



SMR.1751 - 56

Fifth International Conference on
PERSPECTIVES IN HADRONIC PHYSICS
Particle-Nucleus and Nucleus-Nucleus Scattering at Relativistic Energies

22 - 26 May 2006

J-PARC
Japan Proton Accelerator Research Complex

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These are preliminary lecture notes, intended only for distribution to participants



J-PARC

Japan Proton Accelerator Research Complex

Shin'ya Sawada

KEK

(High Energy Accelerator Research Organization, Japan)



- Overview
 - Uniqueness of our accelerator complex.
- Nuclear and Particle Physics Facility at J-PARC
- Construction Schedule and Status



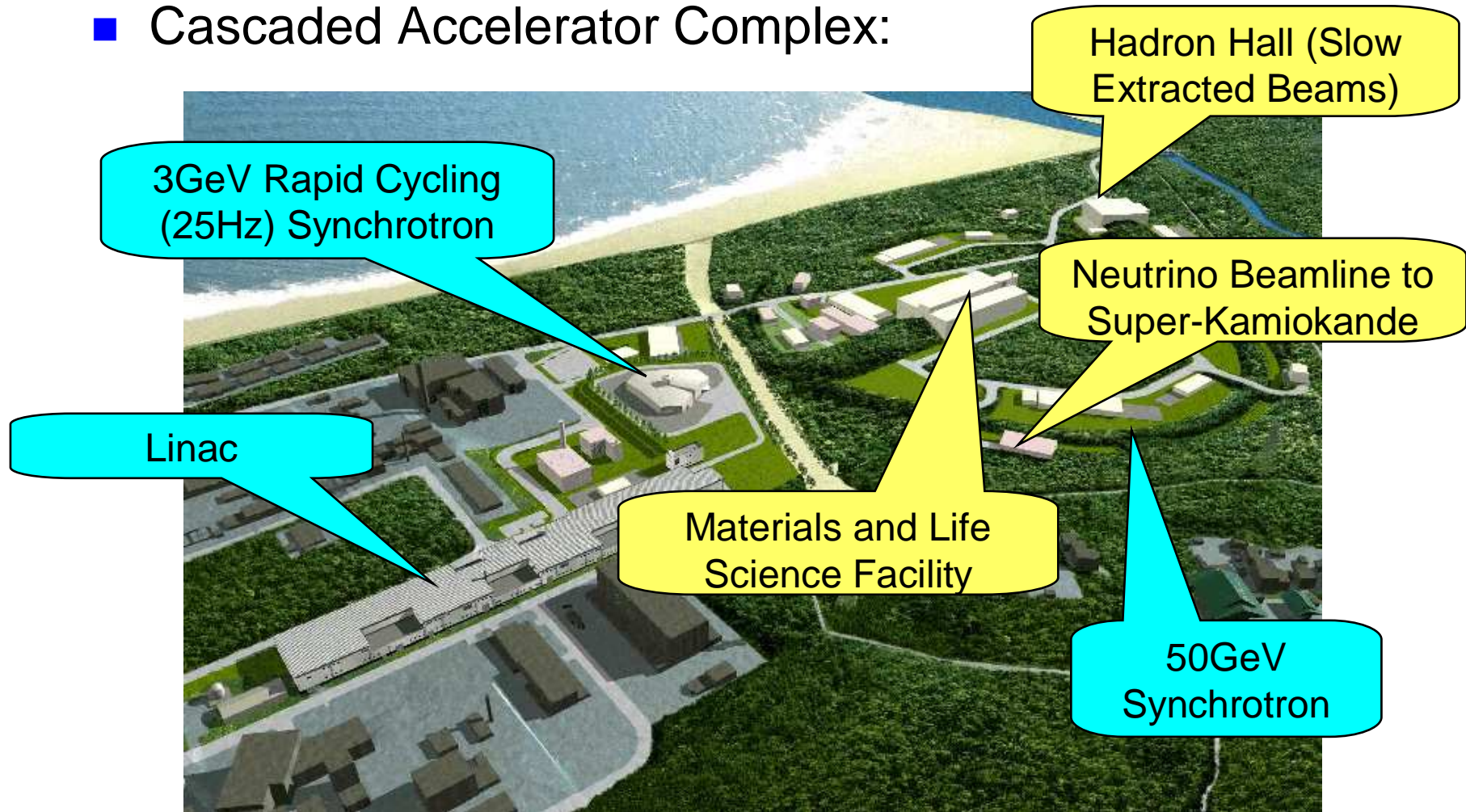
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Accelerator Configuration



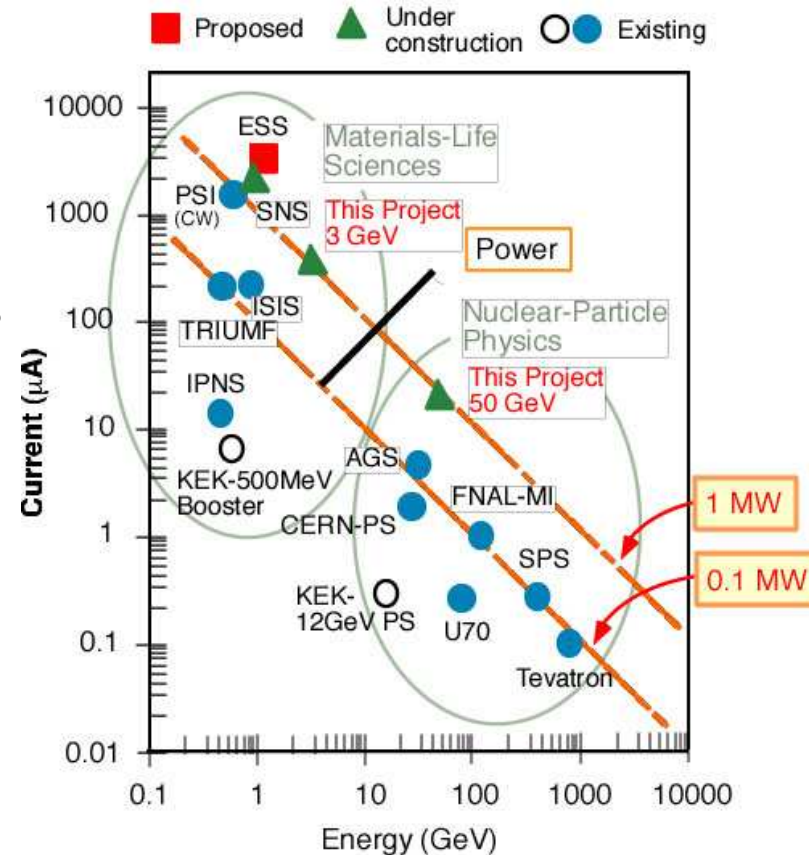
■ Cascaded Accelerator Complex:





J-PARC: the High Intensity Frontier

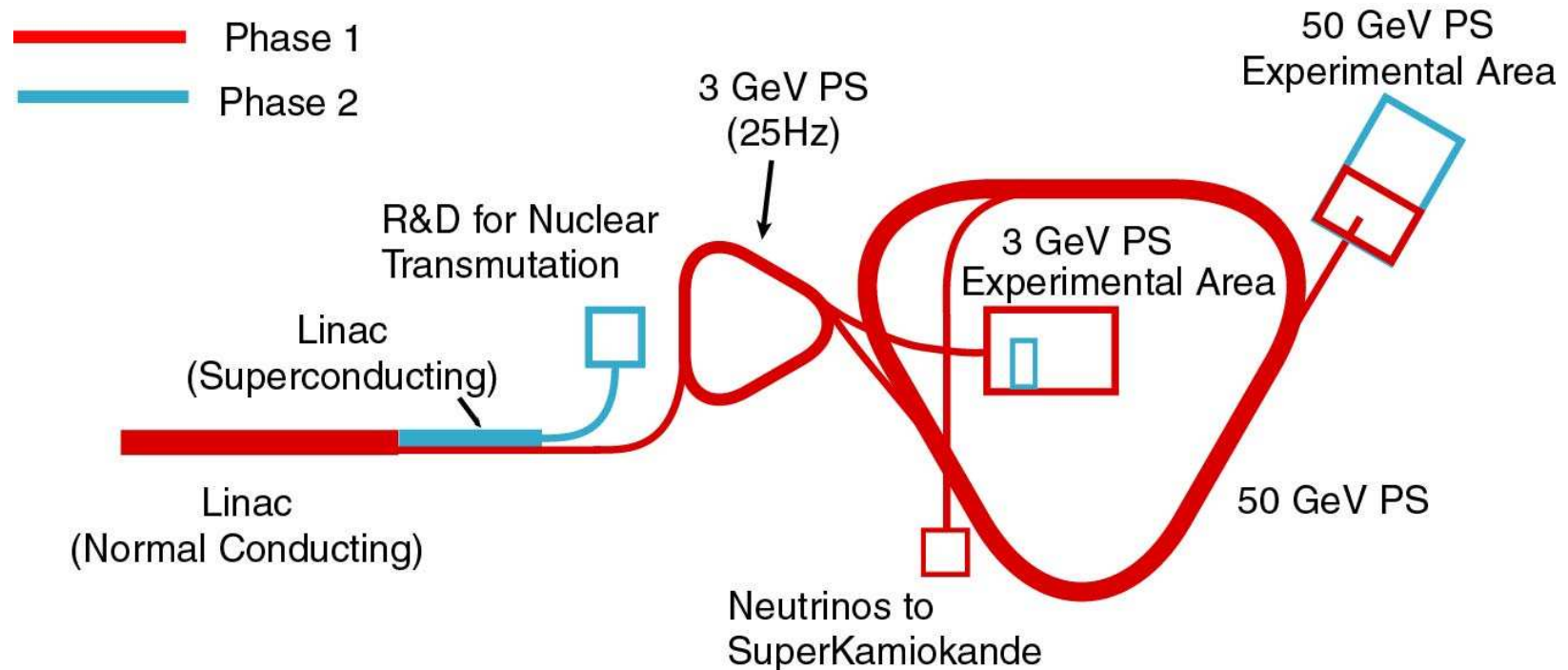
- J-PARC aims for the **high intensity frontier** for
 - materials/life sciences (3GeV), and
 - nuclear/particle physics (50GeV)
- High intensity proton beam leads to high intensity secondary (neutron, meson, ...) beam.
 - The power (= Energy x Current) is a good measure.
- Neutron: from 0.16MW (ISIS) to 1MW
- K meson: 5 to 10 times more intense than existing BNL-AGS.





Phase 1 & 2

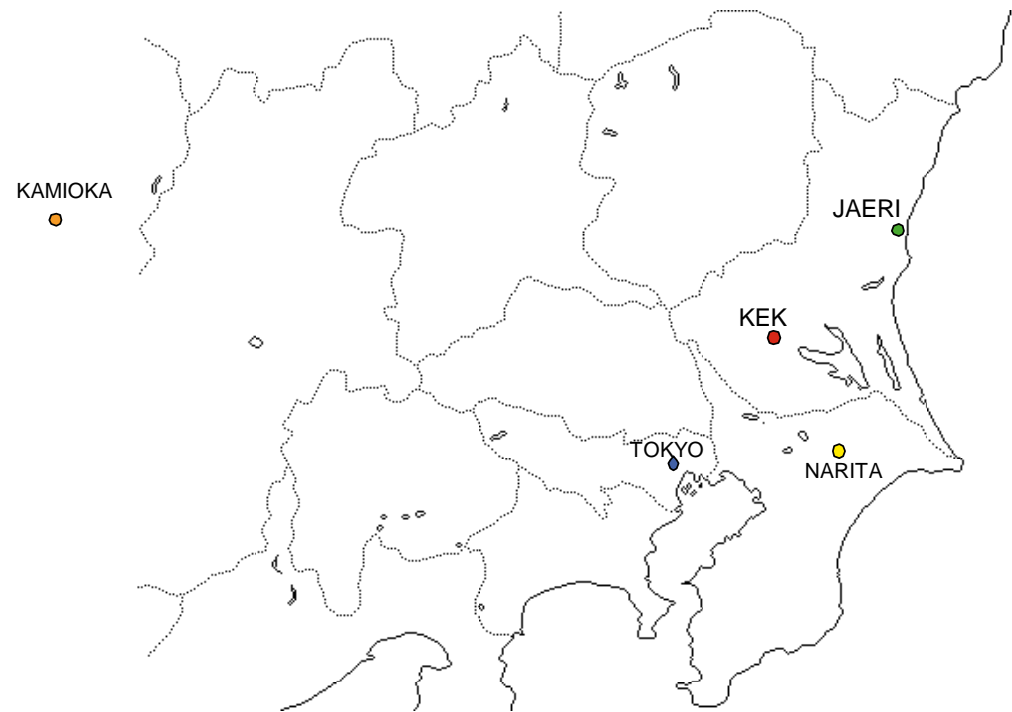
- The budget for about 2/3 of the entire project has been approved by the Japanese government from JFY2001 as **Phase 1**.
- Phase 1 (~151 billion Yen) consists of major accelerator components and a part of experimental facilities.





Organization and Location

- J-PARC is a joint project between KEK and JAEA (Japan Atomic Energy Agency).
- J-PARC will be located at the Tokai campus of JAEA.



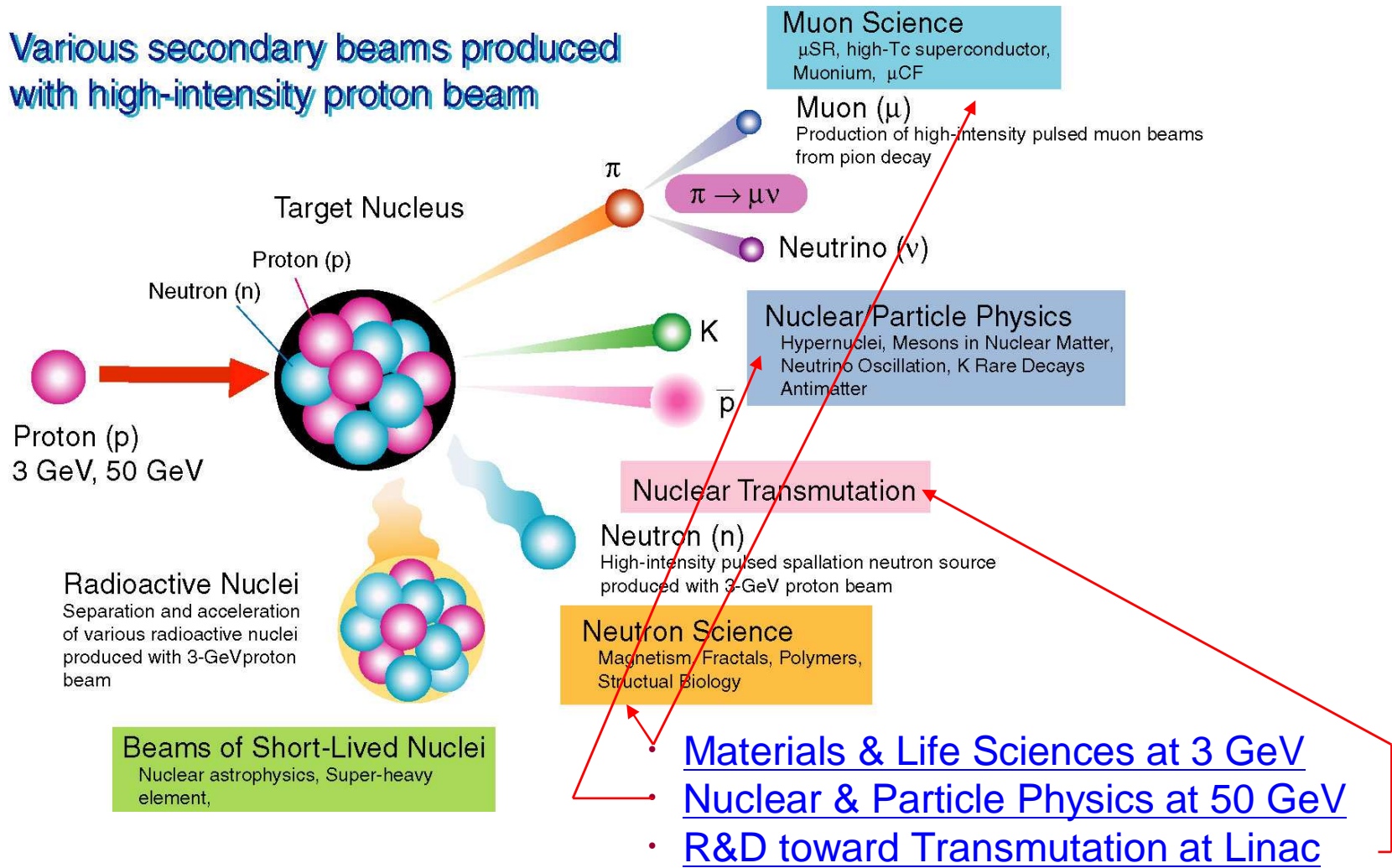
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Three Goals of J-PARC

Various secondary beams produced with high-intensity proton beam





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Performance of the 50-GeV PS

Numbers in red are design values.

Numbers in parentheses are ones for the beginning of Phase 1.
Energy recovery of the linac to 400 MeV is planned just after the completion of the Phase-1 construction in 2009.

- Beam Energy : **50 GeV** $E_{\text{Linac}} = 400\text{MeV}$
(30GeV for **Slow Beam**) $E_{\text{Linac}} = (180\text{MeV})$
(40GeV for **Fast Beam**)
- Repetition: **3.4 ~ 5-6s**
- Flat Top Width : **0.7 ~ 2-3s**
- Beam Intensity: **3.3×10^{14} ppp, 15 μ A**
(2×10^{14} ppp, 9 μ A)
- Beam Power: **750kW**
(270kW)



Discussions on Physics at the 50-GeV PS



■ Workshops

- NP01: December 2001
- NP02: October 2002 – Discussions for Letters of Intent
- NP04: August 2004 – Discussions for full proposals
 - Neutrino oscillation physics
 - Kaon decay physics
 - Strangeness nuclear physics
 - Hadron physics
 - Muon physics

<http://www-ps.kek.jp/jhf-np/NP04/presentations/>

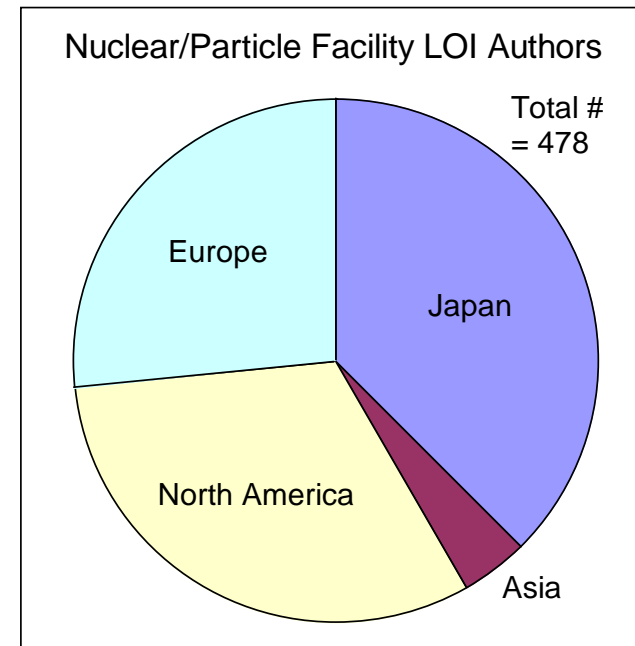
■ Letters of Intent

<http://www-ps.kek.jp/jhf-np/LOIlist/LOIlist.html>



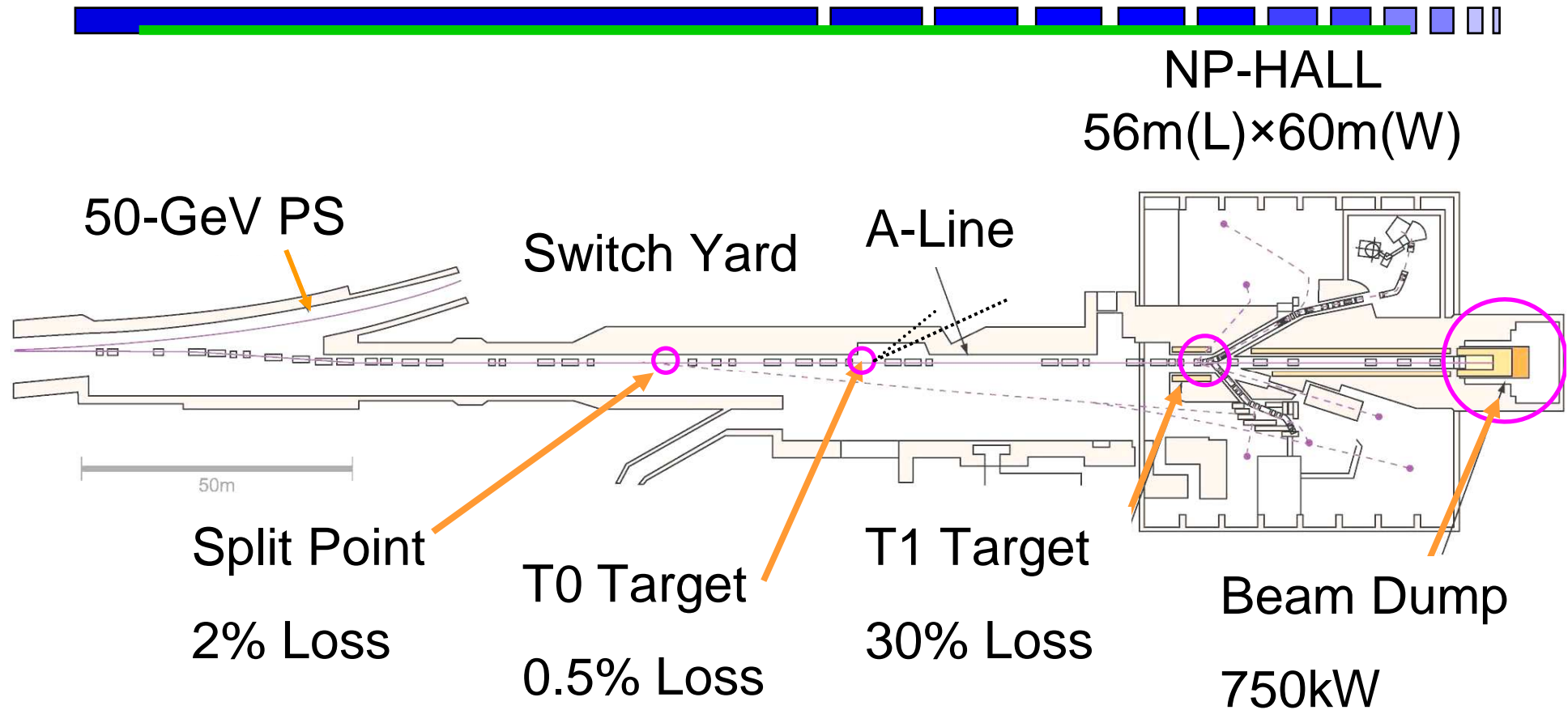
Letters of Intent for 50 GeV

- Announce of Lol call : July 2002
- Thirty Lol's were submitted by early 2003
 - Strangeness nuclear physics 6
 - Nuclear/hadron physics 7
 - Kaon decay physics 4
 - Muon physics 3
 - Neutrino physics 1
 - Future facilities 9
- 478 physicists with 2/3 from outside Japan.
- Committee meetings to evaluate the Lol's:
 - Feedback to the facility design
- The full proposals:
 - **The first deadline was April 28, 2006!**
 - **16 proposals and 4 Lols were submitted.**
 - **The first PAC meeting will be held from June 30 through July 2.**





Slow Extraction Beamline (Phase 1)



Plan to extend the hall downstream (~50m)
in the Phase 2.



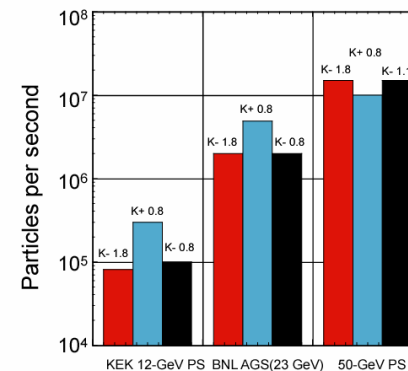
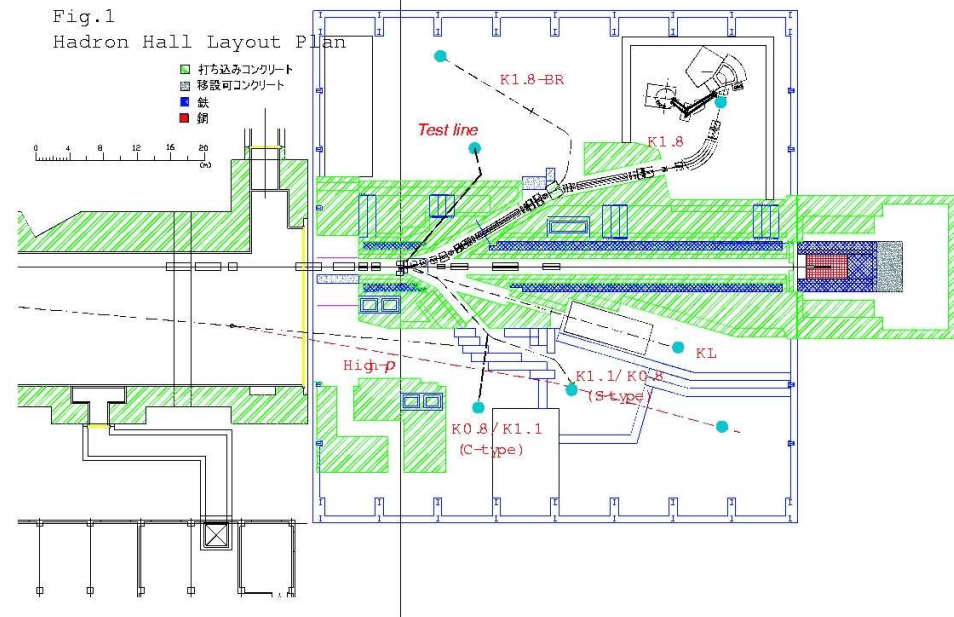
Slow Extracted Beams at the Hadron Hall





Slow Extracted Beams at the Hadron Hall

- The building is being constructed so that phase-1 experiments (Lols) can be accommodated.
- K1.8 (and K1.1) has a higher priority for the day-1 exps.
 - much higher K intensity than existing facilities.
- Major physics topics:
 - Kaon decays
 - Hypernuclear physics
 - Hadron physics

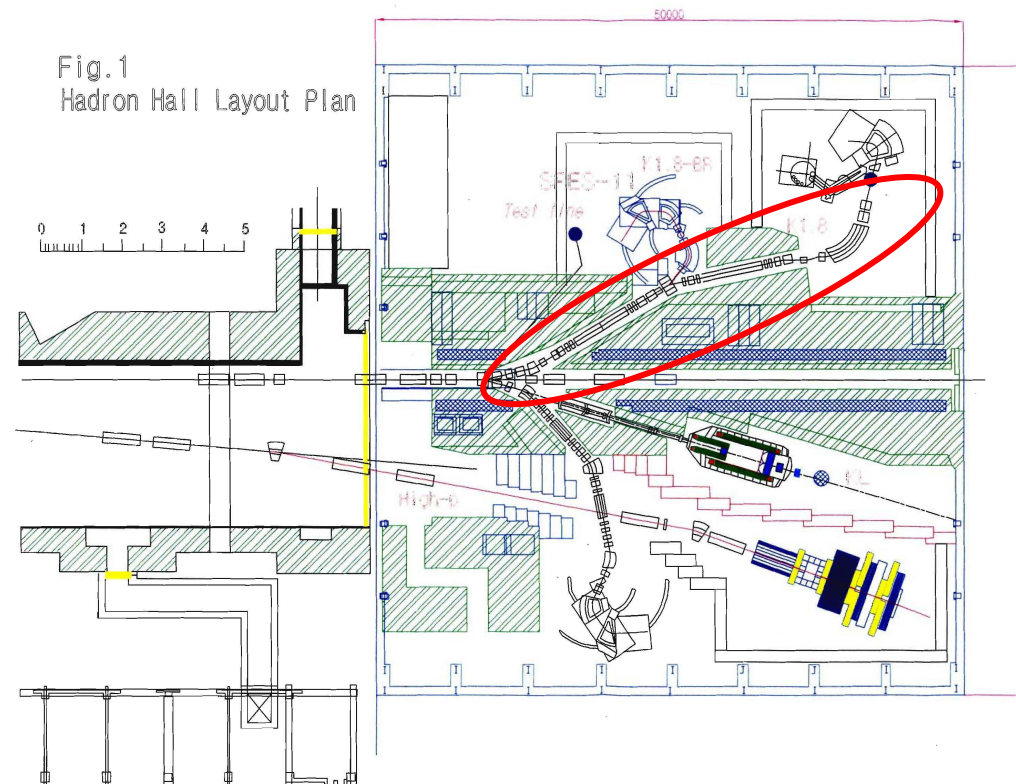


- K⁻(1.8 GeV/c)
(K⁻, K⁺), S=-2
- K⁺(0.8 GeV/c)
K⁺ rare decay
- K⁻(1.1 GeV/c)
(K⁻, π⁻), S=-1



K1.8 beamline

- Most probable at Day-1 (the first day of the Phase 1)
 - Some day in 2008 – 2009.
- High quality kaon beamline.
 - Best suitable for hypernuclear study, especially of $S=-2$ systems, using (π, K) , (K, π) , and (K, K) reactions.

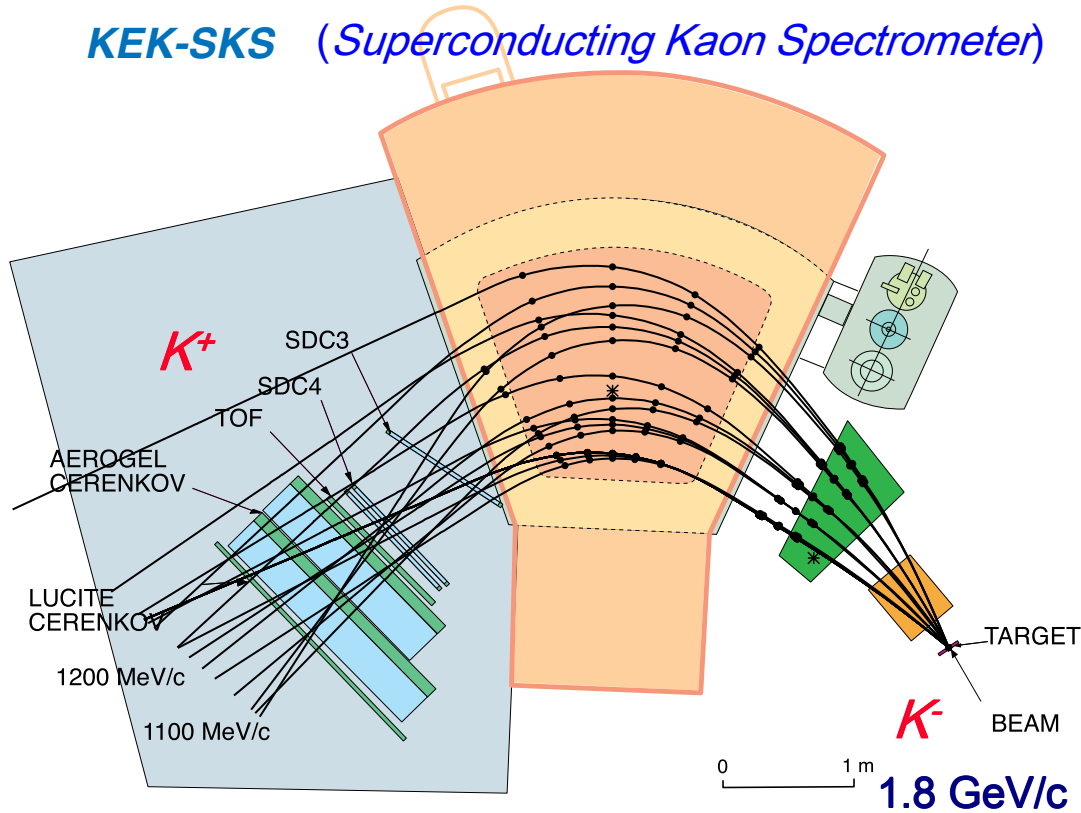




E Spectroscopy with (K^-, K^+)



KEK-SKS (Superconducting Kaon Spectrometer)

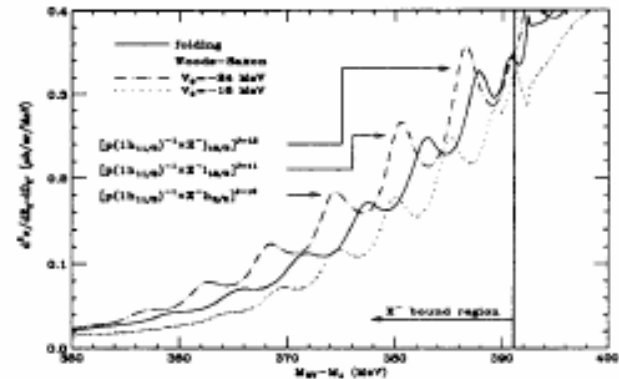
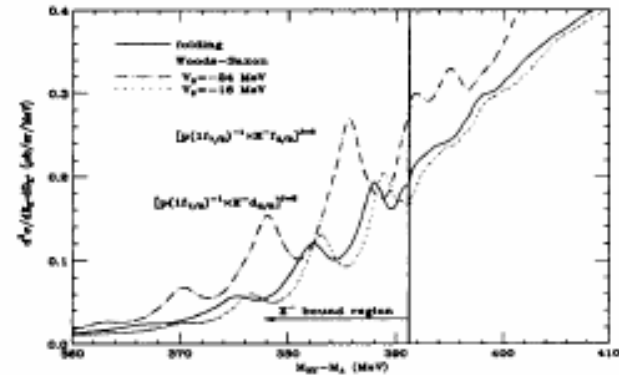


$\Delta E \sim 2$ MeV (FWHM)

$BL = 6$ Tm

~ 6 events/day/MeV for 50 msr, 2g/cm²-thick Pb \rightarrow ~ 20 days

expectation

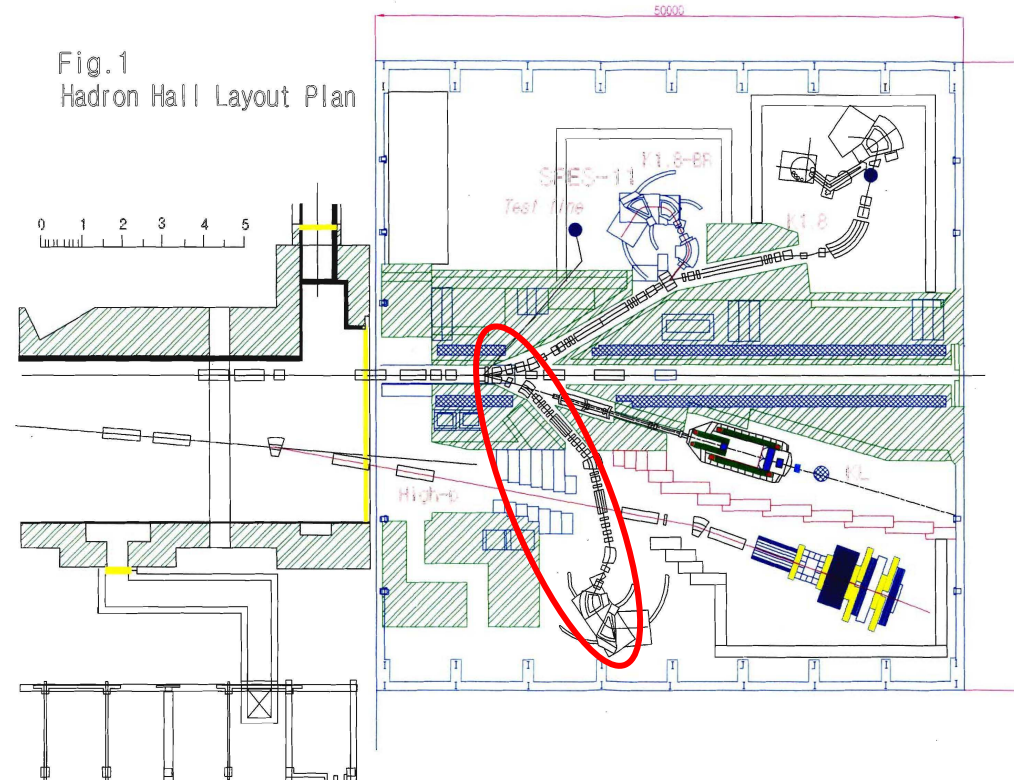


$M_{HY} - M_A$



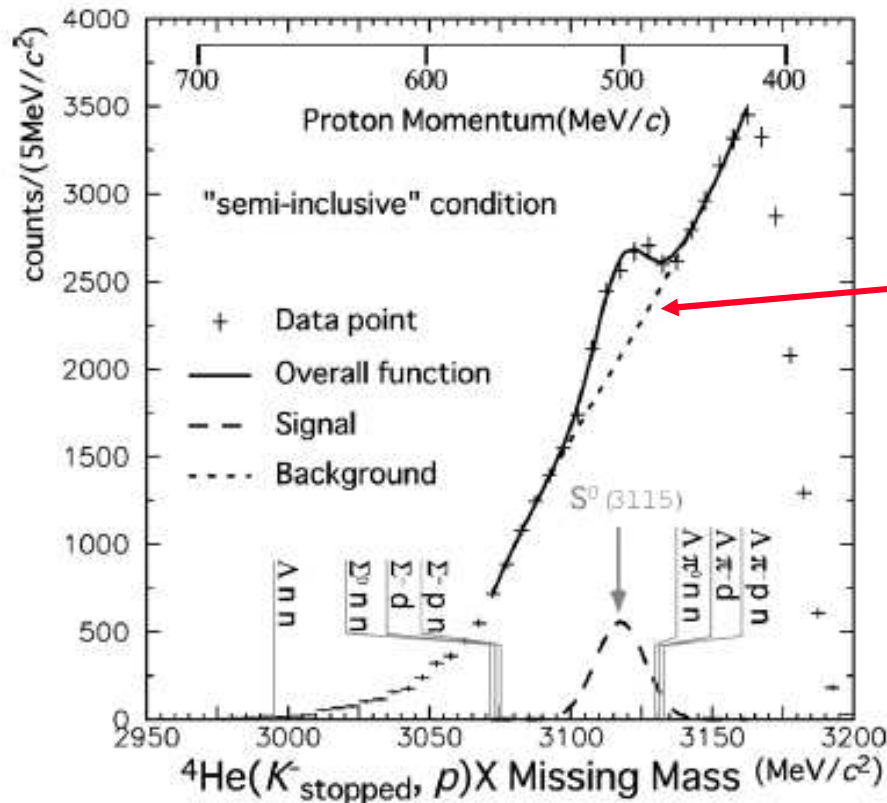
K1.1/K0.8 beamline

- Another probable beamline at Day-1 (the first day of the Phase 1)
- People are trying to get funding also from agencies other than KEK (RIKEN, Korea, ...)
- High quality kaon beamline with lower momenta.
 - Suitable for stopped kaon experiments as well as K^+ decay experiments etc.



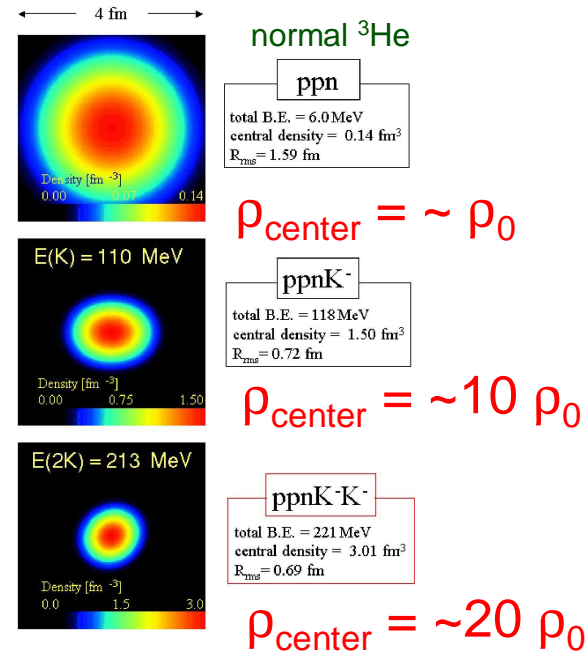


Hadron Physics: Strange Meson Implantation



T. Suzuki et al., NPA 754 (2005) 374.

Theory by Y. Akaishi, et al.



$\rho_{\text{center}} = \sim \rho_0$

$\rho_{\text{center}} = \sim 10 \rho_0$

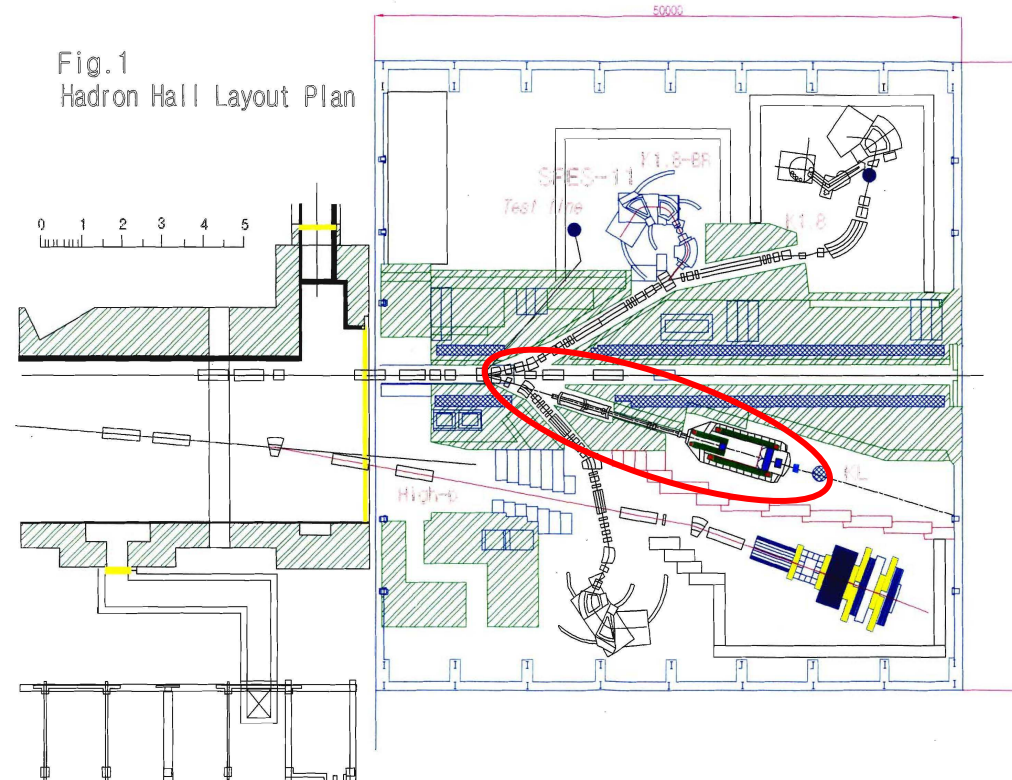
$\rho_{\text{center}} = \sim 20 \rho_0$

production of dense nuclear matter which can correspond to neutron stars. \rightarrow Study of dense matter will be continued to J-PARC



K0 beamline

- Beamline specifically designed for $K^0 \rightarrow \pi^0 \nu \bar{\nu}$.
- Shielding is designed so that this experiment can be accommodated.
- A prototype experiment has been done at KEK-PS.





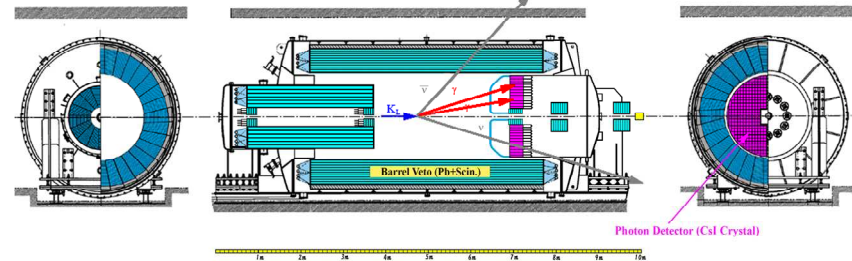
CP violation in $K_L \rightarrow \pi^0 \nu \bar{\nu}$

Most important rare decay channel in the J-PARC era

- Direct CP violation in FCNC process
- Clean measurement of $\text{Im}(V_{td}) \sim \eta$
- Clear test of the Standard Model
- Clue for new physics in comparison with B physics

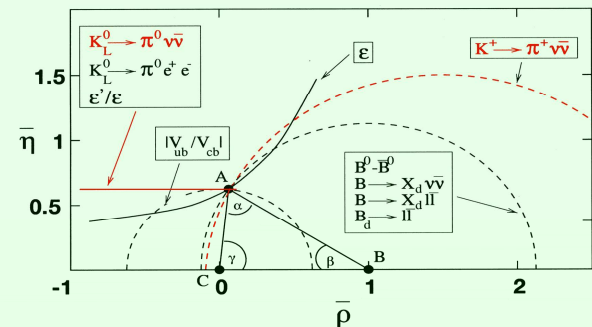
Experiments

- E391a : $10^{-9} - 10^{-10}$
- KOPIO : 10^{-12} (50 events)
- J-PARC : $< 10^{-13}$ (100? events)



Unitarity relation

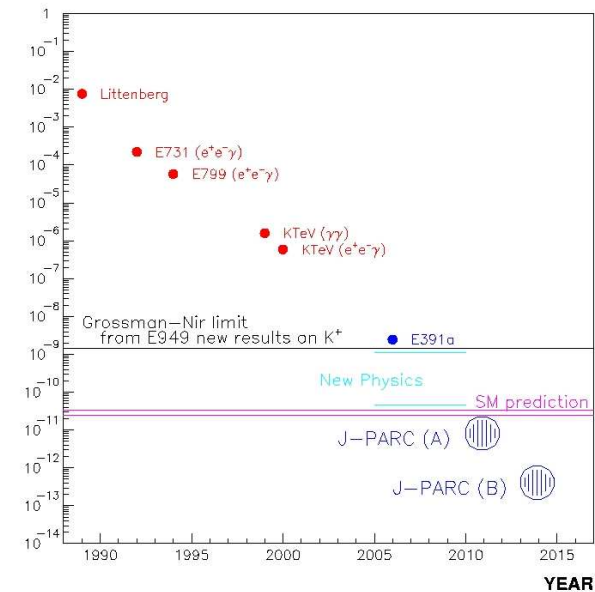
$$V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0$$



Standard Model prediction

$$\begin{aligned} \text{BR}(K_L \rightarrow \pi^0 \nu \nu) &= 6 \kappa_1 \cdot \text{Im}(V_{td} V_{ts})^2 X^2(x_t) \\ &= 1.94 \cdot 10^{-10} \eta^2 A^4 X^2 \\ &\sim 3 \times 10^{-11} \end{aligned}$$

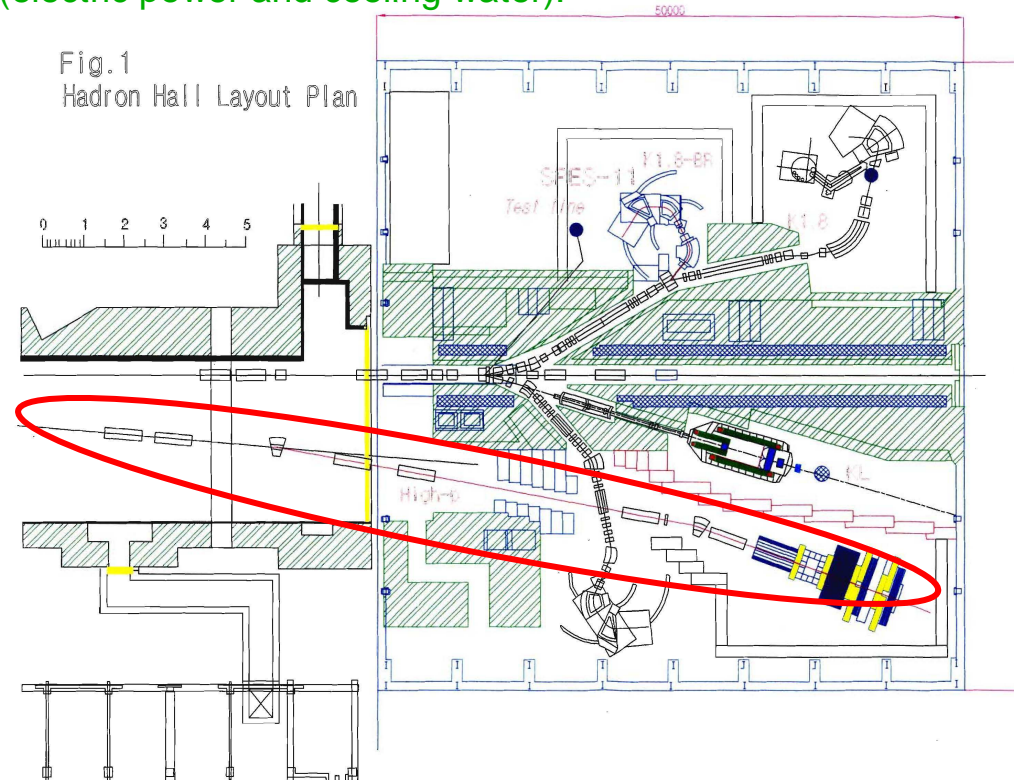
Determination of η
 10% precision





High momentum beamline

- Not day-1, but I (we) expect early realization.
- Primary protons and high mom. 2ndary beams.
- Foreign colleagues are interested in experiments at this beamline.
- Issues:
 - Budget.
 - Development of equipments at the separation point.
 - Utilities (electric power and cooling water).

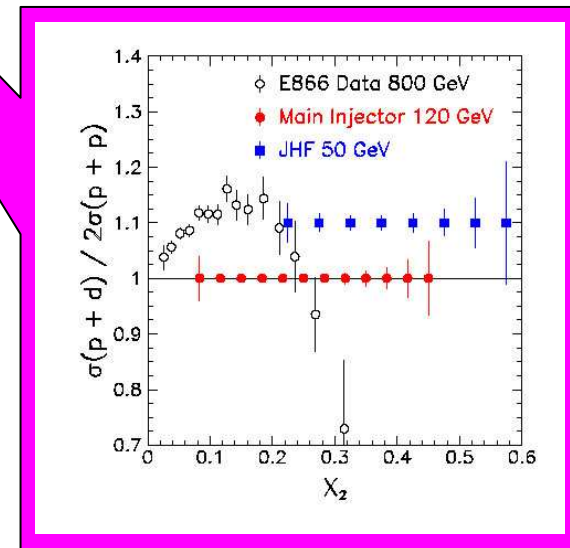
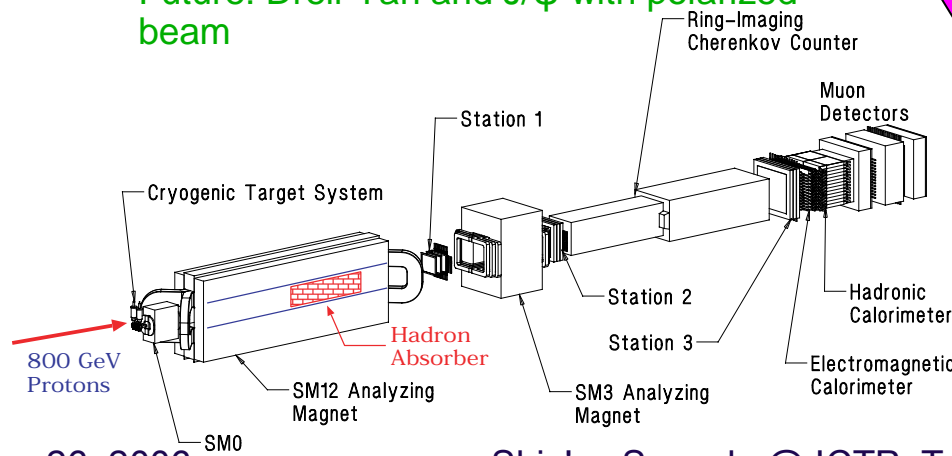
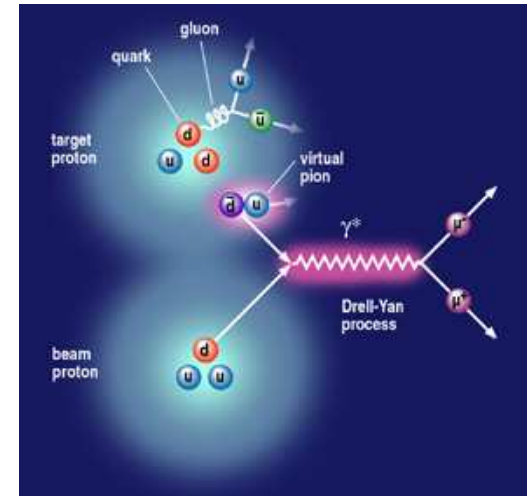


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Hadron Physics: Sea Quark at Large x_{Bj}

- Direct investigation of quark-gluon multibody system
- Proton beams (50 GeV) +hydrogen/deuterium target+dimuon (\leftarrow Drell-Yan process) spectrometer
 - \bar{d}/\bar{u} (flavor asymmetry) at large x
 - Anti quark PDF in A
 - Quark energy loss in A
 - PDF in large x
 - Future: Drell-Yan and J/ψ with polarized beam



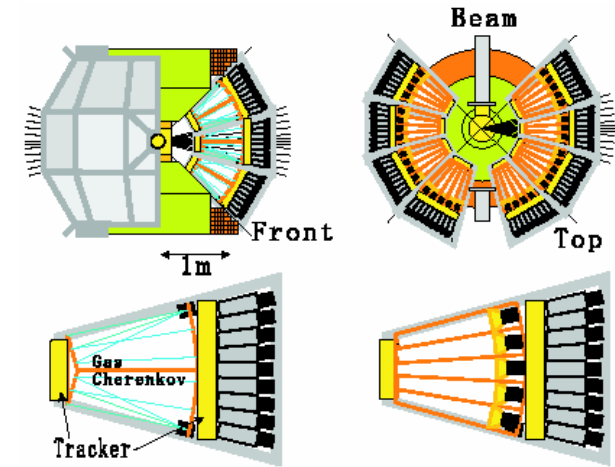
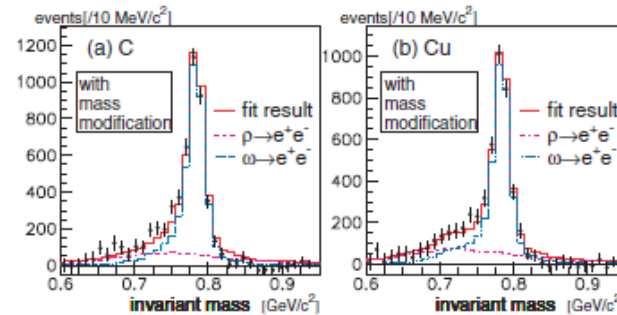
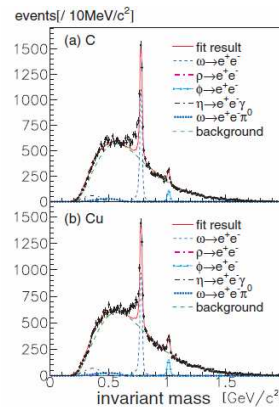
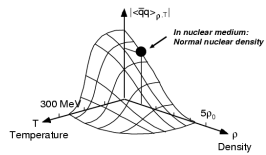


Vector Meson Modification in Nuclear Matter



KEK-PS E325:

PRL 96 (2006) 092301



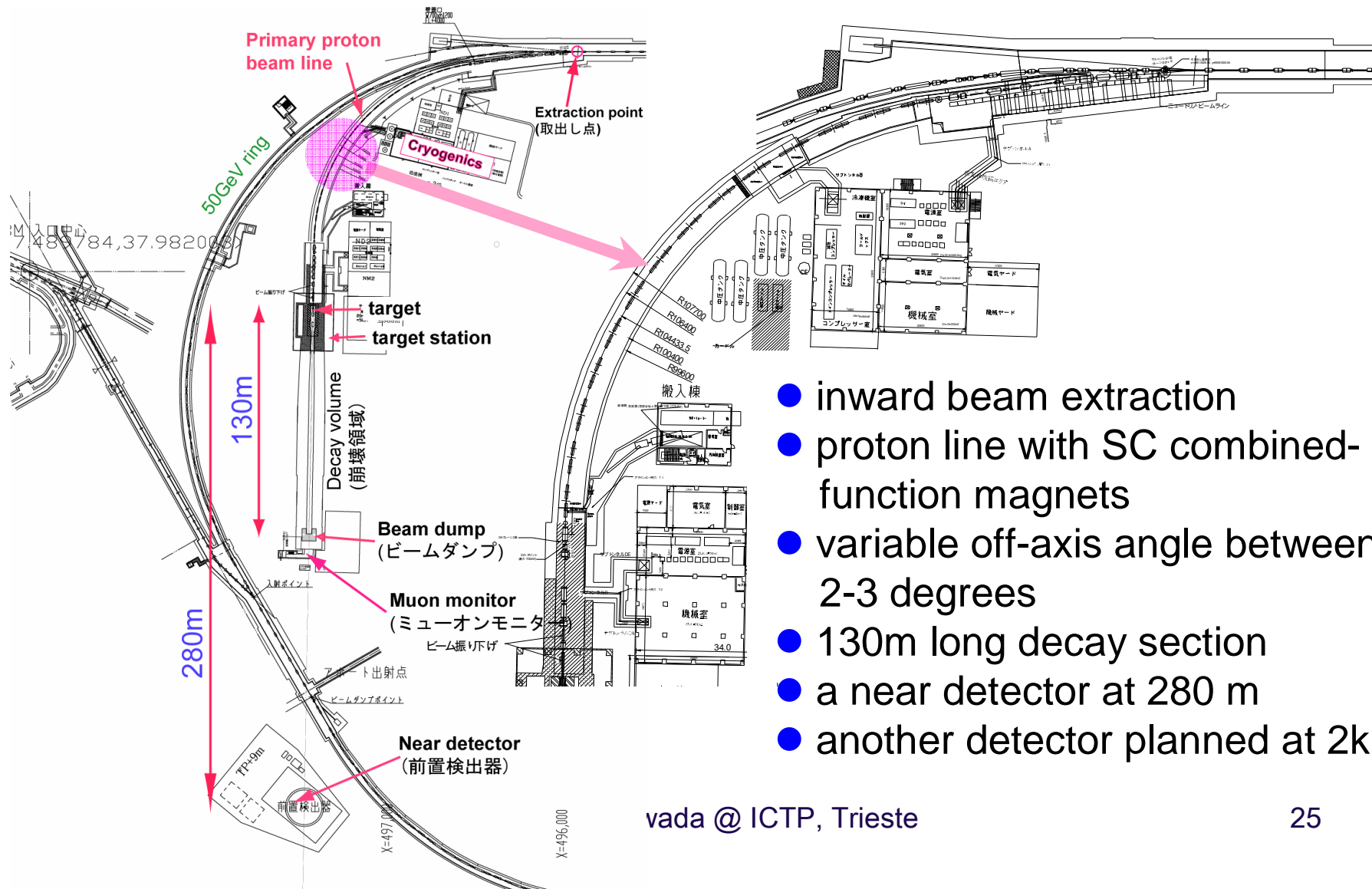
Electron Pair Spectrometer

- Improve KEK-PS E325
 - thin target / primary beam ($10^9 \sim 10^{10}$ pp)/ slowly moving mesons
- Main goal : collect $10^4 \sim 10^5 \phi \rightarrow ee$ for each target in 100 shifts
 - 10-100 times as large as E325
 - velocity dependence of 'modified' component
 - new nuclear targets : proton (CH_2 -C subtract), Pb
 - narrow width -> sensitive to modification
 - free from ω - ρ interference
- ω , ρ and J/ψ can be collected at the same time
 - higher statistics of ω , ρ than E325 with different A targets
 - 100-1000 J/ψ are expected in 50GeV operation
- Normal nuclear density ($\rho+A$)
 - but also high matter density (A+A, $\sim 20\text{GeV/u}$) in the future

- Tracking Device
 - Drift Chamber
 - GEM(Gas electron multiplier): strip readout
- Two-stage Electron ID
 - Gas Cherenkov:
 - PMT+2 mirrors
 - GEM+CsI photocathode: pad readout
 - Leadglass EMC
- $\sim 30\text{K}$ Readout Channels (in 20 units)
 - E325: 3.6K, PHENIX: $\sim 300\text{K}$
- Cost : $\sim \$5\text{M}$ (including $\$2\text{M}$ electronics)



Neutrino Facility



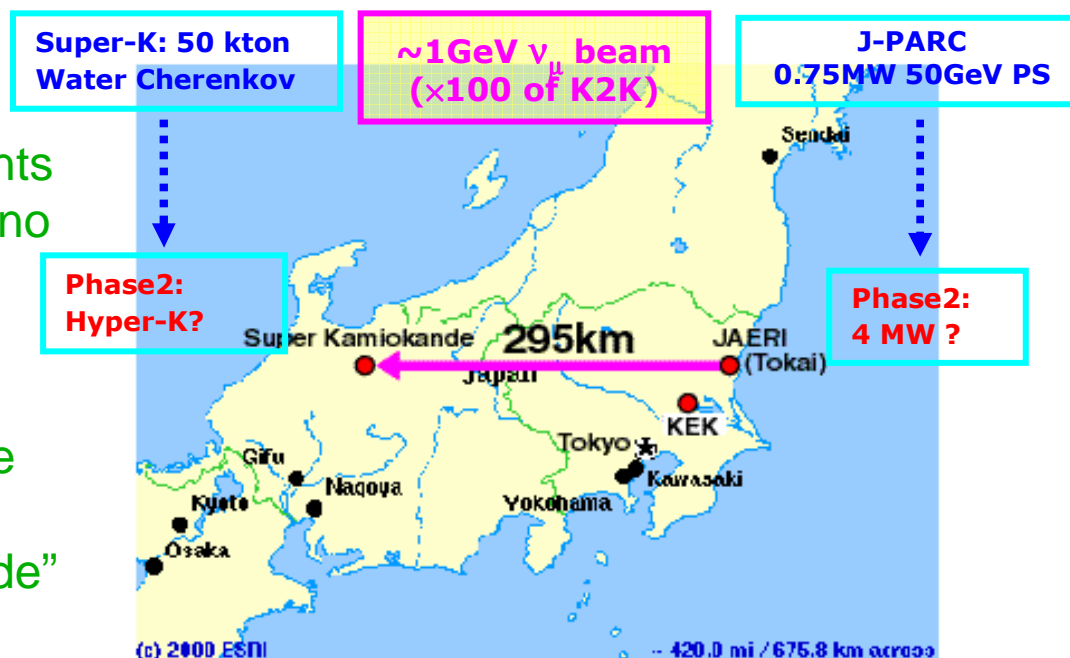
- inward beam extraction
- proton line with SC combined-function magnets
- variable off-axis angle between 2-3 degrees
- 130m long decay section
- a near detector at 280 m
- another detector planned at 2km



T2K (Tokai-to-Kamioka) Neutrino Experiment

■ Status of ν oscillation and neutrino mass:

- Atmospheric ν experiments (SK...) discovered neutrino oscillation and thus finite masses of neutrinos.
- K2K ν_μ disappearance experiment confirmed the existence of the neutrino oscillation with “man-made” neutrinos.



■ Motivations of T2K (Tokai to Kamioka):

- Precise measurement of disappearance ν_μ to ν_x .
- Discovery of ν_e appearance: High flux of ν_μ enables us to observe it.
 - Flux (ν_μ) at the 50 GeV PS > 100 x Flux (ν_μ) at KEK 12 GeV PS

■ Future upgrade ... towards CP violation in the lepton sector



Hadron Physics

- **Drell-Yan, J/Psi production**
→ **structure at large x**

- **Neutrino scattering** → Δs

The Quest of QCD

Quark confinement and chiral symmetry breaking

The foundation for nuclear physics

From where we are now to the early universe

Nucleon Structure

- Form factors
- Parton distributions
- EMC effects
- Spin structure

Hadron Spectroscopy

- Mesons, baryons
- Glueballs, Multiquark states
- Heavy quark hadrons

Nuclear Force

- NN, YN, YY interactions
- Hypernuclei
- Nuclear Physics

Experiment

- Elastic and inelastic scatterings
- Production reactions
- Deep-inelastic scatterings
- Heavy-ion collisions

Theory

- Quark models, Effective Lagrangians
- Chiral perturbation theories
- Lattice QCD

Quark Nuclear Matter

- QCD phases at finite temperature and density
- Equation of states
- Compact stars
- Supernovae

Meson-Baryon Dynamics

- Scatterings
- Meson productions
- Resonance productions

- **π , K scattering**

- **Hypernuclei formation via π , K beams**

- **Spectroscopy with π and K beams**
- **Chiral perturbation theory via K decays**

- **Vector meson modification in matter**

Many of the issues can be studied at J-
if once the facility is well prepared through the plan.



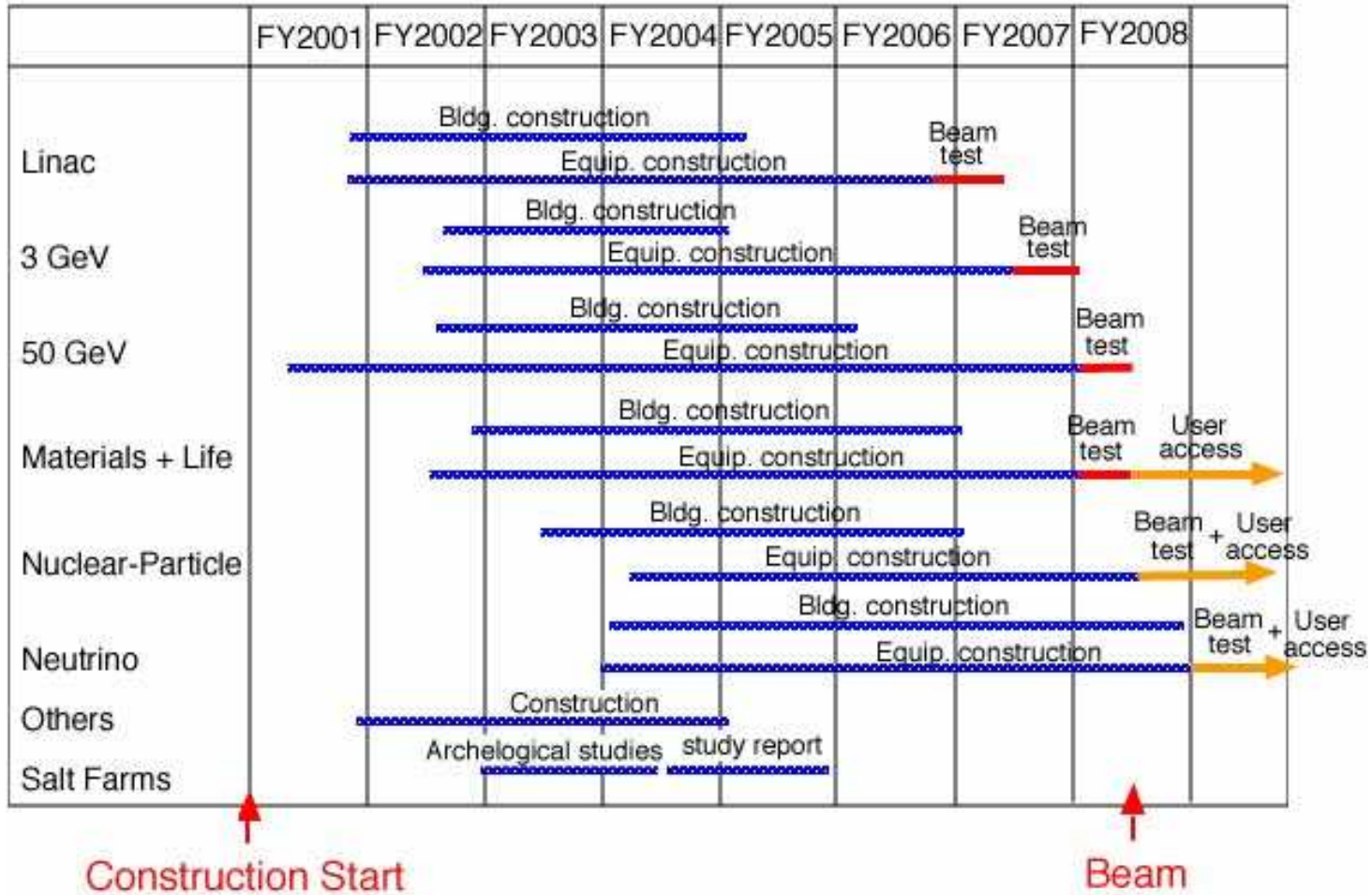
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Construction Schedule & Commissioning (Phase-1)



Construction Schedule (as of Oct., 2005)





Scenes of Construction



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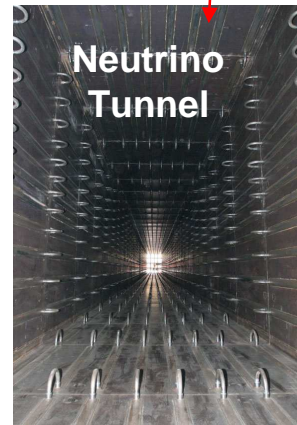
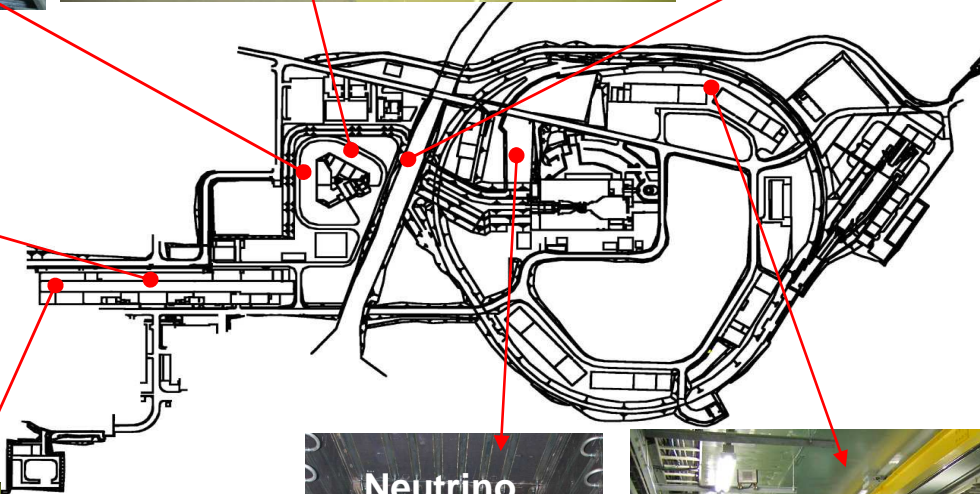
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Scenes of Construction





Tunnel Tour

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Scenes of Construction



■ Linac Area



■ 3 GeV Area





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Scenes of Construction



- Neutron source being prepared





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■ 50 GeV Area



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Scenes of Construction



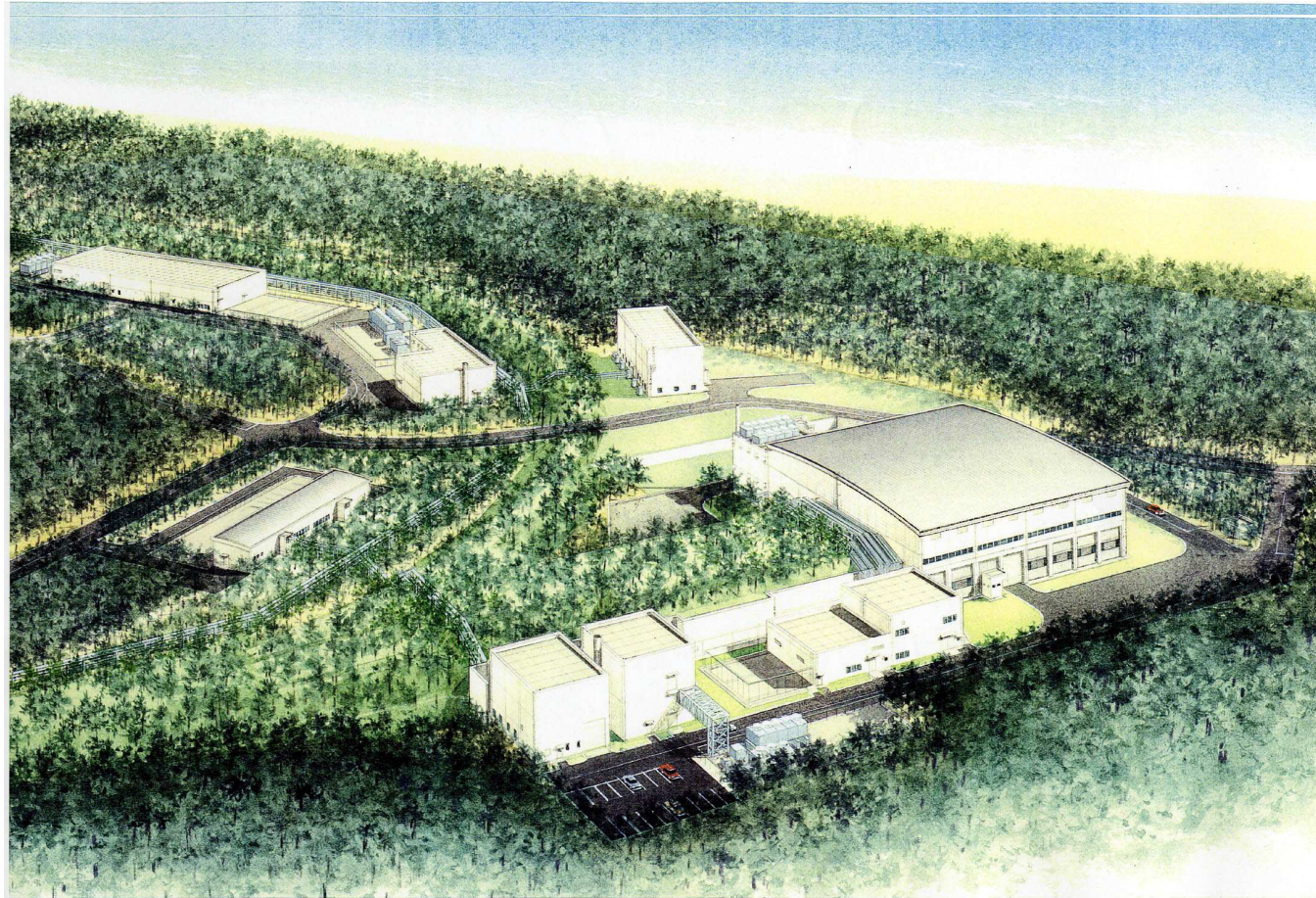
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Scenes of Construction



- Hadron Experimental Hall



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Scenes of Construction



- Hadron Experimental Hall



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Summary

- J-PARC will be the highest intensity accelerator complex of the GeV and ten-GeV energy regions in the world.
- The major aims are materials and life sciences by the 3-GeV synchrotron, nuclear and particle physics by the 50-GeV synchrotron, and R&D for nuclear transmutation technology by the linear accelerator.
- The phase-1 construction began 2001, and will be completed in 2008.
- There is a wide variety of physics possibilities.
 - Hadron physics, including Drell-Yan and quarkonium production, vector mesons etc. at the slow extracted facility.
 - Neutrino beam
 - Etc. etc.