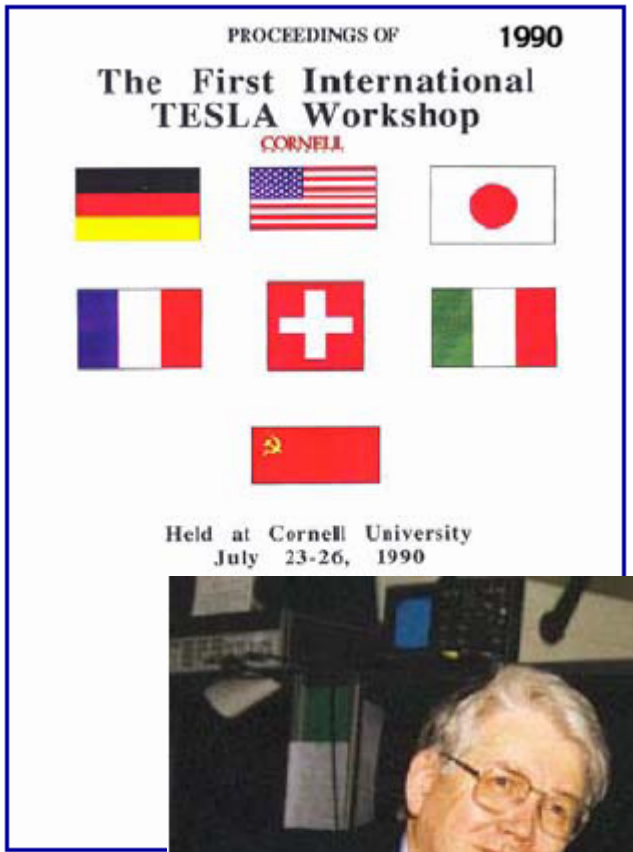
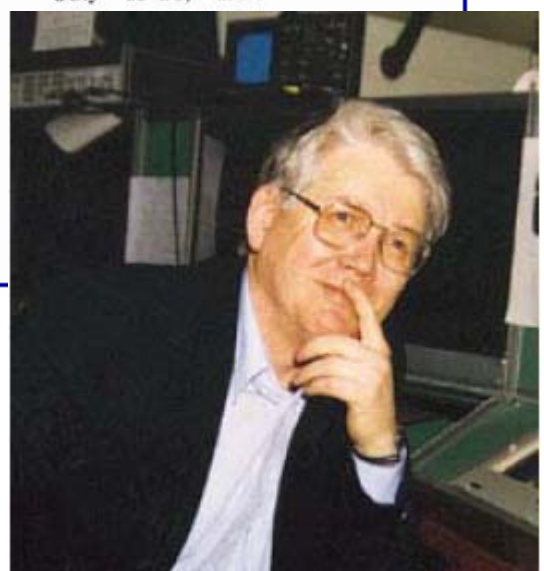
Status and Perspectives of Superconducting RF Accelerator Technology

- Ongoing R&D activities in Europe
- Ongoing R&D activities in America and Asia
- Cooperation with industry

Albrecht Wagner

The TESLA Collaboration





- The TESLA Collaboration:

- 55 Institutes in 12 countries

These institutes shared the know-how concerning the construction and operation of the SC linac and have contributed through hardware, manpower, and ideas to the TESLA Test Facility

The Improvement of SC Cavities

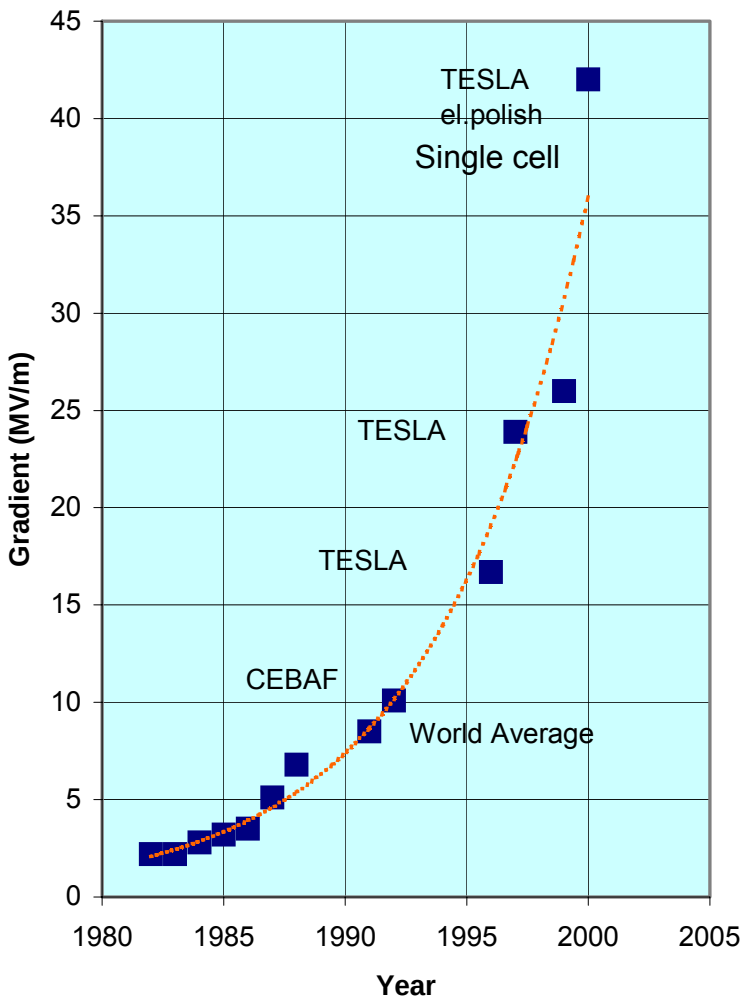
SC RF structures for accelerators were developed in many countries

The TESLA collaboration, centred at DESY combined ~ all the world expertise in SC, thus leading to major progress:

>25-fold improvement in performance/cost in 10 years

Major impact on next generation light sources (XFEL, ERL) , proton accelerators etc

Development (schematic) of gradient in SCRF cavities



Start of the Global Design Initiative

The ITRP recommendation of the cold technology as base line for the ILC has led to a unification of forces around the globe.

A lot of new activities have been started.

~ 220 participants from 3 regions, most of them accelerator experts

TESLA Technology Collaboration

Taking into account all recent developments (XFEL, ILC) the TESLA collaboration has redefined its mission and has changed its name in to TESLA Technology Collaboration. The mission:

- advance SCRF technology research and development and related accelerator aspects across the broad diversity of scientific applications,

- keep open and provide a bridge for communication and sharing of ideas, developments, and testing across projects.

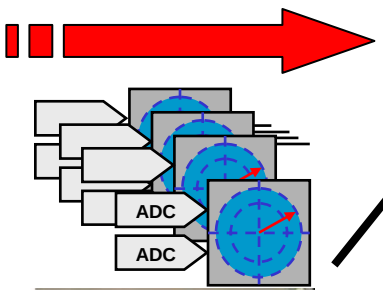
The collaboration will support and encourage free and open exchange of knowledge, expertise, engineering designs, and equipment.

- KEK and SLAC have joined TTC
- other labs have stated that they want to join

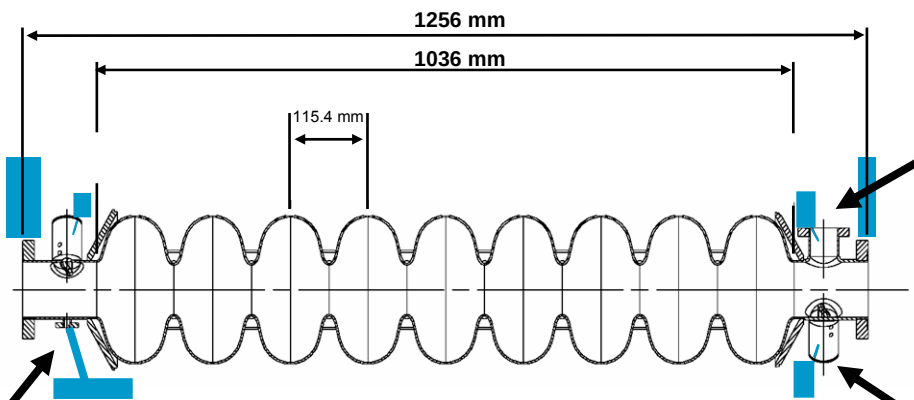
The Key Elements of the SC Linac

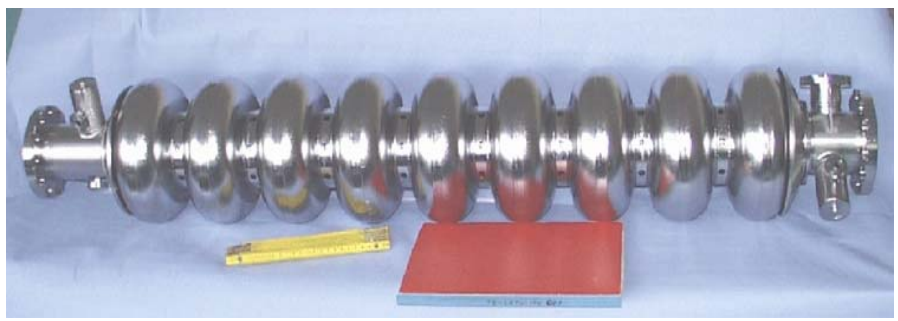
Test all the components in a real linac environment with

e^- - beam



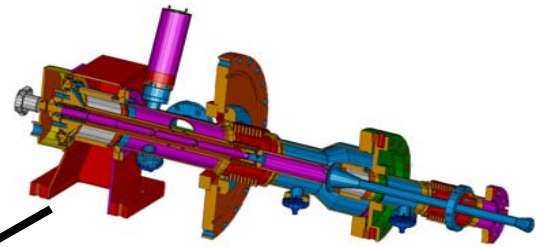
RF pick up & LLRF



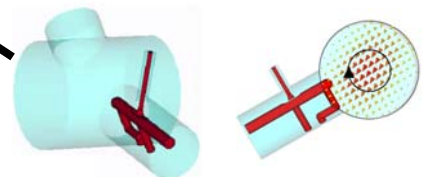


One standard **9-cell TESLA accelerating structure** operated as a π-mode standing-wave cavity.

One 230 kW **rf power coupler**, an **rf pick up** antenna and two **Higher Order Mode antennas** are assembled to each cavity.



RF power coupler



HOM coupler

Examples of R&D Activities in Europe

- Cavity R&D
- Couplers
- Tuner
- RF Controls
- Module Test Stand

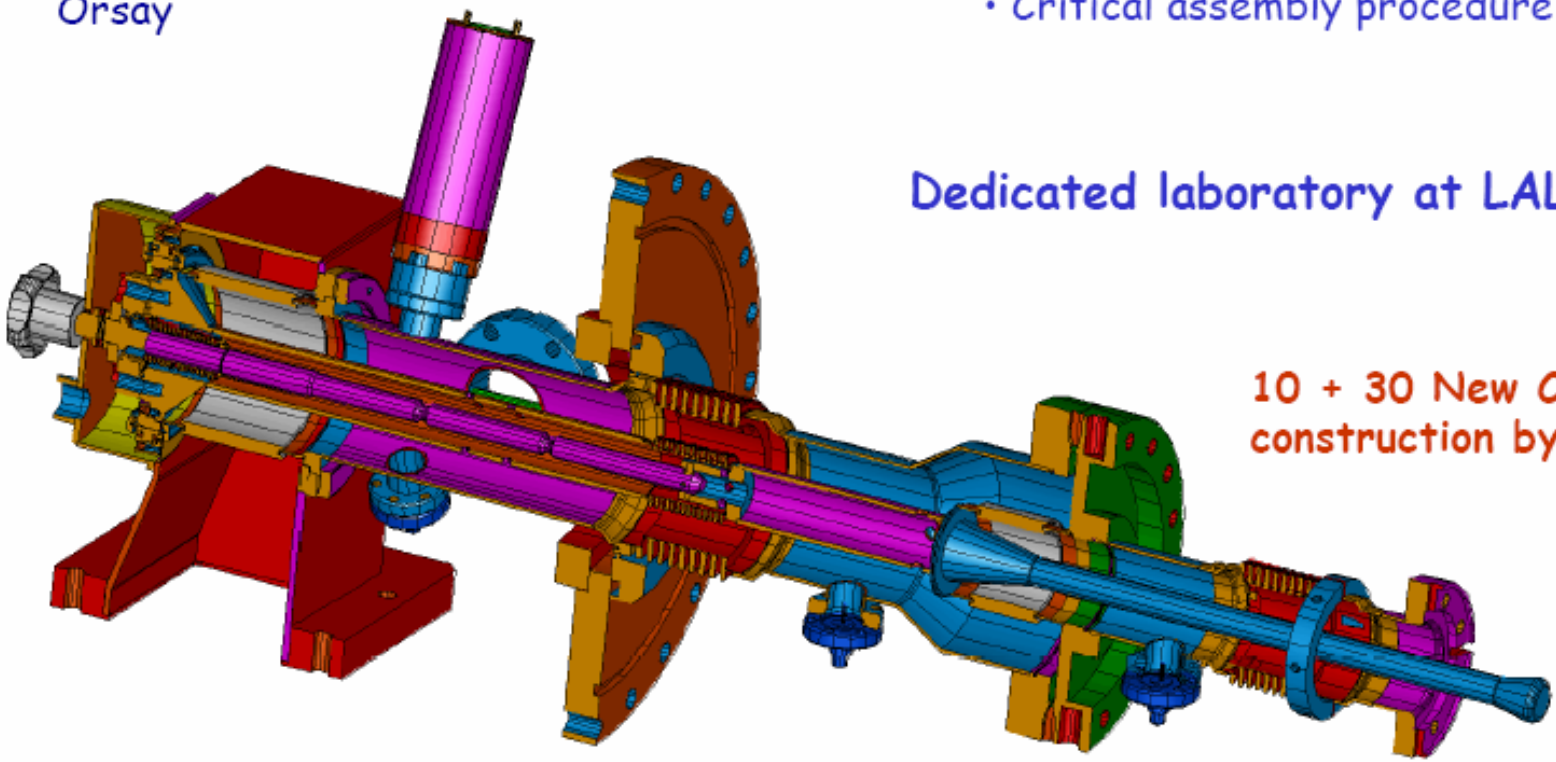
Many other issues will not be mentioned, like klystron development, modulators etc

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

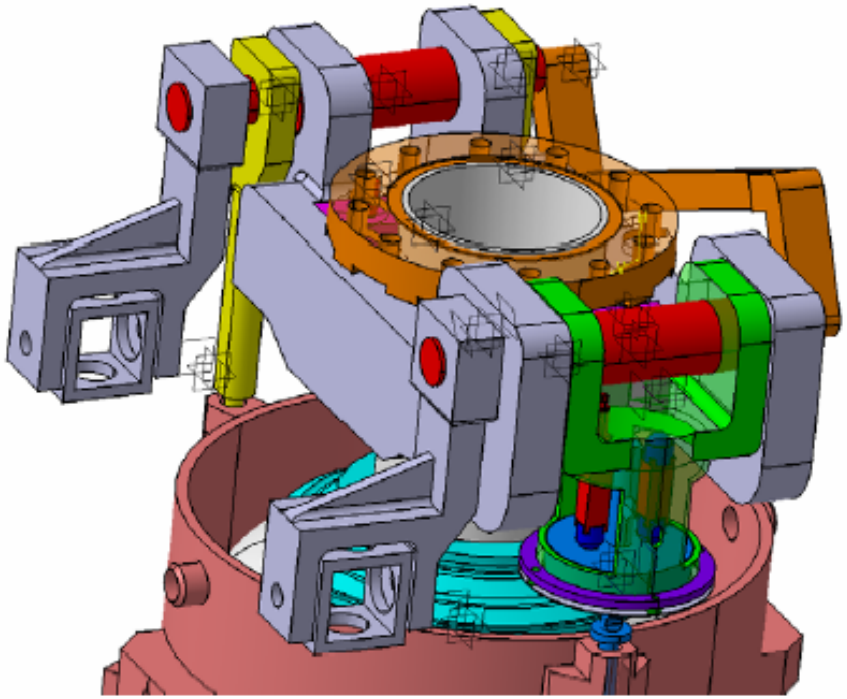
10 + 30 New Couplers in construction by industry

© C. Pagani

Example for Tuner Development (Saclay): Tuner for XFEL

New design with piezos

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

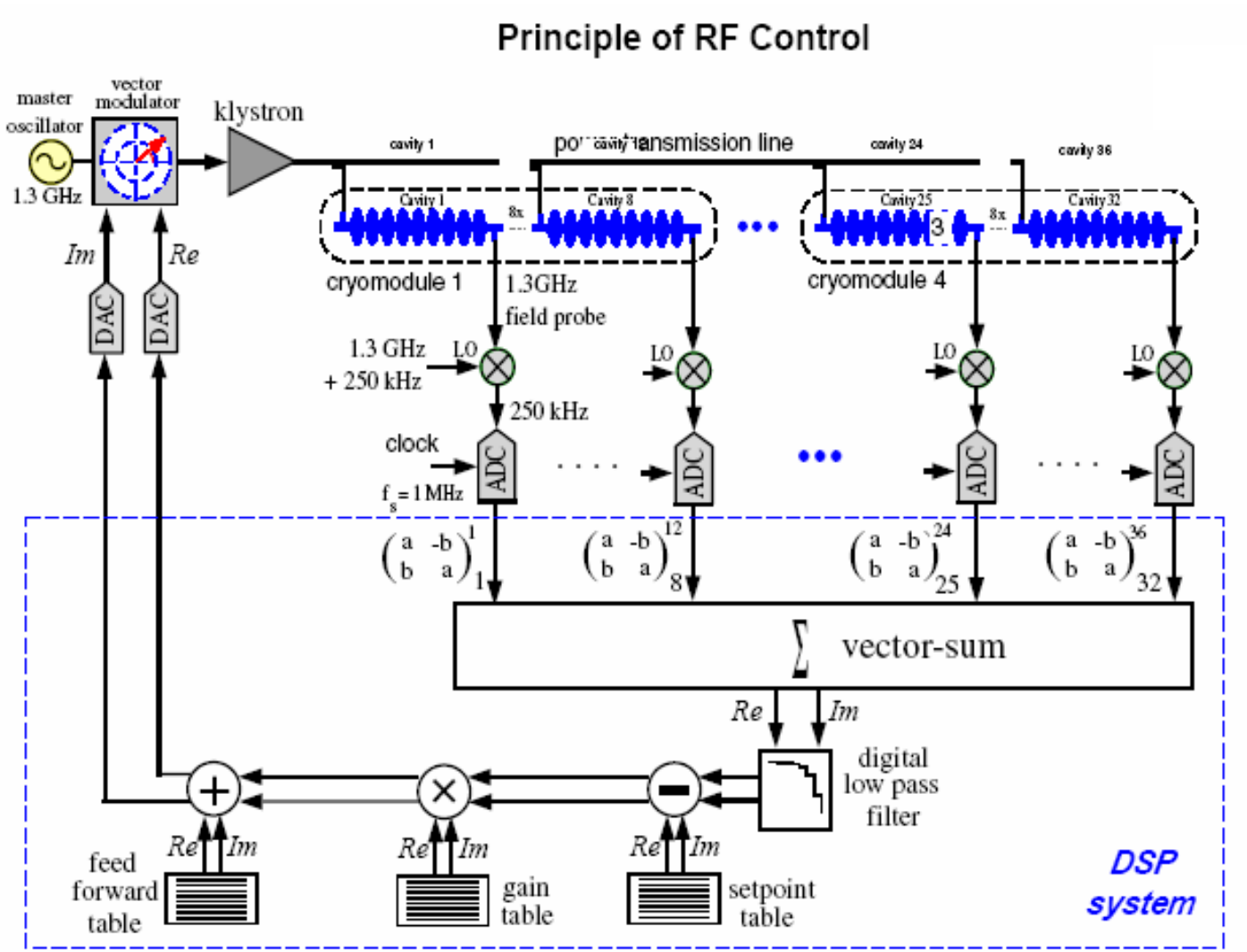


- Fabrication of 2 tuners since beginning of 2005
- 12 NOLIAC piezos, 2 PHYTRON stepping motors ordered
- Coll. with IPN Orsay: CEA send NOLIAC piezos to IPN for characterization, and IPN send P.I. piezos for tests on tuners
- Coll. with INFN-Milano for measurement with stress sensors @ 2K

Blade tuner development at INFN

© C. Pagani

RF Controls (LLRF)

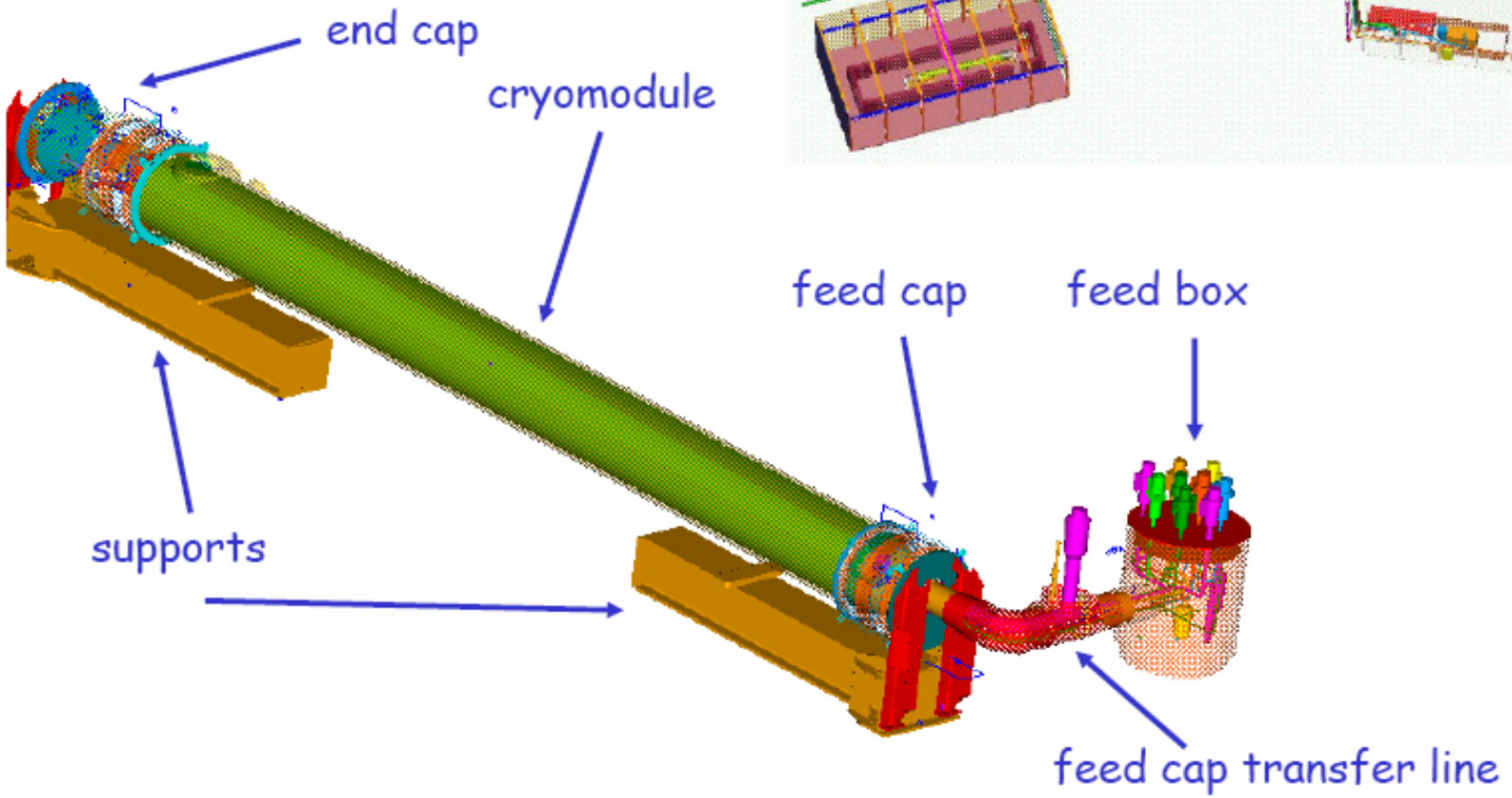


Scope of task: # of measurement/control channels XFEL: 3000 each

Module Test Stand at DESY

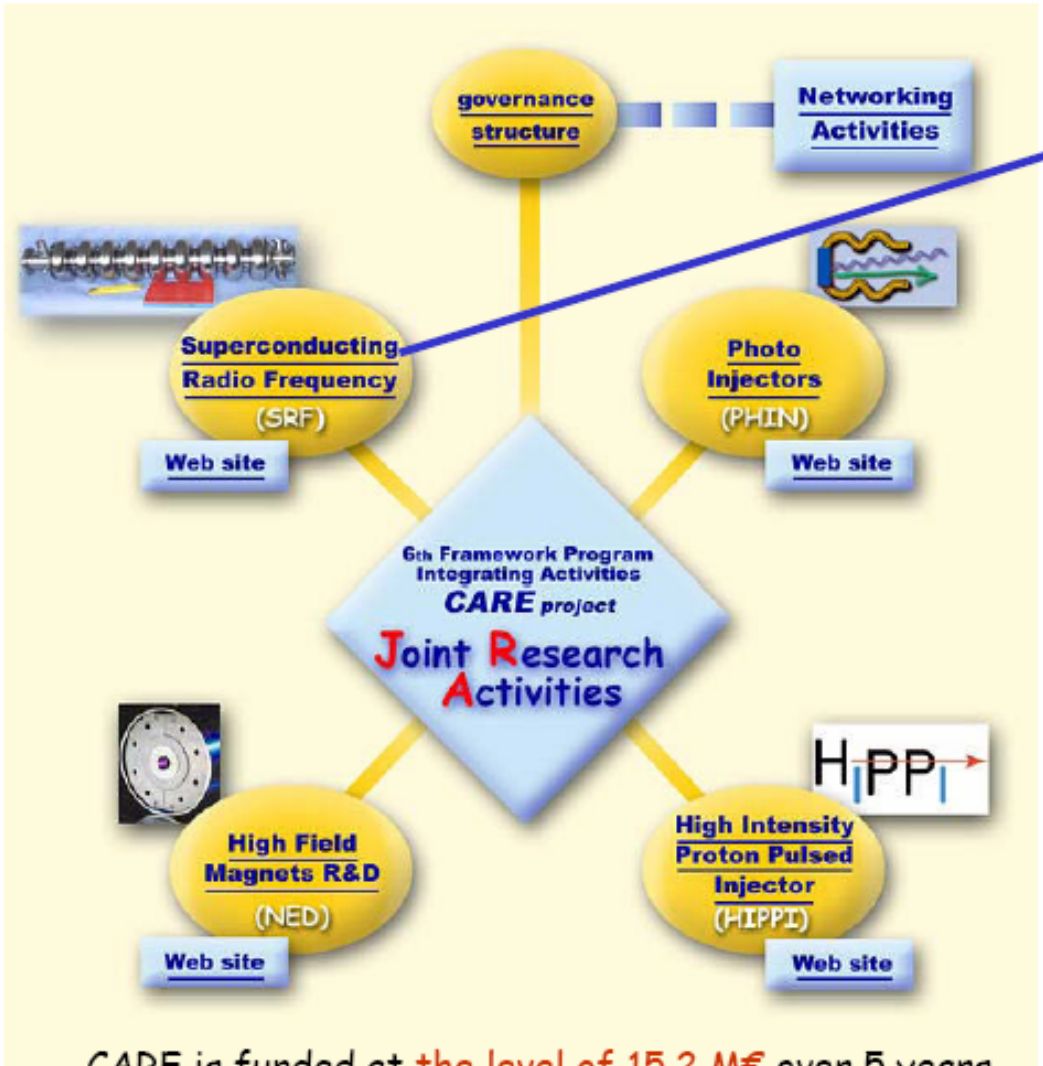
Needed for module development and testing outside TTF

- Under construction
- Commissioning 2005/06



© C. Pagani

EU funded R&D on SCRF



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

JRA1-SRF

5M€ from EU

- 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

Activities in Asia and US

Cornell

Work on cavity shapes

Energy Recovery Linac (ERL), based on TESLA technology

Fermilab

Superconducting Module Test Facility (SMTF)

JLAB

Cavities from large Nb crystals

KEK

Work on cavity shapes

Superconducting Test Facility

SLAC

Development of Solid State Modulators (No cold tech work)

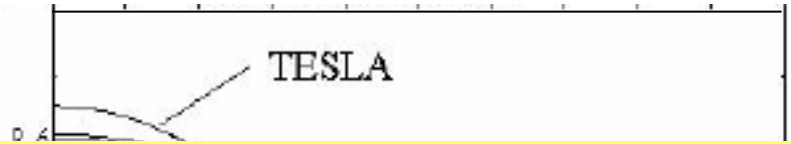
New Cavity Shapes for Higher Gradients

- Re-entrant (RE)
- Low Loss (LL):

For same stored energy less power dissipated in surface

Which is optimal balance between electric and magnetic field limitations?

Critical magnetic field vs field emission due to high electric field



But also Trade-offs

Wakefields
- higher in LL shape
- RE shape : same as TESLA

Smaller cell-to-cell coupling in LL shape
- More sensitivity to mechanical tolerances
- 1.5% instead of TTF 1.9%

LL and RE
- Slightly higher Lorentz-Force detuning

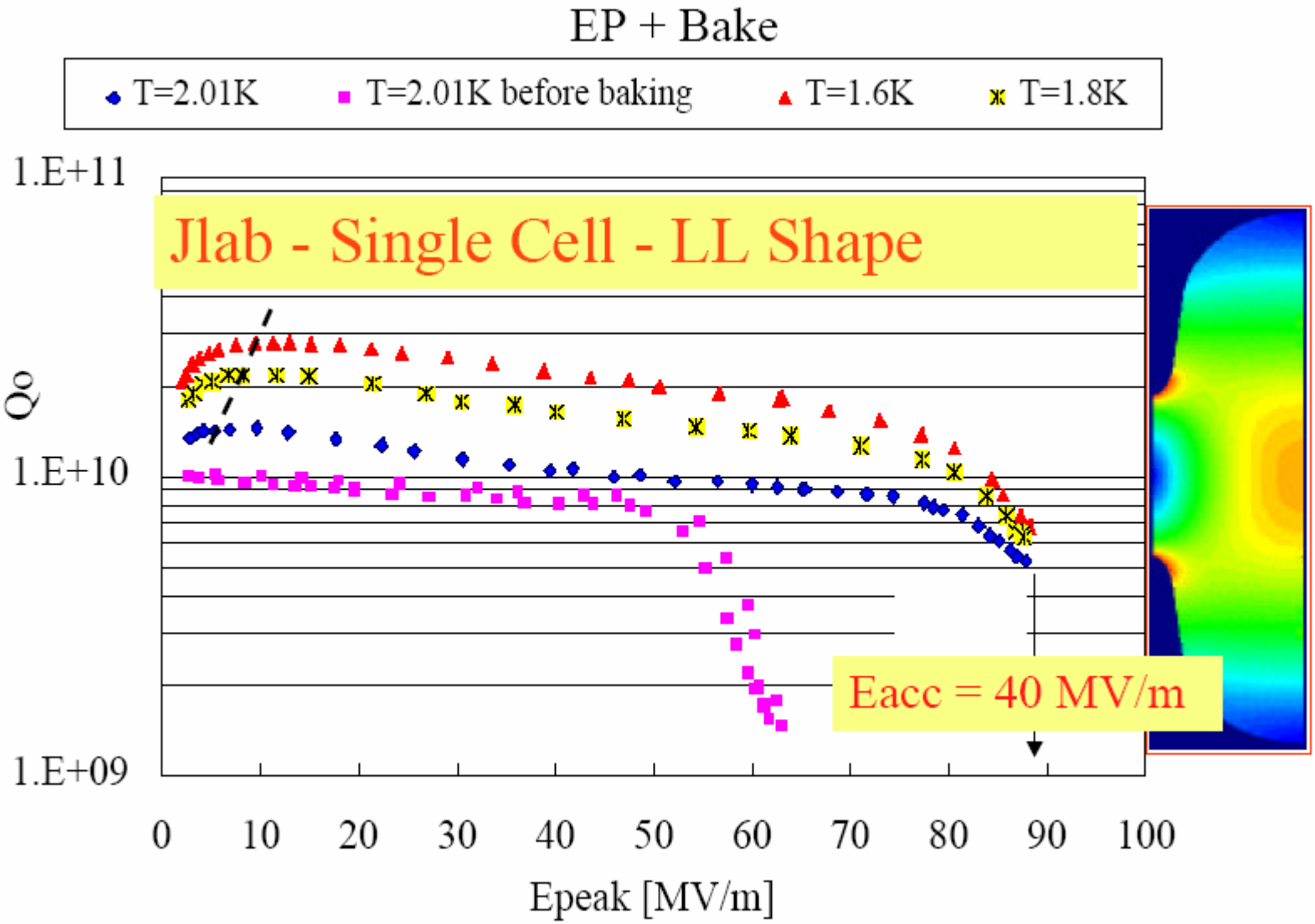
Opt_70_20 - reentrant cavity with aperture 70 m
higher than in TESLA, magnetic field 10 % less
same acceleration.

Opt_60_20 - aperture 60 mm, el. field: +20 %,

Opt_53_20- aperture 53 mm, el. field: +20 %, mag. field: - 20 %.

A

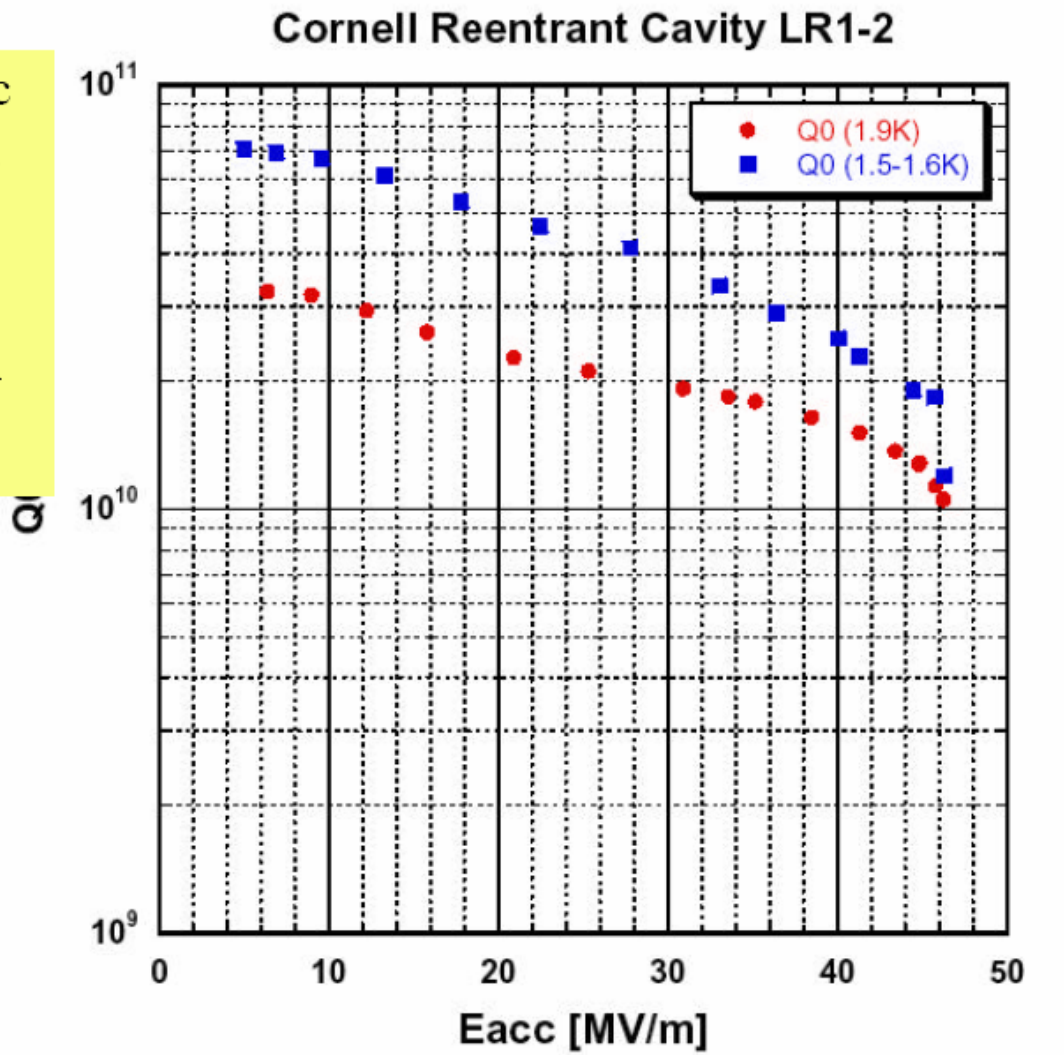
Test of Single Cell LL Shape Cavity



Single Cell RE Test at Cornell

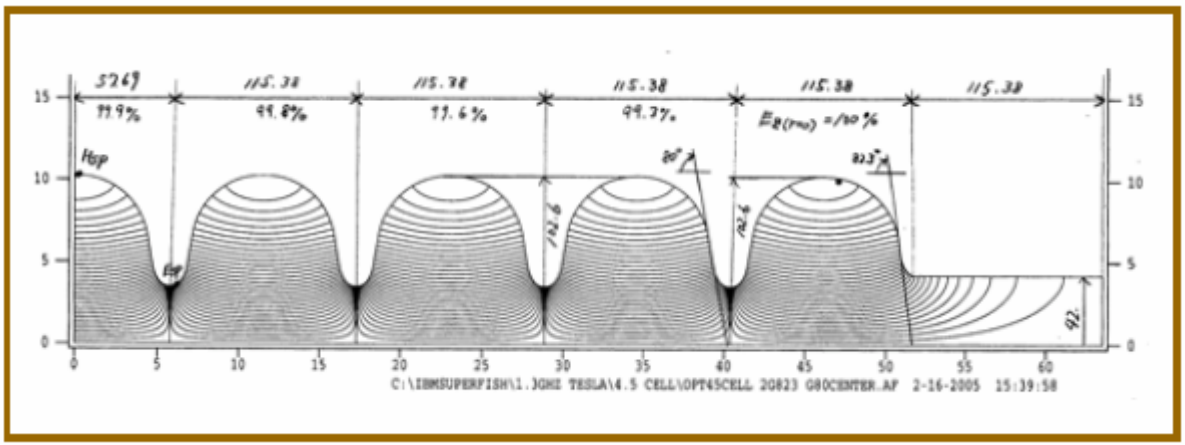
World Record Eacc
= 46.4 MV/m, CW

Pulsed = 47 MV/m
= 1800 Oersted

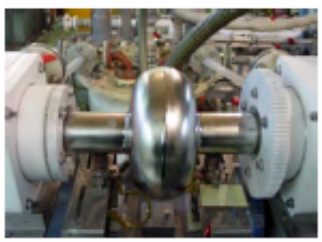


R&D on Cavity Shapes at KEK

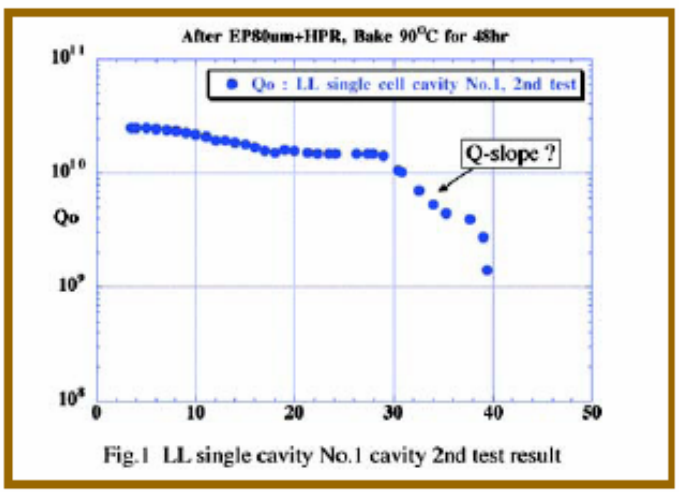
Low Loss cavity shape



Single cell High gradient cavity Test
(re-startup of surface process,
vertical test stand)



9-cell LL cavity design was completed.



First 9-cell LL cavity ready for tests this week at KEK

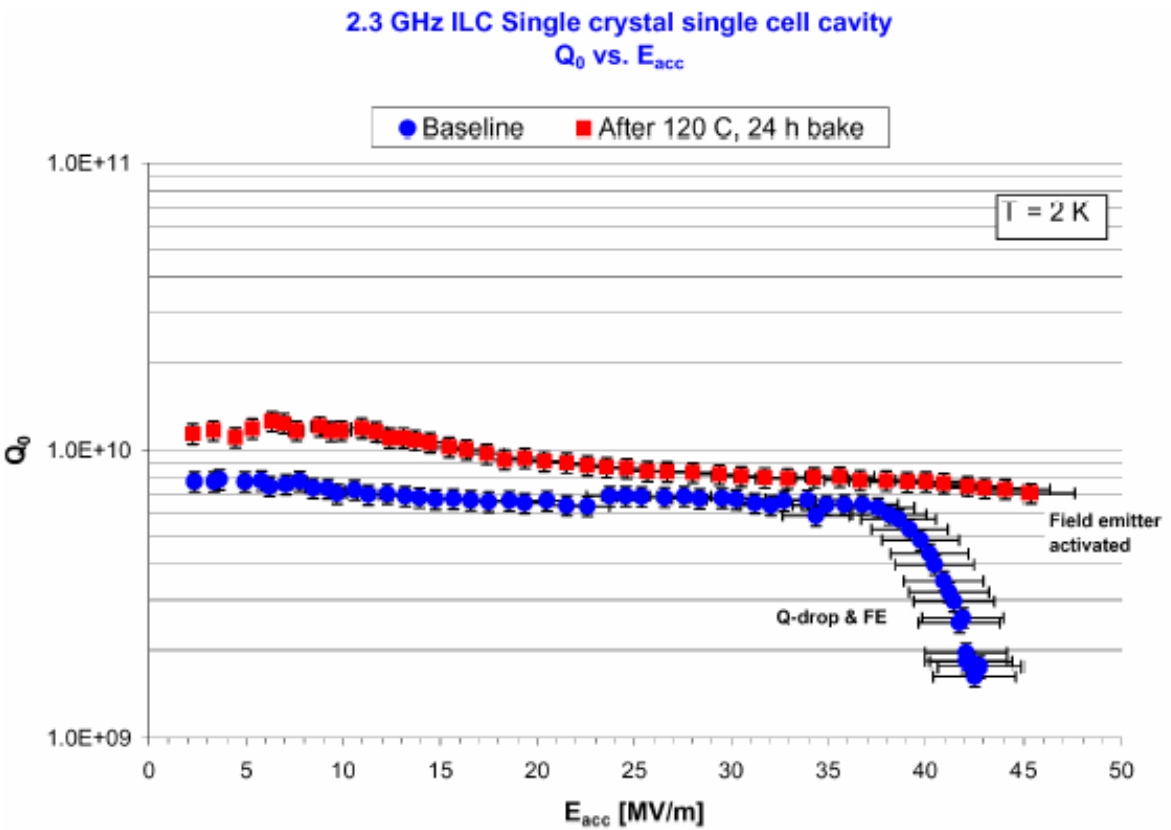
Single Crystal Cavity

P. Kneisel at al., JLAB

Single cell cavity made from a single crystal of niobium.

Low-Loss shape design

Cavity performs better than the ILC design goal



Large Crystal Tests at DESY

Fabricate cavities directly from Nb ingot

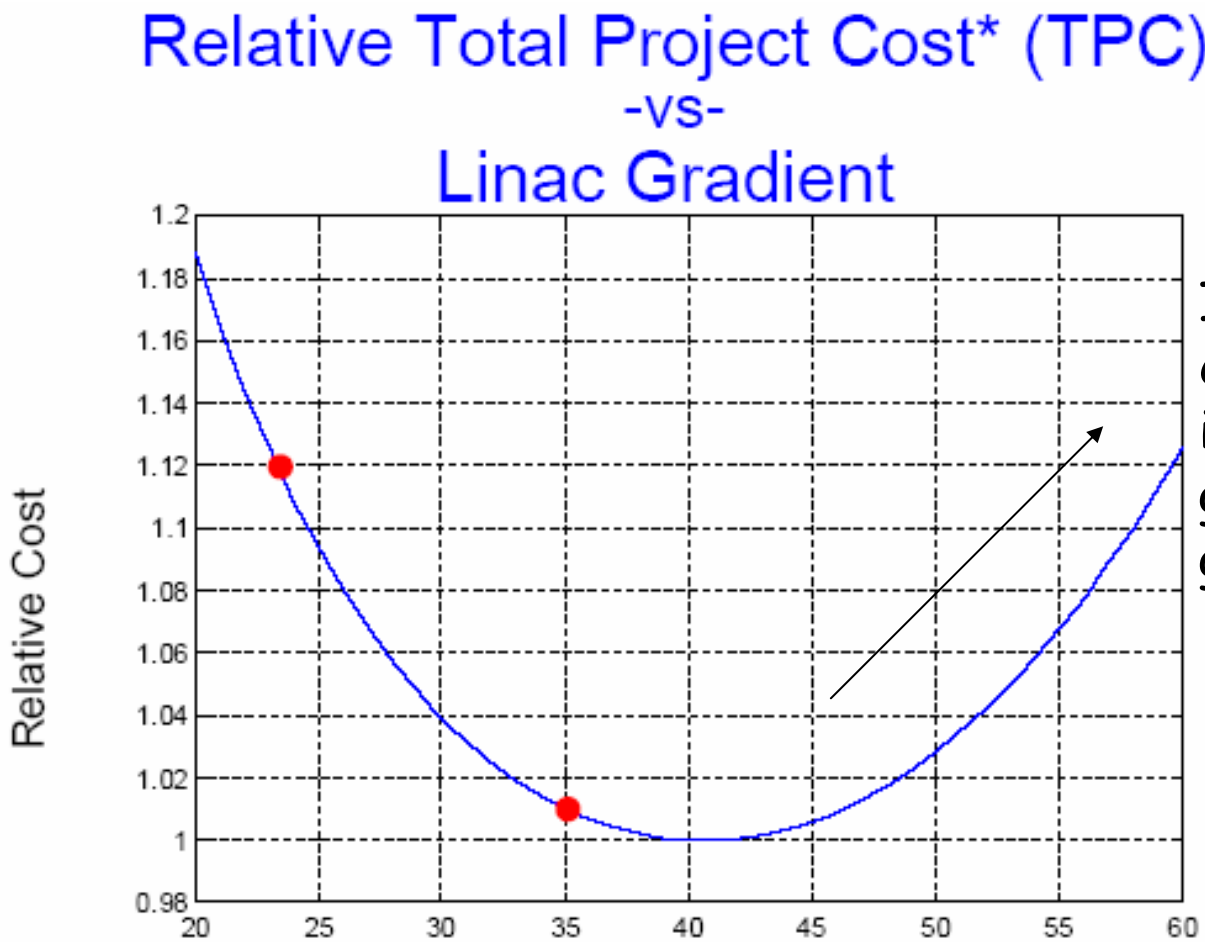
Potential advantages:

Simpler (cheaper?) production

Smaller impurities due to absence of rolling/forging

~ 70 sheets ordered from industry

Cost Optimised Gradient



Increasing cryoload with increasing gradient for given Q value

Taking into account construction and operation cost

Similar results from three independent studies

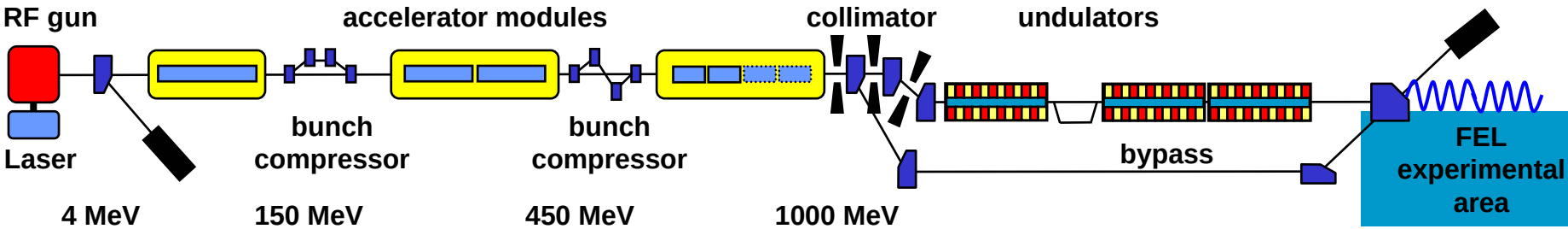
Test Facilities

TTF at DESY is running steadily for VUV-FEL, XFEL studies and ILC studies

At Fermilab and KEK new Test Facilities are in preparation

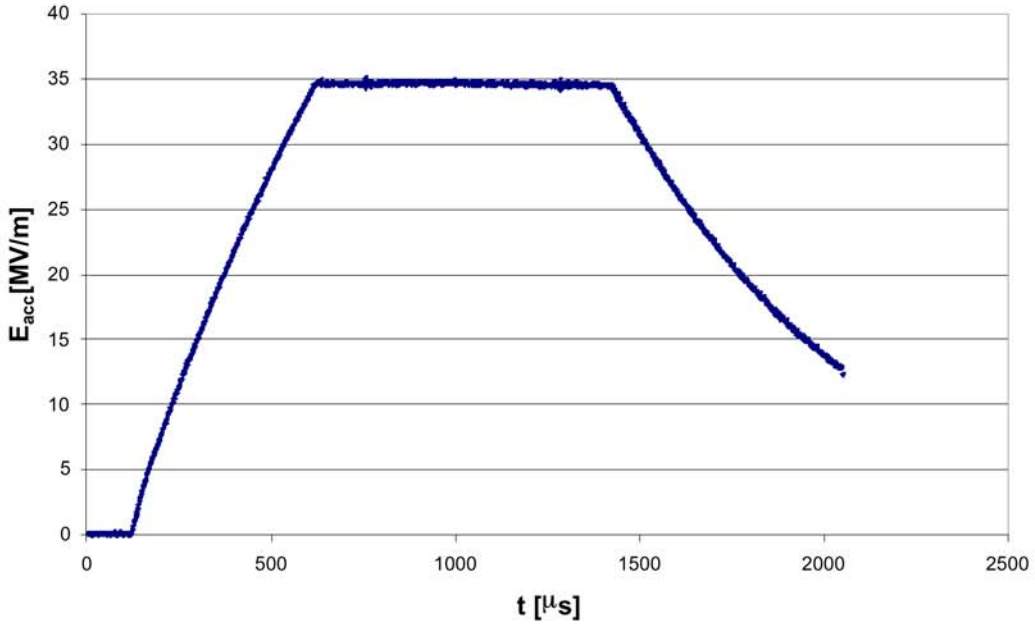
One facility in each region is an important asset for creating a base for successful industrialisation

The VUV-FEL as Prototype for the XFEL and ILC



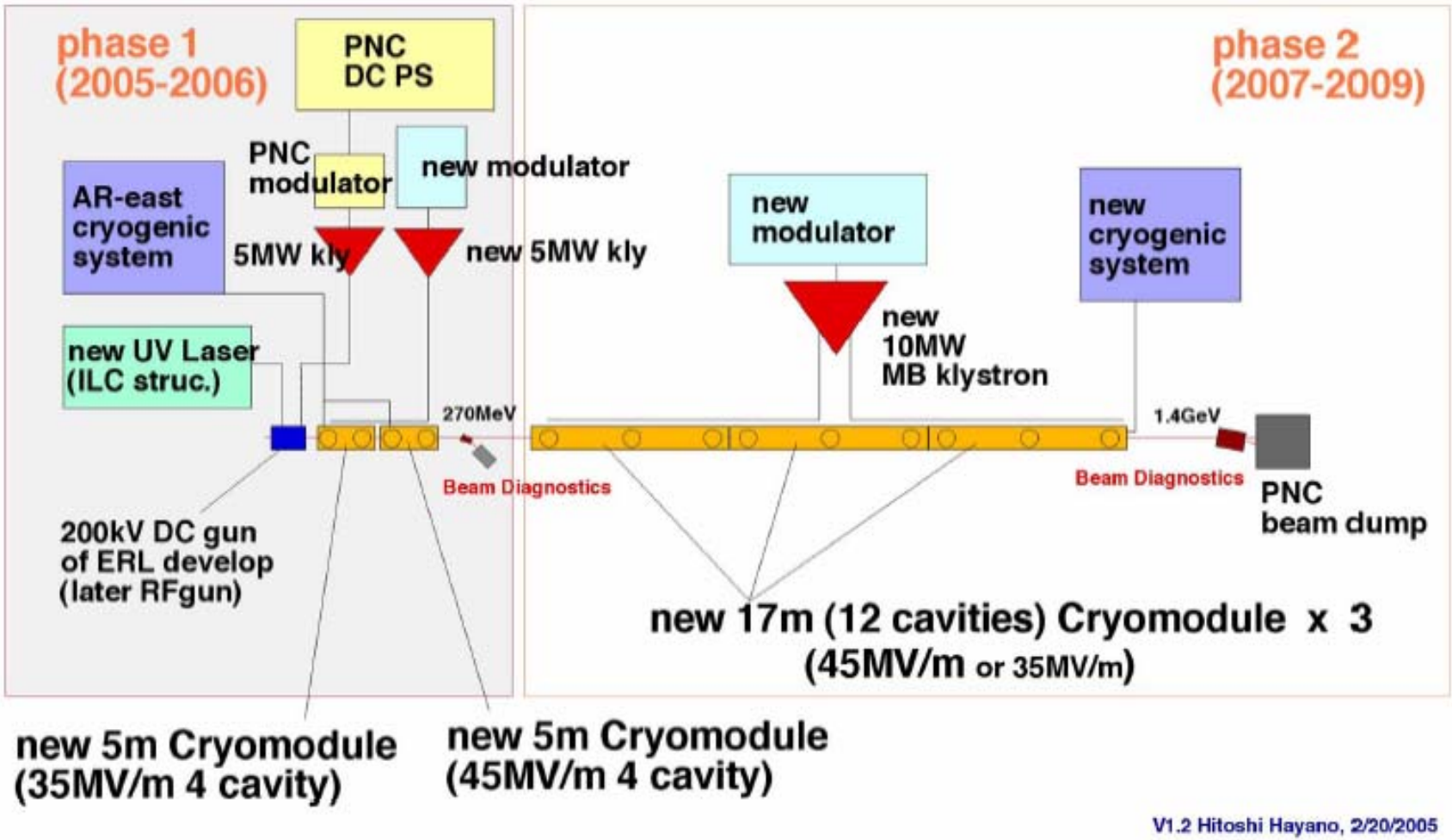
Test of EP Cavity in Accelerator Module with Beam

Cavity Test Inside a Module of TTF



- One of the electropolished cavities (AC72) was installed into an accelerating module for the TTF (VUV-FEL)
- Cooldown of the LINAC finished a few weeks ago
- Cavity was individually tested in the accelerator with high power RF and beam
- Result: **35 MV/m** in the accelerator!

Superconducting Test Facility (STF) at KEK



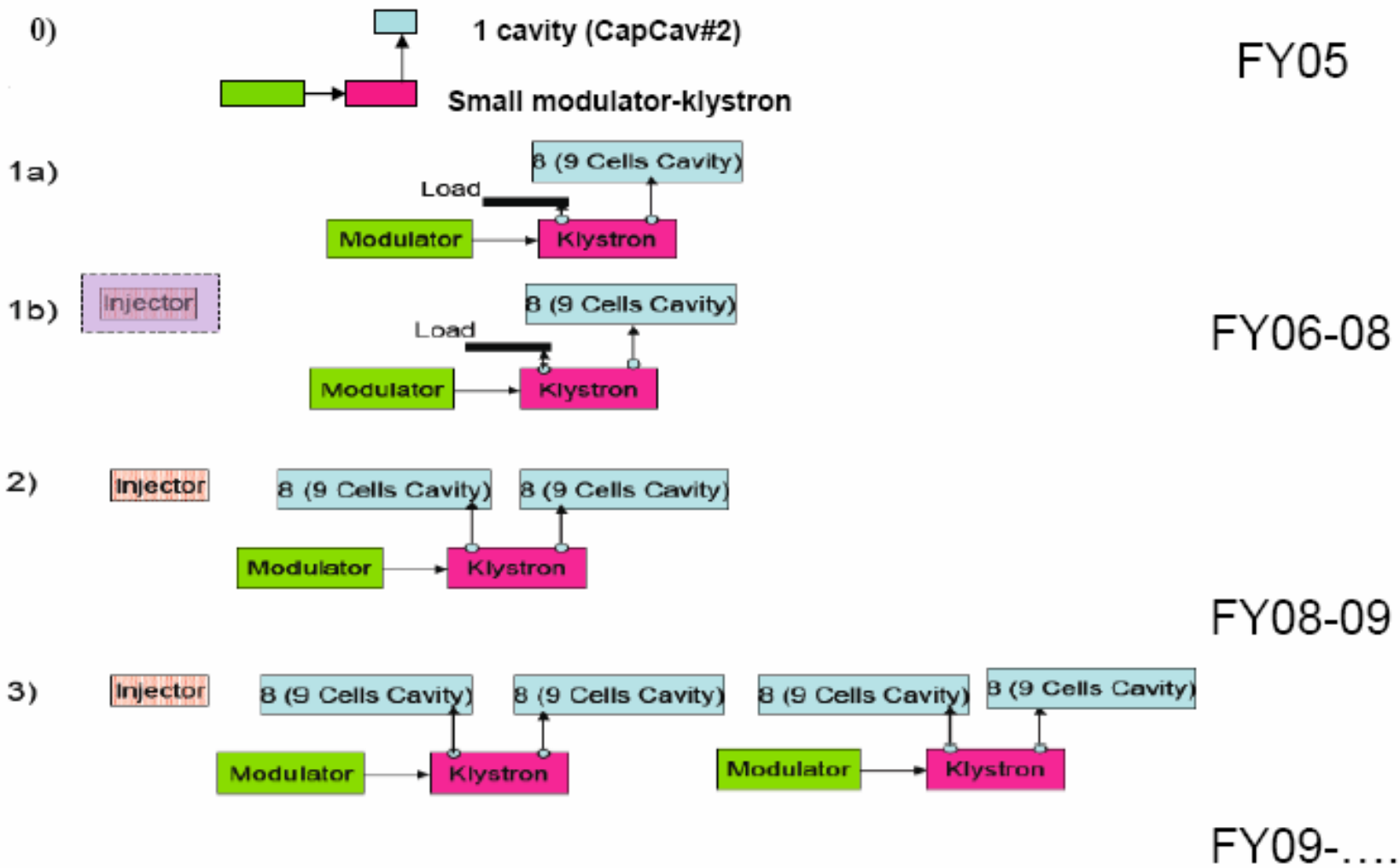
SC Cavitiy Work at Beijing

SMTF at Fermilab

Superconducting Modul Test Facility (SMTF):

- SMTF will be a national facility located at Fermilab for the fabrication & testing of superconducting modules.
- SMTF supplies infrastructure including space, cryogenics, power and other utilities, controls, radiation shielding, etc., for complete high power tests.
- SMTF will be a test bed for many different types of modules, $\beta<1$, $\beta=1$, and CW

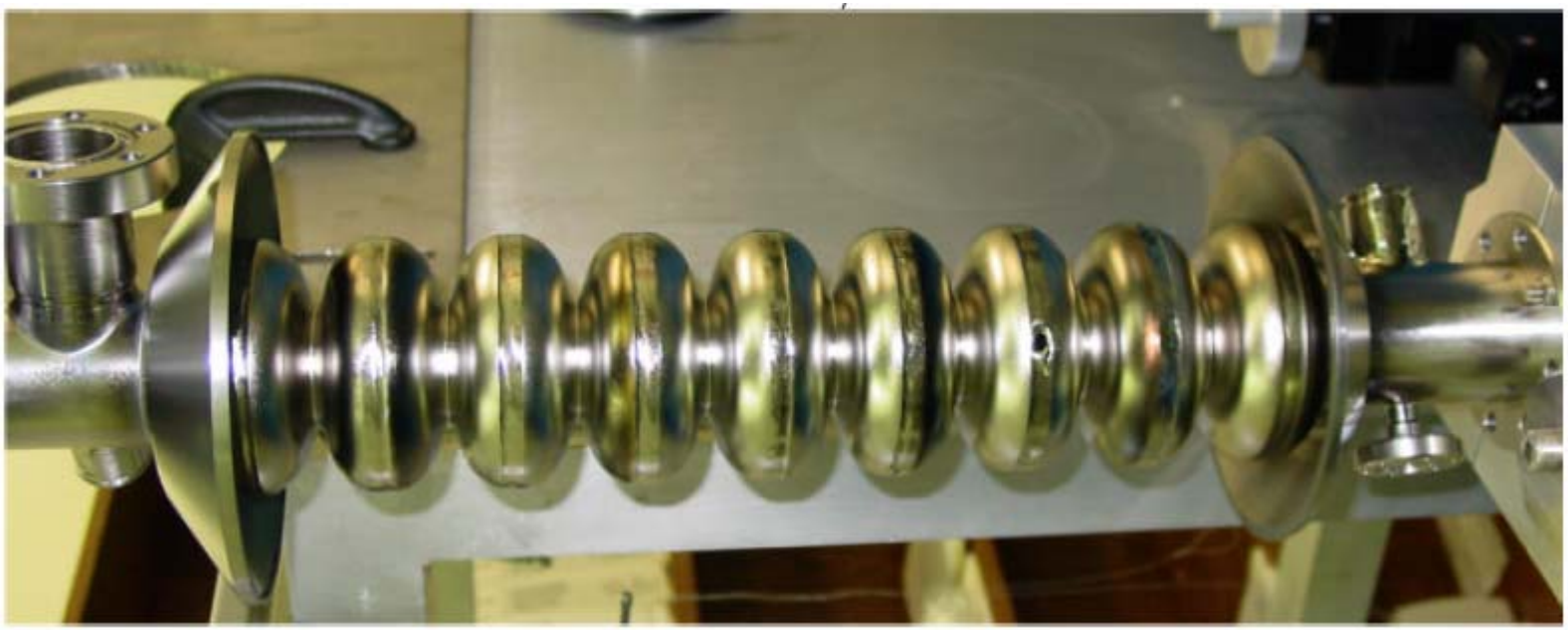
Evolution of SMTF



3rd Harmonic (3.9 GHz) Cavity for TTF

Development at Fermilab:

3 cell prototype test:
Achieved Gradient: ***Eacc = 19 MV/m Hpeak = 103 mT***
Goal: Eacc = 14 MV/m Hpeak = 68 mT



Industrial Forum on SC FR

In discussions with companies which have already provided components for TTF the idea emerged that it might be useful to create a European Superconducting RF Forum

Kick-off meeting took place at DESY on 7/8 April 2005, attended by ~ 100 participants from more than 40 companies and institutes.

A similar forum exists in Japan for the ILC

At present also in the US such a forum is being organised.

Statements by During the Forum

- The leading position of European science and industry in SCRF needs further strengthening. The Forum can help in this respect.
- Core components for the SCRF technology need long-term partnership by science and industry as they are not off-the-shelf products. The Forum can enable such partnerships.
- The Forum should act as a distributor for first-hand information on SCRF projects.
- For participating companies it is valuable to know, what the other companies do or can do.
- The main tasks of the Forum should be the exchange of ideas and know-how and the generation of a strong political funding support.
- The Forum is a valuable chance for especially small companies as they have special needs and need personal networks like this one. A European SCRF network could be an enhancement of the existing personal networks.

Industrial Studies

Key element in the ongoing preparation of the XFEL

Technical Specification
of
XFEL-Cryomodule Design&Assembly
Industrial Studies

DESY EV 010-04

Version 2.4
15.02.2005

Bernd Petersen DESY –MKS- (technical coordinator)
phone: +49 40 8998 3596
Bernd.Petersen@desy.de

- 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

Summary

SCRF Technology is booming

Substantial effort in R&D is driven by XFEL and ILC

The TESLA Technology Collaboration (TTC) will provide the link between the different projects

Cost-effective, reliable production of large numbers of structures (cavities, modules, tuners etc.) remains a major challenge

Another challenge is the coordination of the world-wide efforts