Search for the H-dibaryon
with a Large Acceptance Hyperon Spectrometer

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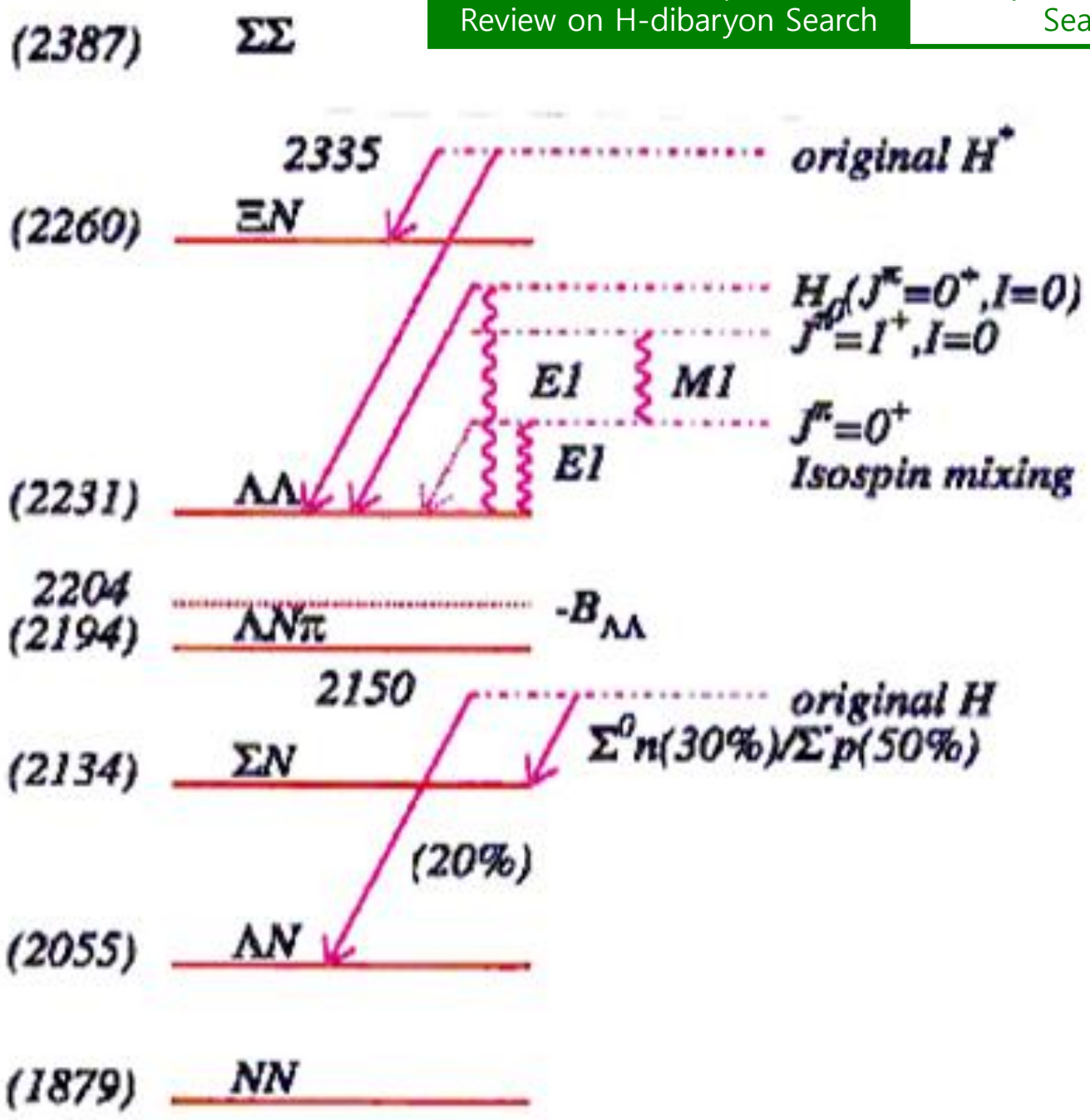
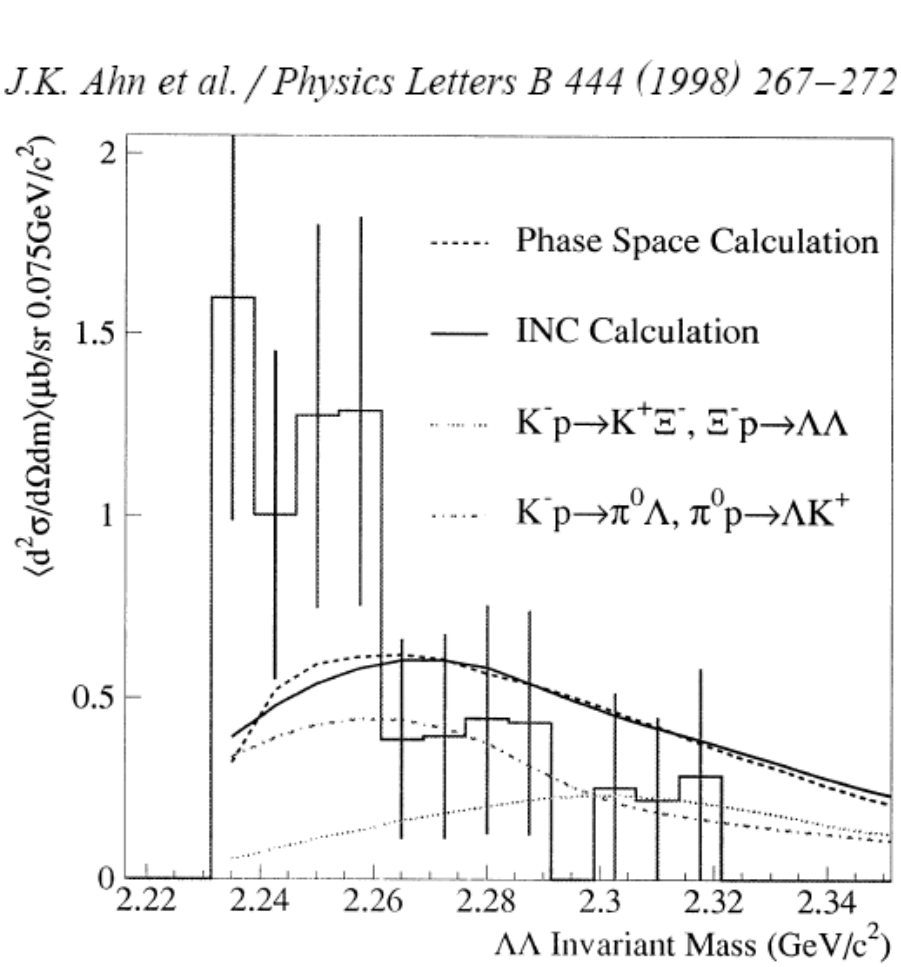
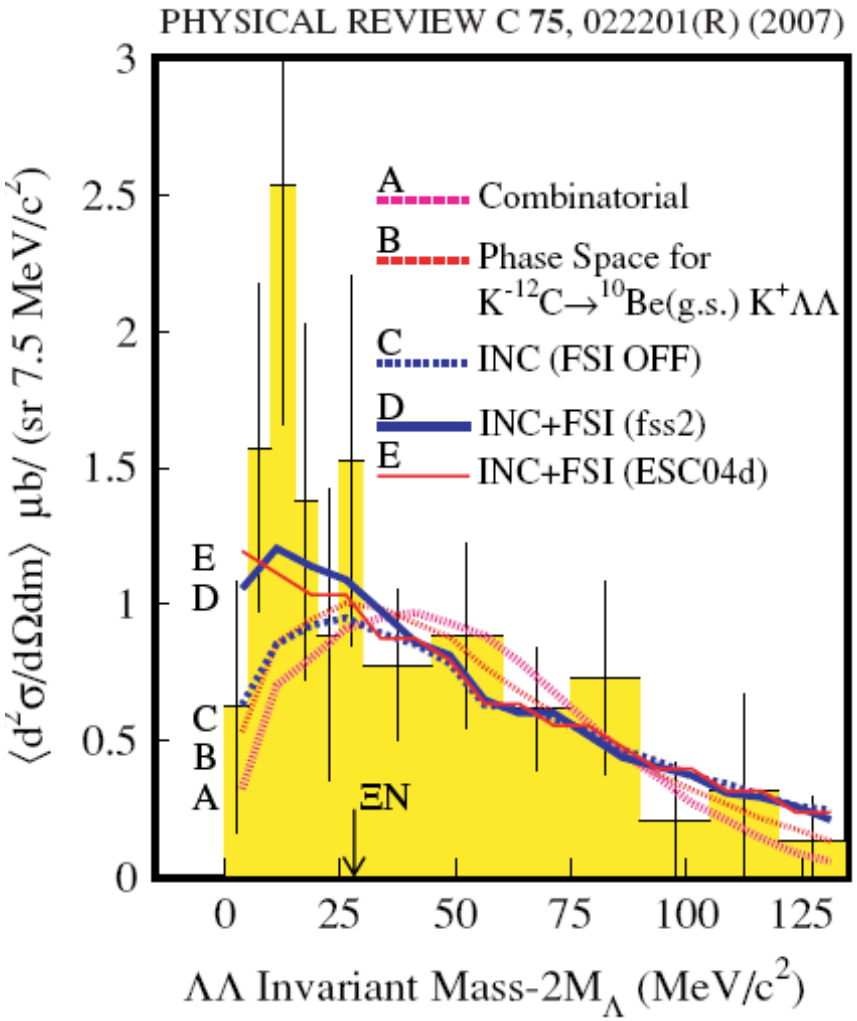
H-Dibaryon

- A stable $SU(3)_f$ singlet 6-quark (uuddss) state due to QCD color magnetic force.
- It has not been unambiguously observed experimentally.
- The observation of several double-Λ hypernuclear events ($^{\Lambda\Lambda}_{\ \ \ \ }{}^{6}$He, $^{\Lambda\Lambda}_{\ \ \ \ }{}^{10}$Be*, $^{\Lambda\Lambda}_{\ \ \ \ }{}^{11}$Be, $^{\Lambda\Lambda}_{\ \ \ \ }{}^{13}$B) in nuclear emulsion suggests that the H dibaryon is very loosely bound (< 7 MeV) or unbound relative to $2m_\Lambda$.

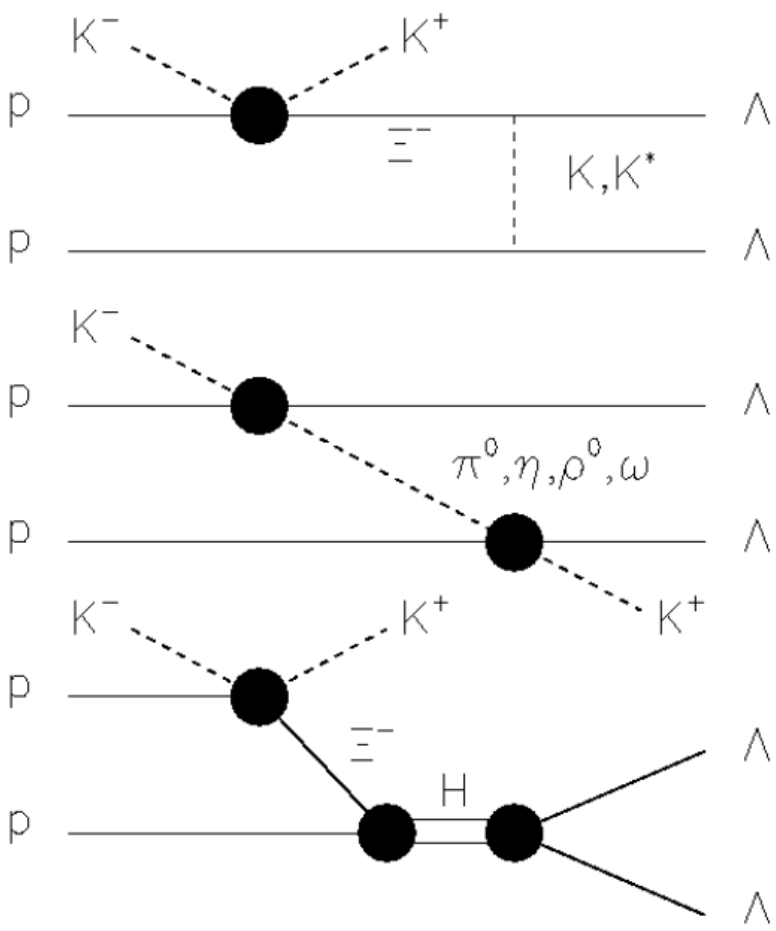

(2387) ΣΣ
2335
original H*
(2260) ΞN
H0(J^π=0+,I=0)
J^π=1+,I=0
E1
M1
J^π=0+
E1
Isospin mixing
(2231) ΛΛ
2204
(2194) ΛNπ
-BΛΛ
2150
original H
Σ0n(30%)/Σ-p(50%)
(2134) ΣN
(20%)
(2055) ΛN
(1879) NN

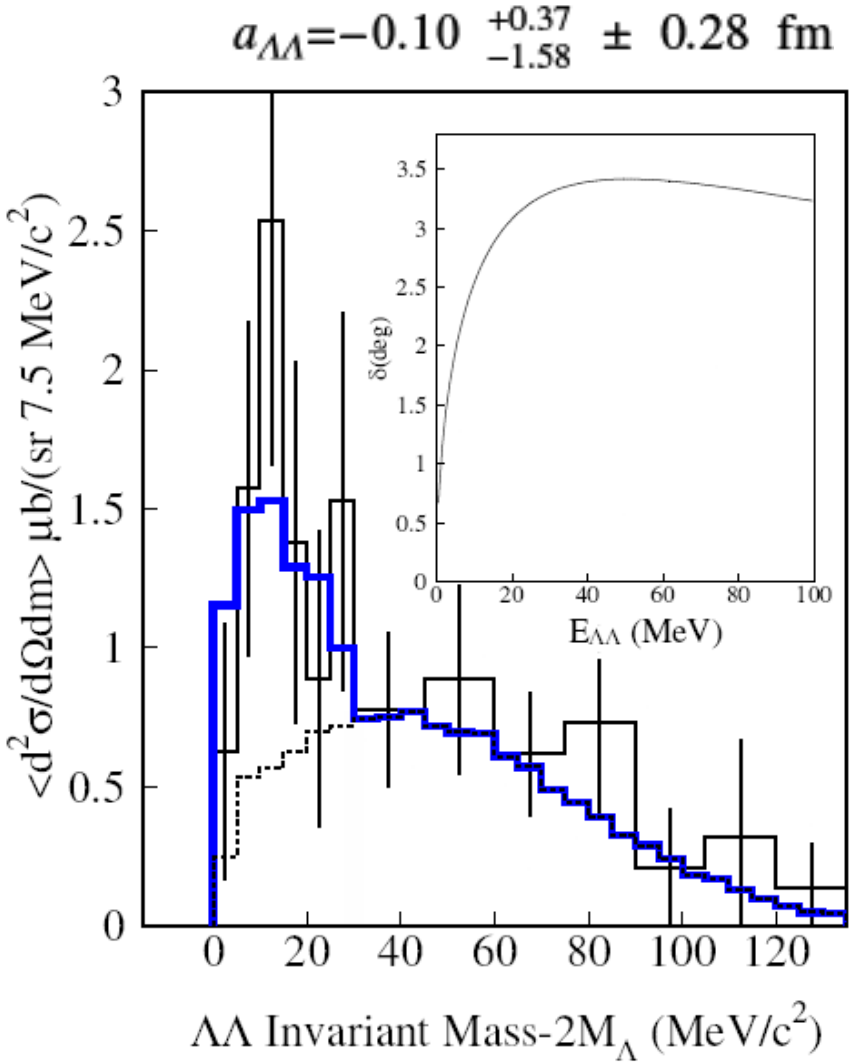
H-Dibaryon as a ΛΛ Resonance?

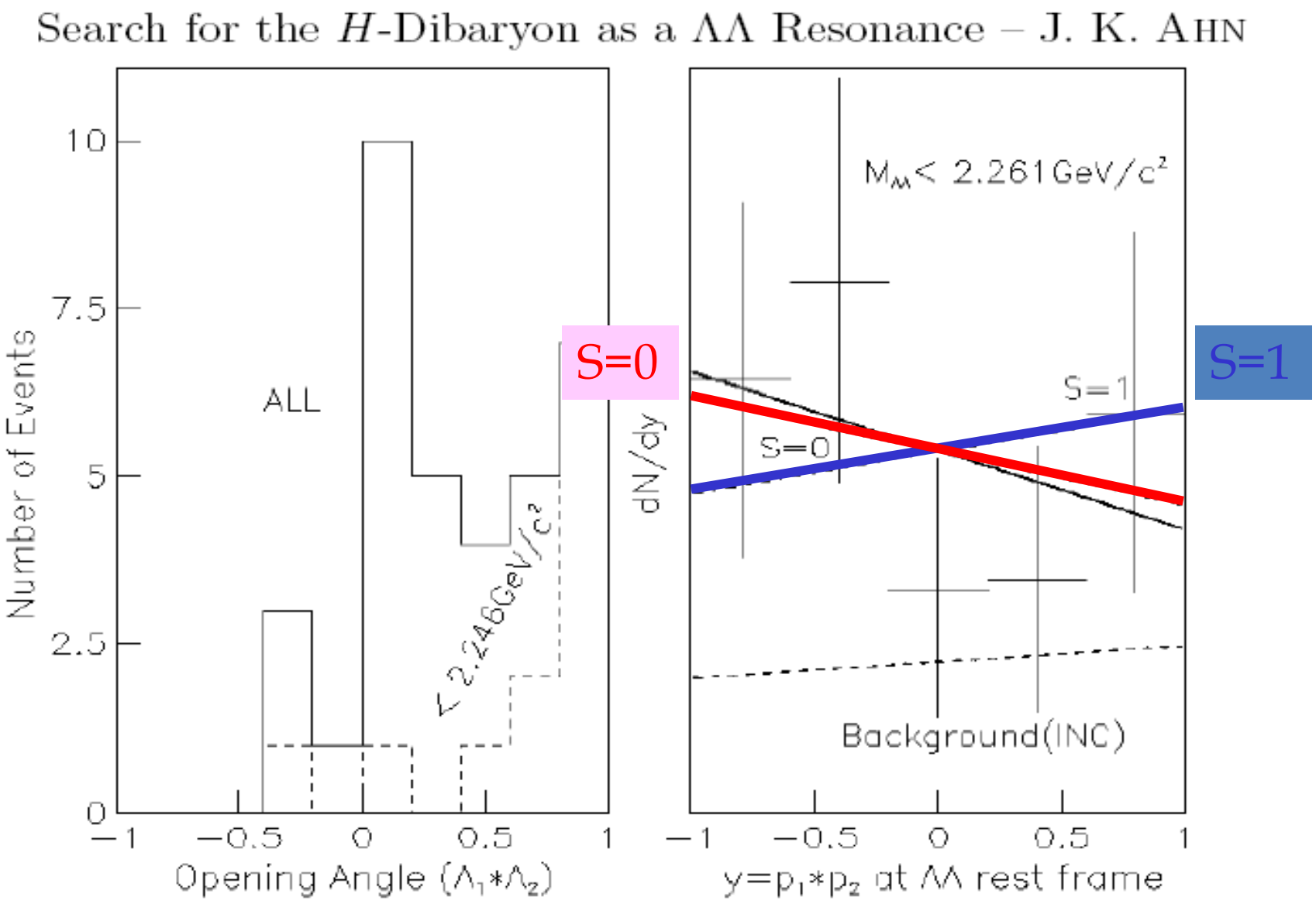




ΛΛ Resonance or ΛΛ Scattering

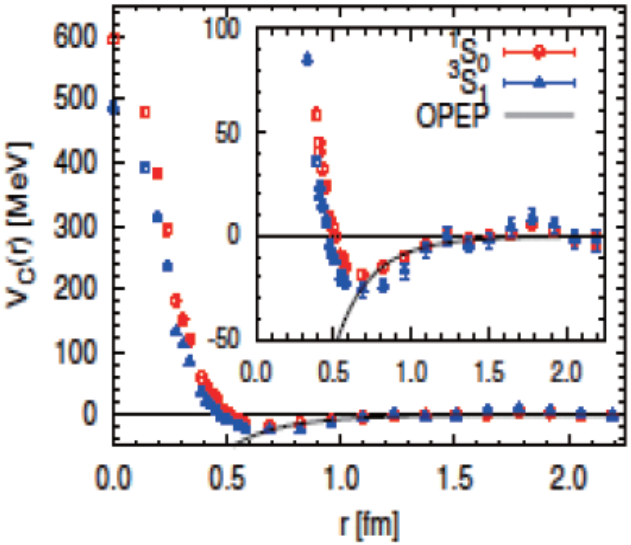





Search for the H-Dibaryon as a ΛΛ Resonance – J. K. AHN
Number of Events
ALL
M_ΛΛ< 2.246GeV/c²
Opening Angle (Λ1*Λ2)
S=0
dN/dy
M_ΛΛ< 2.261GeV/c²
S=1
S=0
Background(INC)
y=p1*p2 at ΛΛ rest frame
S=1

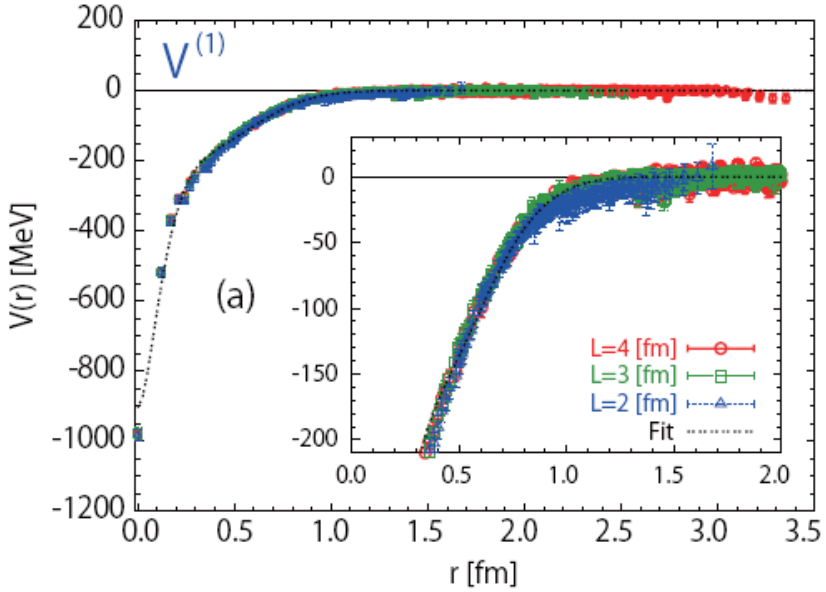
Recent Lattice QCD Results

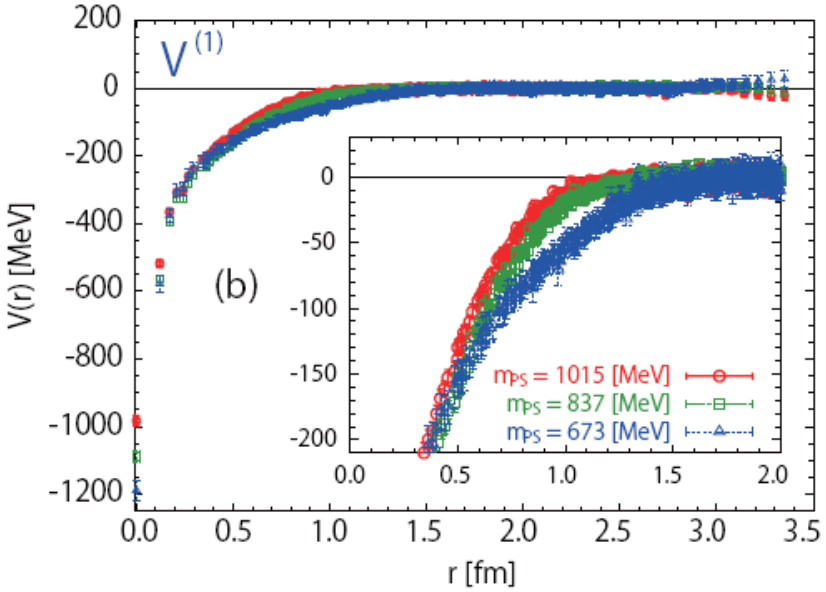
- NN interactions reproduced successfully.
- The HAL collaboration extended the LQCD calculation to BB interactions under $SU(3)_f$ symmetry.

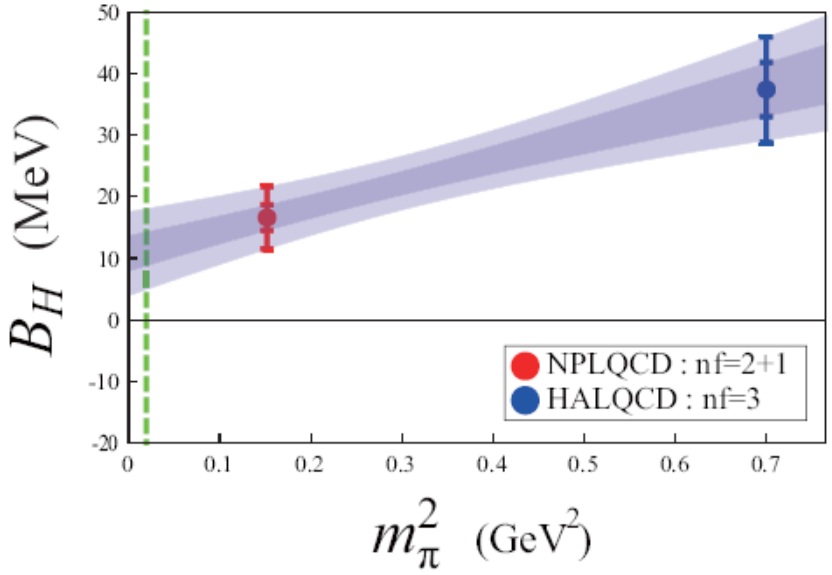


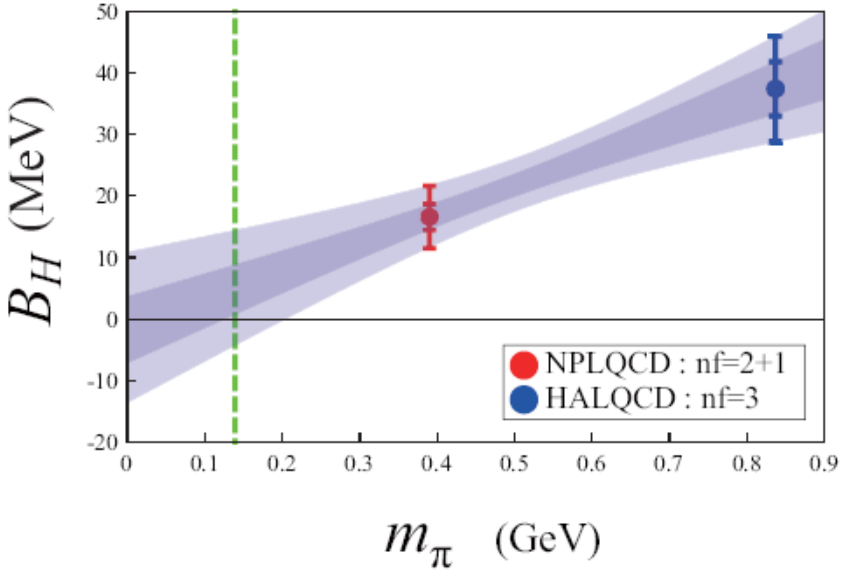
- They predict the H to be bound by 35.6 ± 7.4 ± 4.0 MeV at the pion mass of 673 MeV.
- The NPLQCD collaboration predicts 16.6 ± 2.1 ± 4.5 MeV at the pion mass of 389 MeV.

HAL Collab., PRL 106 (2011) / NP LQCD Collab. PRL 106 (2011)


V(1)
(a)
V(r) [MeV]
r [fm]
L=4 [fm]
L=3 [fm]
L=2 [fm]
Fit


V(1)
(b)
V(r) [MeV]
r [fm]
mPS = 1015 [MeV]
mPS = 837 [MeV]
mPS = 673 [MeV]


B_H (MeV)
m_π^2 (GeV^2)
NPLQCD : nf=2+1
HALQCD : nf=3


B_H (MeV)
m_π (GeV)
NPLQCD : nf=2+1
HALQCD : nf=3

Virtual State or Resonance?

- The quark model calculations of the H-mass indicate an attractive QCD force in the singlet channel, but they are much less conclusive on whether it results in a bound state, a virtual state, or a resonance.
- An attractive interaction in the S-wave may very well produce a weakly bound ΛΛ bound state, similar in character to the deuteron or the NN-isotriplet s-wave virtual state.

How Does It Look Like?

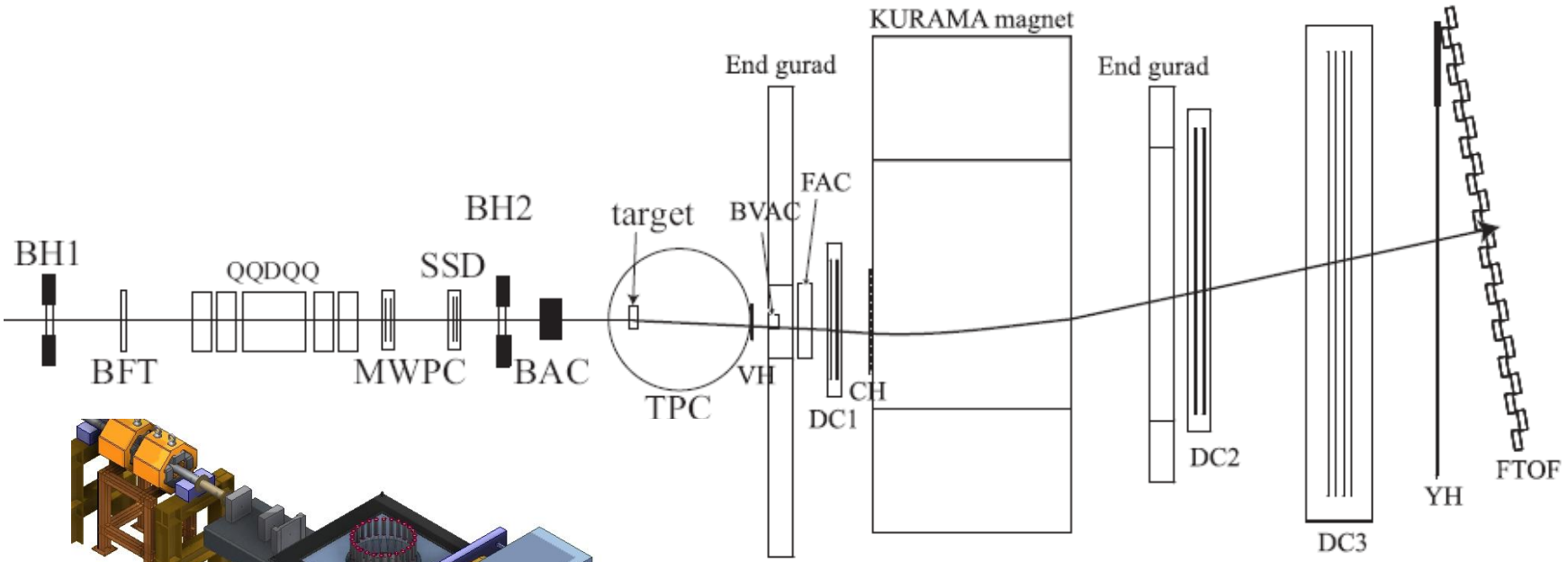
- It could show up as a virtual state in the ΛΛ S-wave, not as a resonance.
- Anomalously large scattering length (like the NN-isotriplet) leading to a threshold enhancement in the ΛΛ spectrum near threshold
- It could come either from a virtual state (like the NN-isotriplet) or it could be a sign of a bound state just below threshold (like the NN-isosinglet, where the deuteron lies).

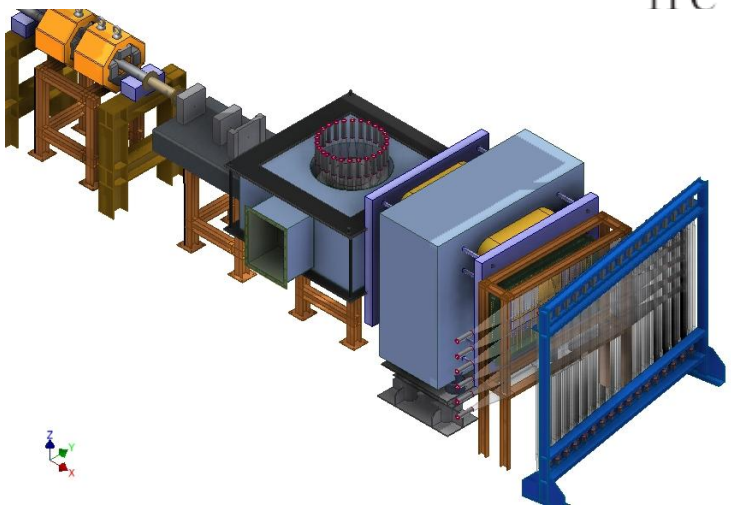
The H-dibaryon Search at J-PARC

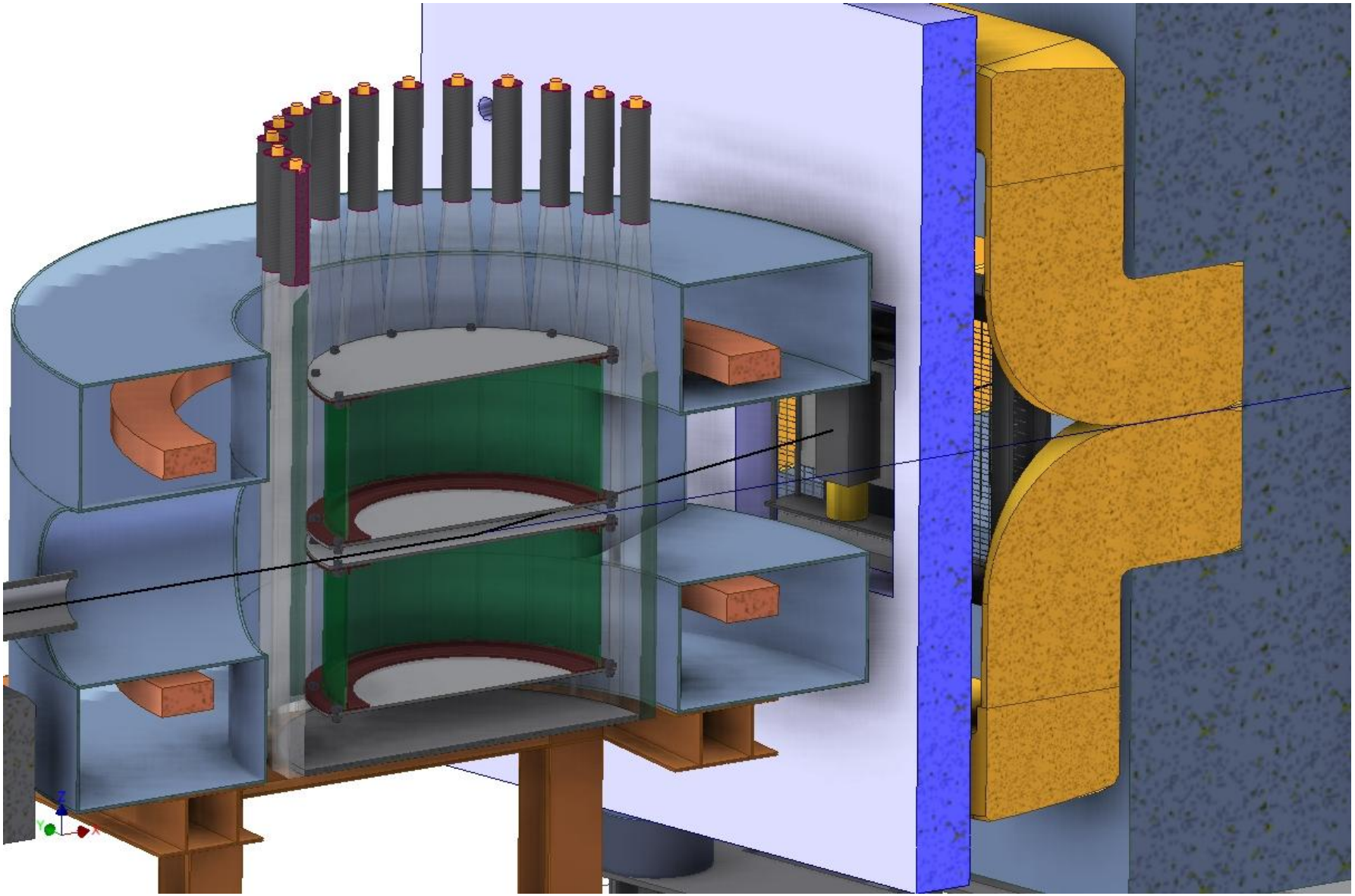
- LoI submitted to the 2001/July J-PARC PAC.
- To confirm whether the previously observed enhancement is due to the H-dibaryon or not with much higher statistics.
- (K-,K+) reaction on a Cu target at p=1.8 GeV/c.
- Large acceptance for ΛΛ detection near the target (A Helmholtz-type dipole magnet with a TPC and trigger counters).

Experimental Setup

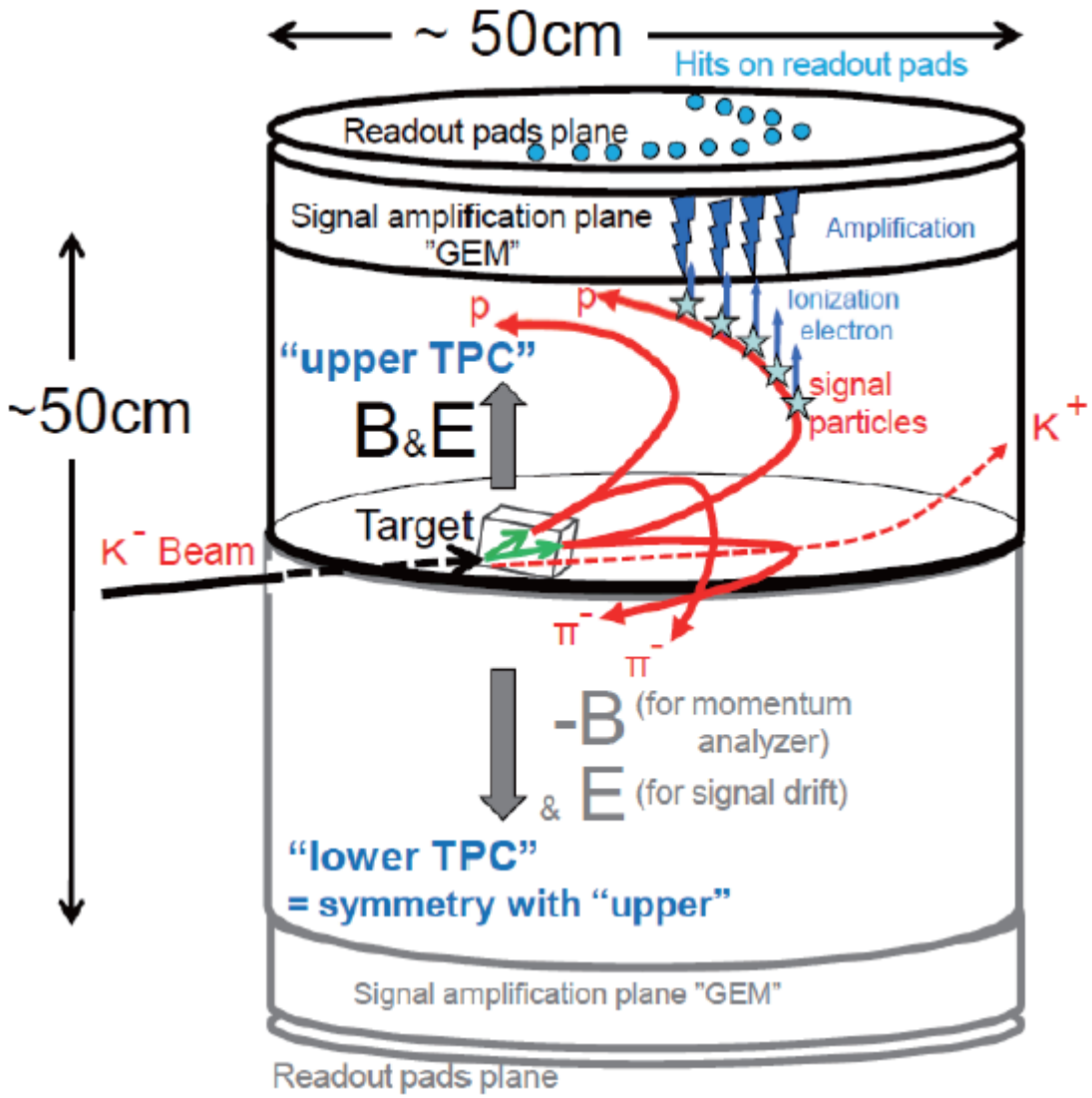
- Hyperon Spectrometer + K^+ Spectrometer

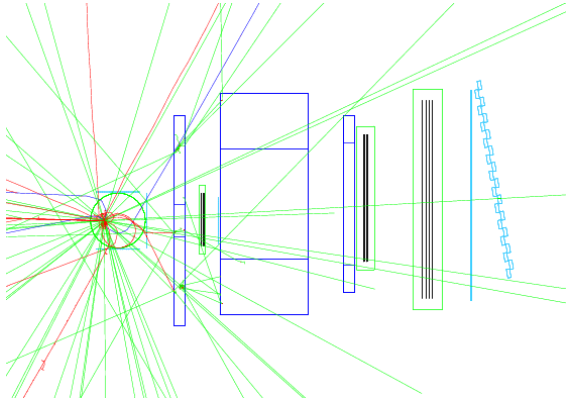


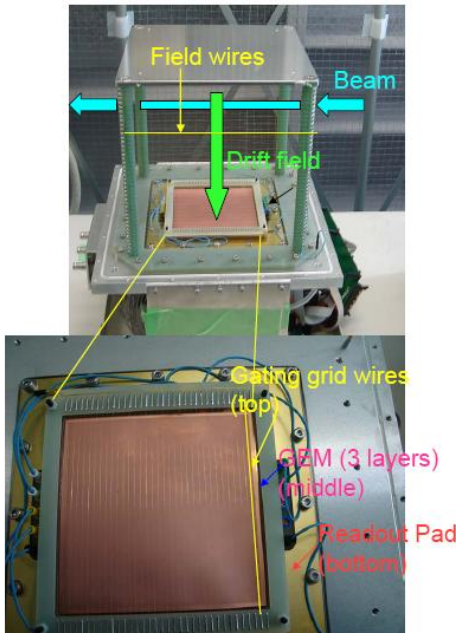




Time Projection Chamber (TPC)

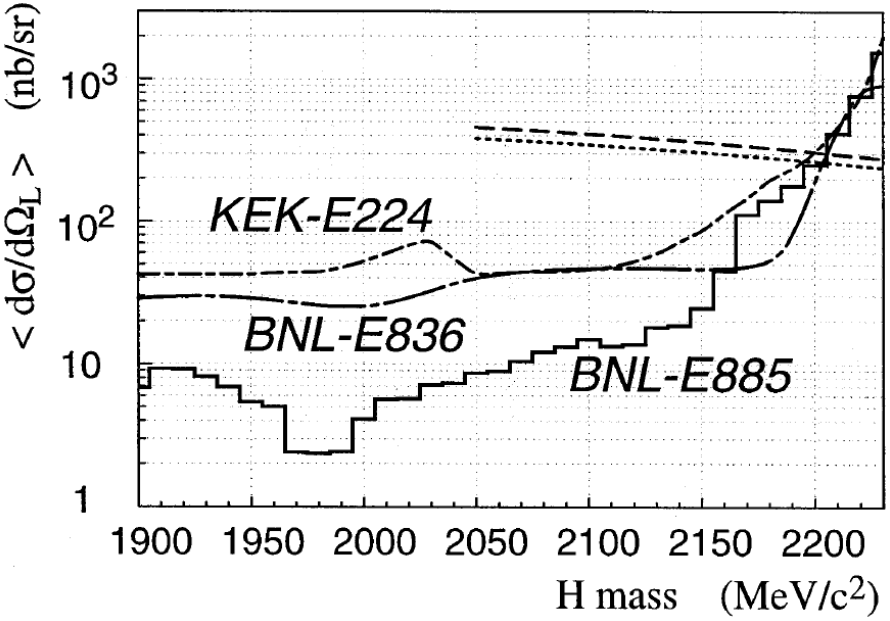


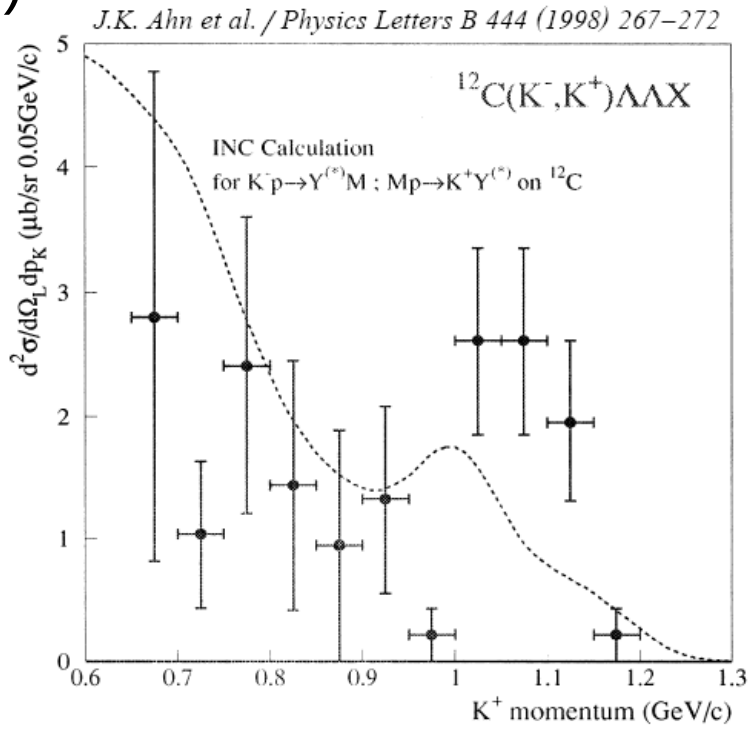




The H Production Cross Section?

- Theoretical prediction by Aerts and Dover for K-(pp) → K+H on ^{3}He (~0.2 μb/sr)
- KEK-E224 measurement for ^{12}C(K-,K+)ΛΛX (7.6 μb/sr and 1 μb/sr for the H)



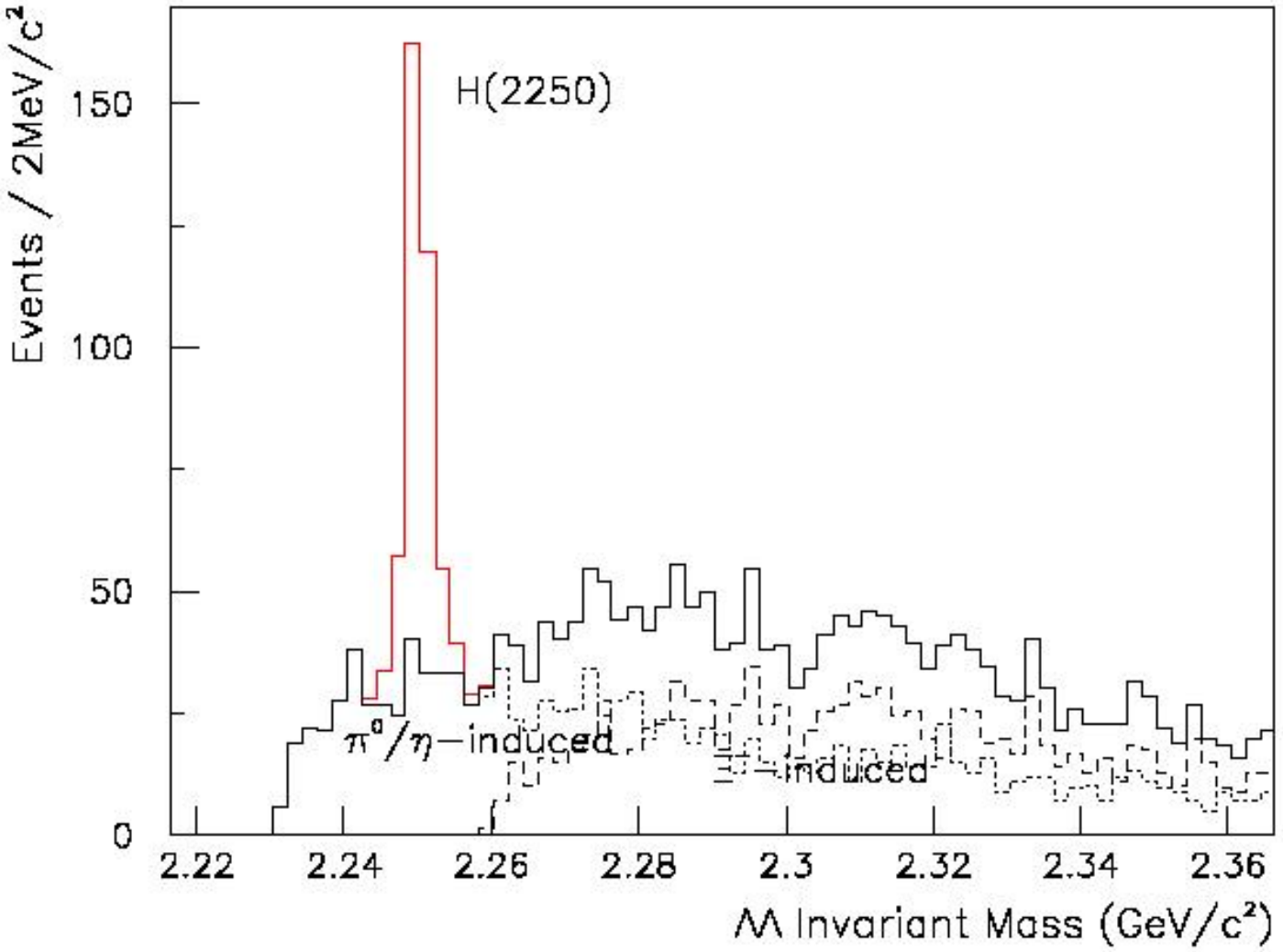


Yield Estimation

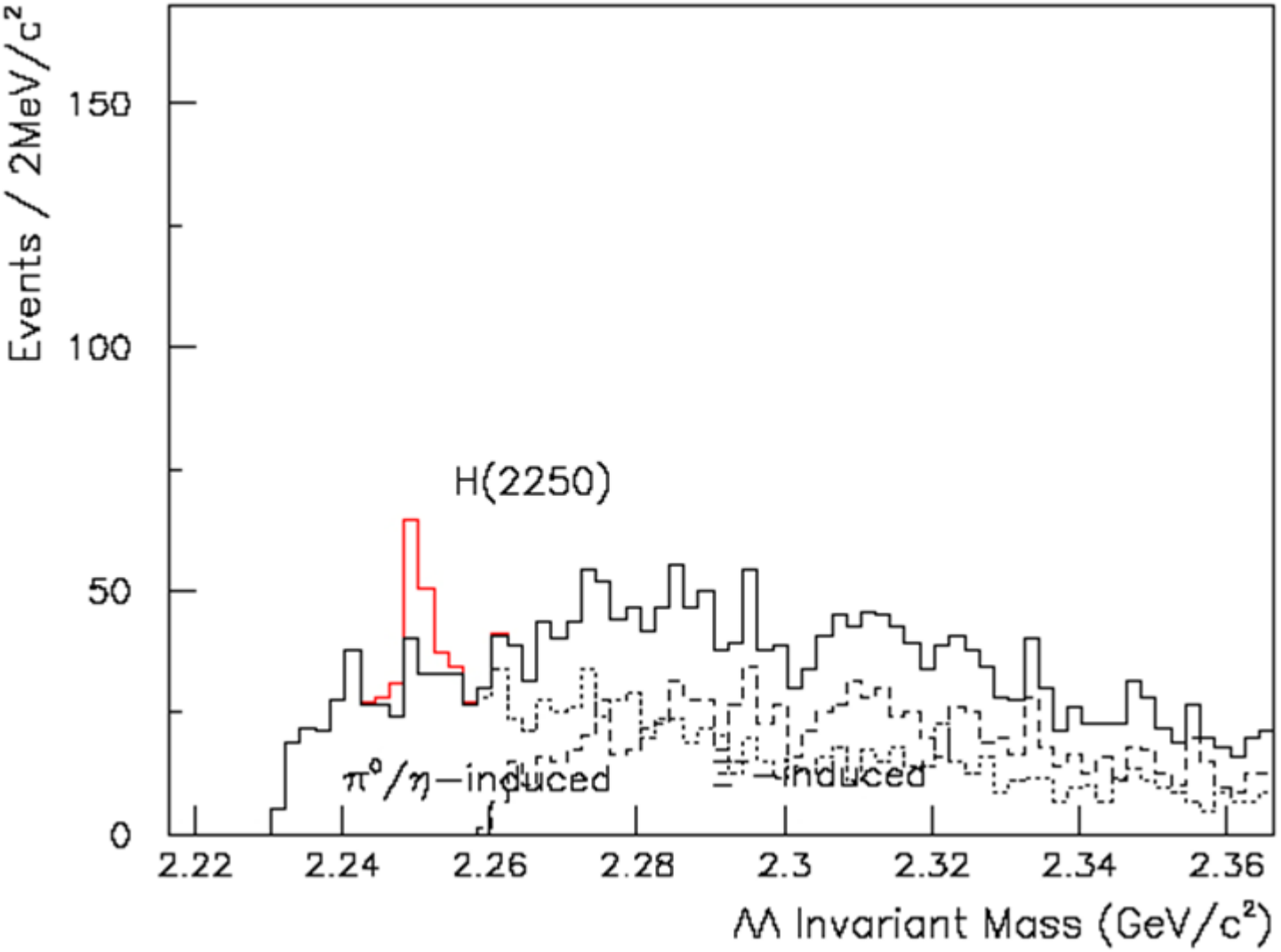
- 3300 ΛΛ events for 100 shifts and 47 H(2250) events for 0.2 μb/sr.

Parameters	Values
K^- beam	$10^6 K^-$ per spill (6 second)
Cu target	4.25×10^{22}
$d\sigma/d\Omega_L^{Cu}(\Lambda\Lambda)$	14.6μb/sr
$\Delta\Omega$	0.11 sr
Branching ratio ($\Lambda \to p\pi^-$)	0.64
Detection efficiency of K^+ with Kurama	0.5
Detection efficiency of two Λ with TPC	0.5
Yield	0.007 event / spill

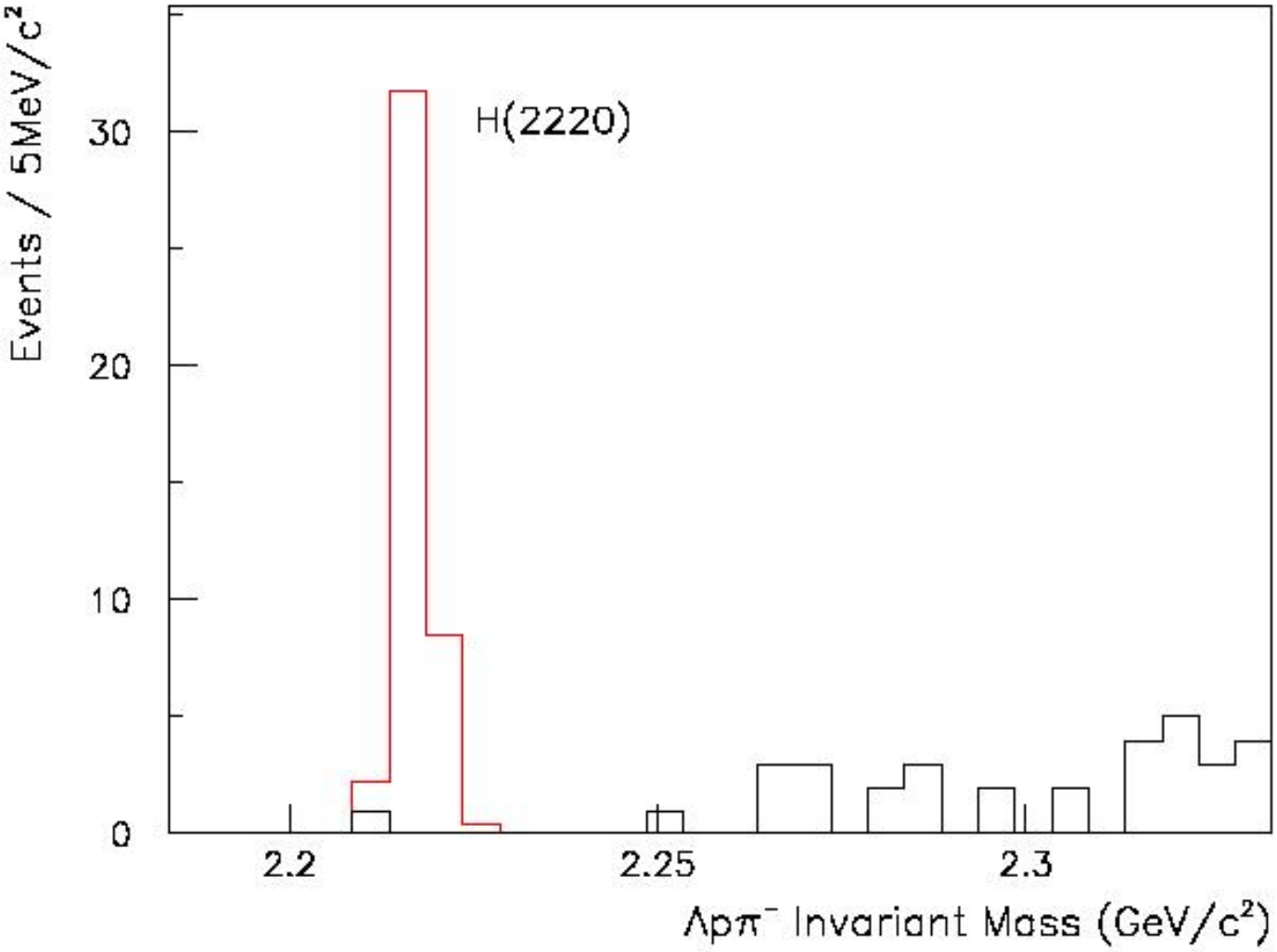
H(2250) for 1 μb/sr



H(2250) for 0.2 μb/sr



H(2220) in Λpπ Mass



Summary

- 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.
- We propose to search for the H-dibaryon resonance in ΛΛ system and the bound one decaying weakly into Λpπ system at J-PARC.
- We plan to construct a hyperon spectrometer with a TPC to track Λ decays.
- We expect to collect 3300 ΛΛ events for 100 shifts.