SRF workshop July,2005

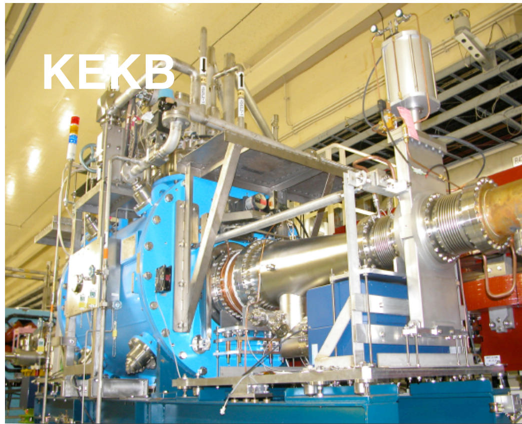
# Superconducting RF Test Facility (STF) in KEK

H. Hayano, KEK

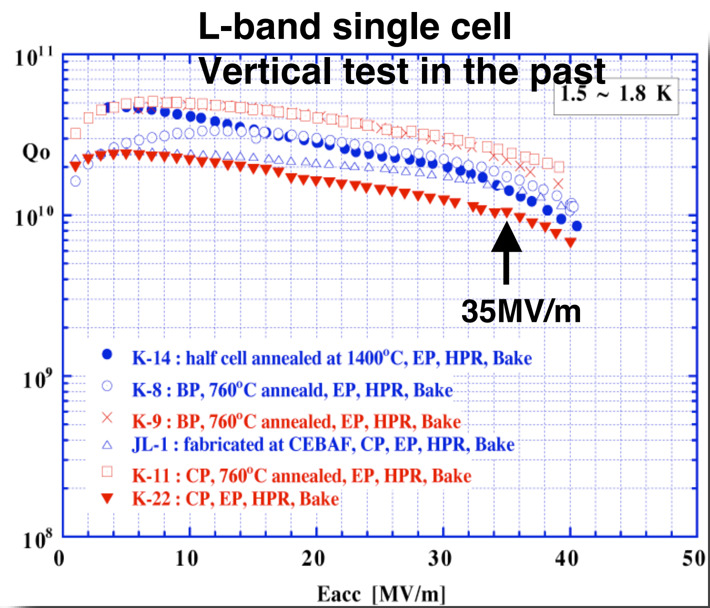
*Test Facility for ILC*

# Superconducting Technologies at KEK

- TRISTAN
- KEKB
- L-band R&D
- J-PARC R&D
- KEKB crab-cavity
- collab. to IHEP






# Purpose of STF

- Establish an industrial design of 35MV/m cavity system by improving the TESLA cavity design and peripherals, and develop 45MV/m cavity system for possibility of high gradient.

- Conduct actual system construction by Asian/Japanese industries for accurate cost estimation.

- Build the base infrastructure at KEK as an Asian regional center, for the Asian region’s share of the construction.

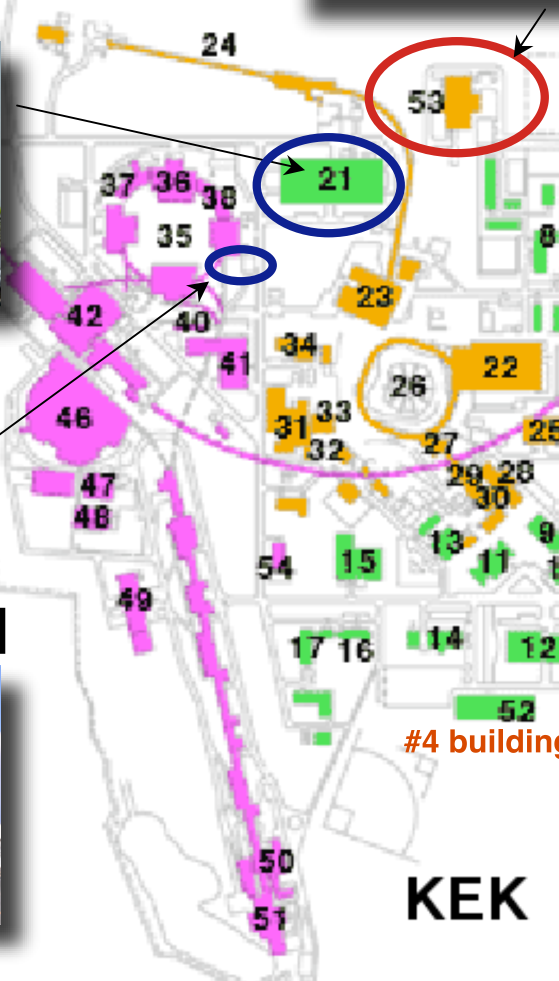
- Build up a pool of experts at both the labs and the industries towards future mass-production.

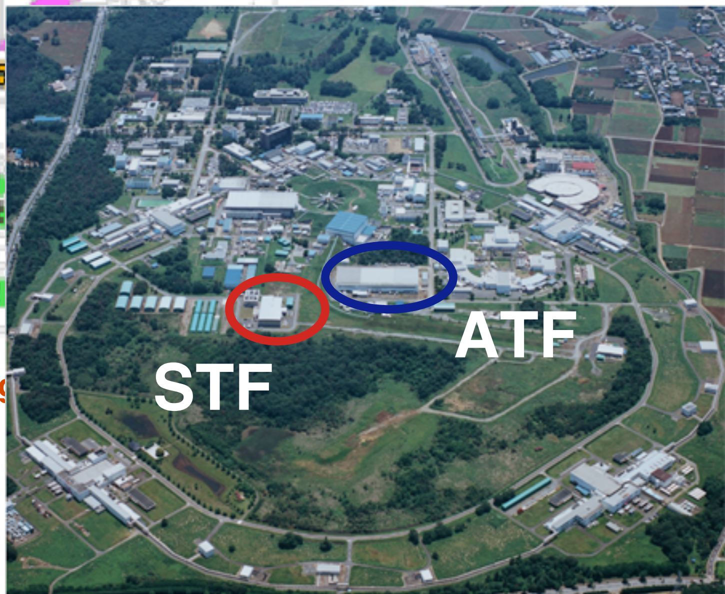
# *Location of Test Facilities*

## Proton Linac Building(STF)

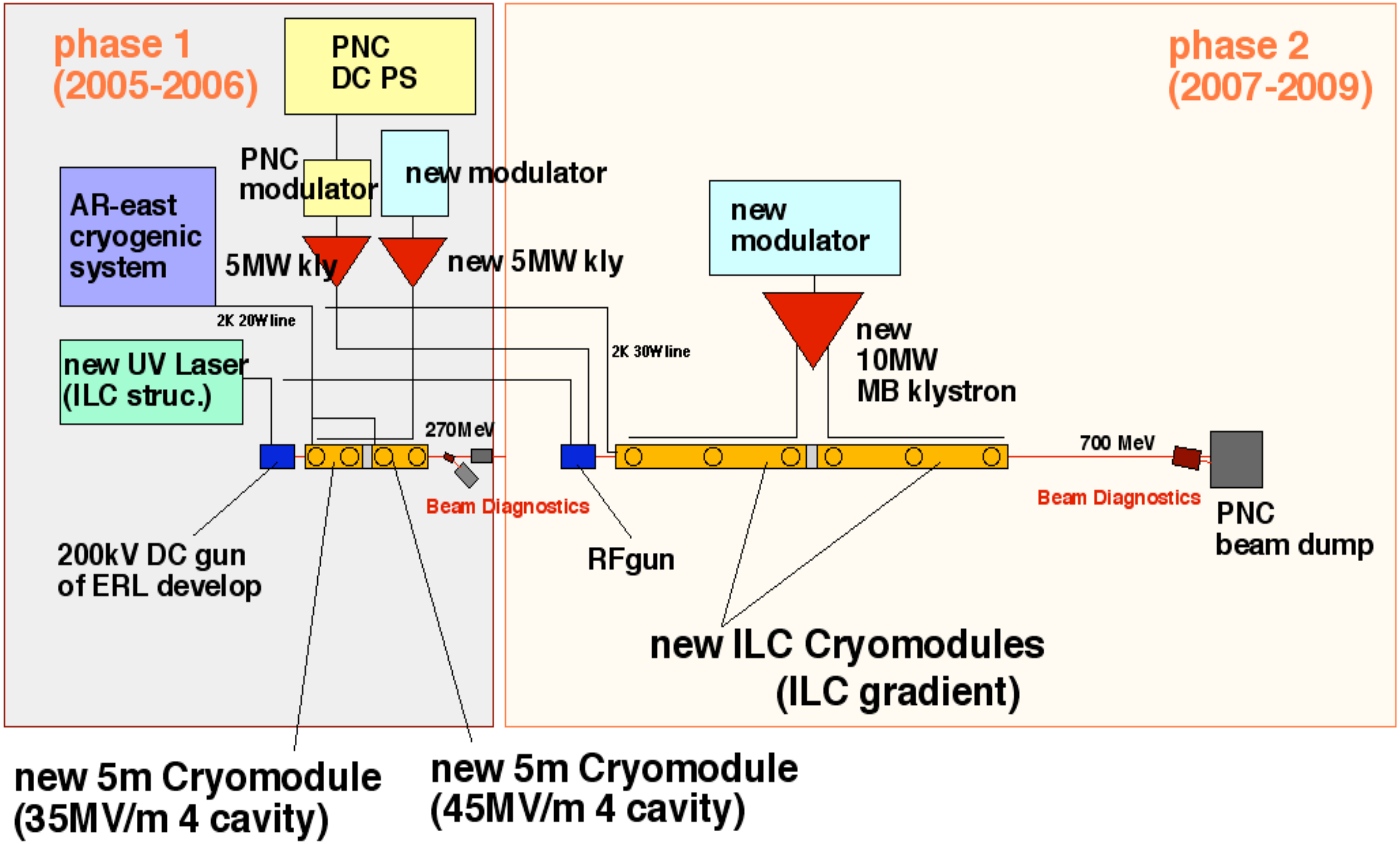
1) 60m x 30m building:
   Klystron Gallery/Cavity installation room
   EP&clean room/Control room
   Cooling water facility/AC power yard
   external Tent House

2) 5m x 3.85m x 93.5m tunnel:
   Access hatch only 2m x 4.5m



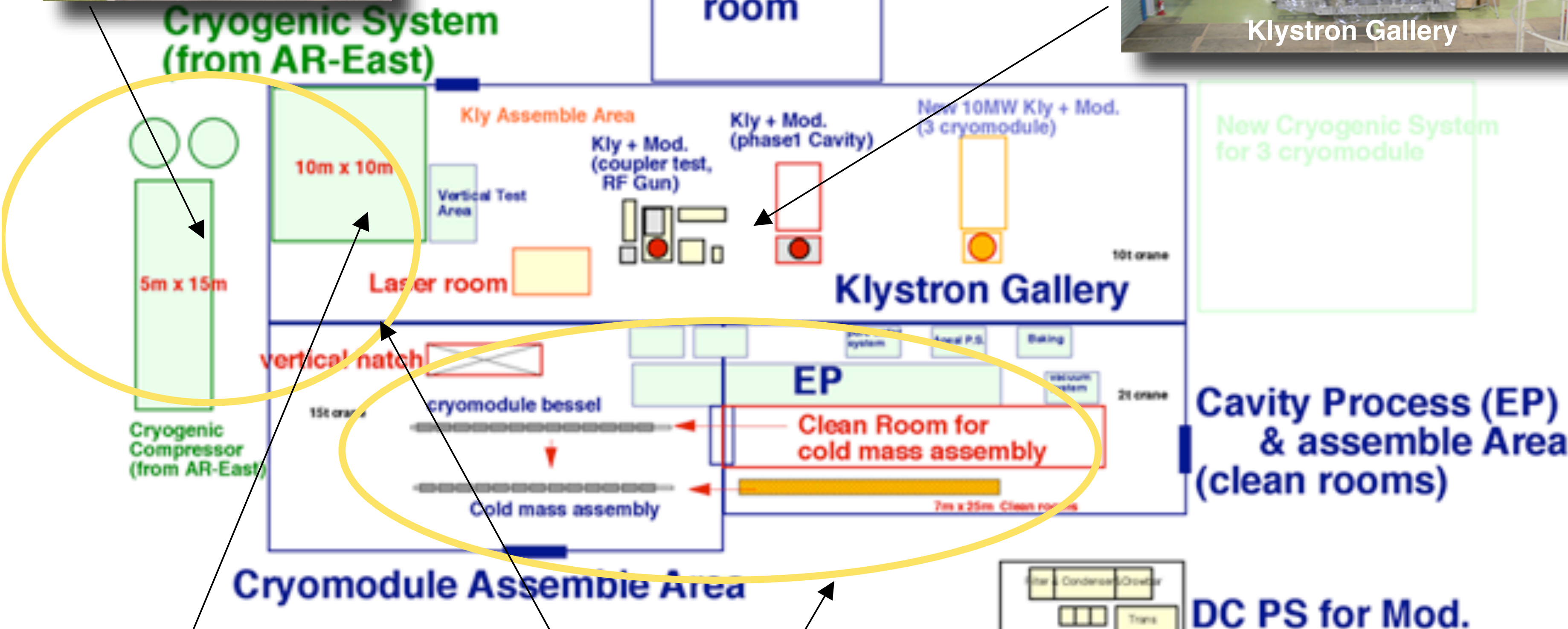



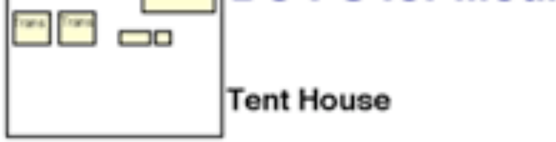
# Plan of Superconducting RF Test Facility (STF)




V2.1 Hitoshi Hayano, 6/24/2005


## STF Building plane view

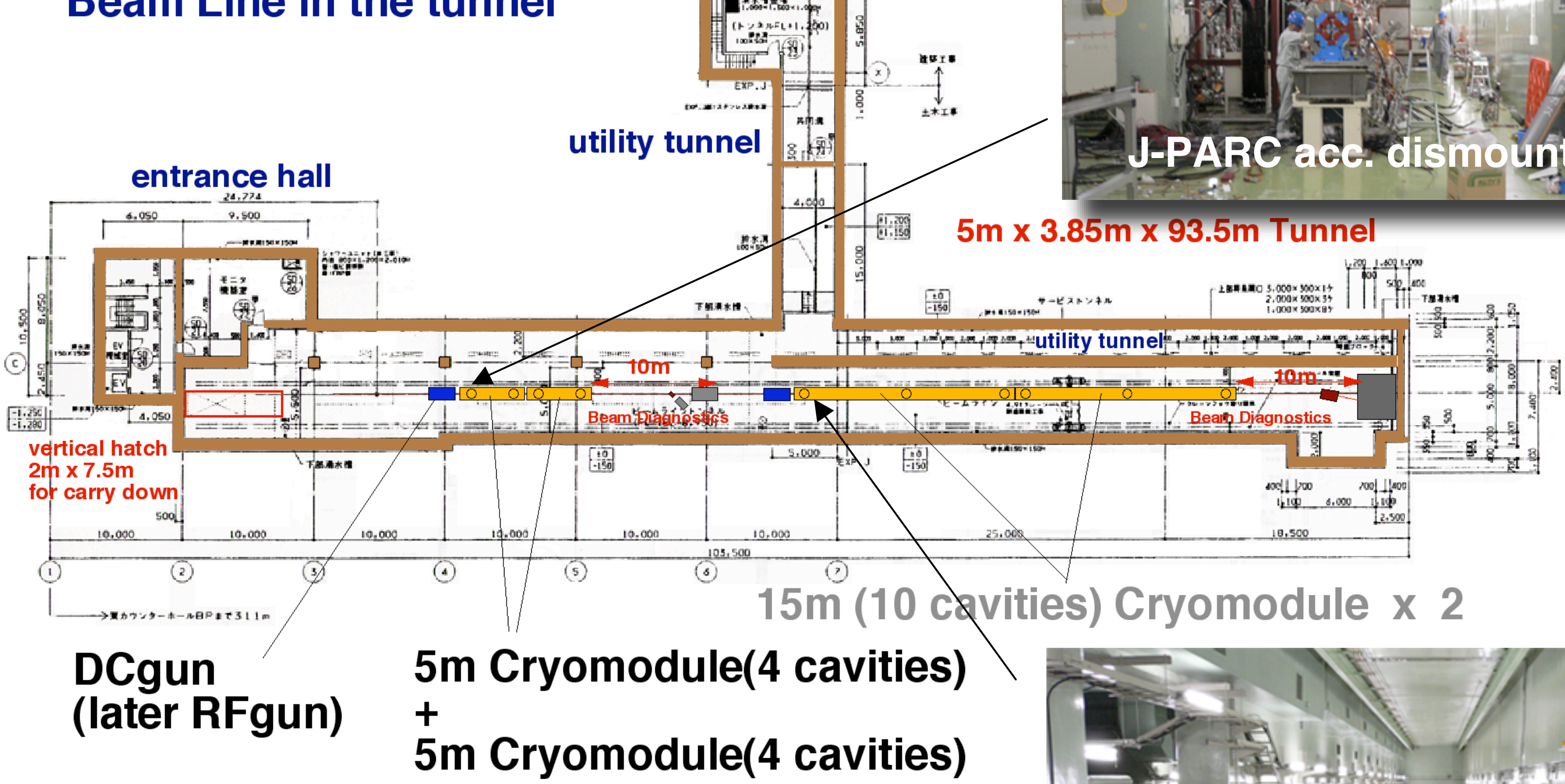


V4.0 Hitoshi Hayano, 06/13/2005

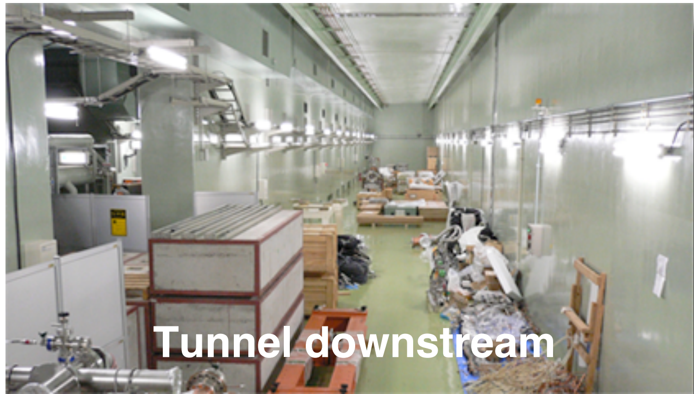
# Infra-structure for SC-RF production

# STF underground tunnel plane view

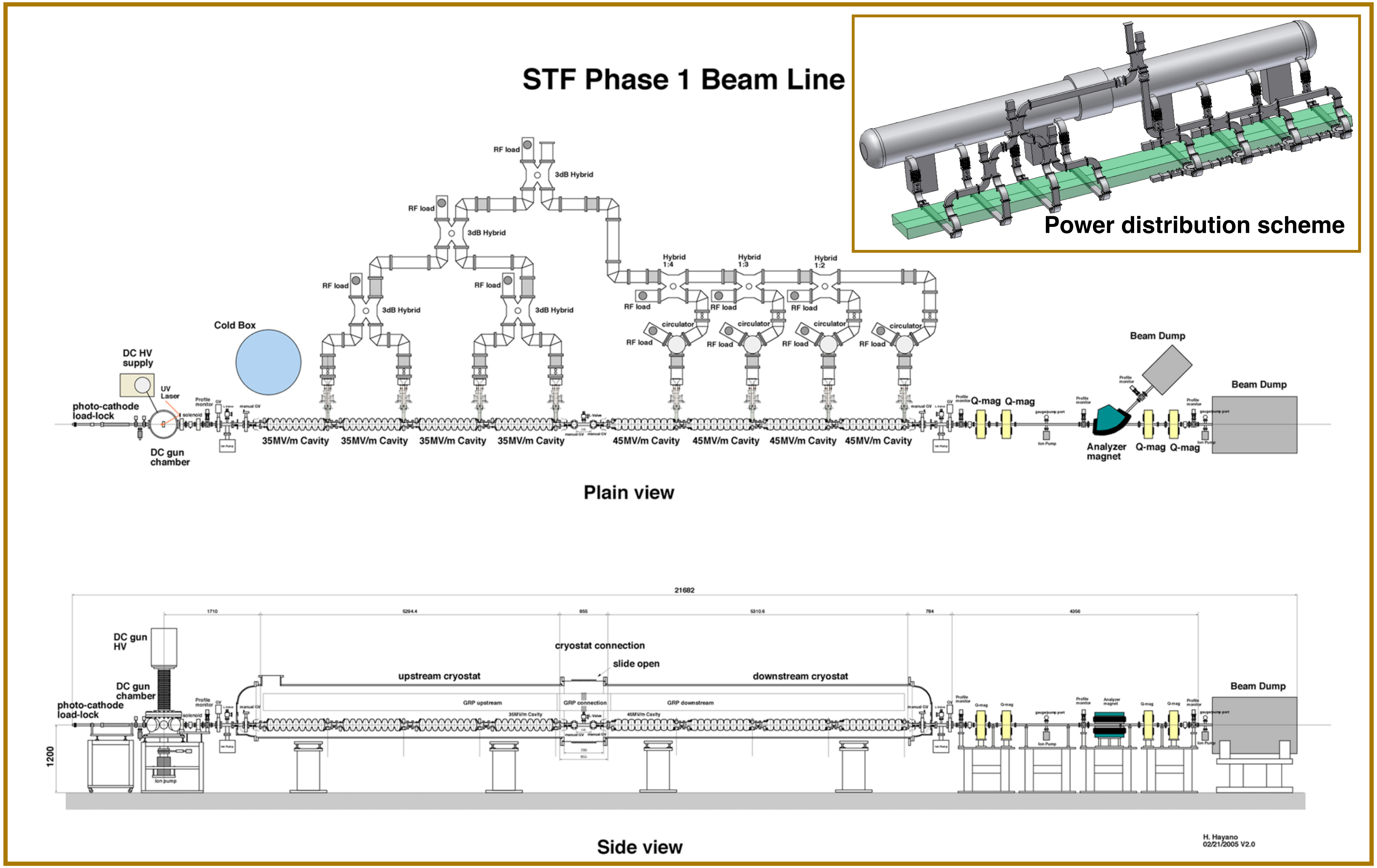
## Beam Line in the tunnel







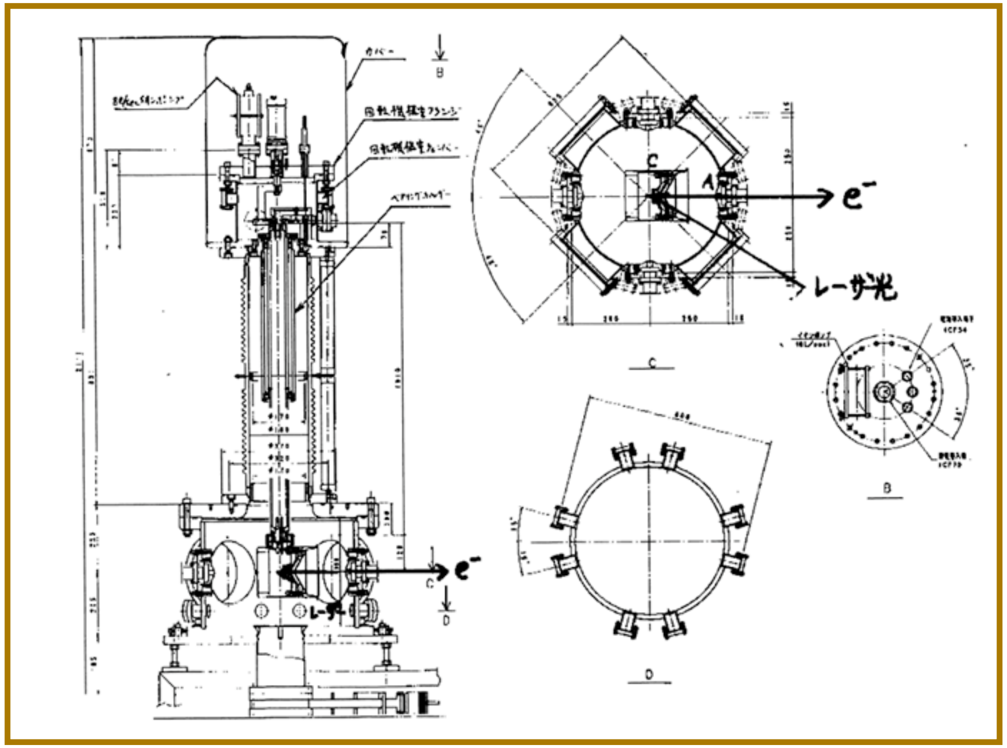
# STF Phase 1  Beam Line Plan



# STF Beam source Plan

1. **Photo-cathode DC-gun (borrowed from ERL development)**

   **200kV CsTe photocathode +UV(262nm) Laser (337ns spacing, 2820bunches)**





2. **Photo-cathode Load-lock System (extension of ATF load-lock)**

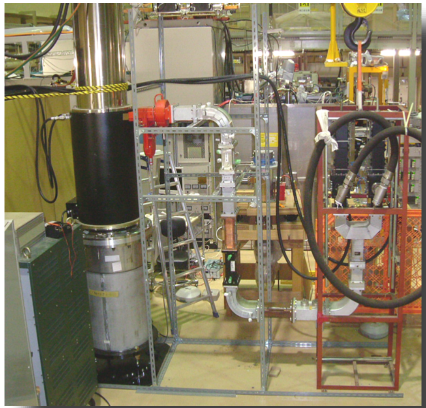
3. **Laser Development in 2006 (next year)**

4. **RF gun cavity design & fabrication in 2006 for STF Phase2 beam source.**

# 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.**

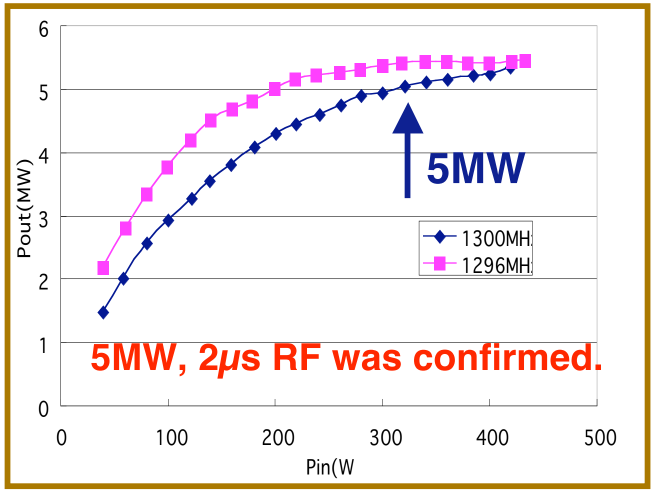


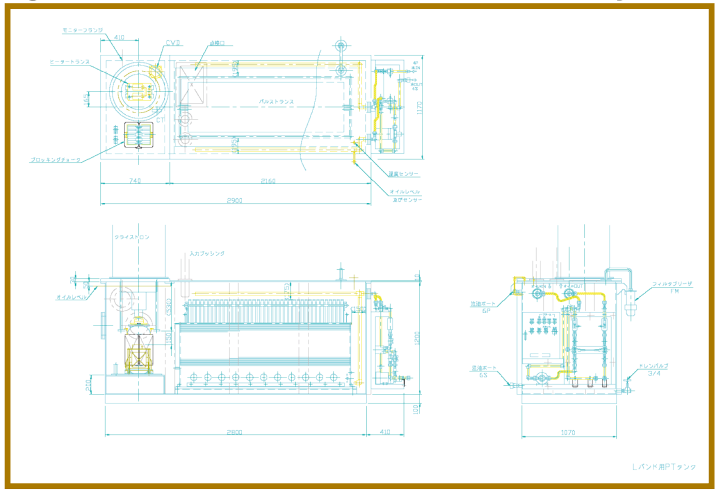
**Existing PNC modulator**

**Additional Pulse Trans + Bouncer circuit allows to use TH2104A.**

**TH2104A old klystron short pulse test.**

**Design of Pulse Trans is underway.**

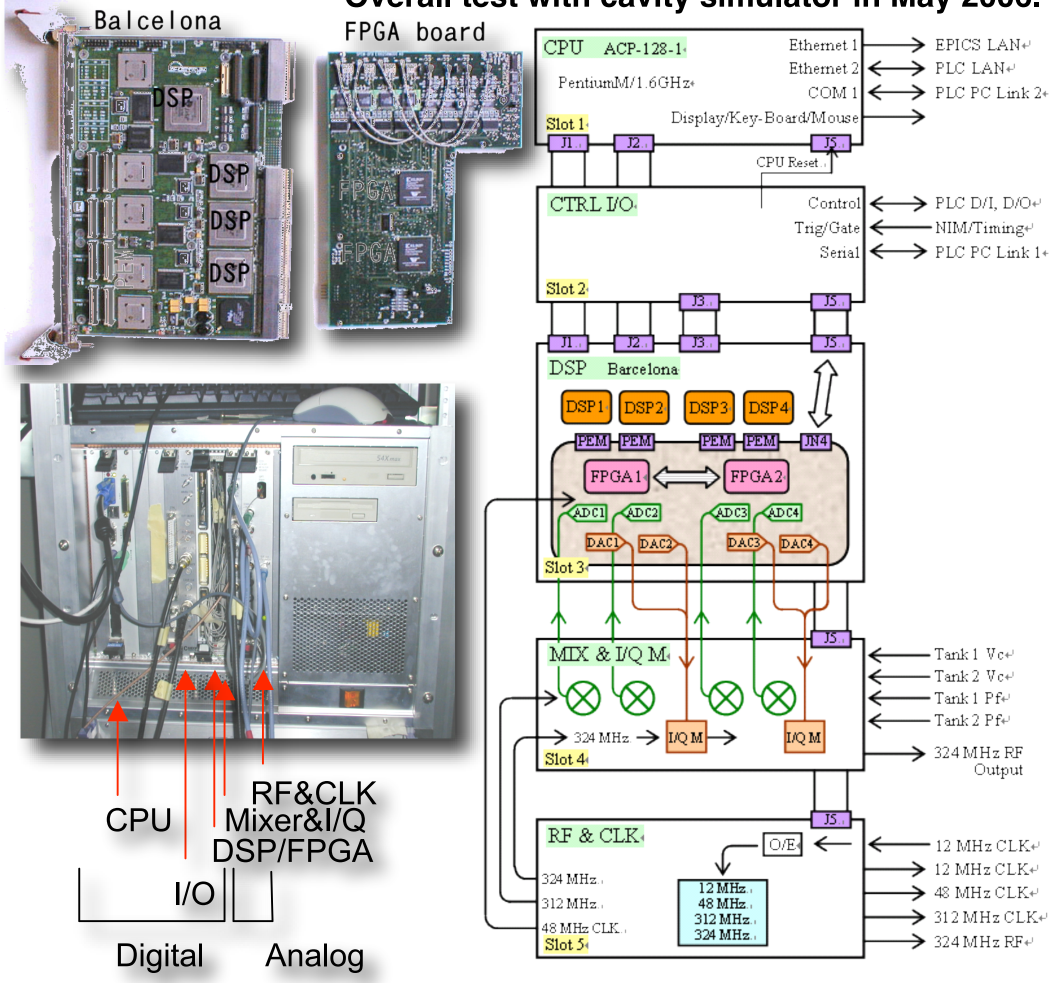


# STF Modulator, klystron plan&status cont.

**2. LLRF control, modified from J-PARC LLRF, is under design.**

**Overall test with cavity simulator in May 2006.**

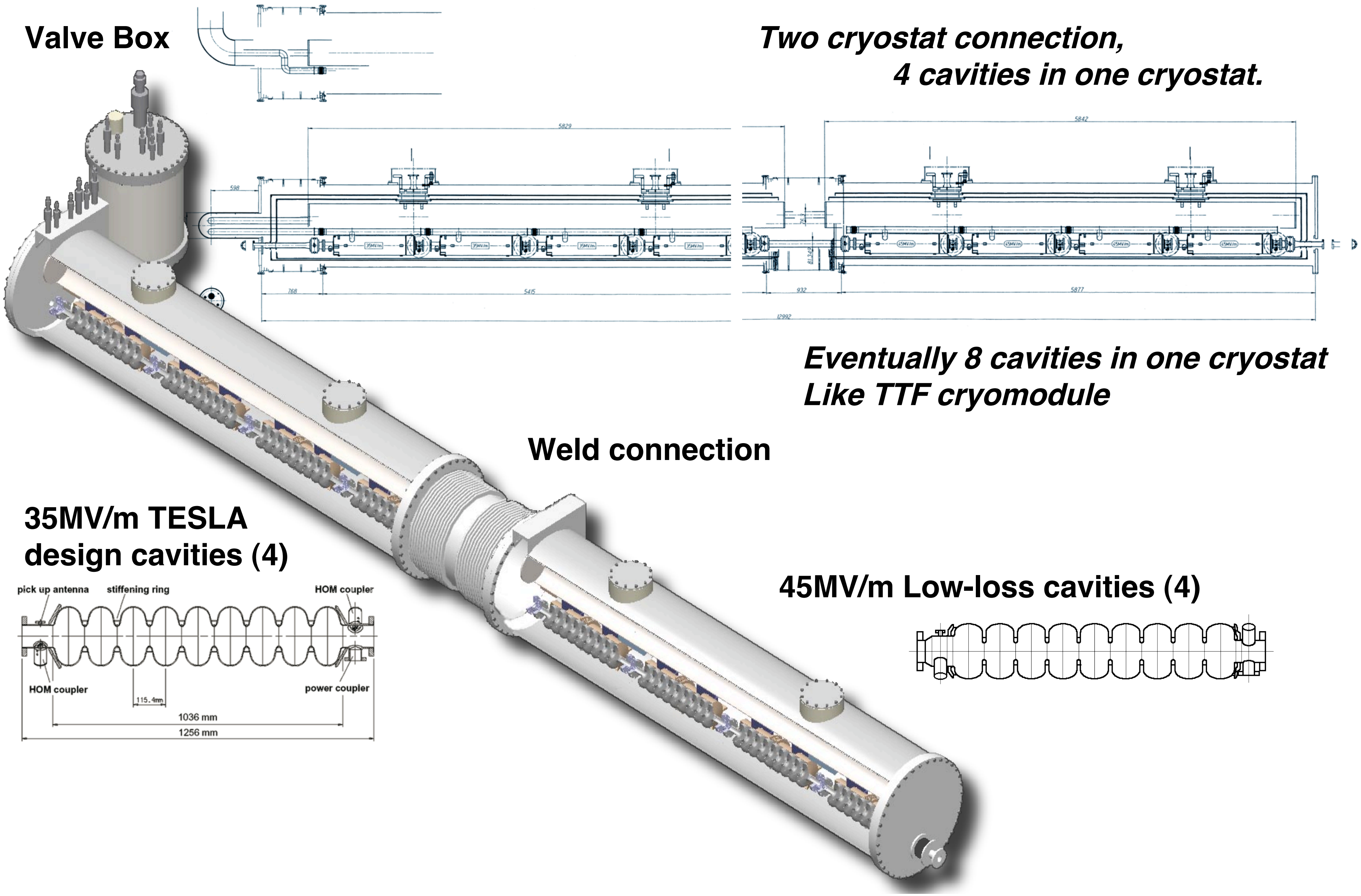



**Existing J-PARC LLRF**

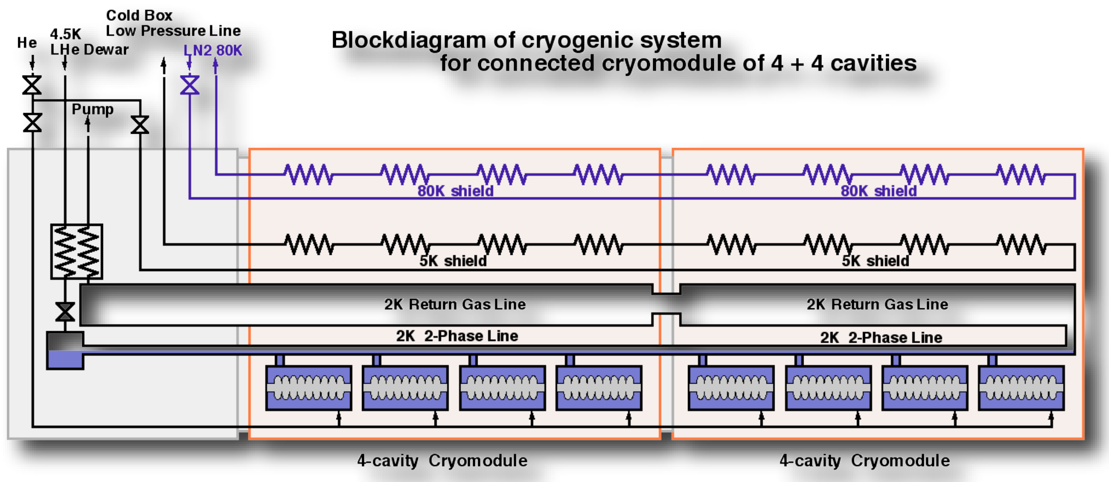
**3. Purchase a 5MW Klystron from Thales (TH2104C), and Build one more modulator for running the cavities (in 2006).**

**TH2104C**

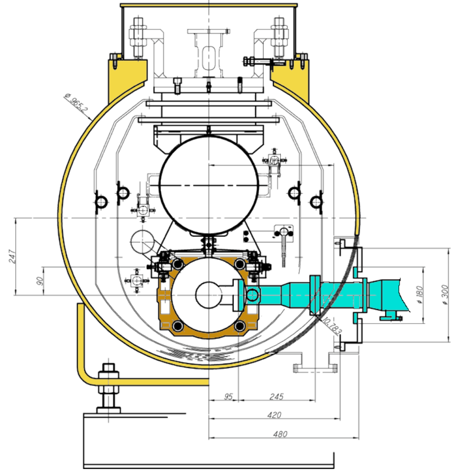
# Cryomodule : Cryostat Design



# Cryomodule : Cryostat Design cont.

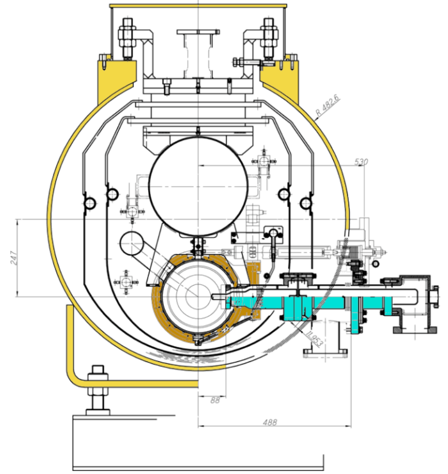



*KEK cryomodule cross-section for 35MV/m cavities*



| Description | OD (mm) | | Dt (mm) | | Notes |
|---|---|---|---|---|---|
| | STF | TESLA | STF | TESLA | |
| Vacuum vessel | 965.2 | 965.2 | 12.0 | 9.52 | carbon steel |
| 2 K gas return | 318.5 | 300 | 10.3 | 8 | stainless steel |
| 2 K two-phase supply | 89.1 | | 2.1 | | Ti |
| Cool down / warm up | 38.1 | 42.2 | 1.65 | 1.65 | stainless steel |
| 5 K shield supply | 42.7 | 60.3 | 1.65 | 2.77 | stainless steel |
| 5 K shield return | 42.7 | 60.0 | 1.65 | 5 | stainless steel |
| 90 K shield supply | 42.7 | 60.3 | 1.65 | 2.77 | stainless steel |
| 90 K shield return | 42.7 | 60.0 | 1.65 | 5 | stainless steel |

*KEK cryomodule cross-section for 45MV/m cavities*

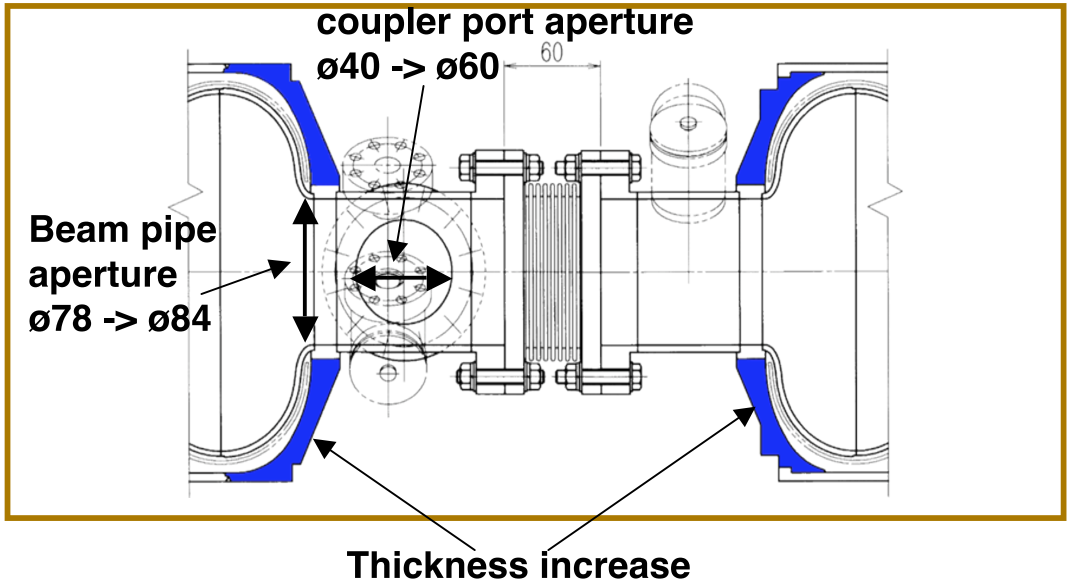


# 35MV/m Baseline Cavity Design Improvement

## 1. He jacket rigidity improvement for small Lorentz detuning.

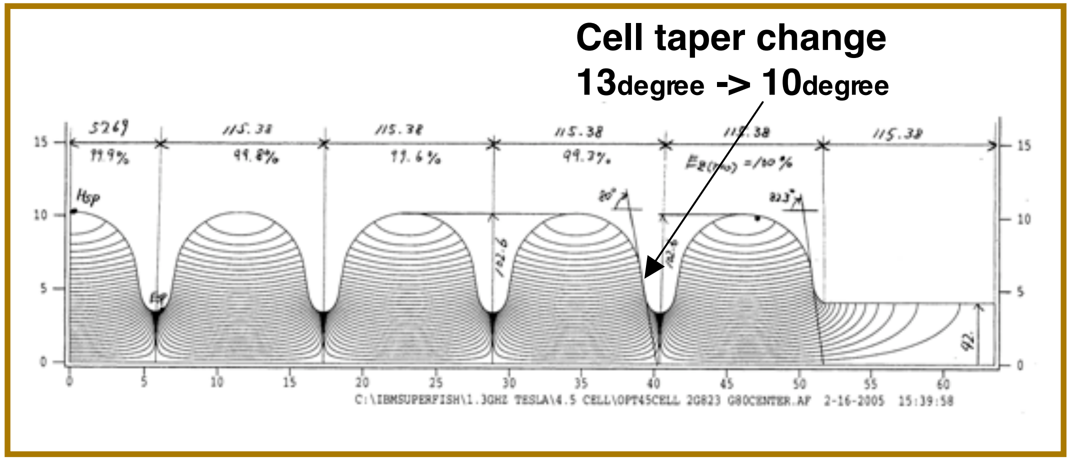
The End-Plate of the Helium jacket is increased, so as to increase the system rigidity against the Lorentz detuning force at 35MV/m. The RF coupling is maintained by increasing the beam pipe aperture of the end cell. This allows the aperture of the coupler port to increase – a good match with high input power.

Note: Small Lorentz detuning is good for precise field control, and for reducing the piezo stack length.



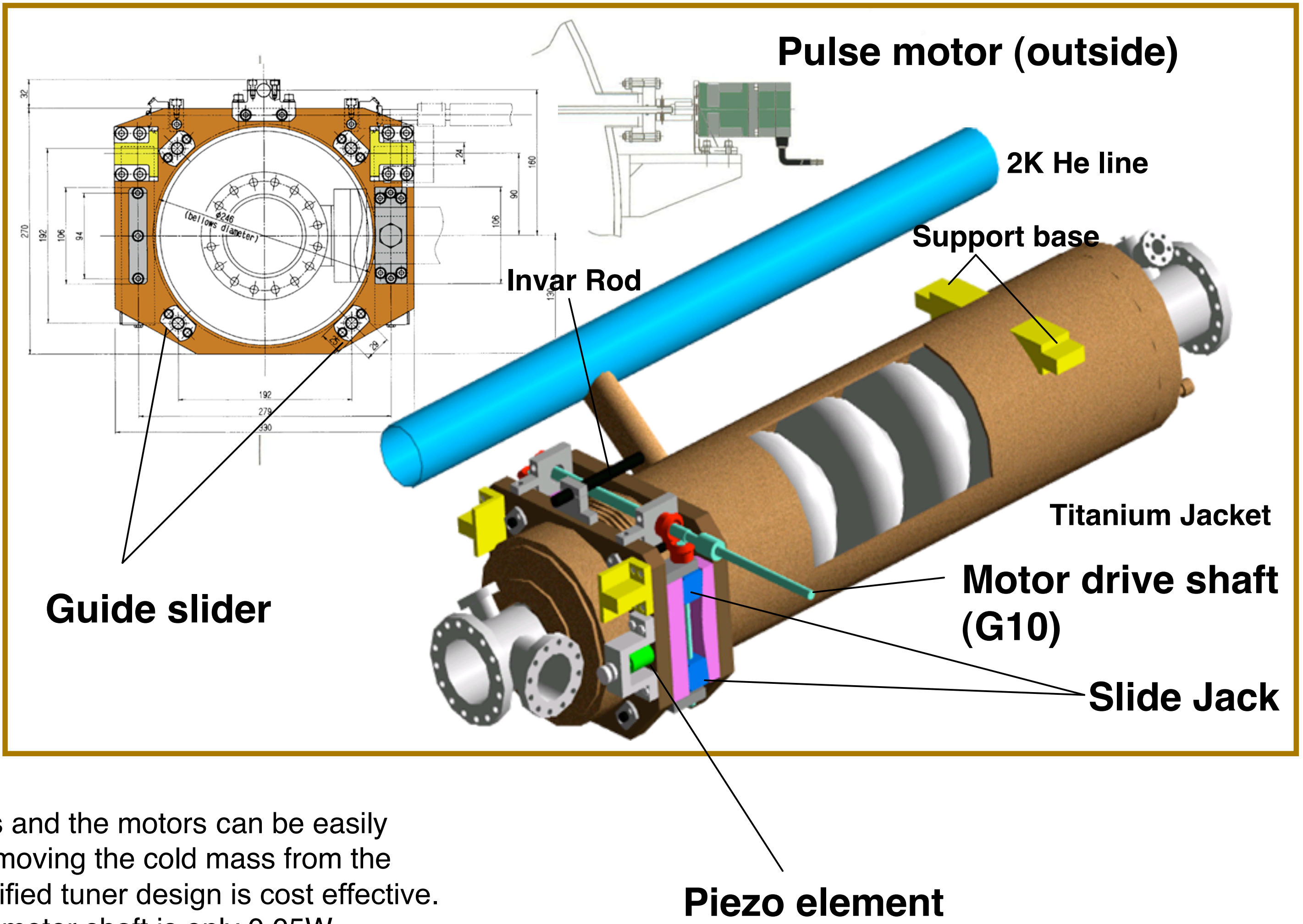

## 2. Cavity Shape optimization for beam pipe aperture increase.

“Cell taper” is optimized for field flatness on the beam axis, in accordance with increase apertures of the beam pipe and the coupler port and resultant high power transmission.



# Baseline Cavity Design Improvement cont.

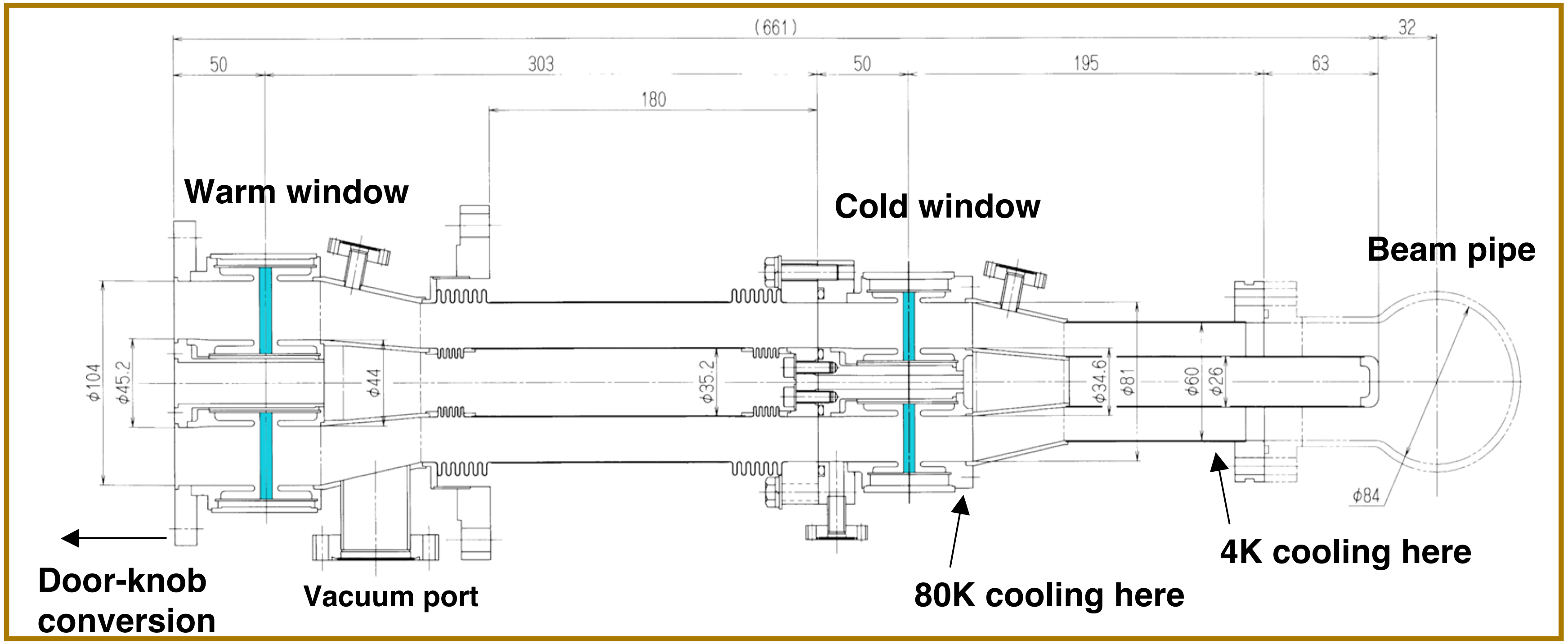
3. **Simplification of Tuner mechanism, serviceability of Piezo Element, Pulse Motor to stay outside, etc**




The piezo elements and the motors can be easily serviced without removing the cold mass from the cryostat. This simplified tuner design is cost effective. The heat load from motor shaft is only 0.05W.

# Baseline Cavity Design Improvement cont.

## 4. Improved input coupler design for simplicity & reduced cost (no tuning)




Co-axial coupler with disc ceramic window is known as a good high power coupler used at TRISTAN, KEKB, SNS and J-PARC ADS. RF input of 2MW for this type coupler has been proven at SNS and ADS.
The co-axial diameter at the cavity input is increased for high power transmission.
By fabricating with enough accuracy for correct input coupling, the coupler adjuster can be eliminated, leading to a cost reduction. Tunability is not required in ILC operation.
By keeping the bellows short enough, the surface conditioning time of RF power can be reduced.

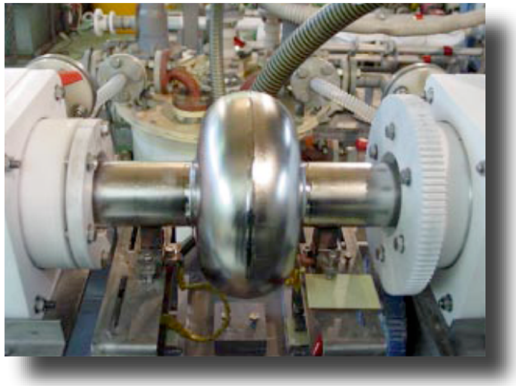
# Comparison of Cavity Designs

| Cavity system | TTF | | STF | improvement |
|---|---|---|---|---|
| Operation Gradient | 24MV/m (TESLA500) | 35MV/m (TESLA800) | 35MV/m | |
| cavity shape | iris ø70mm<br>beam pipe ø78mm<br>cell taper 13degree | ← | iris ø70mm<br>beam pipe ø84mm<br>cell taper 10degree | beam pipe diameter increase |
| cavity system regidity including jacket&tuner | ~ 40000 N/mm | ← | ~ 110000 N/mm | jacket end plate reinforcement |
| correction of Lorentz detuning | ~ 200 Hz | ~ 600 Hz | ~ 300 Hz | within cavity resonance half width |
| correction by Piezo | 1.3 μm | 4 μm | 1.5 μm | enough short piezo<br>small klystron mergin |
| Tuner mechanism | Lever arm<br>at beam pipe | Brade + Lever arm<br>at He jacket center | Slide jack<br>at He jacket center<br>motor outside | easy exchange of piezo and motor,<br>simple mechanism |
| Input coupler | TTF-III | TTF-IV ? | TRISTAN type coaxial | simple structure<br>good for high power<br>low cost |
| dimension of coupling port | outer ø40mm<br>70Ω | outer ø60mm<br>70Ω | outer ø60mm<br>50Ω | |
| RF power transmission | 240 kW | 350 kW | 350 kW | |
| ceramic window | cylindrical | ? | disc | |
| coupling adjustment | tunable | ? | fixed | |

# High gradient Cavity (type LL, 45MV/m) named ‘ICHIRO Cavity’

## 1 cell LL cavity Test

**( re-startup of surface treatment facilities, vertical test stand )**



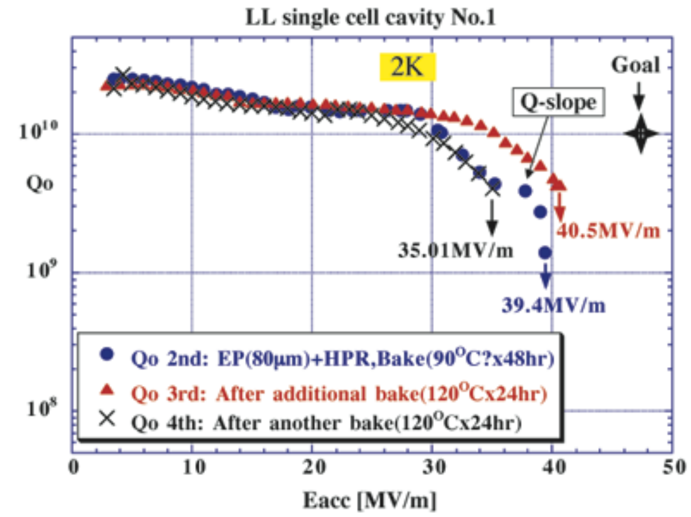
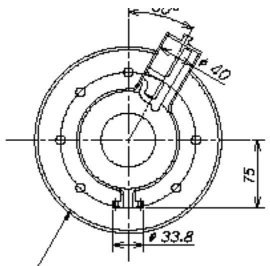


Fig.1 LL single cavity No.1 2nd-4th test results

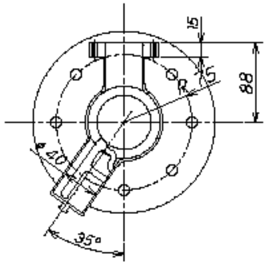
**Found & fixed the problems on procedure & facility:**

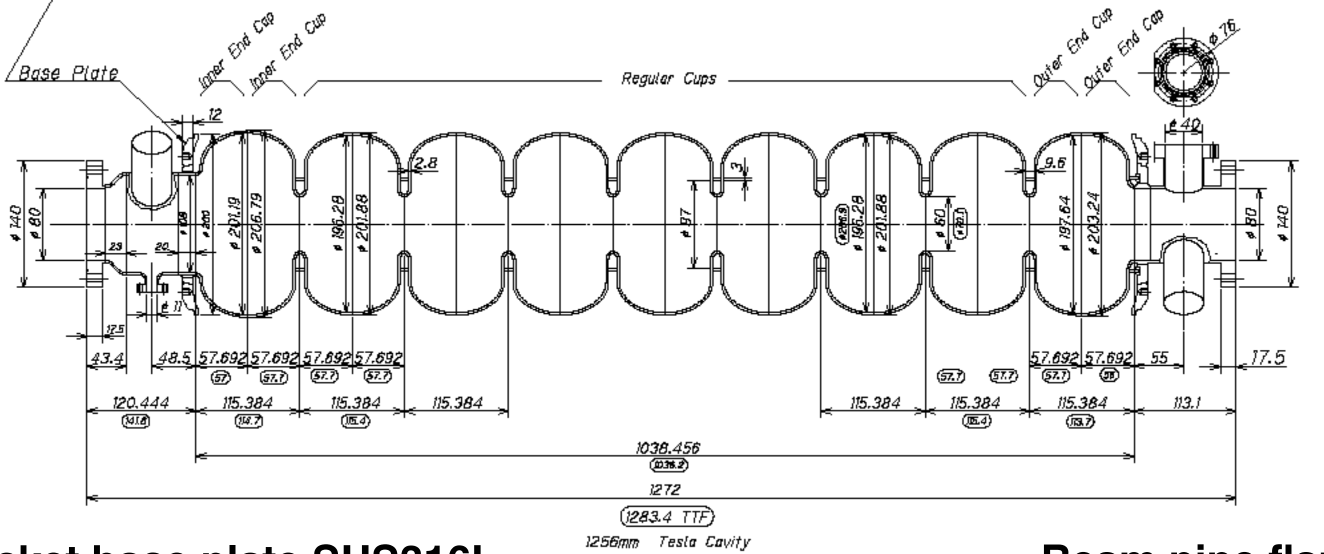
1. Procedure of EP acid level control.
2. Aged EP acid cause oxidation on the surface.
3. Oil contamination in HPR water.

# ICHIRO 9-cell cavity



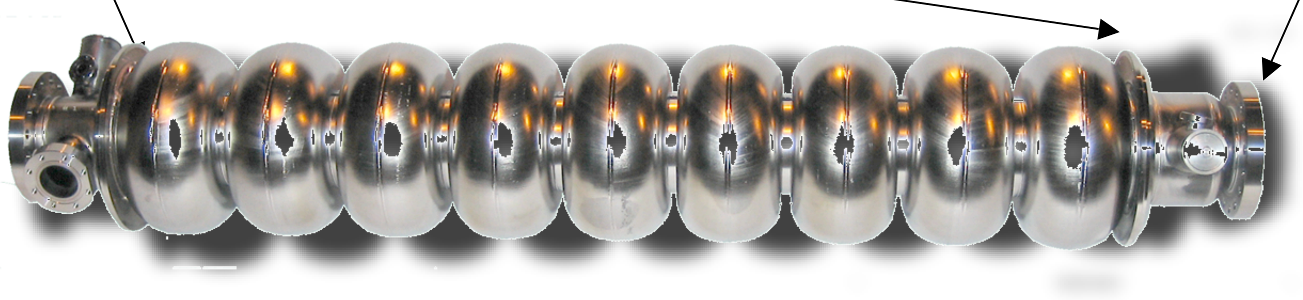

**Already completed and waiting for cold test**




**He jacket base plate SUS316L**

**Beam pipe flange SUS316L**

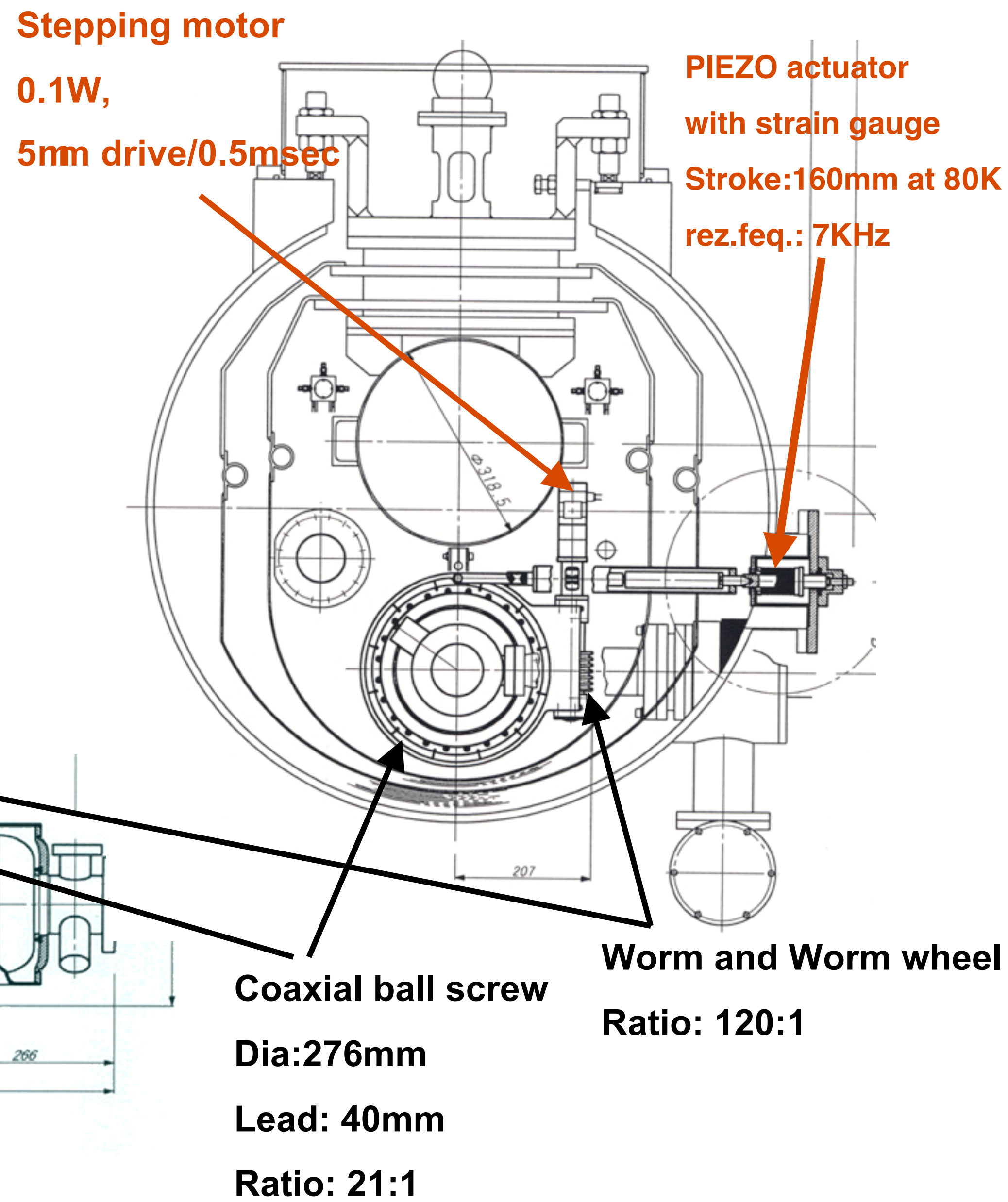


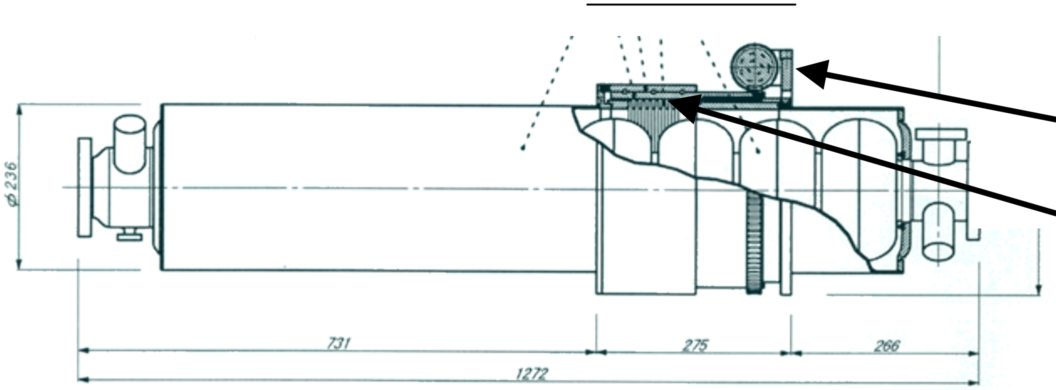
# Cavity Design comparison with TESLA

| | TTF | STF 45MV/m | Advantage/Disadvantage |
|---|---|---|---|
| Operation gradient | 23.4MV/m 35MV/m<br>XFEL TESLA800 | 45MV/m | 1-1.1 TeV in 40km tunnel.<br>If superstructure, 33km for 1TeV |
| Cavity shape | Iris ø70<br>Beam pipe ø78<br>cell taper 14° | Iris ø60<br>Beam pipe ø80/ø108<br>cell taper 0° | Tighter tolerance due to severe wake field |
| R/Q[Ω] | 1036 | 1144 | 10% higher electric efficiency |
| Ep/Eacc | 2.00 | 2.31 | |
| Hp/Eacc[Oe/(MV/m)] | 42.6 | 37.8 | Eacc max 46-49MV/m |
| Cell-to-cell coupling | 1.86 | 1.55 | F-flatness more sensitive on fabrication error |
| Tolerance[mm] | 250 | 170 | |
| Sensitivity for Lorenz detuning[Hz/(MV/m)$^2$] | 1 | 1.18 | Wide detuning range |
| Lorenz detuning[Hz] | 200 600 | ~1500 | Need wide range tuner |
| He jacket material | 5t Ti | 3t SUS316L | No matter with Japanese high pressure code |
| RF transmission power[kW] | 240 350 | 500 | Need higher input coupler |

# Tuner mechanism for ICHIRO cavity

| | TTF | KEK Tuner |
|---|---|---|
| **Motor location** | Beam pipe 2K | No anchor |
| **Tuner mechanism** | Lever type | Coaxial ball screw |
| **Motor driving power** | | 0.3gf / 5mm 0.1W |
| **PIEZO location** | Beam pipe 2K | 80K shield |
| **PIEZO tuning range** | 600Hz | ~1500Hz |
| **Resolution** | | |
| **Ball screw tuner** | | 120Hz |
| **PIEZO tuner** | | 1Hz |

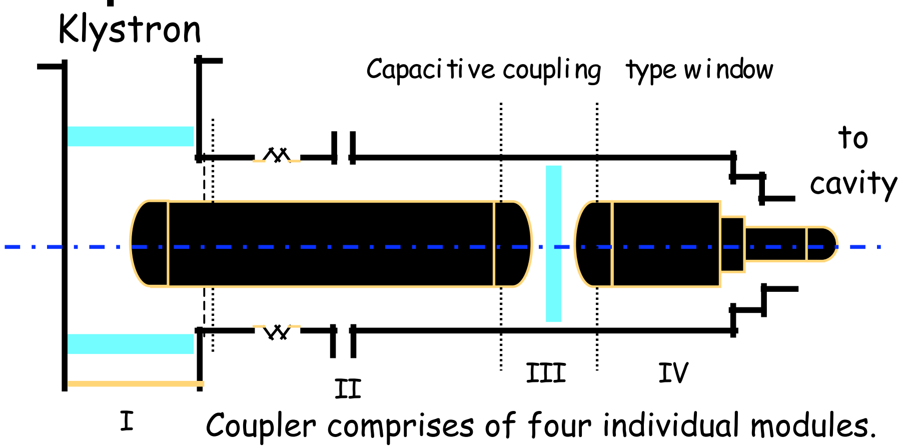


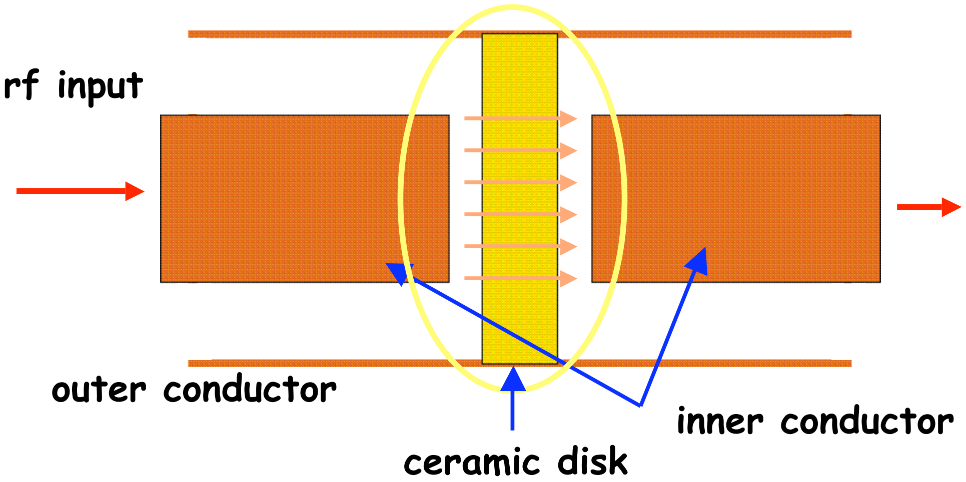



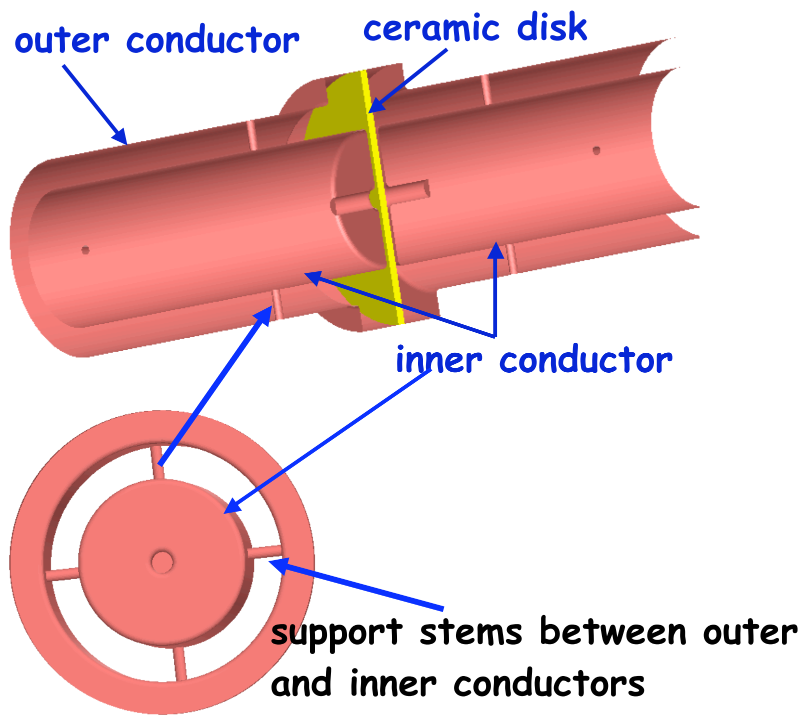
# Input Coupler for ICHIRO cavity

## Capacitive Coupling Coaxial Line for Input Coupler

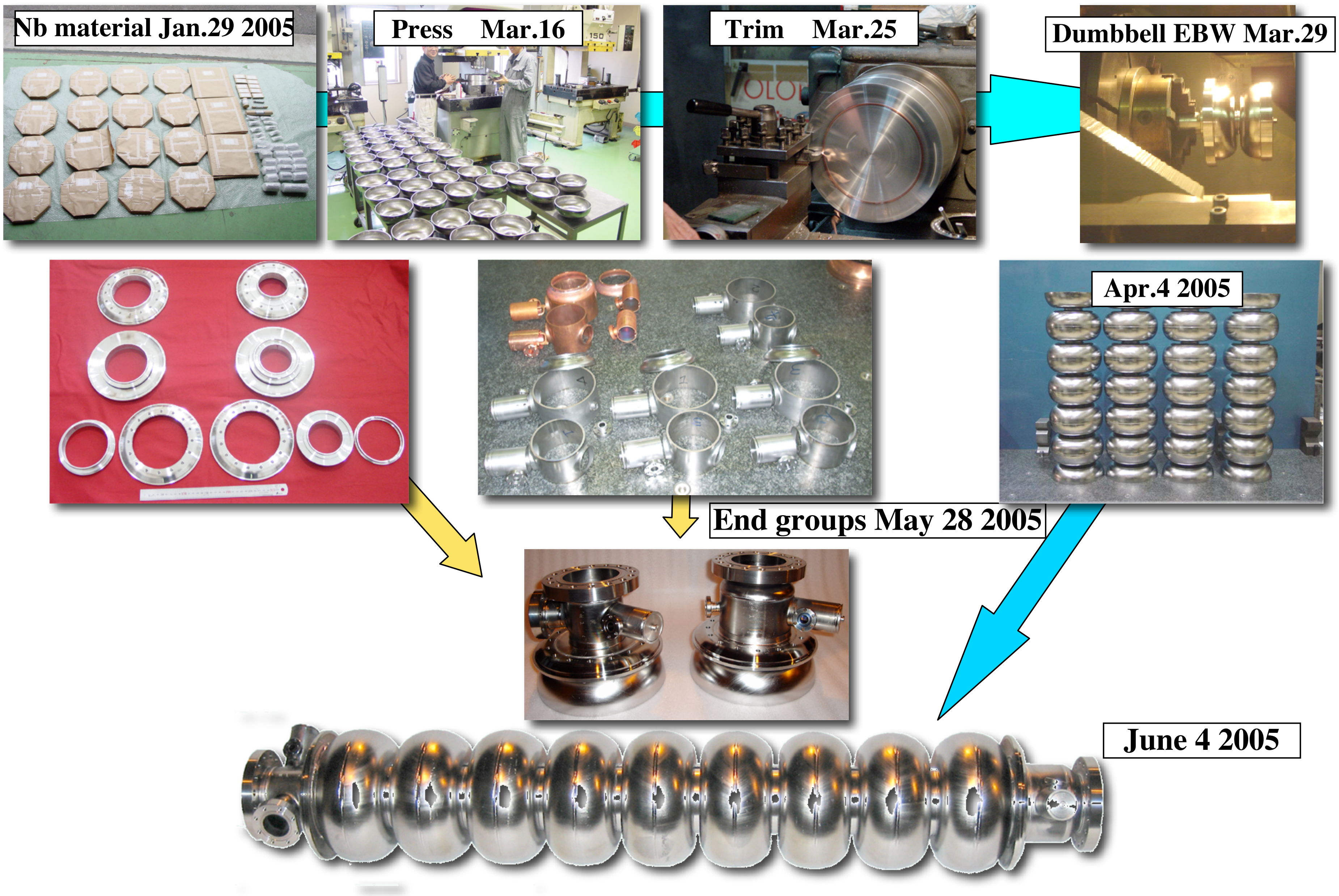
- **Capacitive coupling type rf** window at cold temperature.
  - reduce the thermal energy flow.
- **Modular structure.**
  - improve reliability.
  - system simple.
  - reduce cost.
- **Conventional fabrication method as klystron.**
  - keep reliability.
  - improve mass productivity



# ICHIRO cavity fabrication



# ICHIRO cavity treatments

Pre-tuning after annealing
on May 21-24

Electropolishing @Nomura Plating
on May 27

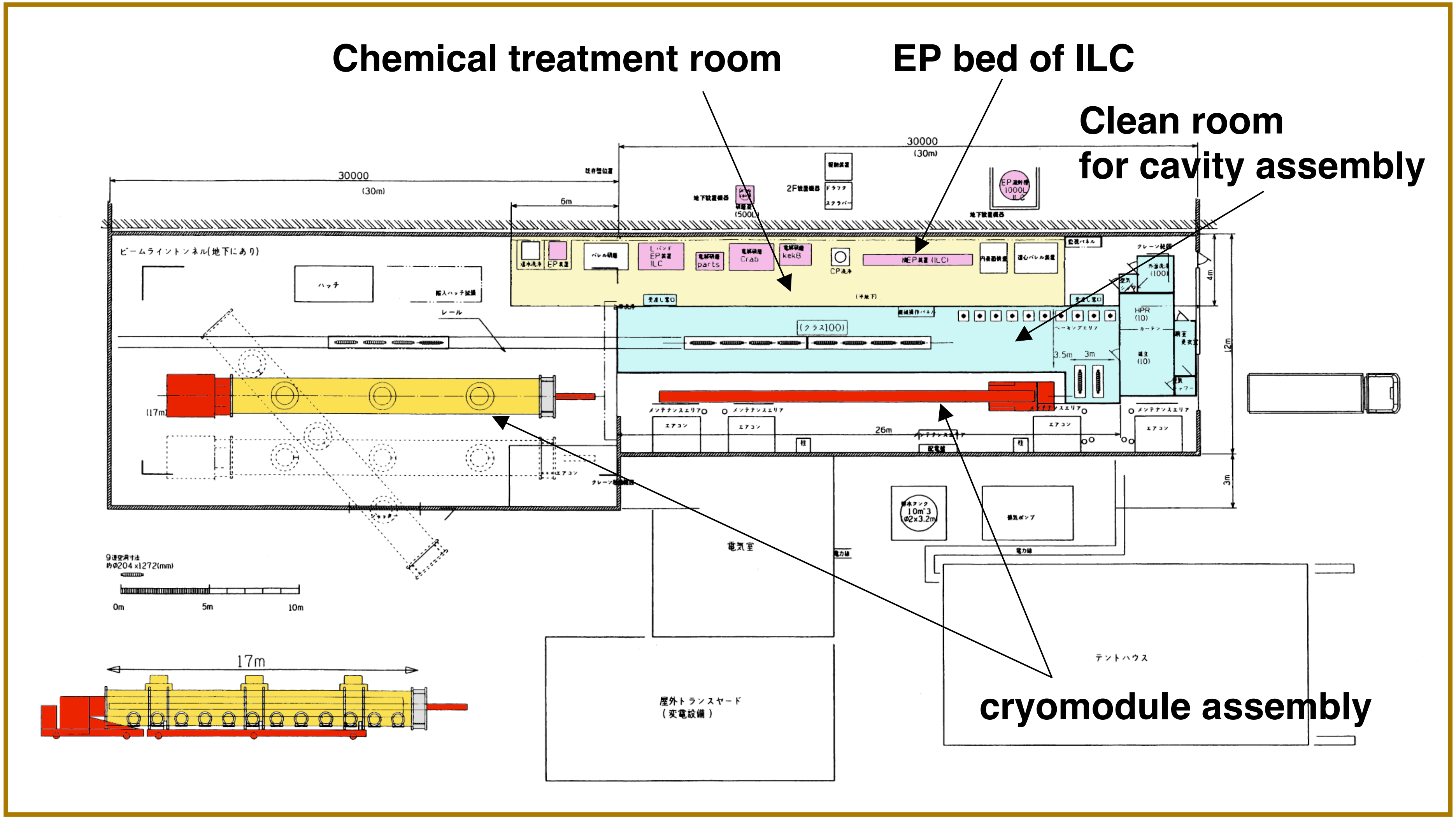
HPR @ KEK on May 27-28

$120^{O}$C baking on May 29-31

Cavity assembly on May 28

# STF Infra-structure

**EP: new EP(Electro chemical Polishing) facility is under design.**
**Clean room: new clean room for cavity assemble is under design.**



# Time Line & Milestone of STF accelerator

2005.05~07 tender for 35MV/m cavities, couplers & cryostats.

2005.01~09 fabrication and test of 45MV/m cavities.

2005.04~2006.03 fabrication and test of couplers for 45MV/m cavities.

2005.10 1st 35MV/m cavity delivered to KEK.

2005.11 5MW RF power source ready.

2005.12 couplers high power test begin.

2006.03 8 cavities ready for installation (vertical test complete).

2006.04 8 couplers ready for installation (high power test complete).

2006.04 cryostat ready for installation.

2006.07 cryomodule complete.

2006.09 cryomodule in the tunnel.

2006.10 cryomodule cool down start.

2006.12 beam test start.

# Time Line & Milestone of STF infra-structure

2005.04 movement of cryogenic system to STF.

2005.07 tender for clean room.

2006.03 cryogenic system ready to operation.

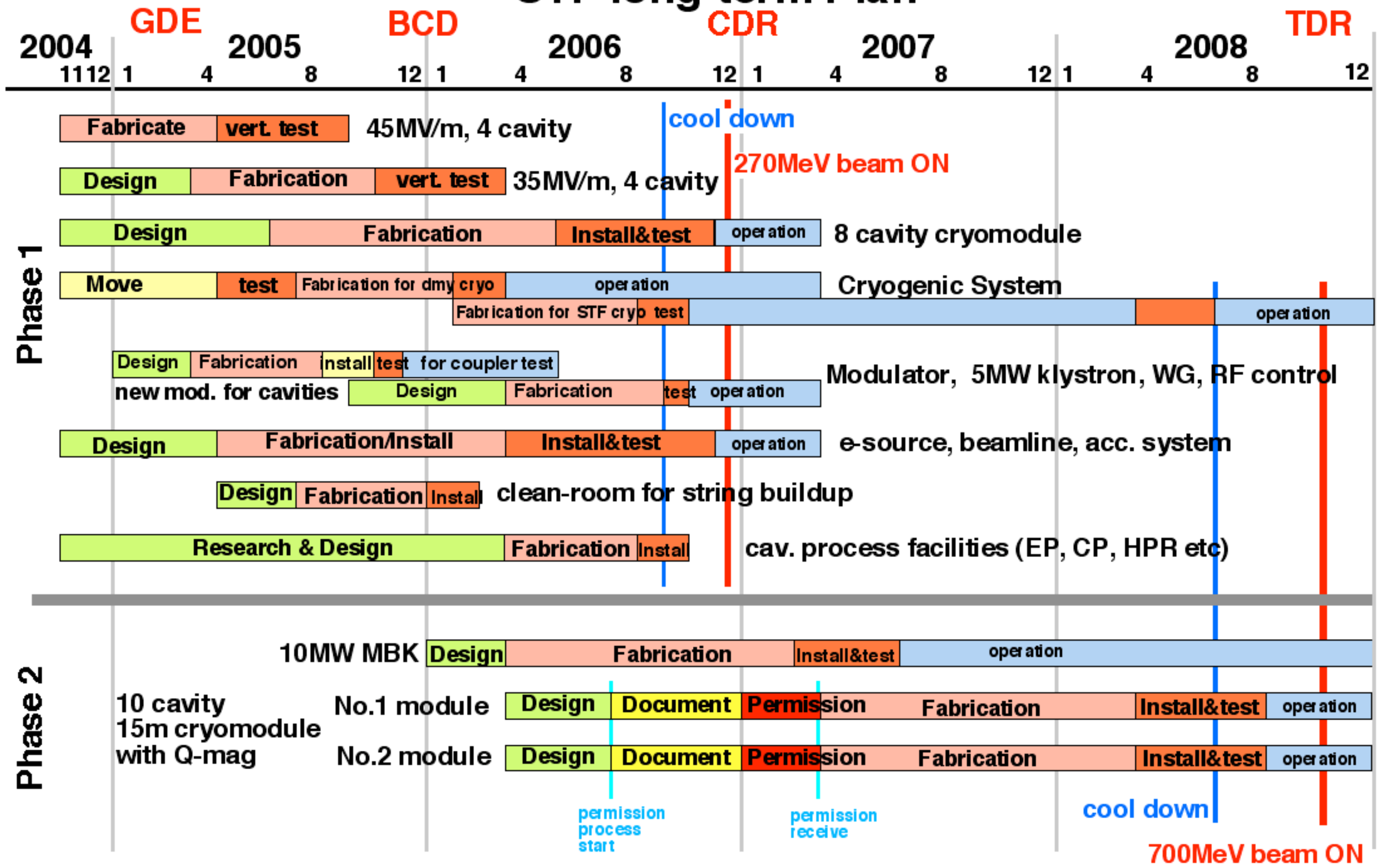
2006.03 clean room complete.

2006.04 tender for EP, HPR and vertical test facilities.

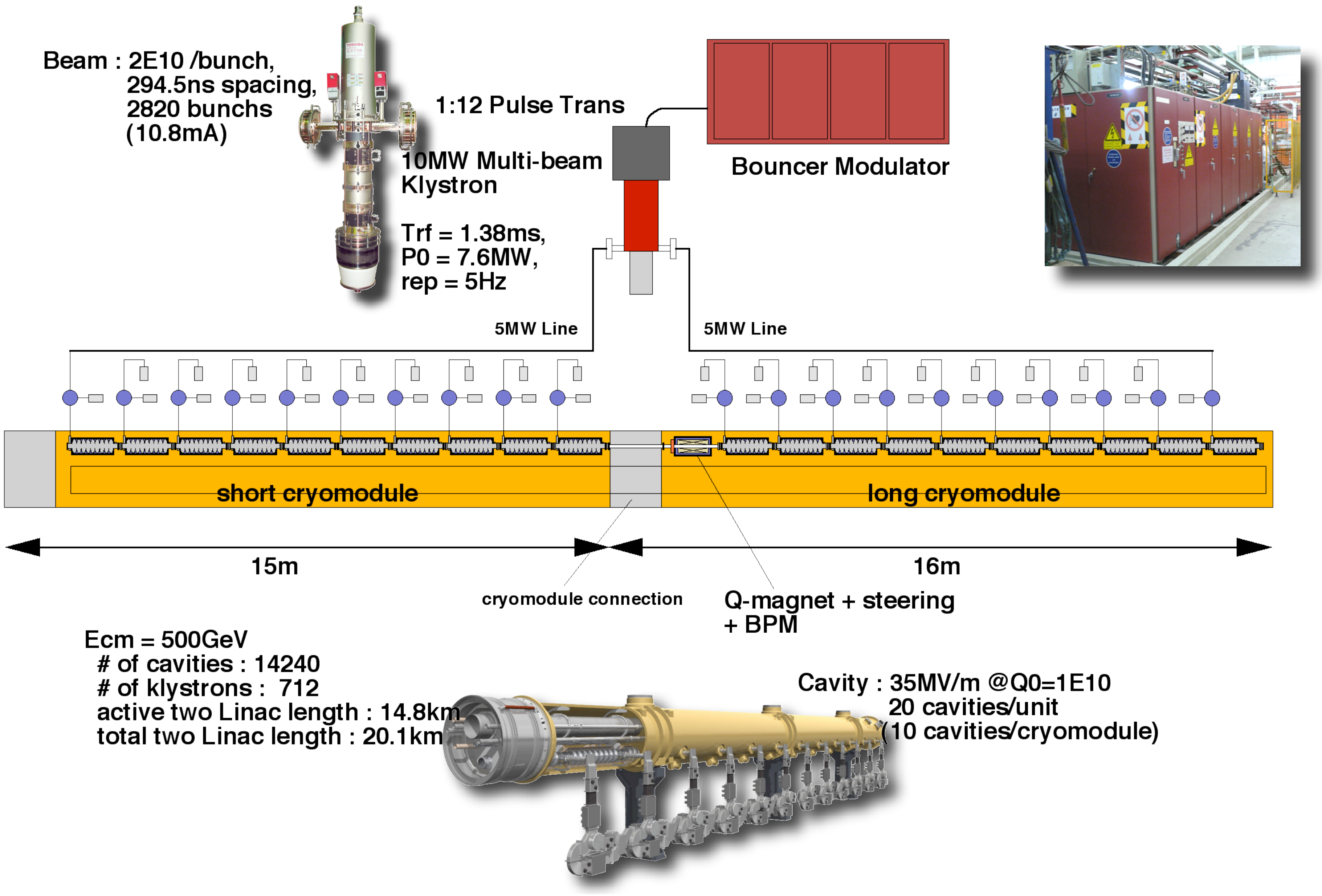
2006.10 EP, HPR and vertical test facilities complete.
(infra-structure ready for STF phase 2 production.)

# STF long-term Plan

H. Hayano 04102005



# STF Phase 2 : Build ILC Main Linac RF unit



# STF phase 1 status summary

**(July, 2005)**

## Cryogenics

Cryogenic plant movement: done

2K cooling system: under construction

## Power source

modification of existing modulator:under construction.

new 5MW klystron:under fabrication.

LLRF:under design

## Cryostats (cryomodules)

calling for tender.

## Cavity system

35 cavity: calling for tender.

45 cavity: under vertical testing.

## Infra-structures

(cryogenics: He plant movement was over.)

STF place: J-PARC accelerator is under moving.

new EP: detail design started.

new clean room: detail design started.

end