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The high granularity and large solid angle detection array EXPADES

E. Strano [a,b,*], A. Anastasio [c], M. Bettini [b], A. Boiano [c], C. Boiano [d], C. Cassese [c], L. Castellani [b], D. Corti [b], P. Di Meo [c], G. Galet [a], T. Glodariu [e], J. Grebosz [f], A. Guglielmetti [g,d], M. La Commara [h,c], C. Manea [b], M. Mazzocco [a,b], P. Molini [a,b], M. Nicoletto [b], C. Parascandolo [a,b], L. Parascandolo [c], D. Pierroutsakou [c], G. Pontoriere [c], L. Roscilli [c], C. Signorini [a,b], F. Soramel [a,b], L. Stroe [e], M. Tessaro [b], N. Toniolo [i], D. Torresi [a,b], P.G. Zatti [b]

[a] *Dipartimento di Fisica e Astronomia, Università di Padova, Via Marzolo 8, I-35131 Padova, Italy*
[b] *INFN – Sezione di Padova, Via Marzolo 8, I-35131 Padova, Italy*
[c] *INFN – Sezione di Napoli, Via Cintia, I-80126 Napoli, Italy*
[d] *INFN – Sezione di Milano, Via Celoria 16, I-20133 Milano, Italy*
[e] *NIPNE, Str. Reactorului No. 30, P.O. Box MG-6, Bucharest-Magurele, Romania*
[f] *IFJ PAN, ul. Radzikowskiego 152, 31-342 Kraków, Poland*
[g] *Dipartimento di Fisica, Università di Milano, Via Celoria 16, I-20133 Milano, Italy*
[h] *Dipartimento di Scienze Fisiche, Università di Napoli, Via Cintia, I-80126 Napoli, Italy*
[i] *INFN – LNL, Viale dell'Università 2, I-35020 Legnaro (PD), Italy*

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ABSTRACT

The EXPADES (EXotic PArticle DEtection System) detector array consists of 16 Double Side Silicon Strip Detectors (DSSSD) with active areas of 64×64 mm^2, arranged in 8 ΔE (40/50 μm)–E (300 μm) telescopes. All detector faces are segmented into 32×2-mm wide strips, ensuring a 2×2 mm^2 pixel configuration. Eight ionization chambers can be alternatively used as ΔE stages or, if needed, as an additional third layer for more complex triple telescopes. The signals from silicon ΔE layers and from ionization chambers are read by standard electronics, while innovative 32-channel ASIC chips are employed for the readout of the E stages. The results of off-line tests with alpha sources and from the first in-beam experiment with a ^{17}O beam are presented.

1. The detector array EXPADES

Experiments involving Radioactive Ion Beams (RIBs) are typically characterized by low beam intensity, poor emittance and low energy resolution. The detector array EXPADES (EXotic PArticle DEtection System) [1] was designed to the purpose of a detection set-up (i) covering a solid angle as large as possible (to compensate the low beam intensity), (ii) with high granularity, (iii) able to discriminate different reaction channels and (iv) to allow coincidence measurements of reaction products. The whole array, shown in Fig. 1, will consist of 16 squared Double Side Silicon Strip Detectors (DSSSD) arranged in 8 two-stage ΔE–E telescopes in a cylindrical configuration. The detectors have active areas of 64×64 mm^2 with 32 strips on front side orthogonally oriented with respect to the 32 strips on back side in order to define 1024 pixels 2×2 mm^2 wide. The detector thickness is 40/50 μm and 300 μm for the ΔE and for the E, respectively (see in Fig. 1). Ionization chambers, to be used as possible alternative ΔE stages have also been developed. The solid angle coverage of the whole array is 0.65 and 2.6 sr in the configuration with ΔE–E silicon telescopes and with triple telescopes, respectively.

2. Off-line tests of the ΔE silicon detectors

Due to the high capacitance of the 40/50 μm DSSSD (BB7-40/50 design from Micron Semiconductor Ltd., UK) we developed home made electronics (see in Fig. 2) that includes a charge sensitive preamplifier and a spectroscopy amplifier with Constant Fraction Discriminator (CFD) and Time to Amplitude Converter (TAC). In addition, in order to reduce complexity and costs, the number of the DSSSD strips has been lowered to 16, by short-circuiting two adjacent strips together. The preamplifier outputs are sent to a specially developed 16 channel NIM module "MEGAMP" [2]. The TAC circuits start with the first CFD output (set at 30% of the leading edge) and is stopped by an External Common Stop Signal in order to give a time of flight measurement. Alternatively the Stop Signal can come from a second CFD (set at 80% of the leading edge) to give the pulse shape information [3].

* Corresponding author at: Dipartimento di Fisica e Astronomia, Università di Padova, Via Marzolo 8, I-35131 Padova, Italy.
E-mail address: estrano@pd.infn.it (E. Strano).

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Off-line tests of the 40/50 μm DSSSD and related readout electronics were performed using a ^{239}Pu–^{241}Am–^{244}Cm composite alpha source placed at a distance of 150 mm from the detector. Fig. 3 shows that an energy resolution of 31–35 keV (0.6%) and a time resolution (from 30% to 80%) of 0.9 ns were achieved. The intrinsic time resolution (FWHM) of the MEGAMP single CFD channel was found to be 85 ps for a 500-mV and 20-ns rise time pulse.

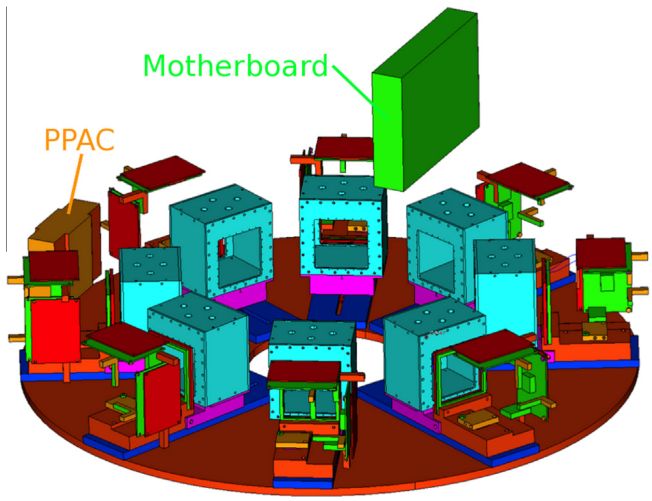

Fig. 1. Schematic view of the EXPADES array. The beam enters from the left side of the figure and crosses at first a Parallel Plate Avalanche Counter (PPAC) for beam tracking (depicted in light brown on the left). The ΔE silicon detectors and the related electronics are colored in red, while the green color is used for the E detector stages and related electronics. Ionization chambers are indicated in light blue. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

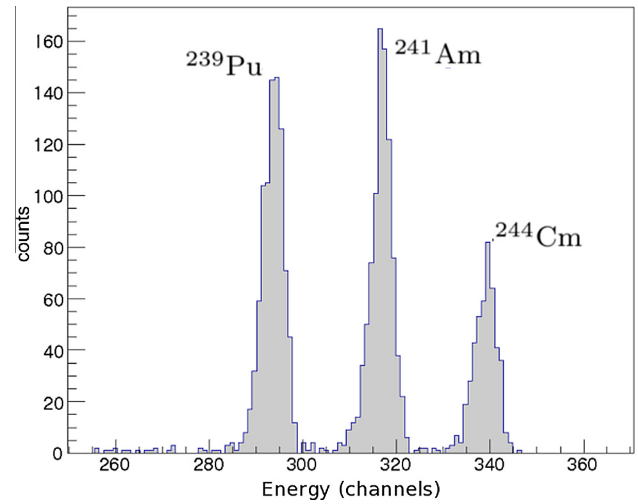

Fig. 3. 40/50 μm silicon ΔE detector energy spectrum for a triple alpha source.

3. Off-line test of the E silicon detectors

32-channel (one for strip) ASIC chips manufactured by IDEAS-GM (Norway) were employed for the readout of the electronic signals of the EXPADES E stages (300 μm DSSSD, BB7-300 design from Micron Semiconductor Ltd., UK): the **VA**32HDR14.2 for the linear processing of the electronic signals and the **TA**32CG.3 for the logical trigger signal generation. The output signal of each chip VA is a serial stream of 32 analog signals containing the information of the charge collected by each detector strip (see Fig. 4). The acquisition of these signal streams is performed by a home-made 12 bit sampling ADC. The performances of the detector were tested with a tri-

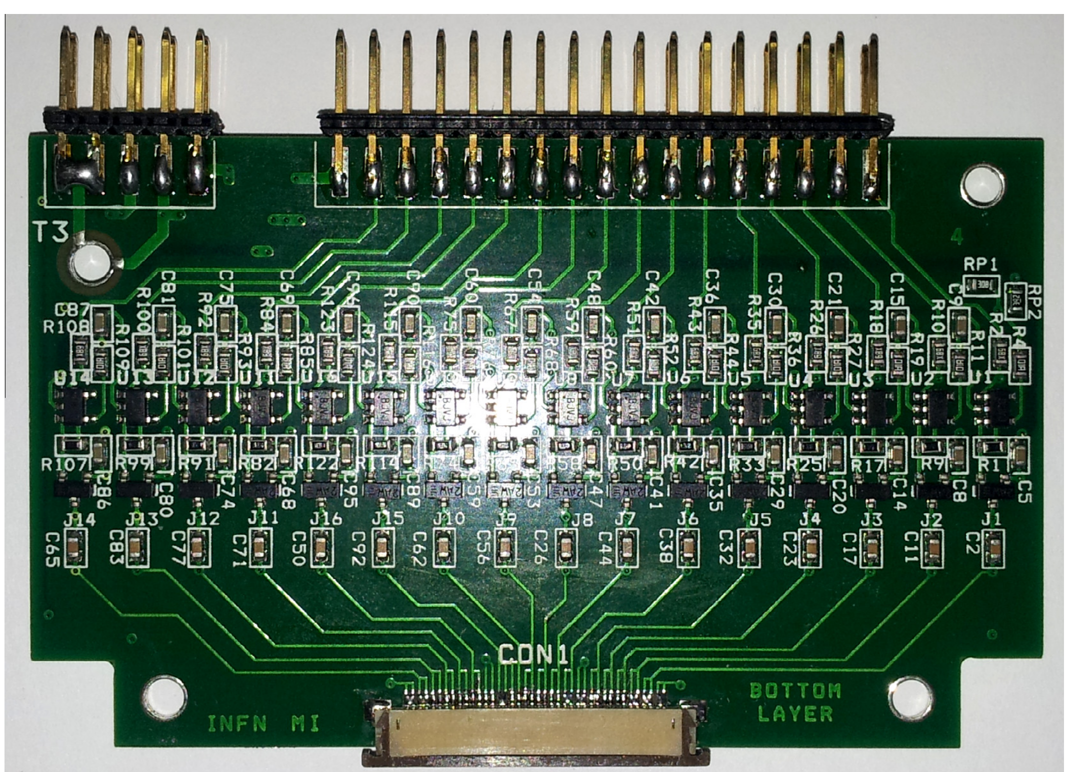

Fig. 2. Charge preamplifier for the readout of the BB7-40/50 μm DSSSD.

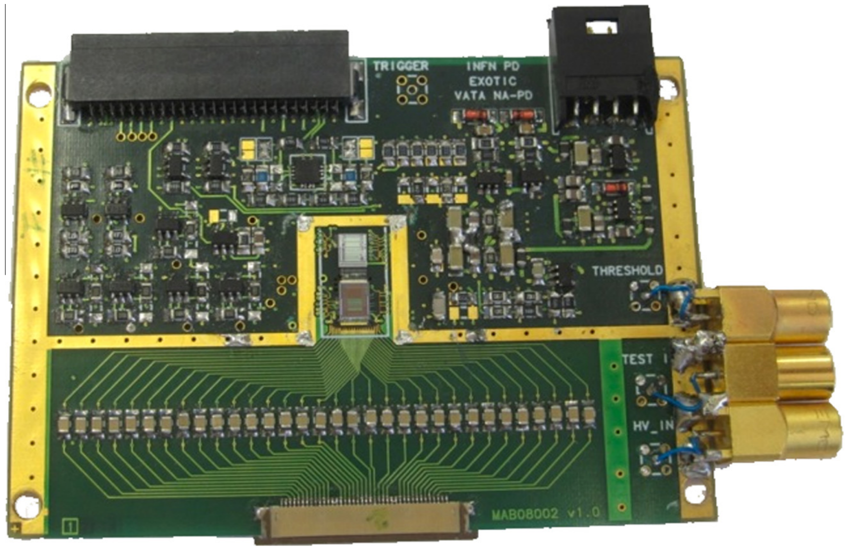

Fig. 4. The ASIC electronic board VATA housing the chips TA and VA.

ple alpha ^{239}Pu–^{241}Am–^{244}Cm source (see Fig. 5) and we measured an energy resolution of about 80–85 keV.

We also measured the body capacitance (one whole side versus the opposite whole side) of the 300 μm DSSSD using the circuit in Fig. 6. A fixed height pulse was injected in the detector anode. The charge preamplifier was collecting the equivalent charge on its surface and the relation between the pulser amplitude and the measured charge is proportional to the detector capacitance. The system was calibrated using known commercial capacitors in the range 10–650 pF. The body capacitance (see Fig. 7) reaches a plateau (corresponding to the detector full depletion) for a bias voltage of about 25 V. The interstrip capacitance (between two adjacent strips) on the back side, biasing the front side, reaches its plateau at about 50 V whereas the interstrip capacitance on the front side reaches its minimum at the same bias voltage as the body capacitance.

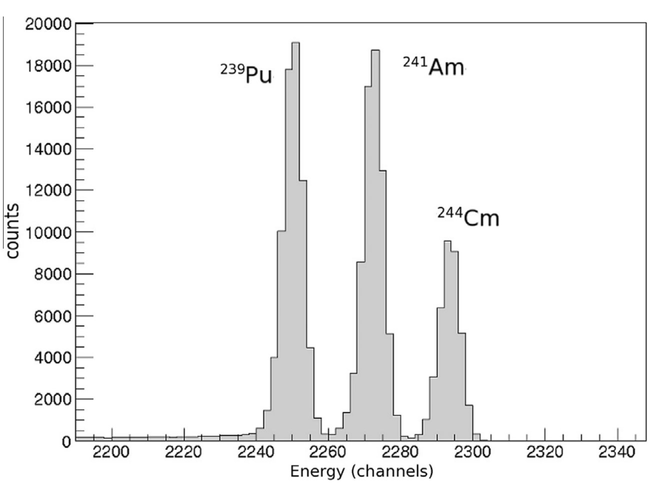

Fig. 5. 300 μm silicon E detector energy spectrum for a triple alpha source.

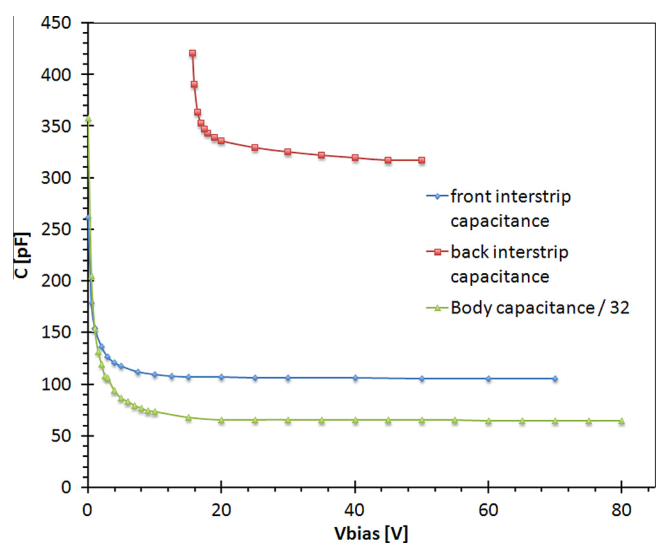

Fig. 7. Body capacitance and interstrip capacitance of a E (300 μm) stage versus the detector bias voltage.

4. Off-line tests of the Ionization Chambers

The transverse-field Ionization Chamber (IC) is housed in a $100 \times 100 \times 68\ mm^3$ chromium-plated brass envelope and its active depth along the ion direction is 61.5 mm. The detector is operated with carbon tetrafluoride (CF_4), characterized by a high

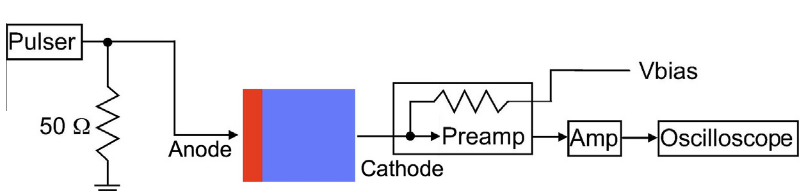

Fig. 6. Schematic circuit used to measure the body capacitance and the interstrip capacitance of the 300 μm detector as a function of the bias voltage.

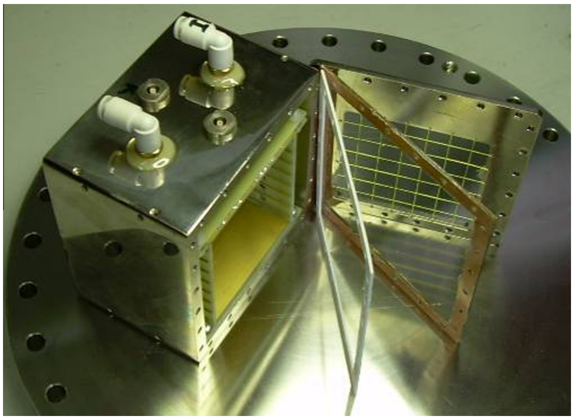

Fig. 8. Picture of the ionization chamber together with the components of the mylar entrance window.

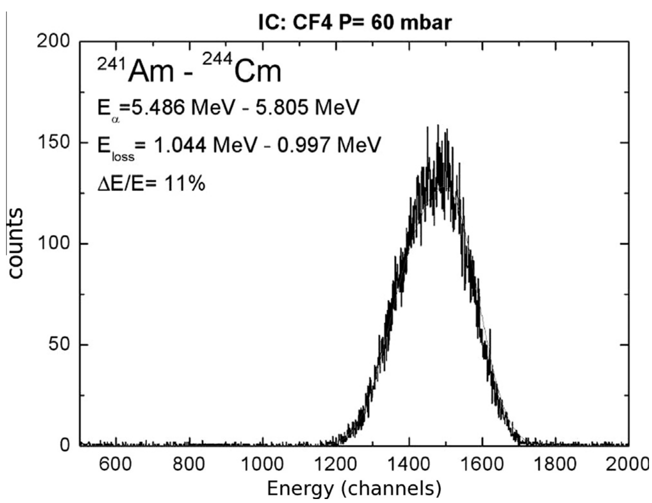

Fig. 9. Energy spectrum of the ionization chamber for a composite alpha source.

electronic stopping power and a high electron drift velocity [4]. The maximum gas pressure is 100 mbar. The cathode (anode) is biased at −300(+50) V while the Frisch grid is grounded. The IC entrance and exit windows are made of 1.5 μm-thick mylar foils and are modular in order to be easily replaced after a breaking. Fig. 8 shows the exploded view of the modular entrance window. The IC anode signal is sent to a low-noise charge preamplifier with fast rise-time and active discharge mechanism [5]. Conventional electronics is used to handle the IC anode signal. An energy resolution ΔE/E = 11% was obtained for alpha particles from a ^{241}Am–^{244}Cm composite source by using CF_4 gas at 60 mbar (see Fig. 9).

5. In-beam commissioning

We have recently tested the performances of the EXPADES E modules in a real in-beam experimental environment measuring the elastic scattering process of ^{17}O ions from a ^{58}Ni–^{208}Pb composite target [6]. The thin ^{208}Pb layer was added to the ^{58}Ni target for normalization purposes. Two 300 μm DSSSD were located at $\langle\theta_{lab}\rangle = 50°$ and $\langle\theta_{lab}\rangle = 110°$ at a distance of about 100 mm from the target. Fig. 10 shows the elastic scattering angular distributions for the ^{17}O + ^{58}Ni system in the energy range 42.5–55 MeV in 2.5-MeV bins and with intensity between 1 and 10 pnA.

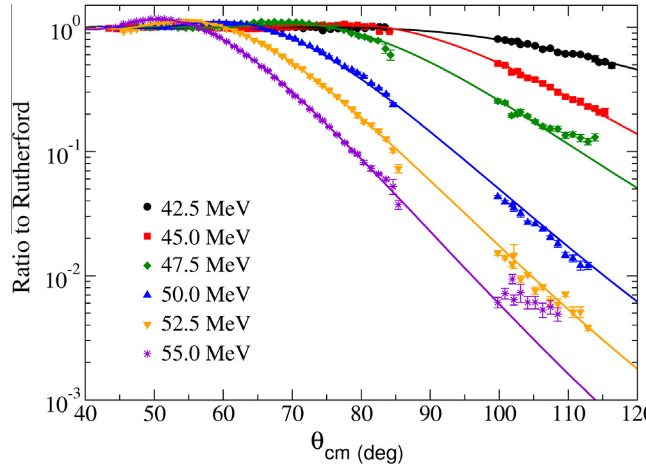

Fig. 10. Elastic scattering angular distributions for the ^{17}O + ^{58}Ni system in the energy range 42.5–55 MeV. The solid lines are the optical model fits of the plotted data.

6. Conclusions

The EXPADES detection array is nearly completed and ready to be employed in the study of nuclear reactions involving exotic nuclei. Its key features are the high granularity, the large solid angle coverage, the modularity and the compact electronics, that make it usable in several laboratories over the world. The modules of the three elements of the array – IC; DSSSD ΔE 40 μm and DSSSD 300 μm – were off-line tested with alpha particles with very good performances and the E layer has been already used in a real experimental environment to study the collisions ^{17}O + ^{58}Ni at Coulomb barrier energies.

Acknowledgment

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Update

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Corrigendum

Corrigendum to "The high granularity and large solid angle detection array EXPADES" [Nucl. Instr. Meth. B 317 (2013) 657–660]

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[a] *Dipartimento di Fisica e Astronomia, Università di Padova, Via Marzolo 8, I-35131 Padova, Italy*
[b] *INFN – Sezione di Padova, Via Marzolo 8, I-35131 Padova, Italy*
[c] *INFN – Sezione di Napoli, Via Cintia, I-80126 Napoli, Italy*
[d] *INFN – Sezione di Milano, Via Celoria 16, I-20133 Milano, Italy*
[e] *NIPNE, Str. Reactorului No. 30, P.O. Box MG-6, Bucharest-Magurele, Romania*
[f] *IFJ PAN, ul. Radzikowskiego 152, 31-342 Kraków, Poland*
[g] *Dipartimento di Fisica, Università di Milano, Via Celoria 16, I-20133 Milano, Italy*
[h] *Dipartimento di Scienze Fisiche, Università di Napoli, Via Cintia, I-80126 Napoli, Italy*
[i] *INFN – LNL, Viale dell'Università 2, I-35020 Legnaro (PD), Italy*

The author line in the originally published version of the article is incorrect and the correct author line is as above.

Mauro Romoli has been added as a contributing author for the above-mentioned article since he also contributed to the early phase of the project yielding this article, which qualified him to be included as a co-author. He also gave the name "EXPADES" to the detector array which is described in the article.

Unfortunately, he left the EXOTIC collaboration several years ago and his name was accidentally left out from the list of authors. Nevertheless he laid out the basis of this project.

All previously listed authors agreed upon adding him to the authors list as a contributing author.

The authors regret for this mistake in the original version of the article.

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* Corresponding author at: Dipartimento di Fisica e Astronomia, Università di Padova, Via Marzolo 8, I-35131 Padova, Italy.
E-mail address: estrano@pd.infn.it (E. Strano).

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