Measurement of light hypernuclear B_Λ and τ at MAMI and ELPH

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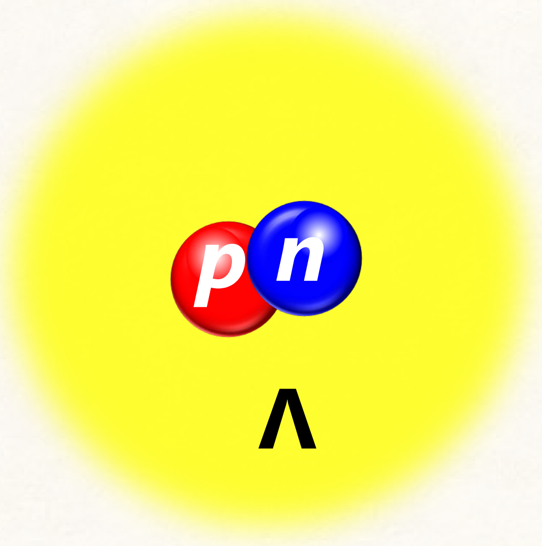
Contents

B_Λ measurement of $^{3}_{\Lambda}H$ at MAMI

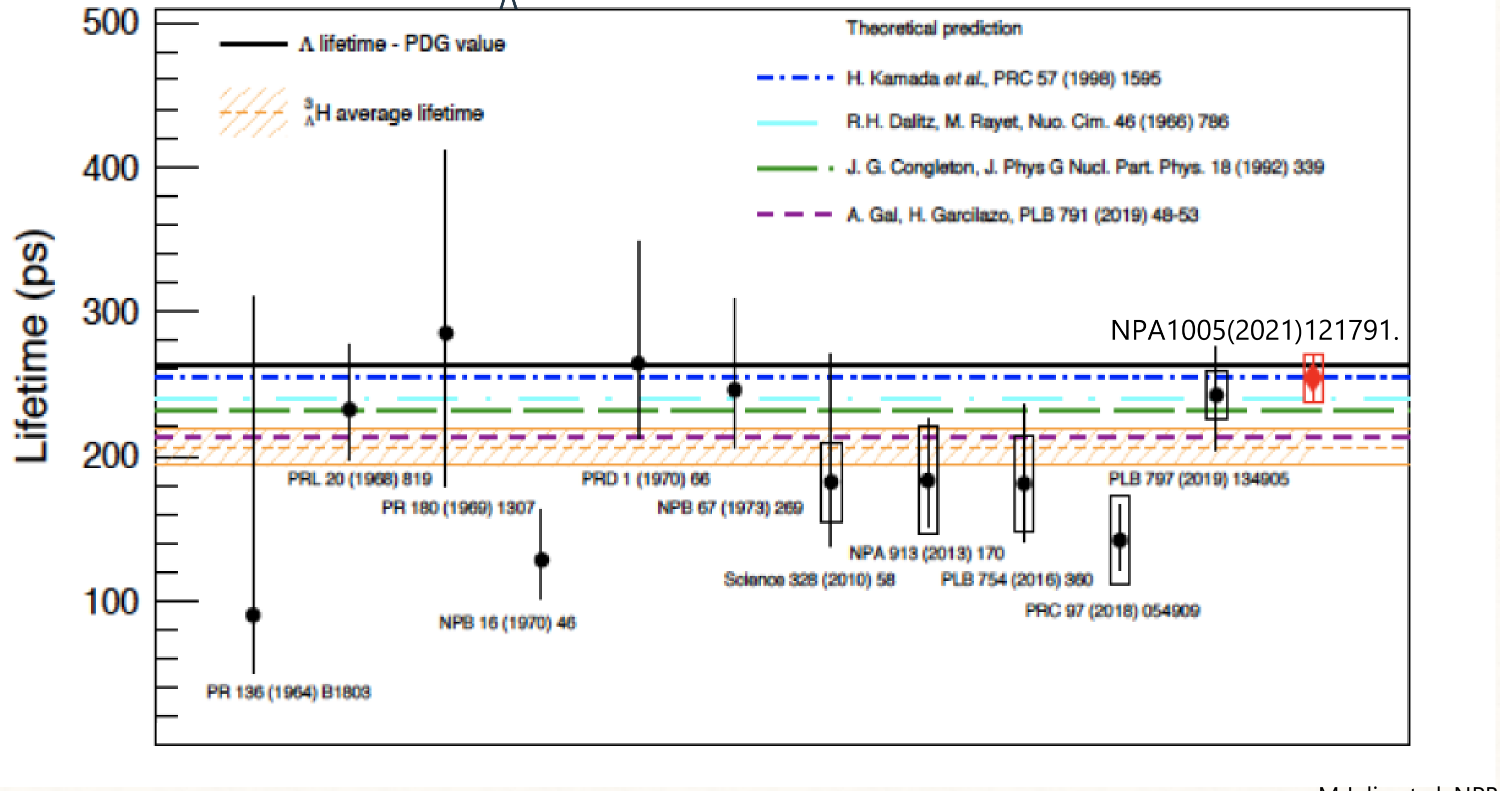
Lifetime measurement of $^{3}_{\Lambda}H$ at ELPH

Elementary Cross Section measurement

Hypertriton Lifetime and Binding Energy



World Data of $^{3}_{\Lambda}$H lifetime



M.Julic et al. NPB52(1973)1.

d-Λ bound system

Λ loosely bound (0.13±0.05 MeV)

→ Radius ~10 fm

d-Λ weak interaction

$\tau \sim \tau_{\Lambda}$ (= 263 ps) due to d-Λ weak interaction

Emulsion Average: small binding energy 0.13±0.05 MeV.

Heavy Ion : deeper binding energy 0.41±0.12±0.11 MeV.

STAR Collaboration NP16(2020)409.

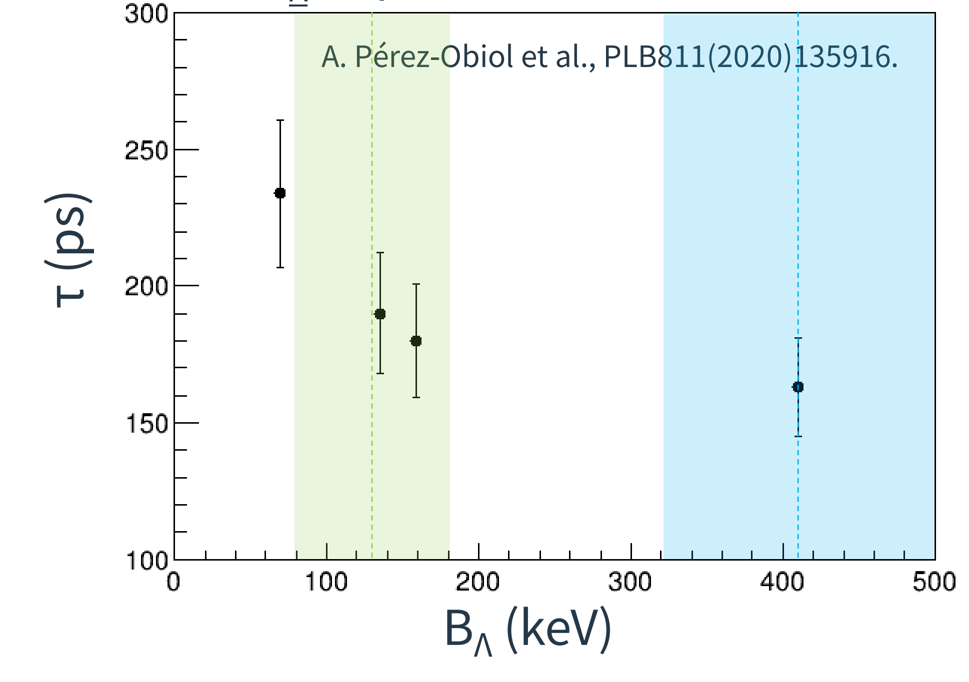
Hypertriton has a short lifetime? deeper bound state ?
"Hypertriton Puzzle"

Theoretical Predictions

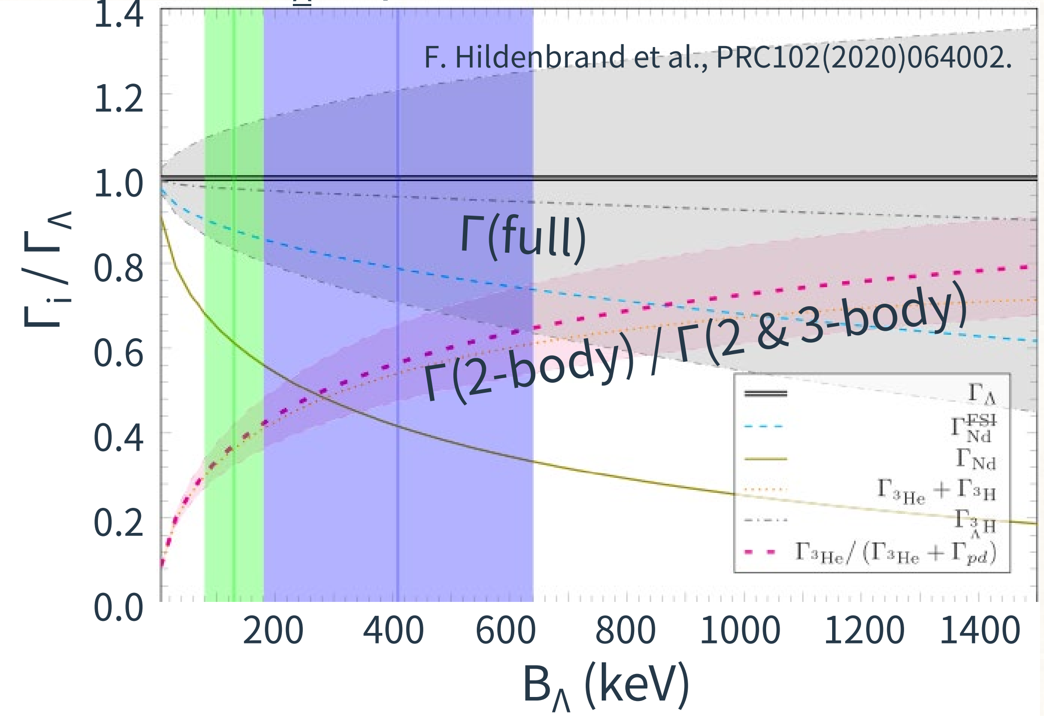
Three-body Faddeev approach: 256 ps H.Kamada et al., PRC57(1998)1595.

Faddeev + attractive pion FSI : 213 ps A.Gal et al., PLB791(2019)48.

τ—B_Λ dependence



Γ—B_Λ dependence



Strong correlation with lifetime—B_Λ and width—B_Λ.

Measurement of B_Λ, lifetime, and decay branch is important.

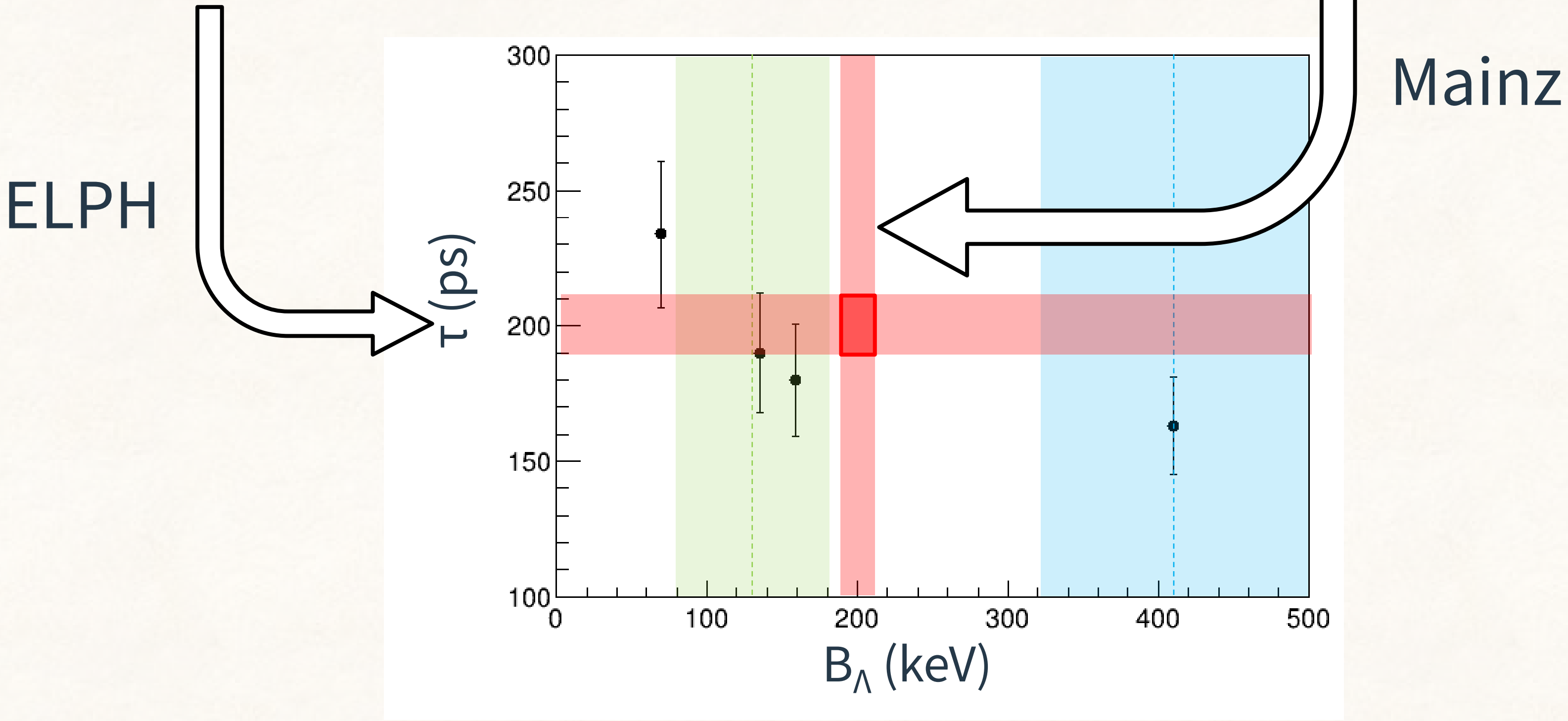
Towards resolving the hypertriton puzzle

Lifetime

- Data with a different approach.
- $^3He(\gamma, K^+)^3_\Lambda H$ reaction at ELPH.
- $\delta\tau$ ~ 10 ps.
- Measurement of decay branch.

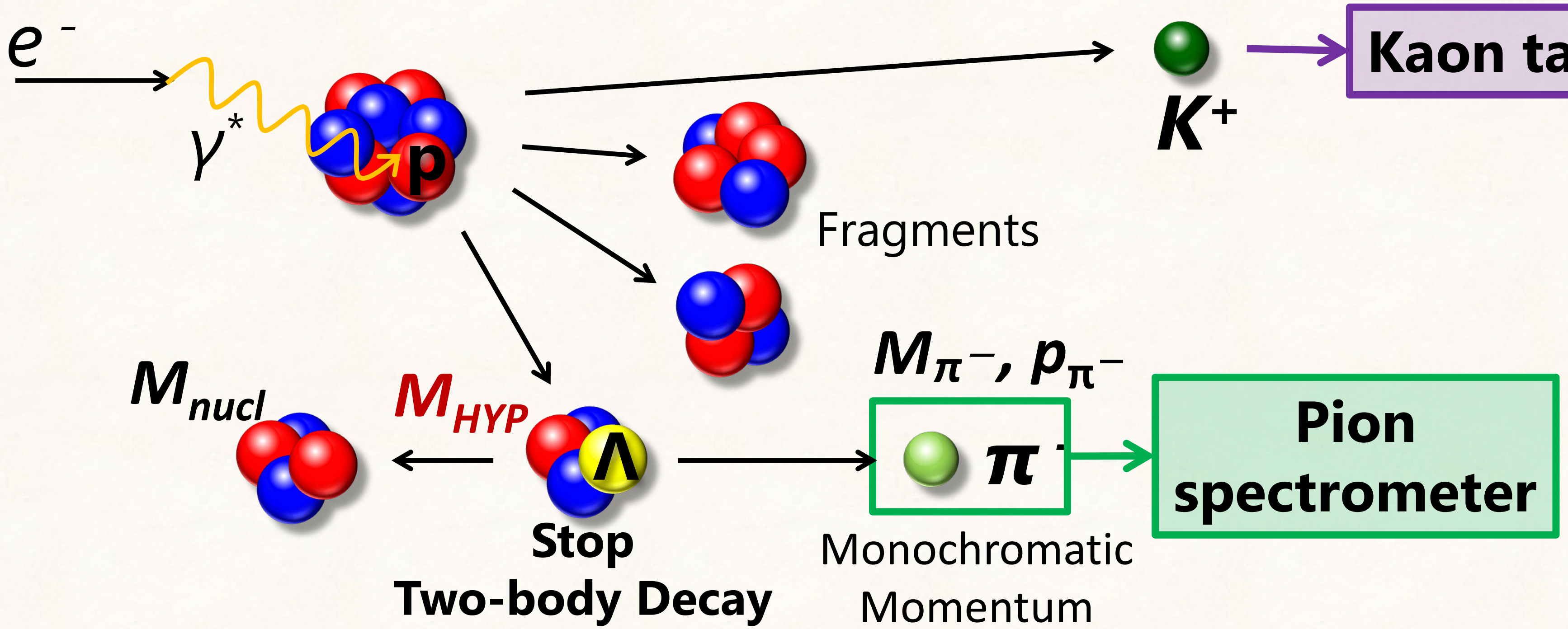
Λ Binding Energy

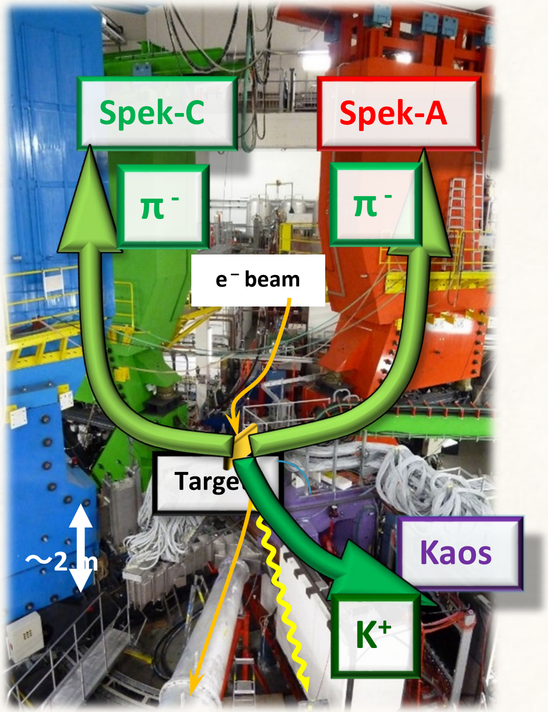
- More precise and accurate measurement.
- Decay pion spectroscopy at MAMI.
- δB_Λ ~ 10 keV (including syst.).



MAMI
(B_Λ measurement)

Decay pion spectroscopy





$$\mathrm{M_{HYP}} = \sqrt{\mathrm{M}^2_{\mathrm{nucl}} + p^2_{\pi^-}} + \sqrt{\mathrm{M}^2_{\pi^-} + p^2_{\pi^-}}$$

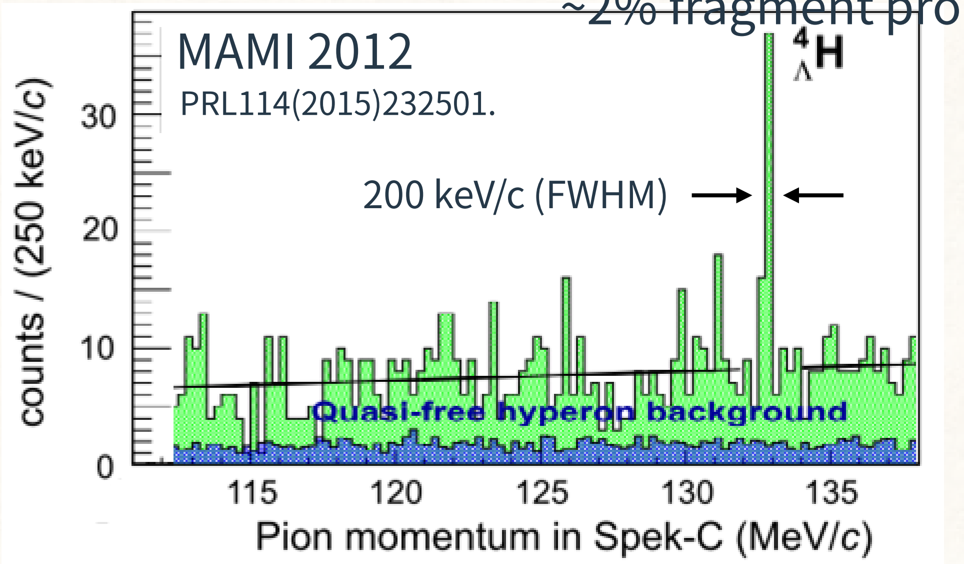
High resolution spectroscopy of low momentum charged pion.

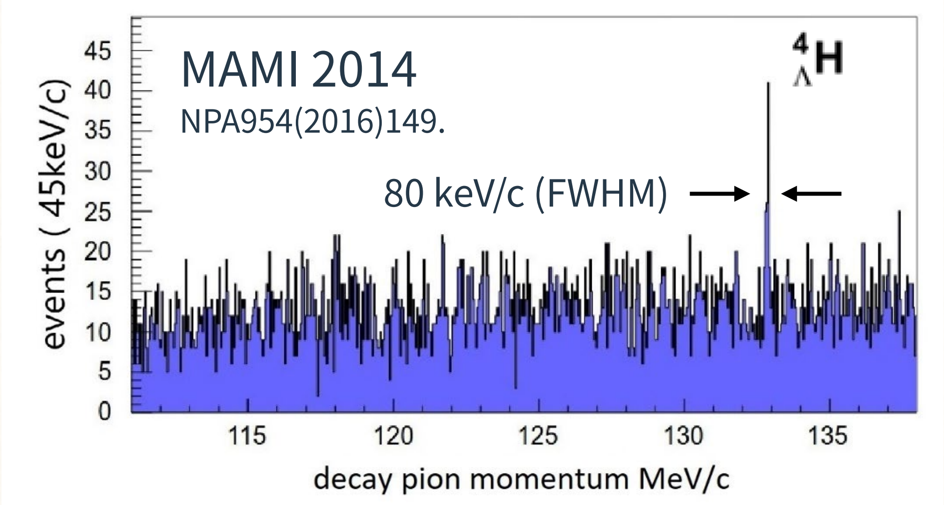
Excellent resolution and precision thanks to high quality beam and less material.

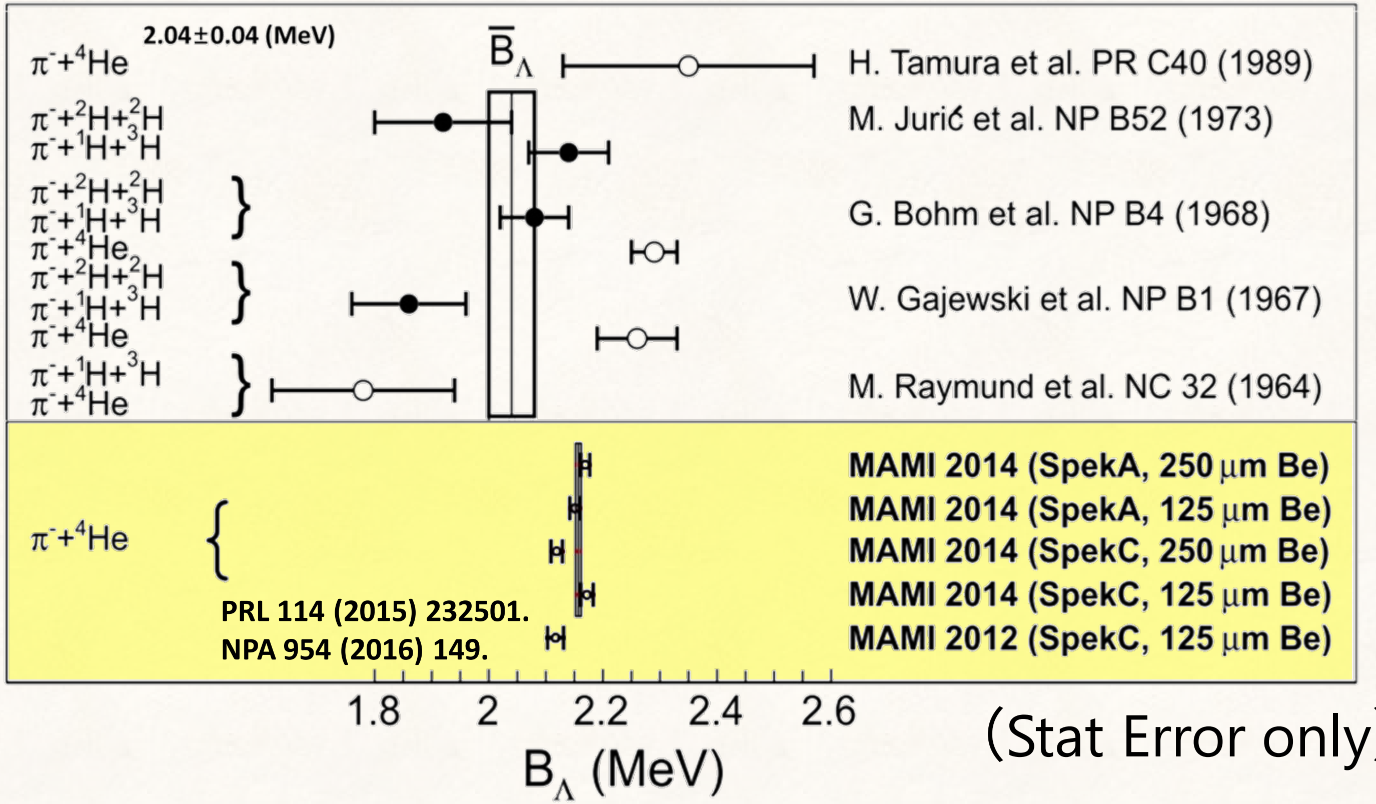
Small systematic uncertainty thanks to well studied spectrometer.

New Determination of ${}^{4}_{\Lambda}$H binding energy

~2% fragment prob.







(Stat Error only)

B_Λ (MAMI 2012) = 2.12±0.01(stat.)±0.09(syst.) MeV

B_Λ (MAMI 2014) = 2.157±0.005(stat.)±0.077(syst.) MeV

Higher accuracy

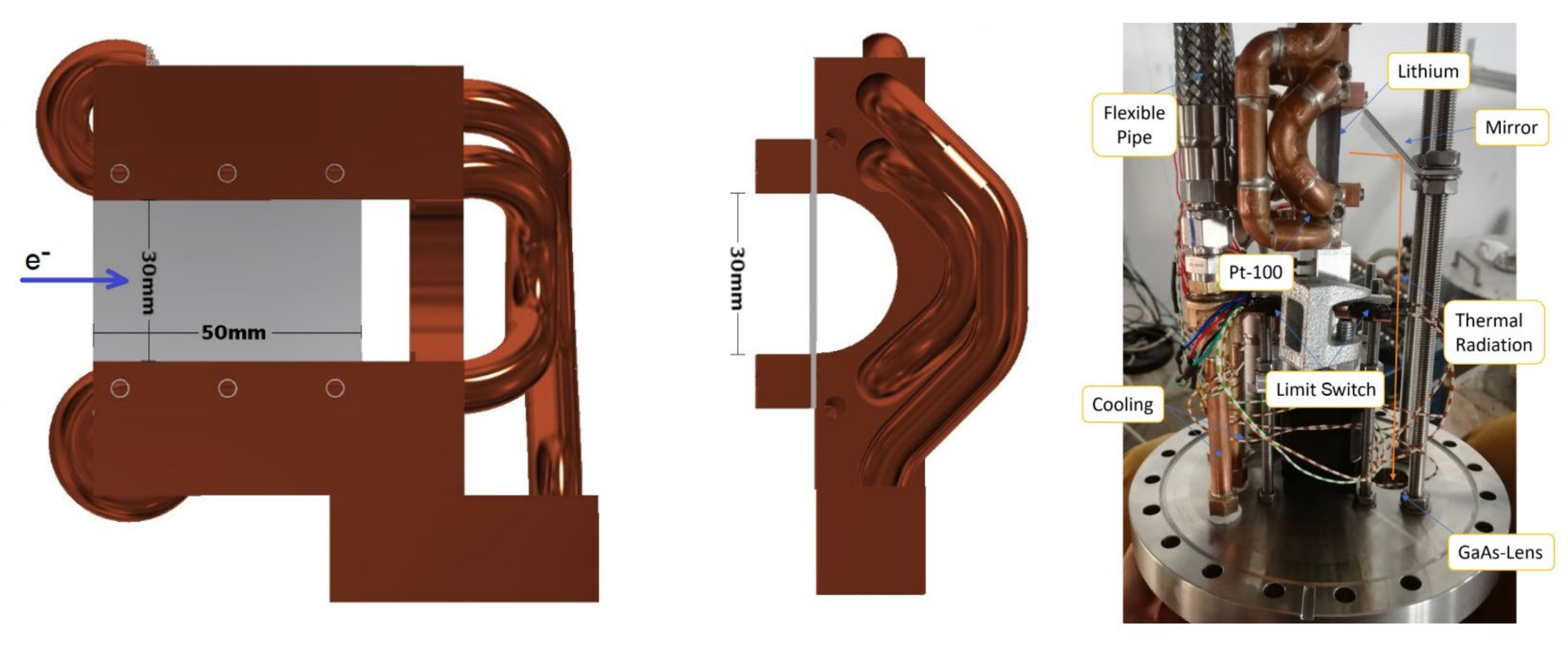
High yield & background suppression

New target for the next experiment

Background suppression and higher yield is very important.

Last : ^{9}Be 47mg/cm^2 40~60 μA

Next : Li 2700 mg/cm^2 2~10 μA

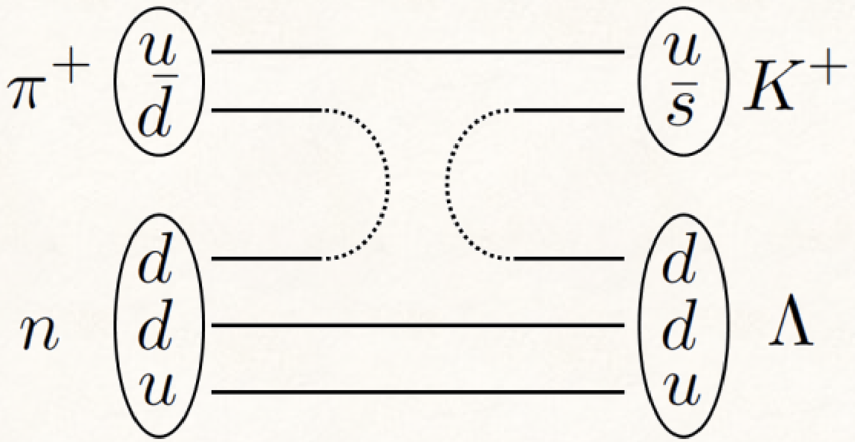


Beamtime assignment in July~

NKS2
(Lifetime measurement)

Difficulties of hypertriton production

(π^+, K^+) or (K^-, π^-) reaction



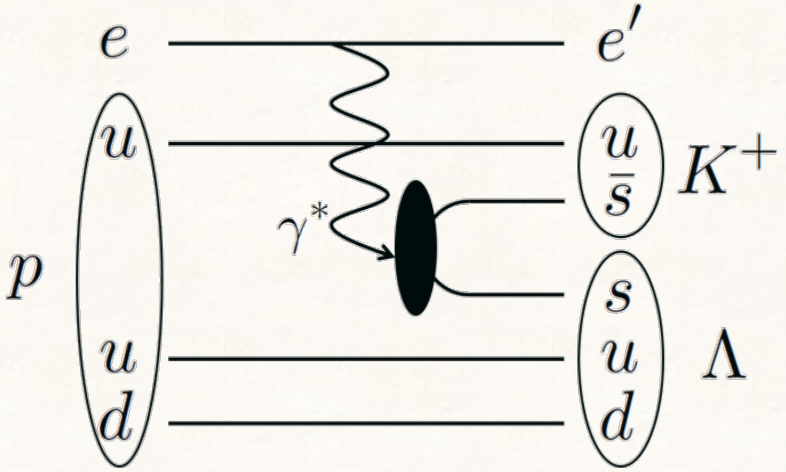
$n \rightarrow \Lambda \;\Rightarrow\; T_2 \rightarrow {}^3_\Lambda H$

Studied by (π^+, K^0) or (K^-, π^0) reaction

Measurement of non-charge particle is difficult.

Mass spectroscopy would be difficult.

(e,e'K^+) reaction



$p \rightarrow \Lambda \;\Rightarrow\; {}^3He \rightarrow {}^3_\Lambda H$

Electron beam intensity is too high.

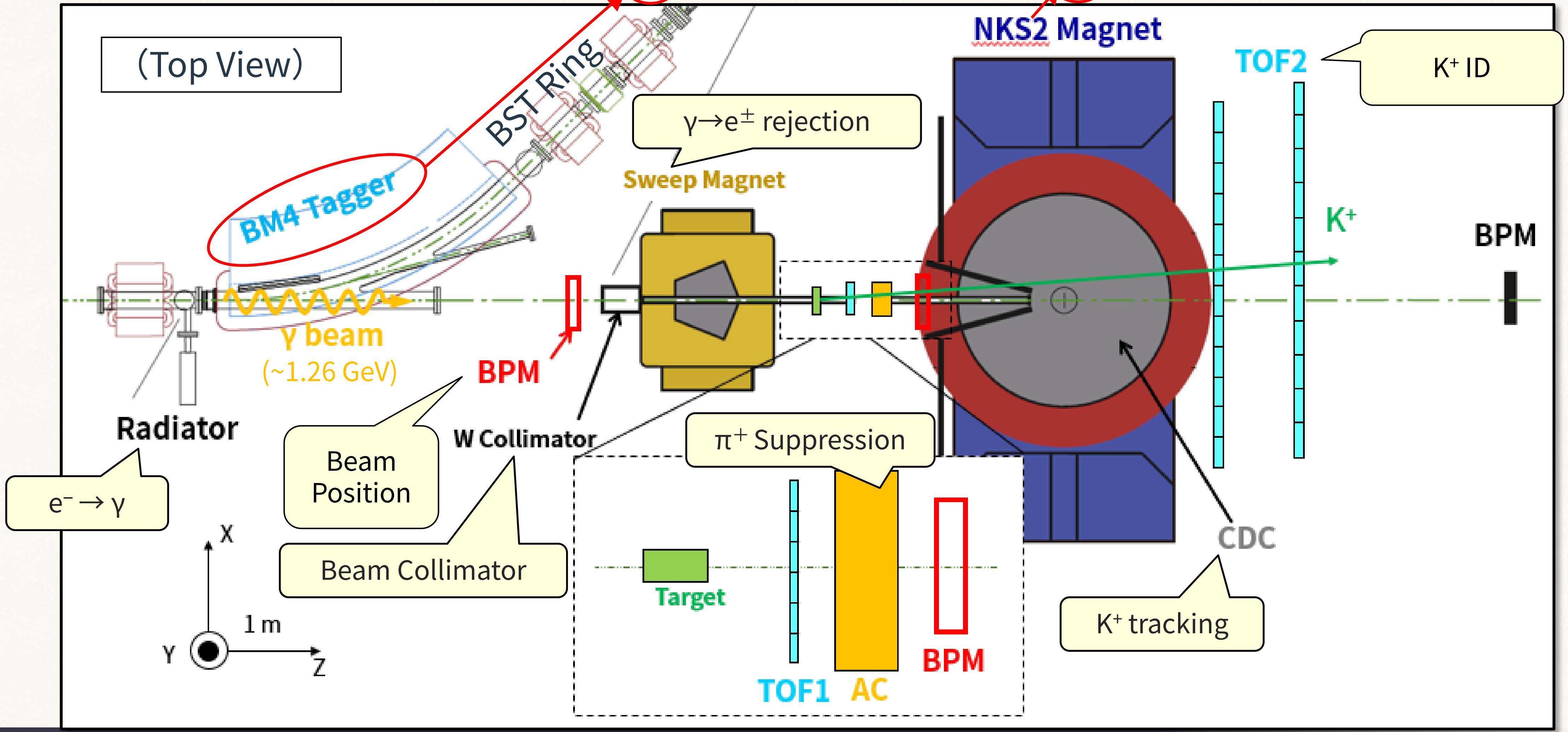
Measurement of decay products is difficult.

⇒ Experiment with the (γ, K^+) reaction

Experimental Setup

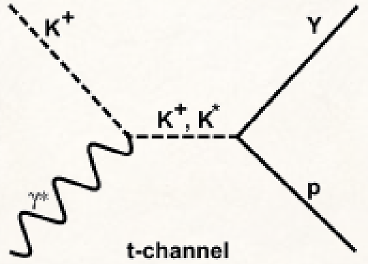
Hypertriton Production from ³He target. $^{3}_{\Lambda}H$ detection on the Missing Mass

Missing Mass $M_Y^2 = (E_\gamma + E_T - E_K)^2 - (p_\gamma - p_K)^2$



C.S. measurement of the p(γ, K^+)Λ at forward angles

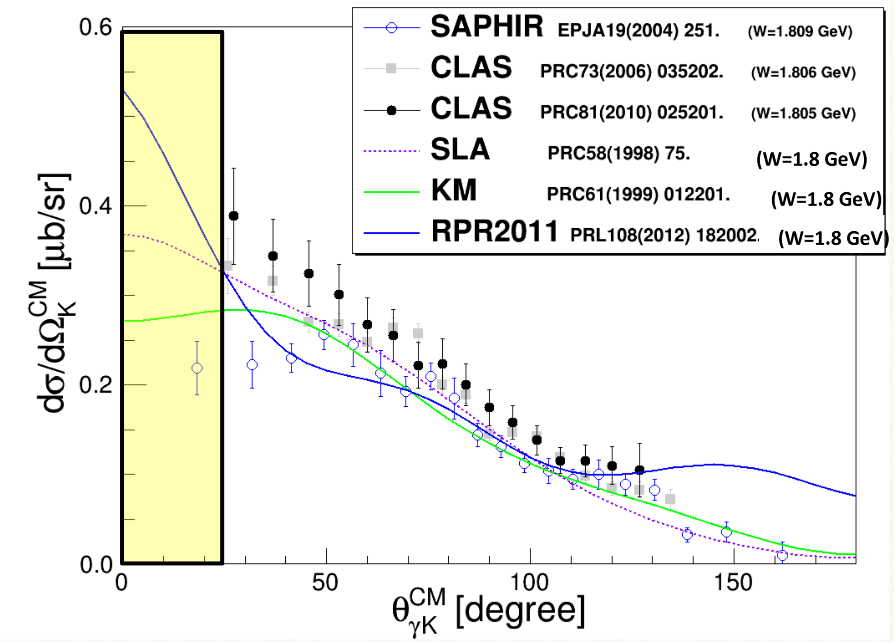
$$\frac{d\sigma_v}{d\Omega_K^*} = \frac{d\sigma_T}{d\Omega_K^*} + \epsilon\frac{d\sigma_L}{d\Omega_K^*} + \sqrt{2\epsilon(1+\epsilon)}\frac{d\sigma_{LT}}{d\Omega_K^*}\cos\phi_K^* + \epsilon\frac{d\sigma_{TT}}{d\Omega_K^*}\cos 2\phi_K^*$$

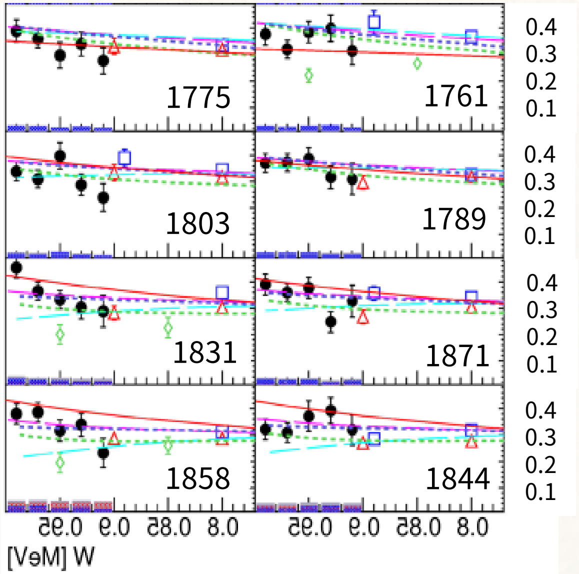


iso-bar model (K-MAID, SLA etc.)
[PRC61(2000)012201., PRC58(1998)75.]

Regge + Resonance model
[Phys. Rev. C 73 (2006) 045207]

Angular dependence on K+L cross section





S. Alef et al., EPJ A (2021) 57.

There are not enough data at the forward angles.

New NKS2 experiment has an acceptance at $\theta_{\gamma K}$ = 5 - 20°, W < 1.8 GeV

Experiment is already approved, it will run in June 2022.

Summary

Precise measurement of light hypernuclei is important resolving the effective ΛN interaction.

- Inconsistency of hypertriton binding energy and lifetime

Experimental approach

More accurate B_Λ measurement with decay pion spectroscopy at Mainz (July 2022~)

High intensity electron beam and new Li target will be used.

δB_Λ ~ 10 keV will be expected.

More precise lifetime measurement with (γ,K^+) reaction at ELPH (2022~)

Real photon beam and He target will be used.

$\delta\tau$ ~ 10 ps will be expected.

p(γ,K+)Λ experiment will be performed in June 2022.