



Experimental Program at J-PARC

Kiyoshi Tanida (Seoul National Univ.)

14 Sep 2009

Hyp-X@Tokai

J-PARC

Materials and Life Science
Experimental Facility

Nuclear and Particle
Experimental Facility

Nuclear
Transmutation

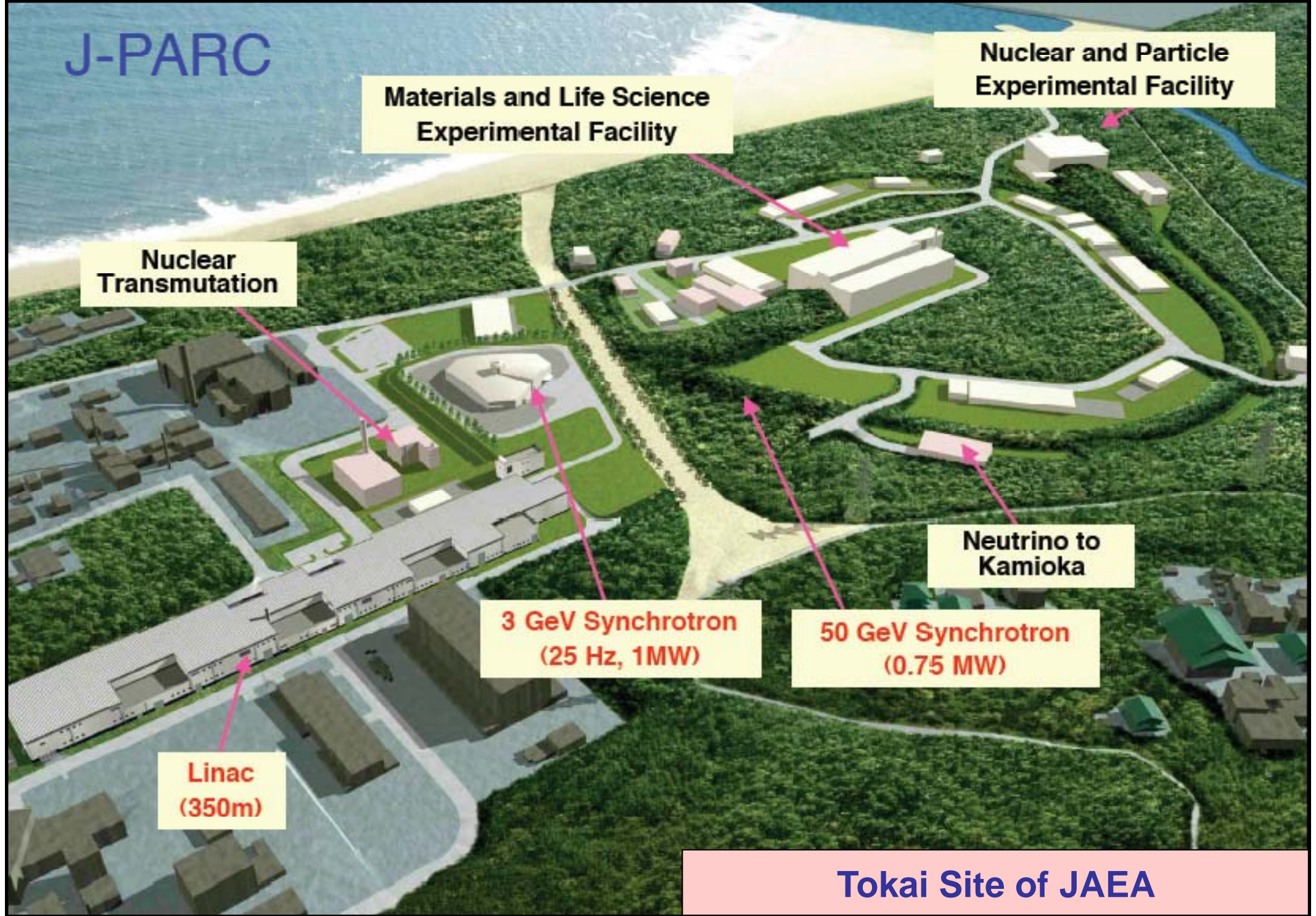
3 GeV Synchrotron
(25 Hz, 1MW)

50 GeV Synchrotron
(0.75 MW)

Neutrino to
Kamioka

Linac
(350m)

Tokai Site of JAEA



J-PARC

- J-PARC =
Japan **P**roton **A**ccelerator **R**esearch **C**omplex
- Main accelerator: 50 GeV PS
 - $50 \text{ GeV} \times 15 \mu\text{A} = 750 \text{ kW}$
 - World leading facility with **the ever strongest kaon beam**
- Construction almost done
 - **First beam extracted from 50 GeV PS on Jan. 27**
 - Strangeness nuclear physics experiments starts **SOON**.
 - Details are explained by the next speakers.

Projects in J-PARC

- Material & Life science (neutron, μ)
- Transmutation of nuclear waste
- Nuclear Physics
 - Strangeness nuclear physics
 - Hadron spectroscopy
 - Nucleon structure
 - Hot and/or dense nuclear matter
 - Unstable nuclei
- Particle Physics
 - Neutrino oscillation
 - Kaon rare decay
 - μ rare decay

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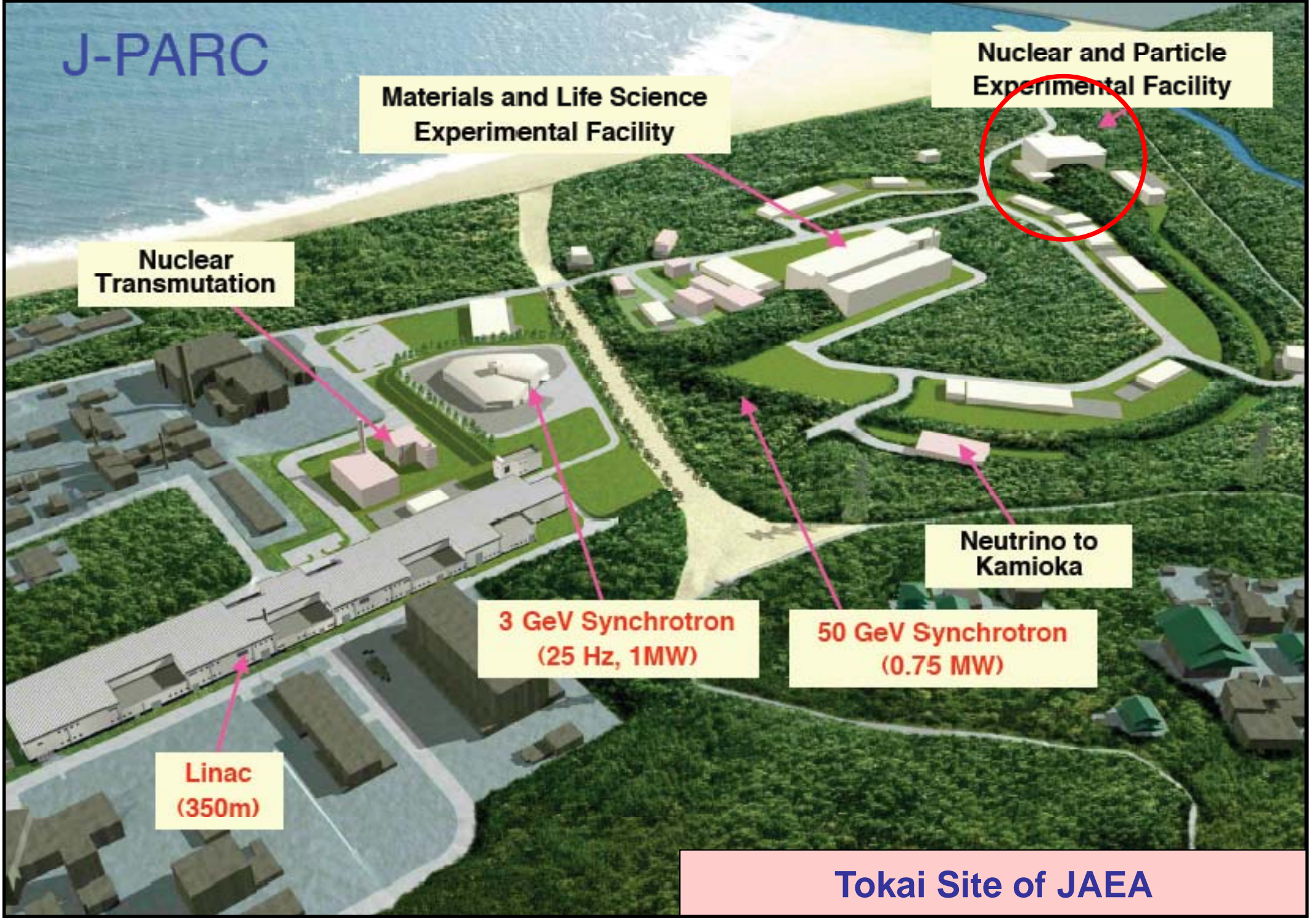
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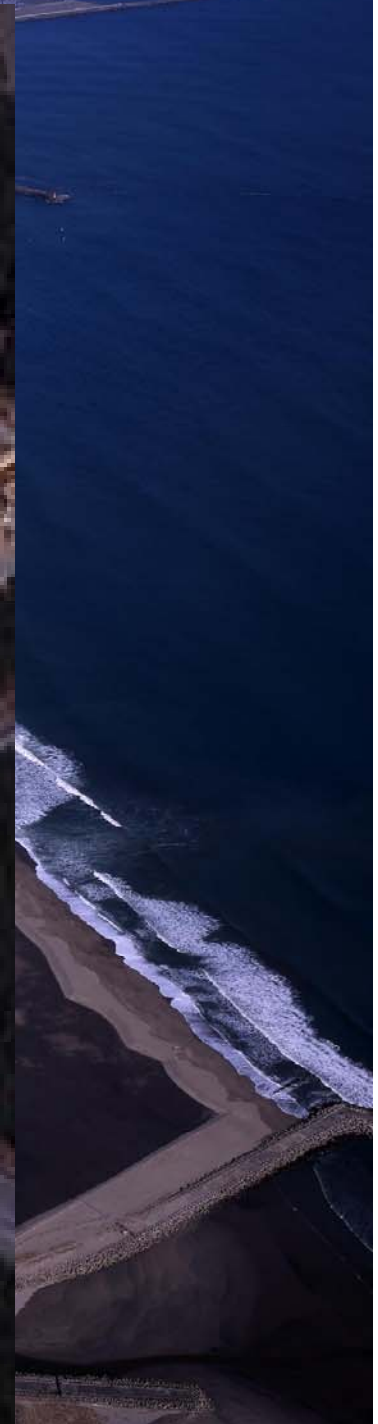
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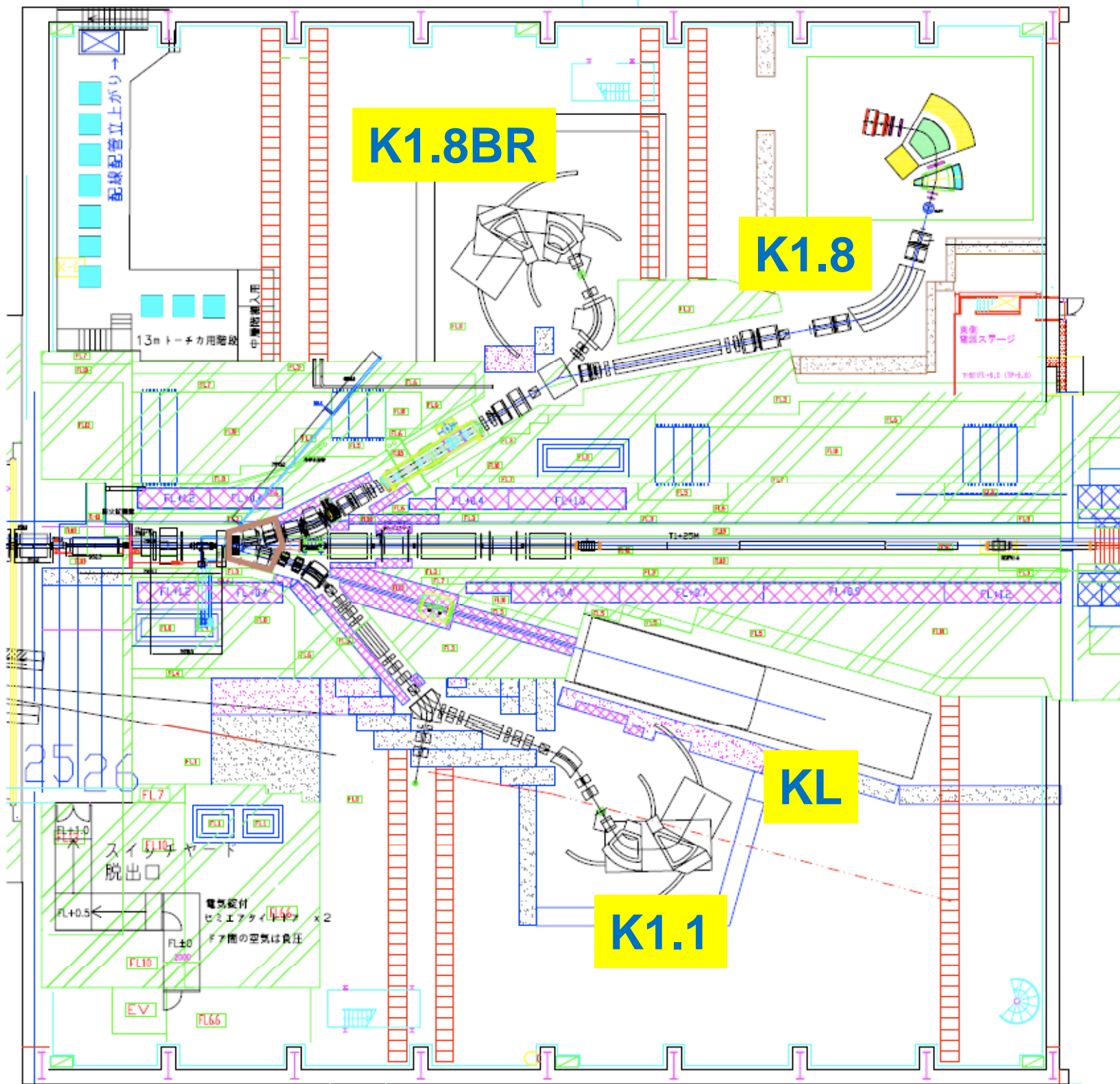


Feb. 2008



Feb. 2008





Experiment summary

	strange nuclei	strange hadrons	other nuclei & hadrons	particle	Total
Proposed	11	3	6	4	24
Stage-1 (sci. approval)	3	1	2	2	8
Stage-2 (full approval)	7	1	0	2	10
rejected	0	1	2	0	3

More than half of the approved experiments are related to nuclei and hadrons with strangeness

List of approved experiments

S = -2 nuclei & atoms

E03: Measurement of X rays from Ξ^- atom

Spokesperson – K. Tanida (Seoul)

E05: Spectroscopic study of Ξ -hypernucleus, $^{12}_{\Xi}\text{Be}$,
via the $^{12}\text{C}(\text{K}^-, \text{K}^+)$ reaction (Day 1 – 1st priority)

Spokesperson – T. Nagae (Kyoto)

E07: Systematic study of double strangeness system
with an emulsion-counter hybrid method

Spokespersons – K. Imai (Kyoto)

K. Nakazawa (Gifu)

H. Tamura (Tohoku)

S = -1 nuclei

- E10: Production of **neutron-rich Lambda-hypernuclei** with the double charge exchange reaction
Spokespersons – A. Sakaguchi (Osaka), T. Fukuda (Osaka E. -C.)
- E13: **Gamma-ray spectroscopy** of light hypernuclei
Spokesperson – H. Tamura (Tohoku)
- E15: A search for **deeply-bound kaonic nuclear states** by in-flight ${}^3\text{He}(K^-,n)$ reaction
Spokespersons – M. Iwasaki (RIKEN), T. Nagae (Kyoto)
- E18: Coincidence measurement of the weak decay of ${}^{12}_{\Lambda}\text{C}$ and the **three-body weak interaction process**
Spokespersons: H. C. Bhang (Seoul), H. Ota (RIKEN), H. Park (KRISS)
- E22: Exclusive study on the **ΛN weak interaction** in $A=4$ Λ -Hypernuclei
Spokespersons: S. Ajimura (Osaka), A. Sakaguchi (Osaka)

Other strangeness exp.

- E17: Precision spectroscopy of **kaonic ^3He $3d \rightarrow 2p$ X-rays**
Spokespersons – R. S. Hayano (Tokyo), H. Ota (RIKEN)
- E19: **High-resolution search for Θ^+ pentaquark** in $\pi^-p \rightarrow K^-X$ reactions
Spokesperson – M. Naruki (KEK)
- E27: Search for a **nuclear K bar bound state K^-pp** in the $d(\pi^+, K^+)$ reaction
Spokesperson – T. Nagae (Kyoto)
- P29 : Study of in medium **mass modification for phi meson** using phi meson bound state in nucleus
Spokesperson – H. Ohnishi (RIKEN)
- P31 : Spectroscopic study of **hyperon resonances below KN threshold** via the (K^-, N) reaction on deuteron
Spokesperson – H. Noumi (Osaka)

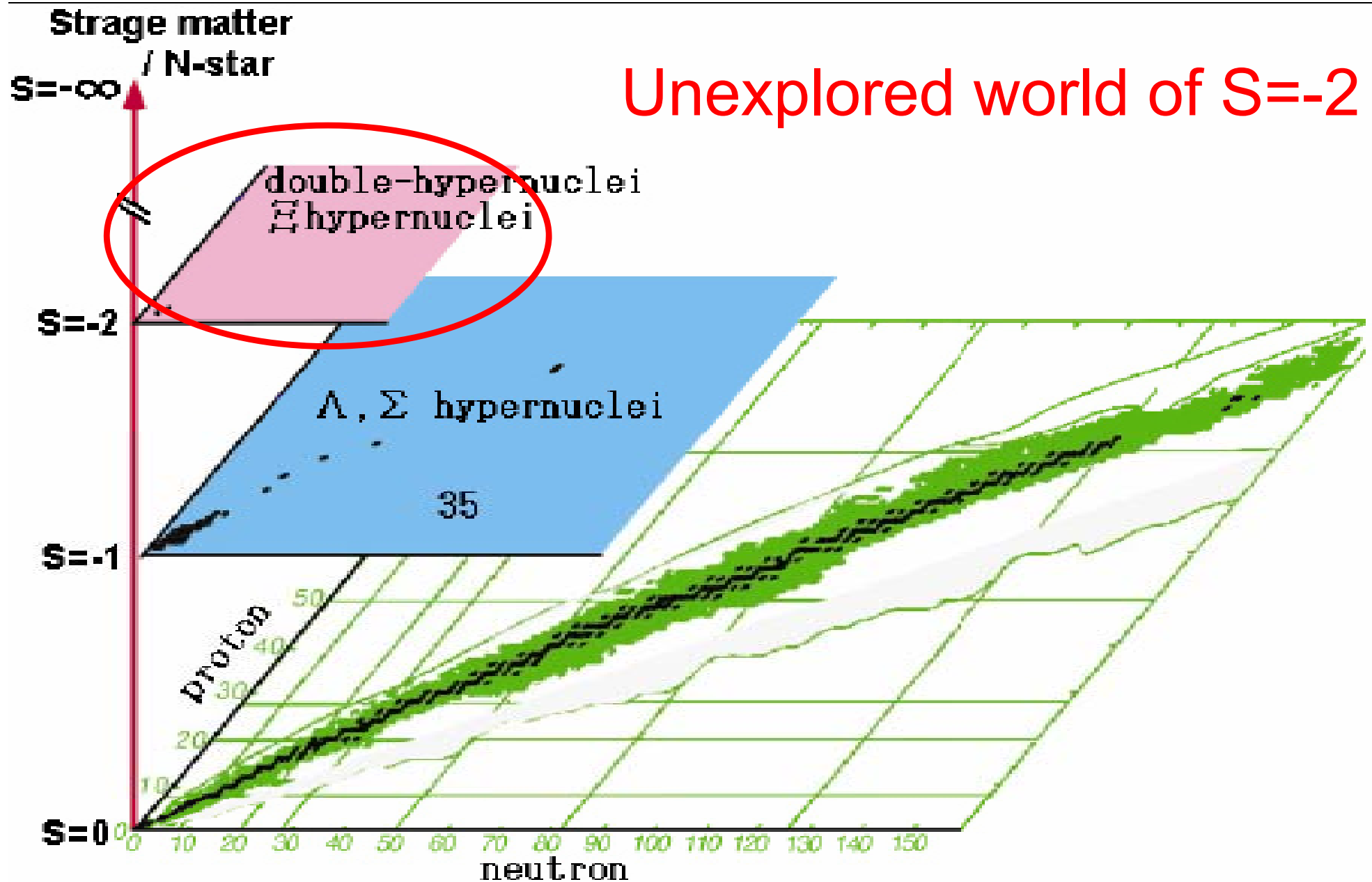
List of related talks

talker	date/time	title	exp #
H. Tamura (Tohoku)	Mon. 9:20~ (Plenary)	Gamma-ray spectroscopy of hypernuclei	E13
K. Nakazawa (Gifu)	Thu. 9:30~ (Plenary)	Double- Λ hypernuclei in Hybrid-Emulsion experiments	E07
K. Shirotori (Tohoku)	Mon. 18:00~ (poster M02)	Hypernuclear gamma-ray spectroscopy detector system at J-PARC: Hyperball-J	E13/03
K. Yoshida (Osaka)	Mon. 18:00~ (poster M05)	Development of tracking chamber for J-PARC E10 experiment	E10
A. Sakaguchi (Osaka)	Mon. 18:00~ (poster M06)	Study of neutron-rich Λ -hypernuclei by the double charge-exchange reaction at J-PARC	E10
T. Koike (Tohoku)	Mon. 18:00~ (poster M07)	γ -ray spectroscopy of well deformed sd-shell hypernuclei	E13
S. Ajimura (Osaka)	Mon. 18:00~ (poster M10)	Study of the Nonmesonic Weak Decay of 4-body Λ Hypernuclei at J-PARC	E22

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H. Noumi (Osaka)	Mon. 18:00~ (poster M15)	Spectroscopic Study of $\Lambda(1405)$ with a Low Energy Kaon Beam	P31
T. Suzuki (Tokyo)	Mon. 18:00~ (poster M16)	The investigation of $\Lambda(1405)$ state in the stopped K- reaction on deuterium	P30
A.P. Krutenkova (ITEP)	Mon. 18:00~ (poster M24)	Pion double charge exchange on oxygen at J-PARC	E08
T. Ishiwatari (SMI, Vienna)	Tue. 18:00~ (poster T04)	Adjustment of the SDDs for experiment E17 at J-PARC	E17
T. Ishiwatari (SMI, Vienna)	Tue. 18:00~ (poster T05)	Precision spectroscopy of kaonic ^3He $3d \rightarrow 2p$ X-rays at J-PARC	E17
K. Tsukada (RIKEN)	Tue. 18:00~ (poster T10)	A search for deeply-bound kaonic nuclear states at J-PARC	E15
K. Mijung (Seoul)	Thu. 16:30 (Parallel 2B)	Coincidence measurement of the weak decay of $^{12}_{\Lambda}\text{C}$ and the threebody weak decay process at J-PARC 50-GeV PS	E18

Hyper-nuclear chart



S = -2 nuclei & atoms

unique at J-PARC

E03: Measurement of X rays from Ξ^- atom

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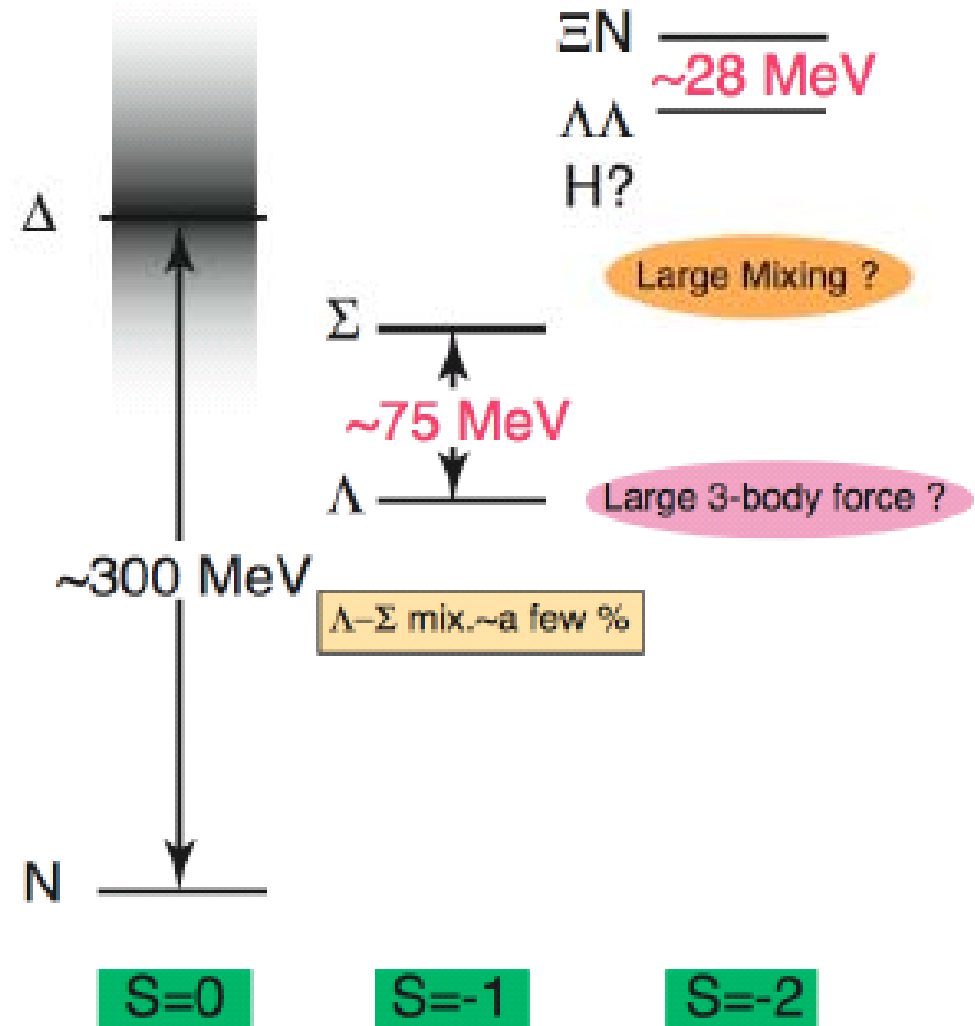
Spokespersons – K. Imai (Kyoto)

K. Nakazawa (Gifu)

H. Tamura (Tohoku)

Physics Motivation for S=-2 world

- A doorway to the multi-strangeness system
- **Very dynamic system?**
 - Large baryon mixing? Inversely proportional to mass difference.
 - H dibaryon as a mixed state of $\Lambda\Lambda$ - ΞN - $\Sigma\Sigma$?
- Little is known so far
 → Main motivation of the J-PARC

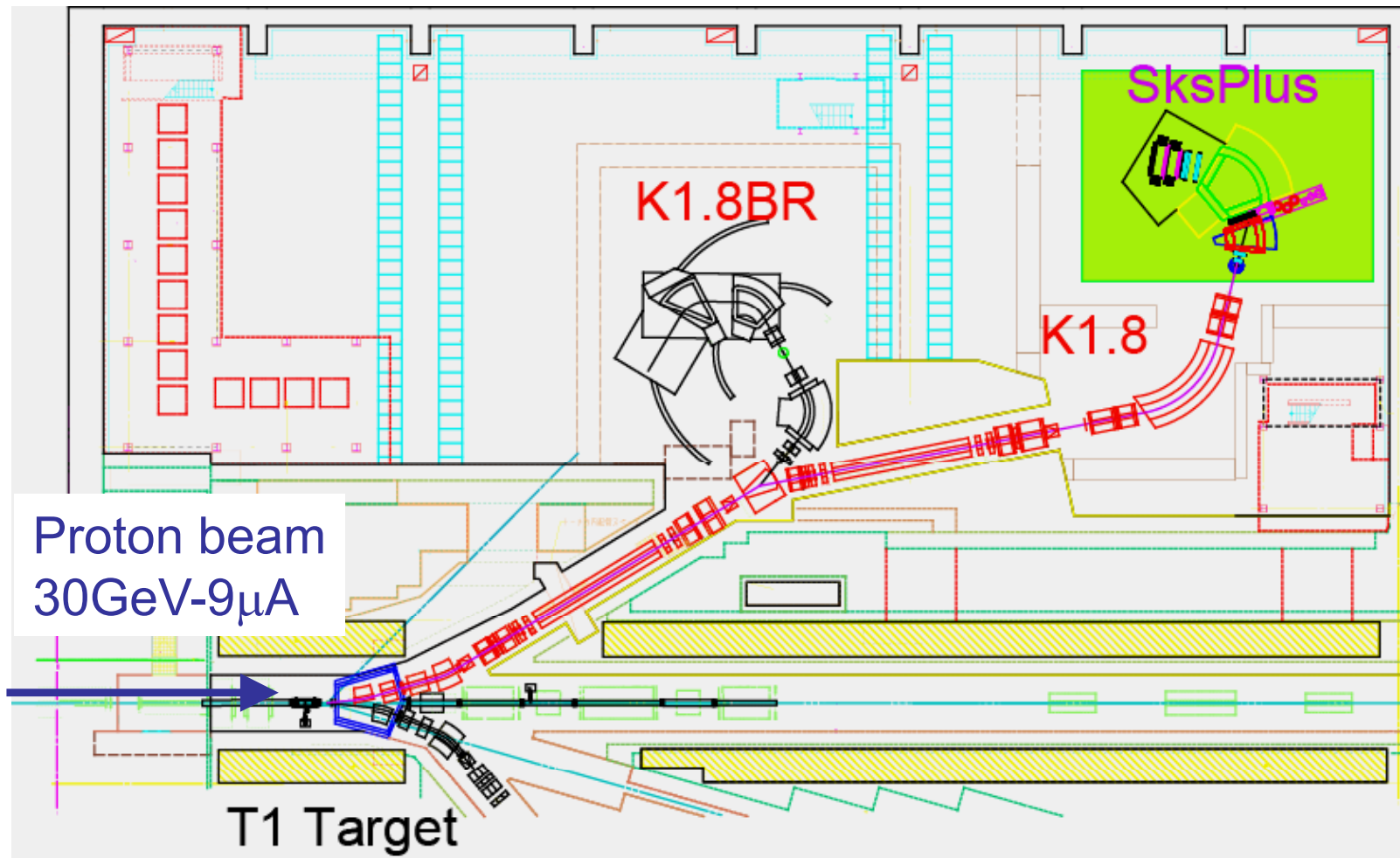


E05 Ξ -hypernuclei



Missing mass spectroscopy of $^{12}\text{C}(\text{K}^-, \text{K}^+)\text{X}$

\rightarrow $^{12}_{\Xi}\text{Be}$, $^{12}_{\Lambda\Lambda}\text{Be}$



1.8 GeV/c
K⁻ beam

high intensity
 1.4×10^6 K⁻ /spill
(Phase-1)

high purity
K⁻/π⁻ ~6.9

Importance of Ξ systems

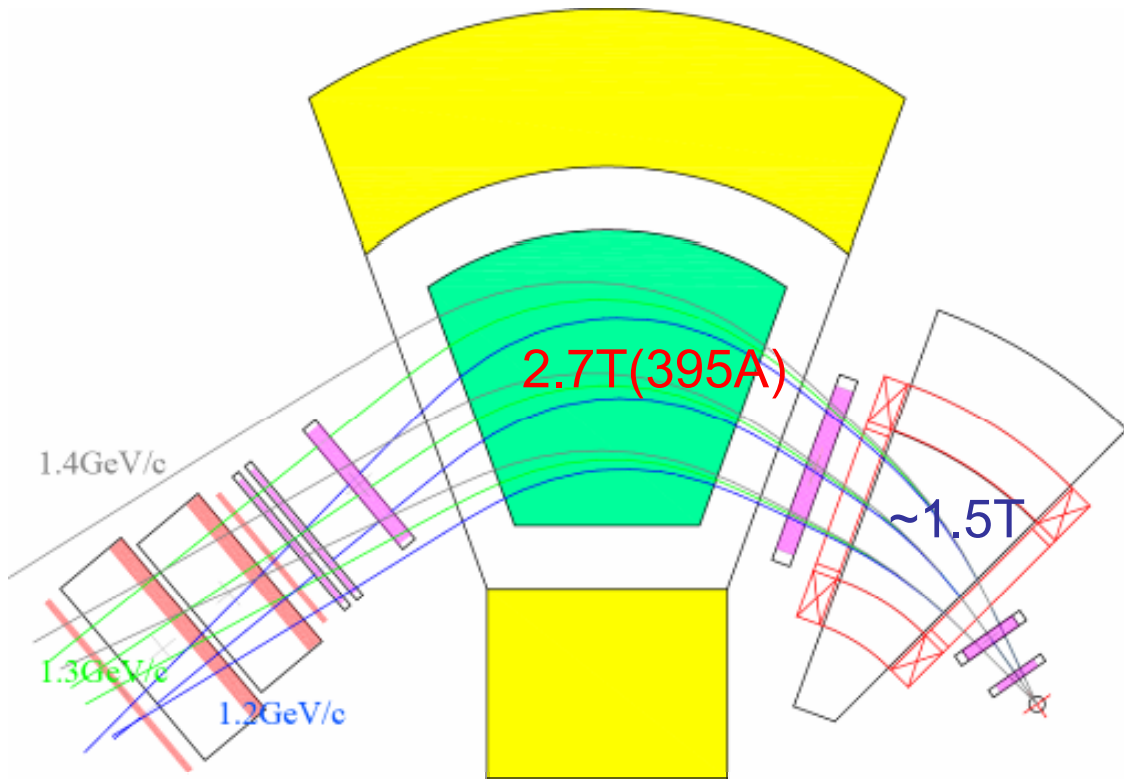
- Valuable information on ΞN (effective) interaction
 - e.g., How strong $\Xi N \rightarrow \Lambda\Lambda$ (and thus ΞN - $\Lambda\Lambda$ mixing) is?
 - Relevant to the existence of H dibaryon
 - ΞN component in $\Lambda\Lambda$ -hypernuclei
 - Exchange interaction is prohibited in one-meson exchange models
- How about A dependence?
- Impact on neutron stars
 - Does Ξ^- play significant role in neutron stars because of its negative charge?
 - Σ^- was supposed to be important, but its interaction with neutron matter is found to be strongly repulsive.

Ξ N interaction model and Ξ A optical potential

Model	T	1S_0	3S_1	1P_1	3P_0	3P_1	3P_2	U_{Ξ}	Γ_{Ξ}
NHC-D	0	-2.6	0.1	-2.1	-0.2	-0.7	-1.9		
	1	-3.2	-2.3	-3.0	-0.0	-3.1	-6.3	-25.2	0.9
Ehime	0	-0.9	-0.5	-1.0	0.3	-2.4	-0.7		
	1	-1.3	-8.6	-0.8	-0.4	-1.7	-4.2	-22.3	0.5
ESC04d*	0	6.3	-18.4	1.2	1.5	-1.3	-1.9		
	1	7.2	-1.7	-0.8	-0.5	-1.2	-2.8	-12.1	12.7

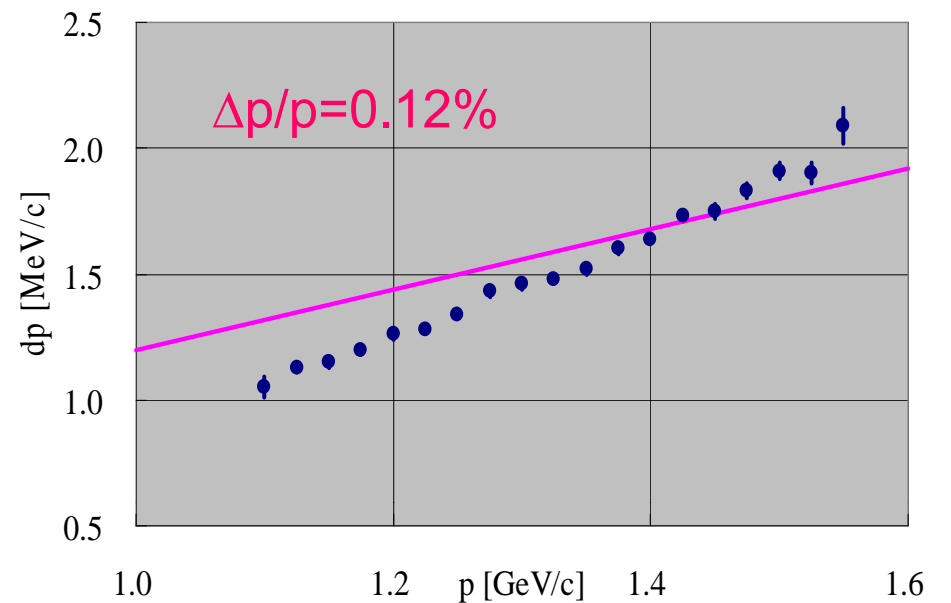
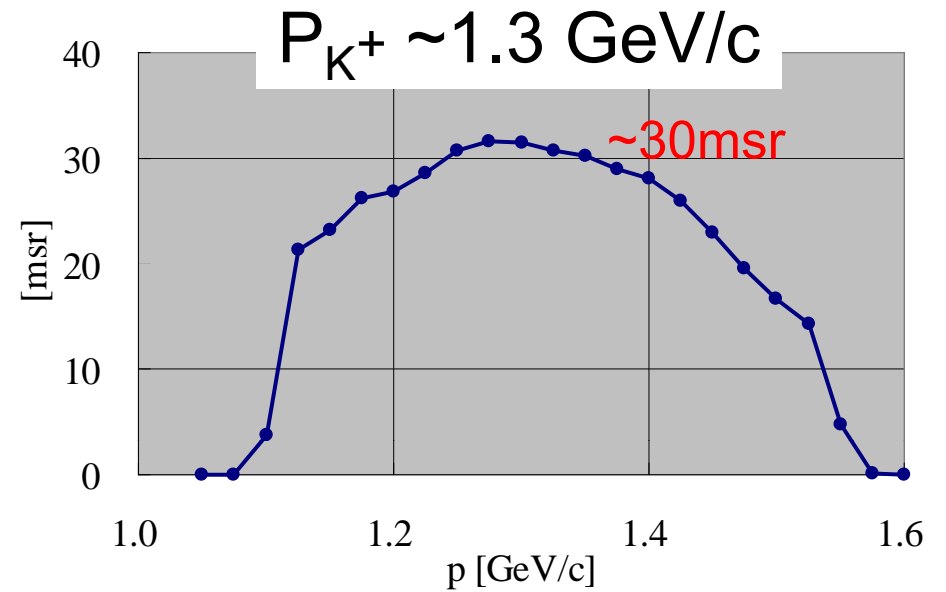
- One boson exchange (NHC-D, Ehime)
 - strong attraction in odd states \rightarrow strong A dependence
- ESC04d*
 - strong attraction in 3S_1 (T=0)

SksPlus Spectrometer

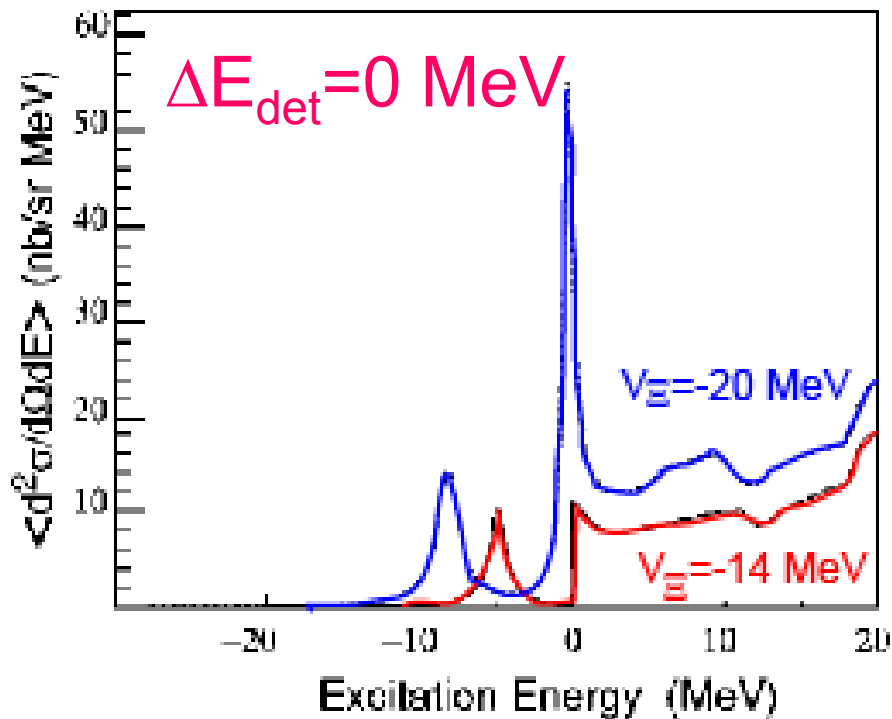


- 95° total bend
- ~7m flight path
- $\Delta x = 0.3$ mm (RMS)

high resolution: $\Delta E \sim 3$ MeV



$^{12}\text{C}(K^-, K^+)^{12}_{\Xi}\text{Be}$ spectra calculated by W.S. potential

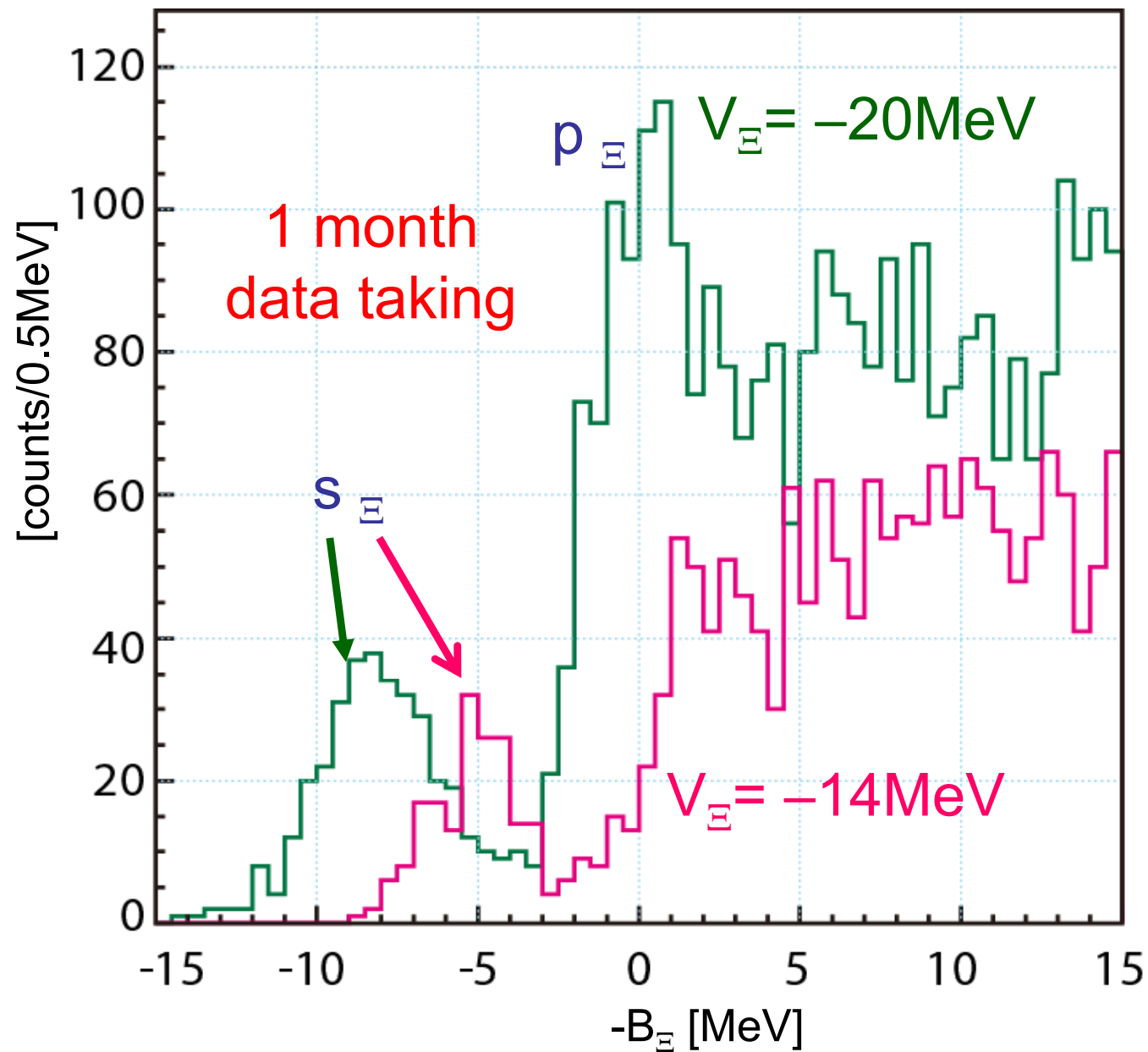


P.Khaustov, et al.
Phys. Rev. C61(2000)054603

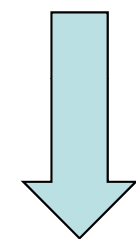
		V_{Ξ}^0 [MeV]			
states		-24	-20	-16	-12
s-state		[nb/sr]			
$0p_{3/2} \rightarrow 0s_{1/2}$	1^-	215	168	123	81
p-states		[nb/sr]			
$0p_{3/2} \rightarrow 0p_{3/2}$	0^+	29	20	—	—
	2^+	164	103	—	—
$0p_{3/2} \rightarrow 0p_{1/2}$	2^+	152	93	—	—
sum		345	216	—	—

K.Ikeda, et al,
Prog. Theor. Phys. 91 (1994) 747 ;
Y.Yamamoto, et al,
Prog. Theor. Phys. Suppl. 117 (1994) 281

Expected $^{12}_{\text{B}}\text{Be}$ Spectrum



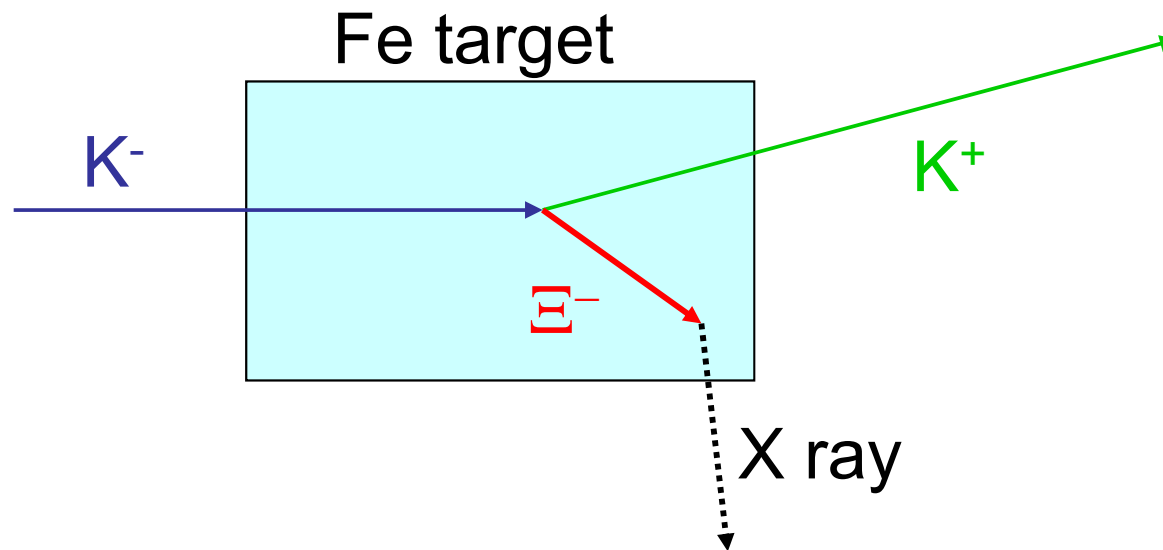
$\Delta E = 3 \text{ MeV}_{\text{FWHM}}$



Optical potential

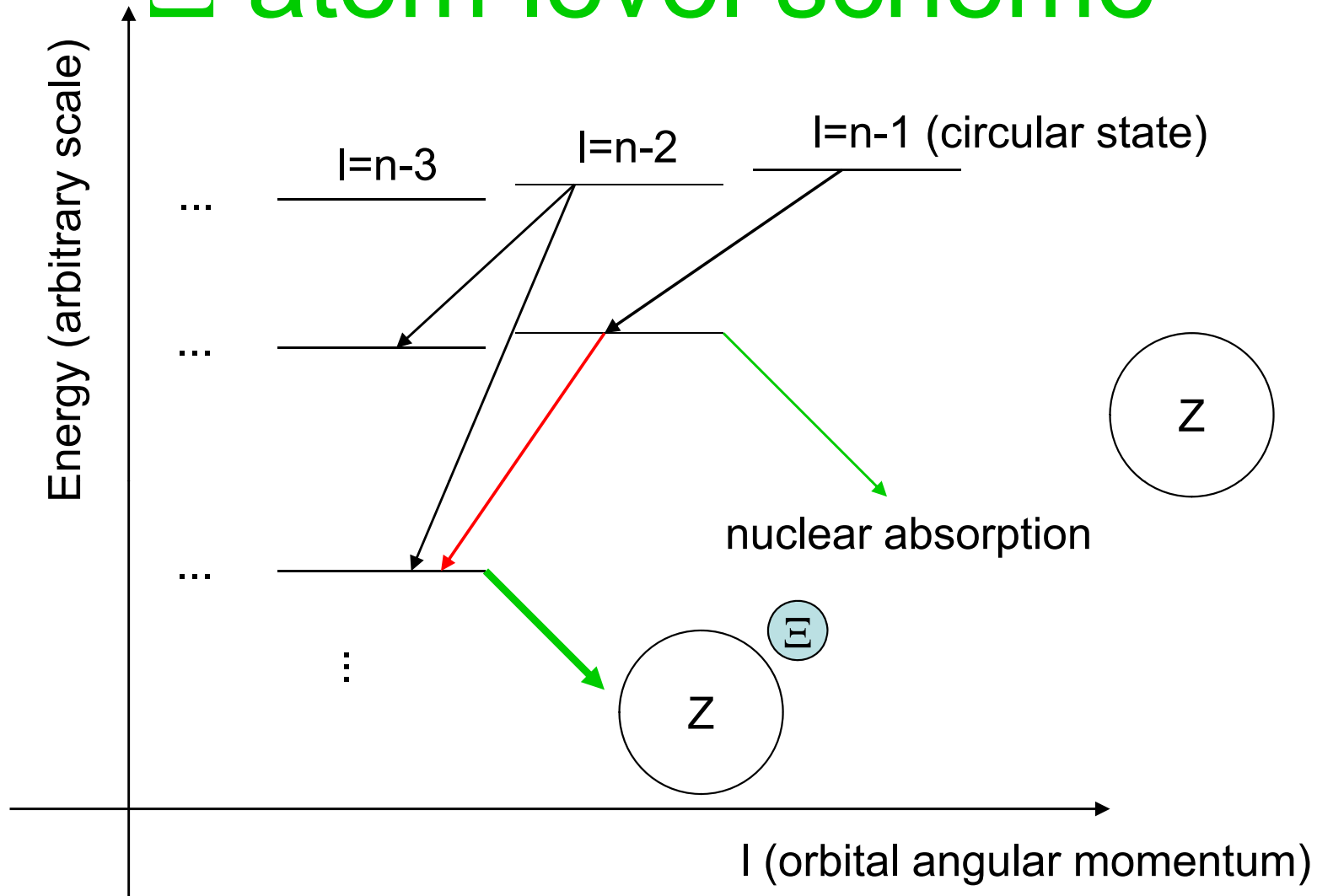
E03 X-ray spectroscopy of Ξ atom

- The first measurement of X rays from Ξ -atom
 - Gives direct information on the Ξ A optical potential
- Produce Ξ^- by the $\text{Fe}(K^-, K^+)$ reaction, make it stop in the target, and measure X rays.



- Aiming at establishing the experimental method
- Possibility for double- Λ hypernuclear γ -ray

Ξ atom level scheme

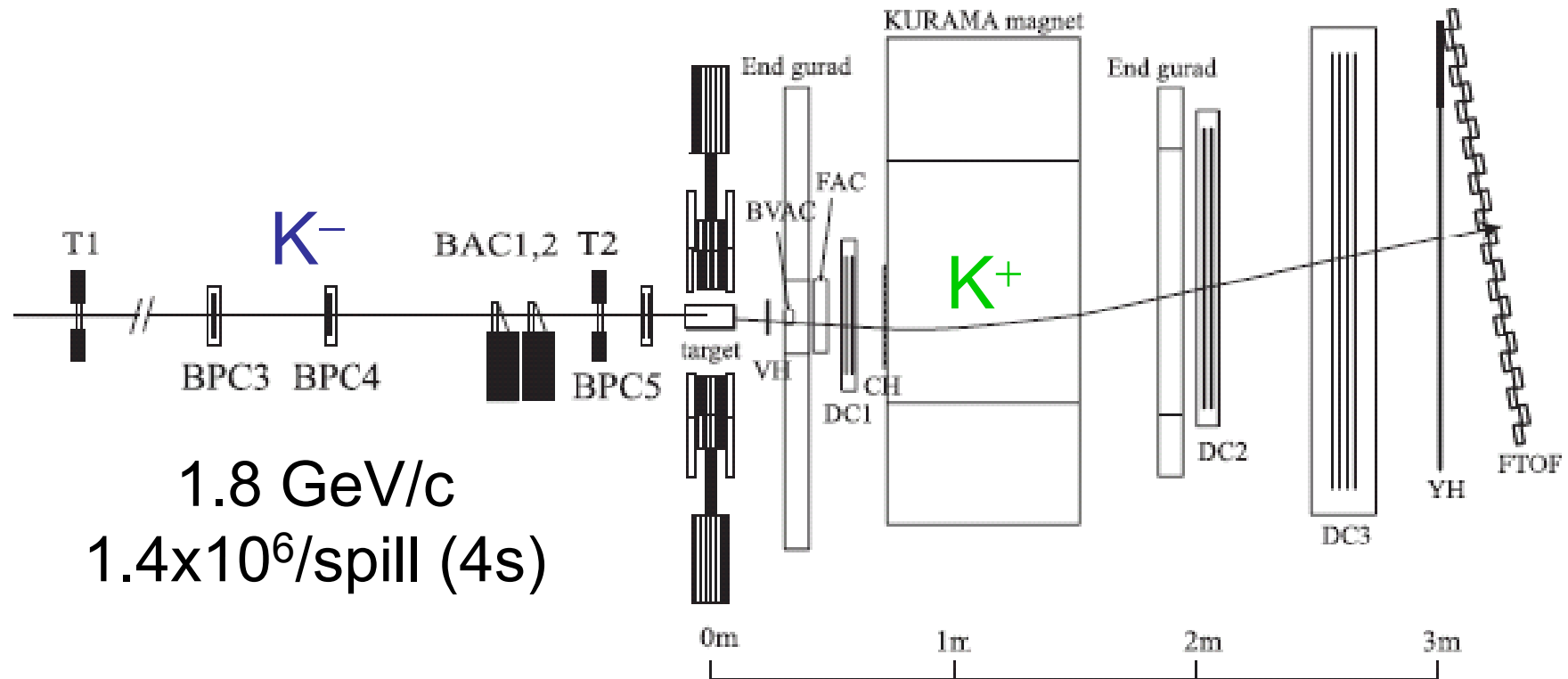


X ray energy shift – real part

Width, yield – imaginary part

Successfully used for π^- , K^- , \bar{p} , and Σ^-

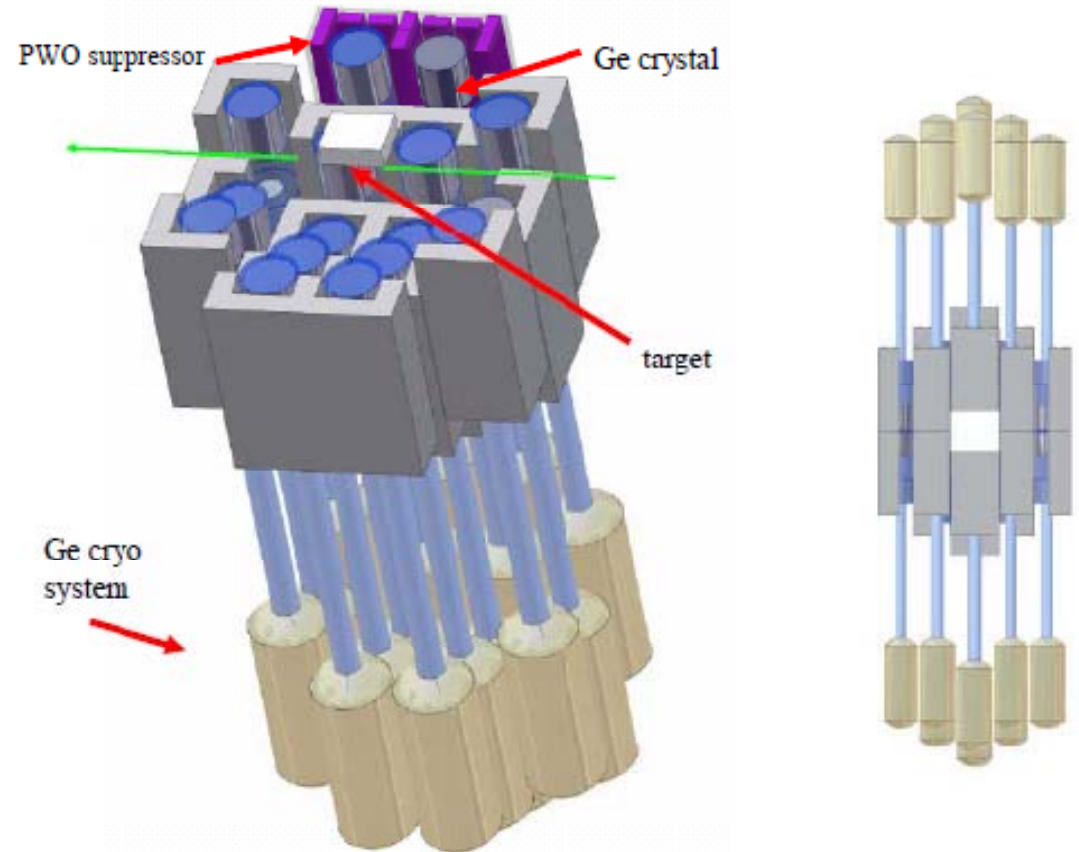
Experimental setup



- Long used at KEK-PS K2 beamline (E373, E522, ...)
- Large acceptance (~0.2 sr)

X-ray detector

- **Hyperball-J**
 - 30 Ge detectors
 - PWO anti-Compton
- Detection efficiency
 - **16%** at 286 keV
- High-rate capability
 - < 50% deadtime
- Calibration
 - In-beam, simultaneous
 - Accuracy \sim **0.05 keV**
- Resolution
 - **\sim 2 keV (FWHM)**



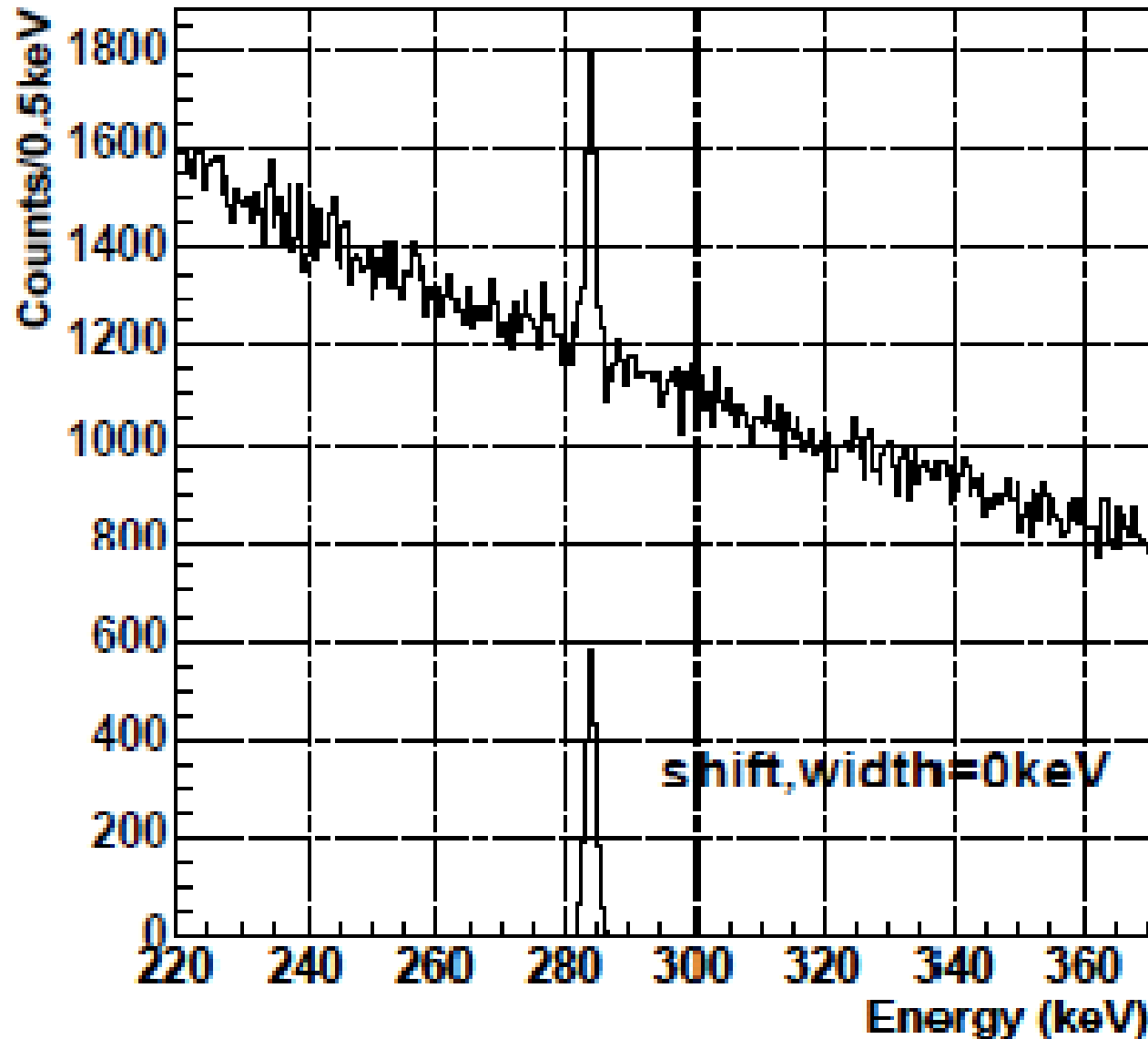
Details by K. Shirotori
(Mon. Poster M02)

Yield & sensitivity estimation

- Total number of K⁻: 1.0×10^{12} for 800 hours.
- Yield of Ξ
 - production: 3.7×10^6
 - stopped: 7.5×10^5
- X-ray yield: **2500** for n=6→5 transition
 - 7200 for n=7→6
- Expected sensitivity
 - Energy shift: ~ 0.05 keV (systematic dominant)
 - Good for expected shift (~ 1 keV, 4.4 keV by Koike)
< 5% accuracy for optical potential depth
 - Width: directly measurable down to ~ 1 keV
 - X-ray yield gives additional (indirect) information on absorption potential.

Expected X-ray spectrum

(b) (6,5) \rightarrow (5,4)

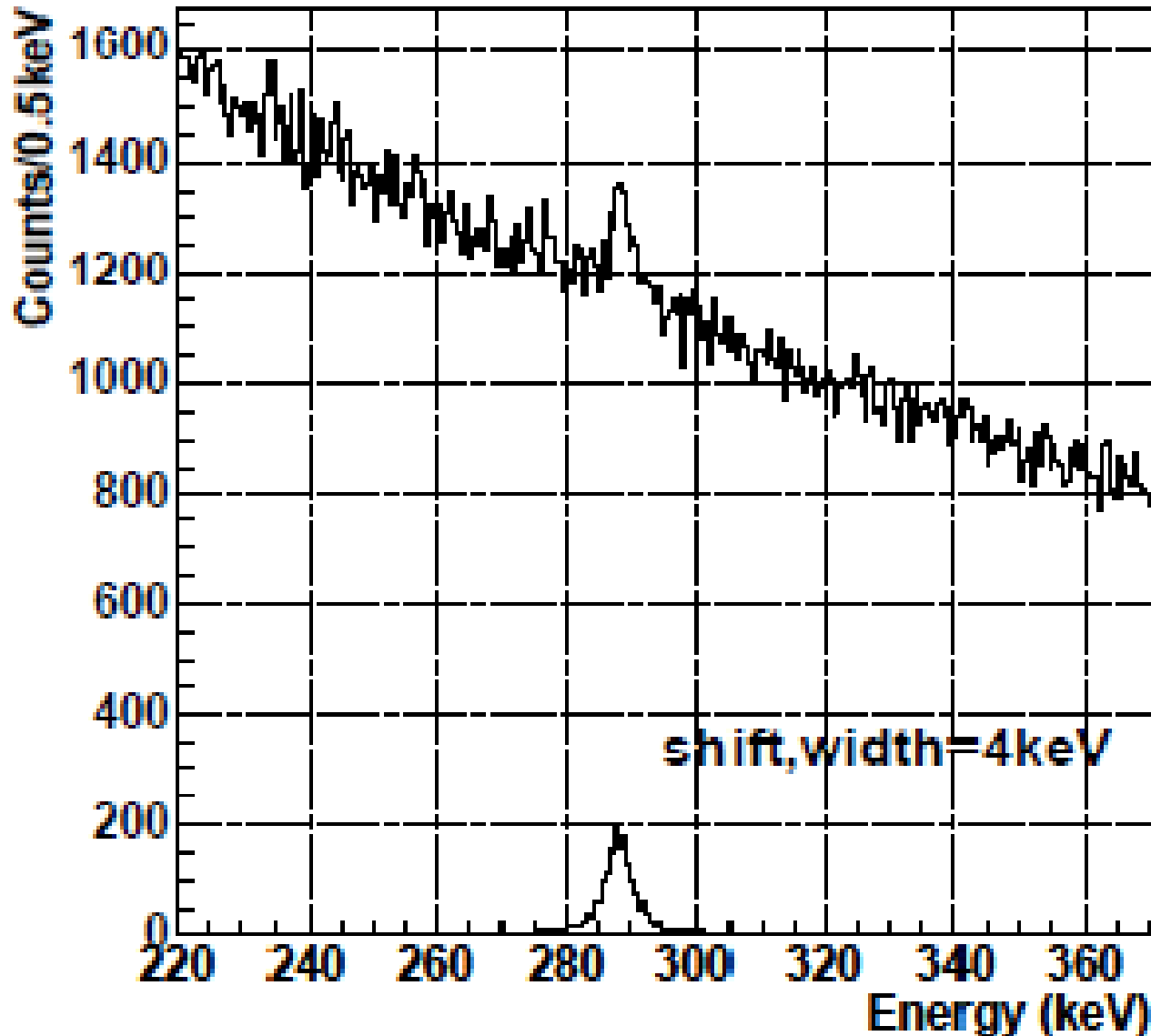


$n = 6 \rightarrow 5$

shift & width
0 keV

Expected X-ray spectrum(2)

(a) (6,5) \rightarrow (5,4)



$n = 6 \rightarrow 5$

shift & width
4 keV

$\delta E \sim 0.05$ keV

$\delta \Gamma \sim 1$ keV

+ additional info.
by γ -ray yield

Summary & perspective

- Ever-strongest kaon beam:
 - Unique feature of J-PARC
- Nuclei & hadrons with strangeness:
 - 12 experiments (out of total 18) are approved
→ **Main topic of J-PARC physics**
- Variety of experiments: From $S=+1$ to -2
 - 14 talks and posters for specific experiments
→ **Please refer to them for details**
- Uniqueness in $S=-2$ nuclei and atoms
 - 3 experiments: E03, E05, and E07
- **Beamtime is coming SOON!**
 - From this October

	(Co-)Spokespersons	Affiliation	Title of the experiment	Approval status (PAC recommendation)
E03	K. Tanida	Kyoto U	Measurement of X rays from Ξ^- Atom	Stage 2
P04	J. C. Peng; S. Sawada	U. of Illinois at Urbana-Champaign; KEK	Measurement of High-Mass Dimuon Production at the 50-GeV Proton Synchrotron	Deferred
E05	T. Nagae	KEK	Spectroscopic Study of Ξ -Hypernucleus, $^{13}_{\Xi}\text{Be}$, via the $^{12}\text{C}(K^-, K^+)$ Reaction	Stage 2
E06	J. Imazato	KEK	Measurement of T-violating Transverse Muon Polarization in $K^+ \rightarrow \pi^0 \mu^+ \nu$ Decays	Stage 1
E07	K. Inai, K. Nakazawa, H. Tamura	Kyoto U., Gifu U., Tohoku U.	Systematic Study of Double Strangeness System with an Emulsion-counter Hybrid Method	Stage 2
E08	A. Krutenkova	IITP	Pion double charge exchange on oxygen at J-PARC	Stage 1
E10	A. Sakaguchi, T. Fukuda	Osaka U	Production of Neutron-Rich Lambda-Hypernuclei with the Double Charge-Exchange Reaction (Revised from Initial P10)	Stage 2
E11	K. Nishikawa	KEK	Tokai-to-Kamioka (T2K) Long Baseline Neutrino Oscillation Experimental Proposal	Stage 2
E13	T. Tamura	Tohoku U.	Gamma-ray spectroscopy of light hypernuclei	Stage 2
E14	T. Yamanaka	Osaka University	Proposal for $K_L \rightarrow \pi^0 \nu \bar{\nu}$ Experiment at J-PARC	Stage 2
E15	M. Iwasaki,	RIKEN, KEK	A Search for deeply-bound kaonic nuclear states by in-flight $^3\text{He}(K^-, n)$ reaction	Stage 2
E16	S. Yokkaichi	RIKEN	Electron pair spectrometer at the J-PARC 50-GeV PS to explore the chiral symmetry in QCD	Stage 1
E17	R. Hayano, H. Ota	U. Tokyo, RIKEN	Precision spectroscopy of Kaonic ^3He $3d \rightarrow 2p$ X-rays	Stage 2
E18	H. Bhang, H. Ota, H. Park	SNU, RIKEN, KRISS	Coincidence Measurement of the Weak Decay of $^{12}_{\Lambda}\text{C}$ and the three-body weak interaction process	Stage 1
E19	M. Naruki	RIKEN	High-resolution Search for Θ^+ Pentaquark in $\pi^+ p \rightarrow K^+ X$ Reactions	Stage 2
E21	Y. Kuno	Osaka U	An Experimental Search for $\mu - e$ Conversion at a Sensitivity of 10^{-16} with a Slow-Extracted Bunched Beam	Stage 1
E22	S. Ajimura, A. Sakaguchi	Osaka U	Exclusive Study on the Lambda-N Weak Interaction in A=4 Lambda-Hypernuclei (Revised from Initial P10)	Stage 1
T25	S. Mihara	KEK	Extinction Measurement of J-PARC Proton Beam at KI. 8BR	test experiment
P26	K. Ozawa	U. Tokyo	Direct measurements of omega mass modification in $A(\pi^- n)\omega$ reaction and $\omega \rightarrow \pi^0 \gamma$ decays	Deferred
E27	T. Nagae	Kyoto U	Search for a nuclear Kbar bound state $K^+ pp$ in the $d(\pi^+, K^+)$ reaction	Stage 1
P28	H. Fujioka	Kyoto U	Study of isospin dependence of kaon-nucleus interaction by in-flight $^3\text{He}(K^-, n/p)$ reactions	approved as a part of E15
P29	H. Ohnisi	RIKEN	Study of in medium mass modification for phi meson using phi meson bound state in nucleus	Deferred
P30	T. Suzuki	U. Tokyo	The investigation of $\Lambda(1405)$ state via the $d(K^+ \text{stopped}, n) (\Sigma \pi^0)$ reaction	Rejected
P31	M. Nomi	Osaka U	Spectroscopic study of hyperon resonances below KN threshold via the $(K^- n)$ reaction on Deuteron	Deferred

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