고려대학교
KOREA UNIVERSITY

Hadron & Nuclear Physics Lab

Search for the H-Dibaryon in (K^-, K^+) Reaction at J-PARC

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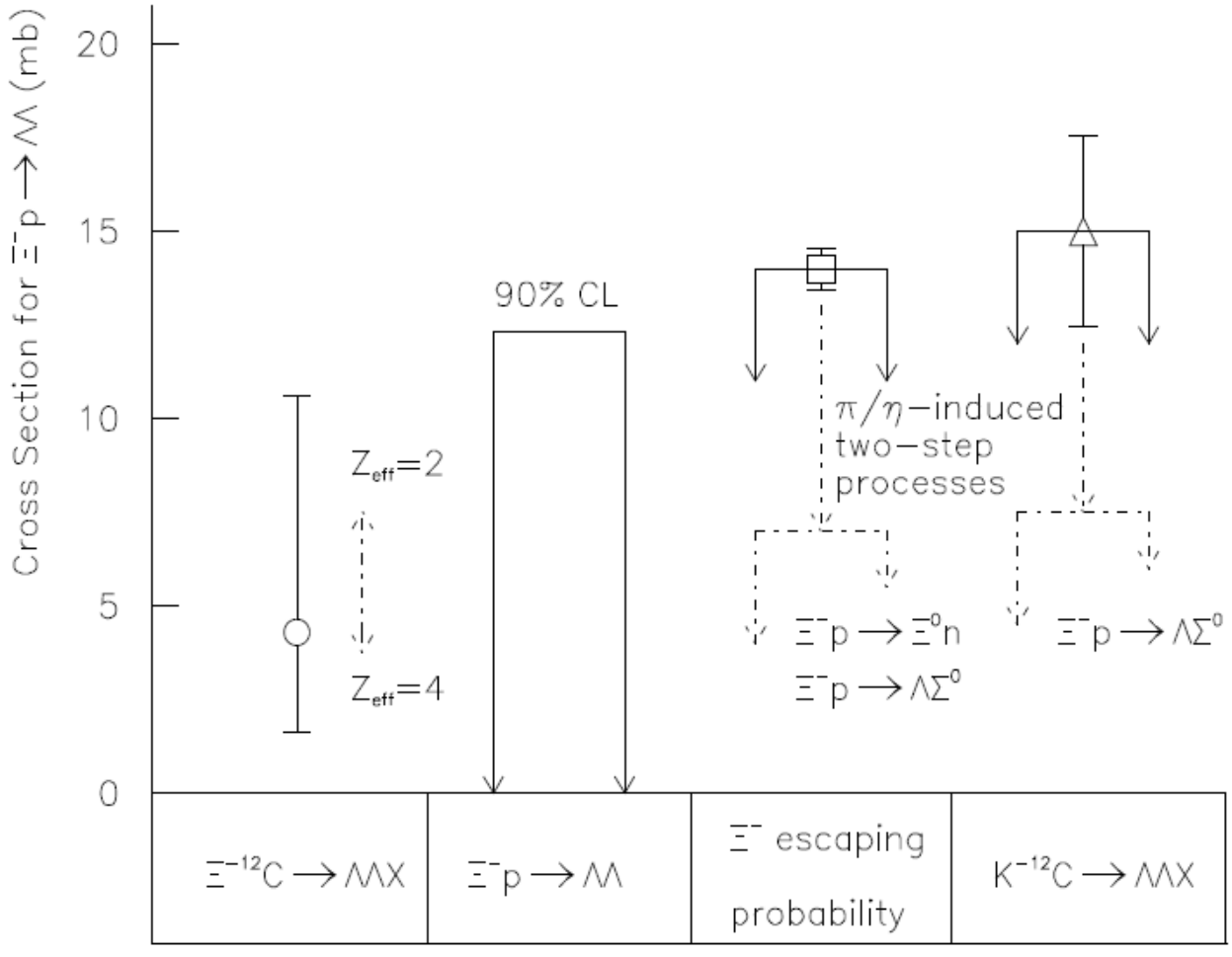
Hyperon-Nucleon Scattering in $S = -2$ Systems

$$\underbrace{\Lambda\Lambda}_{I=0} \qquad \underbrace{\Xi N}_{I=0,\ 1} \qquad \underbrace{\Lambda\Sigma}_{I=0,\ 1} \qquad \underbrace{\Sigma\Sigma}_{I=0,\ 1,\ 2}$$

- Hyperon-nucleon interaction, particularly in $S = -2$ system, may shed light on our understanding of the nature of $SU(3)$ symmetry breaking in a baryon-baryon interaction.
- In particular, a measurement of the $\Xi^- p \to \Lambda\Lambda$ conversion cross section is crucial in assessing the stability of Ξ^- quasi-particle state in nuclei.
- Low energy $\Xi^- p$ elastic and $\Xi^- p \to \Lambda\Lambda$ cross sections in the range of 0.2 GeV/c to 0.8 GeV/c, which are less than 24 mb at 90% CL and $4.3^{+6.3}_{-2.7}$ mb, respectively.[1]

[1] J.K. Ahn *et al.*, Phys. Lett. B633 (2006) 214

$\Xi^- p \to \Lambda\Lambda$ Cross Sections [2]

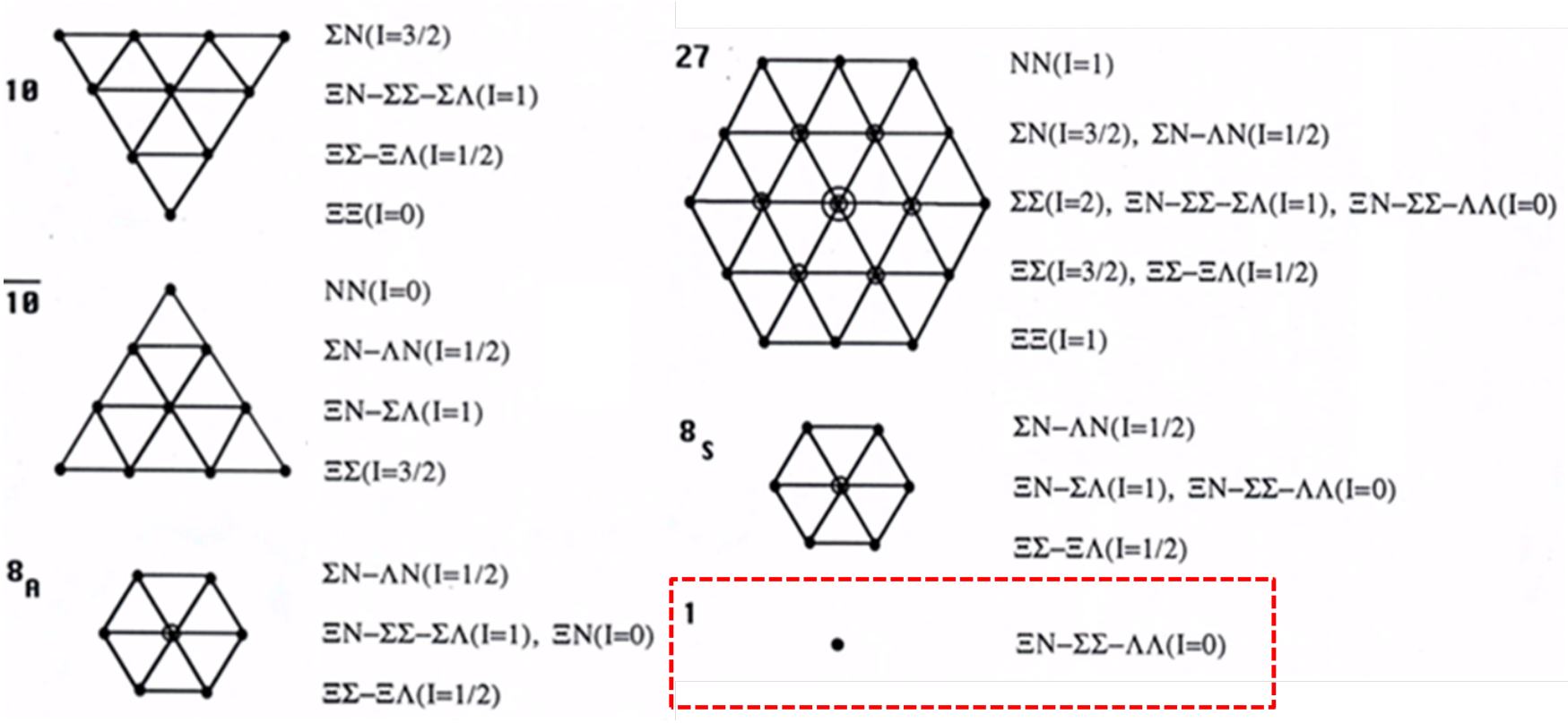


[2] J.K. Ahn *et al.*, Phys. Lett. B633 (2006) 214

Dibaryon Multiplets

- For baryon-octet + baryon-octet

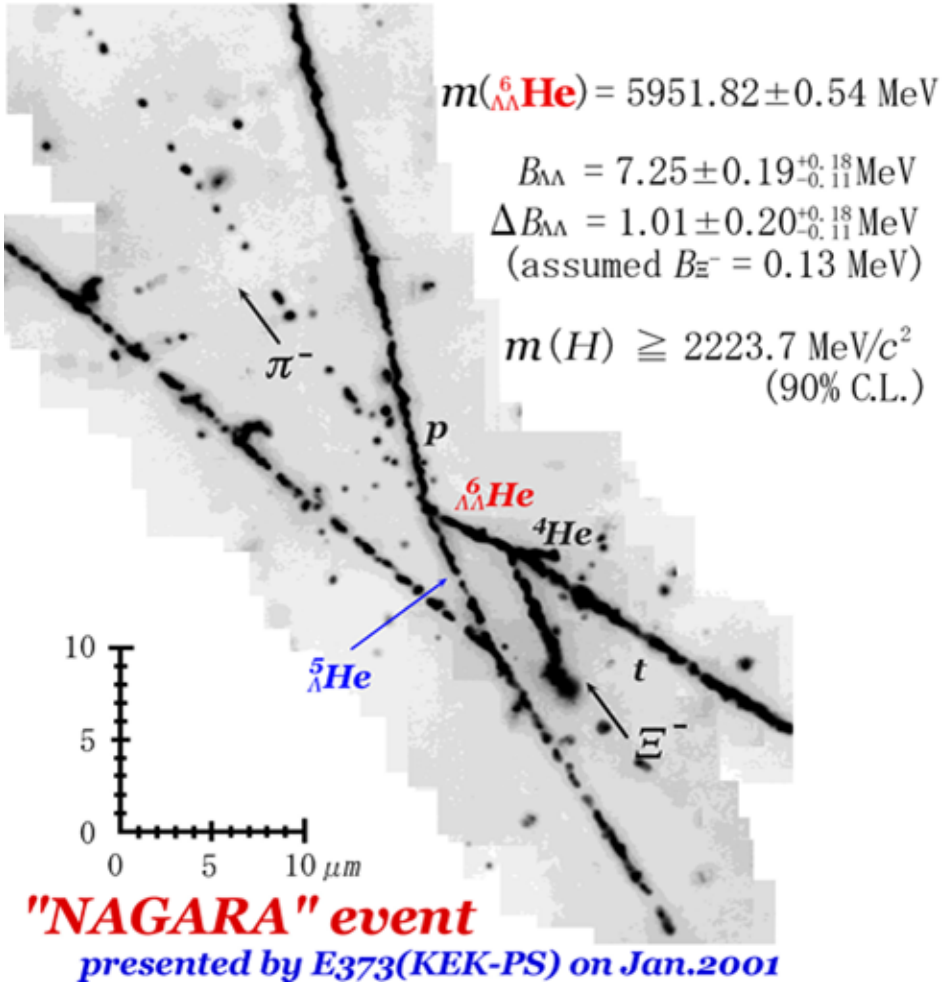
$$8 \otimes 8 = 1 \oplus 8 \oplus 8 \oplus 10 \oplus \overline{10} \oplus 27$$



Brief History about the H-Dibaryon Search

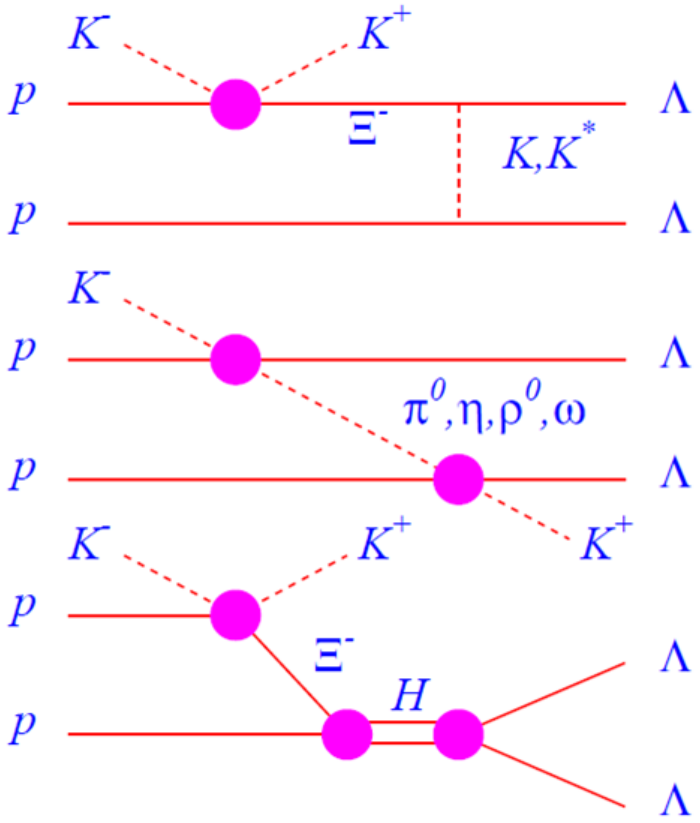
- Deeply-bound di-hyperon predicted by R. Jaffe (1977).
- No evidence for the deeply-bound H from KEK, BNL, and CERN experimental efforts by more than 80 MeV (1980-2000s).
- Mass constraint from observation of ${}^{6}_{\Lambda\Lambda}\mathrm{He}$ (E373).
- Enhanced $\Lambda\Lambda$ production near threshold was reported from E224 and E522 at KEK-PS.
- No evidence for $H \to \Lambda p \pi^-$ and $H \to \Lambda\Lambda$ in high-energy e^+e^-, pp and AA collisions from Belle, STAR, and ALICE.

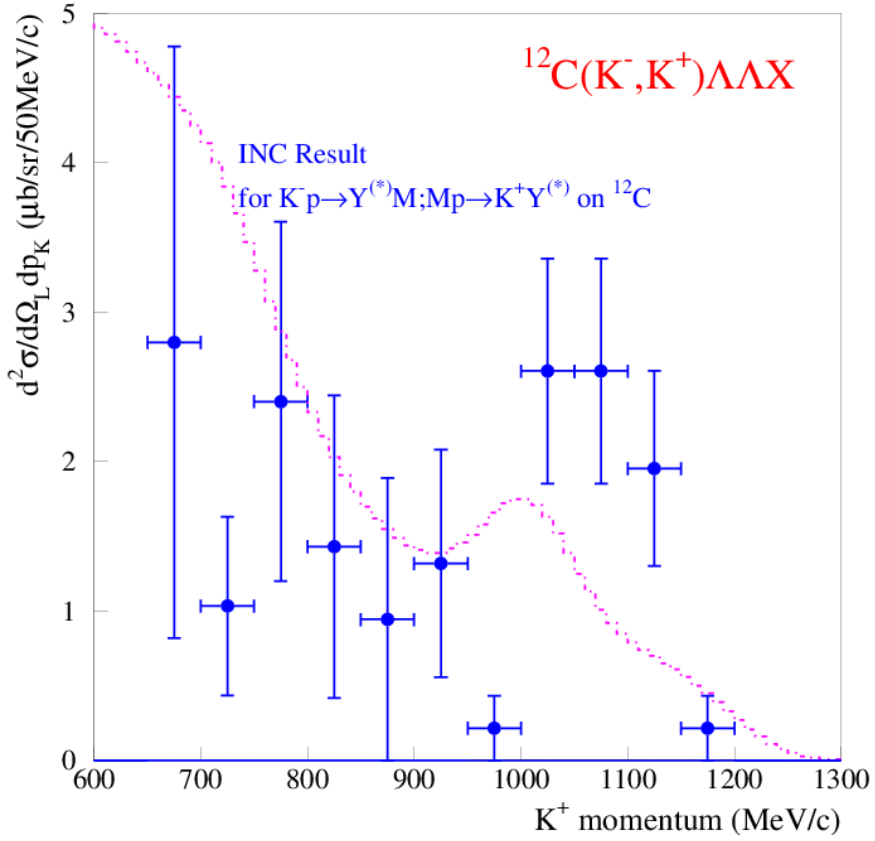
Mass Constraint from Double-Λ Hypernuclei



- $\Lambda\Lambda$ pair decays strongly to the H in a nucleus if H is lighter than $\Lambda\Lambda$ in a nucleus.
- $\Lambda\Lambda$ bound in the lowest s-orbit of a hypernucleus may be kept apart by a repulsive short-range potential barrier long enough to allow weak decay to compete with H formation ?

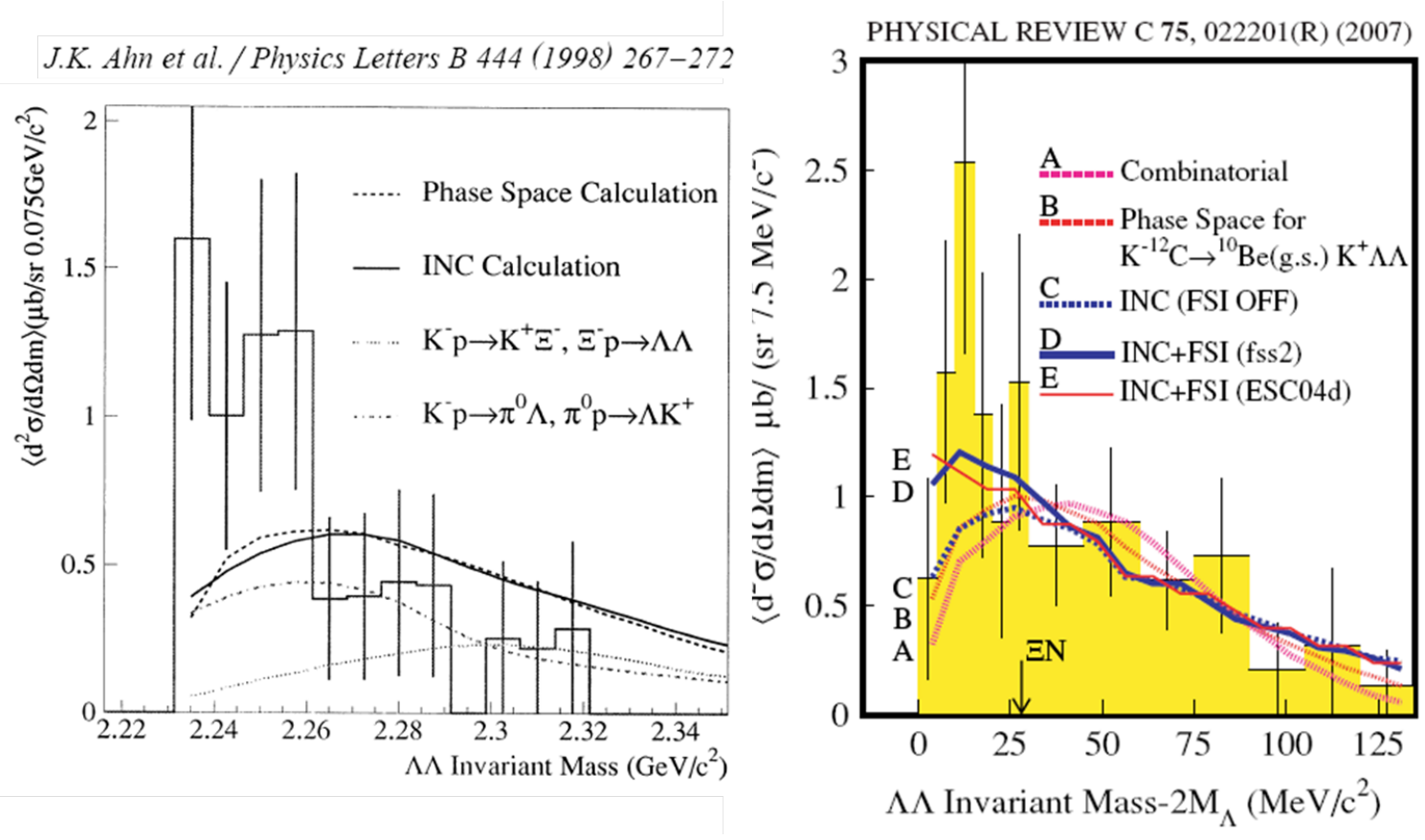
$\Lambda\Lambda$ Production in (K^-, K^+) Reaction near Threshold





- KEK-E224 measurement for $^{12}C(K^-, K^+)\Lambda\Lambda X$ (7.6 μb/sr and 3 μb/sr for the H)

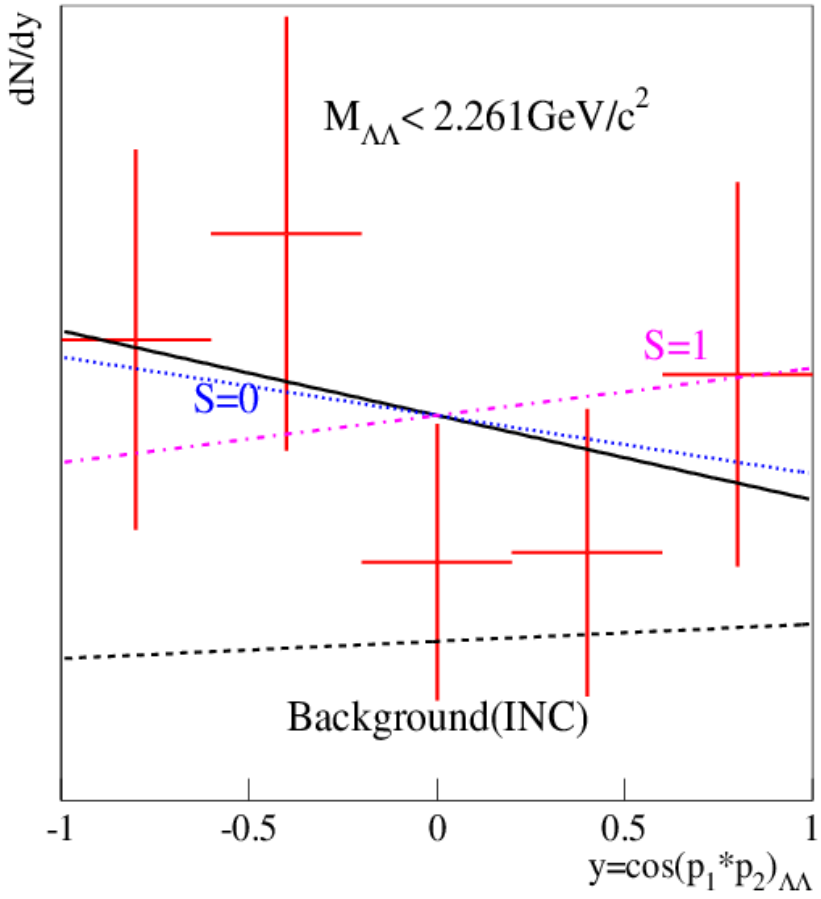
H-Dibaryon as a ΛΛ Resonance?



- Indications to the enhanced ΛΛ production from KEK-PS E224 and E522 beyond prediction from INC calculations.[3]

[3] Y. Nara *et al.*, Nucl. Phys. A614 (1997) 433.

Spin Analysis



- Spin composition measurement from E224:

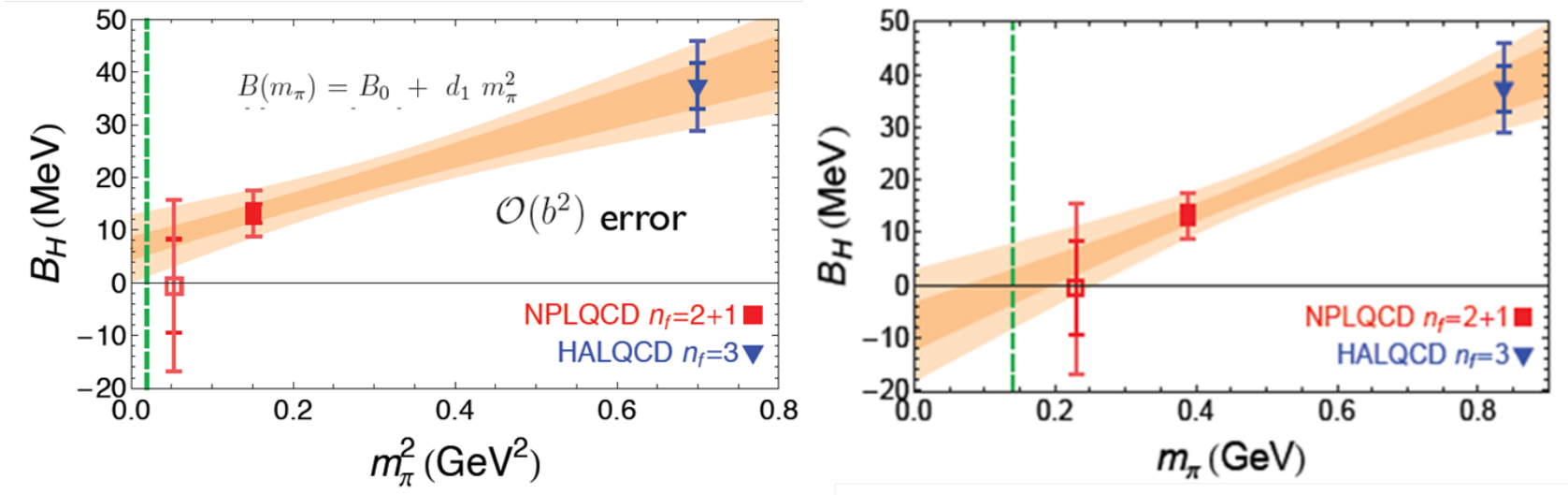
$$\left.\frac{dN}{d\cos\theta^*}\right|_{S=0} = 1 - \alpha_\Lambda^2 \cdot \cos\theta^*$$

$$\left.\frac{dN}{d\cos\theta^*}\right|_{S=1} = 1 + \frac{1}{3}\alpha_\Lambda^2 \cdot \cos\theta^*,$$

where θ^* is the angle between the two decay protons in the $\Lambda\Lambda$ rest frame.

H-Dibaryon from Lattice QCD[4]

- Recent LQCD calculations seem to point to a weekly bound H or resonant state although we have got to wait for definite results with physical quark masses.



[4]HAL Collab., PRL 106 (2011)/ NPLQCD Collab. PRL 106 (2011)/ Shanahan, Thomas, Young, PRL 107 (2011)

H-Dibaryon Search at J-PARC : E42

- The J-PARC-E42 experiment searches for the H-dibaryon in $\Sigma^- p$, $\Lambda p \pi^-$,$\Lambda\Lambda$, and $\Xi^- p$ channels by tagging the $S = -2$ system production via (K^-, K^+) reactions with a diamond (^{12}C) target.

PROPOSAL FOR 50 GEV PROTON SYNCHROTRON

Search for H-Dibaryon with a Large Acceptance Hyperon Spectrometer

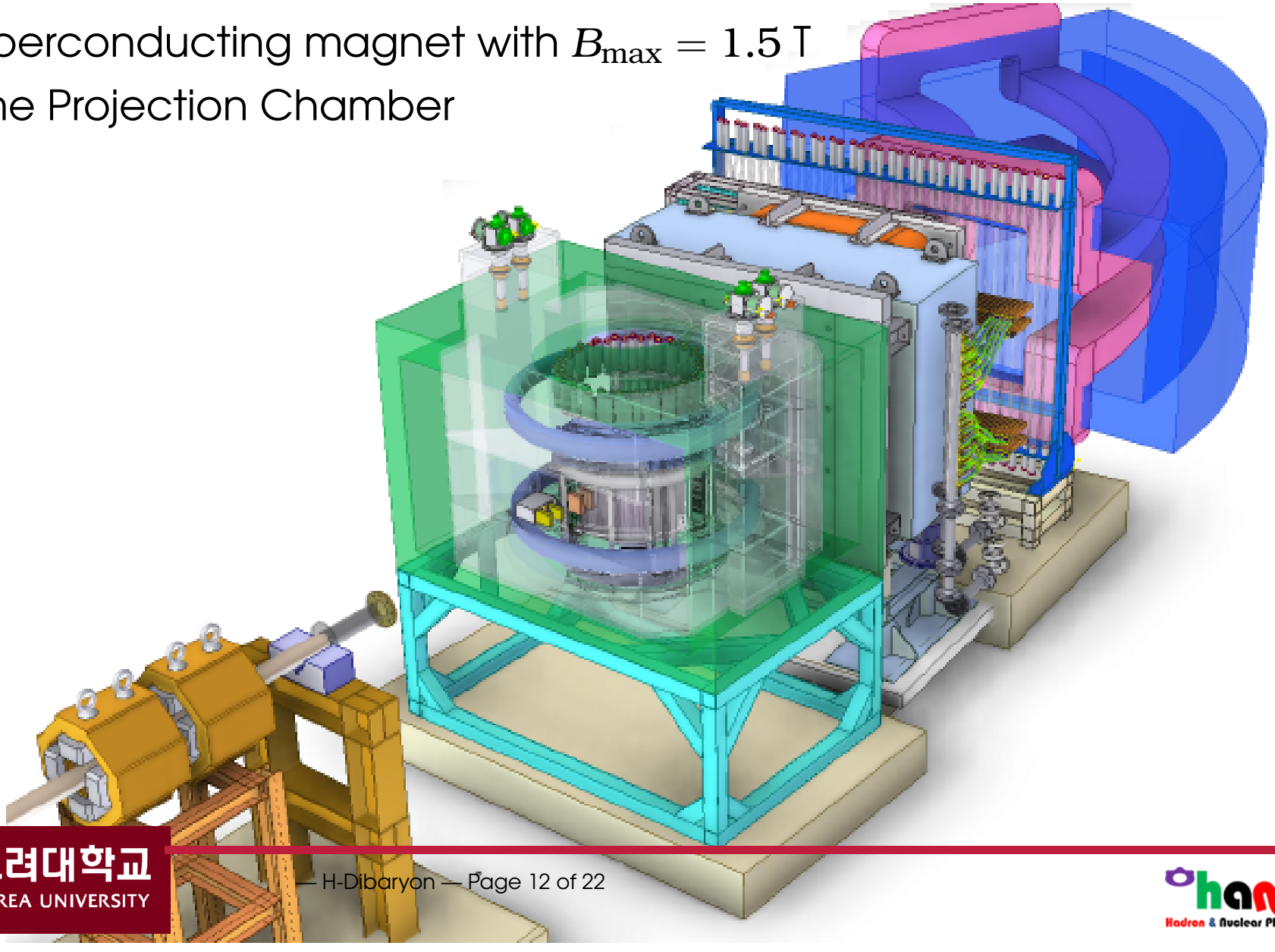
J.K. Ahn (*spokesperson*), K. Imai (*co-spokesperson*)

- Hyperon Spectrometer : 1 MeV $\Lambda\Lambda$ mass resolution!

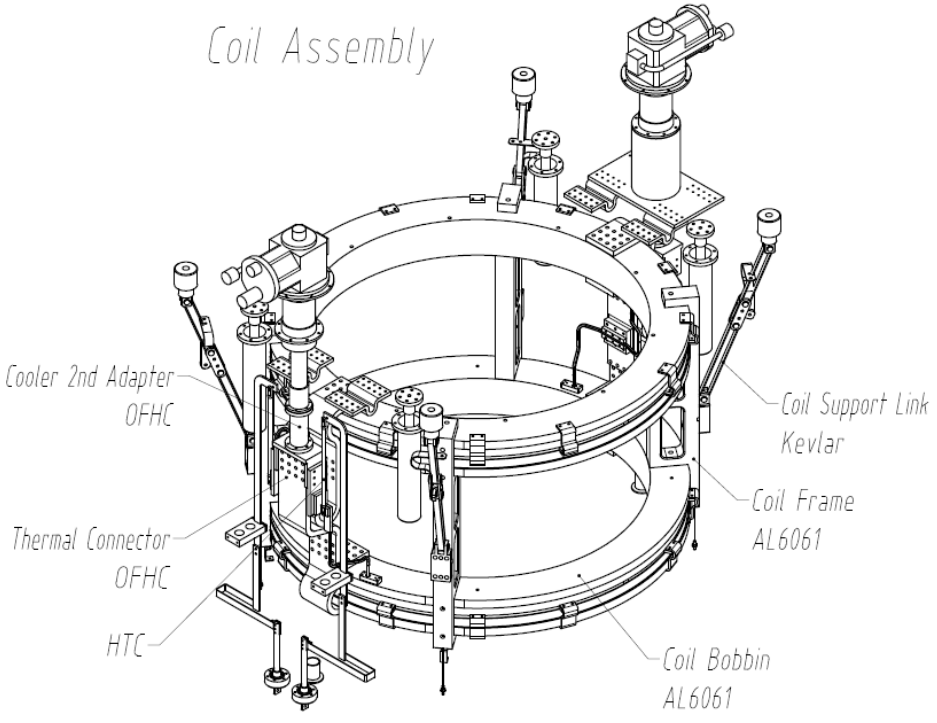
Hyperon Spectrometer

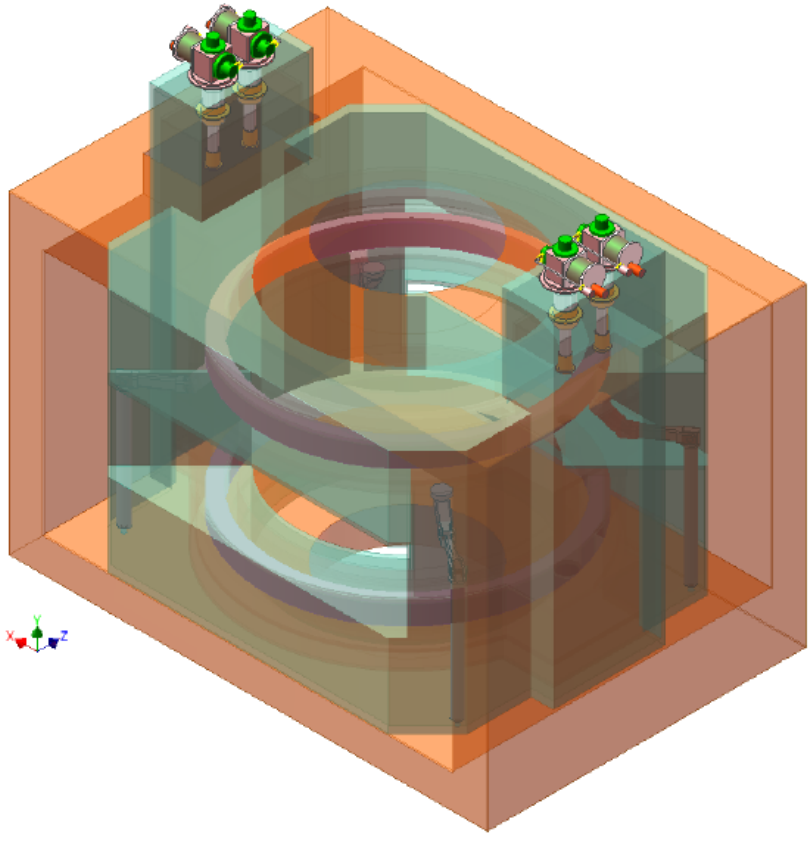
Superconducting magnet with $B_{\max} = 1.5$ T

Time Projection Chamber



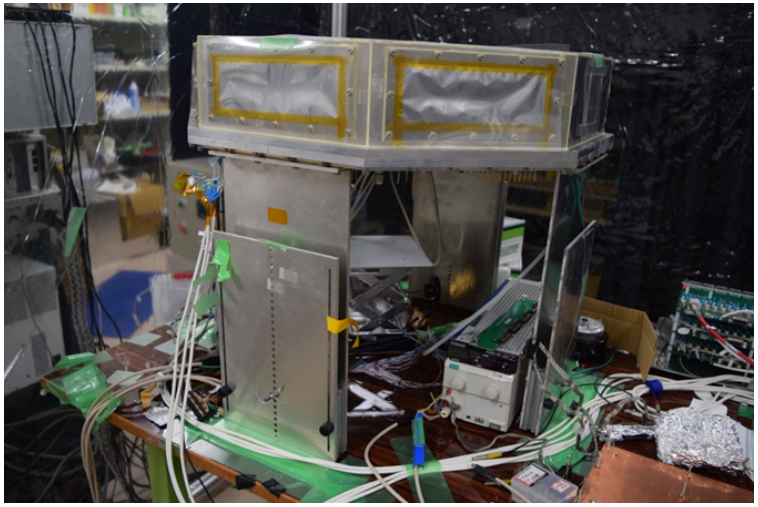
Conduction-cooled Superconducting Magnet

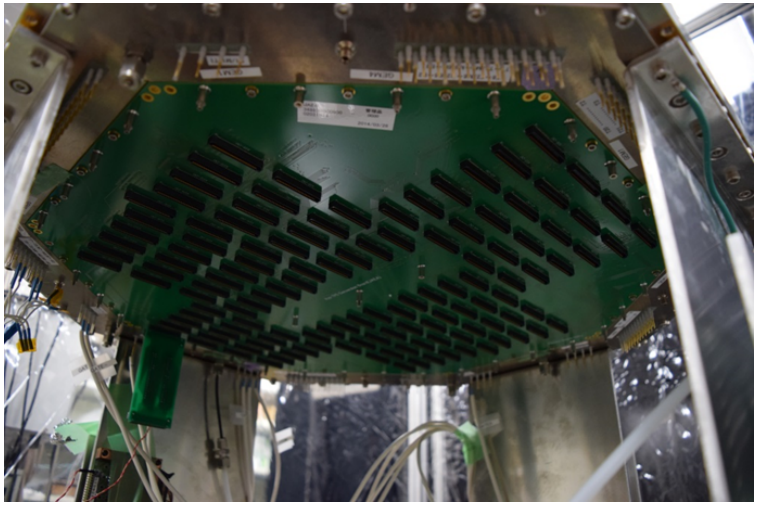


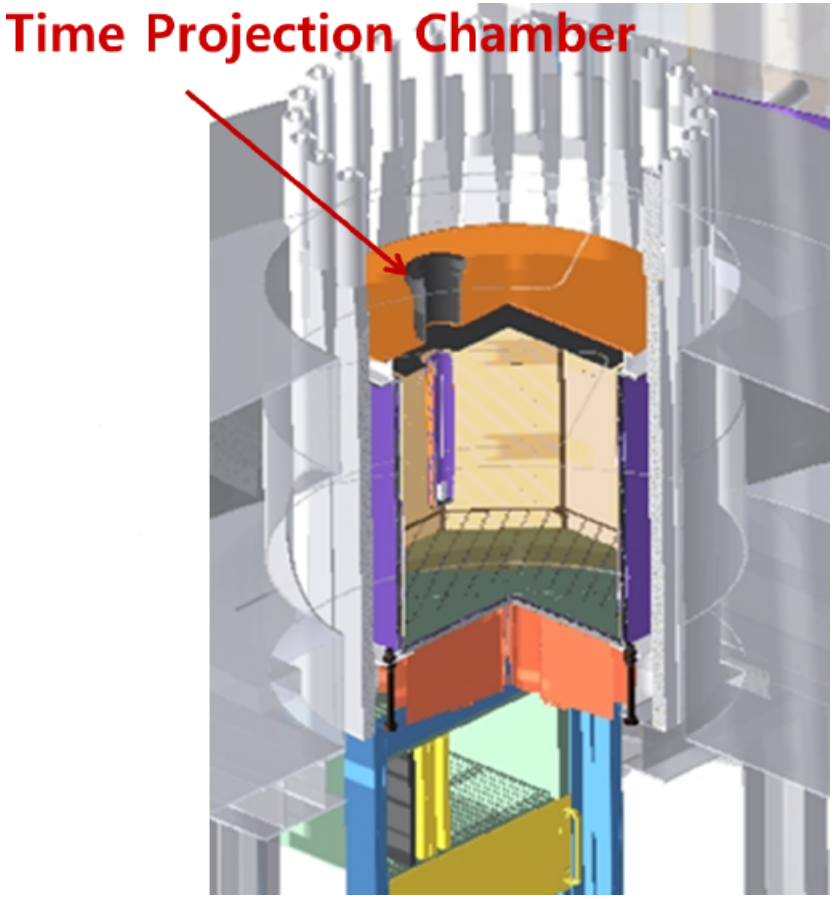


- Large aperture with an inner diameter of 800 mm.
- The magnet is now under construction and will be delivered in March, 2016.

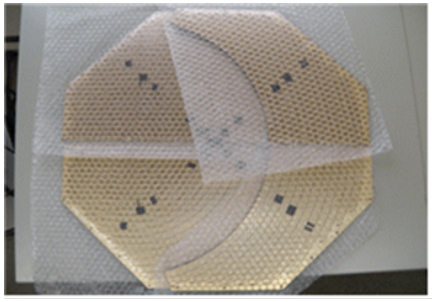
Time Projection Chamber : HypTPC

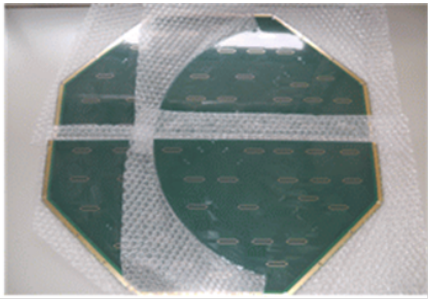


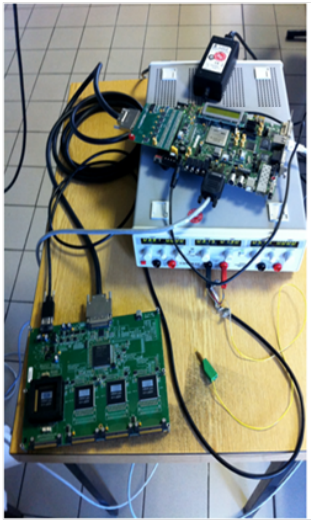


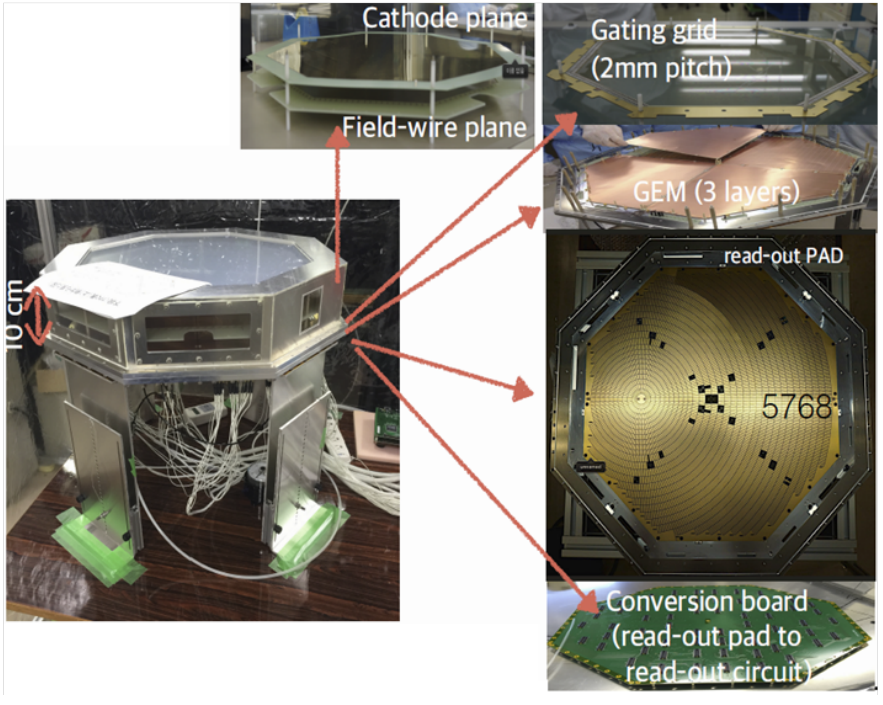


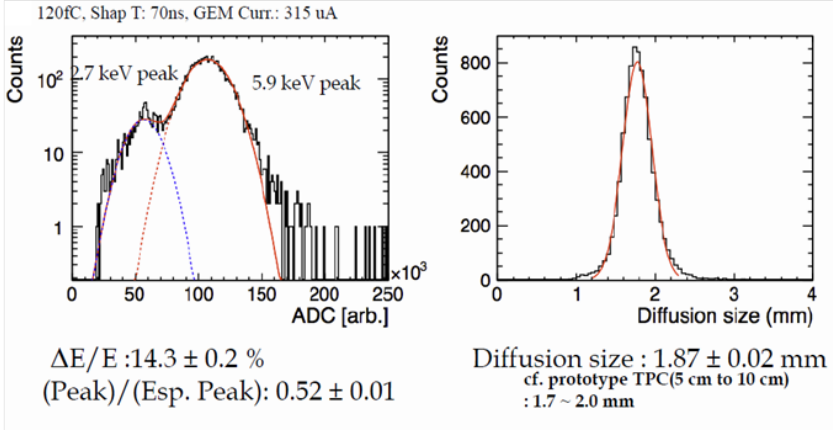
Time Projection Chamber : HypTPC



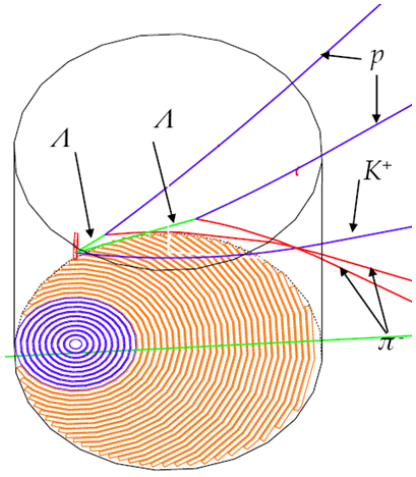


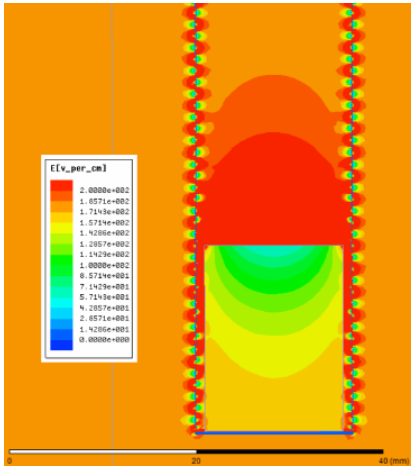






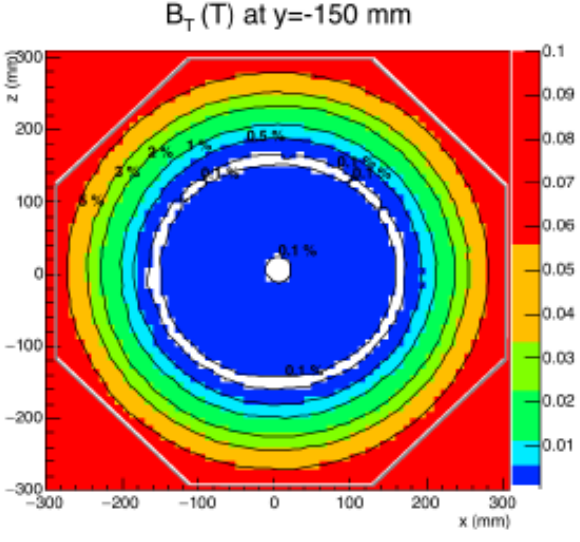
Uniform Electric and Magnetic Fields

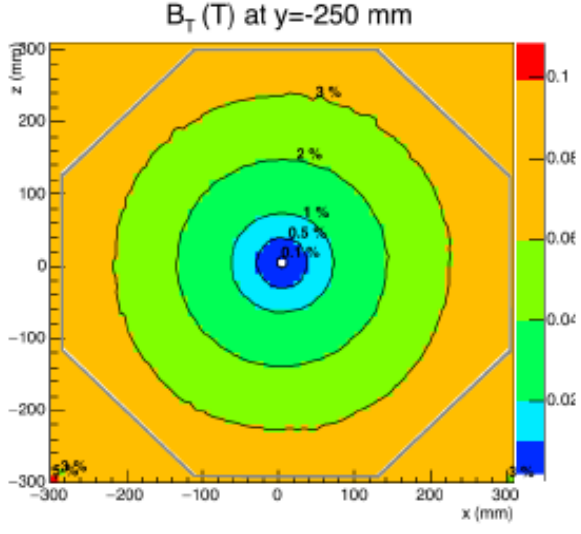


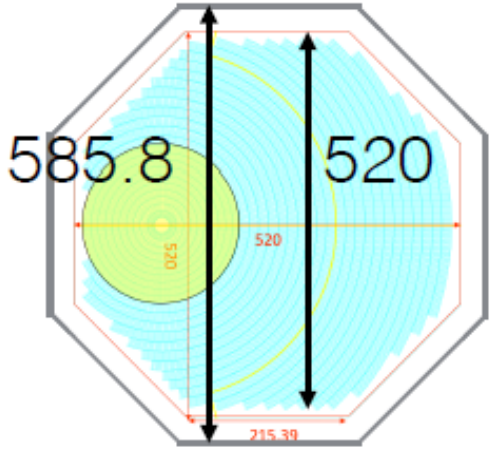


Poster Sessions:

- A15 : S.H. Kim (Korea U)
- A16 : S.H. Hwang (JAEA)







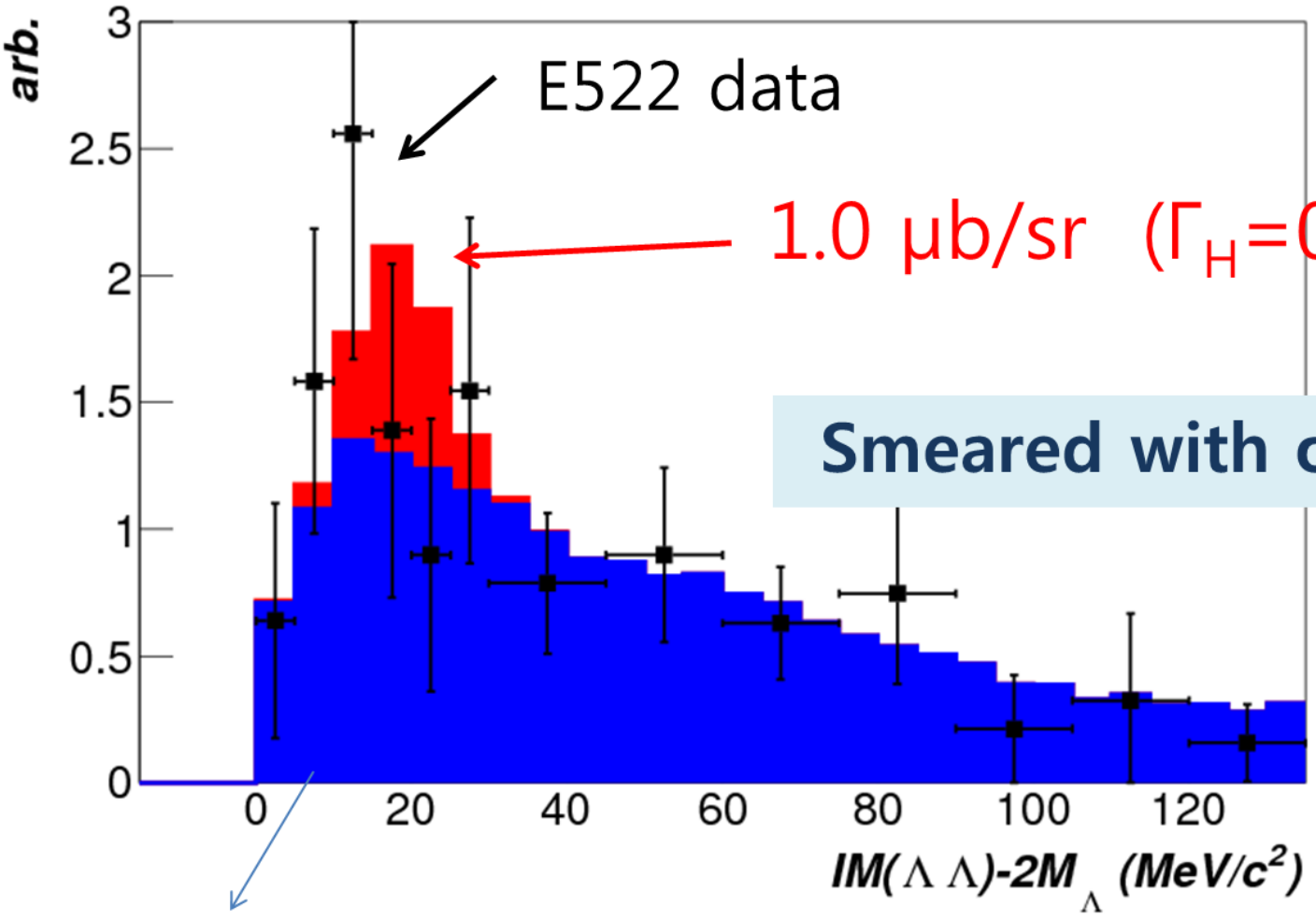
Yield Estimate

Parameters	Diamond target
K^- beam	$10^6 K^-$ per spill (6 s)
Target length	15 mm
Number of nuclei	$2.65 \times 10^{23}/\mathrm{cm}^2$
$d\sigma/d\Omega^C_L(\Lambda\Lambda)$	7.6 μb/sr
$\Delta\Omega(K^+)$	0.11 sr
Br $(\Lambda \to p\pi^-)^2$	0.41
KURAMA for K^+	0.5
HypTPC for $\Lambda\Lambda$	0.4-0.6 (0.4 for H(2250))
Yield	0.023 event / spill

from E224 data (PLB444 (1998))

- 11000 $\Lambda\Lambda$ events for 100 shifts and 1440 $H(2250)$ events for 1.0 μb/sr with a 15-mm thick diamond target.

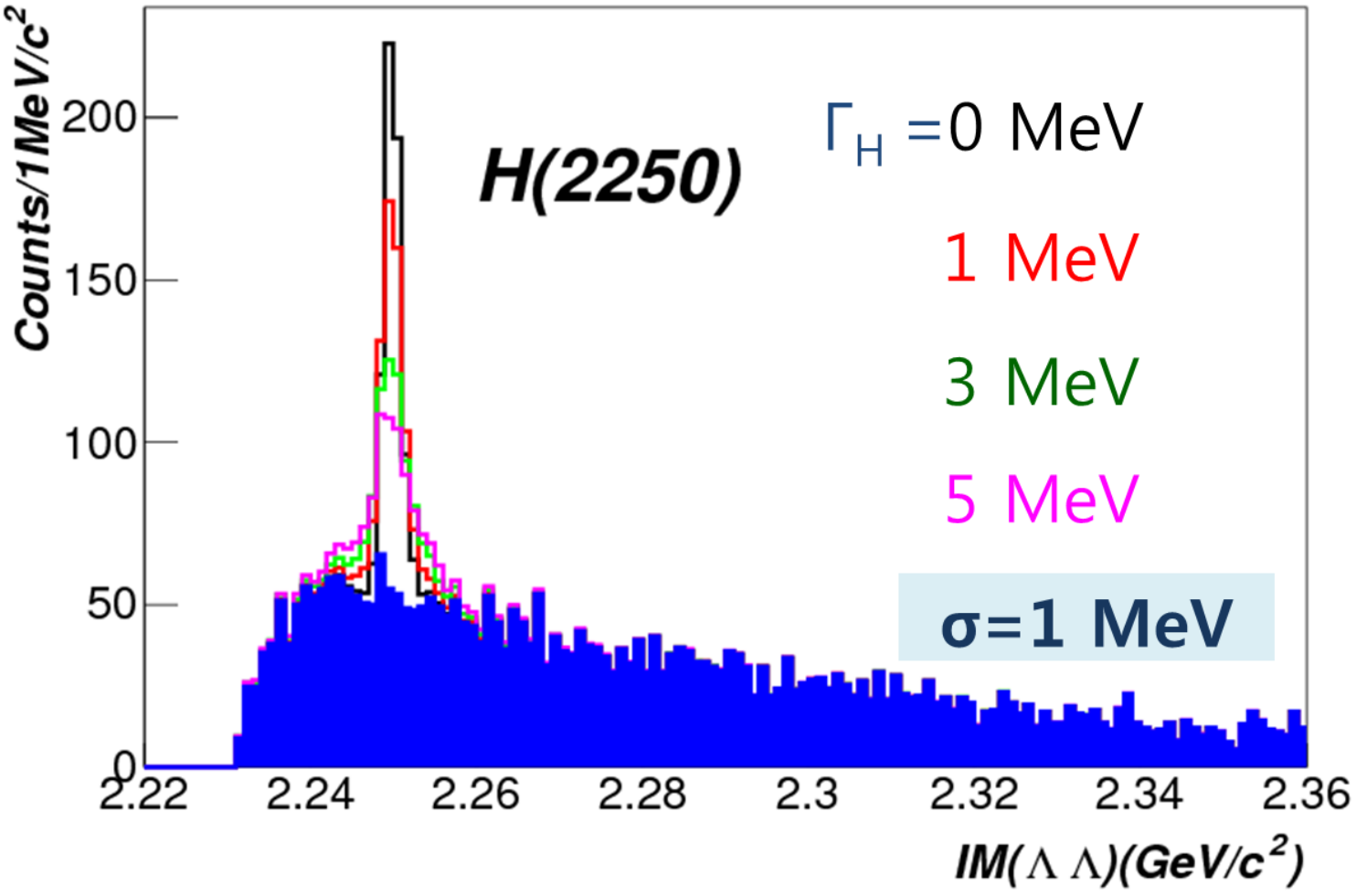
ΛΛ Spectrum from E522



INC calculation results based on Ref (Y. Nara et al, NPA 614 (1997) 433)

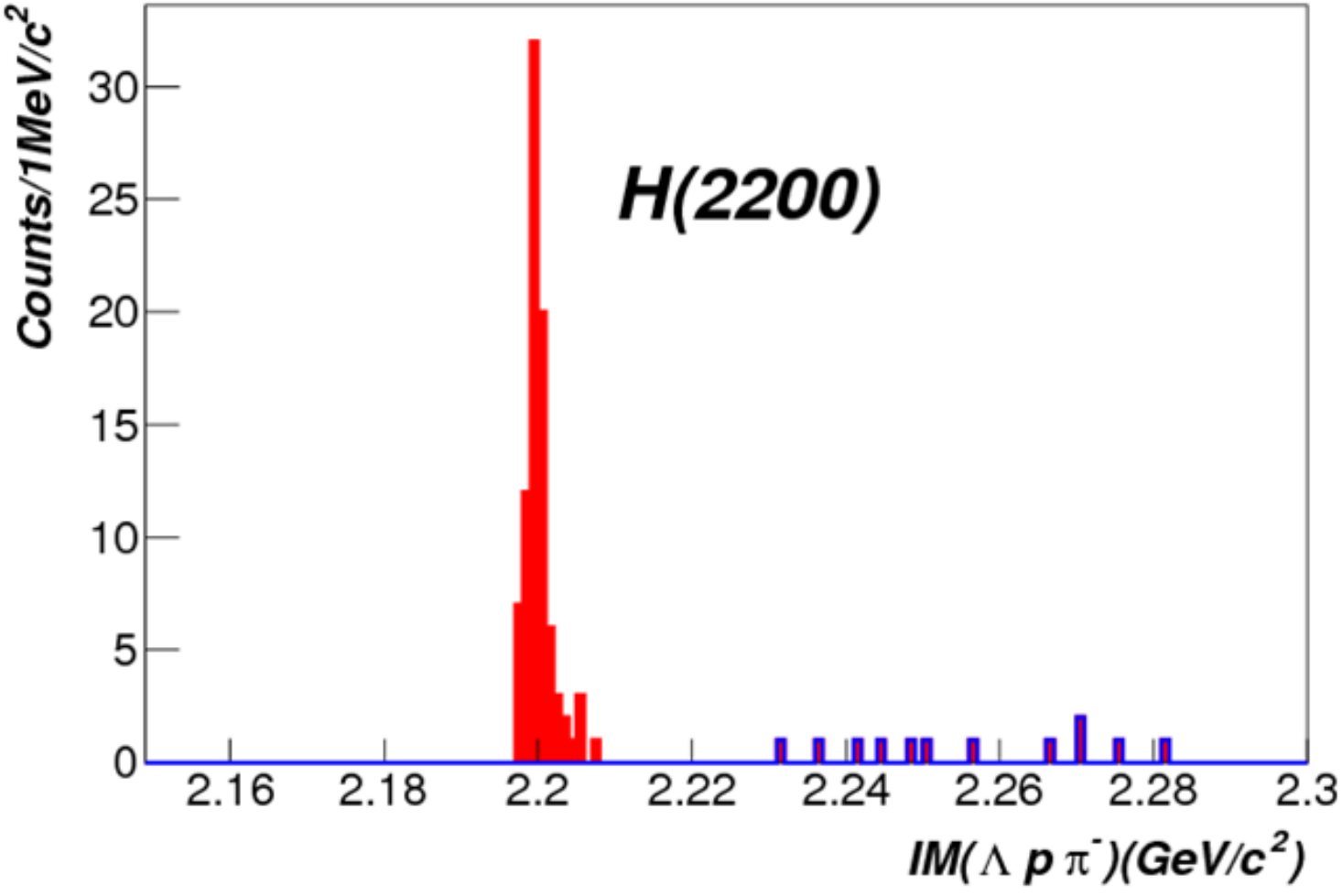
Expected $\Lambda\Lambda$ Spectrum from E42

- Lineshapes with respect to Γ_H (assuming $\sigma_m = 1$ MeV).



Simulated $\Lambda p\pi^-$ Spectrum from E42

- Almost free from background events (assuming $\sigma_m = 1$ MeV).

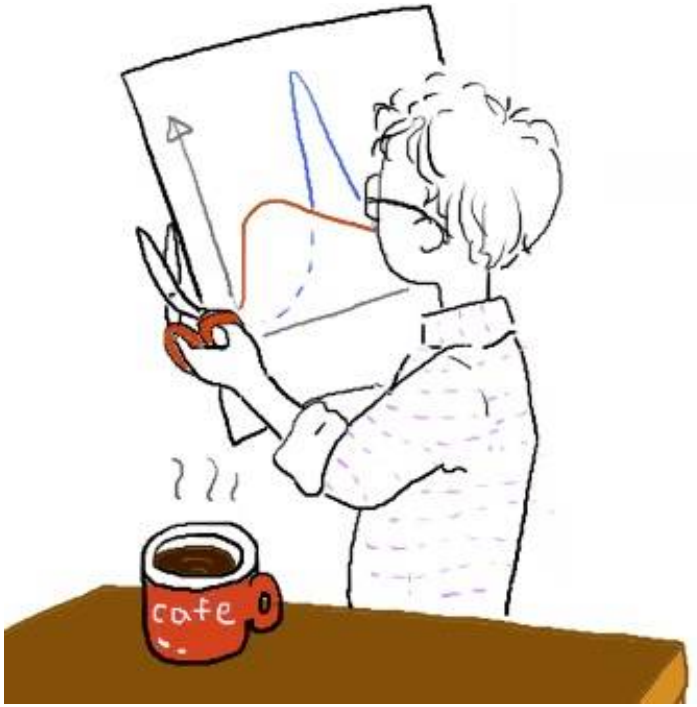


$\Xi^- p$ Scattering from E42/E45

- E45 : Missing nucleon resonances in πN and $\pi\pi N$ channels.
- $\Xi^- p \to \Xi^- p$ and $\Xi^- p \to \Lambda\Lambda$ scattering processes with a liquid hydrogen target.
- Two orders of magnitude higher statistics than ever measured in dedicated physics runs for 1 month.

Summary

- Please join J-PARC E42 and we can enjoy multi-strangeness world with the H-dibaryon search.



Thank you for your attention!