

# TEST OF FAZIA-PROTOTYPES at LNS

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### ABSTRACT

In the framework of the first R&D phase of the recently started FAZIA [1] Collaboration (the list of the members is reported at the end of the document), a few telescope prototypes have been prepared, with associated digital electronics. These prototypes implement new solutions for improving the Z and A identification performances, necessary for the Physics cases addressed by the FAZIA Collaboration [2,3].

We propose an experiment dedicated to test, under beam conditions at Fermi Energies, the prototypes and the associated electronics. In particular, new Silicon detectors cut along a skew “random” angle with respect to the <100> crystal axis and carefully selected for good resistivity uniformity will be used. The Single Chip configuration [4] will also be compared with standard photo-diode readout. The sensitivity of the identification performances on the doping uniformity of the Silicon detectors will be studied and –for punching through particles– on the CsI(Tl) element, too. Finally a novel system, based on light flashes, to determine the time offset of the used silicon detectors will be tested. The apparatus has been already partially tested at low energies in LNL, and provided quite stimulating results, in terms of charge and mass discrimination using Digital Pulse Shape Analysis (DPSA) [5]. Tests at LNS are needed, exploiting the high-energy and heavy-mass beams available: in this way a much larger dynamic range of charge, mass and energy will be covered so that the DPSA performances will be fully characterized and determined. Moreover the good time-quality of the beam will permit to test the possible simultaneous use of Digital ToF [5,6] and Digital PSA, checking under severe in-beam condition solutions that are under study within FAZIA since many years. The CICLOPE scattering chamber will be used for the tests.

### DESCRIPTION OF THE EXPERIMENT

We present a proposal aimed at testing detector prototypes developed in the framework of the FAZIA Collaboration. The idea is to test the prototypes and the associated custom Front End Electronics under realistic beam conditions at Fermi Energies.

In the high-energy configuration of the FAZIA prototypes, each telescope includes three elements: Si-Si-CsI(Tl). The first two Si elements act as a high-resolution telescope. Both detectors are mounted in the reverse-field configuration. The reverse-field configuration of the first element permits PSA with very low thresholds, while the reverse-field configuration in the second and thicker Si provides a redundant PSA and the implementation, together with the third element CsI(Tl), of an original Si-CsI(Tl) DE-E configuration, called Single Chip [4] where the Si detector acts both as a standard semiconductor detector and as a photodiode to catch the CsI fluorescence.

FAZIA is characterized by a fully digital implementation, except for the preamplifiers, which nevertheless present original solutions. In fact, the Silicon detectors are coupled to pre-amplifiers able to produce charge and current outputs (PACI, [7]). These outputs are digitized by fast ADCs. The MAR ASIC analog-memory digitizers developed within FAZIA (able to convert at 2 GSamples/s with 12 bits) are used to sample the current and compared with commercial state-of-the-art digitizers. The digitized signals are processed in order to extract all the relevant information: energy, timing, Pulse Shape (i.e. Z, A), [5,7].

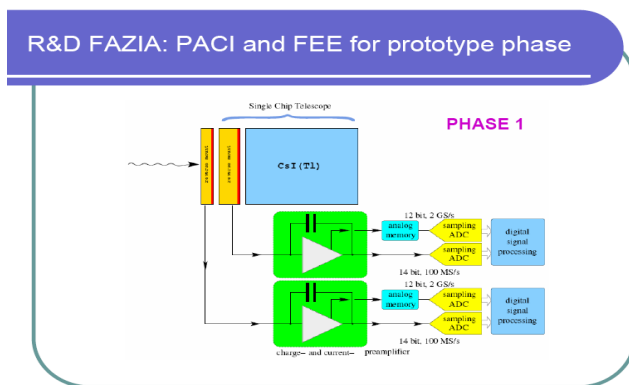


Figure 1. R&D Fazio: prototype phase, Front End Electronics

The Front End Electronics is schematically shown in Fig.1, while Fig.2 shows one of the mechanical supports for the telescopes which have been build and already used at the lower energy beams of LNL.

As far as Silicon detectors are concerned, they are mounted in the so called “reverse-side” configuration [9], presently believed to be the best suited for optimizing the Pulse Shape performances. One of the prototype telescopes will be mounted with a “front-side” configuration, which is expected to better perform in terms of timing [10], to compare the two alternative solutions. Two telescopes will be provided with the Single Chip read-out [4], based on the idea of using the Silicon detector to act both as ionization detector element and as a photodiode to read the fluorescence of the CsI(Tl). That configuration, which already showed good performances in preliminary tests in LNL, has to be checked as a realistic and large-scale alternative to the standard solution.

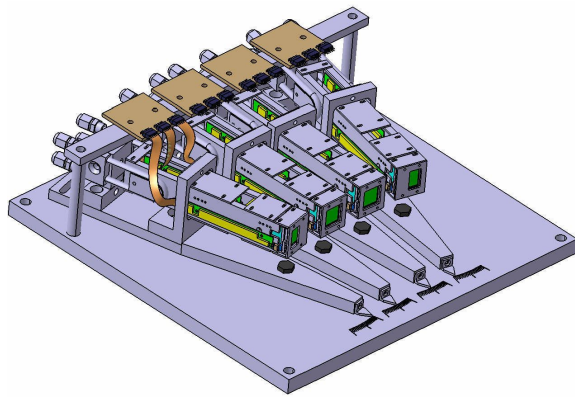


Figure 2. R&D Fazio: prototype phase, Telescope and mechanical support

The experiment will use 20x20mm silicon detectors build by FBK-Trento and Canberra, starting from silicon wafers provided by the FAZIA collaboration, i.e. wafers obtained by a special “random orientation” cut, starting from a <100> nTD Silicon ingot from TopSil.

In fact, from a series of experiments [11,12] performed with stopped ions at LNL, we learned that this procedure guarantees the best performances because it reduces at most the “channelling” (i.e. crystal orientation) effects in the Silicon crystal. As an example, the left panel of Fig. 3 shows the current signals obtained during an experiment at LNL with Se beam, when the 300 μm-Silicon detector was oriented perpendicular to the scattered particles (thus entering along the <100> axis), while the right side shows the same signals when the Silicon detector was oriented in the “non-channelled”, i.e. “random” direction. The improvement in the stability of the current signals is apparent.

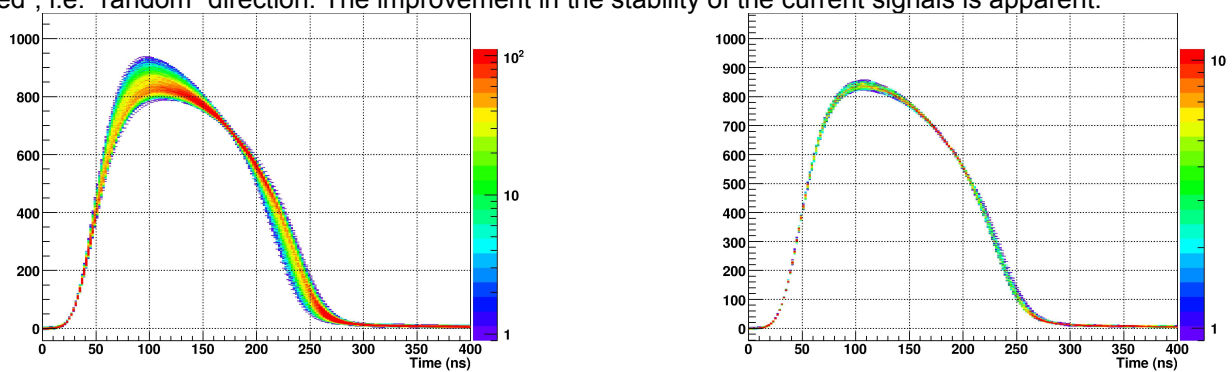


Figure 3. Current signals for channelled (left panel) and “random” entering (right) ions. Elastic scattering of <sup>80</sup>Se at 400 MeV total energy, ions stopped in the Si detector.

The mechanics of the telescopes is equipped with various angular degrees of freedom, in order to be able to test also other detectors and different silicon wafer cuts.

The Si detectors are all of the “nTD” kind, having average resistivity of about 3kΩ·cm; they have been characterized in terms of resistivity uniformity, which is indeed a very critical parameter for getting the necessary PSA resolution. Typical off-the-shelf detectors have resistivity uniformity of 10% or larger, while we estimate that the present application requires uniformity at least a factor of five better.

The resistivity uniformity test has been performed using a technique based on pulsed-laser irradiation of the detectors developed by the collaboration [13].

Measured maps of two detectors are shown in Fig.4. On the left side a detector with typical resistivity non-uniformity around 10% is presented, showing the residual circular striations, remnants of the original Float Zone processing. A significantly better uniformity (around 1%) characterizes the detector on the right side.

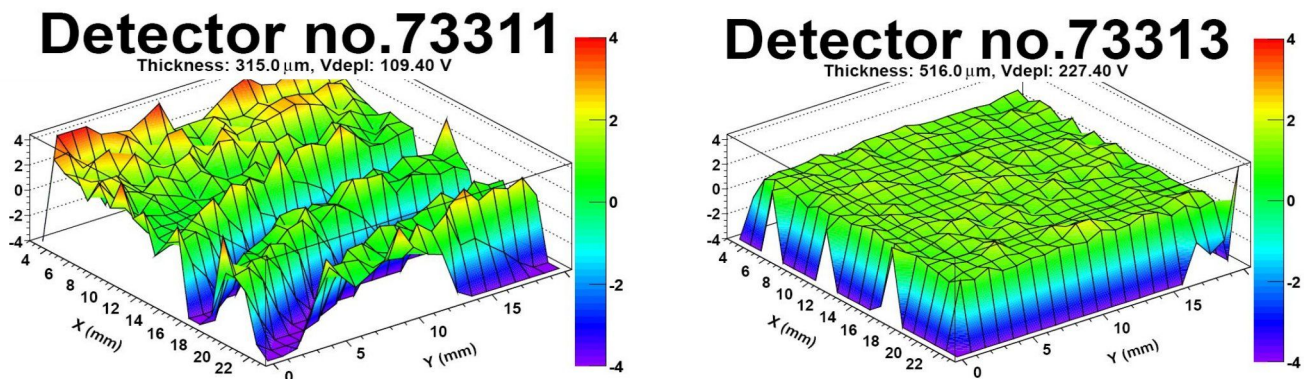


Figure 4. Experimental maps of resistivity (doping uniformity) of two Silicon nTD detectors of the FAZIA project. On the left side a detector with “typical” uniformity around 10% is shown. On the right side a detector with 1.5% uniformity is shown.

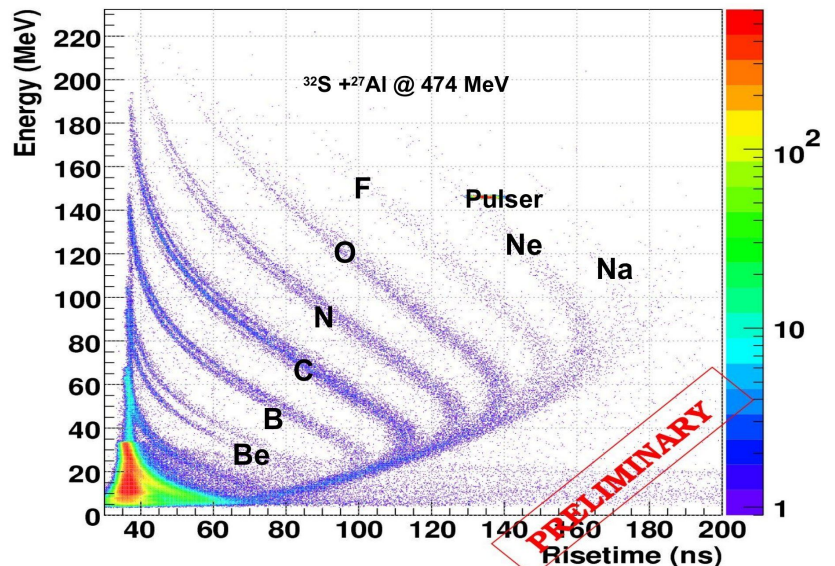


Figure 5. The energy vs risetime (charge signal) obtained from a 500 $\mu$ m detector, having a 1.5% resistivity uniformity and oriented in such a way to avoid “crystal orientation effects”. Beyond charge separation, clear mass identification is observed for a significant energy range, for many elements. The full scale of the system was 1.3 GeV.

The experience gained within the FAZIA collaboration about silicon material (channeling and homogeneity) and digital signal processing, has permitted to progress in the field of PSA in silicon: as an example, Fig.5 shows the recent results obtained at LNL, using the reaction  $^{32}\text{S} + ^{27}\text{Al}$  at beam energy of 474 MeV.

This quite standard plot [9] is one of the many correlations that can be used for particle identification and that are under study. These data (and some other similar results involving both charge and current information) show unprecedented identification quality by means of PSA using digital sampling techniques. The low maximum available energies and the limited Z range explored in LNL did not permit to determine the very limit of the proposed approach.

An experiment at LNS would be of paramount importance to determine ranges and thresholds for the Z and A identification in our approach over a much broader range of energies. To that purpose we intend to use a high energy, medium-mass beam to produce a large variety of reaction products.

Finally, we plan also to test a novel system for measuring Time of Flight based on synchronization of the detectors via an analog periodic signal and the use of flashes of light [6].

The issue of rear/front injection will also be addressed, with the main goal of determining in a sound and reproducible way the energy thresholds of the two approaches. The associated issue of timing performances will also be addressed. Finally, we plan to check the issue of radiation damage and associated possible PSA degradation by studying the performances of a selected detector as a function of the total fluence of elastically scattered ions (implanted and not-implanted).

For the tests the CICLOPE scattering chamber appears to be well suited, mainly because it permits to have a sufficiently long flight path to carefully test the ToF performances of our digital system and the associated synchronization method.

## BEAM TIME REQUEST

For the purposes of the measurement campaign, the experimental availability of a large variety of ions species with a wide energy distribution is needed. For a given ion in a given energy range, an adequate statistics is necessary in order to provide quantitative and reliable assessments about the identification performances. We estimate that  $N(Z,A,DE) \sim 300$  events per ion species and per 100 MeV energy interval (over the whole explored energy span, few GeVs) would suffice. The planned time-of-flight tests require also a pulsed beam with the best available time resolution (of the order of 0.5ns FWHM).

According to the accelerator crew, the best suited beam for good timing and intensity would be  $^{132}\text{Xe}$  around 35A MeV. By bombarding a Sn target a good deal of projectile fragments will be available in the very forward cone (few degrees). Lighter reaction products, IMF's and LCP's are found at somewhat larger angles. Assuming a 1 mg/cm<sup>2</sup> thick target and a realistic beam current intensity (about 20 particle-pA, according to the accelerator crew), a quantitative estimate of the needed beam time has been performed.

In order to do that, we used the production rate of LCPs, IMFs, and heavier fragments observed with the same reaction (Xe+Sn) at about the same energy performed by the INDRA collaboration at GANIL, and cross-checked with similar reaction (Sn+Nb) available during the FIASCO campaigns, performed around year 2000 at LNS.

If most of the telescopes are placed just above the grazing angle (in order to avoid elastic scattering) and a  $\sim 3$ m flight path is used for having good mass resolution from time-of-flight for heavy fragments, about 10 days of beam on target are needed in order to fulfill the aforementioned statistics requirement on  $N(Z,A,DE)$ . The less demanding time-of-flight requirements for lighter ions will allow to perform the relevant PSA tests at somewhat larger angles and at closer distance, still fulfilling the aforementioned statistics requirements.

Over this time period it will be possible to perform the planned tests over radiation damage and rear/front side injection.

## REFERENCES

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