Working Group 2 – Introductory presentation.

Convenors –

C. Adolphsen, T. Garvey, H. Hayano

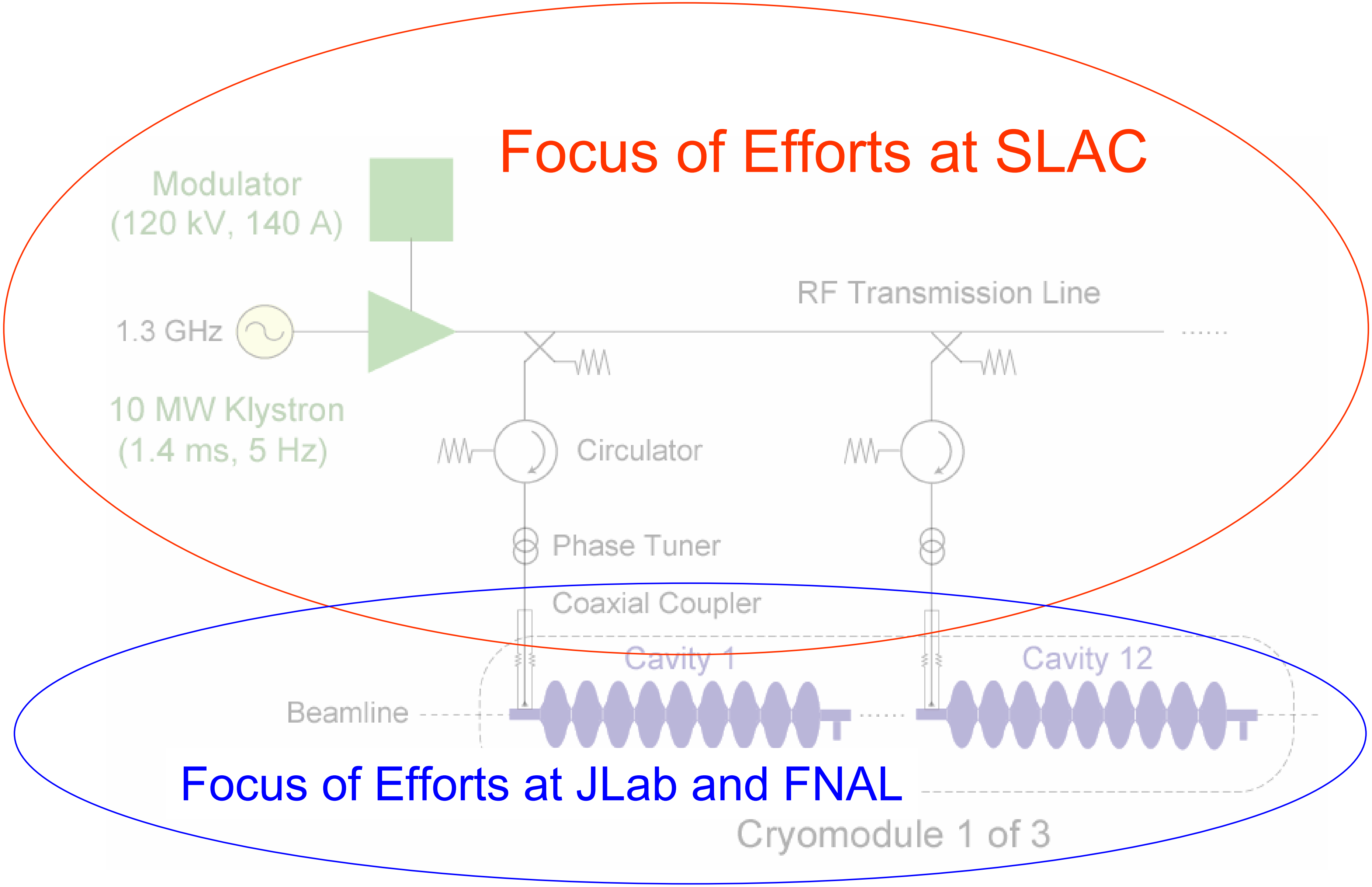
Topics covered by WG2

- Modulators / klystrons
- RF wave-guide distribution
- Low Level RF
- Beam interfaces (quadrupoles, BPM's)
- Cryomodule
- Cryo-systems

Important interfaces with other WG's especially WG5

Outline of presentation

- Progress in WG2 topics since last ILC meeting (will not necessarily be exhaustive!).
  - Not new R&D results; rather, “firming up” of plans for future R&D, re-orientation of Americas and Asian accelerator activities towards L-band / SC RF.
  - CARE / SRF activities in Europe
  - TTF-linac / X-FEL activities
- Overview of WG2 sessions to be held here.
- What WG2 hope to accomplish at this meeting.



FNAL-Based SMTF Proposal: “It is anticipated that, with coordination from the ILC-Americas collaboration, SLAC will lead the ILC rf power source efforts ...

SLAC plans for ILC RF Sources

- Initial SLAC program will focus on:
  - Establishing a 1.3 GHz test stand to gain experience with L-band technology. Will test NC structures and cavity power couplers.
  - Developing alternatives to the baseline modulator and klystron to reduce cost and improve efficiency and reliability.

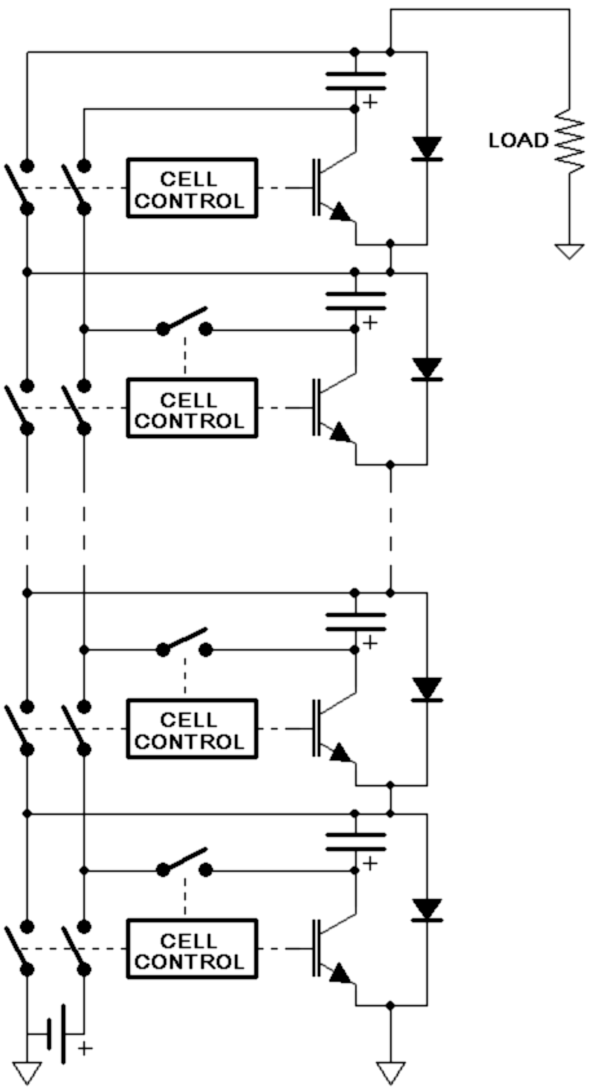
Modulators for ILC

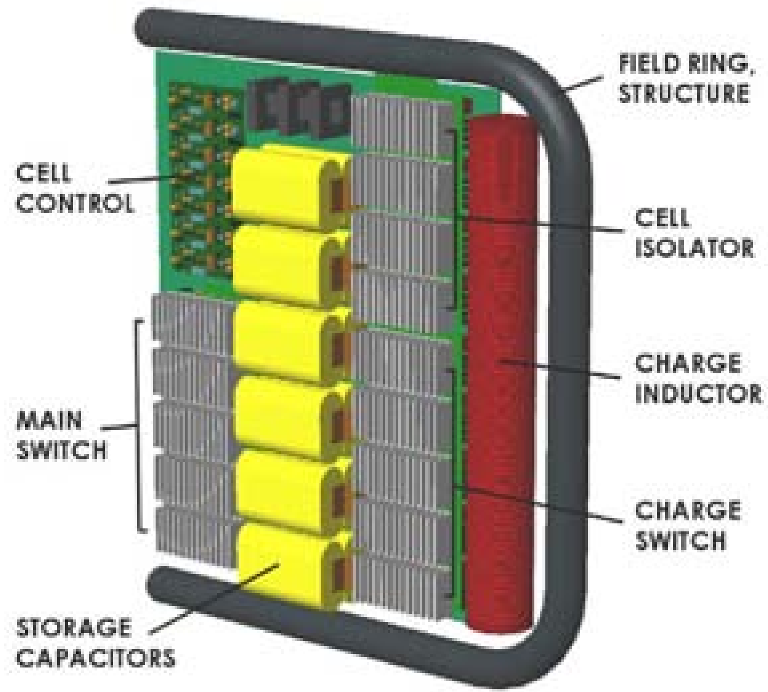
Specification

RF Pulse Length	1.37 ms
Modulator Rise/Fall Time	0.2 ms max
Modulator Pulse Length	1.7 ms max
Klystron Gun Voltage	120 kV max
Klystron Gun Current @120kV	140 A max
Pulse Flatness	+/- 0.5%
Total Energy per Pulse	25 kJ
Repetition Rate	5 Hz
Modulator Efficiency	85%
AC Power per RF Station	120 kW
Number of Modulators	~ 600

- TESLA TDR choice is the FNAL/DESY/PPT ‘Pulse Transformer’ modulator.
- SLAC is evaluating three alternative designs (SNS High Voltage Converter Modulator, DTI Series Switch Modulator and SLAC Marx Generator).

SLAC Marx Generator Modulator





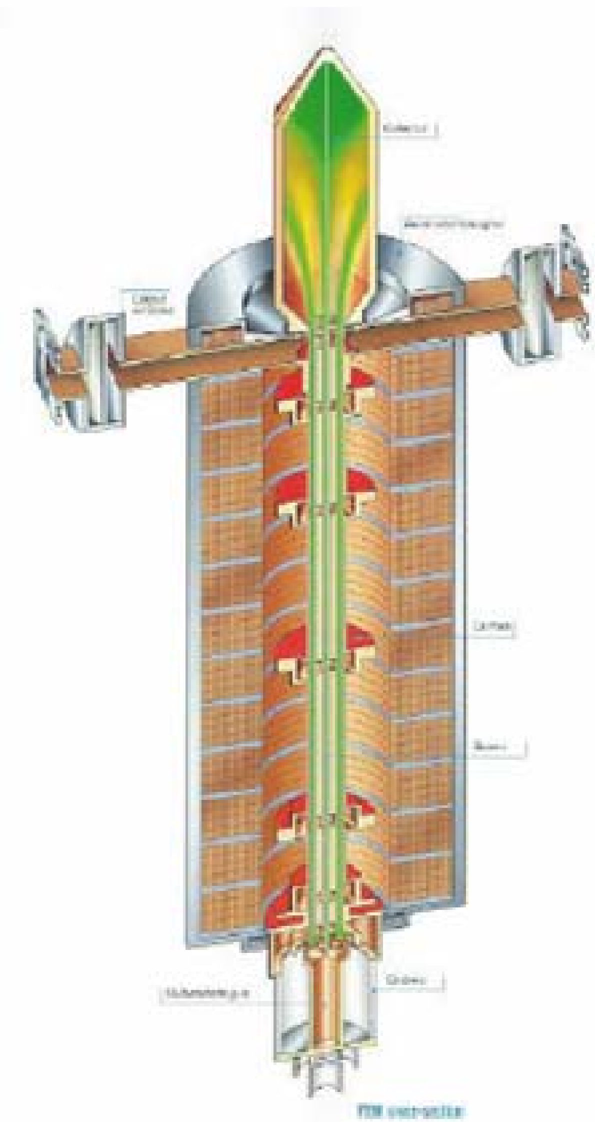
12 kV Marx Cell (1 of 24)

- IGBT switched
- No magnetic core
- Air cooled (no oil)
- Building prototype (2007)

Klystron Development

- DESY 10 MW Klystron Program Status
  - Three Thales tubes built, five more ordered – all 3 tubes developed gun arcing problems – two rebuilt to correct problem but not fully tested, the other has run for 18 khour at lower voltage (~ 95 kV).
  - One CPI tube built – achieved 10 MW at short pulse length, limited by CPI modulator - was accepted by DESY.
  - One Toshiba tube built and under test – 10 MW, 1 ms achieved – longer pulses limited by modulator, which is being upgraded.

ILC Klystron Development



GOAL

Reduce HV Requirements
and Improve Efficiency
(Lower Space Charge)
with a
Multiple Beam Klystron

Use Seven 19 A, 110 kV
Beams to Produce 10 MW
with a 70% Efficiency

Thales TH1801 MultiBeam Klystron

Spec's:
10 MW, 10 Hz, 1.5 ms
with 4 kW Solenoid Power

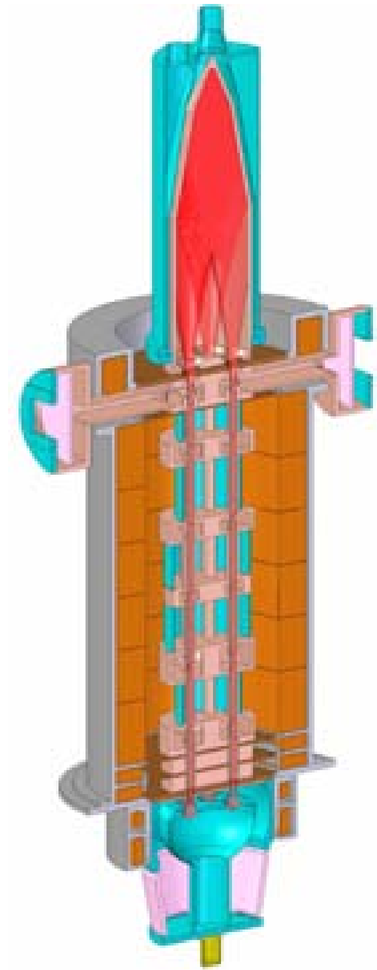
First Tube Achieved 65%
Efficiency at 1.5 ms, 5 Hz
and Is Used in TTF

Photo of TH1801 Tube (top) and Cathode (bottom)

Other 10 MW Multi-Beam Klystrons Being Developed

Communications & Power Industries

These klystrons boast a 100 khour cathode life-time.
THALES MB klystron claims 40 khour



TOSHIBA E3736
(Collaboration with KEK)

VKL-8301

SLAC Klystron program

– Developing a 10 MW L-band Sheet-Beam Klystron.

– If multi-beam program falters, consider lower perveance, single beam, 5 MW tube, possibly with PPM focusing.

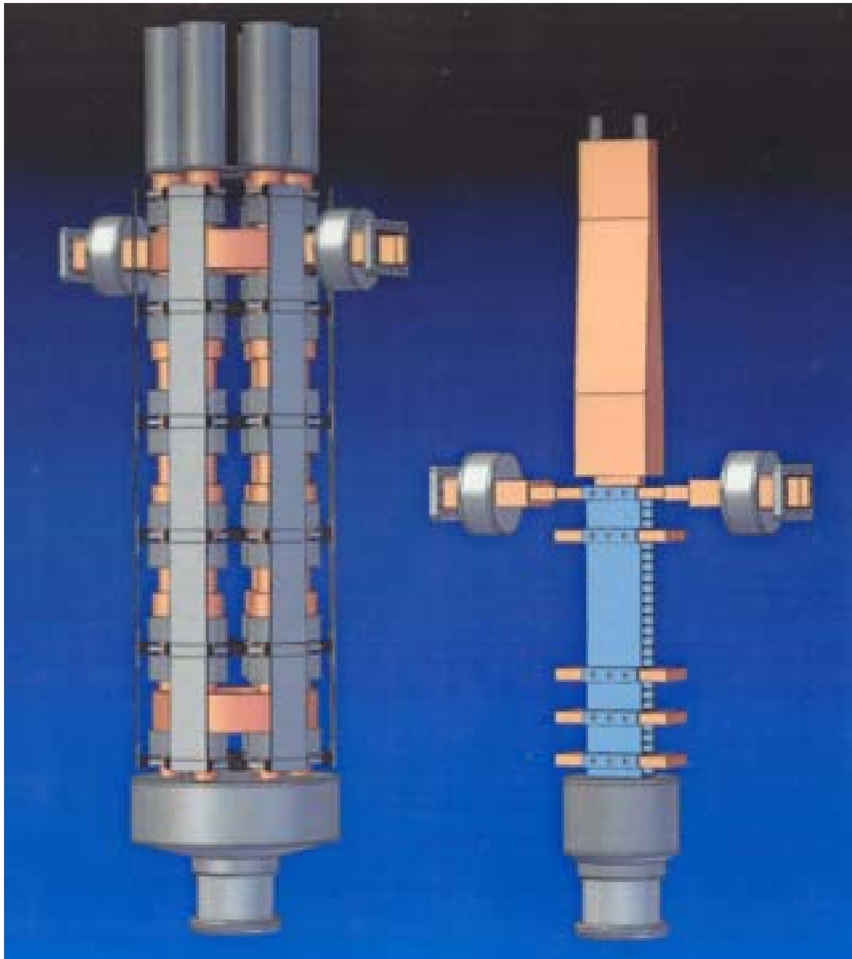
– Buy commercial 5 MW tubes as needed for 1.3 GHz NC structure and coupler program.

– Possibly collaborate with DESY and CPI on 10 MW tube.

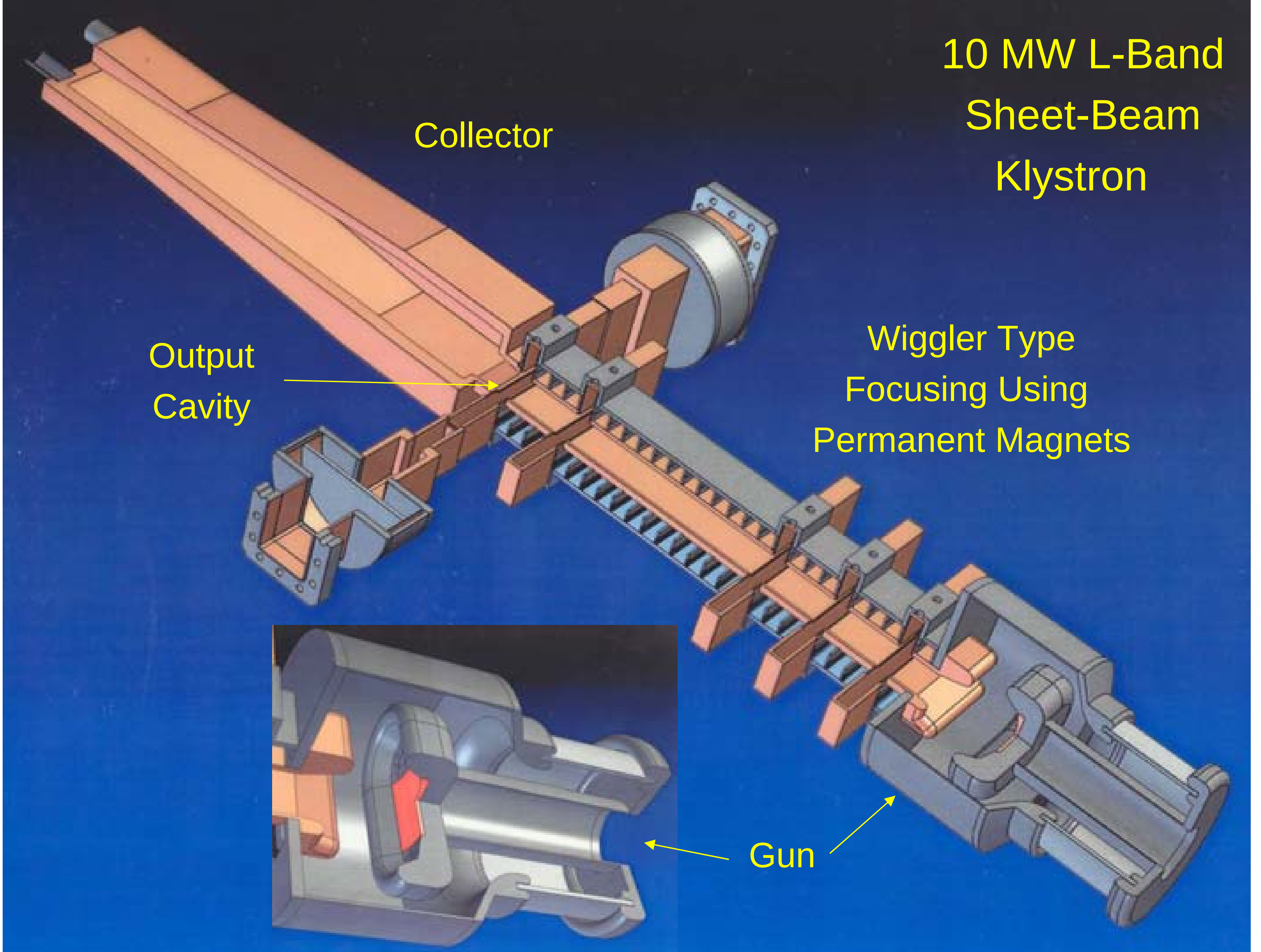
SLAC Sheet-Beam Klystron

- Developing a 10 MW sheet beam klystron as an alternate to the multi-beam tubes to reduce cost

Multi-beam tube   Sheet-beam tube



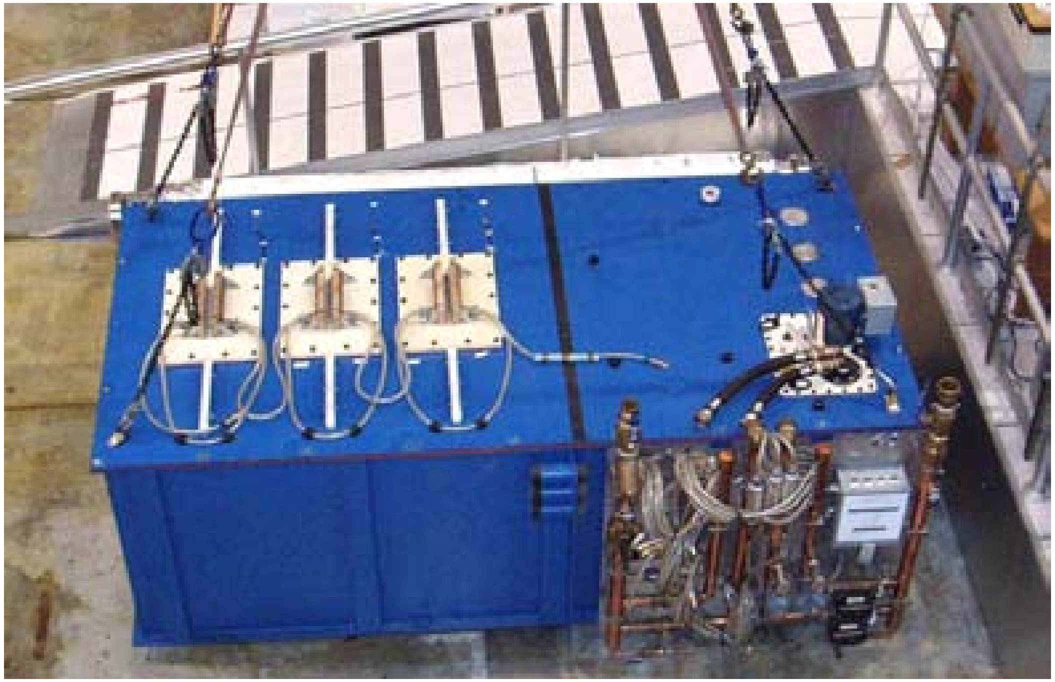
  - Uses flat beams instead of six beamlets to reduce space charge forces.
  - It is smaller with a planar geometry for easier construction.
  - No solenoid magnet (saves ~ 4 MW of power).
  - W-band ‘proof-of-principle’ version in progress using external funding.


10 MW L-Band
Sheet-Beam
Klystron
Collector
Output
Cavity
Wiggler Type
Focusing Using
Permanent Magnets
Gun

L-Band Test Facility at NLCTA

- Recently acquired a 10 MW HVCM Modulator from SNS.
- Buying a 5 MW TH2104C tube from Thales (1 year delivery).
  - In meantime use a SDI-Legacy tube from Titan (TH2104U).
- All major LLRF and waveguide components on order.

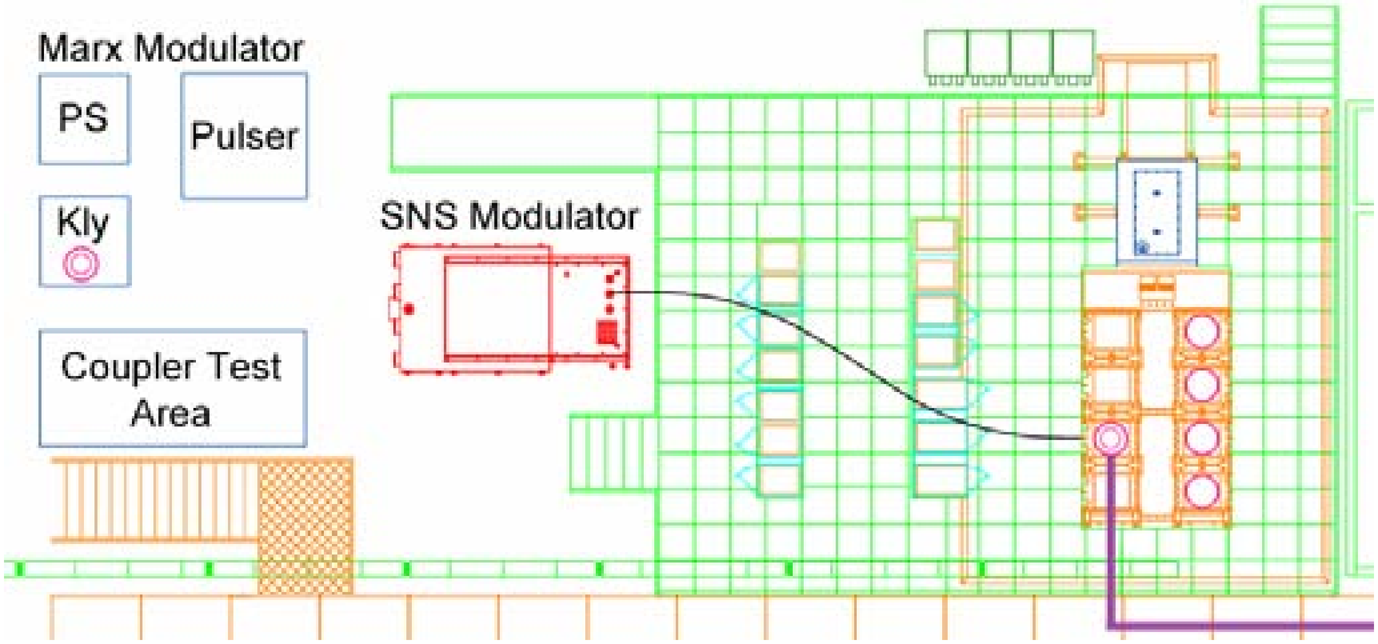
SNS Modulator Being Assembled at NLCTA



Thales 2104U Klystron

SLAC Test Facility Program in 2006 (C. Adolphsen)

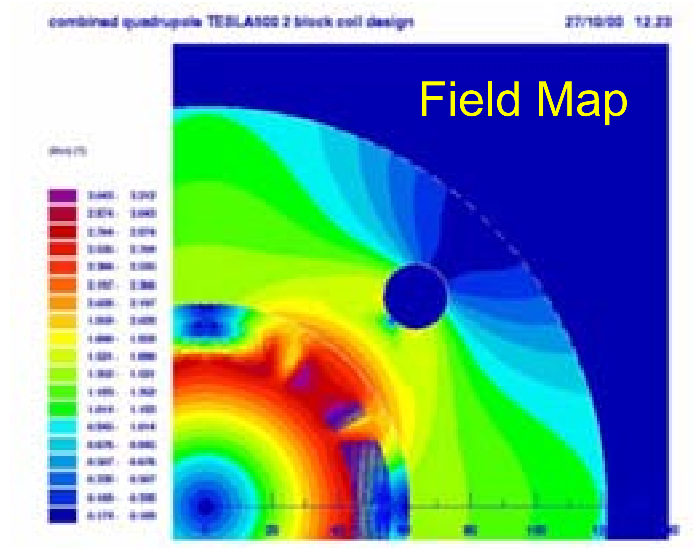
- Use 5 MW source for coupler and normal-conducting cavity tests
- Propose to add a second L-band station using ILC prototypes.
  - Depending on progress, use Marx Generator, DTI Direct Switch or buy a “baseline” modulator from PPT.
  - Buy (or borrow) a CPI or Toshiba 10 MW klystron.



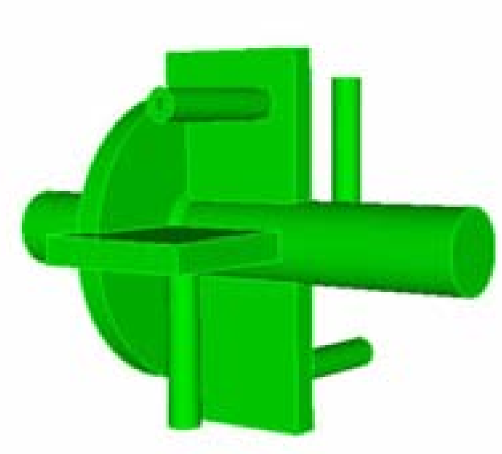
SLAC ILC Linac SC Quad/BPM Evaluation

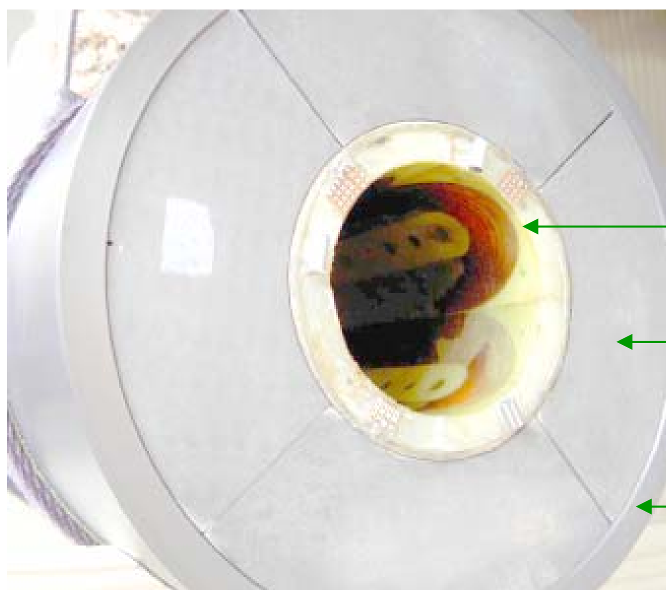
- Goal: Demonstrate Quad/BPM performance required for ILC beam-based alignment:
  - Verify < ~ 5 micron movement of Quad magnetic center with field change.
  - Show ~ 1 micron BPM resolution and < ~ 5 micron Quad-to-BPM stability with a compact RF cavity BPM.
- For this program we plan to
  - Develop linac rRF cavity BPMs and test them with beam.
  - Acquire the ILC prototype Quad built by CIEMAT (Spain) and build a test cryostat for it at SLAC.
  - Do quad center stability tests with a rotating coil at the SLAC Magnetic Measurements Lab.
- Status
  - Quad nearly finished and cryostat and coil engineering underway – expect first magnet test in 2/06.
  - BPM design complete – test with beam in 2006.

SC Quad
(~ 0.7 m long)



S-Band BPM Design
(36 mm ID, 126 mm OD)



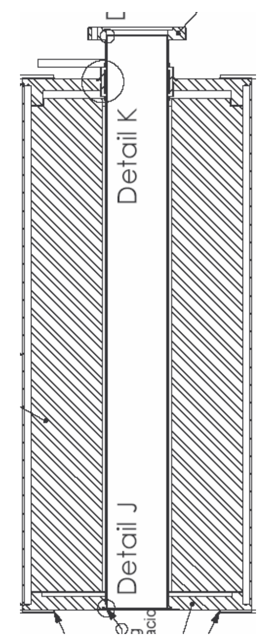


He Vessel →

SC Coils

Iron Yoke Block

Al Cylinder

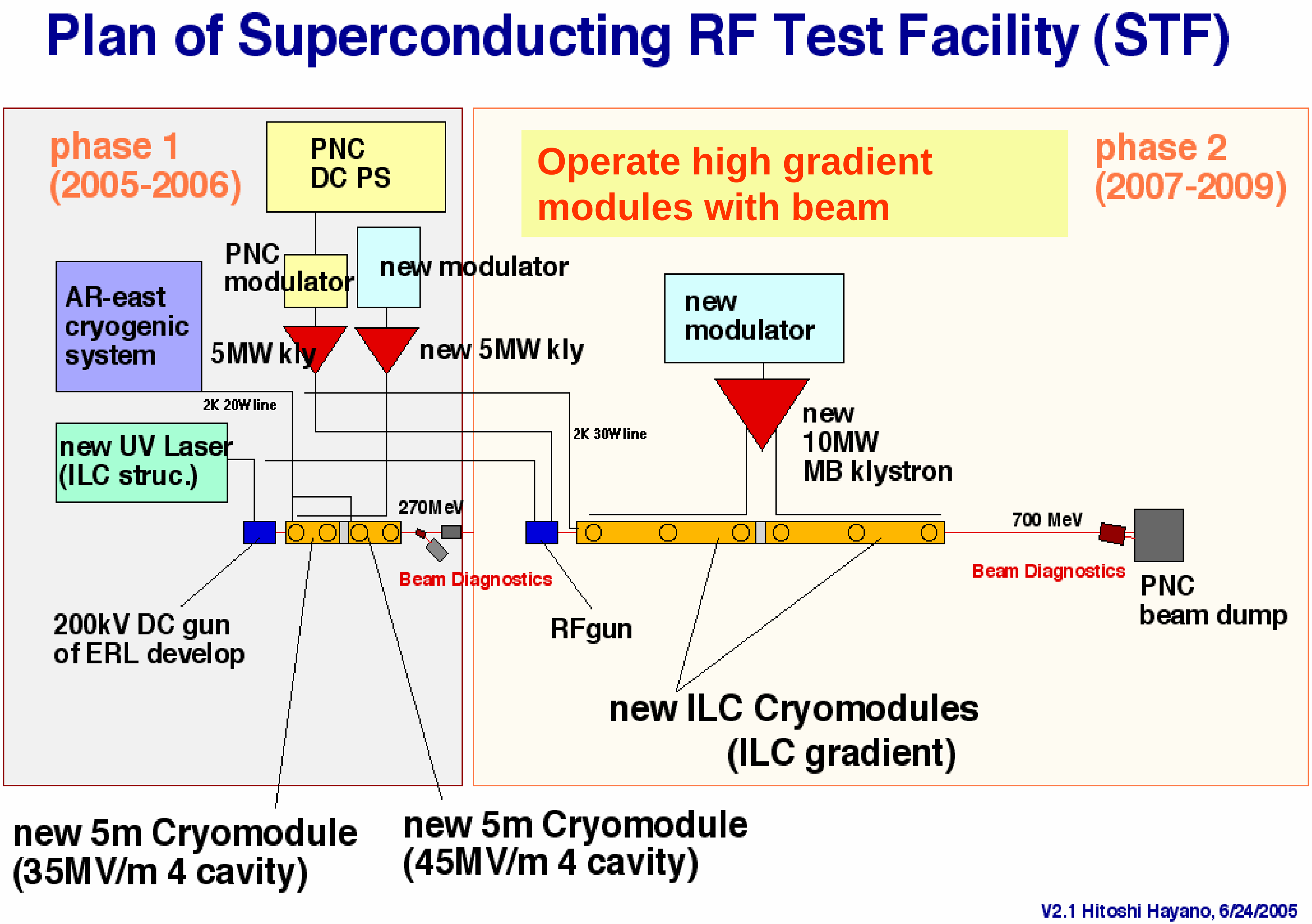


SLAC WG2 Activity Summary

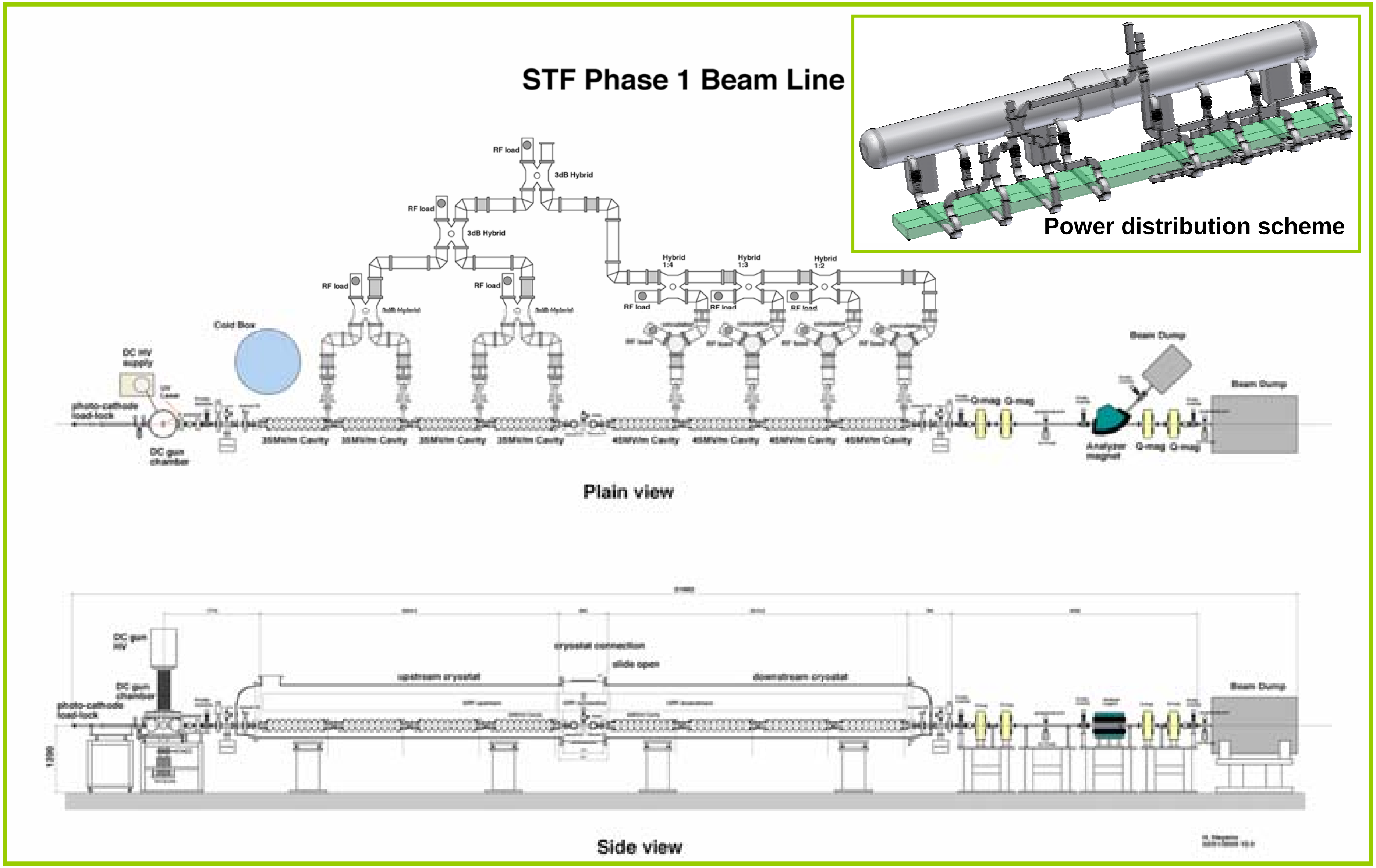
- Programs started in FY05
  - Assemble an L-band RF station at NLCTA
  - Build IGBT switching circuits for two SMTF modulators
  - Develop a Marx-generator style modulator
  - Develop an L-band sheet-beam klystron
  - Demonstrate linac quad and bpm performance for ILC beam-based alignment.

- Programs proposed for FY06
  - Build a second L-band station with ILC prototype modulator and klystron (collaborate with DESY).

Plans at KEK for an L-band Test Facility



STF Phase 1 RF Wave-guide Distribution



STF Modulator, klystron plan & status

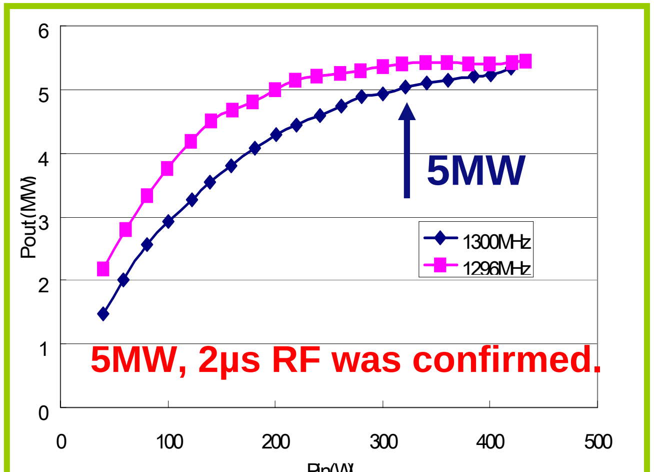
1. **Reuse an old TH2104A klystron, driven by an existing PNC modulator by adding a bouncer circuit and a new pulse transformer.**

   Initial operation is scheduled in Dec. 2005 for testing the cavity input couplers. Relocate this system later for running an RF-gun.

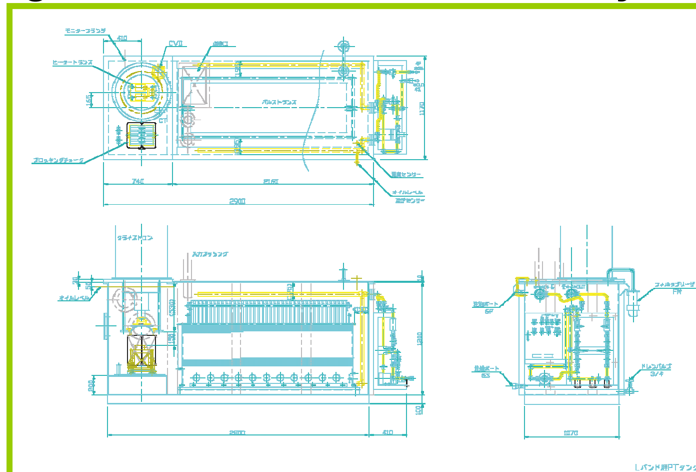
Existing PNC modulator

Additional Pulse Trans + Bouncer circuit allows to use TH2104A.

TH2104A old klystron short pulse test.



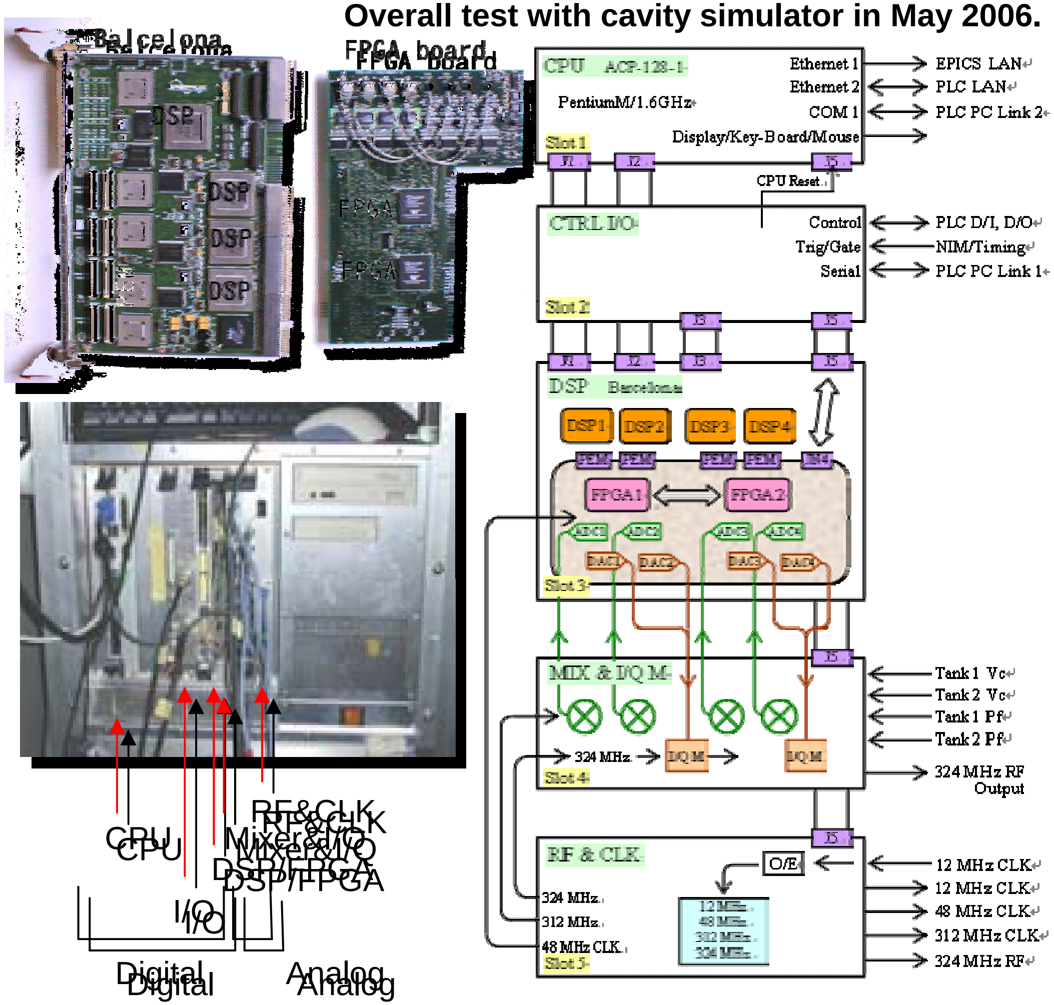
Design of Pulse Trans is underway.



STF Modulator / klystron plans & status cont.

2. Developing LLRF control based on J-PARC design.

Overall test with cavity simulator in May 2006.



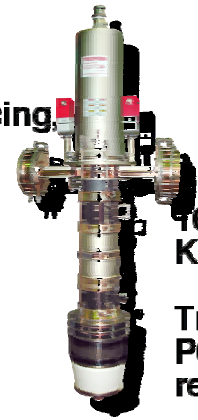
Existing J-PARC LLRF

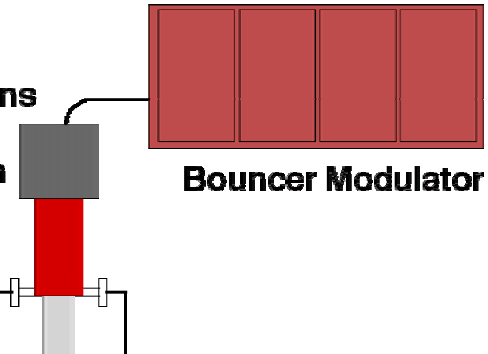
3. Purchase a 5MW Klystron from Thales (TH2104C), and Build one more modulator for running the cavities (in 2006).

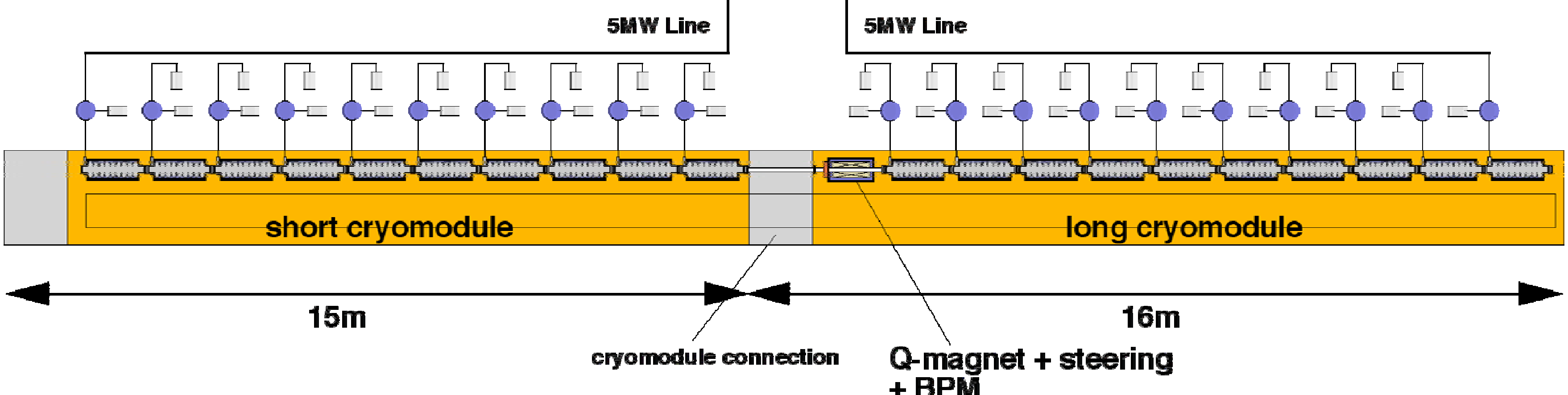
TH2104C

STF Phase 2 : Build ILC Main Linac RF unit

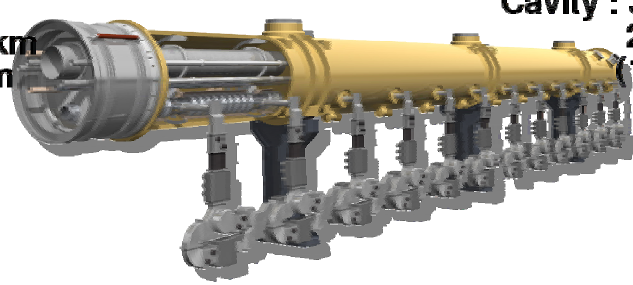
Beam : 2E10 /bunch,
294.5ns spacing,
2820 bunchs
(10.8mA)







Ecm = 500GeV
# of cavities : 14240
# of klystrons : 712
active two Linac length : 14.8km
total two Linac length : 20.1km



Cavity : 35MV/m @Q0=1E10
20 cavities/unit
(10 cavities/cryomodule)

Low Level RF Development

Digital control systems being developed by S. Simrock and collaborators from Warsaw.

Work performed within SRF JRA of CARE (WP8).

Design of Eight Channel 81 MHz IF Down-converter Board in Digital RF Feedback System for TTF2 -

Modular & Reconfigurable Common PCB-Platform of FPGA Based LLRF Control System for TESLA Test Facility

DSP Integrated Parameterized FPGA Based Cavity Simulator & Controller

FPGA Based, Full-Duplex, Multi-Channel, Multi-Gigabit, Optical, Synchronous Data Transceiver for TESLA Technology LLRF Control System

First Generation of Optical Fiber Phase Reference Distribution System for TESLA

DOOCS Environment for FPGA Based Cavity Control System and Control Algorithms Development

FPGA and Optical Network Based LLRF Distributed Control System for TESLA-XFEL Linear Accelerator

Prototype Implementation of the Embedded PC Based Control and DAQ Module for TESLA Cavity SIMCON

New Cryomodule Test Facilities

- SMTF at FNAL
- STF at KEK
- CMTB at DESY

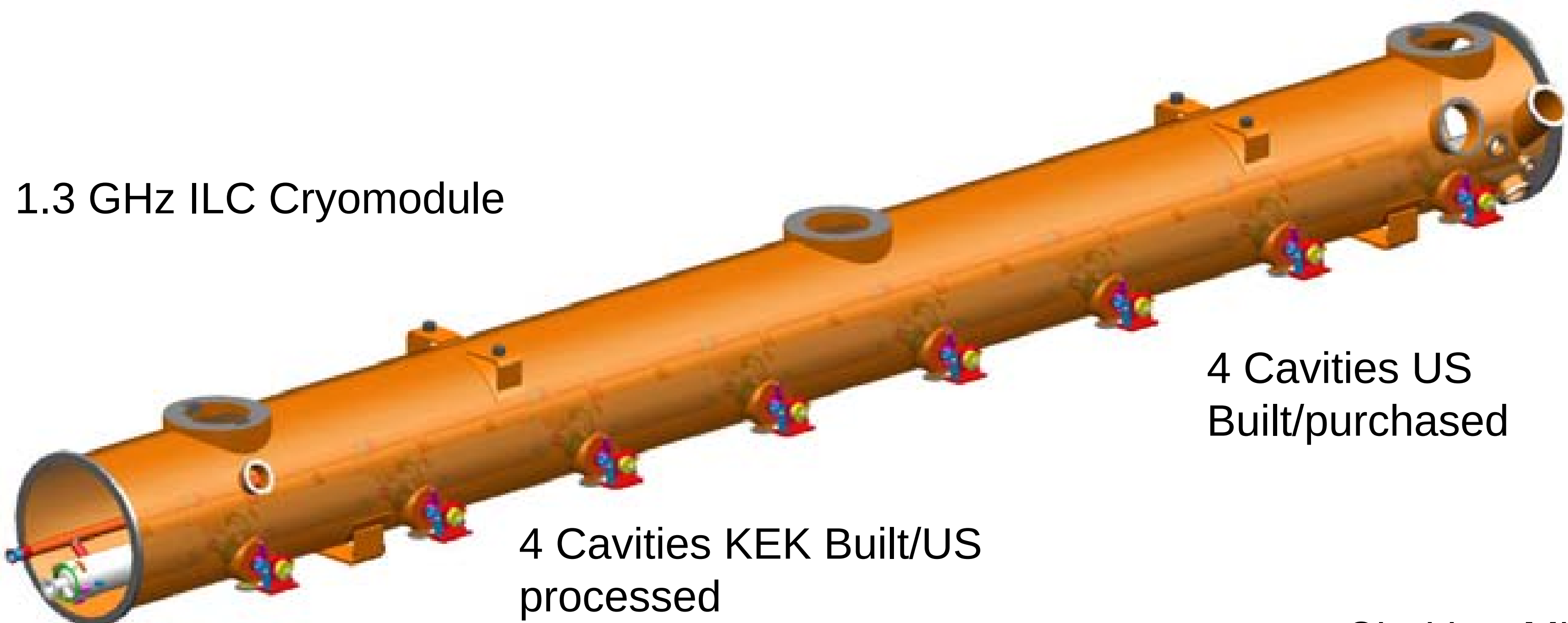
Existing TTF modules remain important means of test (alignment, vibration….).

Superconducting Module Test Facility (SMTF) at FNAL

Main Goal: Develop U.S. Capabilities in fabricating and operating with Beam Superconducting accelerating cavities and cryomodule in support of the International Linear Collider.

High gradient (35 MV/m or Greater) and high Q (~0.5-1e10)

1.3 GHz ILC Cryomodule



Shekhar Mishra

Cryomodule : Cryostat Design

Valve Box

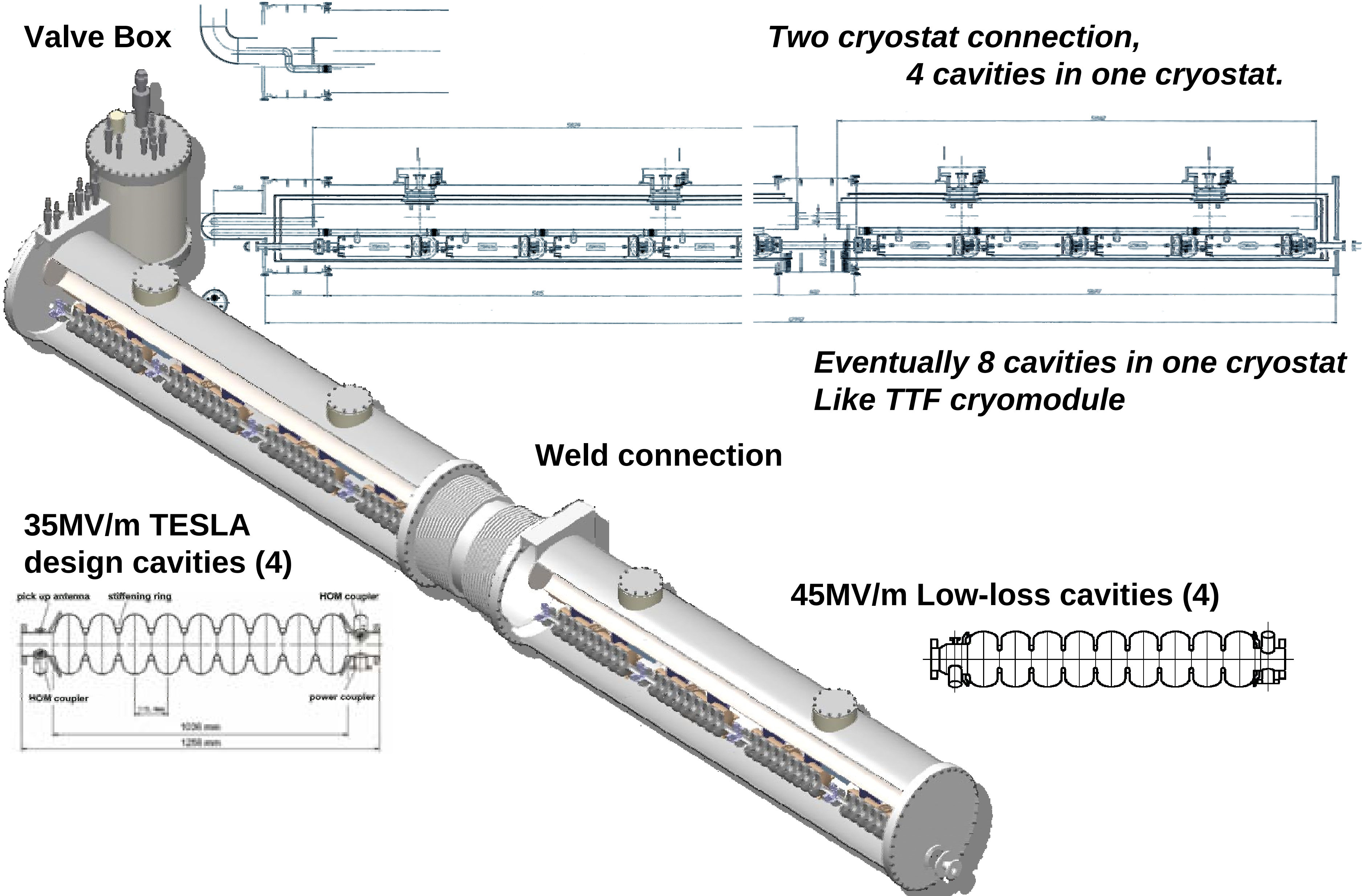
Two cryostat connection,
4 cavities in one cryostat.

Eventually 8 cavities in one cryostat
Like TTF cryomodule

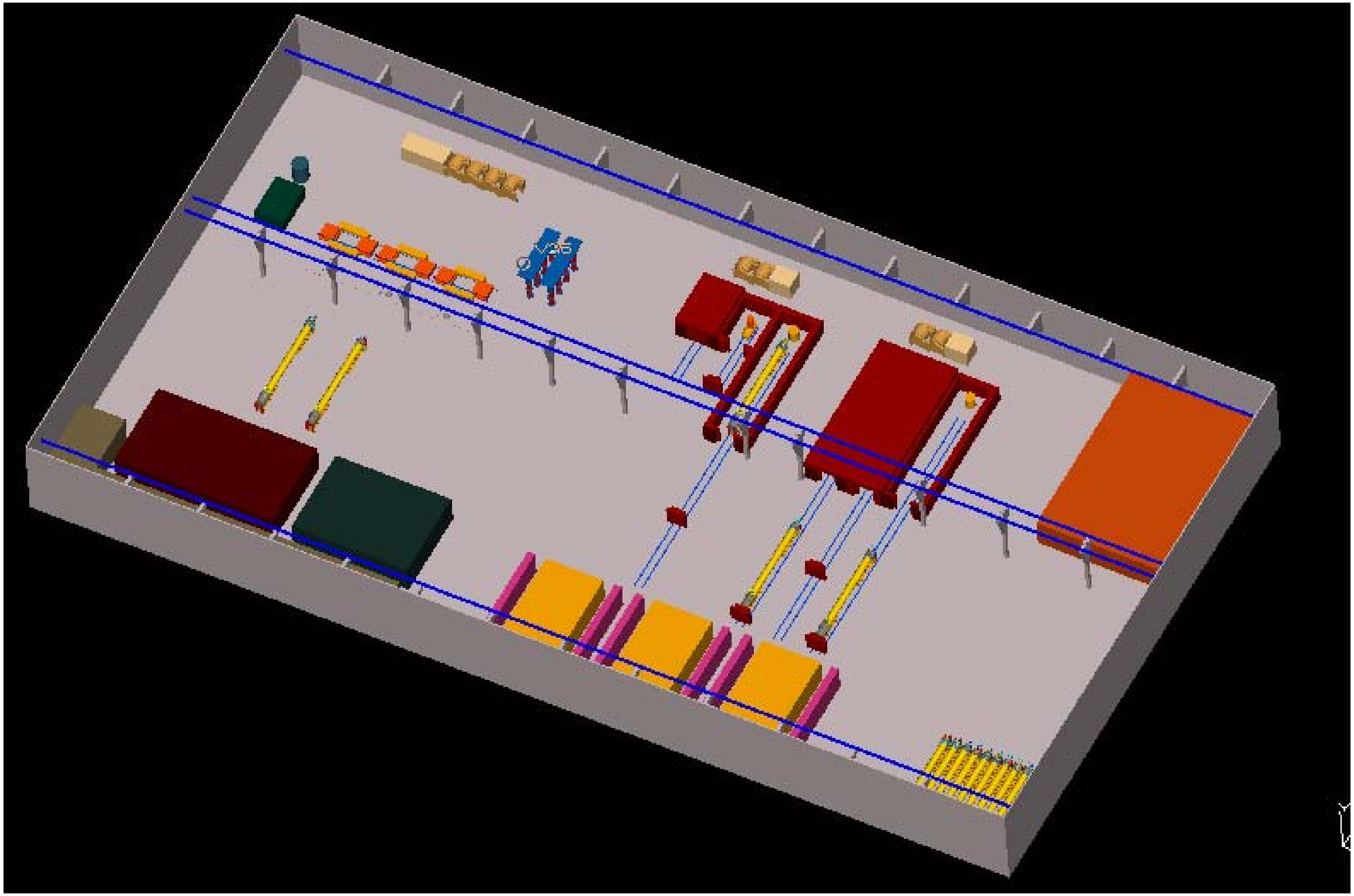
Weld connection

35MV/m TESLA design cavities (4)

45MV/m Low-loss cavities (4)



XFEL Test Hall Layout



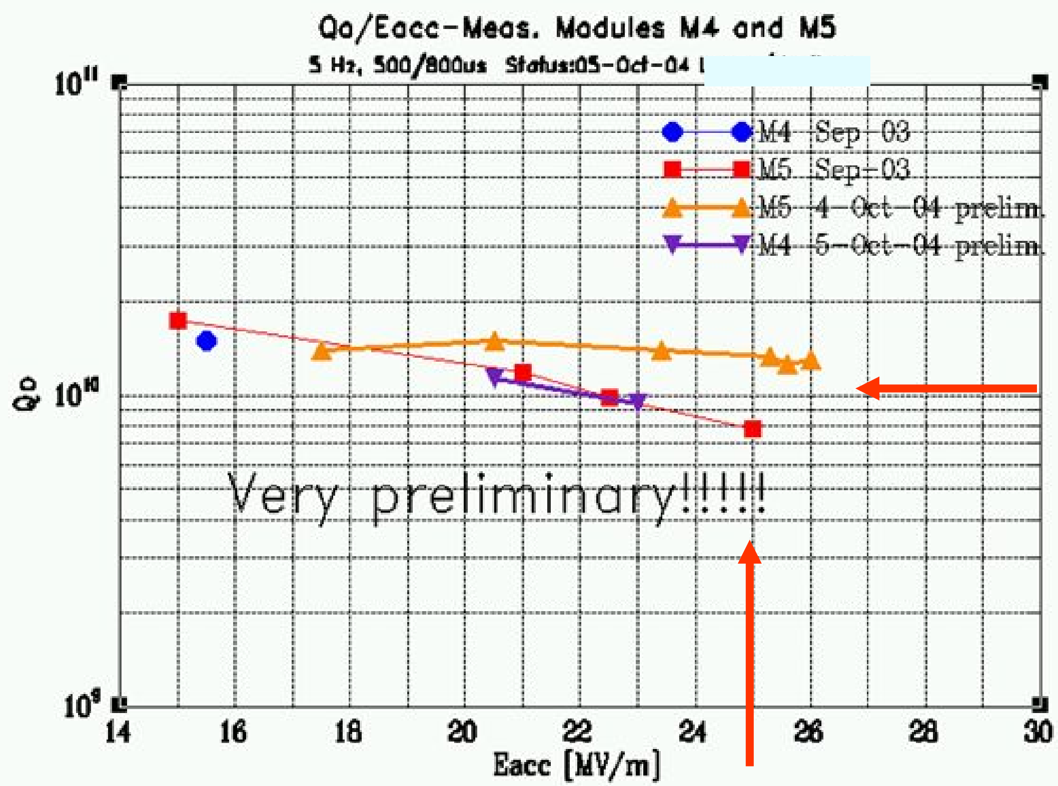
Prototype test program CMTB (DESY)

- In general: cryomodule tests independent from linac operation
- RF cavity processing / performance
- processing of RF couplers
- cryogenic performance
- tests of vacuum systems
- tests after repairs before installation into linac
- tests of new design features (2K quad ...etc.)
- dark current
- stretched wire, WPMs
- thermal cycling
- operation at different HE II bath temperatures
- ....

TTF cryomodule – dynamic heat losses.

2K Dynamic heat losses of module 4 & 5 (type III) : about 3 W at 25 MV/m each

(5 Hz, 500/800μ s)



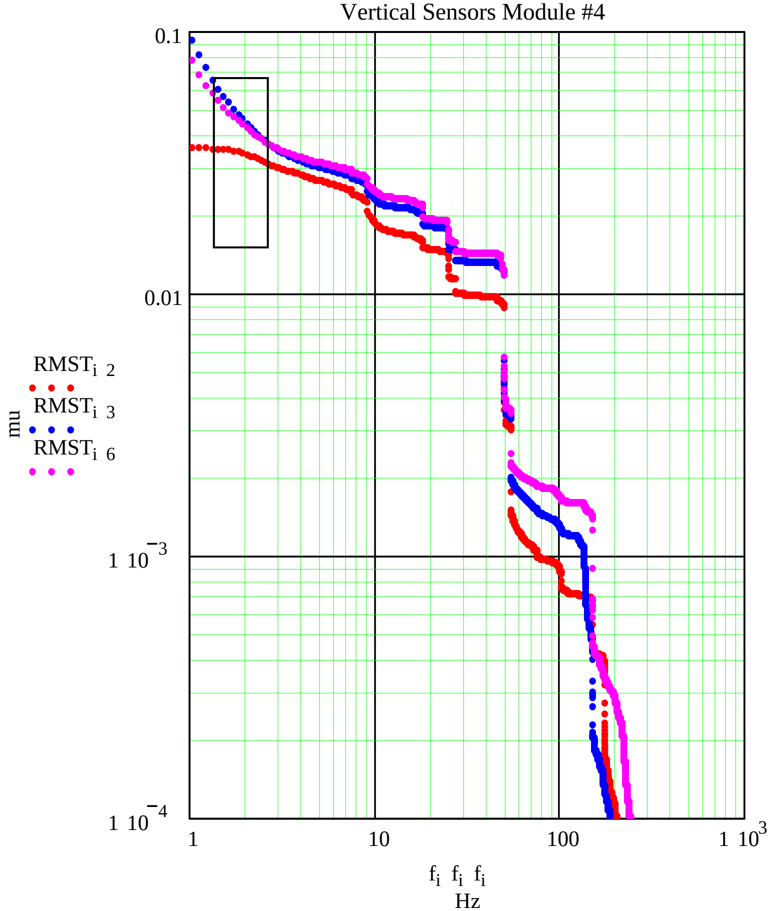
0.38 W/cavity

Most cavities can be operated at higher gradients !

corresponds to about 3 W each

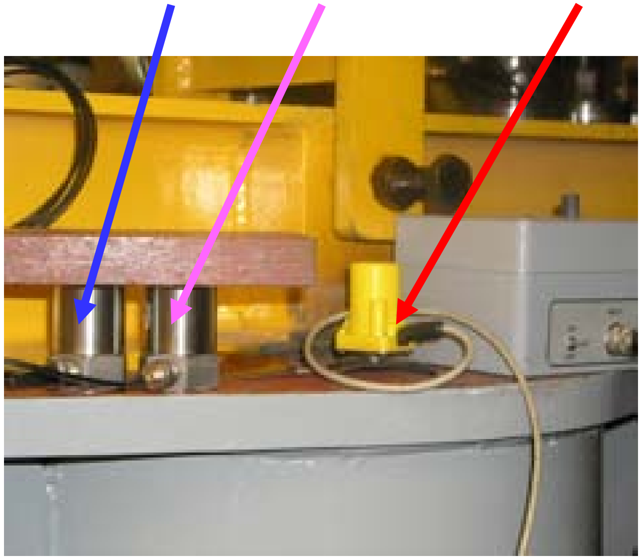
Vibration measurements on quad at end of module ACC4 (H. Brueck / DESY)

RMS average, Saturday midnight ± 1 hour



210804 2300 220804 0100

Piezo blue and pink, Geophone red



- Good agreement between
  - the two piezos
  - piezo and geophone (20%)
- Low RMS: 34 43 45 nm for f>2Hz
- Comparable with ground motions measured by Ehrlichmann
- At low frequencies the noise signal is probably getting dominant

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

X-FEL Module Industrial Study

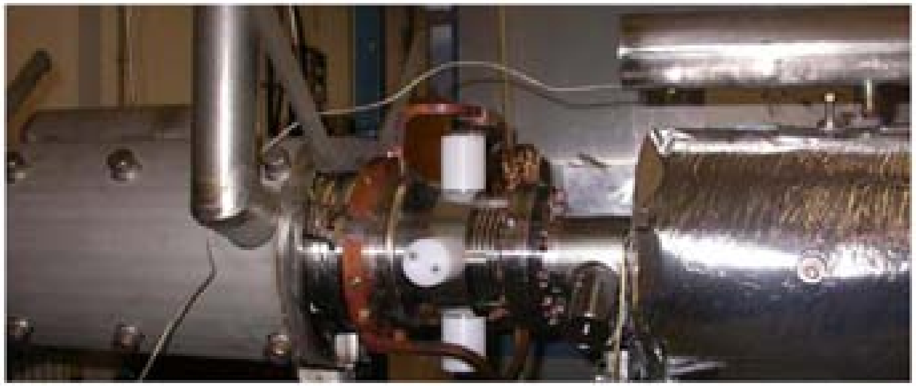
Deutsches Elektronen Synchrotron (DESY) to launch a call for tender and for contracting of the Industrial Study on behalf of the **TESLA-collaboration**, the **X-FEL project**, the **EUROFEL design study** and **BESSY.**

The present cryomodule assembly procedures and some aspects of the present design shall be analyzed and questioned with respect to the most cost effective series production.

The key aspects of the study are as follows:
1.2.1 Define the assembly procedure
1.2.1 Analyze cost-reduction and production efficiency measures
1.2.3 Analyze performance improvement measures
1.2.4 Supply a cost estimate for the module production

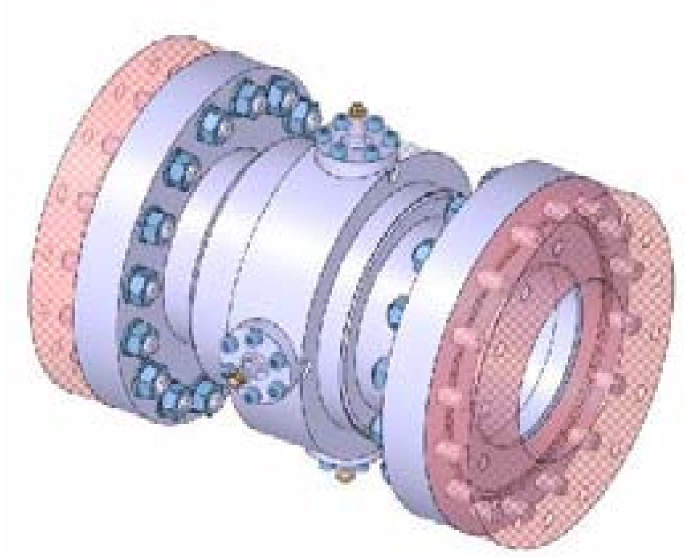
An important of the IS will be the presence of CONTRACTORs' experts during the assembly of two prototype cryo-modules at DESY.

Re-entrant BPM development (Saclay)



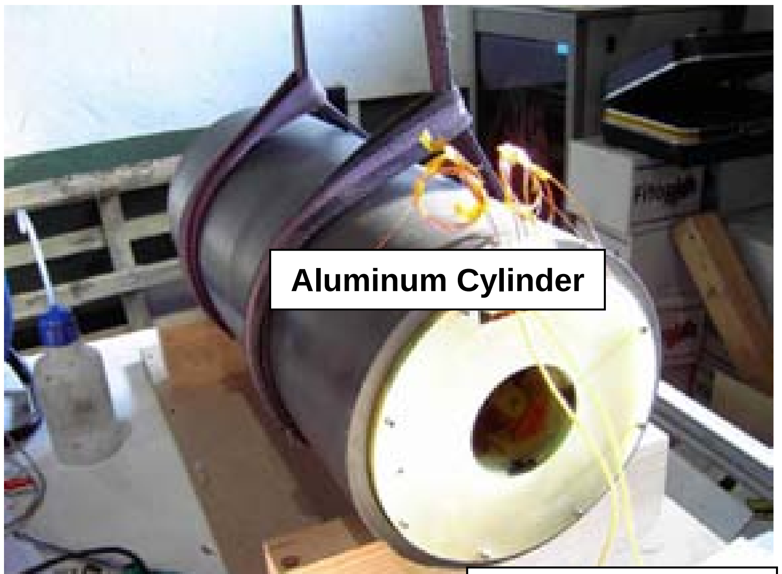
Re-entrant BPM tested on ACC1 at DESY, 10 μm resolution.

CARE supported R&D for BPM with improved version - 1 μm, 10 ns resolution. C. Simon et. al.

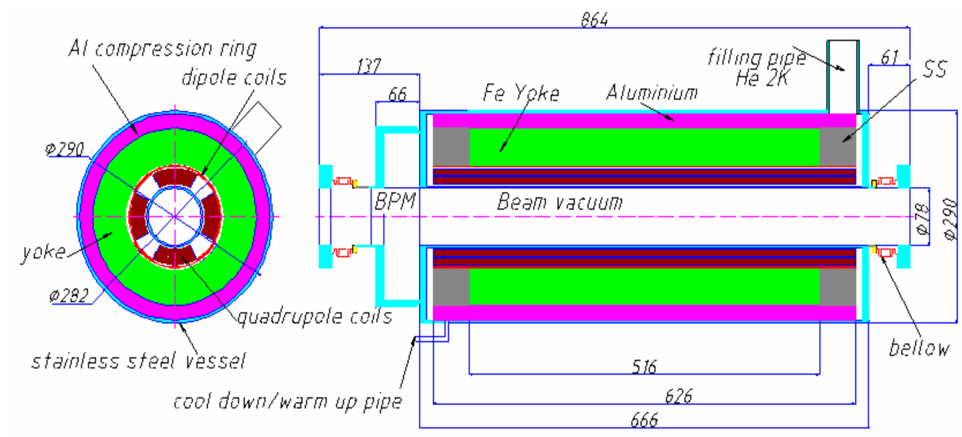


TESLA Quad Magnet Package – Ciemat (Spain)

- TESLA-Magnet tested in February at DESY



Connection plate side



Discussed Tasks of the Forum

- Create a European industrial base (esp. for the European XFEL and the future International Linear Collider)
- Provide a point of contact between
  - European industry active and interested in all aspects of SC RF accelerators
  - European accelerator laboratories, scientists and engineers
  - the European Union and its member countries
  - accelerator laboratories in Asia and the US
- Strengthen the discussion between science, industry and politics
- Develop ways of co-operation and knowledge transfer between the partners
- Provide all partners with a regular up-date of the project developments (esp. smaller ones and from other regions), e.g. through seminars
- Open information channels which single partners have no access to (like foreign administrations) and guarantee a transparent view on the competitive situation concerning the ILC in the different world regions
- Make rules transparent for administration of projects and tendering

Schedule for Linac Design Sessions (WG2)

Tuesday Morning : Modulators and LLRF

Tuesday Afternoon : Klystrons and RF Distribution

Wednesday Morning : Cryomodules with WG5

Wednesday Afternoon : Couplers with WG5

Thursday Morning : Beam Dynamics and Wakefields with WG1

Thursday Afternoon : Baseline Design Options with WG1,5

Talks with Global Groups

Talks During the Second Week

Tuesday Morning, August 16						
Time	Duration	Topic	Presentation	Institution	Speaker / Moderator	Joint with
8:30	30	Modulator overview	Modulator requirements and comparison of the various proposals in terms of functionality, serviceability and cost.	SLAC	Ray Larsen	
9:00	15	TDR modulator design	Status of the PPT modulators at DESY and modulator plans for the XFEL	DESY	Stefan Choroba	
9:15	15		Upgrade of the FNAL modulator for SMTF	FNAL	Howie Pfeffer	
9:30	30	Coffee Break				
10:00	20	Alternative modulator designs	Marx modulator development program	SLAC	Greg Leyh	
10:20	20		Overview of solid state modulator options and assessments	DTI	Jeff Casey	
10:40	10		Optimized Converter-Modulator Design Topology for the ILC Application	LANL	Bill Reass	
10:50	10		Long distance transmission of HV pulses	SLAC	Dick Cassel	
10:00	10	LLRF	Phase and amplitude requirements on various length and time scales	SLAC	Peter Tenenbaum	
10:10	20		Experience at TTF and development for the XFEL and ILC	DESY	Stefan Simrock	
11:30	20		SNS LLRF design experience and its possible adoption for ILC	FNAL	Brian Chase	
11:50	10	Summary	Discussion of summary slides			

Tuesday Afternoon, August 16						
Time	Duration	Topic	Presentation	Institution	Speaker / Moderator	Joint with
1:30	20	RF Sources	Status of the 10 MW klystron development, rf distribution schemes and rf source plans for the XFEL	DESY	Stefan Choroba	
1:50	20		Alternative klystron designs and klystron industrialization	SLAC	George Caryotakis	
2:10	20		Alternative low voltage power source	KEK	Tetsuo Shidara	
2:30	20		10 MW MBK Development at CPI	CPI	Ed Wright	
2:50	20	RF Distribution	Overview of distribution system and cost drivers.	LLNL	Brian Rusnak	
3:10	10		Breakdown limits in waveguide and circulators and alternatives to SF6	FNAL	Al Moretti	
3:20	10	Summary	Discussion of summary slides			

Wednesday Morning, August 17

Time	Duration	Topic	Presentation	Institution	Speaker / Moderator	Joint with
10:00	20	Cryomodule plans	Development of cryomodules for the XFEL	DESY	Reinhard Brinkmann	WG5
10:20	20		Cryomodule plans at KEK	KEK	Norihito Ohuchi	WG5
10:40	20		Cryomodule Assembly and Testing Facility at Fermilab	FNAL	Tug Arkan	WG5
11:00	30	Cryomodule issues	Performance of current cryomodules (including vacuum integrity, heat loss, cavity and quad straightness and quad vibrations) and changes required for ILC	INFN	Carlo Pagani	WG5
11:30	20		Layout options for quad/bpms	SLAC	Chris Adolphsen	WG5
11:50	10		Discussion			WG5

Wednesday Afternoon, August 17

Time	Duration	Topic	Presentation	Institution	Speaker / Moderator	Joint with
1:30	20	Cryomodule and coupler industrialization	Cryomodule cost drivers and industrialization	DESY	Dieter Proch	WG5
1:50	20		Production of couplers for the XFEL	LAL-Orsay	Terry Garvey	WG5
2:10	15 +15	Coupler design and performance	Experience and plans to improve TTF3 performance	DESY LAL-Orsay	Wolf-Dietrich Moeller Alessandro Variola	WG5
2:40	15		New design for a 1.3 GHz coupler	FNAL	Nikolay Solyak	WG5
2:55	15		New coupler design for STF baseline cavity	KEK	Shuichi Noguchi	WG5
3:10	10		Design for a non-contacting, dielectric-loaded waveguide coupler	SLAC	Chris Nantista	WG5
3:20	10		Discussion			

Thursday Morning, August 18

Time	Duration	Topic	Presentation	Institution	Speaker / Moderator	Joint with
8:30	20	Beam Dynamics	Linac Simulations	CERN	Daniel Schulte	WG1
8:50	20		Linac Simulations	KEK	Kiyoshi Kubo	WG1
9:10	20		Linac Simulations	FNAL	Kirti Ranjan	WG1
9:30	30	Coffee Break				
10:00	20	Beam Dynamics	Linac Simulations	Cornell	Jeff Smith	WG1
10:20	20		Coupled orbit motion	SLAC	Roger Jones	WG1
10:40	20	Cavity Wakefields	Lattice Configuration Studies	FNAL	Nikolay Solyak	WG1
11:00	20		Wakefield simulation plans by the ACD group at SLAC	SLAC	Zenghai Li	WG1
11:20	20		Equivalent circuit simulation of high frequency modes	SLAC	Roger Jones	WG1
11:40	20		Discussion			

Thursday Afternoon, August 18

Time	Duration	Topic	Presentation	Institution	Speaker / Moderator	Joint with
1:30	120	Baseline Configuration	Joint WG2/WG2/WG1 discussion of the various linac configuration options			WG1, WG5

Objectives of Working-group ?

Make "Baseline Configuration" choices for linac components
or at least identify BC "options" (criteria for doing this ? – established technique, proof of principle ??

- Work to agree upon the baseline configuration choices. Use the Workshop to identify paths to decisions for unresolved issues with the expectation that these could be decided at one or two subsequent meetings during the fall of 2005.
- Start writing the BCD !
- Identify critical R&D topics and timescales necessary for alternative options to the ILC Baseline Configuration that could have a significant impact on the performance or cost of the linear collider.

ILC Cryomodule WBS

1 Level 1

This is an example of the type of information I think would be useful to concisely document.

Note that it is heavily centred on the choice of baseline.

1.1 Component

1.1.1 requirements

The basic requiremens / specifications for the component. If we cannot specifcy them exactly because it depends on some other choices (outside the scope of this breakdown), then those dependencies should be stated.

1.1.2 baseline

the suggested baseline choice.

Note that for the Baseline Configuration Document (BCD), we want to attempt to identify a single baseline solution, even if we believe this will get superceeded later by 'an option'.

1.1.3 baseline justification

The justification for why we believe this should be the (current) baseline.

1.1.4

1.1.5

1.1.6 baseline status

The current status of the baseline choice, including known limitations that required further R&D. We might consider putting information about cost here.

1.1.7 foreseen/required baseline R&D

List of on-going R&D on the baseline (including industrialisation studies). We might want to indicate R&D that's known to be needed but is currently not happening (lack of resources?)

1.1.8 options

Options should be effectively parallel R&D paths that may possible lead reduced cost, increased performance (or both). The GDE will probably only directly support a limited number of such options.

opt 1

For each option some brief text about the pros and cons for the option would be useful.

opt 2….

Cavity Shape

- Choice based on experience
  - TESLA design shape:
    - Achieved 35 MV/m in 5 cavities (over 200 built).
    - HOM damping / wakes / Lorentz detuning well characterized.
    - 40 cavities currently running at TTF.
    - Two industrial suppliers (1000 will be used in XFEL).
- Choice based on potential cost savings
  - Low loss or reentrant:
    - These designs potentially allow higher gradients, and if the iris diameter is reduced, require less stored energy and cooling (but produce higher wakes).
    - Only one cell versions have been fabricated, achieving up to 45 MV/m. Will require several year, > 10 M$ effort to qualify design – KEK is actively pursuing this approach.