Energy response of CsI(Tl) scintillators of the forward RING counter coupled to GARFIELD apparatus

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Abstract

Measurements are proposed concerning the study of the light response of CsI(Tl) scintillators with photodiode readout from the charge and the energy of the detected particle. The aim of these measurements is to calibrate the scintillators of a new ring detector which will be coupled to the Garfield apparatus in an experimental programme concerning the study of thermodynamical observables in heavy ion reactions. As in the case of the CsI(Tl) crystals of the Garfield array, the calibration procedure needs several combinations of projectiles and energies in order to study both the linear and the non-linear part of the light output-energy correlation. Since a pulse shape analysis of CsI signals allows Z and A identification, we ask also different isotopes of H, Li and C beams in order to investigate the limits of the digital processing. At the same time some hints of mass dependence of light output could be investigated.

The request is for 6 days of Tandem beams, divided as follows:

- 4 days for beams of $^{12}C,^{16}O,^{28}Si,^{32}S,^{48}Ti,^{58}Ni$ in the Garfield scattering chamber (Hall III) at energies ranging from 32 to 270 MeV;
- 3 days for beams of $^{1}H,^{2}H,^{6}Li,^{7}Li,^{12}C,^{13}C$ in the sliding seal scattering chamber (Hall I) at energies ranging from 16 to 60 MeV.

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The GARFIELD apparatus was recently improved with a forward RING detector, composed of 16 three-stage (ionization chambers, total transmission Si diodes and CsI(Tl) scintillators with PD readout) telescopes. The $\Delta E - E$ technique applied to the first (second) stage allows to identify the charge (charge and mass) of the reaction products. An example of a $\Delta E - E$ matrix, concerning the measurements of ^{32}S + ^{64}Ni at 15 A MeV, is presented in Fig. 1.

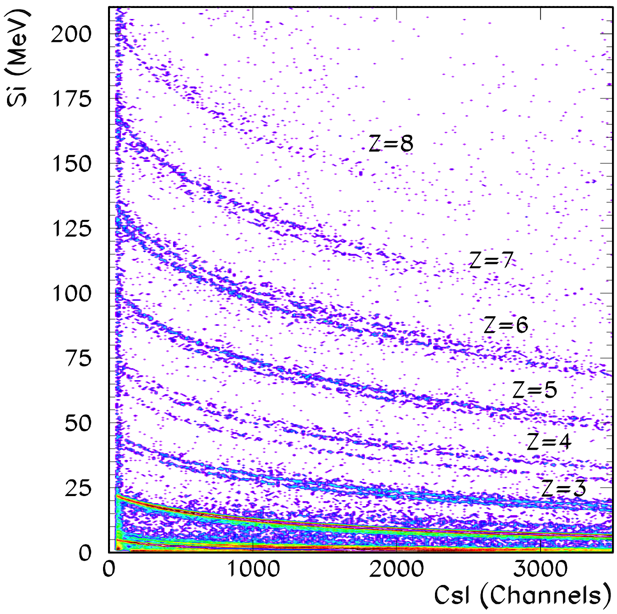

Figure 1: Mass identification in Si - CsI(Tl) matrices. The separation of different charges, indicated in the figure is clearly visible, as well as the separation of different masses for every charge. For charges $Z \leq 2$ see Fig. 3

The response function of both the ionization chambers and Silicon detectors is linear with the energy of the detected ion and therefore their calibration is straightforward. On the other hand, the light output of CsI(Tl) crystals depends, in a non linear way, on the deposited energy and on the atomic and mass number of the incident ion.

It is thus necessary a detailed calibration, similar to the one already performed [3] for the Garfield CsI(Tl) crystals (see Fig. 2).

The easiest method of extracting the total energy, through the measurement of the energy loss and charge and/or mass identification, shows indeed a limit in the energy determination when the energy loss changes very little with the total energy. This can be easily understood from Fig. 3 where part

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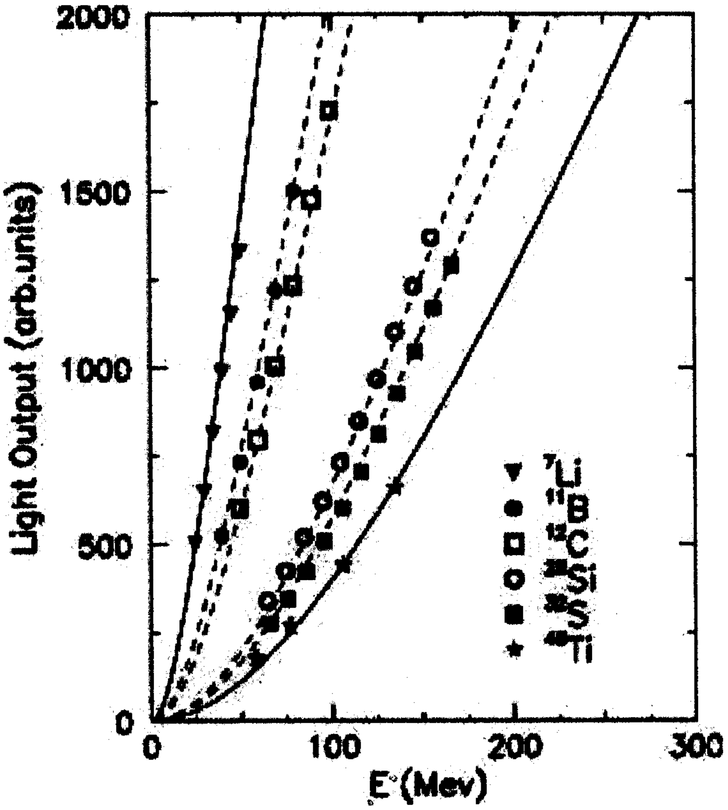

Figure 2: Results of Garfield CsI(Tl) calibration procedure

of the experimental data shown in Fig. 1 are presented, with the ΔE axis calibrated in energy. For a constant value $\Delta E = 6$ MeV (dashed line) the same total energy of 77 MeV would be assigned to α-particles with residual energy from channel 2250 to 2750, with a resulting indetermination of $\sim 20\%$ on the total energy.

The better experimental method to get data reliable for calibrating CsI(Tl) crystals is to detect ions with a well determined value of charge, mass and energy: the elastic scattering on thin $(100\frac{\mu g}{cm^2})$ Au targets of a variety of ions is suitable to this purpose.

The low energy region is very important to investigate since it presents the largest non-linearities. Therefore we propose a series of measurements with Tandem beams up to the maximal reachable energy. To make a reasonable fit to the data with the formula proposed in Ref.[3], we would need 11 beams from protons to ^{58}Ni at $5 \div 8$ energies per beam. The total combinations of beam-energies (see Table I) would be therefore 67.

The energy range we intend to cover for every beam type has been chosen to have calibrations in the energy region foreseen for future experiments, assuming initial energies of $\sim$ 25 $AMeV$ [4].

[4] The value of 25 AMeV is the maximum energy planned for the measurements presented in our Letter of intent "Thermodynamical coordinates of excited nuclear systems"

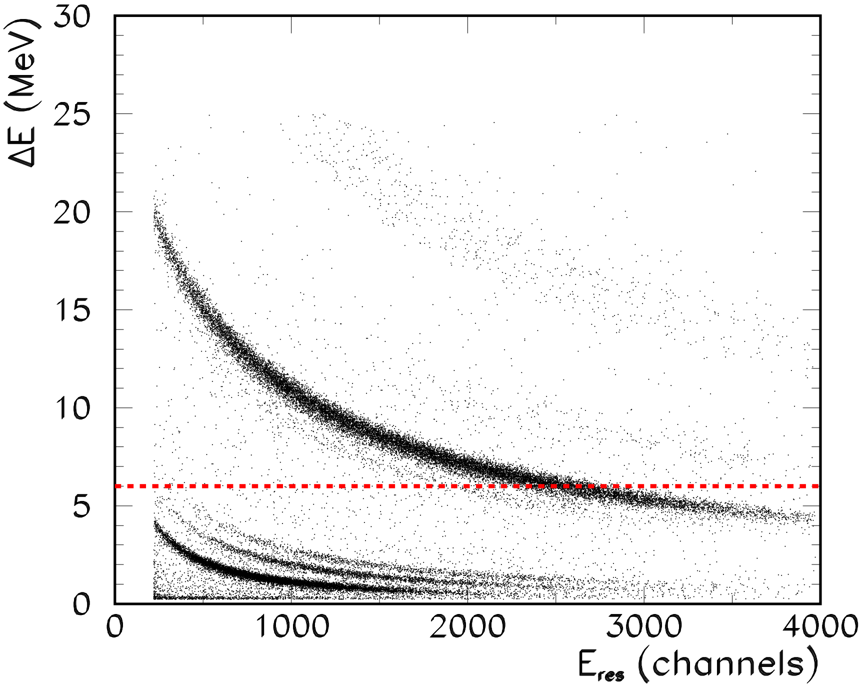

Figure 3: Experimental $\Delta E - E$ matrix. The dashed line is drawn at a fixed value of 6 MeV for the ΔE.

Table I - Plan of beams and energies

N.	beam	from(MeV)	to(MeV)	n. of steps
1	p	16	28	5
1	d	16	28	5
2	^{6}Li	24	55	6
2	^{7}Li	24	55	6
3	^{12}C	32	90	6
3	^{13}C	32	90	6
4	^{16}O	32	120	6
5	^{28}Si	50	175	6
6	^{32}S	50	200	6
7	^{48}Ti	50	230	7
8	^{58}Ni	60	270	8

The first four beams (H and Li isotopes), in our knowledge, cannot be injected in Hall III for radioprotection reasons. Therefore we plan to perform the measurements with beams from Carbon to Nickel in Hall III and the ones with the lighter beams in the sliding seal scattering chamber in Hall I. Some measurements will be repeated in both the experimental configurations (Halls I and III) for normalization purposes.

Since we would like to perform also a test on the homogeneity of the crystal response, we plan to make measurements with the whole crystal and measurements with some diaphragms.

An estimate of the statistics necessary to have good calibration results indicates a time of about 30 minutes for each beam/energy combination. Taking into account a mean time of 3-4 hours to change the beam or the energy in Hall III and 1-2 hours in Hall I (that was the time interval during the calibration of Garfield detectors performed in Hall 1 some years ago), the total beam time would be ≈ 230 hours. If we shift some of the measurements from hall III to Hall I we can shorten this time.

Taking therefore into account that separate measurements are planned in Hall I and Hall III (starting with Hall III) and that almost two days are necessary to dismount some of the scintillators and the electronics related and mount them in the other scattering chamber, we ask for 4 days in Hall III and 3 days in Hall I, with an interval of at least 2 days. We think that this is the minimal time needed to get a reasonable calibration of CsI(Tl) scintillators.

Finally we would like to point out that, as we have written in our letter of intent and in the proposal for thermodynamical measurements, we are working on the upgrading of the apparatus and we plan to test, using the same beam time, these improvements, as the coupling of the digital electronics developed by the Florence group to some of the detectors of our apparatus. With this electronics we can analyze in shape the signals coming from the CsI(Tl) crystals in order to get information on the masses of the lighter products and therefore the measurements of different isotopes can be used as a test of this digital processing.