# Monolithic Si telescope @ CMAM

*The objective of this practice is to familiarize the student in the use of a silicon detector telescope to detect charged particles. To achieve this objective, it is proposed first to acquire a spectrum from an alpha source and perform the energy calibration of the spectrum. Next, to do a Rutherford scattering study using two different isotopes of Mg and see if we are able to separate the two isotopes in a mass-plot E vs $\Delta$E for different energies.*

## Introduction

A novel monolithic detector telescope with its associated digitized electronic system will be tested. The telescope consists of 64 x 9 mm$^2$ monolithic devices over a surface of 5x 5 cm$^2$. The 128 channels of spectroscopy electronics are connected to 4x MDPP32 digitizer modules. The system first must be tested with pulser and alpha sources in the laboratory, calibrated, and finally to see the possible separation of heavy ions. This is easily done by Rutherford scattering of ions on Au. For a specific experiment at the DRAGON facility at TRIUMF, we needed the separation of Na, Mg and Al beams at different energies. We will perform this experiment using two Mg isotopes (23, 26) at different energie s.

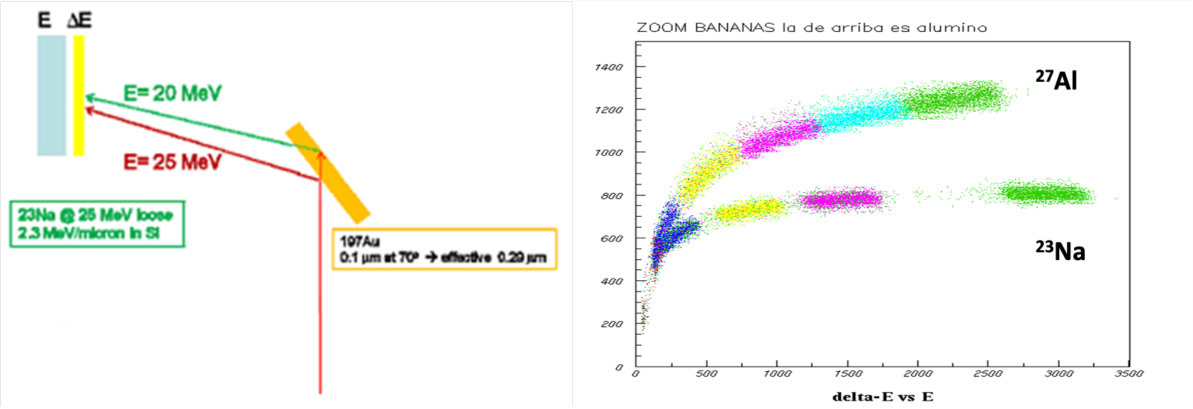


Figure 1. Schematic of the experiment and expected typical result (we are not using these isotopes!)

The study of excited states of unbound light nuclei includes the simultaneous detection of several charge particles emitted with very low energy. These puts severe constrains on the detection system to be used. For the detectors, high segmentation is needed to be able to detect several coincident particles, very thin dead layers to reduce the cut-off energy in combination with thin detectors to minimize sensitivity to beta and neutral particles.

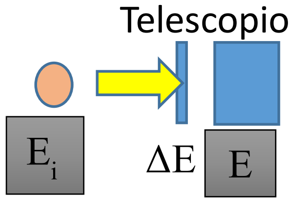
For particle mass identification different techniques can be applied, time of flight, pulse shape analysis, or telescopes. At low energy heavy particles are easily stopped in the ΔE detector, this makes the pulse shape technique very difficult to apply due to very weak signal and high noise level. One approach is to use extremely thin (1 µm) ΔE detectors in monolithic assembly on a thick (500 µm) E detector, both doped into the same wafer, with common ground in the interior. The energy losses ΔE in a Si thin thickness of Δx

$$\Delta E = C\frac{AZ^2}{E_i} \approx C\frac{AZ^2}{\Delta E + E}$$

Where A, is the mass of the ion and Z the charge and Ei

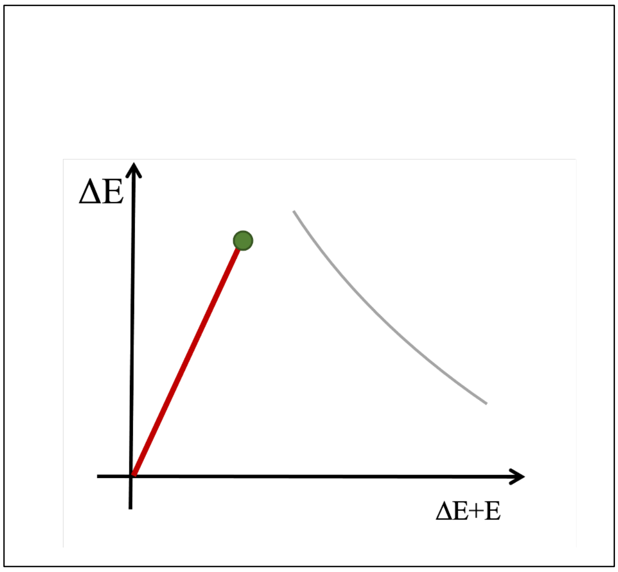
Energy deposited in Δx

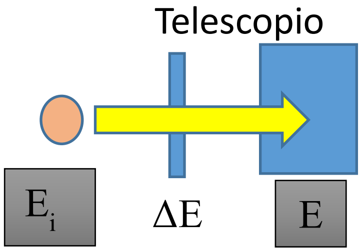
**Case 1:** The incoming ion has low energy and gets fully deposited in the detector

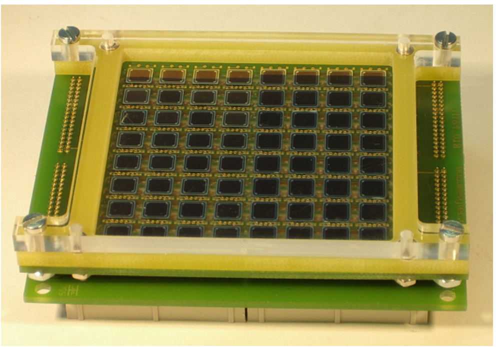


**Case 2:** the incoming ion has energy enough

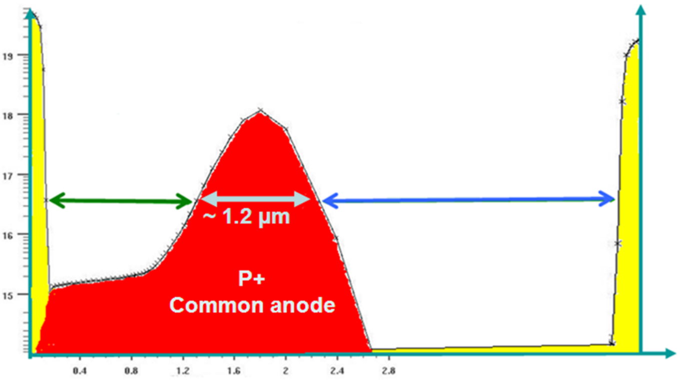
to traverse the thickness Δx of the Si detector



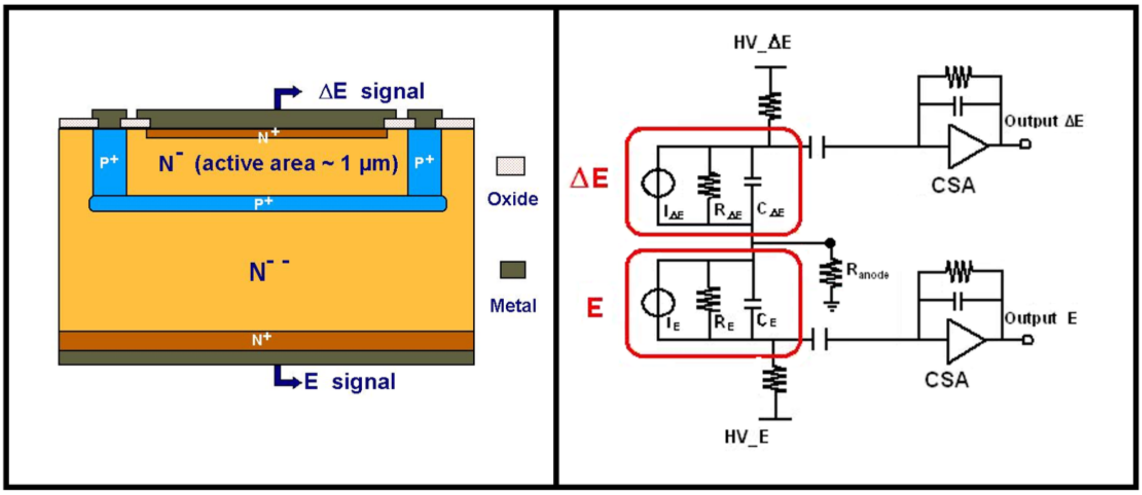




a) Photo of the monolithic detector.



b) Doping structure of the Si wafer.



c) Electronic equivalent circuit of the monolithic detector.

Figure 2. Detector details.

Table 1: Energy loss of charged particles (p, d, t, and $\alpha$) at different energies in ΔE detectors of thickness 1 µm / 3 µm.

| **T (keV)** | **130** | **150** | **200** | **500** | **1000** | **1500** | **2000** | **5000** |
|---|---|---|---|---|---|---|---|---|
| **Particle** | Energy loss in 1-micron/3-micron silicon | | | | | | | |
| **Proton** | 121/130 | 128/150 | 120/200 | 66/219 | 42/131 | 32/98 | 27/80 | 14/41 |
| **Deuteron** | 108/130 | 118/150 | 133/200 | 96/333 | 64/200 | 50/153 | 41/126 | 22/68 |
| **Tritium** | 96/130 | 105/150 | 123/200 | 118/381 | 80/253 | 63/195 | 54/163 | 30/89 |
| **Alpha** | 130/130 | 150/150 | 188/200 | 343/500 | 330/950 | 285/935 | 251/806 | 146/448 |

## Objectives

The main objective of this exercise is to introduce the student to the concepts of particle telescope techniques for the identification, and separation of different masses.

## Materials

1. Vacuum chamber
2. Monolithic Si ΔE-E telescope
3. Oscilloscope
4. MVLC controller
5. MVME Mesytec acquisition software
6. Radioactive alpha sources

| Isotope | α-Energy | % |
|---|---|---|
| $^{148}$Gd | 3.180 | 100 |
| $^{244}$Cm | 5.763 | 23.3 |
| | 5.805 | 76.7 |
| $^{239}$Pu | 5.105 | 11.5 |
| | 5.143 | 15.1 |
| | 5.155 | 73.4 |
| $^{241}$Am | 5.388 | 1.4 |
| | 5.443 | 12.8 |
| | 5.486 | 85.2 |

## Laboratory procedure

1. Observe/open the vacuum chamber.
2. Place the radioactive source to calibrate the telescopes.
3. Close the chamber and pump vacuum.
4. Bias the detectors while checking the signals in oscilloscope.
5. Take a spectrum and calibrate the detector. To do this, the spectrum must have enough statistics.
6. Open the chamber and remove the sources. Place the Au target. Close chamber.
7. Pump up to 5x10-6 mbar.
8. Open valves.
9. Let the accelerated beam into the chamber.
10. Start acquisition.

## Laboratory report

The report of this practice must include the following:

I. Show a diagram and explain the CMAM accelerator.
II. Give some ideas of the different beamline activities at CMAM.
III. Explain the main characteristics of the monolithic detector.
IV. Present a diagram of the experimental setup in which the function of each element of the DAQ is described.
V. Discuss the experimental setup, vacuum chamber, etc.…
VI. Experimental procedure
VII. Calibration spectra of the two detector stages ΔE and E, you will use the ROOT calibration program provided from the lecture “LAB1-ROOT”.
VIII. Explain the difference in resolution between the ΔE and E stages

IX. Produce ONE mass identification plot including the data for the different isotopes and energies.

## Reports

All reports must be sent to: master.nuclear@iem.cfmac.csic.es
For questions you can contact: olof.tengblad@csic.es, silvia.vinnals@inv.uam.es