IL NUOVO CIMENTO Vol. 34 C, N. 6 Novembre-Dicembre 2011
DOI 10.1393/ncc/i2011-11024-7

Colloquia: IFAE 2011

Study of the ^{12}C + ^{12}C reaction at 62 A MeV for hadrontherapy applications

D. Nicolosi(1)(2), C. Agodi(2), A. A. Blancato(2), G. A. P. Cirrone(2), G. Cuttone(2), M. De Napoli(2), E. Rapisarda(2), F. Romano(2), D. Sardina(2), C. Sfienti(3)(4) and S. Tropea(1)(2)

(1) *Dipartimento di Fisica ed Astronomia, Università di Catania - Catania, Italy*
(2) *INFN, Laboratori Nazionali del Sud - Catania, Italy*
(3) *Università di Catania - Catania, Italy*
(4) *INFN, Sezione di Catania - Catania, Italy*

(ricevuto il 29 Luglio 2011; pubblicato online il 25 Ottobre 2011)

Summary. — The largest uncertainty on the physical dose deposition in hadrontherapy is due to ion's nuclear interaction through the traversed material. Today the simulation codes are not able to reproduce the fragmentation process with the required precision. To improve the knowledge of ^{12}C fragmentation at intermediate energies we have measured at the Laboratori Nazionali del Sud in Catania production cross sections, energy spectra and angular distributions of fragments produced in ^{12}C fragmentation on thin ^{12}C target, at 62 A MeV.

PACS 87.53.-j – Effects of ionizing radiation on biological systems.
PACS 87.55.D- – Treatment planning.
PACS 25.70.Mn – Projectile and target fragmentation.

Hadrontherapy with carbon ions, a techique widely used nowadays for cancer treatments, presents two main advantages compared to conventional radiotherapy: a maximum of dose deposition at the Bragg peak and an enhanced biological effectiveness in the Bragg peak region. However, along the penetration path in the patient tissue, the incident ions undergo nuclear reactions wich reduce the primary beam up to 50% and cause ion fragmentation, with the consequence that a non-negligible part of the dose is released in the healthy tissues surrounding the cancer site. This makes very clear that a precise knowledge of the nuclear reaction effects is necessary for treatment planning [1].

The accuracy of the simulation tools [2], like GEANT4, which simulate in detail the physical interactions of particles as they pass through matter, is not sufficient to obtain the precision of about 2.5% on the deposited dose required by medical applications. The largest uncertainty comes from the physical models and the lack in the fragmentation production cross sections [3]. This is the reason why it becomes mandatory to perform extensive measurements of heavy ion fragmentation reactions, especially in the energy

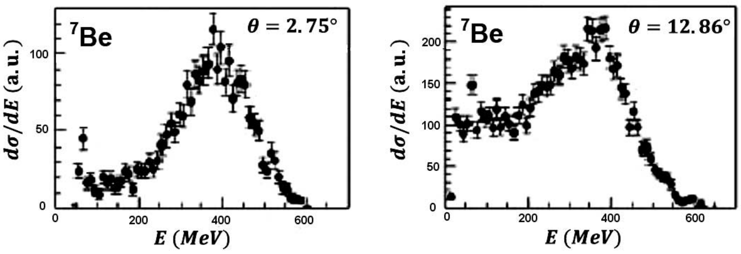

Fig. 1. – Kinetic energy spectra for fragments in the laboratory frame detected at different angles.

domain where lack of data exists or where the existing data do not have the required precision.

The aim of the experiment performed at Laboratori Nazionali del Sud (LNS) in Catania is the measurement of production cross sections, energy spectra and angular distribution of light fragments produced in the collision of ^{12}C beam on thin ^{12}C, $^{\text{nat}}$Pb and PMMA target and to compare the results with Monte Carlo simulations. The ^{12}C beam was delivered by the LNS Superconducting Cyclotron at incident energy of 62 MeV/nucleon. The detection system consists on two Si-CsI hodoscopes with different granularity. The whole array covers 0.34 sr of the forward solid angle with a geometrical efficiency of 72%. Its high granularity is suitable for accurate measurements of angular distributions.

Typical inclusive energy spectra for fragments detected at two different angles, $\theta = 2.75°$ and $\theta = 12.86°$, respectively, are shown in fig. 1 for ^{12}C + ^{12}C at 62 MeV/nucleon [4]. The data display the well-known behavior of a bump centered at the projectile's velocity which is the typical feature of pure fragmentation reactions [5, 6]. The distributions however are not completely Gaussian but show a tail towards smaller energies. The contribution of the tail appears almost negligible at the smaller angle but becomes larger for larger scattering angle clearly showing an increased fragment emission from nuclear sources (mid-rapidity or target-like sources) other than the projectile one. As expected in the intermediate energy regime, various reaction mechanisms (break-up, fusion, stripping in the continuum, deep-inelastic, etc.), which cannot be easily disentangled, are superimposed in the energy spectra with relative contributions depending on the incident energy and target. Data analysis is still ongoing with the aim of extracting angular distributions and production cross sections. Furthermore, extensive comparisons with GEANT4 simulations will be performed in order to evaluate the accuracy of the different adronic models implemented in the code in this energy regime. These results will allow to complete the set of fragmentation production cross sections required at energy lower than 100 MeV/nucleon.

REFERENCES

[1] Agodi C. *et al.*, *Nuovo Cimento C*, **31** (2008) 99.
[2] Agostinelli S. *et al.*, *Nucl. Instrum. Methods A*, **506** (2003) 250.
[3] Schardt D. *et al.*, *Adv. Space Res.*, **17** (1996) 87.
[4] Nicolosi D. *et al.*, LNS Report (2010).
[5] Serber R., *Phys. Rev.*, **72** (1947) 1114.
[6] Goldhaber A. S., *Phys. Lett. B*, **53** (1974) 306.