The J-PARC Linac

Initial Results
Status
Upgrade Plan

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For J-PARC Accelerator Group

TH101, XXII International Linear Accelerator Conference
Luebeck, Germany, August 16th to 20th, 2004

J-PARC Contributions to LINAC04 (1)

[1] MOP18: "Cold-Model Tests and Fabrication Status for J-PARC ACS", H. Ao, H.A. Akikawa, K. Hasegawa, A. Ueno,Y. Yamazaki, M. Ikegami, S. Noguchi, N. Hayashizaki, V.V. Paramonov.

[2] MOP19: "Particle Distributions at the Exit of the J-PARC RFQ", Y. Kondo, A. Ueno, K. Ikegami and M. Ikegami.

[3] TUP06: "Results of the High-Power Conditioning and the First Beam Acceleration of the DTL-1 for J-PARC", F. Naito, S. Anami, J. Chiba, Y. Fukui, K. Furukawa, Z. Igarashi, K. Ikegami, M. Ikegami, E. Kadokura, N. Kamikubota, T. Kato, M. Kawamura, H. Kobayashi, C. Kubota, E. Takasaki, H. Tanaka, S. Yamaguchi, K. Yoshino K. Hasegawa, Y. Kondo, A. Ueno T. Itou, Y. Yamazaki, T. Kobayashi.

[4] TUP21: "Beam Dynamics Design of J-PARC Linac High Energy Section", M. Ikegami, S. Noguchi, T. Kato, N. Hayashizaki, V. V. Paramonov, T. Ohkawa, H. Ao, A. Ueno, K, Hasegawa, Y. Yamazaki.

[5] TUP22: "A Simulation Study on Chopper Transient Effects in J-PARC Linac", M. Ikegami, T. Ohkawa, Y. Kondo, A. Ueno.

[6] TUP70: "Systematic Calibration of Beam Position Monitor in the High Intensity Proton Accelerator (J-PARC) LINAC", Susumu SATO, ZenEi IGARASHI, Seishu LEE, Tetsuo TOMISAWA, Fumio HIROKI, JunIchi KISHIRO, Masanori IKEGAMI, Kazuo HASEGAWA, Akira UENO, Norihiko KAMIKUBOTA, Yasuhiro KONDO, Takeshi TOYAMA, Hiroshi YOSHIKAWA, Kazuyuki NIGORIKAWA, Mikio TANAKA.

[7] TUP74: "The Beam Diagnostics System in the J-PARC Linac", S.Lee, Z. Igarashi, M. Tanaka, S. Sato, F. Hiroki, T. Tomisawa, H. Akikawa, H. Yoshikawa, J. Kishiro and T. Toyama.

[8] TUP83: "Results of the Magnetic Field Measurements of the DTL Quadrupole Magnets for J-PARC," E. Takasaki, F. Naito, K. Yoshino, H.Ino, Z.Kabeya and T.Kawasumi, and T.Itou.

J-PARC Contributions to LINAC04 (2)

[9] TUP85: "J-PARC linac alignment," M. Ikegami, F. Naito, H. Tanaka, K. Yoshino, C. Kubota, E. Takasaki, H. Ao, T. Morishita, T. Ito, A. Ueno, and K. Hasegawa.

[10] TUP87:"Technologies of the Peripheral Equipments of the J-Parc DTL1 for the Beam Test ," K. Yoshino, E. Takasaki, F. Naito, Y. Fukui, E. Kadokura, C. Kubota, H. Tanaka, T. Kato, T. Ito

[11] TH101: "Status of J-PARC Linac, Initial Results and Upgrade Plan, " Y. Yamazaki.

[12] THP52: "RF Reference Distribution System for J-PARC Linac, " T. Kobayashi, E. Chishiro, S. Anami, S. Michizono, S. Yamaguchi.

[13] THP56: "Control of the Low Level RF System for the J-PARC Linac," S. Michizono, S. Anami, E. Kadokura, S. Yamaguchi, E. Chishiro, T. Kobayashi, H. Suzuki.

[14] THP57: "Digital Feedback System for J-PARC Linac RF Source, " S. Michizono, S. A. Anami, S. Yamaguchi, and T. Kobayashi.

[15] THP88: "Longitudinal Bunch Shape Monitor Using the Beam Chopper Of J-Parc," F. Naito.

[16] THP89: "Measured RF Properties of the DTL for J-Parc, " H. Tanaka, T. Kato, F. Naito, E. Takasaki, H. Asano, T. Itou, T. Morishita

Outline

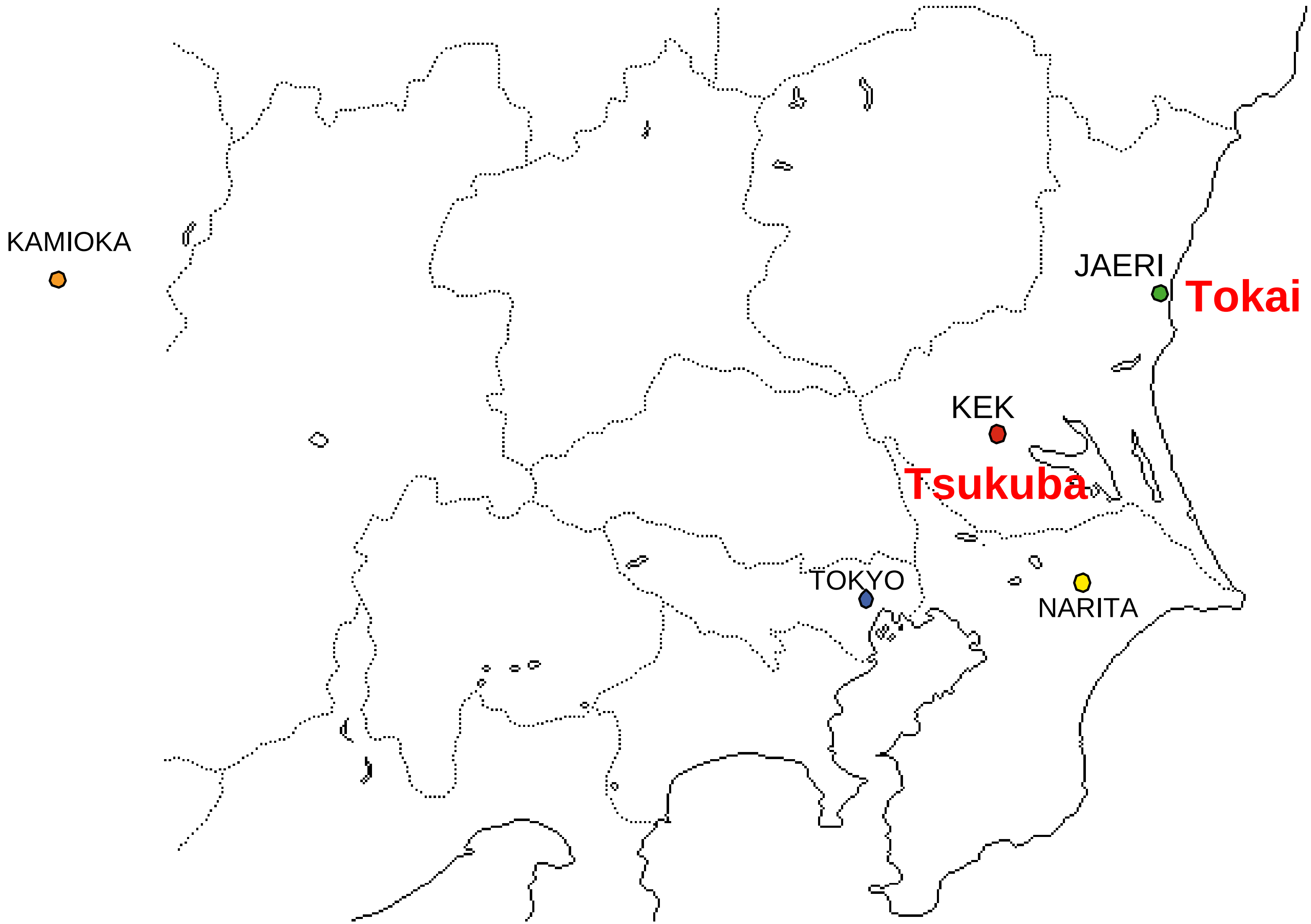
- Introduction
- Linac Scheme
- Initial Results
- Project Status
- Accelerator Status
- Linac Energy Recovery Plan and High Energy Structure
- Future Upgrade Plan
- Summary

Introduction

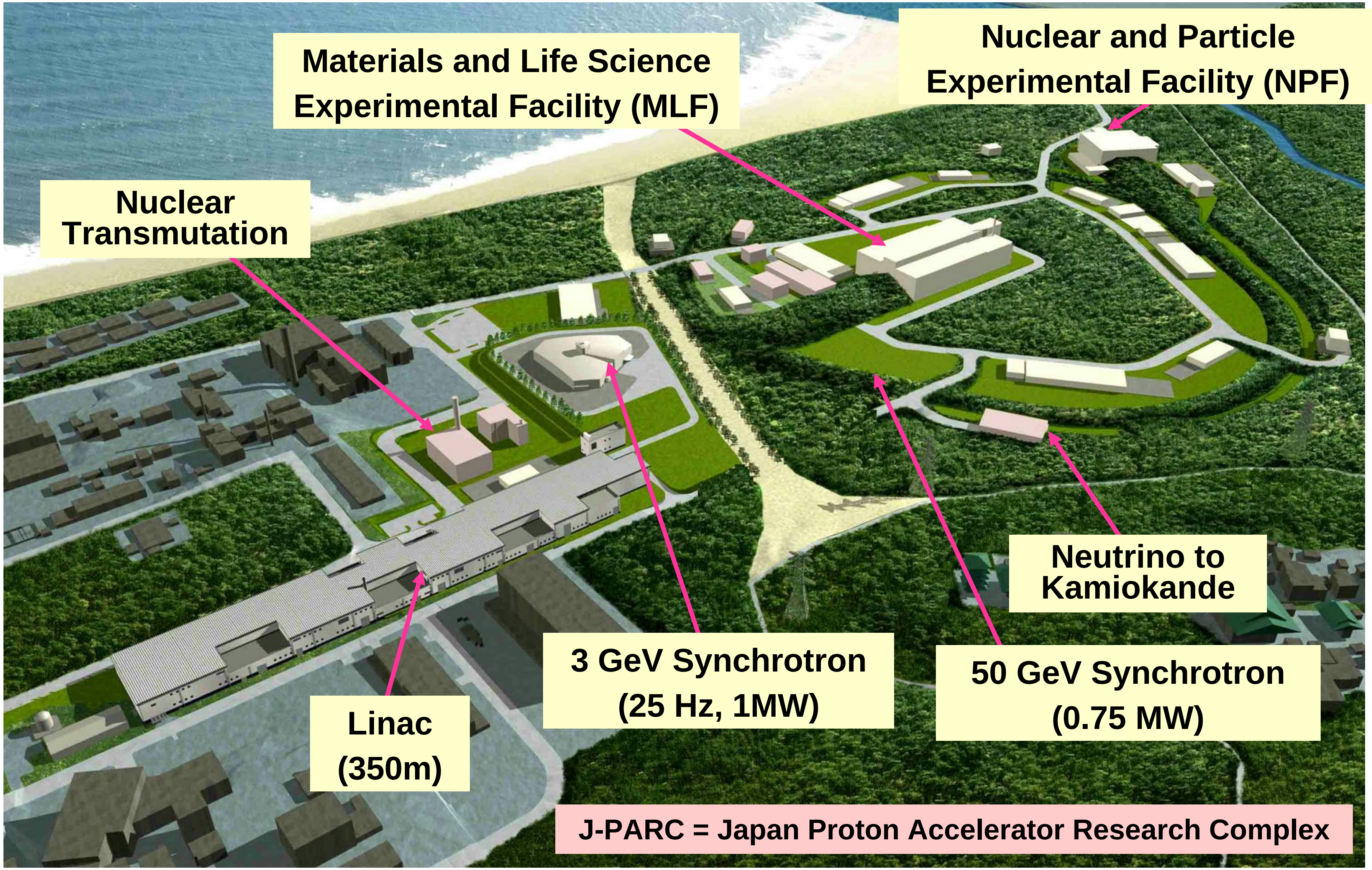
Asian Map

Introduction

Location of JAERI at Tokai



Introduction — *Site View of the Project*

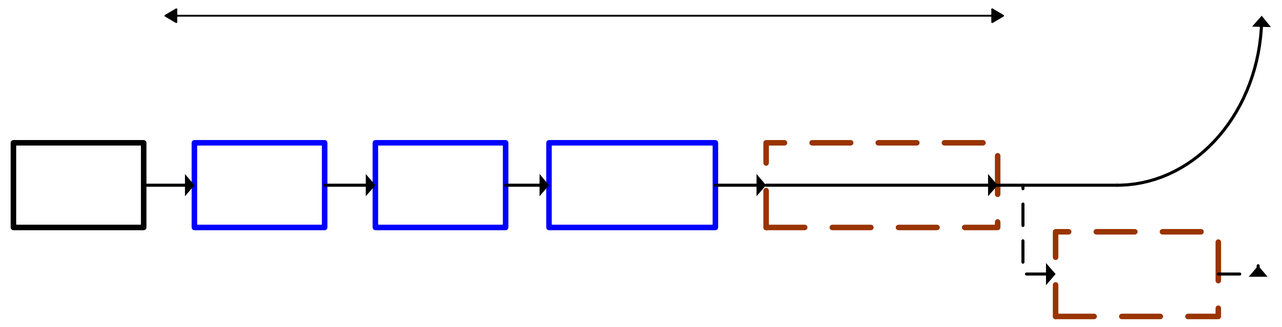


Intoduction Present Status of the J-PARC

Linac Scheme

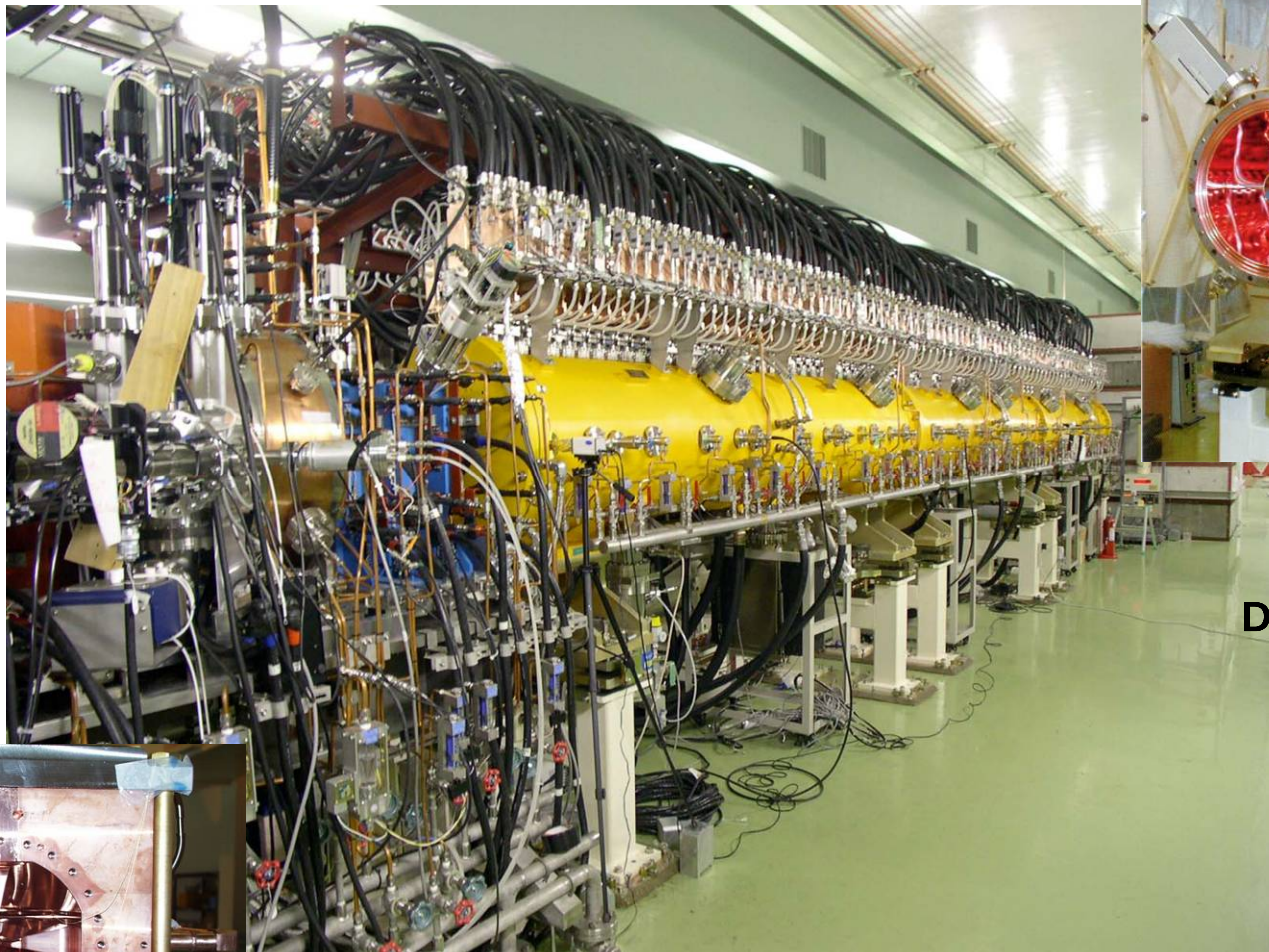
Linac Scheme

Accelerated particles:	**H^-**
Energy:	**181 MeV (400 MeV for ACS, 600 MeV for SCC)**
Peak current:	**30 mA (50 mA@ 400 MeV for 1MW at 3GeV)**
Repetition:	**25 Hz (additional 25 Hz for ADS application)**
Beam Pulse Length:	**500 μs**
Average Current:	**200 μA (333 μA @ 400 MeV for 1MW at 3GeV)**
	(Chopped to 53 %)



Block Diagram of the Linac

Initial Results *Drift-Tube Linac (DTL)*

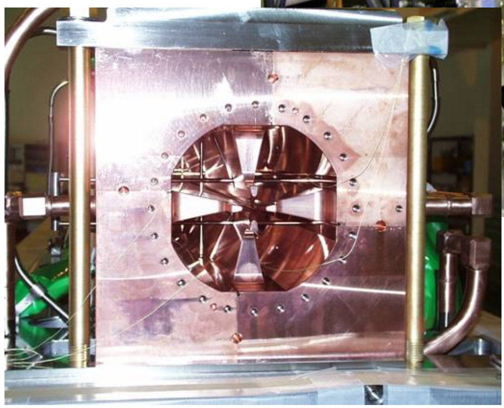


Inside of DTL

DTL by Mitsubishi

出力管

Klystrons by Toshiba
Power Supplies by Hitachi

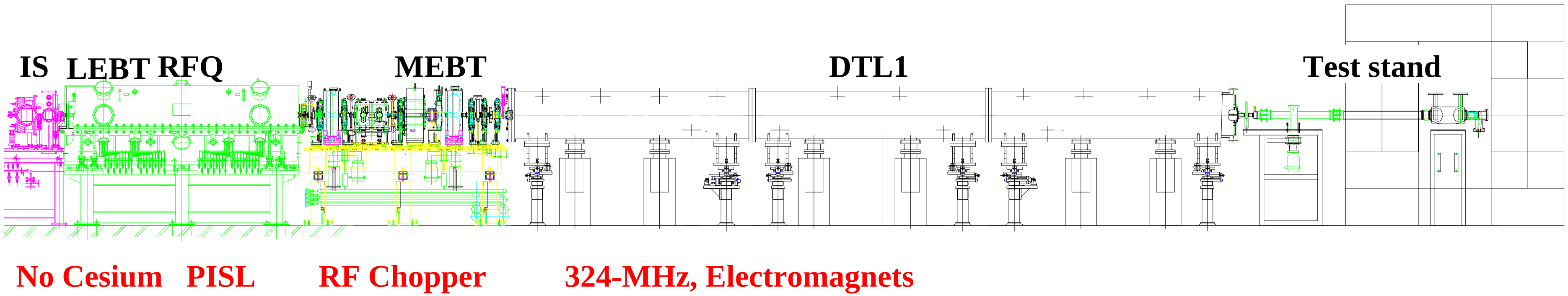


RFQ
by Hitachi and partly by Toshiba

Beam Test: 6 mA (20 MeV) on Oct. 30, 03
30 mA on Nov. 7, 03

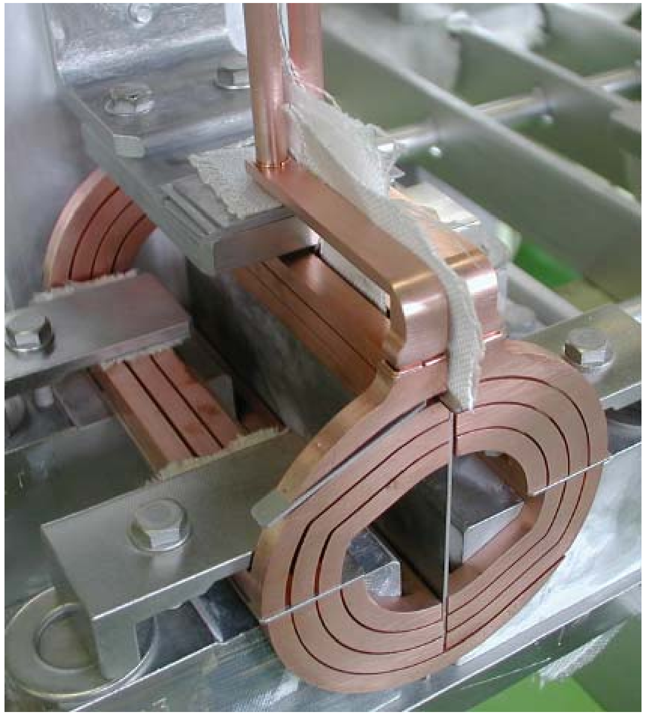
Initial Results *Overview of the experimental apparatus*

- **The first cavity DTL1 (19.7MeV) is under beam commissioning, among three DTL cavities (50MeV).**
- **DTL1: 76cells (77 Q-magnets)**
- **The beam test stand is located at the exit of the DTL1..**
- **Typical Beams: 5mA, 50μsec, 5 ~ 25Hz (monitor study)**
  30mA, 50μsec, 5Hz (DTL study)
  30mA, 250μsec, 25Hz (MEBT study)
  cf. J-PARC Linac phase1 requirement:
  30mA, 500μsec, 25Hz



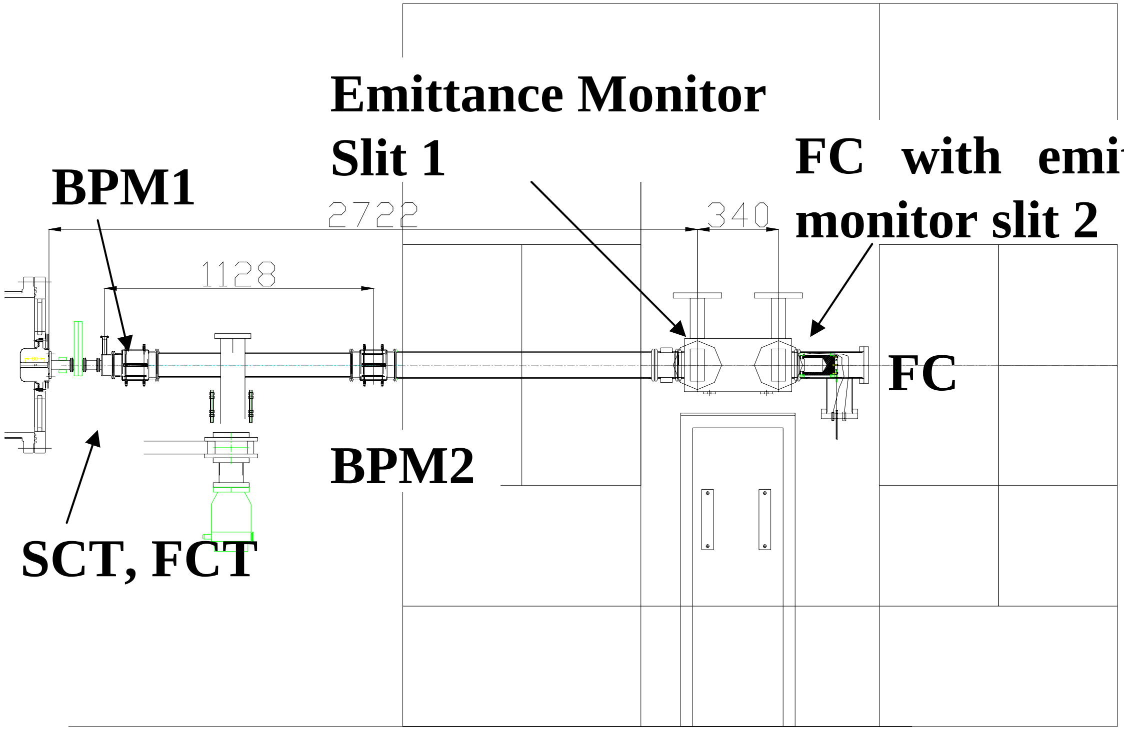
Coil of Electromagnet in 324-MHz Drift Tube

The coil is electroformed and wire-cutted.



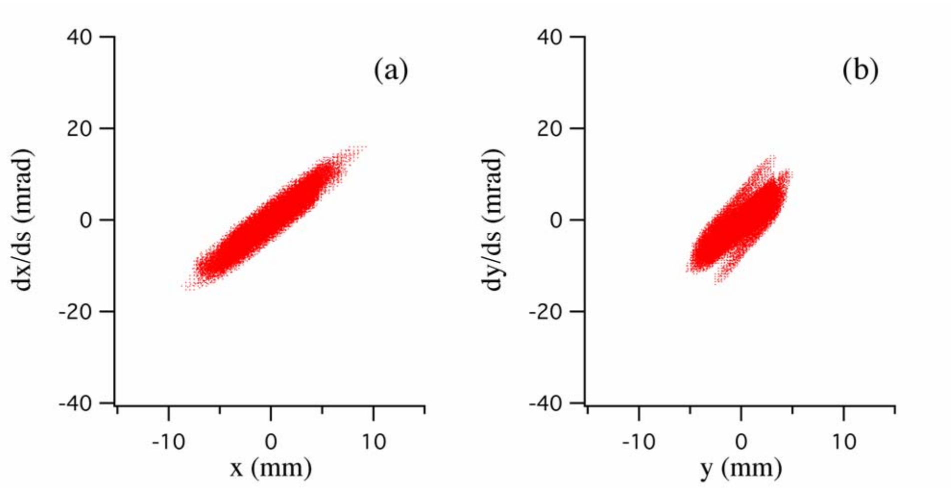
Initial Results — *DTL1 Test Stand*

- **The Slow Current Transformer (SCT) and Faraday Cup (FC) were used to measure the beam currents.**
- **The Time of Flight from the FCS and BPM2 was used to measure the beam energy.**
- **The BPM1 and BPM2 were used to measure the beam position and angle.**
- **The double slit type emittance monitor was used to measure the emittances.**

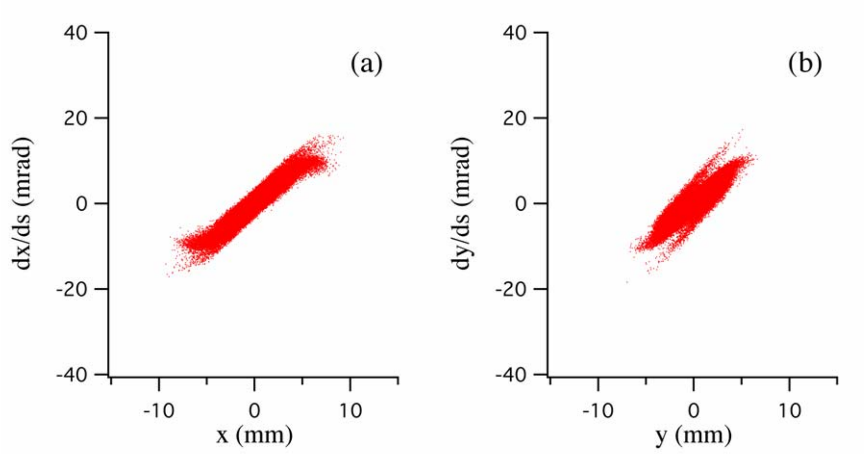


Linac Status *Emittance Comparison at MEBT*

Measured emittances

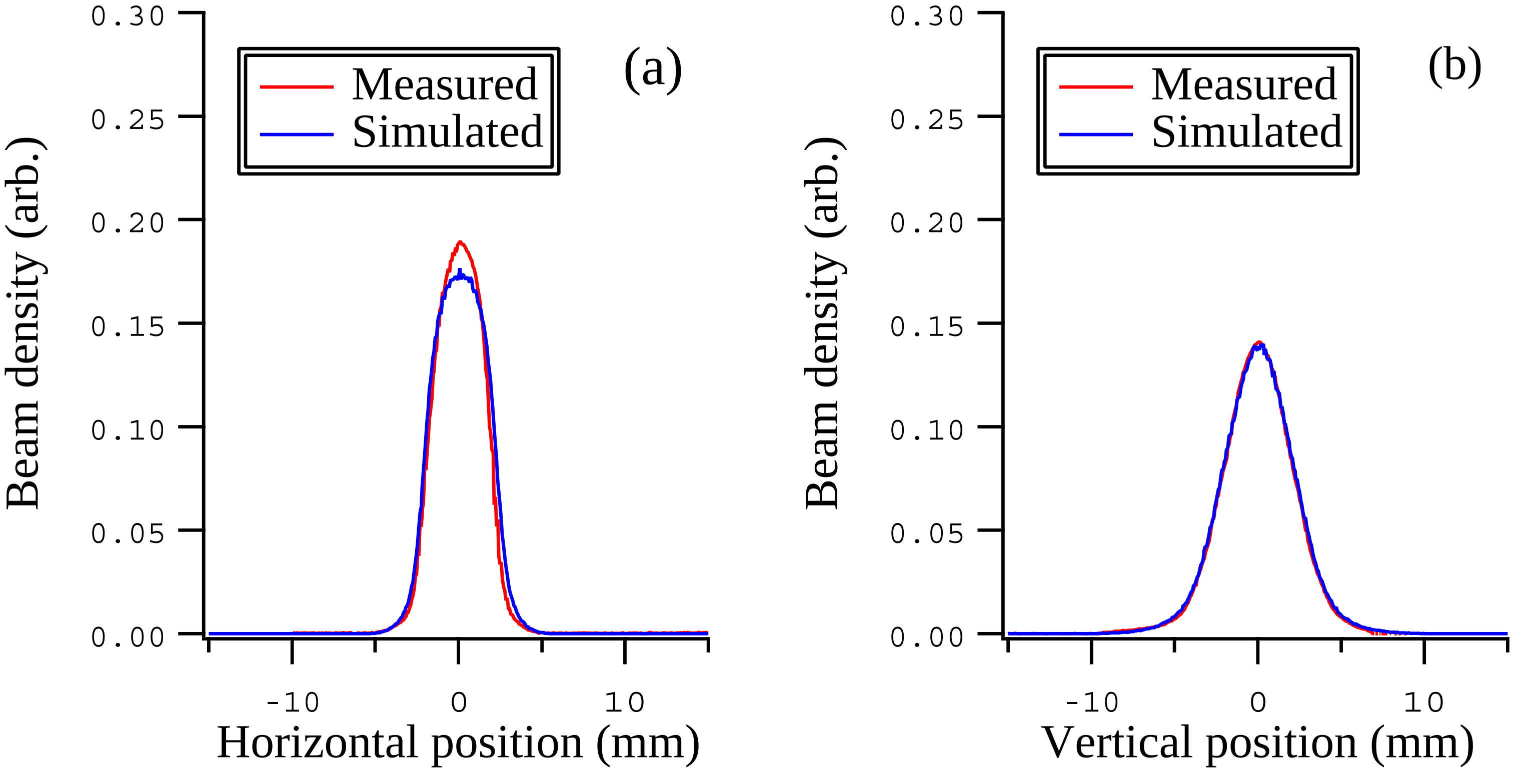


Simulation results
(IMPACT by LBNL)

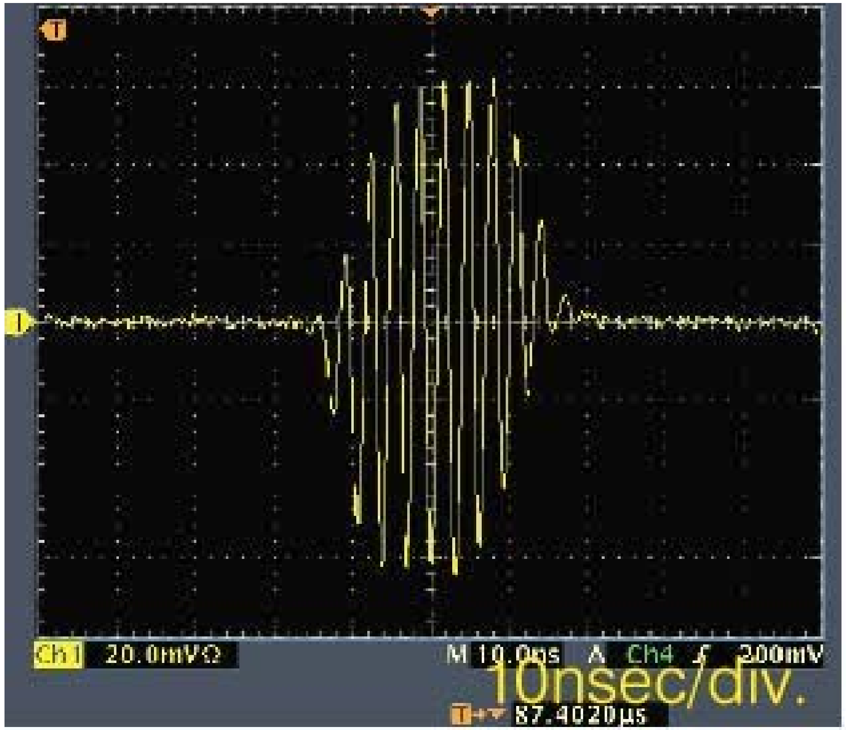


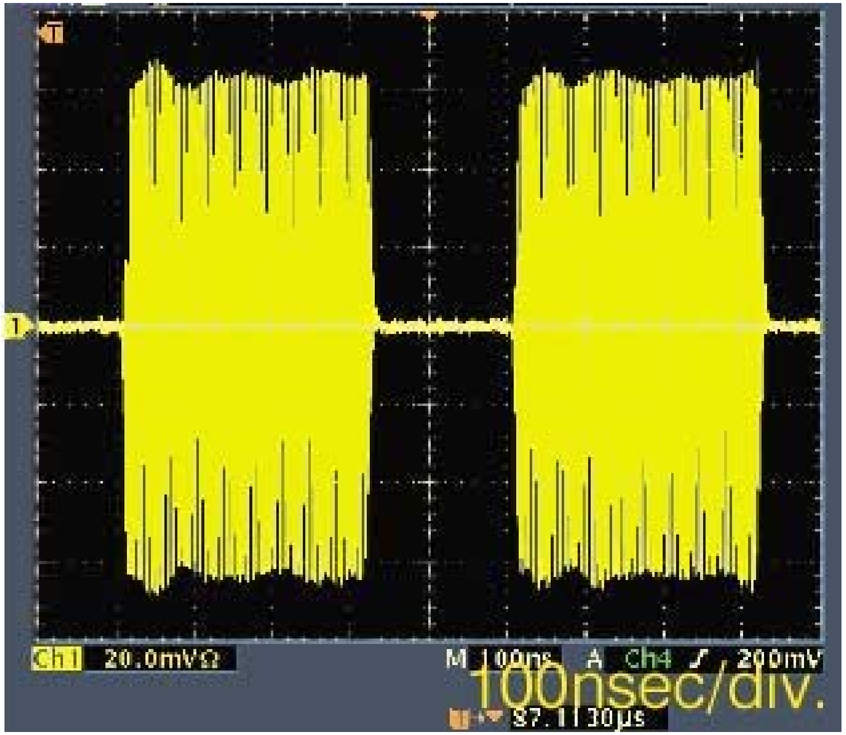
Linac Status

Profile Measurement and Simulation

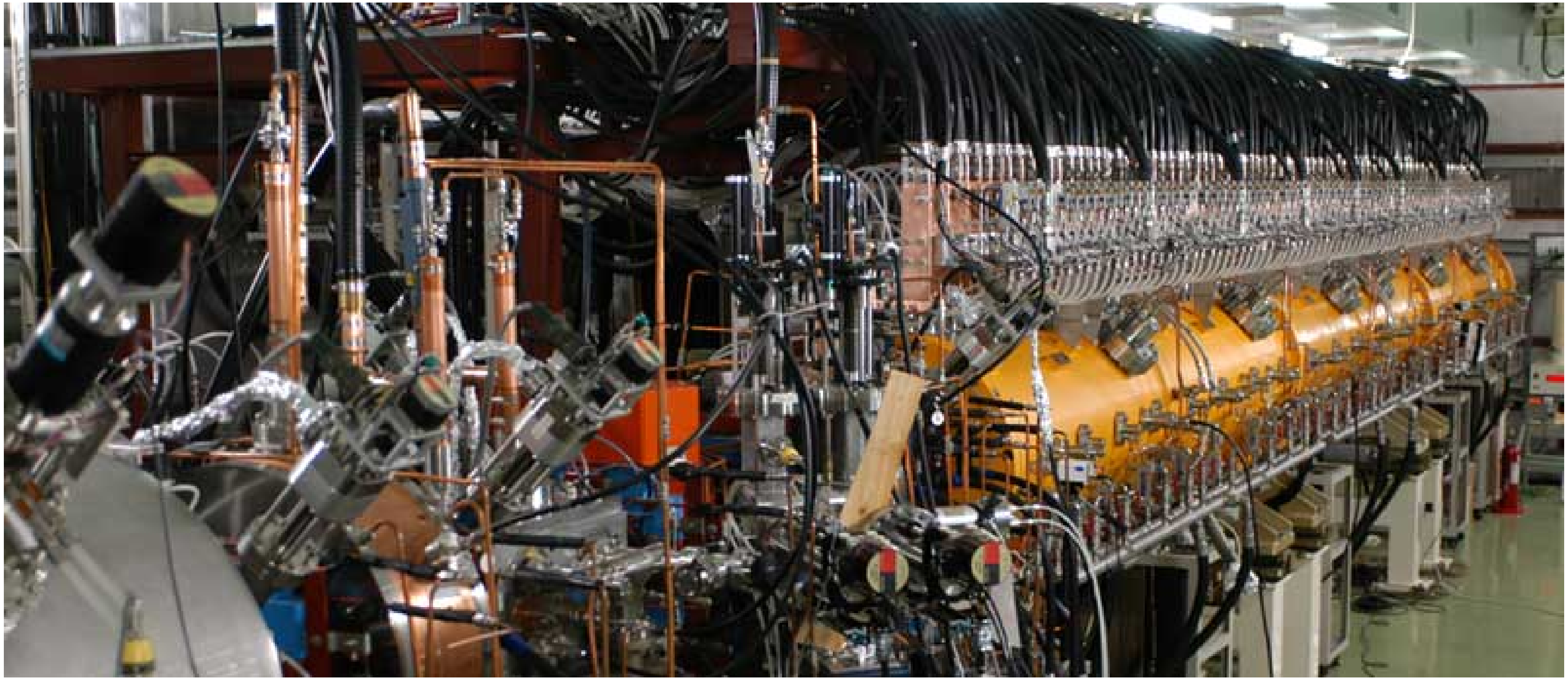


Initial Results   Wave Forms of Chopped Beam

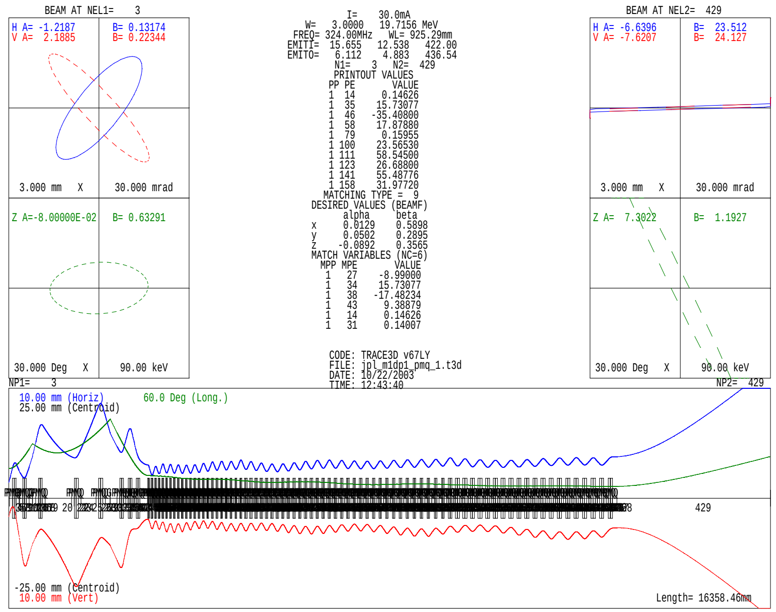


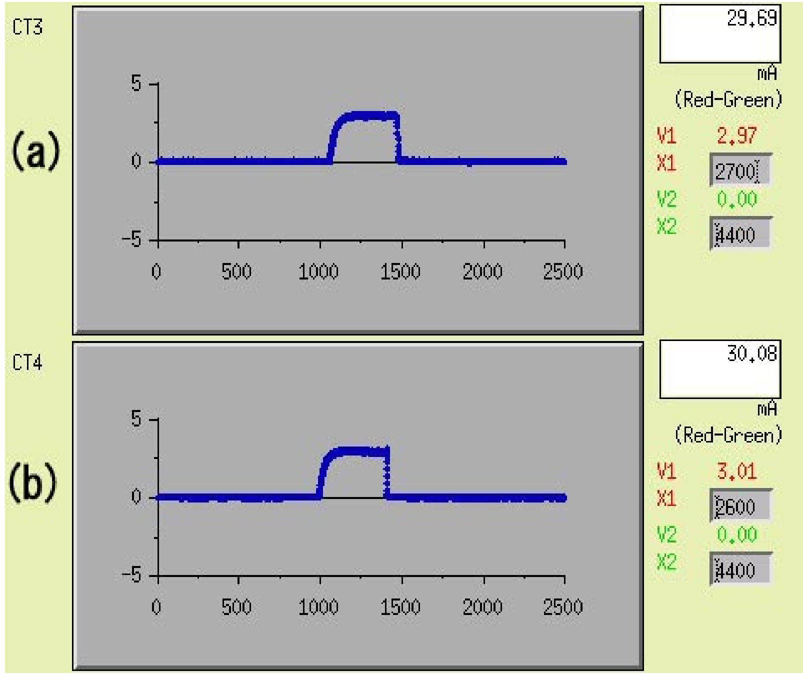


Initial Results *DTL1 under commissioning*



Linac Status TRACE3D Simulation and the Beam Test Results





Q magnet excitation currents in the MEBT(8) and in the DTL(77) are determined by the TRACE-3D estimation. All the Q magnets are excited in DC mode.
Beam transmission of 100%(a few % accuracy) has been successfully achieved with no adjustments of the Q magnet currents.

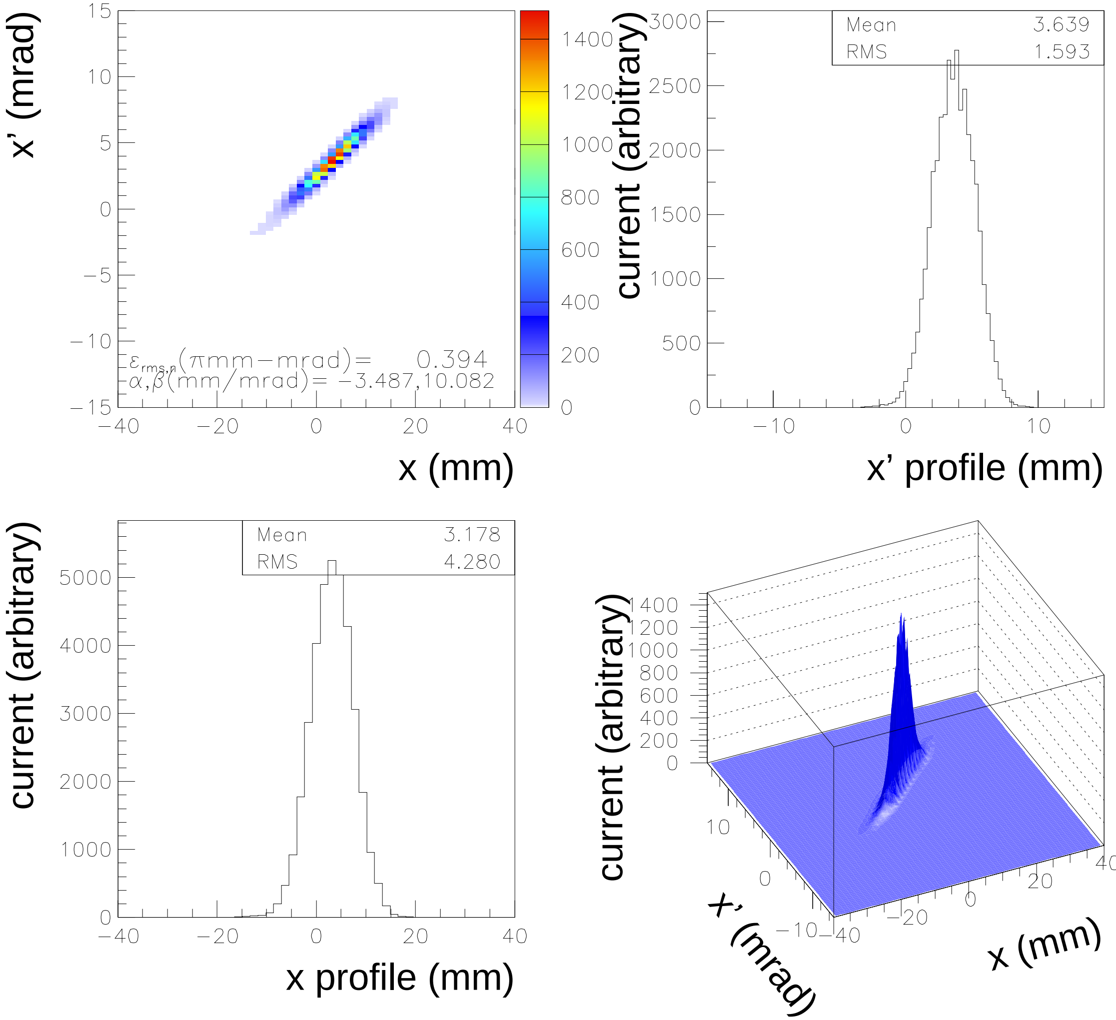
Waveforms at the entrance of the DTL(a) and at the exit of the DTL(b).

Beam Pulse length = 20μsec,

Repetition = 12.5Hz(duty 0.025%)

Initial Results *Emittance measurement (horizontal)*

horizontal emittance of DTL1



$\varepsilon = 0.39\pi mm \cdot mrad$

(normalized rms.)

design emittance:

$0.25\ \pi\ mm \cdot mrad$

(normalized rms.)

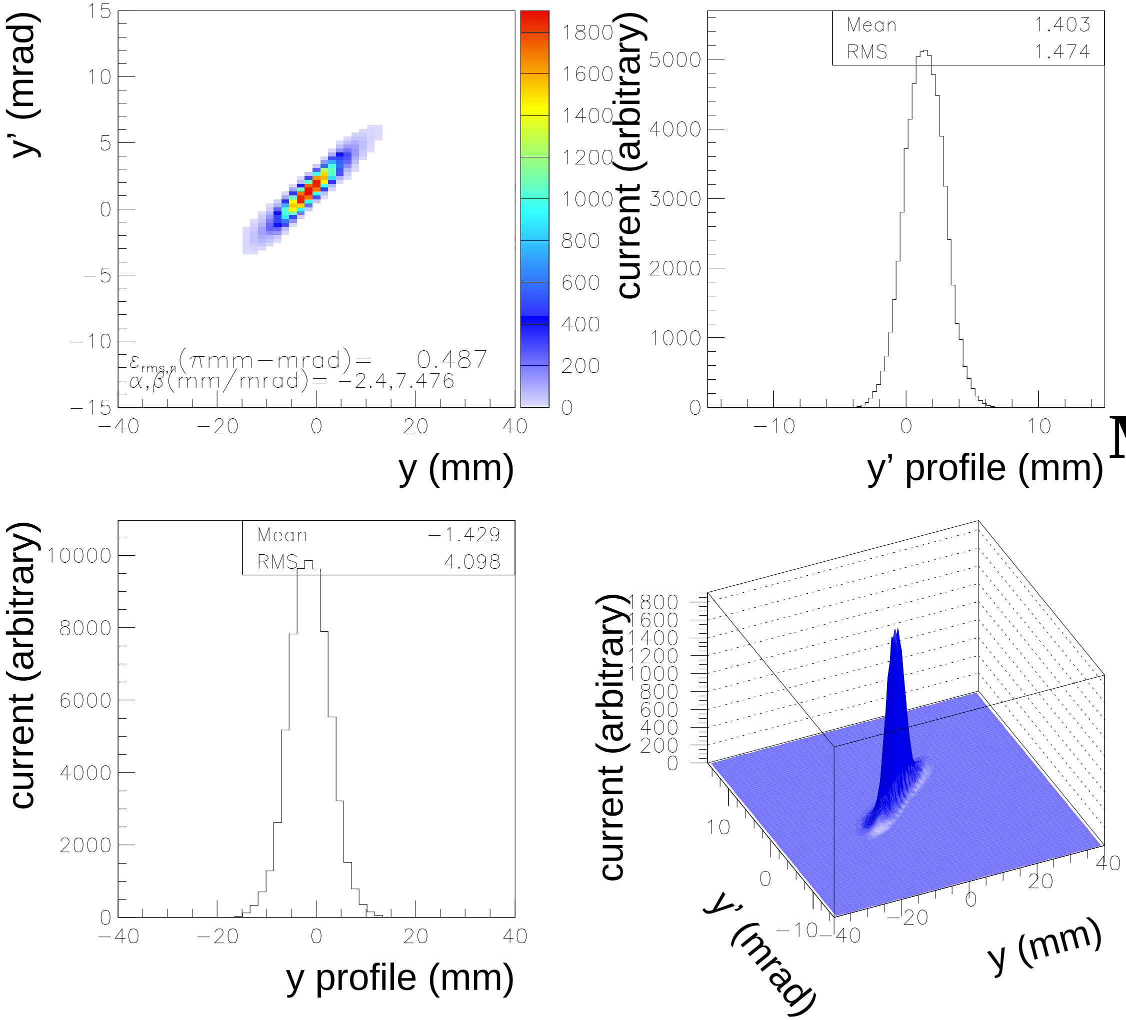
measured at MEBT exit:

$0.25\ \pi\ mm \cdot mrad$

(normalized rms.)

Initial Results *Emittance measurement (vertical)*

vertical emittance of DTL1



ε = 0.49 π mm·mrad

(normalized rms.)

Design emittance:

0.27 π mm·mrad

(normalized rms.)

Measured at MEBT exit:

0.21 π mm·mrad

(normalized rms.)

Initial Results *Summary of emittance measurements*

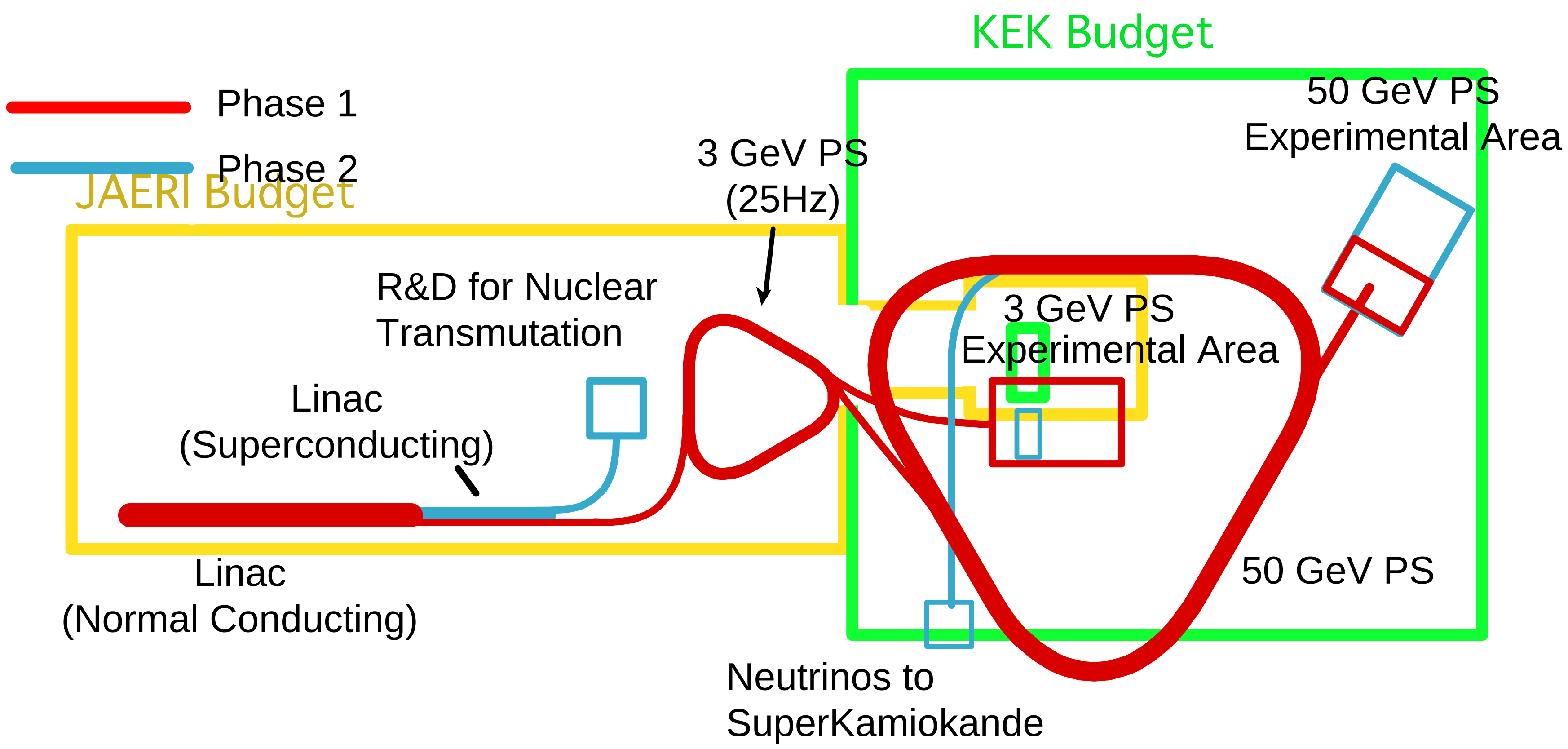
- **Measured and Calculated Emittances(normalized rms in π mm mrad)**

	Horizontal	Vertical
After MEBT[a)](Measured at 29 mA)	0.25	0.21
After DTL1(Measured at 30 mA)	0.39	0.49
After DTL1 (calculated)	0.25	0.27
After DTL1 (Measured at 5 mA)	0.26	0.37

a) This is in reasonable agreement with the simulation result by IMPACT.

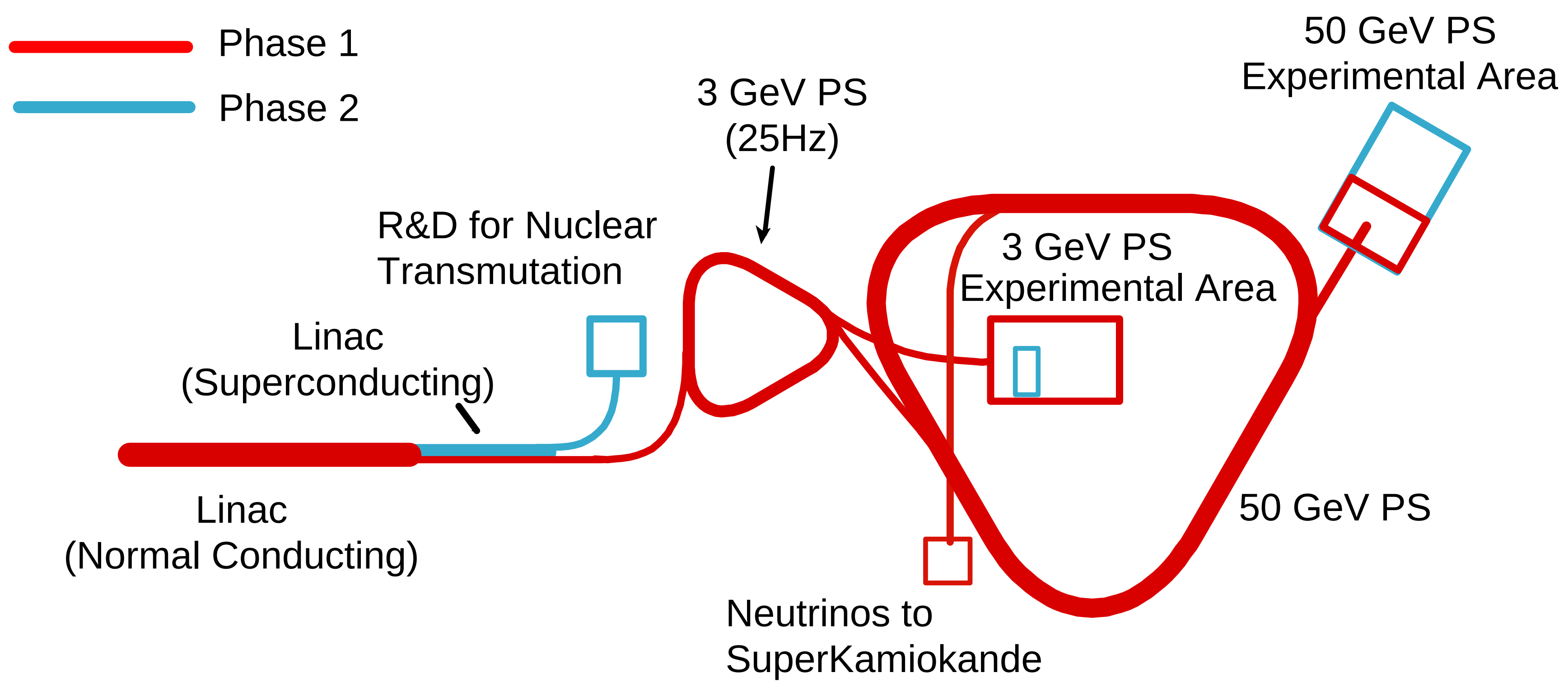
The speaker is allowed by his young colleagues to report the above data by adding a word "preliminary."

Project Status *Phase 1 and Phase 2 (as of 2001)*



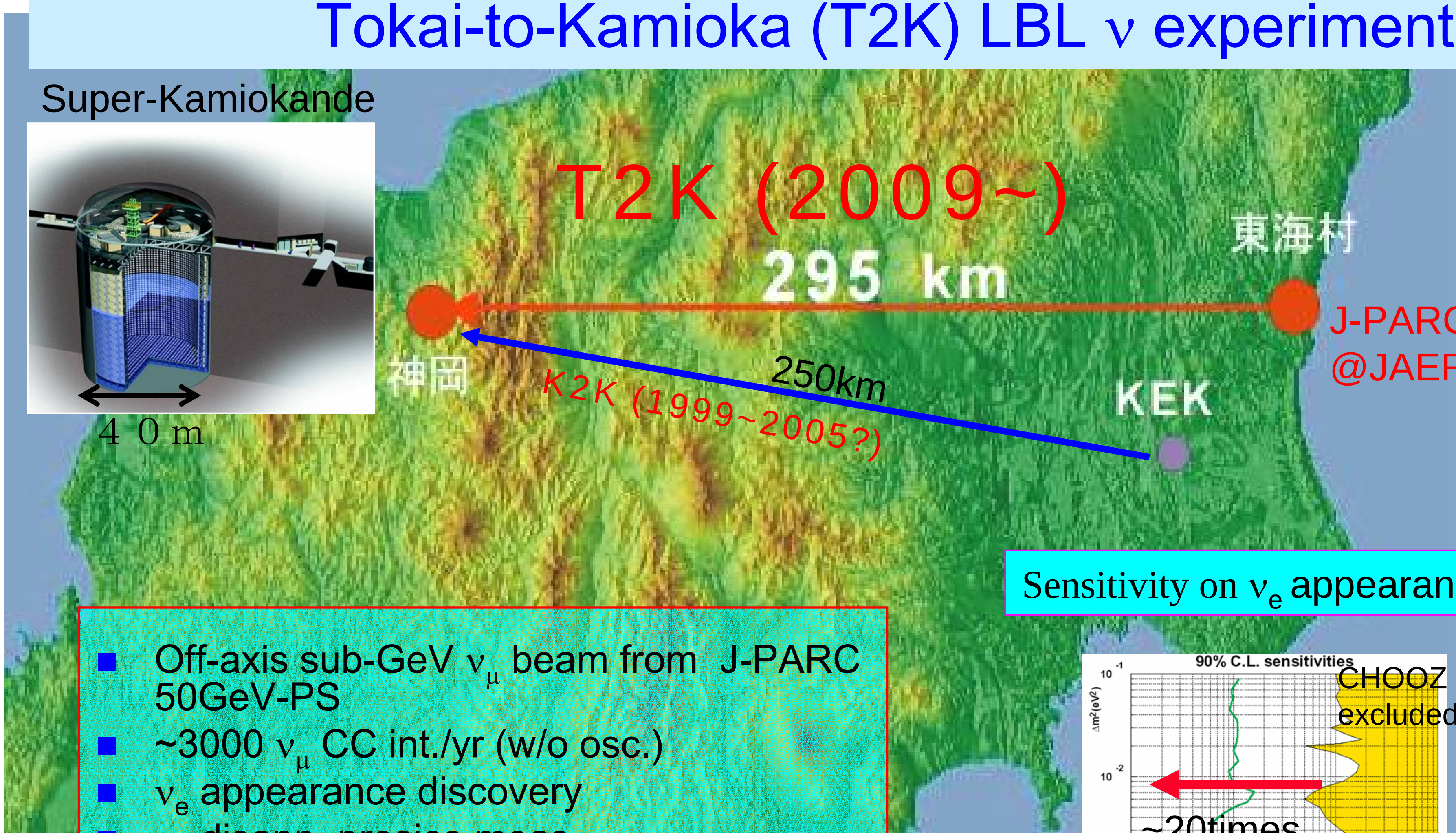
Project Status 1) *Phase 1 and Phase 2 (as of today)*

1) **The long-base line neutrino experiment project from J-PARC to Super Kamiokande (T2K) was approved for construction starting from April, 2004 to be completed by March, 2008.**



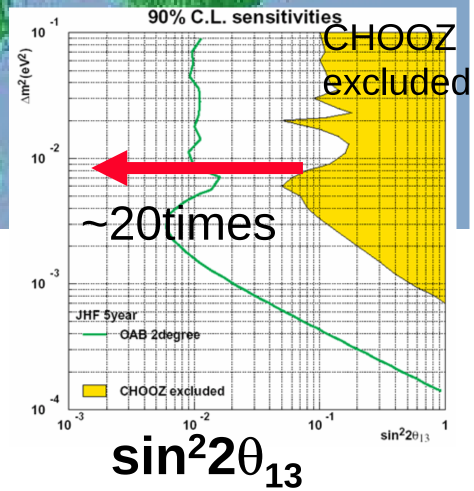
Project Status 1)

Neutrino physics at J-PARC
Tokai-to-Kamioka (T2K) LBL ν experiment



- Off-axis sub-GeV ν_μ beam from J-PARC 50GeV-PS
- ~3000 ν_μ CC int./yr (w/o osc.)
- ν_e appearance discovery
- ν_μ disapp. presice meas.
- 5 year const. Start exp. in 2009.

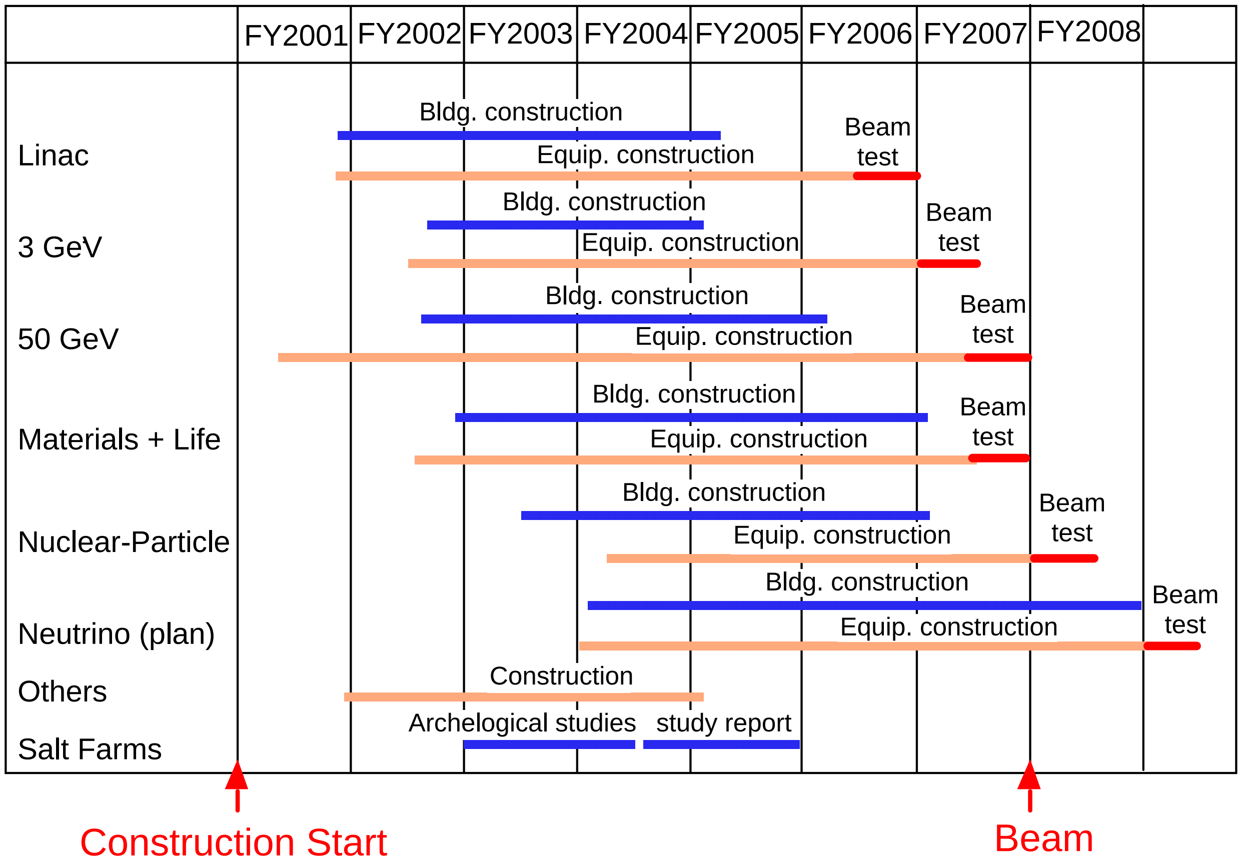
Sensitivity on ν_e appearance



Project Status 2) *Revised Construction Schedule*

2) The funding to the linac and the RCS was delayed by one year. The scheudule for the MR building had been delayed by more than one year for the archaeological investigation of the ancient salt pans. However, the delay in the beam commissioning schedule was managed to decrease to half a year.

Construction Schedule (as of Oct., 2003)



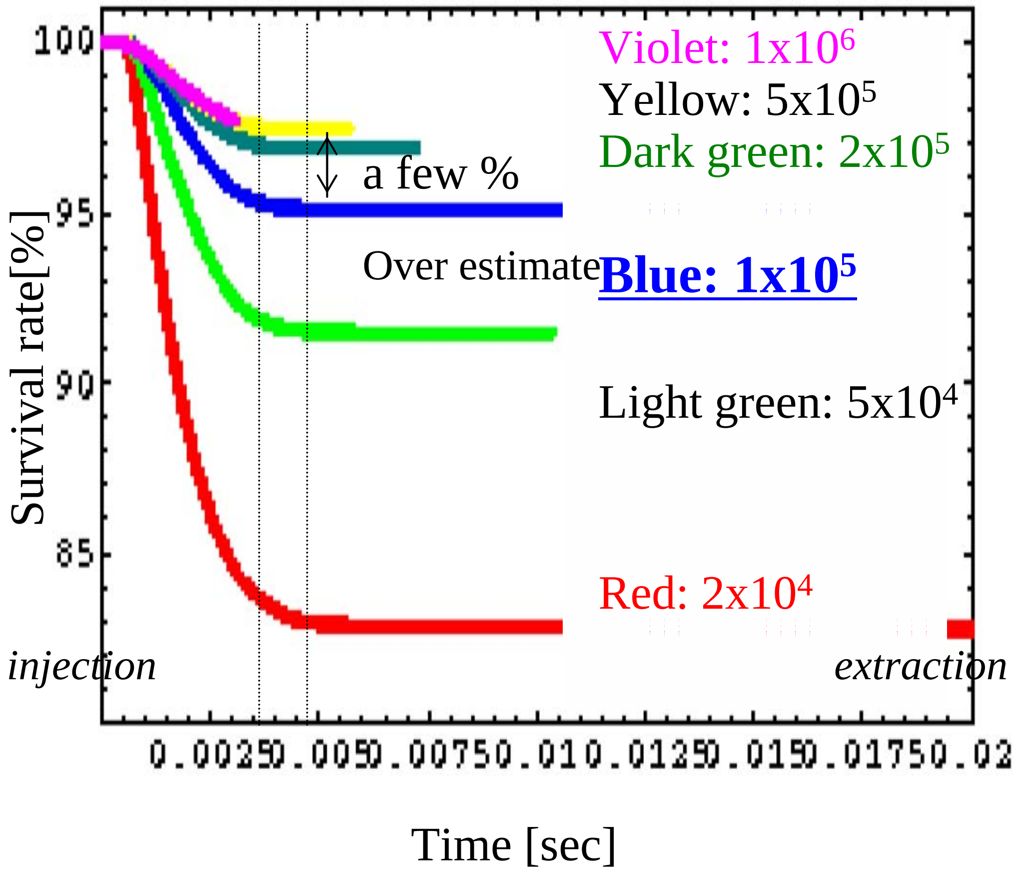
Project Status 3) *Linac Energy Decrease*

3) The linac energy was decreased from 400 MeV to 181 MeV in order to compensate the budget overflow in the linac and RCS. The RCS beam power is reduced from 1 MW to 0.6 MW by this.

The RCS collimation system can stand the 10 % beam loss at the 181 MeV injection for the 0.6-MW beam power.

The simulation results depend on the number of macro particles.

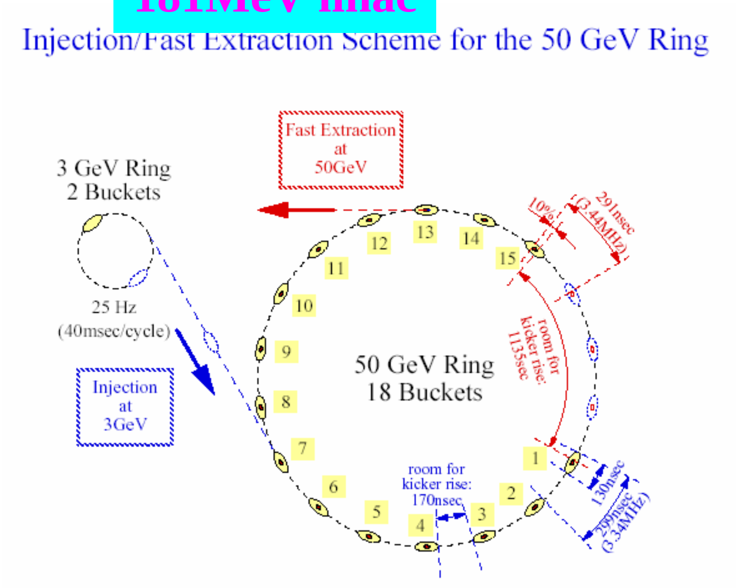
Injection energy :181MeV
Beam Power: 0.6MW at Ext.
No error,realistic aperture



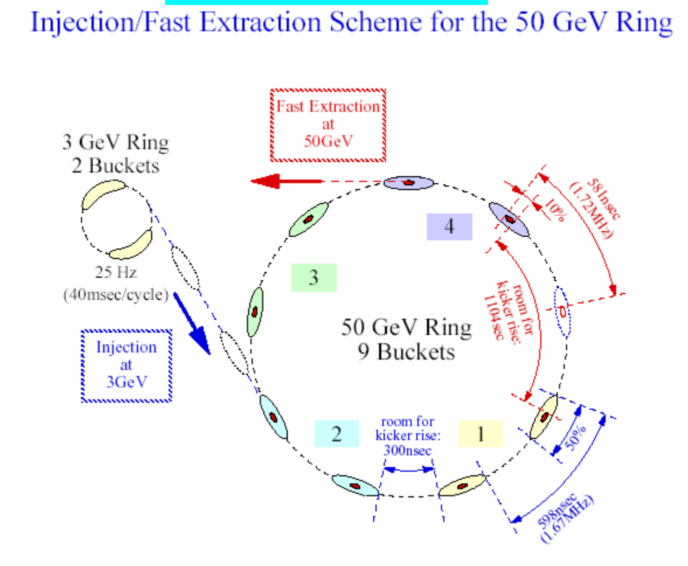
Project Status *Injection Scheme to the 50 GeV MR*

Although the RCS beam power is reduced from 1 MW to 0.6 MW, the beam power of the MR may be kept as original by increasing the time duration of the injection from the RCS to the MR.

181MeV linac

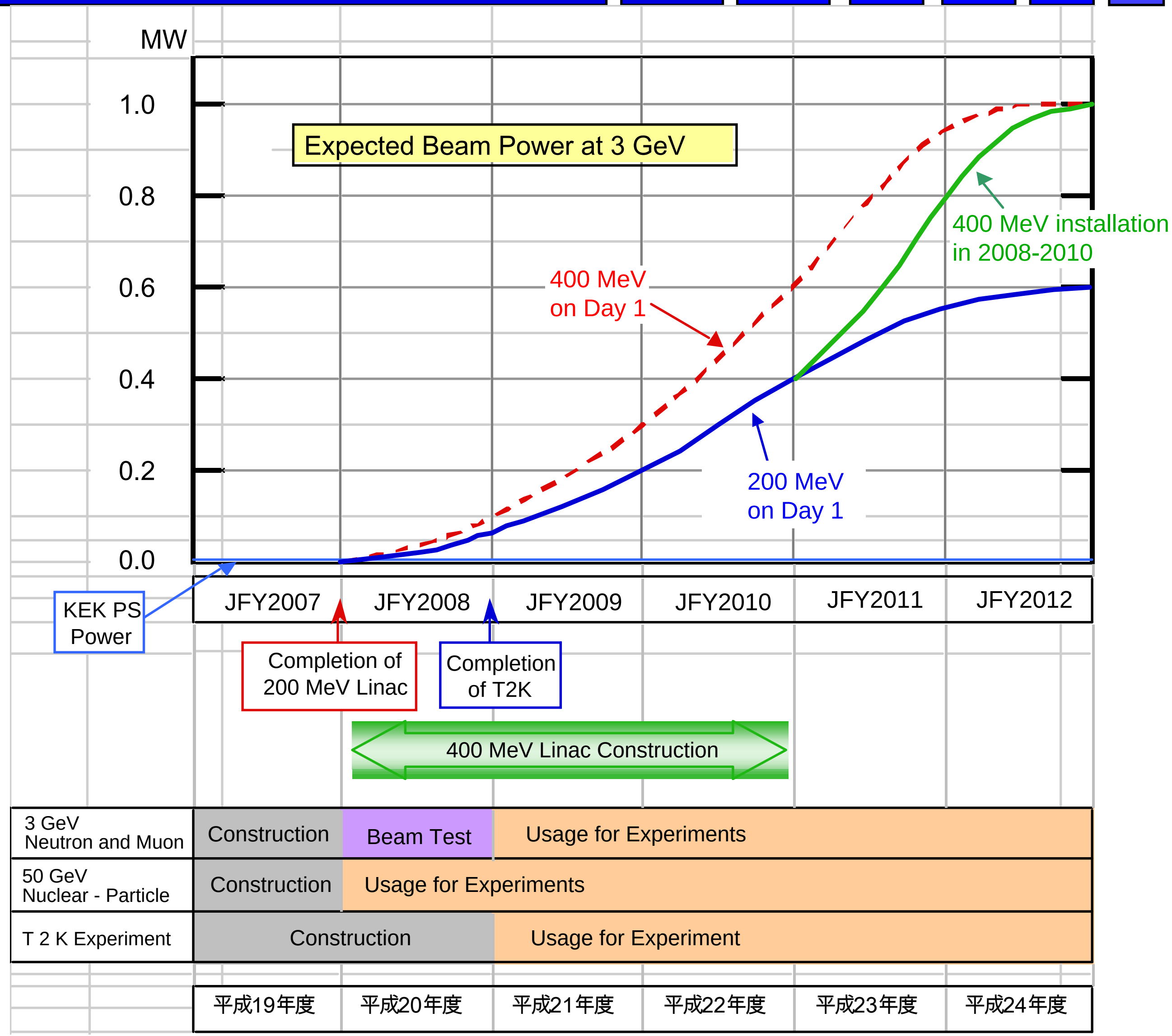


400MeV linac



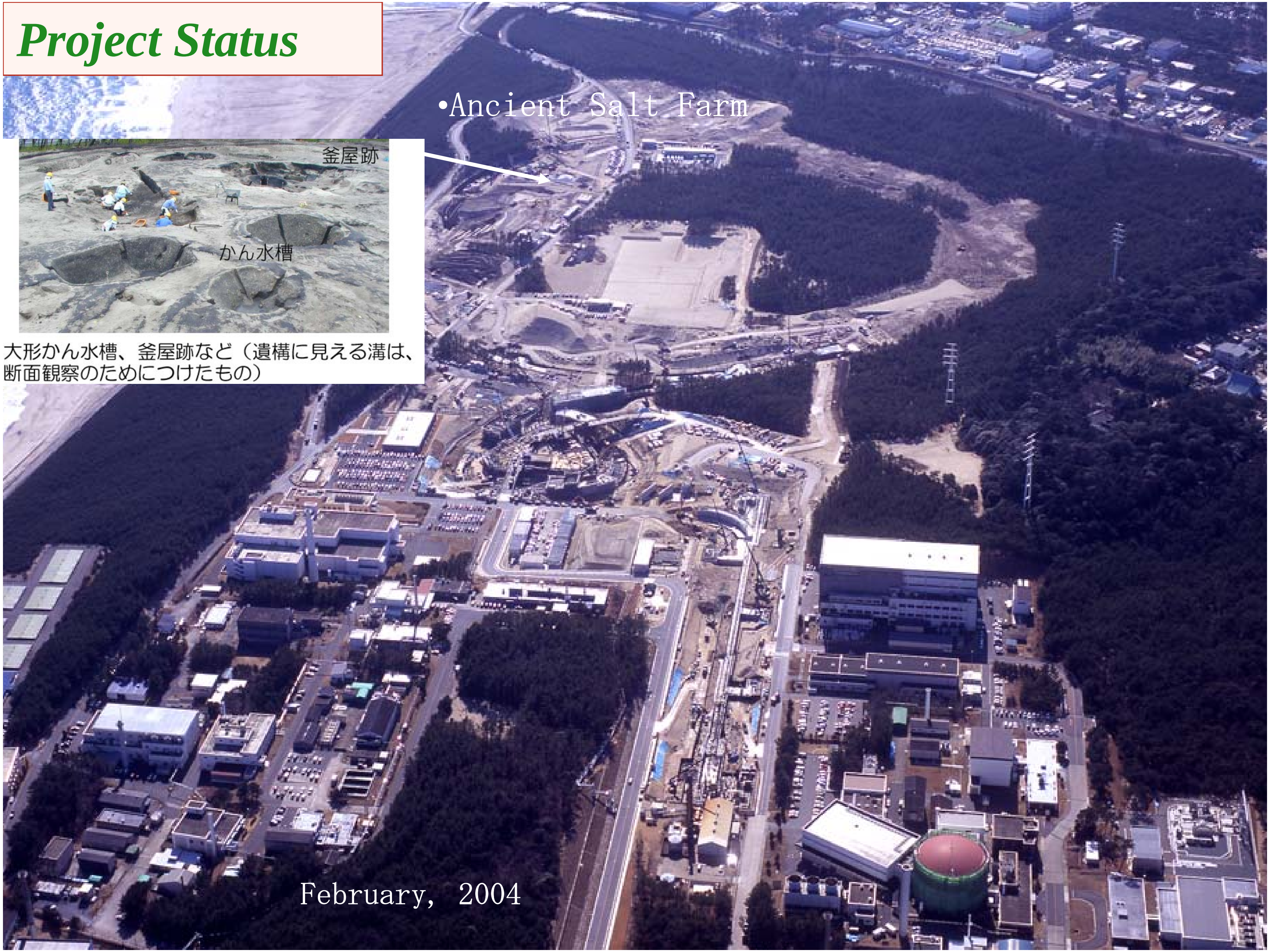
Injection time	**560ms**	**120ms**
RF frequency	**3.34-3.44**	**1.67-1.72 MHz**
Injection kicker flat top	**130ns**	**900ns :longer PFN cable**
Pulse bending magnet flat top	**600ms**	**120ms :only pattern change**
Injection kicker rise time	**170ns**	**<300ns :no change**

Project Status Expected Beam Power (not guaranteed)



Project Status

Project Status



大形かん水槽、釜屋跡など（遺構に見える溝は、断面観察のためにつけたもの）

Project Status

Project Status

Project Status

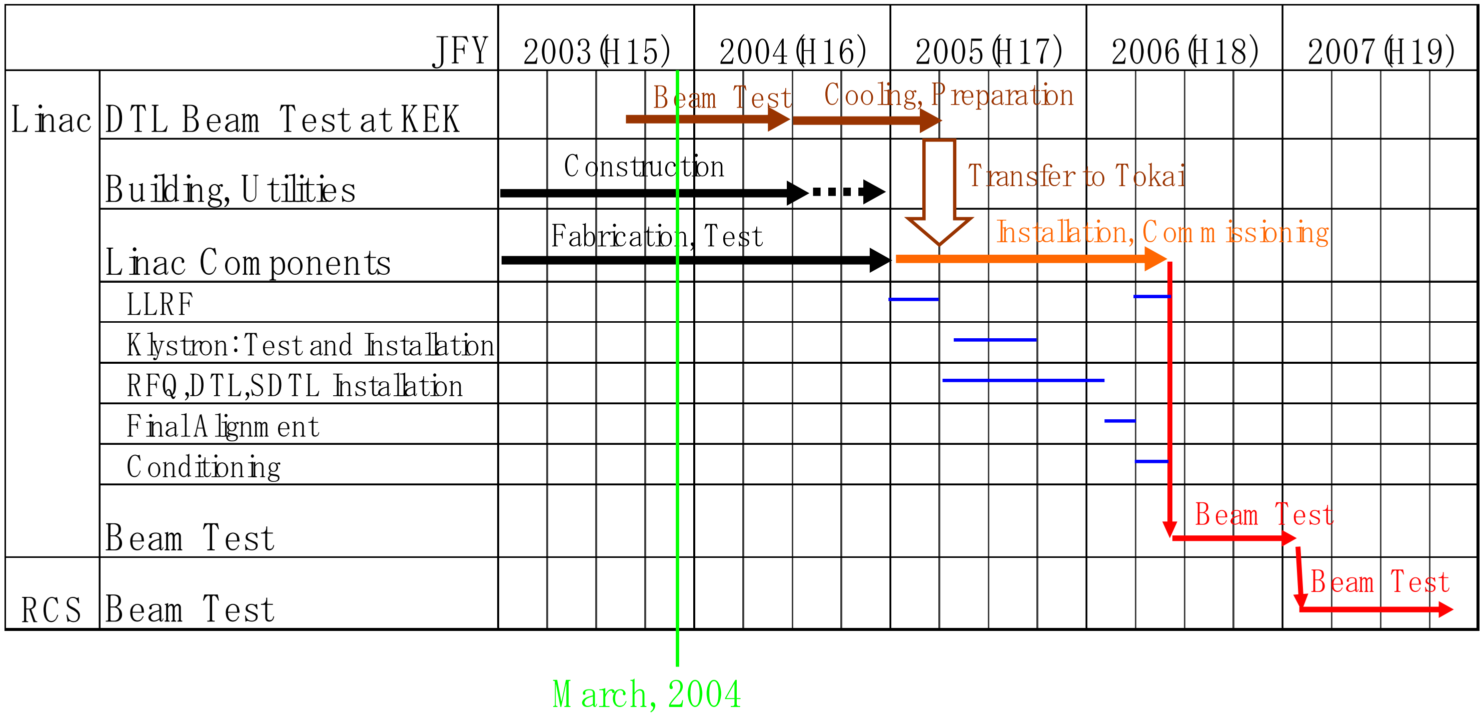
Linac Status

Schedule

The commissioning schedule will be 0.5 year behind the original schedule, although the budget profile will be extended by 1 year.

Key Dates

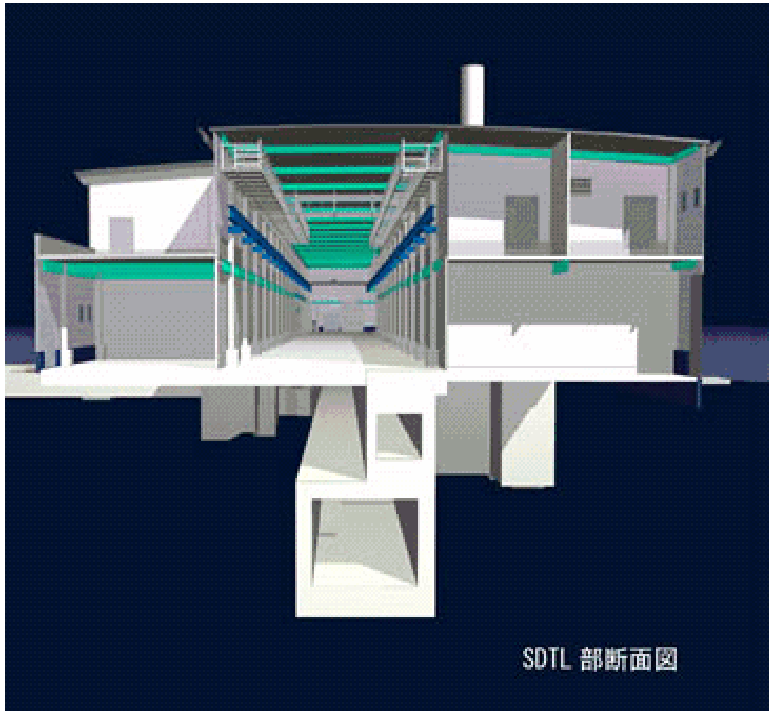
- April, 2005 Start installation for main components
- Sept., 2006 Start linac beam test
- May, 2007 Start RCS beam test



Linac Status

Linac Status

Linac Building



Cross sectional view at the SDTL part

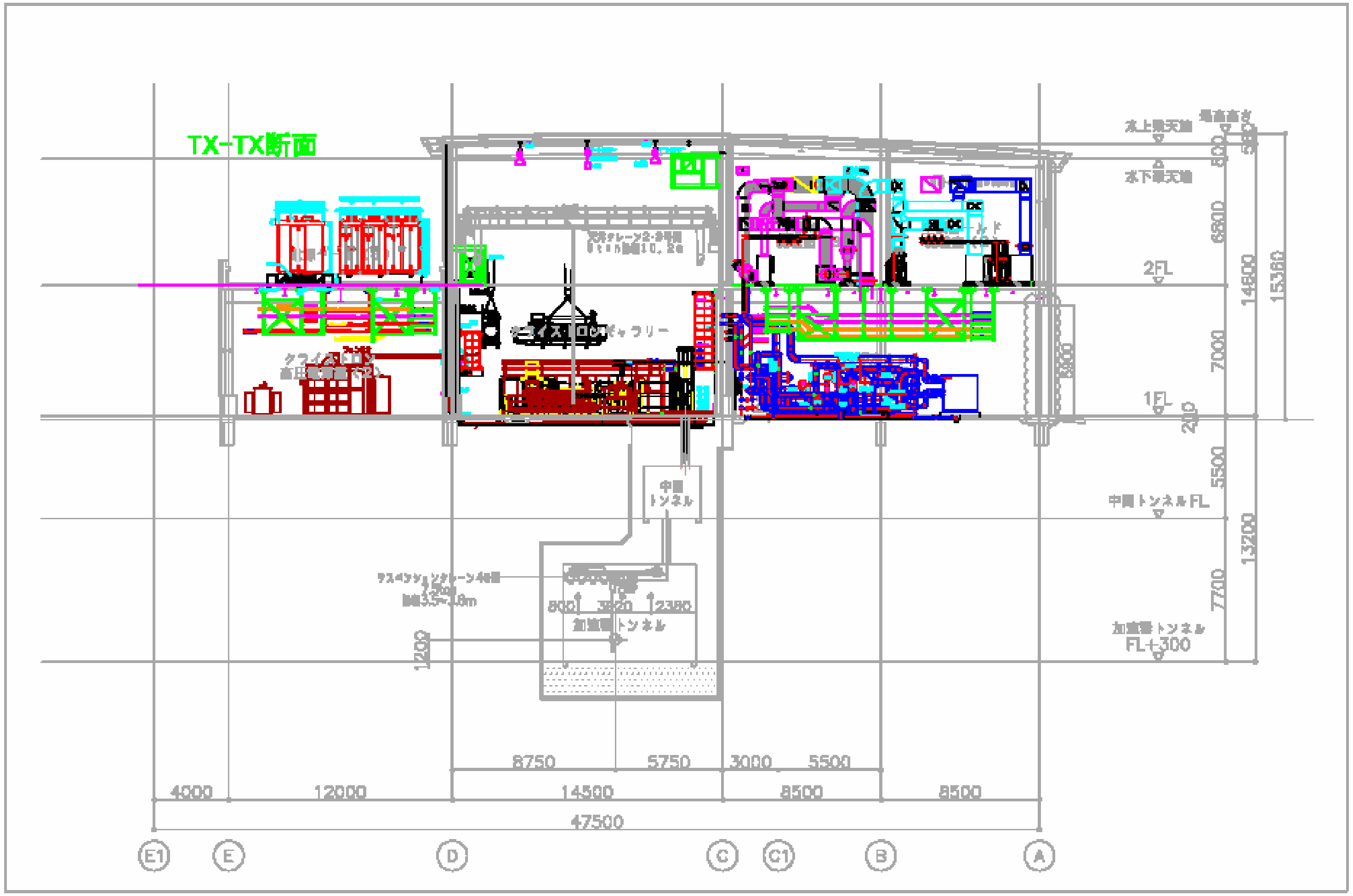
Linac tunnel (floor level -13.5m), sub- tunnel, klystron gallery, rooms for power supply and cooling water system.

Plan view of the linac building

（W:47.5m、L:330m、H:15.3m）

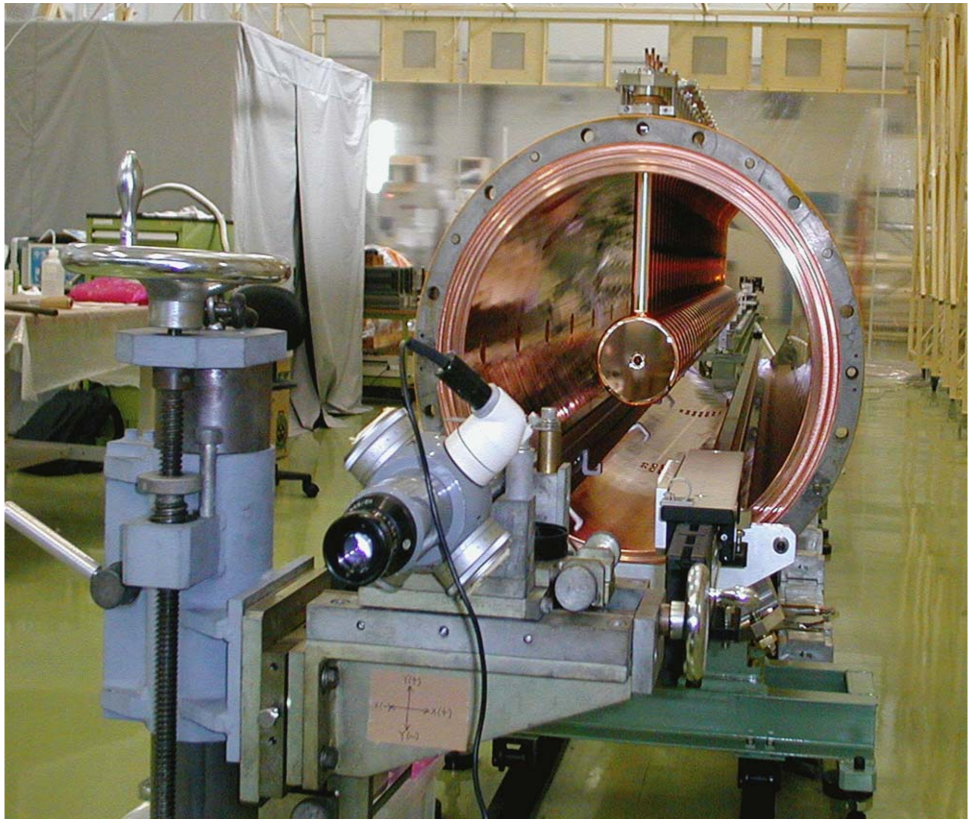
Linac Status

Cut-away View of the Linac Building



Status of the DTL#2,#3 Cavities

The tuning of the #2 cavity has been finished, while that of the #3 cavity is under way.



Installation of the drift tubes in the cavity.

Status of the SDTL Cavities

Fabrication of 22 cavities out of 32 has already been completed as planned. Fabrication will be finished by this October. The next major step is assembling.

Some of the cavities are stored at KEK.

Some cavities are under the electro-forming process.

The seven cavities have been assembled, while the three were power-tested.

Status of the Other Components

- ***RF Power Sources***

Among twenty klystrons for RFQ, DTL and SDTL's the sixteen have been assembled, while the seven were power-tested. All the twenty anode-modulators and the five cathode power supplies were ready.

- ***BT to RCS***

Most of the Beam Transport (BT) components from the linac to the RCS will be completed by March, 2005, while some will be finished one year later.

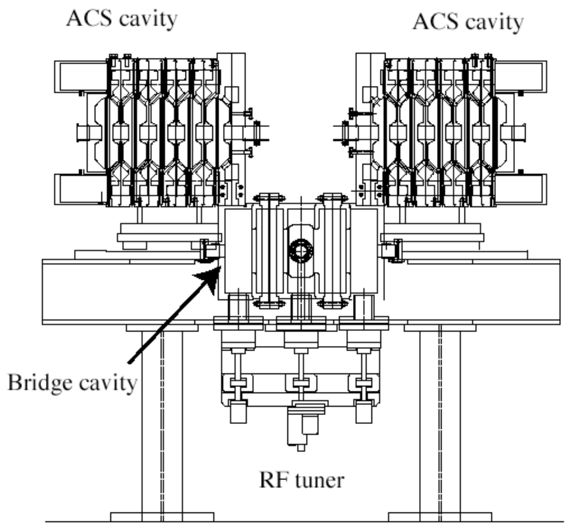
Future Upgrade Plan

The future upgrade plans are divided into three categories.

1) **Linac energy recovery, which will start immediately after the Phase I completion.**
2) **The Phase II of the J-PARC project, which has been already agreed between the two institutes.**
3) **The facilities proposed by the J-PARC users as extensions of the present J-PARC facilities.**

1) Linac Energy Recovery ACS

- The Annular-ring Coupled Structure is geometrically an axial symmetric version of the Side-Coupled Strucutre (SCS).
- The two ACS cavities are already under construction.
- The two ACS bunchers are also under production for the beam transport from the 190-MeV SDTL to the ACS.
- The three klystrons have been ordered, while the two is under power test.
- The ACS first appeared in famous Andreev's paper[1972] had been long useless for its Q degradation, although its advantage regarding the axial symmetry has been realized. The 1300-MHz ACS was developed for JHP in KEK, with deep insight to the RF characteristics of the structure. The prototype of the ACS with two five-cell cavities bridged by a five-cell bridge coupler was first power-tested up to more than designed field with a pulse length of 600 μs and a repetition of 50 Hz [1990]. Afterwards a few ACS cavities were fabricated and power-tested with different β values and different coupling slots.
- After the J-PARC project started, the new 972-MHz ACS cavity was developed in order to keep the same size as that of 1300-MHz ACS in close collaboration with Institute for Nuclear Research (INR), Moscow, and Tokyo Institute of Technology. One disadvantage of the ACS cavity is its big size, since the ACS can be formed by rotating the side-coupled structure around the beam axis, geometrically speaking. This disadvantage is partly compensated by this new structure. The present version of the ACS is the one thus developed.



1) Linac Energy Recovery   Setting up to measure the Frequency of ACS

1)

3)

2)

4)

1) Linac Energy Recovery Schedule Proposed

	LINAC 400 MeV Recovery Schedule			2003.2.18	
	The First Year	The 2-nd Year	The 3-rd Year	The 4-th Year	The 5-th Year
Shut Down	July,Aug.	July-Sept.	July-Sept.	July-Sept.	July-Dec.
Operation	Scheduled Operation				400MeV Commissioning
Electricity		Distribution Step up			Sep.-Dec.
		Wiring			
Cooling Water	Step up Work	Test Run			
Control		Device Control Program			
			Wirig		
		Commissioning Program			
ACS Assembly	Test Area Set up				
	RF System Set up				
	ACS Cavity Production				
		ACS Cavity Assembly ,High Power Test			
		ACS+Q-Mag Assembly, Alignment			
	Q-Mag,Beam Monitor Production and Test				
Kly.PS		Set up			
		Wiring			
RF System	Production				
			Set up ,Test		
		ACS System Test, Tuning (Occasional)			
			Beam Acceleration Test (If Possible)		
Tunnel	WG Set up	Wiring,Piping	Wiring,Piping	Wiring,Piping	
		ACS Installation	ACS Installation	ACS Installation	RFQ,Debuncher Replace
		Buncher(MEBT2) Installation			RF System Tuning
					LINAC Commissioning
					3GeVCommissioning

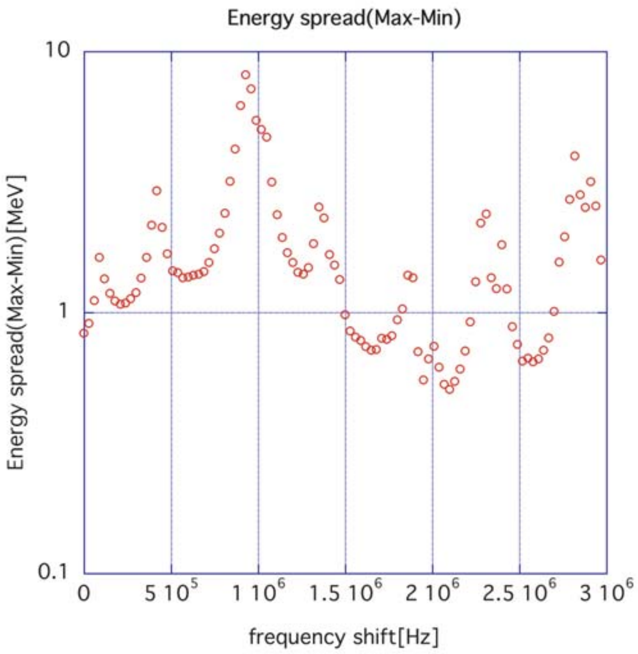
1) Linac Energy Recovery *Problems in Scenario*

Energy spread of the beam, passing through the idle detuned accelerating structure (without transient effects)

Energy spread is <u>0.615 MeV</u> at 2.04MeV detuned, while it should be less than 0.4 MeV.

We have to give up the installation of the 200-400 MeV high-energy structures on beam line, detuned and being idle. .

The structures should be installed to the beam line, followed by the beam commissioning.



This will increase the peiod of the beam shut down in the final year by one month or more.

Future Upgrade Plan 2, 3) *Two Types of Letters of Intent (LoI’s)*

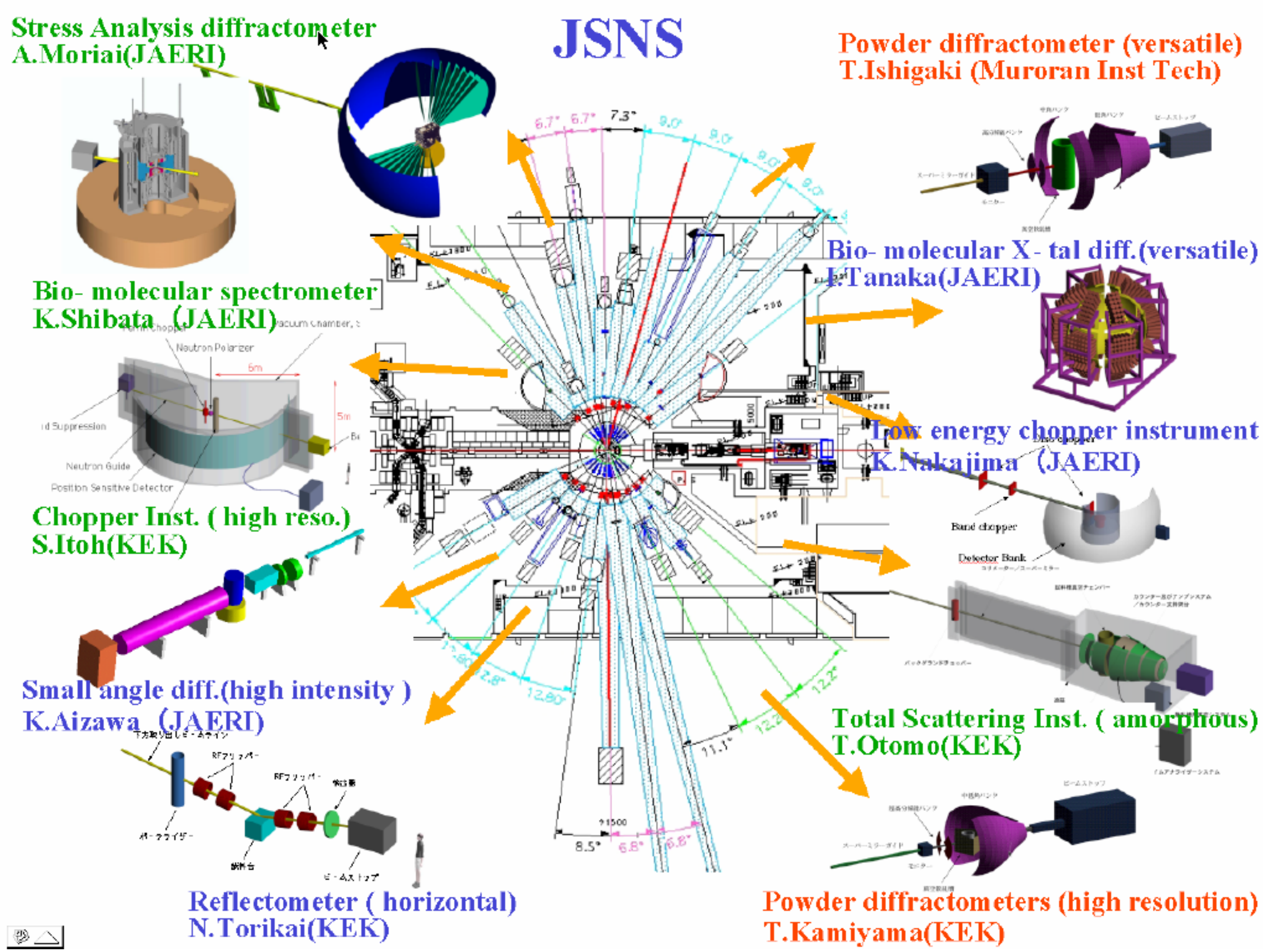
Neutron Scatterings

- Call for LoI’s: Once a year.
- Fall of 2002: Accepted 18 LoI’s.
- Recommended 9 LoI’s into the next detailed proposals.
- Additional LoI’s came in.
- Approved LoI’s need to proceed into the funding request.

Nuclear Particle Experiments

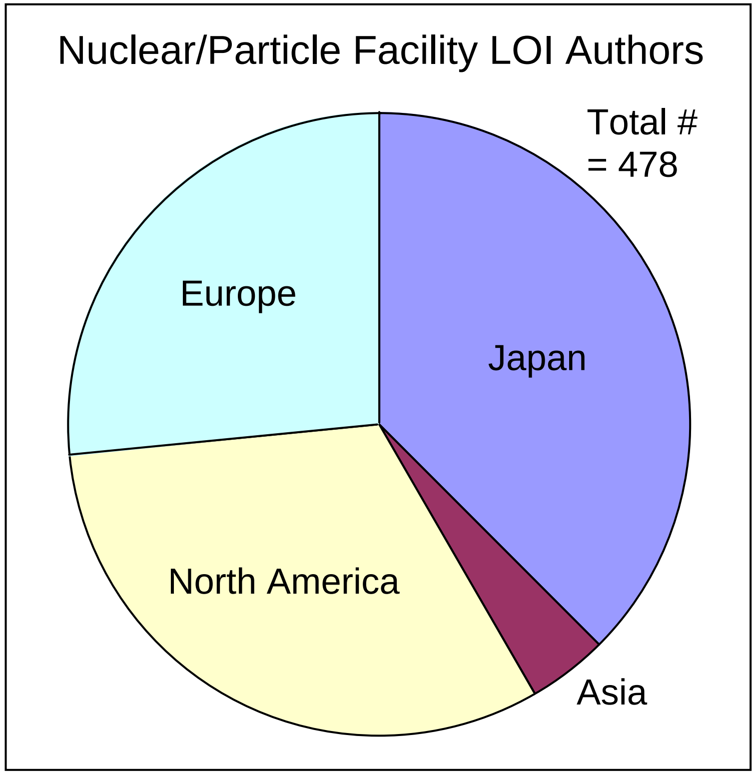
- Call for LoI’s: June, 2002.
- Early 2003: Accepted 30 LoI’s.
- Committee for Nuclear and Particle Experimental Facilities
  - Three meetings: March & June, 2003 + February, 2004.
- Discussions on ν experiment, Day-1 experiments with K-beams, Phase-1 experiments, and Phase 2+ experiments.
- Need on redesign of experimental area, etc. to allow high priority experiments.

Future Upgrade Plan 2) *23 neutron beam lines*

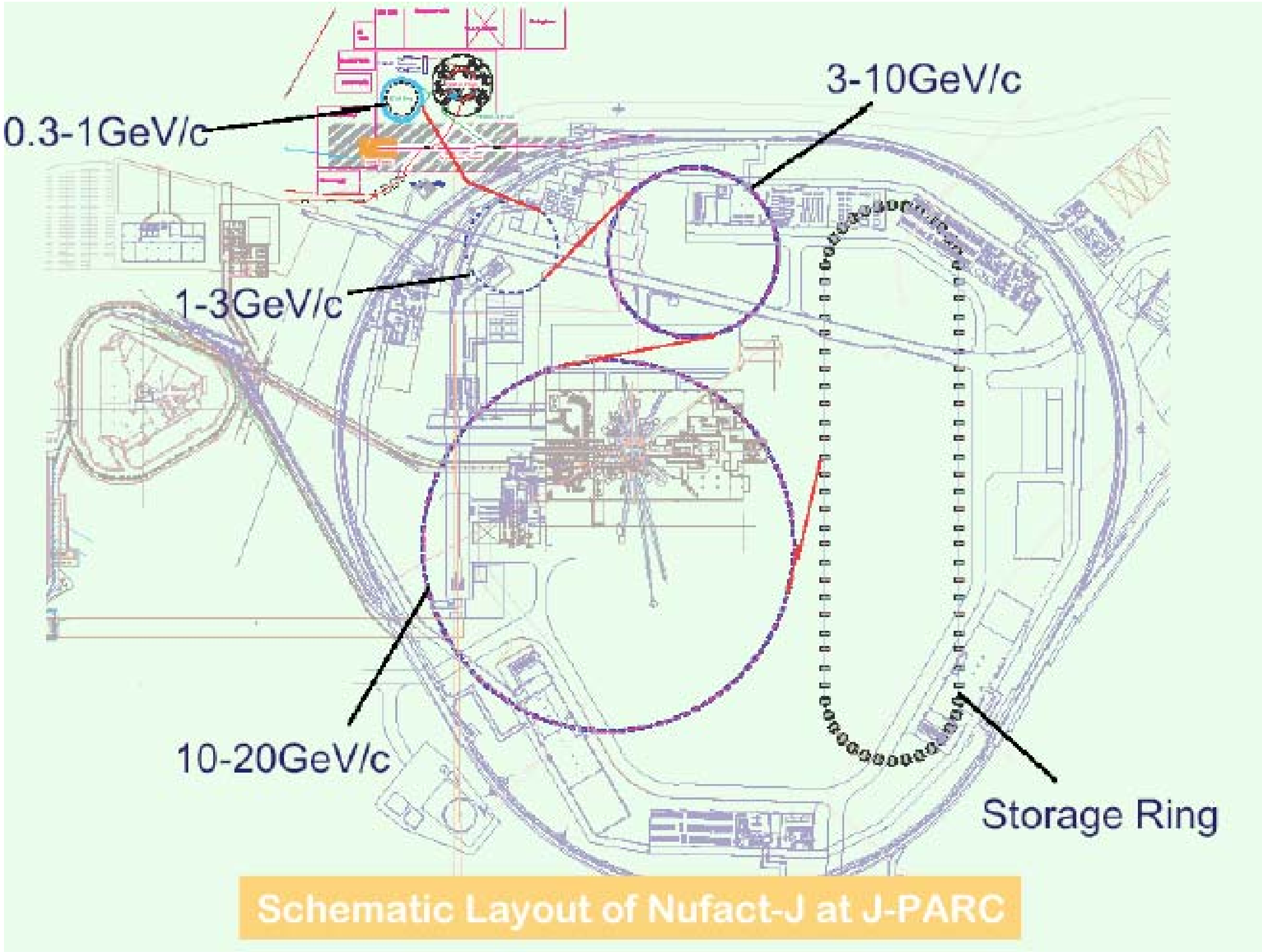


Future Upgrade Plan 2, 3) *Letters of Intent for 50-GeV MR*

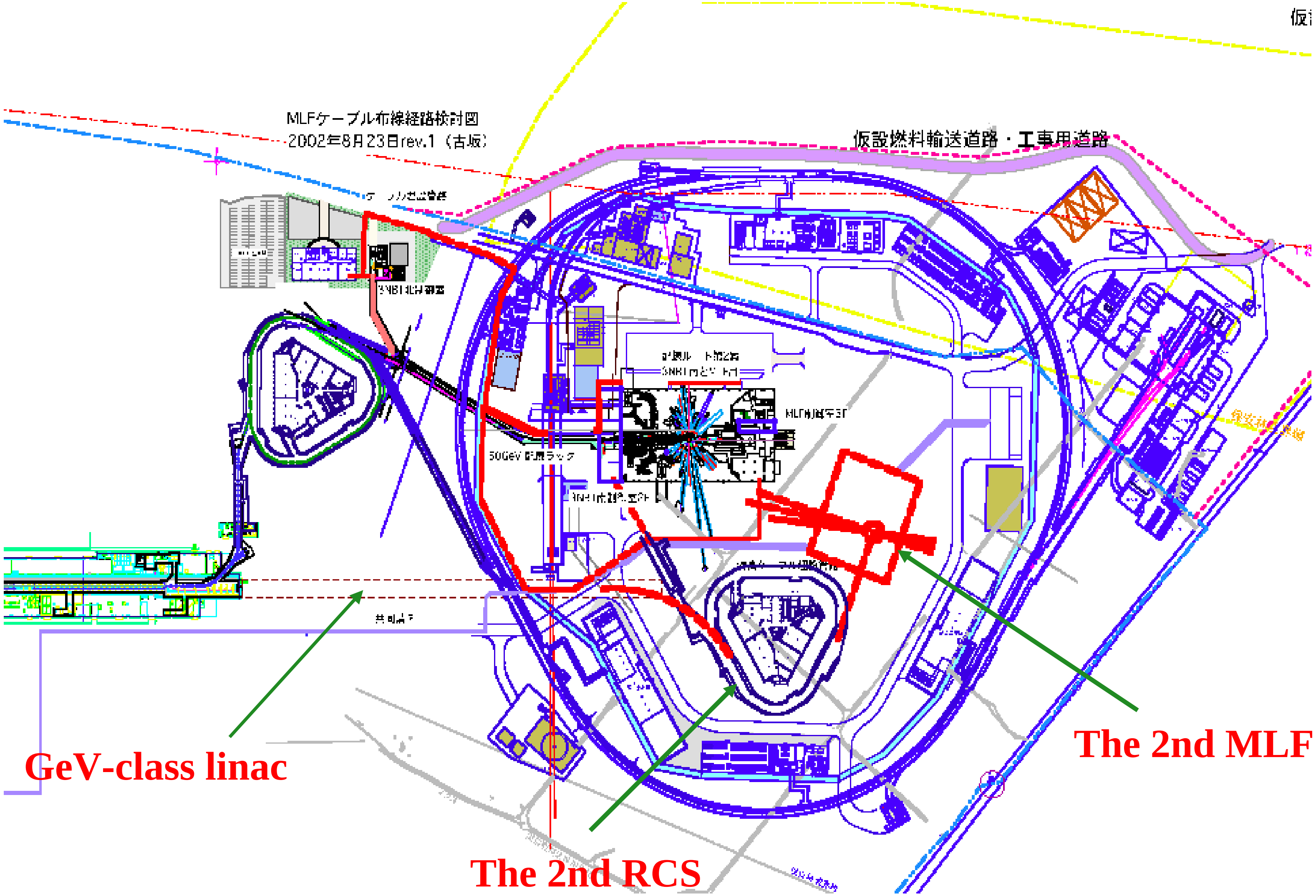
- Announce of LoI call : July 2002
- Thirty LoI's were submitted by early 2003
  - Strangeness nuclear physics 7
  - Nuclear/hadron physics 7
  - Kaon decay physics 4
  - Muon physics 3
  - Neutrino physics 1
  - Future facilities 8
- 478 physicists with 2/3 from outside Japan. Asian participation is still few.
- Call for proposals: Most likely, within a year, if no further delay is observed for the 50-GeV MR construction.



Future Upgrade Plan 3) *Neutrino factory with J-PARC proton driver*



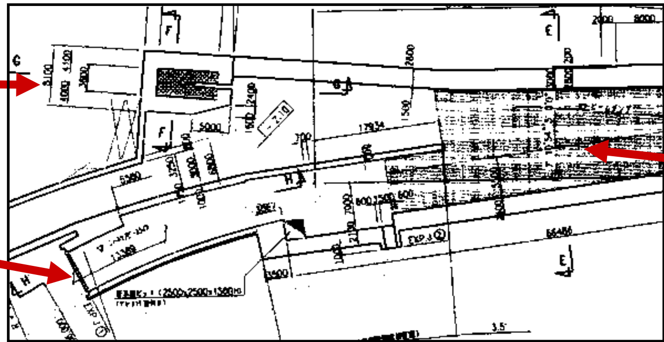
Future Upgrade Plan 3) *Severeal-MW Neutron Source*



Future Upgrade Plan 3)Arrangements Made for the Future

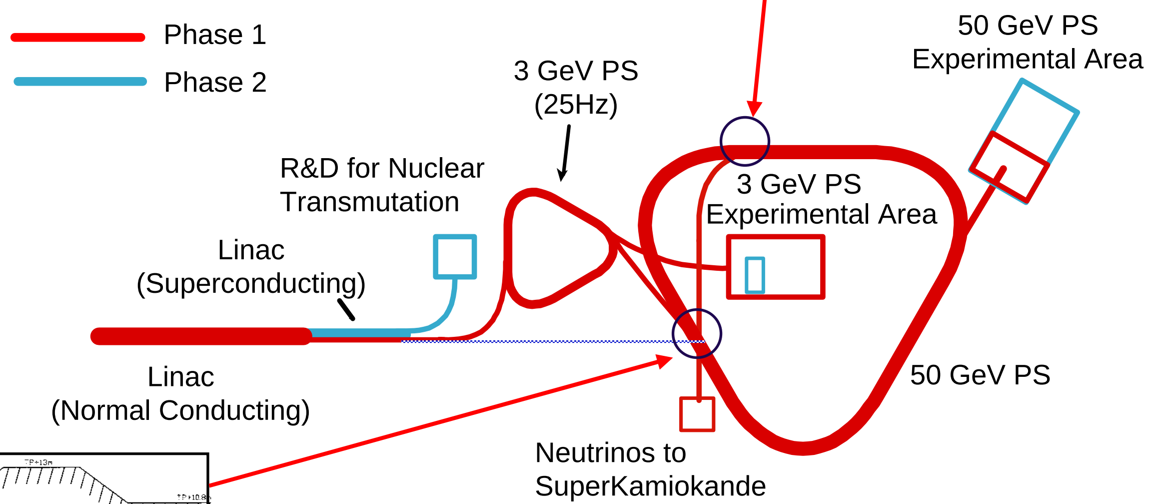
Reserved area for an additional fast extraction

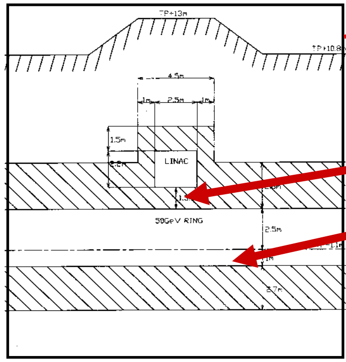
Fast extraction for neutrinos



50 GeV main ring

Plan view





Tunnel for a future linac

50-GeV MR tunnel

Vertical View from the left

Summary

- In general, the construction of the J-PARC accelerator is on schedule for starting the linac beam commissioning in mid-2006 and extracting the 40-GeV beam by the end of JFY2007 (a half year later than original schedule), although the funding was stretched by one year.
- The linac front end was beam-commissioned for DTL1 up to 20 MeV. More tuning is necessary to obtain the satisfactory emittances.
- The further effort is necessary for reducing the shut down period of the final year of the linac energy recovery, since the high-energy structure cannot be located on beam line.
- Future upgrade plans beyond the Phase II were proposed by both the neutron and particle physics communities.