TUZAPA01

Present Status of J-PARC Accelerator

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KEK

J-PARC Accelerator Team

(Japan Proton Accelerator Research Complex)

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- Construction status
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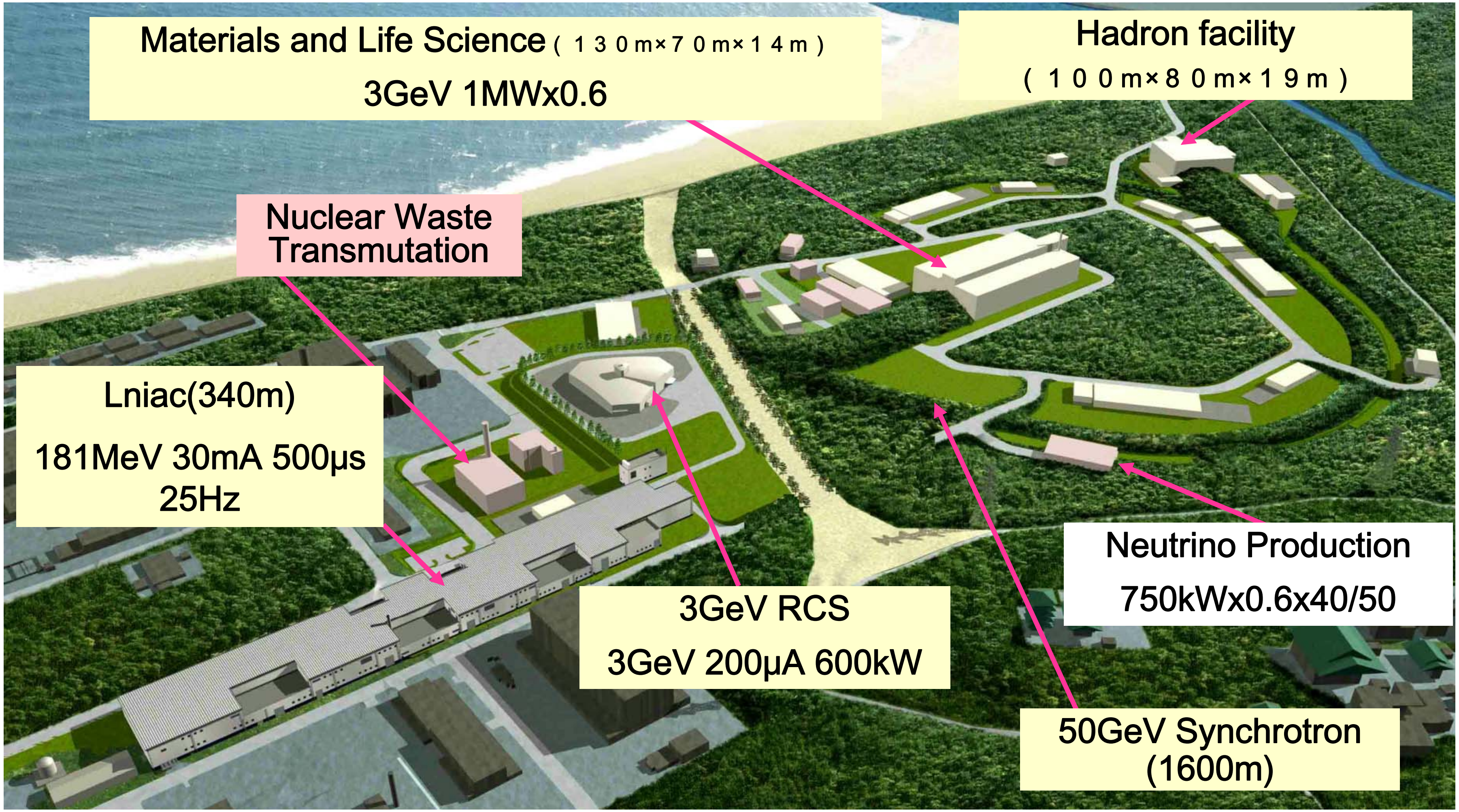
  - High field acceleration
  - Large aperture magnet and interference between them
- Power recovery scenario of MR
- Summary

Site View of the Project



Phase I

Phase II

J - PARC Status

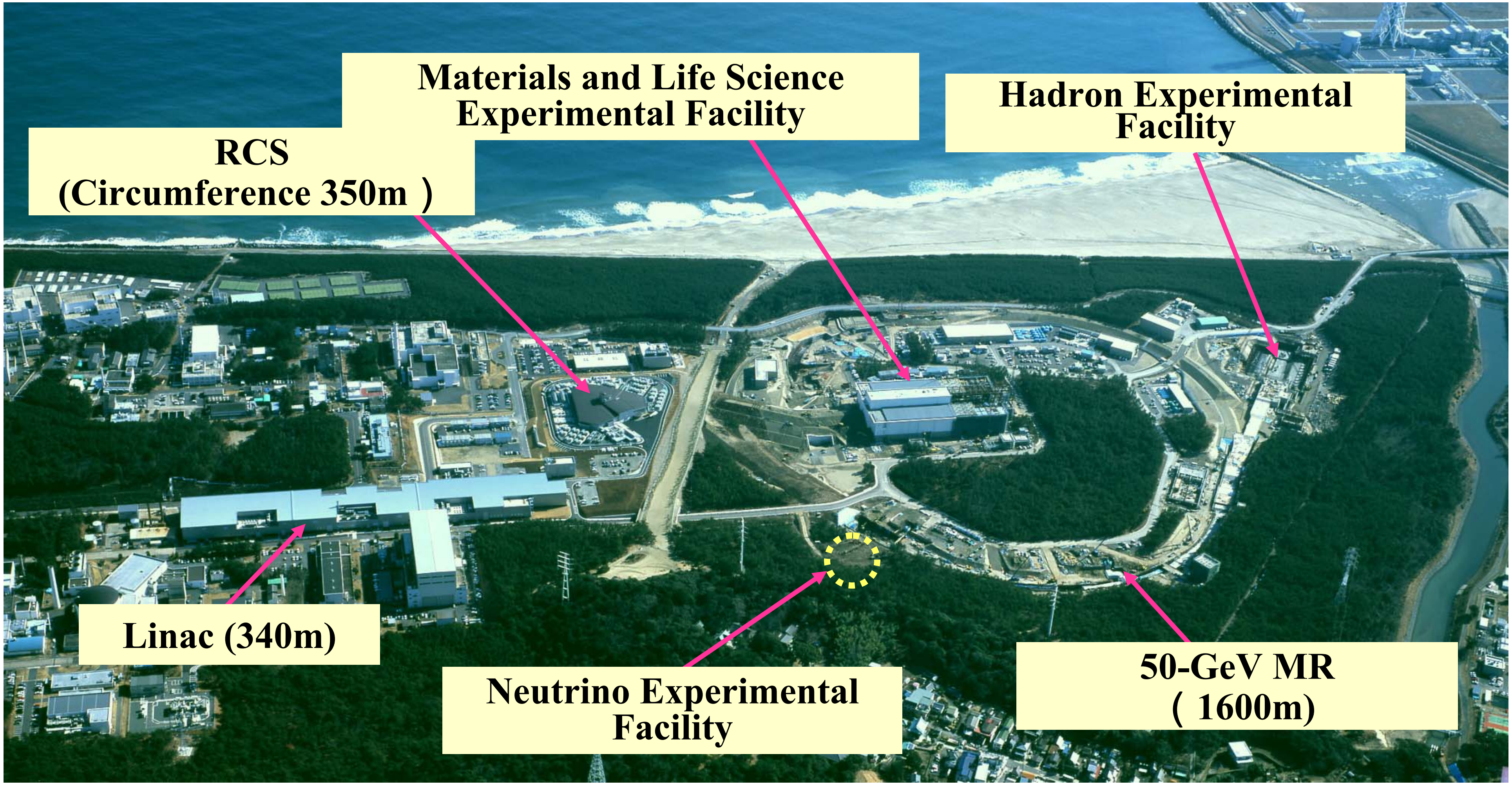
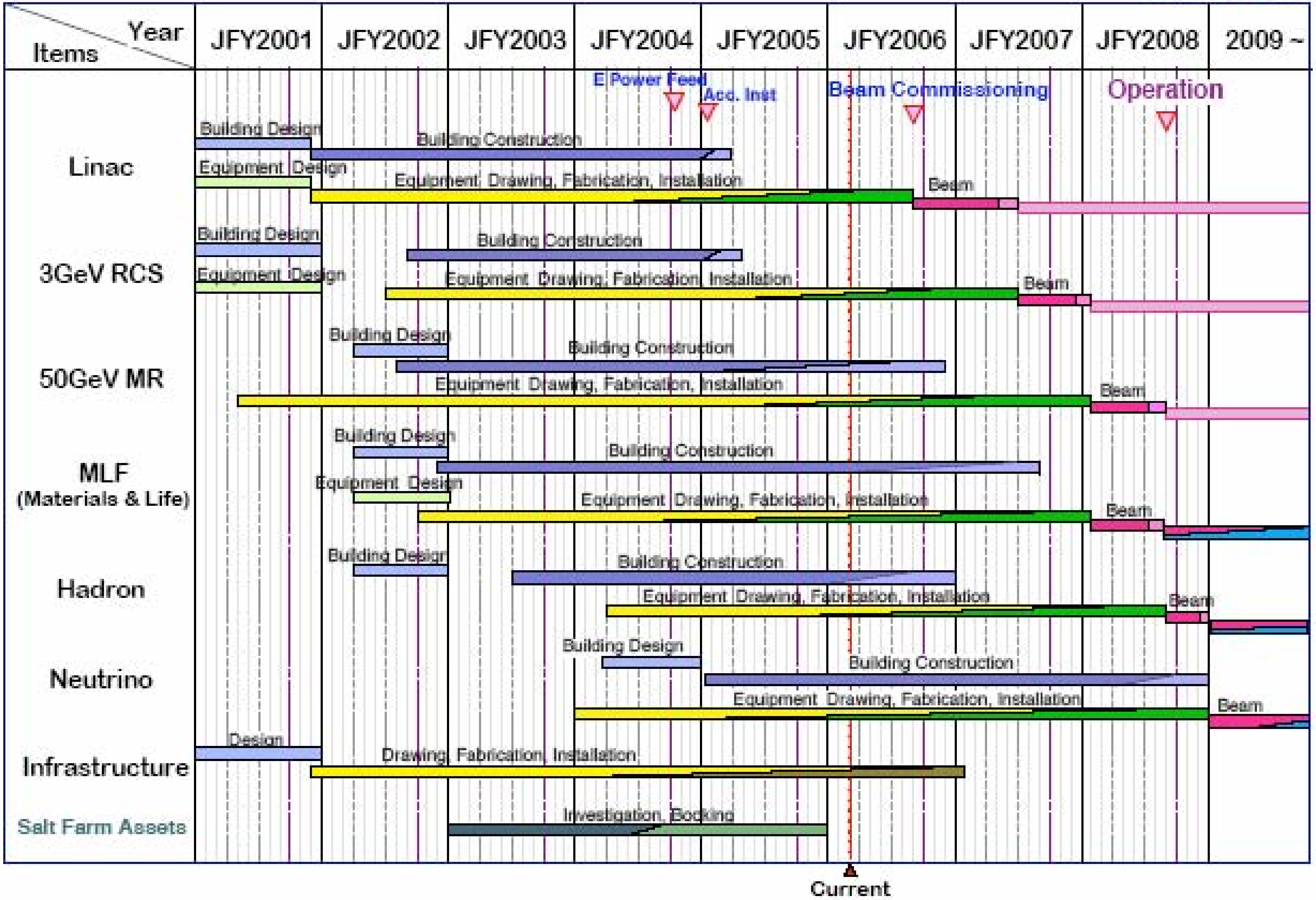


Photo in Feb. 2006

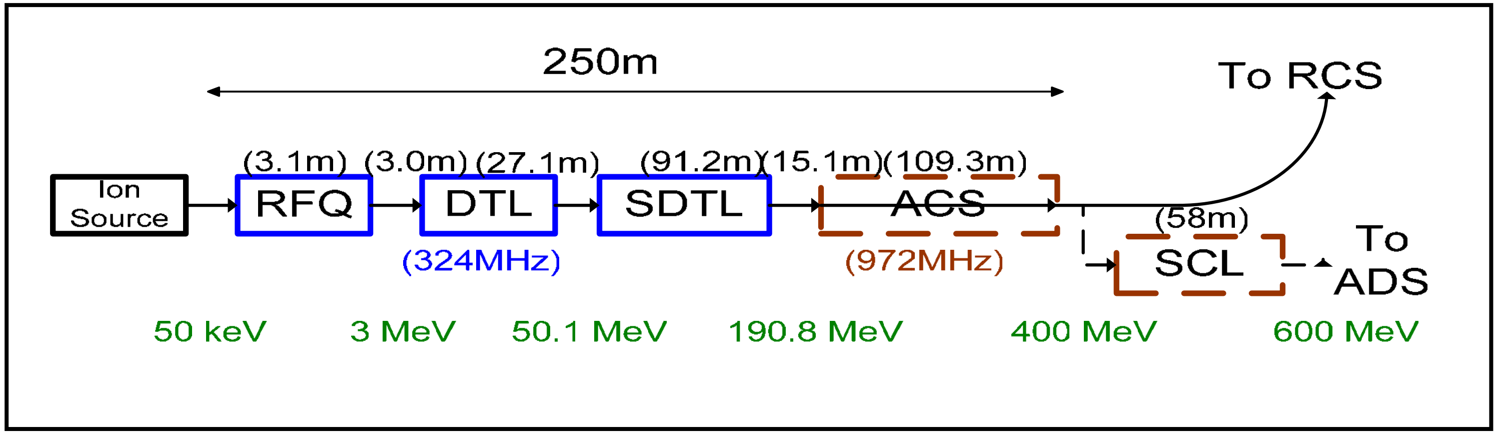
J-PARC Construction Schedule

June 01 2006



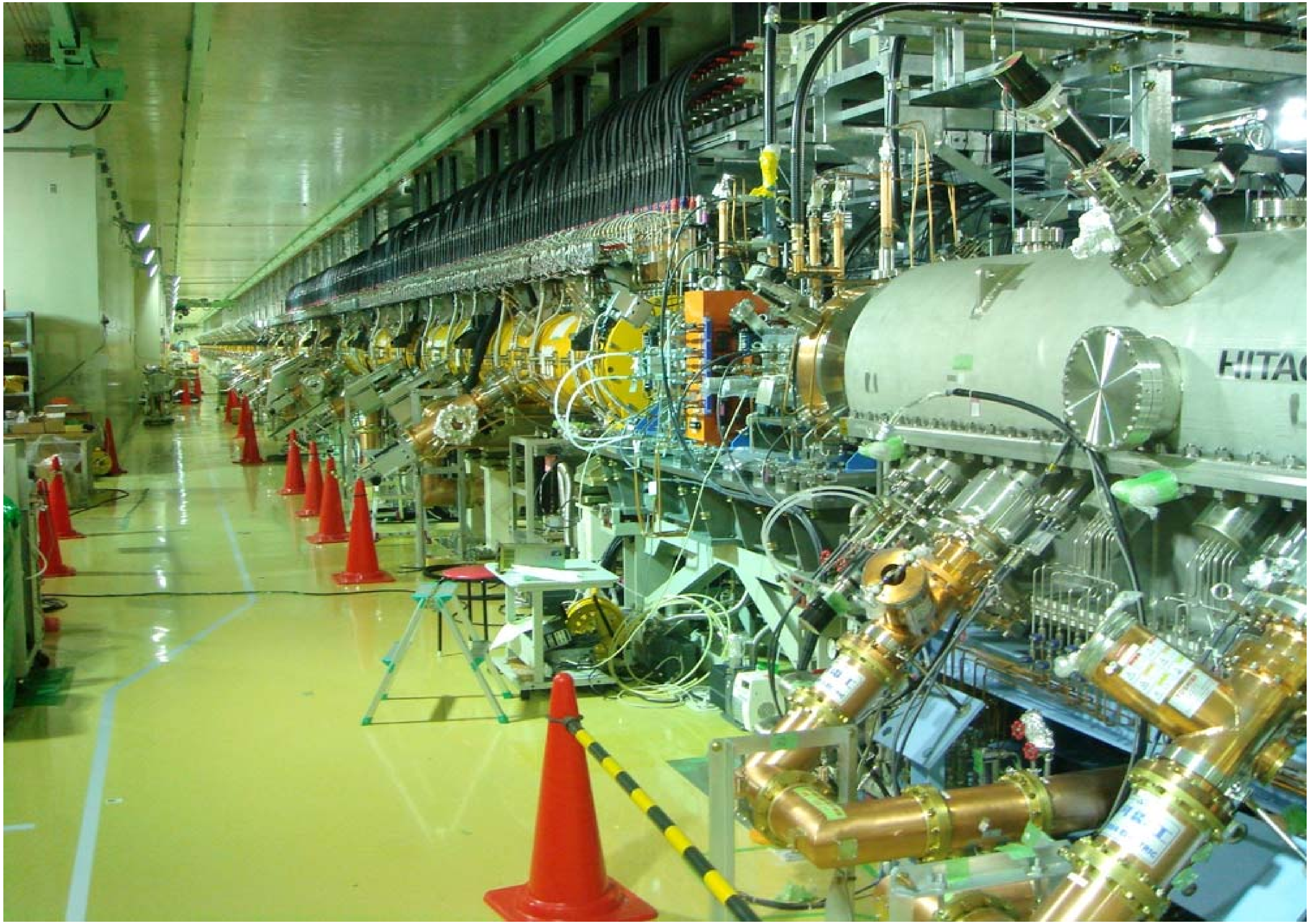
Linac Parameters

- Major Parameters
  - Accelerated particles: H^- (negative hydrogen)
  - Energy: 181 MeV, The last two SDTLs are debunchers (400 MeV for ACS)
  - Peak current: 30 mA (50 mA for 1MW at 3GeV)
  - Repetition: 25 Hz (additional 25 Hz for ADS application)
  - Pulse width: 0.5 msec



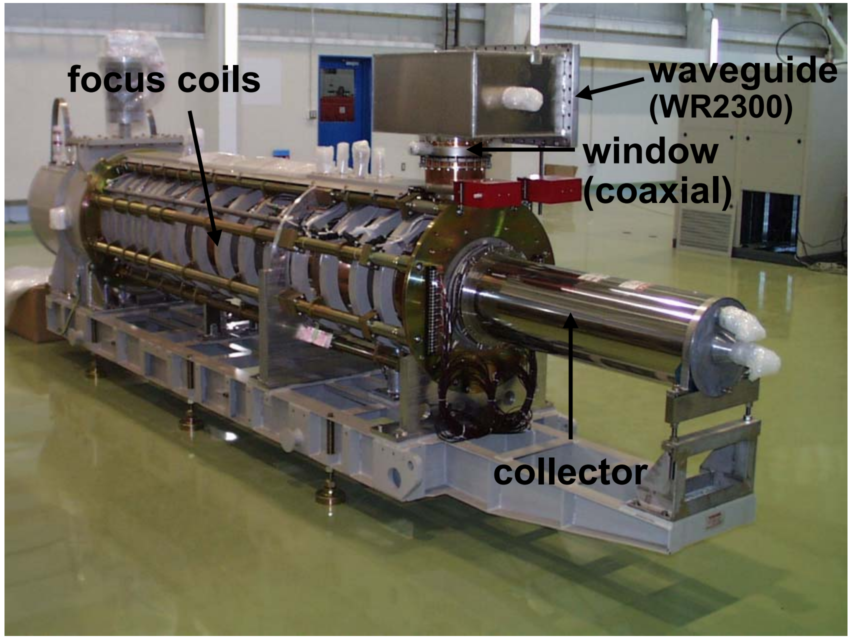
Block Diagram of the Linac

LINAC



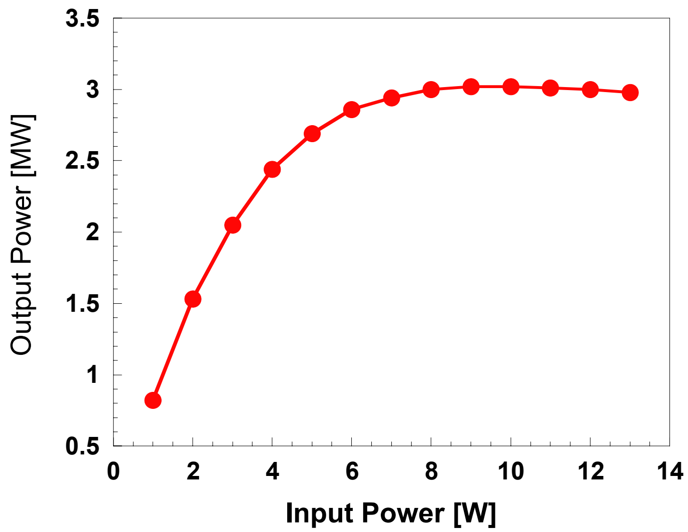
324 MHz Klystron

Peak Power	2.5 (max. 3.0) MW
Pulse Width	650 μs
Repetition	50 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)

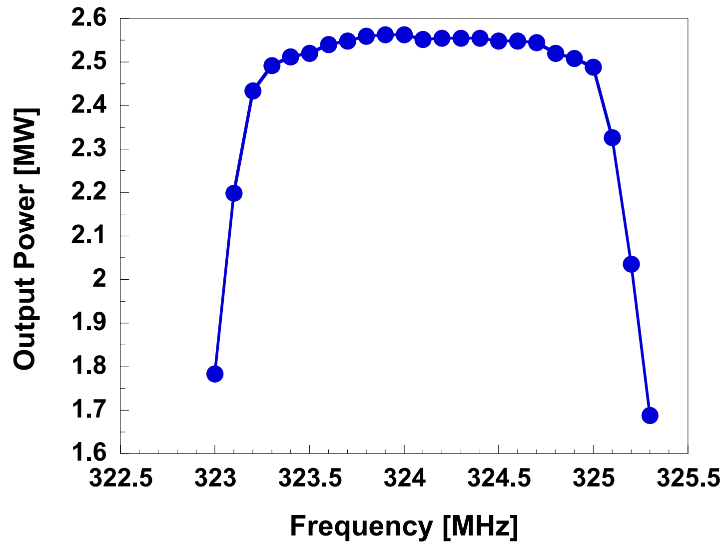


324 MHz Klystron - characteristics

- P_{out} *vs* P_{in}



- P_{out} *vs* Frequency



Compact Electro-quadrupole magnets

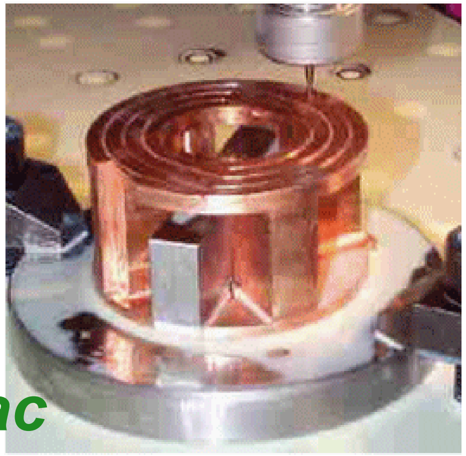
Q-magnets in Drift Tubes have been developed with electroforming:

Compact(14cm dia.DT) & High duty

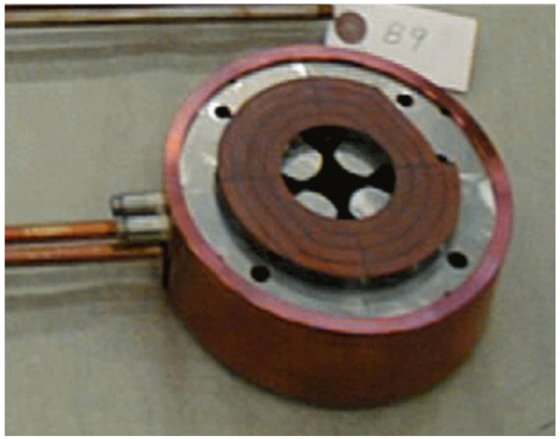
Original design was for pulsed, but DC excitation was taken at the DTL commissioning.

Grooves and through holes for water channel

The surface is electrofromed.

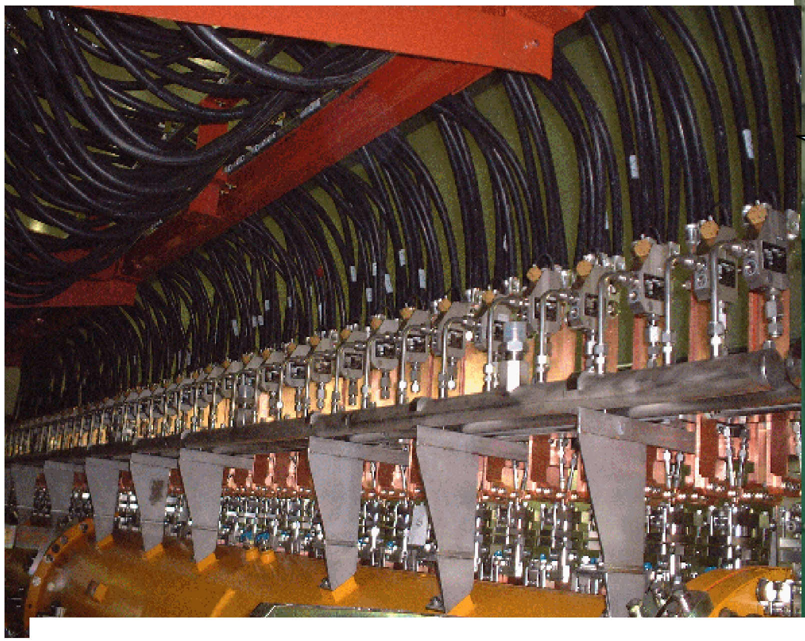


Forming the coil by wire cutting.

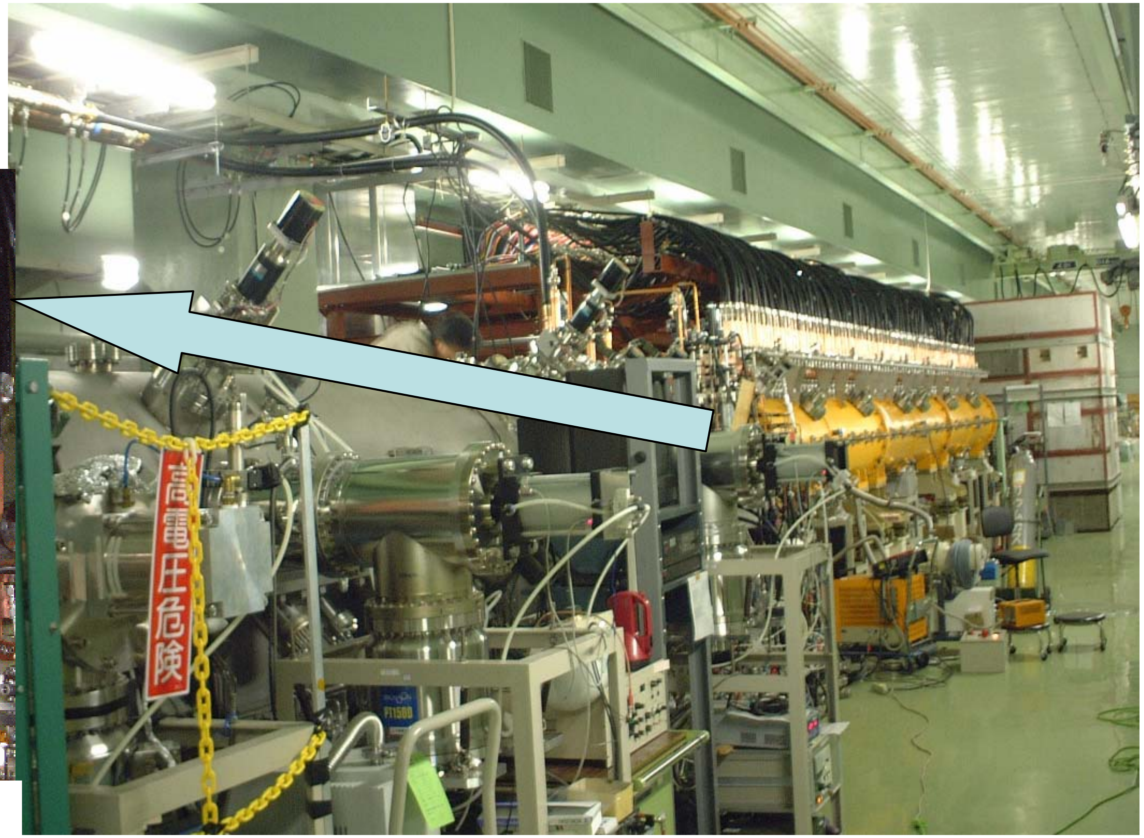


Assembled Q-magnet.

Linac Beam Commissioning of DTL-1

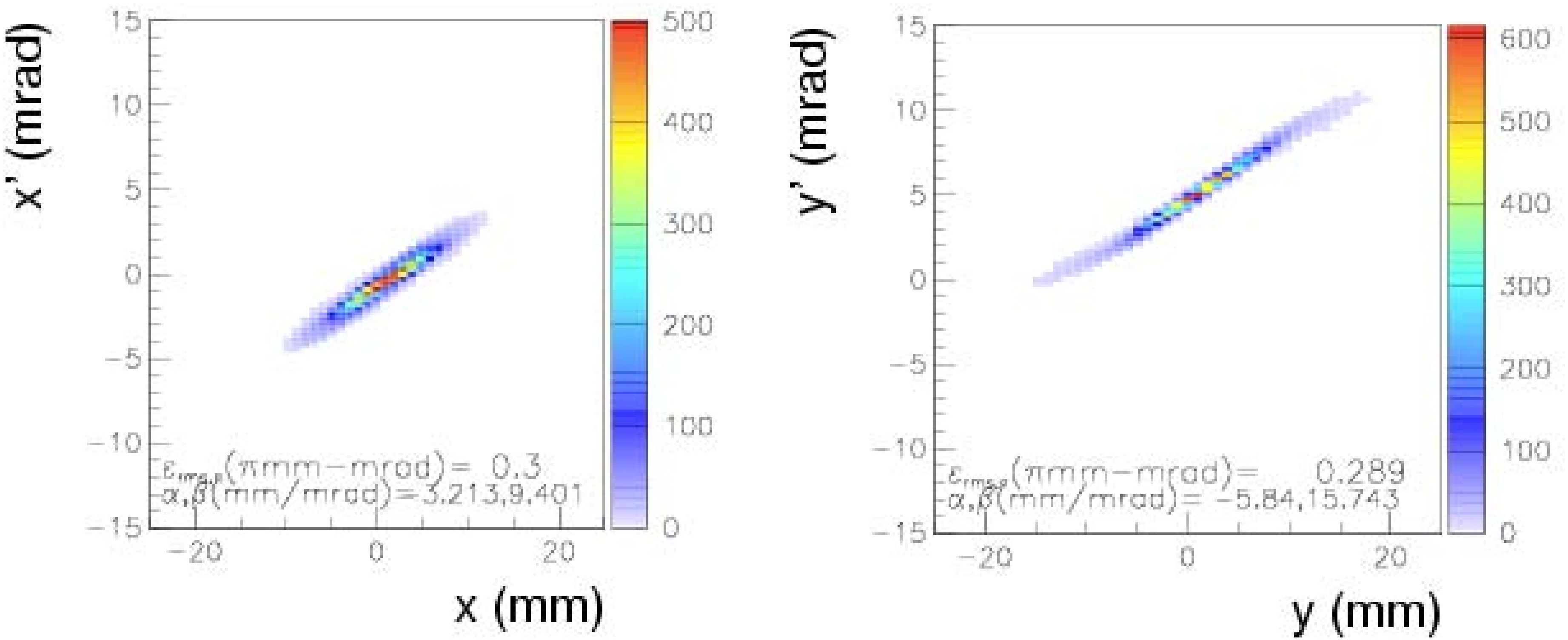


Feeder lines for the Q-magnets



Photograph of the RFQ and DTL-1 (orange cavity).

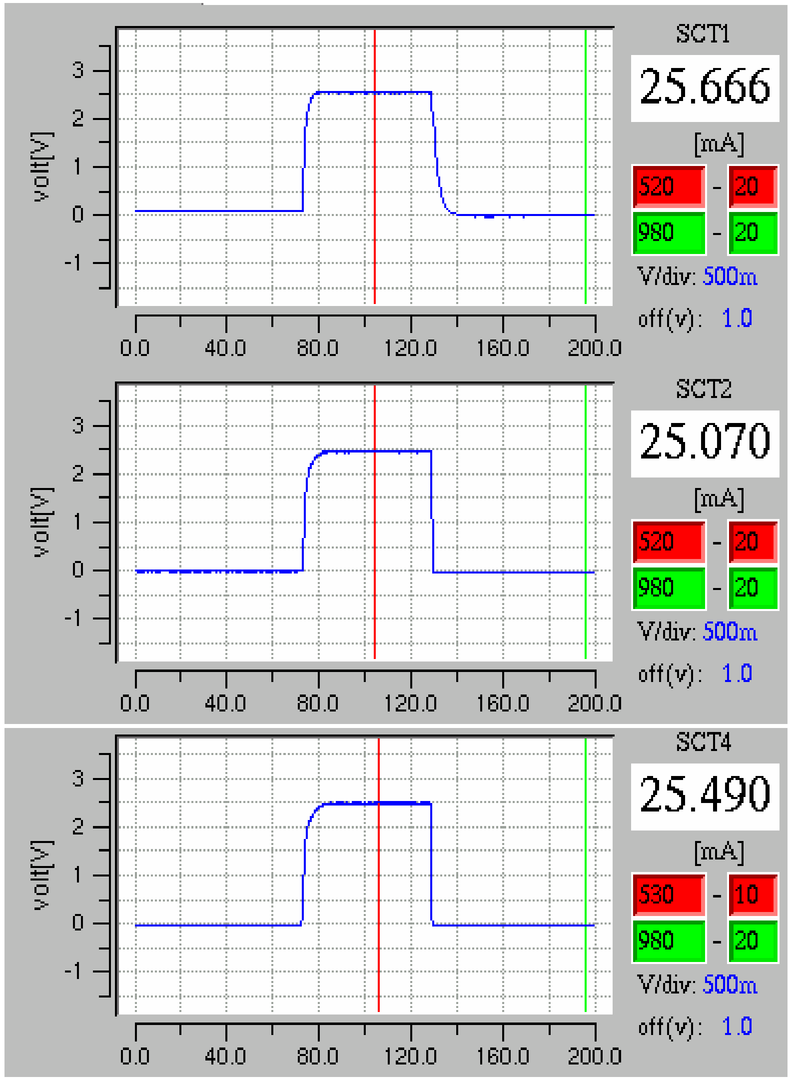
Linac Transverse emittance after the DTL-1



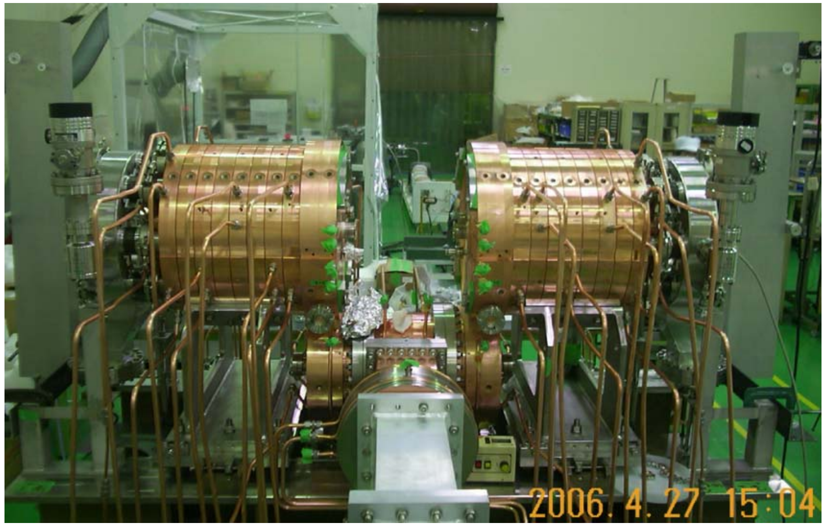
- Transverse rms emittances are measured to be 0.3π-mm-mrad for horizontal and 0.29π-mm-mrad for vertical.
- Transverse rms emittances of the reference design are 0.25π-mm-mrad and 0.26π-mm-mrad, respectively.

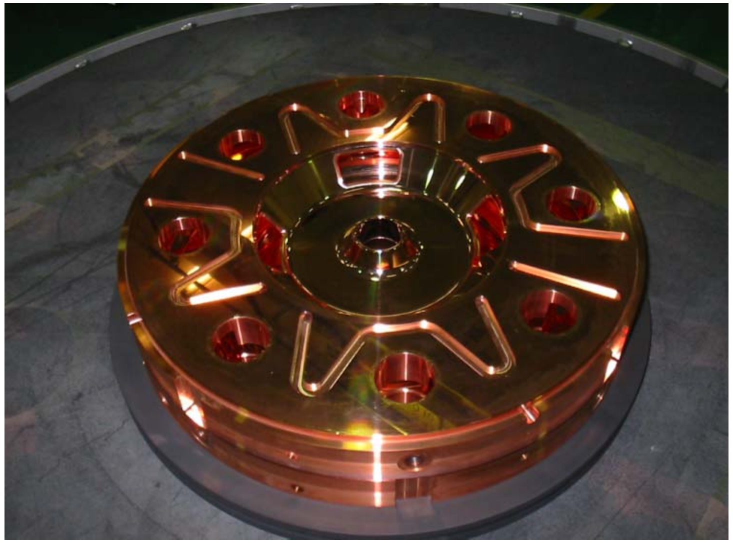
Linac DTL-1 Transmission

- Beam current waveforms at the exits of the RFQ (top), the MEBT (middle), the DTL-1 (bottom)
- 50μsec,5Hz
  (duty 0.025%)
- Transmission through DTL-1:100%



Axially Symmetric Annular-Ring Coupled Structure (ACS) for High-Energy Structure





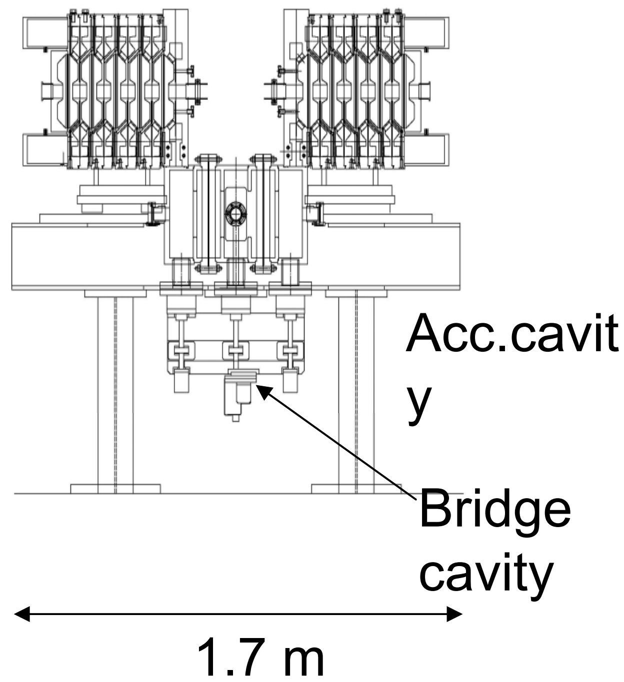
R&D of ACS (buncher)

The linac starts with 180 MeV at first, but will be upgraded to 400 MeV with 21 ACS modules, two bunchers and two debunchers.

- A buncher cavity (β=0.556) has been completed.
  972MHz,5+5 accelerating cell cavities and 5-cell bridge cavity

Major Parameters of the ACS section

Energy	190.8-400	MeV
Frequency	972	MHz
Section Length	107.2	m
E0	4.12	MV/m
Number of module	21	

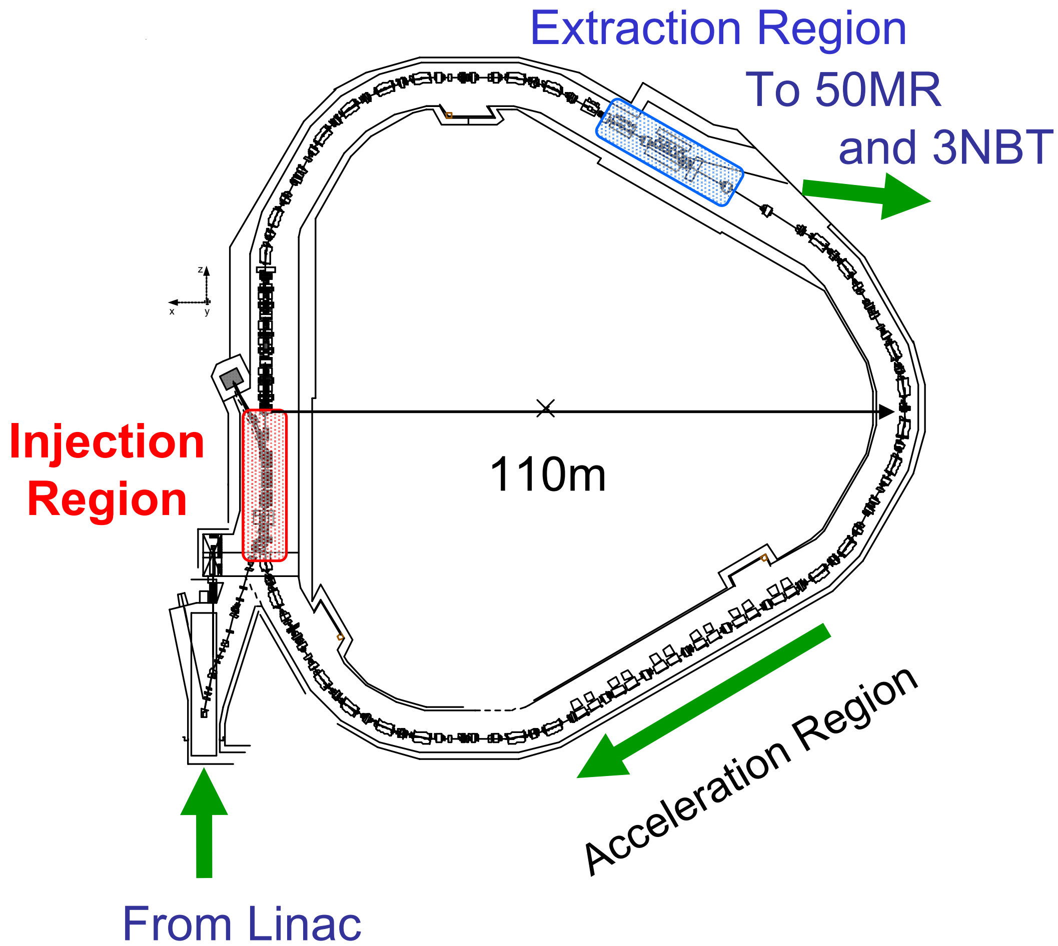


ACS-type buncher cavity

Summary of LINAC

- Installation: almost finished
- Klystron test: finished
- Microwave aging: Sep. 2006
- Beam commissioning: Dec. 2006
- R&D of ACS for 400 MeV upgrade: high power test completed

Rapid Cycling Synchrotron(RCS)

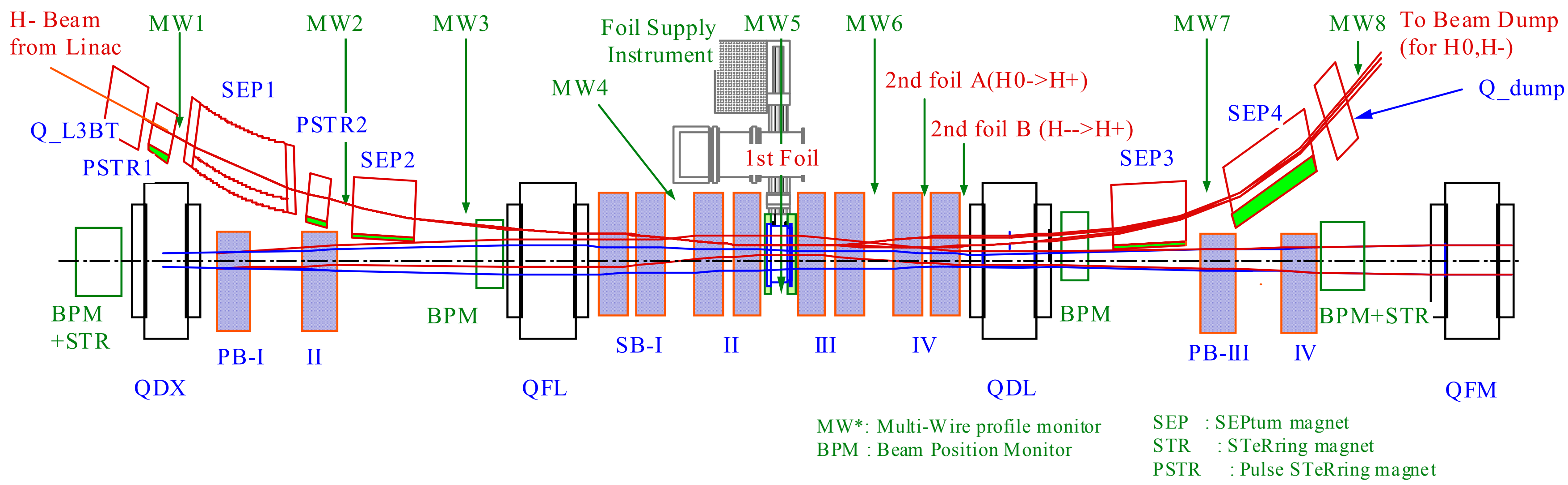


- **main composition machine**
- RF 12
- Qmag 60
- Bmag 24
- Collimator 7
- Septum 7
- Kicker 8
- bump 10

3GeV-200μA: 600kW

(3GeV-333μA: 1MW)

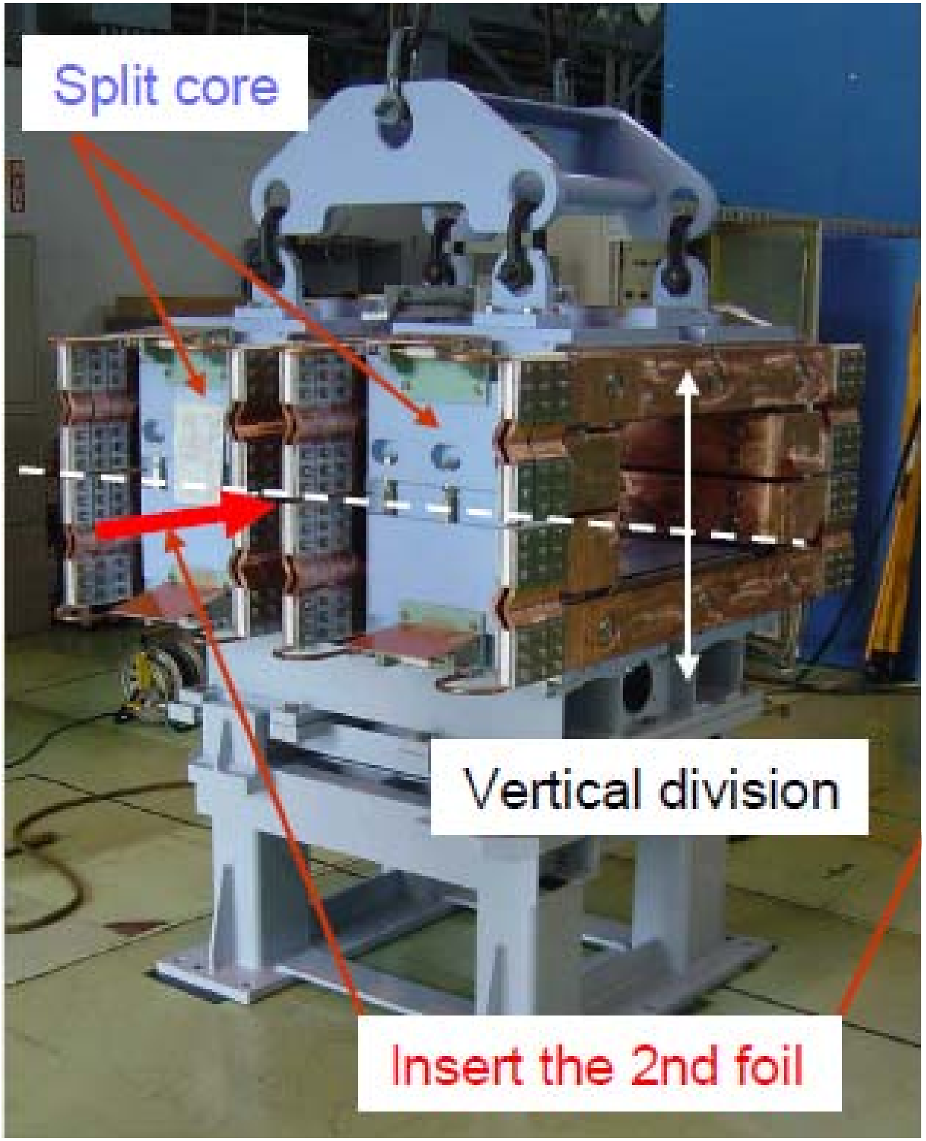
H- Painting Injection System the J-PARC 3GeV High Intensity Proton Synchrotron

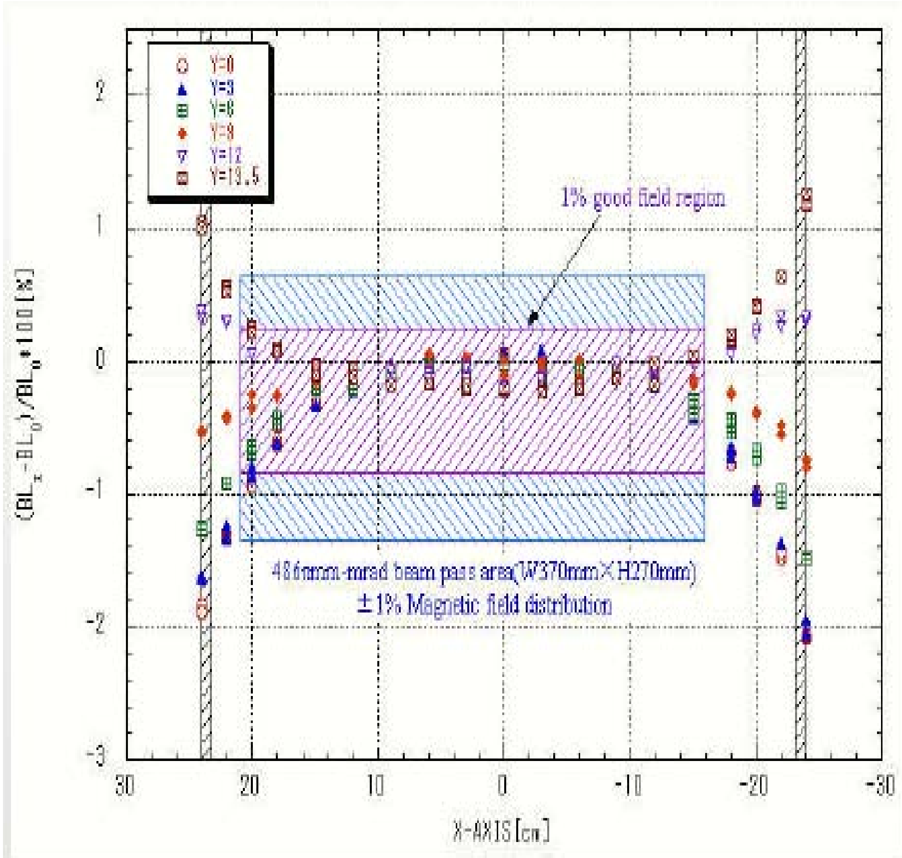


- The injection system is designed to be constructed in the FODO structure, which has rather short drift space.
- The bump orbit for painting injection has a full acceptance for the circulating beams.
- The H- injection line and the H0,H- disposal lines can be designed so as to have a sufficient acceptance for low-loss injection
- The painting area is optimized for both 3-GeV users and 50-GeV users in a pulse-to-pulse mode operation.

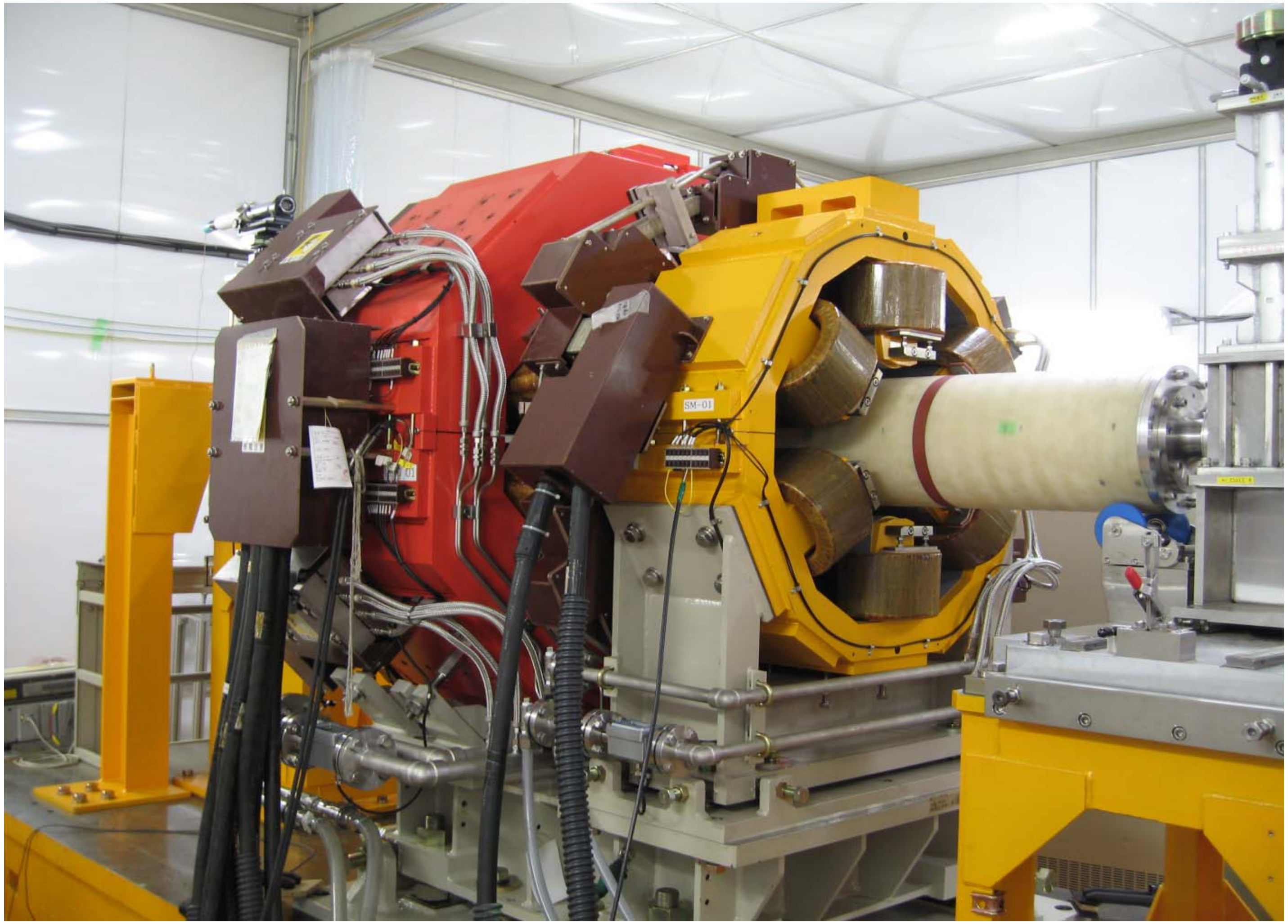
By Izumi Sakai

TEST OF SHIFT BUMP

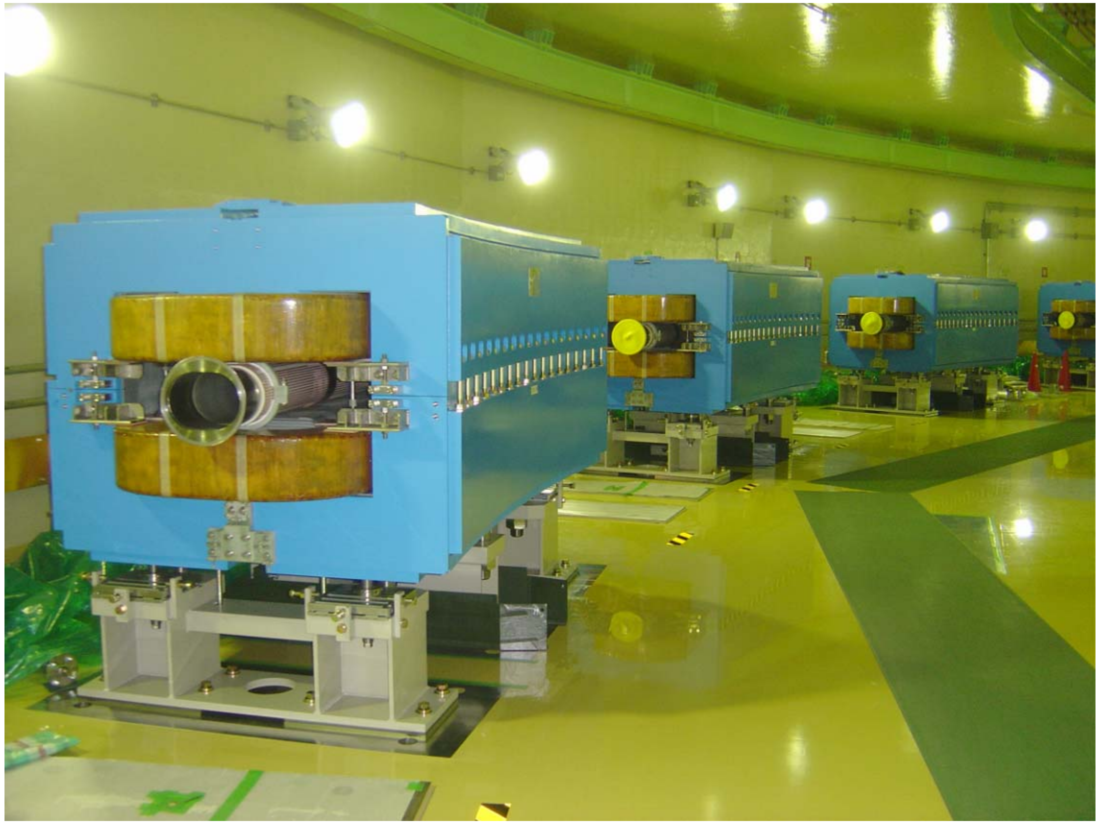


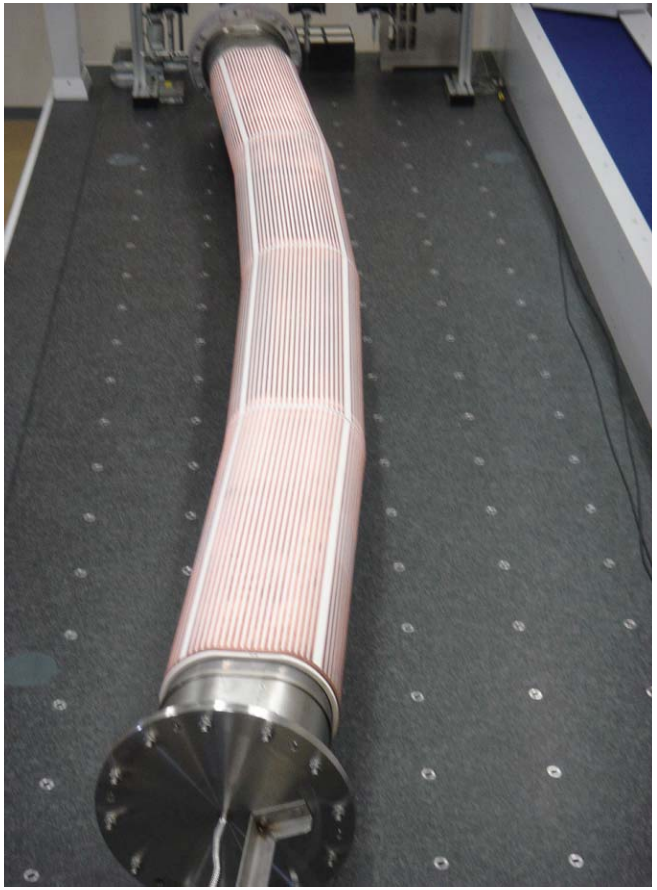


Interference between Q and Sextupole magnet



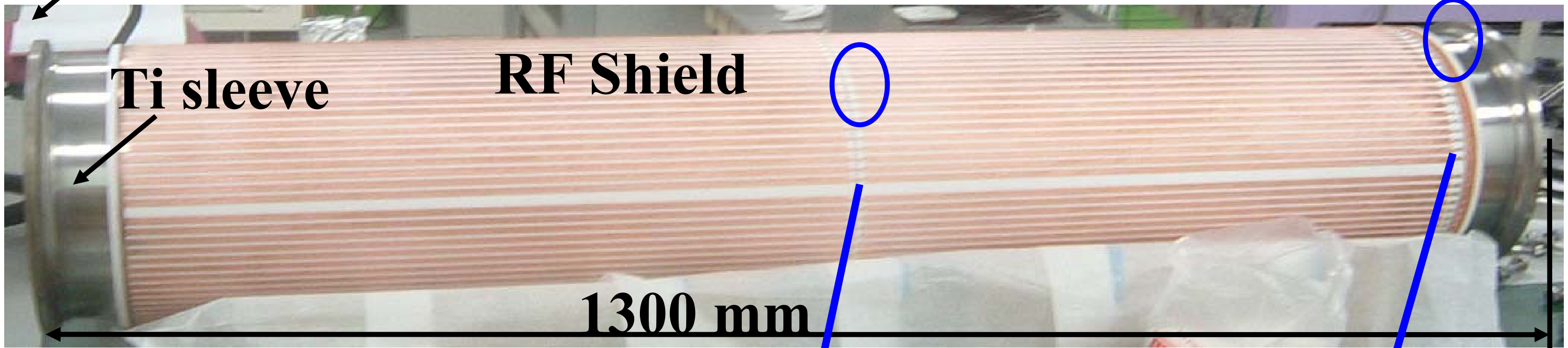
Large-aperture magnets and ceramics-chamber

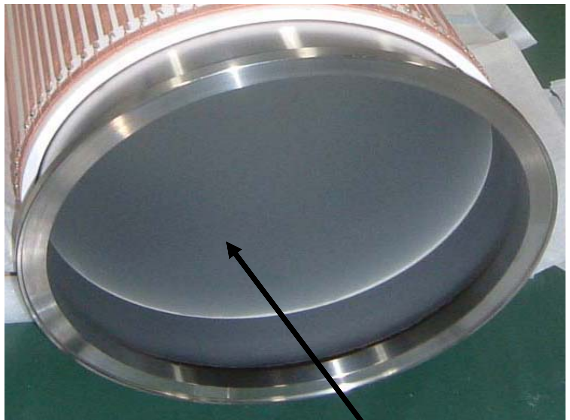




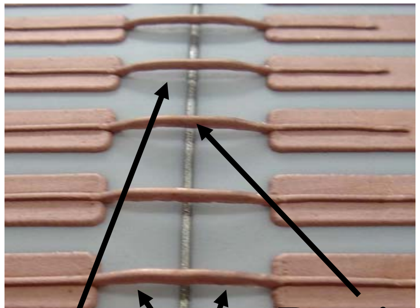
RCS Ceramics Duct

Ti flange





TiN coating
Thickness : 15



segment

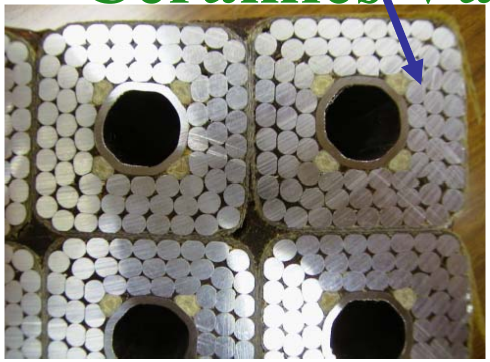
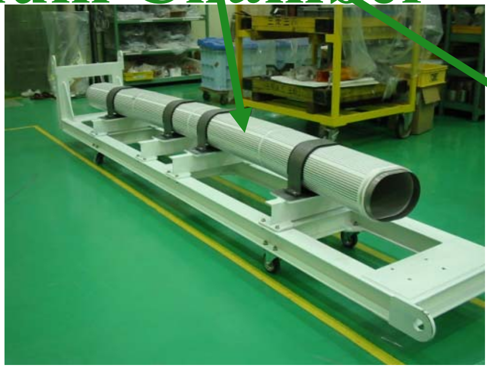
Brazing joint

Every stripe jumps over the joint area.

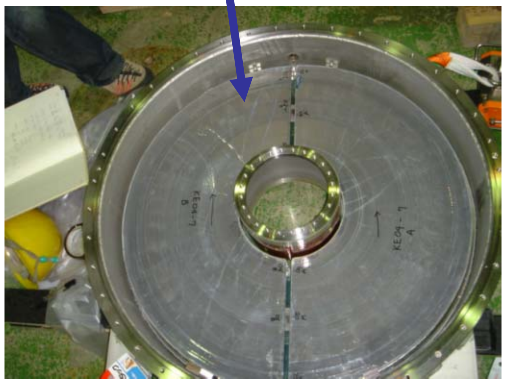
Capacitor
Capacitance : 330 nF

Development
for High Intensity Rapid-Cycling Synchrotron

- **Stranded Coil, Wide Aperture Magnets**
- **Ceramics Vacuum Chamber**


- **Magnetic Alloy（FINEMET）-Loaded Cavity**

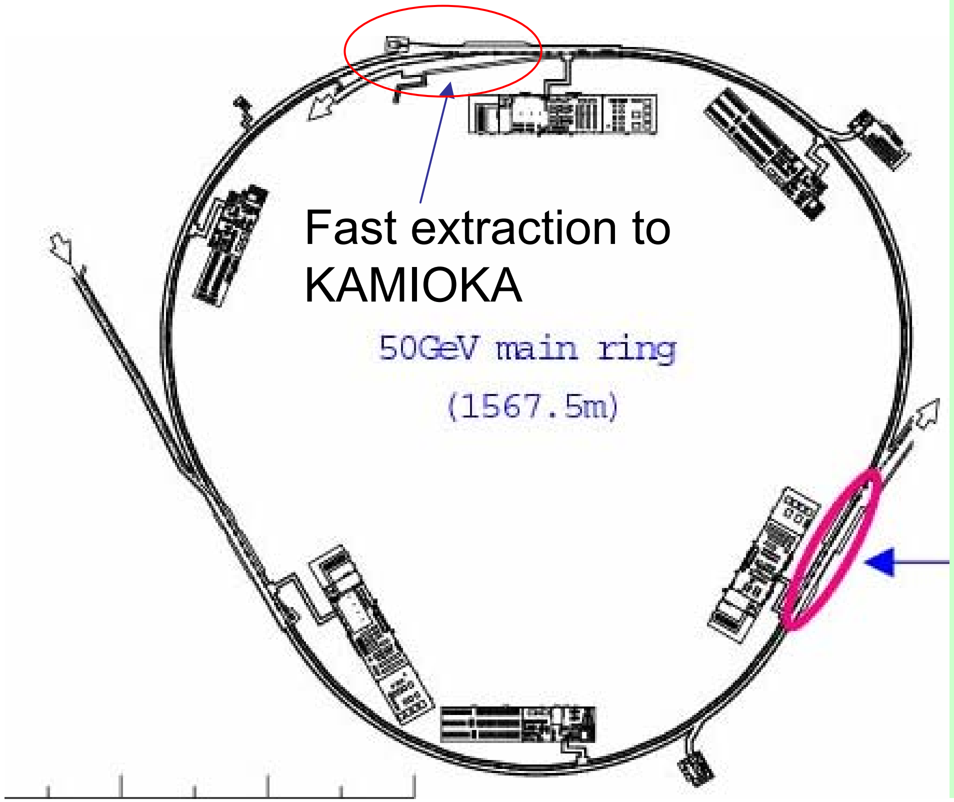



High Field Gradient Cavity For Rapid Acceleration (25 kV/m in contrast to around 10 kV/m of conventional ferrite-loaded cavities)

Summary of RCS

- Installation is now progressed
- Ceramic ducts with wide aperture have been completed.
- Stranded wire is well developed and high Q of network is realized.
- Measurements of magnetic interference in the tightest area are being progressed.
- Test of bending and Q magnet network will start Dec. 2006, beam commissioning will start in Sep. 2007.

J-PARC Main Ring



- 3.3×10^{14} protons per pulse(15μA)
  full beam power : 750kW @50GeV
- Circumference 1567.5m
  with 3x116m long straight sections

Beam Power

- 750kWx0.6(linac energy)x40/50(30/50)
- Power recovery scheme is discussed

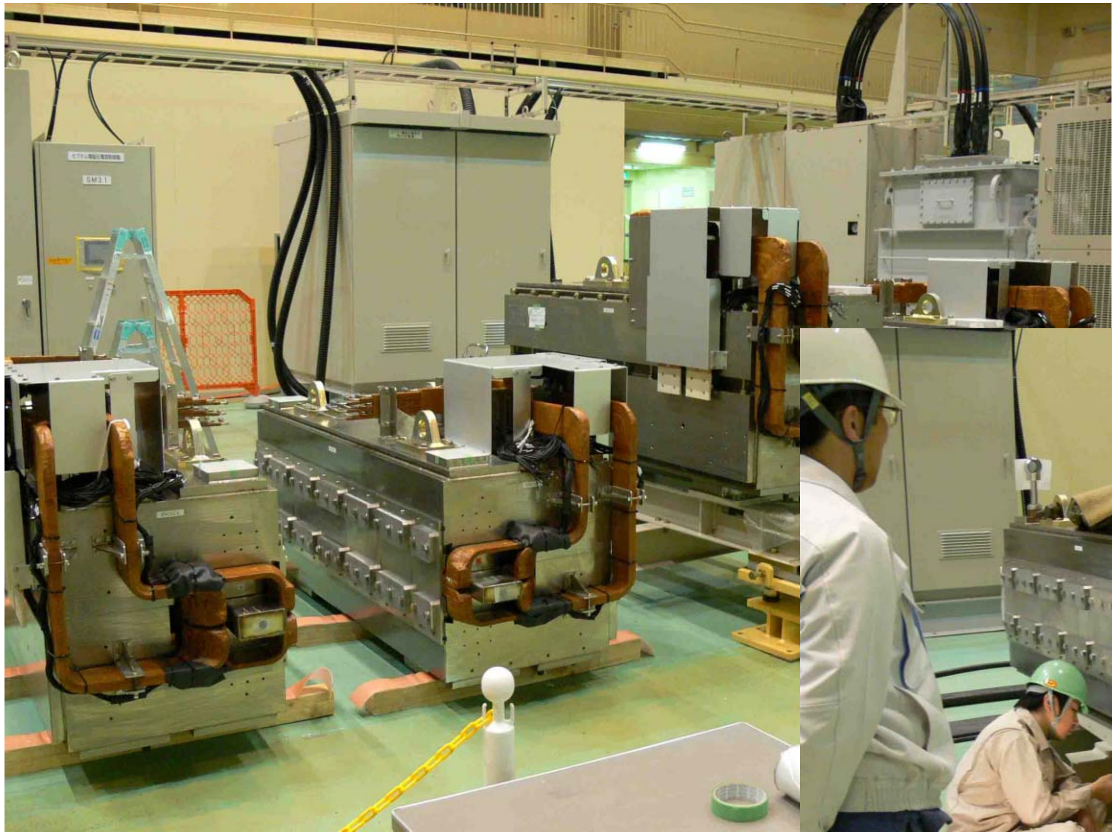
- Energy
  - Phase I
    - 30GeV slow extraction
    - 40GeV fast extraction
  - phase II(MR+Lab.) →50GeV

MR Lattice

Imaginary transition gamma

No transition which makes longitudinal oscillation frequency zero

MR SEPTUM MAGNET TEST



J-PARC

All of the MR injection and extraction components are ready and are tested.

Injection:Opposite field septum(SEPⅡ)

Dump septum

Kicker magnets for fast extraction

Septum for Fast Extraction

Pulsed Bending Magnet for swinging the beams to MLF and MR

Injection kicker

MR summary

Schedule

- 2006. Dec. Civil Eng. Finish
- 2007. Dec. All system commissioning w/o beam
- 2008. May Beam commissioning

Status

- Magnet installation:40% bending magnet. 35% of Q-magnet finished
- Septum magnets and kickers for injection and extraction are under test.

Challenges in RCS (from TDR 2003)

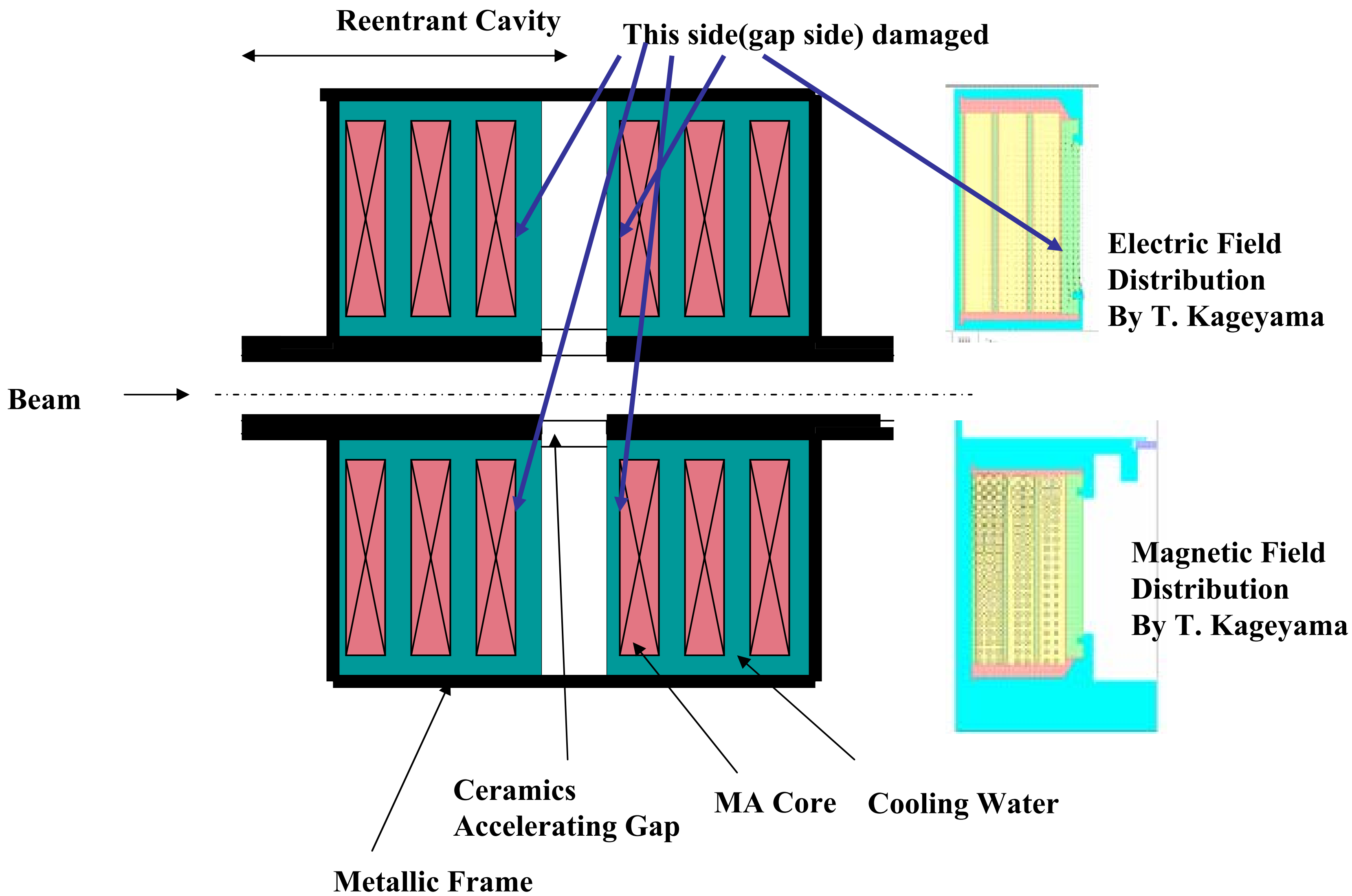
- Lower injection energy in turn implies higher space charge effect. Large aperture magnets are required, giving rise to large fringing fields.
- Ceramics vacuum chamber with RF shield to avoid the eddy current effect
- Stranded coil to overcome the eddy current effect on the magnet coils.
- Injection to make large aperture beam and its extraction are hard to manage.
- Precise magnet field tacking is necessary for each family of magnets
- Powerful RF accelerating system for rapid acceleration

Magnetic Alloy (MA)-Loaded Cavity

- Challenge to High Field Acceleration

  25 kV/m is so high gradient in contrast to around to 10 kV/m of conventional ferrite-loaded cavities.

Damage of Core


Reentrant Cavity
This side(gap side) damaged
Electric Field
Distribution
By T. Kageyama
Beam
Magnetic Field
Distribution
By T. Kageyama
Ceramics
Accelerating Gap
MA Core
Cooling Water
Metallic Frame

Summary of Ring RF

- We are solving problems one by one which encounter in challenge to new technology.
- Causes of damage of core are getting clearer.

Investigate:
●Cores which withstand higher electric field.
●Configuration to reduce electric field on the surface of cores.

Beam Power Recovery Scenario of MR(1/2)

- During 180 MeV Injection, RCS output <600 kW
  Then, beam power of MR <0.6X0.6X750 kW (at 30 GeV)

➢ **But possible to increase Rep. rate of MR**

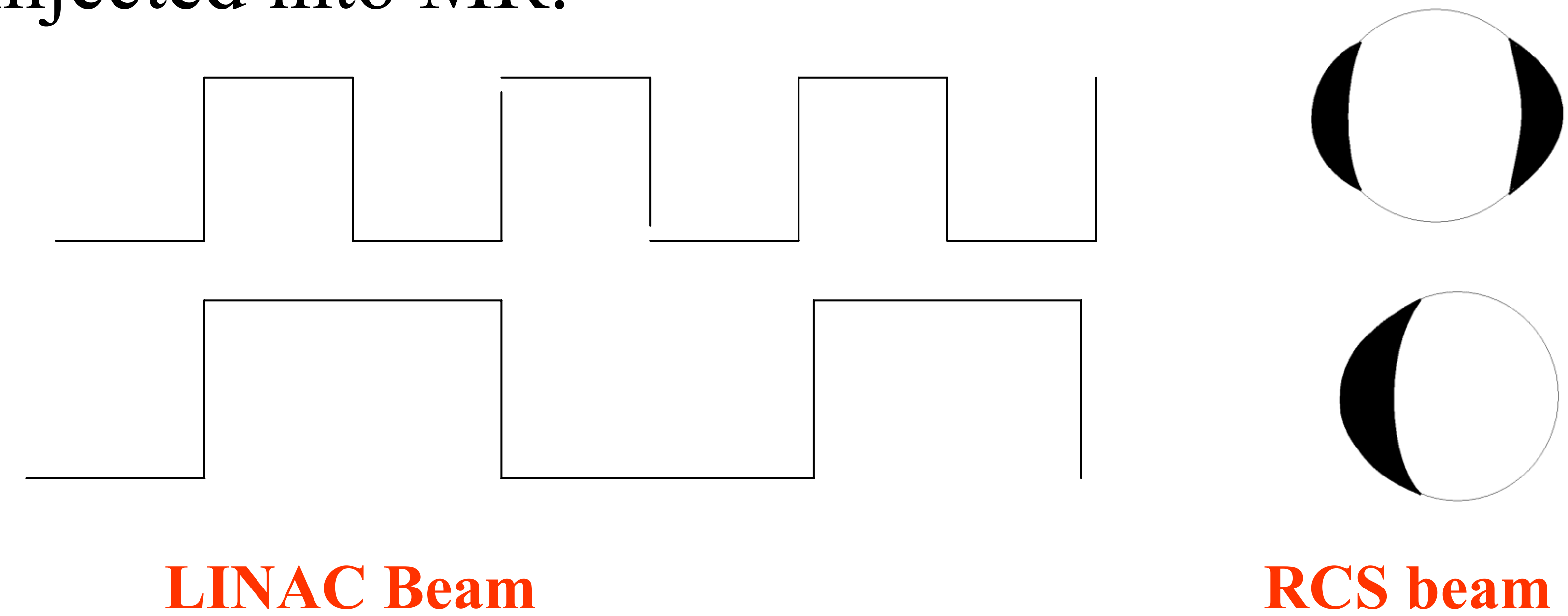
3.64 sec. (baseline) to 2.04 sec. (30 GeV)

1.8 times=480 kW

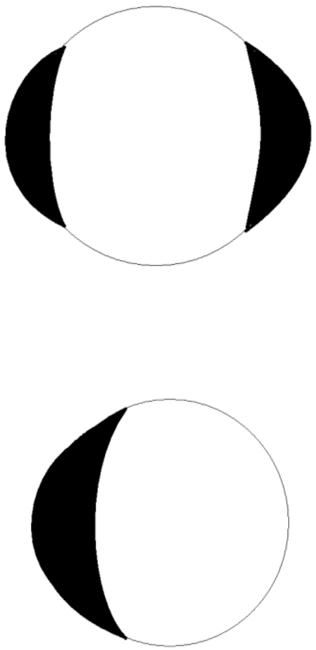
	Inj.	Acc.	Top	reset	period
50 GeV	0.17	1.9	0.7	0.87	3.64
30 GeV	0.17	1.1	0.1	0.67	2.04

Beam Power Recovery Scenario of MR (2/2)

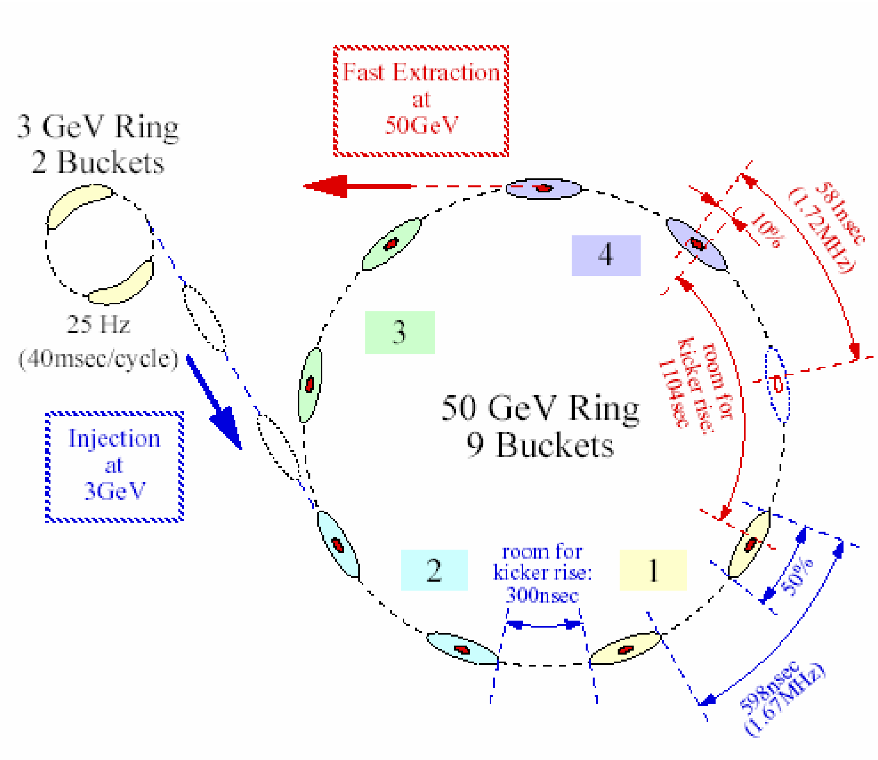
- Reduce HN of RCS from 2 to 1 and inject 8 pulses in MR, then almost twice of beam is injected into MR.



HN of RCS :2 to 1



MR h=9, 8bunches



Present: 2 pulseX4 injection: 8 bunches

Upgrade: 1 pulseX8 injection: 8 bunches

MR Power Recovery scenario

- Recover by repetition rate bunch number & of MR

  MR output reduced by 181 MeV injection(0.6), if 30 GeV is used(0.6),

1. Only rep. rate : 3.64/2.04=1.8 times
2. Decrease RCS harmonic number and increase rep. rate:2 x3.64/2.2=3.3 times (increase injection time)

We need more discussion! RF source, Beam dynamics etc.

Summary

- Linac

  Klystron ready, Beam commissioning scenario ready, and beam commissioning will start in Dec. this year
- RCS

  Installation and wiring are progressing. Test of magnets and their power supplies will start in Dec. this year. Beam will start in Sep. 2007.
- MR

  Installation and wiring are progressing. All system commissioning w/o beam will start in Dec. 2007 and beam in May 2008.

Still we have several issues and go forward solving them one by one.

Papers in EPAC2006 from J-PARC

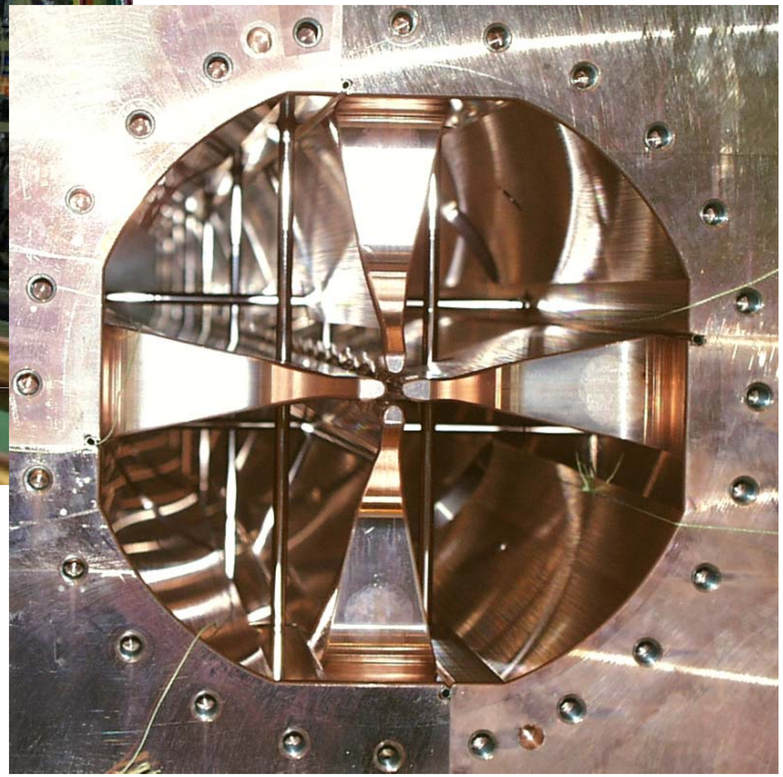
- Injection and extraction: TUPLS106,TUPLS107,TUPLS110,TUPLS111,TUPLS112,TUPLS113,WEPCH029,WEPLS071
- Ring RF: TUPCH128,TUPCH130,TUPCH131,TUPCH193
- Beam dynamics: THPCH054,THPCH013,WEPCH079
- Beam collimator: TUPCH172,TUPCH060,TUPLS109
- Beam monitor: TUPCH061,TUPCH064,TUPCH065
- Charge stripping foil: MOPCH122,TUPLS028,TUPLS108
- Control: THPCH117,THPCH118
- Magnet/Power supply: WEPLS129,WEPLS072,WEPCH028
- Ground motion: MOPCH120

appendix

30mA RFQ

The 30mA RFQ
installed in the test area

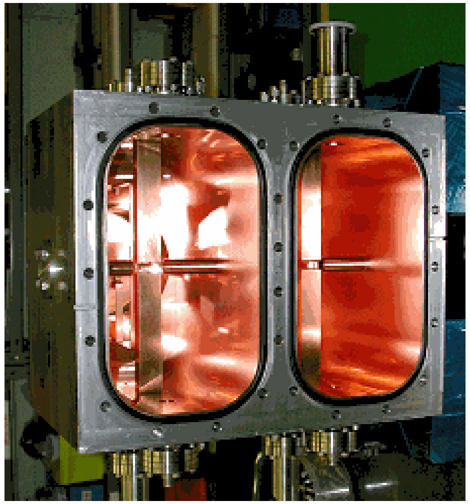
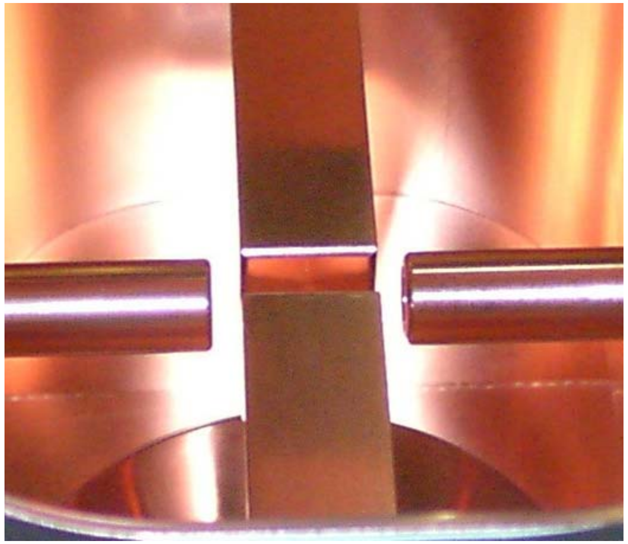
Inside view of the RFQ
stabilized with PISLs



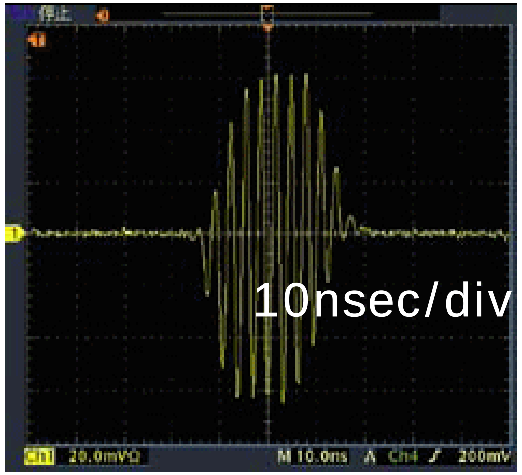
Beam Chopping

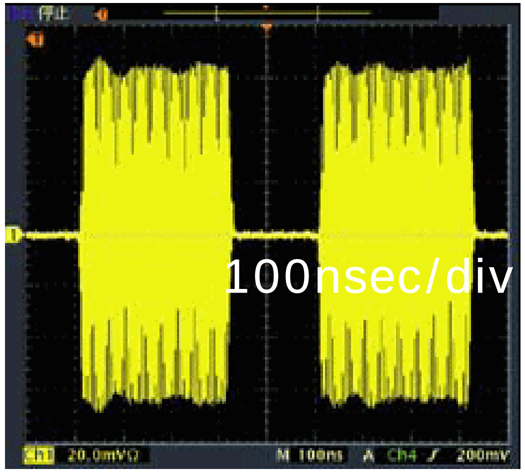
The beams which can be accepted by the ring RF are accelerated in the linac.

- **RF deflecting chopper**
  - **Frequency 324 MHz**
  - **Mode TE110**
  - **Rise and Fall times: 15 nsec**

Inside view of the deflecting chopper cavity





Signal of a chopped beam measured by a BPM

Magnetic Alloy(MA)-Loaded Cavity

- **The high RF magnetic flux does not degrade the mQf of MA core. Therefore, higher field gradient is potentially feasible by using MA core.**
- **The extremely low Q-value (a value of less than one is possible) drastically simplifies the RF system by eliminating any tuning system.**
- **On the other hand, its high R/Q (low stored energy) with the low Q value requires the wide-band beam loading compensation via feed-forward control.**
- **As a result, even the high power system should be wide-band.**
- **In order to minimize the band width necessary for the compensation, the Q-value is optimized by adjusting the gap between the MA cores radially cut under the condition of no tuning system.**
- **The Q values thus optimized are 2.9 (1.5-mm gap) [2 (1-mm gap) for 180-MeV injection] and 10 (10-mm gap) for the RCS and the MR, respectively.**

Acceleration Patterns and Design Beam Power

4 batch injection
same dB/dt as 50 GeV case

	Inj.	Acc.	Top	reset	period
50 GeV	0.17	1.9	0.7	0.87	3.64
30 GeV	0.17	1.1	0.1	0.67	2.04