A SIMPLE PROBE FOR THE RELATIVE MEASUREMENT OF BEAM ENERGIES

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Summary

The method presented is used as a check on the energy adjustment and stability of extracted protons from a variable energy cyclotron. Using the specific properties of the energy loss of charged particles in matter, the relative energy can be detected with an accuracy better than 0.1 MeV for 25 MeV protons within a few minutes. The technique is cheap, simple to realize and applicable also to other energetic ions.

Introduction

The energy of accelerated charged particles is one of the essential parameters in the radioisotope production processes, proton beam therapy and in many scientific experiments. Thus several energy measurement techniques are in use, for example a Time-of-Flight facility as described in [1]. Methods for the absolute measurement of the beam energy in general consist of a complicated and expensive equipment. The required floor space may also be a problem. The large-scale facilities are undesirable to perform a simple task of controlling and adjusting the energy to a required value. In our case of irradiating machine parts for wear measurements [2,3,4], the beam energies have to be reproduced with an accuracy of about 0.1 MeV.

The probe described below consists of three separate degrader foils situated in the beam, with two foils connected to thermocouples. If the thicknesses of the foils are properly chosen, the temperature difference of two foils is strongly dependent on variations of the initial particle energy. The required space in the beam line is comparable to that of a beamstop.

Experimental method

Fig.1 shows a schematic view of the probe consisting essentially of monitor-foil (1), degrader (3) and measuring-foil (2). After losing only a small amount of energy in the monitor-foil and significantly more in the degrader, particles are stopped in the measuring-foil. The energy loss of protons in copper is given in fig.2 for two different initial proton energies. A small variation in the initial proton energy is associated with large energy changes in the measuring-foil if particles emerging from the degrader have energies close to the maximum stopping power. For example, a variation in the initial proton energy of 4% corresponds to a change of 85% in the energy absorbed by the measuring-foil, as indicated in fig.2. The absorbing power is the product of the beam current and the energy loss in a target. Thus measurements of energy variations are possible only, if the beam current is constant. The monitor-foil and the measuring foil are each connected to a thermocouple. The relative energy measurement is carried out by regulating the beam current to a constant temperature of the monitor-foil. The absorbing power of the foil

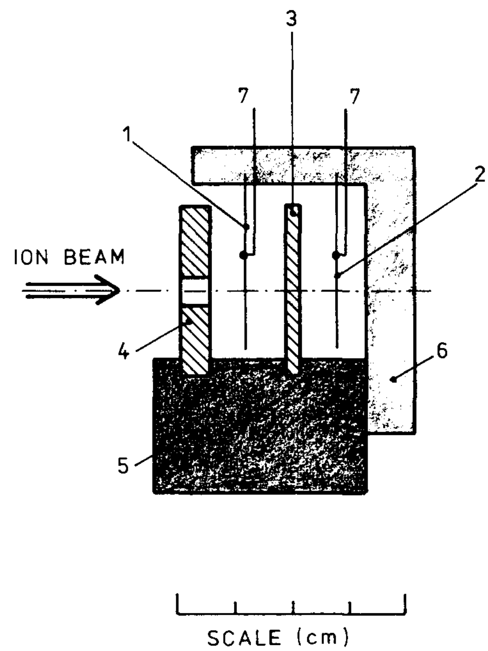

Fig.1: Schematic view of the probe.

(1) monitor-foil (Cu), (2) measuring-foil (Cu), (3) degrader (Cu), (4) collimator, (5) support leg, (6) support frame, (7) thermocouples.

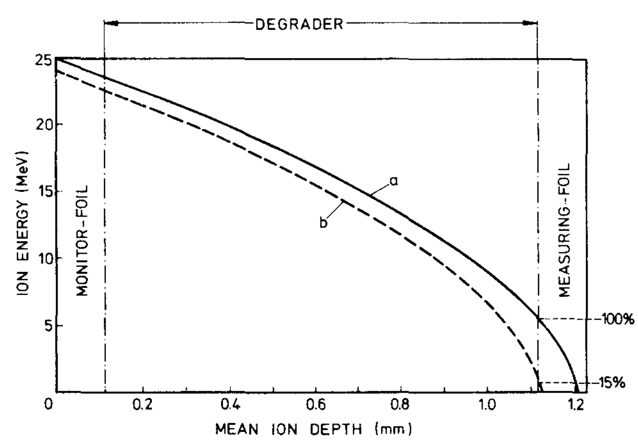

Fig.2: Energy loss of protons in copper. E_0 = 25 MeV (a), E_0 = 24 MeV (b).

facing the beam is sensitive only to beam current fluctuations because the stopping power of charged particles with sufficiently high energy is insensitive to energy variations (s.fig.2). As expected, a linear dependence of the temperature on the beam current was measured for both of the foils. If the temperature of the monitor-foil is constant, then the temperature of the measuring-foil is a sensitive indicator of deviations from the desired particle energy.

Calibration.- In general the relation between energy variation and the temperature of the measuring-foil has to be measured using any arbitrary facility for the absolute measurement of the beam energy. We have used a 25.2 MeV proton beam extracted from the fixed energy Isochronous Cyclotron in Karlsruhe. Precise variation of particle energies was achieved by placing in front of the probe copper foils having well chosen thicknesses. A section of the recorder output obtained during calibration is illustrated in fig.3. It shows sensitive dependence of the measuring-foil temperature on variations of the beam energy. The calibration curve is given in fig.4.

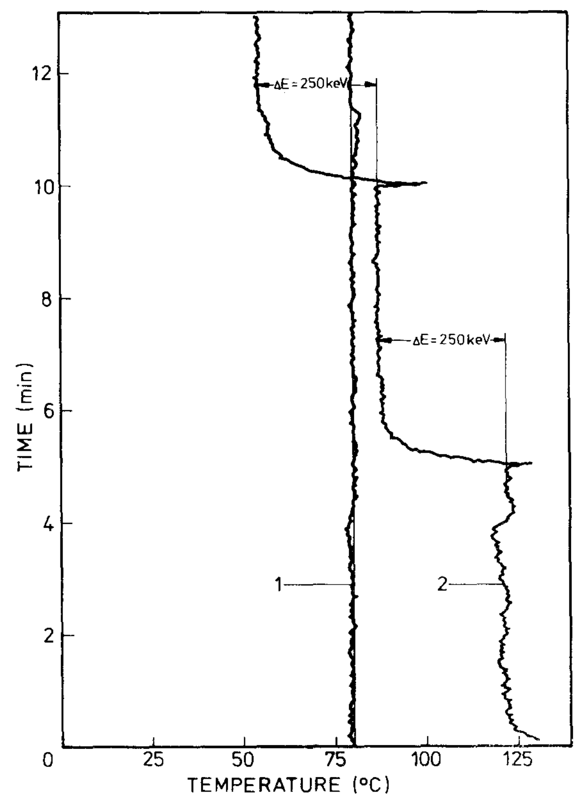

Fig.3: Recorder output obtained during calibration.
(1) Monitor-foil, (2) measuring foil

As indicated in fig.4, the calibration curve was measured three times on different dates and a good reproducibility is demonstrated. The accuracy of determining a deviation from the desired energy E_0 is estimated to be ± 50 keV in a measurement range of about 1 MeV.

The calibrated probe is used in a routine way for checking of the energy adjustment of 25.2 MeV protons extracted from the CP42H machine in Karlsruhe. The degrader of the probe was chosen to be 0.057 mm thicker than for the calibration procedure in order to locate the operating level in the sensitive center of the calibration curve. In our case, the probe is operated in air, since in general the irradiations of machine parts are not carried out in vacuum.

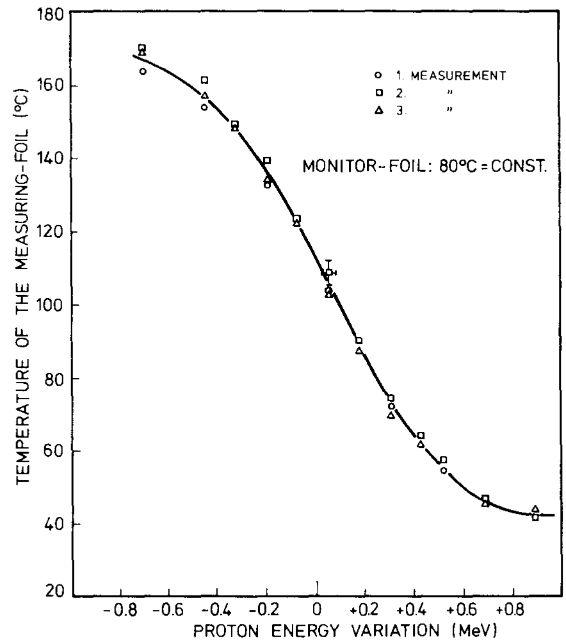

Fig.4: Calibration curve for protons E_0 = 25.2 MeV
Temperature of the monitor-foil: 80°C = const.
(Beam current: 1.7 μA)

It is expected, that the sensitivity of the probe will decrease slightly with increasing initial particle energy, because of the growing longitudinal energy straggling of the beam reaching the measuring-foil. The probe is used to monitor proton beams. There is, however, no apparent reason why it should not be also suitable for other energetic ions as long as foils of adequate thicknesses are used.

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