"GAMMA RAY SPECTROMETRY" GRS

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The project GRS is part of the project of diagnostic enhancements package to be implemented during the Framework Programme 7.

The objective for the year 2007 was the installation and the availability of intense gamma ray and neutron sources at the tandem accelerator of IFIN-HH, Magurele-Bucharest, in order to carry out testing of three new spectrometers, with complementary performance: a high energy resolution HPGe spectrometer and two high efficiency, high rate spectrometers with large detection crystal.

In order to attain this objective an irradiation experiment of an aluminum target with a 10 MeV proton beam was carried out.

The target was placed between the optical elements of the beam line so that a maximum value of the current of approximately 500 nA on the target was obtained. The detection of the gamma rays was carried out using an HPGe placed at a distance of approximately 6 m of target. The recording of gamma spectra was performed using the data acquisition system of the Department of Nuclear Physics of IFIN-HH. The off-line processing of spectra gave a rate of approximately 1.4 x 10^9 gamma rays/s. The obtained gamma-ray spectrum is shown in Fig. 1

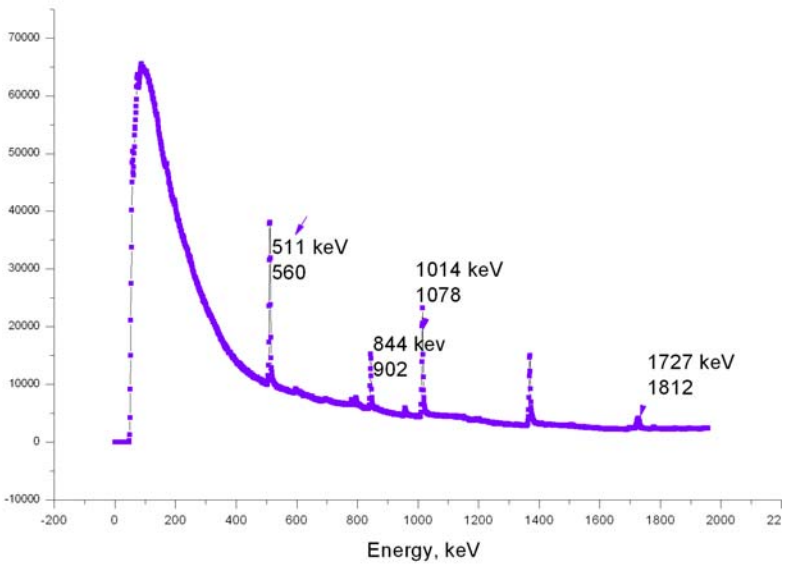

Figure1. Gamma ray spectrum obtained by bombarding an aluminium target with a proton beam of 10 MeV.

The lines of 843 keV and 1014 keV are obtained from the reaction ^{27}Al(p,n)^{27}Si. The half life for the nucleus ^{27}Si is of 4 s and its decay feeds the transitions of the nucleus ^{27}Al, as it is shown in Fig. 2.

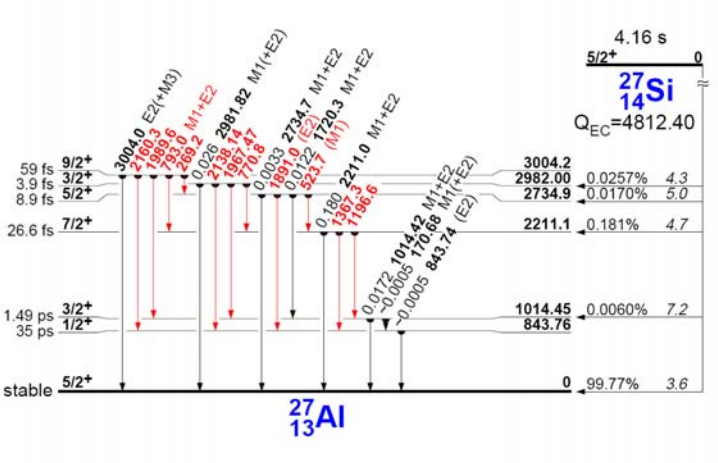

Figure 2. Level scheme for the nucleus ^{27}Al.

The gamma ray of 1368 keV was obtained from the reaction of $^{27}Al(p,\alpha)^{24}Mg$ which feeds the level of 1368 keV of nucleus ^{24}Mg.

The number of photons of gamma rays was obtained using the formula:

Area_photopeak/ t_measuring_time=detector_ efficiency x geometric_ factor x Λ,

where Λ is the number of gamma rays/t.

In Table 1 we present the processed experimental data.

Table 1. Number of photons generated by a beam of protons with an energy of 10 MeV and the current of 500 nA,on a Al target

Energy	Area	Error	Efficiency of detector x geometric factor	No gamma rays	Isotope
170.68 keV			7.6E-7		27Si
511keV	166110	627	6.3E-7	3.7E8	27Si
597 keV			5.9E-7		
781 keV			5.3E-7		
795.4 keV			5.2E-7		
843.74 keV	48790	403	5.0E-7	1.4E8	27Si
1014.42 keV	100500	452	4.4E-7	3.3E8	27Si
1368.63 keV	78451	421	3.1E-7	3.7E8	24Mg
1720.3 keV	23124	314	1.7E-7	1.9E8	27Si

A total of approximately 1.4 x 10^9 gamma ray photons / s was obtained.

The reaction rates expected in this (type of) experiment were calculated according to the formula :

Number of (p,n) reactions / second = σ x ρ x d x N / A x J /q , where

σ, cross section of the reaction 27Al9(p,n),

ρ, density for pentru aluminium, 2.7 g/cm^3

d, the thickness of the target

N, Avogadro number,

A, molar mass, 26.9815 g,

J, current of protons, 500 nA,

q, elementary charge, 1.6 x 10^{-19} C.

We have considered the stopping power for protons in aluminum target and we made calculations with the code SRIM2006

We have also considered the cross-sections data for the reaction 27Al(p,n) from the data base EXFOR.

Table 2. Calculated values for the number of p,n/s reactions for a beam line of protons of 500 nA on an aluminium target

Energy of protons, MeV	Cross section, mb	Delta energy	Stopping power,	Stopping power, MeV/mm	D, mm	No. p,n reactions/s
5.53	0	0.24	0.0533	14.44531	0.01661	0
5.77	23.4	0.24	0.05168	14.00626	0.01714	7.55206E6
6.01	32	0.24	0.05007	13.56992	0.01769	1.06597E7
6.25	35.8	0.24	0.04998	13.54553	0.01772	1.1947E7
6.5	34.3	0.25	0.04719	12.78939	0.01955	1.26283E7
6.74	37.6	0.24	0.04596	12.45603	0.01927	1.36452E7
6.98	44.6	0.24	0.04472	12.11997	0.0198	1.66343E7
7.22	56.4	0.24	0.04367	11.8354	0.02028	2.15411E7
7.46	72.3	0.24	0.04264	11.55625	0.02077	2.82809E7
7.7	77.2	0.24	0.0416	11.27439	0.02129	3.09525E7
7.94	86.3	0.24	0.04057	10.99524	0.02183	3.54795E7
8.18	92	0.24	0.03968	10.75403	0.02232	3.86713E7
8.43	98.5	0.25	0.03882	10.52096	0.02376	4.40841E7
8.67	98	0.24	0.03798	10.2933	0.02332	4.30371E7
8.91	96	0.24	0.03715	10.06836	0.02384	4.31007E7
9.15	102	0.24	0.0364	9.86509	0.02433	4.67381E7
9.39	102	0.24	0.03571	9.67809	0.0248	4.76412E7
9.63	103	0.61	0.03502	9.49109	0.06427	1.24684E8

Thus, the total number of (p,n)/s reactions which occurred during the stopping for the beam of protons of 10 MeV and intensity of 500 nA on an aluminium target is approximately 5.7 x 10^{8} (p,n) reactions / s.

This value is consistent with the number of photons per second experimetally obtained, since the multiplicity of photons of gamma rays per reaction is higher than 1.

This experiment shows that the using of a beam of protons of 10 MeV with the intensity of 500 nA on a aluminium target allows the generation of high fluxes of gamma rays and neutrons and therefore is appropriate for testing of the new detectors of germanium and scintillators, mentioned above.

Moreover the data acquisition system was optimized. The acquisition system dMCApro was installed. It is composed of a multichannel analyzing card which could be integrated into a computer, an amplifier, an analog-to-digital convertor, a high voltage supply and a computer code winTMCA32.

This data acquisition system integrated into a computer can be transported to the place where the irradiation experiments are to be conducted. It is to be designed at the IRASM facility, for intense gamma ray fluxes and irradiation from a high activity ^{60}Co source, of approximately 150.000 Ci.

Implementation of acquisition system MIDAS

In order to develop a data acquisition system for high rates a Hytec 5331card was also considered. We studied the possibilities of this card interfacing with the data acquisition system of Tandem, based on CAMAC modules, from the Department of Nuclear Physics

It was studied the data acquisition system MIDAS (Maximum Integration Data Acquisition System), which is a system for small and medium-scale experiments.

This data acquisition system can be used in operation systems based on TCP/IP protocol and allows high transfer rates.

A Hytec 1331 card is also considered for the command of the Hytec 5331 controller. This will allow the measuring on gamma spectra at high rates which are produced in intense fluxes generated by the irradiation of targets with beams of protons with the energy of 10 MeV.

For measurements of neutron spectra a neutron detector was considered, which is based on a ionizing chamber with ^{3}He and has a good energetic resolution as well as a sufficient efficiency for measuring the neutrons in intense beams

The energetic resolution is of 20 keV for thermic neutrons and 30 keV for neutrons having the energy of 1 MeV and the efficiency of 3×10^{-4} at 1 MeV.

The development of the methodology of measuring gamma and neutrons spectra with energetic resolution at high counting rates will be used for testing of a new detector of HPGe and of two scintillation detectors which will be used at JET for upgrading both the instrumentation of gamma radiation detection and the discrimination methods between gamma and neutron emission.