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STUDY OF DIFFERENTIAL AND ENERGY DISTRIBUTIONS IN THE REACTION $^{45}Sc(p,\alpha)^{42}Ca$ AT A PROTON BEAM ENERGY OF 22 MeV

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Introduction

Modern nuclear physics actively studies clustering in medium-mass nuclei with N=Z≥20 on the example of ^{45}Sc. Light clusters (deuterons, tritons, α-particles) form in the surface region of the nucleus, manifesting through characteristic excited states with large moments of inertia and mirror asymmetry in spectra.

Analysis of inelastic excitations and angular distributions in reactions with protons and light clusters contributes to understanding clustering mechanisms and nucleon-nucleon interaction features.

Experimental Setup

- Proton beam with energy of 22 MeV incident on a ^{45}Sc target of 2 μm thickness.
- U-150M cyclotron, Institute of Nuclear Physics (Almaty, Kazakhstan).
- Scattering chamber diameter 60 cm.
- Detection system — telescope with two semiconductor detectors: ΔE (100 μm) and E (3200 μm) for particle identification and energy measurement.
- Enables particle identification by charge and mass number, and measurement of total kinetic energy by summing calibrated energy losses.

Results

1. Particle Identification (dE-E Spectrum)

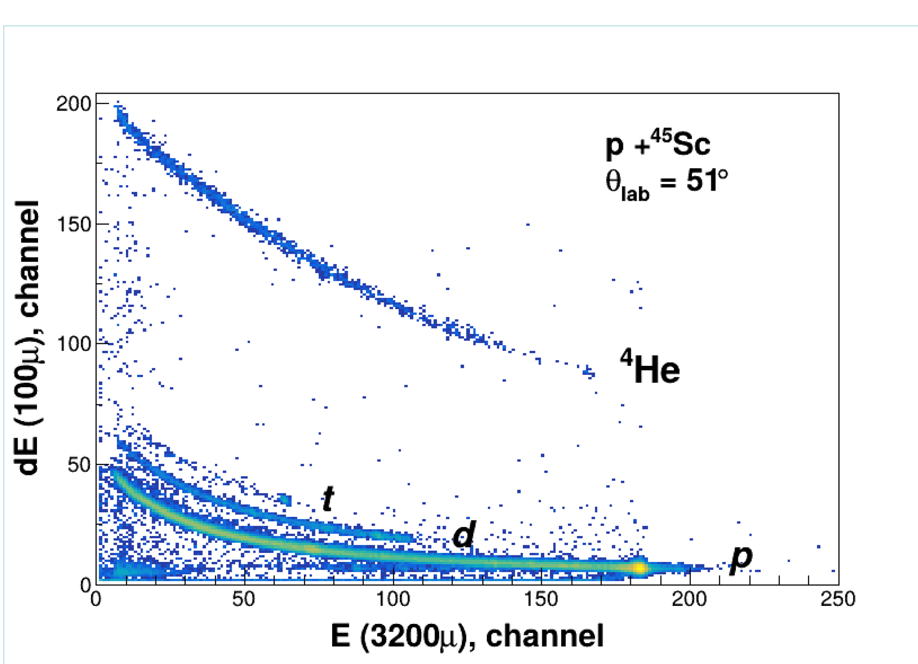

Fig. 1 — dE-E spectrum for p + ^{45}Sc at θ_lab=51°

The dE (100 μm) versus E (3200 μm) diagram separates protons (p), deuterons (d), tritons (t), and alpha particles (^{4}He).

2. Energy Spectrum of α-Particles

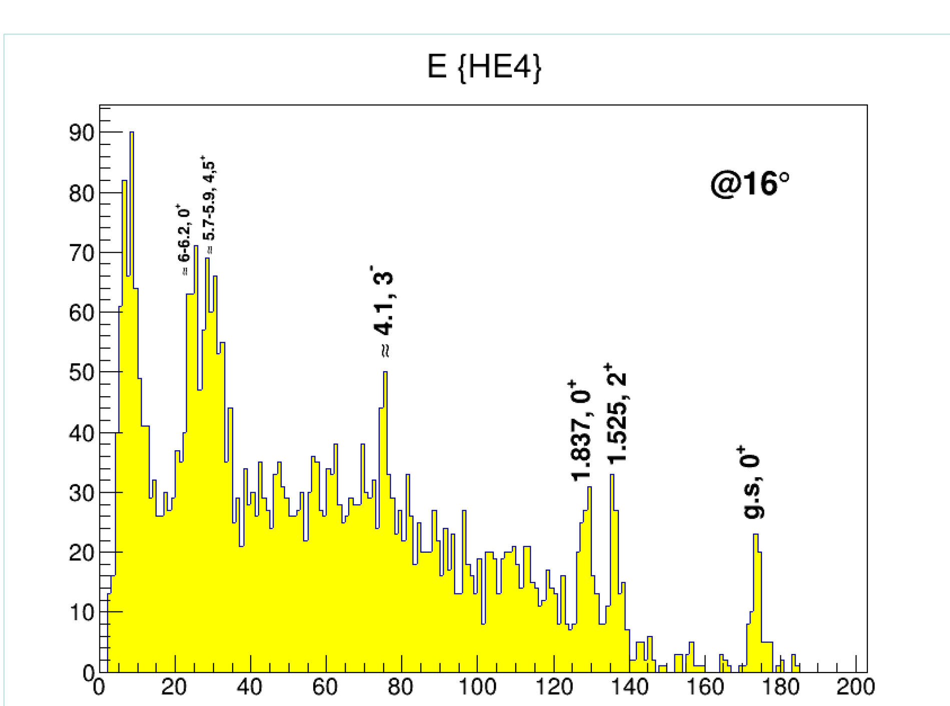

Fig. 2 — Energy spectrum of α-particles at θ=16°

The spectrum shows peaks corresponding to excited states of ^{42}Ca: ground state (g.s., 0^+), as well as excitations at 1.525, 1.837, ≈4.1 and ≈6.6 MeV.

3. Angular Distribution of Differential Cross Sections

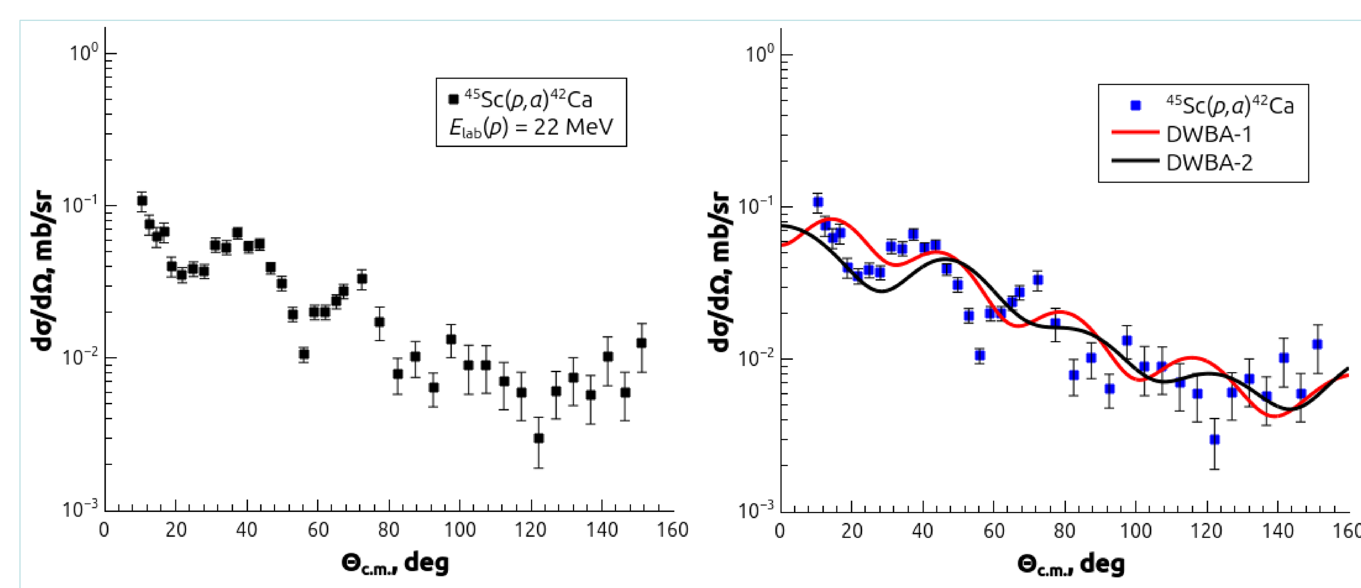

Fig. 3 — Differential cross sections for the $^{45}Sc(p,\alpha)^{42}Ca$ reaction

Experimental data and DWBA calculations (DWBA-1 and DWBA-2 models).

Discussion

Reaction mechanism:

The incident proton picks up a triton cluster from the ^{45}Sc nucleus, forming an α-particle and leaving a ^{42}Ca residual nucleus. According to Wildermuth–Moshinsky rules, the transferred triton occupies the $1f_{7/2}$ orbital (l=3, j=7/2, one node), which fixes the angular momentum transfer and shapes the characteristic angular oscillations in the cross sections.

Model and calculations:

- Entrance channel: p + ^{45}Sc, optical potential fitted from elastic scattering data.
- Exit channel α + ^{42}Ca modeled with two optical potentials:

  DWBA-1 — McFadden–Satchler (volume imaginary potential).

  DWBA-2 — Avrigeanu (surface-dominant imaginary potential).

Conclusions:

- Realistic α-optical potential in the exit channel is critical for accurate reproduction of angular distributions and their oscillations.
- Surface absorption reduces amplitude and correctly positions the phase of interference minima.
- Structural assumptions based on Wildermuth–Moshinsky rules are supported by the data.

The (p, α) reaction serves as an effective probe for triton clustering in ^{45}Sc.

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