E391a and Japanese future plans

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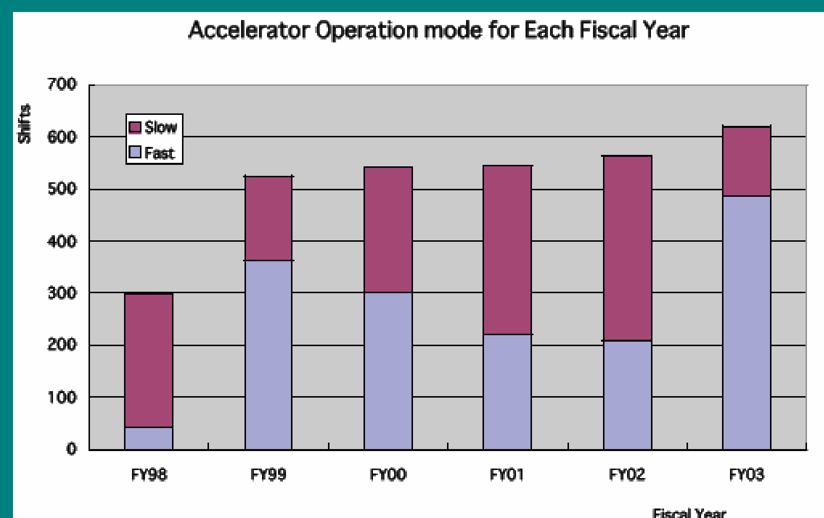
Brief reports on:

- Activity on K-decay at KEK
- J-PARC
- LOI experiments
- E391a : Method and Plan

26 Sept. 04 Villars meeting for CERN future plan
Takao Inagaki (KEK)

KEK 12 GeV PS

	Fast Ext	Slow Ext	
	to		
	ν Beamline	East Hall North Hall	
protons per pulse	6.5	2.5	$\times 10^{12}$
beam spill	1.1 micro	2.0	sec
cycle	every 2.2	every 4.0	sec
operation in a year	6	2~4	months



K-decay experiments so far

Experiments started in 1977.

E10: $K^+ \to \pi^+ \nu \nu$

E89, 104: $K^+ \to \mu^+ \nu_H$

E99, 195: P_L in $K^+ \to \mu^+ \nu$

E137: $K_L \to \mu$ e

E162: $K_L \to \pi^+ \pi^- e^+ e^-$

E246, 470: P_T in $K^+ \to \pi^0 \mu^+ \nu$

E391a: $K_L \to \pi^0 \nu \nu$

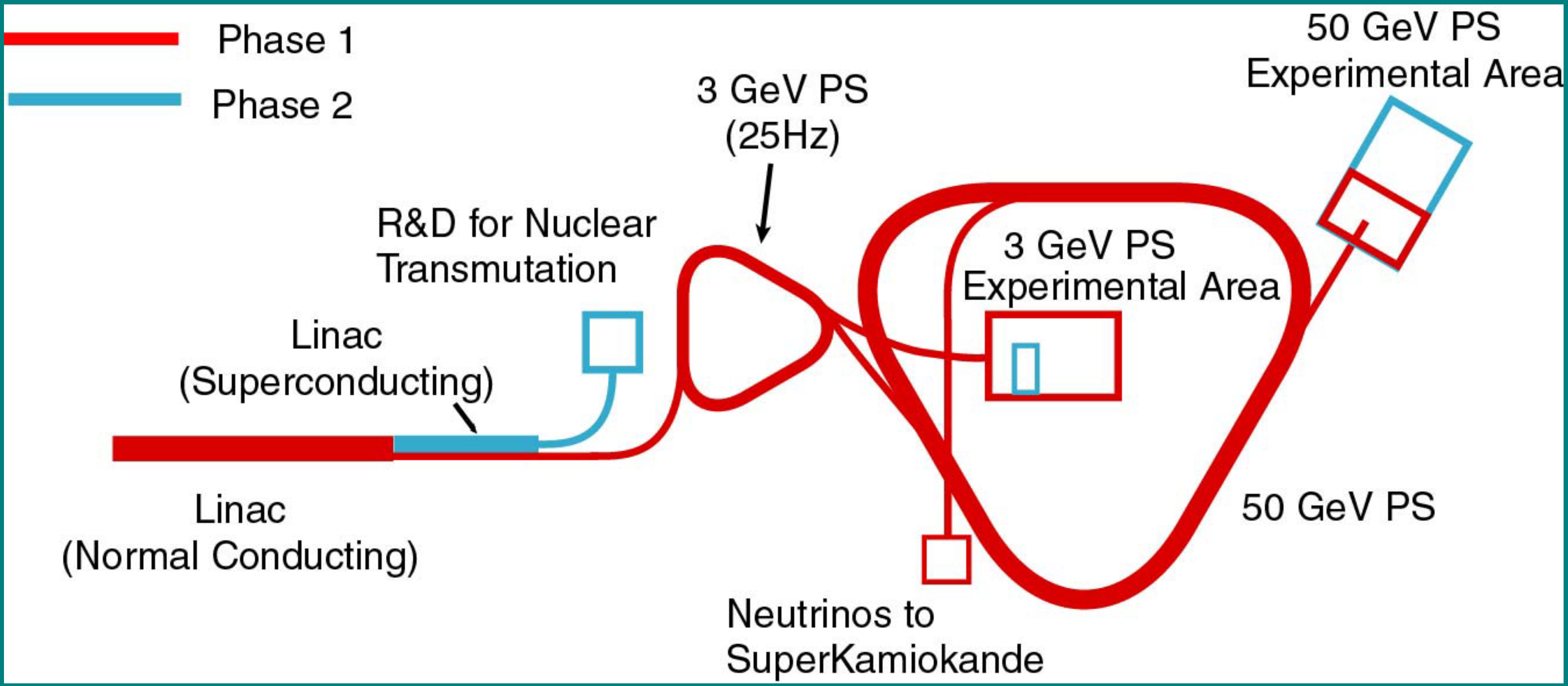
Not small activities to contribute to E787/949 and KTeV

From the report of the external review of KEK-PS, June 2004

KEK PS Particle Physics Program since the Year 2000:

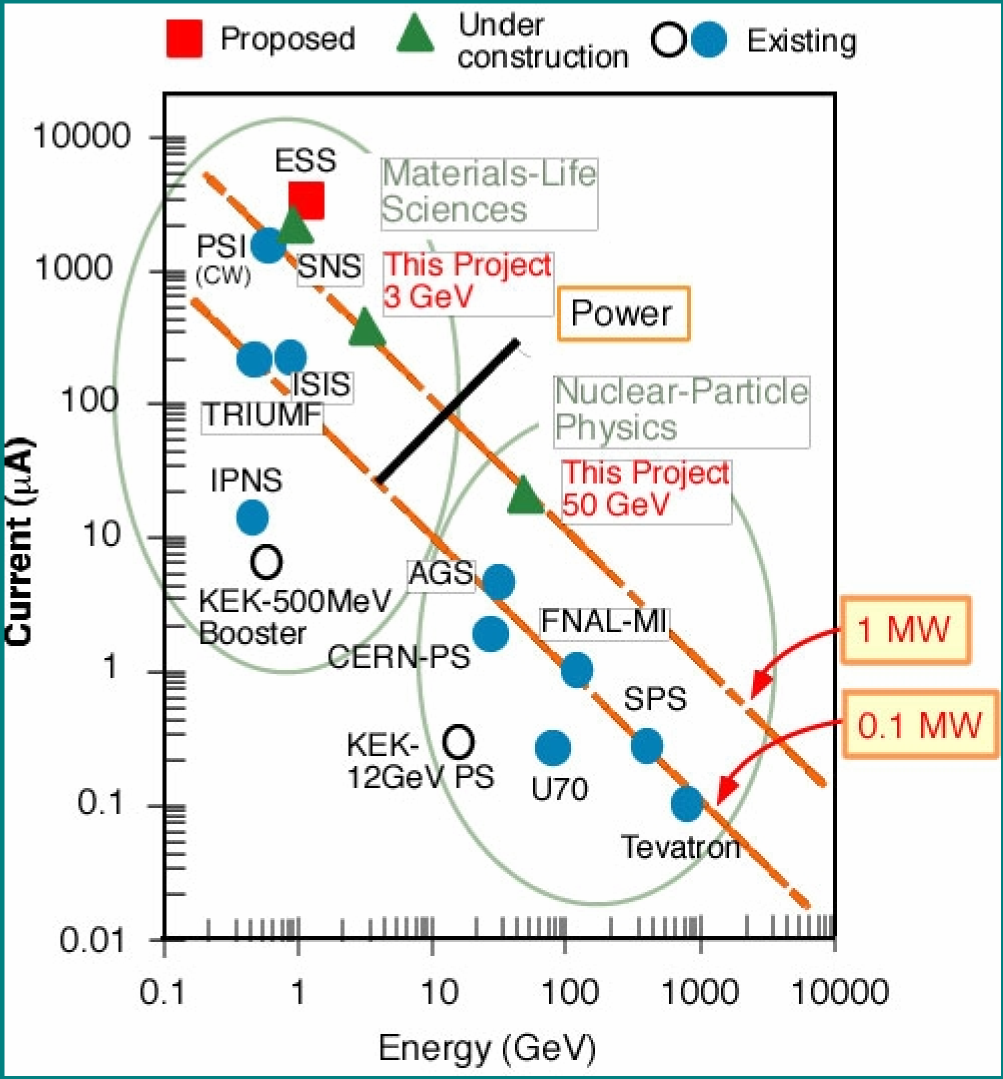
The recent KEK program in particle physics has addressed frontier issues in its neutrino and kaon experiments. The results obtained are significant and the experience gained in their pursuit will be extremely valuable for the next generation of neutrino and kaon studies to be carried out at J-PARC. The much higher flux of neutrinos and kaons attainable at J-PARC will improve the experimental sensitivity and could lead to major discoveries. The neutrino and kaon experiments carried out at KEK in recent years include: E362, E246, E470, and E391a.

J-PARC:
Accelerator complex

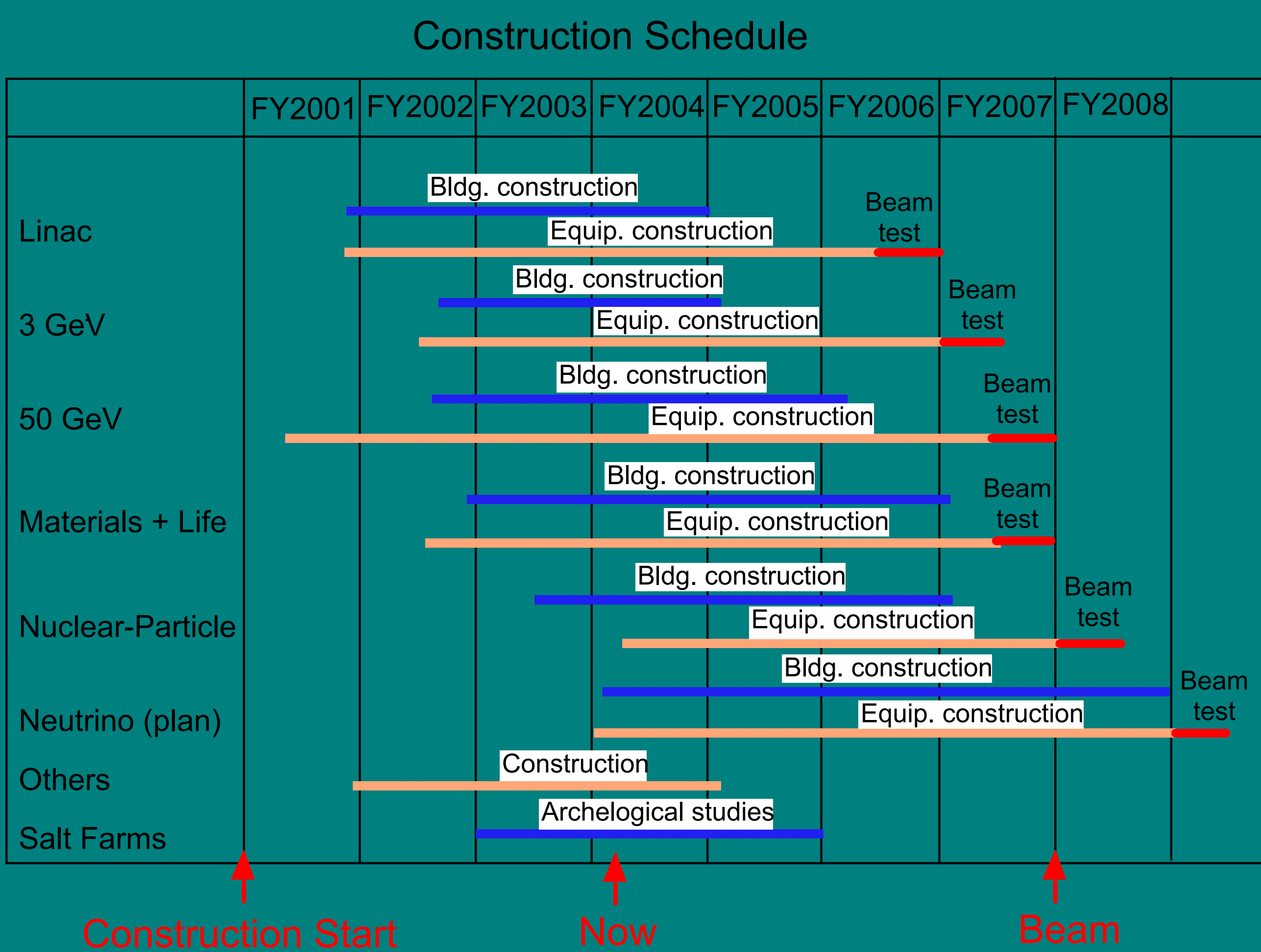


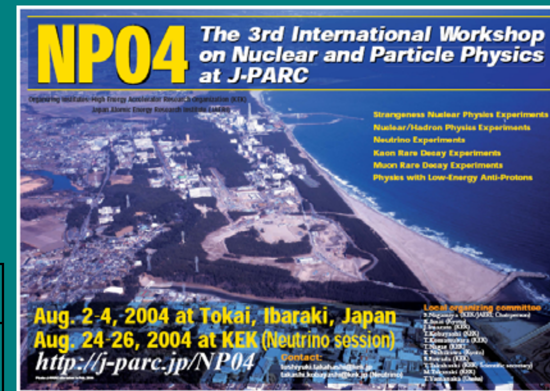
- Phase 1 + Phase 2 = 189 billion Yen (= $1.89 billion if $1 = 100 Yen).
- Phase 1 = 151 billion Yen for 7 years.
- Construction budget does not include salaries.

Proton accelerator in the world

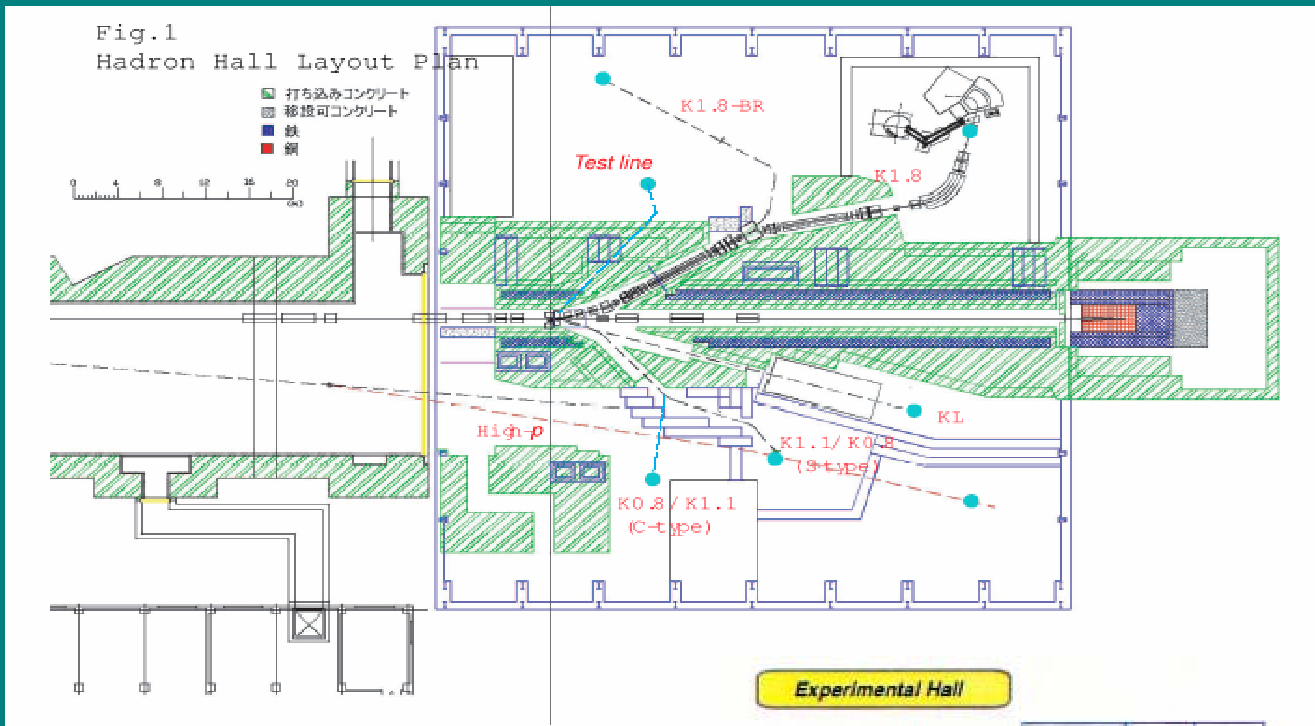


Construction Schedule



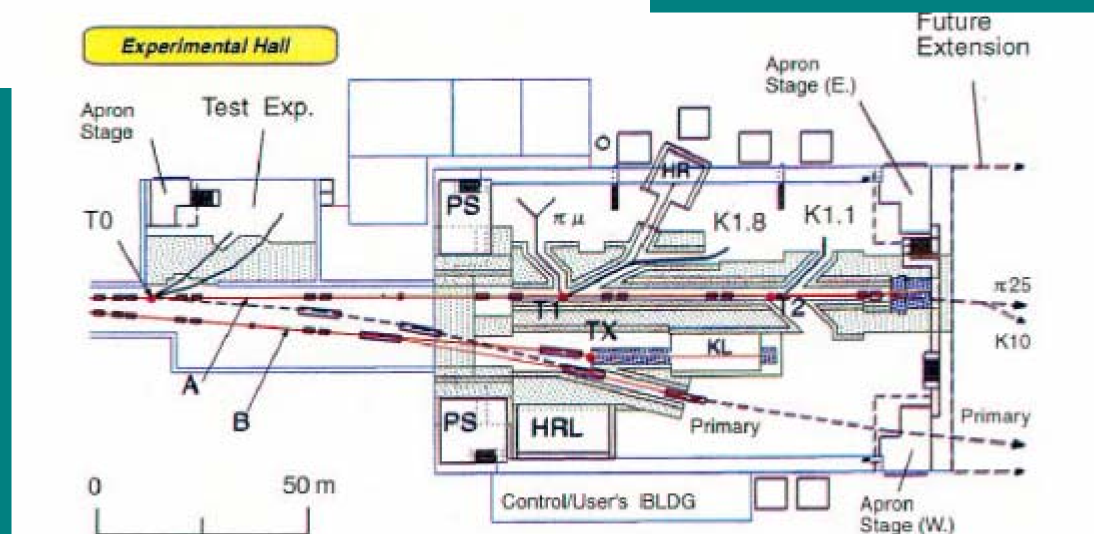


Hadron Hall Layout Plan

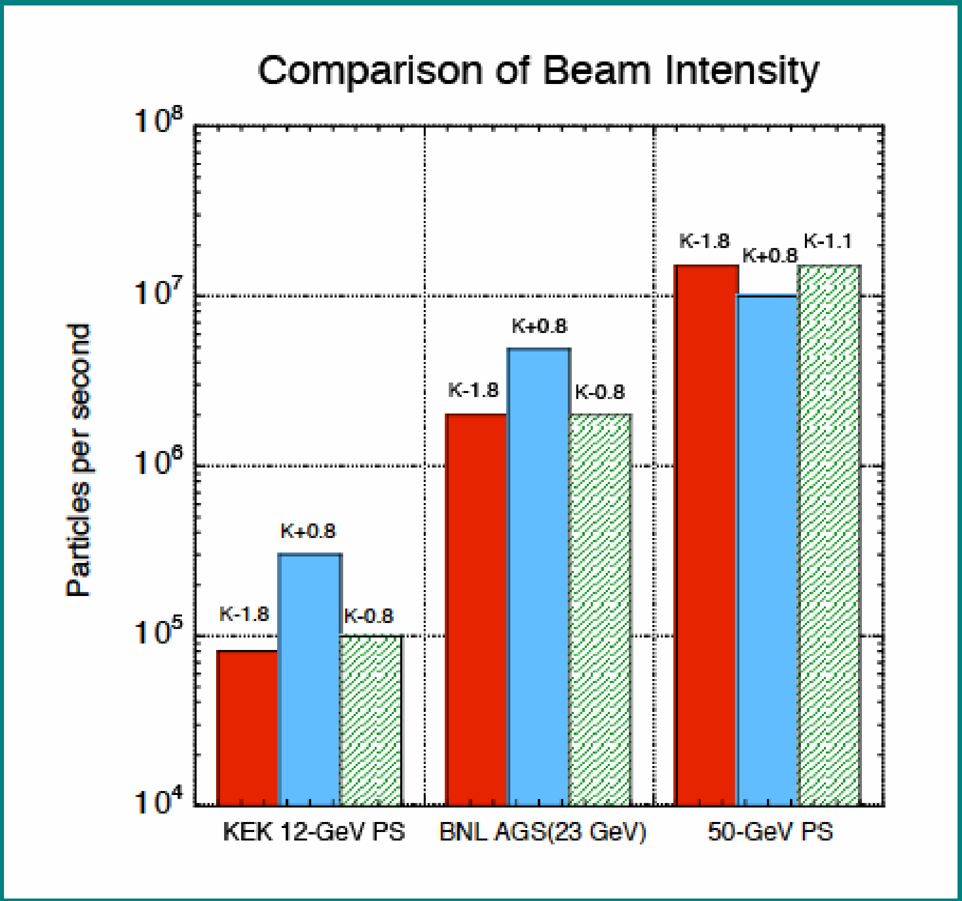


← Phase 1 plan

Phase 2 plan →



Expected intensity of charged K beam



- 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

- Relatively high increase for K^- and K^0 of higher momentum (≧1 GeV).

More than two orders increase from the present.

five LoI's for J-PARC kaon experiments

- K_L neutral beamline
  - L-05: $K^0_L \to \pi^0 \nu \bar{\nu}$ [T.Inagaki(KEK)]

    $\Longleftarrow$ KEK-E391a

- K^+ beamline of low-momentum ($0.6 - 0.8$ GeV/c): K^+ decay at rest
  - L-04: $K^+ \to \pi^+ \nu \bar{\nu}$ [T.Komatsubara(KEK)]

    $\Longleftarrow$ BNL-E949/E787
  - L-19: T-violation in K^+ decays [J.Imazato(KEK)/Yu.Kudenko(INR)]

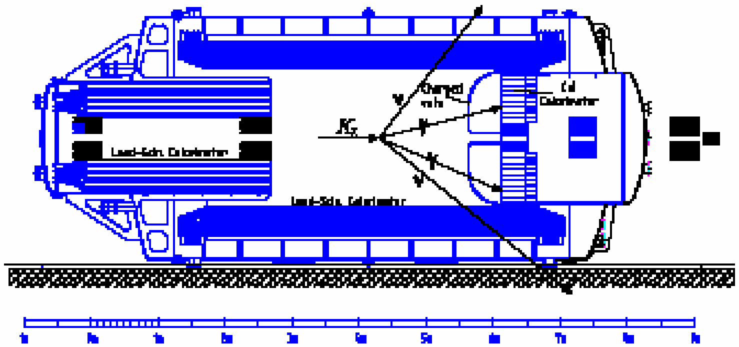
    $\Longleftarrow$ KEK-E246
  - L-16: medium-rare K^+ decays [C.Rangacharyulu(Saskatchewan)]

    $\Longleftarrow$ KEK-E470
  - L-20: K_{e3} branching ratio [S.Shimizu(Osaka)]

    $\Longleftarrow$ KEK-E470/E246

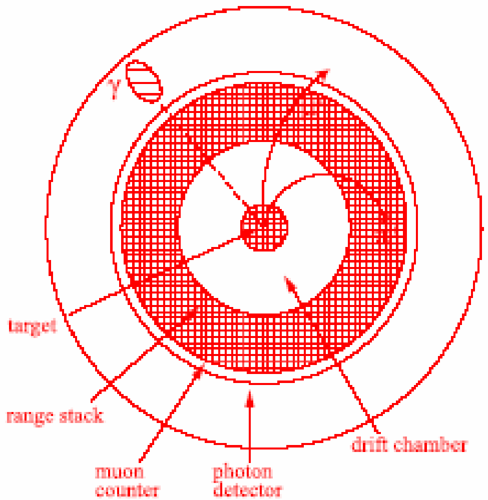
* L-05, L-04, and L-19 were regarded as "highlight" experiments of J-PARC Phase-1 in the assessment of the facility committee (NPFC).

L-05: $K_L^0 \to \pi^0 \nu\bar{\nu}$



- KEK-PS E391a
  $\to$ Phase-1 $\to$ Phase-2
- $>$ 100 signal events

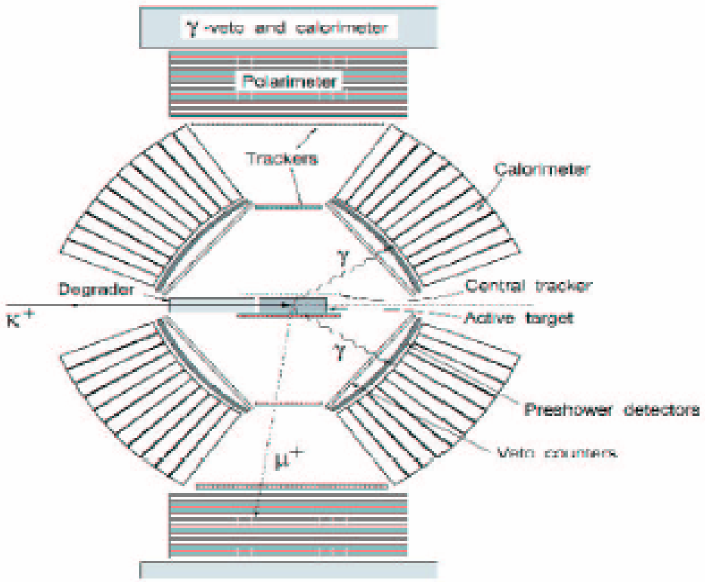
L-04: $K^+ \to \pi^+ \nu\bar{\nu}$

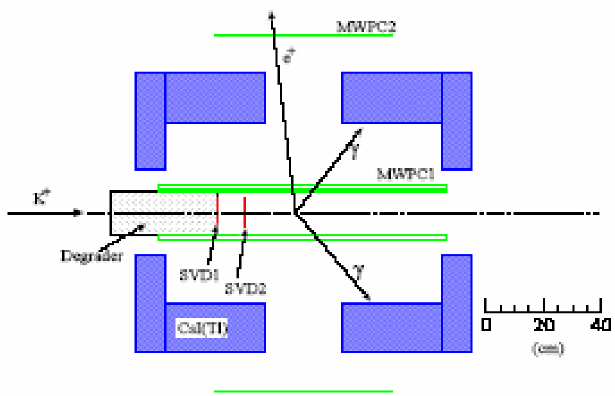


- solenoidal spectrometer
  as BNL E949/E787
- high-magfield (>2.0-Tesla),
  compact and segmented detector
- $>$ 50 signal events

L-19/-16: $K^+ \to \pi^0 \mu^+ \nu$,
$K^+ \to \mu^+ \nu \gamma$, ..

L-20: $K^+ \to \pi^0 e^+ \nu$





- π^0 detector, μ^+ polarimeter
- sensitivity to P_T: $\sim 10^{-4}$
- semileptonic, hadronic and radiative modes

- $|V_{us}|$: precision of 10^{-3}
- high-magfield (>2.0-Tesla), compact and segmented detector
- slowed-down K^+ decay in flight

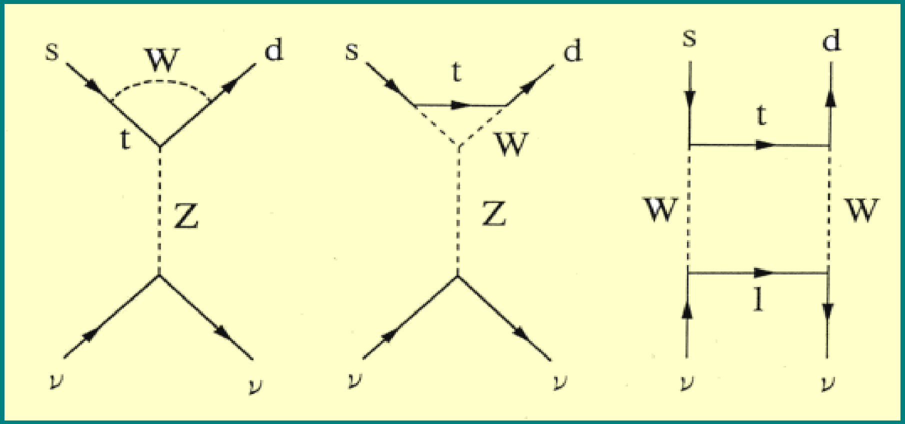
Important future mile stones

- Full proposal will be called for in this fall, and the dead line for submission of full proposal is within a year, the fall of 2005.
- A commissioning of 50 GeV PS will start in the summer of 2007. The first beam will come to the experimental hall in the spring of 2008.
- The accelerator might be operated at 30 GeV (>50% duty factor) and only T1 target might be available.

E391a: the first dedicated experiment for the $K_L \rightarrow \pi^0\nu\nu$ decay

KEK, Saga, Osaka, RCNP, Kyoto, NDA,Yamagata, Taiwan, Pusan, Chicago, JINR (60 members, 12 institutes, 5 countries)

$K_L \rightarrow \pi^0\nu\nu$ decay



Very small theoretical ambiguity

Only top loop in SM

Im(Vtd) measurement

clean and pure

Last frontier in K-decay

challenging

Ligeti

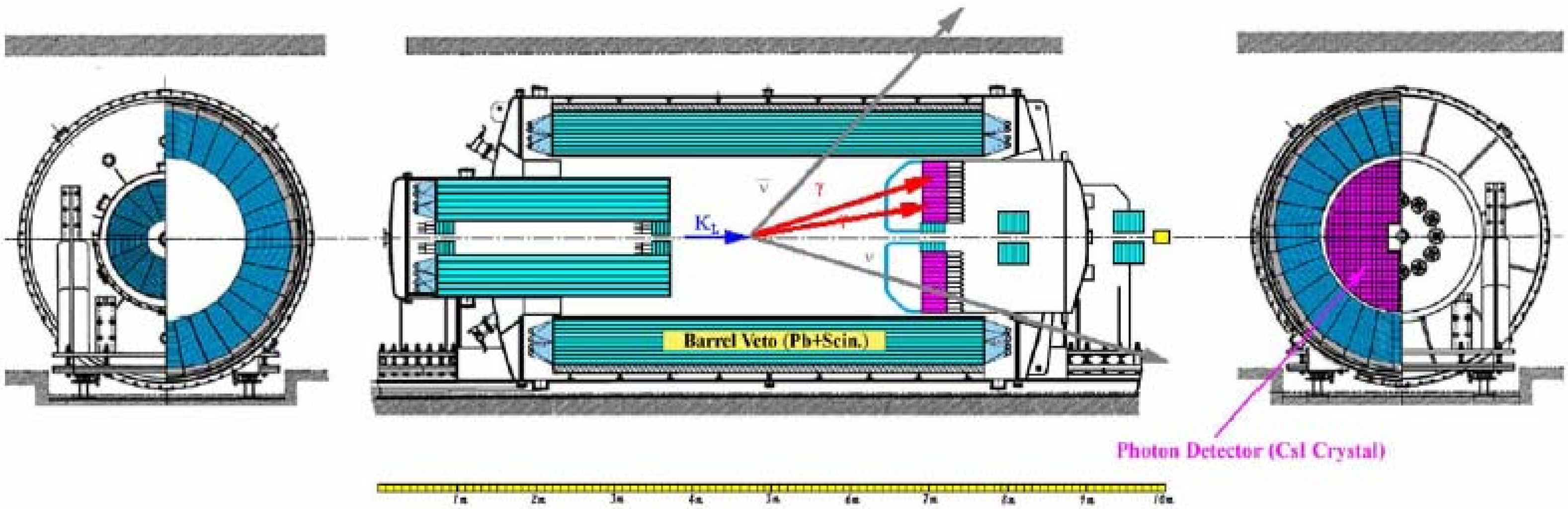
Still Room for Future Progress

- Many interesting decay modes will not be theory limited for a long time

Measurement (in SM)	Theoretical limit	Present error
$B \to \psi K_S \ (\beta)$	$\sim 0.2^\circ$	1.6°
$B \to \phi K_S,\ \eta^{(\prime)} K_S, \ldots (\beta)$	$\sim 2^\circ$	$\sim 10^\circ$
$B \to \pi\pi,\ \rho\rho,\ \rho\pi \ (\alpha)$	$\sim 1^\circ$	$\sim 15^\circ$
$B \to DK \ (\gamma)$	$\ll 1^\circ$	$\sim 25^\circ$
$B_s \to \psi\phi \ (\beta_s)$	$\sim 0.2^\circ$	—
$B_s \to D_s K \ (\gamma - 2\beta_s)$	$\ll 1^\circ$	—
$\lvert V_{cb} \rvert$	$\sim 1\%$	$\sim 3\%$
$\lvert V_{ub} \rvert$	$\sim 5\%$	$\sim 15\%$
$B \to X \ell^+ \ell^-$	$\sim 5\%$	$\sim 25\%$
$B \to K^{(*)} \nu\bar{\nu}$	$\sim 5\%$	—
$K^+ \to \pi^+ \nu\bar{\nu}$	$\sim 5\%$	$\sim 70\%$
$K_L \to \pi^0 \nu\bar{\nu}$	$< 1\%$	—

It would require breakthroughs to go significantly below these theory limits

Detection Method



$K_L \rightarrow \pi^0 \nu \nu$

$\gamma\gamma$ → pure CsI calorimeter

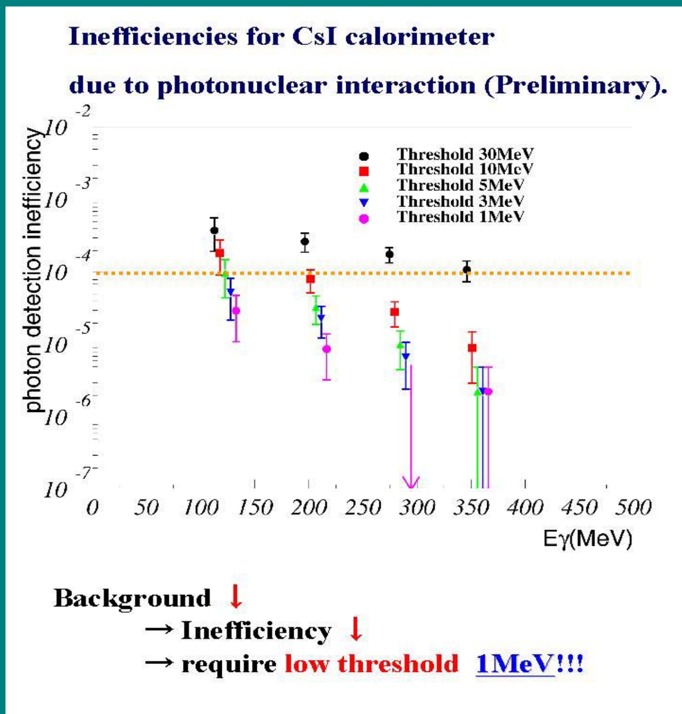
Nothing → 4π veto system

Characteristics

1. Tight veto:

$K_L \rightarrow \pi^0 \pi^0 \rightarrow 4\gamma$ (additinal 2 γ)

10^{-3} $\Rightarrow 10^{-11}$ obtained by $(10^{-4})^2$



Main concern is how we can lower the veto threshold

2. Pencil beam and high P_T selection

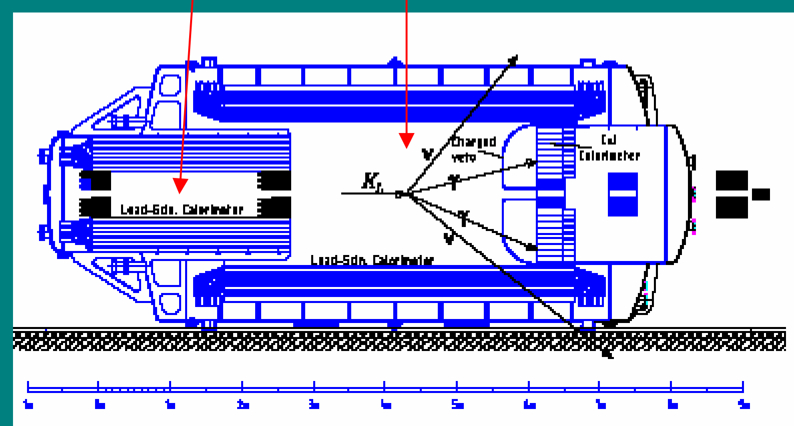
- reject dominant multi-body K_L and hyperon decays,
- request for missing high-energy photons, and
- reduce odd combination

3. Double decay chambers

- reject decays outside the fiducial region

Upstream chamber

Downstream chamber

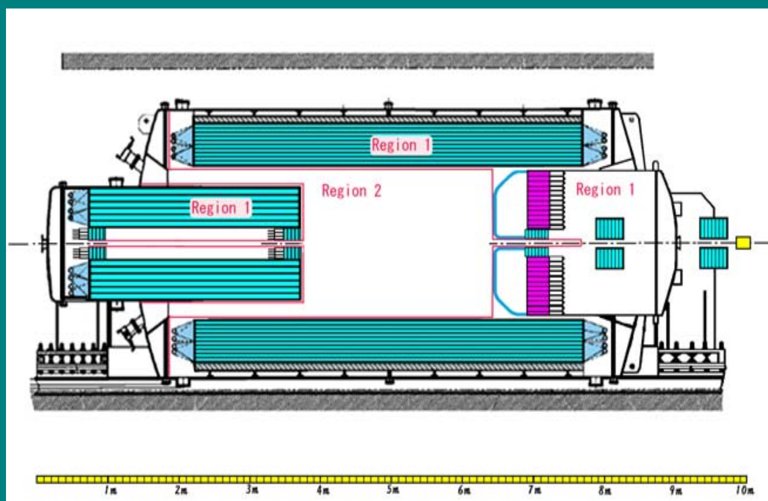


4. Differential pumping

・ to meet two requirements:

1. high vacuum 10^{-10} atm (10^{-5} Pa, 10^{-7} Torr) along the beam.

2. minimize dead material in front of detectors



	Region 1	Region 2
Volume (V, m3)	100	10
Surface (A, m2)	220	40
Contents	100 ton	empty

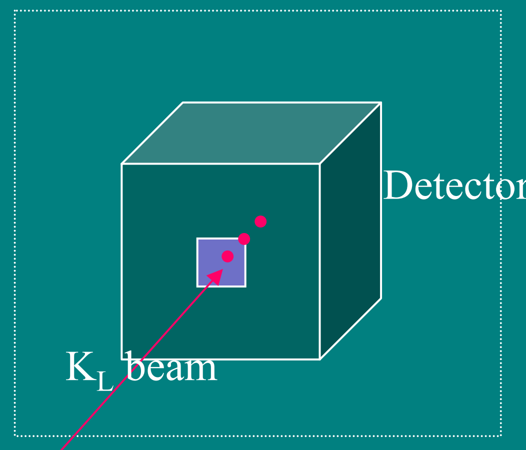
Using thin membrane of 20 mg/cm^2

5 High acceptance

$S = 1 / (A \cdot T \cdot D)$

- S: single event sensitivity
- A: acceptance for $K_L \rightarrow \pi^0 \nu\nu$ decay
- T: data collection time
- D: decay rate in the fiducial region

C(counting rate) > D



$S<10^{-13}$, $T=10^7$ sec

C > D > 10MHz for A=0.1

C > D > 100MHz for A=0.01

High acceptance is crucial for high sensitivity

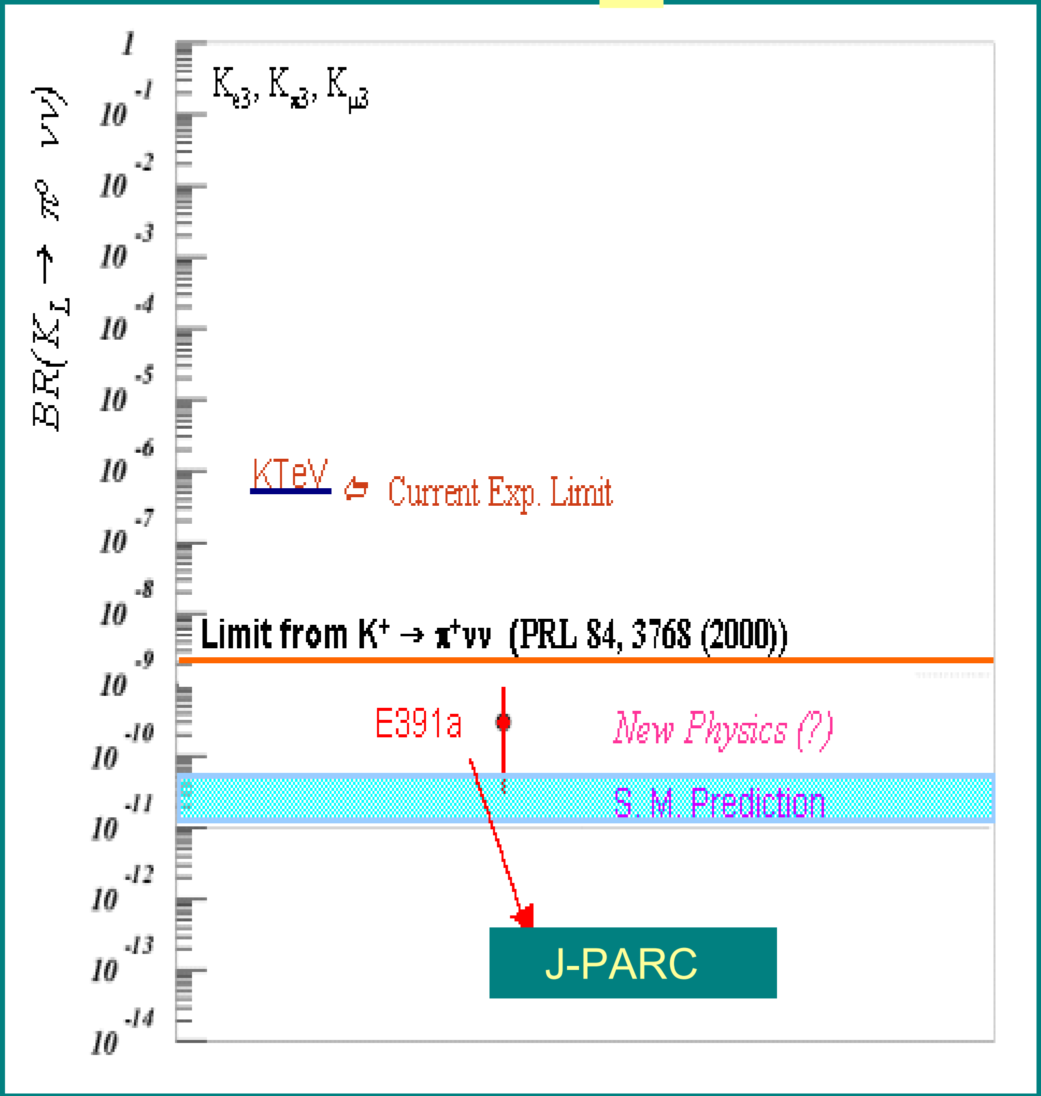
Step-by-step approach

E391a: O(10^{-10})

- **Pilot experiment**
- **Search for the decay in the region beyond the Grossman-Nir limit**

↓

J-PARC: O(10^{-13})



History of E391a

- Dec.1996: conditionally approved
- Mar.1999: constructed the beam line
- July 2001: approved
- Oct. 2002: engineering run
- Jan. 2004: finish detector assembling
- 18 Feb. –June 30 2004: Data taking
- Oct. 2005-: Run-2 (requesting)

Data taking

12 GeV incident protons

- 2.2×10^{12}/spill at target
- 2s spill length
- 4s repetition

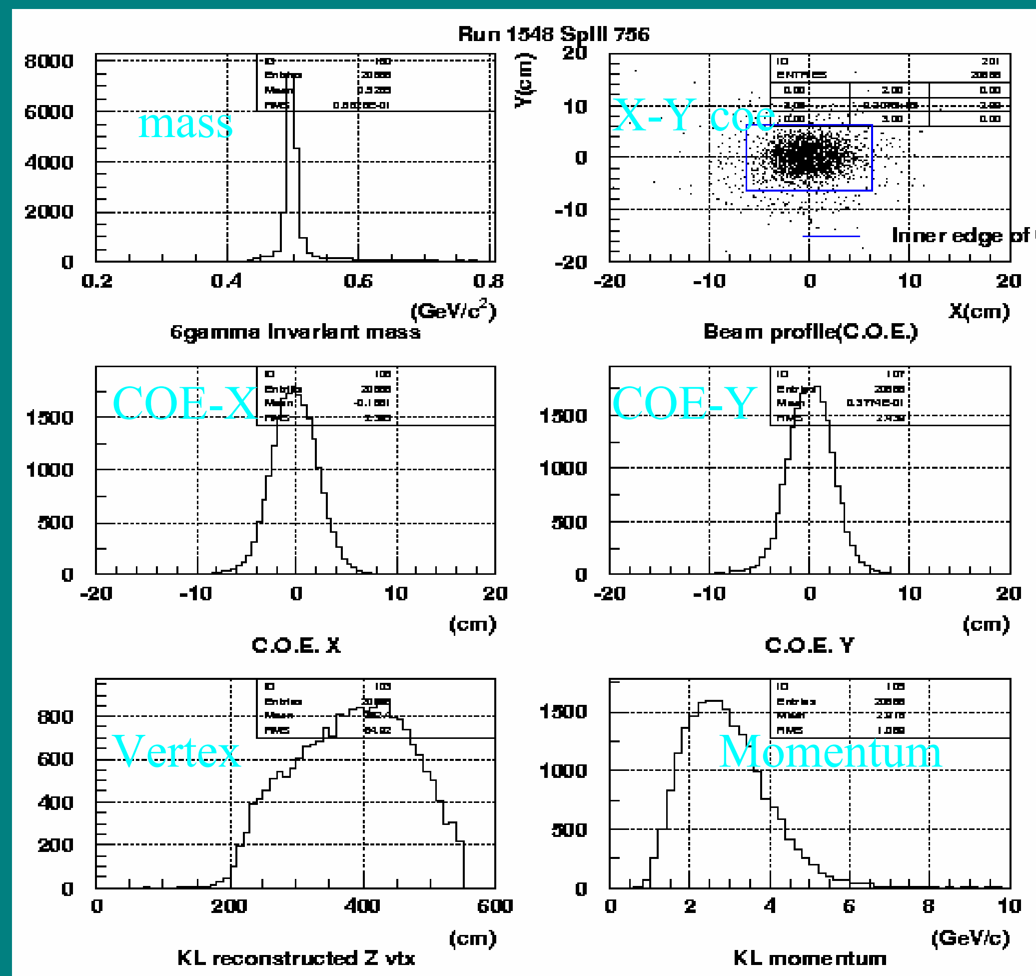
K_L Yield in front of detector

- 5×10^{5} /spill
- peak momentum : 2 GeV/c

DAQ live-time ratio : 75 %

Vacuum pressure : 1×10^{-5} Pa

Online monitoring using $K_L \rightarrow \pi^0\pi^0\pi^0$ decay



Expected sensitivity

$$S_{\pi\nu\nu} = (A_{3\pi}/A_{\pi\nu\nu}/Y_{3\pi}) \cdot Br_{3\pi},$$

$A_{3\pi}/A_{\pi\nu\nu} \sim 1/20$

$Y_{3\pi} \sim 19$(/spill) ・ 7.2×10^{3} (spill/shift) ・ ($300-80-3\times15$)(shifts)

・80 shifts: cooling water trouble(30)+tuning with shared beam(30)+tuning with full beam(20)

・3×15 shifts: 3 special runs (air, short bunch, π^0 calibration)

$\sim 2.4\times10^{7}$

$Br_{3\pi}$ = 0.21

$S_{\pi\nu\nu} \sim 4.4\times10^{-10}$ (without study for acceptance loss)

E391a status & prospects

- First physics run Feb-June this year
  - 2.2×10^{12} POT, 50% duty factor
  - 5×10^{5} K_L/pulse
  - Detector worked well
  - Nominal s.e.s. 4×10^{-10}
  - Analysis underway
  - first sight of the enemy
    - Halo neutrons, self-vetoing, etc.
- Second run proposed for next year

Possible scenarios for J-PARC experiment

- Choice of two primary lines A or B

  General consensus: only A-line is ready at time 0.

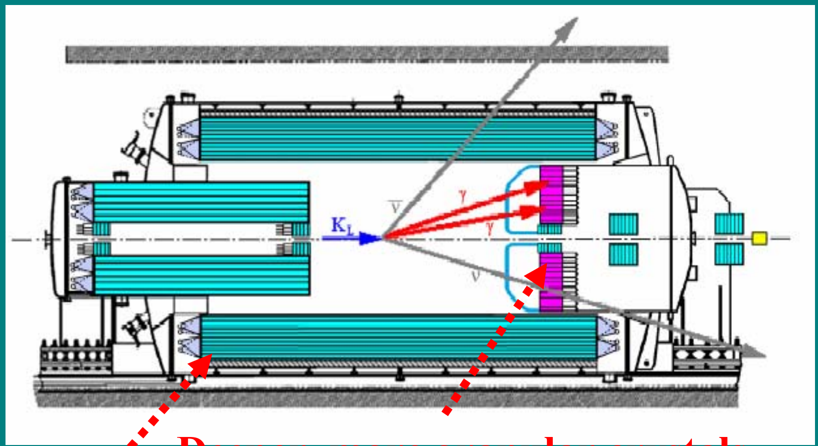
  ⇒take A at the beginning

- The present E391a detector or new detector

  Move the present detector with minor modifications is a bottom-line.

  New detector: longer fiducial decay-region and larger geometrical acceptance.

  The choice mostly depends on what we will learn by E391a data and does partly on the boundary conditions (budget, schedule, status of KOPIO, etc)



Deeper, more granular crystals

Faster electronics

Thicker photon vetoes

We just started a design study with R&D for various calorimeters,

sandwich, shashilik, spagetti, etc.

Summary and a few words

- J-PARC will start physics program from the spring of 2008.
- E391a started a step-by-step approach to the $K_L \rightarrow \pi^0 \nu\nu$ decay.

  - Real competitor is biologist or material scientist, and we have to justify the meaning of basic science more.

  - All of LOI plans are the extension of the experiments at the present facilities. This is quite natural and sure, but is not so very much appealing from the view point of the “Hundred Flowers”.

  - High intensity proton machine might have a potentiality to open new frontier, because of its flexibility and variety.