J-Parc

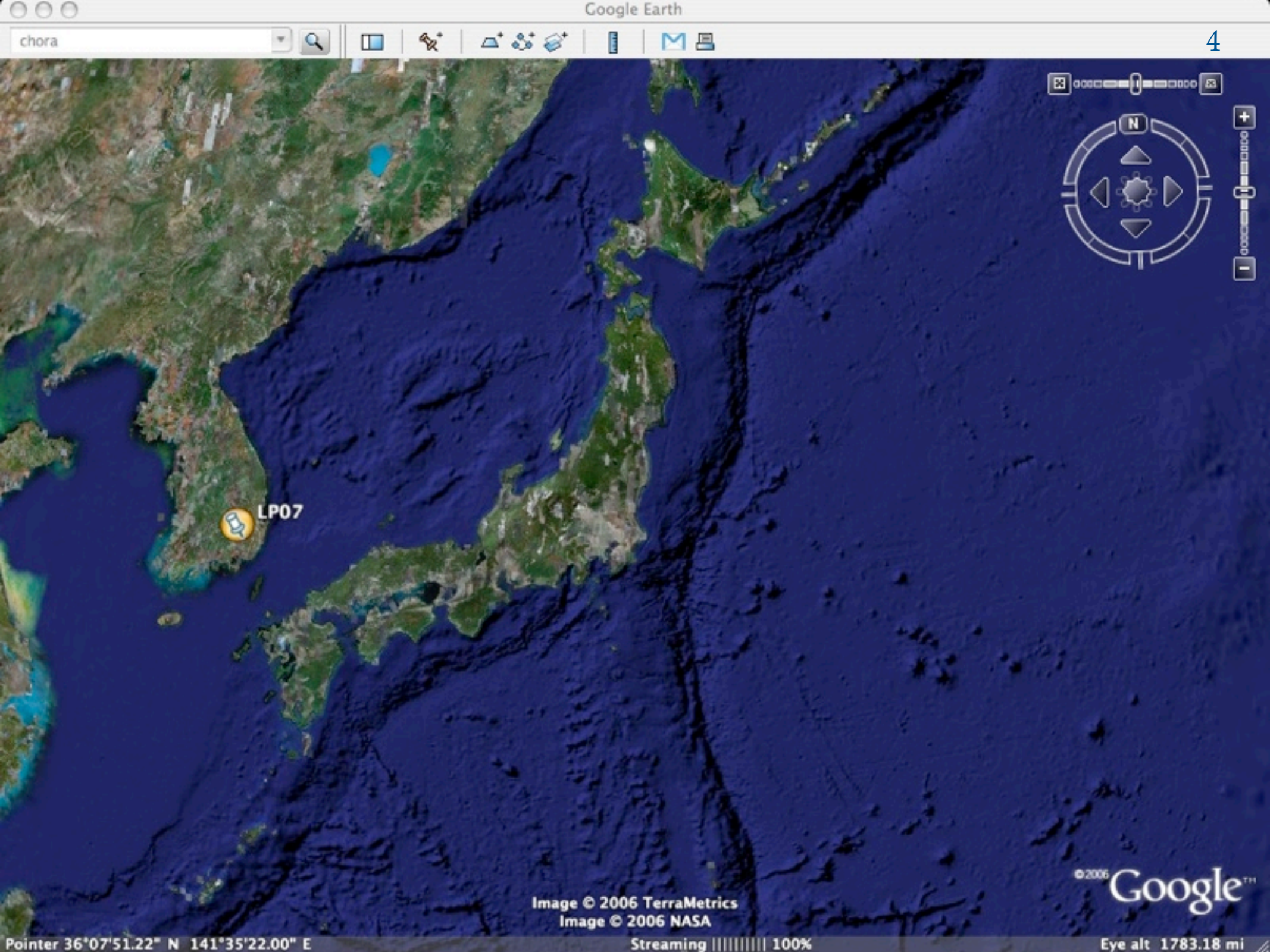
Taku Yamanaka
Osaka Univ.

Nov. 16, 2007@Fermilab
Workshop on Physics
with a high intensity proton source

J-Parc

* Joint (between KEK and JAEA)
* Proton Accelerator Research Complex

Where is it?


Google Earth
chora
LP07
Image © 2006 TerraMetrics
Image © 2006 NASA
©2006 Google
Pointer 36°07'51.22" N 141°35'22.00" E
Streaming 100%
Eye alt 1783.18 mi

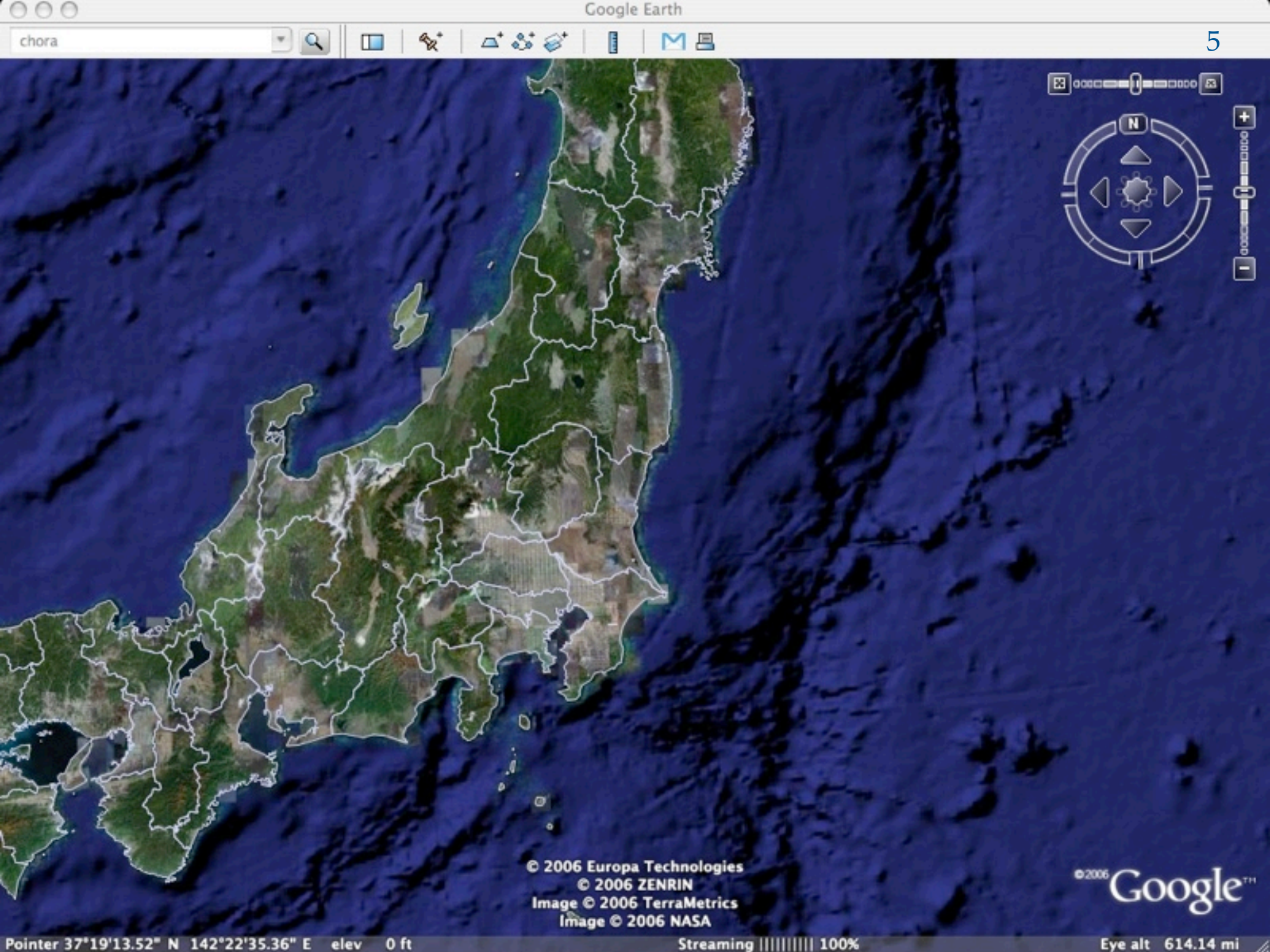

Google Earth
chora
N
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Image © 2006 TerraMetrics
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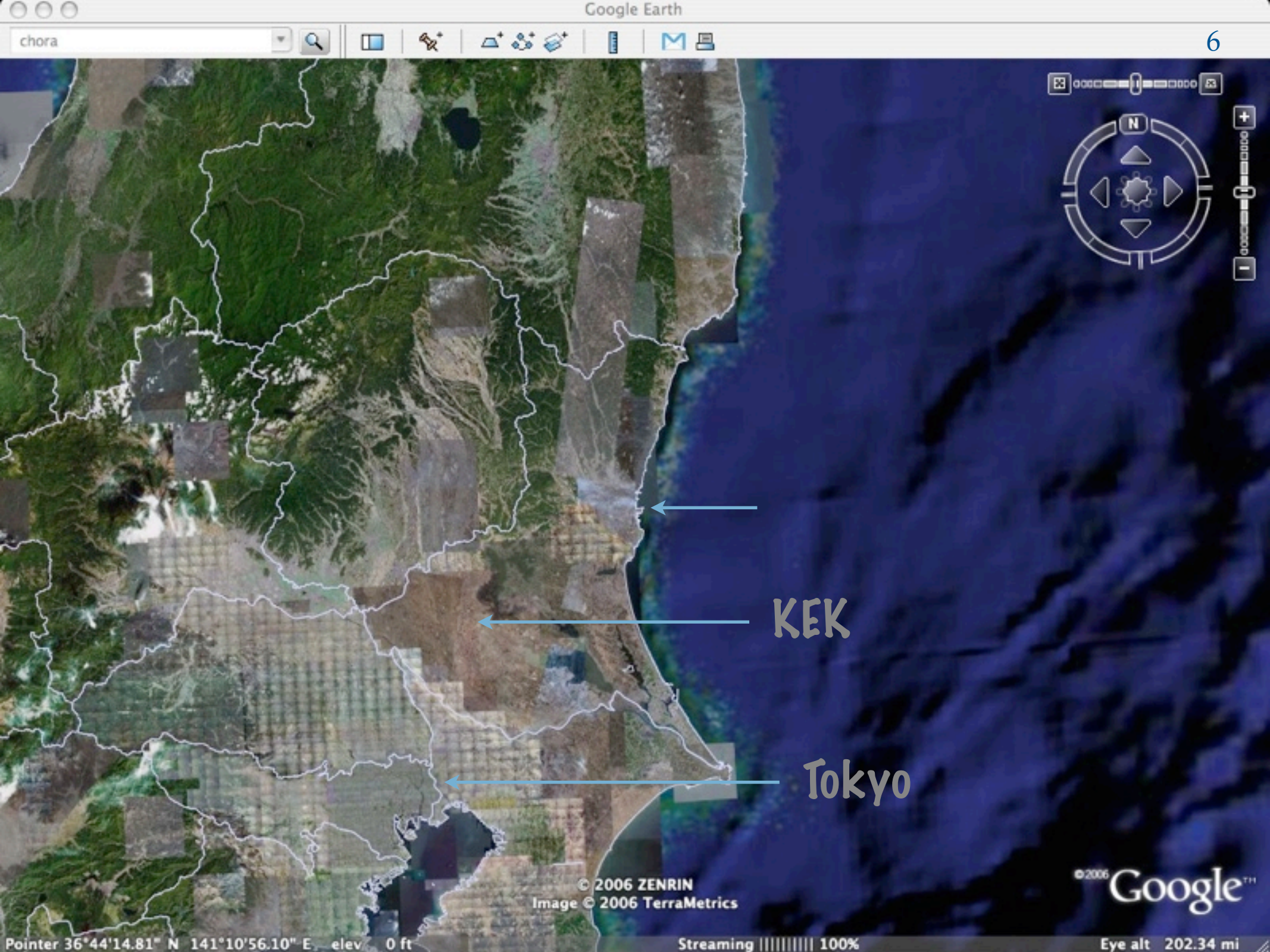
Eye alt 614.14 mi


Google Earth
chora
KEK
Tokyo
© 2006 ZENRIN
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Eye alt 202.34 mi

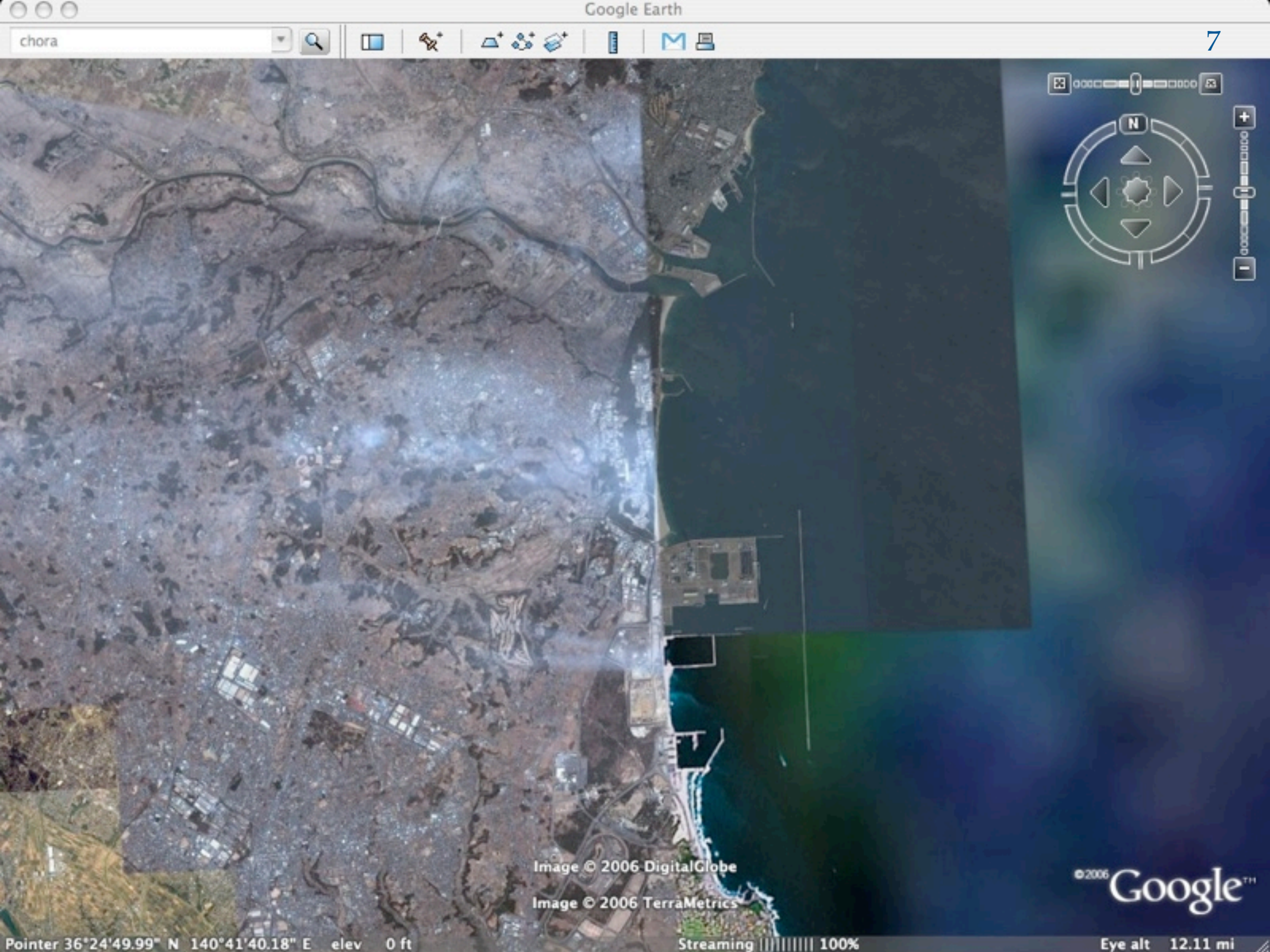
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Image © 2006 DigitalGlobe
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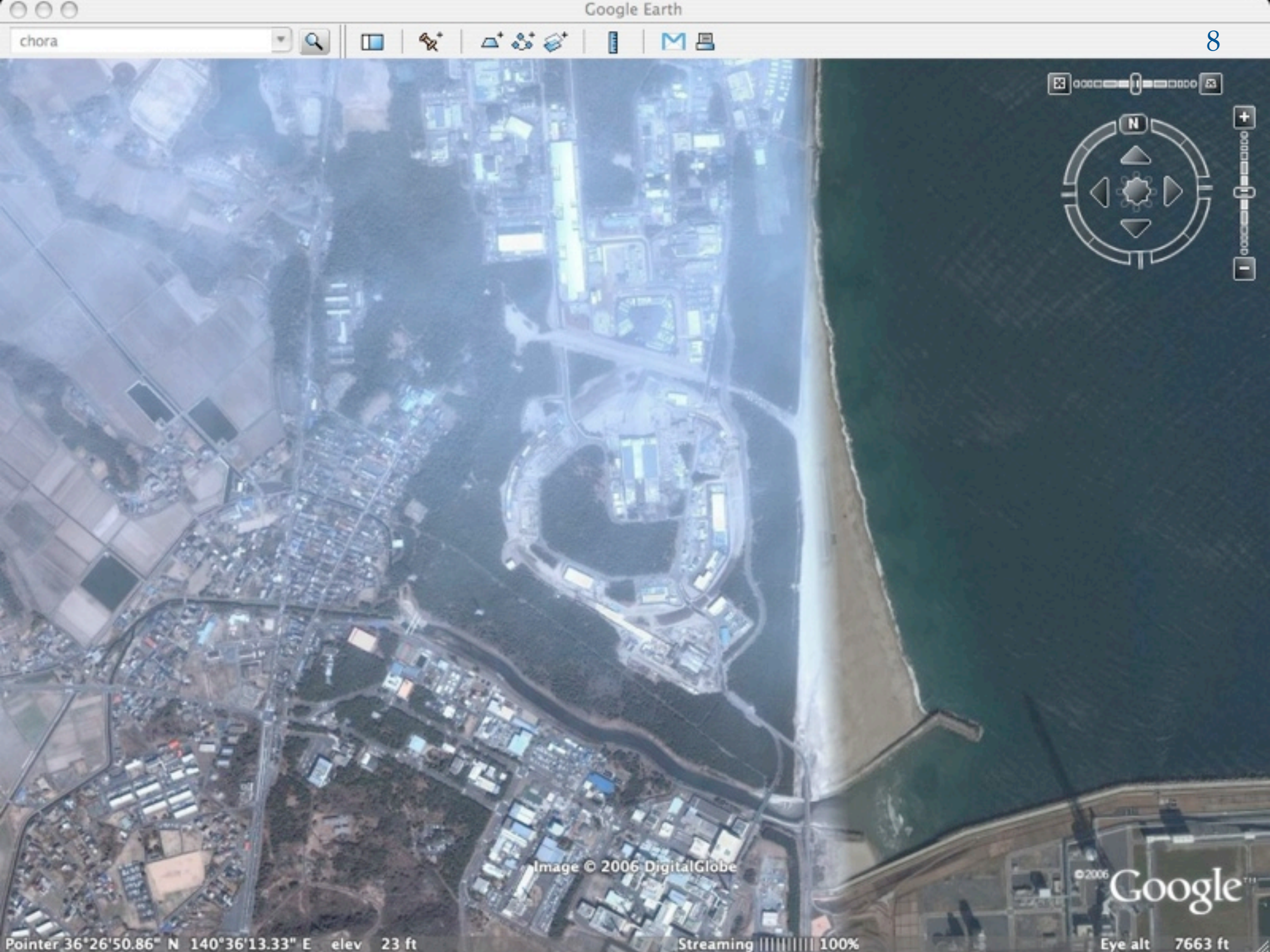
Eye alt 12.11 mi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©2006 Google
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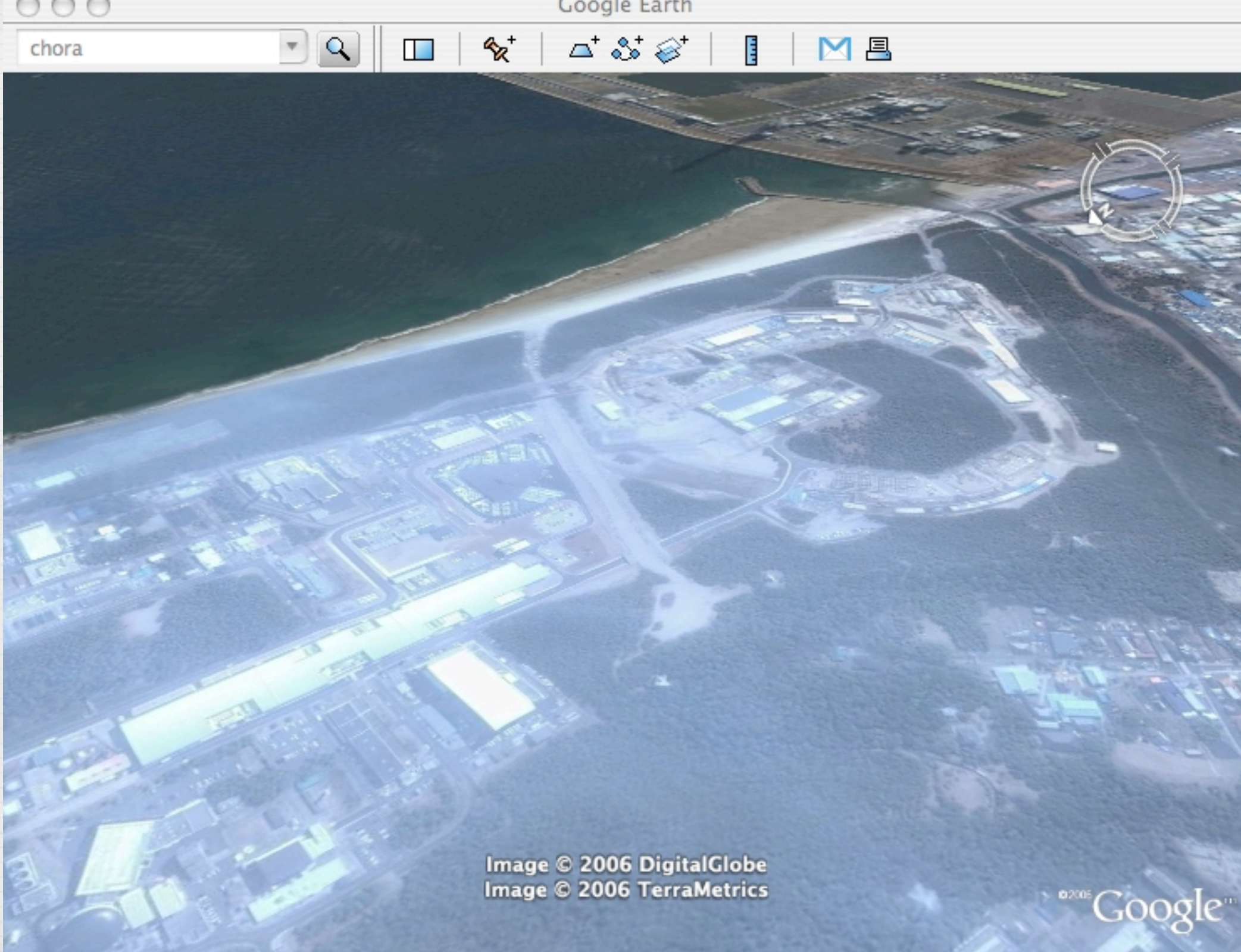
Streaming 100%
Eye alt 7663 ft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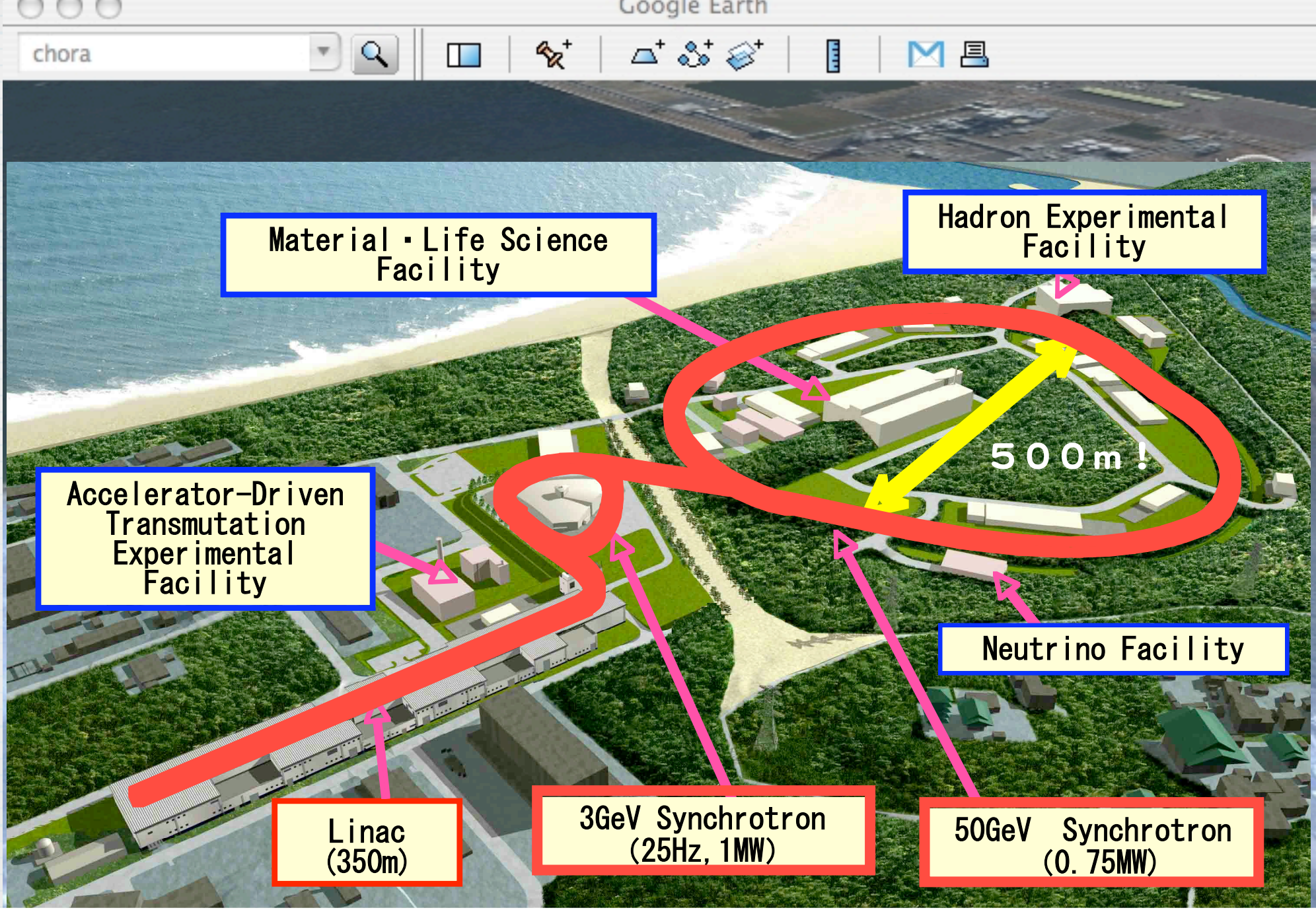
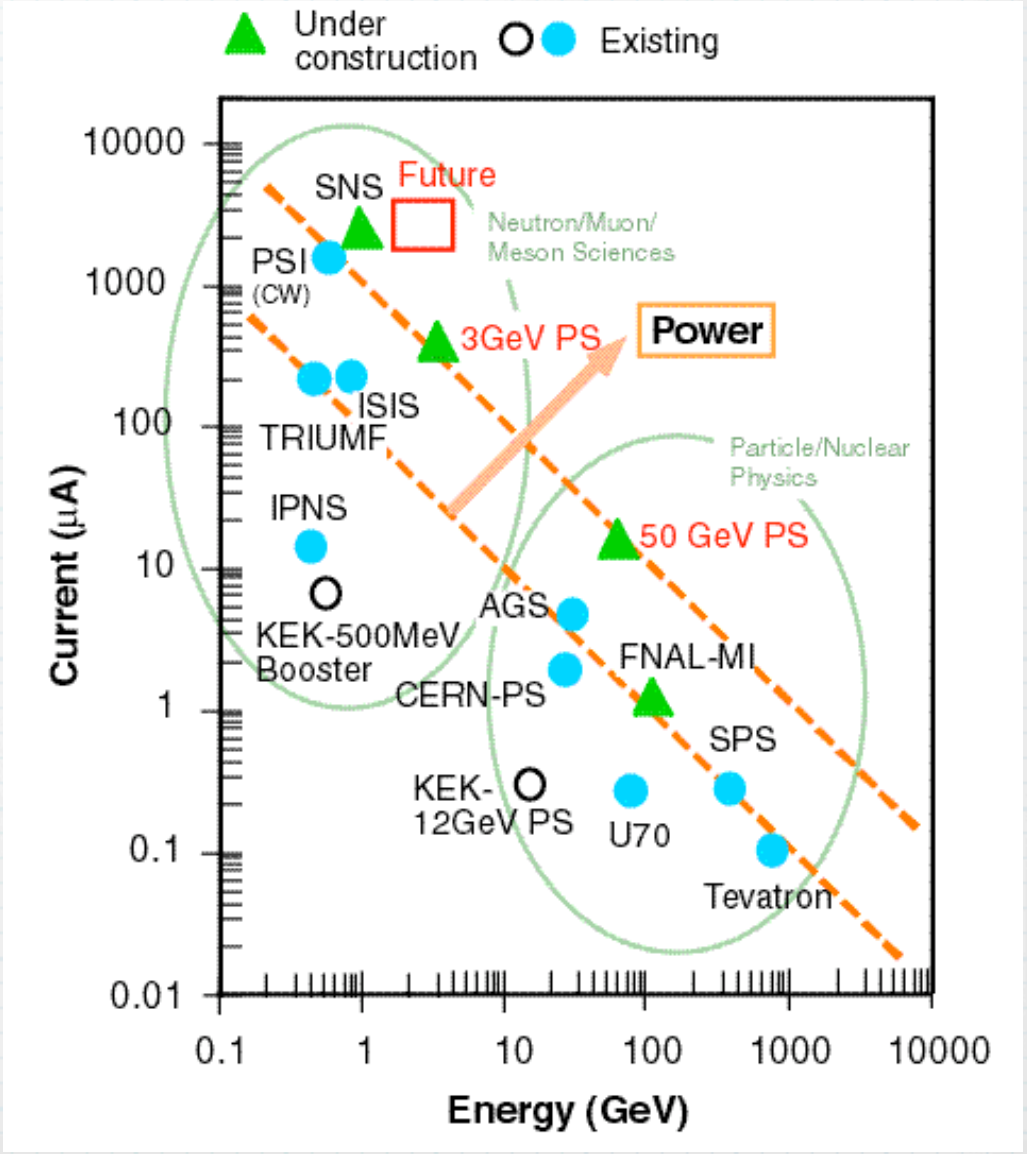

Google Earth
chora
Material・Life Science Facility
Hadron Experimental Facility
500m！
Accelerator-Driven Transmutation Experimental Facility
Neutrino Facility
Linac (350m)
3GeV Synchrotron (25Hz, 1MW)
50GeV Synchrotron (0.75MW)

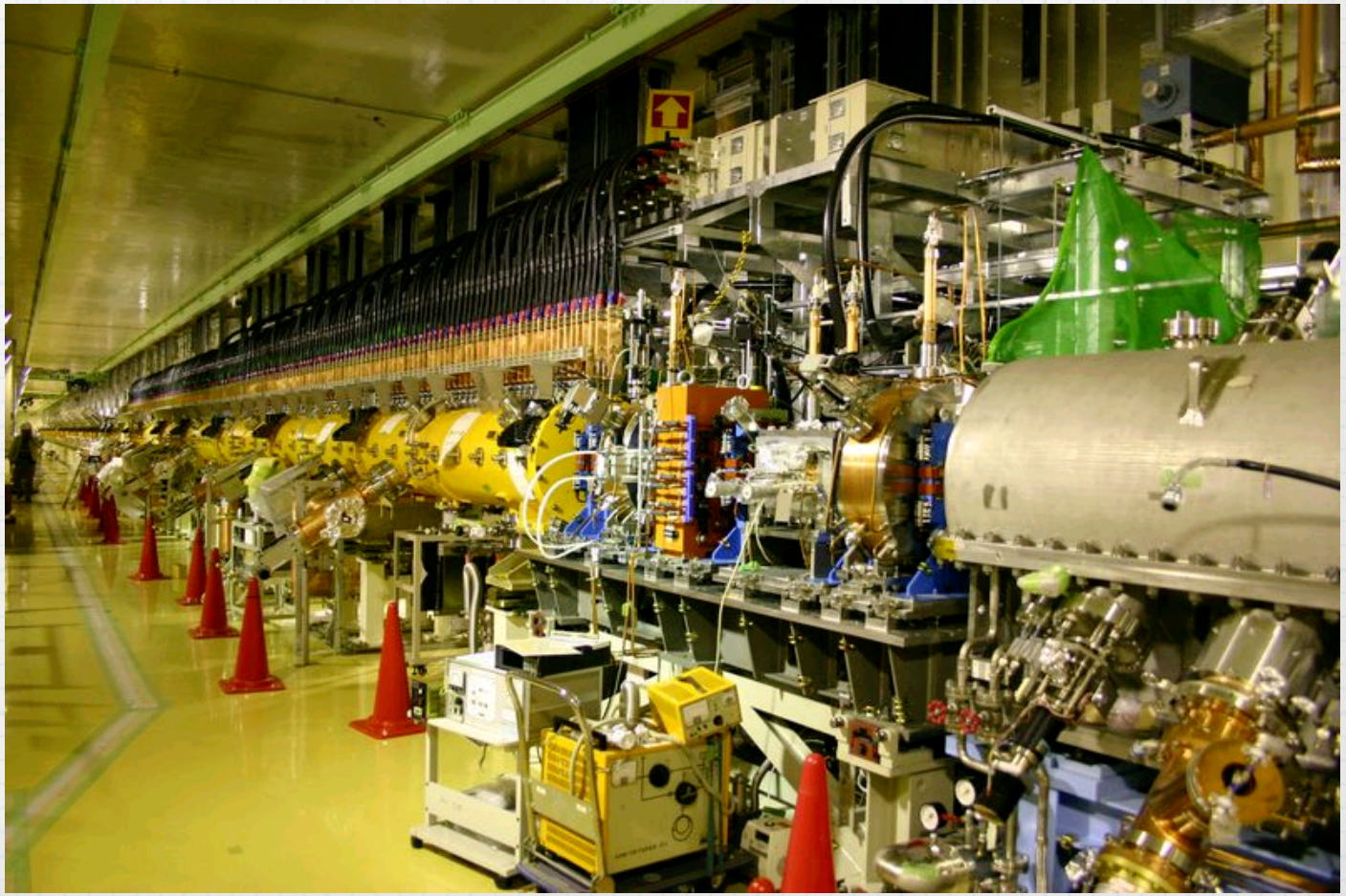
Design Spec.

* 30-50GeV
* 3E14 protons/3.3sec
* Fast extraction for neutrino experiment
* Slow extraction for Kaon, nuclear physics, hadron physics



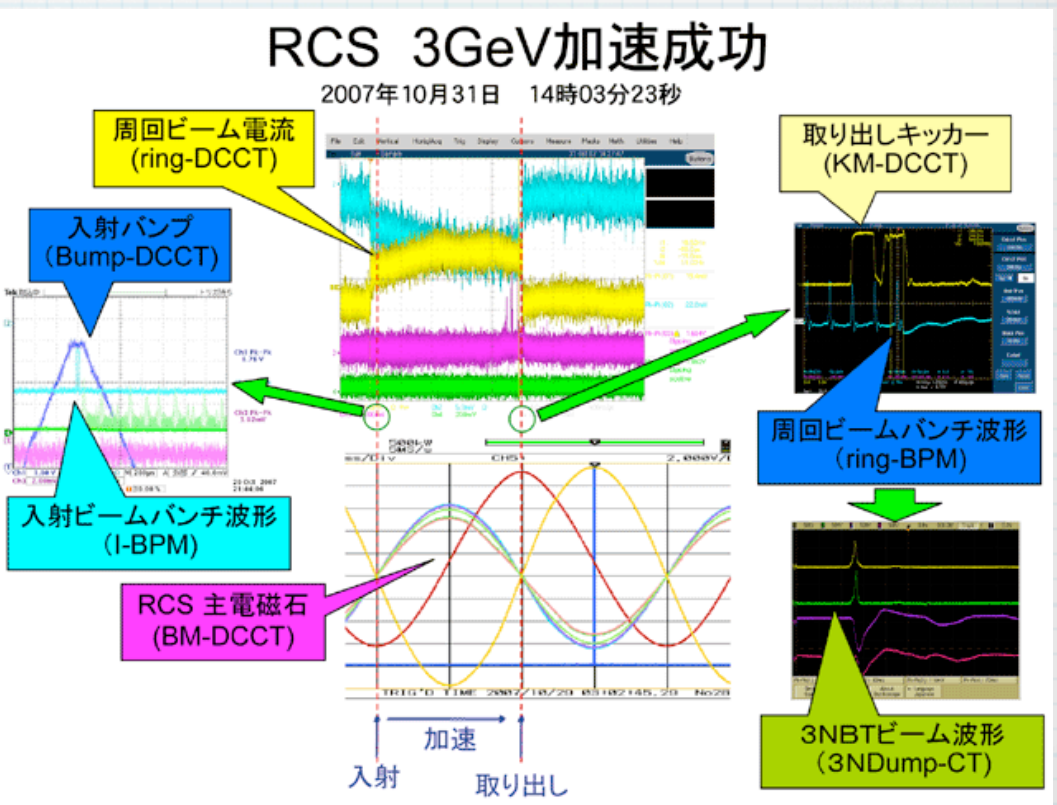
Linac

* Nov. 20th, 2006 : 50keV→3 MeV by RFQ
* Jan. 24, 2007 : 181MeV, beam at the end of Linac



3GeV Synchrotron

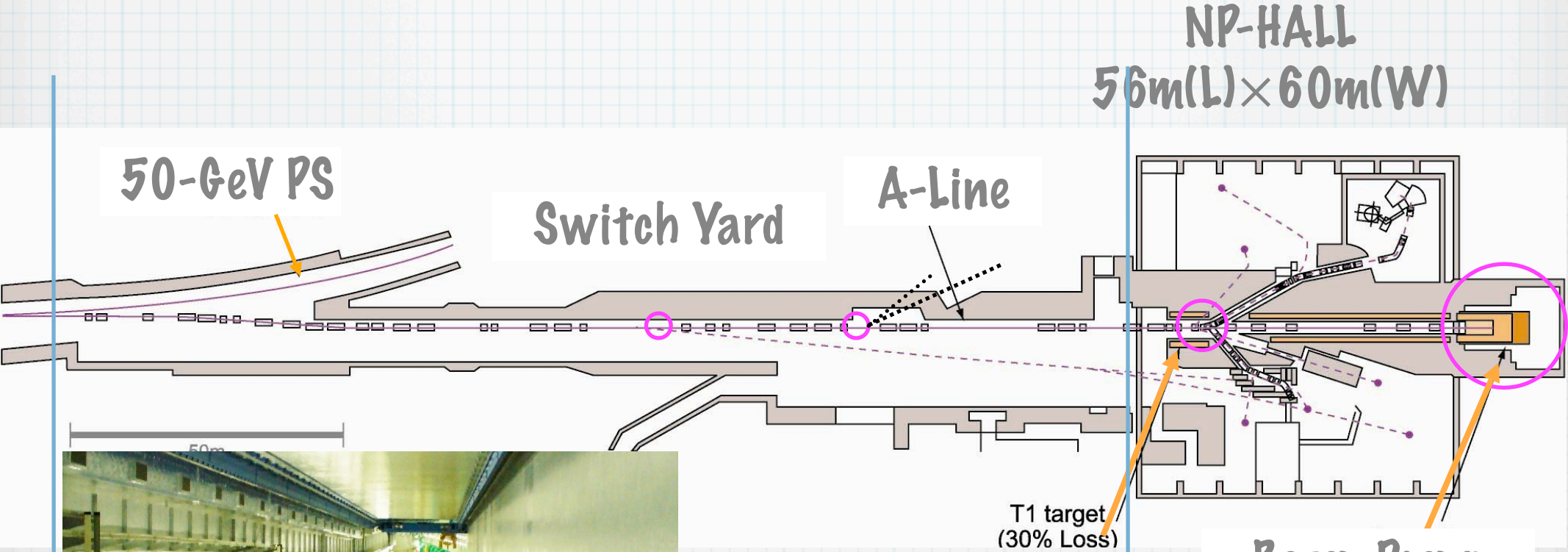
* 25Hz cycle
* Oct. 31, 2007: Accelerated up to 3GeV!



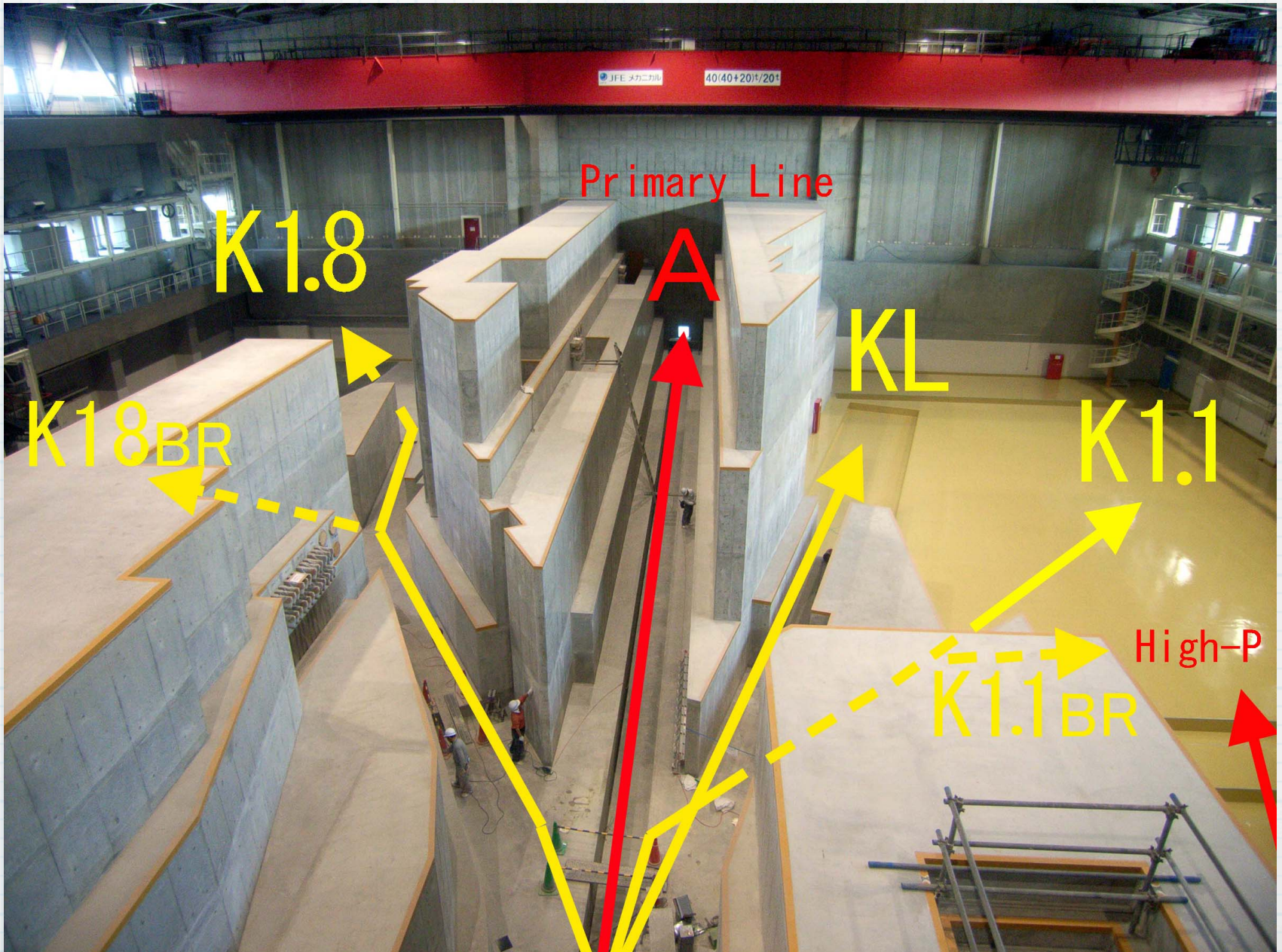
50GeV Ring

* March 2007: All magnets were installed.
* Start dry run in Dec. 2007.

Plane view of Hadron Beamline



Hadron Hall



Official Schedule

- 50GeV-Ring will
  - start Dry Run in Dec, 2007.
  - accept beam from 3GeV-Ring in April ~ July, 2008.
  - install extraction magnets for Hadron bl. during summer shutdown in 2008.

- Hadron beamline will
  - accept first beam in Dec. 2008.
  - start beam tuning → until end of March, 2009.

☆Hadron Experimental Hall will be available in Summer, 2007.

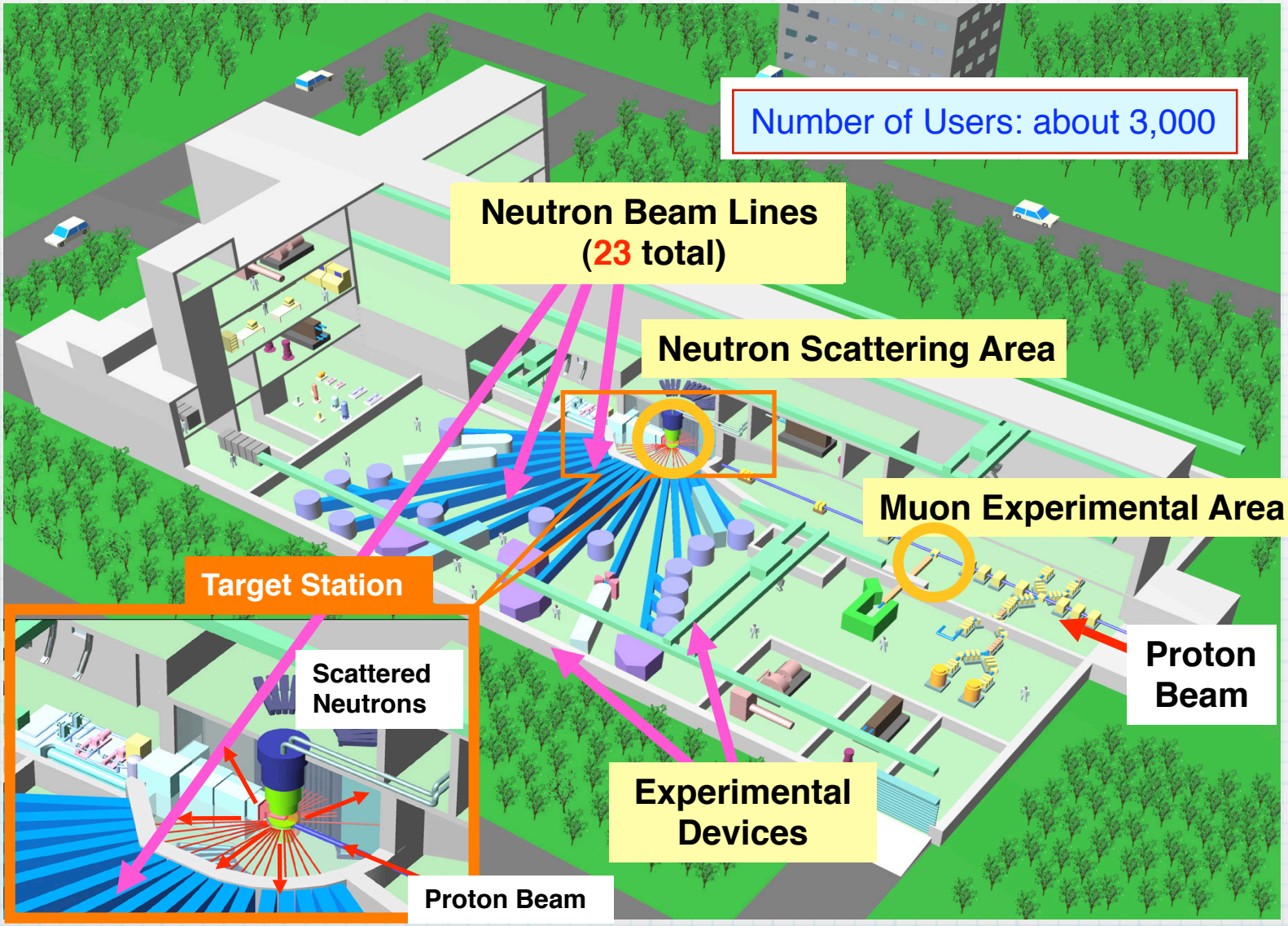
- Neutrino beamline will accept first beam on April 1st, 2009, and will start T2K experiment.

Multi-purpose accelerator complex

* Material and Life (neutrons and muons)
* High energy physics (neutrinos and Kaons)
* Nuclear physics (Kaons and protons)
* R&D for transmutation

Material & Life Experimental Facility

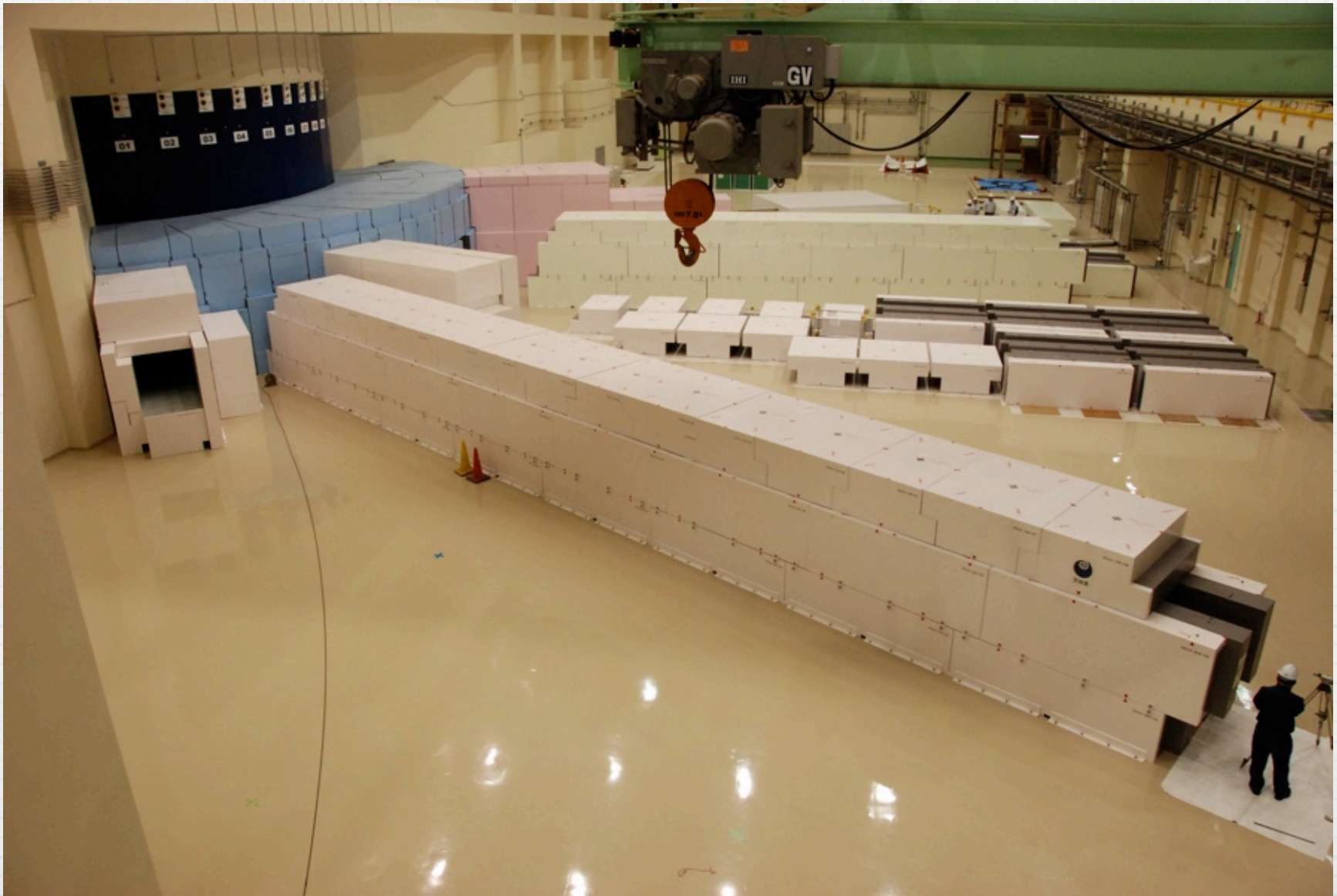
Material & Life Experimental Facility



Mercury target for neutron source

Beamlines

July 19, 2007



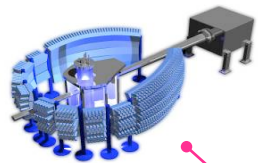
Tentatively Approved Instruments

Life Science

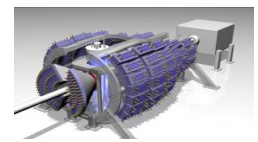
Industrial Consortium was formed

Materials Science

Versatile powder diffractometer – JAEA

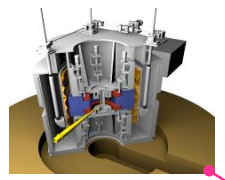


Super High Resolution Powder Diffractometer (SHRPD) – KEK

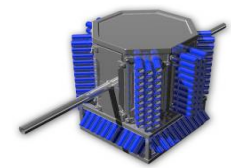


IBARAKI Biological Crystal Diffractometer – Ibaraki Prefecture

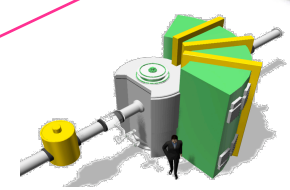
Protein Dynamics Analysis Instrument (DIANA) - JAEA



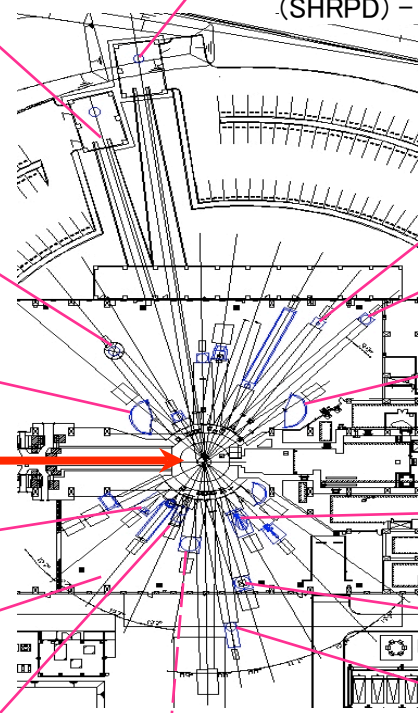
Diffractometer for Biological X' tallography (BIX-PN) – JAEA



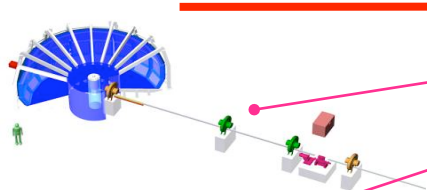
4d Space Access Neutron Spectrometer(4SEASONS) -Grant-in-Aid for Specially -Promoted Research, MEXT,



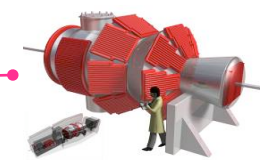
Proton beam

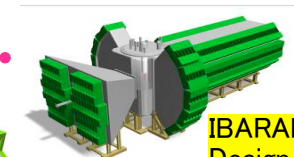


Cold Neutron Double Chopper Spectrometer (CNDCS) – JAEA



High-intensity Versatile Neutron Total Diffractometer – KEK

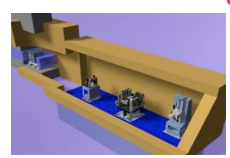




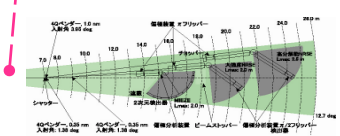
IBARAKI Materials Design Diffractometer – Ibaraki Prefecture

Engineering Diffractometer – JAEA

High-intensity SANS (HI-SANS) – JAEA



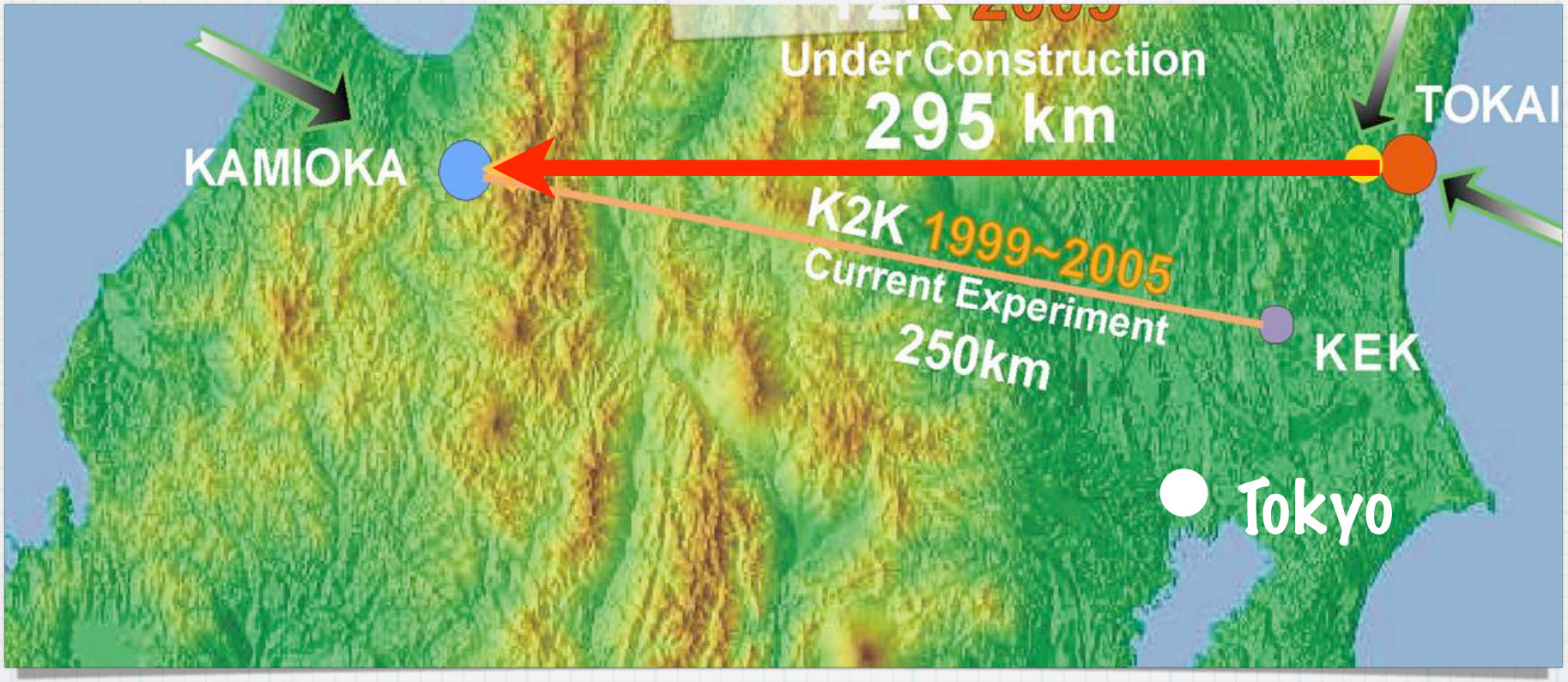
Neutron Reflectometer with Horizontal-Sample Geometry – KEK



Neutron Resonance Spin Echo spectrometers – KUR, Kyoto University

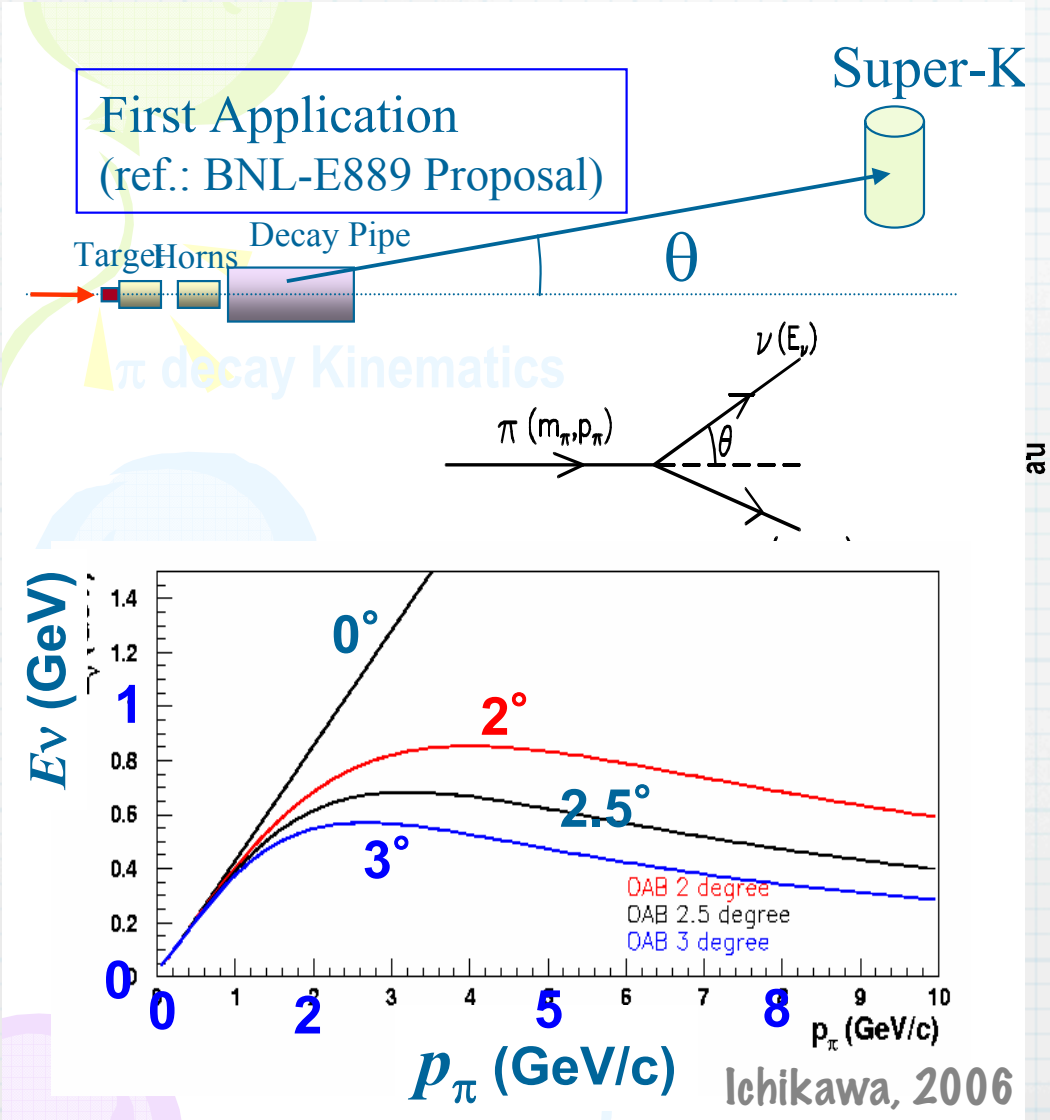
A doorway to New Physics

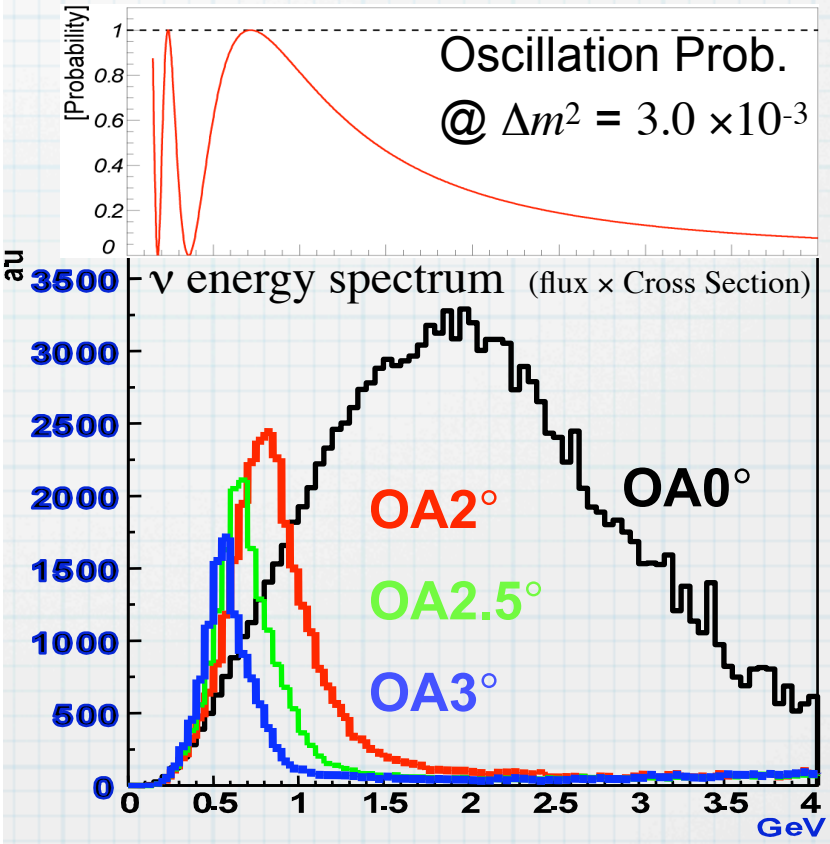
Neutrino Oscillation



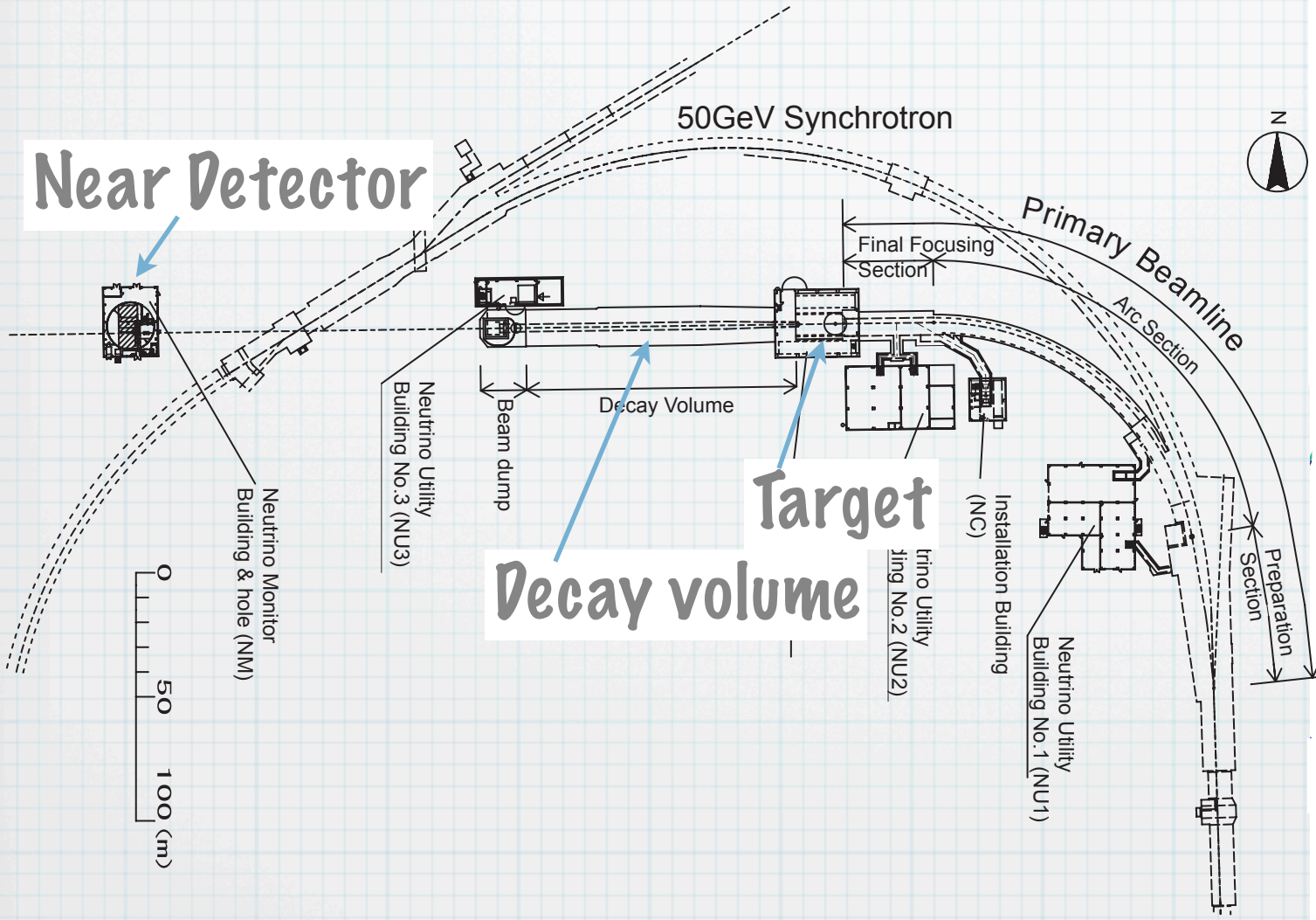
T2K:
Tokai to Kamioka

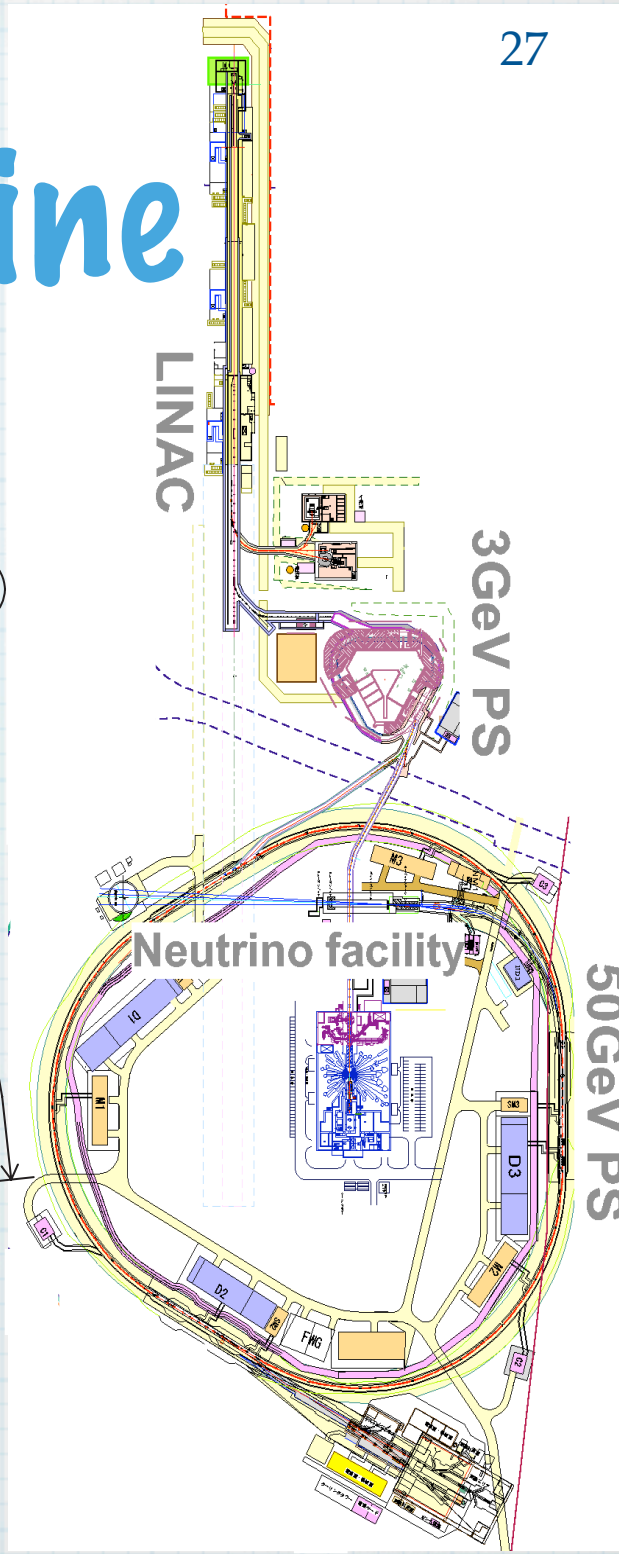
How to make ν_μ





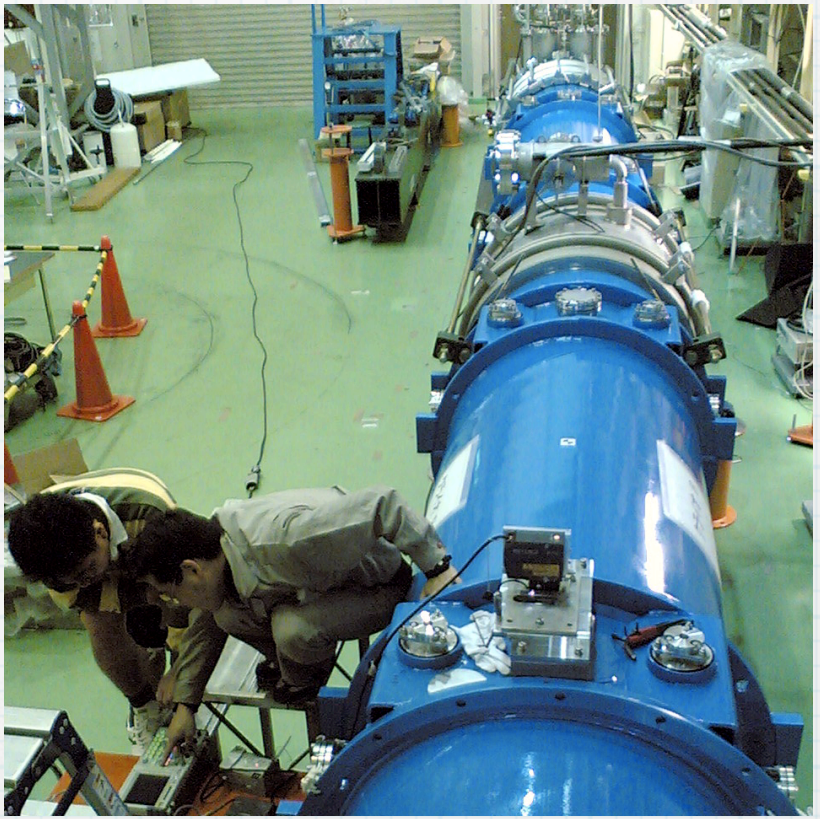
Neutrino beamline





Bend protons hard

The Arc

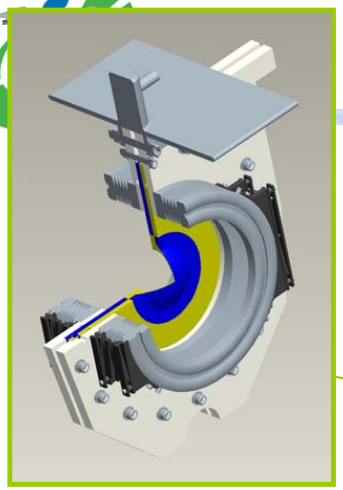


Superconducting bending magnet

Target Station

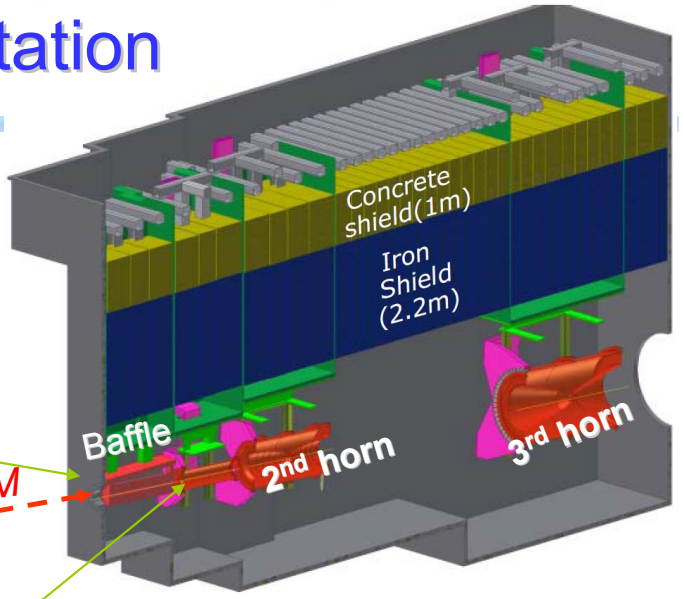
1/16, 2007

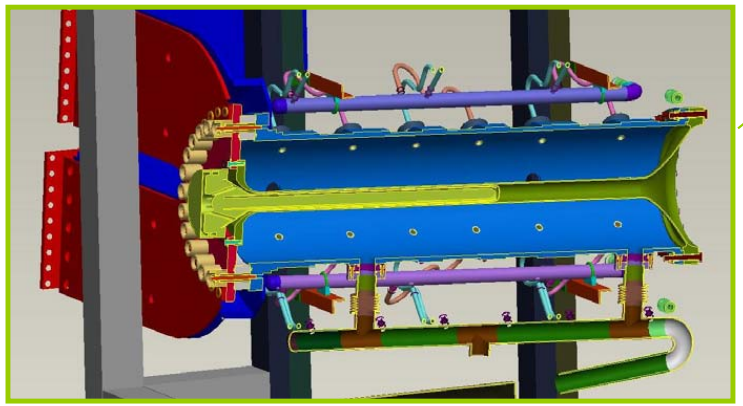
Final Focusing Section / ARC



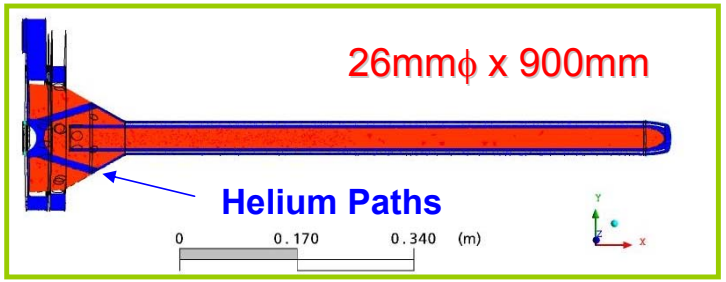
Ti-alloy Beam Window with pillow-seal

Target Station





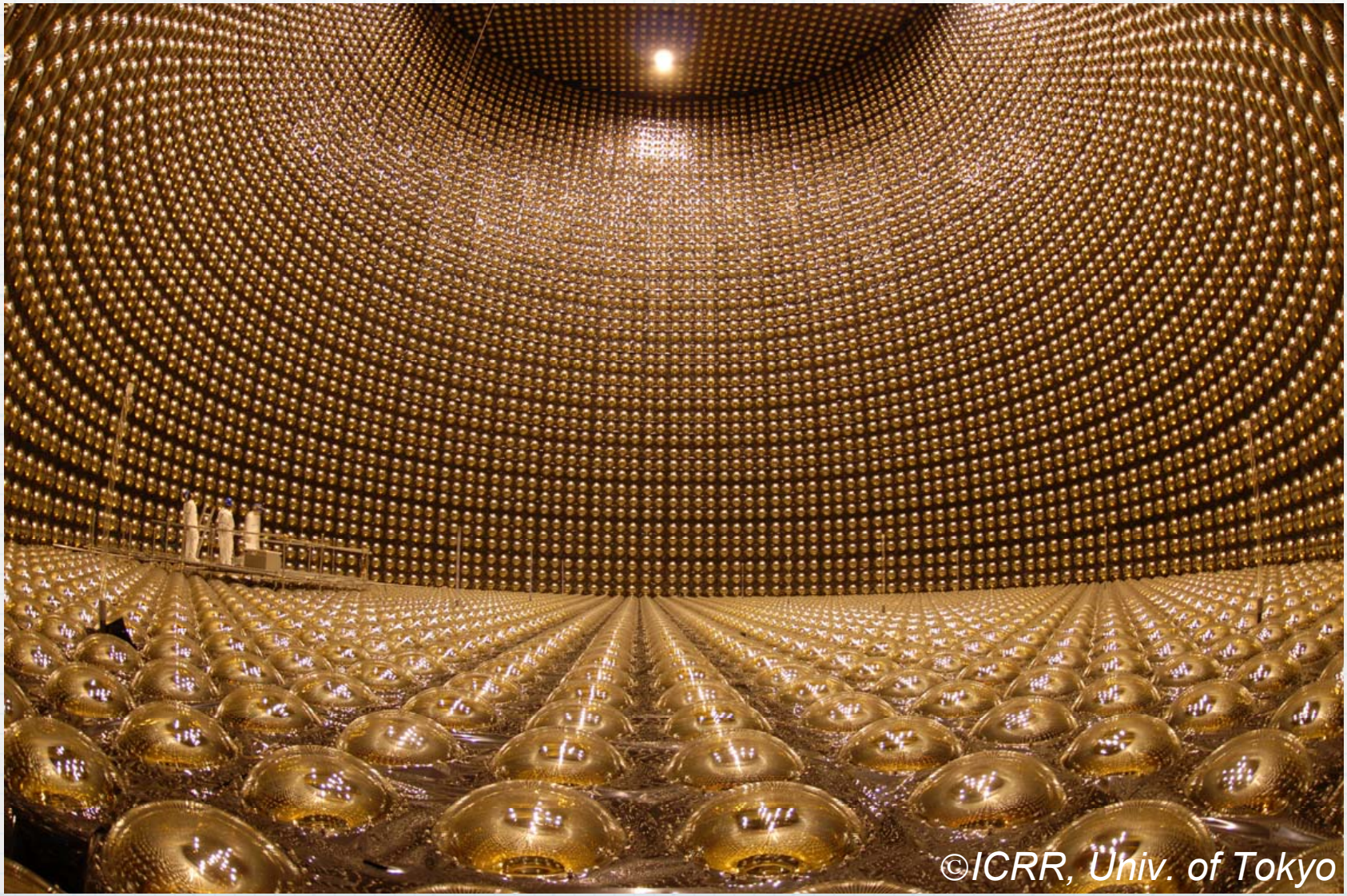
Helium-Cooled Graphite Target in the 1st Horn



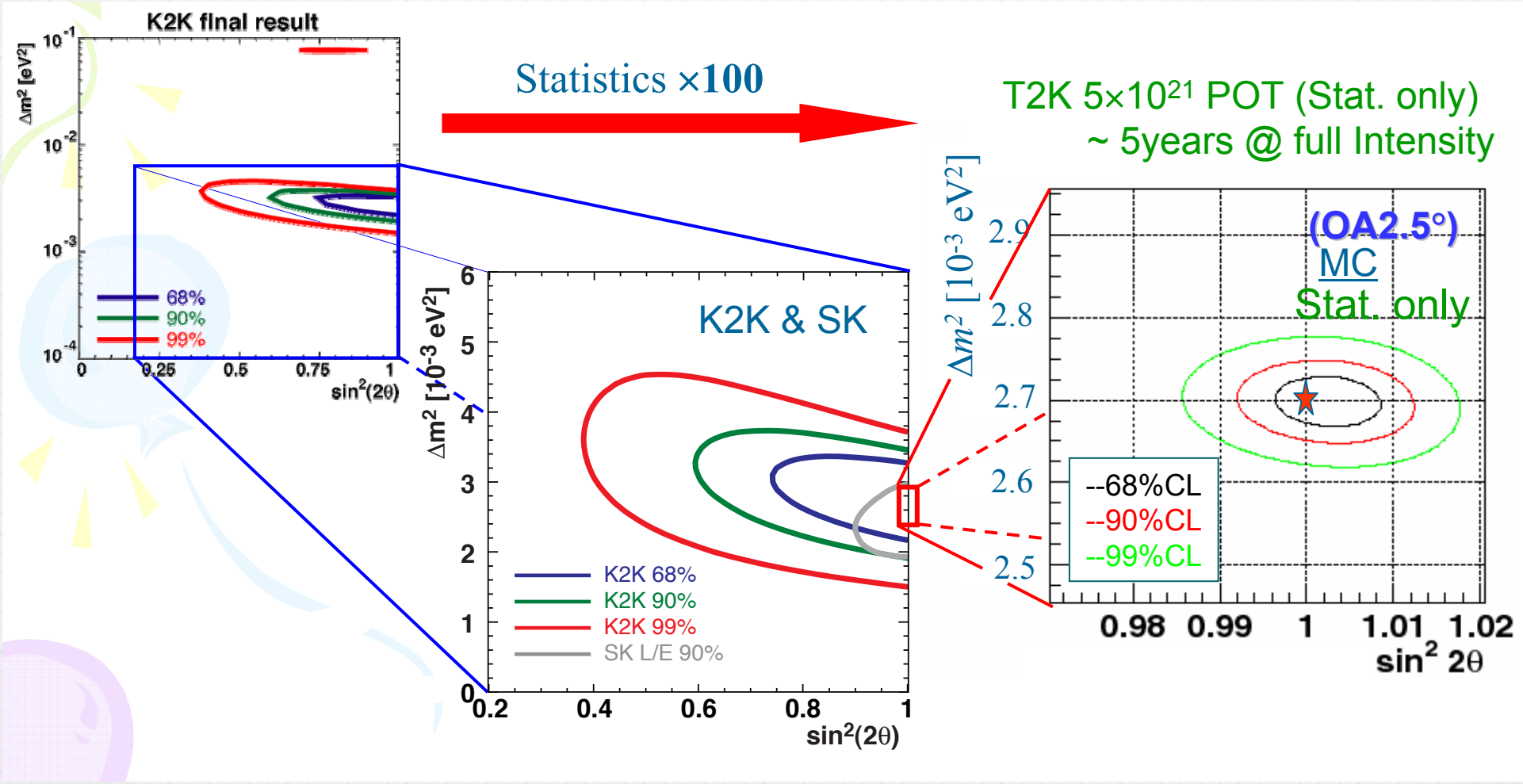
Supported by CCLRC/RAL and
BARTOSZEK ENGINEERING

π->μν Decay volume

Far Detector=50kton SuperKamiokande

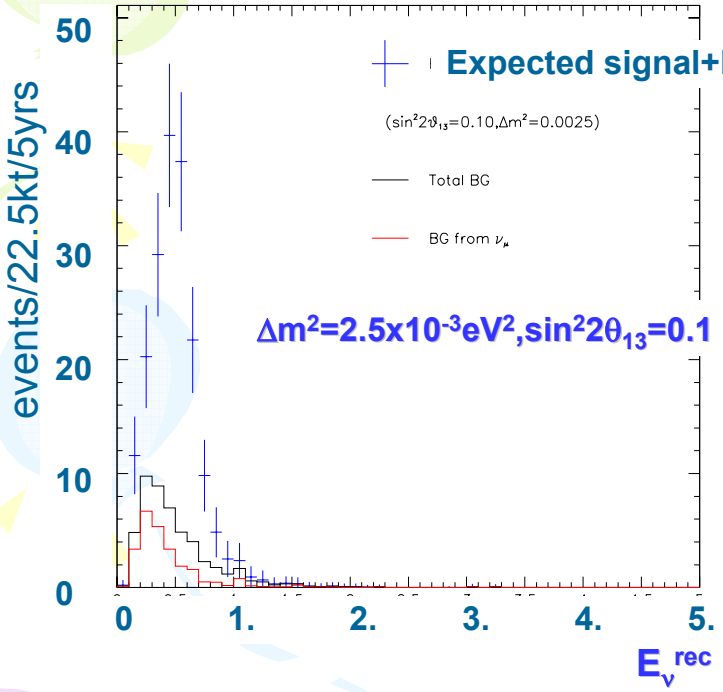


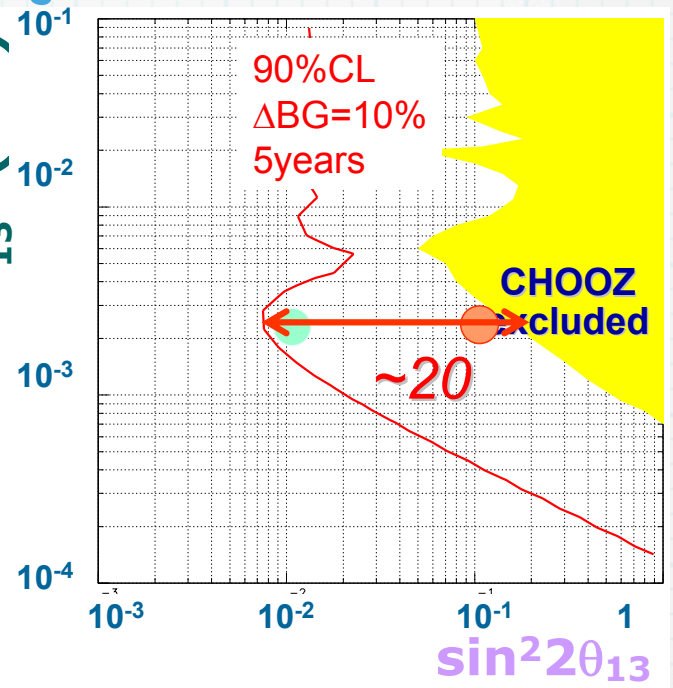
Sensitivity to ϑ_{23}



Ichikawa, 2006

Sensitivity to ϑ_{13}

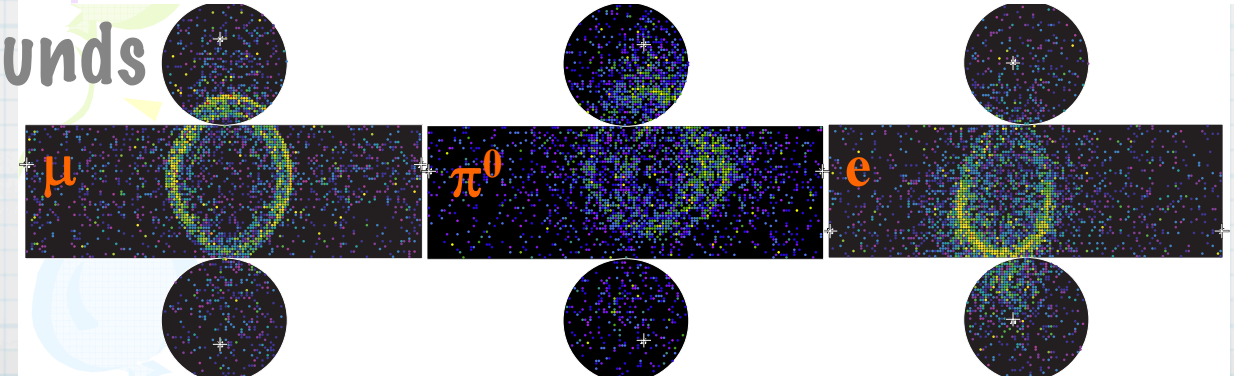




Assuming $\sin^2\theta_{23}=0.5$, $\delta=0$, no matter

$\sin^2 2\theta_{13}$	Background in Super-K			Signal	Signal + BG
	ν_μ	ν_e	total		
0.1	10	13	23	103	126
0.01				10	33

Backgrounds



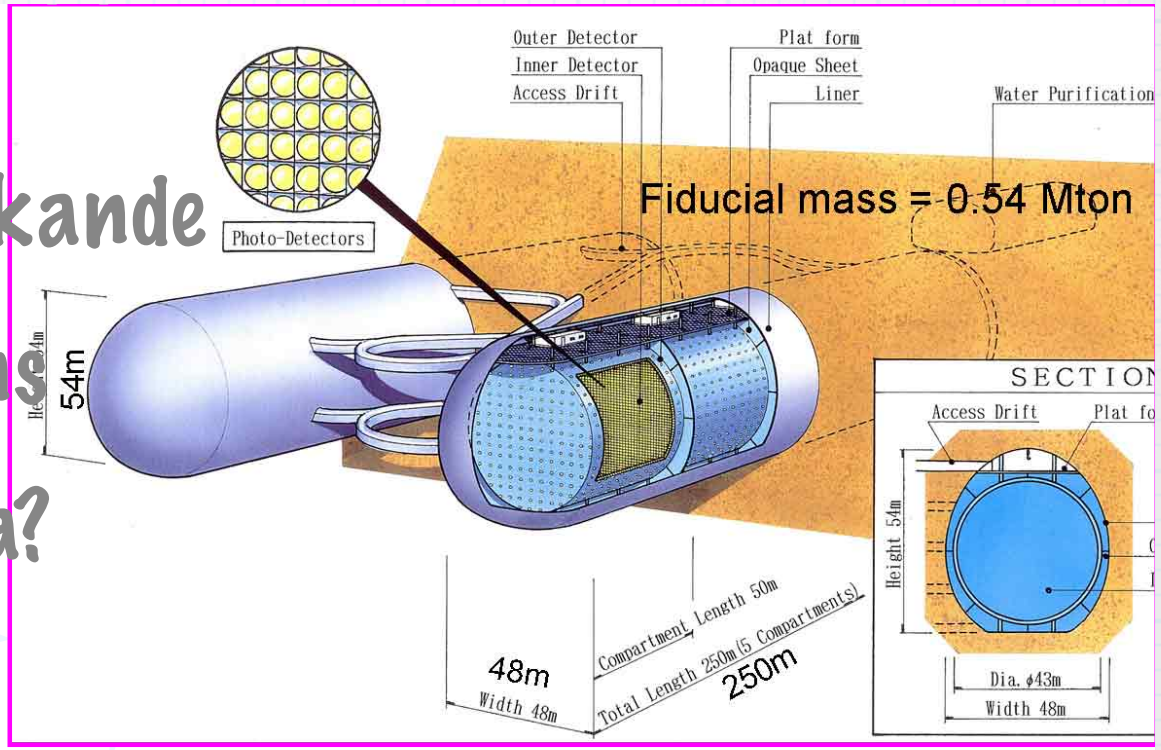
Ichikawa, 2006

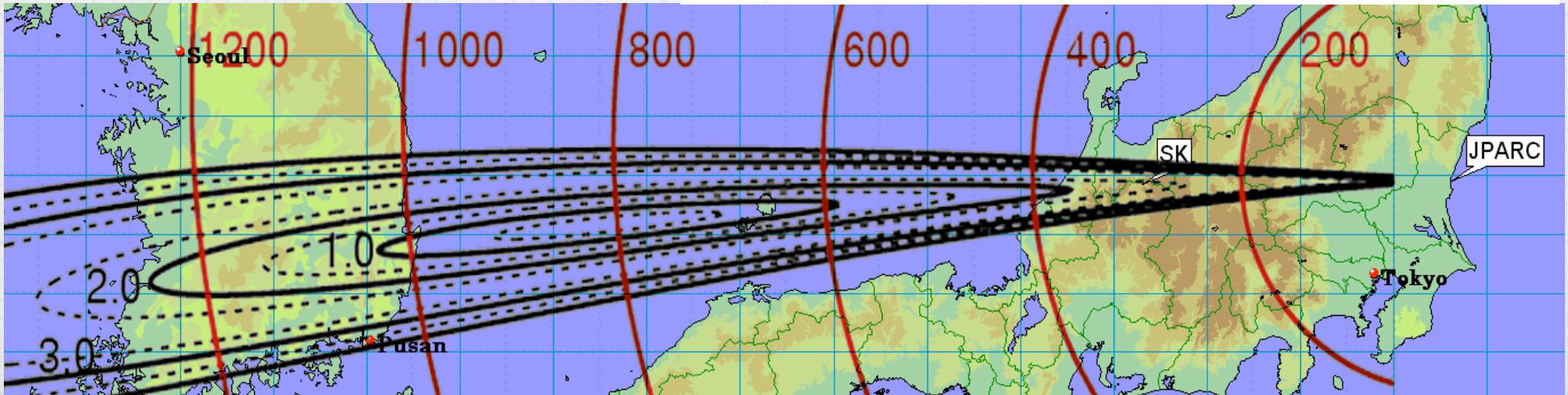
if $\theta_{13} \neq 0$, CP violation?

* Super-->Hyper Kamiokande

  50ktons --> 540ktons

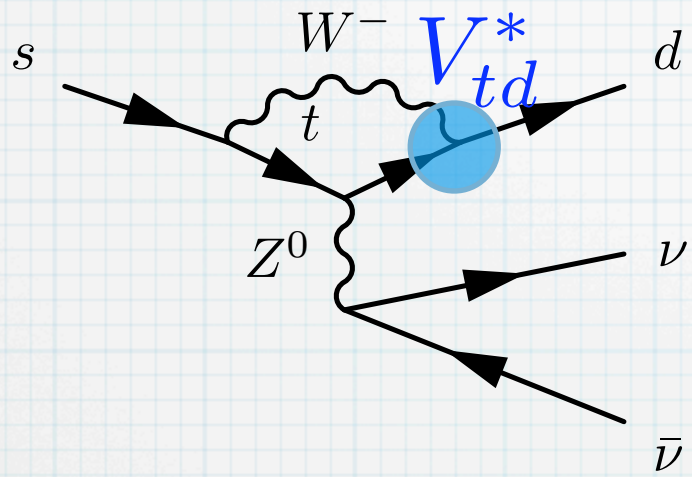
* 2nd detector in Korea?



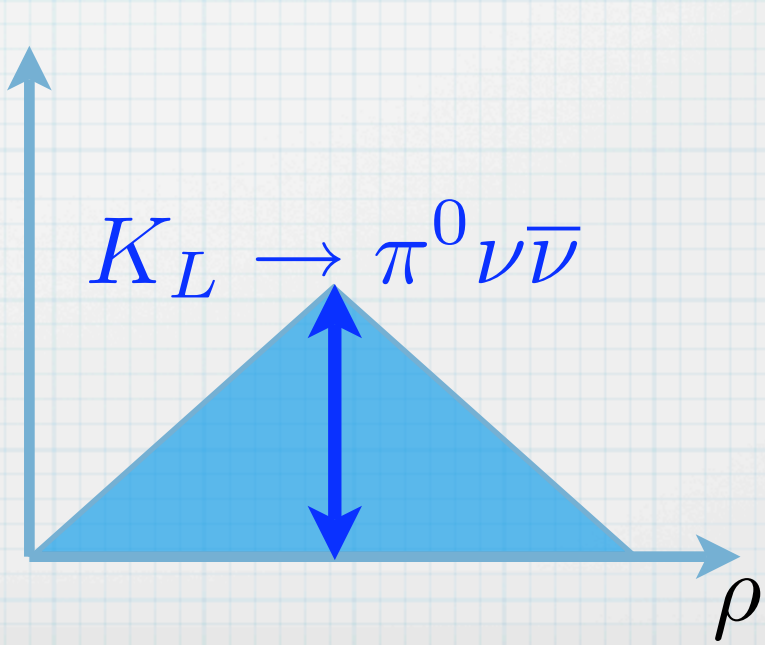


$K_L \to \pi^0 \nu\bar{\nu}$

$K_L \to \pi^0 \nu\nu$ in Standard Model

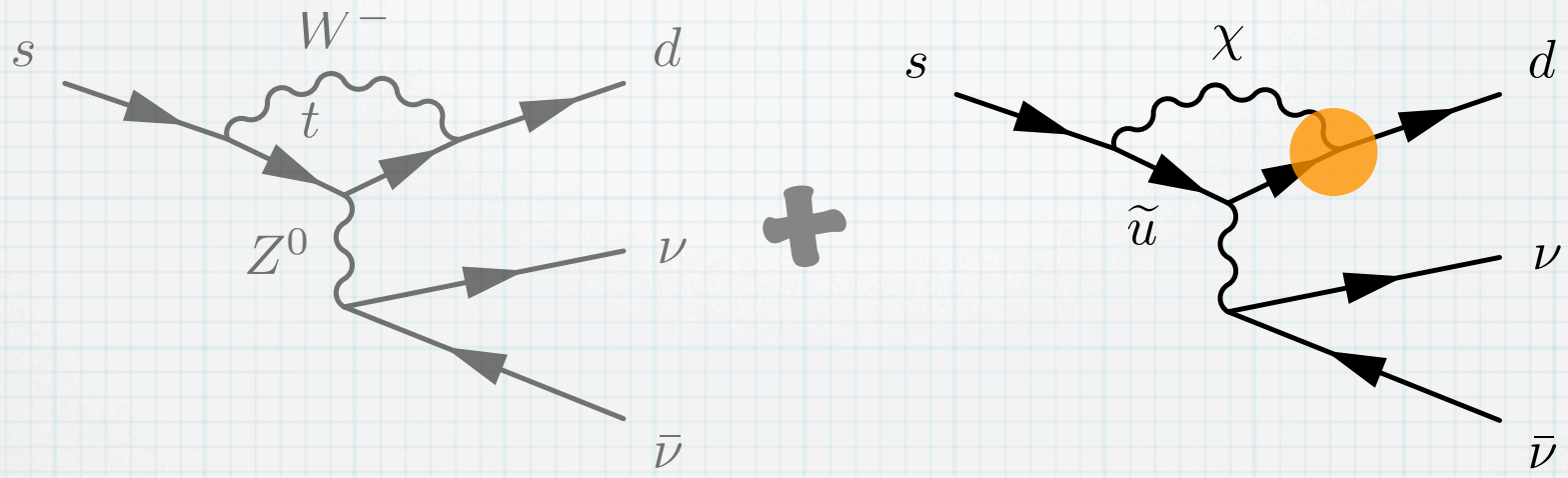


$$A(K_L \to \pi^0 \nu\bar{\nu}) \propto V_{td} - V_{td}^*$$

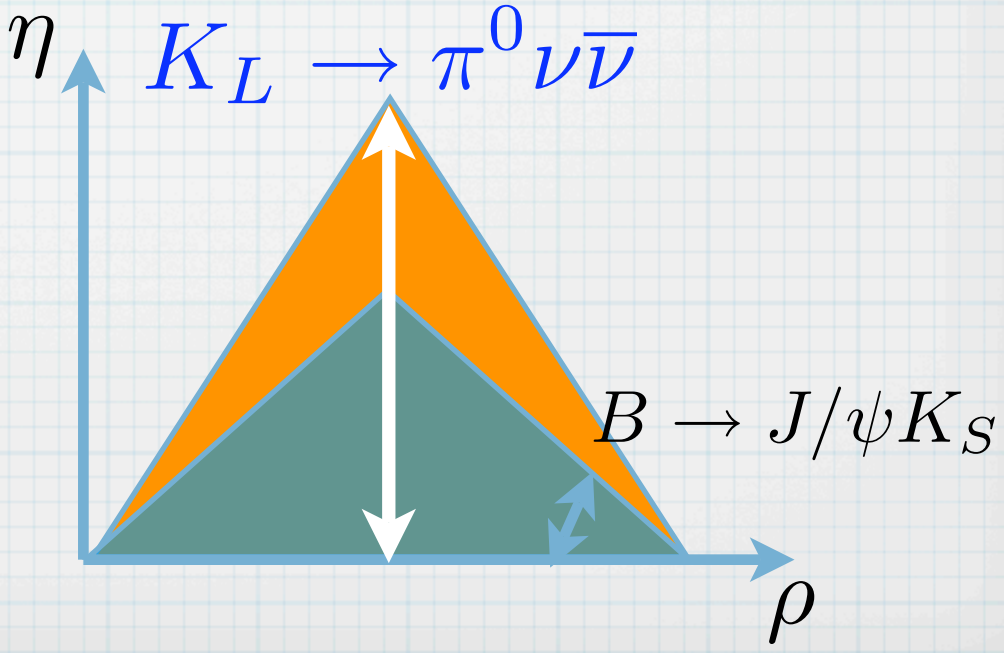


- BR = (2.8±0.4) x 10^{-11} (w/currently known CKM parameters)
- 1 - 2% theoretical error

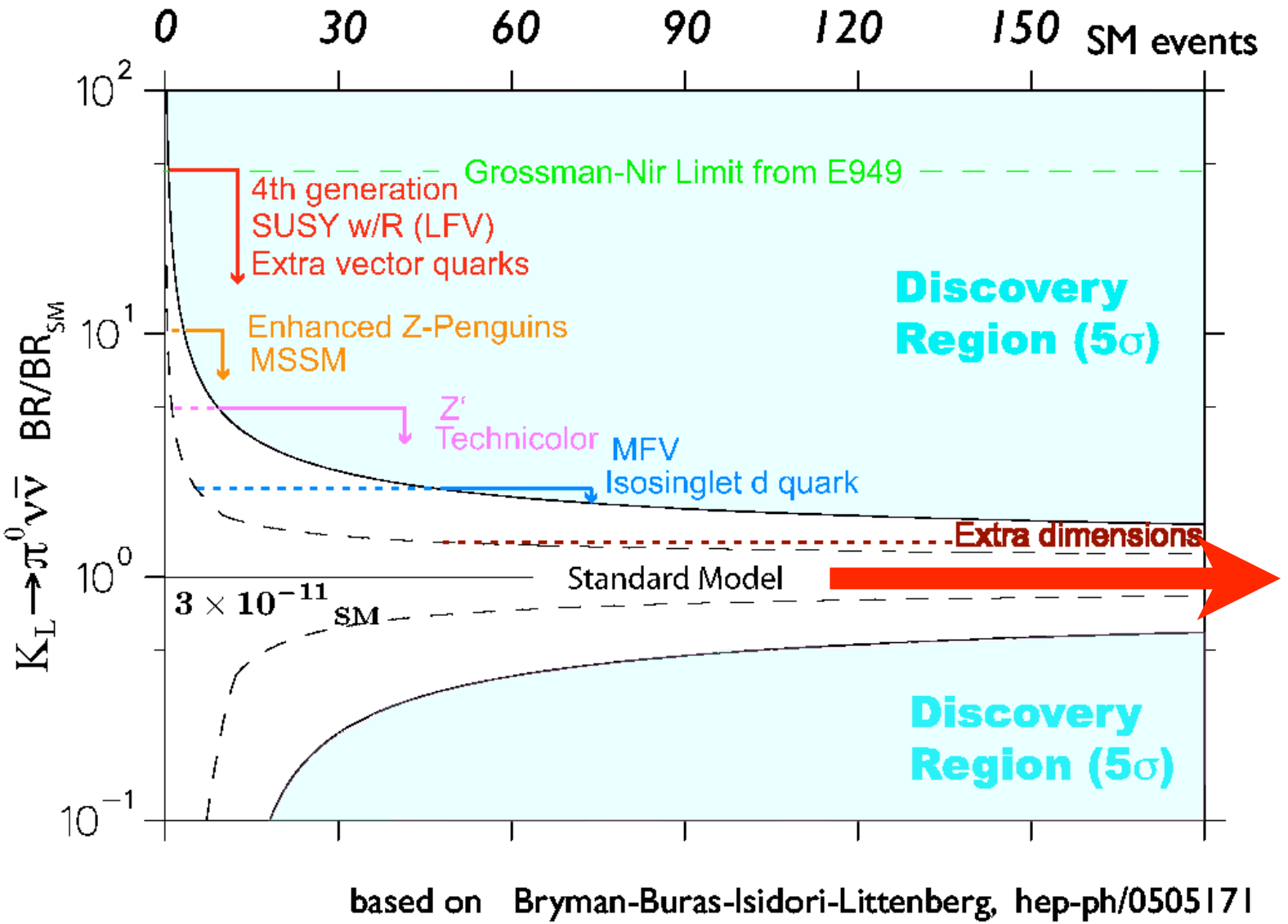
New Physics adds extra amplitude



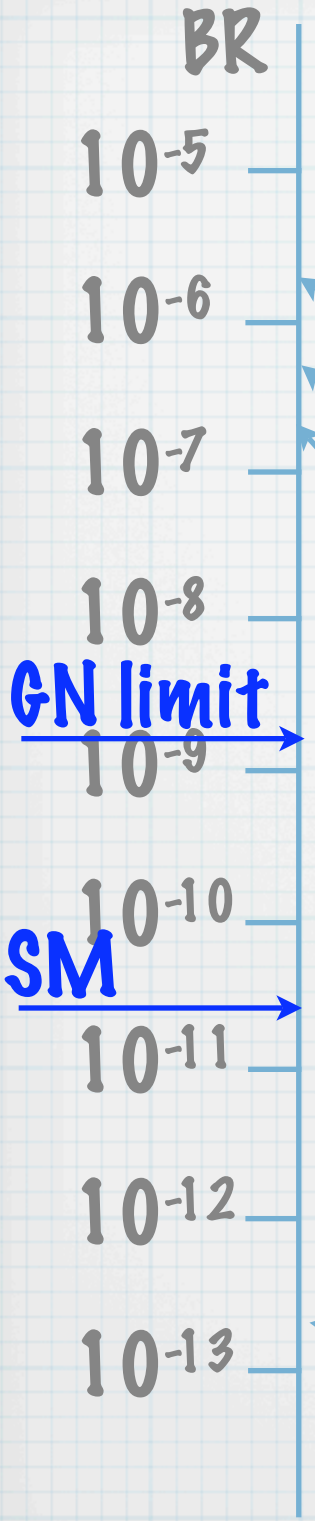
- Still the same 1-2% theoretical error!
- Compare with B results



probe New Physics



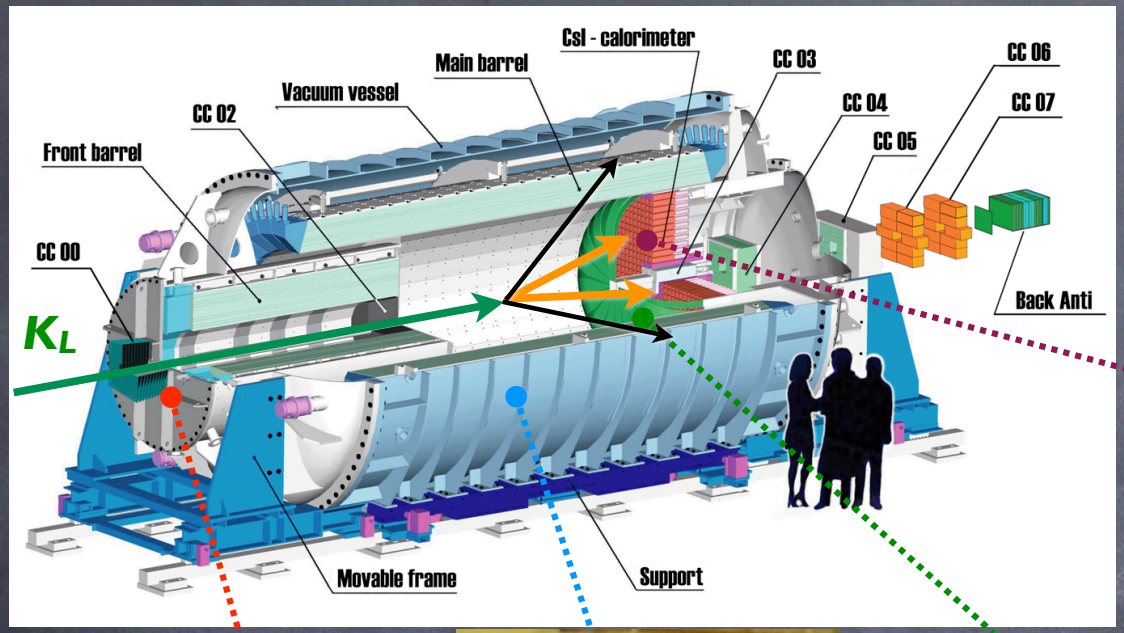
Step by Step

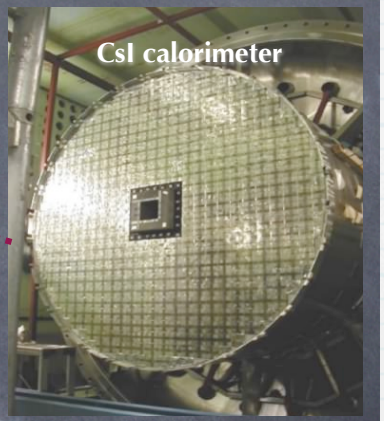


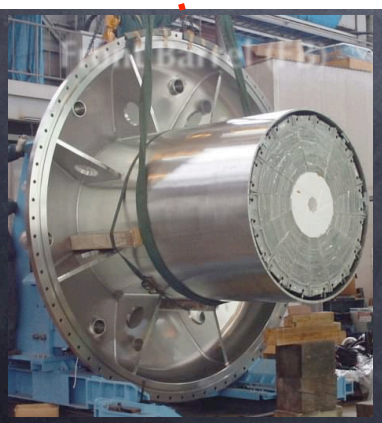
* KTeV/Nakaya
* KTeV/Hanagaki: π^0->eeγ
* KEK PS E391a 1week/Sakashita
* KEK PS E391a
* J-Parc Step 1: beyond GN limit, 1st observation
* J-Parc Step 2: >100 SM events

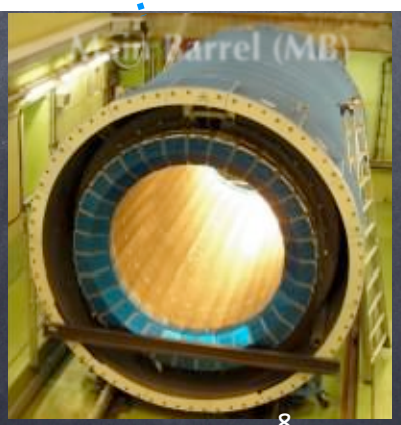
Step 0=KEK E391a w/12GeV protons

E391a Detector



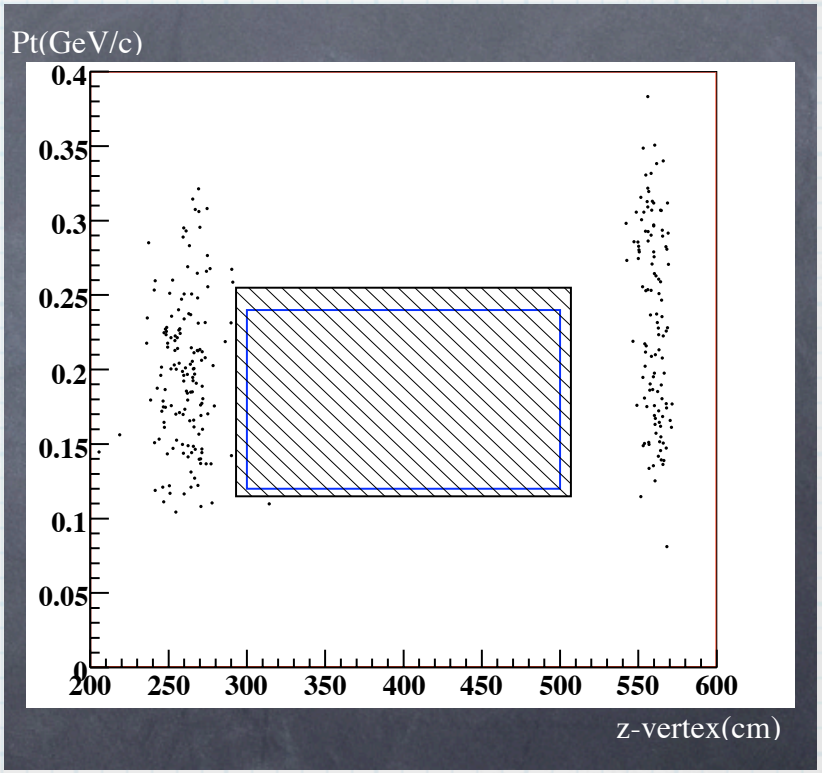






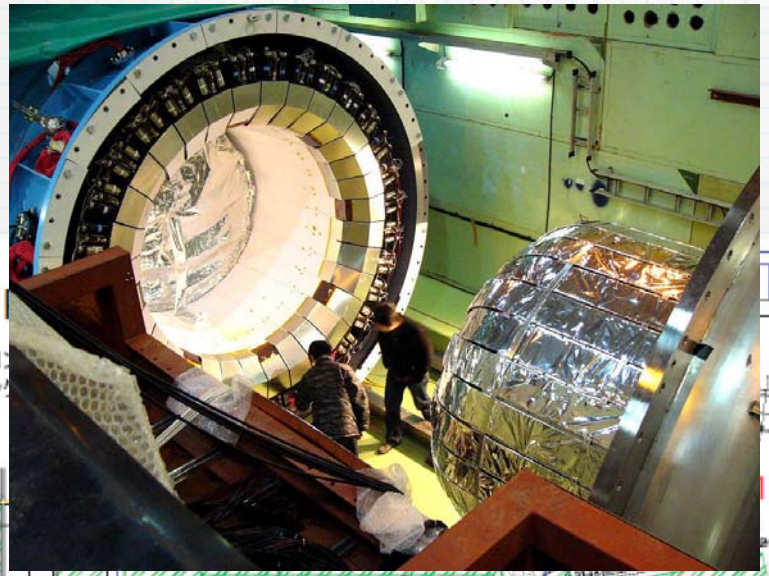
E391a status

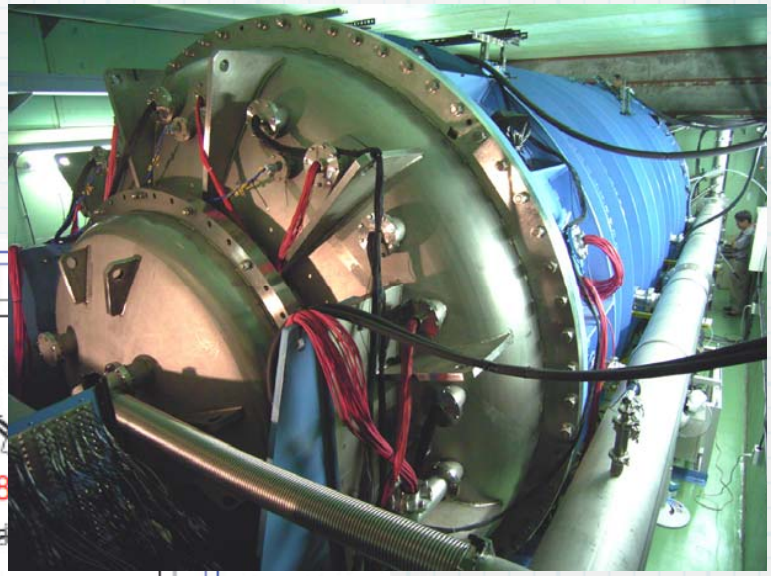
* Had Runs 1, 2 and 3
* Published BR<2.1x10^{-7} (90% CL) based on 10% of Run 1
* Analyzing 1/3 of Run 2.



J-Parc E14 Step 1

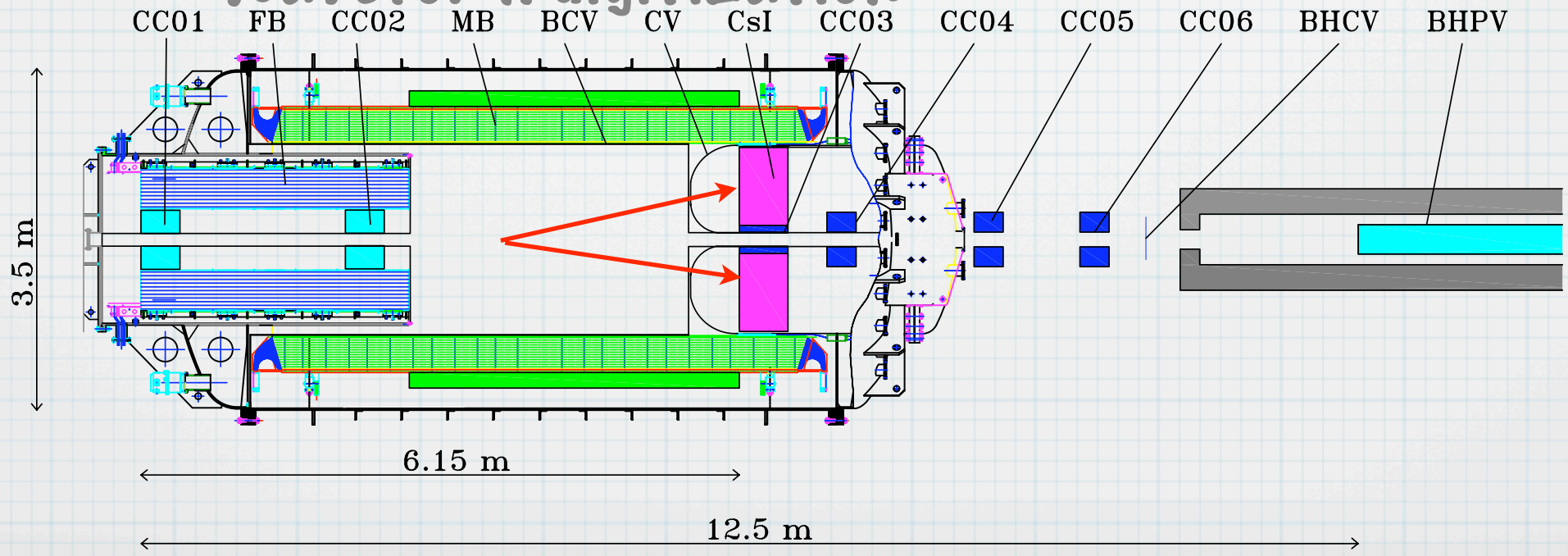
* Modified E391a detector at K0 beamline





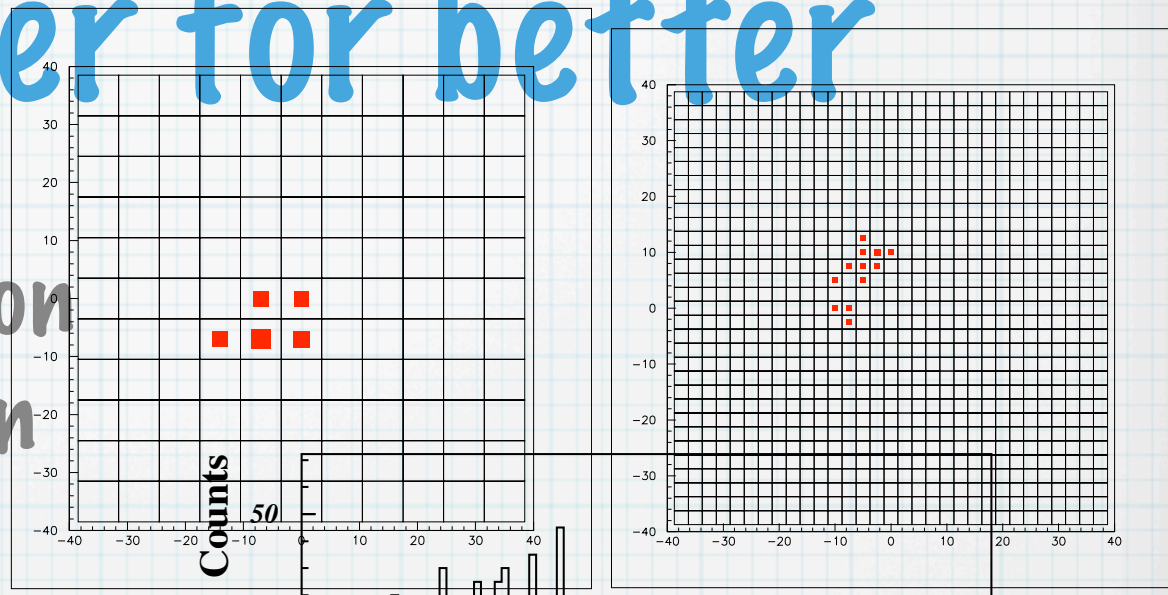
Step 1 Detector

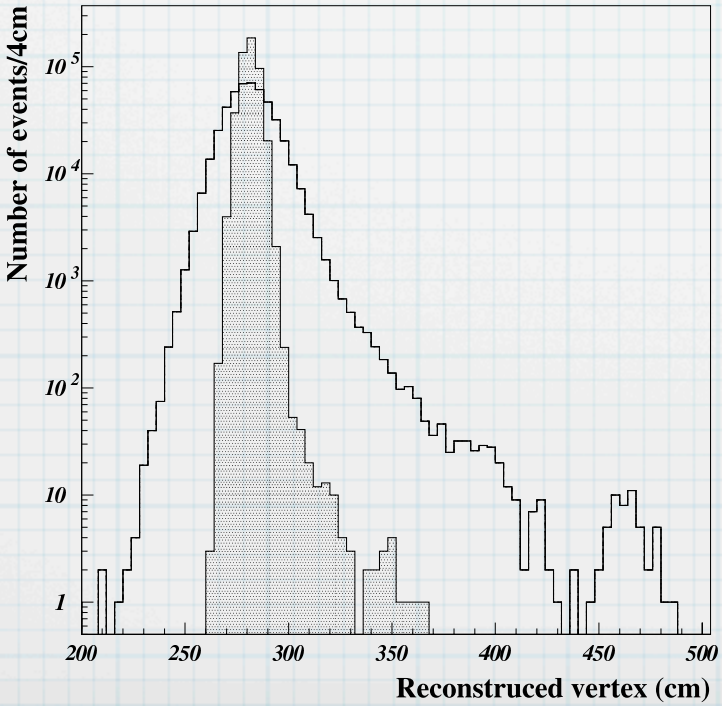
* fine granularity calorimeter
* Hermetic veto system w/high detection efficiency
* Waveform digitization

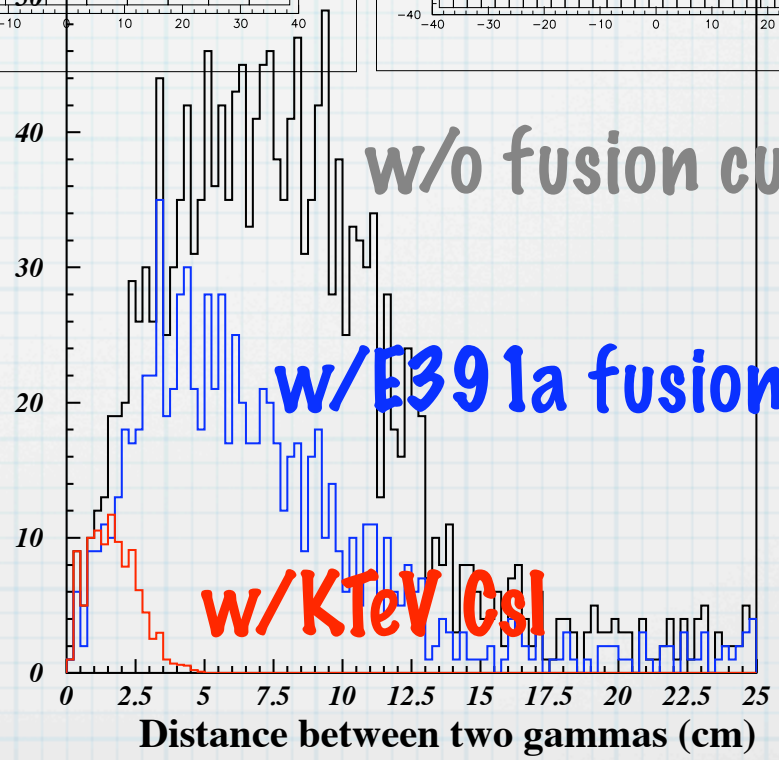


Fine granularity calorimeter for better

* photon isolation
* x8 bkg reduction
* energy resolution
* suppress n bkg



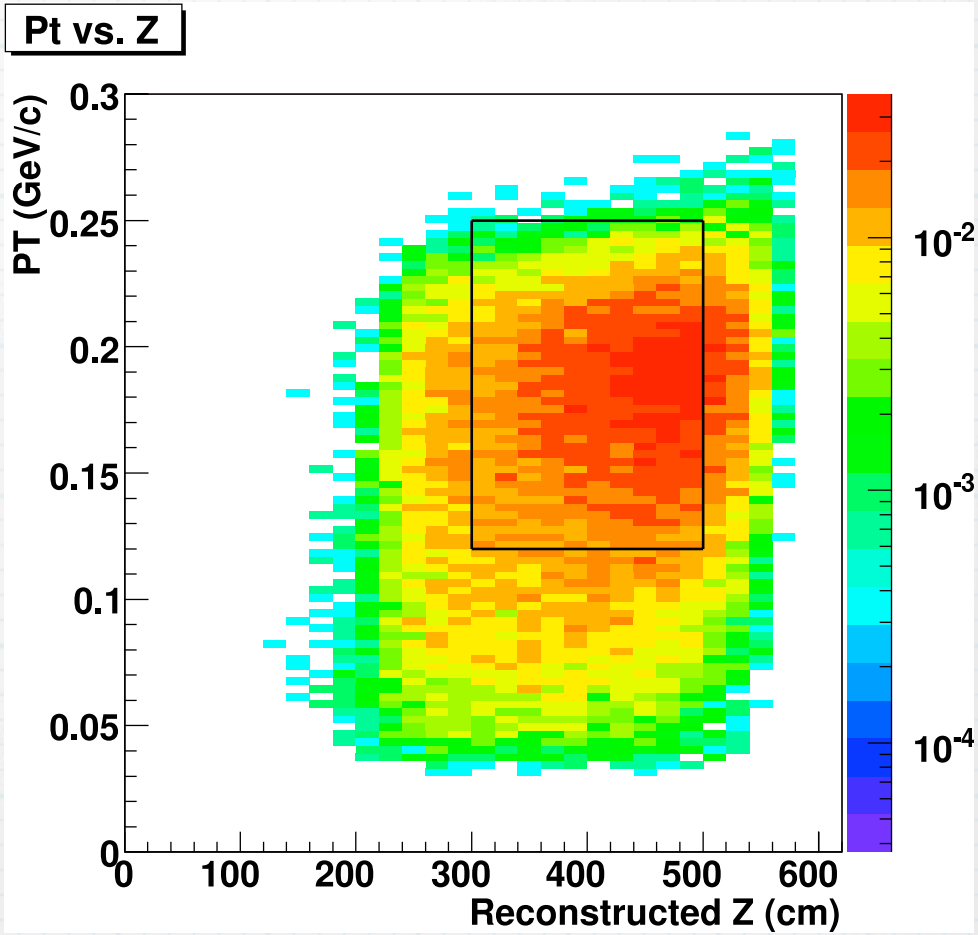




Signal Sensitivity

- 2.6x10^{12} K_L decays w/ 2E14 protons x 3E7 sec
- Sensitivity =8x10^{-12}

  3.5 SM evts
- Background = 2evts



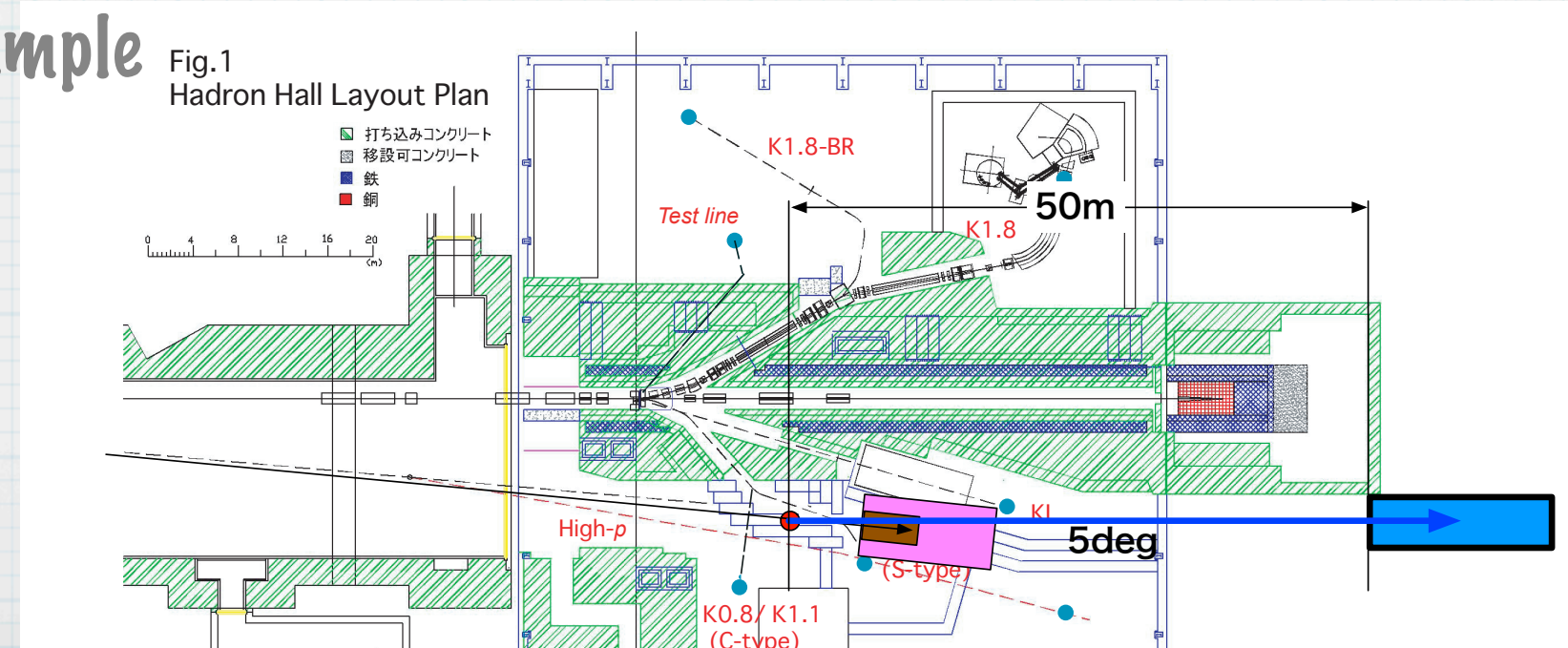
Step 1 status

- July 2006: Stage 1 approval
- July 2007: Stage 2 approval recommended by PAC
- KEK is reviewing the experiment to schedule beamline construction etc..

Step 2

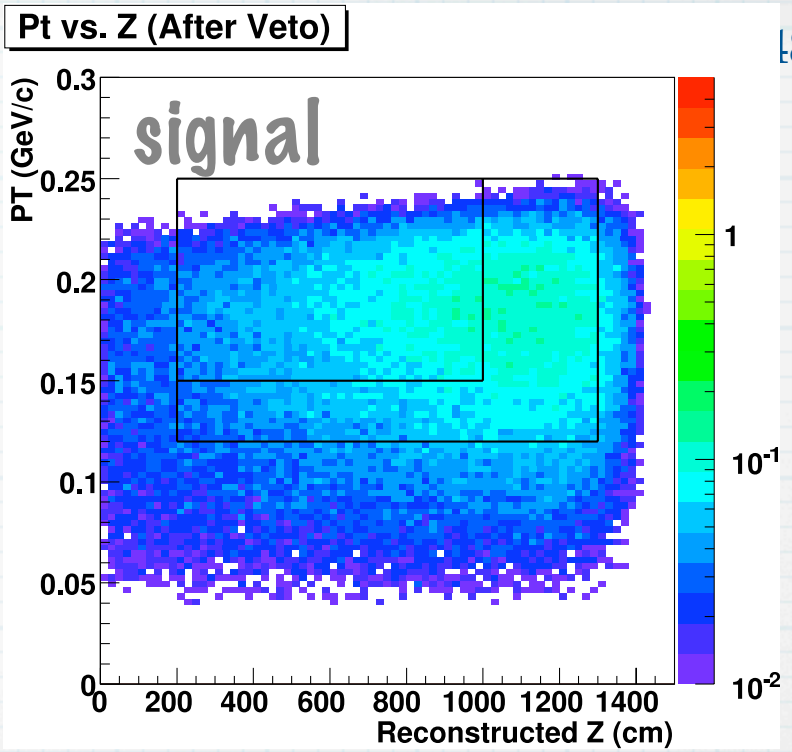
* Optimized beamline with 5deg angle for
  * higher KL momentum <PK>=5.2GeV/c
  * higher yield: 4.4E7/2μsr /3E14pot

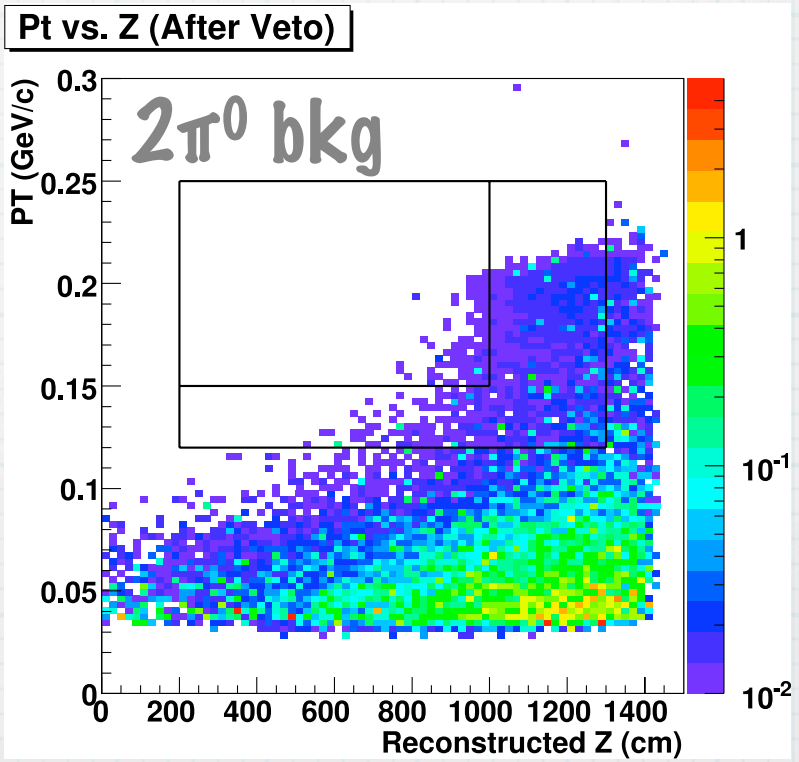
Example



Step 2

- Longer(15m) and larger (3m) detector for
  - longer decay volume: 6% decay in 11m
  - higher KL momentum
  - higher acceptance
- 133 SM events/ 3E14 x 3E7sec
- S/N = 4.8
  - 19 2pi0 bkg
  - 8 $\pi^+\pi^-\pi^0$ bkg





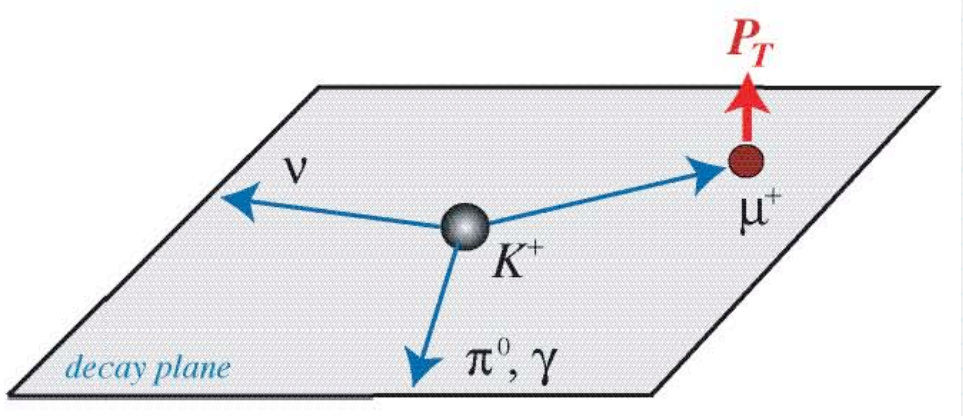
T-violation experiment

Thanks to Jun Imazato@KEK

Transverse muon polarization in Kμ3

$$K^+ \to \pi^0 \mu^+ \nu$$

$$P_T = \frac{\boldsymbol{\sigma}_\mu \cdot (\boldsymbol{p}_{\pi^0} \times \boldsymbol{p}_\mu)}{|\boldsymbol{p}_{\pi^0} \times \boldsymbol{p}_\mu|}$$



t → -t

p → -p

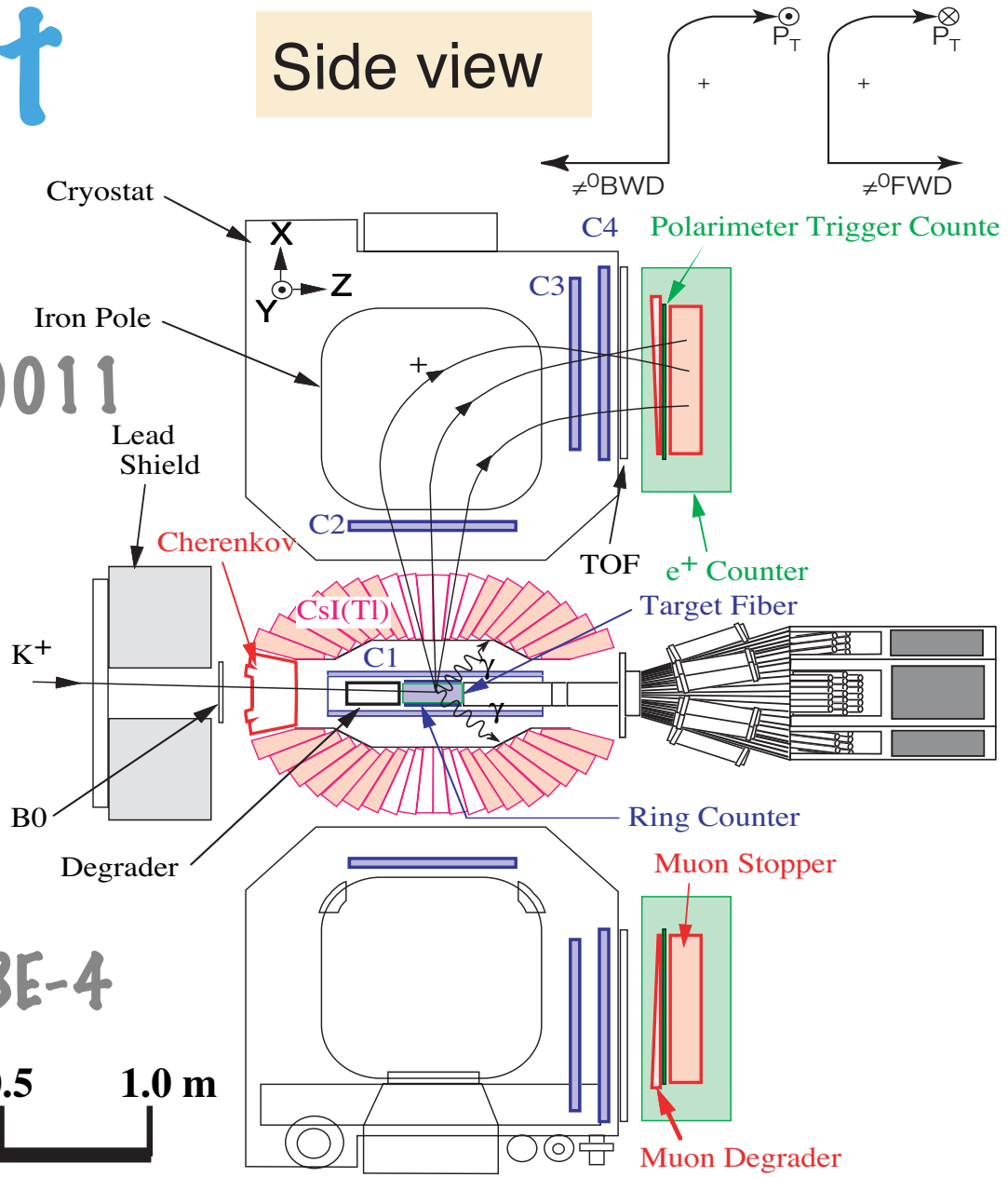
σ → -σ

$$P'_T = \frac{-\boldsymbol{\sigma}_\mu \cdot (-\boldsymbol{p}_{\pi^0} \times -\boldsymbol{p}_\mu)}{|-\boldsymbol{p}_{\pi^0} \times -\boldsymbol{p}_\mu|}$$

$$= \ominus P_T$$

KEK E246 experiment

- PRD 73, 072005 (2006)
- P_T = -0.0017±0.0023±0.0011
- Syst. errors
  - μ scattering 7.1E-4
  - B-field rot. 5.3E-4
  - detector alignment 2.8E-4

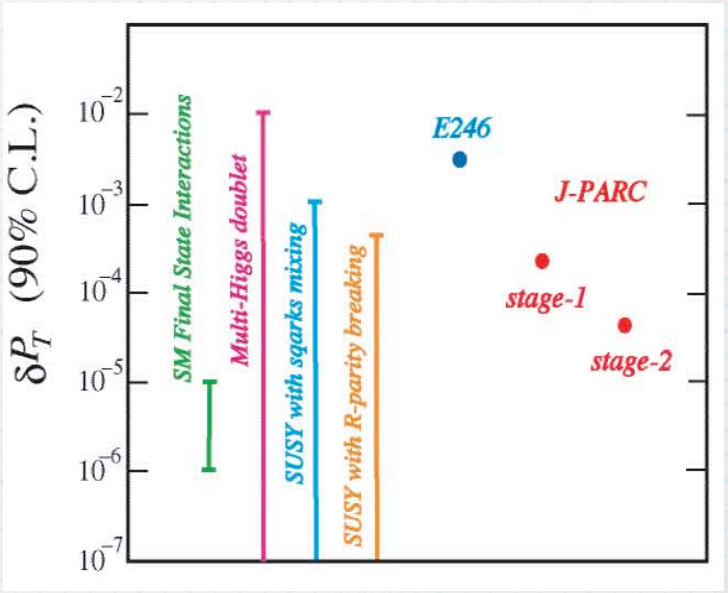


T-violation exp. @ J-Parc

* J-Parc E04 aims $dP_T = 10^{-4}$
  * x 30 beam intensity
  * x 10 acceptance
  * high analyzing power for polarization
  * better misalignment measurements
  * correction of systematic effects

Sensitivity

- Statistical error : 1.35E-4 w/
  - 1E7 sec running time
  - 9μA proton beam on target
  - 3MHz K^+ beam
  - 7.2E8 events for analysis
- Systematic error: 1E-4



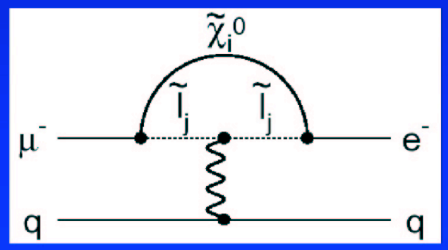
Lepton Number Violation?

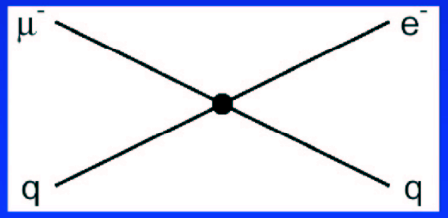
$\mu \rightarrow e$?

Sensitivity to Different Muon Conversion Mechanisms

Supersymmetry

Predictions at 10^{-15}





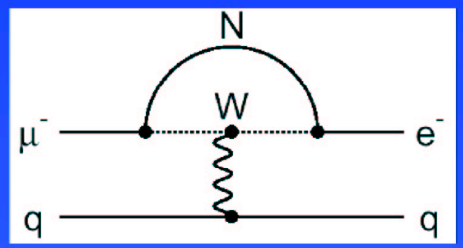
Compositeness

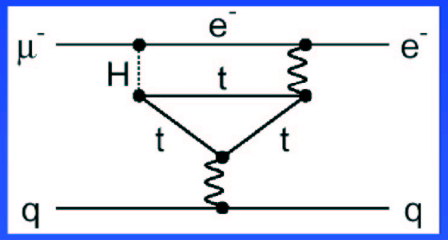
Λ_c = 3000 TeV

Heavy Neutrinos

$|U^*_{\mu N} U_{eN}|^2 =$

8×10^{-13}

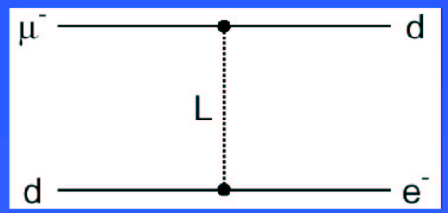


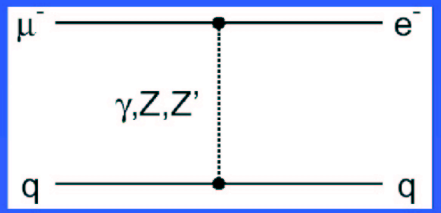


Second Higgs doublet

$g_{H\mu e} = 10^{-4} \times g_{H\mu\mu}$

Leptoquarks





Heavy Z', Anomalous Z coupling

$M_{Z'}$ = 3000 TeV/c^2

$B(Z \rightarrow \mu e) < 10^{-17}$

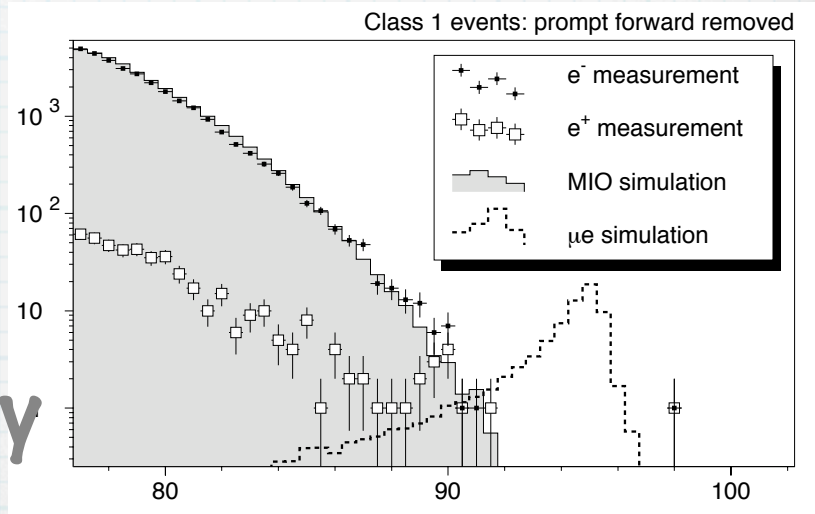
$M_L =$

$3000\ (\lambda_{\mu d}\lambda_{ed})^{1/2}$ TeV/c^2

After W. Marciano

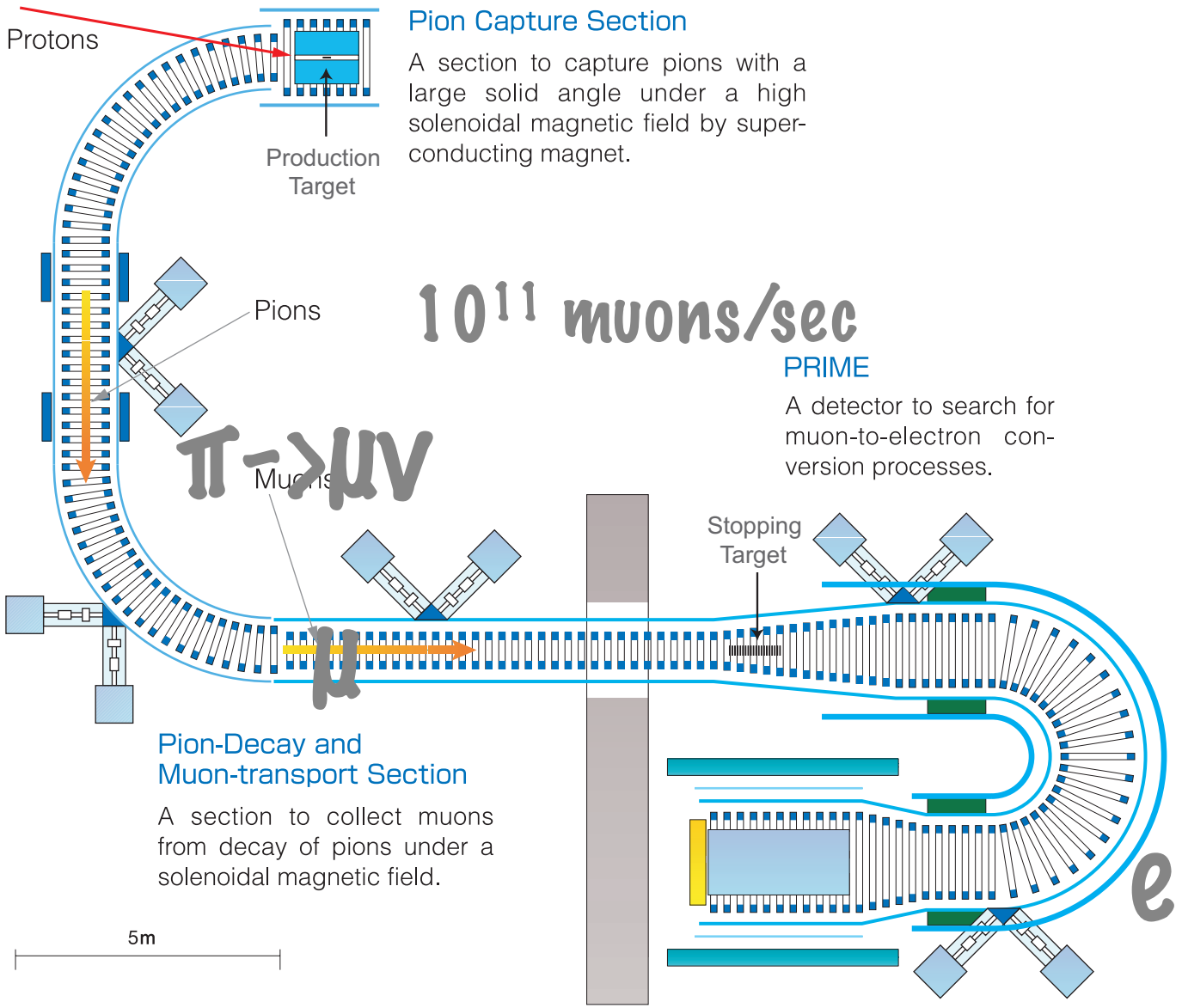
μ-e conversion in atom

* muon is captured in 1s state
* $\mu^- + N(A,Z) \rightarrow e^- + N(A,Z)$
* Signal = 105MeV e^-
* Background
  * end point of μ->evv decay
  * beam related background



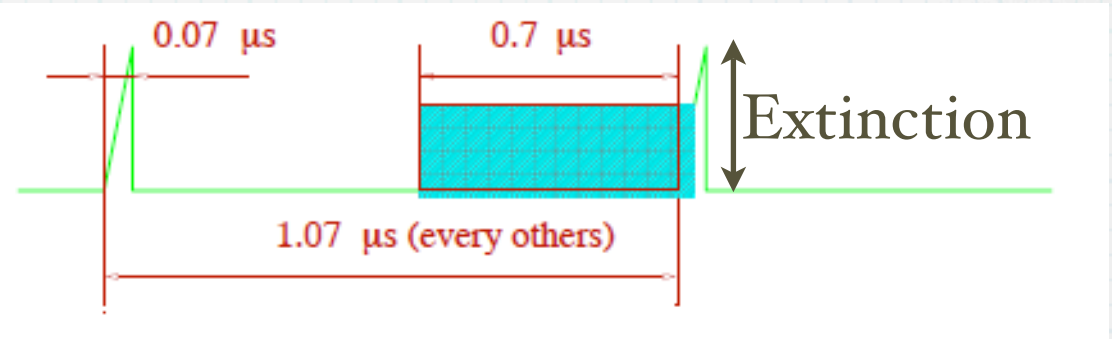
COMET = COherent Muon Electron Transition

pulsed proton beam



Backgrounds

* pion capture in atom (prompt)
  * $\pi^- + (A,Z) \rightarrow (A,Z-1)^* \rightarrow \gamma + (A,Z-1);\ \gamma \rightarrow e^+e^-$
  * Need <1E-9 proton extinction



* muon decay in orbit
  * Need accurate E and t measurements

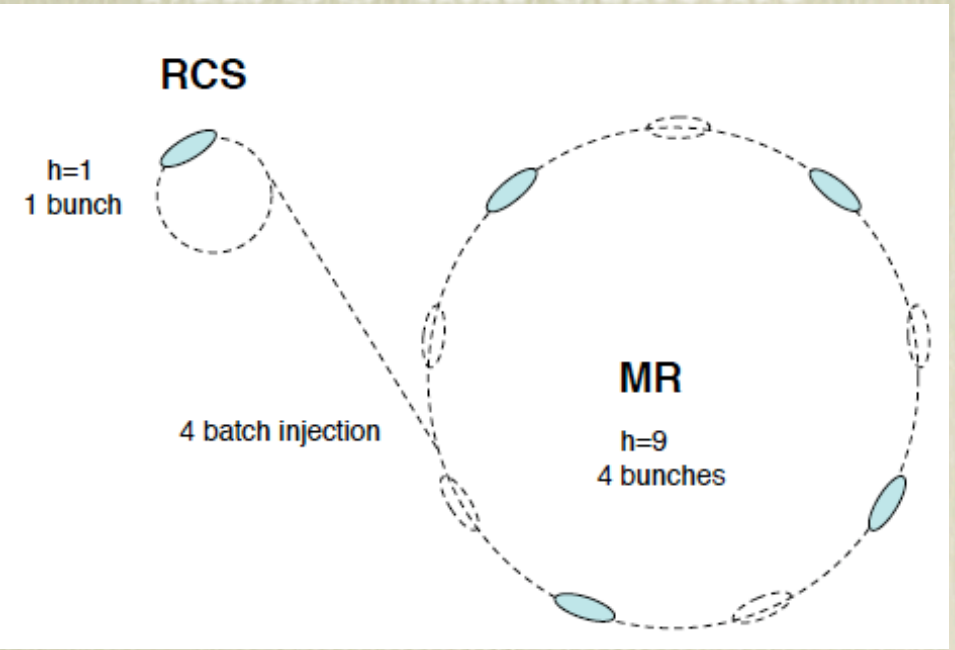
Pulsed Proton Beam (2) : Bunching Scheme

PRISM

J-PARC Accelerator Complex

- RCS : 1 bunch operation
  - h=1 or h=2 w/ empty bucket
- MR : Empty bucket Scheme
  - h=9 or h=8
- Adiabatic dumping : small
  - 30 GeV → 8 GeV
  - Reduce RCS painting area
  - Smaller 3-50BT collimator
- 8 GeV, 7 μA ; 56 kW to NP-Hall

MECO-like Scheme

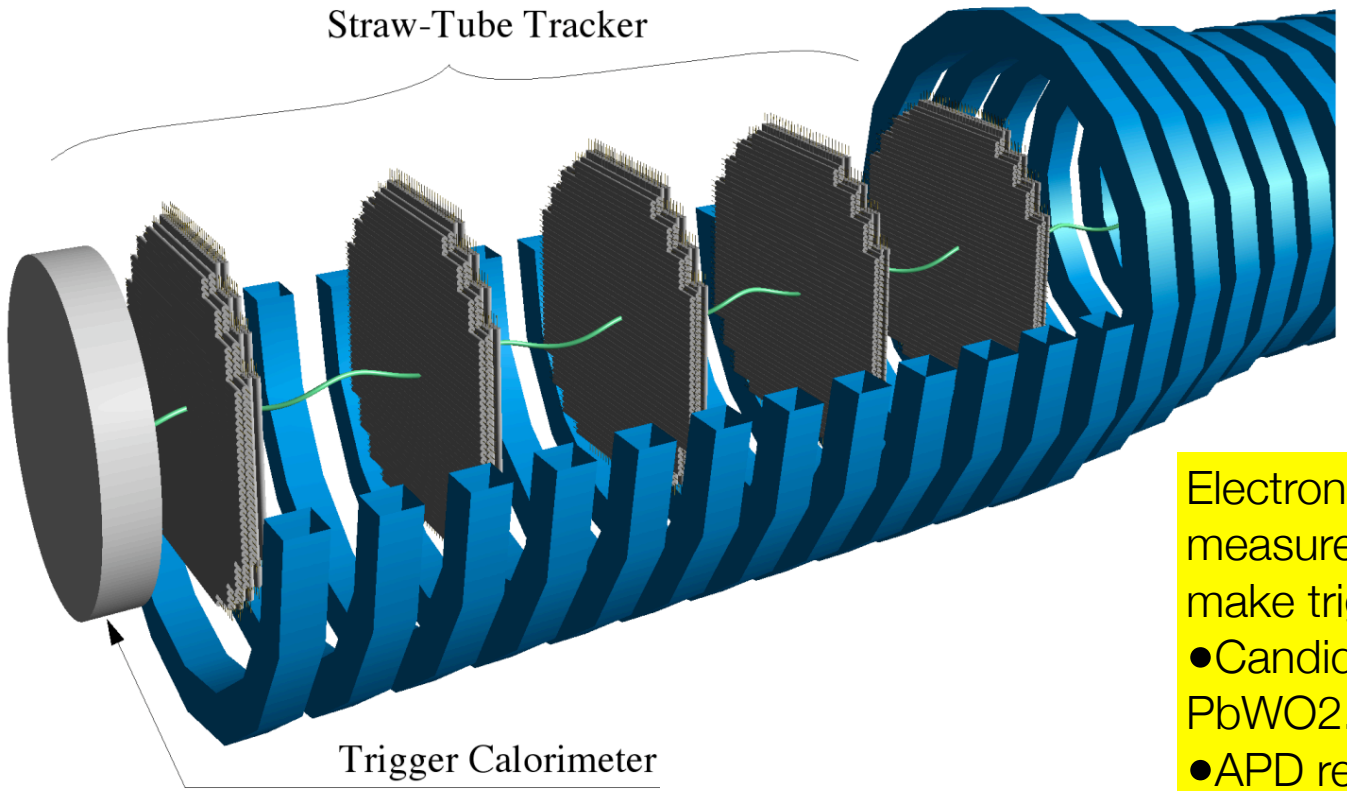


Electron Detection (preliminary)

Under a solenoidal magnetic field of 1 Tesla.

In vacuum to reduce multiple scattering.

Straw-tube Trackers to measure electron momentum.
- should work in vacuum and under a magnetic field.
- A straw tube has 25μm thick, 5 mm diameter.
- One plane has 2 views (x and y) with 2 layers per view.
- Five planes are placed with 48 cm distance.
- 250μm position resolution.



Electron calorimeter to measure electron energy and make triggers.
- Candidate are GSO or PbWO2.
- APD readout (no PMT).

Sensitivity and background

* 8E20 8GeV protons x 2.4E-3 muons/p

  x 0.29 stopping eff = 6E17 stopping muons

* x 0.6 muon capture eff x 7% acceptance

* ==> BR<1E-16 (90%CL)

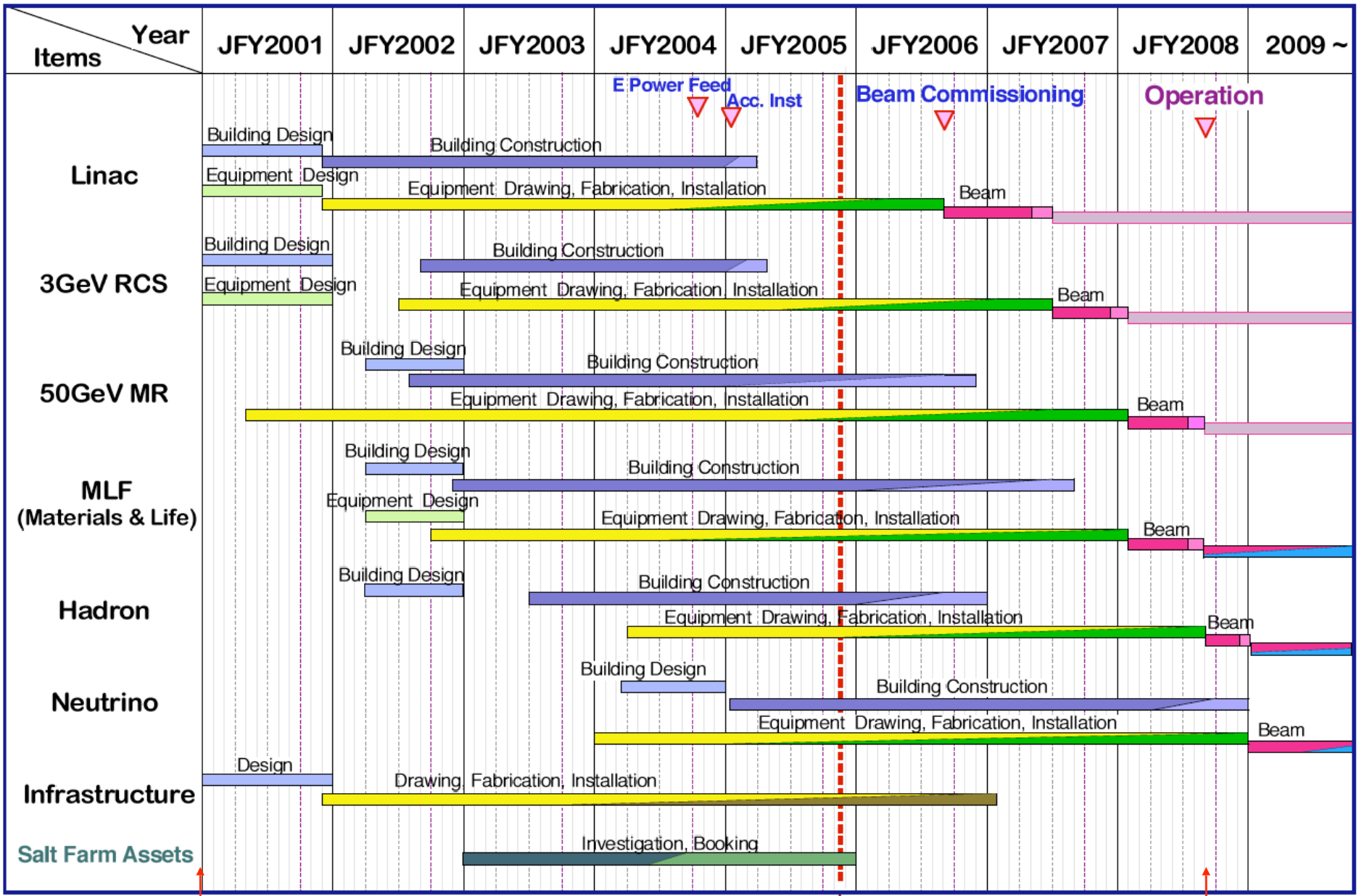
* 0.34 bkg events (0.12 radiative pion capture, 0.05 muon decay in orbit, ...)

J-Parc future

JFY starts in April

J-PARC Construction Schedule

Feb. 27 2006



Time when this schedule was created

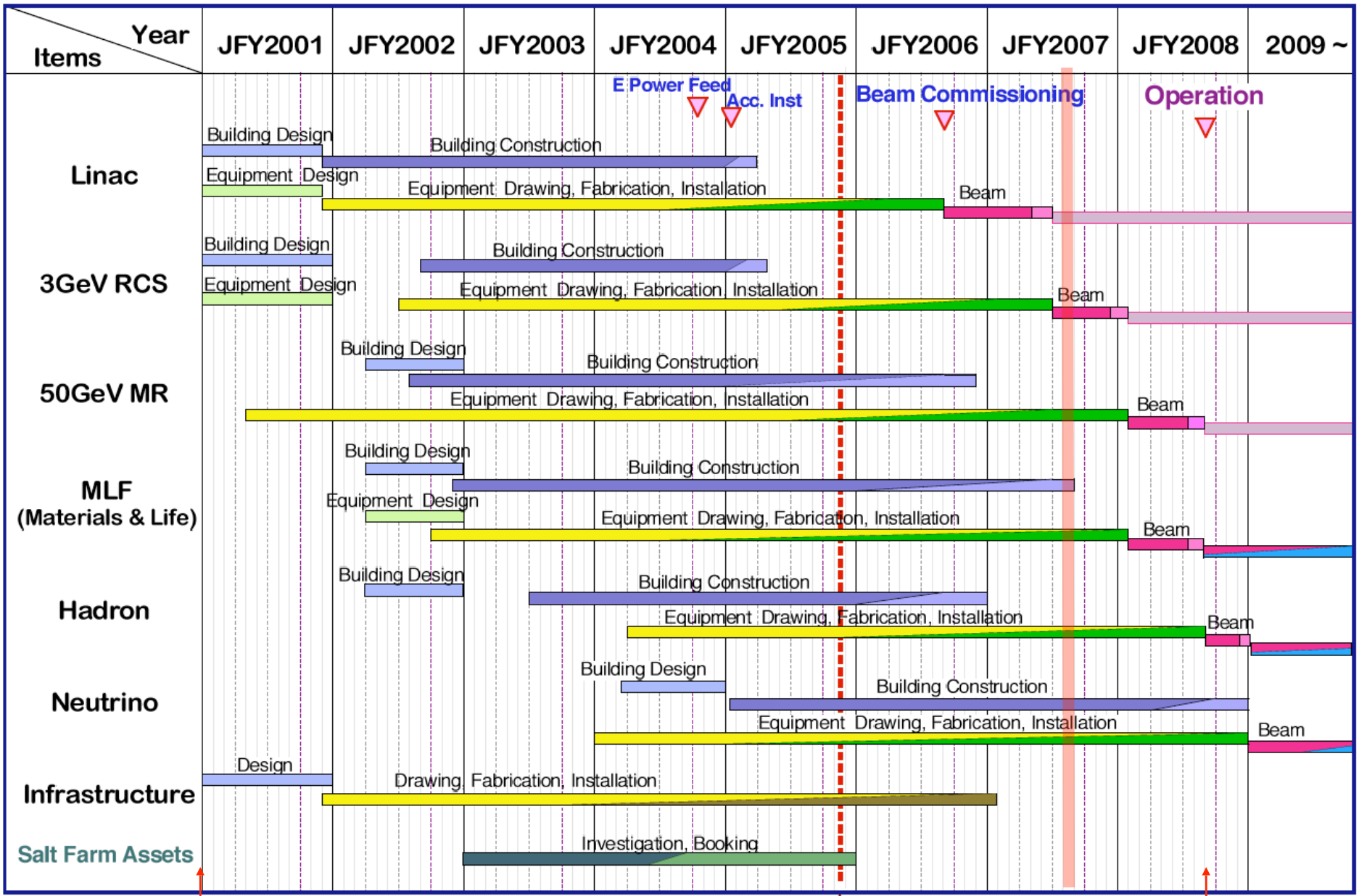
Construction Start

Facility Operation

JFY starts in April

J-PARC Construction Schedule

Feb. 27 2006



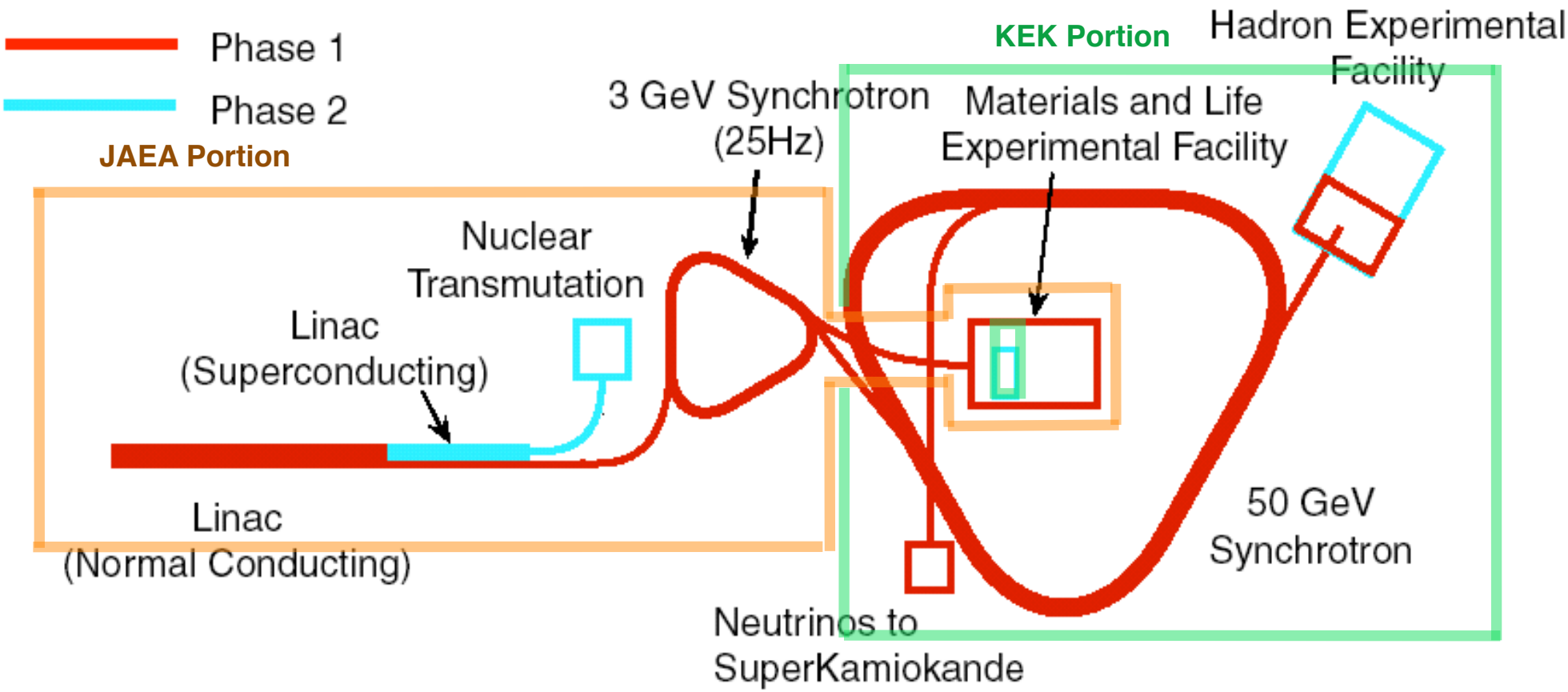
Time when this schedule was created

NOW

Construction Start

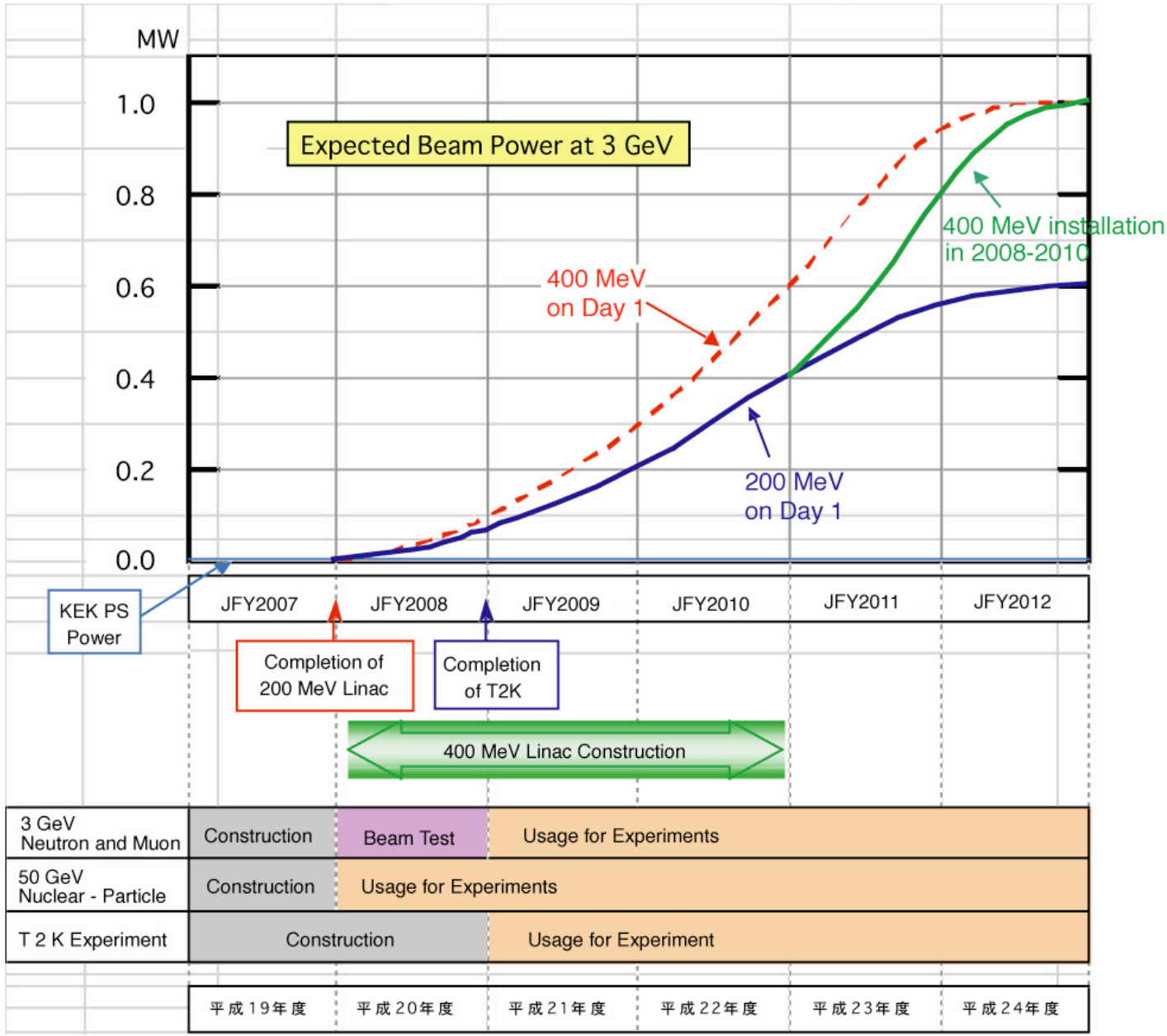
Facility Operation

Phase 1 and Phase 2



- Phase 1 + Phase 2 = 1,890 Oku Yen (= $1.89 billions if $1 = 100 Yen).
- Phase 1 = 1,527 Oku Yen (= $1.5 billions) for ~8 years.
- JAEA: 860 Oku Yen (56%), KEK: 667 Oku Yen (44%).

Commissioning & Linac Energy Recovery



Construction needs to start from JFY2008 or JFY2009, hopefully for 3 years, as shown in this figure.

Upgrade Plans for 50 GeV

- Power beyond 1 MW (neutrinos to study CP violation in the leptonic sector)
  - Design study was advanced to 1.3 MW.
  - Possibility up to 2.7 MW is in progress by the Accelerator group.
  - Users want up to 4 MW.
- Muon Storage Ring (LFV, muon g-2, etc.)
  - Need additional extraction beam line.
  - Exit was already prepared.
  - Anti-protons together with muons?
- Polarized Protons
  - Study group was formed.
  - Installation of Siberian snakes seems possible.
- Heavy Ion Acceleration
  - Interest exists among users.
  - Need technical studies.

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Summary

* J-Parc is the Intensity Frontier in the world
* J-Parc covers wide scientific areas; life, materials, nuclear and particle physics
* Coming up soon!

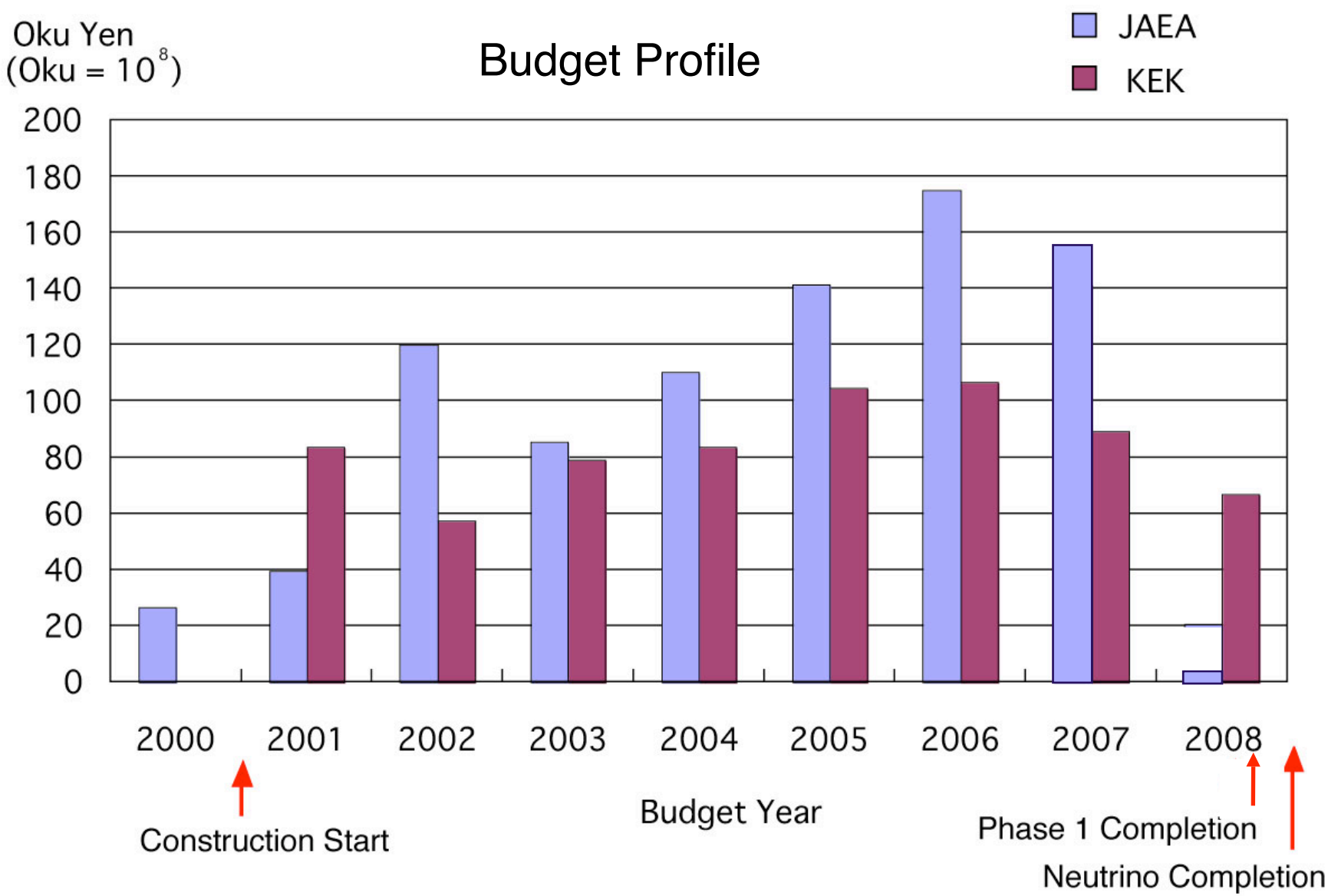
Backup slides

PRISM

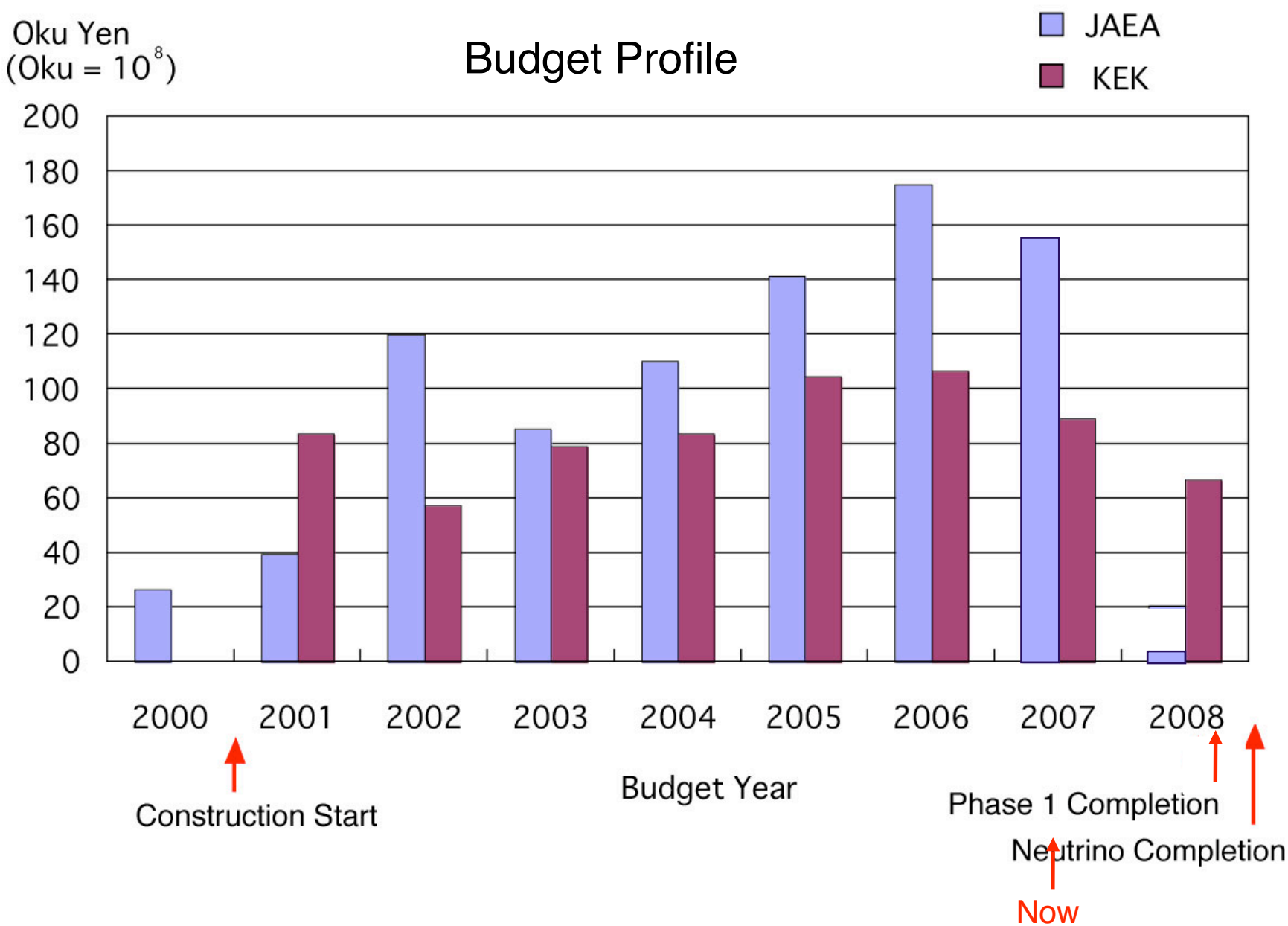
Backgroundの評価

	Backgrounds	Events	Comments
(1)	Muon decay in orbit	0.05	230 keV resolution
	Radiative muon capture	<0.001	
	Muon capture with neutron emission	<0.001	
	Muon capture with charged particle emission	<0.001	
(2)	Radiative pion capture*	0.12	prompt
	Radiative pion capture	0.002	late arriving pions
	Muon decay in flight*	<0.02	
	Pion decay in flight*	<0.001	
	Beam electrons*	0.08	
	Neutron induced*	0.024	for high energy neutrons
	Antiproton induced	0.007	for 8 GeV protons
(3)	Cosmic-ray induced	0.04	10^{-4} veto efficiency
	Pattern recognition errors	<0.001	
	Total	0.34	

Construction Budget

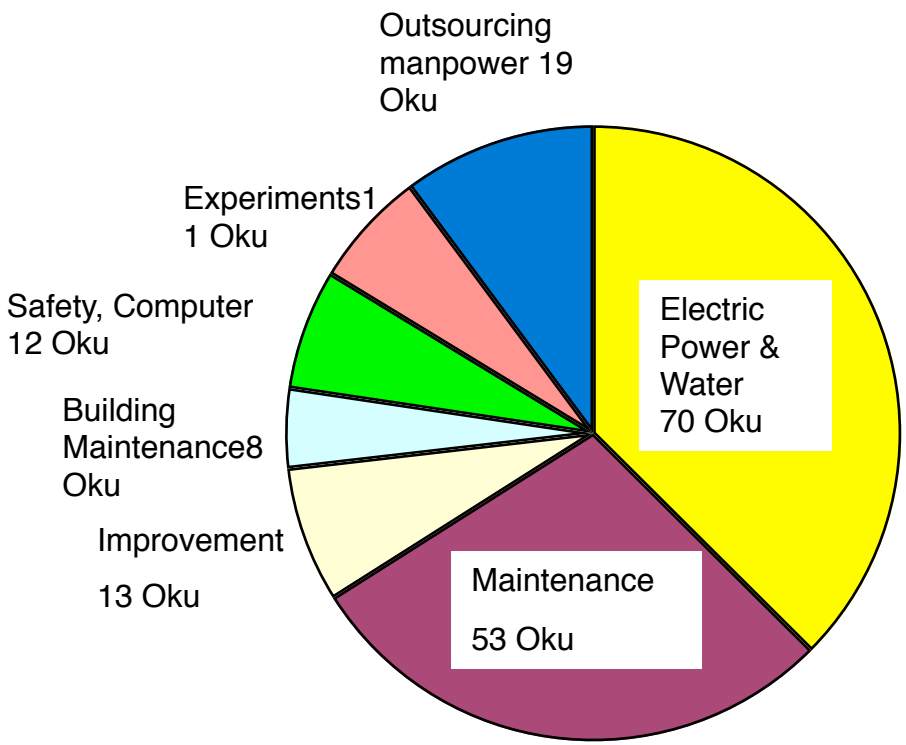


Construction Budget



Operational Cost of J-PARC

200 day data taking

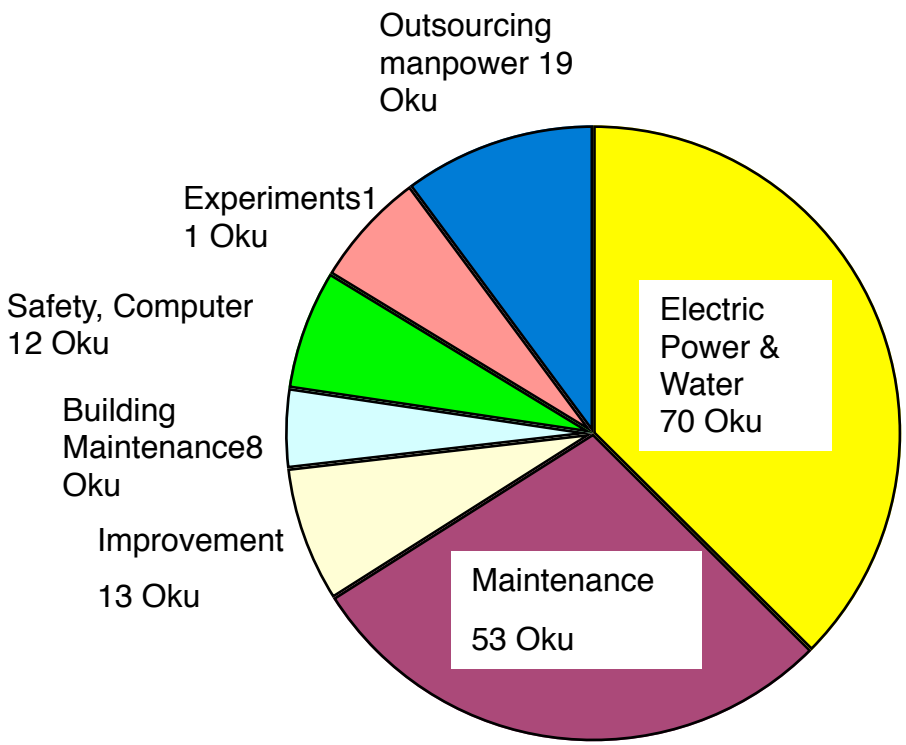


Total: 187 Oku Yen

(Other personnel's: About 30 Oku Yen)

Operational Cost of J-PARC

200 day data taking



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The Review Committee understood the reason why this budget is needed. However, an effort to reduce the cost was also recommended.

Operational Cost of J-PARC

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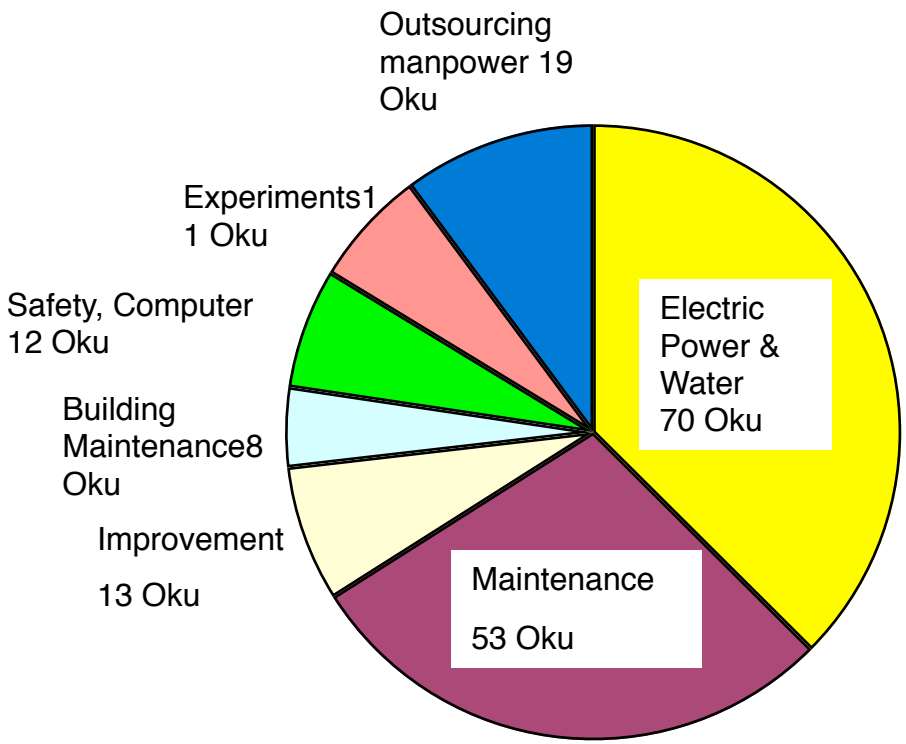

Total: 187 Oku Yen
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The Review Committee understood the reason why this budget is needed. However, an effort to reduce the cost was also recommended.

Request for JFY2008:

- All except neutrino start to run.
- 110day operation for neutrons.

Operational cost for JFY2008

KEK : 39 Oku Yen

JAEA: 53 Oku Yen

Total 92 Oku Yen

Plane view of Hadron Experimental Hall