



# Hadron Facility of J-PARC

Shin'ya Sawada

澤田 真也

KEK

(High Energy Accelerator Research Organization, Japan)

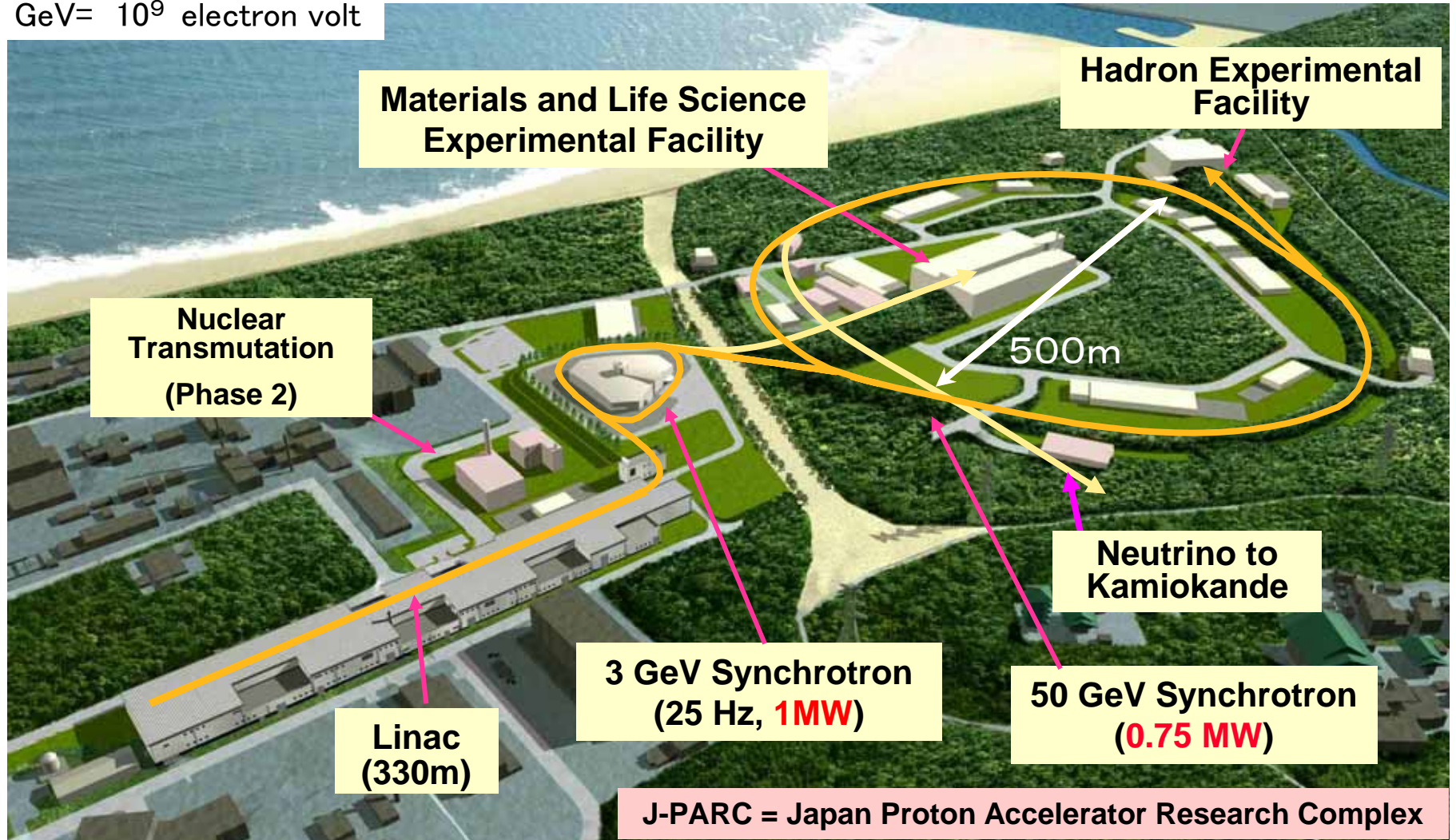


- Overview of J-PARC
- Hadron Experimental Facility (Hadron Hall)
- Hadron Physics
- Summary



# J-PARC Facility

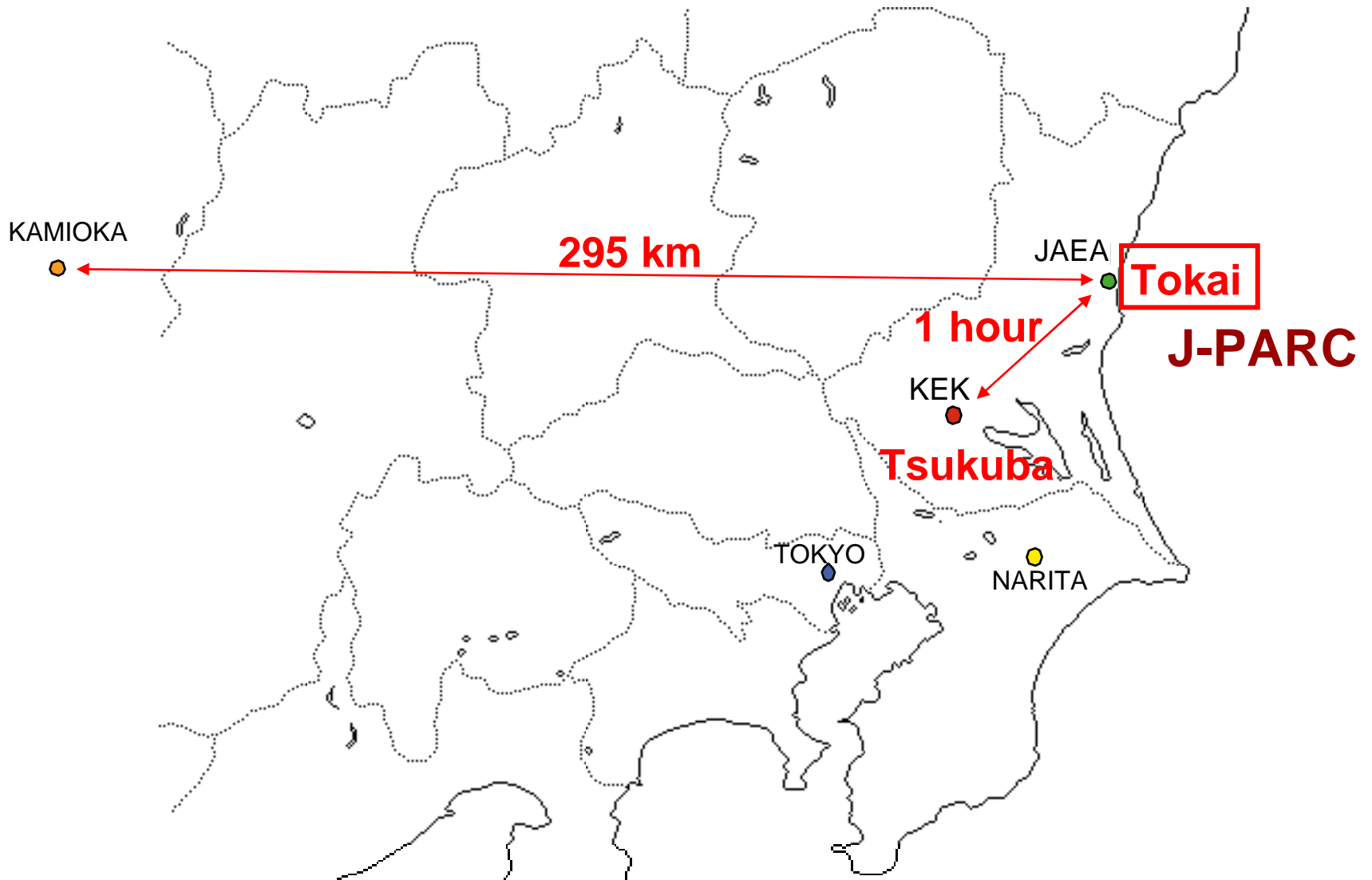
GeV=  $10^9$  electron volt



**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)

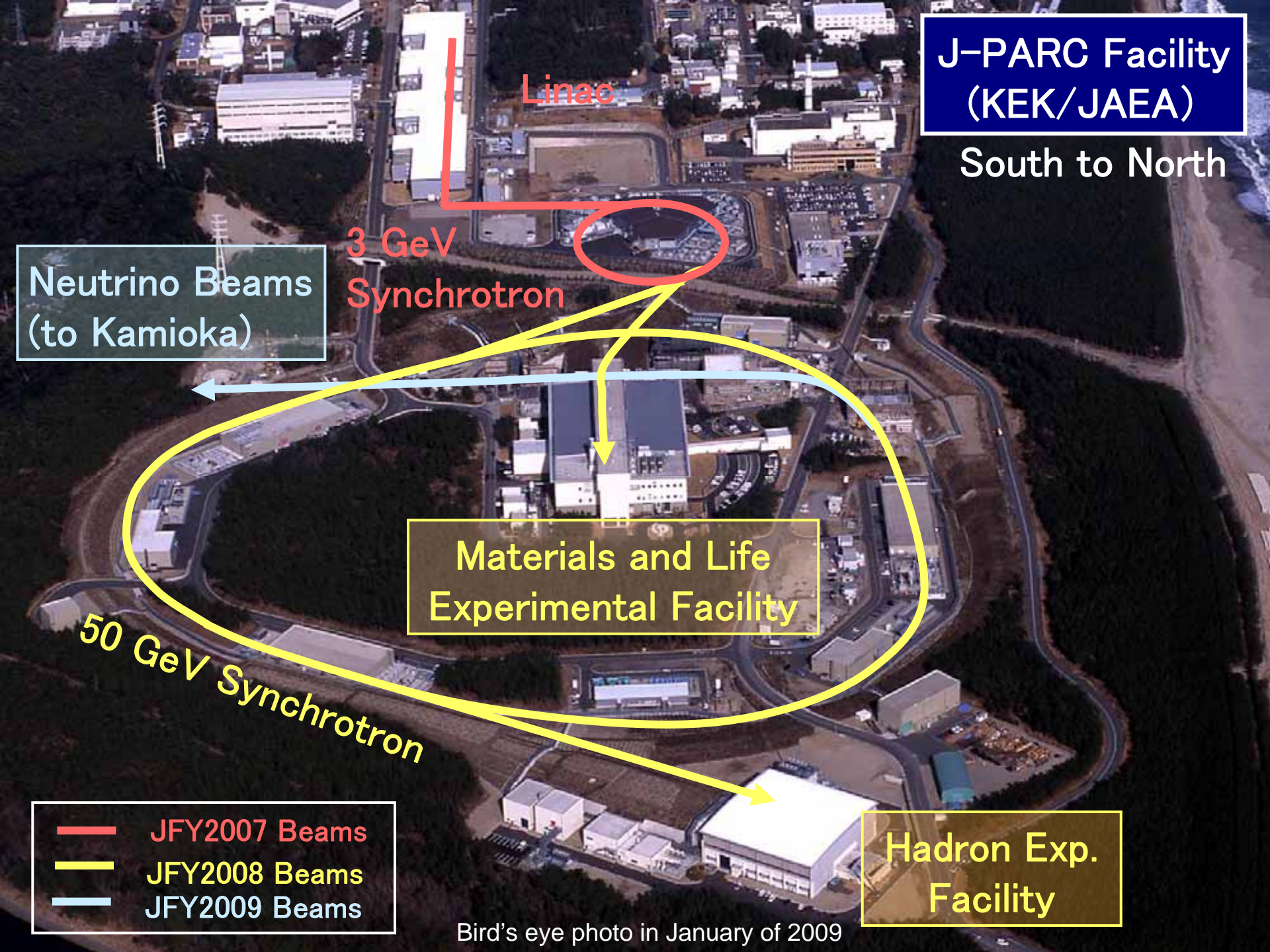
Materials and Life  
Experimental Facility

50 GeV Synchrotron

Hadron Exp.  
Facility

- JFY2007 Beams
- JFY2008 Beams
- JFY2009 Beams

Bird's eye photo in January of 2009

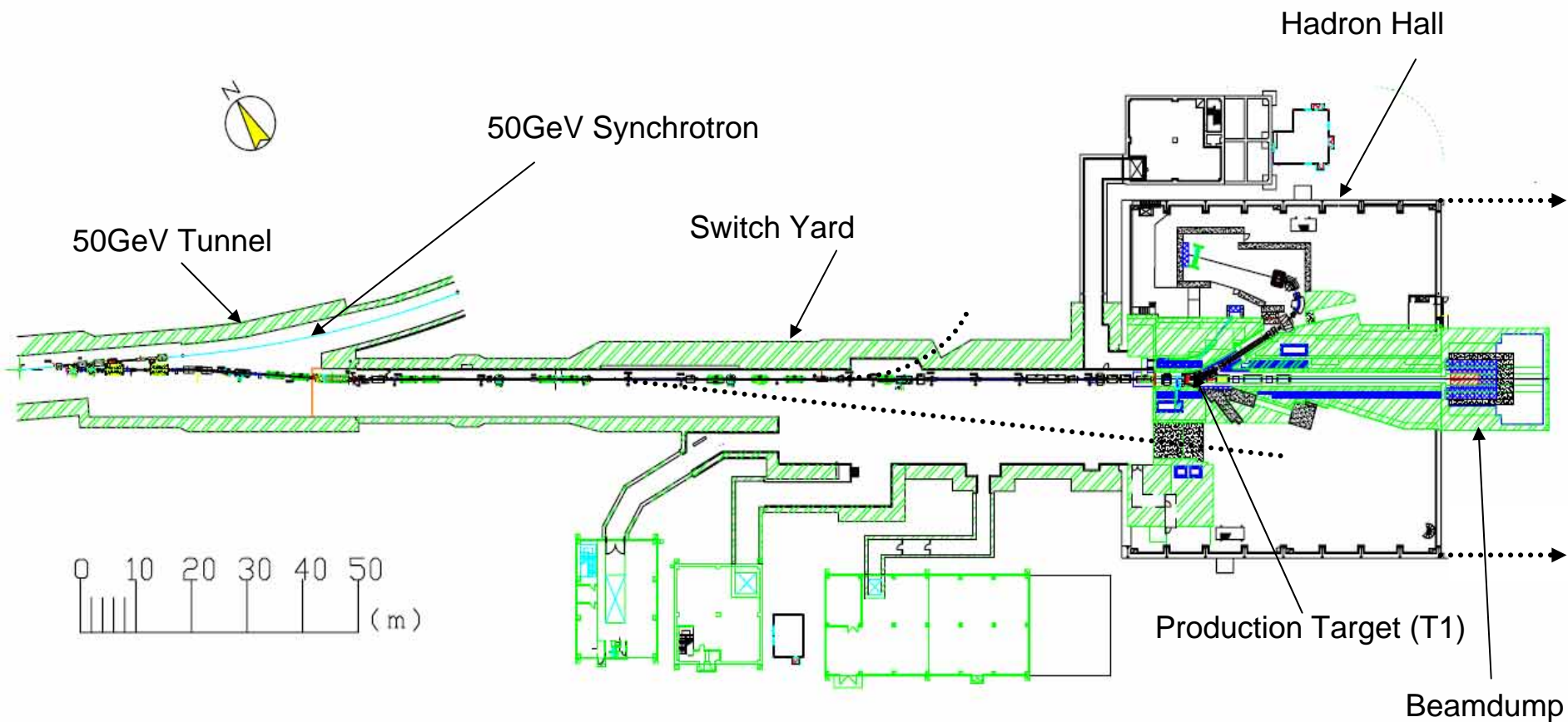


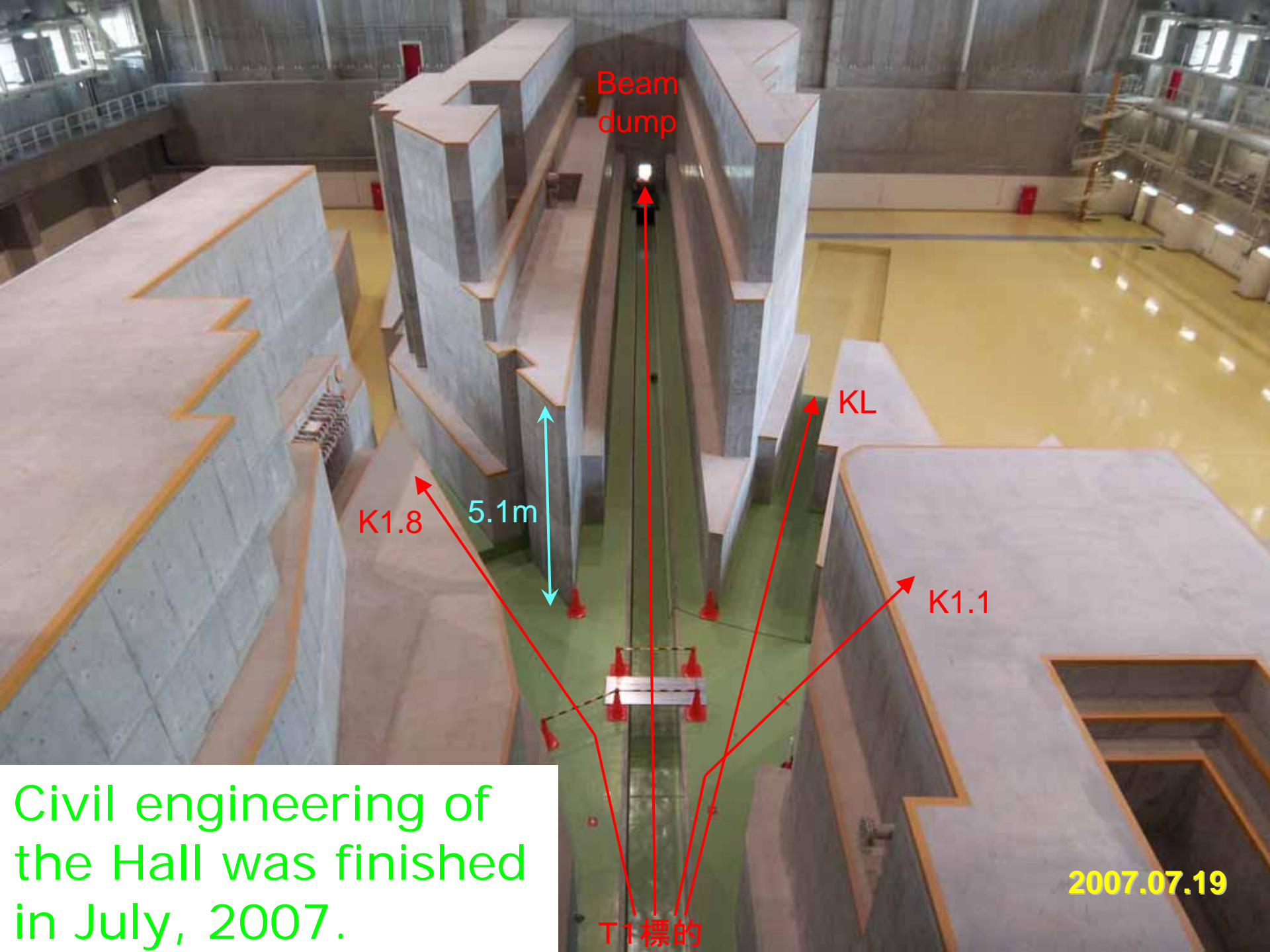


- Overview of J-PARC
- Hadron Experimental Facility (Hadron Hall)
- Hadron Physics
- Summary



# Hadron Experimental Facility (December, 2008)





Beam dump

K1.8

5.1m

KL

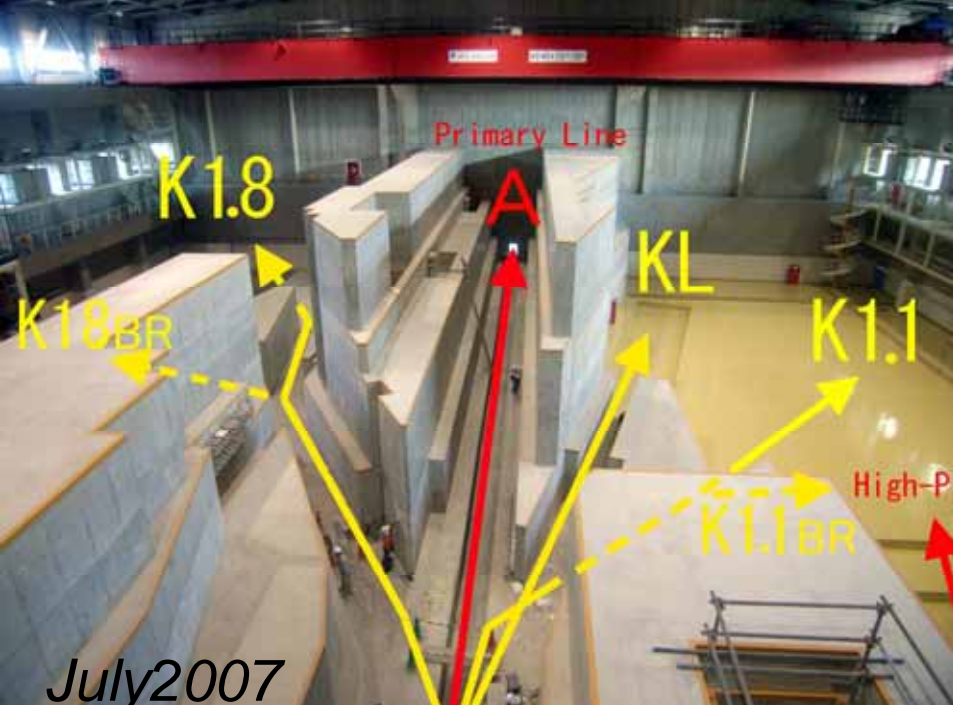
K1.1

T1 標的

2007.07.19

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

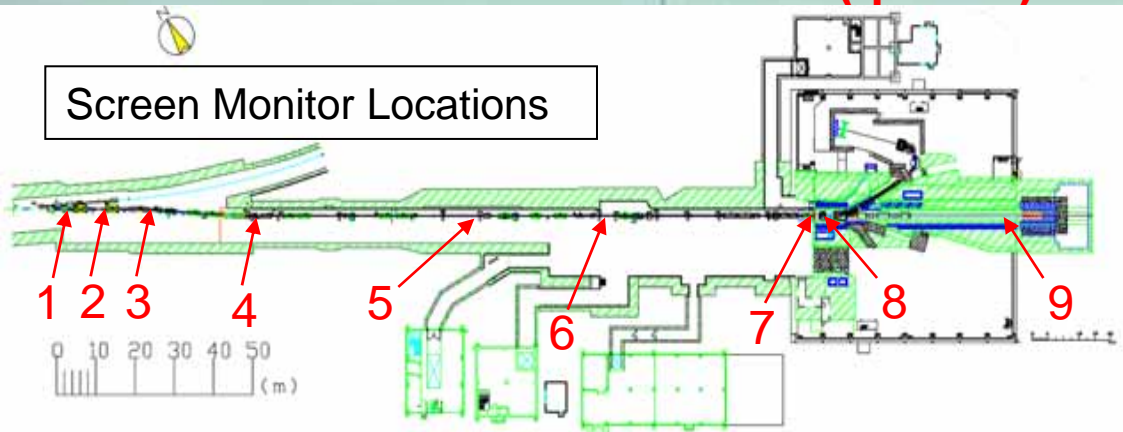
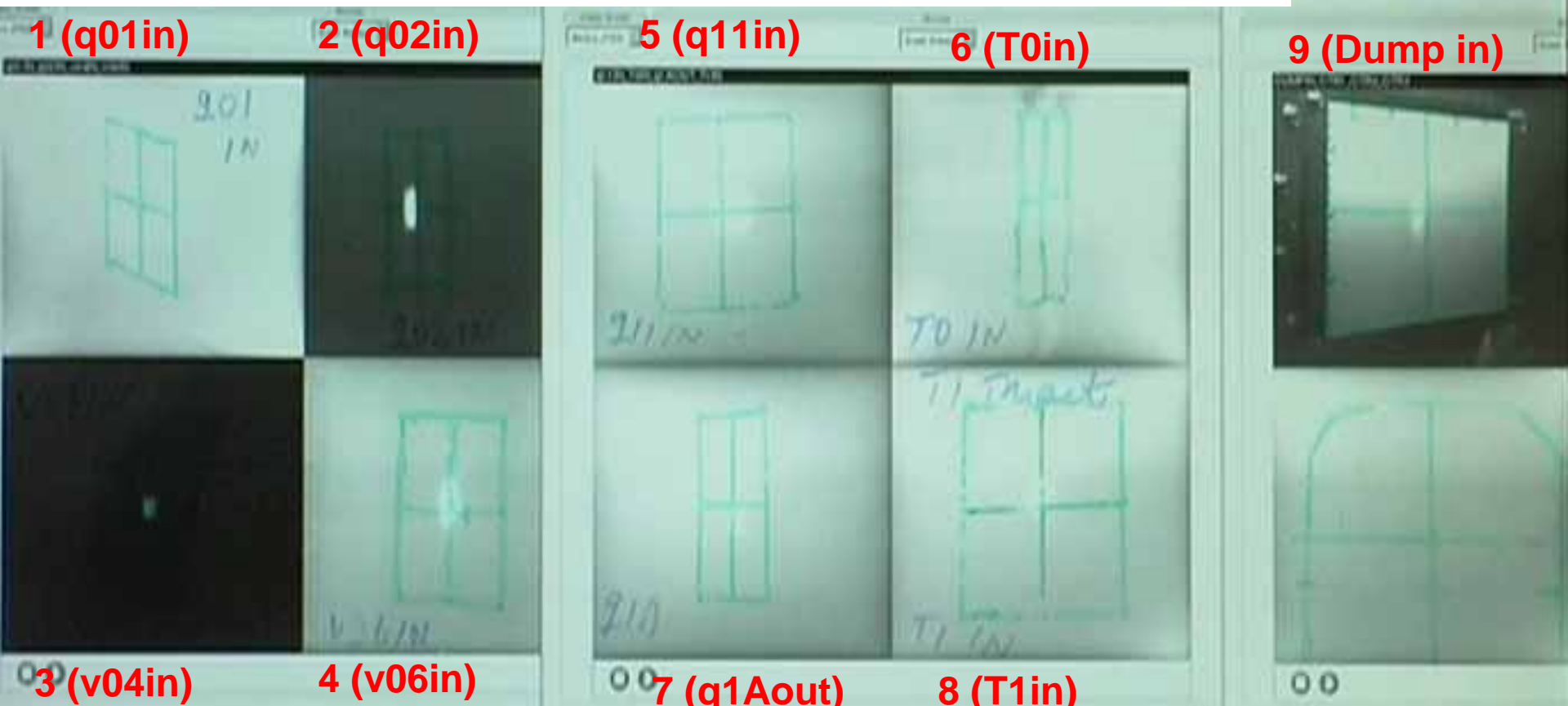




## Construction of Hadron Experimental Hall



# Typical Beam Profiles measured with Screen Monitors



January 27<sup>th</sup>, 2009



祝 ハドロンビームライン  
ビーム取り出し・輸送成功  
平成 21 年 1 月 27 日 19 時 35 分



# Plan View: Hadron Experimental Hall

Strangeness Nuclear  
Physics on Day-1

Beam Dump  
(Movable on the Rail)

Baryons in Nuclei

K1.8

Mesons in Nuclei

K1.8BR

Rare Decay  
KL

Production  
target (T1)

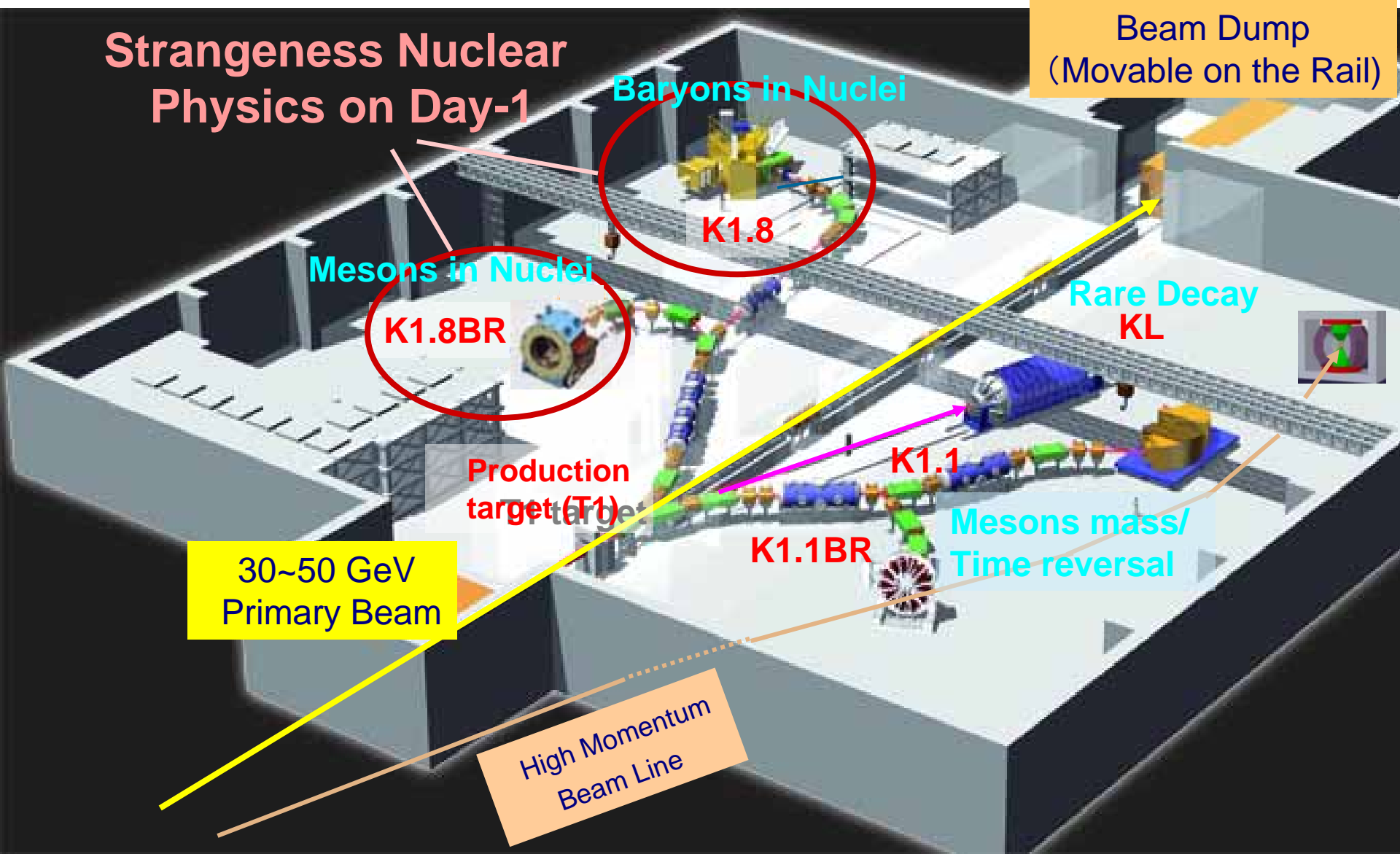
K1.1

Mesons mass/  
Time reversal

30~50 GeV  
Primary Beam

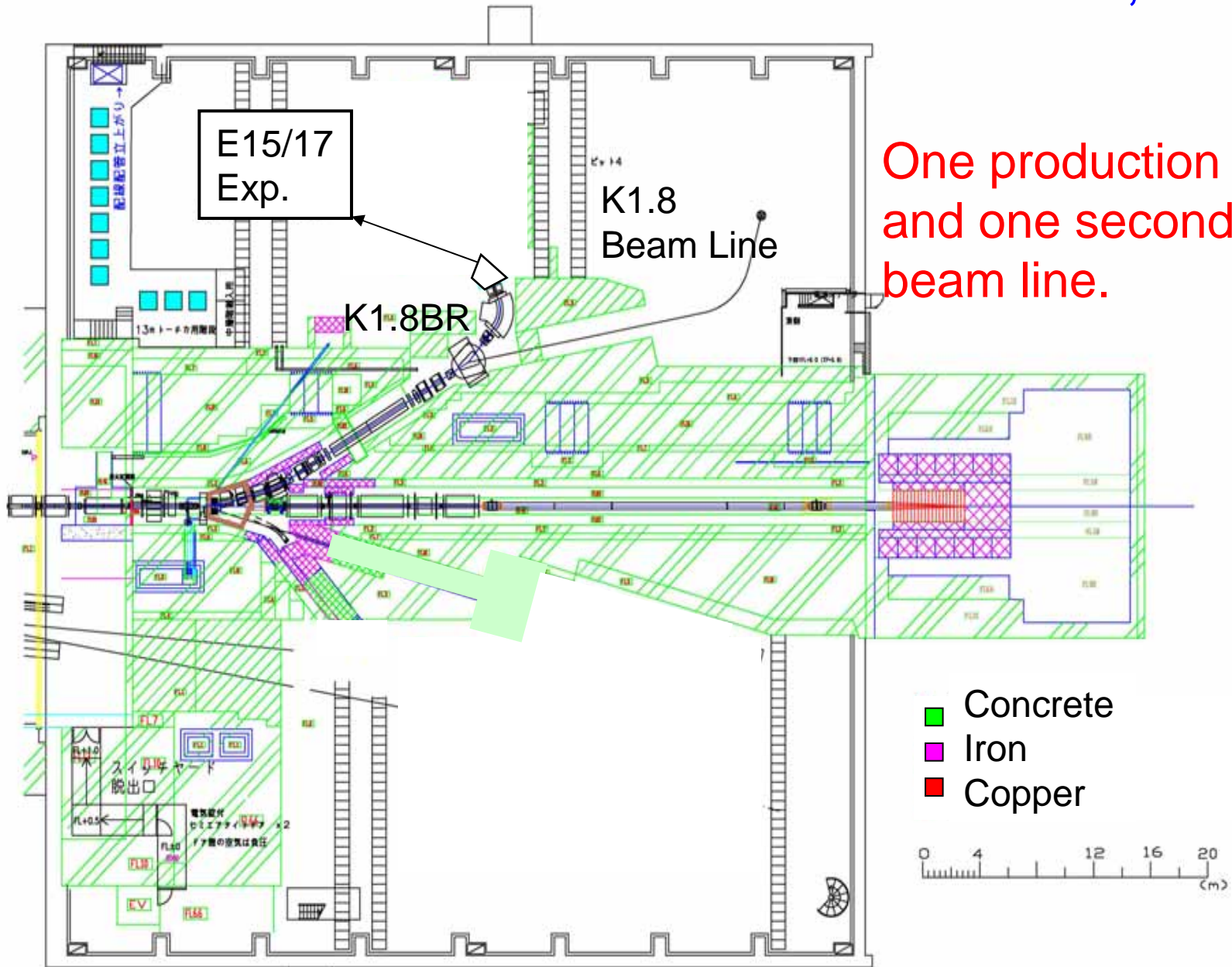
K1.1BR

High Momentum  
Beam Line





# Hadron Hall in March, 2009



One production target and one secondary beam line.

- Concrete
- Iron
- Copper

0 4 12 16 20 (m)

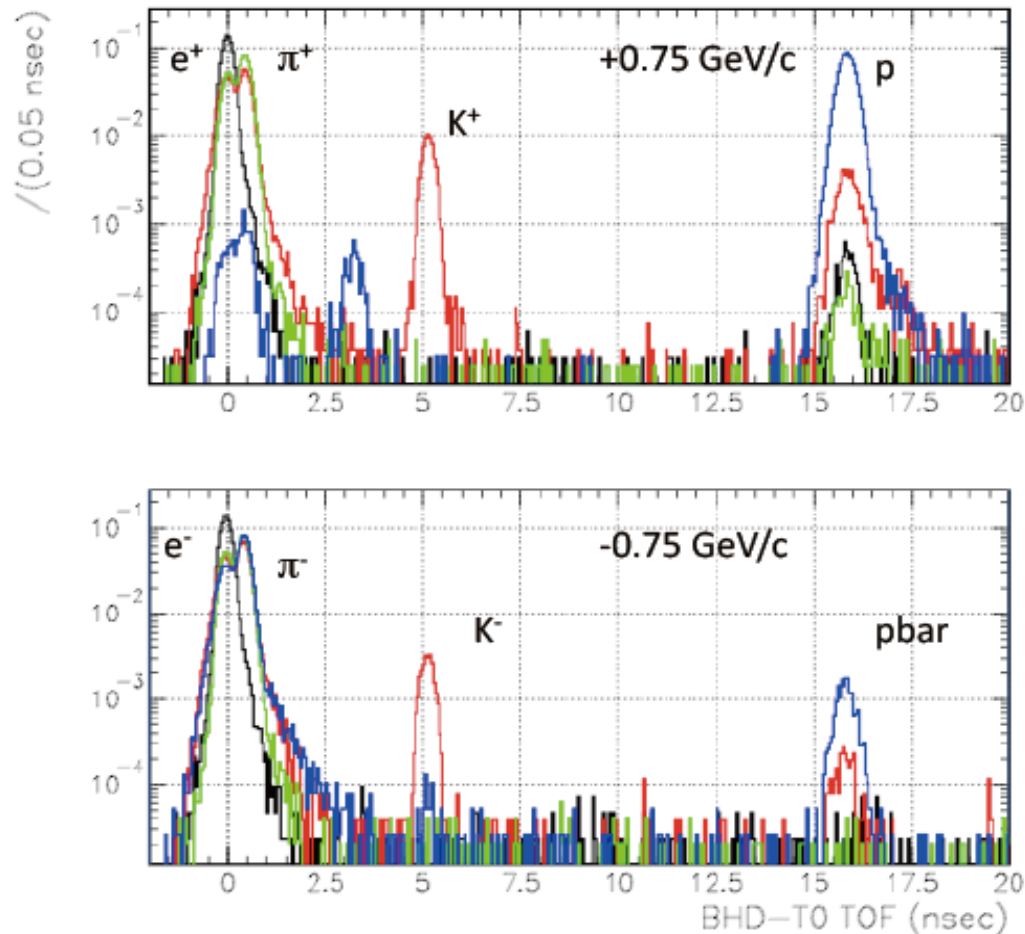


# Secondary Particles at K1.8BR

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”/“ $\pi$ ”/“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/ $\pi$ 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。

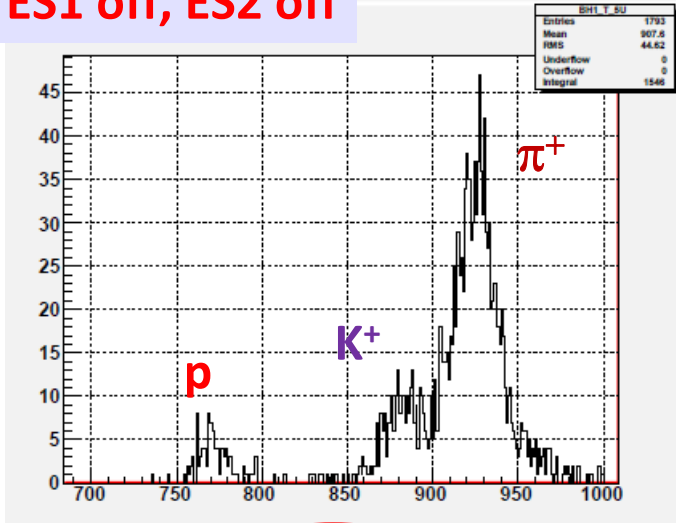
$7 \times 10^{10}$  pppのビーム強度においては $K^+/K^-$ の個数はそれぞれショット当りで全スリット開状態で30/7個であることが確定したため調整を進行するためには、さらなるビーム強度が必須。



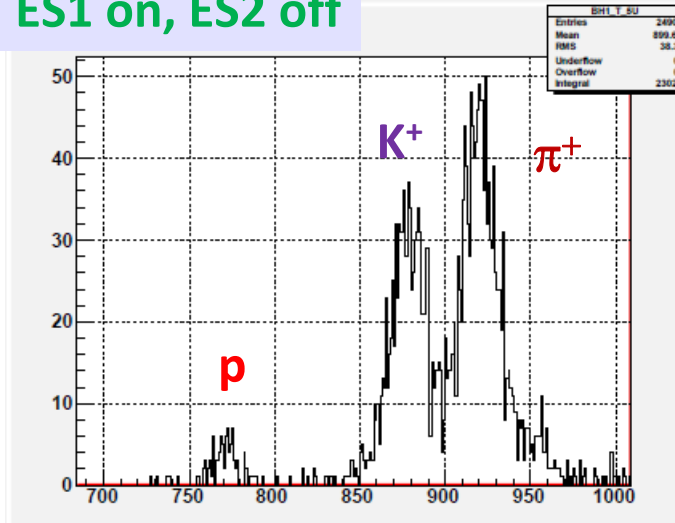


# Online Monitor at the 1<sup>st</sup> Beam Tuning

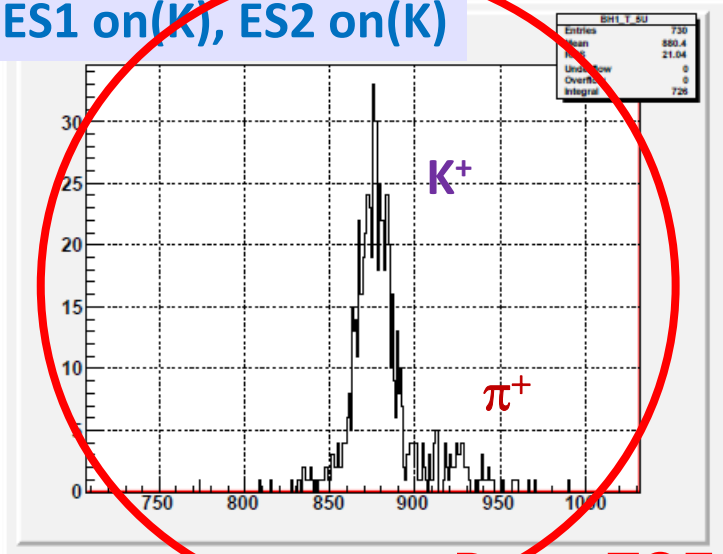
ES1 off, ES2 off



ES1 on, ES2 off



ES1 on(K), ES2 on(K)



ES1 off, ES2 on



Shin'

Beam TOF with "kaon" trigger

Nov. 15, 2009.





- Overview of J-PARC
- Hadron Experimental Facility (Hadron Hall)
- **Hadron Physics**
- Summary



# 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 $\Xi^-$ 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 $\Xi$ -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 $^3\text{He}$ 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 $^{12}\text{C}$ and the three-body weak interaction process	Stage 1		K1.8	16 (1/15)
E19	M. Naruki	KEK	High-resolution Search for $\Theta^+$ pentaquark in $\pi$ -p $\rightarrow$ K-X Reactions	Stage 2	Y	K1.8	22 (21/1)
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		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	



# Approved Hadron Experiments

## Hadron Spectroscopy

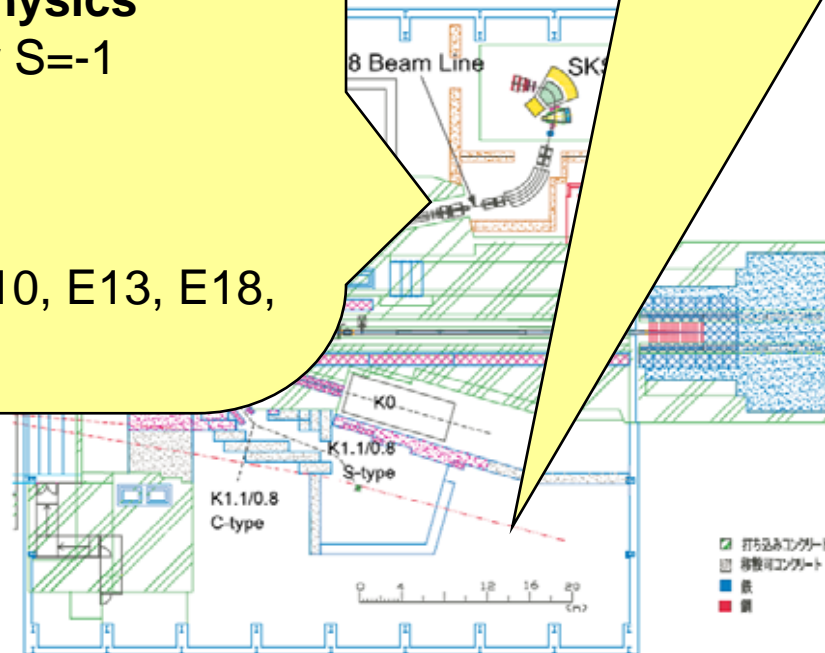
- Theta+ via ( $\pi^-$ ,  $K^-$ ): E19
- Xrays from Kaonic Atom: E17
- K-pp bound State: E15

## Hypernuclear Physics

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

## Origin of QCD Mass

- Modification of vector meson mass in nuclear medium  
E16





## ■ 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  $d(K^-, n)$

## ■ Lol's

- P09:  $S=+1$  spectroscopy and  $K^+$  rare decay with low momentum  $K^+$  beams
- PDF of mesons via Drell-Yan
- eta mesic nuclei via  $(\pi^-, n)$
- 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



# Directions of hadron physics at J-PARC

## Hypernuclear Spectroscopy

- A major direction.
- Precise  $S=-1$  measurement
- 1<sup>st</sup> 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?

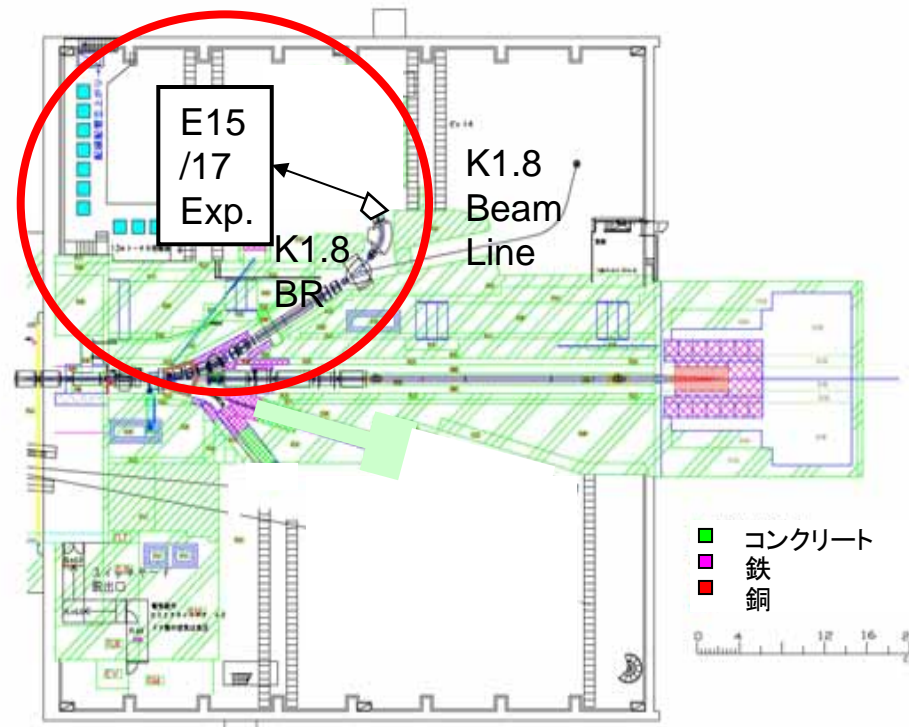


- Already started experiments at K1.8BR
  - E17/E15
- Almost started experiment at K1.8
  - E19: Pentaquark
- Hadron physics experiments with high momentum beam line in the near future
  - E16: Vector meson mass
  - P04: Nucleon structure



# Already started hadron experiment

- E17 at K1.8BR: Precision spectroscopy of Kaonic  $^3\text{He}$  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



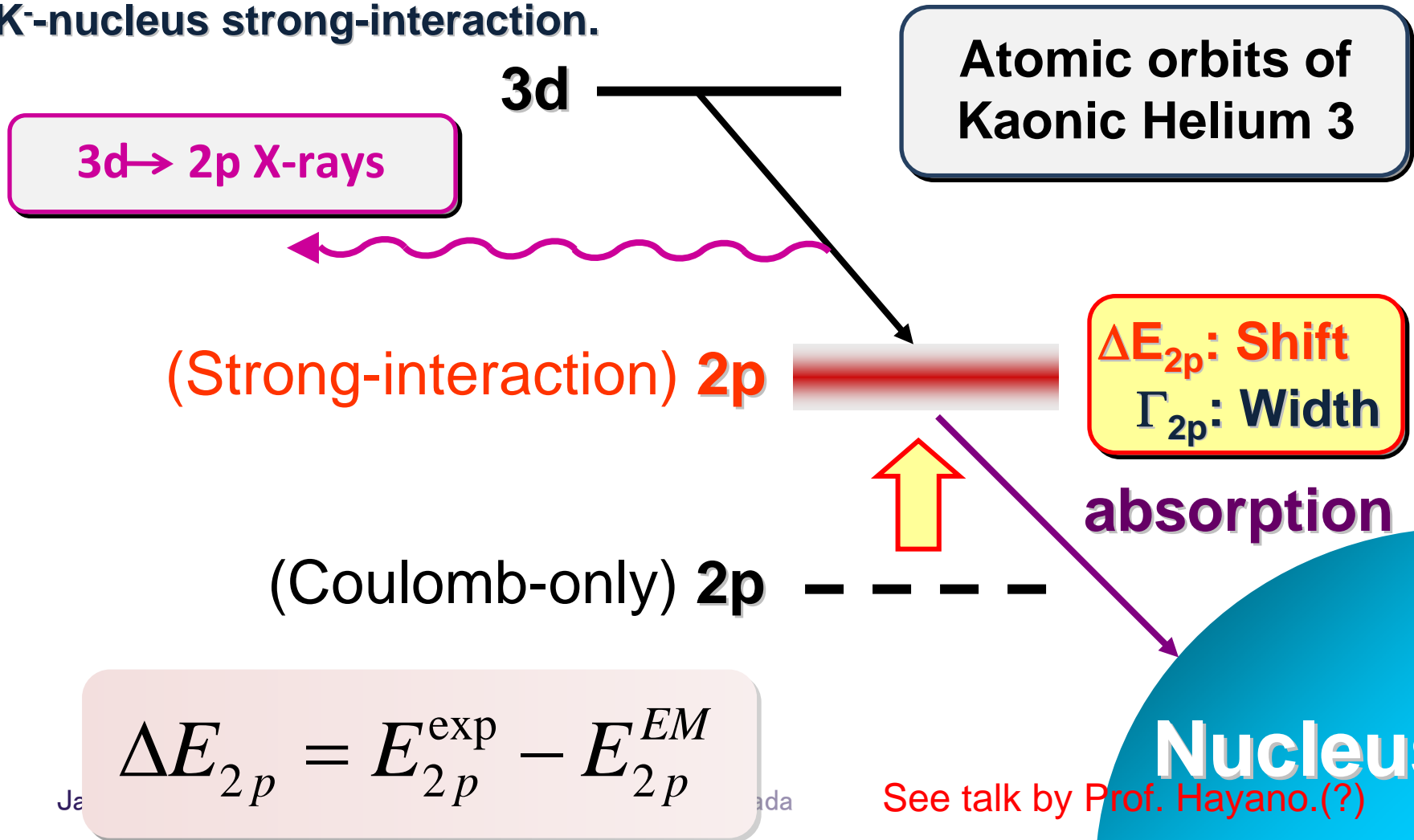




# Already started hadron experiment: E17: Strong-interaction Shift and Width of Kaonic Helium 3

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

Slide by Dr. M. Iio



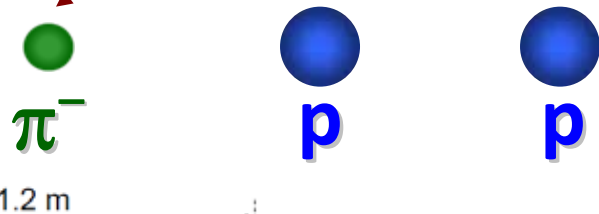
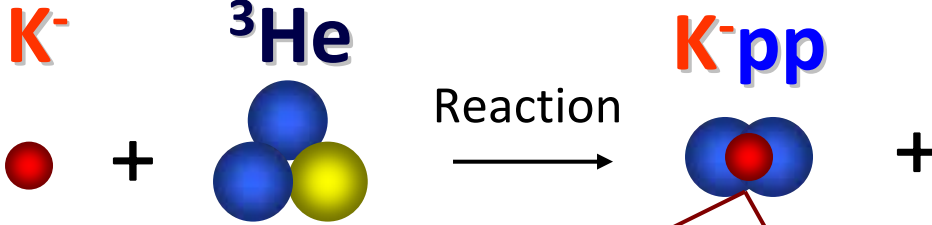
$$\Delta E_{2p} = E_{2p}^{\text{exp}} - E_{2p}^{\text{EM}}$$

Nucleus

See talk by Prof. Hayano.(?)



# E15: Next to E17



Missing mass spectroscopy

$n$



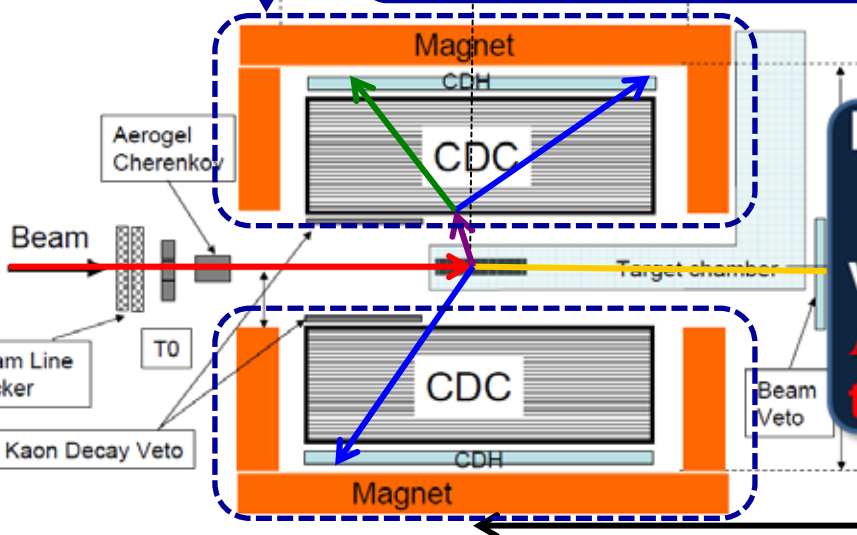
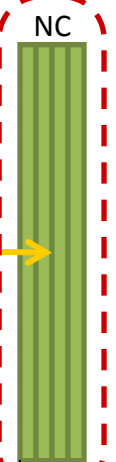
$K^-pp$  search with TOF measurement of neutron

Decay particle measurement

$K^-pp$  search with exclusive decay particle measurement

$K^-pp$  state is investigated in well distinguished final state.  $\Lambda$  is always attributed to  $K^-$  in the initial state.

NC



a Sawada

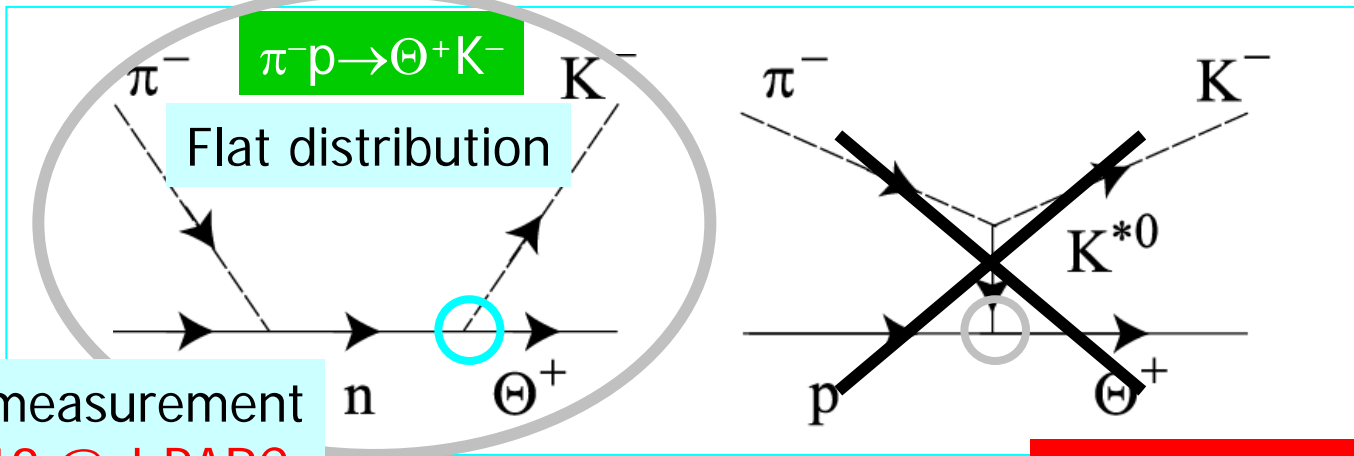
15 m

26



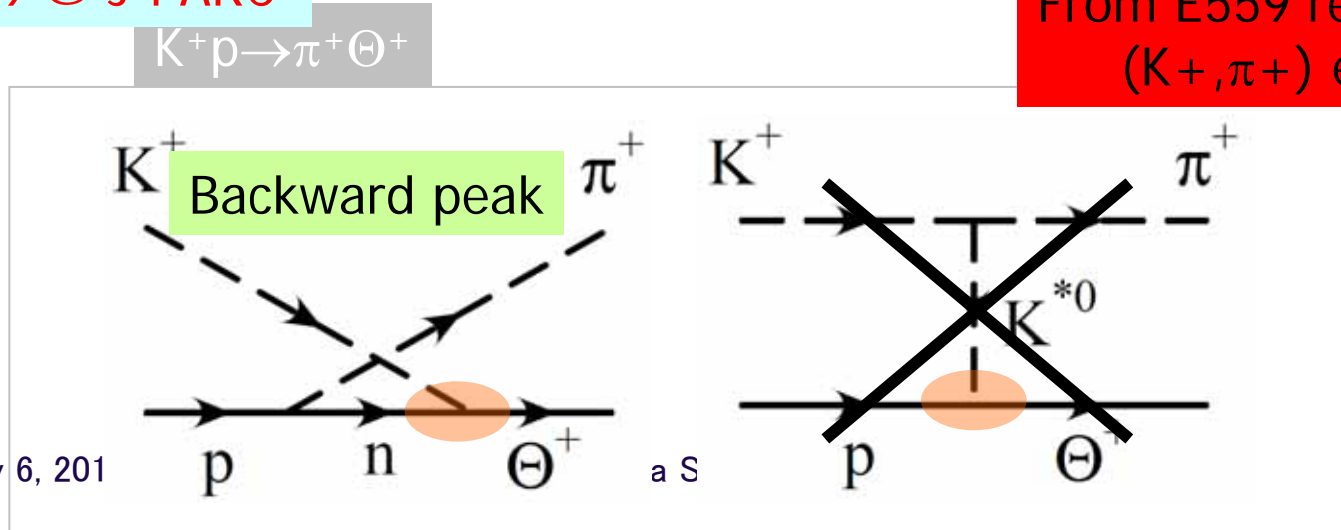
# Almost started hadron experiments

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



Precise measurement  
E19 @ J-PARC

From E559 result  
( $K^+, \pi^+$ ) experiment





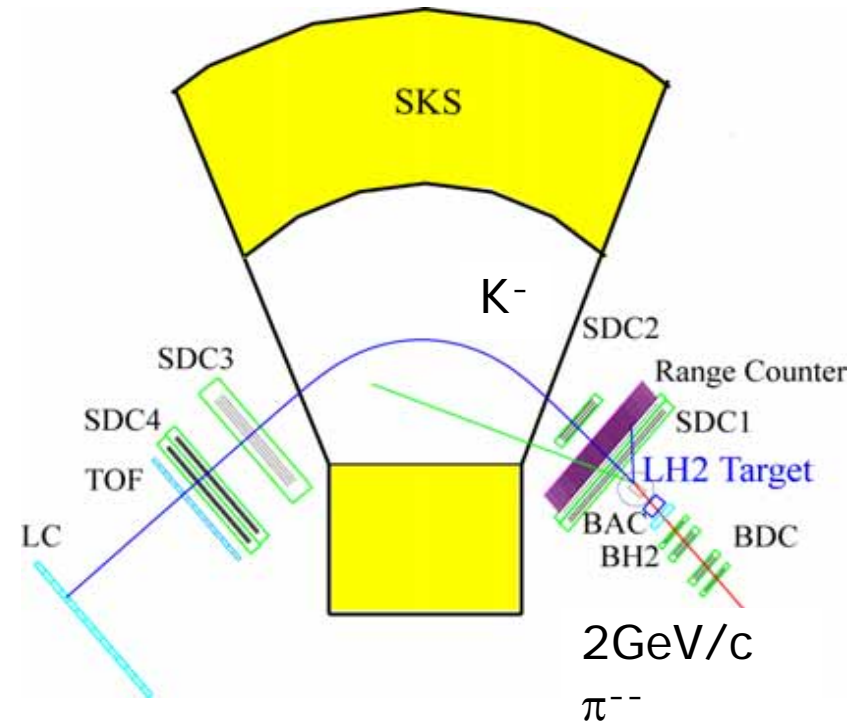
# Experimental Method

K1.8 beam line + SKS

$2\text{GeV}/c \pi^- + p \rightarrow K^- + \Theta^+$   
target : liquid  $\text{H}_2$ , reuse E559's

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

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

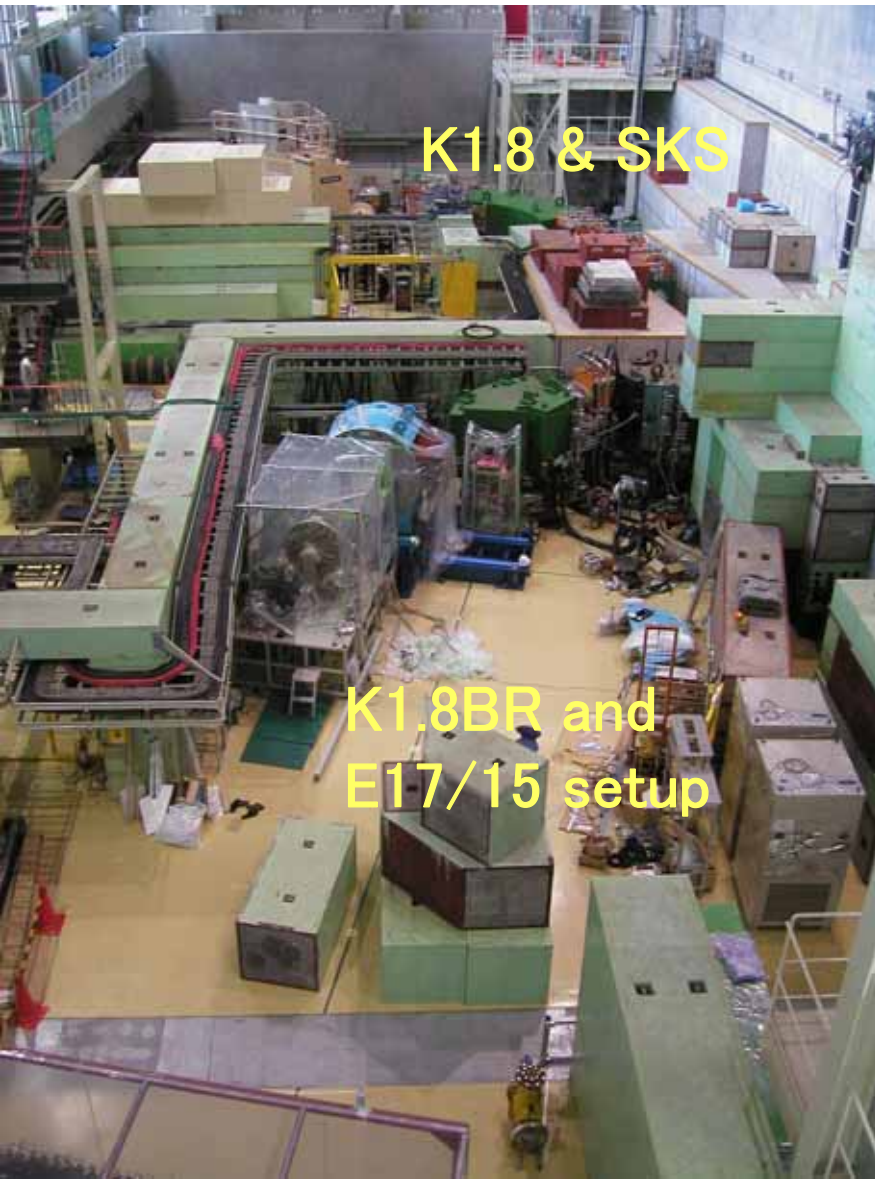


Even with the initial beam intensity, this experiment will take enough data in a short period.

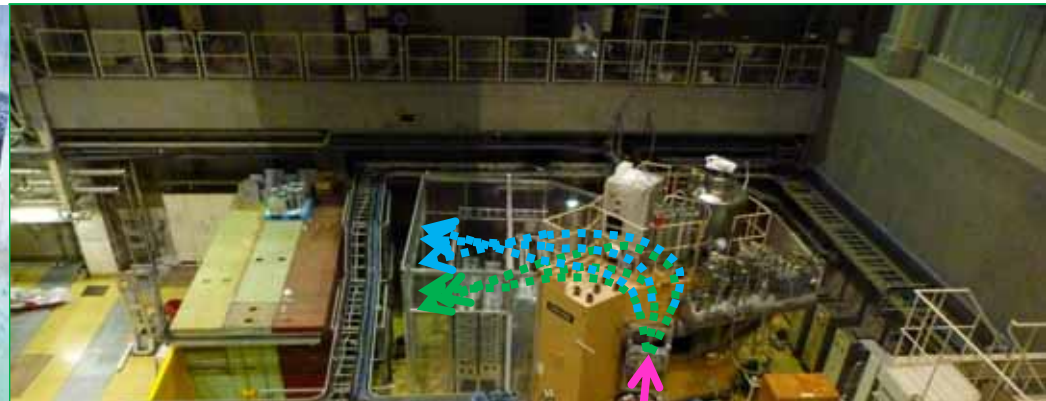




# Recent K1.8/K1.8BR Beamlines



K1.8 & SKS



K1.8BR and E17/15 setup



K1.8:  
Tohoku U., KEK  
U. Tokyo, Kyoto U.  
Nara W.U., Osaka U.

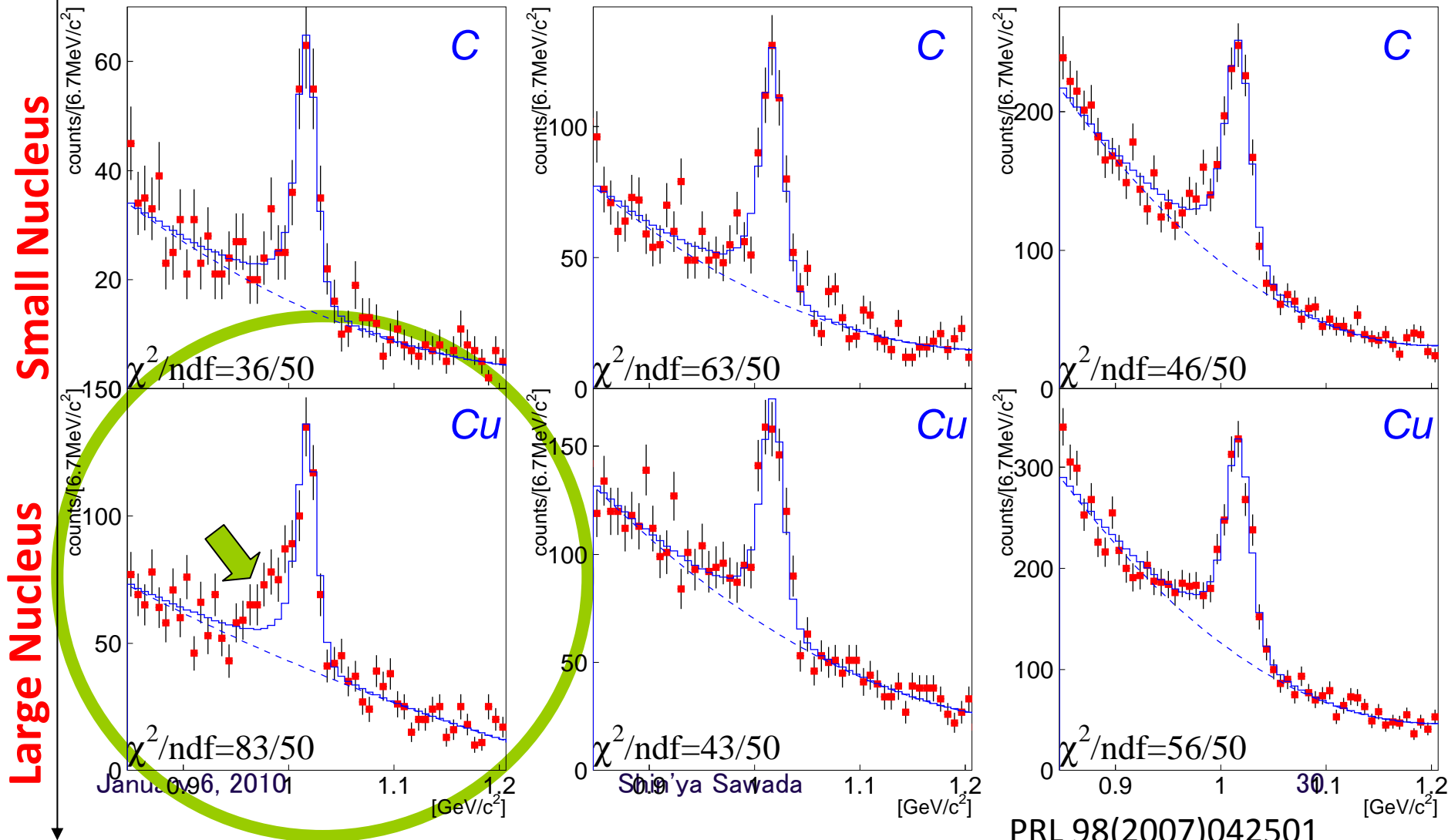


# E16: Results of a previous experiment (KEK-PS E325): Invariant mass spectra of $\phi \rightarrow e+e-$

$\beta\gamma < 1.25$  (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

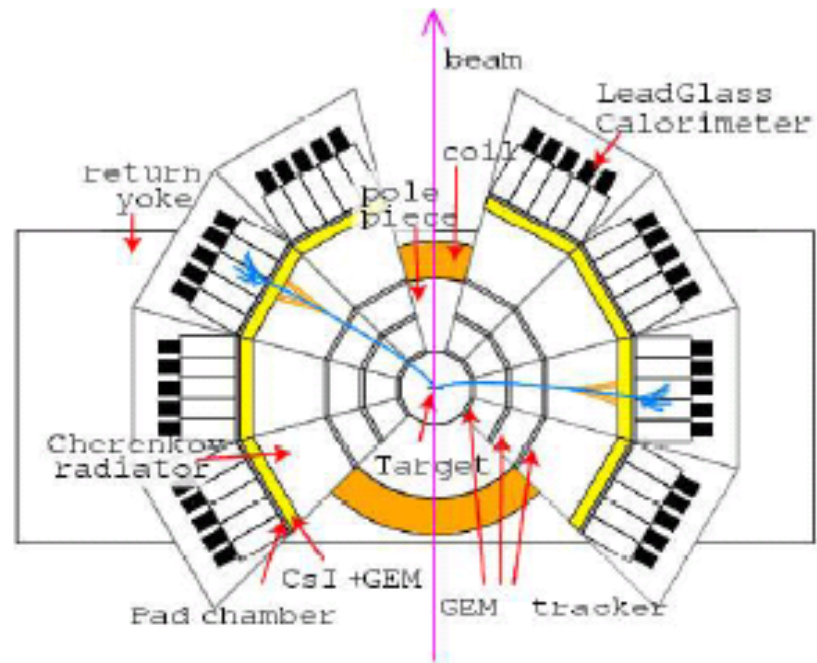
$10^7$  interaction ( $10 \times E325$ )  
 $10^{10}$  protons/spill  
with 0.1% interaction length target

→ GEM Tracker  
eID : Gas Cherenkov  
+ Lead Glass

Large Acceptance ( $5 \times E325$ )  
→ x100 statistics

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

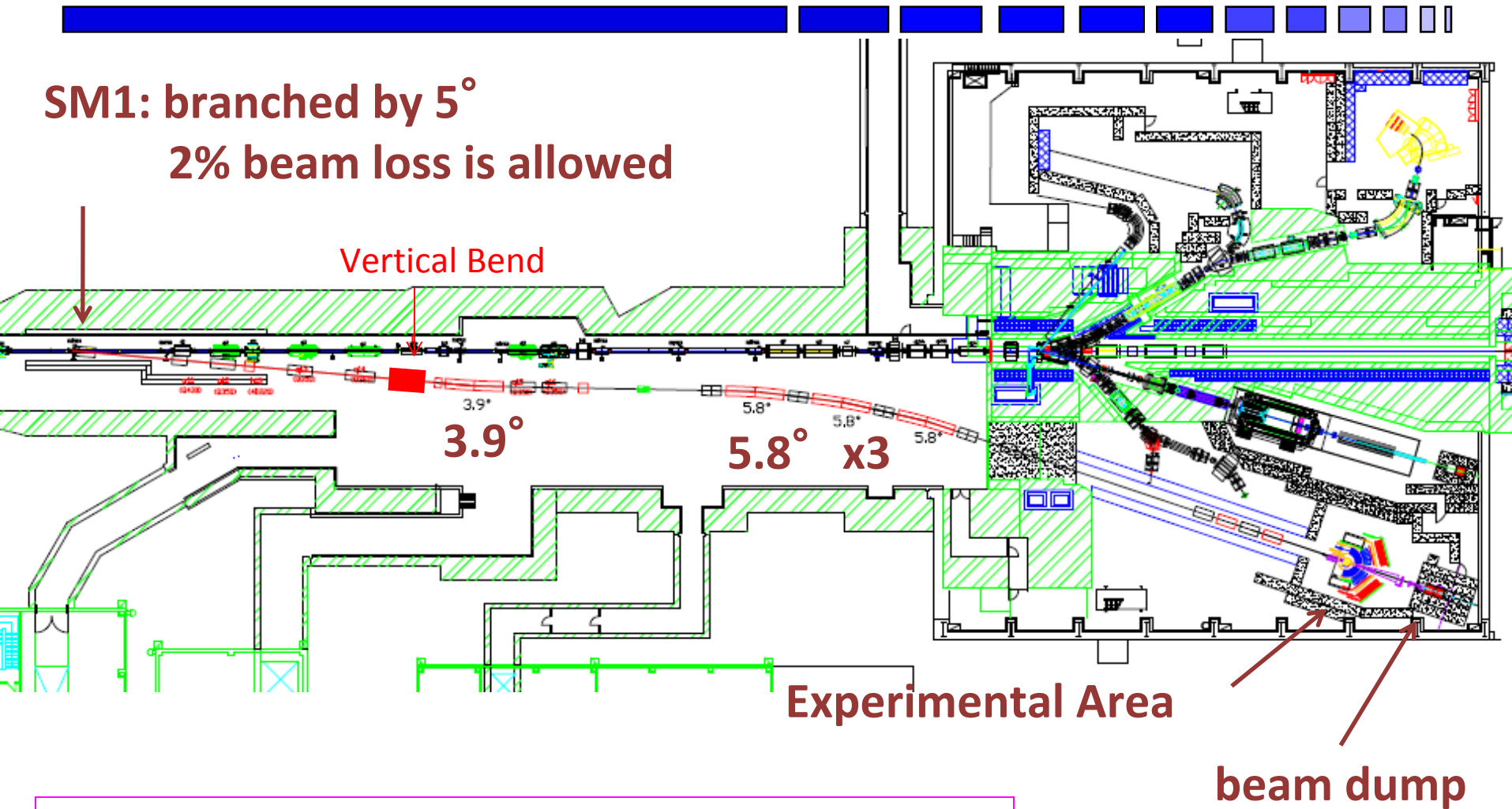
→ systematic study of mass modification





# Location of E16 : High-momentum beam line

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



Beam dump and shields are for  $10^{10}$  protons/s

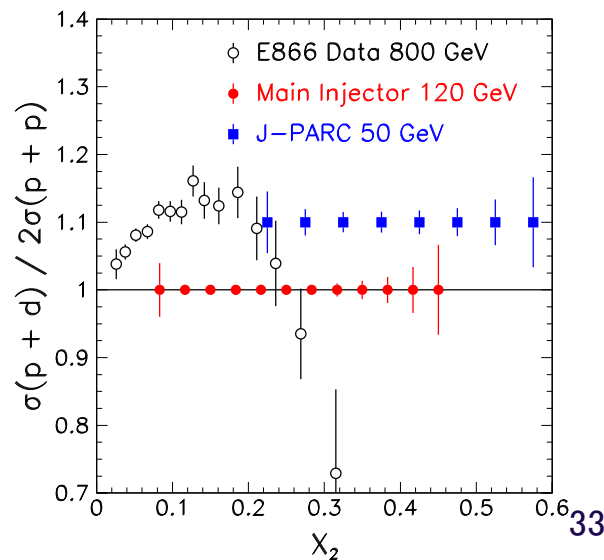
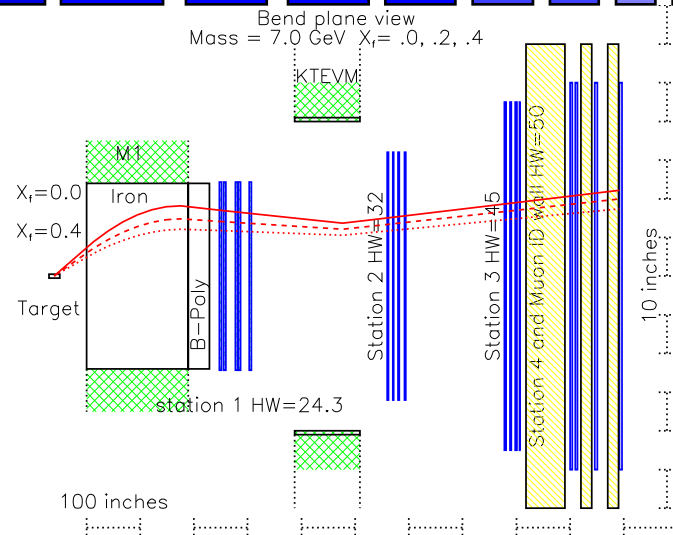




# P04: High mass dimuon measurement

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

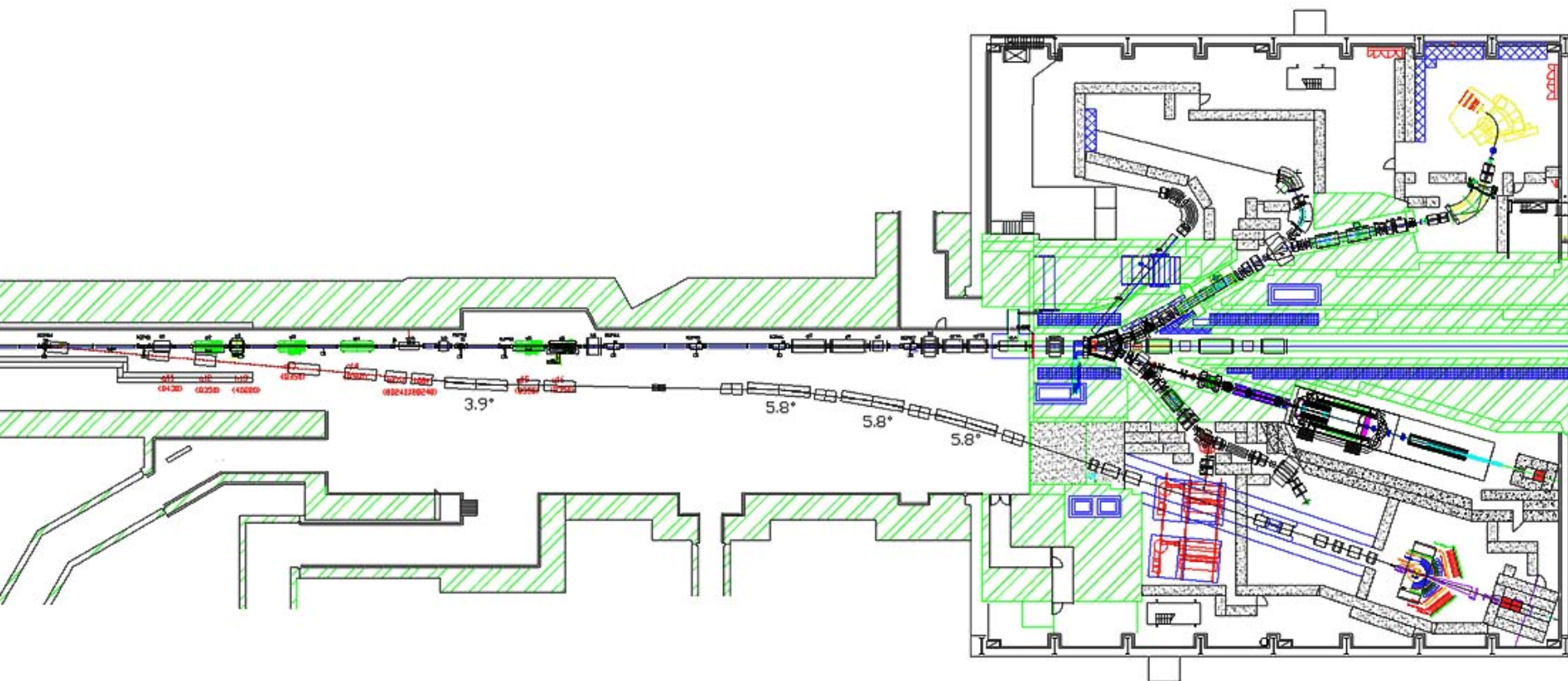
See talk by Prof. Peng.





# Near Term Future of the Hadron Hall

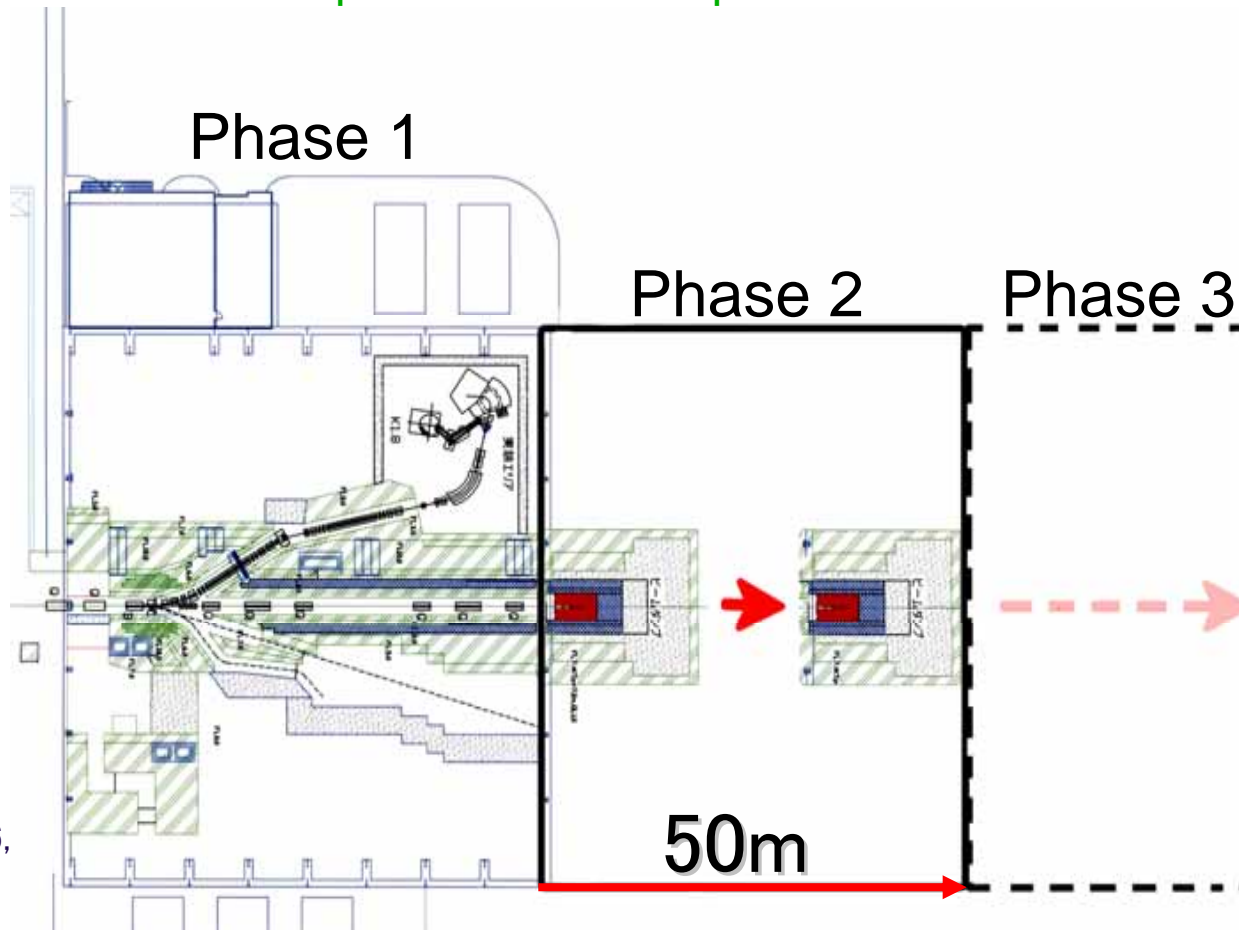
- K1.8 and KL will be ready by autumn 2009.
- K1.1BR Beam Line will be available by the middle JFY2010.
- Budget Request of the High Momentum Beam Line started in JFY2009.





# Mid Term Future of the Hadron Hall

- Extension of the Hall!!
  - ~50m downstream.
  - Beam dump is movable.
  - Ideas of the experiments and required beams are essential!





- 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. Experiments will be proposed.
  - Physics with hard processes, such as nucleon structure and short range correlation, is also under consideration.
- Efforts toward budget request for the extension is being started. Ideas of experiments and beams are essential!