

"DIAMANT" : A 4π LIGHT CHARGED PARTICLE DETECTOR ARRAY. AN EFFICIENT TOOL FOR NUCLEAR SPECTROSCOPY

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Abstract

The contribution of an ancillary detector triggering a γ -spectrometer is reminded through the usual features of a γ -spectrometer.

The first measured performances of DIAMANT are presented.

Let us introduce briefly what fields are opened to a 4π light charged particle multi-detector like DIAMANT, inserted in a 4π - γ spectrometer, what are the requirements for such a detector and the characteristics of DIAMANT.

I - INTRODUCTION

The new generation of 4π - γ spectrometer allows precise spectroscopy of weak transitions. That is the case for instance for residual nuclei obtained in fusion evaporation reactions : inter-band transitions, superdeformed bands etc... Exotic shaped, very high spin nuclei can then be evidenced, and their properties can be studied. But in

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the same time questions are raised : how are these nuclei formed, what are their decaying links with more common shapes, what is the role of the dynamics, how these channels compete with the fission, where are the γ entry lines located ?

To try to answer such questions, attention has also to be paid at least to evaporated particles or to fission fragments.

To improve channel selectivity, recoil mass spectrometers have been used in conjunction with 4π - γ spectrometer. But then no additional information is gathered. A 4π light charged particle multidetector like DIAMANT, inserted into a 4π - γ spectrometer allows not only a channel selection, and then a higher sensitivity of the γ -spectrometer, but also can give additional informations on the exit channel and the path leading to the final nucleus studied by its γ emission. Of course this is especially true for channels mostly decaying by charged particles. The γ -spectrometer then help to achieve the channel selection. Charged particle is sensitive to the charge distribution in the nucleus, through the coulomb barrier, and the angular distribution of evaporated particles versus the nucleus spin axis gives access to the nucleus shape.

If light or heavy fragments detectors are inserted in such a particle multidetector, the fields of transfer reactions and fission decay can be investigated.

II - DIAMANT AS A TRIGGER FOR γ SPECTROMETERS

The channel selection achieved by such a detector leads to cleaner γ spectra.

RESOLVING POWER

A γ -spectrometer can be characterized⁽¹⁾ by its resolving power $R_\gamma = k P_T$ where P_T is the peak/total fraction and k depends on the resolution of the spectrometer and the average separation in energy between gamma rays.

For a n coincidence order, the peak/background ratio f_n is proportional to $R_\gamma^n = R_{n\gamma}$, the resolving power in this case.

Similarly a resolving power can be defined for the ancillary detector:

$$R_p = \frac{1}{\alpha_0 + \sum_{i \neq 0} p_i \alpha_i} > 1$$

where $\alpha_i = \frac{\sigma_i}{\sigma_T}$, σ_i and σ_T being respectively the i channel and the total cross sections, and 0 refers to the selected channel ; p_i is the probability for the channel i to be taken into account by the particle trigger.

Then the resolving power for the two linked detectors is : $R = R'_\gamma R_p$, where R'_γ is the actual resolving power of the γ -spectrometer surrounding the particle detector array. Roughly $\frac{R'_\gamma}{R_\gamma} = T_\gamma$ is the γ -ray transmission factor of this detector.

OBSERVATIONAL LIMIT

For a n coincidence order the overall observational limit $I'_n(1)$ is approximately proportional to : $\frac{1}{R'_{n\gamma} R_p} = \frac{1}{T_\gamma^n R_\gamma} \frac{1}{R_{n\gamma}}$.

Then $I'_n = \frac{I_n}{T_\gamma^n R_p}$ where I_n is the observational limit for a n

coincidence order without the charged particle detector array.

This observational limit is part of the sensitivity of the apparatus. But the efficiency has also to be taken into account, leading to the concept of measurement power.

MEASUREMENT POWER

For a γ -spectrometer with an ϵ_γ total photopeak efficiency, the measurement power can be defined⁽¹⁾ by $P_\gamma = R_\gamma \epsilon_\gamma$.

In a first approximation, for a n γ -coincidence order it can be written: $P_{n\gamma} = R_{n\gamma} \epsilon_\gamma^n$.

Increasing by one the coincidence order improves the resulting resolving power : $R_{n\gamma} = R_{(n-1)\gamma} \cdot R_\gamma$, but leads to a greatly decreased measurement power, and therefore to a much lower statistics :

$$\frac{P_{n\gamma}}{P_{(n-1)\gamma}} = R_\gamma \epsilon_\gamma$$

If this additional γ coincidence is replaced by a coincidence with the ancillary detector we get :

$$\frac{P_{(n-1)\gamma,p}}{P_{n\gamma}} = T_{\gamma}^{n-1} \frac{R_p \epsilon_p}{R_{\gamma} \epsilon_{\gamma}}$$

where ϵ_p is the ancillary detector efficiency

For instance, all gates being set on γ rays of about 600 keV ($T_{\gamma} = 0.8$), and for $R_{\gamma} = 4$, $R_p = 2$, $\epsilon_p = 0.8$ and $\epsilon_{\gamma} = 0.05$ we get.

$$P_{(n-1)\gamma,p} = 8(0.8)^{n-1} P_{n\gamma,p}$$

To have the same measurement power with and without the ancillary detector needs to reach $n = 10$ coincidence order, even for such a rather low resolving power for the ancillary detector.

Setting all the gates on 200 keV γ -lines still implies a $n = 4$ coincidence order to get equal measurement powers without and with the charged particle array detector.

For any lower coincidence order, the measurement power for the γ -spectrometer triggered by the ancillary detector is much larger than the one obtained with the γ -spectrometer used alone.

III - REQUIREMENTS FOR AN EFFICIENT 4π PARTICLE DETECTOR ARRAY

First of all such a detector must be able to identify at least protons and alpha particles.

The actual efficiency, including the particle identification thresholds, has to be as large as possible, first to have a good fold response and then a high resolving power, second to improve the measurement power, in other words to give access to very weak light charged particle decaying channels. This efficiency is also necessary to obtain a good calorimeter.

The resolving power depends also crucially on the granularity, which must be at least eight times the expected multiplicity of charged particle to have less than a 5 % double hit probability.

The ancillary detector has to be as transparent as possible to the γ rays, in order not to spoil too much the peak/total fraction and thus the

resolving power of the γ -spectrometer, while stopping all particle in the calorimeter.

High granularity is also requested to have a good enough energy resolution to analyse particle energy spectra, and to make angular distribution or correlation.

Finally the detector array has to be inserted in a 4π γ -spectrometer and therefore to be sheltered in a small scattering chamber with a thin wall.

DIAMANT fulfill all these requirements, as previously described in more details(2). Let us remind that a 3 mm thick CsI(Tl) scintillator linked to PIN diode by a plexiglass light guide is used, allowing light charged particle identification by pulse rise-time analysis and stopping 25 MeV/A light charged particles.

DIAMANT has 54 such detectors with approximately the same solid angle, once the center of mass-laboratory jacobian taken into account, set in a close arrangement leading to a 95 % geometrical efficiency measured with an α source.

IV - FIRST PERFORMANCES OF DIAMANT

An example of the transparency of DIAMANT is given on the figure 1.

For 1.33 MeV γ rays the average measured value of P_T evolves from about 0.56 for EUROGAM to 0.46 for EUROGAM with DIAMANT.

In the case of the reaction $^{37}\text{Cl} + ^{120}\text{Sn}$ at 187 MeV bombarding energy, the peak/background ratio for the ^{149}Tb γ rays is improved by a factor of about 1.5 in the γ spectrum when EUROGAM is triggered by DIAMANT, without further particle identification. That is what is expected, because the cross sections for pure xn channels and channels involving light charged particles have approximately the same value, thus leading to $R_p \sim 2$.

Figure 2 shows an example of particle matrix exhibiting the proton and α lines.

The data sorting is still in progress, and has to be completed to extract the set of DIAMANT actual performances, like fold response and efficiency to a given exit channel, from which the resolving and measurement powers can be deduced.

REFERENCES

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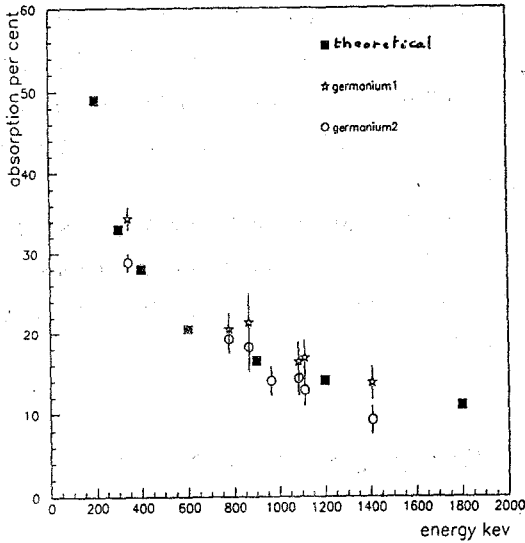


Fig. 1 : γ -ray absorption curve

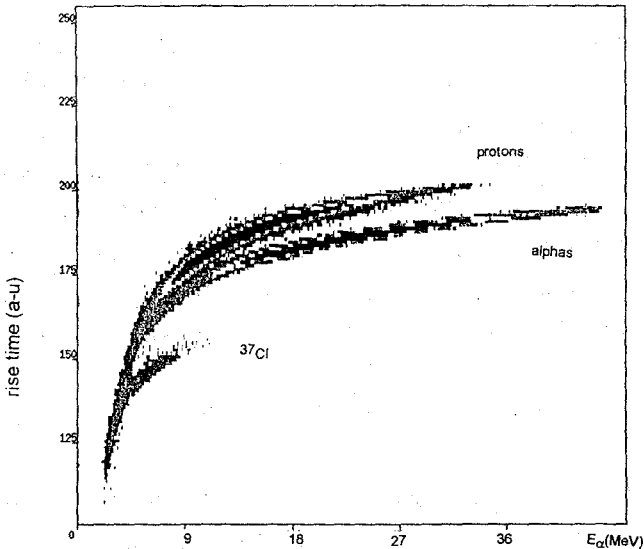


Fig. 2 : Particle energy-pulse rise time matrix for $^{37}\text{Cl} + ^{120}\text{Sn}$ at 187 MeV reaction and $\theta = 35^\circ$. The α equivalent energy is the CsI impinging energy, after a $10\ \mu\text{m}$ Ta absorber.