Overview of KEK-PS Experiments

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KEK-PS External Review

Brief History of KEK-PS

- 1971 April — KEK established
- 1976 March — Construction of the KEK-PS completed
  Proton beam accelerated to 8 GeV
- 1976 December — Proton beam accelerated to 12 GeV
- 1977 May — Physics experiments started
  fast extracted beam for bubble ch. exp'ts
  internal target for counter experiments
- 1978 April — Slow extracted beams for counter exp'ts
- 1981 June — First External Review
- 1987 February — Polarized proton beam accelerated and extracted
- 1990 February — New experimental hall (North Hall) completed
- 1990 November — Second External Review
- 1994 December — Third External Review

Brief History of KEK-PS, cont'ed

- 1996 September Construction of a neutrino beam line started
- 1999 February Commissioning of the neutrino beam line
- 1999 June 19 Detection of the first K2K neutrino event in Super-K
- 2000 December Fourth External Review
- 2001 November 12 Super-Kamiokande accident, End of K2K-I
- 2002 December Super-Kamiokande rebuilt, Start of K2K-II
- 2004 June Fifth External Review
- 2004 November End of K2K-II
- 2005 December End of experiments using extracted beams from the main ring
- 2008 January Sixth, and final External Review

Threefold Purposes of this External Review

- Review the achievements of seven recent experiments conducted after the previous review in 2004, and the final results of K2K.
- Evaluate recently published results from eight other experiments. (These experiments were already reviewed in 2004, but their new results need to be evaluated.)
- Review historical quality of KEK-PS experiments --- A sort of "Exit Review" as chairman says.

Historical Position of the KEK-PS (from the 1981 review report)

- KEK-PS was launched when hundreds of GeV proton machines appeared and 6-12 GeV machines were shut down.
  - 1972 March: NAL accelerator reached 200 GeV.
  - 1976 June: CERN SPS commissioned.
    300 GeV planned, 400 GeV reached.
  - 1978: Nimrod (7 GeV) shut down
  - 1979: ZGS (12.5 GeV) shut down
- Not possible to make the forefront research in particle physics.
- Domestic significance:
  - The first step to catch up the world level.
  - Obtain experience, educate and foster young researchers, and give confidence to the Japanese high-energy physics community.

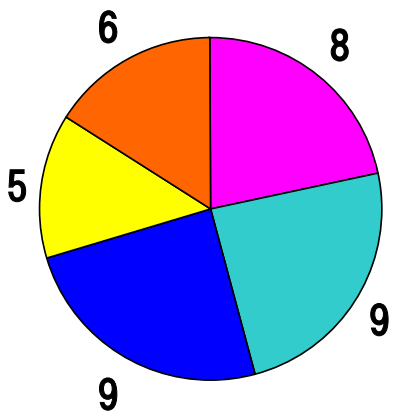
Trend of KEK-PS Experiments

- 1977 - 1984 (Before TRISTAN)
  - KEK-PS was the only high-energy machine in Japan.
  - Particle and hadron physics experiments were dominant.
- 1984 - 1998 (After start of TRISTAN and before K2K)
  - Nuclear and hadron physics experiments were dominant.
  - Particle physics experiments mainly focused on K_L and K^+ decays.
  - Nuclear physics experiments mainly focused on hypernuclear physics.
  - Demands for test beams for detector R&D increased considerably.
- 1999 – 2004 (After start of K2K)
  - As a strategy to provide 10^{20} POT to K2K as early as possible, PS-PAC authorized to allocate
    - 2/3 of available beam time for K2K (fast extracted beam)
    - 1/3 for other experiments (slow extracted beam)
  - About 60% of beam time given to particle physics experiments.

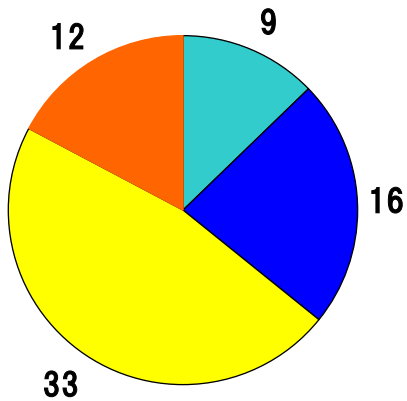
Statistics of KEK-PS Experiments

Number of experiments

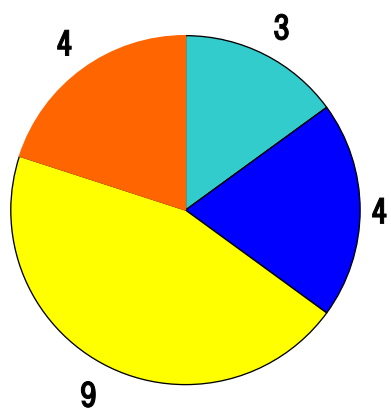
Before TRISTAN



After TRISTAN and before K2K

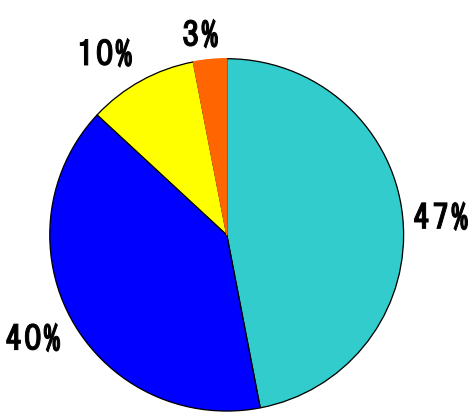


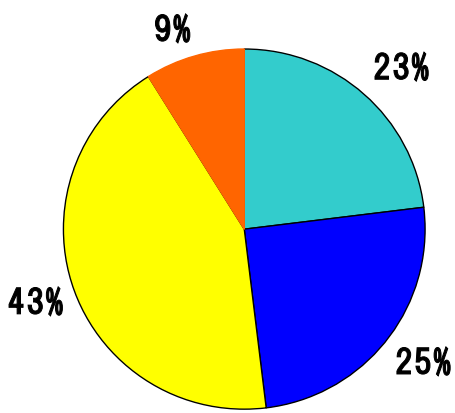
After K2K started

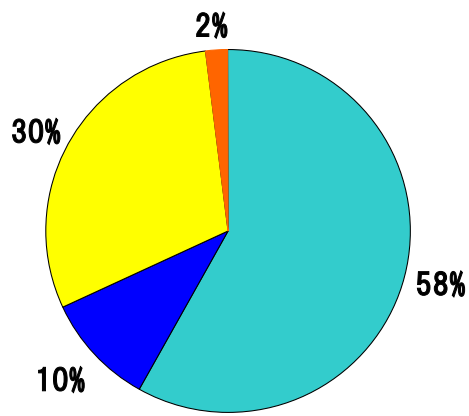


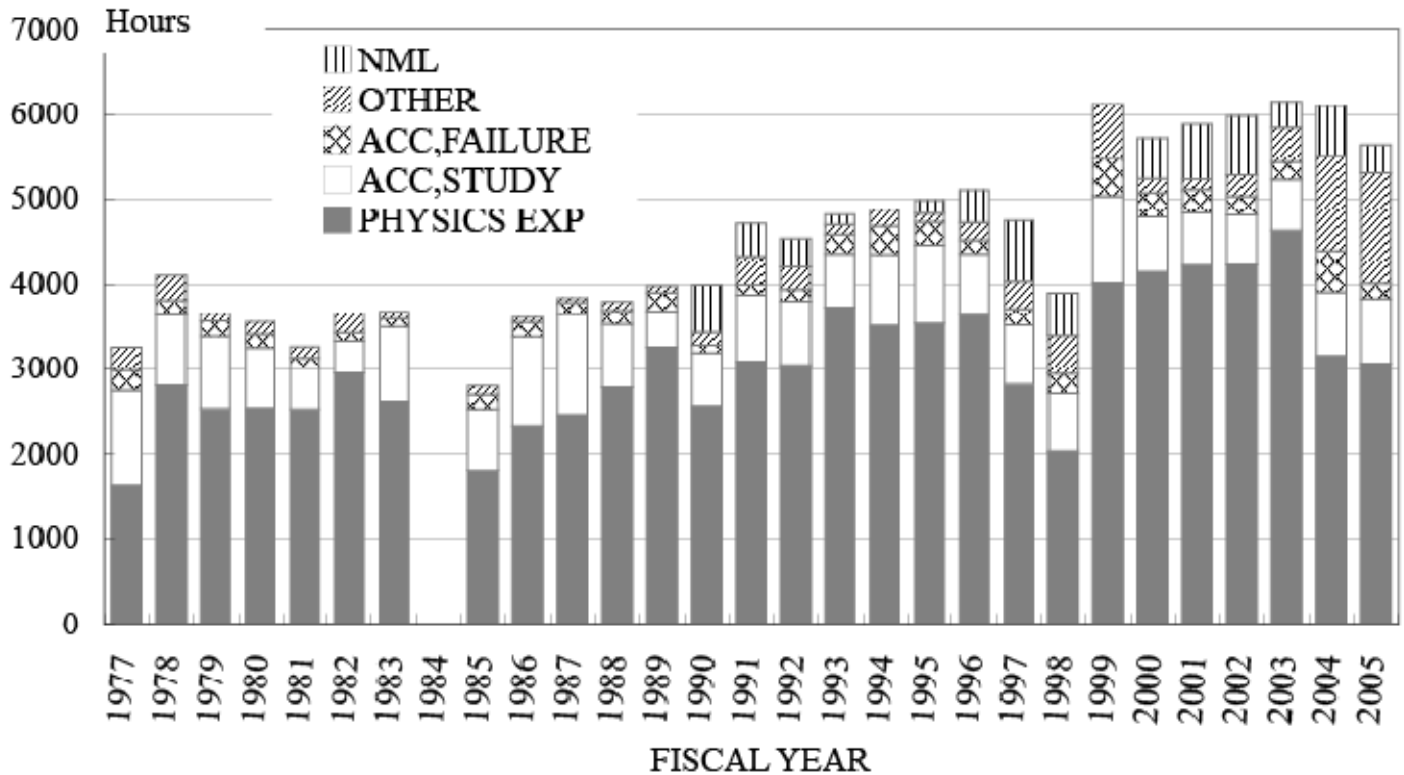
Bubble Ch. | Particle Phys. | Hadron Phys. | Nuclear Phys. | Others

Beam time





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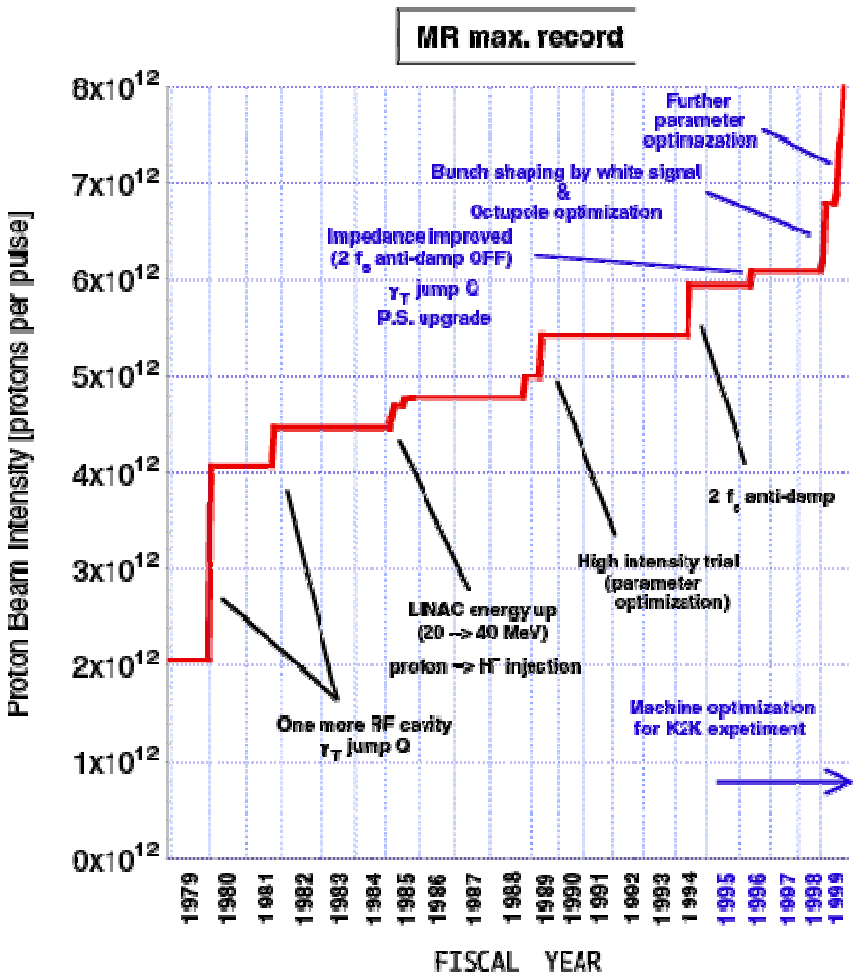
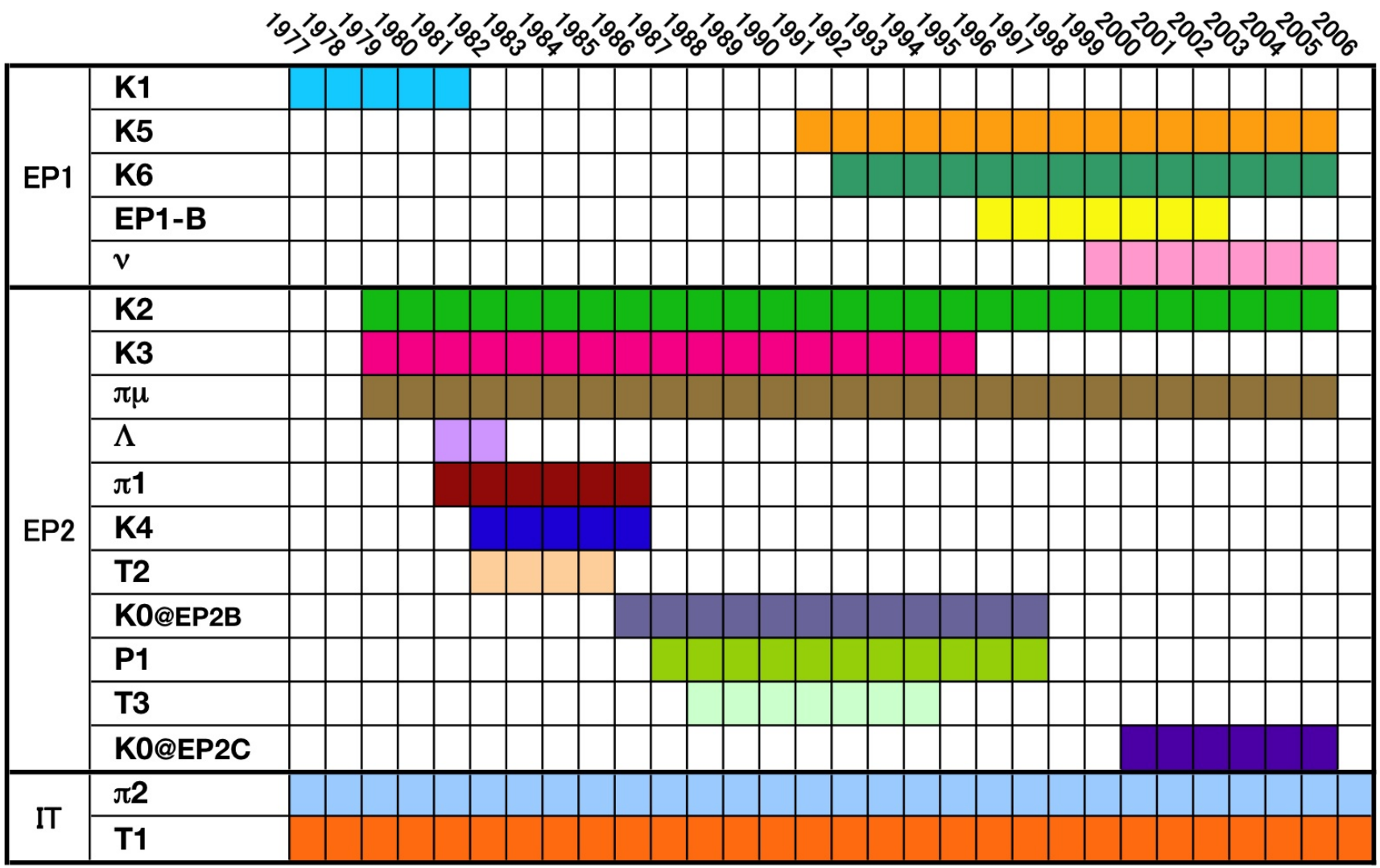
Maximum Intensity of Main Ring by H. Sato



KEK-PS Beam Lines

	Beam Line	Particles	Momentum[GeV/c]	note	term
EP1	K1	$p, \bar{p}, K^+, K^-, \pi^+, \pi^-$	0.5-4.5	separated	1977-1981
	K5	$p, \bar{p}, K^+, K^-, \pi^+, \pi^-$	0.3-0.6	separated	1991-2005
	K6	$p, \bar{p}, K^+, K^-, \pi^+, \pi^-$	0.5-2	separated	1992-2005
	EP1-B	p, d, α	≤12.9 for p	primary	1996-2002
	ν	ν	-	long baseline exp.	1999-2005
EP2	K2	$p, \bar{p}, K^+, K^-, \pi^+, \pi^-$	1.0-2.1	separated	1979-2005
	K3	$p, \bar{p}, K^+, K^-, \pi^+, \pi^-$	0.5-1.0	separated	1979-1995
	$\pi\mu$	p, π^+, π^-, μ	0.1-1.0	low momentum	1979-2005
	Λ	Λ	-	Λ exp.	1981-1982
	π1	π^+, π^-	4-8	superconducting line	1981-1986
	K4	$\bar{p}$	0.4-0.8	separated	1982-1986
	T2	π^+, π^-	1-6	test line for TRISTAN	1982-1985
	K0@EP2B	K^0	-	neutral	1986-1997
	P1	p, d, n	≤12.9 for p	primary	1987-1997
	T3	p, π^+, π^-	1-6	reconstruction of π1	1988-1994
	K0@EP2C	K^0	-	neutral	2000-2005
IT	π2	p, π^+, π^-	1.0-4.3	unseparated	1977-2006
	T1	p, π^+, π^-	0.2-2.3	unseparated	1977-2006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K0@EP2B
P1
T3
K0@EP2C
IT
π2
T1

First KEK-PS External Review in 1981

1. Domestic purposes of gaining experiences, training researchers, and giving confidence to the community fully achieved.
2. Basic design relatively conservative, but a number of ingenious ideas.

   Accelerator performance reached the design level.

   However, beam quality did not improve rapidly.
3. Physics outputs obtained are not impressive. No remarkable discoveries.

   Quality of the data less than expected.

   A few noteworthy experiments in nuclear or intermediate energy physics, suggesting one of the directions for future activities.
4. Coordination of the experimental program should be improved.
5. Strong in-house groups needed.

Recommendations:

Internationalization of KEK.

Periodical review

No.	Subject	Spokesperson	Affiliation(then)	Approved
6	Study of Pion Nucleon Inelastic Scattering in the Intermediate Energy Region	R. Sugahara	KEK	1975.5.2
10	Study of Rare Decay $K^+ \rightarrow \pi^+ \nu \bar{\nu}$	Y.Nagashima	KEK	1976.2.4
12	Study of $\pi^- p$ Three-Body Reaction with Emphasis on Diffraction	T.Hirose	Tokyo Metro. Univ.	1975.5.2
19	Measurements of Differential Cross Section and Polarization for $\pi^- p \rightarrow \pi^0 n$ in 1.8-3.0 GeV/c	K. Miyake	Kyoto Univ.	1975.5.2
21	Measurements of Differential Cross Section and Polarization for $\pi^+ p$ Elastic Scattering at 2-4 GeV/c	R.Kajikawa	Nagoya Univ.	1975.5.2
26	Radiochemical Studies of Nuclei by Stopping π^+	K.Otozai	Osaka Univ.	1975.6.17
33	Study of Narrow Resonance in pp Reaction below 1 GeV/c	T.Kamae	Univ. of Tokyo	1976.2.4
34	Study of $K^+ n \uparrow \rightarrow K^+ n$, $K^0 p$ and $K^- p \uparrow \rightarrow K^0 n$ Reaction	F.Takasaki	KEK	1976.2.4
45	Direct Lepton Production by Proton	S.Mikamo	KEK	1977.6.7
50	Direct Electrons in pp Interaction at 8 GeV/c	T.Kitagaki	Tohoku Univ.	1977.6.7
53	Pion-nucteus interaction at 5GeV/c in bubble chamber	S.Kaneko	Hirosima Univ.	1977.11.30
57	Studies of pp Interaction in the Range of 0.8-2.0 GeV/c	S.S.Yamamoto	Univ. of Tokyo	1978.6.1
63	Measurements of Polarization at Forward Angles for $\pi^- p \rightarrow \pi^0 n$ in 3.5-4.0 GeV/c	K. Miyake	Kyoto Univ.	1978.9.25
71	Space-Time Structure and Correlation in Particle Production in Hadron-Nucleus Interaction	K.Nakai	Univ. of Tokyo	1979.10.12
75	Measurement of P-parameter in pn Elastic Scattering	K.Ogawa	KEK	1980.2.13

KEK-PS External Review 1990

- Critical comments:
  - Particle physics experiments at KEK-PS in the 80's were topical but "one-shot" type rather than systematic and programmatic. Follow-up efforts needed.
  - Limited use of new detection technologies.
  - Low international visibility.
- Recommendations
  - Maintain flexibility to pursue topical experiments.
  - Develop a small number of well focused and selected projects. Pursue them with the necessary implementation of detector systems taking full advantage of new technology.

KEK-PS External Review 1994

✓: respected or achieved at least partly
✖: not respected or achieved

- Recommendations:
  - ✓ Encourage the neutrino oscillation experiment to start in 1998 and complete data taking with 10^{20} protons hopefully in 1-2 year run.
  - ✓ Higher priority for E246 (T-violation) ; lower priority for E162 (CP-violation)
  - ✓ Among strangeness experiments at KEK-PS, the SKS work on hypernuclei likely to have the highest priority.
  - ✖ Experiments with d and α beams generally encouraged.
  - ✓ Many groups move too quickly from one uncompleted experiment to the next new experiment which requires substantial equipment construction. KEK management and PAC must provide a guide to conduct thorough studies of "hints" explored in one experiment before that group moves on to the next.
  - ✖ Encourage the formation of a strong user's association.

KEK-PS External Review 2000

✓: achieved

- Recommendations:
  - ✓ Give the first priority to the K2K experiment. The proposed detector upgrade and beam time of 1×10^{20} pot (protons on target) should be approved.
  - ✓ Give a reasonable amount of time (about 25%) to slow extracted beam allowing timely completion of on-going experiments and additional beam time for programs including hypernuclei experiments using SKS. Availability of test beams is also an important factor.
  - ✓ Give E391 a priority assuming it successfully passes the laboratory review on the feasibility of the proposed detector construction in a timely manner. Then the laboratory should make an effort to deliver beam time of 50 days to E391.

KEK-PS External Review 2004

- Executive Summary mentions "The KEK PS Program since 1976."
- K2K: little need for a long extension; J-PARC will come on-line in 2008.
- Shut down of the KEK-PS should be delayed to the end of FY2005 if not into FY2006 to complete some critical experiments before the shut down.
- E391a: it is important to establish the feasibility of data taking with low background before the shut down so that further investment and planning for the J-PARC experiment can be made with confidence.
- A timely completion and commissioning of J-PARC with well equipped experimental hall must be the top priority, considering the worldwide situation (BNL is working towards RSVP program and CERN is organizing a large workshop for future fixed target program.)

Doctoral Degrees, Physics and Technical Papers Produced in the KEK PS Program

	Doctoral Degrees	Physics Papers published in refereed Journal	Technical Papers
Total	170	320	112
High Energy Physics	89	118	71
Nuclear Physics	78	179	38
Chemistry	3	23	3

High Energy Physics

	Doctoral Degrees	Physics Papers published in refereed Journal	Technical Papers
Total	89	118	71
First period	43	73	45
Second period	11	20	6
Third period	35	25	20

Nuclear Physics

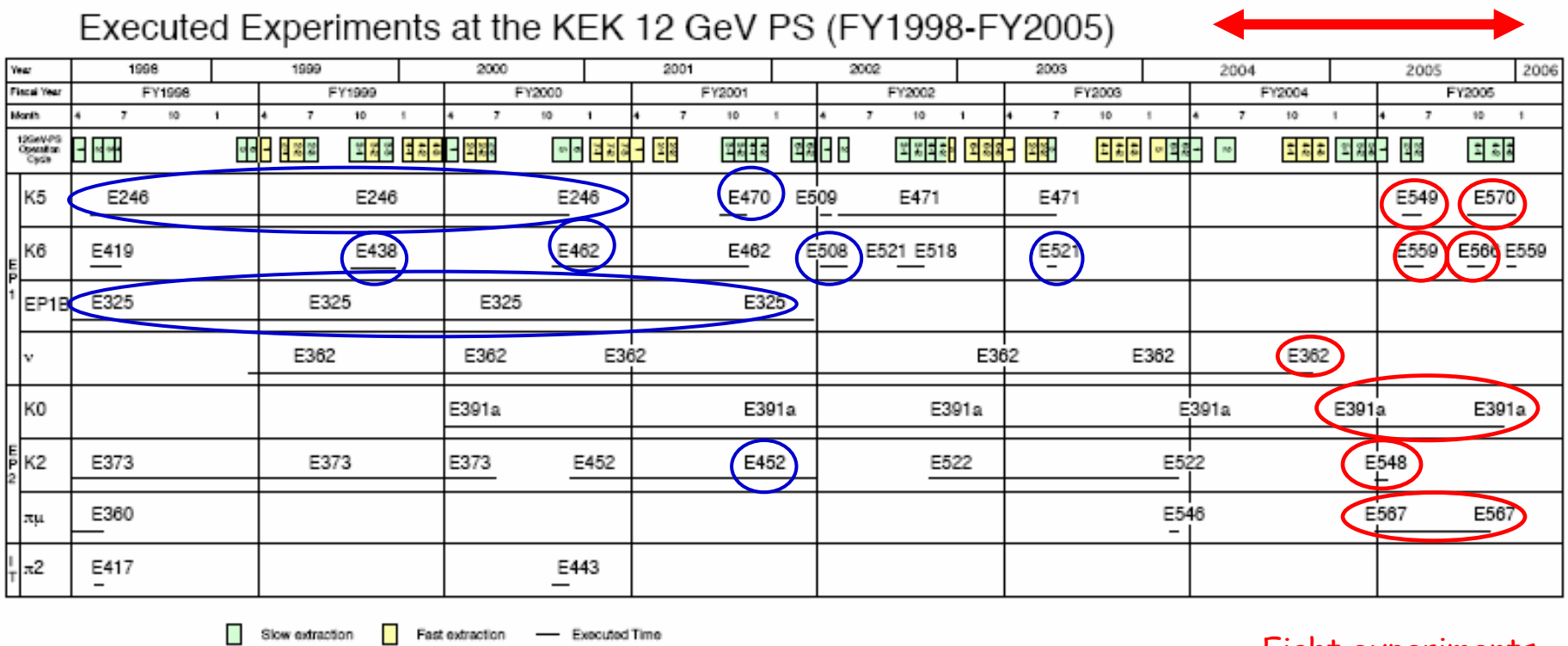
	Doctoral Degrees	Physics Papers published in refereed Journal	Technical Papers
Total	78	179	38
First period	10	28	4
Second period	39	100	25
Third period	29	51	9

Chemistry

	Doctoral Degrees	Physics Papers published in refereed Journal	Technical Papers
Total	3	23	3
First period	1	3	0
Second period	1	8	3
Third period	1	12	0

Review of the last-period PS experiments

Period covered by
this external review



Recently published results from these eight experiments should be evaluated.

Eight experiments to be reviewed by this committee

KEK-PS Experiments in 2004 - 2005

- Neutrino physics
  - E362 Long Baseline Neutrino Oscillation Experiment
- K Decay Experiment
  - E391a Measurement of the $K_L \rightarrow \pi^0 \nu\nu$ Decay
- Hadron and Strangeness Nuclear Physics
  - E522 Search for H-dibaryon resonance via $^{12}C(K^-,K^+\Lambda\Lambda)$ and study of Ξ-N interactions
  - E548 Study of Kaonic Nuclei by the (K^-, p) Reactions
  - E549 Confirmation of Nuclear Kaonic State and Search for its Excited States
  - E559 High Resolution Spectroscopy of Penta-quark Θ^+
- Atomic X-Ray Experiment
  - E567 Precise Measurement of Electronic X rays from pionic atoms
  - E570 Precision Spectroscopy of Kaonic Helium 3d-2p X-rays

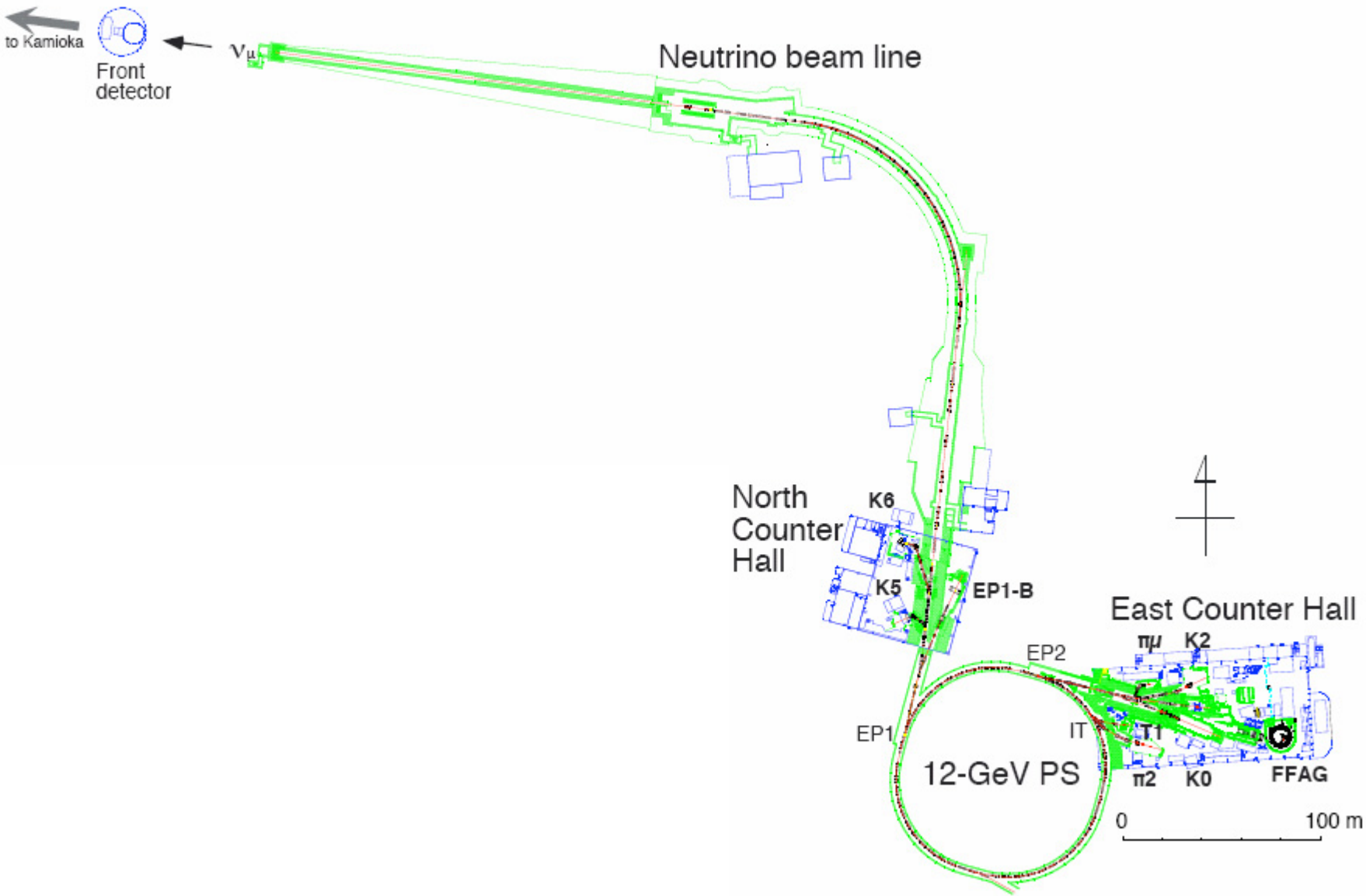
FY2004

Experiment			Cycle	2004-1	2004-2	2004-4-1	2004-4-2	2004-4-3	2004-5-1	2004-5-2	2004-5-3
			start	2004.4.1	2004.5.18	2004.9.30	2004.10.25	2004.11.22	2005.1.13	2005.2.14	2005.3.7
			end	2004.4.28	2004.7.1	2004.10.25	2004.11.22	2004.12.22	2005.2.14	2005.3.7	2005.3.31
Number	Spokesperson	Beam line	Scheduled shift								
E362	K. Nishikawa	ν				0.14×10^{19}	0.19×10^{19}	–			
E391a	T. Inagaki	K0		72	97				35	53	55

FY2005

Experiment			Cycle	2005-1	2005-2-1	2005-2-2	2005-4-1	2005-4-2	2005-4-3
			start	2005.4.1	2005.5.24	2005.6.13	2005.9.27	2005.10.31	2005.12.12
			end	2005.4.22	2005.6.13	2005.7.1	2005.10.31	2005.12.12	2005.12.28
Number	Spokesperson	Beam line	Scheduled shift	52	50	40	81	112	41
E391a	T. Inagaki	K0		12				112	
E548	T. Kishimoto	K2		50					
E549	M. Iwasaki	K5			[25]+24	39			
E559	K. Imai	K6			[25]+24	39			40
E566	H. Tamura	K6					81		
E567	A. Shinohara	$\pi\mu$		40				15	
E570	R. S. Hayano	K5					81		40

Layout of Experimental Areas in September 2003



Beam Lines in the E-Hall 2004

[Secondary Beam Lines]

Beam Line	Particles	Momentum Range (GeV/c)	Momentum Bite [Δp/p] (%)	Typical Intensity (particles / 10^{12} protons)	
K0	K_L	1-8	-	3.0×10^{7}	
K2	K^+	1-2	± 3	5.0×10^{5}	@ 2 GeV/c
	K^-			1.0×10^{5}	
	π^+	0.5-2	± 3	2.2×10^{7}	
	π^-			1.5×10^{7}	
	$\bar{p}$			1.5×10^{4}	
π2	π^+	1-4	± 1	2.0×10^{5}	@ 3 GeV/c
	π^-			1.0×10^{5}	
$\pi\mu$	π^+	0.1-0.26	± 4	1.2×10^{6}	@ 0.23 GeV/c
	π^-			1.0×10^{6}	
T1	π^+	0.5-2	± 5	5.0×10^{4}	@ 1 GeV/c
	π^-			4.0×10^{4}	

[Primary Beam Line]

Beam Line	Particles	Energy Range (GeV)	Momentum Spread [ΔE/E] (%)	Typical Intensity (particles/ sec)	
P1	pol.p	3.5	± 0.5	4.0×10^{8}	pol. = 40 %
	p	2-12.0		4.0×10^{8}	
	d	2-11.2		2.0×10^{8}	
	n	1-5.6		4.0×10^{8}	

Beam Lines in the N-Hall 2004

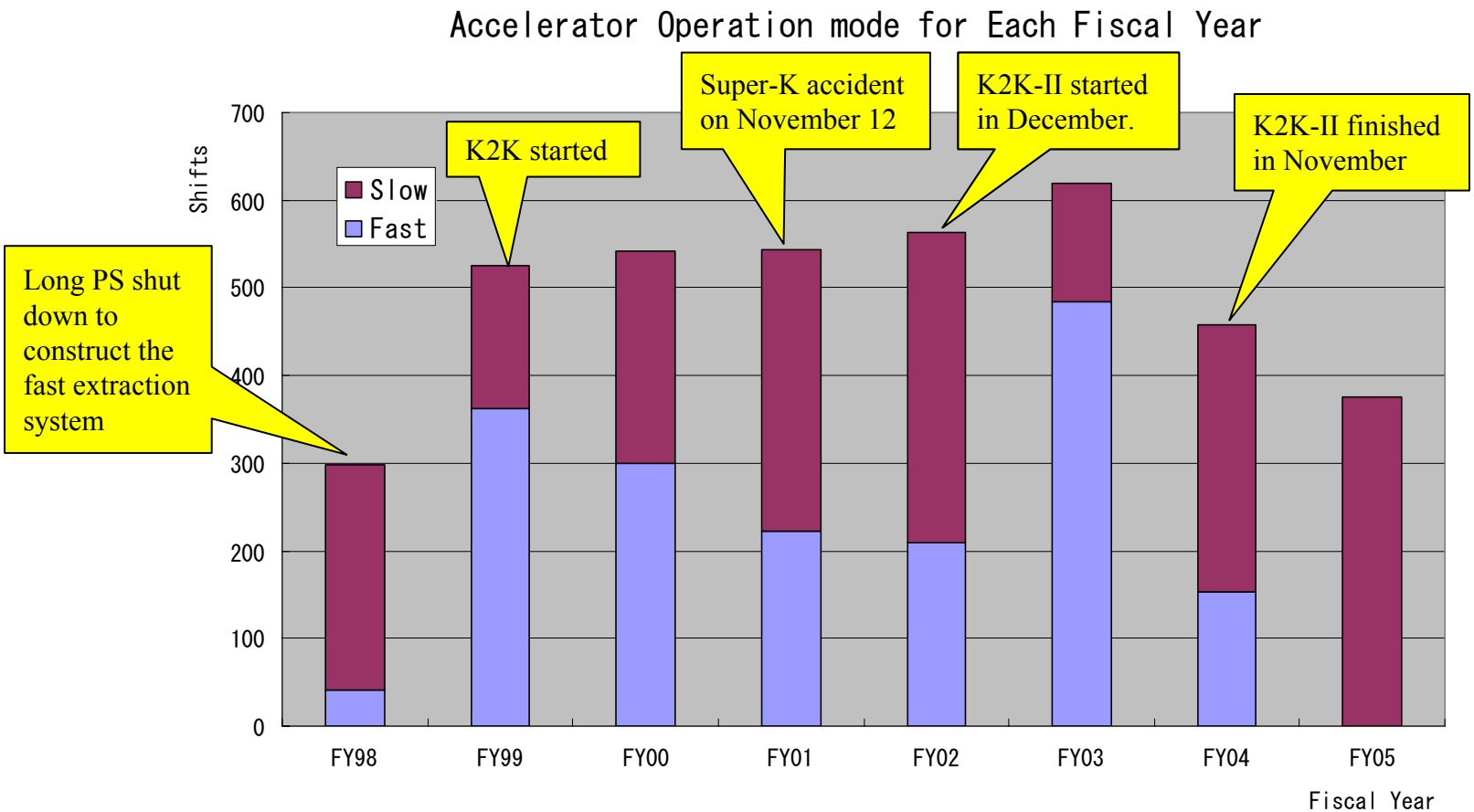
[Secondary Beam Lines]

Beam Line	Particles	Momentum Range (GeV/c)	Momentum Bite [Δp/p] (%)	Typical Intensity (particles / 10^{12} protons)	
K5	K^+	0.3-0.6	± 3	5.0×10^{4}	@ 0.55 GeV/c
	K^-			1.0×10^{4}	
	π^+			3.5×10^{7}	
	π^-			2.8×10^{7}	
	$\bar{p}$			2.6×10^{2}	
K6	K^+	0.5-2	± 2.8	8.7×10^{3}	@ 1 GeV/c
	K^-			3.3×10^{3}	
	π^+			6.5×10^{6}	
	π^-			5.0×10^{6}	
	$\bar{p}$			1.6×10^{3}	

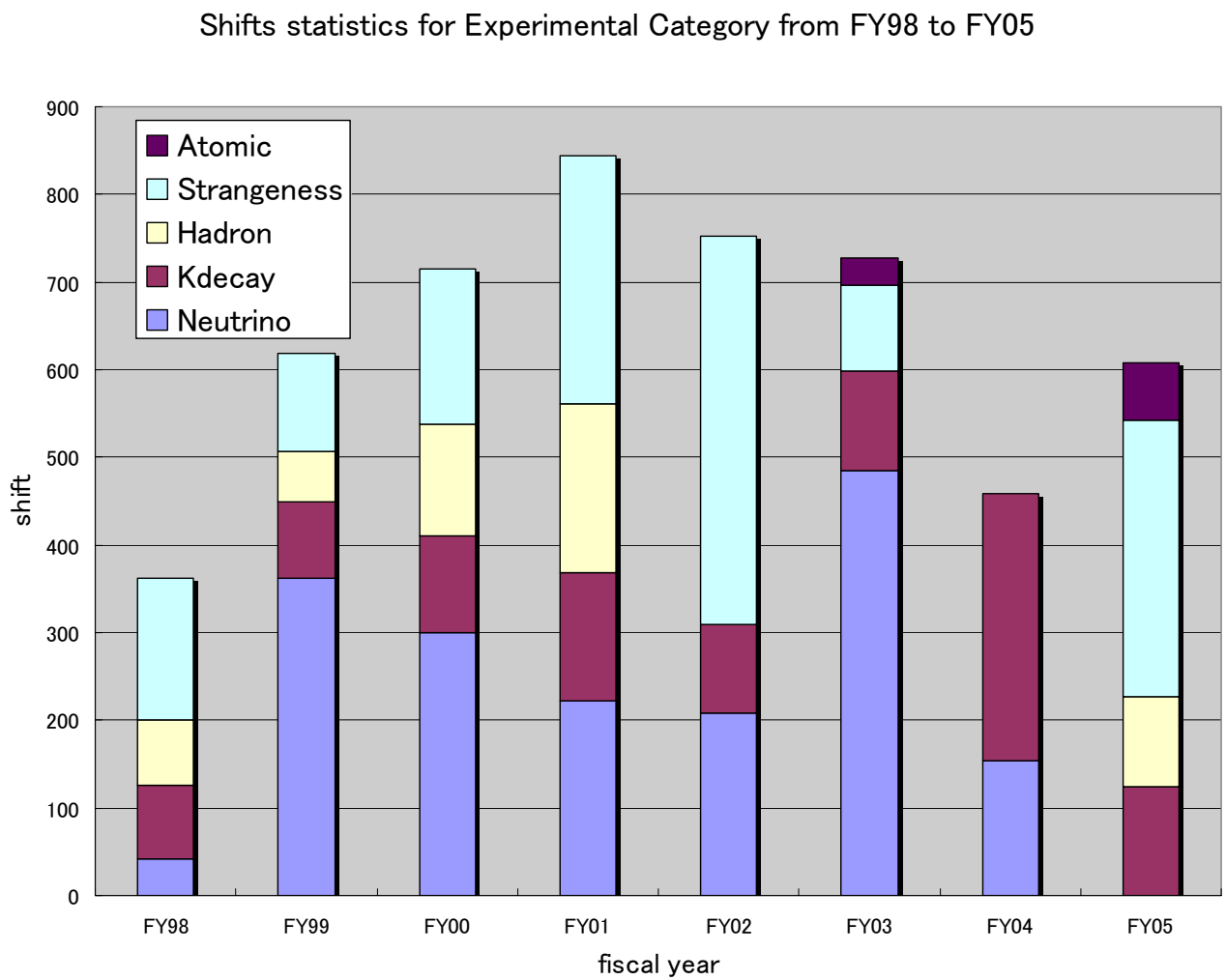
[Primary Beam Line]

Beam Line	Particles	Energy Range (GeV)	Momentum Spread [ΔE/E] (%)	Typical Intensity (particles/ sec)
EP1B	p	2-12.0		4.0×10^{8}
	d	2-11.2		2.0×10^{8}

Accelerator Operation Mode for Each Fiscal Year from FY1998 to FY2005

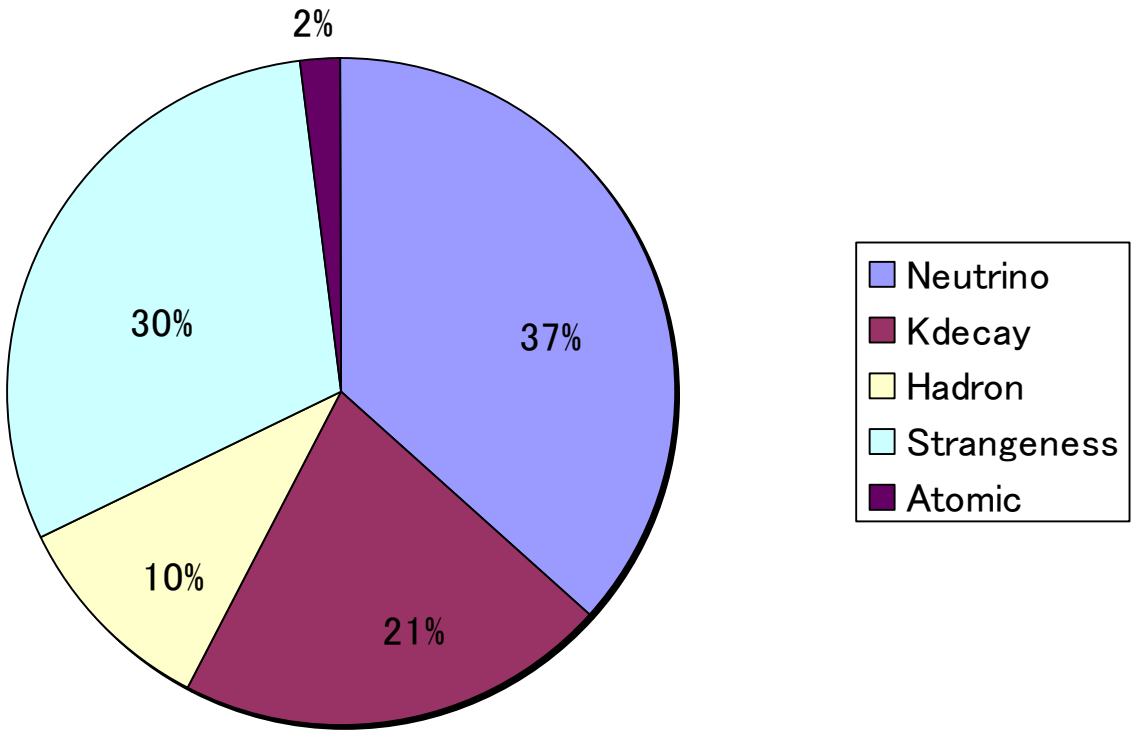


Allocated Beam Time for Each Category of Experiments from FY1998 to FY2005



Beam Time Allocation: FY1999 - FY2005

Total Executed Shifts from FY1999 to FY2005 [%]



Plan of presentations

- Overview of KEK-PS accelerator → H. Sato
- Overview of particle phys. expt's → Y. Nagashima
- Overview of nuclear phys. expt's → K. Nakai

- Presentations from previous expt's which have recent publications

- Test experiments → M. Ieiri

- Overview of J-PARC expt's → N. Saito

- Presentations from eight recent expt's