Evidence of direct tetraneutron transfer in near-barrier ^{8}He induced reactions

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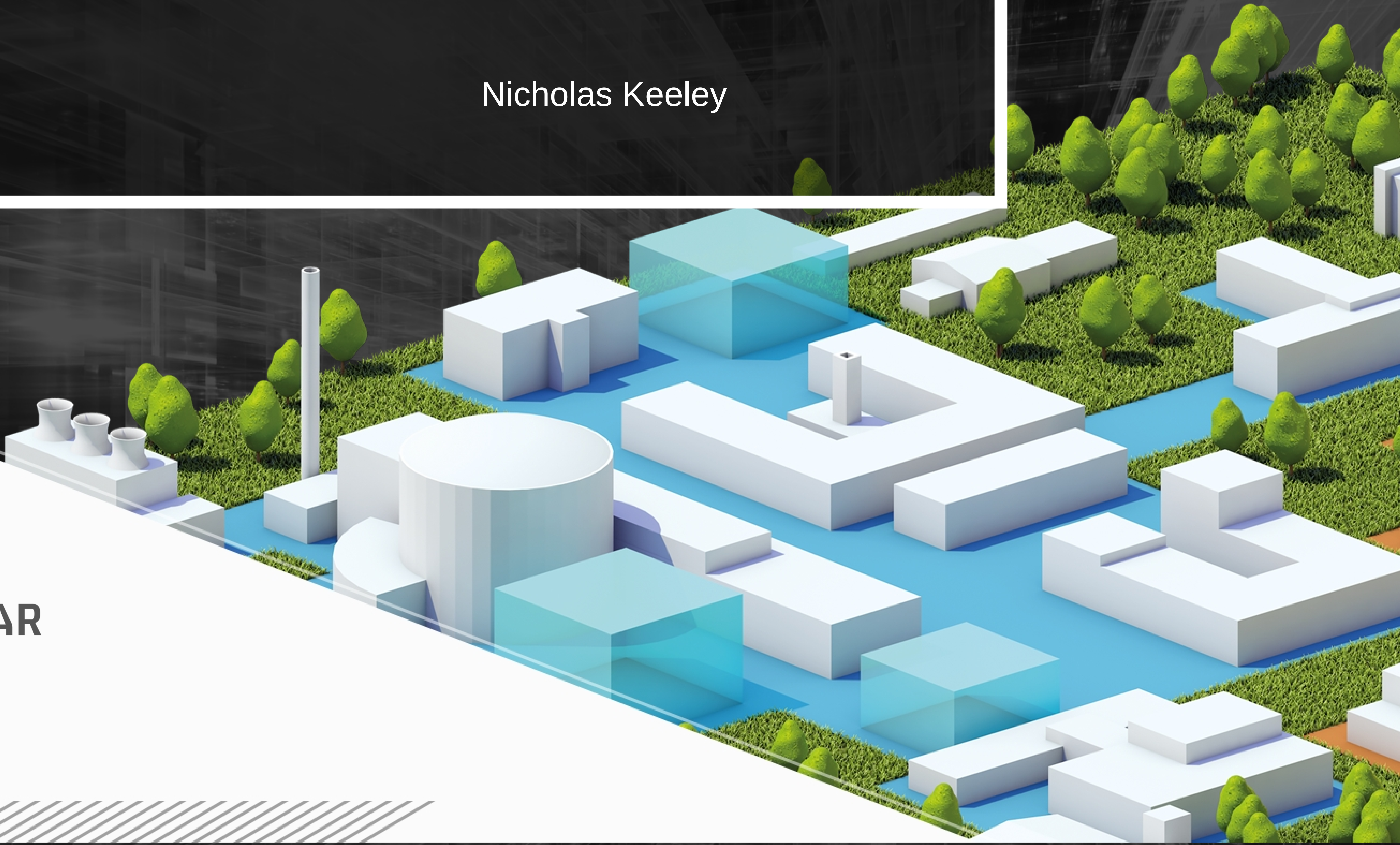

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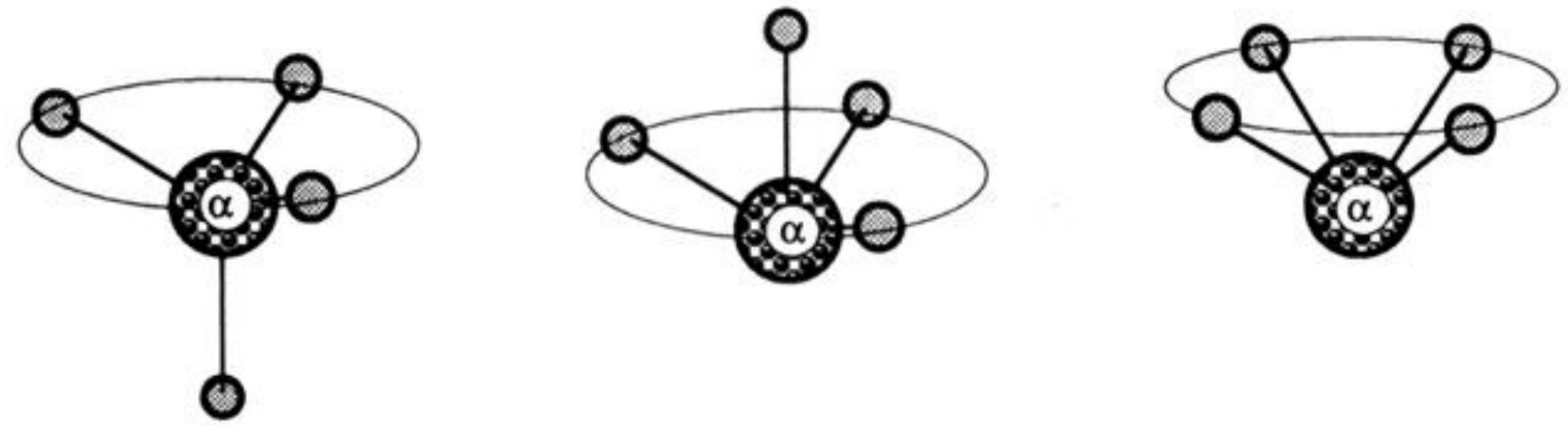
The ^{8}He nucleus is considered to consist of a compact ^{4}He core surrounded by a “skin” of four valence neutrons. These neutrons may be correlated in various ways, e.g.:



from M. V. Zhukov *et al.*, Phys. Rev. C **50**, R1 (1994)

This raises the possibility of 2n, 3n and 4n clustering in the ground state of ^{8}He. Using a beam of radioactive ^{8}He ions we can probe these possibilities using direct nuclear reactions, specifically neutron stripping.

However, measuring the charged ejectile does not give us exclusive information on the reaction; more than one stripping reaction will lead to the same final result (^{6}He and ^{4}He nuclei):

(^{8}He,^{6}He), (^{8}He,^{7}He → ^{6}He + n) **and ^{8}He → ^{6}He + 2n breakup**

(^{8}He,^{4}He), (^{8}He,^{5}He → ^{4}He +n), (^{8}He,^{6}He* → ^{4}He + 2n), (^{8}He,^{6}He)(^{6}He,^{4}He), (^{8}He,^{7}He* → (^{6}He* → ^{4}He + 2n) + n), (^{8}He,^{7}He)(^{7}He,^{6}He* → ^{4}He + 2n), (^{8}He,^{7}He)(^{7}He,^{4}He) **and ^{8}He → ^{4}He + 4n breakup**

Unambiguously to disentangle the various possible contributions would require multiple coincidence measurements between neutrons, charged particles and γ rays – difficult to obtain sufficient statistics with currently available beams.

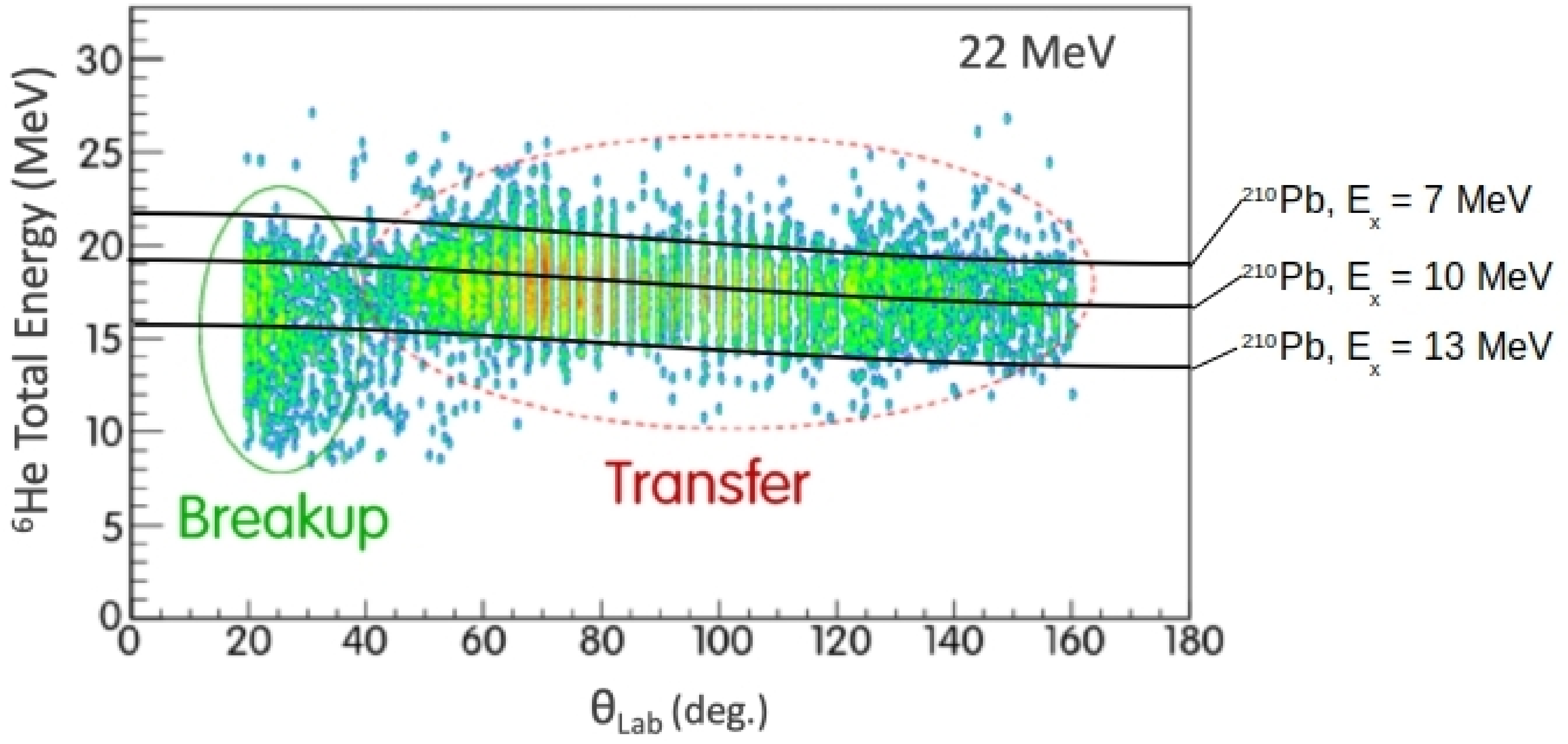
However, even inclusive measurements of the ^{6}He and ^{4}He yield can give us some information through detailed consideration of reaction kinematics to apply constraints to distorted wave Born approximation (DWBA) calculations of the reaction process.

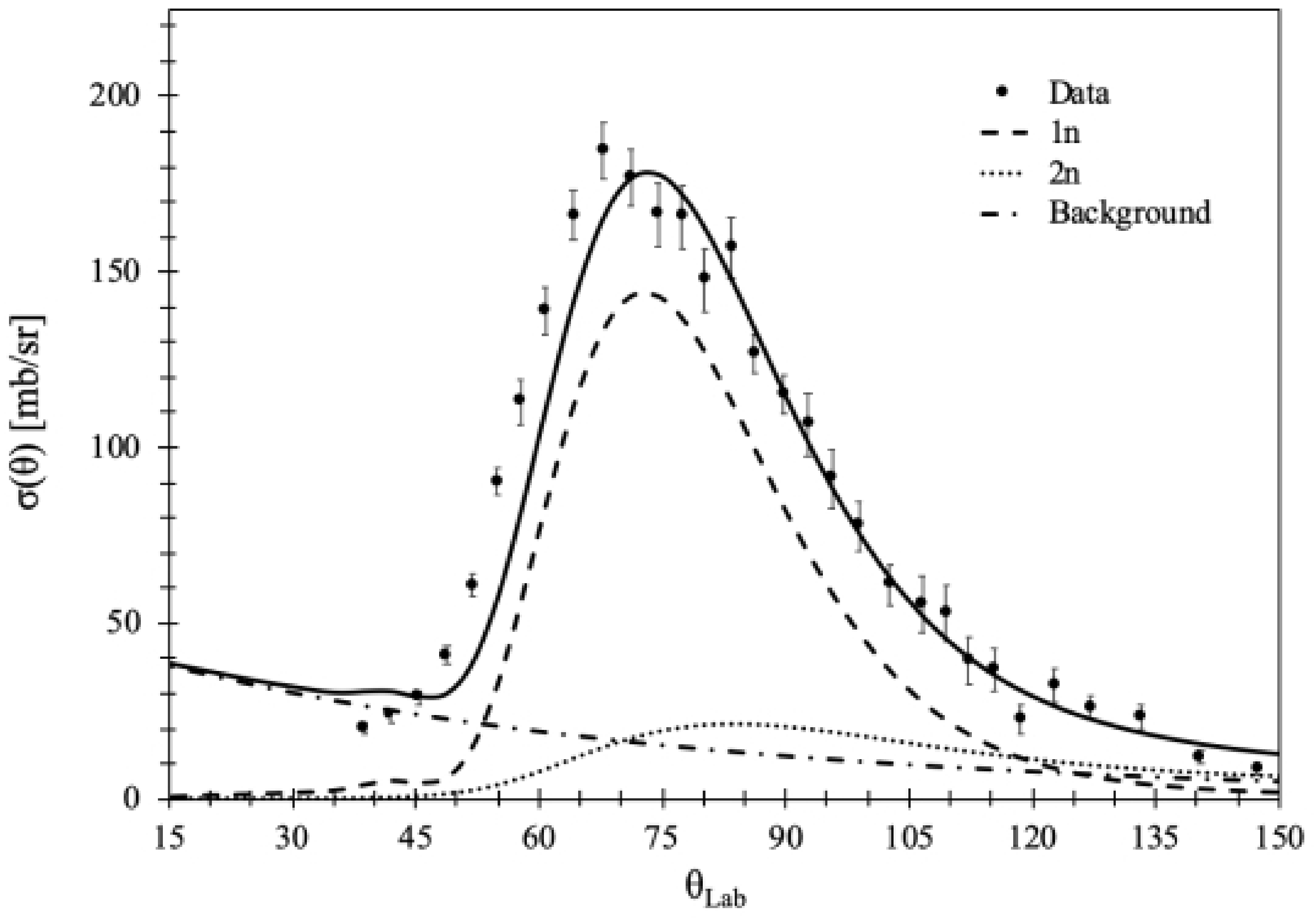
Recently published data for the ^{8}He + ^{208}Pb system at E_{lab} = 22 MeV [G. Marquínez-Durán *et al.*, Phys. Rev. C **98**, 034615 (2018)] enable us to perform this exercise.

We begin by considering the ^{6}He production. There are two processes we need to investigate: ^{208}Pb(^{8}He,^{7}He → ^{6}He + n)^{209}Pb and ^{208}Pb(^{8}He,^{6}He)^{210}Pb.

The first can be modelled accurately; only unknown is exit channel potential

The second populates states in ^{210}Pb at E_{ex} ~ 8 MeV; nothing known of structure in this region. However, we can constrain the allowed range of E_{ex} values using kinematics. Feed these into DWBA calculations and compare shape of resulting angular distributions with measured one.

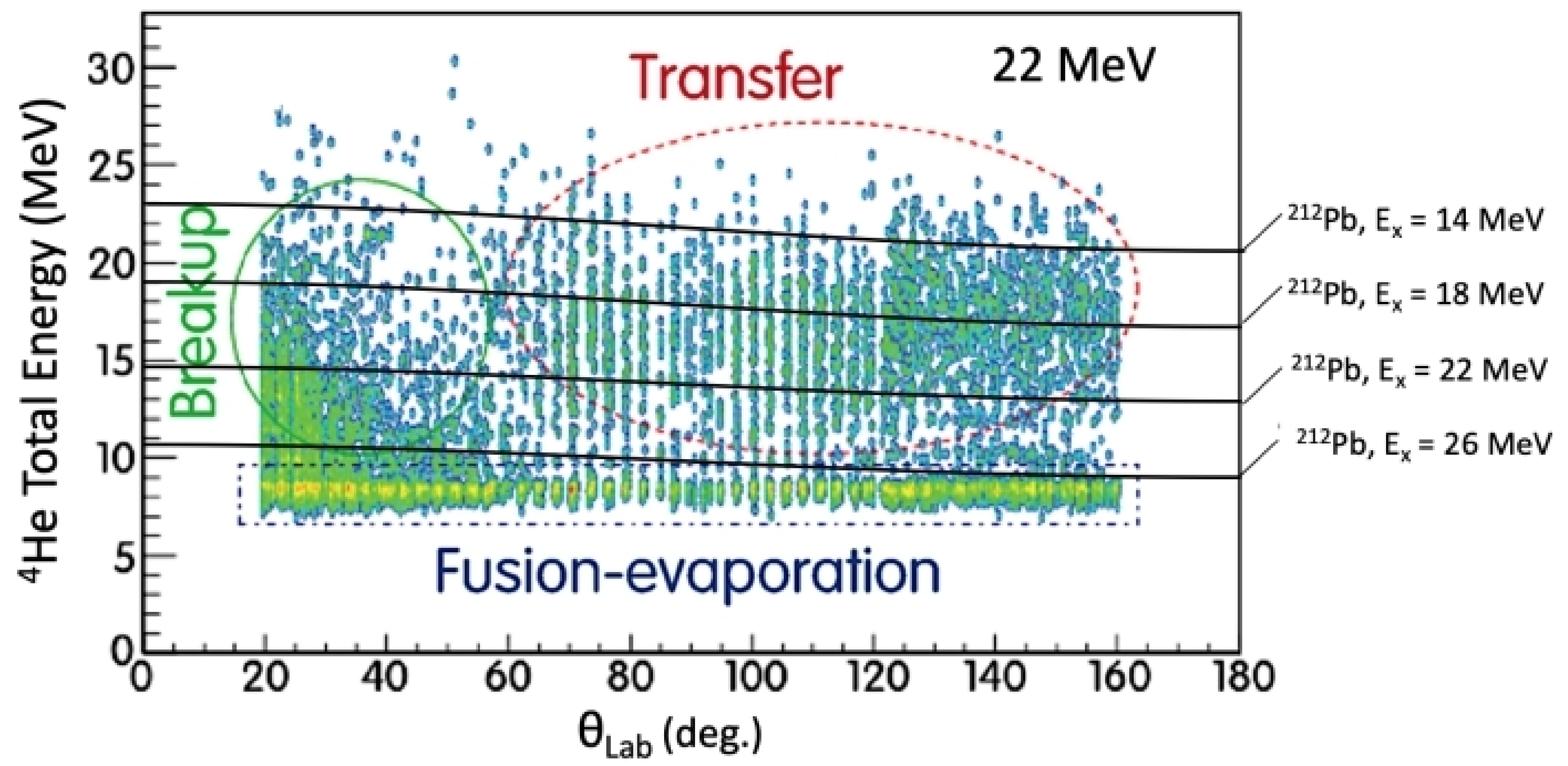


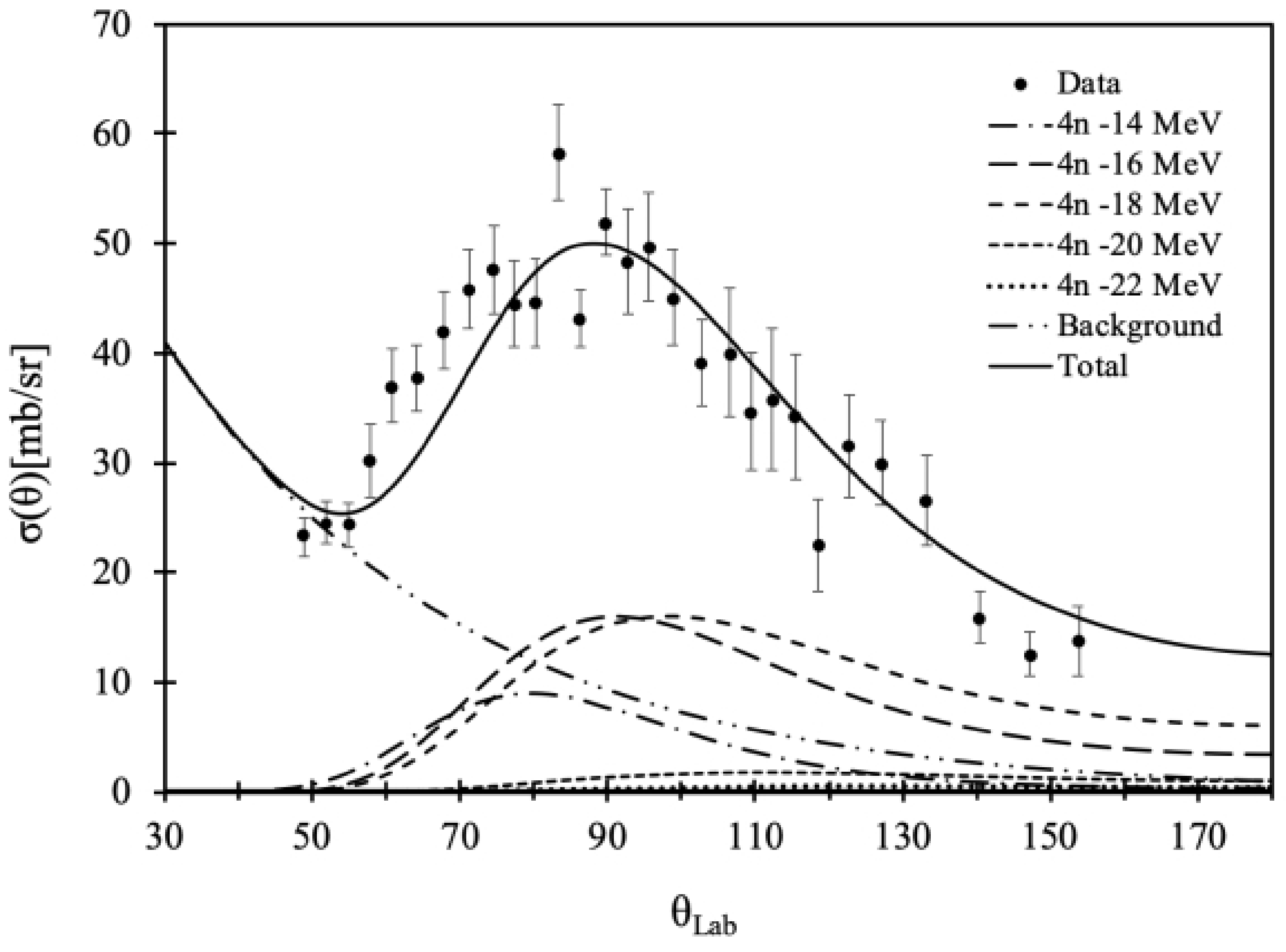


Lines are kinematic curves for 2n stripping to ^{210}Pb states at energies shown.

Dashed curve is 1n-stripping calculation with exit channel potential optimised to give largest cross section. Dotted curve is 2n-stripping calculation to state at 10 MeV.

Inclusive ^{6}He angular distribution can only be described consistent with 2D-plot if 1n stripping dominates completely (67%)





This result means we can rule out 2-step 2n-2n stripping as a possible source of ^{4}He. Other considerations point to direct 4n stripping as main mechanism: is this consistent with what we observe?

Reaction should populate states in ^{212}Pb at around E_{ex} ~ 17 MeV. Kinematics limits this to values between 14 and 22 MeV. DWBA calculations show this is feasible: 4n stripping 73% of total, rest background (breakup + fusion-evaporation)

Combination of kinematics and DWBA modelling shows that ^{6}He production is dominated by 1n stripping. **This is a strong result**, since **kinematics alone** tells us that 2n stripping cannot contribute much to main peak of observed angular distribution.

From this, rule out 2n-2n 2-step stripping mechanism for ^{4}He production. Results consistent with direct, 1-step tetraneutron stripping. Perhaps strongest evidence to date of 4n clustering in ^{8}He ground state.

Thank you for your attention

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