Power Pulsing of the CMOS Sensor Mimosa26

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for the **PLUME** collaboration

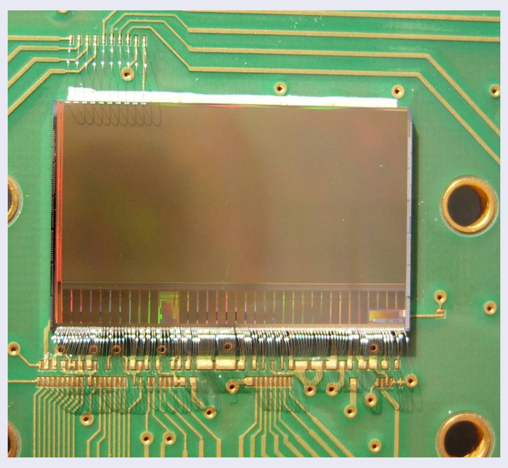
Introduction

- Mimosa26 is a monolithic active pixel sensor developed by IPHC (Strasbourg) & IRFU (Saclay) as a first prototype for the ILC vertex detector studies
- The resolution requirements for the ILC tracking detector are extreme, demanding very low material in the detector, thus only air cooling can be considered
- The beam structure of the ILC allows the possibility of power pulsing
- Power pulsing allows to significantly reduce the heating of the chip and divides power consumption approximately by a factor of 6

Mimosa26

- Monolithic active pixel sensor with fast binary readout (readout time $\sim 115\ \mu s$)
- Size 13.7 mm x 21.5 mm, 576x1152 pixels of $18.4 \times 18.4\ \mu m^2$ pitch
- Thickness of the epitaxial layer is 14-$20\ \mu m$ (depending on chip version)
- Sensor thinned to $\sim 50\ \mu m$

Figure: Mimosa26 pixel sensor

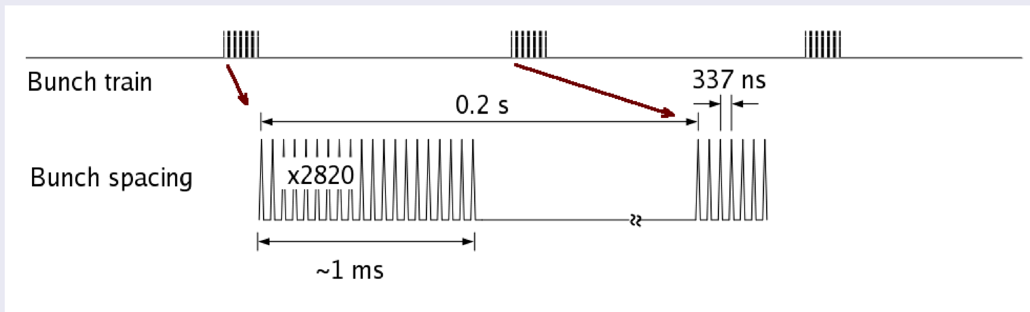


- In-pixel amplification and CDS, in-sensor zero-suppression

International Linear Collider

- Energy up to 1 TeV
- Luminosity: $2 \cdot 10^{34}\ cm^{-2}s^{-1}$
- Two detectors (ILD & SiD)
- Polarized beams

Figure: Bunch train structure at ILC

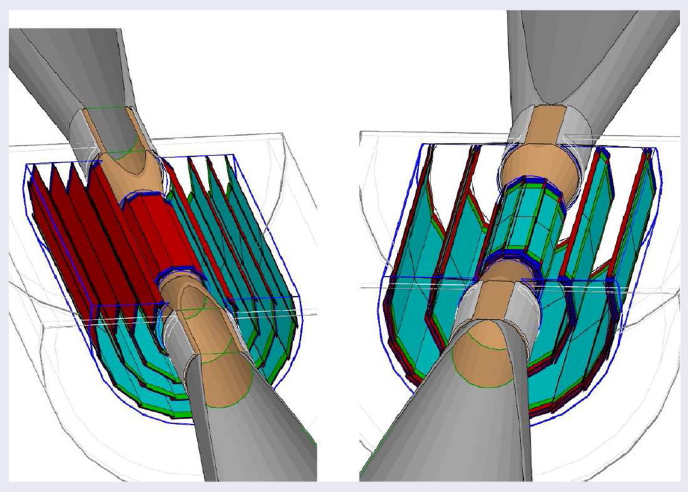


Power pulsing

- Large spacing between bunch trains
- The pixel detectors in ILD could be switched to the "standby" mode in between the trains
- The power consumption and heating can be significantly reduced

ILC vertex detector

Figure: Two layout options for the ILD vertex detector: single sensor per layer (left) or double-sided layers (right)



- The double sided option offers several important advantages (less supporting material is needed, allow to reconstruct mini-vectors)

PLUME ladder concept

- Pixelated Ladder with Ultra-Low Material Embedding
- Double-sided ladder, 6 Mimosa26 per side, active area 1x12 cm^2
- Allows to reconstruct mini-vectors ⟶ better resolution
- Material budget (including two sensors, kapton-metal flex cable and silicon carbide foam stiffener):
  - first prototype: $0.60\% X_0$
  - goal: $\sim 0.3\% X_0$
- Air cooling
- Power pulsing
- PLUME collaboration: Bristol University, DESY (Hamburg), IPHC (Strasbourg)

Figure: Schematic view of the double-sided PLUME ladder

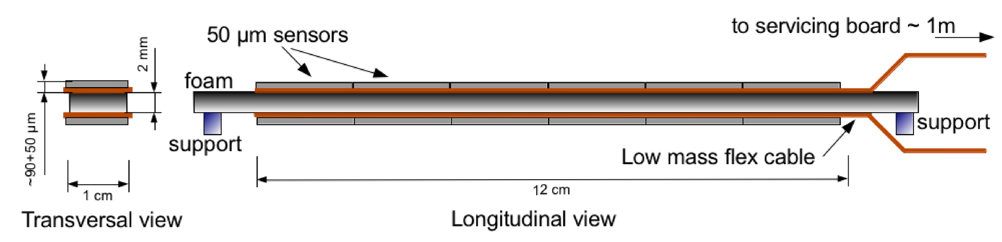
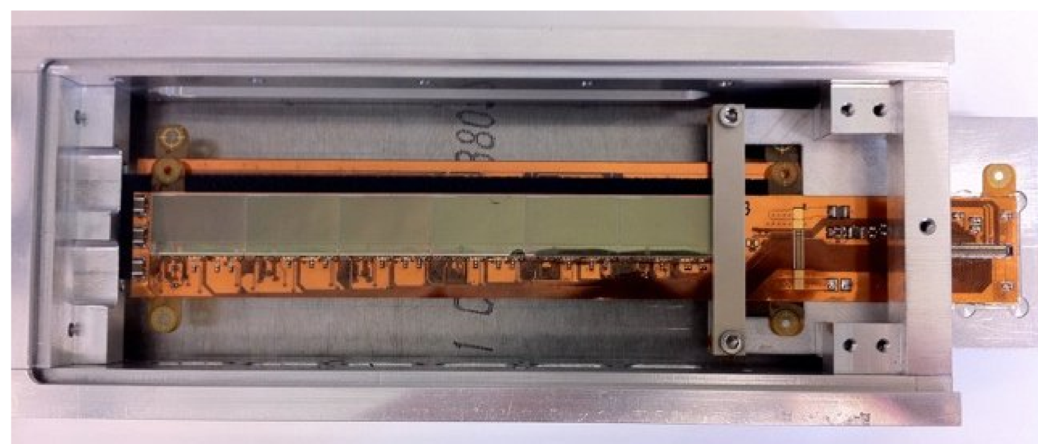


Figure: First ladder (2010 design) equipped with 12 Mimosa26 sensors in protecting box



Power pulsing of single Mimosa26

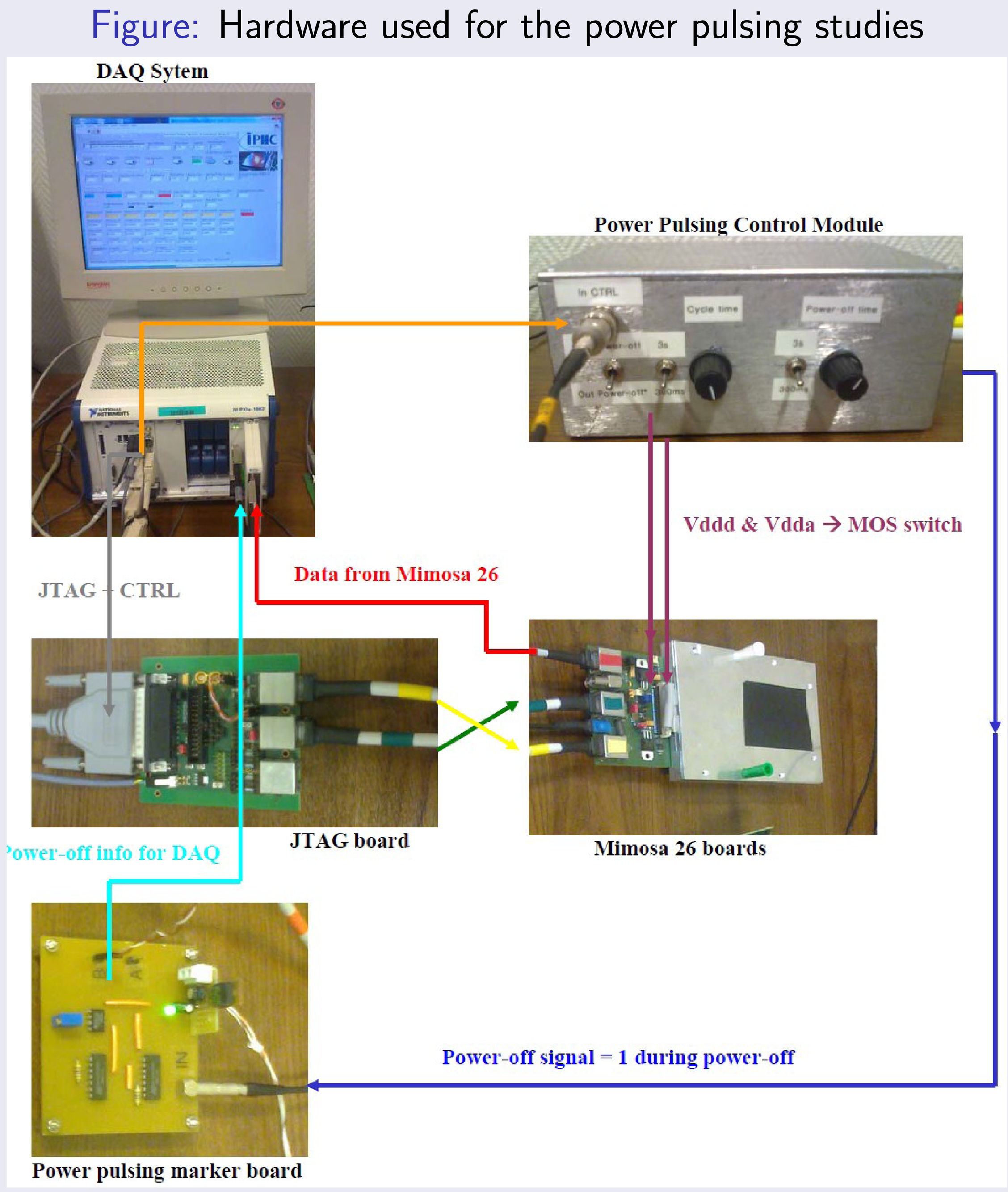
- Mimosa26 has not been designed to operate in a fast power cycling mode (there is no on-chip standby mode logic)
- Its performances may be degraded while operating in power cycling mode

There is only one "easy" way to perform power cycling with M26 - by reducing the voltage during the power-off phase (nominal value is 3.3 V).

A minimal operation voltage of 1.8 V must be kept during "power-off":

- to maintain M26 configuration registers (JTAG) content, otherwise the sensor must be reprogrammed at the beginning of each power-on phase
- to allow continuous clock and synchro signals for the DAQ

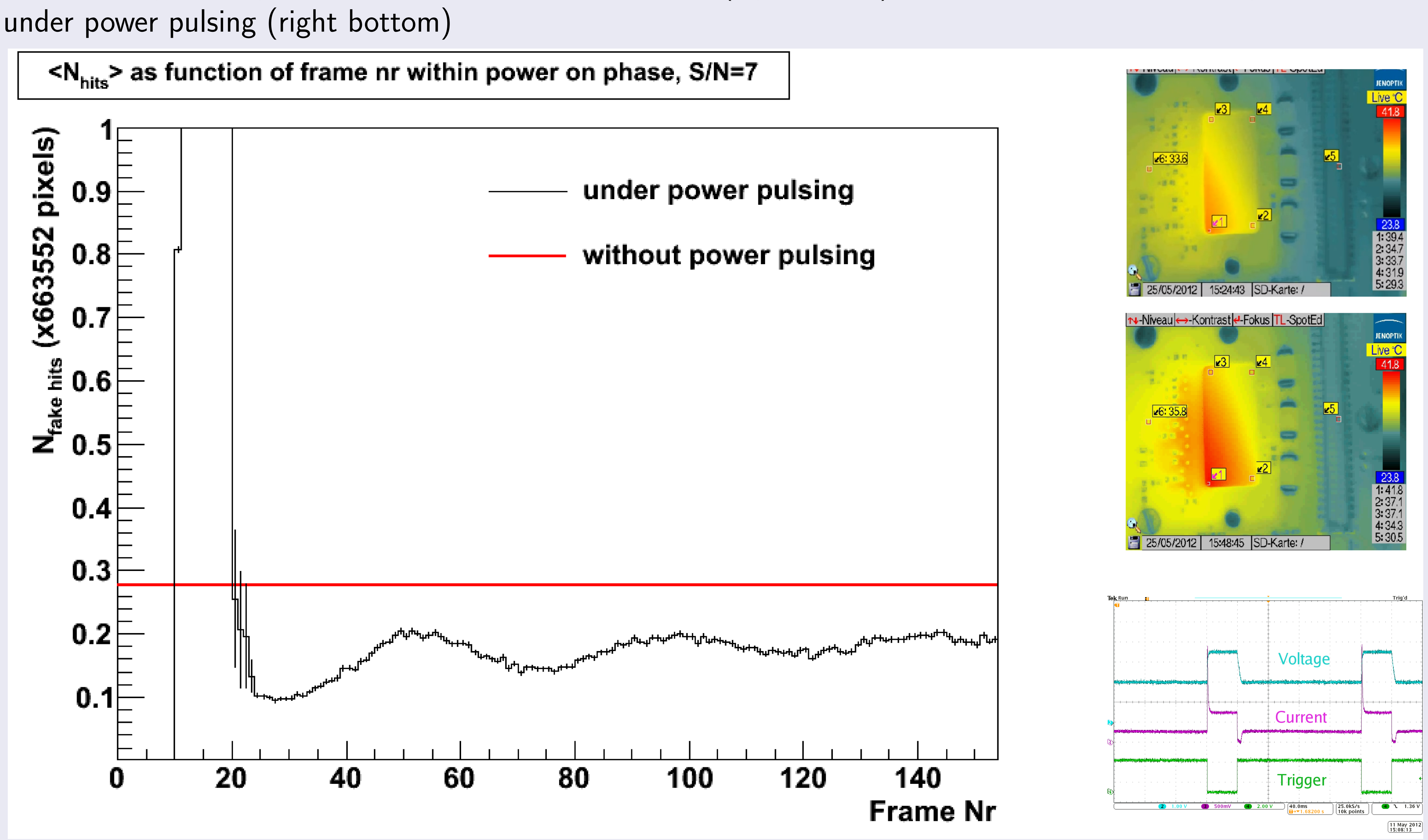
Figure: Hardware used for the power pulsing studies



Results

- Fake hit rates with and without power pulsing are compared (see figure)
- Stable operation is reached after ~ 50 frames (~ 6 ms)
- The observed limit in response time stems from the absence of specific power-pulsing management inside the sensor

Figure: Comparison of fake hit rate under the power pulsing and under normal conditions (left); sensor photographed in the infrared range during operation under power pulsing (right top); sensor photographed in the infrared range during operation under normal conditions (right center); current consumption during operation under power pulsing (right bottom)



- Remaining difference is probably due to non-uniform heat distribution, which is different under power pulsing conditions and under normal conditions
- Power consumption is divided approximately by the factor of 6

Outlook

- Tests of another sensor prototype including a specific power-management
- Study behavior of the pulsed ladder in magnetic field (~ 1 T, DESY site)

References and contact:

- PLUME collaboration: Ultra-light ladders for linear collider vertex detector, Nucl.Instr.Meth. A650 (2011) 208-212
- http://www.iphc.cnrs.fr/PLUME