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Time of flight identification with FAZIA

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Summary. — This contribution reports on the time of flight implementation in the FAZIA Si-Si-CsI(Tl) telescopes, focusing on the basic ideas of the method and on some preliminary results from recent experiments at LNS.

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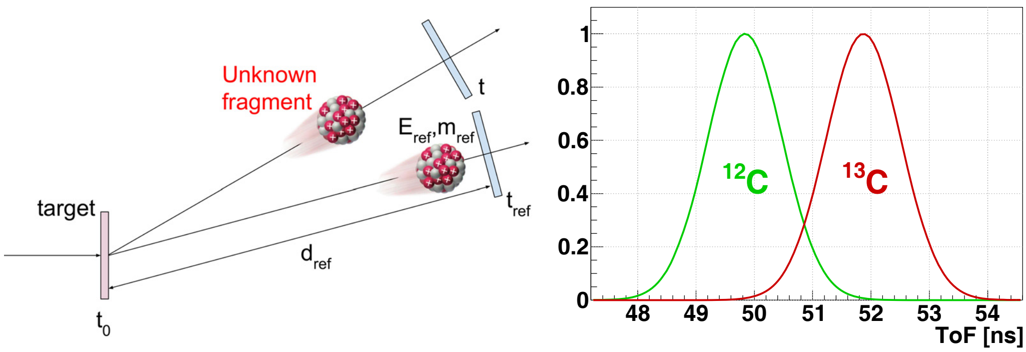
1. – The FAZIA telescope array

FAZIA is a modern and innovative three-layer telescope [Si + Si + CsI(Tl)] array. The main characteristics of FAZIA are the modularity and the portability. In fact, FAZIA is expected to measure in various laboratories, in different geometrical setups and coupled to other detector arrays. Another important aspect is the capability to identify with unitary mass accuracy the highest possible number of ions produced in heavy-ion reactions around the Fermi energy. So far, we verified the identification in charge up to $Z \sim 55$ and in mass up to $Z \sim 25$. This goal was achieved using custom detectors produced following a well-studied recipe [1, 2] and using original electronics with novel pulse-shape discrimination (PSD) techniques [3-5] based on high speed ADC with rates up to 250 MS/s and 14-bit resolution. More details on the FAZIA apparatus can be found on [6, 7].

2. – Time of flight implementation

The Time of Flight (ToF) information could be used to further lower the identification thresholds, also in the perspective of using FAZIA at the new ISOL facilities (e.g. SPES and Spiral2). Our collaboration recently renewed important efforts in this direction [10, 11]. Once the ToF of a particle is measured, the mass discrimination is possible by correlating that quantity with the energy released in the first Si layer [12]. We expect to extend mass identification for Hydrogen isotopes (not resolved at all with PSD) and charged particles up to $Z \sim 10$ with an energy threshold of around 1 MeV/u.

Time of flight implementation requires a start and a stop time mark. The ToF is the difference between the two time marks. Usually, the start time mark is given by a dedicated detector (not feasible with high granularity detectors like FAZIA) or by the accelerator radio-frequency (available with pulsed beams only). We implemented a method to recover the start time mark from the measured energy E_{ref} of a fully identified particle (i.e. a particle with known mass m_{ref}). The procedure was first described in [13], it is valid only for at least two-fold coincidence events and it is sketched in fig. 1(a).



(a) (b)

Fig. 1. – (a) Our implementation of a ToF measurement not needing a start detector or accelerator RF (more details in the text). (b) Expected ToF distribution (where the width is due to the jitter) for ^{12}C and ^{13}C ions of 25 MeV kinetic energy detected on a flight base of 1 m. The two isotopes are clearly discriminated.

To apply our procedure to an unknown particle we need, within the same event, at least a reference ion. Knowing the flight base d_{ref}, the kinetic energy E_{ref} and the mass m_{ref}, we can calculate the ToF for the reference fragment. The time of the reference ion production can be obtained from the ToF and the arrival time in the detector and it is the same also for the unknown particle because they are produced in the same collision. The arrival time is obtained via a digital Amplitude and Rise-time Compensated Constant Fraction Discriminator (ARC-CFD). The error on the time marks is mainly due to the jitter (Eq. 1), since the ARC-CFD procedure minimises the amplitude and rise-time walk.

$$\sigma_t = \frac{t_{rise}}{\mathrm{SNR}} \frac{\sqrt{1+f^2}}{1-f} \tag{1}$$

In Eq. 1, which is exact for a linear ramp signal, t_{rise} is the full rise-time (from 0% to 100% of the maximum amplitude), SNR is the Signal to Noise Ratio and f is the fraction of the maximum amplitude at which the ARC-CFD is calculated. If we calculate the error on ToF obtained with our implementation for two isotopes of carbon at 25 MeV (see fig. 1(b)), we can easily conclude that this method can discriminate the isotopes. The energy of 25 MeV was chosen because it is the charge identification threshold for carbon with PSD, while, with the same technique, the mass separation is reached at 60 MeV. So, in principle, our method can considerably lower the energy thresholds for mass discrimination.

3. – First application to experimental data and channel synchronisation

Our implementation of ToF measurement needs at least a fully identified particle, thus we performed the first tests of the method using the data from the first FAZIA experiment. The results (showed in fig. 2) were partly unexpected. On one hand we obtained the isotopic discrimination of Hydrogen isotopes (impossible with PSD), on the other we were not able to clearly resolve any other ion.

While studying this behaviour, we found that the actual sampling times are not the same for the various ADCs. Different relative delays introduce systematic errors in the ToF calculation for the reference fragments, depending on the front-end electronic channel involved, thus spoiling the final ToF resolution. So, even if a refined clock distribution is applied in FAZIA, it is necessary to correct the different delays introduced by each ADC sampling. To estimate and correct this systematic effect, a fast infrared pulsed LED is used to illuminate the first Si layer (i.e. the one used for timing) of every FAZIA telescope, allowing the synchronisation of the different channels with respect to a reference silicon detector. A calibration map of FAZIA detectors is then filled with the time differences between the ARC-CFD time marks corresponding to each detector and the reference time mark and it is used to correct the hit time marks obtained in physics events.

The use of the synchronisation LED was tested and then implemented. During the last FAZIA experiments it was acquired and thus we plan to verify soon the effect of the correction on the quality of the mass identification.

4. – Conclusions

In this contribution we propose an innovative method to extract the start time mark for the ToF measurement. We tested the method on the first fully calibrated FAZIA

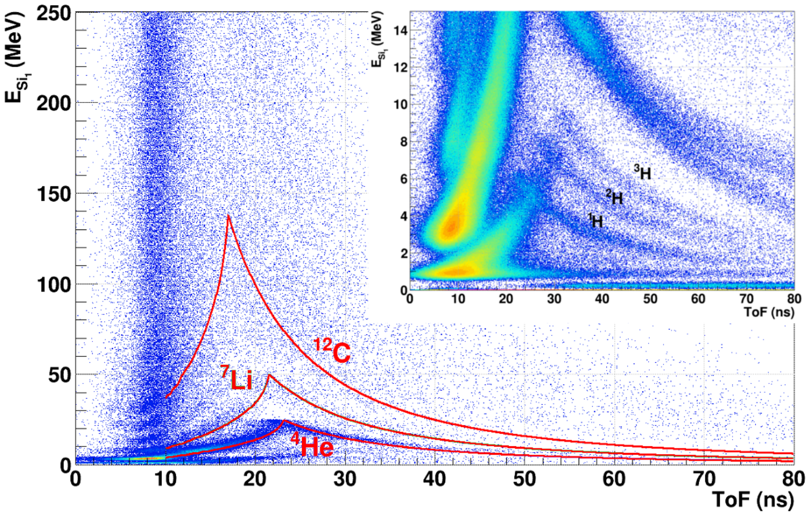


Fig. 2. – $E - ToF$ correlation for a typical first layer silicon detector during the first FAZIA experiment. Only Hydrogen isotopes are resolved.

experiment, but unfortunately the obtained ToF resolution was poor due to the residual relative delays between the sampling times of the different ADCs. To correct for this systematic effect, we implemented a procedure which uses fast infrared LED pulses to synchronise the channels. In this way we correct the time marks obtained in our experiments. The time correction maps for the various detectors were obtained during the last FAZIA experiment. Once the first calibrated events will be available, we will verify the effectiveness of this synchronisation method on the quality of mass identification.

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