



Highlights from J-PARC Hadron Facility

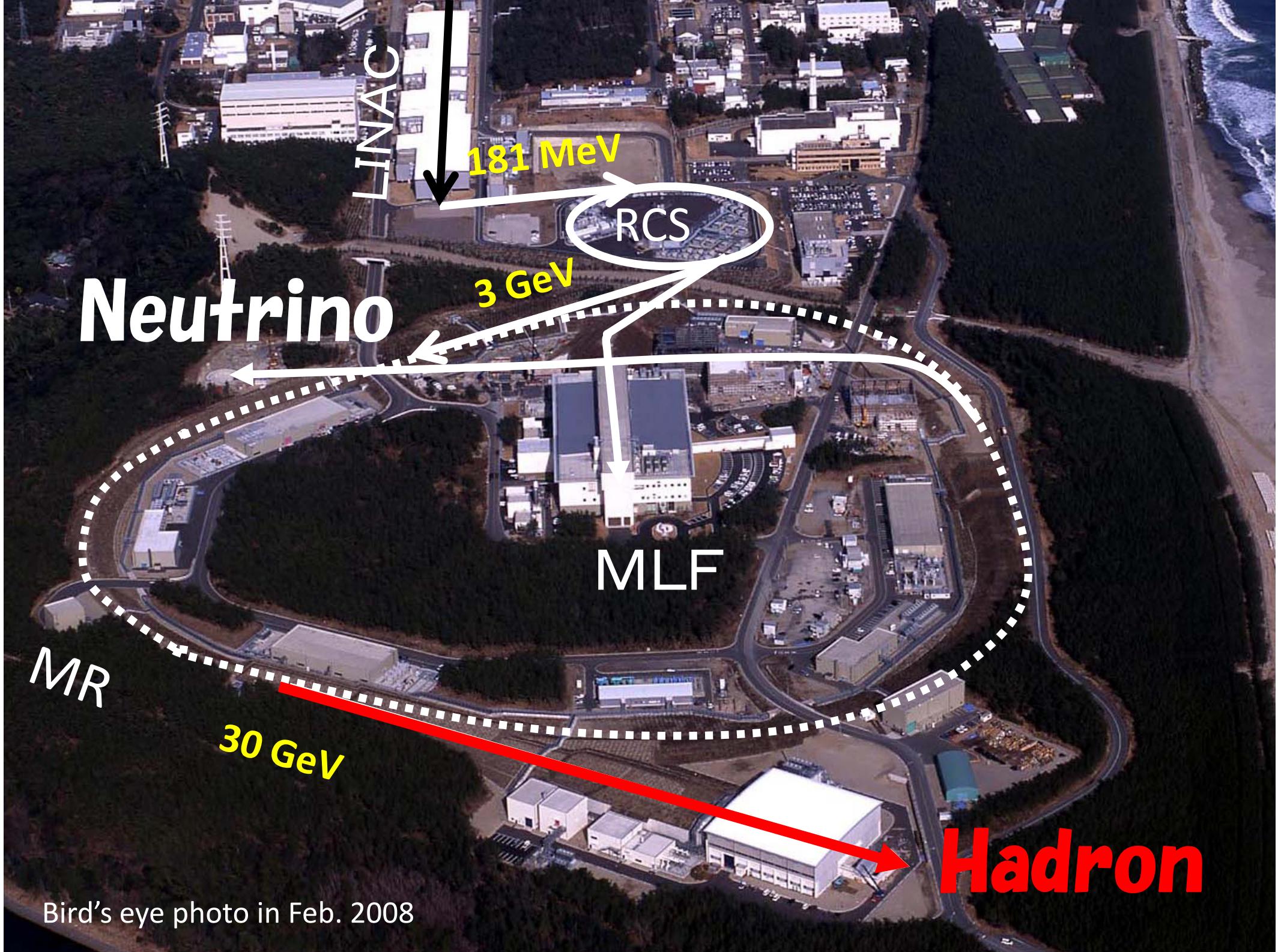
IPNS, KEK / J-PARC Center

T.Takahashi

1. Introduction of J-PARC & Hadron Facility
2. History of J-PARC
3. E19 results
4. Other program
5. Effect of Earthquake
6. Summary

J-PARC at Tokai Village





Hadron Experimental Hall at J-PARC

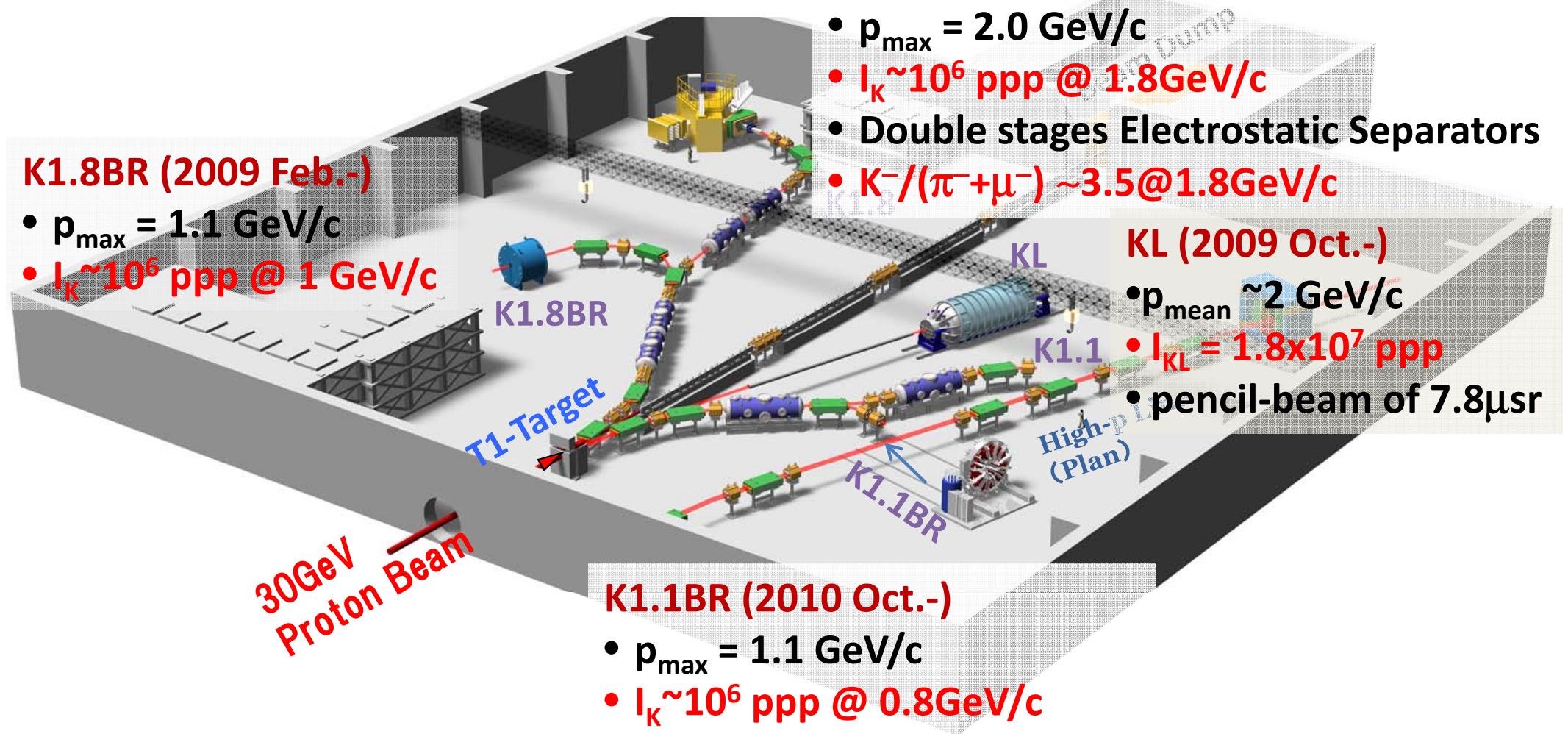
Design Beam Power: 750kW (3.4×10^{14} ppp, 50GeV-15μA)



270kW (2.0×10^{14} ppp, 30GeV-9μA)

2010 Achievement: ~5kW ($\sim 6 \times 10^{12}$ ppp, 6sec. duration)

2011 Plan: ~50kW

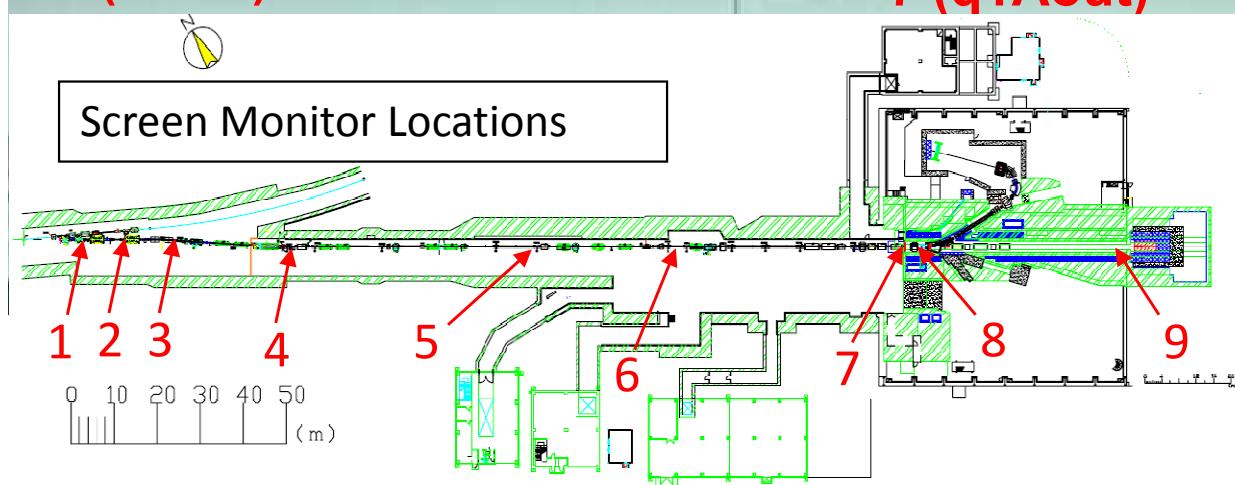
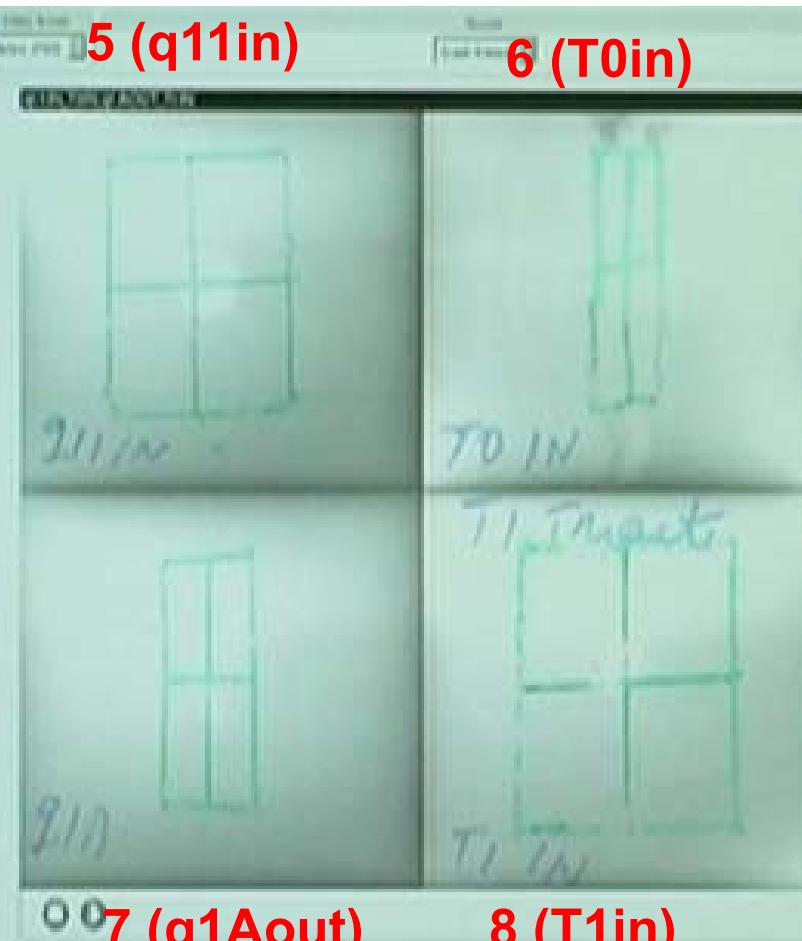
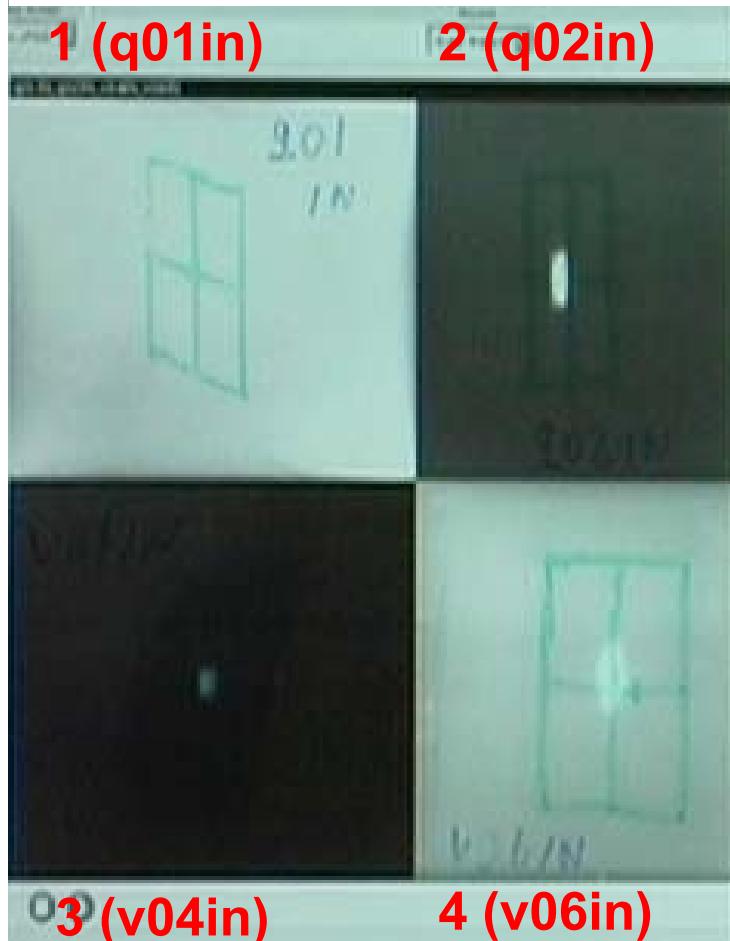




History of J-PARC, esp. on Hadron Facility

- | | |
|---|-------------|
| • Construction Start | Apr. 2001 |
| • 181MeV Acceleration at LINAC | Jan.24 2007 |
| • Complete of Civil Construction of Hadron Hall | Jul. 2007 |
| • 3 GeV Acceleration at RCS | Oct.31 2007 |
| • 3 GeV Beam Injection to MR | May 22 2008 |
| • 30 GeV Acceleration at MR | Dec.23 2008 |
| • Beam Extraction to Hadron Beamline | Jan.27 2009 |
| • Secondary Beam at K1.8BR | Feb.12 2009 |

Typical Beam Profiles measured with Screen Monitors



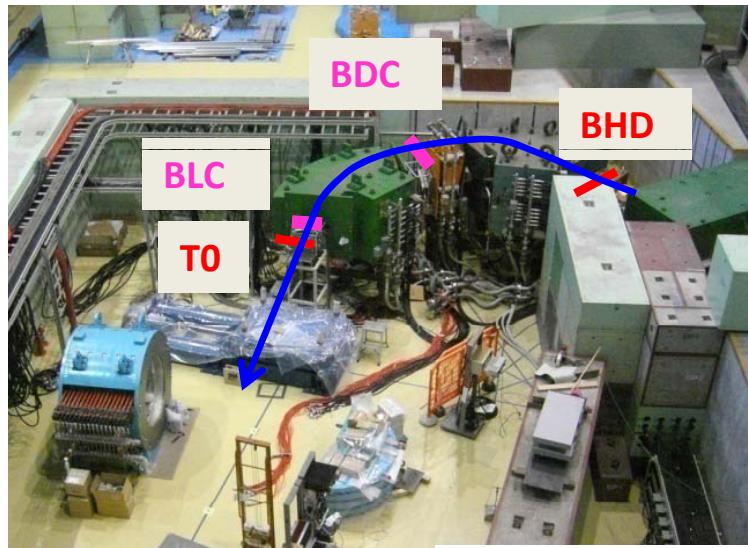
January 27th, 2009

於：ハドロンビームライン制御棟

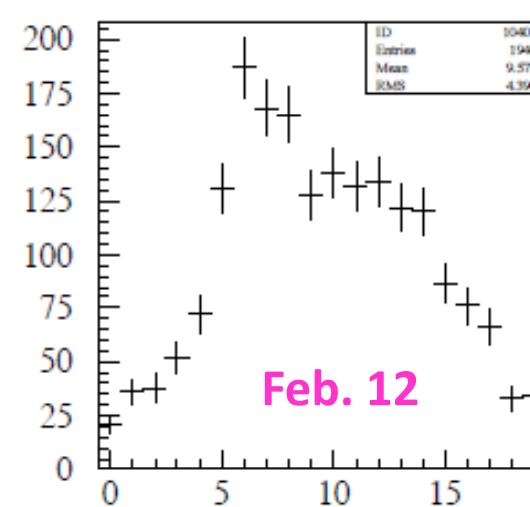


The first secondary beam at K1.8BR Feb. 12 2009

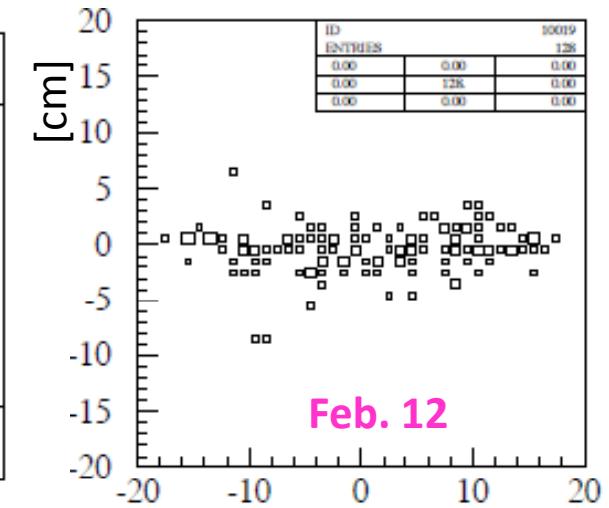
1.1GeV/c



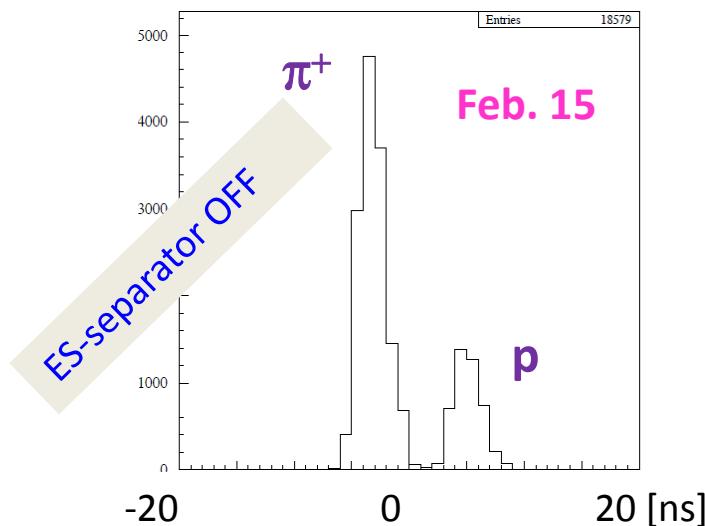
BHD hit pattern



X-Y profile at BDC

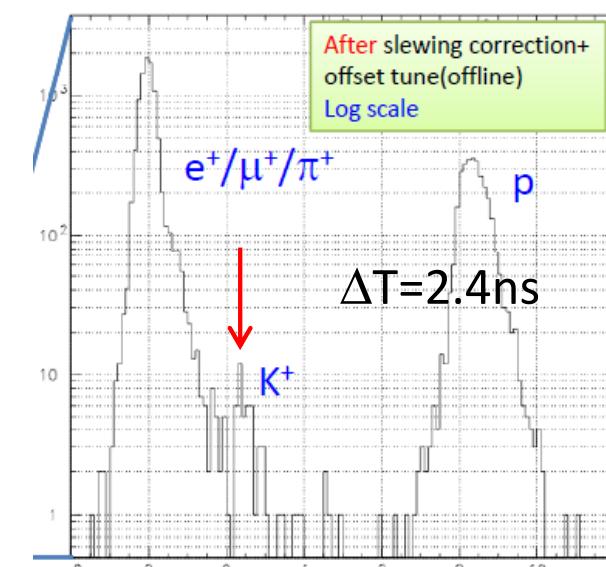


BHD-T0 time difference



2cm/seg.

[cm]

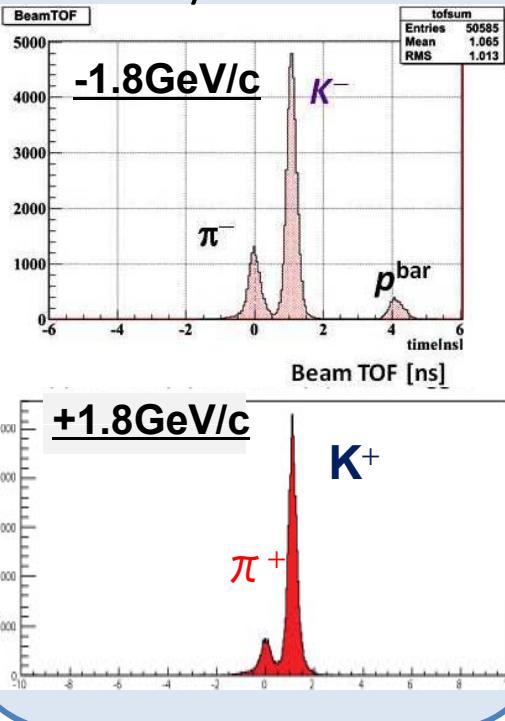




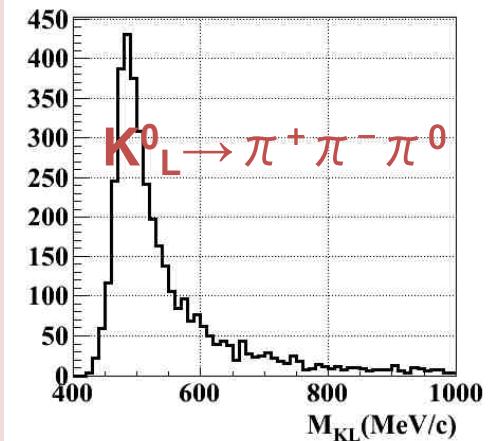
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| • The First Neutrino Beam | Apr.23 2009 |
| • The first Beam at K1.8 & KL | Oct.22 2009 |
| • The first Beam at K1.1BR | Oct.12 2010 |
| • The First Physics RUN for E19 at K1.8+SKS | Oct.-Nov. 2010 |

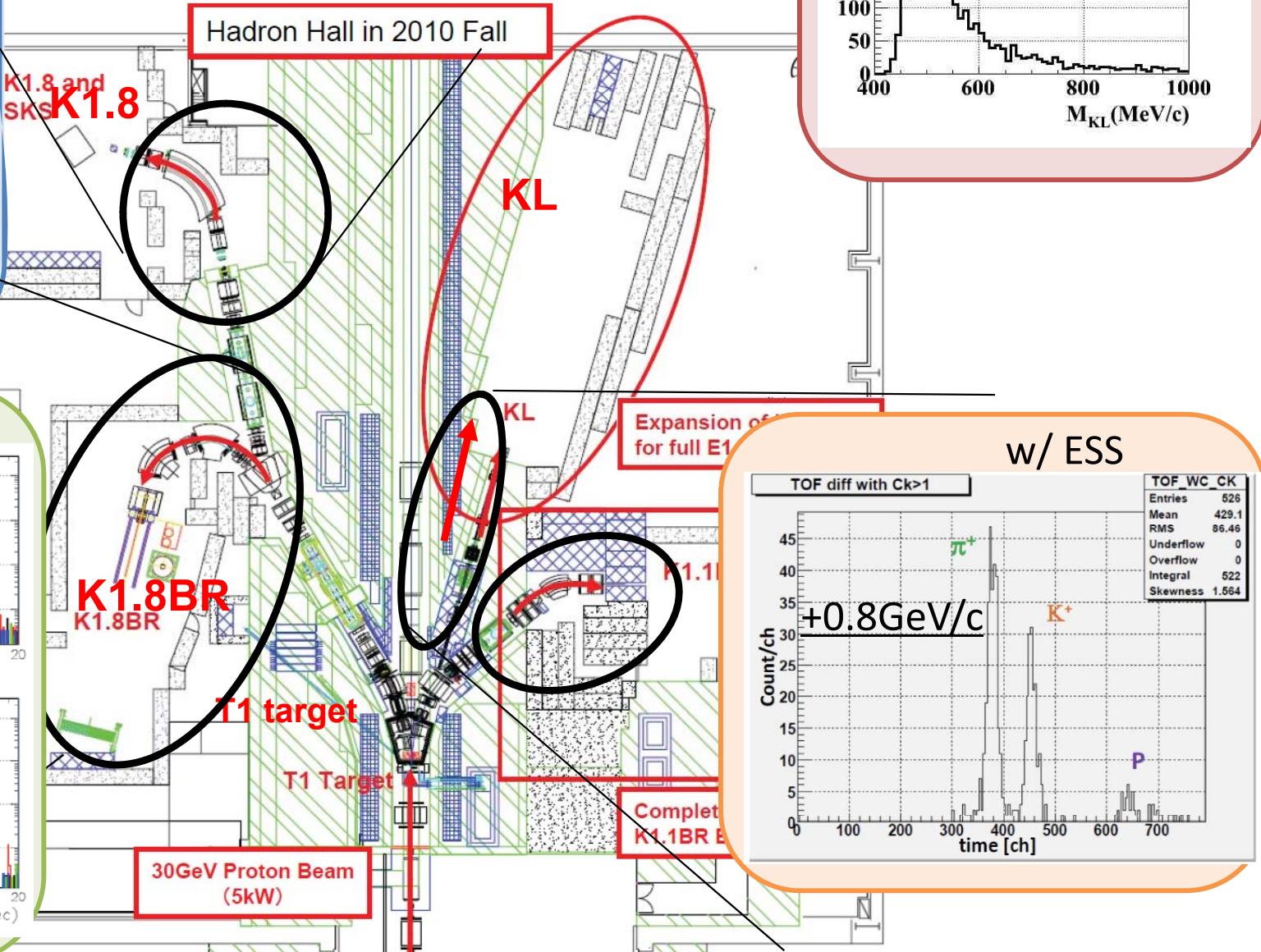
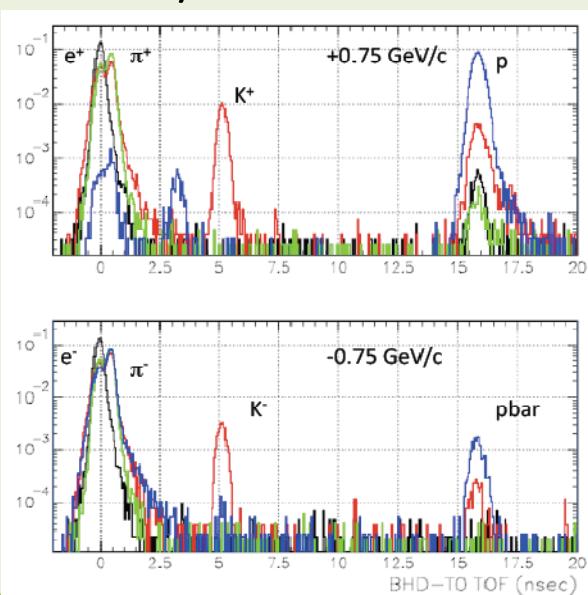
w/ ESS



We have observed charged and neutral kaons in the secondary beam lines (**K1.8BR**, **K1.8**, **KL** and **K1.1BR**) of Hadron Experimental Hall.



w/o ESS





E19 High Resolution Search for Θ^+ via the $p(\pi^-, K^-)X$ Reaction



- K.Aoki, M.Ieiri, Y.Igarashi, S.Ishimoto, **M.Naruki***, K.Ozawa, N.Saito, Y.Sato, S.Sawada, M.Sekimoto, S.Suzuki, H.Takahashi, T.Takahashi (KEK, Japan)
- F.Hiruma, R.Honda, K.Hosomi, K.Miwa, T.Koike, M.Sato, H.Tamura, K.Yagi, T.O.Yamamoto, **Y.Yonemoto**, M.Ukai (Tohoku Univ., Japan))
- K.Imai, H.Sako, S.Sato, **K.Shirotori** (JAEA, Japan)
- K.Itahashi, **T.N.Takahashi** (RIKEN, Japan)
- Y.Komatsu, S.Masumoto, K.Utsunomiya (Univ. of Tokyo, Japan)
- K.Nakazawa (Gifu Univ., Japan)
- S.Adachi, H.Fujioka, Y.Ichikawa, M.Moritsu, T.Nagae, M.Niiyama, H.Sugimura, A.O.Tokiyasu, N.Tomida (Kyoto Univ. , Japan)
- **R.Iwasaki** (Nara Women's Univ. , Japan)
- N.Ishibashi, K.Matsuoka, H.Noumi, A.Sakaguchi, T.Tanaka, K.Yoshida (Osaka Univ., Japan)
- M.J.Kim, R.Kiuchi, S.J.Kim, G.G.Joo, K.Tanida, S.B.Yang, C.J.Yoon (Seoul National Univ., Korea)
- **B.Bassalleck** (Univ. of New Mexico, USA)
- P.Evtoukhovitch, A.Kulikov, D.Mzhavia, V.Samoilov, Z.Tsamalaidze (JINR, Russia)
- A.Krutenkova, V.V.Kulikov (ITEP, Russia)
- S.Bufalino, E.Botta, S.Marcello, A.Feliciello, M.Agnello (Torino, Italy)
- J.Franz (Freiburg, Germany)

71 persons, 15 Institutes

Production mechanism is a KEY



- CLAS(2006) $\gamma d \rightarrow p K^- K^+ (n) < 0.15\text{--}3\text{nb}$
- LEPS(2009) $\gamma C \rightarrow K^+ K^- (n) 5.1\sigma$

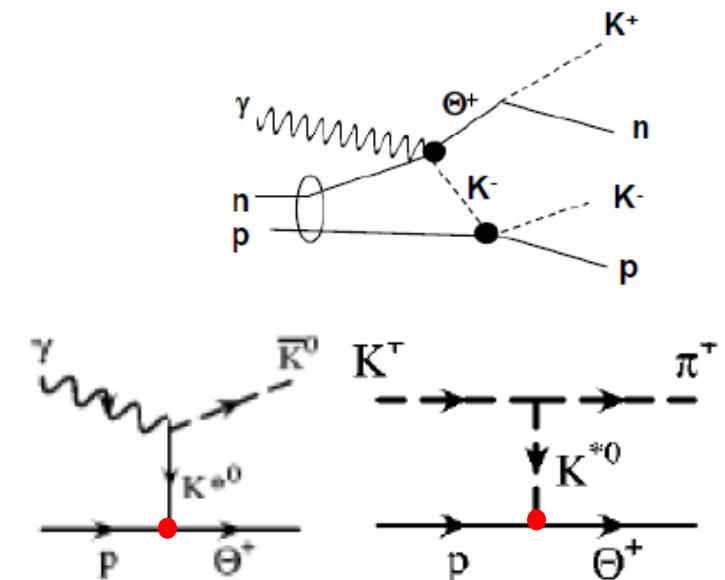
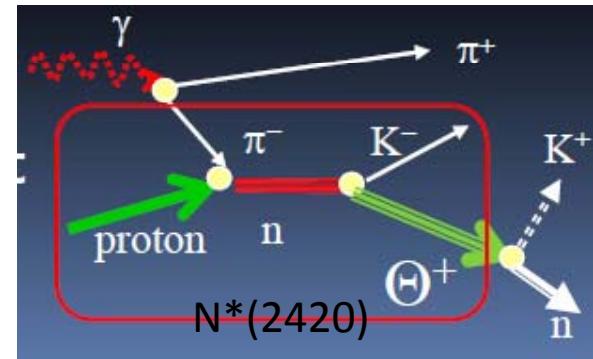
not inconsistent with each other
due to strong angle/energy dependence

- CLAS(2006) $\gamma p \rightarrow K^0 K^+ n < 0.8\text{nb}$
- E559(2008) $K^+ p \rightarrow \pi^+ X < 3.5\mu\text{b}/\text{sr}$

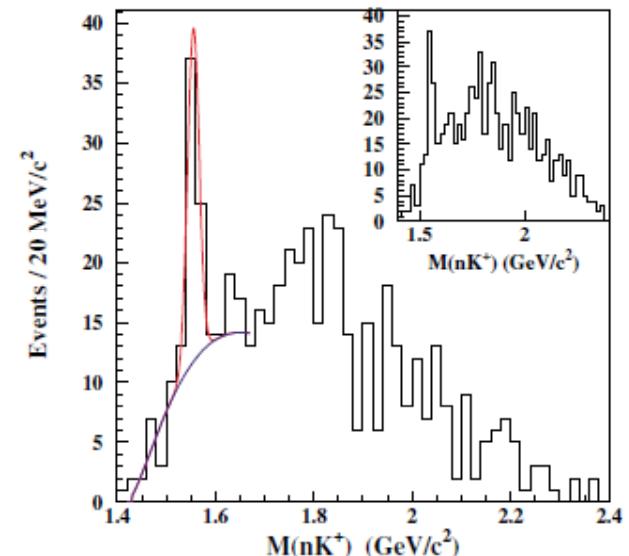
imply a very small coupling to K^* ($g_{NK^*\Theta} \sim 0$)

Pion-induced Θ^+ production could be significant!

$$\sigma(\pi^- p \rightarrow K^- \Theta^+) \quad \Gamma_{K\bar{N}\Theta}$$



CLAS: $\gamma p \rightarrow \pi^+ K^- K^+ n$
PRL92(2004)032001

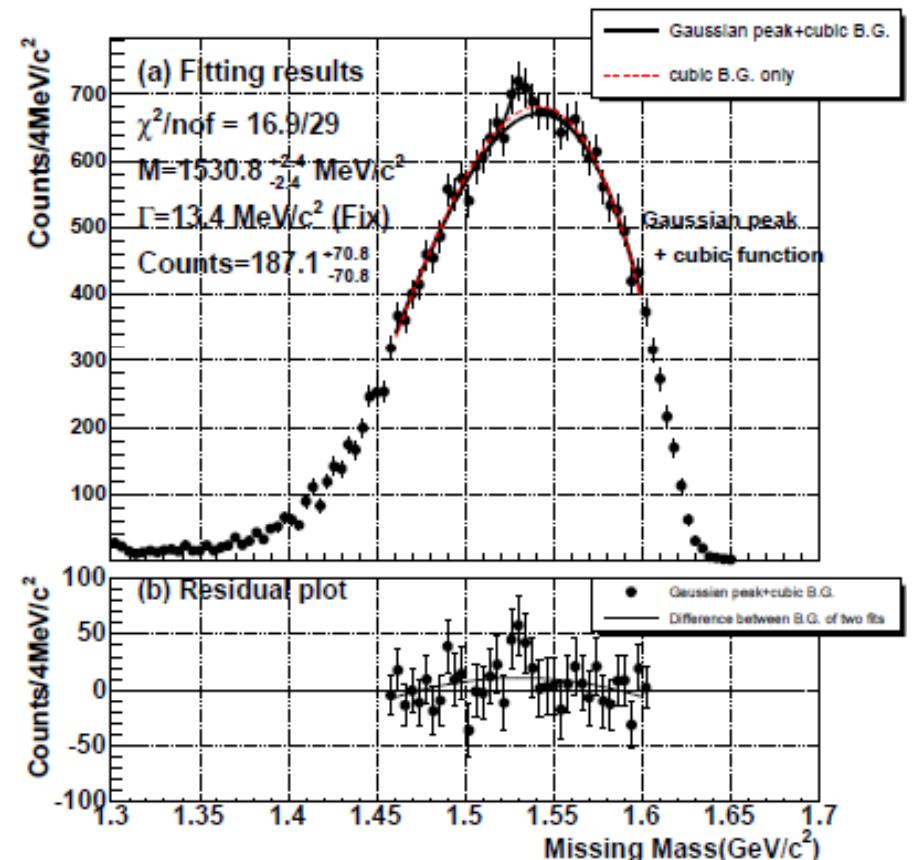




Search for Θ^+ via the $p(\pi^-, K^-)X$

- **K2 beamline + KURAMA at forward angle**
 - Resolution of **13.4 MeV(FWHM)**
- **Polyethylene target (CH_x)**
- **Beam momentum: 1.87, 1.92 GeV/c**
- **Intensity:** $3.3 \times 10^5 \pi / \text{spill}$
- **Time:**
 - $32 \times 2 \text{ hours}$
 - $7 \times 10^9 \pi$
- **S/N : 2.5σ**
- **U.L. $2.9 \mu\text{b}/\text{sr}$**

PLB635(2006)72



A bump structure !? at $1.53 \text{ GeV}/c^2$
only at $P_\pi = 1.92 \text{ GeV}/c$
if true, $d\sigma/d\Omega = 1.9 \mu\text{b}/\text{sr}$ (lab)

KEK E522

- K2 beamline + KURAMA at forward angle
 - Resolution of 13.4MeV(FWHM)
- Polyethylene target (CH_x)
- Beam momentum: 1.87, 1.92 GeV/c
- Intensity: $3.3 \times 10^5 \pi / \text{spill}$
- Time:
 - $32 \times 2 \text{ hours}$
 - $7 \times 10^9 \pi$
- S/N : 2.5σ
- U.L. $2.9 \mu\text{b}/\text{sr}$

E19 Goal

- K1.8 beamline + SKS
 - 0 – 18°
 - 2.5MeV (FWHM)
- Liquid H₂ target
 - No quasi-free B.G.
- 1.87, 1.92, and 1.97 GeV/c
 - Energy Dependence
- High Intensity of $\sim 10^7 / \text{spill}$
 - $4.8 \times 10^{11} \pi$ on target for each momentum

10^4 events ($1.9 \mu\text{b}/\text{sr}$)
Sensitivity of 75nb/sr



E19 Step 1 Data-taking

Oct.12–Nov.16, 2010



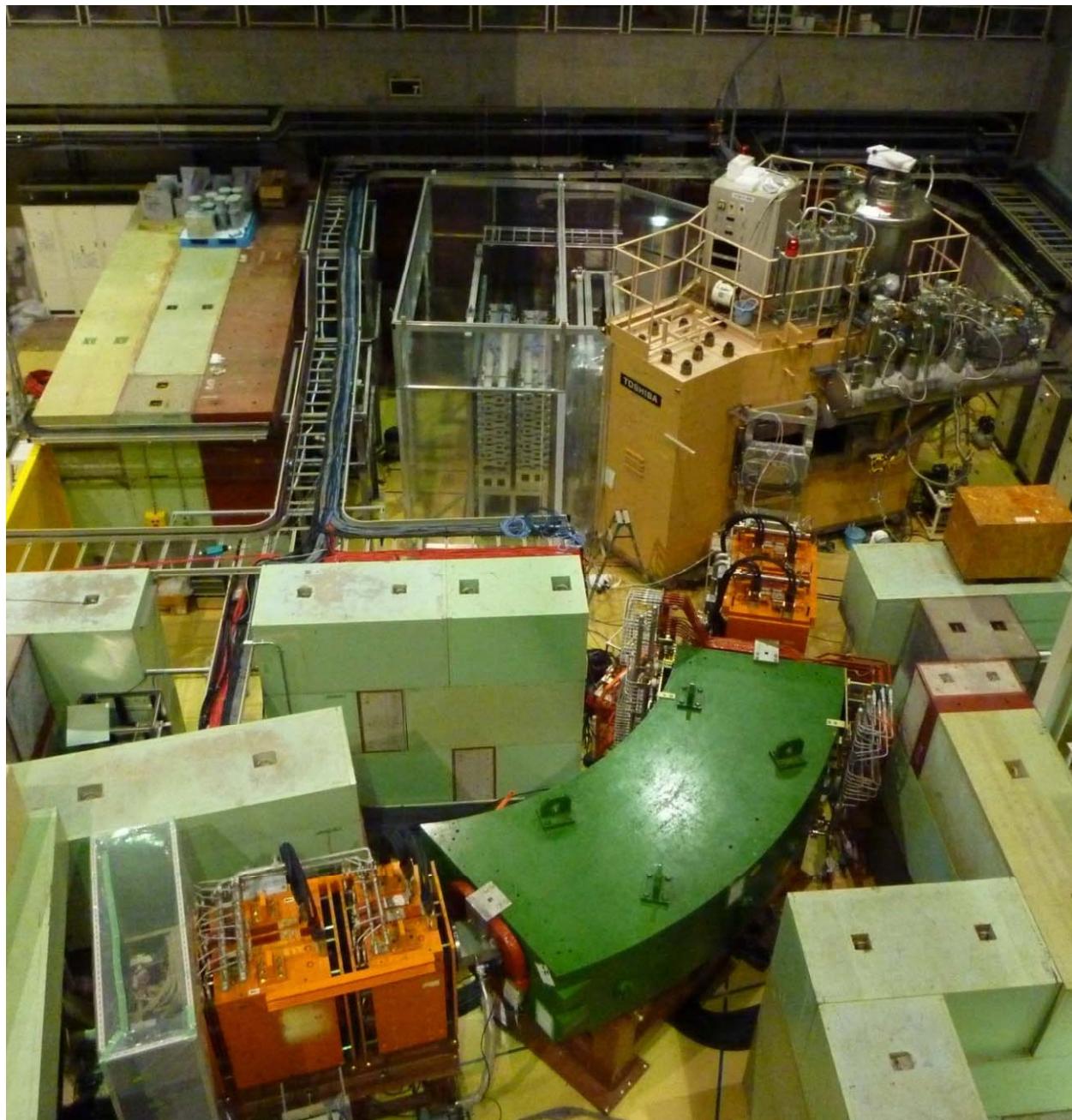
Due to time structure of the beam (duty factor $\sim 16\%$),
intensity was limited to 1.1M/spill (1spill = 6 sec.)

**Goal: To confirm Θ^+ with 10σ at $1.92\text{GeV}/c$
assuming $1.9\mu b/\text{sr}$ (E522)**

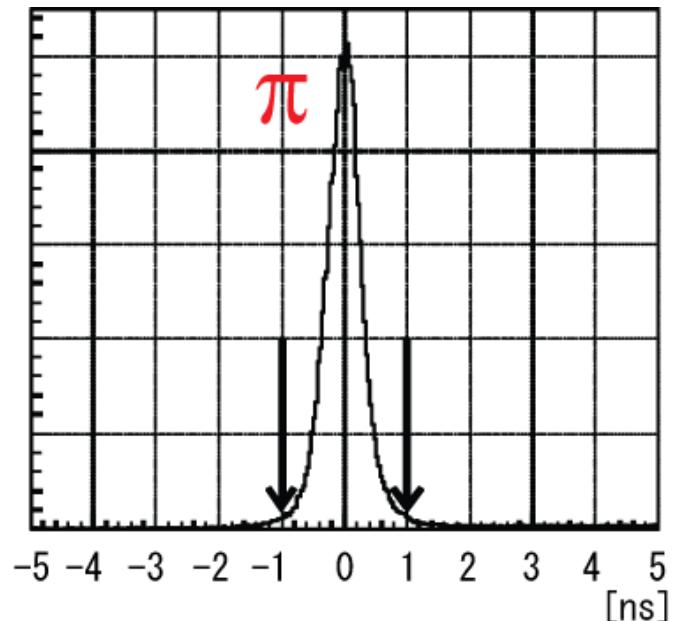
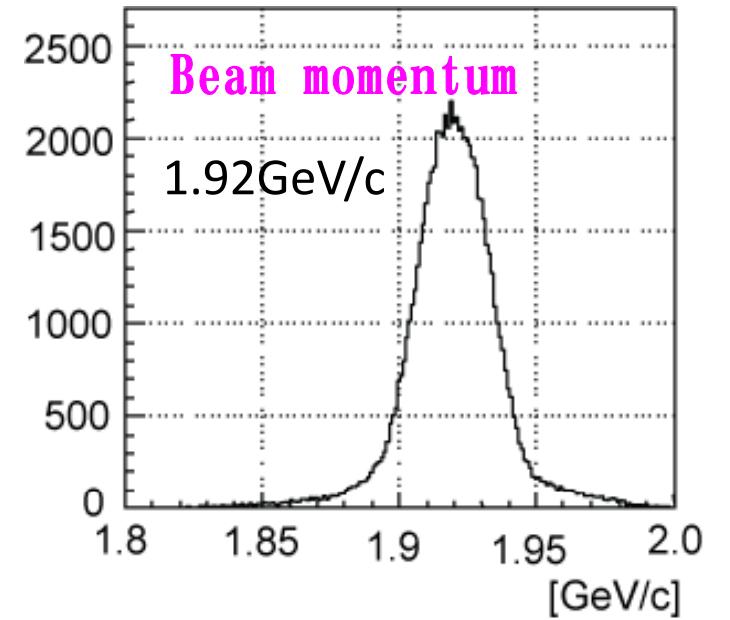
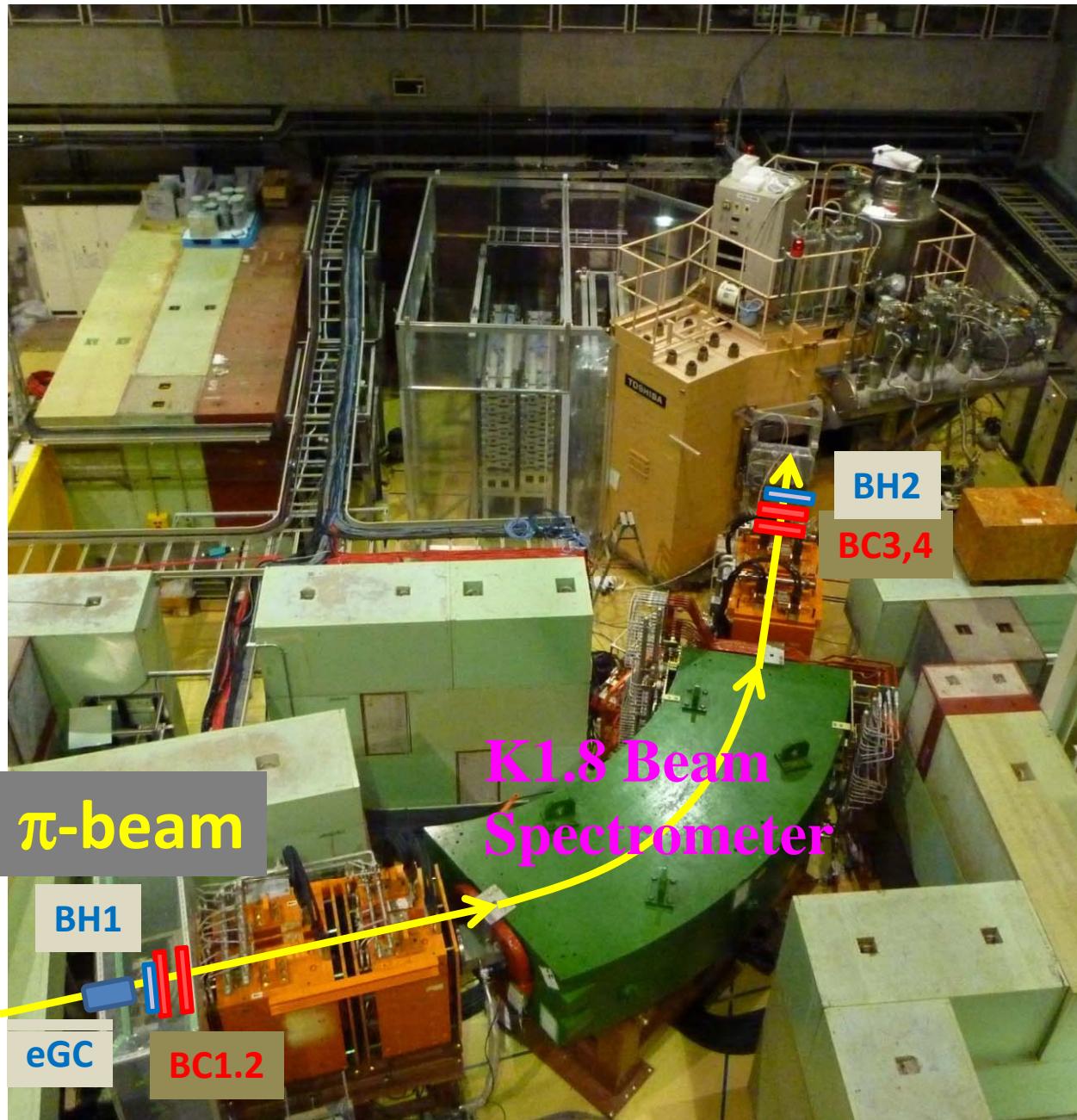
RUN Summary total 272 hours (incl. down time)

• Beamline & Detector Commissioning	52 hours	
• Calibration Data	64 hours	
➤ Beam Through		
➤ Empty target		
➤ $p(\pi^-, K^+) \Sigma^-$ at $1.37\text{ GeV}/c$		$1.2 \times 10^{10} \pi$
➤ $p(\pi^+, K^+) \Sigma^+$ at $1.37\text{ GeV}/c$		$3.0 \times 10^9 \pi$
➤ $p(\pi^-, p) \pi^-$ at $0.5\text{ GeV}/c$		$2.0 \times 10^8 \pi$
• E19 Production Run	151 hours	
➤ $p(\pi^-, K^+) X$ at $1.92\text{ GeV}/c$		$7.8 \times 10^{10} \pi$

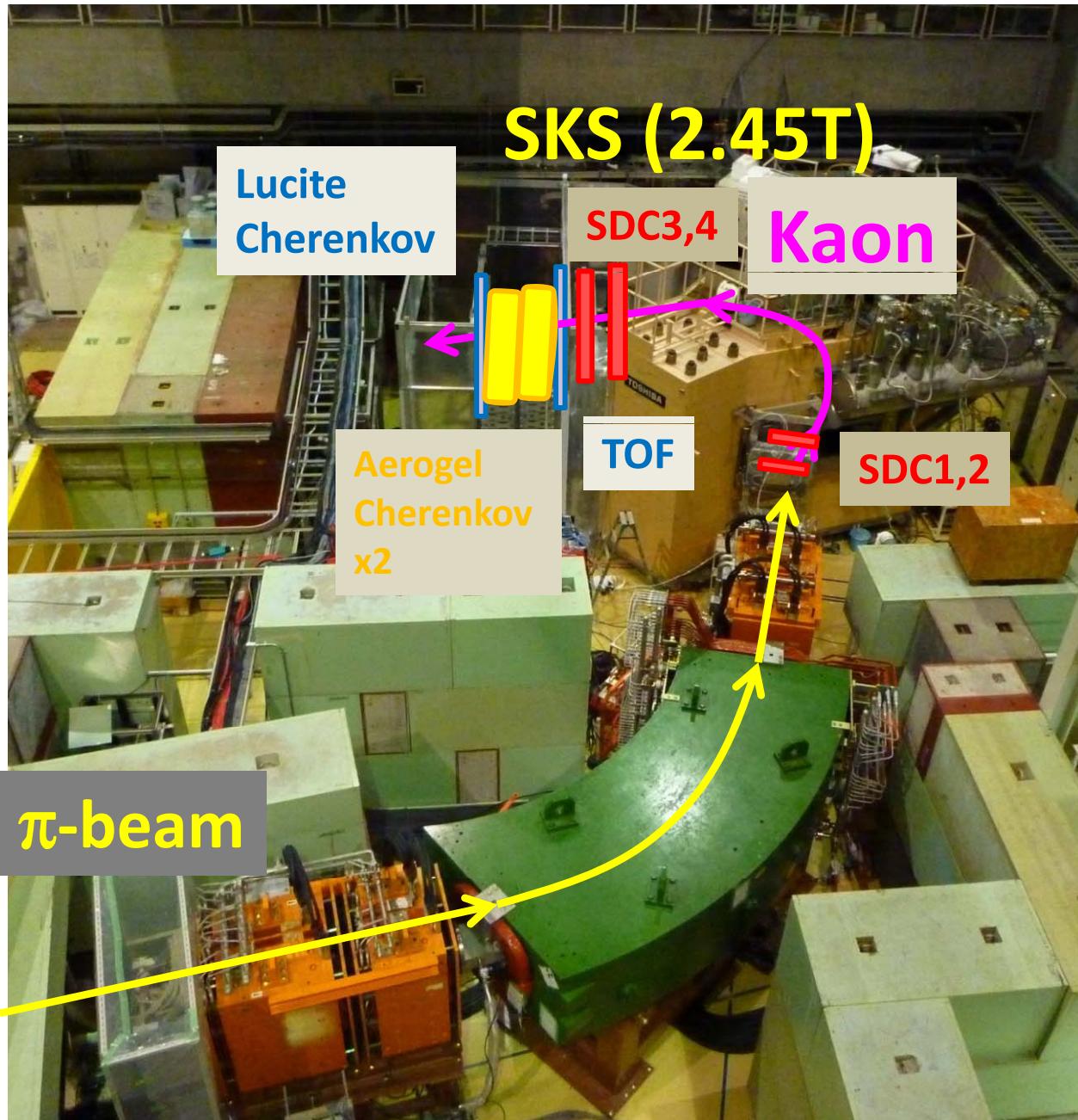
Setup – K1.8 Beam Spectrometer and SKS –



Setup – K1.8 Beam Spectrometer and SKS –

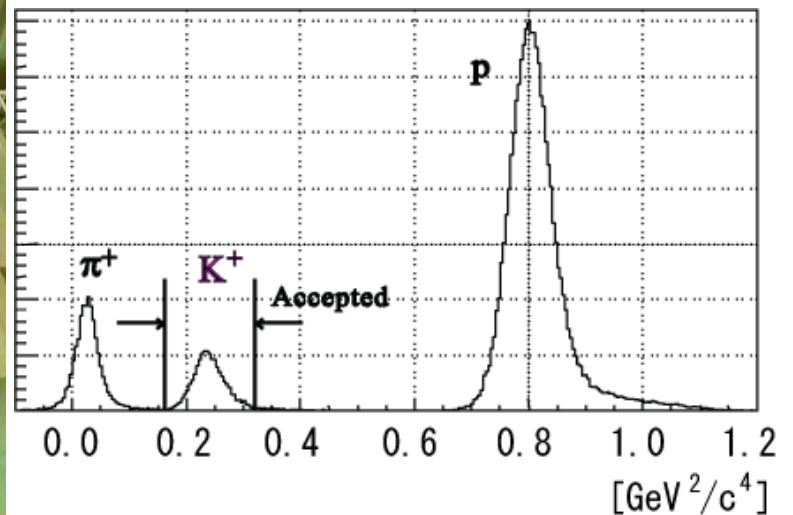


Setup – K1.8 Beam Spectrometer and SKS –



100msr solid angle
0.7 < p < 1.0 GeV/c

M² of Particles (Σ^- RUN)

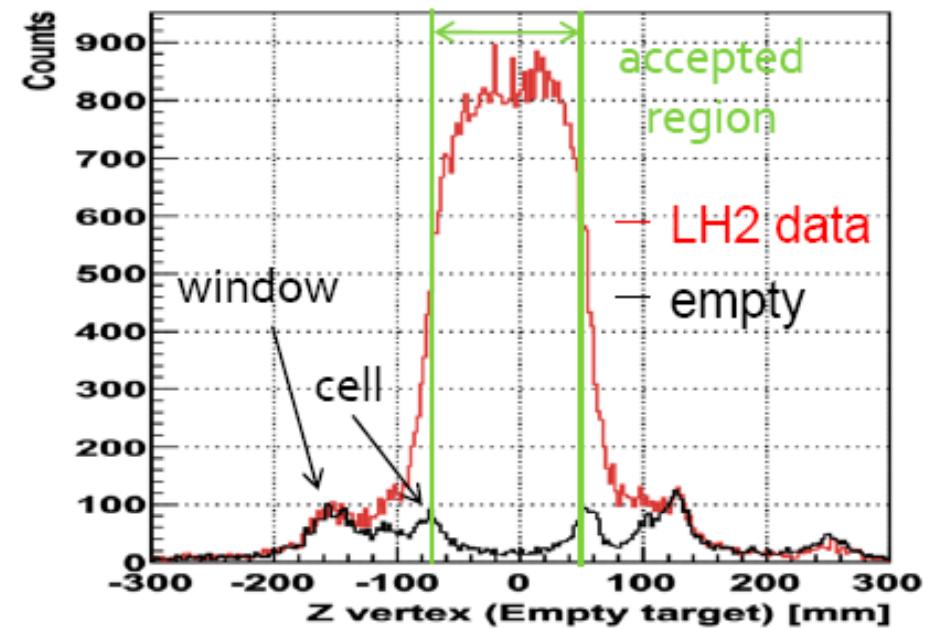
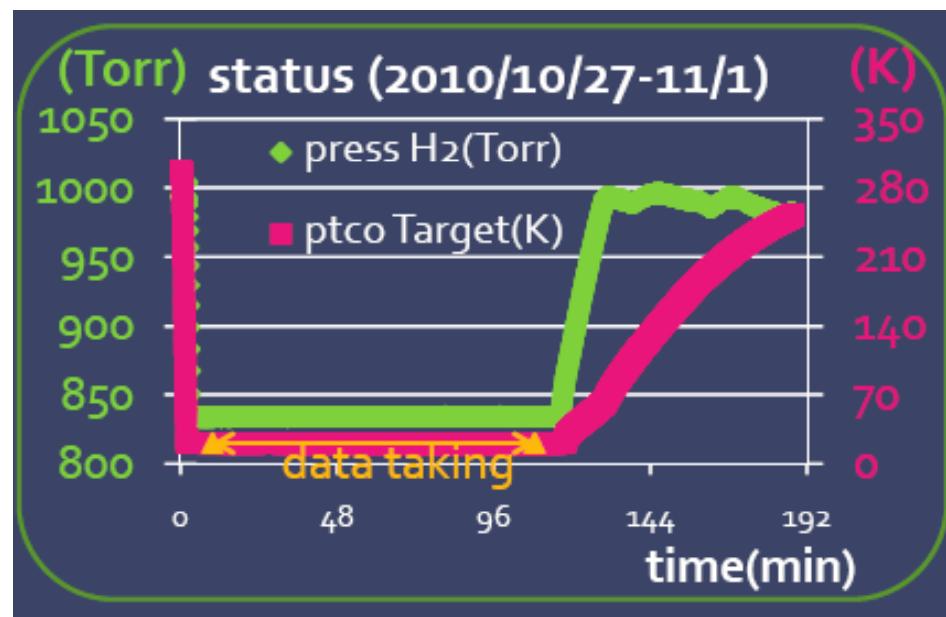




Liquid H₂ target

Continuous-flow Liquid Helium Cryostat
Cell Size of 67.8 mm ϕ \times 120mm L (PET)
Window of 0.25mm Mylar (x2)

Z-vertex distribution by (π^- , π^-)



Stable operation during data-taking
 $\square \delta\rho/\rho \leq 10^{-5}$

B.G. contamination < 3%

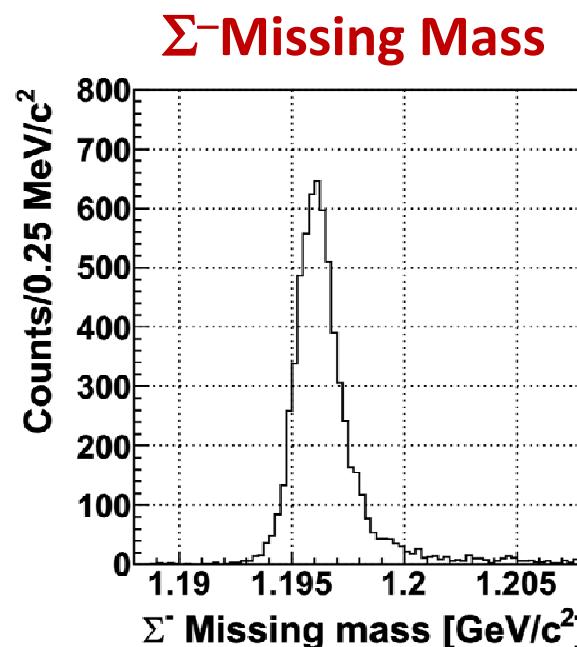
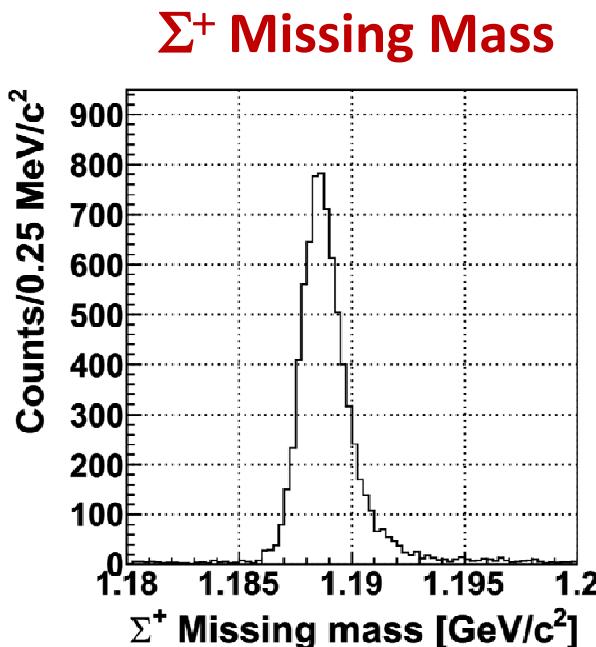
Spectrometers' Calibration & Performance



	B.S. [GeV/c]	SKS [T]	Meas. [MeV/c ²]	PDG [MeV/c ²]
Θ^+ RUN	-1.92	-2.45		
Σ^+ RUN	+1.37	+2.45	1186.2	1189.37 ± 0.07
Σ^- RUN	-1.37	+2.45	1196.2	1197.45 ± 0.03

Adjust offset and scale factor ($B \rightarrow p_0$) of B.S. to reproduce PDG values

Calibration error of ± 1.4 MeV/c²

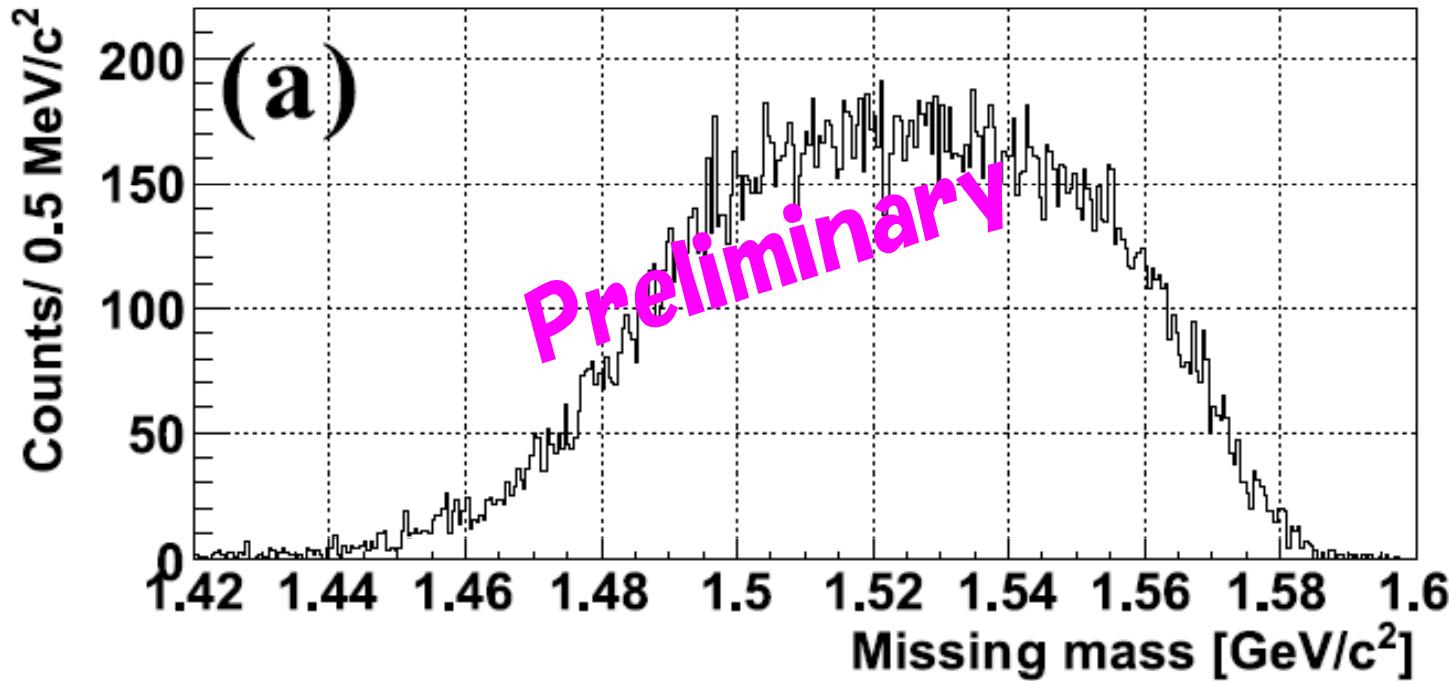


$$\Delta M_{FWHM} = 1.9 \pm 0.1 \text{ MeV/c}^2$$



1.5 MeV/c² (FWHM)
resolution for Θ^+ (1530 MeV/c²)

$p(\pi^-, K^-)X$ Missing Mass

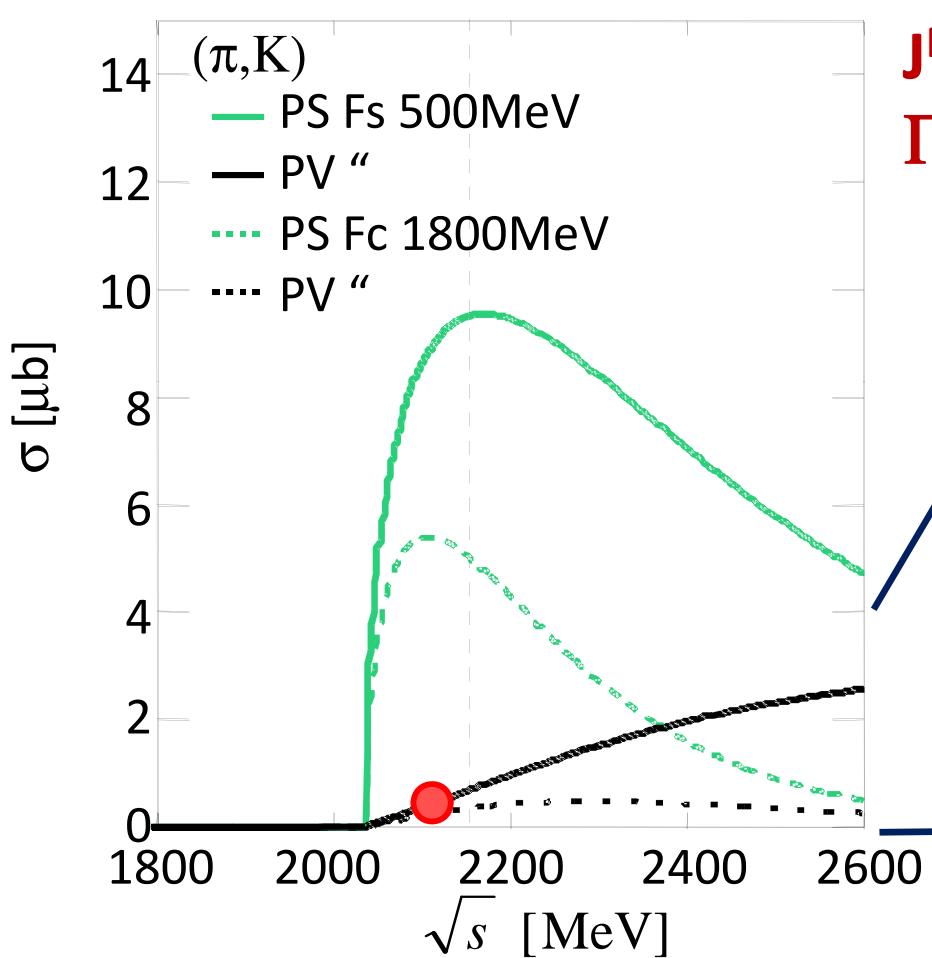


- Expected resolution 1.5MeV/c²
- No peak structure was observed.
 - Present upper limit $\sim 0.3\mu\text{b}/\text{sr}$ (averaged 2–15°)
 $\sim 0.3\mu\text{b}$ (isotopic K distribution)

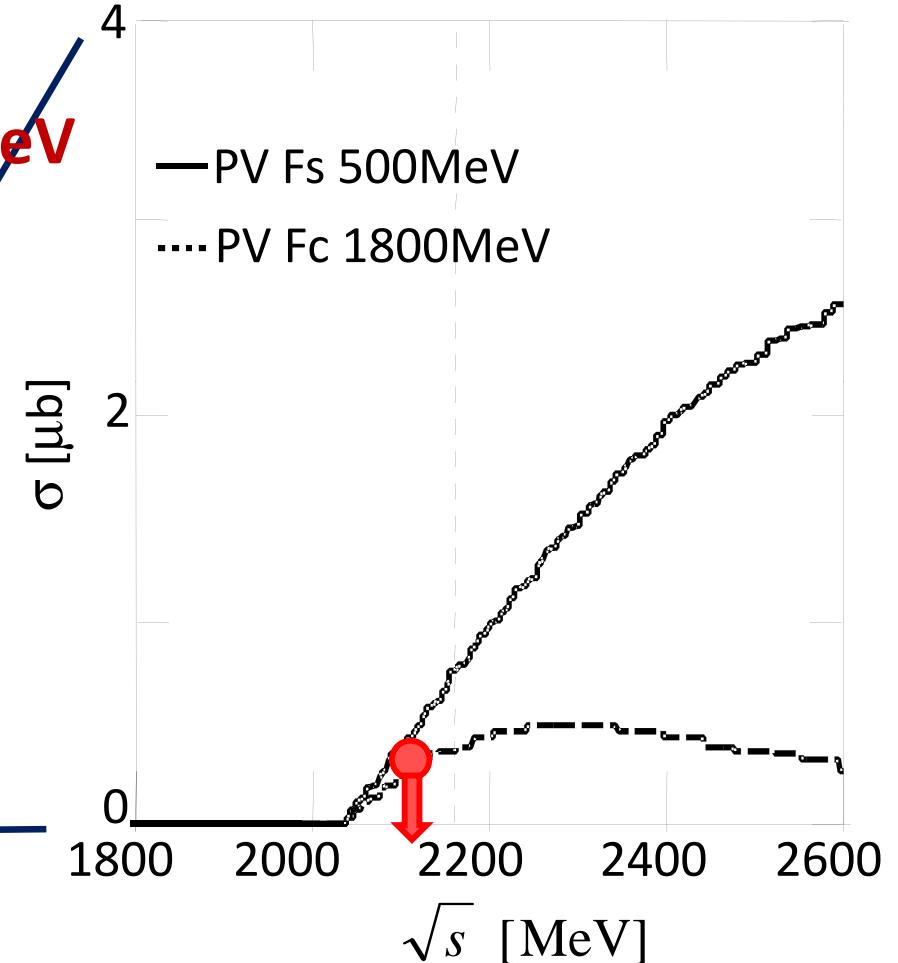
Comparison with Theory



T.Hyodo, Private Cominication



$J^P = 1/2^+$
 $\Gamma_\Theta = 1 \text{ MeV}$



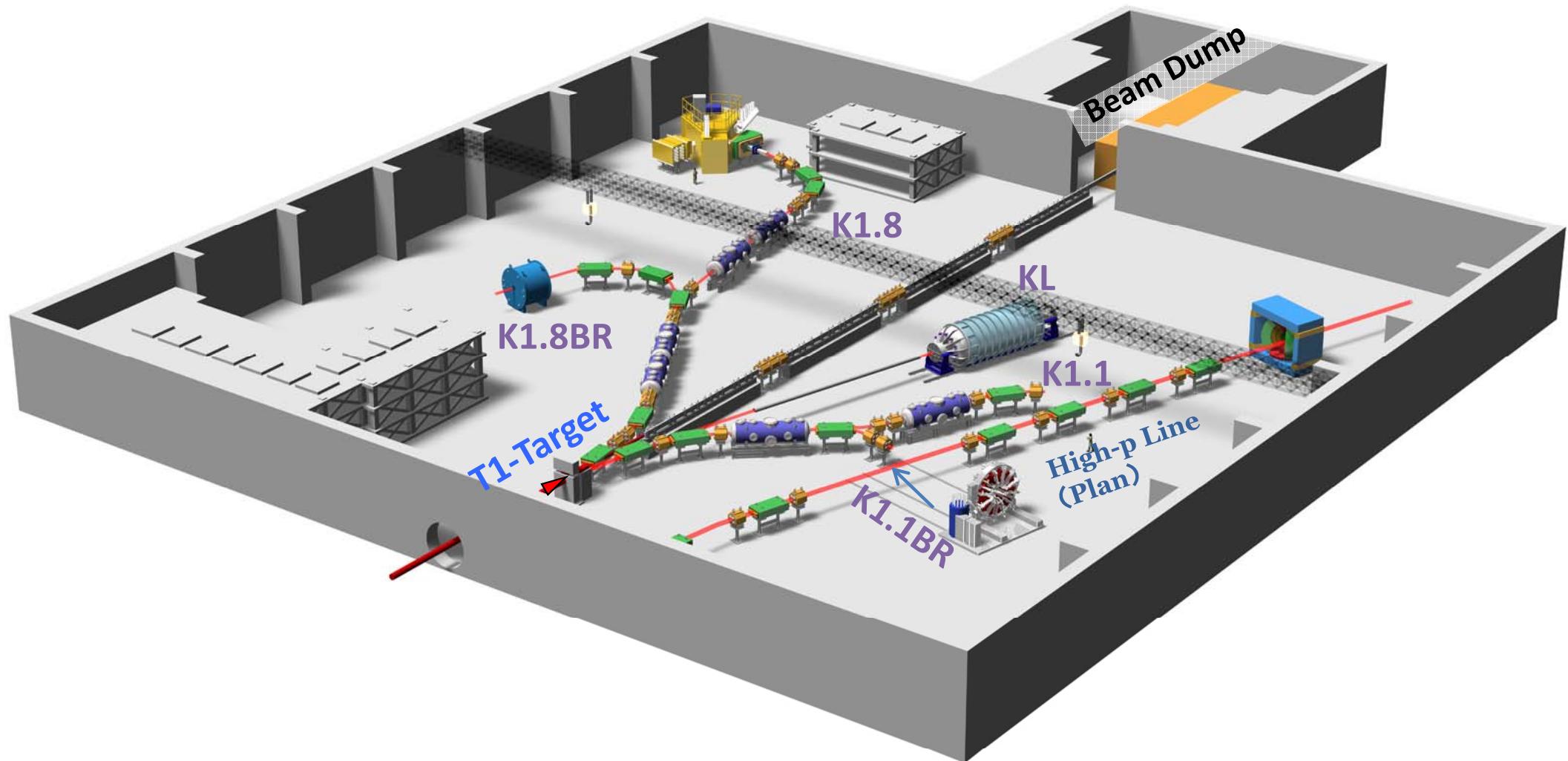
$\sqrt{s} = 2120 \text{ MeV} @ 1.92 \text{ GeV/c}$
 $2160 \text{ MeV} @ 2.0 \text{ GeV/c}$

$0.3 \mu b / \text{sr} \rightarrow 75 \text{ nb/sr}$
 $\Gamma_\Theta = 1 \text{ MeV} \rightarrow 0.25 \text{ MeV}$

Future Plan of E19

- **New analysis is underway.**
 - **improve statistics by $\sim 20\%$ by adding multi-track events.**
- **Data-taking at 2.0 GeV/c with $\sim 0.3 \mu b/sr$ sensitivity.**
 - **6 days data-taking with $\sim 1.1M$ /spill beam**
 - **We were planning to run in April RUN.**
- **Achieve the original statistics to reach $75nb/sr$ with much improved beam condition.**

Nuclear & Hadron Physics at Hadron Hall



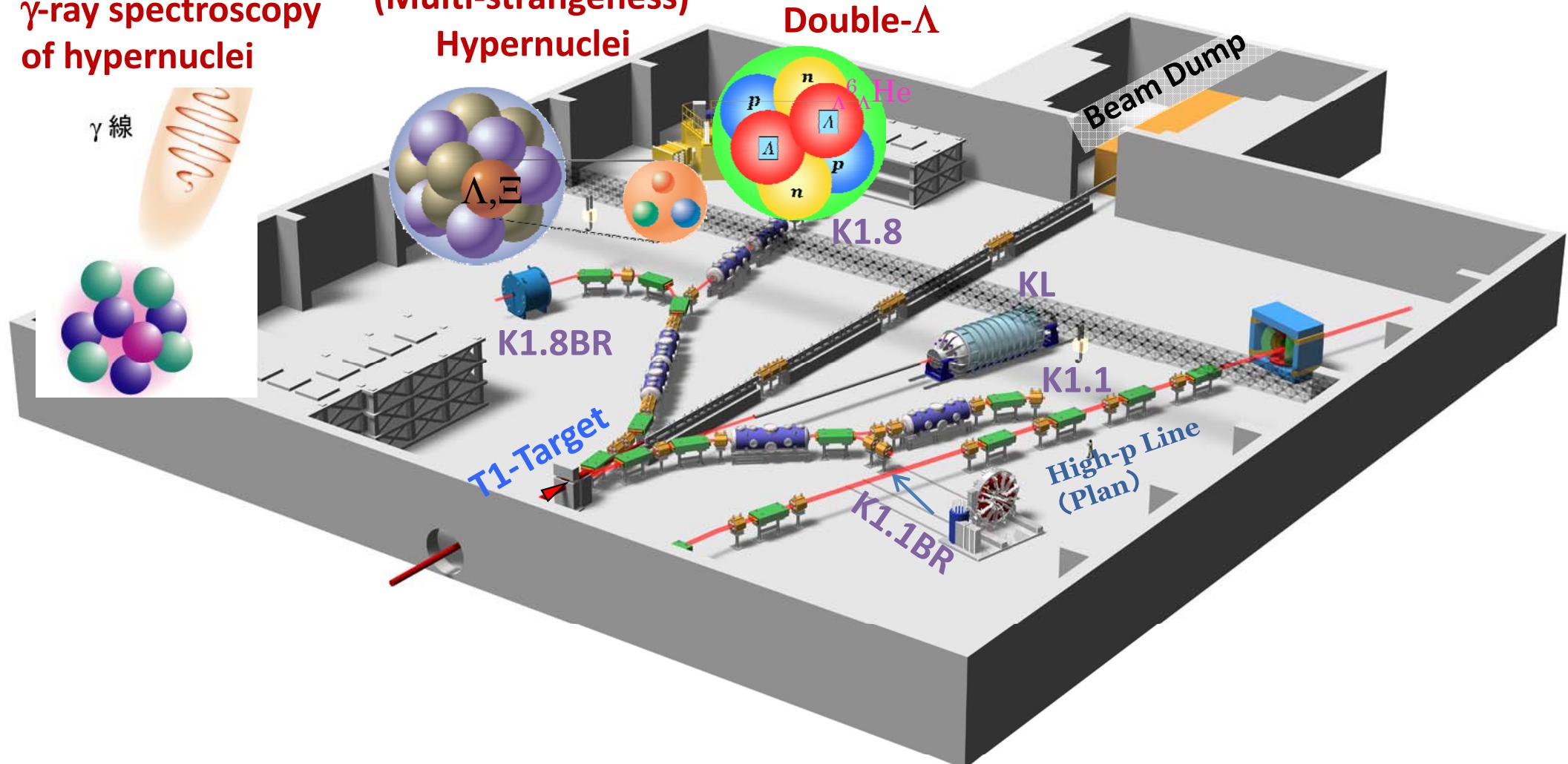
Nuclear & Hadron Physics at Hadron Hall



Hypernuclear Physics

γ-ray spectroscopy
of hypernuclei

(Multi-strangeness)
Hypernuclei

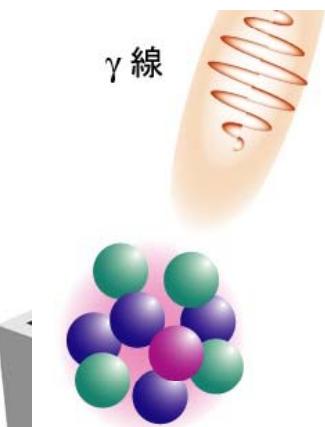


Nuclear & Hadron Physics at Hadron Hall



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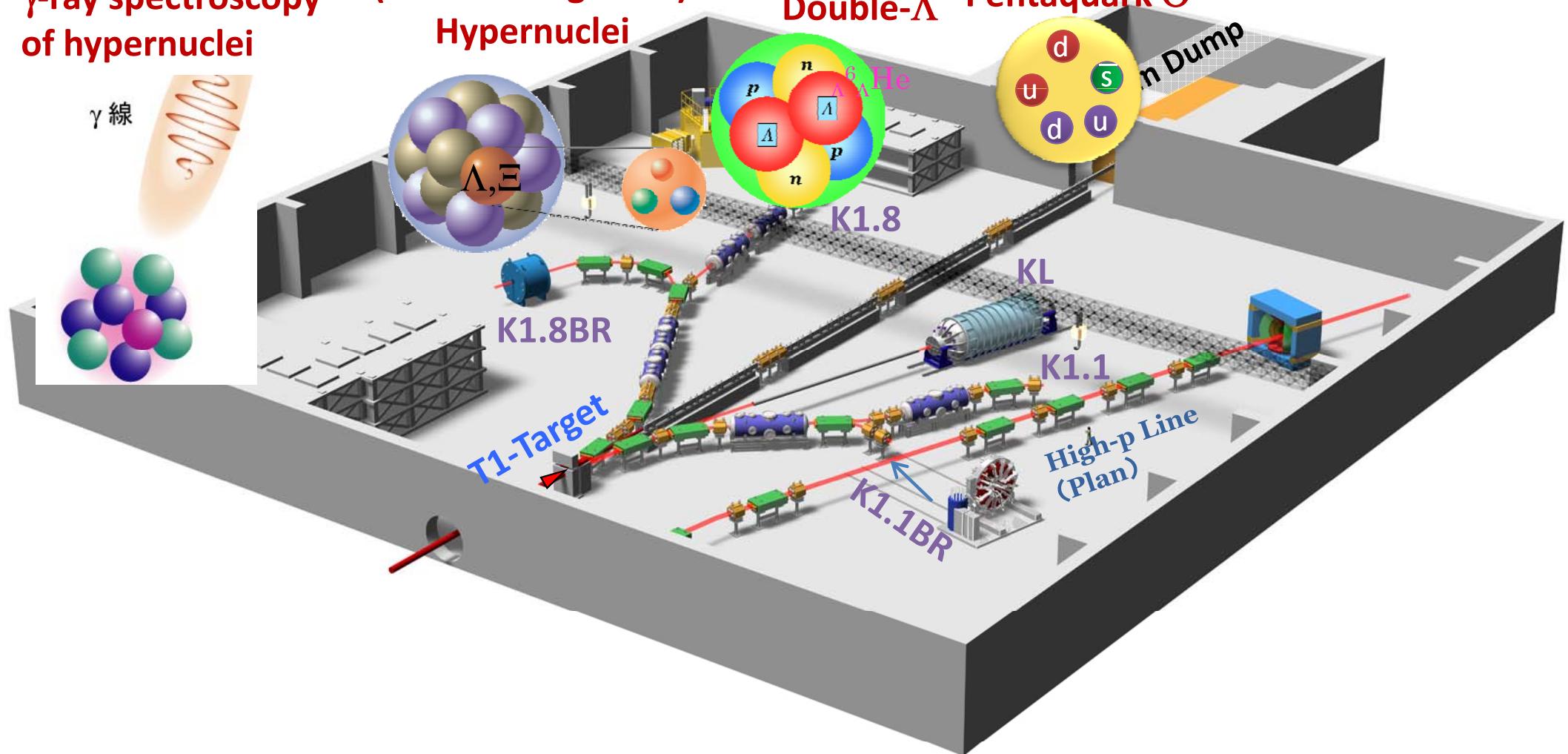


(Multi-strangeness)
Hypernuclei

Exotic Hadrons

Double- Λ

Pentaquark Θ^+

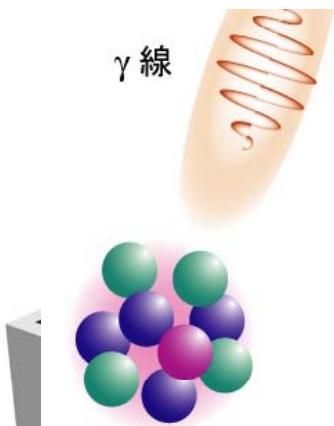


Nuclear & Hadron Physics at Hadron Hall



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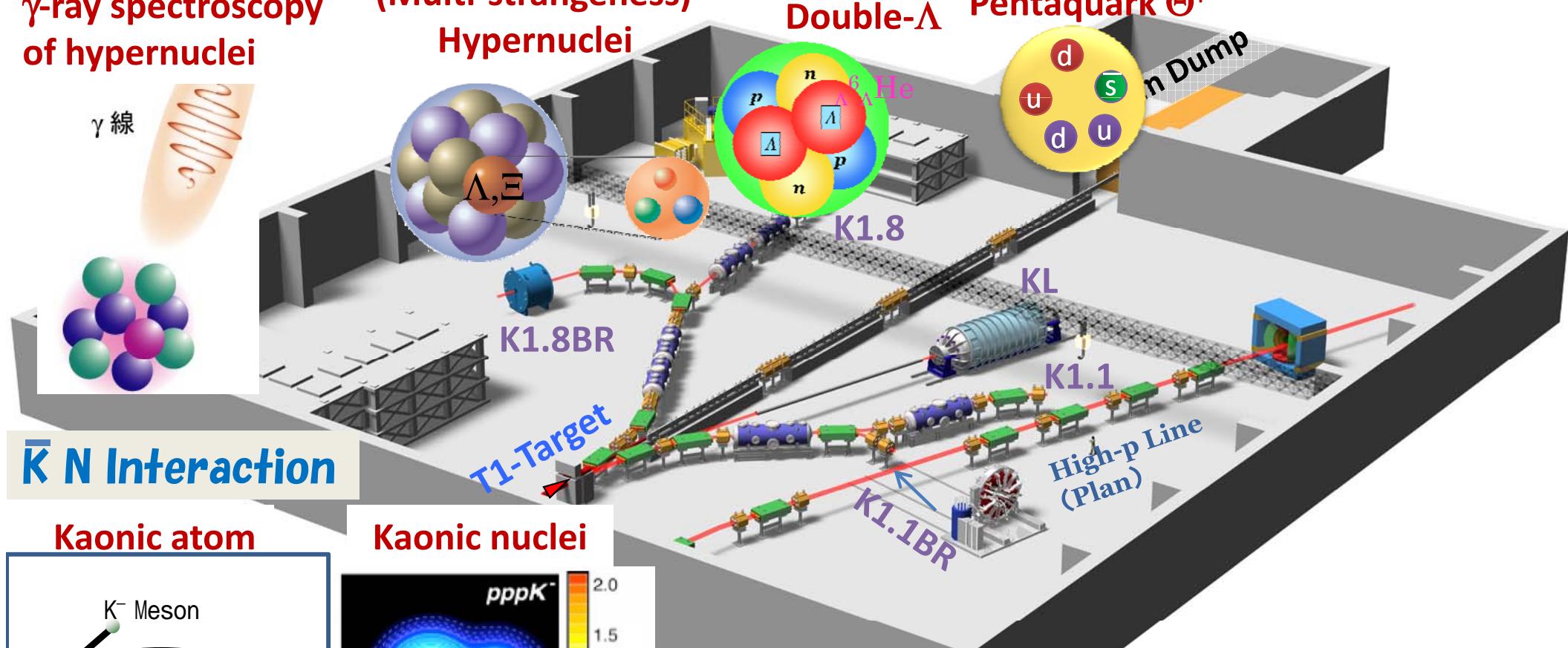


(Multi-strangeness)
Hypernuclei



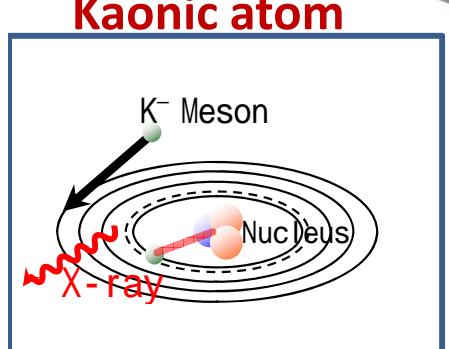
Exotic Hadrons

Double- Λ Pentaquark Θ^+

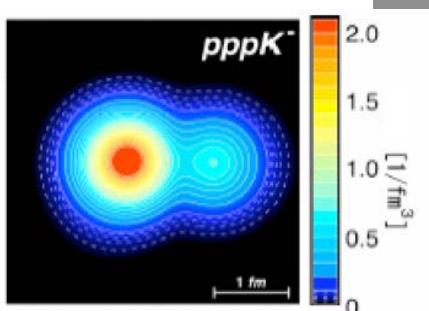


\bar{K} N Interaction

Kaonic atom



Kaonic nuclei

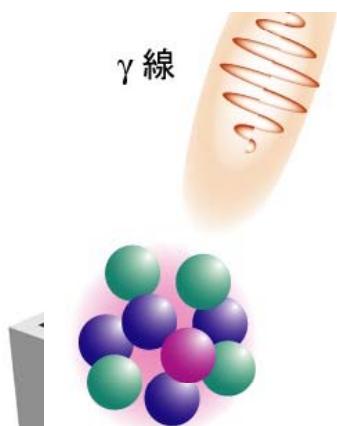


Nuclear & Hadron Physics at Hadron Hall

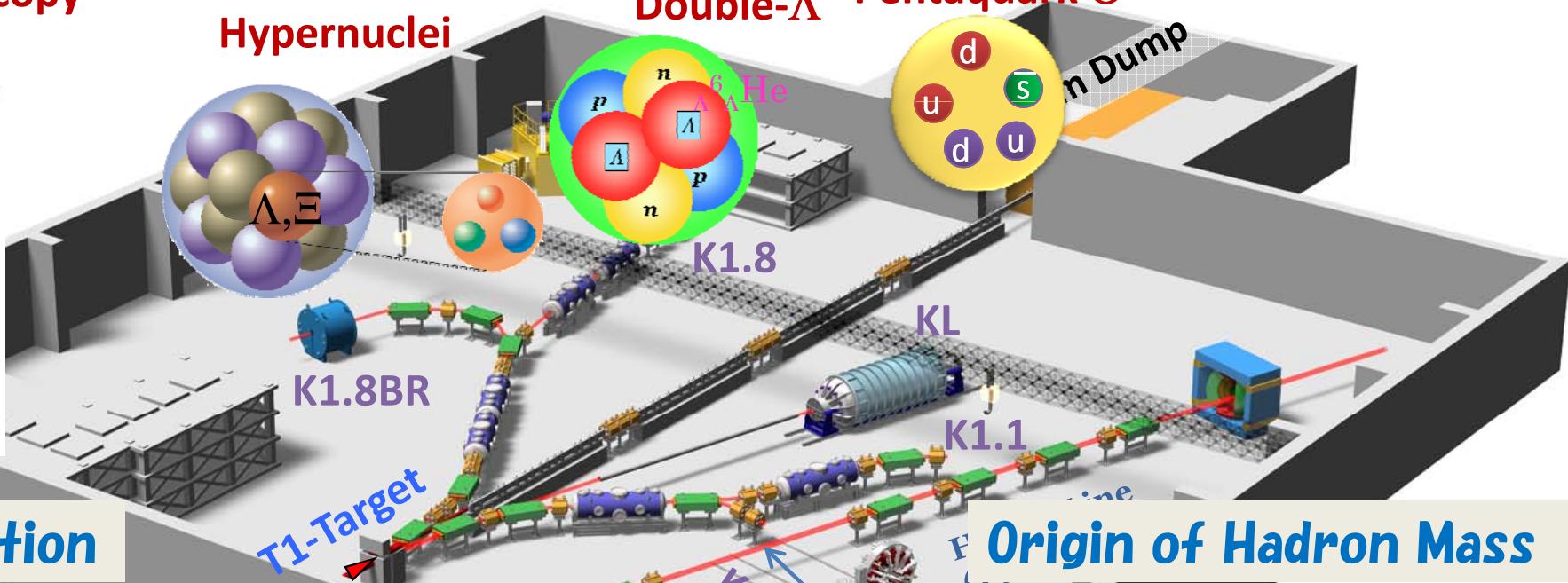


Hypernuclear Physics

γ -ray spectroscopy
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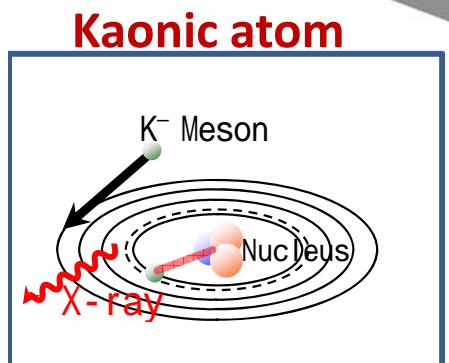


(Multi-strangeness)
Hypernuclei

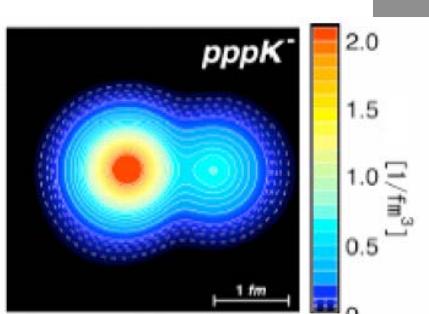


$\bar{K} N$ Interaction

Kaonic atom

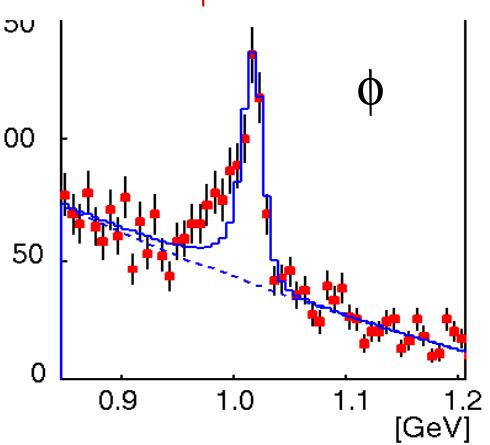


Kaonic nuclei



Origin of Hadron Mass

In-medium ϕ meson mass

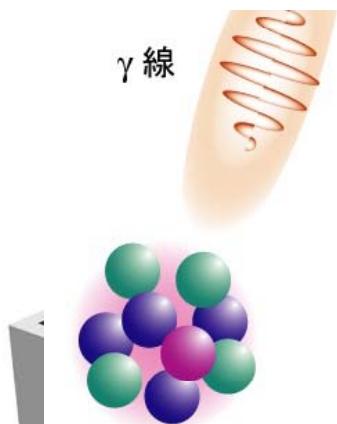


Nuclear & Hadron Physics at Hadron Hall



Hypernuclear Physics

γ -ray spectroscopy
of hypernuclei

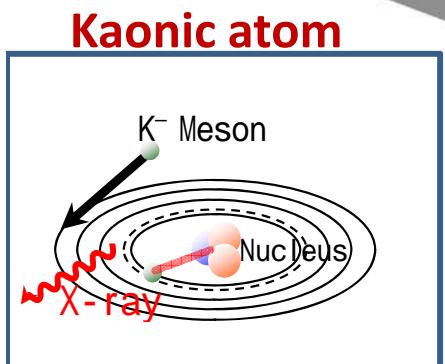


(Multi-strangeness)
Hypernuclei

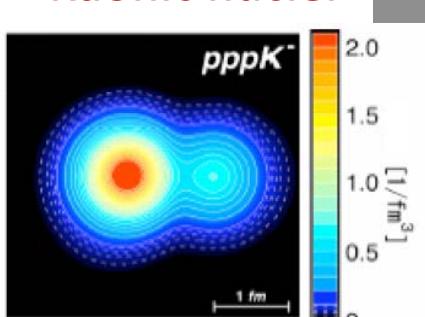


$\bar{K} N$ Interaction

Kaonic atom



Kaonic nuclei



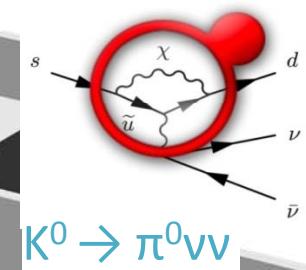
Exotic Hadrons

Double- Λ

Pentaquark Θ^+

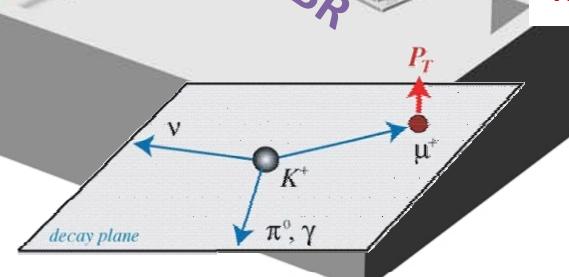


Kaon rare decay

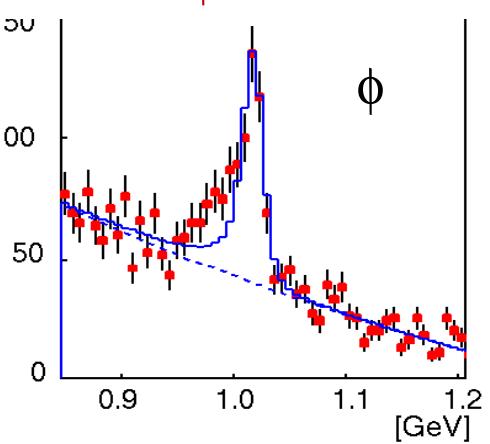


$$K^0 \rightarrow \pi^0 \nu \bar{\nu}$$

Origin of Hadron Mass



In-medium ϕ meson mass



T-violation



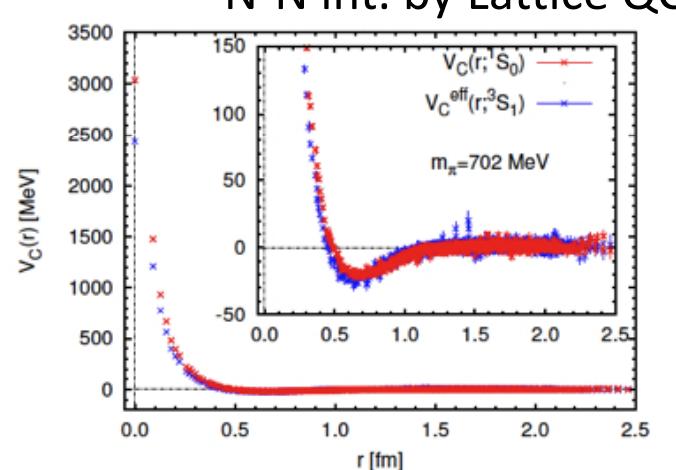
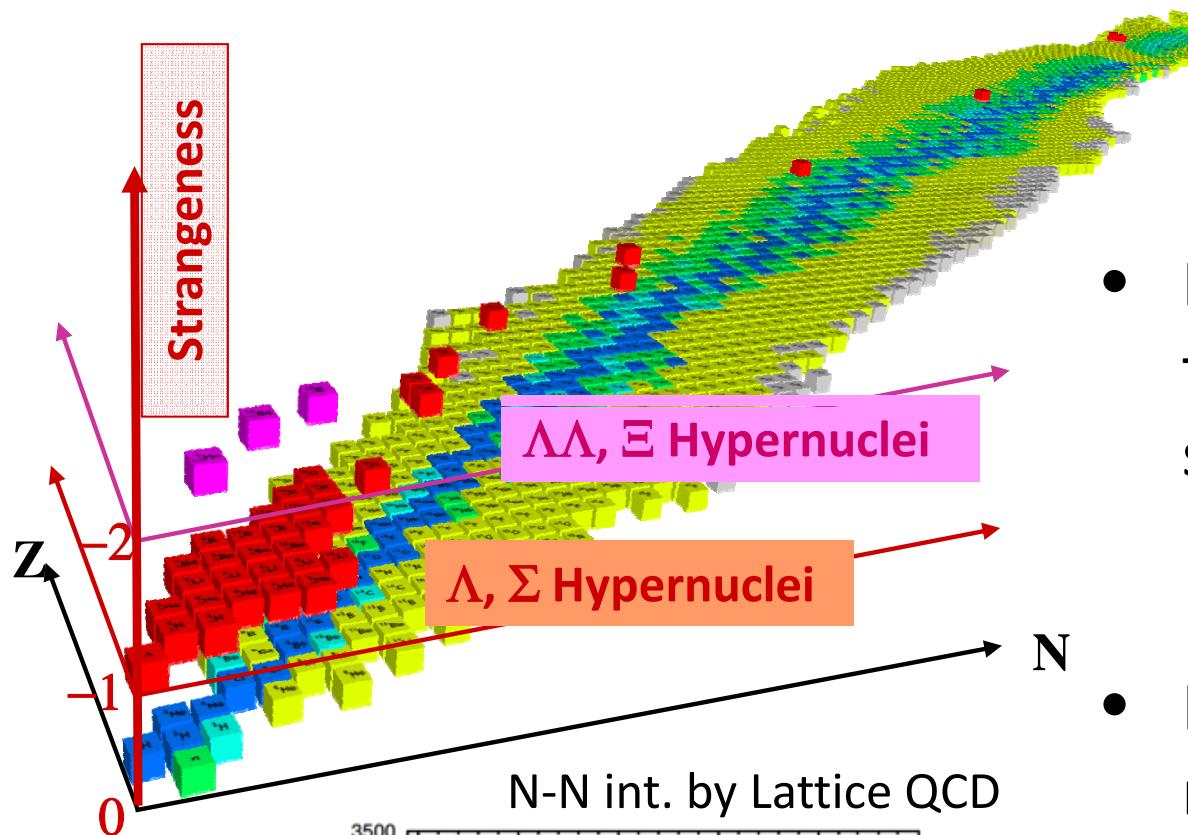
Hadron Physics Programs



Spokespersons	Title of the experiment	Approval status	Slow line priority		Beamline
			Day1?	Priority	
E15 M.Iwasaki, T.Nagae	A Search for deeply-bound kaonic nuclear states by in-flight ${}^3\text{He}(\text{K}^-, \text{n})$ reaction	Stage 2	Day1		K1.8BR
E17 R.Hayano, H.Outa	Precision spectroscopy of Kaonic ${}^3\text{He}$ $3\text{d} \rightarrow 2\text{p}$ X-rays	Stage 2	Day1		K1.8BR
E31 H. Noumi	Spectroscopic study of hyperon resonances below KN threshold via the (K^-n) reaction on Deuteron	Stage1			K1.8BR
E03 K.Tanida	Measurement of X rays from Ξ^- Atom	Stage 2			K1.8
E05 T.Nagae	Spectroscopic Study of Ξ -Hypernucleus, ${}^{12}\Xi\text{Be}$, via the ${}^{12}\text{C}(\text{K}^-, \text{K}^+)$ Reaction	Stage 2	Day1	1	K1.8
E07 K.Imai, Nakazawa, Tamura	Systematic Study of Double Strangeness System with an Emulsion-counter Hybrid Method	Stage 2			K1.8
E08 A.Krutenkova	Pion double charge exchange on oxygen at J-PARC	Stage 1			K1.8
E10 A. Sakaguchi, T. Fukuda	Production of Neutron-Rich Lambda-Hypernuclei with the Double Charge-Exchange Reaction (Revised from Initial P10)	Stage 2			K1.8
E13 T.Tamura	Gamma-ray spectroscopy of light hypernuclei	Stage 2	Day1	2	K1.8
E18 H.Bhang, H.Outa, H.Park	Coincidence Measurement of the Weak Decay of ${}^{12}\Lambda\text{C}$ and the three-body weak interaction process	Stage 1			K1.8
E19 M.Naruki	High-resolution Search for Θ^+ Pentaquark in $\pi^-\text{p} \rightarrow \text{KX}$ Reactions	Stage 2	Day1		K1.8
E22 S. Ajimura, A.Sakaguchi	Exclusive Study on the Lambda-N Weak Interaction in A=4 Lambda-Hypernuclei	Stage 1			K1.8
E27 T. Nagae	Search for a nuclear Kbar bound state K-pp in the $d(\pi^+, \text{K}^+)$ reaction	Stage 2			K1.8
E14 K.Ozawa	Search for ω -meson nuclear bound states in the $\pi^- + {}^A\text{Z} \rightarrow \text{n} + {}^{(A-1)}\omega(\text{Z}-1)$ reaction, and for ω mass modification in the in-medium $\omega \rightarrow \pi^0\gamma$ decay.	Stage 1			K1.8
E06 H. Ohnishi	Search for ϕ -meson nuclear bound states in the $\text{pbar} + {}^A\text{Z} \rightarrow \phi + {}^{(A-1)}\phi(\text{Z}-1)$ reaction	Stage 1			K1.1
E16 S.Yokkaichi	Electron pair spectrometer at the J-PARC 50-GeV PS to explore the chiral symmetry in QCD	Stage 1			High pT

Hypernuclear Physics

H.Tamura Jun.17



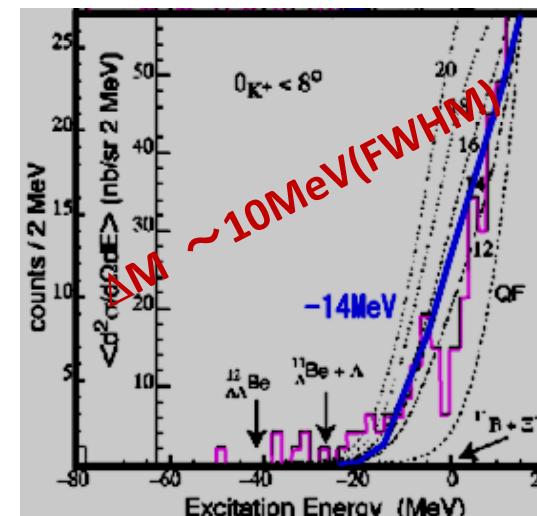
- Baryon-Baryon interaction through the hypernuclear structure
 - ΞN and $\Lambda\Lambda$ interaction
 - ΛN interaction in n-rich environment
- Hadron property in nuclear medium
 - g-factor of Λ by $B(M1)$ measurement
- Change of nuclear property by addition of hyperon(s)
 - change of nuclear size etc..

E05: Spectroscopy of $^{12}\Xi\text{Be}$ via the $^{12}\text{C}(\text{K}^-, \text{K}^+)$



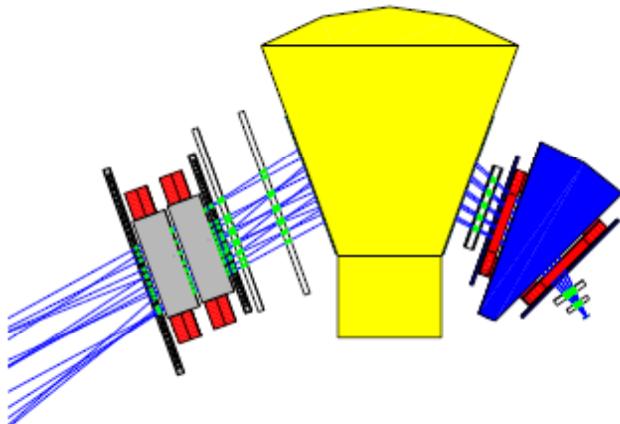
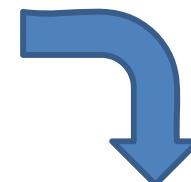
**aims to observe the Ξ -hypernuclear states, for the first time,
with high resolution of 3MeV(FWHM)**

- **$S = -2$ Baryon-Baryon interaction**
 - ΞN interaction
 - $\Xi N \rightarrow \Lambda \Lambda$ interaction
- **Strange nuclear matter with Ξ**
 - Core of Neutron Star
 - Ξ -Nucleus potential
- **Strong $\Xi N - \Lambda \Lambda$ mixing effect**

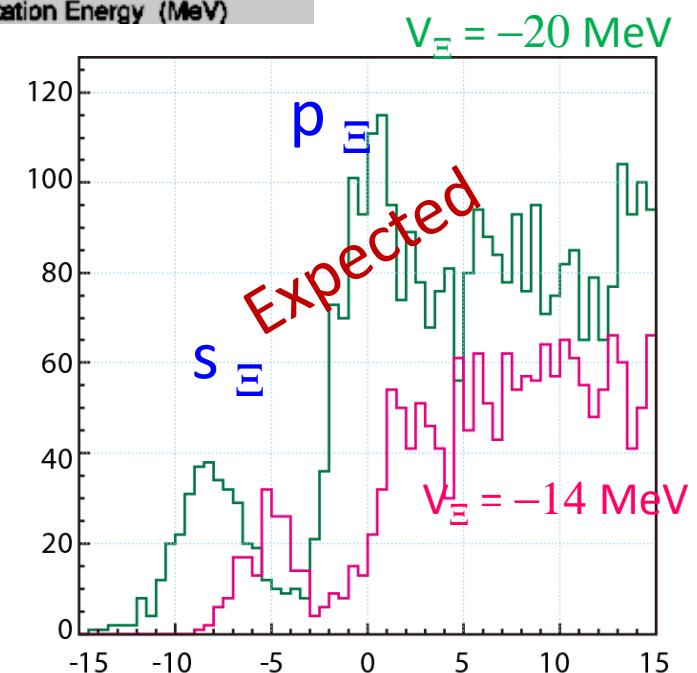


BNL-AGS E885

P.Khaustov et al,
PRC61(2000)0546



K1.8 BS + SksPlus
5.4g/cm² target
 1.6×10^6 /spill K^- beam
1 month data-taking



The Earthquake on March 11



Entrance of LINIC Building



CCR



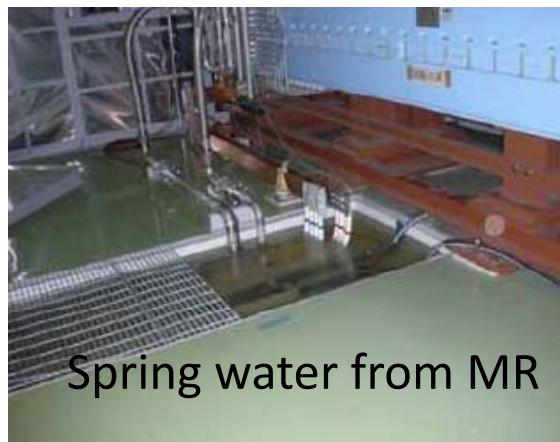
Neutrino Beam Dump



RCS Substation



Hadron Switch Yard



Outskirt of Hadron Hall



The serious damages are

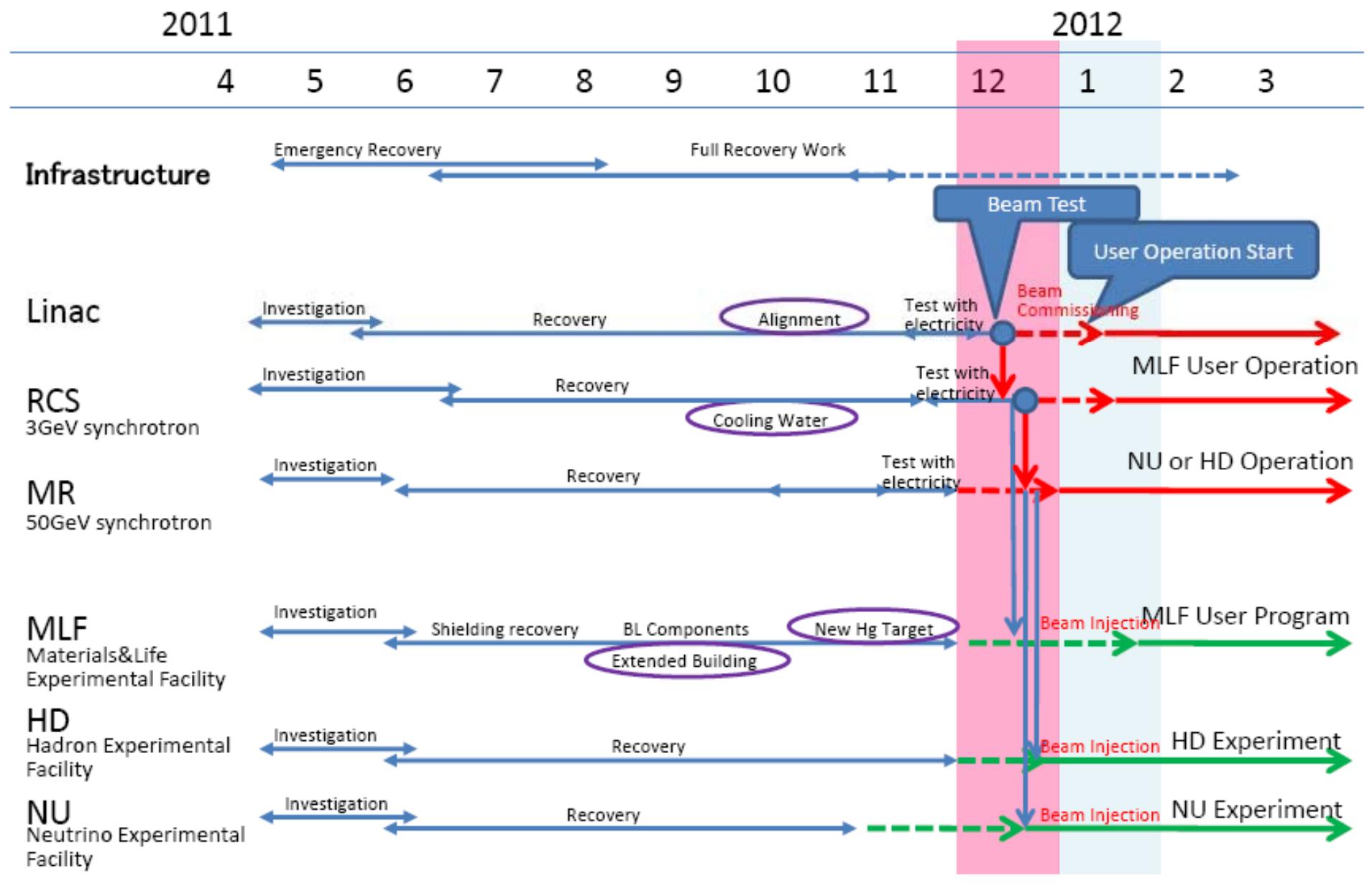
LINAC Power lines, alignment of the elements

RCS Power supplies, Cooling-water

In Hadron Facility, alignment of the primary & secondary beamline elements is necessary.



J-PARC Recovery Schedule (@2011.5.20)



Summary

- **J-PARC Hadron Facility has started its operational era!**
 - **4 secondary beamlines, K1.8BR, K1.8, KL, and K1.1BR, are in operation.**
- **The first physics RUN of E19 was successfully done at K1.8.**
 - **No peak structure was observed in $p(\pi^-, K^-)X$ missing mass at $P_\pi = 1.92 \text{ GeV}/c$. $d\sigma/d\Omega < 0.3 \mu b/\text{sr}$**
- **A lot of experiments on nuclear/hadron physics are planned at Hadron Facility**
 - **Hypernuclear physics at $S = -1$ and $S = -2$**
 - **$K^{\bar{b}ar}$ N Interaction by Kaonic Nuclei and Atom**
 - **In medium mass modification of ϕ meson**
- **Effect of the Earthquake at March 11.**
 - **Beam recovery in December 2011**

People at J-PARC Hadron Experimental Hall

Graduate Students, Professors, Researchers, Engineers..., all over the world

2009.1.27 First Beam to Hd Hall



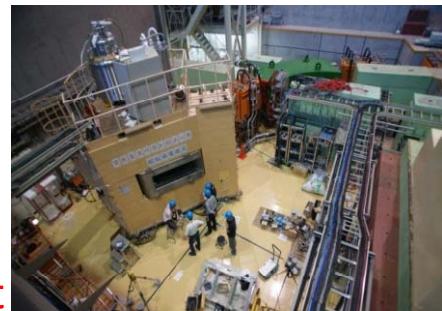
2009.10.22 First beam to K1.8



KOTO (E15) Experimental Team
(KL Rare Decay Search)



Start up of K1.8 Counting Hat



Line marking at K1.8 area



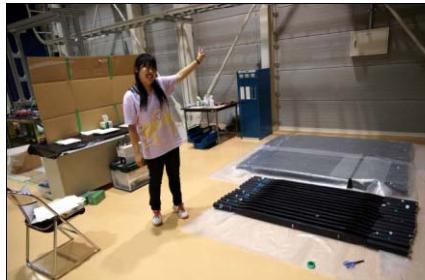
Background survey before construction of KL!



Front end circuits at K1.8BR



Our TOF wall is ready!



My beautiful TOF counters!

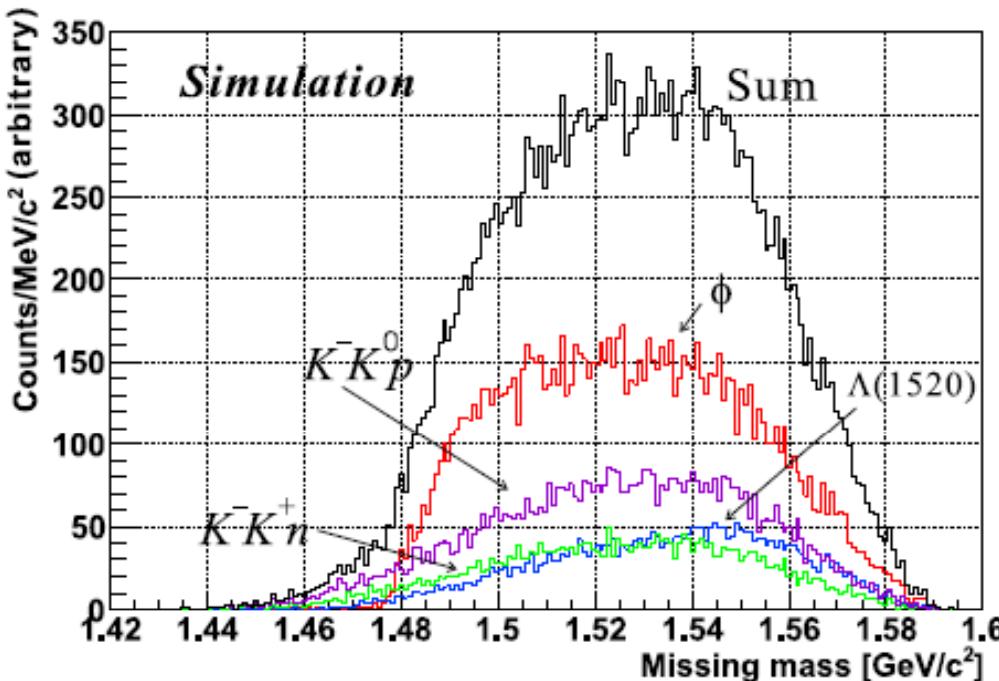


New comers and a senior



Midnight in KL Counting Hat

Backgrounds



- ϕ production $30 \pm 8 \mu\text{b}$
 $\pi^- p \rightarrow \phi n, (\phi \rightarrow K^+ K^-)$
- $\Lambda(1520)$ production $20.8 \pm 5.0 \mu\text{b}$
 $\pi^- p \rightarrow \Lambda(1520) K^0, (\Lambda(1520) \rightarrow p K^-)$
- Phase space $25 \mu\text{b}$
 $\pi^- p \rightarrow K^- K^0 p$
 $\pi^- p \rightarrow K^- K^+ n$

