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FB23

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Study of the neutron-rich nucleus ^{6}H in an electron scattering experiment at MAMI-A1

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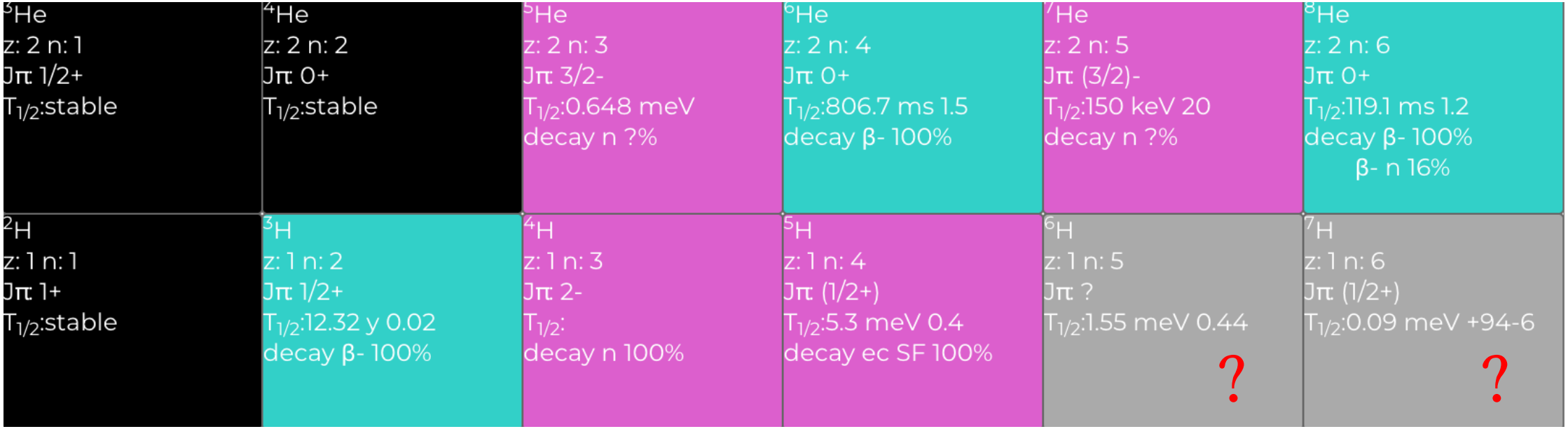
Outline

- Motivation
- Experiment principle
- MAMI-A1 setup
- Calibration
- Data analysis
- Summary

Motivation

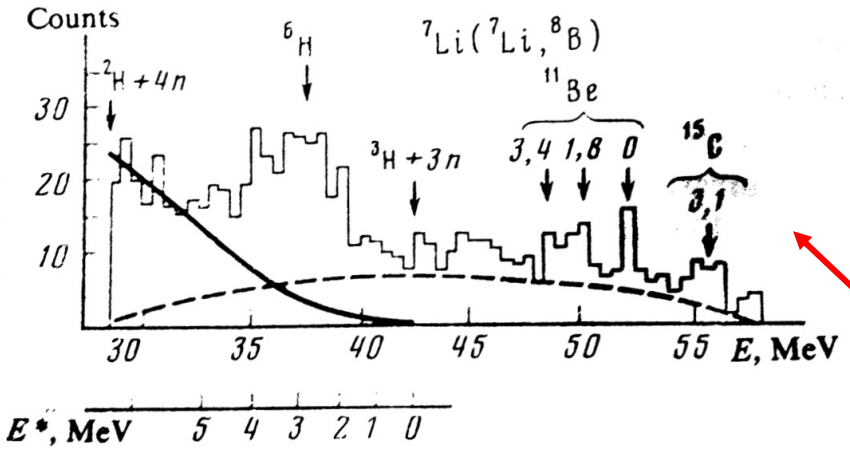


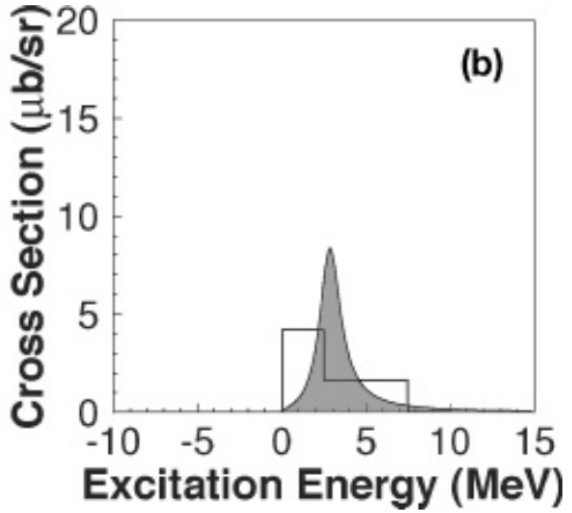
- ^{4}H, ^{5}H: clear signal observed
- ^{6}H, ^{7}H : Indistinct signal, controversial results
- Largest neutron-to-proton ratios known so far. Good platforms to study NN and many-nuclei interactions in neutron-rich environments.

Motivation

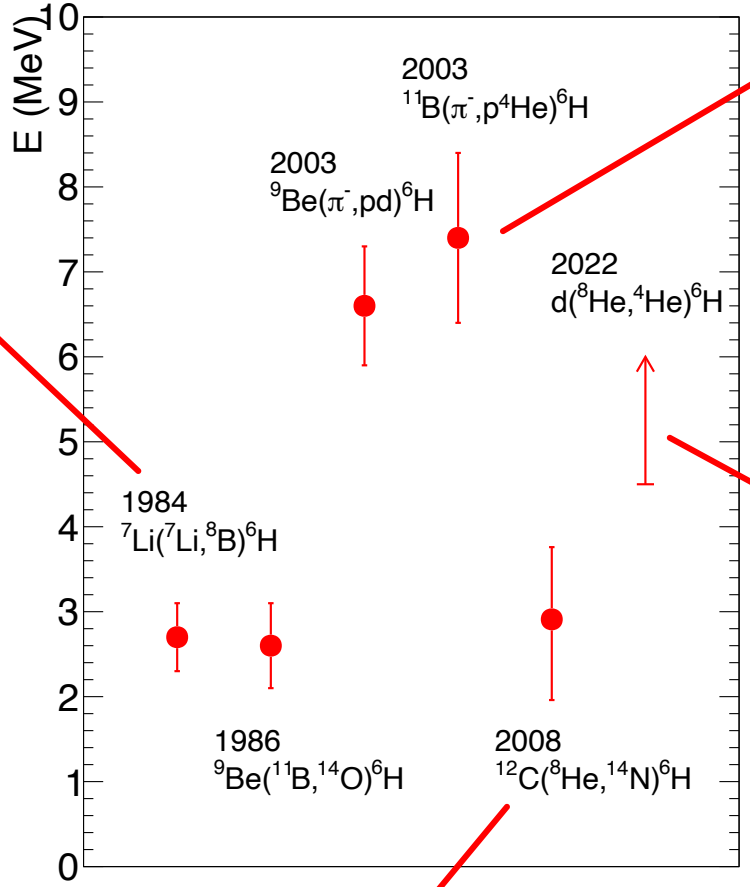
- Experiments with ^{6}H signal

D. Aleksandrov et al. , Yadernaya Fizika 39 (1984), pp. 513–517



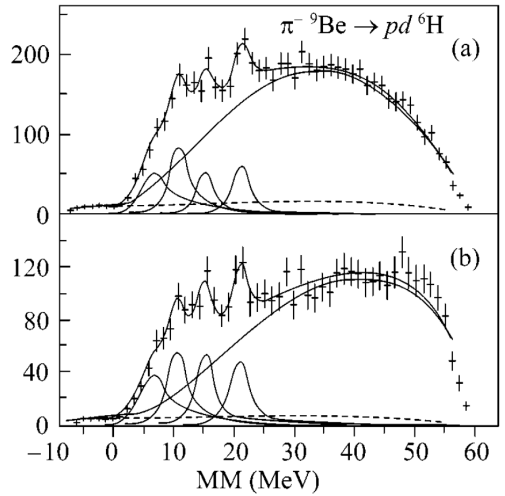


^{6}H ground state energy from experiments

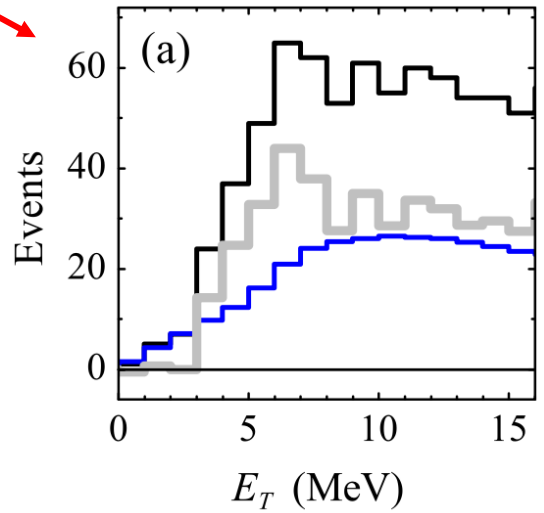


M. Caamaño et al. , PHYSICAL REVIEW C **78**, 044001 (2008)

Yu.B.Gurov et. al., JETP Letters, Vol.78, No.4, 2003, pp. 183-187



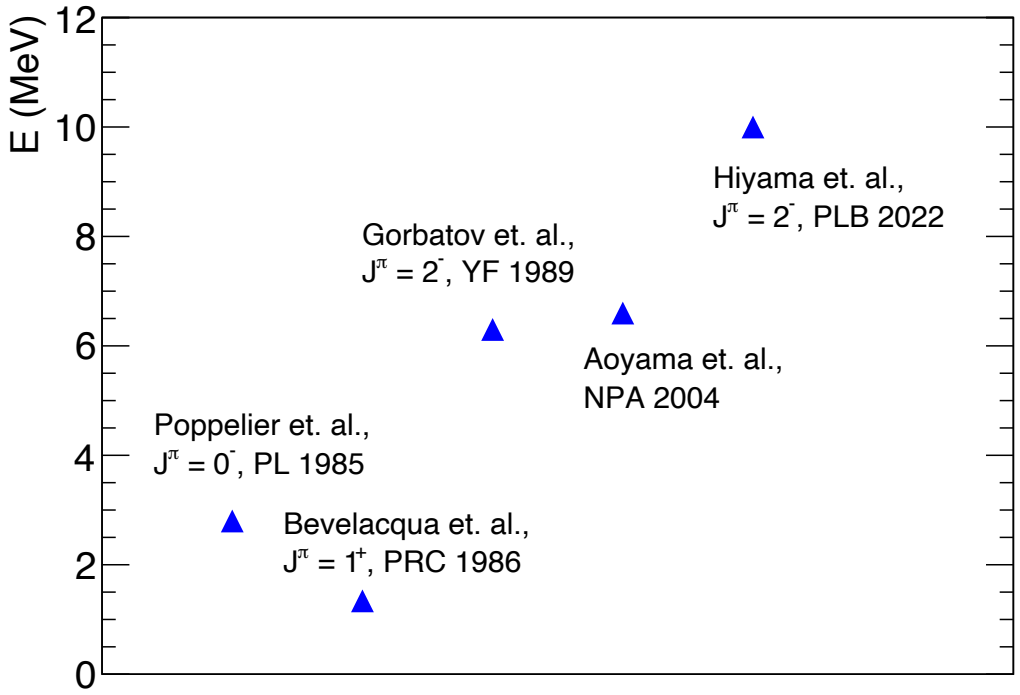
E. Yu. Nikolskii et al. , PHYSICAL REVIEW C 105, 064605 (2022)



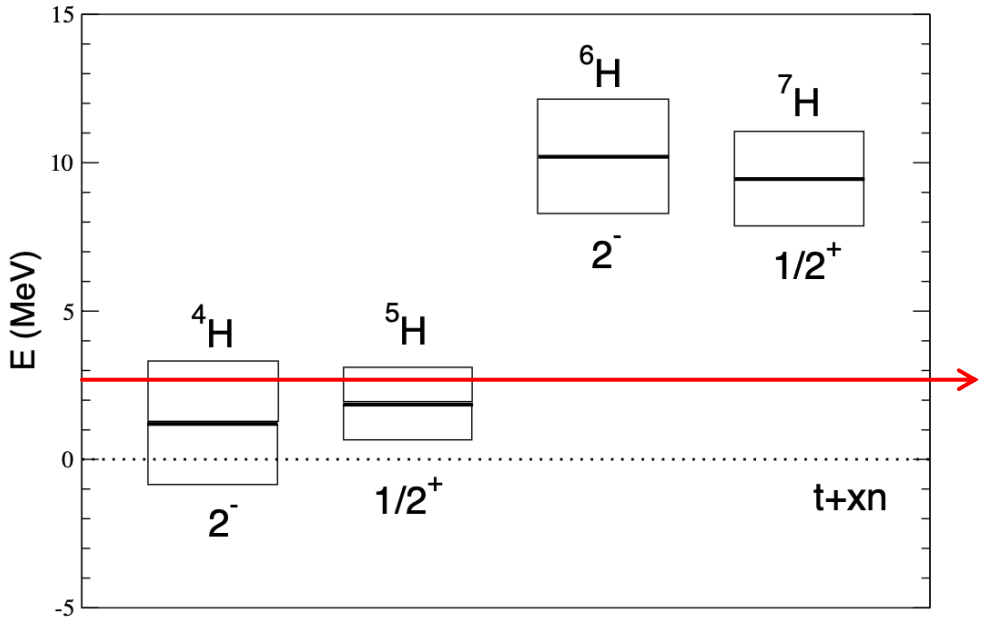
Motivation

- Theoretical calculations

^{6}H ground state energy from calculations



E. Hiyama et. al., Physics Letters B 833 (2022) 137367

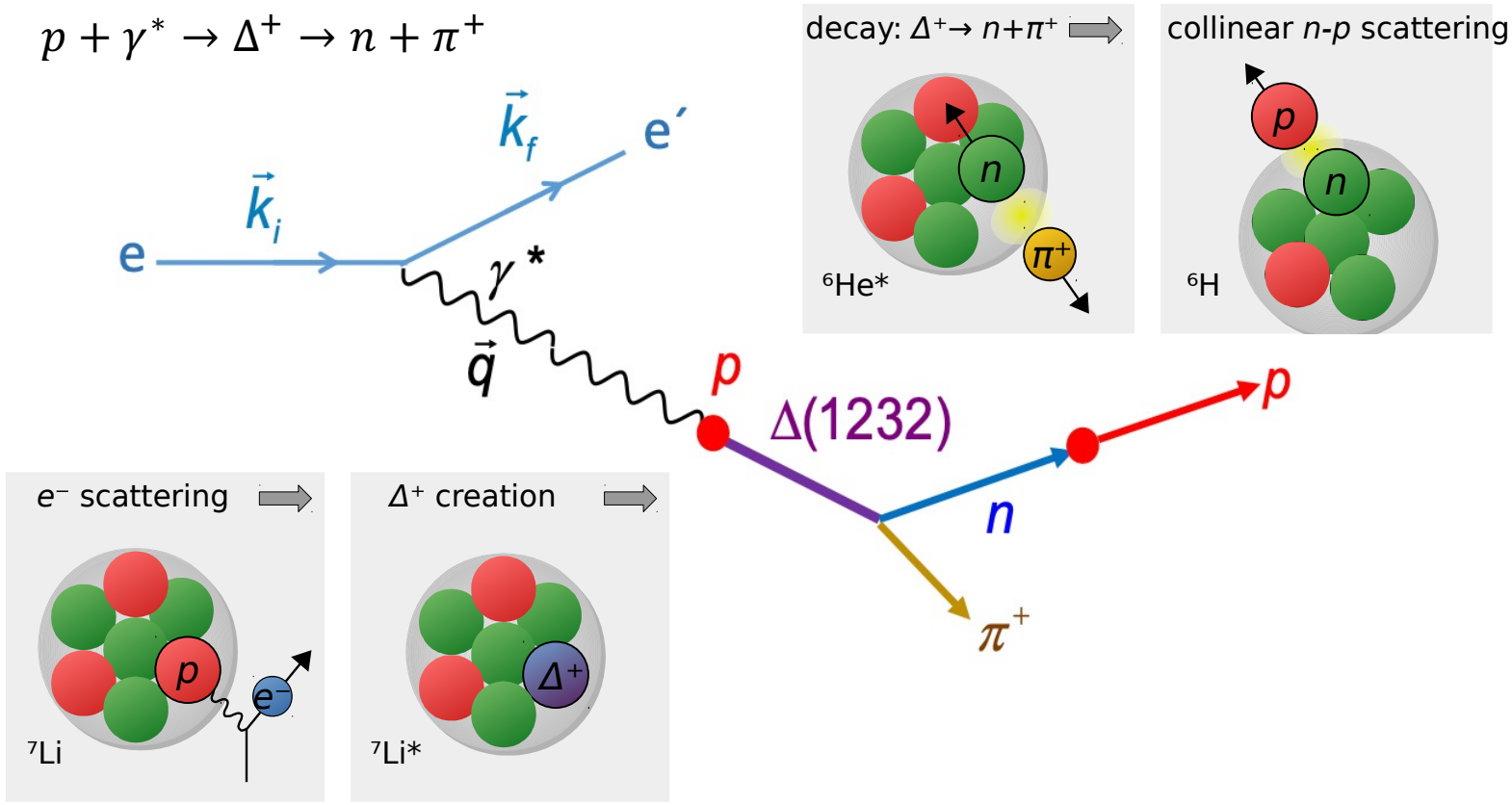


^{6}H ground state from nuclear database

The story of ^{6}H has not ended.

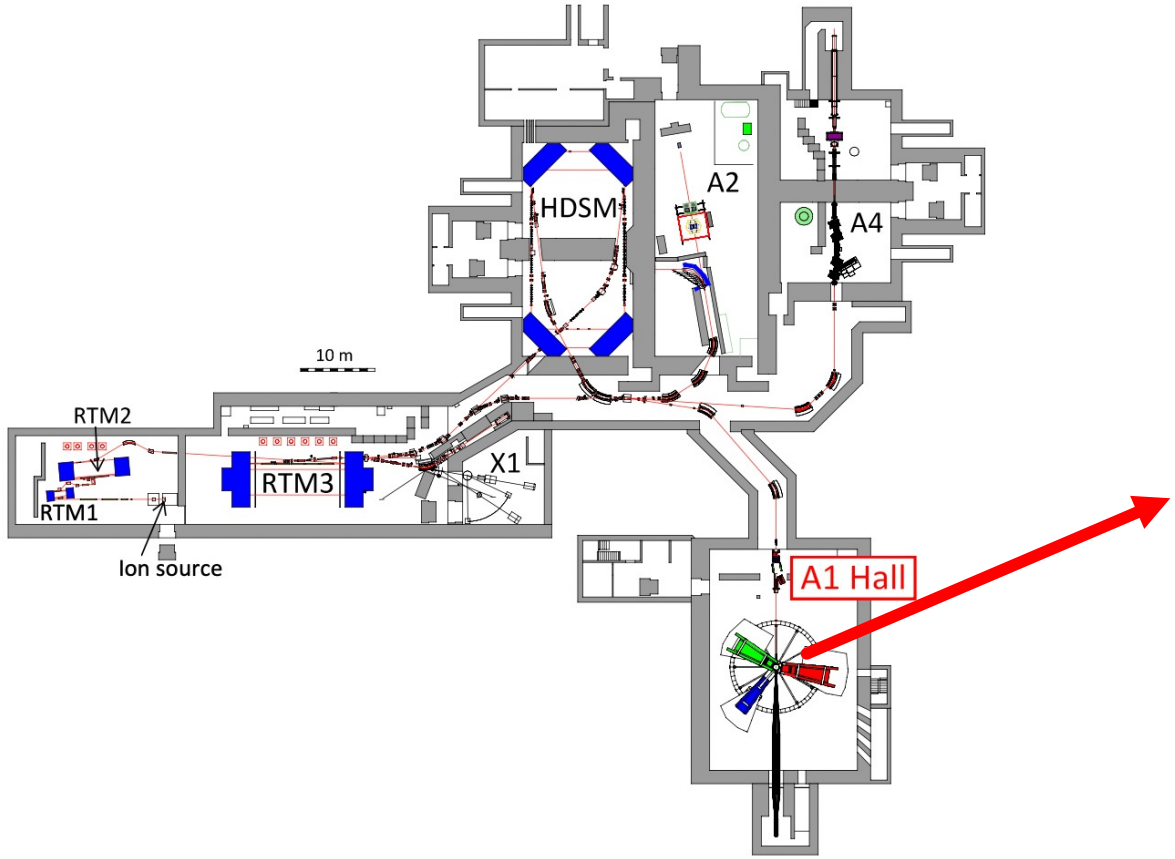
Experiment principle

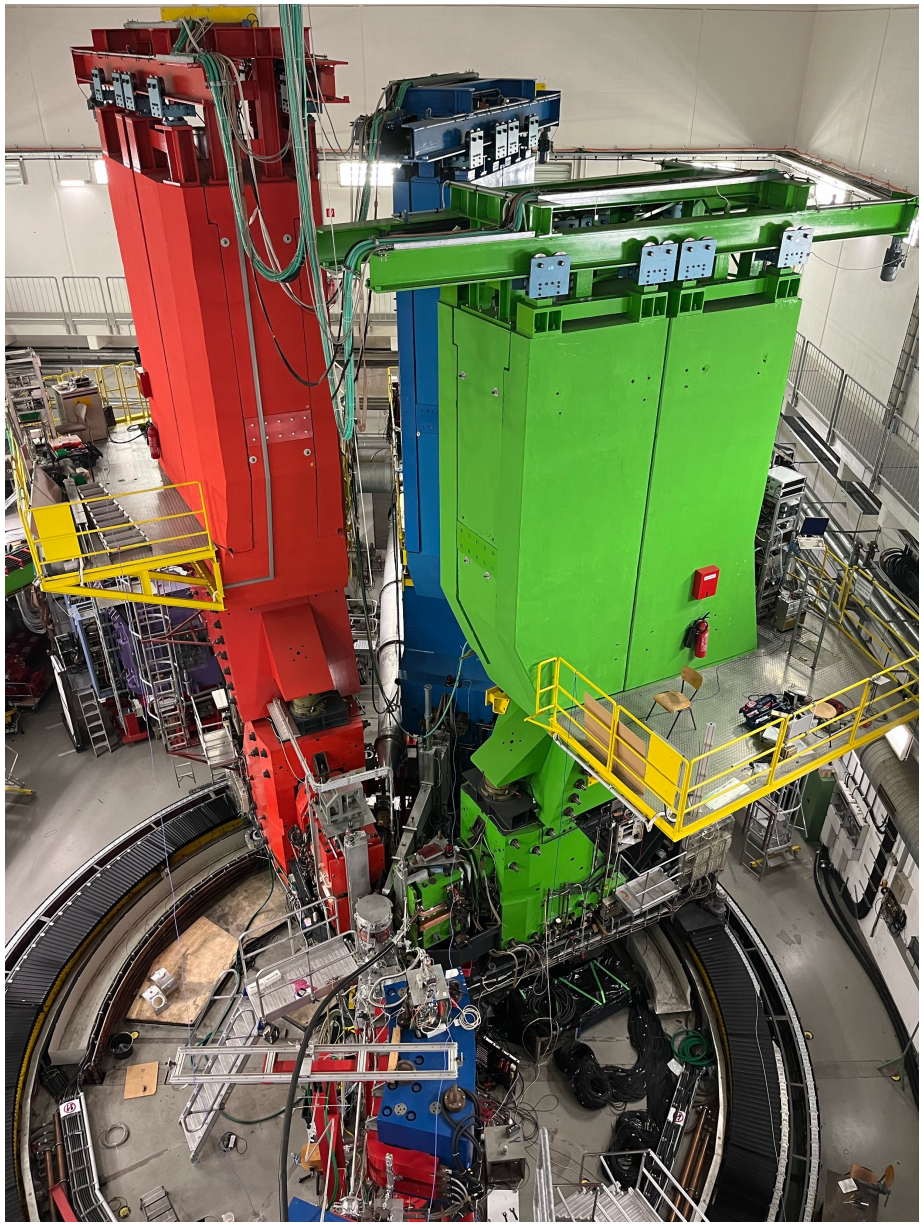
- Reaction: $^{7}\mathrm{Li}(\mathrm{e},\mathrm{e}'\mathrm{p}\pi^{+})$
- Measure the momentum of the scattered electron, the produced proton and π+. Then reconstruct the miss-mass spectrum.
- Expected rate: 1 count in interested region per day.
- Expected missing mass resolution: 1.18 MeV with 1mm thickness target



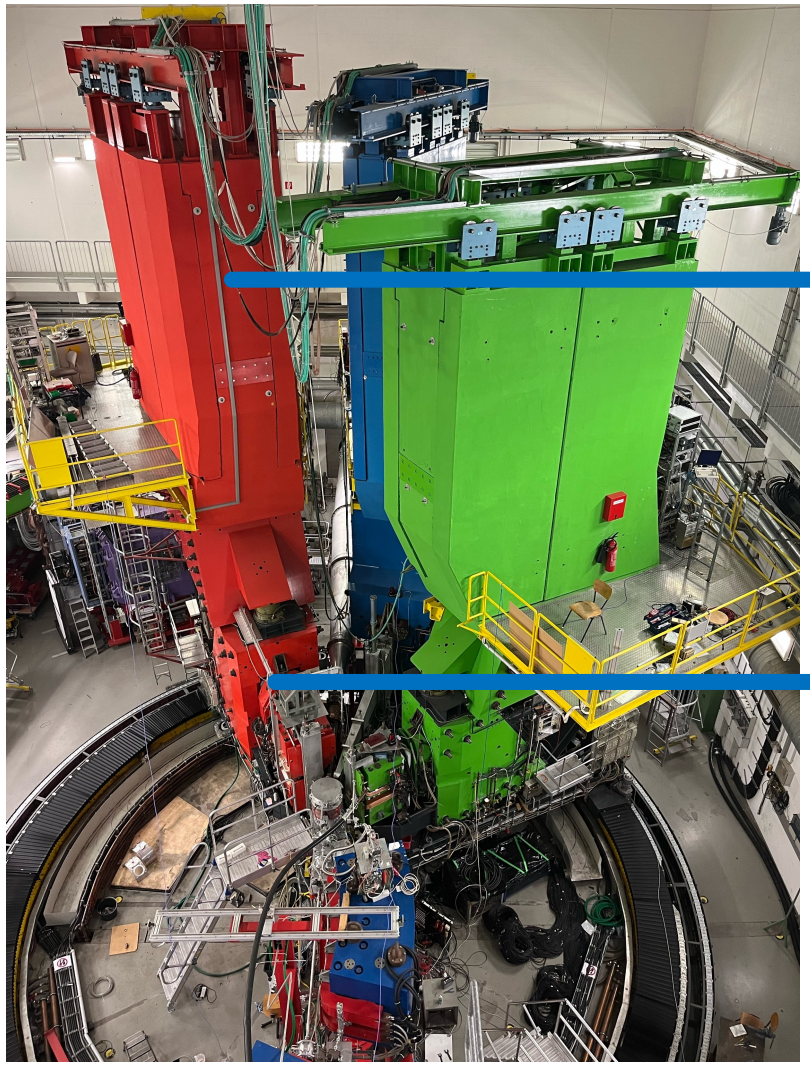
MAMI-A1 setup

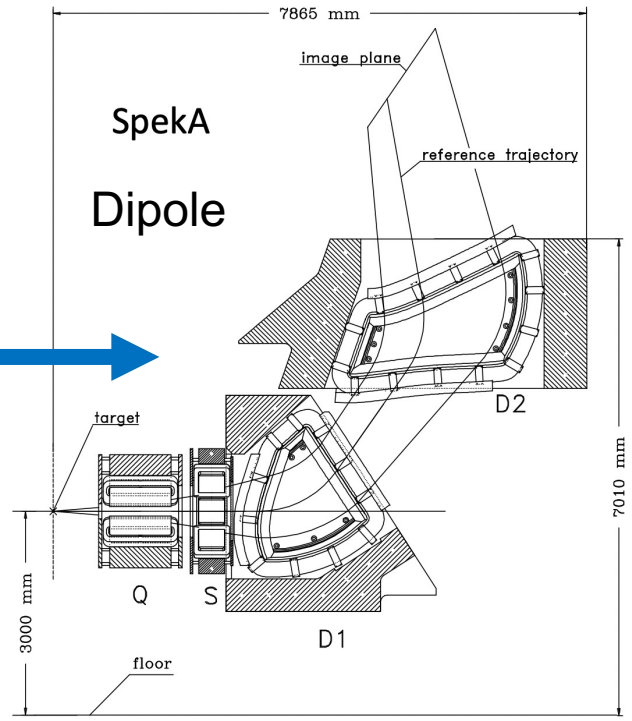
- MAMI-B: 855 MeV electron beam

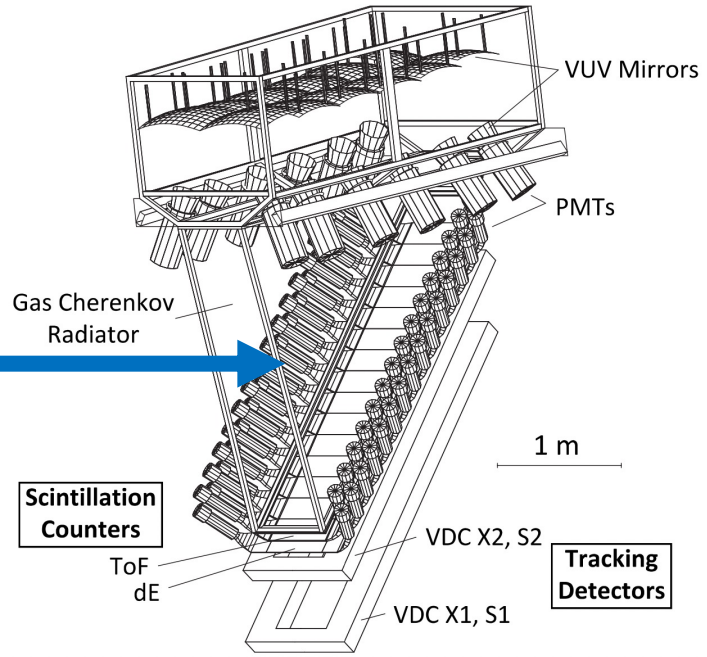




MAMI-A1 setup





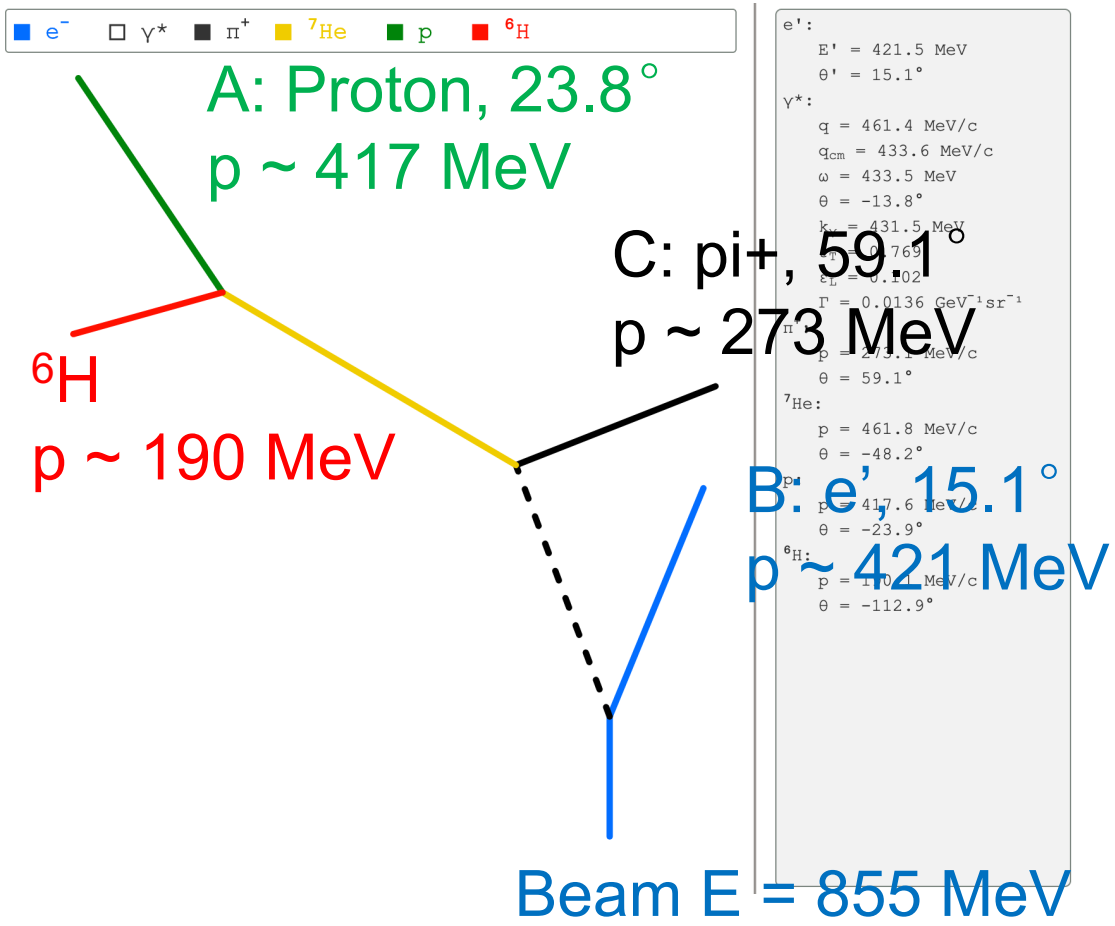


Detector system：

- VDC：track reconstruction
- dE：Energy loss measurement
- TOF：Energy loss and time of flight
- Cherenkov：identify electron and pion

MAMI-A1 setup

- Choice of kinematics: 1. W ~ 1200 MeV for proton to produce Delta^{+}(1232); 2. low momentum transfer to ^{6}H; 3. feasible with the setups of three spectrometers.

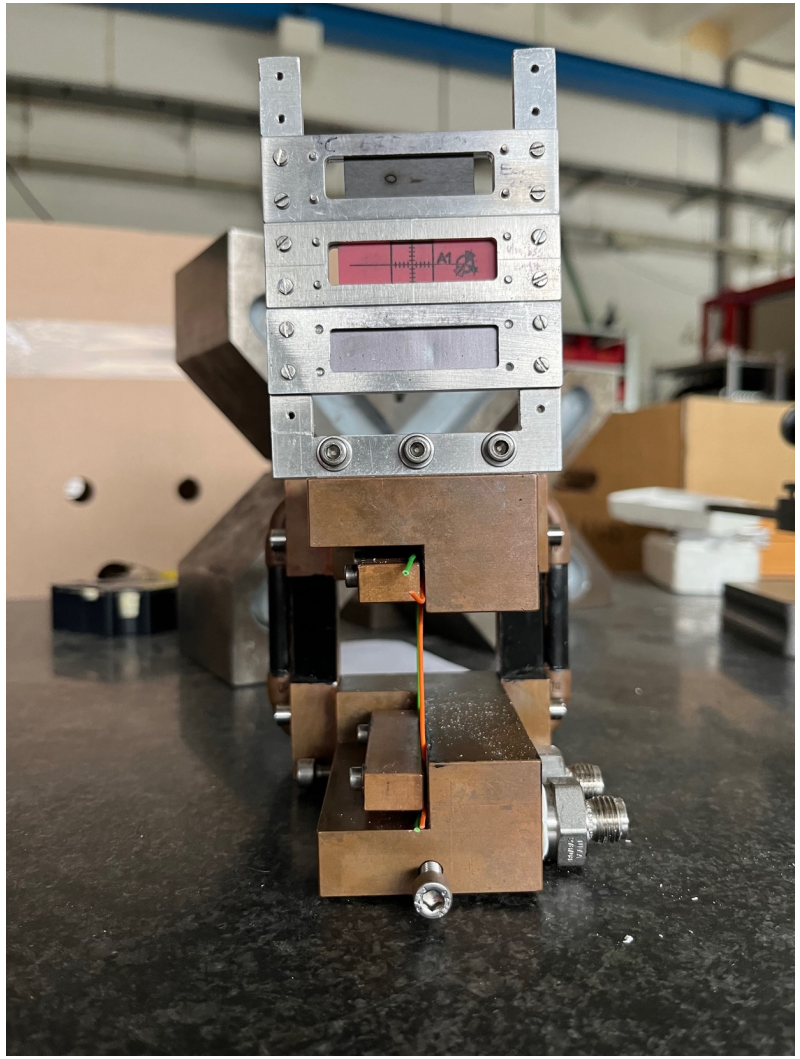


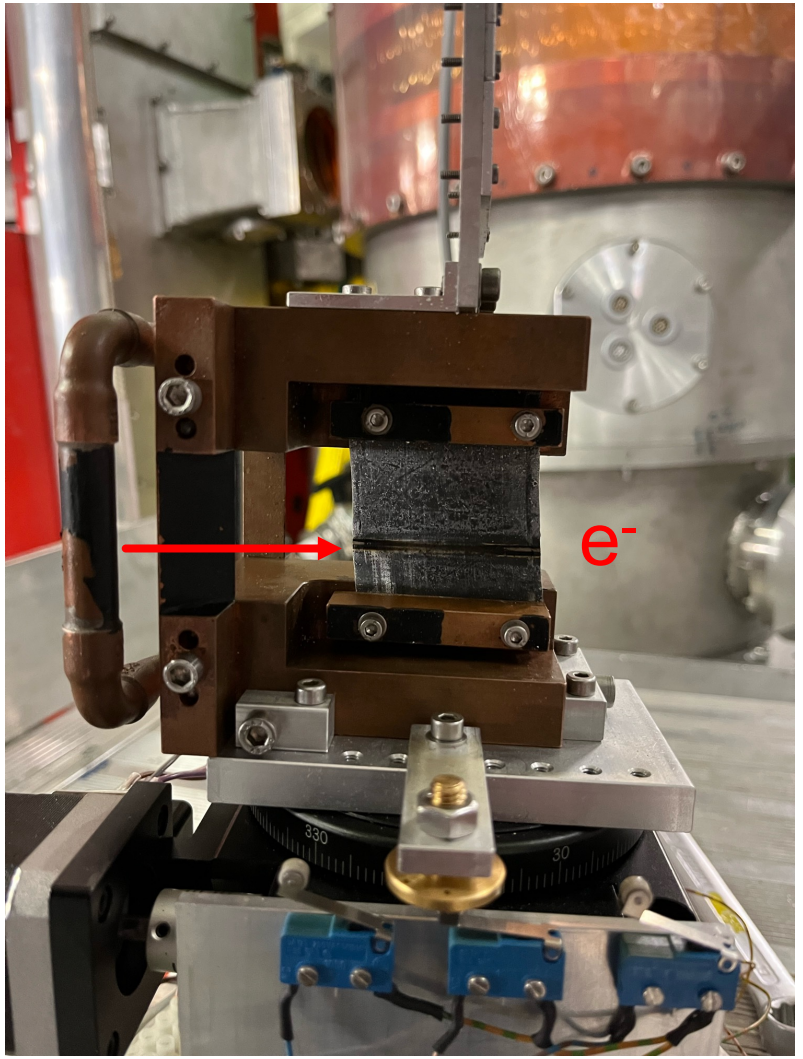
Optical properties of the A1 spectrometers

	units	A	B	C
Configuration	-	QSDD	D	QSDD
dispersive plane	-	point-ponit	point-ponit	point-ponit
non dispersive plane	-	parallel-ponit	point-ponit	parallel-ponit
Maximum momentum	[MeV/c]	735	870	551
Reference momentum	[MeV/c]	630	810	459
Central Momentum	[MeV/c]	665	810	490
Solid Angle	[msr]	28	5.6	28
Scattering Angle	-	-	-	-
minimum angle	-	18°	7°	8°
maximum angle	-	160°	62°	160°
Momentum acceptance	-	20%	15%	25%

Target setup

- Empty
- C12
- Aluminum
- Ta
- Li-7 (run_2023: 92.7% natural lithium, run_2024: 99.99% enriched lithium-7)





Beam time summary

Date	July 2023	July 2023	Sep 2023	April 2024
Beam energy (MeV)	855	855	855	855
Beam current (nA)	400	400	400	700
Kinematic	1	2	2	2
Target	Natural Li	Natural Li	Natural Li	Enriched ^{7}Li
Target length (cm)	4.5	4.5	4.5	2.5
Target width (mm)	0.75	0.75	0.75	1.0
Effective time	~ 120 h	~ 120 h	~ 160 h	~ 160 h

Kinematic 1

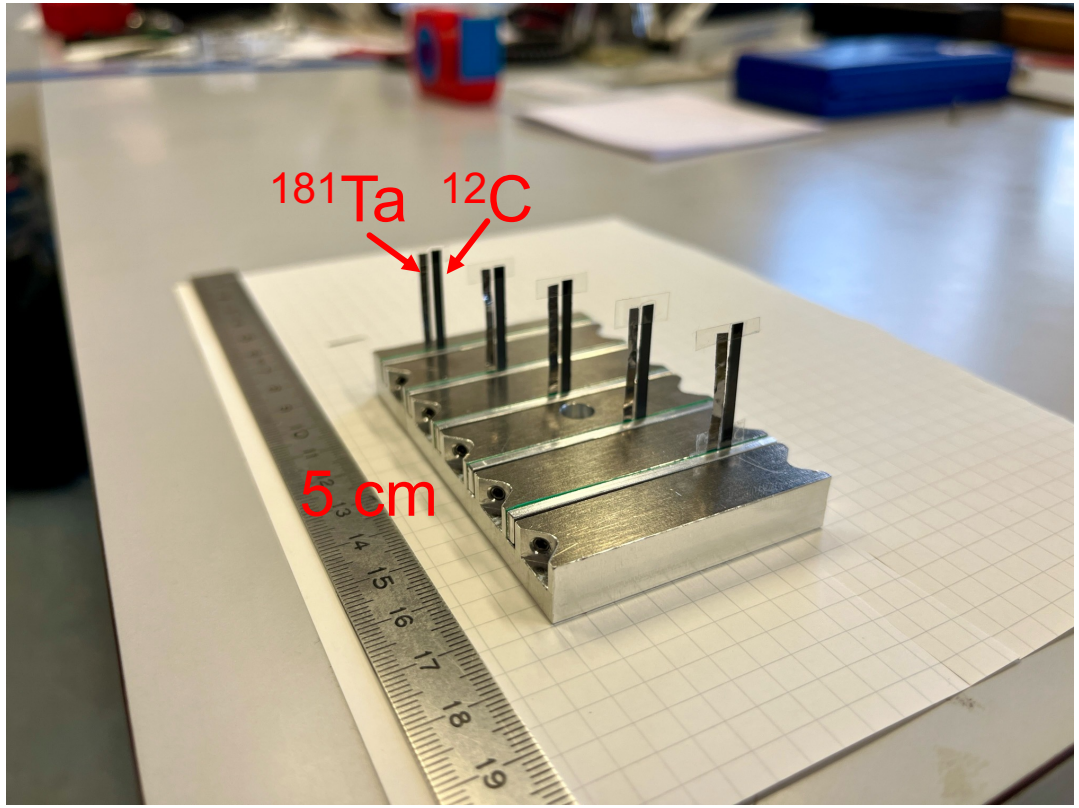
Spectrometer	Degree (°)	Momentum (MeV/c)
A (proton)	-23.8	379
B (e')	15.1	531
C (π^+)	59.1	162

Kinematic 2

Spectrometer	Degree (°)	Momentum (MeV/c)
A (proton)	-23.8	417
B (e')	15.1	421
C (π^+)	59.1	273

Momentum calibration

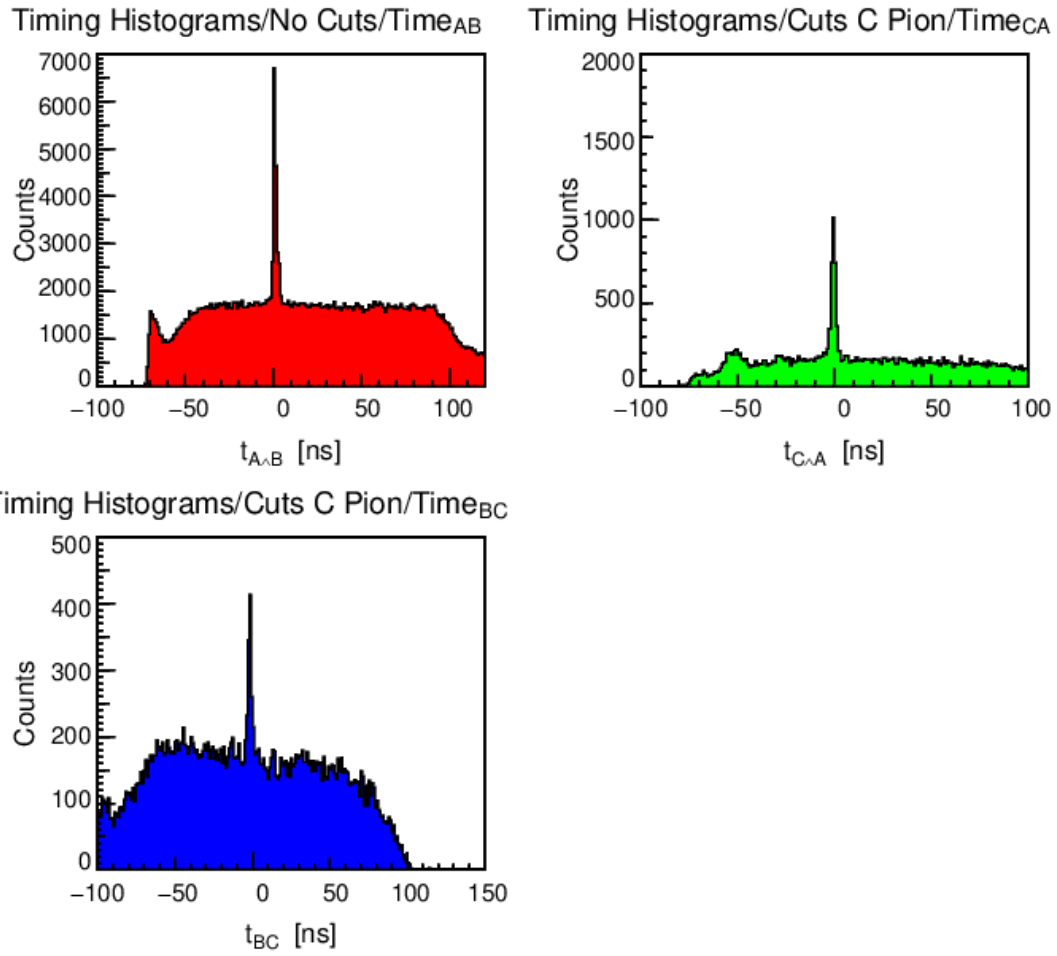
- Principle：Electron scattering with ^{181}Ta and ^{12}C target. Compare with the certain input momentum the correction factors can be obtained.
- Ebeam (MeV) = 180, 195, 210 with undulator (~10keV uncertainty); 225, 420 without undulator (~160 keV uncertainty)
- Electron scattering with several target positions and momentum settings.
- Calibration beam time has been done in May 2024.

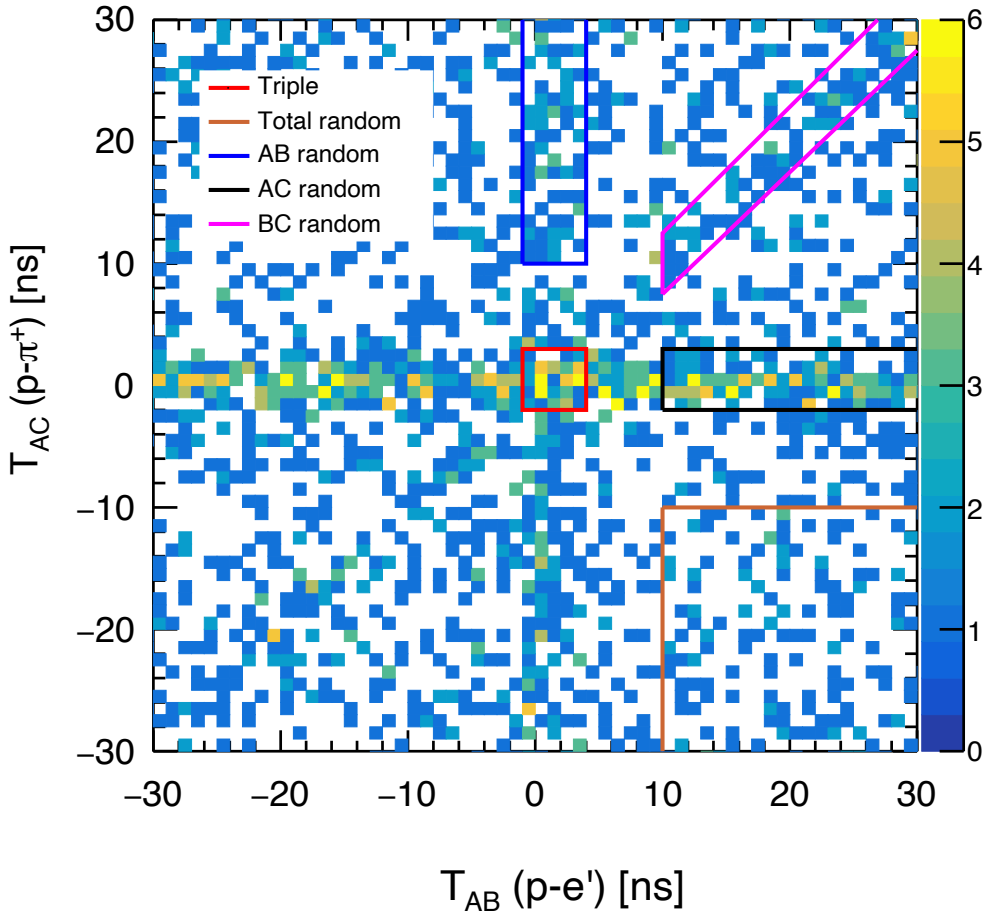


Analysis of calibration data is on going.

Data analysis

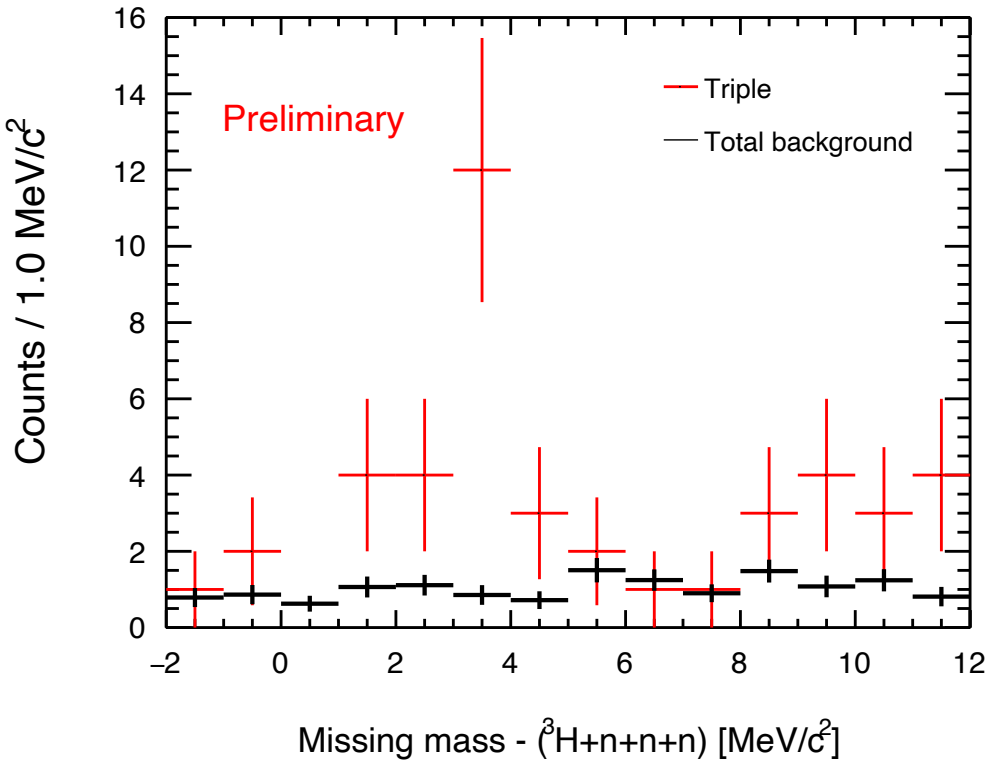
- Select the events in the region of triple coincidence.





Data analysis

- Combine the data from all setups, run_2023 + run_2024. With preliminary calibrations.
- Clear peak of H6 ground state at about 3 MeV Preliminary!
- Count and resolution are similar as we expected.



Summary

- To study the neutron-rich nucleus ^{6}H, an electron scattering experiment with triple coincidence is designed and done with several beam times at MAMI-A1.
- Calibration data taking for the three spectrometers are done. Analysis work is going on.
- Preliminary results show the ground state ^{6}H energy is near 3 MeV.

Outlook

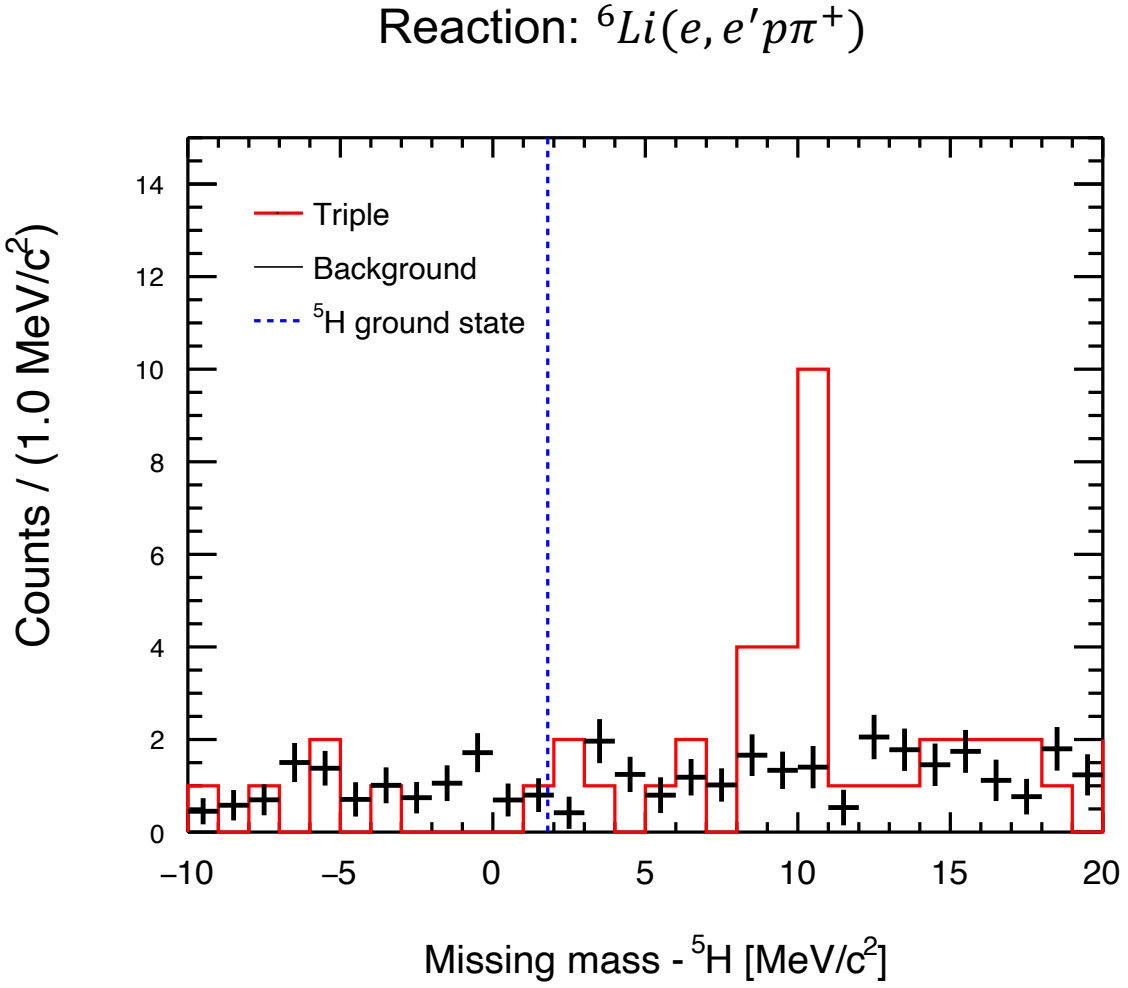
- Finalize the calibration work of the detectors.
- Analyze the systematic uncertainties for the result.

Thank our co-workers : Patrick Achenbach, Jinhui Chen, Mirco Christmann, Michael O. Distler, Luca Doria, Anselm Esser, Julian Geratz, Christian Helmel, Matthias Hoek, Ryoko Kino, Pascal Klag, Yu-Gang Ma, David Markus, Harald Merkel, Miha Mihovilović, Ulrich Muller, Sho Nagao, Kotaro Nishi, Fumiya Oura, Jonas Pätschke, Josef Pochodzalla, Bj¨orn S¨oren Schlimme, Concettina Sfienti, Marcell Steinen, Michaela Thiel, Andrzej Wilczek, and Luca Wilhelm

Backups

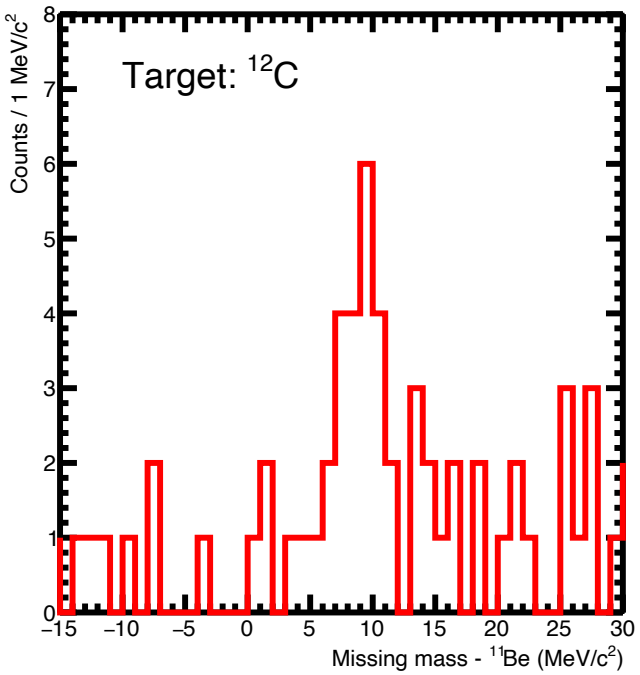
Data analysis

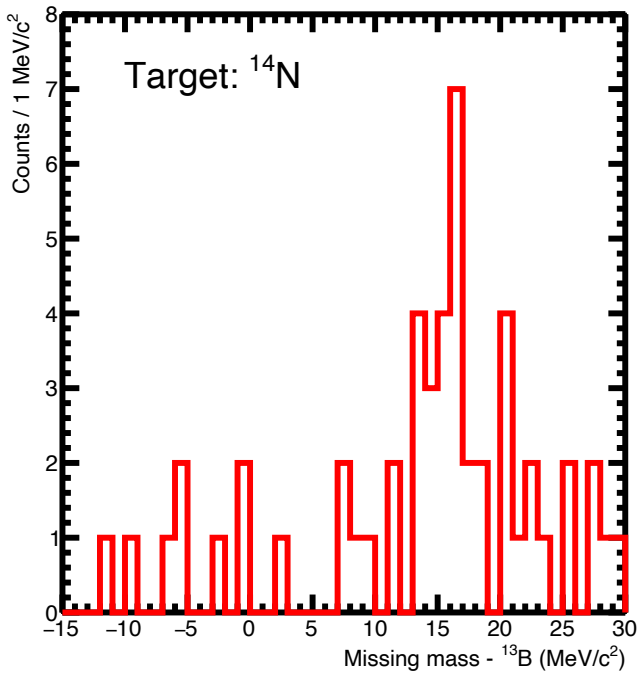
- Can the signal come from ^{6}Li which can produce ^{5}H? About 7.3% ^{6}Li in natural lithium.
- The peak near 3 MeV can also be seen with enriched ^{7}Li target.
- Replace ^{7}Li with ^{6}Li in analysis. The energy is about 10 MeV, which is much large than ^{5}H ground state ~ 1.8 MeV.

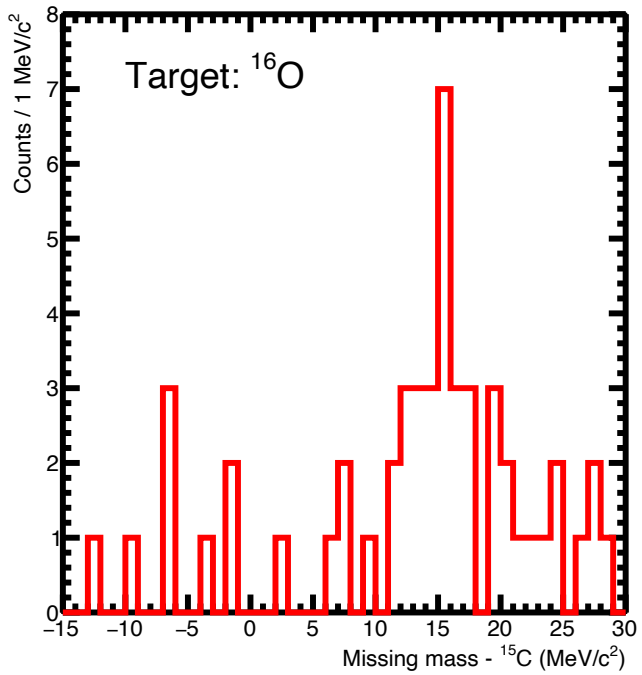


Backup

- Can the signal come from the C, N, and O in air?
- Replace the target with C, N, or O. The obtained energies are also much larger than ground states.







Backup: Momentum calibration

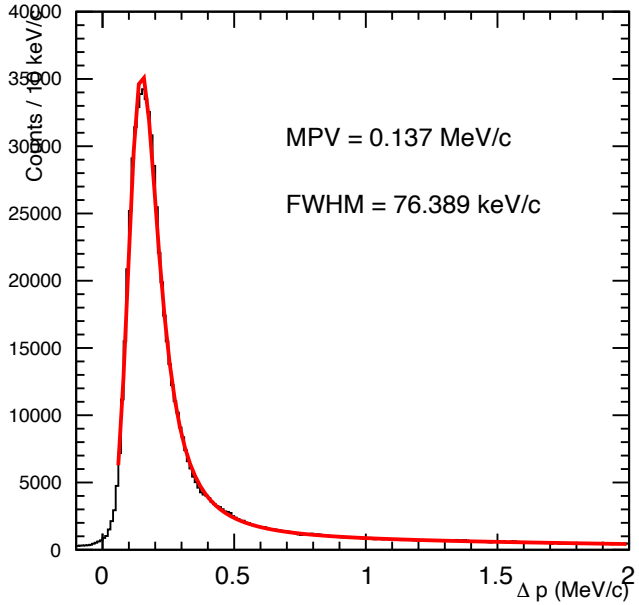
- Scattering electron on ^{181}Ta target
- $\Delta p = p_{in} - p_{measured}$, energy losses in target and detector system are considered.
- Fit function: Landau (energy loss) and Gaussian (detector resolution) convolution.

Spectrometer	Δp (MeV/c)	Correction factor
A	0.136821	1.00032587
B	0.36578	1.00087166
C	-0.87746	0.99791517

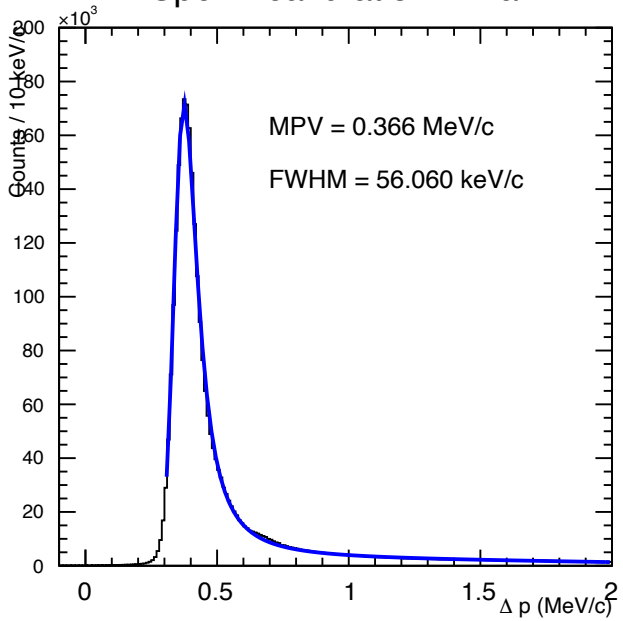
Momentum calibration

- Scattering electron on ^{181}Ta target
- $\Delta p = p_{in} - p_{measured}$, energy losses in target and detector system are considered.
- Fit function: Landau (energy loss) and Gaussian (detector resolution) convolution.

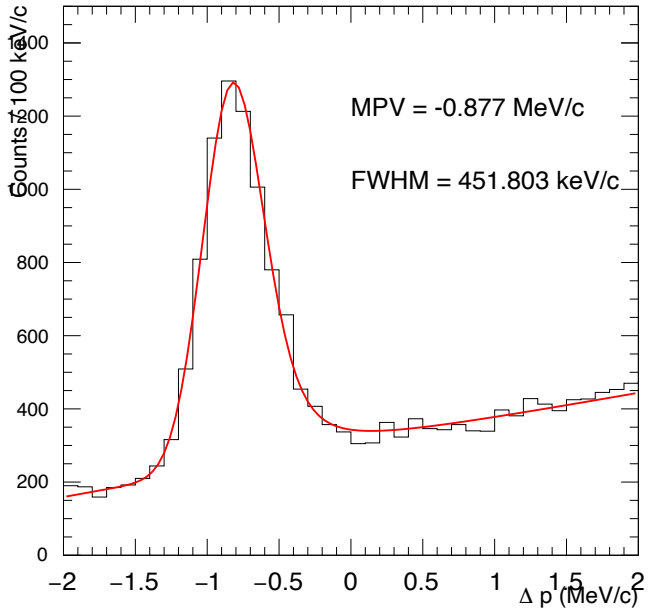
SpekA calibration ^{181}Ta



SpekB calibration ^{181}Ta



SpekC calibration ^{181}Ta



Momentum calibration

- Correction factor check: missing mass spectrum of ^{12}C ground and excited states.