TEST OF PROTOTYPE DOUBLE SIDED SILICON DETECTORS FOR EXL PROJECT AT GSI DARMSTADT, GERMANY

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Abstract: Prototype double-sided silicon strip detectors (DSSD) of 300 μm thickness produced at PTI St. Petersburg (Russia) were tested for the use as position sensitive, ΔE and E detectors for tracking and particle identification in the EXL (EXotic nuclei studied in Light-ion induced reactions) setup at the FAIR (Facility for Antiproton and Ion Research) project at GSI. We describe the characteristics of detectors with 16x16 strips of 300 μm pitch size and 7.1x7.1 mm^2 chip dimension, and also with 64x64 and 64x16 strips of 300 μm and 1250 μm pitch size, respectively, and 21.2x21.2 mm^2 chip dimension. The response of these detectors for ^{241}Am α particles injected either from the p or n side was examined. The test measurements were performed partially at GSI and the University of Edinburgh. The results reveal good spectroscopic properties of these detectors. Our work will continue with 100 μm thick detectors and larger active area, up to 65x65 mm^2.

Keywords: Double-sided Silicon Strip Detectors (DSSD)

1. INTRODUCTION

The study of neutron-rich light nuclei near the drip line has attracted much attention as they exhibit an extended distribution (so-called hallo) of the valence neutrons surrounding a compact core. One of the most powerful classical method for obtaining spectroscopic information on the structure of nuclei is the investigation of light ion induced direct reactions. The availability of radioactive beam enables to extend such studies on exotic nuclei by using method of inverse kinematics. Presently, the future facility FAIR [1] is under construction. Its condition provides unique opportunities in experimental studies on nuclei far off stability, exploring new regions in the chart of nuclides which are paramount interest in nuclear structure and astrophysics.

The objective of the EXL-project, which is part of the NUSTAR (Nuclear STructure, Astrophysics and Reactions) program at FAIR, is to capitalize on light-ion induced direct reactions in inverse kinematics using novel storage ring techniques. For the key physics issues addressed in [2], a complex detection system was designed with the aim to provide a highly efficient, high-resolution universal system, and applicable to a wide class of reaction.

Double-sided silicon detectors (DSSDs) are major part of the EXL silicon particle array (ESPA) [2] surrounding the gas-jet target those will be used as a position sensitive integrated ΔE-E detectors. In this paper, the response of the DSSDs, similar to used ones in EXL, produced the first time at PTI St. Petersburg under the collaboration program with GSI will be presented.

2. DETECTORS AND EXPERIMENTAL SETUP

The 16x16, 64x64 and 64x16 prototype DSSDs are used in this study and of 300 μm thickness fabricated at PTI St. Petersburg (Russia). The small one (16x16 DSSD) has the size of 0.71x0.71 cm^2 and 300 μm strip length, meanwhile those of the biggers (64x64(16) DSSD) are of 21.2x21.2 mm^2 and 1200 μm.

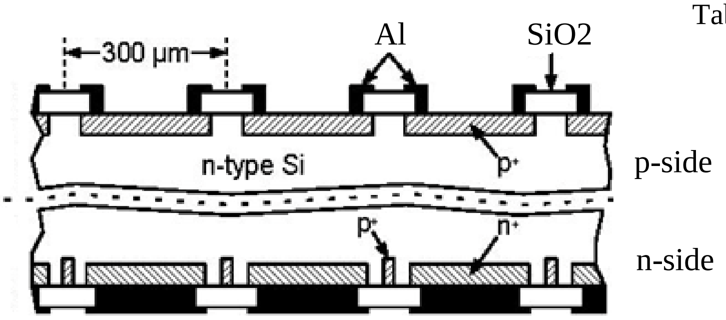

Figure 1: Cross face of p- and n-side of DSSD

Table 1: 5 main peaks of ^{241}Am α-source

Peak	E (keV)	Intensity (%)
1	5389	1.66
2	5443	13.1
3	5485	84.8
4	5512	0.225
5	5545	0.37

The first two samples have the same wafer structure. On the p-side, the strip is formed by a thin oxide layer and an approximately 400 nm p^+ implantation. The ohmic contact is realized through an 800 nm thick and 17.5 µm wide aluminum frame surrounding each strip. An 185 µm wide strip window together with an interstrip gap made of a 0.44 µm thick and 15 µm wide silicon oxide as strip isolation complete a pitch size of 300 µm. The strips of the rear side (n-side) are entirely covered with aluminium of the same thickness. The isolations of the strips is done by a 450 nm thick p+ implantation. The rear side interstrip gap is 65 µm wide and the pitch size is equal to that on the front. The 64x16 sample has the same p-side pattern as the two previous ones, but a 1200 µm wide pitch on the rear side with an 1135 µm strip and a 65 interstrip gap. A schematic view of detector structure is drawn in figure 1. The test experiment was done with an americium ^{241}Am α-source which has 5 intensive peaks tabulated in table 1.

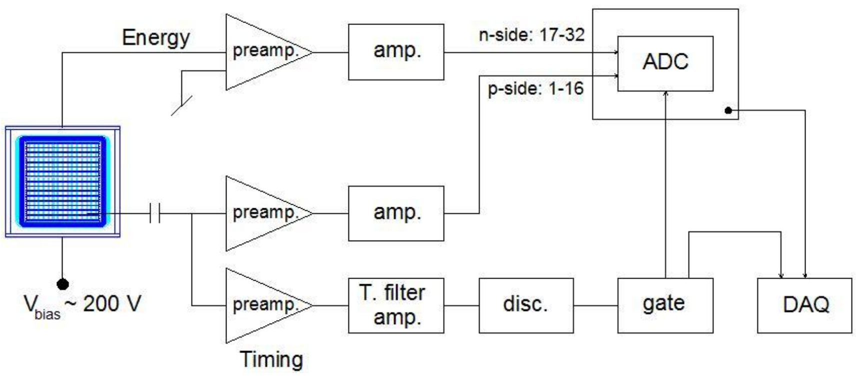

Figure 2: The electronic scheme of test experiments

The depletion voltage was established by punch through biasing with a -200 V applied to p-side AC-coupled preamplifiers. The ground was done through DC-coupled preamplifiers coupled to the n-side. Figure 2 is the electronic scheme used in this study. The energy signal from the strips go to the preamplifiers, to amplifiers, to ADCs and finally to DAQ. The DAQ opens and records events only when the energy signal is coincident with the gate which is the sum of all timing signals from front side.

3. RESULT AND DISCUSSION

3.1 P-side inject

In the EXL experiment particles will always impact perpendicularly on the DSSDs and inject from p-side. A test experiment for 16x16 DSSDs was setup at GSI where 32 readout channels available. The signals of the strips on front side were connected with channels from 1 to 16, and the left (17-32 channels) were used for the strip signals from the rear.

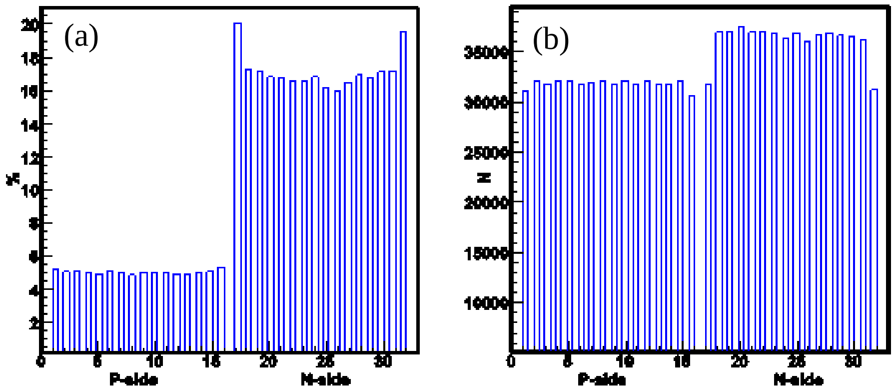

Figure 3: Percentage of interstrip events (a), count rate distribution per strip (b)

Except the outer ones, each strip has two neighbors. The interstrip percentages were calculated by half of interstrip counts divided by strip count rate. The result was approximately 5 % and 17 % for strips on p- and n-side, respectively. Those conforms with the geometry of the sample. Figure 3.b show a homogeneous count rate distribution over strips. The strip count rate was added if any signal above threshold induced. Moreover, inner strips have more interstrip event so, it explain the outer strip count rates are less than others on n-side. And because of smaller interstrip gaps, the count rates on p-side are less.

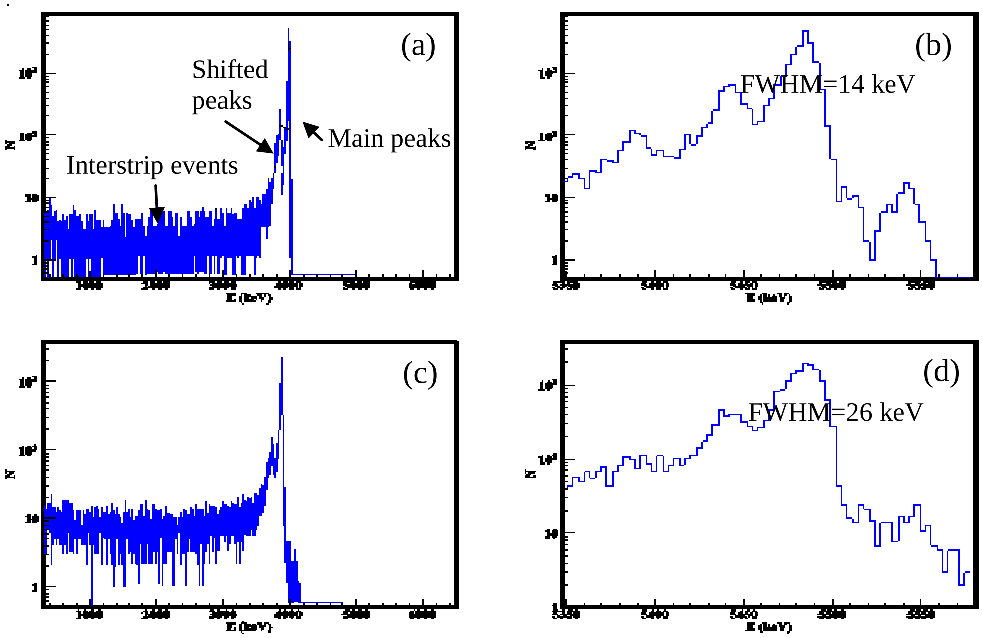

Figure 4: Energy spectrum

(a) p-side strip 5 with the zoom of main peak region (b),

(c) n-side strip 5 the zoom of main peak region (d)

The characteristic energy spectra taken from a strip at p- and n-side are displayed in figure 4. Each spectrum consists of 3 regions: main peaks (of ^{241}Am source), shifted peaks (energy lost by Al frame, the partial overlap of opposite side bonding pads or by inducing positive signal in adjacent strips), and interstrip events (particles share energy over two neighboring strips). The 5 main peaks of the radioactive source are well separated as in panel (b) and (d) which give 14 and 26 keV energy resolution, respectively.

There are four types of event detected by the DSSD: (1) strip-strip, (2) strip-interstrip, (3) interstrip-strip and (4) interstrip-interstrip. Where, 'strip' means all the charges created by the incident particle drift toward only one strip, and 'interstrip' if the charges are shared over two neighbors. The order is front–rear side as opposite charges will drift toward opposite sides. As a new method for the information about detector efficiency, we made the correlation between energy signals induced on p- and n-side strips and delimit the scatter plot into regions corresponding to event types (figure 5). The efficiency was calculated in table 2.

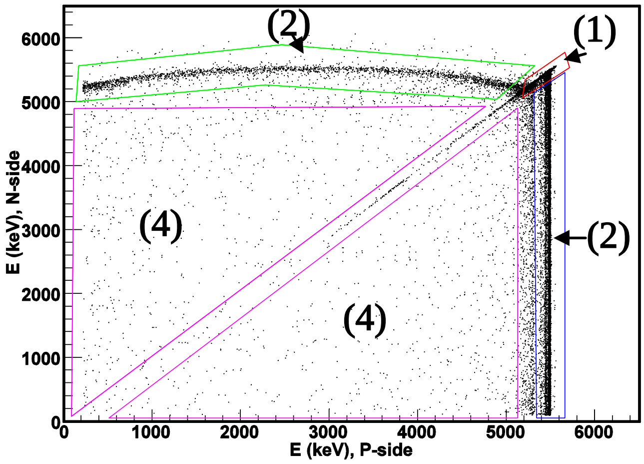

Figure 5: 2-D energy signal correlation between p- and n-side

Table 2: Event statistics

Event type	Percentage (%)
(1)	76.8
(2)	18.2
(3)	4.1
(4)	0.9

The performance of the 64x64 DSSD was very similar to that of the 16x16 DSSD. Because at the University of Edinburg different electronics were used so obtained resolutions were 29 and 32 keV for energy spectra of the strips on p- and n-side, respectively.

3.2 N-side injection

The behavior of DSSD with n-side injection is not yet fully understood and still under investigation.

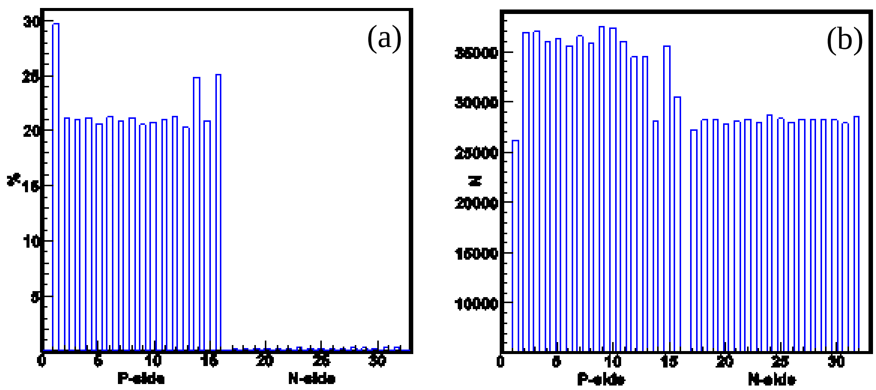

Figure 6: Percentage of interstrip events (a), count rate distribution per strip (b), 16x16 DSSD

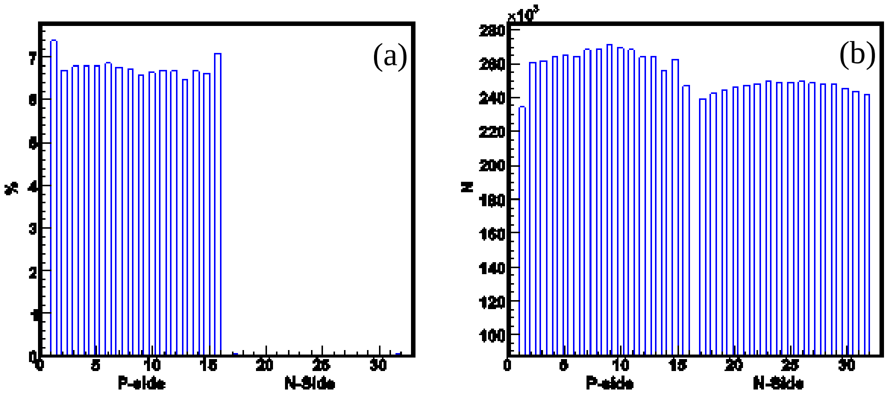

Figure 7: Percentage of interstrip events (a), count rate distribution per strip (b), 64x16 DSSD

The homogeneous event distribution can be seen in panel (b) on figure 6. The interstrip percentage is very different from the detector geometry as discussed before. With 64x16 DSSD, the homogeneity of count rate is representative. The slight difference (n-side in panel (b), figure 7) can be explained by different geometrical measurement angles as small source size and large size of the detector.

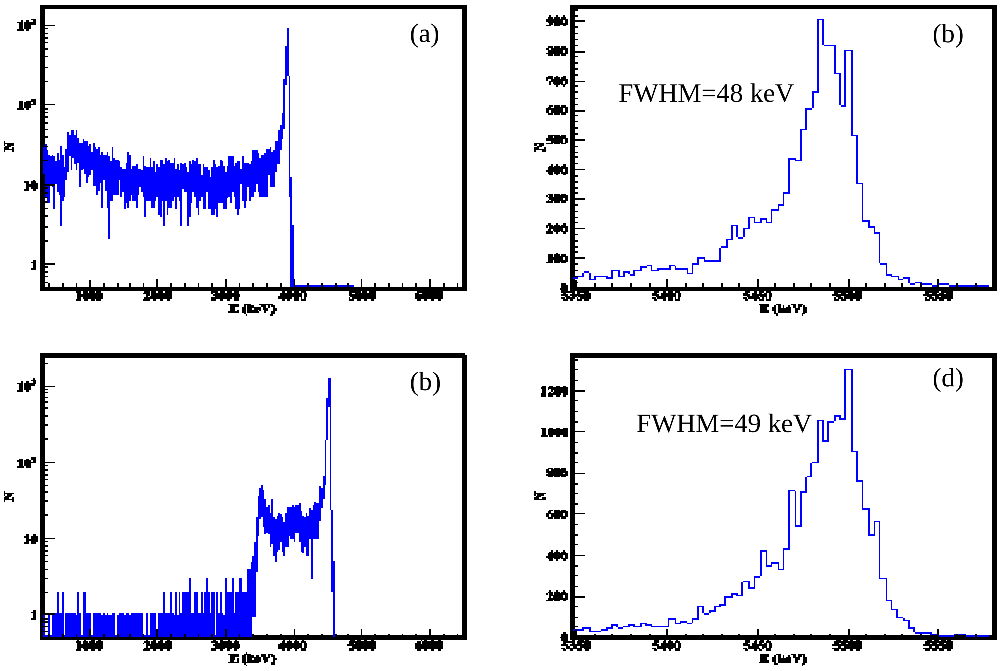

Figure 8: Energy spectrum

(a) p-side strip 5 with the zoom of main peak region (b),

(c) n-side strip 5 the zoom of main peak region (d)

The characteristic energy spectra are displayed in figure 8. As the energy resolution becomes worse approximately 50 keV in both sides, the 5 main peaks of ^{241}Am α source are no longer resolved. The drop of n-side spectrum around 3850 keV (panel (c)) is consistent with the correlation figure below as interstrip events become less. The efficiencies are tabulated in table 3.

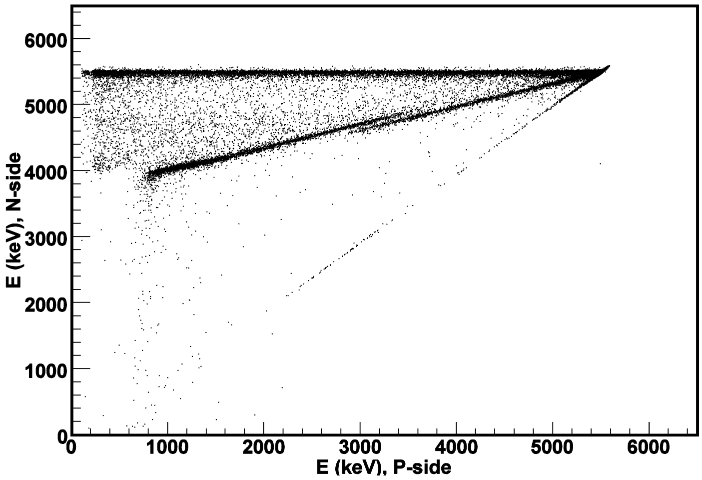

Figure 9: 2-D energy signal correlation between

p- and n-side, n-side injection

Table 3: Event statistics, rear-front side order

Event type	Percentage (%)	
	16x16 DSSD	64x16 DSSD
(1)	75.3	93.9
(2)	24.7	6.1
(3)	~ 0	~ 0.0
(4)	~ 0	~ 0.0

4. SUMMARY

The first test phase has been completed. With p-side injection, the result shows good spectroscopic properties of the detector samples. The interstrip behavior conforms with detector geometry and the interstrip-interstrip events are negligible (0.9 % in total number). The energy resolution of strip energy spectrum on p-side is better than on n-side. And it becomes worse in the case of n-side injection. The performance in this case is not fully understood and still under investigation. Bigger 64x64 DSSD sample with an 1 mm pitch size and a thickness of 100 μm will be available and tested.

5. REFERENCES

[1] Facility for Antiproton and Ion Research, http://www.gsi.de/fair.

[2] EXL Technical Proposal, http://www-linux.gsi.de/wwwnusta/tech report/05-exl.pdf.

[3] Shin'ichiro Takeda, Shin Watanabe, Takaaki Tanaka, Kazuhiro Nakazawa, Tadayuki Takahashi, Yasushi Fukazawa, Hajimu Yasuda, Hiroyasu Tajima, Yoshikatsu Kuroda, Mitsunobu Onishi, Kei Genba, Nucl. Instr. And Meth. A 579, 2007, pp. 859-865.

[4] Y. Blumenfeld et al., Nucl. Instr. and Meth. A 421, 1999, pp. 471-491.

[5] E. Verbitskaya, V. Eremin, G. Ruggiero, S. Roe, P. Weilhammer, N. Egorov, S. Golubkov, K. Konkov, Yu. Kozlov, and A. Sidorov, IEEE Transactions on Nuclear Science, Vol. 52, No. 5, October 2005.