ANDESPix: A Digital SiPM for Muon Detectors

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ANDES

- ANDES laboratory (andeslab.org) will be 1750 m deep underground as part of the Agua Negra International Tunnel between Argentina and Chile
- Effective shield against cosmic radiation providing low cosmic background necessary for e.g. dark matter or neutrino experiments
- Very low muon flux but non-zero (roughly 1 $m^{-2}day^{-1}$) [1]
- Necessary to detect these muons with scintillators [2-3] for muon-veto

ANDESPix

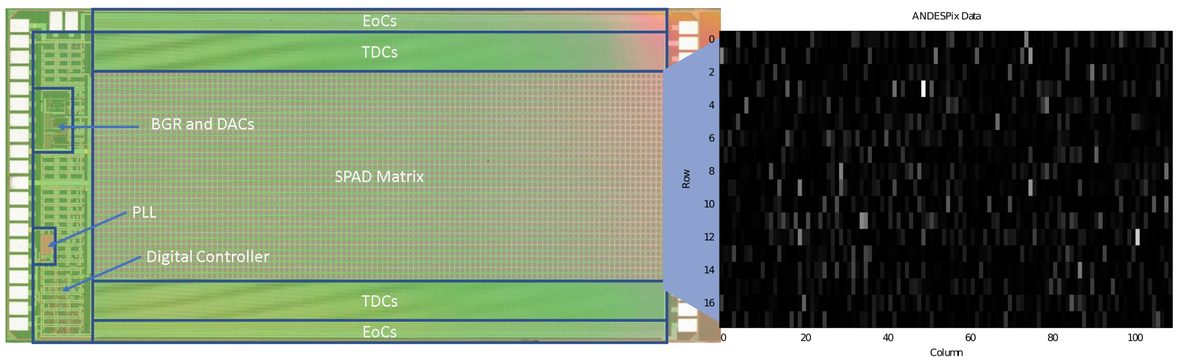
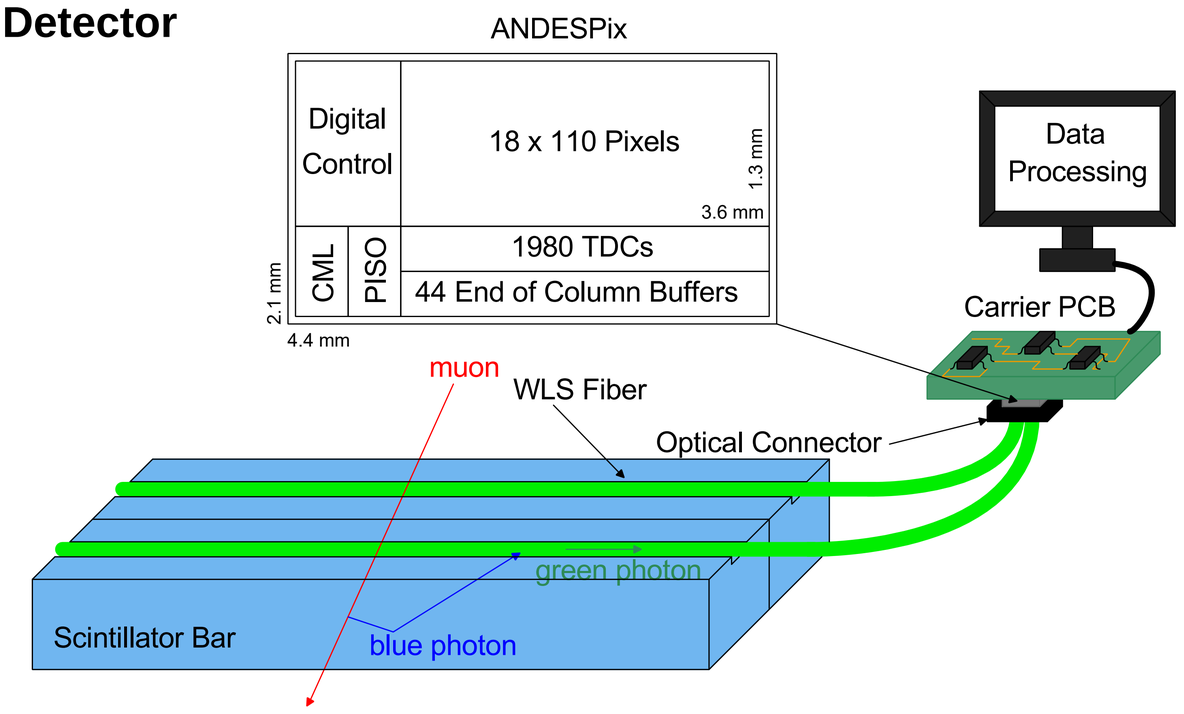


Image of ANDESPix and relative Dark Count Rate for each Pixel

- Digital SiPM [4] fabricated in LFoundry 110 nm CMOS technology
- Every pixel has its own readout electronics including a time to digital converter (TDC) with ~100 ps resolution
- Every detected photon generates digital output with position and timing data

Muon Detector

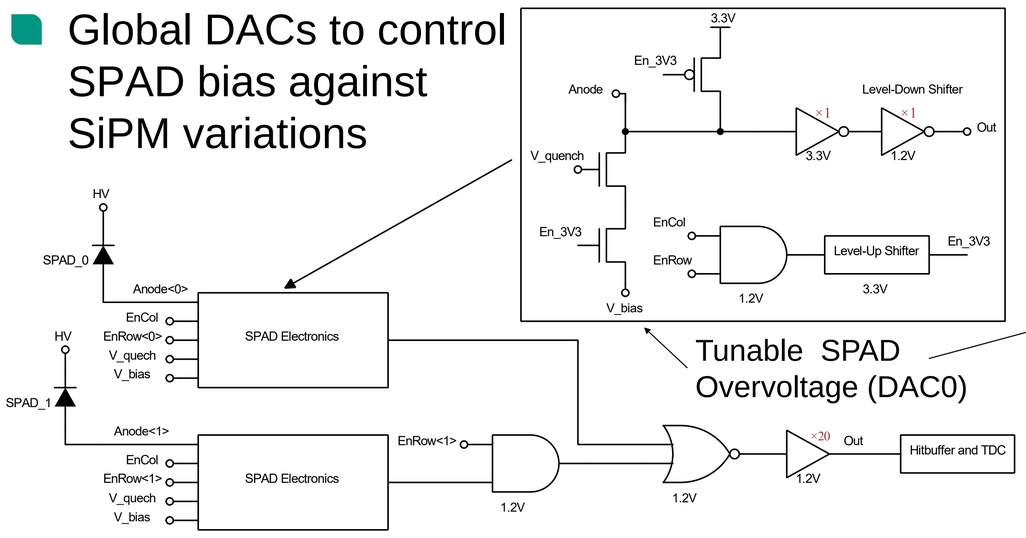
- Muon generates photons (410 nm/blue) in scintillator
- Photons are absorbed (+re-emitted at 485 nm (green)) by wavelength shifting (WLS) fiber and detected by SiPM
- Improve detector with ANDESPix
  - Detect **position** of impinging muon by measuring the arrival time of **each** single photon individually
  - Avoid power consuming analog readout
  - Acquire data about fiber alignment and crosstalk
  - Disable noisy SPADs
  - Time-of-flight measurements by double-sided fiber readout possible



Schematic of proposed Muon Scintillator Detector [1-3]

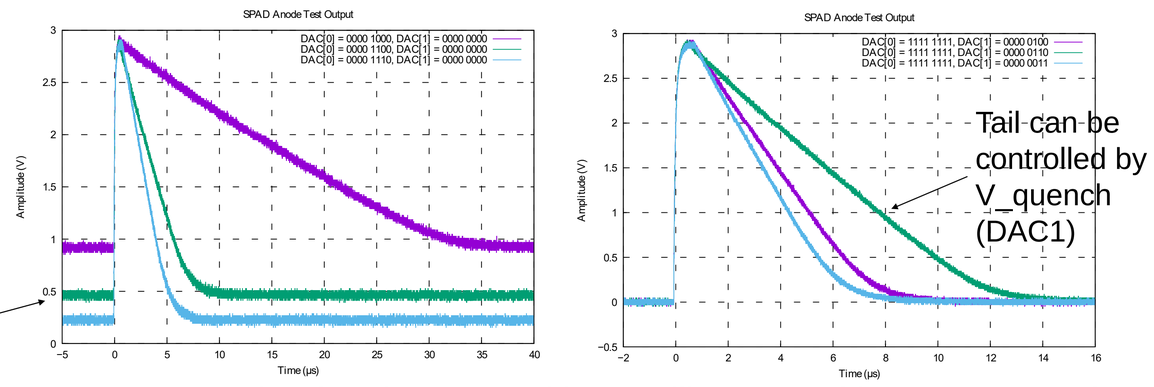
Pixel Electronics

- Global DACs to control SPAD bias against SiPM variations



Schematic of Electronics of one Pixel

First Measurement Results



SPAD Anode Signal Measured by Oscilloscope with ~100 pF Load for Different DAC Settings

- SPAD and analog electronics blocks are working
- Full characterization is in progress

List of Abbrevations	
SiPM	Silicon Photomultiplier
SPAD	Single Photon Avalanche Diode
WLS Fiber	Wavelength Shifting Fiber
TDC	Time to Digital Converter
CML	Current Mode Logic
PISO	Parallel In Serial Out shift register
EoC	End of Column buffer
BGR	Bandgap Reference
DAC	Digital to Analog Converter

References

[1] X. Bertou, “The ANDES Deep Underground Laboratory,” Sci. Rev. - End World, vol. 1, no. 4, Art. no. 4, Sep. 2020, doi: 10.52712/sciencereviews.v1i4.24.
[2] A. Aab et al., “Design, upgrade and characterization of the silicon photomultiplier front-end for the AMIGA detector at the Pierre Auger Observatory,” J. Inst., vol. 16, no. 01, pp. P01026–P01026, Jan. 2021, doi: 10.1088/1748-0221/16/01/P01026.
[3] A. Aab et al., “Muon counting using silicon photomultipliers in the AMIGA detector of the Pierre Auger observatory,” J. Inst., vol. 12, no.03, pp. P03002–P03002, Mar. 2017, doi: 10.1088/1748-0221/12/03/P03002.
[4] T. Frach, G. Prescher, C. Degenhardt, R. de Gruyter, A. Schmitz, and R. Ballizany, “The digital silicon photomultiplier — Principle of operation and intrinsic detector performance,” in 2009 IEEE Nuclear Science Symposium Conference Record (NSS/MIC), Oct. 2009, pp. 1959–1965. doi: 10.1109/NSSMIC.2009.5402143.

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