J-PARC Linac：Status and Upgrade

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Japan Atomic Energy Agency

4th SPL Collaboration Meeting jointly with ESS

Lund, June 30 -July 02 2010

Outline

- -J-PARC facilities
- -Linac
  - Parameters
  - Status of components
- -Availability of J-PARC Accelerator
- -Upgrade of the linac
  - Energy upgrade
  - Beam current upgrade

J-PARC Facility Layout at Tokai, JAEA Site

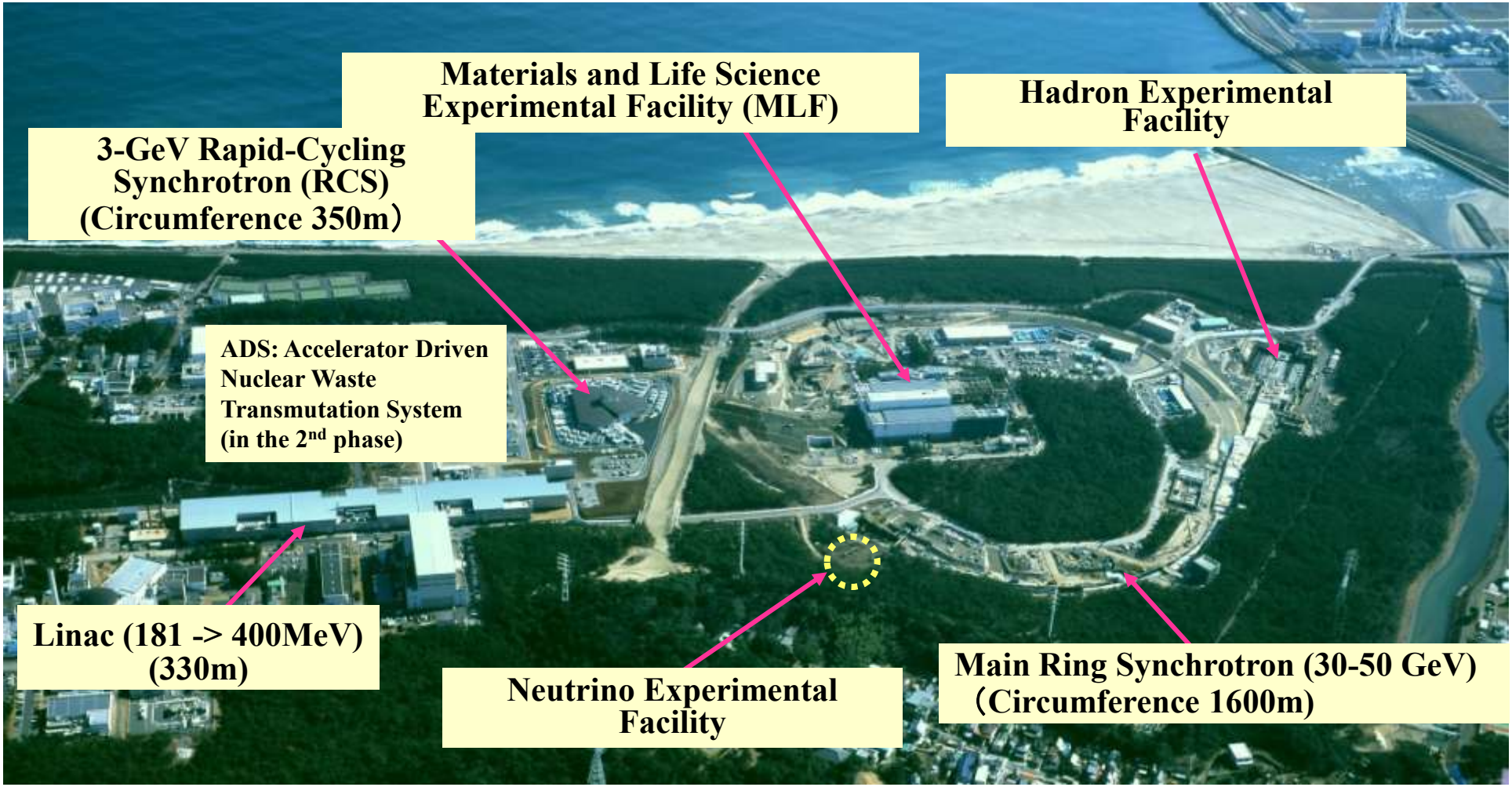
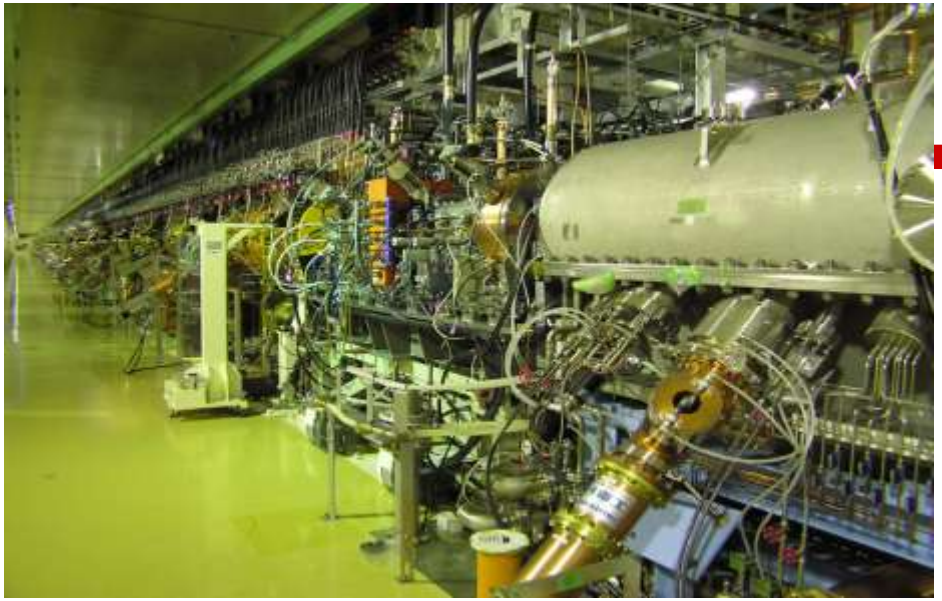


Photo in Feb. 2006

Multi-Purpose Facility

Joint Project between KEK and JAEA

Location of J-PARC at Tokai



Linac (330m)

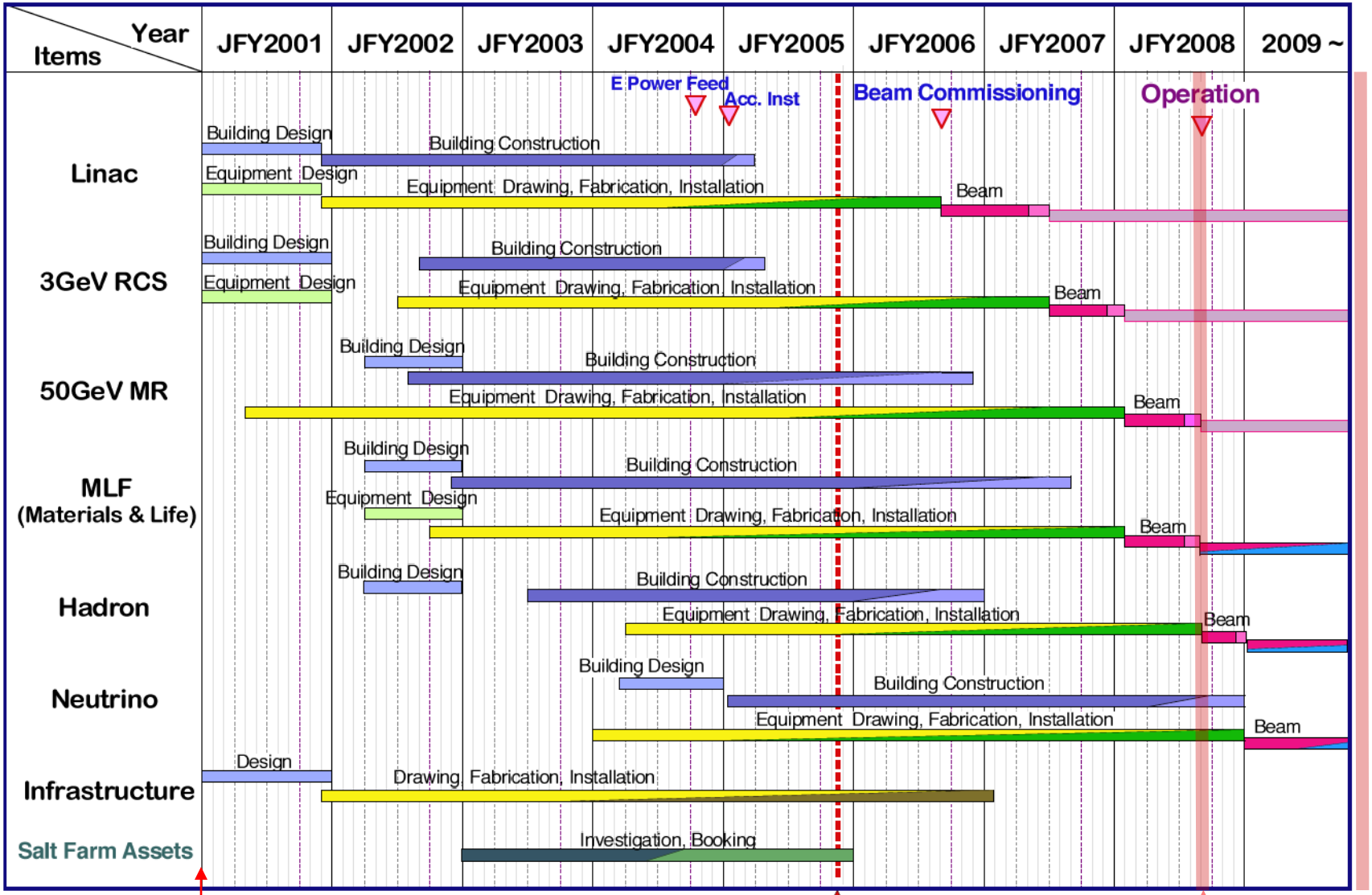
3 GeV Synchrotron (350m)

Main Ring Synchrotron (1600 m)

Superconducting magnets for the neutrino beamline

J-PARC Construction Schedule

Feb. 27 2006



Construction Start

Time when this schedule was created (J-PARC Center started)

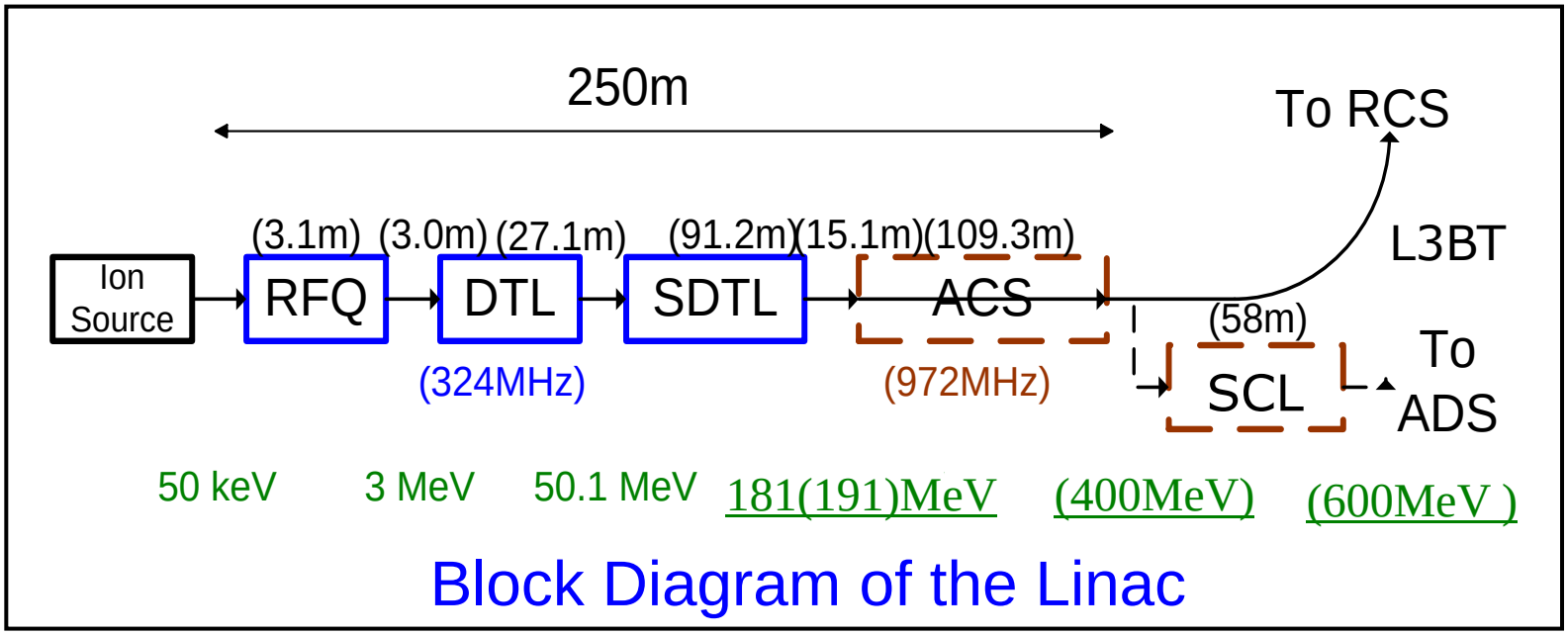
Start of n & μ User Programs

Now

Linac Parameters

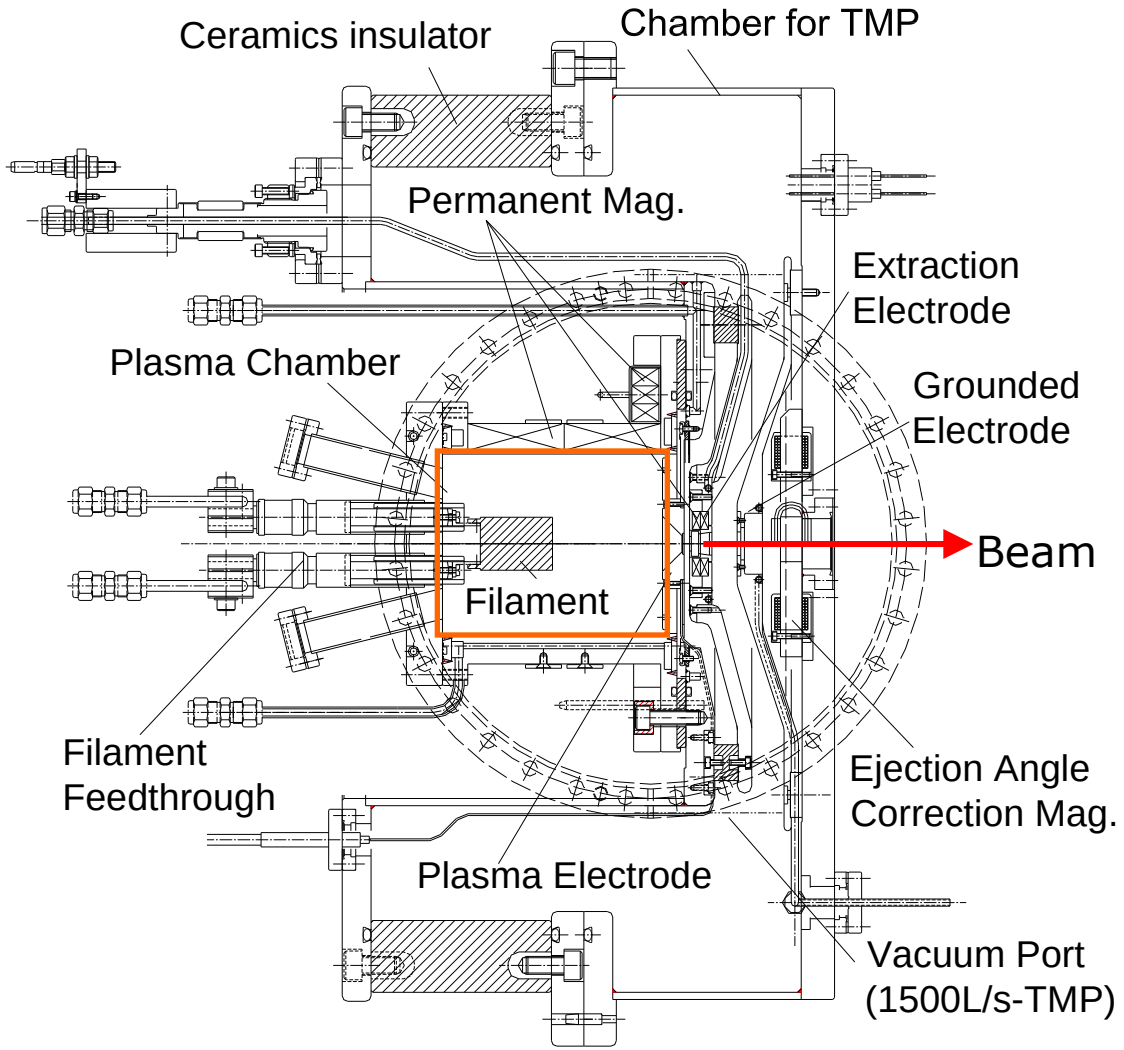
Major Parameters

- Particles: H^- (negative hydrogen)
- Energy: 181 MeV, The last two SDTLs are used as debunchers. (400 MeV for ACS, 600 MeV for SCL)
- Peak current: 30 mA (50 mA for 1MW at 3GeV-> Ion source, RFQ)
- Repetition: 25 Hz (additional 25 Hz for ADS application)
- Pulse width: 0.5 msec



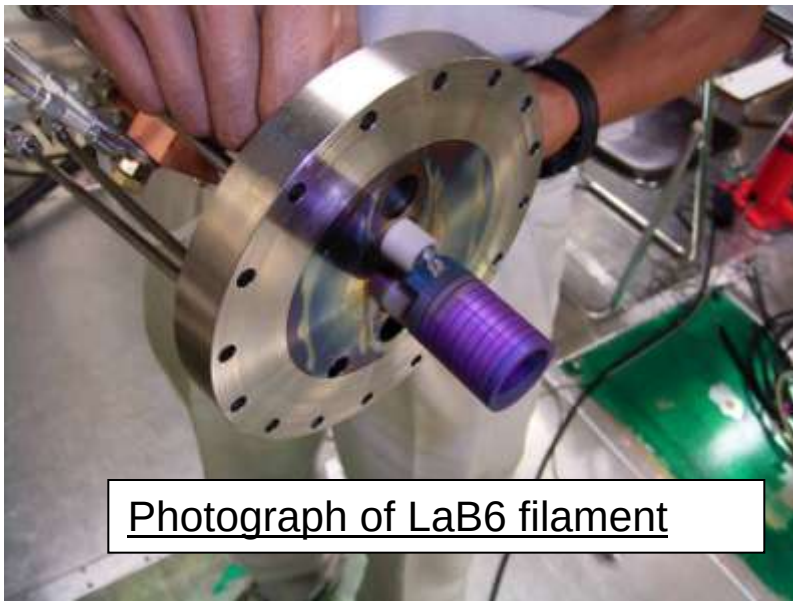
Block Diagram of the Linac

Ion Source



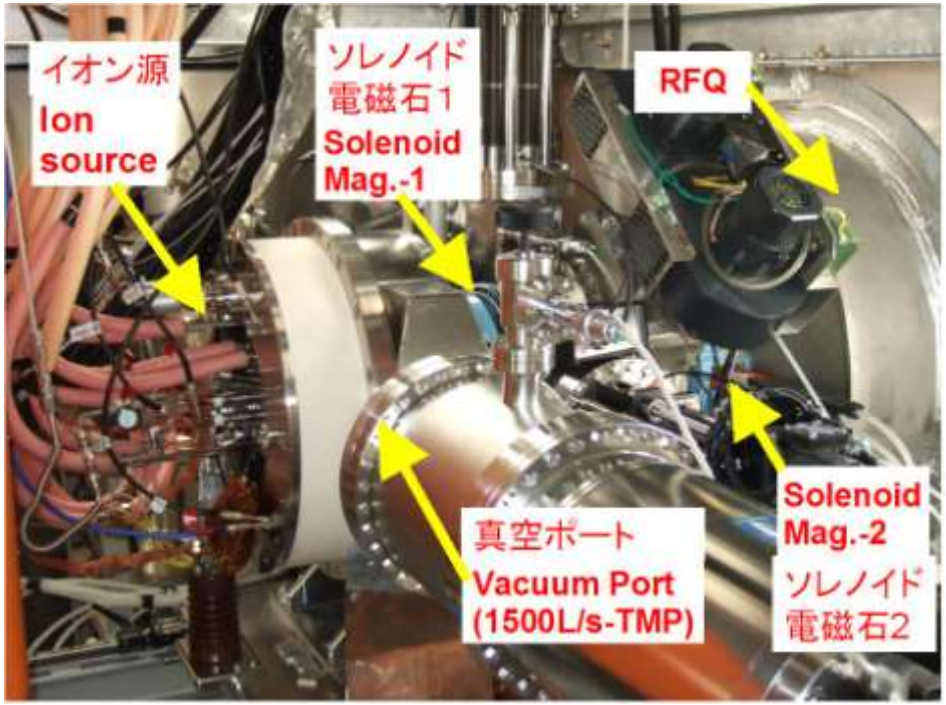
J-PARC Ion source

*Plasma chamber :
100mm diam. 120mm length
*Plasma production :
Arc discharge (LaB6 filament)
*Number of filament : 1
*Cesium : free
*Beam aperture : 9mm diam.
*Number of electrode : 3
*electron suppression :
magnets in extraction electrode

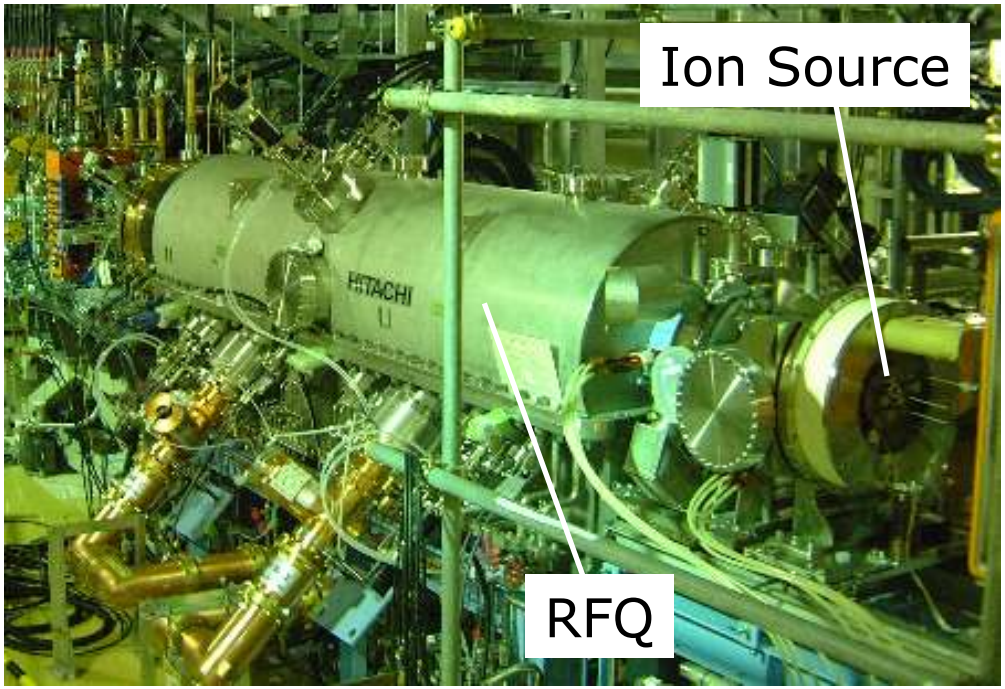


Photograph of LaB6 filament

Front End



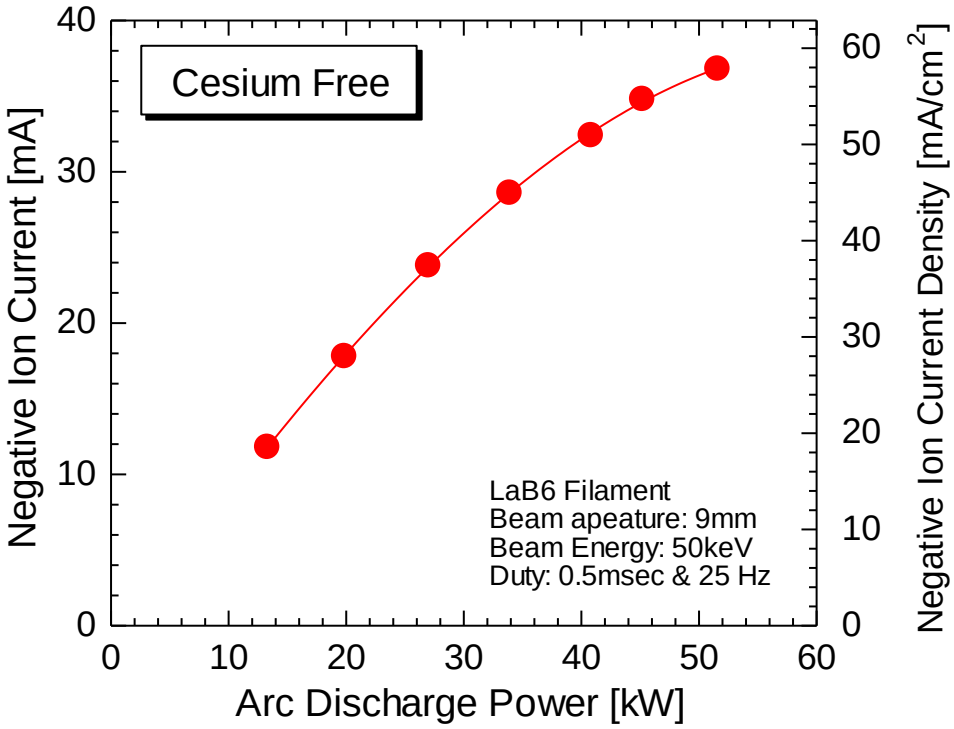
Ion source and LEBT

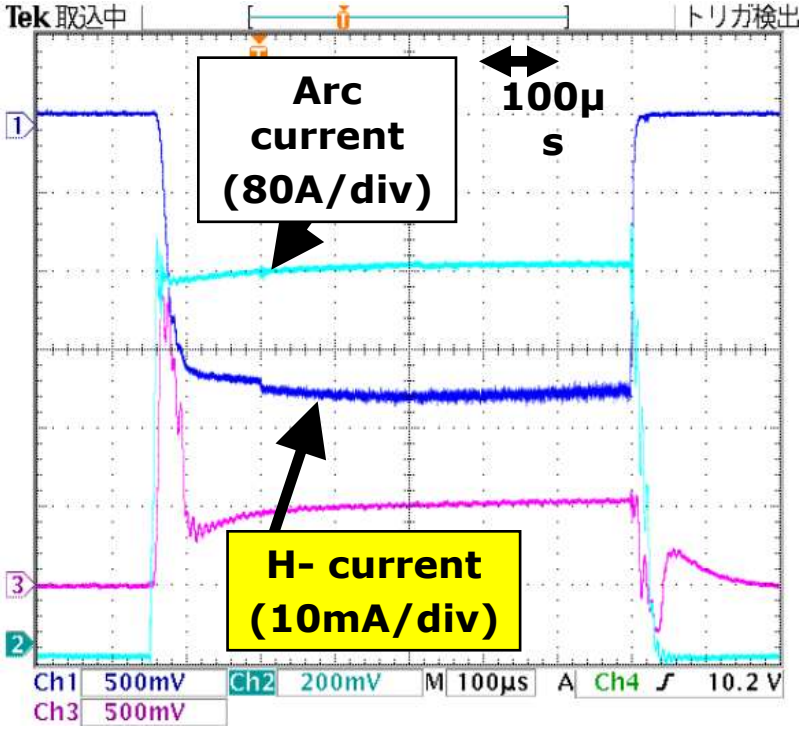


Ion source and RFQ

The ion source is in the insulator to take minimum length to the RFQ

Ion source performance: beam current





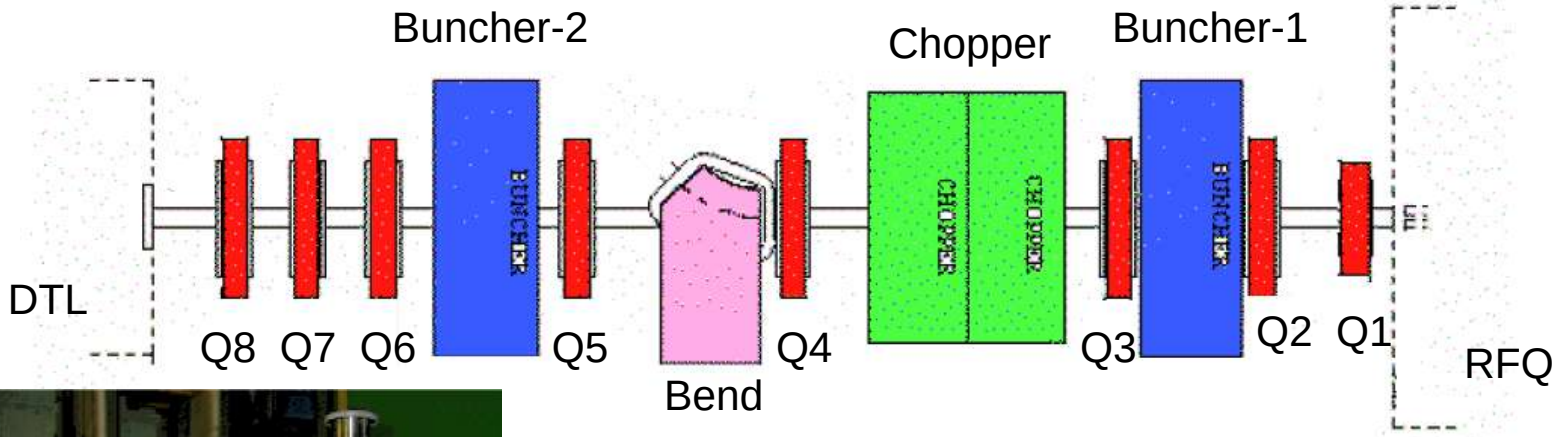
Beam current : 36 mA

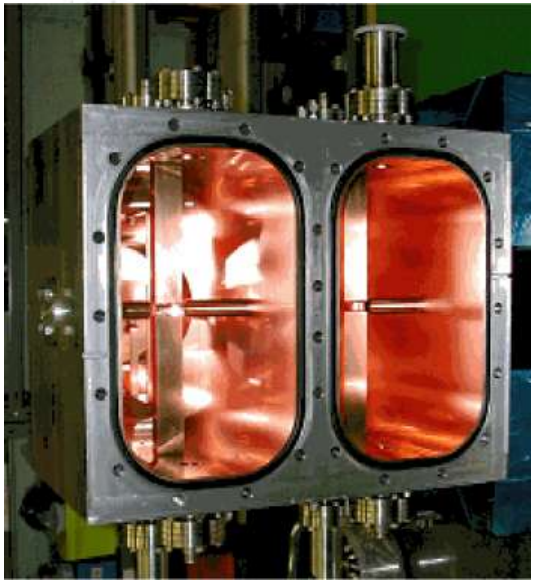
Pulse length : 500µs

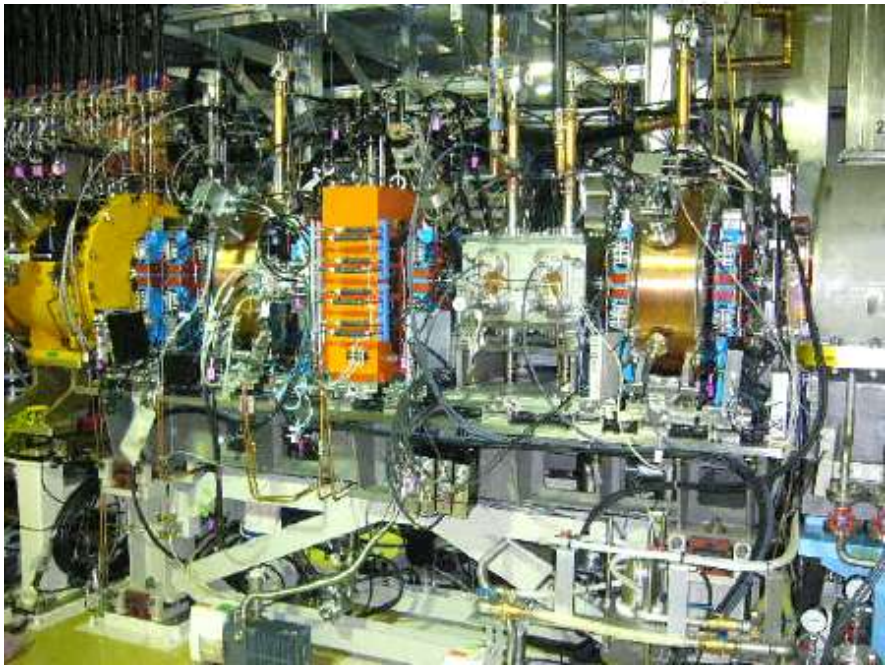
Repetition : 25 Hz

The ion source meets the specification of the 1st stage of the J-PARC.

Medium Energy Beam Transport







Inside of the chopper cavity

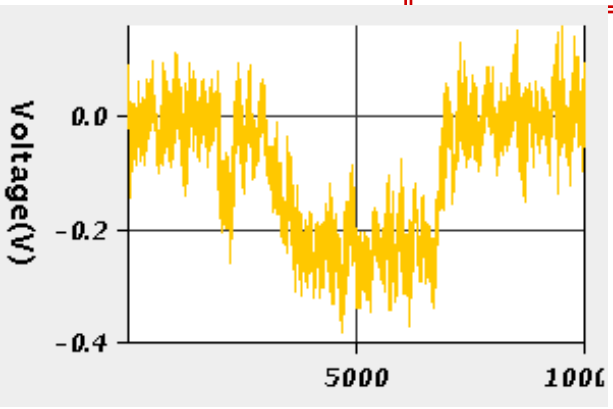
324 MHz, Mode TE11, QL~11

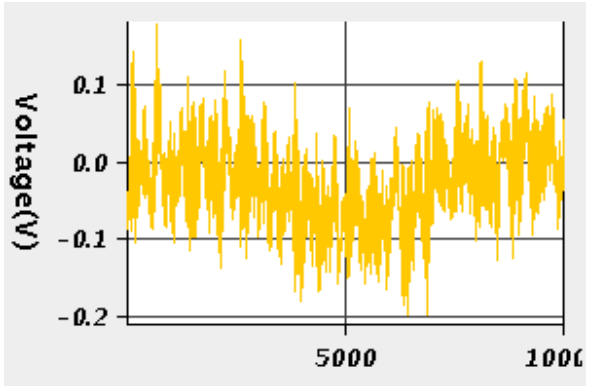
Rise and Fall times: 15 nsec

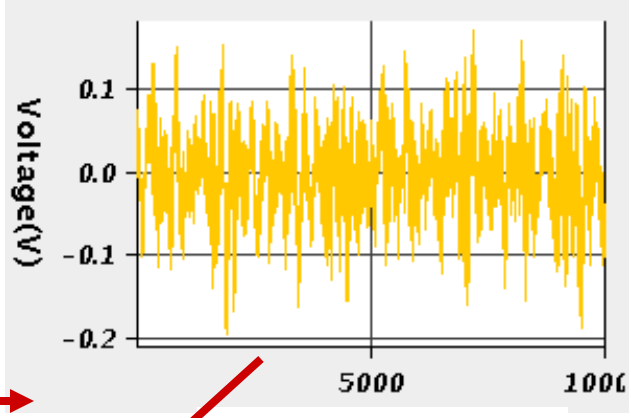
Chopper tuning

Measured residual current with a wire scanner

Peak current: 25 mA

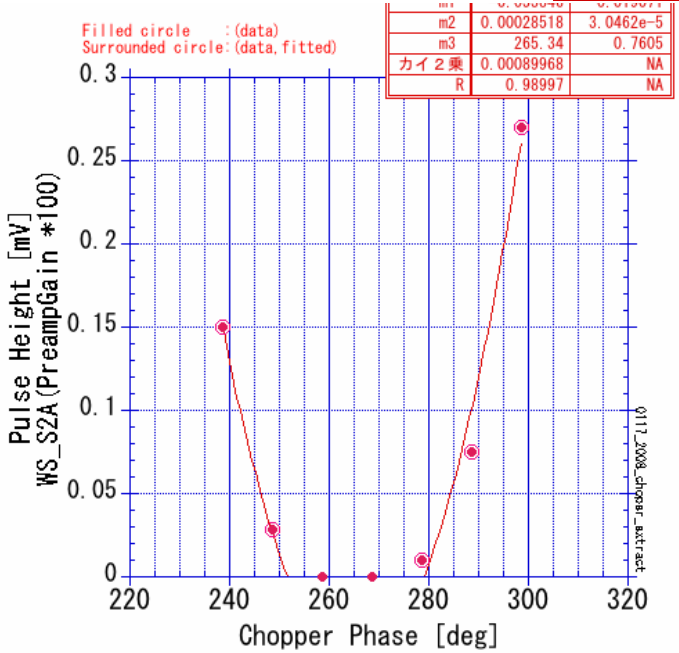


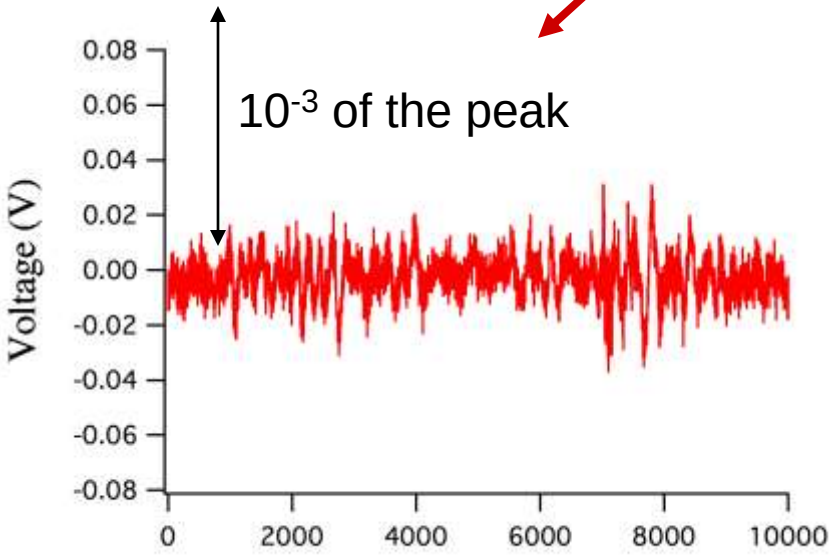




Phase optimization

100-shot average

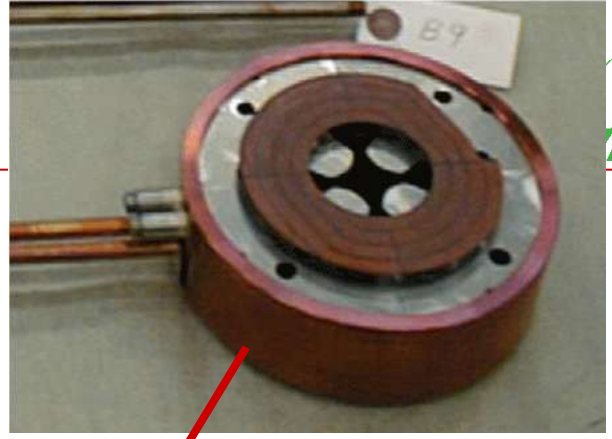




DTL/SDTL

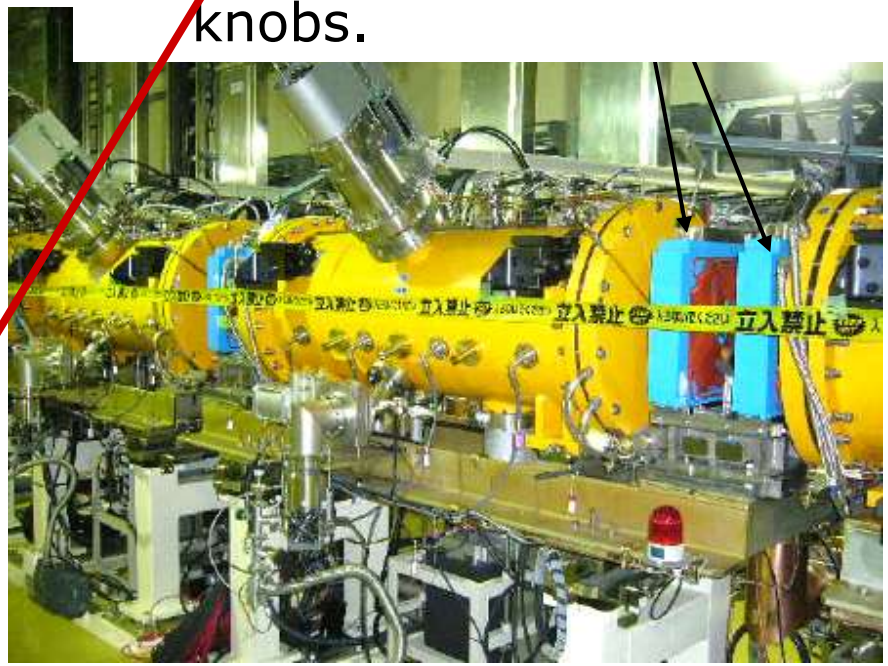
Main Parameters

	DTL	SDTL	
Energy	3-50	50-190.8	MeV
Frequncy	324	324	MHz
Section Length	27.1	91.2	m
Accelerating Field, E0	2.5-2.9	2.5-3.7	MV/m
Number of Cavities	3	32	



Compact electro-quadrupole magnets are accommodated as tuning knobs.

DTL

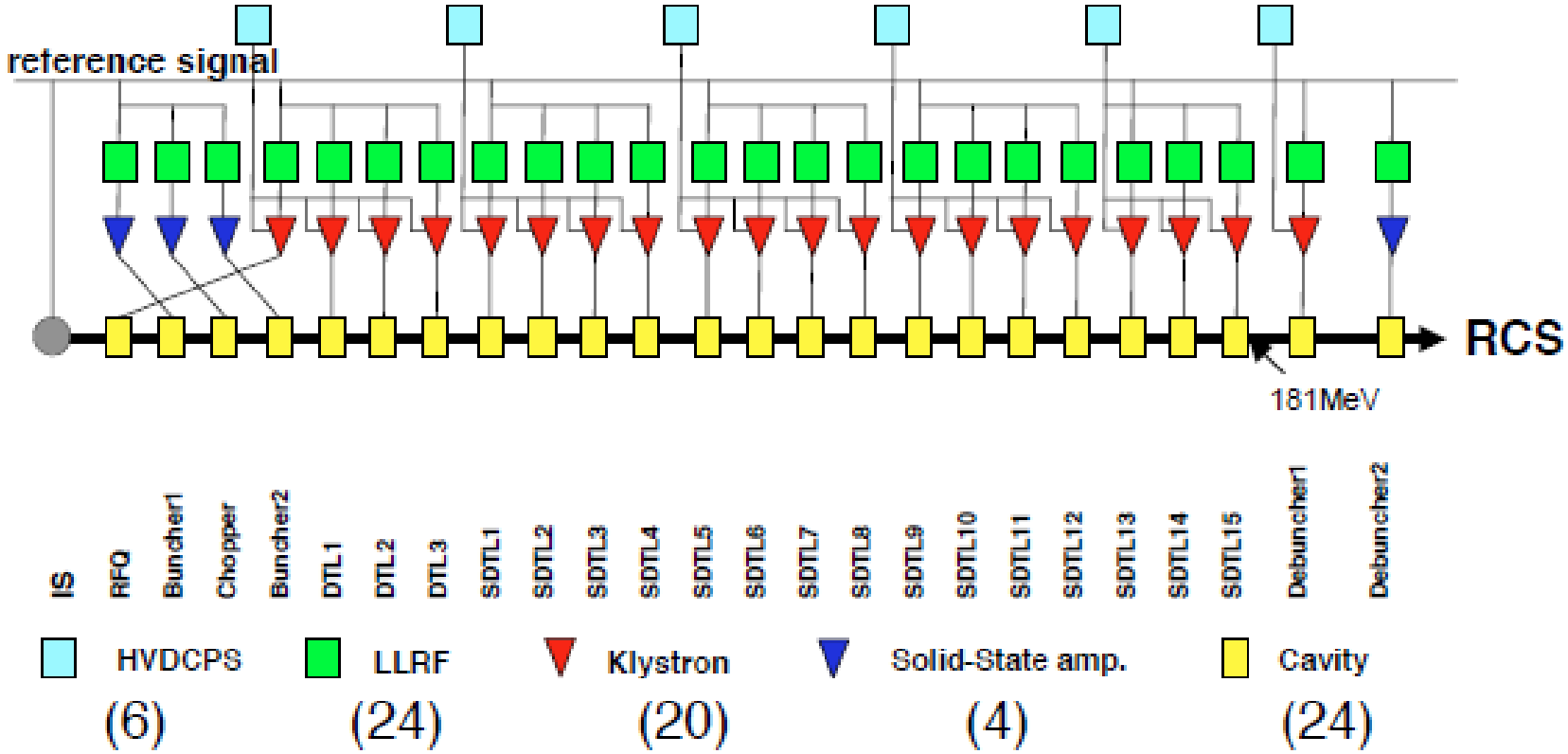


SDTL

Linac RF System

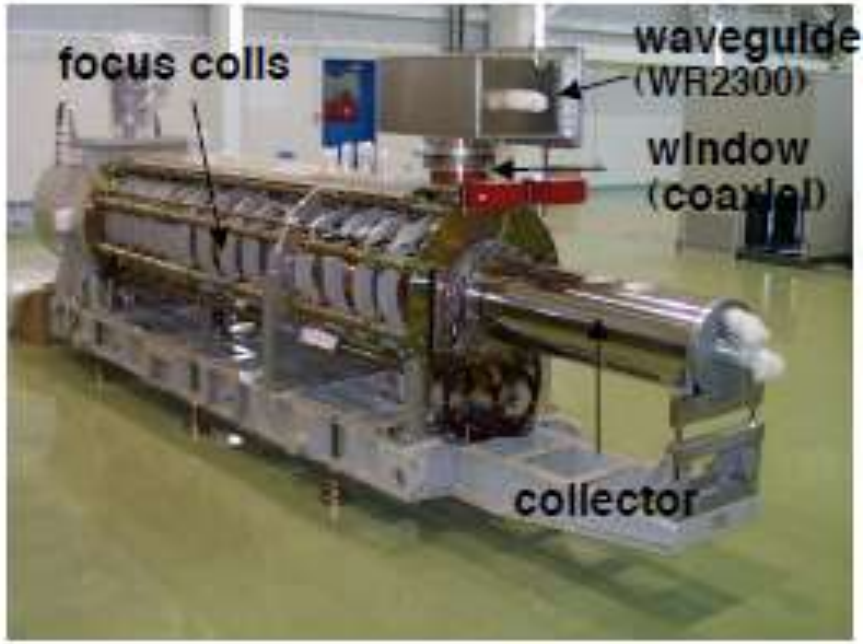
- Operation frequency: 324 MHz
- Total 20 klystrons (max.3 MW), 6 DCPS (#1~6)
- RF flat top: 600 μs (25Hz)
- Requirements of cavity field stability

  <+/-1% (amplitude), <+/-1deg (phase)



RF System: Klystron

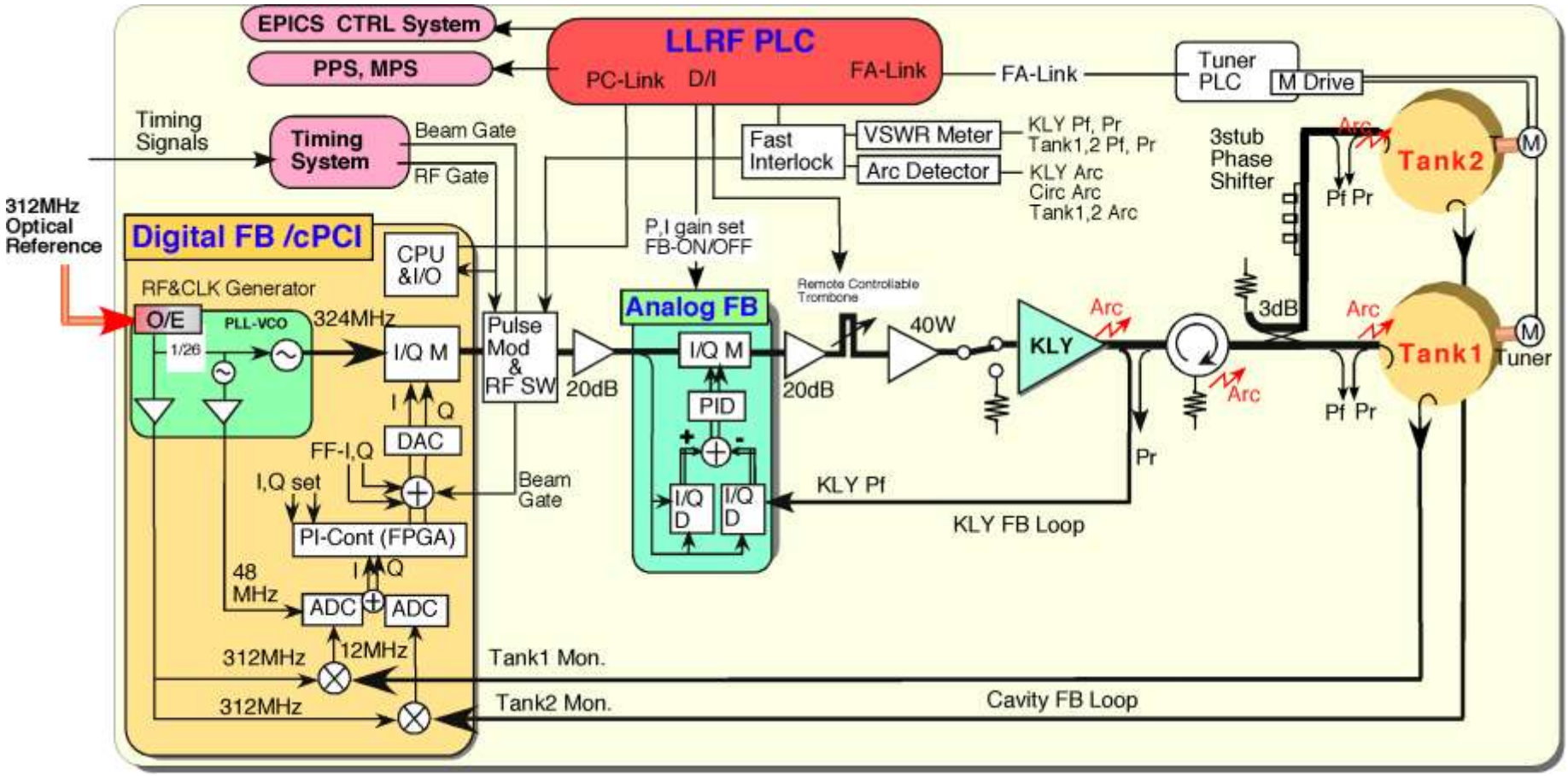
- 20-unit of klystrons have been operated for 16,400 hours. (from 2006 Oct. to 2010 June)
- There are no serious troubles, such as a discharge in e-gun, vacuum degradation, arcing in output window.



Peak Power	2.5 (max. 3.0) MW
Pulse Width	650 μs
Repetition	50 Hz (25 Hz)
μ-Perveance	1.37 $A/V^{3/2}$
Gain	50 dB
Efficiency	55 %
Beam Voltage	105 (max. 110) kV
Beam Current	45 (max. 50) A
Mounting Position	Horizontal
No of Klystron	23 = 20 + 3 (spare)

324MHz Klystron (E3740A)

Low Level RF System



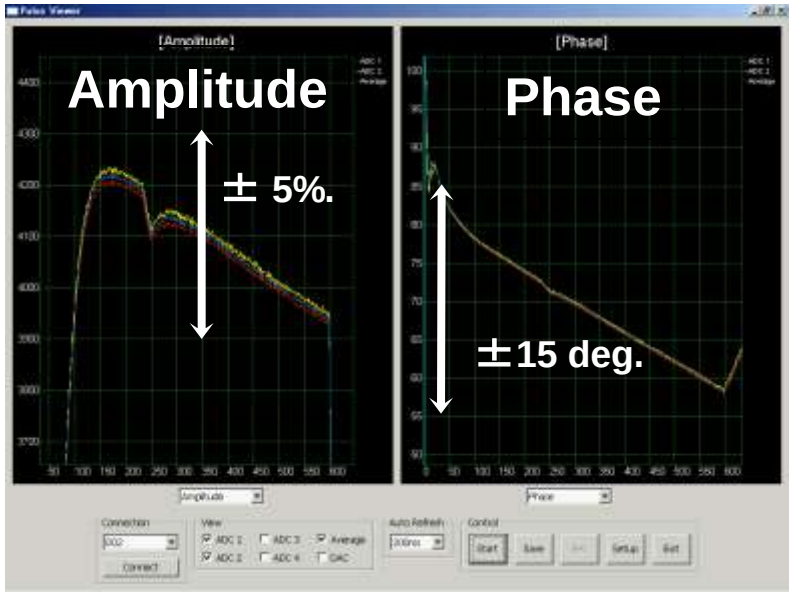
Digital FB&FF Control for Stabilization of Cavity Field

One klystron powers 2 cavities (SDTL section)

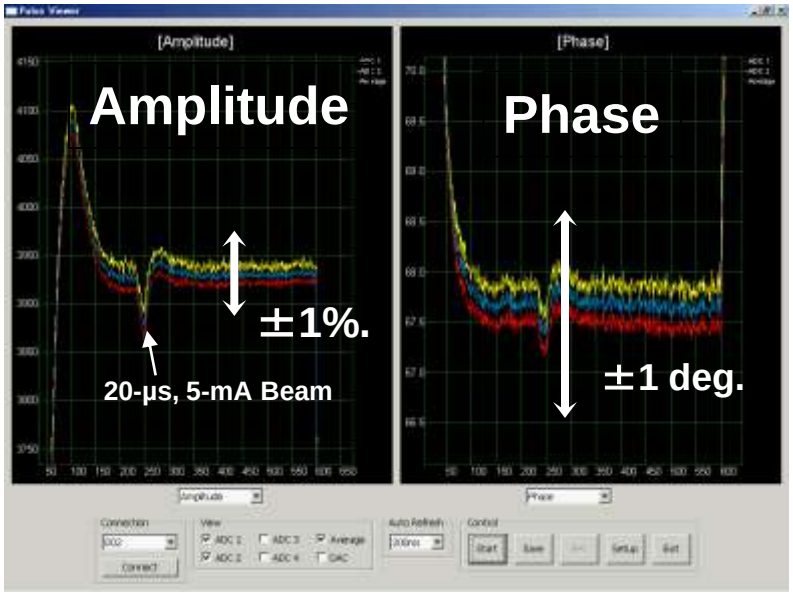
The FB system controls the vector sum of the 2 cavity fields.

Performance of the FB Control

Cavity field stabilization (600-μs RF pulse)



No Feedback Control



With Feedback Control
(Gain: P=5, I=5/1000)

10% in amplitude and 25 degrees in phase sages are due to the Klystron DC voltage sag of about 3.4%

Amplitude and phase are stabilized to be ±0.15% and ±0.15 degrees, respectively. These ripples at the transient have been compensated with FF system.

Performance recovery of the RFQ

Since the autumn of 2008, the most urgent issue of the linac was discharge in the RFQ. The RCS beam power for users was limited at 20 kW due to the RFQ problem.

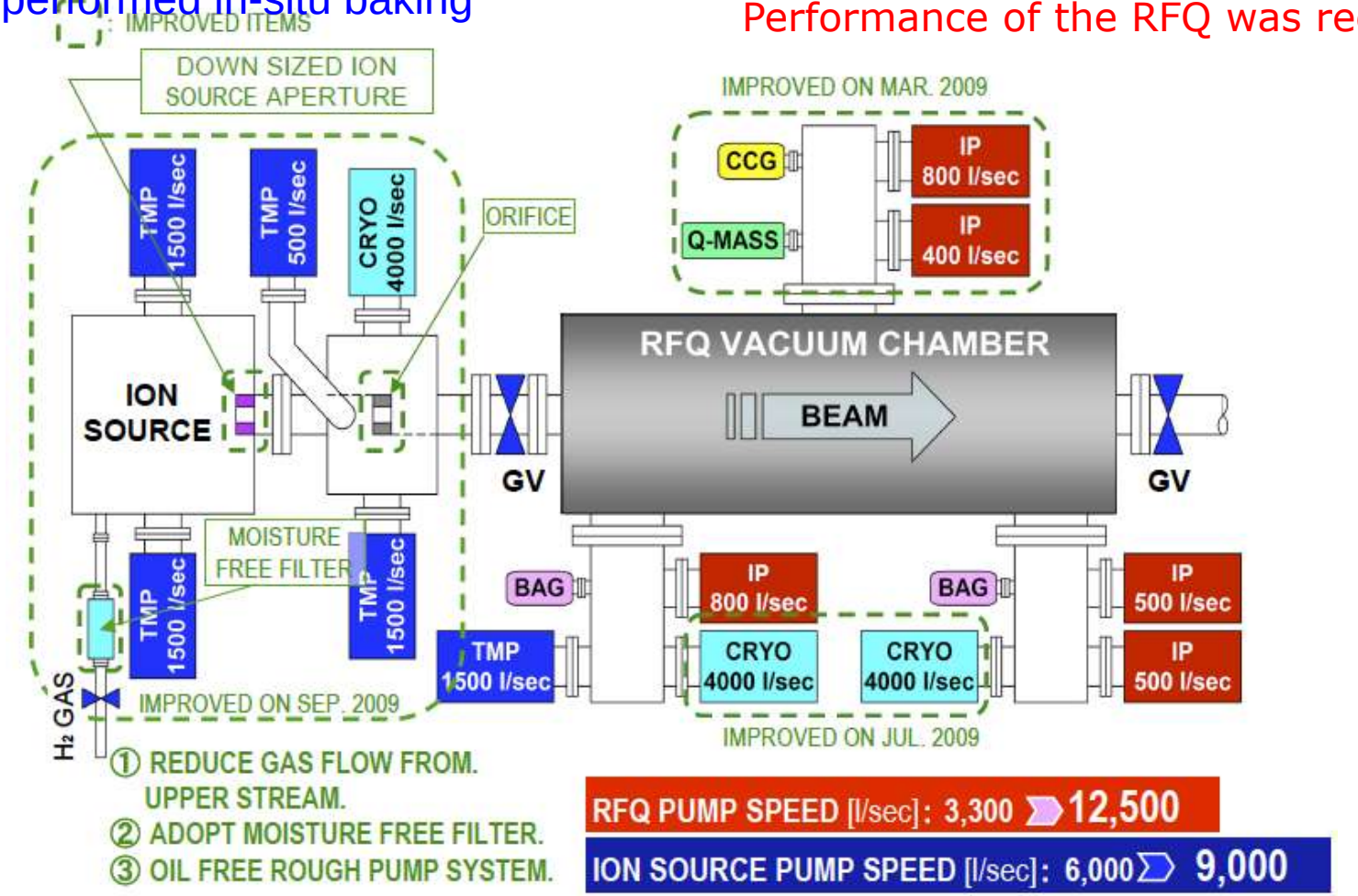
In the 2009 summer shutdown,

improved vacuum system

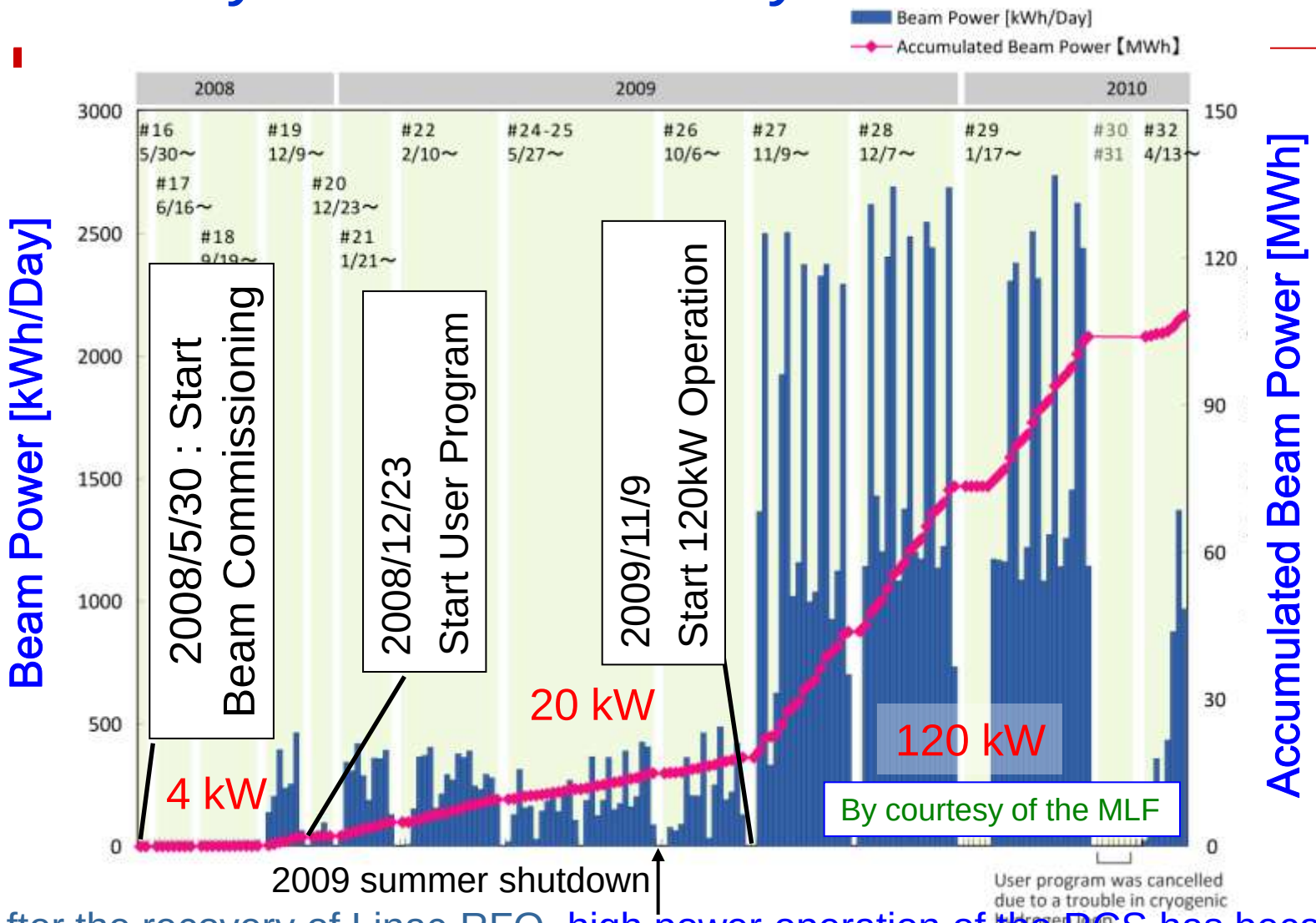
performed in-situ baking

→ Hydro-carbon components in residual gases gradually reduce during rf conditioning

Performance of the RFQ was recovered.



History of beam delivery to the MLF

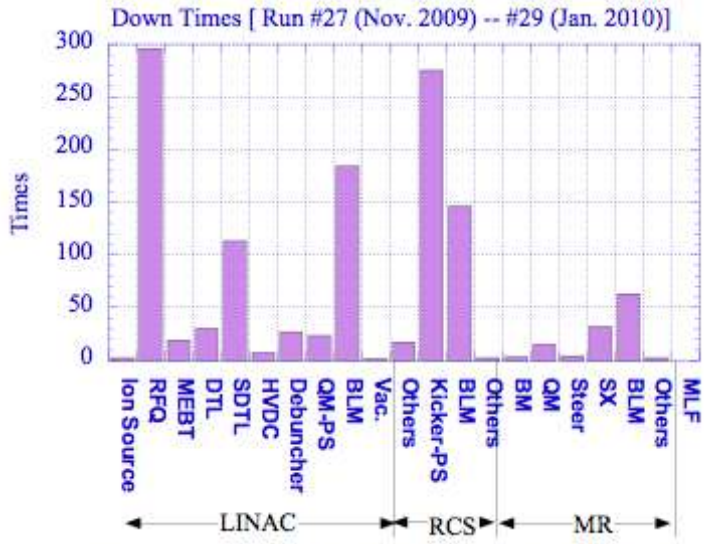


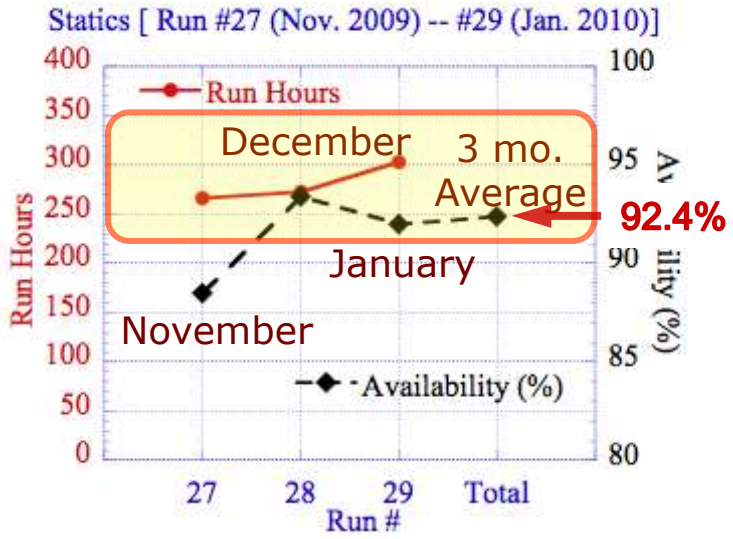
After the recovery of Linac-RFQ, high power operation of the RCS has became possible and 120 kW operation has started for the MLF users.

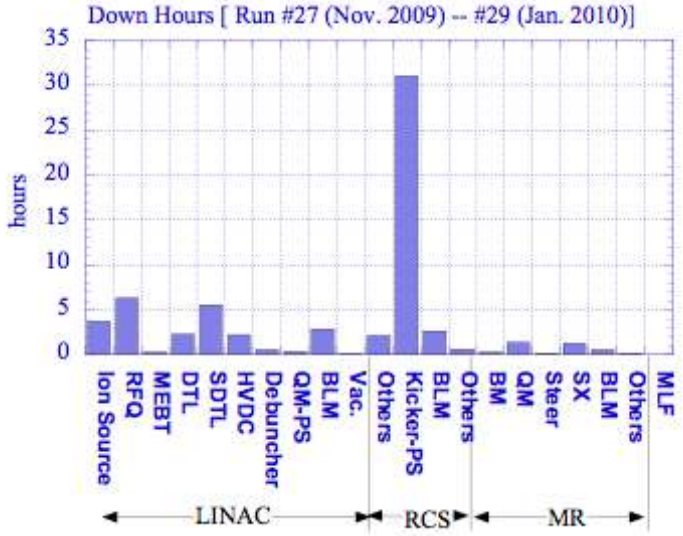
Neutron beamline : 12 beamlines are now under commissioning and open for users.

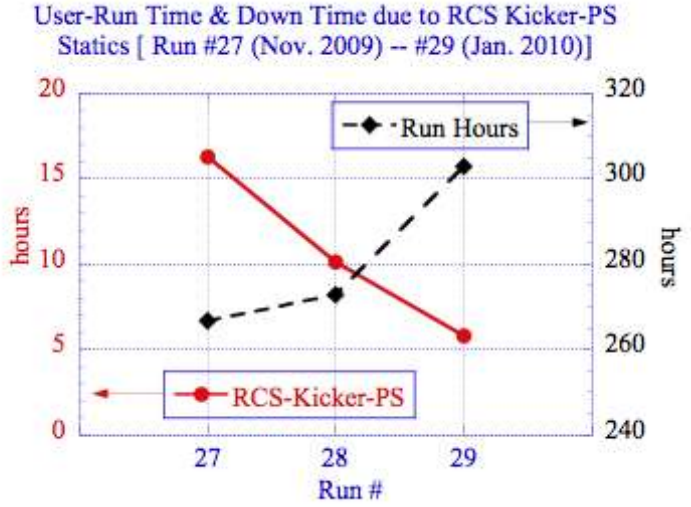
Muon beamline: The highest intensity beamline in the world with the 120 kW beam.

Availability of the Accelerator





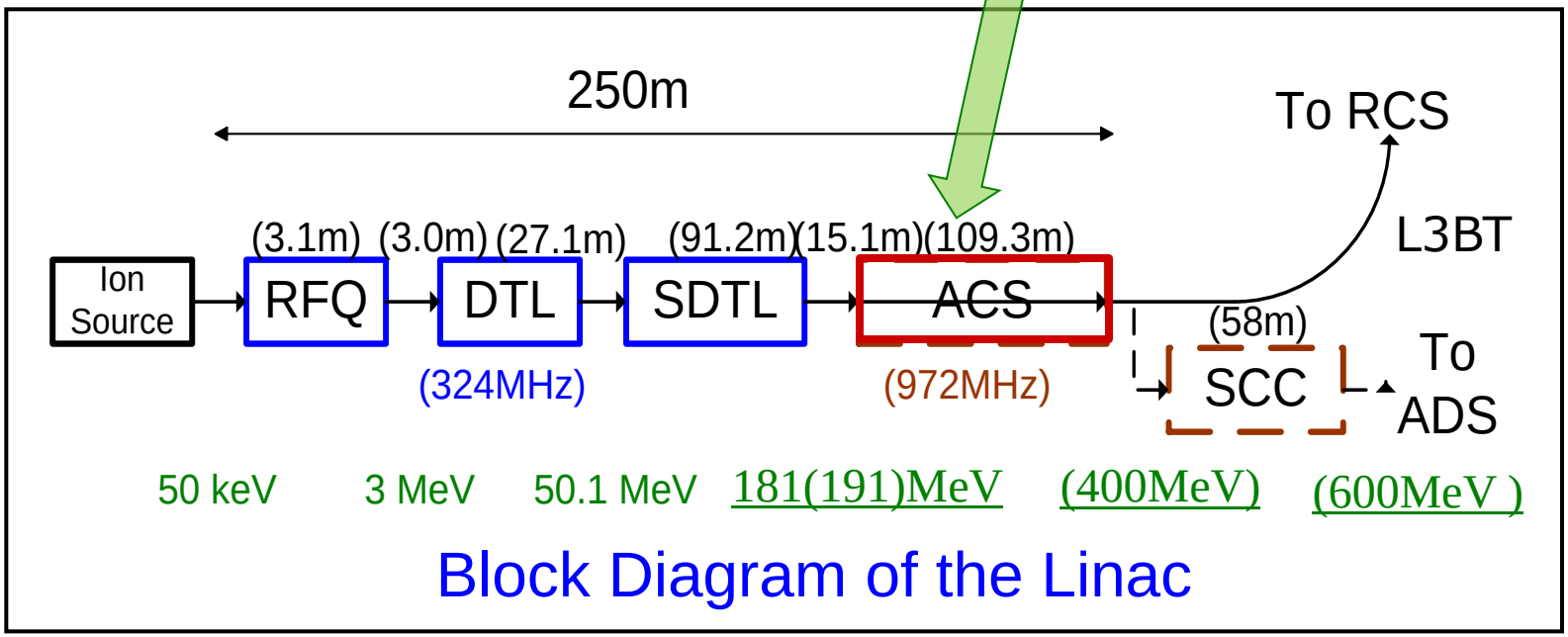




Energy upgrade of the Linac

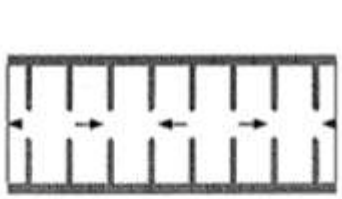
We have successfully marked the milestones of the J-PARC.

- The full potential of the J-PARC complex cannot be realized with a 181 MeV linac. (e.g. 1MW@RCS, 0.75MW@MR)
- The construction of 200 to 400MeV part of the linac was funded through the supplementary budget of JFY2008.

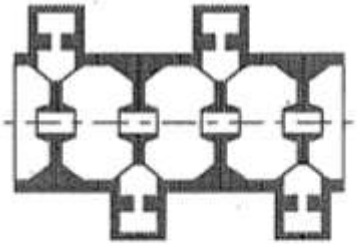


Block Diagram of the Linac

Annular Coupled Structure (ACS) for High-Energy Structure

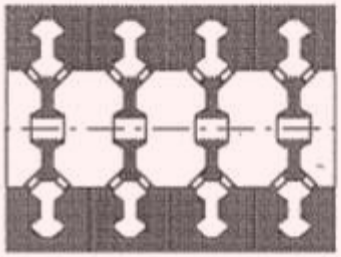


a) Disc-loaded

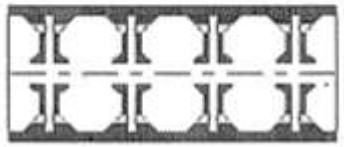


d) SCS (Knapp, LANL)

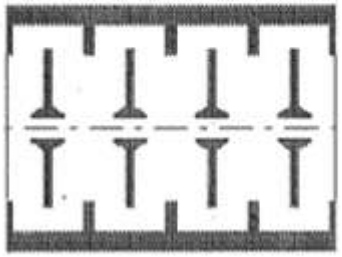
b) APS-I (T. Nishikawa, KEK)



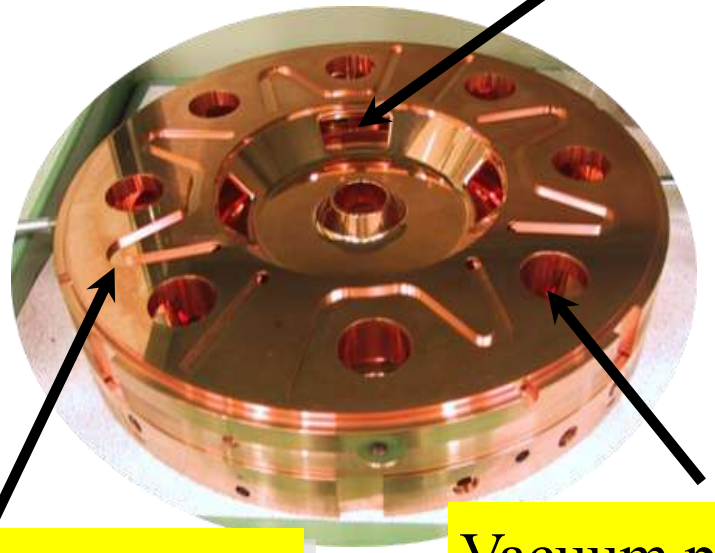
c) ACS (Kageyama, Yamazaki, KEK)



c) APS-II



f) DAW (Andreev, Moscow)



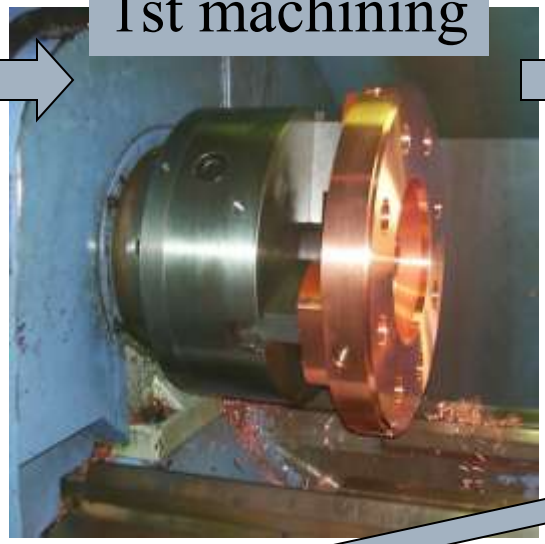
Half-cell piece

Energy	190.8-400	MeV
Frequency	972	MHz
Section Length	108.3	m
E0	4.1	MV/m
RF pulse width	0.6	ms
Duty factor	3	% max
Number of modules	21	Acceleration
	2	Bunchers
	2	Debunchers

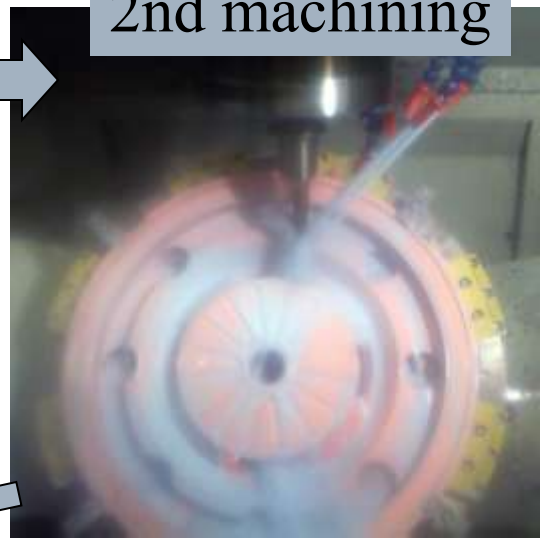
Machining of ACS disks

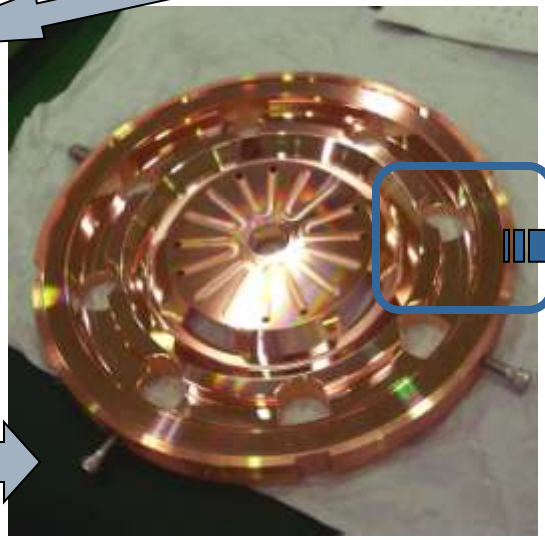
Copper plates

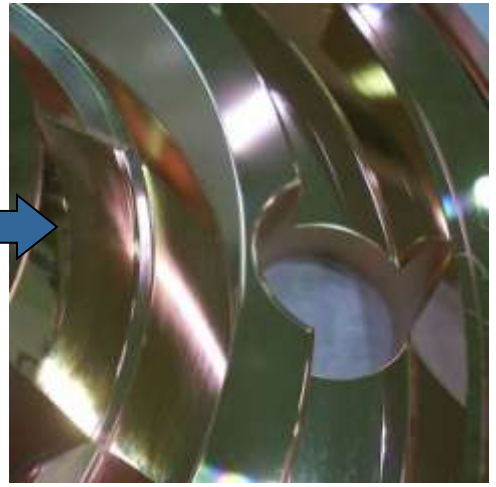
1st machining



2nd machining





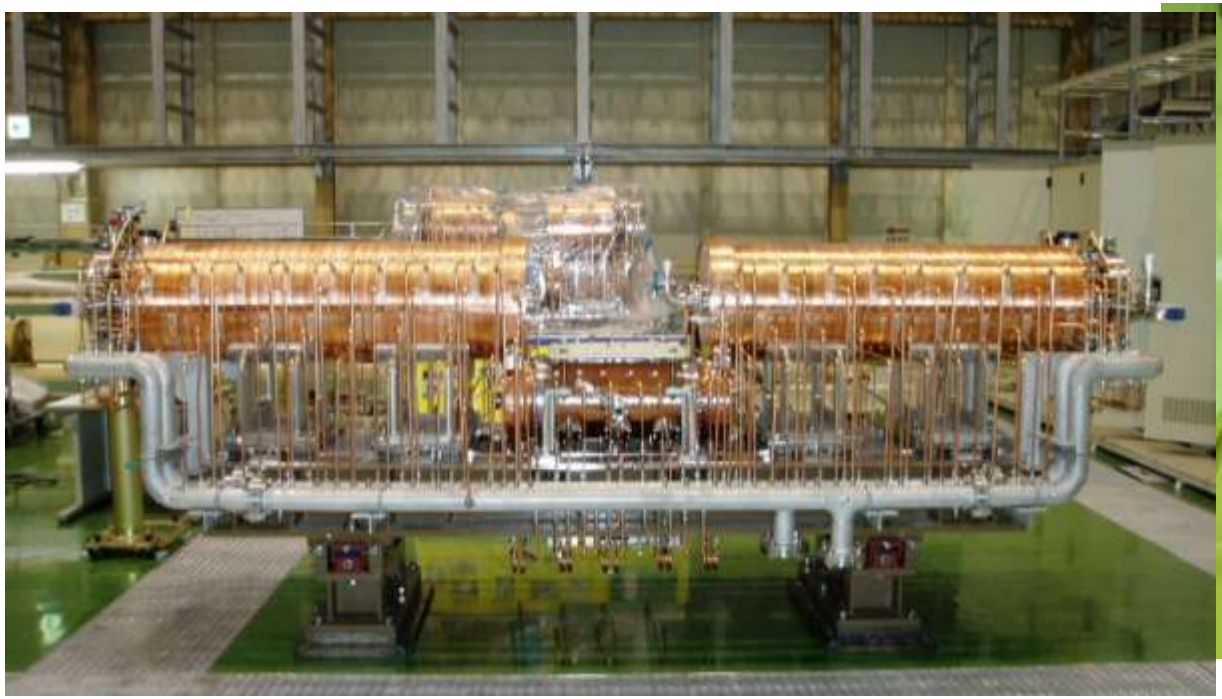


Brazing and Assembling of ACS

Vacuum furnace

Assembling

ACS Structure



The lowest energy ACS module

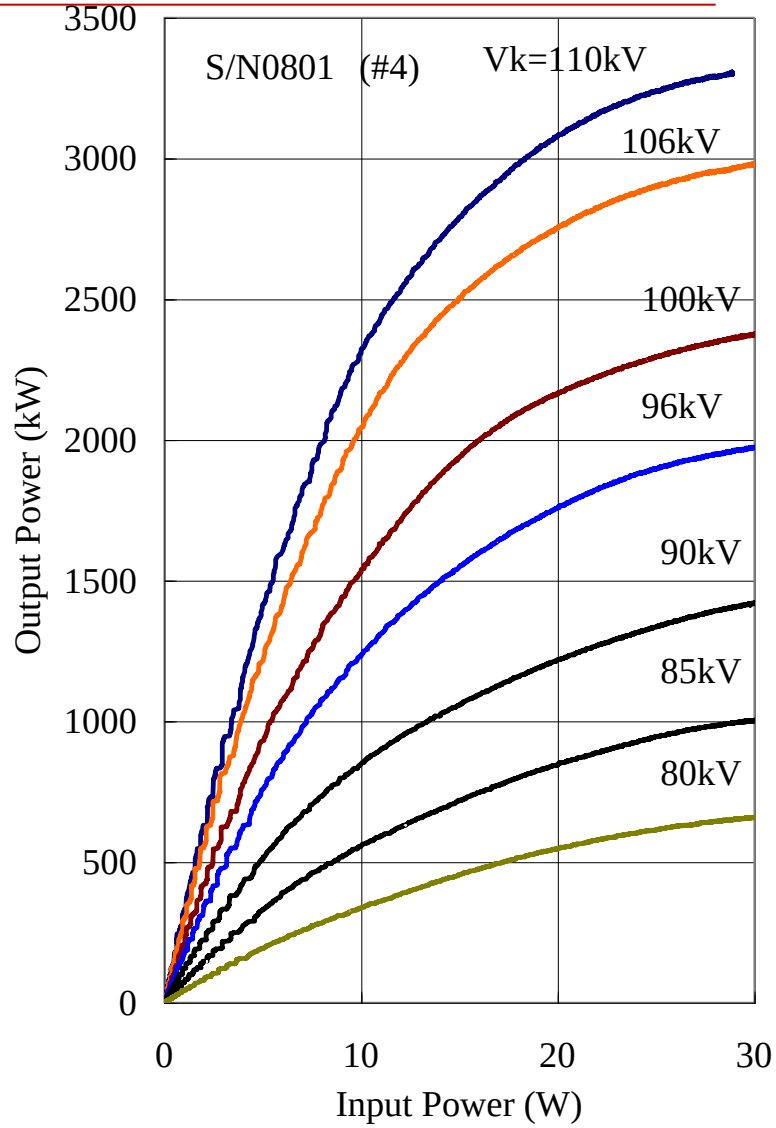
The ACS cavities are preparing for mass production at factories.

ACSs will be installed in the tunnel in 2012, where currently using as a beam transport line.

972MHz Klystrons

Cathode voltage	106kV (110kV)
Cathode Current	45A (50A)
Saturated RF power	3.1MW (3MW)
Gain	51dB (>50dB)
Efficiency	>60% (>55%)
Band width	±5MHz(>5MHz)
	(Specifications)

Three tubes of klystrons.



Input-Output characteristics.

Installation at the Gallery

Klystron stations under construction.

Waveguides were installed from the klystron gallery to the accelerator tunnel during the summer shutdown in 2009.

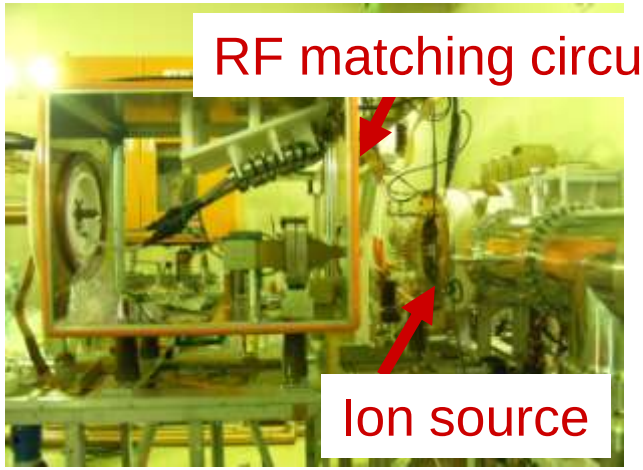
Ion Source Towards 1MW Goal

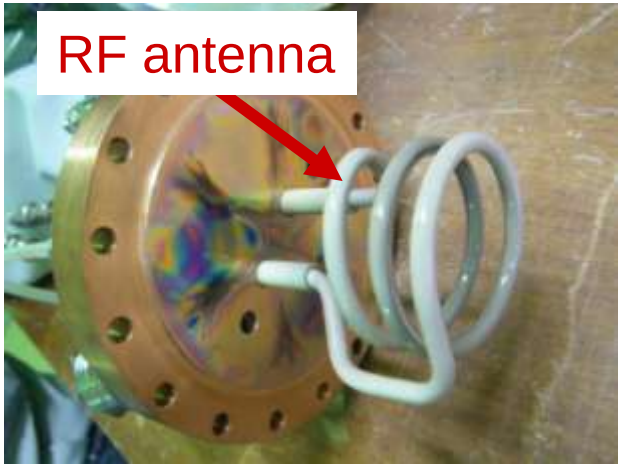
We have been operated at 30 mA without Cs routinely. But we need 50 mA for 1MW goal.

We decided Cs-seeded source driven with RF is the first candidate for 1MW source.

->An RF source is superior to filament one for reduction of the amount of Cs.

Jan- 2010: Start of preparatory-experiment with existing RF ion source





Photograph of RF pre-experiment set up

Mar- 2010: Visit SNS to study RF ion source technology

*SNS RF source has good performance.

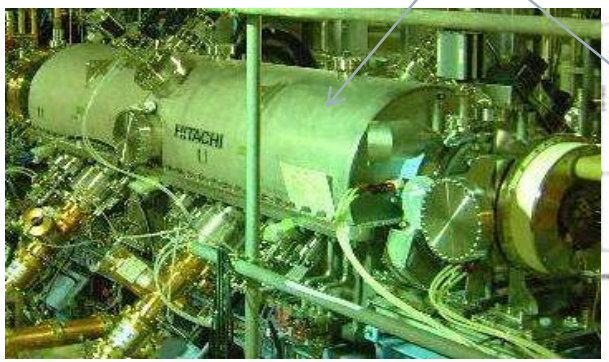
R&D of an RF ion source is underway.

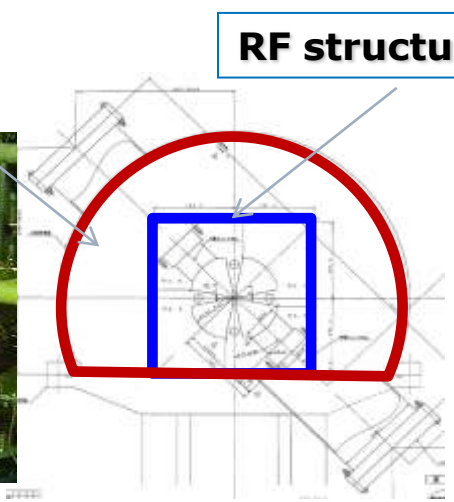
RFQ-#1,#2 and #3

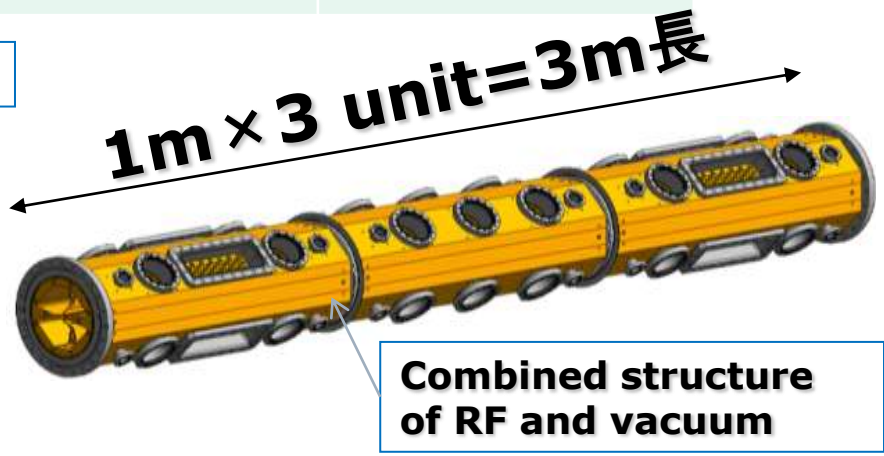
The performance of the present RFQ (#1) is getting better, we continue to make a back up RFQ (#2) and designing a final (#3) RFQ.

The #2 RFQ is a demonstration of #3 structure.

	#1(present)	#2 (backup)	#3(final goal)
Peak current	30mA	30mA Beam dynamics follows the #1	50mA
Structure	RF-Vacuum dual structure	One structure	One structure

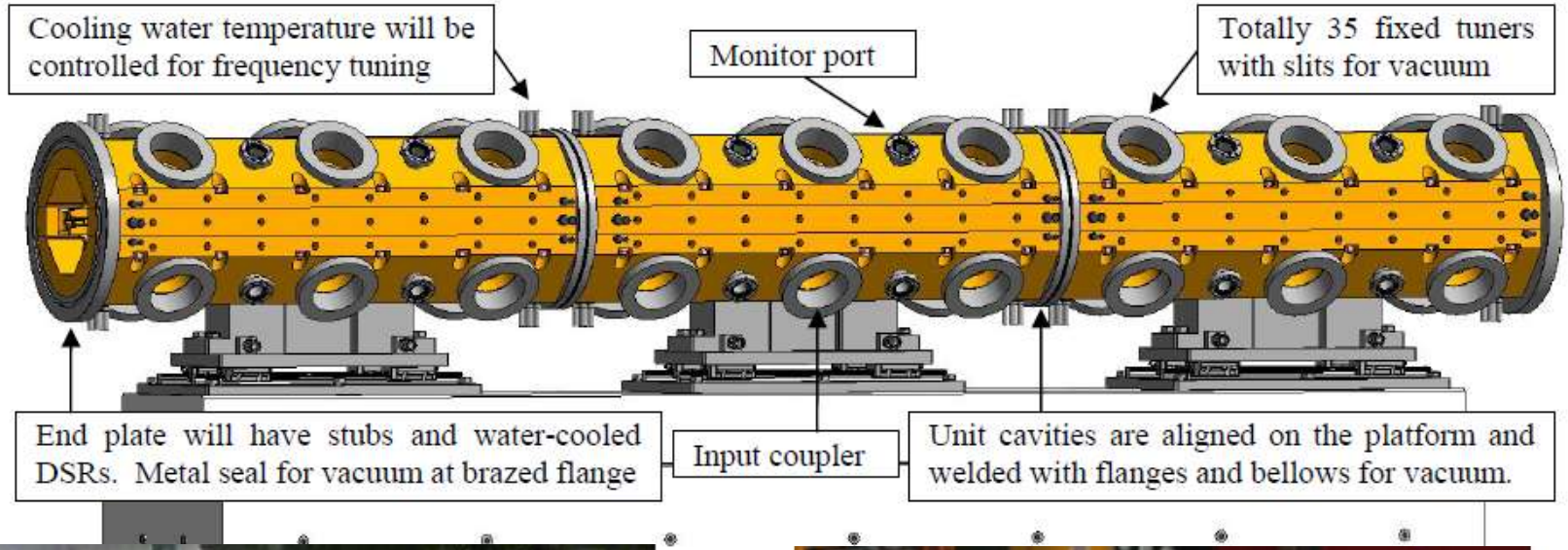


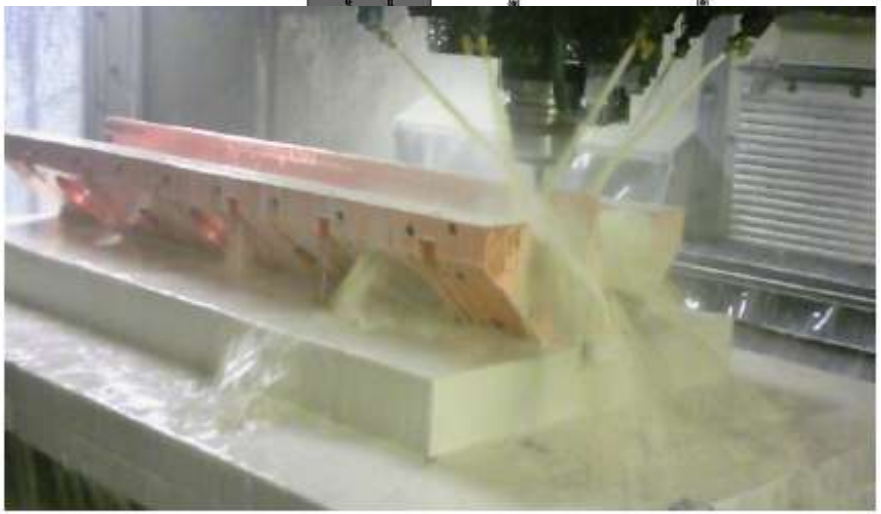




View of #1 RFQ and cross section **Image of #2 and #3**

RFQ-#2





Vane modulation is produced by an NC ball-end mill.

Set up before brazing

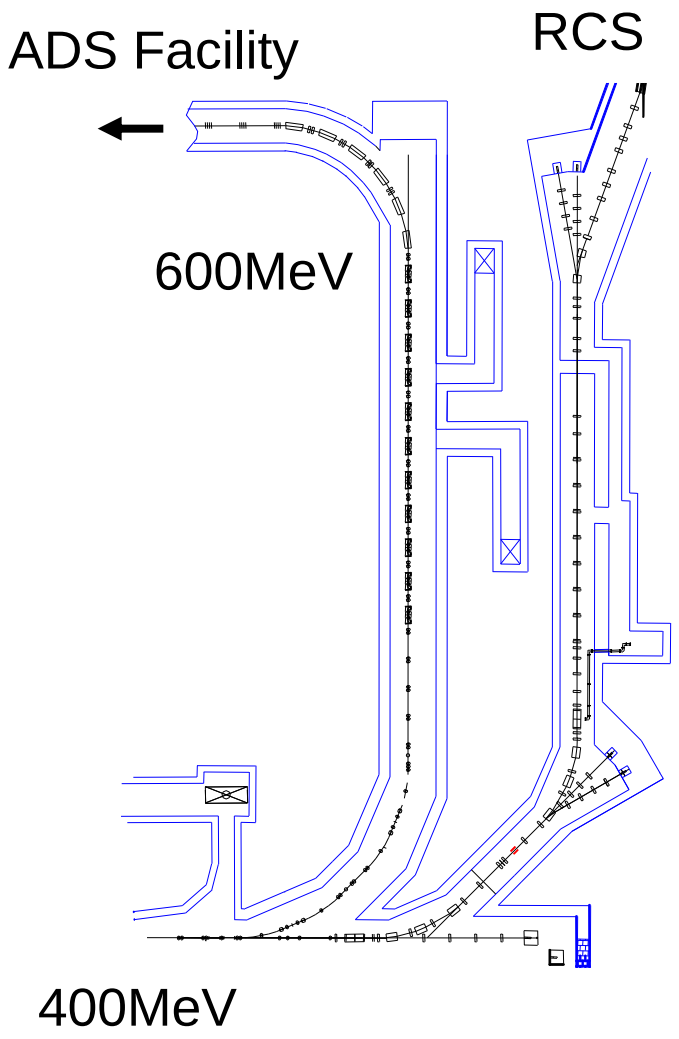
Superconducting Proton Linac

History of SCL at J-PARC(JAERI)

- 1995 R&D of the SCL started
- 2000 Test of 600 MHz cryomodule, β=0.886, 5 cells
- 2002 Design of 972 MHz cryomodule
- 2002-2009 Test of 972 MHz cryomodule

Design Parameters

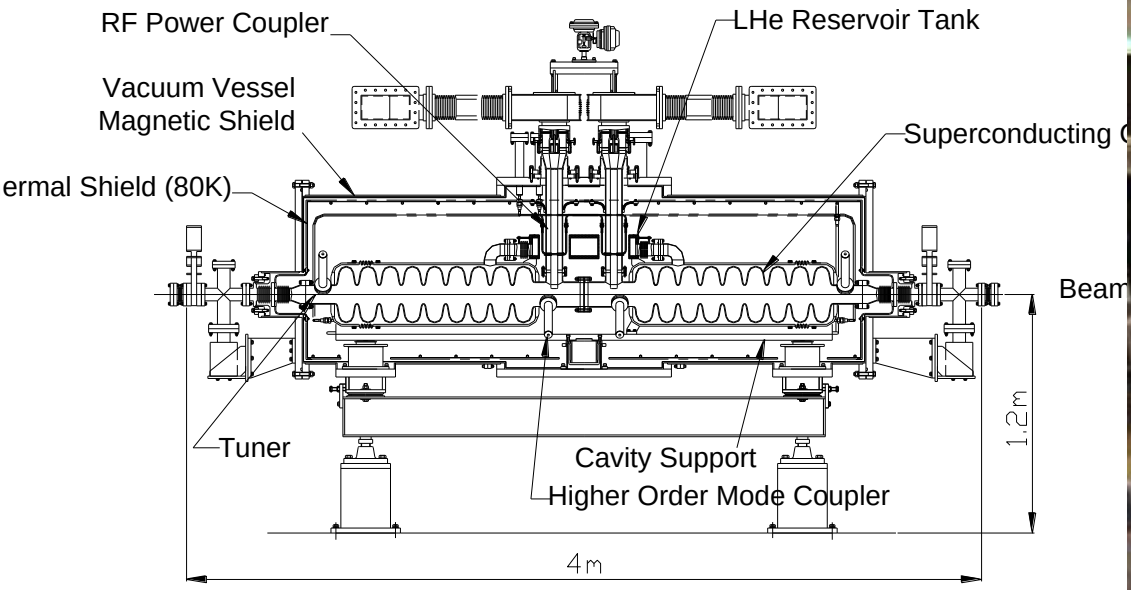
Energy	400-600 MeV
Frequency	972 MHz
β	0.71-0.79
No. of Cell	9 cell/cavity
No. of Cavity	2 cavity/cryomodule
No. of Cryomodule	11 cryomodules
Length	57.7 m
Surface Peak Field	30 MV/m
Accelerating Field	9.7-11.1MV/m

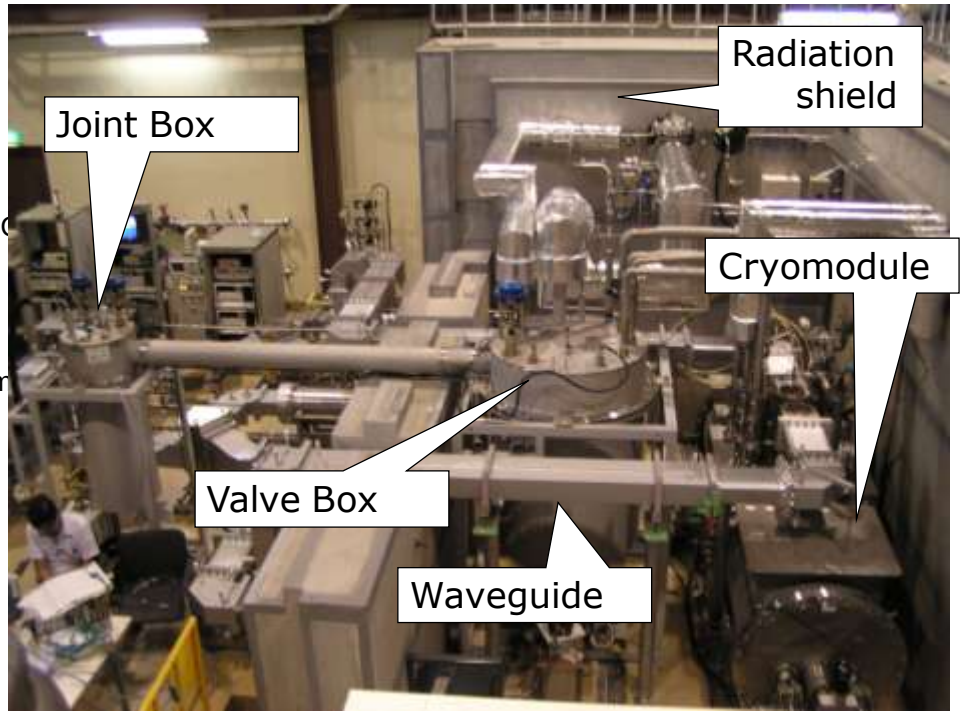


Superconducting Proton Linac

Cryomodule design

- Two 9-cell elliptical cavities at 2K (972 MHz)
- Stiff structure for cavity and tuner to reduce Lorentz force detuning
- 80K thermal shield by LN_2 and 5K thermal intercept by LHe





SC Linac Experimental Results

- RF Properties

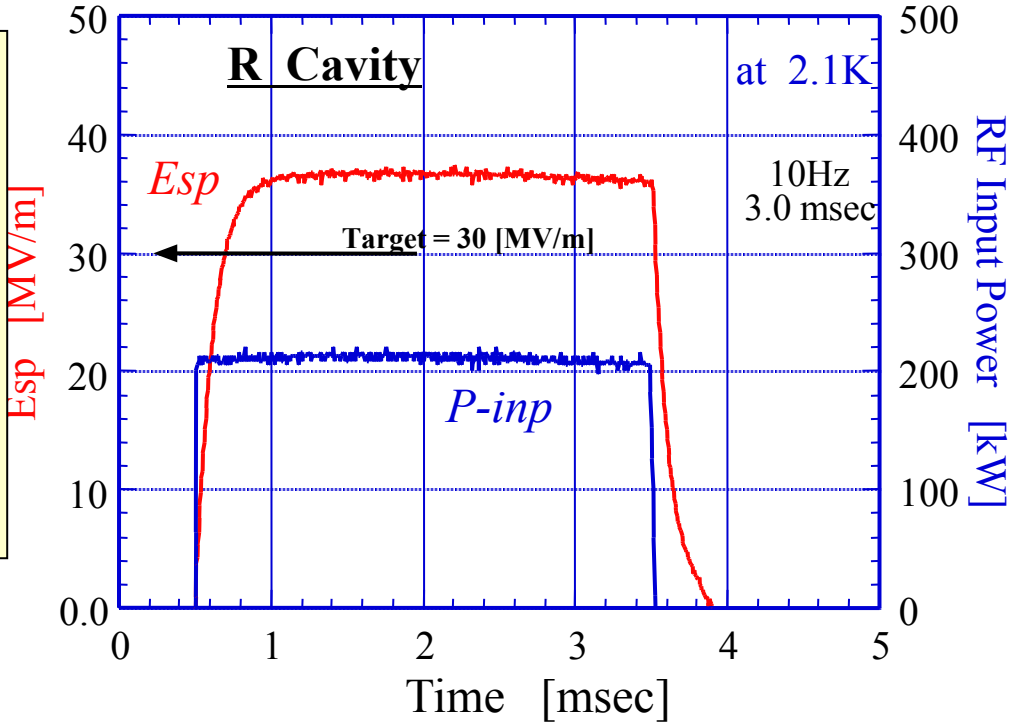
  Surface peak Field (Esp)

  37, 35 MV/m (Target 30MV/m)

  at duty factor of 3%

- Cryogenic Properties

  Heat leak : 10W (Design 5W)



- At the first test, higher duty factor operation is limited up to 3% due to poor cryogenic performance. Improvement of the cryogenic performance was done in 2007.
- Vector sum test was well performed in 2009.
- The RF power supply is moved to the J-PARC linac building for the energy upgrade (reuse to reduce cost). No activity since then, but still in the Phase-2 upgrade plan.

Summary

- Commissioning and operation of the J-PARC linac is progressing well.
  - The RFQ discharge problem has been almost resolved. Beam delivery to MLF(120kW), Neutrino (50-100kW), and Hadron users.
  - Beam availability of the accelerator is more than 90%.

- Performance upgrade
  - The 200-400 MeV linac part was funded and construction is underway.
  - The 2nd RFQ is under construction as a backup and R&D of the next high current RFQ.
  - The R&D of RF ion source for higher beam current has been started.
  - Superconducting linac is still in the second phase of the project.

End of the talk