AC-LGAD readout using ALTIROC 0

Status report Jan 2022

Brookhaven National Laboratory

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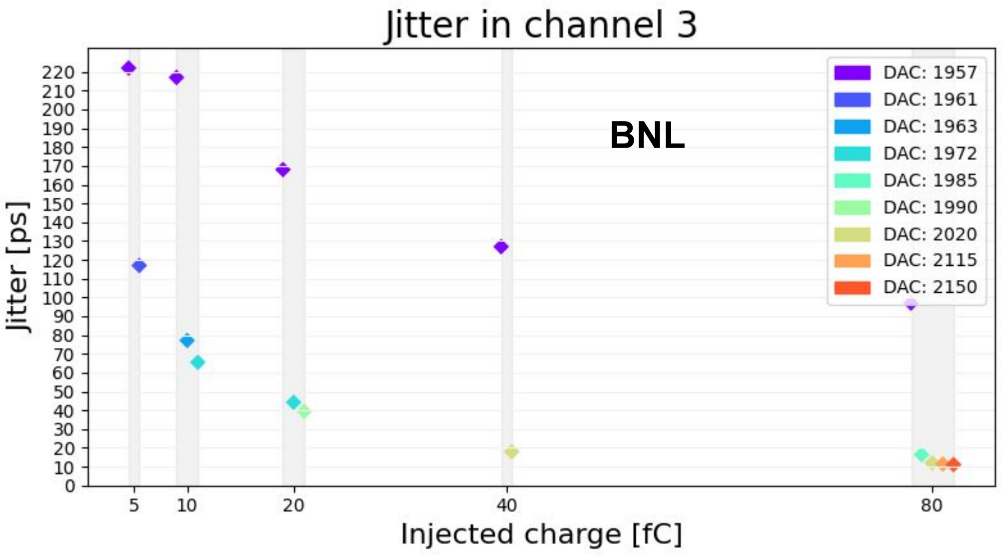
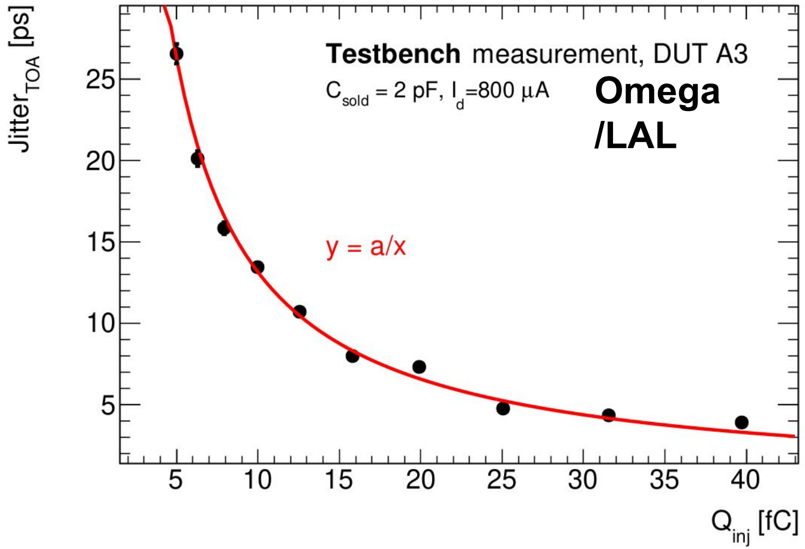
Brookhaven National Lab (US)
27 January 2022

Quick reminder…



from: Thesis by Christina AGAPOPOULOU, page 167



$C_{soldered}$ = 2 pF, 2.5 fC discriminator threshold and **signal rise time = 70 ps**

Even in the best case, **our jitters are about 4 times worse than those in ALTIROC0 literature** at the same injected charge

Since this is injected test signal, the **only AC-LGADs parameter entering the equation is the sensor capacitance** (unknown parameter)

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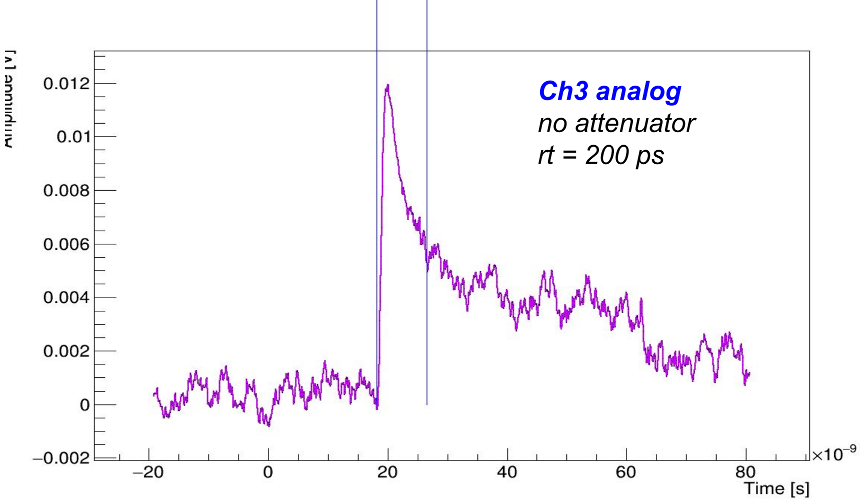
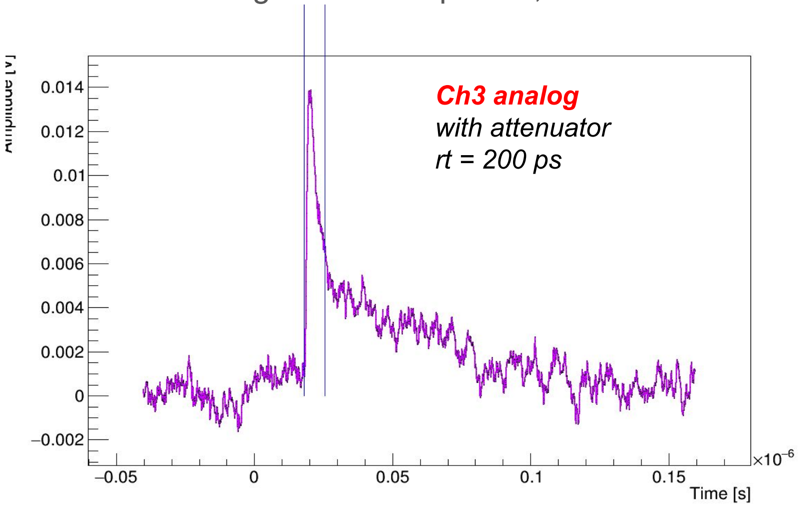
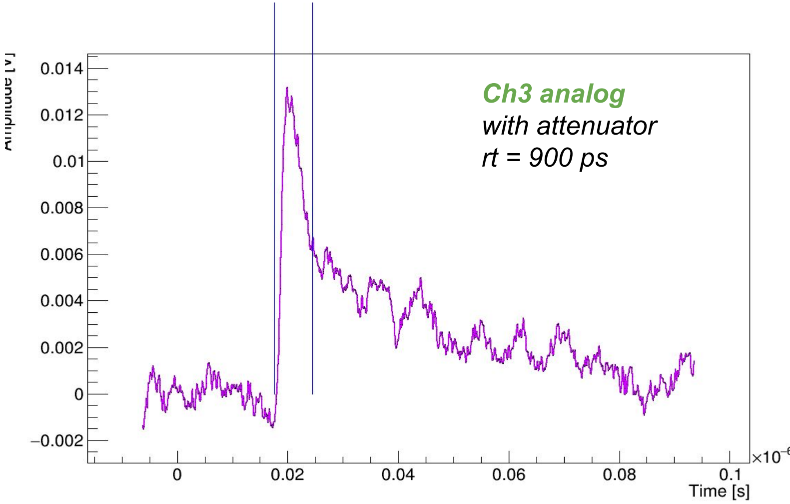
Tests at different rise times

Analog signals

- Performances tested with **fast Pulse Generator** (PG) (200 ps rise-time), **slower PG** (900 ps rise-time), and **fast PG with no attenuator**
- **Non-attenuated** signals: 100mV amplitude
- **Attenuated** signals: 4V amplitude, reduced to 100mV







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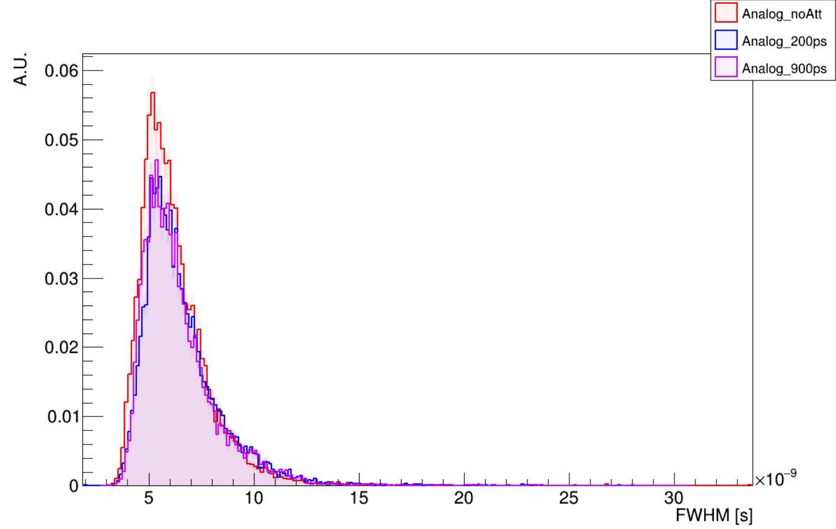
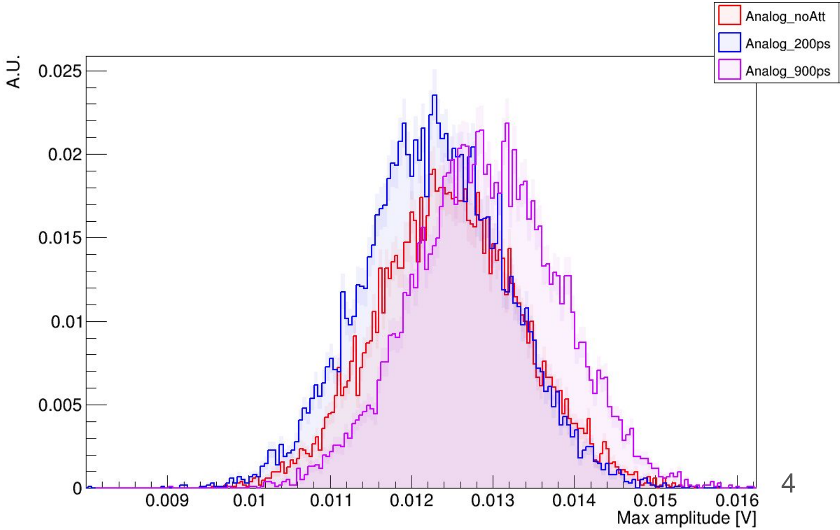
Tests at different rise times

Amplitude & FWHM comparison

- Channel 3, different pulse generator rise time and attenuator settings

- Basically no effect on **FWHM** of analog signal and minimal effect on **signal amplitude**





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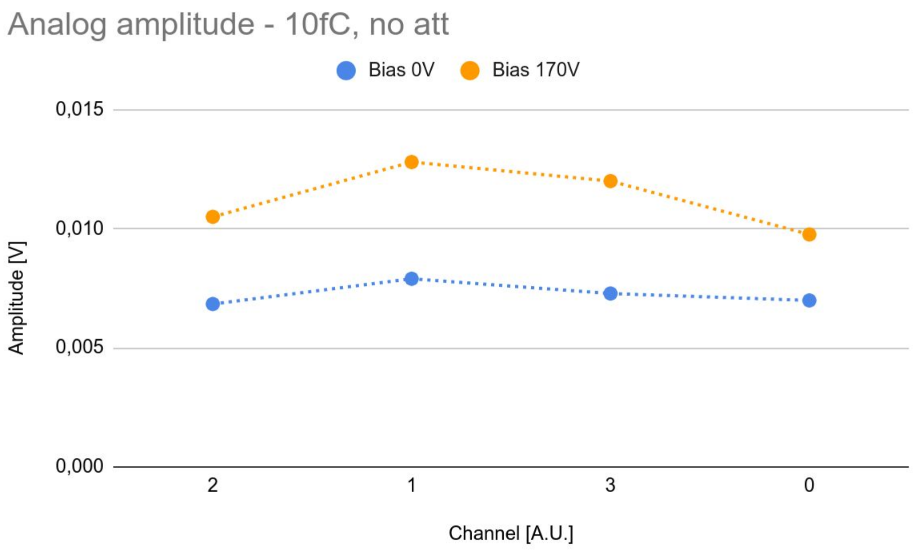
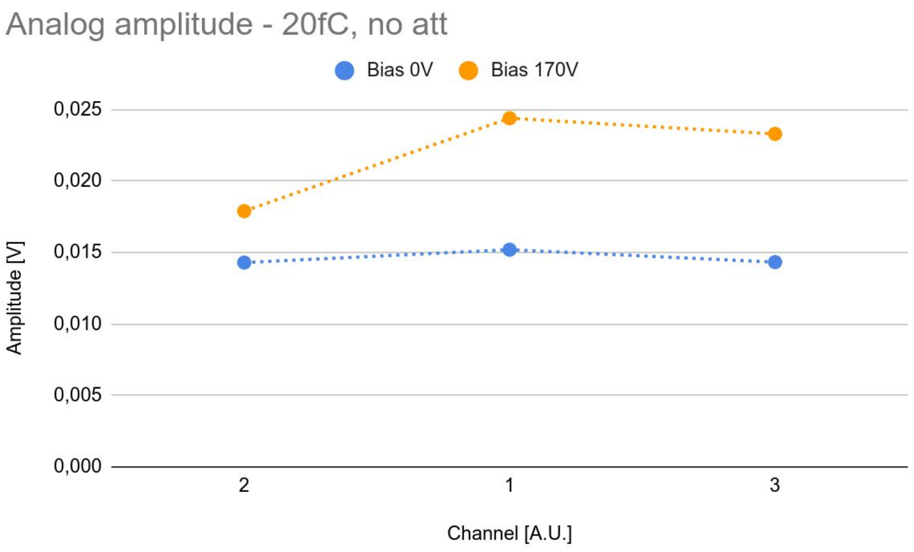
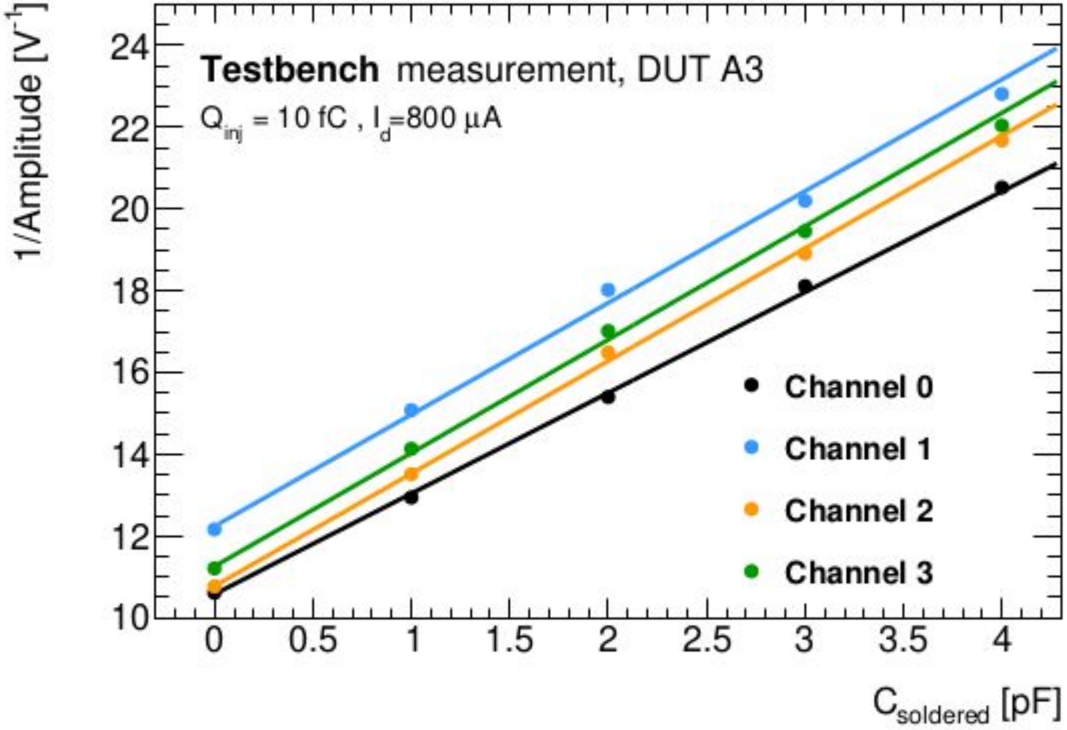
Signal parameters on different channels
Amplitude





Calibration from paper
Capacitance



ch 0:

$$A^{-1} = C_{soldered} * (21 - 10.5)/4 + 10.5$$
$$= 2.625 * C_{soldered} + 10.5$$
$$C_{soldered} = (A^{-1} - 10.5)/2.625$$

ch 1:

$$A^{-1} = C_{soldered} * (23 - 12)/4 + 12$$
$$= 2.75 * C_{soldered} + 12$$
$$C_{soldered} = (A^{-1} - 12)/2.75$$

ch 2:

$$A^{-1} = C_{soldered} * (21.7 - 10.7)/4 + 10.7$$
$$= 2.75 * C_{soldered} + 10.7$$
$$C_{soldered} = (A^{-1} - 10.7)/2.75$$

ch 3:

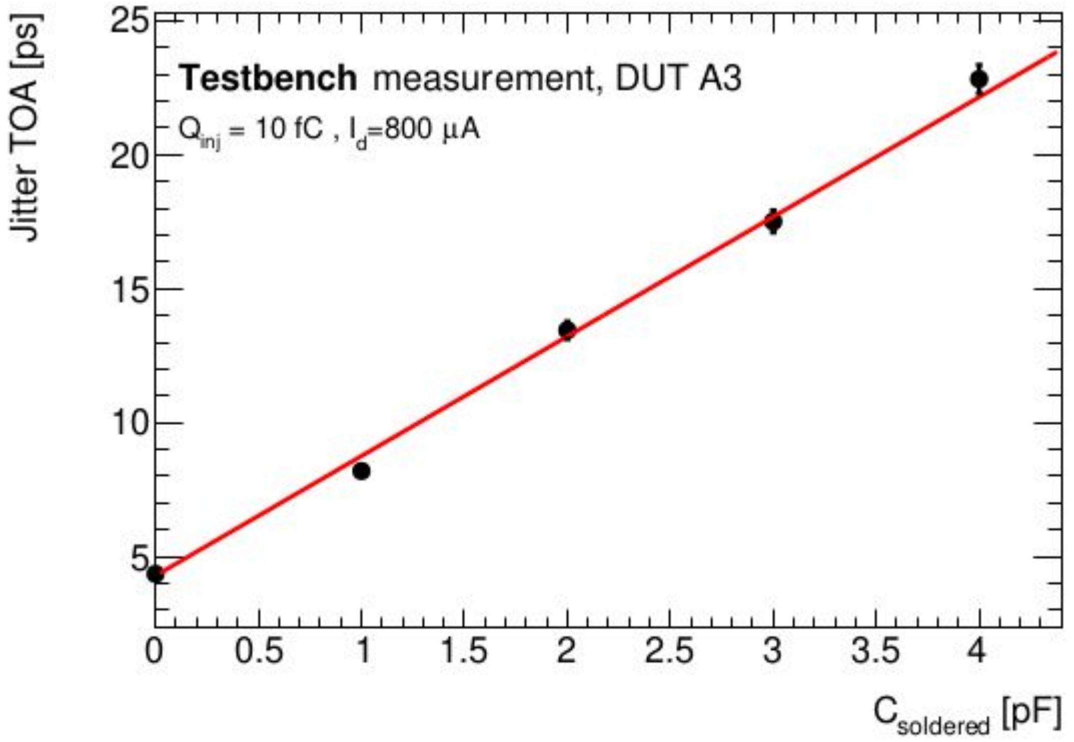
$$A^{-1} = C_{soldered} * (22 - 11)/4 + 11$$
$$= 2.75 * C_{soldered} + 11$$
$$C_{soldered} = (A^{-1} - 11)/2.75$$

In general (rule of thumb):

$$C_{soldered}\,[pF] \sim (A^{-1}\,[V^{-1}] - 11)/2.75$$

Calibration from paper

Jitter



In general:

$$jitter[ps] \sim C_{soldered}[pF] * \frac{23 - 4.5}{4} + 4.5$$

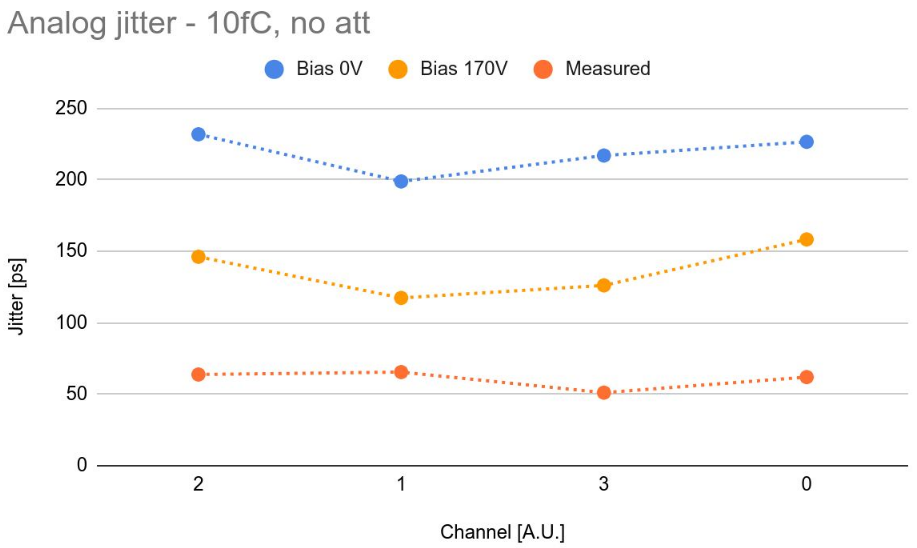
$$\sim C_{soldered}[pF] * 4.625 + 4.5$$

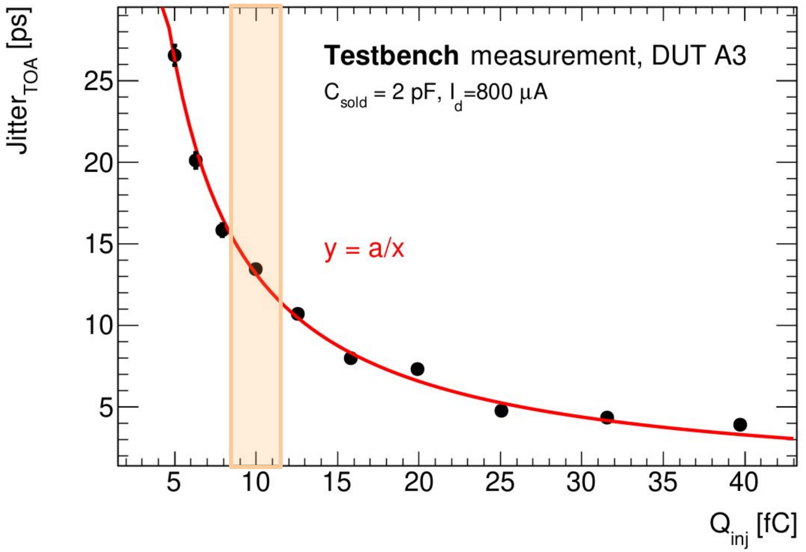
$$\sim \frac{A^{-1}[V^{-1}] - 11}{2.75} * 4.625 + 4.5$$

Would be really useful to obtain the **calibration for different injected charges!**

Signal parameters on different channels

Jitter

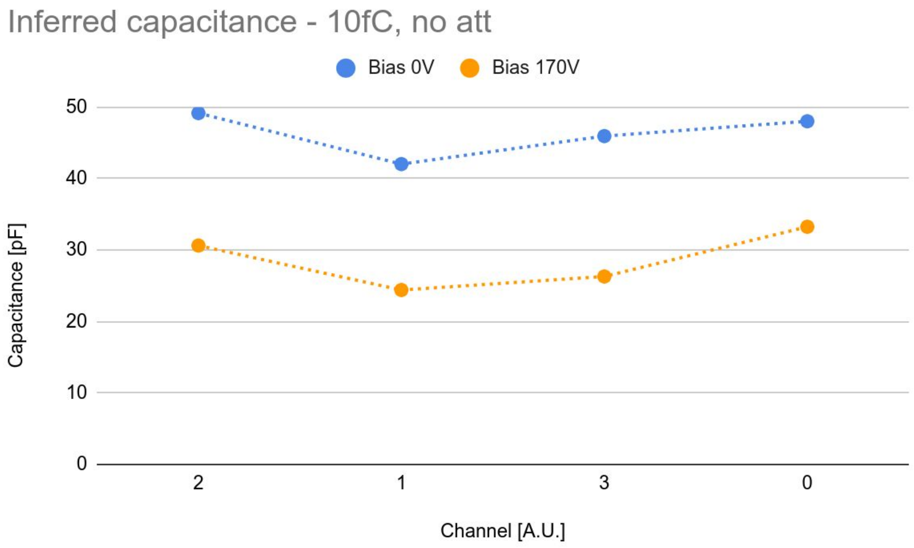


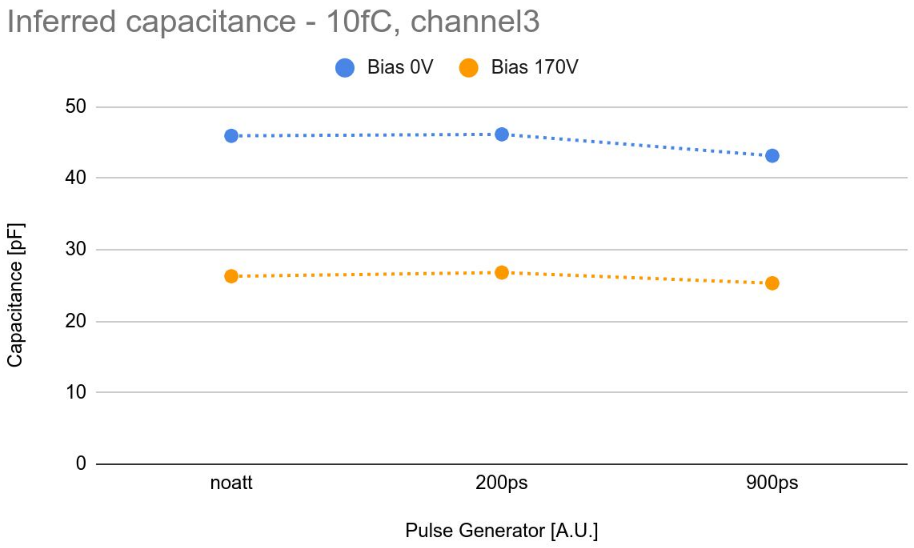


$$jitter\ [ps] \sim \frac{A^{-1}[V^{-1}] - 11}{2.75} * 4.625 + 4.5$$

Signal parameters on different channels

Inferred capacitance



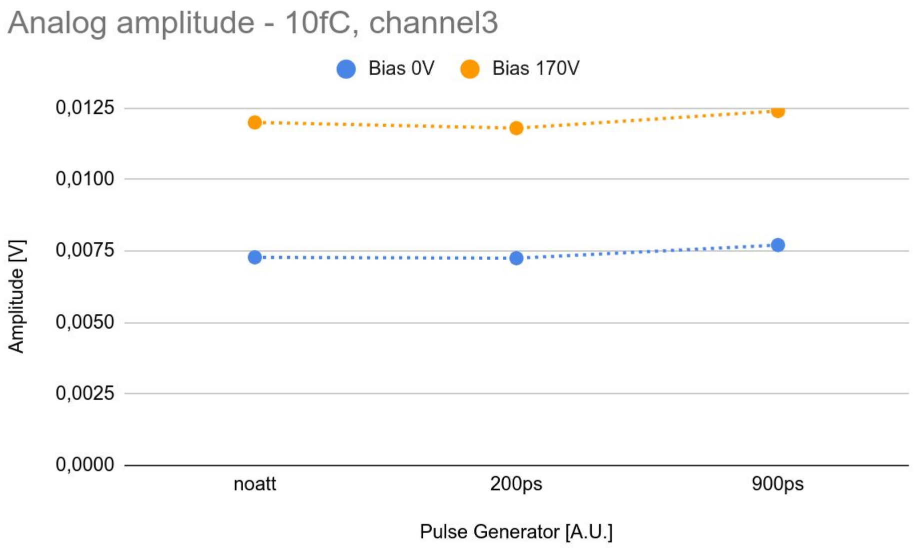


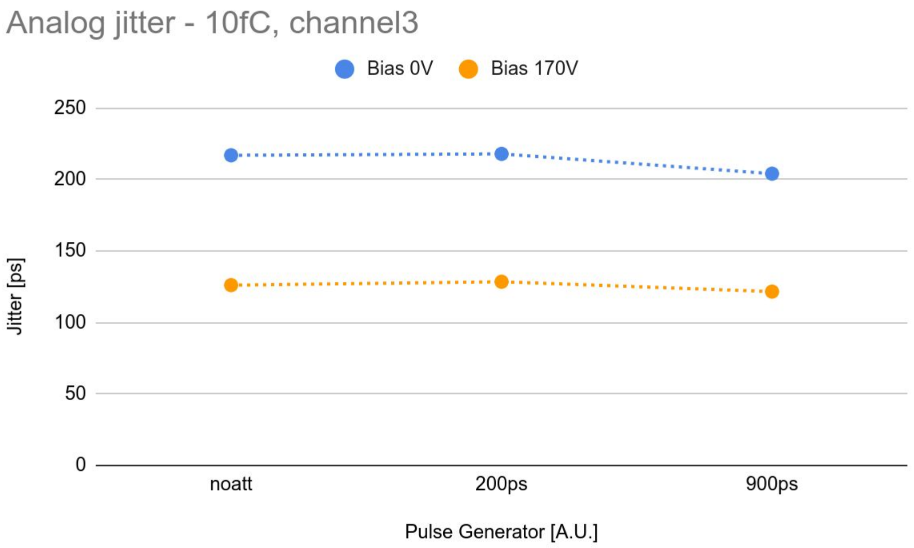
In general (rule of thumb):

$$C_{soldered}\ [pF] \sim (A^{-1}\ [V^{-1}] - 11)/2.75$$

Test with different PGs

Amplitude and Jitter





Recap and future prospects

- **Pulse rise-time** does not seems to affect signal amplitude significantly (up to 10%), with **minimal effect on jitter and capacitance estimation**
- High jitter (~100 ps) leads to **high expected capacitance** for AC-LGAD sensor (~25 pF)
- Independent preliminary measurements of AC-LGAD capacitance leads to believe that this measurement is **approximately correct**
- It would be really interesting to compare to results obtained by ALTIROC0 for LGADs for different injected charges

BACKUP

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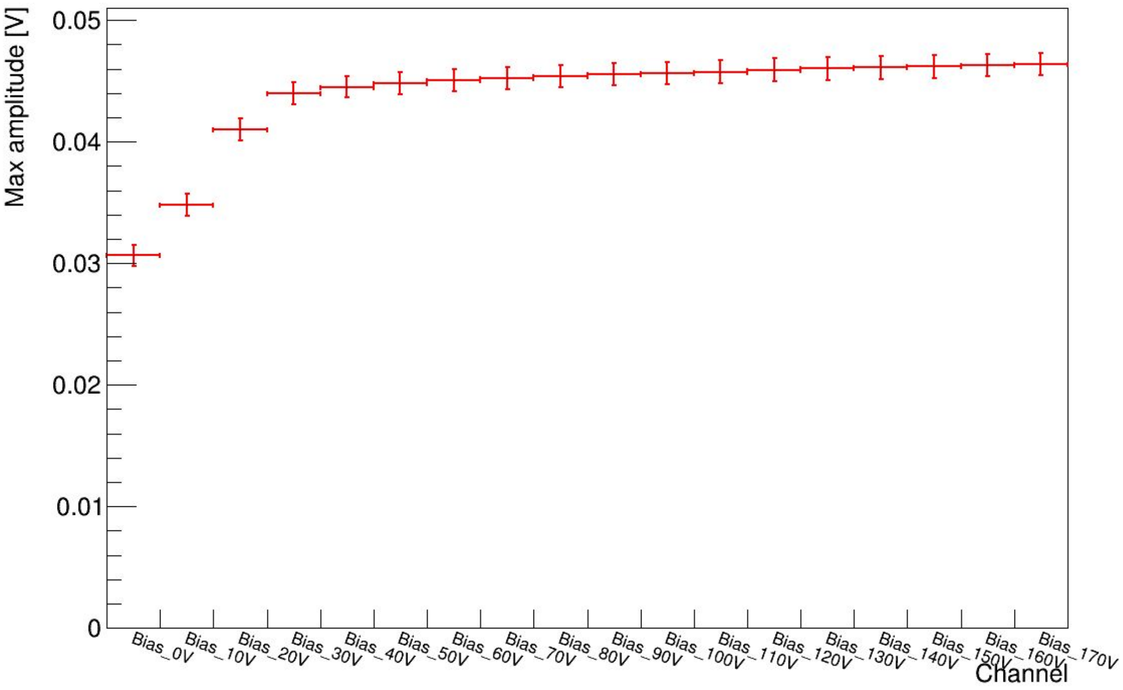
Bias response

Ch3 - 400mV, DAC 2000 (Amplitude)

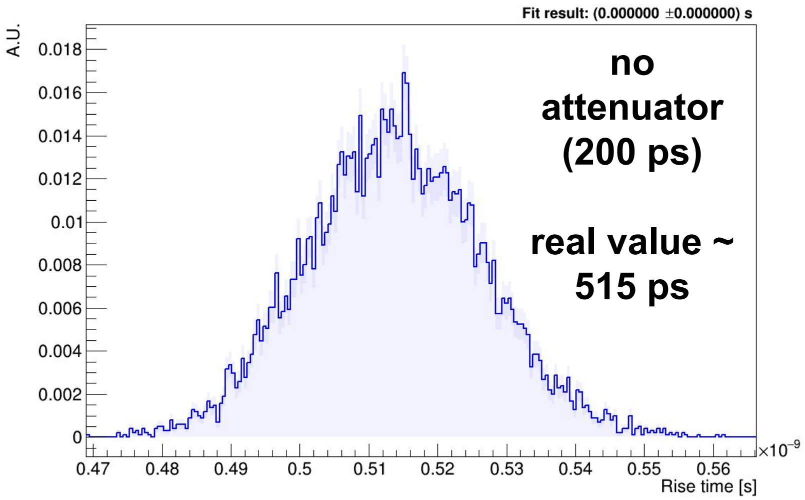
Amplitude distributions for analog signals are fitted using Landau function

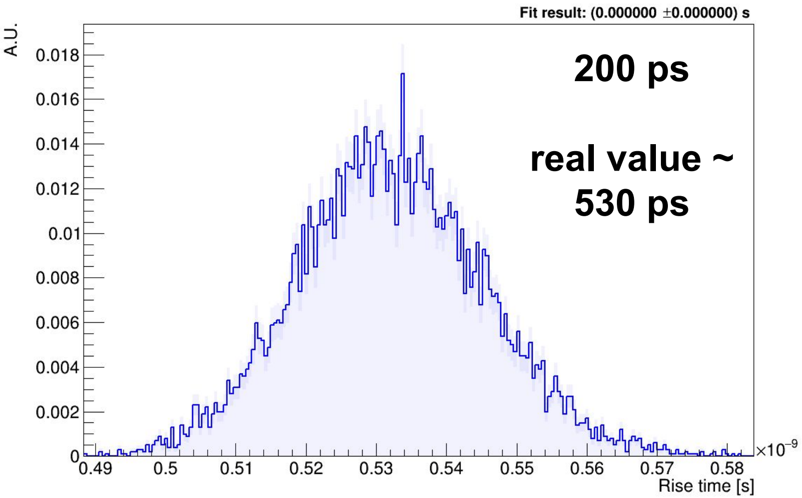
Plot shows mean value of Landau fit as a function of sensor bias voltage on the *x-axis*

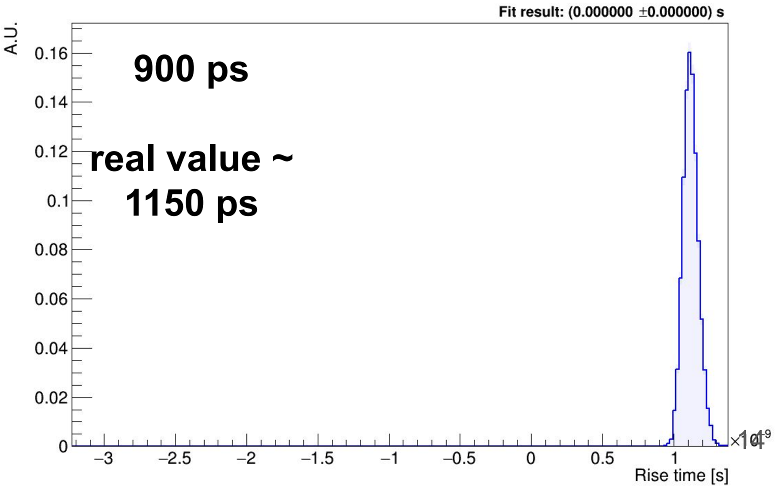
Analog signal amplitude increases of about 60% when passing from 0 V and 170 V of Bias Voltage, for the same injected signal of 40 fC



Test at different rise times





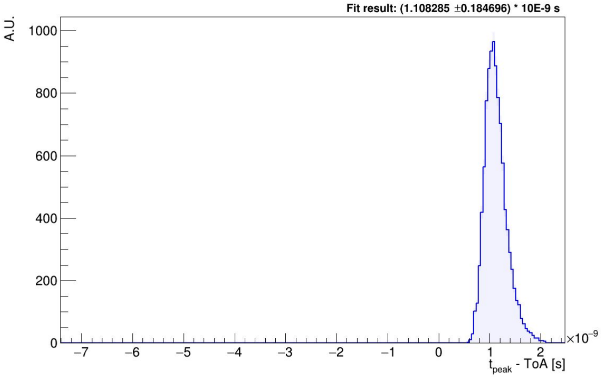


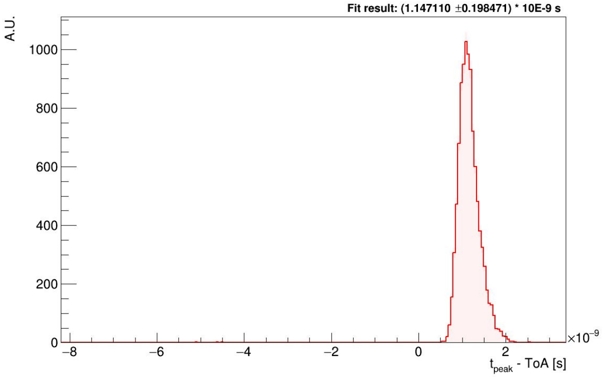
Tests at different rise times

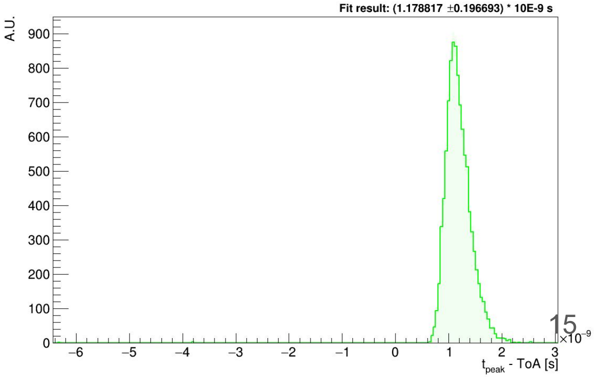
Time dispersion comparison

Difference between t_{peak} (computed at amplitude maximum) and ToA (computed at 50% CFD) for analog signals from channel 3, when injecting 10 fC charge

Time dispersion (rise-time 200ps, noatt) **1.108 ± 0.185 ns**
Time dispersion (rise-time 200ps, att) **1.147 ± 0.198 ns**
Time dispersion (rise-time 900ps, att) **1.179 ± 0.197 ns**







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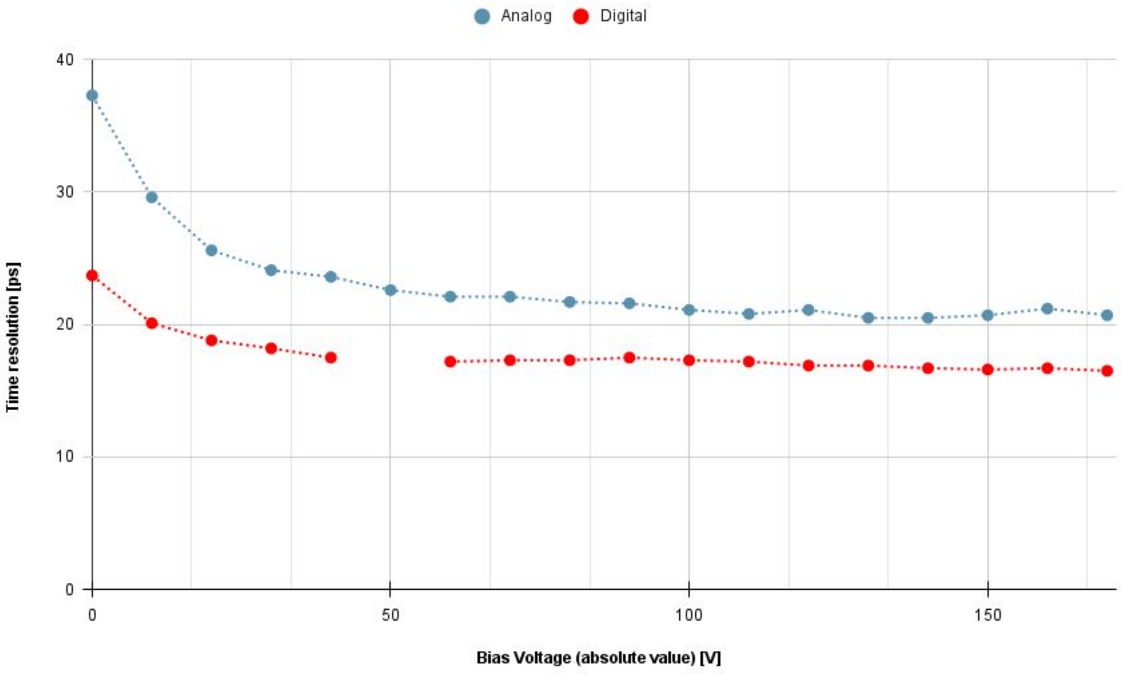
Bias response

Ch3 - 400mV, DAC 2000 (Jitter)

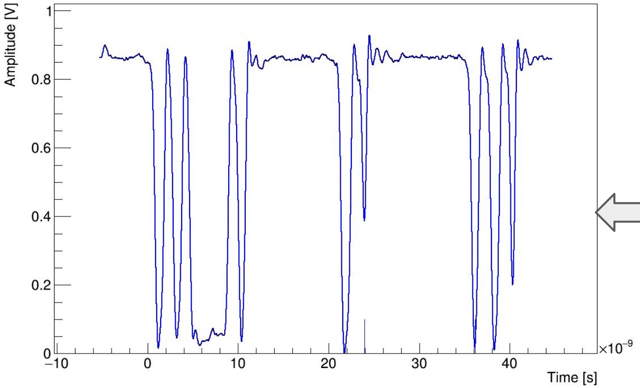
Jitter value when injecting 40fC of charge through Ctest as a function of Bias Voltage applied to AC-LGAD

Measurement made using difference in ToA between input signal from Pulse Generator and **Analog** or **Digital** signals from ALTIROC

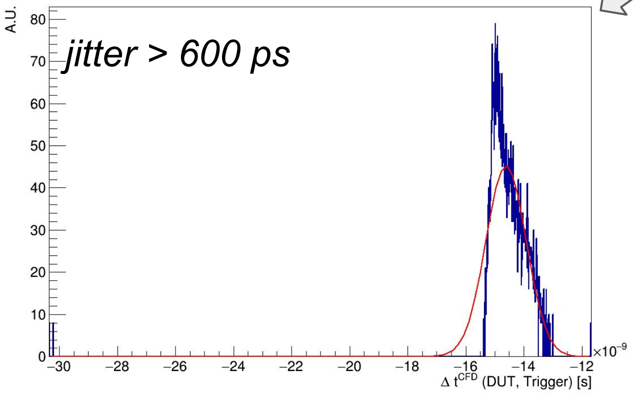


Multiple Pre-amplifiers ON/OFF on Ch1 - 5fC - DAC1963

*example Digital output (**All PA**)*



*TOA differences (**All PA**)*



- **Probe OFF** (as recommended)
- Study of the **effect of multiple PAs open in parallel** when injecting 5fC of charge

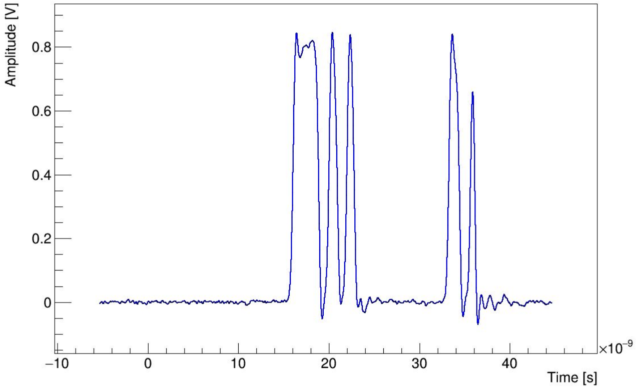
All PA dataset: all PAs turned on during data taking:

- **Lots of noise above threshold**,
- Digital signal almost always above threshold
- **ToA difference distribution not gaussian** leading to huge jitters

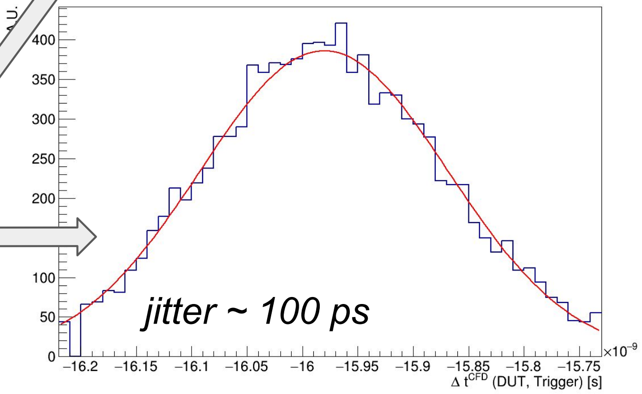
One PA dataset: only readout PA turned on during data-taking

- **Noise reduced considerably**
- **ToA Difference distribution much more gaussian** than before
- Better jitter with same conditions

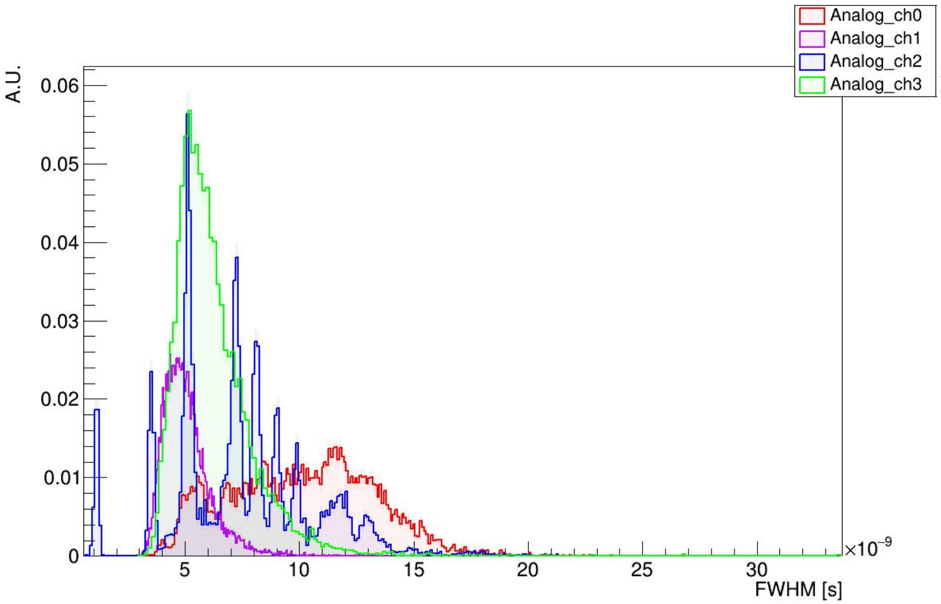
*example Digital output (**One PA**)*

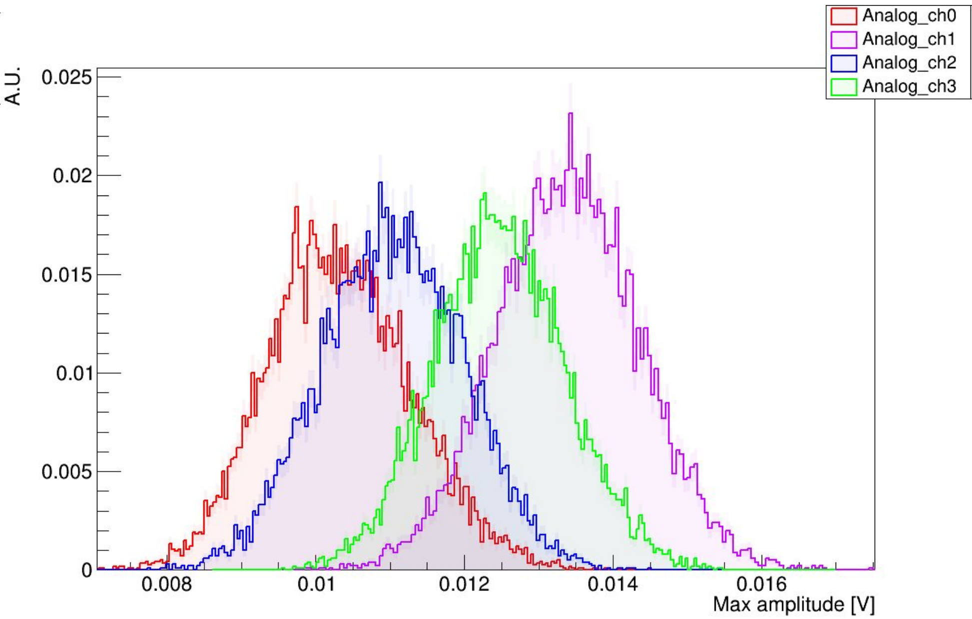


*TOA differences (**One PA**)*

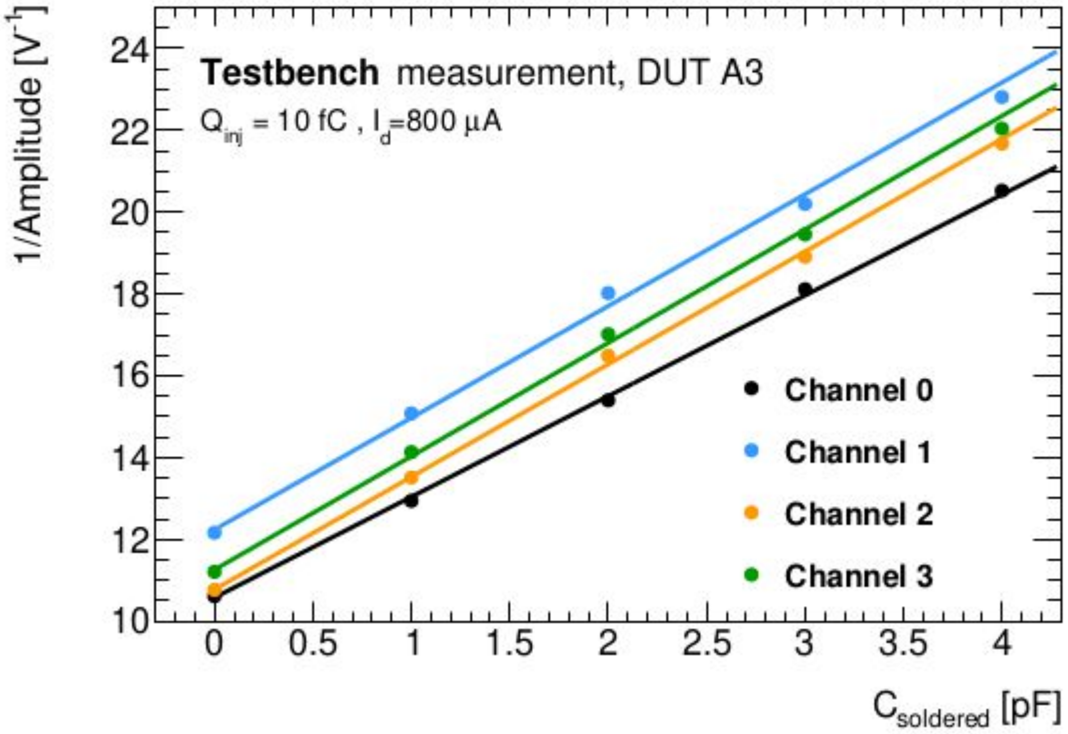


Test on different channels





Calibration from paper



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ch 1:

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In general (rule of thumb):

$$C_{soldered} [pF] \sim (A^{-1} [V^{-1}] - 11)/2.75$$

Test on different channels

Channel 0, noatt, 10fC

Amplitude

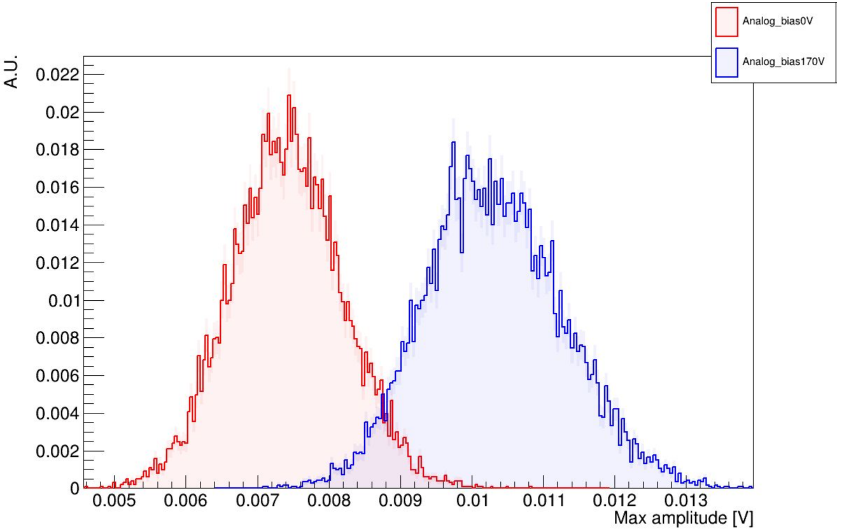
[INFO] Channel : Analog_bias0V 0.00699 ± 0.000263 V

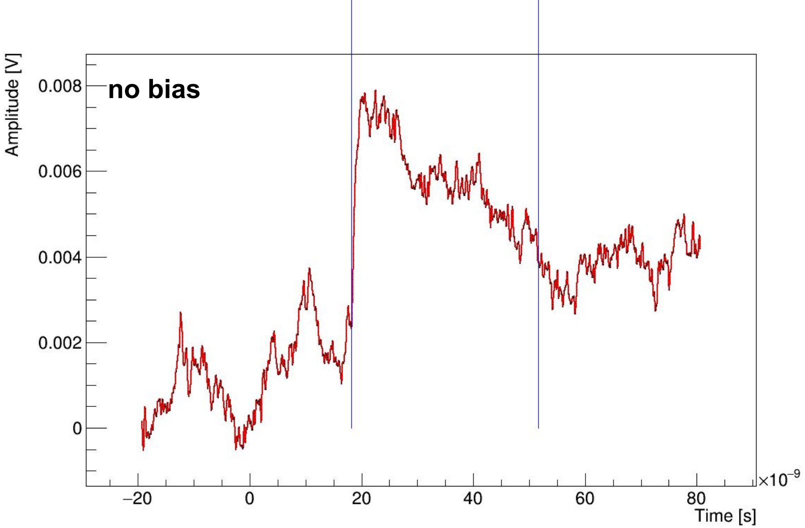
[INFO] Channel : Analog_bias170V 0.00976 ± 0.00034 V

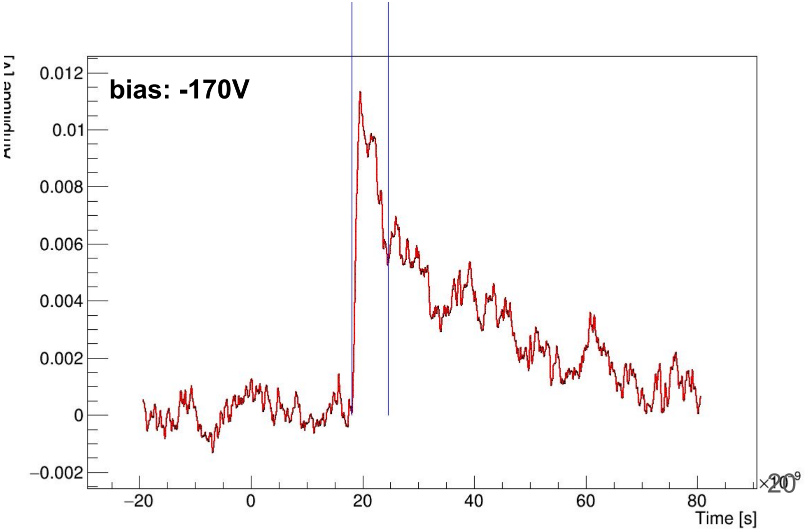
FWHM

[INFO] Channel : Analog_bias0V 1.41e-08 ± 1.29e-09 s

[INFO] Channel : Analog_bias170V 7.41e-09 ± 1.36e-09 s







Test on different channels

Channel 1, noatt, 10fC

Amplitude

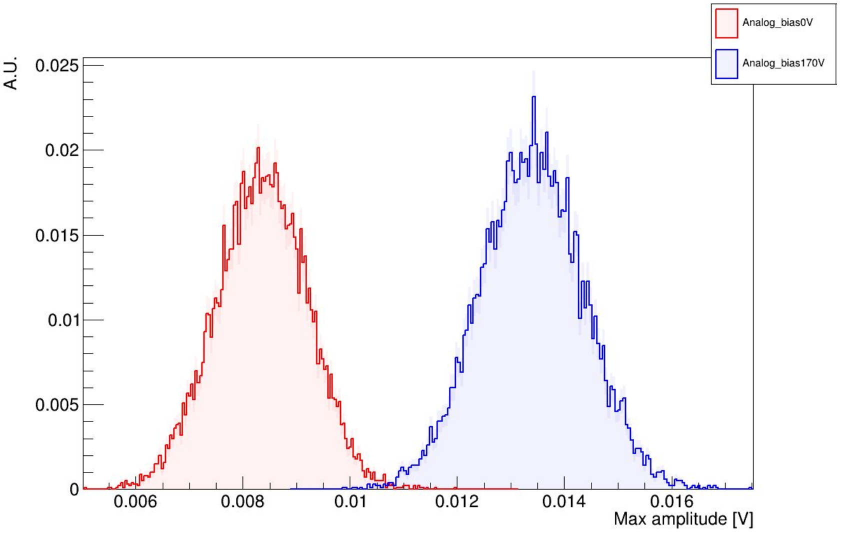
[INFO] Channel : Analog_bias0V 0.0079 ± 0.000275 V

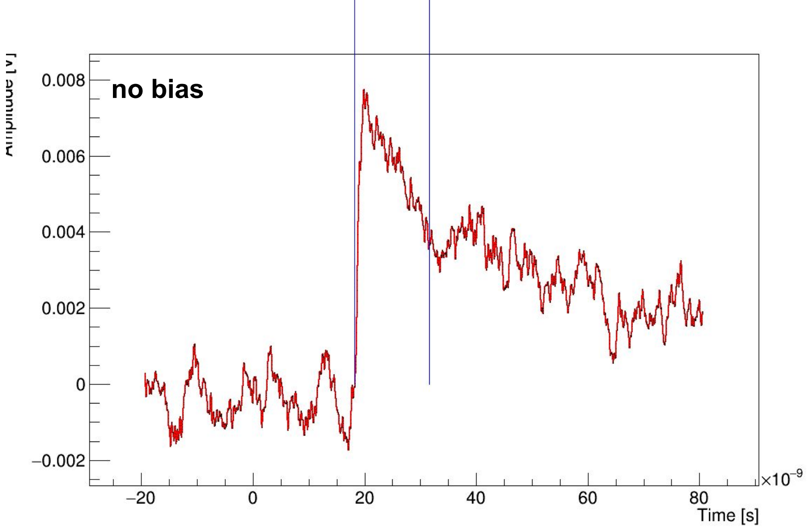
[INFO] Channel : Analog_bias170V 0.0128 ± 0.000327 V

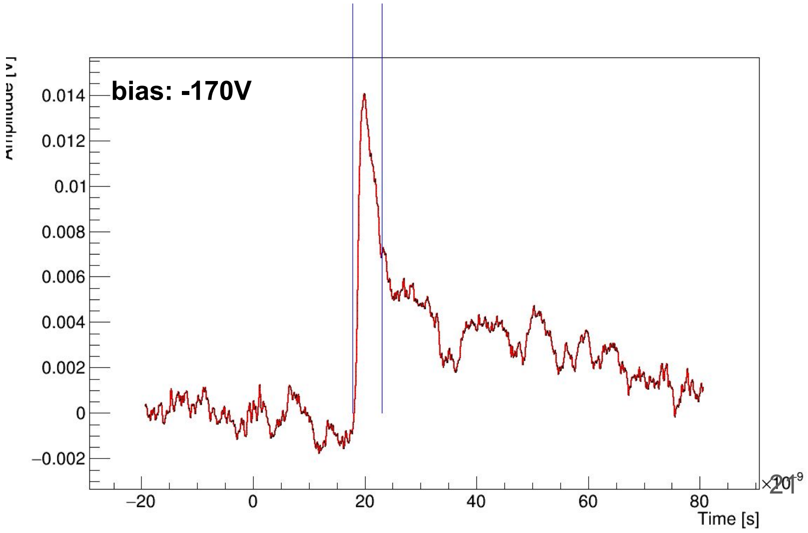
FWHM

[INFO] Channel : Analog_bias0V 1.17e-08 ± 1.14e-09 s

[INFO] Channel : Analog_bias170V 4.39e-09 ± 3.16e-10 s







Test on different channels

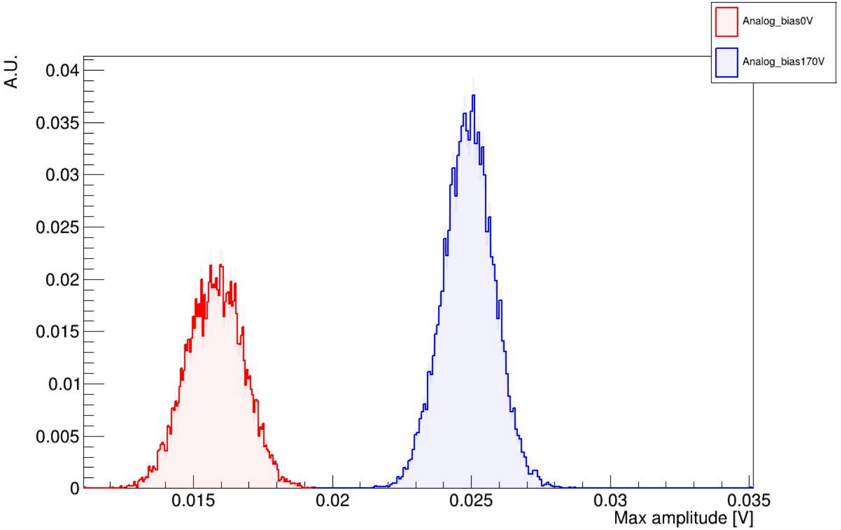
Channel 1, noatt, 20fC

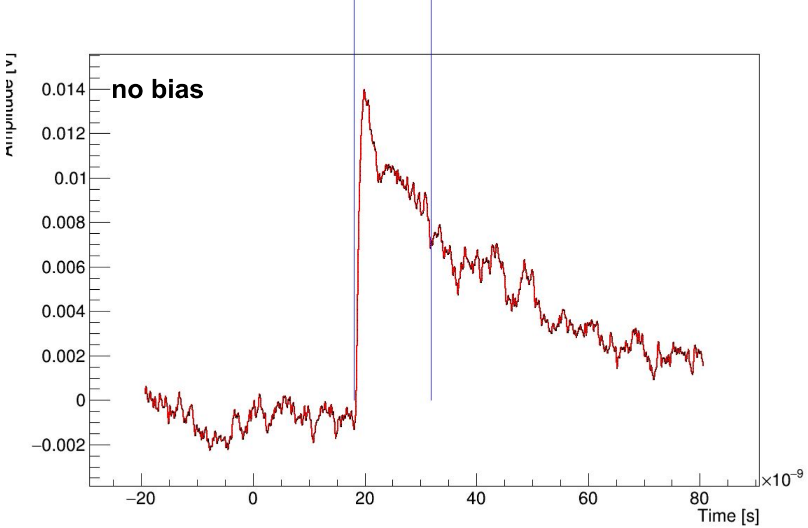
Amplitude

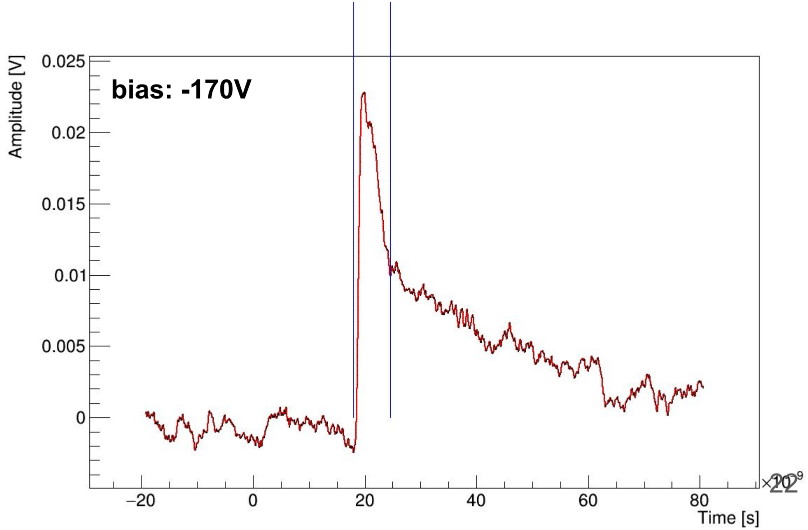
[INFO] Channel : Analog_bias0V	0.0152 ± 0.000367 V
[INFO] Channel : Analog_bias170V	0.0244 ± 0.00026 V

FWHM

[INFO] Channel : Analog_bias0V	1.43e-08 ± 9.46e-10 s
[INFO] Channel : Analog_bias170V	5.25e-09 ± 9.63e-11 s







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Test on different channels

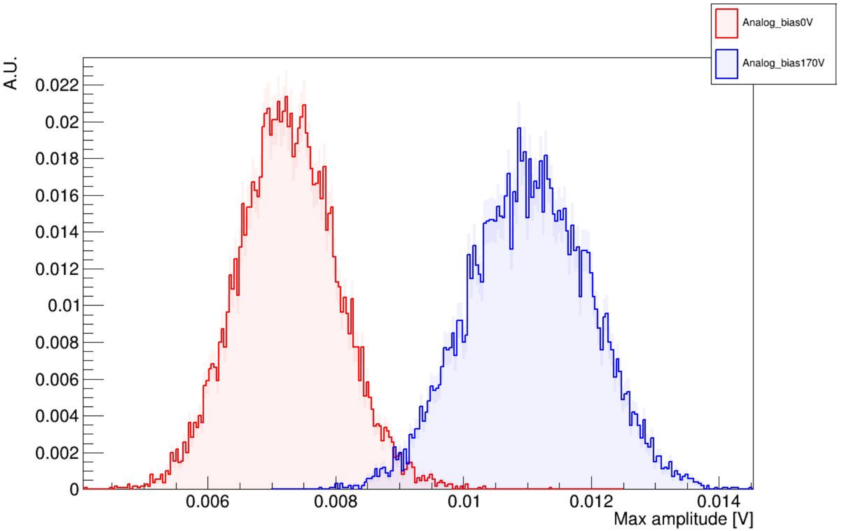
Channel 2, noatt, 10fC

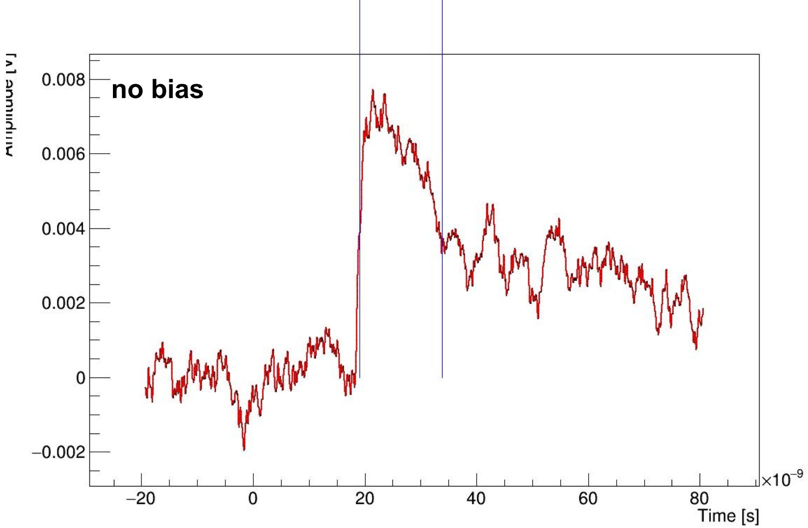
Amplitude

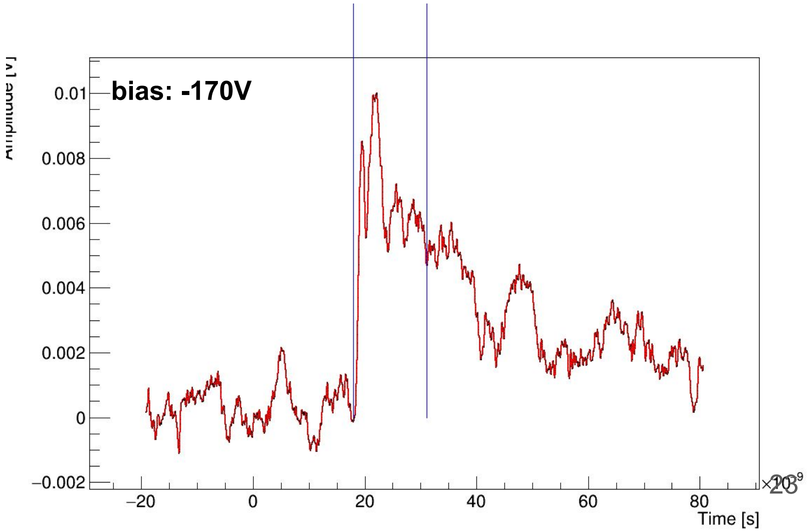
[INFO] Channel : Analog_bias0V	0.00684 ± 0.000279 V
[INFO] Channel : Analog_bias170V	0.0105 ± 0.000343 V

FWHM

[INFO] Channel : Analog_bias0V	1.41e-08 ± 1.28e-09 s
[INFO] Channel : Analog_bias170V	6.37e-09 ± 1.08e-09 s







Test on different channels

Channel 2, noatt, 20fC

Amplitude

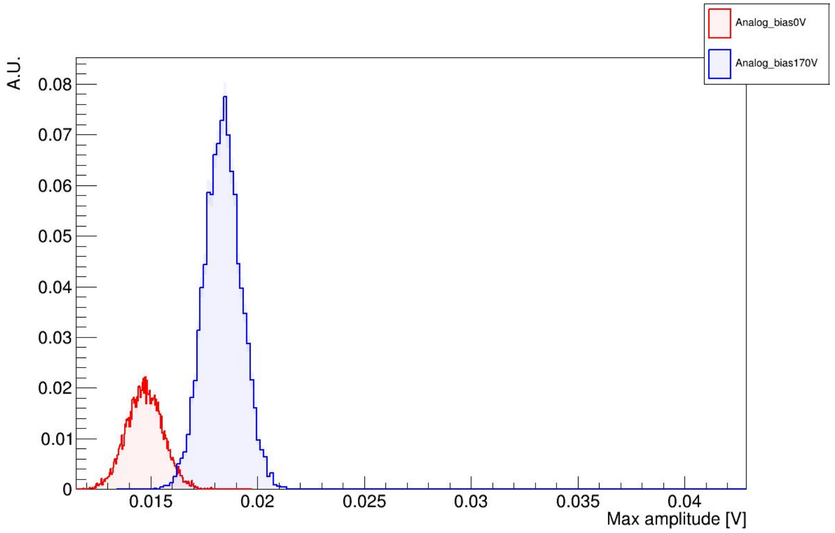
[INFO] Channel : Analog_bias0V 0.0143 ± 0.00029 V

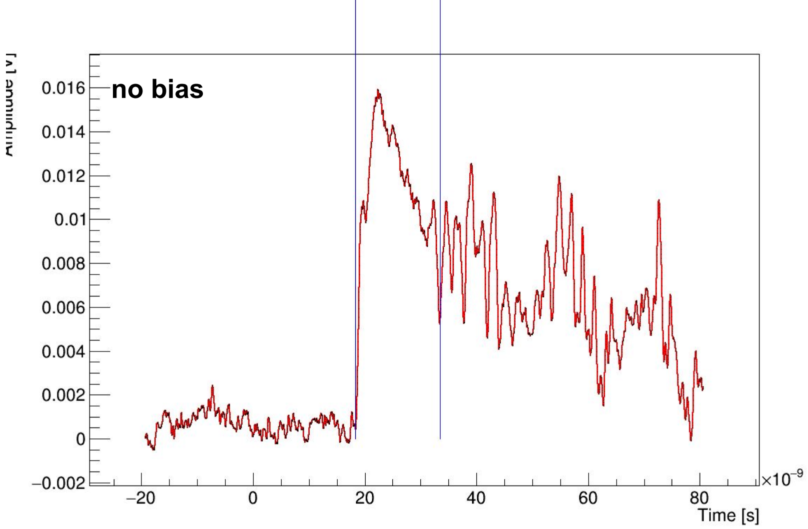
[INFO] Channel : Analog_bias170V 0.0179 ± 0.000228 V

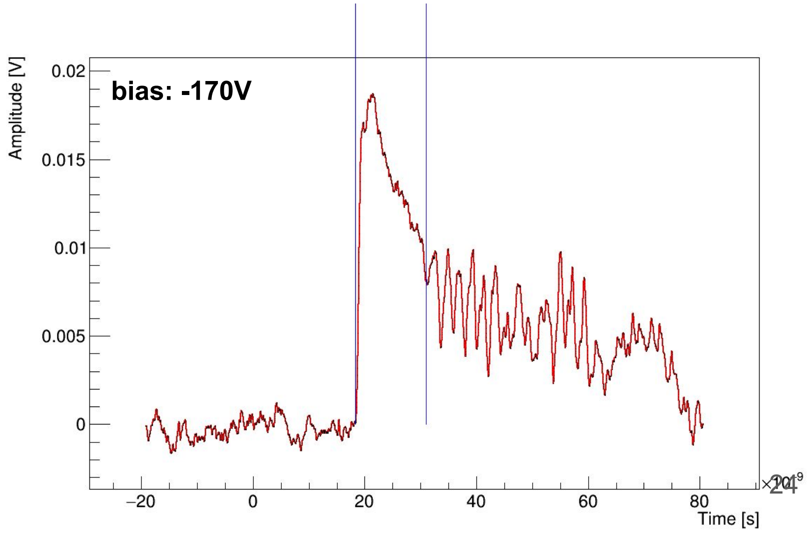
FWHM

[INFO] Channel : Analog_bias0V 1.46e-08 ± 3.1e-10 s

[INFO] Channel : Analog_bias170V 1.2e-08 ± 4.08e-10 s







Test on different channels

Channel 3, noatt, 10fC

Amplitude

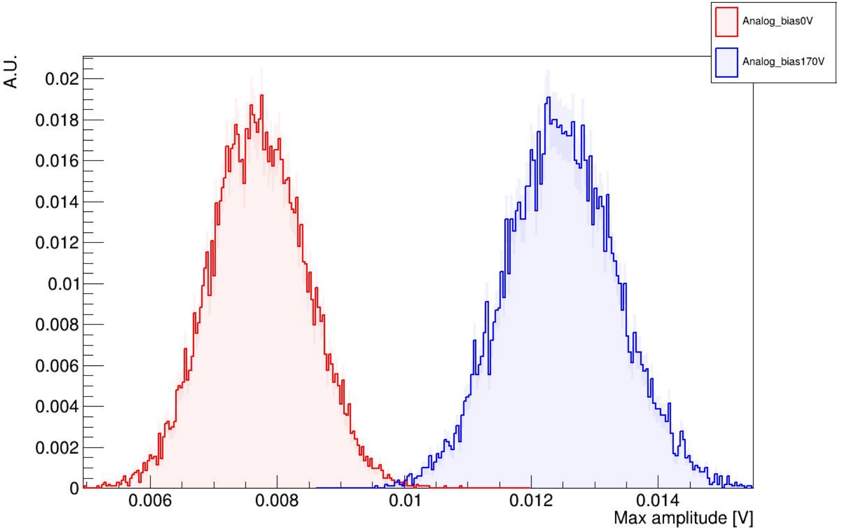
[INFO] Channel : Analog_bias0V 0.00728 ± 0.000249 V

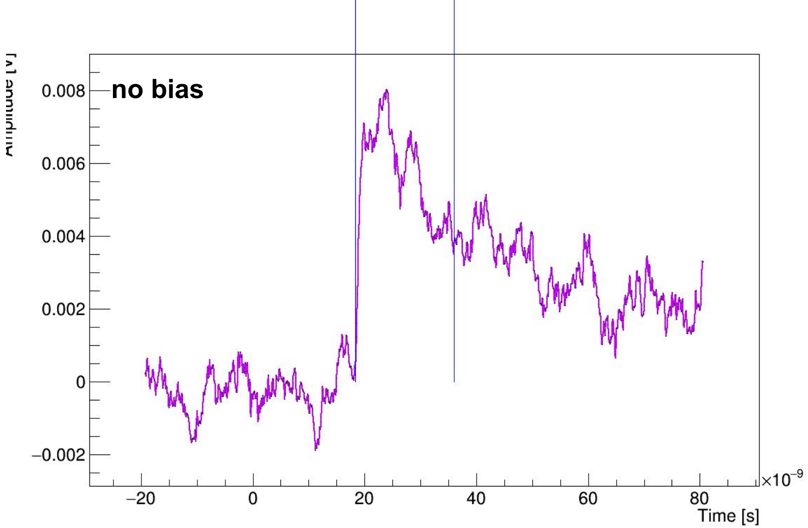
[INFO] Channel : Analog_bias170V 0.012 ± 0.00031 V

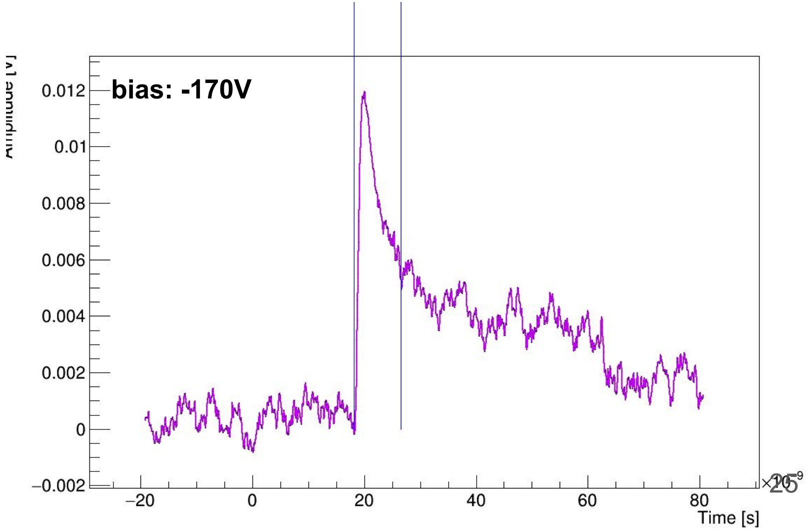
FWHM

[INFO] Channel : Analog_bias0V 1.35e-08 ± 1.37e-09 s

[INFO] Channel : Analog_bias170V 5.19e-09 ± 4.36e-10 s







Test on different channels

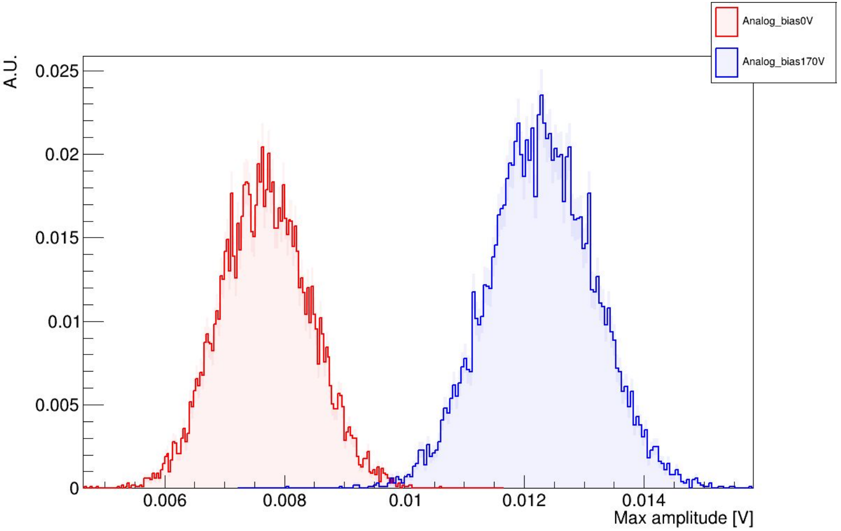
Channel 3, 200 ps, 10fC

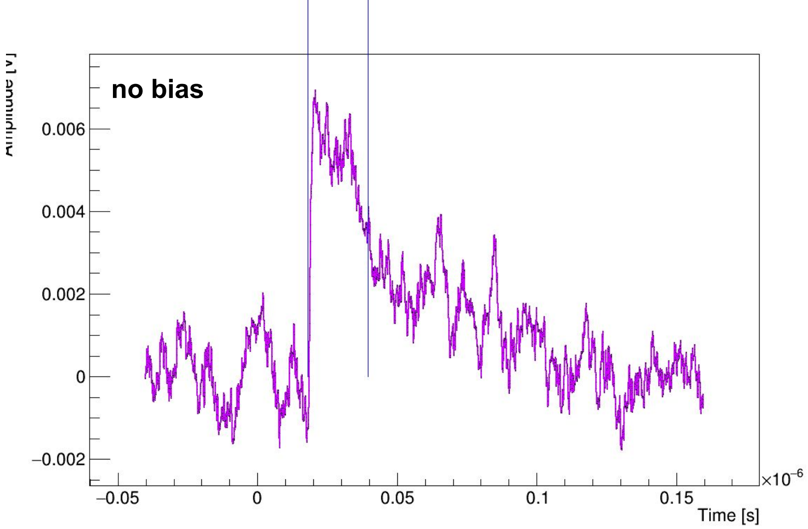
Amplitude

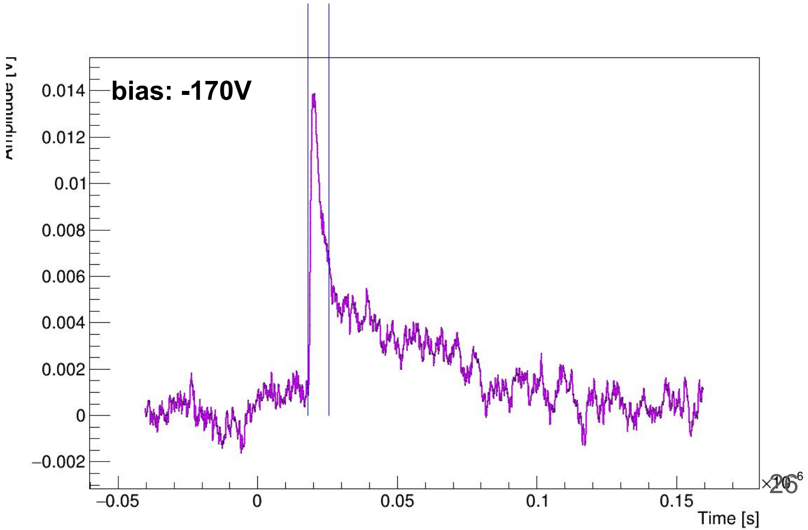
[INFO] Channel : Analog_bias0V	0.00725 ± 0.000278 V
[INFO] Channel : Analog_bias170V	0.0118 ± 0.000284 V

FWHM

[INFO] Channel : Analog_bias0V	1.4e-08 ± 1.43e-09 s
[INFO] Channel : Analog_bias170V	5.42e-09 ± 4.75e-10 s







Test on different channels

Channel 3, 900 ps, 10fC

Amplitude

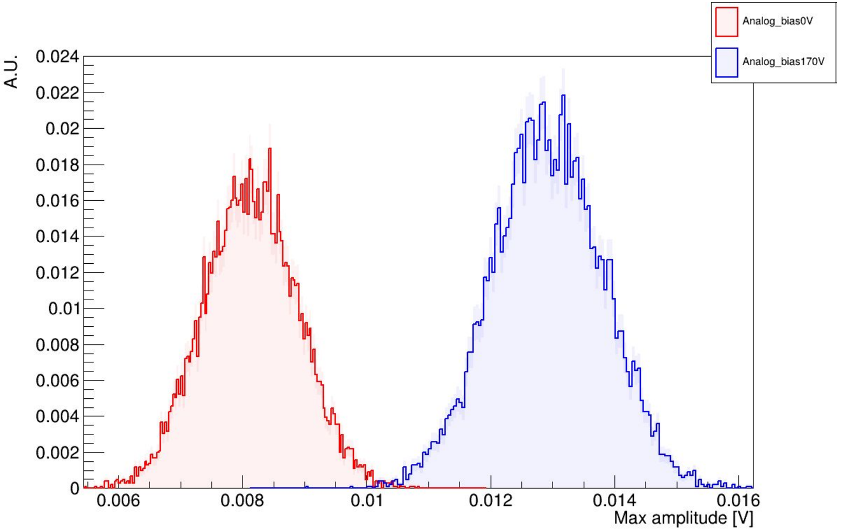
[INFO] Channel : Analog_bias0V   0.00771 ± 0.000262 V

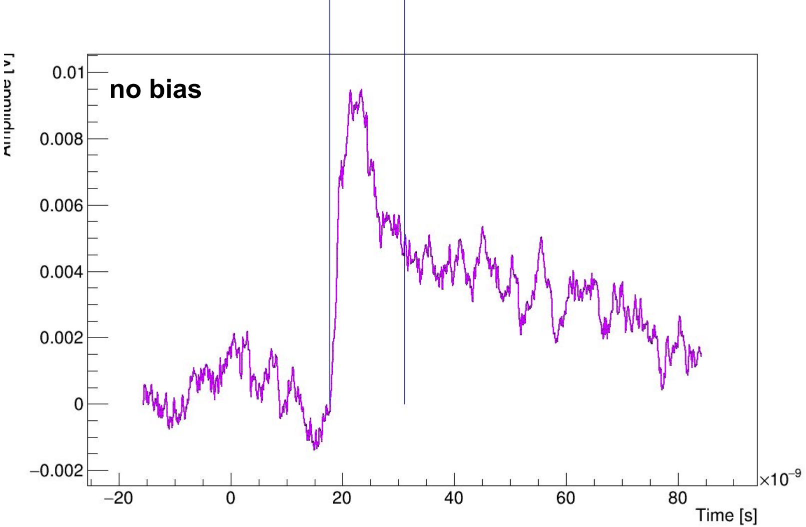
[INFO] Channel : Analog_bias170V   0.0124 ± 0.000297 V

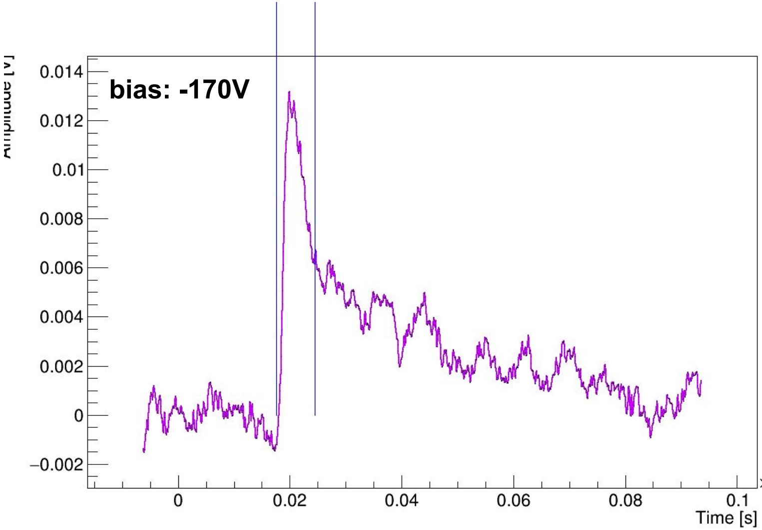
FWHM

[INFO] Channel : Analog_bias0V   1.39e-08 ± 1.42e-09 s

[INFO] Channel : Analog_bias170V   5.25e-09 ± 4.68e-10 s







Test on different channels

Channel 3, noatt, 20fC

Amplitude

[INFO] Channel : Analog_bias0V	0.0143 ± 0.000282 V
[INFO] Channel : Analog_bias170V	0.0233 ± 0.000299 V

FWHM

[INFO] Channel : Analog_bias0V	1.71e-08 ± 1.58e-09 s
[INFO] Channel : Analog_bias170V	5.22e-09 ± 8.07e-11 s