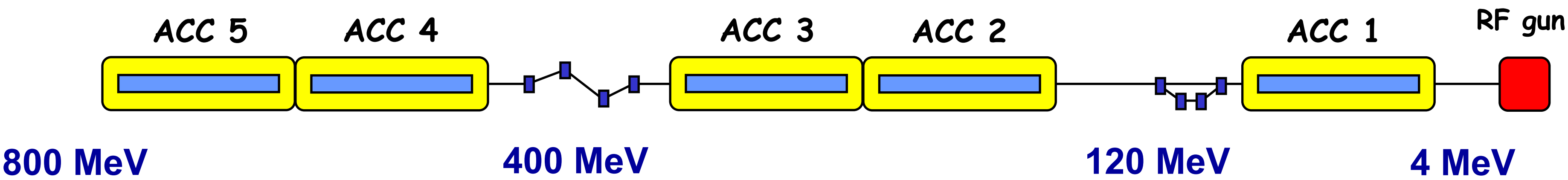
The TTF I Linac – 6 Year exp.

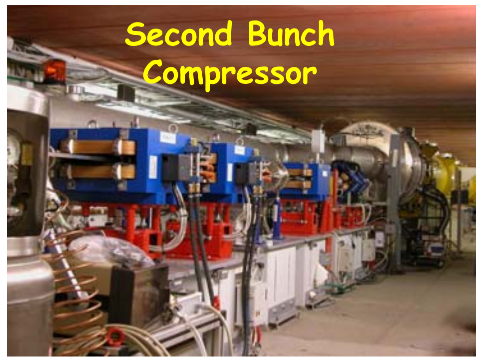






TTF II - VUV FEL





VUV FEL User Facility

- Linac Commissioning done
- SASE FEL Commissioning
  - High Gain done
  - Saturation coming soon

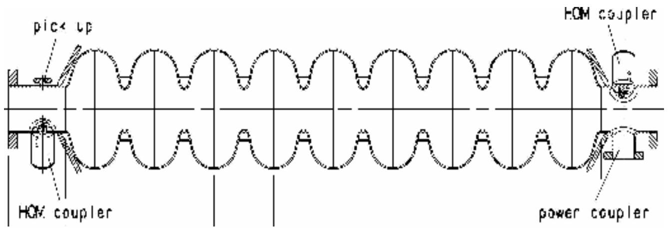
TTF2/VUV-FEL Schedule to 2007

Saturation in wavelength range 30-120 nm	July 2005
User operation (extended period)	
Operation with long bunch train	Dec. 2005
User operation (extended period)	
3rd Harmonic RF system and ACC6 installed	Feb. 2006
1 GeV beam energy	April 2006
Saturation 6 nm	June 2006
User operation (extended period)	
Seeding Option installed	Dec. 2006
Seeding demonstration	April 2007

The TESLA Cavity

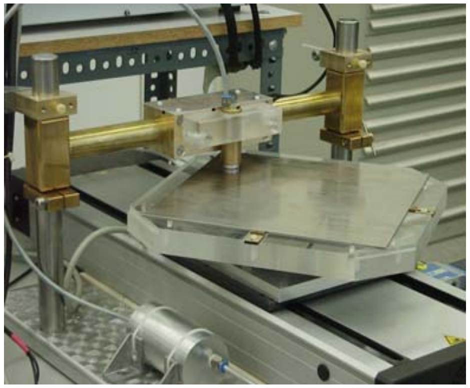
Major contributions from: CERN, Cornell, DESY, CEA-Saclay

- 9-cell, 1.3 GHz



TESLA cavity parameters

R/Q	1036	Ω
E_{peak}/E_{acc}	2.0	
B_{peak}/E_{acc}	4.26	mT/(MV/m)
$\Delta f/\Delta l$	315	kHz/mm
$K_{Lorentz}$	≈ -1	$Hz/(MV/m)^2$



Eddy-current scanning system for niobium sheets

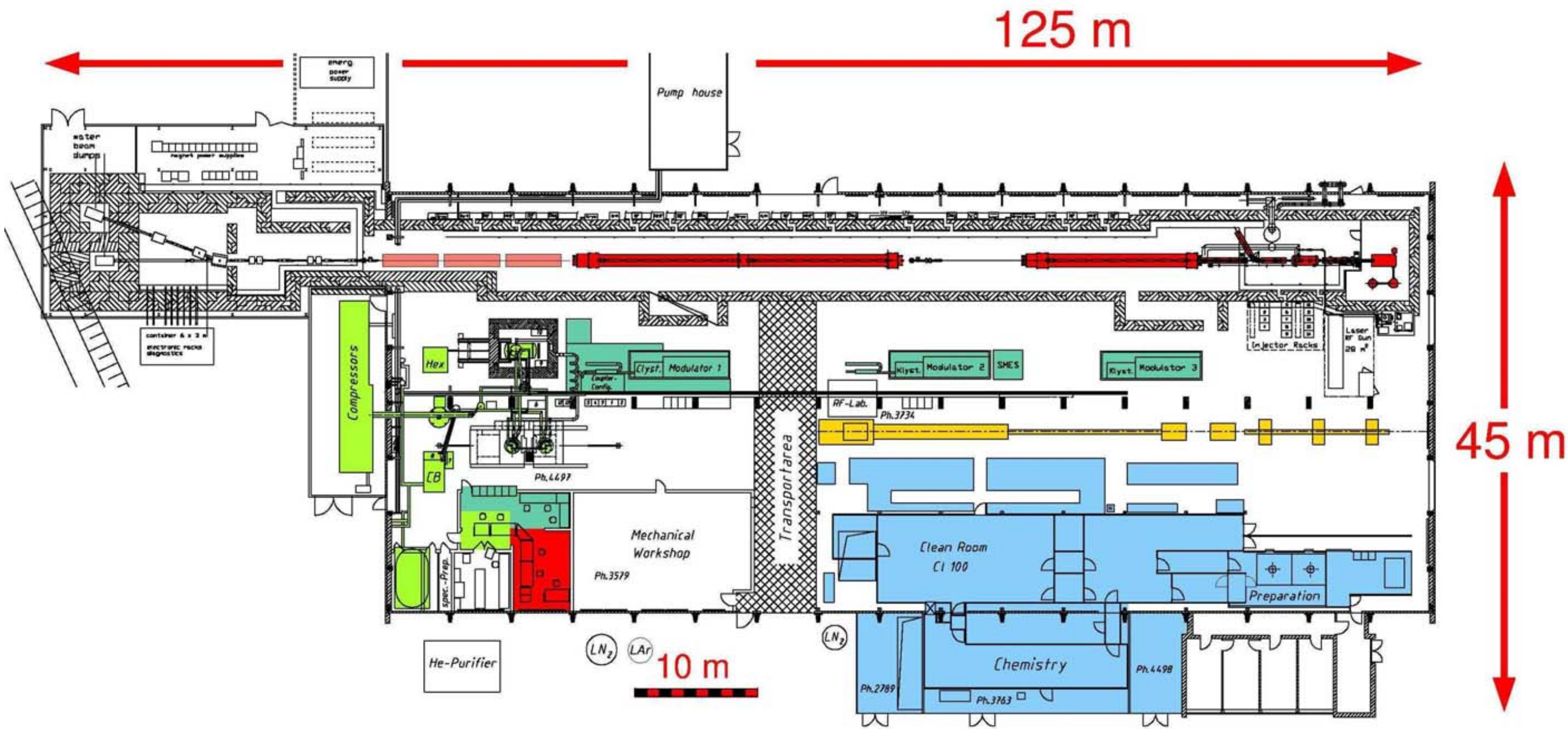
Cleanroom handling of niobium cavities

Preparation Sequence

- Niobium sheets (RRR=300) are scanned by eddy-currents to detect avoid foreign material inclusions like tantalum and iron
- Industrial production of full nine-cell cavities:
  - Deep-drawing of subunits (half-cells, etc.) from niobium sheets
  - Chemical preparation for welding, cleanroom preparation
  - Electron-beam welding according to detailed specification
- 800 °C high temperature heat treatment to stress anneal the Nb and to remove hydrogen from the Nb
- 1400 °C high temperature heat treatment with titanium getter layer to increase the thermal conductivity (RRR=500)
- Cleanroom handling:
  - Chemical etching to remove damage layer and titanium getter layer
  - High pressure water rinsing as final treatment to avoid particle contamination

A dedicated new infrastructure at DESY

- Scanning niobium material for inclusion
- Clean closed loop chemistry (Buffer Chemical Polishing – BCP)
- High Pressure Rinsing, HPR, and clean room drying
- Clean Room handling and assembling (Class 10 and 100)



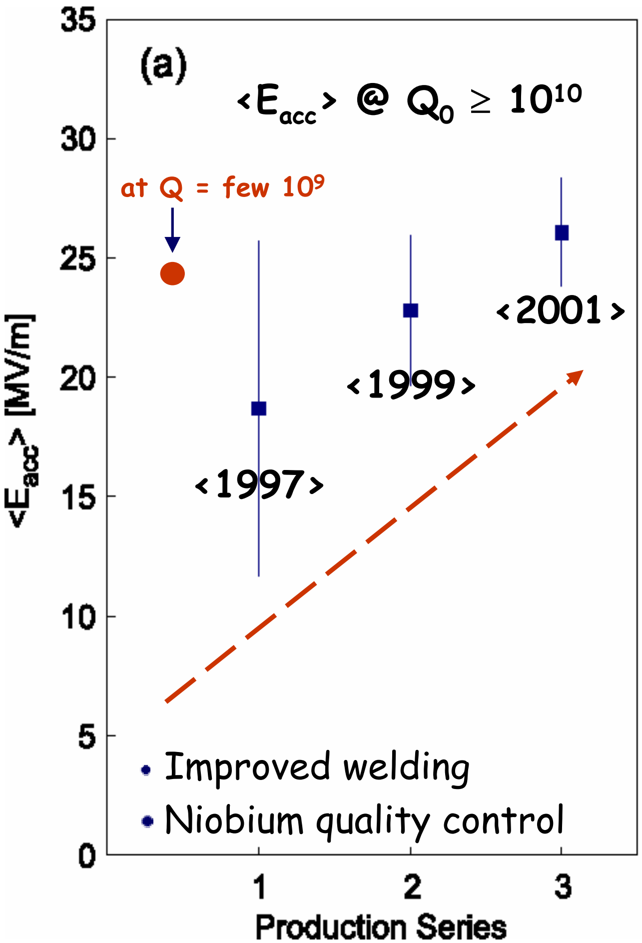
Learning curve with BCP

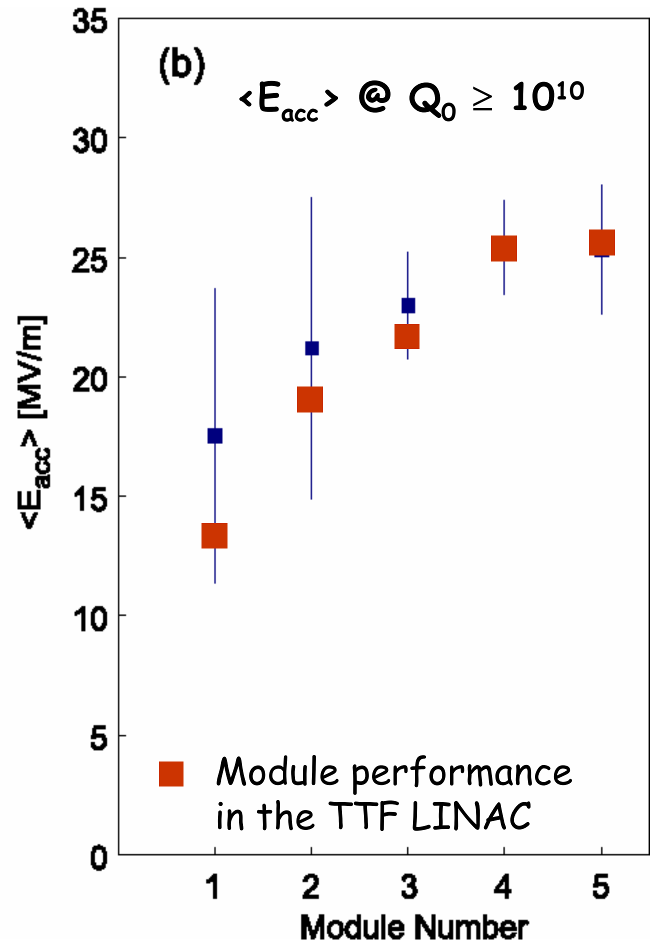
BCP = Buffered Chemical Polishing

3 cavity productions from 4 European industries: Accel, Cerca, Dornier, Zanon

Cornell 1995

5-cell





Electro-Polishing & Baking for 35 MV/m

The AC 70 example

EP at the DESY plant

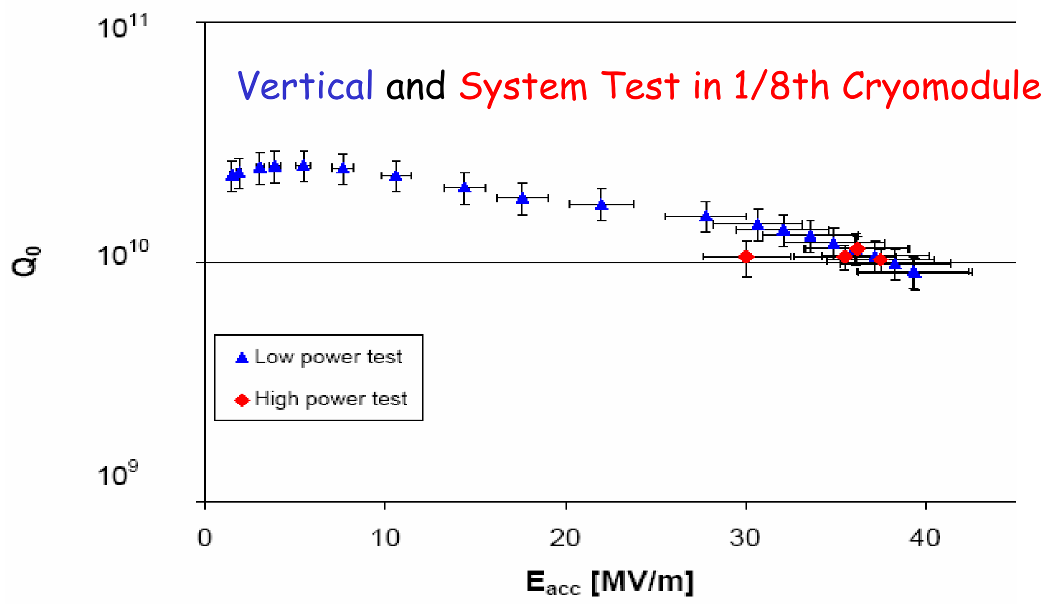
- Low Field Emission

800°C annealing

120°C, 24 h, Baking

- high field Q drop cured

High Pressure Water Rinsing



Electro-Polishing (EP)

instead of

Buffered Chemical Polishing (BCP)

- less local field enhancement
- High Pressure Rinsing more effective
- Field Emission onset at higher field

In Situ Baking

@ 120-140 ° C for 24-48 hours

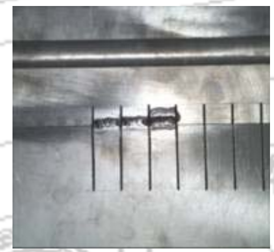
- to re-distribute oxygen at the surface
- cures Q drop at high field

Performing Cryomodules

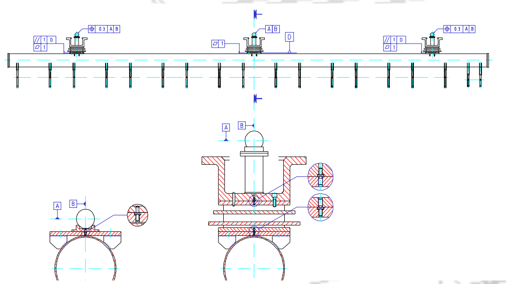
Three cryomodule generations to:

- improve simplicity and performances
- minimize costs

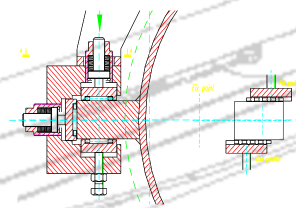
"Finger Welded" Shields



Reliable Alignment Strategy



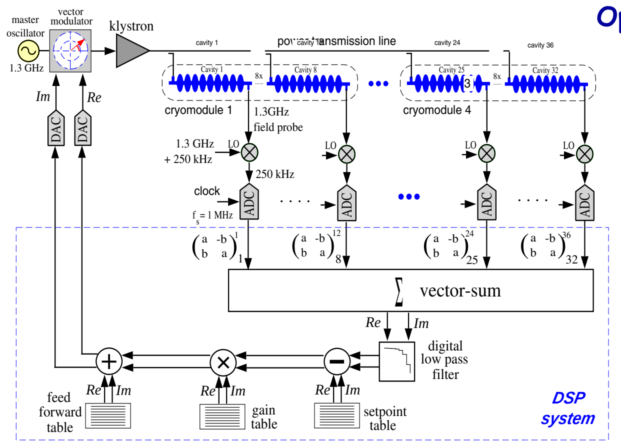
Sliding Fixtures @ 2 K



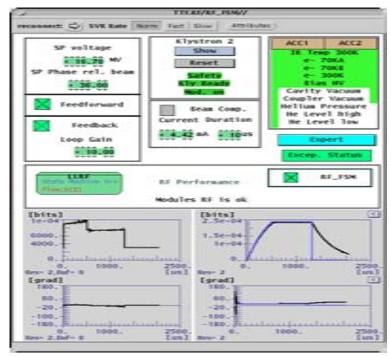
Required plug power for static losses < 5 kW/(12 m module)

LLRF performance in TTF

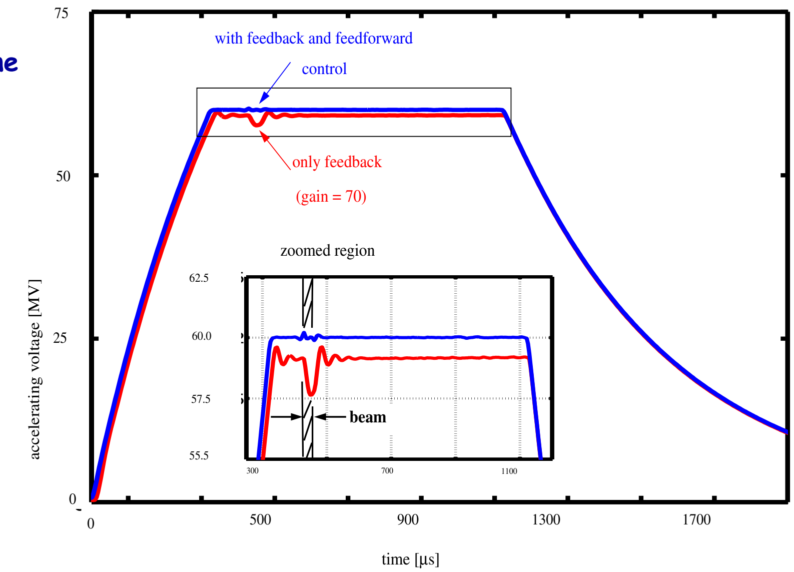
Principle of RF Control



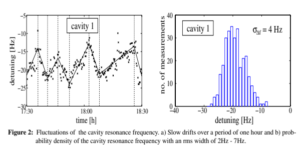
Operation with Final State Machine



from TTF Console in Milano



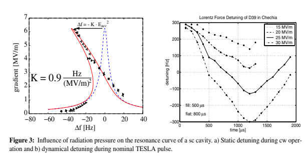
Microphonics



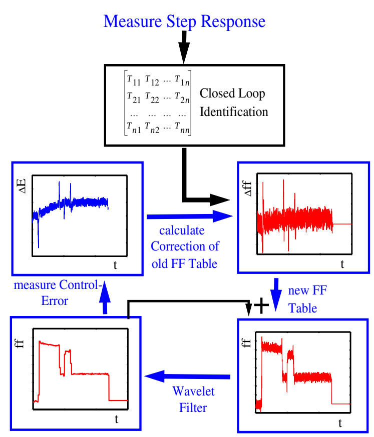
Contributions to Energy Fluctuations

1. Lorentz Force
2. Microphonics
3. Bunch-to Bunch Charge Fluctuations
4. Calibration error of the vector-sum
5. Phase noise from master oscillator
6. Non-linearity of field detector
7. Klystron Saturation
8. RF curvature (finite bunch length)
9. Wakefield and HOMs

Lorentz Force Detuning

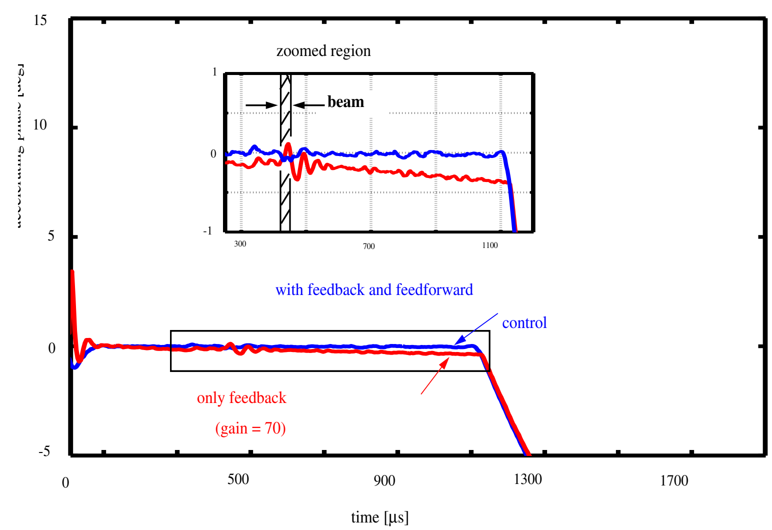


Adaptive Feedforward



Adaptive Feed Forward can handle nonlinear systems through linarisation around the operating point.

The calculation of a new feed forward table needs only a few seconds.

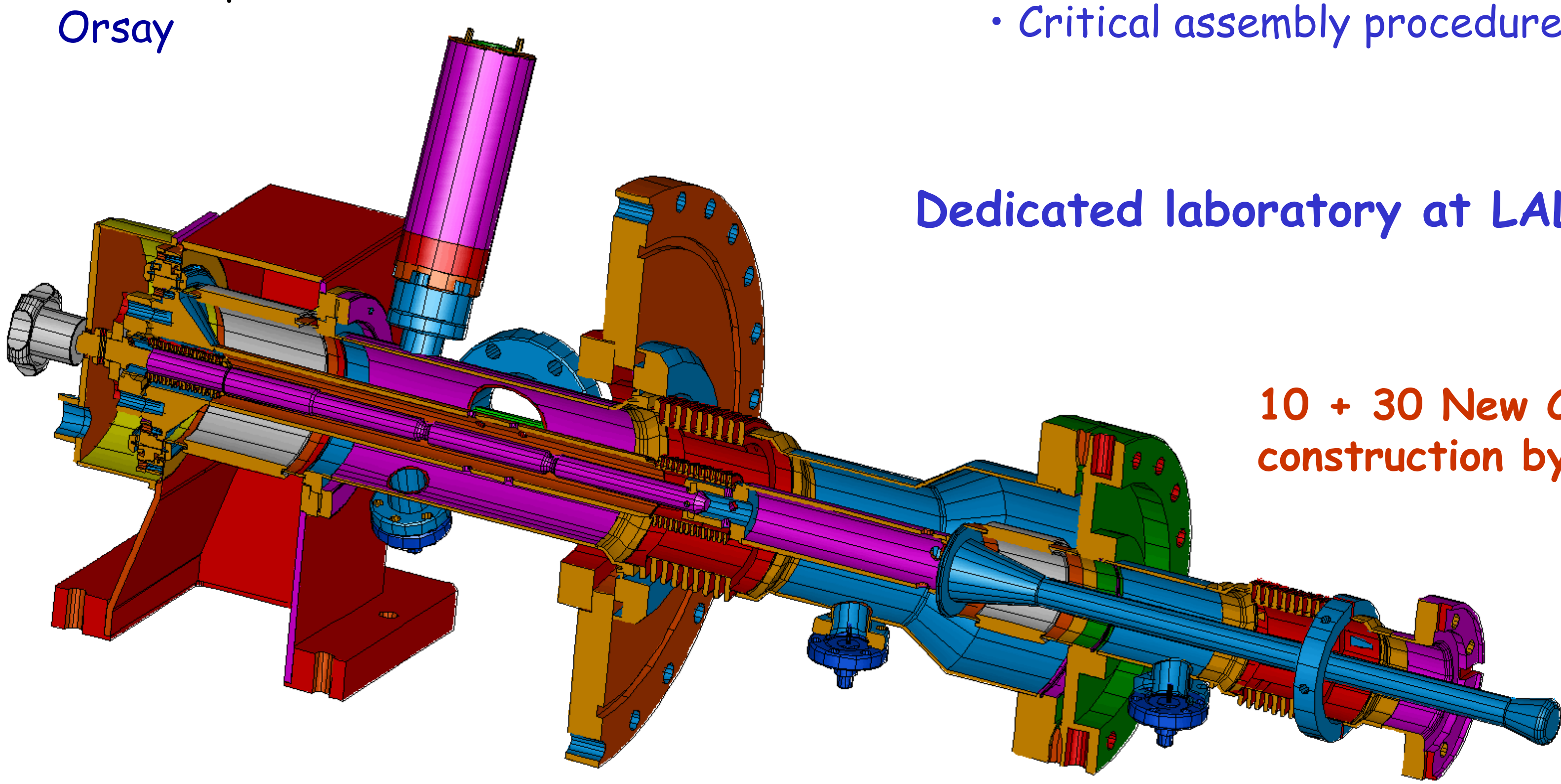


Power Coupler

- TTF III Coupler has a robust and reliable design.
- Extensively power tested with significant margin
- New Coupler Test Stand at LAL, Orsay

Pending Problems

- Long processing time: ~ 100 h
- High cost (cavity/2)
- Critical assembly procedure

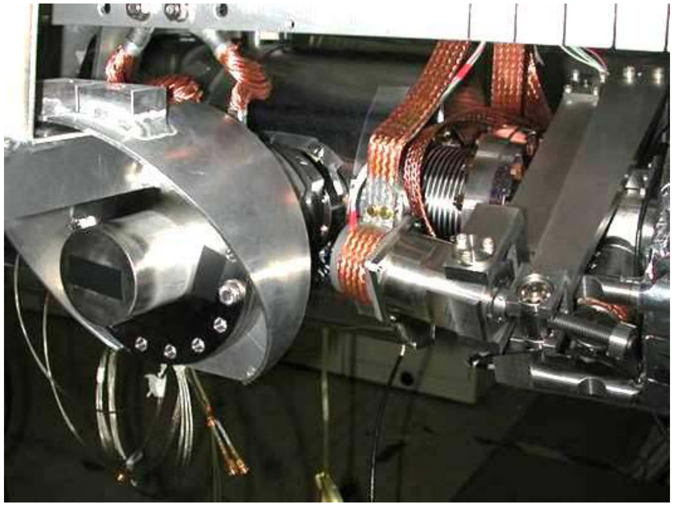


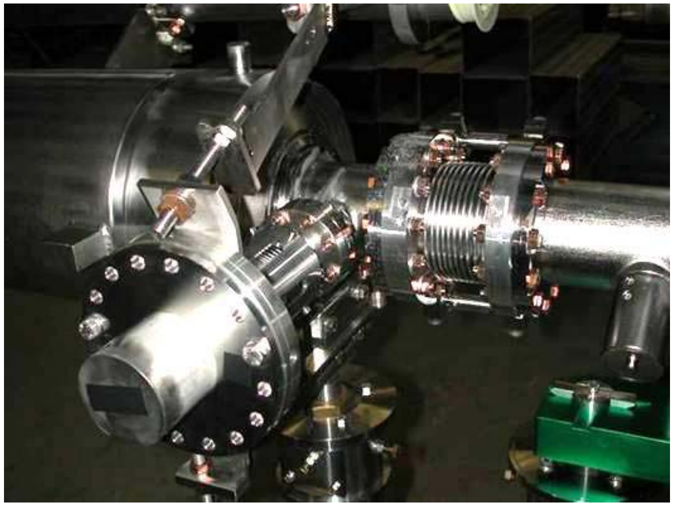
Dedicated laboratory at LAL/Orsay

10 + 30 New Couplers in construction by industry

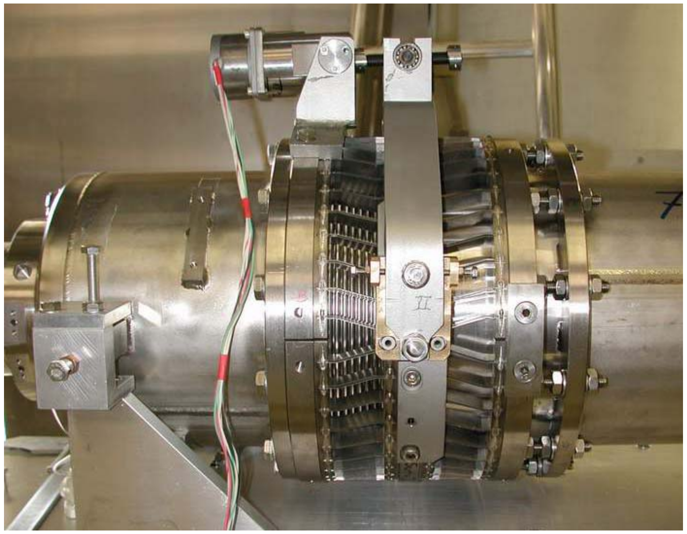
SC Cavity Tuners

The Saclay Tuner in TTF

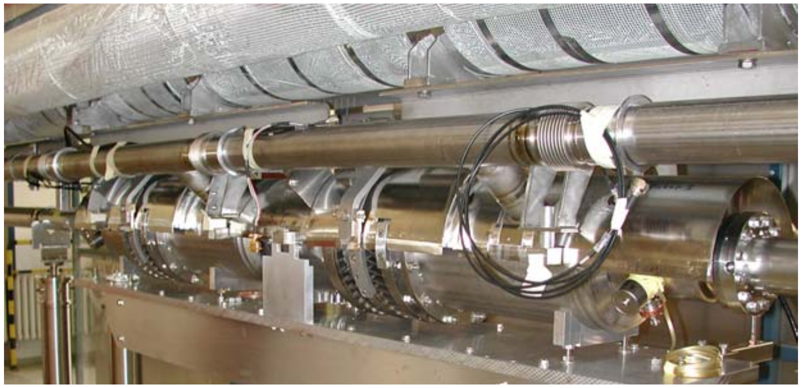




The INFN Blade-Tuner

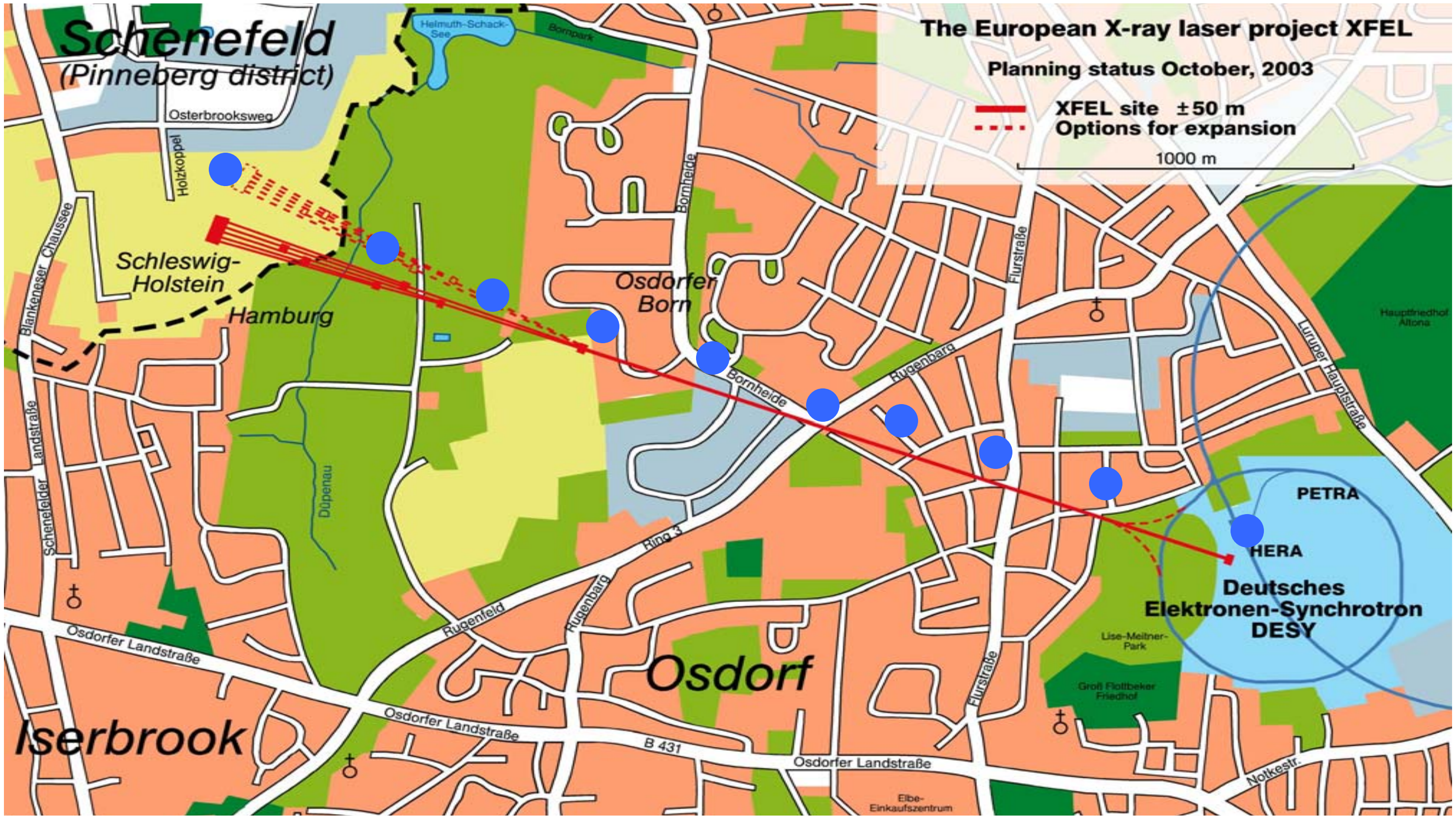


Successfully operated with superstructures

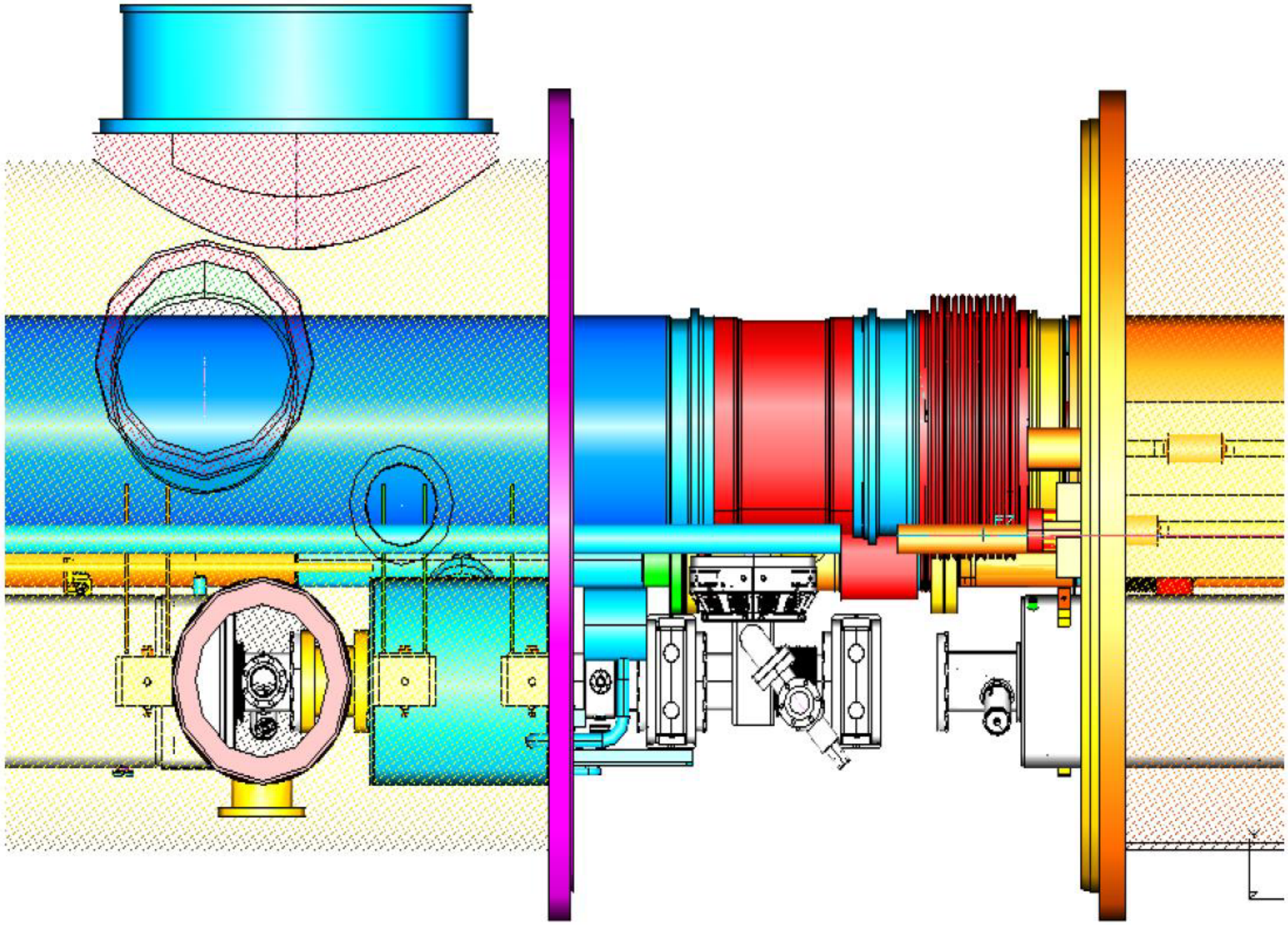


X-FEL coming soon

- 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)



Cry3 improved design 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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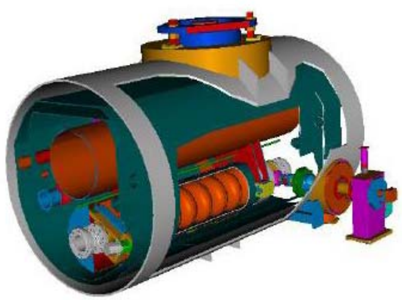

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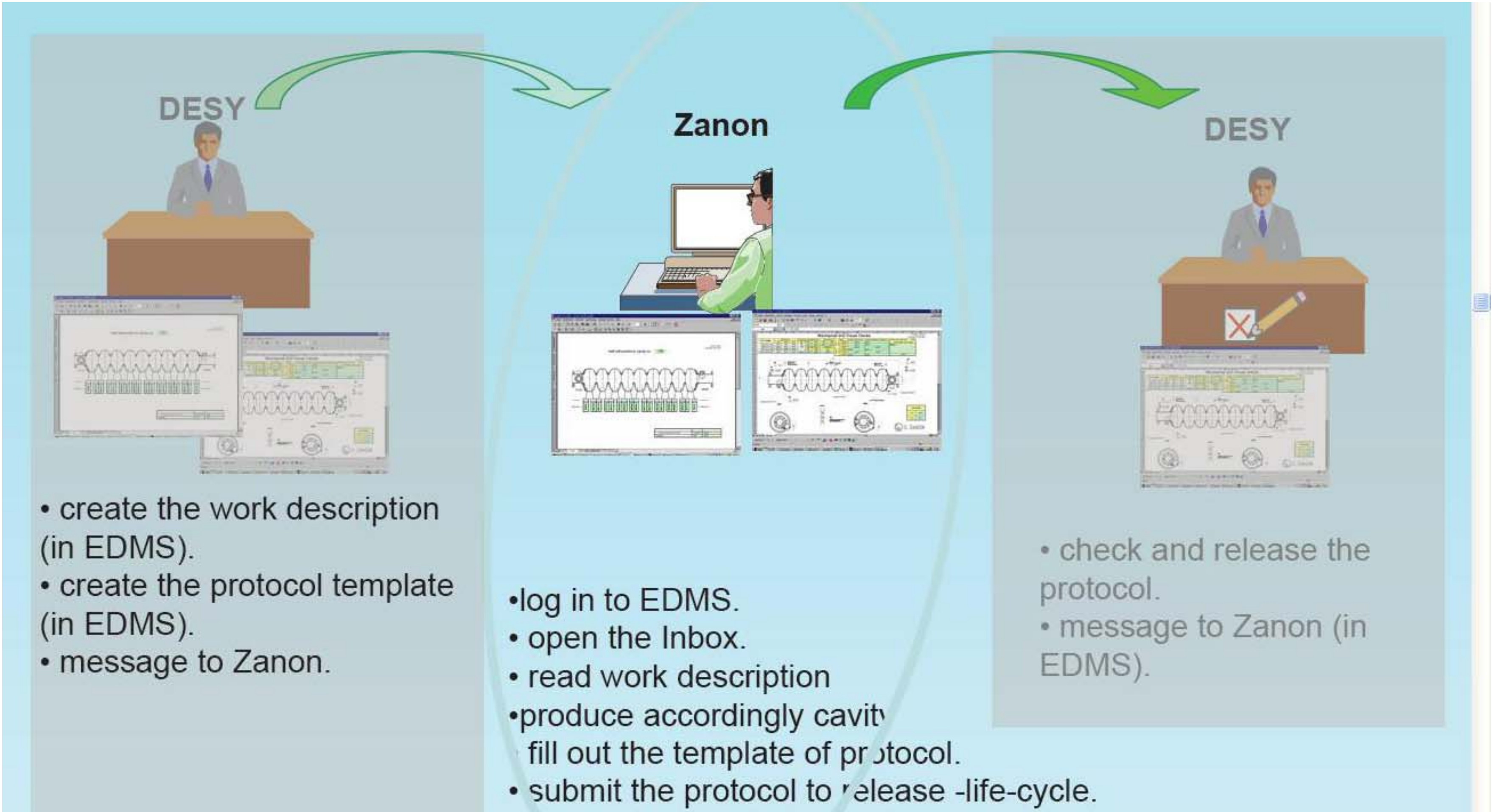
- Technology transfer from Research to Industry
- Review with industry of the cryomodule design and assembly to focus:
    - Cost drivers
    - Critical steps of the assembly procedure
- Suggestion based on industrial experience in term of:
    - Similar productions
    - Labor organization
    - Quality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

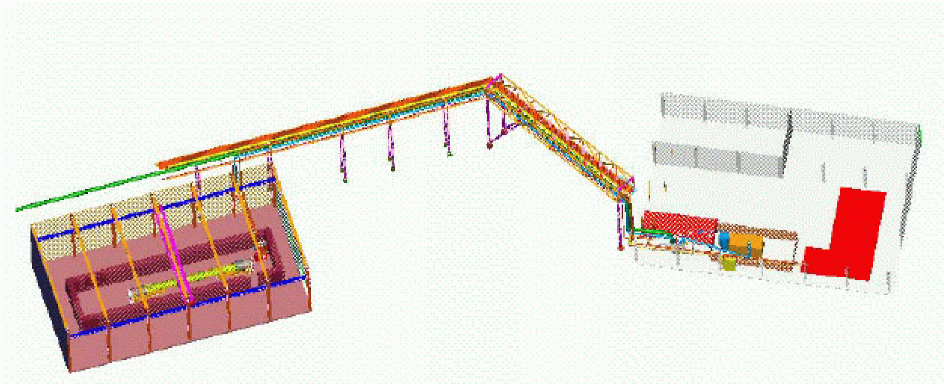
New QC in cavity production

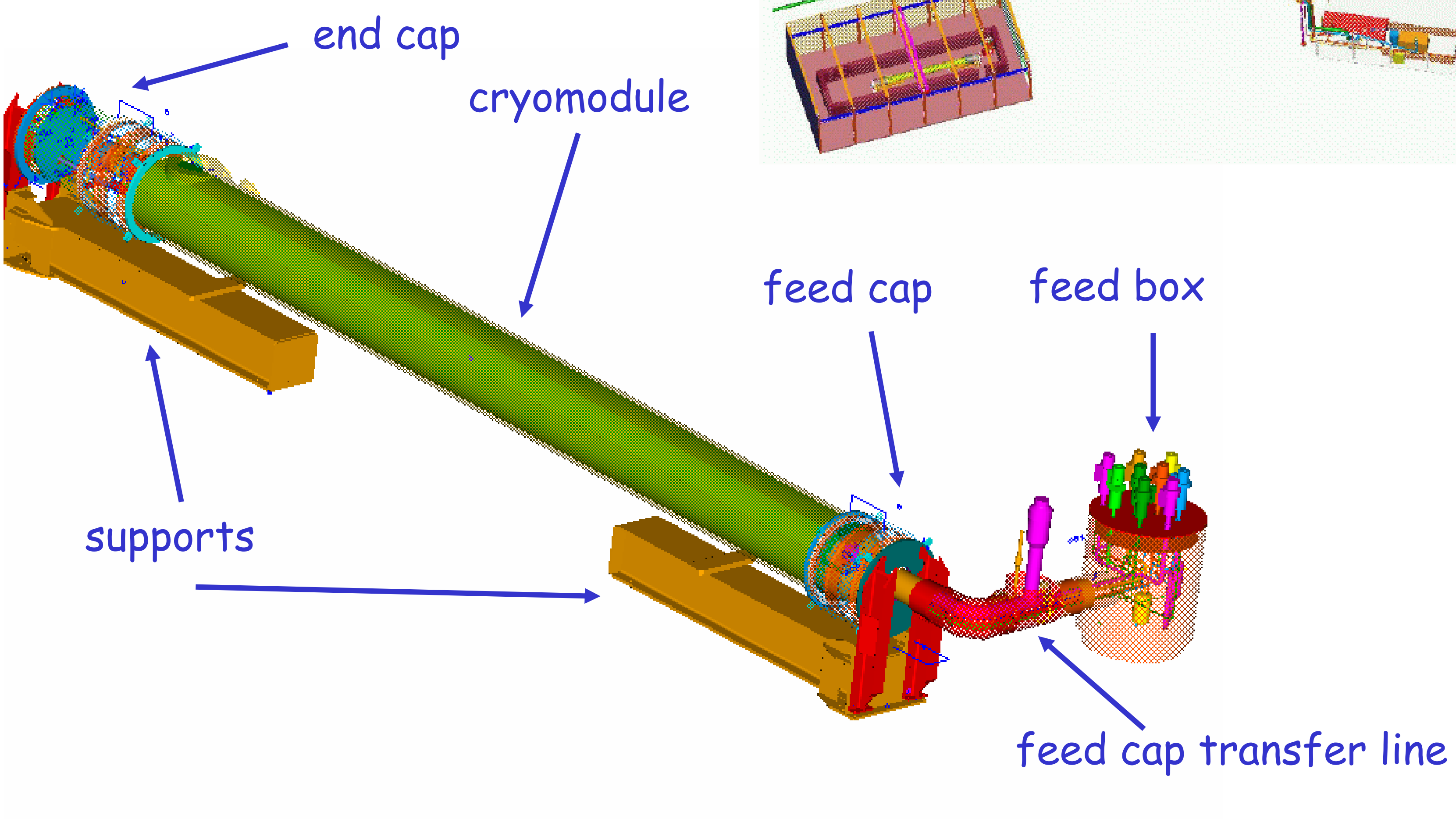


From Valdemar Singer

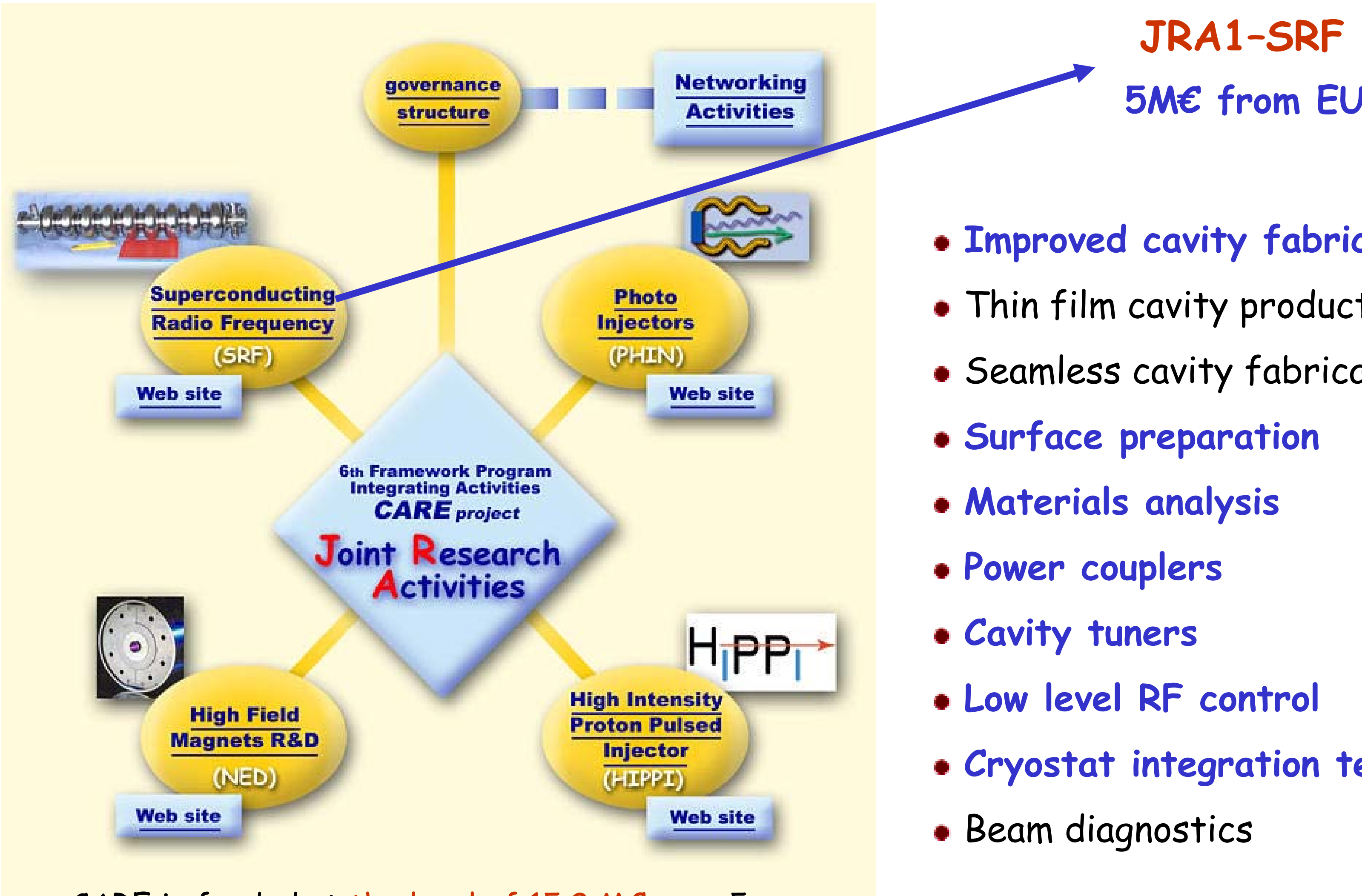
Cryomodule Test Stand @ DESY

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





EU Funding: CARE-JRA1



CARE is funded at the level of 15.2 M€ over 5 years

- Improved cavity fabrication
- Thin film cavity production
- Seamless cavity fabrication
- Surface preparation
- Materials analysis
- Power couplers
- Cavity tuners
- Low level RF control
- Cryostat integration test
- Beam diagnostics

Coupler Laboratory at LAL-Orsay

Class 10 Clean Room

400 °C vacuum oven

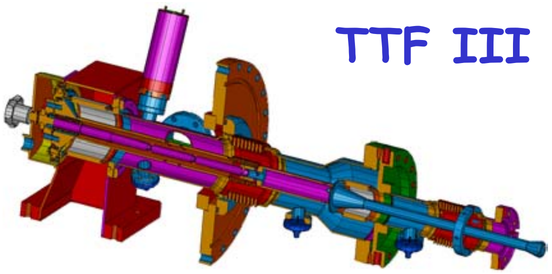
LABORATOIRE
DE L'ACCÉLÉRATEUR
LINÉAIRE

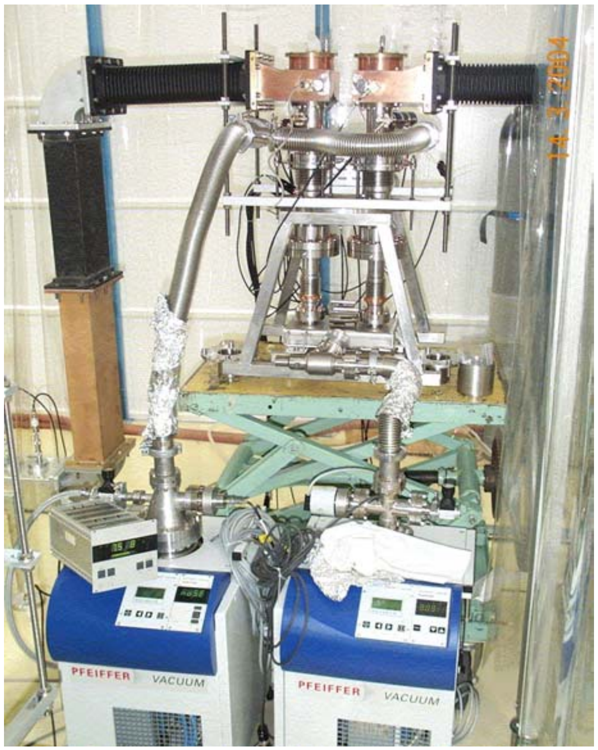
klystron / modulator

Ultra-pure water production

Coupler Development at LAL-Orsay

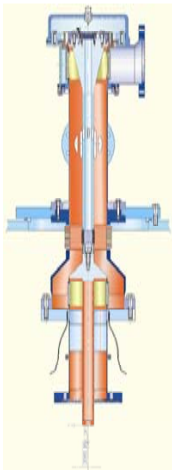
TTF III

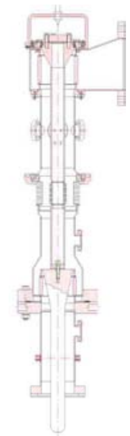


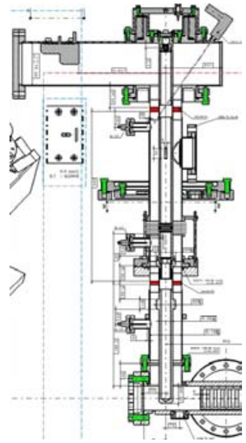


High Power Coupler Test Stand

Alternative Designs





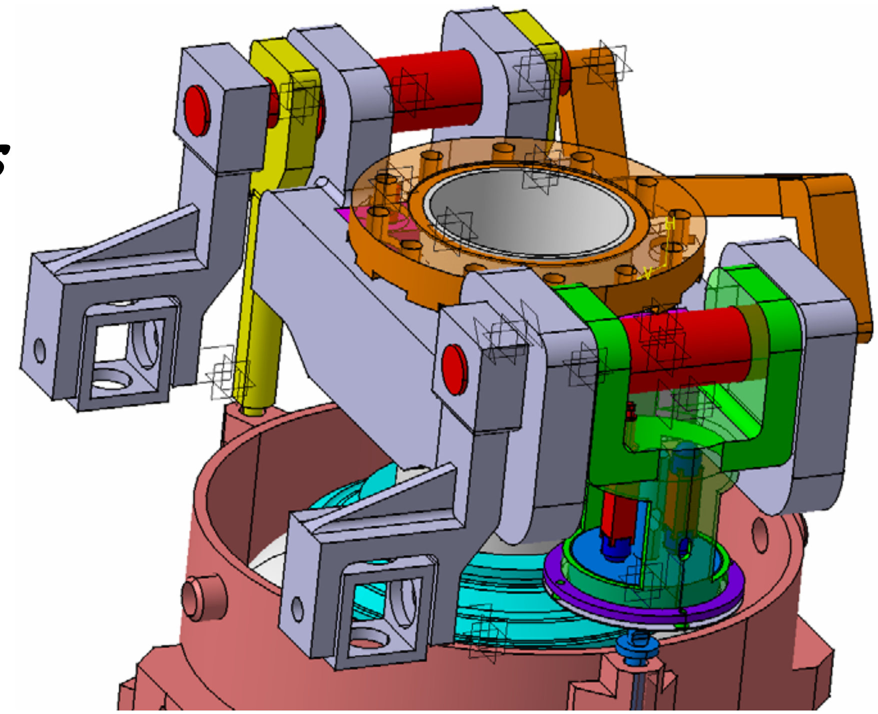


Clean room assembly

New Saclay Tuner for XFEL

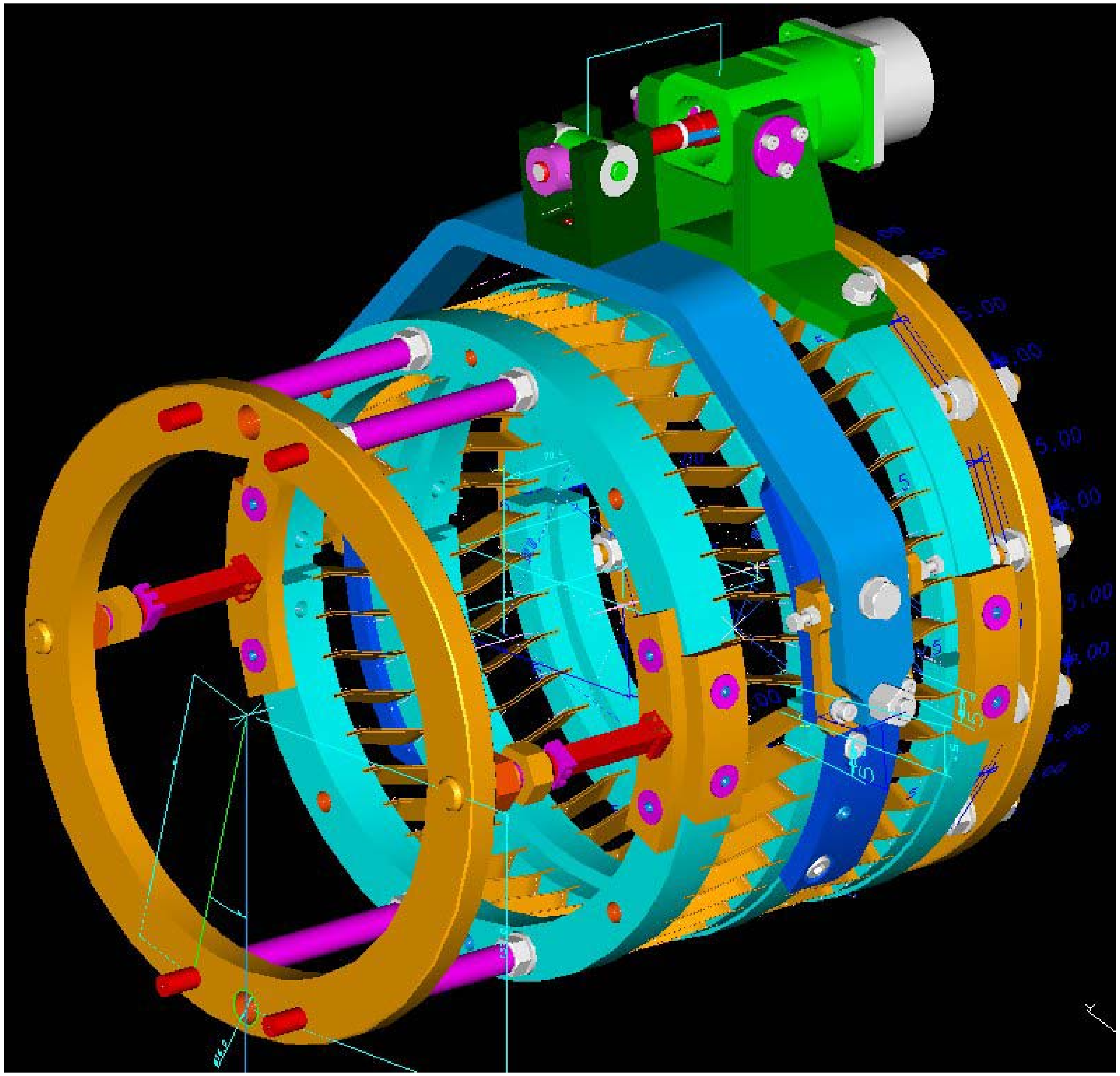
New design with piezos

- CARE/JRA-SRF
- SOLEIL upgrades
- larger rigidity

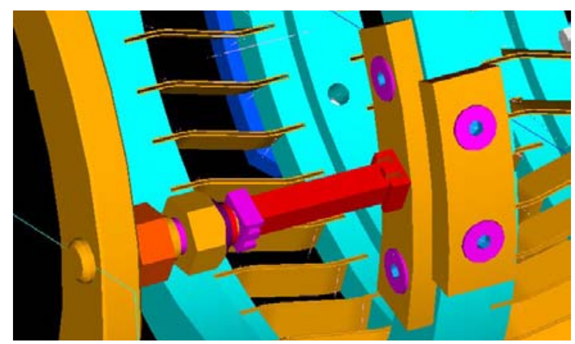


- Fabrication of 2 tuners since beginning of 2005
- 12 NOLIAC piezos, 2 PHYTRON stepping motors ordered
- Coll. with IPN Orsay: CEA send NOLIAC piezos to IPN for characterization, and IPN send P.I. piezos for tests on tuners
- Coll. with INFN-Milano for measurement with stress sensors @ 2K

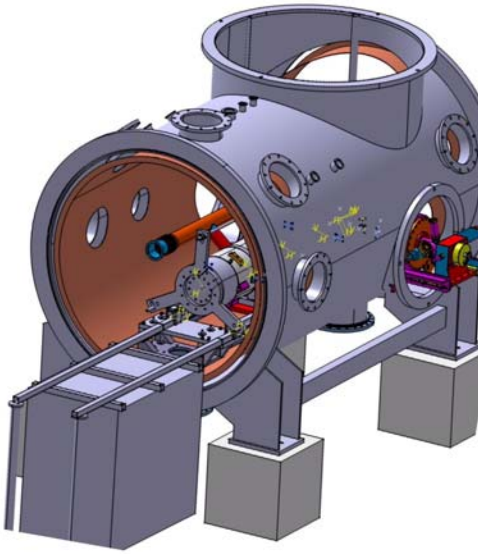
New INFN Blade-Tuner

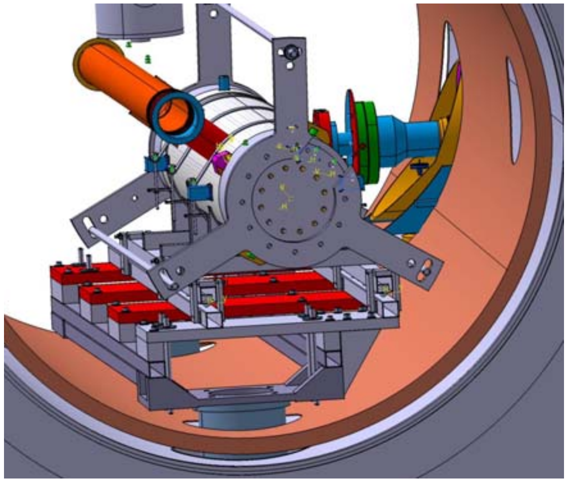


- Integration of piezos for Lorentz forces and microphonics completed.
- Final Drawing delivered for fabrication.
- Two prototype, including the modified helium tank, are expected by end of June 2005
- Cold tests results by fall 2005 (DESY, BESSY, Cornell?)

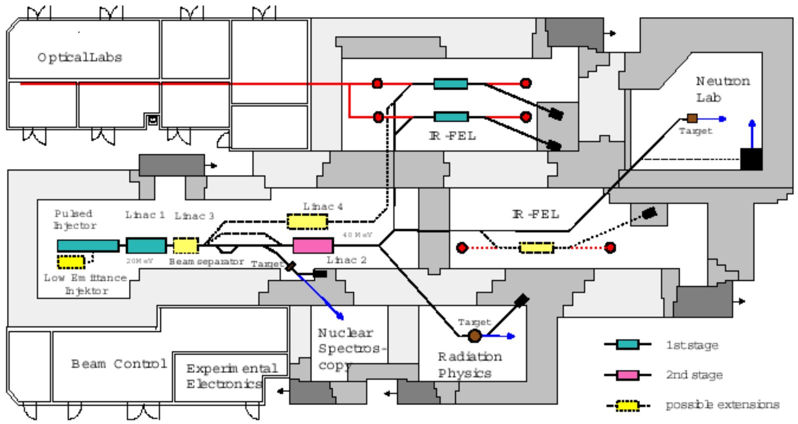


CryHoLab at Saclay/Orsay

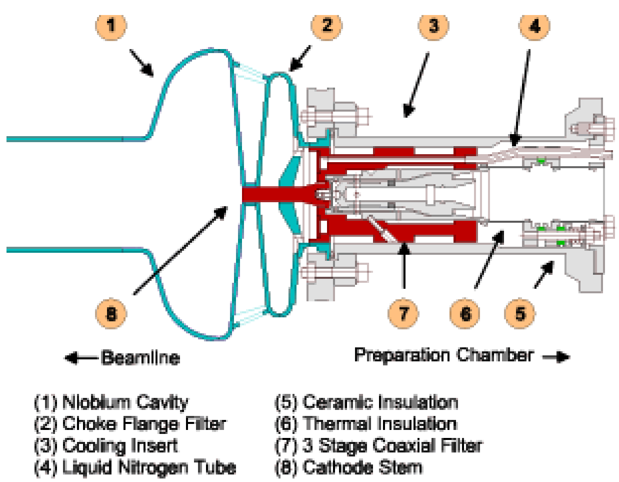




ELBE at FZR



The ELBE beam line layout

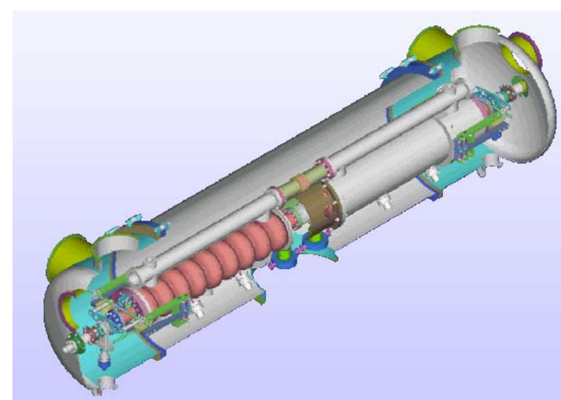


The successful SRF Gun

The Forschungszentrum Rossendorf (FZR) is commissioning a superconducting Electron accelerator with high Brilliance and low Emittance (ELBE) and a maximum beam power of 40 kW.

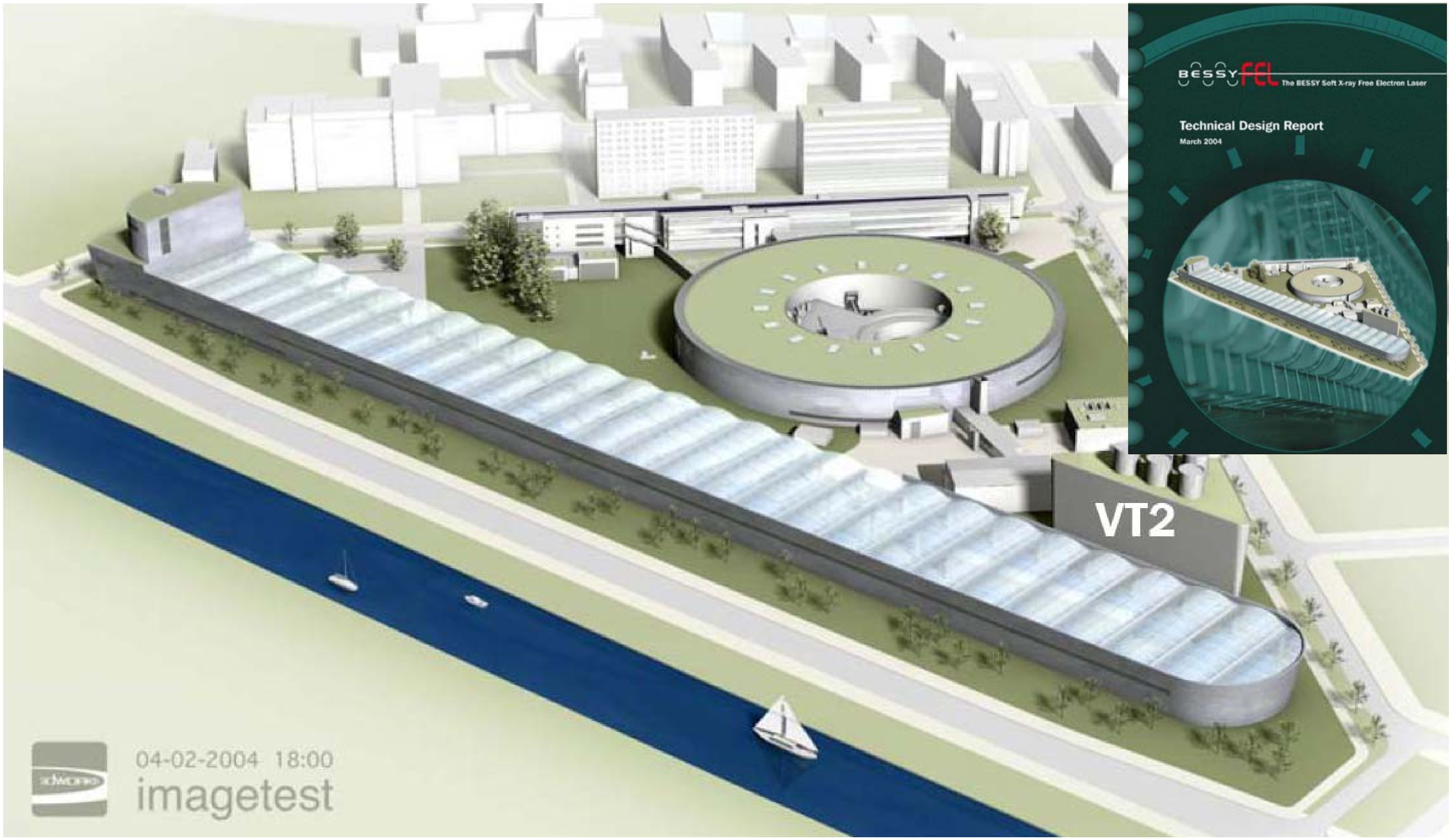
Each accelerating module contains 2 TESLA cavities to accelerate a 1 mA electron beam to energies of 12 - 40 MeV.

Two undulators allow access to a wide range of wavelengths.



The 2 TESLA Cavity Cryomodule

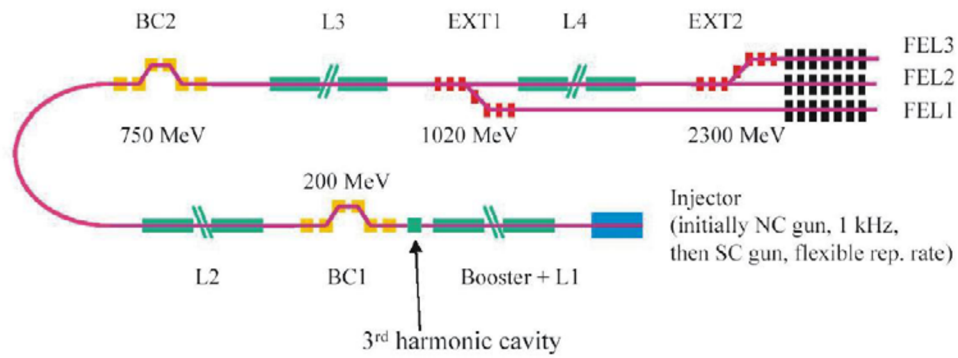
BESSY soft X-ray FEL

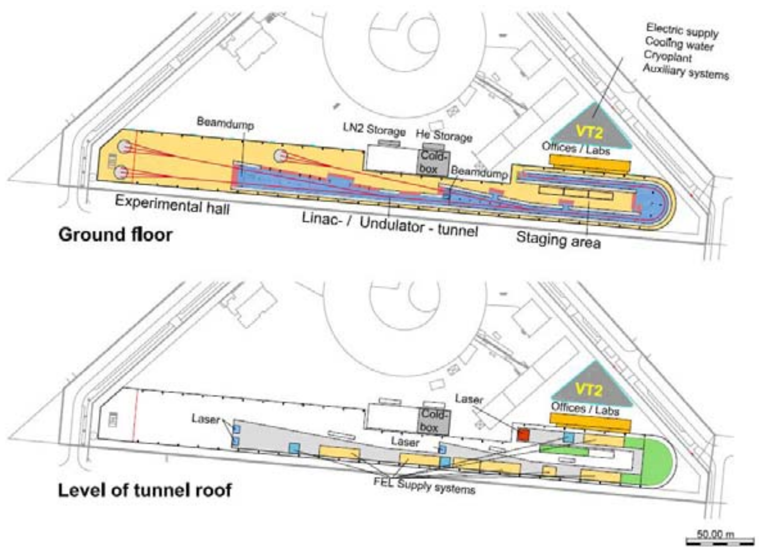


BESSY soft X-ray FEL

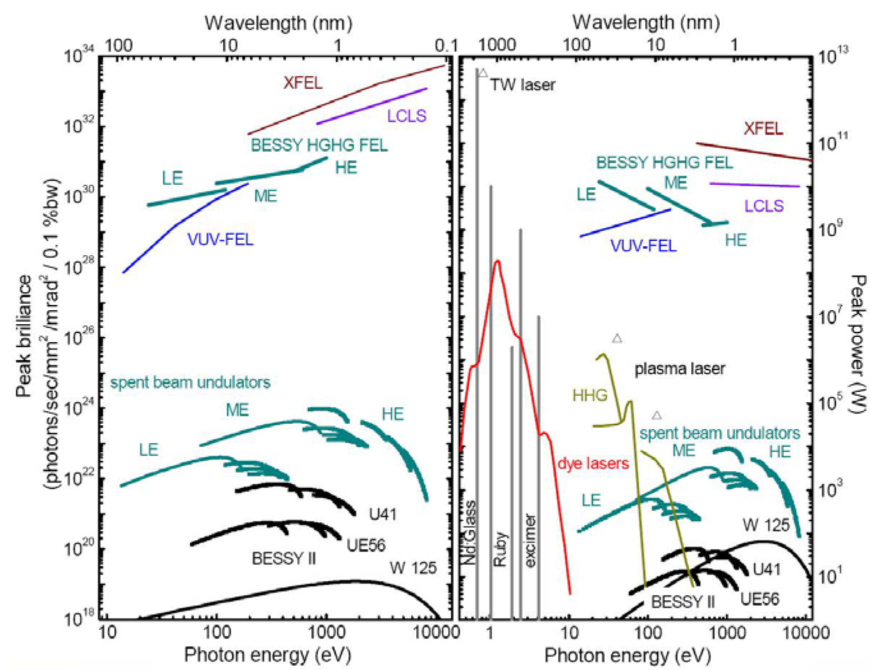
- 18 Cryomodules – 8 cavities per module - based on the TESLA Technology with minor modifications
- CW operation (IOT Amplifiers)
- SRF Gun with FZR, DESY & UK

Schematic of the BESSY Linac

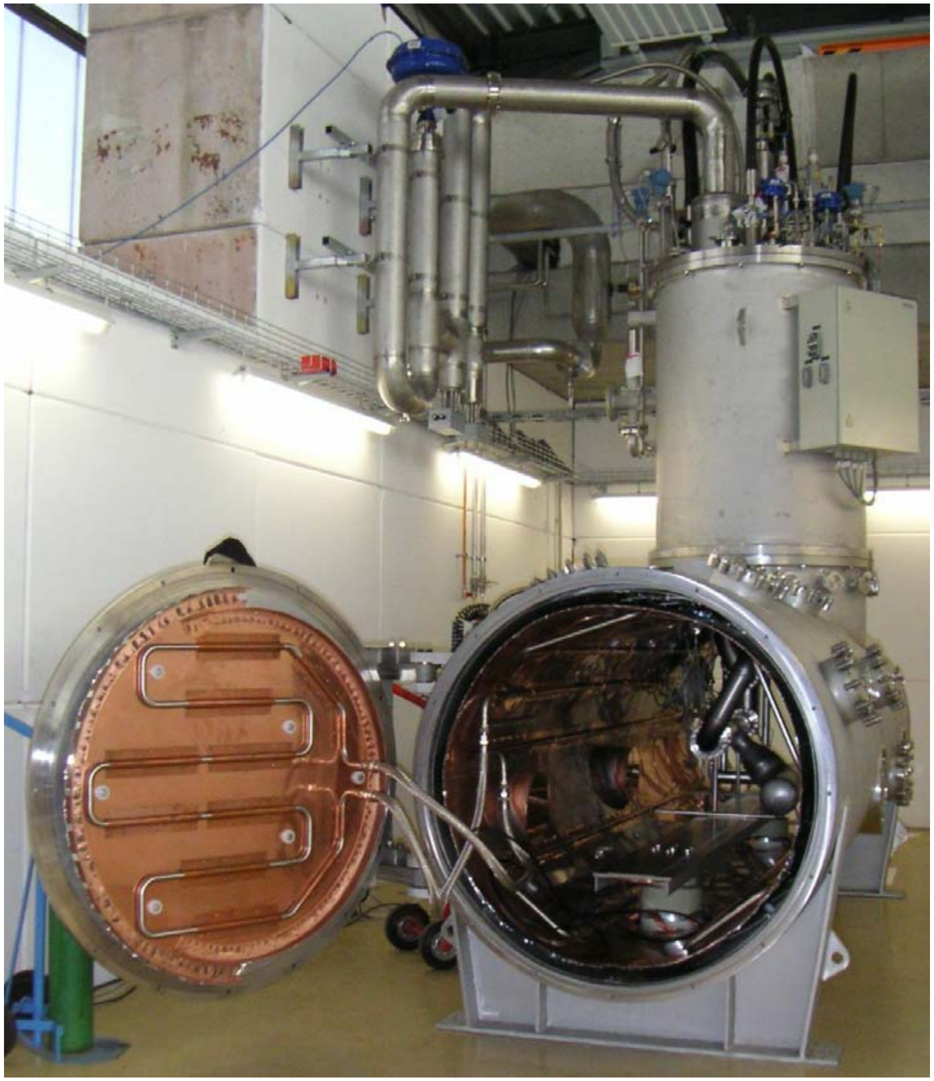




Layout of the BESSY soft X-ray FEL



HoBiCaT @ BESSY



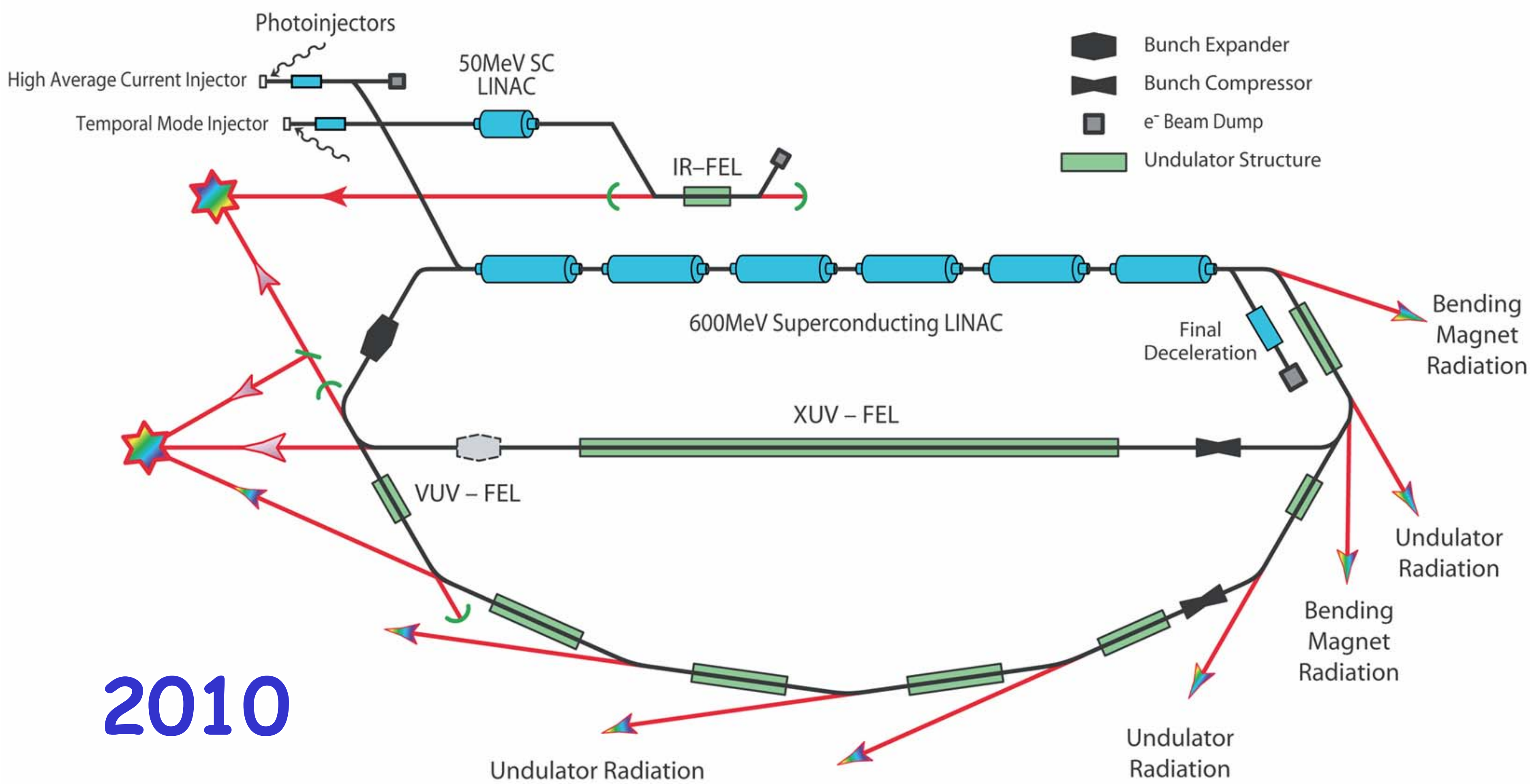
Designed to test 2 fully equipped TESLA like cavities in CW

Cryogenics successfully commissioned

Cavity test in the coming months

Extensive test of a cavity equipped with the Blade-Tuner for microphonics handling is being considered.

The 4GLS Project in UK

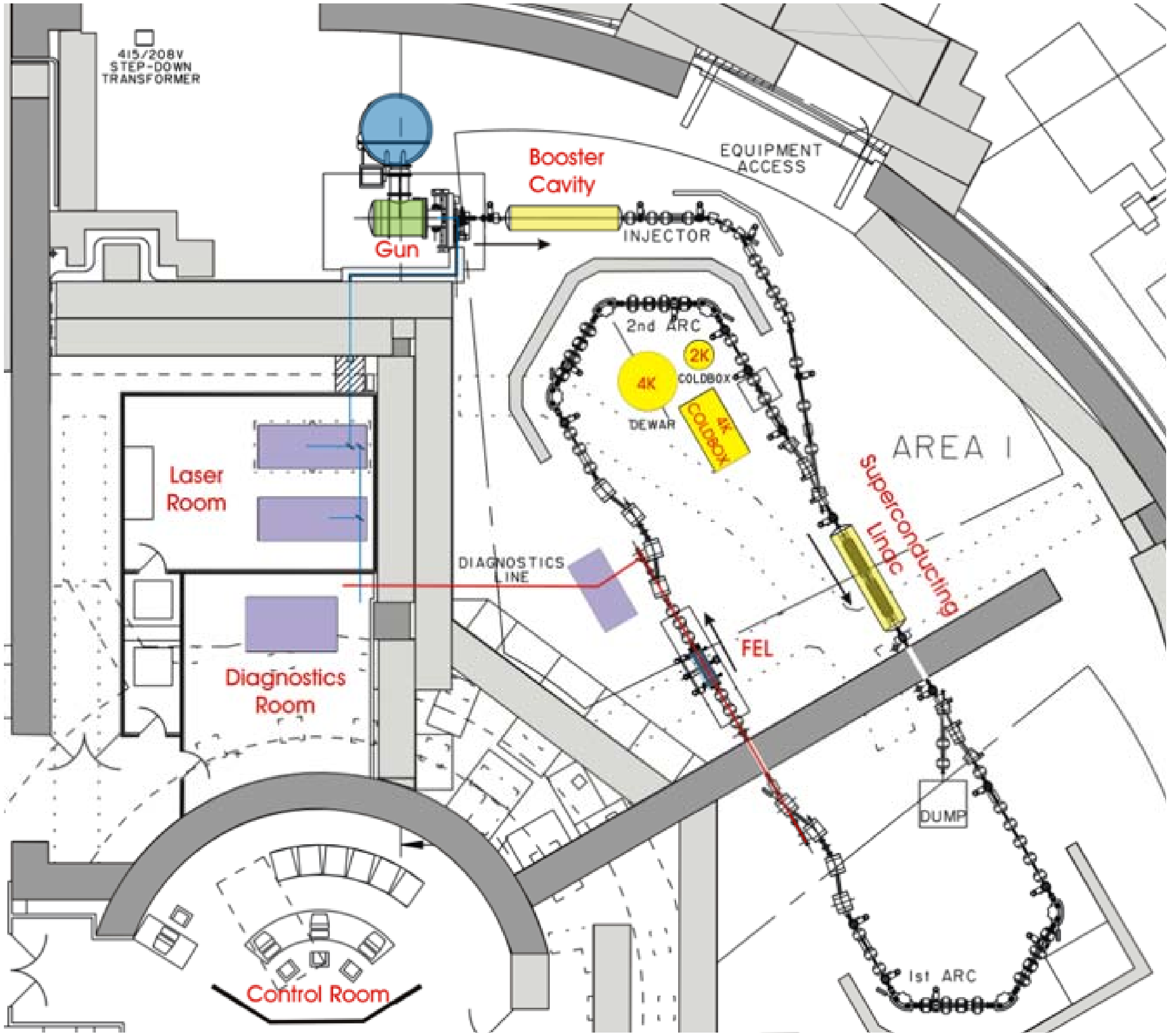


2010

About 4GLS

- 2010 - 4GLS is a uniquely flexible source of ultra-high brightness continuous and pulsed radiation covering the IR to XUV parts of the spectrum.
-
- ERL (energy recovery linac) provides high brightness, short pulse radiation, which vastly surpasses that provided by conventional storage ring technology. It also allows tailored pulse characteristics, leading to a high level of experimental flexibility.
- FEL (free electron laser) technology provides the opportunity to exploit very short, ultra-high brightness pulses from IR-, VUV- and XUV-FELs.
- The use of locked laser photoinjectors and superconducting technology throughout confers high stability and allows the different parts of the facility to be brought together as a unified whole. In particular the sources can be used in combination, with the pulses from one source matched and synchronised with those from another.

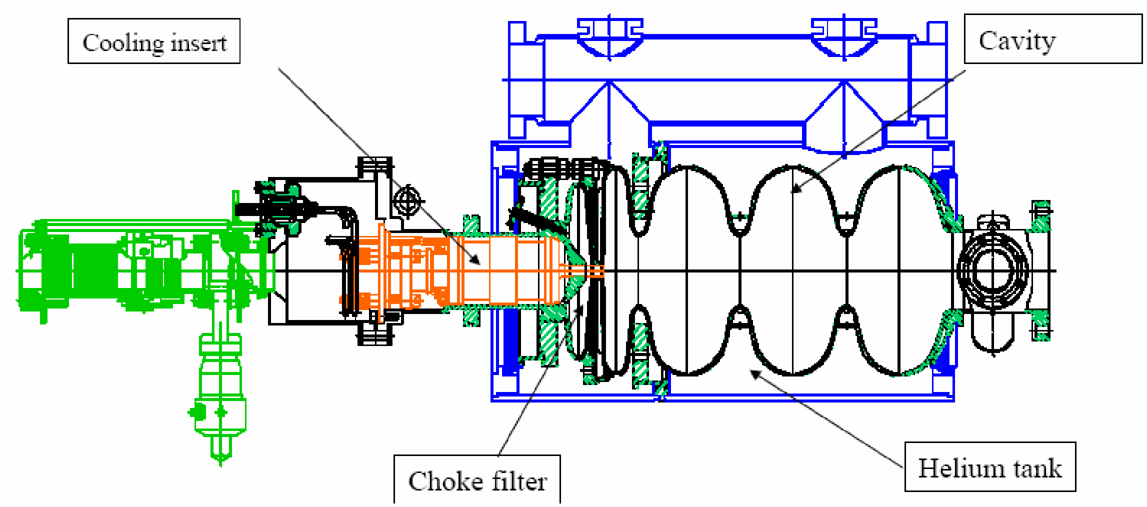
The Funded ERLP



- A prototype Energy recovery Linac (ERLP) got £11.5M funding in April 03 to establish a skills base capable of building 4GLS.
- One Rossendorf like module has been chosen to act as both booster and linac for the ERLP.
- The module consists of 2 TESLA cavities capable of operating at 15 MV/m

CW SRF Gun Development

Conceptual design of the 3 ½ cell SRF Gun for 4GLS



The ELBE SRF Gun

A 3 ½ cell superconducting gun in collaboration with ELBE, Rossendorf, is under development as a vital part for 4GLS.

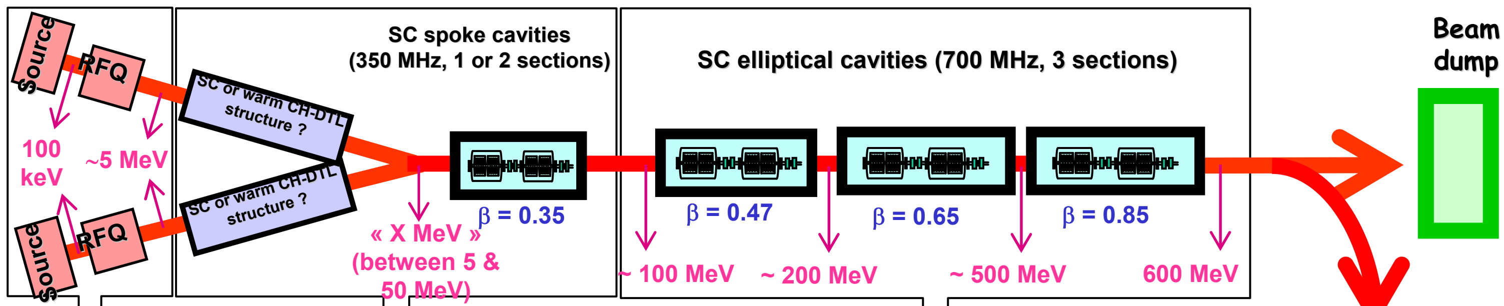
The aim is to produce a gun with high photon brightness, short pulse and high coherence.

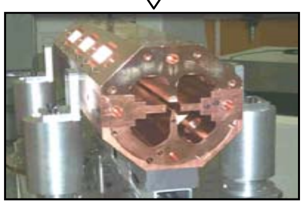
The design is based on TESLA cavity design and technology.

CW operation is a requirement for 4GLS

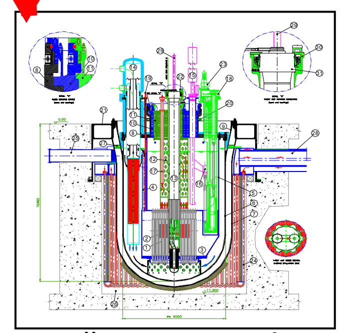
TESLA Technology for ADS

EU Program named PDS-XADS now moving to EuroTrans

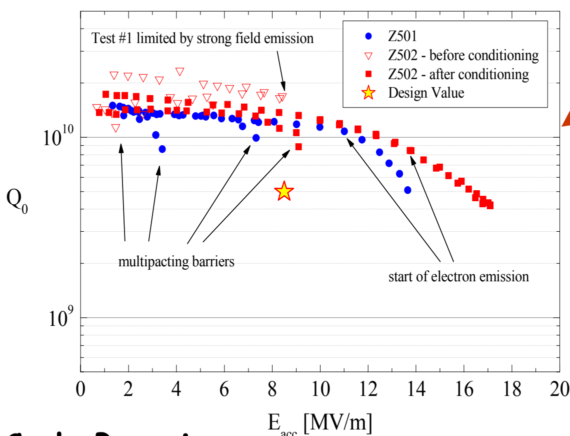




High Energy Section



Spallation target & sub-critical core



The accelerator design has been developed for Nuclear Waste Transmutation by an INFN-CEA-CNRS collaboration.

The high energy section is now used by HIPPI and SPL too

Concluding Remarks

- The interest for the TESLA Technology is wide and growing
- The TESLA Collaboration achievements with TTF were sufficient to convince ITRP to recommend cold for ILC
- Europe is doing a big effort to coordinate activities in different labs and for different projects
- That's fine, but still not enough
- Also in Europe the cold technology experts are not sufficient to develop all major projects in parallel