Future Directions
in High Energy QCD
Oct/20-22/2011 RIKEN

QCD at J–PARC

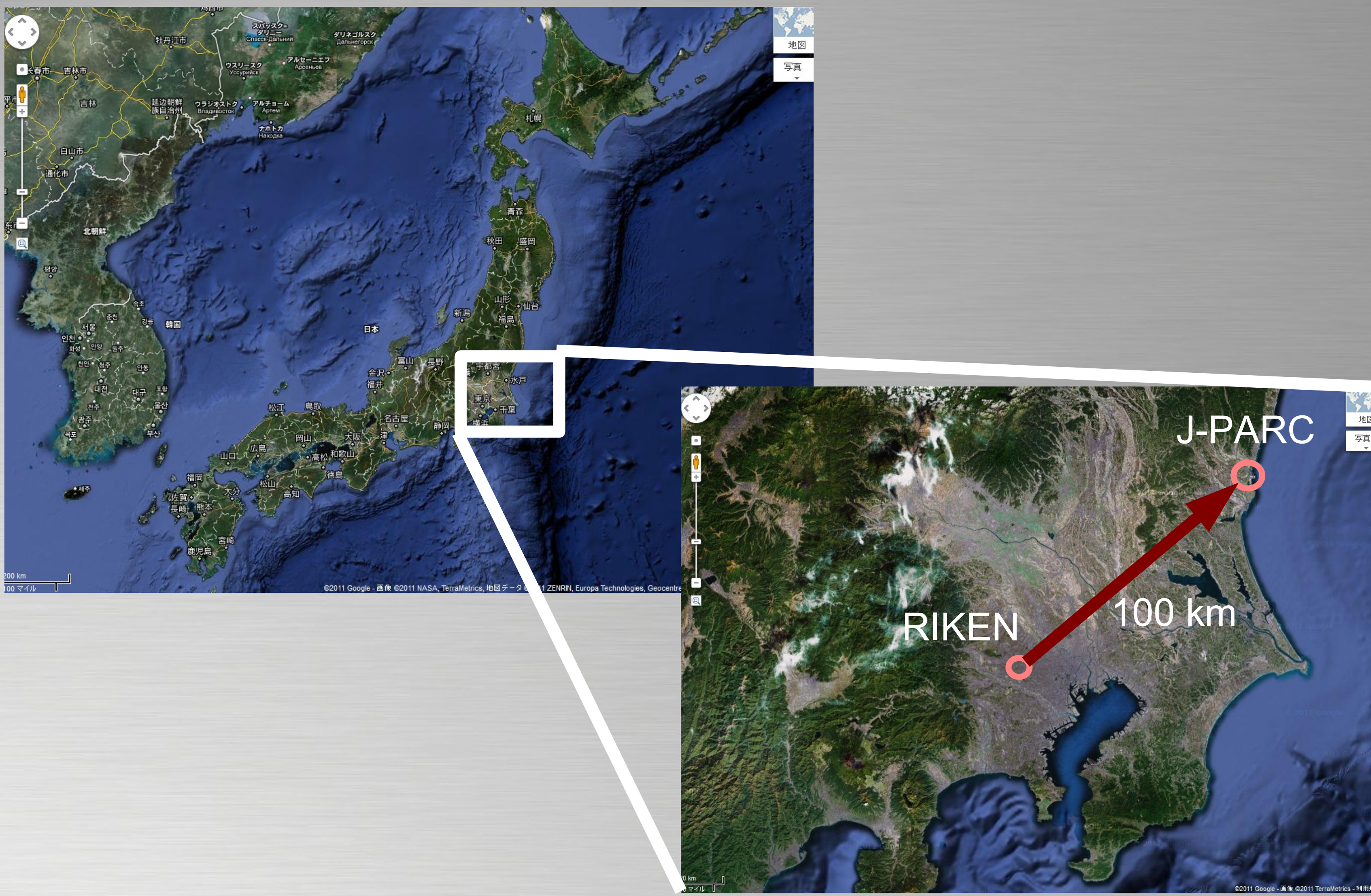
Hiroaki Ohnishi
RIKEN
Nishina Center

Future Directions
in High Energy QCD
Oct/20-22/2011 RIKEN

QCD at J-PARC
Super low energy
Hadron Physics

Hiroaki Ohnishi
RIKEN
Nishina Center

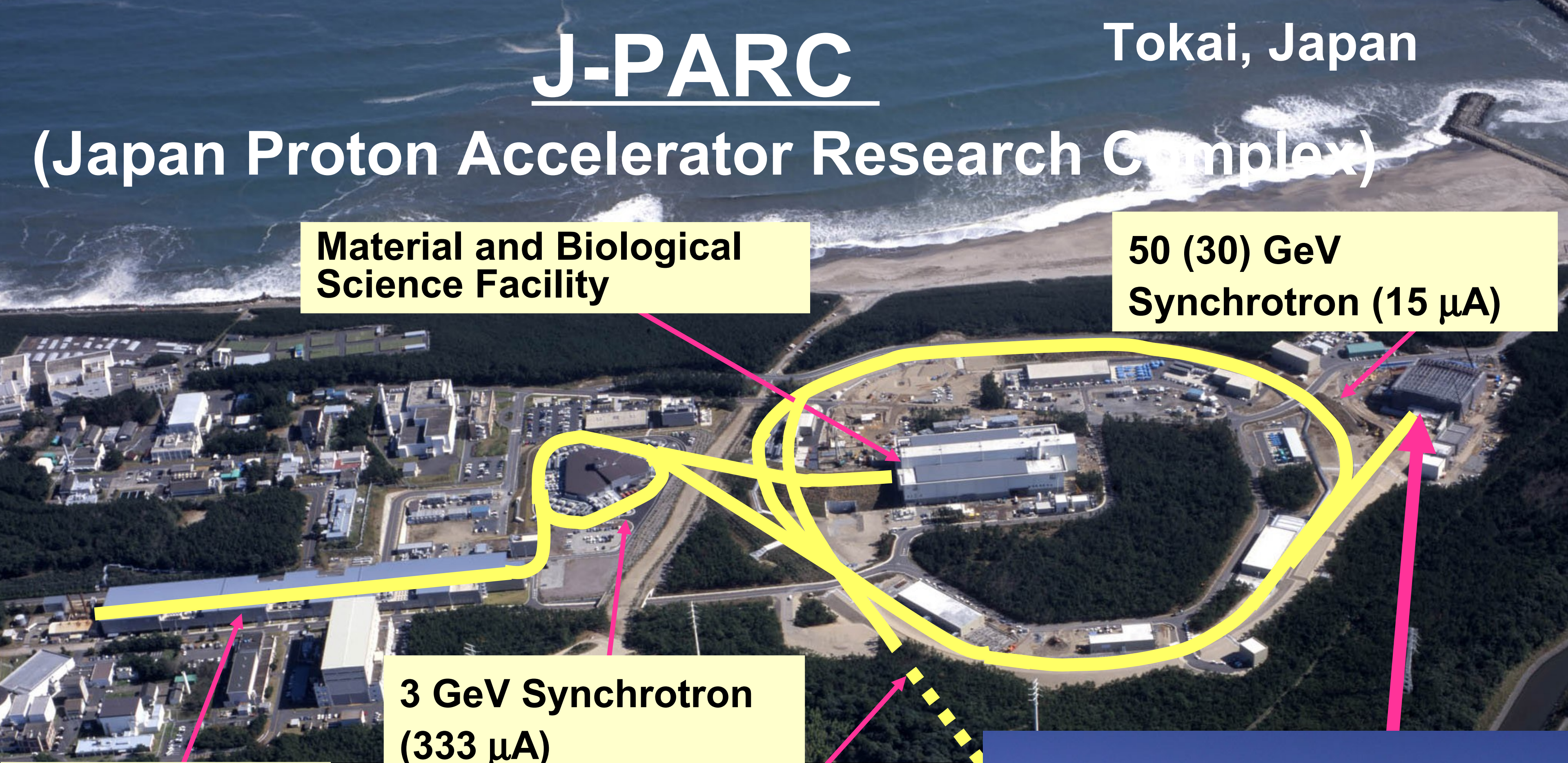
J-PARC : Proton synchrotron



J-PARC

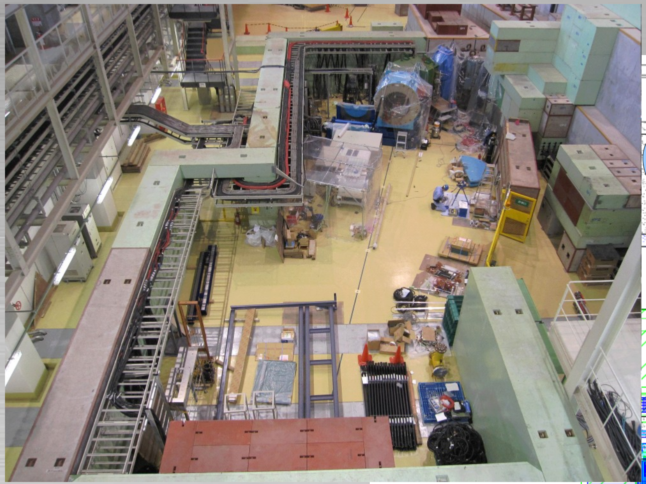
Tokai, Japan

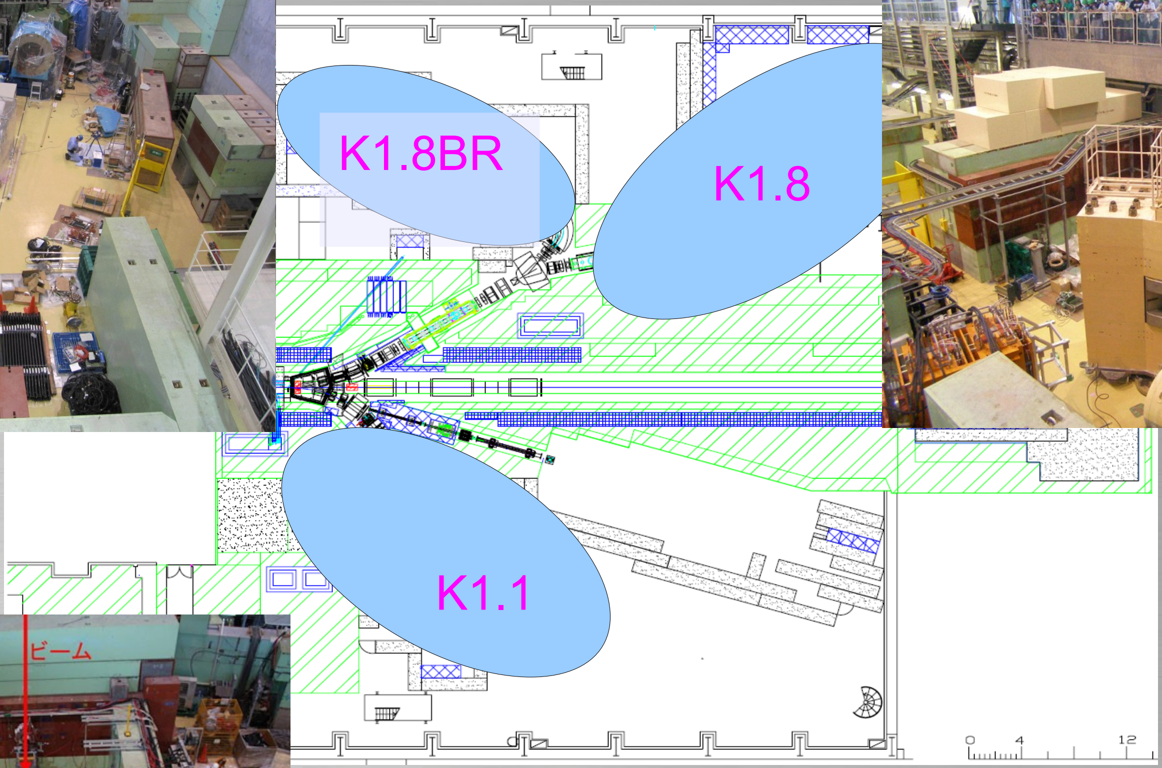
(Japan Proton Accelerator Research Complex)

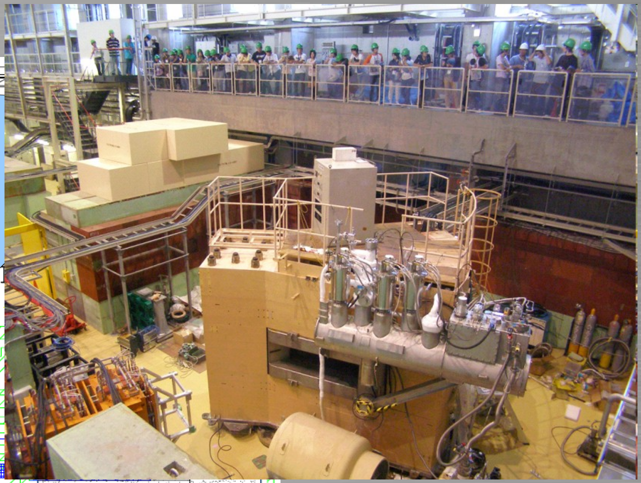


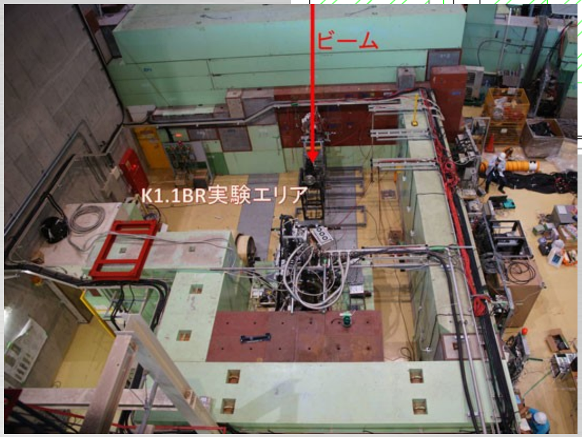
World-highest beam intensity : ~1 MW
x10 of BNL-AGS, x100 of KEK-PS

Beam Lines at J-PARC







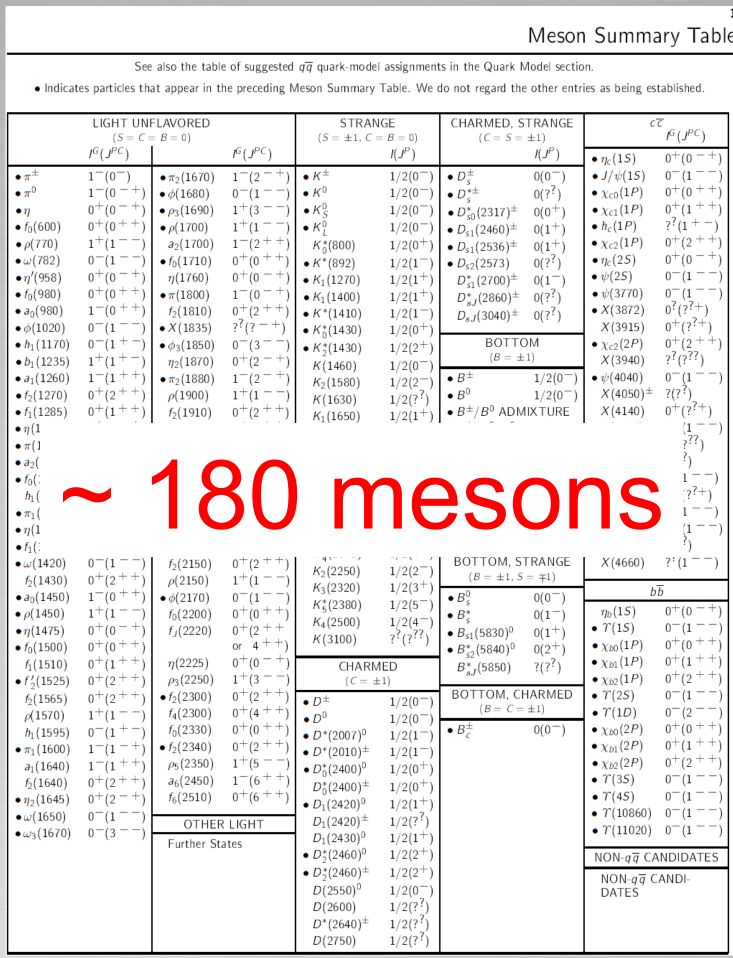


- One production target for secondary beam ($\pi^{\pm}$, $K^{\pm}$, p, $\bar{p}$)
- Three secondary beamlines (max. momentum)

K1.8BR	: up to 1.1 GeV/c
K1.8	: up to 2.0 GeV/c
K1.1	: up to 1.1 GeV/c

Hadron physics at J-PARC

Table of Meson, Baryon



Meson Summary Table

See also the table of suggested $q\bar{q}$ quark-model assignments in the Quark Model section.

• Indicates particles that appear in the preceding Meson Summary Table. We do not regard the other entries as being established.

LIGHT UNFLAVORED ($S = C = B = 0$)

	$I^G(J^{PC})$
• $\pi^\pm$	$1^-(0^-)$
• π^0	$1^-(0^{-+})$
• η	$0^+(0^{-+})$
• $f_0(600)$	$0^+(0^{++})$
• $\rho(770)$	$1^+(1^{--})$
• $\omega(782)$	$0^-(1^{--})$
• $\eta'(958)$	$0^+(0^{-+})$
• $f_0(980)$	$0^+(0^{++})$
• $a_0(980)$	$1^-(0^{++})$
• $\phi(1020)$	$0^-(1^{--})$
• $h_1(1170)$	$0^-(1^{+-})$
• $b_1(1235)$	$1^+(1^{+-})$
• $a_1(1260)$	$1^-(1^{++})$
• $f_2(1270)$	$0^+(2^{++})$
• $f_1(1285)$	$0^+(1^{++})$
• $\eta(1$	
• $\pi(1$	
• $a_2($	
• $f_0($	
$h_1($	
• $\pi_1($	
• $\eta(1$	
• $f_1($	
• $\omega(1420)$	$0^-(1^{--})$
$f_2(1430)$	$0^+(2^{++})$
• $a_0(1450)$	$1^-(0^{++})$
• $\rho(1450)$	$1^+(1^{--})$
• $\eta(1475)$	$0^+(0^{-+})$
• $f_0(1500)$	$0^+(0^{++})$
$f_1(1510)$	$0^+(1^{++})$
• $f'_2(1525)$	$0^+(2^{++})$
$f_2(1565)$	$0^+(2^{++})$
$\rho(1570)$	$1^+(1^{--})$
$h_1(1595)$	$0^-(1^{+-})$
• $\pi_1(1600)$	$1^-(1^{-+})$
$a_1(1640)$	$1^-(1^{++})$
$f_2(1640)$	$0^+(2^{++})$
• $\eta_2(1645)$	$0^+(2^{-+})$
• $\omega(1650)$	$0^-(1^{--})$
• $\omega_3(1670)$	$0^-(3^{--})$

	$I^G(J^{PC})$
• $\pi_2(1670)$	$1^-(2^{-+})$
• $\phi(1680)$	$0^-(1^{--})$
• $\rho_3(1690)$	$1^+(3^{--})$
• $\rho(1700)$	$1^+(1^{--})$
$a_2(1700)$	$1^-(2^{++})$
• $f_0(1710)$	$0^+(0^{++})$
$\eta(1760)$	$0^+(0^{-+})$
• $\pi(1800)$	$1^-(0^{-+})$
$f_2(1810)$	$0^+(2^{++})$
• $X(1835)$	$?^?(?^{-+})$
• $\phi_3(1850)$	$0^-(3^{--})$
$\eta_2(1870)$	$0^+(2^{-+})$
• $\pi_2(1880)$	$1^-(2^{-+})$
$\rho(1900)$	$1^+(1^{--})$
$f_2(1910)$	$0^+(2^{++})$
$f_2(2150)$	$0^+(2^{++})$
$\rho(2150)$	$1^+(1^{--})$
• $\phi(2170)$	$0^-(1^{--})$
$f_0(2200)$	$0^+(0^{++})$
$f_J(2220)$	$0^+(2^{++}$ or $4^{++})$
$\eta(2225)$	$0^+(0^{-+})$
$\rho_3(2250)$	$1^+(3^{--})$
• $f_2(2300)$	$0^+(2^{++})$
$f_4(2300)$	$0^+(4^{++})$
$f_0(2330)$	$0^+(0^{++})$
• $f_2(2340)$	$0^+(2^{++})$
$\rho_5(2350)$	$1^+(5^{--})$
$a_6(2450)$	$1^-(6^{++})$
$f_6(2510)$	$0^+(6^{++})$

OTHER LIGHT

Further States

STRANGE ($S = \pm1$, $C = B = 0$)

	$I(J^P)$
• $K^\pm$	$1/2(0^-)$
• K^0	$1/2(0^-)$
• K^0_S	$1/2(0^-)$
• K^0_L	$1/2(0^-)$
$K^*_0(800)$	$1/2(0^+)$
• $K^*(892)$	$1/2(1^-)$
• $K_1(1270)$	$1/2(1^+)$
• $K_1(1400)$	$1/2(1^+)$
• $K^*(1410)$	$1/2(1^-)$
• $K^*_0(1430)$	$1/2(0^+)$
• $K^*_2(1430)$	$1/2(2^+)$
$K(1460)$	$1/2(0^-)$
$K_2(1580)$	$1/2(2^-)$
$K(1630)$	$1/2(?^?)$
$K_1(1650)$	$1/2(1^+)$
$K_2(2250)$	$1/2(2^-)$
$K_3(2320)$	$1/2(3^+)$
$K^*_5(2380)$	$1/2(5^-)$
$K_4(2500)$	$1/2(4^-)$
$K(3100)$	$?^?(?^{??})$

CHARMED ($C = \pm1$)

	$I(J^P)$
• $D^\pm$	$1/2(0^-)$
• D^0	$1/2(0^-)$
• $D^*(2007)^0$	$1/2(1^-)$
• $D^*(2010)^\pm$	$1/2(1^-)$
• $D^*_0(2400)^0$	$1/2(0^+)$
$D^*_0(2400)^\pm$	$1/2(0^+)$
• $D_1(2420)^0$	$1/2(1^+)$
$D_1(2420)^\pm$	$1/2(?^?)$
$D_1(2430)^0$	$1/2(1^+)$
• $D^*_2(2460)^0$	$1/2(2^+)$
• $D^*_2(2460)^\pm$	$1/2(2^+)$
$D(2550)^0$	$1/2(0^-)$
$D(2600)$	$1/2(?^?)$
$D^*(2640)^\pm$	$1/2(?^?)$
$D(2750)$	$1/2(?^?)$

CHARMED, STRANGE ($C = S = \pm1$)

	$I(J^P)$
• $D^\pm_s$	$0(0^-)$
• $D^{*\pm}_s$	$0(?^?)$
• $D^*_{s0}(2317)^\pm$	$0(0^+)$
• $D_{s1}(2460)^\pm$	$0(1^+)$
• $D_{s1}(2536)^\pm$	$0(1^+)$
• $D_{s2}(2573)$	$0(?^?)$
$D^*_{s1}(2700)^\pm$	$0(1^-)$
$D^*_{sJ}(2860)^\pm$	$0(?^?)$
$D_{sJ}(3040)^\pm$	$0(?^?)$

BOTTOM ($B = \pm1$)

	$I(J^P)$
• $B^\pm$	$1/2(0^-)$
• B^0	$1/2(0^-)$
• $B^\pm/B^0$ ADMIXTURE	

BOTTOM, STRANGE ($B = \pm1$, $S = \mp1$)

	$I(J^P)$
• B^0_s	$0(0^-)$
• B^*_s	$0(1^-)$
• $B_{s1}(5830)^0$	$0(1^+)$
• $B^*_{s2}(5840)^0$	$0(2^+)$
$B^*_{sJ}(5850)$	$?(?^?)$

BOTTOM, CHARMED ($B = C = \pm1$)

	$I(J^P)$
• $B^\pm_c$	$0(0^-)$

$c\bar{c}$

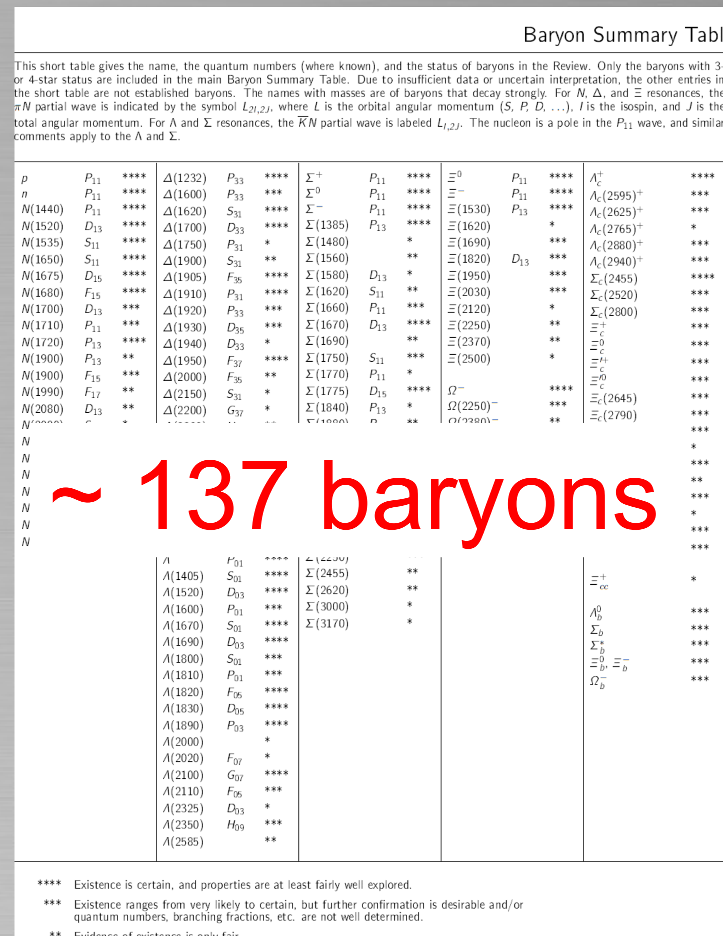
	$I^G(J^{PC})$
• $\eta_c(1S)$	$0^+(0^{-+})$
• $J/\psi(1S)$	$0^-(1^{--})$
• $\chi_{c0}(1P)$	$0^+(0^{++})$
• $\chi_{c1}(1P)$	$0^+(1^{++})$
• $h_c(1P)$	$?^?(1^{+-})$
• $\chi_{c2}(1P)$	$0^+(2^{++})$
• $\eta_c(2S)$	$0^+(0^{-+})$
• $\psi(2S)$	$0^-(1^{--})$
• $\psi(3770)$	$0^-(1^{--})$
• $X(3872)$	$0^?(?^{?+})$
$X(3915)$	$0^+(?^{?+})$
• $\chi_{c2}(2P)$	$0^+(2^{++})$
$X(3940)$	$?^?(?^{??})$
• $\psi(4040)$	$0^-(1^{--})$
$X(4050)^\pm$	$?(?^?)$
$X(4140)$	$0^+(?^{?+})$
$X(4660)$	$?^?(1^{--})$

$b\bar{b}$

	$I^G(J^{PC})$
$\eta_b(1S)$	$0^+(0^{-+})$
• $\Upsilon(1S)$	$0^-(1^{--})$
• $\chi_{b0}(1P)$	$0^+(0^{++})$
• $\chi_{b1}(1P)$	$0^+(1^{++})$
• $\chi_{b2}(1P)$	$0^+(2^{++})$
• $\Upsilon(2S)$	$0^-(1^{--})$
• $\Upsilon(1D)$	$0^-(2^{--})$
• $\chi_{b0}(2P)$	$0^+(0^{++})$
• $\chi_{b1}(2P)$	$0^+(1^{++})$
• $\chi_{b2}(2P)$	$0^+(2^{++})$
• $\Upsilon(3S)$	$0^-(1^{--})$
• $\Upsilon(4S)$	$0^-(1^{--})$
• $\Upsilon(10860)$	$0^-(1^{--})$
• $\Upsilon(11020)$	$0^-(1^{--})$

NON-$q\bar{q}$ CANDIDATES

NON-$q\bar{q}$ CANDIDATES



Baryon Summary Table

This short table gives the name, the quantum numbers (where known), and the status of baryons in the Review. Only the baryons with 3- or 4-star status are included in the main Baryon Summary Table. Due to insufficient data or uncertain interpretation, the other entries in the short table are not established baryons. The names with masses are of baryons that decay strongly. For N, Δ, and Ξ resonances, the πN partial wave is indicated by the symbol $L_{2I,2J}$, where L is the orbital angular momentum (S, P, D, ...), I is the isospin, and J is the total angular momentum. For Λ and Σ resonances, the $\overline{K}N$ partial wave is labeled $L_{I,2J}$. The nucleon is a pole in the P_{11} wave, and similar comments apply to the Λ and Σ.

p	P_{11}	****
n	P_{11}	****
$N(1440)$	P_{11}	****
$N(1520)$	D_{13}	****
$N(1535)$	S_{11}	****
$N(1650)$	S_{11}	****
$N(1675)$	D_{15}	****
$N(1680)$	F_{15}	****
$N(1700)$	D_{13}	***
$N(1710)$	P_{11}	***
$N(1720)$	P_{13}	****
$N(1900)$	P_{13}	**
$N(1900)$	F_{15}	***
$N(1990)$	F_{17}	**
$N(2080)$	D_{13}	**

$\Delta(1232)$	P_{33}	****
$\Delta(1600)$	P_{33}	***
$\Delta(1620)$	S_{31}	****
$\Delta(1700)$	D_{33}	****
$\Delta(1750)$	P_{31}	*
$\Delta(1900)$	S_{31}	**
$\Delta(1905)$	F_{35}	****
$\Delta(1910)$	P_{31}	****
$\Delta(1920)$	P_{33}	***
$\Delta(1930)$	D_{35}	***
$\Delta(1940)$	D_{33}	*
$\Delta(1950)$	F_{37}	****
$\Delta(2000)$	F_{35}	**
$\Delta(2150)$	S_{31}	*
$\Delta(2200)$	G_{37}	*
Λ	P_{01}	****
$\Lambda(1405)$	S_{01}	****
$\Lambda(1520)$	D_{03}	****
$\Lambda(1600)$	P_{01}	***
$\Lambda(1670)$	S_{01}	****
$\Lambda(1690)$	D_{03}	****
$\Lambda(1800)$	S_{01}	***
$\Lambda(1810)$	P_{01}	***
$\Lambda(1820)$	F_{05}	****
$\Lambda(1830)$	D_{05}	****
$\Lambda(1890)$	P_{03}	****
$\Lambda(2000)$		*
$\Lambda(2020)$	F_{07}	*
$\Lambda(2100)$	G_{07}	****
$\Lambda(2110)$	F_{05}	***
$\Lambda(2325)$	D_{03}	*
$\Lambda(2350)$	H_{09}	***
$\Lambda(2585)$		**

Σ^+	P_{11}	****
Σ^0	P_{11}	****
Σ^-	P_{11}	****
$\Sigma(1385)$	P_{13}	****
$\Sigma(1480)$		*
$\Sigma(1560)$		**
$\Sigma(1580)$	D_{13}	*
$\Sigma(1620)$	S_{11}	**
$\Sigma(1660)$	P_{11}	***
$\Sigma(1670)$	D_{13}	****
$\Sigma(1690)$		**
$\Sigma(1750)$	S_{11}	***
$\Sigma(1770)$	P_{11}	*
$\Sigma(1775)$	D_{15}	****
$\Sigma(1840)$	P_{13}	*
$\Sigma(2455)$		**
$\Sigma(2620)$		**
$\Sigma(3000)$		*
$\Sigma(3170)$		*

Ξ^0	P_{11}	****
Ξ^-	P_{11}	****
$\Xi(1530)$	P_{13}	****
$\Xi(1620)$		*
$\Xi(1690)$		***
$\Xi(1820)$	D_{13}	***
$\Xi(1950)$		***
$\Xi(2030)$		***
$\Xi(2120)$		*
$\Xi(2250)$		**
$\Xi(2370)$		**
$\Xi(2500)$		*
Ω^-		****
$\Omega(2250)^-$		***

Λ^+_c	****
$\Lambda_c(2595)^+$	***
$\Lambda_c(2625)^+$	***
$\Lambda_c(2765)^+$	*
$\Lambda_c(2880)^+$	***
$\Lambda_c(2940)^+$	***
$\Sigma_c(2455)$	****
$\Sigma_c(2520)$	***
$\Sigma_c(2800)$	***
Ξ^+_c	***
Ξ^0_c	***
Ξ'^+_c	***
Ξ'^0_c	***
$\Xi_c(2645)$	***
$\Xi_c(2790)$	***
Ξ^+_{cc}	*
Λ^0_b	***
Σ_b	***
Σ^*_b	***
Ξ^0_b, Ξ^-_b	***
Ω^-_b	***

**** Existence is certain, and properties are at least fairly well explored.

*** Existence ranges from very likely to certain, but further confirmation is desirable and/or quantum numbers, branching fractions, etc. are not well determined.

** Evidence of existence is only fair.

K. Nakamura et al. (Particle Data Group)
J. Phys. G 37, 075021 (2010)

How those mesons/baryons are generated by QCD?

Structure of inside hadron? / mass of hadron?

Goal for hadron physics at J-PARC

Rich phenomena induced or governed by QCD at Low energy

Chiral symmetry
- hidden symmetry
Hadron mass

Color symmetry
- gauge symmetry
Color confinement

Symmetry of QCD

Hadron in nuclei

Exotic hadron
Hadron spectra

Meson in nuclei

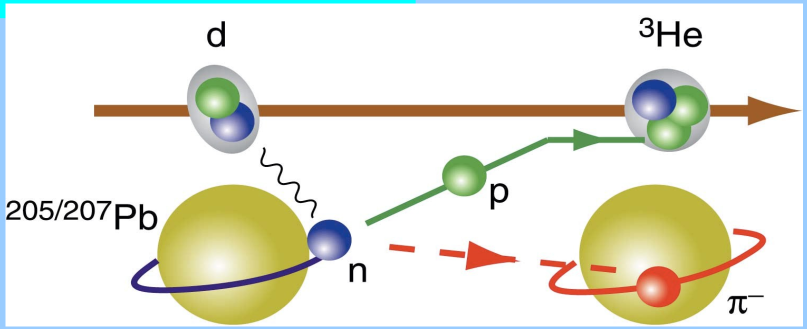
- Create meson in nucleus
- Observing energy spectra
- Compare with the spectra in vacuum

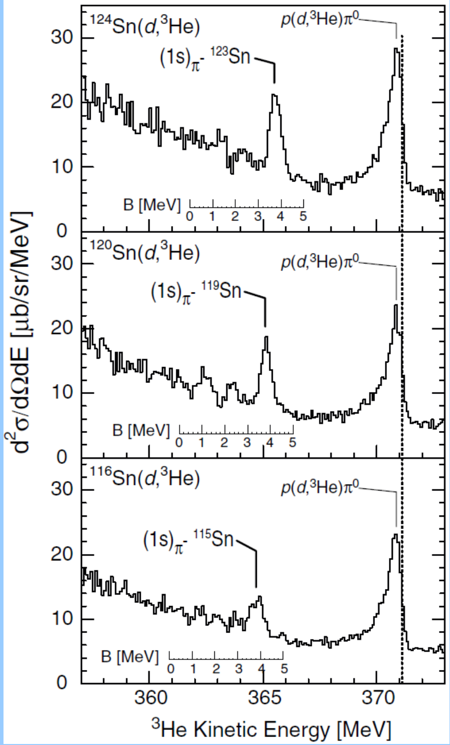
Interaction between Meson and nuclei

Quark condensate

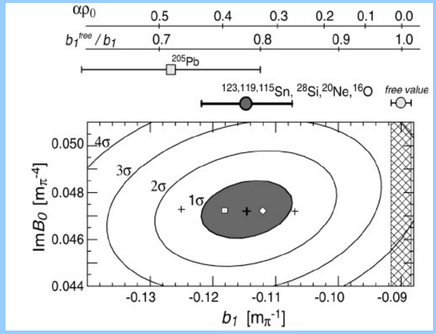
$\langle \bar{q}q \rangle$

Pionic-atom





K. Suzuki et al. Phys. Rev. Lett 92(2004)072302



$$\frac{\langle \bar{q}q \rangle_\rho}{\langle \bar{q}q \rangle_0} \approx 1 - \frac{\sigma_N}{m_\pi^2 f_\pi^2}\rho,$$

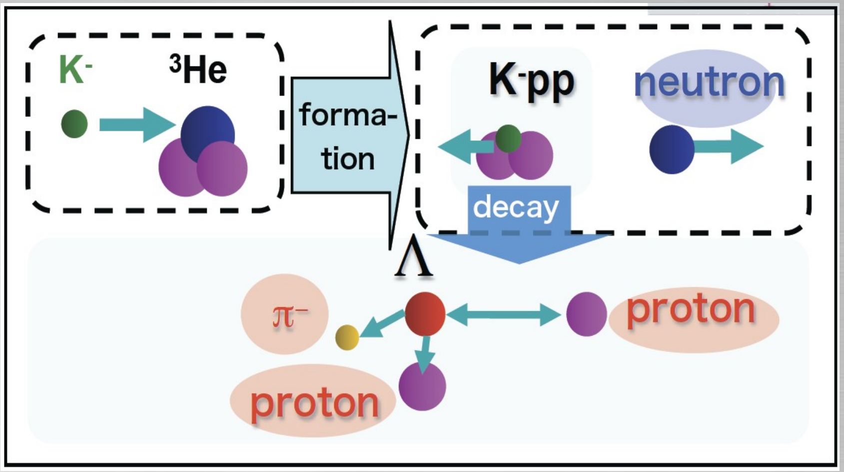
$$R(\rho) = \frac{b_1^{\rm free}}{b_1^*(\rho)} \approx \frac{f_\pi^*(\rho)^2}{f_\pi^2} \approx 1 - \alpha\rho.$$

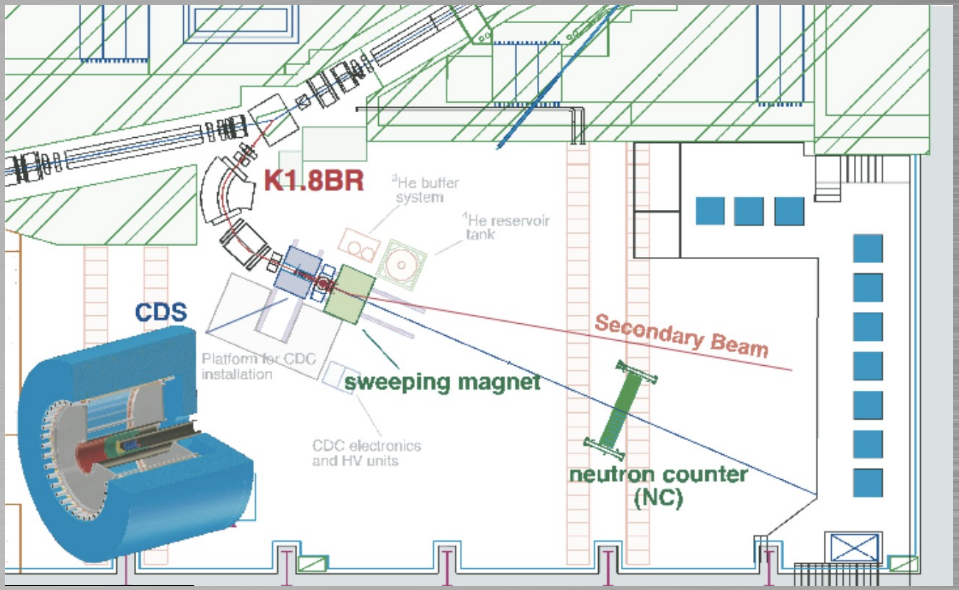
Systematic study of dynamical chiral symmetry breaking and partial restoration

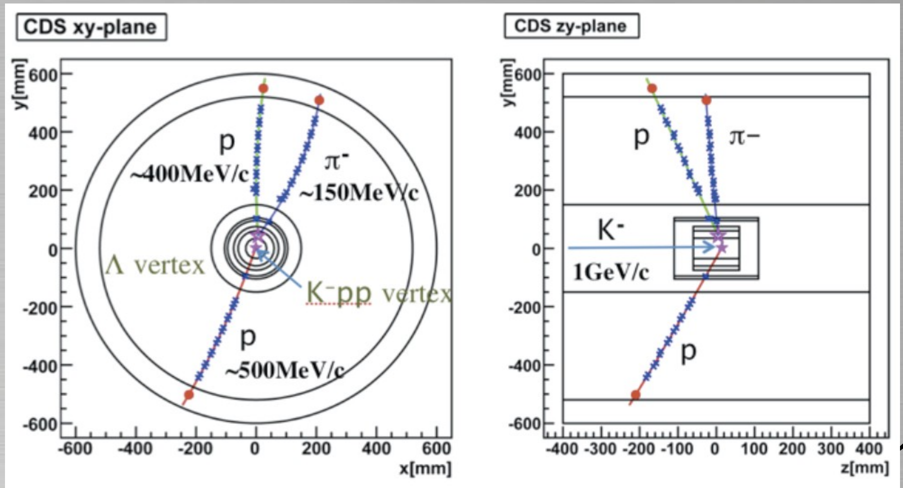
- Mesic-nuclei factory (meson-nucleus bound state!)
  - » Strangeness in nuclei
    - » Kaonic Nucleus (K-pp…) J-PARC E15
    - » double Kaonic nucleus(K-K-pp) J-PARC LoI
  - » Vector meson in nuclei
    - » ω-mesic nucleus J-PARC E26
    - » Φ-mesin nucleus J-PARC E29
  - » Chiral symmetry of baryon : nucleon-N(1535)
    - » η -mesic nucleus J-PARC LoI
  - » $U_A(1)$ amonaly
    - » η '-mesic nucleus

Search for Kaonic nuclei K−pp bound state

- J−PARC E15: 3He(K⁻,n)
  K⁻3He → "ppK⁻" + n
  using 1 GeV/c K⁻

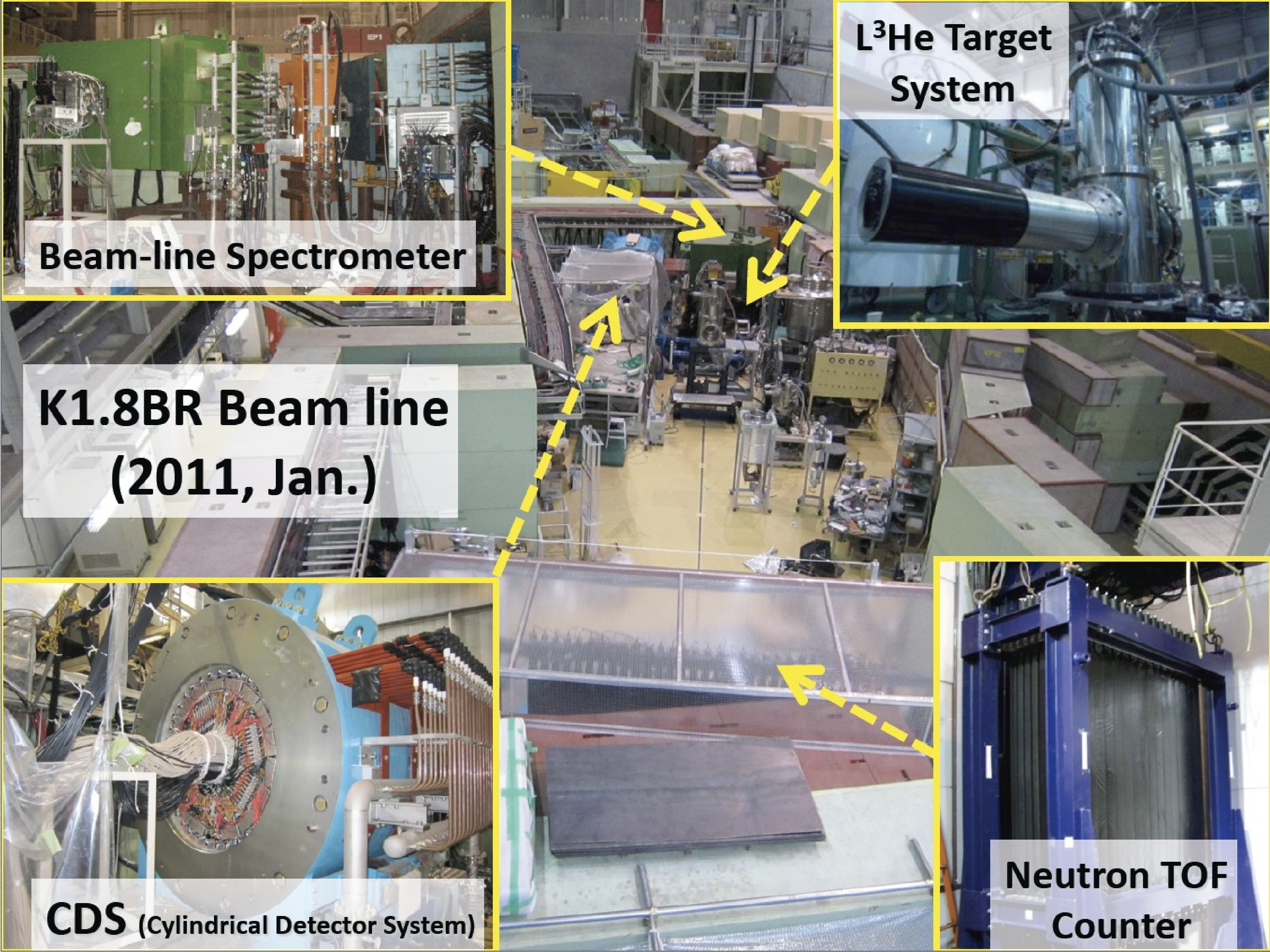






Missing mass (using neutron)
Invariant mass reconstruction (Λ+p)

Full kinematics reconstruction
formation & decay

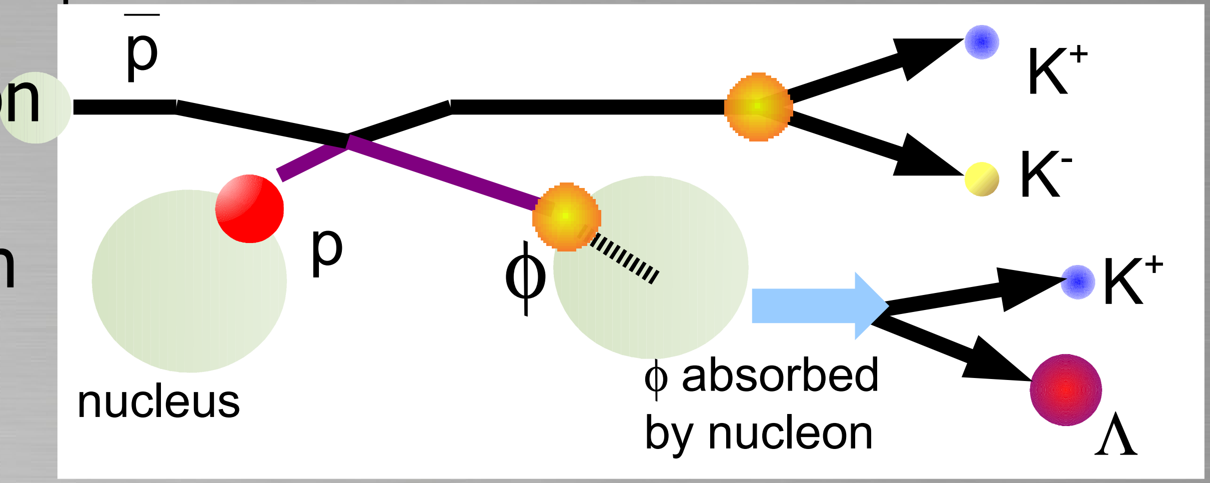


L3He Target System
Beam-line Spectrometer
K1.8BR Beam line
(2011, Jan.)
CDS (Cylindrical Detector System)
Neutron TOF Counter

Search for ϕ meson bound state

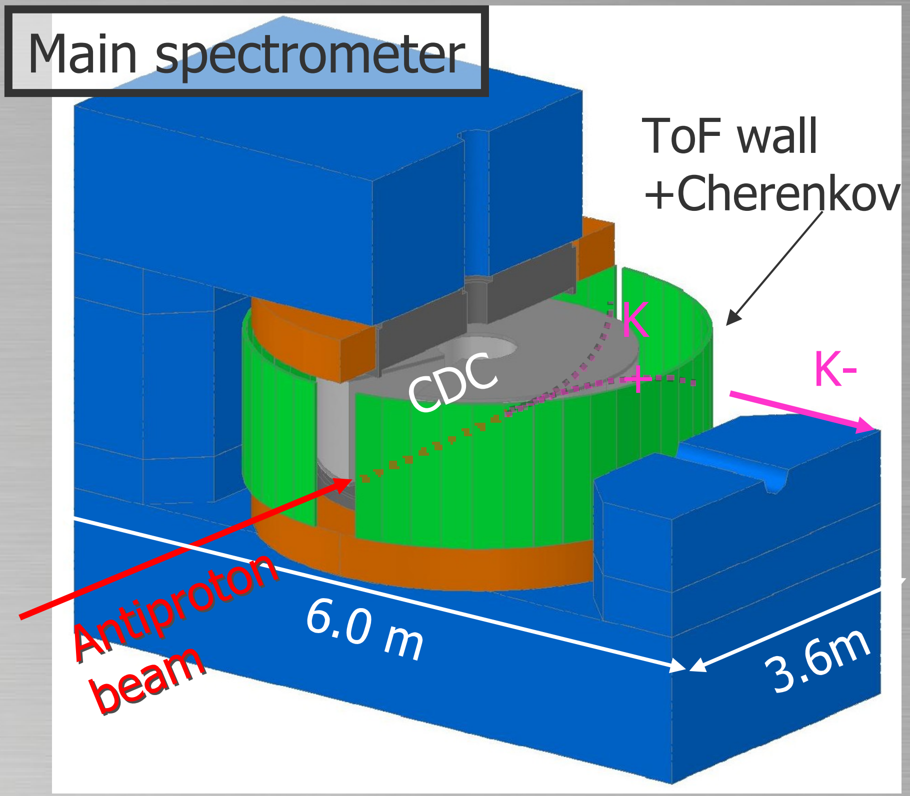
Using p($\bar{p}$,ϕ)ϕ reaction

antiproton beam with 1.0 – 1.1 GeV/c



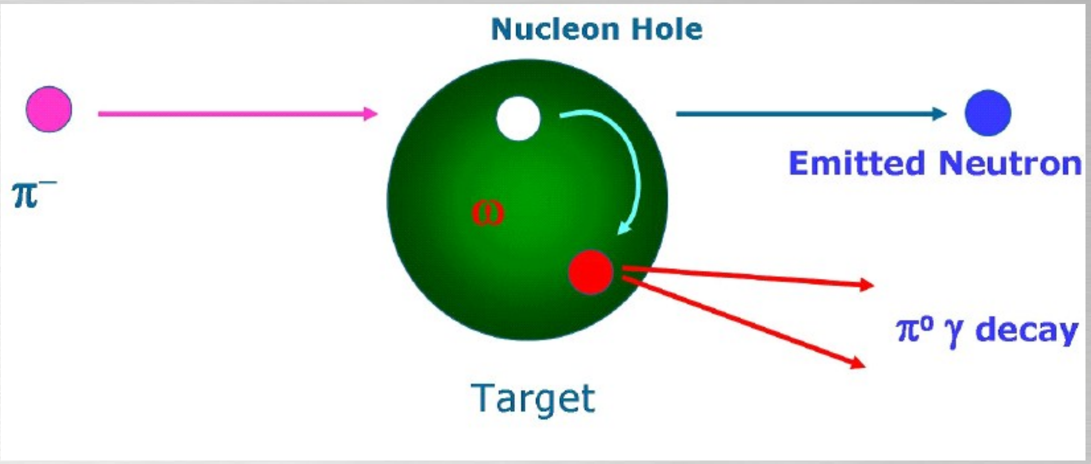
Large acceptance for forward going ϕ meson (for missing mass analysis)

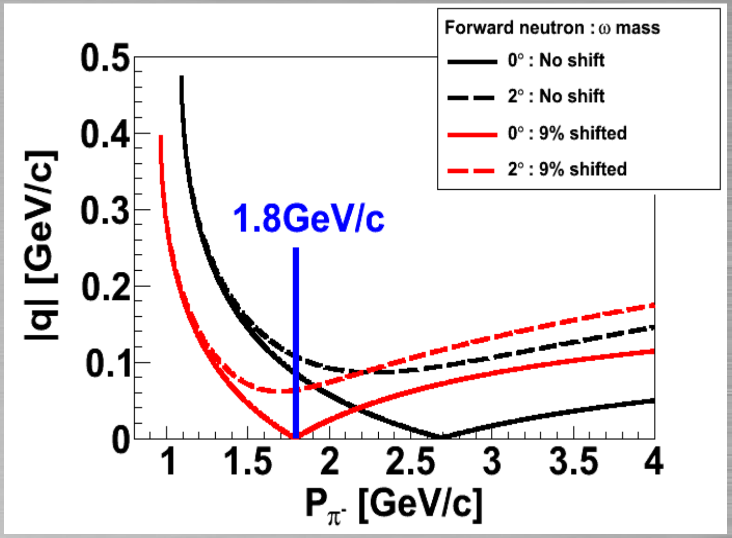
Large solid angle for the decay particles, K^+ / Λ, from ϕ mesic nucleus



ω meson in nucleus

- J–PARC E26 experiment
- Producing w meson using (π^-,n) reaction
- ω meson will be produce at rest (zero momentum respect to nucleus) to choosing incident pion momentum
- ω line shape in nucleus evaluated via $\pi^0\gamma$ decay channel of ω





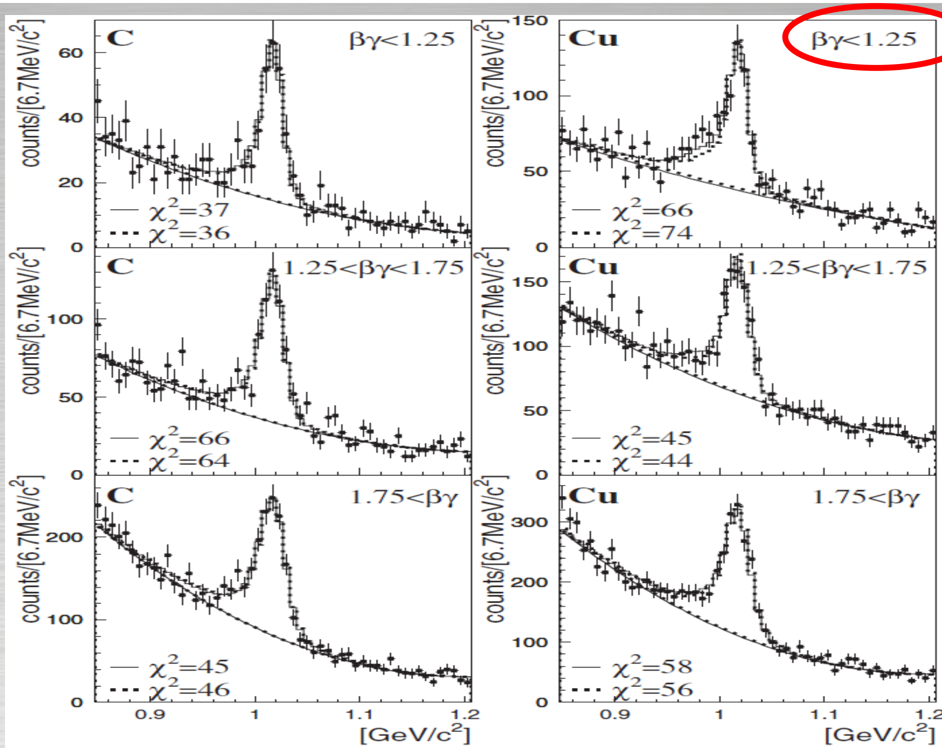
ϕ mesons in normal nuclear media

PRL **98,** 042501 (2007) PHYSICAL REVIEW LETTERS week ending 26 JANUARY 2007

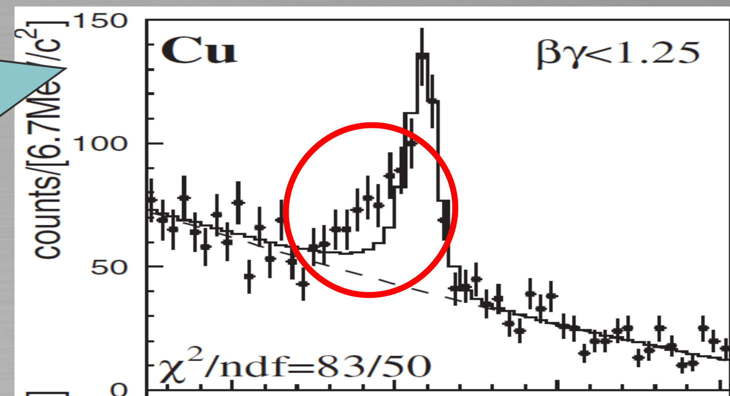
Evidence for In-Medium Modification of the ϕ Meson at Normal Nuclear Density

R. Muto,[1,*] J. Chiba,[2,†] H. En'yo,[1] Y. Fukao,[3] H. Funahashi,[3] H. Hamagaki,[4] M. Ieiri,[2] M. Ishino,[3,‡] H. K... M. Kitaguchi,[3] S. Mihara,[3,‡] K. Miwa,[3] T. Miyashita,[3] T. Murakami,[3] T. Nakura,[3] M. Naruki,[1] K. Ozawa... O. Sasaki,[2] M. Sekimoto,[2] T. Tabaru,[1] K. H. Tanaka,[2] M. Togawa,[3] S. Yamada,[3] S. Yokkaichi,[1] and ...

(KEK-PS E325 Collaboration)



PRL **98,** 042501 (2007)



- Invariant mass spectra for ϕ meson in heavy nucleus shows
  - 3.4% mass shift
  - 3.6 times width broadening

  when only the slowly moving phi mesons with respect to the target nuclei were selected ($\beta\gamma_\phi$<1.25)

δm_ϕ = -35 MeV @ $\rho=\rho_0$

J-PARC E16
High statistics
Systematic study

S. Yokkaichi

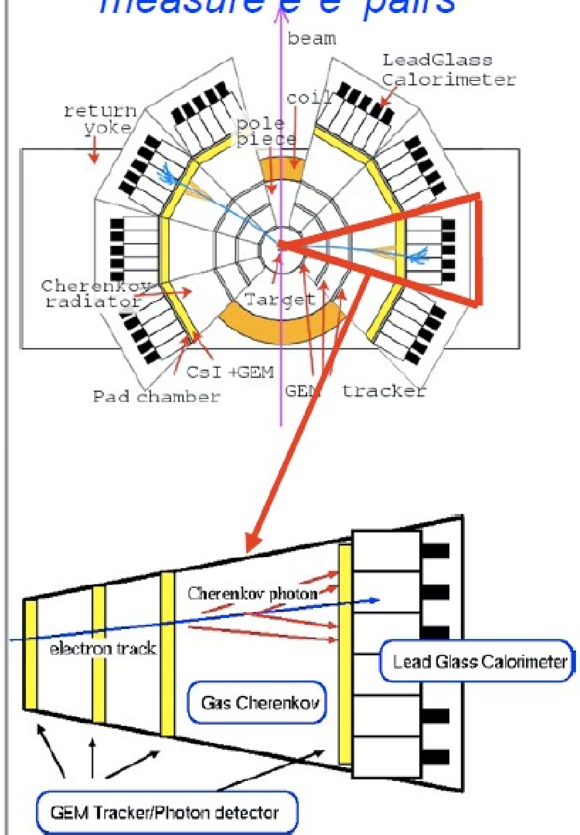
• J-PARC E16 experiment

-Measure the vector-meson mass modification in nuclei systematically with the e^+e^- invariant mass spectrum

-Explore the origin of hadron mass due to the breaking of chiral symmetry proposed by Nambu

-A 30 GeV primary proton beam (10^{10} /spill) / 5 weeks of physics run to collect ~10^5 $\phi \rightarrow e^+e^-$ for each target

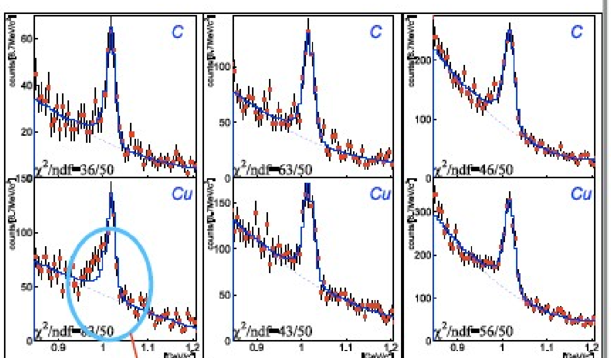
New Spectrometer to measure e^+e^- pairs



modular type detectors : GEM Tracker, HBD (GC) & EMC for the electron ID and tracking

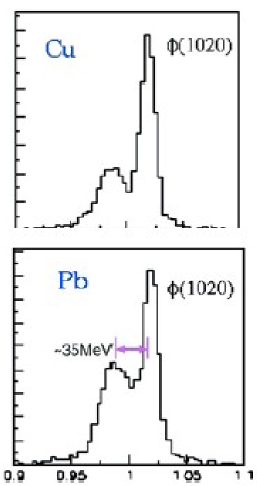
- Prototype detector is tested with electron beam

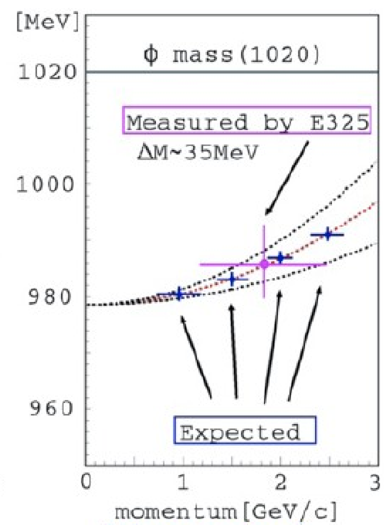
Precedent exp. (KEK-PS E325)



ϕ–mass is modified in large nuclei for slowly moving mesons ... consistent with the prediction based on the QCD sum rule

Proposed exp. E16





Nuclear size dependence & *Momentum dependence* of mass modification

Goal for hadron physics at J-PARC

Rich phenomena induced or governed by QCD at Low energy

Chiral symmetry
- hidden symmetry
Hadron mass

Color symmetry
- gauge symmetry
Color confinement

Symmetry of QCD

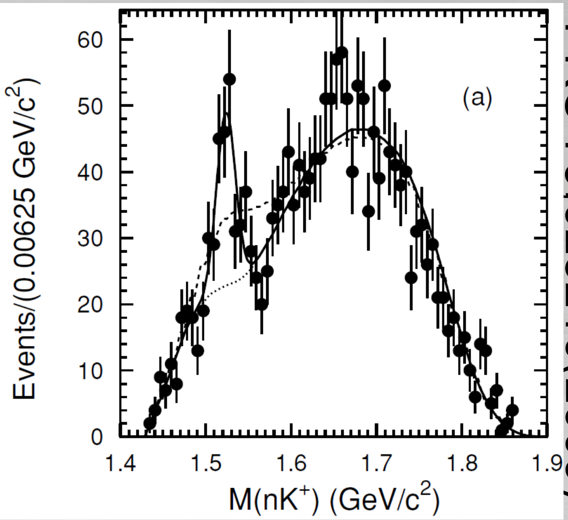
Hadron in nuclei

Exotic hadron
Hadron spectra

Exotic hadron

- Penta-quark state???
  - » Penta quark state is not forbidden in QCD
  - » But... why only a few candidates are observed?
  - » What is the mechanism to forming hadrons
    - » How dose color confinement works?

Spring-8 : LEPS



PRC 79,025210(2009)

$\gamma d \rightarrow K^+K^- pn$

Very narrow width ~ 1 MeV

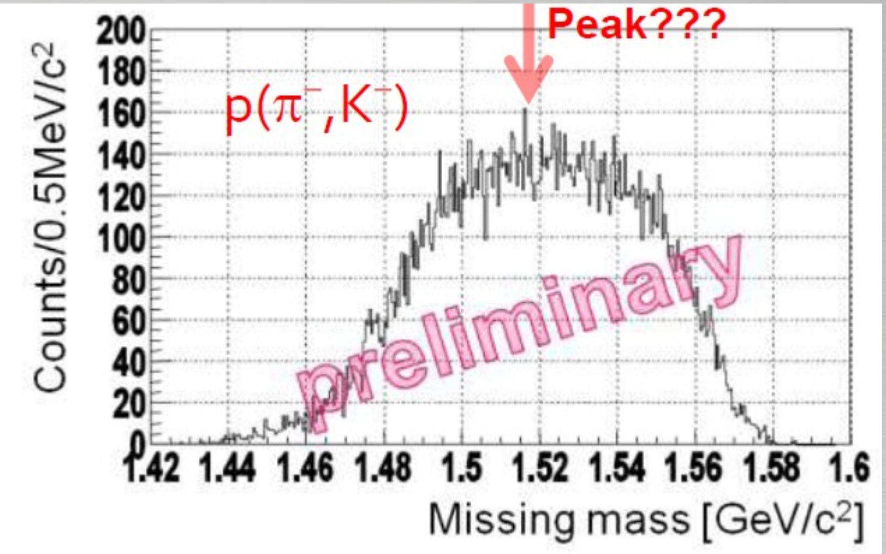
Negative results from High energy

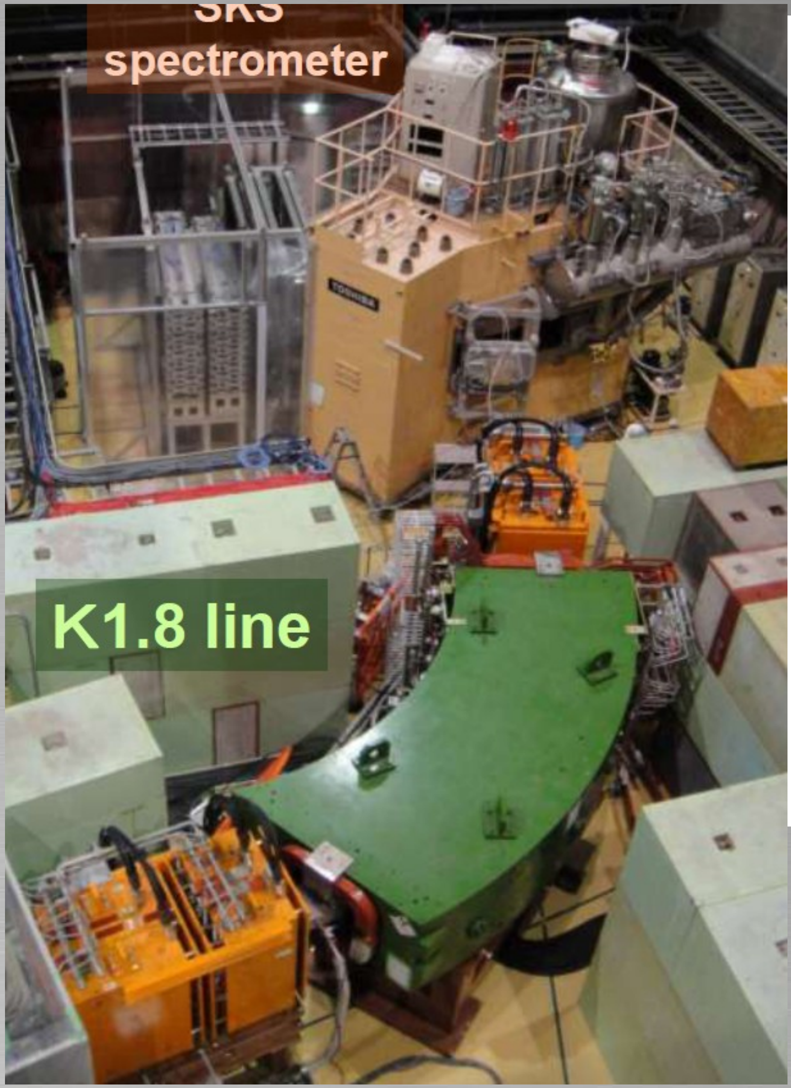
Search for penta-quark at J-PARC

- J-PARC E19 experiment
- Pentaquark formation using (π,K) reaction

  $\pi^{-} + p \rightarrow K^{-} + X$

- Signal identified with missing mass spectroscopy using out going K^{-}

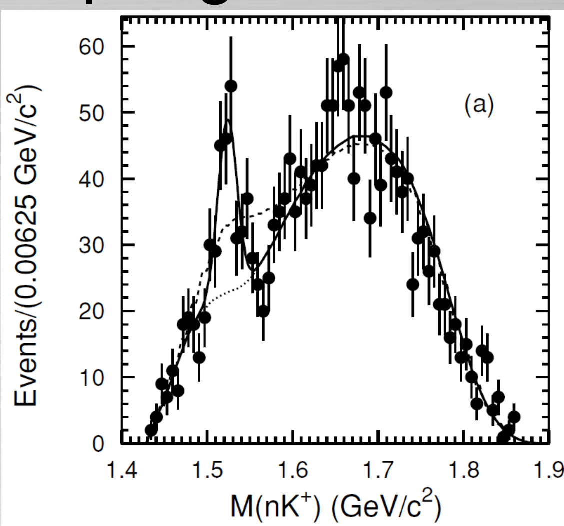




Exotic hadron

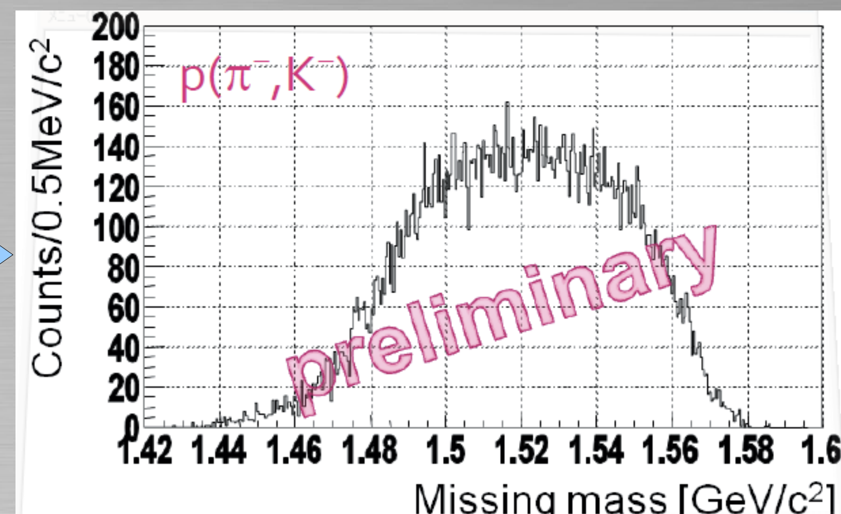
- Penta-quark state???
  - » Penta quark state is not forbidden in QCD
  - » But… why only a few candidates are observed?
  - » What is the mechanism to forming hadrons
    - » How dose color confinement works?

Spring-8 : LEPS



PRC 79,025210(2009)

J-PARC : E19



$\gamma d \rightarrow K^+K^-pn$

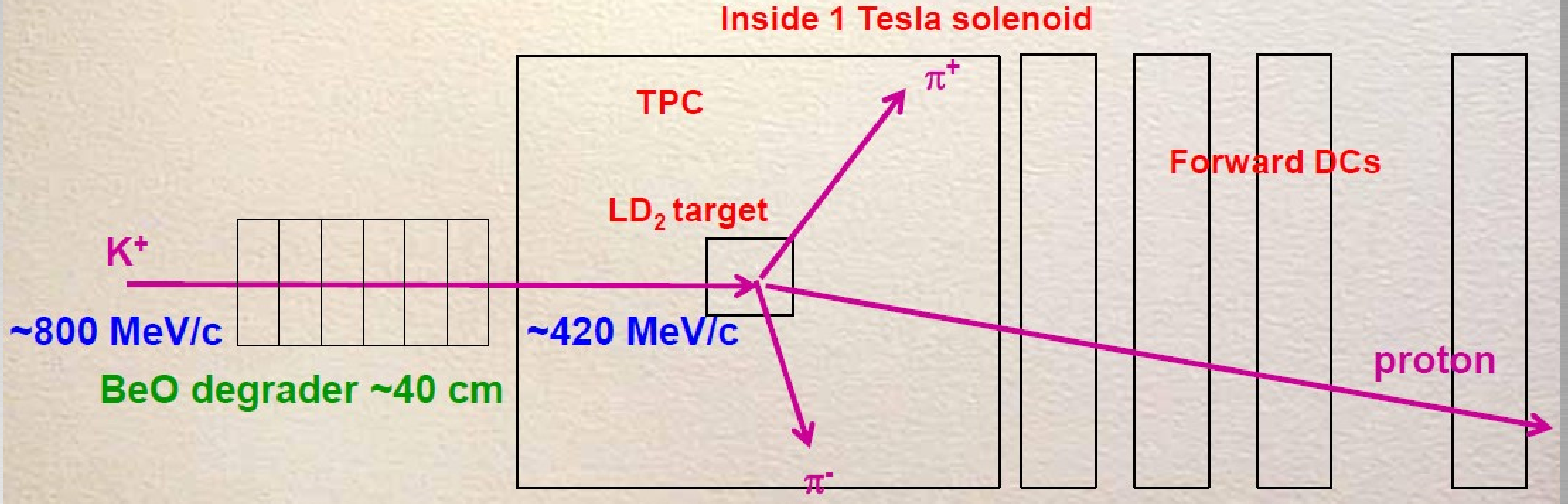
$p(\pi^-,K^-)$

Direct Θ^+ production experiment : $K^+ + n \rightarrow \Theta^+ \rightarrow K^0_s p$ (J-PARC LOI)

Direct Θ^+ production experiment J-PARC (LoI)

- Reverse reaction of the Θ^+ decay using a low energy K^+ beam gives an unambiguous answer.

$$K^+ n \rightarrow \Theta^+ \rightarrow K_S^0 p$$



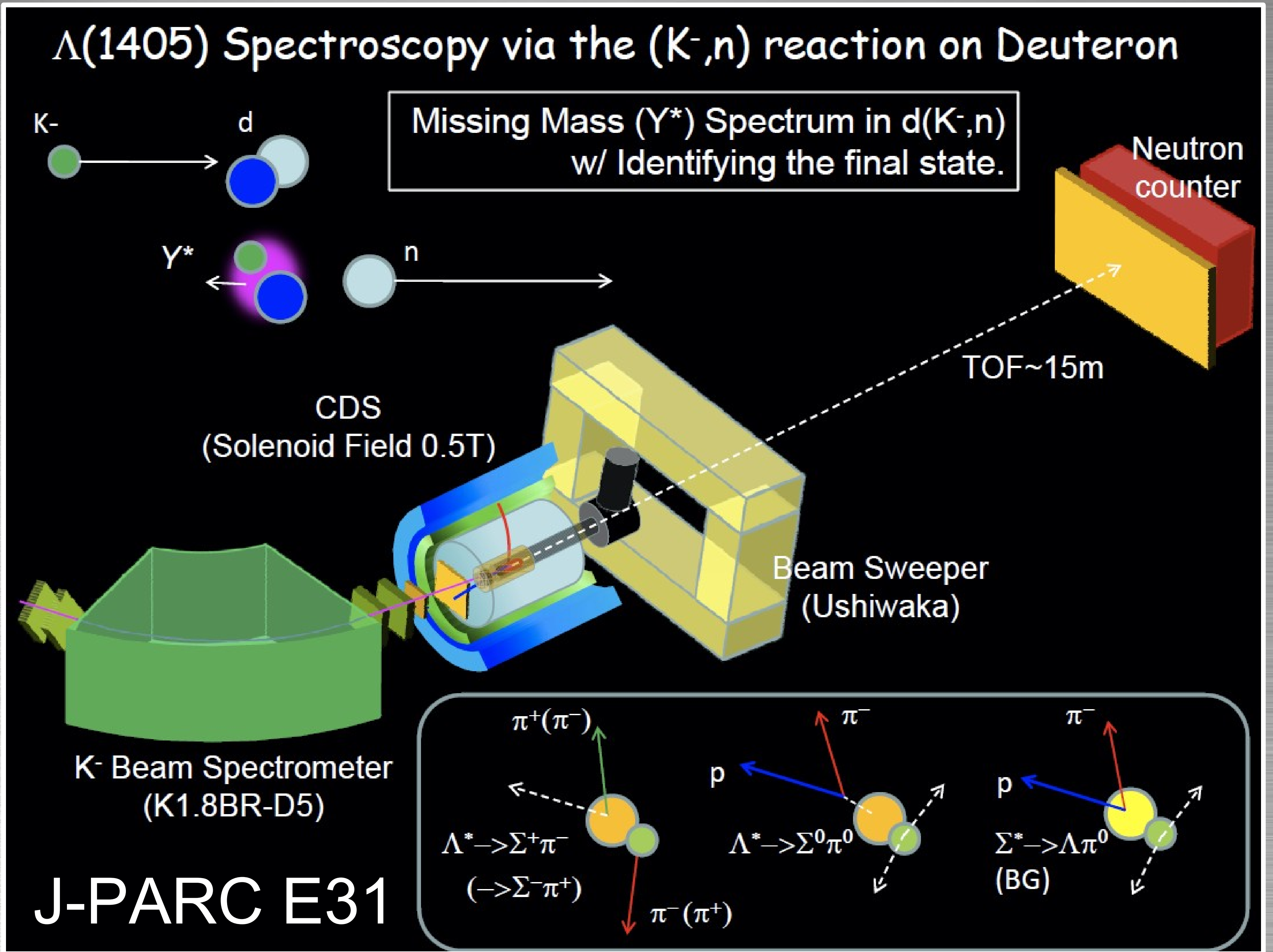
Exotic hadron

- $\Lambda(1405)$:
  - » The lightest excited baryon with $J^P=1/2^-$
  - » Mass : 1406.5±4.0 MeV
    (just bellow $\bar{K}N$ threshold)
  - » Width : 50±2 MeV
  - » Decay : 100 % $\Sigma\pi$

  - » normal baryon or $\bar{K}N$ bound state or penta?

Nature of $\Lambda(1405)$ need to be understood

→ Strongly couple to the $\bar{K}N$ interaction



Λ(1405) Spectroscopy via the (K-,n) reaction on Deuteron
K-
d
Y*
n
Missing Mass (Y*) Spectrum in d(K-,n)
w/ Identifying the final state.
Neutron counter
TOF~15m
CDS
(Solenoid Field 0.5T)
Beam Sweeper
(Ushiwaka)
K- Beam Spectrometer
(K1.8BR-D5)
J-PARC E31
π+(π−)
Λ*−>Σ+π−
(−>Σ−π+)
π−(π+)
π−
p
Λ*−>Σ0π0
π−
p
Σ*−>Λπ0
(BG)

Future direction of Hadron physics at J-PARC

Current situation

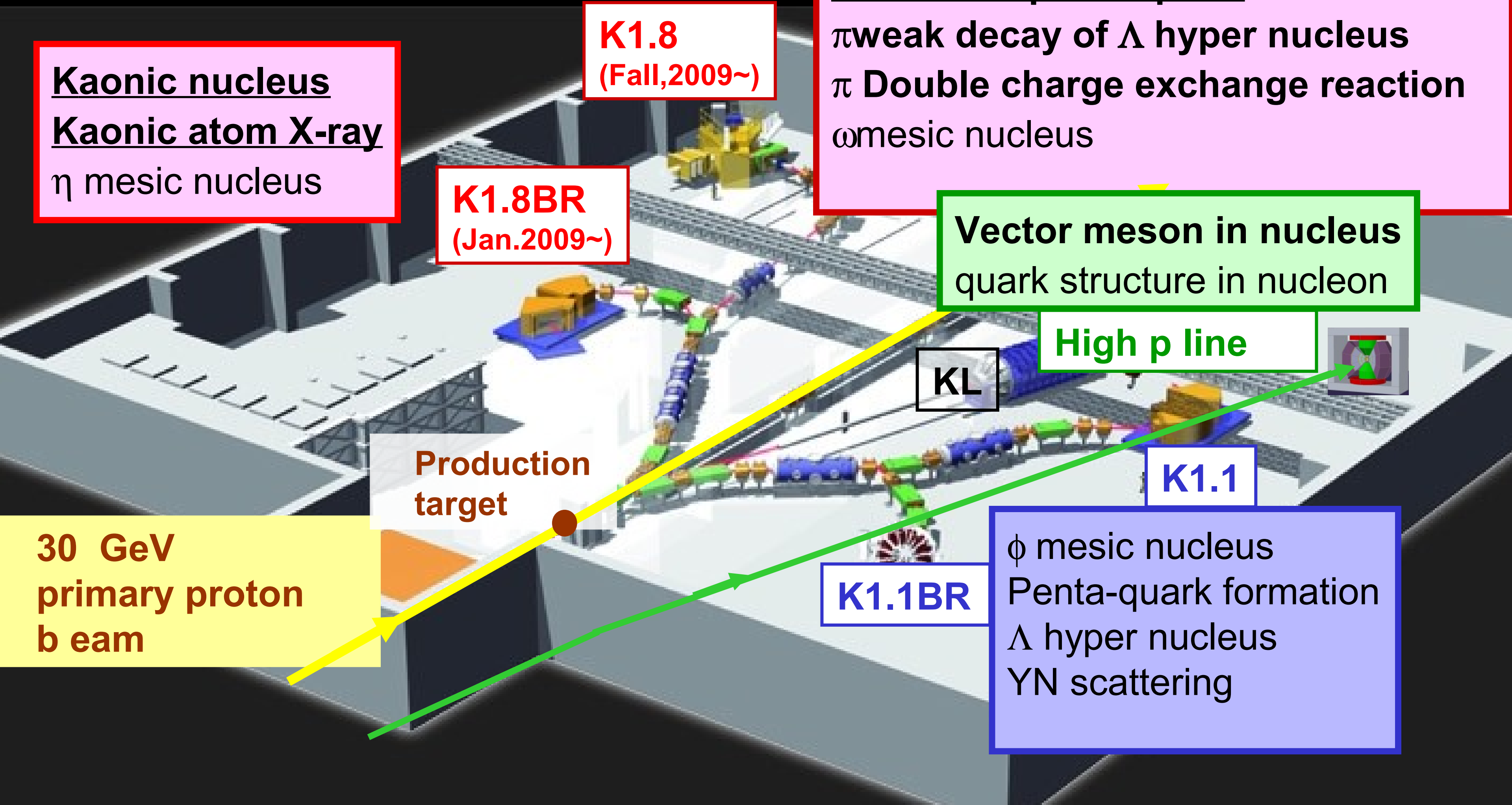
J-PARC :

- Construction of experimental hall is completed
- DAY-1 experiment (penta quark search) has been performed
- Many new results will be available in a few years

- But, only 3 secondary beam lines are available

Approved or proposed nuclear physics experiment

Ξ Hyper nucleus
ΛΛ hyper nucleus
Ξ-atom X-ray
γ ray spectroscopy of Λ hyer nucleus
neutron rich Λ hyper nucleus
Search for penta-quark
πweak decay of Λ hyper nucleus
π Double charge exchange reaction
ωmesic nucleus



New physics topics at J-PARC

- Charm in nucleus?
  - » 30 GeV proton on nucleus
    → more than charm production threshold
  - » High intensity proton beam at J-PARC
    can be produce also high intensity anti-protons!

Charmed meson
bound state?

$\bar{D}N$ bound state,
$\bar{p}\,^3He \rightarrow \eta_c\,^3H$

Physics case
under the discussion

Current situation

J-PARC :

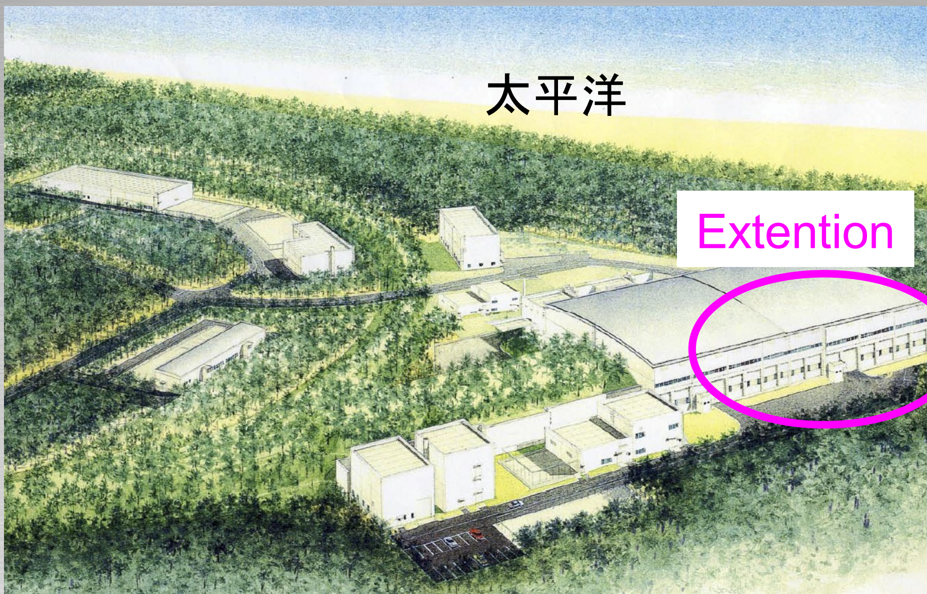
- Construction of experimental hall is completed
- DAY-1 experiment (penta quark search)
  has been performed
- Many new results will be available in a few years

- But, only 3 secondary beam lines are available

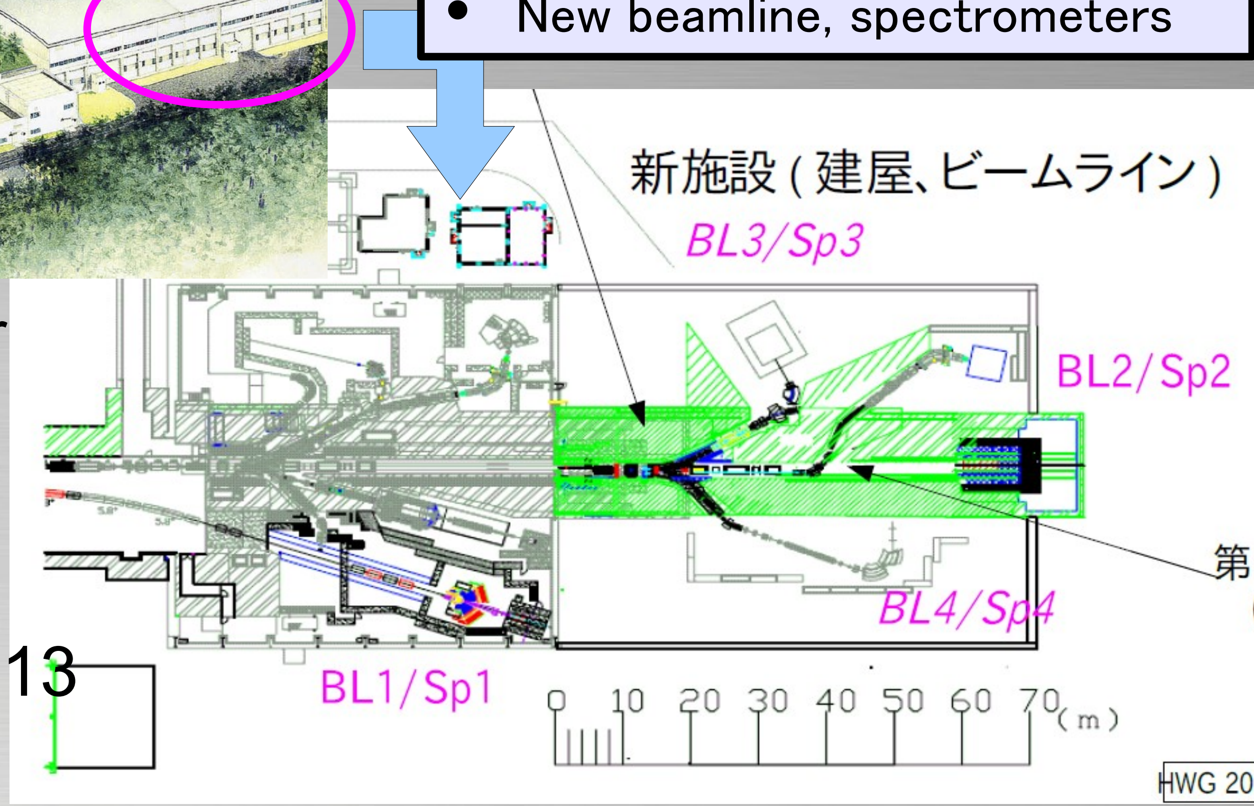
We need new movement to maximize performance of J-PARC facility

J-PARC hadron hall extension

- RIKEN-JPARC cooperation center project



- Extend hadron hall (x 2)
- Two more production targets for secandary beam
- New beamline, spectrometers



Design started together with nuclear physics community

~ $150 M project
We hope to start 2013
Complete 2017

Summary

- J–PARC :
  - contraction phase has been finished
  - now get into (slowly but certainly) "production of physics output" phase
- Many physics ideas are proposed and approved already, but we are facing lack of space (beam lines) to perform experiment

New big project "Hadron hall extension (or RIKEN-JPARC center)" Is most urgent and important issue for nuclear/hadron physics at J-PARC