Group Meeting 6.30

Observation of tetraneutron

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Duer, M., Aumann, T., Gernhäuser, R. *et al.* Observation of a correlated free four-neutron system. *Nature* **606,** 678–682 (2022).

Searching for Multi-neutron System

A long-standing question in nuclear physics is whether the chargeless nuclear systems can exist.

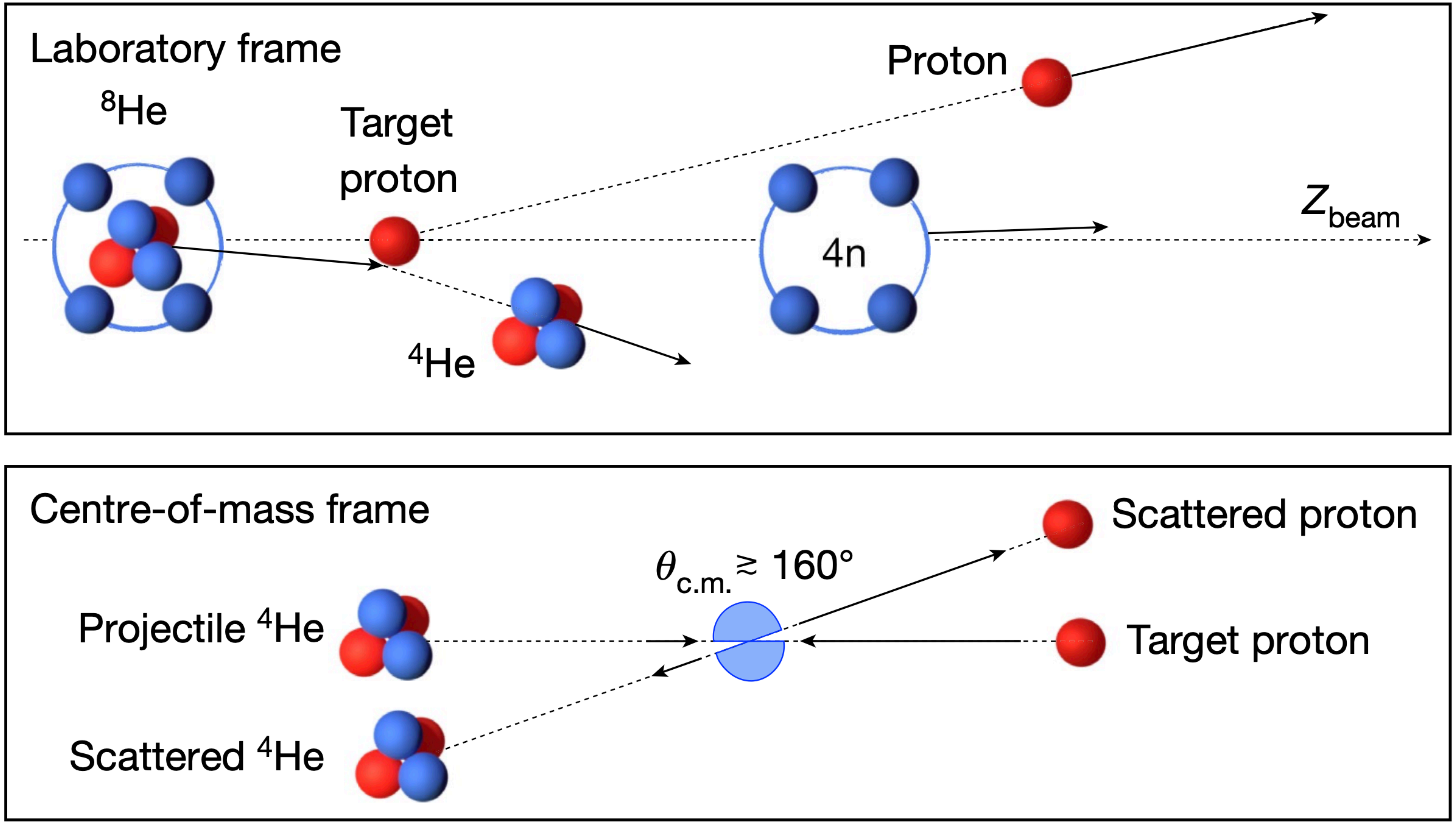
2n ? 3n ? 4n ?

Some attempts:

pion-induced double-charge-exchange (DCX) reactions

Uranium fission reactions

The Reaction



Set up of the Experiment

Article

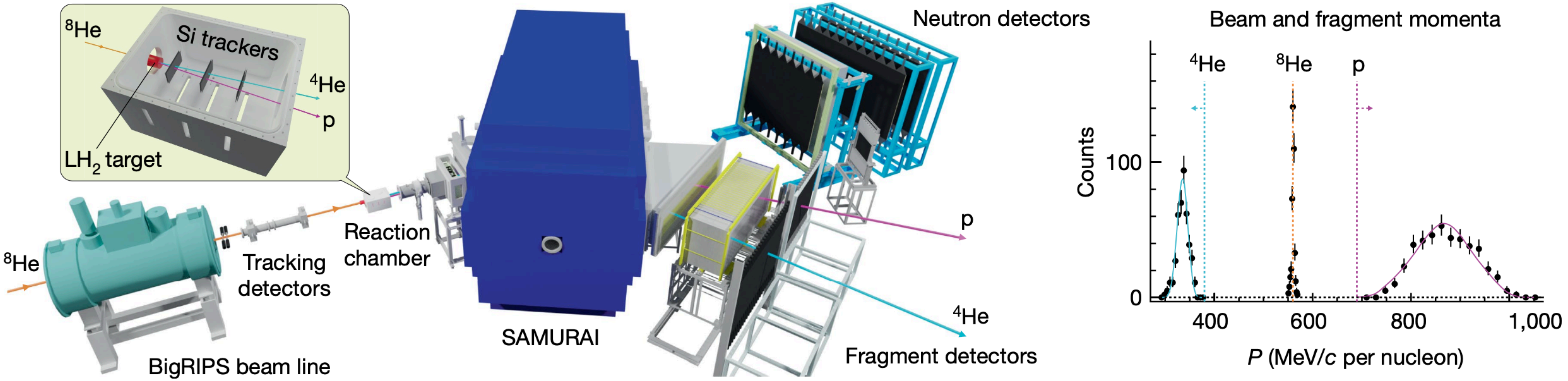


Fig. 2 | Experimental set-up and charged fragments momenta. Left: schematic view of the experimental set-up. The ^{8}He secondary beam at 156 MeV per nucleon is transported from the BigRIPS (Big RIKEN projectile-fragment separator) into the SAMURAI set-up, where it hits a liquid-hydrogen (LH_2) target. In a quasi-elastic (p, p^{4}He) reaction, the ^{4}He core is knocked out from the ^{8}He projectile. Scintillator detectors and drift chambers are used for beam identification and tracking. The trajectories of the outgoing fragments are tracked by three silicon (Si) planes and bent afterwards through the SAMURAI spectrometer towards the focal-plane detectors. Two neutron-detector arrays were placed at a forward angle behind the SAMURAI. An additional scintillator wall was placed at smaller bending angle to detect the unreacted ^{8}He beam. Right: measured momenta of the knocked-out ^{4}He and the scattered proton after the quasi-elastic scattering (symbols). The momentum distribution of the incoming ^{8}He beam is shown for comparison. The solid curves are the results from the simulation. The cyan (magenta) dotted line represents the upper (lower) limit of the ^{4}He (proton) momentum expected from the simulation assuming a quasi-elastic scattering, and the orange line indicates the central beam momentum.

Calculation of the 4n Energy

Conservation Law: $$E_{4n} = \sqrt{E_{miss}^2 - P_{miss}^2} - 4m_n$$

"Miss" Part: $$P_{miss} = P_{^8He} + P_{tar} - P_{^4He} - P_p$$

Resonance Peak

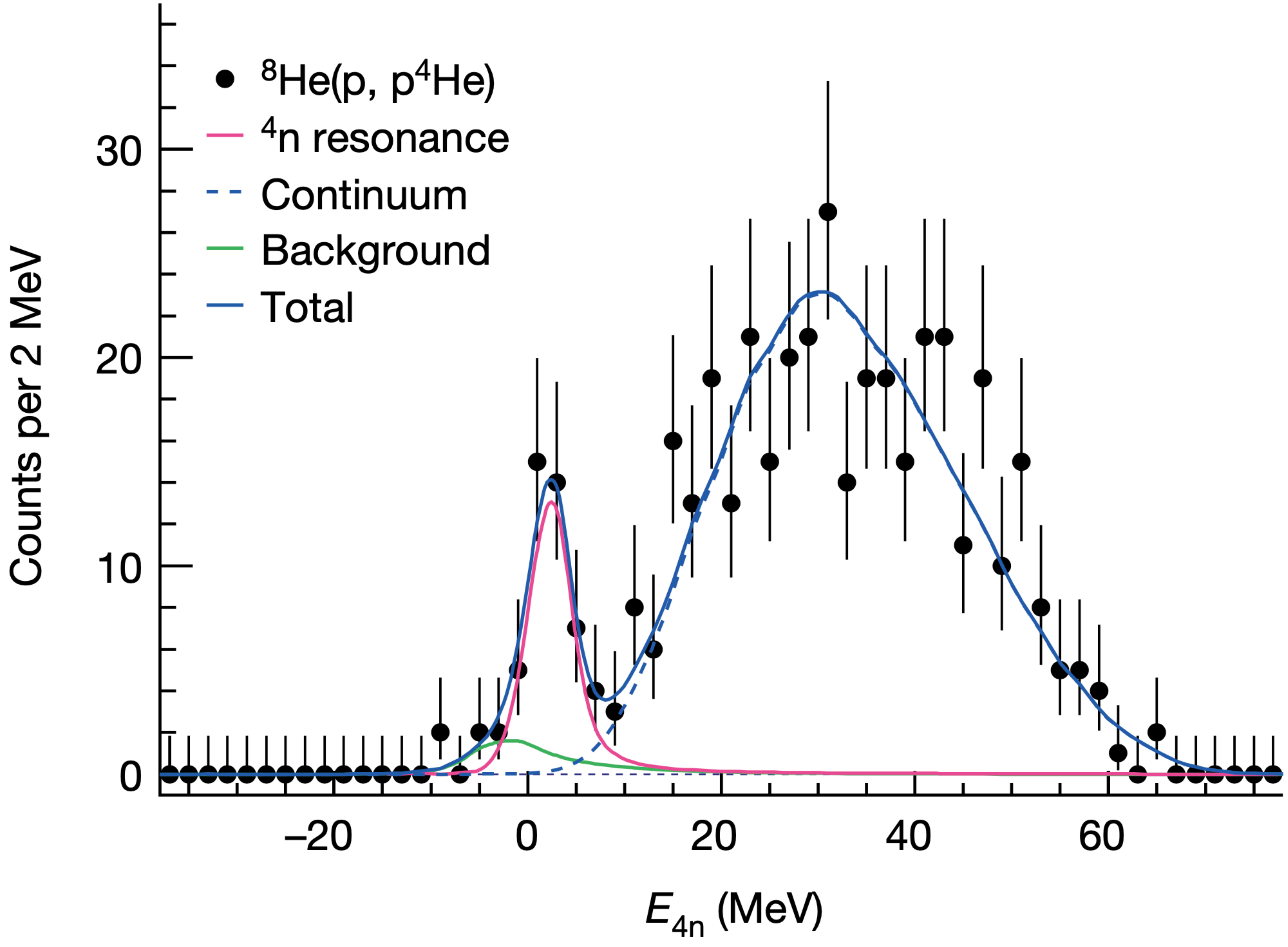
Continuum

+

Resonance

+

Background



Fitting the Data

Model for the whole spectrum: $$f(E_{4n}) = af_{res} + bf_{con} + cf_{bgd}$$

Resonance term: $$f_{res} = \frac{k}{(E^2 - M^2)^2 + M\Gamma^2}$$

Non-resonant term: $$f_{con} = E_{4n} \exp(-\frac{E_{4n}}{\epsilon_a})$$

Error Estimation

Statistical uncertainty: χ^2 Minimization

Systematic uncertainty: Carrying out another experiment

$$^{6}\mathrm{He}(p, p\alpha)$$