
Mainz Hauptbahnhof, June 2022

Mass measurement study of $^{3}_{\Lambda}H$ by Decay-pion spectroscopy at MAMI

“MAMI の崩壊パイ中間子分光法による $^{3}_{\Lambda}H$ の質量測定研究”

Ryoko Kino (Tohoku Univ.) *for the A1 collaboration*

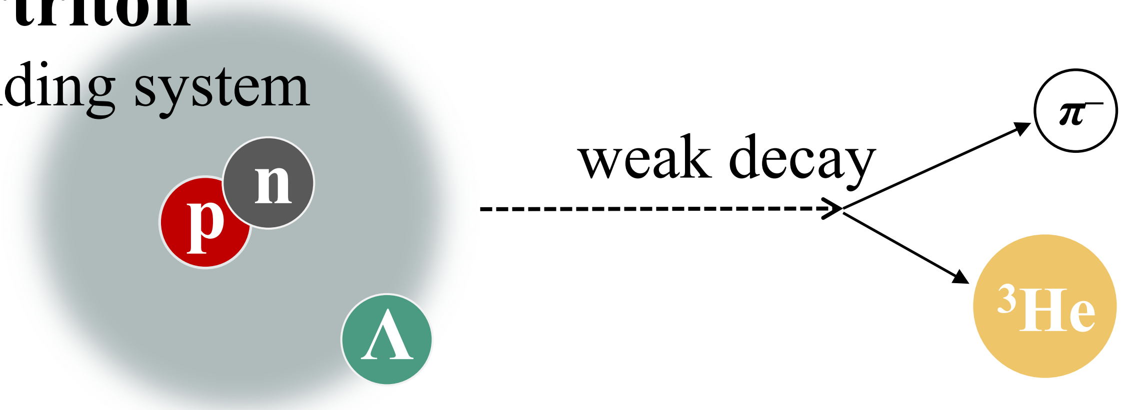
TOHOKU UNIVERSITY

JG|U

ST2-2022 December 16, 2022

Λ Binding Energy of Hypertriton

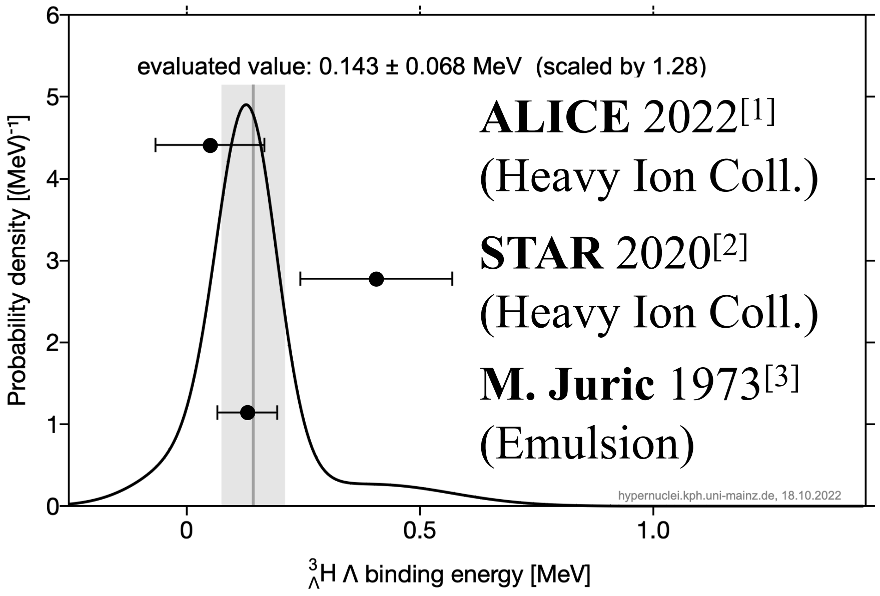
Hypertriton
d-Λ binding system



Small binding energy? v.s **Short lifetime?**

"Hypertriton Puzzle"

➢ Hypernuclear database



- Still large experimental uncertainties
- Value still dominated by Emulsion data – 77 %

Precise measurements are needed!

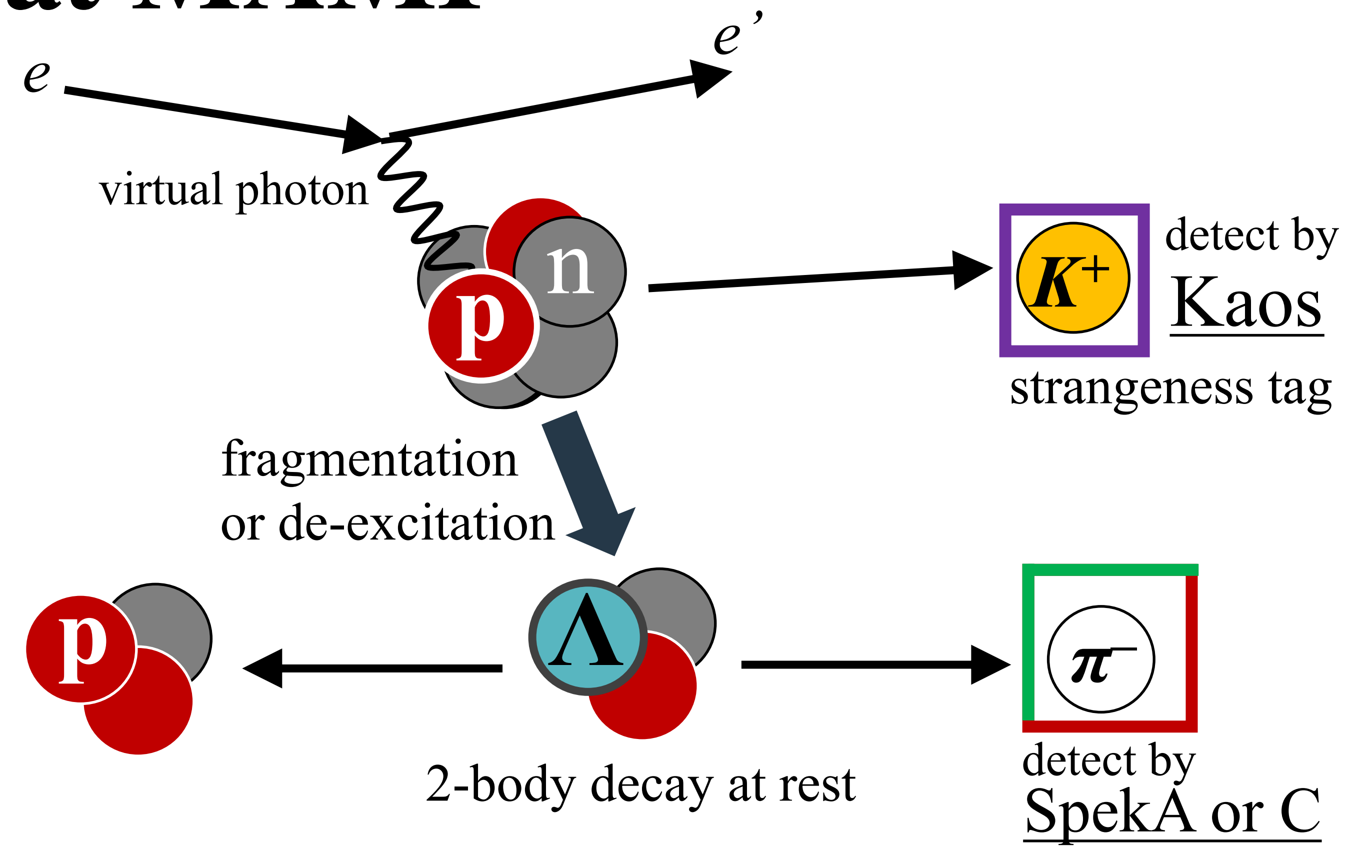
[1] S. Acharya *et al.*, Phys. Rev. Lett. (2022) 128
[2] STAR, Nature Phys. 16 (2020) 4, 409-412
[3] M. Juric, Nucl. Phys. B 52, 1 (1973) 1-30

Decay-pion spectroscopy at MAinz-MIcrotron

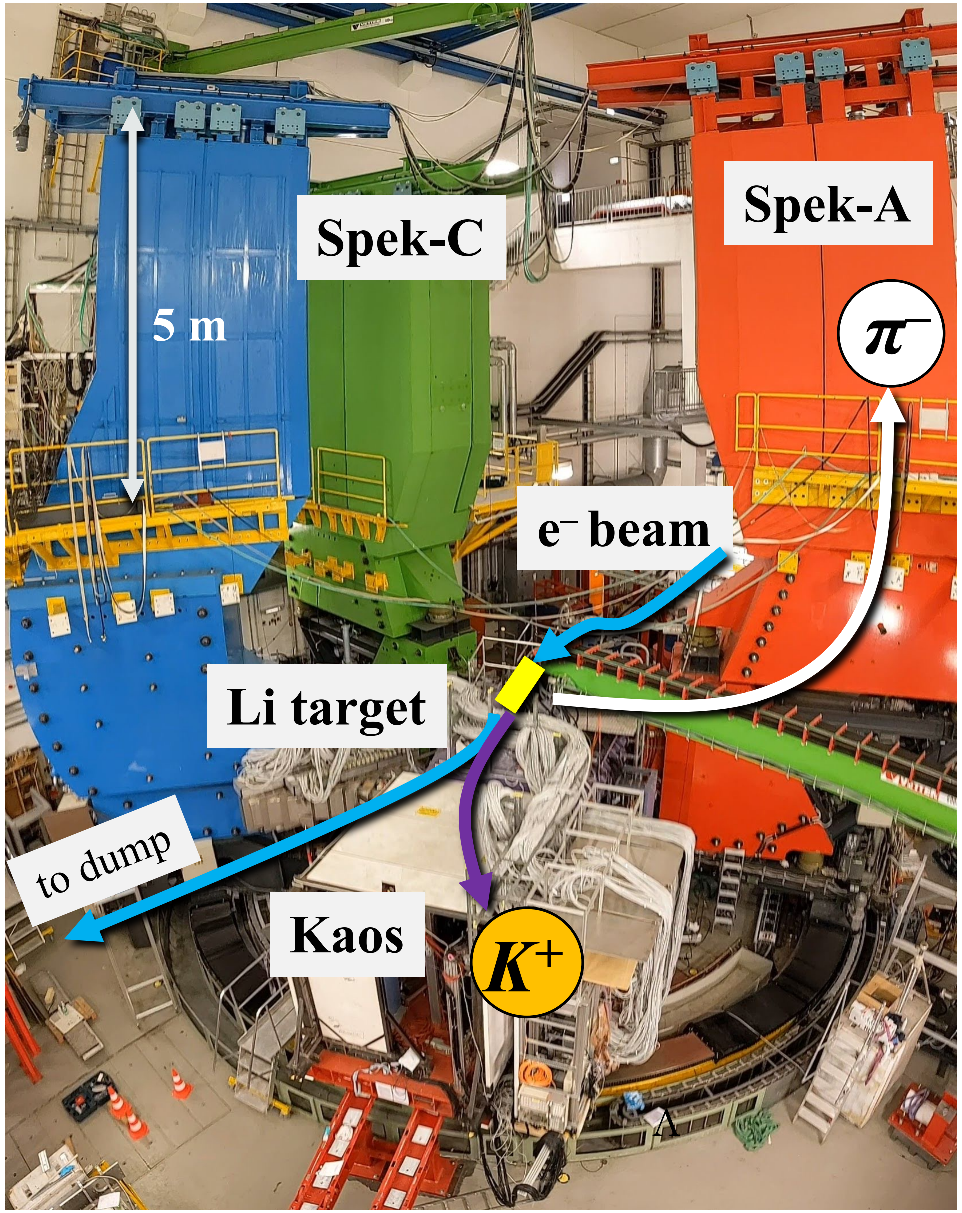
Mainz

Johannes Gutenberg University, Mainz

Decay-pion spectroscopy at MAMI



$$m({}^{A}_{\Lambda}Z) = \sqrt{m({}^{A}(Z+1))^2 + p_\pi^2} + \sqrt{m_\pi^2 + p_\pi^2}$$

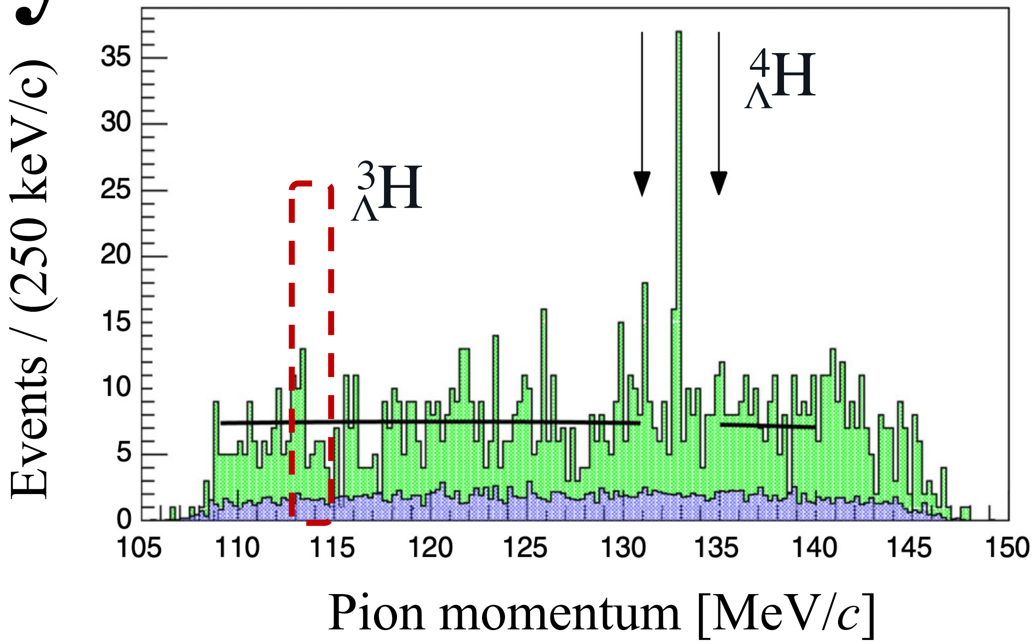


Previous experiment of Decay-pion spectroscopy

- Two body decays of hypernuclei:
  $^{3}_{\Lambda}\mathrm{H} \rightarrow {}^{3}\mathrm{He} + \pi^{-}$ @ 114 MeV/c
  $^{4}_{\Lambda}\mathrm{H} \rightarrow {}^{4}\mathrm{He} + \pi^{-}$ @ 133 MeV/c

- Result of the previous experiment
  $^{4}_{\Lambda}\mathrm{H}$: $B_{\Lambda} = 2.12 \pm 0.01$ (stat.) $\pm$ 0.09 (syst.) MeV[4]

[4] A. Esser, S. Nagao *et al.*, PRL 114 (2015) 232501.

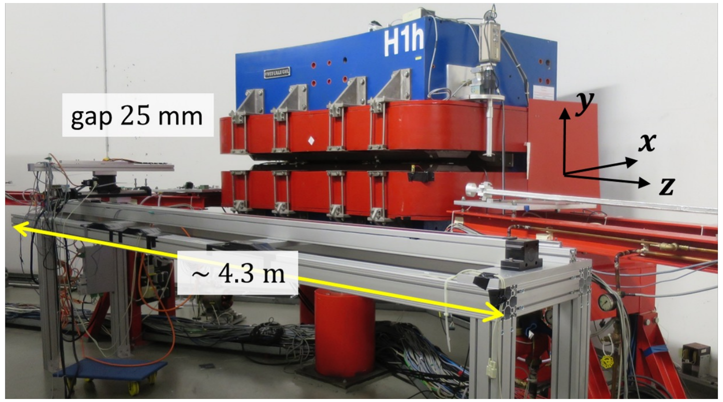


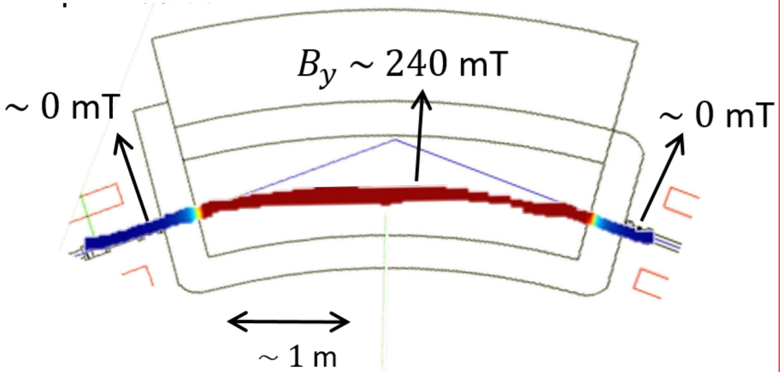
New experiment

- Suppression of systematic errors ➡ High precision beam energy measurement
- Ensuring the yield of $^{3}_{\Lambda}\mathrm{H}$ ➡ The new Lithium target system

Suppression of systematic errors

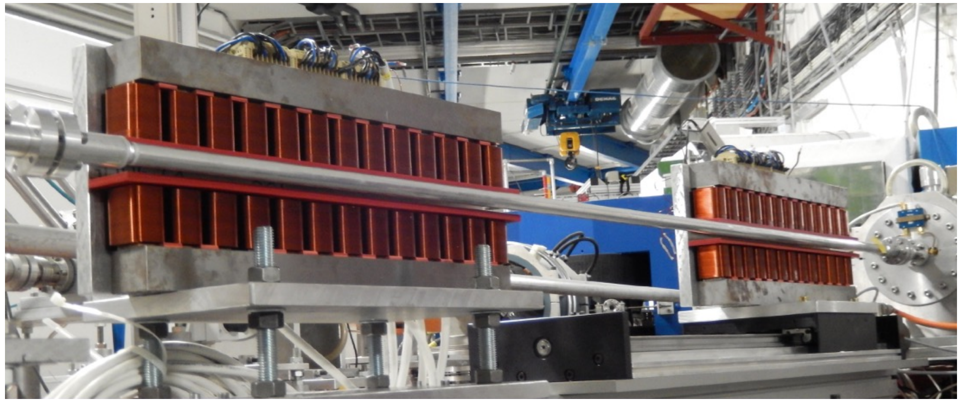
Precise field measurement of an Acc. dipole magnet





S. Tomita, Master thesis, Tohoku Univ. (2016)

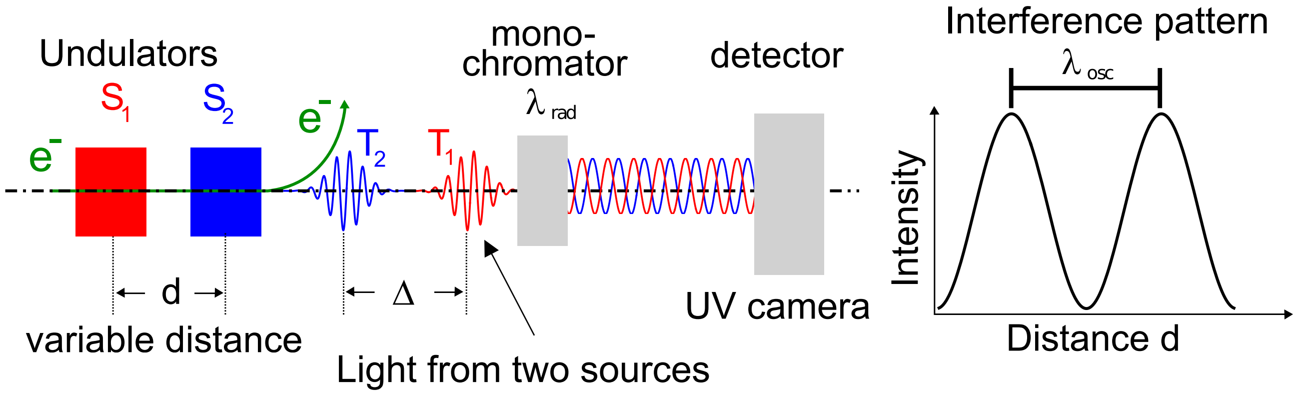
Interference of undulator radiation



Relativistic γ via undulator eq.:

$$\lambda_{osc} = 2\gamma^2 \lambda_{light}$$

→ Precision of 18 keV possible



P. Klag *et al.*, NIM A 910 (2018) 147–156

Beam energy measurement

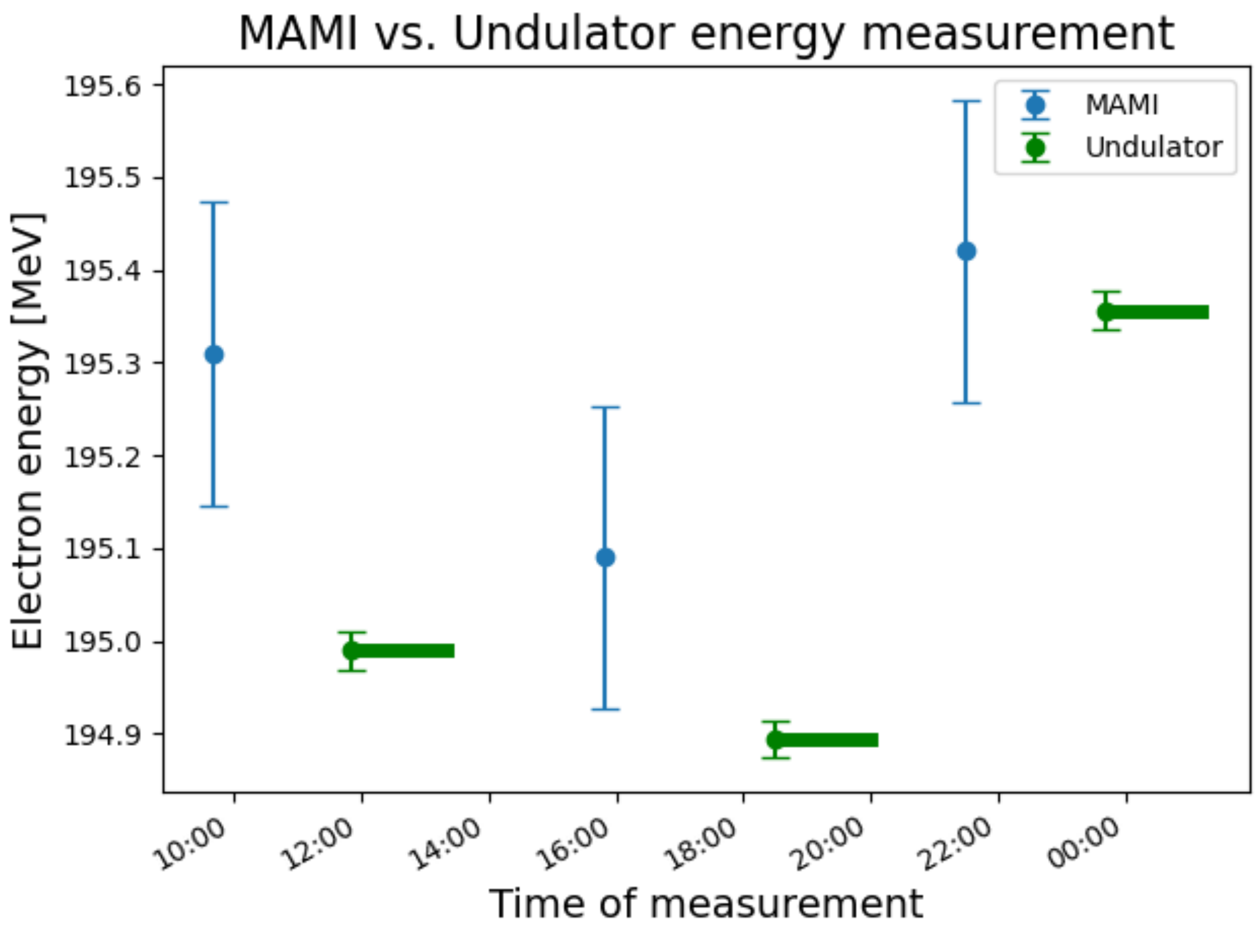
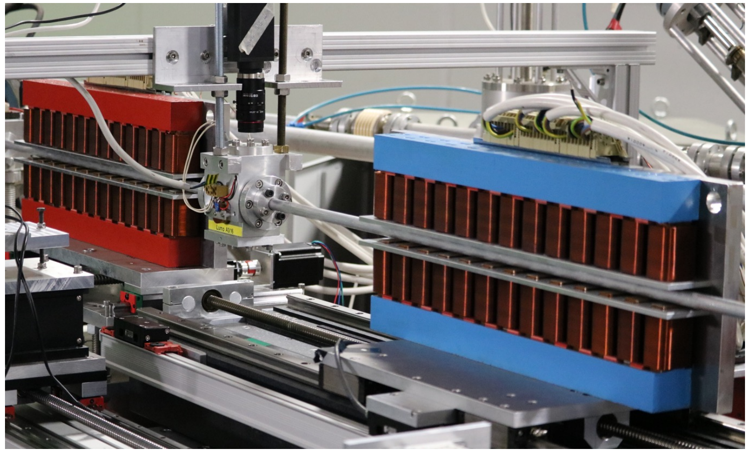


Figure from PhD thesis of P. Klag (in preparation)



Relativistic γ via undulator eq.:

$$\lambda_{osc} = 2\gamma^2 \lambda_{light}$$

Accuracy of gamma depends on:

- Length measurement
- Monochromator-calibration
- Optical alignment

→ Precision of 18 keV possible

How to see $B_\Lambda({}^3_\Lambda\mathrm{H})$ with small errors?

New target system

^{9}Be 47mg/cm^2, 40 – 60 μA ➡ ^{7}Li 2430 mg/cm^2, ~1 μA

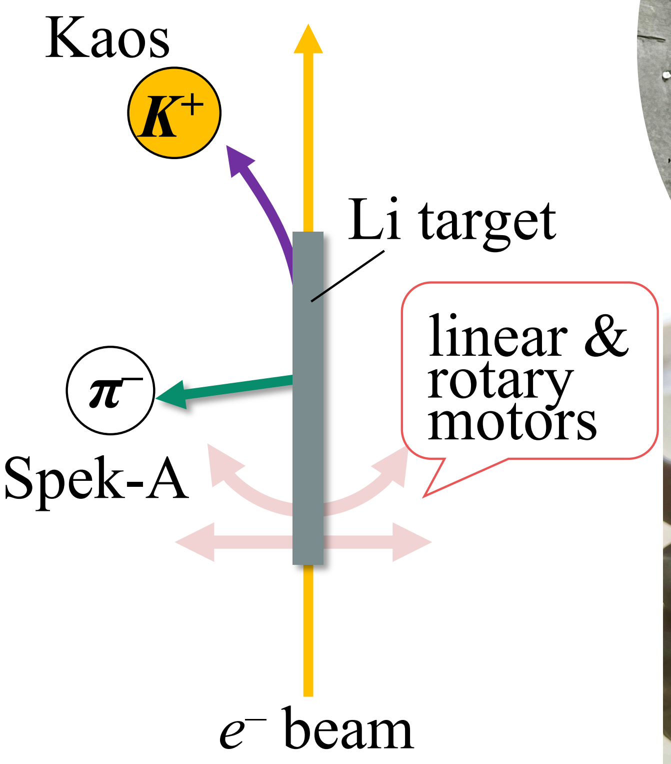
- **Less background** as ^{9}Be

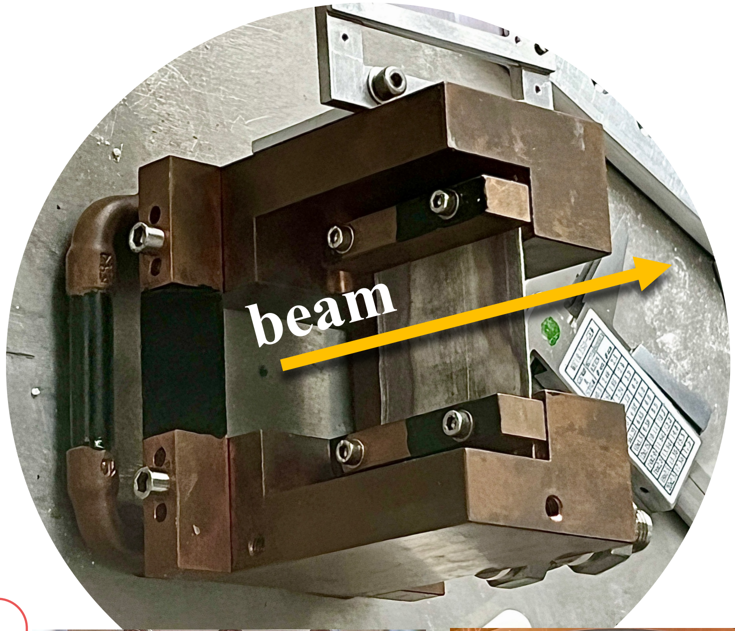
  No heavy Helium with
  similar decay pion momenta:

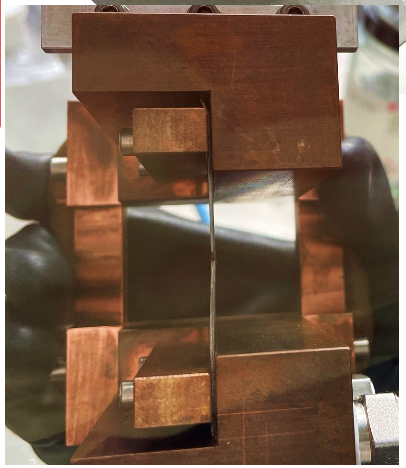
  ${}^7_\Lambda$He: 115.7 ${}^8_\Lambda$He: 116.5 [MeV/c]
  (${}^3_\Lambda$H: 114.3 MeV/c)

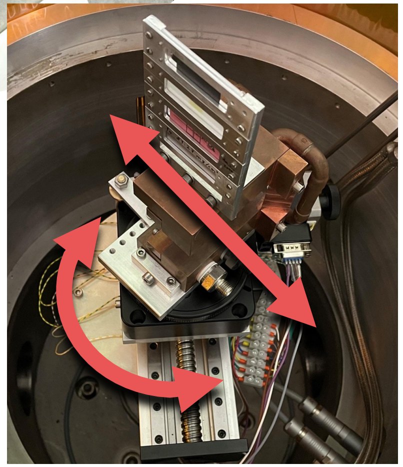
- **Maximized rate** of hypernuclei

  Beam direction – 45 mm long

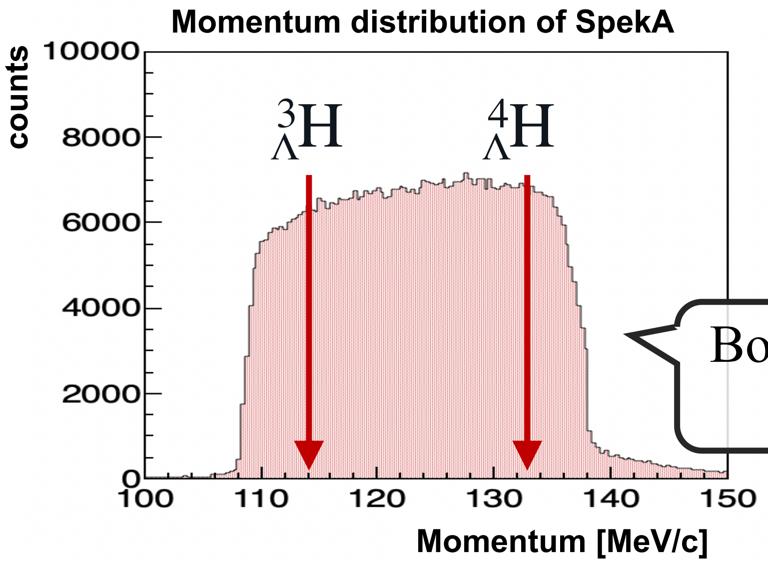




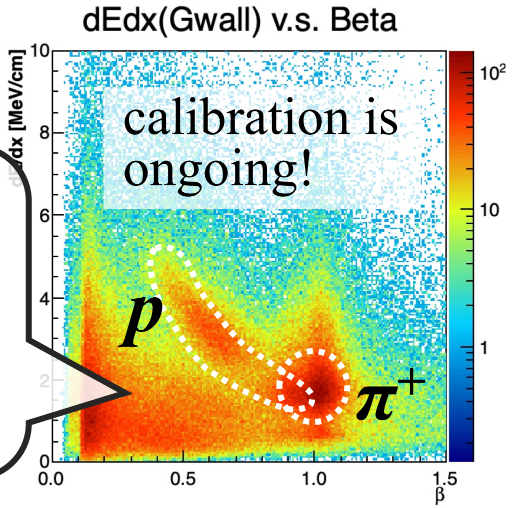




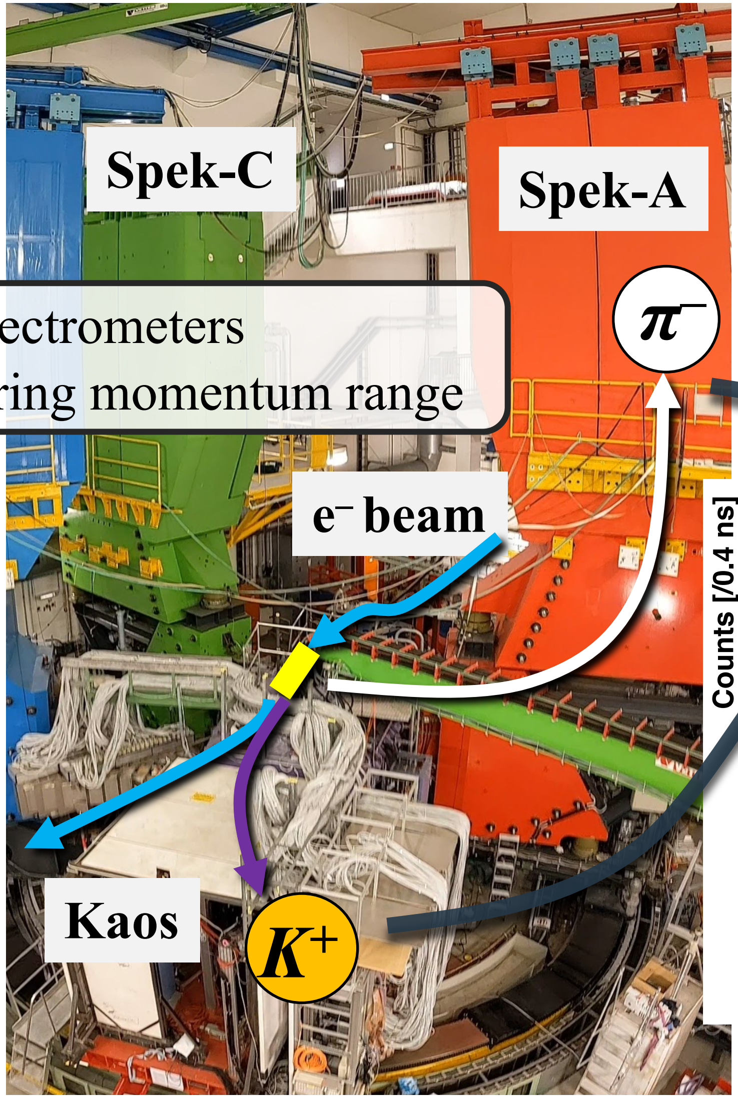
Latest data from the experiment in Oct. 2022



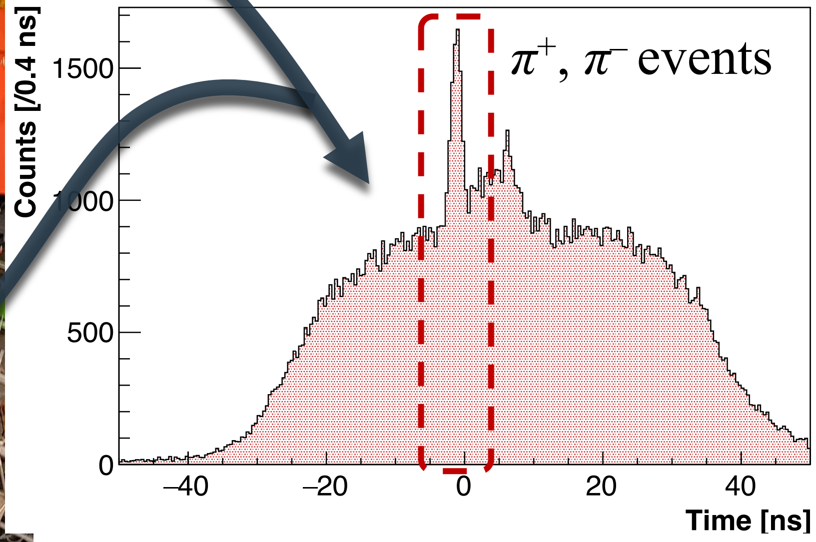
Both spectrometers covering momentum range



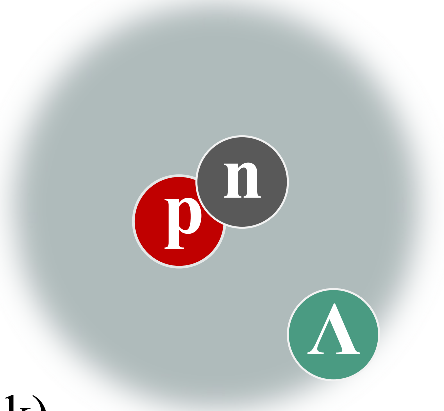
Distribution for PID. Kaons will be visible



Kaos and Spek-A coinsidence time distribution



Summary



- Beamtime schedule 2022

  July 11th – Aug. 1st : Commissioning run

  (Kaos started up again, confirmed coincidence peak)

  Sept. 16th – Oct. 17th : Physics run → **Analysis is ongoing!**

  Apr. – May 2023 : Spectrometer calibration run

- Momentum setting to observe both of $^{3}_{\Lambda}$H and $^{4}_{\Lambda}$H
- New target system → suppress BG & higher luminosity
- New calibration via undulator light interference → minimize syst. error

Our goal: total error of ± 20 keV in Λ binding energy

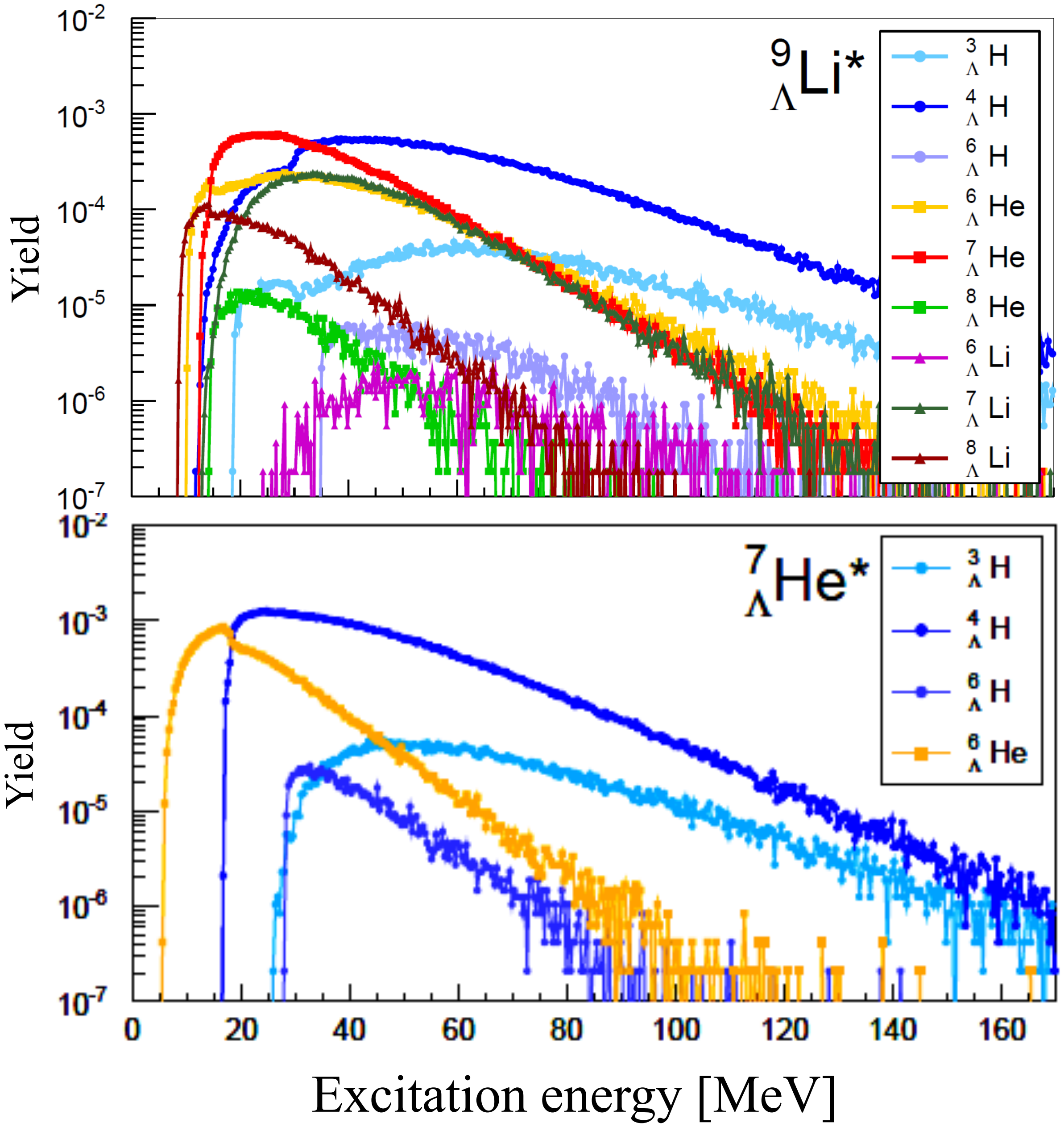
Back Up

Lithium target

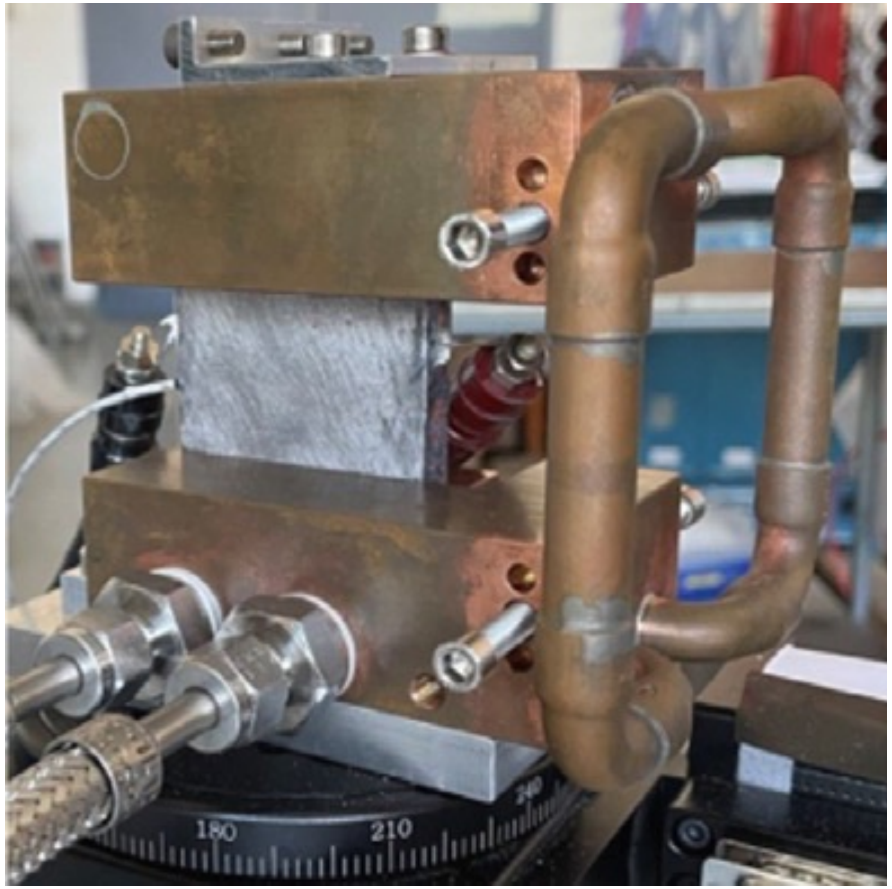
- **Less background** as ^{9}Be

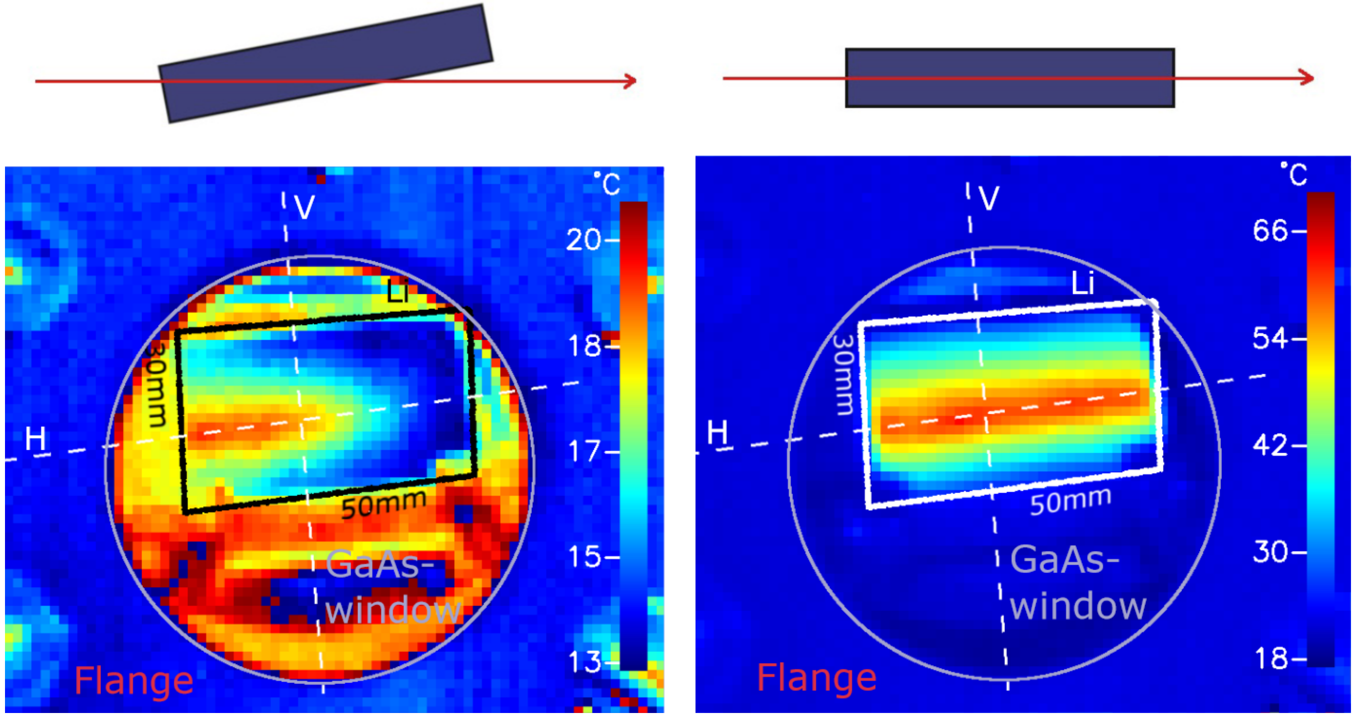
No heavy Helium with similar decay pion momenta:

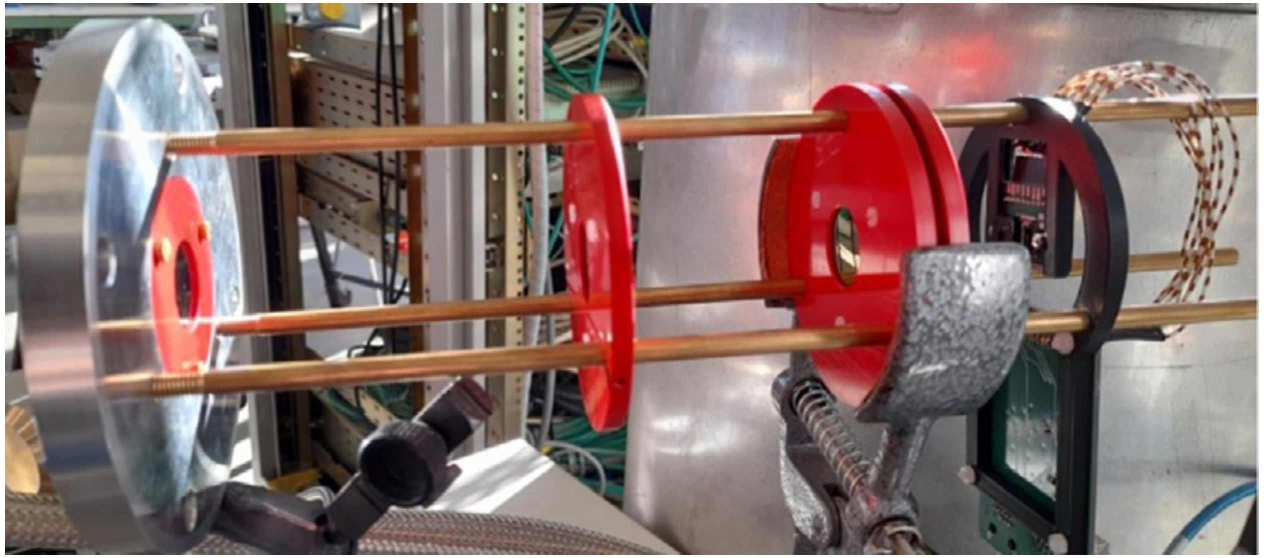
$^{7}_{\Lambda}$He: 115.7 $^{8}_{\Lambda}$He: 116.5 [MeV/c]
($^{3}_{\Lambda}$H: 114.3 MeV/c)



Lithium target







1. P. Eckert, *et al.*, A1 Collaboration, PoS (PANIC2021) 380 (2022) 201
2. P. Achenbach *et al.*, NIM A 1043 (2022) 167500