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The direct determination of the cross section of the 12C + 12C reaction at astrophysical energies

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Carbon burning is the third stage of stellar evolution determining the final destiny of massive stars and of low-mass stars in close binary systems. Only stars with a mass larger than a critical value $M^*_{up} \sim 10M_\odot$, can ignite C in non-degenerate conditions and proceed to the next advanced burning stages up to the formation of a gravitationally unstable iron core. Various final destinies are possible, among which a direct collapse into a black hole or the formation of a neutron star followed by the violent ejection of the external layers (type II SN). Less massive stars $M < M_{up} \sim 7M_\odot$, never attain the conditions for C ignition and will evolve into CO White Dwarfs. The values of M^*_{up} and M_{up} are linked to the $^{12}C +^{12} C$ reaction rate: the little knowledge we have of it at astrophysical energies is the greater contribution to the uncertainty of these masses. Stellar C burning proceeds mainly through the $^{12}C(^{12}C,\alpha)^{20}Ne$ and $^{12}C(^{12}C,p)^{23}Na$ channels. The cross-sections can be measured either detecting the emitted charged particles or the γ-rays produced by the decay of the excited states of ^{20}Ne and ^{23}Na.

$^{12}C +^{12} C$ fusion reactions were investigated in a wide energy range, down to 2.1MeV, still above the astrophysical energies.
Only indirect measurement covers those energies with contradictory results. A direct measurement down to the Gamow peak is therefore crucial.

The aim of the LUNA collaboration is the direct determination of the cross section of the $^{12}C +^{12} C$ reaction at astrophysical energies through γ spectroscopy at LNGS. Here a devoted setup is being developed to reach an extremely low background condition. The experiment will make use of the new MV accelerator available at the Bellotti Ion Beam Facility at LNGS, in the context of the LUNA MV research project. This accelerator is capable of producing a high intensity carbon beam ($150\mu A$ for a beam of $^{12}C^+$ and $50p\mu A$ for a beam of $^{12}C^{++}$) with great energy resolution and stability. The detection setup will be made of several NaI scintillators and an HpGe. NaI detectors will be placed in a compact arrangement around the HpGe, covering a $\sim 3.5\pi$ solid angle: such a configuration guarantees a high detection efficiency, while preserving the excellent HpGe resolution (1.2keV at 1.33MeV).
The NaI configuration will also function as an active veto for Compton, environmental radioactivity and beam-induced background events.
The detectors array will be placed in a 2cm thick copper shielding surrounded by a 25cm lead shielding which will further reduce the
environmental background of more than 2 orders of magnitude.

With this setup, we'll also be able to measure the level density of ^{24}Mg
through the de-excitation of ^{20}Ne and ^{23}Na nuclei.
This will allow us
to explore the possible cluster structures of the ^{24}Mg nucleus. In
particular, we'll be able to examine the $E_{cm} = 1.5\,MeV\ -\ 4\,MeV$ energy
window (15.44 MeV to 17.94 MeV considering the Q-value), where the
cluster states could be found.

With my contribution I will present an overview of the experiment setup and development, together
with details on Geant4 simulations and preliminary measurements.

Primary author: GESUE', Riccardo Maria (Gran Sasso Science Institute, INFN LNGS)

Presenter: GESUE', Riccardo Maria (Gran Sasso Science Institute, INFN LNGS)

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