Main Linac Area System

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Status of Main Linac Area

1. Change Control Request #20
   is under discussion
2. Other possible cost reduction

3. Highlights of Main Linac R&D

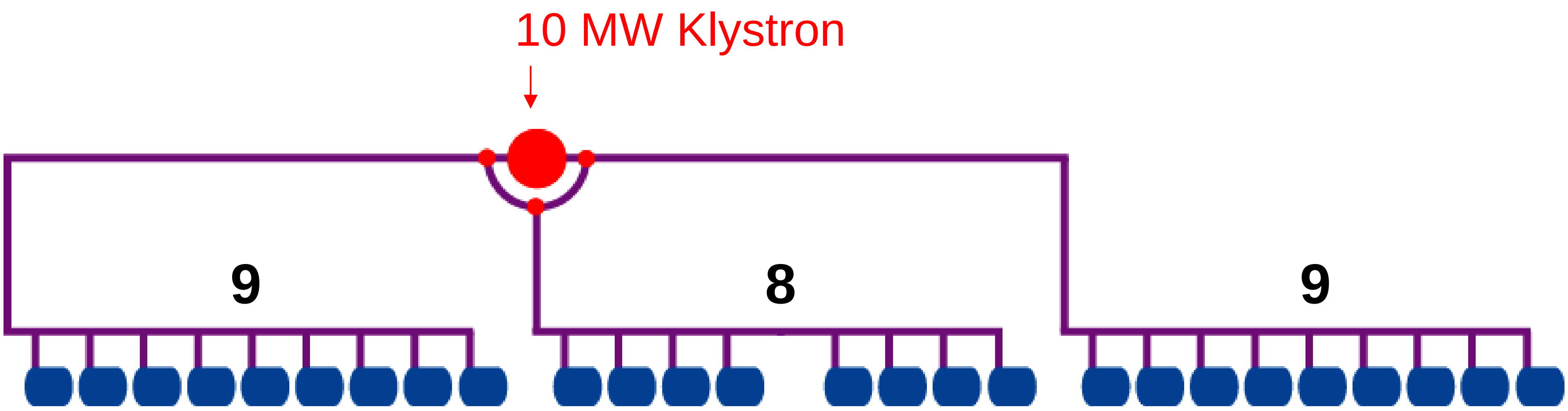
Proposed Cost Cutting Changes to Main Linac Design

- Lower rf power requirement for rf unit so maximum gradient is 33.5 MV/m instead of 35.0 MV/m
  - **One 10 MW klystron would then feed two 9-cavity cryomodules and one 8-cavity cryomodule (instead of three 8-cavity cryomodules).**
  - **Number of rf units reduced by 1/10, as is the AC power and cooling capacity to first order.**

  (408m shorter length for each linac.)

RF Distribution Math

(for 33.5 MV/m Max Operation)



33.5 MV/m * 9.5 mA * 1.038 m = 330.3 kW (Cavity Input Power)

× 26 Cavities

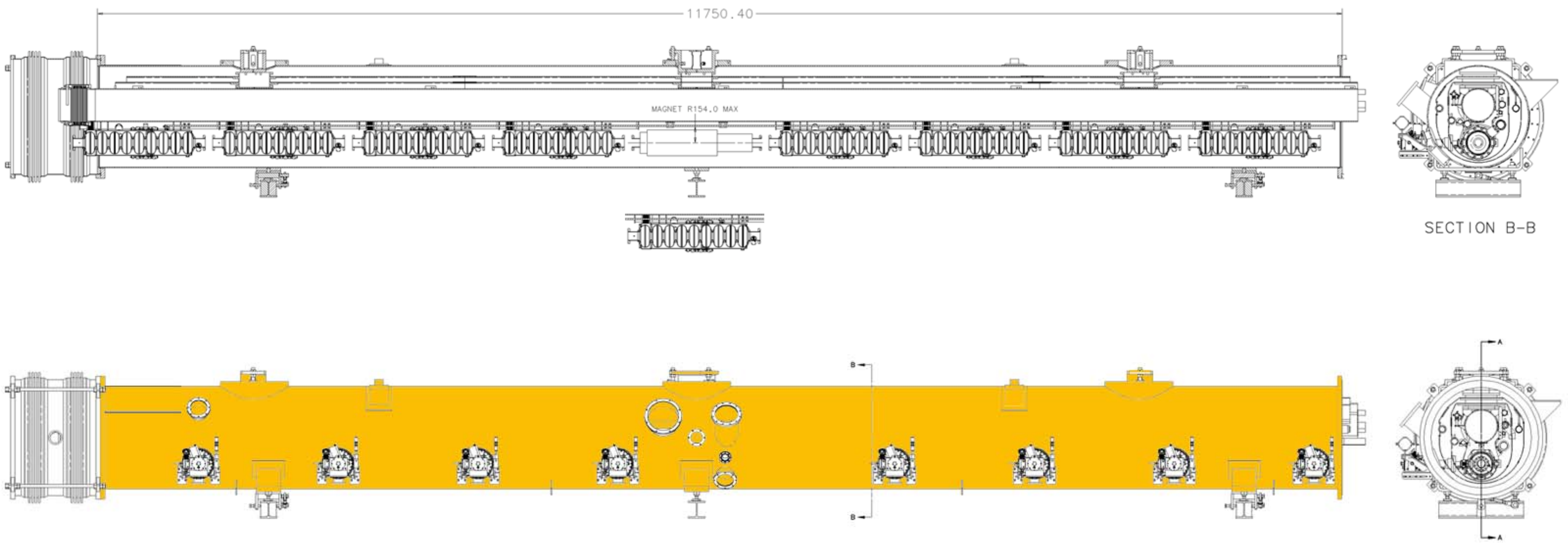
× 1 / 0.95 (Distribution Losses)

× 1 / 0.90 (Tuning Overhead)

= 10.0 MW

(for 31.5MV/m, transferred power to beam is 8.0MW.)

Cryomodule configuration
(for 9 cavities in the module)



Cryomodule with quad:12.543m
9 cavity cryomodule :12.590m (8 cavity module : 11.249m)
Thus, rf unit length = 37.723m (it was 35.041m)

Cost Cutting Changes (cont)

- Eliminate rf unit overhead,
  - **In BCD, have 936 cryomodules per Main Linac (plus 12 for e- undulator losses), whereas 904 required for 5 degree off-crest operation. So overhead is 3.5%**
  - **Without overhead,**

    require 837 cryomodules (plus 12 for e- undulator losses)

    correspond to 279 rf units (plus 4 units for e-)

    31.5MV/m x 1.038m x 26cavities x cos(5) x 279units = 236GeV
  - **Note that still have an effective 33.5/31.5 – 1 = 6.3% overhead if all cryomodules run at 33.5 MV/m, corresponding to the maximum available rf power**

Cost Cutting Changes (cont)

- Change waveguide size,
  - **WR770: between klystron and cryomodules**
  - **WR650: along cryomodules (no change)**

  - **WR770 has 33% lower rf loss than WR650.**

	WR650:	WR770:
cost:	**$50/foot**	**$80/foot**
average power:	**76-115 kW**	**118-175 kW**
peak power:	**41-60 MW**	**60-85 MW**

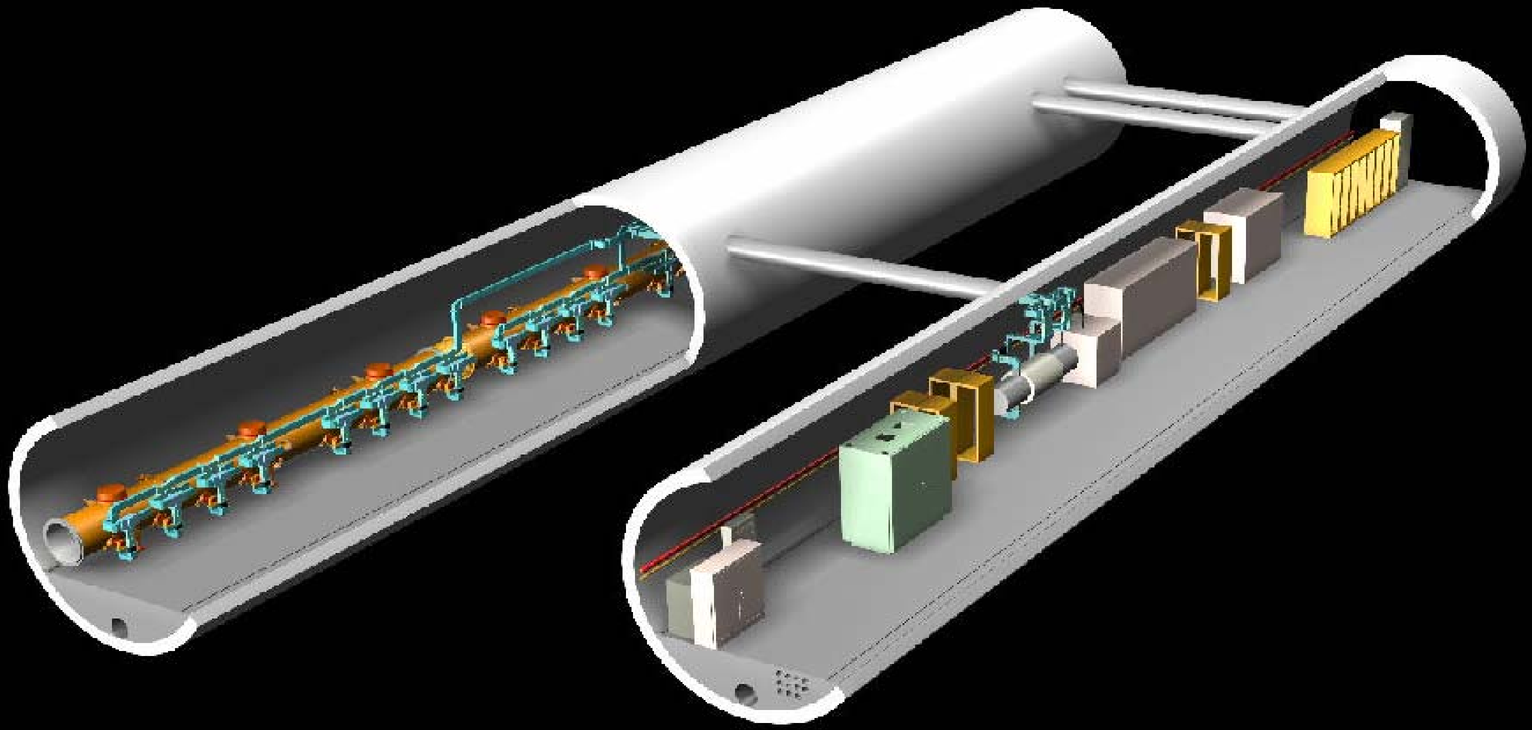
WR770 Pros: ~1/3 less waveguide loss
greater power handling capacity
WR770 Cons: 40% more volume
60% more $/m
less standard

Cost Cutting Changes (cont)

- Lower cryo-system static loss overhead
  - **Currently have a 50% overhead for static losses due to uncertainties in what these values will be**
  - **If reduce this to zero, cryo-capacity reduced by 13%**
  - **40% overcapacity factor remains the same: due to**
    - Factor of 1.2 for degradation of plant performance, which may be due to helium contamination, equipment wear and other factors and is often seen in cryogenic plants. This factor is based on common experience
    - Factor of 1.1 for operational control, for example the need to recover temperature while already at full load.
    - A seasonal factor of 1.075 primarily a detrimental effect due to warm summer temperatures and warmer cooling water in summer

These changes are sent to CCB

- CCR #20
- Cost saving is about 5% of the linac cost



Other Cost Cutting candidates

- Adopt ACD RF System
  - **For pulse charger, use central 10kV DC converter and satellite ~2 kV chargers at each station**
  - **Use Marx Modulator instead Pulse Transformer / Bouncer design**
  - **Use Sheet Beam Klystron (SBK) instead of MBK. Also saves 3 MW of solenoid power and associated cooling.**
  - **Feed cavities in pairs to eliminate circulators. Use manual phase shifters instead of 3-stub tuners, and use adjustable tap-offs to maximize average gradient**
  - **Total rf system savings ~ 50% (plus 11% from lower maximum gradient and 3.5 % from no rf unit overhead).**

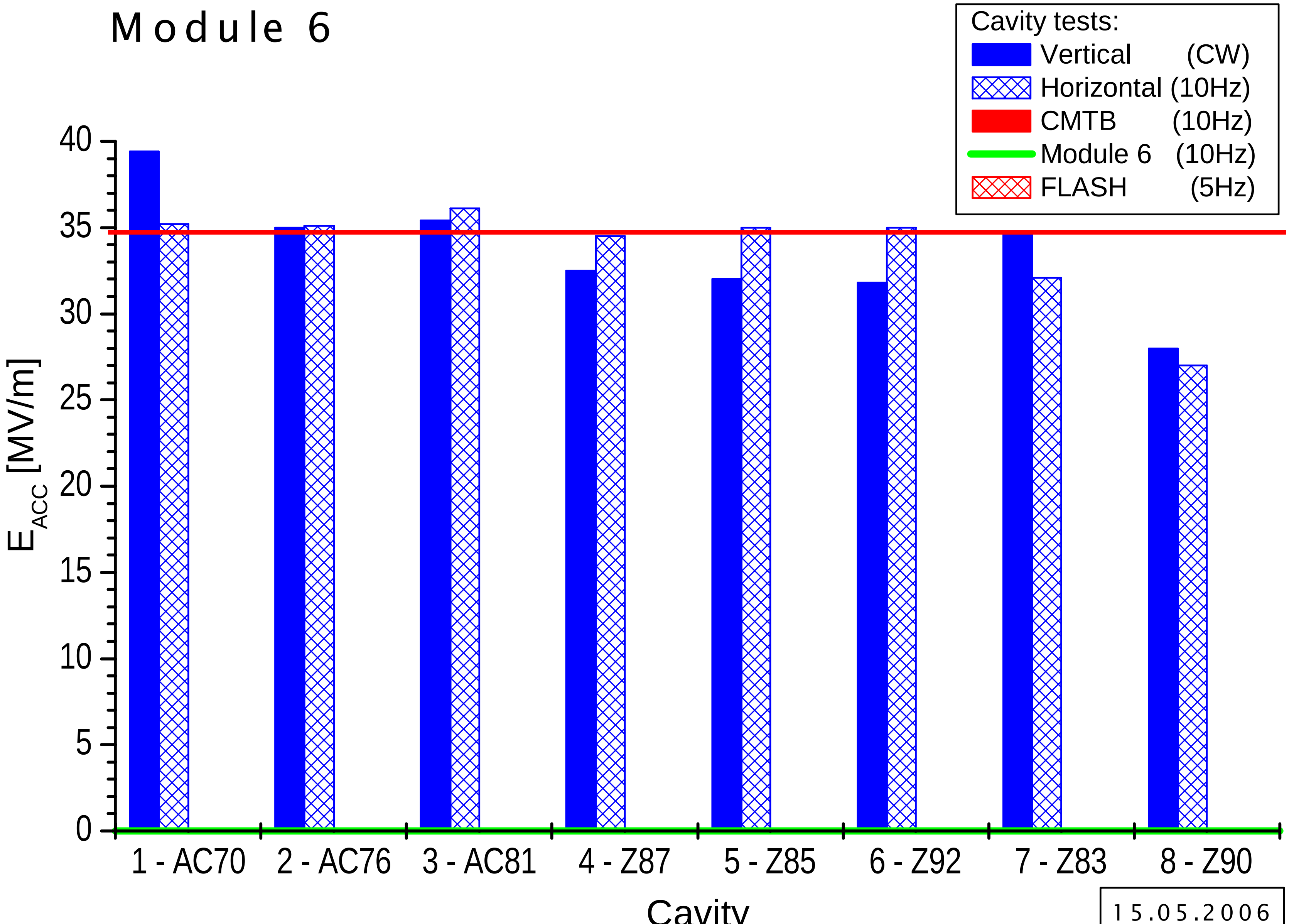
Cost Cutting candidates (cont)

- Streamline LLRF System
  - **Place 100:1 down-mixers in tunnel to drop cable costs by 10X.**
  - **Multiplex forward and reflected power RF signals in tunnel to save cable plant.**
  - **Go to single larger penetration with steel conduit for DC power and copper conduit for signals, shared with two water-cooled waveguides.**
  - **Multiplex motor drives for the cavity tuner motors and coupler Qext control.**
  - **Eliminate core processor redundancy in ATCA crates**
  - **Rack Power: recalculate reduced power requirements for above options.**

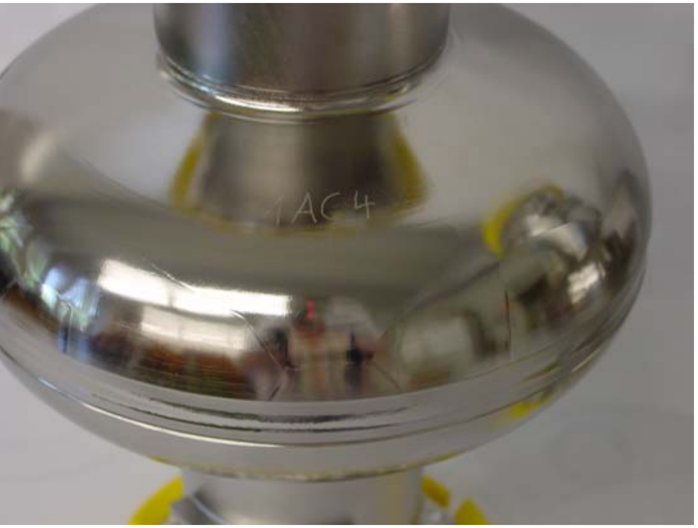
Recent Highlights of Main Linac R&D

- Cavity Development
  - **DESY**
  - **FNAL/Jlab/Cornell**
  - **KEK**
- Other Components
  - **Orsay – Power Coupler**
  - **Saclay – Tuner**
  - **SLAC – Marx modulator, others**
- Infrastructures and Test Facilities
  - **DESY – CMTB**
  - **FNAL – ILCTA**
  - **KEK – STF**

DESY –Module 6 Test Results



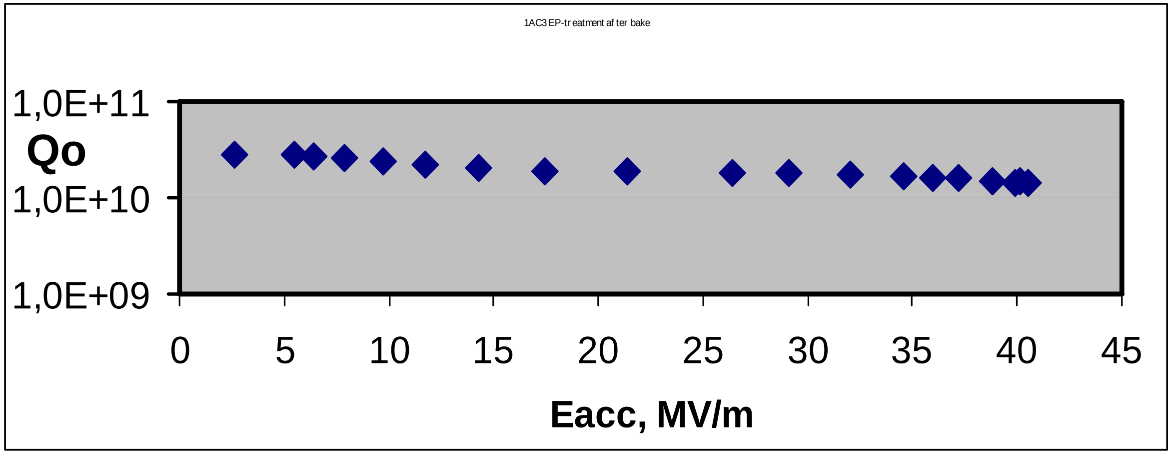
DESY - Cavities from Large Grain Nb



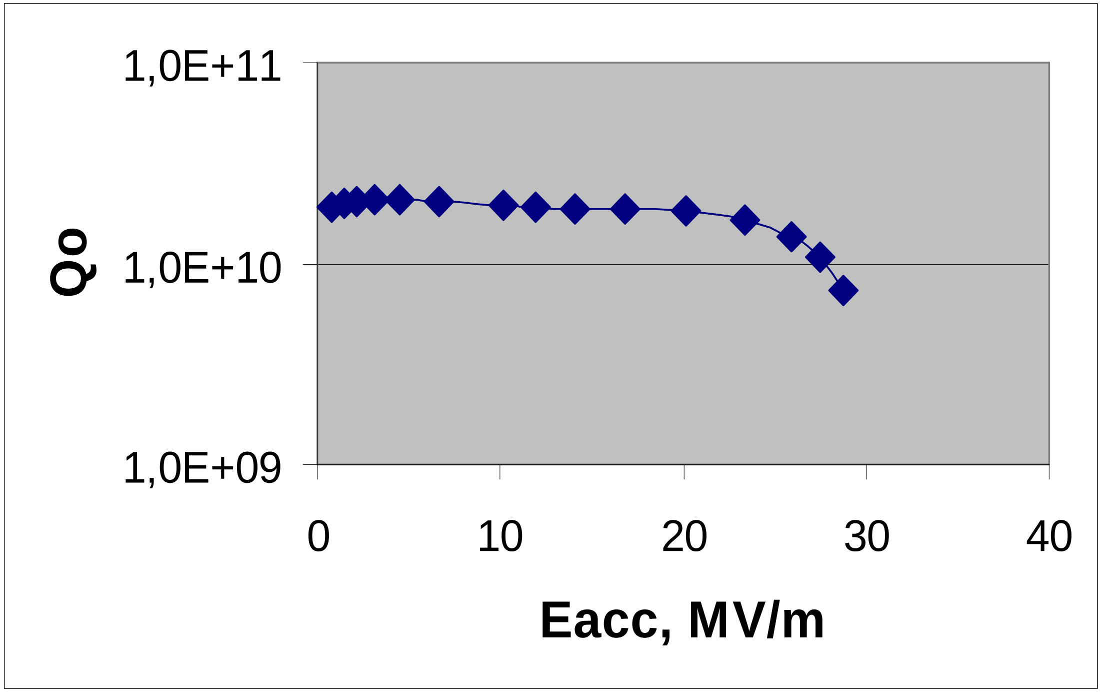
Several single cell and three 9-cell cavities from large grain Nb are fabricated at Fa. ACCEL

The surface is more shiny after BCP. The steps at grain boundaries are more pronounced as in polycrystalline material.

DESY – Results from Large Grain Cavities

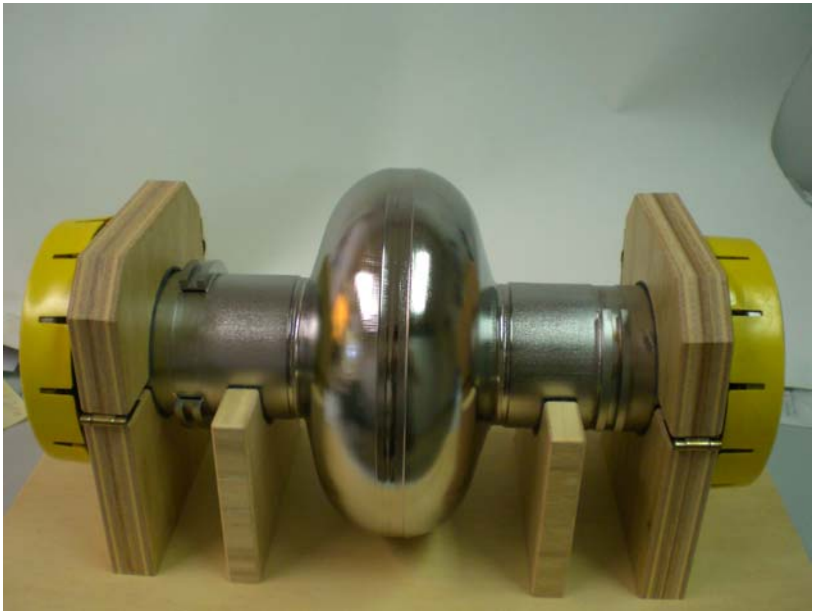


Q(Eacc) curve of the large grain single cell cavity 1AC3 after EP treatment



First Q(Eacc) curve of the large grain nine cell cavity AC114 after BCP treatment

DESY Single Crystal Cavity

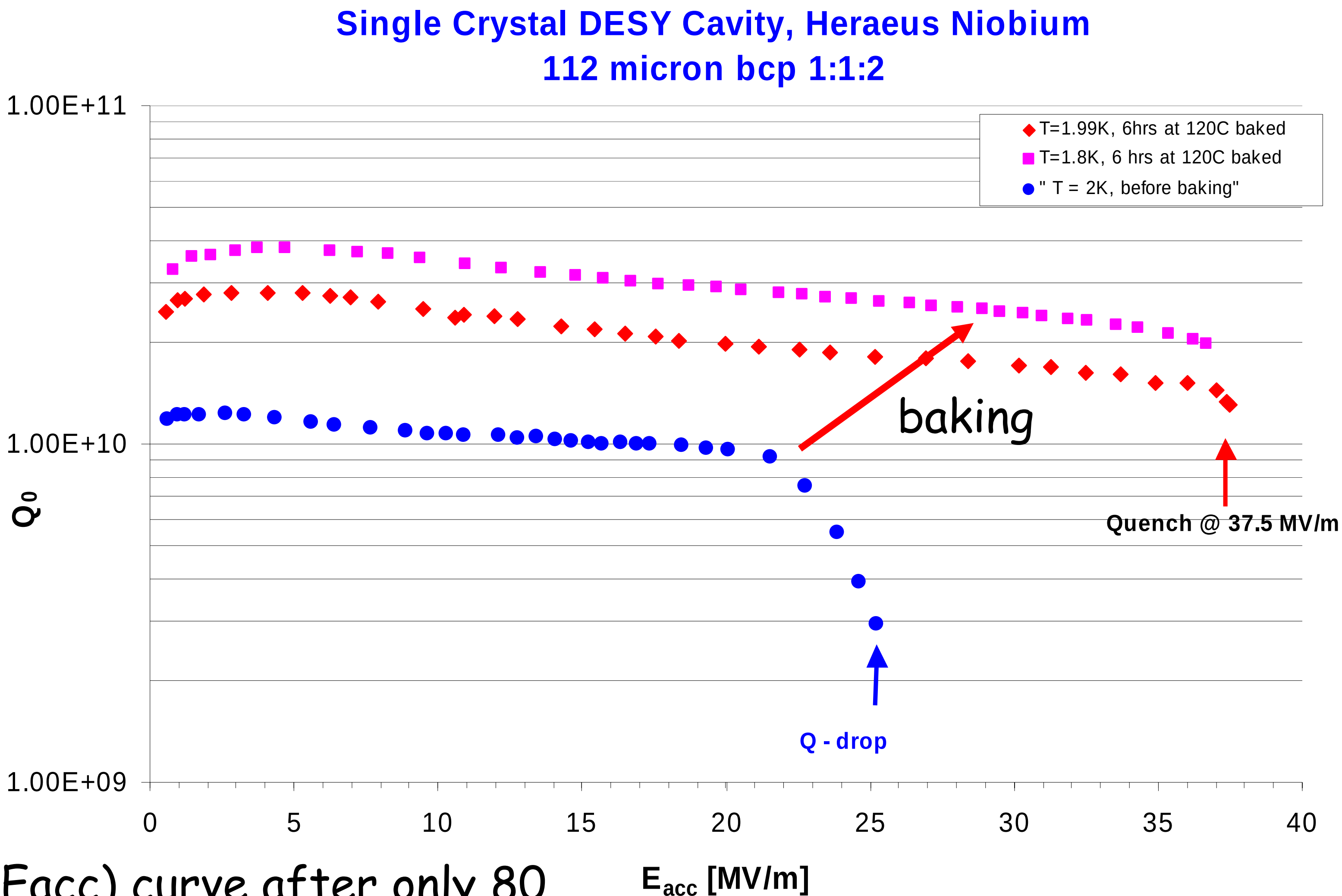


DESY single crystal cavity 1AC8 build at Fa. ACCEL

The Cavity was made from a Heraeus – Single Crystal slice, then rolled, deep drawn and EB-welded by ACCEL (with alignment of the orientation) .

Preparation (BCP only and 120 degree baking) and RF tests of P.Kneisel, JLab

Single Crystal Cavity - Result



Q(Eacc) curve after only 80 μm BCP and in situ baking 120°C for 12 hrs.

DESY **C**ryo **M**odule **T**est **B**ench (CMTB)

Test of module 6 will start in October (week 41)

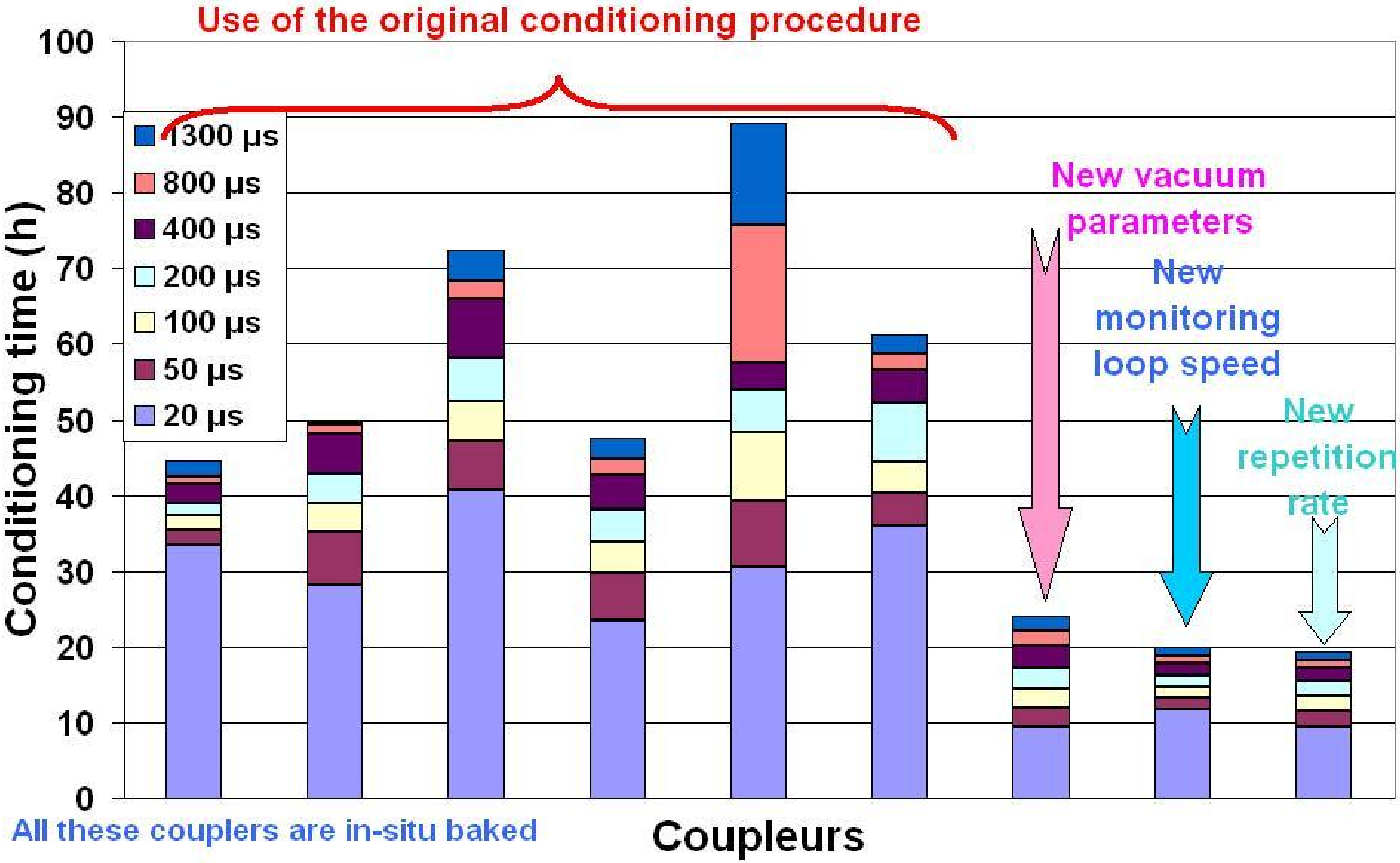
Cryogenic systems commissioned

Now: Installation of module 6 on CMTB

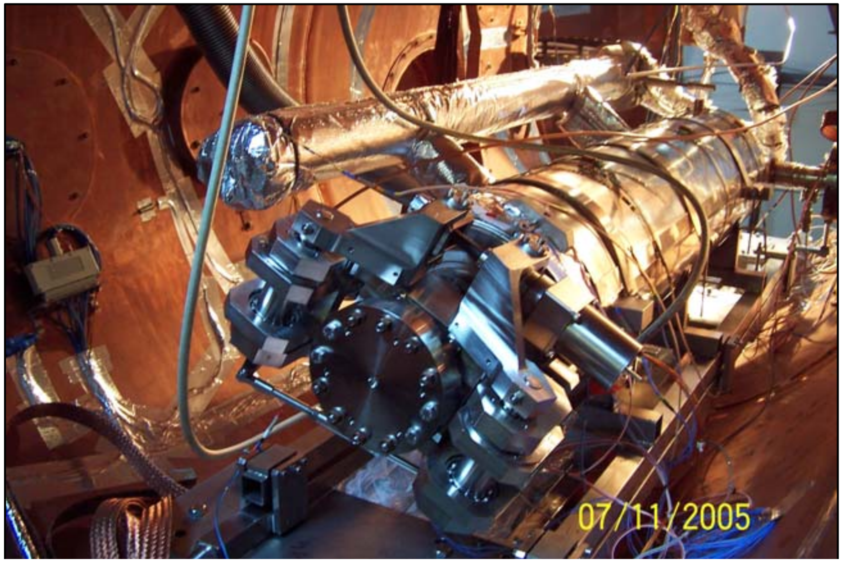
RF interlock tests scheduled for 10.10.06

Orsay: Power Coupler Conditioning for FLASH

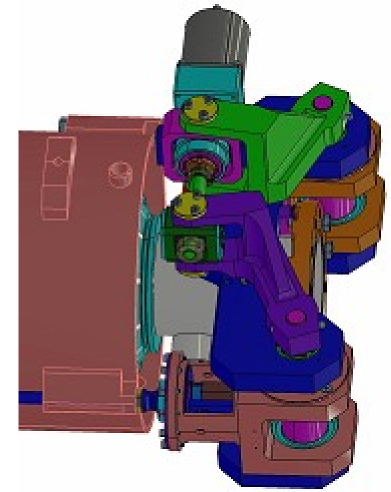
Procedures established for faster conditioning.

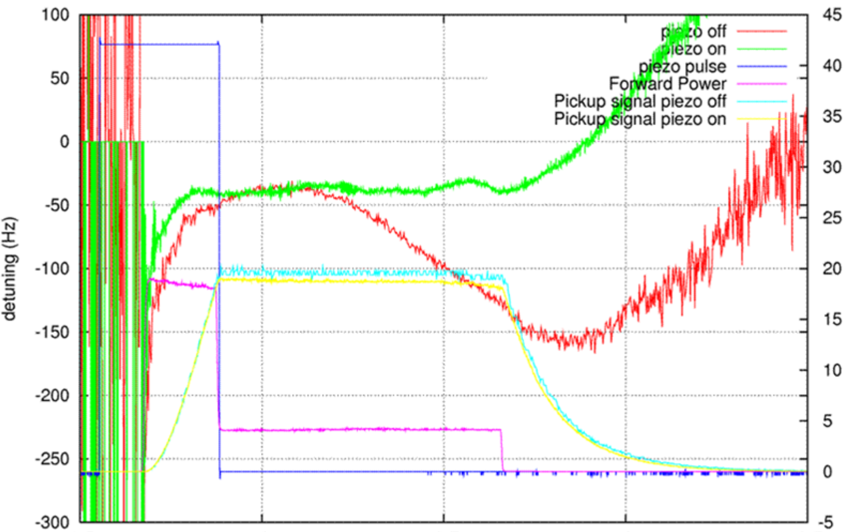


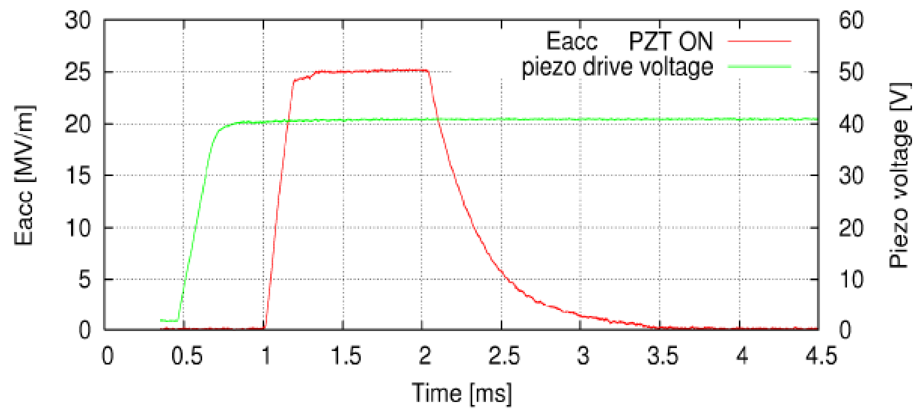
CEA Cold Piezo Tuner: RF Power Test



fully equipped
9-cell cavity (C45)
with TTF III
coupler
& piezo cold tuning
system







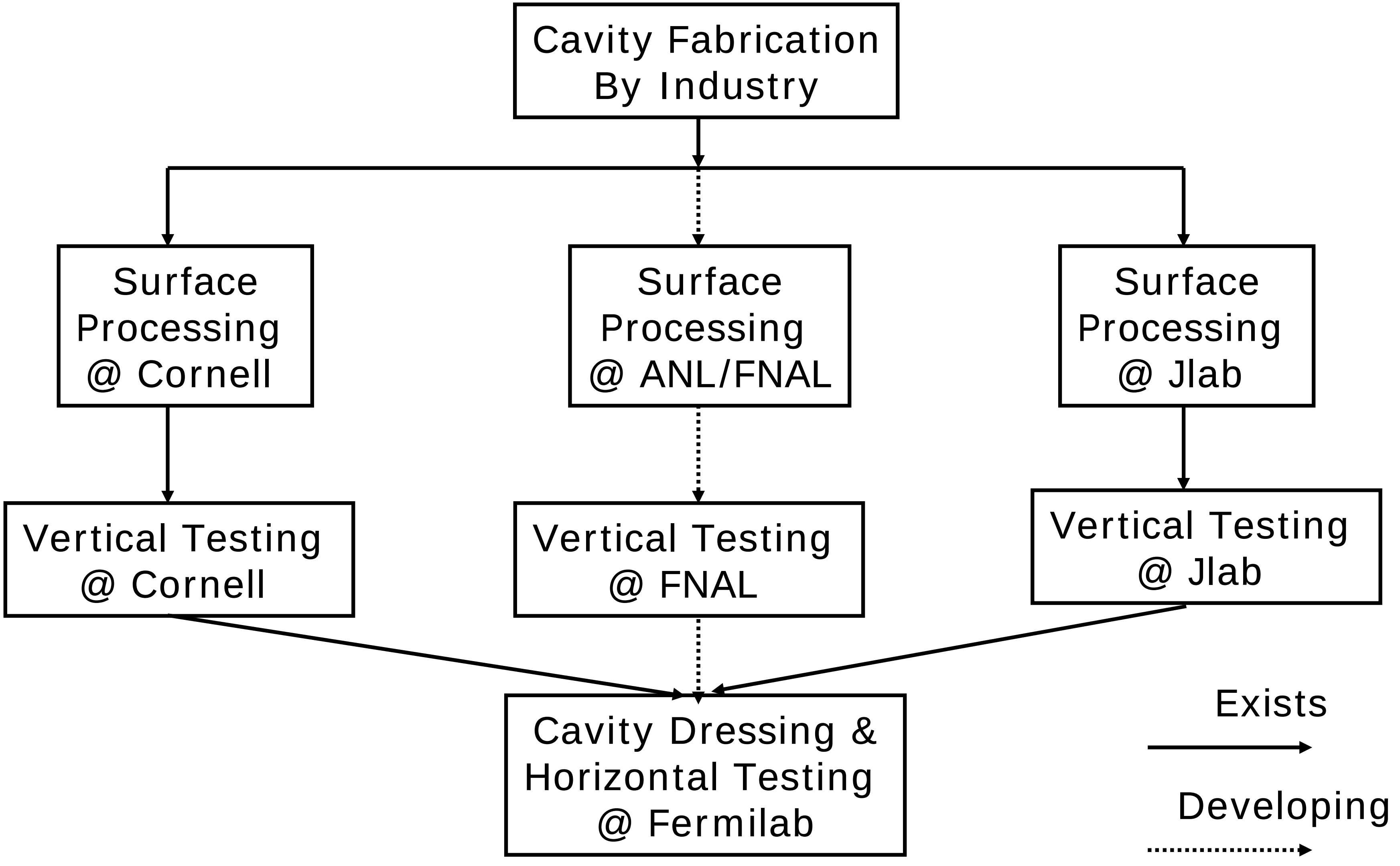
accelerating field and piezo driving pulse

Lorentz Forces Detuning :
compensation with PZT (red $\rightarrow$green curve)

US: Cavity Fabrication

- US has ordered (or will order soon) following cavities.
  - **FY05: 4 Cavities (ACCEL) (TESLA Length)**
  - **FY06:**
    - Phase 1: 4 Cavities (AES), 4 (Jlab) (TESLA Length)
    - Phase 2: 6 Cavities (AES), 9 (Qualified Vendor) (ILC Length)
  - **FY07: 24 Cavities will be ordered in next several weeks. (Last cavities to be delivered mid 07)**
- S0-1 (US Cavities)
  - **3 Cavities from ACCEL is already part of tight loop at Jlab**
  - **3 Cavities from Qualified Vendor (FY06-P2) will be part of tight loop at KEK/DESY**
- Rest will be part of first phase of cavity yield studies, Vendor development, S0-S1 and S2 etc.

US Cavity Fabrication, Processing and Testing Road Map

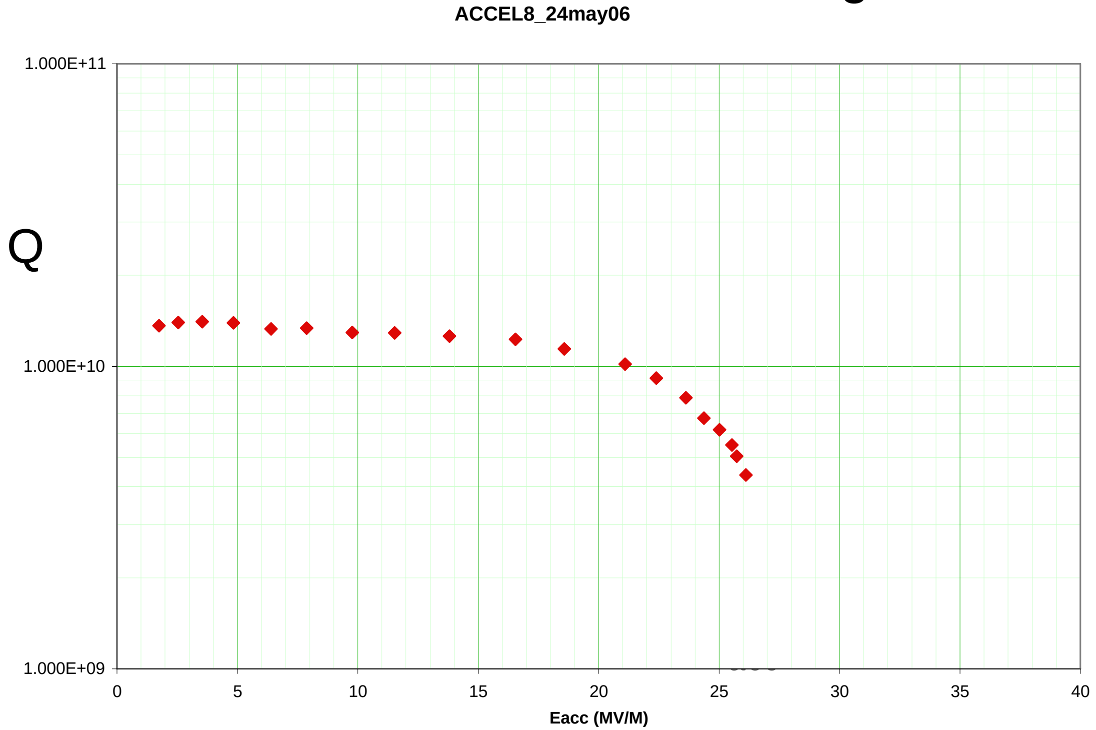


Cornell: BCP and Vertical Test of ACCEL Cavity

BCP (Etching)

50 + 60 μm BCP + 50 μm at ACCEL + HPR

No Field emission, Q > 0.4x10[10], E_{acc} = 26 MV/m, No Heat treatment at 800 Deg C.



Vertical Electropolishing at Cornell

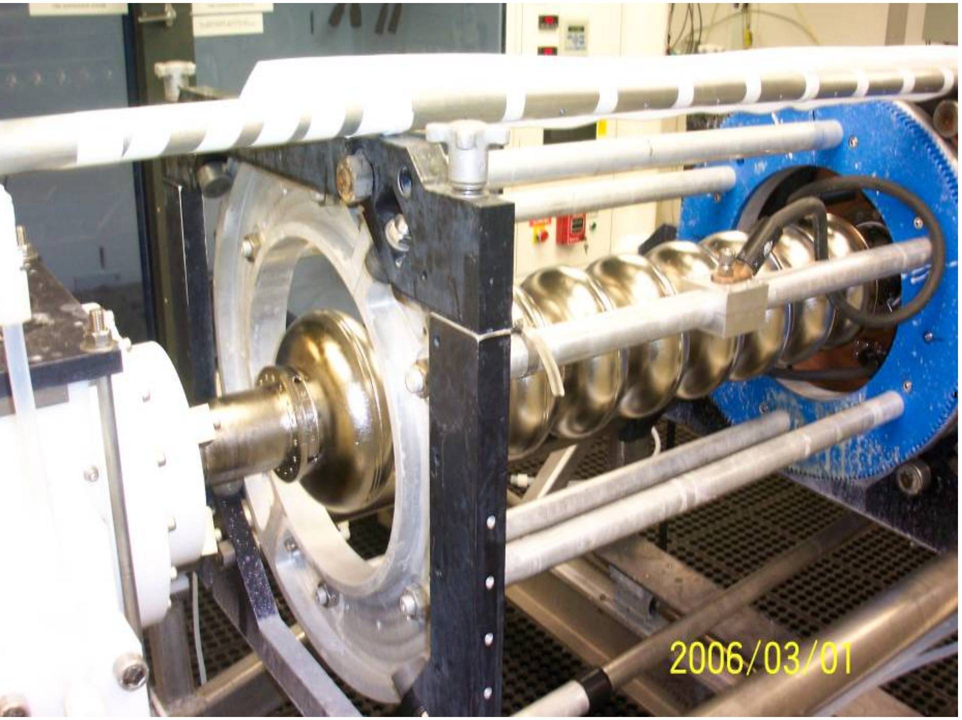
QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

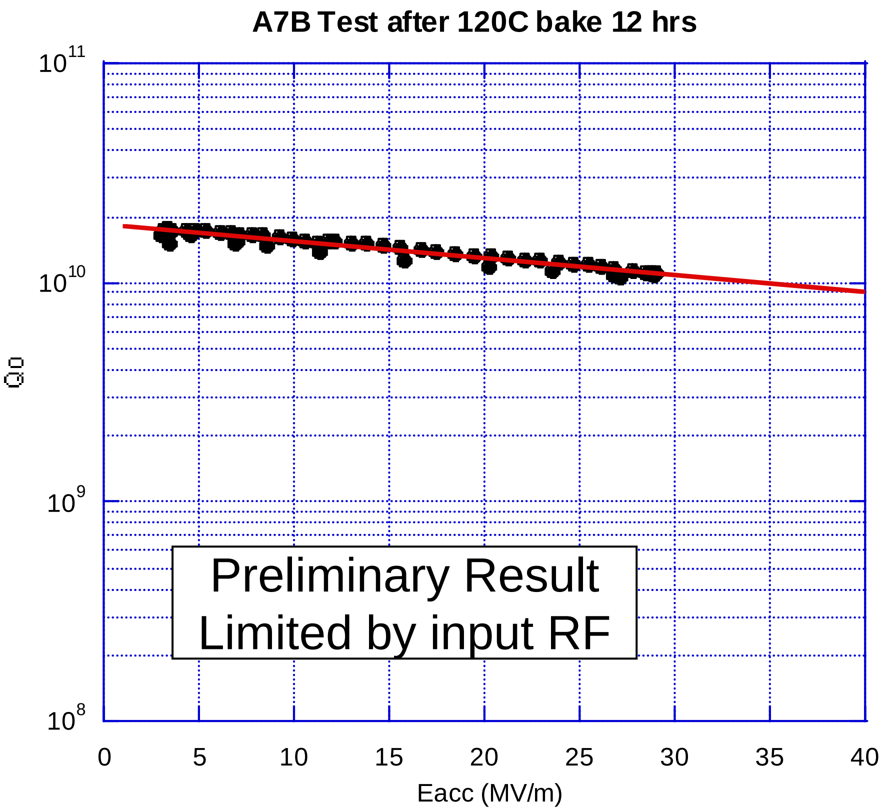
- 600 C treatment underway for H removal

Vertical EP Results are expected soon.

EP and Vertical Testing at Jlab

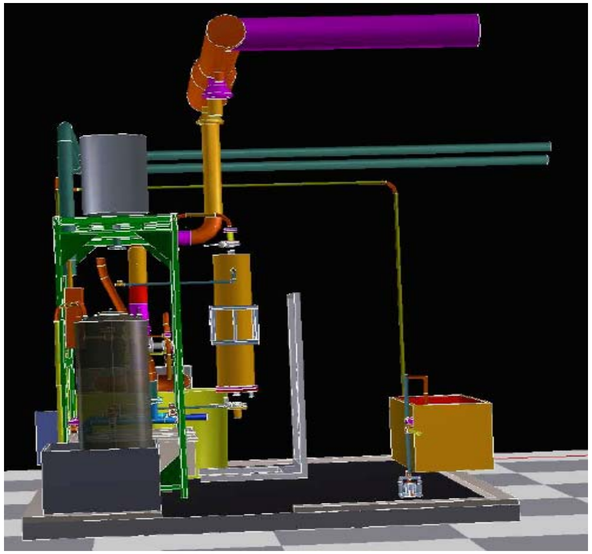
- Jlab has commissioned the EP, HPR, Bake and Vertical Testing for the 1.3 GHz cavities.
- Jlab will be the center of the S0-1 “Tight Loop” actives in USA.

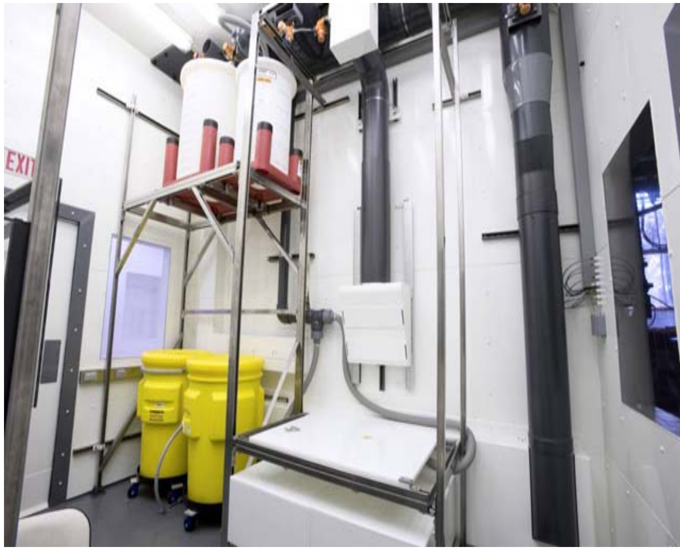




Surface Processing Facility at ANL/FNAL

- Fermilab and Argonne are jointly building a surface processing facility for ILC Cavity R&D.
- The facility will have capability to perform BCP, EP and HPR.
- The BCP Facility is under final phase of construction and will be safety reviewed by Spring of 07.
- Design of the EP facility is progressing with plans to be commission with 9 Cell 1.3 GHz Cavities by the end of FY07.



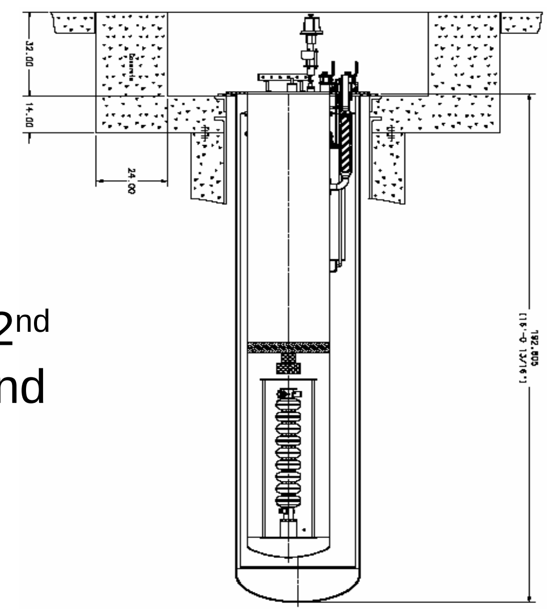


HPR and Vertical Test at Fermilab

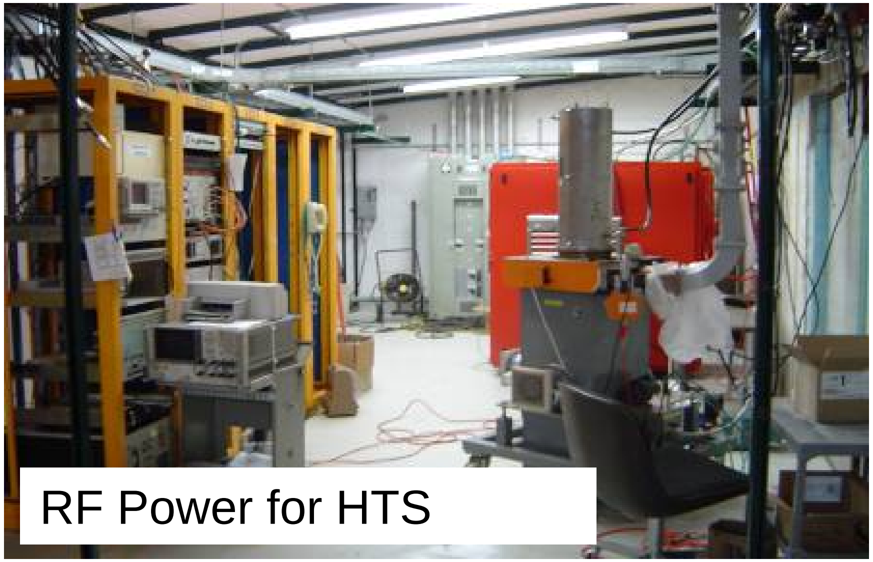
- Fermilab in collaboration with MSU is developing a new HPR system.
- FNAL Vertical Test Stand to be commissioned Summer 07.
  - **Civil Construction finishes Aug. 06**
  - **Cryostat has been ordered**
  - **Changes to cryogenics in IB1 building soon**
  - **RF and controls being developed in collaboration with Jlab.**

Civil Construction 8/06

- Present cryostat top plate can hold two ILC Cavities.
- Plan underway to put 2nd pit. This will share RF and controls.

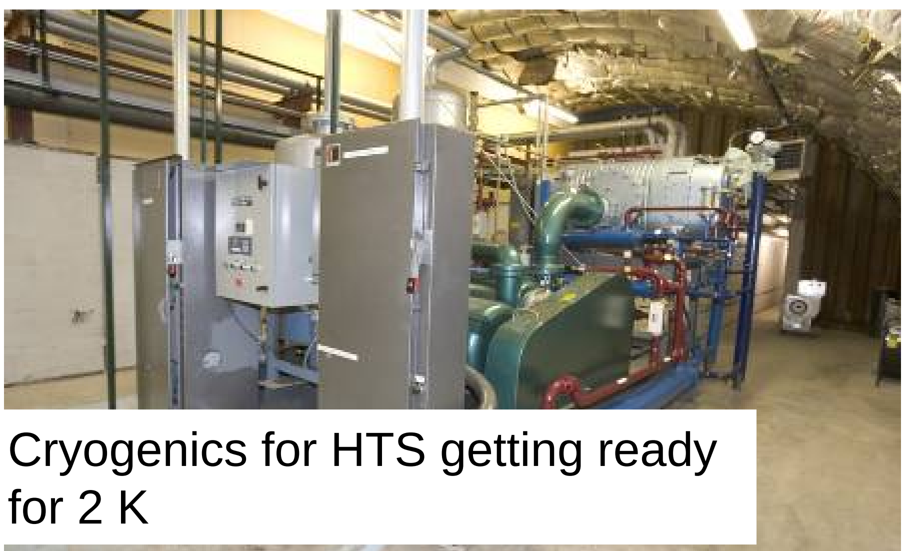


CCII: Cavity Testing Infrastructure

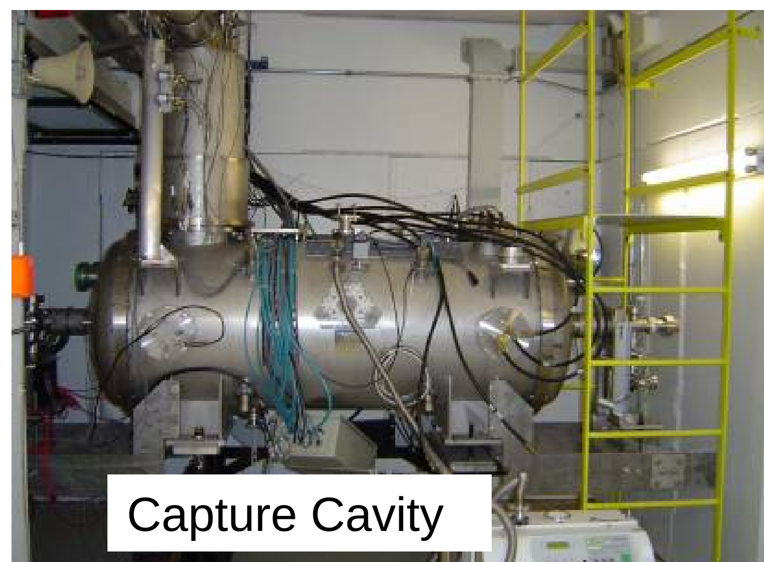


RF Power for HTS

Cryogenics for HTS ready at 2 K



Cryogenics for HTS getting ready for 2 K



Capture Cavity

Horizontal Test Stand

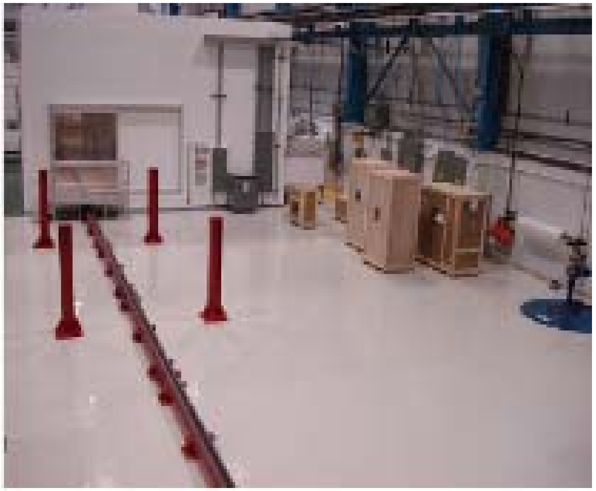
- Fermilab is in progress of building a Horizontal Test Stand for 1.3 and 3.9 GHz cavities.
- All the hardware needed have been delivered and the system in being put together.
- The cryogenic, RF Power, Controls have been debugged using CC-II.
- HTS will be commissioned using a Dressed Cavity from DESY in Oct 06.

LLRF
International
Collaboration

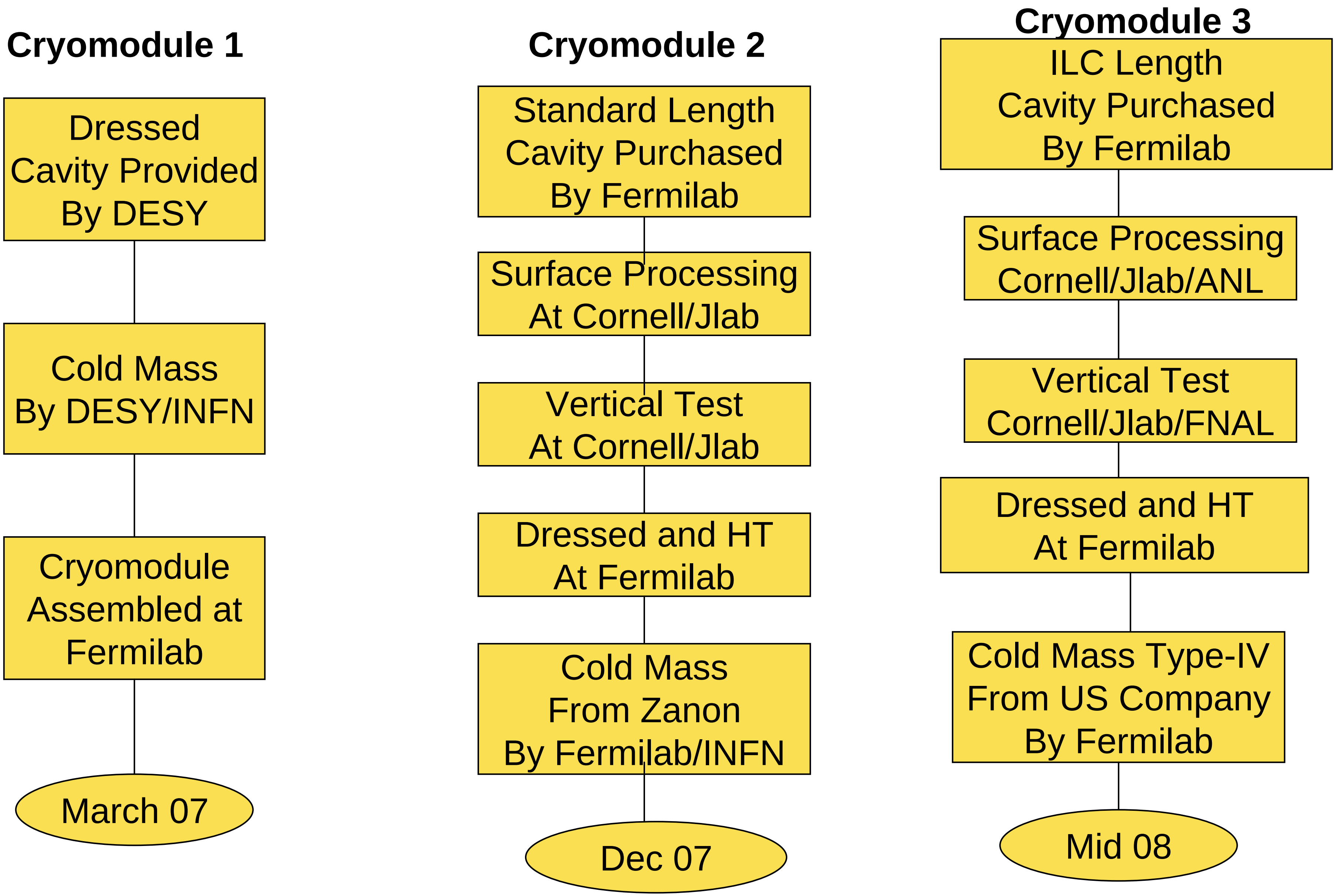
DESY
KEK
Poland
Fermilab
SNS
Cornell
U Penn

Cavity Dressing and Cryomodule Assembly Facility

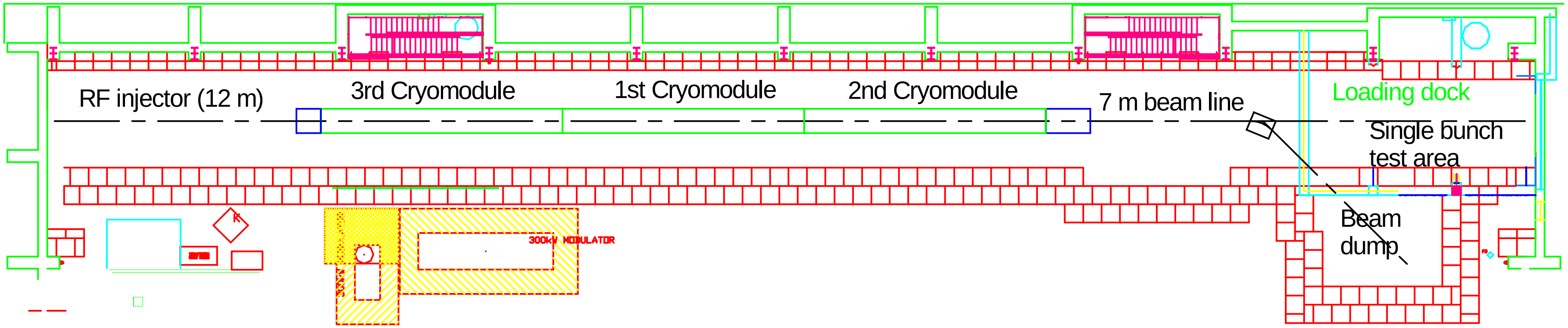
- Fermilab has finished the construction of the Cavity Dressing and Cryomodule Assembly Facility.
    - The design is based on input and recommendations from DESY.
- Detailed development and check out of the tooling is in progress.
    - DESY is sending two dressed cavities to debug this facility.
- FNAL is awaiting the delivery of Cryomodule Kit from DESY.


Cryomodule Fabrication Plans for an RF Unit Test at ILCTA@Fermilab



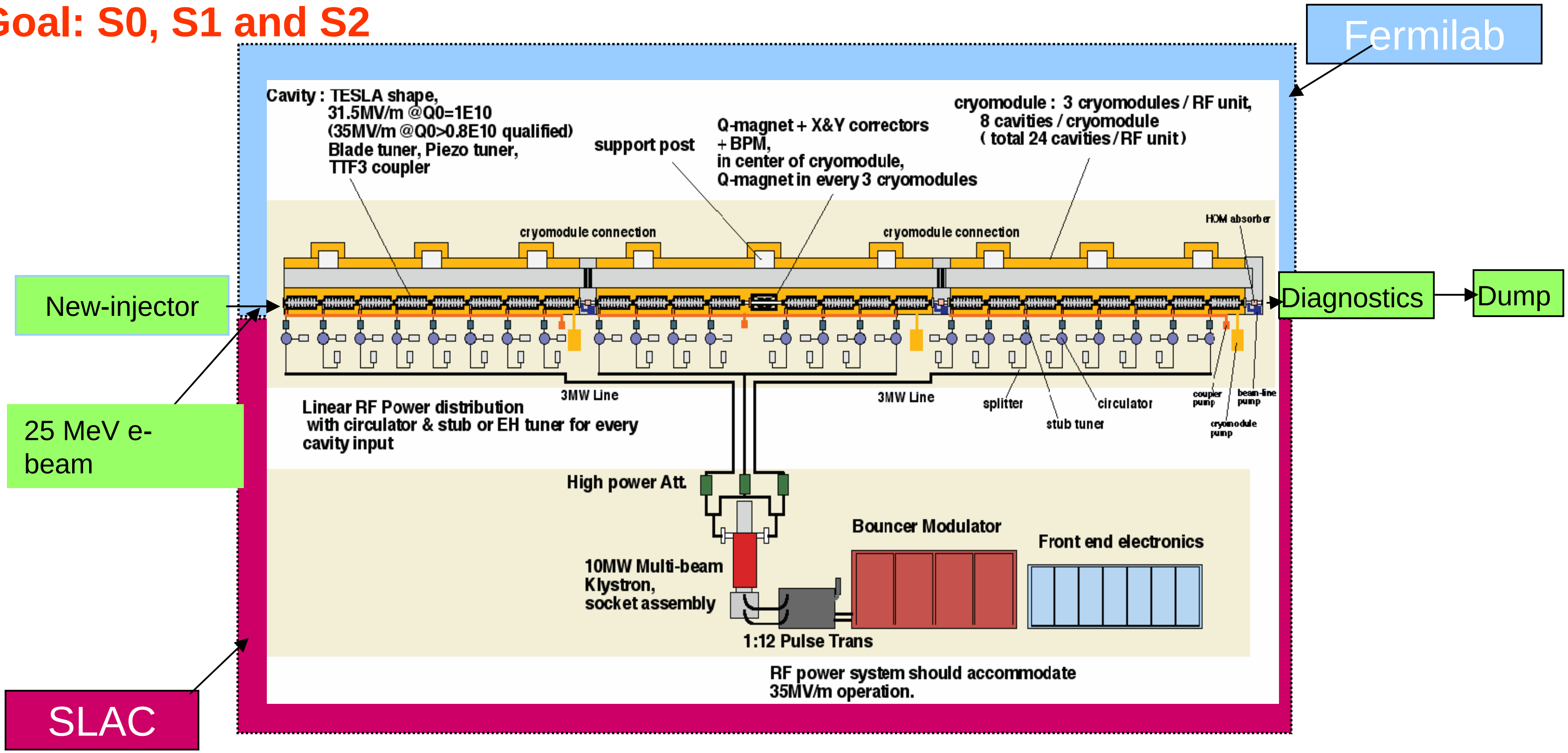
Three cryomodules (fits into NML)



- Mid 2009 - 3 CM's, 750 MeV, 40 kW beam power

ILCTA @ Fermilab Phase 1: 1 RF Unit

Goal: S0, S1 and S2



Components provided by US and International Collaborators

1st RF Unit Integrated by US Laboratories and Universities

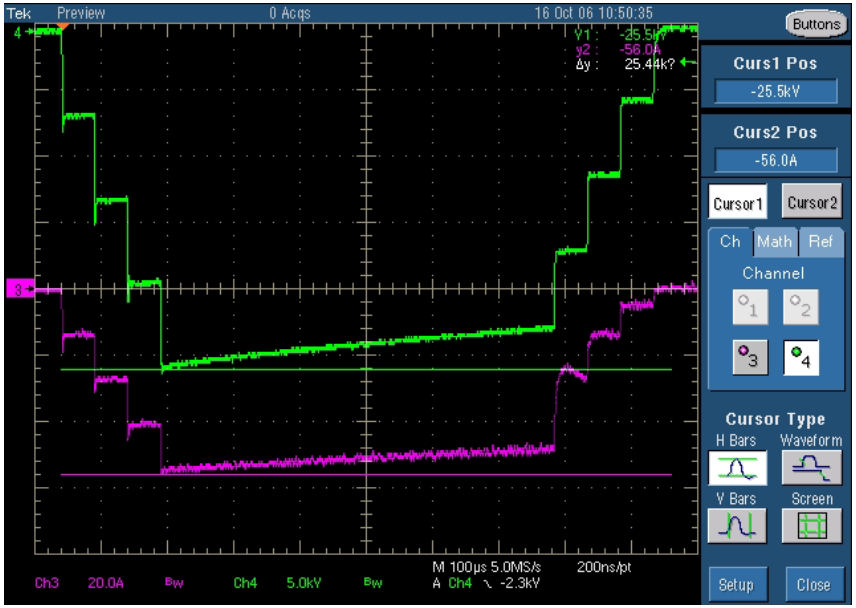
2nd RF Unit Produced and Integrated by ILC laboratories, Universities and Industries

ILC LLRF, Control, Instrumentation, Feedback etc. ILC Institutions

Marx Modulator Test (SLAC)

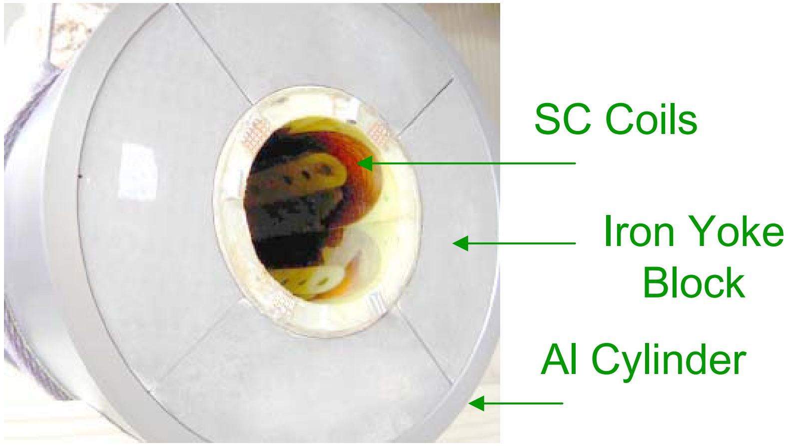
- SLAC Electrical Safety Committee delivered its safety equipment requirements to operate the Marx modulator with more than two cells.
- Six Marx cells are ready for testing in the modulator, two more will be ready this week. Six cell tests will resume when ESC safety equipment is ready. ETA 27 Oct 06.

Modulator Test Chamber

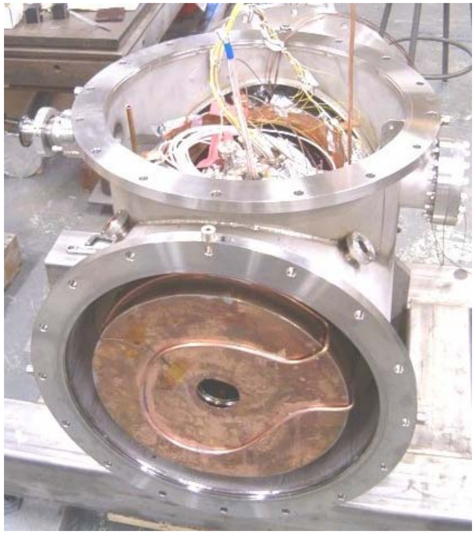


4-Cell Output Waveforms :~25kV,600µs

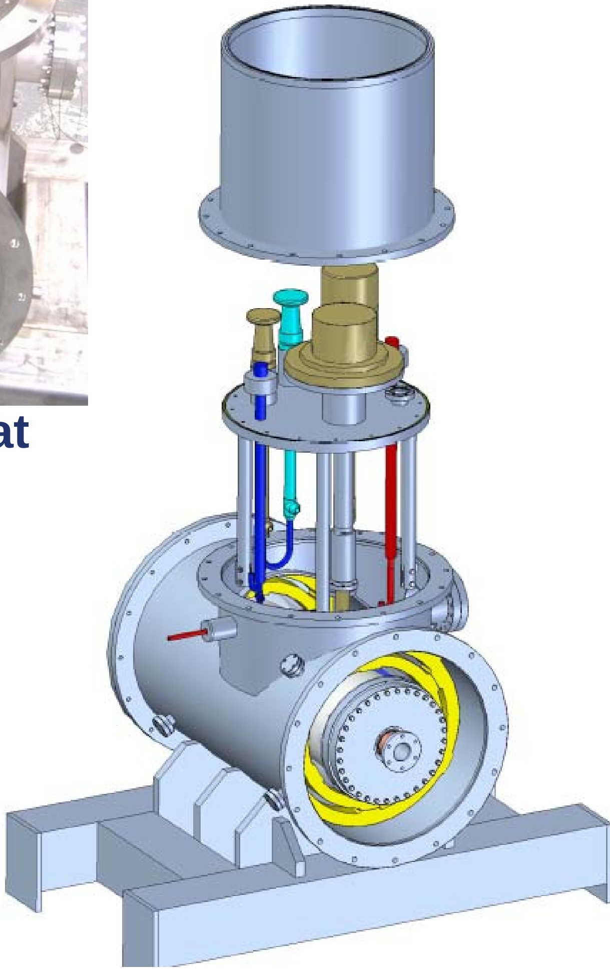
SC-Quad Test (SLAC)

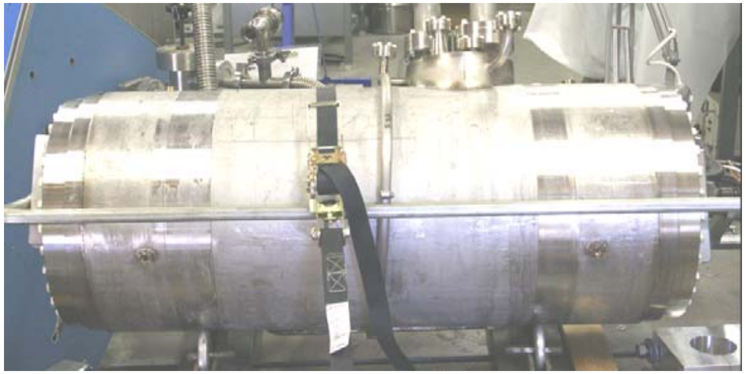


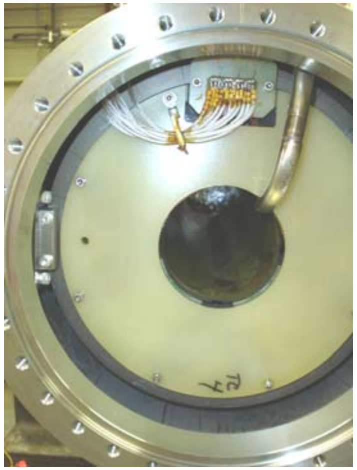
0.7m long Cos (2-phi) SC Quad



Test Cryostat

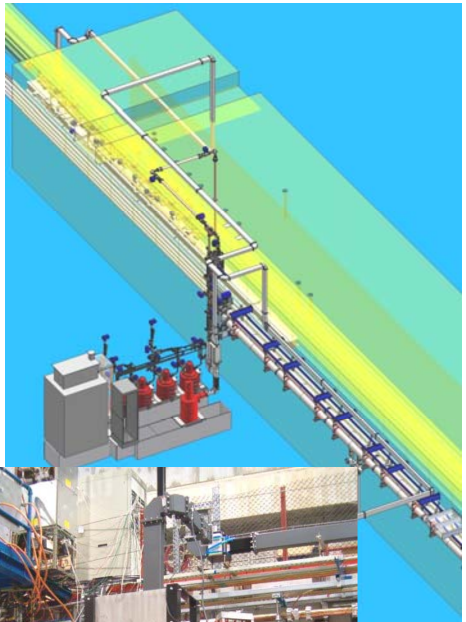


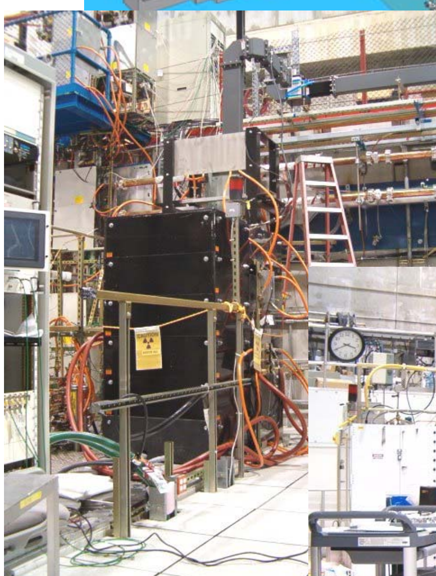




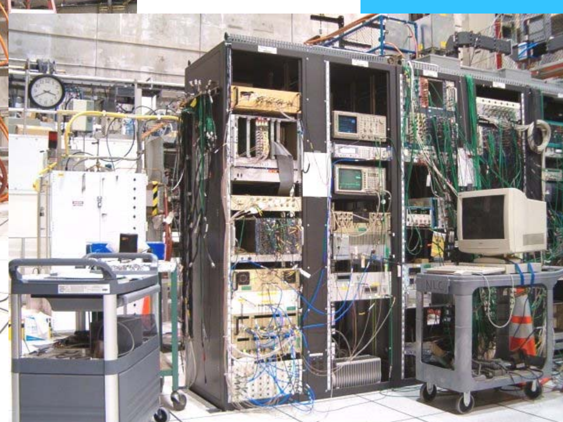
He Vessel

L-band Power Station (SLAC)

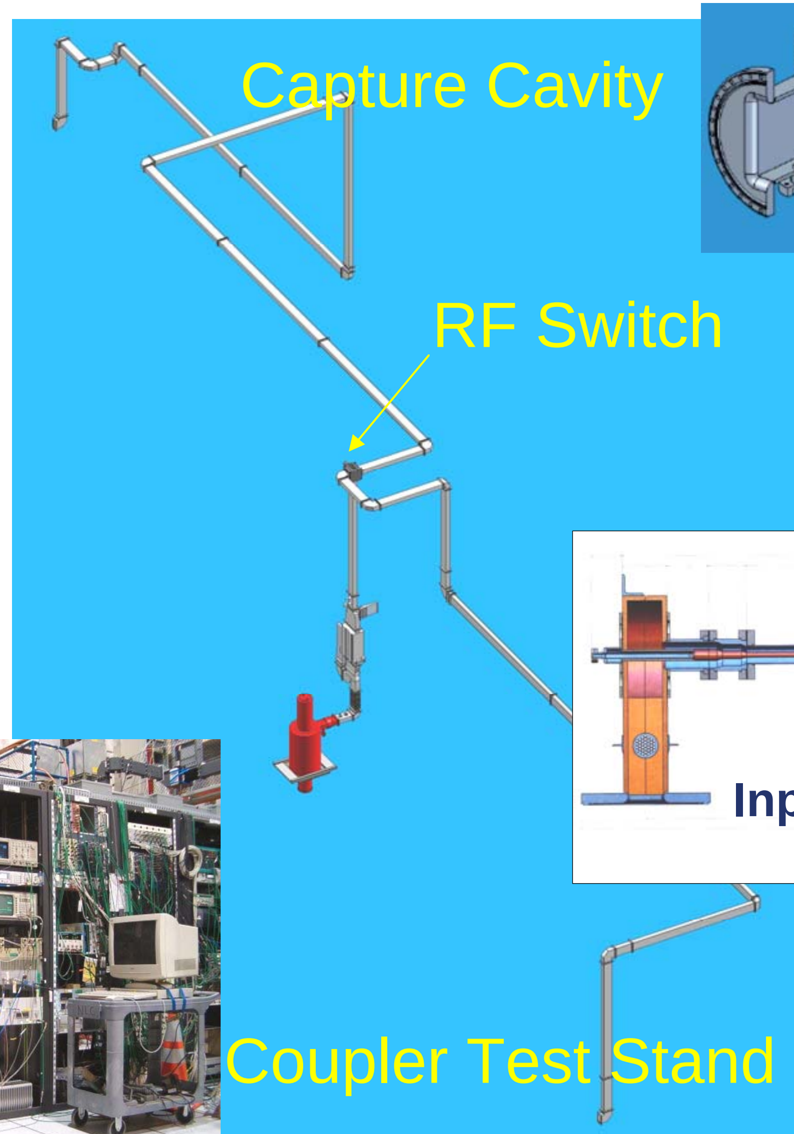


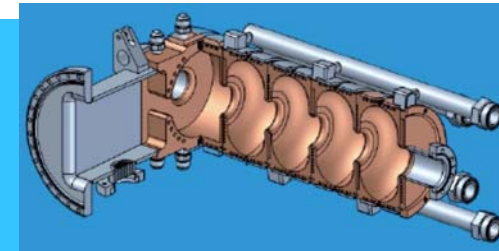


Klystron

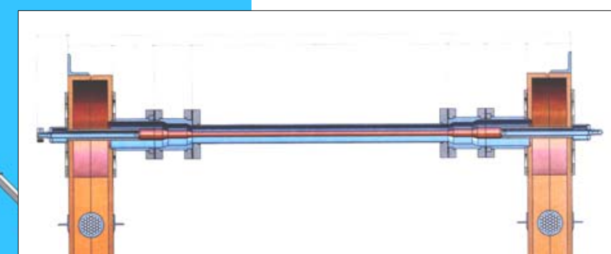


LLRF





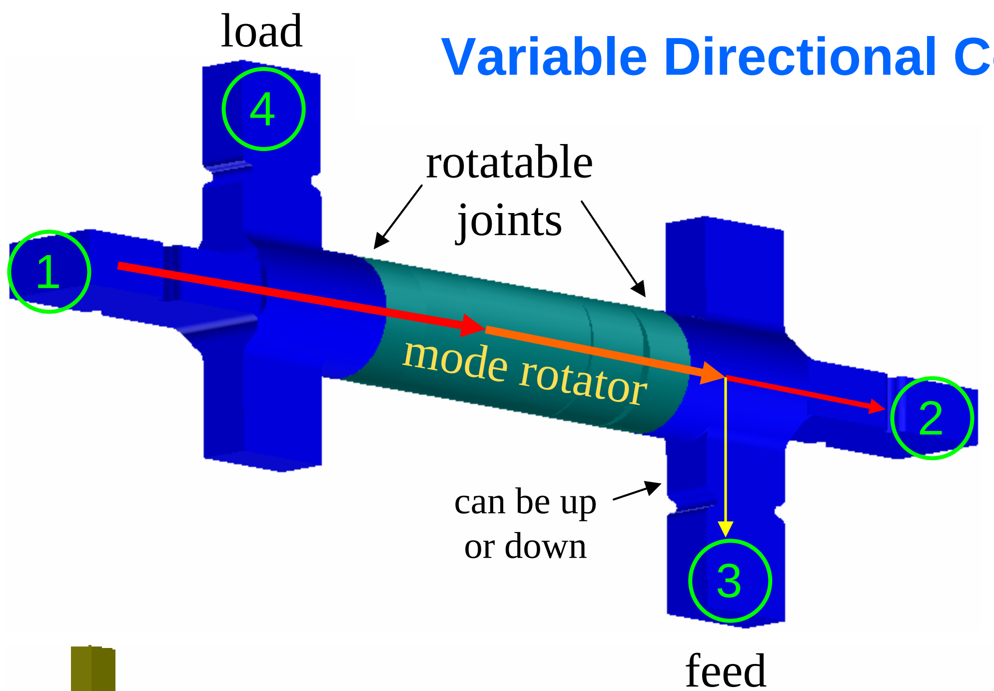
SW cavity



Input coupler
Test

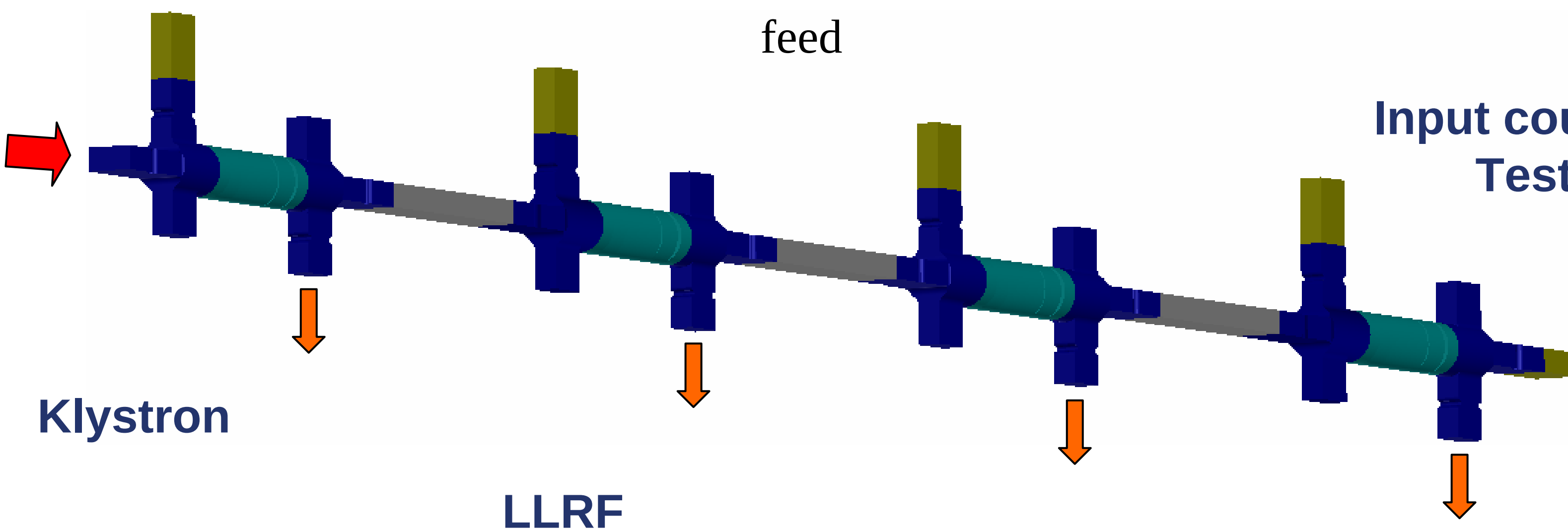
RF distribution design (SLAC)

Variable Directional Coupler



Directional Coupler

$$|\mathbf{S}| = \begin{bmatrix} 0 & \sqrt{1-C} & \sqrt{C} & 0 \\ \sqrt{1-C} & 0 & 0 & \sqrt{C} \\ \sqrt{C} & 0 & 0 & \sqrt{1-C} \\ 0 & \sqrt{C} & \sqrt{1-C} & 0 \end{bmatrix}$$



Input coupler Test

KEK STF development plan update

Phase 1 (2005 -2007),

for quick startup of ILC SCRF, infra-structure development

subdivided to

Phase 0.5 : 1 cavity in each short cryostat (cool-down in Mar.2007)
Phase 1.0 : 4 cavities in each short cryostat (Jul.2007)
Phase 1.5 : replacement of 4 cavities by improved new 4 cavities (Apr.2008)

Phase 2 (2007 - 2009),

develop ILC Main Linac RF unit

start design Apr. 2007
fabrication in 2008 and 2009 (2 years for 24 cavities)
completion middle to end of 2009

* S0 Task Force activities will be done in parallel.

KEK STF Highlights

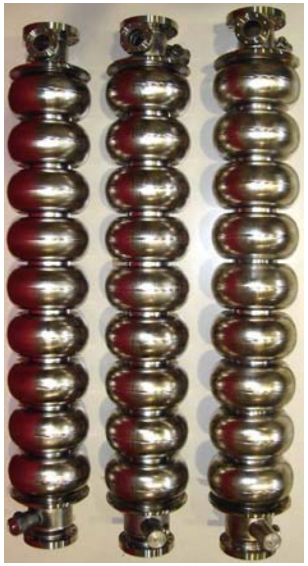
clean room for cavity assembly

5MW power source
and coupler test stand

5m cryomodule vacuum vessels

TESLA-like cavities

disk window
Input Couplers

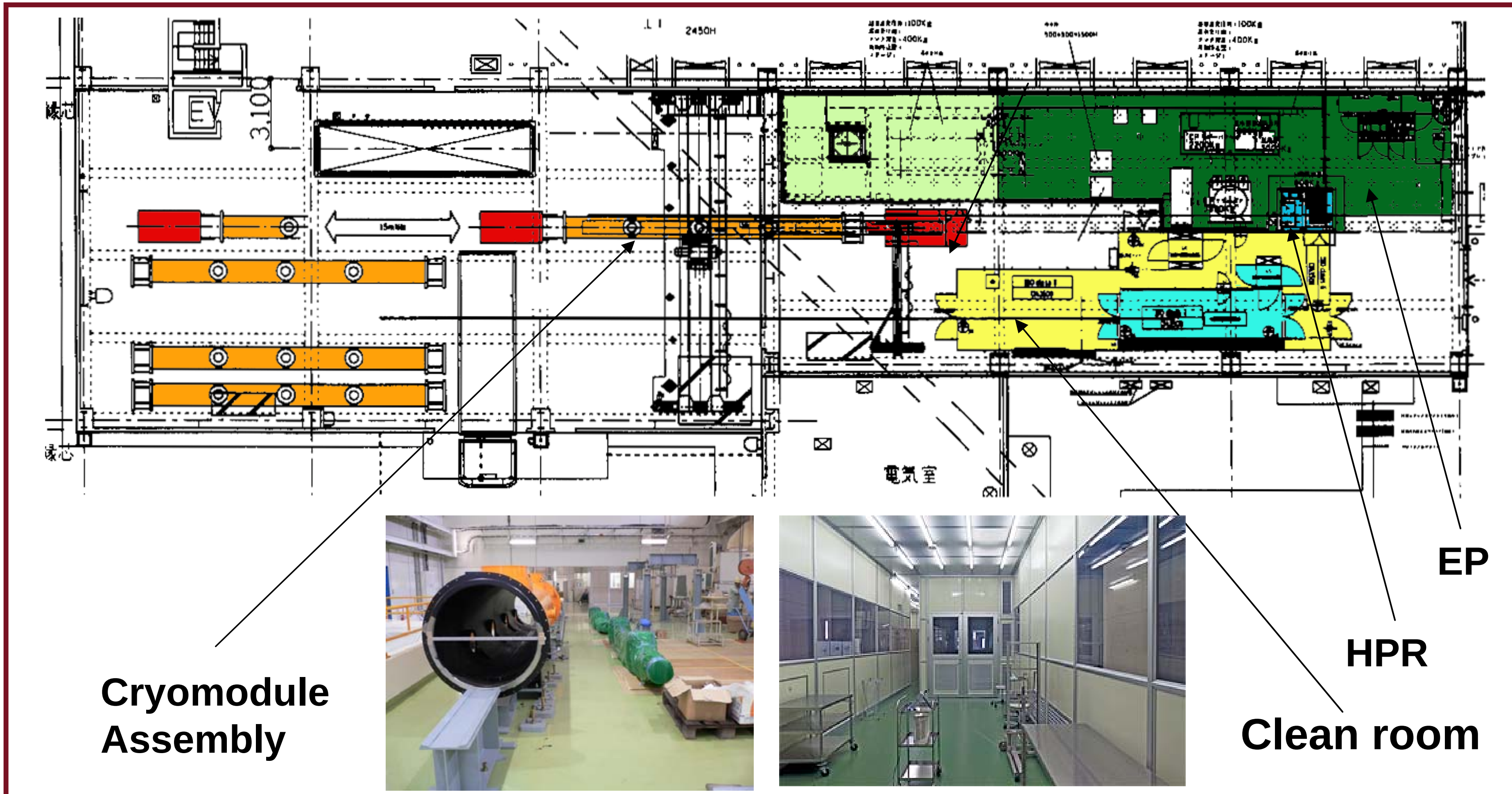


LL shape cavities

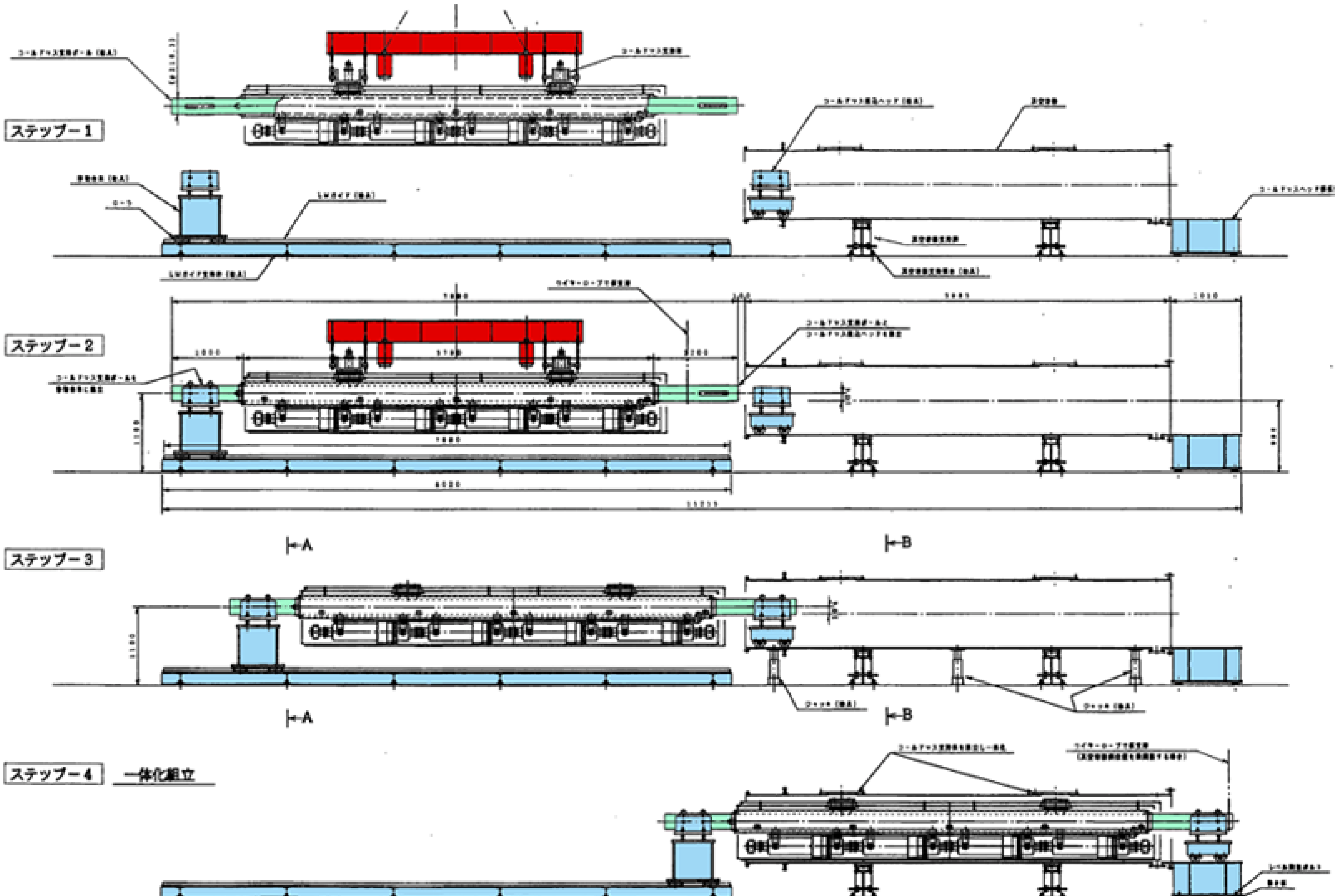
capacitive coupling
Input Couplers

STF SC Infra-structure

EP: under construction. will be completed in Mar. 2007
HPR:under construction. will be completed in Dec. 2006
Clean room: under use of short cryomodule assembly.



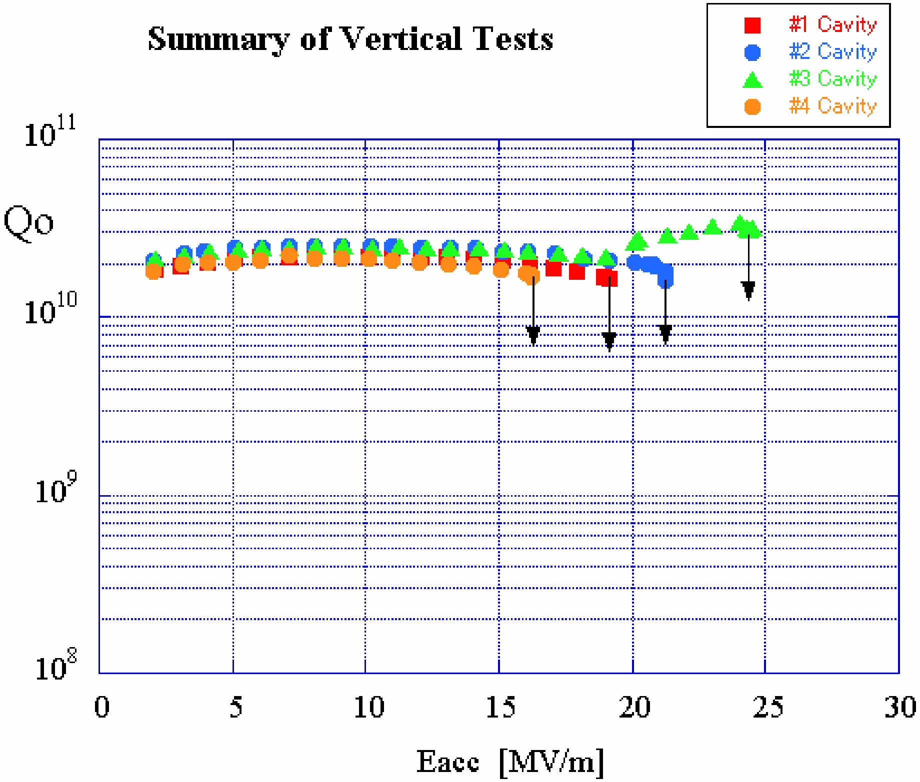
Plan of cryomodule assembly



Vertical Tests of TESLA style Cavities

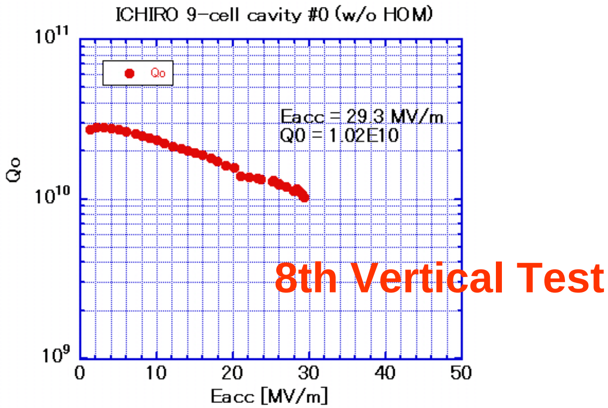
Up to now, 9 tests for 4 cavities.

#1 cavity : 3 tests (max 19.2MV/m)
#2 cavity : 2 tests (max 20.3MV/m)
#3 cavity : 3 tests (max 24.5MV/m)
#4 cavity : 1 test (max 17.1MV/m)



LL-type Ichiro 9-cell Cavity Vertical Test

#0 : without HOM /input port



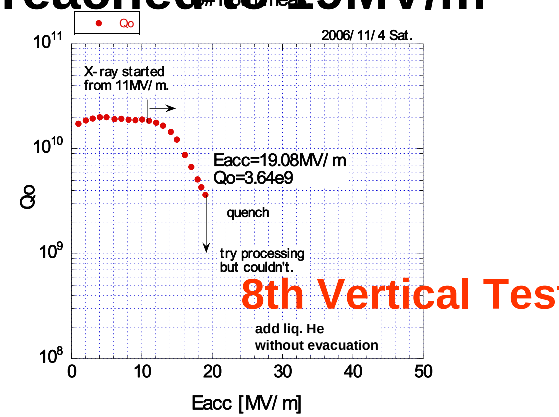
4 EP, 16 measurement -> reached to 30MV/m,

Now under modification of end-group.

#1 : with HOM /input port

4 EP, 8 measurement

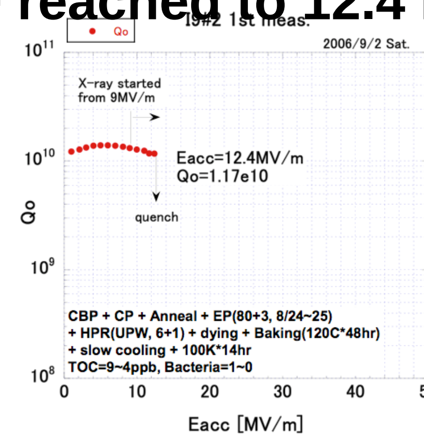
-> reached to 19MV/m



#2 : with HOM /input port

1st measurement

-> reached to 12.4 MV/m



Summary and Plans

- Request to CCB for cost cutting
- Status of R&D
- the plans and goals for this workshop
  – **Cost Review again.**
  – **Discuss Further Cost Reduction**
  – **Structure of RDR paper and responsibilities**