Results from the $^{6}He(p,p\alpha)^{2}n$ reaction

TECHNISCHE UNIVERSITÄT DARMSTADT

Meytal Duer

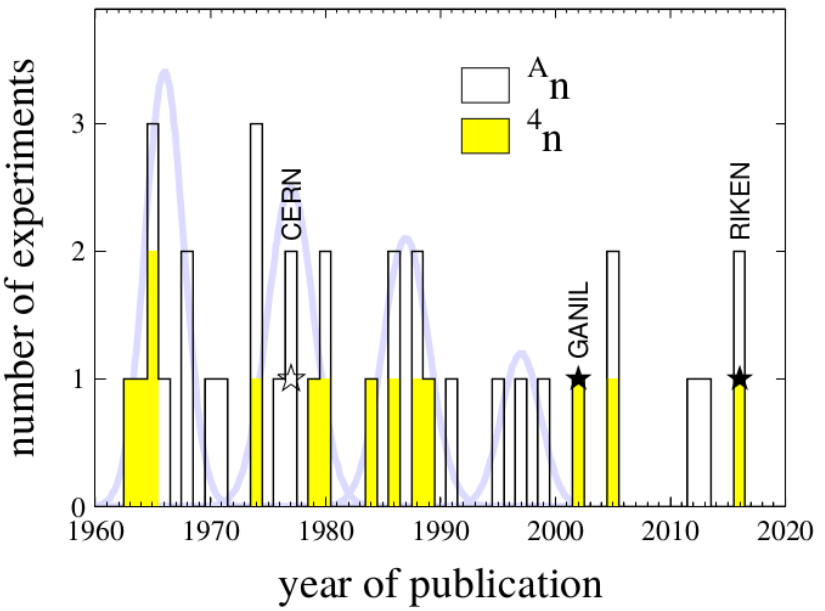
March 24th , 2021

SFB Workshop

SAMURAI19 Experiment

<u>Goal:</u> Search for a tetraneutron state (resonant / bound)

A sixty-year quest



★ possible ^{4}n candidates

F. M. Marques, J. Carbonell, arXiv:2102.10879 (2021)

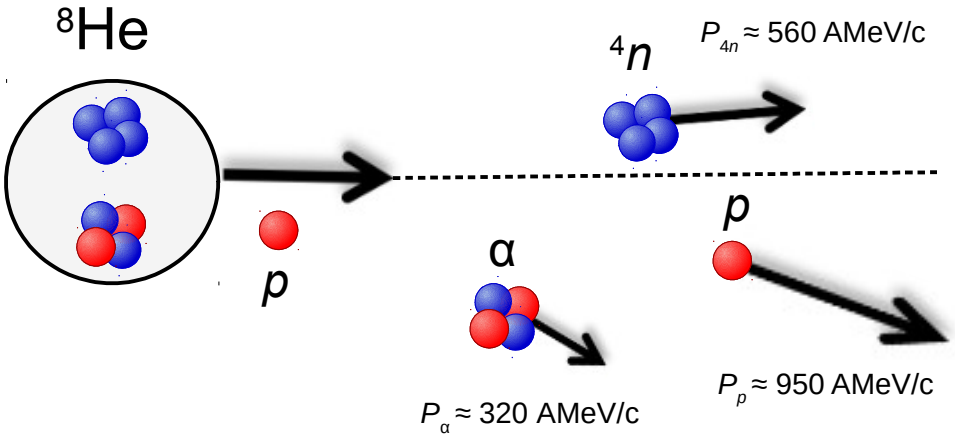
SAMURAI19 Experiment

Goal: Search for a tetraneutron state
(resonant / bound)

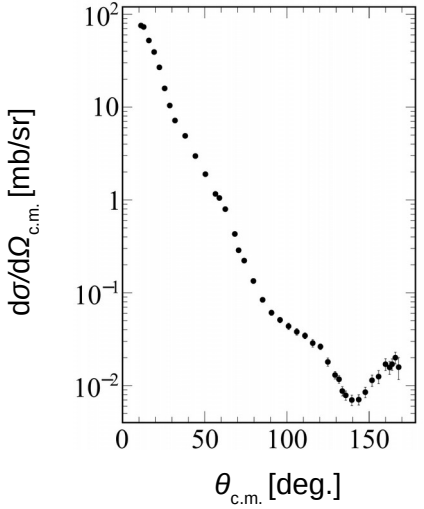
Measurement:

Quasi-free ^{8}He(p,$p\alpha$)^{4}n knockout at 156 AMeV

- Large momentum transfer, ~180° in c.m. system



Measured p-α elastic cross-section @ 156 MeV



V. Comparat et al., PRC (1975)

SAMURAI19 Experiment

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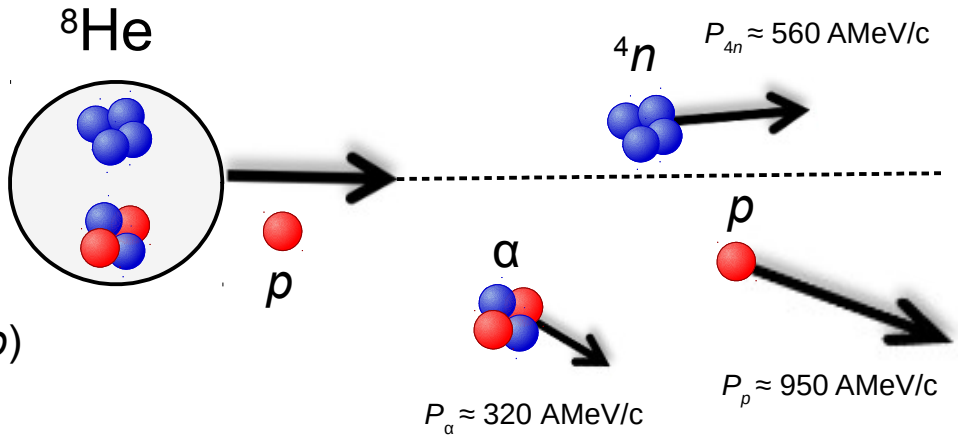
→ Precise measurement of **charged particles** (^{8}He,α,p)



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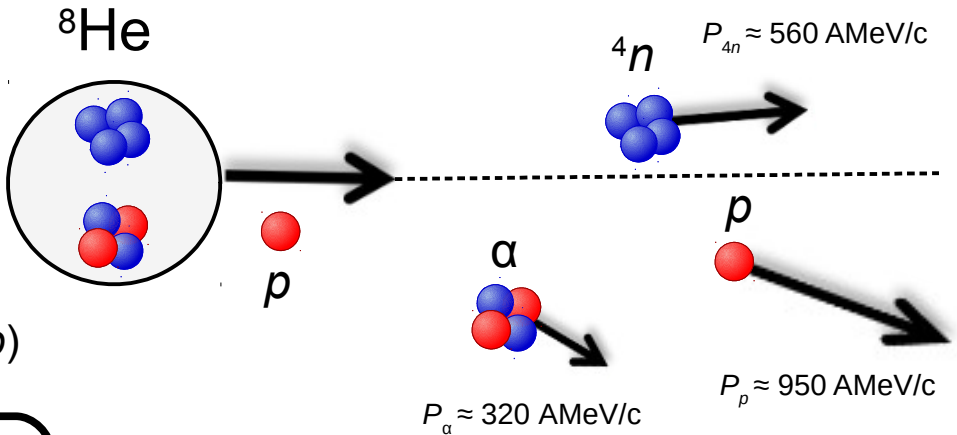

Benchmark measurement: ^{6}He(p,$p\alpha$)^{2}n reaction

→ Expected to be well described by theory

Experimental Setup

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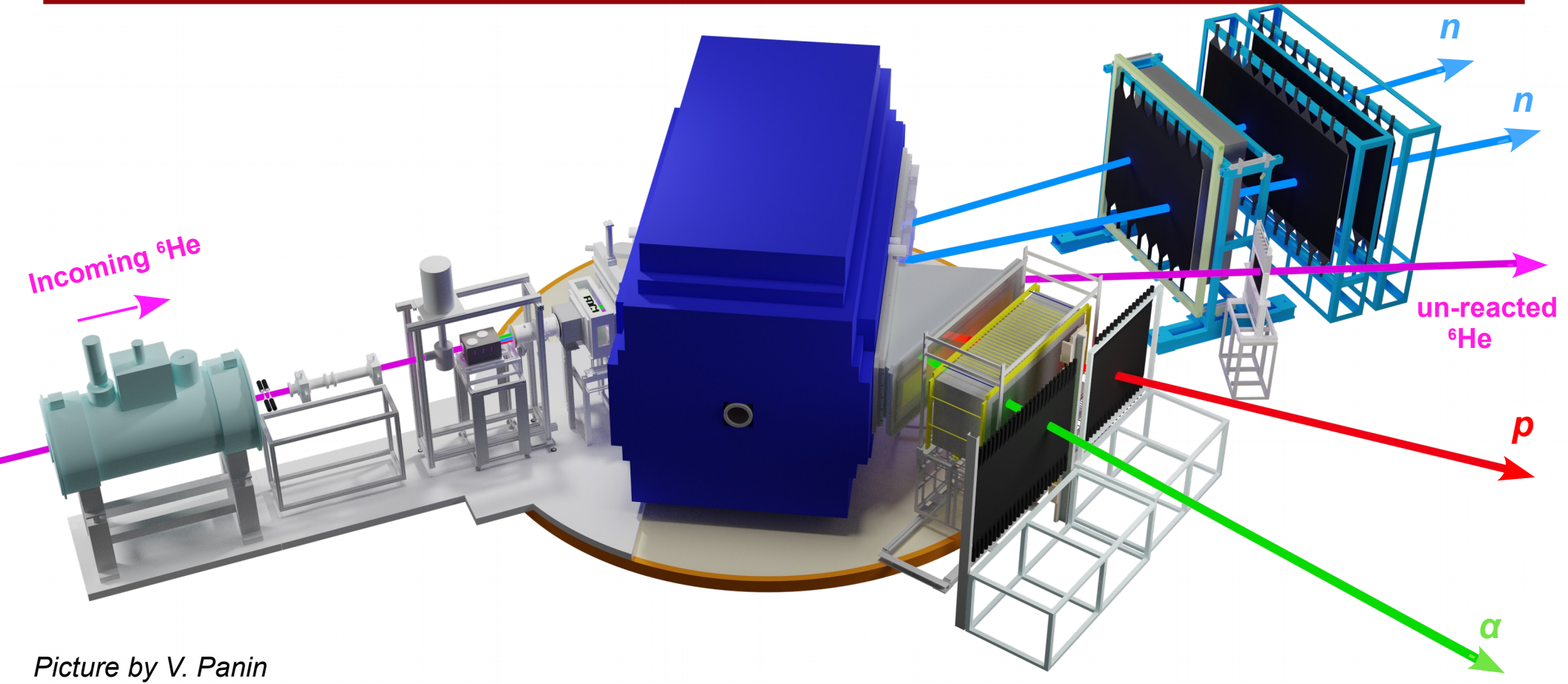

Picture by V. Panin

Incoming PID and Tracking

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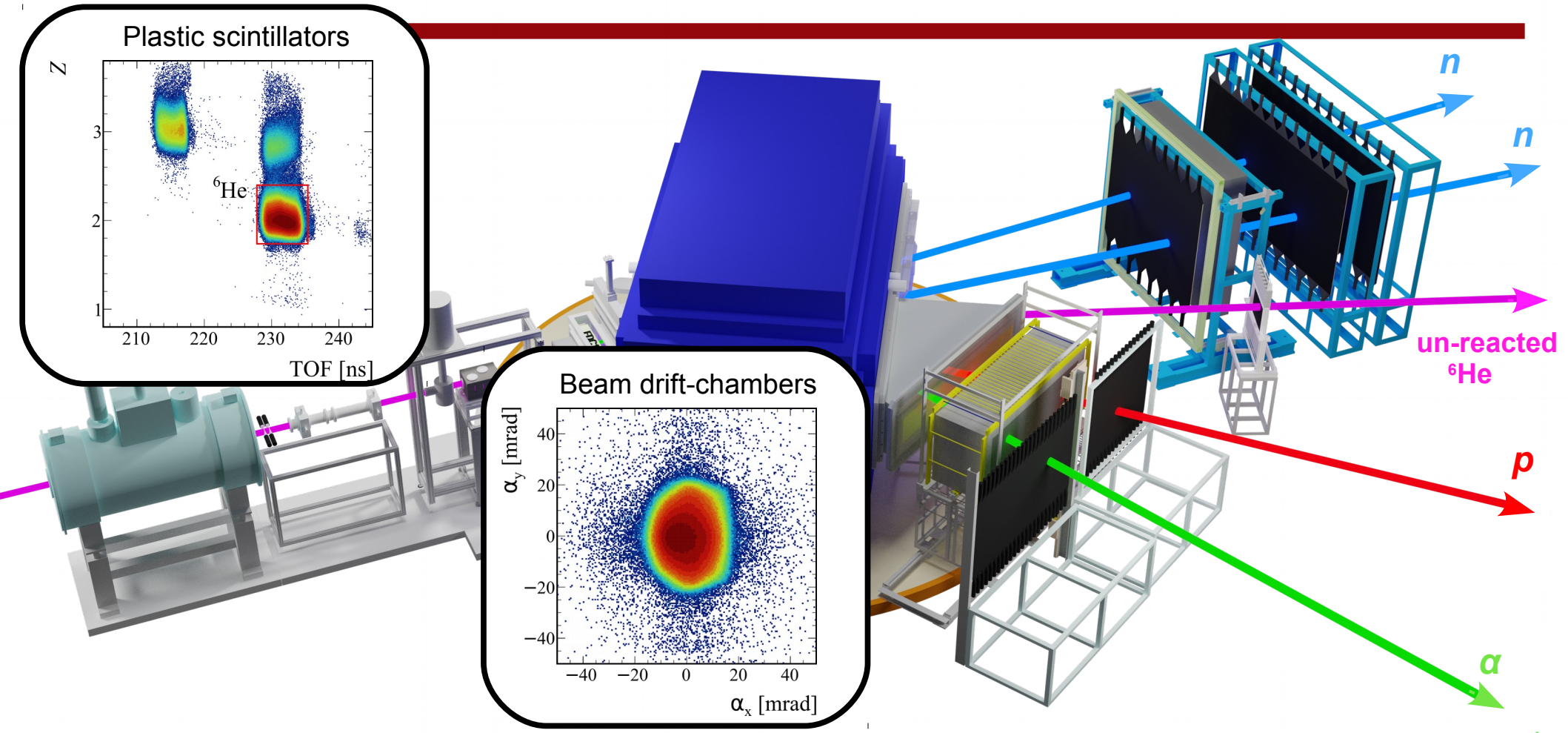

Experimental Setup

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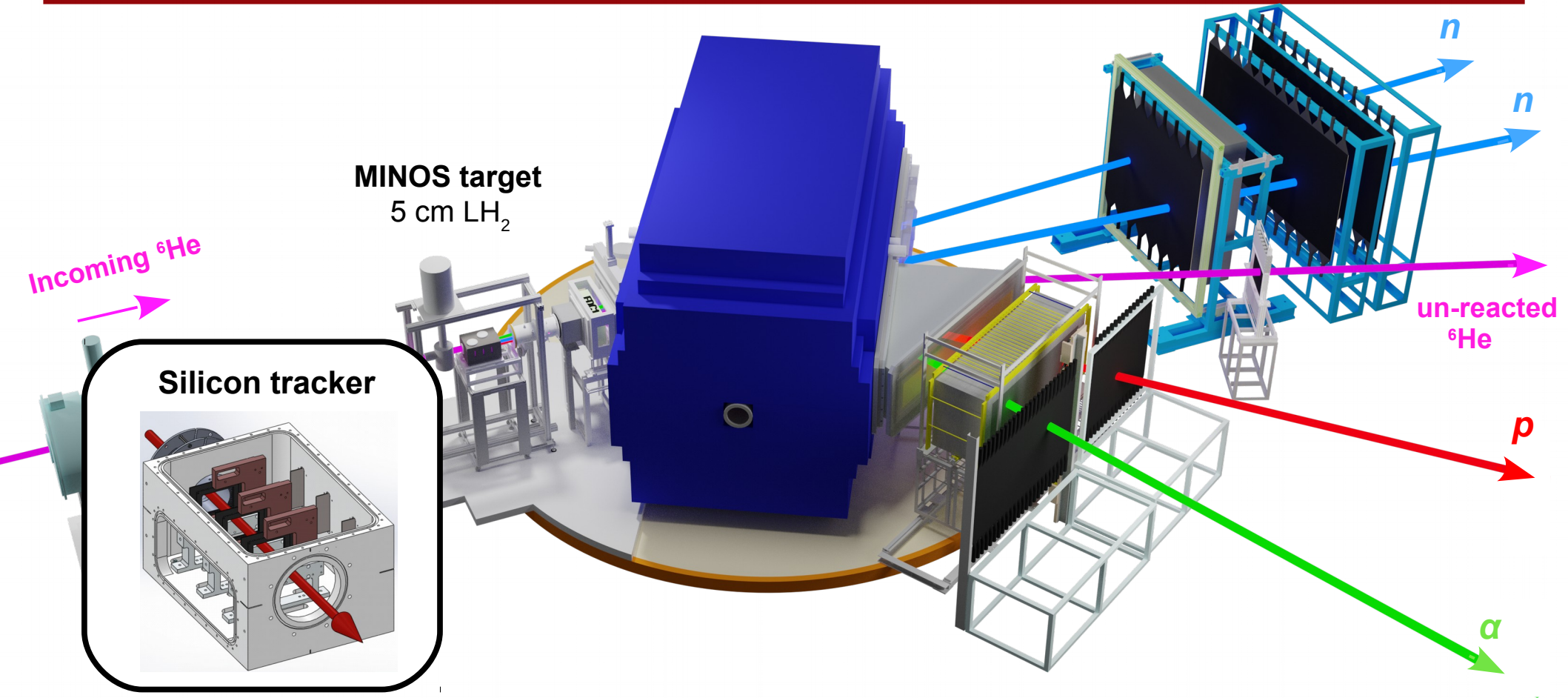

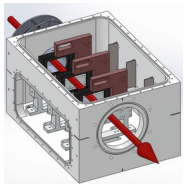

A dedicated silicon tracker

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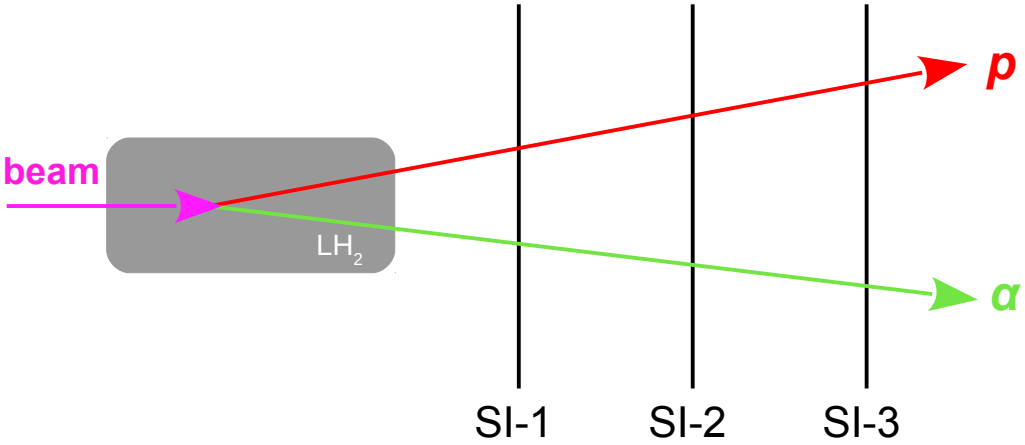
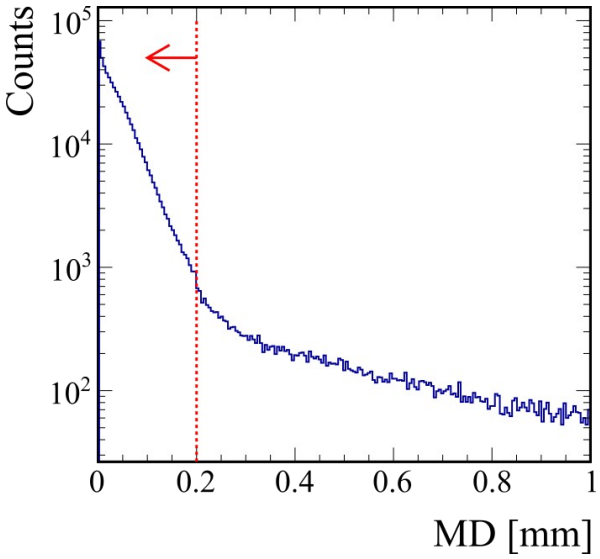


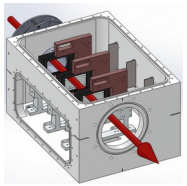
- 3 SI-detector modules with X and Y readout
- Separated by 12 cm
- 8 x 5 cm, 100 µm strips
- Distance between target and 1st detector ~ 6 mm

→ Tracking before the SAMURAI magnet

→ Energy-loss measurement
(very different for fast *p* and slow α)

→ Vertex reconstruction: minimun-distance approach





Vertex Reconstruction

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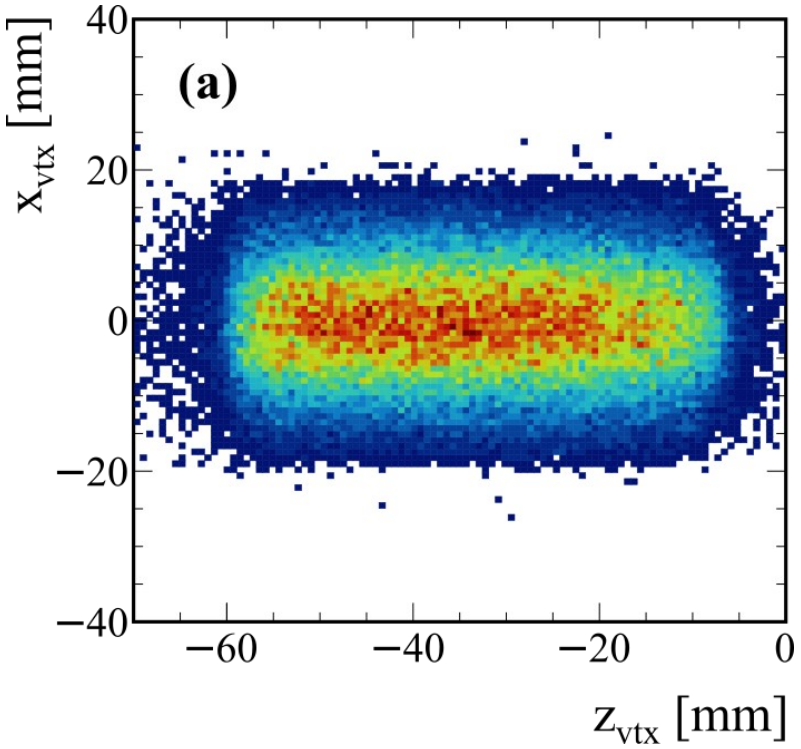
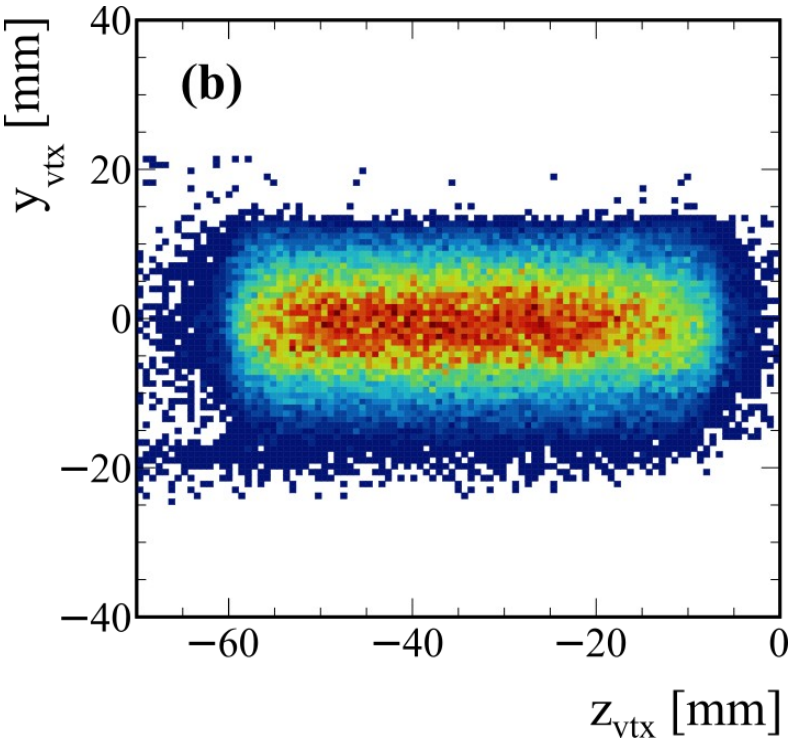
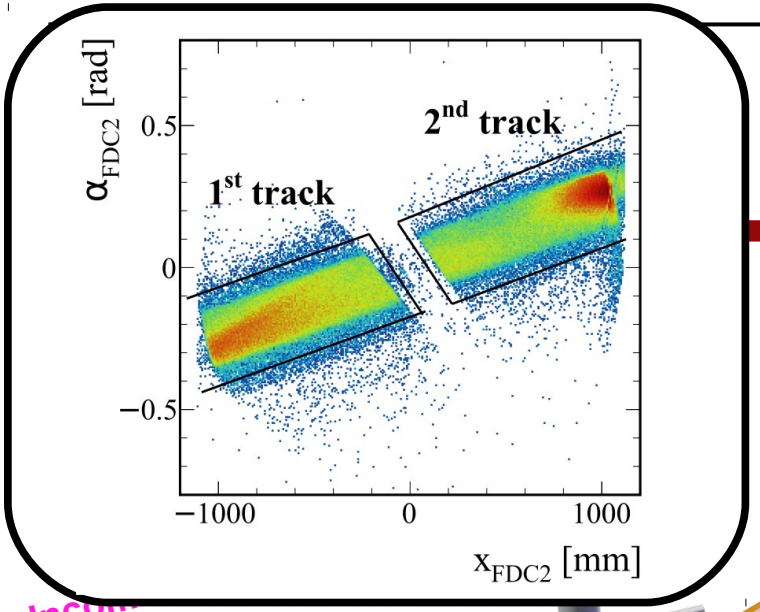
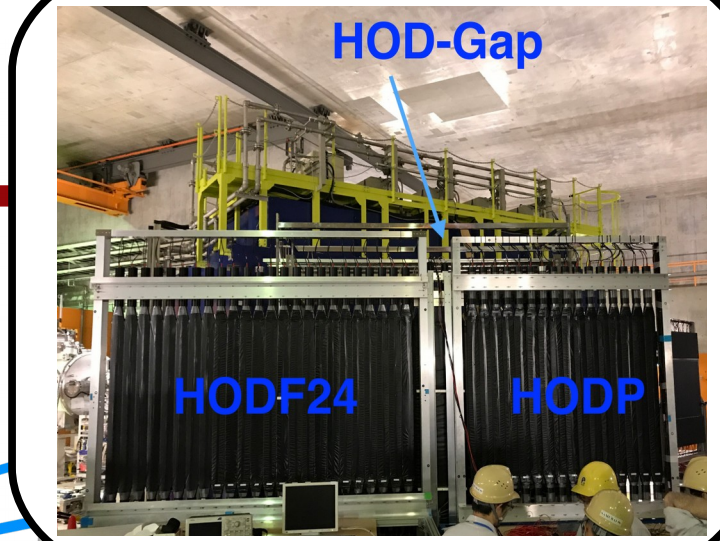




* Vertex resolution of ~1 mm

Focal Plane





Forward Drift Chamber (FDC2):
Tracking after SAMURAI magnet

Plastic scintillator walls:
Energy-loss and TOF

Fragments Identification

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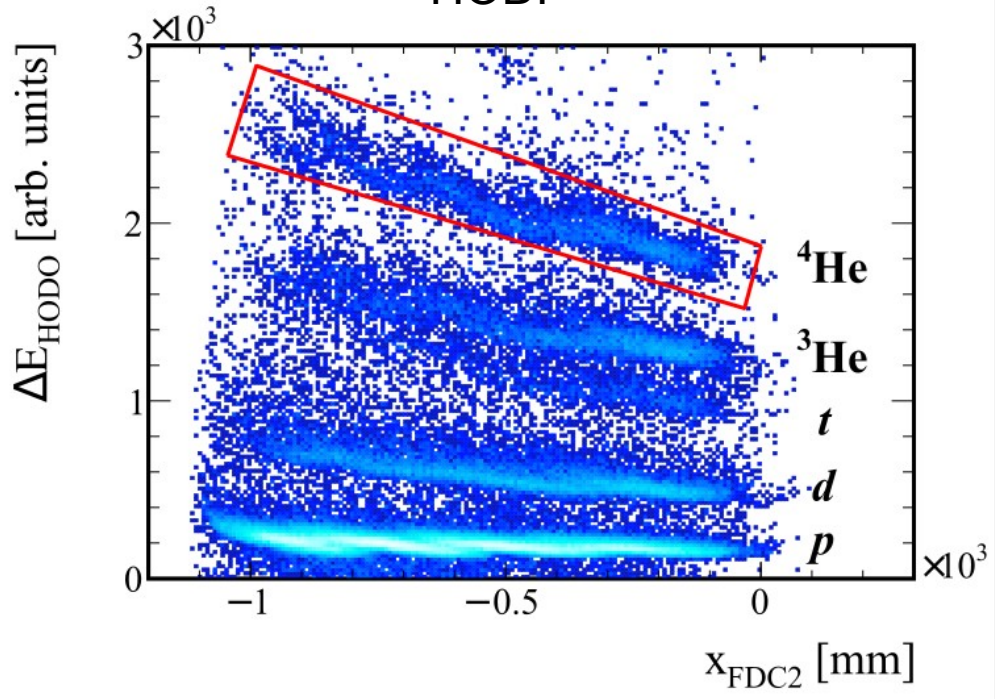
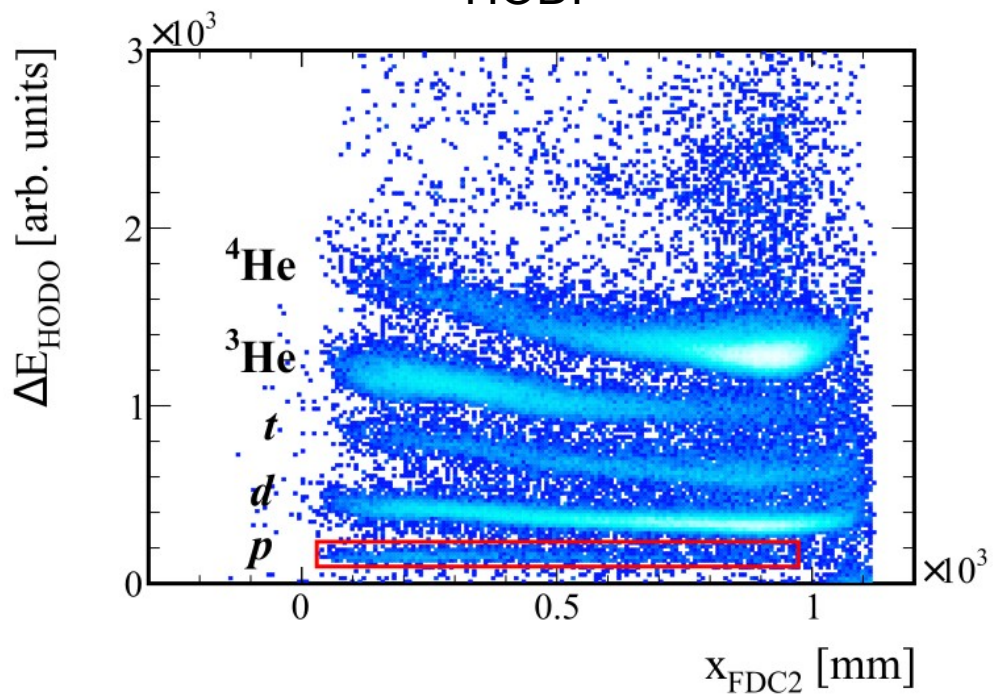
HODF



HODP



* ^{8}He: ~1/2 of the runs do not include TOF from HODOs

Fragments Identification

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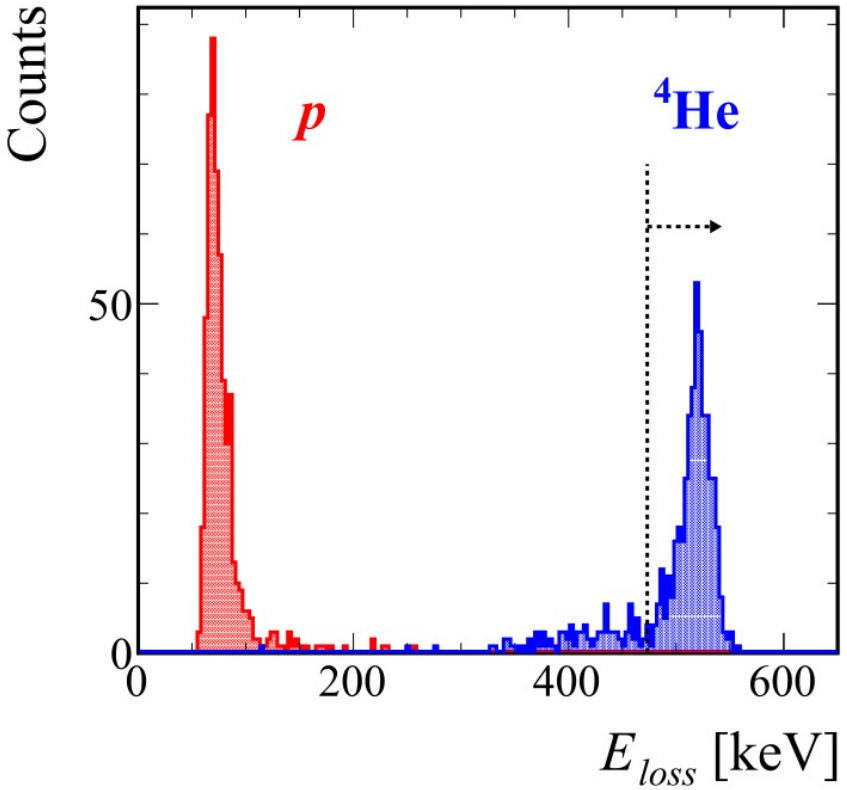
Energy-loss in silicon detectors for selected *p*-α



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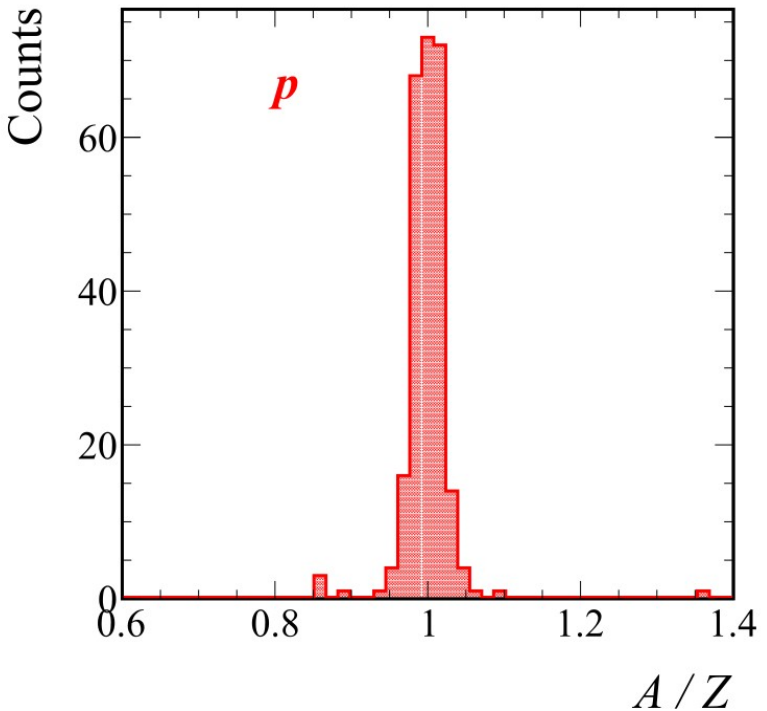
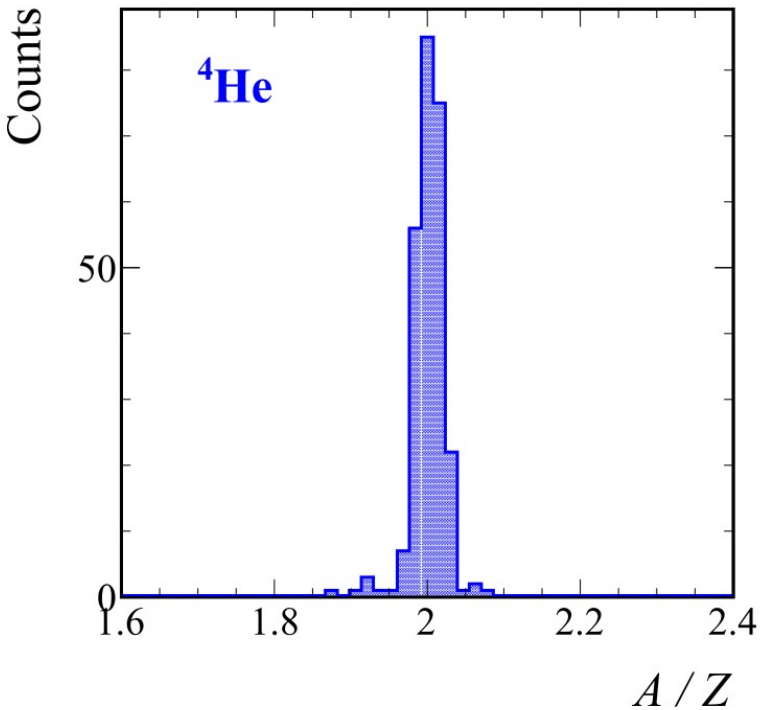
Sanity check: Extracting *A/Z* ratios





Fragments Momentum

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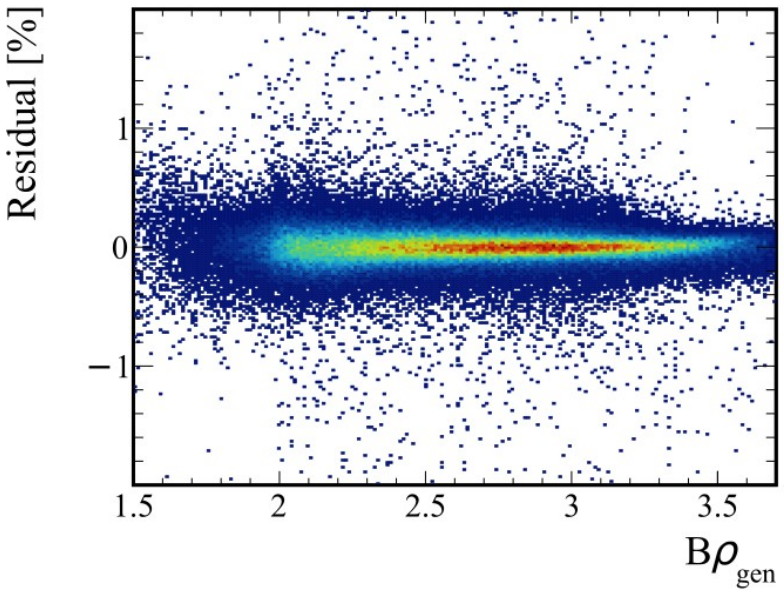
Multi-Dimensional Fit

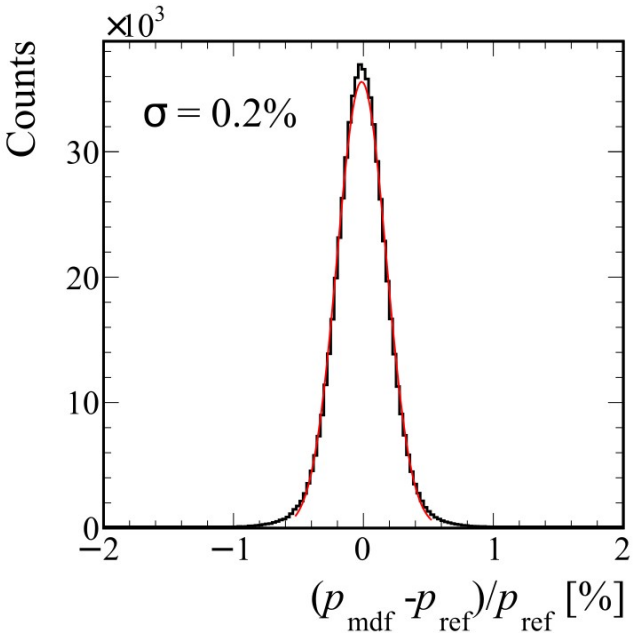
$B\rho = f(x_{SI}, y_{SI}, \alpha_{x,SI}, \alpha_{y,SI}, x_{FDC2}, \alpha_{FDC2})$

$B\rho = P/Z$

Validate with data:

Proton beam @ 596 MeV/c





Quasi-Free ^{6}He(p,pα) events

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Energy-momentum conservation:

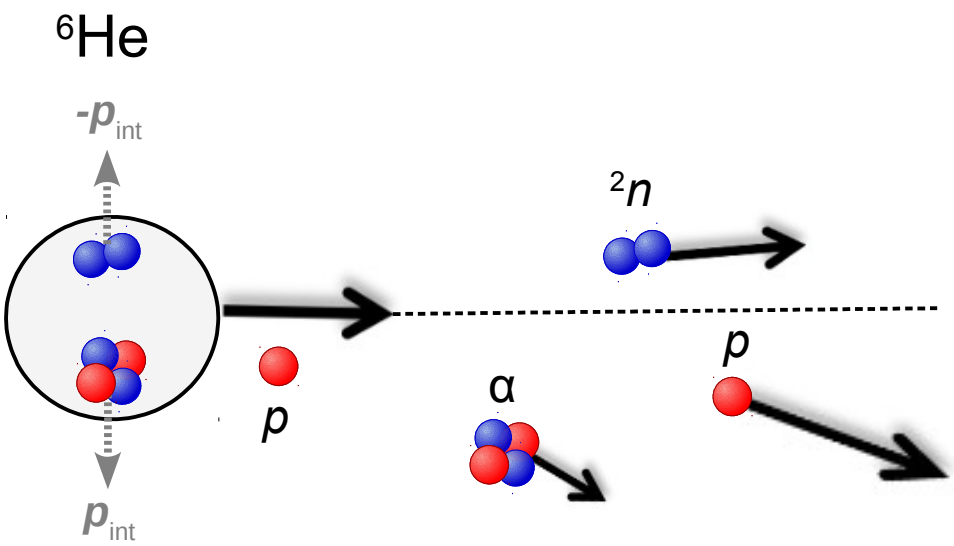
$$P_{^6\mathrm{He}} + P_{p(\mathrm{tgt})} = P_p + P_\alpha + P_{2n}$$

$$P_{miss} = P_{^6\mathrm{He}} + P_{p(\mathrm{tgt})} - P_p - P_\alpha$$

$$E_{2n} = M_{miss} - 2m_n$$

Intrinsic momentum of α:

$$\boldsymbol{p}_{\mathrm{int}} = -\boldsymbol{p}_{miss}$$



QFS Simulation

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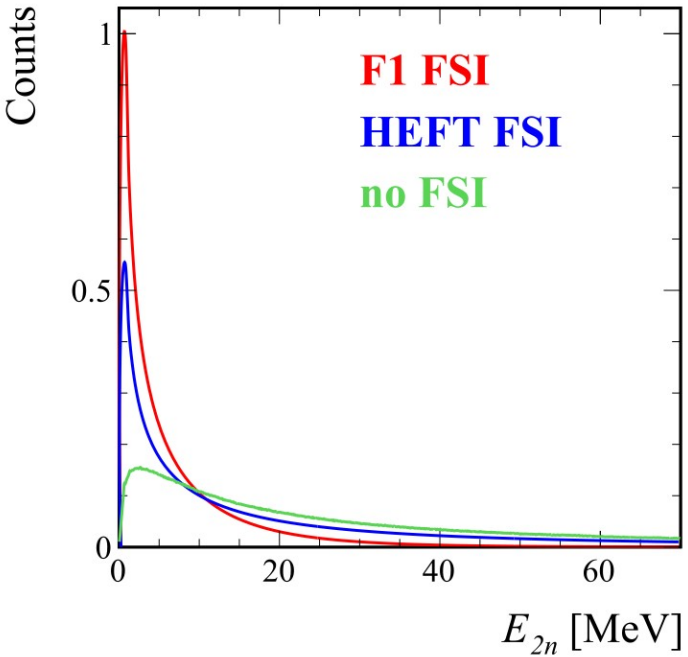
What's needed?

- E_{2n} distribution [M. Göbel]



- Intrinsic momentum of α: Gaussian with FWHM = 75 MeV/c [Chulkov et al., NPA 759 (2005)]
- Measured *p*-α cross-section [V. Comparat et al., PRC (1975)]

F1 FSI: 3-body cluster model

HEFT FSI: Model inspired by Halo Effective Field Theory

No FSI: Model inspired by Halo Effective Field Theory without taking into account *nn* FSI

QFS Simulation

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1. Generate QFS ^{6}He(p,$p\alpha$) events
2. Run through full detector simulation
3. Smear simulated data by internal resolutions
4. Analyze same way as experimental data

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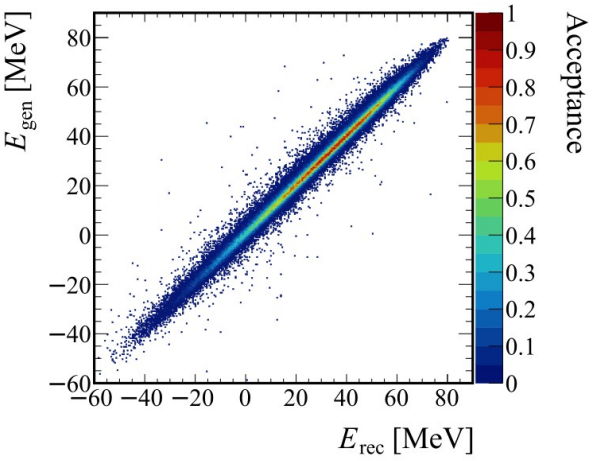

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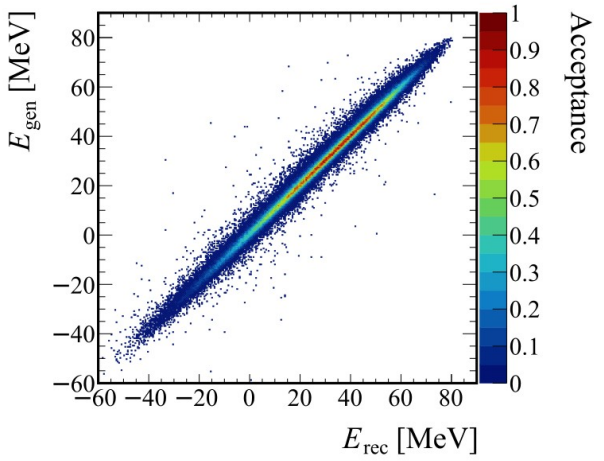
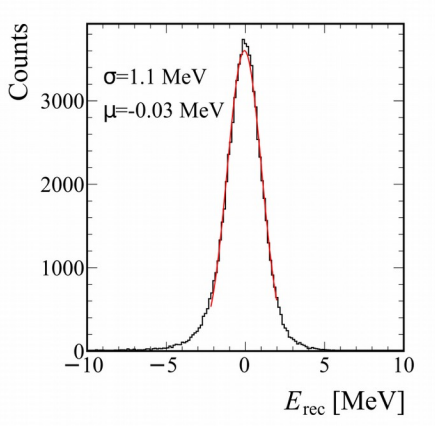
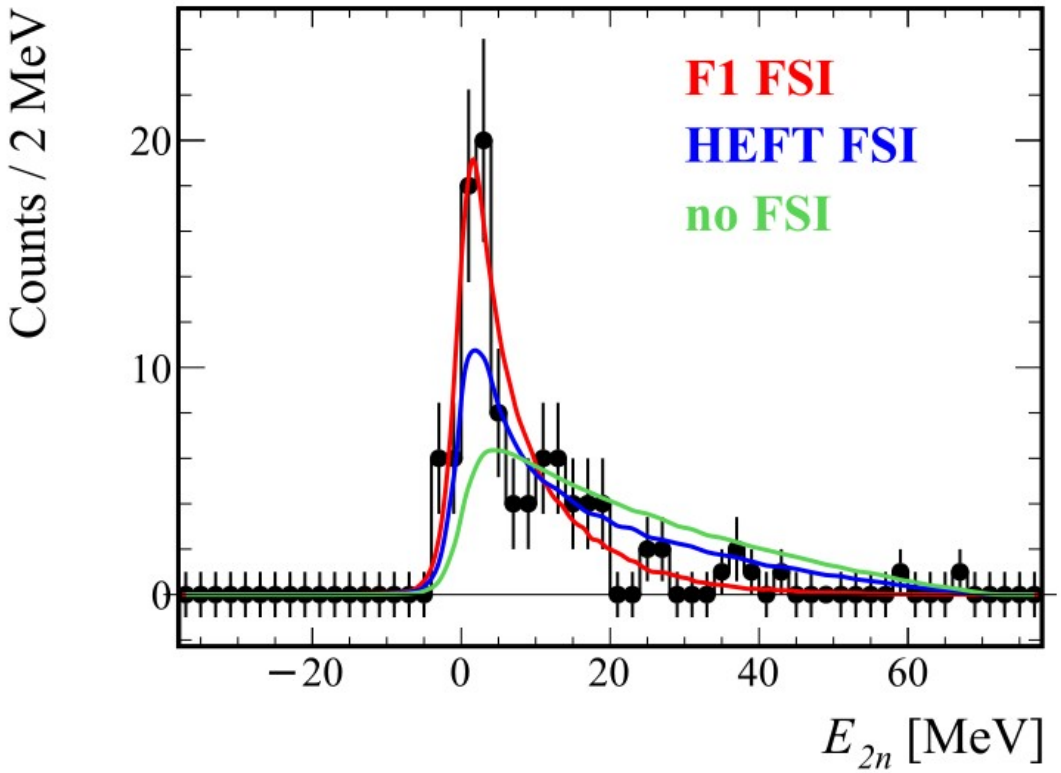


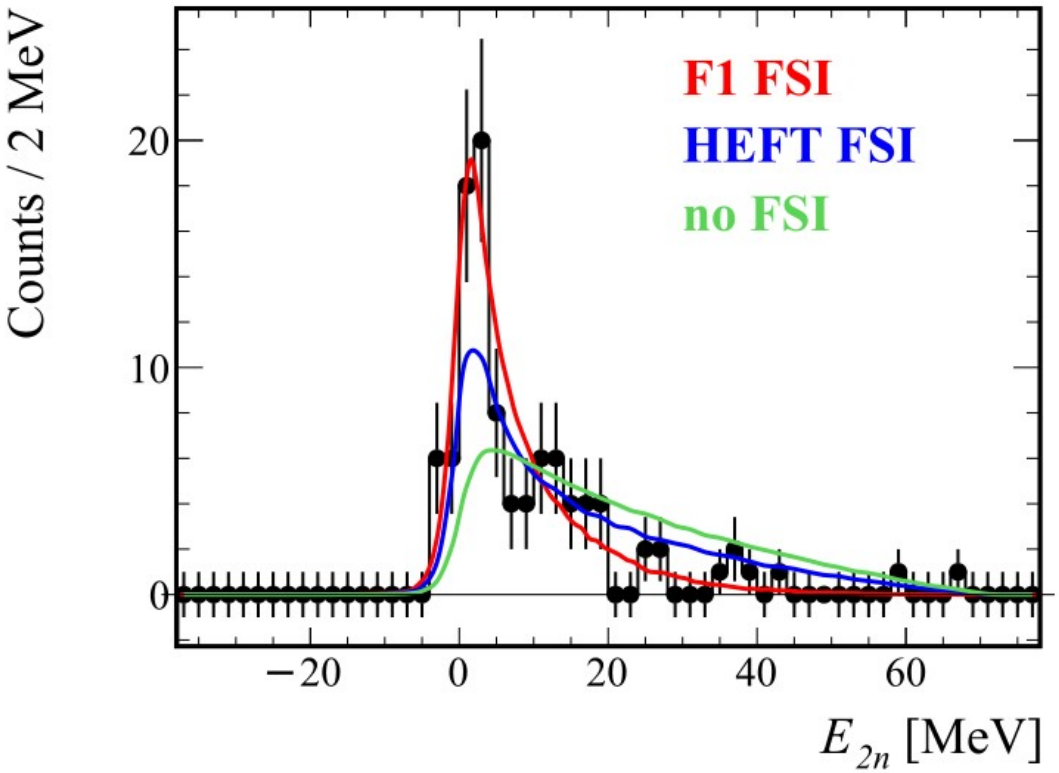


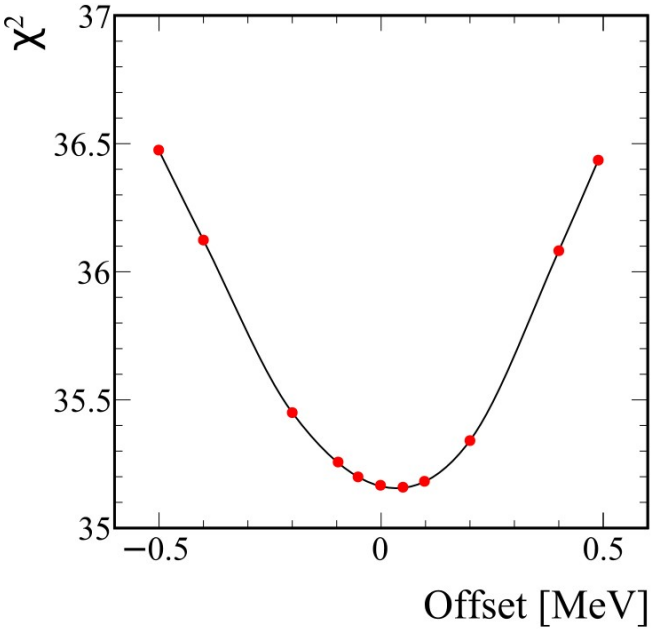
Missing-mass spectrum



* Normalized to the total number of measured events

Missing-mass spectrum





→ Systematic uncertainty 0.4 MeV

* Normalized to the total number of measured events

c.m. angle

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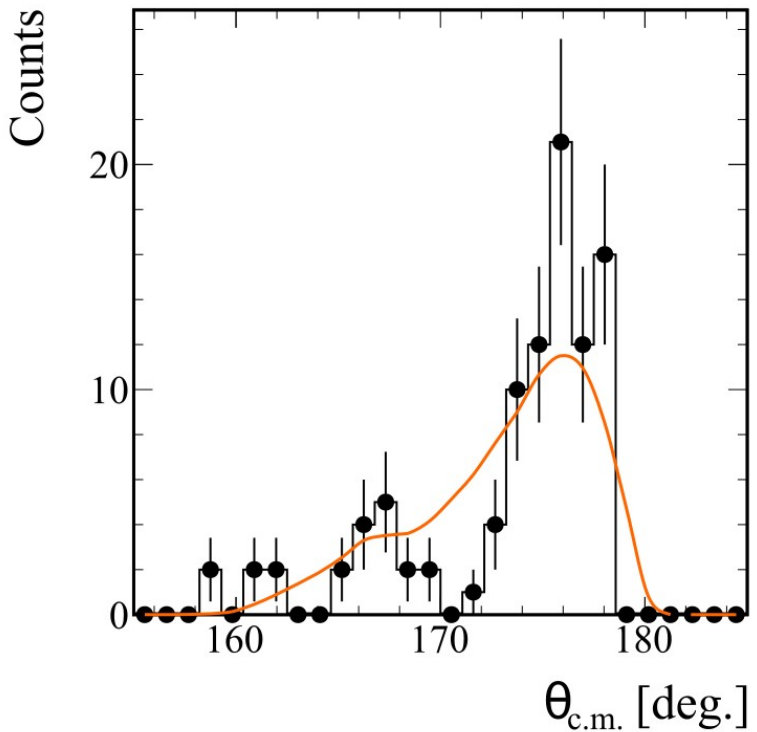
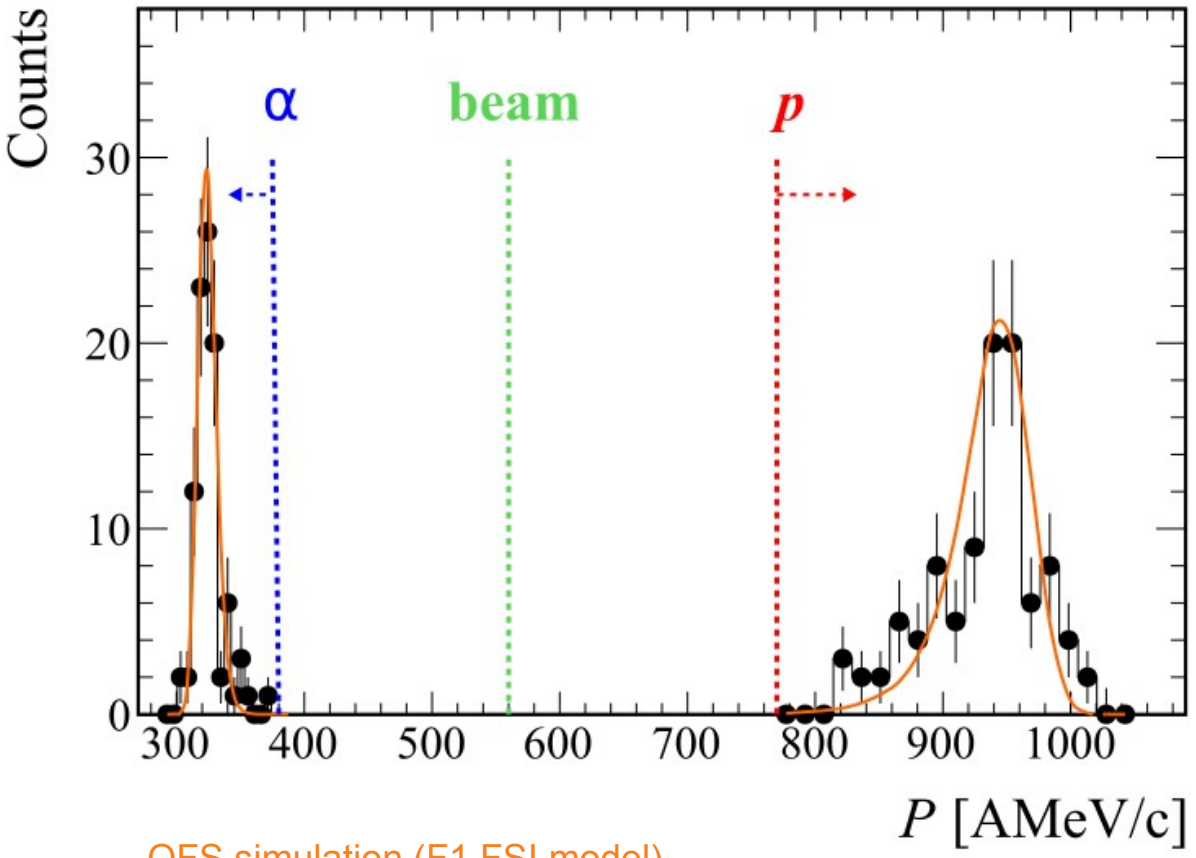
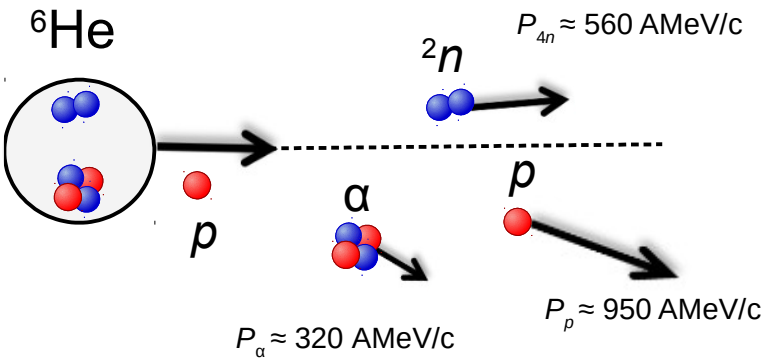
p-α scattering at large c.m. angle to minimize FSI between charged particles and neutrons



QFS simulation (F1 FSI model)

Momentum separation





QFS simulation (F1 FSI model)

Angular distributions

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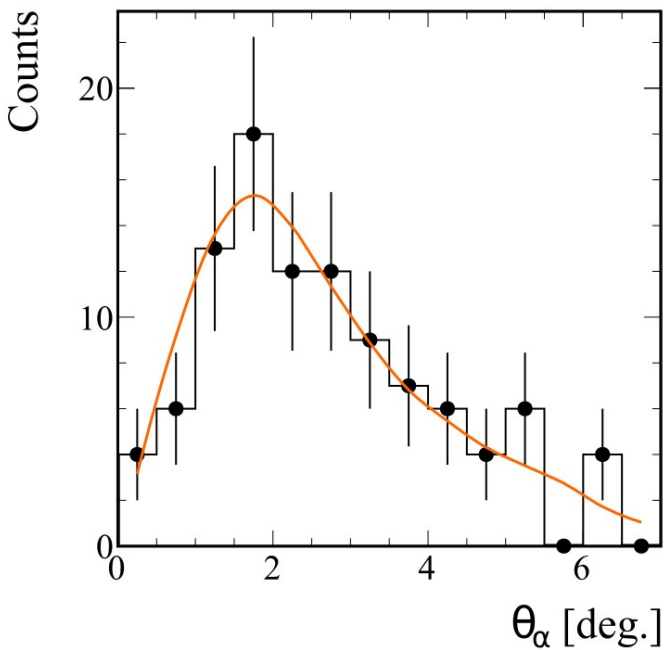
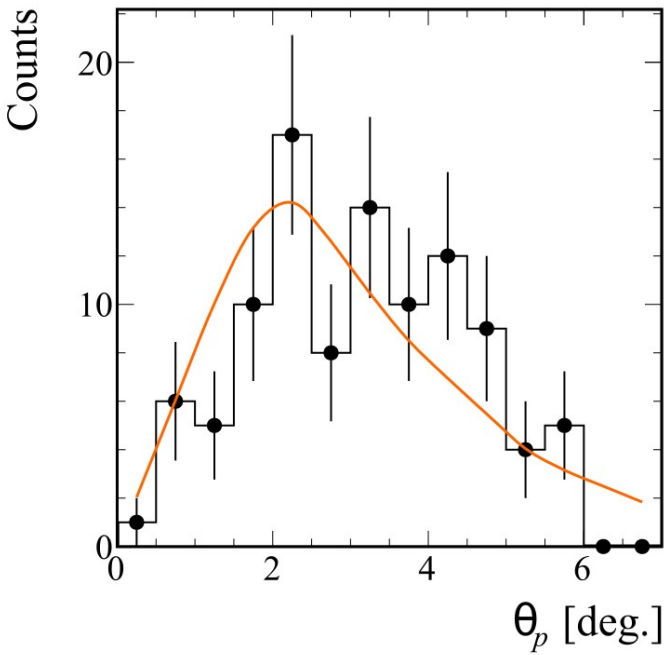
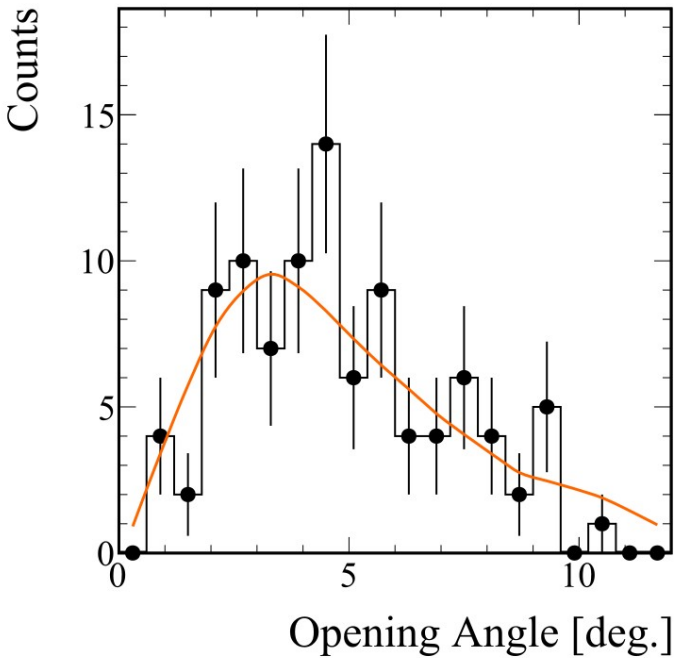
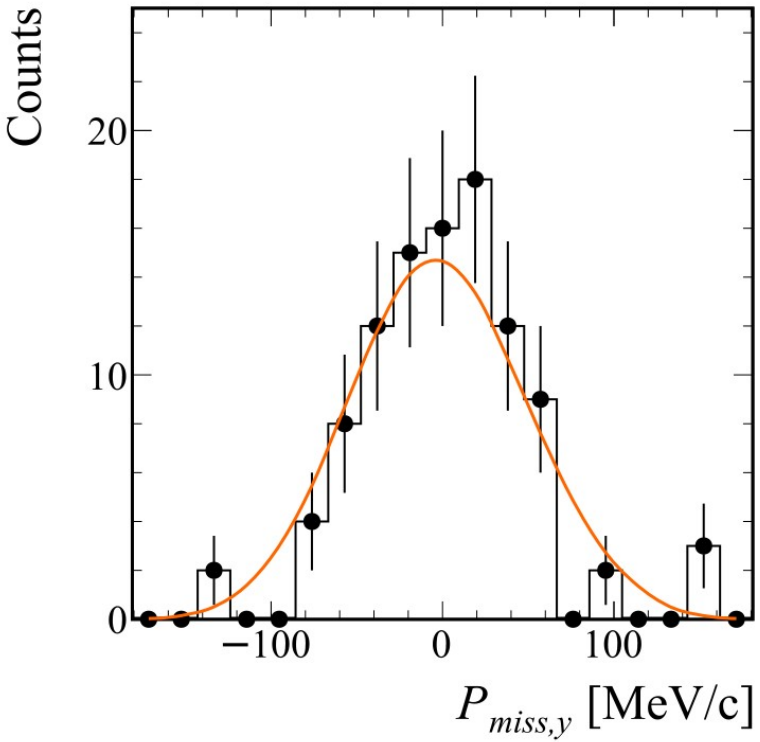






QFS simulation (F1 FSI model)

Intrinsic momentum of α



QFS simulation (F1 FSI model)

$$\boldsymbol{p}_{\text{int}} = -\boldsymbol{p}_{miss}$$

→ Consistent with a Gaussian distribution, FWHM = 75 MeV/c, used as an input

[Chulkov et al., NPA 759 (2005)]

Summary

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- Good agreement for our benchmark ^{6}He(p,$p\alpha$)^{2}n reaction: missing-mass spectrum and observed QFS kinematical characteritsics ⟶ verify calibrations and analysis procedures

- Analysis under review by the experts of the SAMURAI collaboration

SAMURAI19 Analysis Note: Investigation of the 4n system using $(p, p^{4}\mathrm{He})$ quasi-free scattering with a 156 AMeV ^{8}He beam

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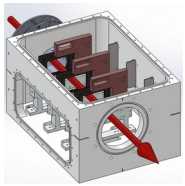
[2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt, Germany
[3]Helmholtz Forschungsakademie Hessen für FAIR, 64289 Darmstadt, Germany

March 11, 2021

Thank you !

- Next step:

'Blind' analysis for ^{8}He(p,$p\alpha$)^{4}n



Vertex Resolution

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Empty target runs