THE MICROMEGAS NEUTRON DETECTOR FOR CERN N_TOF

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AND THE N_TOF COLLABORATION

A novel neutron detector based on the MICROMEGAS concept is presented. One of the applications of this detector is the determination of the high performance and characteristics (neutron beam profile,flux and energy resolution) of the new high-flux spallation neutron source, the neutron Time-Of-Flight facility (n_TOF) at CERN.

1 Introduction

In continuation of the work performed at CERN centred on the search of an innovative concept for energy production and in particular to find a solution related to the nuclear waste [1,2,3], a new neutron Time-Of-Flight (n_TOF) has been performed at CERN [4]. The aim of the project is the measurement of cross-sections needed for the design of innovative Accelerator Driven System (ADS) applications such as incineration of nuclear waste, energy production, radioisotope production for medical applications and for many other basic science subjects, in particular astrophysics. To demonstrate experimentally the high performance and characteristics (neutron beam profile, flux and energy resolution) of the n_TOF facility, a new neutron detector has been developed based on the Micromegas [5,6] concept. The present paper reports the first results obtained with the Micromegas detector at the n_TOF facility.

2 The CERN n_TOF facility

The concept of the n_TOF facility, was based on the experience aquired from TARC [3] and the opportunity offered by CERN accelerator complex: high intensity proton flux (up to 10^{13} protons/bursh at 20 GeV/c) and the existing TT2A tunnel with 200 m long path. A simulation of the detailed geometry of the lead target has been performed to estimate the neutron flux at 200 m. Two

Monte Carlo codes were used successively: FLUKA [7] and the EA-MC Monte Carlo code [8]. FLUKA generates the spallation neutrons and transports them from high energies down to 19.6 MeV. The neutrons from FLUKA simulations with kinetic energy lower than 19.6 MeV are further transported by the EA-MC code using the same geometry as in the previous simulations.

Following an overall optimization between neutron flux and $\Delta\lambda$ resolution (λ = effective neutron path), the spallation target was chosen to be a lead block of $80 \times 80 \times 40 cm^3$, followed by a water moderator of 5 cm thickness [4].

The different parts of the time-of-flight tube are shown in (Fig. 1).

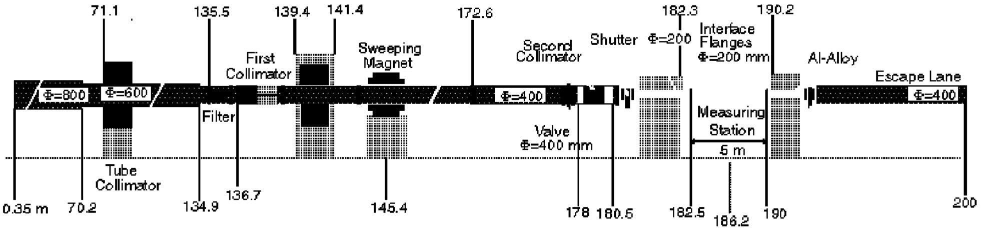

Figure 1. *Time-Of-Flight tube sections up to the end of the TT2A tunnel 200 m.*

Two collimators were installed to reduce the radius of the neutron beam. The first one with 11.5 cm inner diameter, is located at 136.7 m. The second collimator (source screening collimator) with 1.8 cm inner diameter is placed at 178 m.

In spite of the 10° angle between the time-of-flight tube and the proton beam, some charged particles will remain and contaminate the neutron flux. Therefore, a dipole magnet, located at 145 m is used to sweep away these unwanted secondary particles. Detailed simulations were made of the production of charged particles and photons appearing after the magnet [10].

3 Detector description

A detailed description of the Micromegas detector can be found in [ref 5,6]. It is a double-stage parallel plate chamber, consisting of a conversion gap and an amplification gap, separated by a micromesh.

Ionization electrons, created by the energy deposition of an incident charged particle in the conversion gap, drift and can be transferred through the cathode micromesh; they are amplified in the small gap, between anode and cathode, under the action of the electric field, which is high in this region. The electron cloud is finally collected by the anode microstrips, while the positive ions are drifting in the opposite direction and are collected on the micromesh.

In order to operate the MICROMEGAS detector as a neutron beam profile detector for the n-TOF facility at CERN, an appropriate neutron/charged particle converter must be employed which can be either the detector's filling gas or target with appropriate deposit on its entrance window. Since the neutron energy range of the n-TOF facility extends from 1 eV to 250 MeV, there is not a unique choice of an efficient converter. Inter-dependent parameters such as the high neutron reaction cross section, the low charged particles energy loss inside the converter, their subsequent energy-angular distribution and the range inside the filling gas has been considered and optimised (Fig. 2).

The neutron/charged particle converter employed are: (^{6}Li(n,α) for neutron energy up to 1 MeV [11] and H(n,n)H and ^{4}He(n,n)^{4}He for high energy neutron) which are the detector's filling gas. The first converter used consists a ^{6}Li layer, 500 nm thick, protected from oxidation by a very thin layer of aluminum, 25 nm thick, which was deposited over the drift electrode mentioned above. The active surface of the detector is 80x80 mm^2 (Fig. 3). The anode strips (50 in total) have a pitch of 1.5 mm and are separated by 100 μm gaps

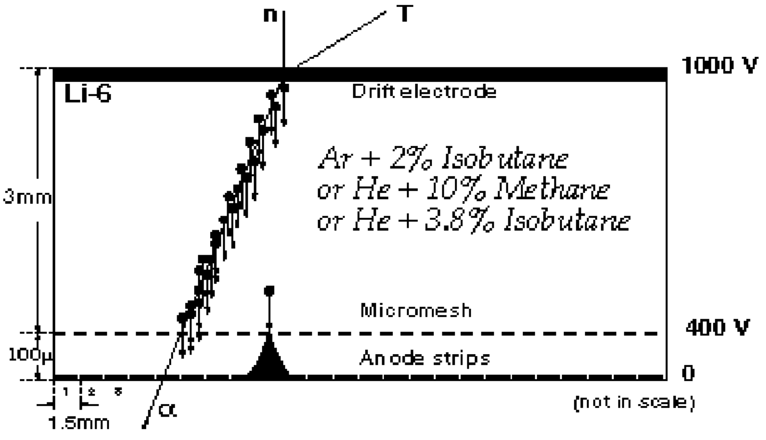

Figure 2. *The principle of the Micromegas concept for neutron detector*

Neutrons going through the ^{6}Li target can react via the reaction

$$n + {}^6\text{Li} \rightarrow \alpha + t$$

For high energy neutron the charged particle has obtained from the elastic reaction on the H and or He atoms contained in the filling gas. Three type of gas mixtures have been used: Ar + iC_4H_{10} (2%) He + CH_4 (10%) and He + iC_4H_{10} (3.8%). The percentage of iC_4H_{10} and CH_4 has been chosen to be low in order to respect the non-flammabilty of the mixed gas.

The neutron detection is based on the detection of one outgoing charged particle from the above reactions, i.e. an alpha or a triton. Thus, such a nucleus should leave the target, entering the conversion gap of the detector, with sufficient energy to create enough ionization in the gas.

In order to achieve a very good profile of the n_TOF beam, the Micromegas detector has been placed in the vacuum chamber under the standard pressure of the n_TOF tube (10^{-3} bar). The main characteristics of this detector is the choice of material having a minimum influence on the high energy neutron.

4 Data analysis and results

As already mentioned, the CERN n_TOF facility provides a direct correlation of the neutron time of flight to its energy, an additional time measurement in the neutron detection allows the determination of the beam profile and the neutron flux as a function of the neutron energy. Since the neutron beam start signal has an RMS of 7ns, a time resolution of few ns is required. In order to operate under these conditions, the anode strips were readout through 50 fast current preamplifier (rise time of 1 ns) associated with the innovative n_TOF Data Acquisition System based on 1 GHz flash ADCs (rates of 180 MHz).

The n_TOF Data acquisition system has a zero suppression algorithm incorporated which removes unnecessary information from the recorded data. In order to preserve all the information needed, a number of pre-samples before the threshold passing must be recorded and a number of post-samples as well. This permits the observation of a base line shift, pulse pile-ups, double pulses, etc. Each signal has been analysed in detail: the base line and RMS, the start and end time, the amplitude of the signal and in particular the total area of the signal which is proportional to the energy deposited on the strip.

A particle passing through Micromegas (recoils, alphas and tritons) creates some electrons that are amplified and then detected by one dimensional strips. The particle is inducing some signal on all the strips over which it has travelled.

An example of the signals recorded for one burst (10^{12} protons) are reported in (Fig. 3). This figure shows clearly the different time of the created electron. The first signal corresponds of the electron created close to the mesh and the last one the electron created just after the drift electrode.

The signal of a charged particle observed by the micromegas detector depends on its direction, namely the angle θ of emission with respect to the incident neutron (perpendicular to the detector) and the angle φ with respect to the detector strips. Obviously, a particle with large θ (almost parallel to the detector plane) and large φ (almost perpendicular to the strips), gives the maximum strip multiplicity. A particle with large θ and small φ (almost parallel to the strips), gives a very low strip multiplicity and high signal saturation, due to the big charge deposition to a limited number of strips. A particle with small θ (almost perpendicular to the detector plane), gives a very low strip multiplicity and low signal amplitude. At large θ and φ, the strip multiplicity gives the track length in the gas. But, as this occurs only at large θ, most of the outgoing particles deposit a large fraction of their energy in the target and the maximum strip multiplicity corresponds to a distance smaller than the maximum range.

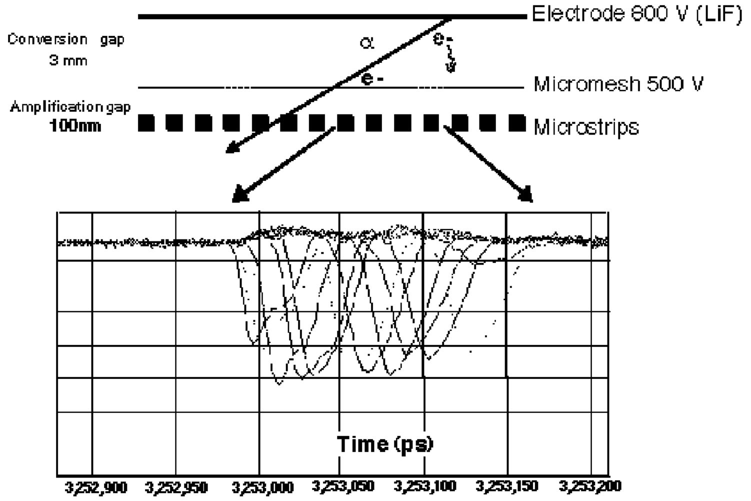

Figure 3. *An example of the signal recorded during the run for* 10^{12} *protons.*

An example of the first preliminary results are shown in figures 4 (Fig. 4) and 5 (Fig. 5).

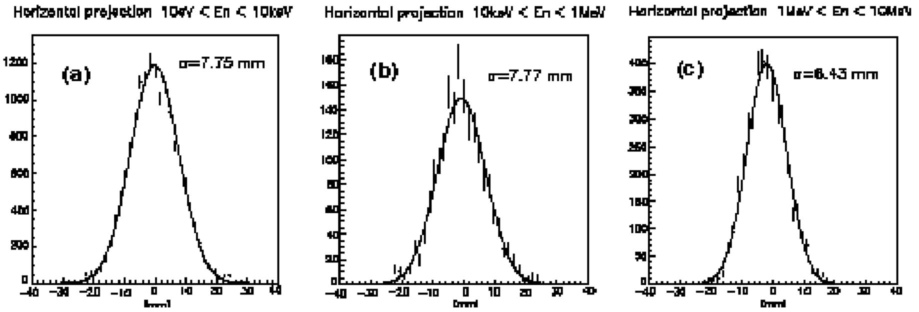

Figure 4. *Horizontal projection of the n_TOF neutron beam profile in the neutron energy range between 10 eV to 10 MeV*

Figure 4 shows the profile of the CERN n_TOF neutron beam at 7 m after a second collimator with diameter of 2 cm placed at the entrance of the experimental area.

In figure 5 are reported the time converted to equivalent neutron energy of the relative flux seen by Micromegas detector. Two plots are reported in figure 6, the result obtained from the ^{4}He + iC_4H_{10} and Ar + iC_4H_{10} respectively.

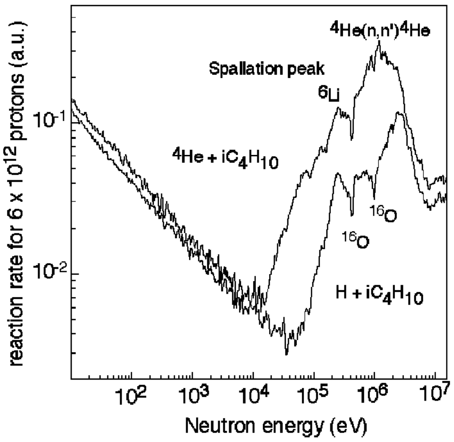

Figure 5. *Relative flux (counts rate) of the n_TOF neutron beam seen by the detector as a function of the neutron energy.*

Figure 5 shows clearly the 1/v response at low energies and the resonance at 250 keV characteristic of the ^{6}Li converter. At higher energy (several MeV) there is a large bump as a consequence of the increase of neutron fluence in this energy (spallation peak) and also the increase of detector efficiency provided by the detection of recoil nuclei from the filling gas. Several deeps are observed in the energies corresponding to the different elastic resonances of the ^{16}O. This is the result of the dispersion of neutron of those energies from the main beam by the oxygen present in the water used for cooling of the lead target. The shift, observed in the figure between the two plots, is the result of the presence of the elastic resonance of the ^{4}He(n,n')^{4}He reaction.

5 Conclusions

Using an appropriate neutron/charged particle converter: - ^{6}Li(n,α) for the neutron having an energy up to 1 MeV - H(n,n')H and ^{4}He(n,n')^{4}He for higher energy neutron - a fast current preamplifer with a rise time of 1 ns - an innovative Data Acquisition System based on 1 GHz flash ADC with a rate of 180 MHz. It is demonstrated that a Micromegas detector is excellent for neutronic studies at a very large energy range from thermal up to 250 MeV. The detector can be used as a good neutron beam profiler for research with neutrons an example is shown for the CERN n_TOF facility. This method can be extended for medical, industrial or other applications.

In the near future, we started the development a two dimensional Micromegas detector for neutron detection. Two different approaches are under investigation. The first is a double Micromegas detector with common drift electrode, where the strips of the first one are normal to the strips of the other one. Since the outgoing charged particles from the neutron reactions go almost back to back, the two chambers should work in coincidence. The second approach is a Micromegas detector with a double strip plane.

Acknowledgments

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