Search for (e, e'$\pi^+\pi^+$) and (e, e'pπ^+) @MAMI-C

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Content

1. Introduction to production of neutron rich nuclei

2. The (e, e'$\pi^+\pi^+$) reaction @MAMI-C

3. Search for (e, e'$\pi^+\pi^+$)

4. Observation of (e, e'pπ^+)

5. Planned study of ^{6}H

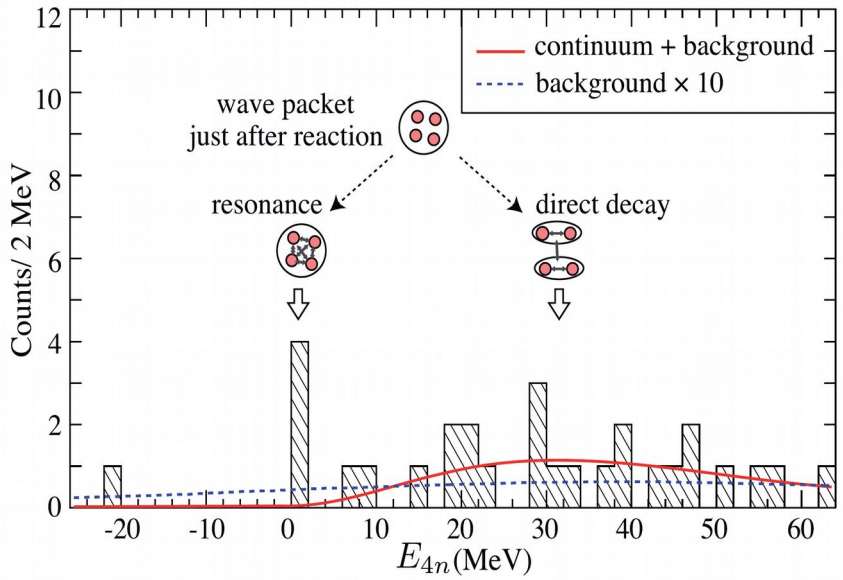
1. Motivation

Goals: 1. High precision spectroscopy of neutron rich nuclei
2. Search for very exotic nuclei

Already done at heavy ion accelerators:

- Measured ^{7}H, hints for ^{4}n
- Problem: limited resolution *O*(MeV)

Hints for existence of ^{4}n @RIKEN via ^{8}He(^{4}He, ^{4}He ^{4}He)X



K. Kisamori *et al.*, RIKEN, PhysRevLett.116.052501 (2016)

1. Motivation

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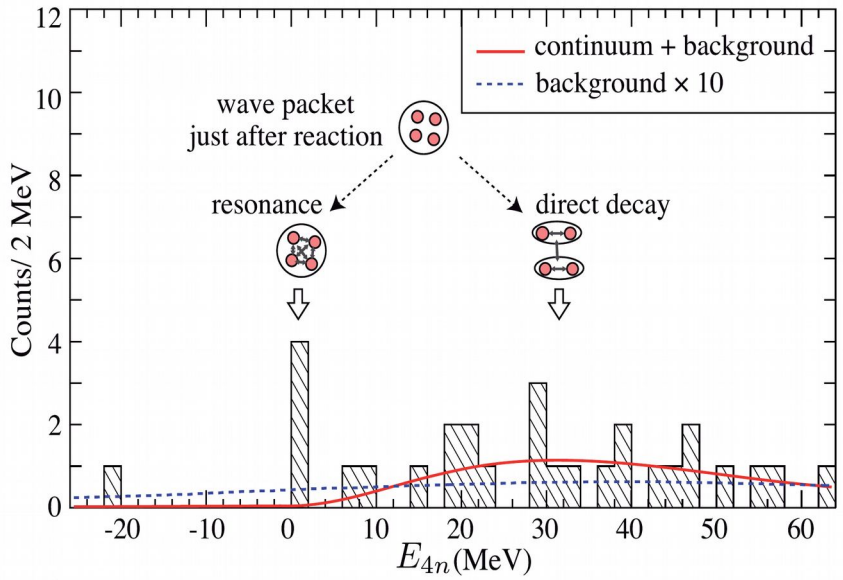
➡ Produce nuclei via electron scattering:

- Reaction: ^{4}He(e, e'$\pi^+\pi^+$)^{4}n
- Requires the detection of triple events

➡ Possible at A1 setup with σ_{mm} ~ 100 keV

Hints for existence of ^{4}n @RIKEN via ^{8}He(^{4}He, ^{4}He ^{4}He)X



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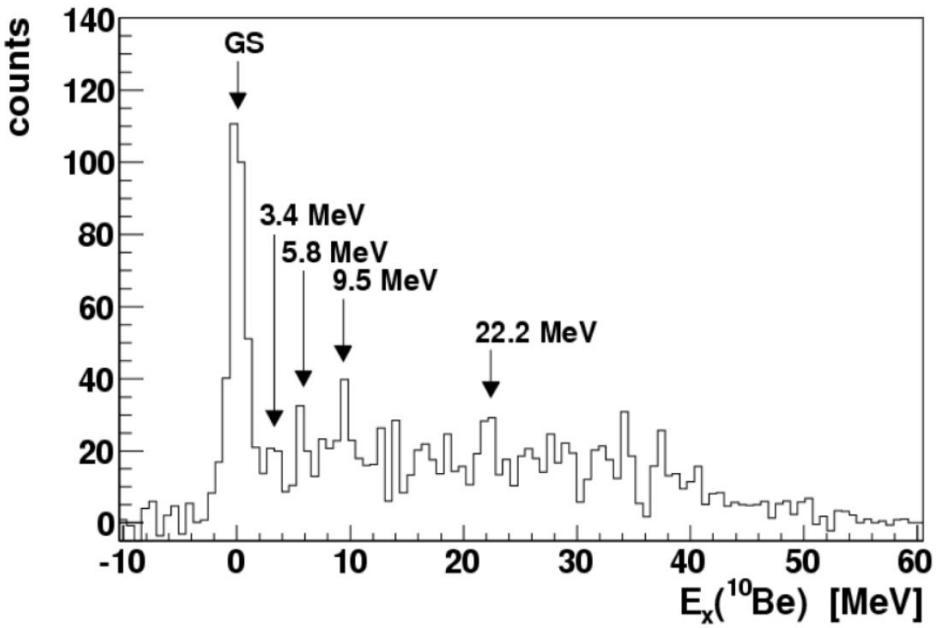
1. Nuclear spectroscopy with e^- beams

Principle:

- scatter electron off target nucleus
- detect electron and two positive particles
- determine produced nucleus via missing mass
- already observed: pp break up

Missing Mass of $^{12}C(e, e'pp)^{10}Be$ @MAMI



M. Makek *et al.*, A1 Collaboration, "Differential cross section measurement of the $^{12}C(e, e'pp)^{10}Be$ g.s. reaction" EPJ A (2016) 52: 298

Further possibilities:

→ detect produced pions

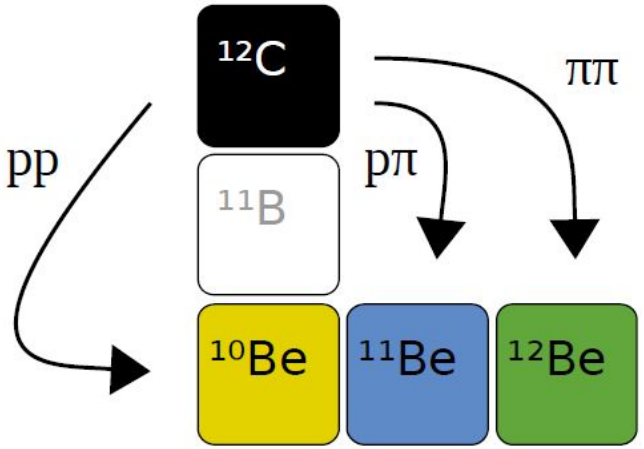
1. Different reaction types

(e, e'pp):

- already successfully studied in 2010 @MAMI

(e, e'$\pi^+\pi^+$):

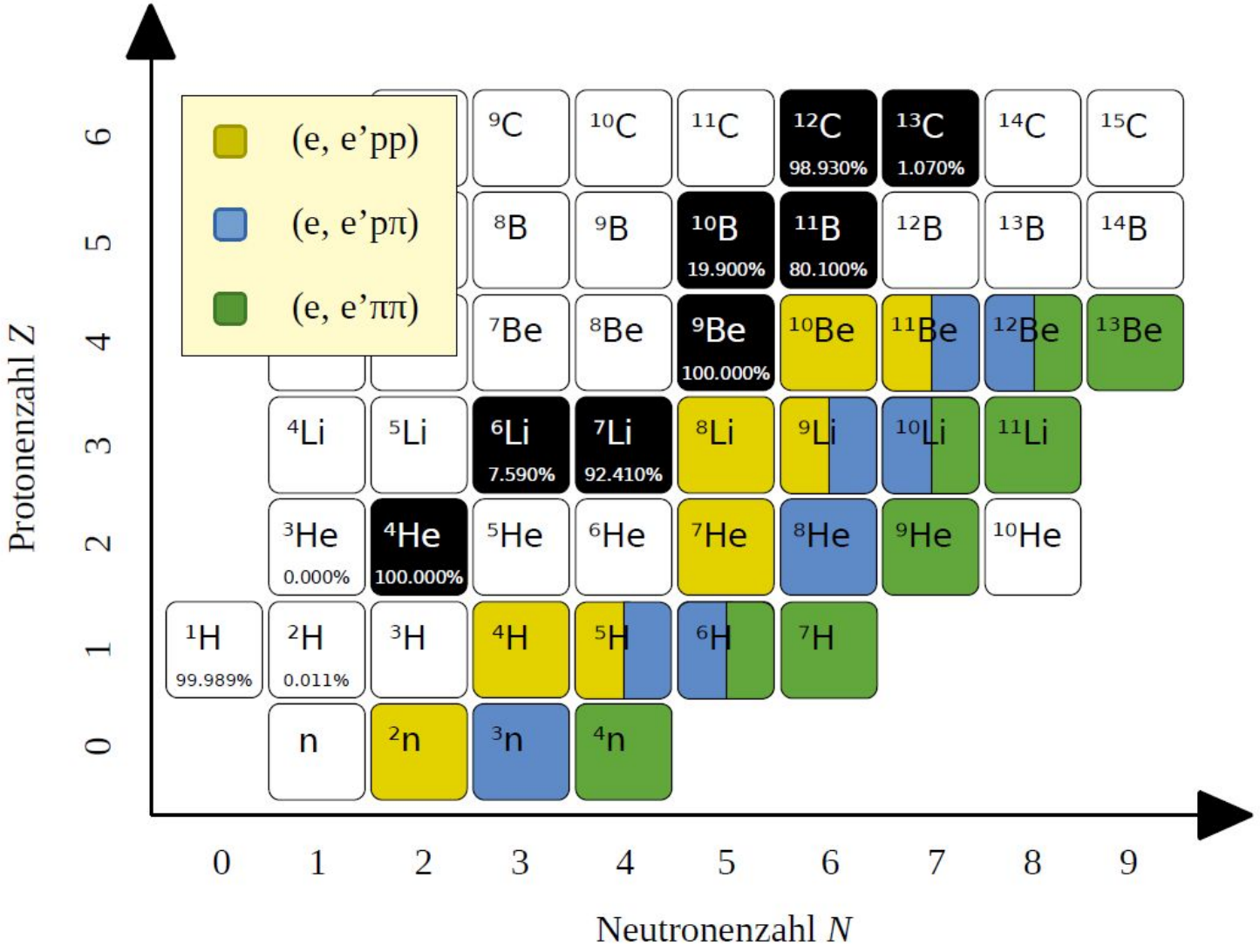
- not explored so far
- allows most exotic proton-neutron ratio
- cross section expected to be small



(e, e'pπ^+):

- not explored, "medium" between the other both types?

1. Observable Nuclei



target nuclei

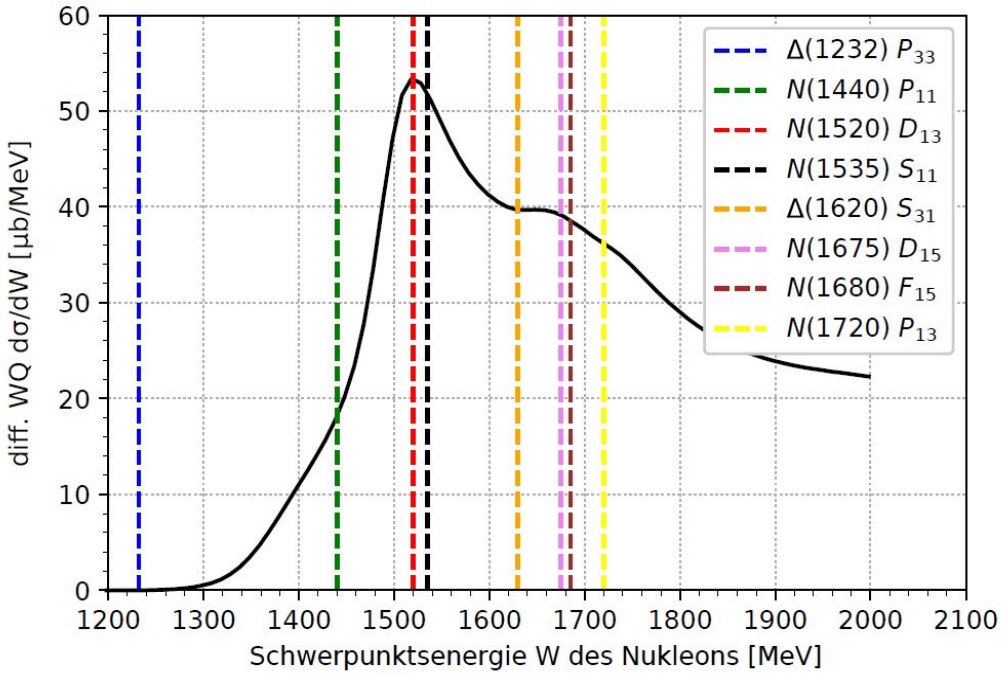
2. How is the (e, e'$\pi^+\pi^+$) reaction possible?

Assumed to be two step process:

1. Two Pion Production:

$$p + \gamma^* \rightarrow n + \pi^+ + \pi^0$$

Cross section for Two Pion Production:



Two Pion MAID *https://maid.kph.uni-mainz.de/twopion/*

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1. Two Pion Production:

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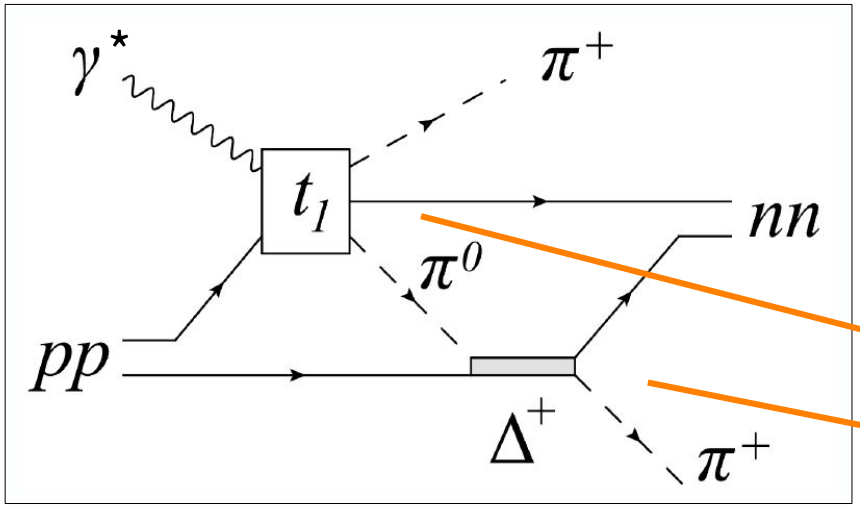
2. Charge exchange:

$$\pi^0 + p \rightarrow \Delta^+ \rightarrow \pi^+ + n$$



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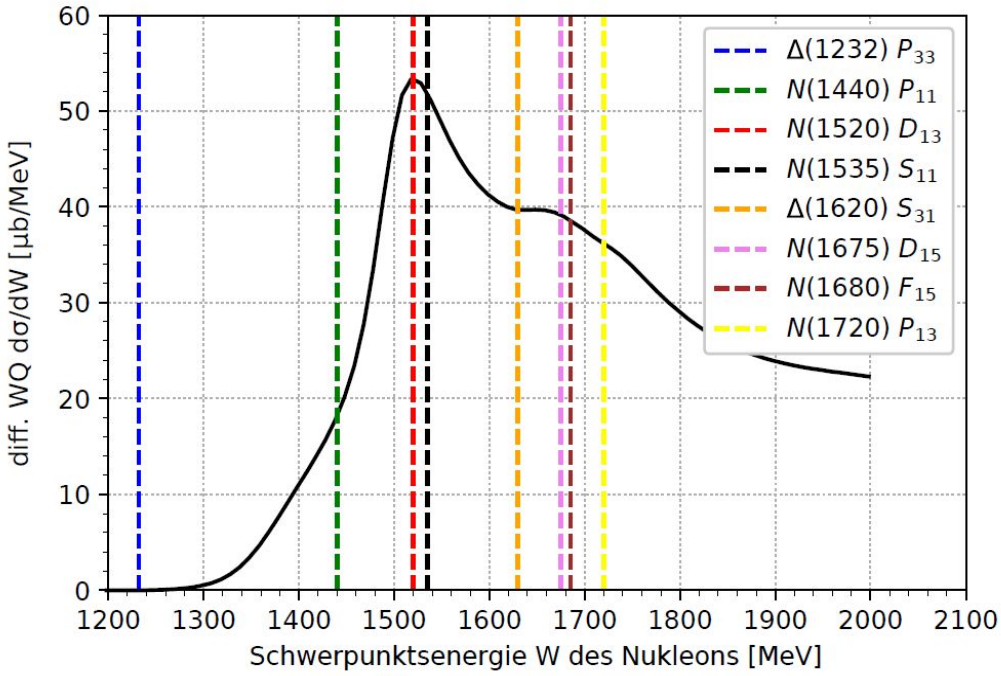


Two Pion MAID *https://maid.kph.uni-mainz.de/twopion/*

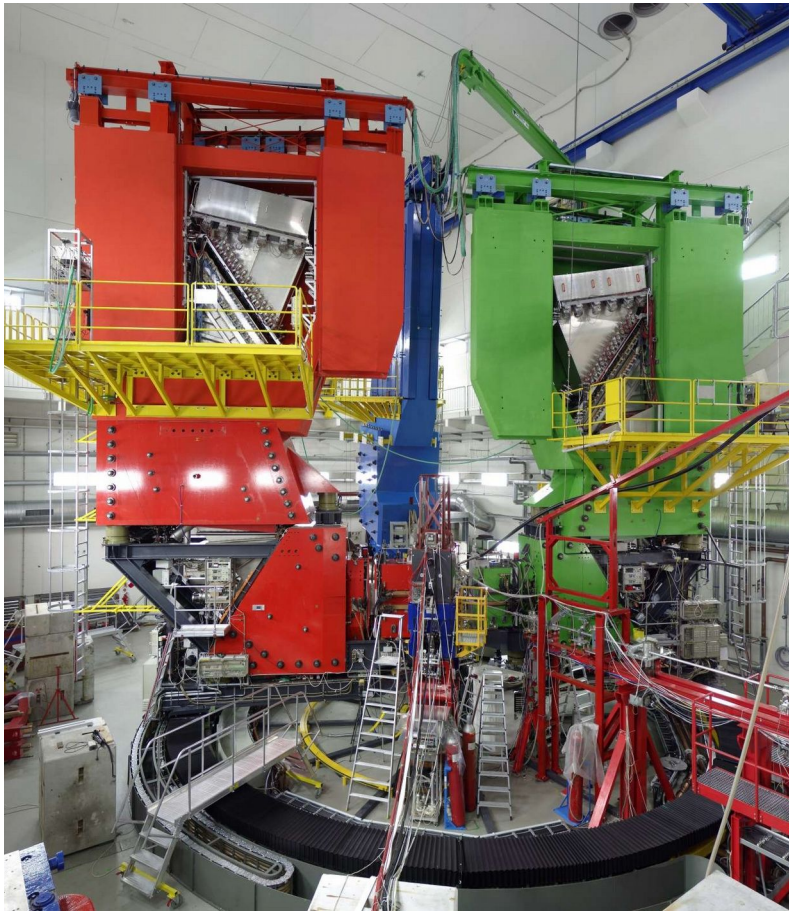
1. **Production and decay of N, Δ (t_1)**
2. **Production and decay of Δ^+**

2. Pilot experiment: ^{12}C(e, e'$\pi^+\pi^+$)^{12}Be @MAMI-C

Used A1 3 spectrometer facility:

- high resolution
- limited momentum and angular acceptance

⟶ reaction specific setup needed



- **Momentum transfer:**

$$Q^2 = 0.072 \;\; \mathrm{GeV}^2/\mathrm{c}^2$$

- **Integrated luminosity:**

$$\mathcal{I} = 65.5\,\mathrm{fb}^{-1} = 6.55 \cdot 10^{14}\,\mathrm{fm}^{-2}$$

- **Total time:**

$$t_{\mathrm{mess}} = 86.3\,\mathrm{h}$$

3. Search for (e, e'$\pi^+\pi^+$) events

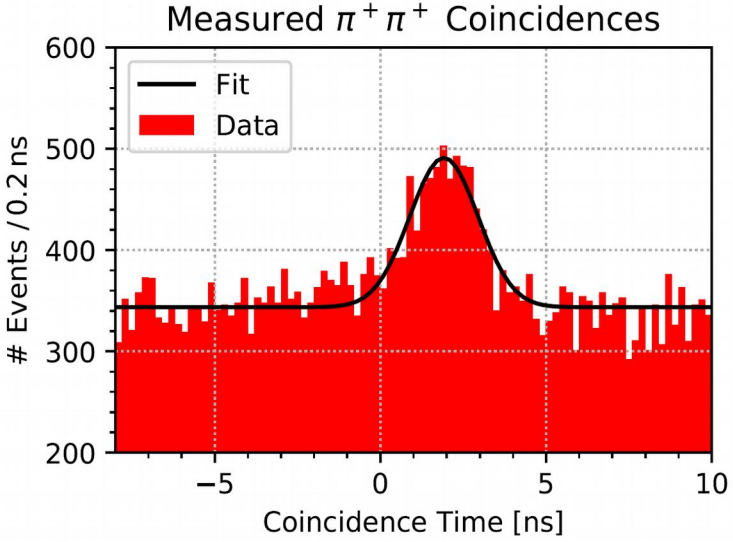
- ^{12}C(e, $\pi^+\pi^+$)X events appeared to be rare
  - ➡ ~ 2000 events
- ^{12}C(e, e'$\pi^+\pi^+$)X even rarer
  - ➡ almost no events detected

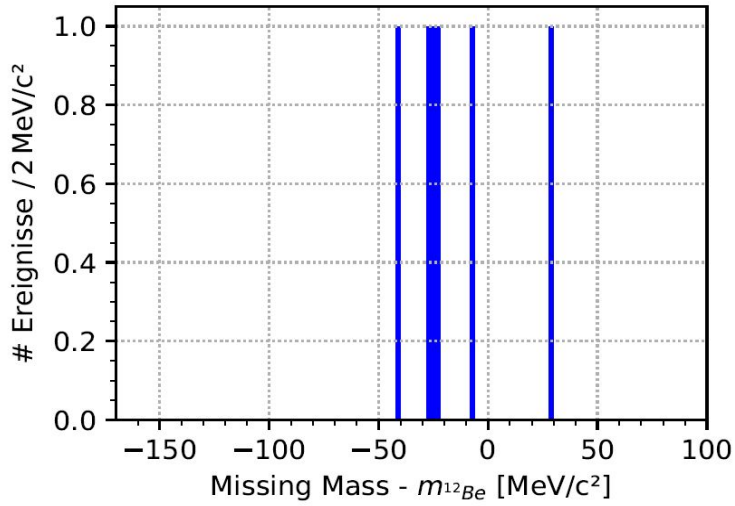
Determined cross section limit:

$$\frac{\mathrm{d}^8\sigma}{\mathrm{d}\Omega_{e'}\,\mathrm{d}E'\,\mathrm{d}\Omega_{\pi_1}\,\mathrm{d}T_{\pi_1}\,\mathrm{d}\Omega_{\pi_2}} < 3\ \mathrm{fb\,MeV^{-2}\,sr^{-3}}$$

- ➡ at least 1000 times smaller than for

$$^{12}\mathrm{C}(e,\ e'pp)^{10}\mathrm{Be}$$





4. Observation of (e, e'pπ^+) events

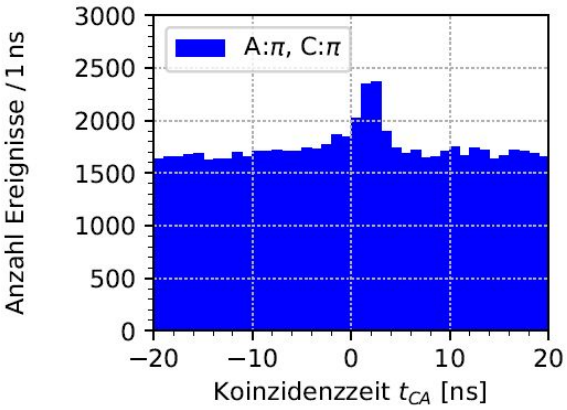
Why look for (e, e'pπ^+) events?

- **lower beam energy sufficient**
- **kinematics allow lower momentum transfers**
- **cross section higher?**

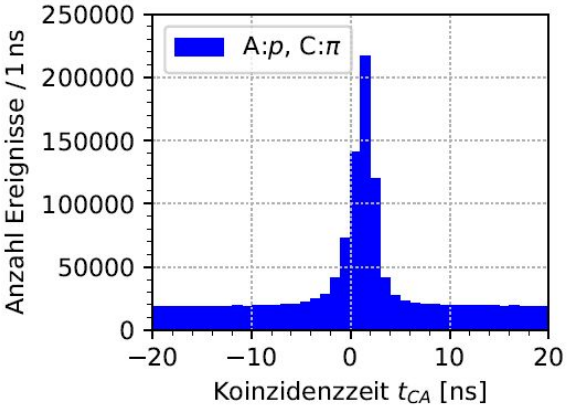
  ➡ **measured 300 times more pπ^+- coincidences than $\pi^+\pi^+$**

- **Study of ^{6}H or ^{3}n would be possible**

Pion-Pion:



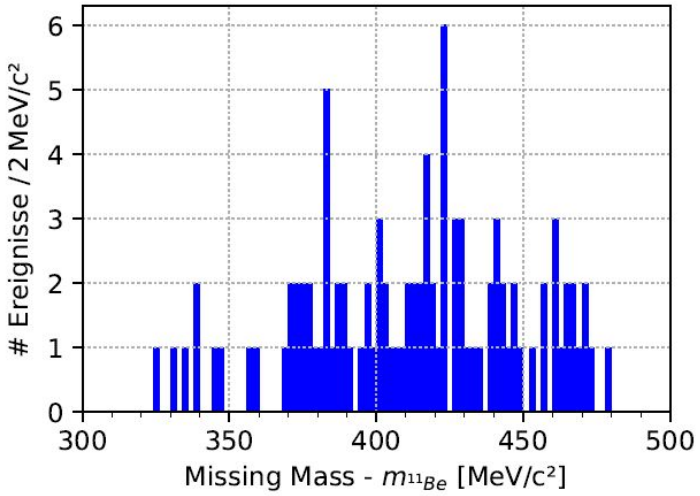
Proton-Pion:

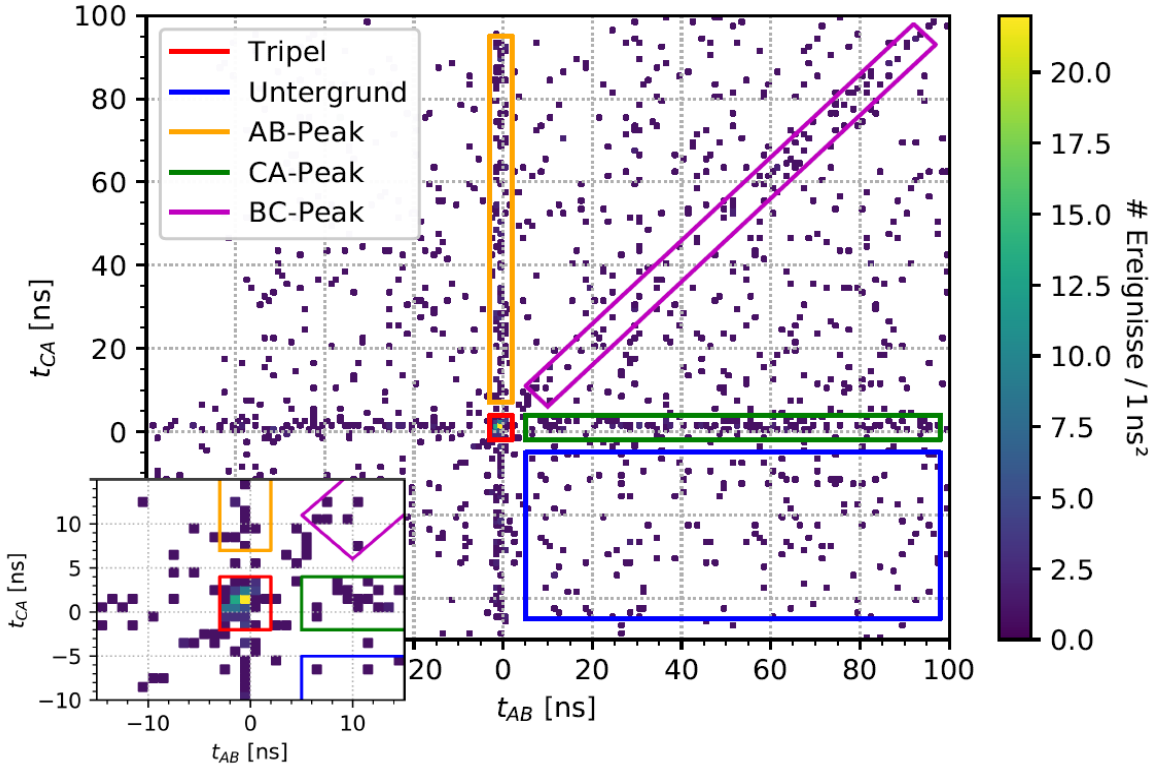


4. Observation of (e, e'pπ$^+$) events

- estimated 83 real events via sideband subtraction
- (e, e'pπ$^+$) bound state region not in momentum acceptance for (e, e'π$^+$π$^+$)

➡ Missing mass centered around 400 MeV/c^2





4. Résumé

(e, e'$\pi^+\pi^+$):

- No real triple event above background
- Estimated cross section limit:

< 3 fb MeV^{-2} sr^{-3}

→ 3 magnitudes smaller than

$^{12}\mathrm{C}(e,\ e'pp)^{10}\mathrm{Be}$

- Too low to produce significant results in further experiments

(e, e'pπ^+):

- 83 +/- 10 unbound triple events
- Estimated cross section:

10^2 fb MeV^{-2} sr^{-3}

→ one magnitude smaller than

$^{12}\mathrm{C}(e,\ e'pp)^{10}\mathrm{Be}$

- New experiment with corresponding momentum setting promising

5. Possible Experiment on ^{6}H

Todays knowledge about ^{6}H is rather unclear:

- Only few experiments were able to measure ^{6}H
- unanswered theoretical questions

➡ Measurement via missing mass at MAMI?

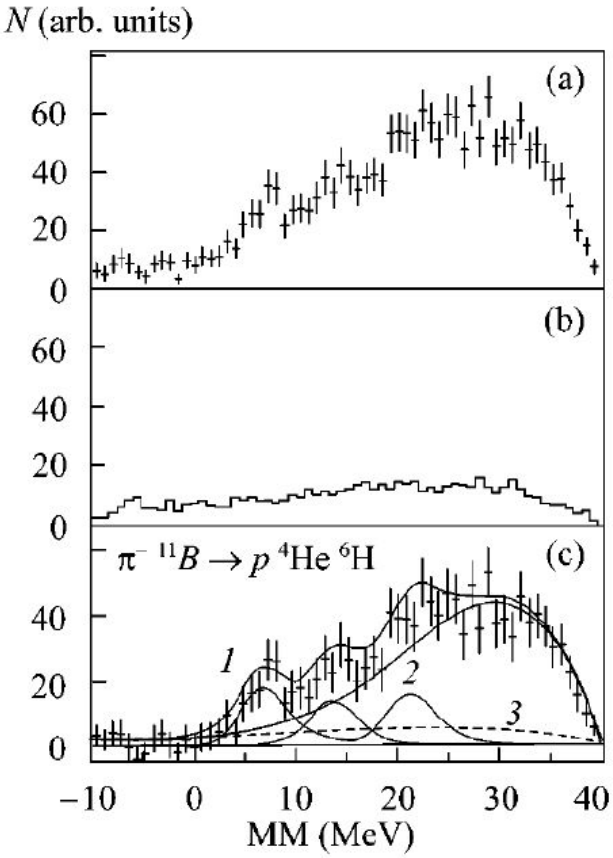
Reaction: ^{7}Li(e, e'pπ^{+})^{6}H

- Lithium target necessary:

Melting Point: 180°C

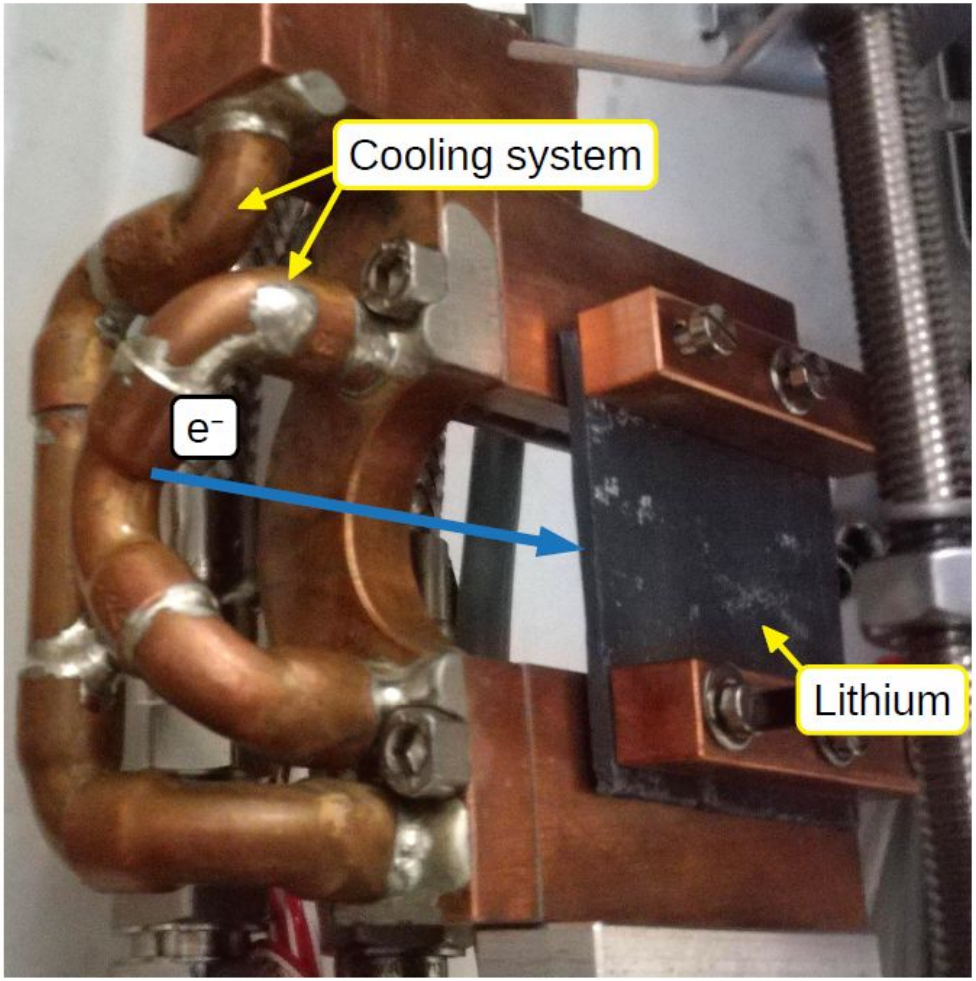
high reactivity: $6\,\mathrm{Li} + \mathrm{N_2} \xrightarrow{20\,^{\circ}\mathrm{C}} 2\,\mathrm{Li_3N}$, etc.

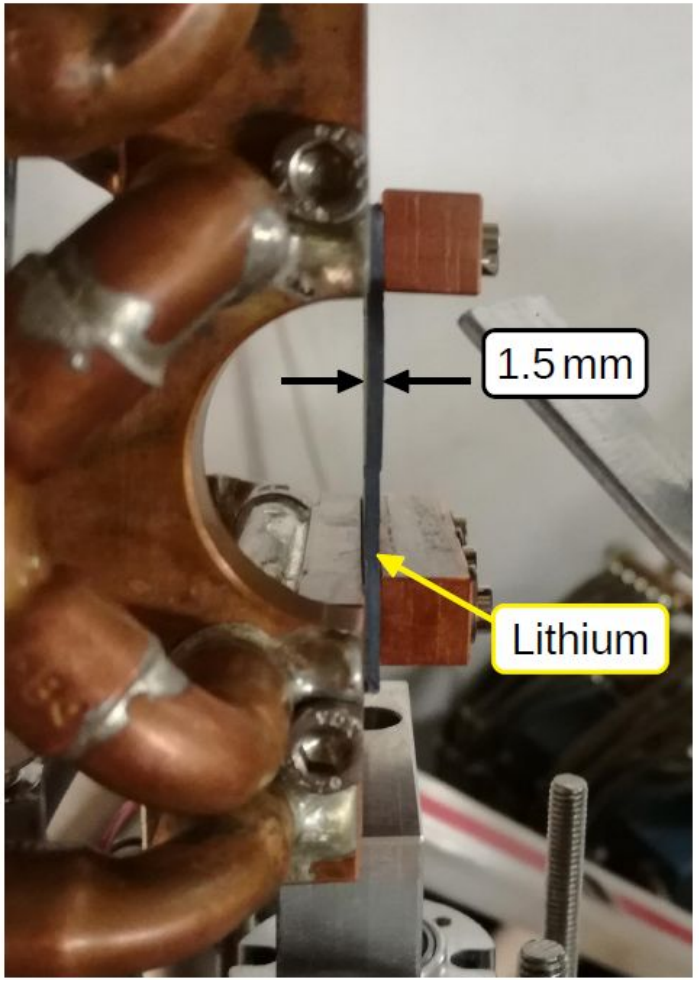
Missing Mass of ^{11}B(π^{-}, p ^{4}He)X:



Gurov *et al.*, Moscow Engineering Physics Institute, EPJ A 32, 261–266 (2007)

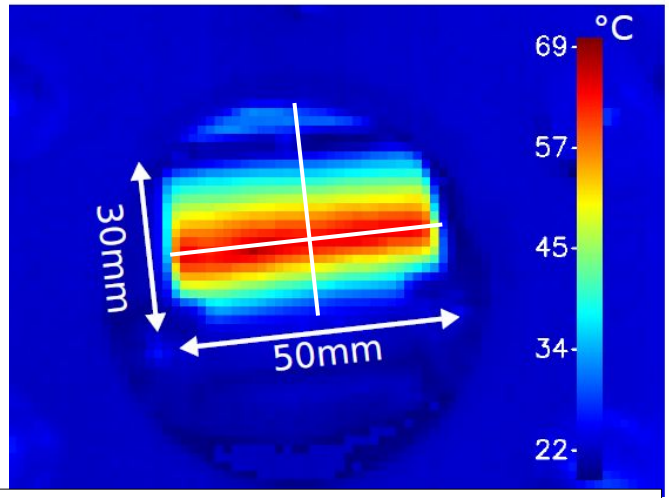
5. Target Prototype





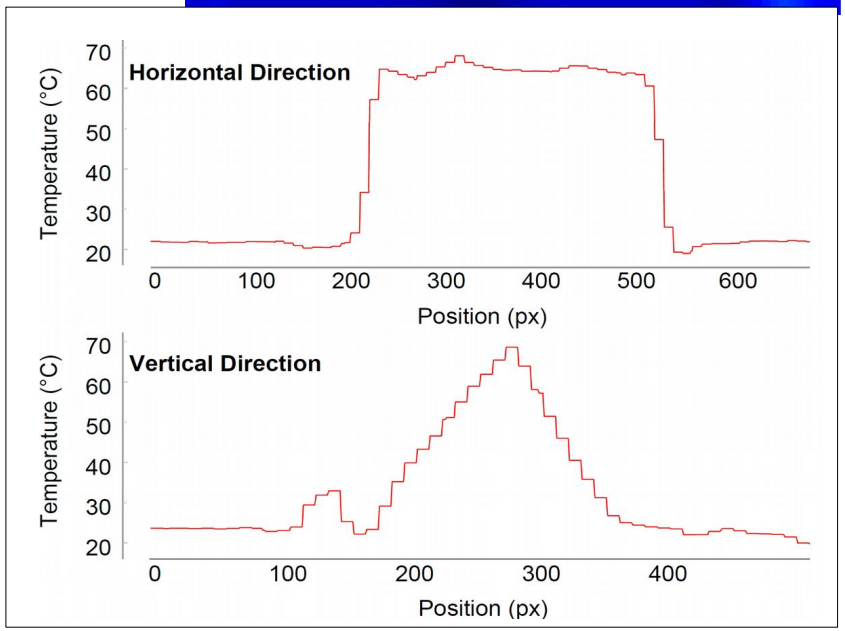
5. First Lithium Target Test

Observed temperature distribution of Lithium during exposition with electron beam by using a thermal cam and infra red optics



Details:

- **Beam Energy:** 855 MeV
- **Beam Current:** 10 µA
- **Maximal Temperature:** ~ 70°C



→ allows target alignment

→ successful cooling

Conclusion

Pilot experiment on observing neutron rich nuclei performed:

- $(e, e'\pi^+\pi^+)$ with current setup @A1 not possible

  ⟶ Cross section too low? Momentum transfer too high?

- $(e, e'p\pi^+)$ events observed

  ⟶ Lithium target developed and successfully tested

  ⟶ $^7Li(e, e'p\pi^+)^6H$ planned in near future

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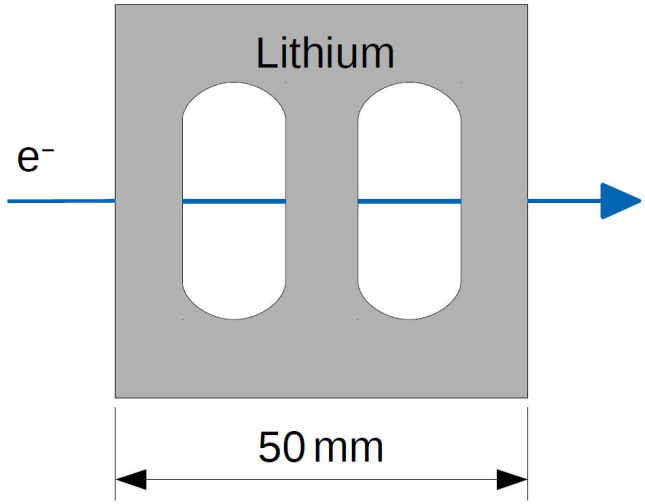
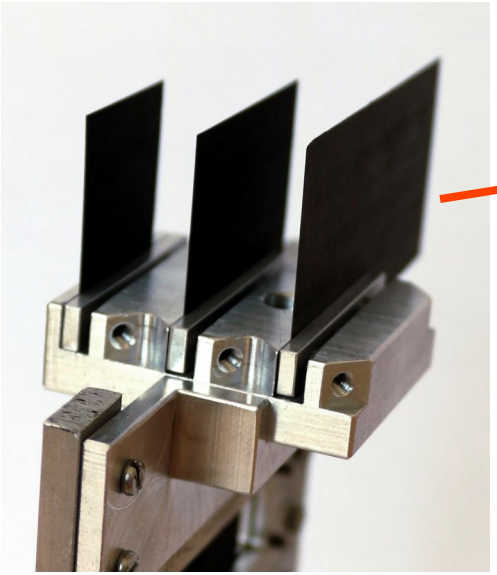
Thank you for your attention!

6. Possible Tagret for ^{6}H measurement

Cut out areas to reconstruct the vertex position:

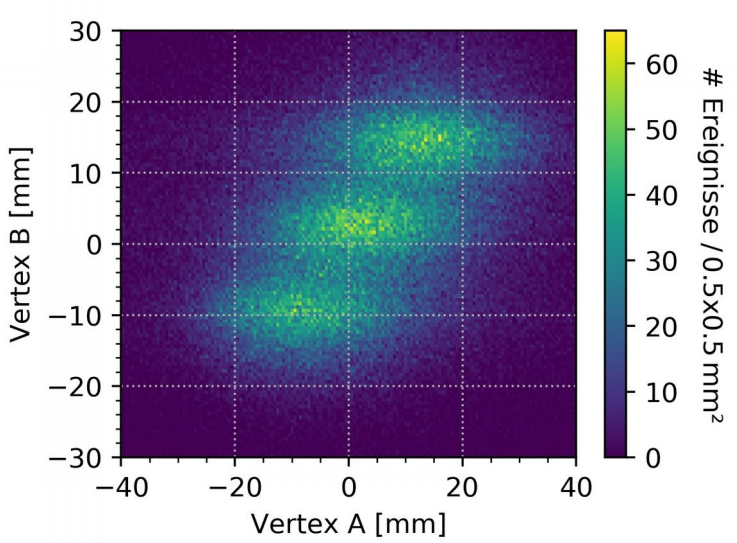
- ➡ **improve resolution by reducing and correcting energy straggling**





carbon target for (e, e'$\pi^+\pi^+$)

observed position



6. Further optimizations for ^{6}H measurement @MAMI

Increase event rate:

- Construct another detector with large angular acceptance

  ⟶ replace one of the A1 spectrometer

- Optimize luminosity

  ⟶ increase target thickness

Keep resolution acceptable:

⟶ target simulation needed