Search for the H-Dibaryon with a Large Hyperon Spectrometer

Jung Keun Ahn
(Pusan National University)

on behalf of
The **P42** Collaboration

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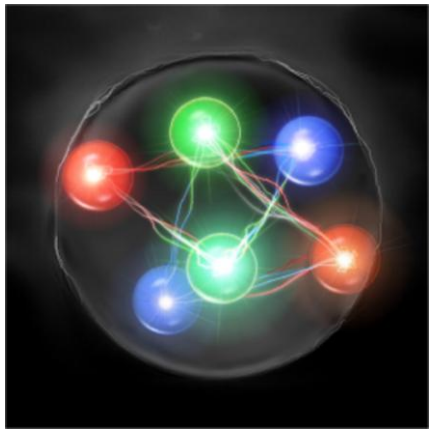

H-Dibaryon

- 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 (${}^{6}_{\Lambda\Lambda}He$, ${}^{10}_{\Lambda\Lambda}Be^{*}$, ${}^{11}_{\Lambda\Lambda}Be$, ${}^{13}_{\Lambda\Lambda}B$) in nuclear emulsion suggests that the H-dibaryon is very loosely bound (< 7 MeV) or unbound relative to $2m_{\Lambda}$.

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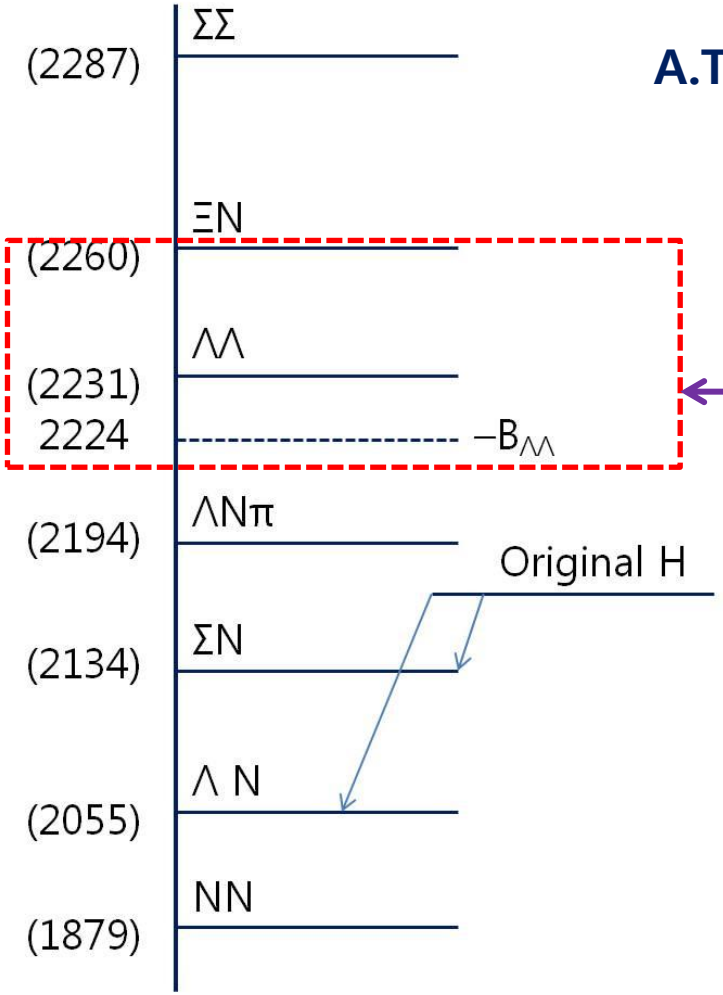
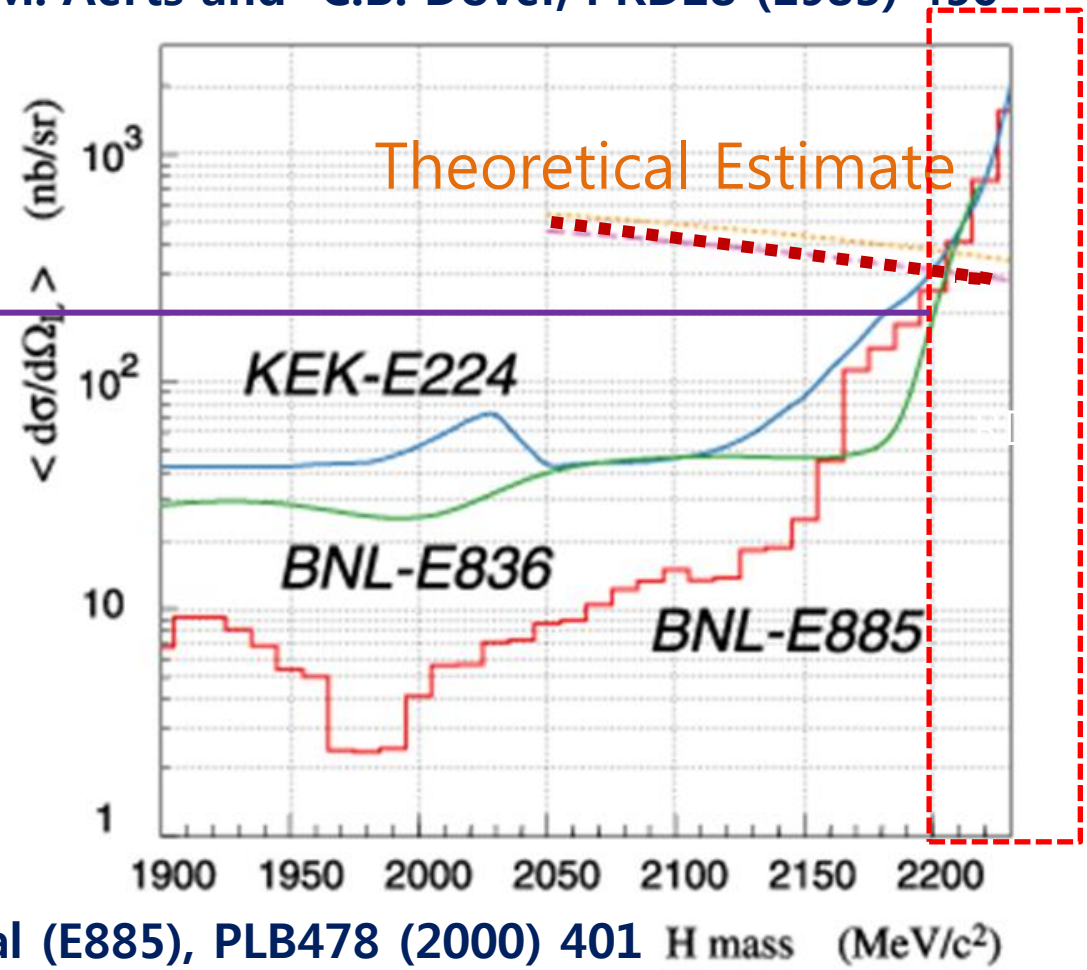
UL on H-Dibaryon Production @ 90% CL



A.T.M. Aerts and C.B. Dover, PRD28 (1983) 450

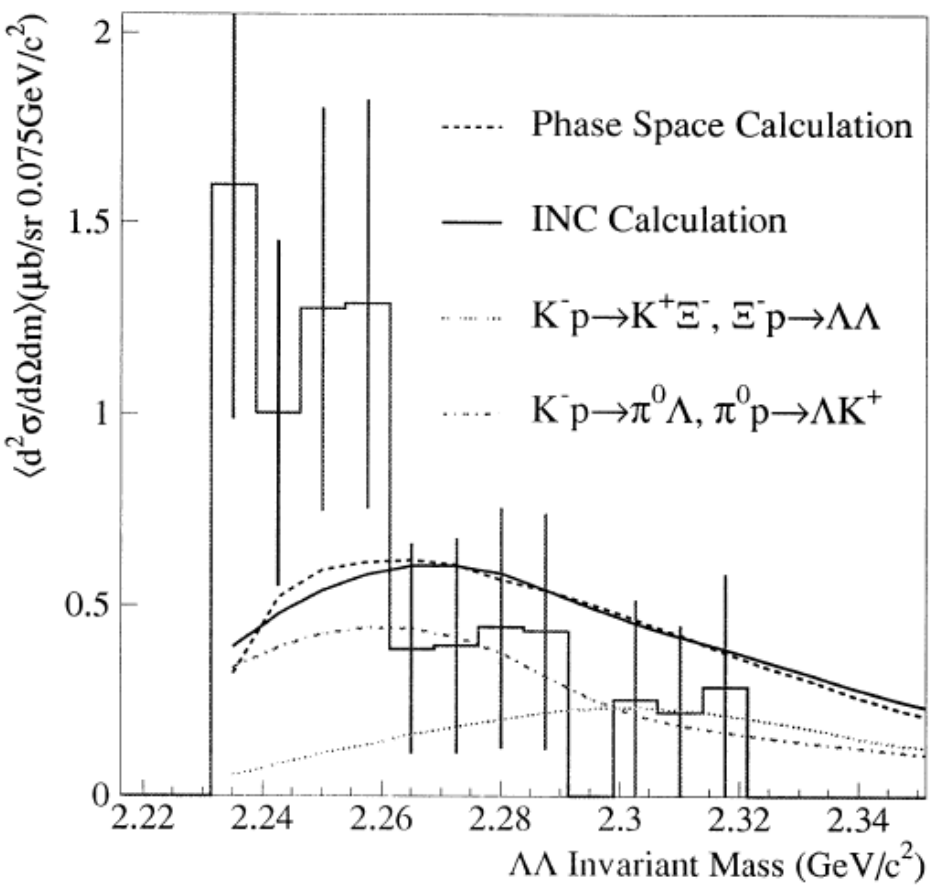


K. Yamamoto et al (E885), PLB478 (2000) 401

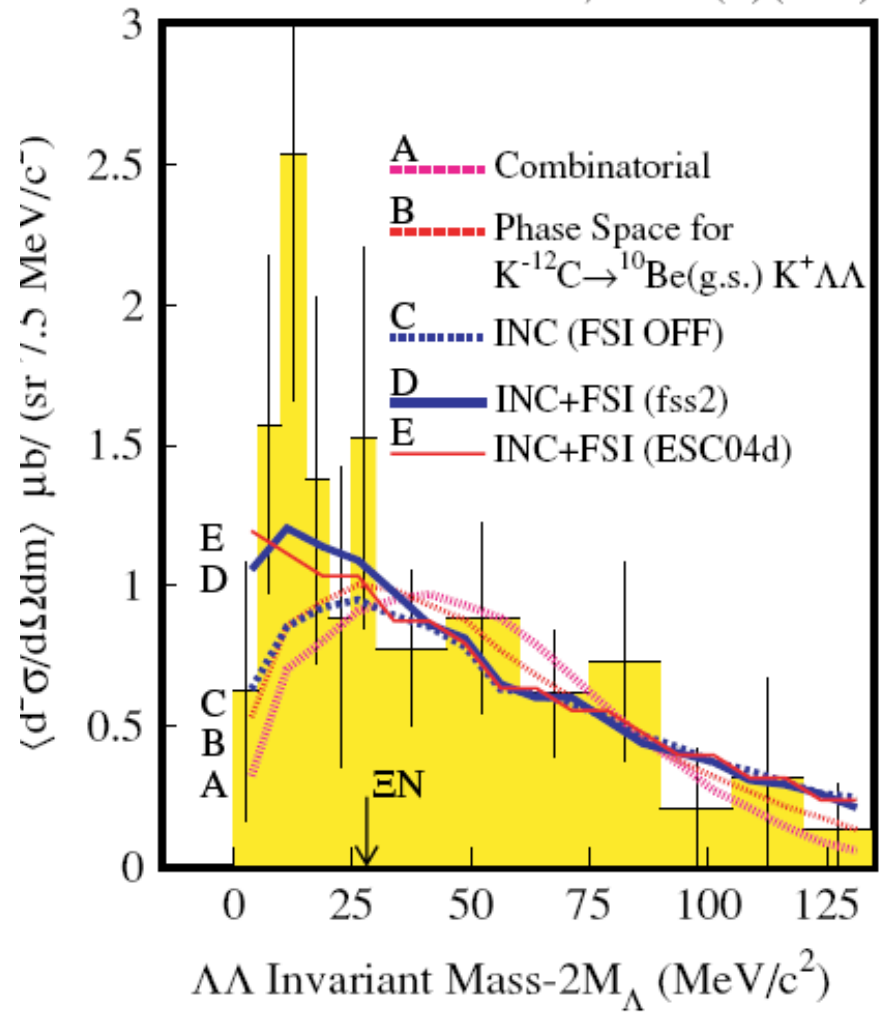
$H(2250)$

H-Dibaryon as a ΛΛ Resonance?

J.K. Ahn et al. / Physics Letters B 444 (1998) 267–272

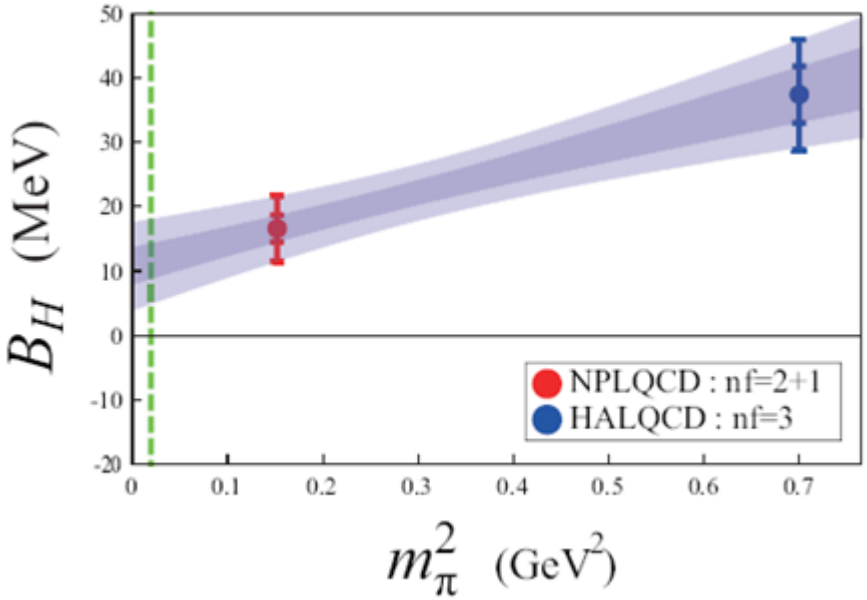


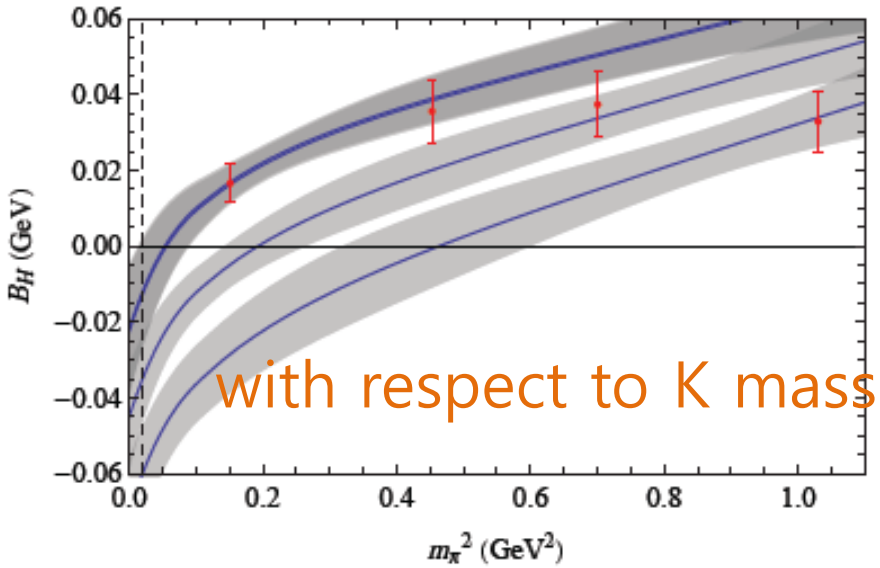
PHYSICAL REVIEW C 75, 022201(R) (2007)



H-Dibaryon from Lattice QCD

- 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.





HAL Collab., PRL 106 (2011) / NP LQCD Collab. PRL 106 (2011)
Shanahan, Thomas, Young, PRL 107 (2011)

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Bound, Virtual State, or Resonance?

- Weakly-bound : H → Λpπ weak decay
- Virtual state : ΛΛ threshold effect
- Anomalously large scattering length (like the NN-isotriplet) leading to a threshold enhancement in the ΛΛ spectrum near threshold
- The enhancement could be a sign of a bound state just below threshold (like the NN-isosinglet, where the deuteron lies).
- Resonance : Breit-Wigner peak in the ΛΛ mass spectrum.

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The H-Dibaryon Search at J-PARC (**P42**)

In respond to the 13th PAC's comments :

- Detailed Design of the Spectrometer and the Time Projection Chamber
- Target Choice
- Full Detector Simulation
- Sensitivity to H-production Cross-section
- Collaboration, Budget, and Schedule

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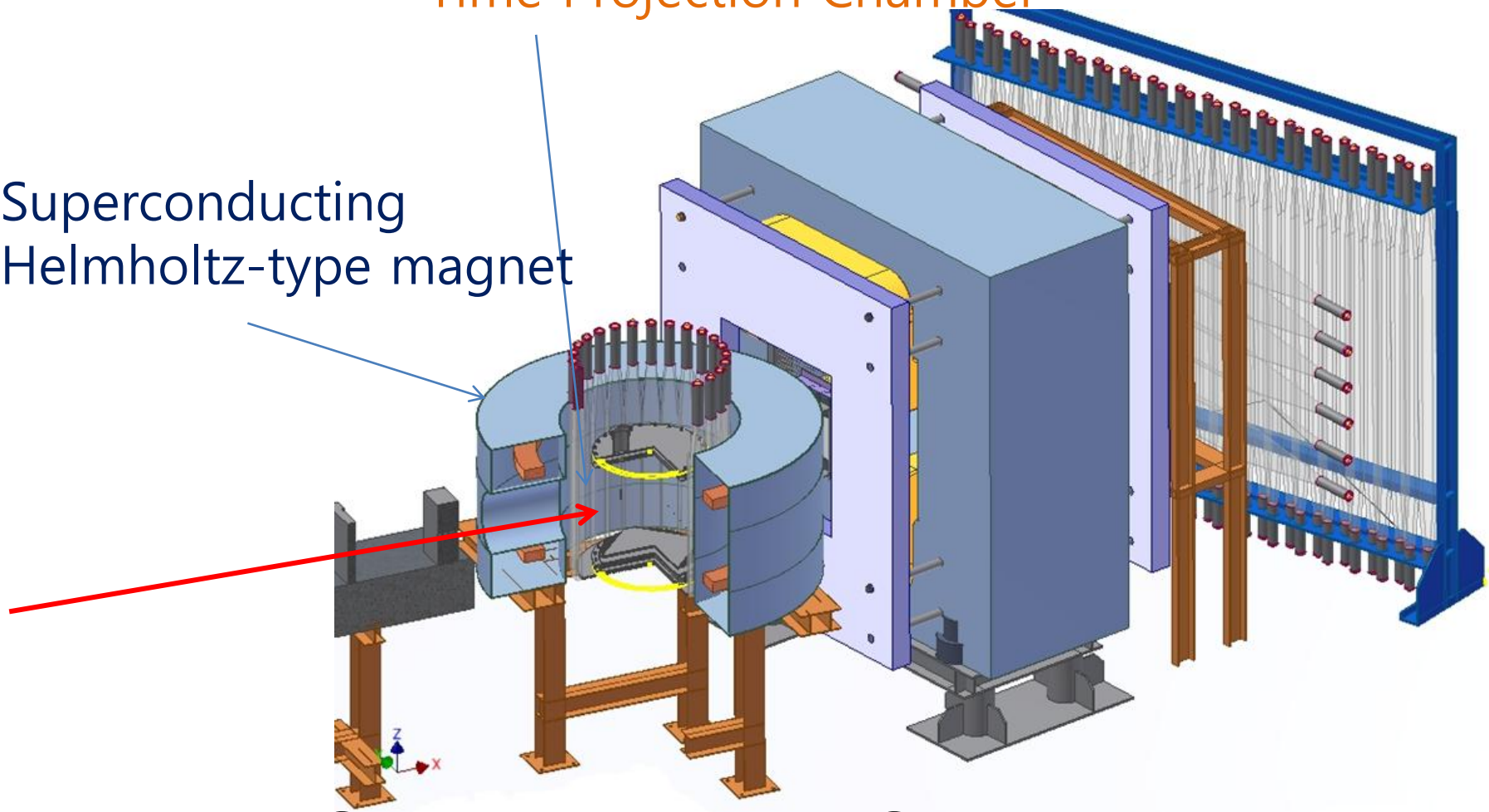
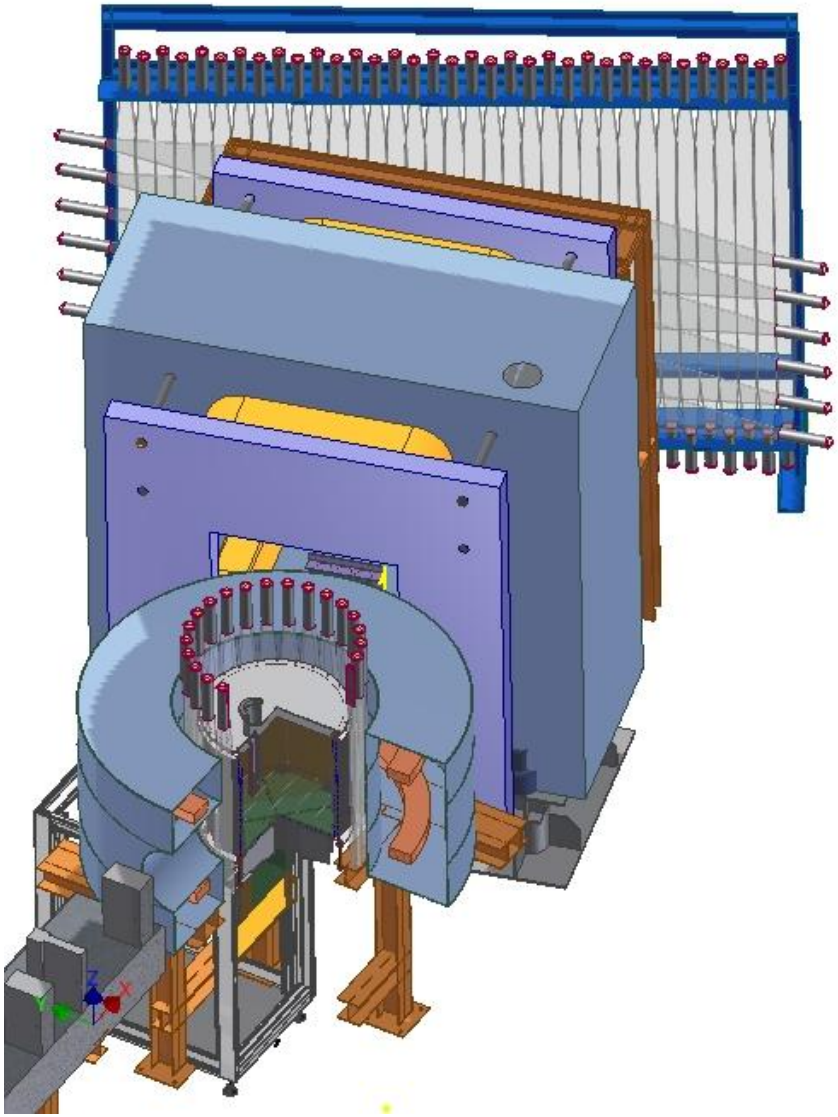
$^{12}C(K^-,K^+\Lambda\Lambda)X$ @ 1.8 GeV/c

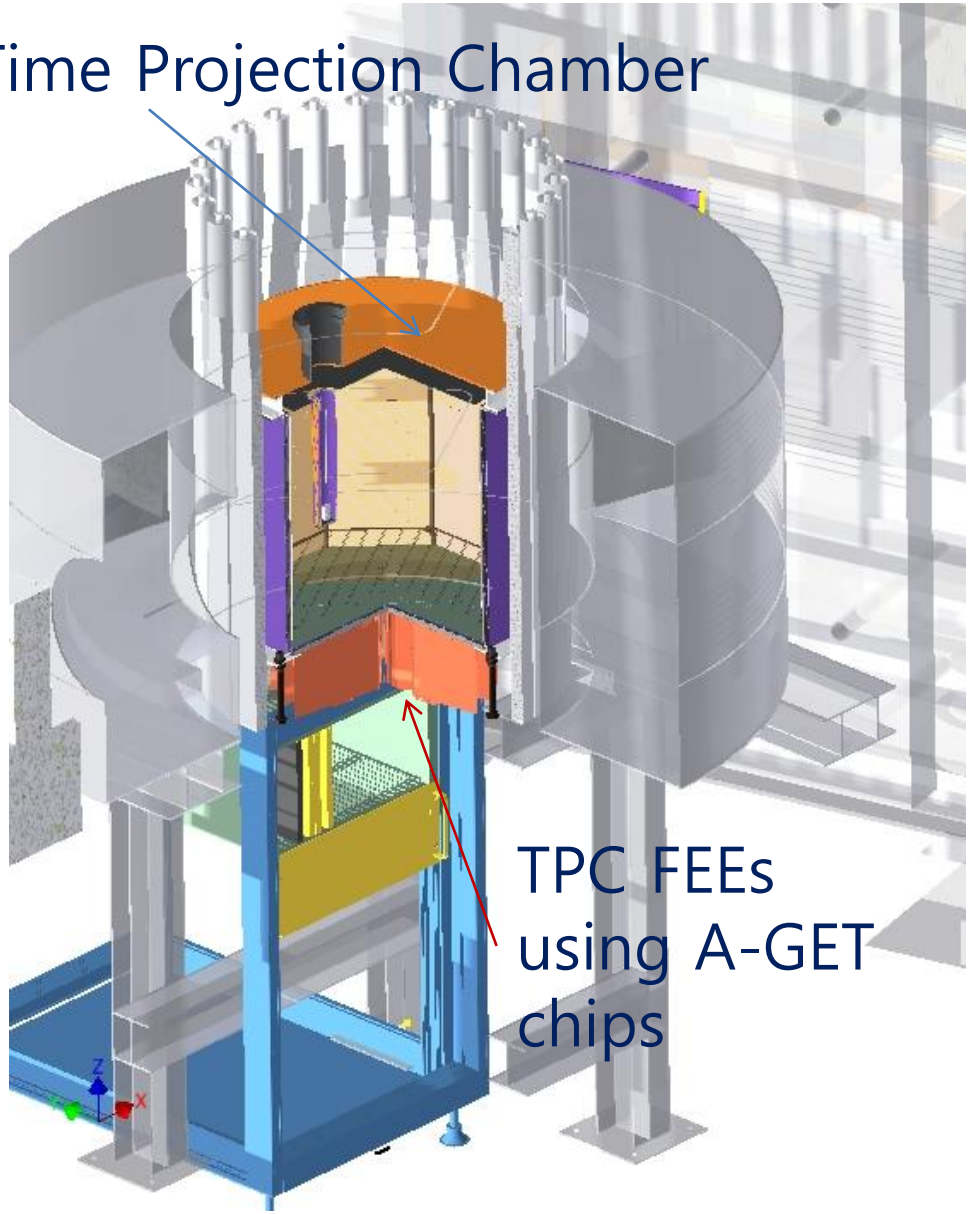
Time Projection Chamber

Superconducting Helmholtz-type magnet

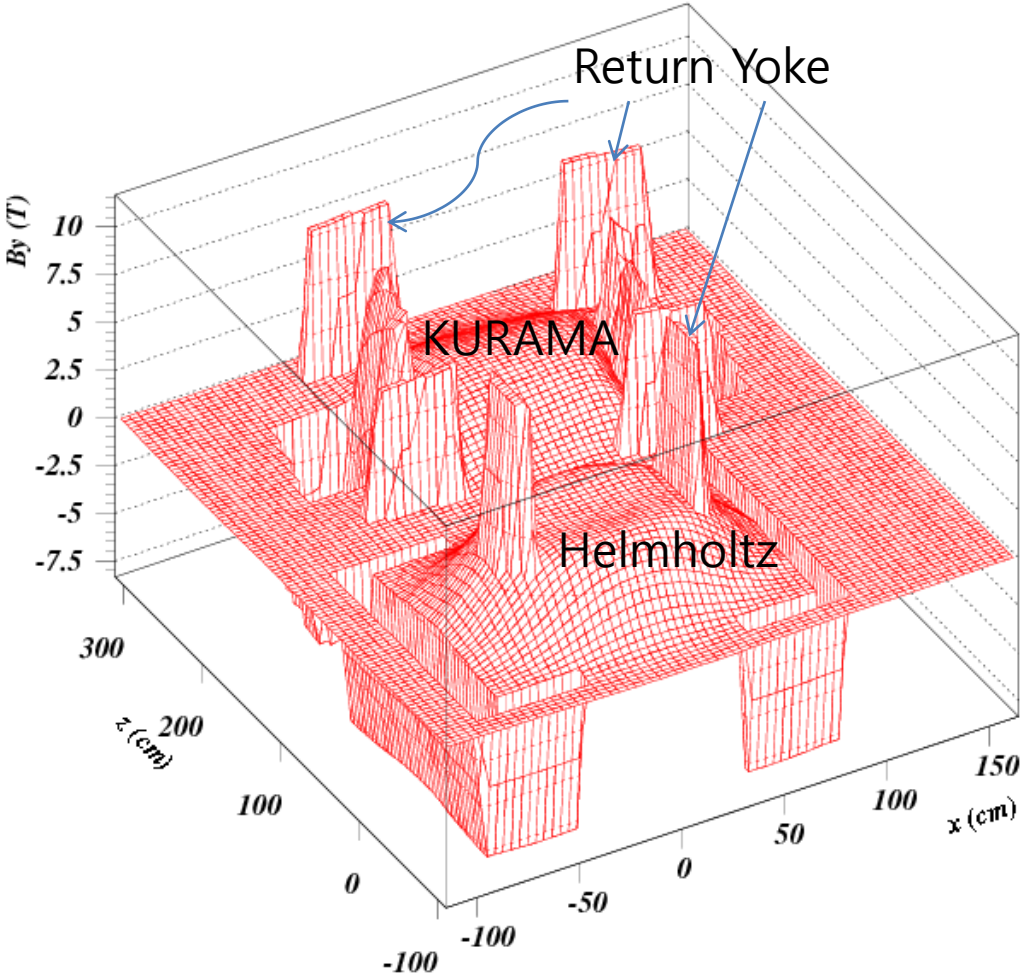


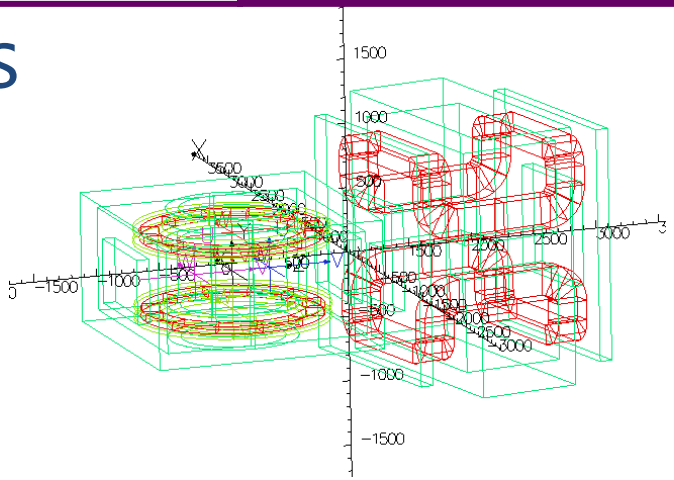
- Hyperon Spectrometer + K^+ Spectrometer

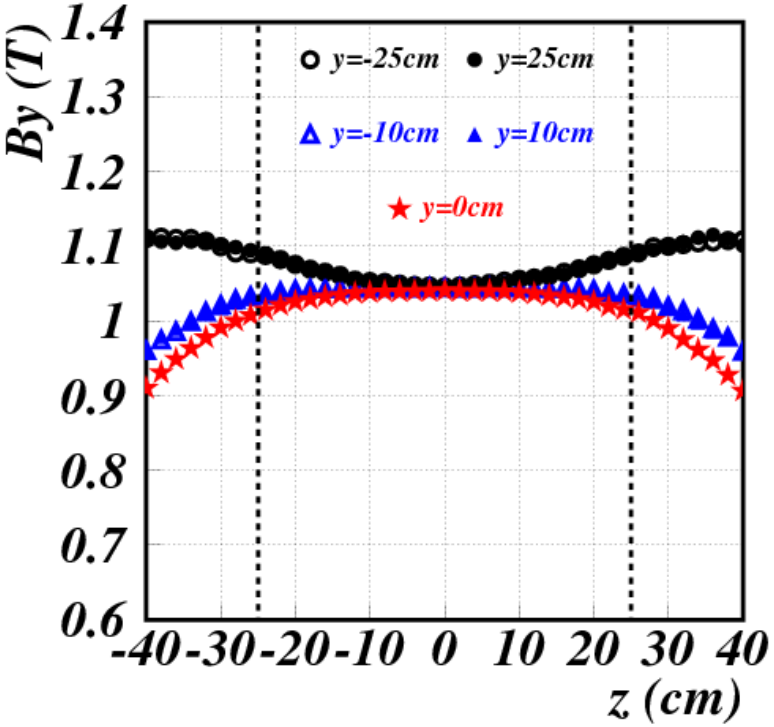



Time Projection Chamber
TPC FEEs using A-GET chips

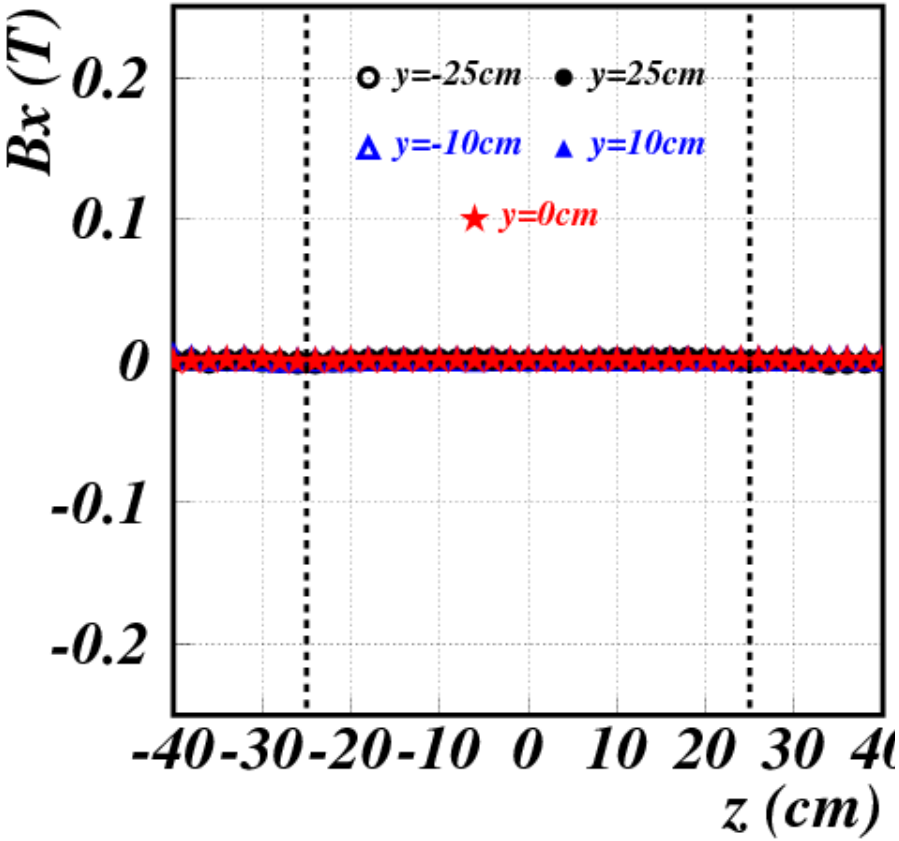
Magnetic Field Strengths calculated using OPERA-3D

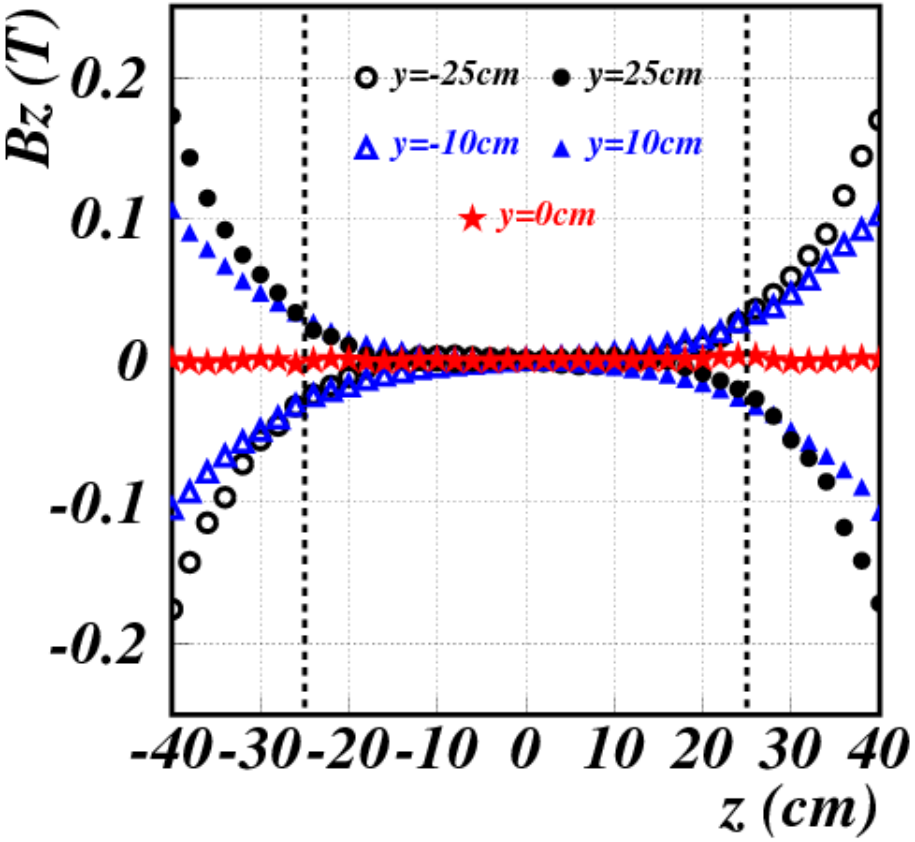




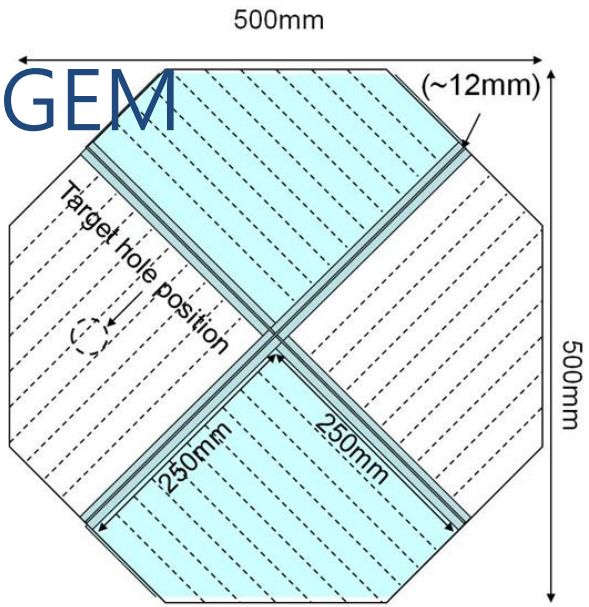


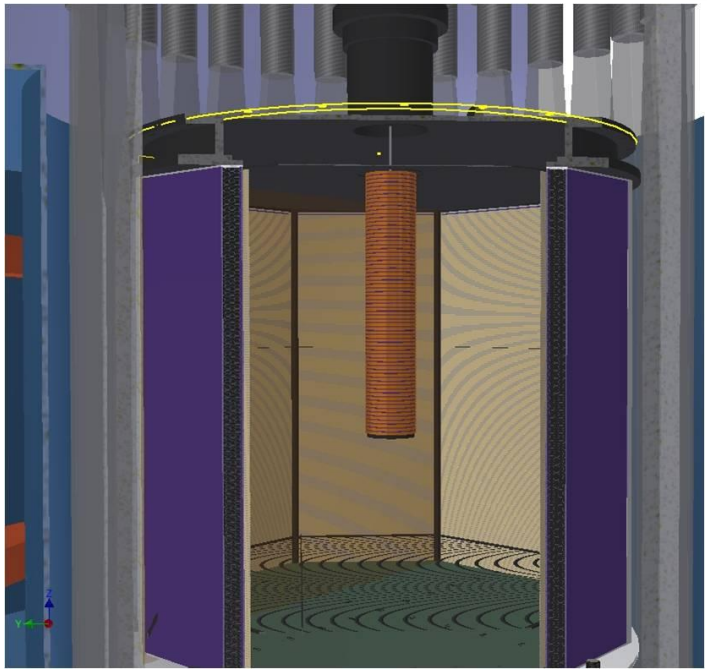
Magnetic Field Strengths of Bx and Bz Components over the TPC Drift Volume



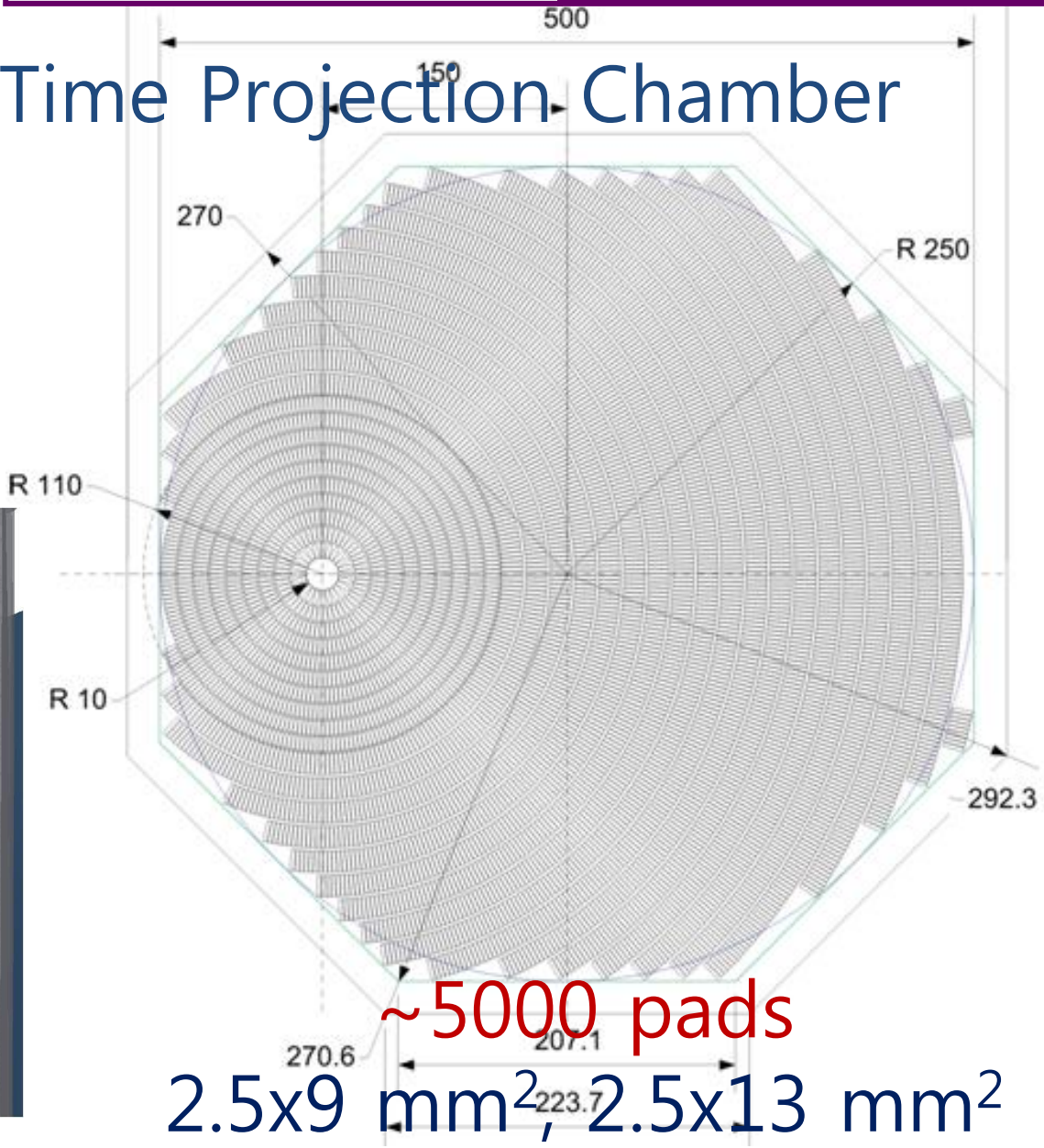


GEM





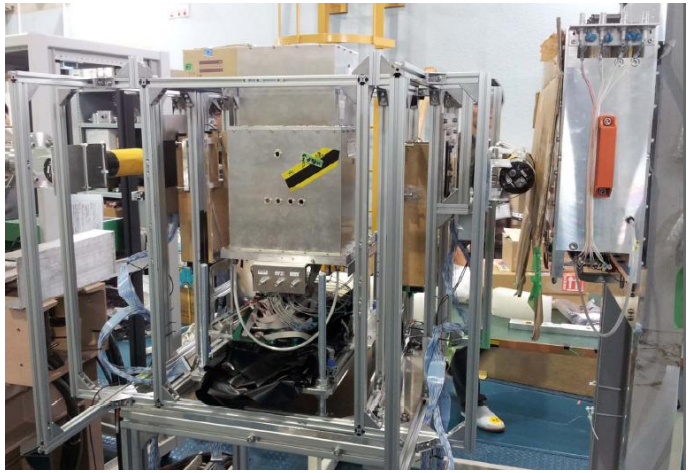
Time Projection Chamber

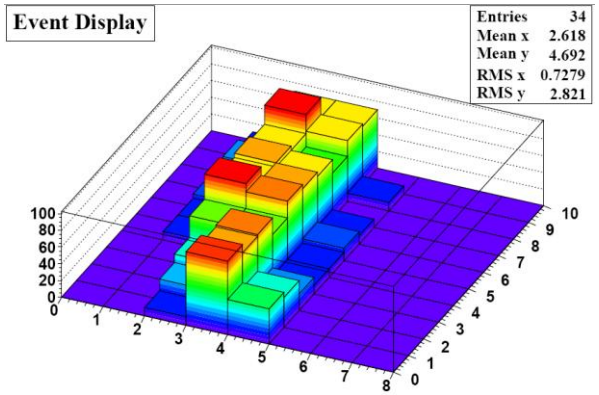


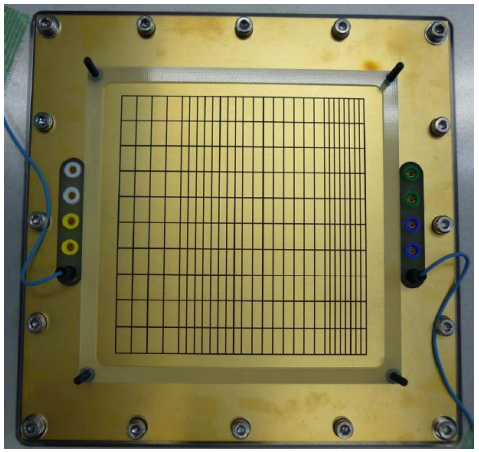
~5000 pads

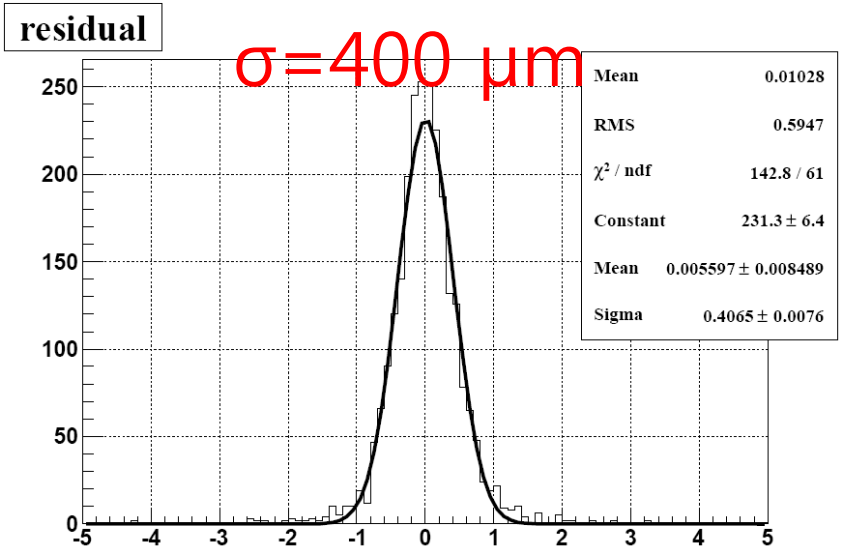
2.5x9 mm^2, 2.5x13 mm^2

Test Experiment (RCNP-E384)









- Tolerable with 10^7Hz beam intensity
- σ=400 μm obtained from the hits on 4-mm wide pads up to 10^6Hz beam intensity.

Target Choice (diamond)

- Number of target nuclei x Cross Section

  $(\rho/W)\ A^{\alpha}$: ρ=density, W=atomic weight

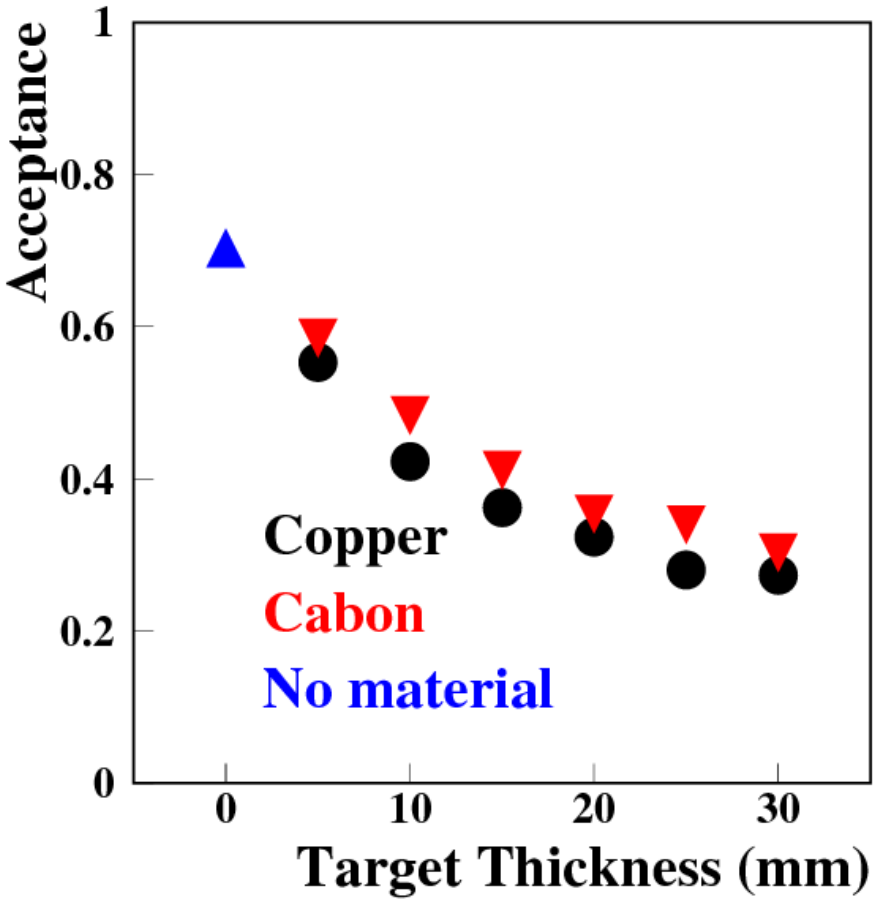
  A=atomic number
- α=0.56 (for two-step processes)
- α=0.38 (for one-step processes)

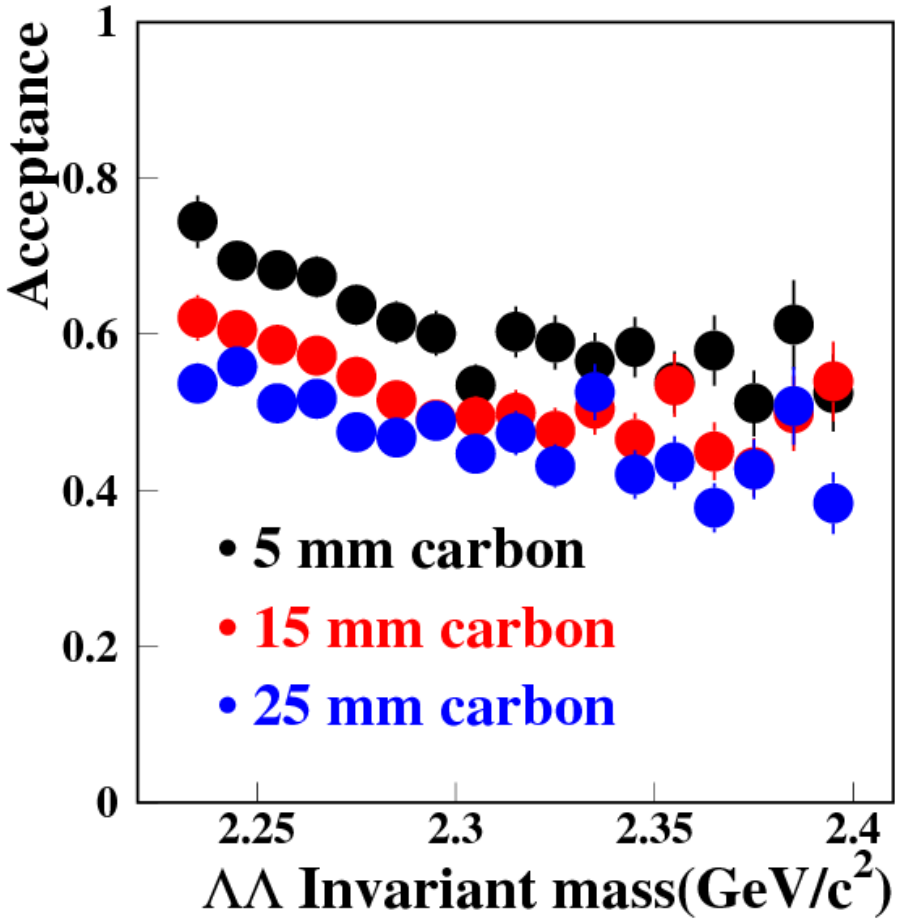
  where α taken from KEK-PS E176 data

  (T. Iijima et al, Nucl. Phys. A 546 (1992), 588)
- Relative factor for Cu/C : 1.44/1.18 for α=0.56

  : 0.68/0.75 for α=0.38

Detection Efficiencies for ΛΛ





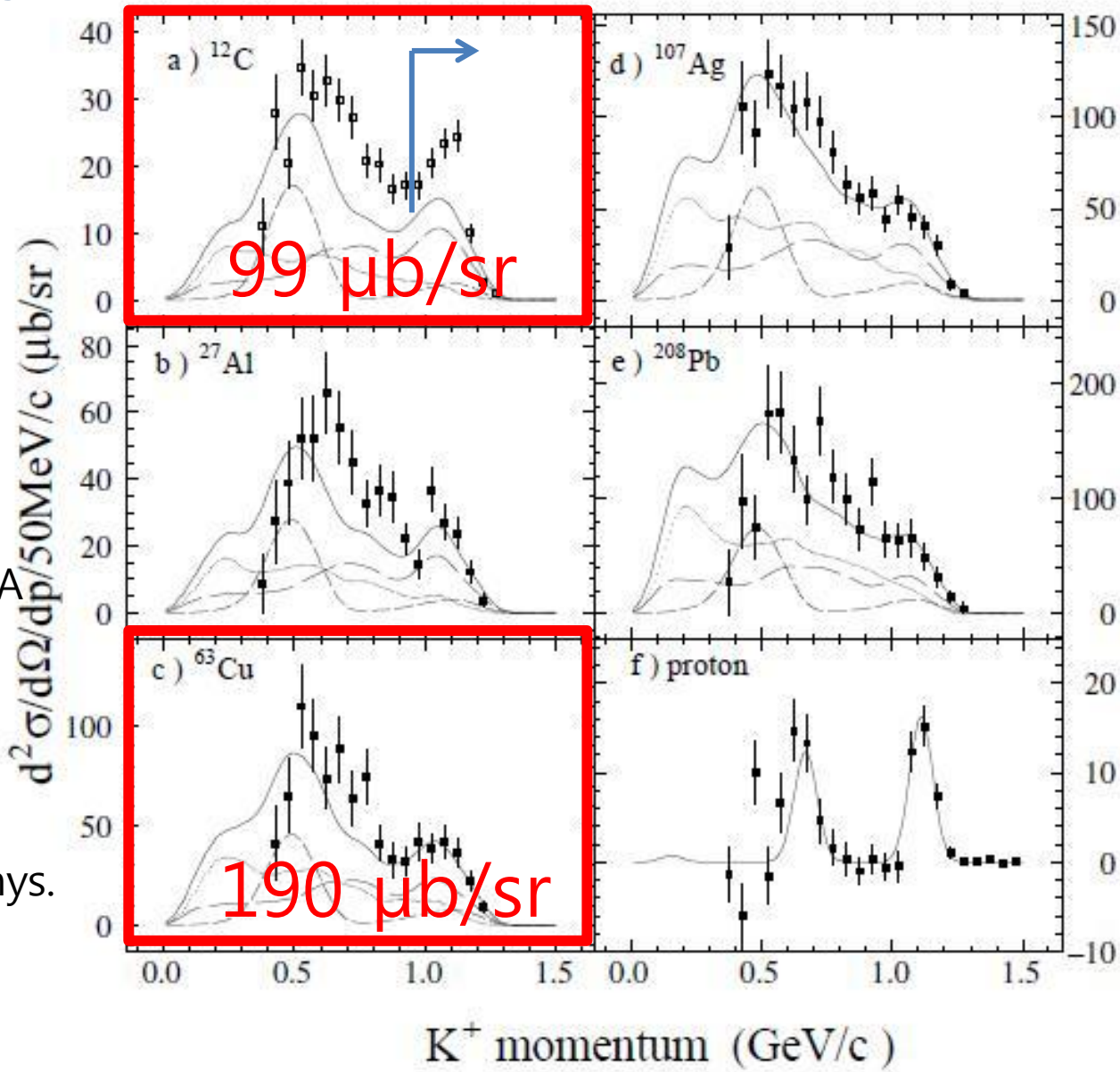
Cross Sections for (K-,K+) Reactions

KEK-PS E176 data on K+ momentum spectra with various nuclear targets.

T. Iijima et al, Nucl. Phys. A 546 (1992), 588

INC model calculation

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



Yield Estimation

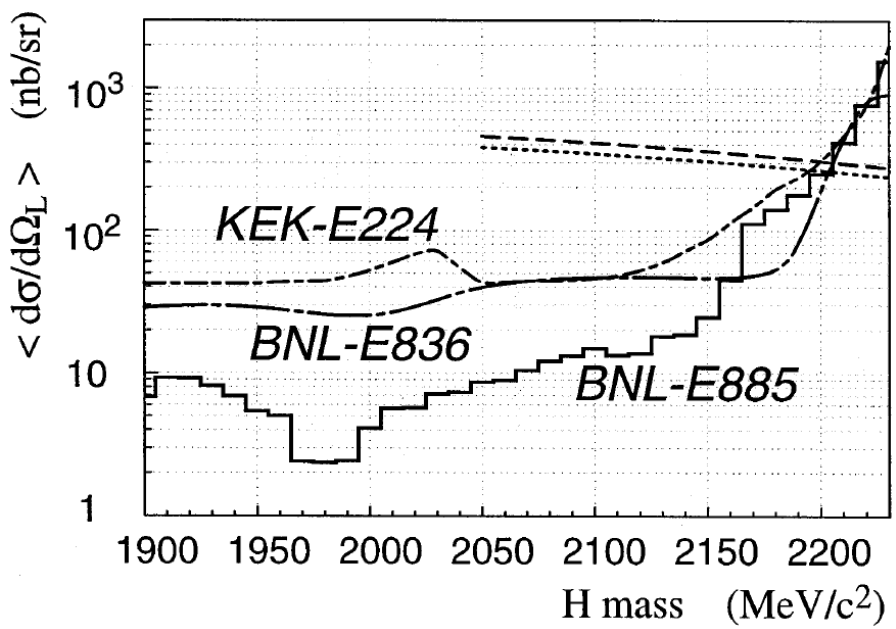
- 11000 ΛΛ events for 100 shifts and 1440 H(2250) events for 1.0 μb/sr with a 15-mm thick diamond target.

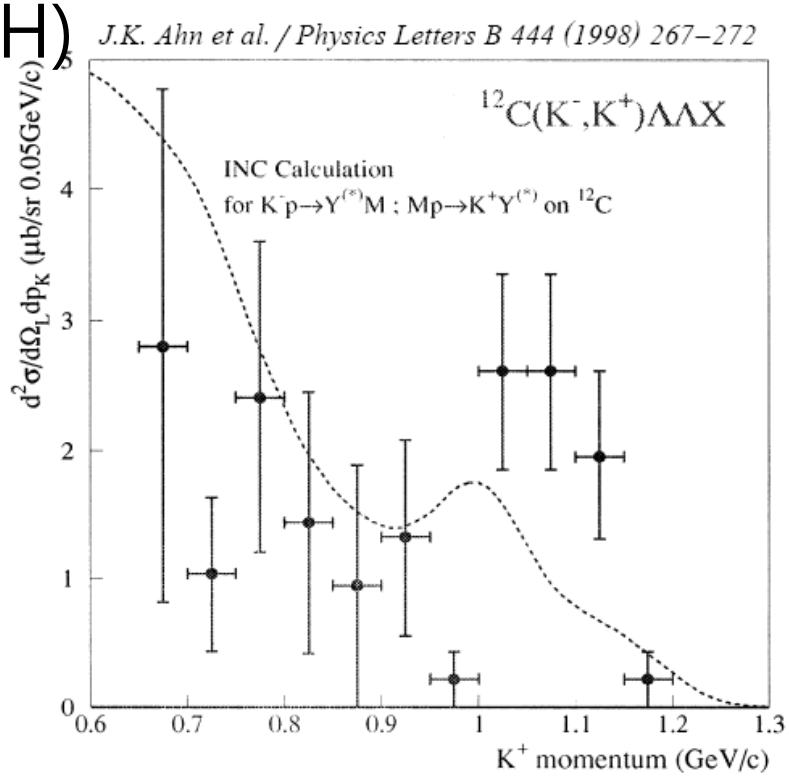
Parameters	Cu target	Diamond target
K^- beam	$10^6 K^-$ per spill (6 s)	
Target length	5 mm	15 mm
Number of nuclei	$4.25 \times 10^{22}/\mathrm{cm}^2$	$2.65 \times 10^{23}/\mathrm{cm}^2$
$d\sigma/d\Omega_L^C(\Lambda\Lambda)$	14.6 μb/sr	7.6 μb/sr
$\Delta\Omega(K^+)$	0.11 sr	
Br $(\Lambda \to p\pi^-)^2$	0.41	
KURAMA for K^+	0.5	
HypTPC for ΛΛ	0.5	0.4-0.6 (0.4 for H(2250))
Yield	0.007 event / spill	0.023 event / spill

from E224 data (PLB444 (1998)

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 3 μb/sr for the H)





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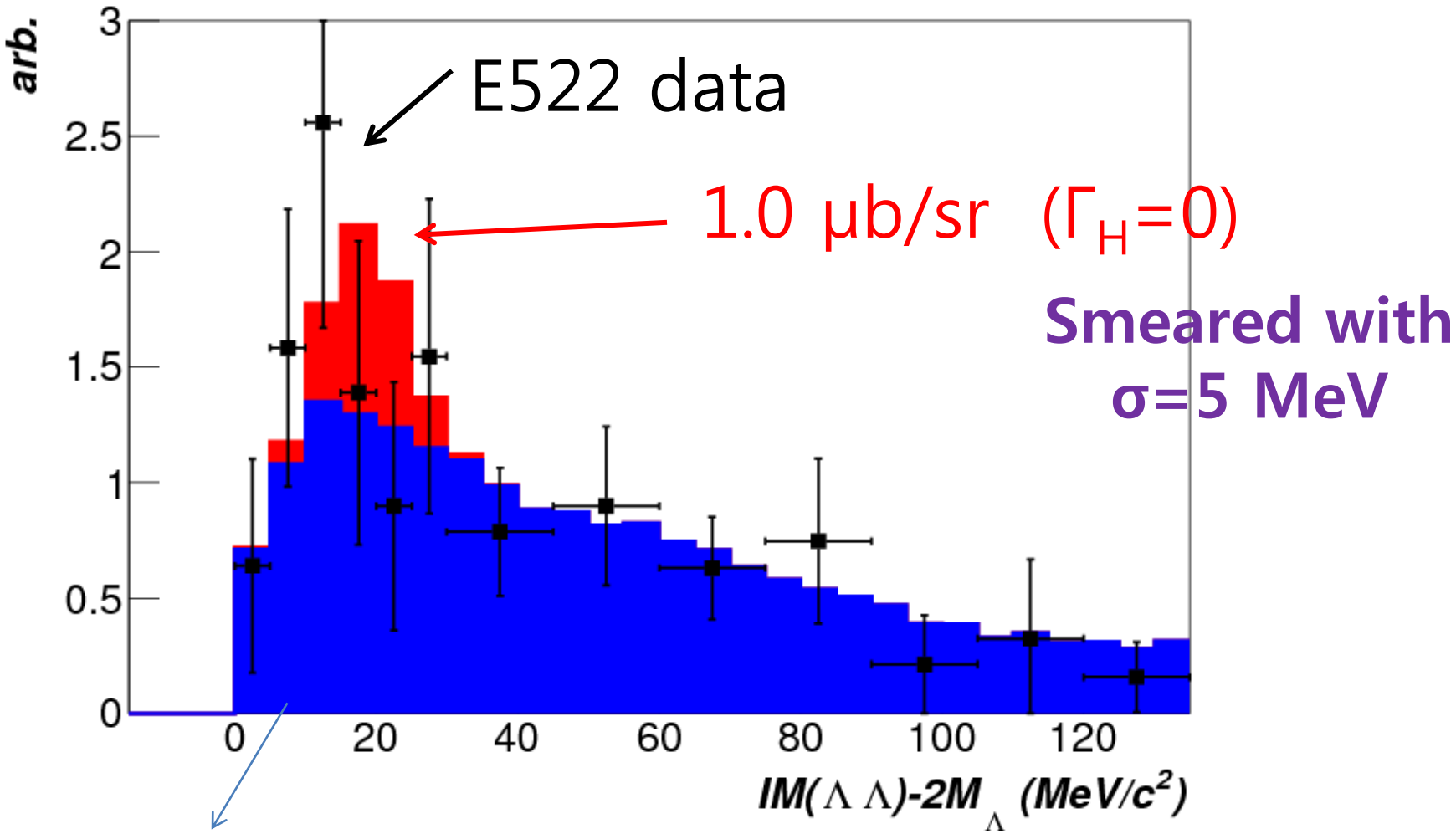
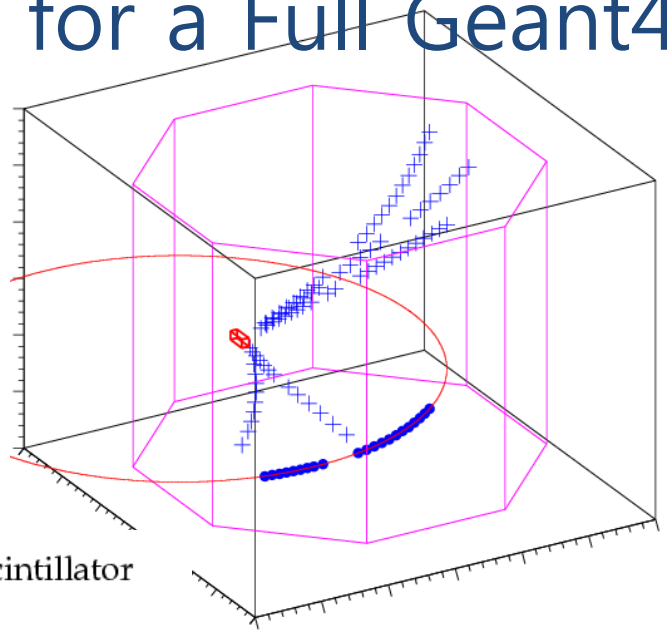
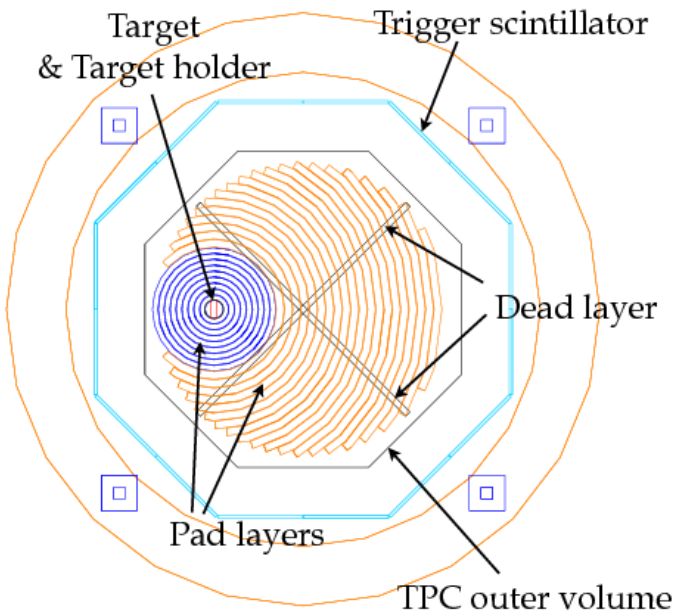
Relative Yields for H to Non-resonant ΛΛ

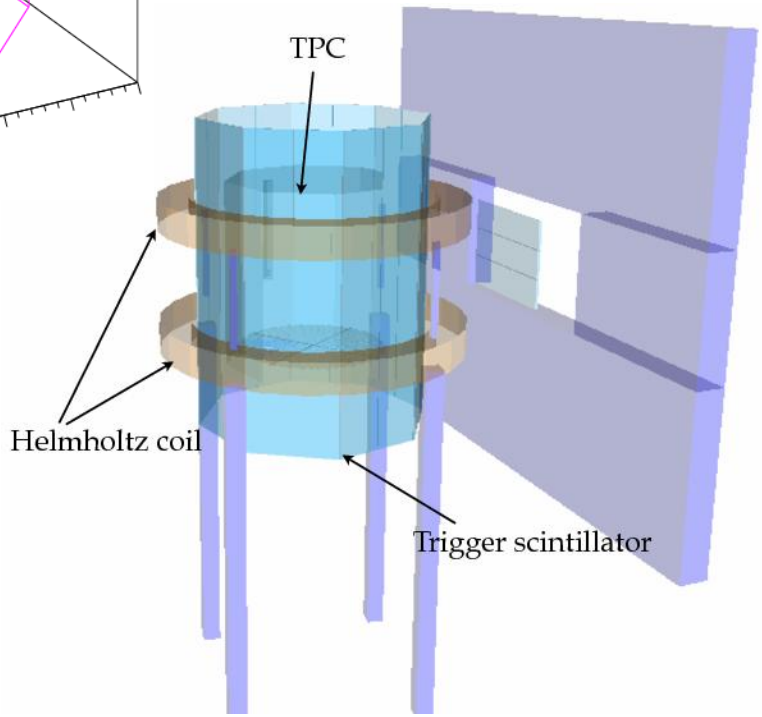


INC calculation results based on Ref (Y. Nara et al, NPA 614 (1997) 433)

Modeling for a Full Geant4 Simulation

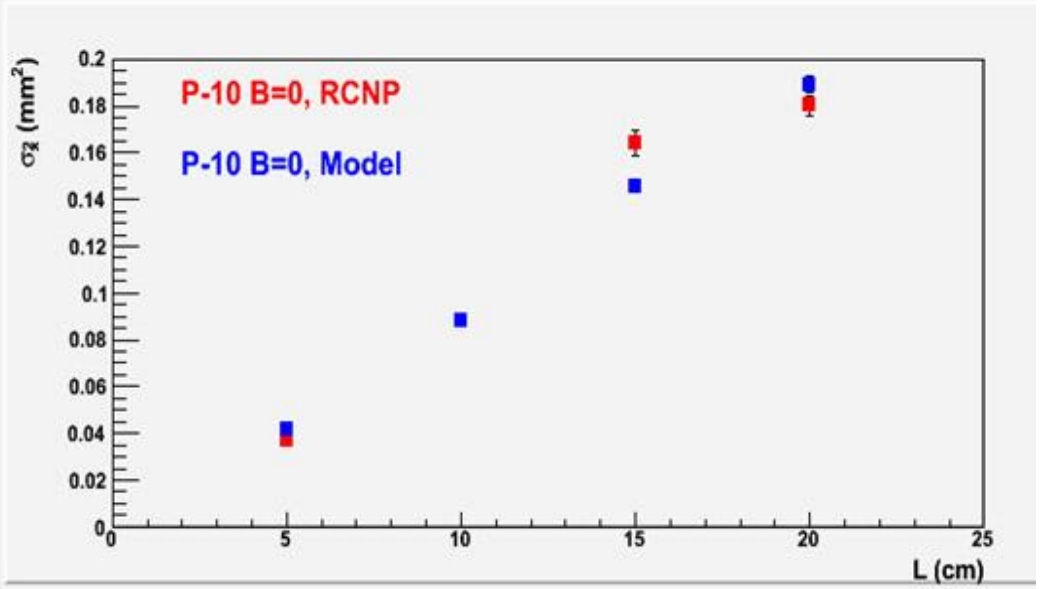


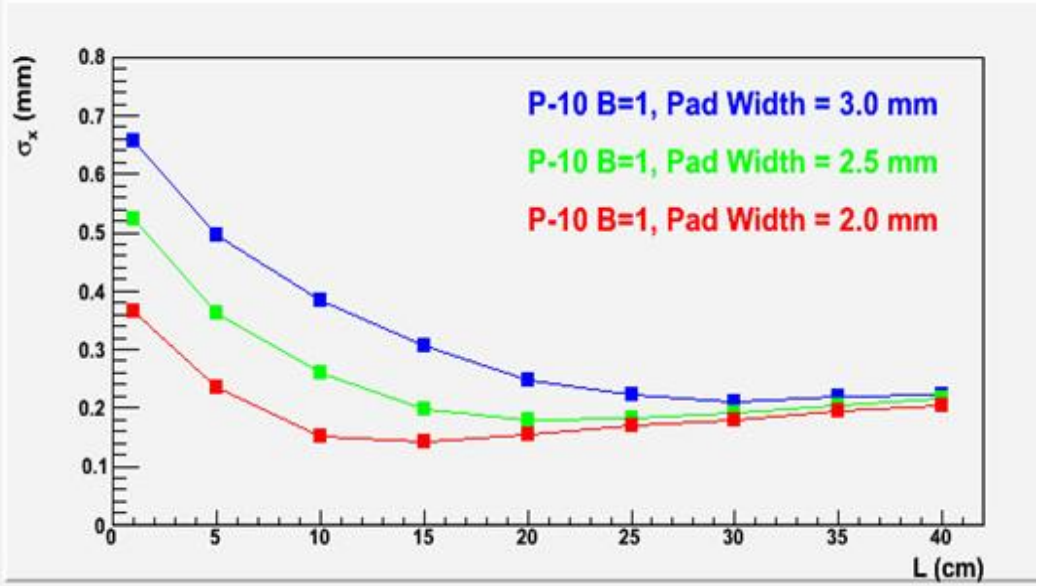




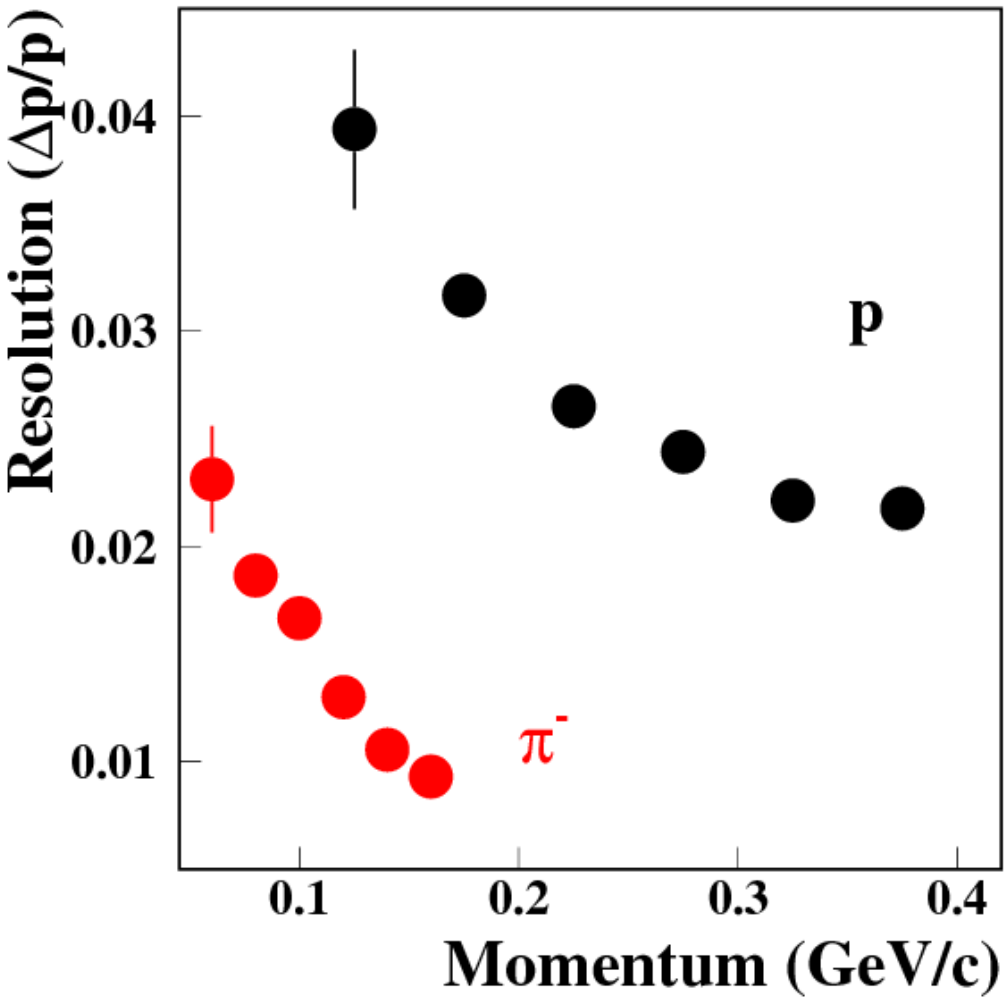
Spatial Resolution with Smaller Pads

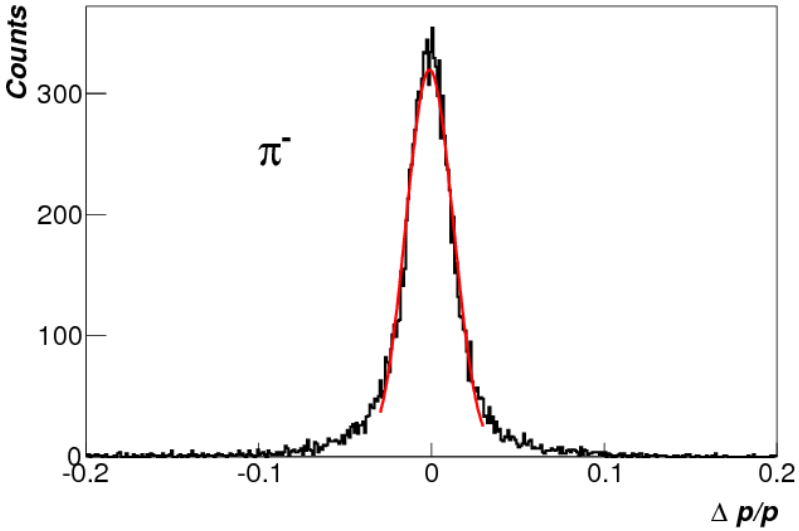
- We modeled electron charge diffusion with small-sized pads under 1 T, based on RCNP test results.
- We assume the worst case with the minimum charge sharing on pads.

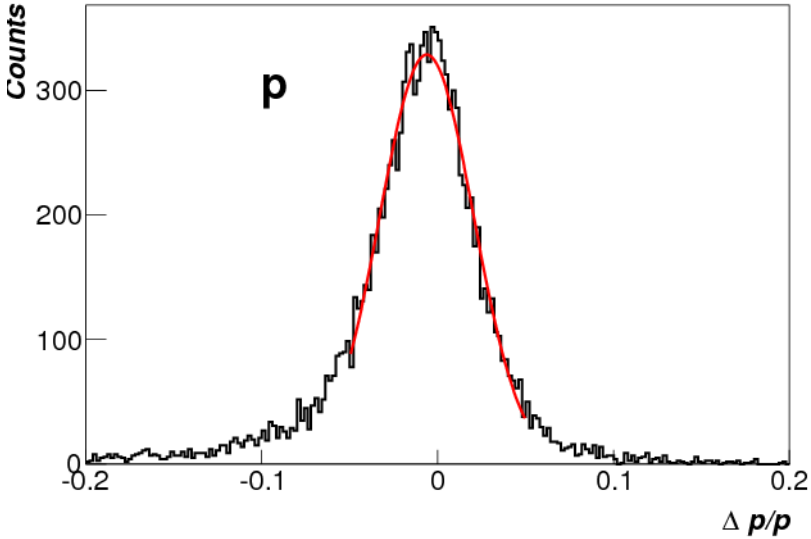




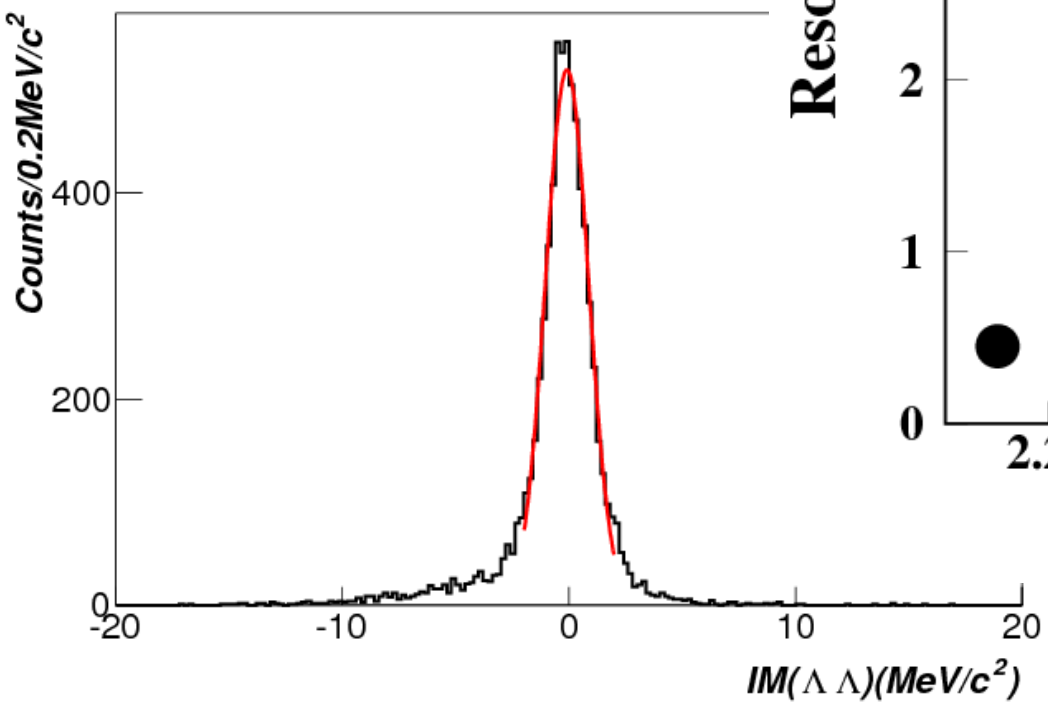
Momentum Resolutions

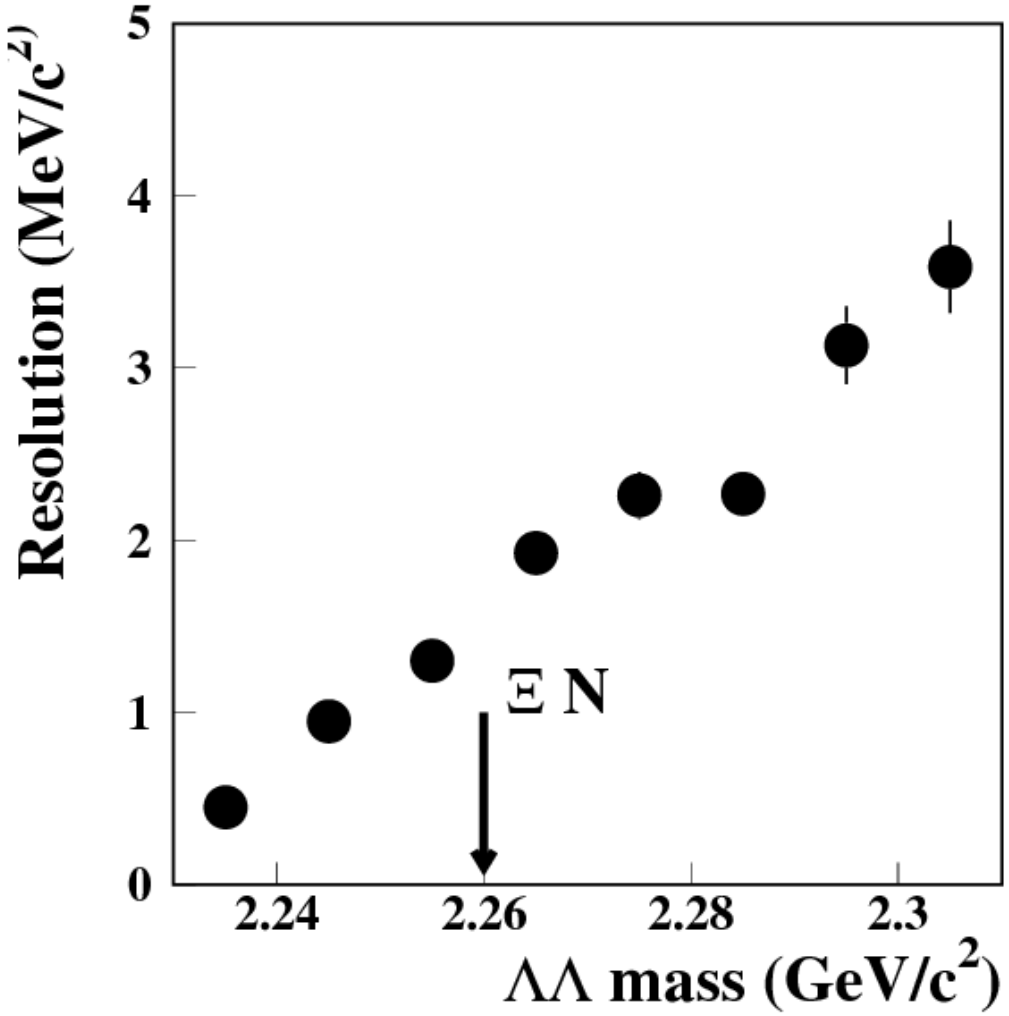




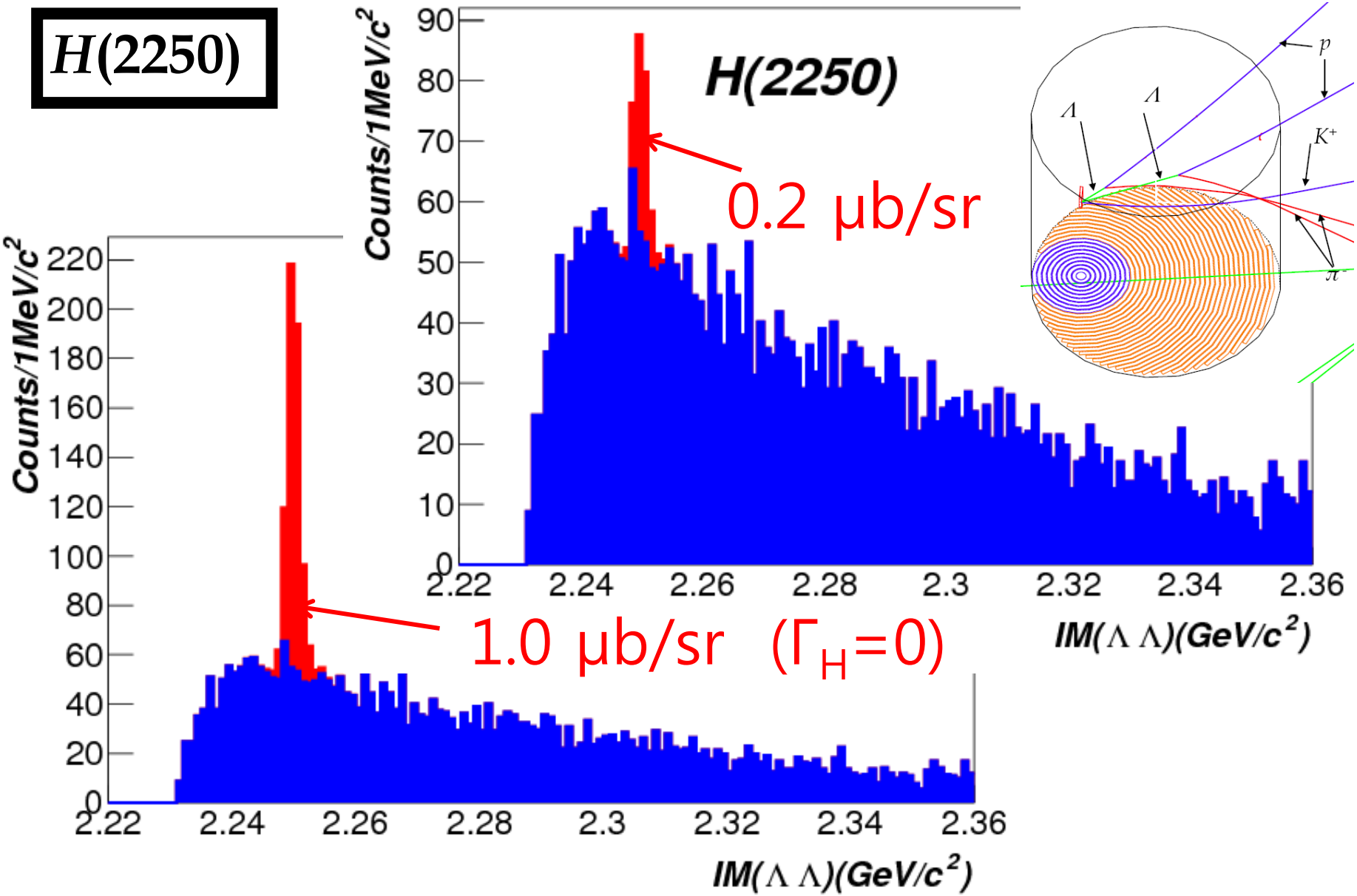


Mass Resolutions

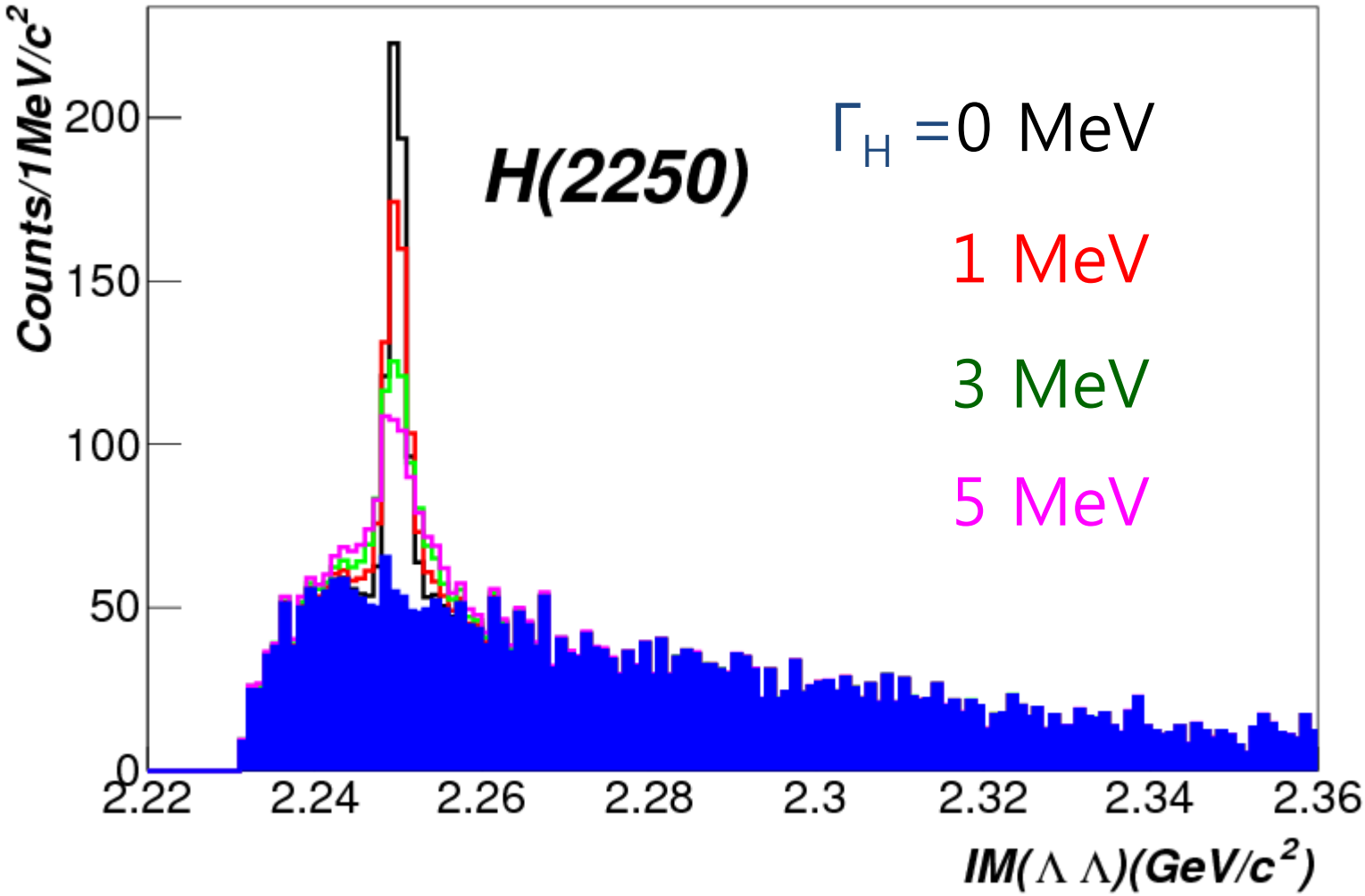




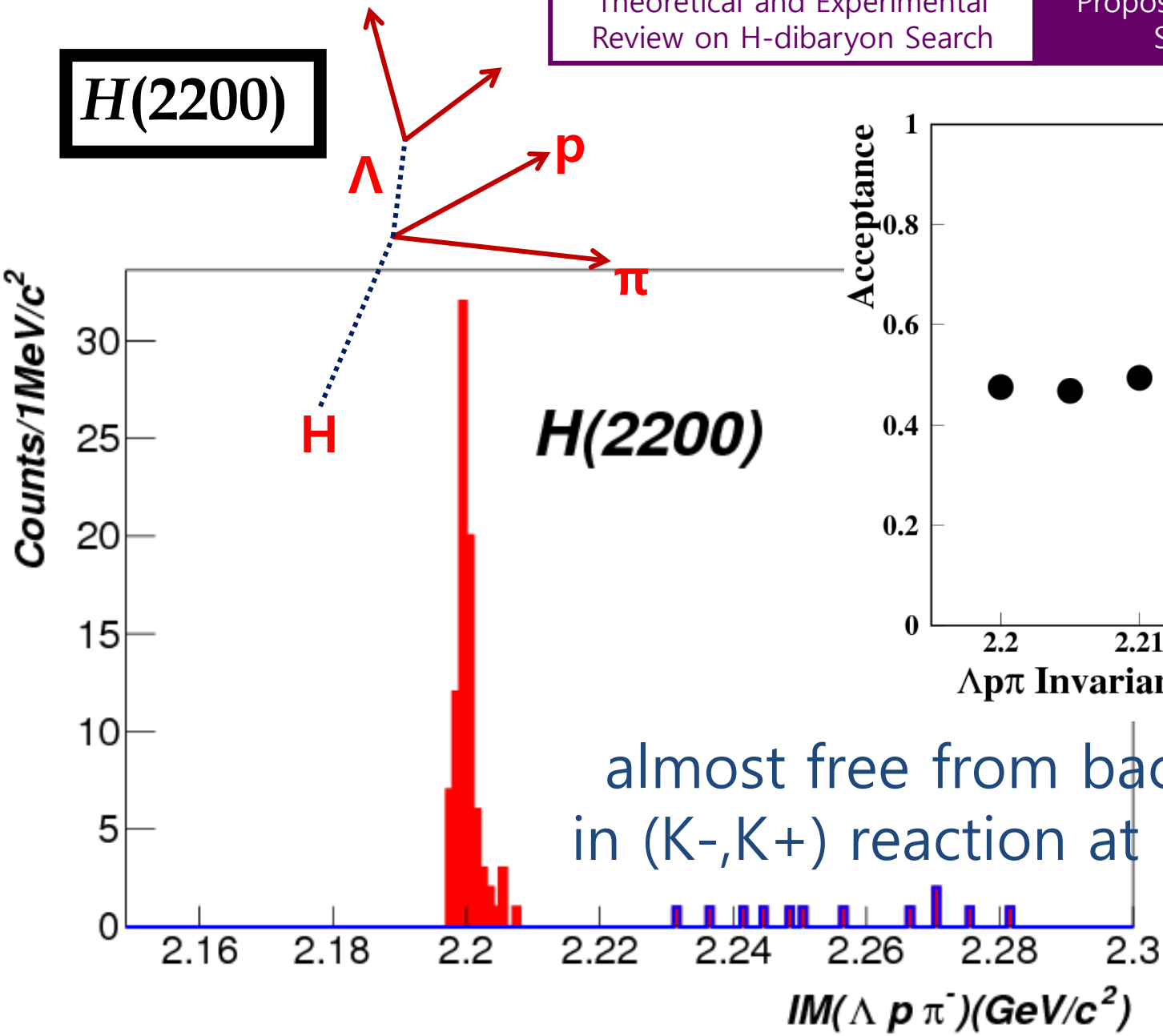
$H(2250)$

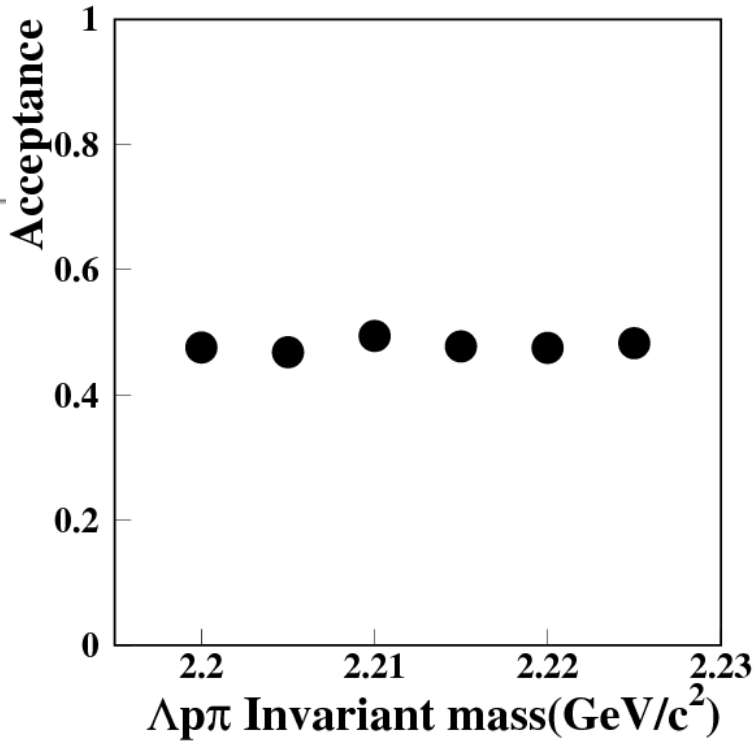


Lineshapes with respect to the H-decay width Γ_H



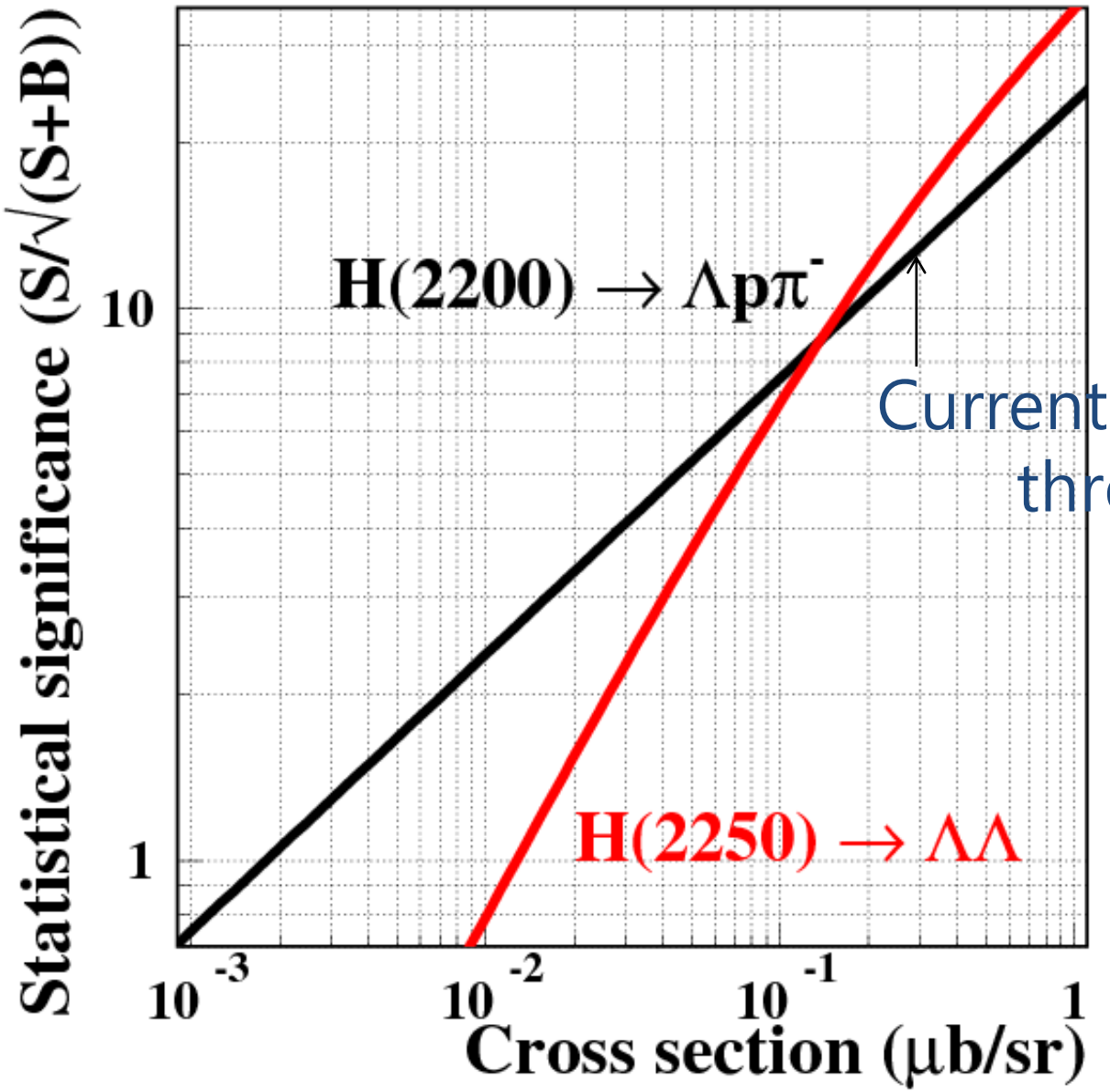
$H(2200)$





almost free from background in (K-,K+) reaction at 1.8 GeV/c.

Sensitivity



Current UL at Λpπ threshold

The P42 Collaboration

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Estimated Costs and Budget Situation

- The estimated costs for the proposed experiment is 120M JPY (or $1.5M), half the cost for a superconducting Helmholtz-type magnet, and the rest for TPC.
- It should be noted that our research grants have been recently approved both in Japan and Korea sides.

1. Grant-in-aid for Scientific Research A : 35M JPY (JAEA)
2. Grant-in-aid for Scientific Research in Innovative Area : 95M JPY (KEK and JAEA) for the Hyperon Spectrometer
3. Do-Yak (Big-jump) Research grant for Leading Scientists : 900M KRW or 60M JPY (Pusan)

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Preparation Schedule

- We are in a position to get ready for the run in a late half of the year 2014.

Period (YYYY.MM)	Preparation Schedule
2012.07-2012.12	1st TPC prototype test under B field and its long-term stability test
2012.08-2012.10	Design and construction of the 2nd TPC prototype
2012.09	ASIC chip submission for TPC electronics
2012.09-2013.03	Magnet design
2012.11-2012.12	The 2nd TPC prototype test
2012.12-2013.03	Final TPC design
2013.04-2013.09	Construction of the final TPC
2013.04-2013.12	TPC electronics fabrication and tests
2013.04-2014.06	Magnet construction
2013.09-2014.06	TPC test
2013.12	TPC electronics completed
2014.06	Magnet and TPC completed

Summary

- 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 11K ΛΛ events for 100 shifts.
- We are going to get ready for physics runs late in 2014.