



Hadronic Physics at the J-PARC Facility

Shin'ya Sawada

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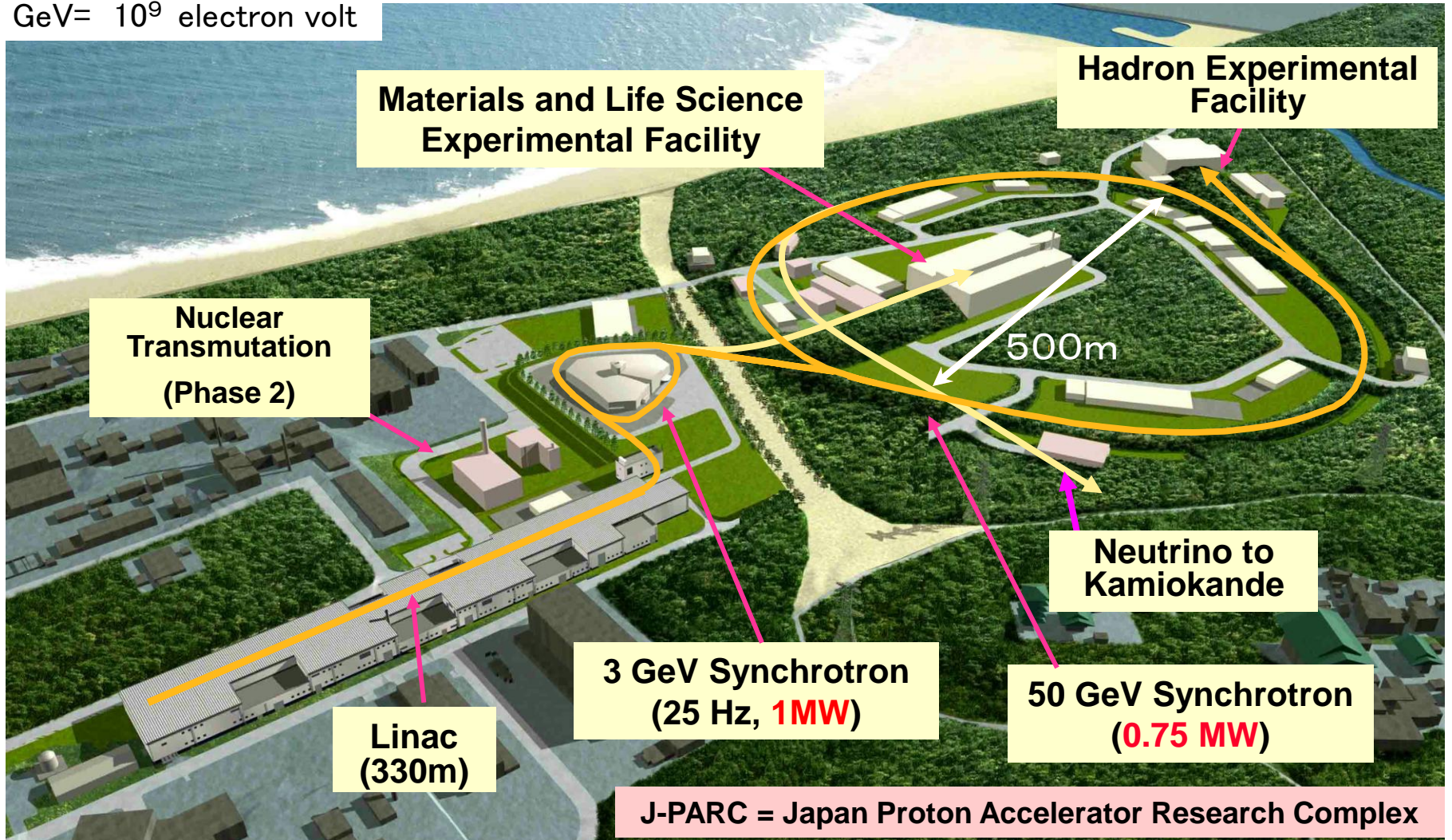


- Overview of J-ARC
- Current Hadron Experimental Facility (Hadron Hall) and the 1st Experiments
- Coming Experiments and Facility
- Summary



J-PARC Facility

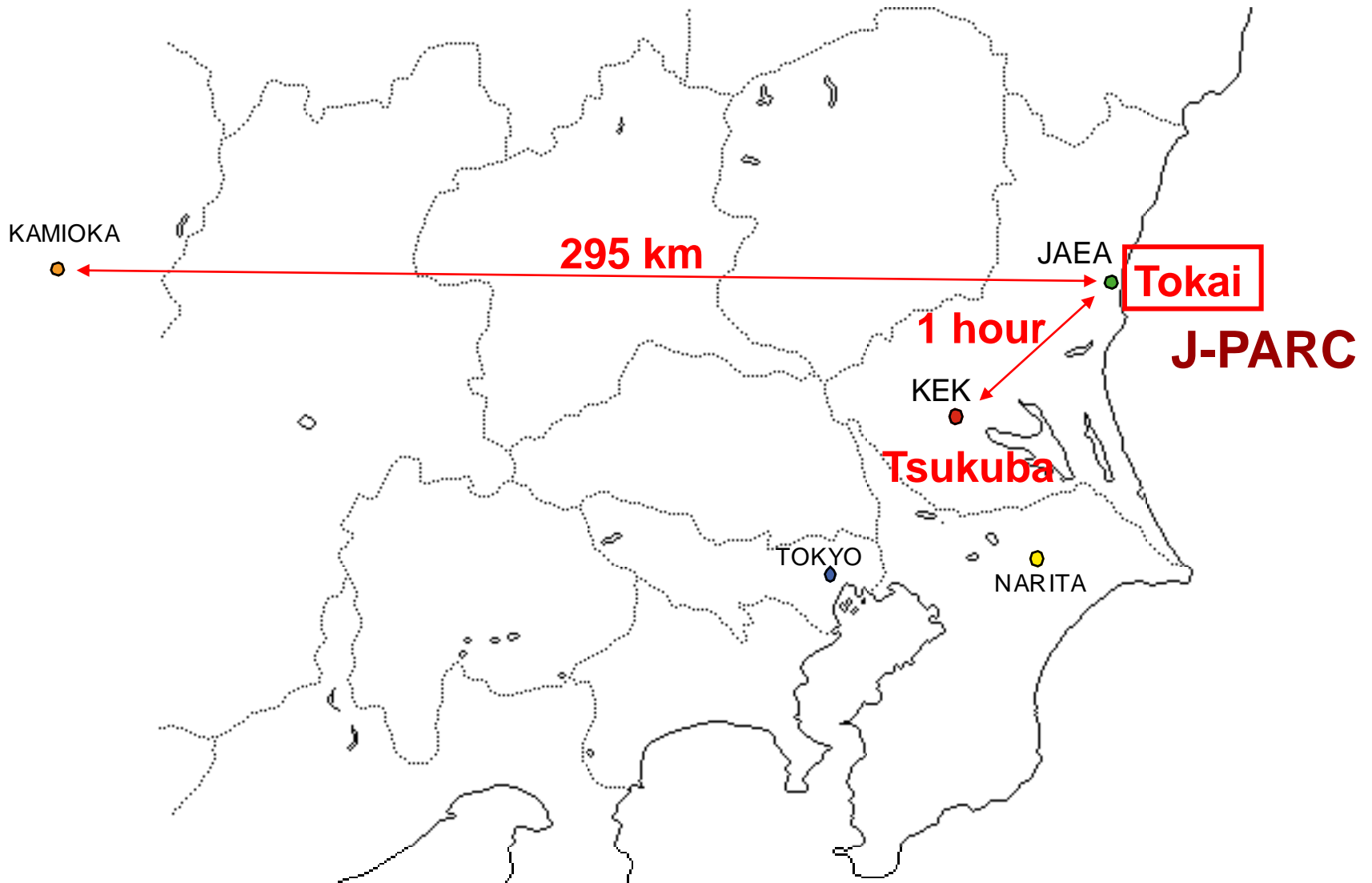
GeV= 10^9 electron volt



Joint Project between KEK and JAEA



Location of J-PARC at Tokai



**J-PARC Facility
(KEK/JAEA)**

South to North

Linac

3 GeV
Synchrotron

Neutrino Beams
(to Kamioka)

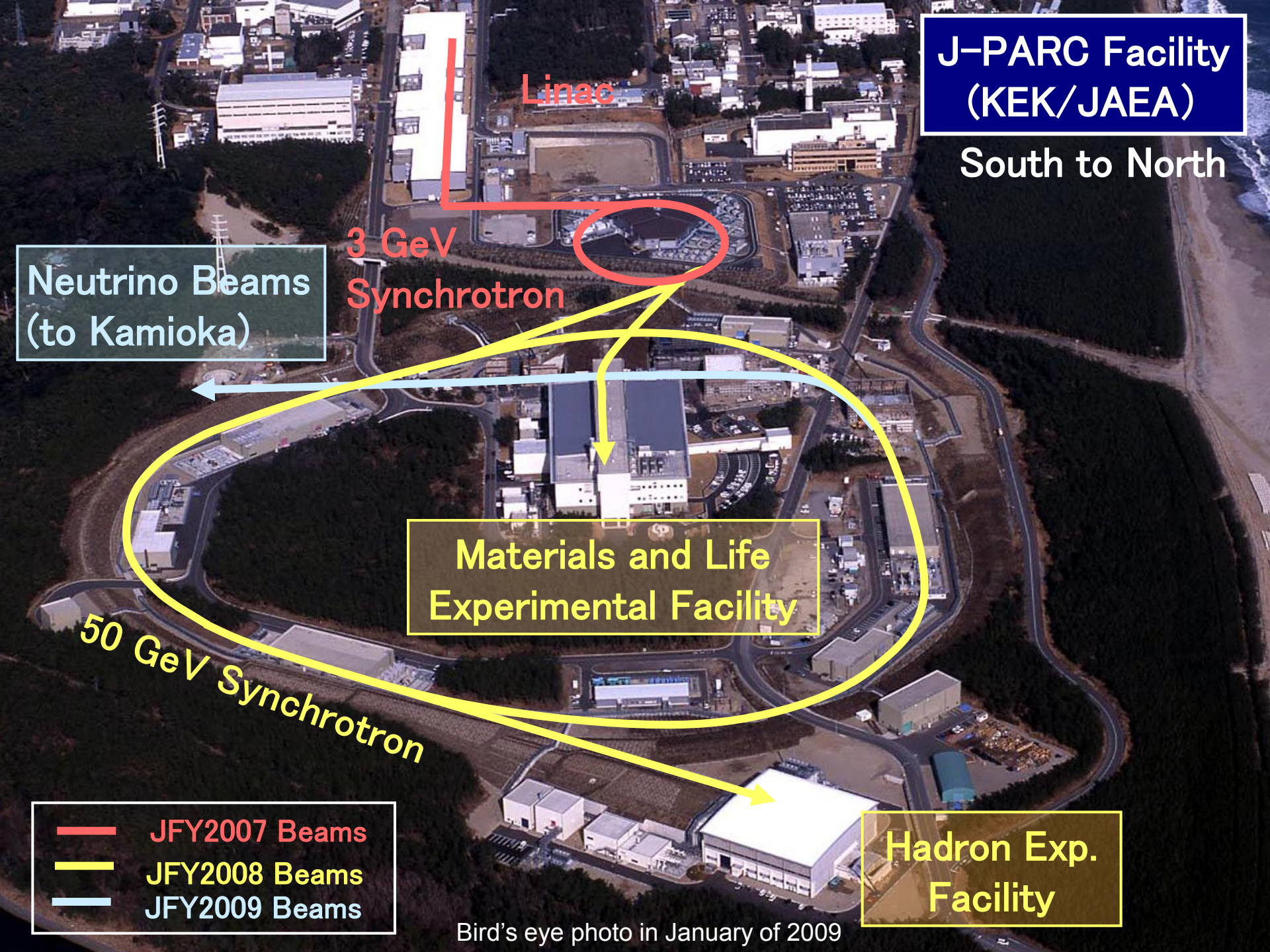
Materials and Life
Experimental Facility

50 GeV Synchrotron

Hadron Exp.
Facility

- JFY2007 Beams
- JFY2008 Beams
- JFY2009 Beams

Bird's eye photo in January of 2009

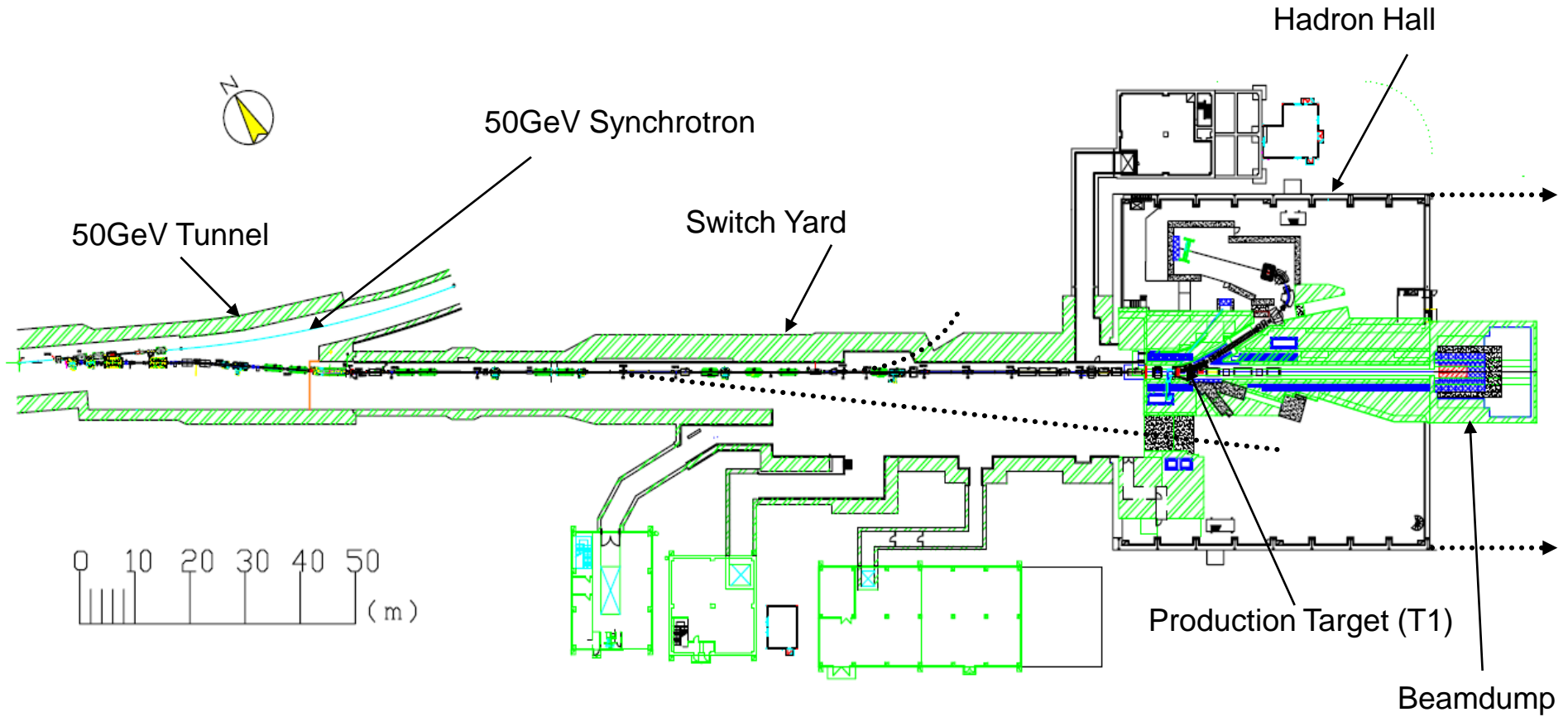


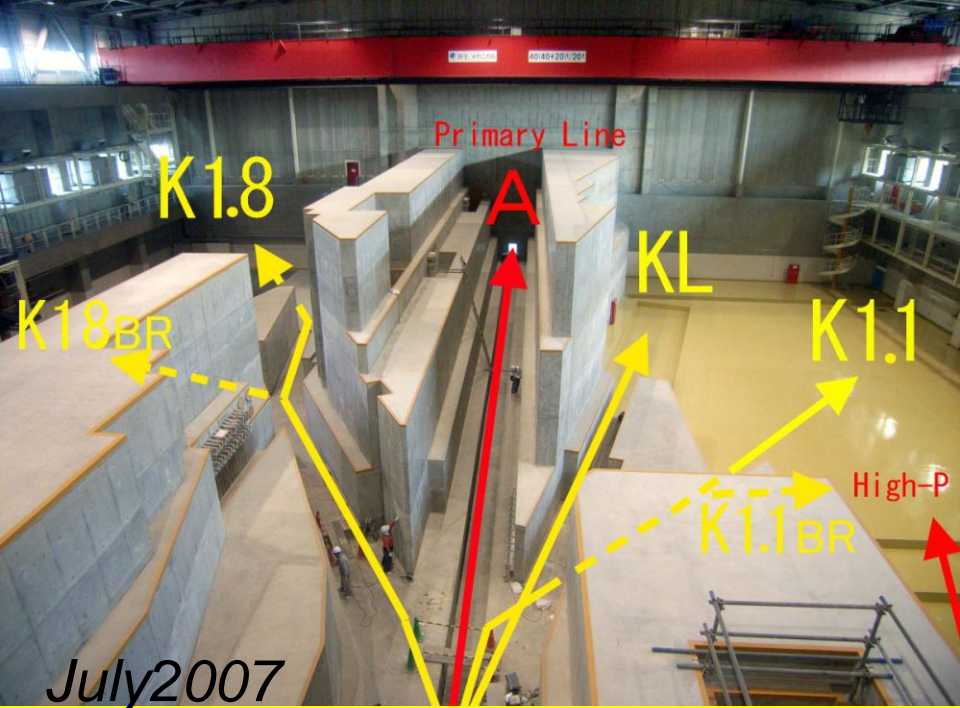


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Hadron Experimental Facility (December, 2008)

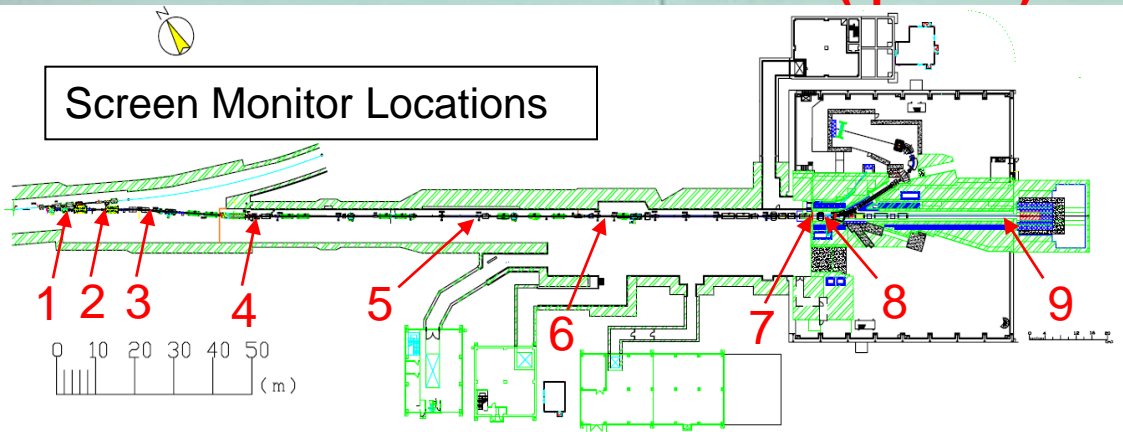
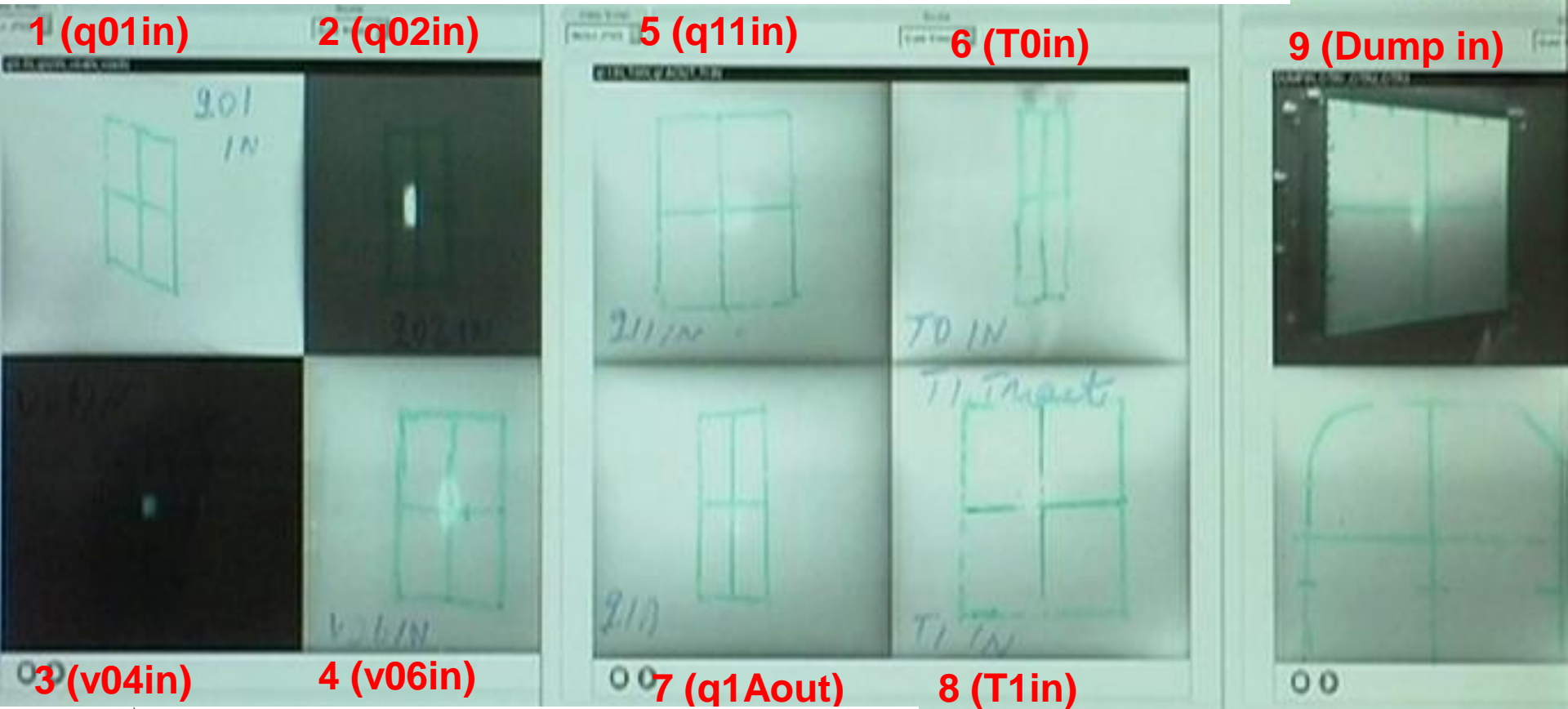




Construction of Hadron Experimental Hall



Typical Beam Profiles measured with Screen Monitors



January 27th, 2009

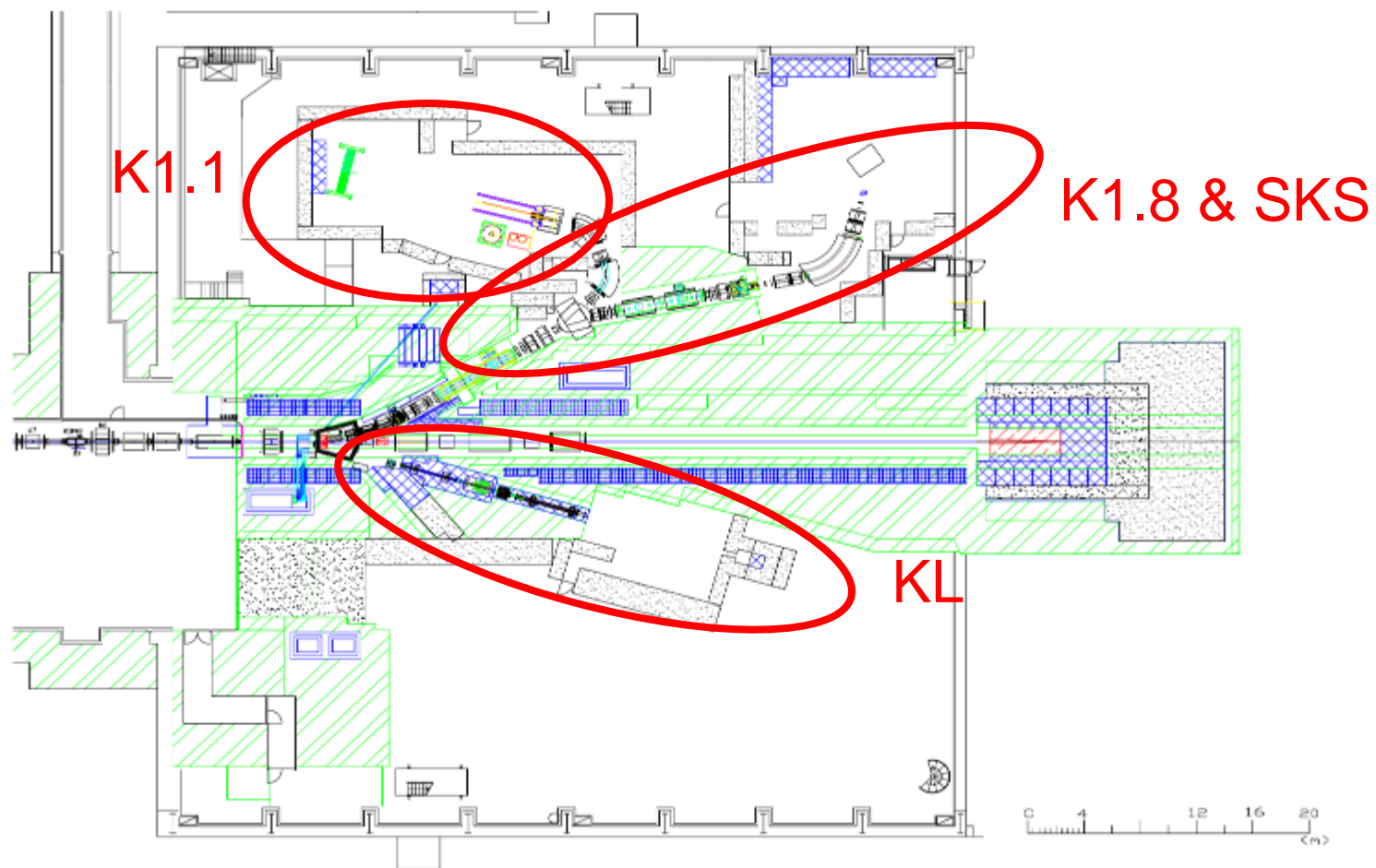


Current Accelerator Status

- 30-GeV protons with slow and fast extraction
- Fast extracted protons are used for the neutrino experiment (T2K).
 - Beam power ~ 40 kW.
 - 100 kW is an immediate goal.
- Slow extracted protons are used at Hadron Hall.
 - Beam power ~ 1 – 2 kW, almost similar to KEK-PS.
 - 5 kW in this fall (October 12 -), and 20 – 30 kW is a goal in a couple of years.
 - Current accelerator cycle is 6 sec with 1.5-2 sec beam spill.
 - Accelerator people, collaborating with our hadron group, work to improve the beam structure for higher duties. It might take a bit time to get a pure “DC” beam.
 - About 10+ days of total beam time to Hadron Hall between October, 2009, and February, 2010.
 - The next beam time at Hadron Hall is from October 12, 2010.

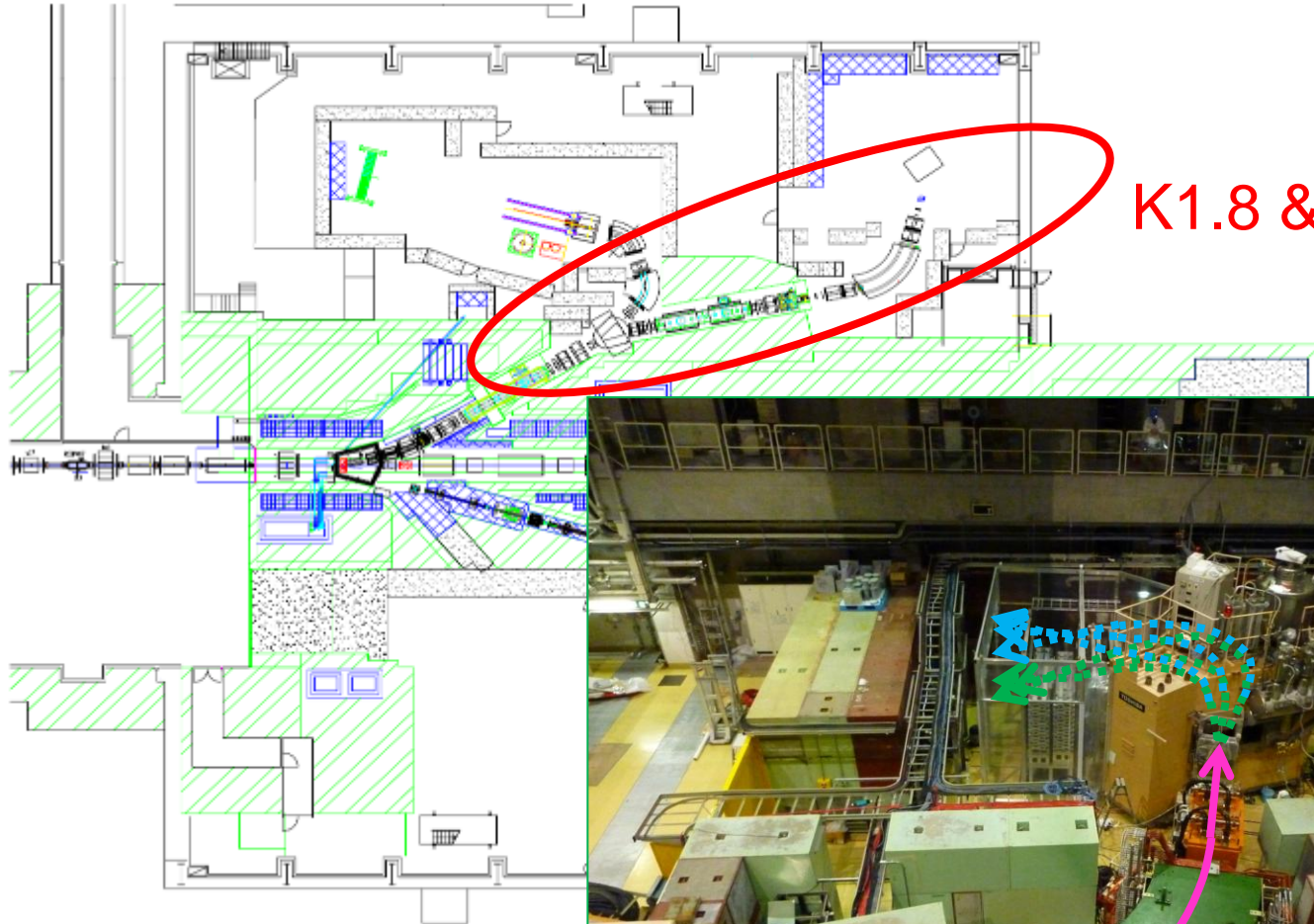


Current Hadron Hall at February, 2010

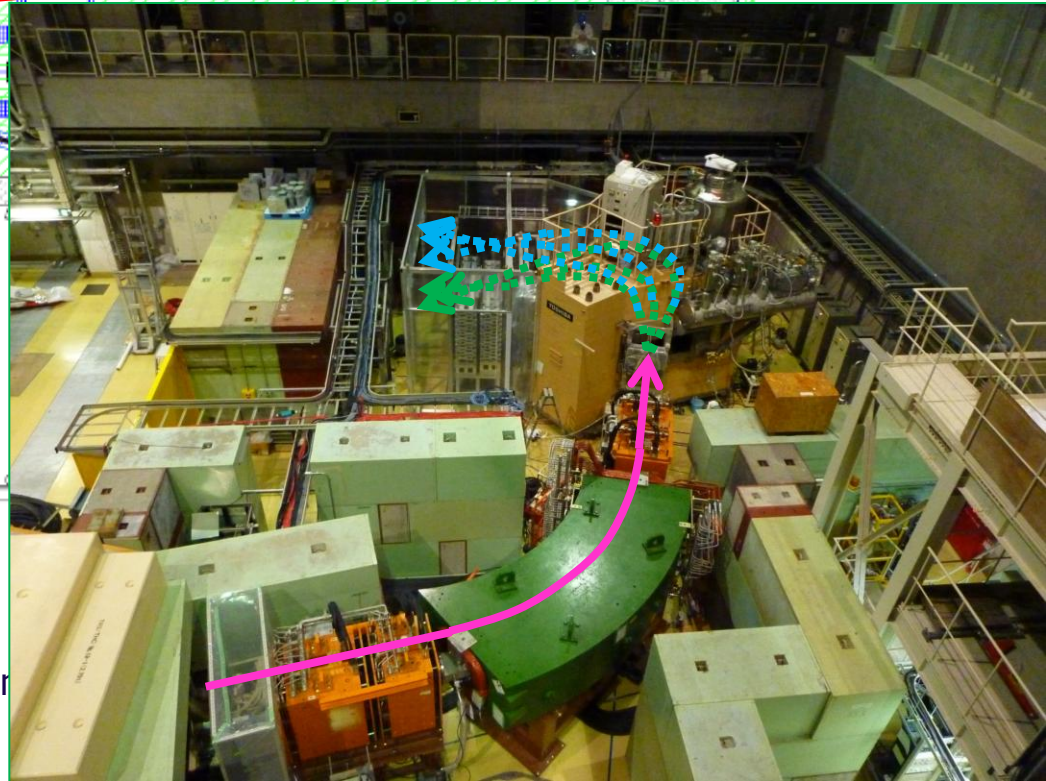




K1.8 Beamline



K1.8 & SKS



June 1, 2010

Shir



K1.8 Beamline

$$P_{\max} = 2.0 \text{ GeV/c}$$

Double stages of E.S. Separators

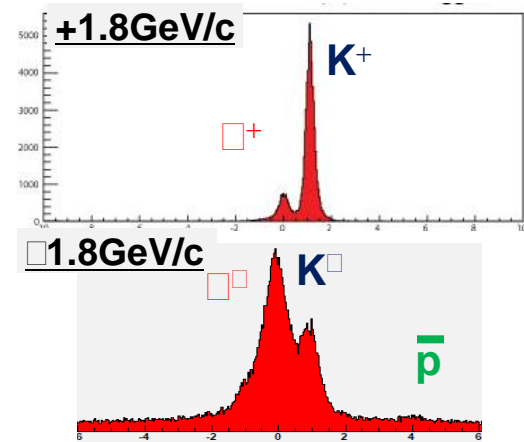
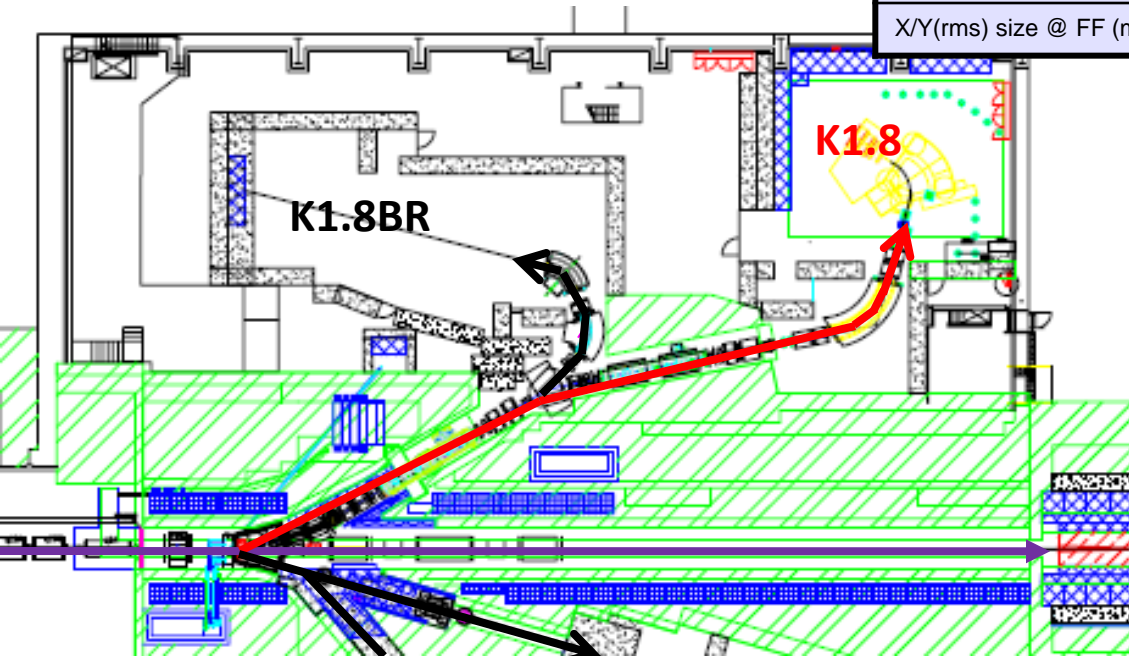
High-resolution beam spectrometer



Suitable for $S=-2$ Spectroscopy

750kW 270kW

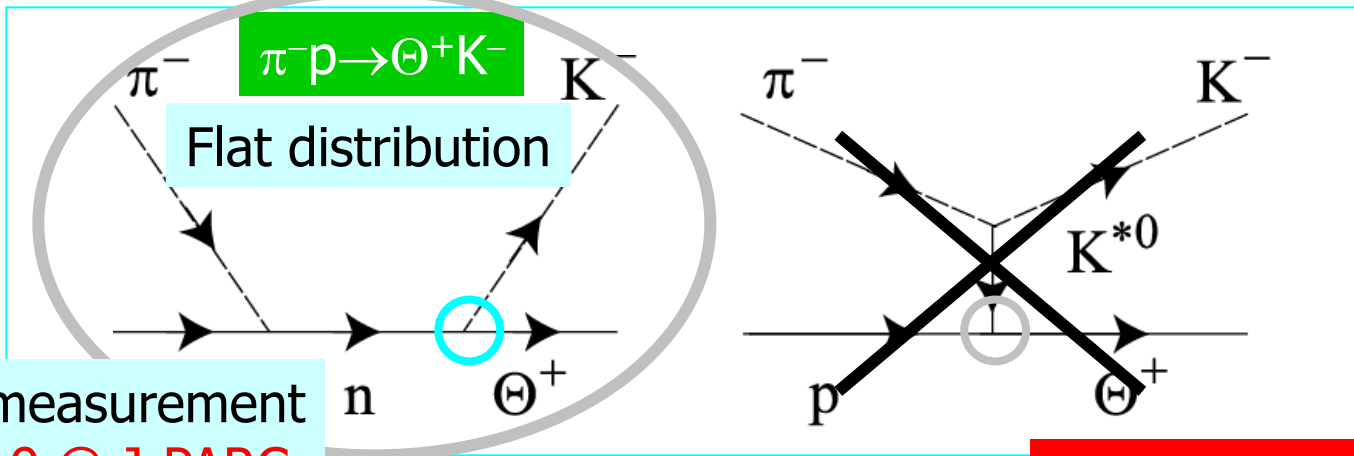
Primary proton beam	50 GeV-15μA	30 GeV-9μA
Length (m)	45.853	
Acceptance (msr.%)	1.4	
K ⁻ (π) intensity (ppp) @ 1.8 GeV/c	6.6E+06	1.4E+06
@ 1.5 GeV/c	2.7E+06	0.54E+06
@ 1.1 GeV/c	0.38E+06	0.08E+06
Electrostatic separators	750kV/10cm, 6m×2	
Single rate @ MS2 @ 1.8 GeV/c	> 33E+06	> 8E+06
K ⁻ /(π+μ ⁻) @ FF @ 1.8 GeV/c	4	3.5
X/Y(rms) size @ FF (mm)	19.8/3.2	





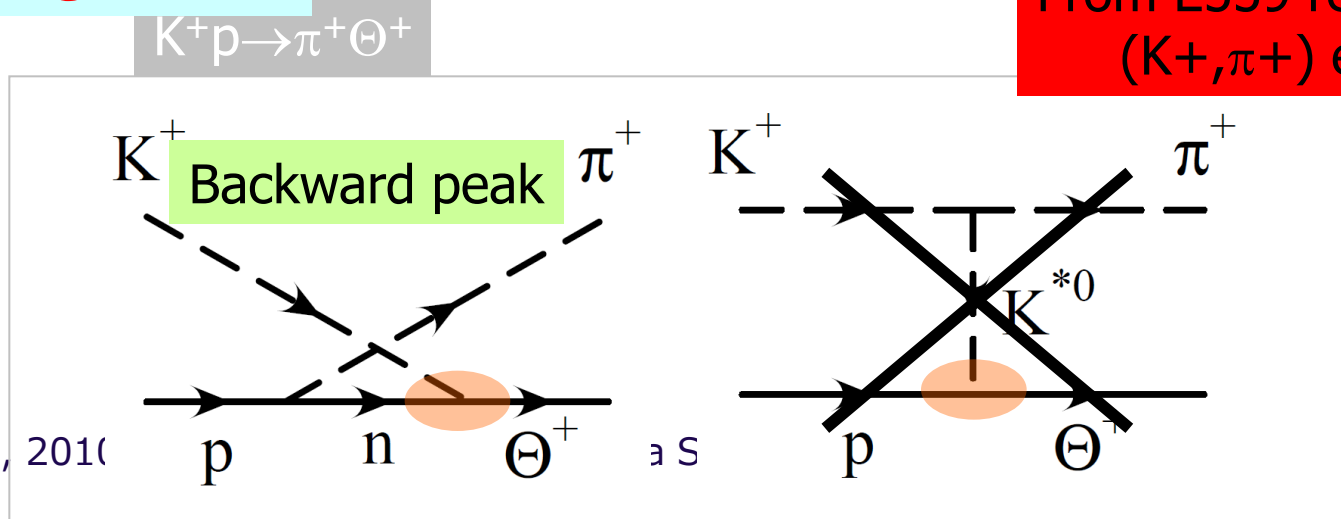
1st experiment at K1.8

- E19 at K1.8/SKS: Θ^+ pentaquark in $\pi^-p \rightarrow K^-X$



Precise measurement
E19 @ J-PARC

From E559 result
(K^+, π^+) experiment



June 1, 2010



E19 at K1.8/SKS: Θ^+ pentaquark in $\pi^- p \rightarrow K^- X$

K1.8 beam line + SKS

$2\text{GeV}/c \pi^- + p \rightarrow K^- + \Theta^+$
target : liquid H_2 , reuse E559's

K^- : scattered angle $\leq 40^\circ$
momentum $< 0.9 \text{ GeV}/c$

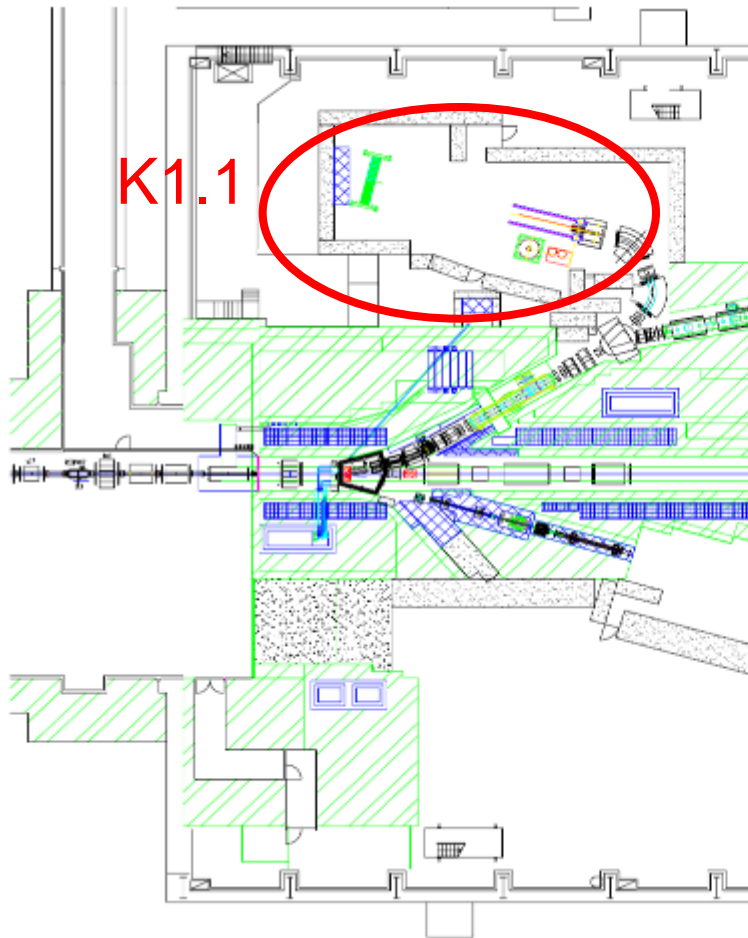
SKS : momentum coverage :
0.7–0.95 GeV/c
angle coverage $\leq 20^\circ$
 $p_{\text{scattered}}$ up to $\sim 1.1 \text{ GeV}/c$
 $dp/p \sim 0.2\% @ 1\text{GeV}/c$
(~ 5 times better than KURAMA)



Even with the initial beam intensity, this experiment will take enough data in a short period.



K1.8BR Beam Line



June 1, 2010

Shin'ya Sawa



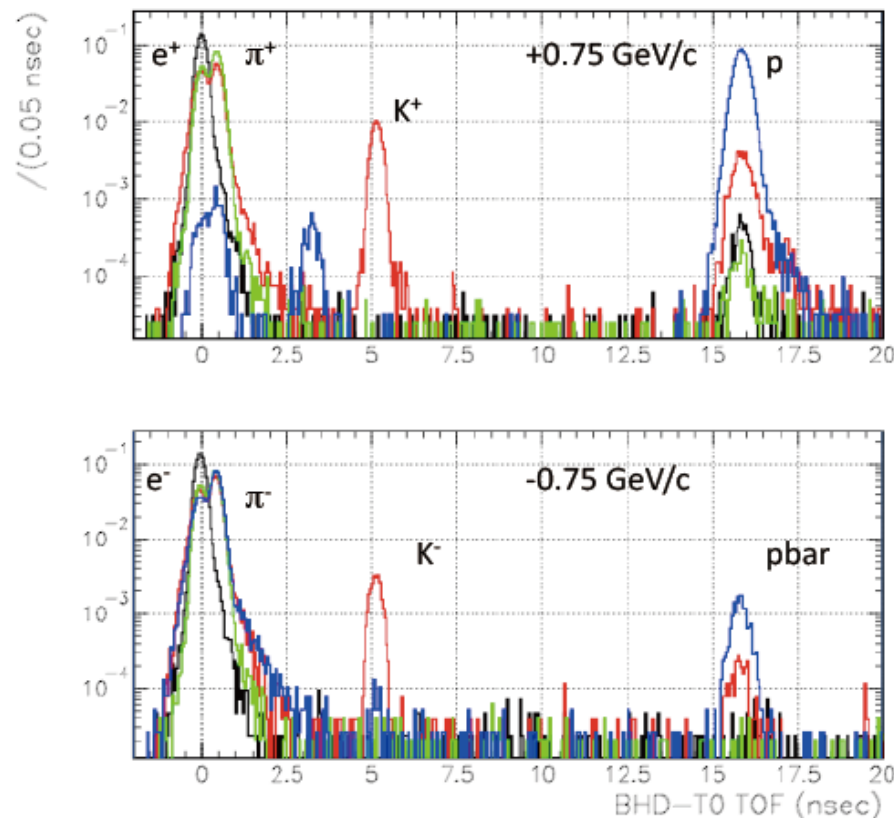
Secondary Particles at K1.8BR

- Beam line commissioning has been almost done.

K1.8BRのrun#27のビーム利用(11/14、11/15、11/19)

By E17/E15 team, T. Suzuki et al.

2009/11/19 08.02



✓ 11/14及び15は+0.75 GeV/c、ESS offで
“e”/“K”/“π”/“p”
のオンライントリガーを構築、KトリガーにおいてはESS offのビームのK/π比を100倍以上改善することが出来た。

✓ 11/19にはCherenov検出器の調整用の大統計データを4時間取得した。

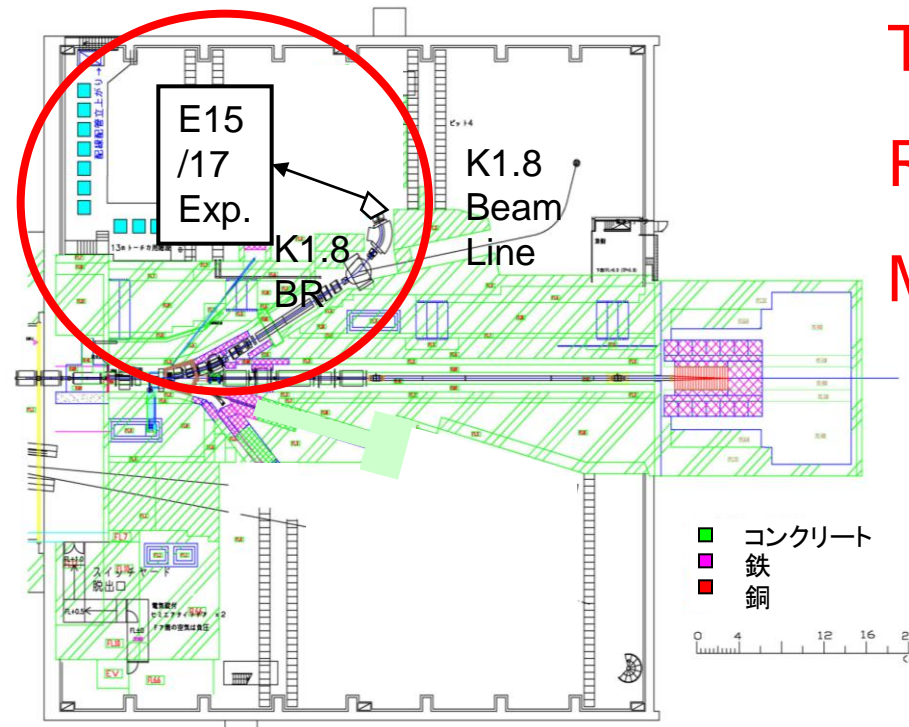
7×10¹⁰ pppのビーム強度においてはK⁺/K⁻の個数はそれぞれショット当たりで全スリット開状態で30/7個であることが確定したため調整を進行するためには、さらなるビーム強度が必須。

June 1, 20



1st Experiments at K1.8BR

- E17 at K1.8BR: Precision spectroscopy of Kaonic ^3He atomic $3d \rightarrow 2p$ X-rays
- E15 at K1.8BR: Next to E17, with almost the same apparatus: Search for K-pp kaonic nuclear bound state



T. Suzuki (2B)

R. Hayano (2B)

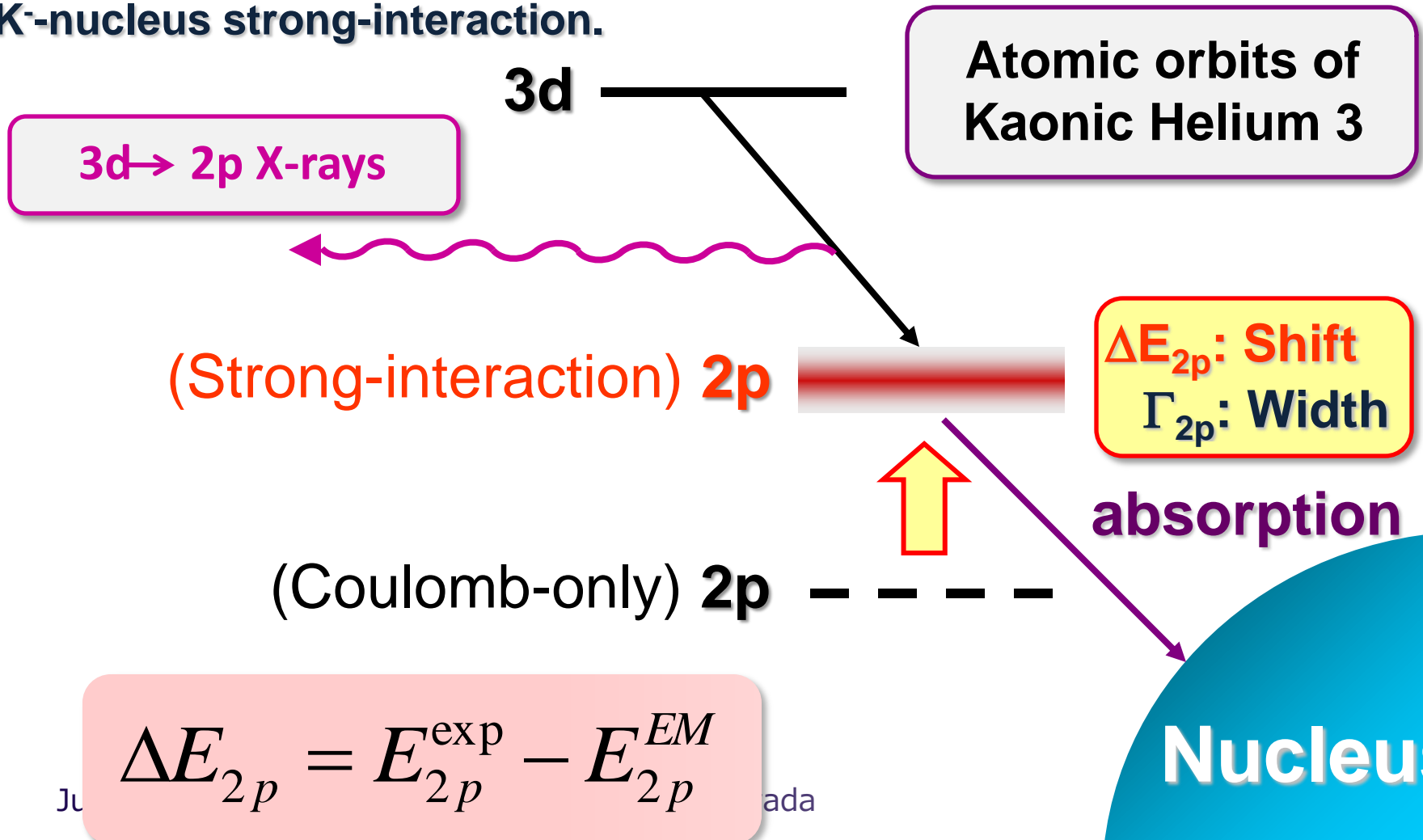
M. Sato (3B)



E17: Strong-interaction Shift and Width of Kaonic Helium 3

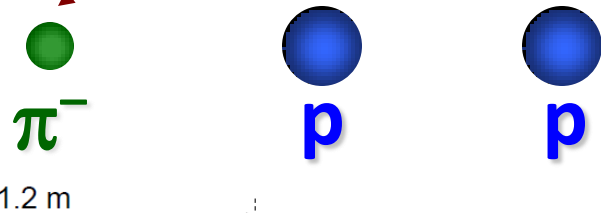
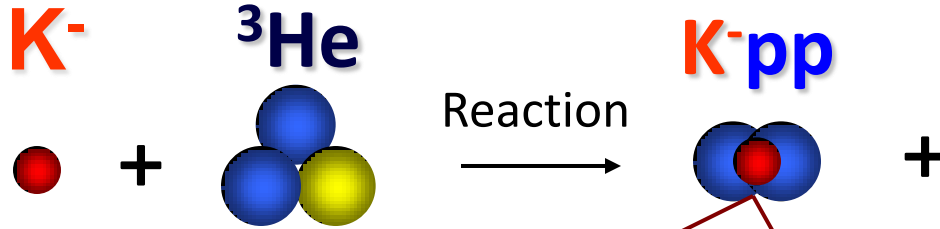
Last orbit of Kaonic atoms is sensitive to K-nucleus strong-interaction.

Slide by Dr. M. Iio





E15: Next to E17



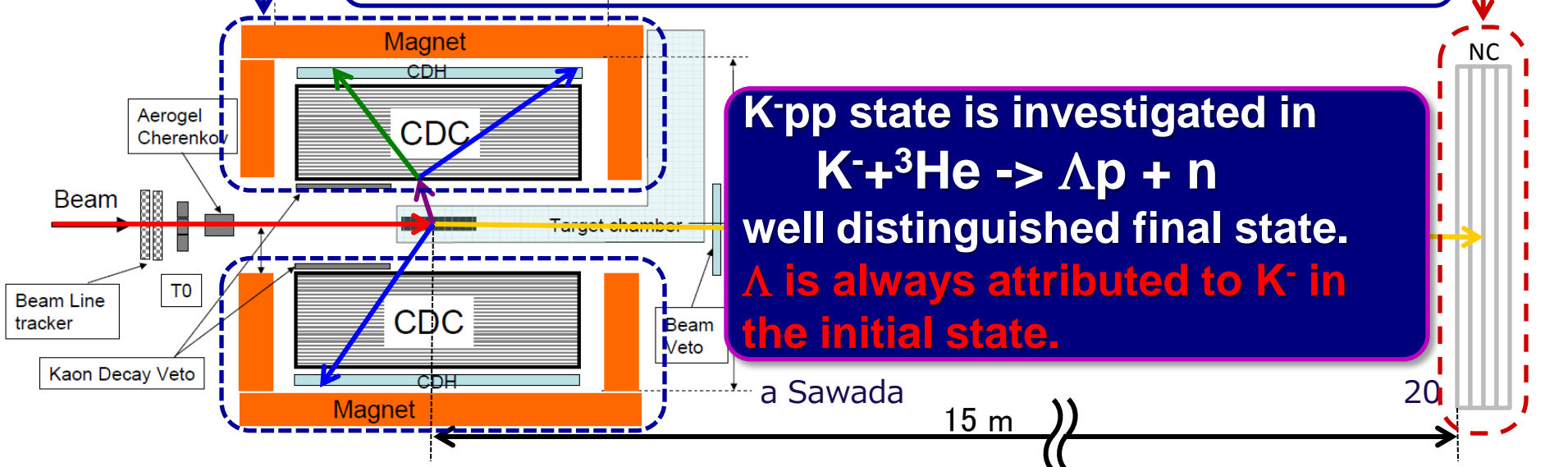
Missing mass spectroscopy

n K^-pp search with TOF measurement of neutron

Decay particle measurement

K^-pp search with exclusive decay particle measurement

K^-pp state is investigated in $K^- + {}^3\text{He} \rightarrow \Lambda p + n$ well distinguished final state. Λ is always attributed to K^- in the initial state.



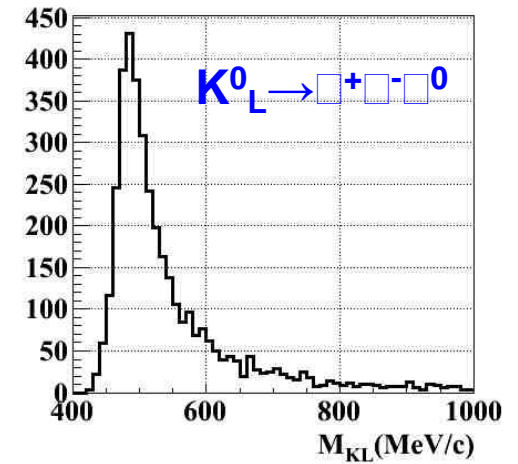
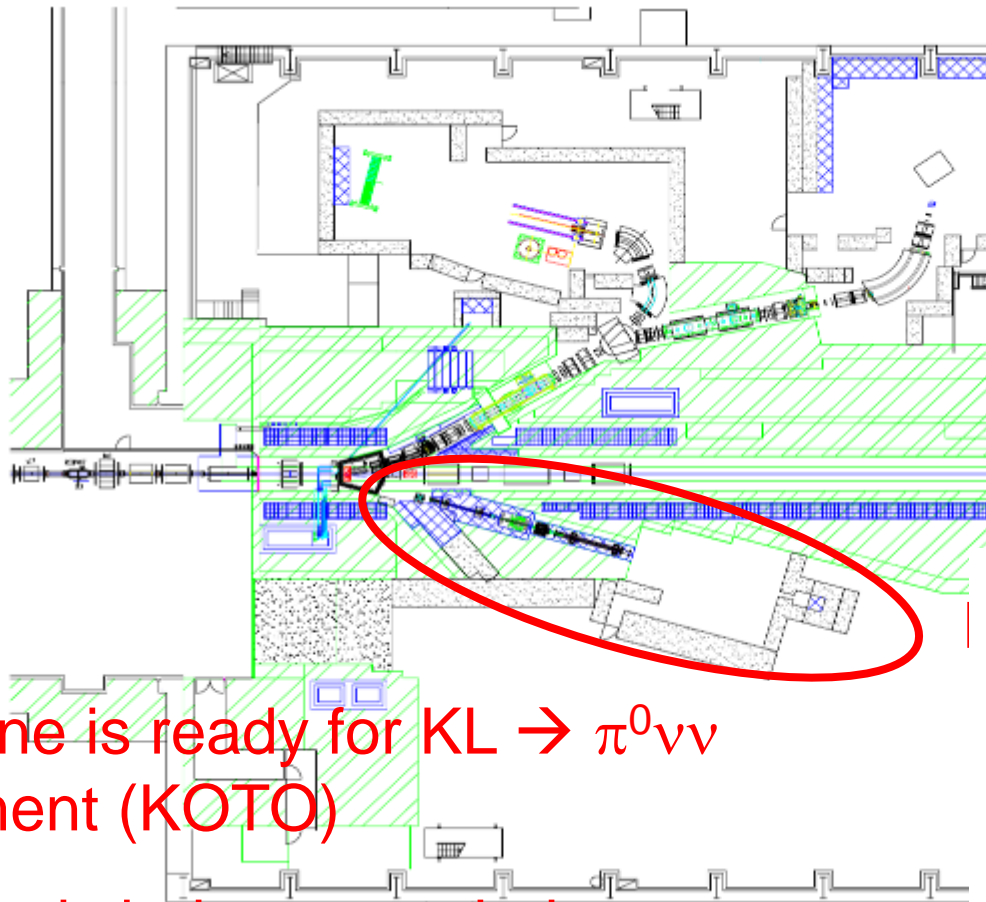
20

15 m

a Sawada

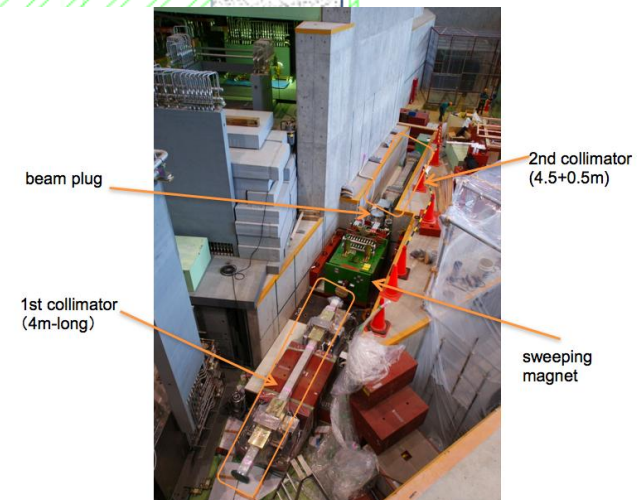


KL Beam Line



Beam line is ready for $KL \rightarrow \pi^0 \nu \nu$ experiment (KOTO)

The area is being extended.



June 1, 2010

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Coming Hadron Physics Experiments: PAC approved experiments

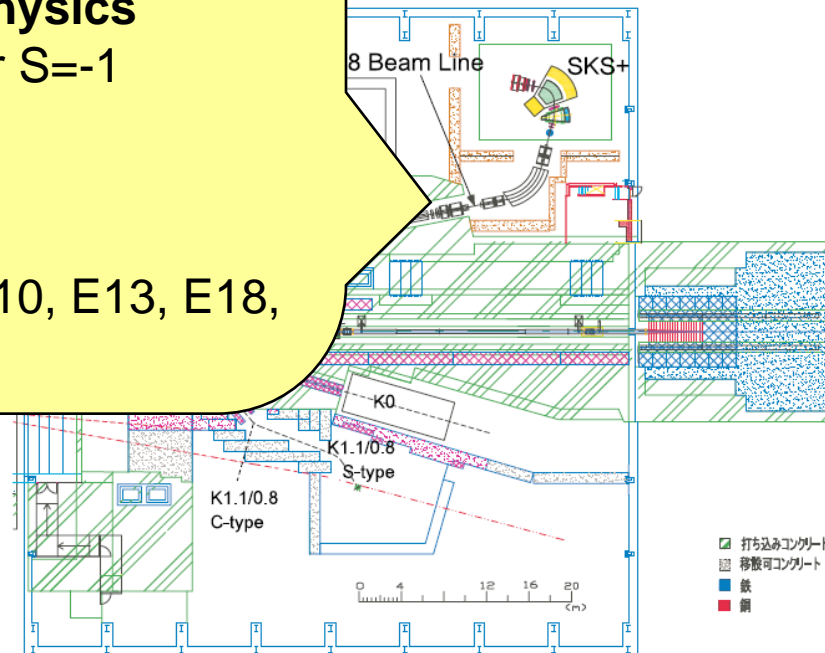


Hadron Spectroscopy

- Theta+ via (π^- , K^-): E19
- Xrays from Kaonic Atom: E17
- K-pp bound State: E15

Hypernuclear Physics

- γ ray spectroscopy for $S=-1$ systems
 - Ξ hypernuclei
 - weak decay etc.
- E03, E05, E07, E08, E10, E13, E18, E22, E27





Three Dimensional Nuclear Chart

$N_u \sim N_d \sim N_s$



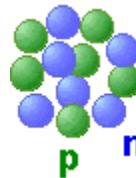
“Stable”

$p, n, \Lambda, \Xi^0, \Xi^-$

Higher density



Λ



p

n

1, 2010 0

Strangeness in neutron stars ($\rho > 3 - 4 \rho_0$)

Strange hadronic matter ($A \rightarrow \infty$)

Strangeness

$\Lambda\Lambda, \Xi$ Hypernuclei

Λ, Σ Hypernuclei

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Coming Hadron Physics Experiments: PAC approved experiments



Hadron Spectroscopy

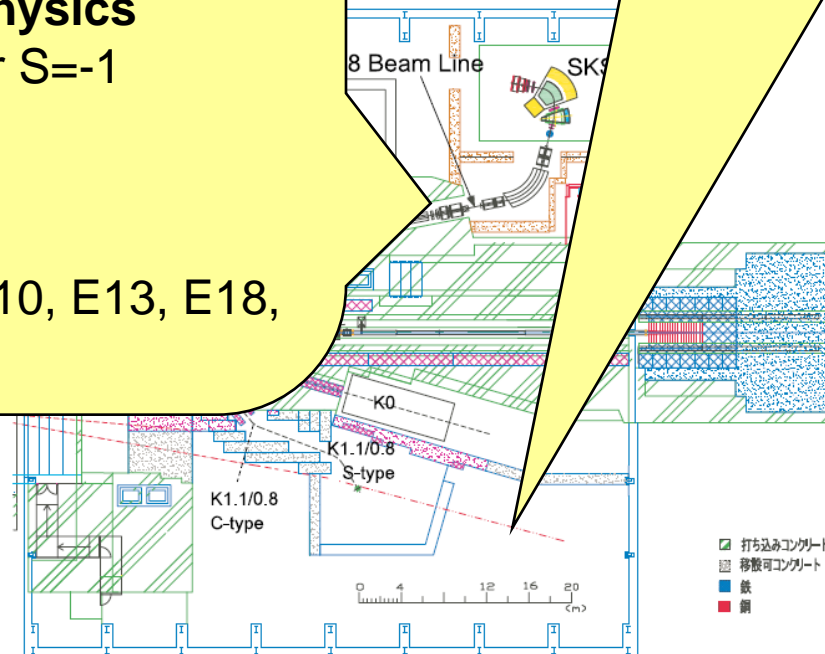
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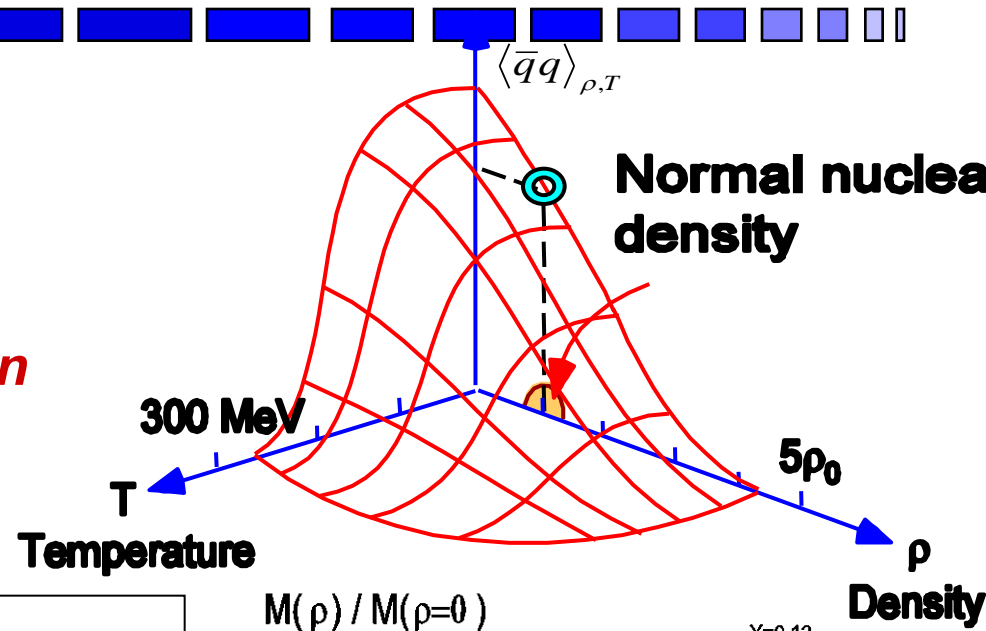
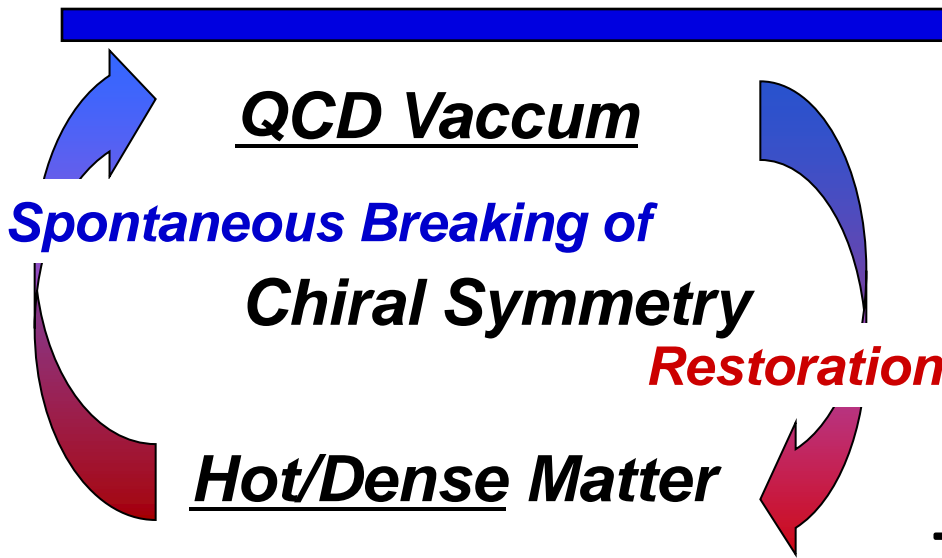
Origin of QCD Mass

- Modification of vector meson mass in nuclear medium
E16





Mass modification of vector meson



Vector meson mass at normal nuclear density

$$m^*/m = 1 - k\rho/\rho_0$$

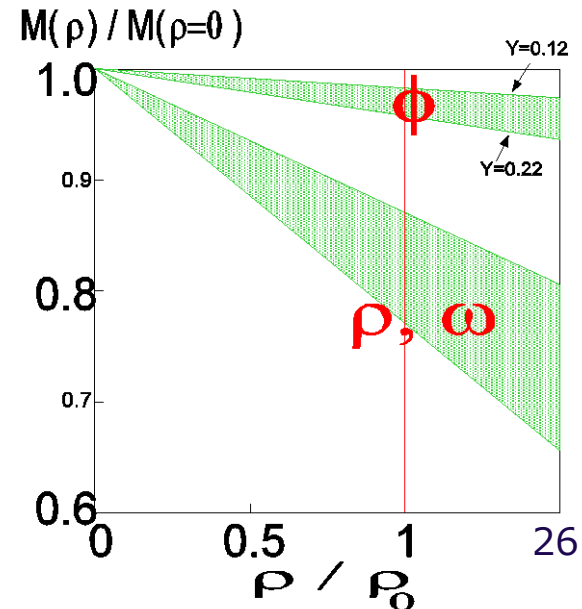
(Hatsuda&Lee PRC46(92)R34)

ρ/ω : $\Delta m = 130$ MeV at ρ_0

ϕ : $\Delta m = 20\sim 40$ MeV at ρ_0

June 1, 2010

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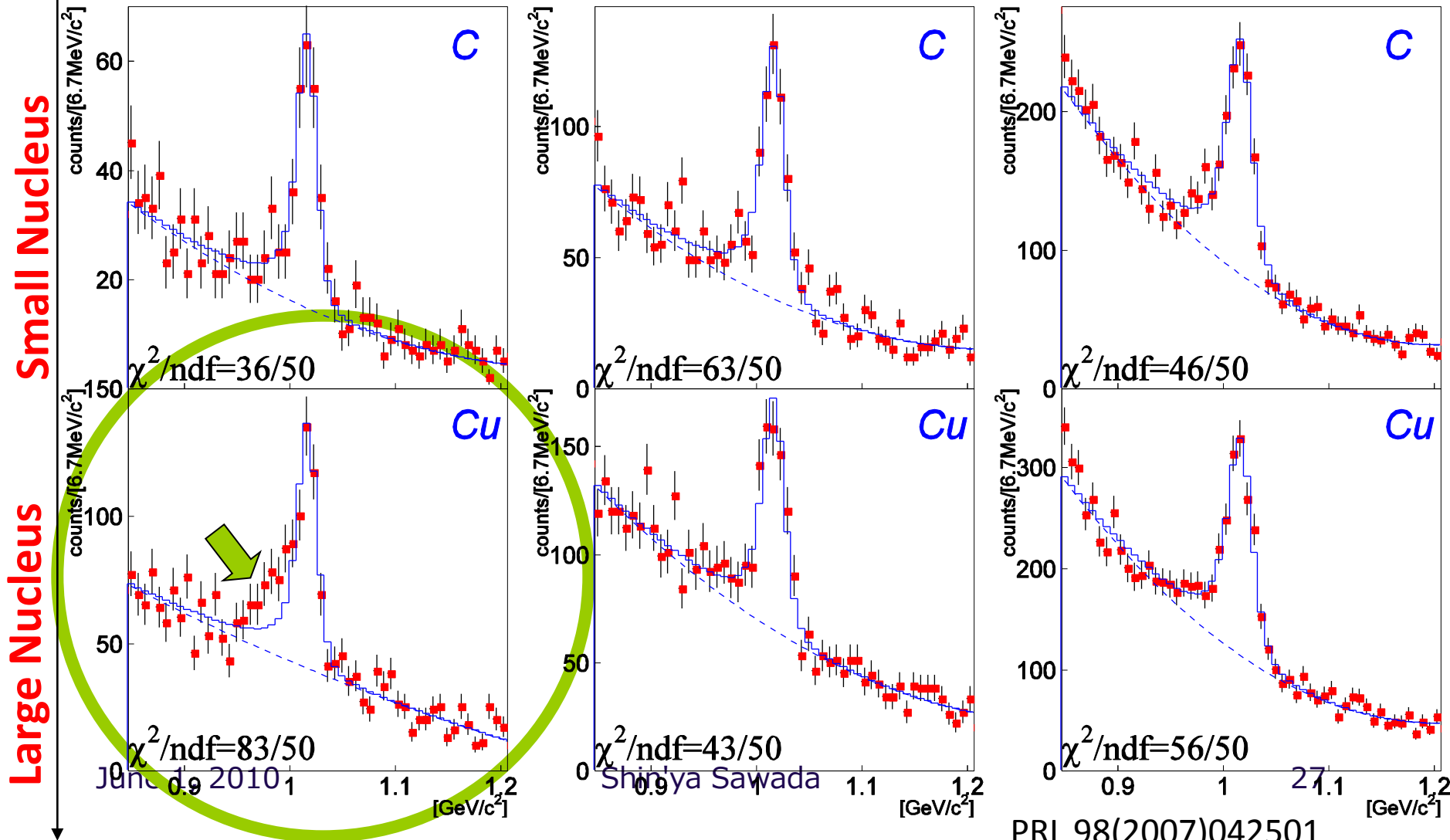


E16: Results of a previous experiment (KEK-PS E325): Invariant mass spectra of $\phi \rightarrow e+e-$

$\beta\gamma < 1.25$ (Slow)

$1.25 < \beta\gamma < 1.75$

$1.75 < \beta\gamma$ (Fast)





J-PARC E16: Electron pair spectrometer to explore the chiral symmetry in QCD



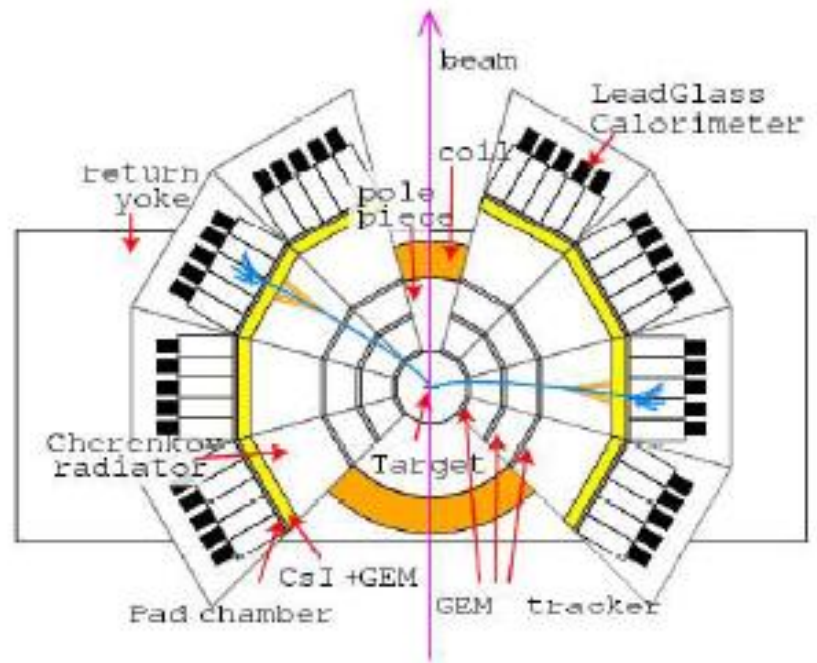
primary proton beam at high momentum beam line
+ large acceptance electron spectrometer

10^7 interaction ($10 \times E325$)
 10^{10} protons/spill
with 0.1% interaction length target

→ GEM Tracker
eID : Gas Cherenkov
+ Lead Glass
Large Acceptance ($5 \times E325$)
→ x100 statistics

velocity dependence
nuclear number dependence ($p \rightarrow Pb$)
centrality dependence

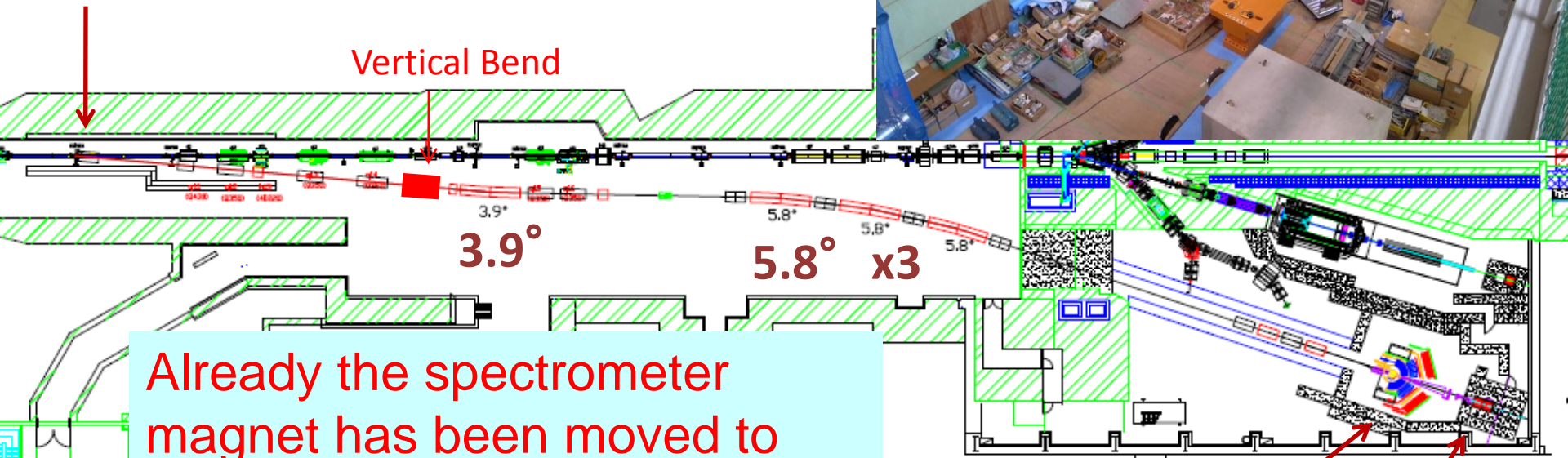
→ systematic study of mass modification





Location of E16 : High

SM1: branched by 5°
2% beam loss is allowed



Already the spectrometer magnet has been moved to Hadron Hall.

Budget being requested.

R&D for the actual beam line is underway.

Experimental Area

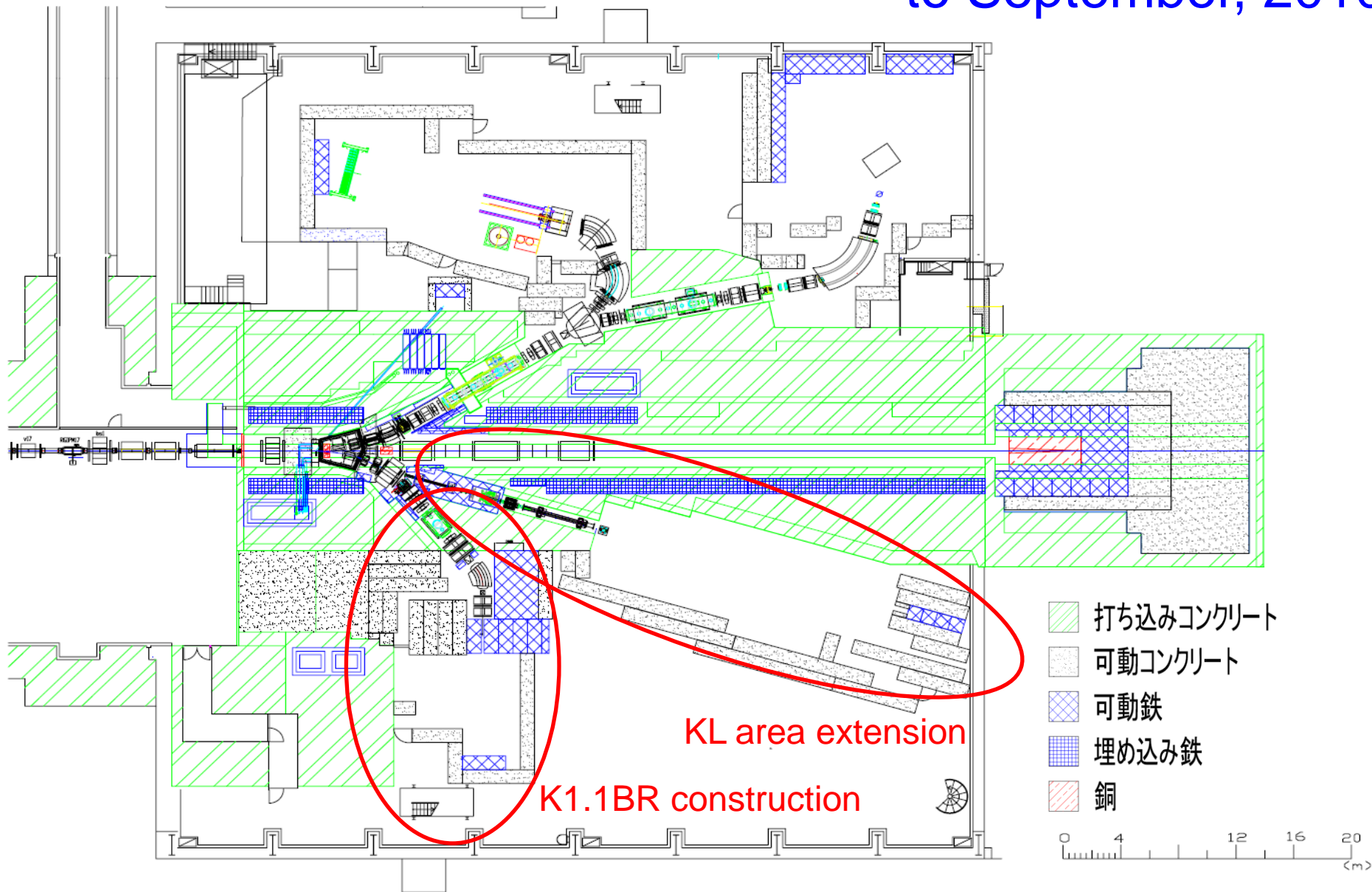
beam dump

Bea

tons/s

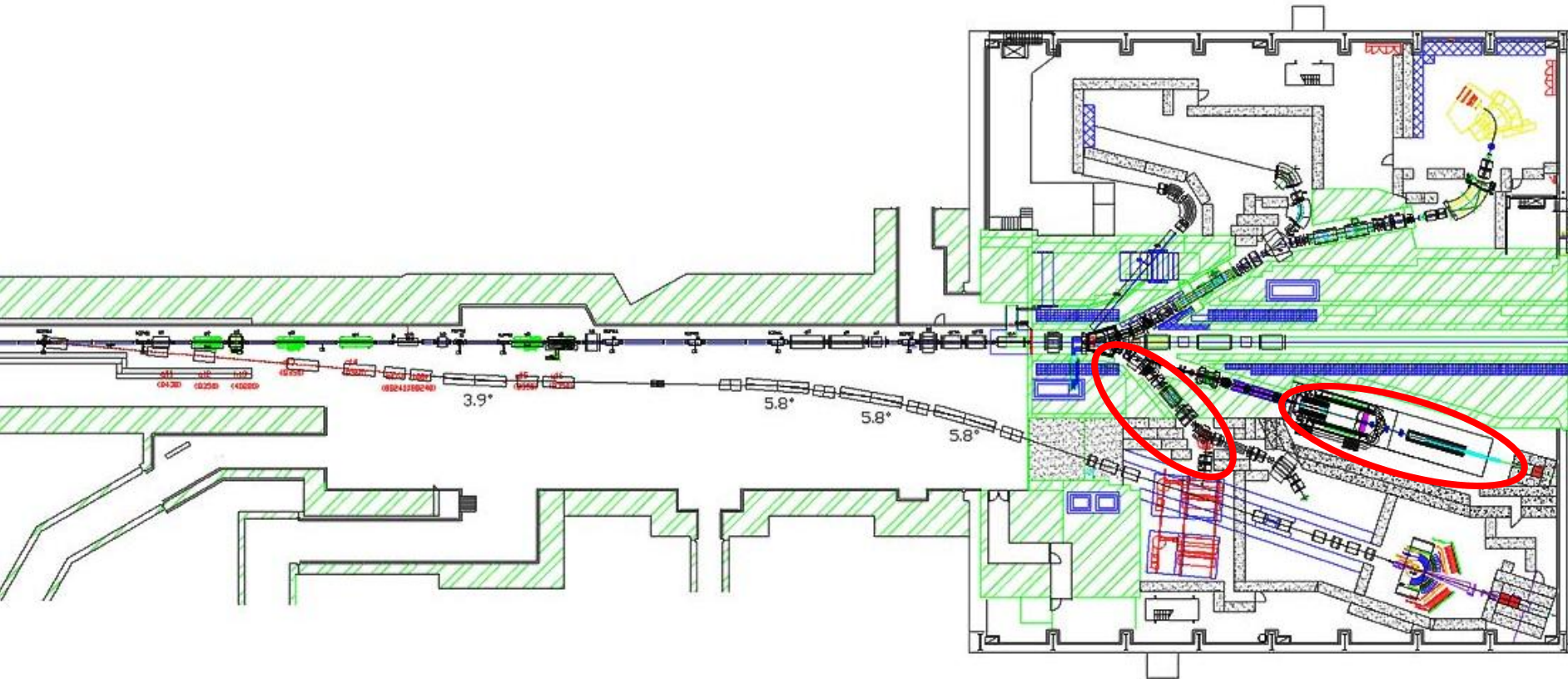


Construction during shutdown from March to September, 2010





Beam Line Plan at Phase 1 of Hadron Hall



- K1.1BR Beam Line will be available by the end of summer, 2010.
- Area extension of KL will be completed by the end of summer, 2010.
- Budget Request of the High Momentum Beam Line started in JFY2009.



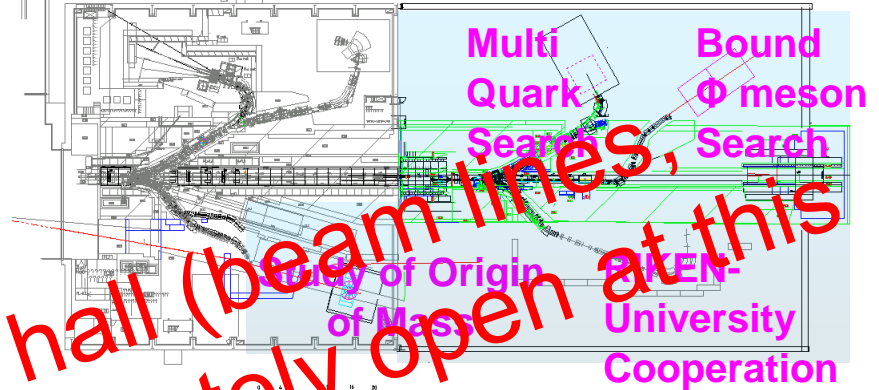
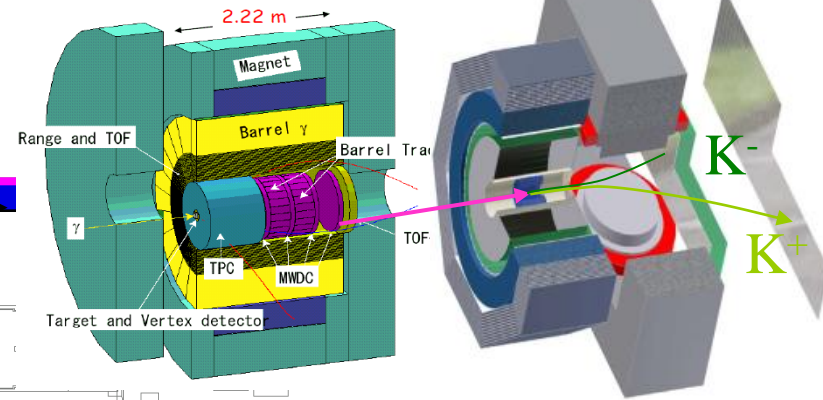
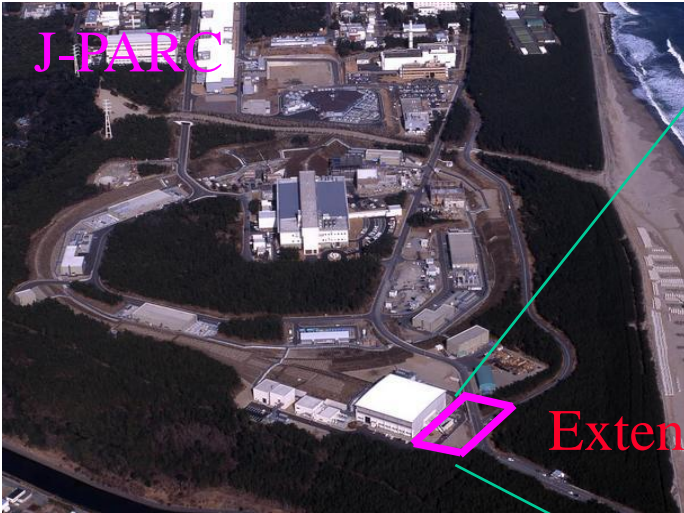
- J-PARC has started its operational era!
 - E17/E15 (X rays from kaonic atom/kaon-nucleus bound states), and E19 (pentaquark) are being started.
- The hadron physics programs;
 - Hypernuclear spectroscopy is one of the major direction. Experiments are soon to be started.
 - Chiral symmetry and hadron mass are another direction. An experiment (E16) is being prepared, and others will come.
 - Exotic hadrons, spectroscopy, and hadron structure are also another direction.
 - Physics with hard processes, such as nucleon structure and short range correlation, is also under consideration.



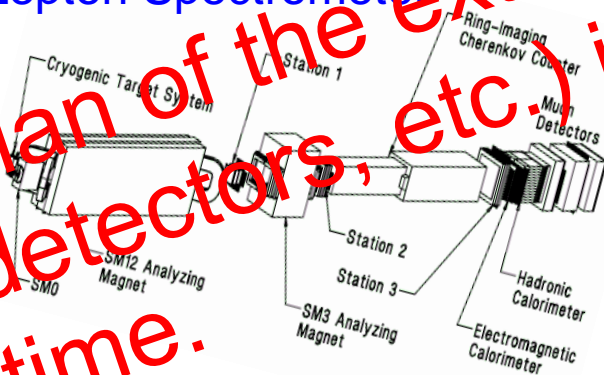
Hadron Hall Extension

- Recently RIKEN expressed interest of contributing to the Hadron Hall extension.
- The Hadron Hall extension was considered as the Phase 2 of the J-PARC, where the Hadron Hall will be extended 50m downstream so that the 2nd target and beam lines from it can be accommodated.
- Hadron Hall Users' Association plays a leading role for the discussion on physics and beam lines at the extended Hadron Hall.

Tentative Plan for Hadron Hall Phase-II

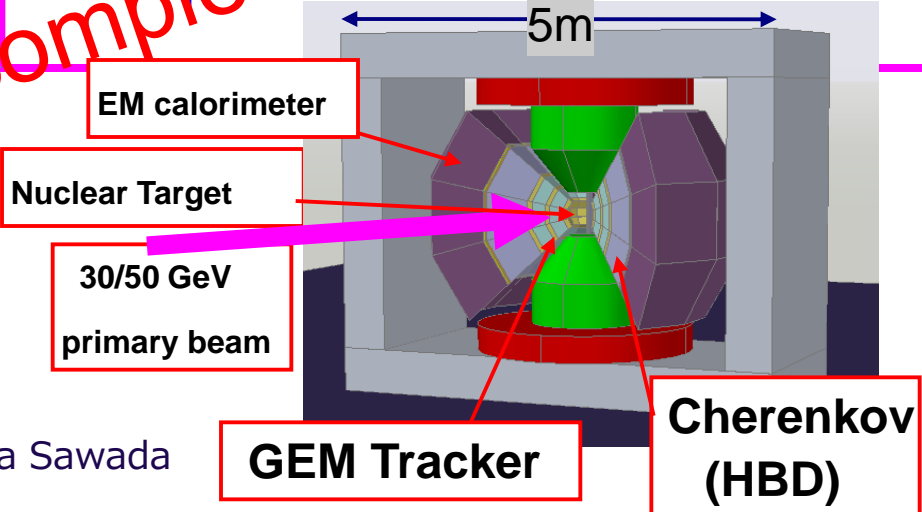


Di-Lepton Spectrometer



Plan of the extended hall (beam lines, detectors, etc.) is completely open at this time.

Chiral Spectrometer



June 1, 2010

Nucleon quark structure Shin'ya Sawada



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 - Exotic hadrons, spectroscopy, and hadron structure are also another direction.
 - Physics with hard processes, such as nucleon structure and short range correlation, is also under consideration.
- We need your input and even collaboration to realize more hadron physics at J-PARC, including the Hadron Hall extension.

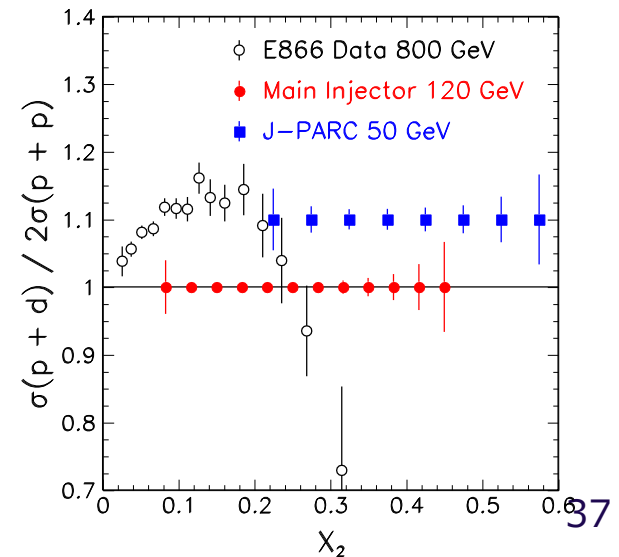
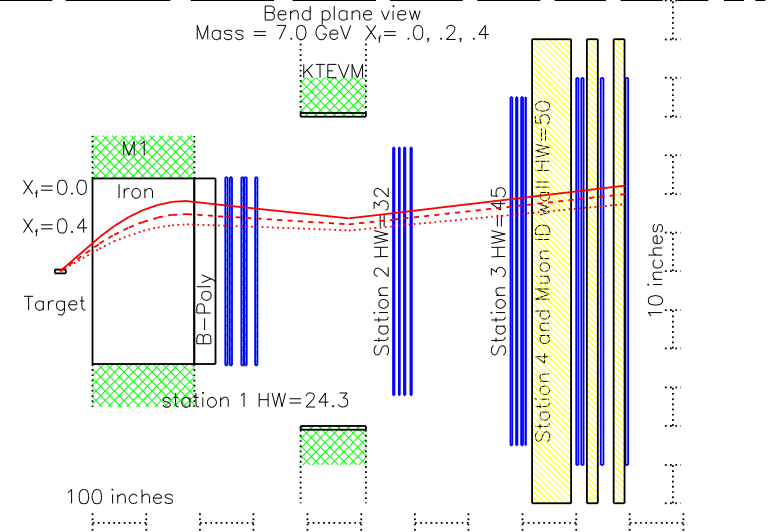


Backups



P04: High mass dimuon measurement

- dimuons from p+p, p+d, p+A
- dbar/ubar asymmetry at large x with Drell-Yan process
- J-PARC can measure d-bar/u-bar at larger x.
- Experiment at Fermilab (=E906) at 120GeV is first.





Directions of hadron physics at J-PARC

Hypernuclear Spectroscopy

- A major direction.
- Precise $S=-1$ measurement
- 1st measurement for $S=-2$

Chiral Phase Transition and Origin of Hadron Mass

- vector meson in nuclear medium

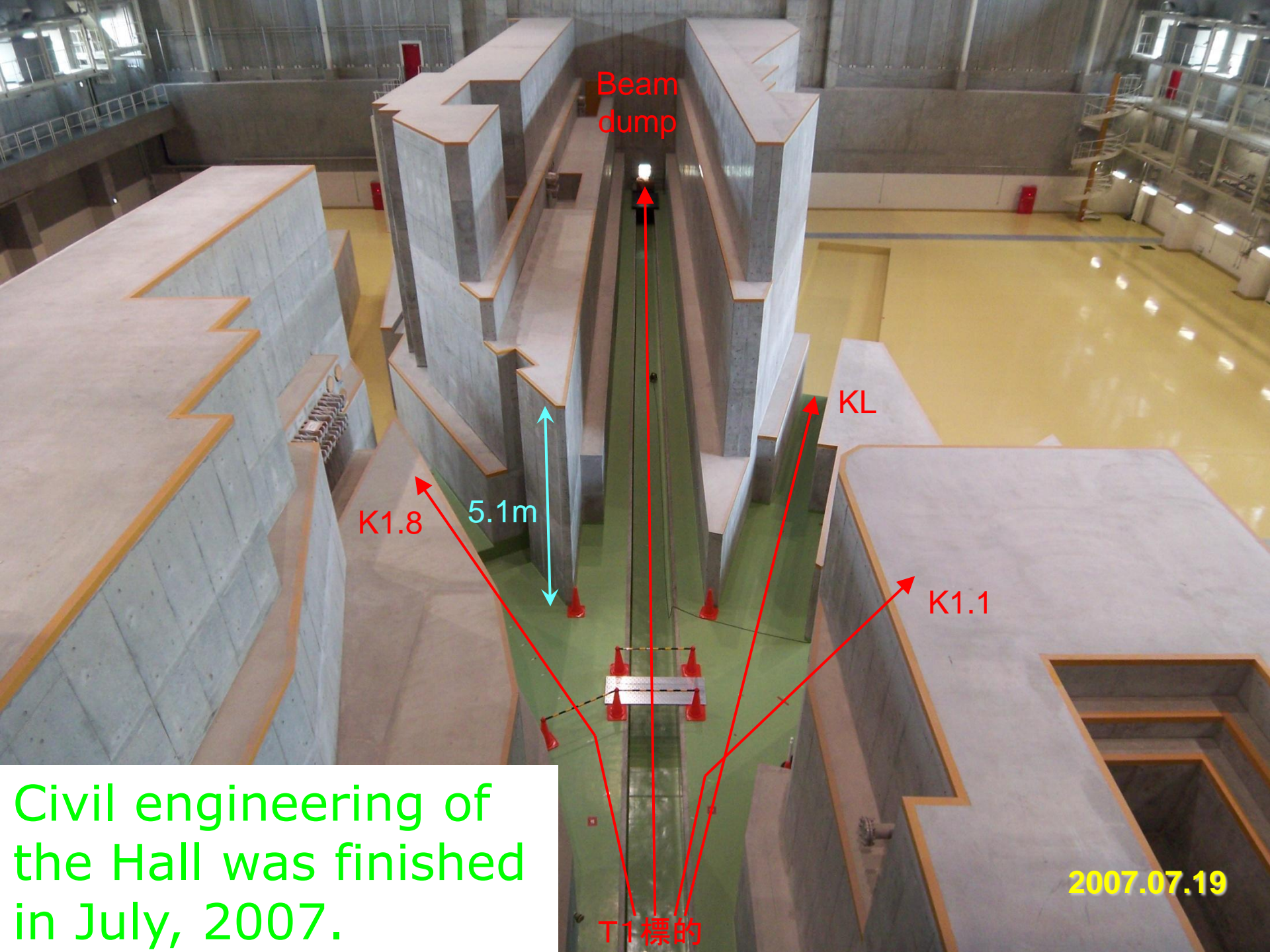
Exotic Hadrons, Spectroscopy, Hadron Structure

- tetraquark, pentaquark, molecular resonance, ...
- K-nucleus

Hard Processes

- Nucleon structure
- Short range correlation

Others?



Beam dump

K1.8

5.1m

KL

K1.1

T1 標的

Civil engineering of the Hall was finished in July, 2007.

2007.07.19



Already Approved Experiments

	(Co-)Spokespersons	Affiliation	Title of the experiment	Approval status (PAC recommendation)	Day1? / priority	Beamline	# of participants, (Domestic/ Foreign)
E03	K. Tanida	Kyoto U	Measurement of X rays from Ξ - Atom	Stage 2		K1.8	35 (22/13)
P04	J.C. Peng, S. Sawada	U. Illinois, KEK	Measurement of High-Mass Dimuon Production at the 50-GeV Proton Synchrotron	Deferred		High p	
E05	T. Nagae	Kyoto U.	Spectroscopic Study of Ξ -Hypernucleus, $^{12}\Xi\text{Be}$, via the $^{12}\text{C}(K^-, K^+)$ Reaction	Stage 2	Y / 1	K1.8	76 (46/30)
E06	J. Imazato	KEK	Measurement of T-violating Transverse Muon Polarization in $K^+ \rightarrow \pi^0 \mu^+ \nu$ Decays	Stage 1		K1.1BR	45 (15/30)
E07	K. Imai, K. Nakazawa, H. Tamura	Kyoto U., Gifu U., Tohoku U.	Systematic Study of Double Strangeness System with an Emulsion-counter Hybrid Method	Stage 2		K1.8	53 (32/21)
E08	A. Krutenkova	ITEP	Pion double charge exchange on oxygen at J-PARC	Stage 1		K1.8	7 (4/3)
E10	A. Sakaguchi, T. Fukuda	Osaka U., Osaka EC U.	Production of Neutron-Rich Lambda-Hypernuclei with the Double Charge-Exchange Reaction (Revised from initial P10)	Stage 2		K1.8	18 (13/5)
E11	K. Nishikawa	KEK	Toka-to-Kamioka (T2K) Long Baseline Neutrino Oscillation Experimental Proposal	Stage 2		Neutrino	
E13	T. Tamura	Tohoku U.	Gamma-ray spectroscopy of light hypernuclei	Stage 2	Y / 2	K1.8	93 (59/43)
E14	T. Yamanaka	Osaka U.	Proposal for $KL \rightarrow \pi^0 \nu \bar{\nu}$ Experiment at J-PARC	Stage 2		K0	66 (34/32)
E15	M. Iwasaki, T. Nagae	RIKEN, Kyoto U.	A Search for deeply-bound kaonic nuclear states by in-flight $^3\text{He}(K^-, n)$ reaction	Stage 2	Y	K1.8BR	55 (32/23)
E16	S. Yokkaichi	RIKEN	Electron pair spectrometer at the J-PARC 50-GeV PS to explore the chiral symmetry in QCD	Stage 1		High p	16 (16/0)



Already Approved Experiments (cont'd)



	(Co-)Spokespersons	Affiliation	Title of the experiment	Approval status (PAC recommendation)	Day1? / priority	Beamline	# of participants, (Domestic/ Foreign)
E17	R. Hayano, H. Ota	U. Tokyo, RIKEN	Precision spectroscopy of Kaonic ^3He 3d \rightarrow 2p X-rays	Stage 2	Y	K1.8BR	38 (21/17)
E18	H. Bhang, H. Ota, H. Park	SMU, RIKEN, KRISS	Coincidence Measurement of the Weak Decay of ^{12}C and the three-body weak interaction process	Stage 1		K1.8	16 (1/15)
E19	M. Naruki	KEK	High-resolution Search for Θ^+ pentaquark in π -p \rightarrow K-X Reactions	Stage 2	Y	K1.8	22 (21/1)
E21	Y. Kuno	Osaka U.	An Experimental Search for μ -e conversion at a Sensitivity of 10^{-16} with a Slow-extracted Bunched Beam	Stage 1		New beam line	
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		K1.8	19 (15/4)
T25	S. Mihara	KEK	Extinction Measurement of J-PARC Proton Beam at K1.8BR	Test experiment		K1.8BR	
P26	K. Ozawa	U. Tokyo	Direct Measurement of omega mass modification in A(pi-, n)omega reaction and omega \rightarrow pi0 gamma decays	Deferred		K1.8	
E27	T. Nagae	Kyoto U.	Search for a nuclear Kbar bound state K-pp in the d(pi+, K+) reaction	Stage 1		K1.8	
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		K1.8BR	
P29	H. Ohnishi	RIKEN	Study of in medium mass modification for phi meson using phi meson bound state in nucleus	Deferred		K1.1	
P31	H. Noumi	Osaka U.	Spectroscopic study of hyperon resonances below KN threshold via the (K-, n) reaction on Deuteron	Deferred		K1.8	

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Total # (D/F):
348 (180/168)

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■ Already submitted Proposals

- P04: dimuon from $p+p$, $p+d$, $p+A$; flavor asymmetry in sea quark, etc.
- P26: omega mass modification via $A(\pi^-, n)\omega$
- P29: phi mass modification by phi bound states with p -bar beam
- P31: hyperon resonance below KN threshold via $d(K^-, n)$

■ LoI's

- P09: $S=+1$ spectroscopy and K^+ rare decay with low momentum K^+ beams
- PDF of mesons via Drell-Yan
- eta mesic nuclei via (π^-, n)
- hyperon-nucleon scattering with SCIFI-MPPC
- gamma-ray spectroscopy of hypernuclei at K1.1
- Sigma-N interaction
- Theta+ via (K^+, p)
- Double anti-kaon production via p -bar annihilation