

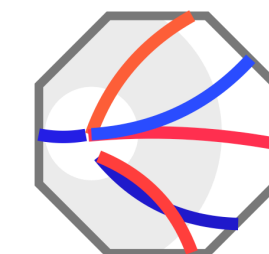
The 29th
International
Nuclear
Physics
Conference

May 25-30, 2025
DCC, Daejeon, Korea



H-dibaryon Search Near The $\Lambda\Lambda$ and E^-p Thresholds

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for the J-PARC E42 Collaboration



J-PARC
HypTPC
Collaboration

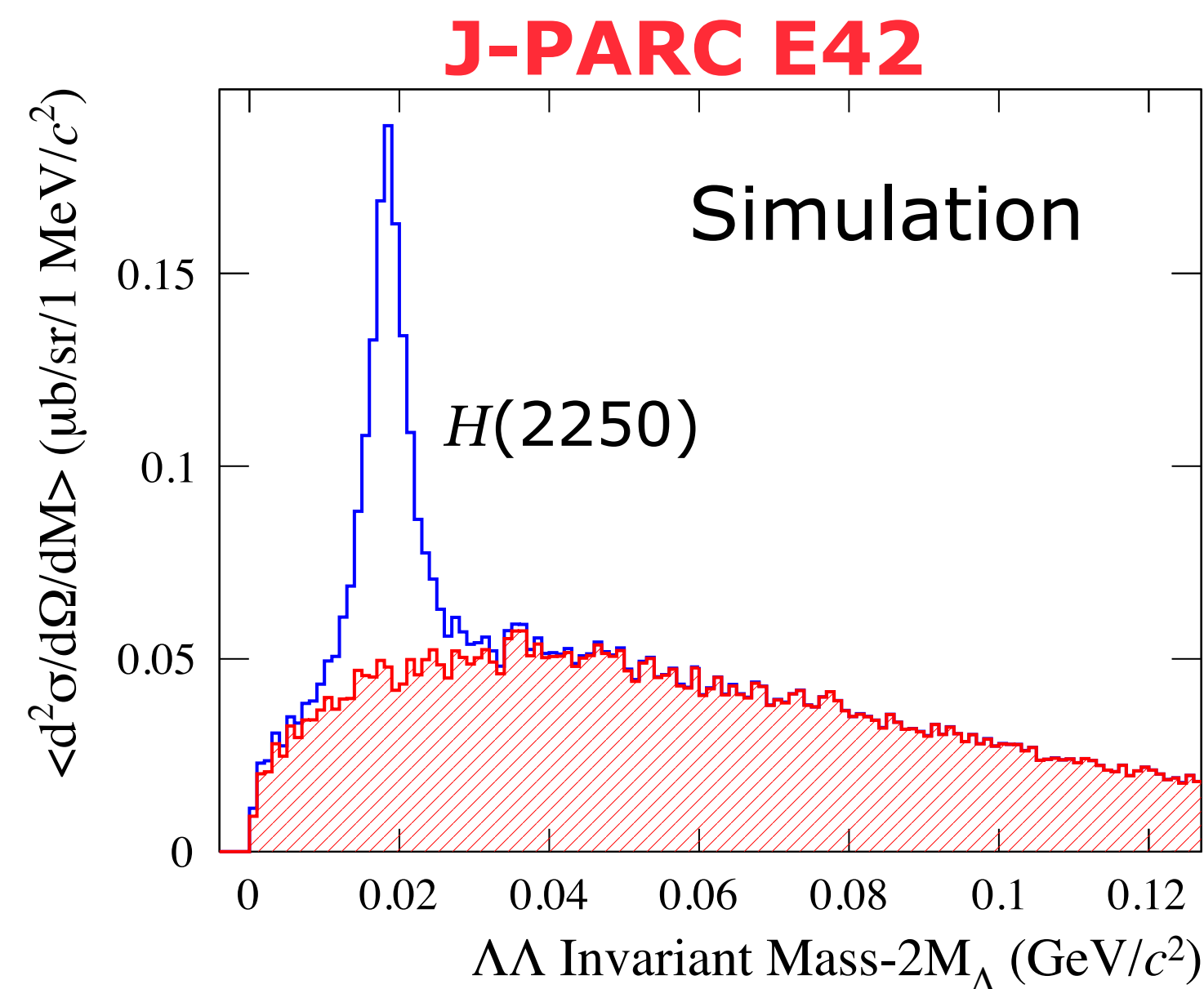
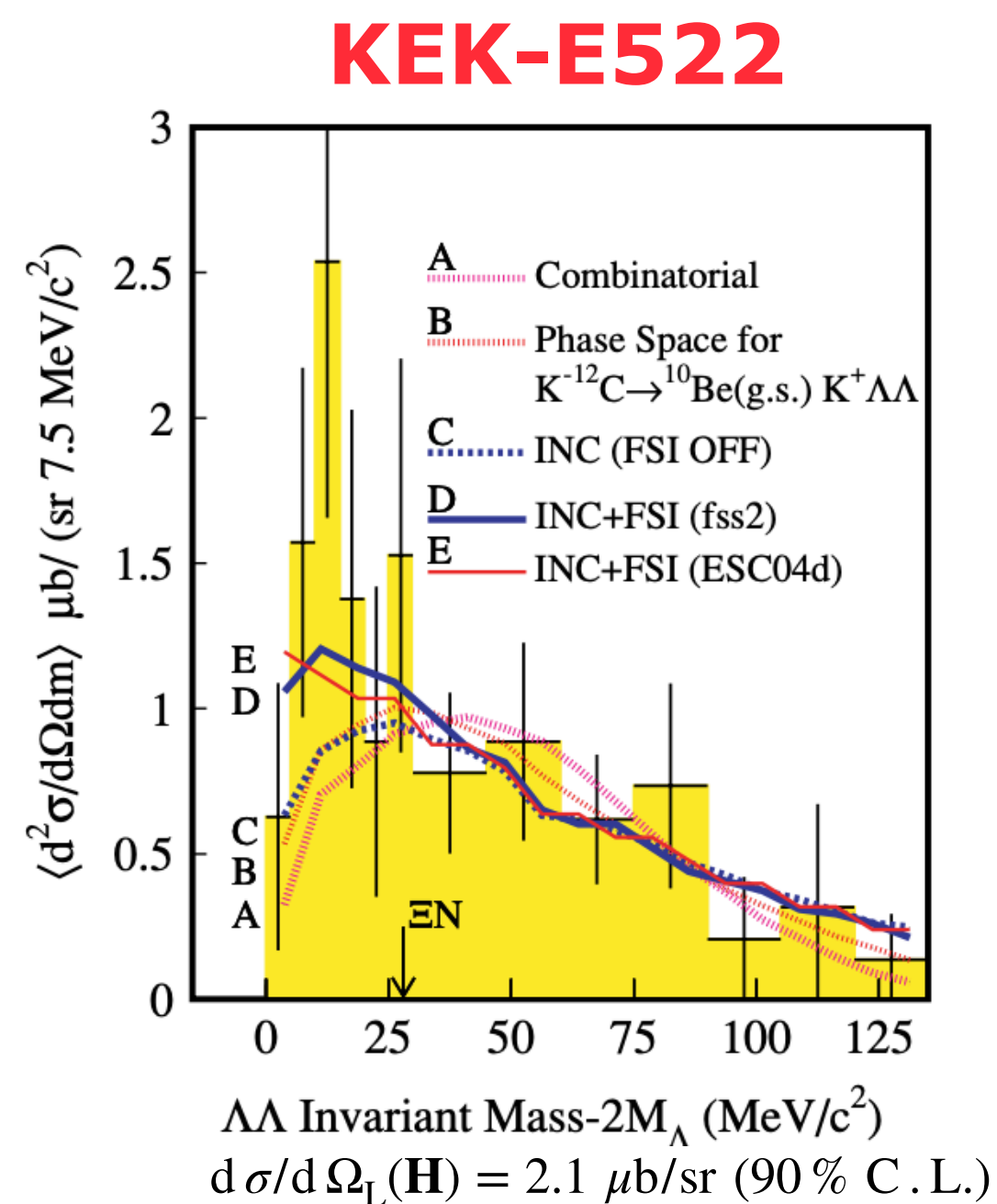
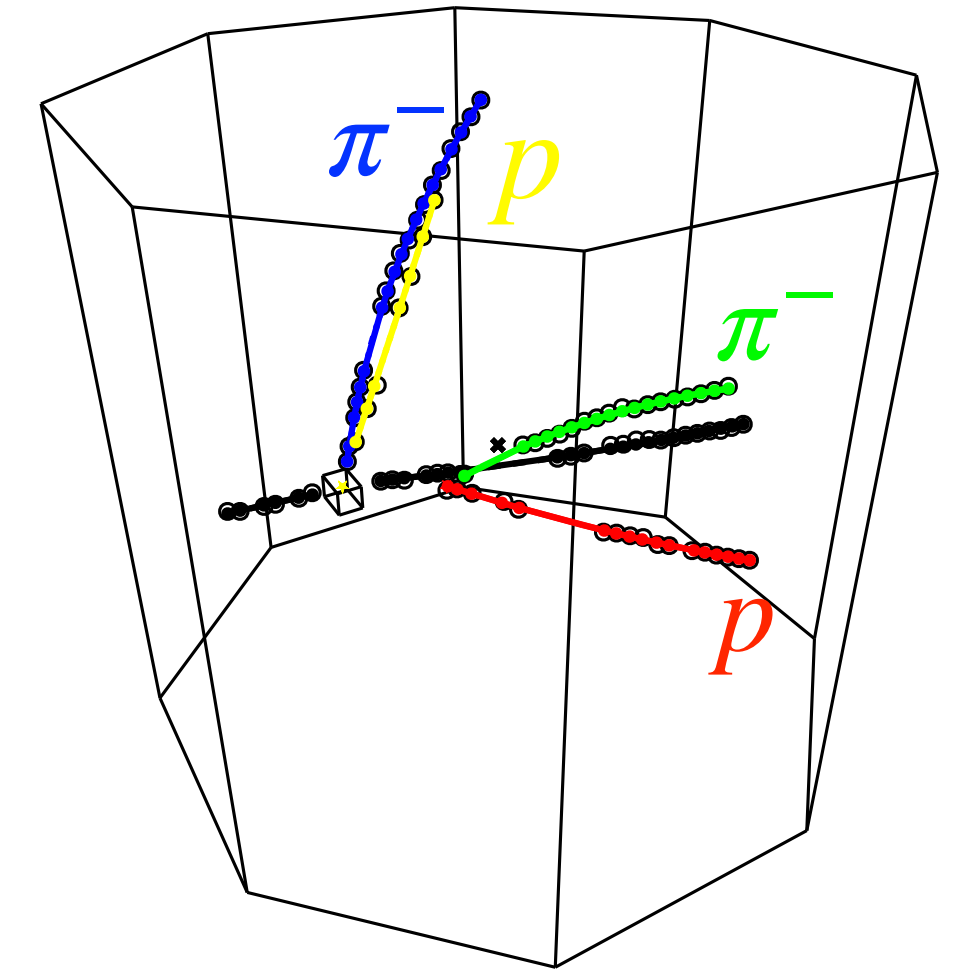


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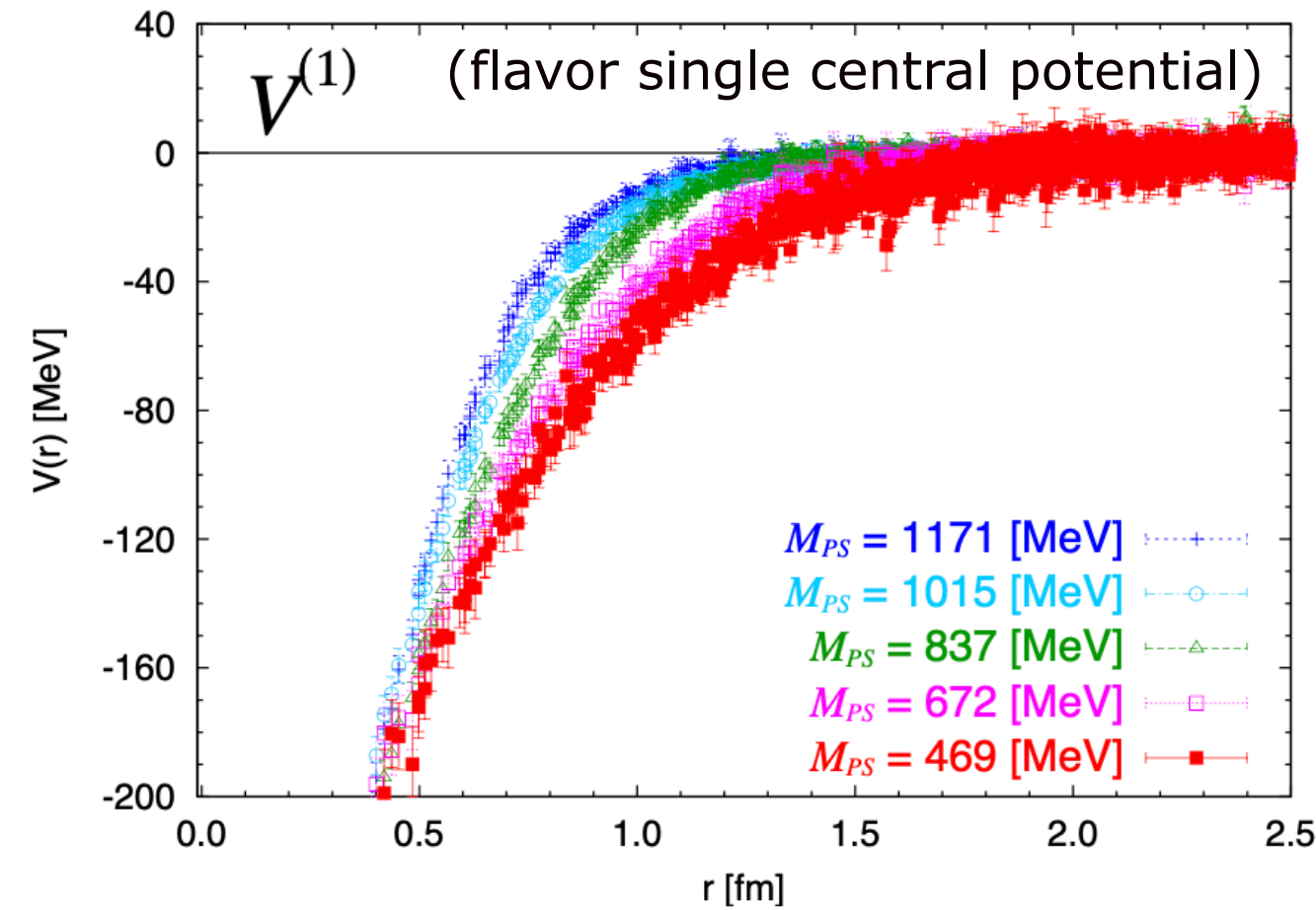
J-PARC E42: H-dibaryon search via $^{12}\text{C}(K^-, K^+)$ reaction

- H-dibaryon: SU(3) flavor-singlet dibaryon consisting of uuddss
- Invariant-mass measurement of $\Lambda\Lambda$ and E^-p systems with HypTPC
- Measurement of all charged decays from $^{12}\text{C}(K^-, K^+)X$ reaction with high statistics. (300K (K^-, K^+) data)

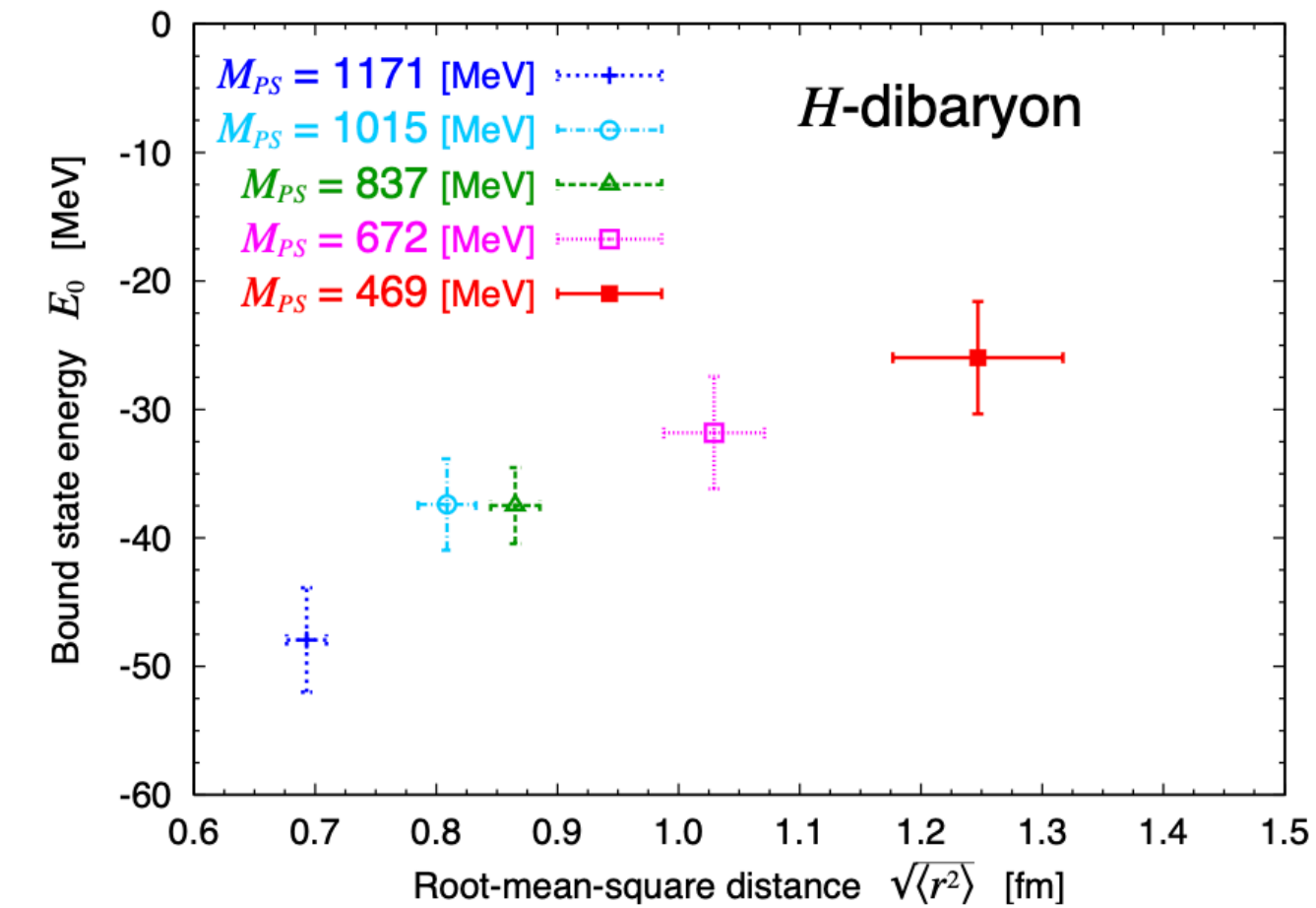


Recent Lattice QCD Calculation Results

- HAL QCD group calculation with $SU(3)_f$ symmetry

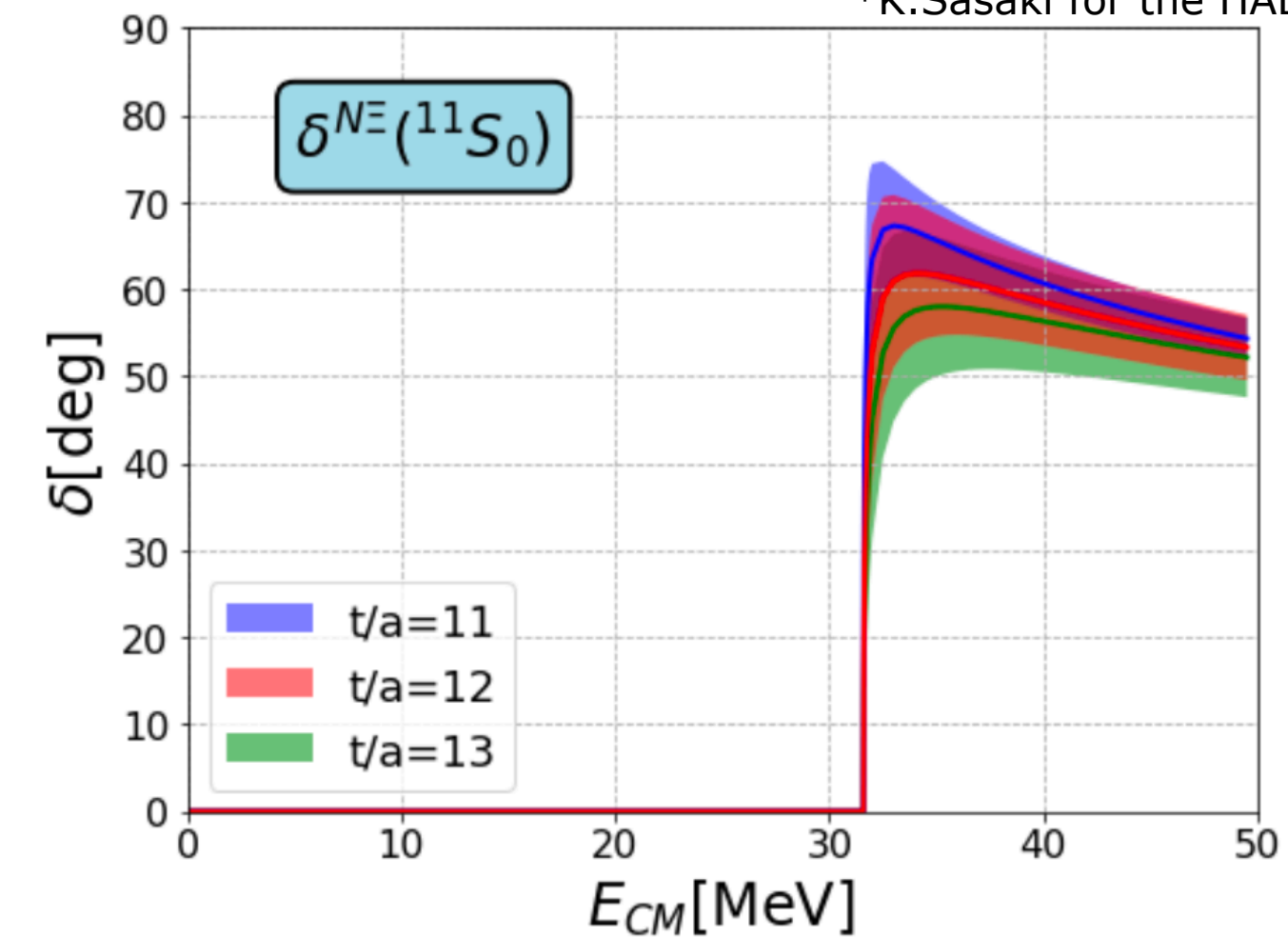
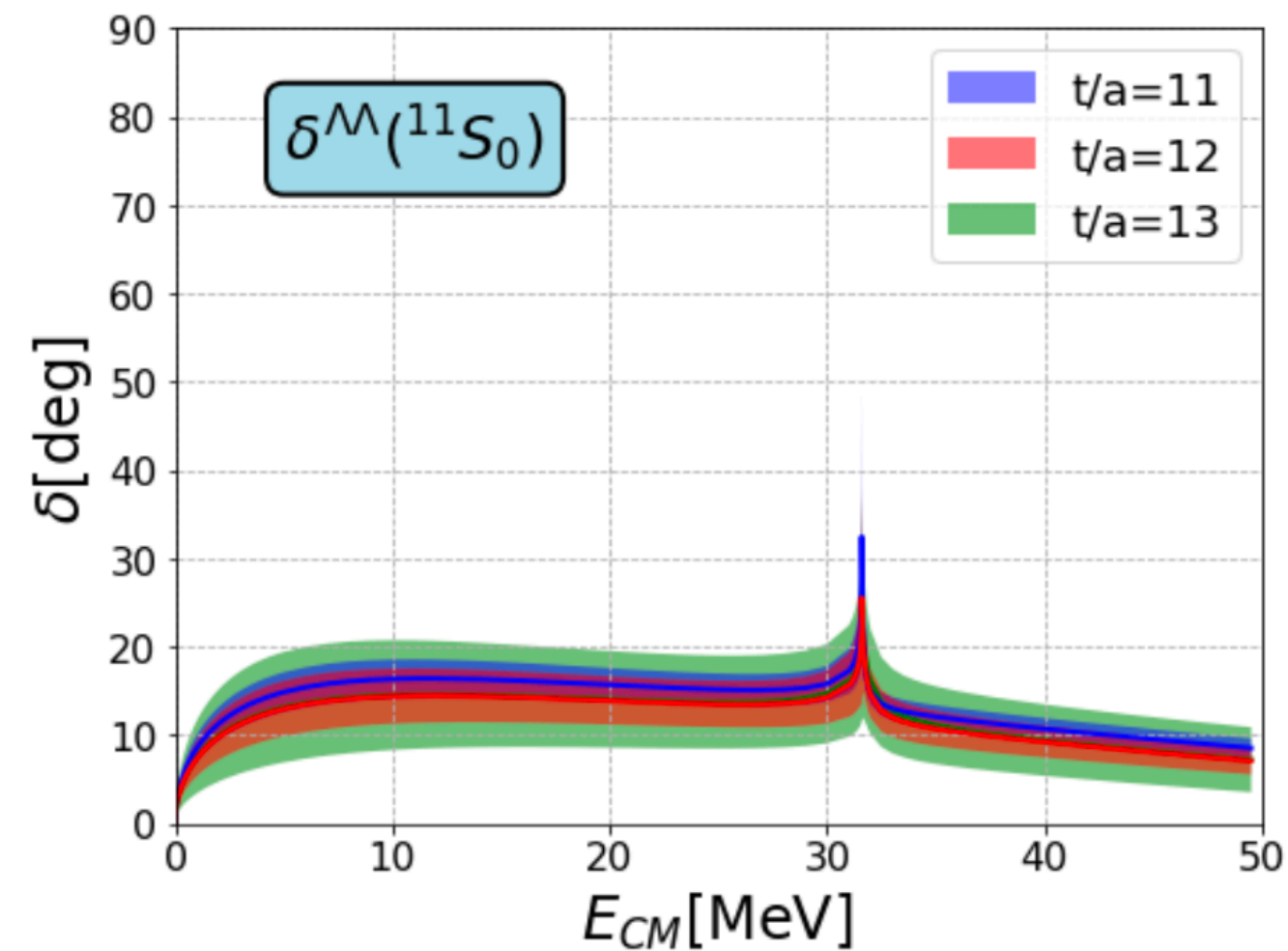


*T. Inoue for HALCollab, NPA 881 (2012) 28-43



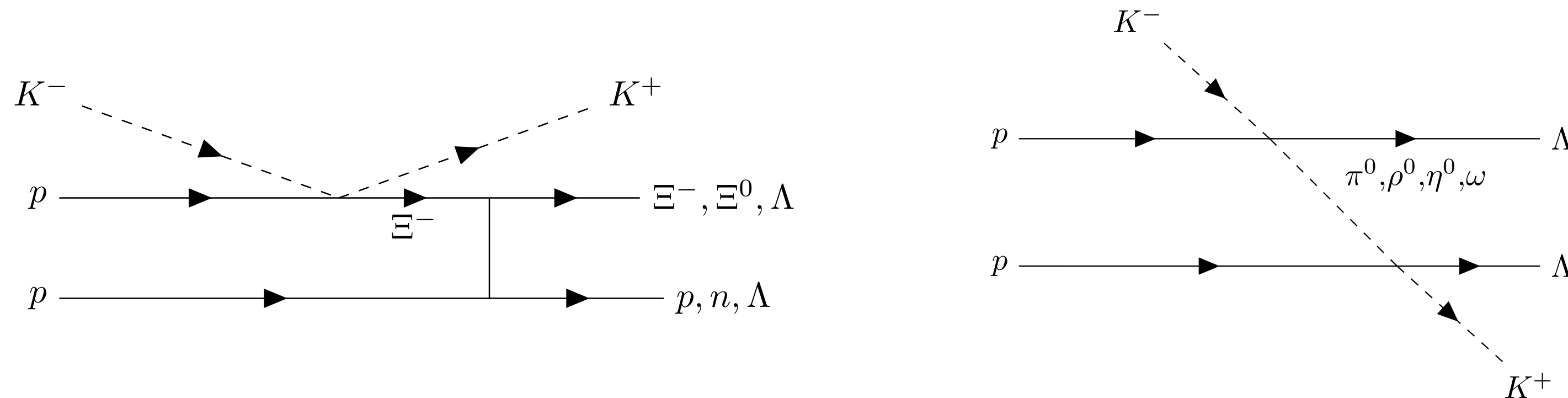
- Coupled channel ($\Lambda\Lambda$, ΞN) analysis with the flavor $SU(3)$ breaking ($n_f = 2+1$, $m_\pi \approx 146$ MeV)

*K.Sasaki for the HALCollab., NPA 998 (2020) 121737



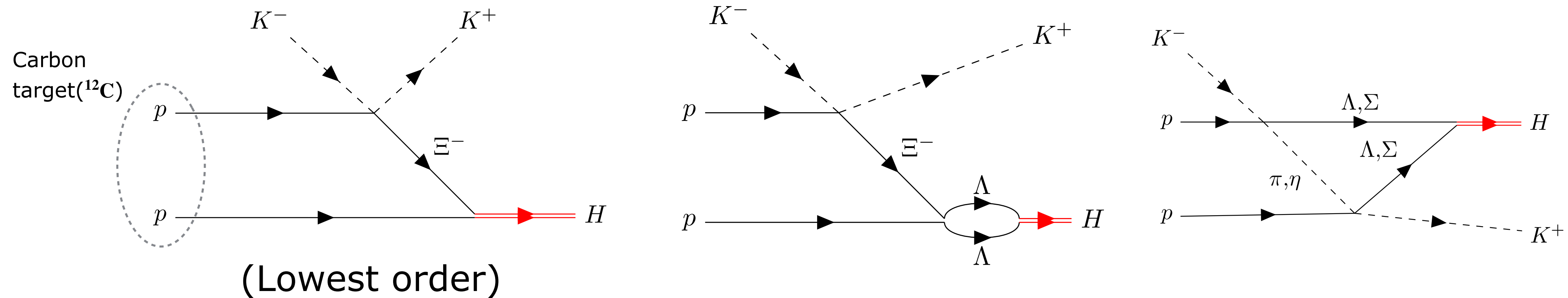
Possible H-dibaryon Formation via the $^{12}\text{C}(K^-, K^+)$ Reaction

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



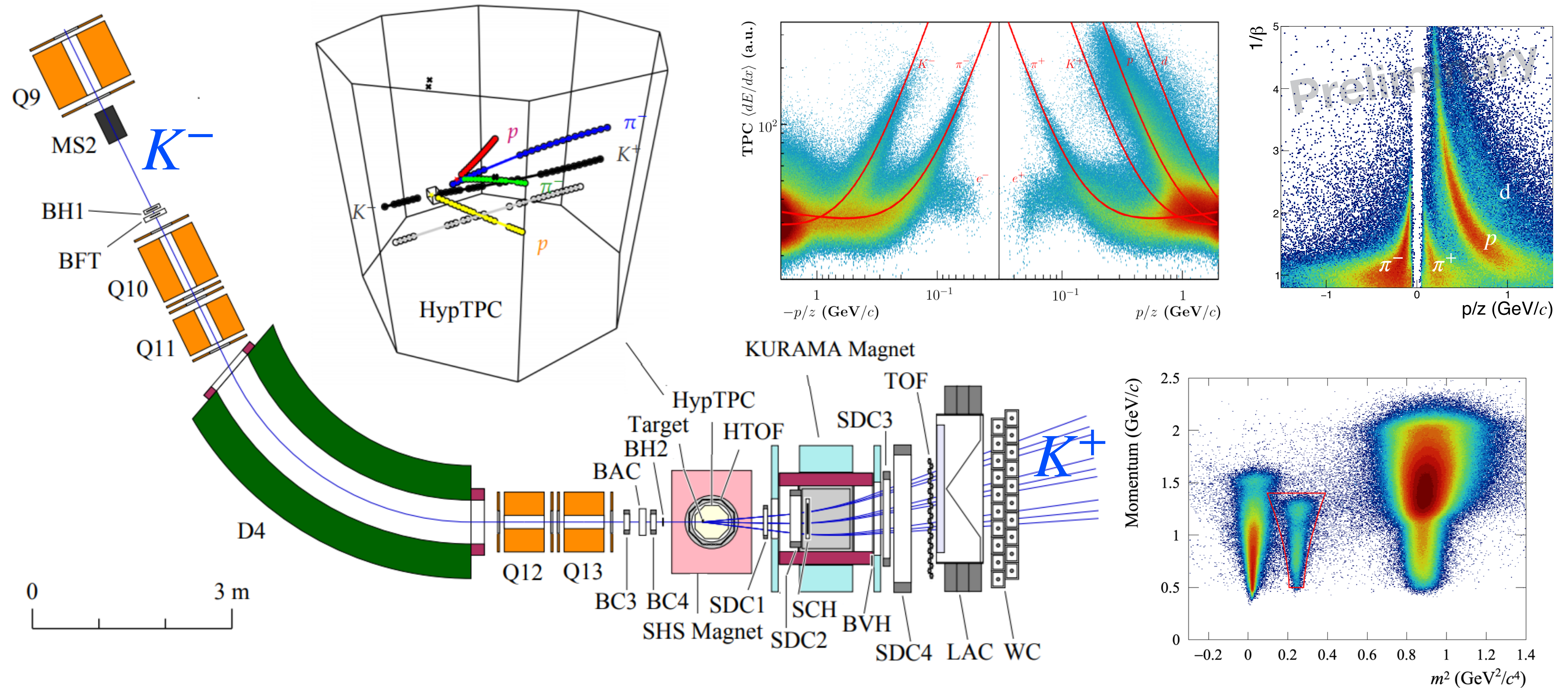
- Possible H production processes on a diproton pair via (K^-, K^+) reaction

*A.T.M. Hertz and C.B. Dover, Phys. Rev. D28, 450 (1983)



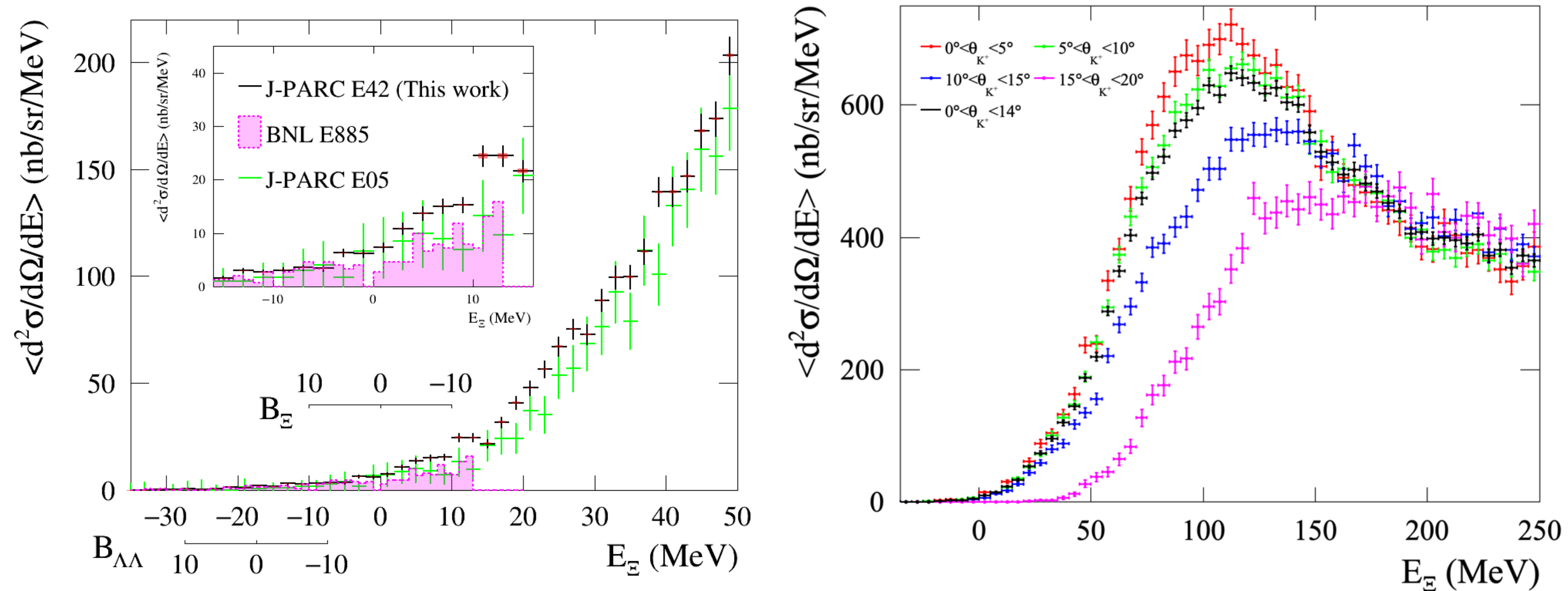
$\Xi N/\Lambda\Lambda$ interactions have a significant role in H-dibaryon formation

J-PARC E42 Detector and Particle Identification



Differential Cross-sections for $^{12}\text{C}(K^-, K^+)X$ Reaction

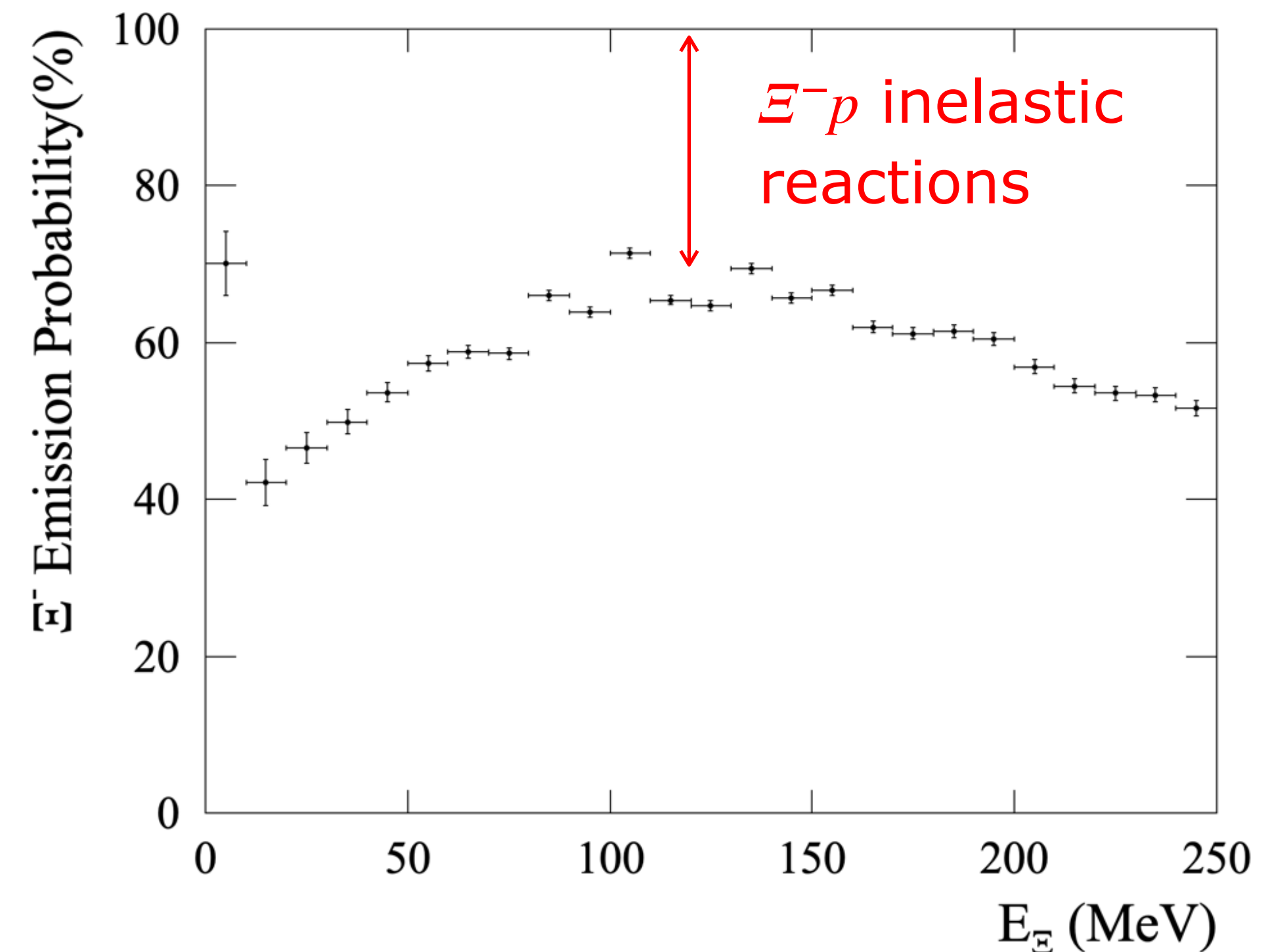
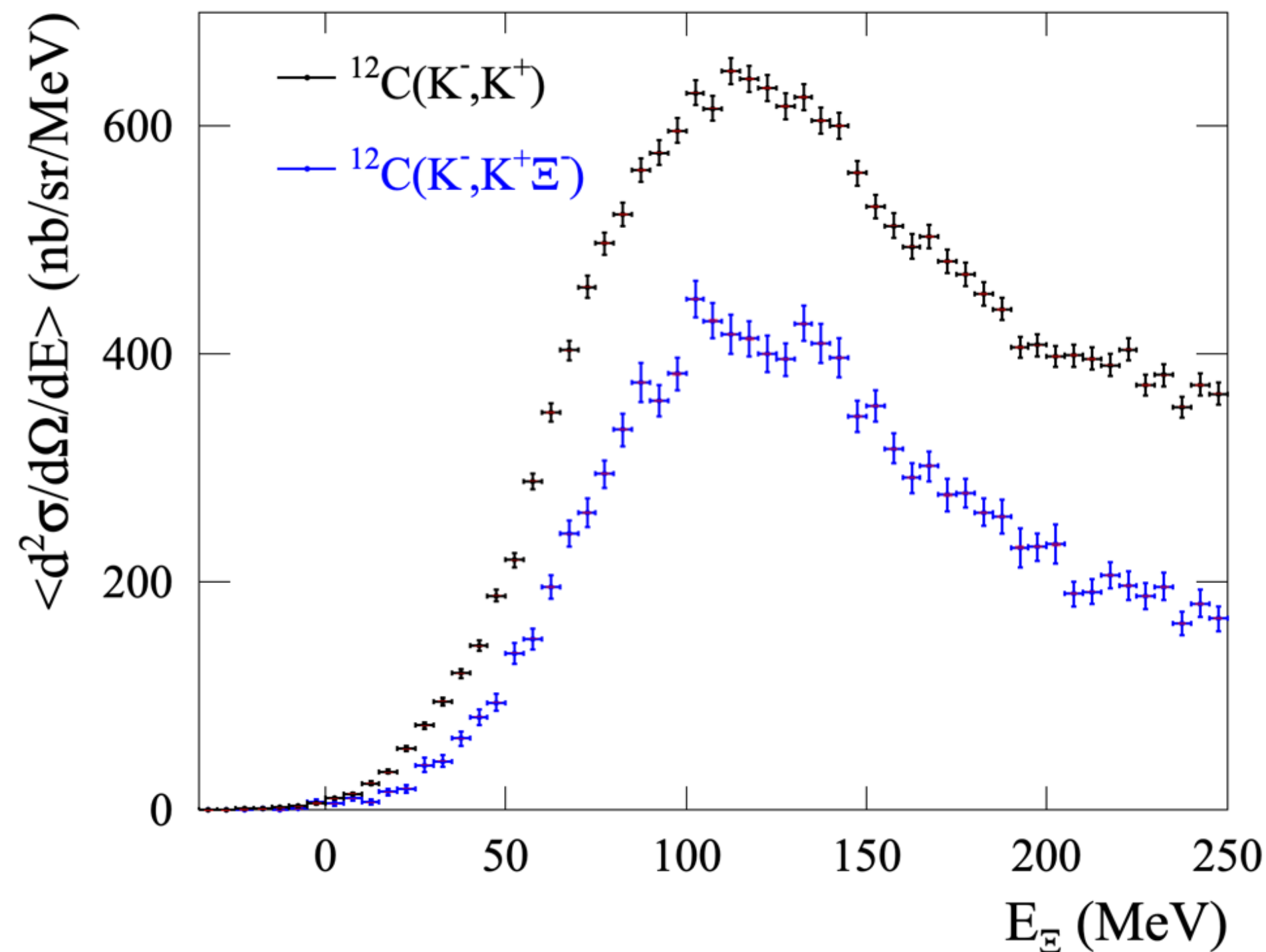
$$E_{\Xi} = M_X - M(\Xi^-) - M(^{11}\text{B}) \text{ where } M_X : ^{12}\text{C}(K^-, K^+)X$$



- J-PARC E42 measured double differential cross section for $^{12}\text{C}(K^-, K^+)X$ reaction.
- The result is consistent with previous experiments at BNL, J-PARC.
- W.S. Jung et al., (E42 Collab) In press, PTEP. (arXiv:2503.17614v2 [nucl-ex])

Ξ^- Emission and Absorption in the $^{12}\text{C}(K^-, K^+)$ Reaction

- Emission of Ξ^- is identified by reconstructing its visible decay via HypTPC.
- Measured Ξ^- escaping probability is $\sim 70\%$. ($100 < E_{\Xi} < 150$ MeV)
- Ξ^- emission probability provides information of Ξ^-p inelastic scattering.

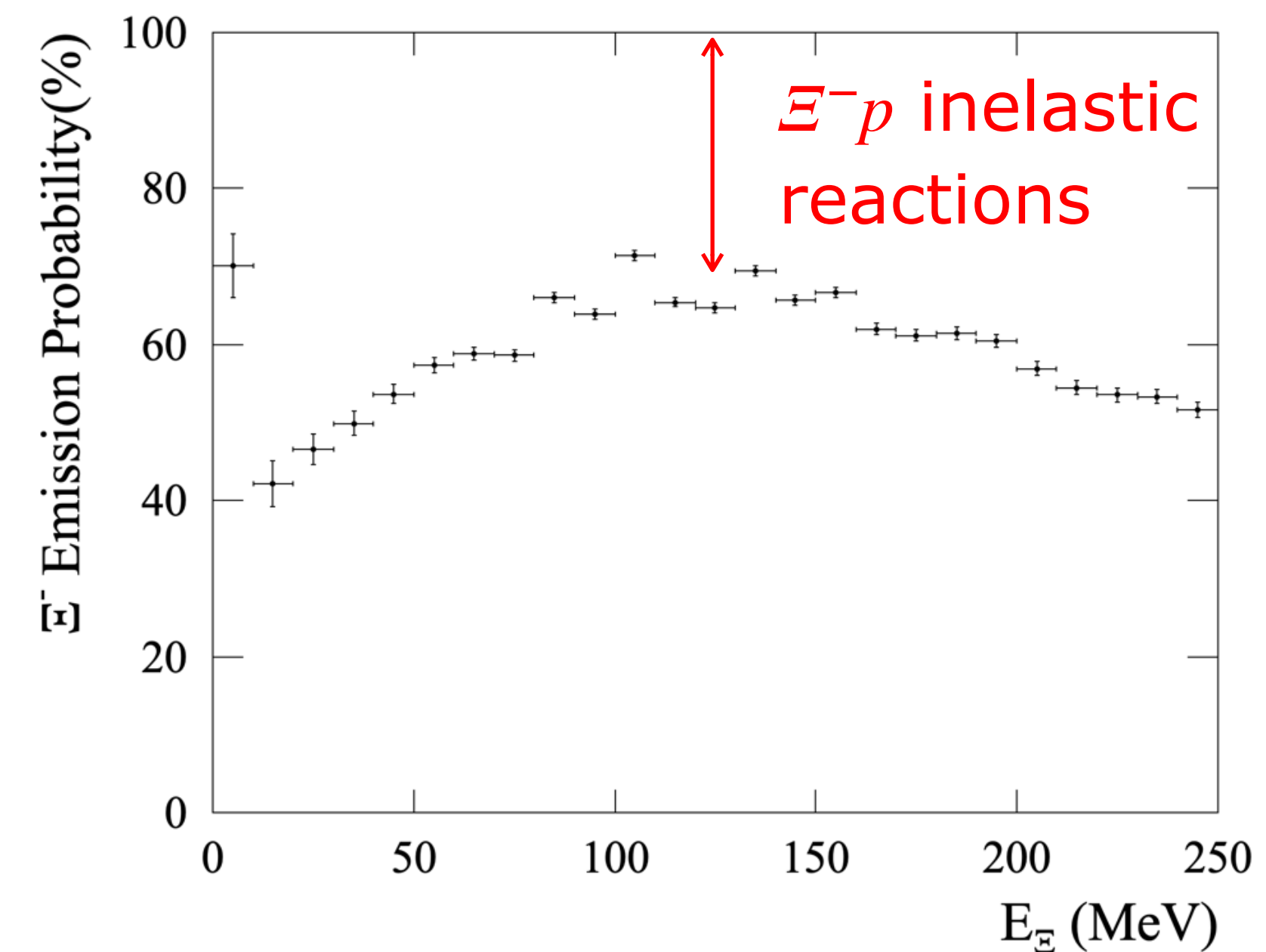
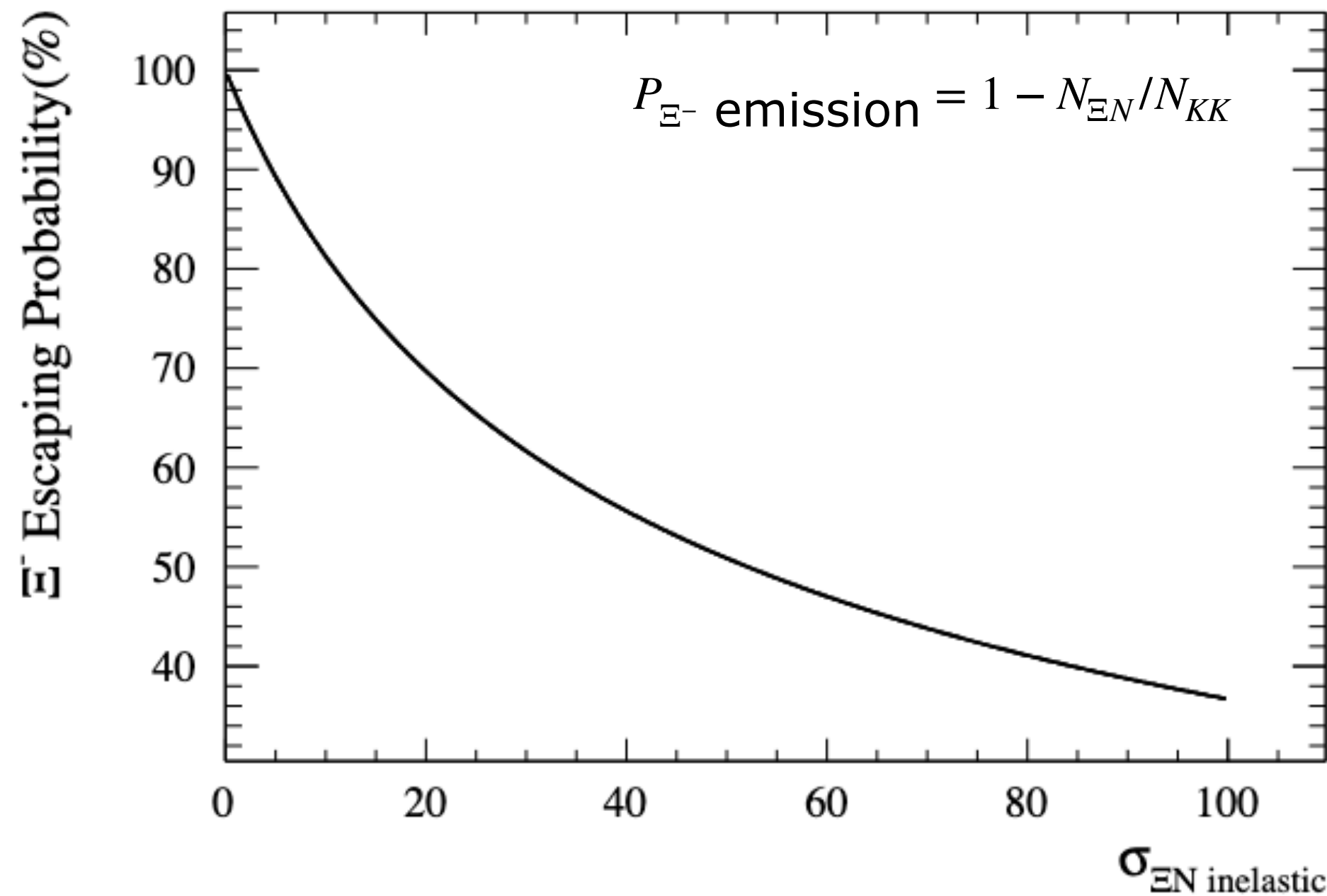


Cross-section for Ξ^-p Inelastic Reactions

- We performed an eikonal approximation for calculation of the effective number of the ΞN process and the (K^-, K^+) reaction are calculated as

$$N_{\Xi N} = \int_0^\infty 2\pi b db \int_{-\infty}^{+\infty} dz \rho(\sqrt{b^2 + z^2}) F(b, z) \left[1 - \exp \left\{ \bar{\sigma}_{\Xi N} \int_z^{+\infty} dz' \rho(\sqrt{b^2 + z'^2}) \right\} \right], N_{KK} = \int_0^\infty 2\pi b db \int_{-\infty}^{+\infty} dz \rho(\sqrt{b^2 + z^2}) F(b, z)$$

where, $F(b, z) = \exp \left[-\bar{\sigma}_{K^-N} \int_{-\infty}^z dz' \rho(\sqrt{b^2 + z'^2}) - \bar{\sigma}_{K^+N} \int_z^{+\infty} dz' \rho(\sqrt{b^2 + z'^2}) \right]$, $\bar{\sigma}(K^-N) = 28.9 \text{ mb}$, $\bar{\sigma}(K^+N) = 19.4 \text{ mb}$.

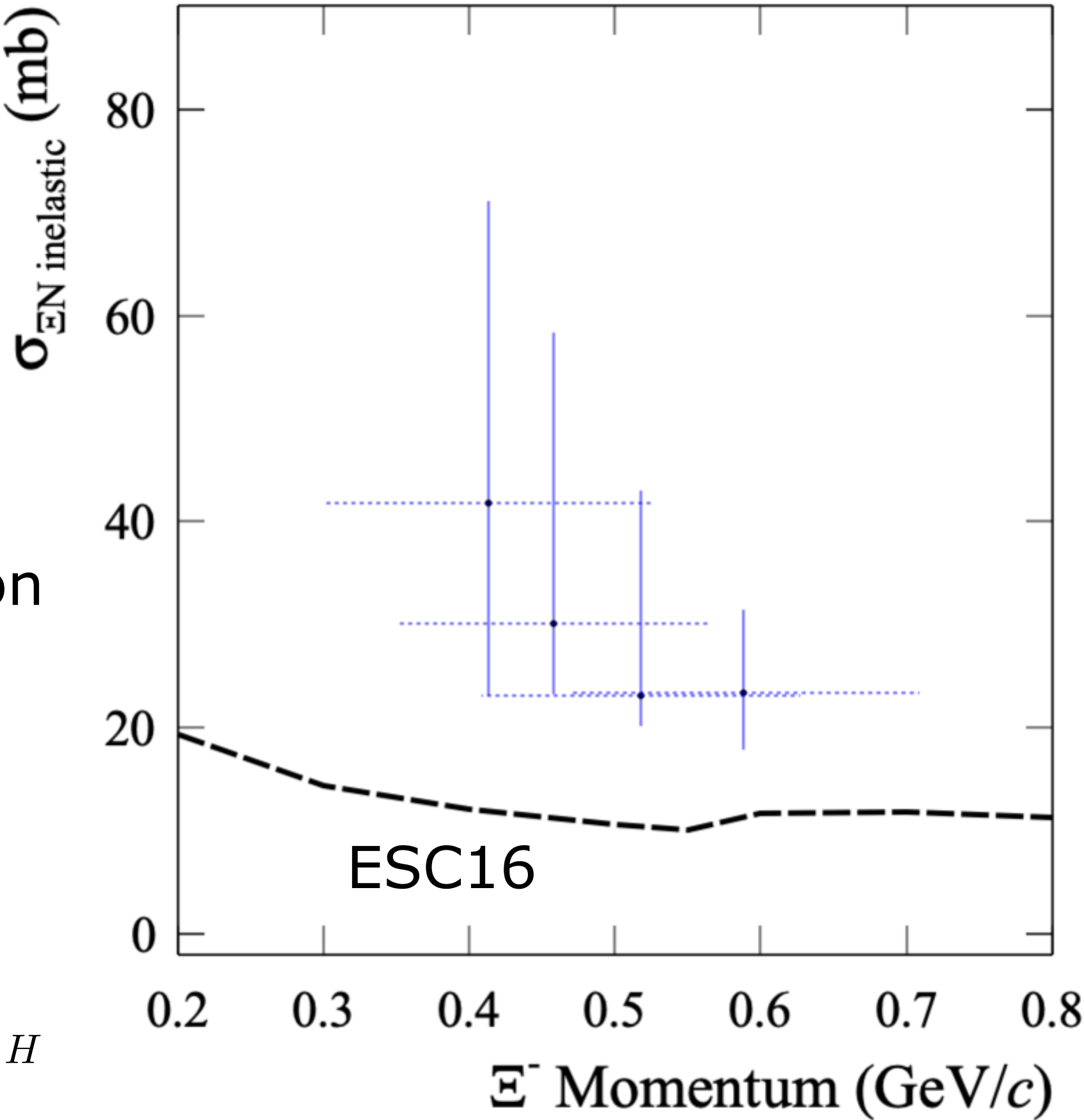
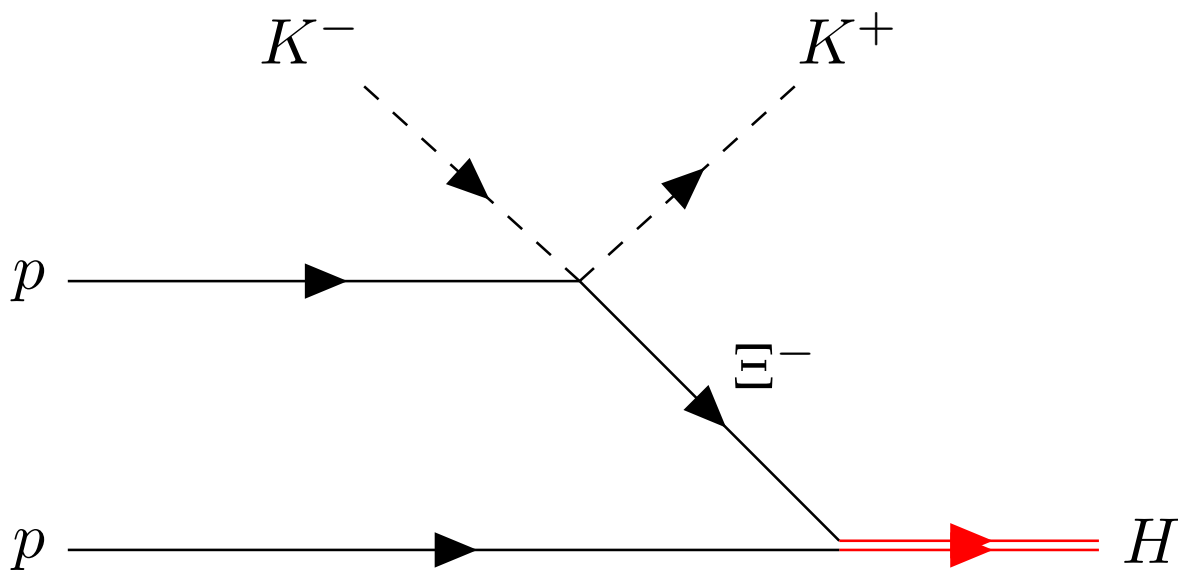


Cross-section for Ξ^-p Inelastic Reactions

Primary processes:

$$\Xi^-p \rightarrow \Xi^0n, \Lambda\Lambda$$

Possible contribution
from H-dibaryon formation



- This work:42 - 23 mb($0.4 < p_{\Xi^-} < 0.6$ GeV/ c)
- Nijmegen-D model calculation based on the BNL E906 data at $p_{\Xi^-} = 0.55$ GeV/ c (α_{two} : a fraction of two-step processes)

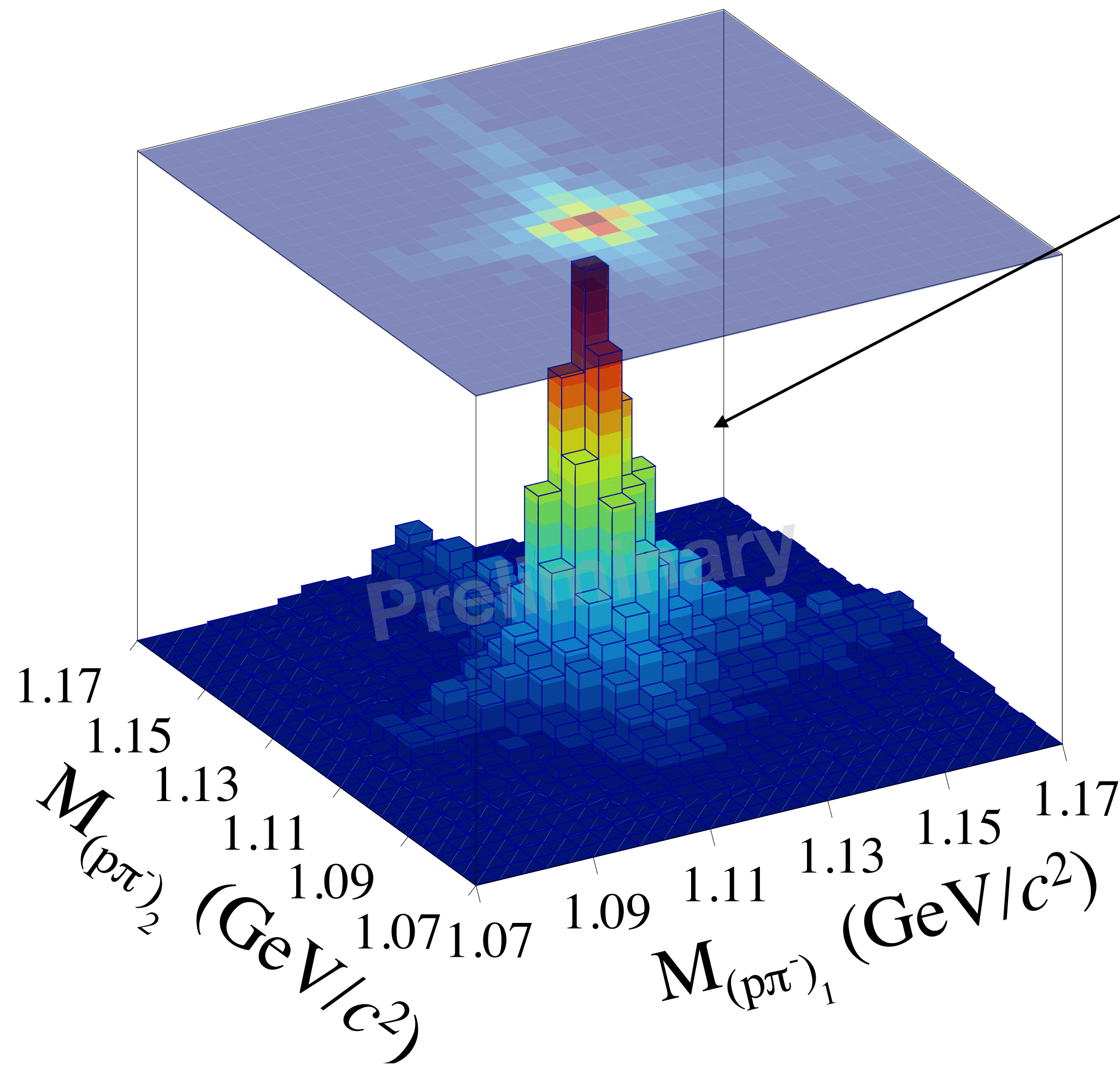
*Y.Yamamoto, et al., PTP106,363 (2001).

α_{two}	σ_{abs}	σ_{scat}
0.00	21.1 mb	21.6 mb
0.05	16.4 mb	20.3 mb
0.10	11.7 mb	19.1 mb

- Extended-soft-core Baryon Baryon model(ESC16)

*M.M. Nagels, Th. A. Rijken, Y. Yamamoto, Phys. Rev. C 102, 054003 (2020).

Reconstructed $\Lambda\Lambda$ Production in $^{12}\text{C}(K^-, K^+)$ reaction



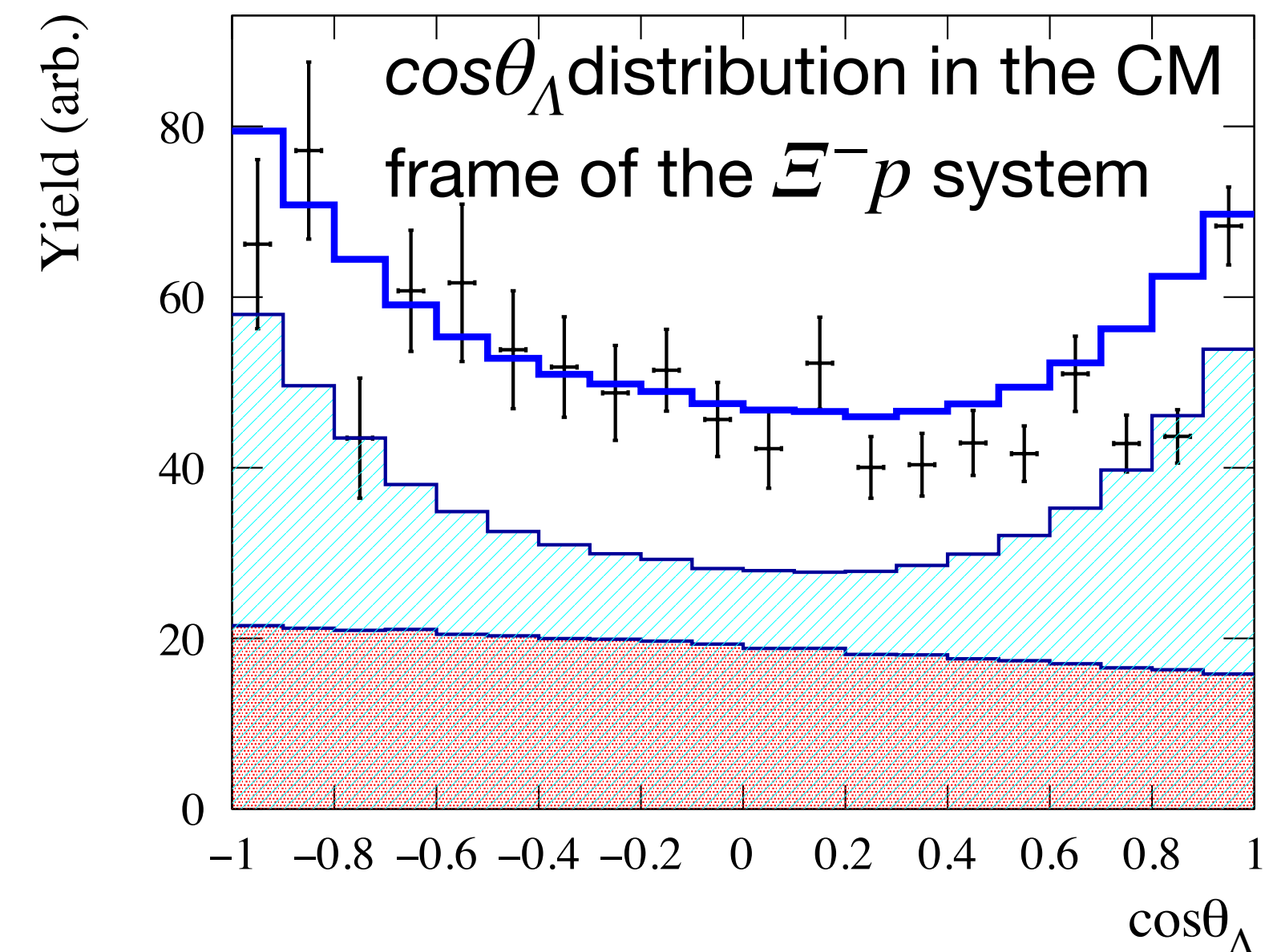
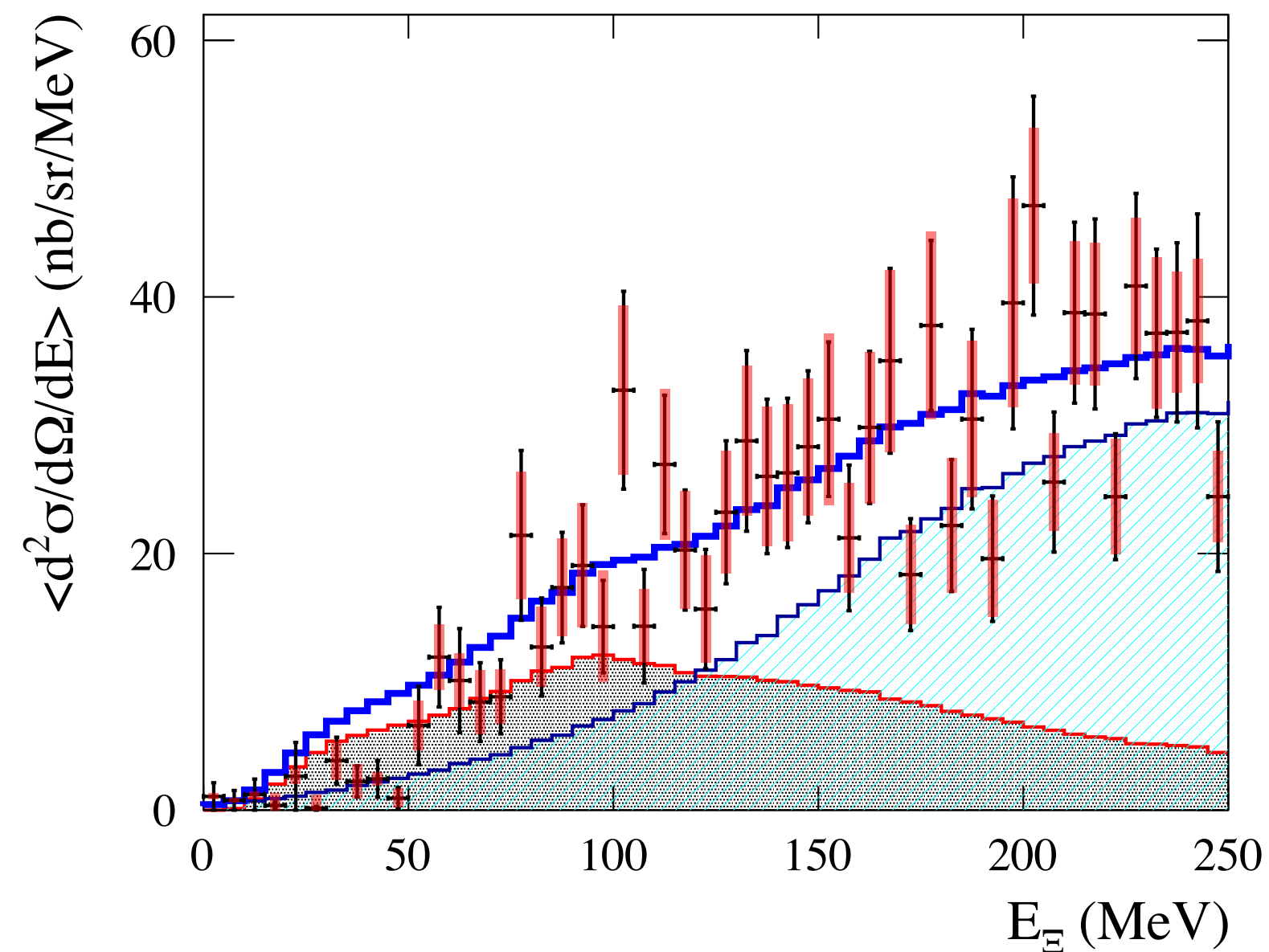
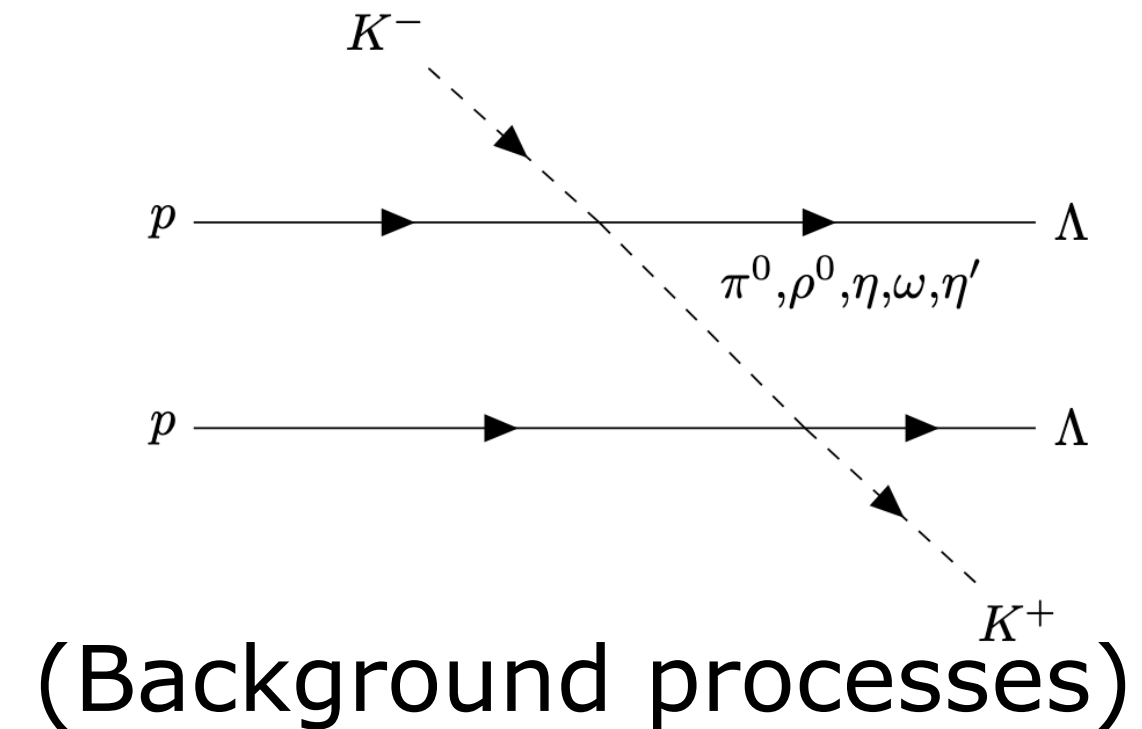
Reconstructed $\Lambda\Lambda$ pairs in the signal box

- J-PARC E42 accumulated $\sim 9,000$ $\Lambda\Lambda$ events which are two orders of magnitude more than ever in past experiments.
- 1,500 events in the region for Ξ^- production ($E_{\Xi} < 250$ MeV).
- A blind analysis is underway.

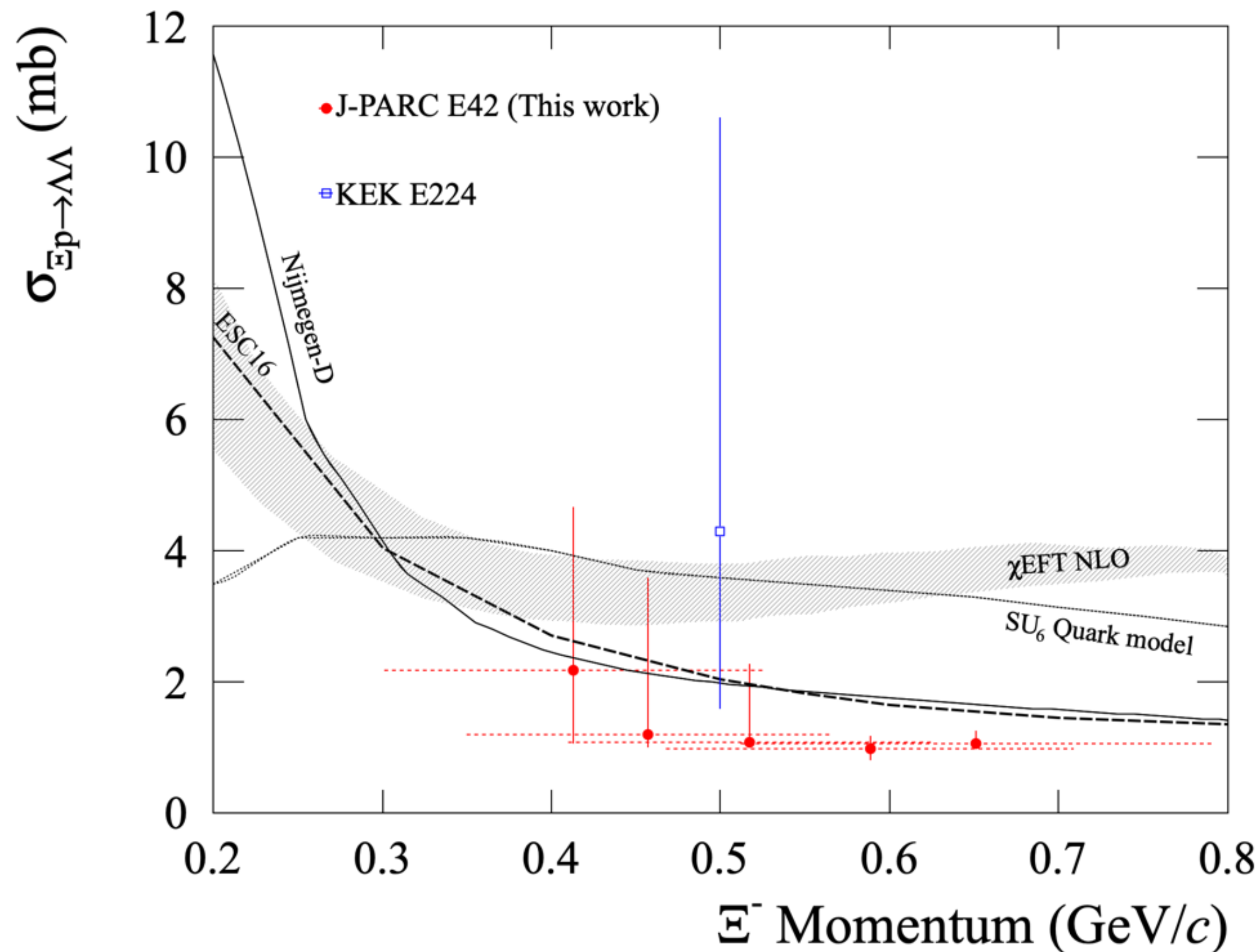
$\Lambda\Lambda$ production and $\Xi^-p \rightarrow \Lambda\Lambda$ Contribution in the $^{12}\text{C}(K^-, K^+)$ Reaction

- $\Lambda\Lambda$ production yield is reproduced by considering two-step processes in $^{12}\text{C}(K^-, K^+)$ reactions.
- J-PARC E42 data with intra-nuclear cascade model calculation for understanding the contribution of $\Xi^-p \rightarrow \Lambda\Lambda$ conversion ($\sim 2\%$).

Based on Ref. "Y. Nara, A. Ohnishi, T. Harada, A. Engel, Nucl. Phys. A 614, 433 (1997)"



Total Cross-section for $\Xi^- p \rightarrow \Lambda\Lambda$ Conversion Process



Dotted lines correspond to momentum spread of Ξ^- (1σ)

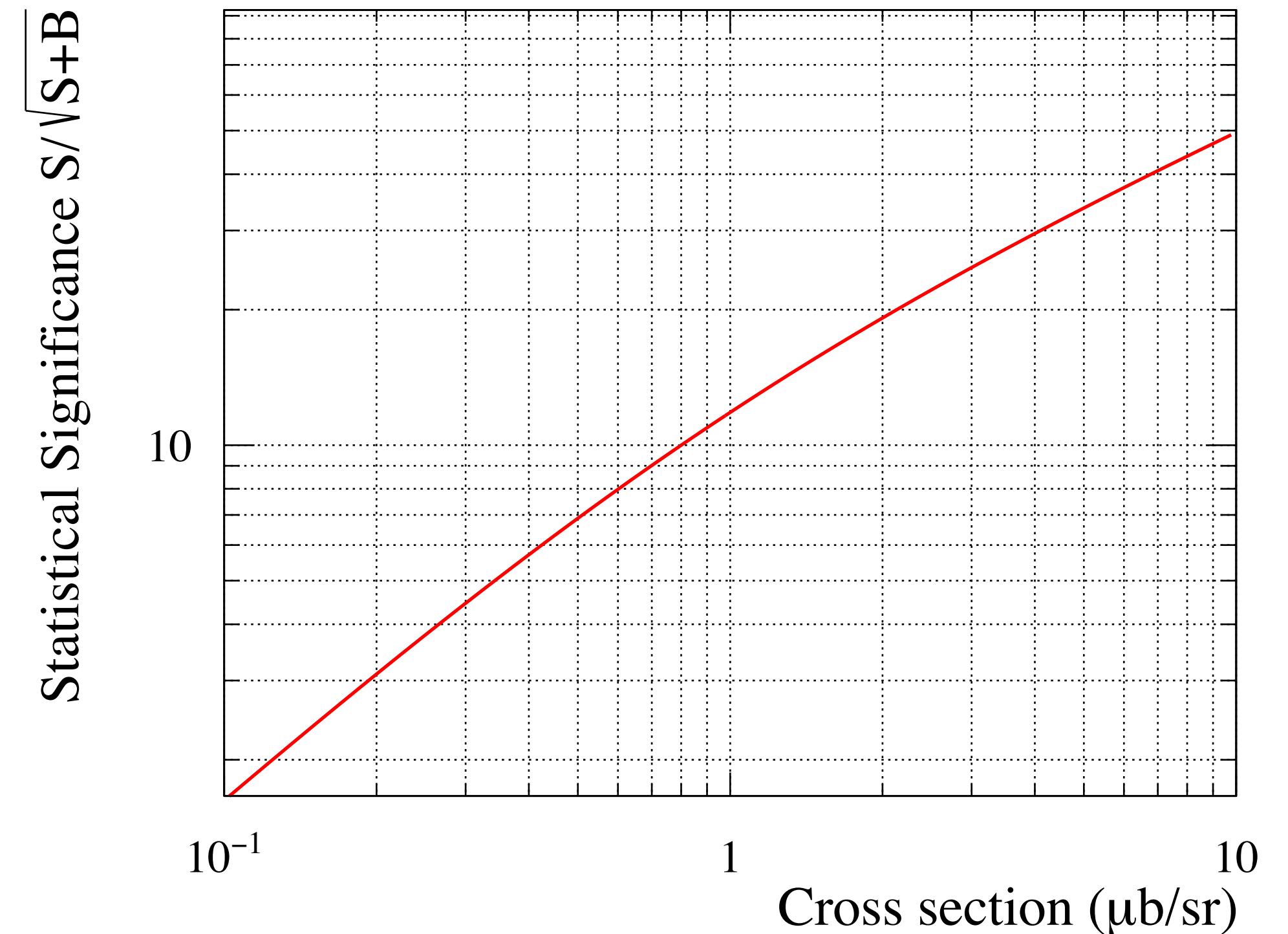
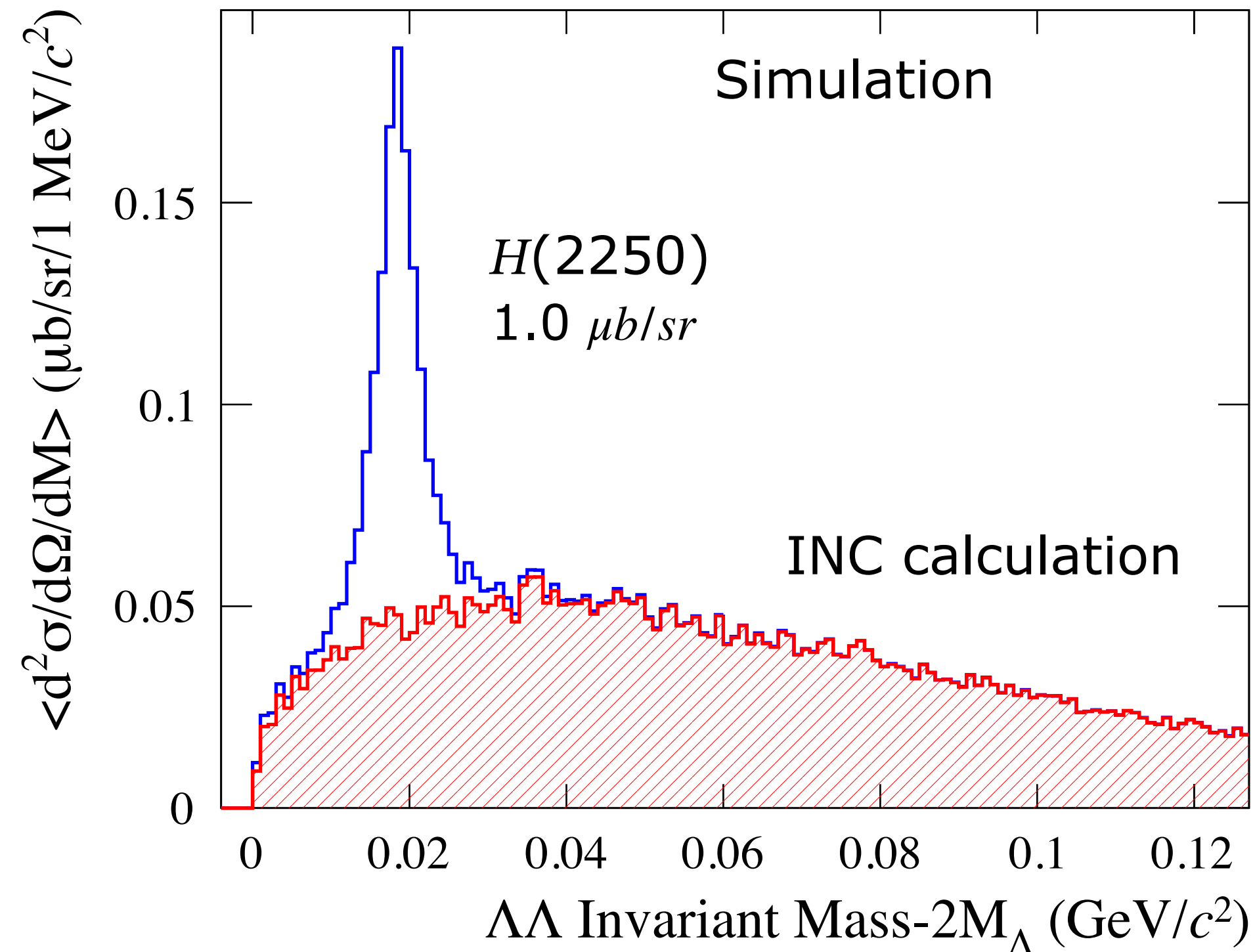
- $\Xi^- p \rightarrow \Lambda\Lambda$ cross section is $1.0^{+1.3}_{-0.9}$ mb at $0.5 < P_{\Xi^-} < 0.6$ GeV/c.
- This result constraints $\Gamma_{\Xi^-} < \sim 0.6$ MeV in nuclear matter, by the relation of $\Gamma_{\Xi} \sim (\rho_0/2) \cdot (v\sigma)_{\Xi^- p \rightarrow \Lambda\Lambda}$ where, $\rho_0/2 \sim 0.08 \text{ fm}^{-3}$.

**C. B. Dover, A. Gal, and D. J. Millener, Nucl. Phys. A 572, 85 (1994)*

- The result is consistent with the previous KEK E224 result. Theoretical predictions from the Nijmegen-D, ESC16, and SU₆ quark models are agree with our result.
- We are looking forward to new theoretical studies, building upon our work.

Expected Result of $\Lambda\Lambda$ Invariant Mass spectroscopy for H-dibaryon

We are close to the final step before opening the signal box.



- Simulated $\Lambda\Lambda$ mass spectrum based on the accumulated $\Lambda\Lambda$ events.
- Statistical significance for H-dibaryon production

Summary

- **J-PARC E42 searches for the H-dibaryon via $^{12}\text{C}(K^-, K^+)$ reaction.**
We collected approximately 0.3M (K^-, K^+) reaction events and measured all charged decays using HypTPC.
- We report J-PARC E42 results on differential cross-section measurement for $^{12}\text{C}(K^-, K^+)$ reactions and cross section of E^-p elementary processes.
- We have collected approximately $\sim 9,000$ $\Lambda\Lambda$ events. The signal box of the $\Lambda\Lambda$ invariant mass will soon be opened, allowing us to search for **the existence of the H-dibaryon** near the $\Lambda\Lambda$ and E^-p thresholds.

