2023 ELPH研究会C035

Production of double-strangeness systems near the threshold in the $^{12}\mathrm{C}(K^-, K^+)X$ reaction at 1.8 GeV/c

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for the J-PARC E42 Collaboration

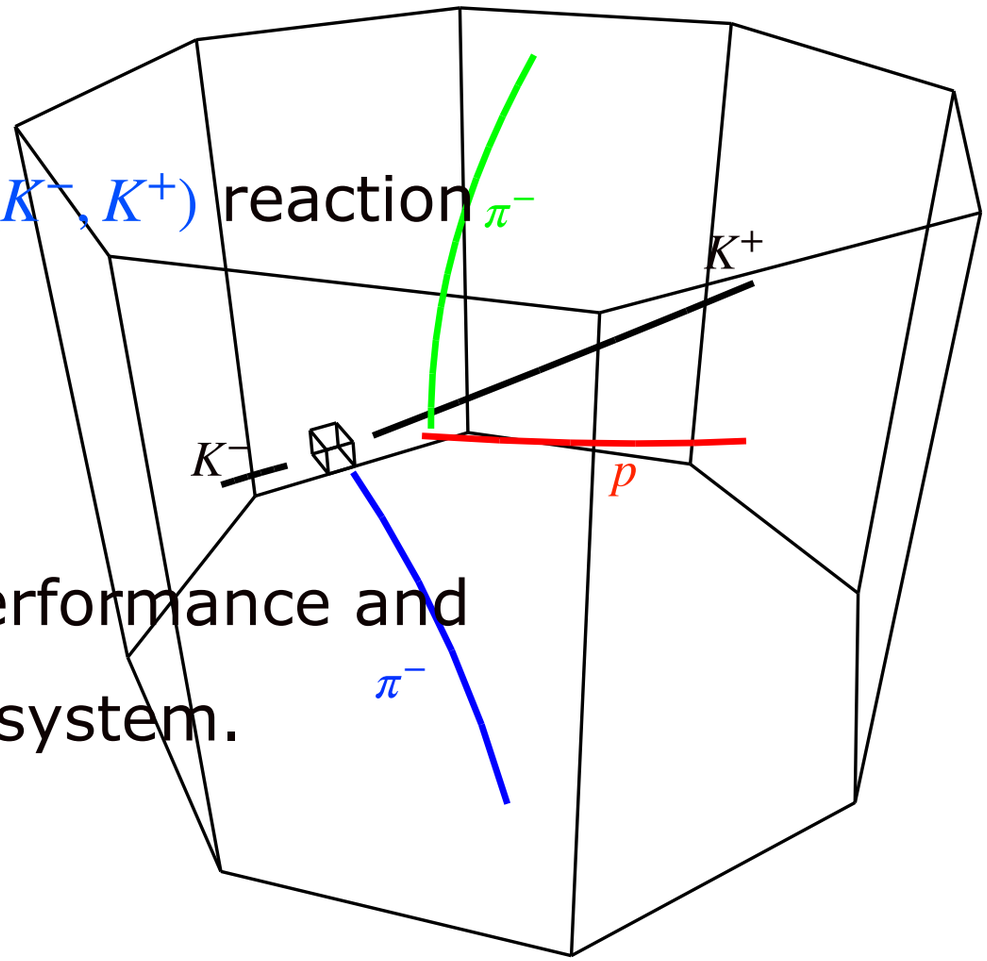
E42 Completed June 29, 2021

고려대학교 KOREA UNIVERSITY

Hadron & Nuclear Physics Lab

Outline

- Production and decay of the double-strangeness systems from $^{12}\mathrm{C}(K^-, K^+)X$ involving double hypernuclei and H-dibaryon

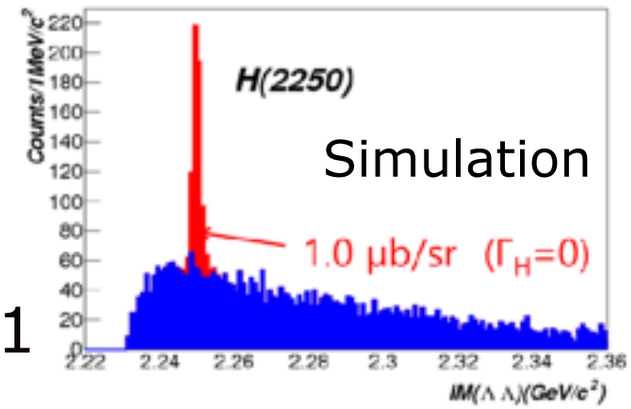


- J-PARC E42 with HypTPC collected 0.3 M (K^-, K^+) reaction events data in 2021

- Preliminary results on the E42 detector performance and binding energy spectra relative to $\Xi^- + {}^{11}\mathrm{B}$ system.

J-PARC E42

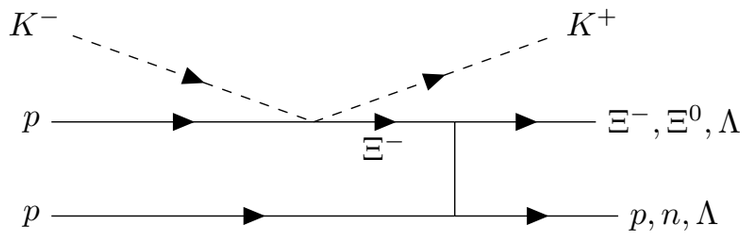
H-dibaryon search via $^{12}\mathrm{C}(K^-, K^+)$ reaction

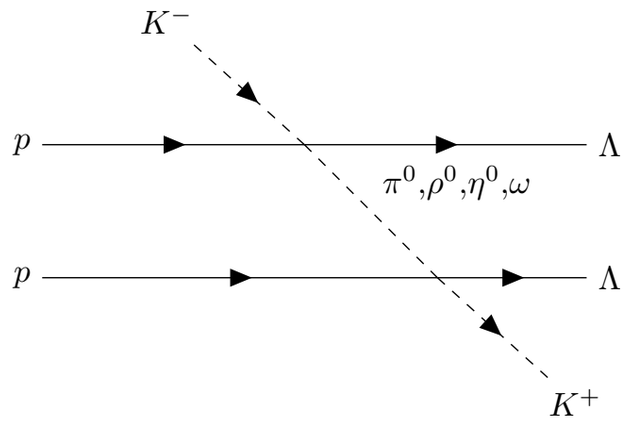


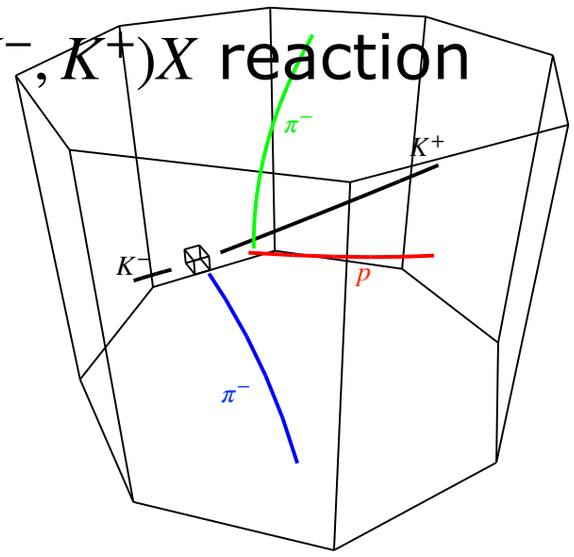
- SU(3) flavor-singlet dibaryon consisting of uuddss
- Collected 0.3 M (K^-, K^+) reaction events data in 2021
- Invariant-mass measurement of $\Lambda\Lambda$ and $\Xi^- p$ systems with HypTPC

First measurement of all charged decays from $^{12}\mathrm{C}(K^-, K^+)X$ reaction with high statistics

- Processes of double-strangeness exchange in $^{12}\mathrm{C}(K^-, K^+)X$ reaction







Study of Ξ^- nucleus Potential

Ξ^--nucleus Potential

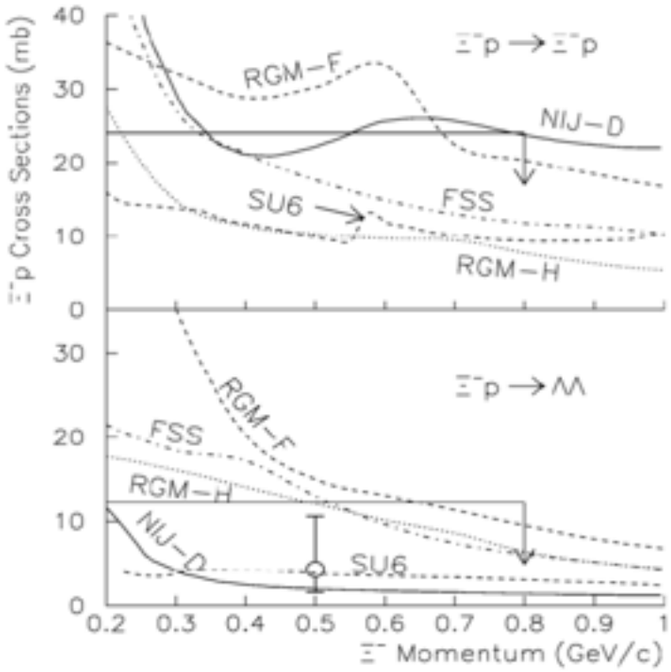
$$U_{\Xi^-} = [V_0^{\Xi} + iW_0{}^{\Xi} g(E)] f(r)$$

where,

$V_{0\Xi}$: Strength of the potential

$W_{0\Xi}$: Absorption processes ($\Xi^- p \to \Lambda\Lambda$, $\Xi^- p \to \Xi^0 n$)

- Past experimental data on low-energy $\Xi^- p$ elastic, $\Xi^- p \to \Lambda\Lambda$ cross-section (KEK E224)



The total cross-section of $\Xi^- p \to \Lambda\Lambda$ and the width of Ξ^- state in nuclear matter

$$\sigma_{\Xi^- p \to \Lambda\Lambda} = 4.3^{+6.3}_{-2.7}\ m\text{b},\ \Gamma_{\Xi^-} \sim 3\ \text{MeV}$$

*J.K. Ahn et al. / Physics Letters B 633 (2006) 214–218

- Recent emulsion experiments($\Xi^- - {}^{14}\mathrm{N}$ bound state):

  J-PARC E07(IRRAWADDY, IBUKI), KEK E373 (KISO)

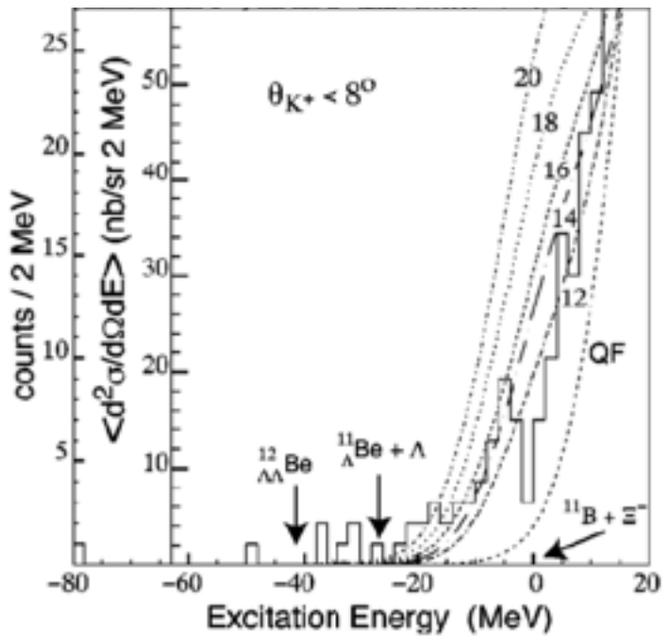
  -> Attractive Ξ^- nucleus potential with a weak ΞN-ΛΛ coupling

*M. Yoshimoto, Prog. Theor. Exp. Phys. **2021**, 073D02.
*S. H. Hayakawa et al./ Phys. Rev. Lett. 126, 062501 (2021).

Study of Ξ^- nucleus Potential($V_{0\Xi}$)

- Reinvestigation of the Ξ^-–nucleus potential using the past data

BNL-E885 : $V_{0\Xi} \sim -14$ MeV
by neglecting the $W_{0\Xi}$



*P. Khaustov et al., PRC 61 (2000) 054603

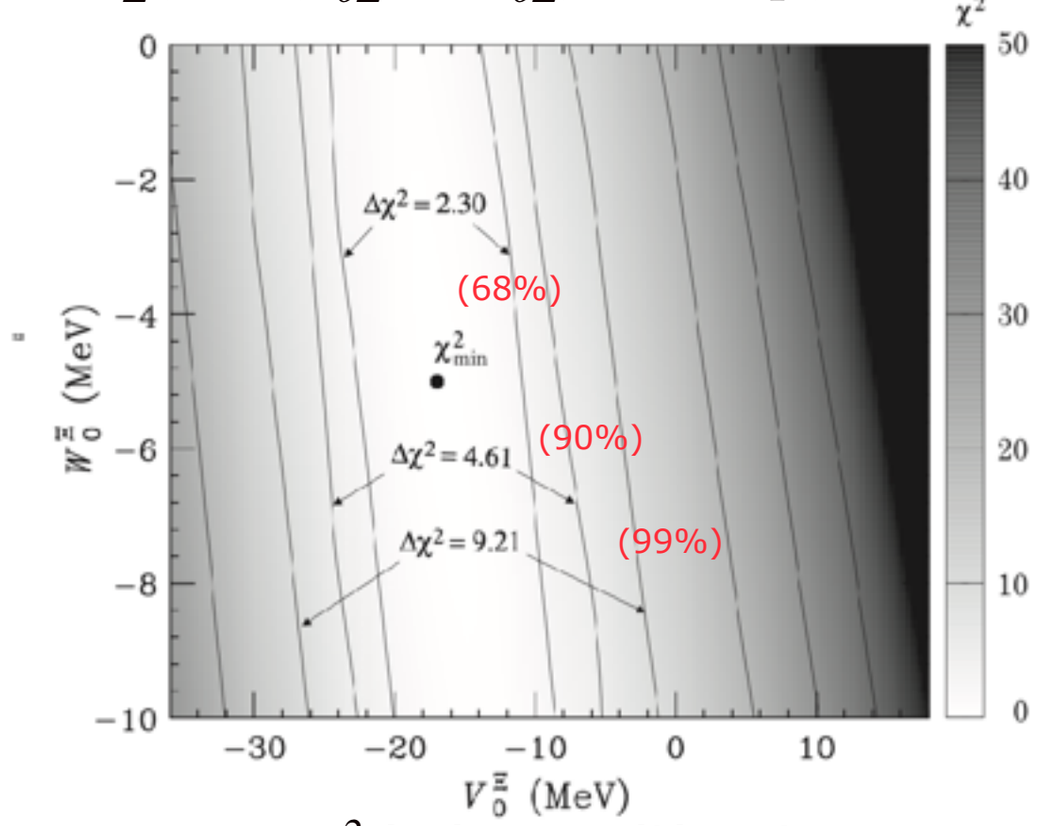
By SCDW model calculations

- $V_{0\Xi} \sim 0$ with $\Gamma/2$=2 MeV also can reproduce above data.

*M. Kohno and S. Hashimoto, Prog. Theor. **123**, (2010).

BNL-E906 $^{9}\mathrm{Be}(K^-, K^+)$ reaction at 1.8 GeV/c spectrum was studied.

$$U_\Xi(r) = (V_{0\Xi} + iW_{0\Xi})/[1 + \exp(r - R)/a]$$



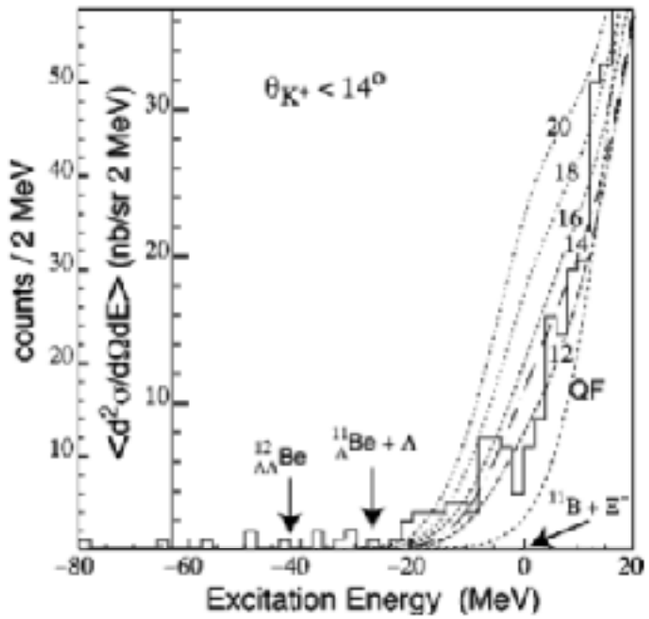
- χ^2 is insensitive to $W_{0\Xi}$

*T.Harada and Y. Hirabayashi, Phys. Rev. C **103**, 024605 (2001)

Experiments Ξ^- Hypernuclear Spectroscopy

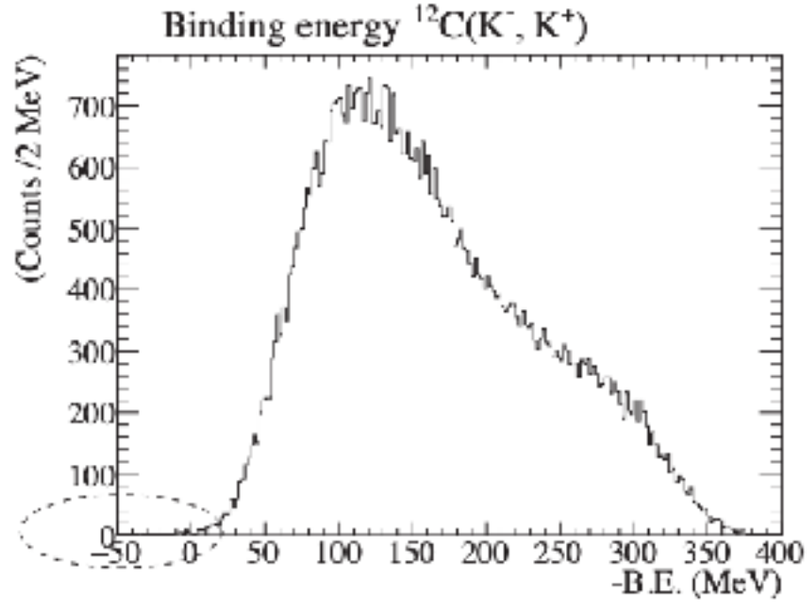
- Search for bound Ξ^- hypernuclei in the excitation-energy spectrum for $^{12}\mathrm{C}(K^-, K^+)\Xi^- X$ reaction

BNL-E885 $V_{0\Xi} \sim -14$ MeV J-PARC E05 / E70 (near future)



*P. Khaustov et al., PRC 61 (2000) 054603

MM Resolution : FWHM 14 MeV



*T. Nagae et al., Proposal to J-PARC, E70 (2018)

MM Resolution : FWHM 2 MeV

- E42 is sensitive to determine $W_{0\Xi}$ by decomposing the inclusive spectrum into $\Xi^- p \to \Lambda\Lambda$ conversion and other processes by HypTPC.

E42 Byproducts

(K^-, K^+) reaction at 1.8 GeV/c

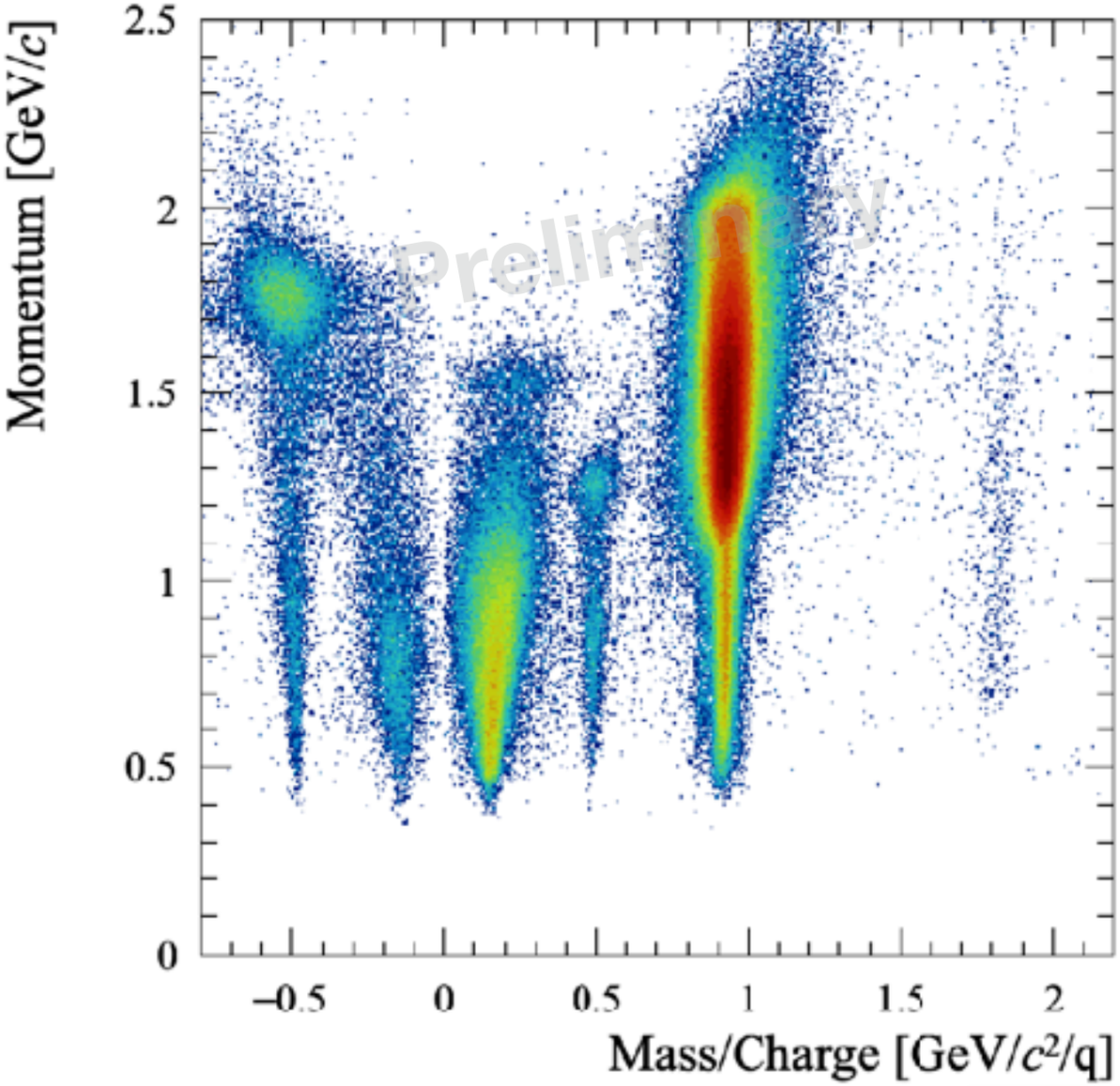
- Differential Cross-section Measurement of $K^- p \to K^+ \Xi(1535)^-$
- Ξ^- Polarization Measurement
- Multi-particle Emission in $^{12}\mathrm{C}(K^-, K^+)$

(K^-, p) reaction at 1.8 GeV/c

- Cross-section Measurement of $\mathrm{p}(K^-, p)K^*(892)X$ and $^{12}\mathrm{C}(K^-, p)K^*(892)X$
- Kaonic Nucleus Search by $^{12}\mathrm{C}(K^-, p)X$

J-PARC E42 Detector

Scattered particles at forward angles



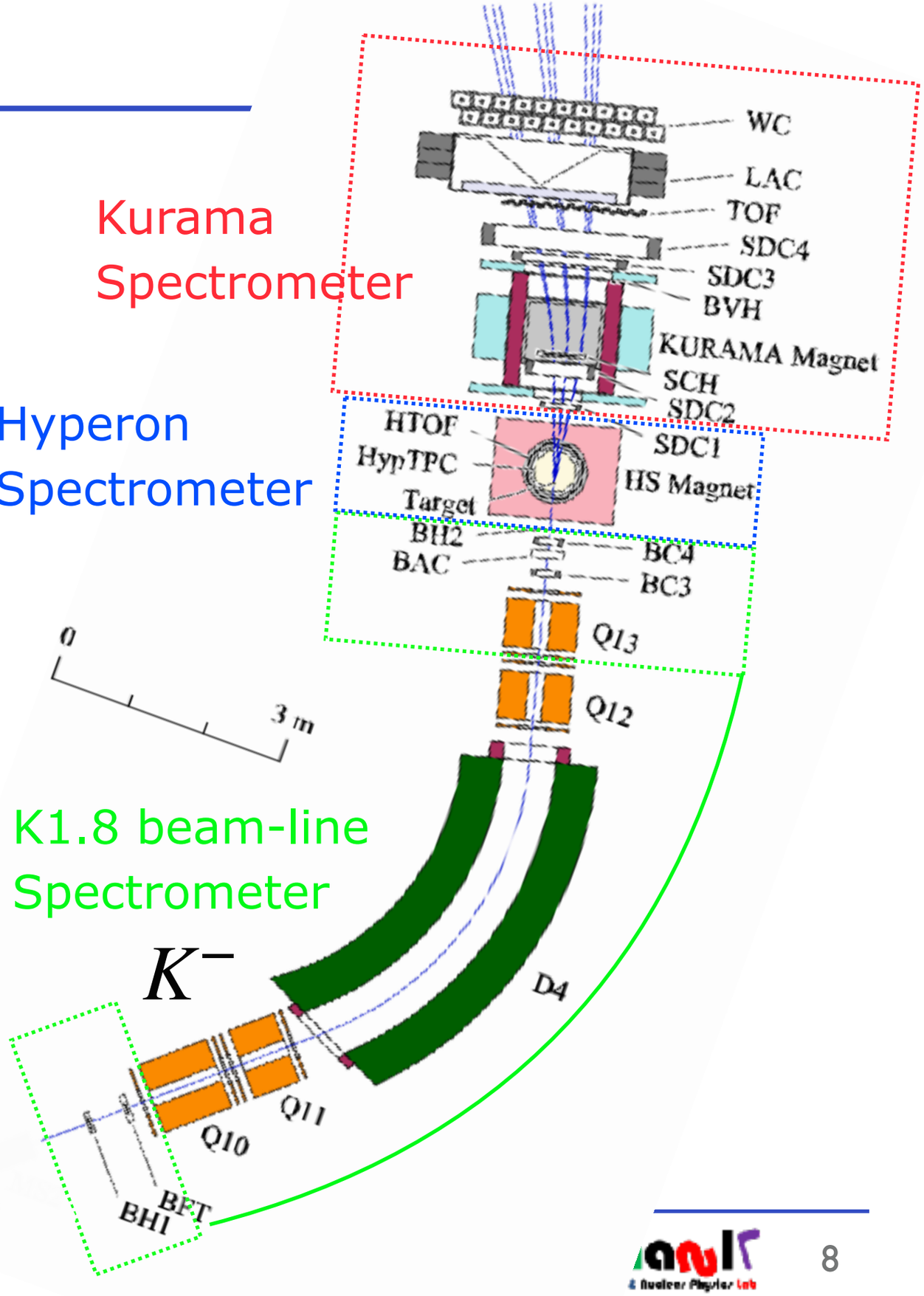
Kurama Spectrometer

Hyperon Spectrometer

K1.8 beam-line Spectrometer

Decay particles K^+

K^-



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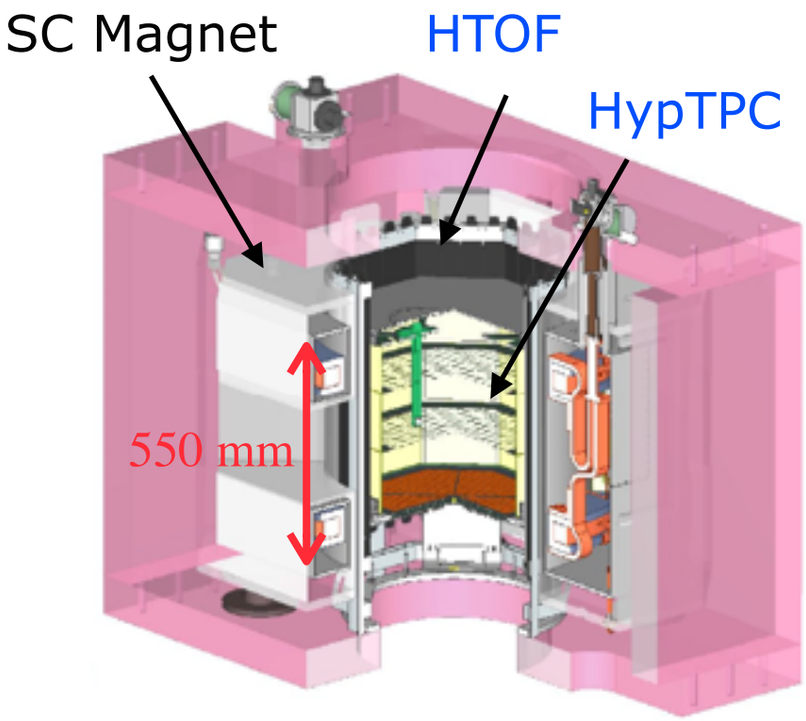
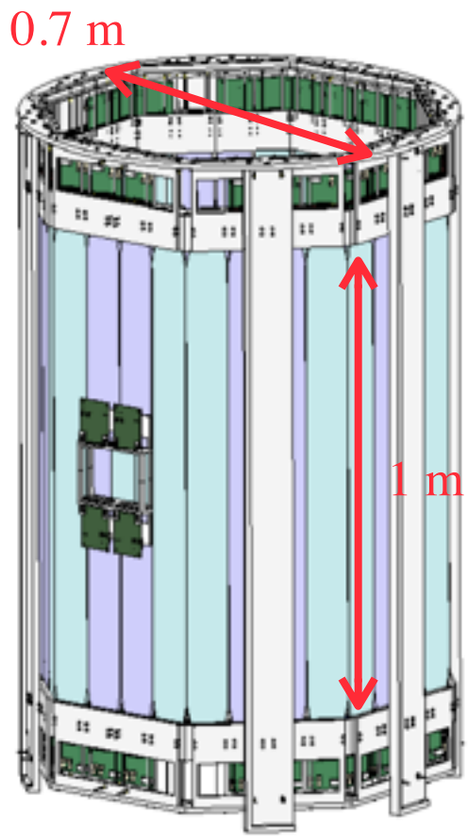
Hyperon Spectrometer



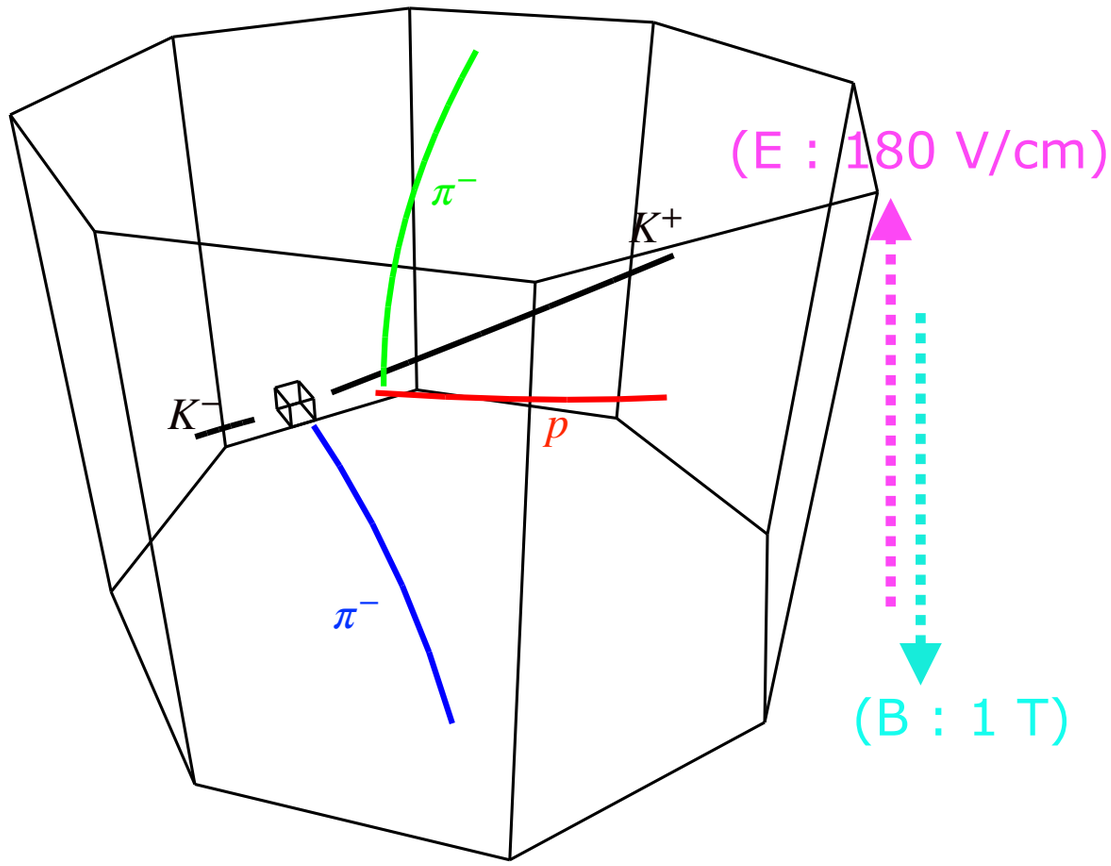


HypTPC

- Main tracker for charged decays.
- E42 target is located inside the TPC off-axis with the beam.

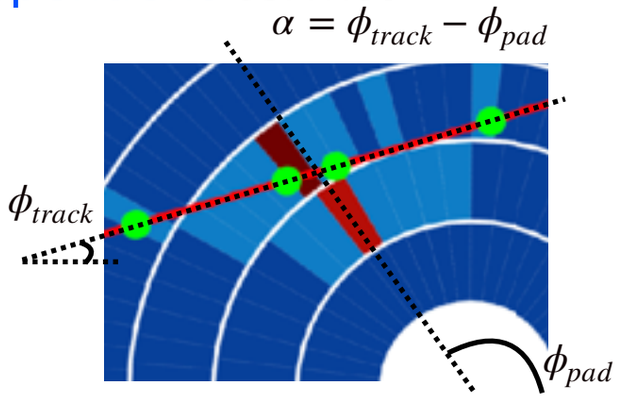
HTOF

- 1m long TOF counter surrounding TPC

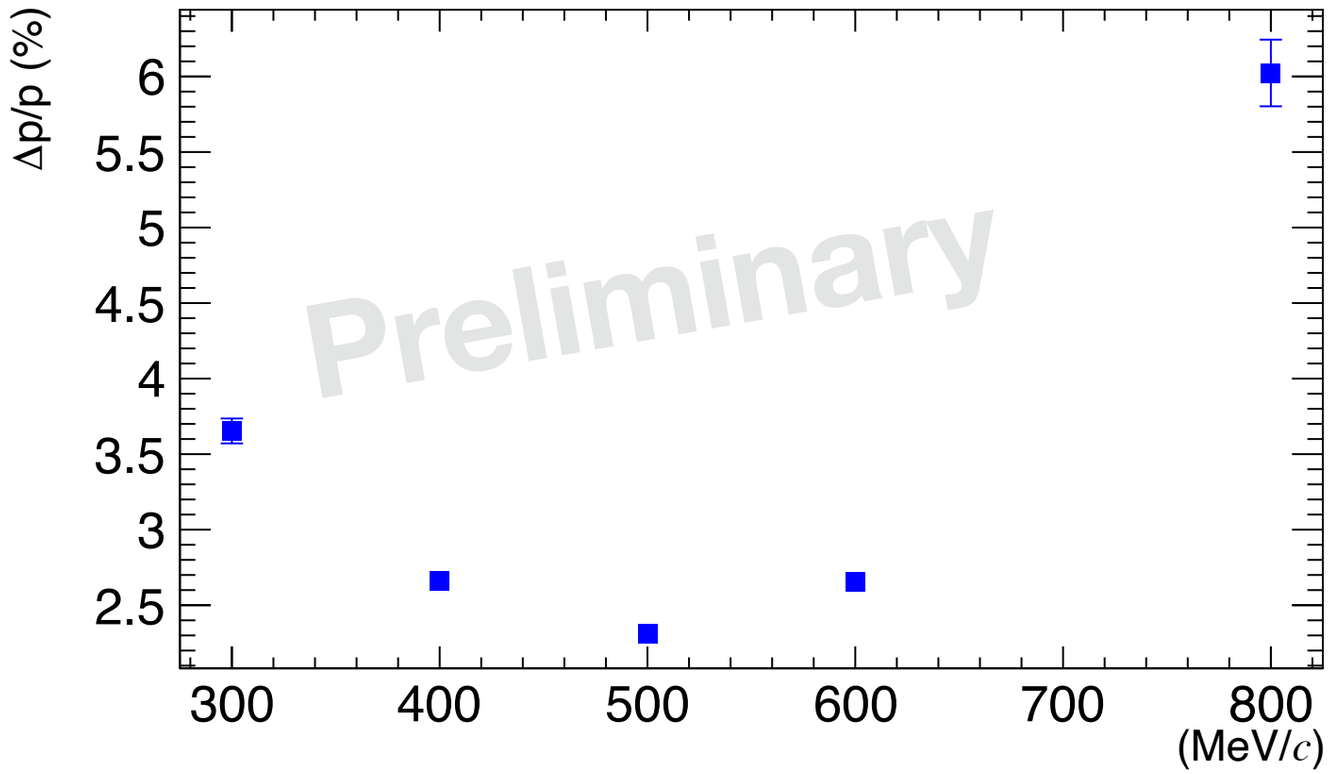


Spatial and Momentum Resolutions of HypTPC

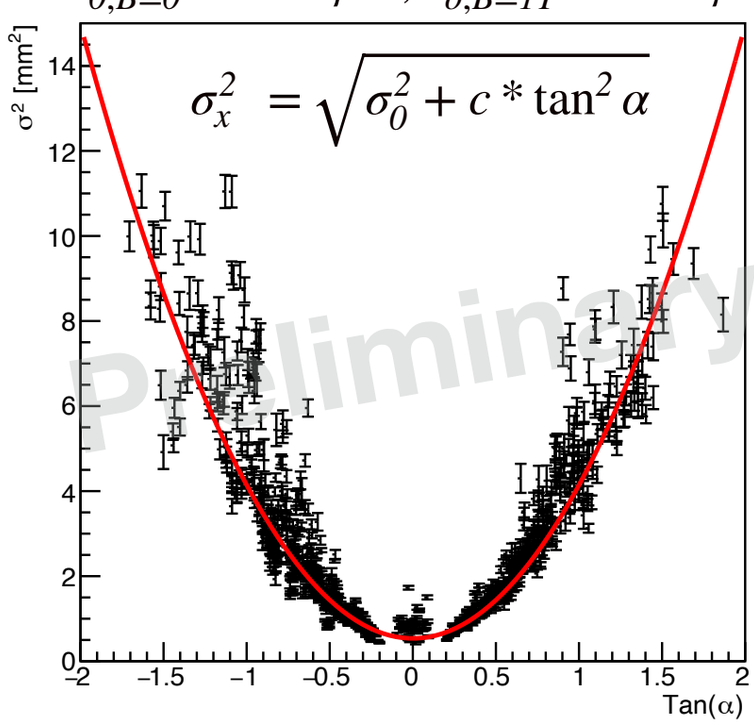
- Momentum resolution was measured with π^- beam-through data of various momenta
- Spatial resolution is parameterized with intrinsic and angular dependent terms.



Momentum resolution for π^-



$\sigma_{0,B=0} \sim 730\ \mu m, \sigma_{o,B=1T} \sim 370\ \mu m$



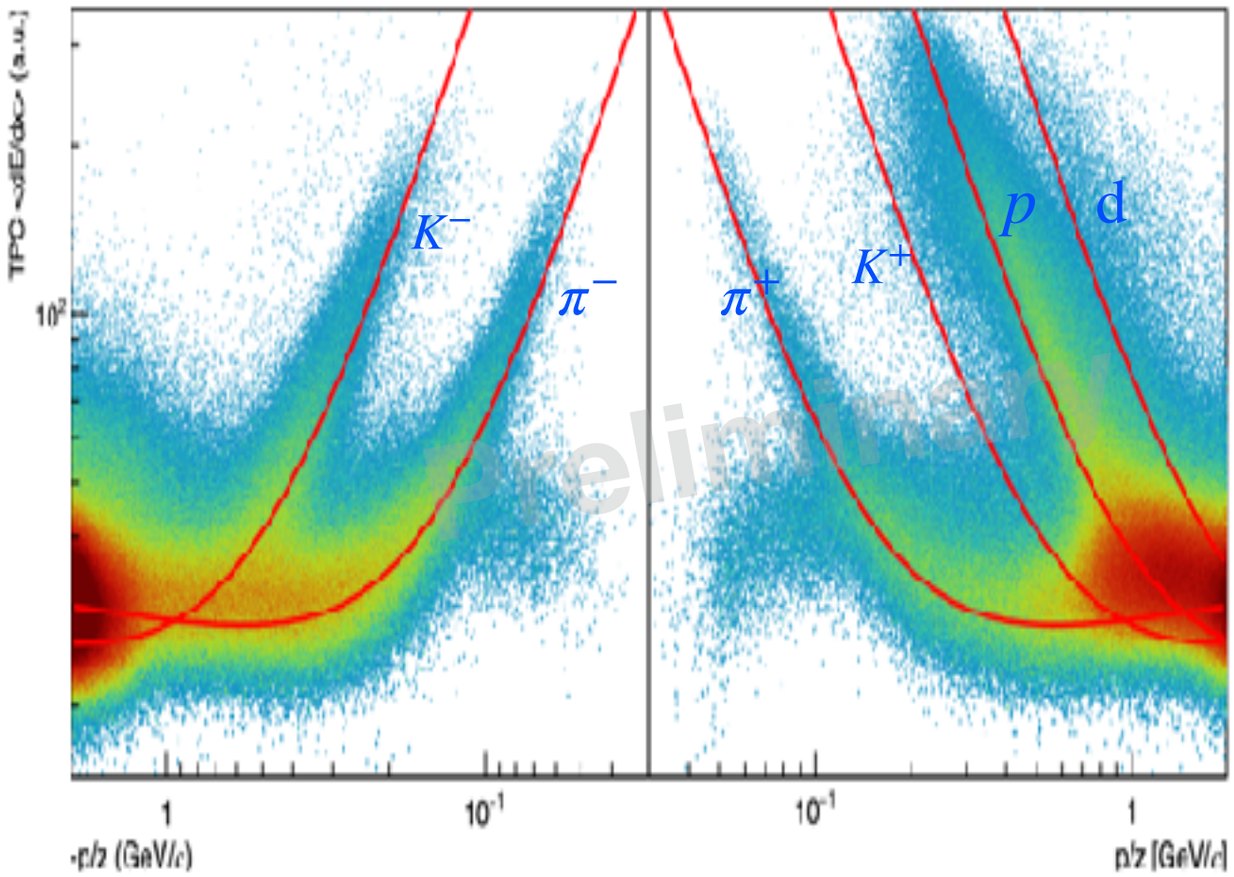
Particle Identification by Hyperon Spectrometer

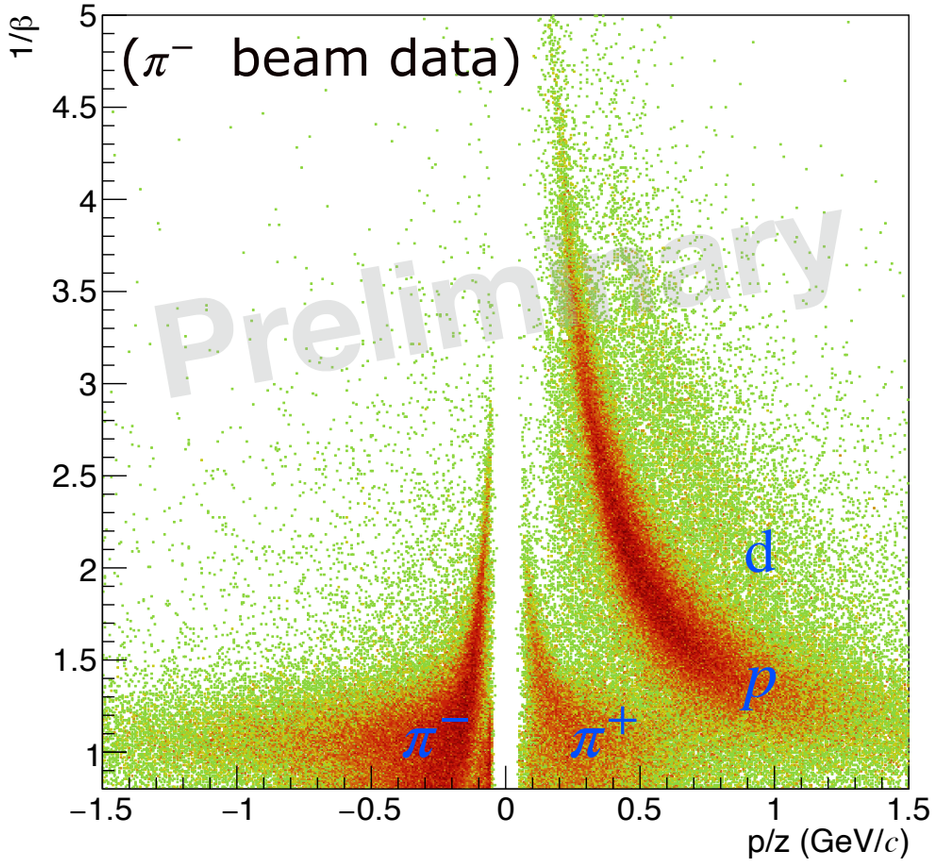
HypTPC dE/dx

- $< dE/dx >_{20\%\ truncated}\ vs\ p/z$ for reconstructed tracks of $^{12}C(K^-, K^+)$ reactions
- $\sigma_{<dE/dx>} / < dE/dx >$ ~ 20% for the range 0.40 < p_T < 0.45 GeV/c

HTOF Time-of-flight

- Flight length about 200 ~ 500 mm, σ_t ~ 120 ps for π^-





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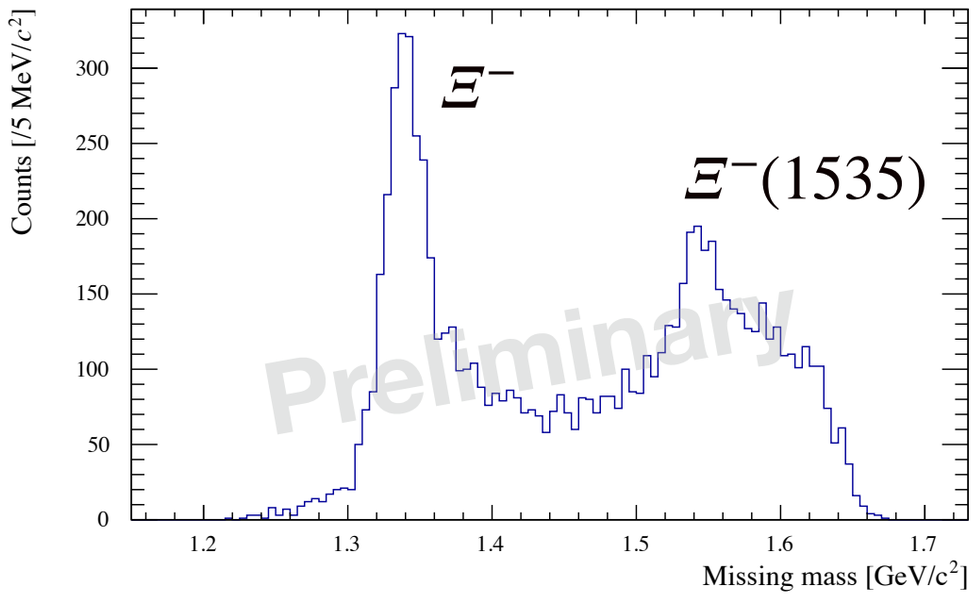
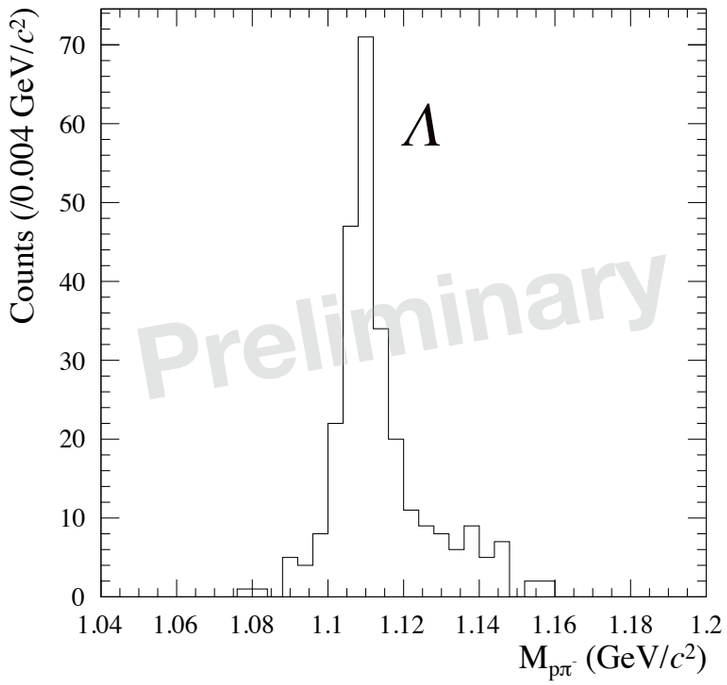
Preliminary Λ / Ξ^- reconstruction via the $\mathbf{CH_2}(K^-, K^+)X$ reaction

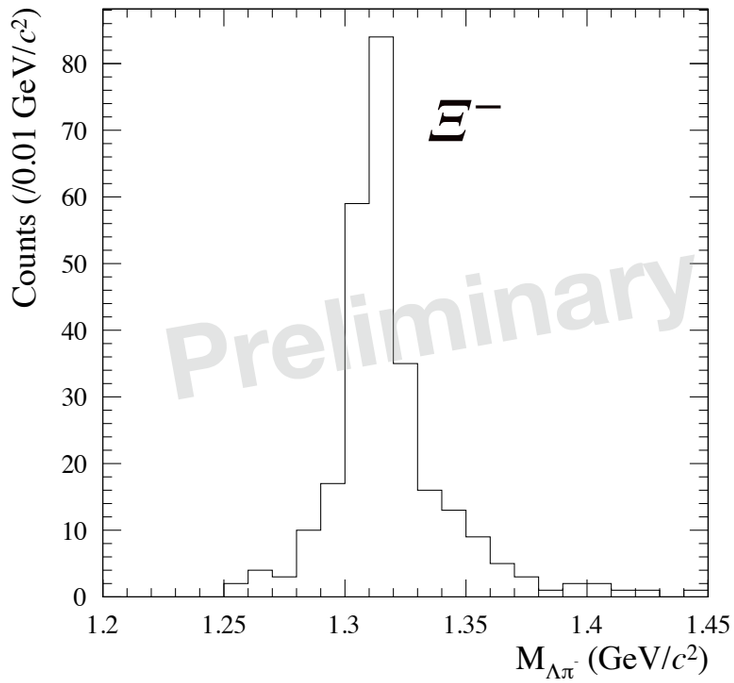
$\mathbf{CH_2}(K^-, K^+)X$ Missing-mass spectrum



- $\Xi^- \to \Lambda\pi^-$ decays are reconstructed by the HypTPC by requiring $|m_\Xi - M_X| < 0.2\ GeV/c^2$

Reconstructed invariant-mass





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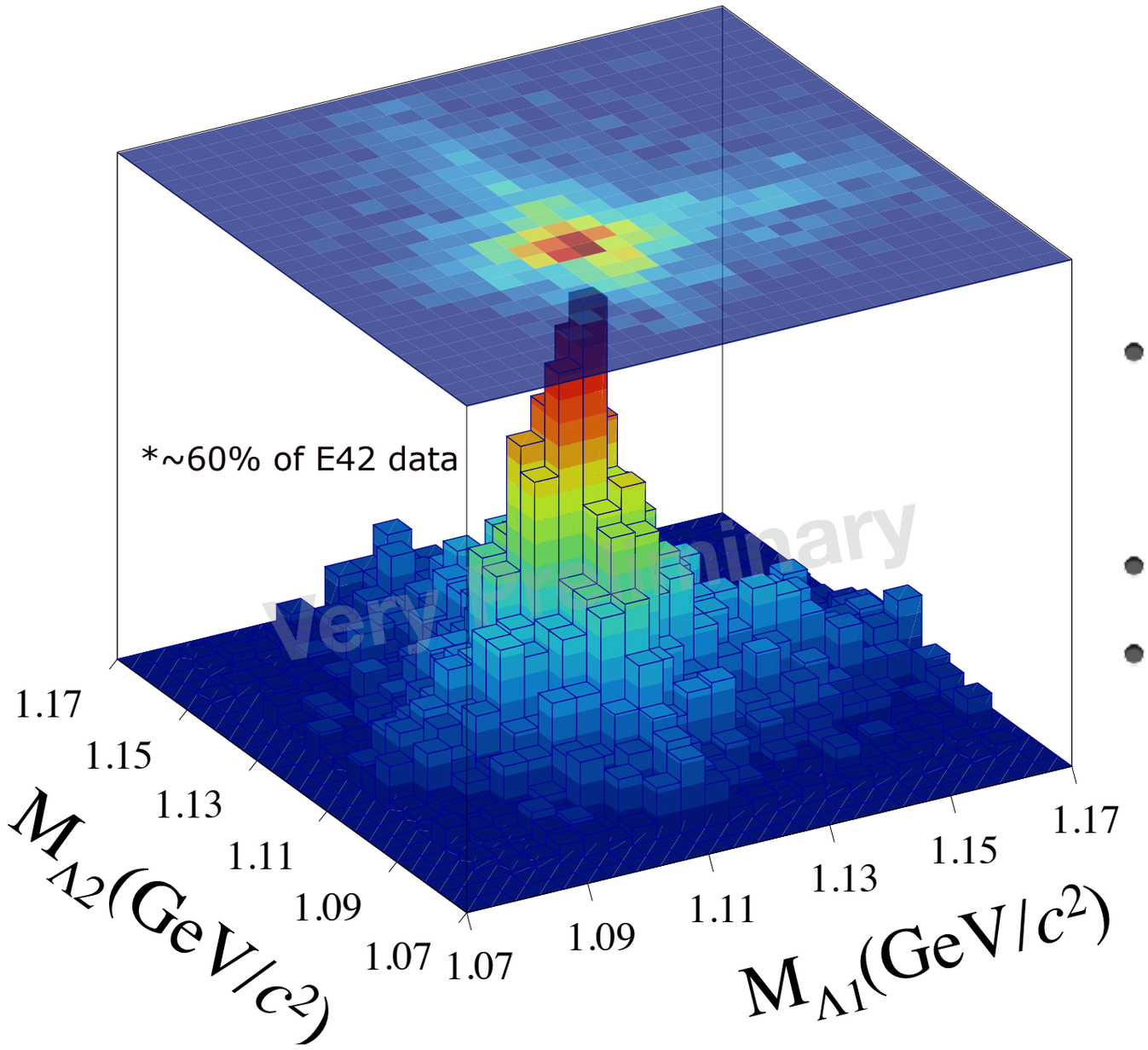
Expected Yield and Reconstructed $\Lambda\Lambda$ Production Events

Reconstructed Λ mass distribution for $\Lambda\Lambda$ production



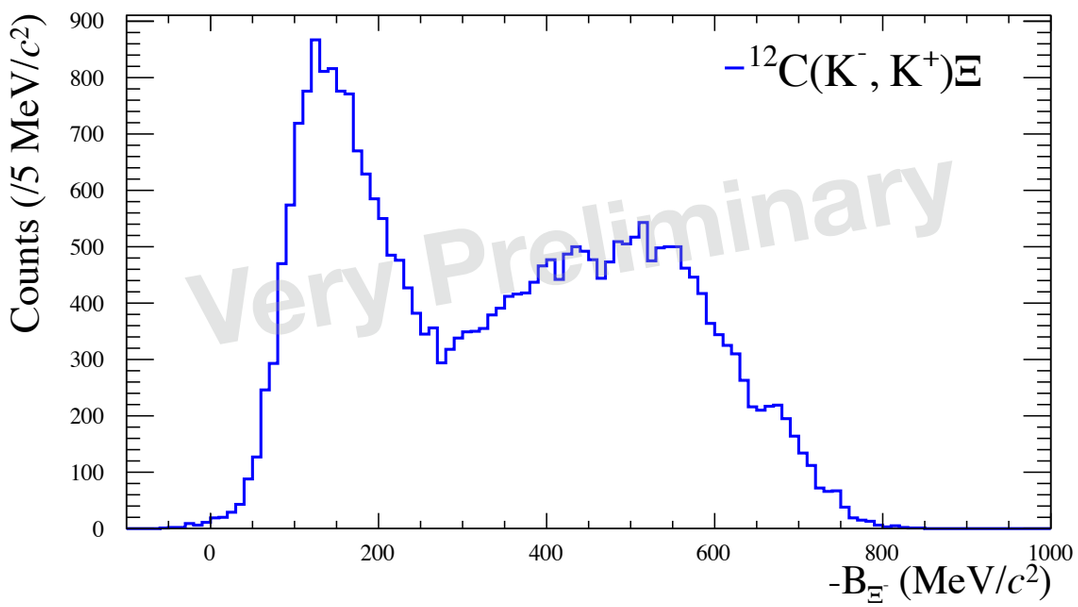
- 5,100 $\Lambda\Lambda$ events were expected with 10 μb/sr cross section for $^{12}\mathrm{C}(K^-, K^+\Lambda\Lambda)$ reactions. ($p_{K^+} > 0.5$ GeV/c)
- ~ 10,000 $\Lambda\Lambda$ events were reconstructed.
- Acceptance study is in-progress.

Exclusive Binding-energy Spectra for Ξ^- nucleus Potential Study

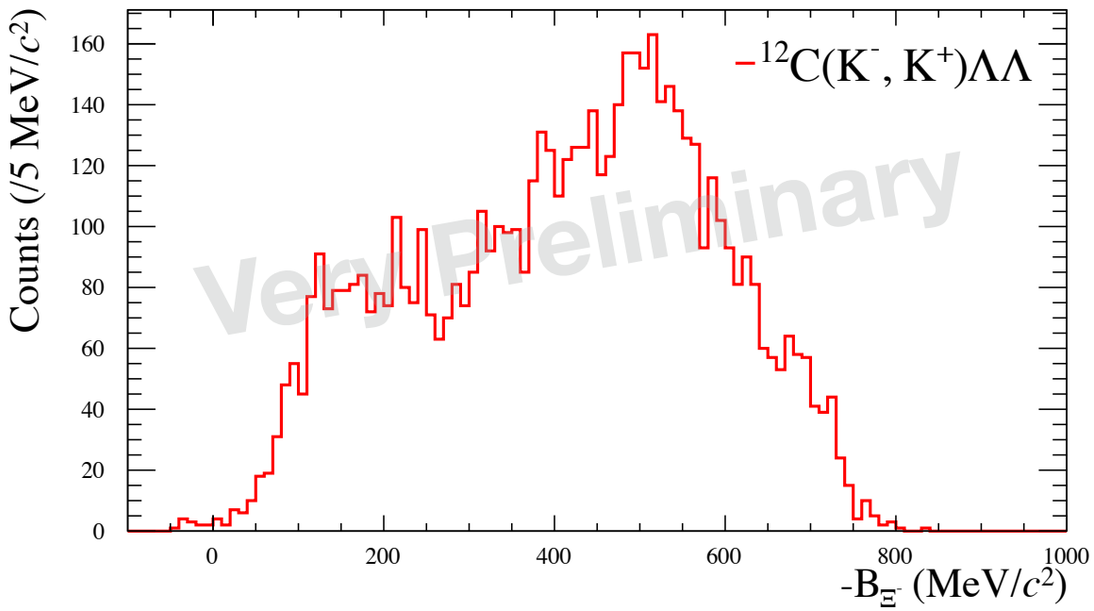
- $B_{\Xi^-} = \mathbf{M_X} - \mathbf{M}(\Xi^-) - \mathbf{M}(^{11}\mathbf{B})$ where $\mathbf{M_X}$:$^{12}\mathbf{C}(K^-, K^+)\mathbf{X}$
- Inclusive binding energy spectrum is decomposed into Ξ^-escaping and conversion spectra.
- Sensitive to determine $W_{0\Xi}$ parameter

*~60% of E42 data

Ξ^- escaping process



$\Xi^- p \rightarrow \Lambda\Lambda$ conversion process



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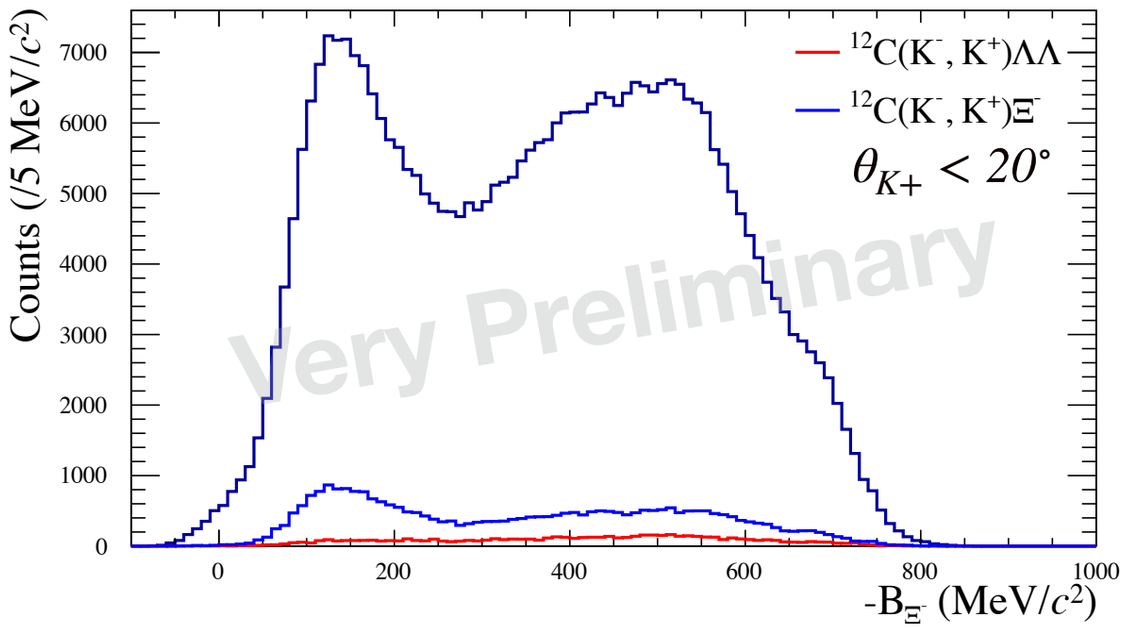
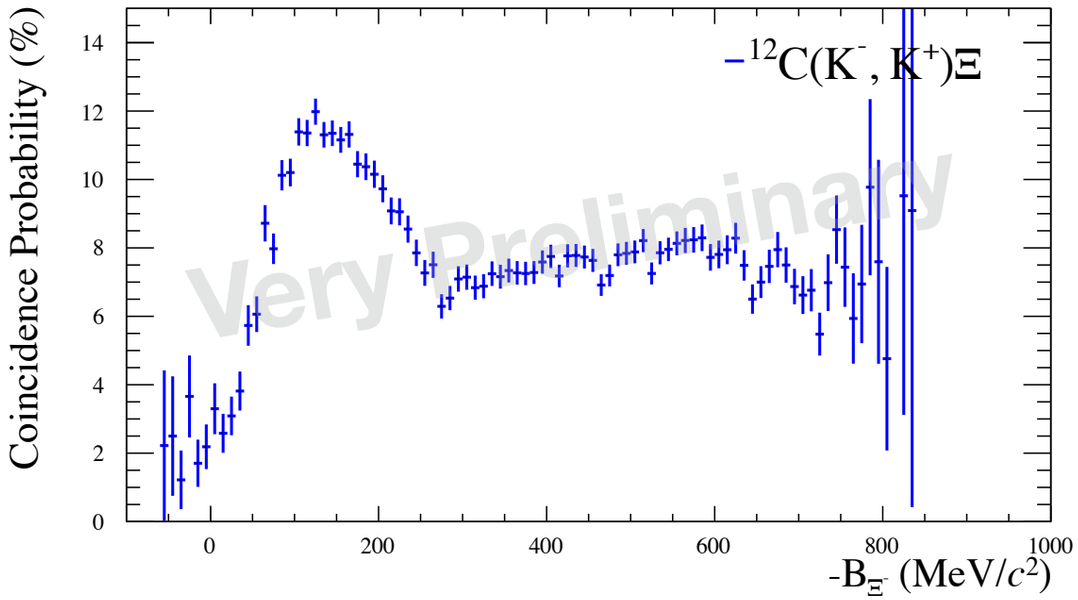
Exclusive Binding-energy Spectra for Ξ^- nucleus Potential Study

- Coincidence probability = N(coin.)/N(Inclusive)
- Acceptance study is in-progress

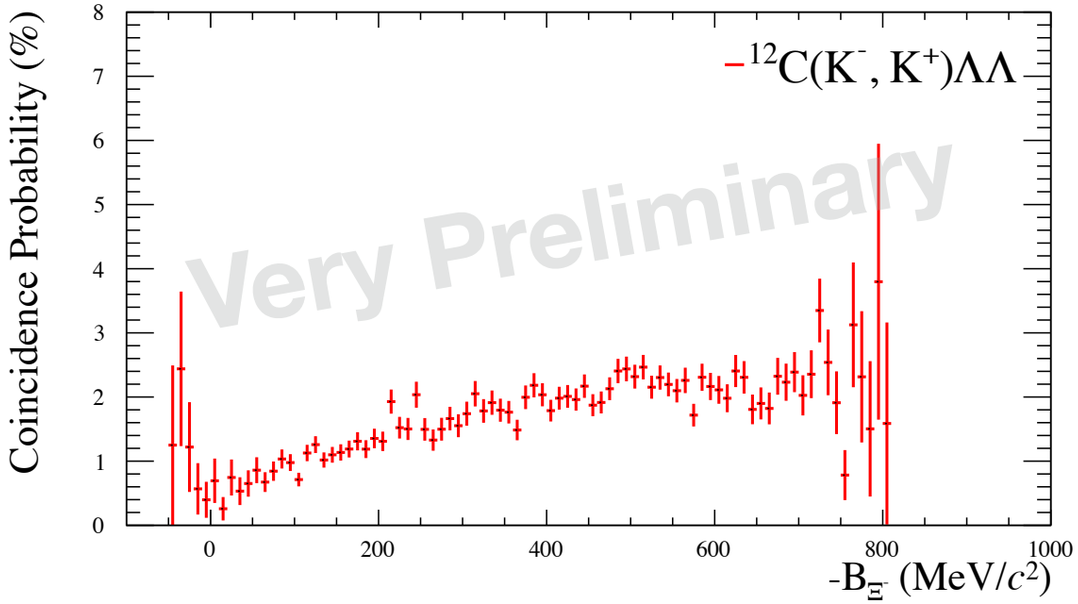
*~60% of E42 data



Ξ^- escaping process



$\Xi^- p \to \Lambda\Lambda$ conversion process



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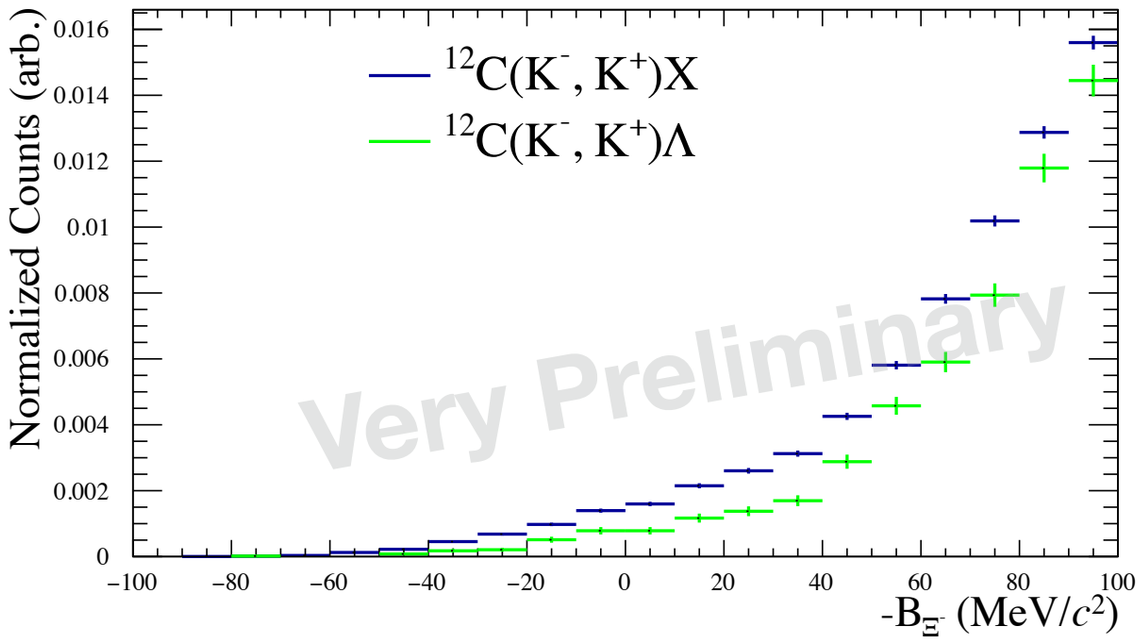
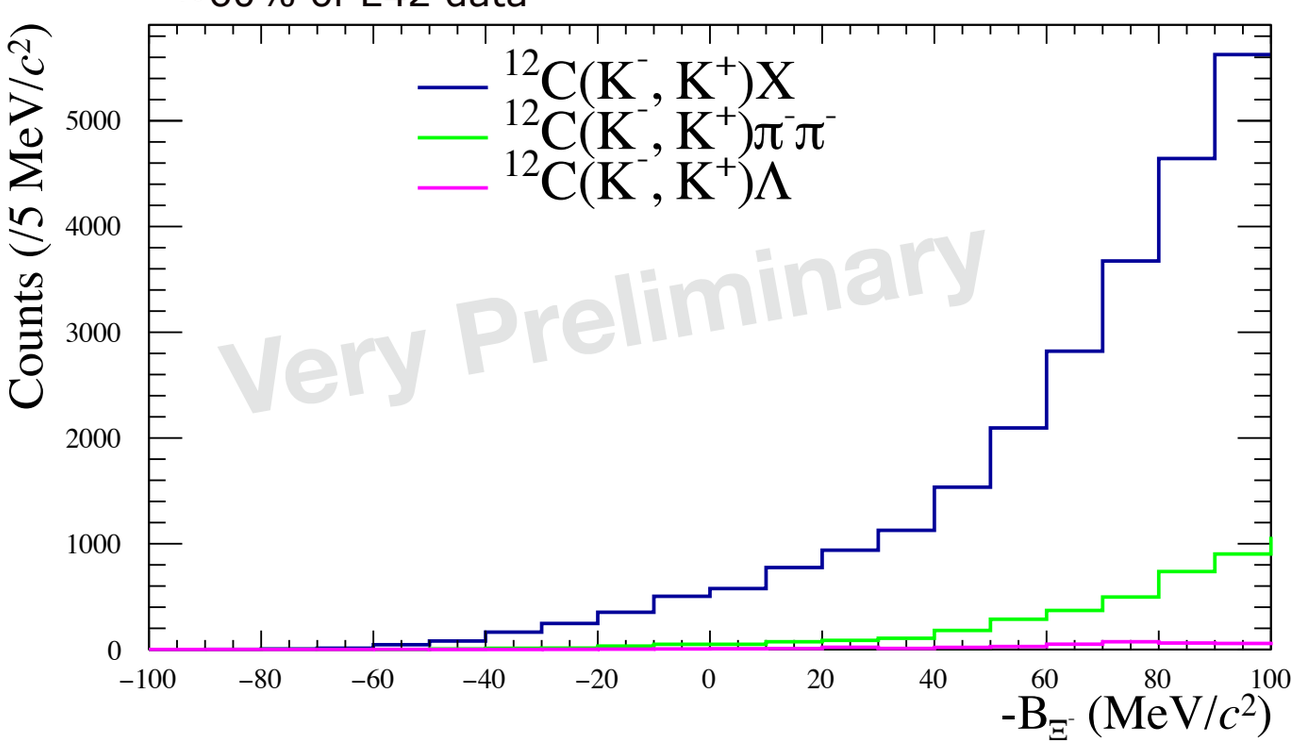
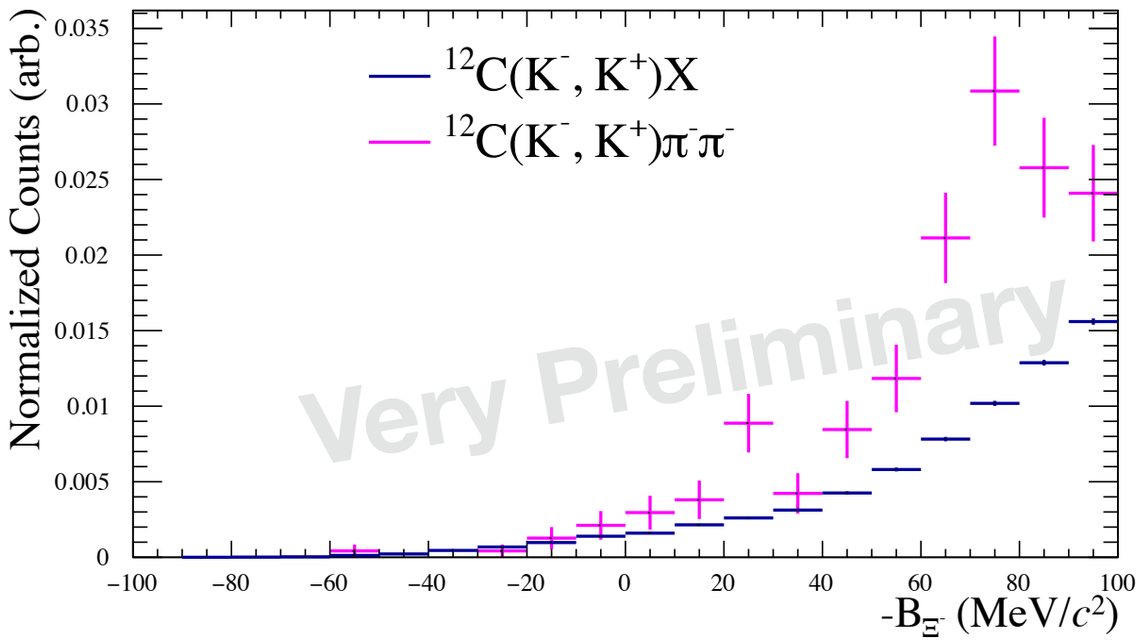
Exclusive Binding-energy Spectra for Double Λ hyper-nucleus Study

- Spectra for an observation of pions produced in sequential mesonic weak decay / Λ emission (ΛΛ, Ξ^- events are excluded)
- Background: escaping $\Xi^- \to \Lambda\pi^-, \Lambda \to p\pi^-$ and the stopped p in the target.



*~60% of E42 data





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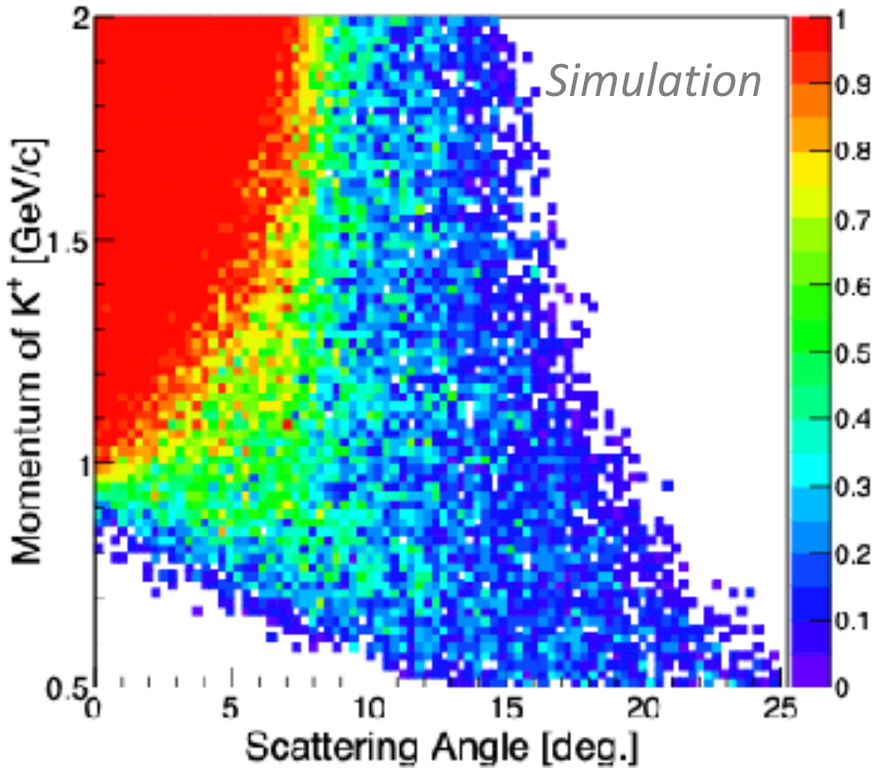
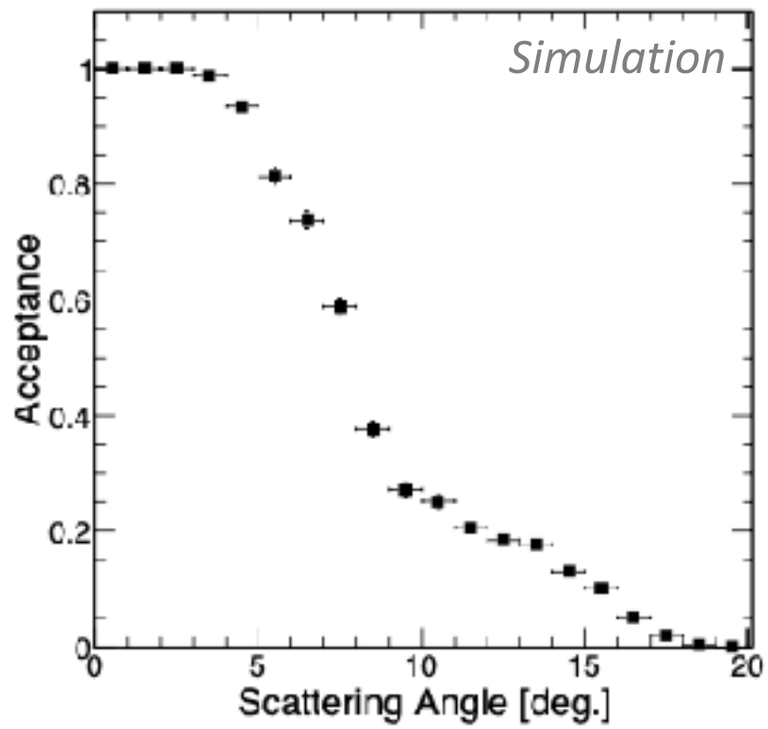
Summary

- J-PARC E42 is searching the H-dibaryon via $^{12}\mathrm{C}(K^-, K^+)$ reaction. We collected approximately 0.3M (K^-, K^+) reaction events.
- E42 would be a first measurement of all charged decays from $^{12}\mathrm{C}(K^-, K^+)X$ reaction with high statistics.
- E42 can decompose $\Xi^- p \to \Lambda\Lambda$ conversion spectrum from the $^{12}\mathrm{C}(K^-, K^+)X$ inclusive missing-mass spectrum. So E42 has high sensitivity for $W_{0\Xi}$ determination.
- E42 data analysis is on-going. We will soon be showing finalize results.

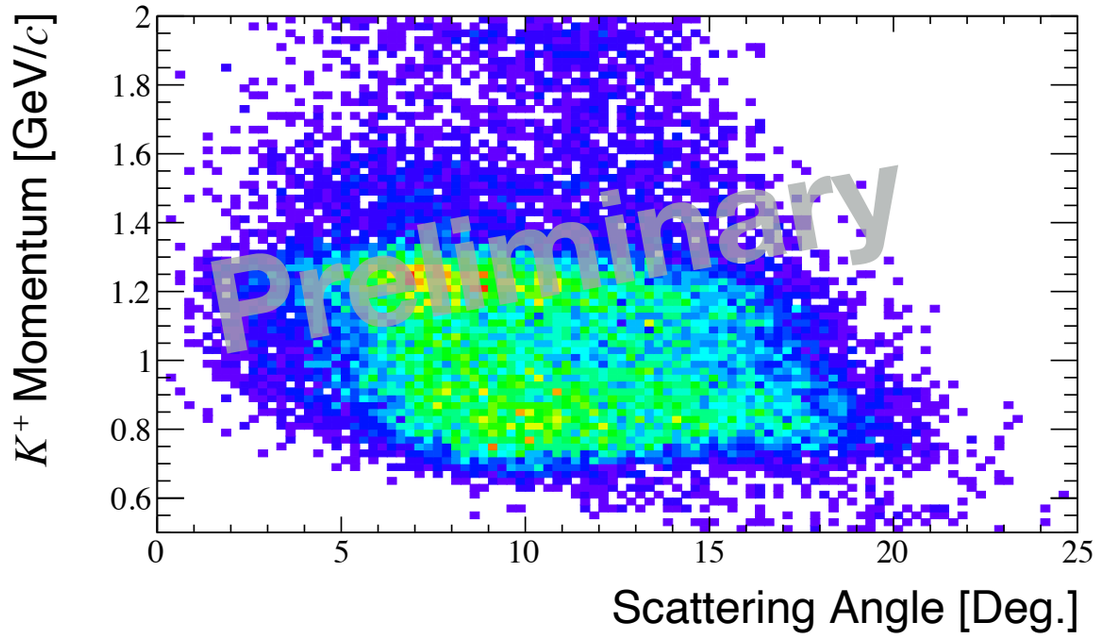
Backup

E42 Spectrometer Acceptance



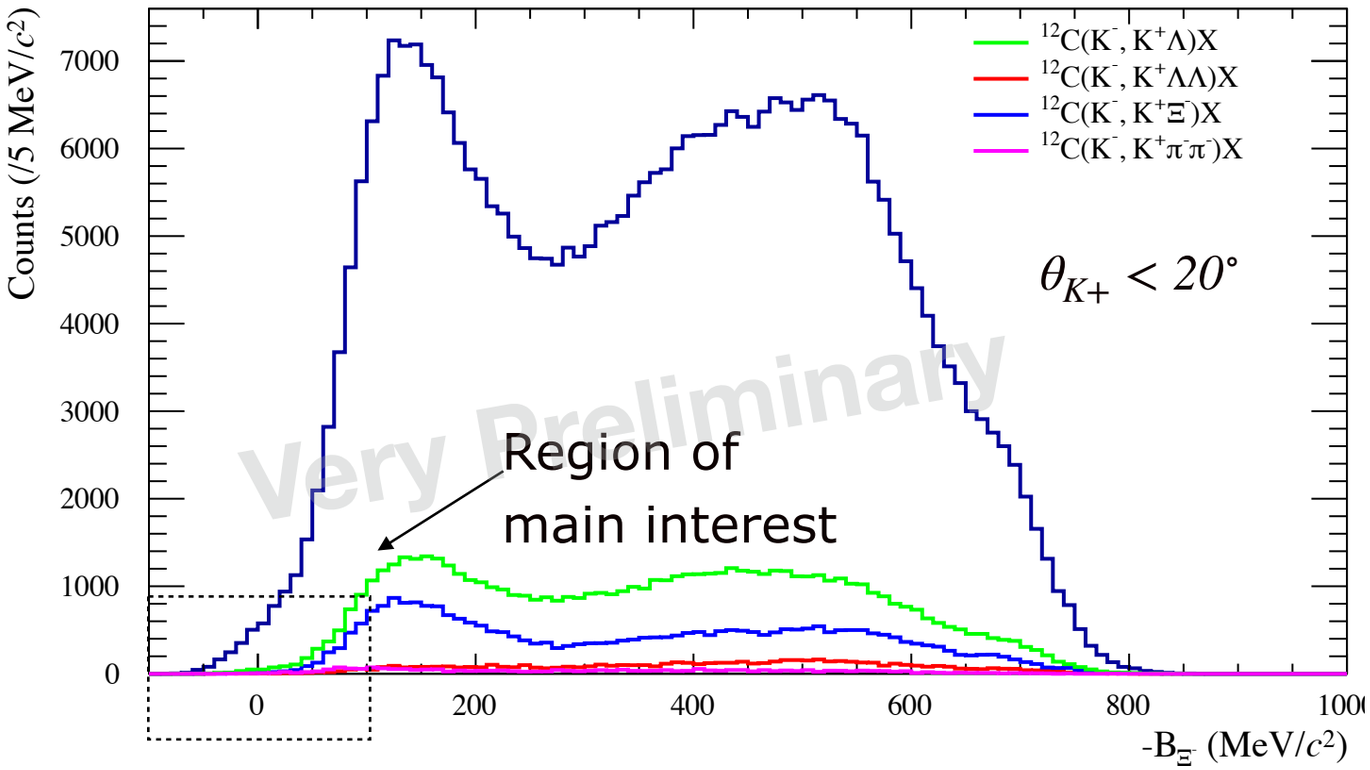


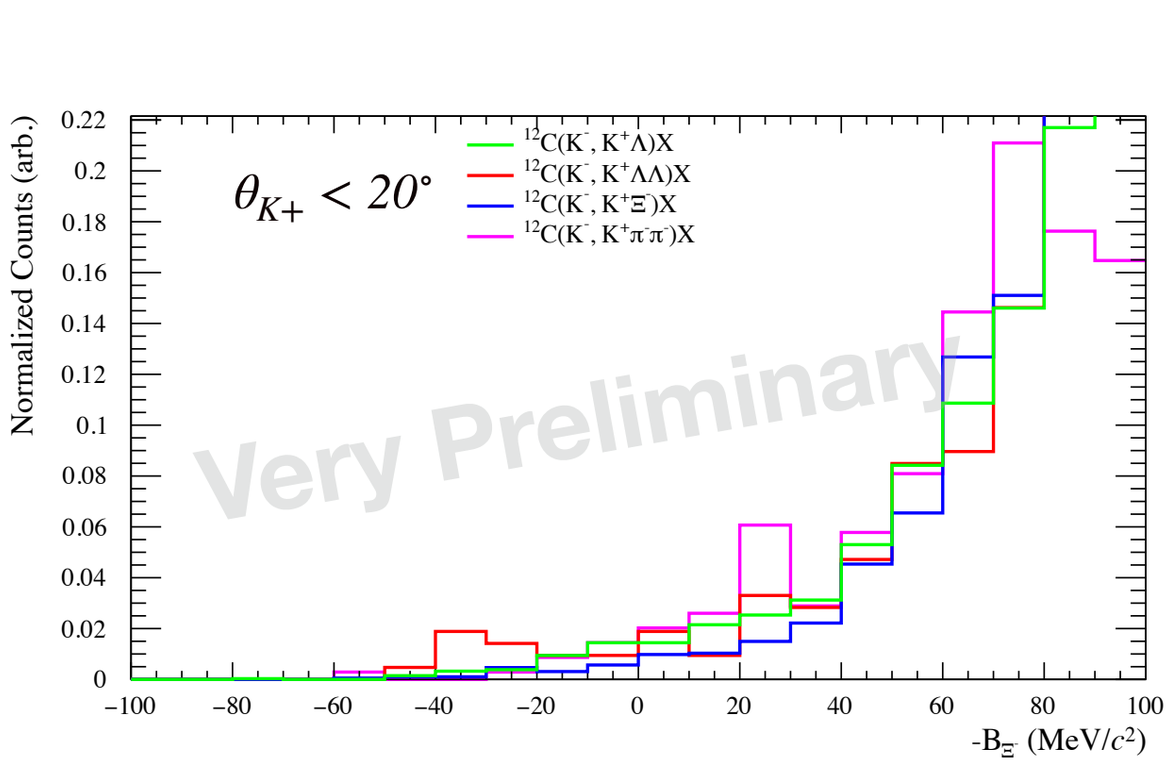
- $\Delta\Omega(K^+) = 0.09$ sr
- $0.5\ \mathrm{GeV}/c < \mathrm{p}_{K^+}$



Preliminary Binding-energy Spectra Relative to Ξ^-+^{11}B system

- $B_{\Xi^-} = \mathbf{M_X} - \mathbf{M}(\Xi^-) - \mathbf{M}(^{11}\mathbf{B})$ where $\mathbf{M_X}$:$^{12}\mathbf{C}(K^-, K^+)\mathbf{X}$
- Inclusive spectrum decomposed into each reaction.





Preliminary Normalized Spectra of $^{12}\mathrm{C}(K^-, K^+)$ reactions