**RESULTS & CONCLUSIONS**

This preamplifier was designed to be sensitive to particle signals, which are time-frequency distributions that depend on the type of impinging particles. This phenomenon may be employed to perform mass and charge studies of the incident radiation. Scientists have been working on establishing a suitable technique for charge identification in recent years, which has experienced large improvements due to the development of new technologies (H. Hamrita et al., NPA 513 (2004) 407-415).

New experiments to develop digital pulse shape analysis (PSA) techniques have been carried out at the Centro Nacional de Aceleradores (Sevilla) from 5-7 February 2007. The aim of this experiment was to study the pulse shape, and its correlation with energy, charge, and mass, of heavy ions at low (0-2 MeV) energies. The results will be an important contribution to the PSA database currently being developed within our collaboration framework.

The possibility of performing isotopic separation at low energy with silicon sensors has direct applications in astrophysics (i.e. determination of reaction cross sections) and heavy isotope identification using AMS; this research program is presently in near future activity at CNA. AMS isotope identification is based on the use of energy-loss particle-detector telescopes or on time of flight (Xiong Dong Ruan et al., NIM B223 (2004) 172-175) methods. At heavy mass regions (C, N), the pulse shape analysis (PSA) may be a competitive technique.

**EXPERIMENTAL SETUP**

On the right hand side (FIGURE 1) a sketch of the experimental setup is shown. The beam line is connected to a primary scattering chamber by a bellows (3 cm) collector placed at the entrance 25 cm from the gold target. This collector was made of 90 cm wide and used in the beam line to improve beam quality and reduce emittance. The scattered ions were directed towards the switching slits, collimators and the scattering on a 1um thick gold target.

**ACCELERATOR AND BEAM CHARACTERISTICS**

The experiments were performed with the 3 MV tandem Van de Graaff facility at “Centro Nacional de Aceleradores” (CNA) in Sevilla. Alkali ions are produced in a negative charge state in a sputtering ion source (BNOS, from NEC). Enriched cathode of the desired nuclear species are replaced in “+High”, i.e., the ion source does not stop during cathode exchange. Nebul ions are produced using a plasma ion source with the appropriate gas admixture. The ions are pre-accelerated to about 60 - 100 KeV before injection into the central terminal using a dipole magnet. The charge exchange is produced with a gas target, post-accelerated and re-focused into an achromatic 90° magnet for charge and mass separation. The magnet has a set of slits at the output to improve beam quality and reduce emittance. The selected ions were directed towards the switching magnet (dipole) before reaching the beam line (FIG. 3). For this experiment we used Na, Li, and Li beams in an energy range from 4 – 12 MeV. To reduce the typical intensity of about 500 nA to the limits permissible for silicon sensors (a few particle-pa) the intensity had to be reduced by using slits, collimators and the scattering on a 1cm thick gold target.

**DETECTORS**

One of the detectors used was a single PAD (FIG.A) made of standard silicon 500-um thick (Micon Semiconductor Ltd) and it was used for beam monitoring purposes: beam intensity, energy spread and the presence of possible beam contaminants. It had a nominal thickness of 500 um with an active area of 2500 mm². The applied bias voltage was 80 V. A second detector made of Neutron Transient Doped silicon material (Canberra) was also used to obtain the data for Pulse Shape Analysis (FIG.B). The nominal thickness was 200 um and it was mounted in reverse field configuration. The active area was 1700 mm².

**ELECTRONICS**

The PMT detector was connected to a high gain charge and current-sensitive preamplifier (H. Hamrita et al.). This preamplifier was designed to be relatively close to the detector (directly connected to the silicon pad using a gold plated SM connector). Figure 5 shows a block diagram of the acquisition system. Both the charge and the current outputs of the preamplifier were taken to a 20 G samples per second (digital) digital oscilloscope (Lecroy). The sampling rate of this oscilloscope was 100 MHz. The raw data was acquired using the MATECOS (2 Gaps, 300 MHz BW, 12 bit) developed at CEA-Saclay (France) in combination with a VME interface. This data were stored into ASCII files (one for each diode and another for current). Typical data rate storage on disk was of about 0.25 GigaByte / minute.

**RESULTS & CONCLUSIONS**

Both the charge and current signal given by the NTD detector yield useful information about the incident ions. Signal rise time and area can differ from one ion to another so plots of rise time versus ion energy or signal area may help to identify two close isotopes. Figure 6 shows both the current and the charge signals for Na, Li, and Li'.

It is well established that current signal rise time (90% to 10%) is more sensitive to small changes in the detector output than the charge one [L. Bardelli et al., NIM A521 (2004) 495]. We have plotted the rise time versus signal area of the current signal for Na and Li in figure 7. The rise time is shorter as the ion energy increases. Meanwhile, the signal area increases with energy.

To compare two close isotopes (Li and Li'), we plotted current signal rise time versus area (see figure 8) and the centroids of their distribution versus energy (see figure 9). Large departures seen at some energies are mainly due to problems during the acquisition (e.g. electronic noise, EM disturbance, coupling problems, etc.) which limit the particle identification at this stage. Despite of that, the dependence of the rise time with energy is rather clear and consistent with previous results [L.Bardelli et al., NIM A521 (2004) 495]. A dedicated low-noise setup for this kind of studies at low energies is desirable for the next generation of experiments. The centroids of plots also show the standard deviation, base on a gaussian fit of the rise time distribution. An interesting feature of this plot is that below 10 MeV we have a clear separation of the isotopes.

Another approach to PSA is being performed using artificial neural networks. Figure 10 shows preliminary results using isotopes of Kr, Ar, S, and Fe. These networks prove the effects of different energies on the pulse shapes. For more information about this we recommend to read the technique described in the related poster “Particle Identification by Neutral Network PSA”.

**Conclusions**

- PSA strongly depends on low-noise electronics.
- More experiments are needed using other light ions at low energies.
- New experimental setup (non scattering) should improve resolution.
- Artificial neural networks is a promising technique for PSA.

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