Nuclear Measurements and Radioactivity

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Abstract

The initial steps in the data analysis for the calibration of a charged particle detector were reproduced. The signals coming from the ionization chamber and the silicon detectors of the Ring Counter were analyzed for errors and using the $\Delta E - E$ correlation plots the Rutherford cross section was reproduced.

1 Set-Up

The experimental set up for the data analysis consists of GARFIELD + Ring Counter (RCo) system.

The GARFIELD apparatus consists of two drift chambers filled at low pressure (50 mbar) with CF4 gas. They have cylindrical symmetry and are placed back to back with respect to the target.

The two gas volumes are divided in 24 and 21 sectors, respectively, in the forward and in the backward chamber. Each sector is equipped with one micro-strip detectors divided in 4 different collecting zones. They are lodged almost perpendicular to the beam axis and have the function of amplifying the electrical signal and therefore improve the Signal to Noise ratio. Moreover they give the information on the energy loss ΔE of the detected products. Each sector is completed by four CsI(Tl) crystals with photodiode readout which give the information on the residual energy E.

The reaction products cross radially the gas region and stop in the CsI(Tl). Their energy and charge identification is obtained mainly through the ΔE-E technique.

The GARFIELD apparatus was coupled with a Ring Counter detector array. The RCo system is a three-stage annular telescope. The first stage is an Ionization Chambers, divided into 8 sectors, followed by 8 sectors of Si, each of which divided in 8 strips, followed again by 48 (8x6) CsI(Tl) crystals. This high granularity system permits to perform high resolution measurements (both in terms of energy, mass, charge and position).

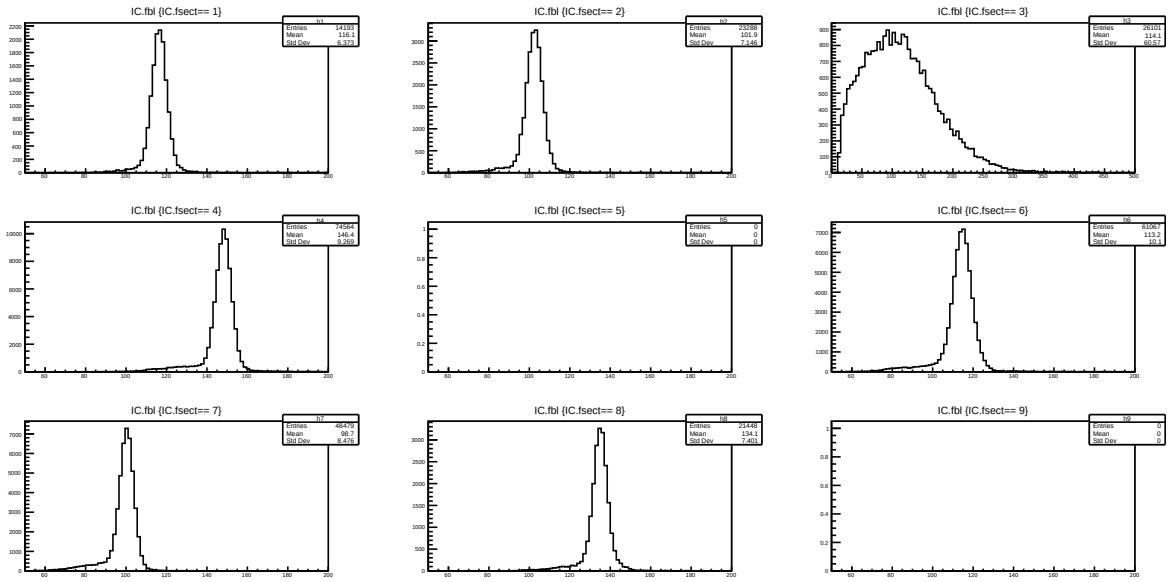

Figure 1: Baselines for the sectors of the ionization chamber (ninth panel to improve visualization)

2 Data Filtering

The data coming from the ionization chamber and the silicon detectors was checked for errors in the baseline measurements and the TCFD. In particular we found no signal coming from:

- Fourth ring - Third sector of the Si detectors
- Fourth ring - Seventh sector of the Si detectors
- Fifth sector of the ionization chamber

Furthermore the third sector of the ionization chamber presented an unexpectedly broad distribution for the baseline, instead of the expected peak, as such it was discarded in the following analysis. In Fig. 1 an example of an expected plot for the baseline and the one for the third sector of the ionization chamber are reported.

In Fig.2 some plot of TCFDs are reported. In this case the plots all presented the expected peaked shape but a gate has been applied to remove the tails present in some cases.

A final gate was applied to remove the events with a multiplicity greater than one, given the presence of a non-negligible fraction of events with multiplicity equal to 2 and not relevant for the analysis (Fig.3).

3 Results

After selecting the events, the $\Delta E - E$ plots were analyzed for every sector-ring combination that was not discarded in the previous paragraph. The resulting plots for the first sector are reported in Fig .4, where for the eighth ring the plot has been magnified on the endpoint of the line related to the isotope used in this case for the calibration, where all the useful information is concentrated.

The spots, corresponding to the full energy of the incoming beam, were integrated to obtain an estimate of the total valid counts for each sector and each ring that were not discarded. The resulting number of count were plotted against the angle in radians formed between the corresponding ring and the beam to verify the expression for the cross section of Rutherford scattering. The polar angle interval covered by each strip is shown in Tab. 1. Values refer to silicon detectors of the RCo

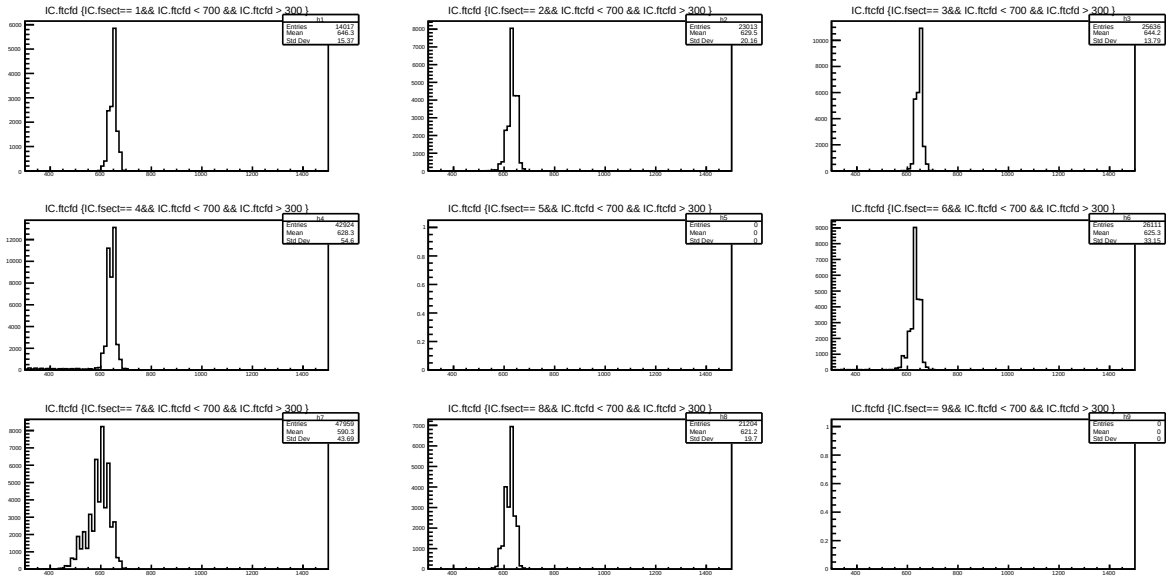

Figure 2: TCDs for the sectors of the ionization chamber (ninth panel to improve visualization)

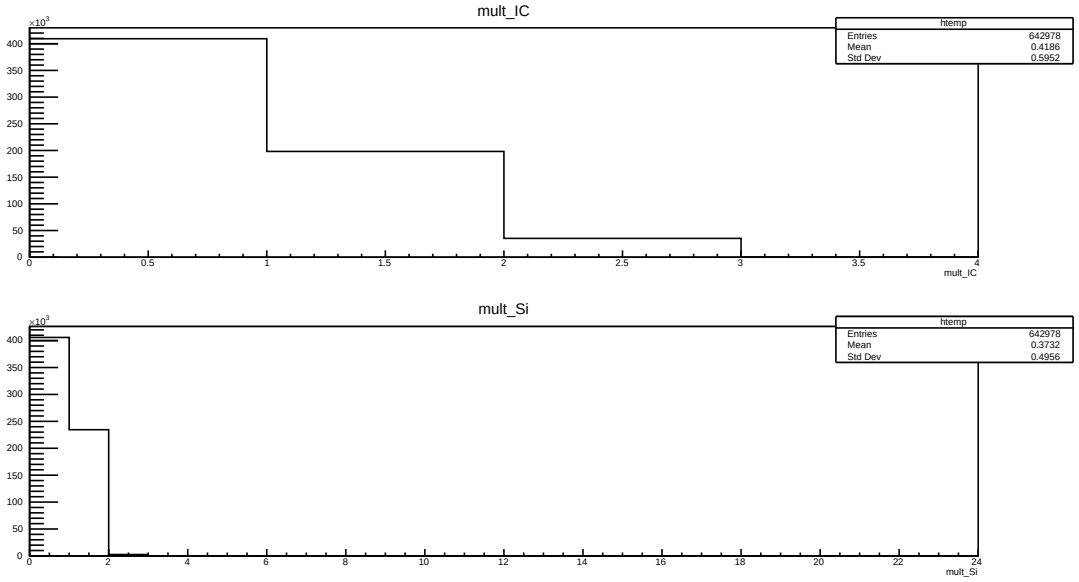

Figure 3: Multiplicity for the measurements of the two detectors

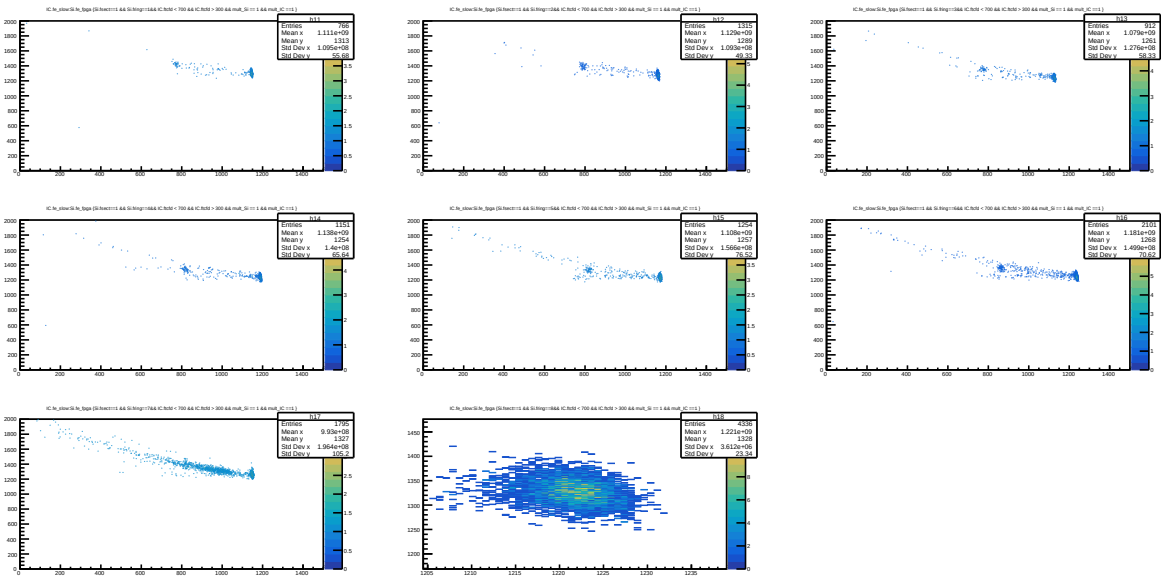

Figure 4: $\Delta E - E$ plots for the first sector with last plot magnified on the relevant information

in the measuring position. For the plot, the mean between the minimum and maximum value was taken. The results are plotted in Fig.5 for the seventh sector and in Fig.6 for the sixth sector.

Strip	**Min angle (deg)**	**Max angle (deg)**
1	15.6	17
2	14.2	15.6
3	12.9	14.2
4	11.5	12.8
5	10.1	11.4
6	8.6	10.0
7	7.2	8.6
8	5.4	7.2

Table 1: Polar strip angles

In all cases the curve $\frac{A}{sin(\frac{\theta}{2})^4}$ was constrained to pass near the first point, being the one with more statistic. As shown, in some cases (S7) the agreement with the typical Rutherford expression is good and the data are compatible with the expression, in other cases (S6) the points at greater angles present a larger than expected number of counts. This has been partially attributed to the missing normalization by the solid angle in the data, needed to account for the presence of holes in the Si detectors.

Finally, as a way to check the symmetry of the system, it was tried to sum the counts of the different sectors corresponding to the same angle in order to try and improve the statistic and thus the agreement of the fit (if a perfect cylindrical symmetry is assumed). The results are reported in Fig.7

The data seems the agree very well with the Rutherford expression at low angles but there seems to still be an underestimation of the counts at higher angles, due to the overestimation in some of the single sectors.

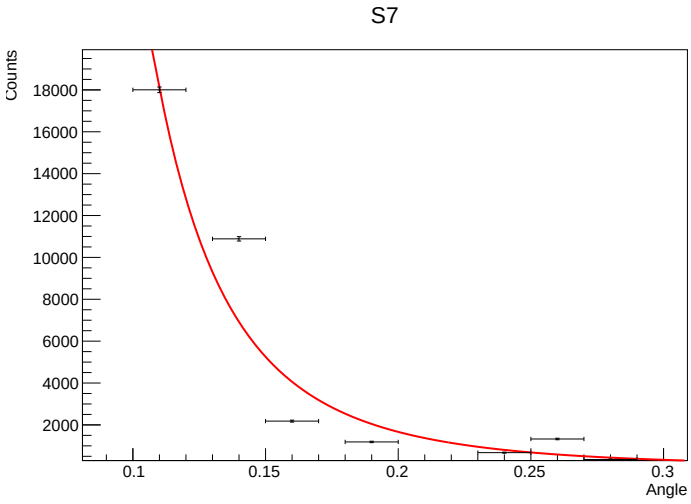

Figure 5: Cross section vs angle for the seventh sector

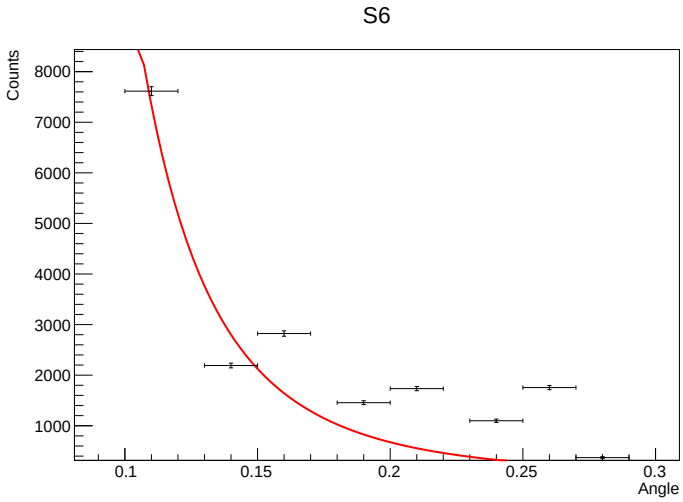

Figure 6: Cross section vs angle for the sixth sector

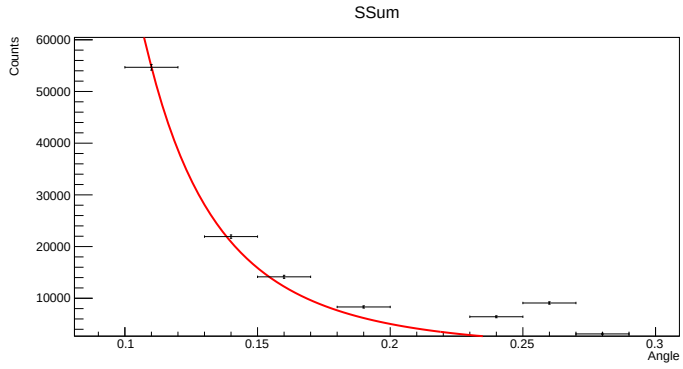

Figure 7: Cross section vs angle, summed over all sectors