Prospects of hypernuclear experiments at MAMI-C

Tohoku University

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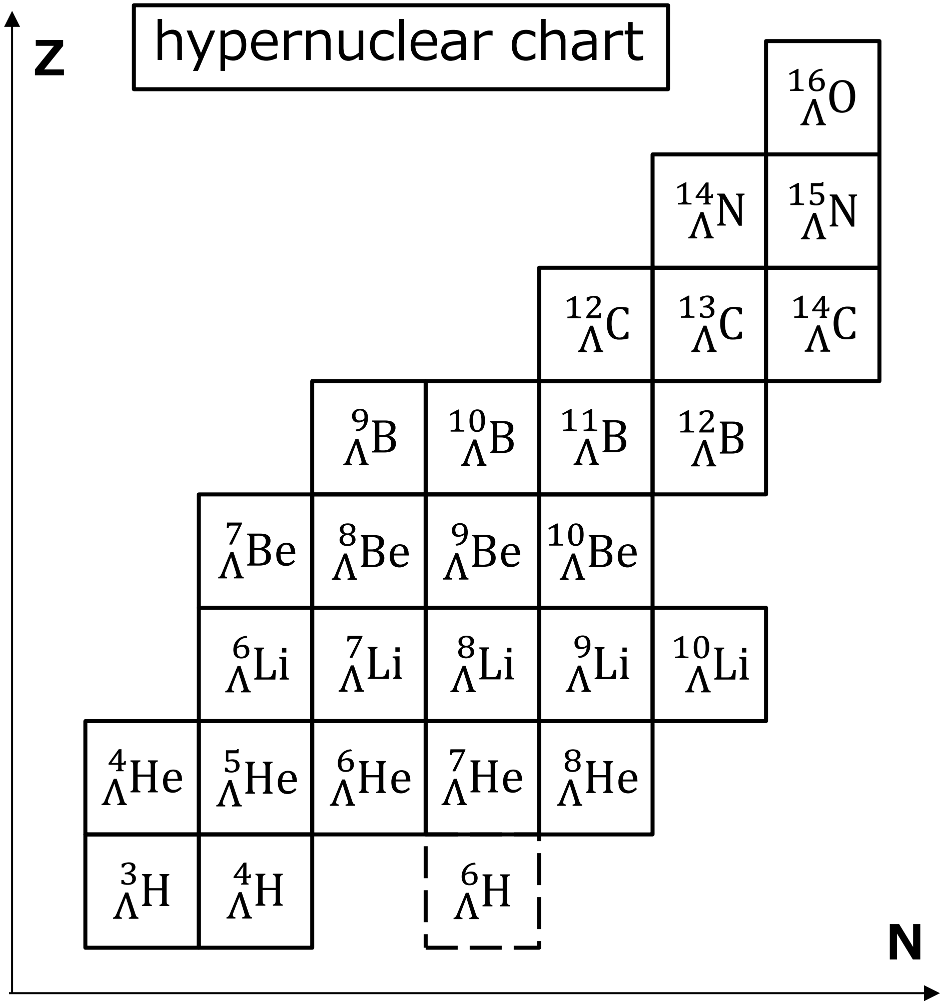
21th Mar. 2014

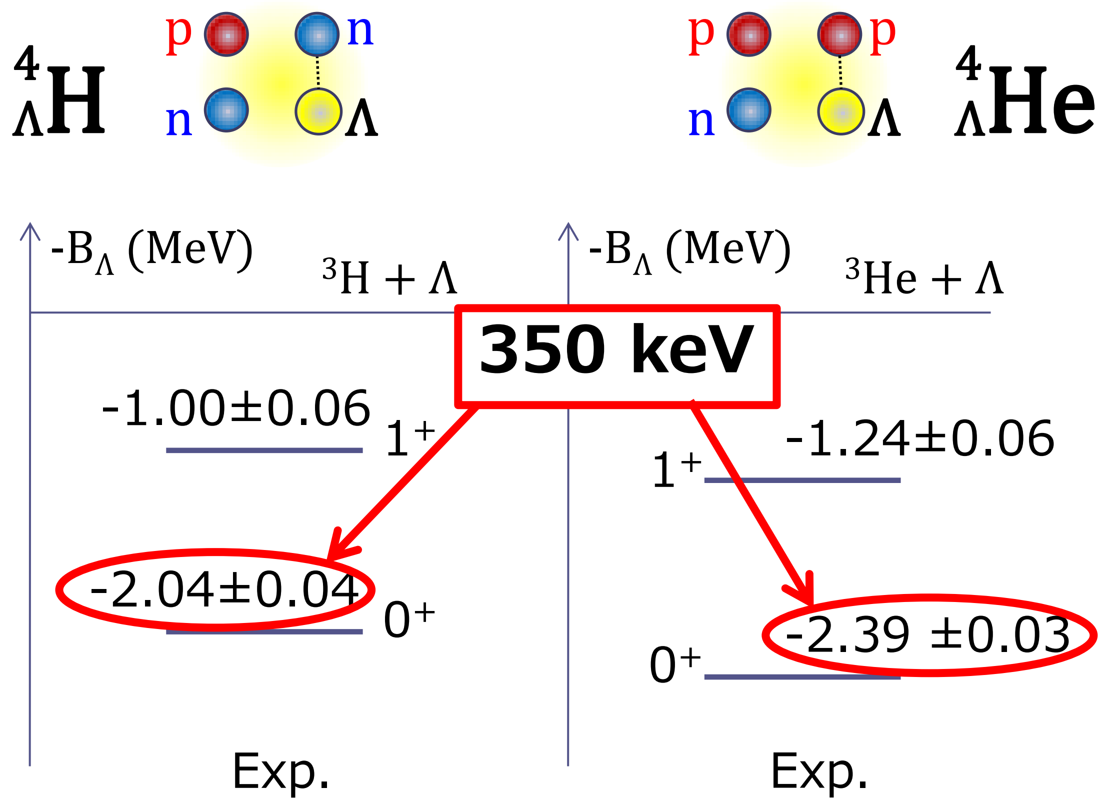
Contents

Light hypernuclei

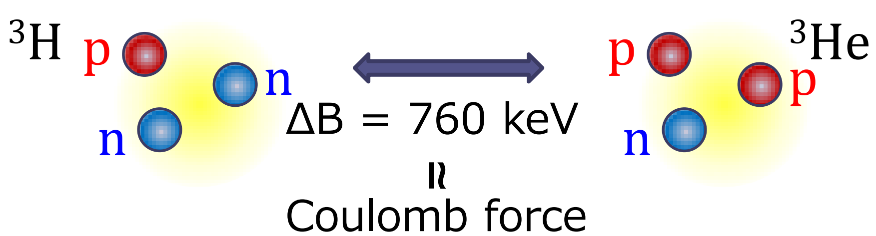


- **Expansion of S=-1 floor**
  - Emulsion
  - (K^-,π^-),(π^+,K^+),$(e,e'K^+)$ etc.
- **ΛN interaction**
  - Effective ΛN interaction
  - ΛN-ΣN coupling
  - Three body ΛNN force
  - Charge symmetry breaking
- **Impurity effect**
  - Deeply bound state
  - Shrinkage effect

Λ-N charge symmetry breaking (CSB)



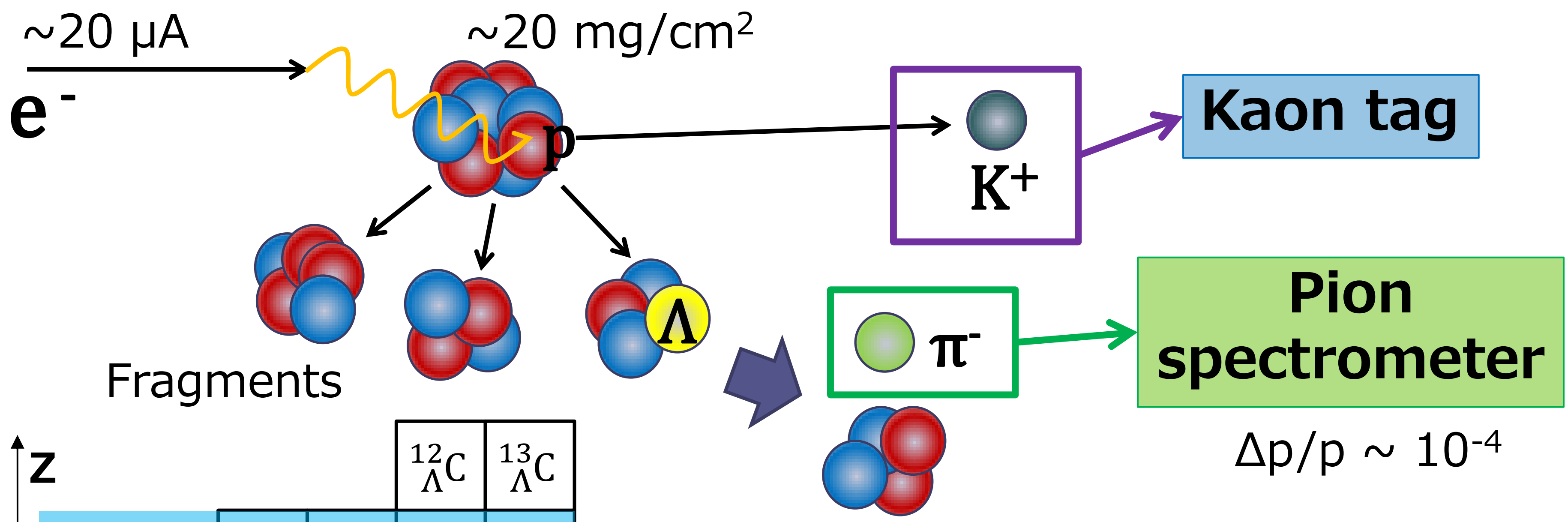
M. Juric et al., Nucl. Phys. B **52** (1973) 1
M. Bedjidian et al., Phys. Lett B **83** (1979) 252

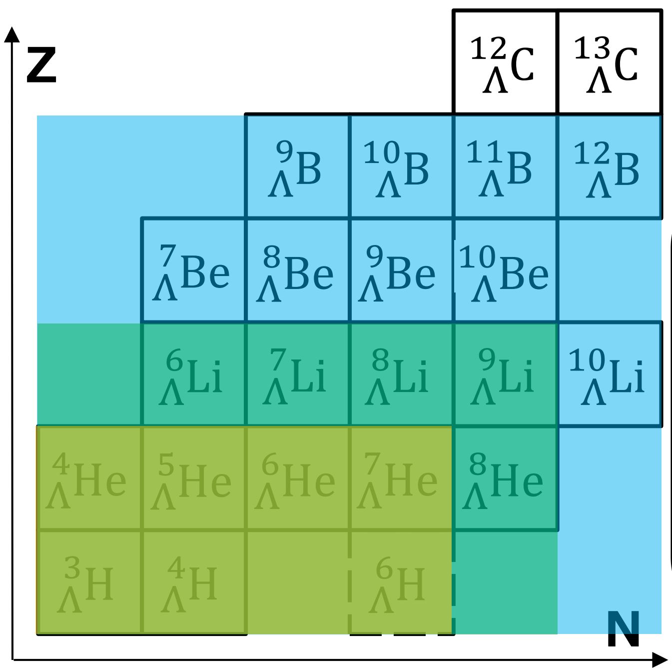


CSB effect : 71 keV

R.A.Brandenburg et al.,
Phys. Rev. C 37 781-785 (1988).

Decay pion spectroscopy of Λ hypernuclei





- **New experimental technique**
- **Hypernuclear mass spectroscopy with high precision** (~30 keV accuracy)
- **Fragmentation probability**

Experimental setup

Target

Material	^{9}Be
Thickness	125 μm (54 deg tilted)

Target thickness optimization

Background suppression in Kaos

Spek-A, C (Pion spectrometer)

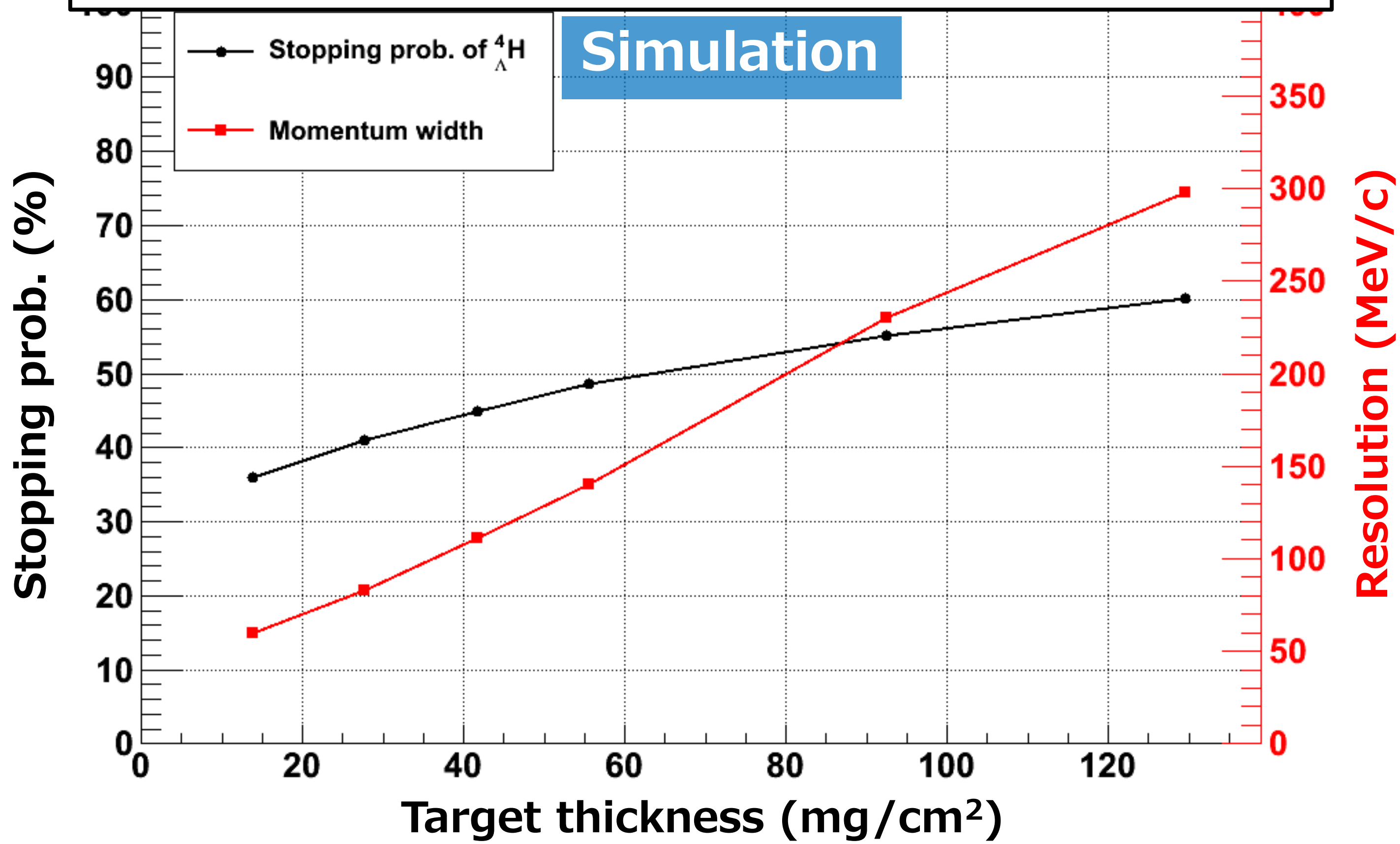
Cent.Mom	A:-115, C:-125 MeV/c
Angle	A:-90, C:+126 degree
Mom. res	$\Delta p/p < 10^{-4}$
Solid angle	28 msr

Target thickness

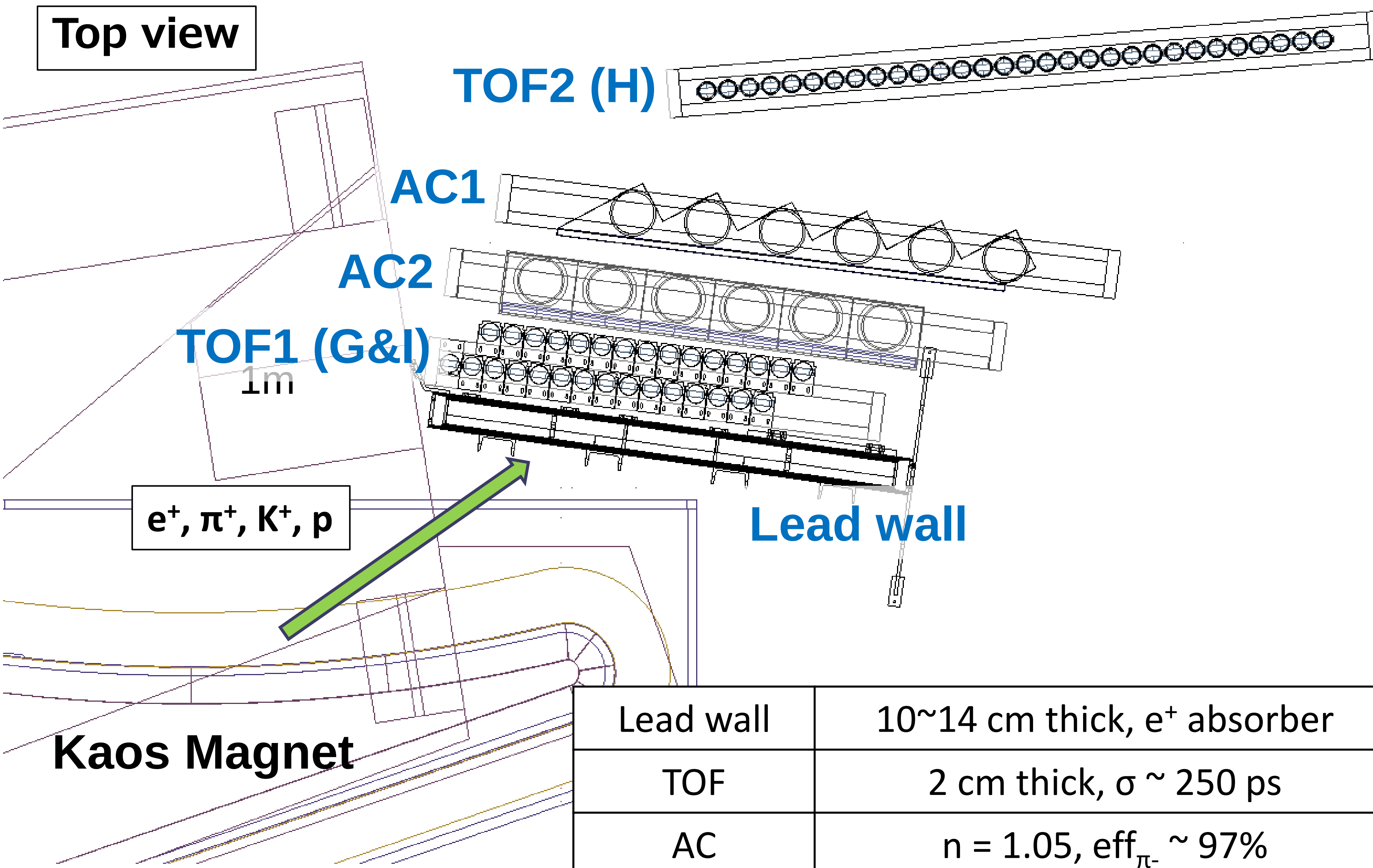
The optimization of target thickness is quite important

Too thin → Less stopping probability
Too thick → More energy struggling
⇒ Worse accuracy

The estimation of target thickness effect using Geant4

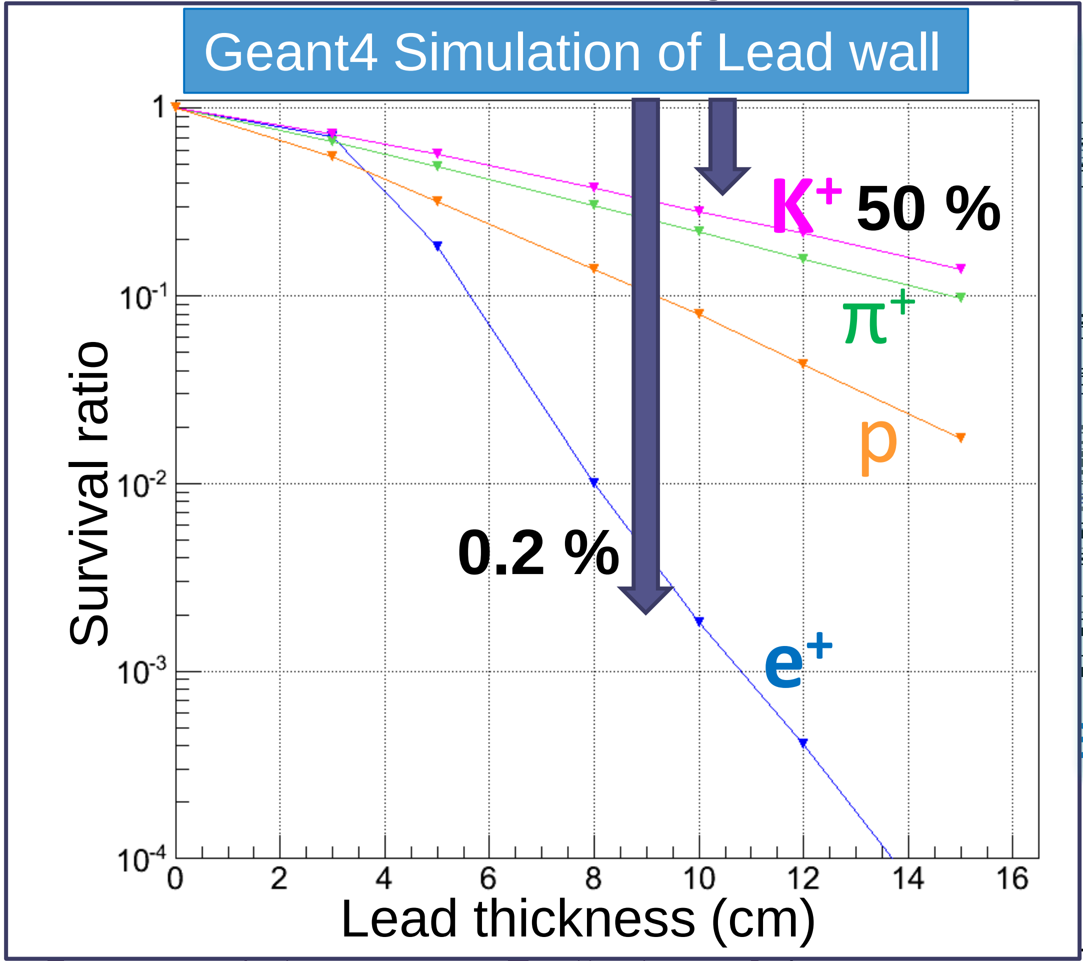


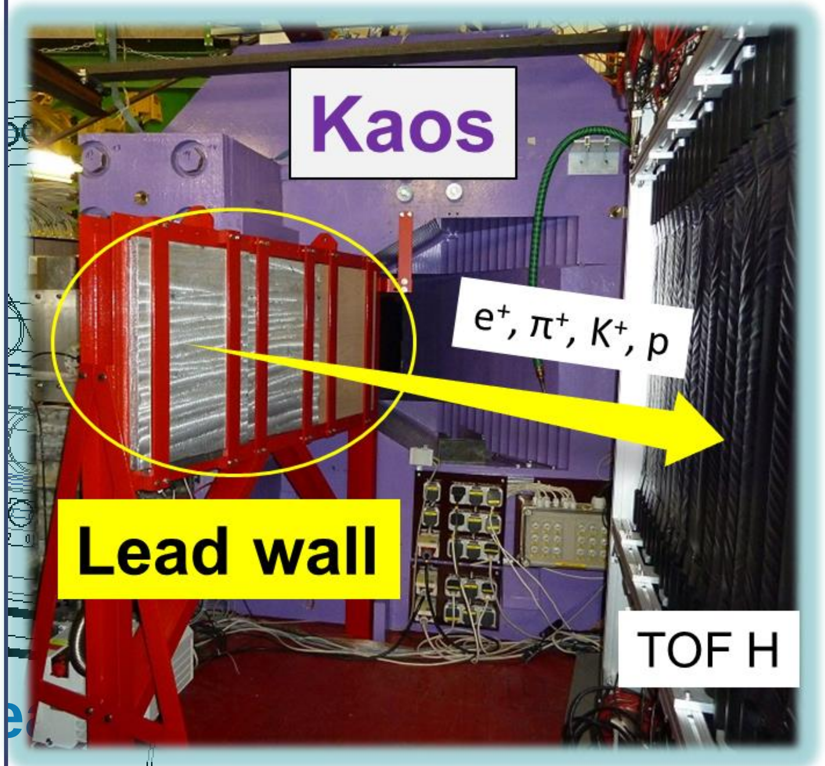
Setup in Kaos



Lead wall	10~14 cm thick, e^+ absorber
TOF	2 cm thick, σ ~ 250 ps
AC	n = 1.05, $eff_{\pi-}$ ~ 97%

Setup in Kaos (Lead wal)



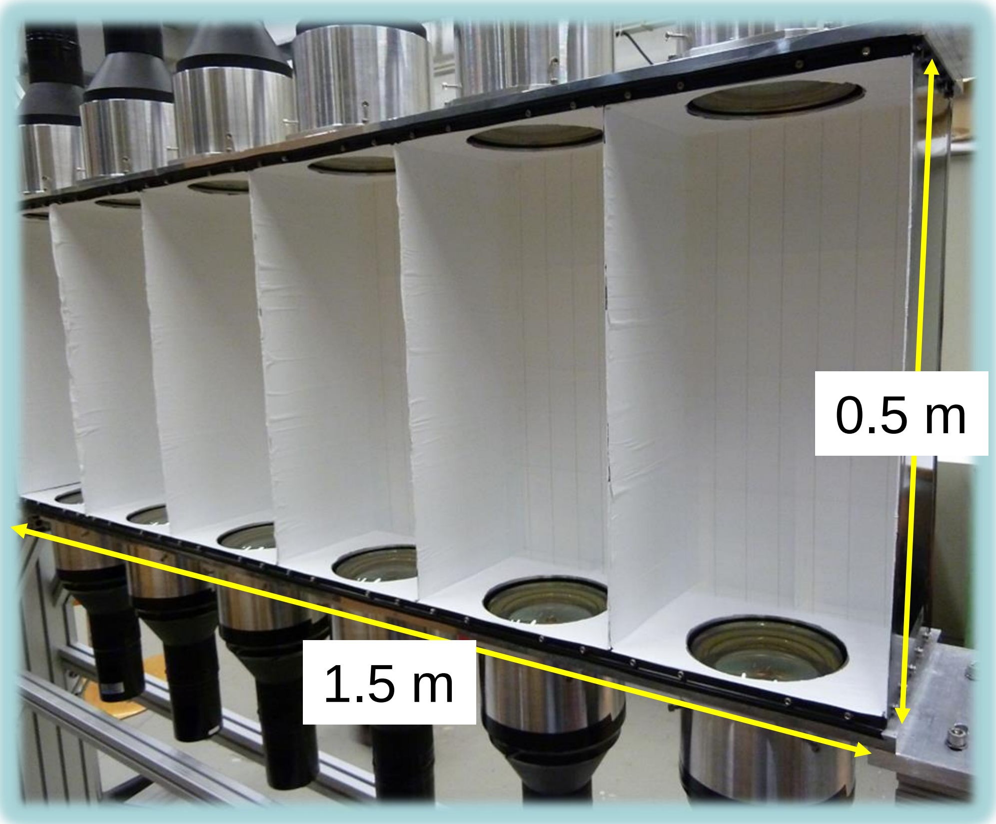


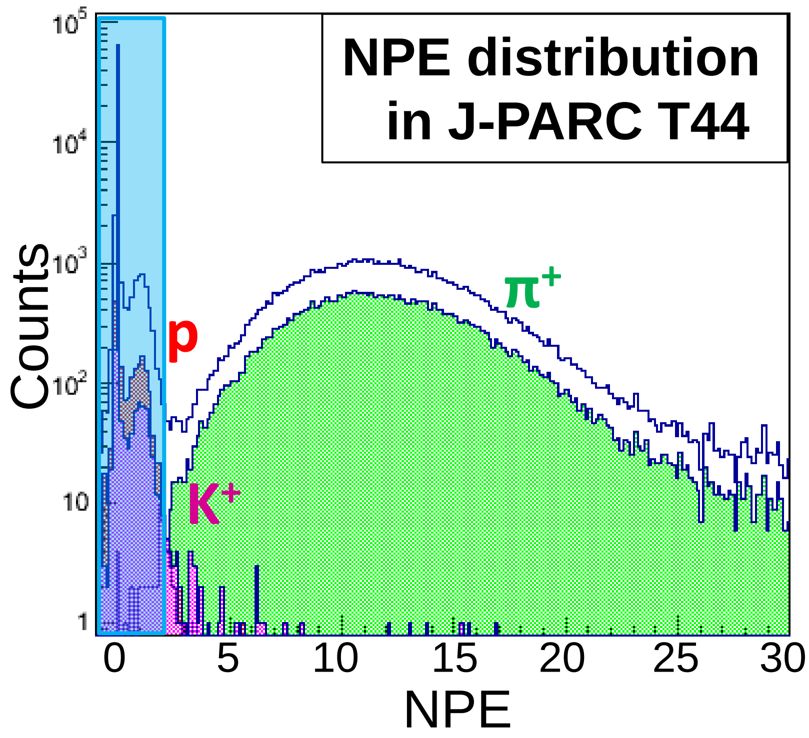
- e+ background : Seriously high (~100 MHz/20 μA beam)
- Momentum resolution : No relation with mass resolution

Kaos setup (Aerogel Cherenkov)

π^+ veto in offline analysis

- 6 segments
- Hamamatsu 5” PMT
- Teflon diffused reflector
- Panasonic 3 cm
- Refractive index = 1.05





Rejection efficiency (NPE<2)

Pion	99.9 %
Kaon	1.0%
Proton	0.1%

Decay pion experiment in 2012

- **2nd decay pion experiment**

  terms : 24 Oct. ~ 11 Nov. in 2012

- **Typical condition**

Target	**^{9}Be (125 μm thickness)**
Beam current	**20 μA**
Kaos rate	**30 kHz** at 20 μA
Spek-A, C rate	**30 kHz** at 20 μA
Total charge	**20.9 C (1.3×10^{20} electrons)**

Identification of decayed pion events

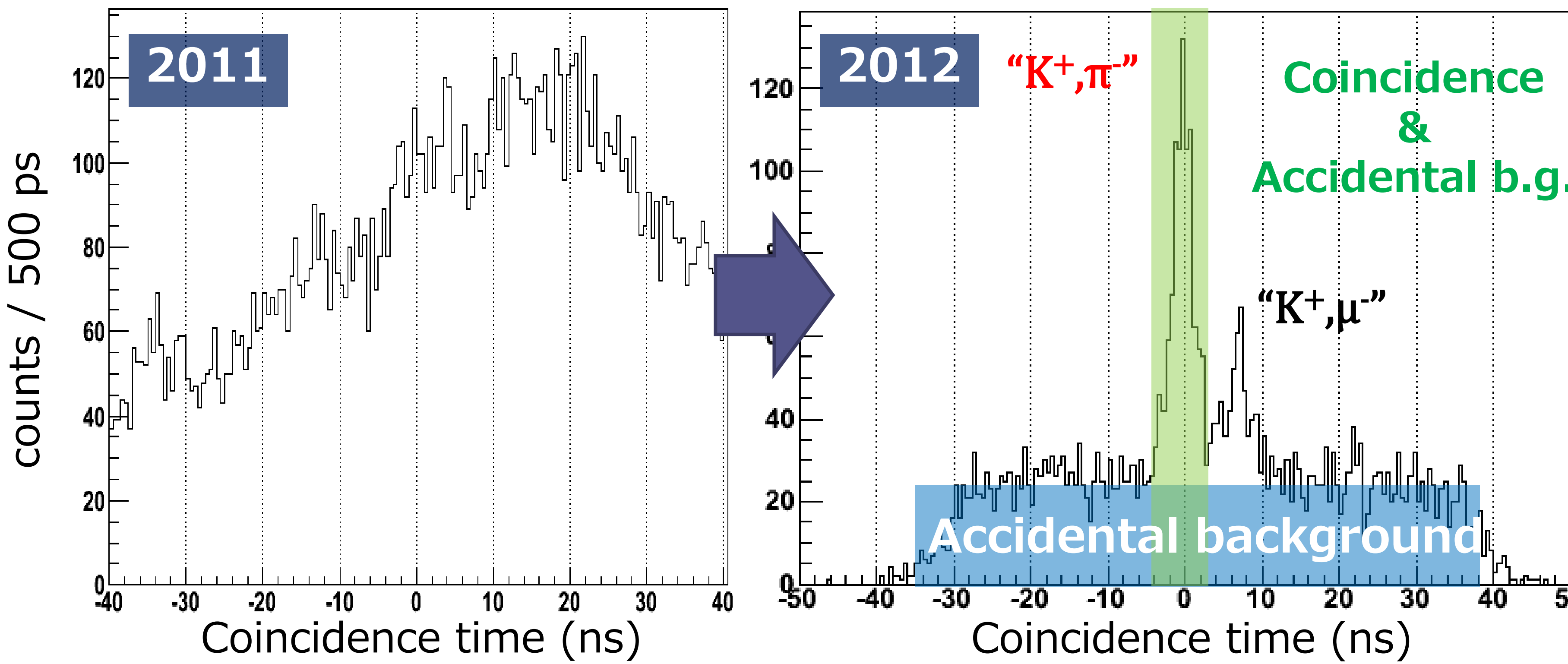
Coincidence time = Time at target of K^+ - Time at target of π^-

Cuts in Kaon tagger

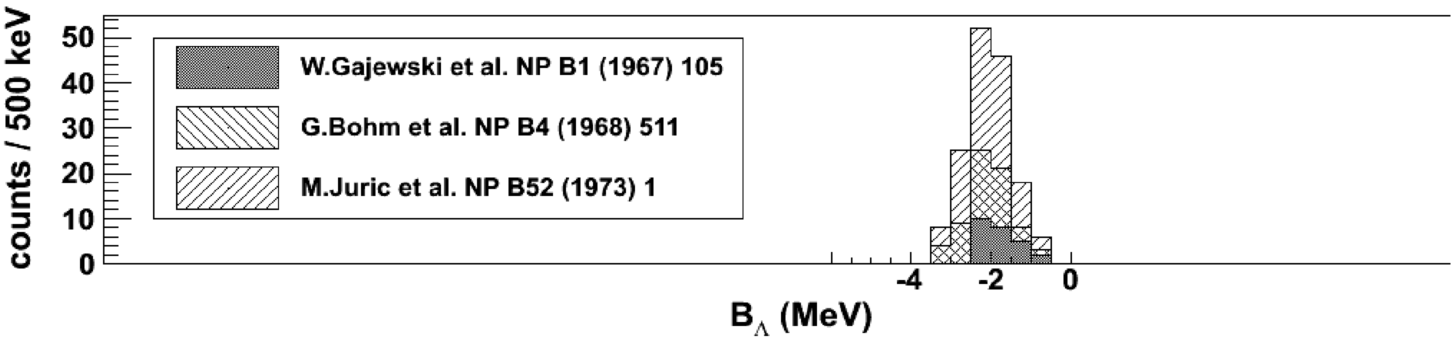
TOF wall : beta, energy deposit
Momentum : mass reconstruction
Aerogel Cherenkov : pion rejection

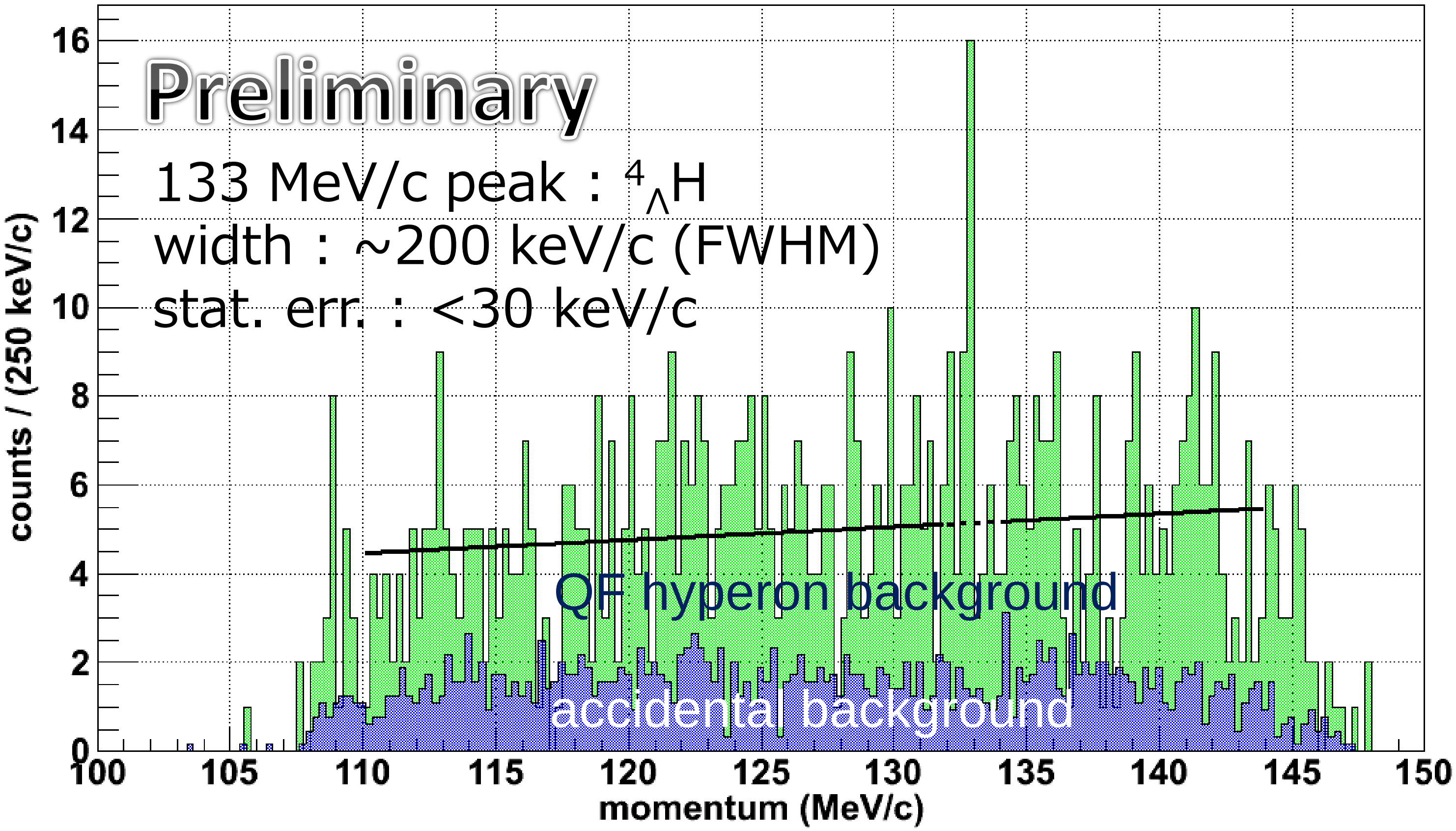
Cuts in Pion spectrometer

Gas Cherenkov : electron rejection



K⁺ tagged π⁻ momentum spectrum





Formation probability of $^4_\Lambda H$

$$Formation\ Prob. = \frac{Total\ No.\ of\ ^4_\Lambda H}{Total\ No.\ of\ \Lambda}$$

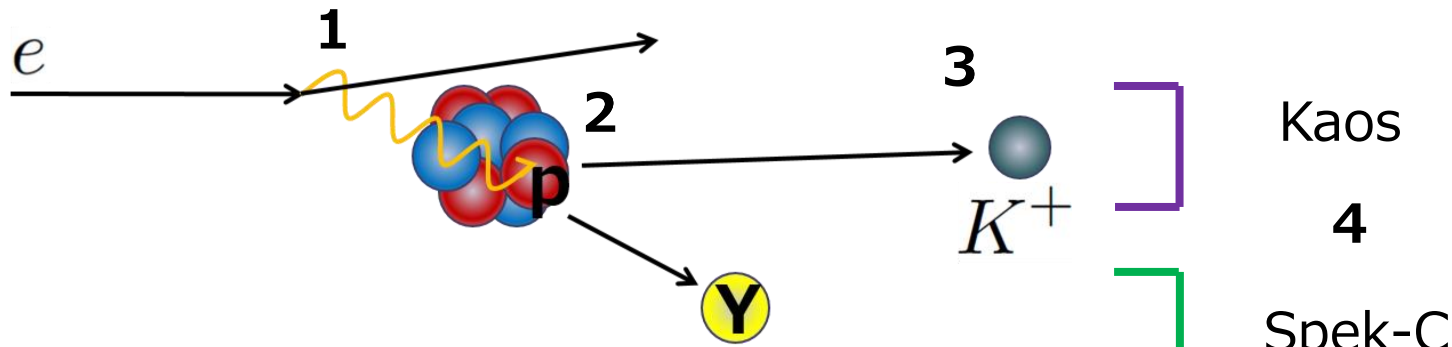
$$Total\ No.\ of\ ^4_\Lambda H = \frac{N_{^4_\Lambda H}}{\Omega_{Spek-C}/4\pi \times BR(\pi^- + ^4He) \times \epsilon_{stop} \times \epsilon_{others}}$$

$$Total\ No.\ of\ \Lambda = \frac{N_Y}{N_{Y_{detect}}/N_{\Lambda_{generate}} \times BR(\pi^- + p) \times \epsilon_{others}}$$

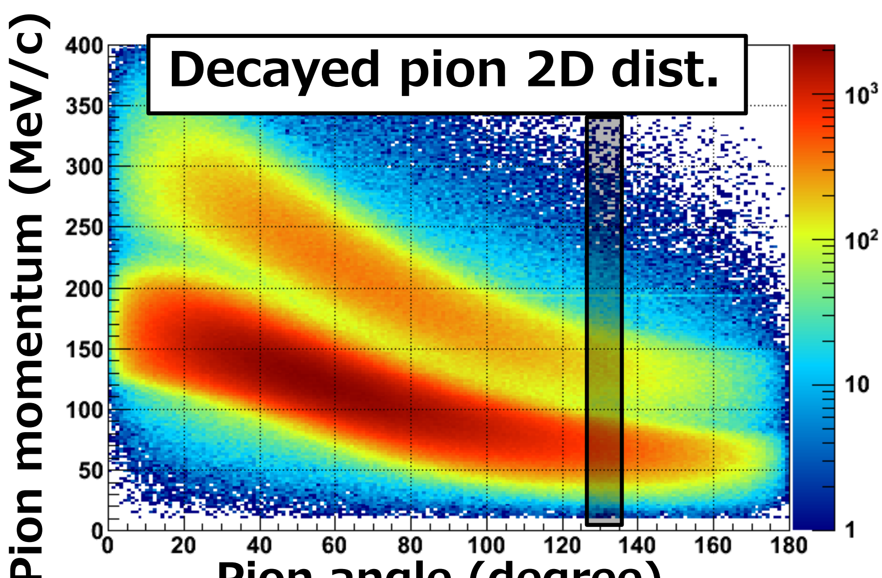
$N_{^4_\Lambda H}$	Counts of $^4_\Lambda$H	15 counts	
Ω_{Spek-C}	Solid angle of Spek-C	28 msr	
BR(π^-+^{4}He)	partial decay ratio of $^4_\Lambda$H $\rightarrow \pi^-$+^{4}He	51 ± 5 %	[2,3]
ϵ_{stop}	Stopping probability of $^4_\Lambda$H	50 ± 10 %	
ϵ_{others}	Survival ratio of π^-, detector efficiency etc.		
N_Y	Counts of Y	510 counts	
$N_{Y_{detect}}/N_{\Lambda_{generate}}$	Detection ratio of Λ in Spek-C	2.0×10^{-4}	
$BR(\pi^- + p)$	Decay branching ratio of $\Lambda \rightarrow \pi^- + p$	63.9 ± 0.5 %	[1]

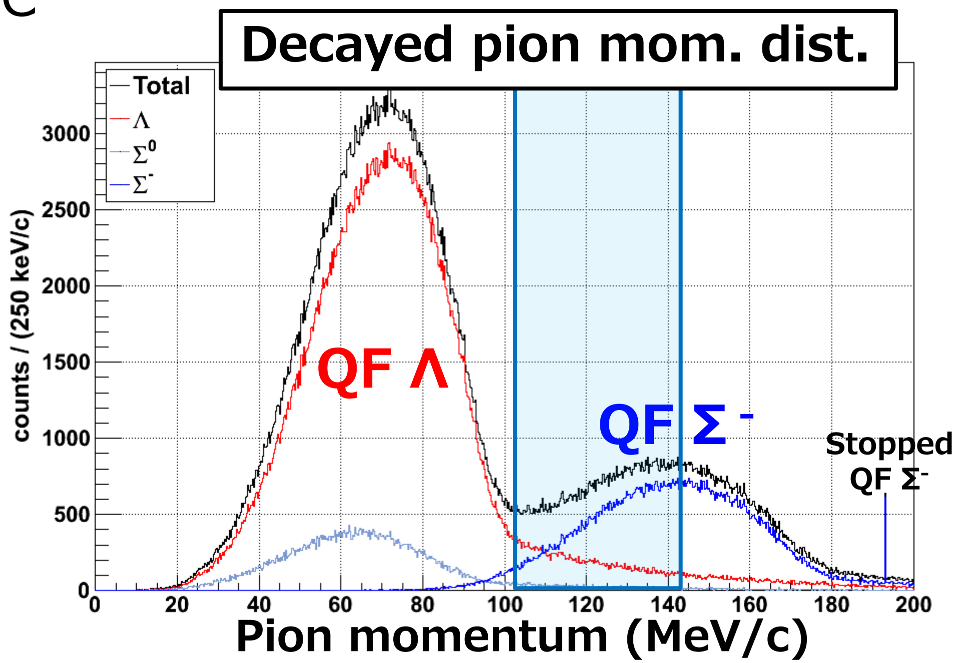
[1] Phys. Rev. D 86 (2012) 1328
[2] M.M Bloch et al. Proceedings of Int. Conf. on Hyperfragments, CERN-Report 64-1 pp.63
[3] D. Bertrand et al. Nucl. Phys. B16 (1970) 77.

Detection ratio of Λ (Simulation)

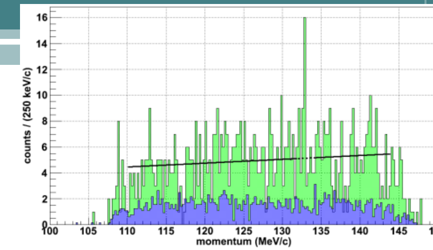


1. Virtual Photon distribution M. Sotona private communication
2. Fermi motion of proton A. Bodek and J.L. Ritchie, Phys. Rev. D 23 1070-1091 (1981).
3. $N(\gamma,K^{+})Y$ cross section : Isobar model (K-MAID) http://wwwkph.kph.uni-mainz.de/MAID/kaon/
4. Acceptance of Kaos & Spek-C





Future plan



Taking data with better S/N ratio

- Higher yield → Longer beam time & Higher beam intensity
- Suppression of background

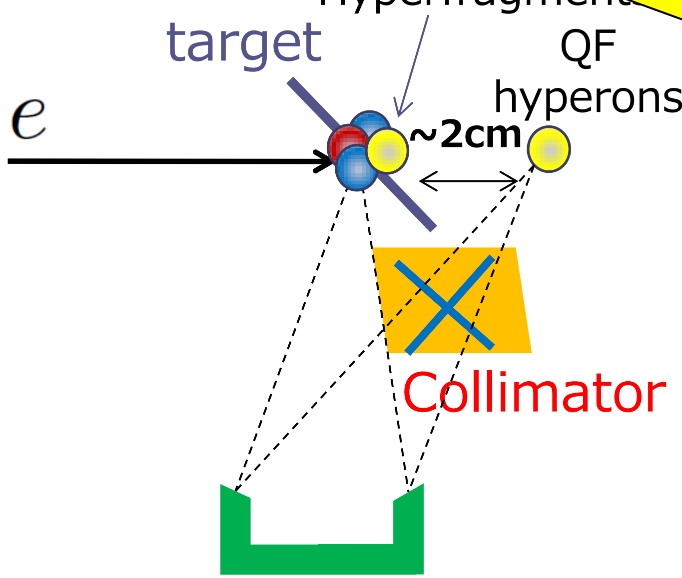
Accidental b.g

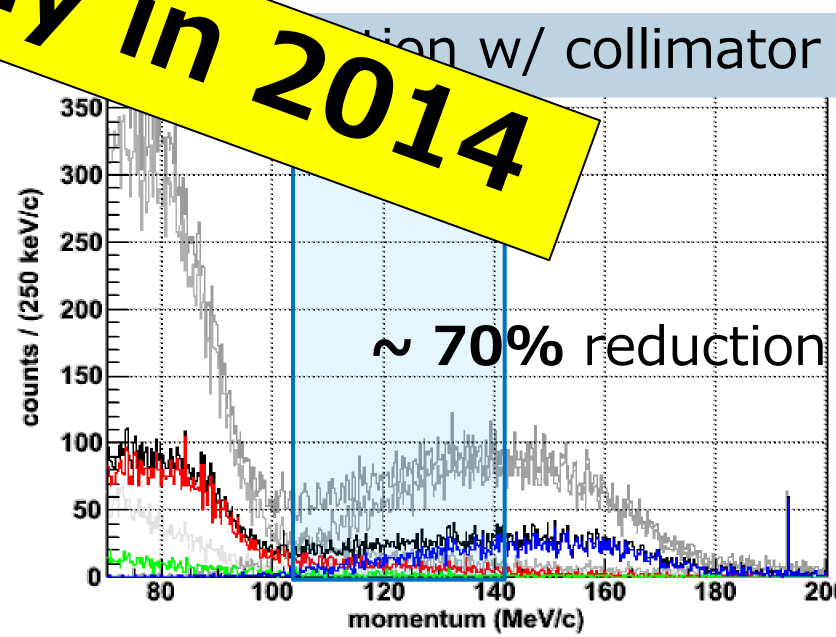
Optimizat… …ead wall : rate→~1/4 (already checked)

Trigger u… …k-C

End of May in 2014

QF hyperon b.g





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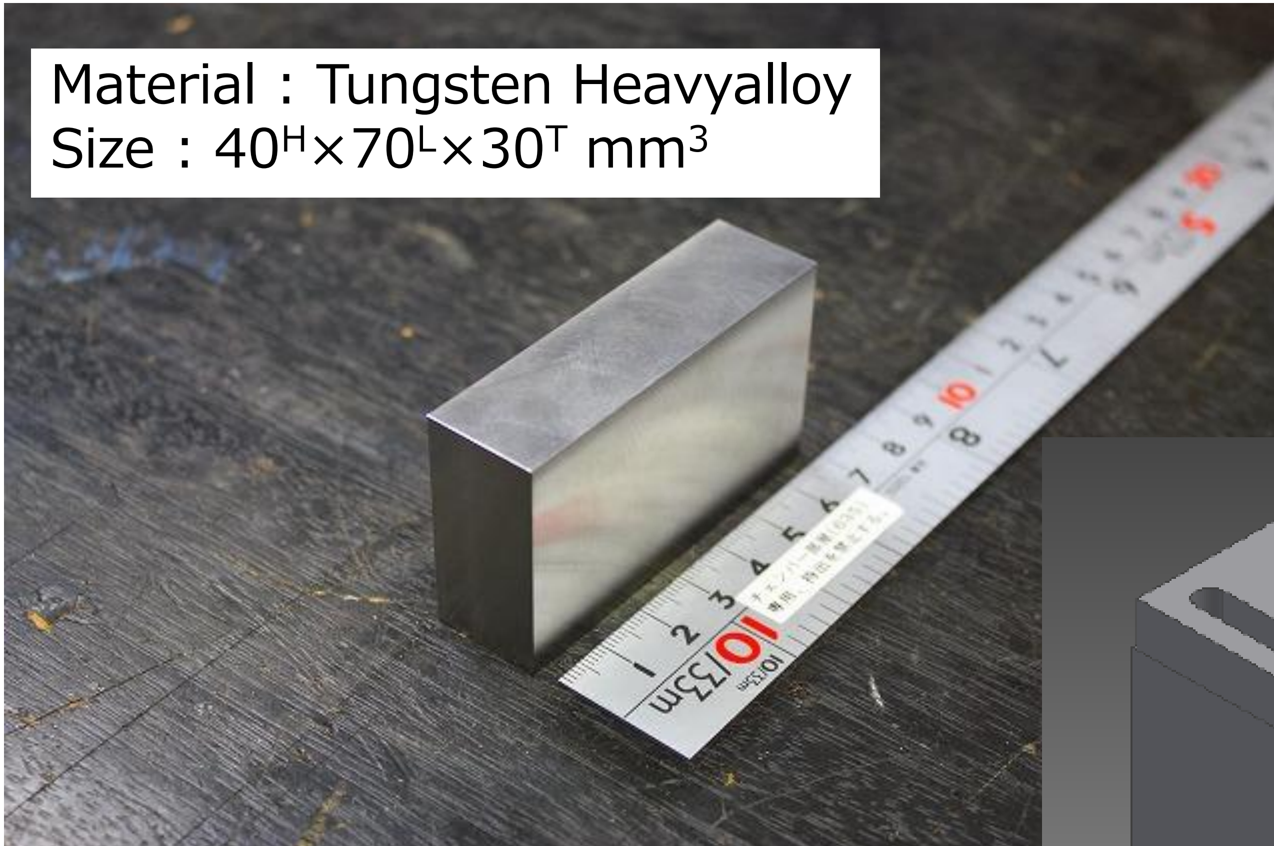
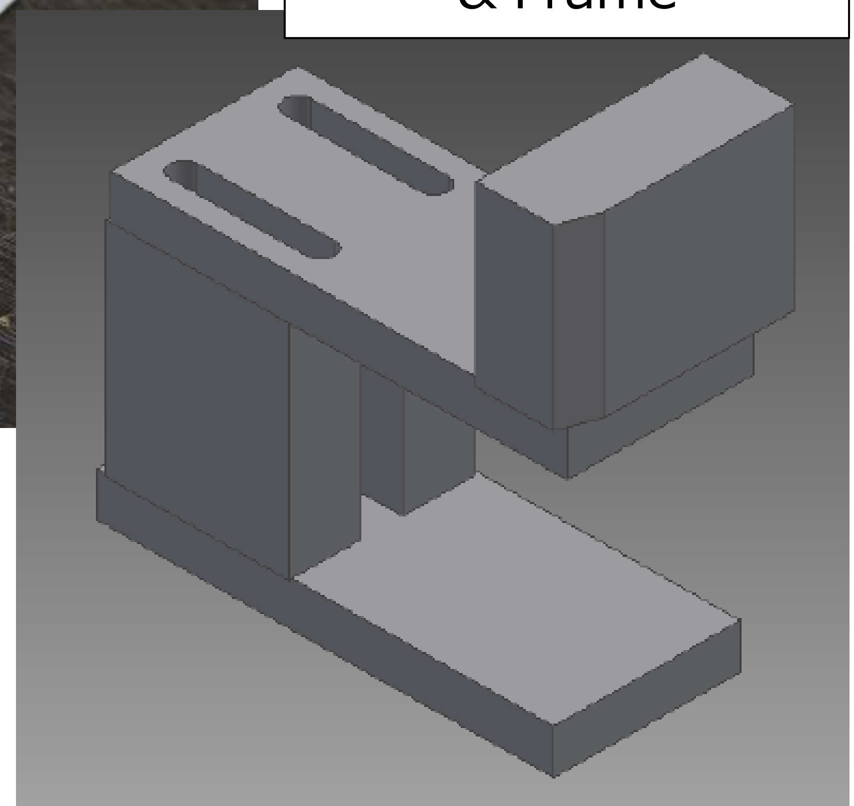


Material : Tungsten Heavyalloy
Size : $40^{H} \times 70^{L} \times 30^{T}$ mm^3

Tungsten Collimator & Frame



Summary

- **Decay pion spectroscopy**
  - new technique
  - ~ 30 keV mass accuracy in light hypernuclei
  - Hypernuclear formation probability
- **Pilot experiment**
  - The experiments have performed in 2011 & 2012
  - ${}^{4}_{\Lambda}H$ peak with small statistical err.
  - Formation probability
- **Future plan**
  - Aiming to better S/N ratio
    - Position optimization of lead wall
    - Collimator to suppress QF hyperon b.g.
  - Next beam time : The end of May (2014) ~