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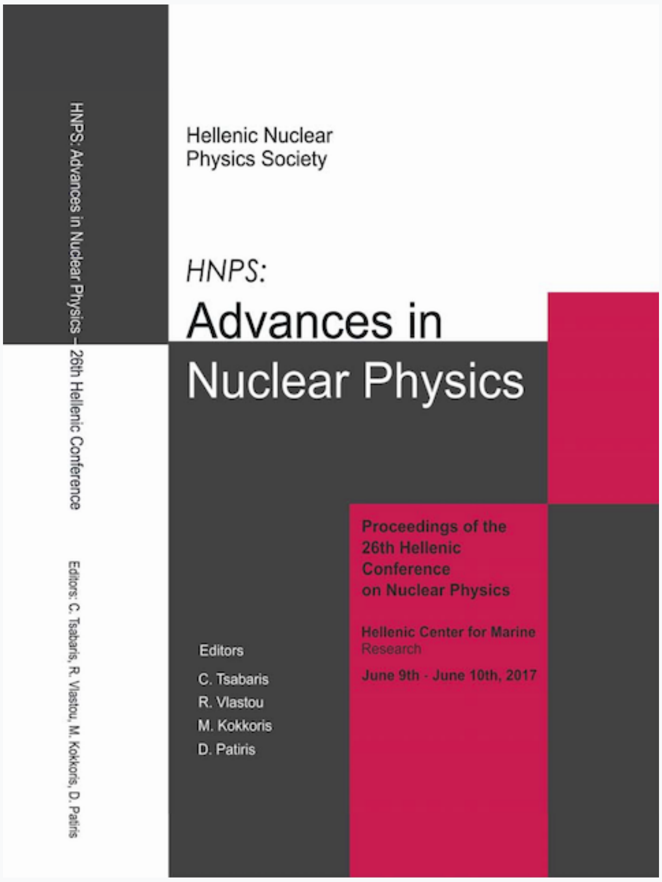

Study and Detection of Solar Neutrons at ground level with the Spherical Proportional Counter

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Study and Detection of Relativistic and Fast Solar Neutrons at ground level with the Spherical Proportional Counter

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Abstract The acceleration mechanisms and nuclear reactions of energetic particles that take place in a stellar environment are of great importance to the field of Astroparticle Physics. A comprehensive examination of the aforementioned issues should start with the Sun. This study aims to approach those issues by detecting specific particles emitted from eruptive solar events, such as flares. The particles of interest in that case are the neutrons emitted from the reactions of energetic particles (proton or alpha particles) with the photosphere of the Sun. The purpose of this research is to study and investigate the plausibility of Solar Neutrons of fast and relativistic energies at various ground levels, with the Spherical Proportional Counter (SPC). In the event of high energy solar neutron detection, the SPC is enhanced with a thin, spherical layer of Bismuth(^{209}Bi), situated inside the large volume of the detector, thus serving as a target, absorbing the secondary neutron flux which bombards the detector. The fission fragments produced from the ^{209}Bi(n,f) reaction are distinguished in the large volume of the detector. Calculations are made for specific atmospheric depths of 700 g/cm^2 and 1000 g/cm^2, with various detector dimensions (r = 0.65 m, 2.5m, 5m).

Keywords Spherical Proportional Counter, Solar Neutrons, Relativistic and Fast Neutrons, Astroparticle Physics

INTRODUCTION

From the discovery of cosmic rays till now, their acceleration mechanism remains in the forefront of research activity regarding Astroparticle Physics. Neutral particles such as neutrons and neutrinos, are not affected by planetary magnetic fields, thus preserving crucial information about their energy and origin. Therefore, Solar Neutrons are selected in order to measure the nuclear reactions in a stellar environment. With a mean lifetime of ~887 seconds, only the most energetic solar neutrons (100 MeV – 10 GeV) will reach the top of the Earth's atmosphere. Even though the solar neutron flux is strongly attenuated throughout the atmosphere, those particles can be tracked via ground based detectors on high altitudes.

EXPERIMENTAL METHOD

The Spherical Proportional Counter

The SPC is novel concept with a wide wide range of applications from thermal and fast neutron detection, to dark matter and low energy neutrino search. The detector's most prominent features are a low energy threshold with good energy resolution and low level of electronic noise. The natural radial focusing of the spherical geometry allows collection and amplification of the deposited charges with a single electronic channel scanning a large gaseous volume. The detector consists of a large spherical copper vessel, 1.3 m in diameter and 6 mm thick. A small stainless ball, usually of 14 mm in diameter, is fixed in the center of the spherical vessel by a stainless steel rod, acting as an electrode with positive high voltage simultaneously as a proportional amplification counter. The SPC is a robust detector with low cost and is proven to operate in a stable mode for a long period of time.

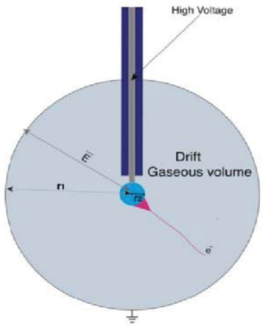

Fig. 1 & 2. The SPC with its electronic components (left) and the electric field (right)

Fast Neutron Detection with ^{14}N

The SPC is tested for fast neutron detection with Nitrogen. The leading reaction in the range of 0.1 MeV to 1.5 MeV is the $^{14}N(n,p)^{12}C$ reaction, while for fast neutron detection from ~2 MeV until 20 MeV, the prominent reaction is $^{14}N(n,a)^{11}B$. The results for the fast neutron detection are shown in figures 3, 4 and 5. The neutron source is ^{241}Am - ^{9}Be, with 500 mbar pressure of Ar – CH4 in the detector.

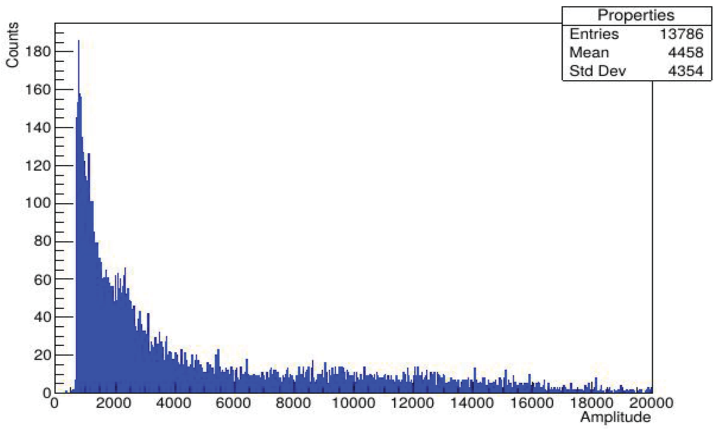

Fig. 3. Amplitude histogram for thermal and fast neutrons

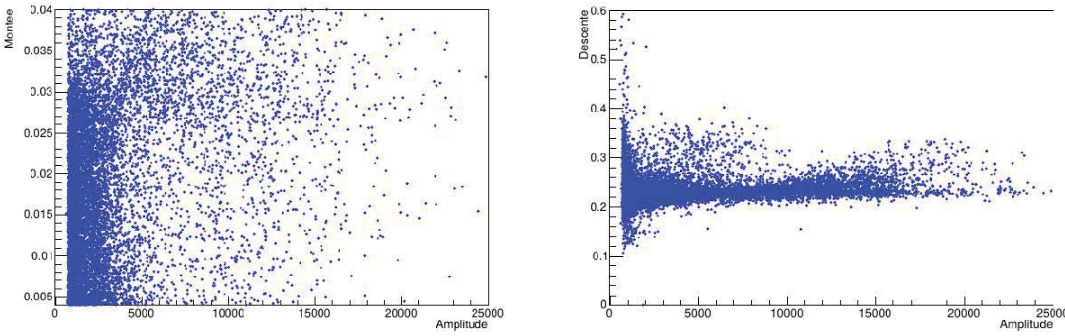

Fig. 4. & 5. Rise time with Amplitude(left) and Fall time with Amplitude(right)

Solar Neutron Detection with ^{209}Bi

In the event of solar neutron detection (E = 100 MeV to 10 GeV), the Spherical Proportional Counter is enhanced with a thin layer(few μm) of Bismuth, situated inside the detector, , thus serving as a target, absorbing the secondary solar neutron flux which bombards the detector. The fission fragments produced from the ^{209}Bi(n, f) reaction are distinguished in the large volume of the detector. The cross section of Bismuth has a range from ~0.075 barn for energies of 100 to 300 MeV and ~0.1 barn for energies of 300 to 1000 MeV.

RESULTS AND DISCUSSION

Calculations are made for specific atmospheric depths of 700 g/cm^2 and 1000 g/cm^2 with various spherical detector dimensions (r = 0.65m, 2.5m, 5m). A typical solar neutron flux of 5 10^{-4} n/cm^2 is used for atmospheric depth of 1000 g/cm^2 (sea level) and a flux of 0.003 n/cm^2 for an atmospheric depth of 700 g/cm^2(2500-3000 m). The results are presented in Tables 1 and 2.

SPC Radius (meters)	Predicted reactions per hour ($E_{neutron}$ ~200 MeV)	Predicted reactions per hour ($E_{neutron}$ > 300 MeV)
0.65	0.2	0.26
2.5	3	4
5	11.94	15.93

Table 1. Results for atmospheric depth of 1000 g/cm^2

SPC Radius (meters)	Predicted reactions per hour ($E_{neutron}$ ~200 MeV)	Predicted reactions per hour ($E_{neutron}$ > 300 MeV)
0.65	1.2	1.6
2.5	17.91	23.88
5	71.6	95.58

Table 2. Results for atmospheric depth of 700 g/cm^2

CONCLUSIONS

The SPC is successfully tested in fast neutron detection with *N2* gas. In the event of high energy solar neutron detection through the fission fragments of the ^{209}Bi(n, f) reaction, the optimal location for the detector placement will be at higher altitudes, where the neutron flux is not as strongly attenuated as at sea level, as shown by Tables 1 & 2. Future study will implement further modifications and optimization in detector radius, design and placement.

References

[1] I.Giomataris et al.”A novel large-volume Spherical Detector with Proportional Amplification read-out”, 2008.

[2] Lev Dorman,”Solar Neutrons and Related Phenomena”,Springer, 2010 M. Papa, T. Maruyama, and A. Bonasera, Constrained Molecular dynamics approach to fermionic systems, Phys.Rev. C64, 024612 (2001).

[3] D. Tarrio et al.”High Energy Neutron-induced Fission Cross Sections of Natural Lead and Bismuth-209”, 2011.