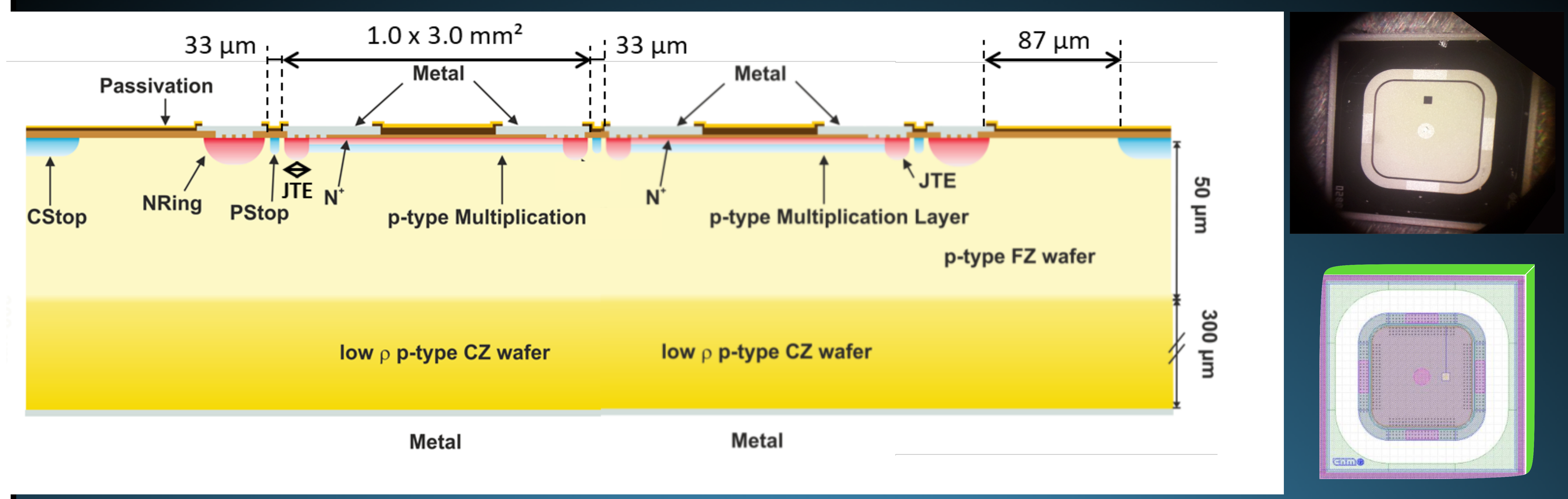
Time resolution of thin Low Gain Avalanche Detectors.

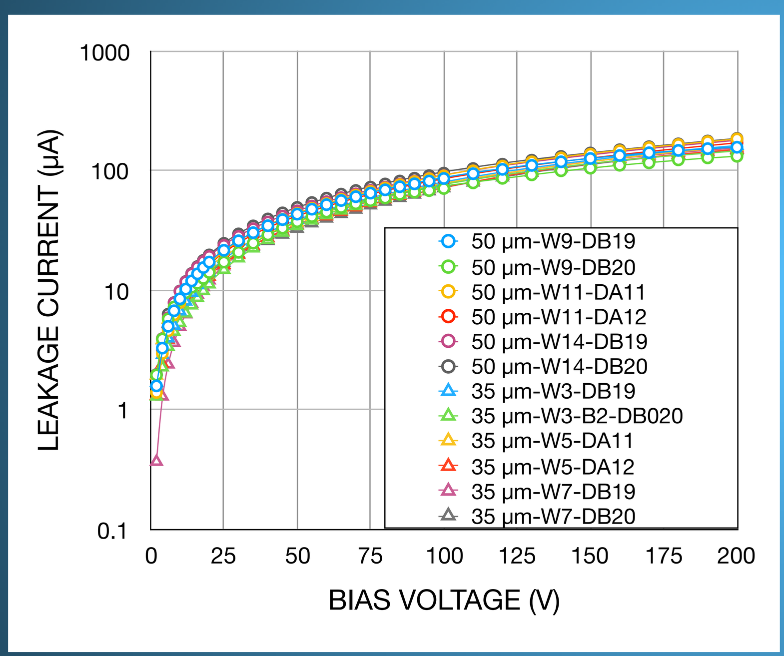
Riccardo Del Burgo, F. Canelli, S. Hidalgo, B. Kilminster, A. Macchiolo, G. Pellegrini, I. Villa Alvarez

ABSTRACT: The CMS MIP Timing Detector, proposed for the HL-LHC upgrade, will be instrumented with O(10) square meters of ultra-fast Silicon detectors (UFSD) in the forward region. These UFSDs are aimed at measuring the time of passage of each track with a precision of about 30 ps. The sensor that will be used for this task is the low gain avalanche detectors (LGAD). In this contribution, we will present the latest results from laboratory measurements on 50 and 35 µm thick LGADs fabricated by CNM. We will concentrate on the timing performance of the sensors. Additionally the electrical characterisation of the sensor will be discussed.

LGADs



AIDA2020 LGAD structure (left). In the figure are visible the multiplication layer and the JTE and the PStop that isolate the single pads. On the right a picture of the single pad (top) and the corresponding TCAD design (bottom),.

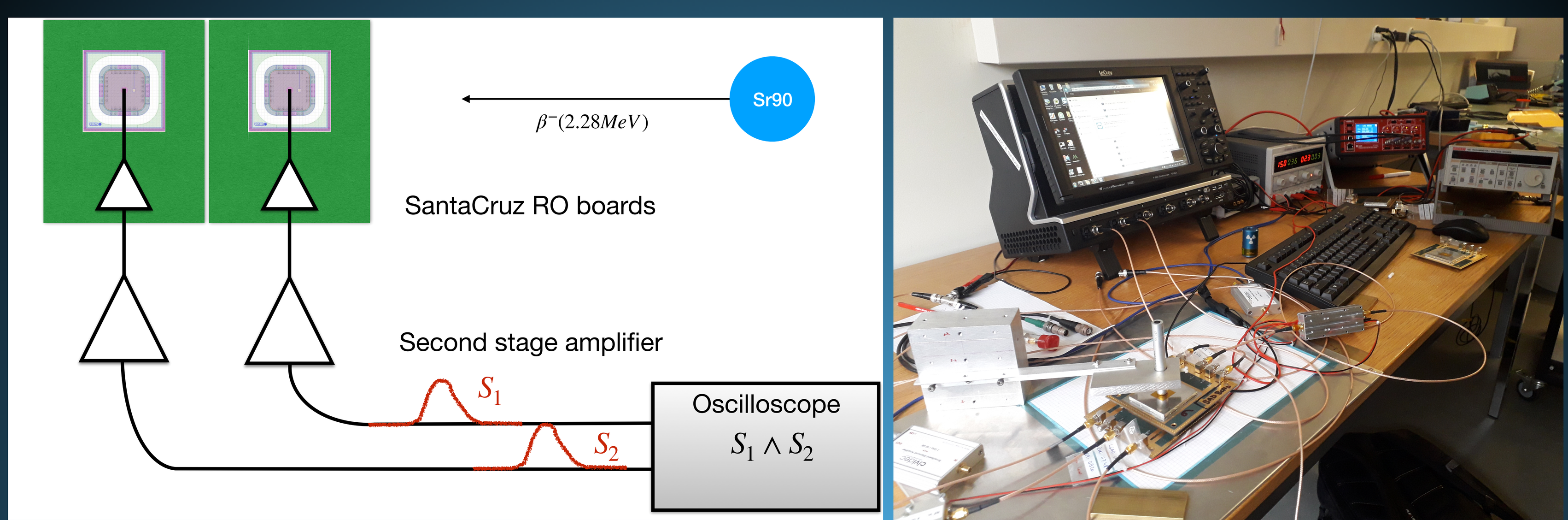


Leakage current of single pad devices in the AIDA-2020 run produced at CNM. The values are 3 orders of magnitude bigger than the typical values.

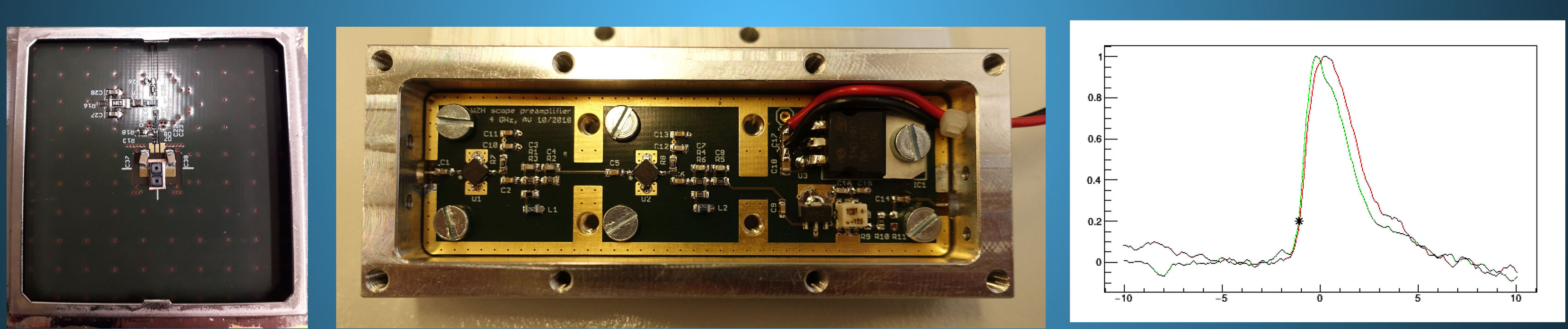
The LGADs are thin silicon sensors of a typical thickness of 50 µm or thinner. The basic structure is the same of a PiN diode in which is inserted a gain layer. The sensor has a small capacitance (pF) and so the signal is fast with a rise-time in the order of hundreds of picoseconds. The gain layer enhance the amplitude of the signal.The sensors investigated in this study are from a common AIDA-2020 run, produced at CNM. This sensor are produced from 4'' wafer using JTE termination. Different JTE width are available for testing, and also different inter-pad gap width.

The sensors used are single pad. The sensors come in two different thickness, 35 µm and 50 µm, and different Boron doping for the gain layer. All the sensors have a production problem and as a result they show a higher leakage current than normal. Even if the leakage current level is very high, it has been measured to be uniform among the different structures and the breakdown voltage is found to be in excess of 200V.

Laboratory setup



Schematic and picture of the test setup @ UZH

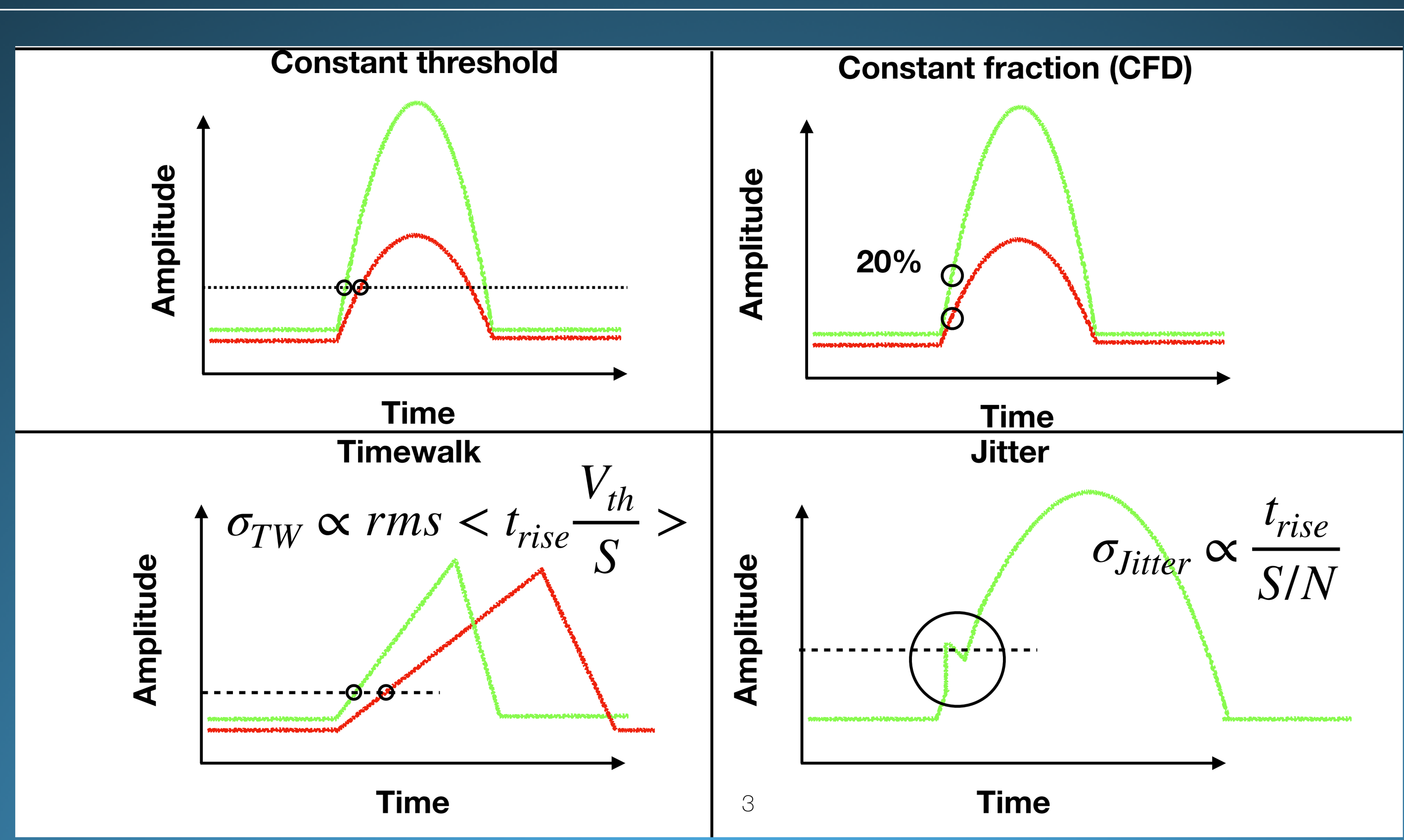


Close up of the sensor on the Santa-Cruz board (left), of the second stage amplifier (center) and of the signals on the oscilloscope (right).

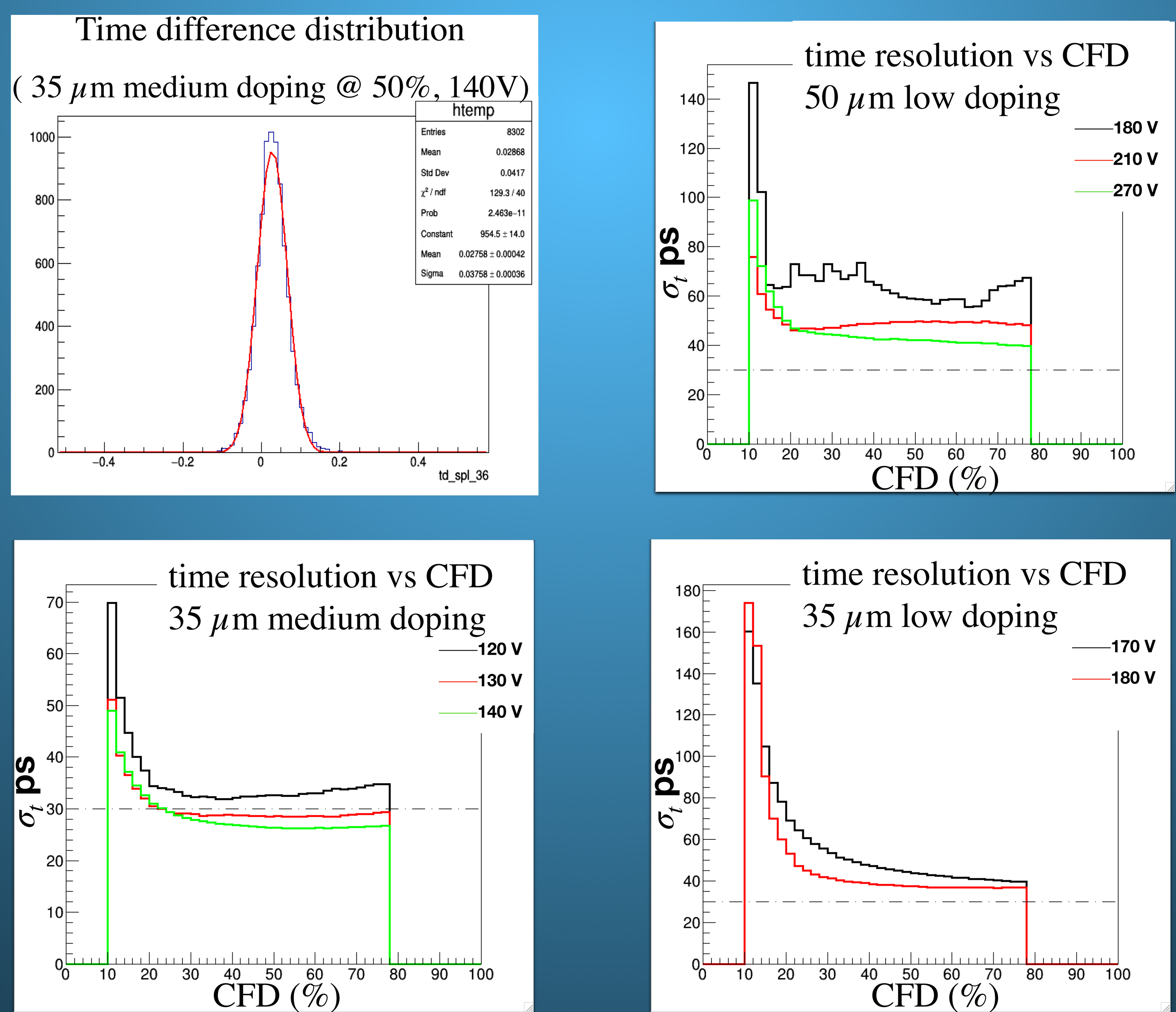
A simple lab setup has been used to obtain the time resolution. Two sensors are wire bonded to to two read-out boards (UCSC design) with a first stage amplifier. The signal is then amplified again with a 36 dB low noise high dynamic range three stage amplifier, and finally read by a fast oscilloscope (40 MS/s 4 GHz bandwidth).

Time resolution

The time resolution is extracted using pair of identical sensors and assuming they have the same characteristic and time resolution. The Time of Arrival (TOA) is extracted using the Constant Fraction method (CFD). This method takes into account that signals with different amplitudes cross a fixed threshold at different times and correct for it. The TOA difference distribution is plotted for a number of events after some basic quality cut on the amplitude, the RMS and the rise-time.The final resolution is affected by different systematic contributions, the most prominent are the Landau effect, and the contributions from the time walk and the jitter.



Principle of the constant threshold (top left) and CFD method (top right). On the bottom sketch of time-walk and jitter contribution to the time resolution.



On the top left, the time difference distribution for a CFD cut = 0.36. The distribution is fit and the time resolution of the single sensor extracted assuming that the timing performance of two sensors are identical. In the other 3 boxes: time resolution as function of the constant fraction cut for different bias voltage for the 50 µm (top right) and 35 µm (bottom) thick productions.

A time resolution of 25 ps has been achieved for the medium gain 35 µm thick sensors for a CFD cut of 35%. On the other hand the low gain sensors performances are worse because of the lower signal to noise ratio. Comparing the two pair of sensors with the same doping but different thickness we conclude that the thinner sensors reach the working point at lower bias voltage.

Acknowledgement

This project has received funding from European Union's Horizon 2020 research and innovation programme under grant agreement No 654 168

riccardo.delburgo@cern.ch

LHCP2019: 7th Conference of Large Hadron Collider Physics, 20-25 May 2019, BUAP, Puebla (Mexico)