1991ICRC....2..511B

RESPONSE OF SCINTILLATORS TO UH NUCLEI

W.R. Binns[1], D.J. Crary[1], J.R. Cummings[2], T.L. Garrard[2], J. Klarmann[1],
B.S. Nilsen[3], and C.J. Waddington[3]
1. Washington University , St. Louis, MO, USA; 2. Caltech, Pasadena, CA. USA;
3. Univ. of Minnesota, Minneapolis, MN, USA

ABSTRACT

In order to evaluate the performance of plastic scintillators for the detection of Ultra-Heavy cosmic ray nuclei, as envisaged in paper OG 10.1.14P, we have conducted experiments at the LBL Bevalac in which we exposed NE-114 and acrylic scintillators to beams of $_{47}$Ag ions and its interaction fragments. As a result we have calibrated these scintillators over the charge range $31 \leq Z \leq 47$. Our results show that a combination of Cherenkov and scintillator detectors can resolve individual charges over this charge range. The resolution obtained in scintillator was 0.24 and 0.28 cu for NE-114 and acrylic scintillator respectively. In addition the light emission is shown to be linear to a good approximation with dE/dx over this charge range.

1. Introduction--New experiments to measure the elemental abundances of the Ultra Heavy (UH) cosmic rays ($Z \geq 30$), e.g. see paper OG 10.1.14P, must be capable not only of collecting adequate statistics, but also of measuring the heaviest nuclei with sufficient resolution to clearly resolve individual elements. Tests that we have previously performed at the Bevalac using Pilot-425 Cherenkov counters have achieved a charge resolution of 0.25 charge units (cu) at $_{79}$Au (Kertzmann, 1987). We have also achieved excellent charge resolution in ionization chambers at these high charges. However, solid dE/dx counters offer significant advantages if they can be shown to have adequate charge resolution since they are more compact, thus allowing a large geometrical factor. In addition, they do not require a pressure vessel. Solid scintillator dE/dx detectors have not previously been used in UH experiments at least in part because of "scintillator saturation" which occurs for heavily ionizing particles. This saturation is believed to result from nonradiative deexcitation reactions of the excited scintillator base polymer π-electrons which occurs most strongly in the high excitation density "core" region of the energy deposition (Voltz, et al., 1966, and Salamon, et al., 1982). These reactions are of the form

$$X^* + X^* \rightarrow X^{**}$$

$$X^{**} \rightarrow X + \Delta E$$

where X* is an excited base polymer (usually Polyvinyltoluene or Polystyrene) π-electron, X** is a doubly excited π-electron, and ΔE is the energy of deexcitation which is disipated nonradiatively. The Voltz model for scintillator saturation predicts that after the core region of the energy deposition becomes completely saturated, the light emission dependence on charge returns to a Z^2 proportionality, as it is for low energy deposition before core saturation becomes significant.

Additionally, it is possible that saturation can be reduced by lowering the excitation density, thus reducing the nonradiative deexcitation reactions. This can be done by selecting scintillator which has a reduced excitation density such as acrylic or glass scintillator (Tarle, 1991). It is also possible that the primary scintillation dye participates in these quenching reactions. If that is the case, then a scintillator with lower (or higher) primary dye

© Dublin Institute for Advanced Studies • Provided by the NASA Astrophysics Data System

1991ICRC....2..511B

concentration than is normally used might exhibit less saturation. Because of the potential advantages of scintillator we decided to measure the resolution obtainable in scintillator for high-Z nuclei and, in particular, to study scintillators which might exhibit less saturation than normal scintillators.

2. Experiment--We selected two types of scintillator for our experiments; the first type was NE-114 (thickness 1.10 cm) which has a factor of 6 lower primary dye concentration than NE-110, and the second type was Polycast acrylic scintillator (90% acrylic and 10% naphthalene; thickness 0.665 cm) which should have a much lower excitation density than NE-110 since there are rougly 10 times fewer pi-electrons available for excitation. Only the naphthalene participates strongly in the scintillation process since acrylic molecules do not have any π-electrons. The acrylic is therefore a less efficient light emitter than Polyvinyltoluene based scintillator. Since resolution in scintillator is not photon limited, it was thought that the use of a lower efficiency scintillator such as acrylic could result in improved resolution owing to reduced saturation, even though the amount of light emitted is reduced.

The scintillator detector was placed at the rear of a detector stack used to measure interaction cross-sections for high-Z nuclei (See paper OG 8.3.4). The two scintillator types were placed in the same light collection box for exposure in different runs. Fig. 1 shows a cross sectional view of the detector stack: I-1, I-2, I-3, and I-4 are ion chambers; C-1, C-2, and C-3 are Cherenkov counters; MW-1 and 2 are multi-wire proportional chambers; and S is the plastic scintillator detector. A target (T) was placed after I-1 to fragment the beam. The charge and energy of the fragments were determined using the Cherenkov counters and ion-chambers as described in Paper OG 8.3.4.

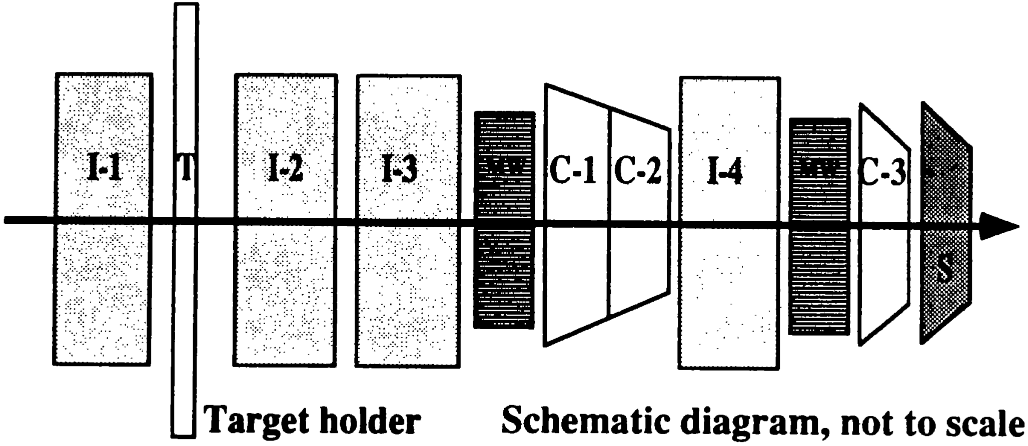

Fig. 1--Instrument Cross Section

Beams of $_{47}$Ag nuclei with energy 1200, 1000, and 650 MeV/n and interaction fragments formed as the primary beam penetrated through the target were used for this test.

3. Results--Figs. 2a and b show cross plots of NE-114 and acrylic scintillator, and Cherenkov signals taken for $_{47}$Ag nuclei and its interaction fragments. Individual charges are clearly resolved down to about Z=31 for both types of scintillator tested. Points on the plot extending down from the diagonal are particles interacting in the scintillator which could not be removed from the data since the scintillator was the last detector in the stack. Fig. 3a and b are histograms of the NE-114 and acrylic scintillator signals. In these plots, only 1 in 32 $_{47}$Ag nuclei have been included so that the Z=46

© Dublin Institute for Advanced Studies • Provided by the NASA Astrophysics Data System

1991ICRC....2..511B

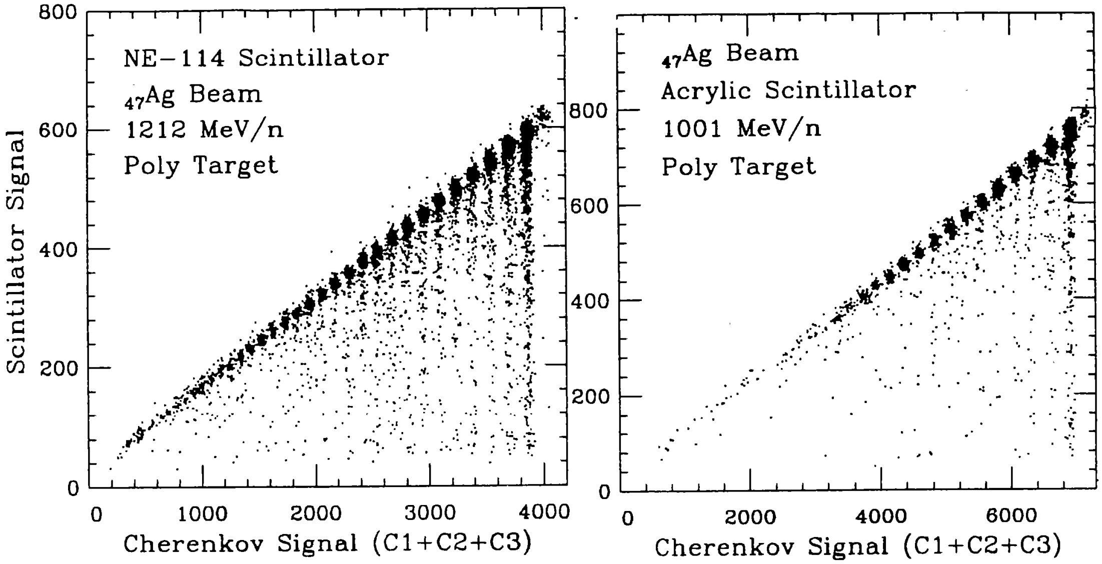

Fig. 2-- a)NE-114 and b) Acrylic scintillator signal vs. Cherenkov plots.

and 47 peaks would be approximately equal in size. The charge resolution standard deviations obtained from the full-width at half-maximum of the Z=47 peak (after selecting Z=47 events by taking a Cherenkov cut) are 0.24 and 0.28 cu for NE-114 and acrylic scintillator respectively. The breadth of the peak included some events which interacted in the sctintillator, thus artificially broadening the resolution. It should also be noted that the NE-114 is a factor of 1.7 thicker than the acrylic scintillator.

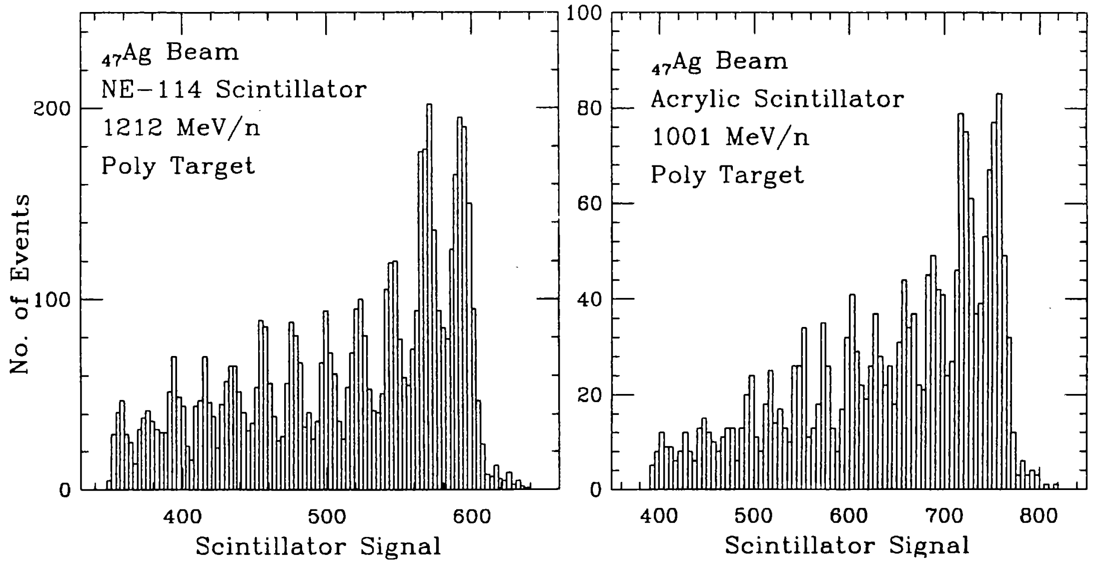

Fig. 3--Histograms of scintillator signals from a) NE-114 and b) Acrylic scintillator.

The signal peaks of the fragmented nuclei can be used to study the light emission as a function of energy deposition in scintillation over the charge range from Z=34 to 47. The energy of each particle as it traversed the scintillator was calculated using the thicknesses of material in the detector. Fig. 4a shows a plot of the scintillator signal vs. dE/dx for NE-114 and acrylic

© Dublin Institute for Advanced Studies • Provided by the NASA Astrophysics Data System

1991ICRC....2..511B

scintillator with beam energies 1212 and 1001 MeV/n respectively. We see that to a very good approximation the signal is linear with dE/dx for both types of scintillator over the full charge range. (It should be noted that we have not attempted to make corrections for the small increase in peak position resulting from light interaction fragments accompanying the heaviest interaction fragment.) In Fig. 4b we have normalized the data for the two scintillator types by multiplying the lowest Z acrylic point by a factor to make it equal to the NE-114 point for the same dE/dx. We see that the slopes are essentially identical. Thus, on the basis of linearity for the charge and energy range studied, there is no significant difference between the two scintillator types. Neither scintillator appears to exhibit saturation resulting in nonlinear behavior in this energy deposition range.

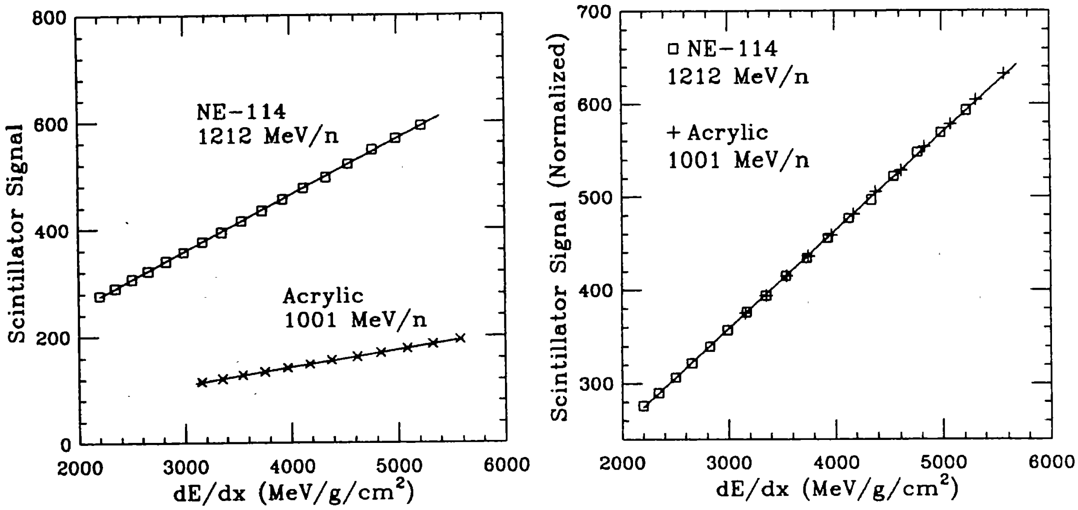

Fig. 4--a) Scintillator signal vs. dE/dx for NE-114 and acrylic scintillator and b) signals normalized at lowest peak in acrylic.

4. Conclusions--We have demonstrated that a charge resolution of about 0.25 cu can be obtained using plastic scintillator over the charge range from $_{31}$Ga through $_{47}$Ag. The resolution of NE-114 was found to be slightly better than the acrylic scintillator tested, but the NE-114 tested was also thicker than the acrylic. The scintillation light emitted as a function of energy deposition was shown to be linear and to have nearly identical slopes for both scintillator types.

Plastic scintillator shows great promise for use in the detection of UH cosmic rays. Additional studies are required to determine its performance in the Uranium charge region.

5. References

Binns,W.R., et al. (1989) Ap. J., 346, 997.
Kertzmann, M.P. Thesis (1987) University of Minnesota.
Salamon, M.H., and S.P. Ahlen (1982) Nucl. Inst. and Meth., 195, 557.
Voltz, R. , J. Lopes da Silva, G. Laustriat and A. Coche (1966) J. Chem Phys.45, 3306.
Tarle, G., (1991) Private Communication.

6. Acknowledgements: This work was supported in part by NASA grants.

© Dublin Institute for Advanced Studies • Provided by the NASA Astrophysics Data System