# Resistive charge-division on thinned microstrips sensors with low signal amplification

**Introduction and Motivation**

In the context of the ILC, the relatively low occupancy environment and the power pulsing operation of the front-end electronics provide an opportunity for the implementation of ultra-lightweight silicon-based tracking systems where the dominant contribution to the material budget in the fiducial volume comes from the sensors. Reducing the material budget has a major impact on the hit position resolution and hence the momentum resolution of the tracker system; therefore, we have pursued during the last three years an RD program for the development of very thin microstrips sensors able to provide two dimensional information of the hit position.

The ultimate goal of this RD is the development of a microstrip sensor which combines signal amplification –allowing the thinning of the sensor’s substrate- and resistive electrodes –allowing the implementation of the charge-division method for the determination of the hit position along the strip direction. In a first phase, we are aiming to demonstrate the feasibility of each of the above mentioned features independently and, in a second phase, to integrate both technological solutions into the same microstrip sensor; the thinning of the sensor will done using the anisotropic wet etching (TMAH process) used for the DEPFET fabrication [here reference to DEPFET section]

**Recent Developments and Milestones**

The use of the charge-division method in long microstrip sensors, with a length of several tens of centimeters, was proposed as a possible tracking technology for the International Linear Collider detector concepts a few years ago [Carman, 2011]. More recently, we have demonstrated [Bassignana 2012],[ Bassignana 2013], [Curras 2014] the feasibility of the charge division concept on fully ﬂedged microstrip sensor with resistive electrodes made of polycristaline silicon achieving a spatial resolution along the strip direction of about 7% the strip length. One of the limitations of this technology is the attenuation of the signal along the resistive electrode; additionally, the position resolution along the strip is proportional to the Signal-to-Noise ratio. Therefore, to maintain or even increase the SNR without increasing the sensor substrate thickness we proposed the integration of signal amplification structures in the sensor itself. The Low Gain Avalanche Detector (LGAD) technology appears as a well suited technique for achieving the signal amplification.

LGAD devices engineered as reach-trough avalanche detectors with a moderate gain where initially proposed and developed for timing application [Pellegrini 2014], the moderate signal amplification ensured that a relatively standard front-end readout electronics could be employed. As a spin-off of this original aim, we introduced the *i-LGAD* microstrip concept for tracking, a LGAD device implemented in a p-type substrate where the ohmic electrode is strip-wise segmented; this design favors the uniform signal amplification over the sensors active volume overcoming the non-uniform gain in LGAD microstrips sensors with a strip-wise segmented amplification layer that we recently characterized [Pellegrini 2015], [Vila 2015].

The former R&D line is complemented with the development of a dedicated ASIC using a 180nm AMS fabrication process which integrates a charge amplifier with long shaping time and time stamping functionalities; finally, we completed the study and testing of several pulsed power system topologies based on supercapacitors .

**Engineering Challenges**

Concerning the component aspects, the main challenges are to complete to proof-of-concept of the thinned microstrips with charge amplification and resistive charge-division in a implementation suitable for the LC tracking needs, namely: proof the i-LGAD concept, integrating amplification and charge division, thinning of sensors substrate, large area sensors, manufacturing long ladder by daisy chaining of the sensors. Concerning the read out ASIC, the main challenge will be the design of the front-end with the required functionalities while keeping the power dissipation low enough.

System wise, the main challenge is the design of an air-based cooling system and its integration on the CFRP supporting structure such that the material budget of the system remains acceptable from the point of view of it tracking performance.

**Future detector R&D**

During the next two years we will focus our activities on the testing of the i-LGAD devices and, if the results were positive, the integration of the low gain amplification and manufacturing of large area sensors (100 cm2). Concerning the front-end electronics, the main goal will be to complete a few channel demonstrator integrating the long shaping time amplifier and power pulsing. A real scale thermomechanical mockup is of the FTD subdetector at ILD is currently under construction to assess different air forced cooling options.

**Applications outside LC.**

The application of LGAD devices to the LC tracking is a spin-off of its original aim as timing devices for high radiation environments, this technology is being proposed as vertex locator technology for the LHC experiments: AFP2 and HGTD (ATLAS); and CT-PPS (CMS) [Sadrozinski 2015].

**References**

Carman, J. K., V. Fadeyev, et al. (2011). "Longitudinal resistive charge division in multi-channel silicon strip sensors." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 646(1): 118-125.

Bassignana, D., M. Fernandez, et al. (2012). "First investigation of a novel 2D position-sensitive semiconductor detector concept." Journal of Instrumentation 7(02): P02005.

Bassignana, D., E. Curras, et al. (2013). "2D position sensitive microstrip sensors with charge division along the strip: Studies on the position measurement error." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 732: 186-189.

E. Currás et al., “2D position sensitive microstrip sensors with resistive charge division along the strip”, International Conference in High Energy Physics 2014, Valencia, Spain.

<http://indico.ific.uv.es/indico/contributionDisplay.py?contribId=788&sessionId=16&confId=2025>

G. Pellegrini et al., “Recent developments on LGAD and iLGAD detectors for tracking and timing applications”, submitted to NIM A.

<https://indico.cern.ch/event/340417/session/1/contribution/12/attachments/1160458/1670618/Hiroshima_pellegrini_2.pdf>

I. Vila et al., “i-LGAD a thin microstrip sensors with integrated charge amplification”, LCWS 2015 Whistler, Canada.

<http://agenda.linearcollider.org/event/6662/session/33/contribution/202/material/slides/0.pdf>

H. Sadrozinski et al, “Ultra-Fast Silicon Detectors”, CPAD Instrumentation Frontier Meeting 2015, Arlington, TX, USA.

<https://indico.hep.anl.gov/indico/contributionDisplay.py?contribId=54&confId=625>

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| **R&D**  **Technology** | **Participating Institutes** | **Description /**  **Concept** | **Achieved Results / Milestones :** | **Future Activities :** |
| **Sensors** | IMB-CNM[[1]](#footnote-1), IFCA[[2]](#footnote-2) | Thinned Microstrips sensors with integrated signal amplification and resistive charge-division along the strip. | Proof of concept of the amplification and charge division mechanisms independently | Combine amplification and charge division Techniques. Manufacturing large area sensors (100cm2) for daisy chaining |
| **Front-End** | UB[[3]](#footnote-3), US[[4]](#footnote-4) | Long shaping time charge amplifier with time stamping in AMS 180nm | Submision of first CSA analog stages | Few channel demonstrator |
| **Powering** | ITA[[5]](#footnote-5) | Power pulsed system based on supercapacitors | Simulation and experimental validation of a topology suitable for the FTD subdector at ILD | Integration in FTD  real scale thermo-mechanical mockup in construction |

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