Laser Timing Measurements

CERN SSD group

31.05.2017
APD meeting

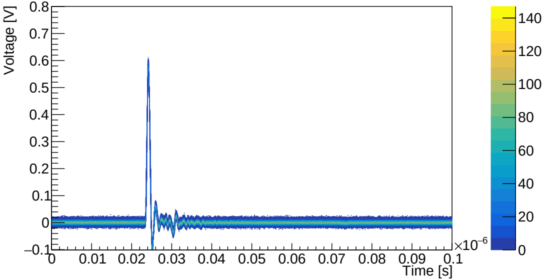
Laser Timing Measurements

- Use our TCT setup for timing
- 1064 nm laser, 200 ps pulses
- There is a photodiode to monitor laser intensity $\rightarrow$ timing reference
- Test done using 300 μm pad-diode
- Both diode and reference signals are amplified
- 5 mV ref amplitude before amplification
- $\approx$ 12.5 MIPs
- No averaging in the scope
- 1000 WF for each bias setting
- 2 different readout schemes
- Thresholds optimized in analysis

Different timing results depending on the readout scheme

Reference Signal

1k repetitions

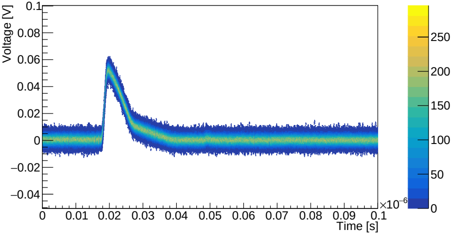


	Reference
Amplitude	579 mV
Noise	6.0 mV
Risetime 20% 80%	313 ps

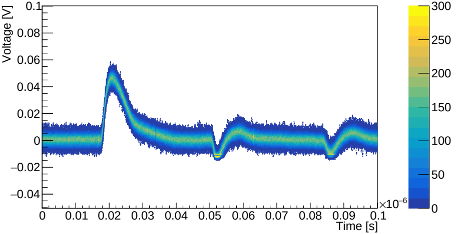
Diode Signals

1k repetitions at 100 V

Front readout and bias



Back bias, front readout

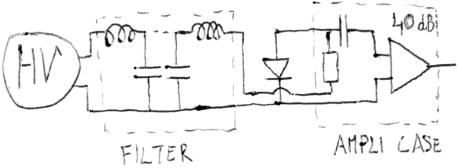


	Front bias and readout	Back bias, front readout
Amplitude	54.5 mV	49.5 mV
Integral	3.55e-10 Vs	3.60e-10 Vs
Noise	2.8 mV	2.9 mV
Risetime 20% 80%	854 ps	1361 ps

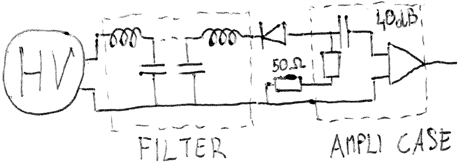
Difference in: amplitude, risetime, reflections

Readout schematics

Front readout and bias



Back bias, front readout



The resistor inside the amplifier case has a value of 3 kΩ, the amplifier input is 50 Ω.

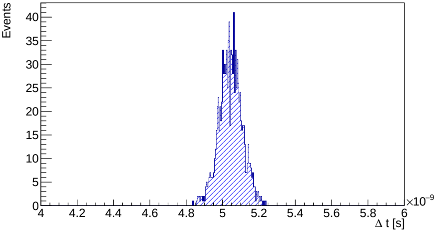
The resistor outside the amplifier case is 50 Ω.

Time Difference Distribution

1k repetitions at 100 V

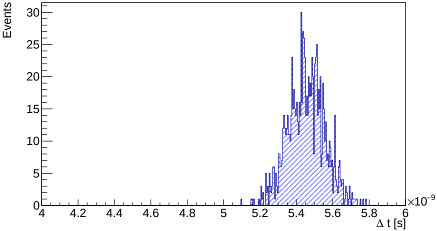
Front readout and bias

CFD: Thr1 0.50, Thr2 0.20, σ = 64.07 ± 1.47 ps, 1000 events



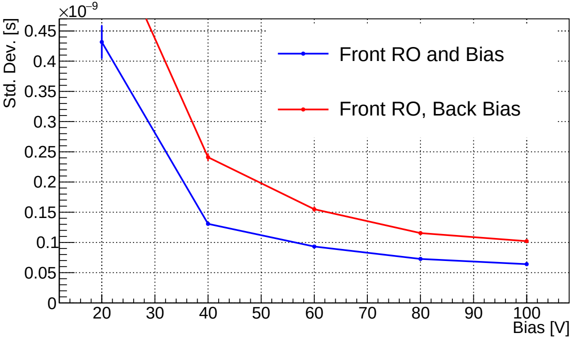
Back bias, front readout

CFD: Thr1 0.35, Thr2 0.70, σ = 102.12 ± 2.31 ps, 1000 events



Timing vs Bias

CFD algorithm, threshods optimized for each bias



Different time performance due to different readout scheme

Timing Measurement of Different Devices

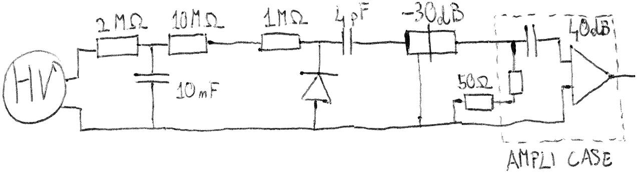
Devices:

- 300 μm pad diode, n-bulk
- 200 μm pad diode, n-bulk (also measured in TB)
- 100 μm pad diode, p-bulk
- 300 μm LGAD
- 8×8 mm^2 APD, gold plated, mounted “p-side down”
- 2×2 mm^2 APD

Conditions:

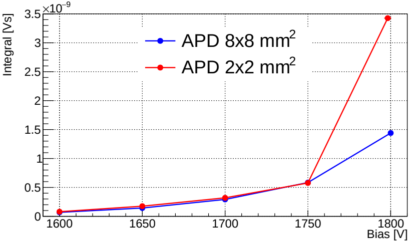
- Reference time resolution: $\approx$ 5 ps (estimated)
- Diodes: front bias and readout, 1500 WF per point
- APD: n-side readout, 1000 WF per point
- $\approx$ 12.5 MIPs, thresholds optimized for each condition

APD readout:

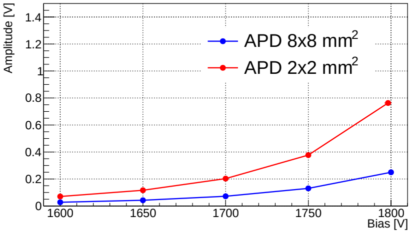


APD Signal

Integral:

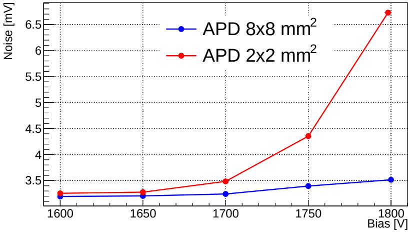


Amplitude:



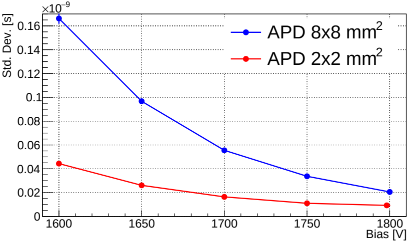
- Similar integral for both
  $\rightarrow$ Similar charge deposition and amplification?
- Different amplitude and noise
  $\rightarrow$ To be checked if amplitude scales with capacitance

Noise:

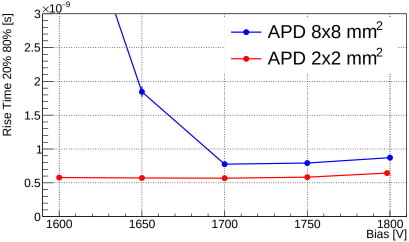


APD Timing

Time resolution:

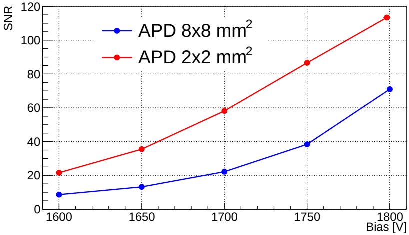


Rise time 20% 80%:



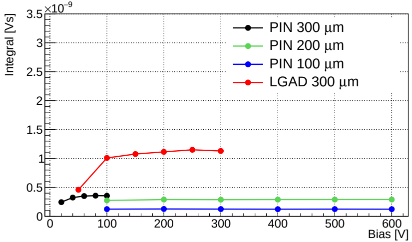
- Better resolution and SNR for the 2×2
- Smaller rise time for the 2×2
- Resolution for 1 MIP equivalent with improved setup

Signal to noise ratio:

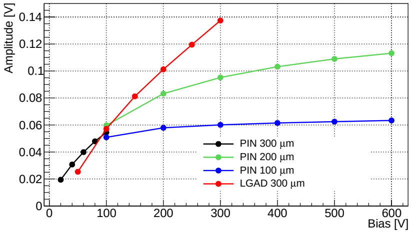


Other Devices Signal

Integral:

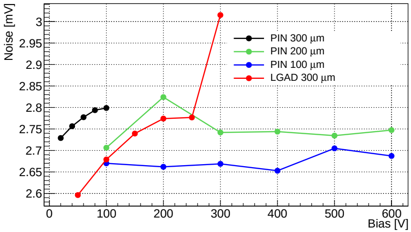


Amplitude:



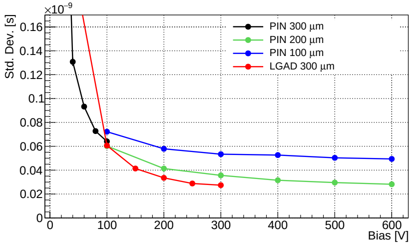
- LGAD has lagest signal amplitude and integral
- Integral almost constant, amplitude increase due to drift velocity

Noise:

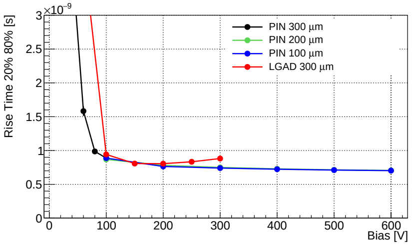


Other Devicess Timing

Time resolution:

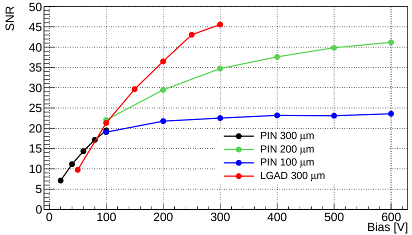


Rise time 20% 80%:



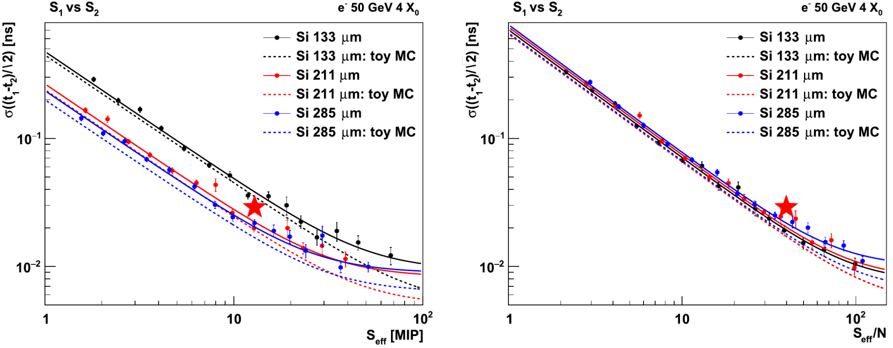
- Best timing resolution for LGAD
- What would be the resolution for a 50 μm LGAD?

Signal to noise ratio:



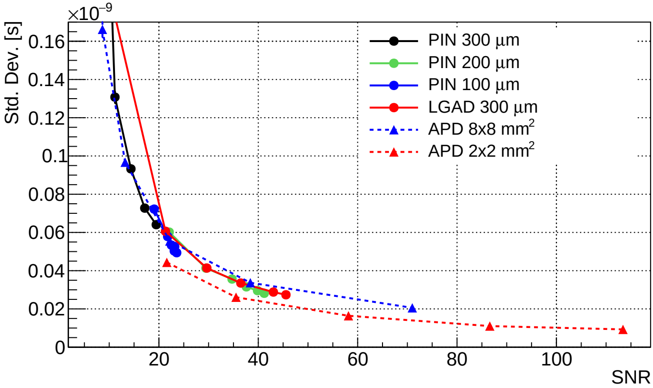
Comparison with TB for 200 μm Diode

Beam test measurements (https://doi.org/10.1016/j.nima.2017.03.065)



- Diode represented by red markers
- Laser measurement at 600 V, 12.5 MIPs: Res. 28 ps, SNR 41
- Close to beam test result

Timing vs SNR



- Similar behavior for all sensors

Summary

- First measurements of timing in our TCT setup
- Comparison of different devices in same conditions
- Improvements of the setup are foreseen: optics to go to 1 MIP, electronics following Mitch suggestions
- These measurements will be presented at the RD50 workshop next week (next slide)

Outline RD50 talk

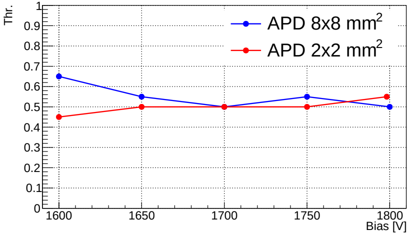
- Introduction to the devices: structure, operation parameters, etc.
- Simulations: E field as a function of bias and position in the sensor
- Challenges in operation: 1800 V on small structures / distances (unpackaged devices, CV mishap)
- IV CV
- Charge collection / amplitude maps measured by Sofia with laser
- P-side resistivity problem
- Solution to the resistivity problem: mesh, gold, aluminum deposition
- Penn amplifier: some material needed
- Some of the measurements shown today

I will circulate the slides on Friday

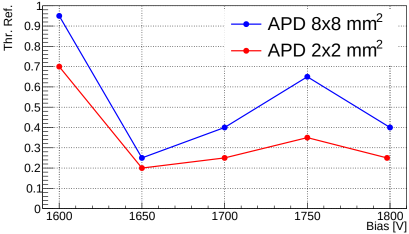
Backup Material

APD Thresholds

APD threshold:



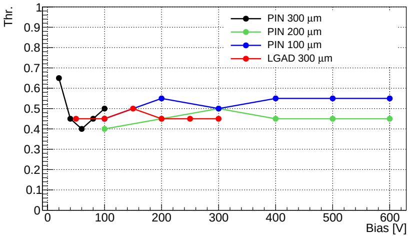
Reference threshold:



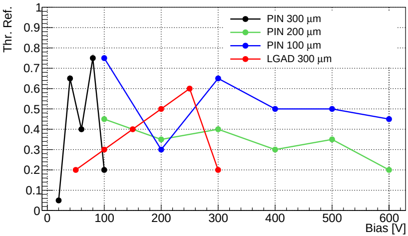
- The ref. threshold has no big impact on the time resolution
- The ref. threshold swings more due to statistical fluctuations

Other Devices Thresholds

Device threshold:



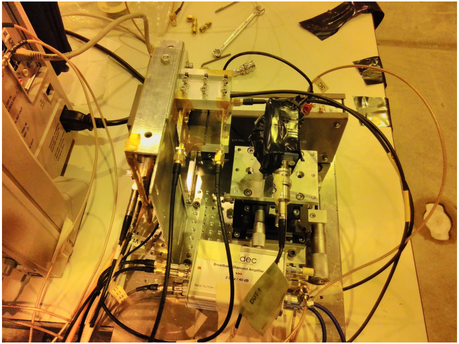
Reference threshold:



- The ref. threshold has no big impact on the time resolution
- The ref. threshold swings more due to statistical fluctuations

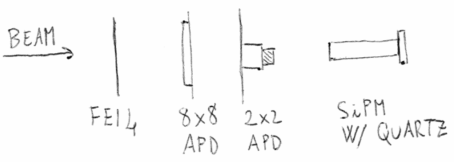
APDs in Beam Test

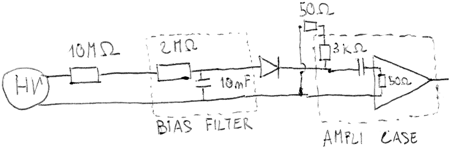
- Sofia and me took part in a LGAD beam test
- Participated in data taking
- Got some beam time for two APDs
- One day preparation of our devices:
  - Mounting on PCBs
  - Short time biasing till 1800 V



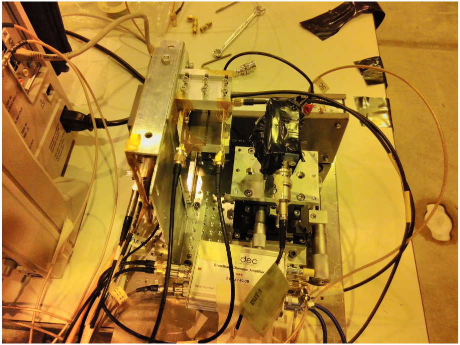
Setup

120 GeV/c π





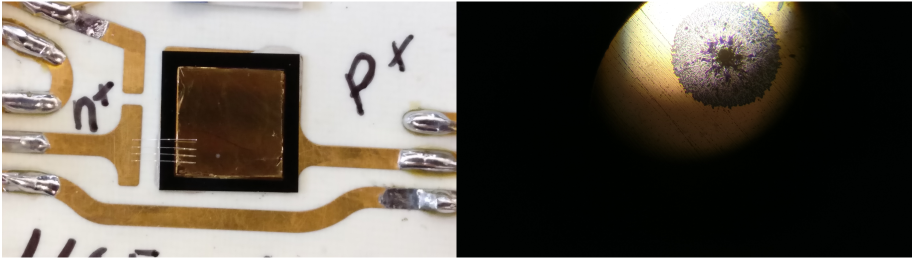
All detectors, bias filters, and amplifiers housed in temperature controlled light-tight box. Readout using scope.



Conclusions

- Got 6 runs with the 8x8 APD (900, 1000, 1100 V, to be analyzed) In these runs the APD seemed very inefficient
- 8x8 APD broke at 1700 V in test beam
- 2x2 APD is unstable under bias: trip of the power supply after some minutes, remains alive (observed multiple times)

8x8 APD, we think that the breakdown of the device left a crater



Crater in “safe” area

Next possibility to be on the beam in July

Better planning and testing are needed