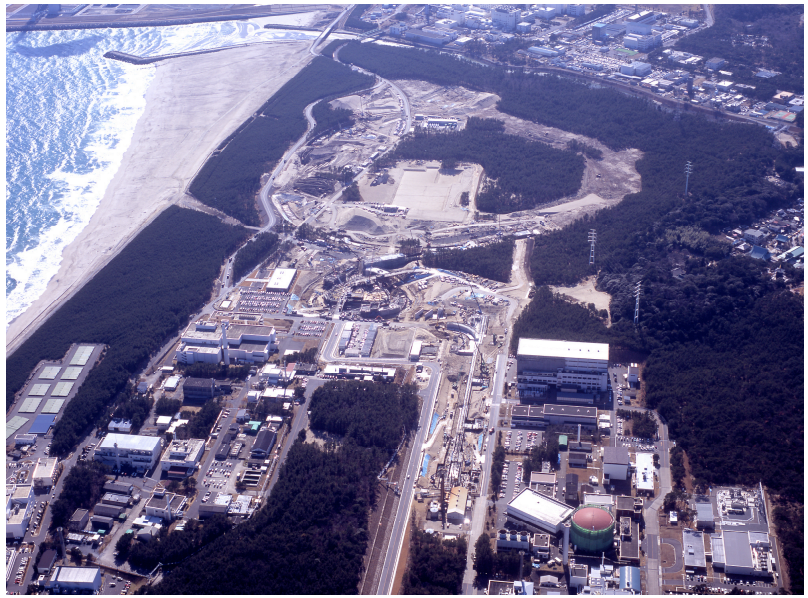


from KEK-PS to J-PARC : future Kaon program

Takeshi K. Komatsubara (KEK-IPNS)

09 Nov 2005, WG2 of FlavLHC workshop at CERN

Outline [in 24 slides, 20 minutes]

- physics motivation [talks by G. Isidori, L. Littenberg, I. Bigi]
- KEK 12GeV PS (1977 - 2005) and J-PARC (2008 -)

  - site / accelerators / facilities

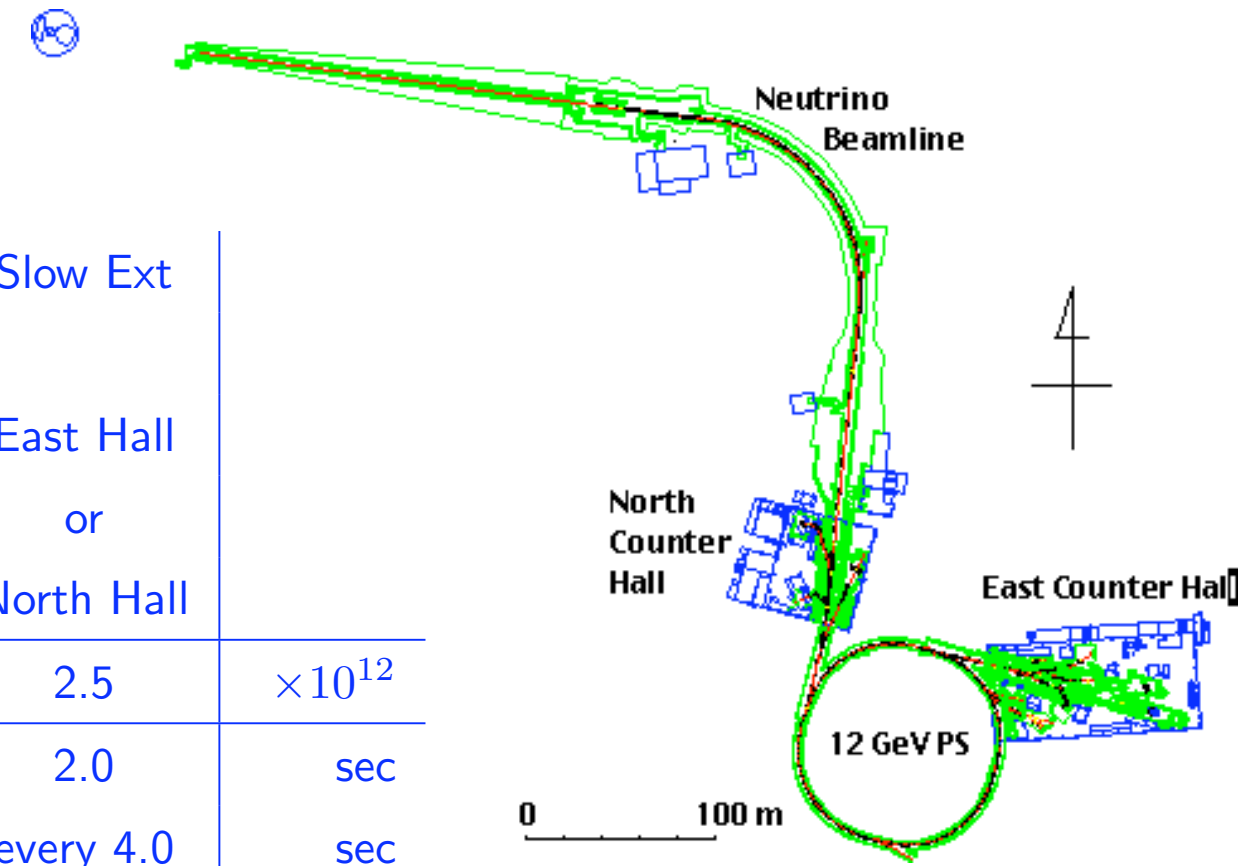
- $\mathbf{K_L^0 \to \pi^0 \nu\bar{\nu}}$
- T-violation in $\mathbf{K^+ \to \pi^0 \mu^+ \nu}$
- $\mathbf{K^+ \to \pi^+ \nu\bar{\nu}}$

  - how we do these measurements at J-PARC:
    Hadron Experimental Hall for kaon physics

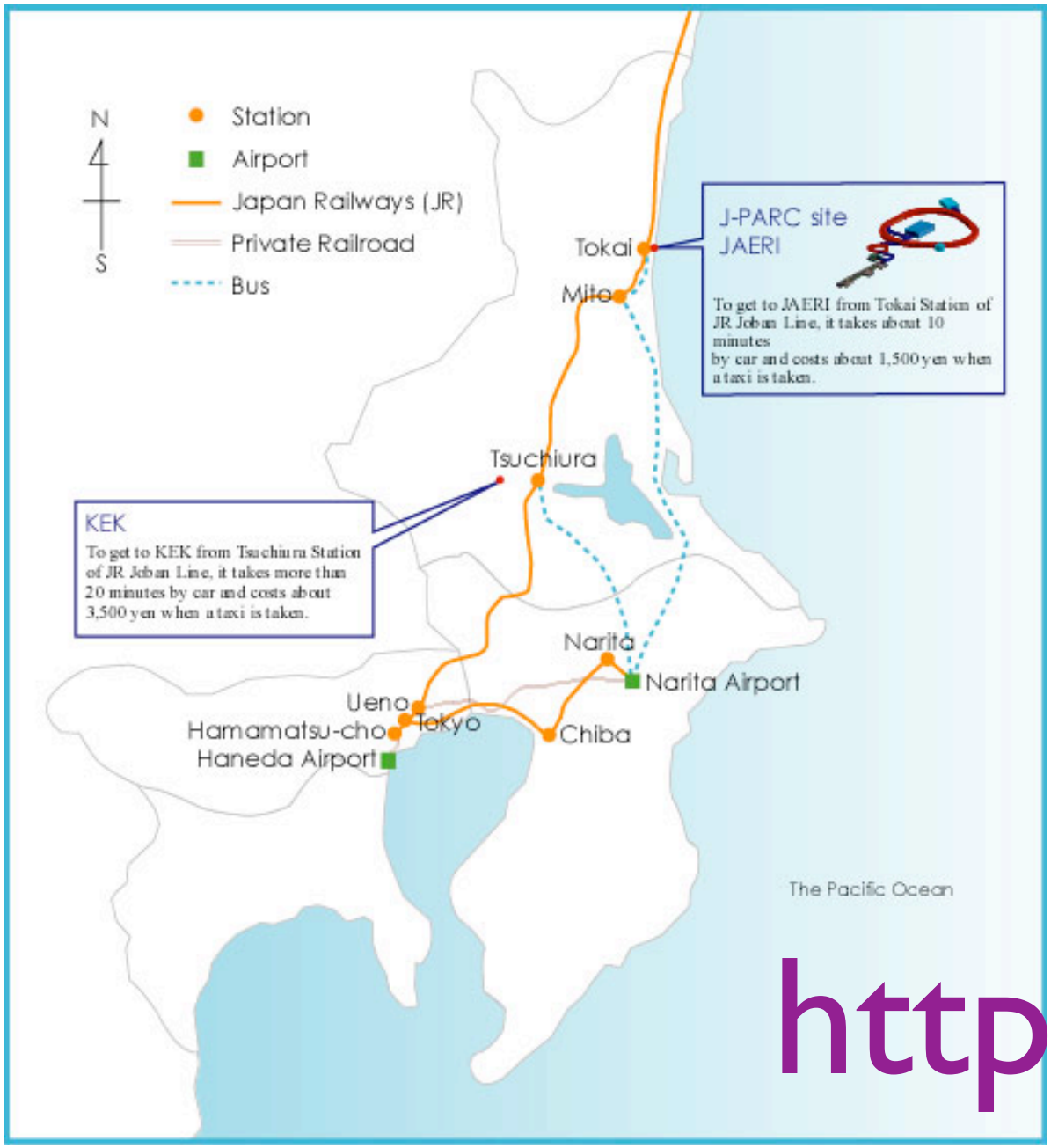
KEK 12GeV PS experiments, by Dec 2005

- K2K long-baseline neutrino: data taking completed
- E391a $\mathbf{K_L^0} \rightarrow \pi^0\nu\bar{\nu}$: running ! [Nov - Dec 12, East Hall]
- hadron/nuclear experiments are scheduled. [- Dec 28, North Hall]

	Fast Ext to ν Beamline	Slow Ext to East Hall or 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



Japan Proton Accelerator Research Complex

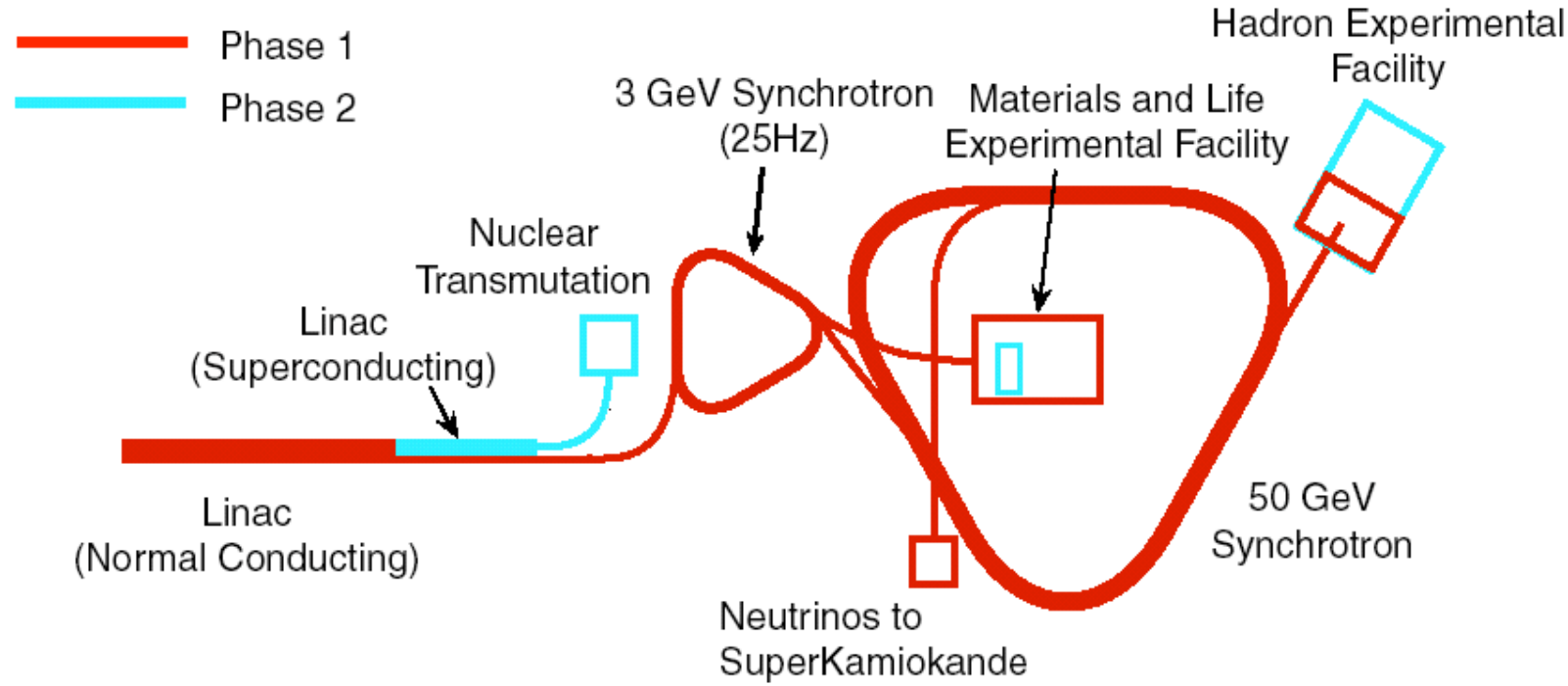


JAEA and KEK joint project

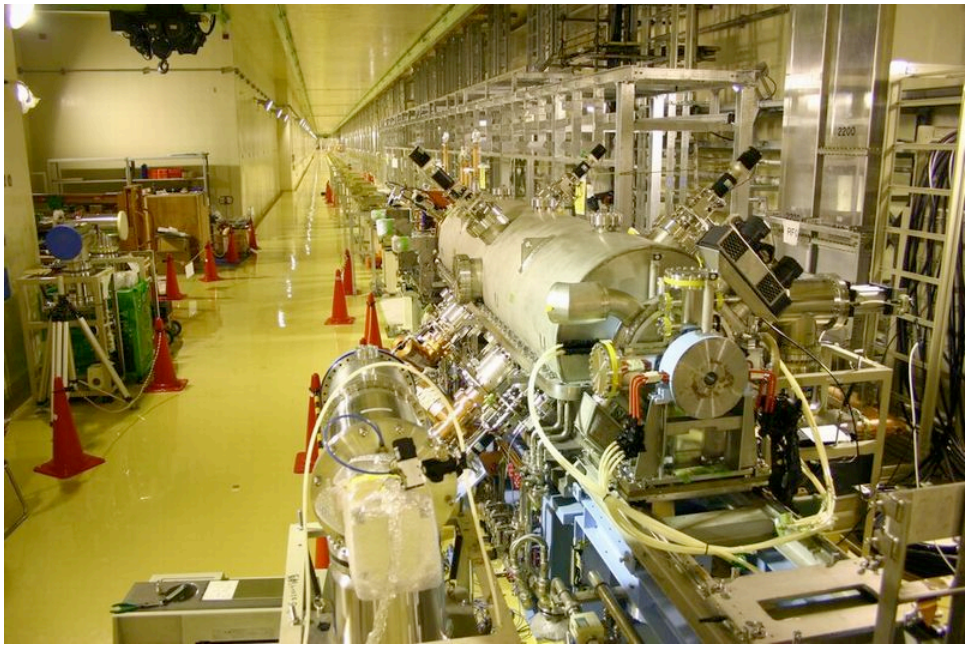
(Japan Atomic Energy Agency)

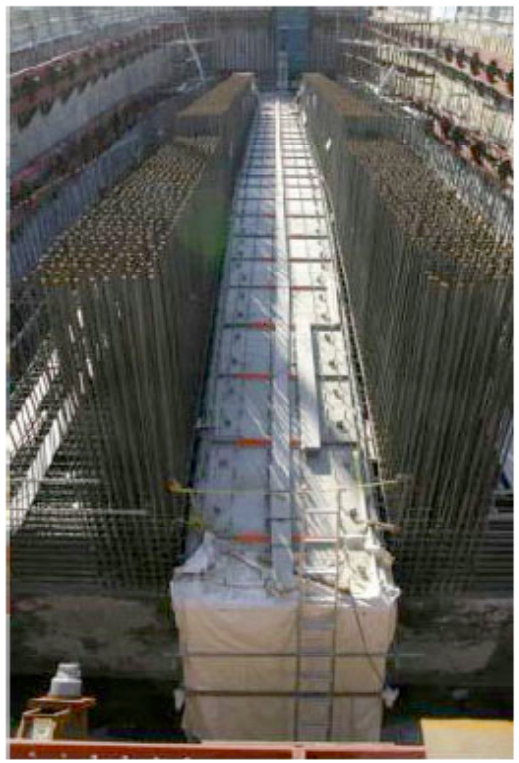
http://j-parc.jp/

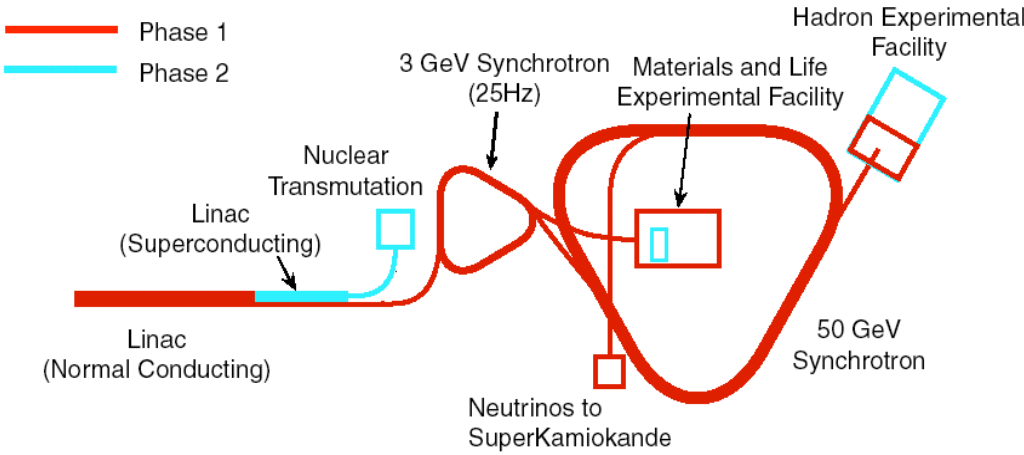
(Do not forget a hyphen between " J " and " PARC " .)

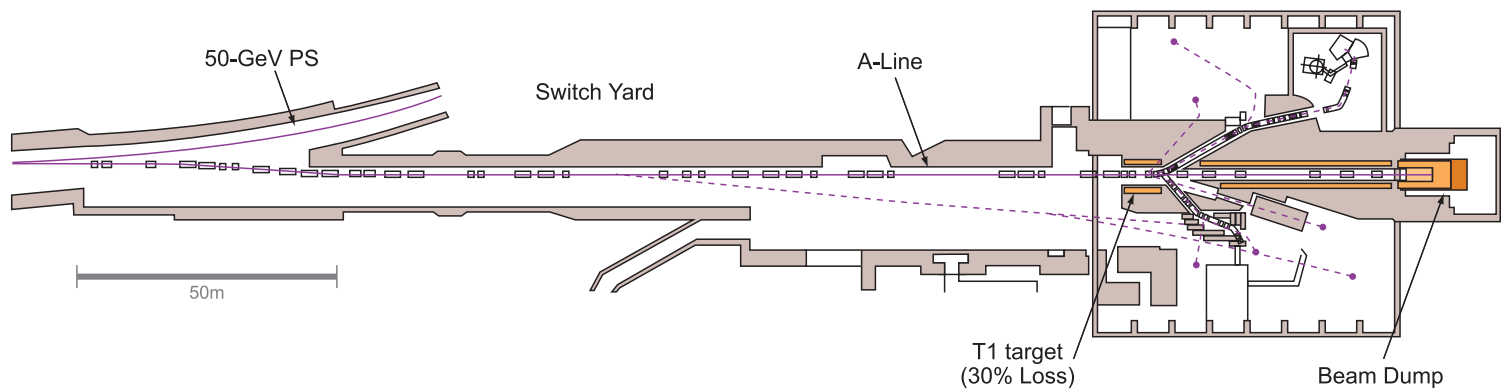

Phase 1
Phase 2
Hadron Experimental Facility
3 GeV Synchrotron (25Hz)
Materials and Life Experimental Facility
Nuclear Transmutation
Linac (Superconducting)
Linac (Normal Conducting)
50 GeV Synchrotron
Neutrinos to SuperKamiokande


January, 2005

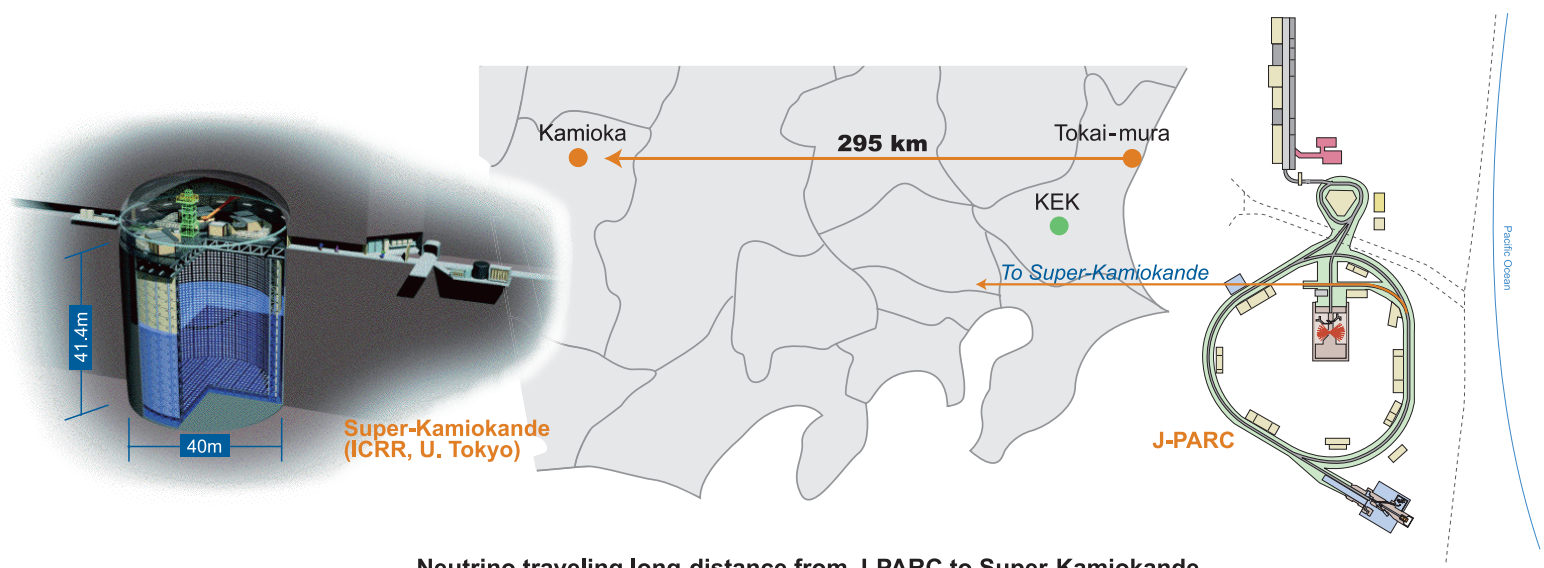






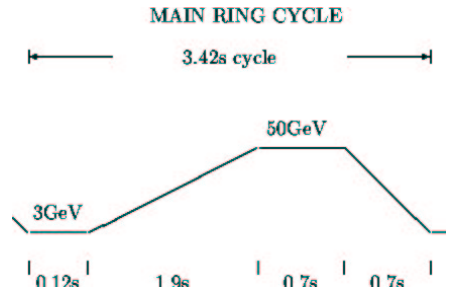


Slow Extraction Hadron Facility (Phase 1)

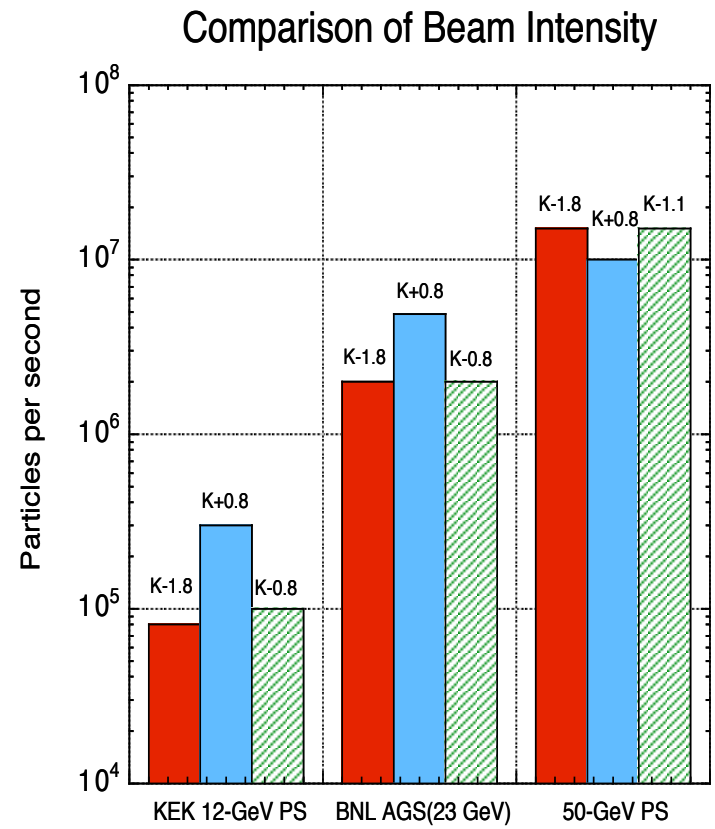


Neutrino traveling long-distance from J-PARC to Super-Kamiokande

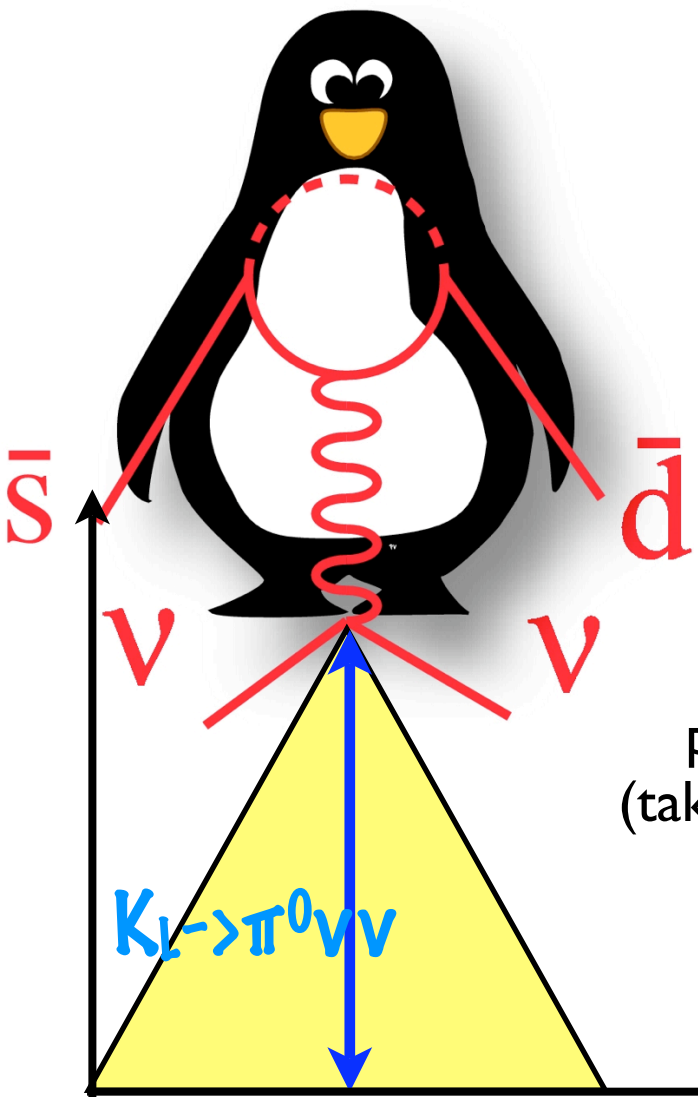
J-PARC 50GeV-PS operation (Slow Ext)



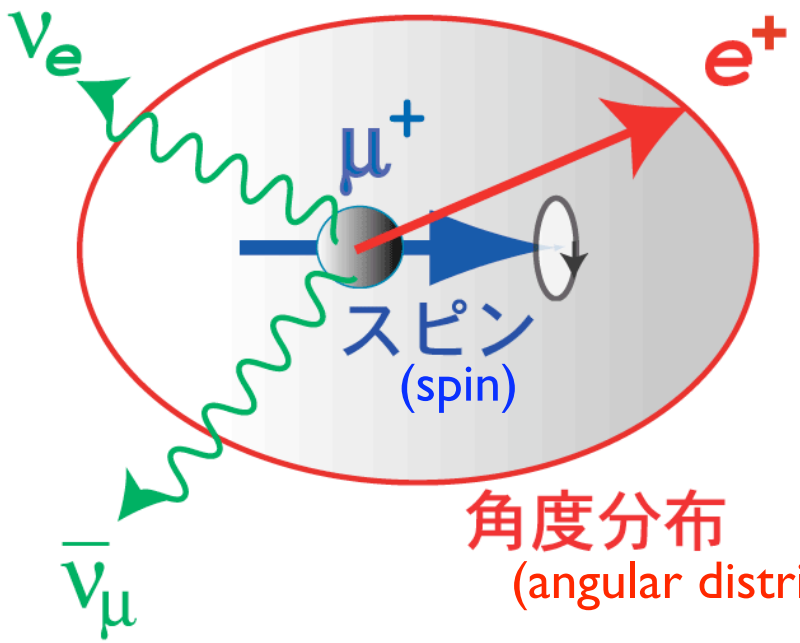
	KEK-PS	AGS	J-PARC Phase-1	(mod ?)	
proton energy	12	24	30	30	GeV
protons per pulse	2.5	65	200	100	10^{12}/spill
cycle	4.0	6.4	3.42	>4.42	sec
average current	0.1	1.63	9.5	<3.6	μA
beam spill	2.0	4.1	0.7	>1.7	sec
duty factor	50	64	20	>39	%
instantaneous rate	1.3	16	286	<59	10^{12}/sec



kaon decay experiments at KEK/J-PARC



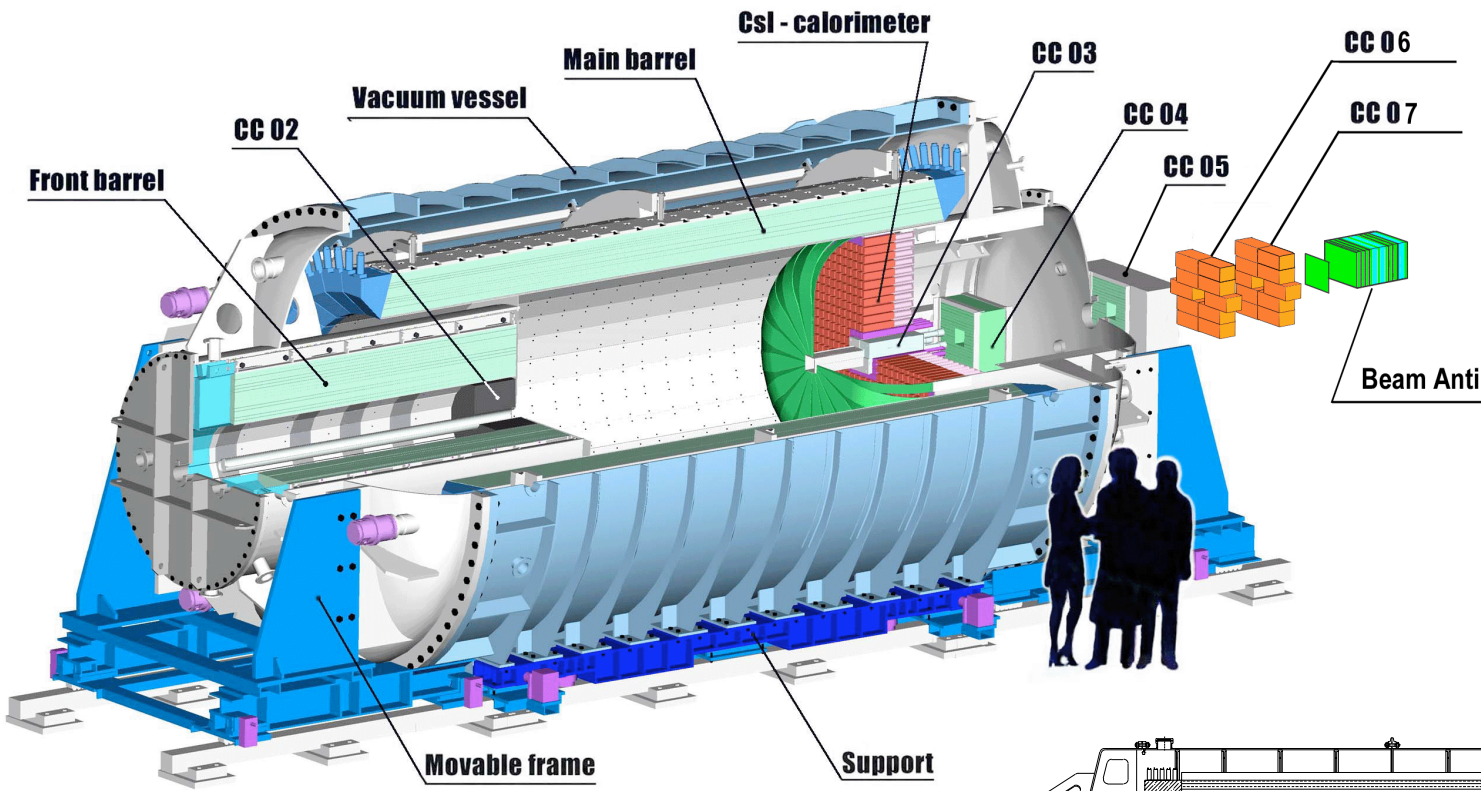
penguin with ν-footed
(taken out of the P326 logo ...)

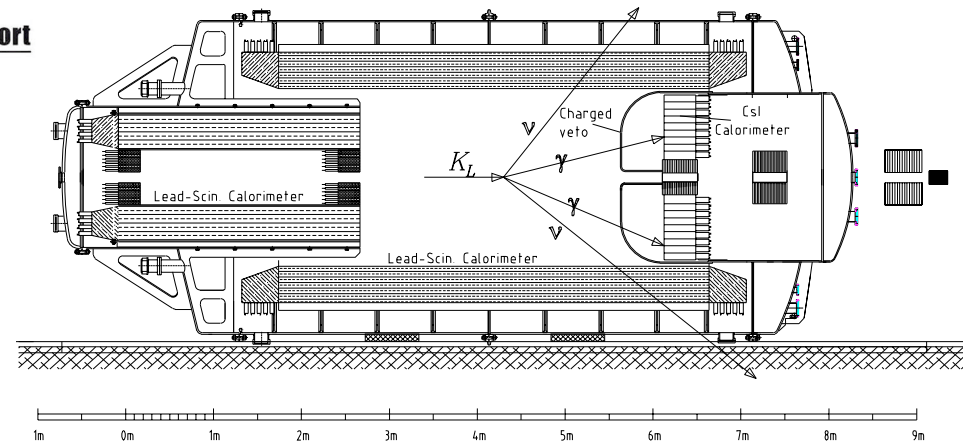


角度分布
(angular distribution)

E391a http://www-ps.kek.jp/e391/ at E-Hall

the first experiment dedicated to $K_L^0 \to \pi^0 \nu\bar{\nu}$

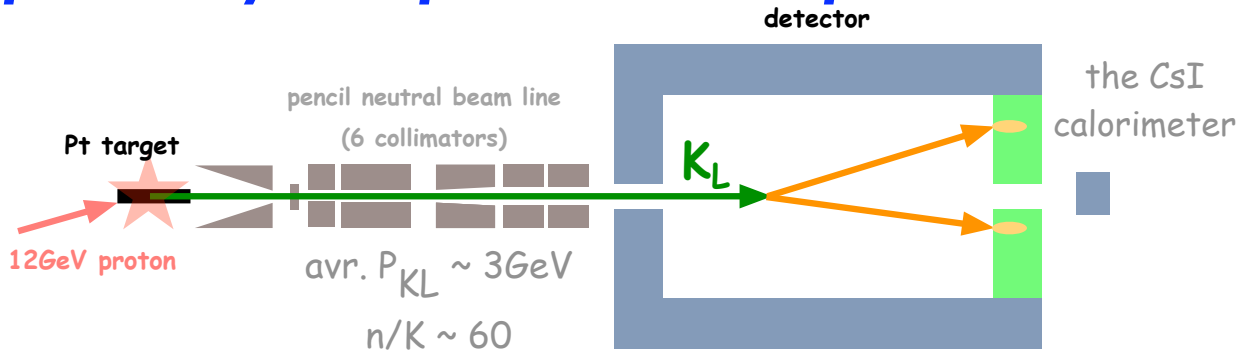




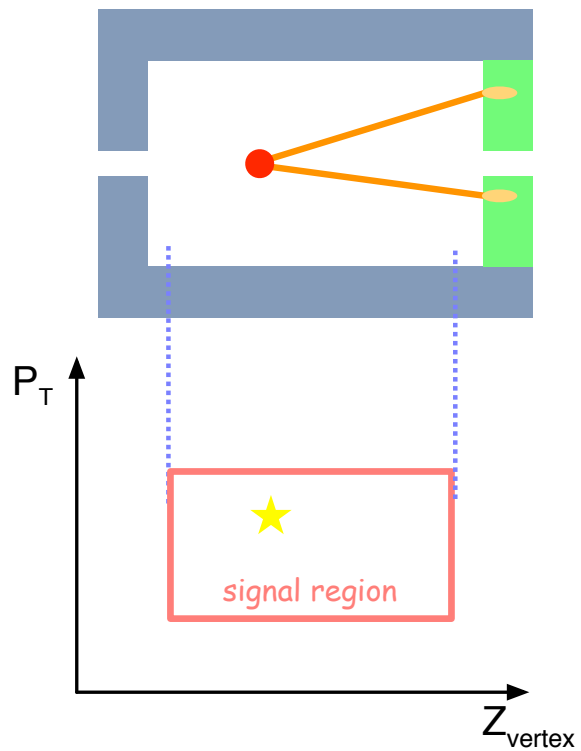
Experimental method

- ***detect 2g from pi0 decay + require no other particles***

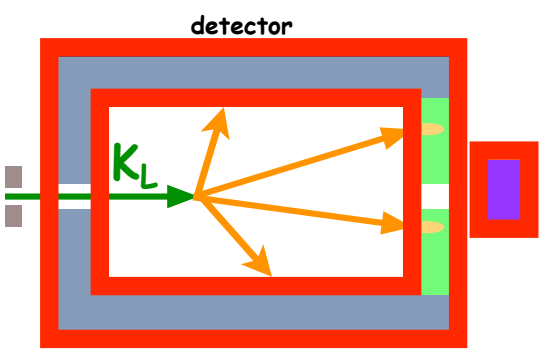
(1) measure gamma hit position and energy



(2) reconstruct decay vertex asuuming $M_{2g}=M_{pi0}$



(3) require missing Pt and decay vertex in the fidutial region

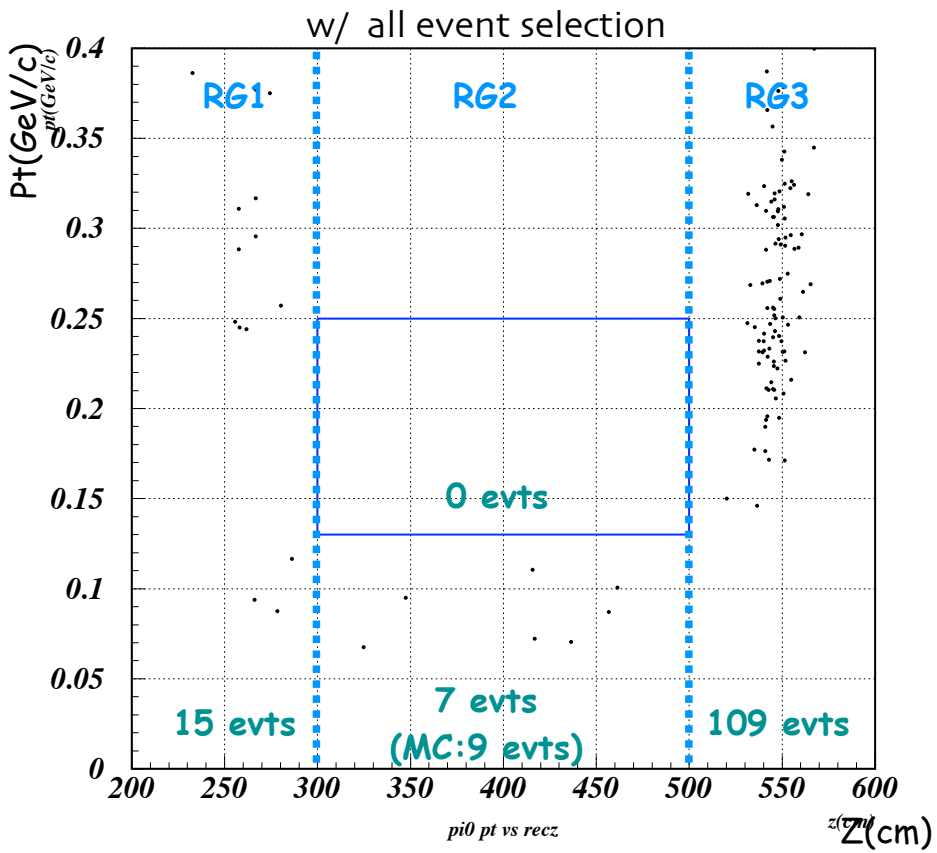


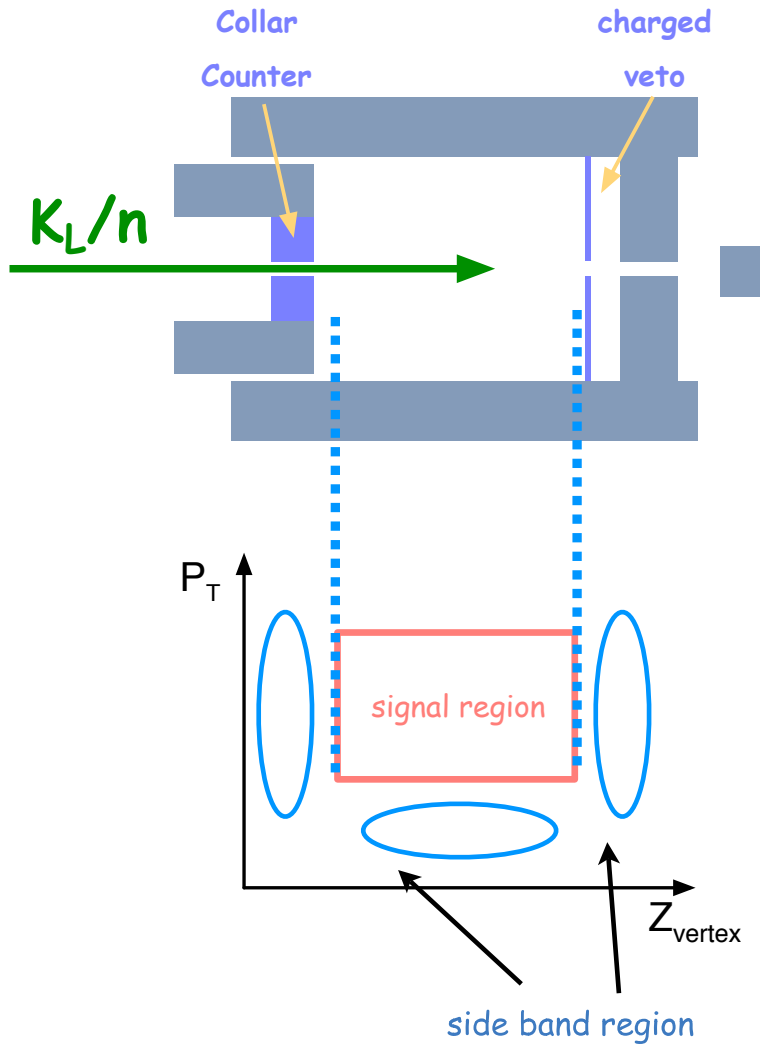
"hermetic" photon detection

Status and Prospects of E391a

- Run-I (Feb-July / 2004)

10% of the dataset (Kaon2005, LP2005)



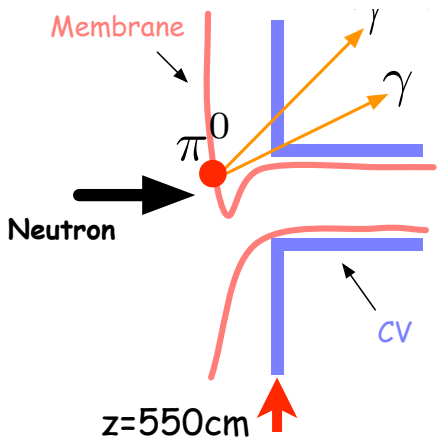


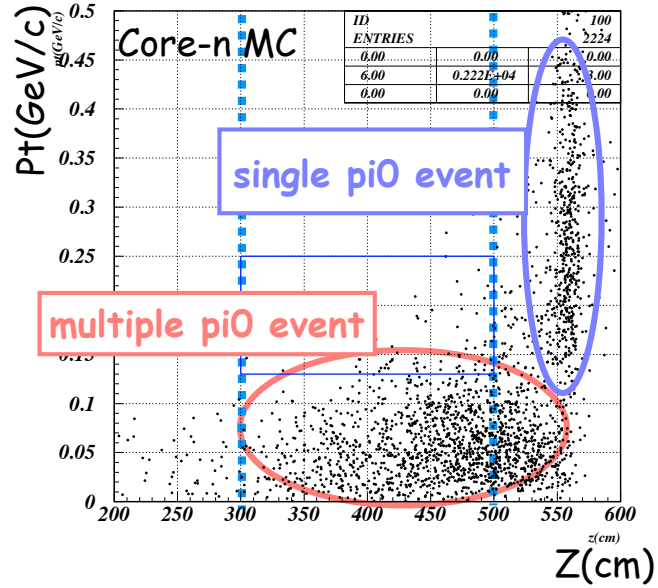
preliminary limit < 2.86×10^{-7}

improved ~2 from KTeV's limit (2000)

Status and Prospects of E391a (cont.)

- Run-I (Feb-July / 2004) ... full-data being analyzed

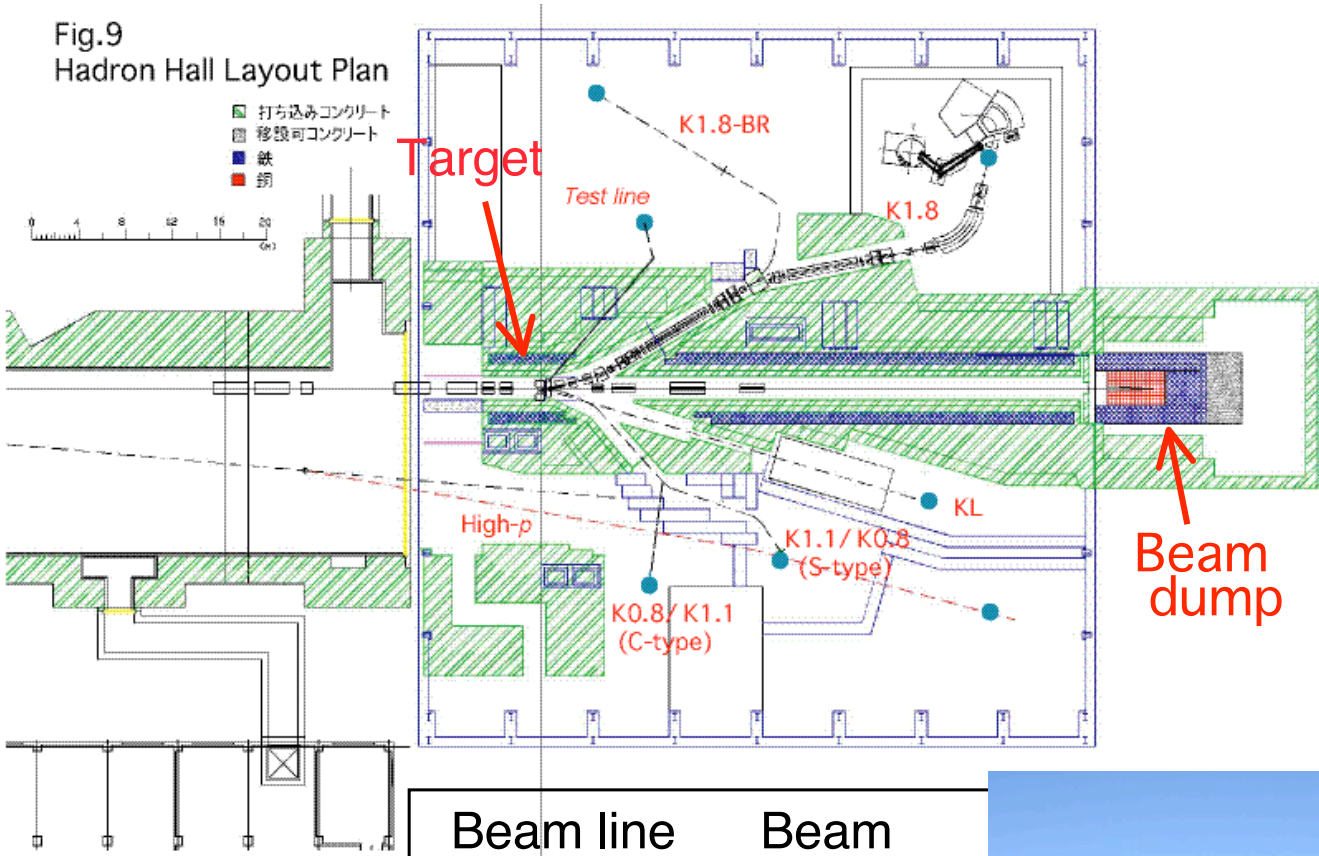




- Run-II (Feb-Apr / 2005)
  The problem was fixed; better quality (and larger acceptance)

- Run-III (Nov.1-Dec.12 / 2005)
  already taking physics data, the same quality as Run-II

goal of E391a: Grossman-Nir limit (1.4×10^{-9})

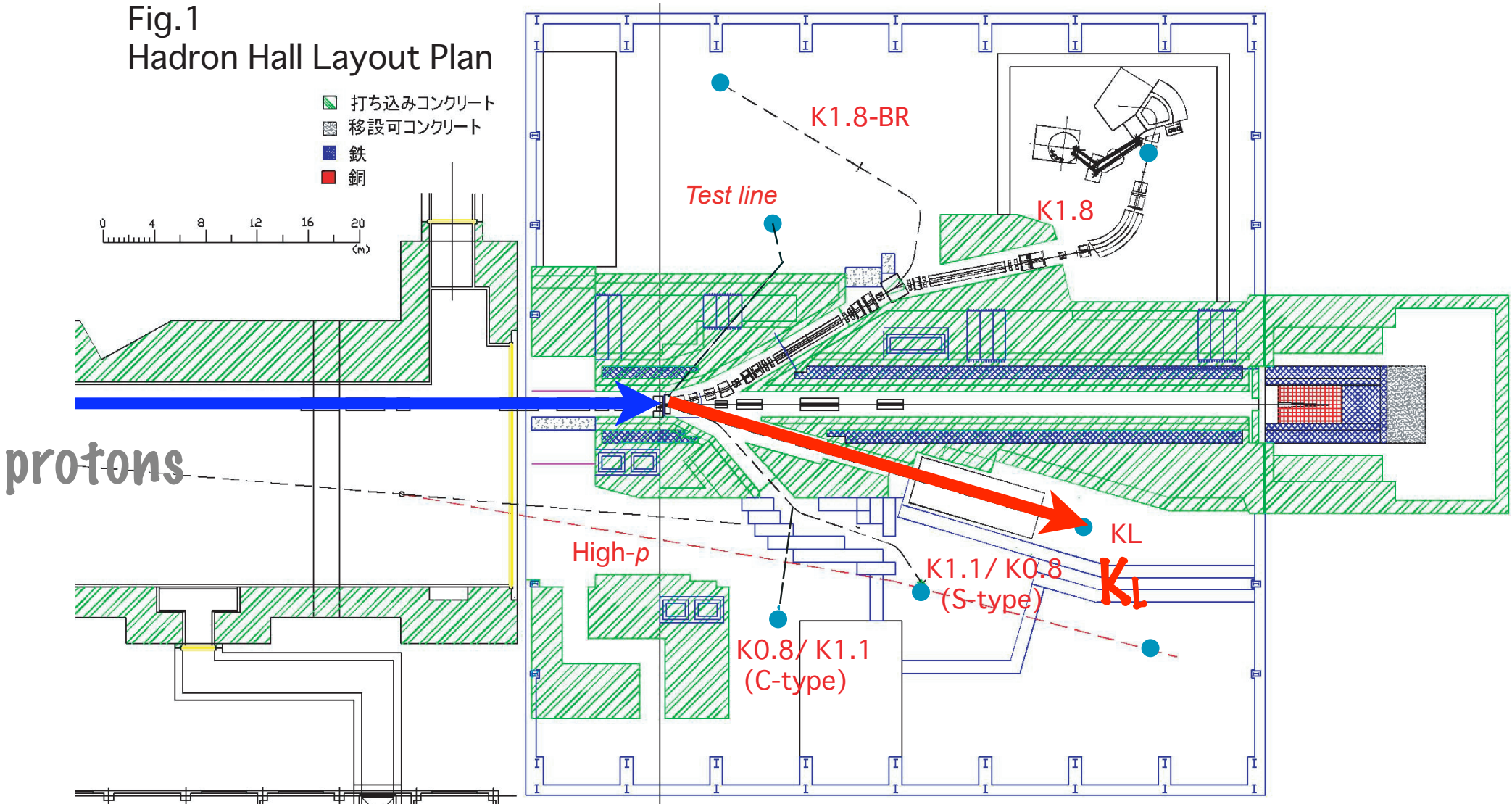


Slow beam hall in Phase 1

- 60m^{W} x 56m^{L}
  extended to 100m^{L} in Phase2
- one primary line
- one target
- several 2nd. lines

Beam line	Beam
K1.8	$K^{\pm}$, $\pi^{\pm}$
K1.8-BR	$K^{\pm}$, $\pi^{\pm}$
K1.1	$K^{\pm}$, $\pi^{\pm}$
K0.8	$K^{\pm}$, $\pi^{\pm}$
KL	K_L
High-*p*	*p*, $\pi^{\pm}$, $K^{\pm}$
Test beam	$\pi^{\pm}$, $K^{\pm}$, *e*-

Fig.1
Hadron Hall Layout Plan



30GeV protons on T1 target,
16deg KL beamline (20m long, 5μstr)
for the 1st-step experiment

- merits of J-PARC experiments
  - higher energy, <PK>=2.1 GeV/c
    efficient photon detection, lower n/K (∼10)
  - larger K flux

- upgrades of the E391a detector
  - CsI calorimeter with smaller blocks (of longer crystals)
  - thicker photon-detection counters
  - new detector prototypes

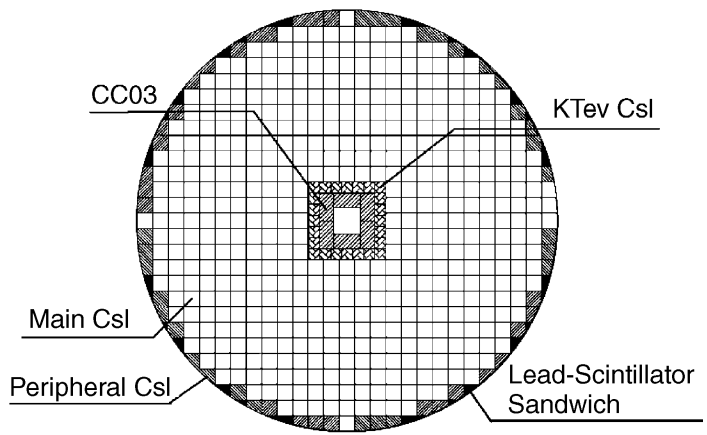
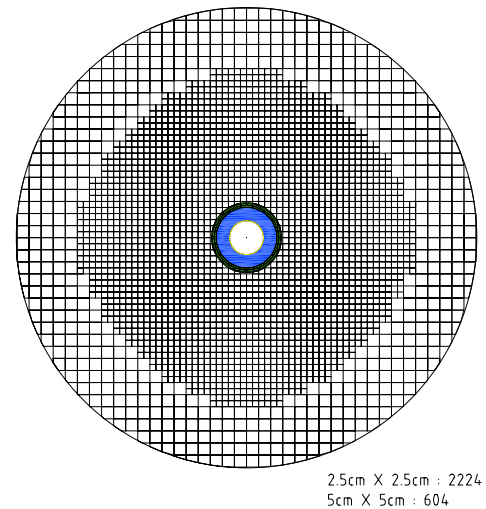
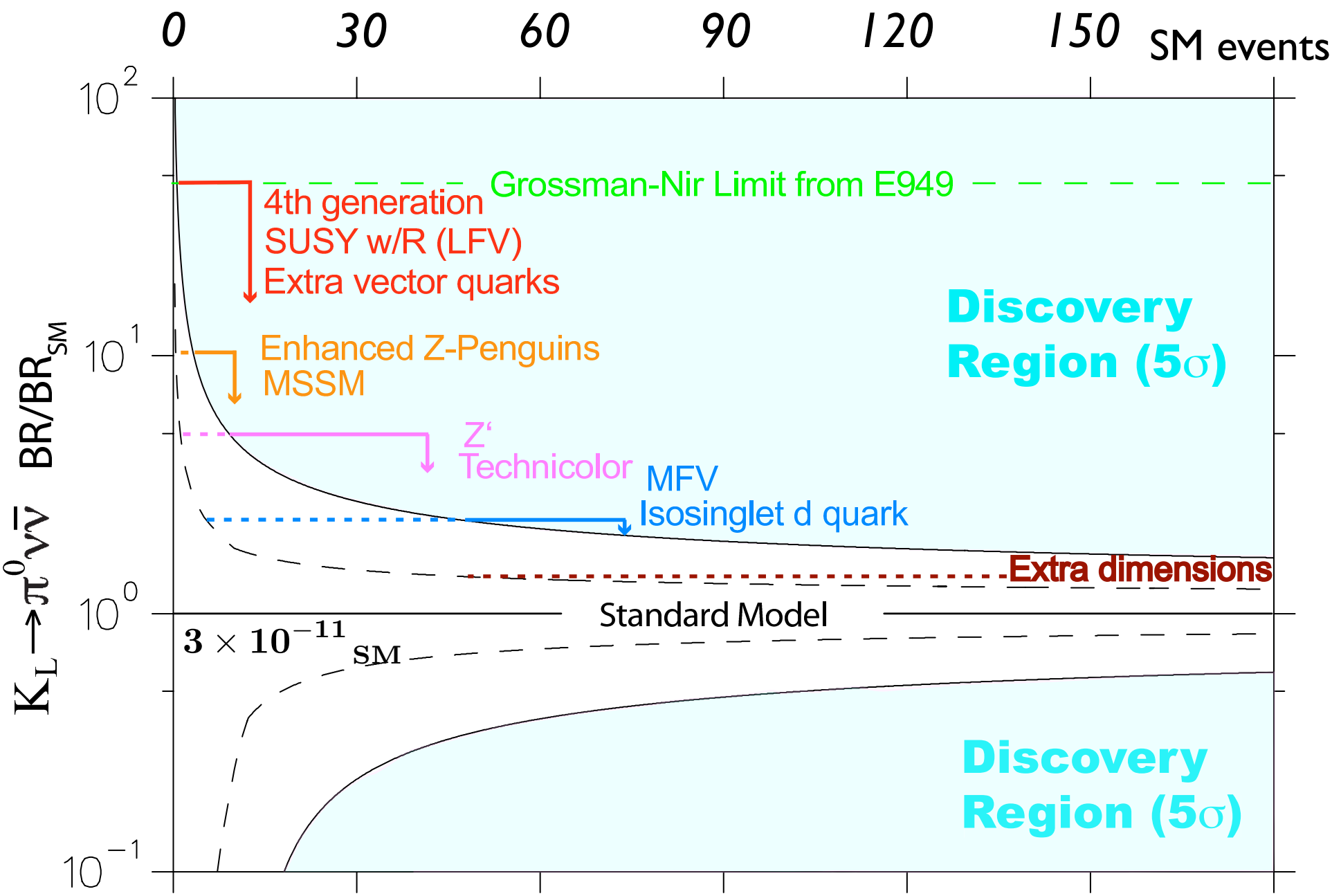


Fig. 2. Arrangement of CsI crystals.



sensitivity: ∼2.6 SM events/Snowmass yr/100Tp

for the first observation

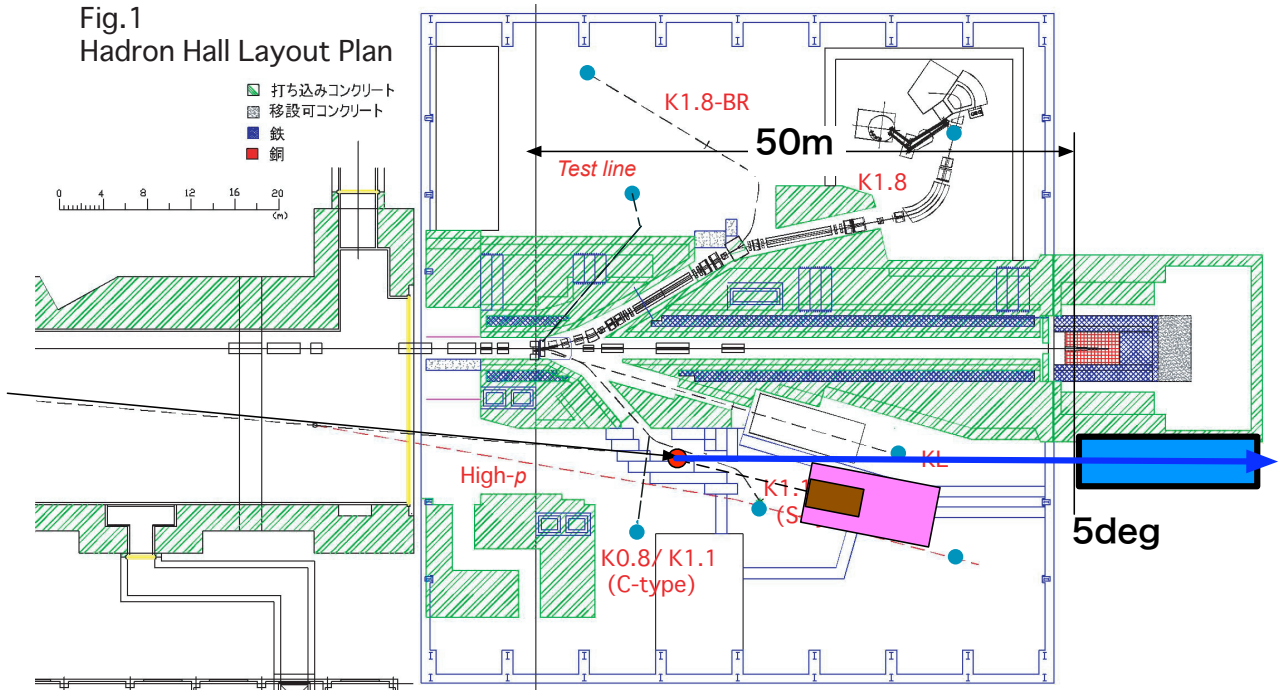


based on Bryman-Buras-Isidori-Littenberg, hep-ph/0505171

in the next step to test MinFlavViol models with

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

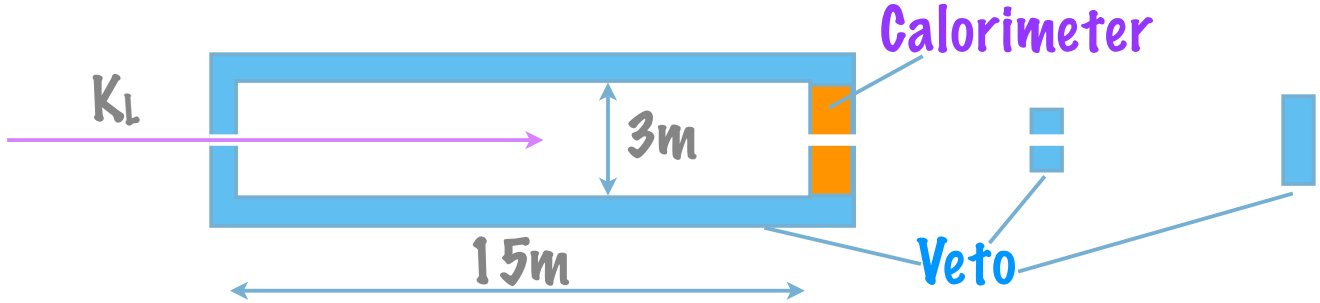
(>100 signal events)



new detector with:

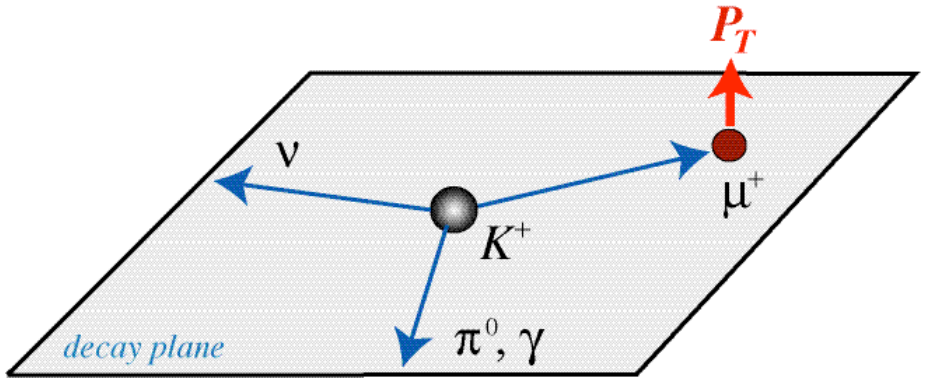
- longer decay region
- larger calorimeter
- high rate capability

... studies in progress



E246/E470 http://www-ps.kek.jp/e246/ at N-Hall

T-violating P_t in $K^+ \to \pi^0\mu^+\nu$(B.R.=3.27%)



- $P_T \equiv s_{\mu^+} \times \dfrac{(p_{\pi^0} \times p_{\mu^+})}{|p_{\pi^0} \times p_{\mu^+}|}$: T-odd

  → an observable of CP violation

Model	$K^+ \to \pi^0\mu^+\nu$	$K^+ \to \mu^+\nu\gamma$
Standard Model	$<10^{-7}$	$<10^{-7}$
Final State Interactions	$<10^{-5}$	$<10^{-3}$
Multi-Higgs	$\le 10^{-3}$	$\le 10^{-3}$
	$P_T(K^+ \to \pi^0\mu^+\nu) \approx 3\, P_T(K^+ \to \pi^0\mu^+\gamma)$	
SUSY with squarks mixing	$\le 10^{-3}$	$\le 10^{-3}$
	$P_T(K^+ \to \pi^0\mu^+\nu) \approx -3\, P_T(K^+ \to \pi^0\mu^+\gamma)$	
SUSY with R-parity breaking	$\le 4\times10^{-4}$	$\le 3\times10^{-4}$
Leptoquarks	$\le 10^{-2}$	$\le 5\times10^{-3}$
Left-Right symmetric model	0	$< 7\times10^{-3}$

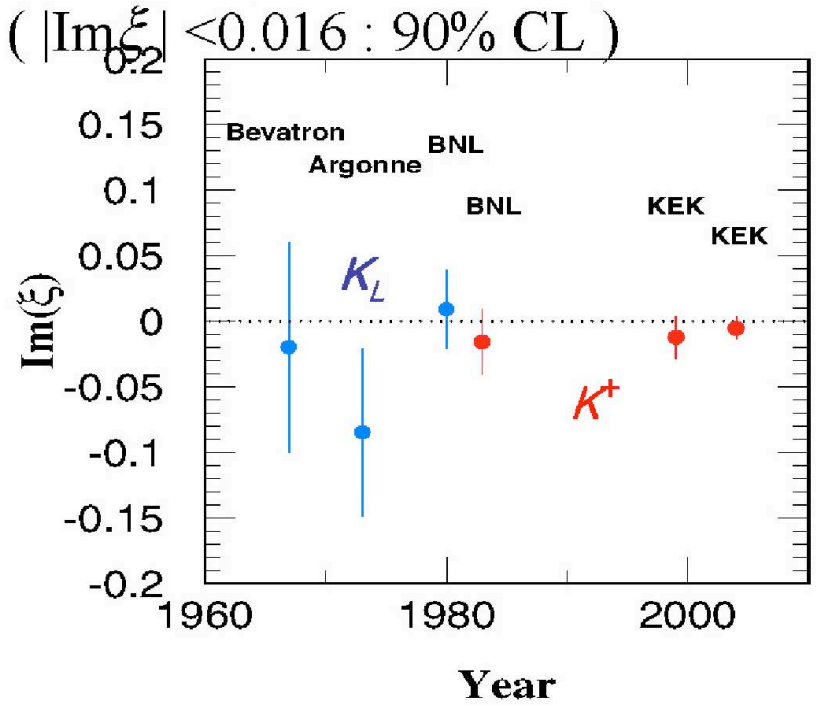
I.Bigi's talk
in the joint session

- P_T ($K \to \pi\mu\nu$) and P_T ($K \to \mu\nu\gamma$) are complementary.

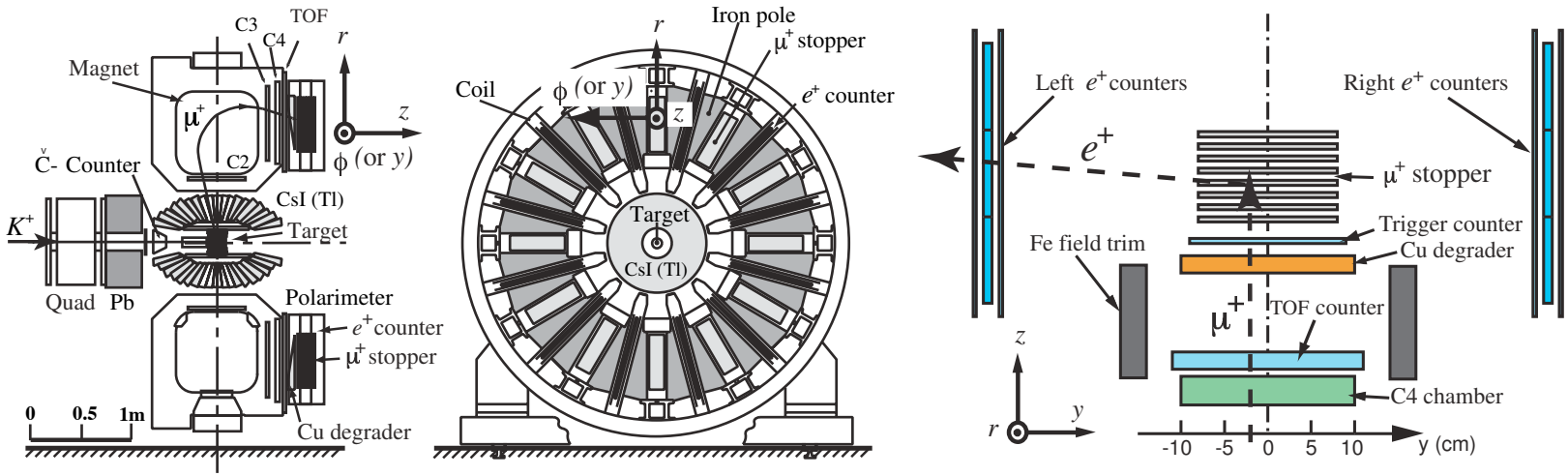
E246 results on P_t in $K^+ \longrightarrow \pi^0 \mu^+ \nu$

PRL 93(2004) 131601 (combining all the datasets: 1996-97, 98, and 99-2000)

- $P_t = -0.0017 \pm 0.0023_{stat} \pm 0.0011_{syst}$
  ($|P_t| < 0.50\%$)
- T-violating physics parameter $\boxed{Im(\xi)}$ ($\xi \equiv \frac{f_+(q^2)}{f_-(q^2)}$):
  $Im(\xi) = -0.0053 \pm 0.0071_{stat} \pm 0.0036_{syst}$



J-PARC T-violation experiment (K^+ decay at rest)

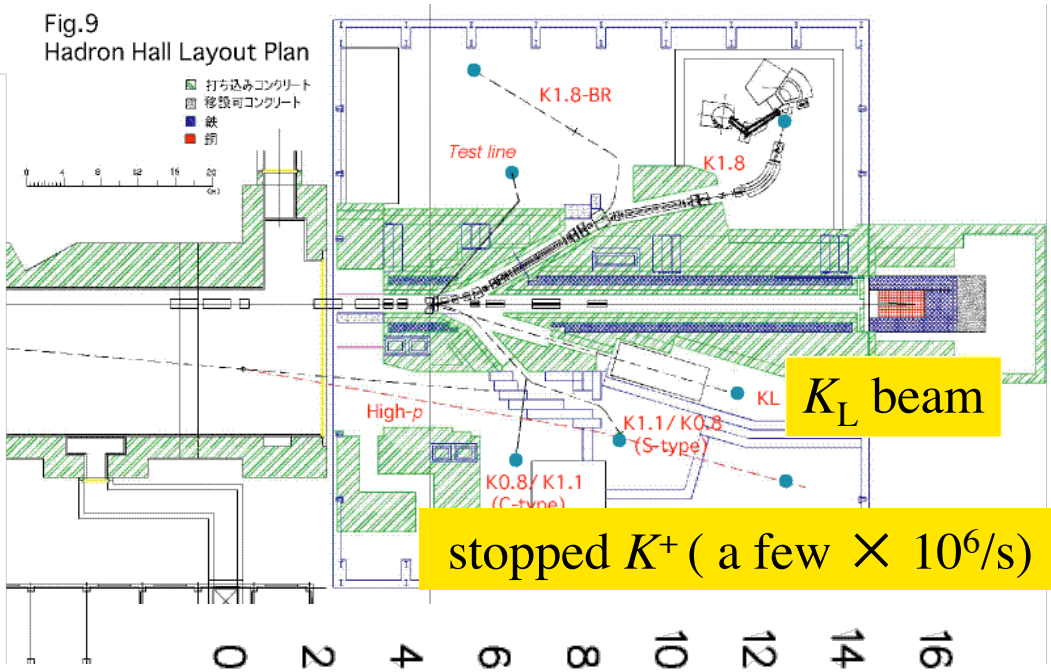


upgrading the E246 apparatus, in an early stage of J-PARC:

- CsI(Tl) readout
- photon veto system
- additional tracker
- polarimeter system

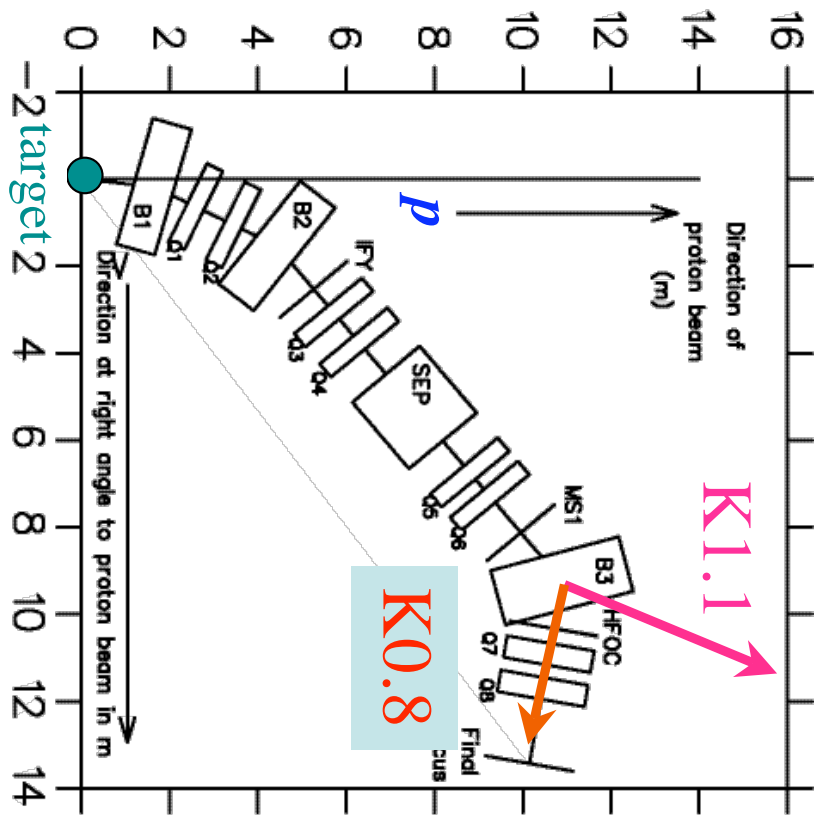
or
new detector for
T-violation exp.
(better sensitivity)

	E246 upgrade	E246(KEK)
K^+ beam intensity	10^6 /s	10^5 /s
K^+ stopping efficiency	0.40	0.40
Net runtime	10^7 s	1.5×10^7 s
Acceptance	3.8×10^{-4}	5.5×10^{-5}
Number of decays	1.5×10^9	3.3×10^7
fwd/bwd events	5×10^8	1.1×10^7
Analyzing power	0.27	0.271
P_T kinematic atten.	1.0	~0.70
δP_T (only *fwd/bwd*)	1.67×10^{-4}	2.3×10^{-3}
δP_T (*fwd/bwd*+ *L/R*)	1.13×10^{-4}	_



K_L beam

stopped K^+ (a few $\times$ 10^6/s)

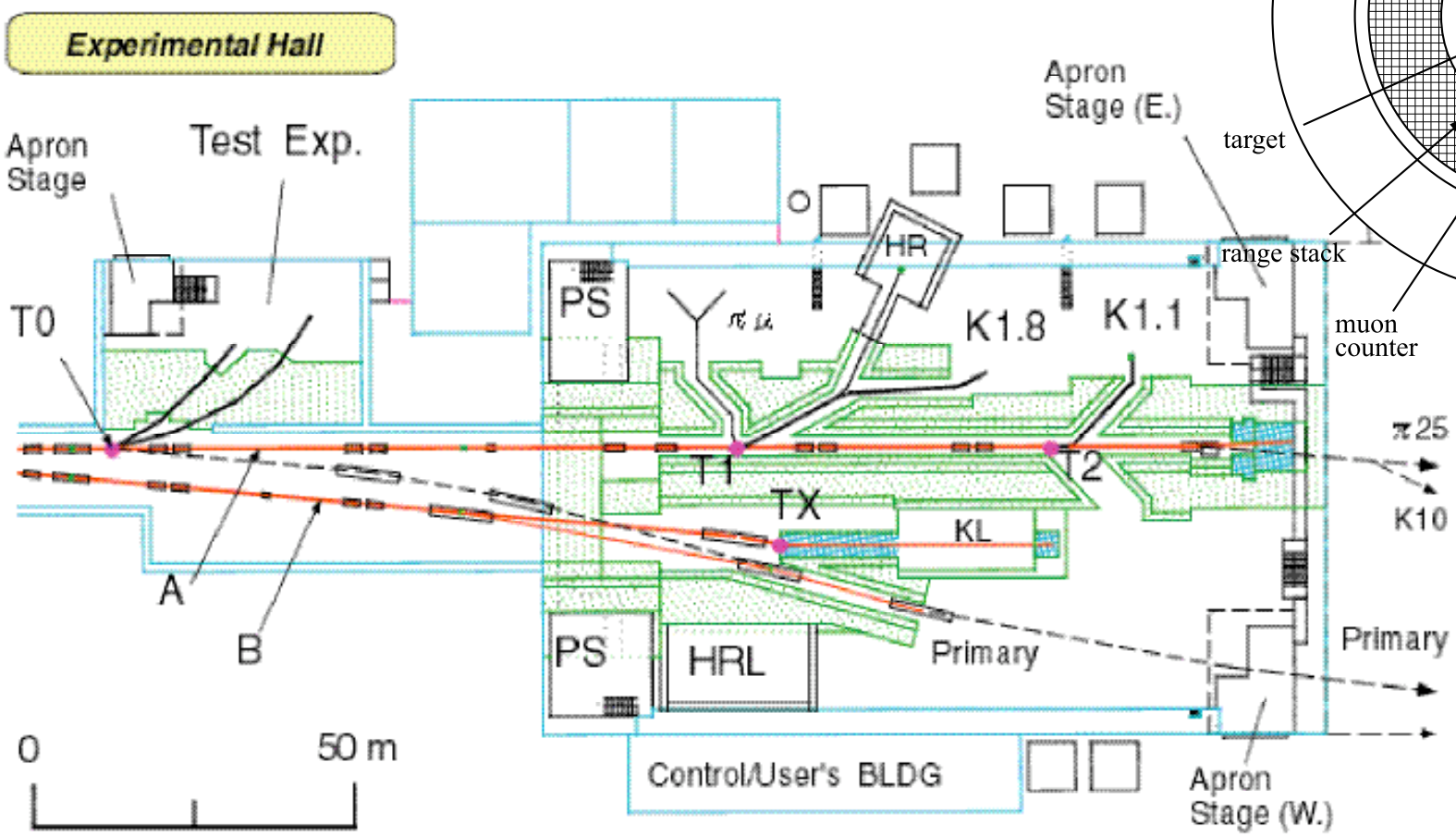


- K0.8 designed by J.Doornbos (2005) as a branch of the K1.1 line
- single-stage DC separator with a vertical intermediate focus

- Acceptance = 6 msr % $\Delta p/p$.
  - Acc (K1.1) ~ 4 msr % $\Delta p/p$
  - Acc (LESB3) ~ 50 msr % $\Delta p/p$
- I_{K^+} ~ (1~ a few) $\times$ 10^6/s
- $\pi^+/K^+ < 0.5$
- Beam spot :
  $d_x \sim d_y \sim 1$ cm << @K5

not suitable for $K^+ \to \pi^+ \nu\bar{\nu}$

for the ultimate goals of kaon program... extension of the Hall



- Hall size = 60m (W) x 100 m (L)
- More than 2 target stations

fully optimized KL and K1.1 lines

summary: kaon program at J-PARC

- new J-PARC accelerators and Hadron Exp Hall under construction
- kaon decay program:
  natural extension of the experiments at KEK-PS (E391a, E246, ...)
- the experimental studies of

  $\mathbf{K_L^0 \to \pi^0 \nu\bar{\nu}}$ $\mathbf{K^+ \to \pi^0 \mu^+ \nu}$ $\mathbf{K^+ \to \pi^+ \nu\bar{\nu}}$

  are unique in quark-flavor physics
  and complementary to the energy-frontier physics at LHC.