Study of ^{4}He + ^{4}He inelastic scattering at the MAGNEX facility

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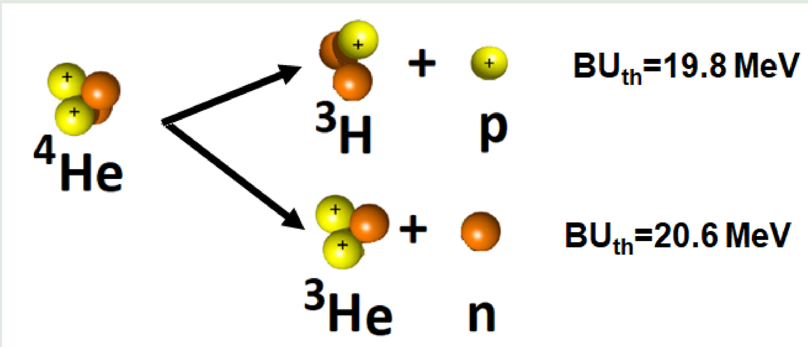
MOTIVATION - INTRODUCTION

^{4}He nucleus

- Well bound
- No bound states [1]
- Pronounced resonance very close to the breakup threshold with the same spin and parity (0$^+$) as the ground state [1]

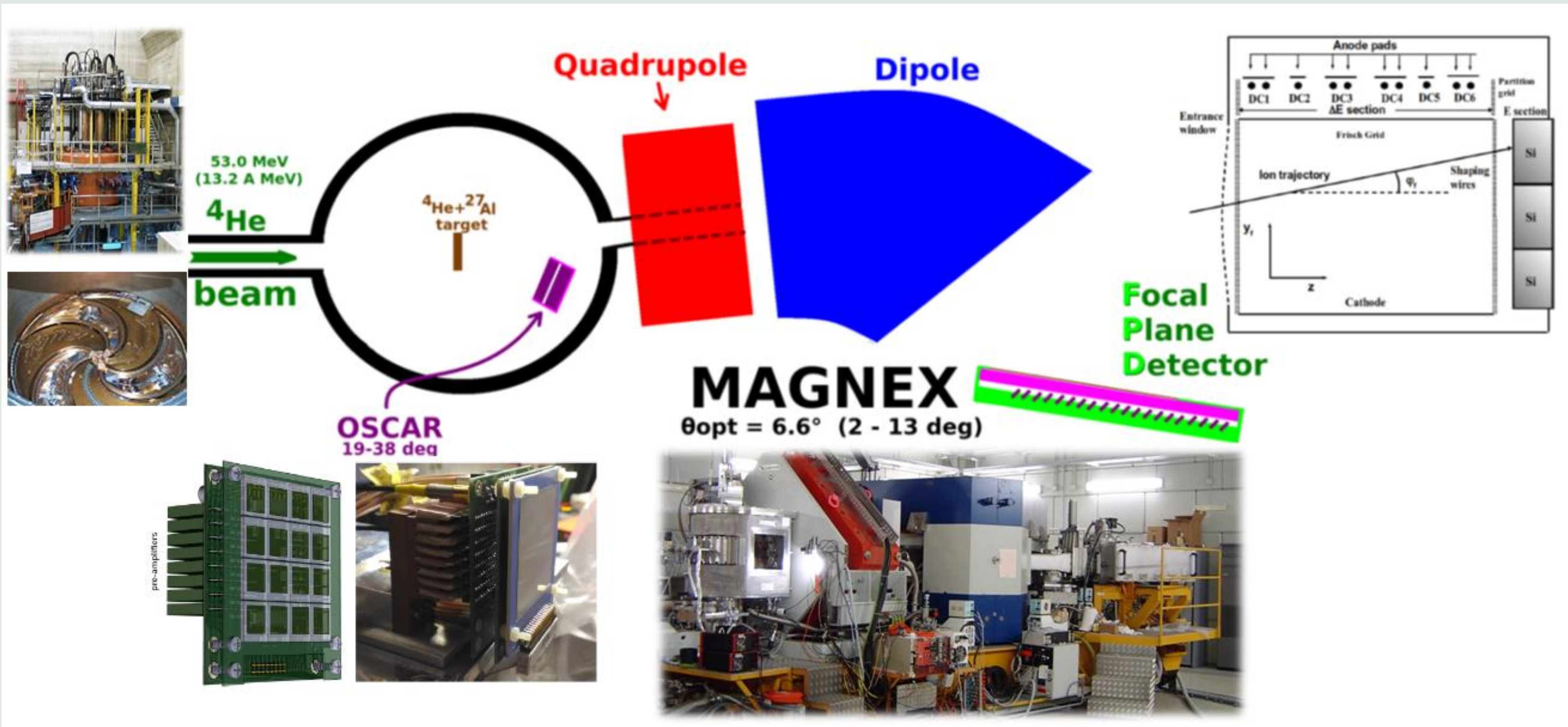


existing studies

^{4}He(e,e´)^{4}He* [2] ^{4}He(^{4}He,^{4}He)^{4}He* [3]

- A recent ab-initio calculation [4] of the monopole transition form factor of ^{4}He with realistic nuclear forces pointed to a strong dependence on the different realistic potential used and revealed a significant disagreement with respect to all existing electron scattering data when a method based on modern Hamiltonians from chiral perturbation theory was adopted.
  → further investigation is needed
- **The goals of the present study for the ^{4}He + ^{4}He reaction at 53 MeV incident energy ($E_{c.m.}$ = 26.5 MeV) are:**
  - ✓ extract the characteristics of the 0$^+$ resonance of ^{4}He in a new measurement
  - ✓ resolve previous inconsistencies between (^{4}He,^{4}He) and (e,e′) data
  - ✓ measure inelastic scattering cross section angular distributions.
  - ✓ a global interpretation of inelastic scattering together with the elastic scattering channel, measured under the same experimental conditions, in an optical model analysis, allowing the extraction of the form factors.

EXPERIMENTAL DETAILS



Facility: MAGNEX, Istituto Nazionale di Fisica Nucleare – Laboratori Nazionali del Sud (INFN-LNS).

Beam: ^{4}He accelerated by the K800 Superconducting Cyclotron of at 53 MeV

Target: ^{4}He target implanted on a thin aluminum foil

Background estimation: measurement with an aluminum target; the majority of the background events was excluded by performing a coincidence measurement

Elastic scattering measurement

- The ^{4}He ejectiles were momentum analysed by the MAGNEX magnetic spectrometer [5].
- The MAGNEX optical axis was set at ϑ_{opt} = 6.6° spanning an angular range between 2° and 13°.
- The different ions were detected by the Focal Plane Detector (FPD) [6] of MAGNEX, which is consisted of a gas tracker followed by a wall of 60 silicon pad detectors.

Inelastic scattering measurement

No bound states are reporting in ^{4}He structure therefore the ^{4}He* excited states can be reconstructed by the detection of its fragments. In particular, the two different decay modes

^{4}He + ^{4}He → ^{4}He + ^{4}He* → ^{4}He + ^{3}H + ^{1}H and

^{4}He + ^{4}He → ^{4}He + ^{4}He* → ^{4}He + ^{3}He + n

were reconstructed by two coincidence measurements. In both modes ^{4}He nuclei were detected by the MAGNEX FPD, while the ^{3}H and ^{3}He fragments were detected by OSCAR (hOdoscope of Silicons for Correlations and Analysis of Reactions) telescope [7]. OSCAR consists of two detection stages: a Single Sided Silicon Strip Detector (SSSSD) 20 μm thick as ΔE, followed by 16 silicon pads (4x4) 300 μm thick, providing the measurement of the residual energy E.

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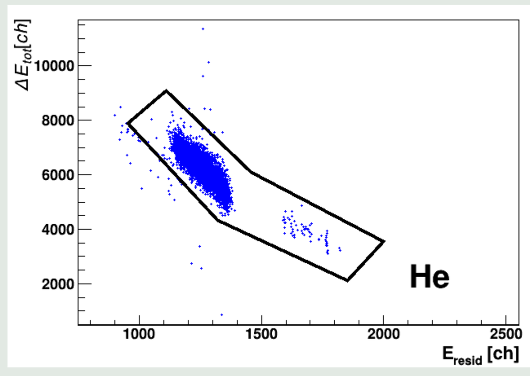
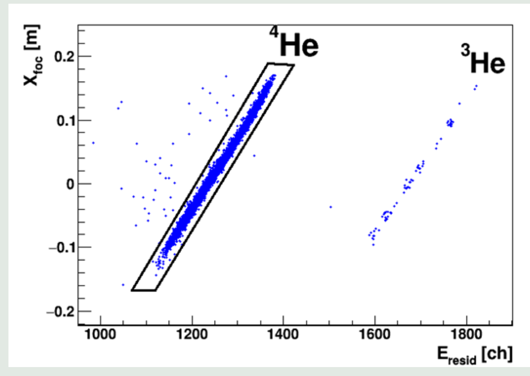
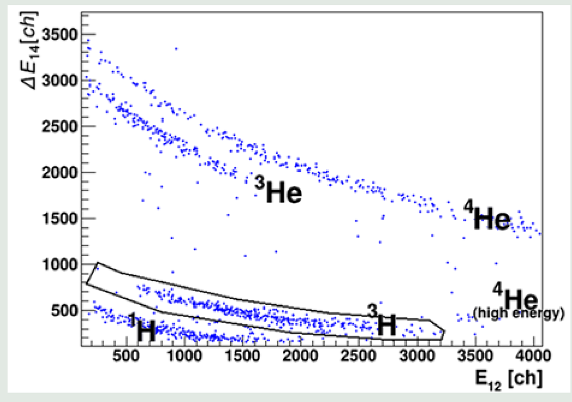
PARTICLE IDENTIFICATION

Particle identification at MAGNEX is based on Z and m/q separation [8]



Particle identification at OSCAR is based on the standard $\Delta E - E$ technique

EXPERIMENTAL DATA vs MONTE CARLO SIMULATIONS

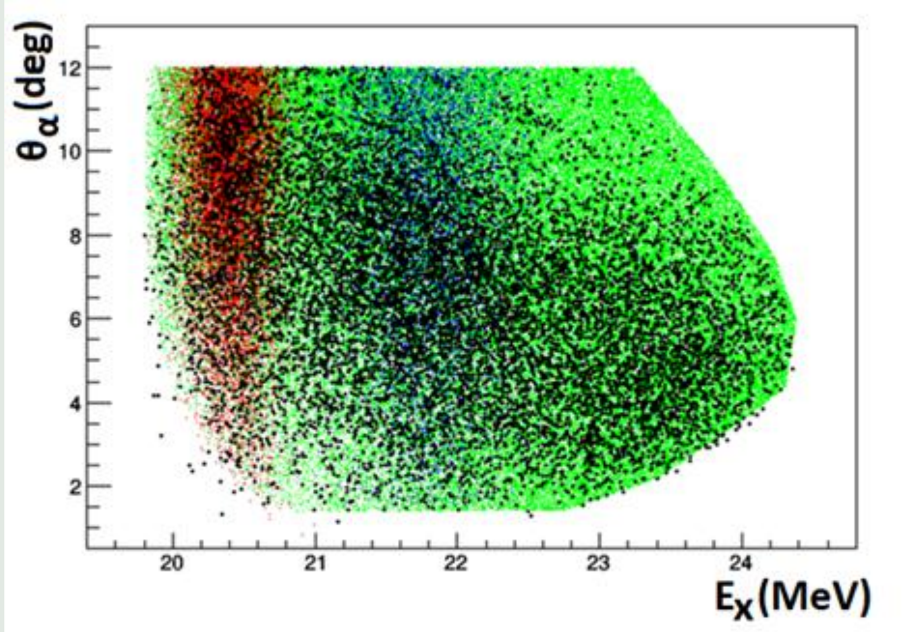
Experimental ϑ_α - E_x spectra (in coincidence with ^{3}H or ^{3}He respectively) were compared with kinematical simulations based on the multipurpose Monte Carlo simulation algorithm MULTIP [9]. The simulations were also useful in order to estimate the energy efficiency due to the coincidence measurements. This efficiency is mainly dominated by the detection threshold of OSCAR. The reactions considered at the simulations are:

^{4}He – ^{3}H coincidences

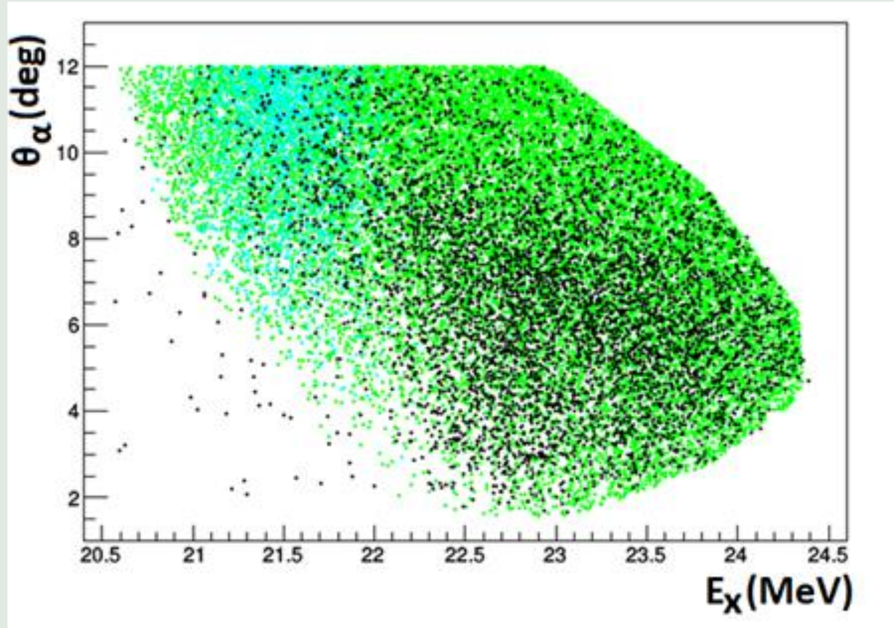
- ❖ ^{4}He + ^{4}He → ^{4}He + ^{4}He* → ^{4}He + ^{3}H + ^{1}H (resonant (0$^+$) and non – resonant breakup)
- ❖ ^{4}He + ^{4}He → ^{3}H + ^{5}Li → ^{4}He + ^{3}H + ^{1}H

^{4}He – ^{3}He coincidences

- ❖ ^{4}He + ^{4}He → ^{4}He + ^{4}He* → ^{4}He + ^{3}He + n (non – resonant breakup)
- ❖ ^{4}He + ^{4}He → ^{3}He + ^{5}He → ^{4}He + ^{3}He + n



A ϑ_α versus excitation energy (E_x) spectrum acquired in a ^{4}He - ^{3}H coincidence measurement is compared with MULTIP simulated data.
Black → **experimental** spectrum
Red → **resonant** continuum
Green → **non-resonant** continuum
Blue → transfer (^{4}He+^{4}He →^{3}H+^{5}Li → ^{4}He+^{3}H+^{1}H)



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Black → **experimental** spectrum
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Blue → transfer (^{4}He+^{4}He →^{3}He+^{5}He → ^{4}He+^{3}He+n)

SUMMARY AND PERSPECTIVES

✓The **^{4}He + ^{4}He → ^{4}He + ^{4}He* → ^{4}He + ^{3}H + ^{1}H** and **^{4}He + ^{4}He → ^{4}He + ^{4}He* → ^{4}He + ^{3}He + n** reactions (inelastic scattering) were measured at the MAGNEX facility of INFN – LNS together with the elastic scattering channel.

✓The challenging inelastic scattering measurement was performed in a coincidence measurement by detecting the heavy ejectile ^{4}He in MAGNEX while the lighter ^{3}H and ^{3}He were detected by the OSCAR telescope. The high Z and mass resolutions of both MAGNEX and OSCAR guaranteed an accurate particle identification.

✓Comprehensive kinematical simulations based on the MULTIP algorithm make feasible to disentangle the inelastic scattering via the first excited state of ^{4}He (0$^+$), the non-resonant breakup processes and the transfer processes leading to the same final channels.

✓The data analysis is underway in a more quantitative basis aiming to extract differential and integrated cross sections.

✓A theoretical analysis is also in progress.

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