## Instrumentation for Nuclear Physics

*[02/09/03 - Poster]*

### Manufactured Silicon Diode used as an Internal Conversion Electrons Detector

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The direct detection capabilities of one silicon diode manufactured at CERN (RD-15 collaboration)for both beta particles and internal conversion electrons have been studied . This ion-implanted diode (type Al/$n^+$/p/n/Al), developed in the framework of R&D programs for the future CMS experiment at Large Hadron Collider (LHC), bears excellent timing properties and high radiation hardness that fulfill the requirements from this accelerator environment. Apart from this diode application, we were encouraged to study its performance for low energy electron and beta particles detection and spectrometry envisaging its use in an electron or beta-gamma coincidence system for nuclear parameters measurements.

The electric contacts of the diode were made at LME/USP, as well as the measurements of its capacity and leakage current as a function of the bias voltage. In order to use this diode as a detector, it was placed inside a stainless steel vacuum chamber and directly connected to a charge sensitive amplifier based on an integrated circuit A250 from *Amptek*. This circuit, originally projected for electromagnetic radiation detection, was slightly modified to match the characteristic of higher charge per pulse associated with charged particles. The pulses from the A250 were shaped and amplified by a linear amplifier and fed to a multichannel analyzer.

The response of the diode for beta particles and internal conversion electrons was studied by using $^{32}P$ and $^{133}Ba$ radioactive sources, respectively. The behavior of the diode relative efficiency as a function of the voltage for both radiations showed that the counting rate increases with the applied voltage as a consequence of the depletion layer enlargement (maximum 200$\mu$m at full depletion, estimated from the diode capacitance measurements).

The spectrometric performance of the diode for internal conversion electrons from the $^{133}Ba$ source was studied recording several energy spectra under different experimental conditions at room temperature. Until now, the best result obtained clearly shows the lines corresponding to the electrons of 45.01keV up to 347.87keV (FWHM = 6.2keV). It should be pointed out, however, that besides the contribution of the preamplifier electronic noise to the broadening of the electron lines, the deterioration of the obtained energy resolution can be attributed to both the energy loss in the diode dead layer and in the *makrofol* covering of the $^{133}Ba$ source. Nevertheless, the energy resolutions measured are sufficiently good to justify the use of this diode for spectrometry of internal conversion electrons.

*[02/09/03 - Poster]*

### The Transition from Proportional to Streamer Mode in Resistive Detectors

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Detectors with highly resistive electrodes, particularly resistive plate chambers (RPC's), have been studied extensively in recent years. Due to its ease of construction and operation, the low cost and the good time resolution, it has been proposed as a suitable detector for the muon trigger for the Large Hadron Collider experiments. However, when RPC's are operated in spark mode, it was found that these devices were only able to operate efficiently at low rates (100Hz/cm$^2$). This behavior was attributed to the mechanism whereby following each spark the charge was deposited on the resistive electrodes, causing the reduction of the electric field across the gas gap. Therefore, there is interest in operating these detectors in regimes where the charge per pulse is much smaller than those associated with spark signals such as proportional or self quenching streamer (SQS) modes.

In this work we decided to use the classical proportional counter geometry, with a resistive cylindrical tube as the cathode, rather then parallel geometry. Indeed, the large amount of information available from SQS using all metal cylindrical counters can be applied, within certain limits, to explain the behavior of the possible streamer data from the resistive detector.

The experimental results were obtained with a long cylindrical counter made of glass (resistivity about 7x10$^{12}\Omega.cm$) fitted with a stainless steel anode wire (50$\mu m$ of diameter). The tube was divided into two sections: one of them was covered externally with a thin grounded layer of *Eletrodag*, forming a simple resistive detector (RD), while the other was covered internally by the same layer as a conventional metallic counter (MD).

The Ar/Isobutane and Ar/Etane gas mixtures were used for the measurements related to the transition from the proportional to the self quenching streamer mode under X-rays irradiation from a $^{109}Cd$ source. The charge spectra were measured using a conventional charge amplifier electronic system and a multichannel analyzer, calibrated using a standard pulse generator. The results obtained with the RD detector showed for both gas mixtures the characteristic discontinuous transition (with efficiency about 50%) from proportional to SQS avalanches. It is important to stress that, although the charge per pulse was increased with the applied voltage, it was clearly visible the loss of pulse height along proportional and the streamer regions, being more pronounced for the higher rate.

On the other hand, studies on the response stability of this detector in SQS regime are under way.

*[02/09/03 - Poster]*

**Characterization of topographical effects in specters RBS**

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Spectrometry RBS is one of the methods of characterization of used samples more, being possible to get information such as thickness and composition of the same ones. Recently, it comes being carried through studies that aim at its use for the study of topographical characteristics, as the roughness, as described in the book text of Chu (1978), Bill and Edge (1980), Shorin and Sosnin (1992). Metzner (1997) established that the form of specter RBS can be influenced by distribution of heights of the surface, p(h), considering incidence and backscattering with regard to normal. The objective of the present work is to expand this model for different angles out of the normal, what it will be made by means of simulations and experiments with models standard (periodic roughness) and samples with random roughness. For the simulation of p(h) was developed a code in C++ in had been gotten the distributions of corresponding heights the regular profiles of roughness, in the cases quadratic and to triagular. The experimental study, it was developed from the model considered for Metzner for attainment of p(h) from specter RBS gotten experimentally and analyzed the light of one simulated by the RUMP, being that the analyzed sample was a composed film for Sn and in two situations: with and without baking, and its surfaces were analyzed through Atomic Force Microscopy (AFM). The analysis for attainment of p(h) was made from a set backscattering angles, that were possible thanks to a mobile system of detectors, developed for such purpose.

*[02/09/03 - Poster]*

**Neutron Flux Spectrum Assessment in an Am-Be Neutron Irradiator**

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A small neutron irradiator prototype is being developed at IPEN's facilities (Instituto de Pesquisas Energéticas e Nucleares - Brazil) so that it can be used outside the reactor premises. Basically, this prototype consists of a $1200mm$ long cylinder with $985mm$ diameter (filled with paraffin) with two Am-Be sources ($\sim 600GBq$ each) arranged in the longitudinal direction of its geometric center. The material to be irradiated can be positioned in different positions at a radial direction of the cylinder between the two $AmBe$ sources. The development of appropriate nuclear instrumentation to perform neutron activation analyses using fast neutrons can be useful to perform neutron dosimetry, to investigate materials outside the reactor premises and for detector testing. The use of this irradiator presents the advantage of supplying a stable neutron flux for long periods, so that it eliminates the need of using standard materials in quantitative analyses. This way induced activity measurements in the irradiated material become agile, practical and economic. To establish the prototype specifications, the neutron flux distribution was calculated using the MCNP-4C. In order to validate these results for a wide range of energies, measurements with activation foils were performed, and the agreement between the experiments and the MCNP simulation is discussed.

*[02/09/03 - Poster]*

**On the Origin of the Satellites Peaks in Alpha Particle Spectra**

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The widespread study on silicon diodes performance in the spectrometry of charged particles is due to the possibility of their use as a research tool both in laboratory and in industrial applications as the measurement of the isotopic ratios between chemical elements. In order to employ this technique in studies related to reactor fuel elements and their properties after irradiation, we have been studying the response of silicon diodes for alpha spectrometry.
The devices studied during this work were: a S3590-06 PIN photodiode (*Hamamatsu*) and an implanted silicon diode (type Al/$n^+$/p/n/Al) manufactured at CERN. The diodes were housed inside a stainless steel vacuum chamber and its electric leads were connected to the charge sensitive preamplifier (based on an integrated circuit A250 from *Amptek*) whose output was further amplified and shaped and finally fed to a multichannel analyzer.
In order to verify the performance of the S3590-06 photodiode (which bears two guard rings) for heavy charged particle spectrometry, several energy spectra were recorded using a 5.5kBq mixed alpha source of $^{239}Pu$, $^{241}Am$ and $^{244}Cm$. The experimental results showed that, even at room temperature and without reverse bias, the alpha particles of the principal group of each isotope were observed. Even though the good influence of the bias voltage on photodiode energy resolution was evidenced (FWHM = 17.4keV for the 5.486Mev line from $^{241}Am$), the results revealed some unexpected low intensity peaks spaced about 200keV below each of the three main peaks.
The origin of these satellites peaks were firstly thought to be due to incomplete charge collection in weak electric fields around the edges of the diode, near the guard ring region. So, one should expect that the relative intensity of