MONOLITHIC AC-LGADs:

A New Frontier in High-Performance Particle Tracking in 4 Dimensions

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MOTIVATIONS

Technology challenges foreseen in **near-future** and in **major upgrades of present** high-energy physics experiments are essentially related to **detector requirements** such

- low **power consumption**: few mW/cm^2
- low **material budget**: $X/X_0 \lesssim 0.1$
- low **cost** per unit area
- very high **space resolution**: few microns
- high **time resolution**: O(30ps)

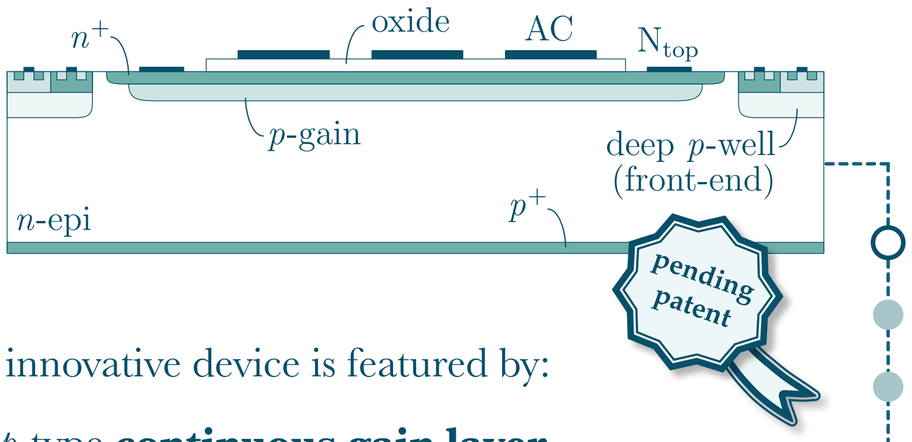
The first three items can be addressed through the use of **monolithic integration**.

Precise tracking can be achieved with a combination of **pixel detectors** and **Low-Gain Avalanche Diodes** (LGADs). However, it is possible to **simultaneously** have good precision in both **space** and **time reconstruction** with the same sensor by exploiting the **Resistive AC-Coupled Silicon Detectors** (RSD) paradigm [1].

☛ we need to **integrate AC-LGADs** in the **CMOS process**

A NEW SENSOR IDEA

The goal is to design a silicon detector for **4D-tracking** characterized by **high precision** of both **space and time reconstruction**. This is the so-called **monolithic AC-LGAD**

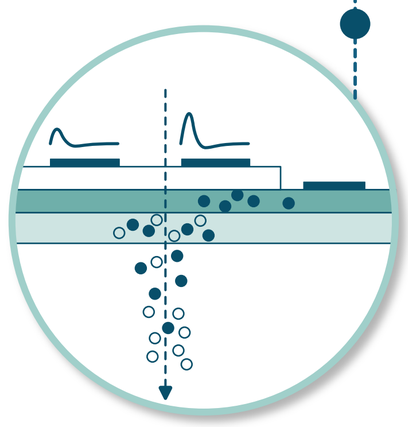


This innovative device is featured by:

- a p-type **continuous gain layer**
- a n-type **continuous resistive cathode**
- a **dielectric** stack on top of the active area
- peripheral ***p*-wells hosting the FEE**

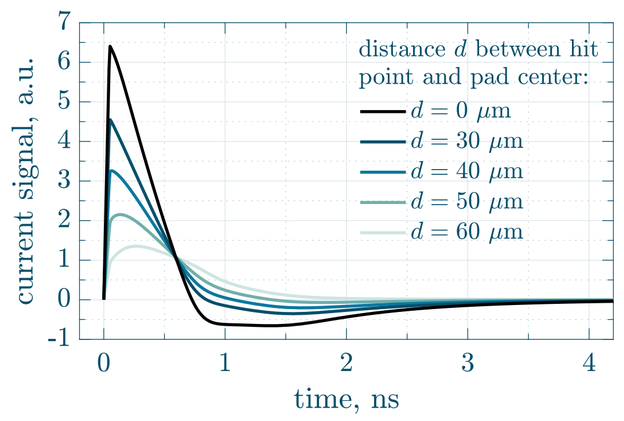
The **multiplied electrons** are **slowed down** in the resistive layer, so that a signal can be induced into AC pads through **capacitive coupling**.

Signal **amplitude** decreases with the **distance** from the **hit point**.

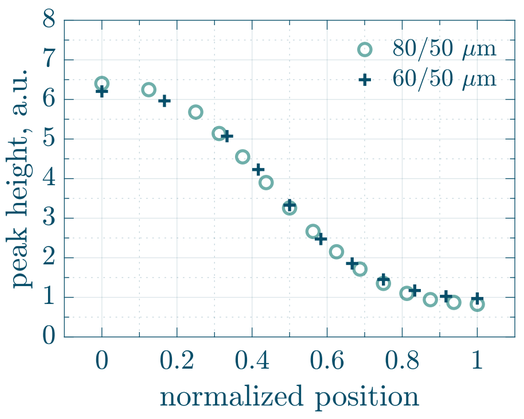


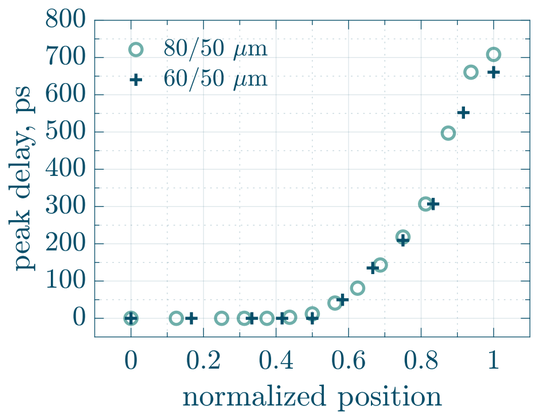
PROOF–OF–CONCEPT

To test the feasibility of **monolithic AC-LGAD** sensors in **110 nm technology**, extensive **numerical simulations** have been conducted (TCAD and Monte Carlo).

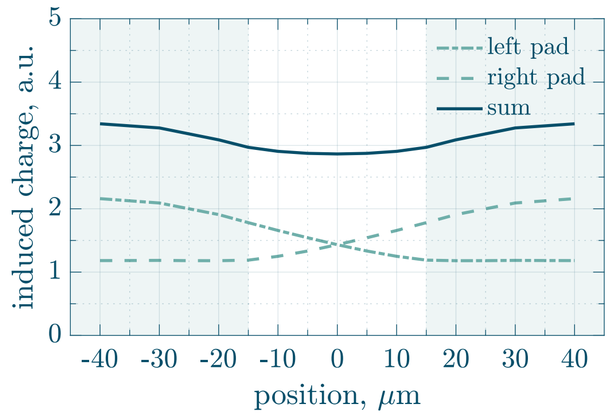


A scan with a MIP in a **50-µm-pad** sensor shows the same trend of the **signal height**, as well as the **peak delay**, **versus hit position** whatever the pitch size



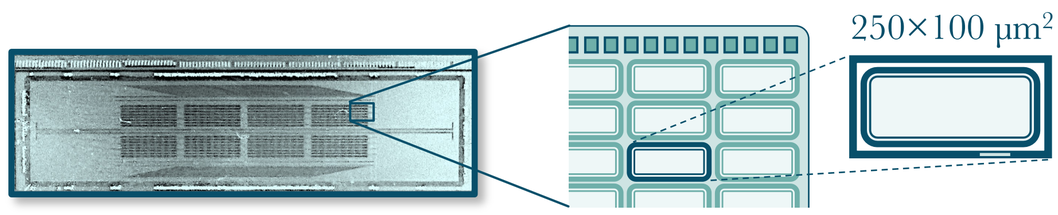


The sum of **induced charges** in two neighboring AC pads is quite **homogeneous** denoting a **100% fill-factor**



TOWARDS A PROTOTYPE

We successfully produced in 2023 a **first batch** of sensors, embodying either the **gain layer** and the **front-end electronics**, which demonstrated that the **LGAD technology** and the **CMOS process** (110 nm) are compatible [2].



CMOS-LGAD
"MadPix" (2023)

off-pixel **buffers**
+
in-pixel **pre-amplifier**

References

[1] M. Mandurrino *et al.*, IEEE EDL 40(11), 1780-1783, 2019, doi: 10.1109/LED.2019.2943242
[2] T. Corradino *et al.*, JINST 19, C02036, 2024, doi: 10.1088/1748-0221/19/02/C02036