J-PARC: Current Status and Prospects

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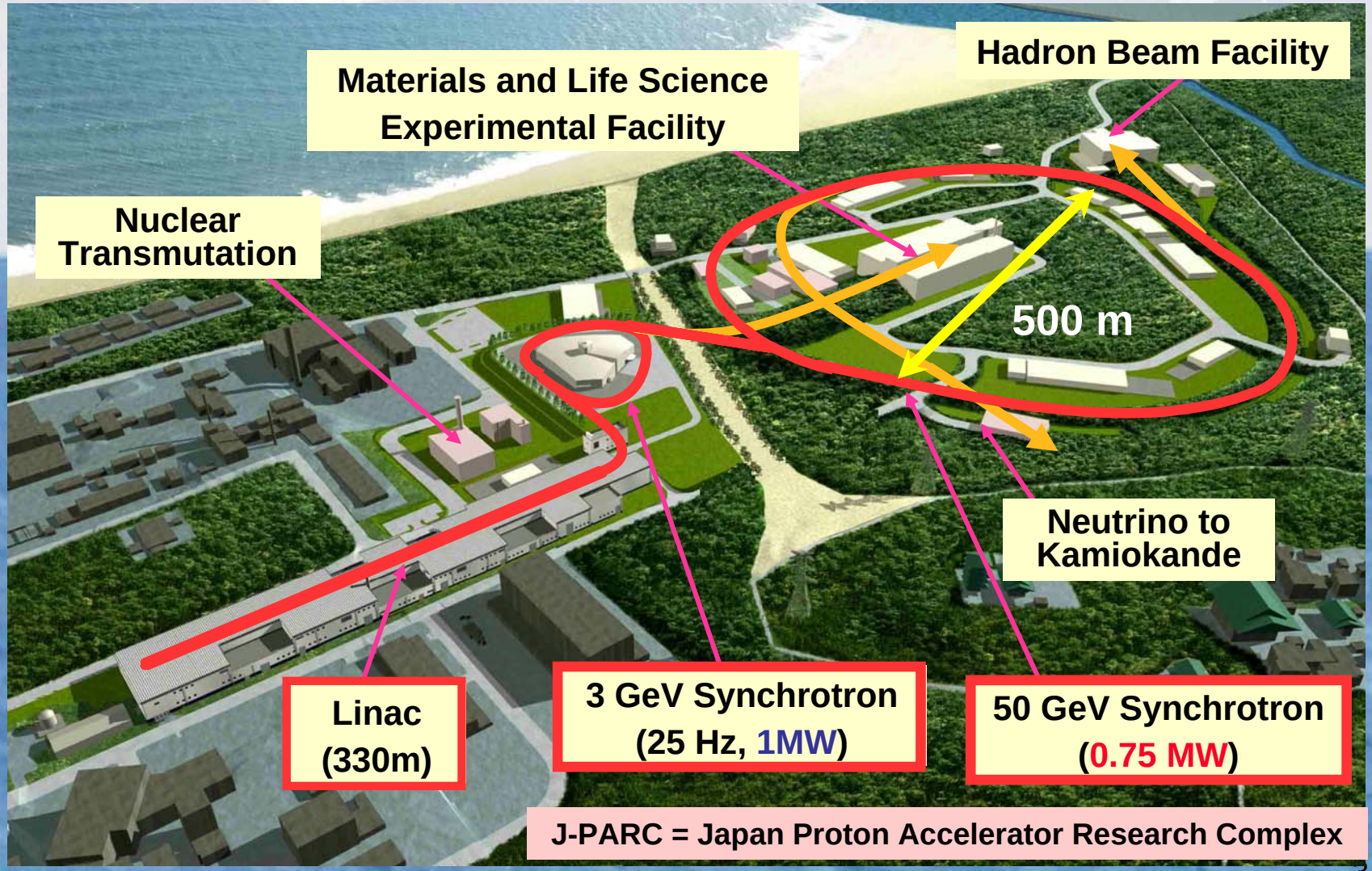
(KEK)

Outline

- What is J-PARC?
- Nuclear and Particle Physics@ J-PARC
  - Hadron Physics
  - Flavor Physics : neutrino, CPV, LFV
- Status of J-PARC
- Summary

J-PARC Facility

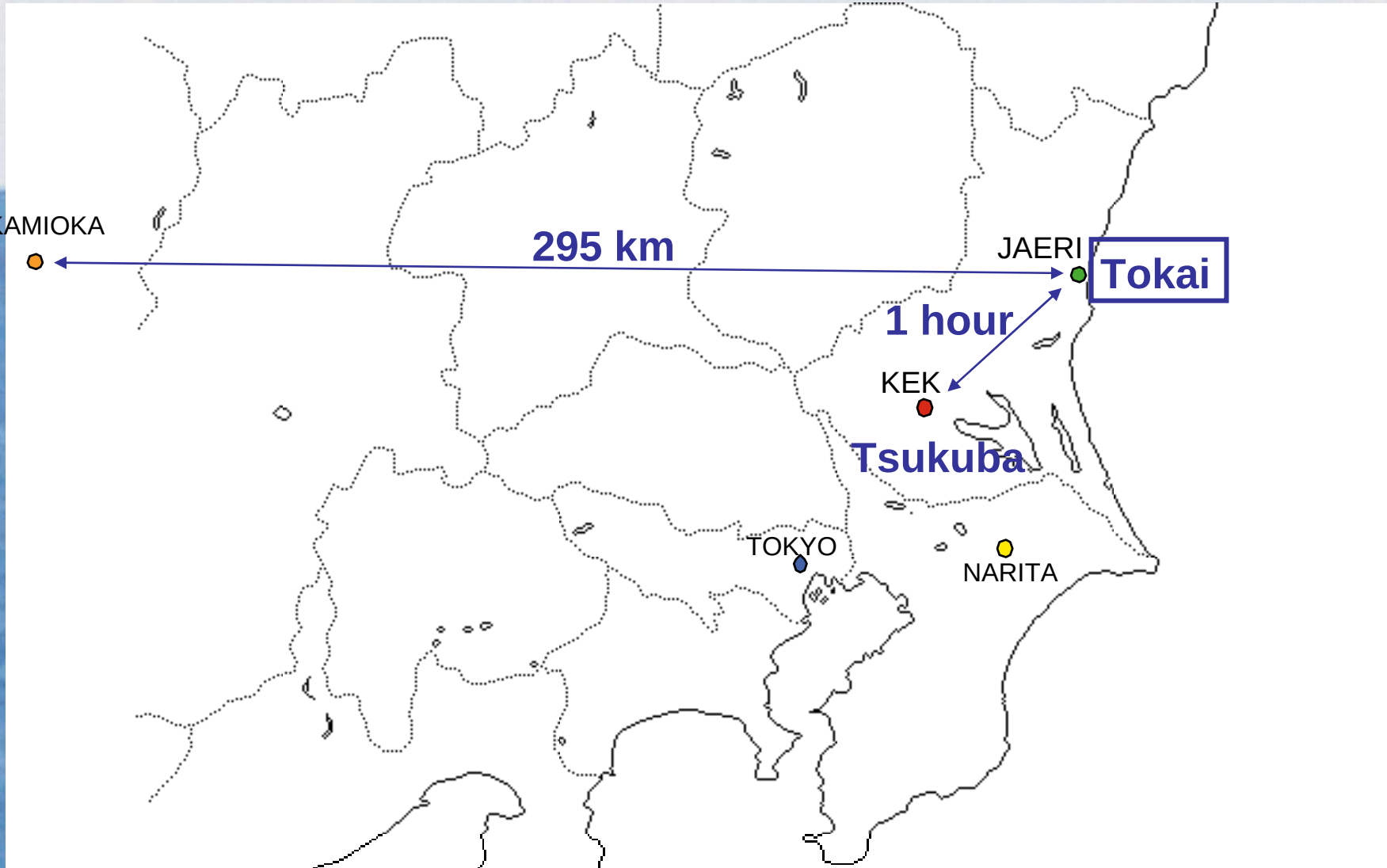


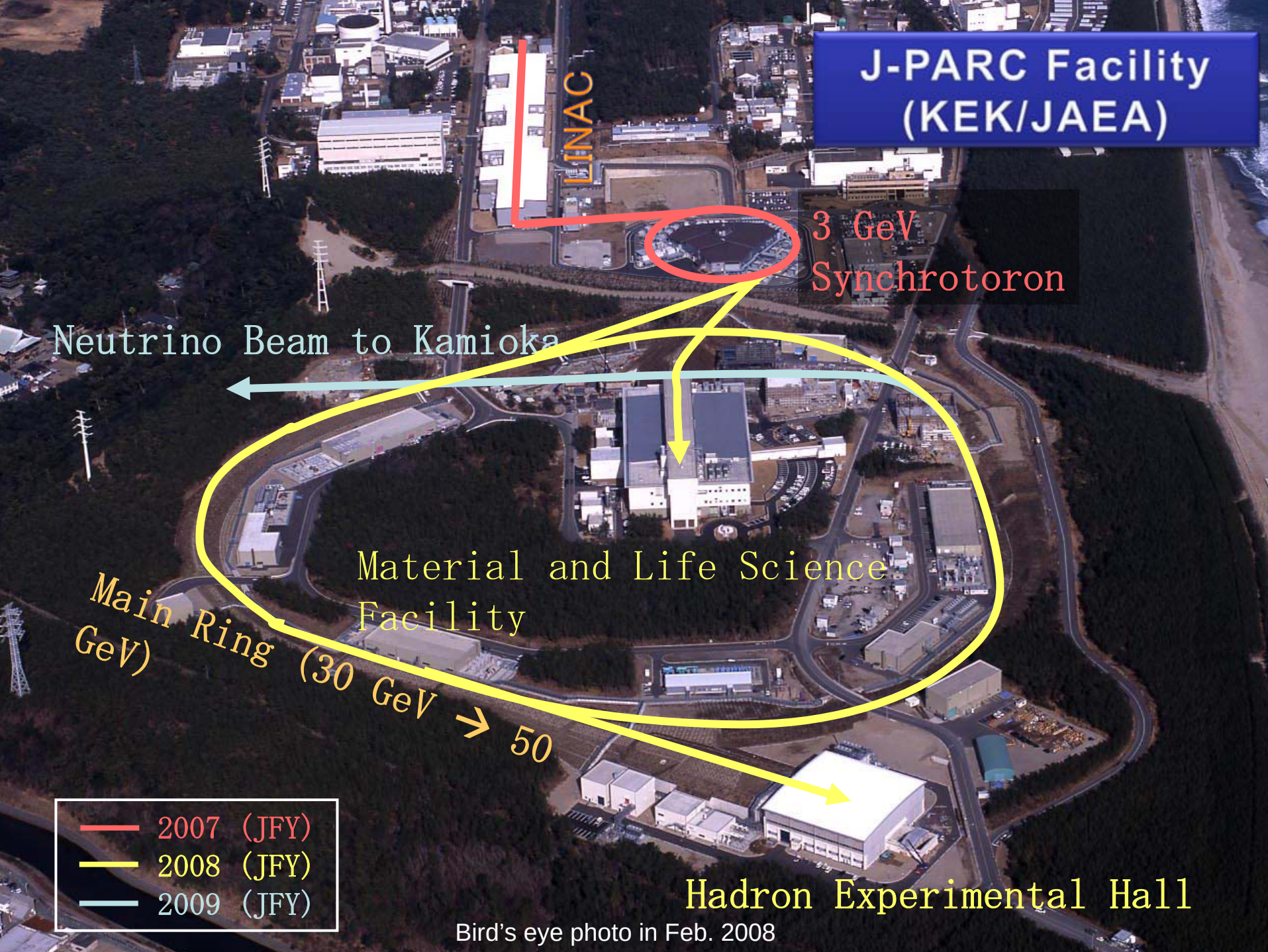
J-PARC = Japan Proton Accelerator Research Complex

Joint Project between KEK and JAEA

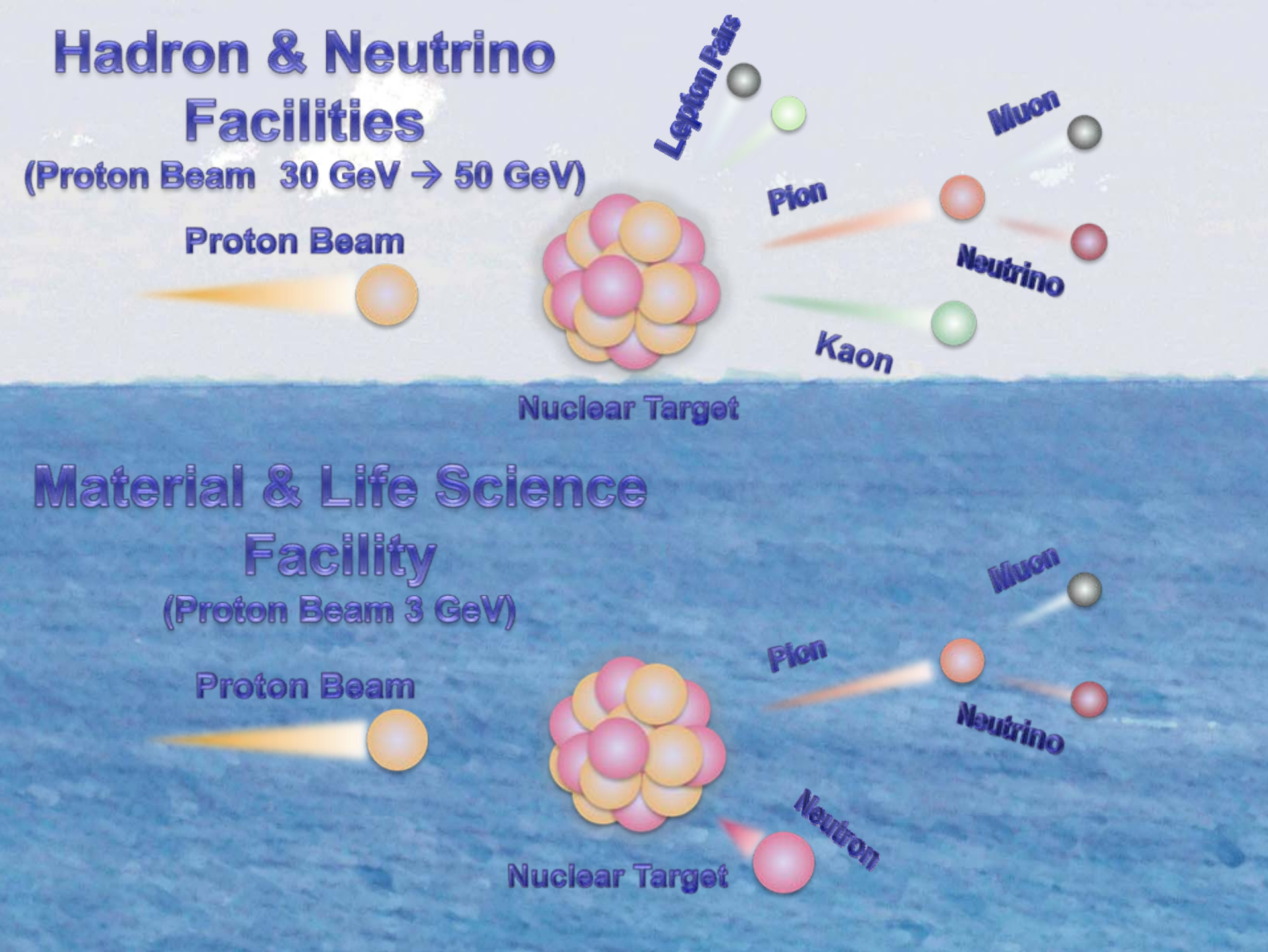
Location of J-PARC at Tokai

- Closer to beach…



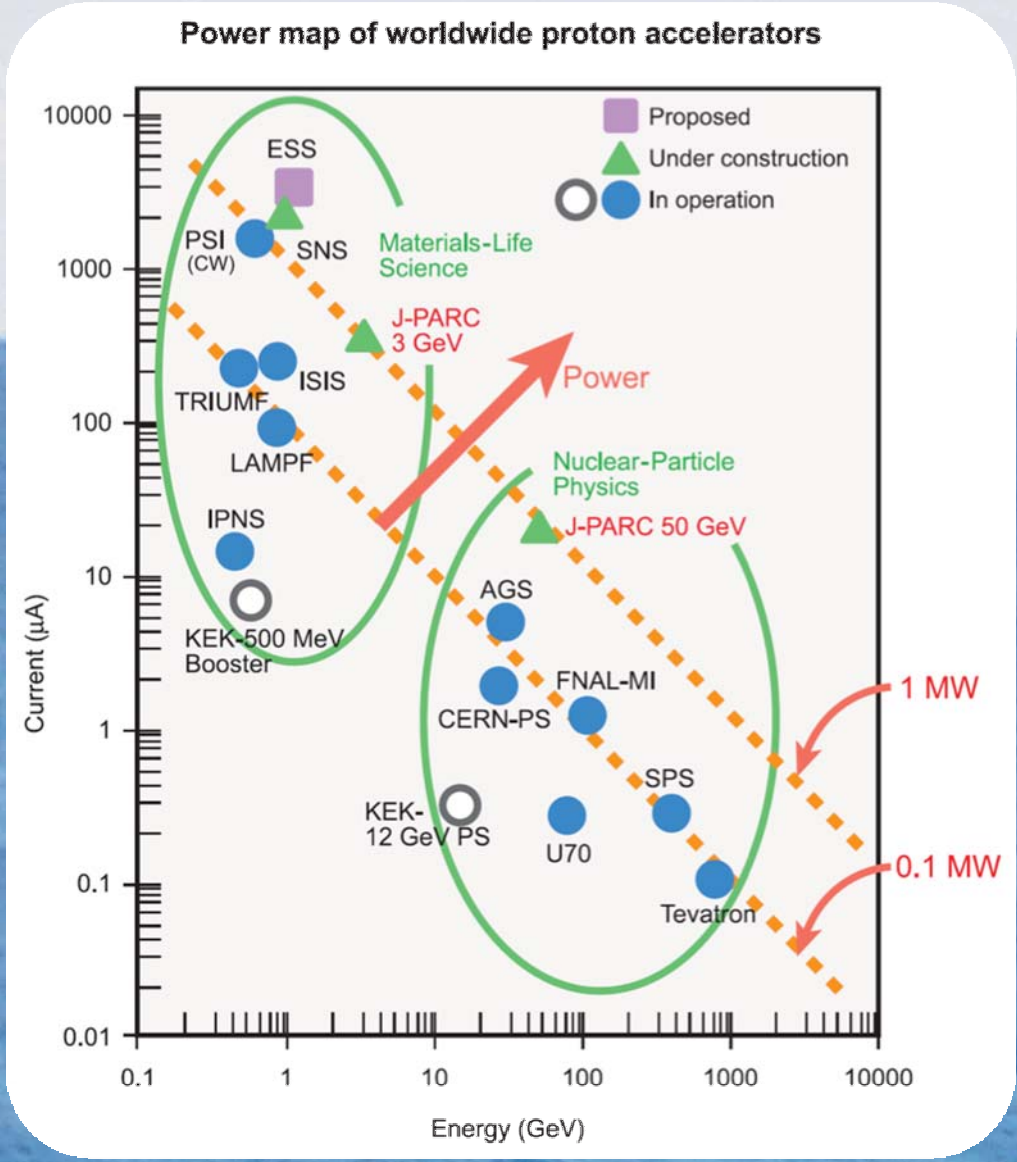


Bird's eye photo in Feb. 2008


Hadron & Neutrino Facilities
(Proton Beam 30 GeV → 50 GeV)
Proton Beam
Lepton Pairs
Pion
Kaon
Muon
Neutrino
Nuclear Target
Material & Life Science Facility
(Proton Beam 3 GeV)
Proton Beam
Pion
Muon
Neutrino
Neutron
Nuclear Target

Aim for MW class facility

- PSI is the top runner,
- SNS is following
  - Current peak ~350 kW (WEB)
- J-PARC is following and eventually…



- How J-PARC can provide answers for
  - How matters (hadrons) are formed?
    - Confinement is understood?
    - How hadron properties are emerged?
  - How matter-dominant universe is emerged?
    - CP violation in quark sector
    - CP violation in lepton sector

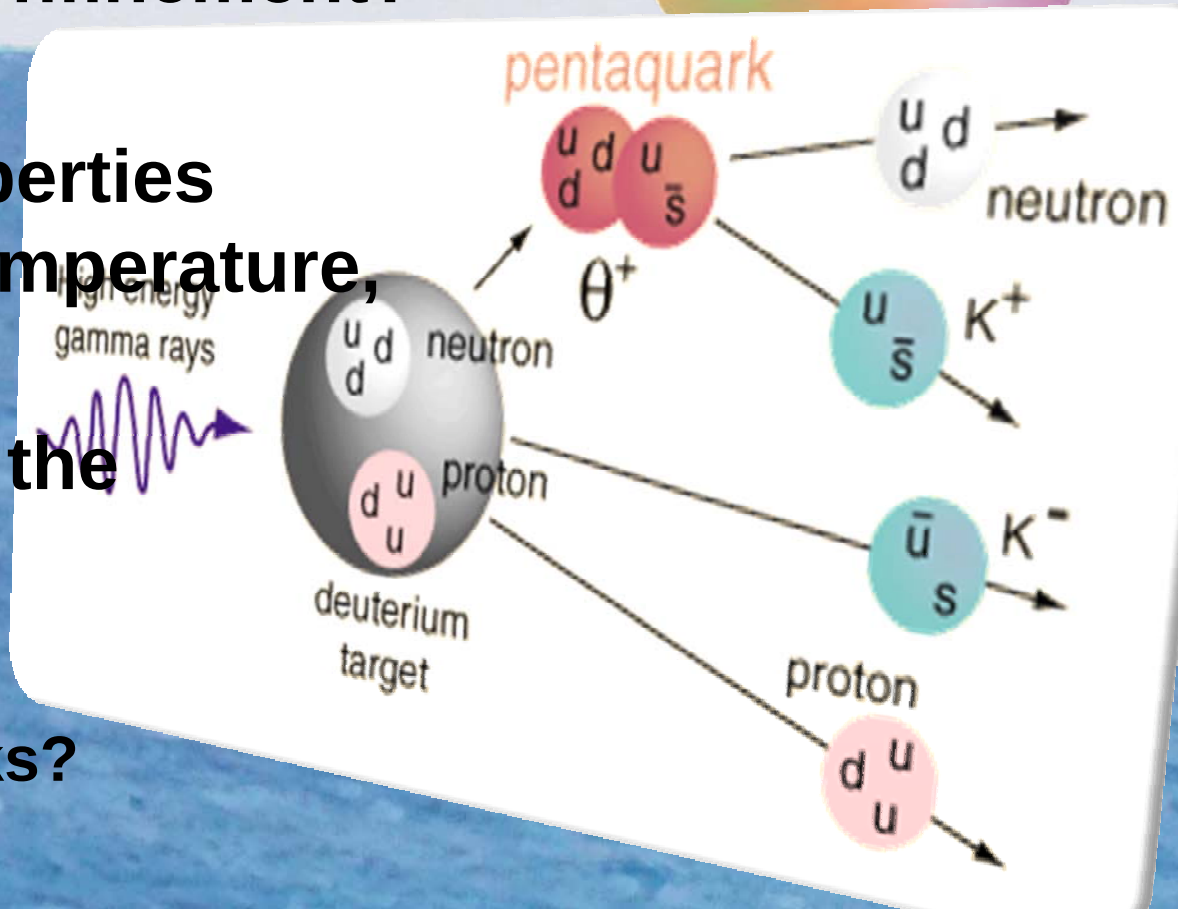
⇒Origin of Matter

- Sakharov's necessary conditions
  - violation of matter number: 0 ν $\beta\beta$, pdecay
  - CP violation
  - out of equilibrium

Hadron Physics

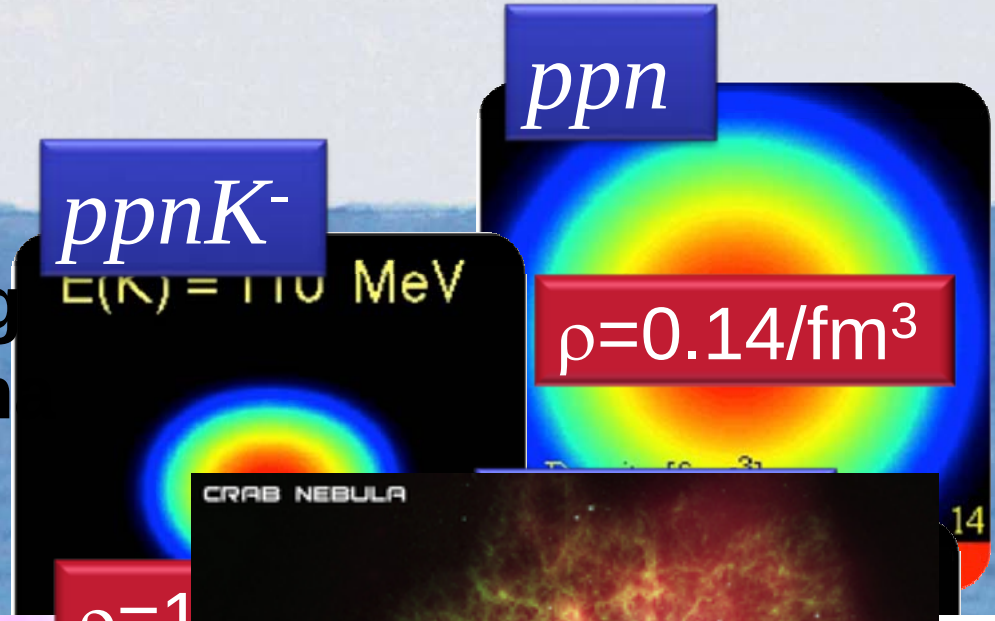
Current Problems in Hadron Physics

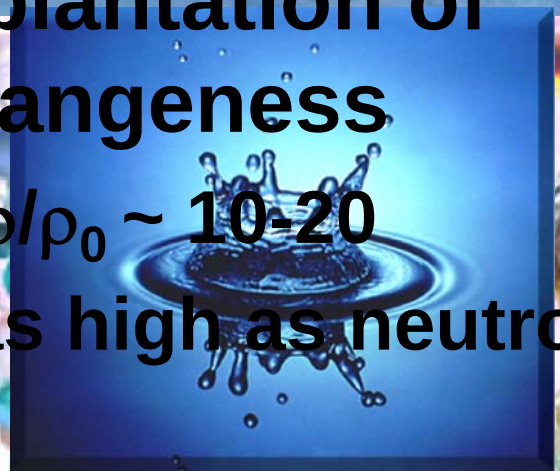
- Confinement Understood?
  - How hadron properties emerge from confinement?
    - Mass, Spin, …
  - How those properties change w.r.t. temperature, density?
  - What is driving the confinement pattern?
    - No penta-quarks?



How we create dense matter?

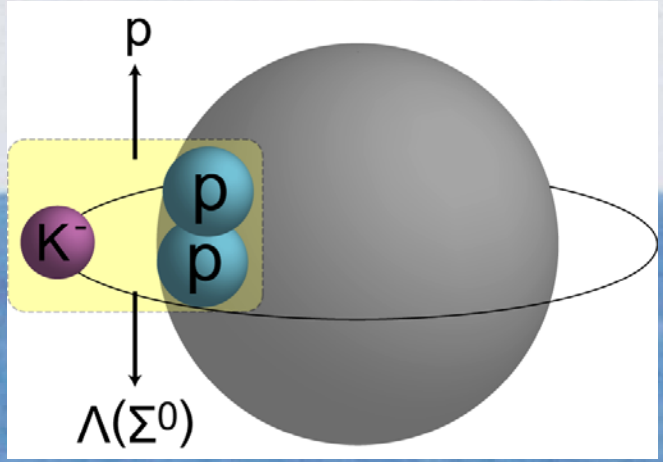
- HE Heavy Ion Collisions?
  - High temperature
  - Strongly Interacting Quark-Gluon Plasm a.k.a perfect Liquid
- Implantation of Strangeness
  - $\Rightarrow \rho/\rho_0 \sim 10\text{-}20$
  - as high as neutron star!





FINUDA (Japan-Italy Coll.)

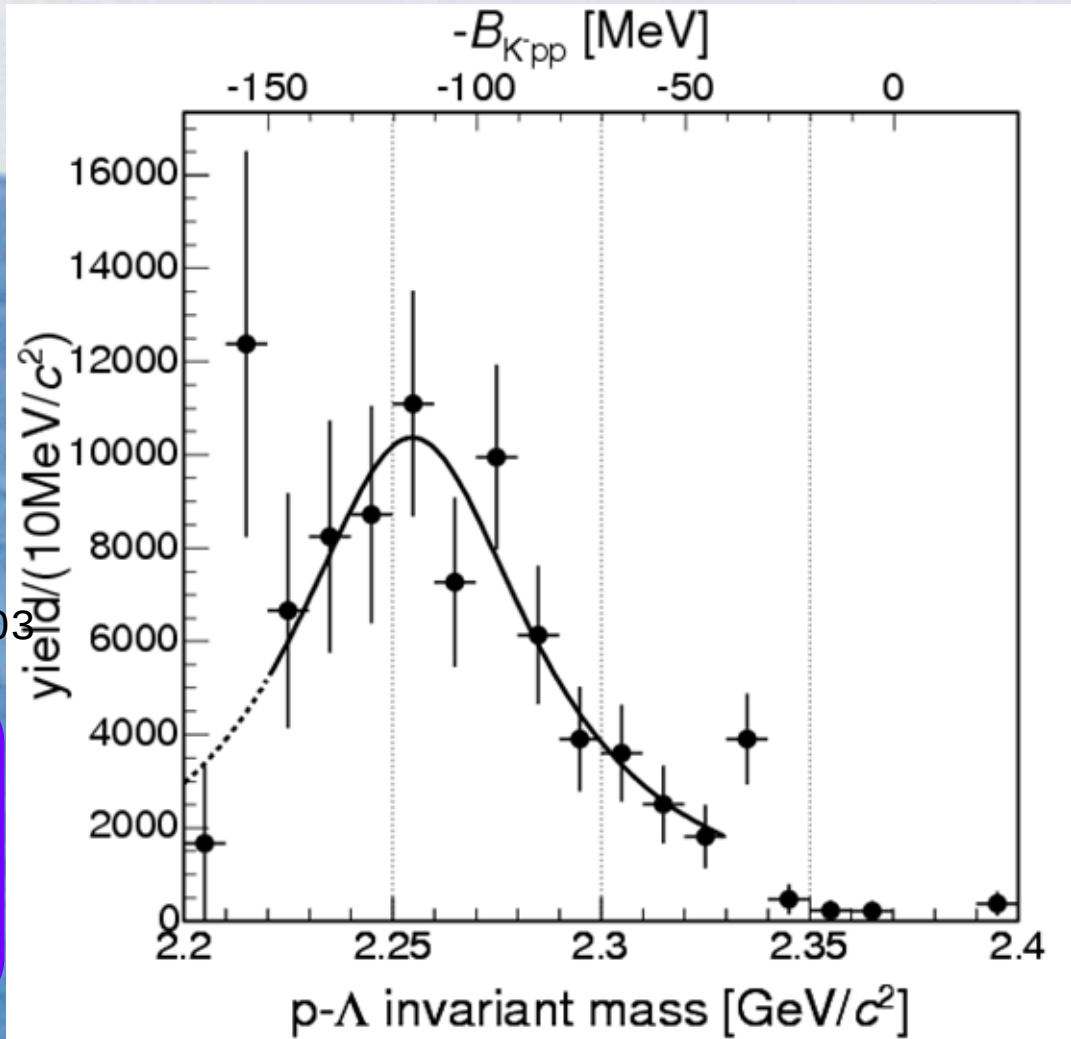
$$K^- + \text{“}pp\text{”} \rightarrow \Lambda + p$$



PRL 94 (2005) 212303

$$B = 115\,^{+6}_{-5}\,^{+3}_{-4}\ \text{MeV}$$

$$\Gamma = 67\,^{+14}_{-11}\,^{+2}_{-3}\ \text{MeV}$$



Rich Structure of Nuclear Matter with Strangeness

Nu ~ Nd ~ Ns

p,n,Λ,Ξ⁰,Ξ⁻

Possible existence in Neutron Star

Strange Quark Matter (Electrically Neutral, Mass →∞)

High Density

Strangeness

World made of u, d, s quark

ΛΛ, Ξ Hyper-Nuclei

3 ΛΛ–Hyper Nuclei

Λ, Σ Hyper-Nuclei

39 Λ-Hyper Nuclei

1 Σ–Hyper Nuclei

Λ

p n

Z

Proton Number

2

1

0

N

Neutron Number

Normal Nuclei : World made of u,d quark

Stable Nuclei

Unstable Nuclei

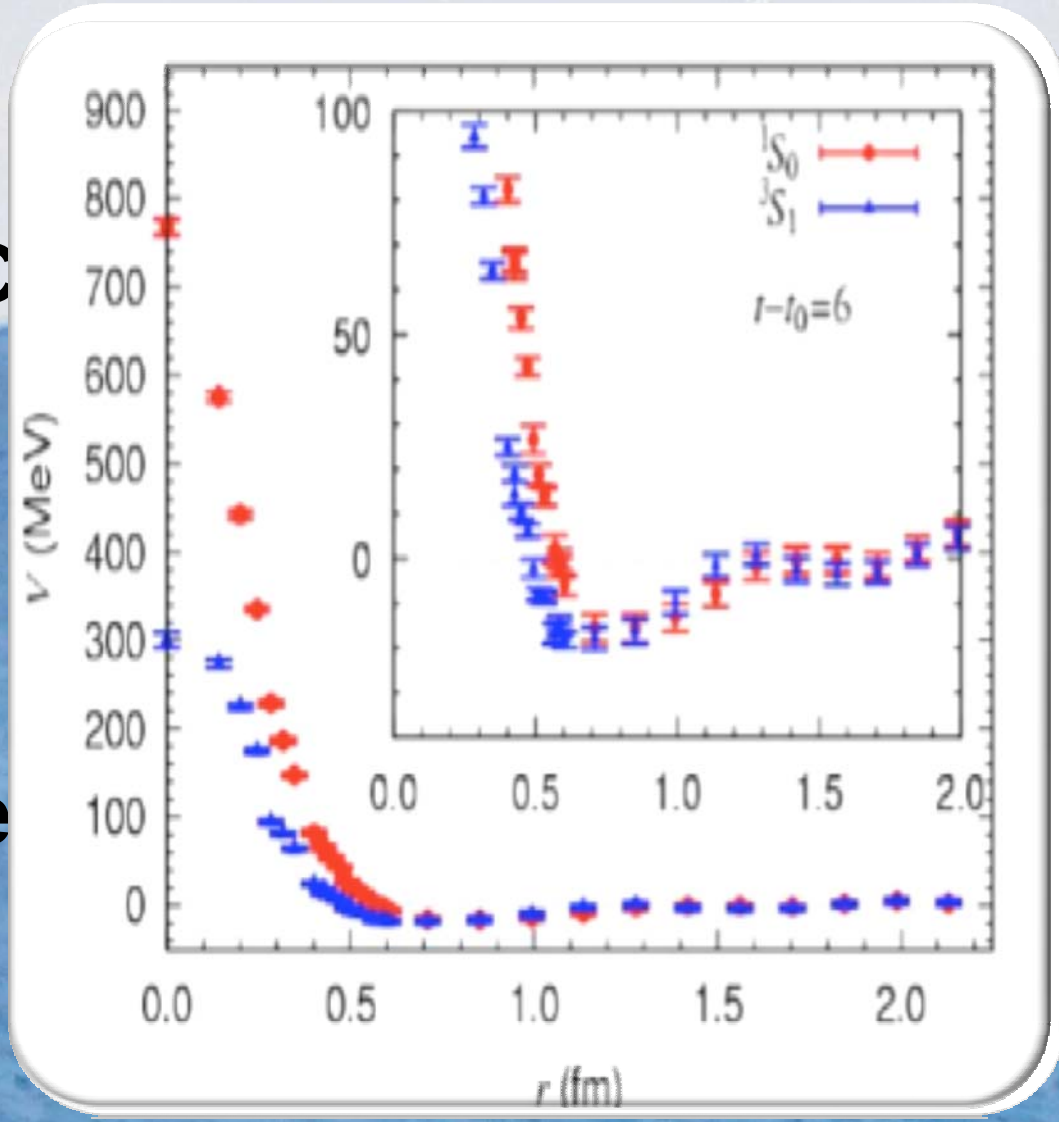
3D Nuclear Chart

Adopted from Prof. Tamura's Slide

Lattice QCD ⇒NN, ΞN Interaction

- NN Interaction is successfully calculated from QC (Hatsuda et al.,)
- Being extended to ΞN
- Provide a solid ground to compare

➔ J-PARC Experiments



Hadron Mass in Dense Matter

- Vector meson mass can be significantly c
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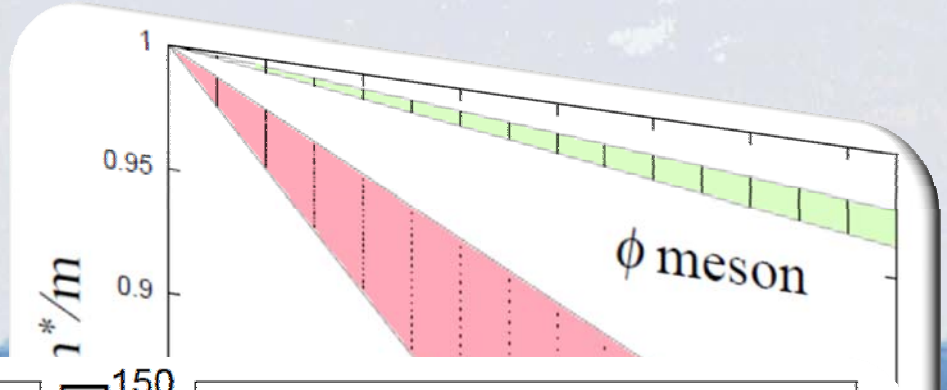
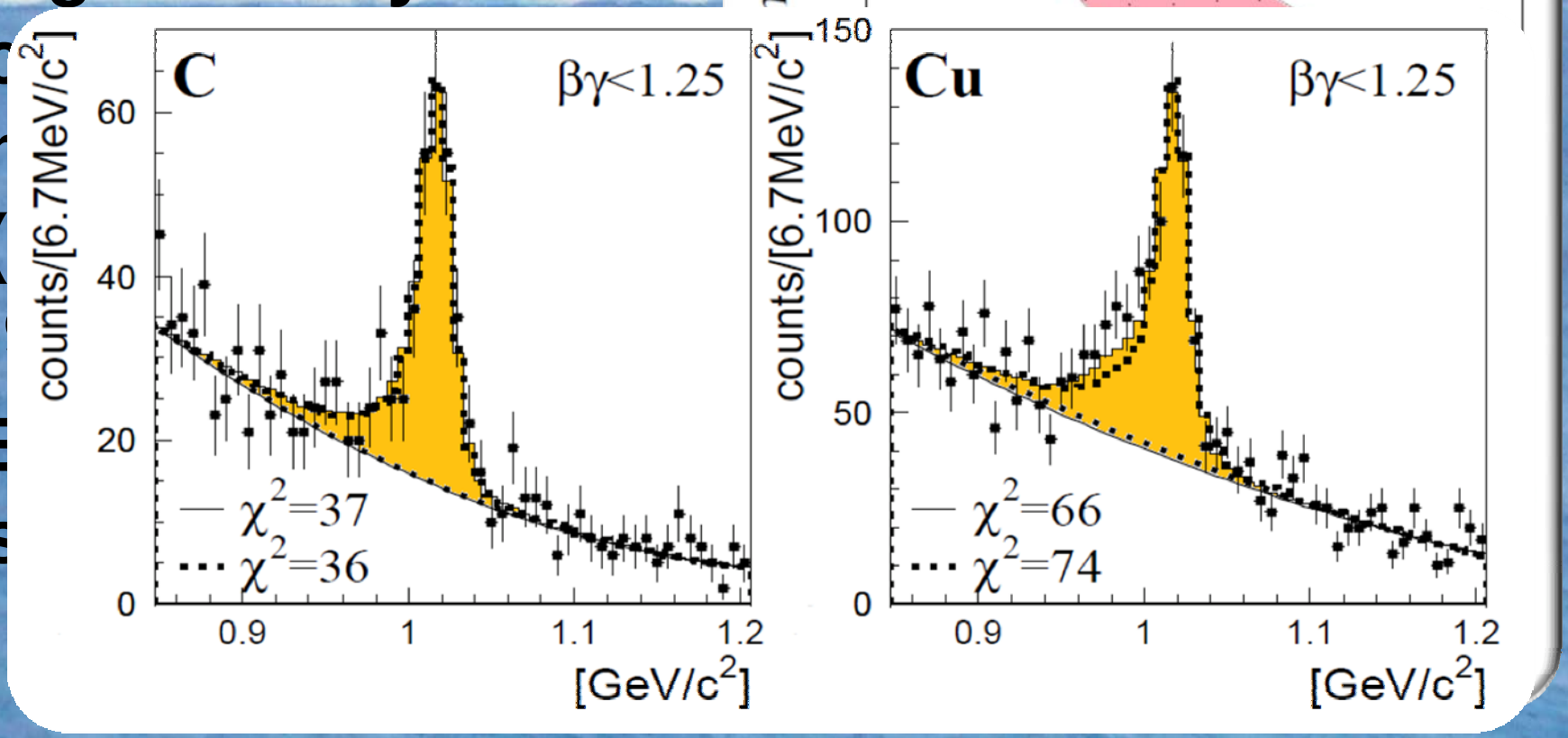
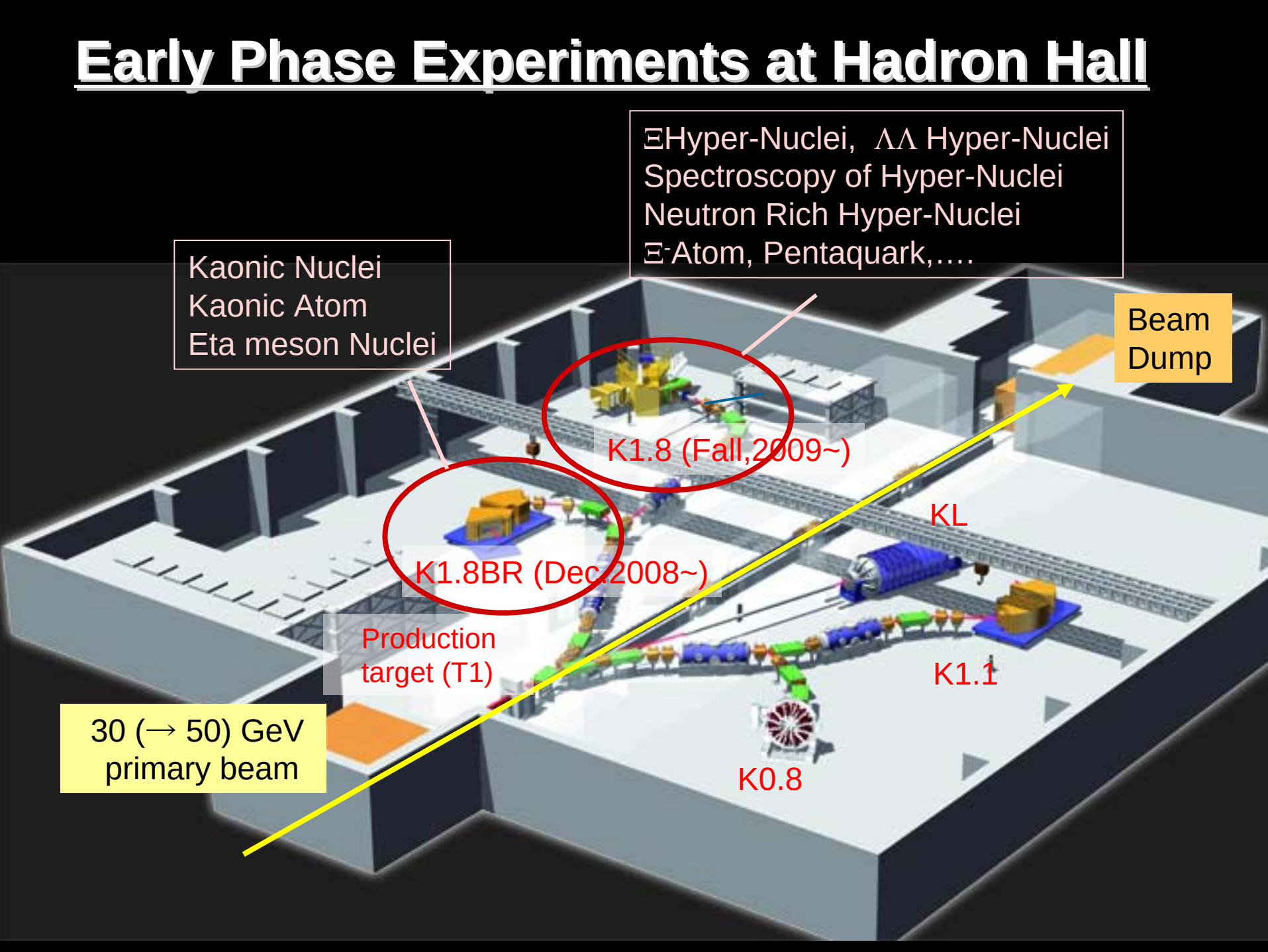
  (
  “
- E
  s





Early Phase Experiments at Hadron Hall



Flavor Physics

T2K Collaboration

- 12 countries, 61 Institutions, >400 collaborators
  - Canada, France, Germany, Italy, Japan, Korea, Poland, Russia, Spain, Switzerland, UK, US

295 km
West

Super Kamiokande

岐阜県神岡町地下1000m

50000トン水チェレンコフ

20インチPMT約12000本

1996～

Neutrino Experimental Facility

Number of Users: about 400

(about 1/7 from Japan)

Experiments with Intense Neutrino Beams

Neutrino Mixing Angle CL 90%

$$U = \begin{pmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} \\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3} \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix} \begin{pmatrix} c_{13} & 0 & s_{13}e^{-i\delta} \\ 0 & 1 & 0 \\ -s_{13}e^{i\delta} & 0 & c_{13} \end{pmatrix} \begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

$\sin^2 2\theta_{13} < 0.16$ $\quad 0.68 < \sin^2 2\theta_{12} < 0.94$ $\quad \sin^2 2\theta_{23} > 0.87$

- $\Delta(\sin^2 2\theta_{23}) = 0.01$, $\sin^2 2\theta_{13}$ down to 0.008
- **severe competition around 2009-2011**

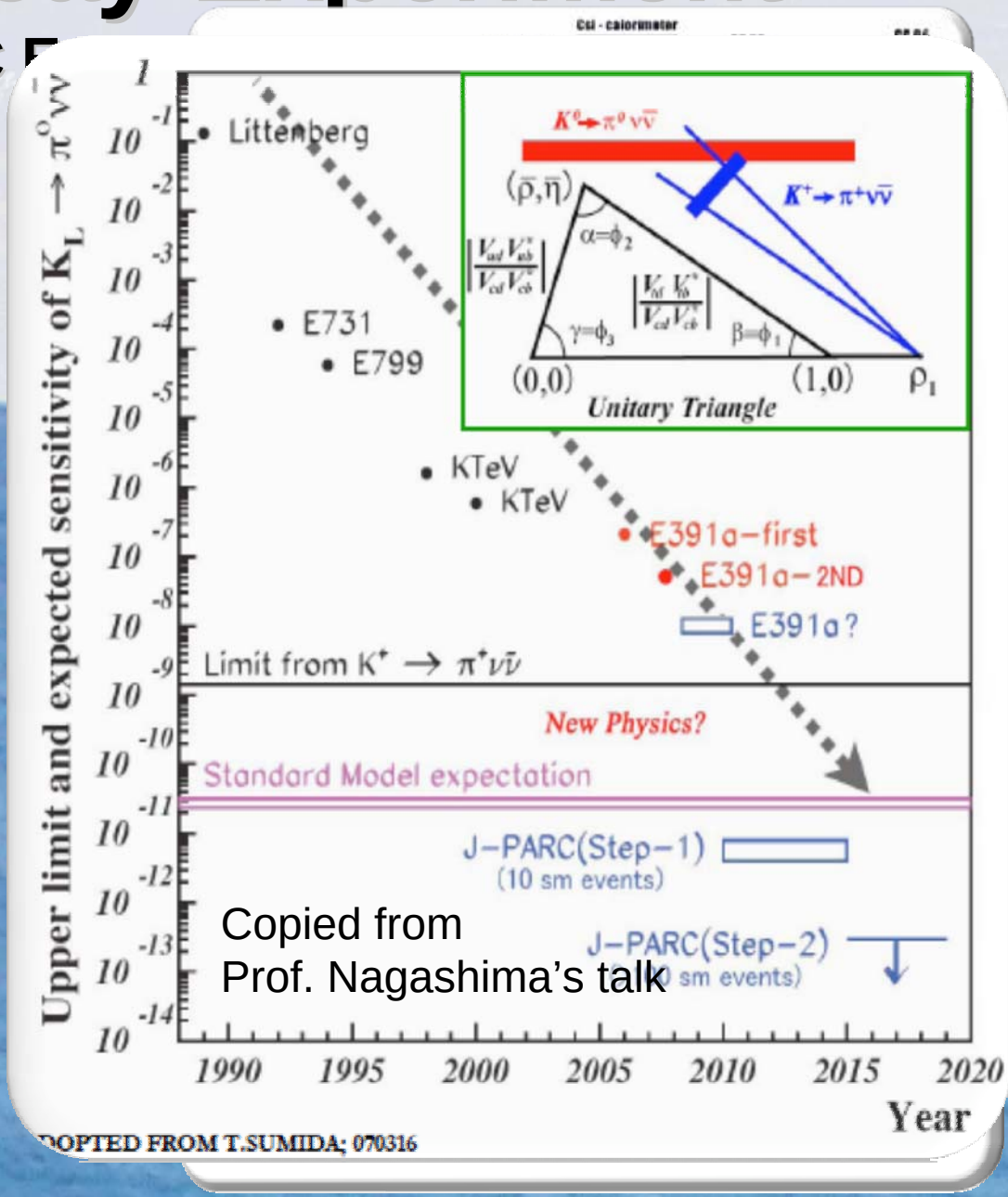
Kaon Rare Decay Experiment

(KEK-PS E391a → J-PARC E

- **CP Violation in K decays**

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

  - Direct CP violation: ΔS=1
  - Small theoretical uncertainties ~1.5%
  - Direct measurement of the height of Unitarity triangle: BR ~ η^2
  - Rare decay: BR~2.8×10^{-11}
  - Strict test of SM, sensitive to new physics
  - Unitarity triangle
  - Check consistency with ΔB=1,2 processes

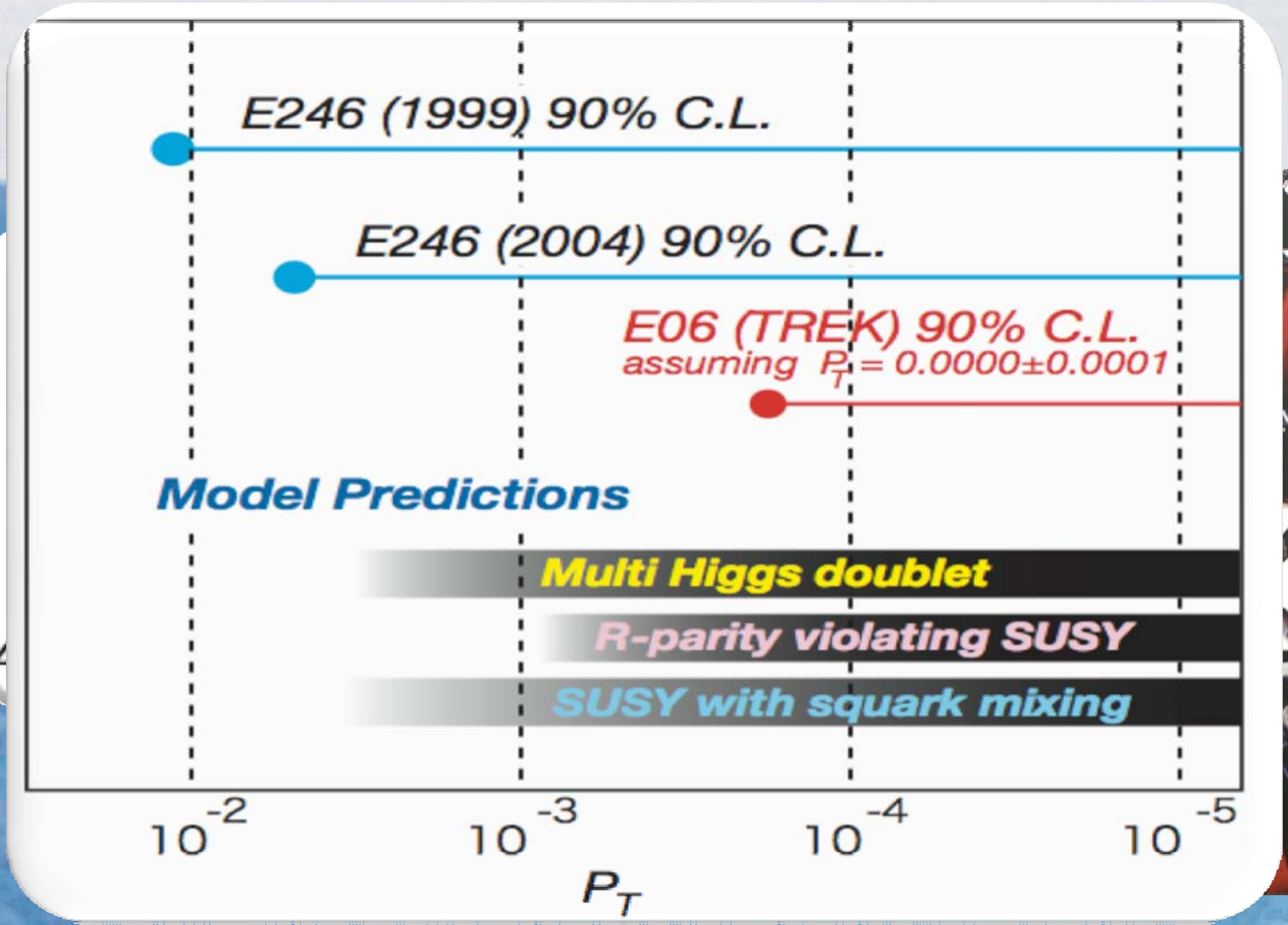


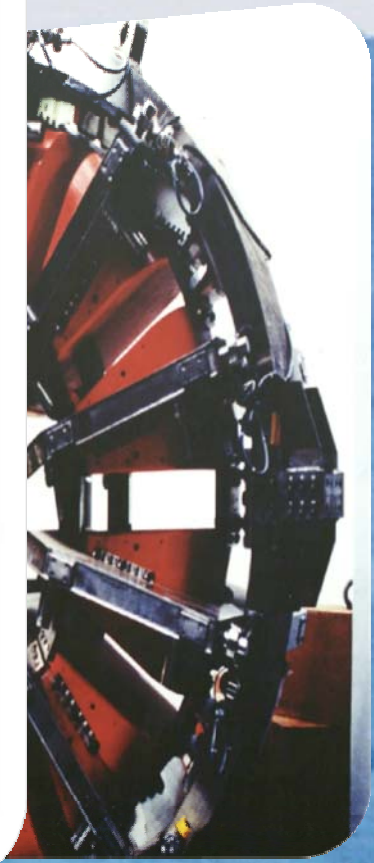
Copied from
Prof. Nagashima's talk

Search for T-Violation

(KEK-PS E246/E470→J-PARC E06 = TREK)

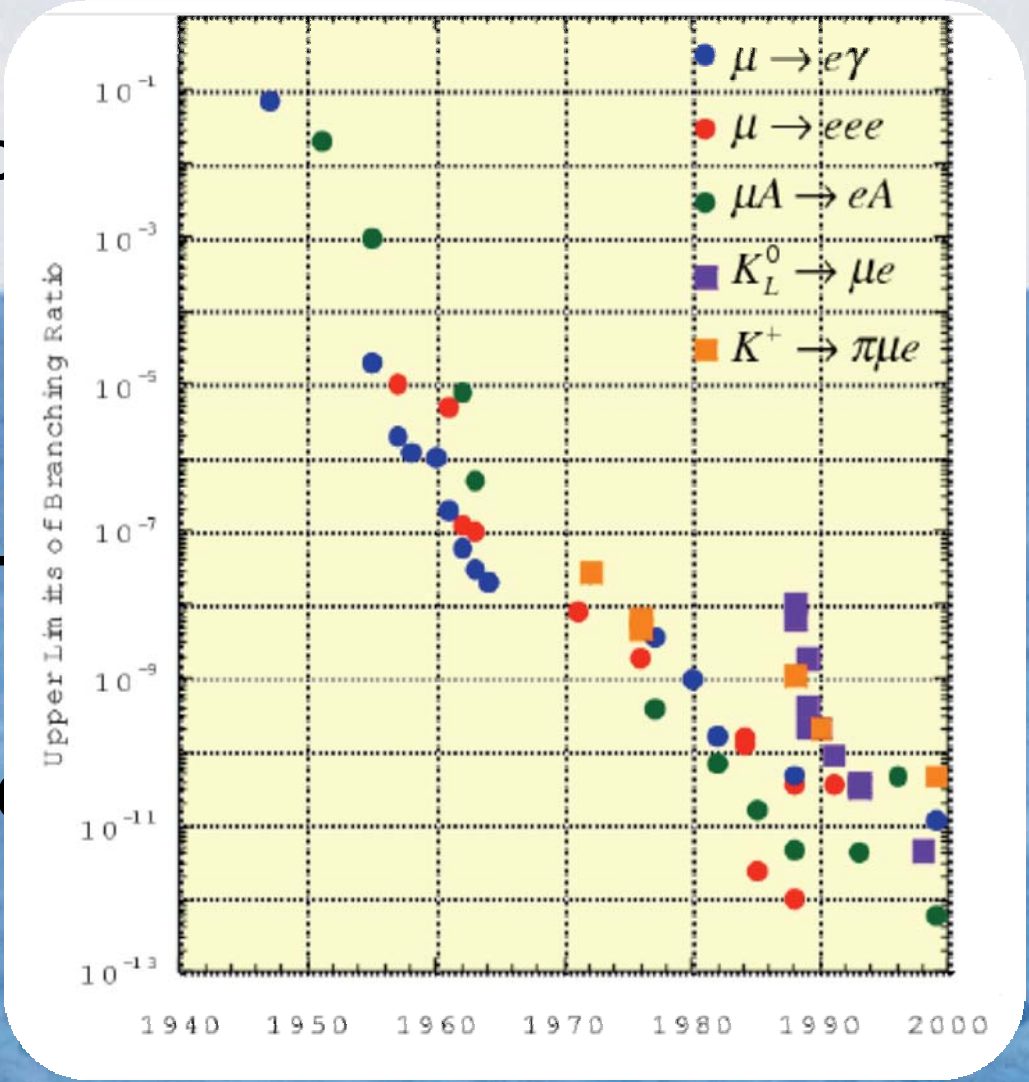
- **Time Reversal Violation with Muon**





Lepton Flavor Violation
(J-PARC P21)

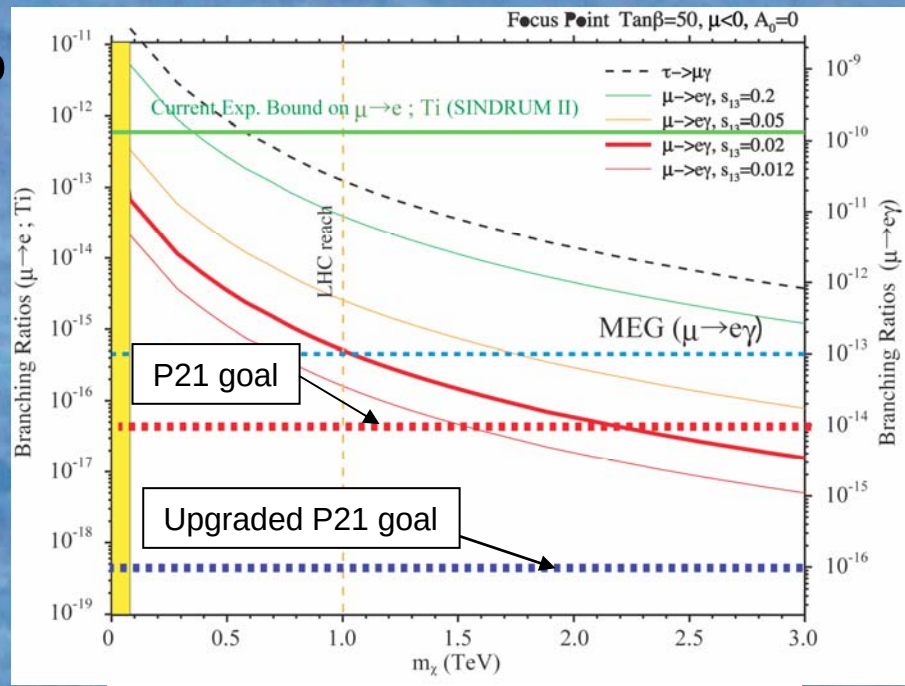
- Very small SM background ~ 10^{-50}
  - $\mu \rightarrow e\gamma$
  - $\mu A \rightarrow e A$
  - $\mu \rightarrow eee$
- Probe SUSY+GUT scale physics
- Current front runn = MEG at PSI expect 10^{-13} sensitivity



Muon Lepton Flavor Violation

- Neutrino mixing is established by discovery of neutrino oscillation. However, lepton flavor violation (LFV) of charged leptons has never been observed so far.
- LFV of charged leptons is sensitive to the slepton mixing caused by SUSY models in MSSM, which is difficult to study at LHC, or even ILC.
- Proposal (P21) has been submitted to J-PARC to carry out a search for muon-to-electron conversion ($\mu^- + N \rightarrow e^- + N$) in a muonic atom at 5×10^{-17} sensitivity.
  - It aims at about 10,000 improvement over the previous limit at PSI. and a factor of 10 -10,000 better than MEG, depending on the LFV operators.
  - Future P21 upgrade expects

Lepton flavor violation of charged leptons

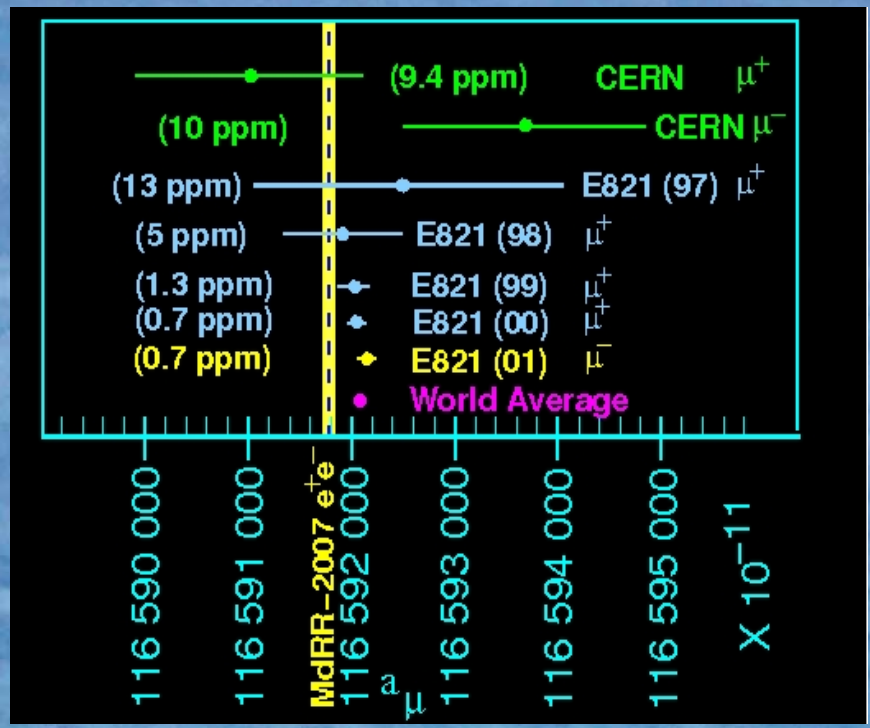


Predictions from SUSY Seesaw Models

Muon g-2@J-PARC

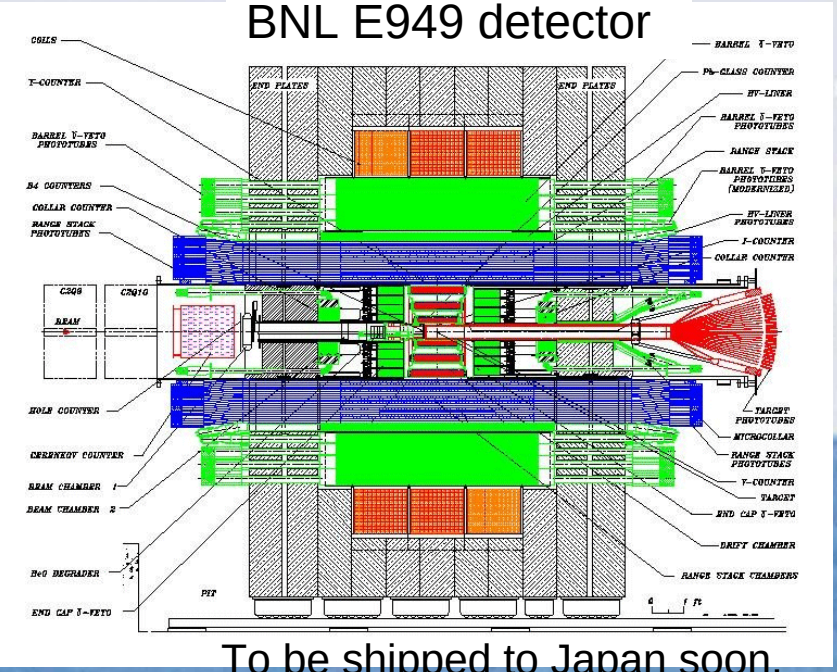
L. Roberts, D. Hertzog, Y. Kuno and
N. Saito et al.

- **Current result is 3.4 sigma above from the SM value**
  - **If LHC discovers SUSY, tan β can be determined to $\Delta_{\tan\beta} \leq 20\%$**
- **LOI submitted in 2003 to improve the precision (AGS) by up to one order of magnitude at J-PARC**
- **Efforts toward a proposal have started to realize the experiment in the earlier phase of J-PARC**
  - **Technical feasibility of bunch sequences and beamline are being explored**
  - **Harmonics changes in the MR and kicker design are key issues**
  - **KEK designed new inflector for a better muon injection efficiency**
  - **g-2 ring to be shipped from BNL**



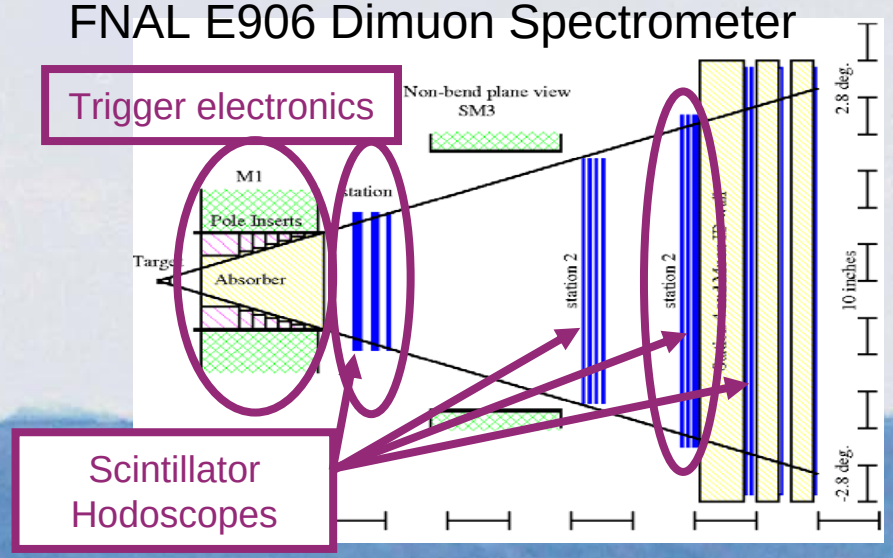
International Collaboration

BNL E949 detector



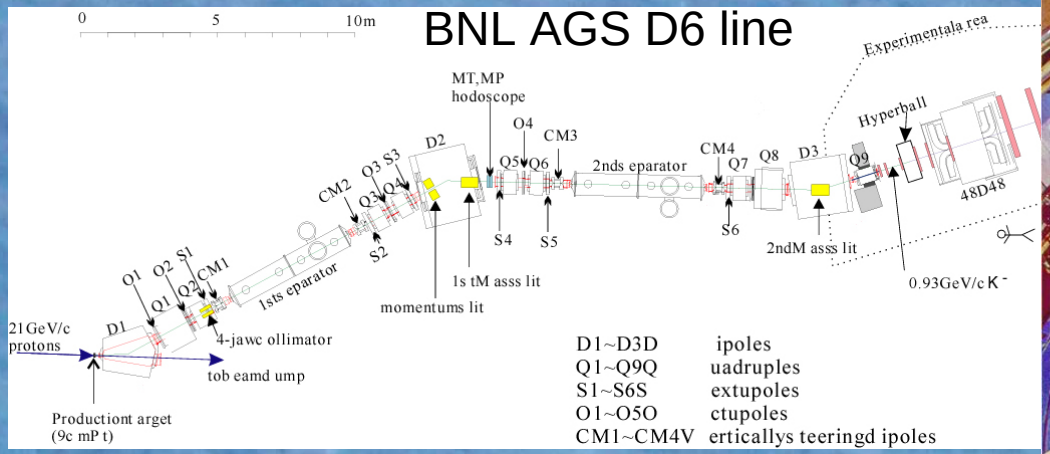
To be shipped to Japan soon.

FNAL E906 Dimuon Spectrometer



To be shipped to J-PARC in 2013.

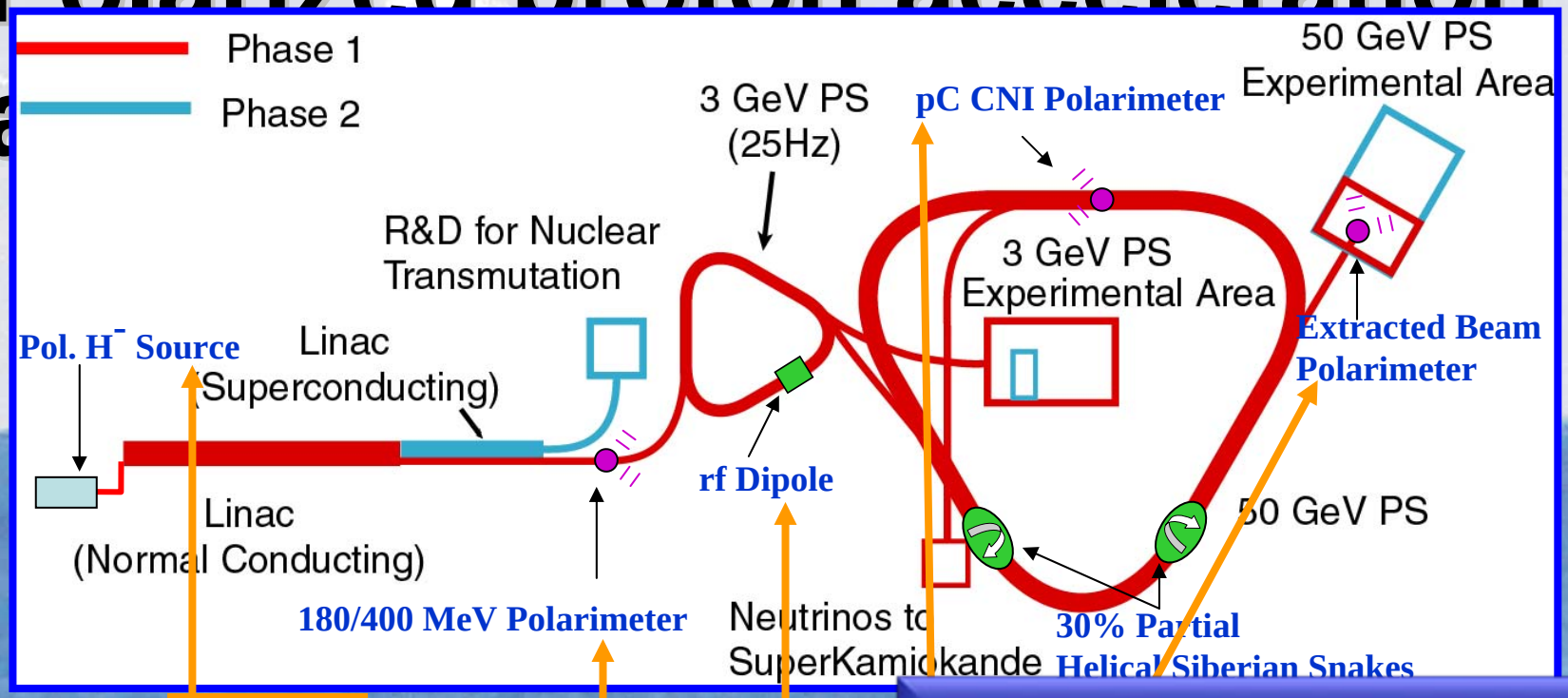
BNL AGS D6 line

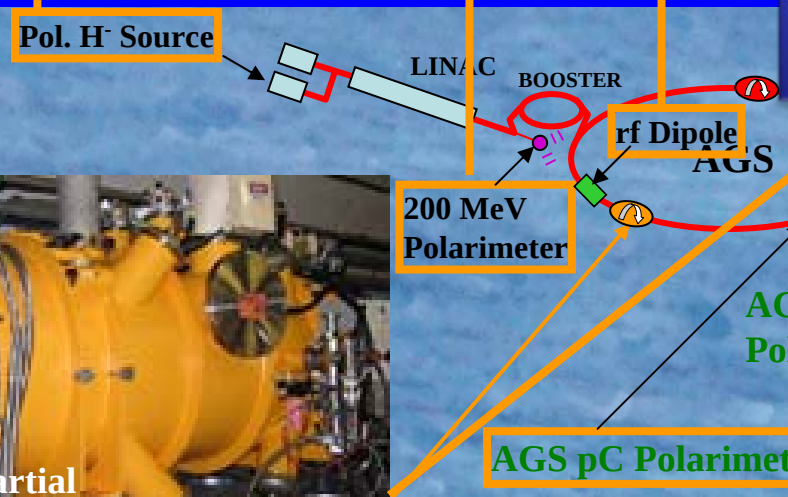


To be shipped to J-PARC soon.

BNL g-2 Ring (collaboration started!)

Polarized proton acceleration a



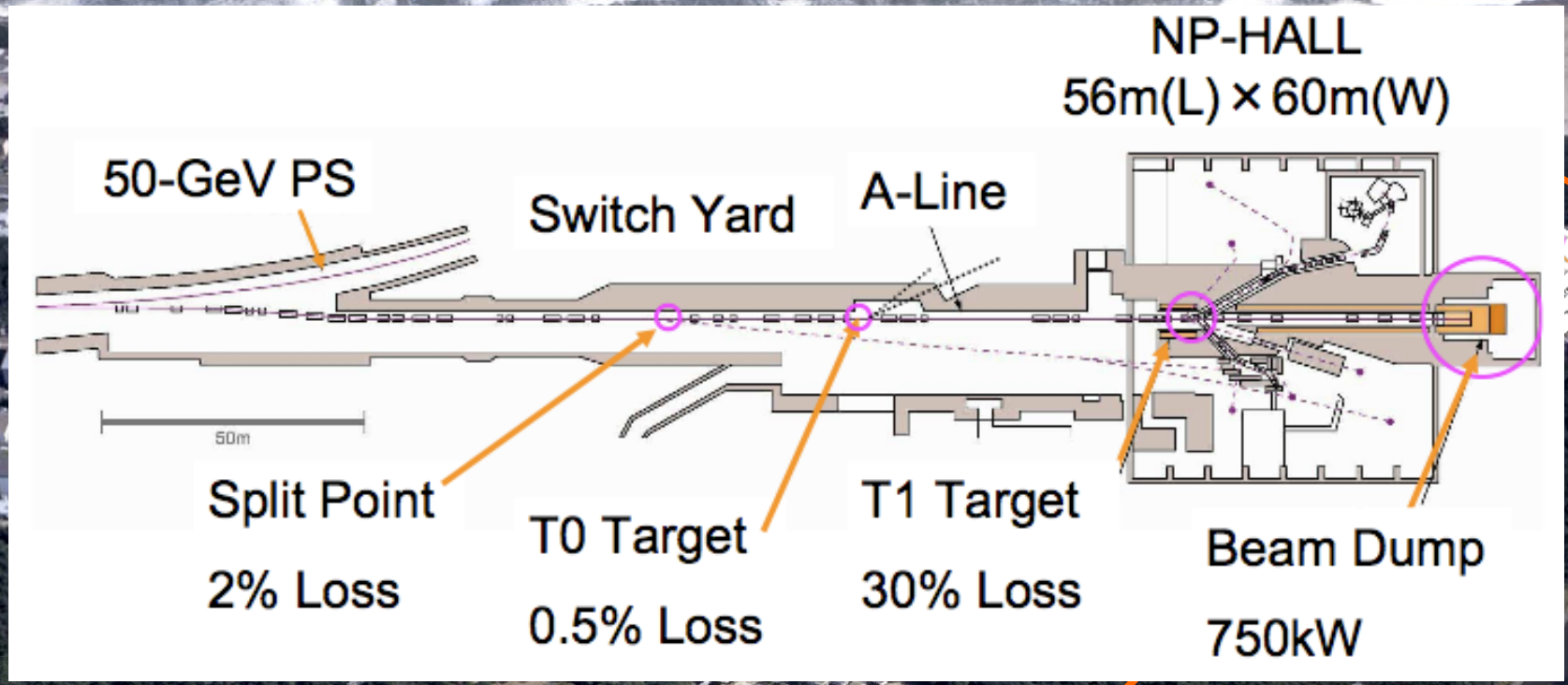


Collaboration with BNL

Status of J-PARC

Ground Breaking Ceremony

June, 2002


NP-HALL
56m(L) × 60m(W)
50-GeV PS
Switch Yard
A-Line
50m
Split Point
2% Loss
T0 Target
0.5% Loss
T1 Target
30% Loss
Beam Dump
750kW

Hadron Exp. Hall Completed!

- Beam lines are being implemented.

Beam transport from LINAC to RCS

J-PARC

Success in RCS Acceleration/Extraction

Successful Beam at MR (3 GeV)

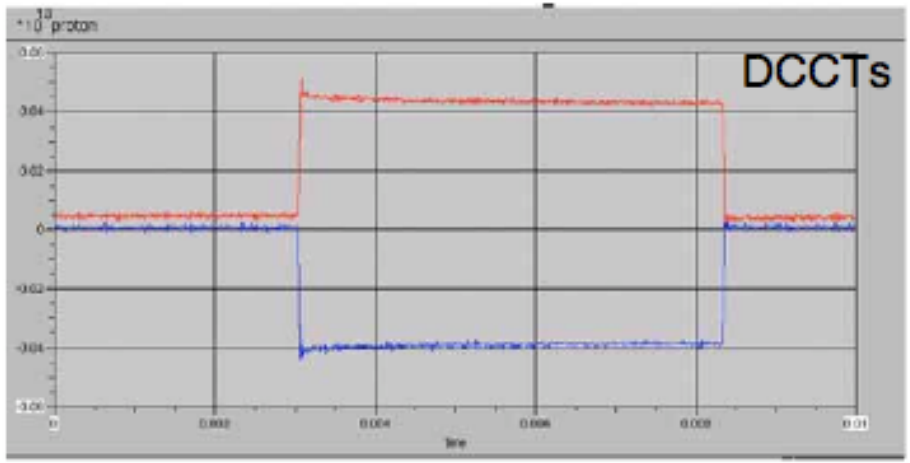
- May 22, 2008 :Circulated / RF Captured/Dumped

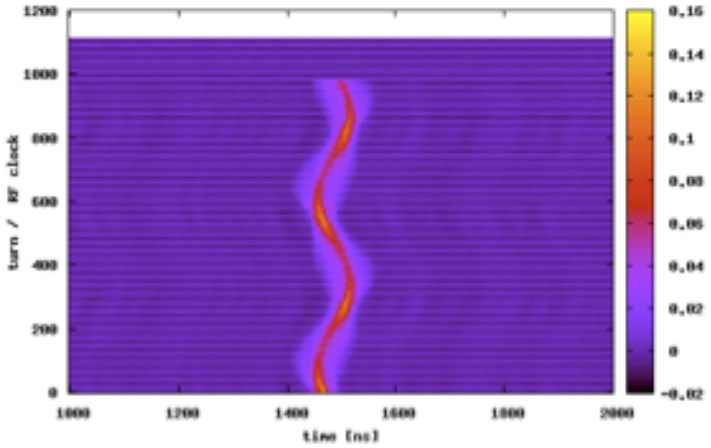
RF capture

- f_{rf}=1.671459 MHz : RF frequency of MR is adjusted to the frequency of RCS
- V_{gap}=160 kV.
- Dump kickers are switched on after 1000 turns from beam injection (5.384msec).

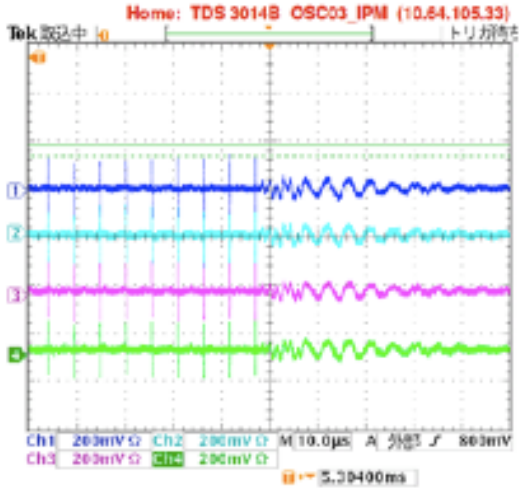
Operating point:
ν_x=22.34, ν_y=20.77

At 10:27pm on May 22,
3 GeV proton beam successfully captures by RF and extracted to injection beam dump.

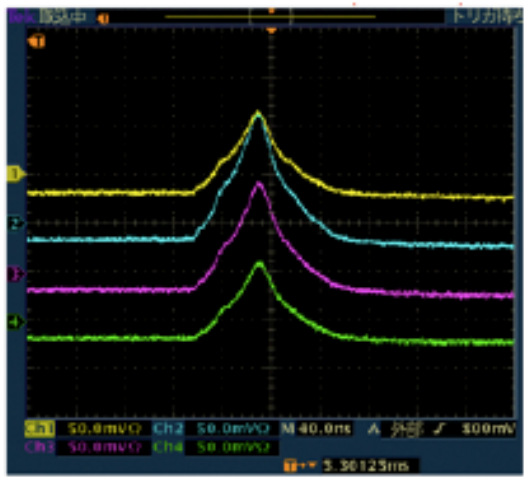




WCM



BPM in the ring



BPM in the dump line

Summary

- J-PARC is Multi-purpose facility with high power proton beams; will be operational soon
- High Intensity Frontier plays KEY role even post LHC era
  - Flavor Physics
    - Neutrino
    - CP violation in Quark and Lepton sector
  - Hadron Physics
- New capabilities: pol-p, muon, etc.
- Beam in the MR !
- Experiments start this Japanese Fiscal Year!

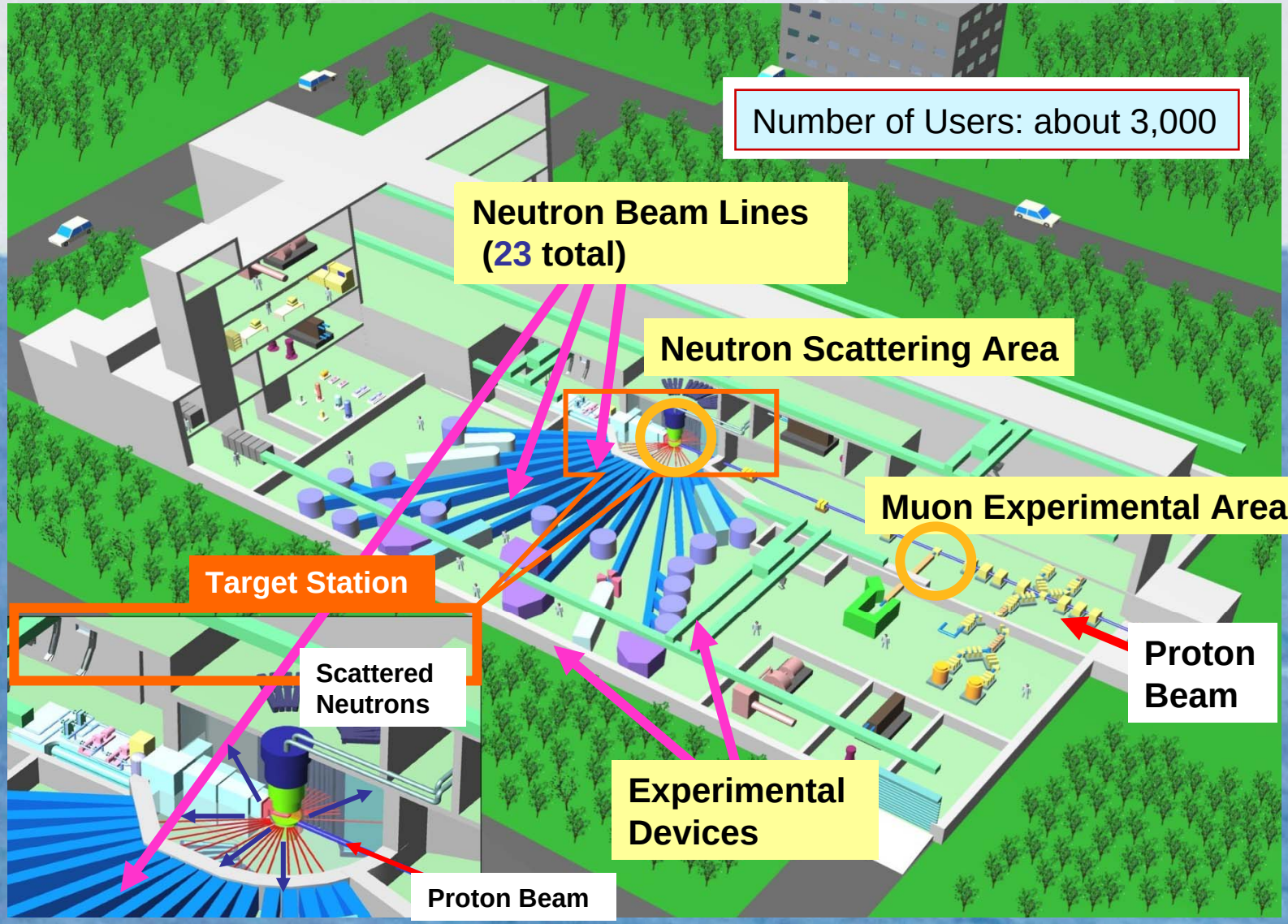
3 GeV Extraction Area

50 GeV Synchrotron Ring

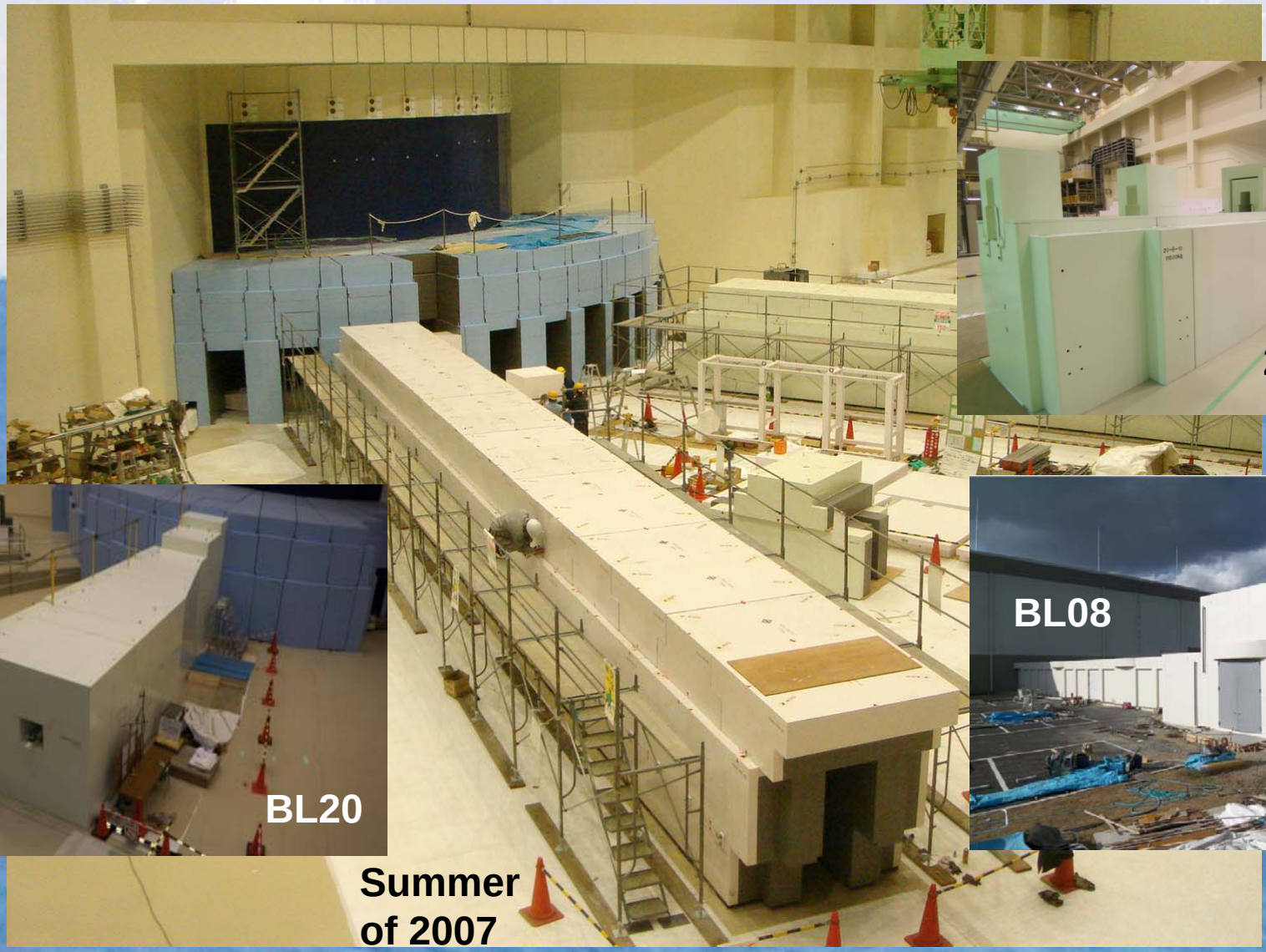
MLF Building

Completion of the MLF Building

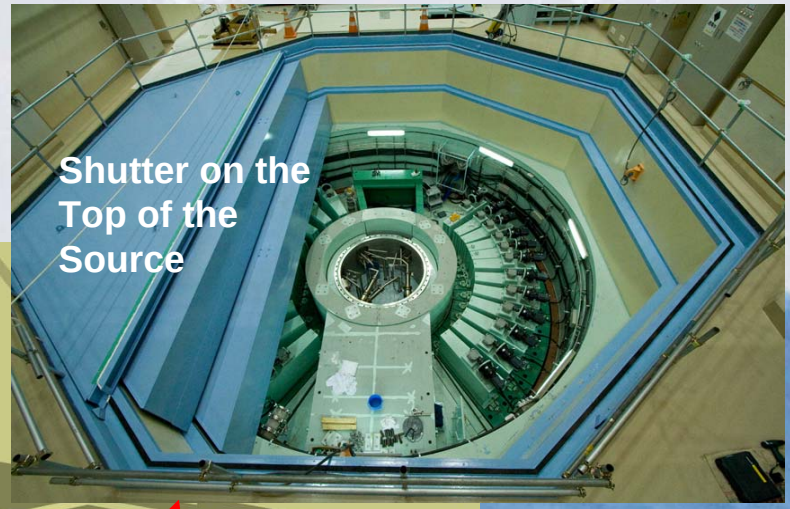
Materials & Life Experimental Facility

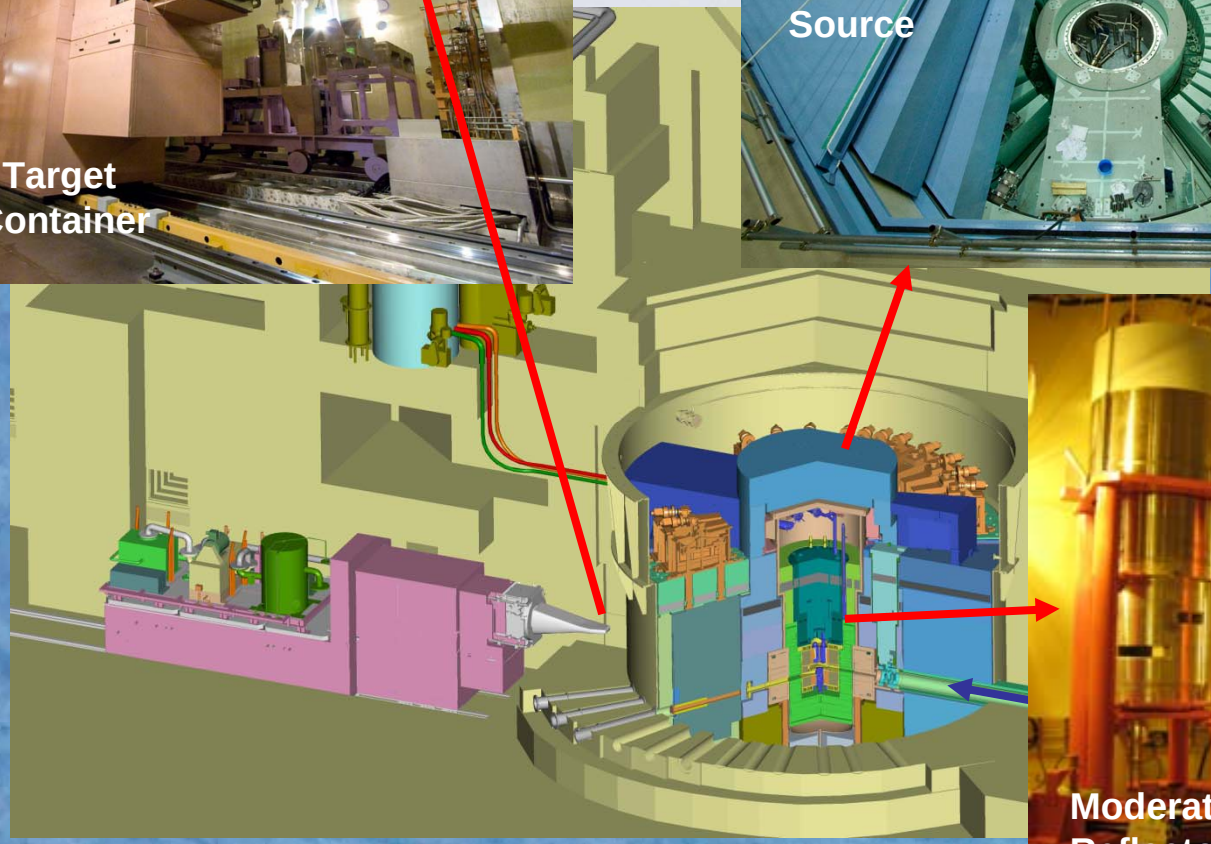


Neutron Beam Lines

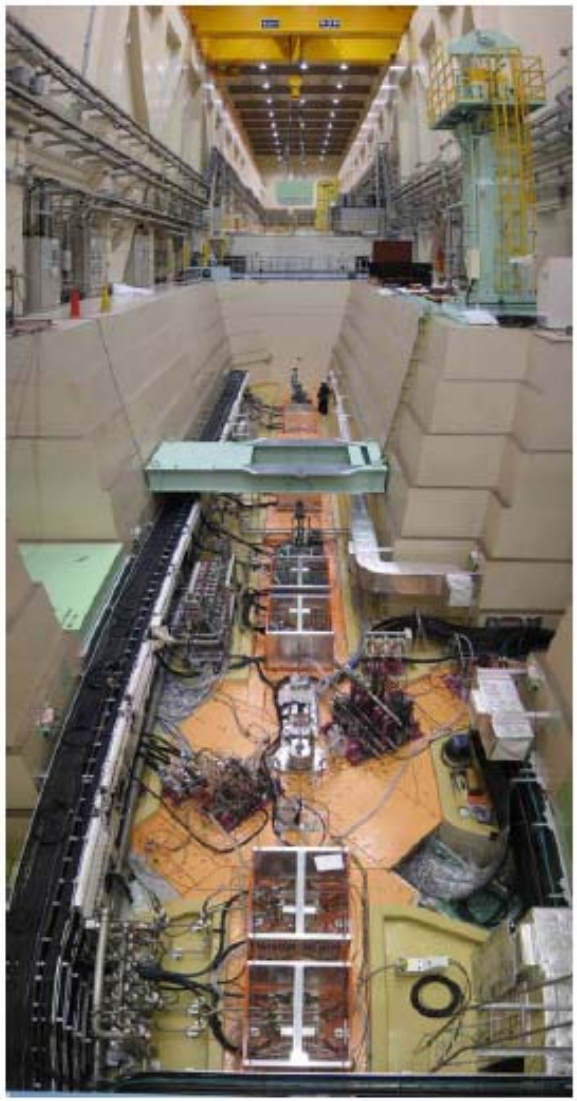


Neutron Source





Muon Beam Production Area

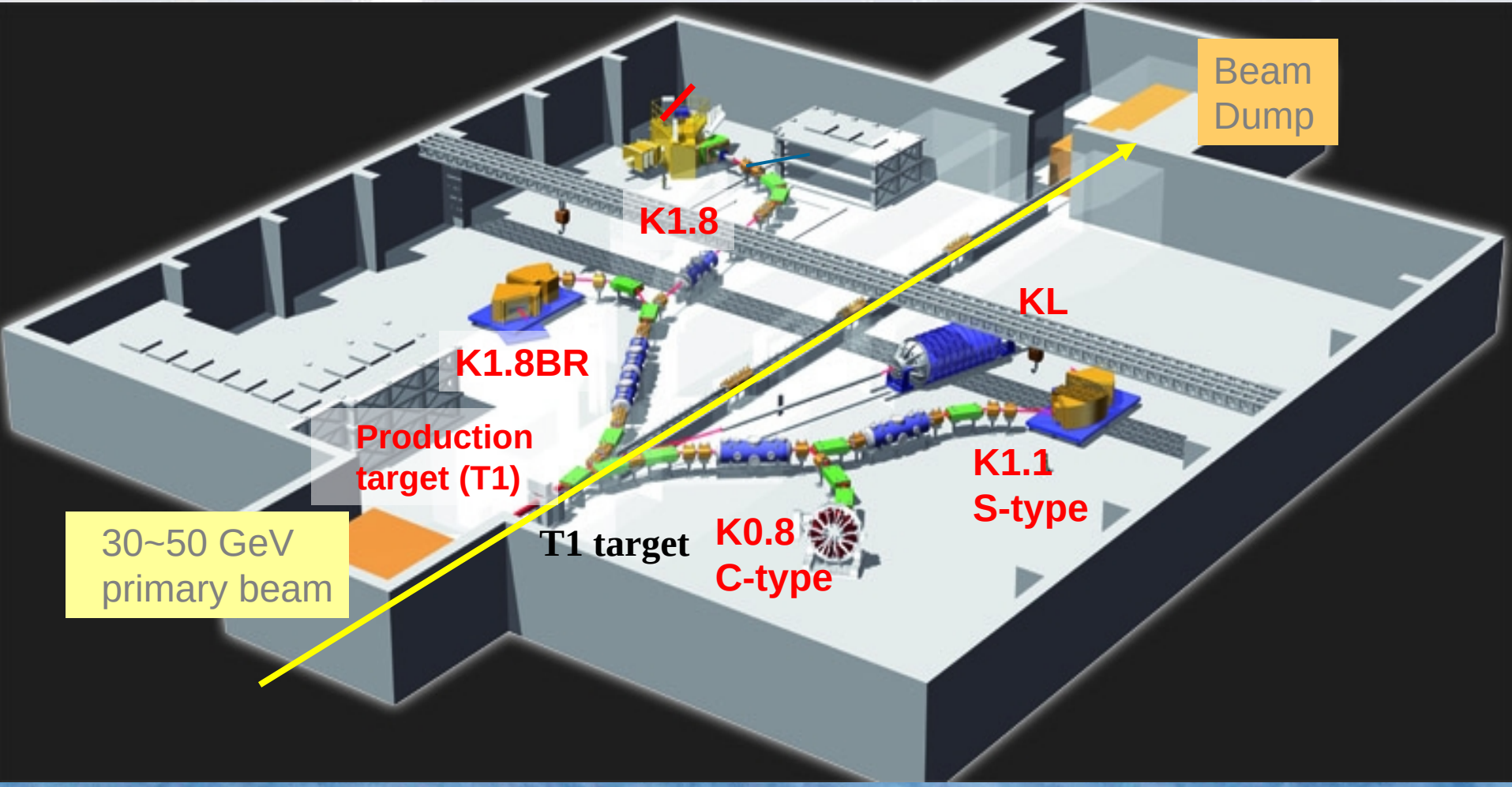


Hadron Hall in August 2007

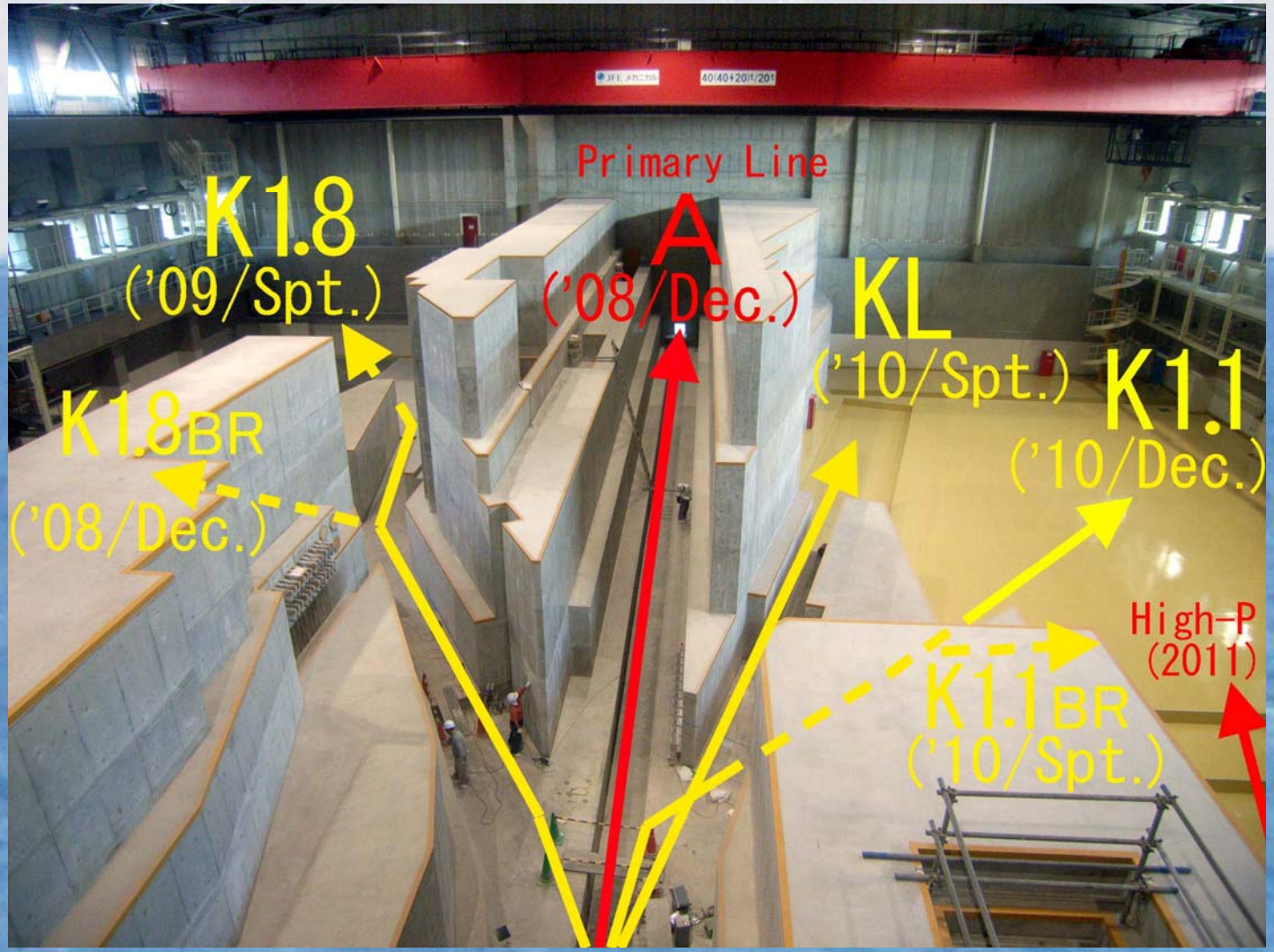
Hadron Hall

Completion of the Hadron Hall Building

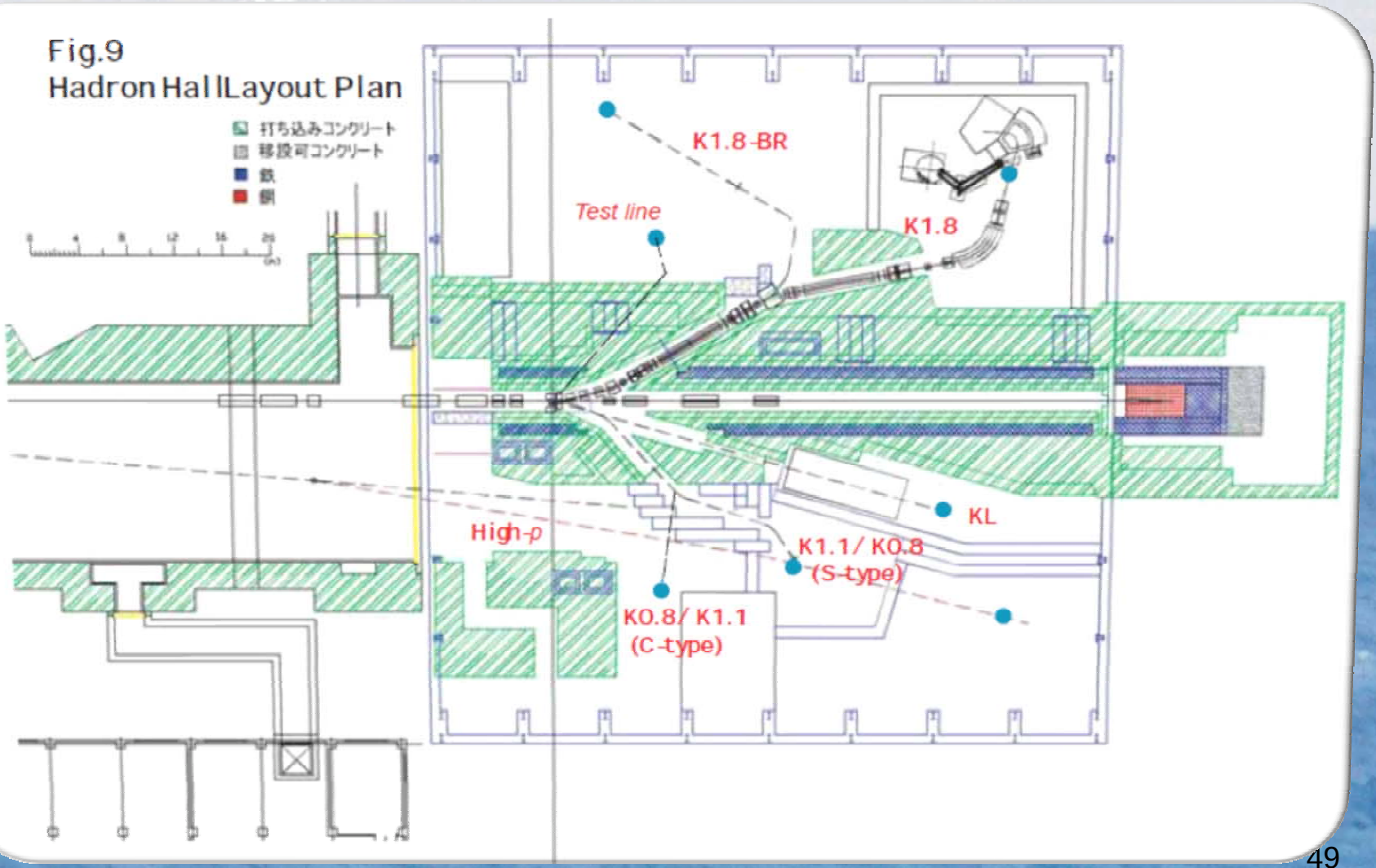
Hadron Experimental Hall



Original Plan for Beamlines



Hadron Hall – phase-1




Hadron Experimental Hall
50 GeV
Materials & Life
Experimental Hall
Neutrino
3 GeV
About 2/3
of the
facilities
were
completed.
Linac
Sept. 15, 2005