Status of a new spectrometer "S-2S" for spectroscopy of hypernuclei with S=-2 at J-PARC

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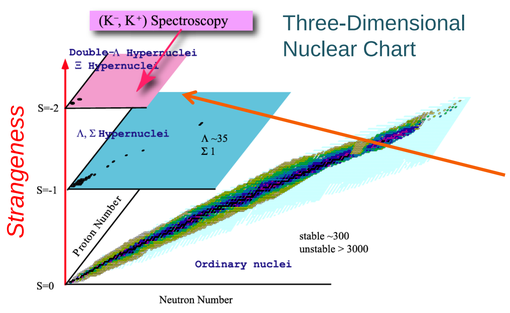
Abstract: Experimental information of B-B interaction with S = -2 is almost nothing at this time and strongly awaited. We plan to observe Ξ-hypernuclei by using the high intensity K^- beam at J-PARC with a new magnetic spectrometer "S-2S". It is designed to have a momentum resolution < 5×10^{-4} and an acceptance of 50 msr. It will lead us to *the S = -2 world*. The progress of magnet construction and counter development are reported.

J-PARC E05 Experiment

Observe Ξ-hypernuclei $^{12}_{\Xi}$Be via the ^{12}C(K^-,K^+) reaction for the first time → **Information of ΞN interaction**



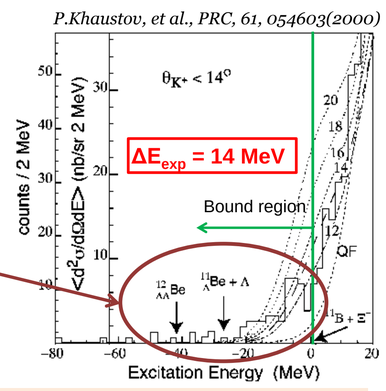
- ✓ Baryon-baryon interaction
- ✓ Multi-strangeness system
  —strange nuclear matter, neutron stars

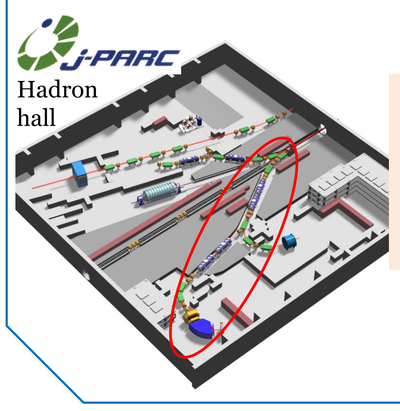
Experimental information of hypernuclei with S=-2 is very limited

Previous experiment

- BNL-E885 : ^{12}C(K^-,K^+) reaction at 1.8 GeV/*c* K^-
- suggested very small cross section ~60 nb/sr
- lack of statistics and energy resolution

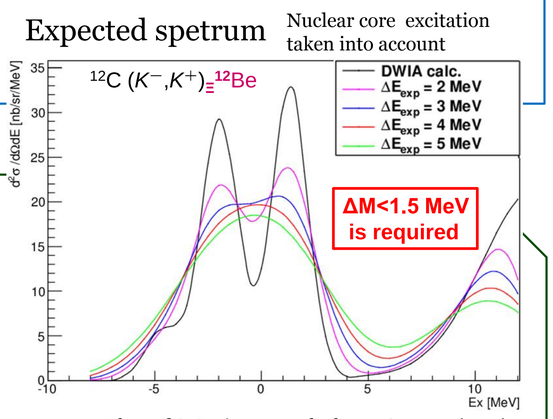
No clear peak





J-PARC K1.8 beam line

- High intensity 1.8 GeV/*c* K^- beam
- High resolution beam spectrometer Δp/p ~3.3×10^{-4}
- spectroscopy of Ξ-, ΛΛ-nuclei using various targets



T. Motoba and S. Sugimoto, Nucl. Phys. A 835, 223 (2010)

Design of S-2S

Strangeness -2 Spectrometer

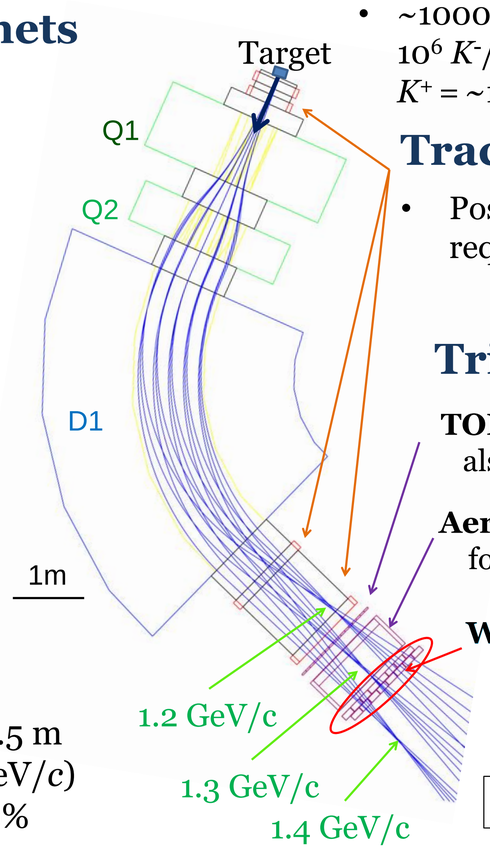
- To analyze scattered K^+ around 1.3 GeV/c
- Momentum resolution Δp/p <5×10^{-4}
  Missing mass resolution ΔM <1.4 MeV
  cf) SKS case: Δp/p ~3×10^{-3}, ΔM~4MeV
- Acceptance >50 msr
- 1.2 GeV/*c* ~ 1.4 GeV/*c*

QQD-type magnets

Q1 - vertical focus
- 8.7 T/m
- Aperture 31 cm
- 37 ton

Q2 - horizontal focus
- 4.9 T/m
- Aperture 36 cm
- 12 ton

D1 - 70 deg. bending
- 1.4 T/m
- Gap 32 cm(H), 80 cm(W)
- 86 ton



Focal point

Target~focal point 8.5 m
βγcτ ~ 9.7 m (1.3 GeV/*c*)
K^+ survival rate ~40%

Main processes caused by K^- beam
- (K^-, π^+), (K^-, *p*) reaction
- ~1000/spill at beam intensity of 10^6 K^-/spill for each π^+, *p*, while K^+ = ~1/spill

Tracking detector

- Position resolution ~200 μm required for Δp/p < 5×10^{-4}

Trigger counter

TOF : plastic scintillator also used in off-line analysis

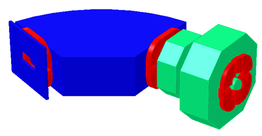
Aerogel Cherenkov (n=1.06) for pion veto in on-line trigger

Water Cherenkov (n=1.33) for proton rejection in on-line trigger

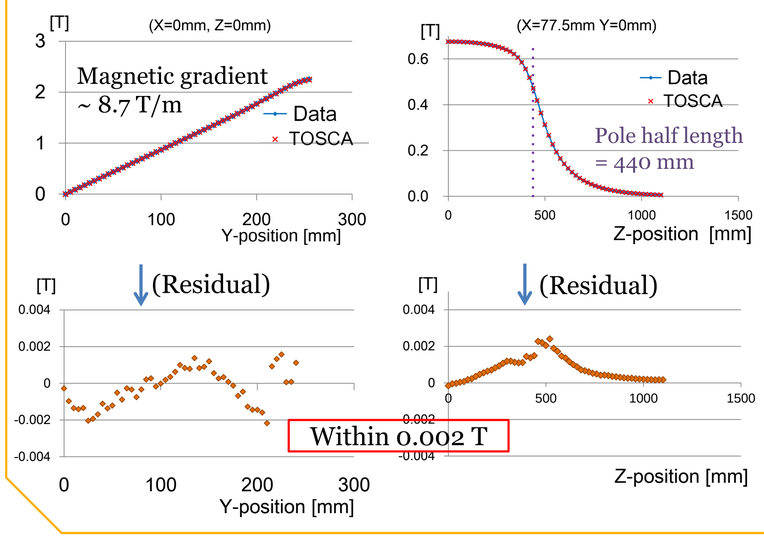
K^+ = **TOF** ∧ $\overline{\textbf{AC}}$ ∧ **WC**

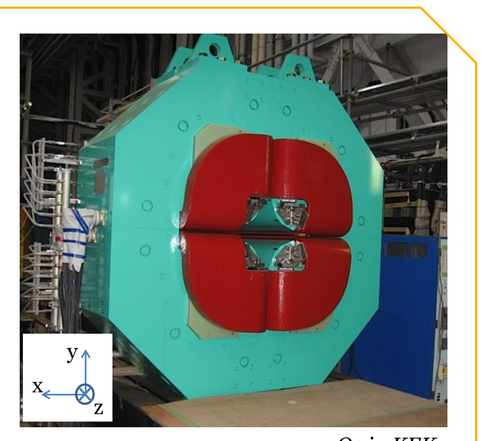
Magnets

Q1 magnet



- constructed in 2013
- Field measurement with hole probe
- Calculation using Opera-3d/TOSCA (finite element method)





Q1 in KEK

Result

- Enough field strength
- TOSCA fits data by adjusting BH curve input in high field region.
- The effect on the momentum resolution is almost negligible.

Q2 and D1 magnets

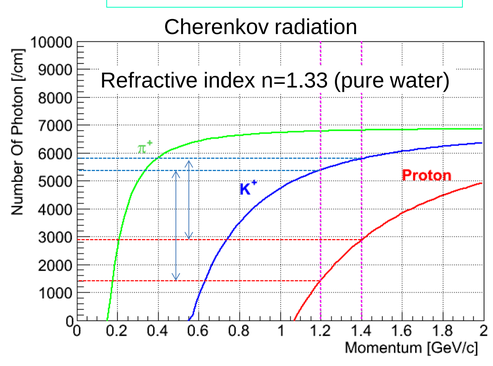
- To be completed in 2014

Water Cherenkov counter

Trigger counter for K^+/p separation

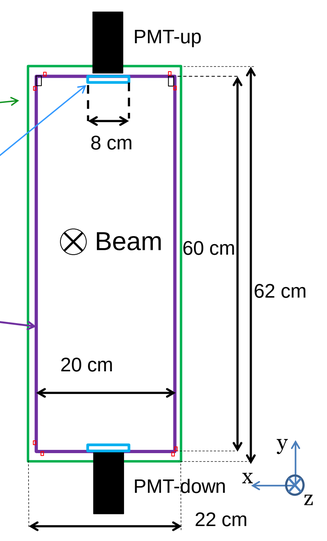
- To reject background protons under good K^+ detection in on-line trigger.
- ~90 % *p* rejection is desired for enough DAQ efficiency.
- *p* and K^+ emit different number of photons.

$$\frac{dN^2}{d\lambda dx} = \frac{2\pi z^2 \alpha}{\lambda^2}\left(1 - \frac{1}{\beta^2 n^2(\lambda)}\right)$$



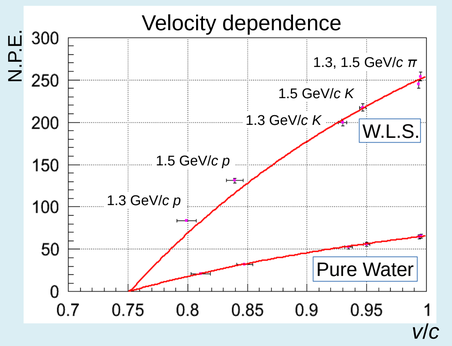
Prototype

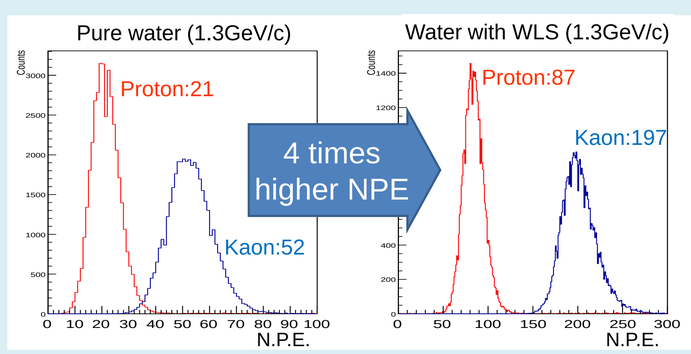
- Acryl tank
  $20^W x 15^T x 60^H$ [cm³]
- Window (tank)
  UVT acryl
- Reflective sheet
  Tyvek 1060B
- PMT (2-inch)
  H6522, H7195UV
  (UV glass window)

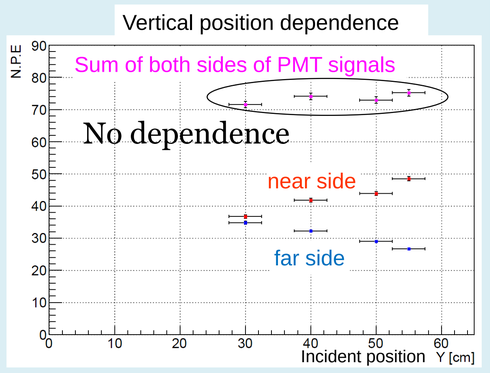


Test experiment

- We used $\pi/K/p$ beam at J-PARC and Cosmic-ray.
- Pure water and water doped with wave length shifter (WLS: Amino-g salt) were tested as radiator.







- Effect of wave length shifter is large, but aging degradation was seen by 20% in 2 weeks.

Proton rejection efficiency is expected to be 88% in 1.2 GeV/c ~ 1.4 GeV/c, even if using pure water.

Summary: J-PARC E05 experiment is planned to obtain the spectroscopic information of hypernuclei with S=-2. A new high resolution spectrometer "S-2S" is under construction. Field measurement and calculation of Q1 have been done, and showed its good performance. The prototype of Water Cherenkov counter was tested. Although the behavior of the WLS has not been understood well, enough rejection efficiency will be achieved using pure water. **Future work:** Q2 and D1 magnet construction in 2014. Study of field calculation and analysis method, and the actual version of WC construction will be carried out.