Timing resolution on an irradiated 3D silicon pixel detector

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CSIC Consejo Superior de Investigaciones Científicas

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39th RD50 Workshop Valencia

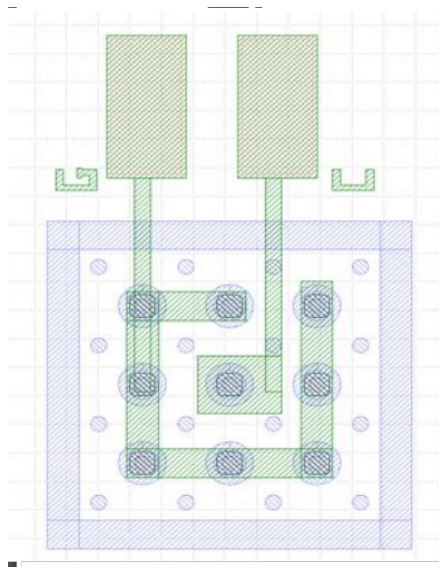
Outline

- Needs timescale 10 y
- 3D Pixel Sensor CNM Production
- Experimental Setup
- 3D Time resolution before and after irradiation for 285µm thick sensor at −20°C and 20°C

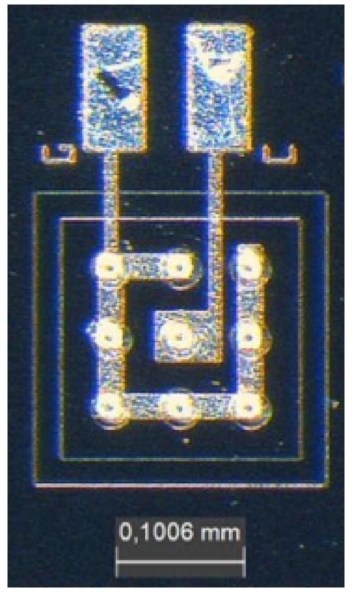
3D Pixel Sensor – CNM production

Features:
- thickness: 285µm
- cell size: 50x50 µm^2
- p-type bulk resistivity: ∼5kΩcm
- diameter holes: 8-10 µm

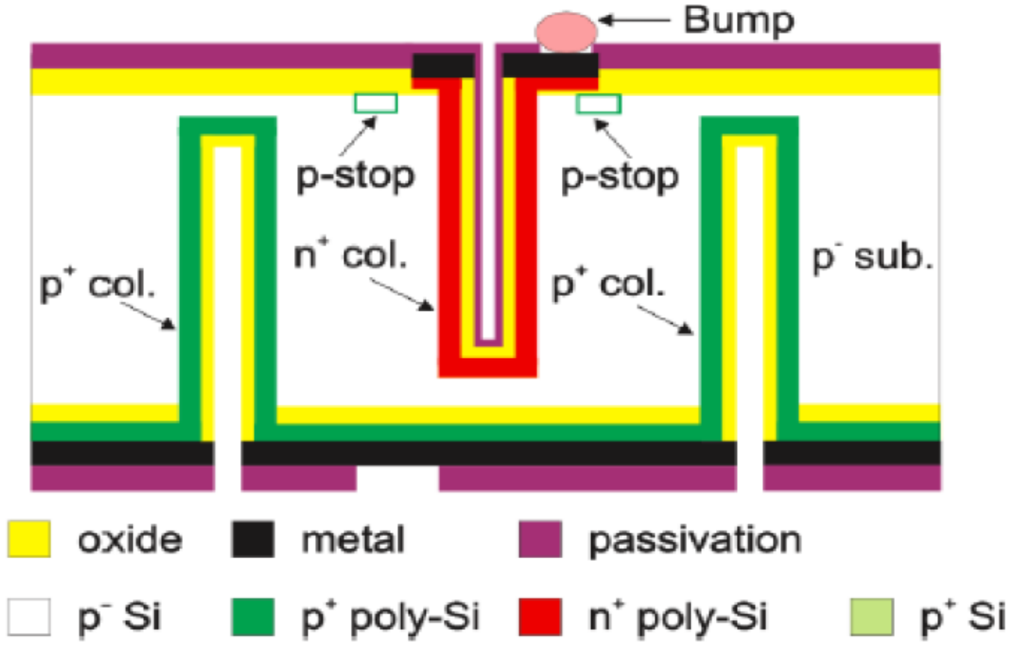
Design of a single cell structure



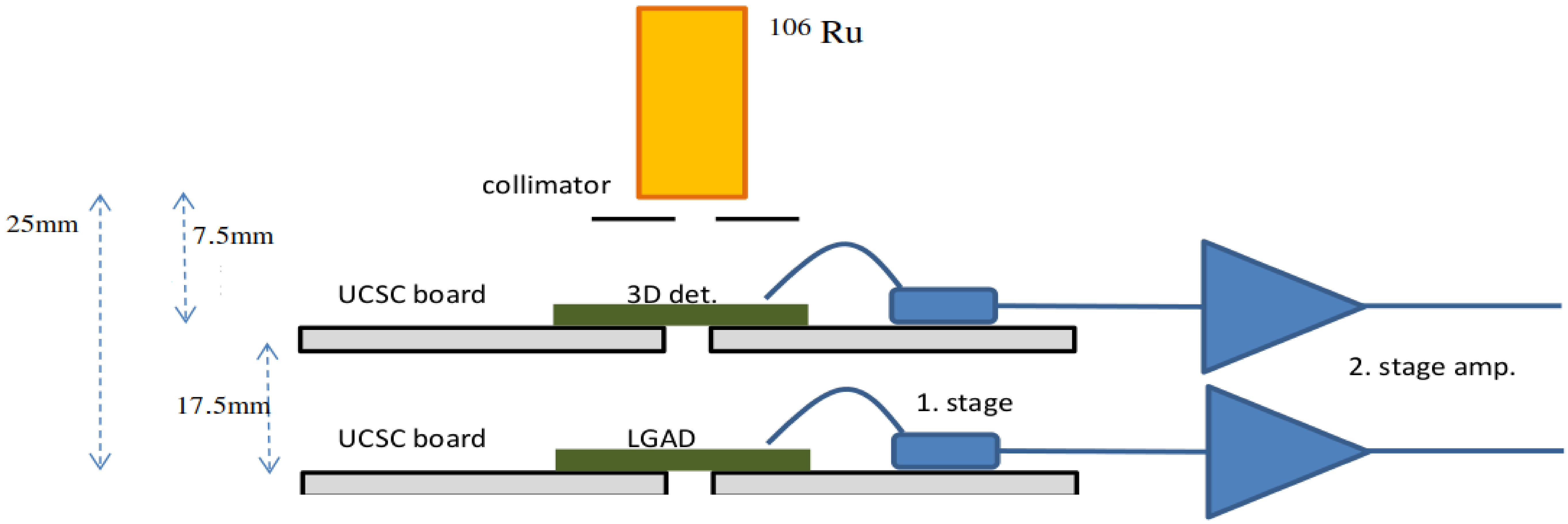
arXiv:1901.02538



Schematic Cross Section



Experimental Setup

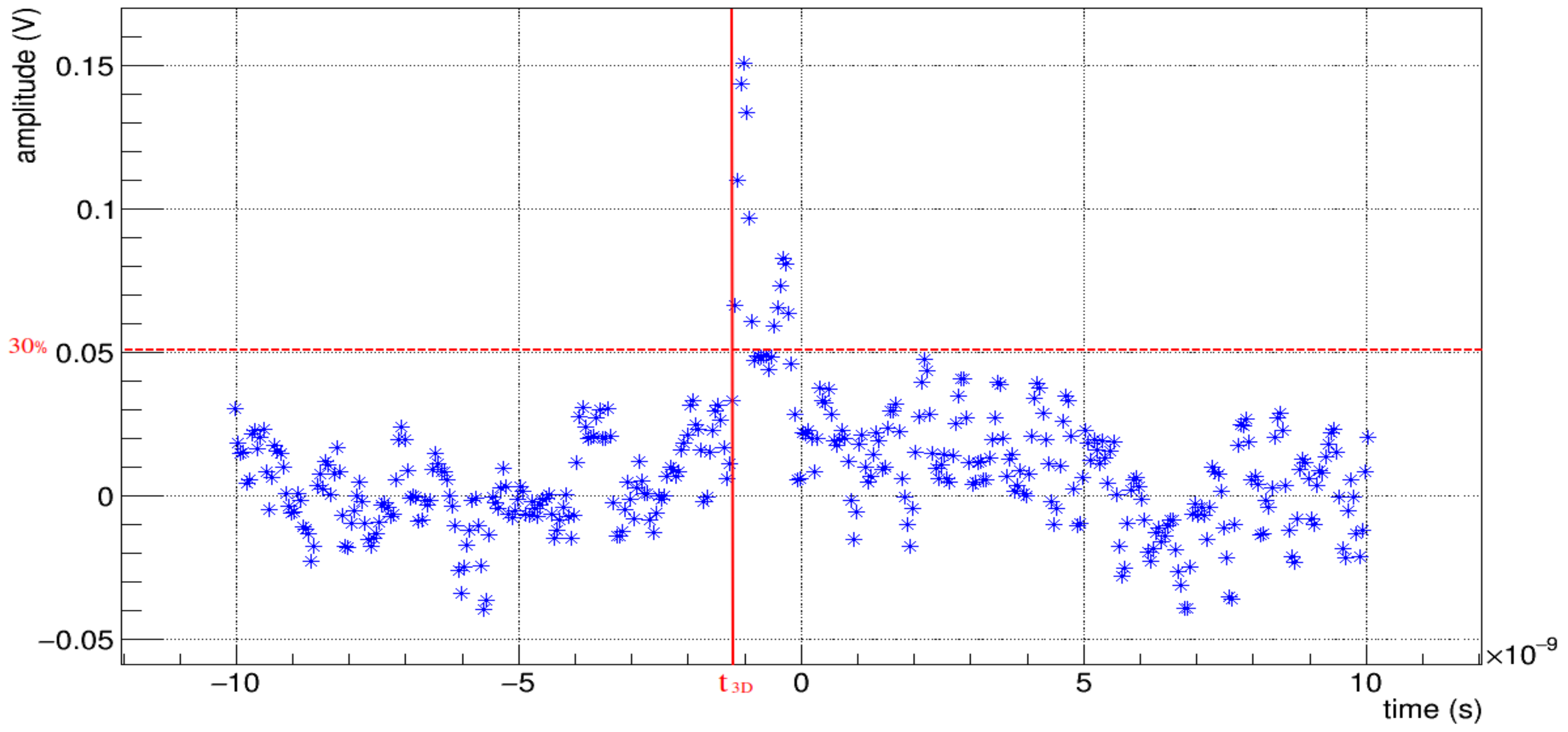


Signals in coincidence are analyzed

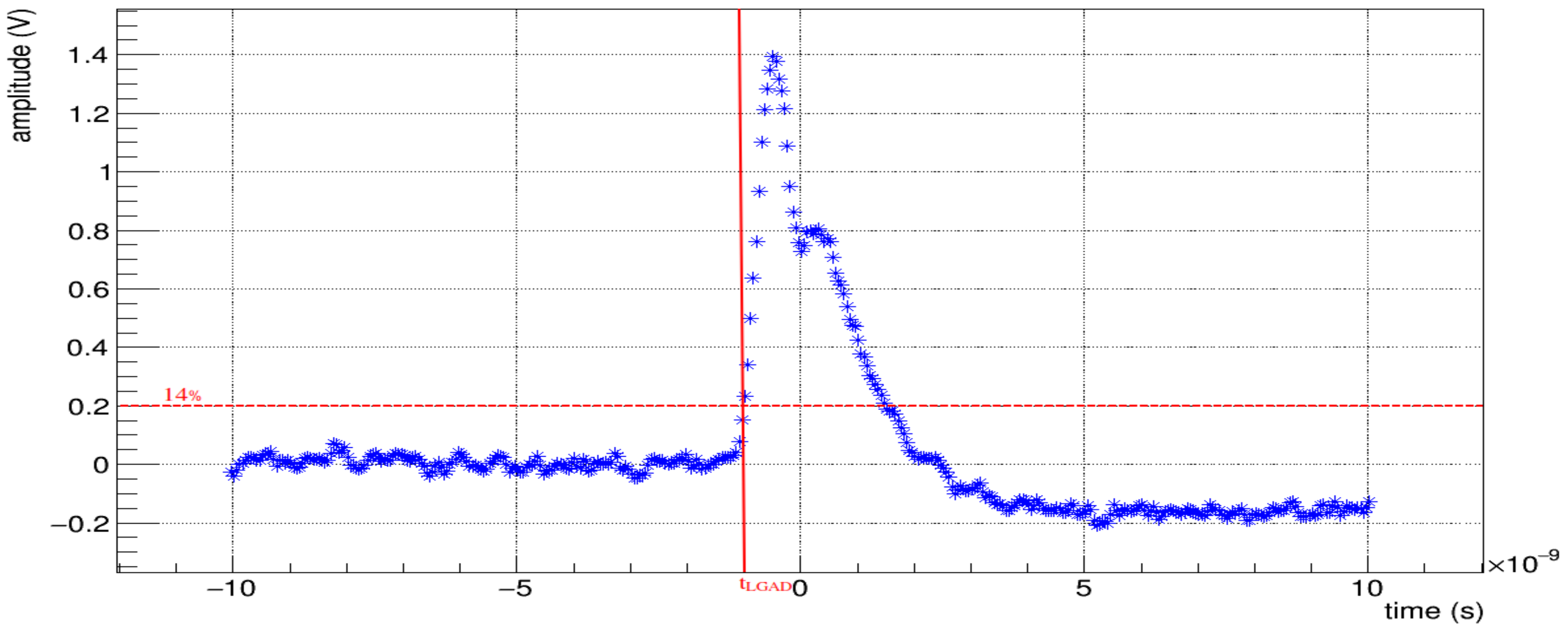
Source: ^{106}Ru
Board: Preamplified UCSC
LGAD: HPK50C - high gain 50 um thick (1 mm diameter)
Time resolution 36 ps (20°C) and 32 ps (-20°C)
2.stage amp: 4GHz
Readout: Waverunner 8404M oscilloscope 4GHz

3D Waveform and analysis - σ_{3D}

3D Waveform

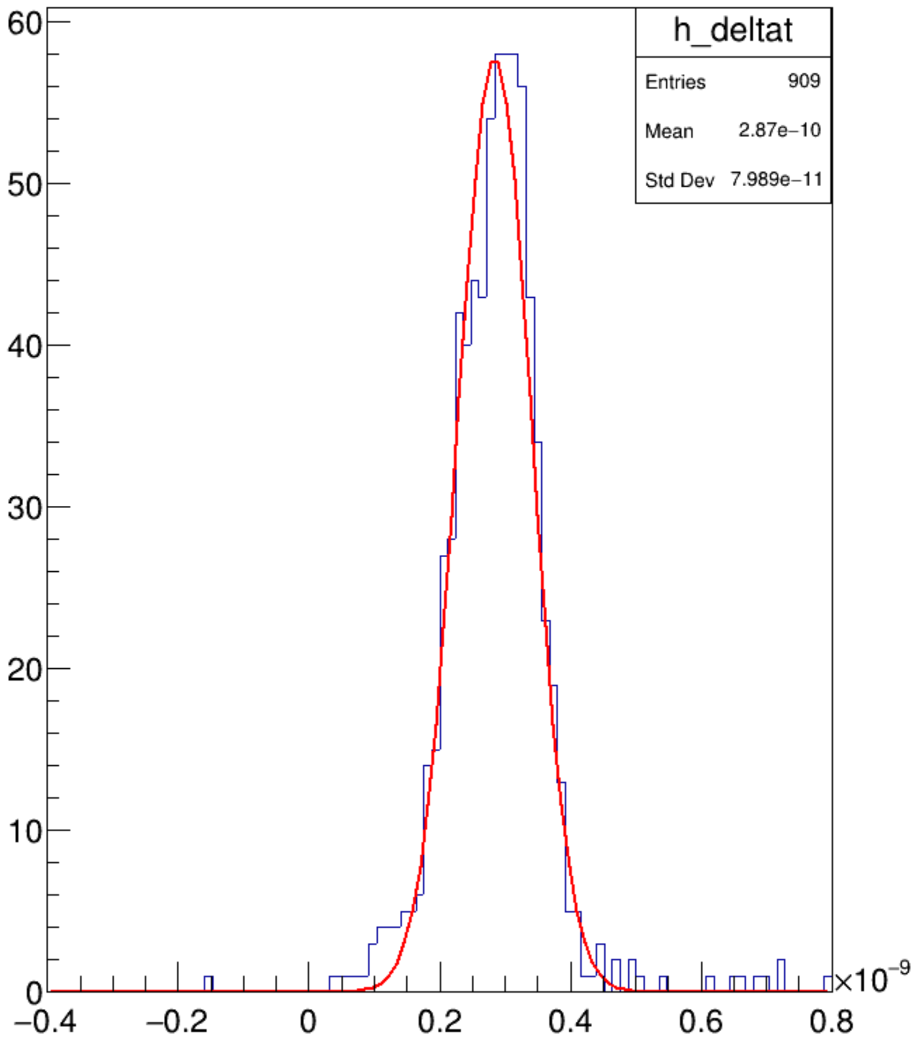


LGAD Waveform



CFD method

$\Delta t = t^*_{LGAD} - t^*_{3D}$



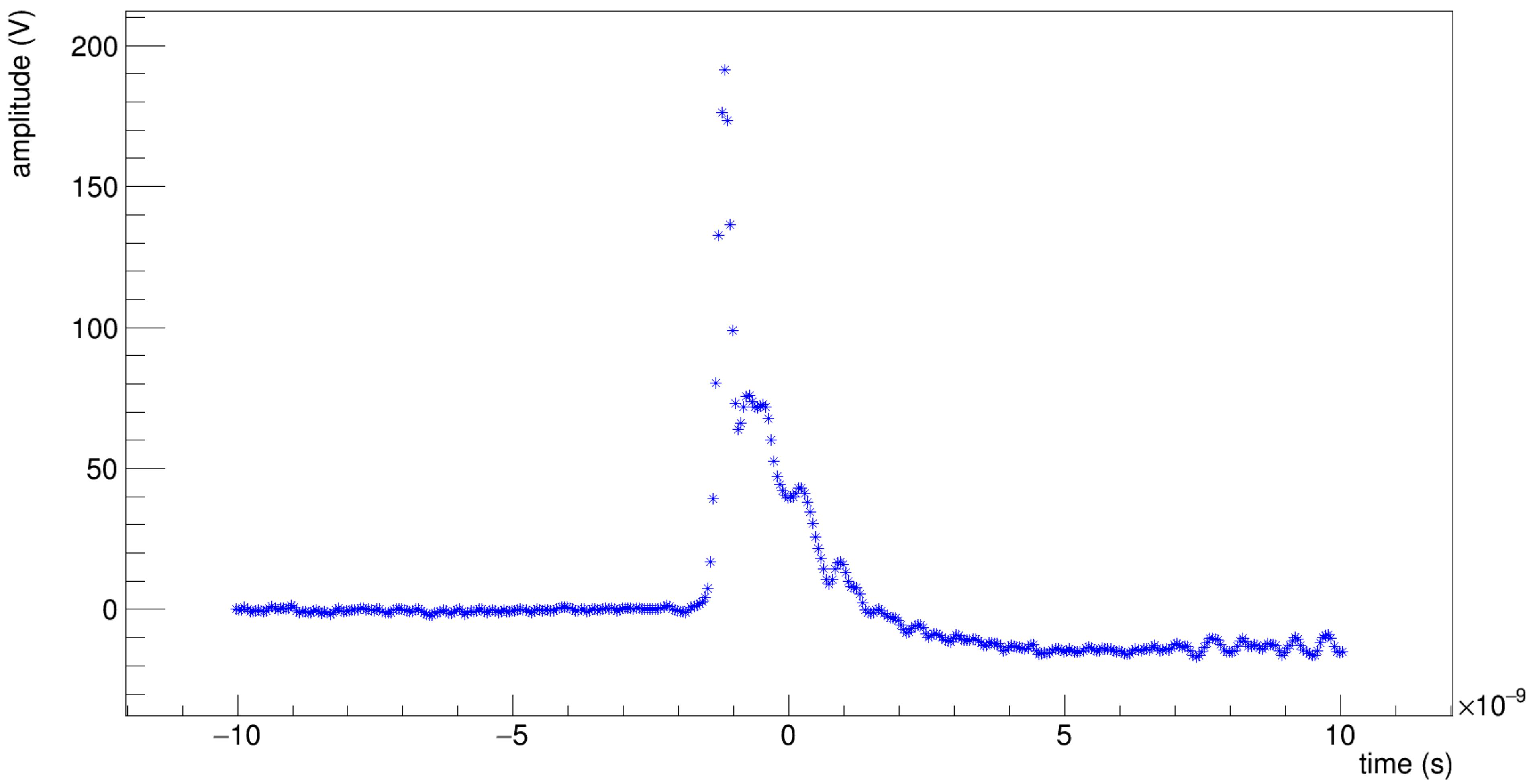
Fit on Δt to obtain: $\sigma_t = (\sigma^2_{LGAD} + \sigma^2_{3D})^{1/2}$

$\sigma^2_{wf} \approx \sigma^2_{3D} - \sigma^2_{j,3D}$

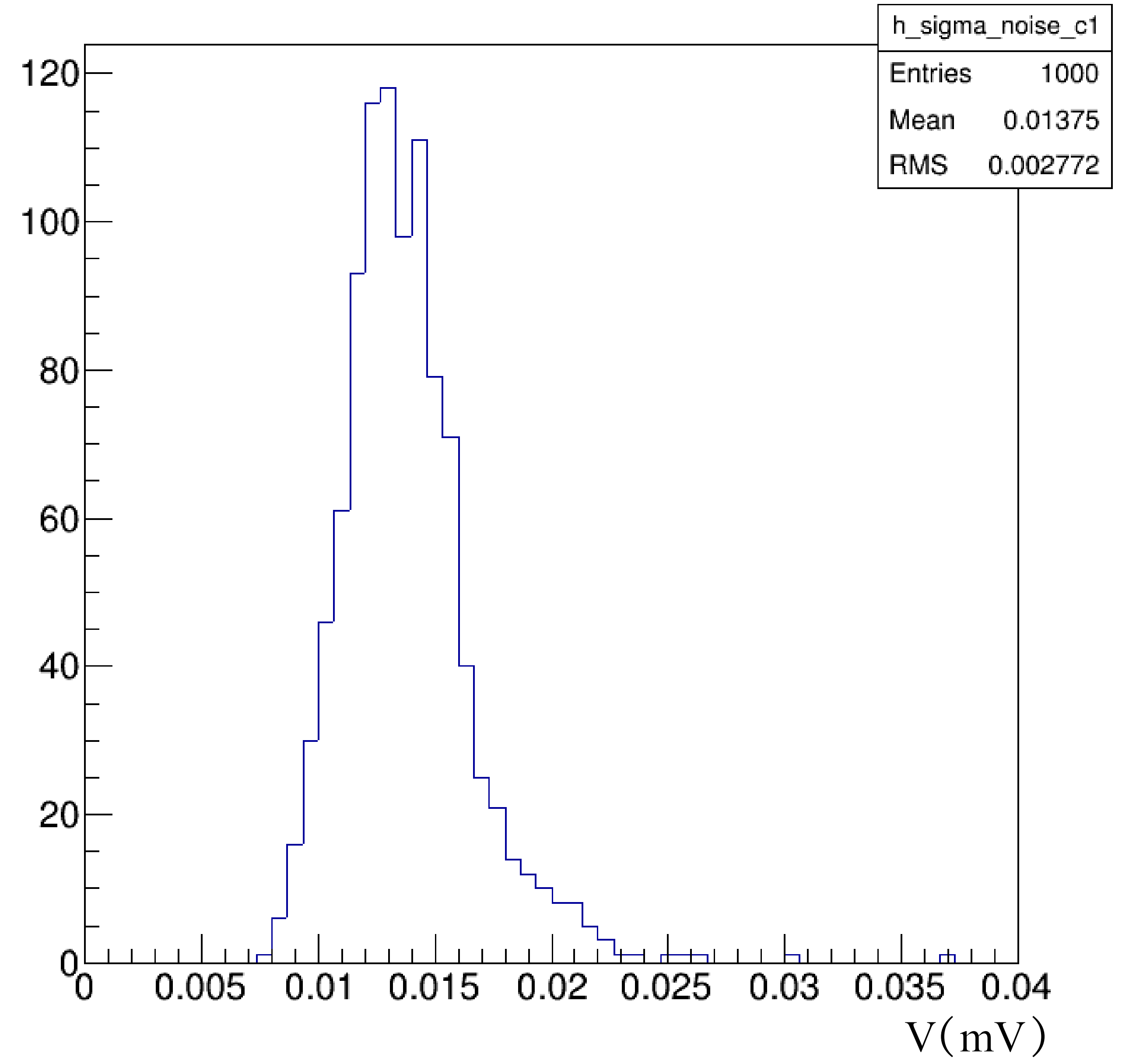
3D Waveform and analysis - σ_j

$$\sigma^2_{wf} \approx \sigma^2_{3D} - \sigma^2_{j,3D}$$

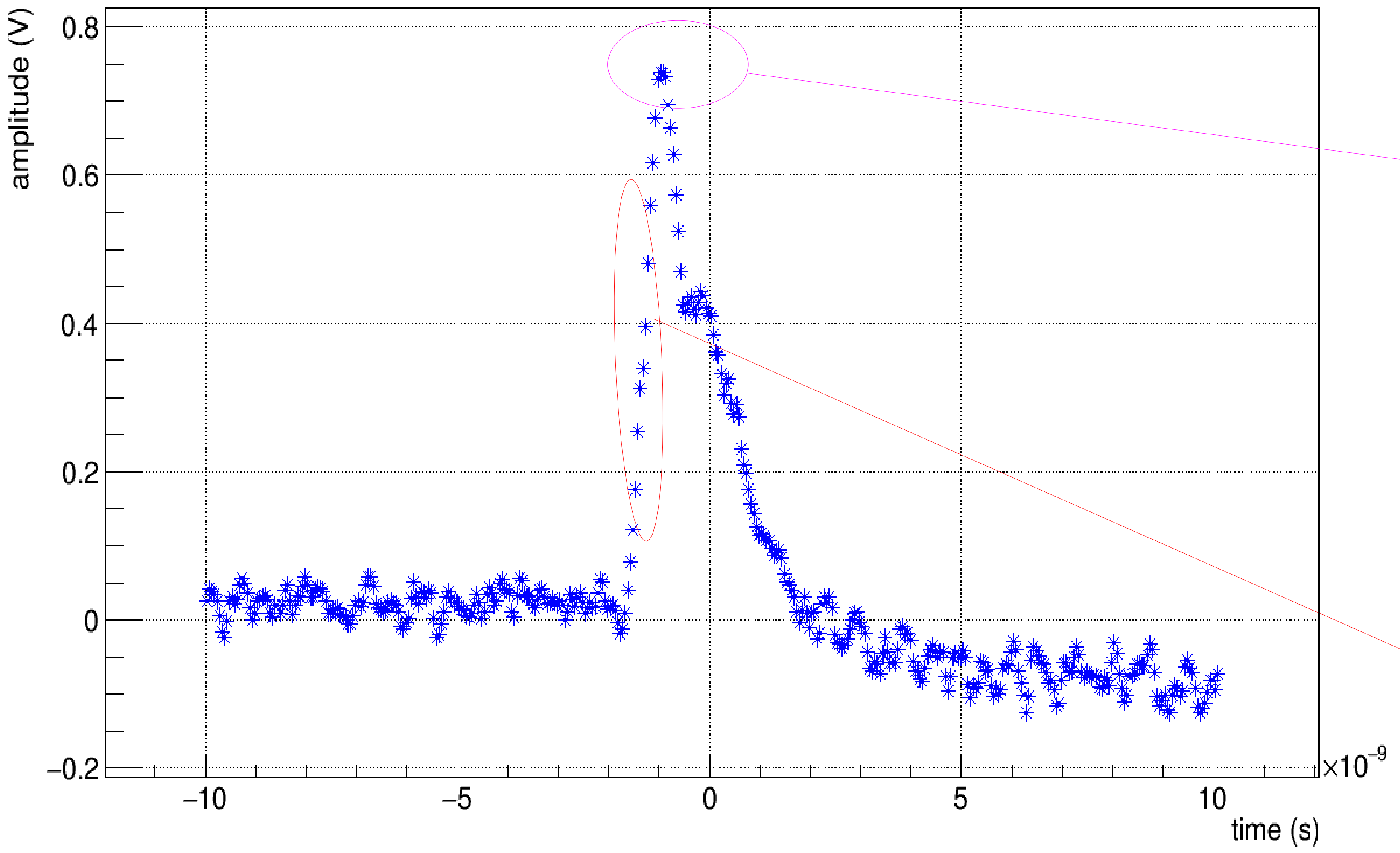
1000 averaged waveforms



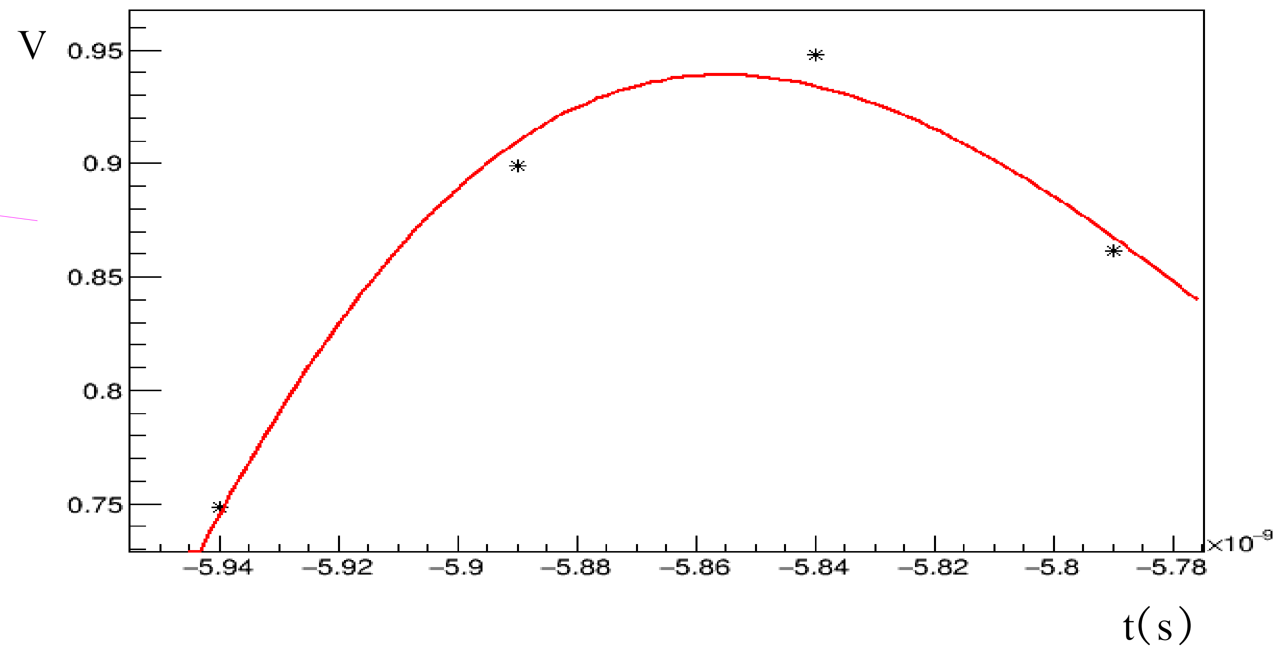
RMS of the noise



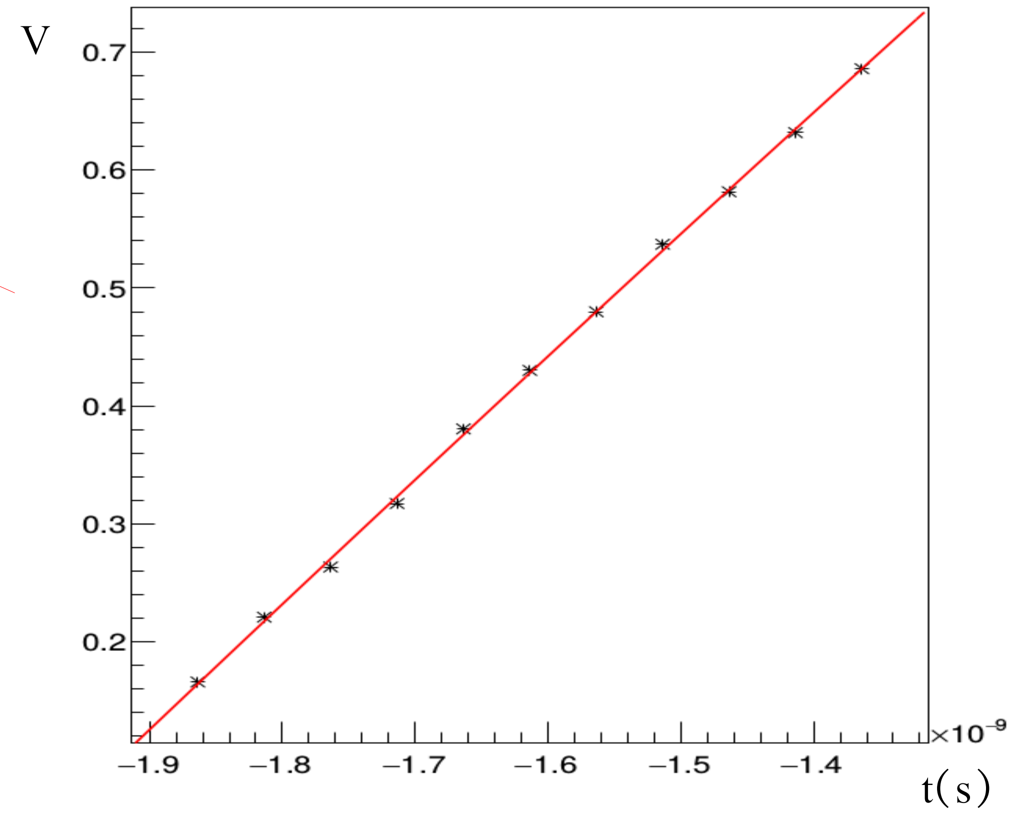
LGAD Waveform Analysis



3)



4)



1) Noise estimation: gaus fit on the first 100 pt. (5 ns)

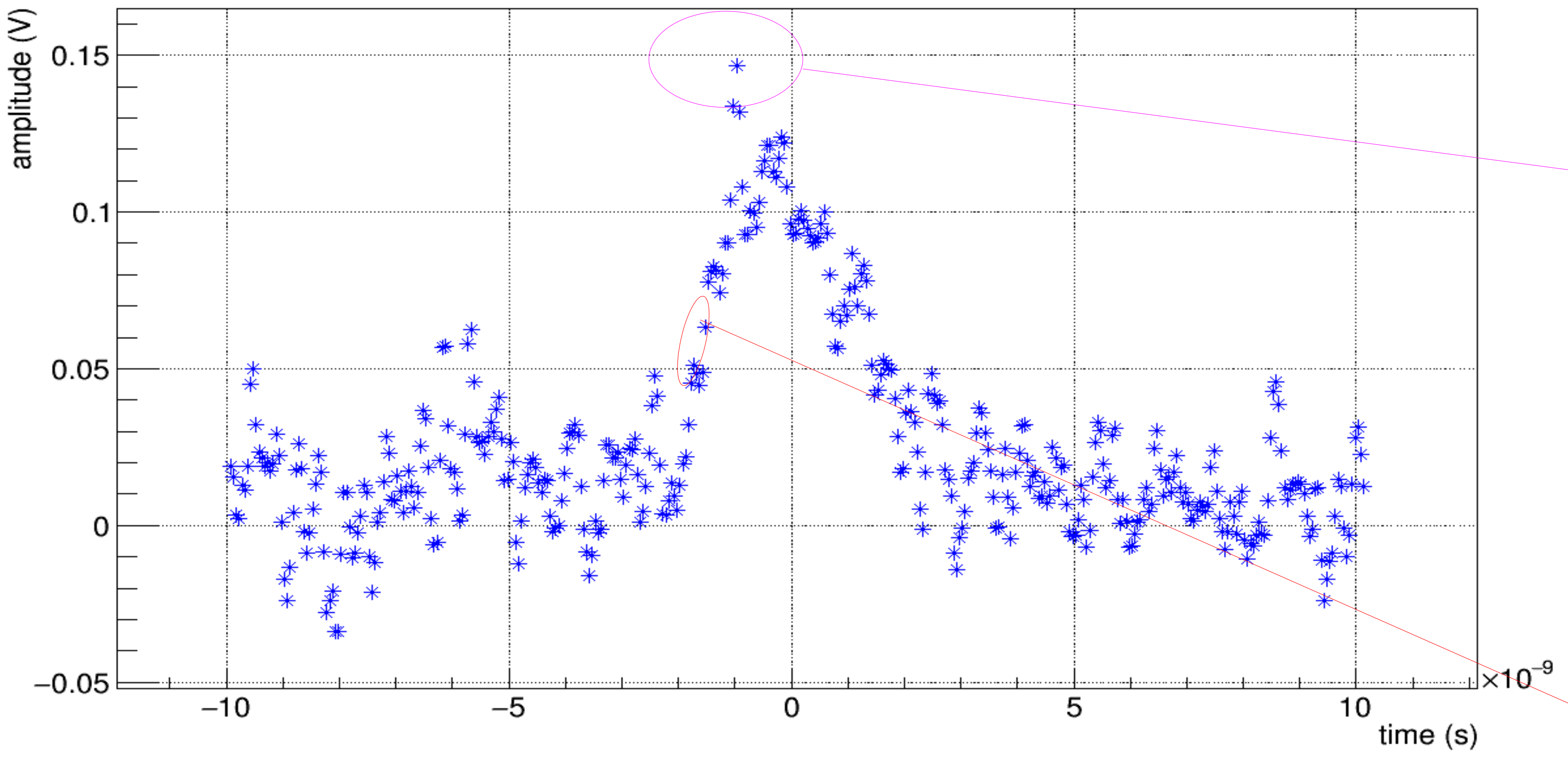
2) Offset correction

3) Landau fit around the maximum value in amplitude (4 pt.) and extrapolation of t_{MAX}

4) Landau fit (11 pt.) on the waveform rising

5) Extrapolation of t^{*}_{LGAD}

3D Waveform analysis



1) Noise estimation: gaus fit on the first 100 pt. (5 ns)

2) Offset correction

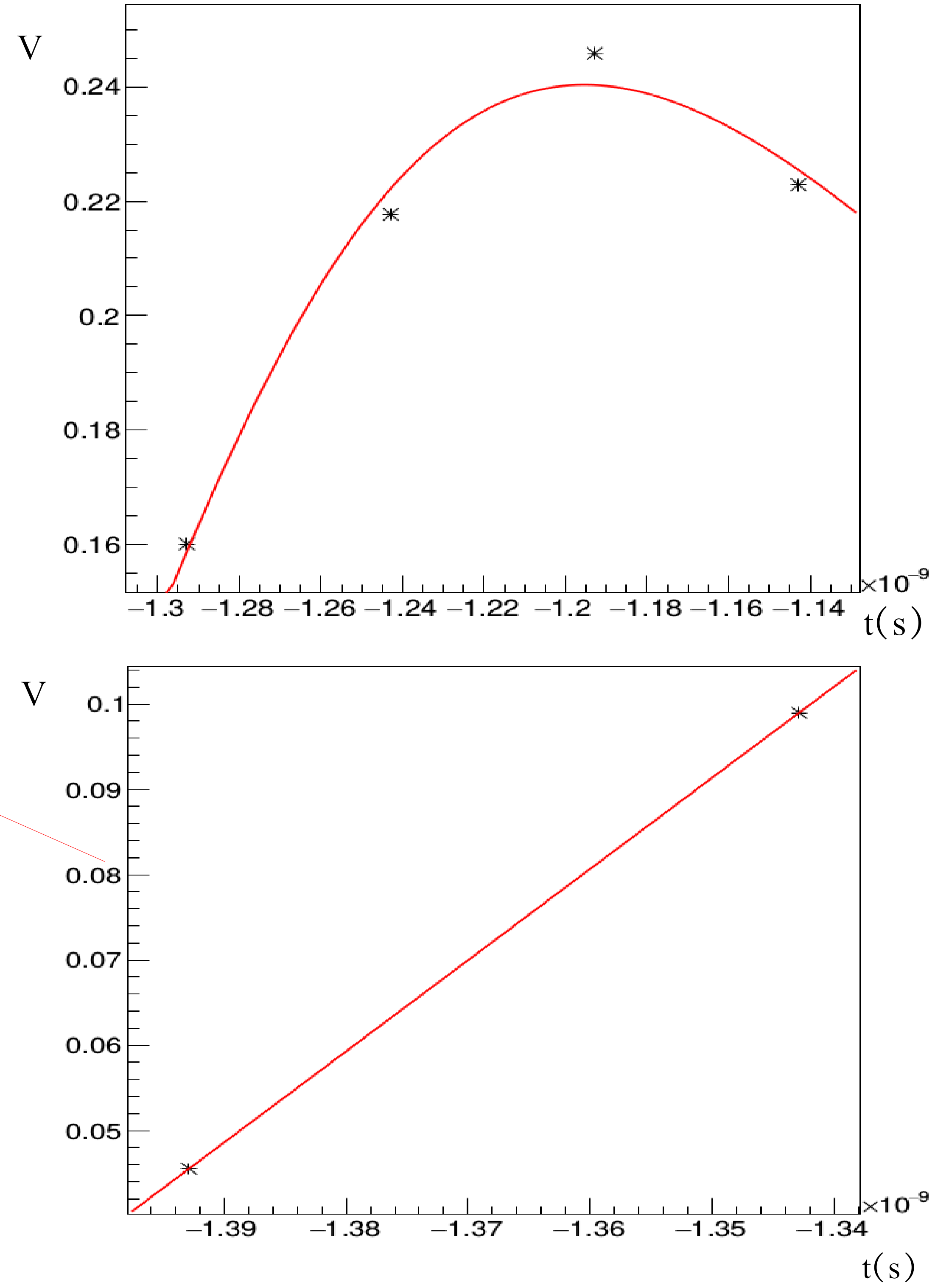
3) Landau fit around the maximum value in amplitude (4 pt.)
and extrapolation of t_{MAX}

4) Linear fit (2 pt.) with the first point which crosses the threshold and the previous one

5) Extrapolation of t^{*}_{3D}

3)

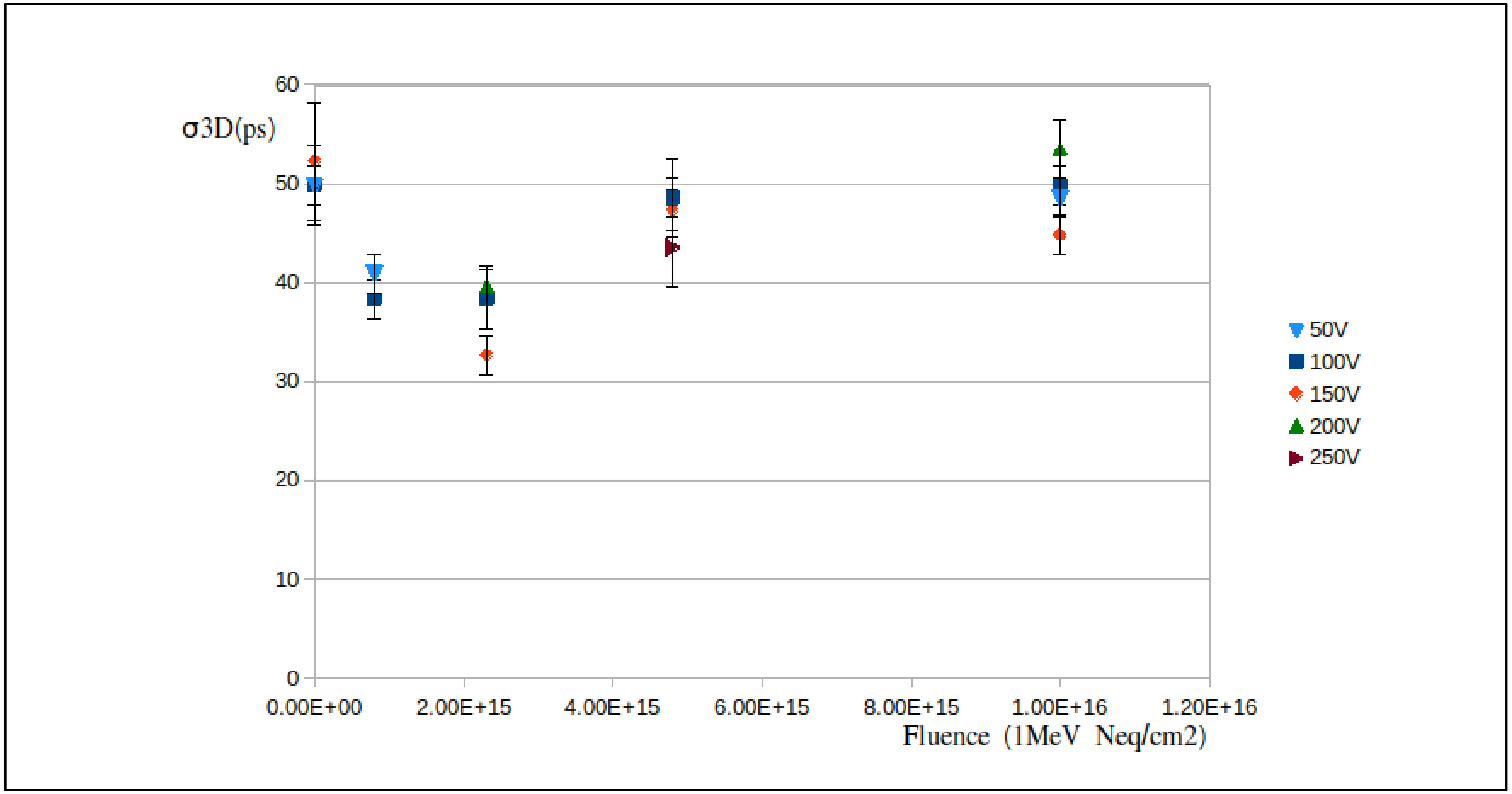
4)



3D time resolution at -20°C VS Fluence

Annealed 60 min at 80°C

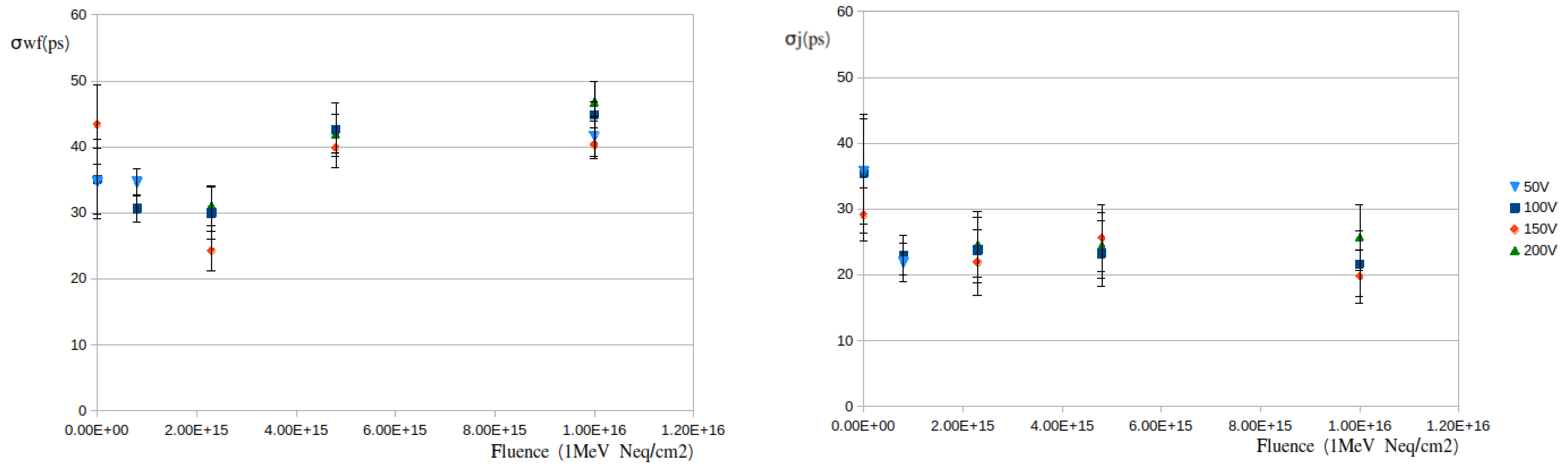
Irradiated at $8x10^{14}$ 1Mev n_{eq}/cm^2 - $2.3x10^{15}$ 1Mev n_{eq}/cm^2 – $4.8x10^{15}$ 1Mev n_{eq}/cm^2 - $1.0x10^{16}$ 1Mev n_{eq}/cm^2 at Ljubjiana



Weighting field and jitter at -20°C VS fluence

Annealed 60 min at 80°C

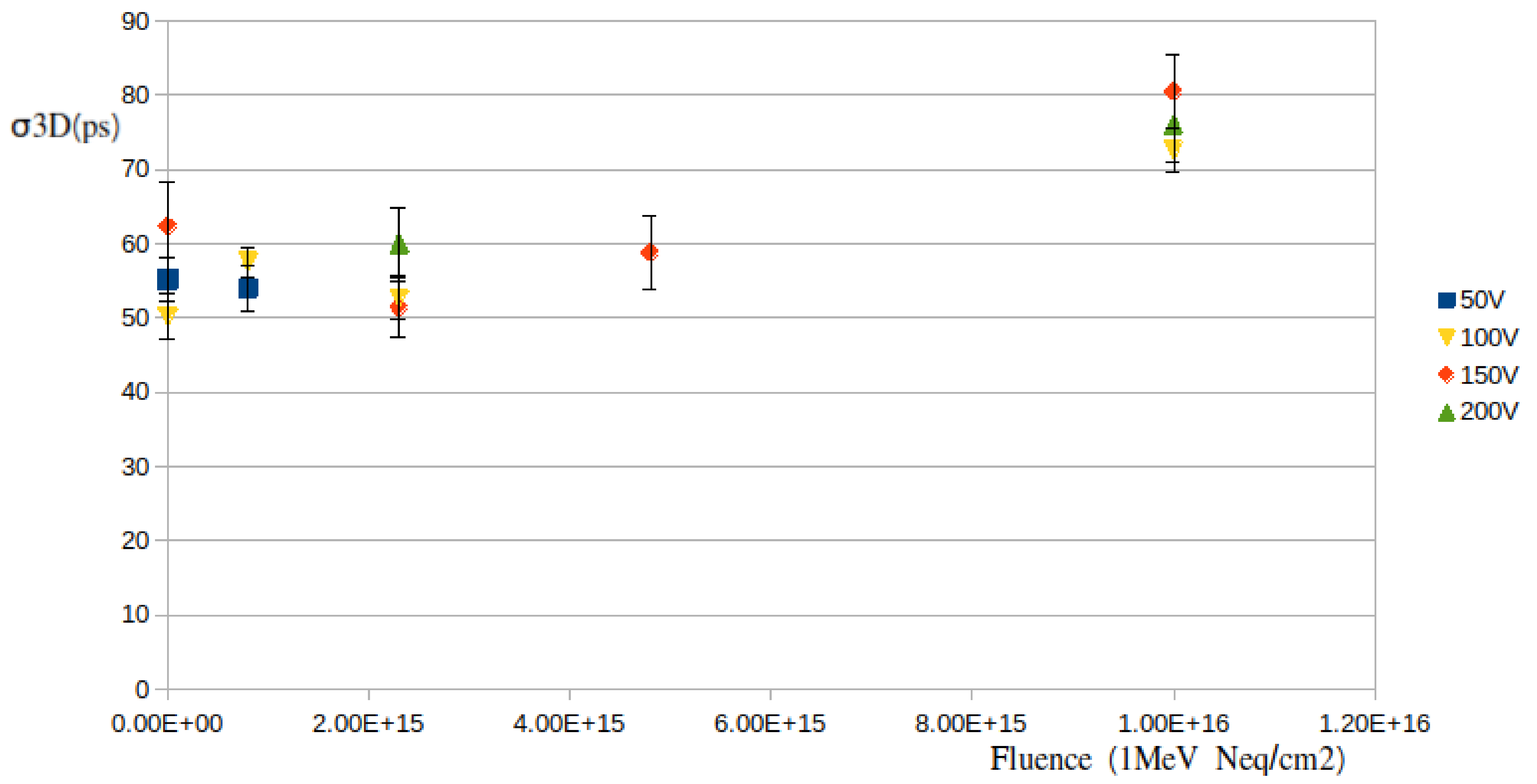
Irradiated at $8x10^{14}$ 1Mev n_{eq}/cm^2 - $2.3x10^{15}$ 1Mev n_{eq}/cm^2 – $4.8x10^{15}$ 1Mev n_{eq}/cm^2 - $1.0x10^{16}$ 1Mev n_{eq}/cm^2 at Ljubjiana



3D time resolution at 20°C VS Fluence

Annealed 60 min at 80°C

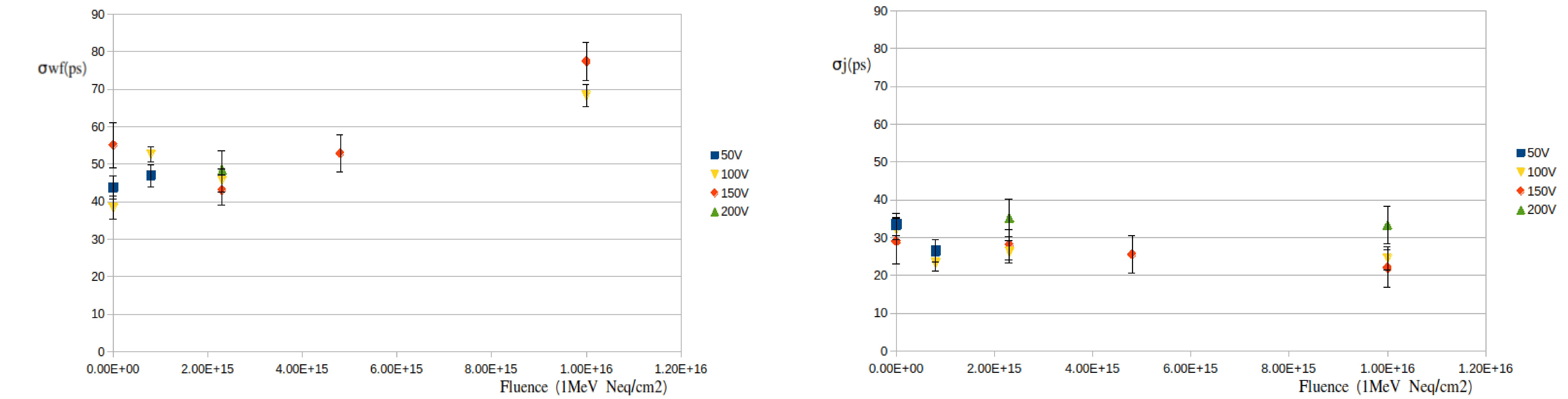
Irradiated at $8x10^{14}$ 1Mev n_{eq}/cm^2 - $2.3x10^{15}$ 1Mev n_{eq}/cm^2 – $4.8x10^{15}$ 1Mev n_{eq}/cm^2 - $1.0x10^{16}$ 1Mev n_{eq}/cm^2 at Ljubjiana



Weighting field and jitter at 20°C VS fluence

Annealed 60 min at 80°C

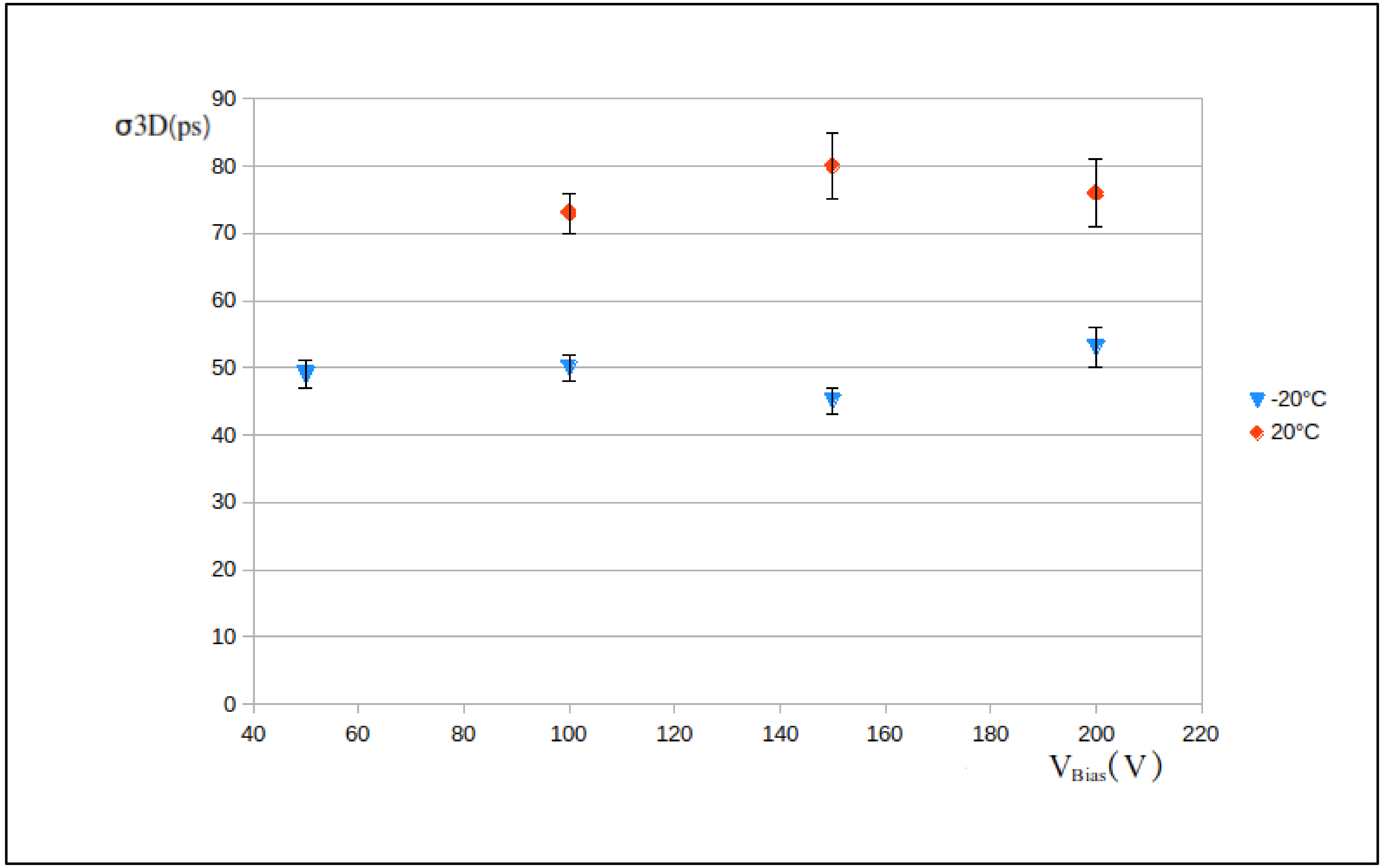
Irradiated at $8x10^{14}$ 1Mev n_{eq}/cm^2 - $2.3x10^{15}$ 1Mev n_{eq}/cm^2 – $4.8x10^{15}$ 1Mev n_{eq}/cm^2 - $1.0x10^{16}$ 1Mev n_{eq}/cm^2 at Ljubjiana



3D time resolution at -20°C and 20°C VS Bias voltage @ 1.0×10^{16} 1Mev n_{eq}/cm^2

Annealed 60 min at 80°C

Irradiated at 8×10^{14} 1Mev n_{eq}/cm^2 - 2.3×10^{15} 1Mev n_{eq}/cm^2 – 4.8×10^{15} 1Mev n_{eq}/cm^2 - 1.0×10^{16} 1Mev n_{eq}/cm^2 at Ljubjiana

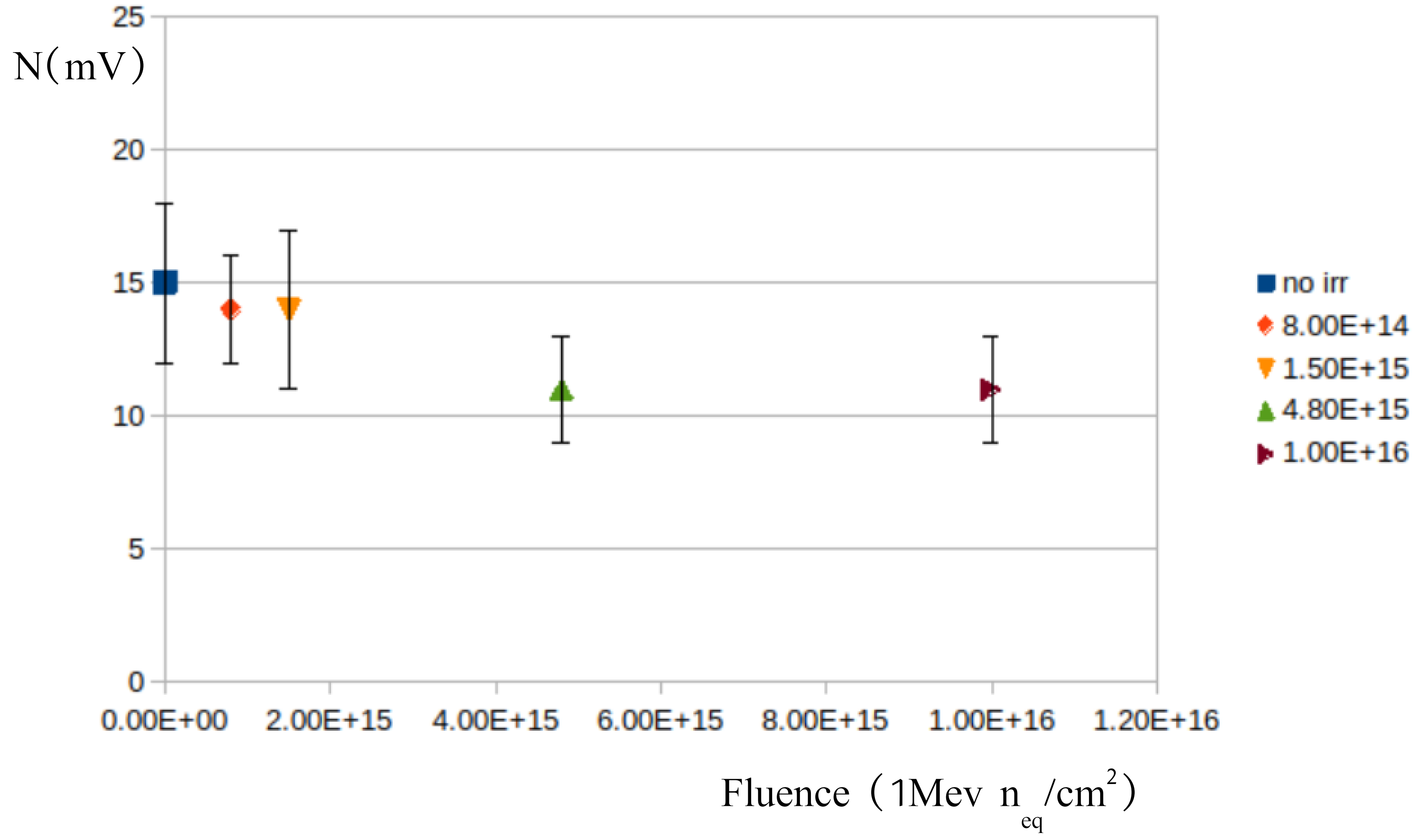


Conclusions

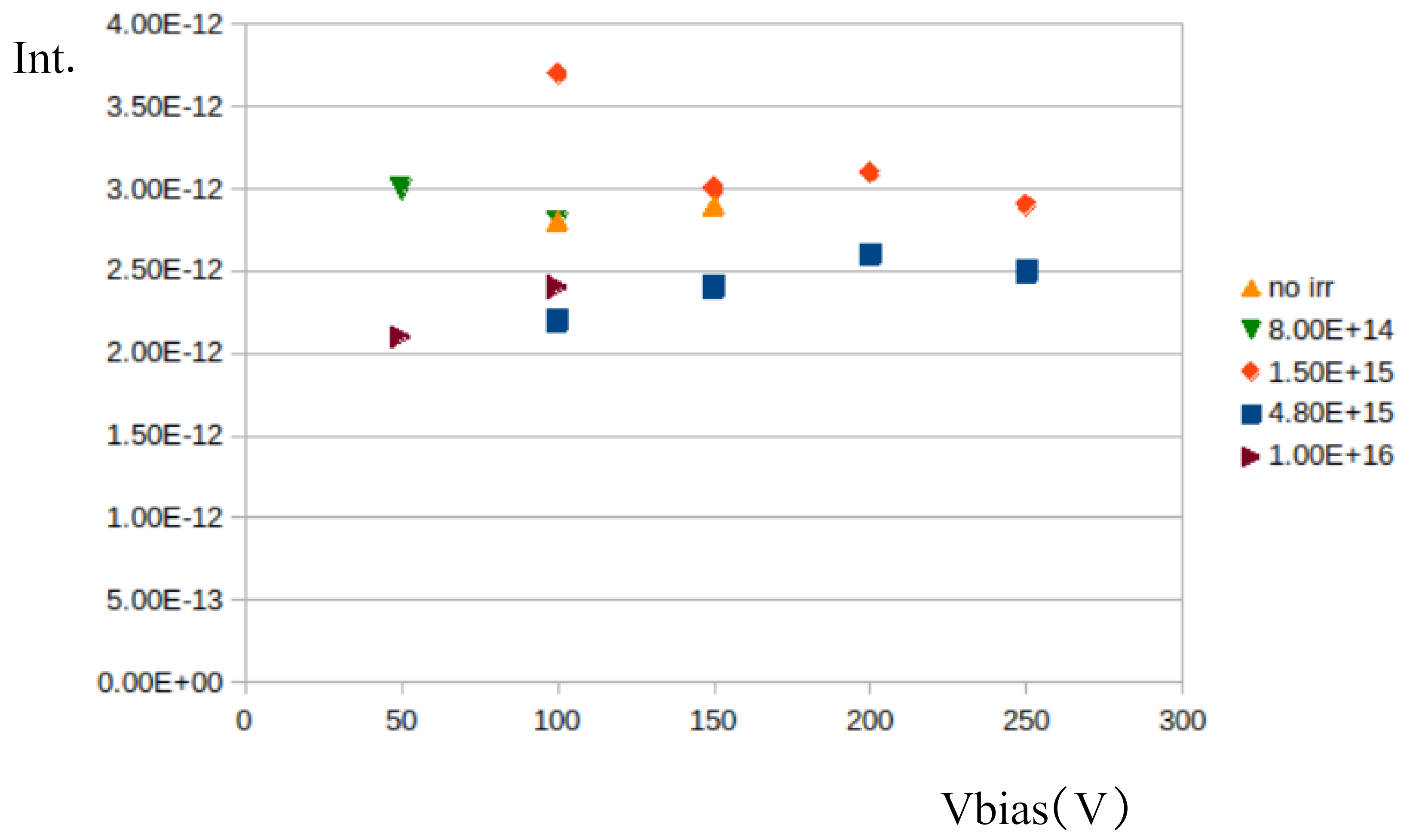
- We have reported data for 3D detector with thickness of 285 µm at 50,100,150,200 V_B at −20°C before and after n irradiation of $8x10^{14}$ 1MeV n_{eq}/cm^2 −$2.3x10^{15}$ 1Mev n_{eq}/cm^2 – $4.8x10^{15}$ 1Mev n_{eq}/cm^2 – $1.0x10^{16}$ 1Mev n_{eq}/cm^2
- Total time resolution of 50 ps, better resolution for intermediate fluences $8x10^{14}$ 1MeV n_{eq}/cm^2 −$2.3x10^{15}$ 1Mev n_{eq}/cm^2
- Behaviour of temporal resolution as a function of fluence attributable to weighting field contribute
- No remarkable difference for Vbias, for the highest radiation dose.
- Ratio between the values at the two temperatures constant except for $1.0x10^{16}$ 1Mev n_{eq}/cm^2 .

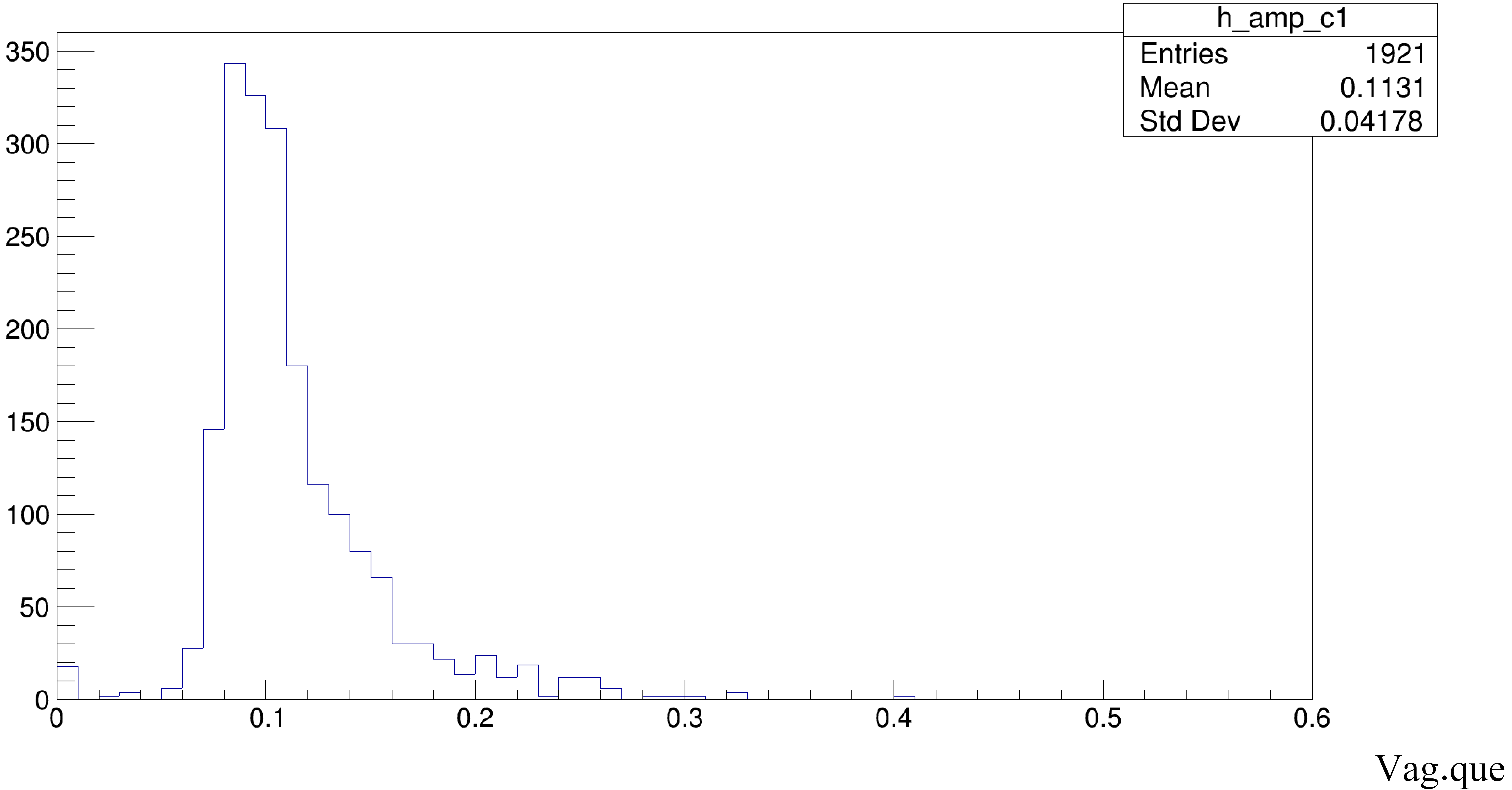
Backup

Noise



Charge Collection -20





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Entries 1921
Mean 0.1131
Std Dev 0.04178
350
300
250
200
150
100
50
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Vag.que