May 22, 2012
IPAC12, New Orleans

Status of the J-PARC Facility

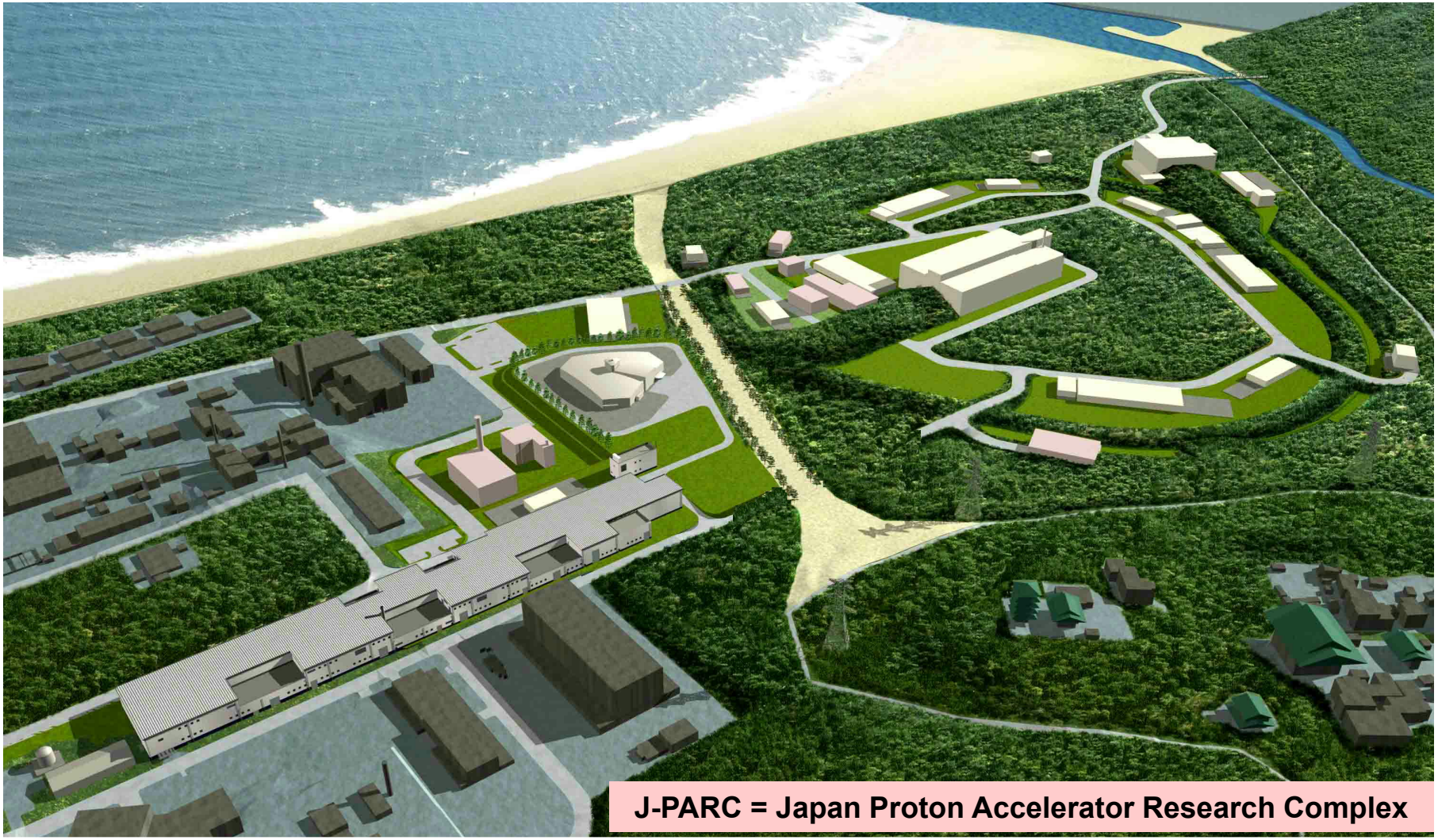
Shoji Nagamiya

J-PARC Center

Japan Atomic Energy Agency (JAEA)
High Energy Accelerator Research Organization (KEK)

1) J-PARC General
2) Status before the Earthquake
3) Status after the Earthquake
4) Accelerator Performance and the Future

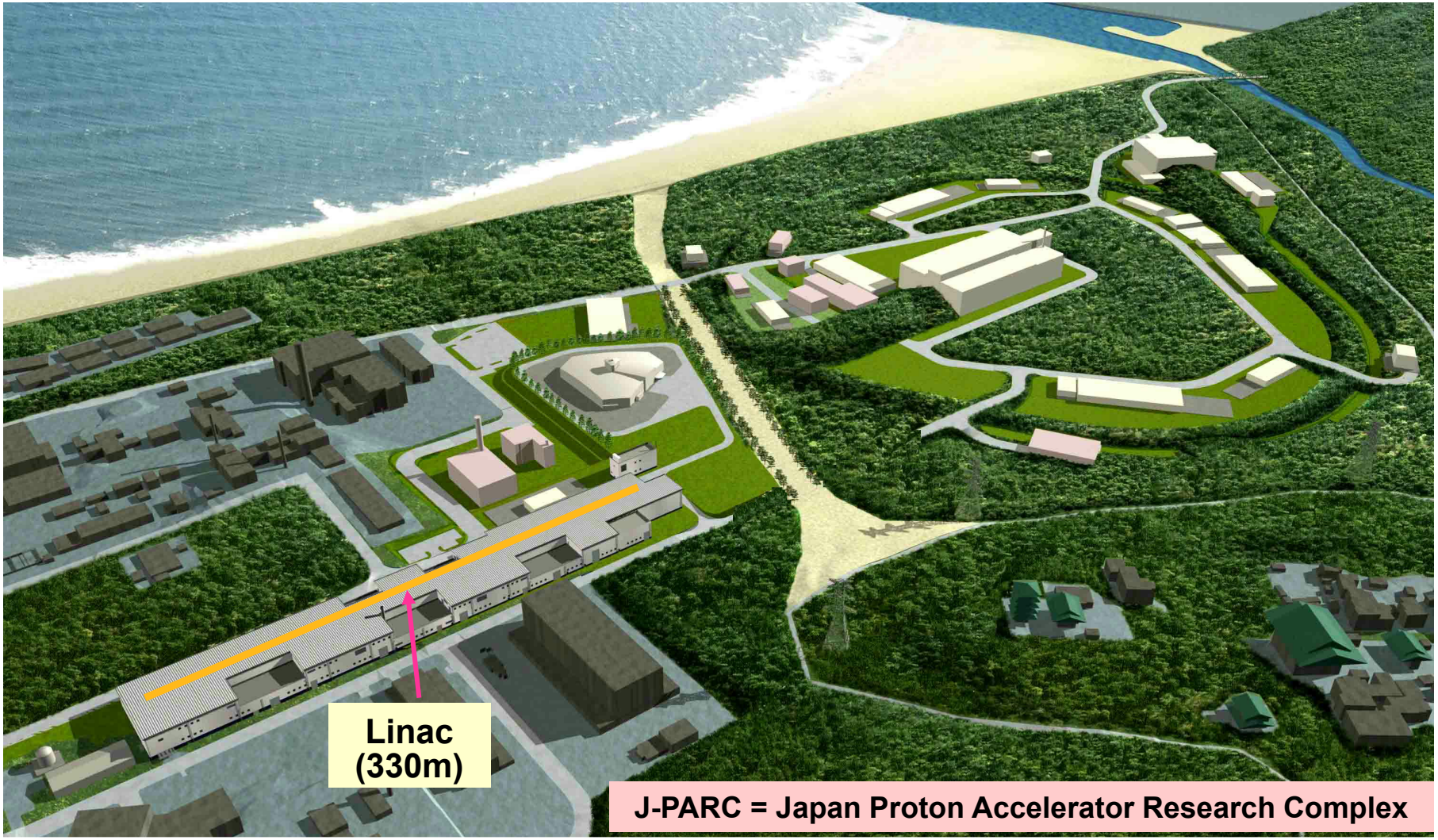
J-PARC Facility



J-PARC = Japan Proton Accelerator Research Complex

Joint Project between KEK and JAEA

J-PARC Facility



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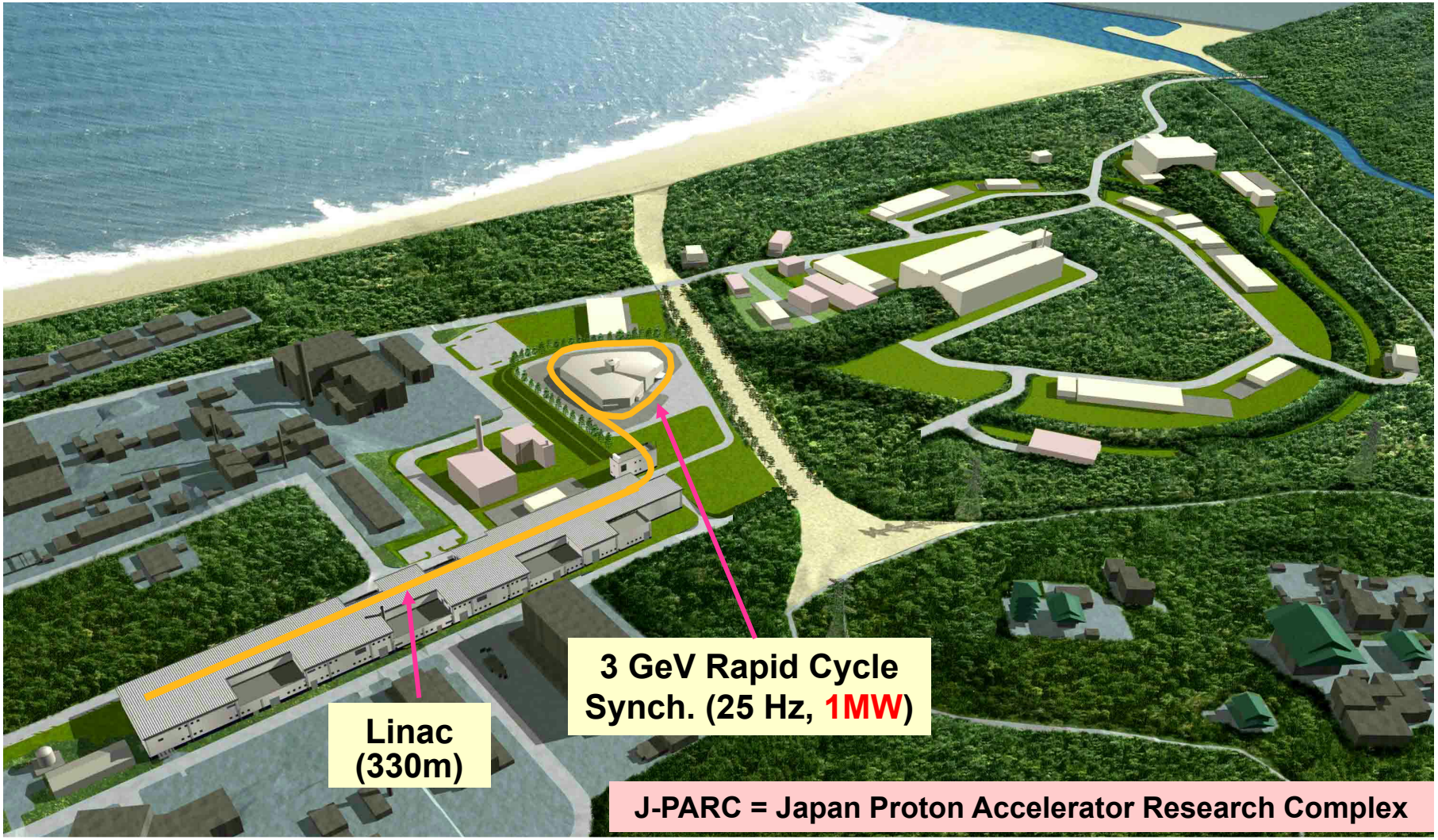

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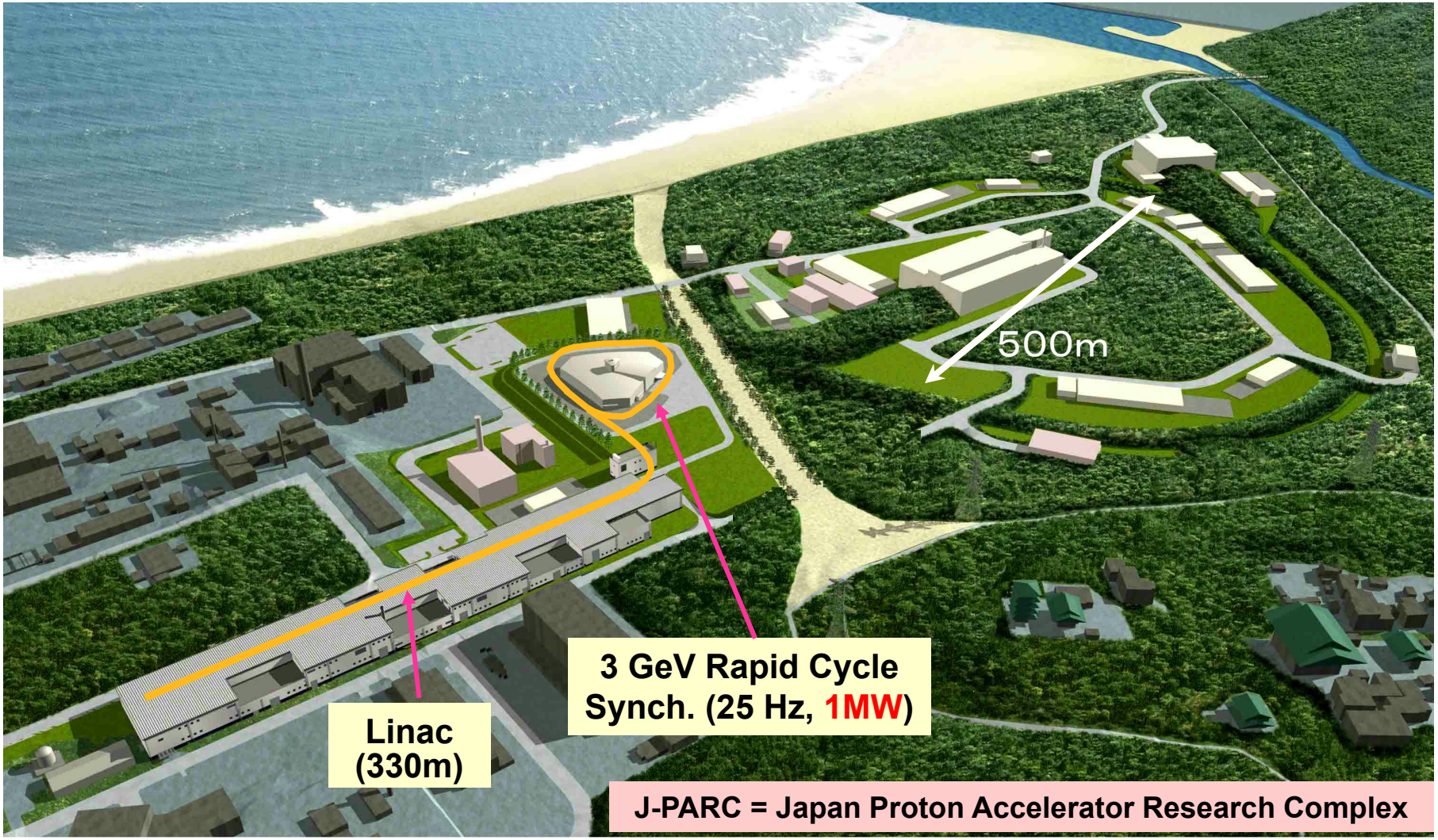
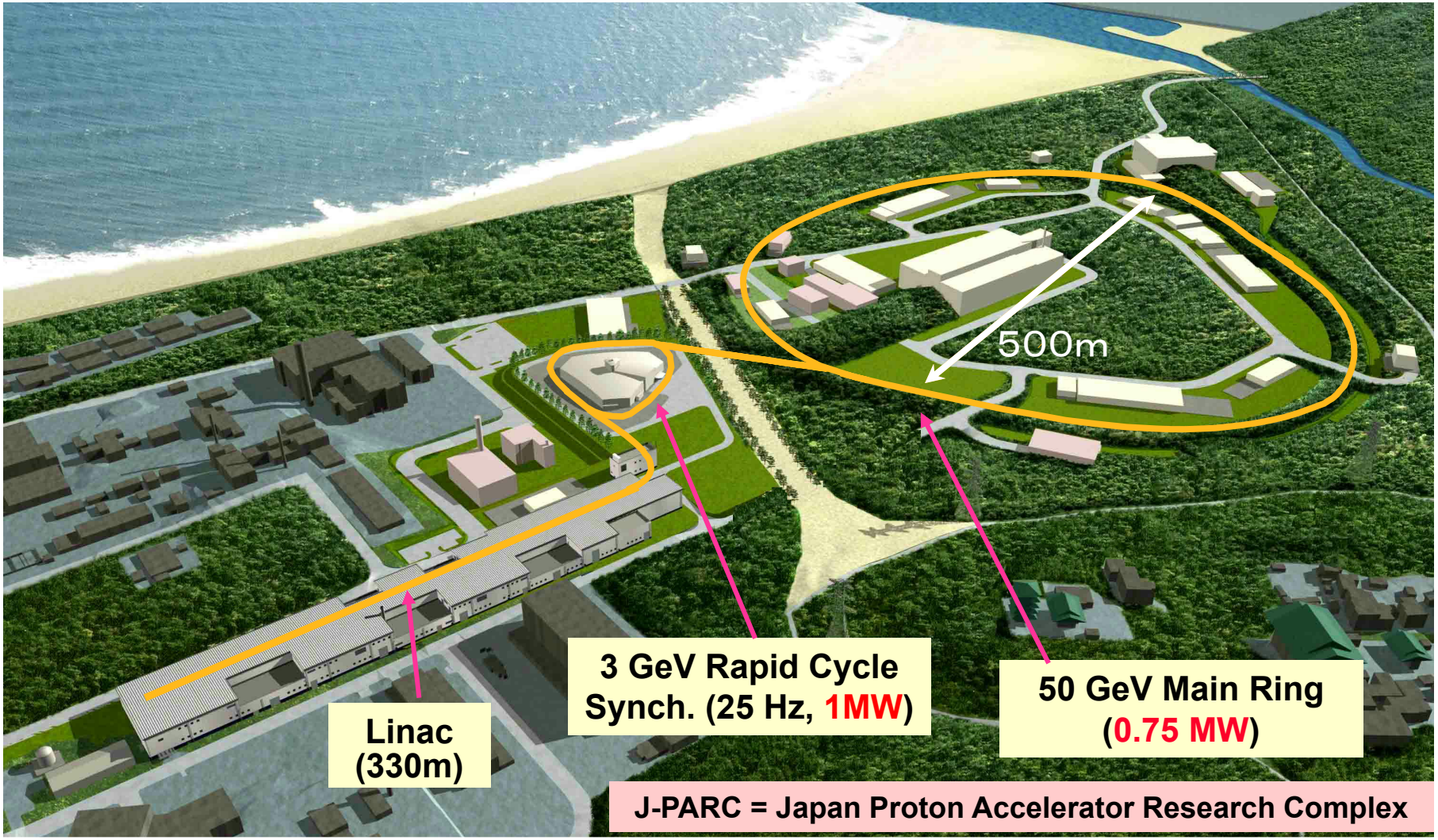
J-PARC Facility



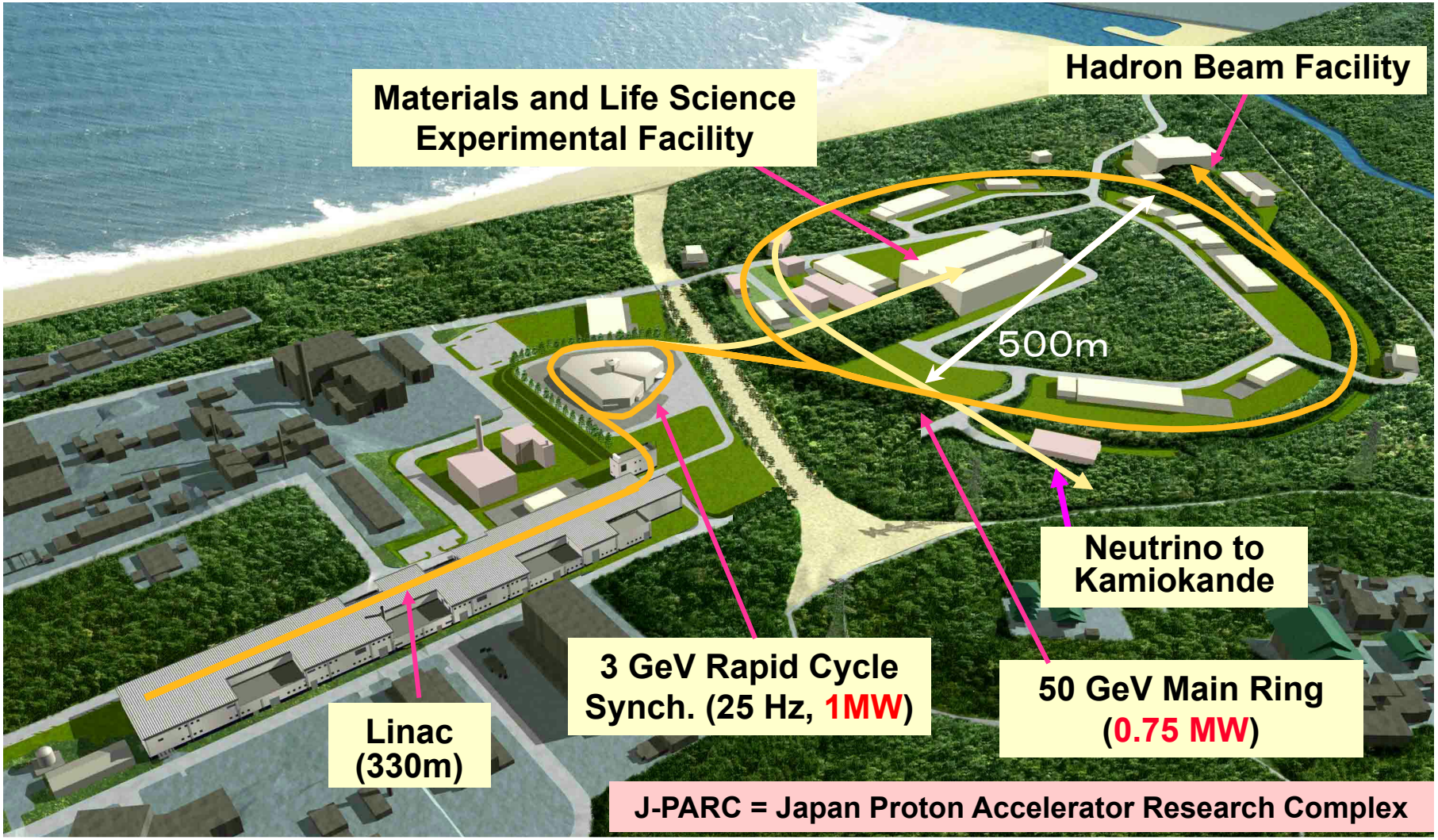
Joint Project between KEK and JAEA

J-PARC Facility



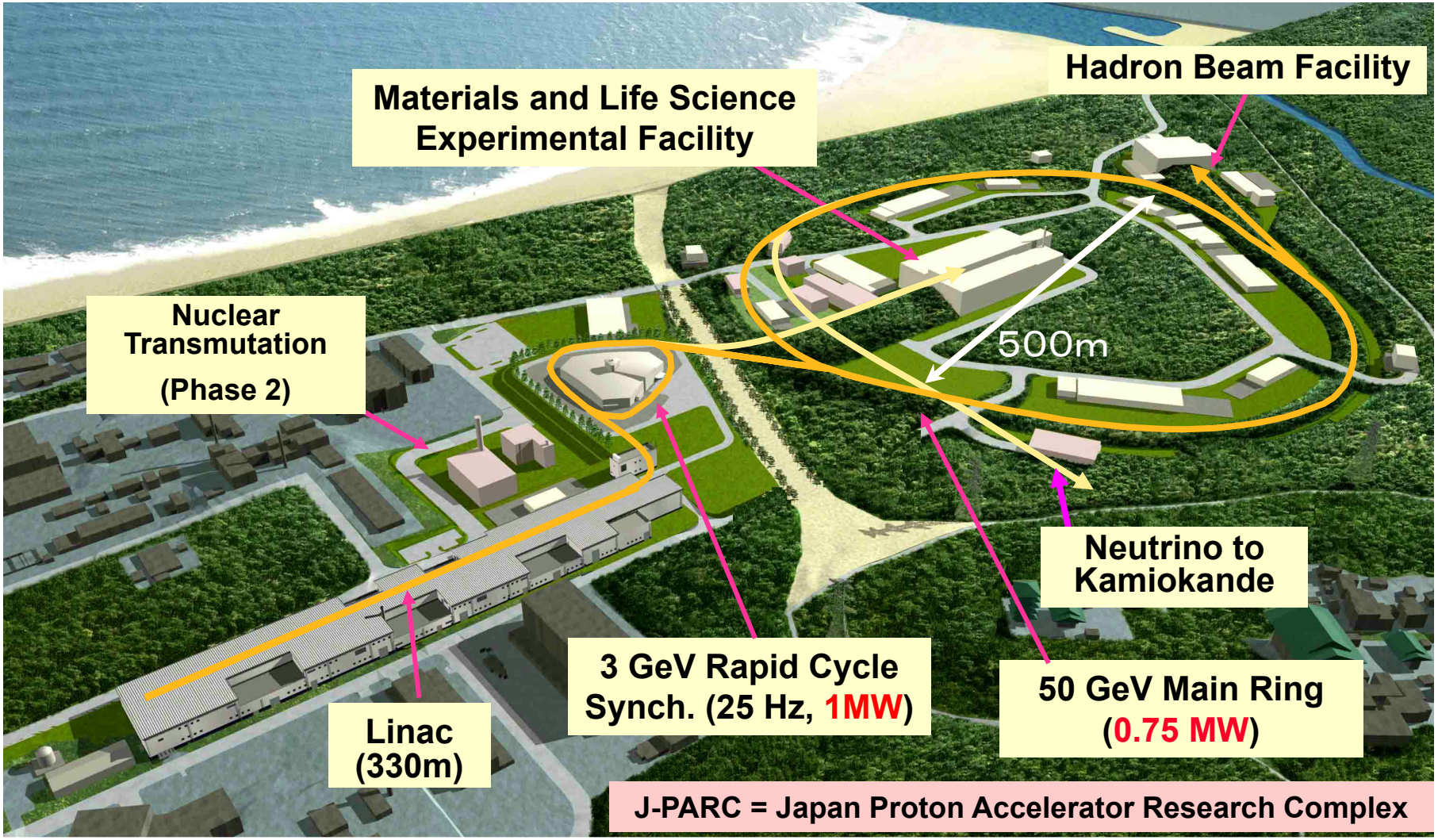
Joint Project between KEK and JAEA

J-PARC Facility



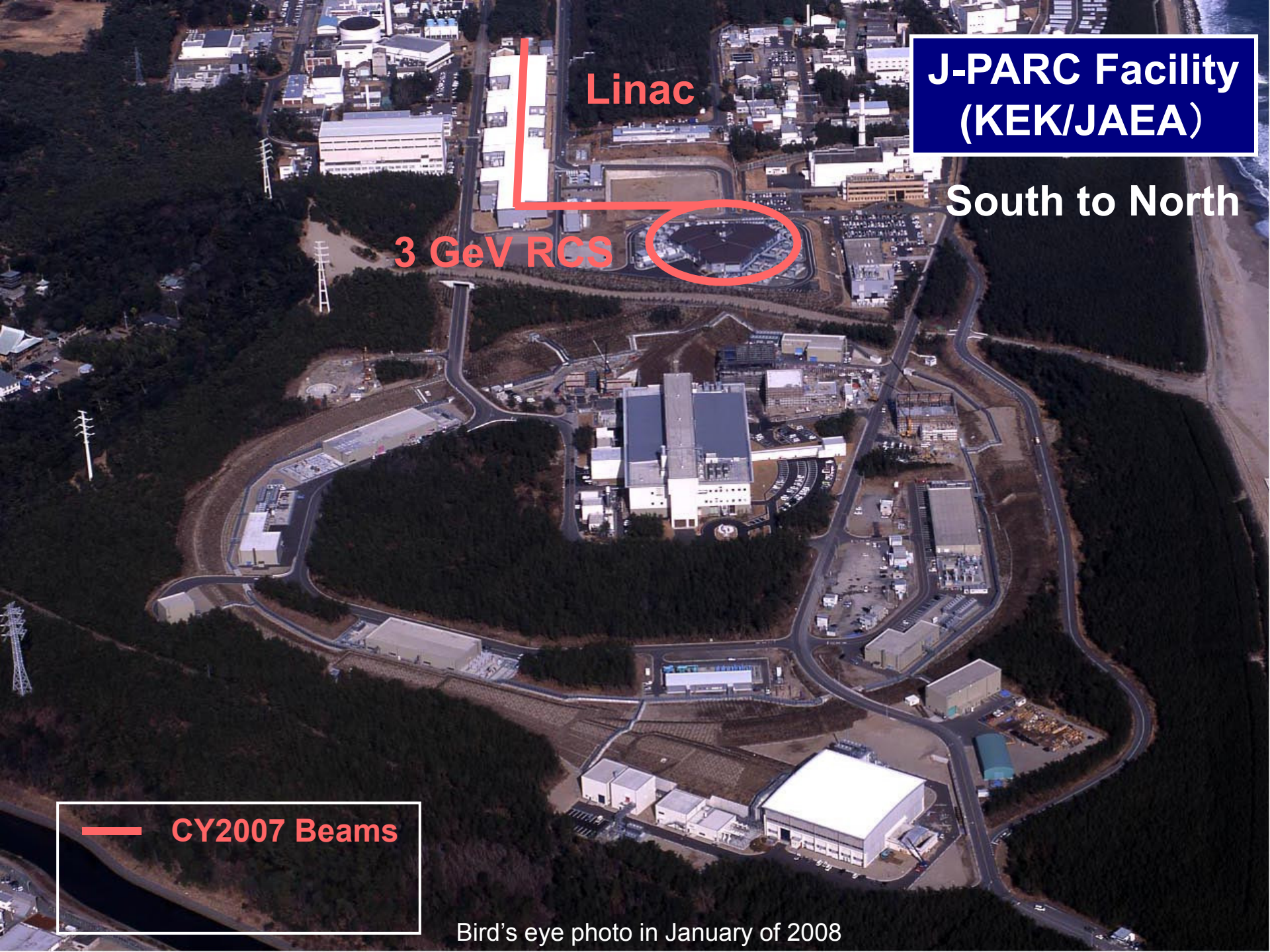
Joint Project between KEK and JAEA

J-PARC Facility

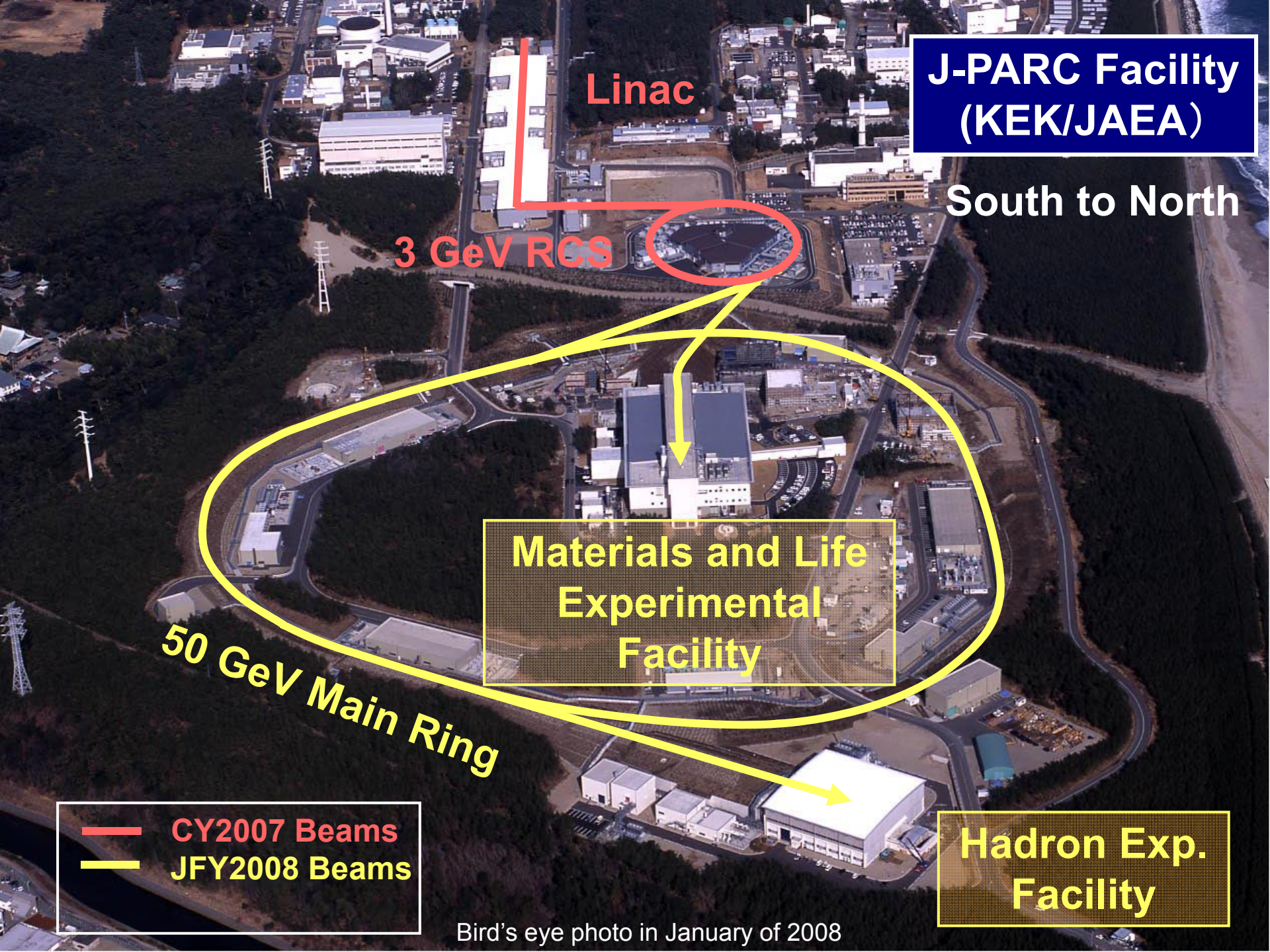


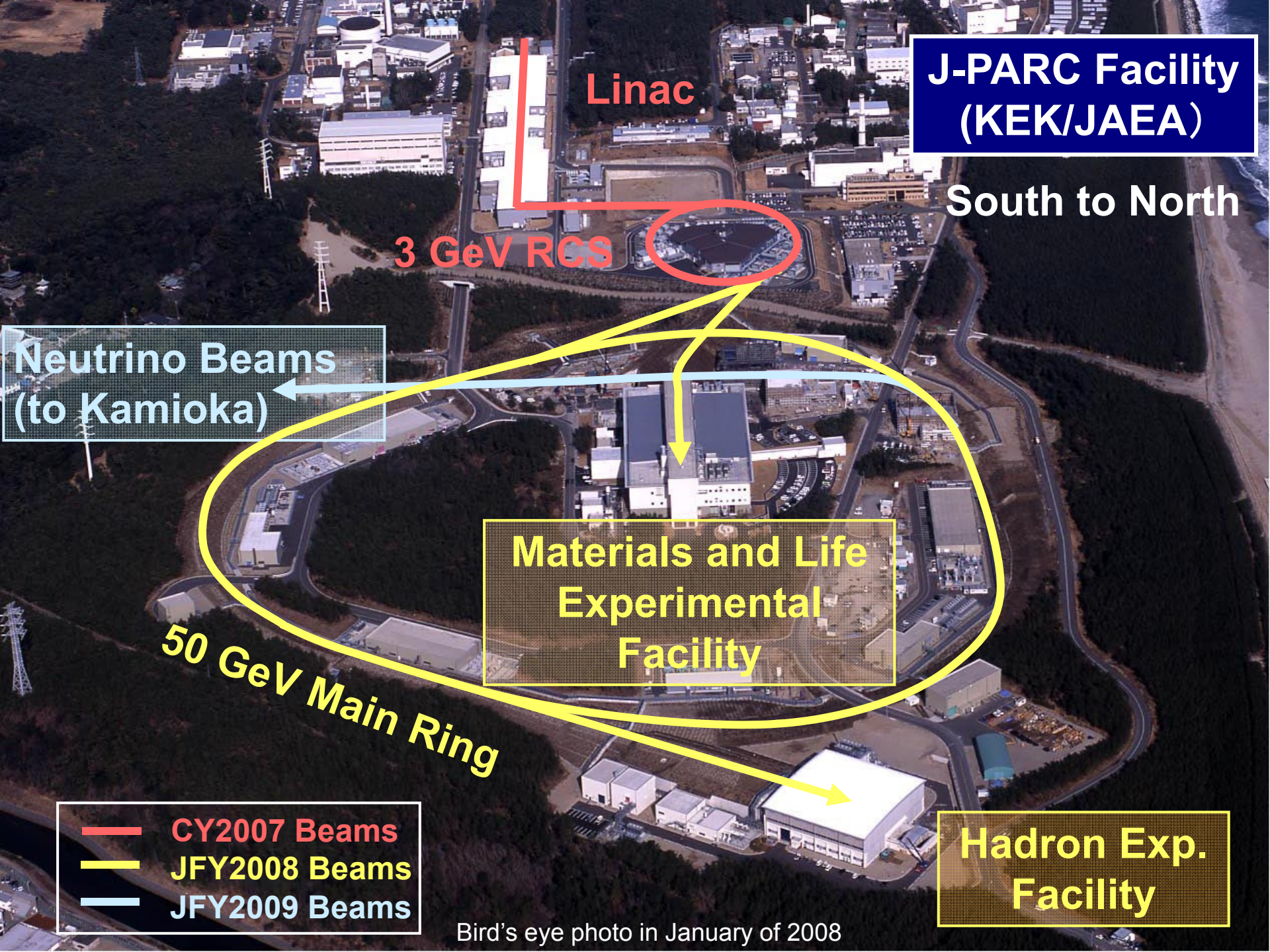
Joint Project between KEK and JAEA

Bird's eye photo in January of 2008

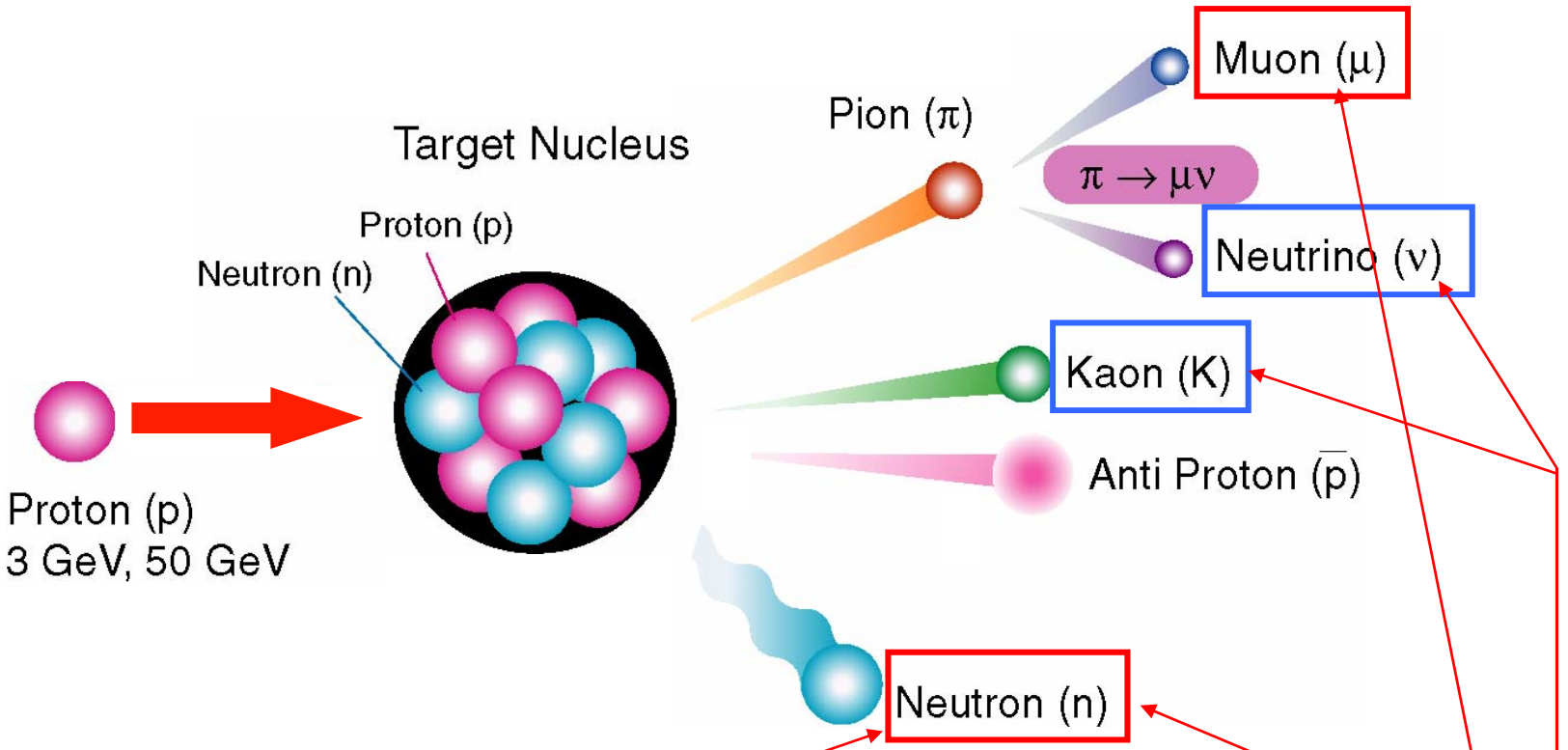


Bird's eye photo in January of 2008


J-PARC Facility
(KEK/JAEA)
South to North
Linac
3 GeV RCS
Materials and Life
Experimental
Facility
50 GeV Main Ring
CY2007 Beams
JFY2008 Beams
Hadron Exp.
Facility
Bird's eye photo in January of 2008


Linac
J-PARC Facility
(KEK/JAEA)
South to North
3 GeV RCS
Neutrino Beams
(to Kamioka)
Materials and Life
Experimental
Facility
50 GeV Main Ring
CY2007 Beams
JFY2008 Beams
JFY2009 Beams
Hadron Exp.
Facility
Bird's eye photo in January of 2008

Goals at J-PARC



Need to have high-power proton beams

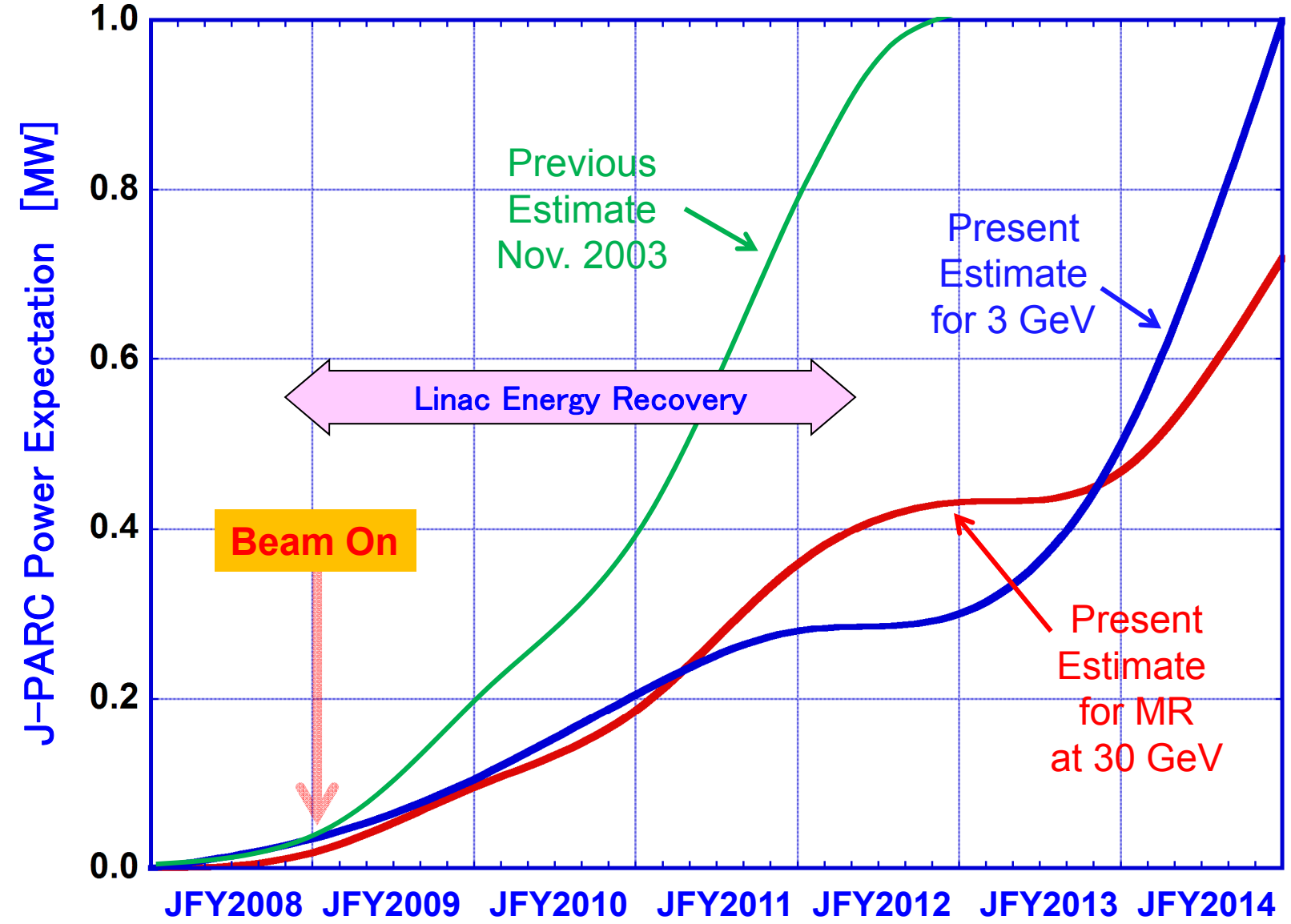
→ MW-class proton accelerator

Materials & Life Sciences at 3 GeV
Nuclear & Particle Physics at 50 GeV
R&D toward Transmutation at 0.6 GeV

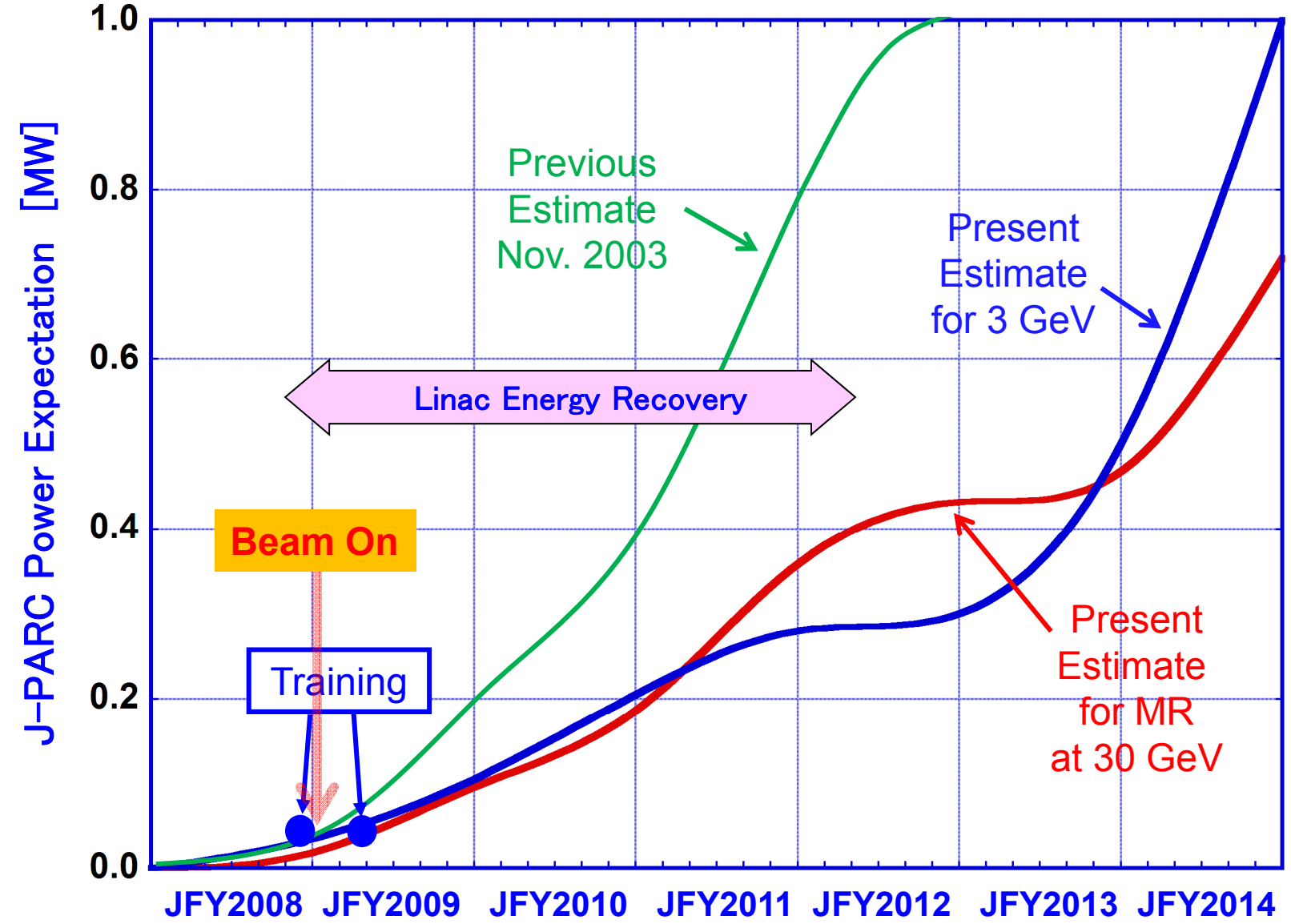
J-PARC

Status (before the Earthquake)

Power Capability



Power Capability



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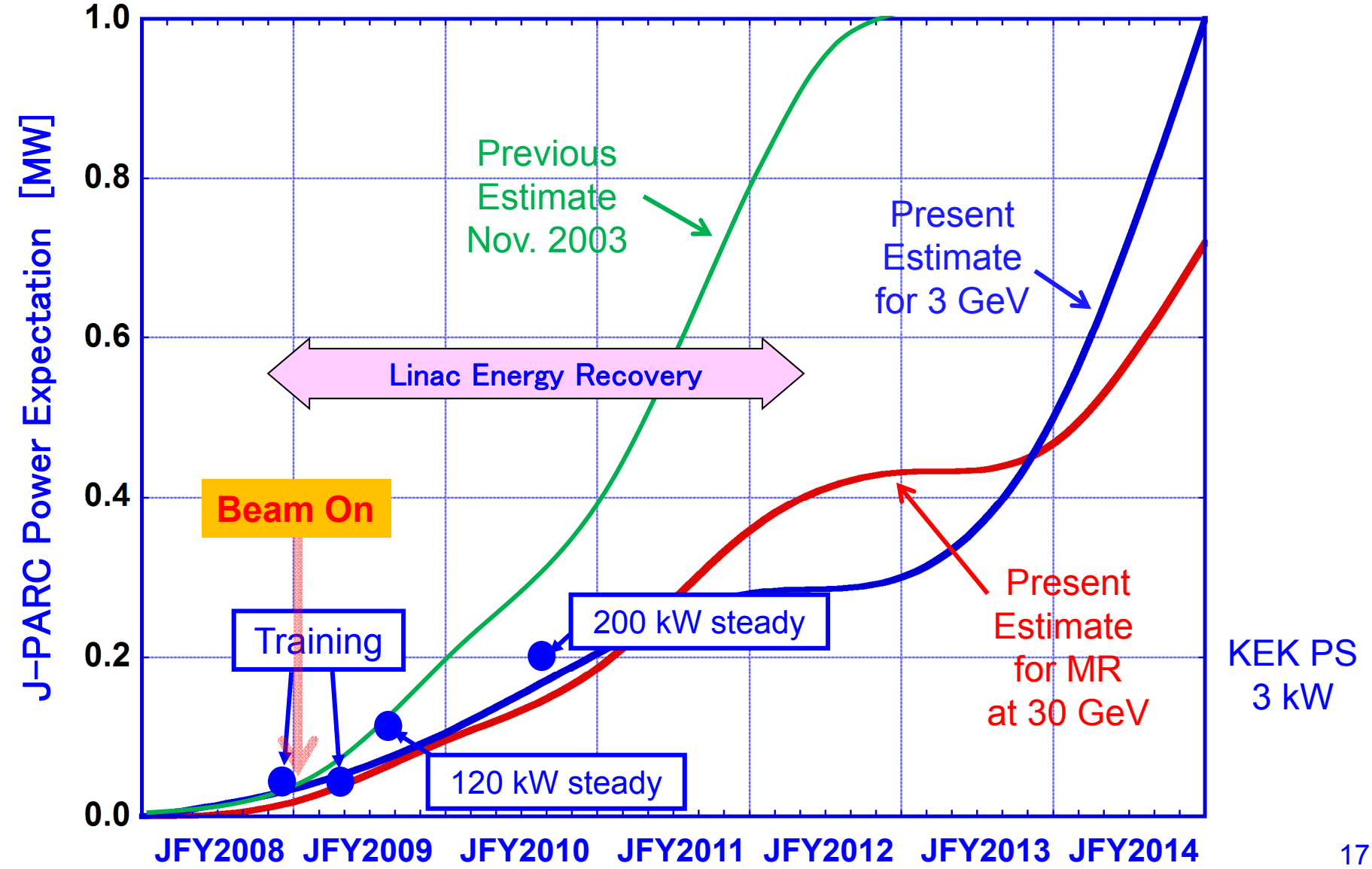

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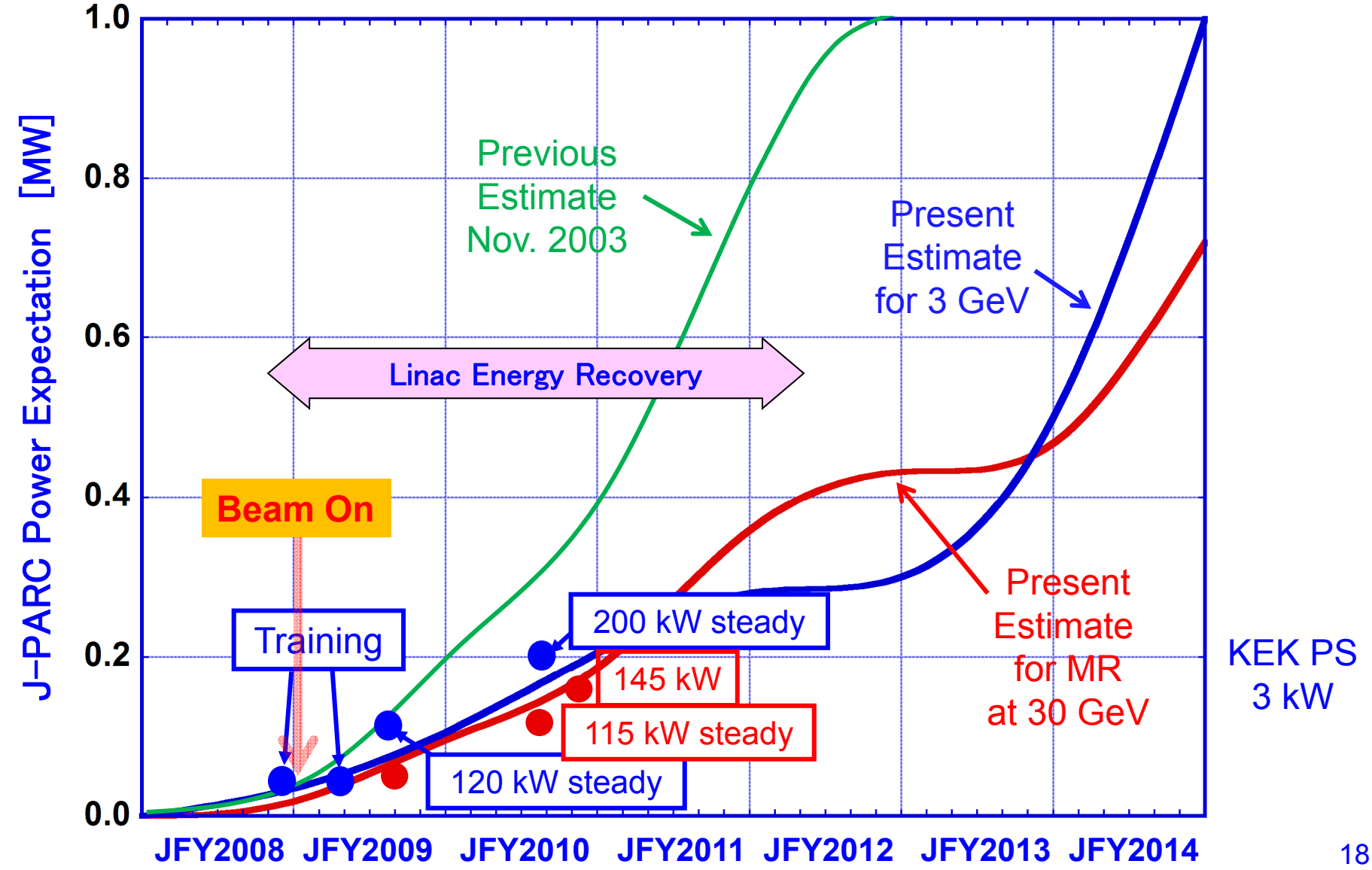
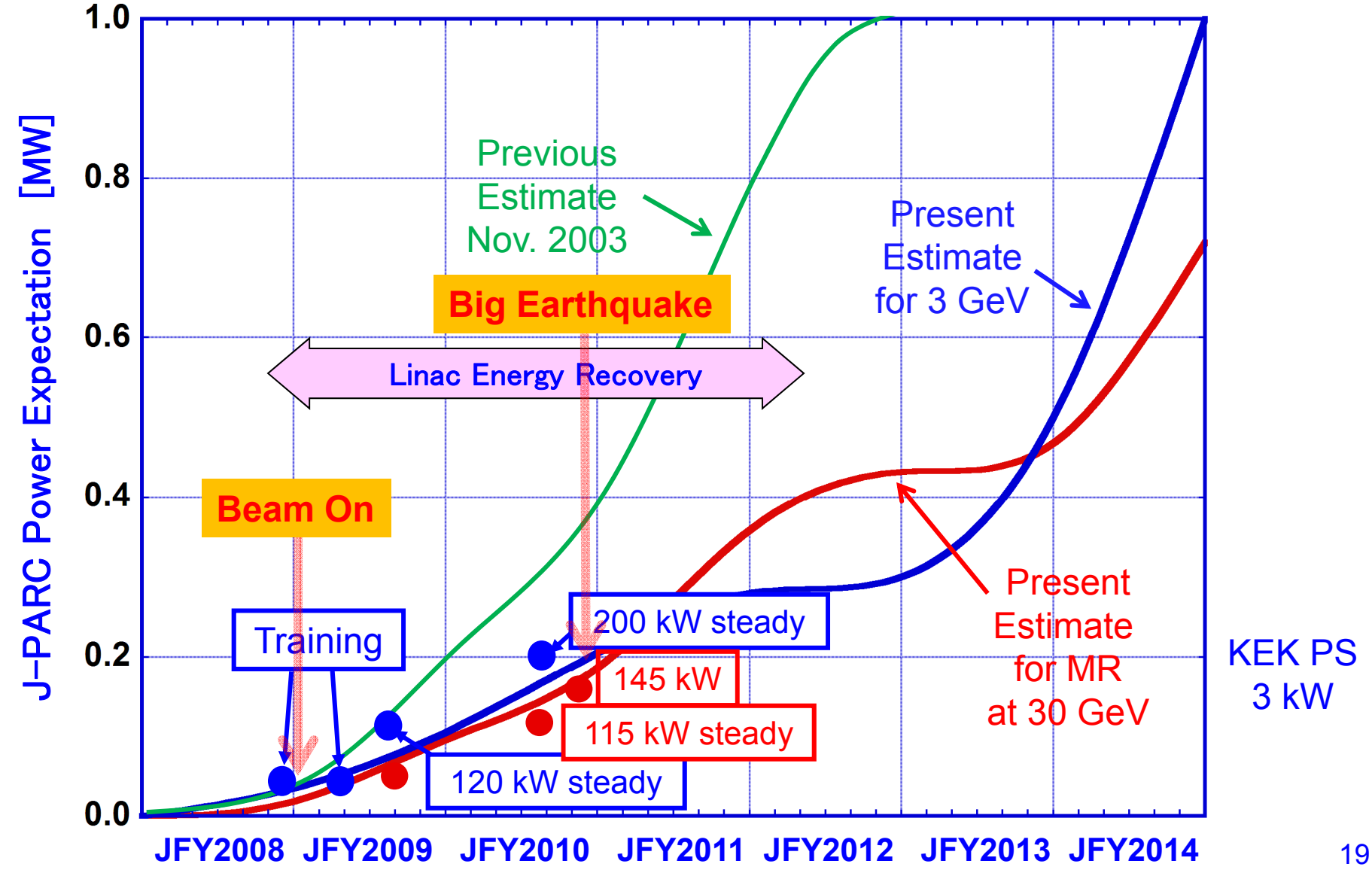
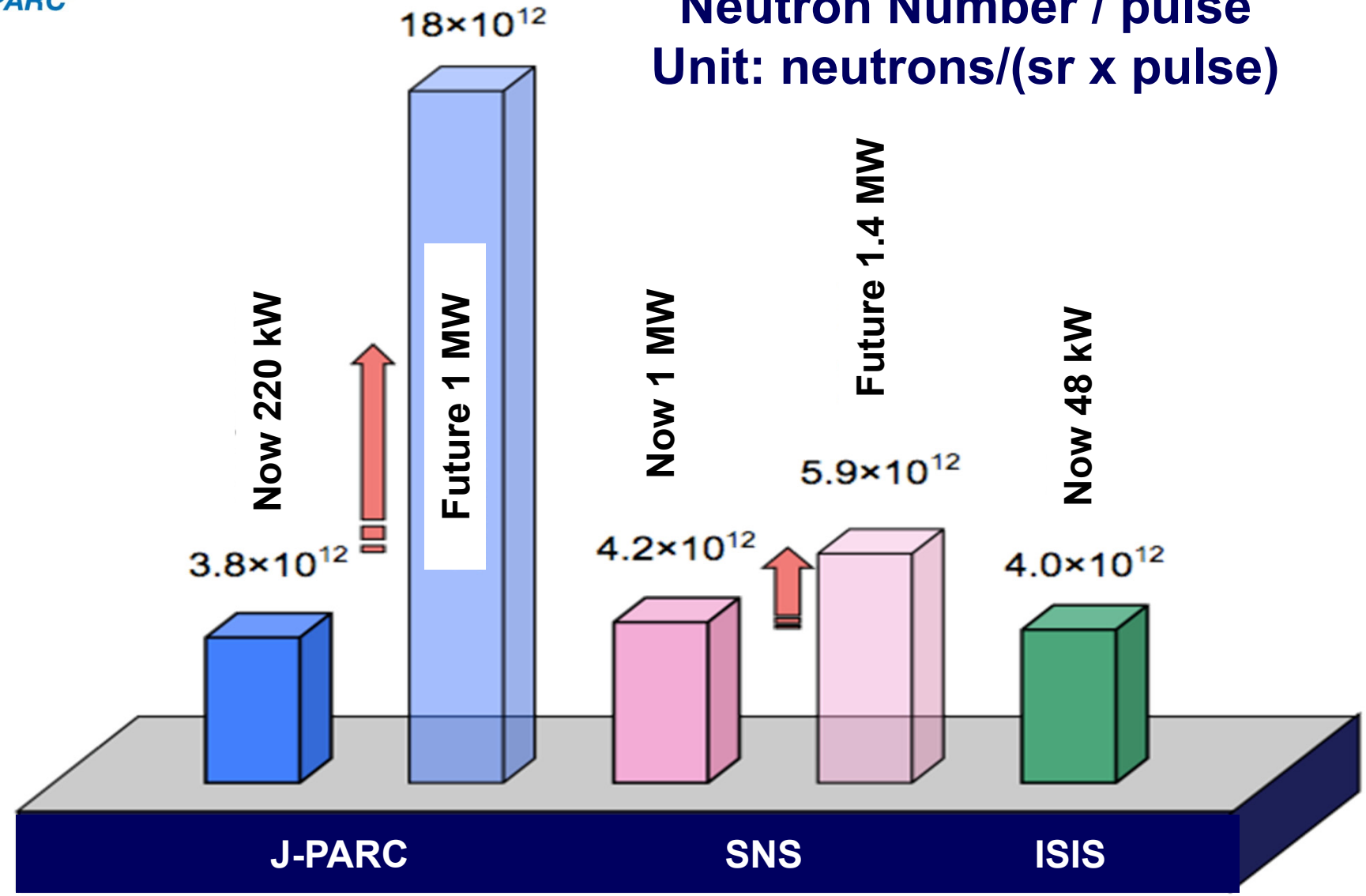


Power Capability

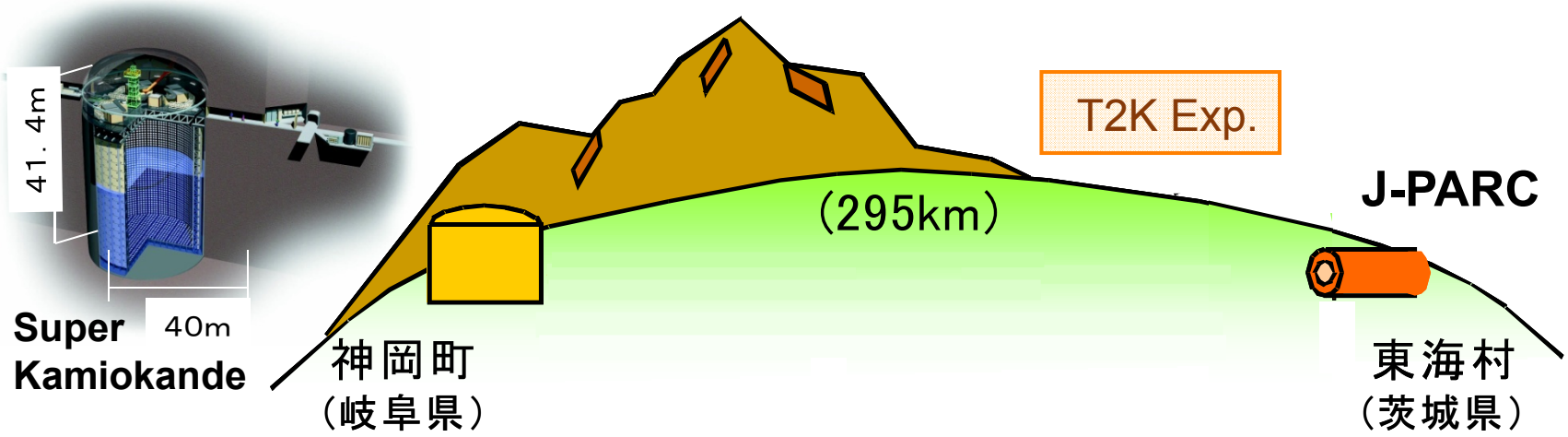


J-PARC

Neutron Number / pulse
Unit: neutrons/(sr x pulse)



Neutrino Oscillation (T2K) Experiment



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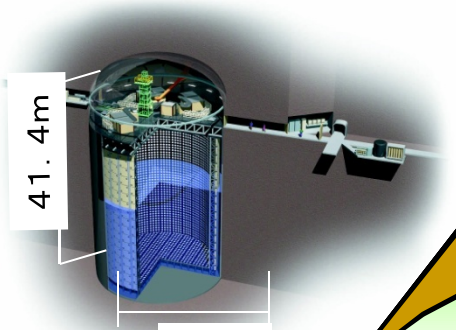
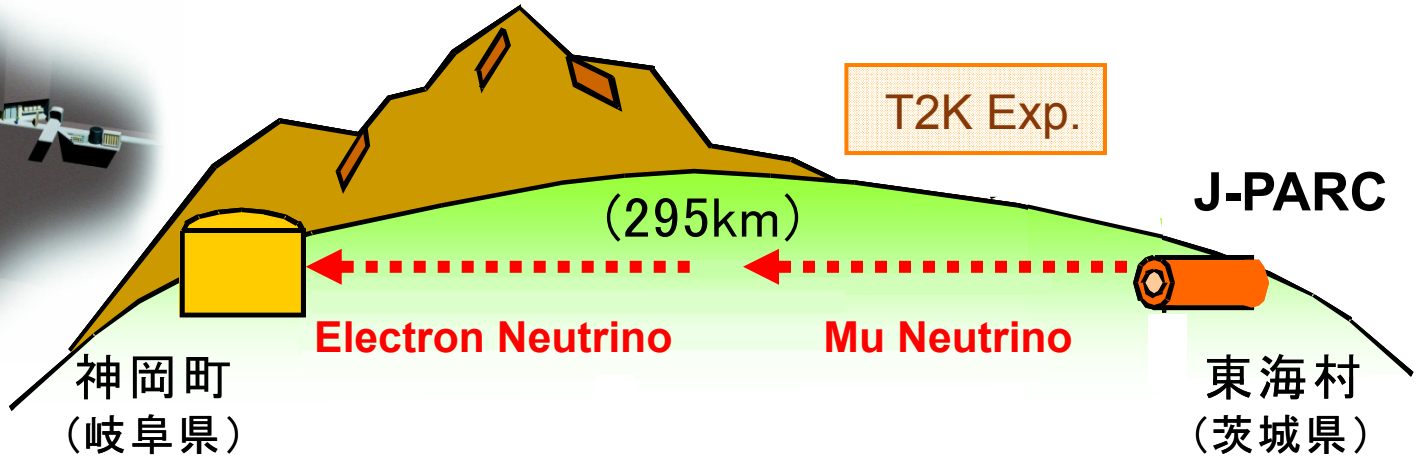


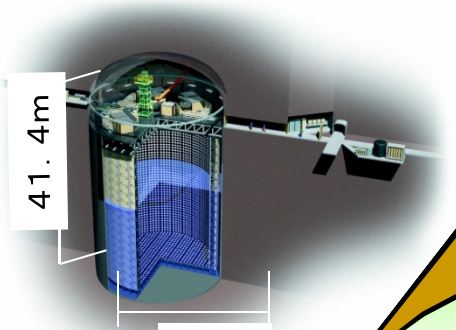
Super Kamiokande



Electron neutrinos ← Mu neutrinos

θ_{13} ⟷ Mixing between the 1st and 3rd generation

Neutrino Oscillation (T2K) Experiment



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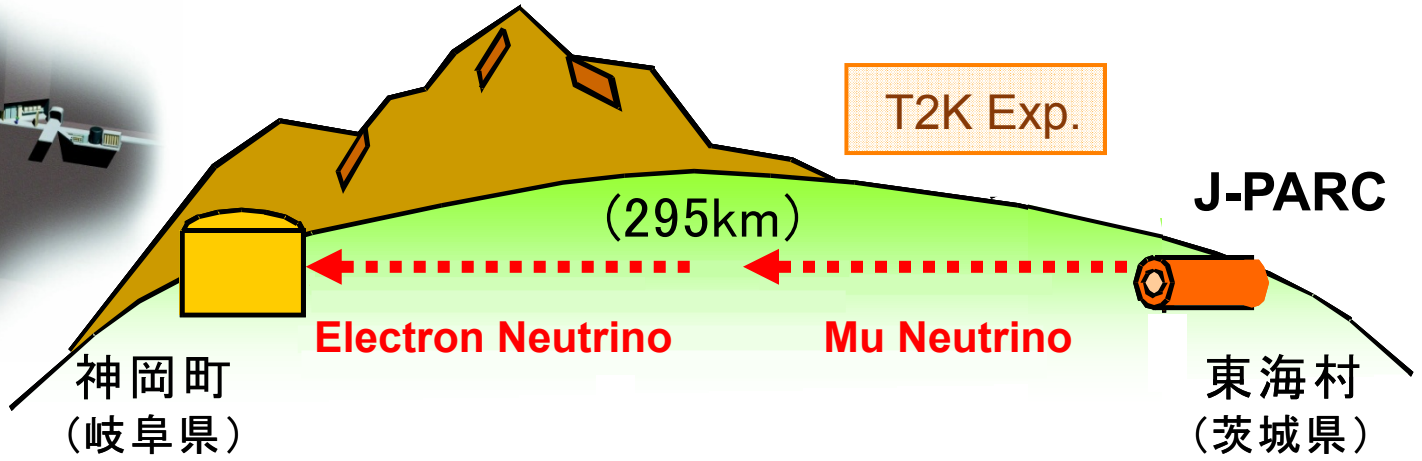
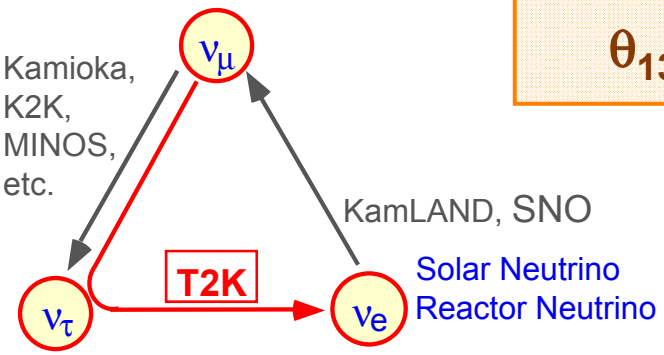


Atmospheric Neutrino
Accelerator Neutrino



Electron neutrinos ← **Mu neutrinos**

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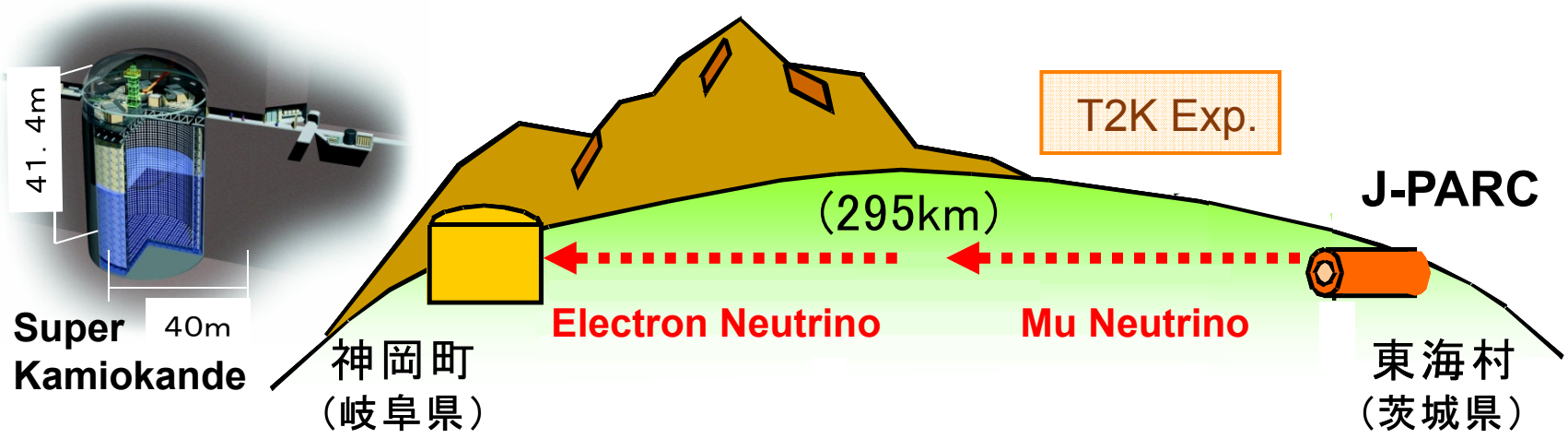
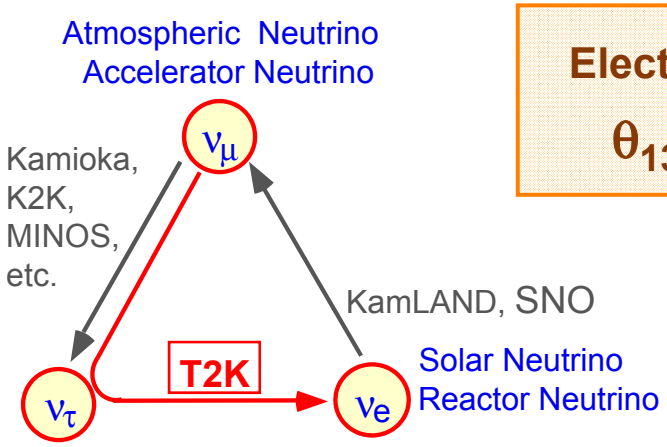




Electron neutrinos ← **Mu neutrinos**

θ_{13} ⟷ **Mixing between the 1st and 3rd generation**

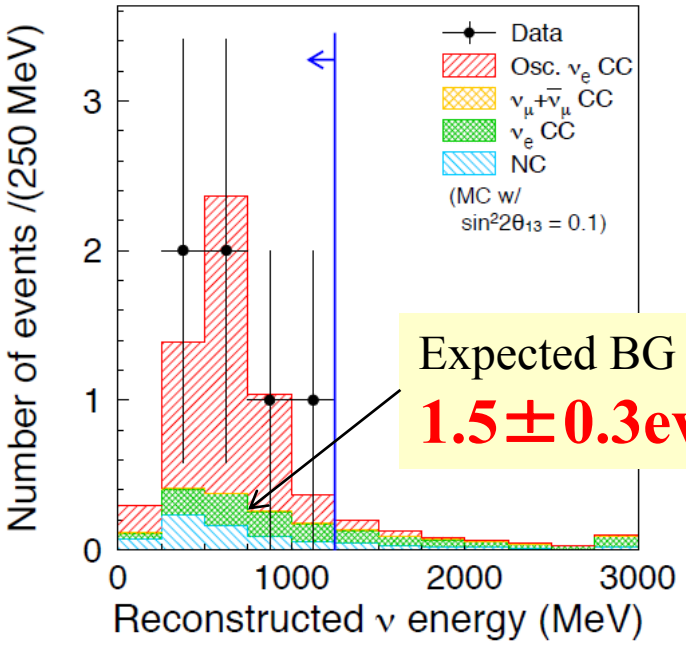
Already 500 non-Japanese joined this experiment !!!
(Japanese participants are only 70)

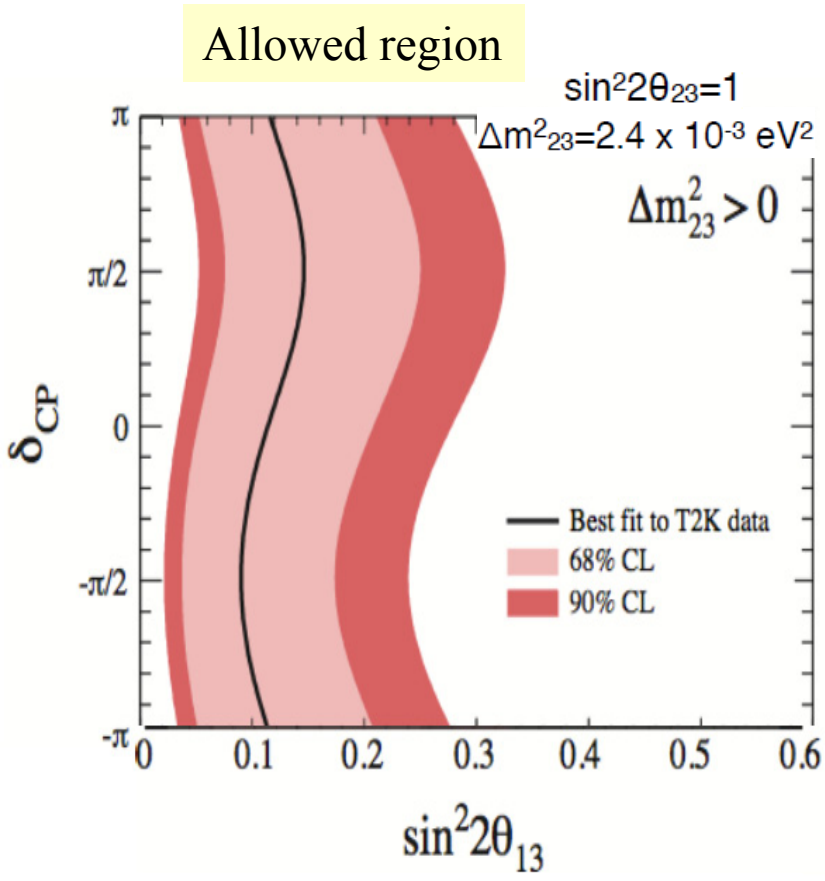
Goal is to measure $\sin^2 2\theta_{13}$ down to 0.01

Competition with Double Chooz, Diya Bay, FNAL, etc.

Indication of ν_e appearance (non-zero θ_{13})

6 ν_e candidates found!





- Prob. of 6 are all BG: **0.7%**
  (2.5σ equiv)

($\Delta m_{23}^2 > 0$)

$0.03 < \sin^2 2\theta_{13} < 0.28$ **90%CL range**

$\sin^2 2\theta_{13} = 0.11$ **Central value**

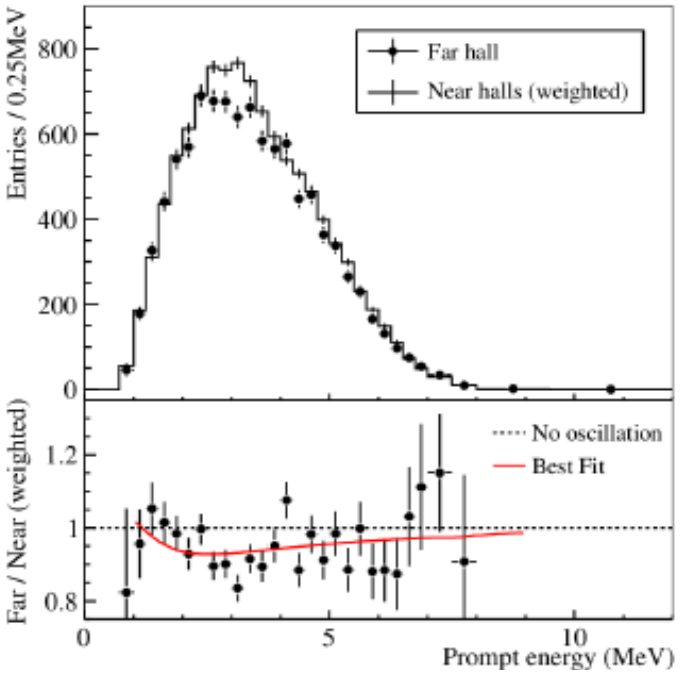
assuming Δm^2_{23}=2.4 x 10^{-3} eV^2, $\sin^2 2\theta_{23}$=1, δ_{CP}=0

Selected to Physics World Top 10 Breakthroughs (England) in 2011

http://physicsworld.com/cws/article/news/48126

Daya Bay and Reno Results

Disappearance Experiment to confirm T2K



Daya Bay

Observed: 9901 neutrinos at far site,
Prediction: 10530 neutrinos if no oscillation

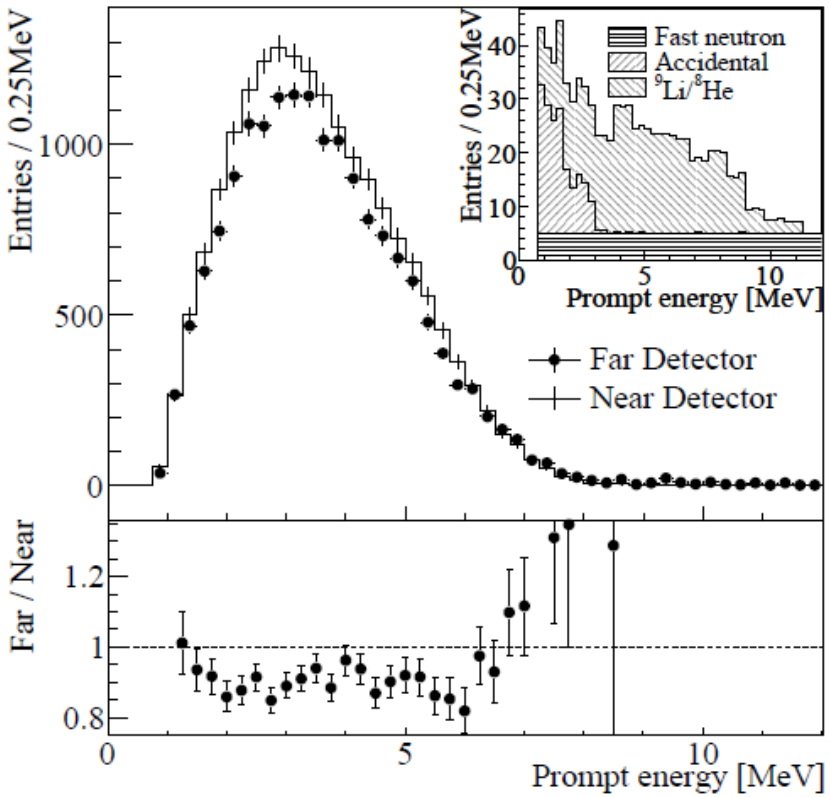
$$R = 0.940 \pm 0.011\,(stat) \pm 0.004\,(syst)$$

$$\mathbf{Sin^2 2\theta_{13} = 0.092 \pm 0.016(stat) \pm 0.005(syst)}$$

5σ Results

Daya Bay and Reno Results

Disappearance Experiment to confirm T2K



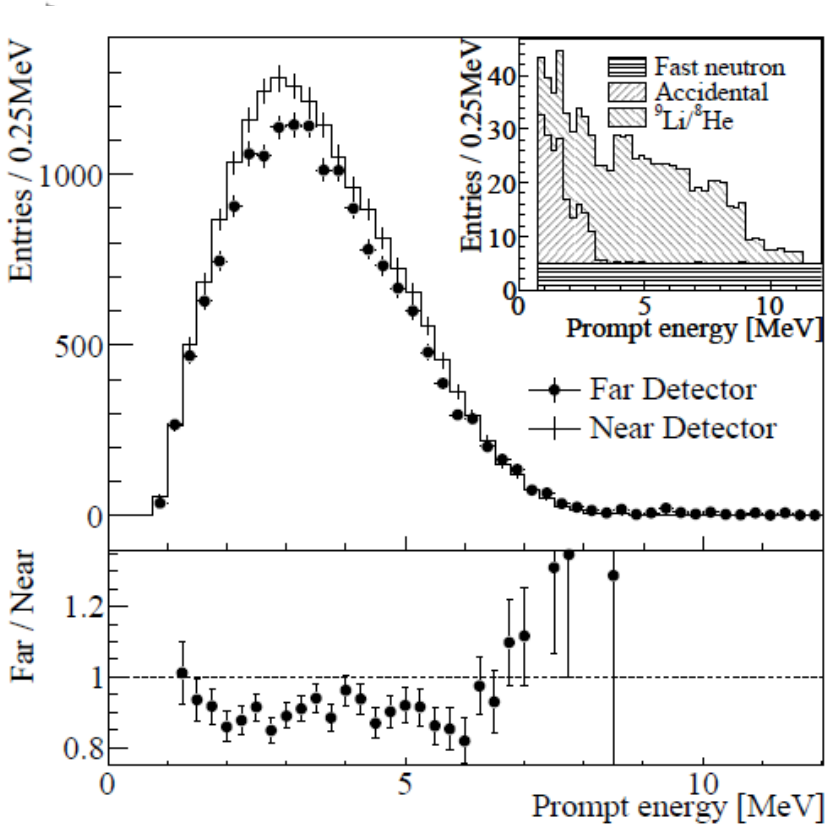
$$\mathrm{Sin}^2 2\theta_{13} = 0.092 \pm 0.016(\mathrm{stat}) \pm 0.005(\mathrm{syst})$$

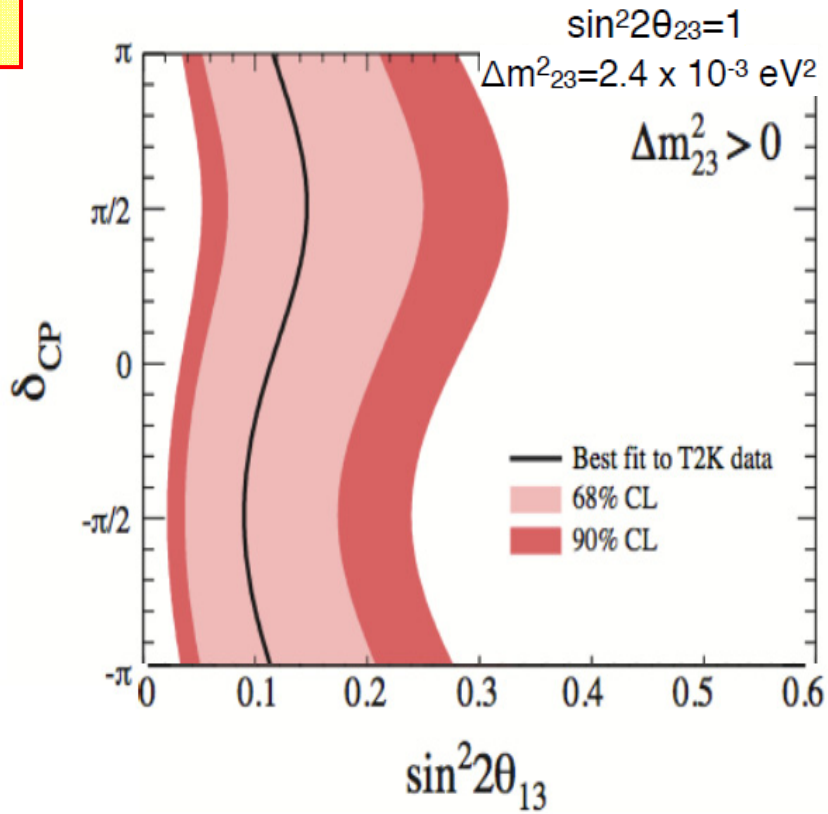
0.113 0.019 0.014

Reno in Korea further confirmed the result

Daya Bay and Reno Results

Disappearance Experiment to confirm T2K





Appearance Experiment

$$\mathrm{Sin}^2 2\theta_{13} = 0.092 \pm 0.016(\mathrm{stat}) \pm 0.005(\mathrm{syst})$$

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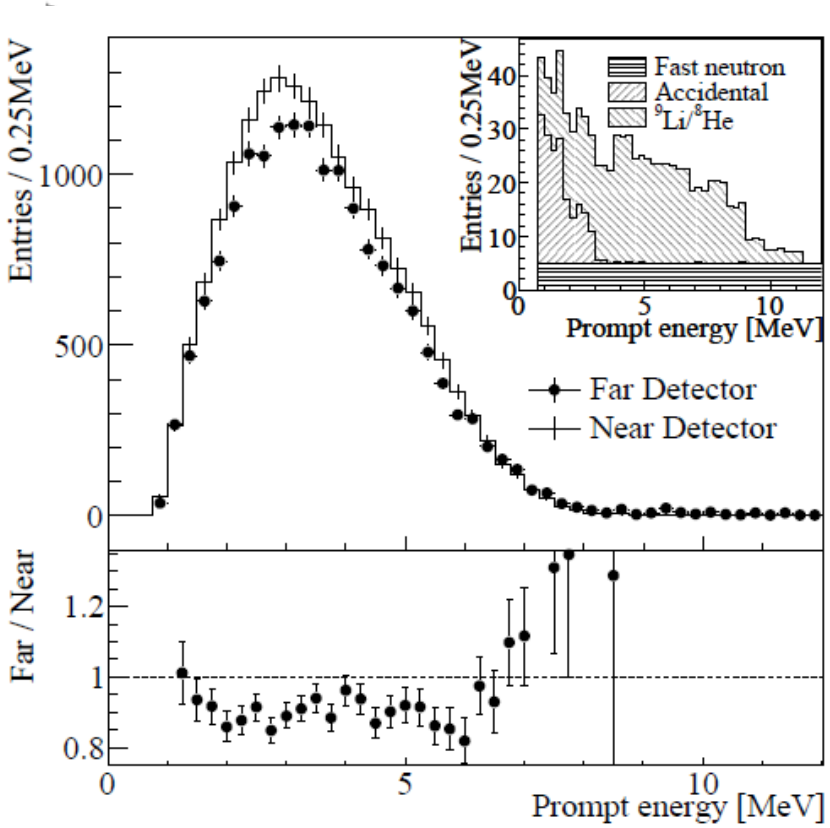
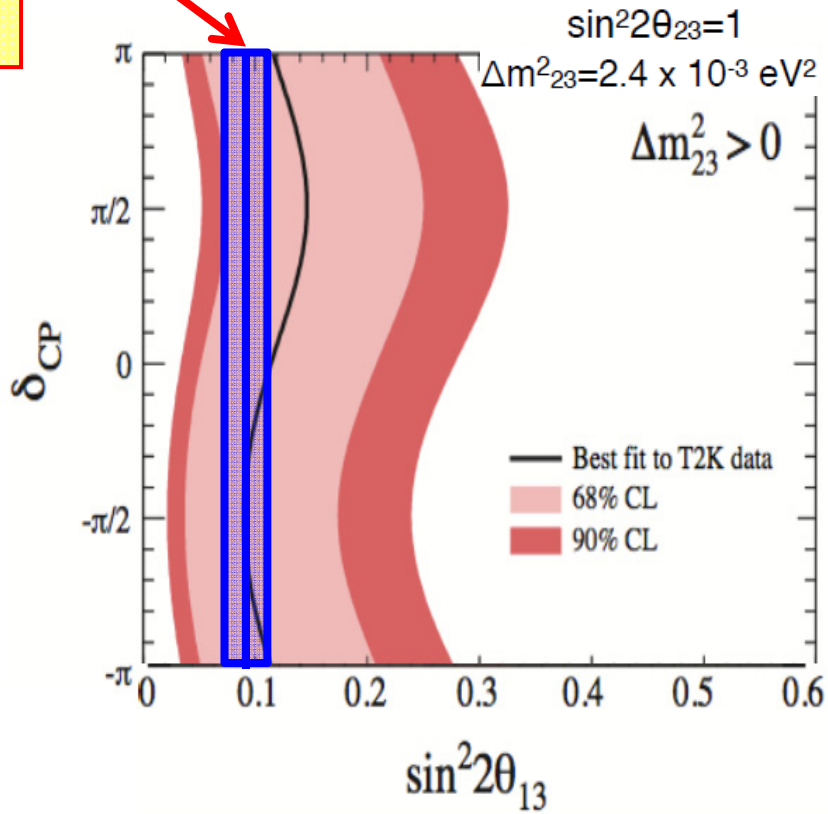
Daya Bay and Reno Results

Disappearance Experiment to confirm T2K





Appearance Experiment

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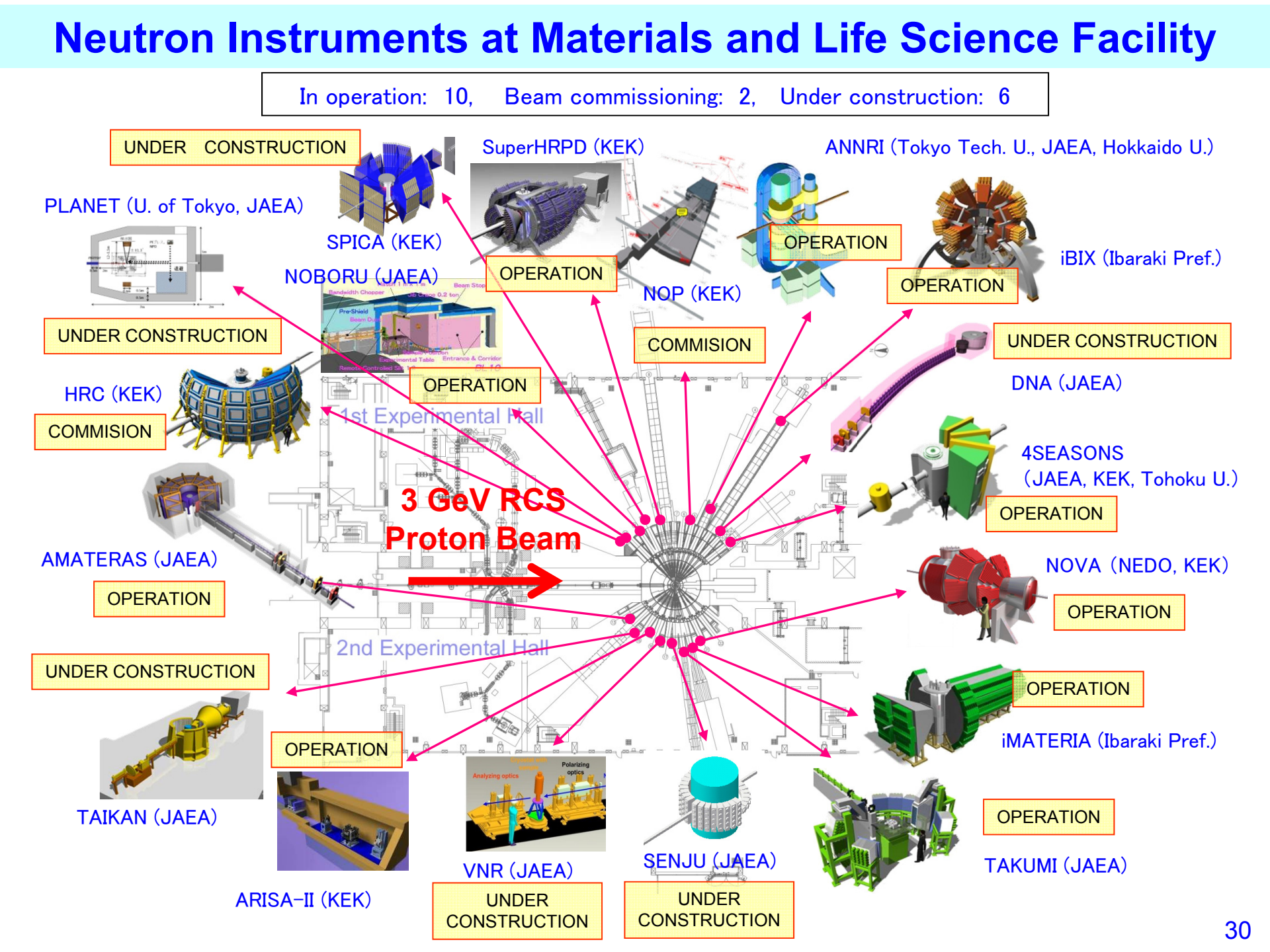
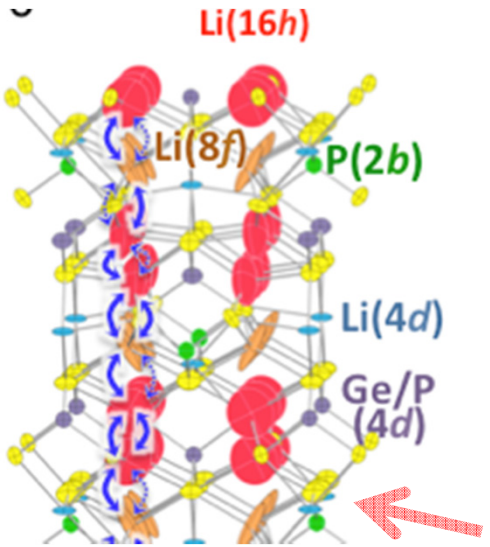
Reno in Korea further confirmed the result

Neutron Instruments at Materials and Life Science Facility

In operation: 10, Beam commissioning: 2, Under construction: 6

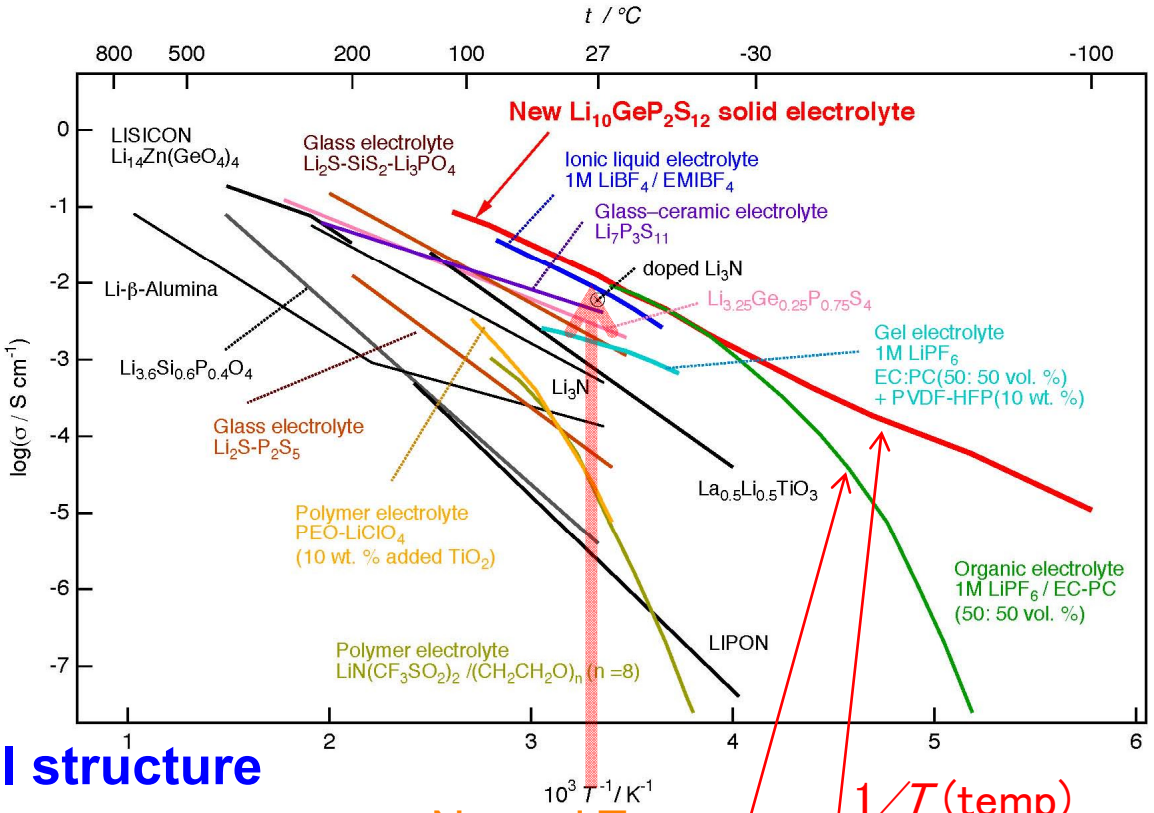


Battery of Ceramics



Crustal structure

log (conductivity)



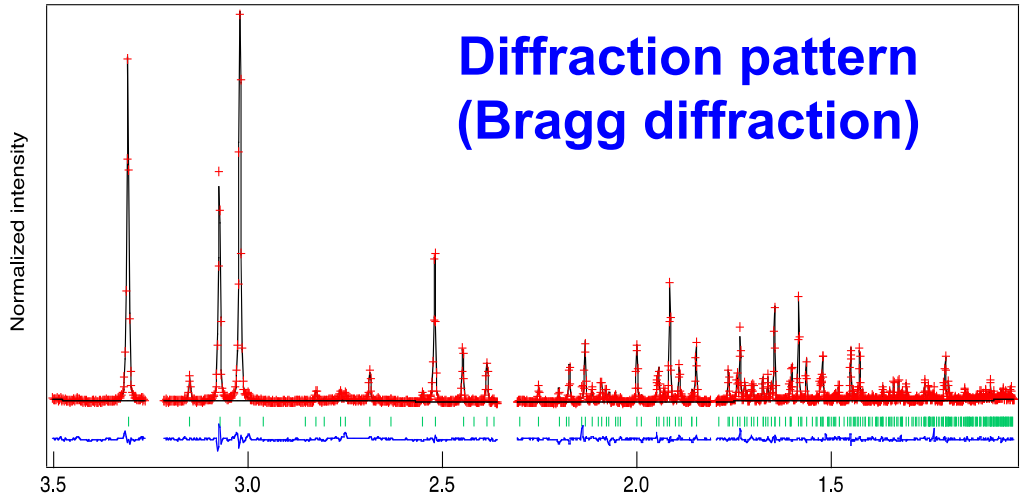
Normal Temp

1/T (temp)

Organic electrolyte

New ceramic electrolyte

TIT, Toyota, KEK, etc.
Nature Materials, 2011.7.31.



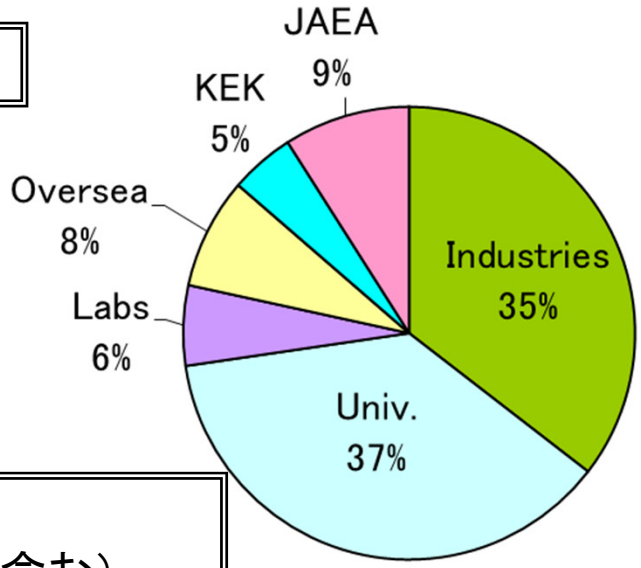
$P4_2/nmc$ (137); a = 8.69407(18) Å, c = 12.5994(4) Å

Top article in Nikkei Newspaper (morning version)

Proposals and Approvals

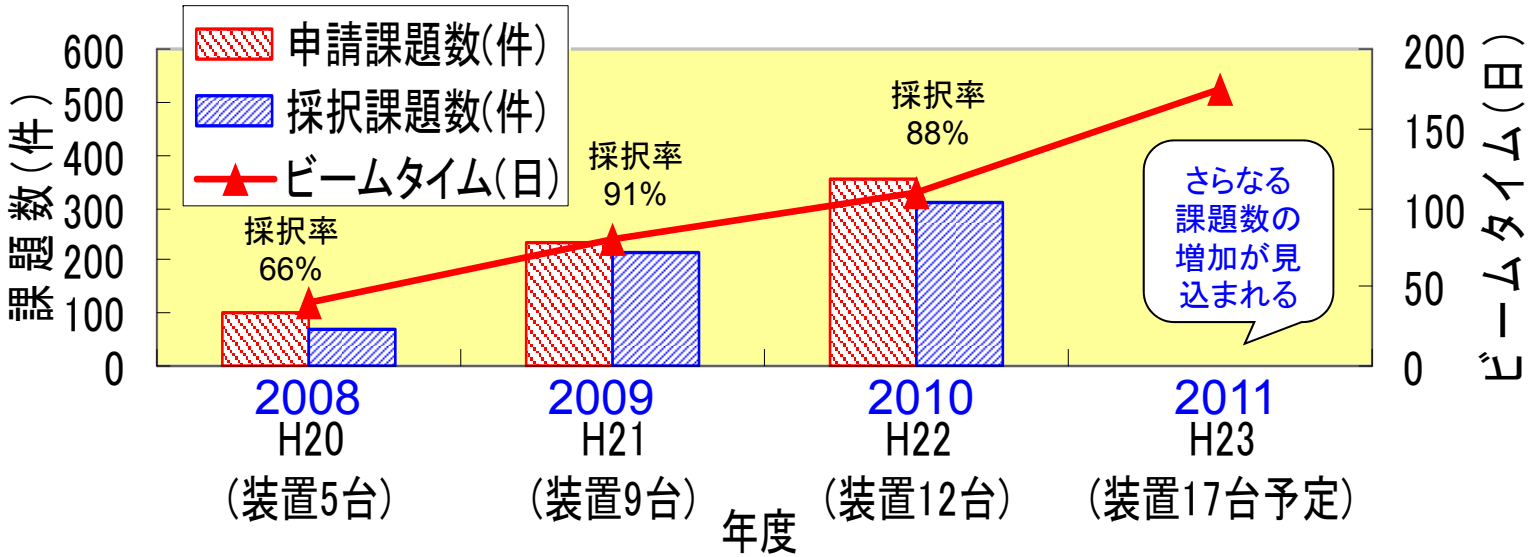
Every year the number of proposals are increasing

Proportion



MLF
Over 100
papers
per year

Proposals and Approvals
（プロジェクト利用、装置グループ利用を含む）



Summary Until March 11, 2011

- Highlights before March 11, 2011 (Earthquake)
  - Beam power has been steadily increasing: 200 kW for 3 GeV RCS and 145 kW for Main Ring at 30 GeV.
  - 400kW long-run test completed. Goal is 1 MW.
  - Neutrino Facility: Started to take data at Super Kamiokande. 6 electron-neutrino events were detected. Possibility of large θ_{13}. Encouragement to go to CP measurement.
  - Hadron Facility: About ready to run for many experiments. First data for penta-quark search were completed.
  - Materials and Life Facility: Neutron and muon beams already produced many fruitful data and the results are being published.
- Need more and serious efforts towards "internationali-zation".
- Also, need more effort toward "industrial usage".

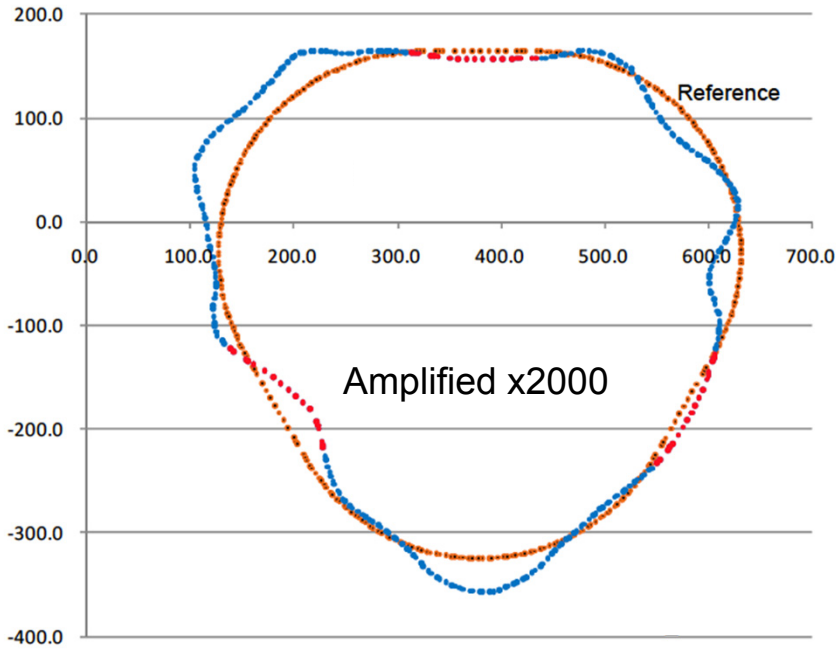
J-PARC

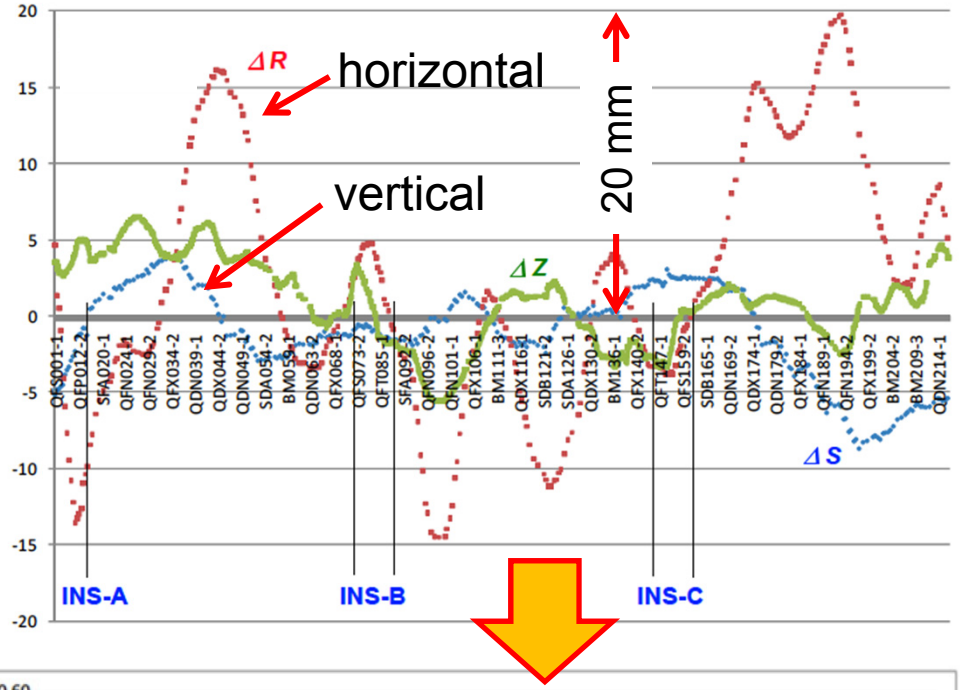
Status (after the Earthquake)

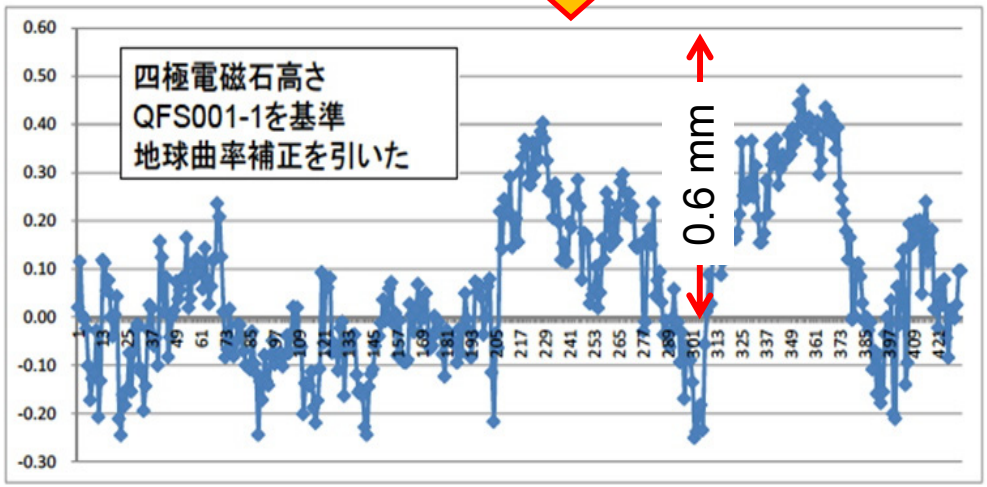
LINAC

3 GeV Synchrotron (RCS)

50 GeV Synchrotron (MR)



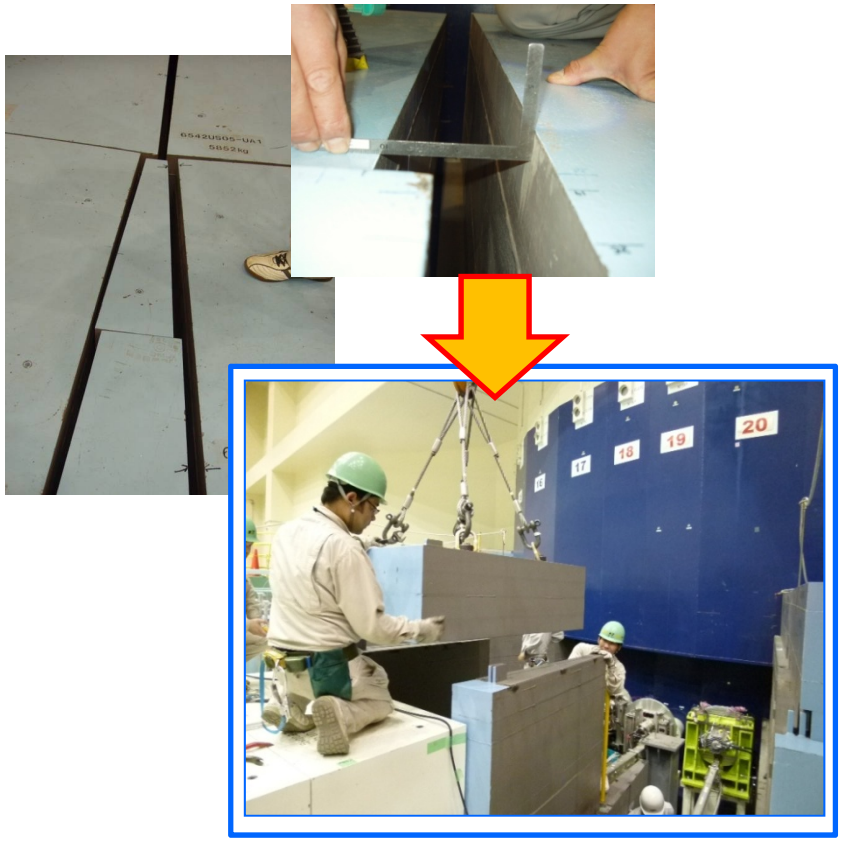




Maximum **20 mm** displacement (horizontal) and **8 mm** (vertical) for 400 magnets
All adjusted to **within 0.4 mm.**

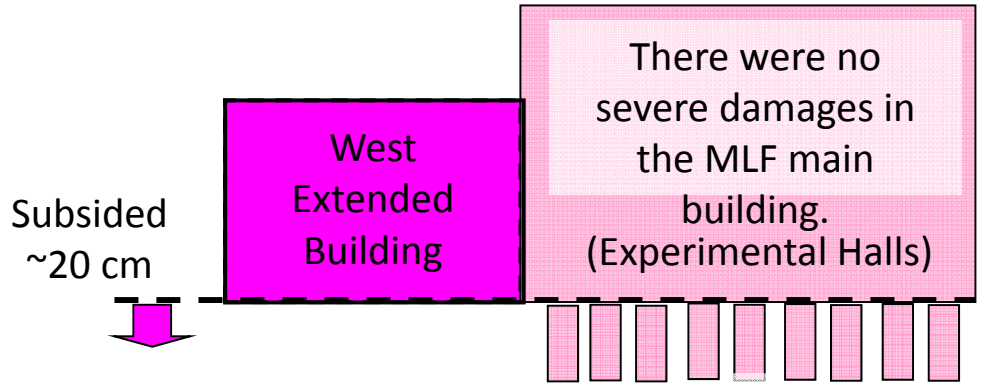
Materials & Life Science Experimental Facility (MLF)

Immediately after the Earthquake



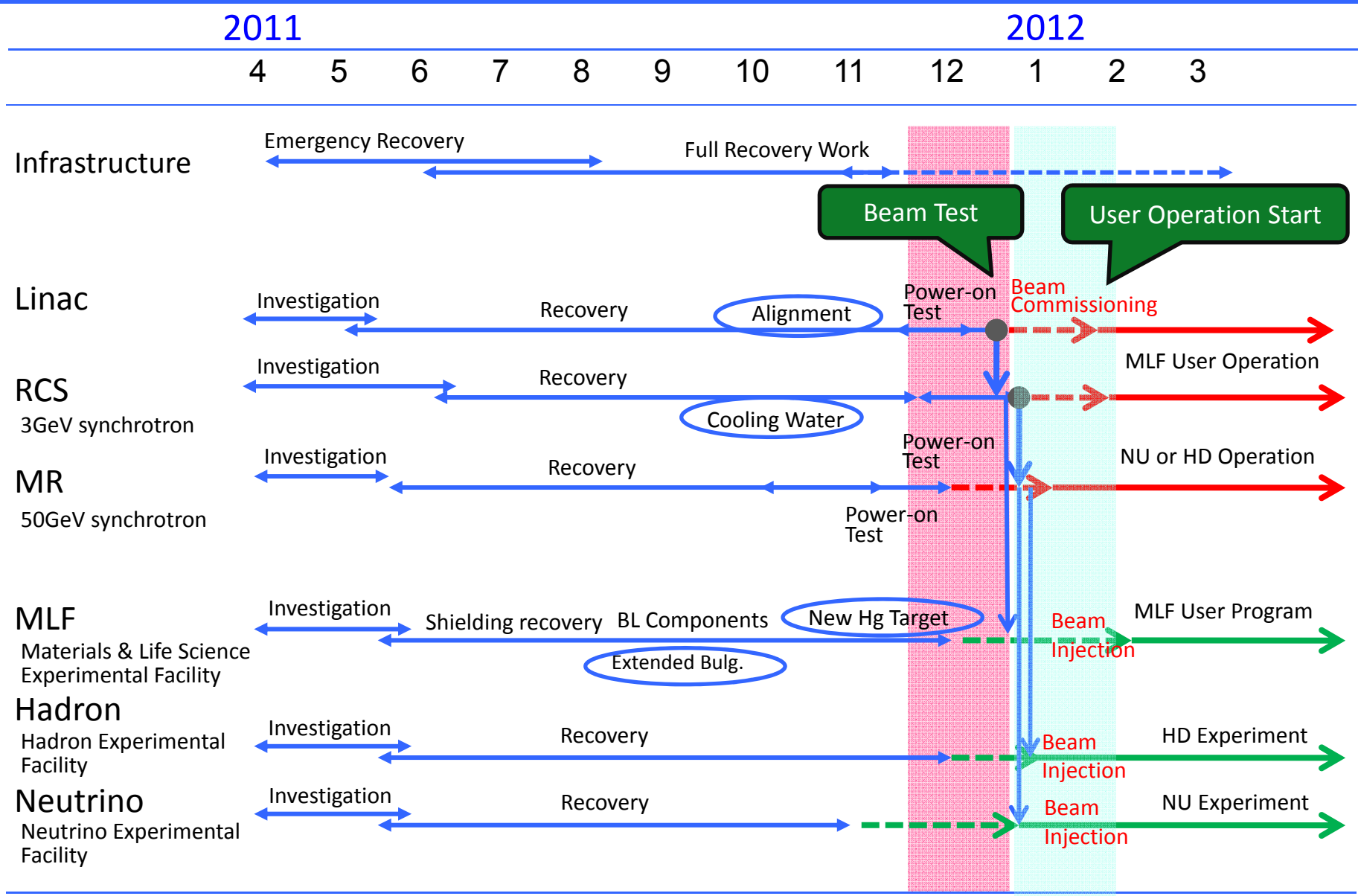
Restacking all Blocks

530 pieces and 2800 tons in total



Neutrino & Hadron Experimental Facilities

J-PARC Recovery Schedule (@2011.5.20)



All the J-PARC members worked hard and coherently to attain the December Recovery.

December 9, 2011

09:30 Key was on.

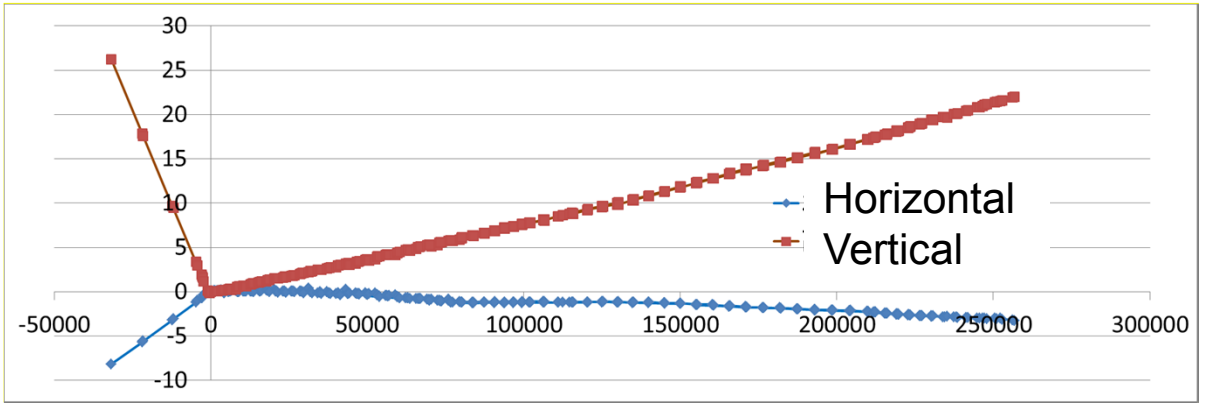
Nov. of 2006. The first beam was on at the Linac.

3 days before the target date

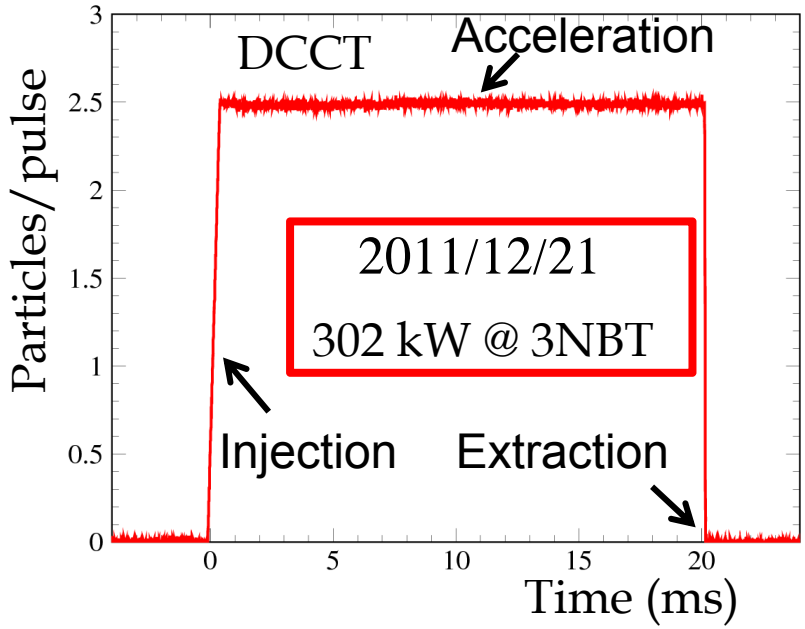
14:00 Beam went throughout the Linac at 3 MeV with RFQ acceleration.

Linac and 3 GeV

Final vacuum leakage test



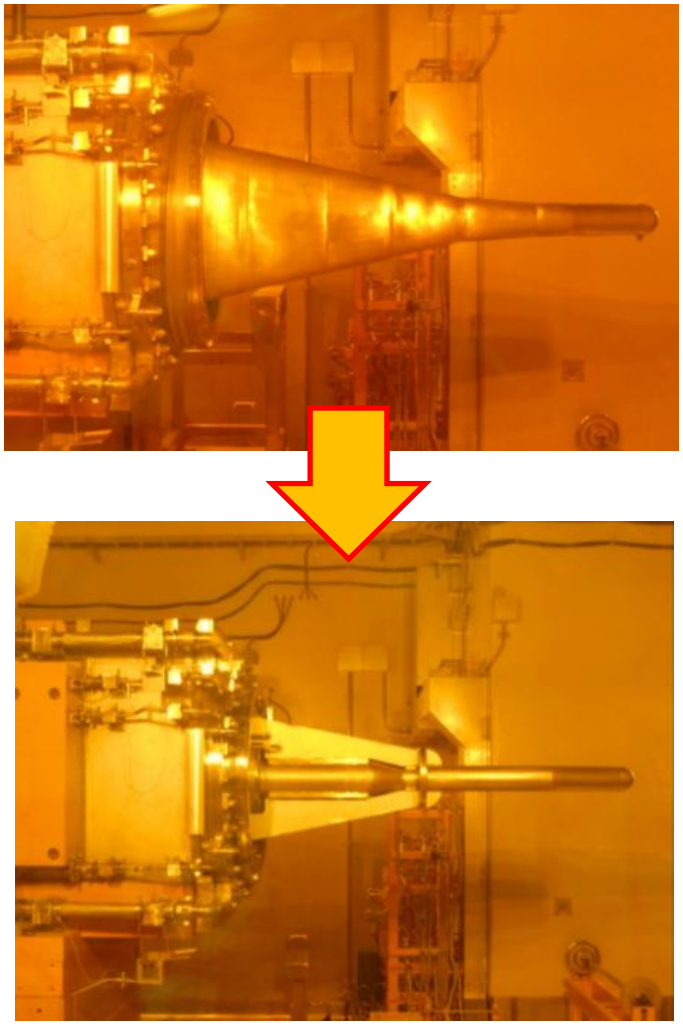
Linac Alignment



Beam to 3 GeV: December 17

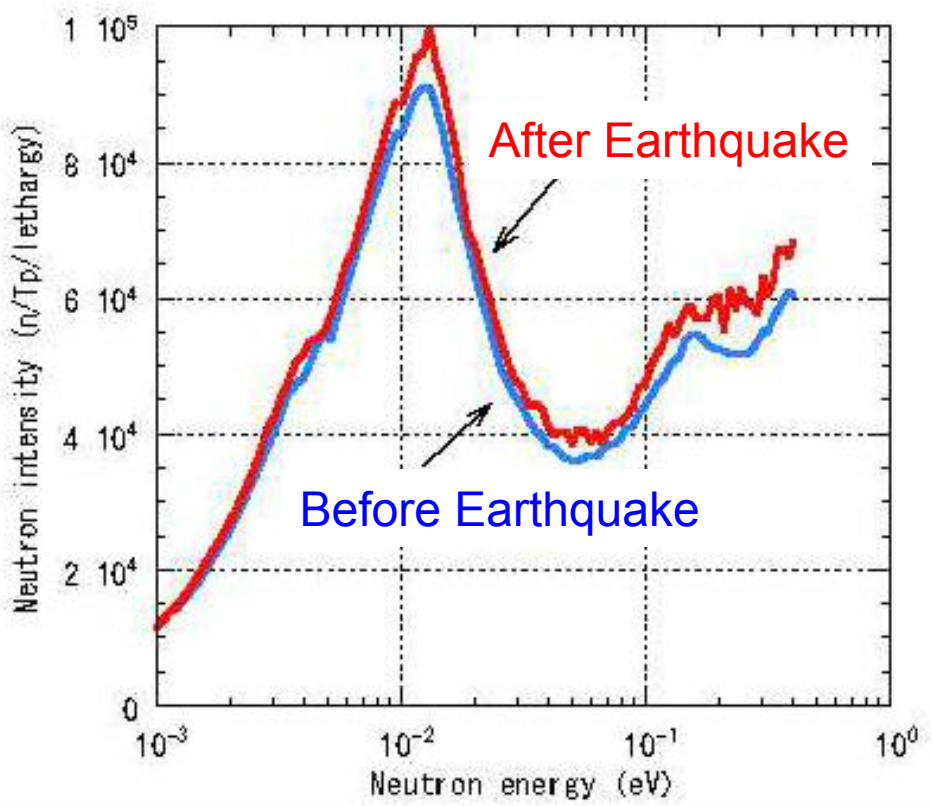
Attained to 300 kW: December 21

Neutron on the Target



Old and New Targets

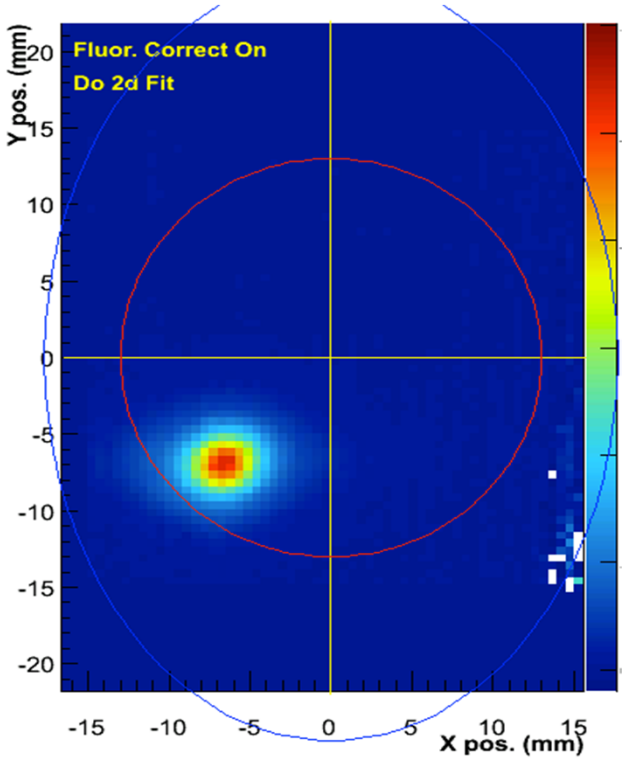
Beam to Neutron: December 22



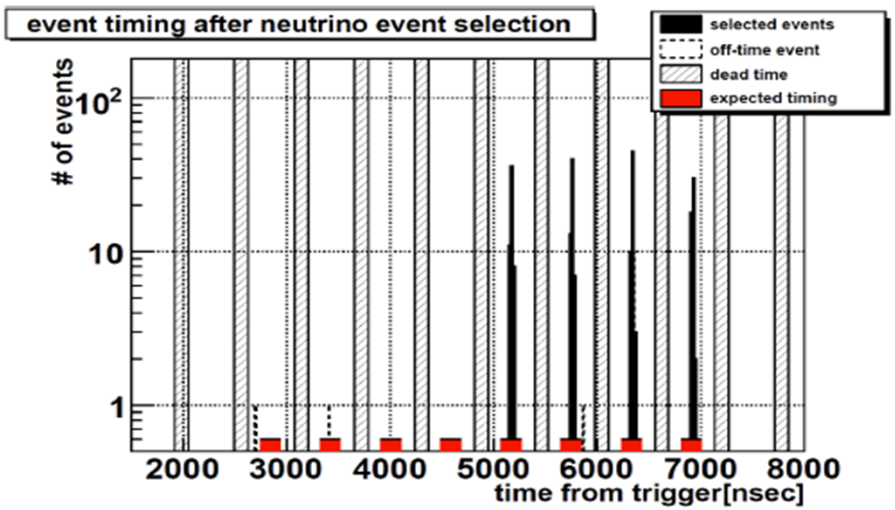
Unfortunately, the bubbler is not working properly, so that the neutron beam line can accept 100 kW at the time of first beams.

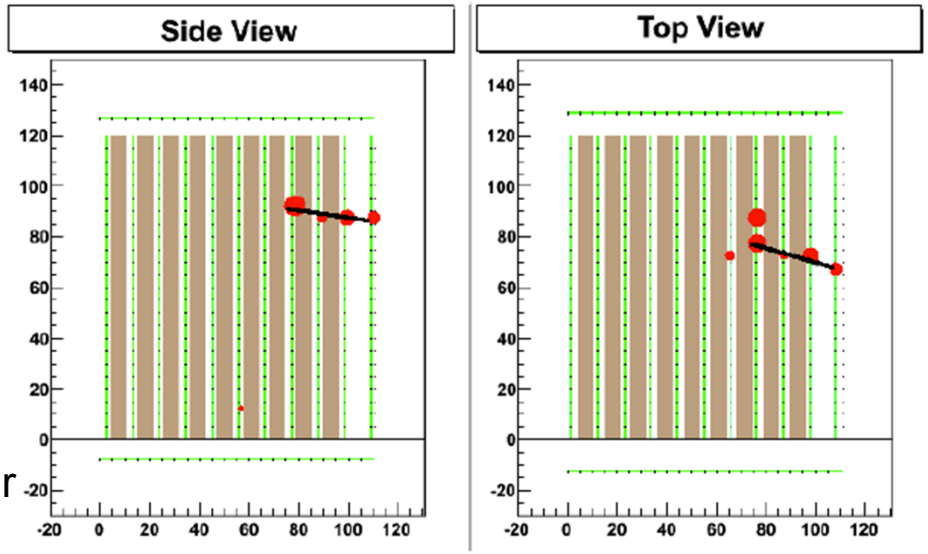
Neutrino Events

Beam to 50 GeV: December 22
Beam to Neutrino: December 24



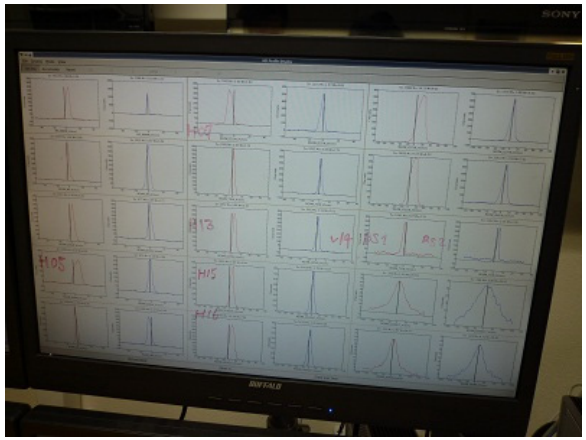
First Proton on Target





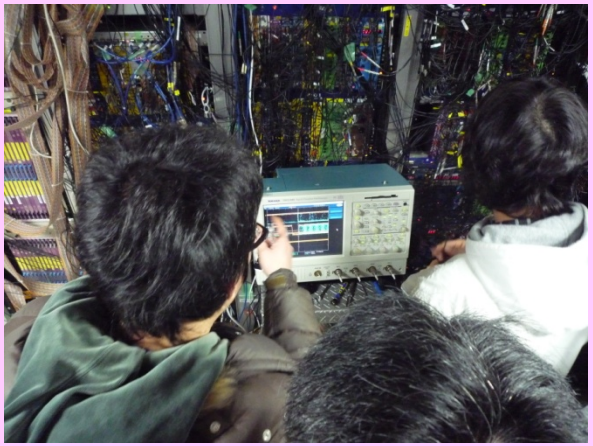
On-site Detector events

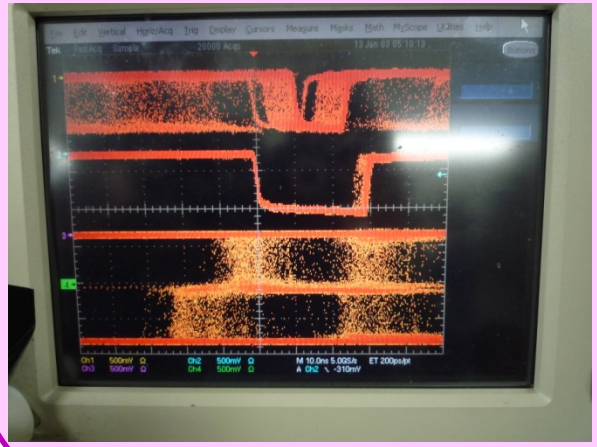
First Beams to Hadron (1/28/12)



Beam adjustment process.

Beam at the Target





Beam=BH1⊗BH2

Beam⊗TOF

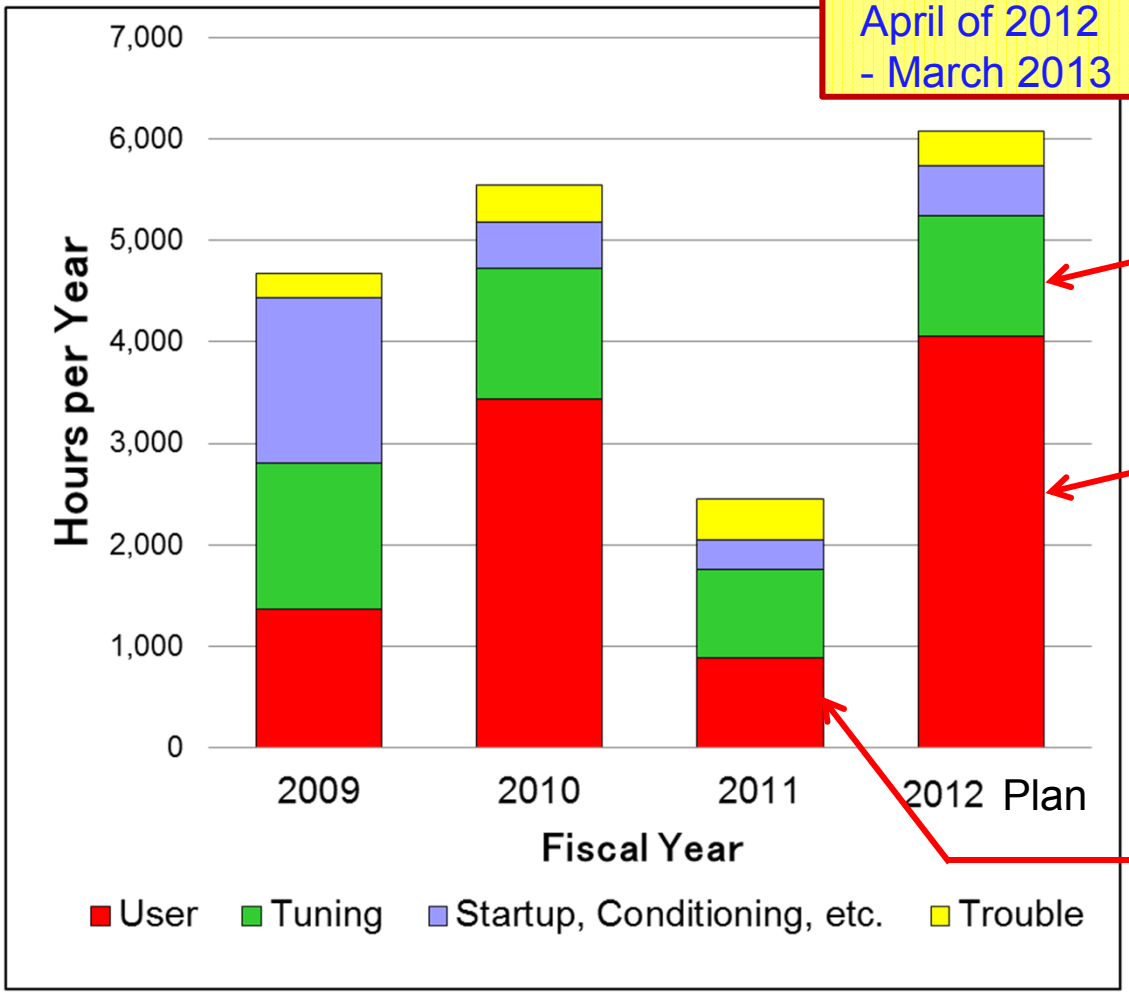
Beam⊗LC⊗AC^{bar}⊗TOF

Veto=TOF⊗AC

Run Plan

JFY2012 = April of 2012 - March 2013

180 days for Users



Tuning

Run for Users

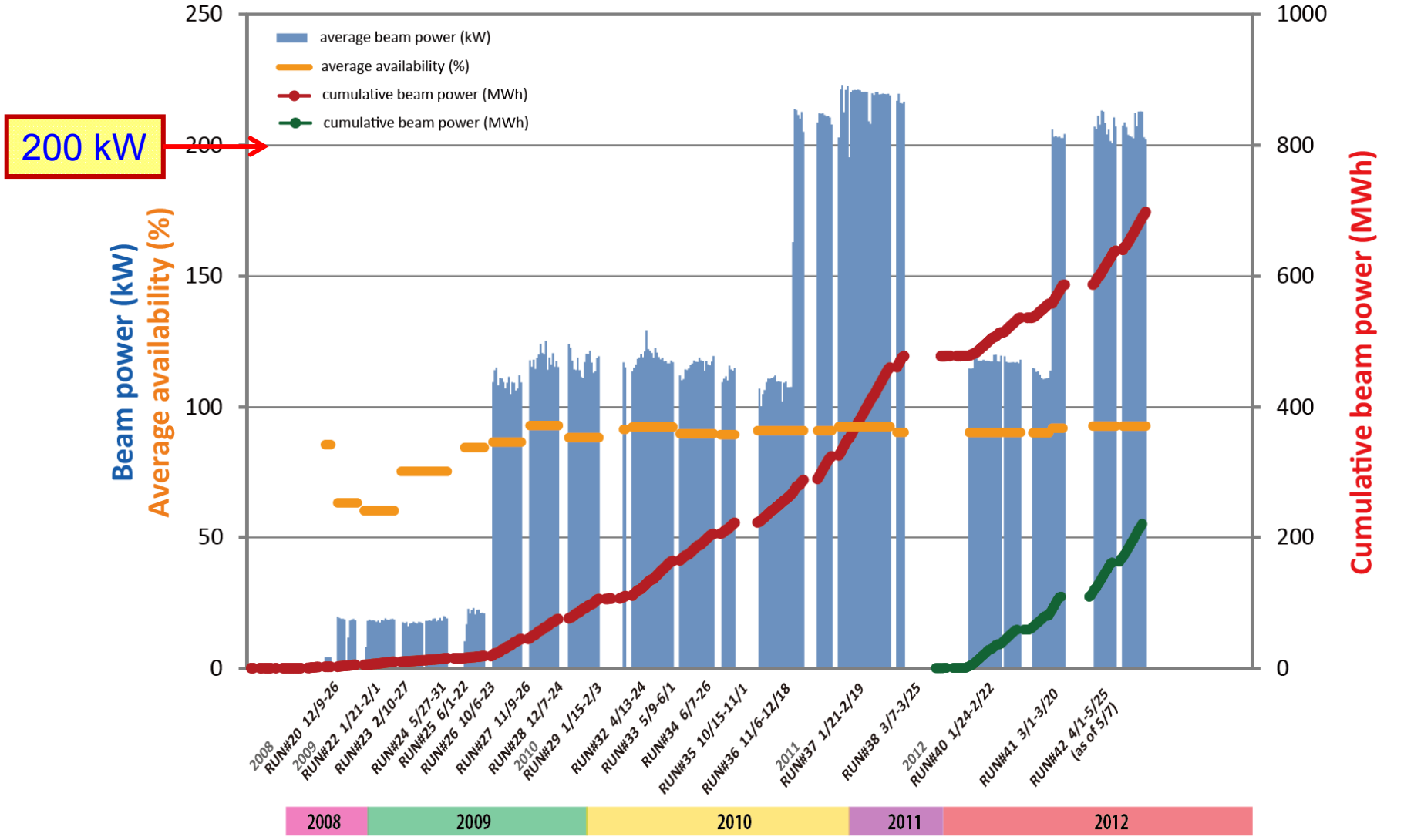
We could provide beams of 1000 hours for users (Jan-Mar, 2012)

Summary of Recovery from the Damage

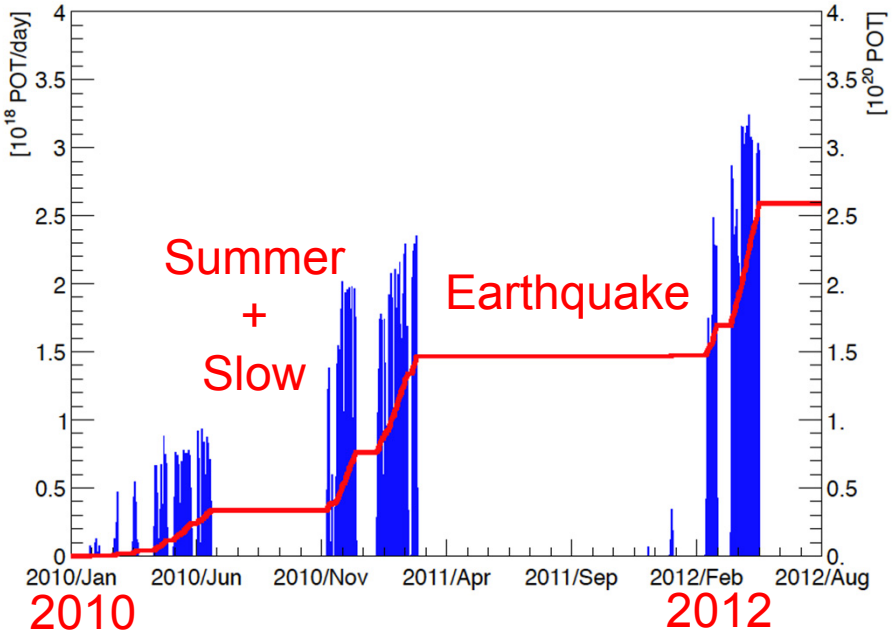
- No Tsunami Effect
  - We prepared up to 8 m Tsunami.
- Main Buildings were almost OK
  - Many underpins for major buildings.
- However, many utility buildings, roads, and extended buildings had significant damage.
- When to recover ?
  - Aiming at recovering by the end of 2011 (Done).
  - Expect to run about 2 mo. in JFY2011 (Done).
  - Obtained permission from TEPCO for 55 MW.
- Operation of JFY2012 (starting 4/1/2012)
  - Planned 8 cycle (~180 day) operations for users.

Accelerator Performance and the Future

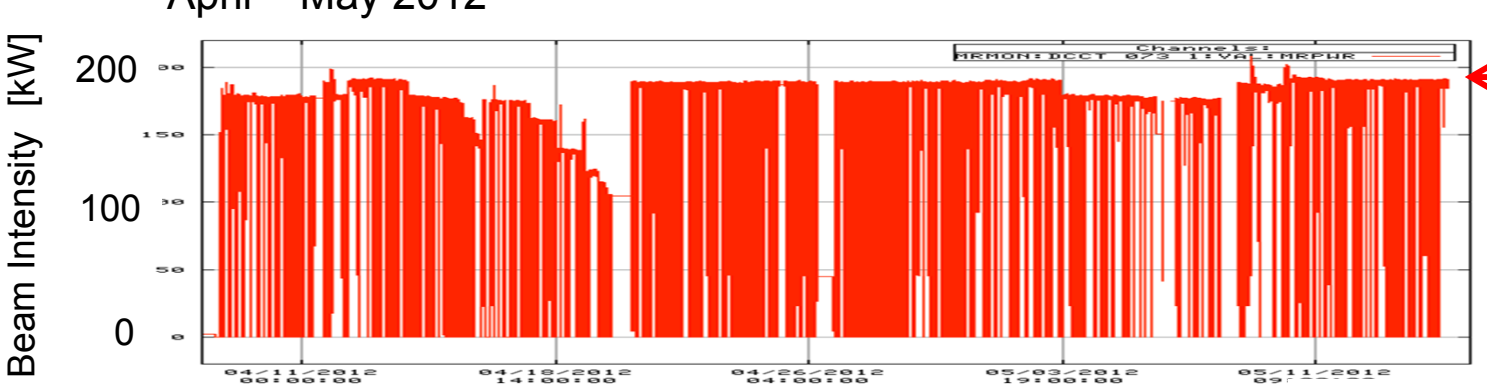
Beam Power at the Neutron (RCS)



Beam Power at the Neutrino (MR)



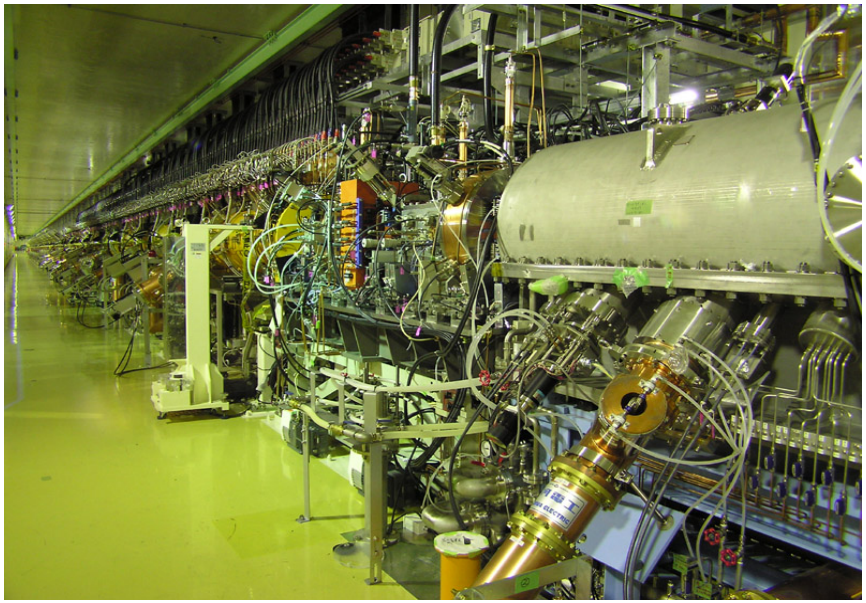
April – May 2012



April 7, 2012

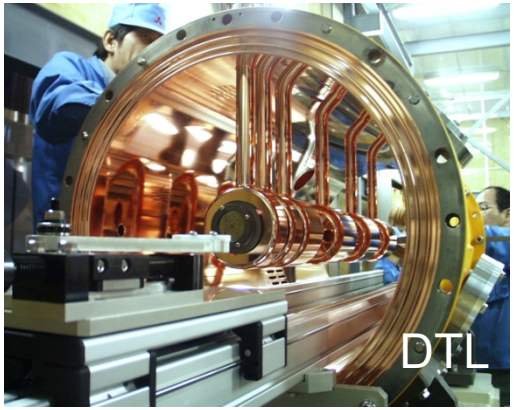
May 15, 2012

Linac

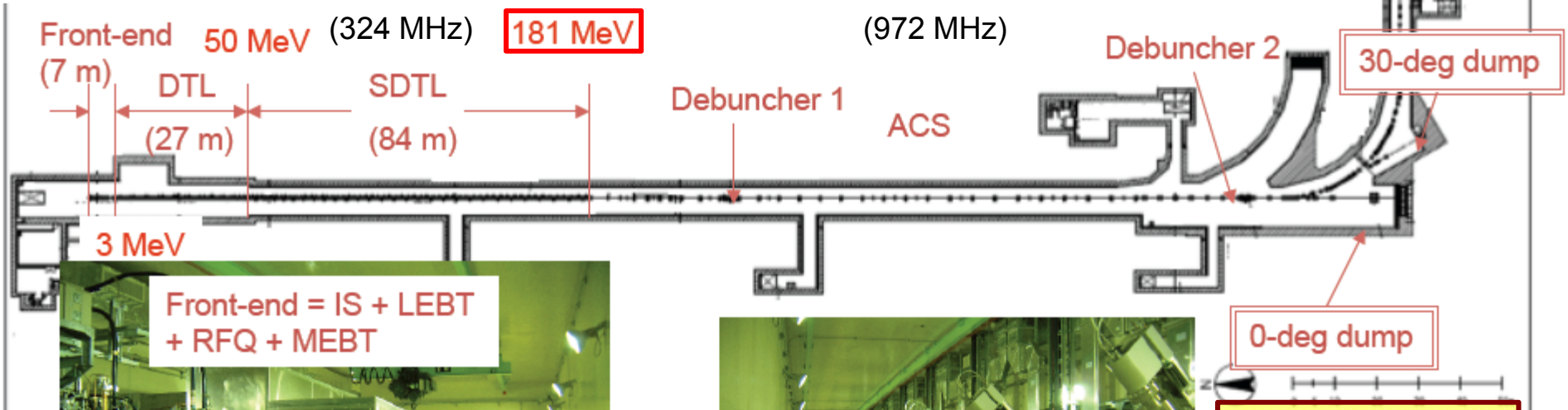


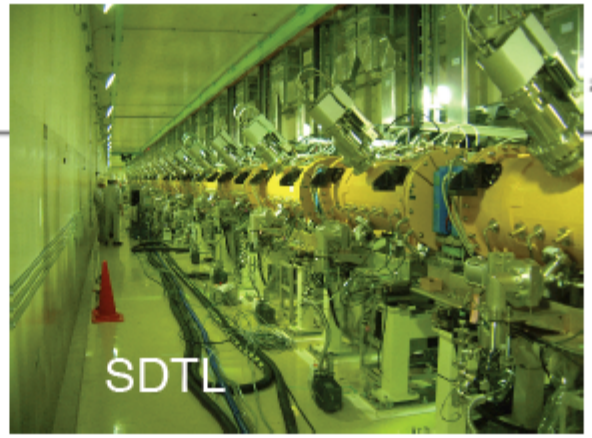
Linac (330m)

J-PARC Linac



Under Construction
presently up to 181 MeV
In JFY2013 the construction
up to 400 MeV will be completed

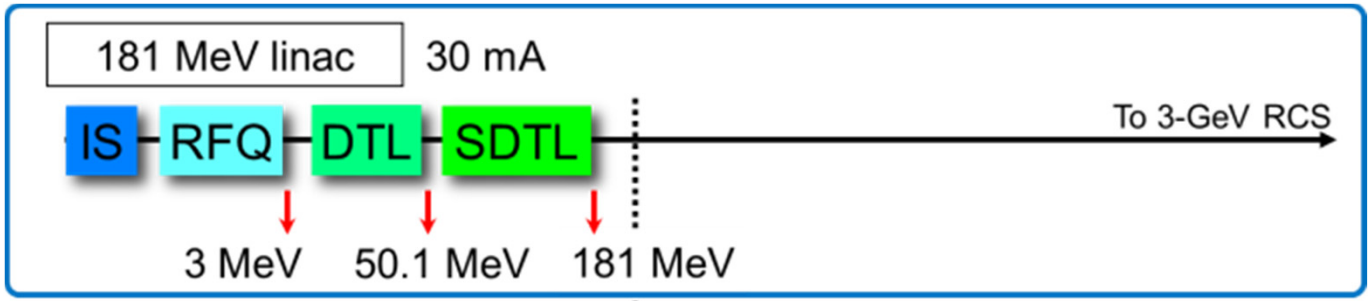




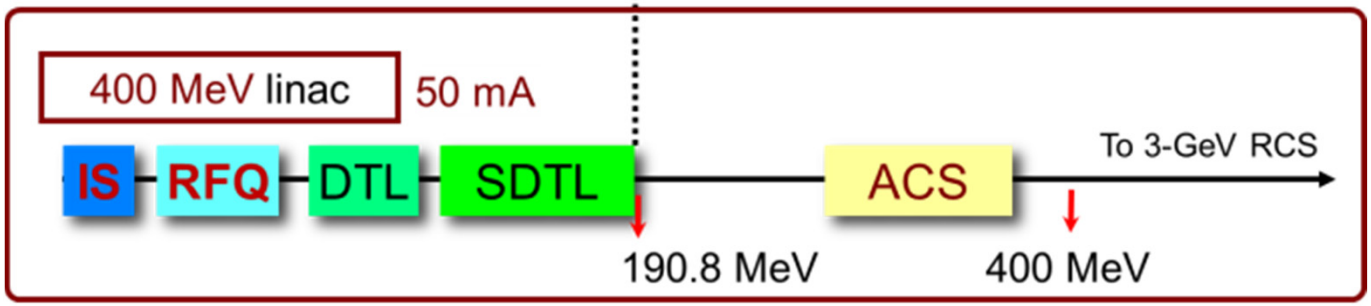
In 2009 RFQ trip was a big issue. After improving vacuum, this problem has disappeared.

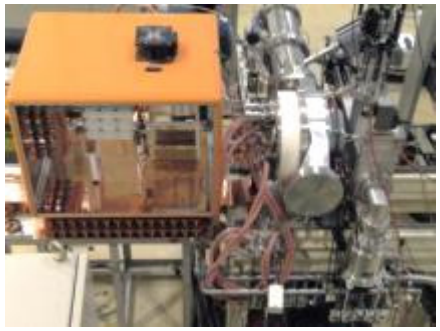
Energy Recovery of Linac to 400 MeV

Present Configuration

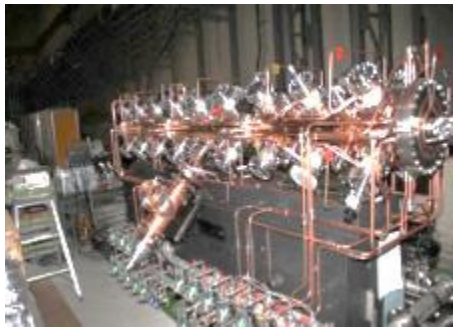


To attain 400 MeV and 50mA





New Ion Source

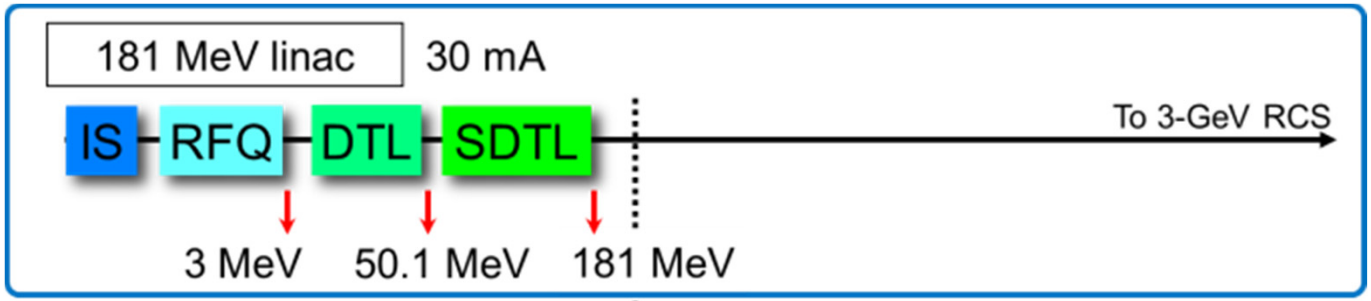


New RFQ

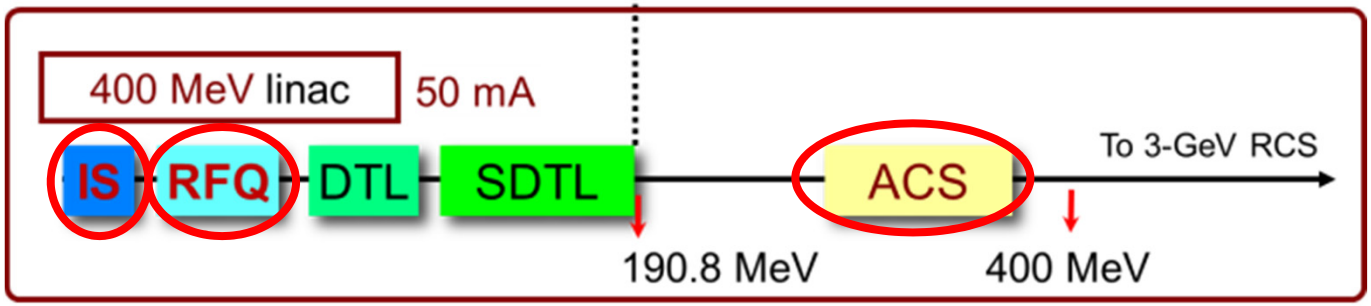
ACS

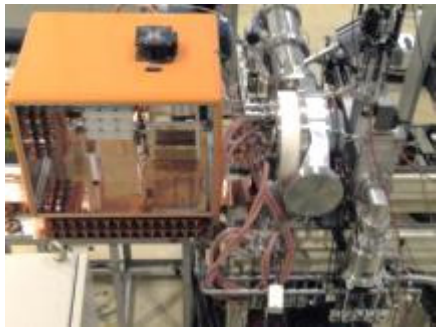
Energy Recovery of Linac to 400 MeV

Present Configuration

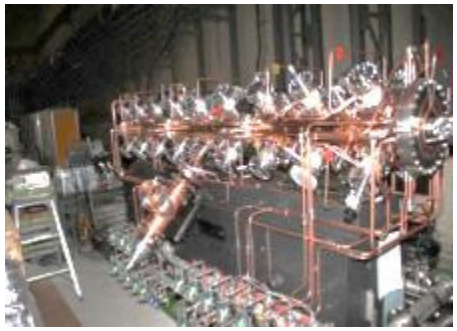


To attain 400 MeV and 50mA





New Ion Source

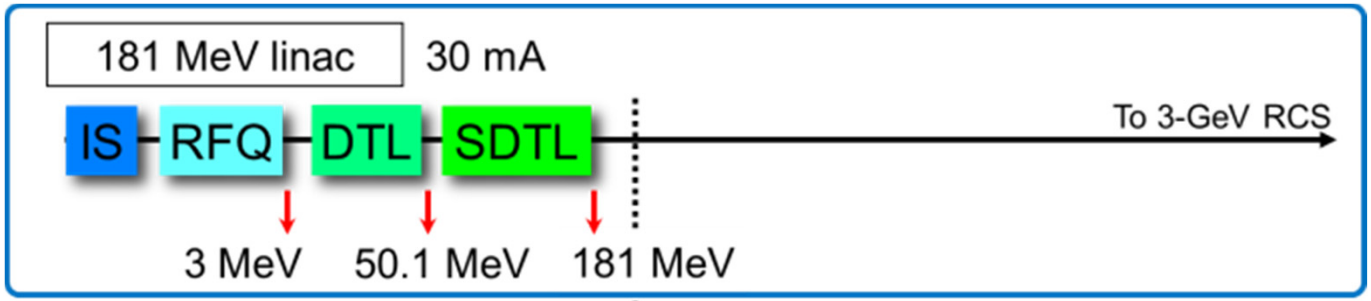


New RFQ

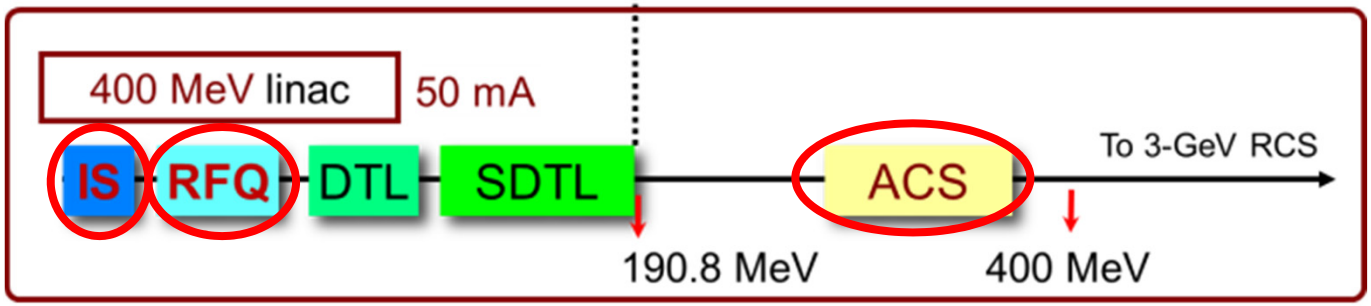
ACS

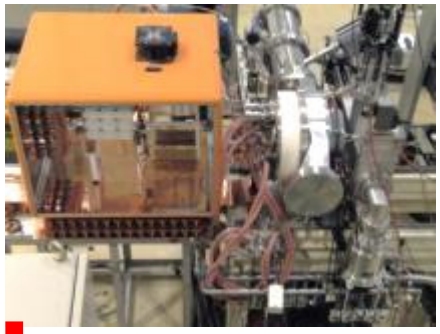
Energy Recovery of Linac to 400 MeV

Present Configuration



To attain 400 MeV and 50mA





New Ion Source

New RFQ

ACS

Construction Status of 400 MeV Linac

2012.3: ACS construction 19 out of 21 completed

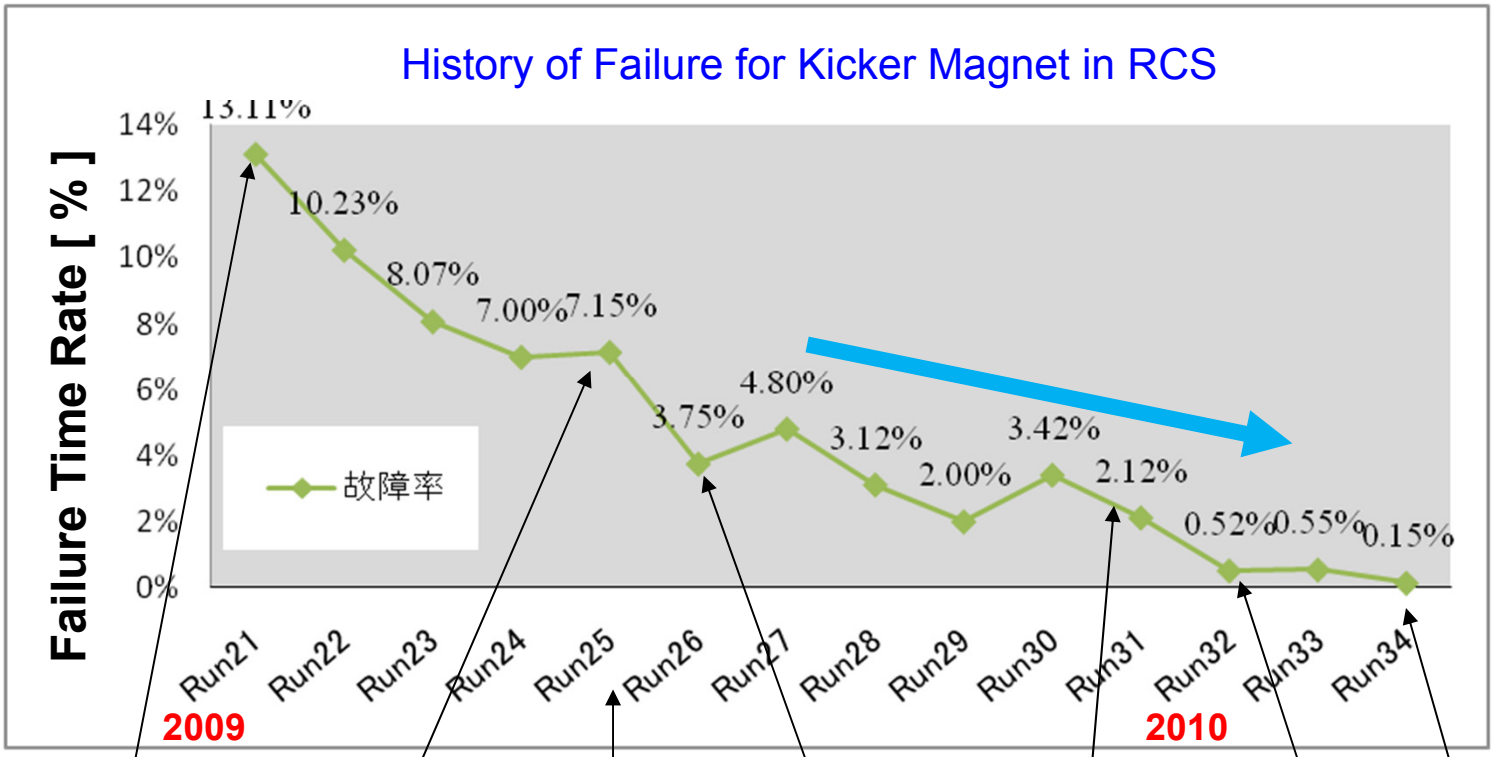
Klystron

High power radio frequency device

3 GeV RCS

3 GeV Synchrotron (350m)

Stabilization of Kicker Magnet



- Conditioning
- Adjusting Reservoir Power

Automatic drift corrections

Conditioning

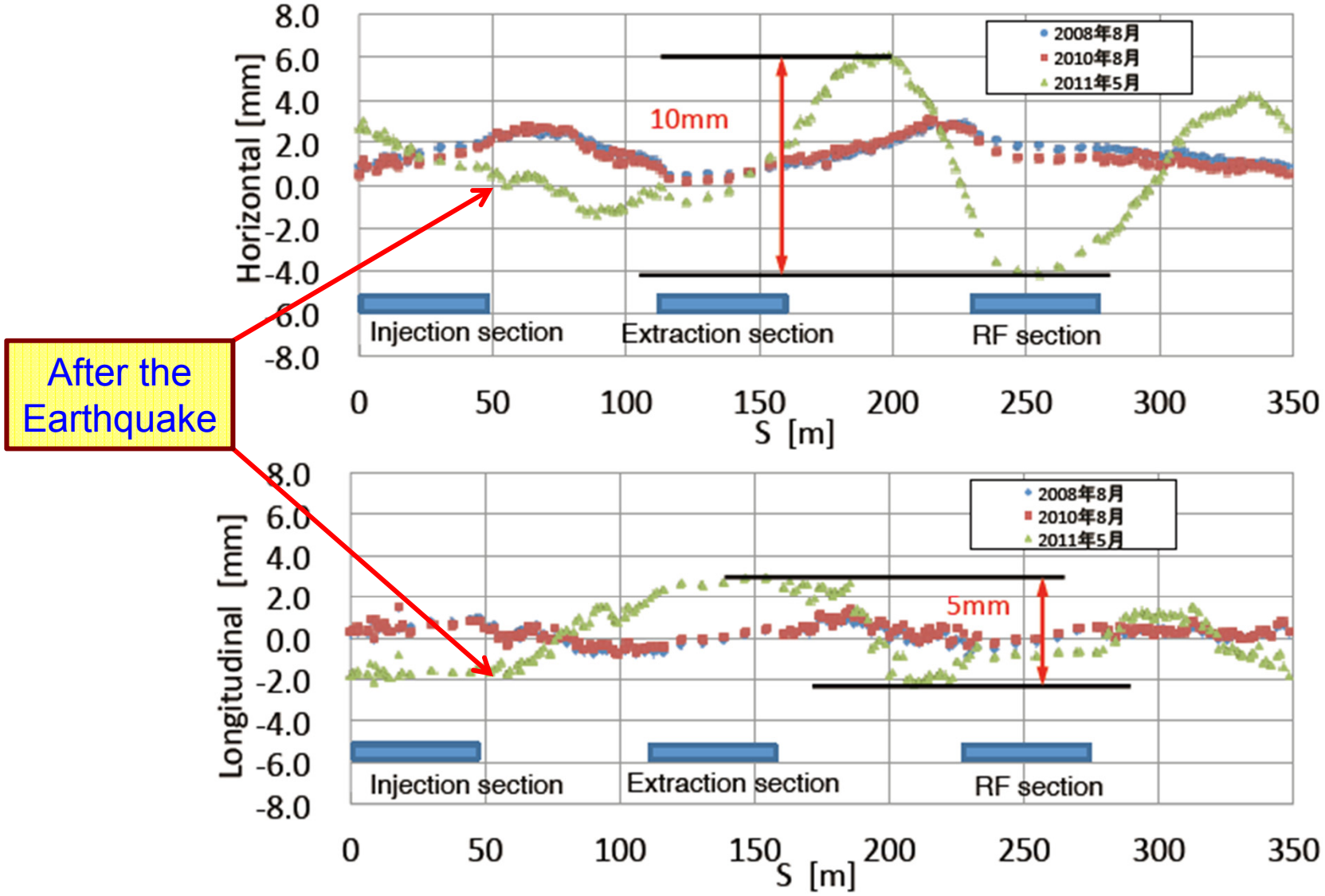
Adjusting Cathode Heater

Replacing Drifting Tubes

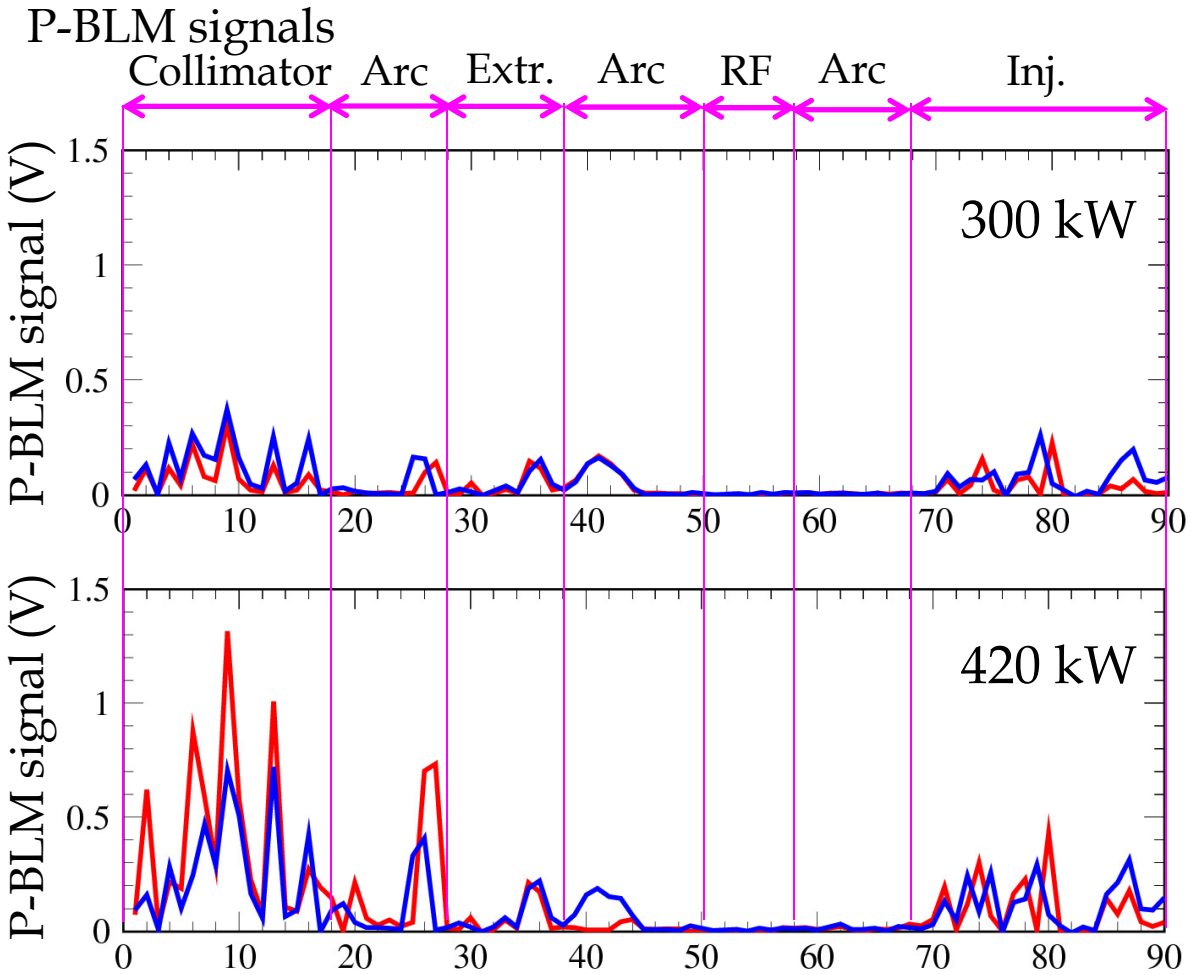
No need to replace Tubes

Shortening the Aging

Earthquake Effect on RCS



Beam loss at 400 kW for the RCS



Before the earthquake

After the earthquake

No large difference in beam loss

Significant difference in beam loss

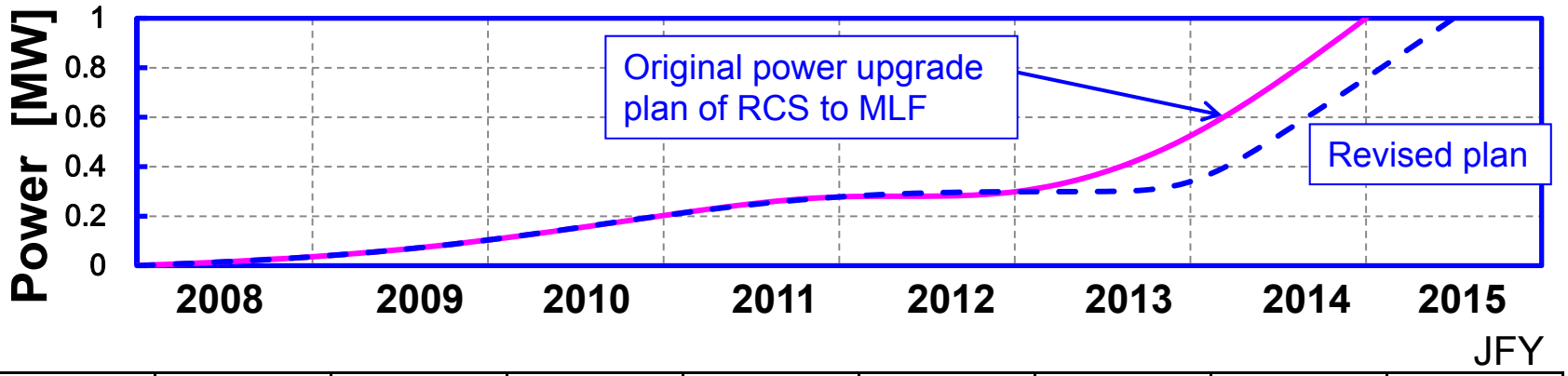
Beam loss increased after the earthquake for 420 kW

Particle loss before the earthquake : ~ 0.4%

Particle loss after the earthquake : ~ 0.8%

In the summer of 2013, the entire adjustment of the RCS will be done

Power upgrade for Linac & RCS



Linac	400MeV			Fabrication, Offline test			Installation, Beam test		
	Ion source, RFQ			R&D, Fabrication, Offline test					
RCS	400MeV Inj.			R&D, Fabrication, Offline test				User operation, Power increase	
	Realign ment								

Budget for the Linac and the RCS upgrade has been secured.

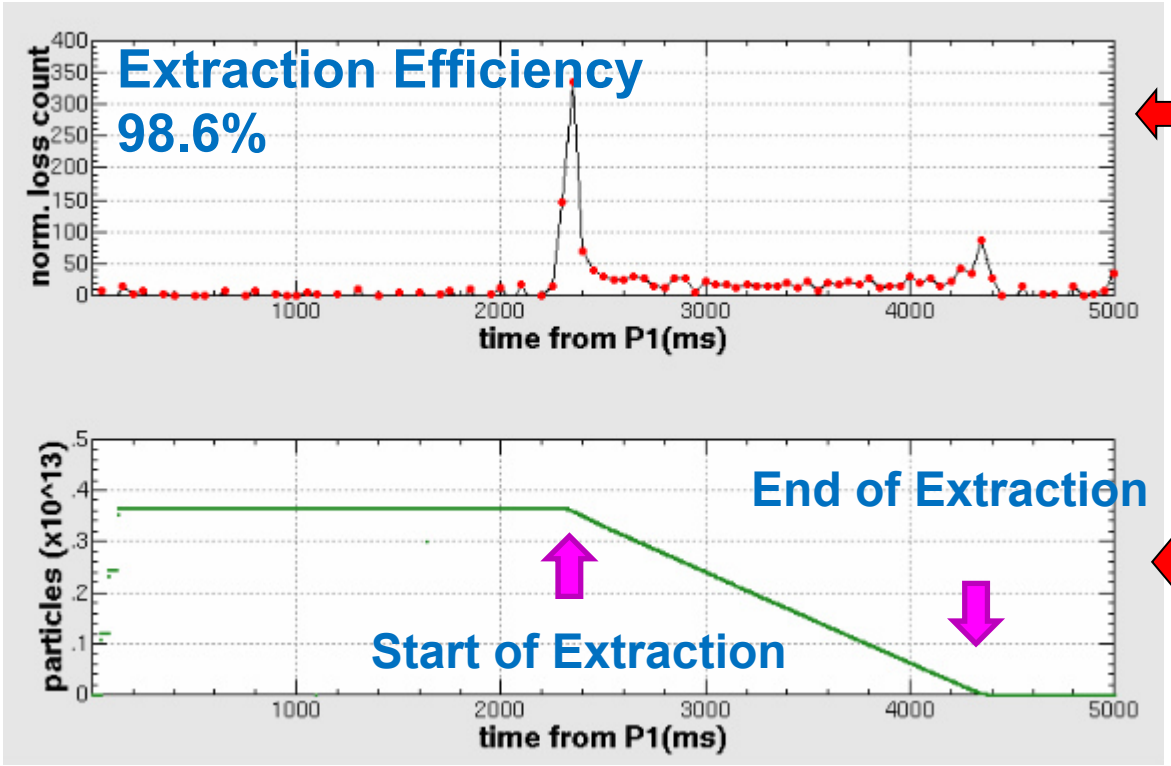
50 GeV MR

50 GeV Synchrotron (1600m)

Special lattice structure to avoid transition energy.

Also, accelerating 100 tera protons/pulse

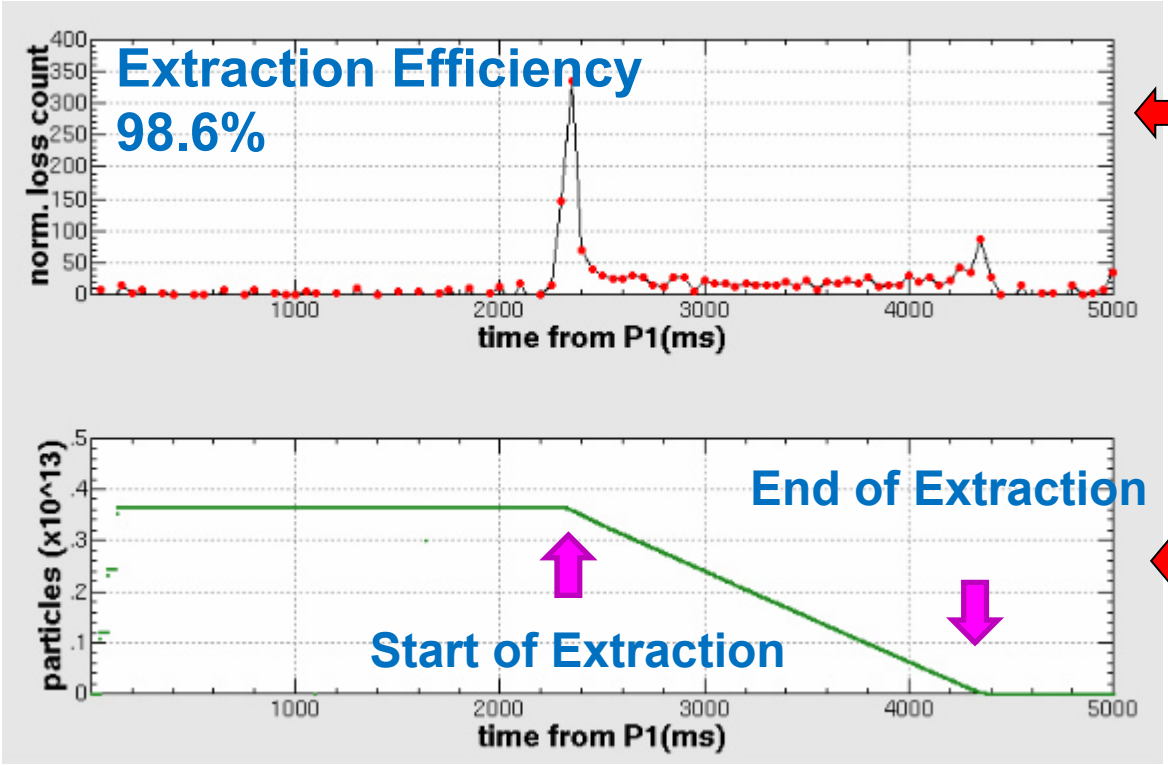
99.5 % Extraction for Slow Beams



Time Dependence of Beam Loss

Stored Beam in MR

99.5 % Extraction for Slow Beams

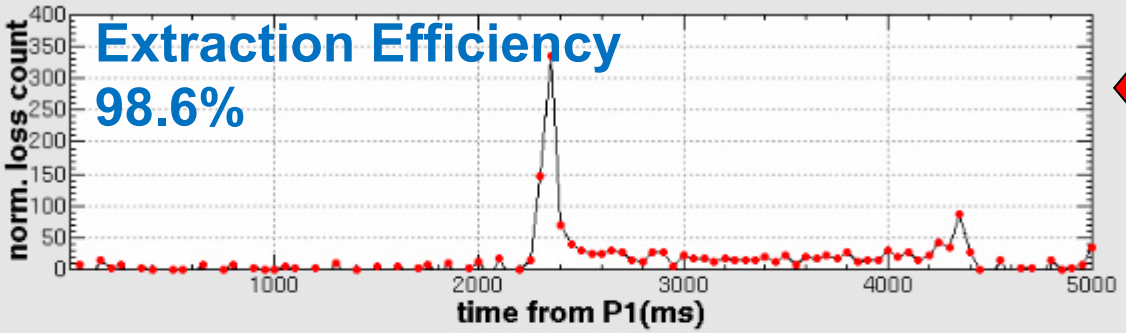


Time Dependence of Beam Loss

Adjusting Dynamic Bump

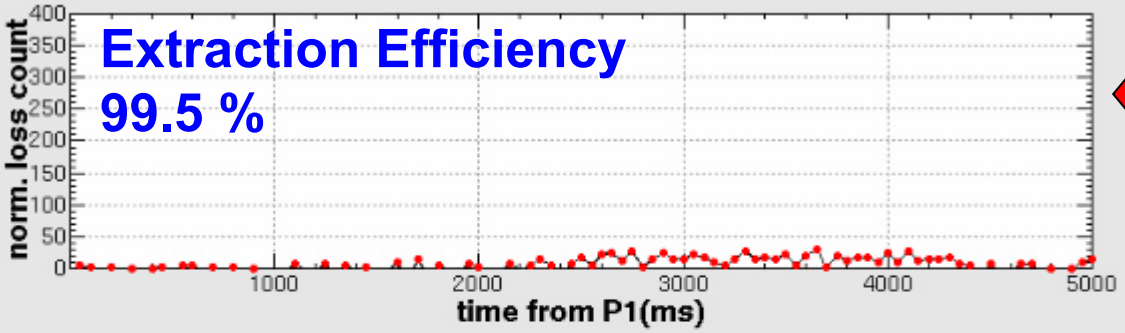
Stored Beam in MR

99.5 % Extraction for Slow Beams

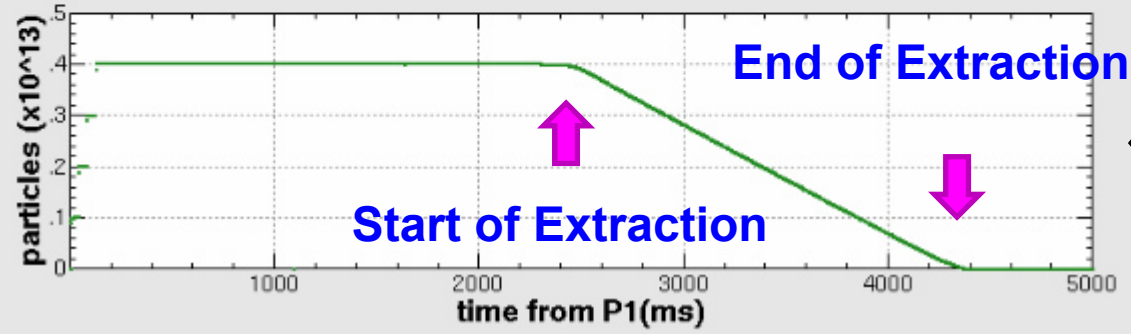


Time Dependence of Beam Loss

Adjusting Dynamic Bump



Time Dependence of Beam Loss

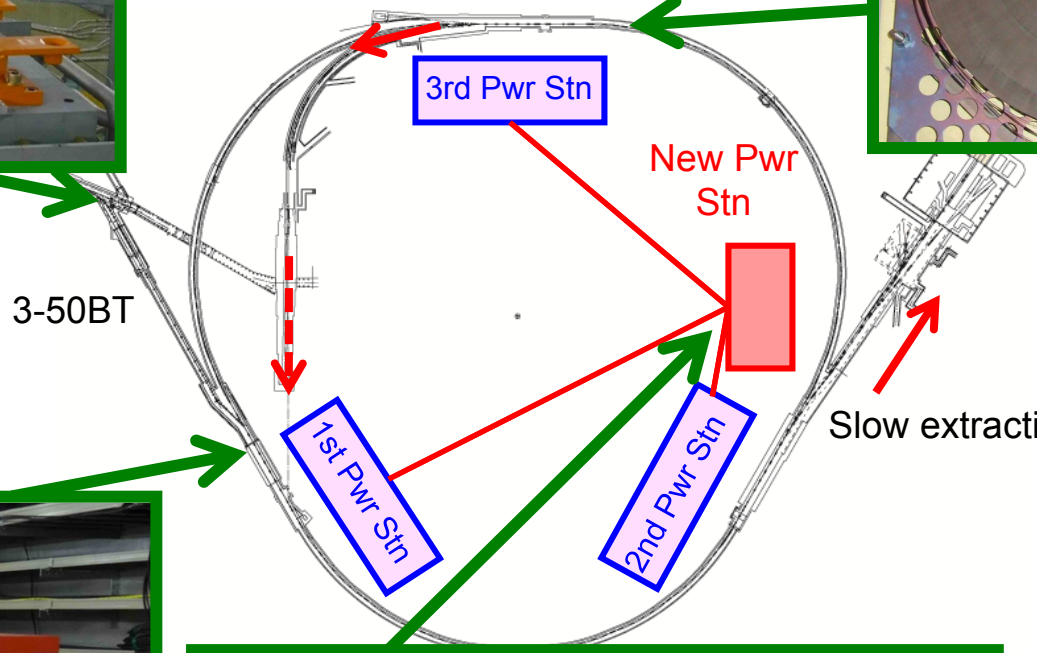


Stored Beam in MR

Higher Repetition Rate

③ Improving Injection and Extraction

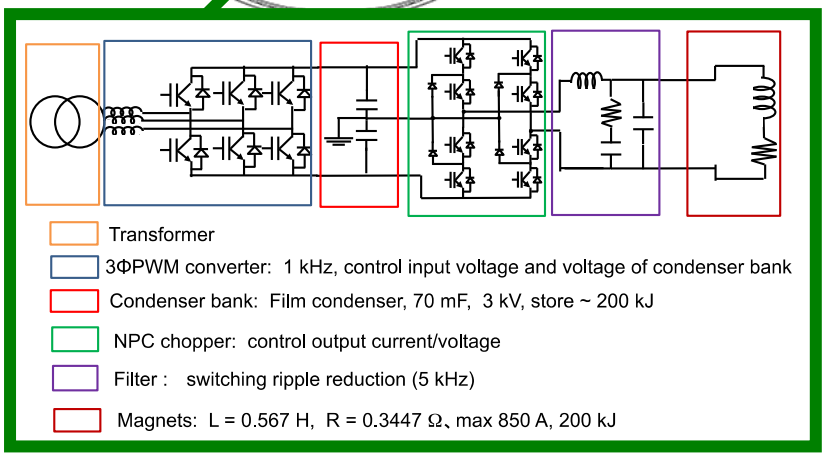
② Improving Voltage/meter by increasing Impedance by a factor of two



Collimeter for Injection

④ Improving Shielding for Injection Collimeter

450 W→2 kW



① New Power Supply to increase Repetition and to reduce Ripple Review will be conducted in 2012

Mid-Term Plan for MR

	2011	2012	2013	2014	2015	2016	2017
Magnet power supply							
R&D and prototypes	←	—	—	→			
Manufacture and installation				←	—	→	
Infrastructure			←	—	—	→	
RF							
#9 RF system (FT3M type)	←	→					
R&D of FT3L cavity	←	—	→				
Manufacture and installation (FT3L type)			←	—	—	→	
Injection and Fast extraction							
Injection kicker & septum upgrade	←	—	—	—	→		
FX kicker & septum upgrade		←	—	—	→		
Collimator upgrade							
Additional collimators		←	→				
Additional shields	←	—	→				
SX upgrade							
SX collimator	←	—	→				
Titanium chambers		←	→				
Expected beam power for FX [kW] *	100	200	300	400	→		750
Expected beam power for SX [kW] *	3	10	50	Toward 100			> 100

* Powers shown in this table are expected powers after each summer shutdown period.

Summary

- Unique Accelerator Project Multi-purpose facility
  - World class proton facility → Variety of secondary beams → Multipurpose
  - Broad fields in Science (materials and Life, Nuclear and Particle, Nuclear Industrial, etc.) → Interdisciplinary facility
- Major Issues for Coming 5 Years
  - The first priority: To achieve 1 MW at 3 GeV RCS and 0.75MW for Main Ring (MR).
  - Experimental devices for hadrons and muons must be expanded.
  - Nuclear transmutation (ADS) must be initiated.
  - Infra Structure, such as main research building, radioactive handling room, lodging for users, etc. must be prepared or expanded.
  - Internationalization and Open to industries
- Major Goal: Production of Top-Level Scientific Results
  - Production of world leading results.

Future Five Years
(Review by MEXT)

Presented in
May 14, 2012

Materials and Life Science --- **Particle and Nuclear Physics**

About 1,000 Users
(Outside Japan 10%)

J-PARC Accelerator

About 1,000 Users
(Outside Japan 60%)

Future Five Years
(Review by MEXT)

Presented in
May 14, 2012

Higher
Specs

Higher Flux

Materials and Life Science

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J-PARC Accelerator

Future Five Years
(Review by MEXT)

Presented in
May 14, 2012

Higher Specs

Higher Flux

Multi-plicity

Muon
μSR, g-2, etc

High Flux
Pulse Neutrons

Neutrino
Oscillation

Kaon Factory
K/**p**/μ/p expts

Multi-plicity

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Higher Flux

Research Building

Lodging

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J-PARC Accelerator

Future Five Years
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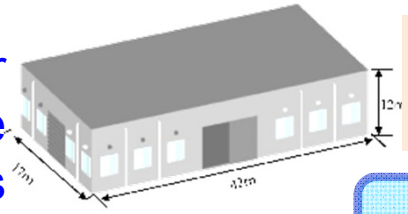
Presented in
May 14, 2012

Storage for Radioactive Materials



Higher Specs

Higher Flux

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Future Five Years
(Review by MEXT)

Presented in
May 14, 2012

Storage for Radioactive Materials

Higher Specs

Safety

Infrastructure

Higher Flux

Research Building

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High Flux
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Oscillation

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K/**p**/μ/p expts

Multi-plicity

Materials and **L**ife **S**cience

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J-PARC Accelerator

Future Five Years
(Review by MEXT)

Presented in
May 14, 2012

Storage for
Radioactive
Materials

Higher
Specs

Industry Usage

Safety

Infrastructure

International
Facility

Higher Flux

Research Building

Lodging

ADS

Multi-
plicity

Muon
μSR, g-2, etc

High Flux
Pulse Neutrons

Neutrino
Oscillation

Kaon Factory
K/**p**/μ/p expts

Multi-
plicity

Materials and Life Science

Particle and Nuclear Physics

**About 1,000 Users
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J-PARC Accelerator

Future Five Years
(Review by MEXT)

Presented in
May 14, 2012

Storage for
Radioactive
Materials

Safety

Higher
Specs

Industry Usage

International
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Higher Flux

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ADS

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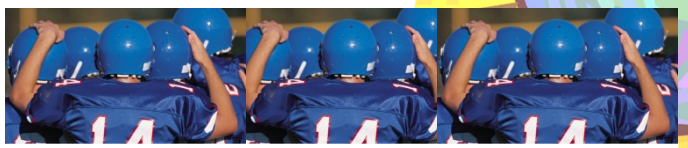
Materials and **L**ife **S**cience

Particle and **N**uclear **P**hysics



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J-PARC Accelerator

Future Five Years
(Review by MEXT)

Presented in
May 14, 2012

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Radioactive
Materials

Higher
Specs

Industry Usage

Safety

Higher Flux

International
Facility

Infrastructure

Research Building

Blooming Inter–
disciplinary Science

Lodging

ADS

Multi–
plicity

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μSR, g-2, etc

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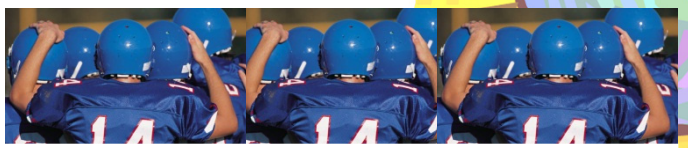
K/**p**/μ/p expts

Multi–
plicity

Materials and **L**ife **S**cience

Particle and **N**uclear **P**hysics



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J-PARC Accelerator

Future Five Years
(Review by MEXT)

Presented in
May 14, 2012

Storage for
Radioactive
Materials

Higher
Specs

Industry Usage

Safety

International
Facility

Infrastructure

Higher Flux

Research Building

Blooming Inter–
disciplinary Science

Lodging

ADS

Multi–
plicity

Muon
μSR, g-2, etc

High Flux
Pulse Neutrons

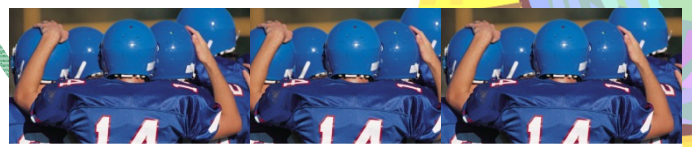
Neutrino
Oscillation

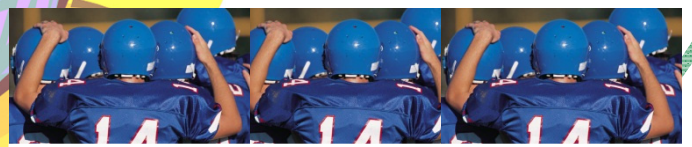
Kaon Factory
K/**p**/μ/p expts

Multi–
plicity

Materials and Life Science

Particle and Nuclear Physics





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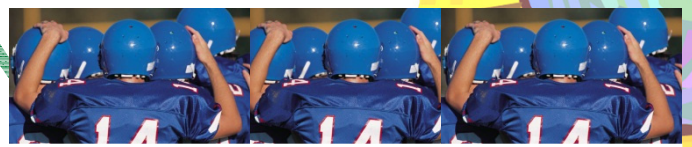

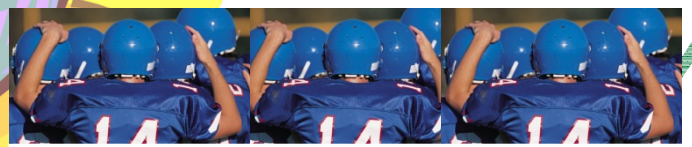

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