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Impact of the pixelation method on the FARCOS telescope performances

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Summary. — In this contribution, the results achieved using the pixelation method for the FARCOS array will be presented. The α coincidence data in events produced in the reaction ^{16}O + ^{12}C will be analysed. A good energy resolution has been obtained in the reconstruction of the excitation energy of the populated resonances. The correction of inter-strip effects and the accurate reconstruction of the detection angles, also in events with 3 or more touched strips, improves the detection efficiency.

1. – Introduction

Double sided silicon strip detectors (DSSSD) are often used in nuclear physics to get good angular and energy resolution, employing a smaller number of electronic channels compared to other detectors [1-4]. The position and angle of impact of a detected particle can be deduced from the front and back strips crossing. However, when more strips are

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fired in the same event, it can be quite difficult to determine the crossing point of each particle. In this case, a first procedure based on the coincidence time analysis is adopted to clean data from spurious coincidences. However, also inter-strip events, electronic cross talk and real particle coincidences produce multiple hits. These events are resolved by the pixelation method that is the focus of this contribution. More in detail, inter-strip events are produced when a particle impinges in the zone near the SiO_2 resistive region separating two adjacent strips, releasing energy in both. To give an idea of the size of the problem, in ref. [5] it has been estimated that, in each side of a DSSSD of the FARCOS array [4] (BB7 Micron semiconductor DSSSD [6], with 32 strips on each side), 3–4% of the events, depending on the electronic thresholds, can produce an inter-strip signal on each side. These kinds of events must be discriminated from real coincidence events. The reconstruction of these events is mandatory to preserve the full detection efficiency of an array and also to clean scatter plots from noise. The loss in efficiency is magnified when particle coincidences are searched for in the experiment. In ref. [5] a 40% efficiency loss was experimentally measured in three particle coincidence events. This was obtained by simulating an inappropriate treatment of multi-hit events in DSSSD detectors in the decay of 3-α particles of the Hoyle state of ^{12}C in the $\alpha + {}^{12}$C reaction at 64 MeV beam energy. The results of a similar data analysis on the reactions ^{16}O + ^{12}C at three beam energies (SIKO experiment [7]) will be shown in this short contribution.

2. – Data analysis and results

In this paragraph the pixelation method used to recover multi-hit events, for the FARCOS array, in the ^{16}O + ^{12}C reaction at 10, 17.5 and 25 AMeV beam energy will be described. This experiment was performed at LNS INFN Laboratories in Catania by using the ^{16}O cyclotron beams for the SIKO campaign. FARCOS is composed of 20 telescopes, each of three stages. The first two stages are DSSSD detectors with 32×32 strips, 2 mm pitch, respectively 300 and 1500 μm thick. The third stage is composed of 4 CsI(Tl) detectors 6 cm thick. A more detailed description can be found in ref. [4]. Only data coming from the 4 prototypes of the FARCOS telescopes mounted from 2° to 7° in the laboratory system will be considered here. While front and back signals have been registered for the first DSSSD stage of the telescopes, only the front signals have been collected for the second 1500 μm stage, making the application of the pixelation method possible only for the first stage. After the exclusion of spurious coincidences by analysing the arrival time difference between the fired strips, the crossing of front and back strips for each detected particle is searched for by comparing the energy detected in both detector sides. When more than one strip is fired and, in particular, if two adjacent strips are touched, two options are explored by the data analysis program; assuming in one case that they can be independent particles or in the other case that this is an inter-strip event. In this last case, the energy of the two adjacent strips is summed before comparing the energy detected in both detector sides. A kind of chi squared is therefore computed, by summing the differences between the energies of the various possible couples of front and back signals. Their best matching is decided by choosing the configuration that minimizes this energy difference for the whole event. This analysis therefore helps to decide and correct, event by event, if there are inter-strip effects. A value of 1.5% of RMS difference from the front and back energy signals was measured, consistent with what was found in ref. [5].

The effectiveness of the method can be appreciated by looking at the resolution of observed resonances which depends strongly on the precision of the detection angle

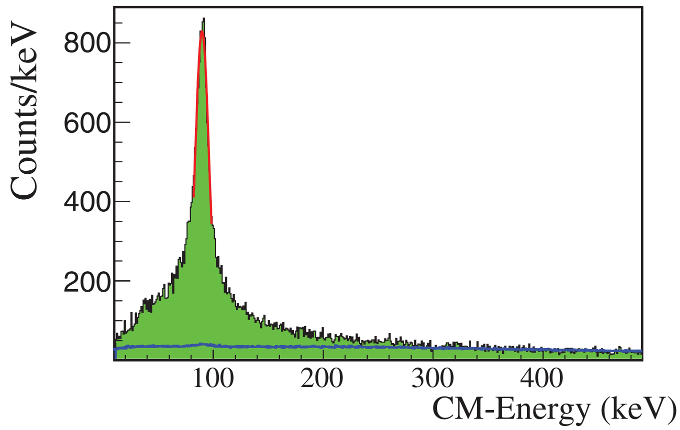

Fig. 1. – The $^{8}\mathrm{Be}_{g.s.}$ resonance measured in 2-α-particles coincidences. The red line is a Gaussian fit of the resonance. The blue line is the background computed with the event mixing technique.

measurement. The most simple resonance observed is the $^{8}\mathrm{Be}_{g.s.}$ one, expected at 92 keV in the centre of mass system, that can be obtained by looking at 2-α-particles coincidences [8]. Its measured width is a combination of the intrinsic width (just 6 eV) due to the relatively long lifetime of the compound nucleus and of the angular and energy resolution of the detection system. The $^{8}\mathrm{Be}_{g.s.}$ resonance measured with the FARCOS telescopes in the reaction $^{16}\mathrm{O} + {}^{12}\mathrm{C}$ at 25 AMeV is shown in fig. 1. The maximum of the resonance is measured at about 90 keV. A RMS value of the peak of around 6.5 keV, extracted using the fit procedure, displays the good precision obtained in the angle determination by adopting the pixelation method. In these data about 45% of the events are from two α particles measured in the same detector for which the pixelation method is essential. A small background was evaluated with the event mixing technique (blue histogram). At the edge of the peak there are some events with worse resolution that will be discussed later.

An even more stringent test of the effectiveness of the method is obtained by looking at 3-α-particles decay of the Hoyle state at about 380 keV in the centre of mass [9, 10]. Again, the intrinsic width of the resonance is quite small, of the order of 9 eV. The measured resonance is shown in fig. 2 obtained by summing the data measured at beam energies 10, 17.5 and 25 AMeV to remedy the lack of statistics.

The red line in the figure is a Gaussian fit of the resonance, centred at approximately 375 keV with an RMS value of approximately 35 keV. The nice agreement with the expected value of the resonance of 380 keV and the relatively good energy resolution are again a signature of the good quality of the performed analysis and of the pixelation method adopted. Part of the background present in the figure is due to uncorrelated α particles and can be reconstructed using the technique of mixed events (see the blue histogram). The remaining background, visible around the edge of the peak (as for the $^{8}\mathrm{Be}$ resonance) at 250 and 450 keV is generated by badly reconstructed inter-strip events due to a too high energy threshold of the prototype electronics used in this experiment.

In summary, in this short report the energy resolution that can be reached with an appropriate pixelation work in two- and three-α-particle coincidences has been shown. More in detail, an energy resolution of 6.5 keV RMS was obtained for the $^{8}\mathrm{Be}_{g.s.}$

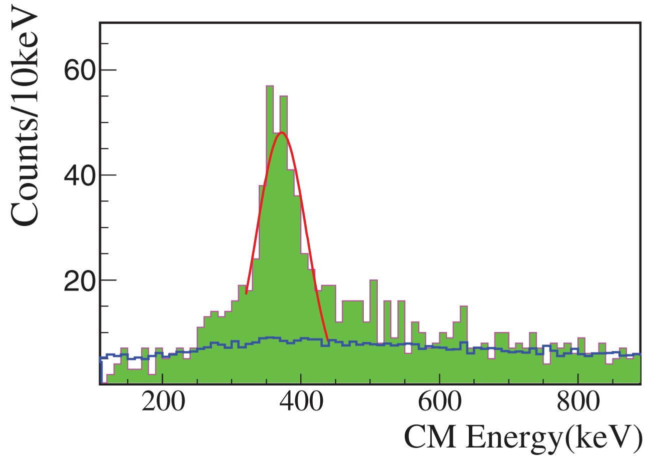

Fig. 2. – The Hoyle state resonance measured in 3-α-particles coincidences. The red line is a Gaussian fit of the resonance. The blue line is the background computed with the event mixing technique.

two-α-particles resonance, while for the Hoyle state resonance, observed in three-α-particles coincidences, an RMS energy resolution of about 35 keV was obtained. For both resonances the presence of a large background was observed. This is mostly due to uncorrelated α particles easily emitted in reactions between alpha-like nuclei. The good obtained performance of the FARCOS telescopes used is promising for their use with the forthcoming beams that will be produced by the new FRAISE fragment separator at LNS [11, 12].

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