ISTITUTO NAZIONALE DI FISICA NUCLEARE

Sezione di Milano

INFN/TC-85/8
10 Giugno 1985

R.Bonetti, E.Fioretto, G.Marcazzan and A.Moroni:

A BRAGG CURVE IONIZATION CHAMBER FOR ACCELERATION MASS SPECTROMETRY

Servizio Documentazione
dei Laboratori Nazionali di Frascati

INFN - ISTITUTO NAZIONALE DI FISICA NUCLEARE
Sezione di Milano

INFN/TC-85/8
10 Giugno 1985

A BRAGG CURVE IONIZATION CHAMBER FOR ACCELERATOR MASS SPECTROMETRY

R.Bonetti, E.Fioretto, G.Marcazzan
Istituto di Fisica Generale Applicata dell'Università di Milano

INFN, Sezione di Milano

and

A.Moroni
INFN, Sezione di Milano

ABSTRACT

An ionization chamber based on the Bragg curve spectrometry method to be used as the final detector in an accelerator mass spectrometry system is described. The first tests with a Cl beam give energy resolution of 1% and Z resolving power of 72 at Z=17.

1. - INTRODUCTION : The Accelerator Mass Spectrometry Method

The need for measuring low isotope concentrations in samples of archeological (^{14}C), geological (^{10}Be, ^{26}Al, ^{36}Cl, ^{129}I) and cosmogenic (^{10}Be, ^{26}Al) interest was recently satisfied by the development of a new ultra-sensitive technique, Accelerator Mass Spectrometry (AMS).

Briefly, this method[1] uses a nuclear physics particle accelerator (a cyclotron or more frequently a tandem) as a mass spectrometer. The beam obtained via a sputtering ion source from the sample being studied is accelerated to the analysing magnet, which selects the particles with a given mass and charge. One might therefore expect that it would be enough to have a simple device just to count the particles selected by the particle accelerator in order to find the concentration of the isotopes of interest after comparison with a "standard" sample. Unfortunately, due to the finite resolution of the analysing magnet and the ultra-low concentrations that must be dealt with (10^{-10} - 10^{-15}), there could be considerable contaminations from the abundant stable isotopes as well as that of possibly interfering isobars. In the case of ^{36}Cl for example, interference is to be expected from $^{35,37}Cl$ (which would pass the analysing magnet with slightly different energies) and ^{36}S.

This means a device must be used that has an appropriate energy and charge resolution, possibly supplemented by mass discrimination.

Heavy-ion nuclear physics for many years has been using a number of such devices with different advantages and disavantages. For our purposes the detector should be set at 0° in order to directly analyze the heavy ion beam made up of several MeV/amu energies. This rules out semiconductor detectors because of the strong radiation damage they would suffer.

Gaseous detectors instead have the advantage of being insensitive to radiation damage, of costing very little and of being capable of detecting ions of different mass and energy through simple variation of the gas pressure.

2. - THE MILANO BRAGG IONIZATION CHAMBER

2.1. - The Bragg curve ionization chamber

Among ionization chambers, the most promising seem to be the recently developed ones[2,3] having the direction of the electric field parallel to the ionization track.

These detectors are based upon precise measurement of the ionization curve (the Bragg curve) and therefore, in principle, can completely identify the ion and measure its energy without the help of subsidiary information (i.e. a time of flight and a ΔE measurement) obtained from other devices. In fact, from the Bragg curve one can get the range (from the length of the track), the energy (from the integral of the specific ionization over the track), the specific energy loss (from the specific ionization at the beginning of the track) and the Bragg peak (from the maximum amplitude of the specific ionization at the end of the track).

While this last signal is proportional only to the atomic number and therefore makes possible unambiguous measurement of Z, the ion mass can be obtained by appropriate elaboration of the remaining information[3].

Typical resolutions obtained with such devices are 0.4% for E, a Z resolving power ~80 in the region Z=15 and a mass resolving power ~25 in the A=30 region[3,4].

These characteristics should make the Bragg curve ionization chamber suitable for our purposes. The detector described below will in fact be used for the AMS measurement of samples up to ^{36}Cl (MICLOS experiment at LNL's Tandem) as well as for the detection of particles up to ^{12}C produced in light heavy-ion induced reactions (PIDIP experiment supported by INFN).

2.2 - Detector lay-out

A schematic cross-sectional view of our axial ionization chamber is shown in Fig. 1.

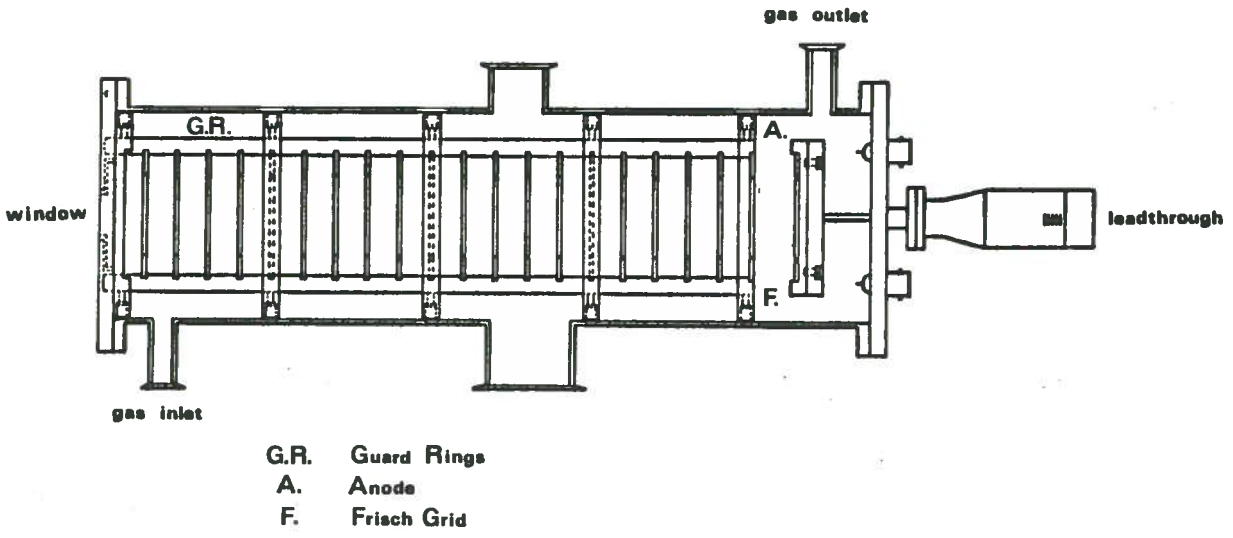

FIG. 1 - Cross sectional view of the Milano Bragg ionization chamber.

The detector was built from a stainless steel tube 380 mm long and with Ø = 103 mm. The entrance window has Ø = 20 mm and is made of mylar, 1.5 μm thick, glued on a stainless steel frame. The catode is a high transparency grid obtained by soldering Cu-Be wires, Ø = 100μm, 1 mm apart on a Cu frame and 1 mm from the entrance window. The Frisch grid is a 45 wire/inch mesh with 88% transparency, glued on a stainless steel ring 1 mm thick.

The voltage between the Frisch grid and the cathode was divided by a resistor chain made of 19 10 MΩ resistors connected to 19 guard rings. These are made of stainless steel 1 mm thick, have an inner diameter of 40 mm and are 14 mm apart. The 19 guard rings and the Frisch grid are supported by three longitudinal teflon bars, 120° apart.

The cathode-grid distance was set at 30 cm, while the grid-anode distance was fixed at 17 mm, but could be varied from 5 to 25 mm by means of an ultra-vacuum leadthrough, to allow experimental optimization from the outside.

The filling gas is the P-10 mixture (Ar 90% + CH_4 10%). The gas is continually replaced to avoid contamination by a two-valve flux system.

In our test runs with beams of ^{36}Cl of 93.7 MeV we used p = 155 mbar.

Once the pressure is set, the grid voltage is given by the condition that the reduced electric field E/p be such that the electron drift velocity reach its maximum value.

In our case we had E/p = 0.3 V/cm·Torr, which gave a grid voltage of 1200 V. The anode voltage was 1400 V.

3. - EXPERIMENTAL TESTS

The first test runs were made at the LNL XTU Tandem. The detector was mounted at 0° on the -50° beam line.

Since in these first runs we were interested mainly in measuring the E and Z resolutions, the electronic apparatus was very simple. The E information was obtained from an Ortec Spectroscopy Amplifier with a time constant of 8 μsec, sufficient to integrate the anode signal (the maximum drift time being 6 μsec). The Z information was obtained from a second amplifier, connected in parallel, with a time constant of 0.5 μsec, therefore of the order of the electron transit time between the grid and the anode. The two pulses were sent to the PDP computer and counted when were in coincidence.

The tests were made with a Cl beam obtained from a ^{36}Cl enriched sample (the ^{36}Cl/Cl concentration was $\sim 10^{-11}$). The beam was first optimized working with mass 35; subsequently the magnet parameters were switched on to mass 36 in order to let the mass 36 pass while inhibiting the abundant masses 35 and 37. Fig. 2 shows a typical Z-E matrix obtained in this way, while Figs. 3 and 4 show the E and Z projections. The measured energy resolution was 1%; the measured Z resolving power was $Z/\Delta Z \sim 72$ for Z = 17.

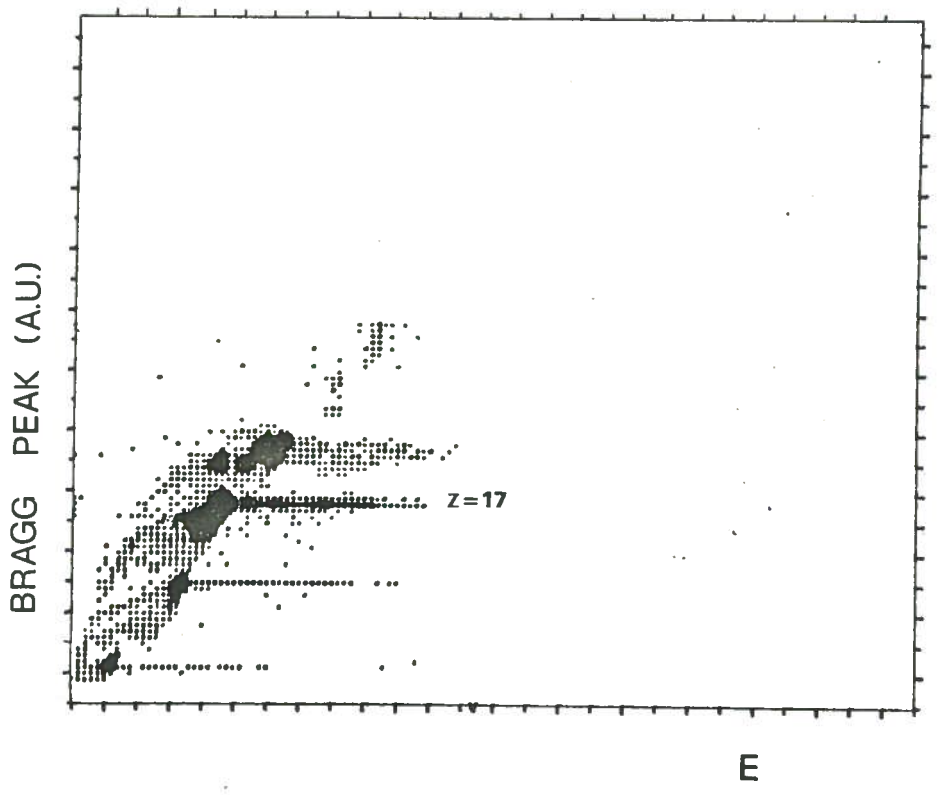

FIG. 2 - Bragg peak (Z) vs. E scatter plot obtained from a Cl sample.

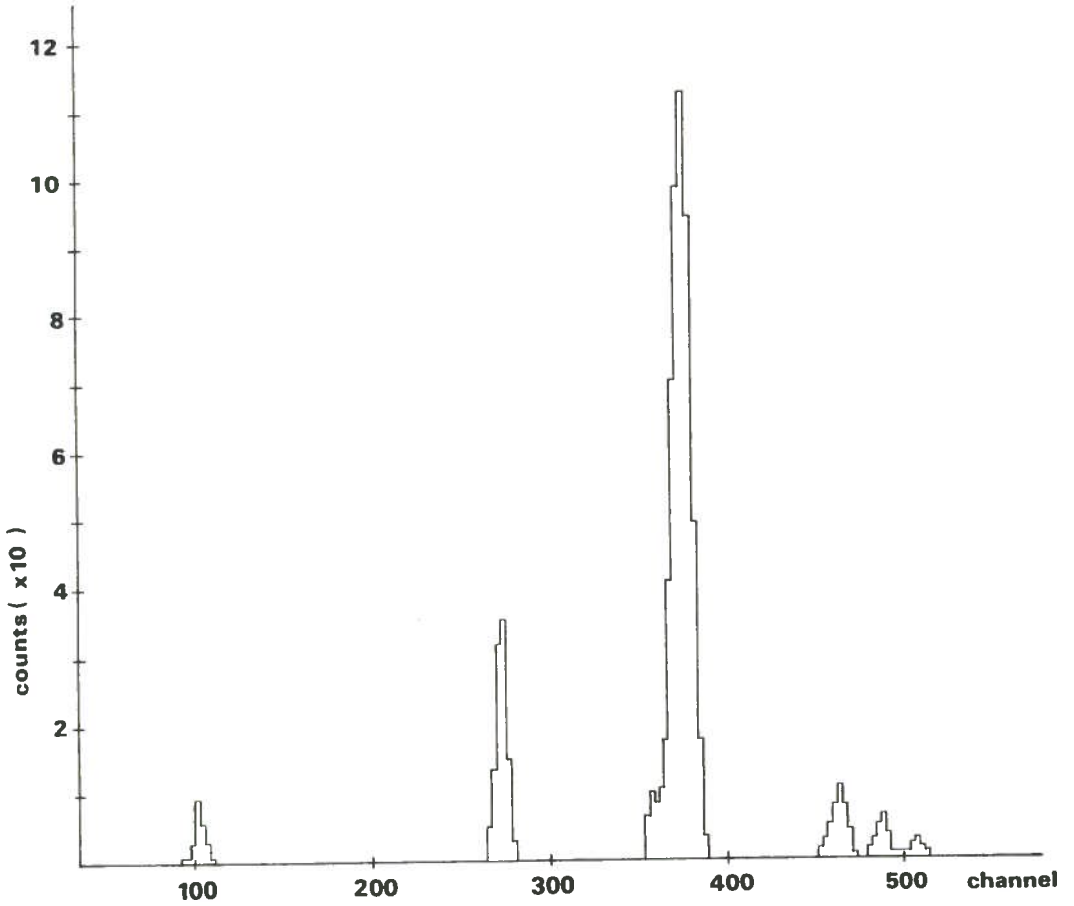

FIG. 3 - Projection of the E axis of the scatter plot of Fig. 2. The E resolution is 1%.

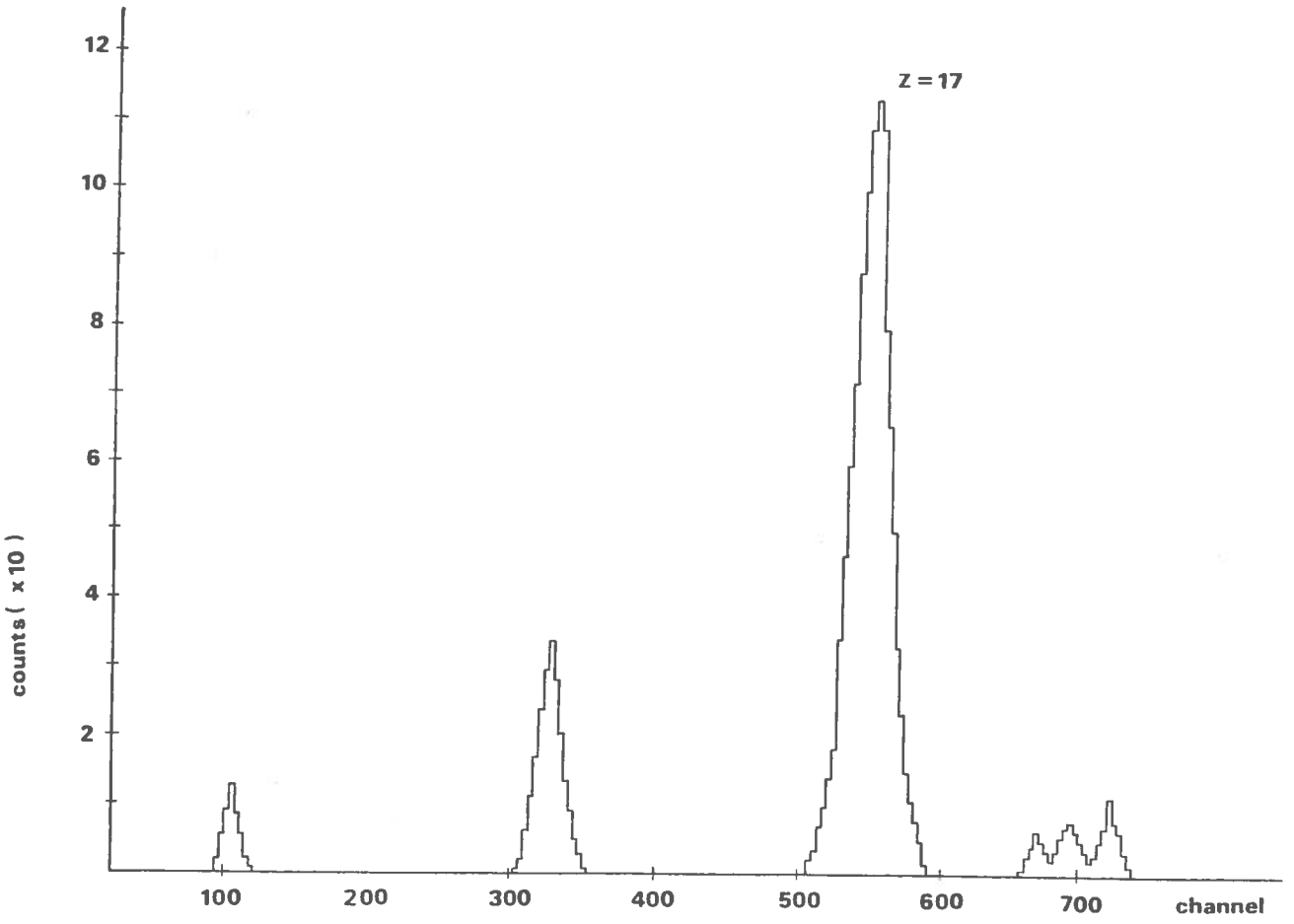

FIG. 4 - Projection of the Bragg peak axis of the scatter plot of Fig. 3. The Z resolving power is 72 for Z=17.

4. - CONCLUSION

The Bragg curve ionization chamber described herein has proven to work satisfactorily.

Its characteristics should be appropriate for the AMS measurement of isotopes up to ^{36}Cl. It should also be suitable as a detector of reaction products from heavy ion induced reactions. In this case, a mass discrimination is also needed, which should be supplied by the range and energy loss information given by the Bragg curve.

REFERENCES

(1) - J.C.Rucklidge, N.M.Evensen, M.P.Gorton, R.P.Beukens, L.R.Kilius, H.W. Lee, A.E.Litherland, D.Elmore, H.E.Gove and K.H.Purser, Nuclear Instr. and Meth. 191, 1 (1981).

(2) - C.R.Gruhn, M.Binimi, R.Legrain, W.Pang, M.Roach, D.K.Scott, A.Shotter, T.J.Symon, J.Wonters, M.Zisman, R.De Vries, Y.C.Peng and W.Sondheim, Nuclear Instr. and Meth. 196, 33 (1982).

(3) - A.Moroni, I.Iori, Li Zu Yu, G.Prete, G.Viesti, F.Gramegna and A.Dainelli, Nuclear Instr. and Meth. in Physics Research 225, 57 (1984).

(4) - A.Moroni, I.Iori, G.Prete, F.Gramegna and G.Viesti, Lett. Nuovo Cimento 40, 321 (1980).