THE JAERI/KEK JOINT PROJECT FOR HIGH-INTENSITY PROTON ACCELERATOR

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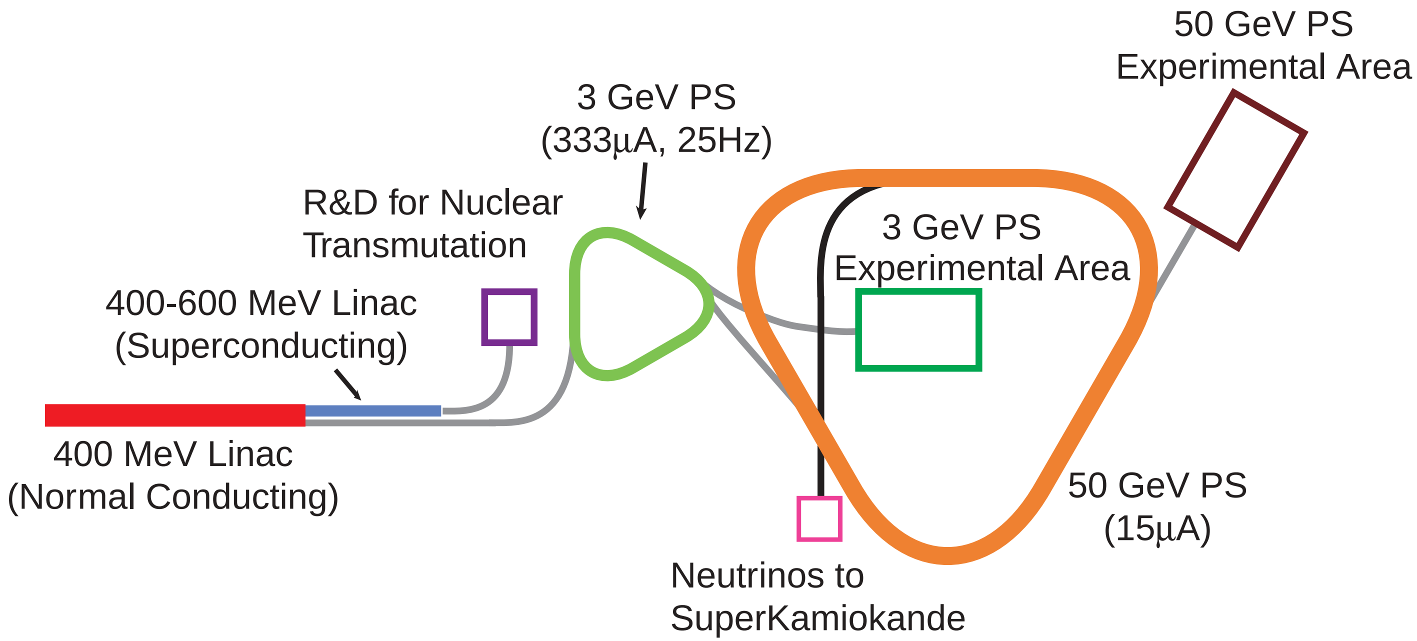
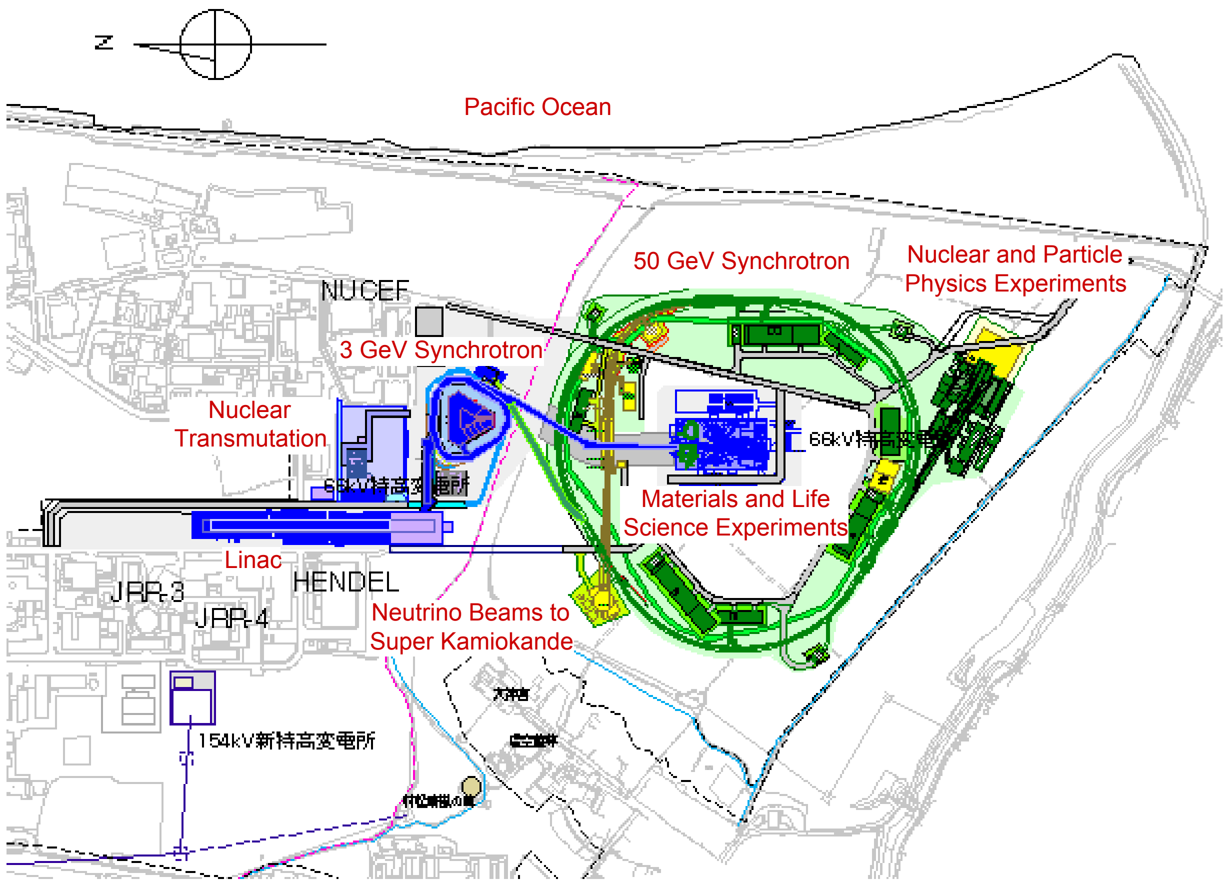
JAERI/KEK Joint Accelerator Group

The 8th European Particle Accelerator Conference
Paris, 3rd to 7th June, 2002

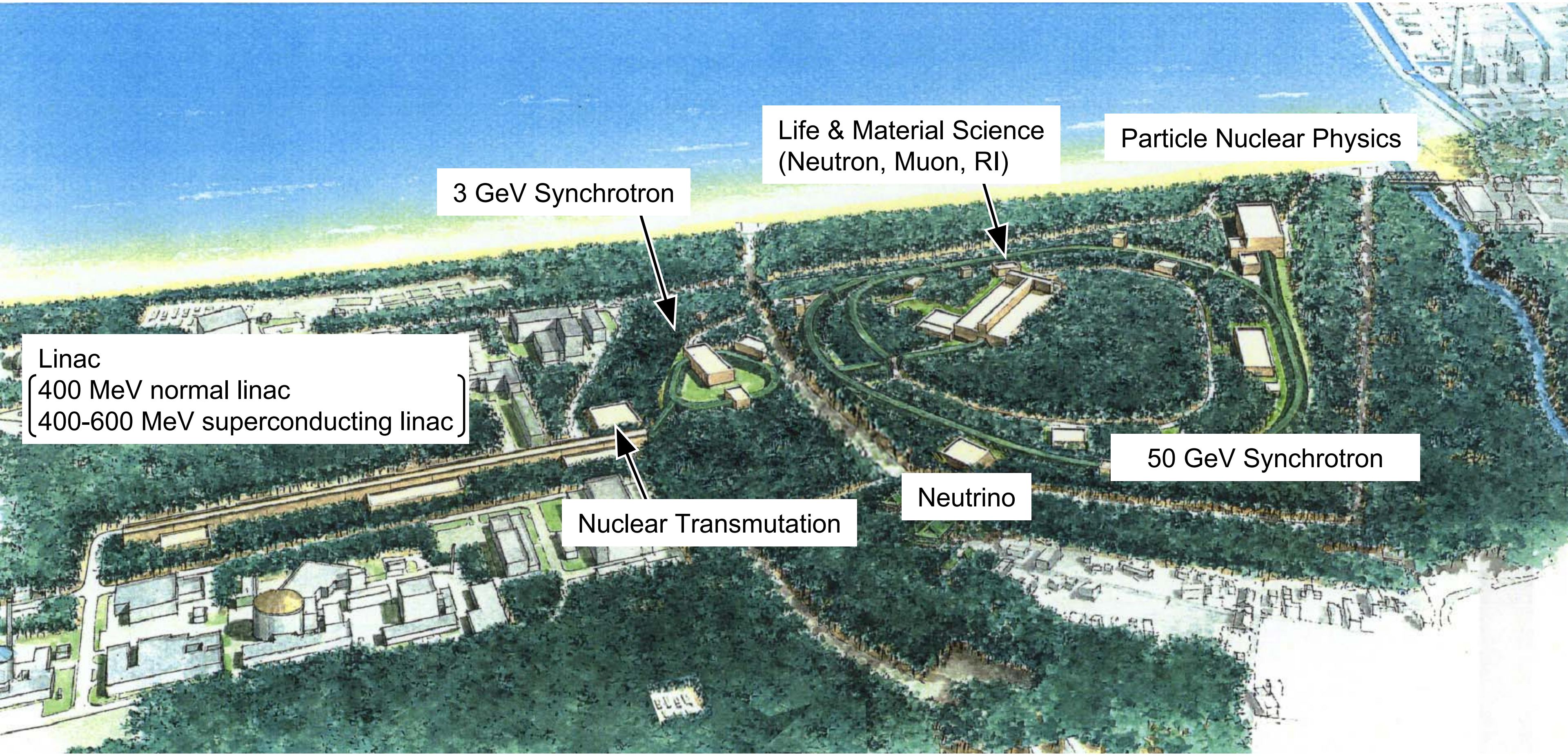
Configuration of the Accelerator Complex



Plan View of the Facility

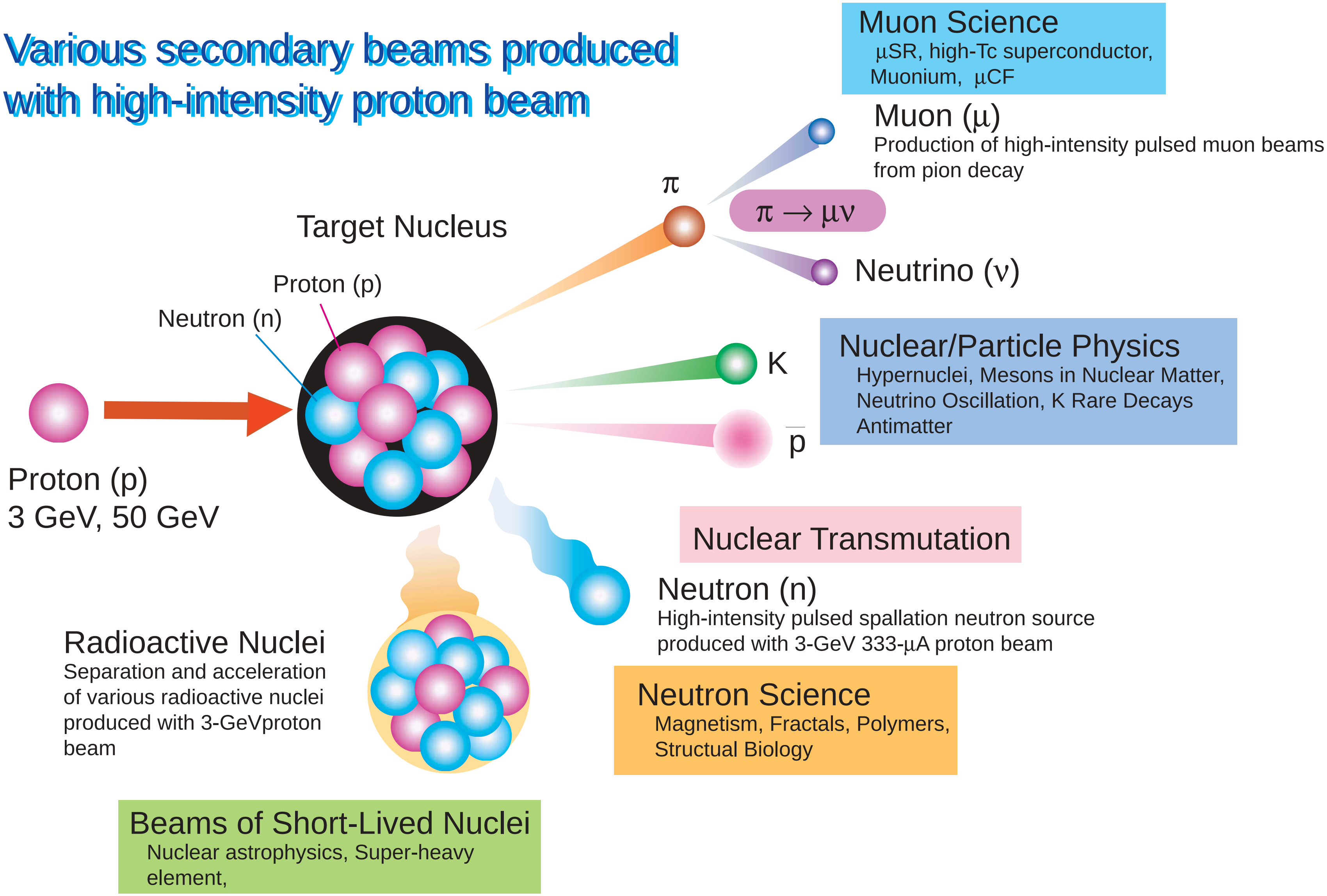


Site View of the Project

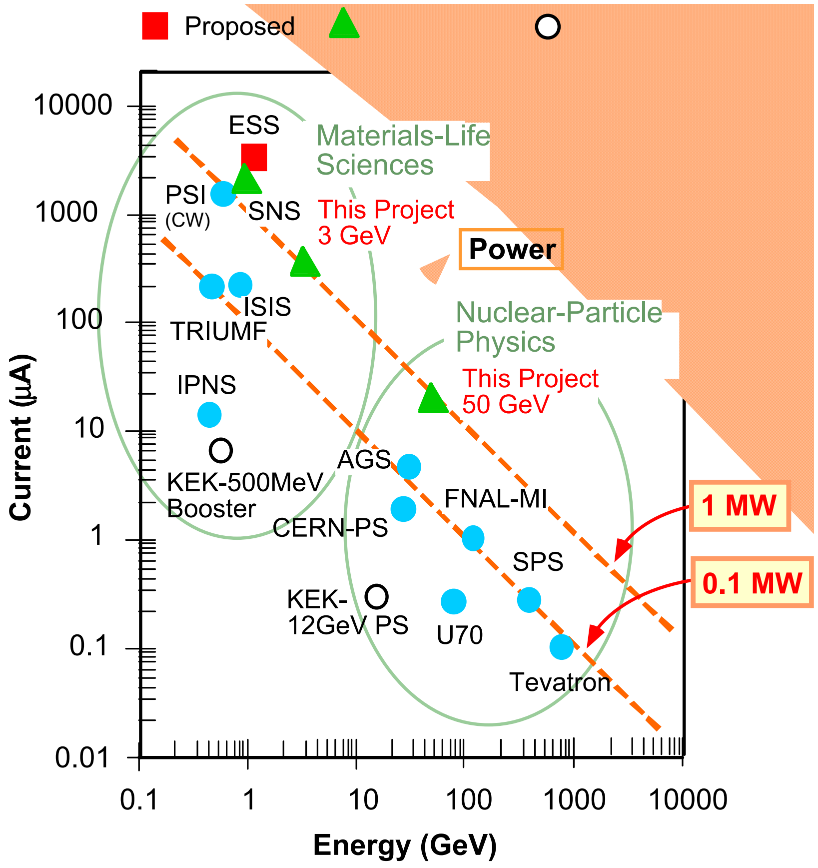


Why Do We Need High Intensity Protons?

Various secondary beams produced with high-intensity proton beam

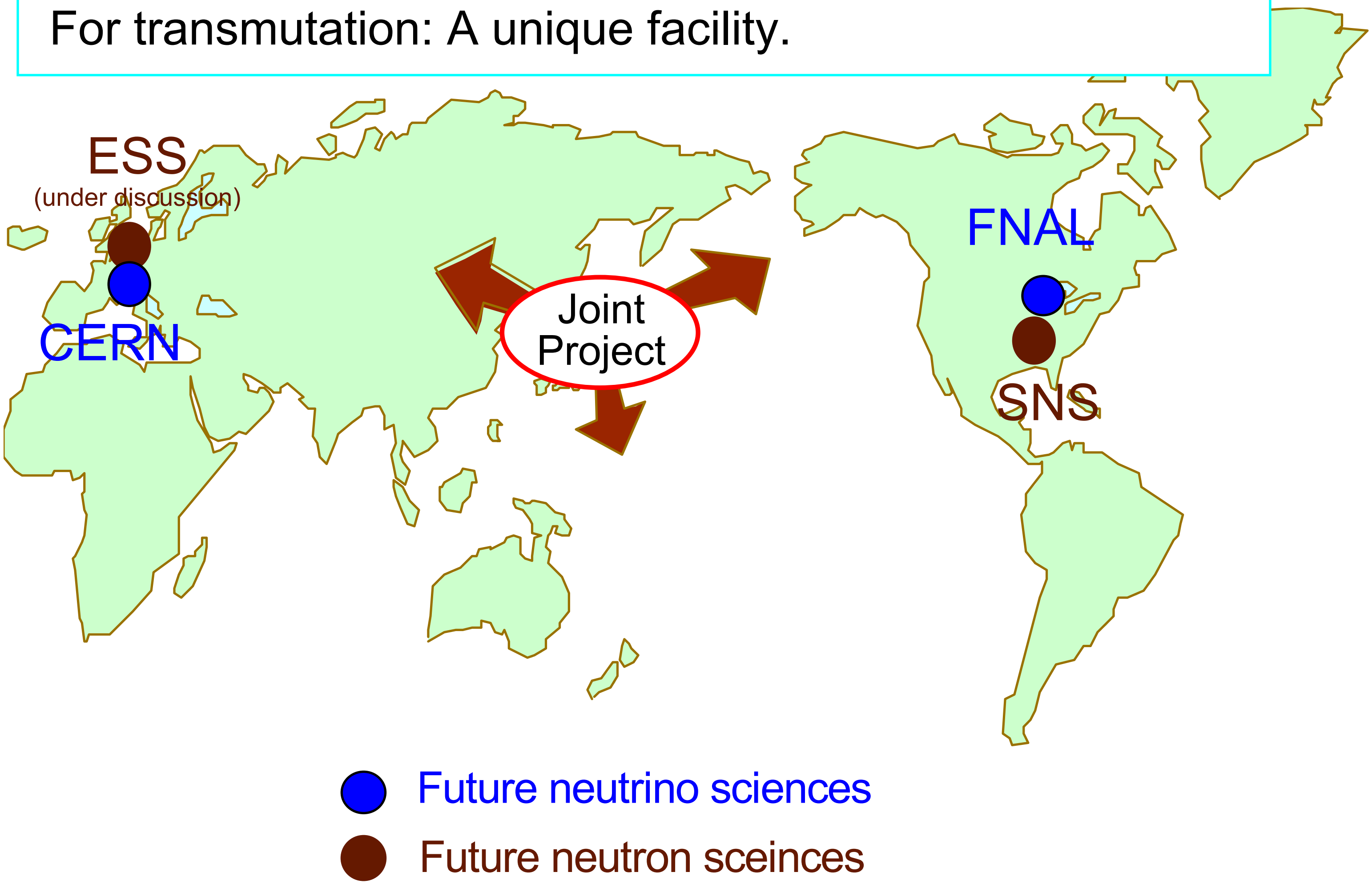


World's Proton Accelerator



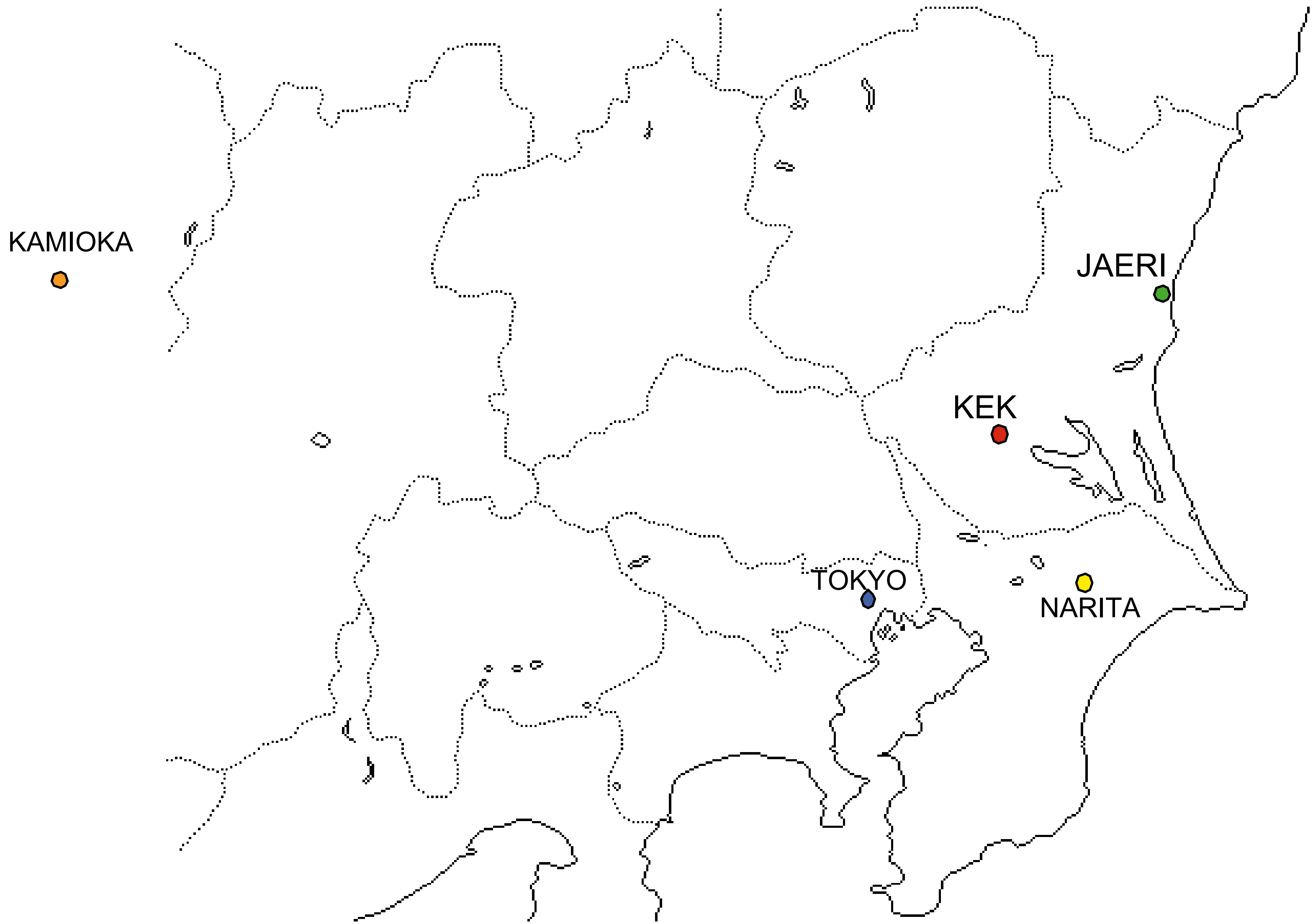
World Centers

For Kaons: World's center.
For neutrinos and for neutrons: One of three big centers.
For transmutation: A unique facility.



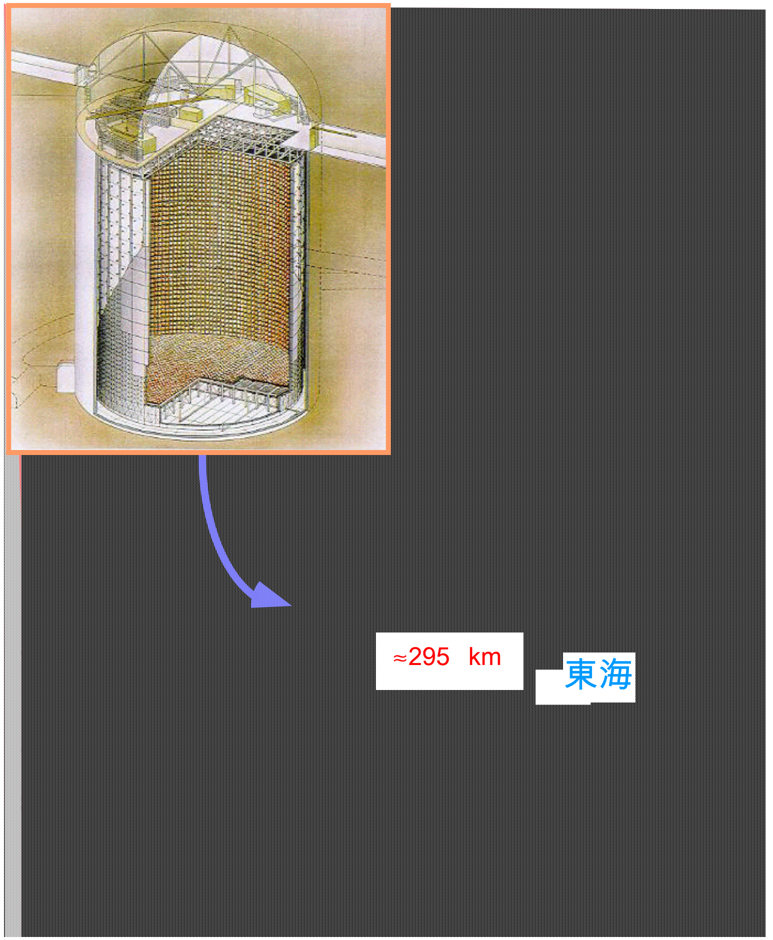
Asian Map

Location of JAERI at Tokai

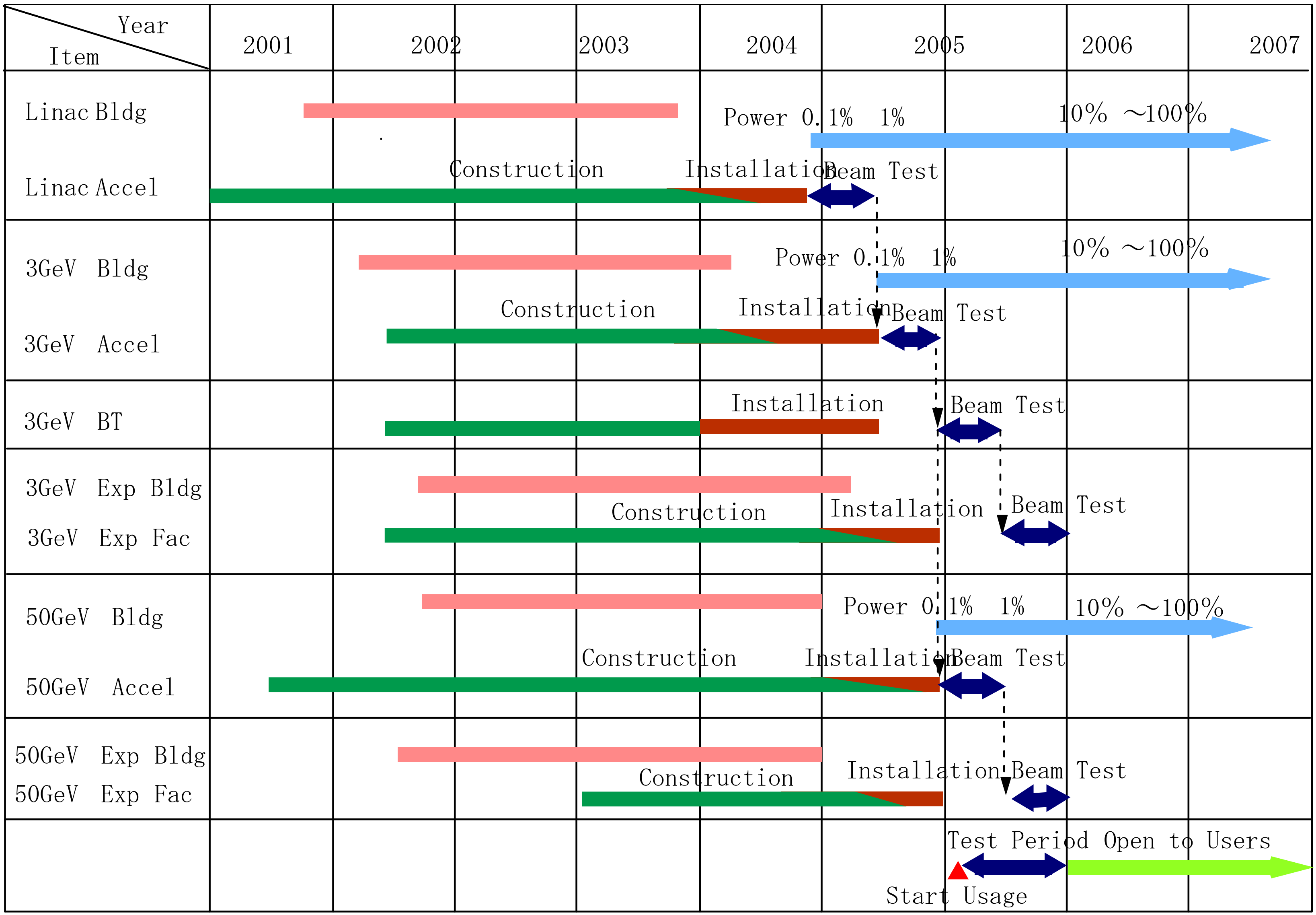


Nuclear/Particle Physics (1)

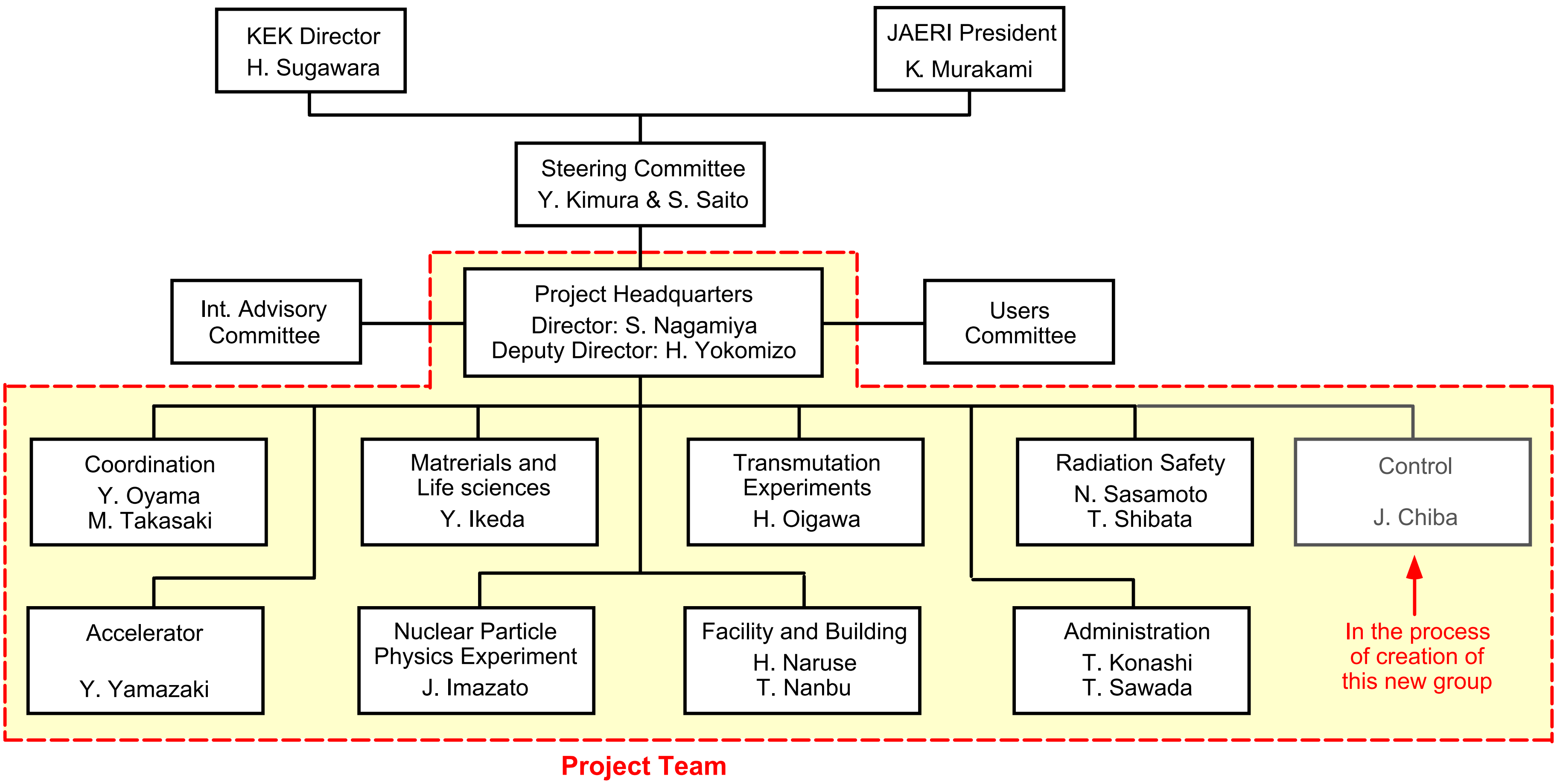
- **Neutrino oscillation and neutrino mass (SuperK + K2K)**
  - SuperK's atmospheric n experiment + recent SNO experiment suggests the finite mass for n_m and $n_{\square}$.
  - K2K n_m disappearance experiment also suggests the finite mass of n_m.
- **From measurement of m_n to the lepton family mixing (Joint Project)**
  - Flux (n_m) at the Planned 50 GeV PS > 100 x Flux (n_m) at KEK 12 GeV PS
- **Future facility … towards CP violation**



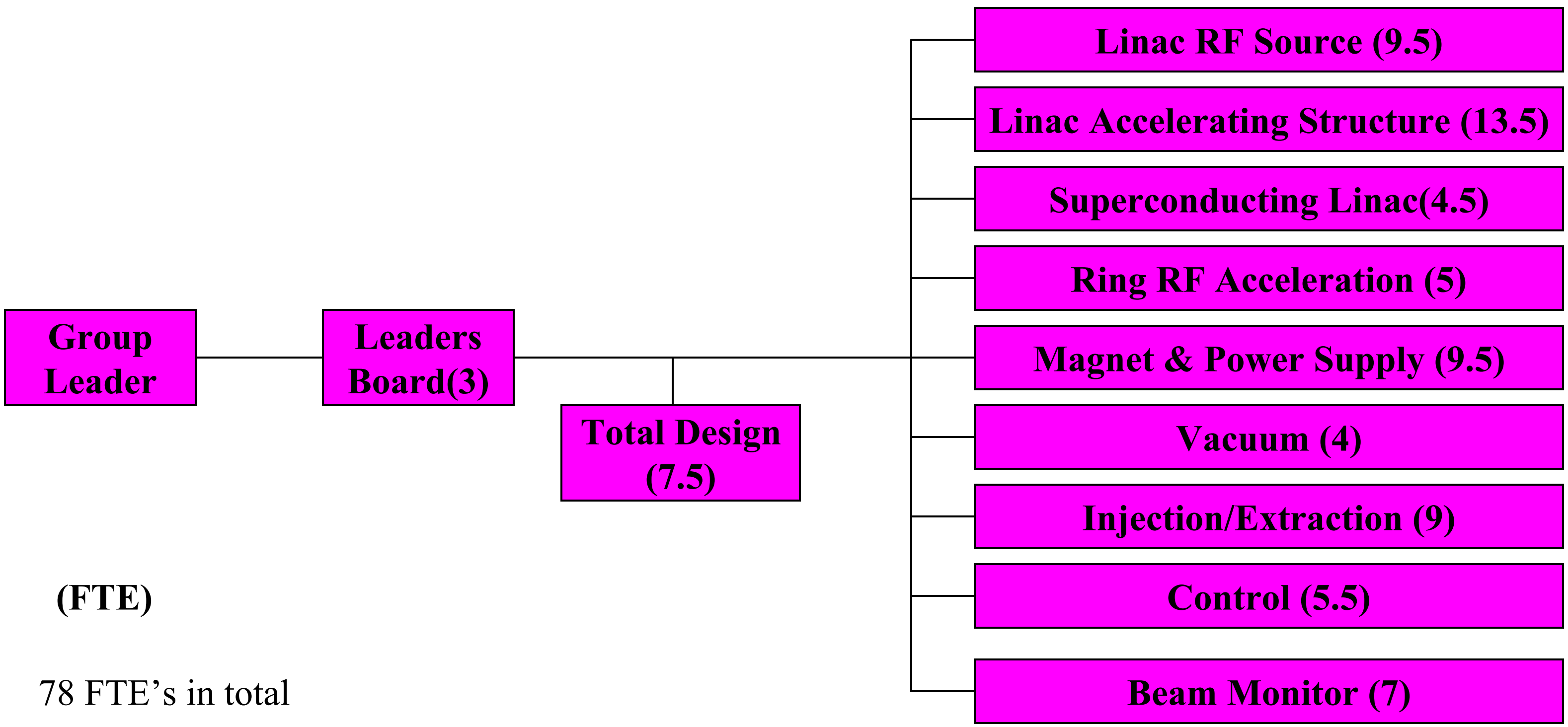
Construction and Commissioning



Organization for Construction



Accelerator Group Organization
(Instrument Construction)



(FTE)

78 FTE's in total

Additionally 32 FTE's are from industries and from post-docs

Requirement

- ~ 50-GeV, 15 μA, slow and fast extraction for nuclear and particle physics experiments
- ~ 1 GeV, 1 MW, <1 μs, ~ 25 Hz for spallation neutron source

Features of the Accelerator Complex

- The cascade system is suitable for the several-ten GeV machine.
- The prototype is the present KEK-PS.
- The booster Rapid-Cycling Synchrotron (RCS) can also be used for the Neutron Souce. This may be more powerful than the accumulator ring (AR) system with a full-energy linac.
- The present project is a kind of scale up of the KEK-PS by a factor of ten.

RCS Advantage vs AR

- **Lower Beam Current**
- **Lower Injection Energy**
- **Higher Injection Beam Loss is allowed.**

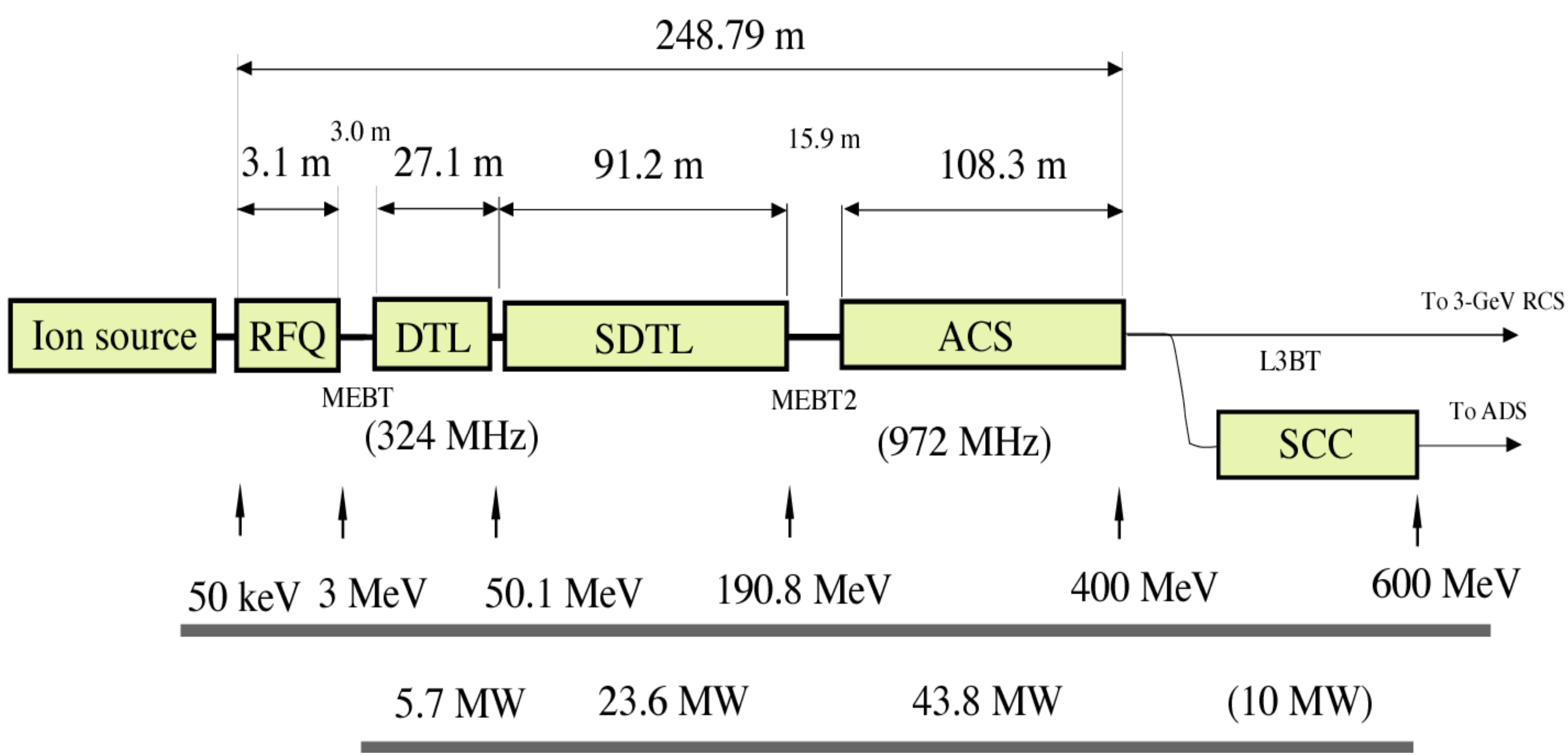
  (If one increases the beam energy by a factor of 7.5 times, the allowed beam loss during the injection is 7.5 times as high as that for AR with the same beam power.)
- **Perhaps immune against the e-p instability**

RCS Disadvantage vs AR

RCS Challenges

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

Proton linac



Features of the Linac Design (1)

Conflicting Requirements

- **Higher accelerating frequency is preferable**
  - lower bunch current
  - short focusing period
- **Electromagnet is preferable in order to keep the flexible knob (Large Drift Tubes, Lower frequency)**
  - Both the equipartitioning and constant phase advance are realized
  - The parametric resonance can be avoided

Electromagnets within small DT's

- **Coils produced by electroforming together with wire cutting**
- **Huge power feeding system**

Coil of Electromagnet in Drift Tube

The coil is electroformed and Wire-cutted.

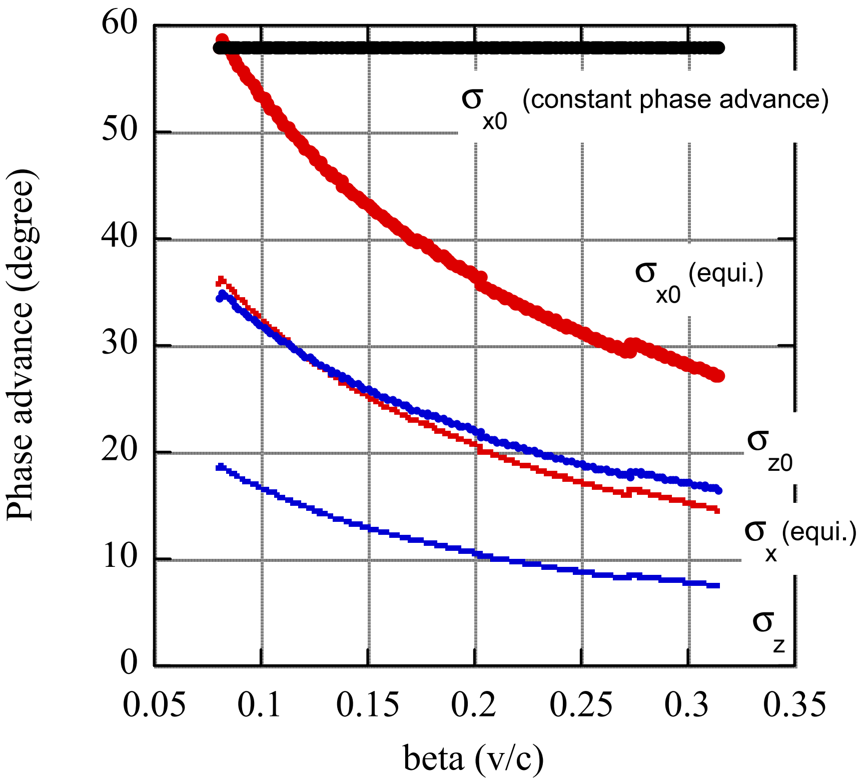
Features of the Linac Design (2)

- **Beam loss, and beam quality degradation arise at the transitions**
- **Beam halos arise from the mismatching**
- **Longitudinal transition (200 MeV from SDTL to ACS) is separated from the transverse transition (50 MeV from DTL to SDTL)**
- **1% amplitude control, 1-degree phase control, ~ 50 μm alignment (perhaps actually ~ 0.1 mm at best), axial symmetry**

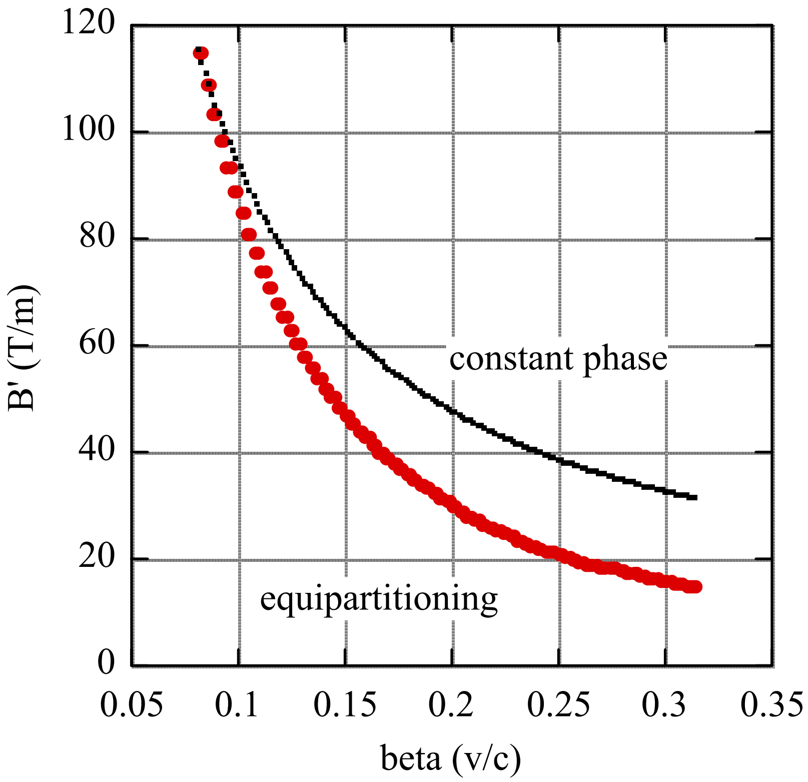
Features of the Linac Design (3)

- π-mode stabilizing loop (PISL)
- High-quality electroplating technique (PR-method)
- Electroformed coil
- Axially symmetric high-energy accelerating structure: Annular-Ring Coupled Structure (ACS)
- Chopping system

Focusing scheme in the DTL



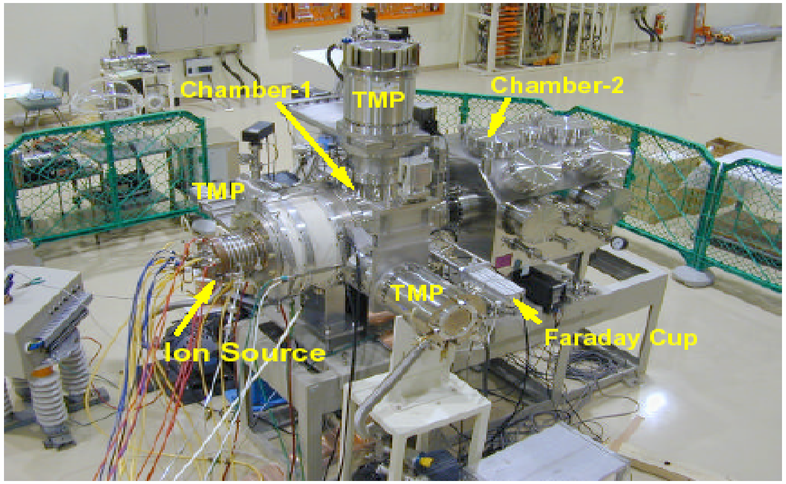
Phase advances in the DTL for equipartitioning and constant phase-advance focusing schemes.

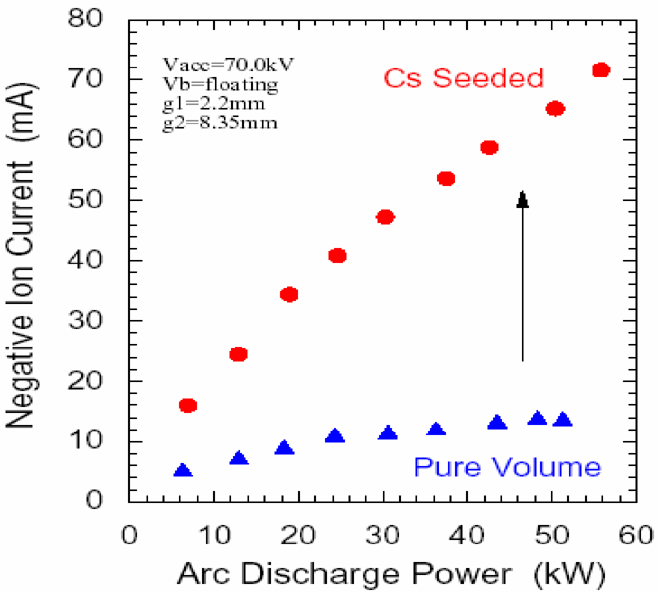


Required magnetic field gradient for equipartitioning and constant phase-advance focusing schemes.

Cs-seeded Ion Source

KEK/JAERI
The Joint Project Team

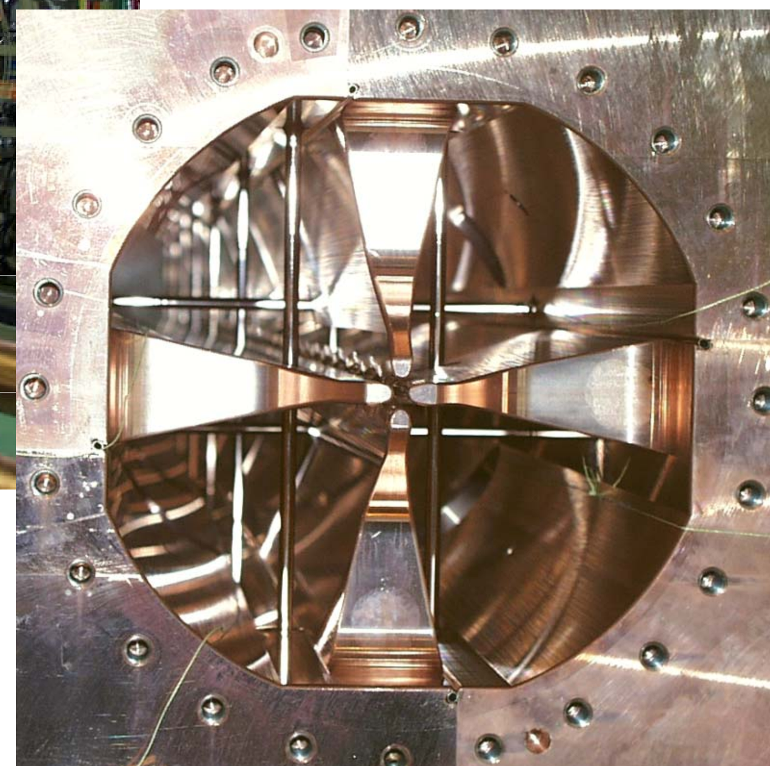




Volume Production Type Negative Ion Source

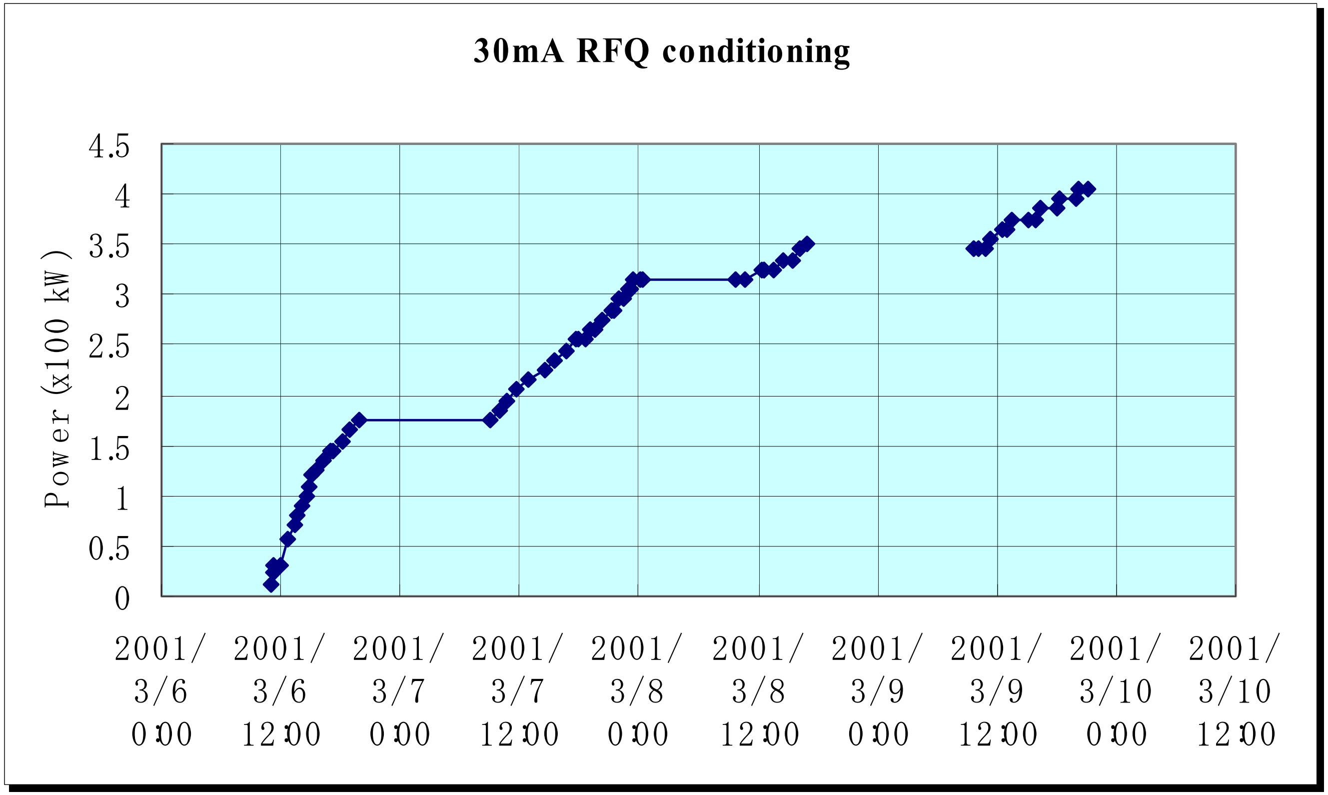
30mA RFQ

Inside view of the RFQ stabilized with PISLs



The 30mA RFQ installed in the test area

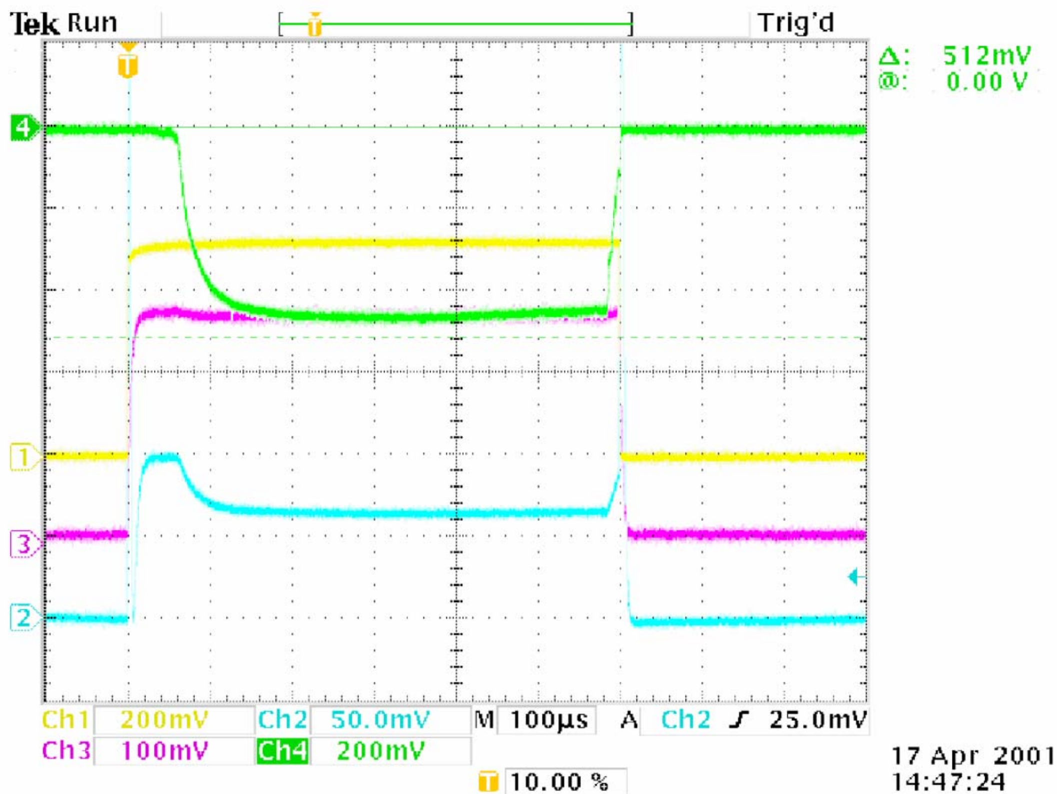
Conditioning of the 30mA RFQ



Conditioning with 20µsec, 50Hz pulse.

Reached 405kW with 600µsec and 50Hz (3% duty), after more 17hours conditioning

Waveform of the RFQ beam



ch1: Klystron output

ch2: coupler-1 reflection

ch3: RFQ tank level

ch4: Beam current

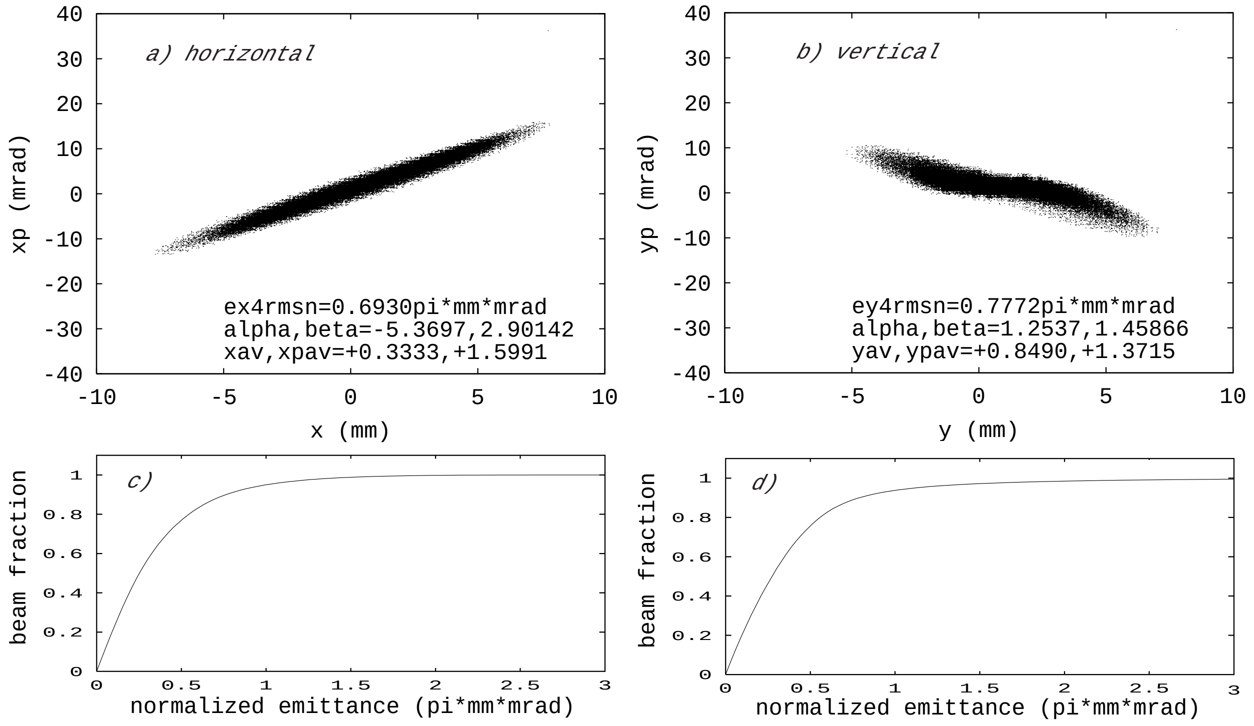
(4mA/div. peak:9.7mA

transmission 93%)

Emittances at the RFQ exit

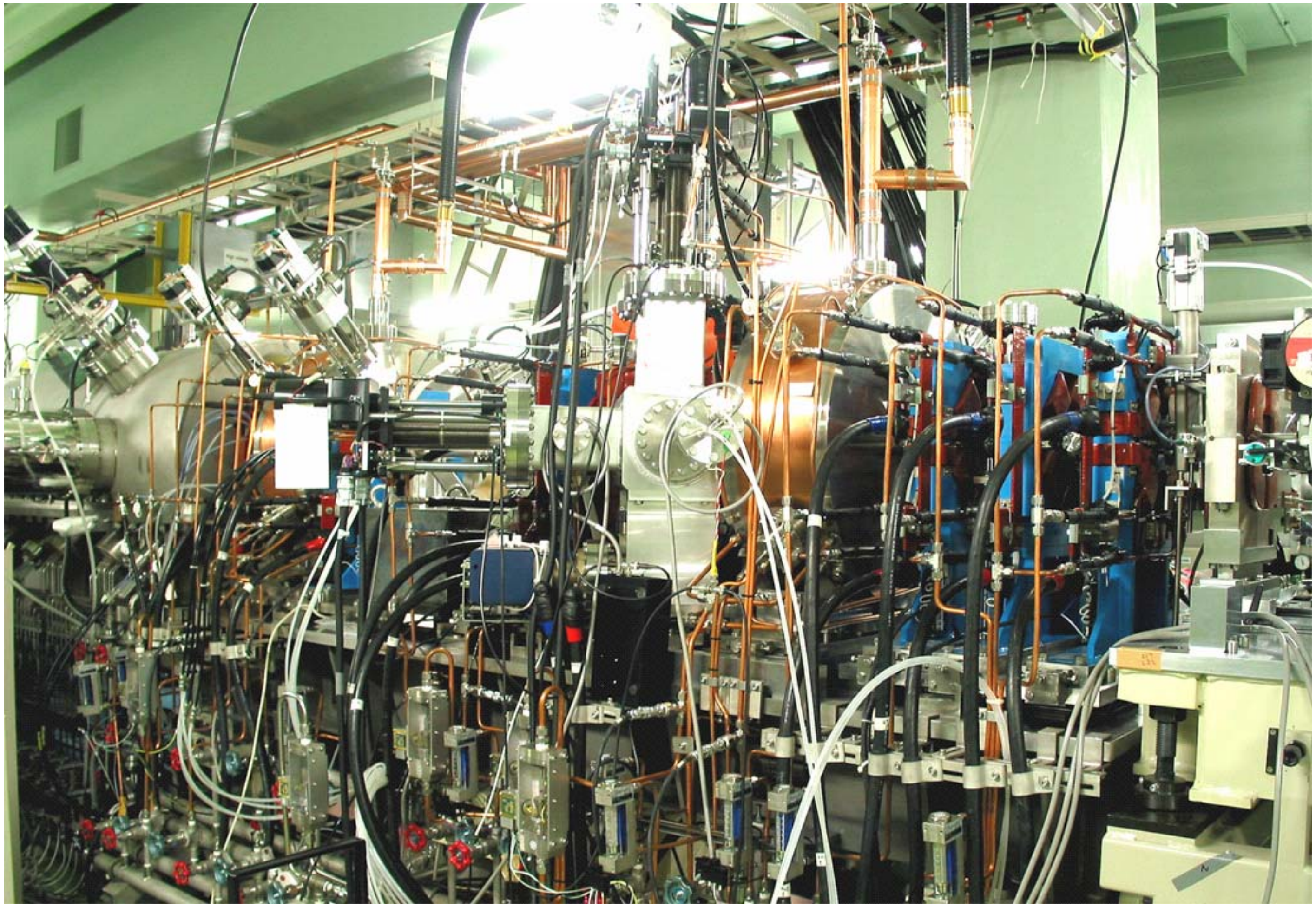
At I = 11 mA

horizontal vertical

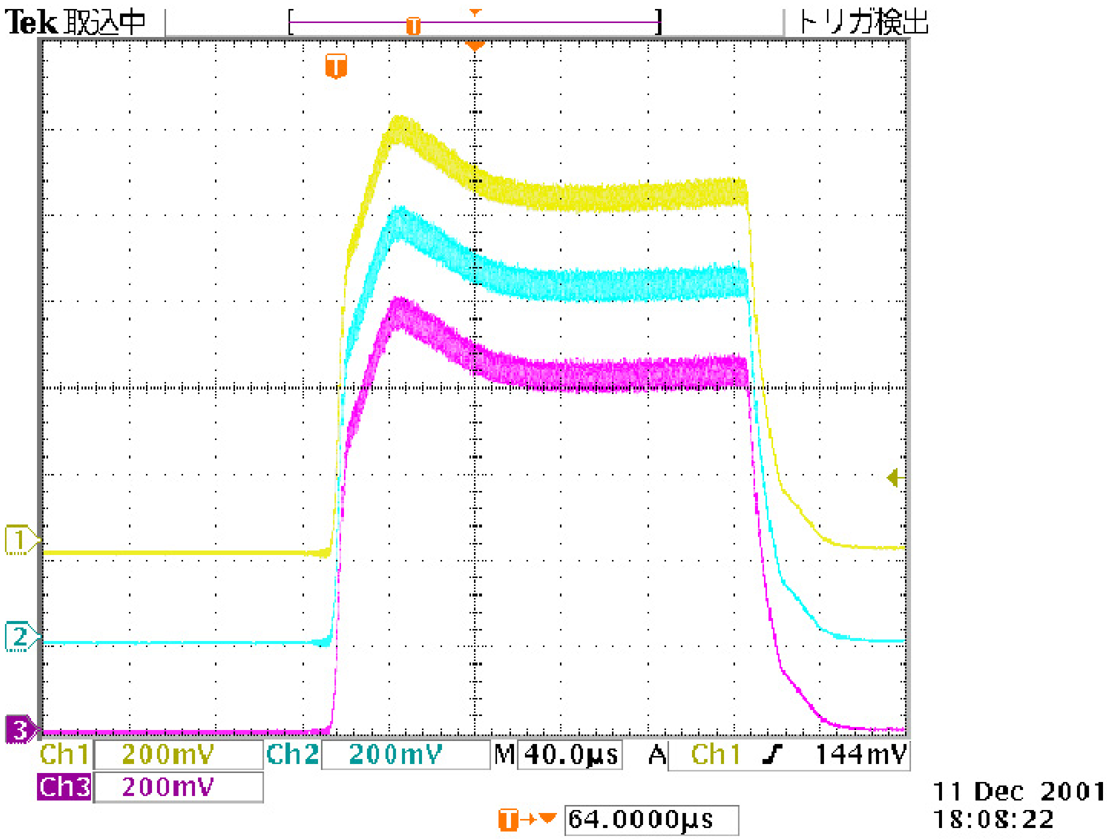


normalized ε_{4rms}=0.69π-mm-mrad ε_{4rms}=0.78π-mm-mrad

MEBT Photograph



MEBT Beam Experiment



Upper:measured at the entrance
Middle: measured at the middle
Lower: measured at the exit

Beam energy 3MeV
Repetition rate 6.25 Hz

2 mA / div
40 µsec / div

Output signals of the three current monitors in the MEBT during first beam experiment. The beam transmission ratio of nearly 100% was achieved with the aid of some tunings of the focusing strength in the MEBT.

DTL Tank 1 with DT's Installed

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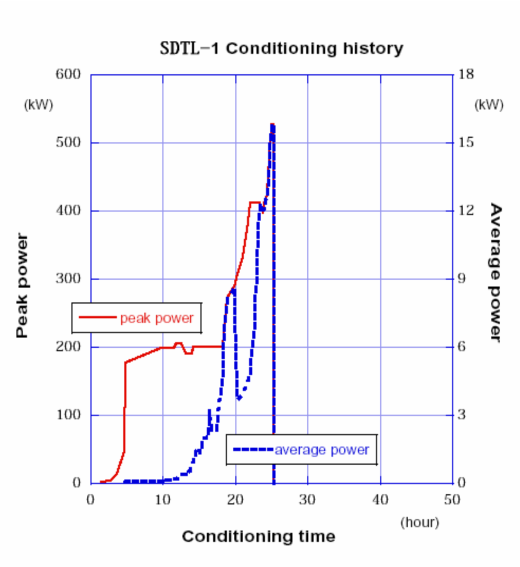
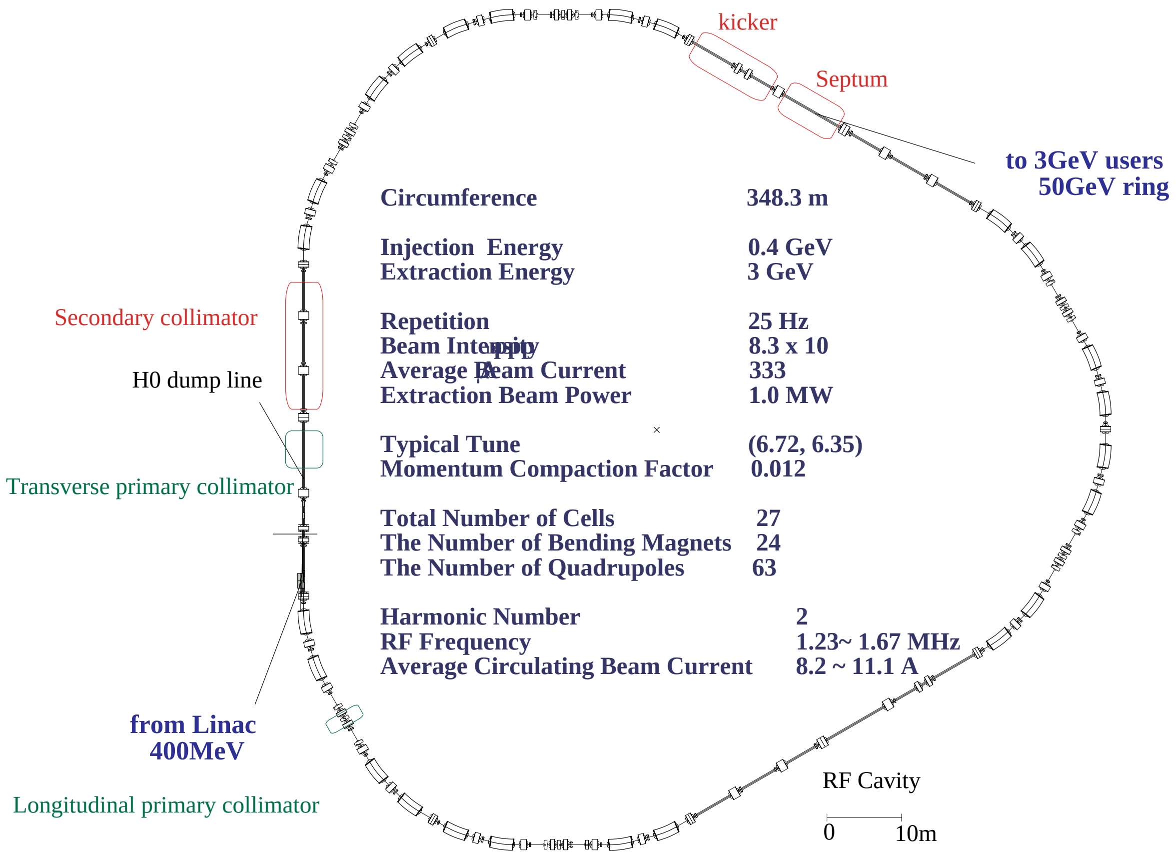
Conditioning of SDTL1



Parameters of the 3-GeV Synchrotron

Painting Emittance at Injection(π mm.mrad)	**216**
Collimator Acceptance	**324**
Physical Aperture	**486**
Bunching Factor with 2nd harmonic	**0.41**
Incoherent Tune Shift with	**0.16**
Bunching Factor without	**0.27**
Incoherent Tune Shift	**0.24**

RCS Configuratiion



Circumference	348.3 m
Injection Energy	0.4 GeV
Extraction Energy	3 GeV
Repetition	25 Hz
Beam Intensity ppp	8.3 x 10
Average μA Beam Current	333
Extraction Beam Power	1.0 MW
Typical Tune	(6.72, 6.35)
Momentum Compaction Factor	0.012
Total Number of Cells	27
The Number of Bending Magnets	24
The Number of Quadrupoles	63
Harmonic Number	2
RF Frequency	1.23~ 1.67 MHz
Average Circulating Beam Current	8.2 ~ 11.1 A

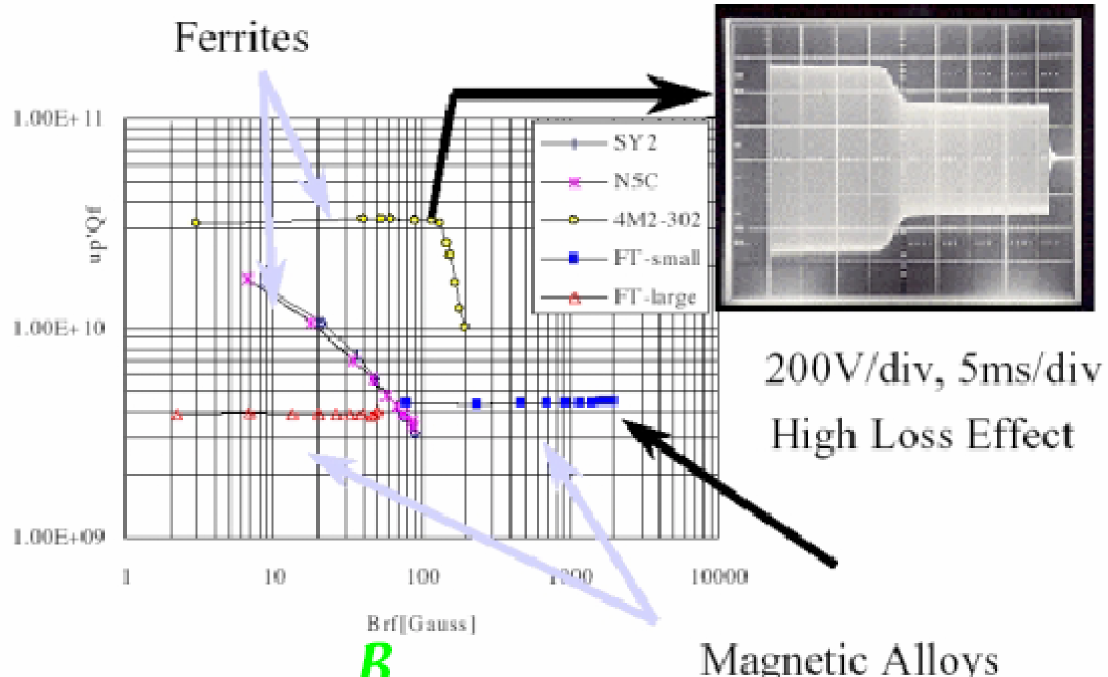
Developments for the RCS

- New RF Cavity loaded with Magnet Alloy
- Ceramics vacuum chamber, being rectangular
- Wide aperture magnets with stranded coils
- Injection system

Magnetic Alloy

* RF behaviour at high field

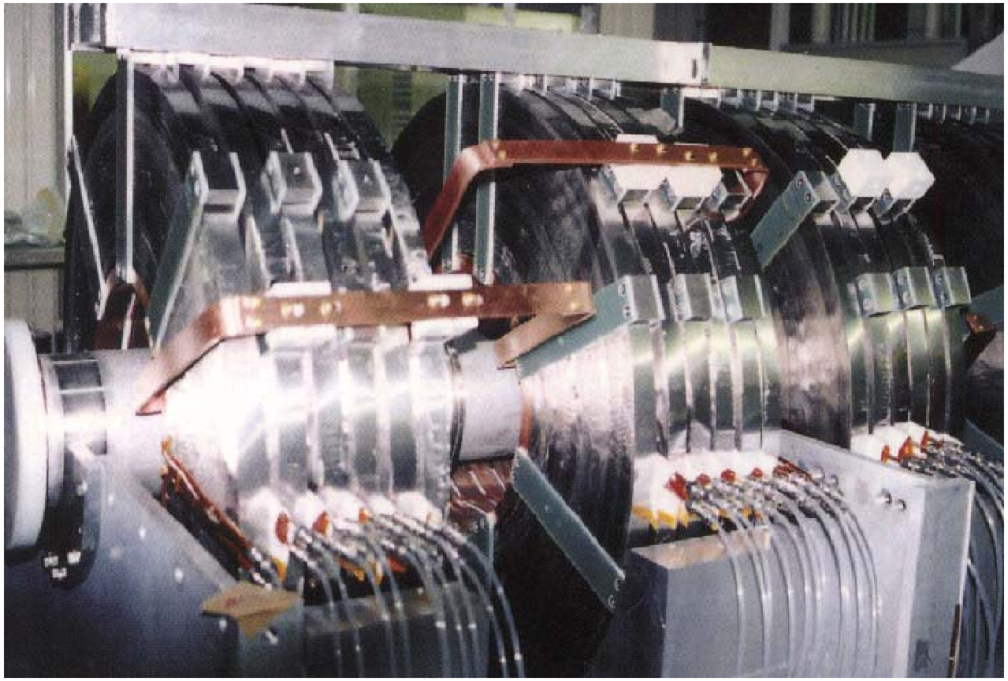
μQf (shunt.imp.) vs. B_{rf}



μQf

B_{rf}

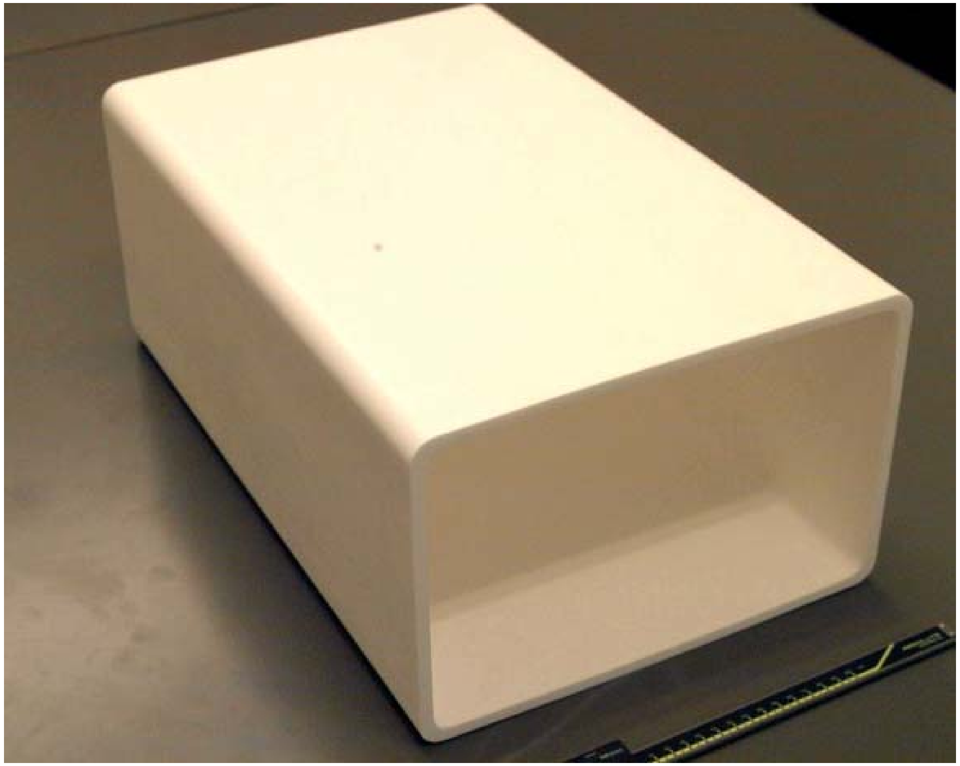
Novel RF Cavity with Finemet



FINEMET-loaded Accelerating RF Cavity

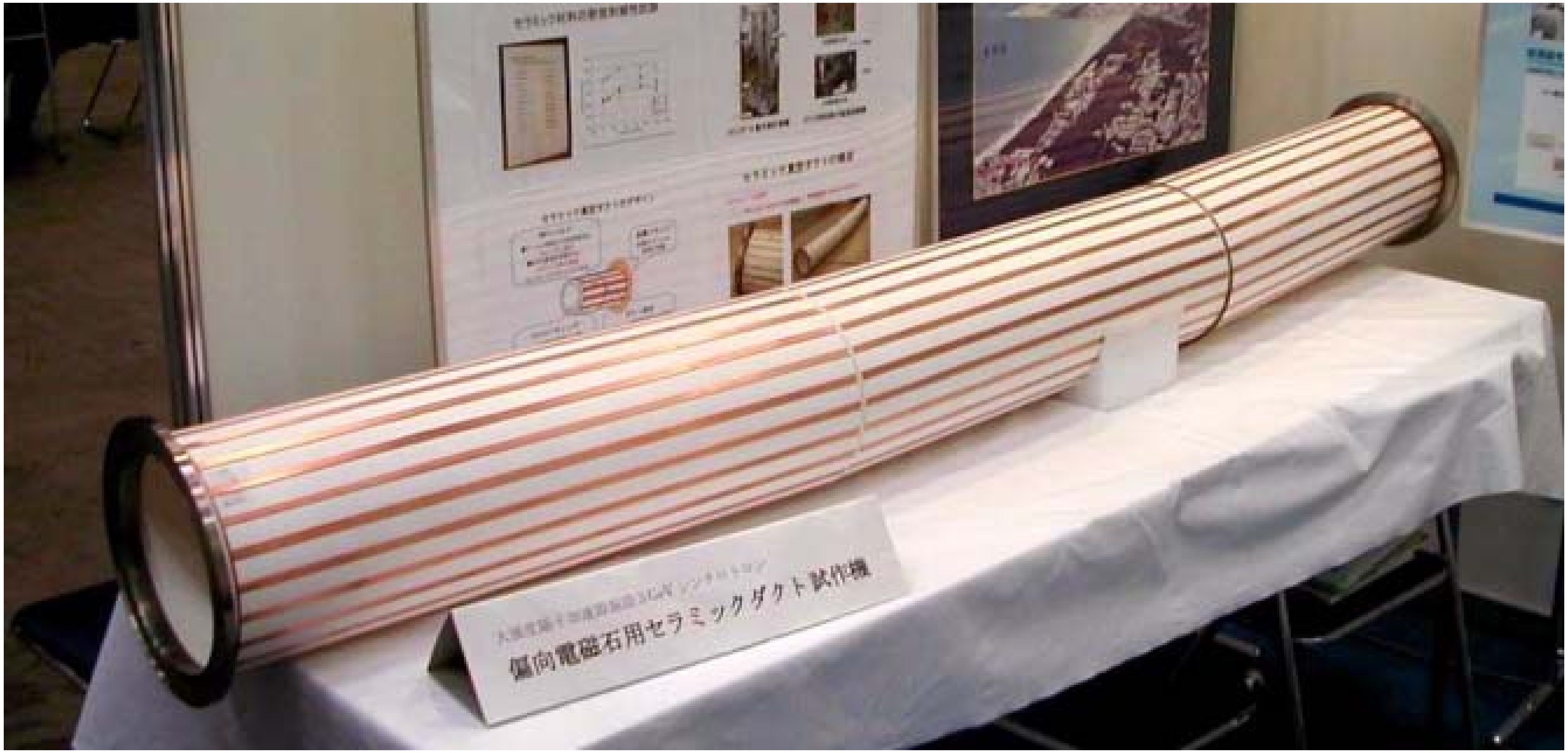
- **High Permeabiility Magnetic Alloy**
- **Highest Accelerating Field Gradient（ 50kV/m Accomplished**

Rectangular Ceramics Vacuum Chamber

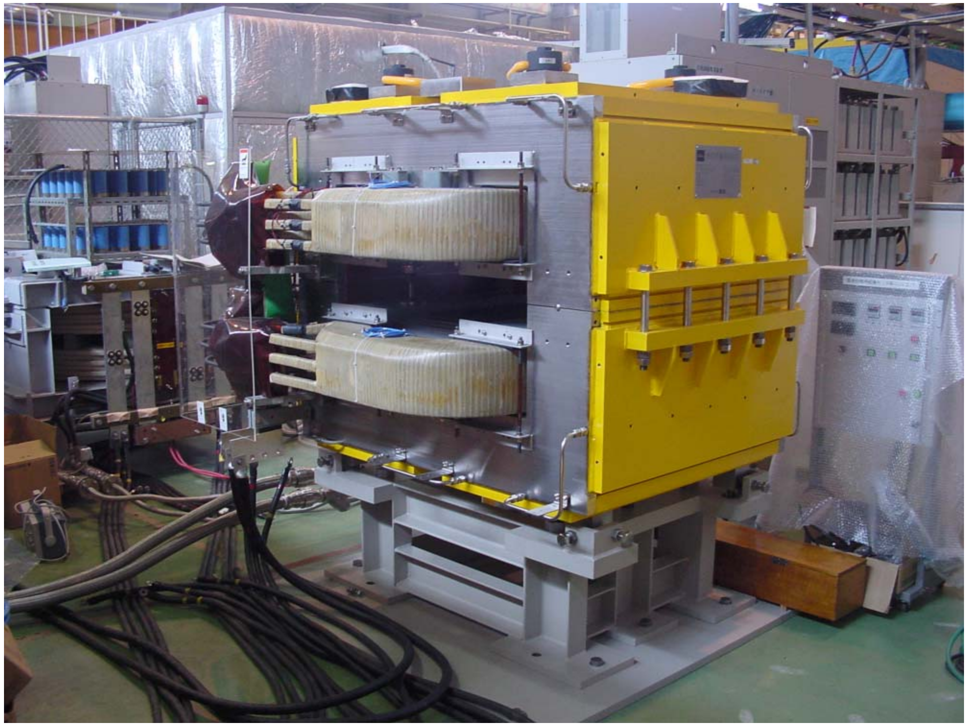


Circular Ceramics Vacuum Chamber

RF shields were electroformed.
Main bodies were metalized and silver-brazed.

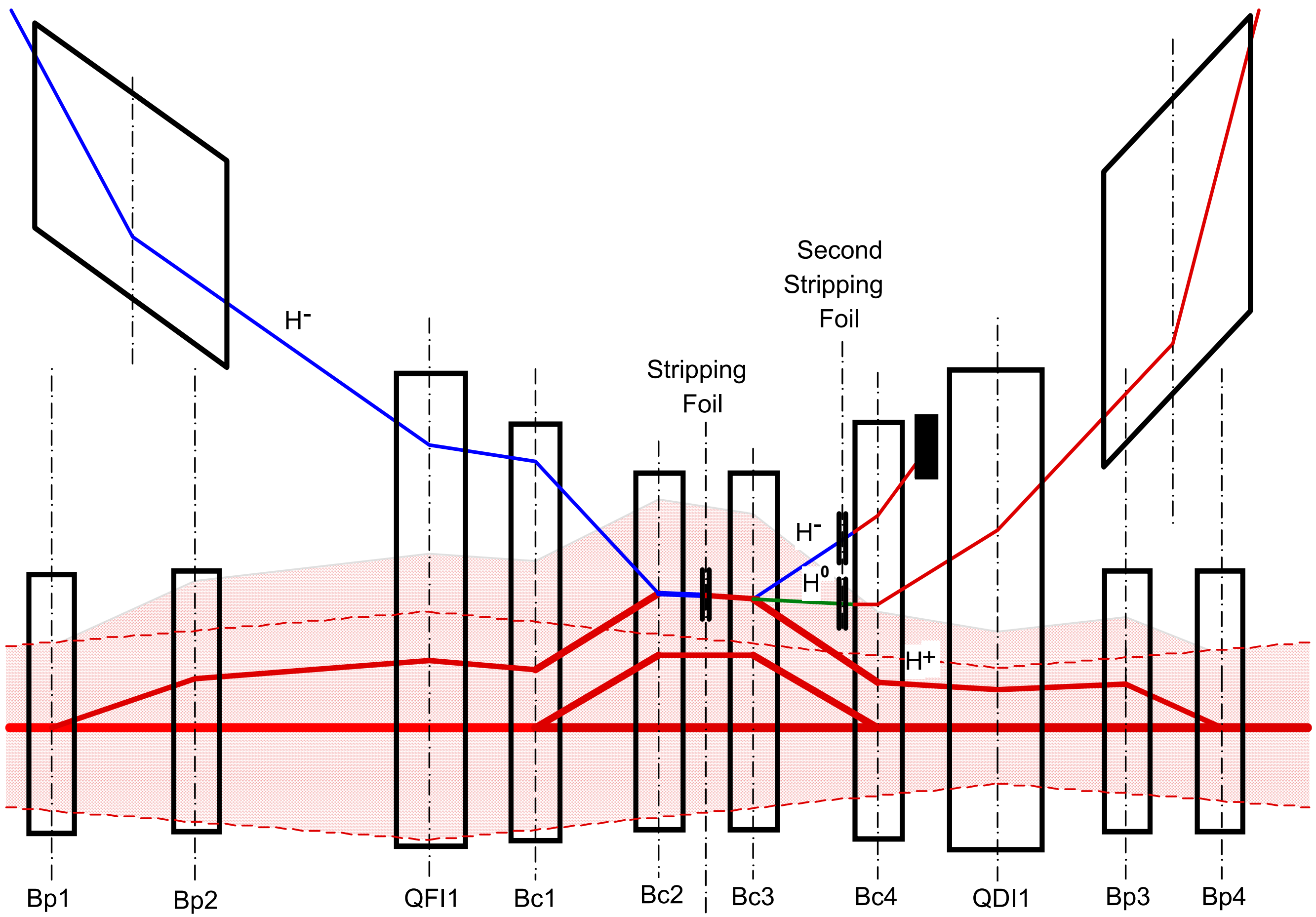


R&D Dipole Magnet for 3-GeV Synchrotron



Repetition rate : 25[Hz],
Core length : 1.0[m], Gap height : 210[mm]
Max. field : 1.1[T]（at 3GeV）, Min. field : 0.27[T]（at 400MeV）

H⁻Injection System for 3GeV Proton Synchrotron



Emittance Growth Simulation in RCS

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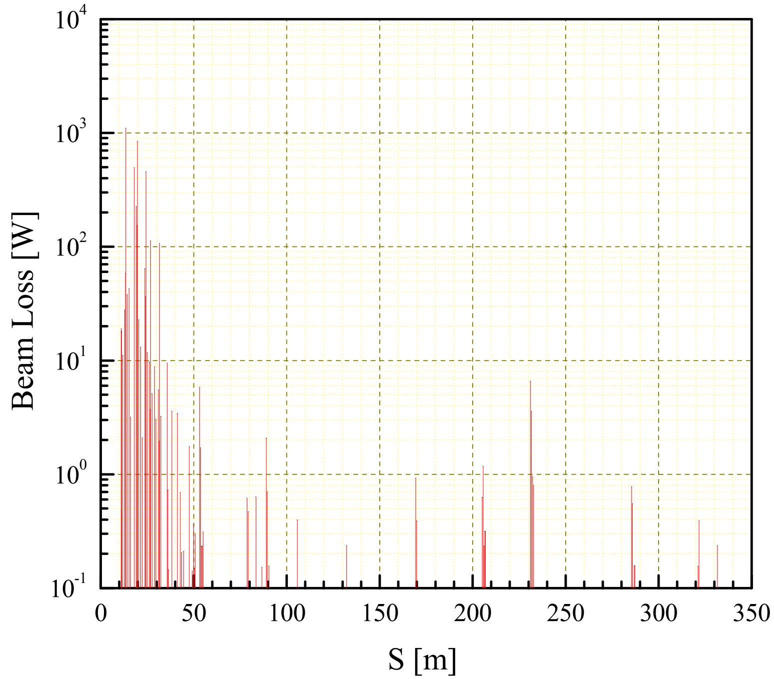
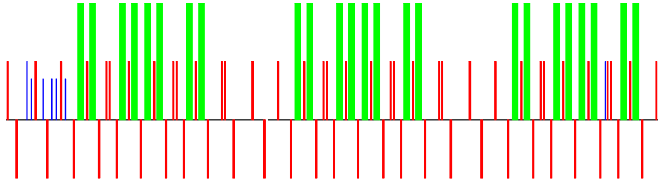
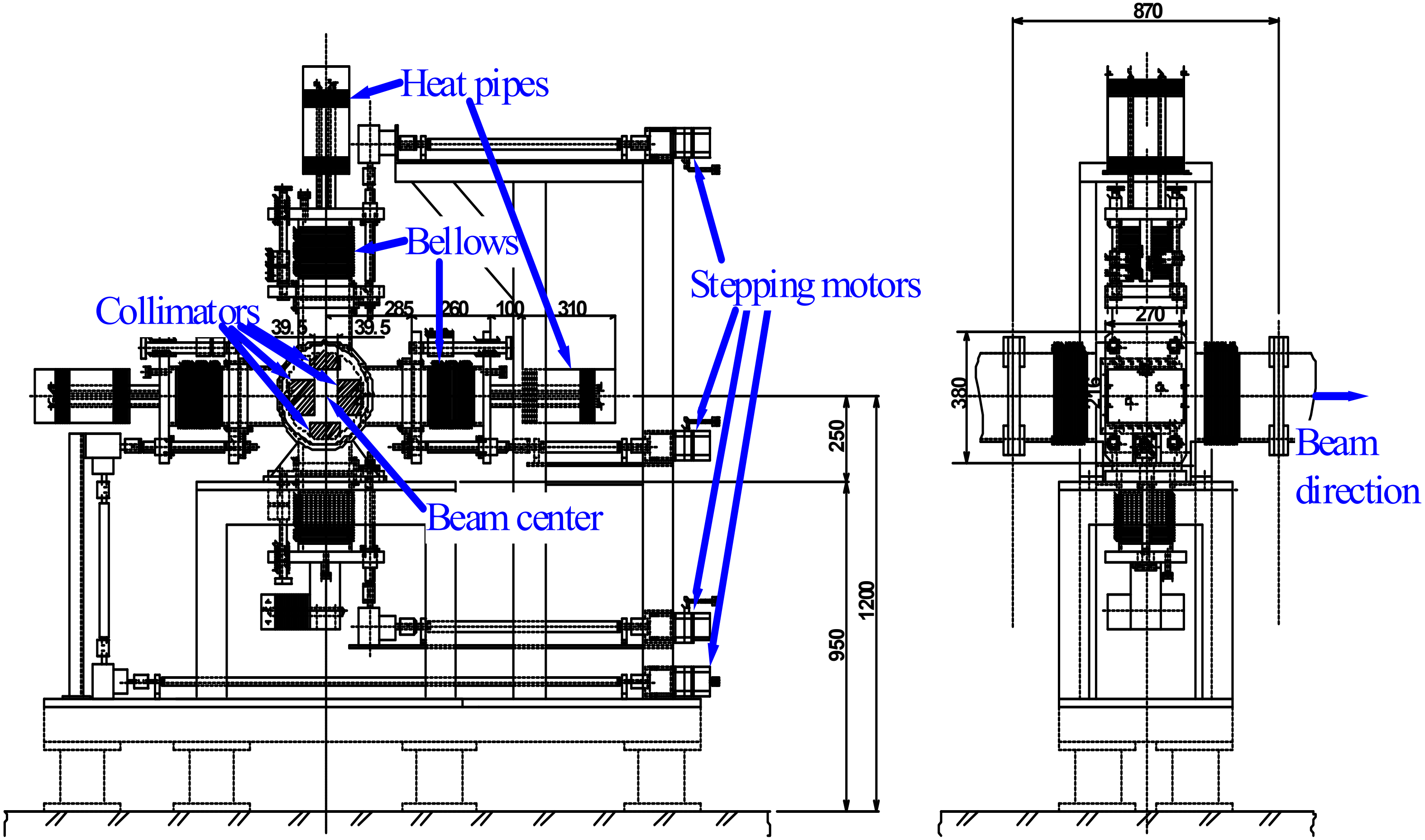
Beam Loss Distribution

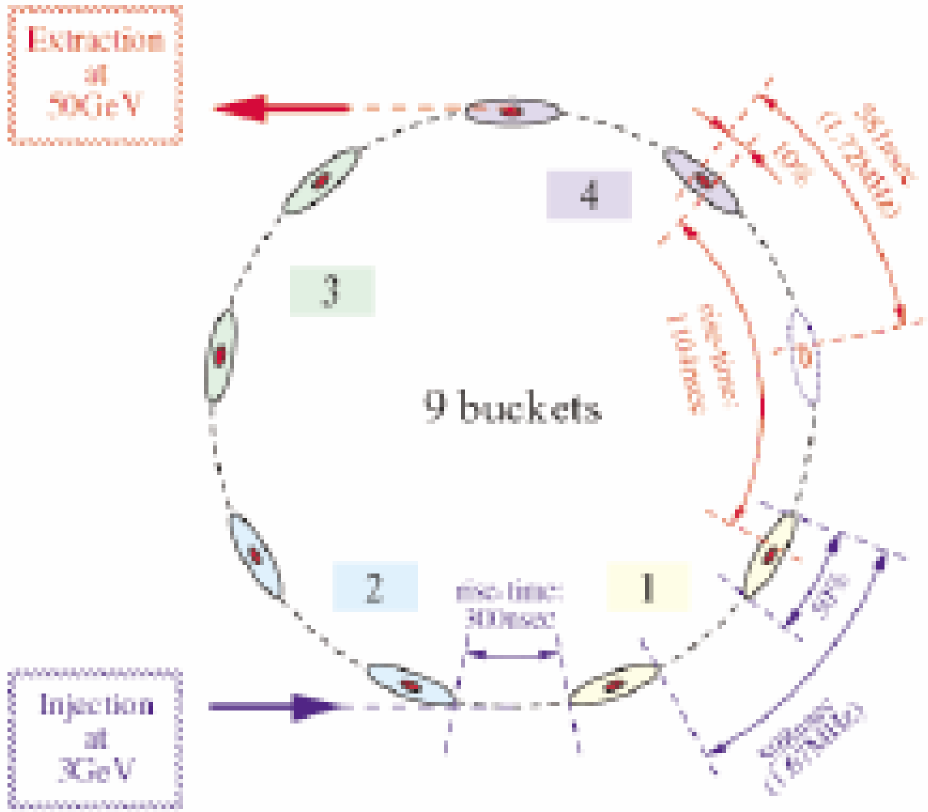




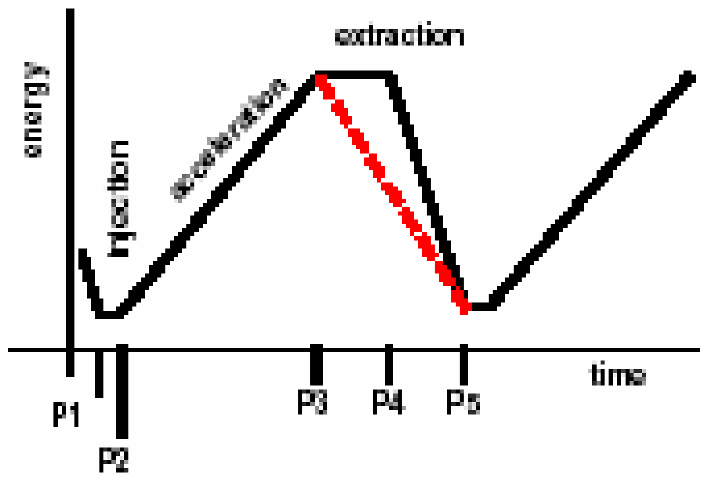
Configuration of R&D collimator hardware



Injection Scheme to 50-GeV Ring



Acceleration Cycle



	P1 - P2(injection)	0.14 s
	P2 - P3(acceleration)	1.9 s
	P3 - P4(extraction)	0.7 s
	P4 - P5	0.9 s
	total	3.64 s
slow extraction of 50GeV		
	duty factor	0.20
	average current	15μA

Space Charge Tune Shift

- 50GeV MR

  $\Delta Q = -0.14$

  - emittance 54 πmm.mrad
  - beam intensity 3.3×10^{14} ppp
  - bunching factor 0.27
  - form factor 1.7

$$\Delta Q = -\frac{rFN_t}{\pi\varepsilon\beta^2\gamma^3 B_f}$$

- 3GeV RCS (for 50GeV MR)

  $\Delta Q = -0.22$

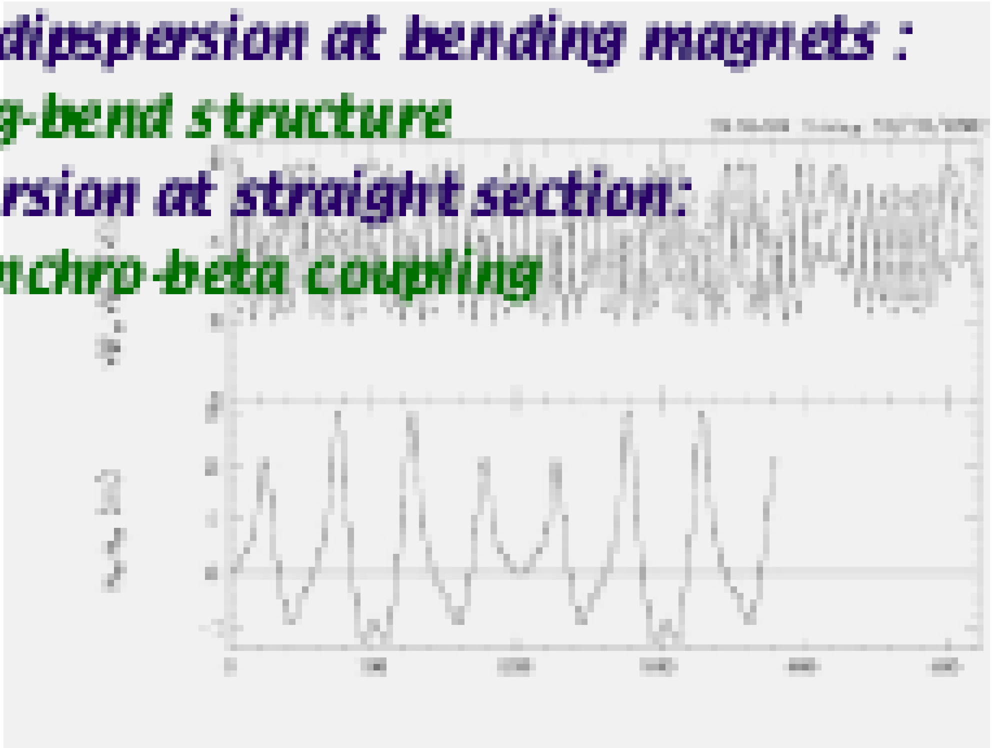
  - emittance 144 πmm.mrad
  - beam intensity 8.3×10^{13} ppp
  - bunching factor 0.42

50-GeV Ring Lattice

*Imaginary transition gamma :
    γ -> 32i (no transition energy)

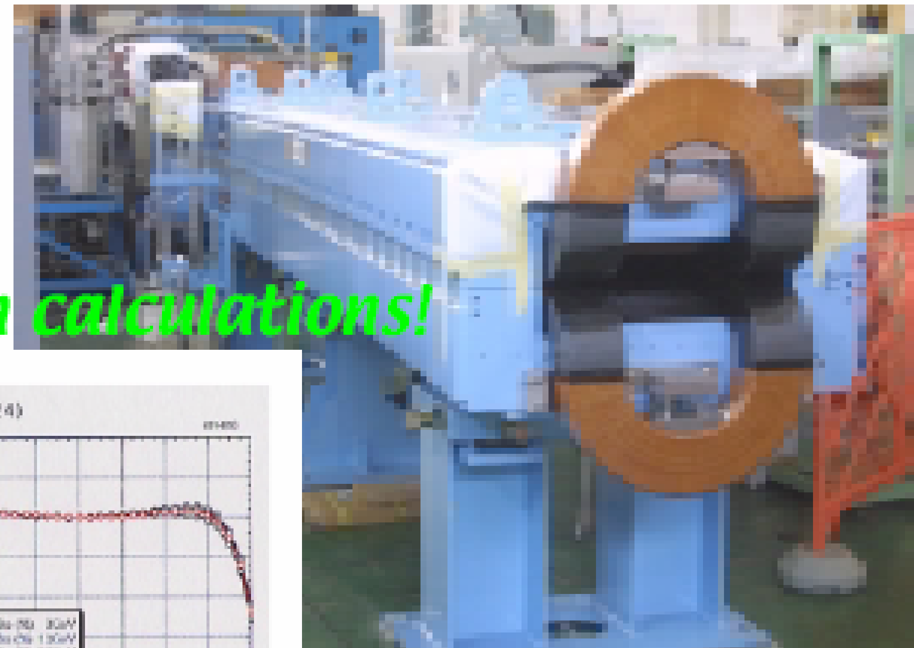
* Negative dipspersion at bending magnets :
    missing-bend structure

*Zero dispersion at straight section:
    non synchro-beta coupling

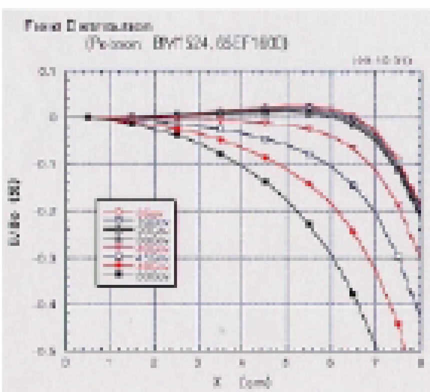


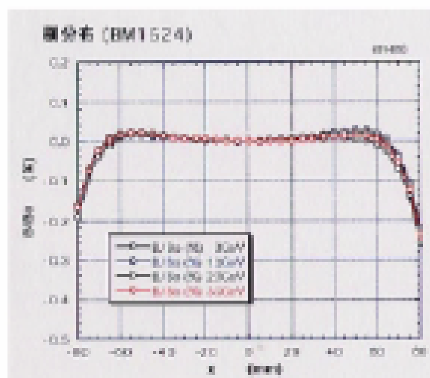
Dipole Magnet for 50-GeV Ring

gap Height	*106mm*
useful Aperture	*120mm*
field	*0.143-1.9T*
length	*5.85m*
weight	*34 ton*



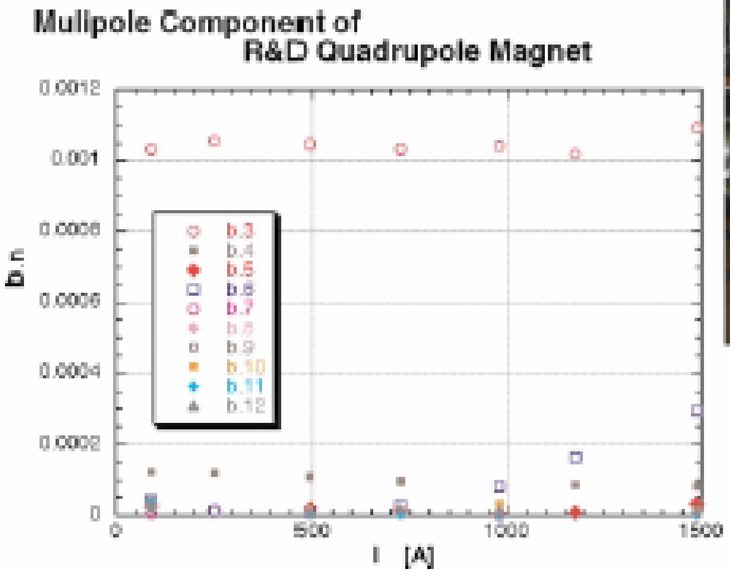
good agreement with calculations!





Quadrupole Magnet for 50-GeV Ring

Bore Radius	63mm
Useful Ap.	132mm
Max. Field	18T/m
Length(max.)	1.86m



Electrostatic Septum R&D

* High Field → 237kV achieved(1.4 x design voltage)
* Need high quality ceramic feedthrough

ESS(R&D) assembly

Linac Schedule Milestones

- **JFY01: Most components for 200-MeV Linac and Bldg. to be ordered**
- **Mid JFY02: Most components for 400-MeV Linac to be ordered**
- **Summer JFY04 : Bldg. Completed, Installation to be started**
- **March JFY05: Commissioning to be started**
- **Mid JFY 06: Beam injection to RCS to be started**

RCS Schedule Milestones

- JFY02: Half of components for and Bldg. to be ordered
- JFY03: Remaining half of components to be ordered
- March JFY04 : Bldg. Completed, Installation to be started
- Mid JFY06: Beam injection to RCS, that is, RCS commissionng to be started
- March JFY06: Beam extraction to the Neutron Source and to the 50-GeV Ring

50-GeV Ring Schedule Milestones

- **JFY01: Most of magnets and power supplies to be ordered**
- **JFY02: Remaining components to be ordered**
- **Mid JFY05 : Bldg. Completed, Installation to be started**
- **March JFY06: Beam injection to the 50-GeV Ring and its commissioning to be started**
- **Mid JFY07: Beam extraction to the Nuclear and Particle Experimental area**

Summary

- **The accelerator scheme for the high-intensity proton accelerator facility project in Japan is unique as follows.**
- ***The RCS scheme is chosen for the MW proton machine producing the pulsed spallation neutrons.***
- ***The MR is attempting to realize the MW proton machine also for the several ten GeV region.***
- **Not only for the scientific and engineering output, but this accelerator complex will also open up the new era for the field of the accelerator technology.**
- **Together with the success of the SNS and/or ESS projects, this project will contribute a lot to the future several or ten MW accelerators, which are really required for the 21st centuary science and technology, including the biology, the nuclear and particle physics, the energy development, the environmetal science/technology and so forth.**