Journal Publication

Development of a novel 2D position-sensitive semiconductor detector concept

Bassignana, D (CSIC) *et al*

13 April 2012

The research leading to these results has received funding from the European Commission under the FP7 Research Infrastructures project AIDA, grant agreement no. 262025.

This work is part of AIDA Work Package 9: **Advanced infrastructures for detector R&D.**

The electronic version of this AIDA Publication is available via the AIDA web site
<<http://cern.ch/aida>> or on the CERN Document Server at the following URL:
<<http://cds.cern.ch/search?p=AIDA-PUB-2012-025>>

Development of a novel 2D position-sensitive semiconductor detector concept

This content has been downloaded from IOPscience. Please scroll down to see the full text.

2012 JINST 7 C04008

(<http://iopscience.iop.org/1748-0221/7/04/C04008>)

View [the table of contents for this issue](#), or go to the [journal homepage](#) for more

Download details:

IP Address: 137.138.31.79

This content was downloaded on 23/03/2015 at 10:50

Please note that [terms and conditions apply](#).

THE 9th INTERNATIONAL CONFERENCE ON POSITION SENSITIVE DETECTORS,
12–16 SEPTEMBER 2011,
ABERYSTWYTH, U.K.

Development of a novel 2D position-sensitive semiconductor detector concept

**D. Bassignana,^{a,1} M. Fernandez,^b R. Jaramillo,^b M. Lozano,^a F.J. Munoz,^b
G. Pellegrini,^a D. Quirion^a and I. Vila^b**

^a*Centro Nacional de Microelectrónica (IMB-CNM-CSIC), Campus Univ. Autónoma de Barcelona
08193 Bellaterra, Barcelona, Spain*

^b*Instituto de Física de Cantabria IFCA (CSIC-UC), Edificio Juan Jordá,
Avenida de los Castros, s/n, E-39005 Santander, Spain*

E-mail: daniela.bassignana@imb-cnm.csic.es

ABSTRACT: A novel 2D position-sensitive semiconductor detector concept has been developed employing resistive electrodes in a single-sided silicon microstrip sensor. The resistive charge division method has been implemented reading out each strip at both ends, in order to get the second coordinate of an ionizing event along the strips length. Two generations of prototypes, with different layout, have been produced and characterized using a pulsed near infra-red laser. The feasibility of the resistive charge division method in silicon microstrip detectors has been demonstrated and the possibility of single-chip readout of the device has been investigated. Experimental data were compared with the theoretical expectations and the electrical simulation of the sensor equivalent circuit coupled to simple electronics readout circuits. The agreement between experimental and simulation results validates the developed simulation as a tool for the optimization of future sensor prototypes.

KEYWORDS: Solid state detectors; Si microstrip and pad detectors

¹Corresponding author.

Contents

1	Introduction	1
2	The new device concept	2
3	First prototype	3
3.1	Specifications and expected performance	3
4	Laser characterization of the prototype	7
4.1	Experimental setup	7
4.2	Comparison between experimental and simulation results	7
5	Second prototypes	8
5.1	Proof-of-concept sensors design	8
5.2	Experimental results and validation of the simulation model	9
6	Conclusions	11

1 Introduction

Solid state detectors have been developed and used as position-sensitive detectors since the early 1980s. Starting from nuclear and high energy physics experiments their application has spread to other field of interests like astrophysics investigations and medical imaging. Especially for those cases where the compactness of the detection system is demanded many two-dimension position-sensitive devices have been invented and produced using double-sided processing (2D microstrip detectors and drift detectors) or implementing a complex readout system with a large number of electronic channels (pixel detectors). Starting from a common single-sided AC coupled microstrip detectors we invented a new device for 2D position measurements, maintaining the simplicity of the fabrication process and just doubling the number of readout channels. A resistive material layer deposited on each strip and equipped with metal pads at the ends (for the connection with the front end electronics) allows the use of the resistive charge division method to obtain spatial information of the event in the second coordinate, along the strip direction.

Recently, the use of the charge division method in very long microstrip sensors, several tens of centimeters, has been proposed as a possible tracking technology for the International Linear Collider detector concepts. Along this application line, the behaviour of a detector equivalent RC network implemented in a PC board and DC coupled with two readout electronics circuits was studied and compared with a SPICE electronic circuit simulation [1]. The results confirmed the overall validity of Radeka's formulation [2] on resistive charge-division.

In this paper, a novel microstrip detector concept is introduced, where the resistive electrodes (light yellow structure in figure 1 (a) and (b)) are made of a thin layer of high doped polycrystalline

Figure 1. Schematic top view of the novel detector (a) and lateral cross-section of the central strip (b)(not to scale). It is possible to distinguish the aluminium elements in blue and the resistive electrodes on the strips (light yellow regions). The aluminium pads are connected each one to a channel of the read-out electronics (two for each strip). When an ionizing particle crosses the detector, different signals (S_1 and S_2) are read by the opposite electronic channels. The X coordinate of the event can be reconstructed using the center of gravity method, whereas the Y coordinate is reconstructed comparing the charges at the ends of each strip.

silicon. This original approach decouples the resistive electrodes from the detector diode structure through a coupling capacitance (gray layer in figure 1 (b)), avoiding in this way any influence of the resistive line on the charge collection behaviour.

In the following sections the development of the device will be presented. After a description of the working principle and expectations, the real sensors will be introduced. Two generations of prototypes, with different layout, have been fabricated at the IMB-CNM clean room facilities in Barcelona [3] and characterized using a pulsed near infra-red laser. The experimental data were compared with the electrical simulation of the sensor equivalent circuit coupled to simple electronics readout circuits. The good agreement between experimental and simulation results establishes the soundness of resistive charge division method in silicon microstrip sensors and validates the developed simulation as a tool for the optimization of future sensor prototypes.

2 The new device concept

In a conventional microstrip detector the metal contacts of the strips extend over almost all the length of the implants and each one is connected to a read-out channel. When an ionizing particle crosses the detector, the propagation of the induced signal along the coupling electrode does not suffer a significant attenuation, i.e., the signal amplitude does not depend on the particle impinging point along the electrode direction.

When using, instead of metal alloy, a resistive material, the resistive electrode act as a diffusive RC line, this translates into not only a signal amplitude attenuation but also into an increase of the rise time of the propagating signal the further the pulse travels [4]. Using a readout electronics characterized by a fixed and short shaping time, it translates into a non constant signal ballistic deficit. In practice, this running ballistic deficit will appears as a degradation in the linearity of the charge division response. There is a second source of degradation in the sensor response caused by the resistive electrodes, increasing the electrode resistance also increases the readout serial noise contribution. Increasing the amplifier peaking time will reduce both the ballistic deficit and the serial noise contribution; however, a longer peaking time increases the parallel readout noise contribution. In reference [2], Radeka derived the optimal peaking time for a resistive charge division configuration, under the assumption of high electrode resistance compared to the amplifiers impedance and long amplifier peaking time compared to input signal rise times. Under these approximations, Radeka concluded that the longitudinal coordinate of the signal generation point linearly depends on the collected charge normalized to the sum of the charges collected in opposite electrodes. The actual functional form (following figure 1 notation with A_1 and A_2 the amplitudes of S_1 and S_2 respectively) is given by equation (2.1):

$$y = L \times \frac{A_2}{A_1 + A_2} \quad (2.1)$$

In this way a conventionally manufactured single-sided microstrip sensor can provide the two-dimensional coordinates of the particle impinging point; the transversal coordinate derived from the usual electrode segmentation [5] and the longitudinal coordinate is determined by relating signal amplitude at both ends of the electrodes using equation (2.1).

3 First prototype

3.1 Specifications and expected performance

The first prototype has been designed and fabricated at the IMB-CNM clean room facilities in Barcelona in 2009 using the conventional technology for p-on-n, AC coupled, silicon microstrip detectors. The sensor consists of 34 p^+ strips 20 μm wide, 1.4 cm long and with a pitch of 160 μm on a $(285 \pm 15) \mu\text{m}$ thick n-type substrate. The resistive material used is highly doped polysilicon with resistance per unit length $R/l = 20 \Omega/\mu\text{m}$.

As shown in figure 2, aluminium routing have been added in order to connect the detector to only one front end chip (see next section). The detectors have been electrically characterized in the IMB-CNM laboratories with the use of a probe station Cascade Microtech, two Keithleys 2410 Source/Meter and an Agilent 4284A LCR Meter. The results are consistent with the ones of the standard microstrip detectors included in the process run. The measured values are listed in table 1.

We have developed a SPICE-like model of the prototype and subsequently one of the readout electronics in order to clarify the possible effect of the non-optimal shaping time on the linearity of the equation (2.1), studying the response of the detector to a simulated current pulse injected at different points along the strip length.

Starting from the work presented in reference [6] we developed the model of our detectors built with standard components from the AnalogLib library of Virtuoso Spectre by Cadence [7]. A portion of the detector including five consecutive strips is modeled by a periodic structure composed

Figure 2. Schematic top view of the first prototype (not in scale)(left). The black color refers to aluminium structures while the striped elements represents the resistive electrodes on the strips. The pitch of the strip implants is $160\text{ }\mu\text{m}$ while the readout pitch is $80\text{ }\mu\text{m}$ due to the aluminium tracks. The two photographs on the right side show the actual prototype layout at the electrode ends.

Table 1. Electrical characterization: measured values of depletion voltage, breakdown voltage, bias resistance, interstrip resistance and capacitance, coupling capacitance and polysilicon electrode resistance.

strip width	V_{dep} [V]	V_{bd} [V]	R_{bias} [M Ω]	R_{int}	C_{int} [pF]	C_{AC} [pF/cm]	R [$\Omega/\mu\text{m}$]
$20\text{ }\mu\text{m}$	40	>400	1.31	>G Ω	0.6	173	20

of 56 cells, each one corresponding to a transversal section ($250\text{ }\mu\text{m}$ long) of the strips. The unit cell is a complex chain of capacitances and resistors representing the main electrical characteristics of the device as the substrate resistance and capacitance (R_{sub} and C_{sub}), the interstrip resistance and capacitance (R_{int} and C_{int}), the p^+ implant resistance (R_{impl}), the coupling capacitance (C_{AC}) and the resistance of the resistive upper electrode (R_{el}). In figure 3 the schematic of the unit cell is shown. The values of the circuit elements have been extrapolated from the ones measured during the electrical characterization of the detectors in full depletion ($V_{bias}=100\text{ V}$). These values are listed in table 2.

For our study, no dedicated analog signal processing electronics was built and therefore the front-end filtering of the signal was not optimized accordingly with Radeka’s conclusions. As will be explained in more detail in the following section, we have used the ALIBAVA DAQ system developed within the framework of the CERN RD50 collaboration. The analog front-end of the ALIBAVA system is based on the Beetle chip used for the microstrip sensor readout of the silicon tracking subsystem of the LHCb experiment at LHC; consequently, the analog front-end shaper peaking time of the ALIVABA system is set around 25 ns.

We simulated a current pulse generator connected to different points along the implant of the central strip with a step of 2 mm and recorded the shape of the current pulses at the output of the

Figure 3. Schematics of one of the 56 cells used to model the detector. Each one represents a portion ($250\ \mu\text{m}$ long) of the strip including the main electrical parameters like the coupling capacitance (C_{AC}), the interstrip resistance and capacitance (R_{int} and C_{int}), the substrate resistance and capacitance (R_{sub} and C_{sub}), the p^+ implant resistance (R_{impl}) and the resistance of the resistive electrode (R_{el}). In the simulation a pulsed current has been induced at different nodes along the central strip implant.

Table 2. List of the values of the models parameters. Detector on the left, readout electronics on the right.

R_{el}	$2500\ \Omega$	R_{fp}	$300\ \text{M}\Omega$
R_{impl}	$800\ \Omega$	C_{fp}	1pF
C_{AC}	$3.43\ \text{pF}$	$C_d = C_i$	25pF
C_{sub}	$16.6\ \text{fF}$	$R_d = R_i$	$1\text{k}\Omega$
R_{sub}	$20000\ \text{G}\Omega$	R_1	$1\text{k}\Omega$
R_{int}	$15\ \text{G}\Omega$	R_2	$1\text{k}\Omega$
C_{int}	$24\ \text{fF}$	R_t	$1\text{M}\Omega$

shapers (S_1 and S_2). The current pulse injected is characterized by a rise time of 2 ns and total integrated charge around 4 fC. The rise time of the diode laser we have used for our study is around 2 ns (measured with a high bandwidth photodiode), similar to the simulated one. The model of the read-out electronics connected to the ends of each strip consists in a generic charge sensitive preamplifier followed by a CR-RC filter, which peaking time matches that of the Beetle chip. The front-end schematic is shown in figure 4 and the parameter values are listed in table 2.

Looking at figure 5, the different colors of the pulses S_1 and S_2 highlight the expected asymmetric dependence of the pulse attenuation on the pulse generator position along the strip length. We have used the amplitude of these pulses to calculate the simulated fractional position $A_2/(A_1 + A_2)$ of the pulse generator: the results are shown in figure 6 as a function of the actual fractional position (y/L).

The effect of a non-constant ballistic deficit on the detector response linearity is pointed up by comparing the simulated data with that predicted by equation (2.1) (green line).

Figure 4. Schematics of the readout electronics modeled for the simulation.

Figure 5. Signals read at the output of the shapers connected to the strip ends in the corresponding position 0 mm (a) and 14 mm (b).

Figure 6. Simulated fractional position as a function of the actual one. The green line represents the linearity predicted by equation (2.1).

4 Laser characterization of the prototype

4.1 Experimental setup

The sensor was mounted in a dedicated PCB sensor carrier and read out using ALIBAVA DAQ system [8]. The ALIBAVA is a DAQ system for the readout of microstrip sensors based on the Beetle analog readout ASIC [9]. The Beetle integrates 128 pipelined channels with low-noise charge-sensitive preamplifiers and shapers with a peaking time of 25 ns. Each detector board has two Beetle chips, but for our prototype we used just one of them to connect all the 34 strips (two channels for each strip), bonding the pads related to one side of the strips to the even channels and the pads related to the other side to the odd ones.

The characterization test-stand, located in the IFCA laboratories [10], allows for the precise injection of laser pulses along the microstrips direction (see figure 7). We used a pulsed distributed-feedback diode laser driven in a constant optical power mode and thermally stabilized. The laser output is coupled to a monomode optical fiber which feeds an inline fiber optic splitter: the first splitter output fiber is connected to a large bandwidth (2 GHz) reference photodiode whose output signal is recorded in a digital scope to monitor the laser pulse trace; the second splitter output fiber feeds a microfocusing optical head illuminating the sensor. The microfocusing optical head was moved by a 3D axis stage with a displacement accuracy better than $10\text{ }\mu\text{m}$ for all the axis. The laser is focused in such a way that the beam waist is at the sensor front plane; the beam intensity profile at the beam waist is a Gaussian with a sigma of $5\text{ }\mu\text{m}$. The laser wavelength is centered at 1060 nm, the amplitude 1 V and the rise time, as measured by the reference photodiode, is 2 ns. For this first investigation, the design of an application-specific sensor optimized for MIP detection was beyond our scope and we did not intend the laser emulation of MIP pulses as we were only interested in the relative amplitude of the signals read at the end of the strips in order to demonstrate the feasibility of the resistive charge division method in microstrip detectors. A study of this prototype (and the others) response to MIPs is currently in progress: the analysis of the data recorded with a pion test beam at the CERN SPS beam line H6 is being carried out.

4.2 Comparison between experimental and simulation results

A longitudinal scan of the detector has been performed moving the focused beam spot along the midline of a polysilicon electrode. Unlike aluminium, polycrystalline silicon is transparent to IR light. We scanned the whole electrode length (14 mm) with a scanning step of 2 mm, reconstructing, for each position, the pulse shape at the output of the front-end electronics shapers stage.

The ALIBAVA DAQ system does not allow the whole shape of the analog signal to be recorded. On the other hand a particular feature of the system let the value of the delay between the trigger time (synchronous with the laser pulse) and the acquisition time (specifying the instant at which the shaper output is sampled), to be changed in order to reconstruct the entire pulse [8]. Setting different delays in step of 5 ns from 170 to 300 ns, we recorded 20000 events for each delay step and we found the mean value of their distribution by means of a Gaussian function. The amplitudes of the reconstructed pulses have been accurately extrapolated by fitting a Gaussian function to the peak region. These values have been used for the calculation of the fractional position defined by equation (2.1).

Figure 7. Experimental setup. The micro focusing optical head mounted on the 3D axis stage is placed a few millimeters upon the detector board.

Figure 8. Measured fractional position compared with the simulated one. The signal induced on the metal guides contributes to signal S_2 generating a shift of the results from the simulation expectation.

Comparing the experimental data with the simulation (figure 8) it is possible to notice a discrepancy due to the contribution of induced signals to the aluminium tracks. The origin of this signal component is a parasitic capacitance between the aluminium routing and the strip implants. In order to avoid this effects, a new generation of prototypes have been developed and fabricated.

5 Second prototypes

5.1 Proof-of-concept sensors design

The new generation of prototypes fabricated in 2010 [4] consists of two samples each one with 384 p^+ strips ($20\ \mu\text{m}$ wide) with a pitch of $80\ \mu\text{m}$ on a $(285 \pm 15)\ \mu\text{m}$ thick n-type substrate. The

Figure 9. Picture of one of the detectors mounted in the PCB sensor carrier. The two Beetle chips are indicated by the white circles. Each one is connected to one side of 128 consecutive strips of the detector in order to provide double-sided readout.

Table 3. Electrical characterization: measured values of the polycrystalline silicon electrode resistance, depletion voltage, breakdown voltage, bias resistance, interstrip resistance, interstrip capacitance and coupling capacitance.

electrodes resistance	V_{dep} [V]	V_{bd} [V]	R_{bias} [M Ω]	R_{int}	C_{int} [pF/cm]	C_{AC} [pF/cm]
$2.8 \Omega/\mu\text{m}$	20	>300	4	>G Ω	0.46	189
$12.2 \Omega/\mu\text{m}$	20	>400	2.41	>G Ω	0.46	189

Table 4. List of the values of the models parameters.

R_{el}	R_{impl}	C_{AC}	C_{sub}	R_{sub}	R_{int}	C_{int}
350 or 1525 Ω	718 Ω	4.7 pF	8.6 fF	20000 G Ω	15 G Ω	11.5 fF

resistive electrodes have a total length of 2 cm with linear resistance $R/\mu\text{m}=2.8 \Omega/\mu\text{m}$ for one of the devices and $R/\mu\text{m}=12.2 \Omega/\mu\text{m}$ for the other. In each detector 128 consecutive strips have been connected to two different chips as shown in figure 9.

Several electrical test structures [11] were included in each wafer of the fabrication run in order to have a more direct measurement of the electrical parameters of the new sensors. The results of their electrical characterization are listed in table 3.

The SPICE-like model developed for the first prototypes has been adapted to the new ones, using 80 cells and the values of the parameters listed in table 4.

5.2 Experimental results and validation of the simulation model

In the same way as for the first sensor, the laser characterization has been repeated for these samples scanning the whole electrode length (20 mm) with a scanning step of 2 mm for each sensor. The same pulse reconstruction method has been used, obtaining a strong suppression of the statistical

Figure 10. Measured fractional position as a function of the actual fractional position for both values of the electrodes resistance: $R=2.8\ \Omega/\mu\text{m}$ (a) and $R=12.2\ \Omega/\mu\text{m}$ (b). The green line represents the linear response predicted by equation (2.1).

error. Figure 10 shows, for both sensors, the measured fractional position of the laser spot against the position given by the displacement of the micrometric stage.

The comparison between the experimental results and the ideal linear behaviour given by equation (2.1) highlights the degradation of the linearity of the detector response due to the systematic error introduced by the non-constant ballistic deficit: the higher the value of the electrode resistivity, the deeper the discrepancy between the data and the expected values. This effect is clearer in these new prototypes, which have longer strips than the first one.

The statistical errors on the experimental data are 0.002 and 0.0035 for the sensors with low and high resistive electrodes respectively; they have been calculated using equation:

$$\sigma = \frac{1}{\left(1 + \frac{A_2}{A_1}\right)^2} \left[\frac{A_2}{A_1} \sqrt{\left(\frac{\sigma_{A_1}}{A_1}\right)^2 + \left(\frac{\sigma_{A_2}}{A_2}\right)^2} - 2\rho \left(\frac{\sigma_{A_1}}{A_1} \frac{\sigma_{A_2}}{A_2}\right) \right] \quad (5.1)$$

with σ_{A_1} and σ_{A_2} the experimental errors of A_1 and A_2 which are the signals S_1 and S_2 amplitudes, and the correlation parameter ρ calculated as follow:

$$\rho = \frac{\langle A'_1 A'_2 \rangle}{(\sigma_{A'_1} \sigma_{A'_2})} \quad (5.2)$$

Where A'_1 and A'_2 are, in this case, the noise excursions with respect to the mean value of the corresponding mean amplitude and $\sigma_{A'_1}$ and $\sigma_{A'_2}$ are the sigma parameters obtained from the Gaussian fit of the amplitude distributions. We obtain a mean value of 0.19 and 0.34 for the sensor with low and high resistive electrodes respectively.

Unlike the case of the first prototype with the aluminium routing, this time the simulation results and the experimental data show a similar systematic behaviour on the fractional position determination (see figure 11 and 12). We note also how the residuals (figure 12) of the low resistive electrodes sensor increase for larger values of the fractional position: this effect was caused by the existence of a slight misalignment between the stage scanning direction and the electrode one.

Figure 11. Experimental results compared with the simulation for both values of the electrodes resistance: $R=2.8 \Omega/\mu\text{m}$ (a) and $R=12.2 \Omega/\mu\text{m}$ (b).

Figure 12. Experimental results (residuals) compared with the simulation for both values of the electrodes resistance: $R=2.8 \Omega/\mu\text{m}$ (a) and $R=12.2 \Omega/\mu\text{m}$ (b).

In general the good agreement between these results confirms the validity of the electrical simulation as a valuable design tool for sensor optimization. At the same time it demonstrates that the results we expected from the simulation of the first prototype are the correct ones in absence of the metal routing. Reducing the parasitic capacitance between aluminium lines and strip implants is an aim of future studies and prototypes.

6 Conclusions

We have introduced a novel 2D position-sensitive semiconductor detector concept based on the resistive charge-division readout method and manufactured using the standard technology of AC coupled microstrip detectors. The implementation of resistive coupling electrodes allows to extract the

information on the longitudinal coordinate of an ionizing event using the resistive charge-division method.

Two different prototypes generations have been fabricated: the first one optimized for a single chip readout adding an aluminium routing to each strip and the second one developed for a double chip readout in order to have genuine proof-of-concept devices. A first investigation of their performance has been carried out using a near infra-red laser and a readout electronics based on the Beetle ASIC. An electrical simulation of the sensor equivalent circuit, including the amplifying and filtering stages, has been developed and benchmarked against the experimental data. In the first case we observed the effect (asymmetry in the detector response) of a parasitic coupling capacitance between the aluminium routing and the strip implant, whose reduction will be object of future studies.

For what concerns the second generation of prototypes, the good agreement between experimental data and simulation results validates the electrical simulation as an adequate tool for future sensor optimization. Actually, in order to meet with different requirements on the strip geometry and on the shaping time of the readout electronics, it is possible to tune the electrode resistivity without affecting the charge collection behaviour of the sensor, as the resistive electrodes are decoupled from the diode structure of the sensor.

This initial study demonstrates the feasibility of the resistive charge division method in a fully fledged microstrip sensor with resistive electrodes. Specific studies on detection of minimum ionizing particles are in progress to assess its soundness as a tracking technology for the future particle physics experiments. Nevertheless, in its current conception, this implementation appears a suitable technology for the detection of highly ionizing particles, like heavy ions, neutron monitoring with the use of conversion layers or other nuclear imaging technologies including Compton cameras.

Acknowledgments

We thanks A.Candelori (INFN, Padova) for the clarifications concerning the SPICE model of ref. [6]; Gianluigi Casse (University of Liverpool) and Ricardo Marco (IFIC, Valencia) for the bonding of the sensors and boards and Marko Dragicevic (HEPHY, Vienna) for contributing to the design of the mask of the sensors.

This work has been supported by the Spanish Ministry of Science and Innovation under grants FPA2010-22163-C02-02 (DET4HEP) and FPA2010-22060-C02-02 and through the GIC-SERV program “Access to ICTS integrated nano-and micro electronics cleanroom” of the same ministry.

References

- [1] J.K. Carman, V. Fadeyev, K. Mistry, R. Partridge, B.A. Schumm, et al., *Longitudinal resistive charge division in multi-channel silicon strip sensors*, *Nucl. Instrum. Meth. A* **646** (2011) 118.
- [2] V. Radeka, *Signal, Noise and Resolution in Position-Sensitive Detectors*, *IEEE T. Nucl. Sci.* **21** (1974) 51.
- [3] Centro Nacional de Microelectrónica, Campus Universidad Autónoma de Barcelona, 08193 Bellaterra (Barcelona), Spain, <http://www.imb-cnm.csic.es/>.

- [4] D. Bassignana, M. Lozano, G. Pellegrini, D. Quirion, M. Fernandez, et al., *First investigation of a novel 2D position-sensitive semiconductor detector concept*, [2012 JINST 7 P02005](#).
- [5] R. Turchetta, *Spatial resolution of silicon microstrip detectors*, [Nucl. Instrum. Meth. A 335 \(1993\) 44](#).
- [6] N. Bacchetta et al., *SPICE analysis of signal propagation in Si microstrip detectors*, [IEEE T. Nucl. Sci. 42 \(1995\) 459](#).
- [7] Cadence, *Virtuoso Spectre data sheet*, http://www.cadence.com/products/custom_ic/index.aspx.
- [8] R. Marco-Hernandez and ALIBAVA collaboration, *A Portable Readout System for Microstrip Silicon Sensors (ALIBAVA)*, [IEEE T. Nucl. Sci. 56 \(2009\) 1642](#).
- [9] *Beetle — a readout chip for LHCb*, <http://www.kip.uni-heidelberg.de/lhcb/>.
- [10] Instituto de Física de Cantabria IFCA (CSIC-UC), Edificio Juan Jordá, Avenida de los Castros, s/n, E-39005 Santander, Spain, <http://www.ifca.unican.es/>.
- [11] T. Bergauer, M. Dragicevic, M. Frey, P. Grabiec, M. Grodner, et al., *Results from a first production of enhanced silicon sensor Test Structures produced by ITE Warsaw*, [Nucl. Instrum. Meth. A 598 \(2009\) 86](#).