Beam Test of Deep Diffused APDs

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on behalf of $(see next page)

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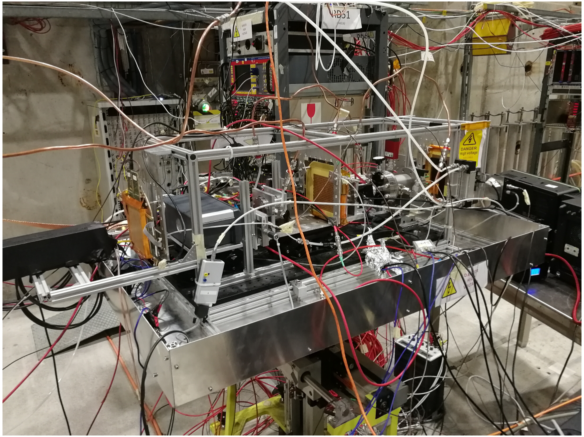
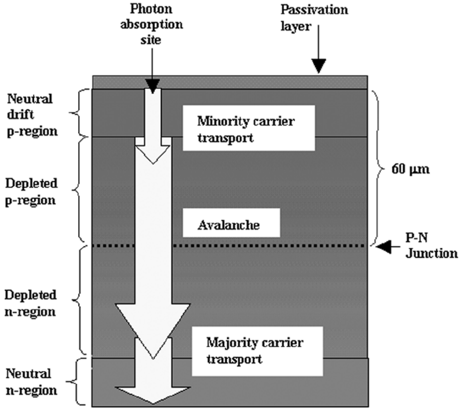
We would like to thank Francisco for the coating of the detectors and PCB.



Deep Diffused Avalanche Photo Detectors

- Charge multiplication
- Gain: ≈ 500
- Bias: ≈ 1800 V
- Never fully depleted
- Die dimensions: $2.8 \times 2.8\,\text{mm}^2$ and $10 \times 10\,\text{mm}^2$
- Nominal active area: $2 \times 2\,\text{mm}^2$ and $8 \times 8\,\text{mm}^2$
- Thickness: $230 - 280\,\mu\text{m}$
- Custom fabrication process
- Produced by Radiation Monitoring Devices (RMD)

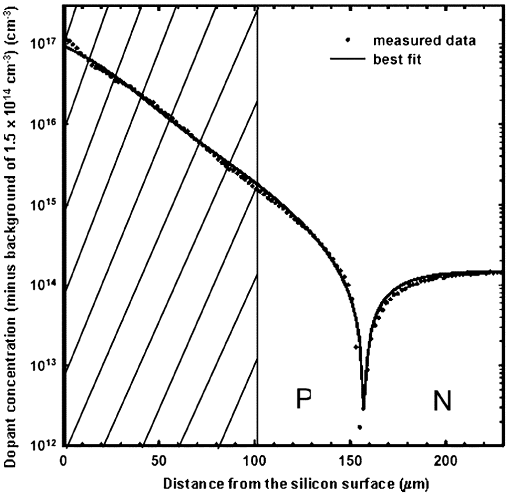


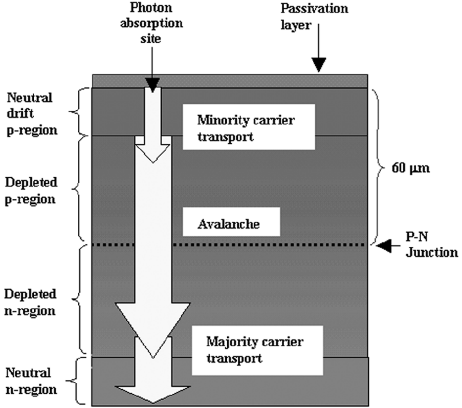
- Diffusion (non-depleted Si)
- Drift (depleted Si)
- Multiplication

M. McClish et. al. IEEE Trans. Nucl. Sci. Vol. 53, No. 5, 2006

Deep Diffused Avalanche Photo Detectors

Doping profile

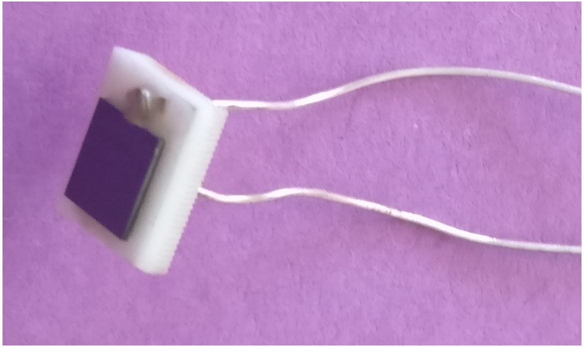




- Maximum of electric field at pn-junction
- Field exceeds 200 kV/cm enabling impact ionization

M. McClish et. al. IEEE Trans. Nucl. Sci. Vol. 53, No. 5, 2006

$2 \times 2\,\mathrm{mm}^2$ DD-APDs

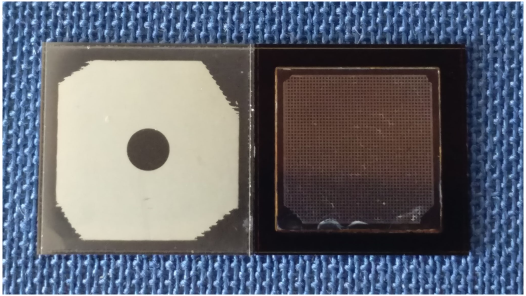


- Packaged
- Usually employed in irradiation studies

8×8 mm^2 DD-APDs

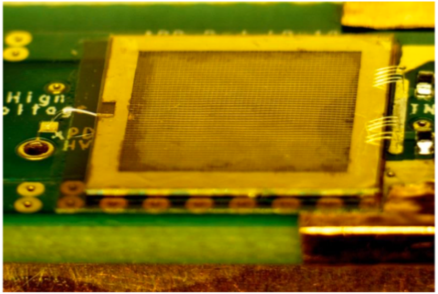
- Uniformity of response improved through metallization or mesh readout
- Baseline for timing applications

DC coupled readout



- Aluminum deposited on both sides
- Metallization on single dies at CMi-EPFL
- Studied in this beam test

AC coupled readout

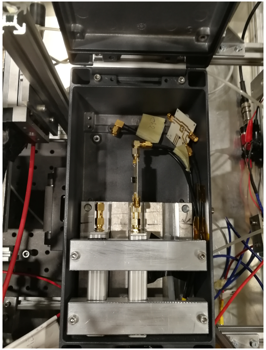


- Mesh on Kapton layer
- Sintered gold on back side
- Studied in previous beam tests ($\sigma_{\Delta t} = 19$ ps)
- See also S. White, CHEF 2013

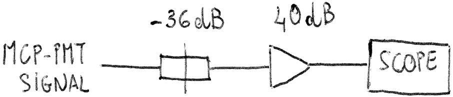
Beam Test Setup

- Sensor box placed downstream first tracking GEM
- Detectors and PCBs coated with FSC 400 to reduce discharges
- Amplifiers: CIVIDEC 2 GHz, 40 dB
- Data acquisition: Agilent 2.5 GHz, 10 Gs/s
  - Ch1: APD
  - Ch2: APD
  - Ch3: Telescope bit pattern (Trigger)
  - Ch4: MCP-PMT
- Temperature, bias, and current logged

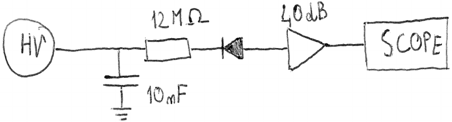
Sensor box



MCP-PMT readout and shaping



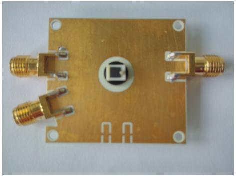
APD readout



Detectors and Goals

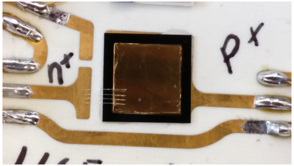
Detectors:

- 4 × Metallized 8 × 8 mm^2 APDs
- 1 × Sintered gold on n-side 8 × 8 mm^2 APD
- 1 × 2 × 2 mm^2 APD
- 1 × LGAD (Low Gain Avalanche Detector)
- 1 × PiN diode



(Planned) Studies:

- Time resolution
- Uniformity of response
- Detection efficiency
- Dependency of time resolution and efficiency on bias voltage and position



Analysis

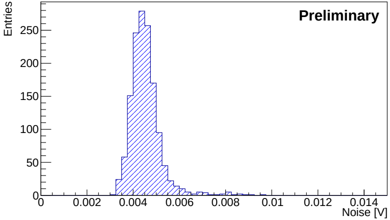
- Analysis using only oscilloscope data (for now), **no tracking info**
- Baseline subtraction, noise, and amplitude extraction
- Thresholds to be fulfilled by all channels to select event
- Cut on amplitude to exclude saturation
- Cut on rise time to exclude noise
- Calculation of Δt using CFD with interpolation between two points

Today's data: a metallized and a gold plated APD operated at 1775 V
All results shown today are PRELIMINARY

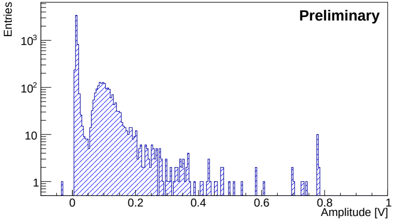
Event Selection

Run 2018-05-04_18-55-07 Metallized APD 1775 V

Noise of each event, around 4.5 mV



Amplitude, before cuts



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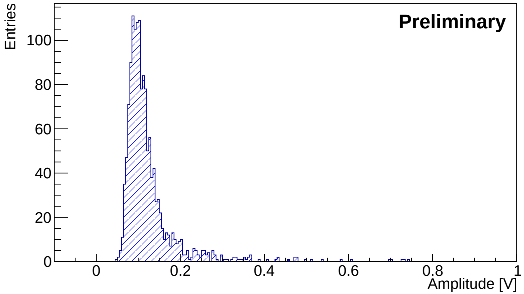
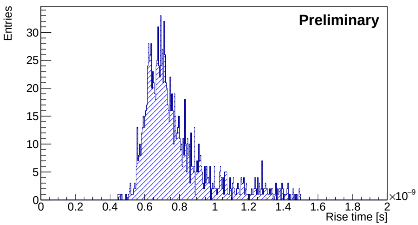


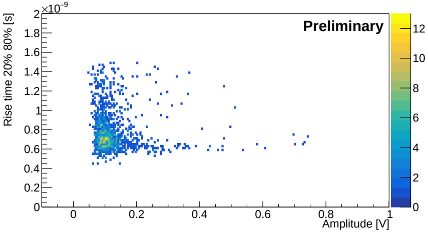
Signal

Run 2018-05-04_18-55-07

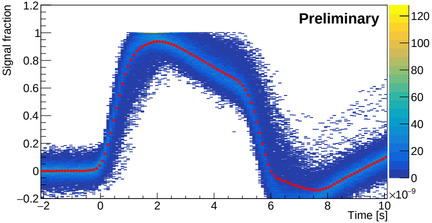
Rise Time 20-80%, cut at 1.5 ns



Rise time vs. amplitude metallized APD



Scaled signal superimposition

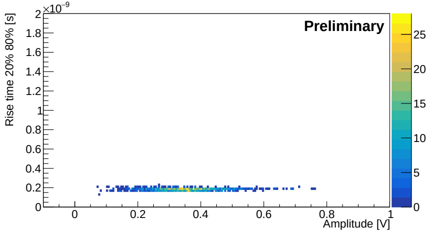


- Reflection due to bias filter at around 5 ns
- Rise time distribution and correlation with amplitude point to different signal shapes
- Possible non-uniformity of response

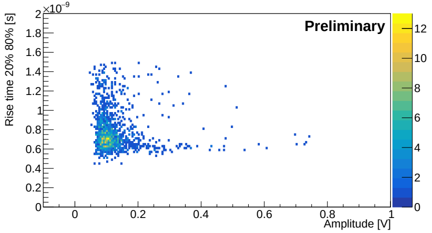
Signal

Run 2018-05-04_18-55-07

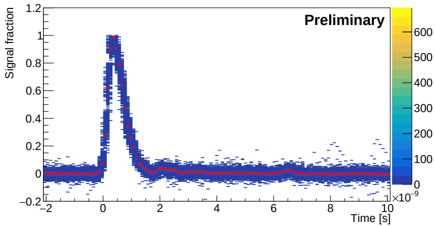
Rise time vs. amplitude MCP-PMT



Rise time vs. amplitude metallized APD



Scaled signal superimposition MCP-PMT



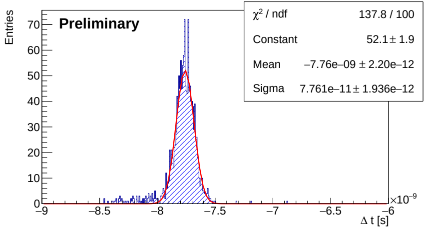
- No correlation in rise time vs. amplitude observed for MCP-PMT

APD Timing

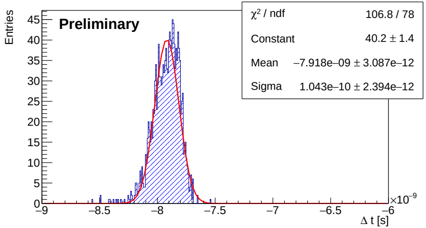
Run 2018-05-04_18-55-07

- Timing using CFD
- APD threshold 0.2
- MCP-PMT threshold 0.5
- Time resolution worse than expected ($\approx$20 ps using laser light, 0.8 MIPs, 1750 V)
- Tracking can provide an explanation

Δt MCP-PMT metallized APD, $\sigma_{\Delta t} = 77$ ps



Δt MCP-PMT gold plated APD, $\sigma_{\Delta t} = 104$ ps



Summary

- First analysis of beam test data, without tracking
- Data is quite clean, DAQ worked as expected during the beam test period
- Time resolution of APDs worse than expected from laser measurement (and making an assumption on “Landau noise”) $\rightarrow$ tracking data analysis can provide explanation
- Signal properties point to non-uniformity in response $\rightarrow$ tracking data analysis

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Thank you for your attention!

Backup Material