Analysis of the α-clustering phenomena in the fragmentation of ^{12}C and ^{16}O ions at 200 MeV/u in the FOOT experiment

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FragmentatiOn Of Target

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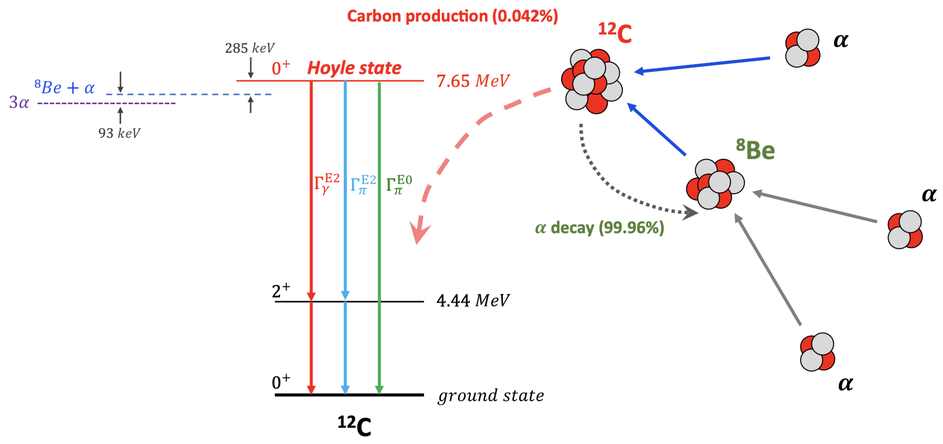
α CLUSTERING: STATE OF THE ART

The interaction between nucleons in nucleus-nucleus collisions promotes the formation of clusters, in particular α particles, within the nuclear medium. The effects of α clustering are relevant for:

- Theoretical nuclear model studies (e.g.: AMD, *quartet* model, MD, DHO)
- Applications where the multiplicity and energy distribution of nucleons and light fragments have a relevant impact (e.g.: hadrontherapy)
- Stellar nucleosynthesis and stellar evolution that are affected by the properties of nuclear states involved in the production of ^{12}C

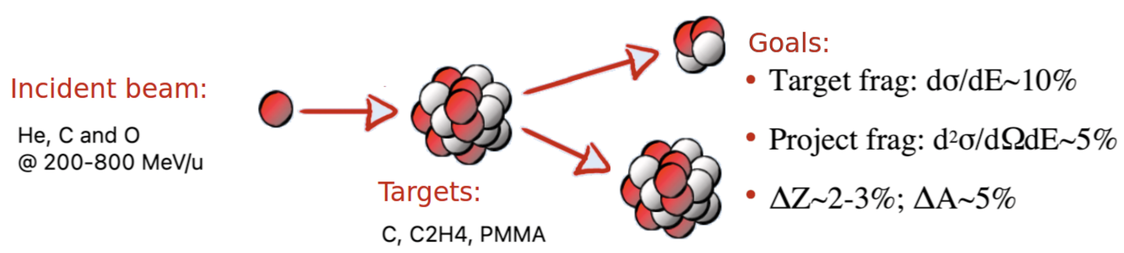
Several experiments have been conducted to investigate clustering in α conjugated nuclei, mainly at the Coulomb barrier and Fermi energy range (1-100 MeV). There are less available data in regimes where nuclear reactions are more and more dominated by nucleon-nucleon collisions. **Nuclear fragmentation for projectile energies above 100 MeV/u offers the possibility to perform this kind of analysis**.



Schematic view of the triple α process in stars and of the states of ^{12}C involved in the process.

I. Lombardo and D. Dell'Aquila, *Clusters in light nuclei: history and recent developments*, Nuovo cimento, 46, 2023

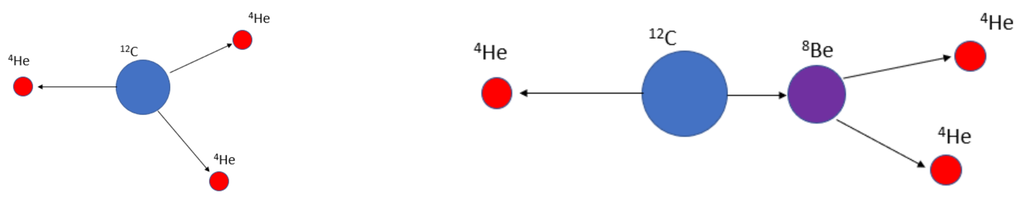
THE FOOT EXPERIMENT: GOALS AND STRATEGIES



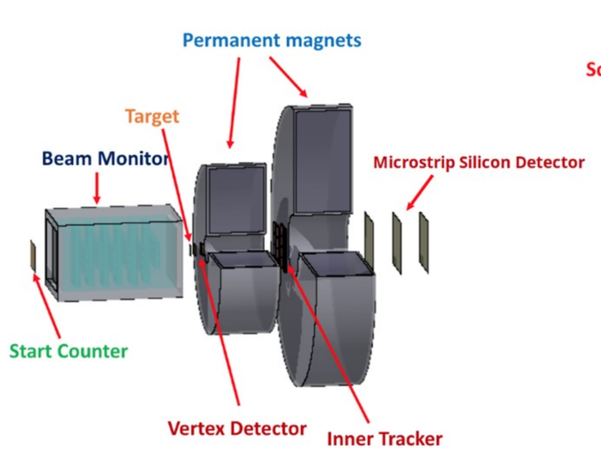
The **FOOT** (FragmentatiOn Of Target) experiment has been designed to measure the double differential cross sections with respect to kinetic energy and emission angle of fragments produced in nuclear interactions of nuclei with energies relevant for hadrontherapy and radioprotection. The obtained data will permit to benchmark the MC simulation tools, thus improving the nuclear models and enhancing the current clinical treatment planning systems.

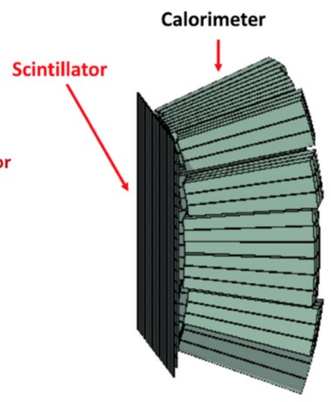
(Talk on the FOOT experiment by S. Muraro on Thursday 25/1 at 6.57 PM)

α-clustering phenomena can be measured by the FOOT experiment at intermediate energies, in the fragmentation of ^{12}C and ^{16}O at energies typical of hadrontherapy **(200-400 MeV/u)**. The formation of intermediate channels in the production of α particles can be studied (e.g.: $^{12}\mathrm{C} \rightarrow {}^{8}\mathrm{Be} + \alpha \rightarrow 3\,\alpha$)

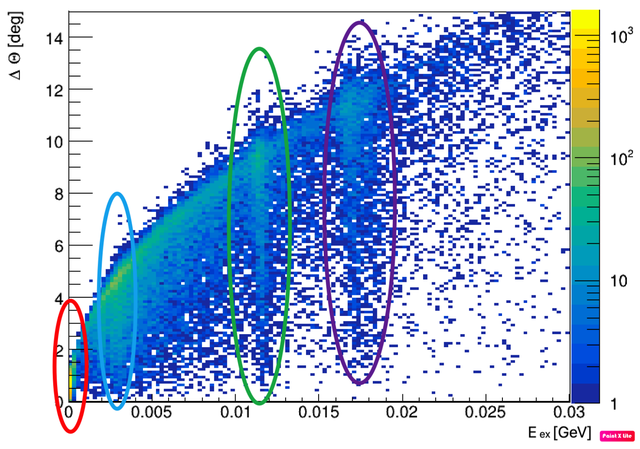


ELECTRONIC SETUP



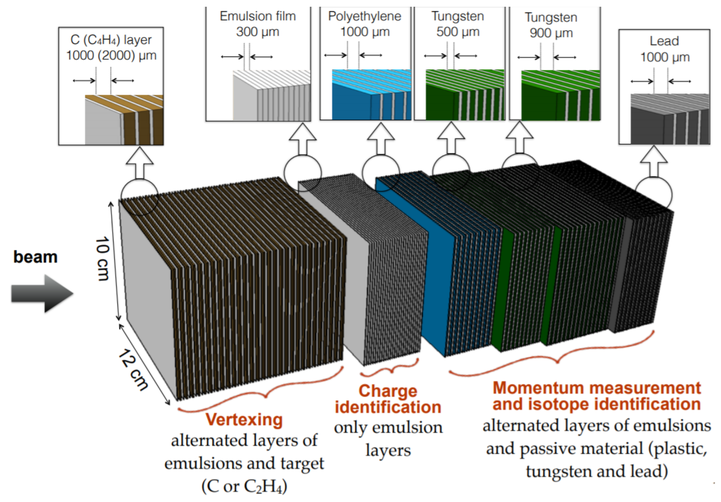


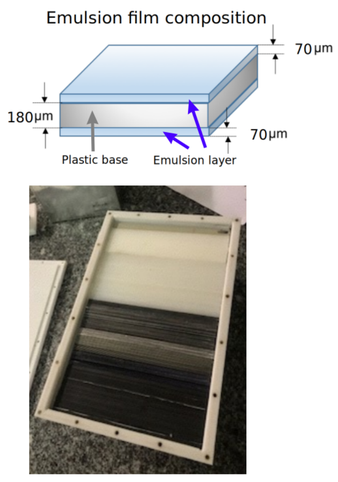
- To detect fragments with $Z \geq 3$ with angular acceptance $\Theta \leq 10°$
- Composed by a high precision tracking system in magnetic field, a time of flight measurement system and a calorimeter



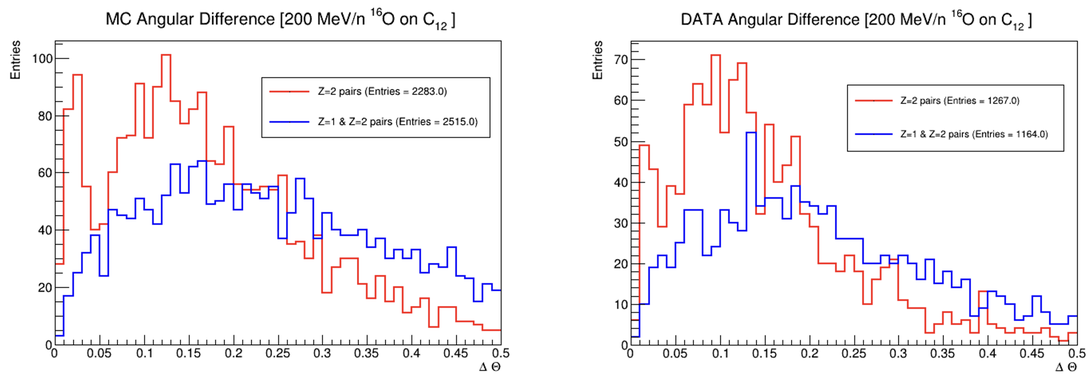
- MC simulation: ^{12}C @ 200 MeV/u on ^{nat}C
- Evaluation of the ^{12}C clustering studying the angular correlation of α pairs and their excitation energy
- MC study of the ^{16}O clustering effect and analysis of the experimental data are ongoing

EMULSION SETUP





- To detect fragments with $Z \leq 3$ and $\Theta \lessapprox 70°$
- Nuclear emulsion cloud chamber technology



- MC and experimental data **preliminary** results with ^{16}O @ 200 MeV/u on ^{nat}C and C_2H_4: evaluation of the ^{16}O clustering effect studying the angular correlation of the detected Z=2 fragments
- Background evaluated comparing Z=1 and Z=2 track angle separation
- Within the limited statistics ($\sim$ 20k primaries/dataset) no significant differences between ^{nat}C and C_2H_4 targets