STF Introduction

H. Hayano, 07202013

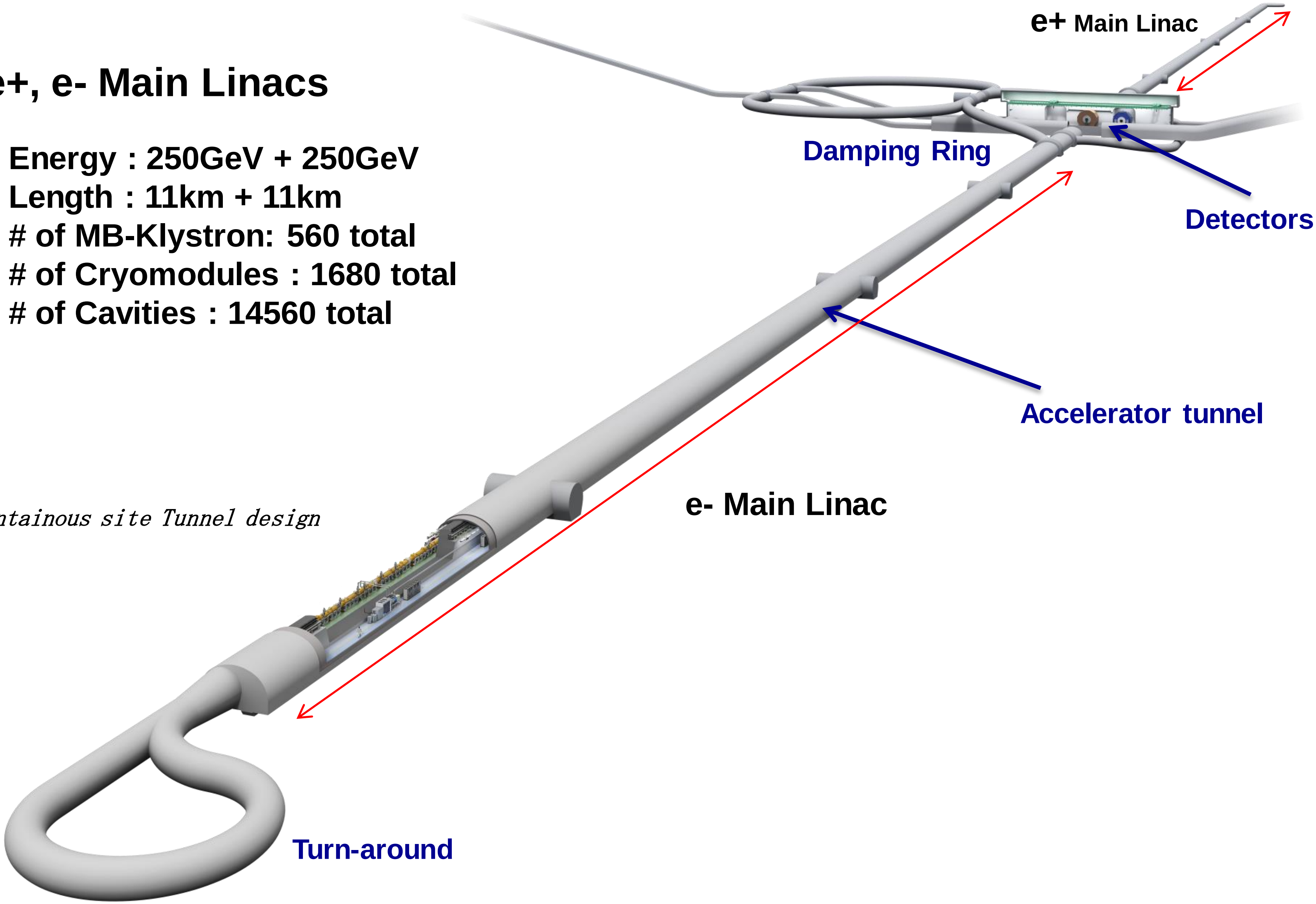
ILC Accelerator Introduction

Birds View of ILC accelerator : compressed image

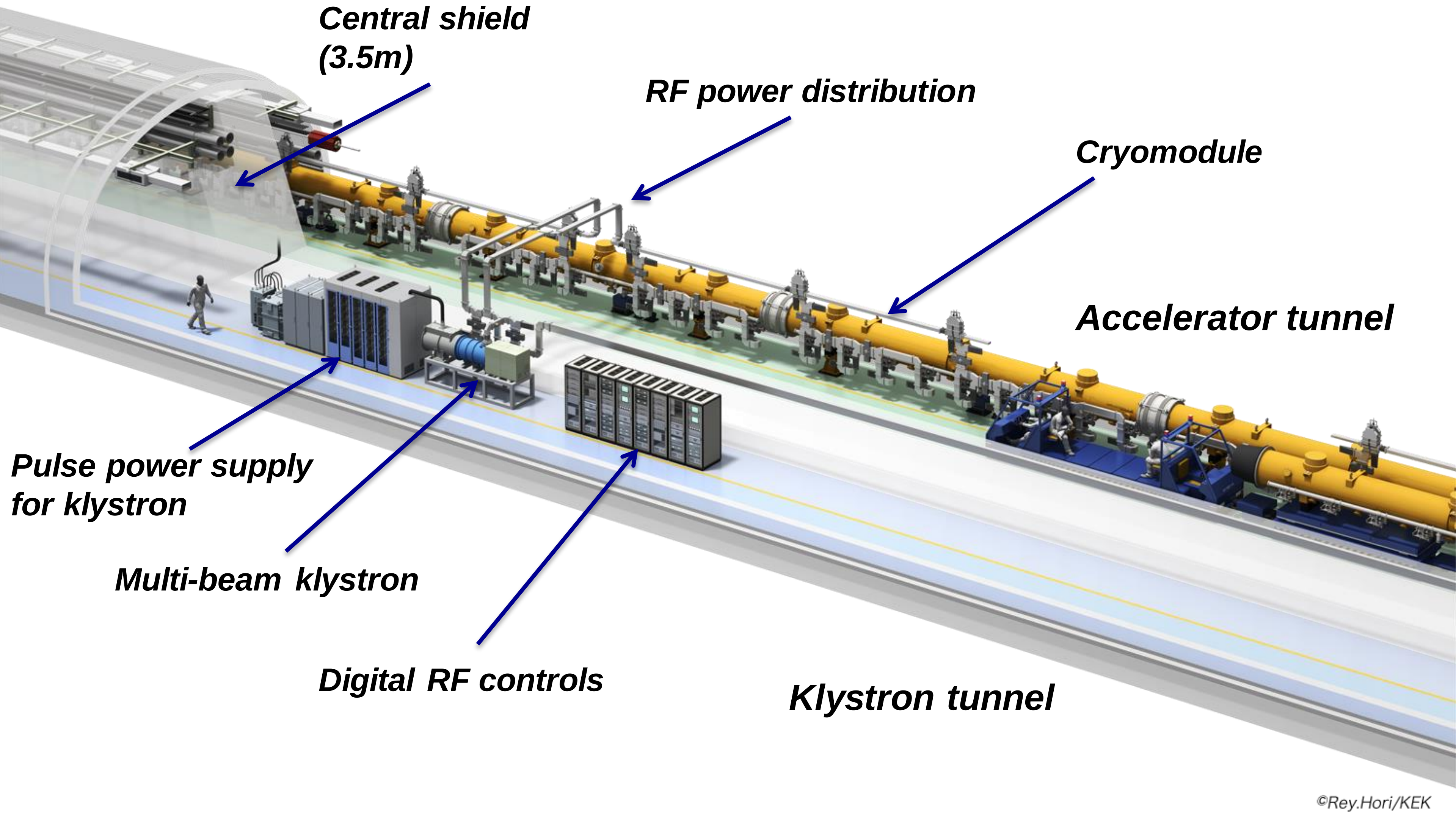
e+, e- Main Linacs

Energy : 250GeV + 250GeV
Length : 11km + 11km
# of MB-Klystron: 560 total
# of Cryomodules : 1680 total
# of Cavities : 14560 total

Mountainous site Tunnel design



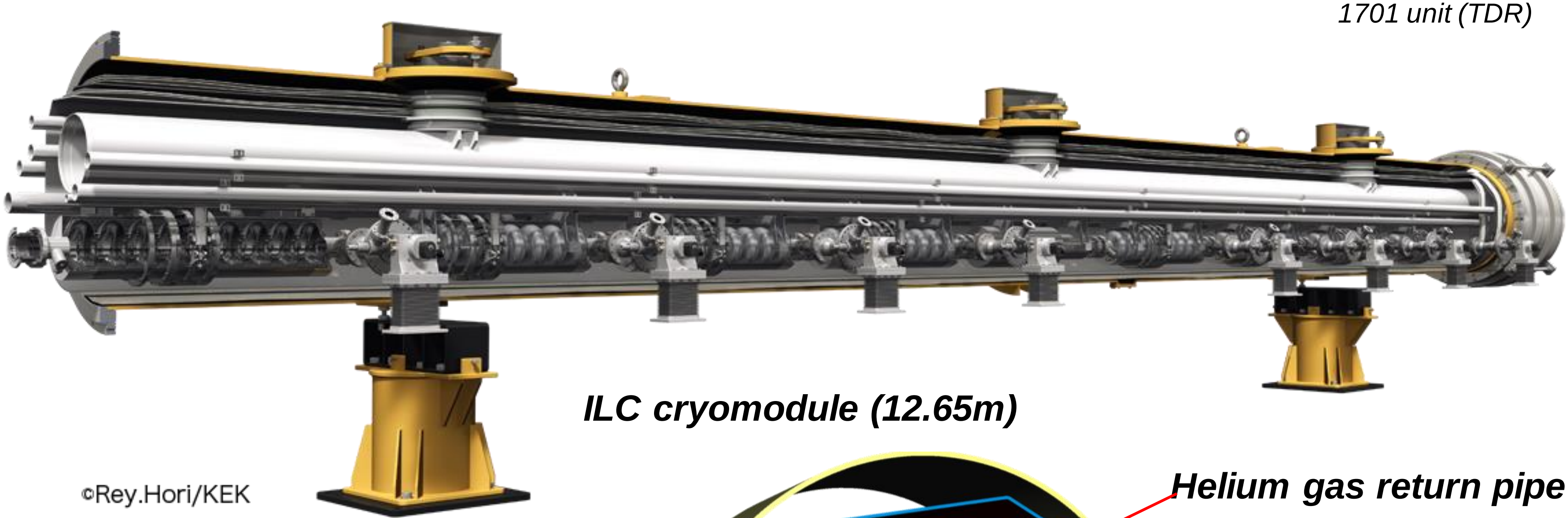
Main Linac Arrangement for Mountainous site Tunnel



Main Accelerator Module: Cryomodule

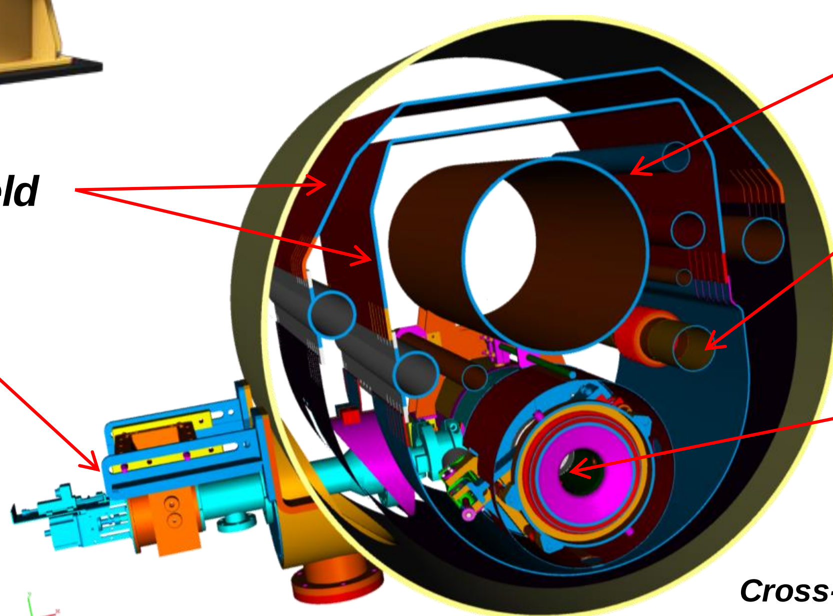
9 Superconducting Cavities in the 12m length, 1m diameter cryostat

1701 unit (TDR)



ILC cryomodule (12.65m)

©Rey.Hori/KEK



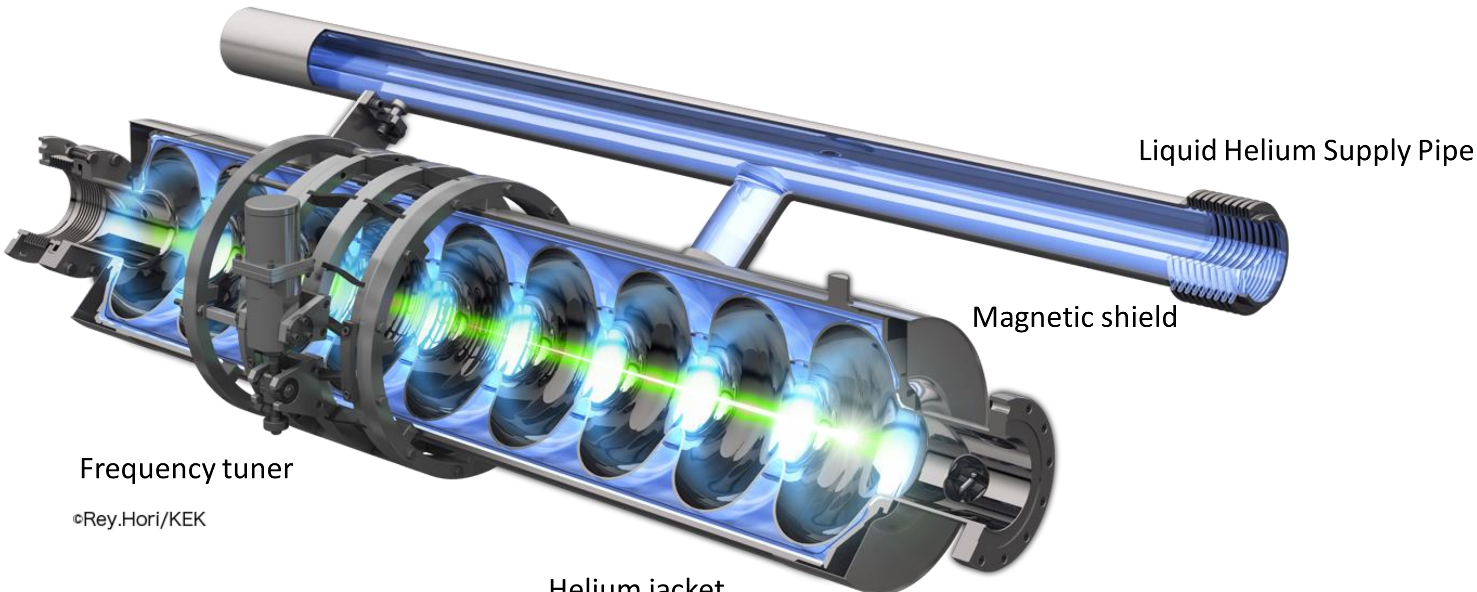
Cross-section from D. Kostin

Superconducting Cavity made by pure Niobium

14560 unit (TDR)

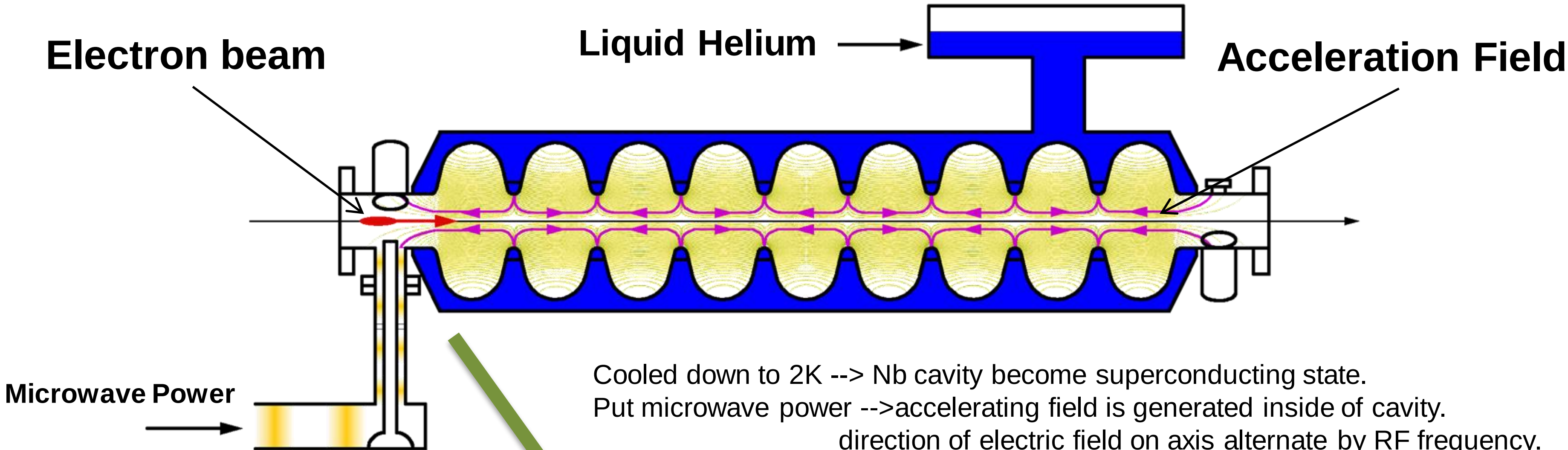
Picture of Superconducting Cavity (length 1.2m, diameter 0.2m)
Cooled down at temperature 2K, then become superconducting state.

Long lasting High Accelerating Field by small input RF power (RF wall loss is very small)

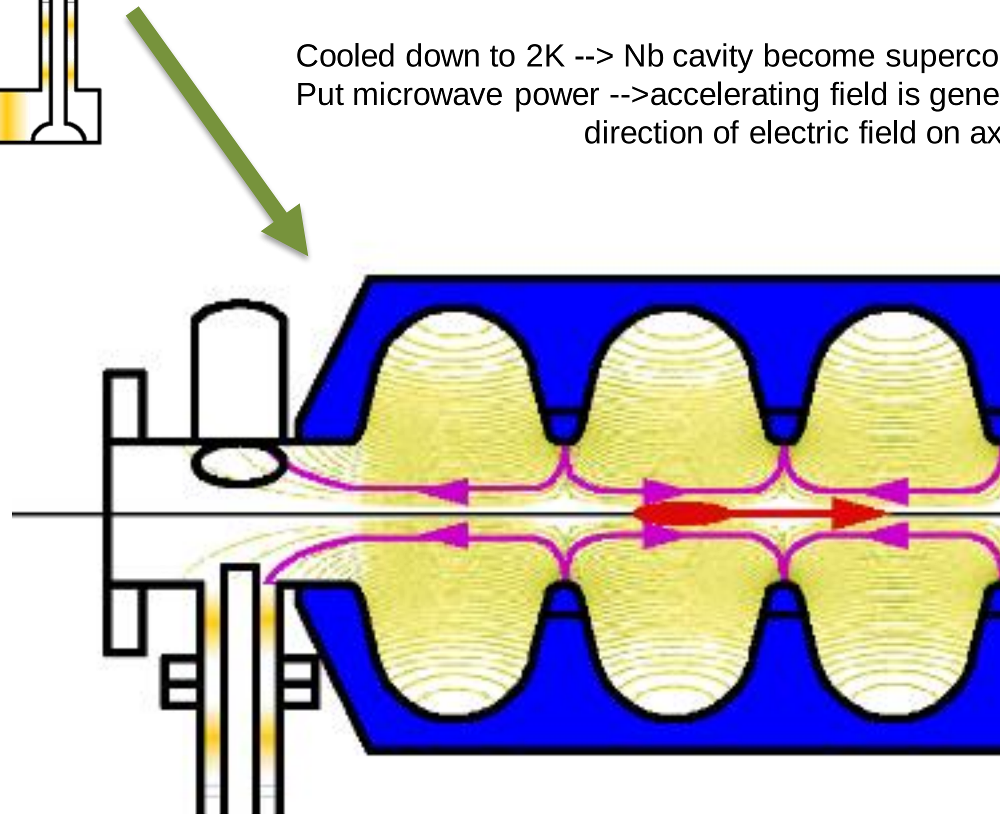


Helium jacket, magnetic shield, frequency tuners are installed around the cavity, then put into the cryomodule.

Principle of Electron beam Acceleration



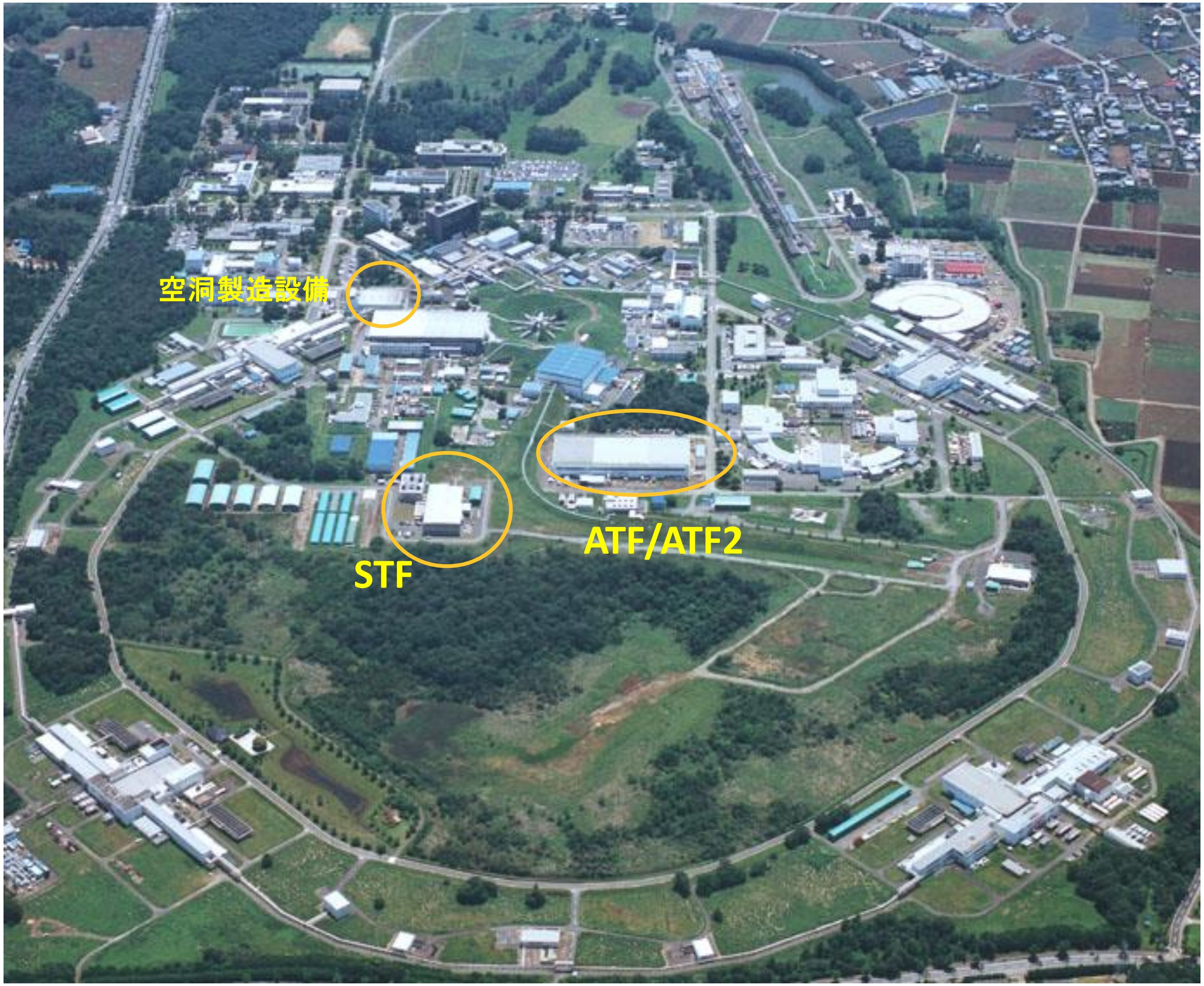
Cooled down to 2K --> Nb cavity become superconducting state.
Put microwave power -->accelerating field is generated inside of cavity.
direction of electric field on axis alternate by RF frequency.



TM_{010} π – mode
1.300 GHz

STF Introduction

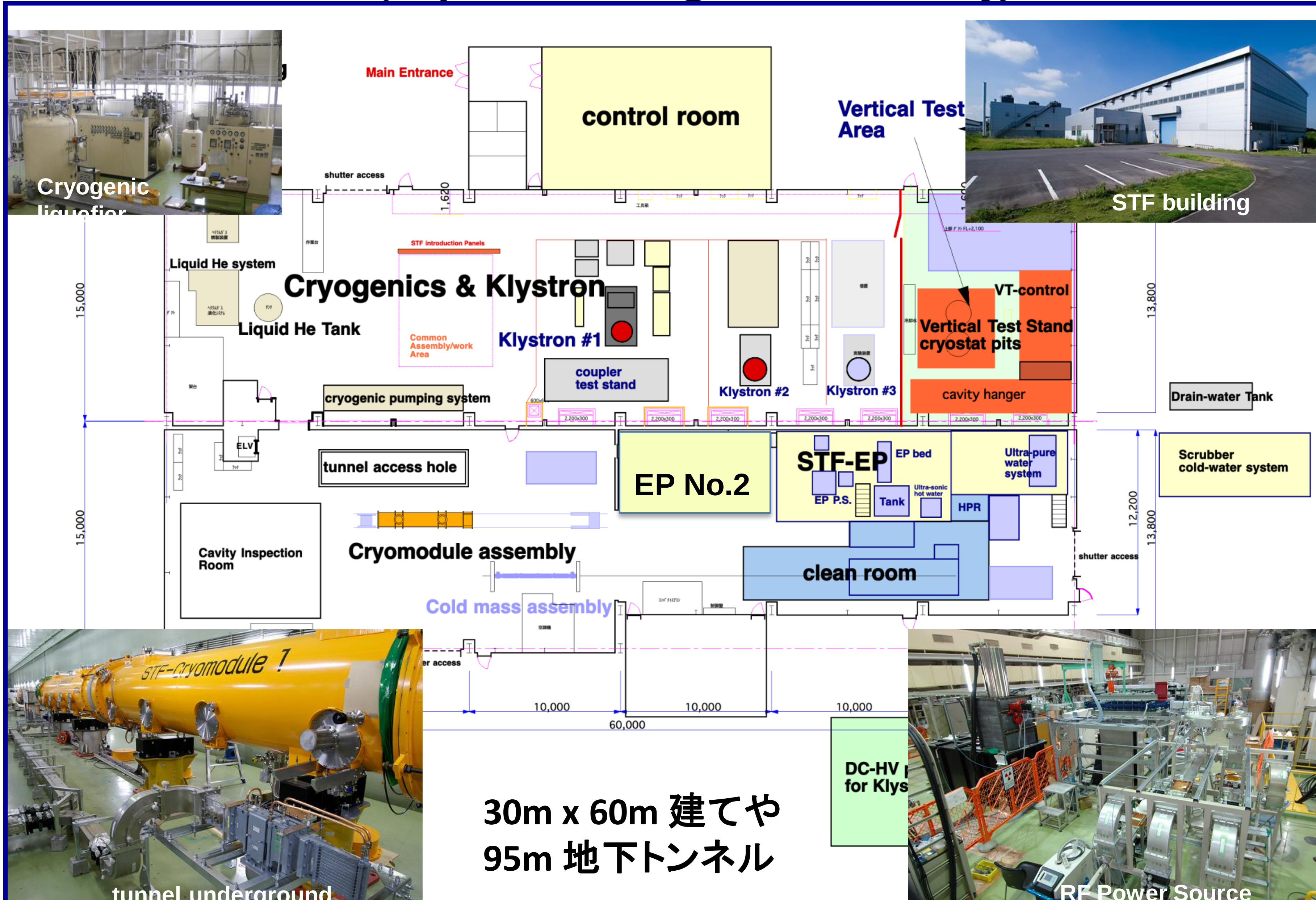
KEKにおけるILC試験設備の場所



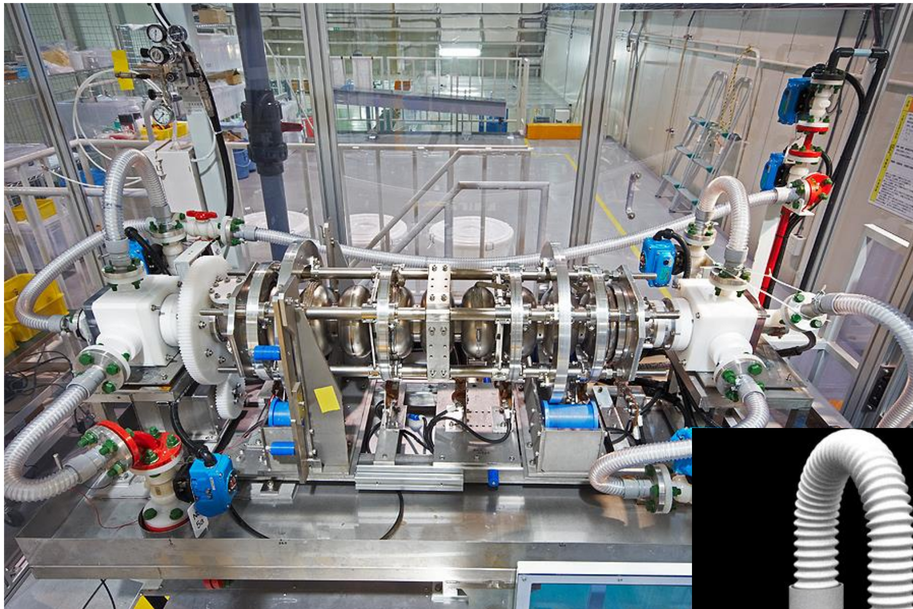
KEK　つくばキャンパス（北側上空より）

超伝導RF試験設備

STF (Superconducting RF Test Facility)



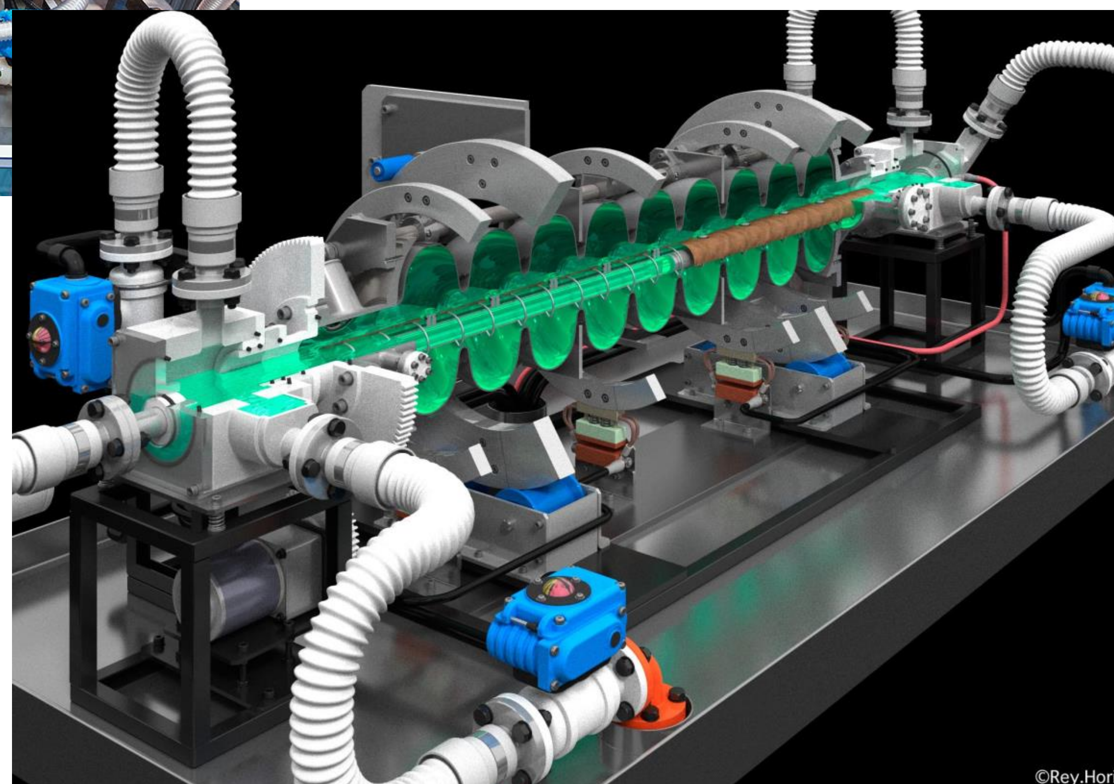
空洞内面の電解研磨処理



Electro-Chemical Polish

- *Use Sulfuric acid + HF mixture*
- *Apply voltage*
  - *between center Al electrode and Nb cavity*
- *Optimize parameter for smooth surface*
  - *without sulfur residual particle*
- *voltage and temperature are key parameter*
- *Successive rinsing is another key technology*

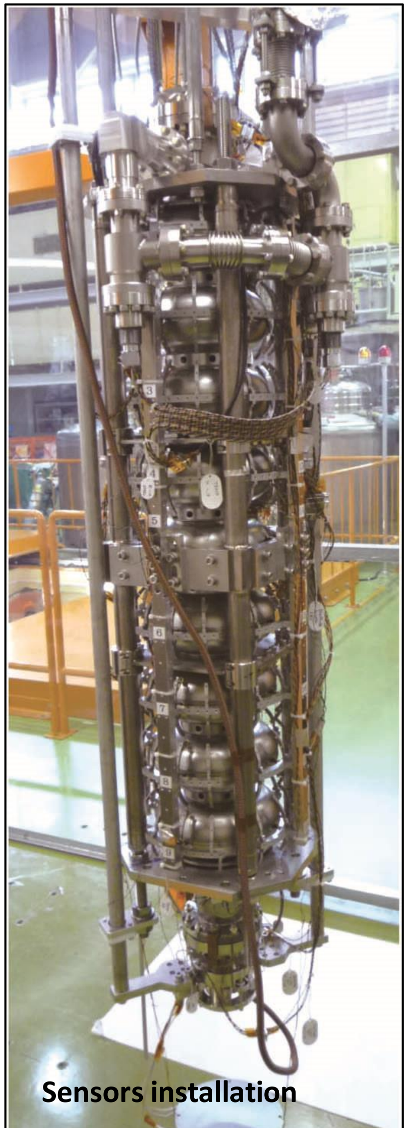
KEK STF EP 実際の写真

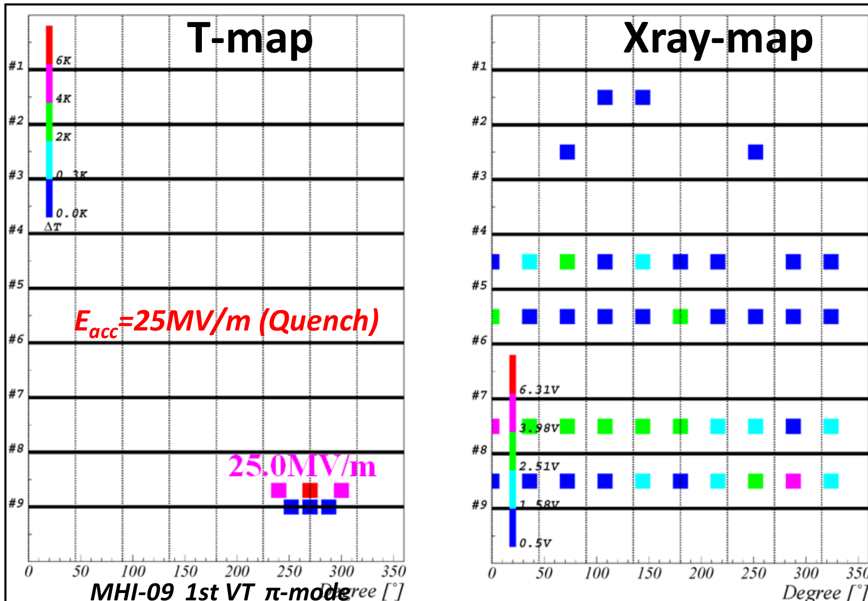


空洞の電界性能試験（縦測定）

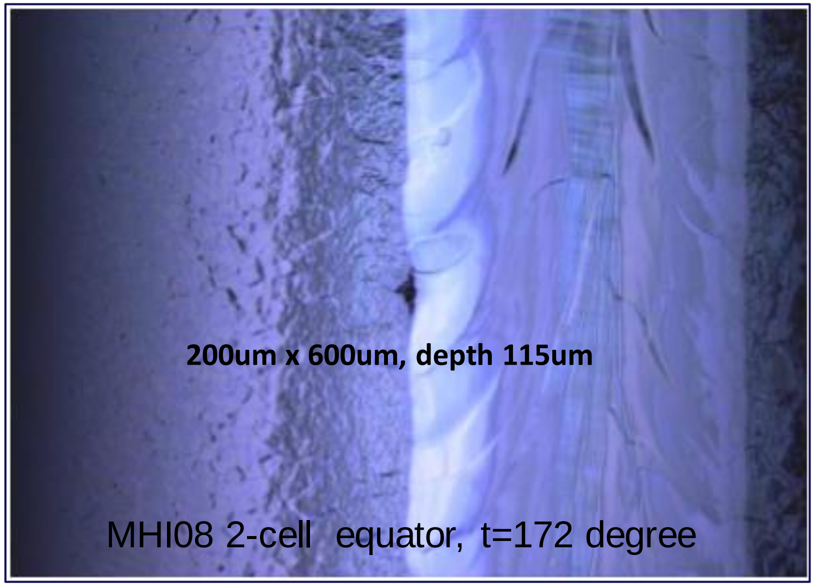
クエンチ場所を特定するための温度センサーマップとX線センサーマップ

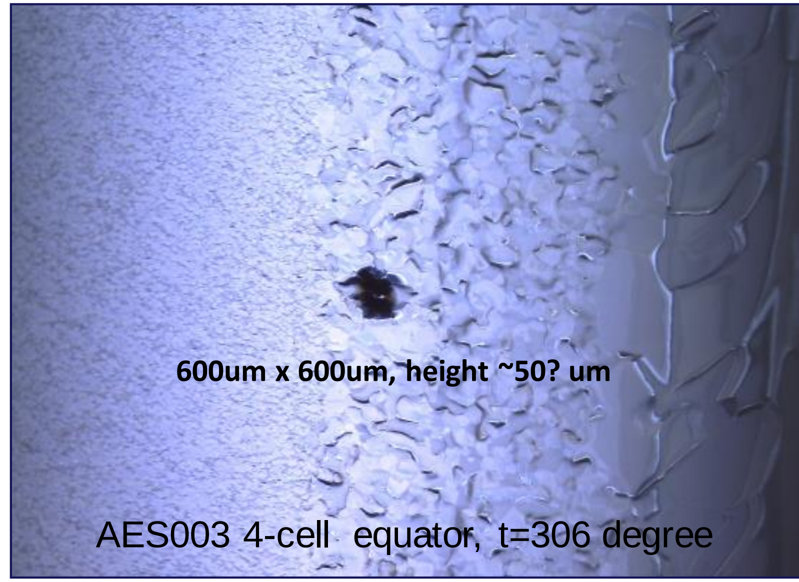
T-map & Xray-map, together with pass-band mode measurement, location of quench is identified. Inspection camera visualize what's happen inside.





クエンチ箇所の局所研磨修理





Pit; appeared after bulk EP, limit to 16MV/m

↓ local grinding & EP

27MV/m

↓ additional EP

38MV/m

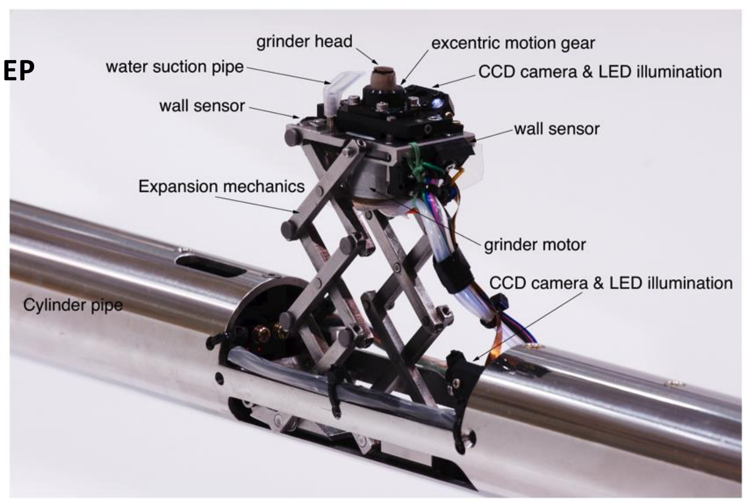
Bump at heat affecting zone, limit to 20MV/m

↓ local grinding & EP

30MV/m

↓ additional HPR and bake

34MV/m

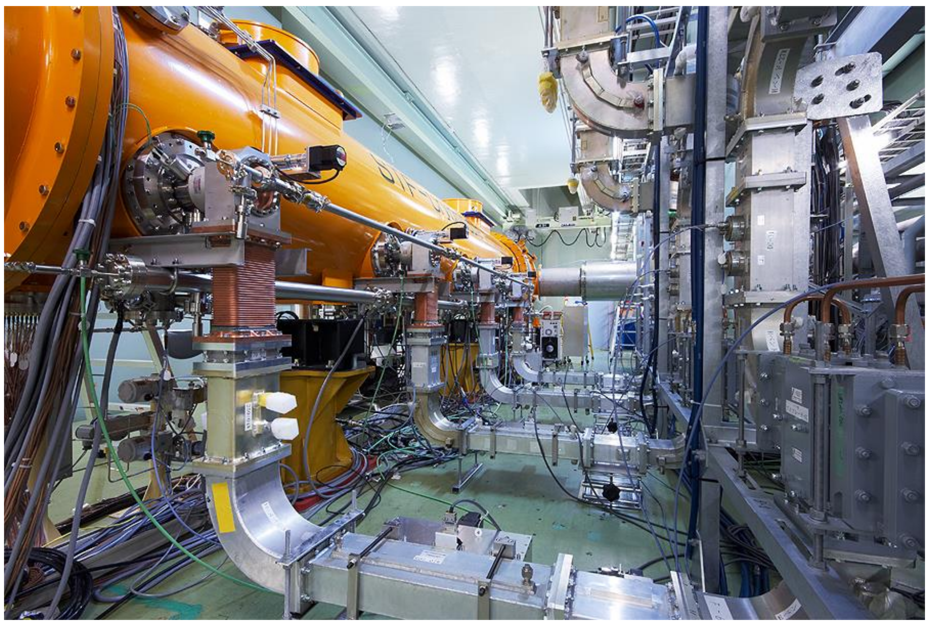


クライオモジュールのアセンブリーと電界性能試験

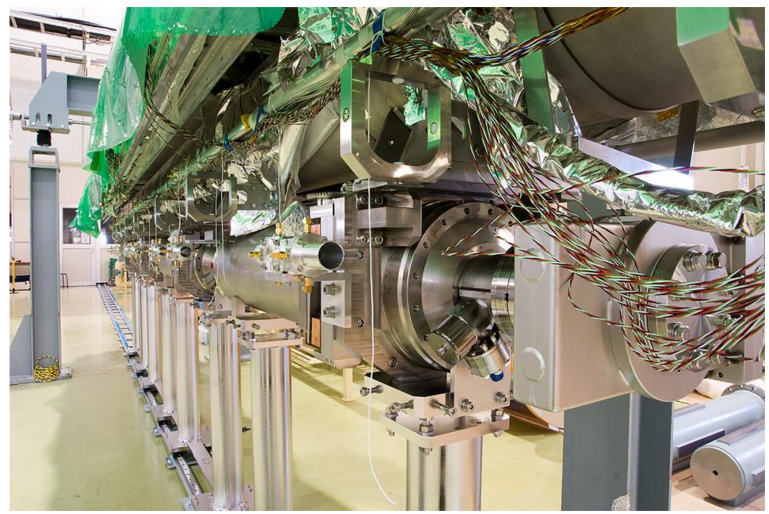
half size cryomodule test: May 2008 – Dec. 2008
Experience of ILC cryomodule technology

cryomodule assembly,
2k cryogenics technology,
low heat load technology,
cavity control for high performance for pulsed RF,
LLRF digital control technology,
RF power distribution, Qext control.

Cavity assembly in clean room



Loaded Q control using external phase shifter and reflector. +/-15% QL control was possible.



Cryomodule cold-mass assembly

Quantum-Beam Experiment

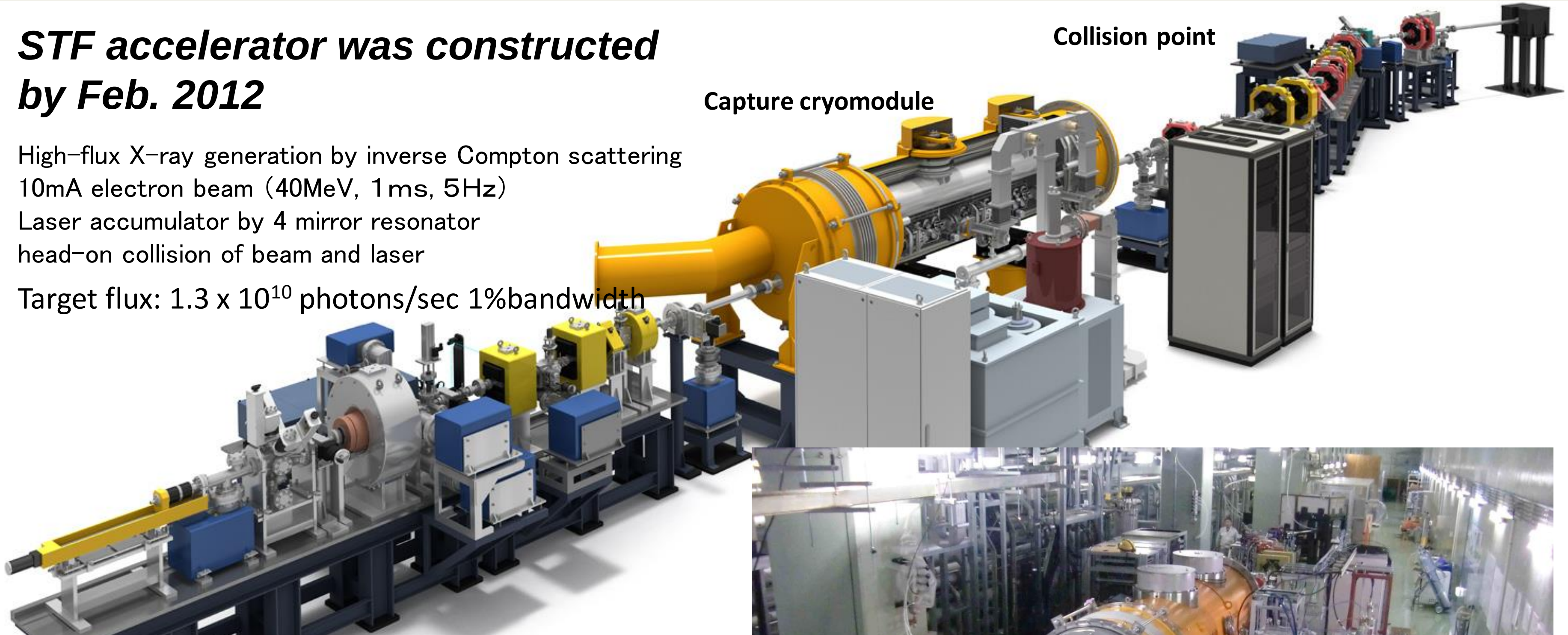
(STF Accelerator Injector-part commissioning)

STF Accelerator Injector (Quantum Beam)

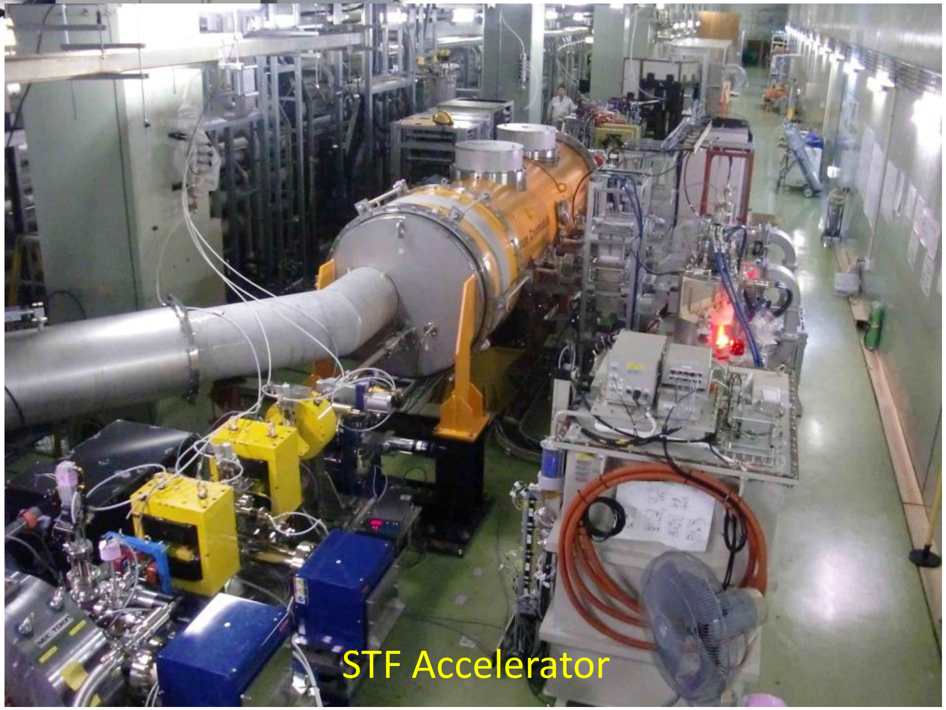
STF accelerator was constructed by Feb. 2012

High-flux X-ray generation by inverse Compton scattering
10mA electron beam (40MeV, 1ms, 5Hz)
Laser accumulator by 4 mirror resonator
head-on collision of beam and laser

Target flux: 1.3 x 10^{10} photons/sec 1%bandwidth

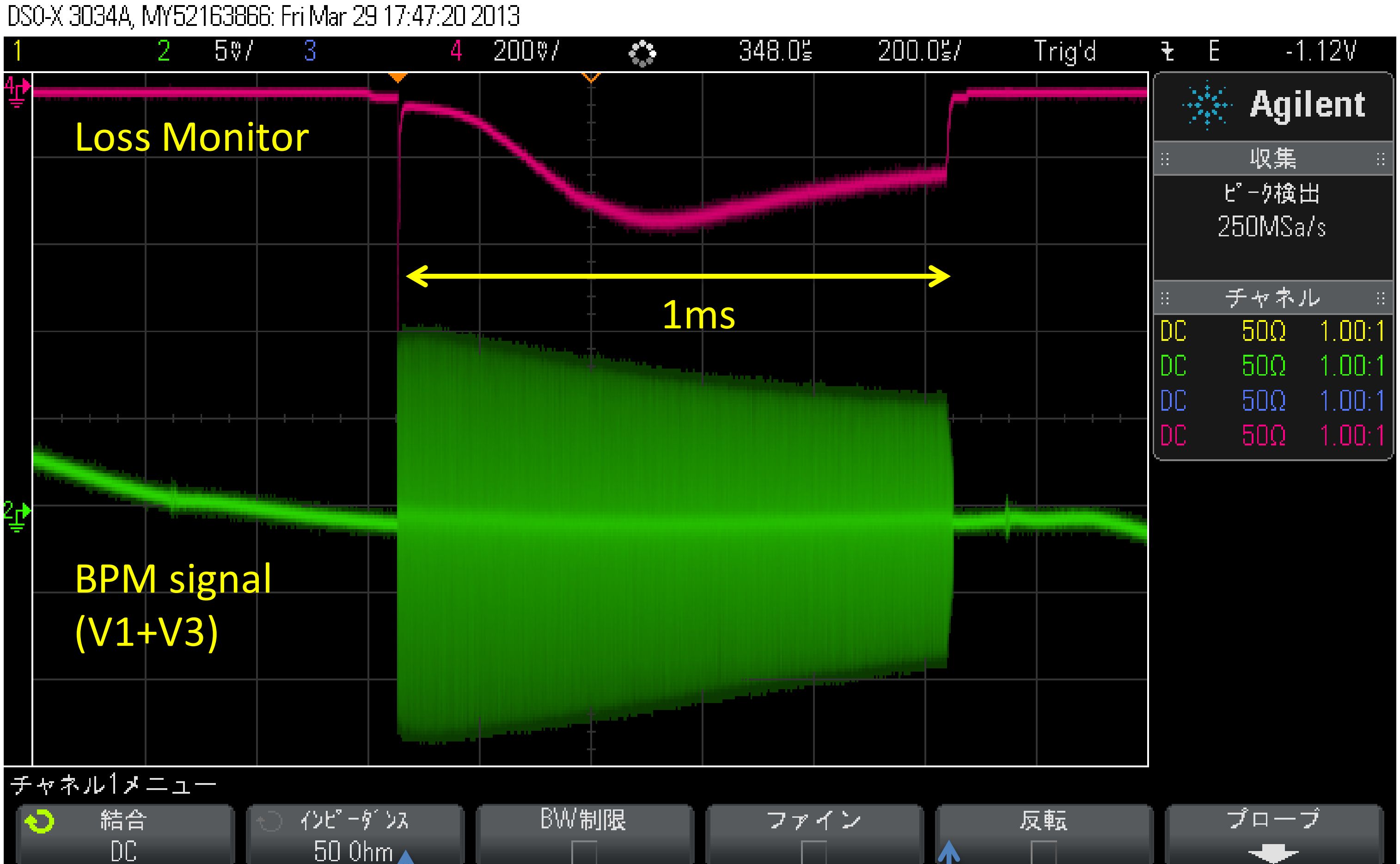


Beam operation : March – December 2012



Addendum : 1ms beam acceleration in STF accelerator

40MeV, 1ms, 7.5mA Beam Operation



9mA(peak current)

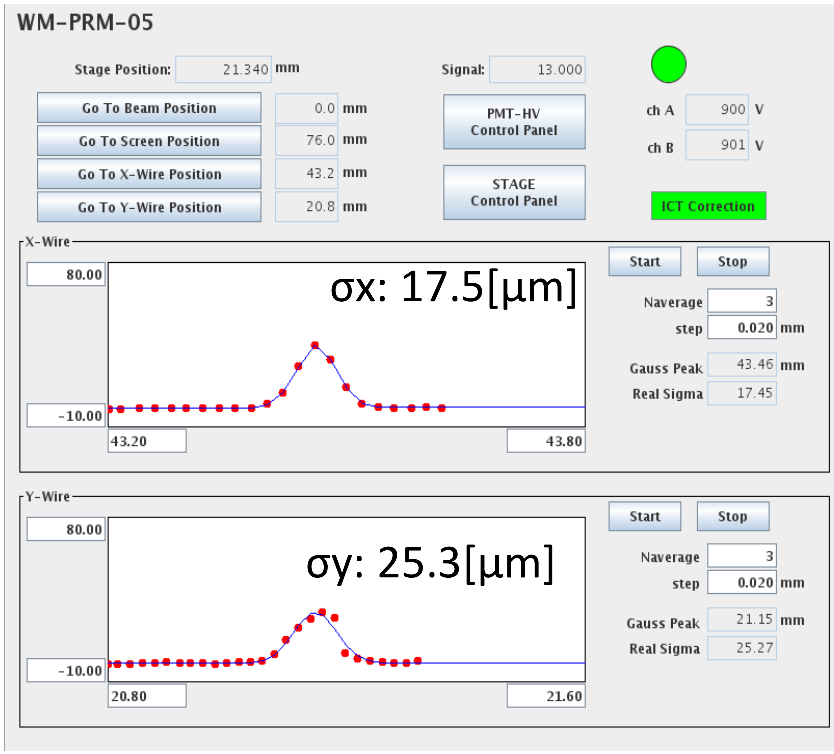
6mA(peak current)

* a sag of beam train came from Gun-laser profile

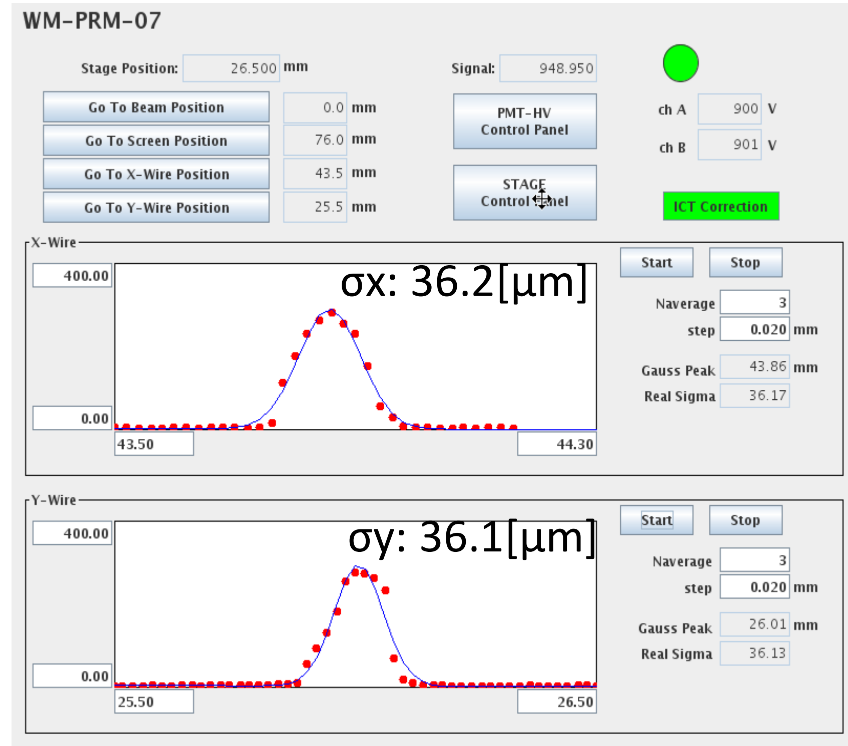
Achieved beam size at laser collision point

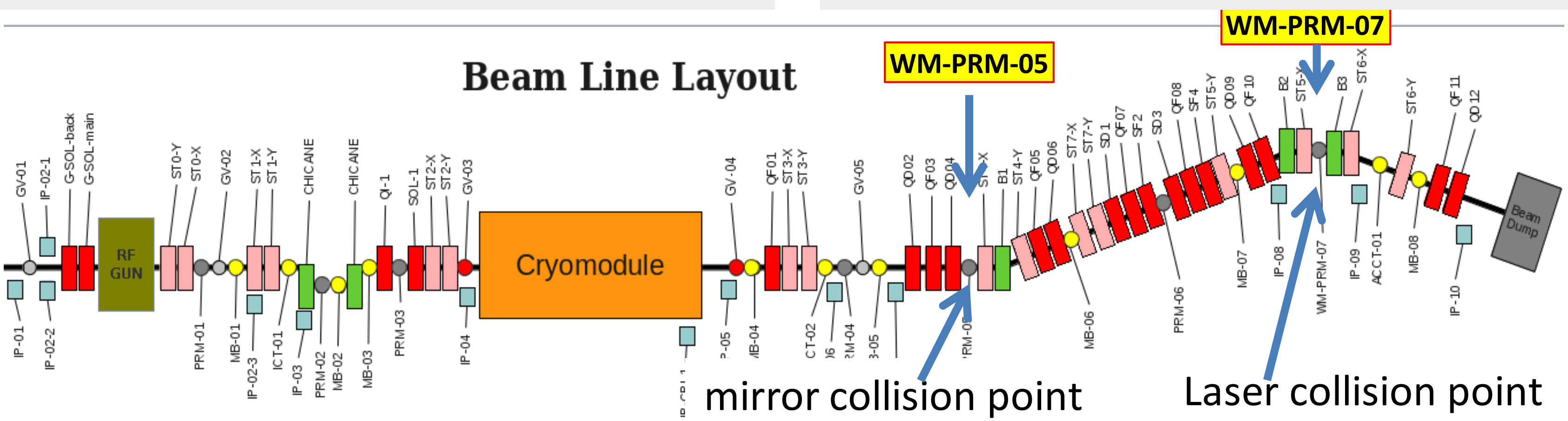
(target= 10-20μm)

Minimum beam size@WM-PRM-05



Minimum beam size@WM-PRM-07





4 mirror Laser Accumulator for Inverse-Compton X-ray generation

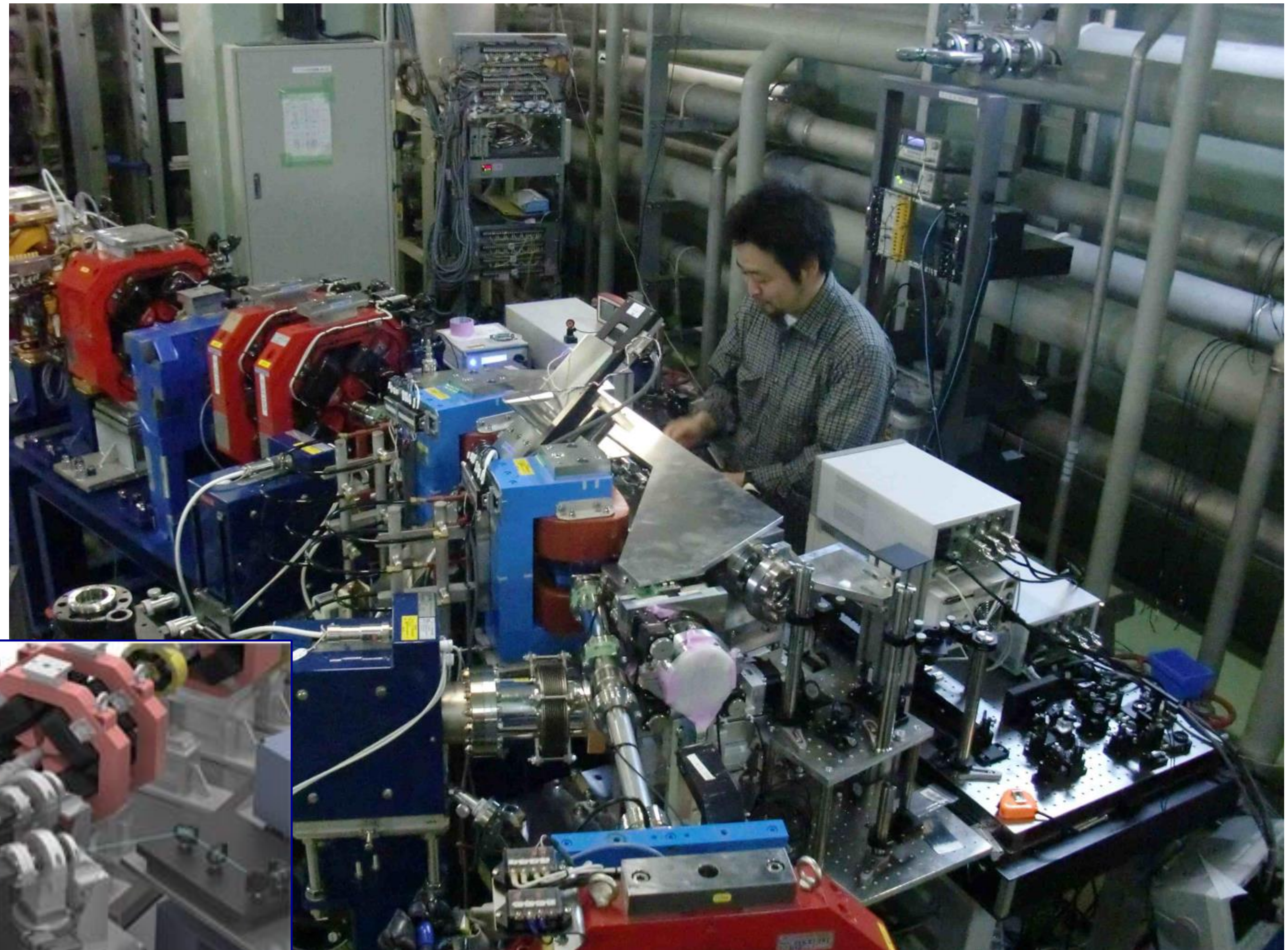
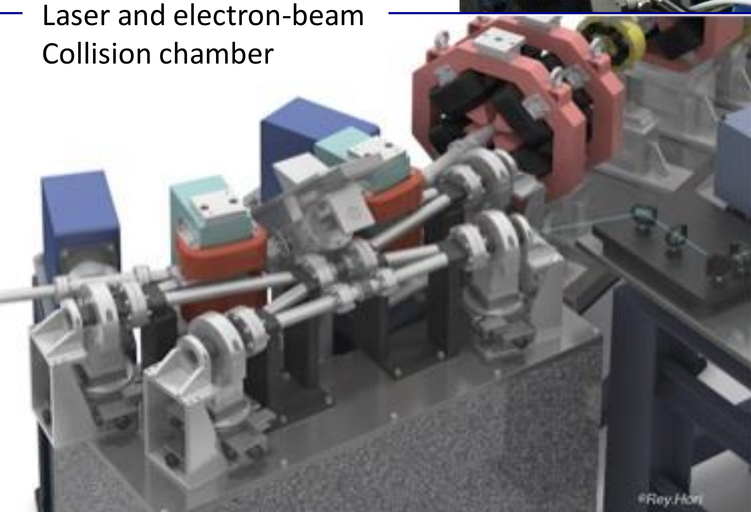
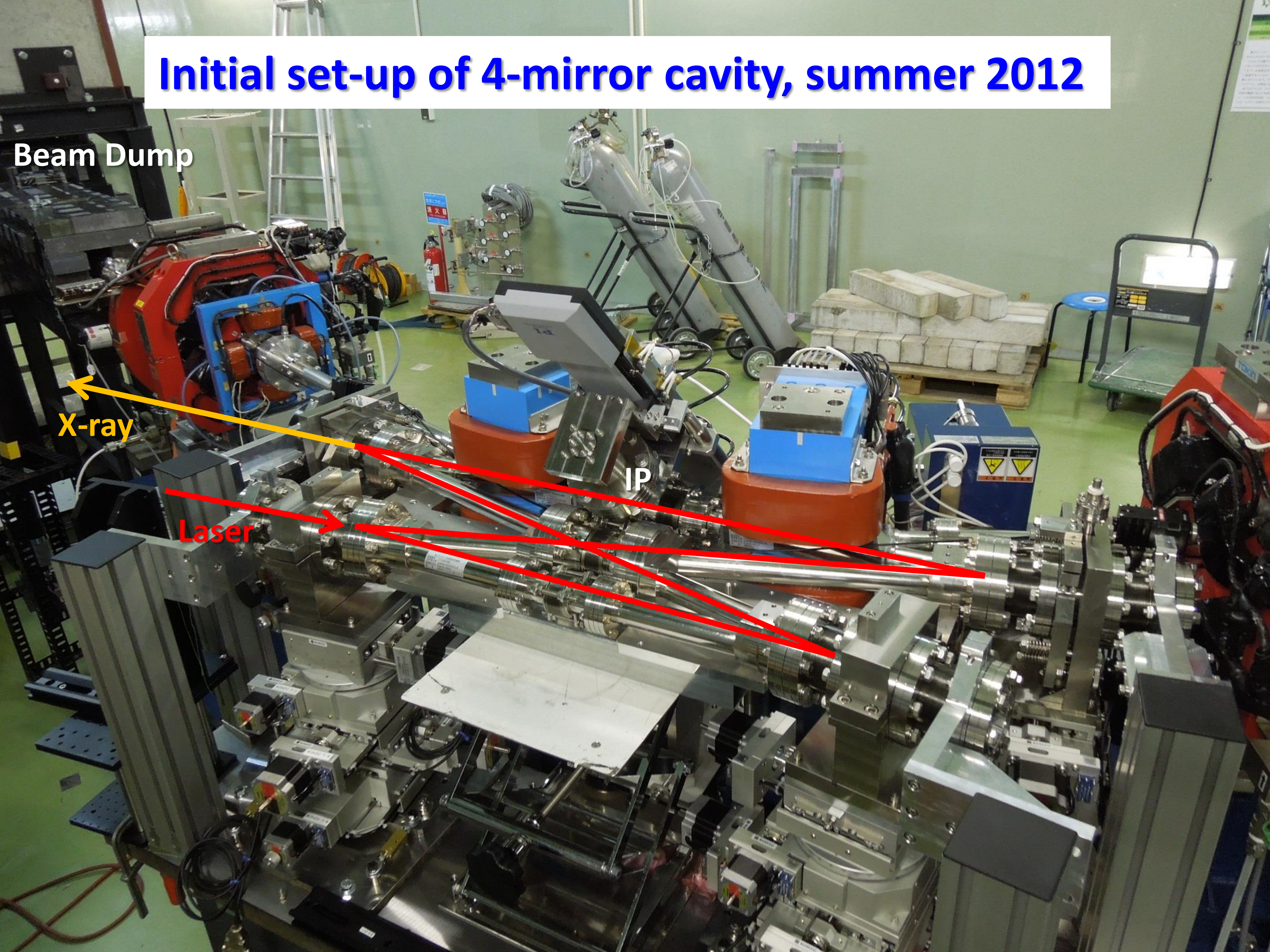


Illustration of
Laser and electron-beam
Collision chamber

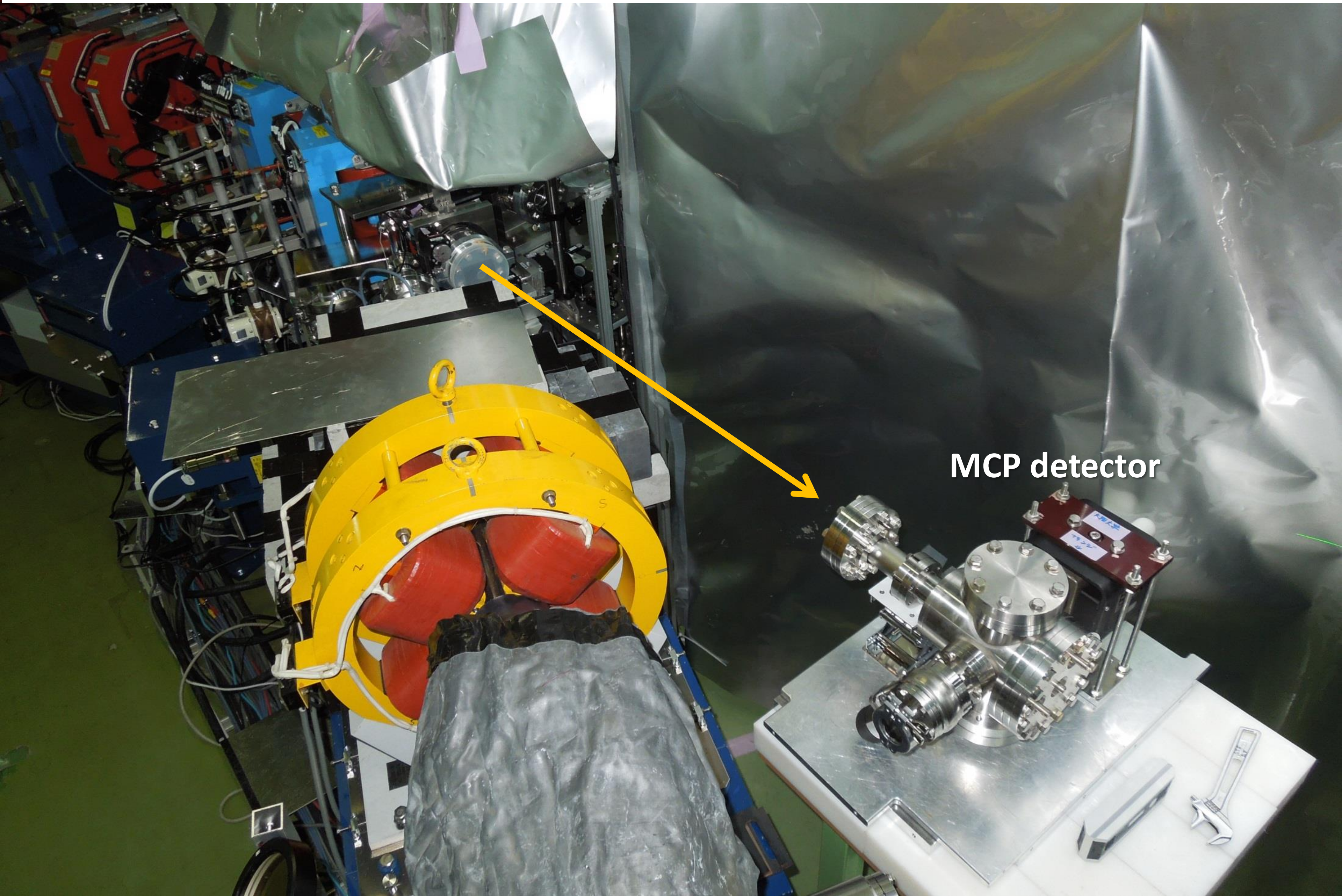


2012/Sep/28 H. Shimizu

Initial set-up of 4-mirror cavity, summer 2012

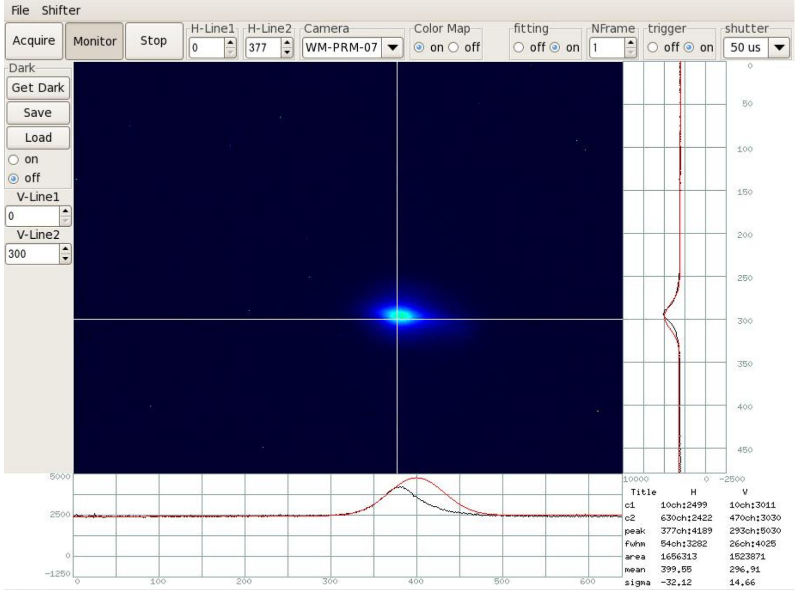


Place MCP detector close to collision point (6m->2m)



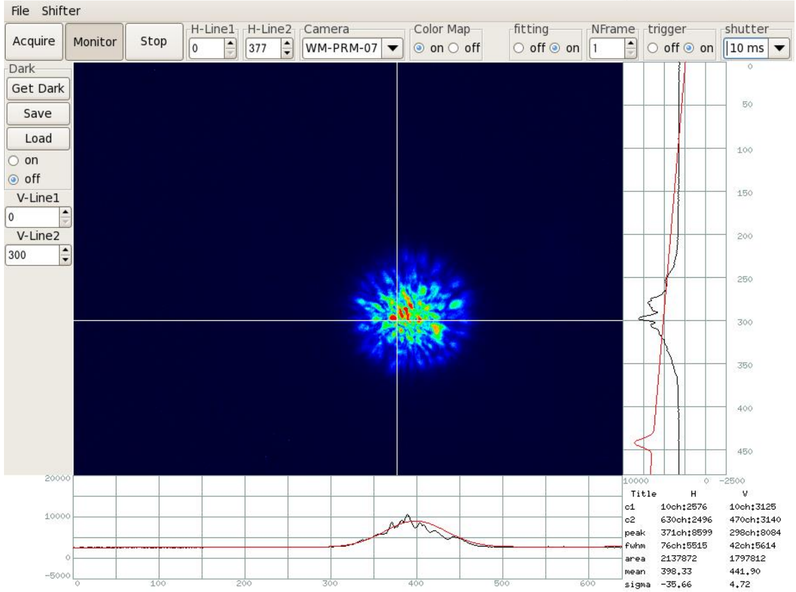
Beam image and laser image at collision point (screen monitor)

Space matching was done by;
(1) Screen monitor,
(2) then, wire scanner
with precision

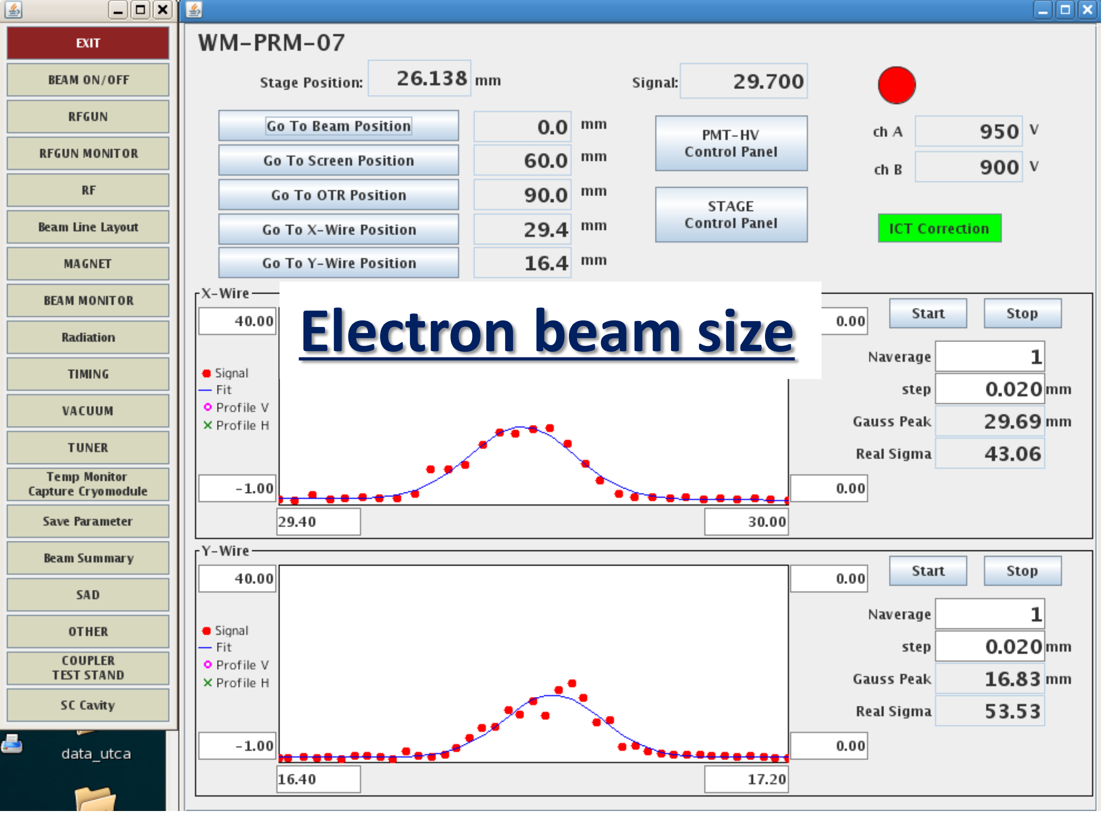


Electron beam
(40 bunches)

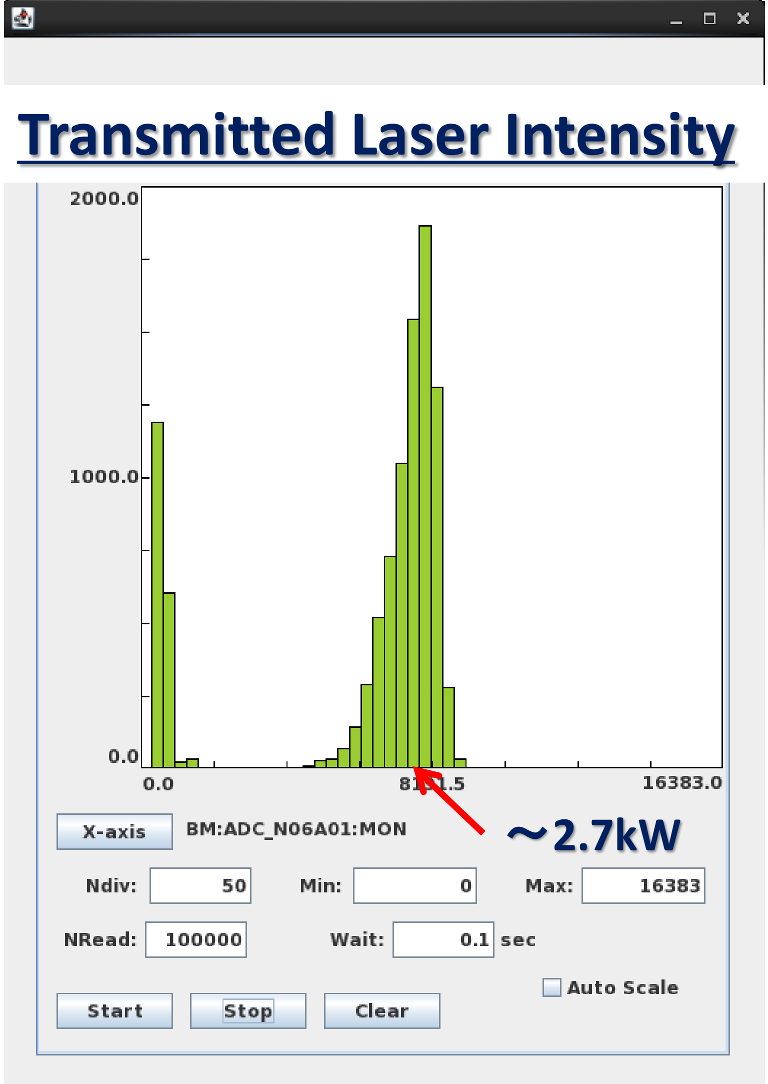
After space matching,
RF phase scan was done.
(between Laser phase and
Accelerator beam phase)



Laser beam
（injected laser image,
Not accumulated laser）



↑ Wire Scan Result at IP



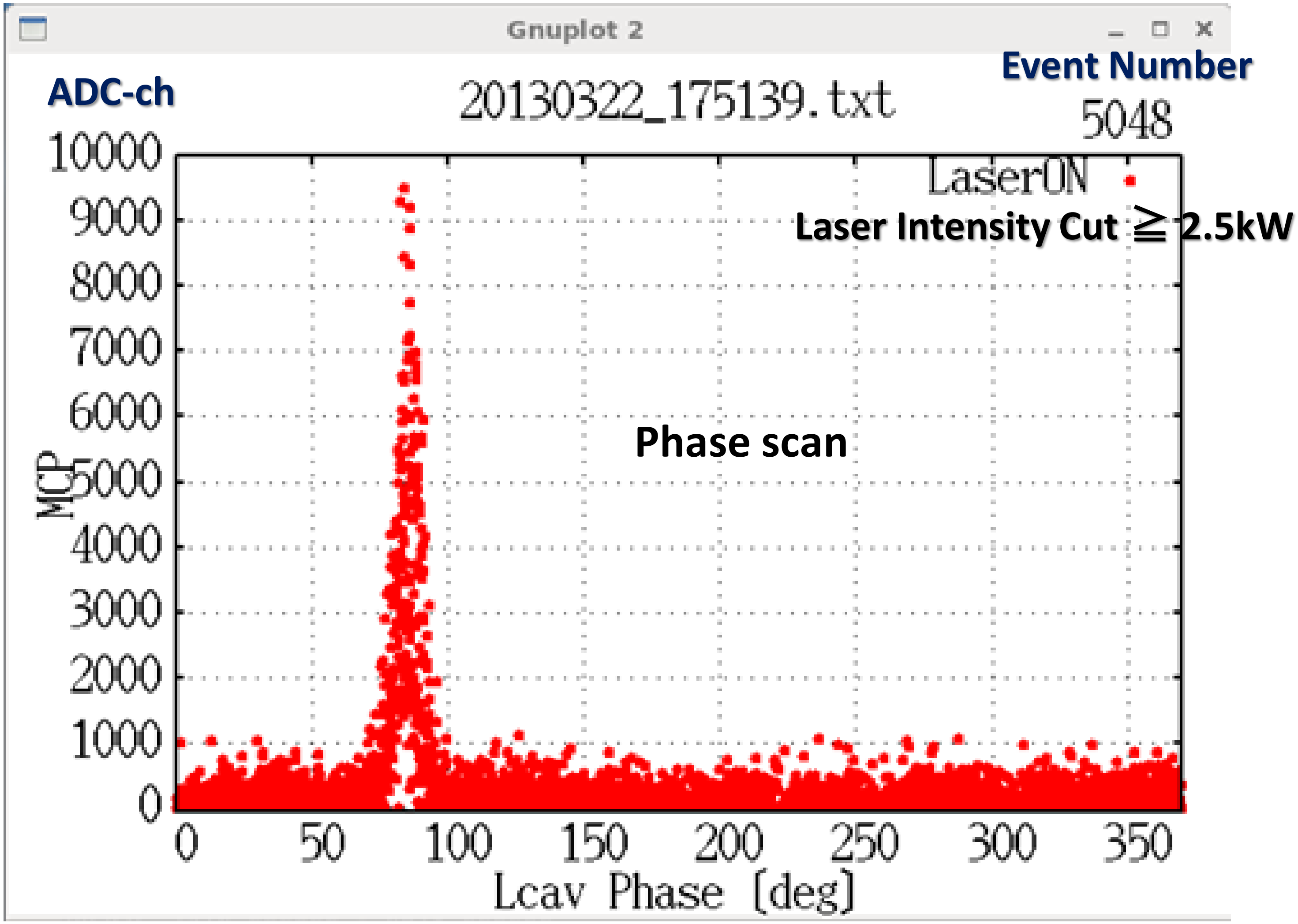
↑ Transmitted Laser Intensity Monitor

Typical Collision Condition

Electron Beam : 40MeV
248-bunch
55pC/bunch
σ_x : 43um/σ_y : 55um

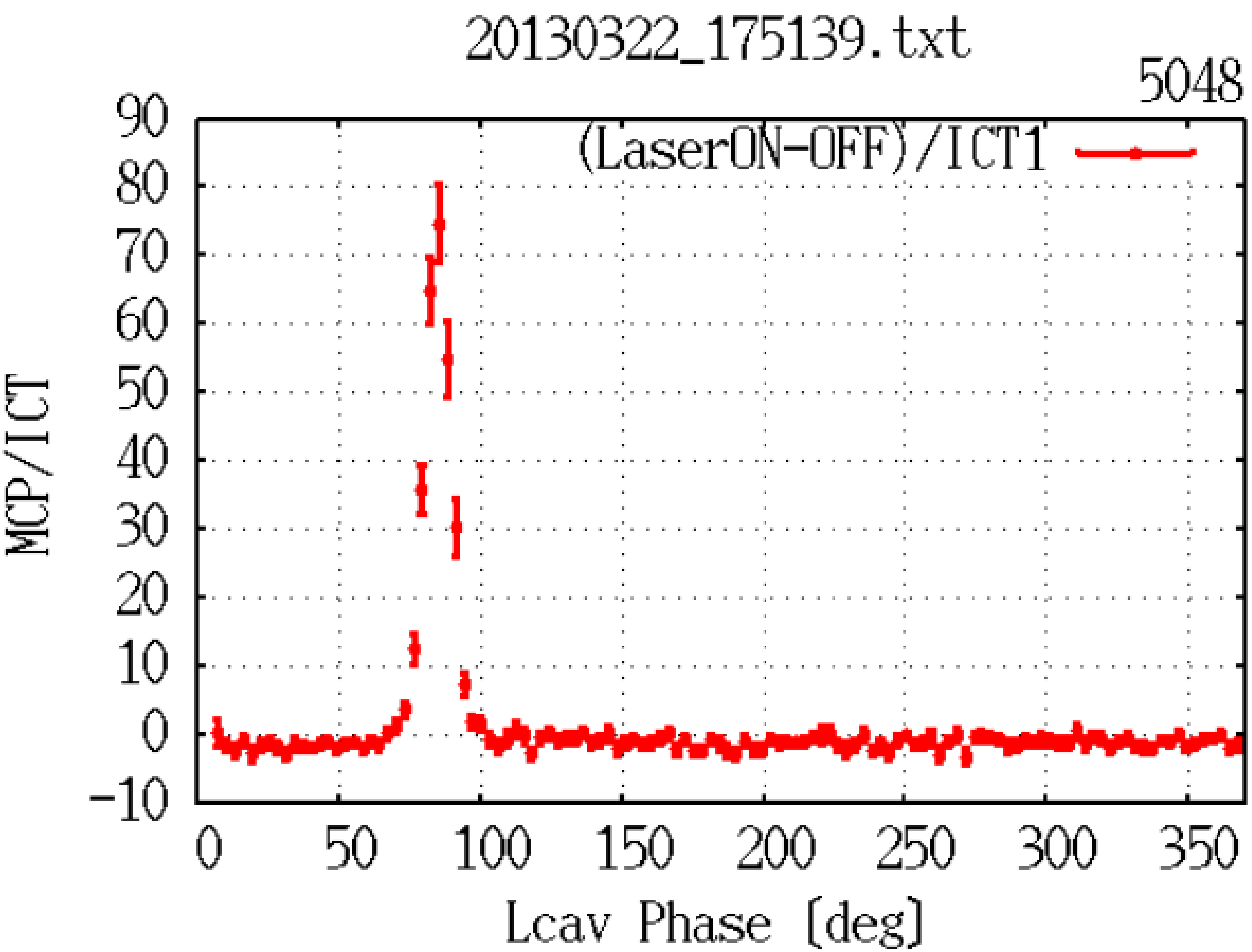
Laser : ～15.4uJ@IP
σ : ～ 80um

Signal Detected by Micro Channel Photomultiplier (22nd Mar. 2013)



Compton Laser (Ext. Cavity) and STF accelerator frequency (162.5MHz) was not synchronized.
The phase between Compton Laser and accelerator frequency is swept by 0-360deg.
There is MCP count excess at around 80-90 degree.

Phase Scan (binning, beam charge normalized)



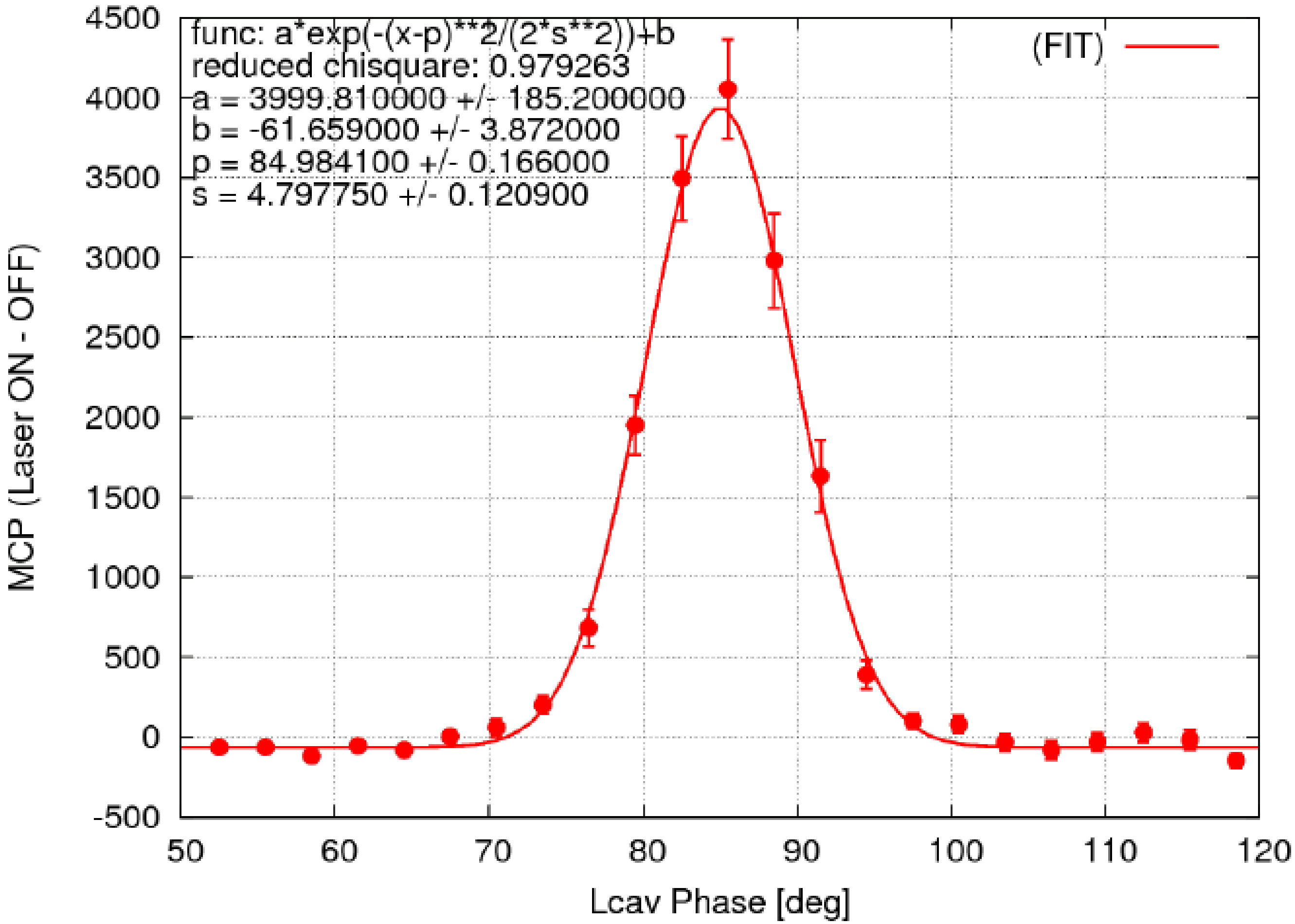
Subtraction
Laser OFF(Background)
from Laser ON

Laser ON definition
Laser power > 70000counts

Laser OFF definition
Laser power < 2000counts

Signal Detected by MCP (22nd Mar. 2013)

- **3-deg. 1-bin**
- **Laser Intensity Cut pick > 7000-ch (～2.5kW) data**

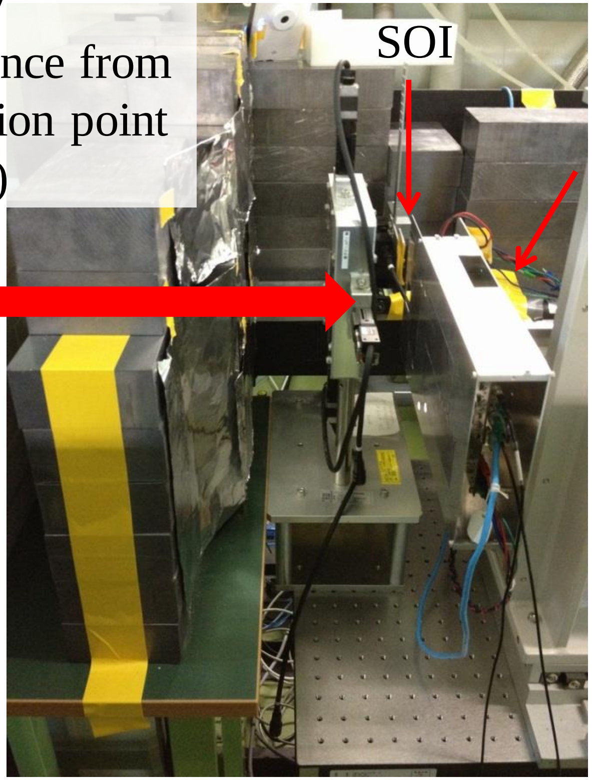


451-photon/train (MCP Aperture), with 248 bunches /train

→ 1.8 photon/bunch (1.5 x 10^6 photons/sec for 1ms beam)

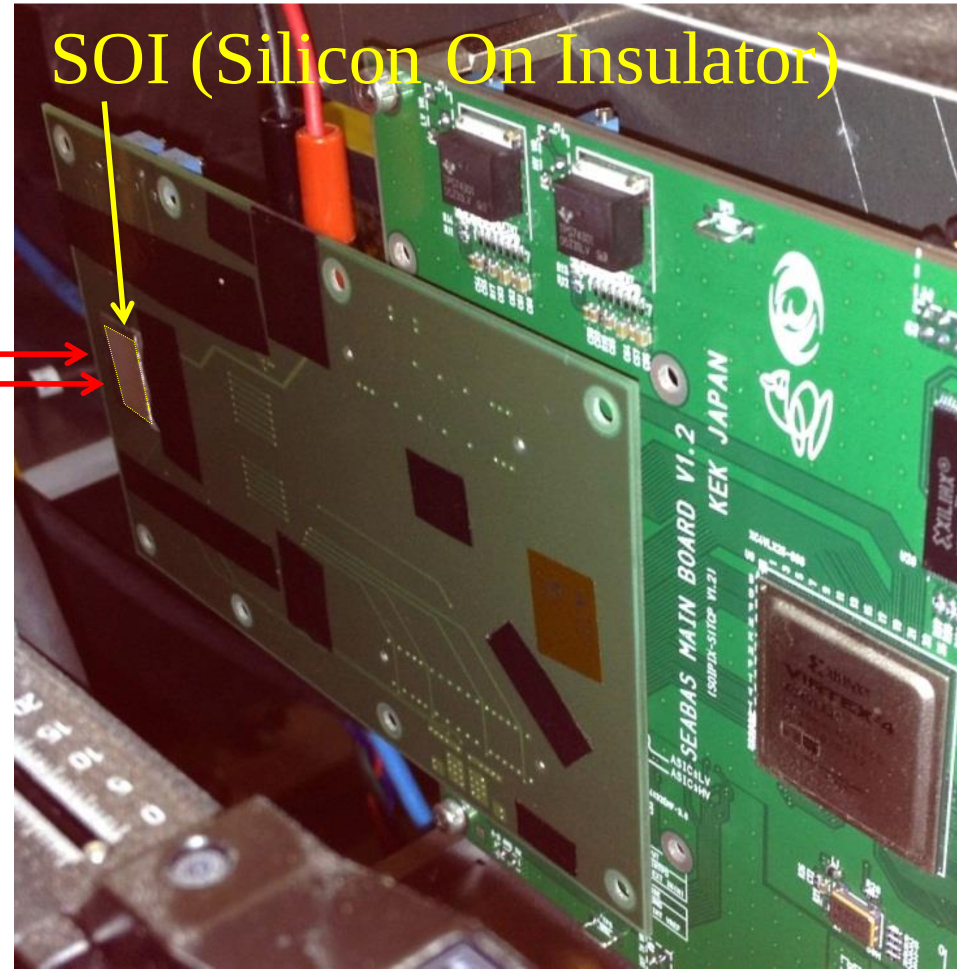
Detector Setup at QB accelerator

X-ray
(distance from
collision point
~ 6m)

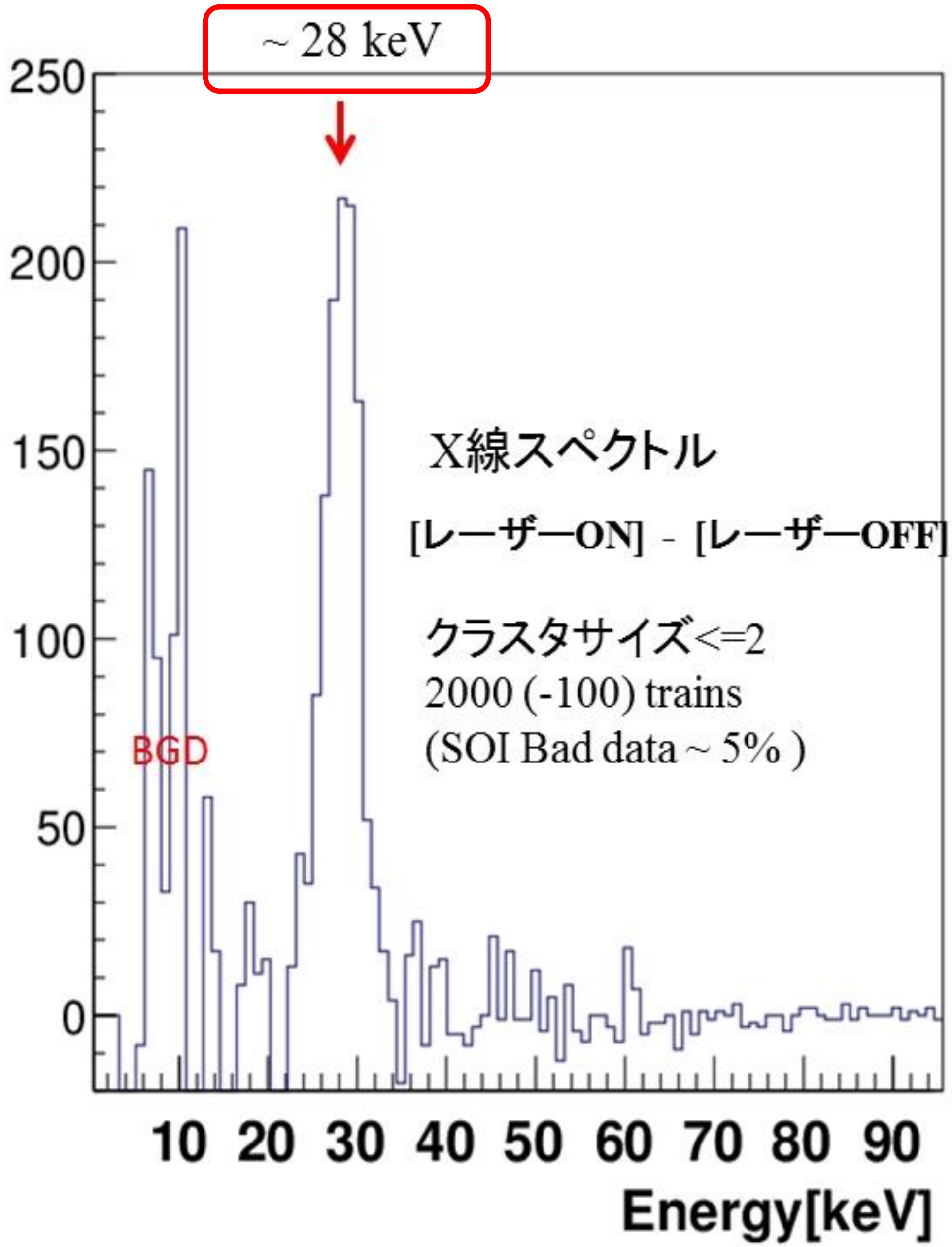


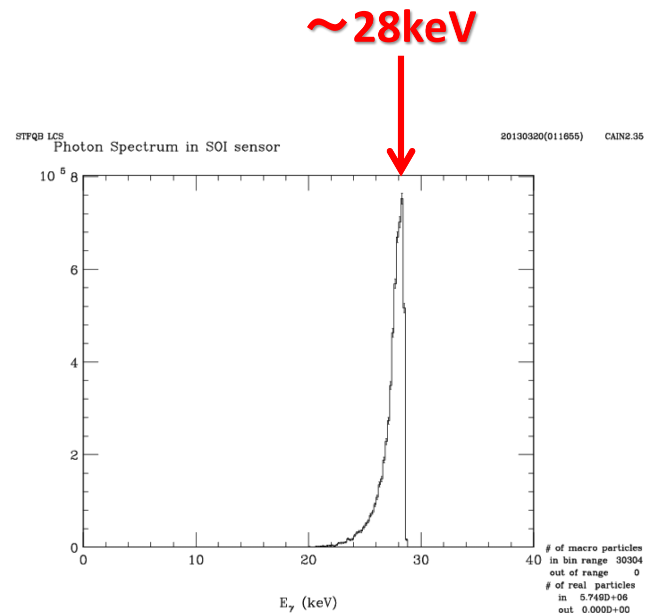
X-ray
NaI
(5mm-thick)

X-ray



BG subtracted X-ray spectrum





↑ Expected Spectrum in SOI

SOI is energy calibrated at around 10-20keV

Summary Quantum-Beam Experiment

- X-ray signal was detected at STF Quantum-Beam Experiment.
  Yield is 1/1000 to 1/10000 lower than the target yield 10^{10},
  because of beam size, laser size, and laser power.

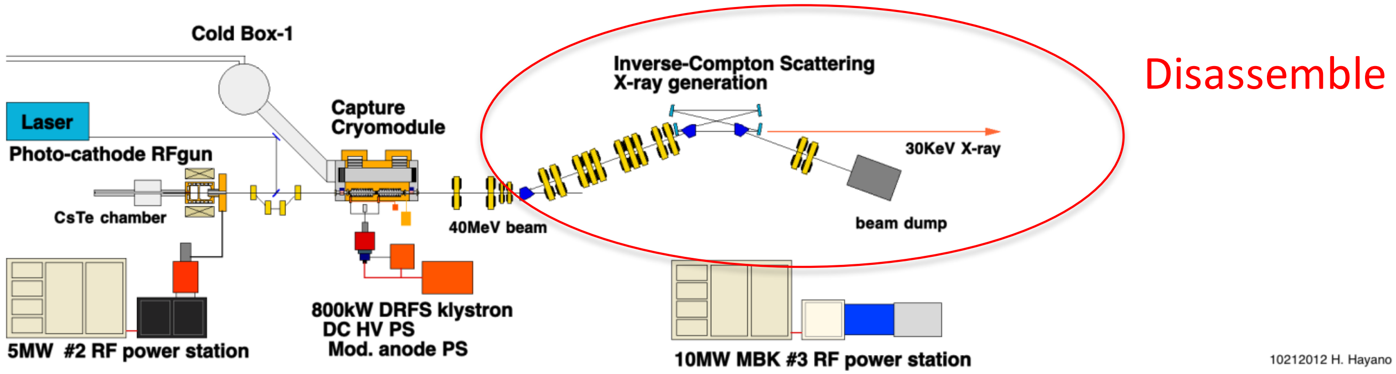
- Big contributions for X-ray detection were;
  mechanical stability improvement of 4 mirror mount
  including feedback electronics improvement,
  expanding chamber aperture to improve S/N ratio.

- Spectrum by SOI shows 28keV peak, consistent with calculation.

Cryomodule Status and Plans

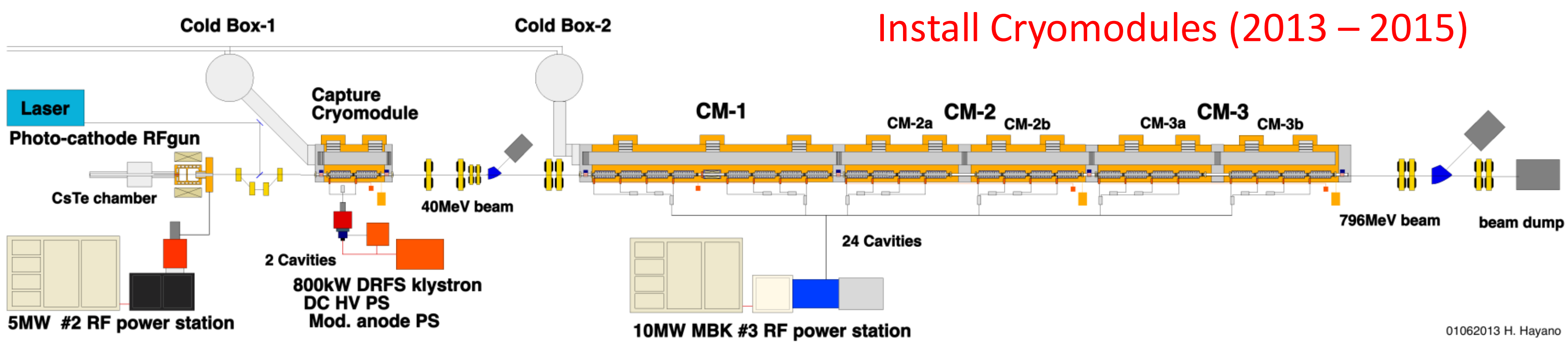
STF Quantum Beam to STF Phase-2 Accelerator

STF Phase-2 Injector part (Quantum Beam Experiment)



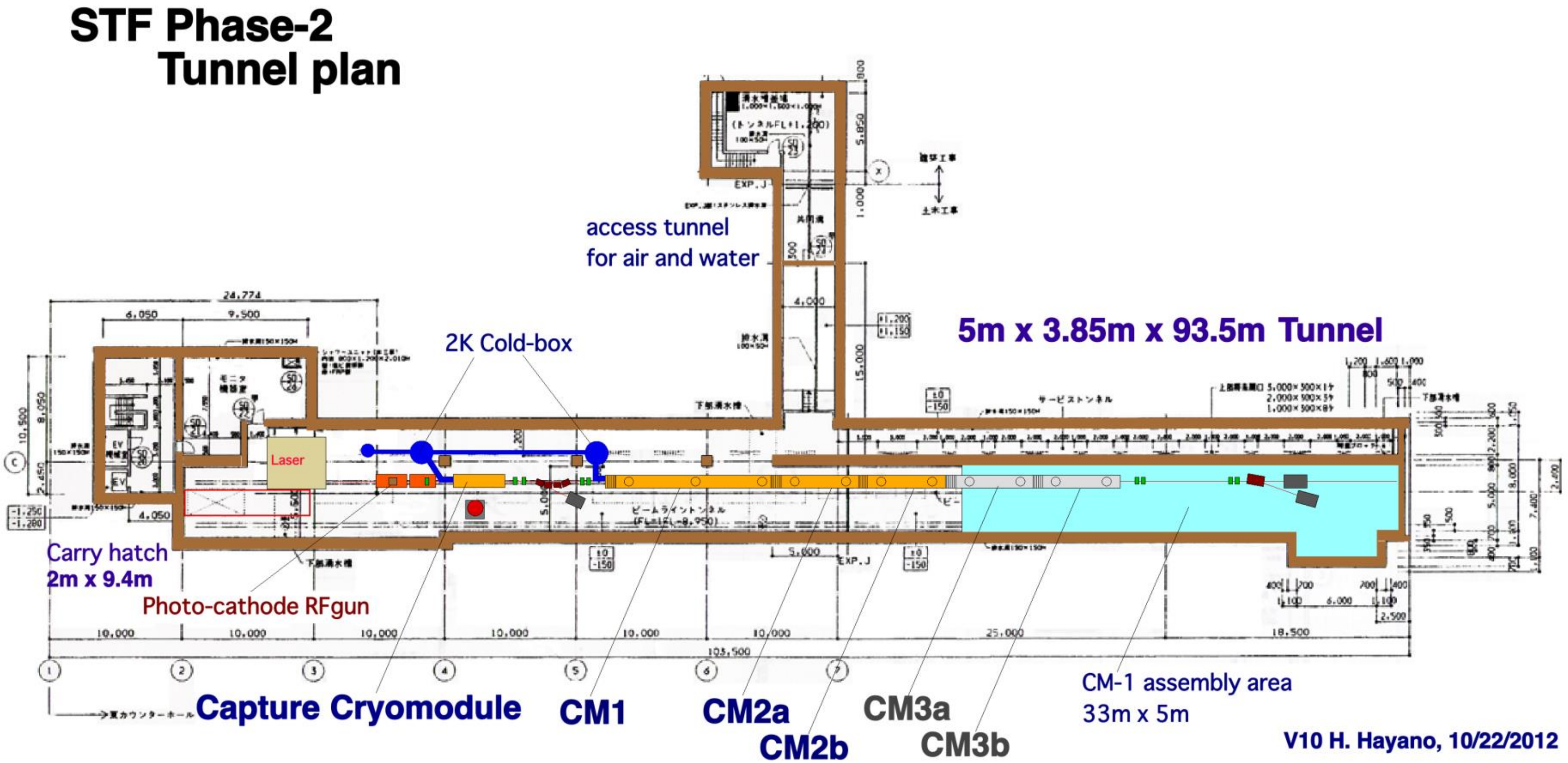
Disassemble in 2013 Summer

STF Phase-2 Accelerator Plan



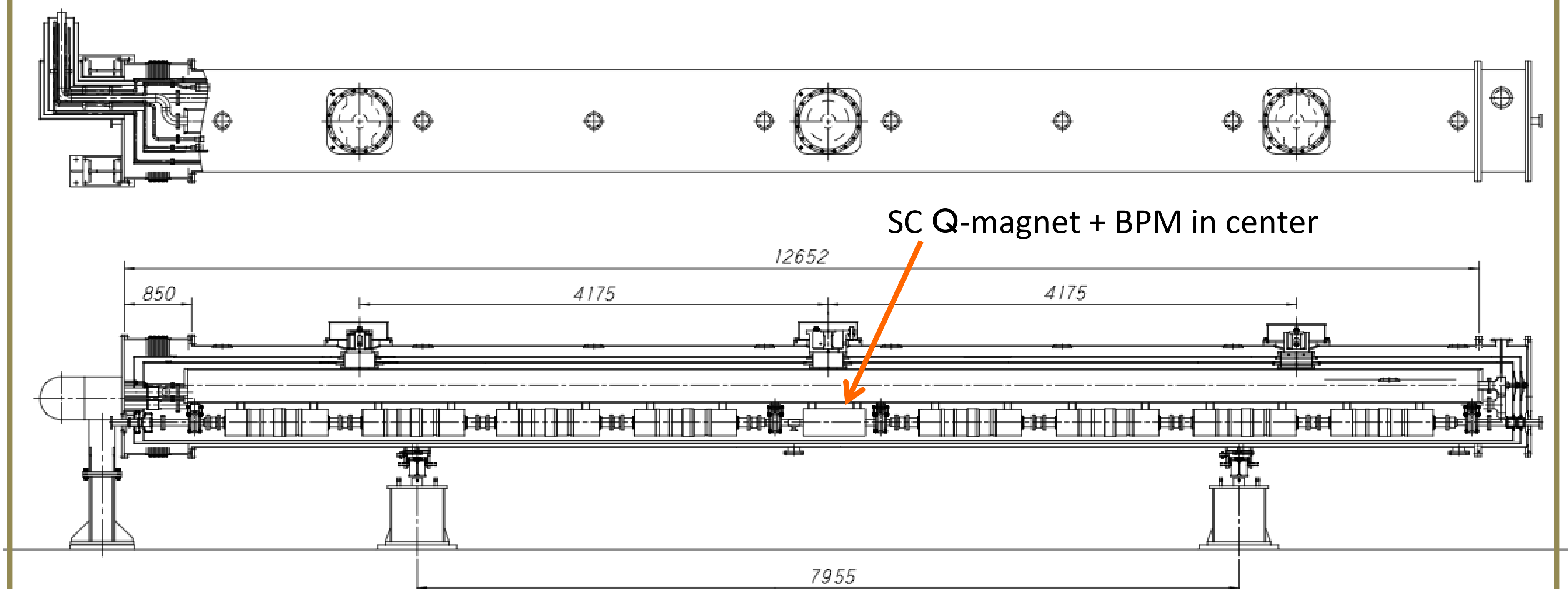
Install Cryomodules (2013 – 2015)

STF Phase-2 Accelerator Tunnel Installation



CM-1 : ILC type cryomodule

CM-1: 13m　　8 cavities ＋ SC Q-magnet・BPM
First ILC-type Cryomodule in the world (magnet in the center)

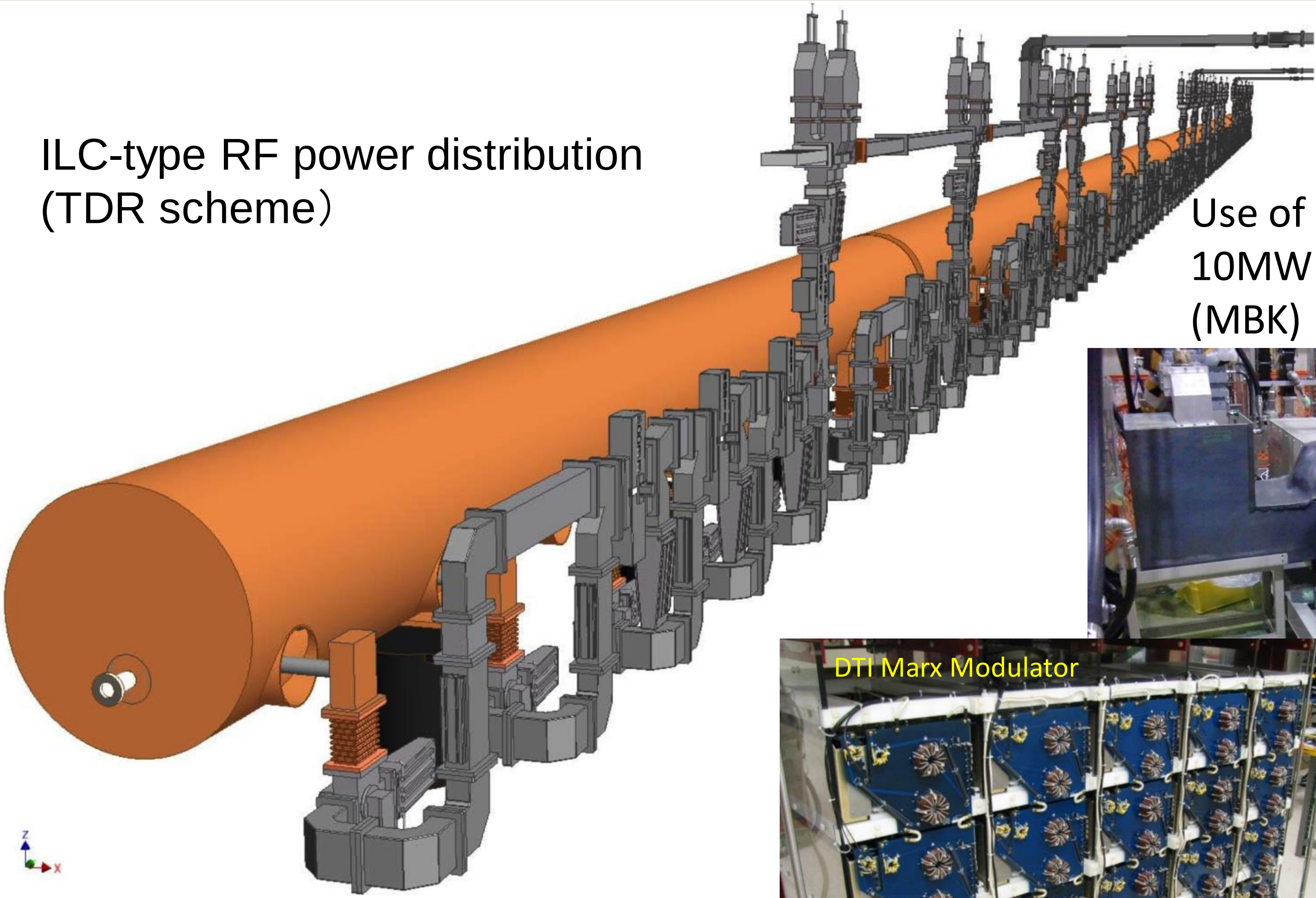


Assembly in 2013, cool-down and beam operation in 2014-2015

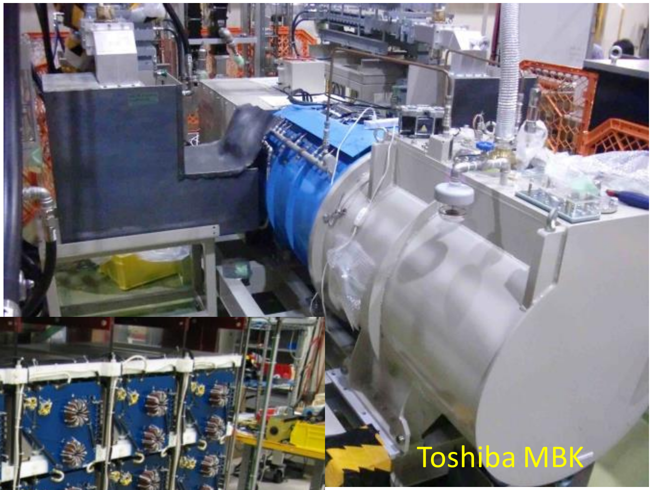
Issues to be solved : cavity gradient degradation,
alignment preservation,
low heat load,
cost-down assembly,
beam acceleration operation by digital LLRF

Powering scheme of STF phase-2 Accelerator

ILC-type RF power distribution
(TDR scheme）



Use of
10MW Multi-beam Klystron
(MBK)



Now MBK is driven
by Inverter PS HV modulator + Pulse trans
Will be replaced by Marx Modulator.

Cavity plan for cryomodule

All cavities must be HPR(High-Pressure code Regulation) clear

Cryomodule	Cavities
CM-1 (8 cavities)	**= 8 cavities selection from MHI-014 to MHI-022**
CM-2a (4 cavities)	**= 4 cavities from MHI-023 to MHI-026**
CM-2b (4 cavities)	**= 4 cavities selection from new bidding, KEK fabrication, other collaborators**
CM-3a (4 cavities)	**= 4 cavities selection from new bidding, KEK fabrication, other collaborators**
CM-3b (4 cavities)	**= 4 cavities selection from new bidding, KEK fabrication, other collaborators**

Next Fabrication (CM-2b, CM-3a, CM-3b)

RF Power scheme plan

(1) One more MBK (Multi-beam Klystron) will be procured in 2013.

(2) DTI Marx Modulator (collaboration with SLAC) will be tested
in 2013 September.

(3) Japanese Marx Modulator will be fabricated in 2013 - 2015.

(4) TDR power distribution will be procured in 2014.

(5) Multi-cavity LLRF will be developed in 2014.
(for 12 cavities, now 10 cavities max)

COI (Center of Innovation)

採択された事業

「地球を守るアース･クリーナー市場を創出する新産学連携拠点」

事業者：高エネルギー加速器研究機構
拠点長：鈴木機構長

（大学共同利用機関法人という事で
大学連合の連携が暗に仮定されている）

連携企業：三菱重工株式会社
株式会社　日立製作所
株式会社　東芝
三菱電機株式会社
京セラ株式会社
株式会社フジクラ

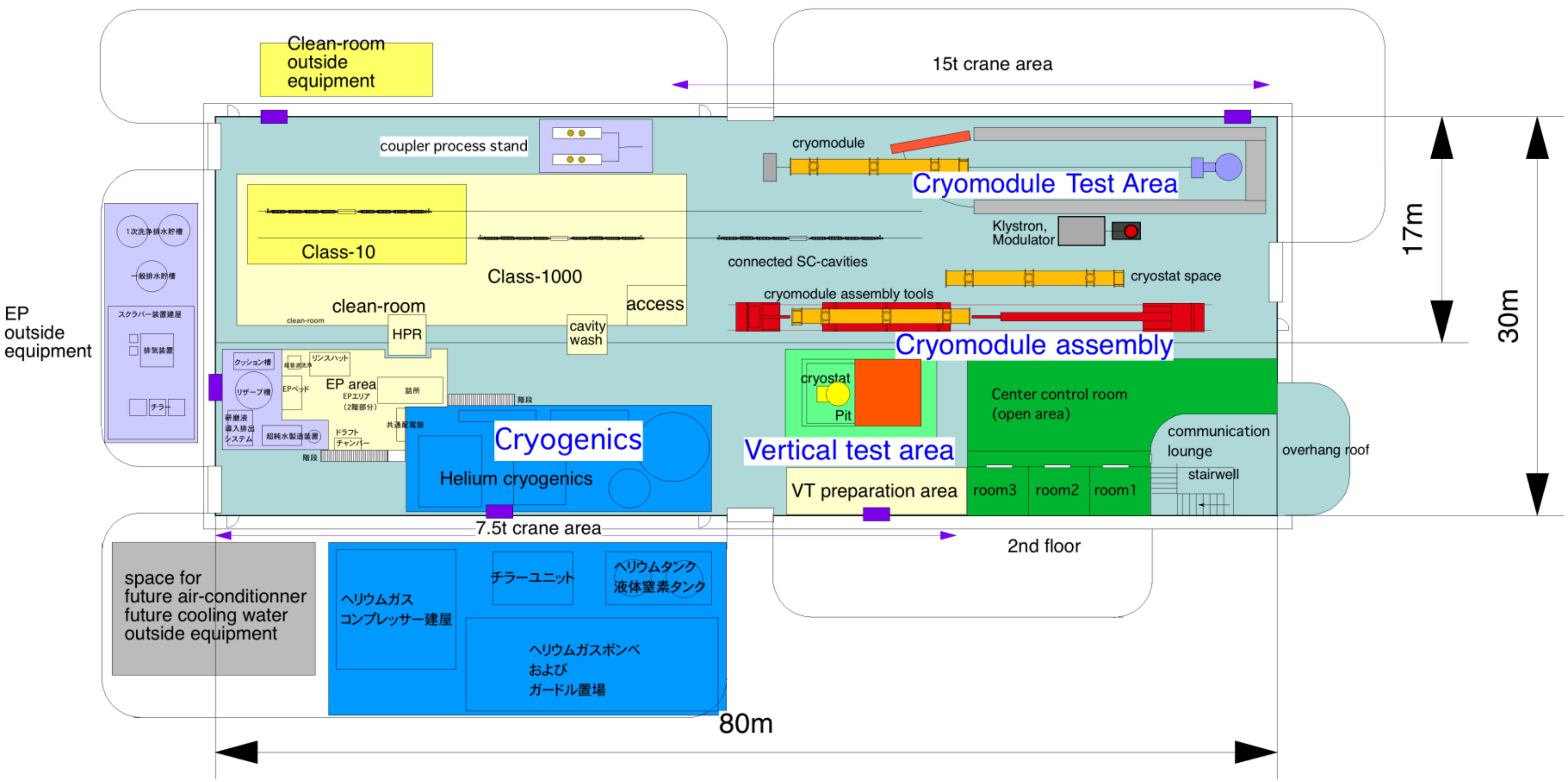
拠点計画の概要

地球を人類の永久の生存圏と可能ならしめるには、「地球汚染」「地球温暖 化」「エネルギー不足」「自然資源枯渇」の問題克服が必須である。ここに、「新エネルギー輸送・変換」や「発電と河川・大気浄化の融合」などの「地球を浄化する」ニーズが生まれる。
本拠点では、超伝導加速器技術と量子 ビーム技術を用いて、「地球を浄化する」技術とその事業化、市場拡大を促進し、「永久生存圏:地球を守る」課題に挑戦する。

新規施設

超伝導加速器利用促進化推進棟（新設）
30m
80m
2013年整備
革新的産学連携推進エリア
STF（既設）
STFトンネル（既設）
ATF
量子ビーム利用新機軸創出エリア

超伝導加速器利用促進化推進棟の整備（最終形）



電解研磨設備の例

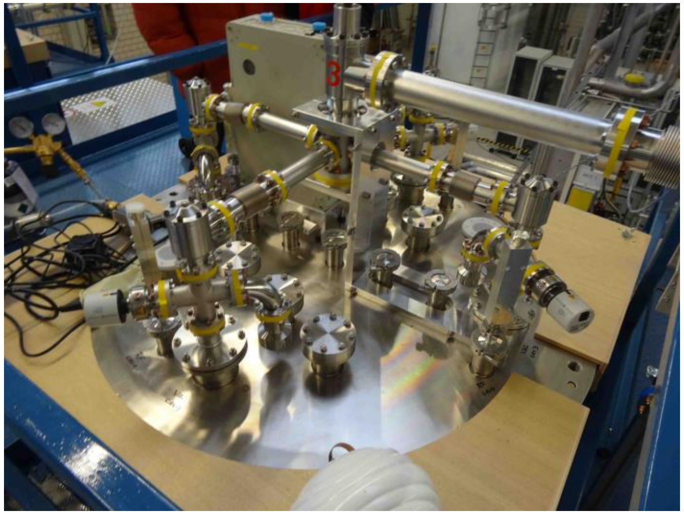
Saclay Vertical-EP

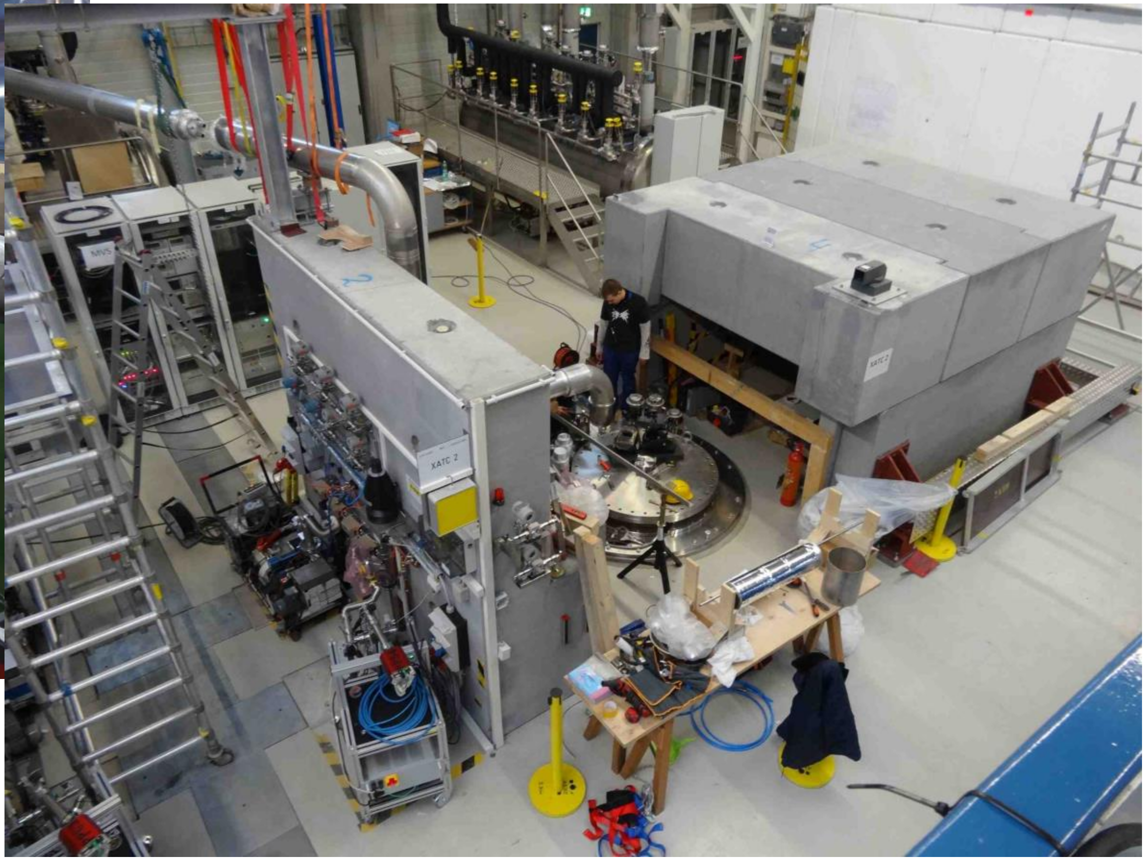
大型クリーンルーム設備の例

ISO-4, ISO-6クリーンルーム、空洞連結用レール２本

Sacaly cryomodule assembly facility

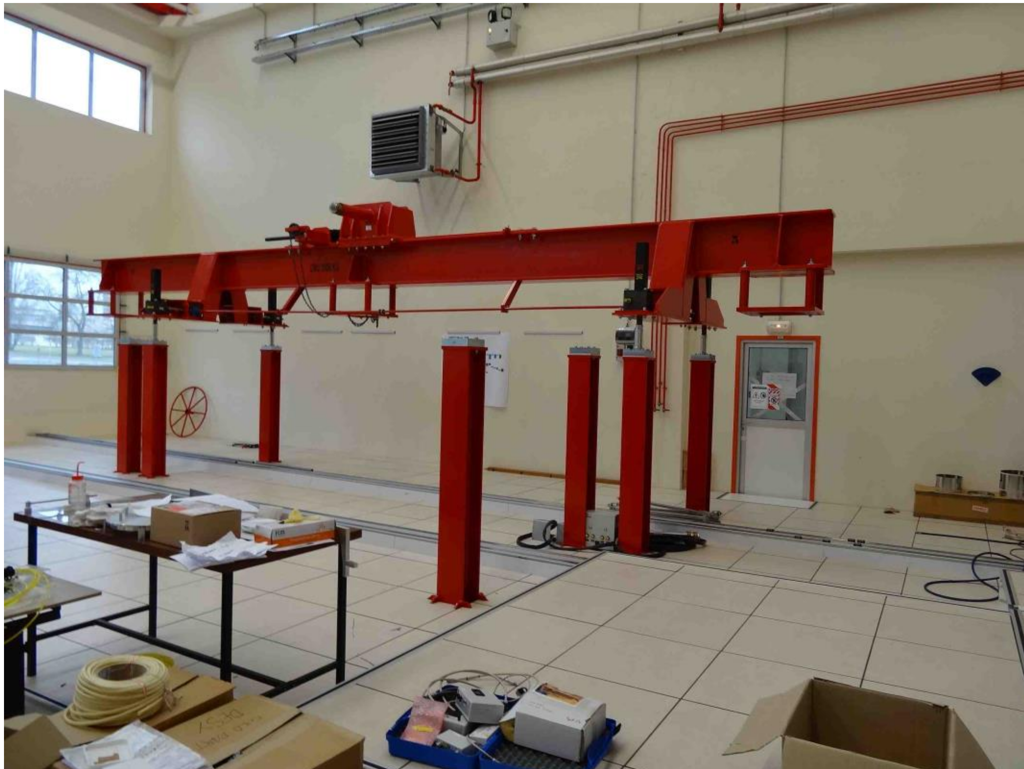
4台空洞用　縦測定設備の例

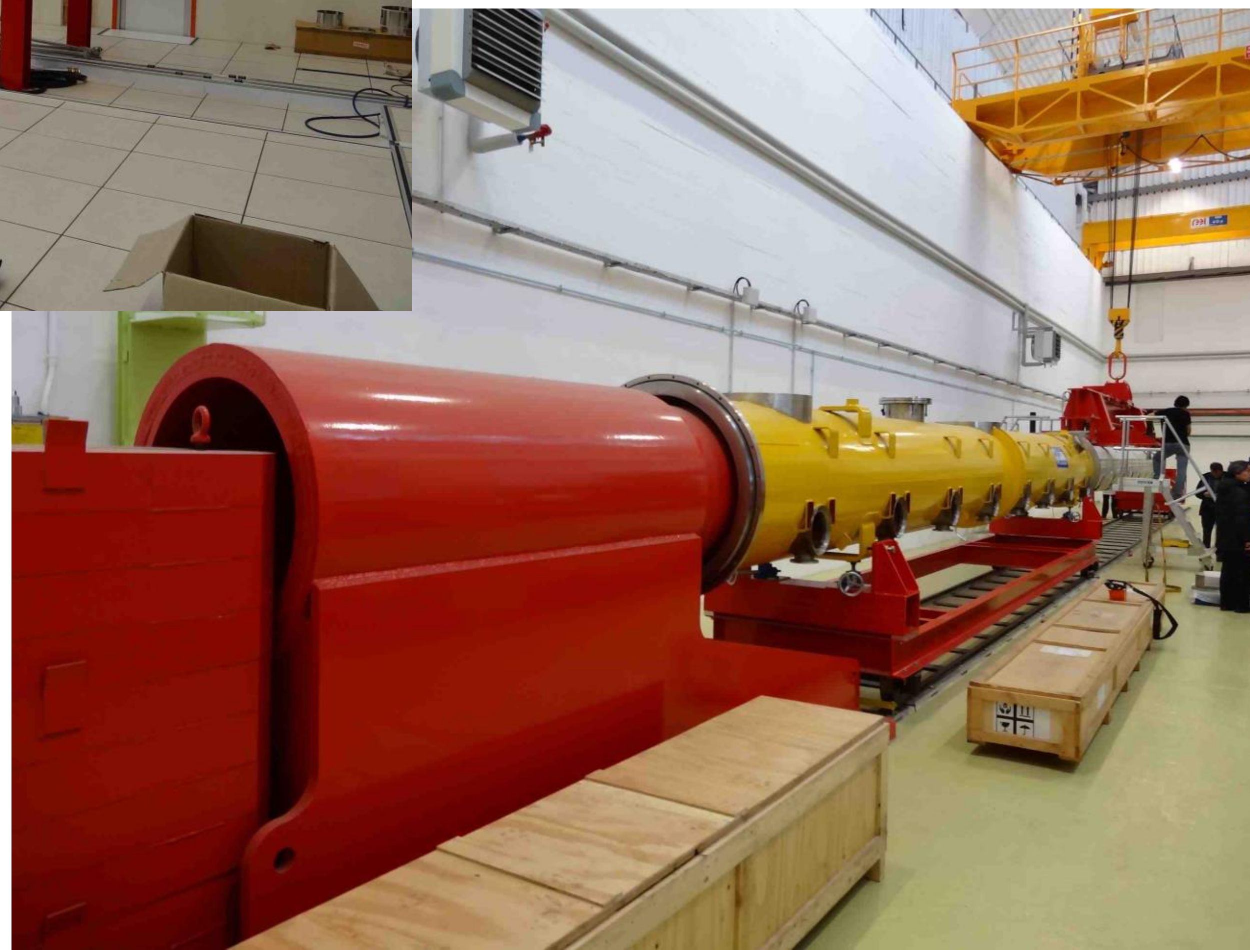




DESY AMTF

クライオモジュール
組立設備の例



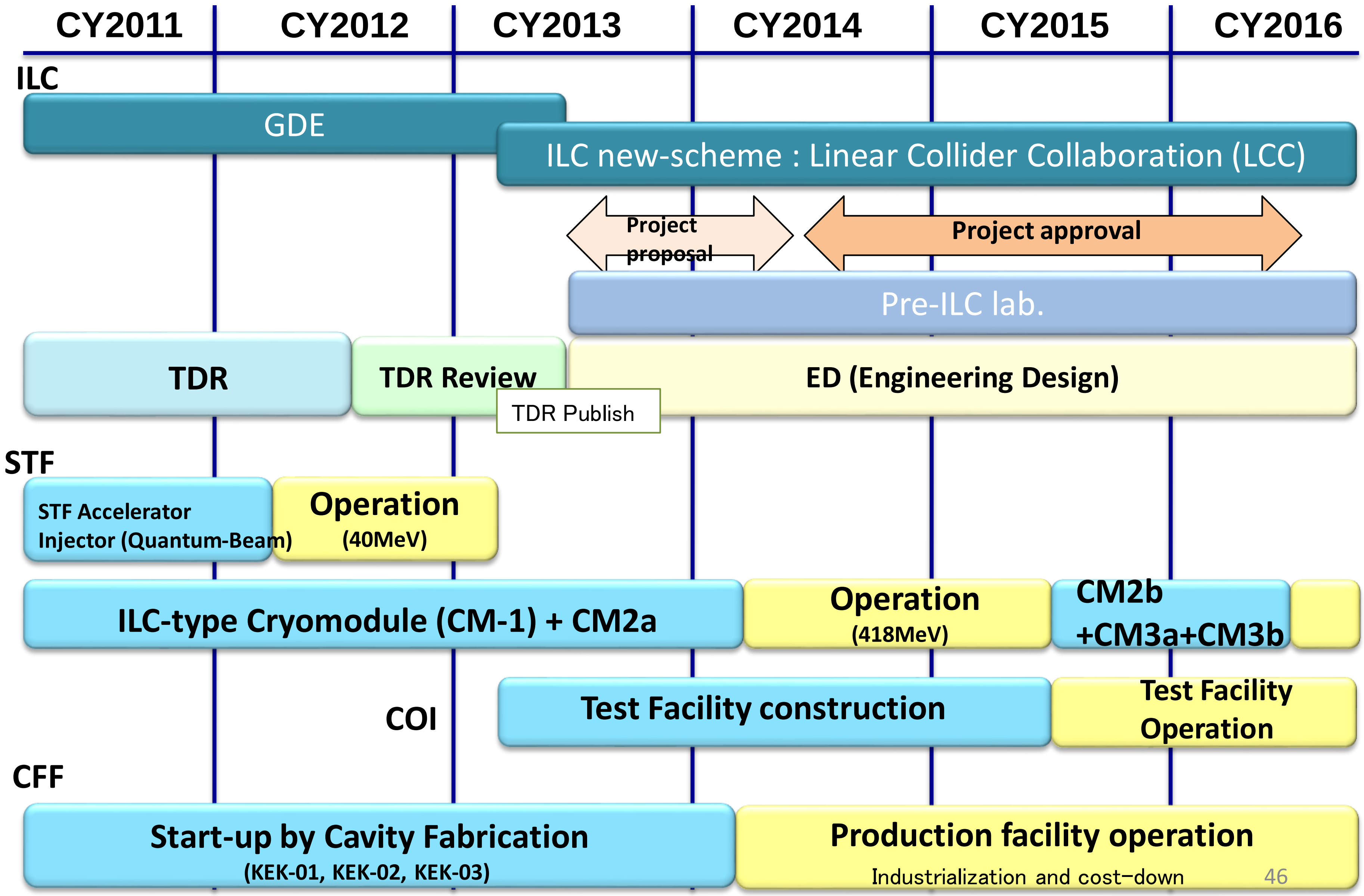


Saclay
cryomodule assembly facility

STF Plan

H. Hayano 07202013

Overall Plans of ILC , STF



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