EXODET: a highly segmented detector array for RIB experiments

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I. INTRODUCTION

Exotic light ion beams will be available in the next future at LNL with the EXOTIC beam line [1] (presently under construction). The experimental studies will mainly address reaction mechanisms at energies around the Coulomb barrier. The low intensity of such beams (about 10^6 pps) requires an experimental apparatus, for charged particle detection and identification, subtending a solid angle as large as possible. Moreover, many RIB experiments require a complete event kinematics reconstruction and it becomes necessary to determine the energy and the position of the detected particles with the maximum achievable resolution. These requirements guided us to design and develop a new detector system for charged particles, named **EXODET** (**EXO**TIC **DET**ector), based on large area silicon SSD. The system has been designed to be installed in the scattering chamber of the EXOTIC beam line but it can be easily fitted into different apparatuses. In fact, an experiment has been performed with the EXODET apparatus at the ANL (Argonne, USA) in 2002 [2] and another one is scheduled before the end of 2003 at RIKEN (Japan).

II. DETECTOR DESCRIPTION

The EXODET system consists of 16 detectors, designed by us and supplied by MICRON Semiconductor Ltd. They are arranged in 8 two-stage telescopes to allow the Z identification of the particles passing through the first layer, by means of the usual ΔE-E technique. The thickness of the first and second layer is 60 μm and 500 μm respectively. The telescopes are placed around the target, as shown in FIG.1, in the forward and backward hemispheres. The solid angle covered is about 50% of 4π sr. Each detector has an active area of 50 x 50 mm^2 and is segmented, on the front side, in 100 strips having a pitch size of 0.5 mm and a separation distance of 50 μm, while the rear side is a unique plaque. The strips of the ΔE layer are orthogonal to the beam direction and perpendicular to the strips of the E layer, as shown in FIG.2. In such a way, it is possible to determine the position of the particles passing through the first layer with an indetermination of about 0.5 mm x 0.5 mm. The maximum energy released in the ΔE layer detectors is 3.4 MeV for protons, 4.2 MeV for deuterons, 4.8 MeV for tritons, 8.2 MeV for ^{3}He and 9.2 MeV for α particles. Light particles, having higher incident energies can be fully identified (energy, position, mass and charge). Also heavier ions in the region of Oxygen or Fluorine at energies around the Coulomb barrier can reach the second layer. The effective detector thickness should be determined taking into account the geometrical constraints due to the non-spherical shape of the apparatus. To this aim a proper computer code has been developed.

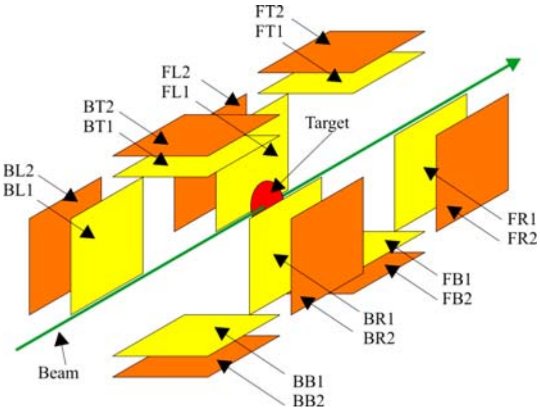

***FIG. 1**: Schematic arrangement of the 8 EXODET large area SSD telescopes around the target. The thin ΔE detectors (60 μm) are the yellow ones, while the orange colored ones constitute the E thick layer (500 μm).*

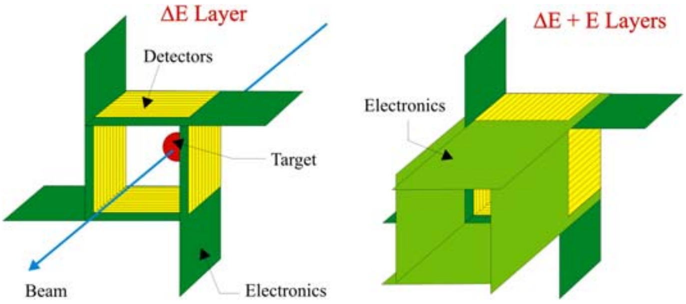

***FIG. 2**: Schematic picture of the assembling of the EXODET forward half box. The strips of the ΔE layer are perpendicular to the beam direction, while the strips of the E layer have the same direction of the beam. The detector support boards (green colored) contain the position readout chips and electronics.*

For the particles stopping in the ΔE layer, it is still possible to reconstruct the θ_{lab} angular distribution, even if the position information of the E layer is not present. In fact, on the bases of Monte Carlo simulations of the geometrical efficiency it is possible to associate to each strip, or strip group, a θ_{lab} value, in the ranges 27°-81° and 99°-153°, with the indetermination of 1 to 3 degrees, depending on the distance between the target and the considered strip, as shown in FIG.3.

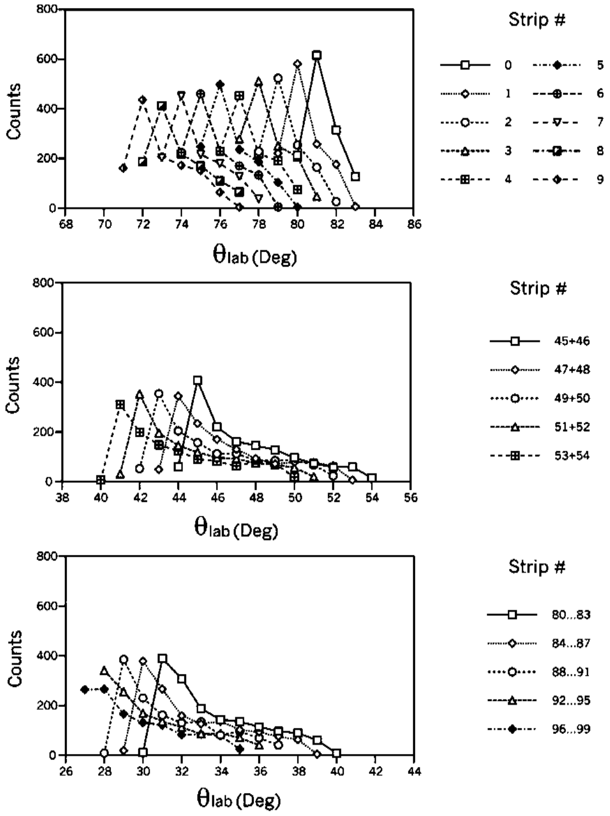

FIG. 3*: Angular geometrical efficiency of the strips or strip groups for one of the EXODET SSD telescopes. Monte Carlo calculations show the possibility to reconstruct the* θ_{lab} *angular distribution also for the particles stopping in the* ΔE *layer of the telescope.*

III. READOUT

The whole array readout system has to consider 16 channels for the processing of the energy signals coming from the rear side of the detectors, and 1600 channels for the position information obtainable from the segmented side. For the energy channels a standard electronic chain has been used. To process the particle position, given the large number of strips, solutions like resistive charge partition chains or delay lines have been discarded due to the unacceptable signal attenuation introduced. The chosen solution for the position readout has been the use of an ASIC chip. Such a device, originally developed for high-energy particle physics experiments [3], was found to be suitable for our purpose with an opportune design of the readout electronics. It has been necessary to build a proper signal amplitude attenuator to reach the required dynamic range and a pitch size adapter to connect the detector strips to the input pads of the chip (about 40 μm pitch size). The chip and the related electronics are placed near the detector, on its support board, to ensure the maximum noise reduction. In FIG.4 the two elements of a single telescope, connected to their support boards, with the related readout chips and electronics, are shown. Each chip, having a size of 5.7 x 8.3 mm^2, simultaneously analyzes up to 128 independent input channels and gives in output a data stream containing the identification number of the chip, the trigger number and, for each strip hit, the strip identification number, the signal TOT (Time Over Threshold) and the Jitter Time. Hardware zero suppression is performed at the chip level. The Jitter Time gives information about the time interval between the signal and the trigger assertion. The TOT is roughly proportional to the energy released by the particle in the strip and it is useful to disentangle the particle position when two particles with different energy ranges hit contemporarily two different strips of the same detector. For the energy signal processing, we used homemade hybrid **CHAPLIN** preamplifier (**CHA**rge **P**reamplifier **L**ow-noise **I**NFN **N**apoli), directly mounted on the detector support board, and standard NIM commercial modules. The front-end electronics consists of standard VME commercial ADC (CAEN, Silena,...) together with homemade VME modules for the chip information readout (AVI boards) and for the trigger supervision (TSI board). The acquisition system of the EXODET setup is reported in ref. [4].

A cooling system built with Peltier cells and using water, as cooling fluid, ensures the correct dissipation required by the electronics and allows the detectors to operate in vacuum.

Future improvements of the apparatus will regard the usage of very thin ΔE detectors (< 40 μm) to enlarge the range of particles completely identifiable by the system.

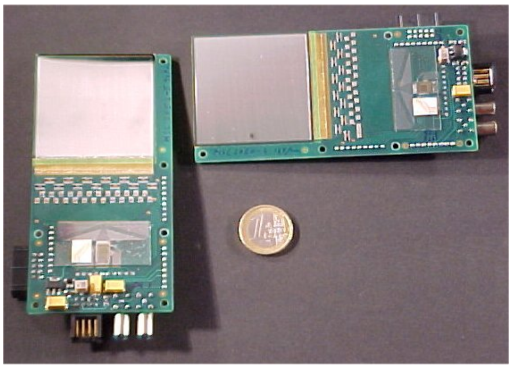

FIG. 4*: Photo of the two detectors of one EXODET telescope, before they are assembled. The readout chips and the related electronics are already mounted on the support boards. The One Euro coin is shown for size comparison.*

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[1] M. Sandoli et al., LNL Ann. Rep. (2001) 192.
[2] M. Romoli et al., *"^{17}F elastic….."* , this Report.
[3] A. Perazzo et al., BABAR Note #501 (1999).
[4] E. Vardaci et al., *"VIPER….."*, this Report.