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Infrared LED Array For Silicon Strip Detector Qualification

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Abstract

The enormous number of silicon strip detector modules for the CMS tracker requires a test-sytem to allow qualification of each individual detector module and its front-end electronics within minutes. The objective is to test the detector with a physical signal. Signals are generated in the detector by illumination with lightpulses emitted by a LED at 950 nm and with a rise time of 10 ns. In order to avoid moving the detector, an array of 64 LEDs is used, overlapping the complete detector width. The total length of an array is 15 cm. The spot size of an individual LED is controlled by apertures to illuminate about 25 strips. Furthermore it is possible to simulate the high leakage current of irradiated sensors by constant illumination of the sensor. This provides an effective means to identifying pinholes on a sensor.

1 Introduction

The CMS tracker is entirely based on silicon detectors. A test sytem was developed which is capable of qualifying detector modules in a secure and fast way. To test the detector modules a physical signal is generated in the detector by irradiation with infrared light because the use of radioactive sources or cosmic rays is too time consuming and more complicated to handle.

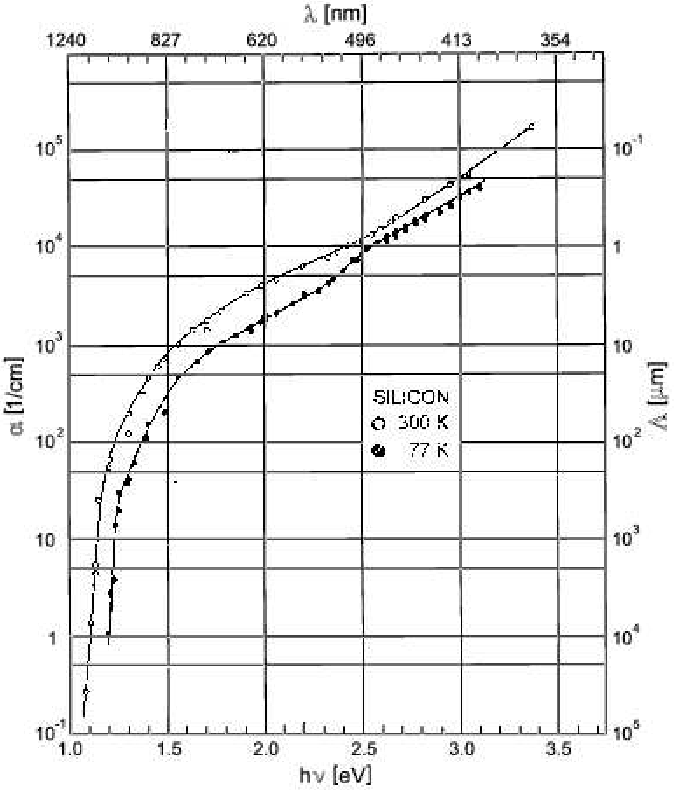

Figure 1: *Penetration depth Λ and absorption coefficient α for light as function of the wavelength λ and energy [1]*

Light from lasers or LEDs of an appropiate wavelength is more comfortable to handle and allows shorter testing times. In order to ensure a penetration depth of more than 45 μm, enough to reach the bulk material of a sensor and being independent of surface effects, light with a wavelength in the region greater than 850 nm is needed as seen in figure 1.

2 The LED Array

2.1 The setup

The LED array consists of two printed circuit boards (PCB). The LED driver card hosts 64 LEDs, the driver electronics and a PLD (1) for selecting a single LED. The other board, the LED control card, is responsible for the communication with the PC and hosts several 8-bit DACs (2).

The LED driver card is mounted about 10 mm above the silicon strip detector, see figure 2. A collimator of 1.5 cm thickness with holes for LEDs of diameter 2 mm is placed between the detector and LED array to restrict the light spot to $20 - 25$ strips.

The LEDs are placed on a printed circuit board as shown in figure 2. The distance between the rows of LEDs is 4.5 mm.

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(1) PLD: **P**rogrammable **L**ogic **D**evice

(2) DAC: **D**igital **A**nalog **C**onverter

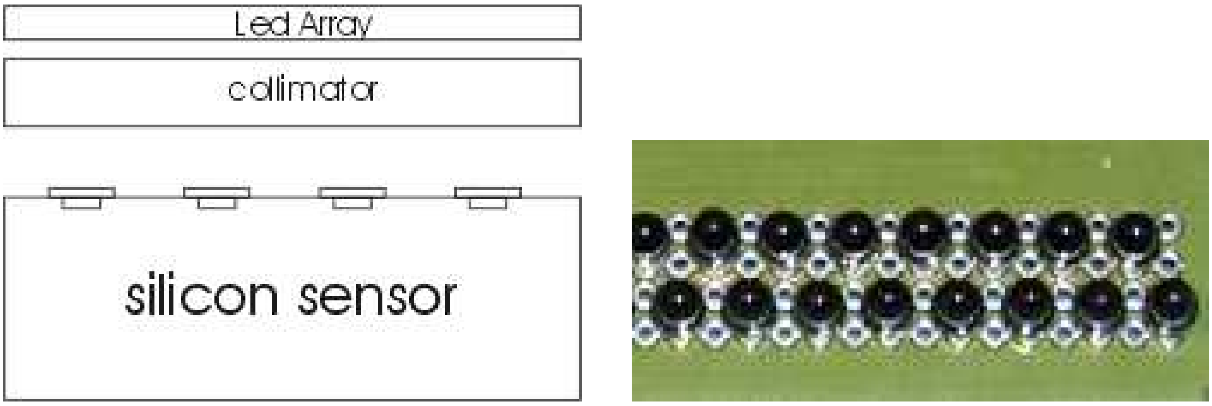

Figure 2: *Scheme of the setup used for the measurements (left), the width of the LED spot is defined by a collimator which is placed between* 5 *and* 10 *mm above the detector. The right picture shows the LEDs mounted on the printed circuit board*

2.2 Electrical layout

The LED control card exists in two different versions. The first one was designed for the Karlsruhe readout system. It has an eight bit parallel data bus which can be connected to a digital I/O card or via a parallel port to a PC. The second version was designed for the use with an I^2C-Bus. The connection between the LED driver card and control card is identical for both versions. Each control card hosts three DACs and a PLD (Altera EPLD7064SLC44) which manages the communication between the PC and LED driver card. It sets the voltages of the three DACs and switches the power to the LED array on or off. The voltages provided by the DACs allow to control the pulse height of LED bias voltage pulse, the other two DAC voltages apply a constant voltage level to the LEDs which reduces the required pulse height for a LED shot and gives the possibility to increase the leakage current of the sensor by illuminating it continuously with light, simulating the increasing leakage current due to irradiation.

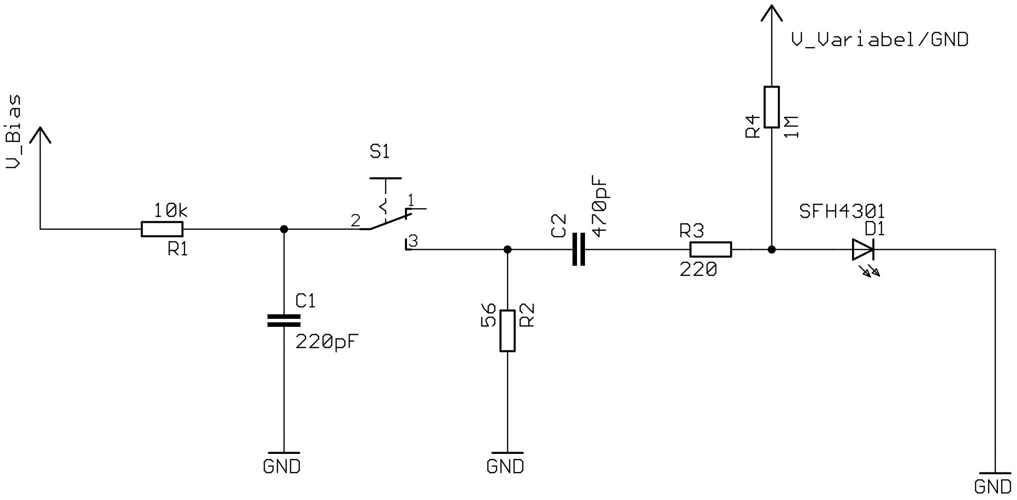

Figure 3: *LED driver circuit. Eight drivers are connected to one multiplexer chip*

The LED driver card consists of 64 LEDs in a 3 mm package with a maximum spectral emission at a wavelength of 950 nm and 10 ns rise time [2]. A LED driver circuit is shown in figure 3, eight of these driver circuits are connected to one multiplexer chip. The selection of the LED and corresponding multiplexer chip is done by a

PLD. The trigger is transmitted as a LVDS 3) signal and a LVDS receiver chip feeds the trigger signal into the PLD triggering the selected multiplexer chip.

2.3 Communication

As seen in the previous section the communication between LED control card and LED array is performed by an eight bit bus with data strobe and acknowledge for handshake. In figure 4 the function of each bit for communication with the LED array is shown.

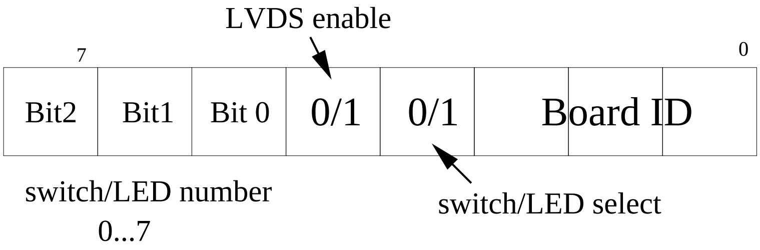

Figure 4: *Communication scheme*

The least significant three bits define the board ID. It is possible to connect up to six arrays to the same bus (ID 000 to 101). The other free combinations (110 and 111) are reserved for setting the DACs and switching array power on or off, for a detailed description see [3]. The three most significant bits in addition with the fourth bit are used for the selection of a LED or a multiplexer chip. The fifth bit enables or disables the trigger signal for the selected array to avoid multiple LED shots from different arrays.

3 The LED Signal

A point of interest is the homogeneity of the LED signal and the collimation of the light spot of an individual LED to a few strips ($20 - 30$). However an overlap of neighbouring fired strips is required to be able to test the whole detector module. Figure 5 shows the signal of a single LED, where the pulseshape spreads over about 20 strips. The same figure also shows the pulseheight distribution for one channel (strip 343) out of a series of shots with a mean value of 42 adc counts and variation of ± 2 adc counts. Several LED shots combined in one figure demonstrates that every strip of the detector can be reached during the qualification without moving the sensor or LED array. The maximum signal height varies between $10 - 25\%$, which is sufficient for detecting strip failures.

4 Detecting errors on a sensor

The most common detector failures are unbonded strips, shorts or pinholes. Except for shorts, all these failures can easily be detected in the LED signal. Through constant illumination the behaviour after radiation damage can be simulated, giving the possibility to find defects which otherwise will only show up after a certain period of operation.

Figures 6 and 7 show some typical failures detectable in the noise distributions and using LEDs. All these measurements were done with an APV25 [4] based readout and ring 6 modules of the CMS Tracker Endcap.

Its relatively easy to find unbonded strips in the noise distribution or with LEDs as demonstrated in figure 6. With LEDs it may also be possible to distinguish between unbonded and broken strips if one uses arrays at both ends of the sensor.

Pinholes can also easily be identified in the LED pulseshape (see figure 7). In the noise distribution the pinhole can be seen as a little deviation from the mean noise of about 2 adc counts.

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3) LVDS: **L**ow **V**oltage **D**ifferential **S**ignal

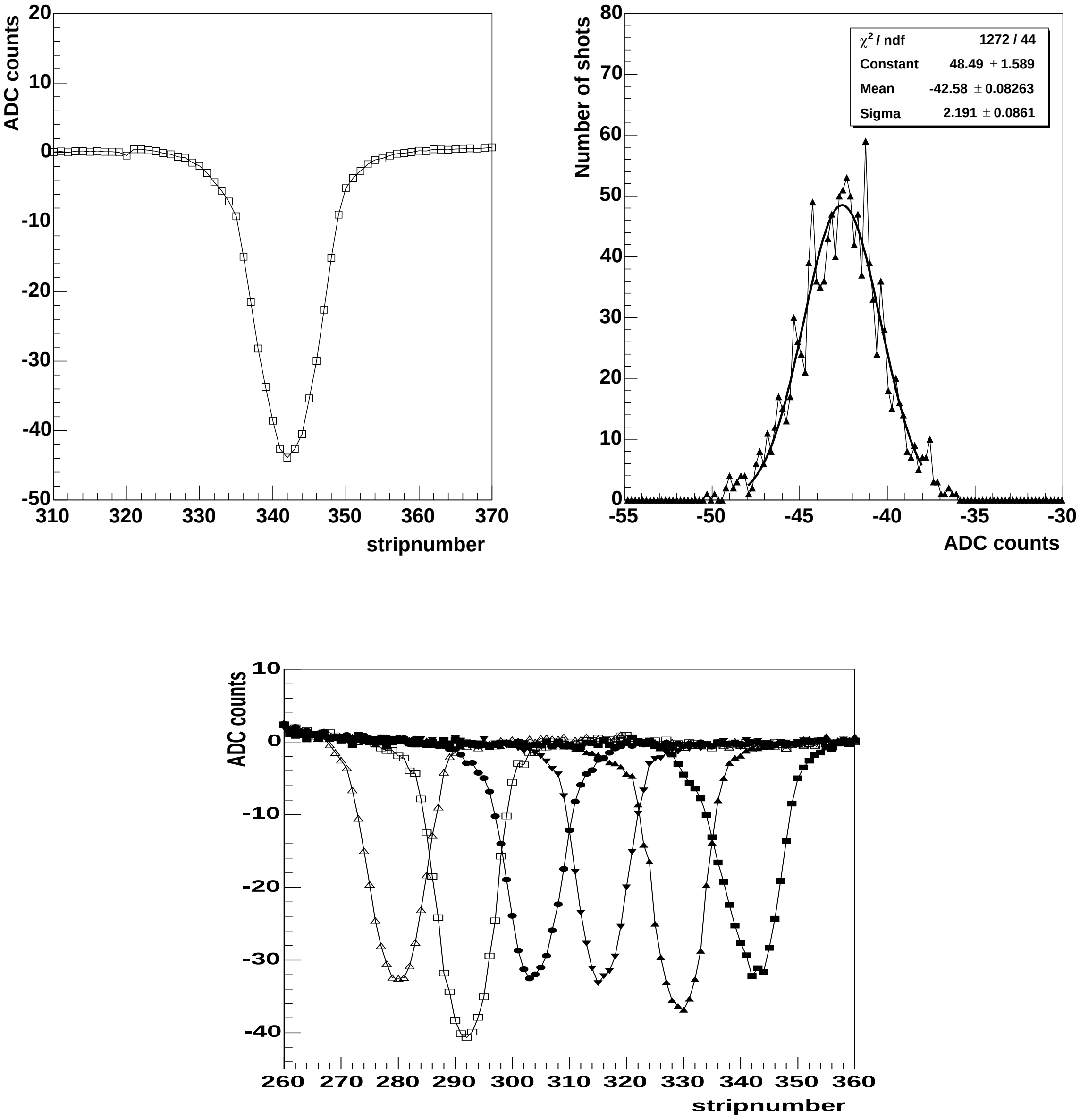

Figure 5: *Signal of one LED with the corresponding signal distribution of strip* 343 *and some LED shots combined in one figure to show the overlap*

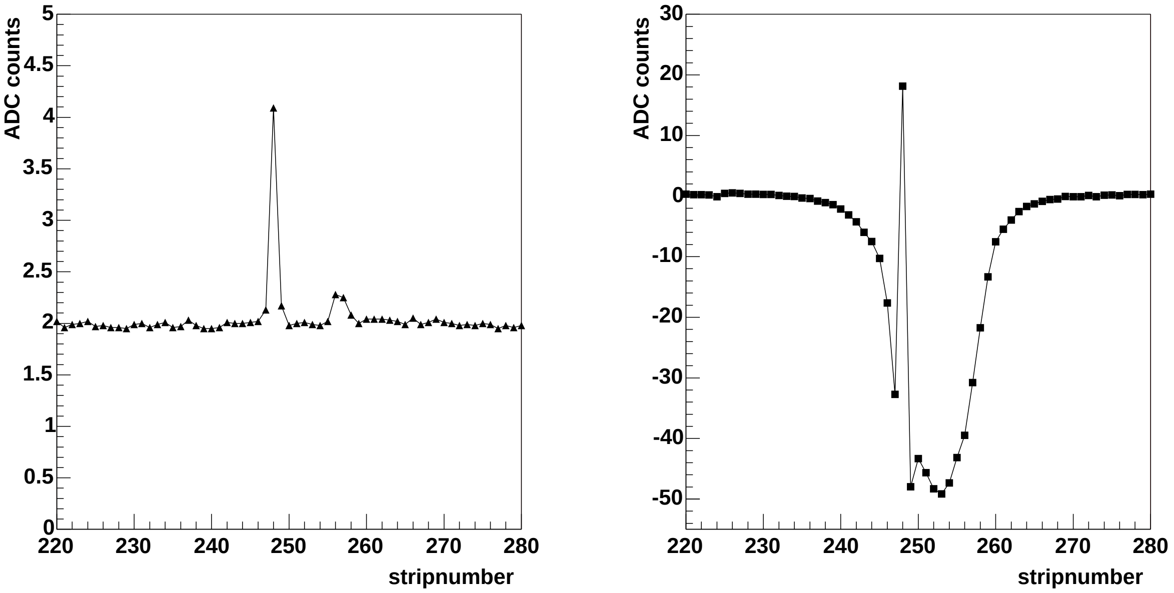

Figure 6: *Unbonded strip as seen in noise (left) and in the LED spot (right)*

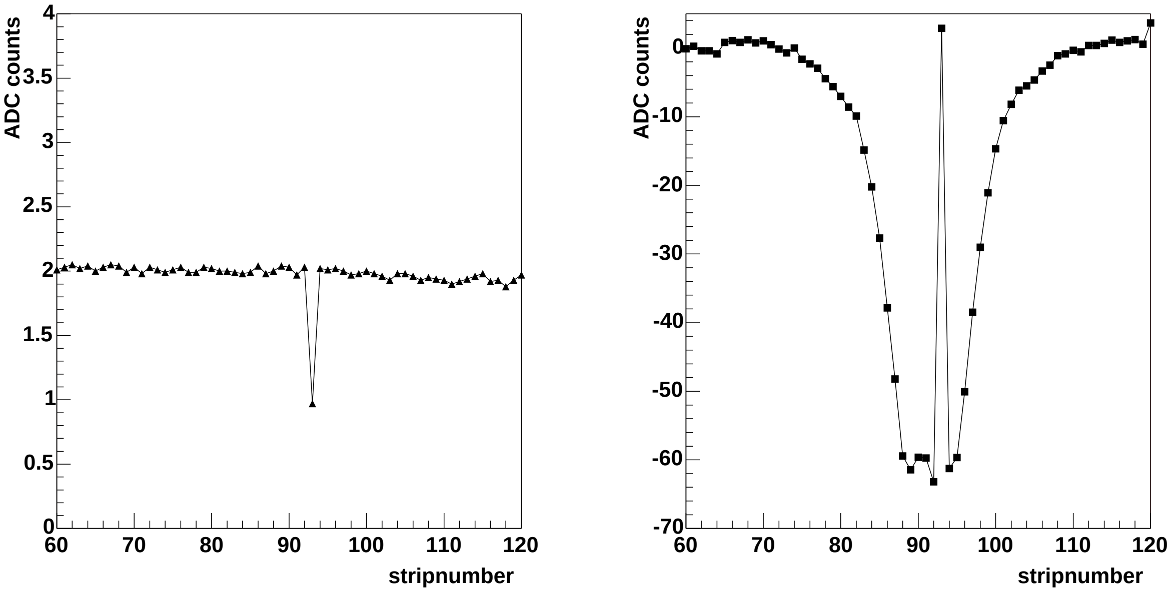

Figure 7: *Pinhole at strip number 93 (ohmic contact between aluminum strip and implant) as seen in the noise (left) and with LED (right)*

5 Pinhole detection by increasing leakage current

As mentioned above an additional feature of the LED array consists of identifying pinholes by increasing the leakage current artificially thus simulating an irradiated silicon detector.

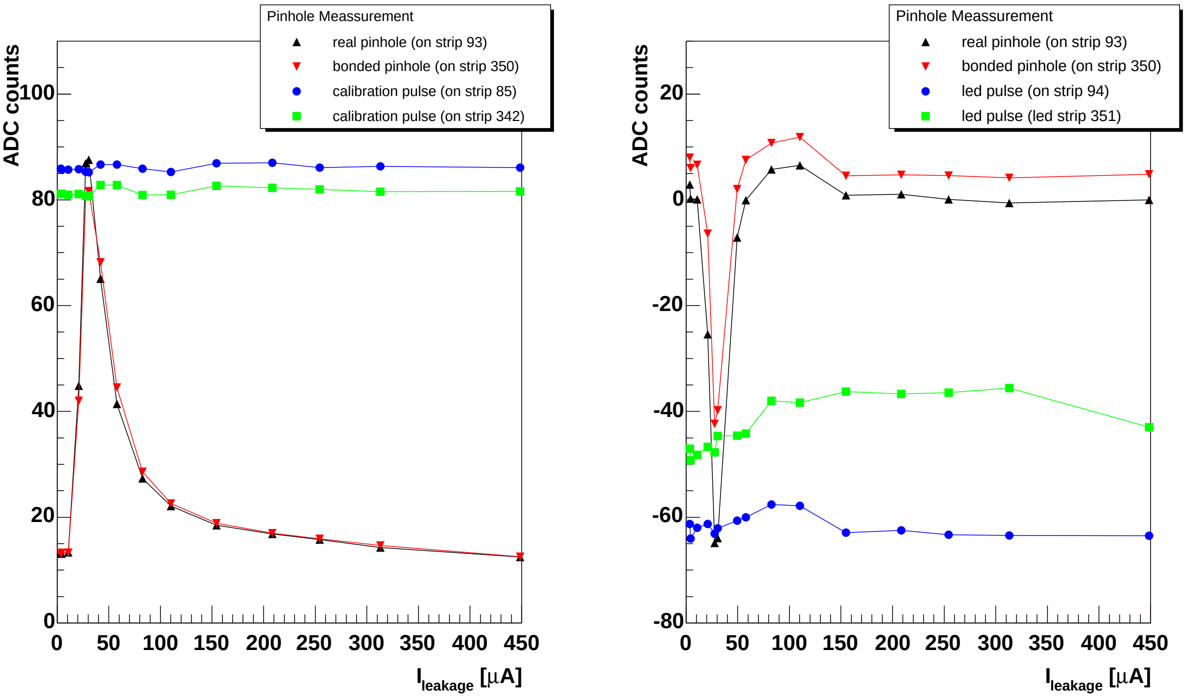

Figure 8: *Behaviour of calibration pulses (left) and LED pulses (right) for strips with (triangles) and without (square and circle) pinholes for different leakage currents*

The leakage current is increased by constant illumination with infrared light of the led array. Figure 8 shows the calibration pulses for different leakage currents. Genuine good strips show the same ADC counts either on calibration or LED pulses. Strips with pinholes instead, can easily be identified. In fact their behaviour as a function of the leakage current is not normal, except for a point of about 30μA where they behave like a normal strips. The voltage drop over the poly-resistor (1.8 MΩ) and the bias resistors (2.2 kΩ) for a leakage current of 30μA is equal to the virtual ground of the APV25 (0.7 V). For lower and higher leakage currents the amplifier is saturated and therefore not responding to calibration and LED signals.

References

[1] W.C. Dash and R. Newman, Phys. Rev. **99** (1955) 1154.

[2] **Datasheet**, Infineon, *"SFH 4301 and SFH4501"*.

[3] **Datasheet**, http://www-ekp.physik.uni-karlsruhe.de/~weiler/readout/datasheets/datasheets.html, *"Infrared LED Array for silicon strip detector tests"*

[4] M. J. French et al., Design and results from the APV25, a deep sub-micron CMOS front-end chip for the CMS tracker, Nucl. Instrum. and Methods **A466** (2001) 359.