Timing resolution on an irradiated 3D silicon pixel detector

D. De Simone[1], C. Betancourt[1], G. Kramberger[2], M. Manna[3], G. Pellegrini[3,4], Nicola Serra[1]

[1] University of Zurich
[2] Jožef Stefan Institute, Ljubljana, Slovenia
[3] Centro Nacional de Microelectrónica, Barcelona, Spain
[4] IMB-CNM-CSIC

Outline

- 3D Pixel Sensor CNM Production

- Experimental Setup

- 3D Time resolution before and after irradiation for 285μm thick sensor.

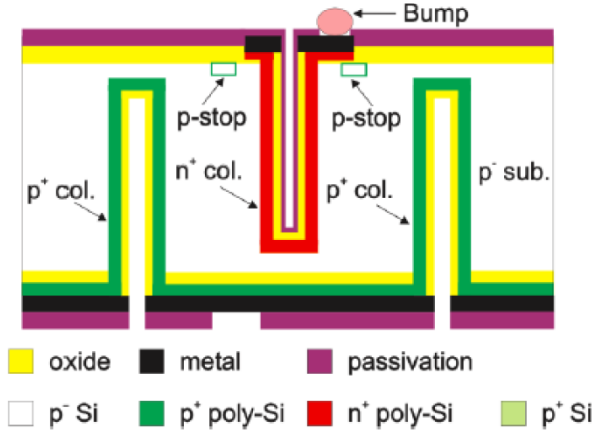
- 3D Time resolution for a 235 μm thick sensor.

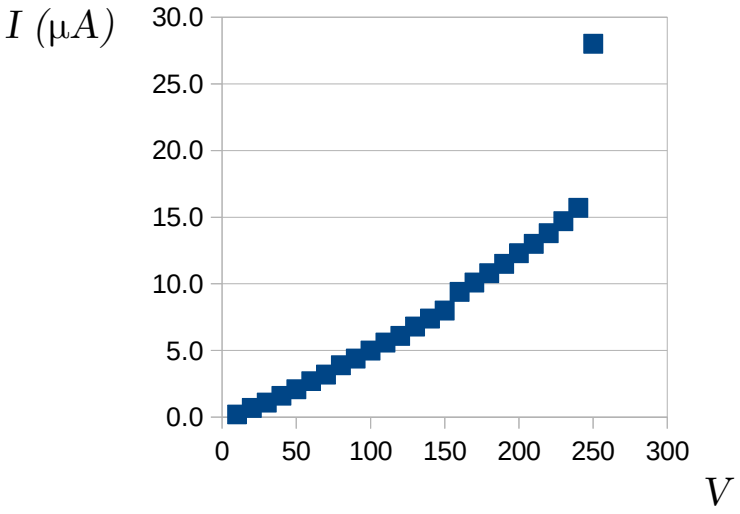
3D Pixel Sensor – CNM production

Features:

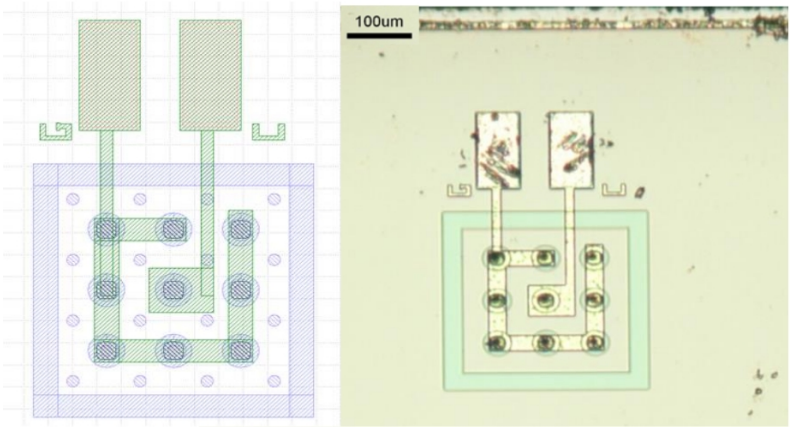
- thickness: 285µm
- cell size: 50x50 µm^2
- p-type bulk resistivity: ~5kΩcm
- diameter holes: 8-10 µm

Schematic Cross Section



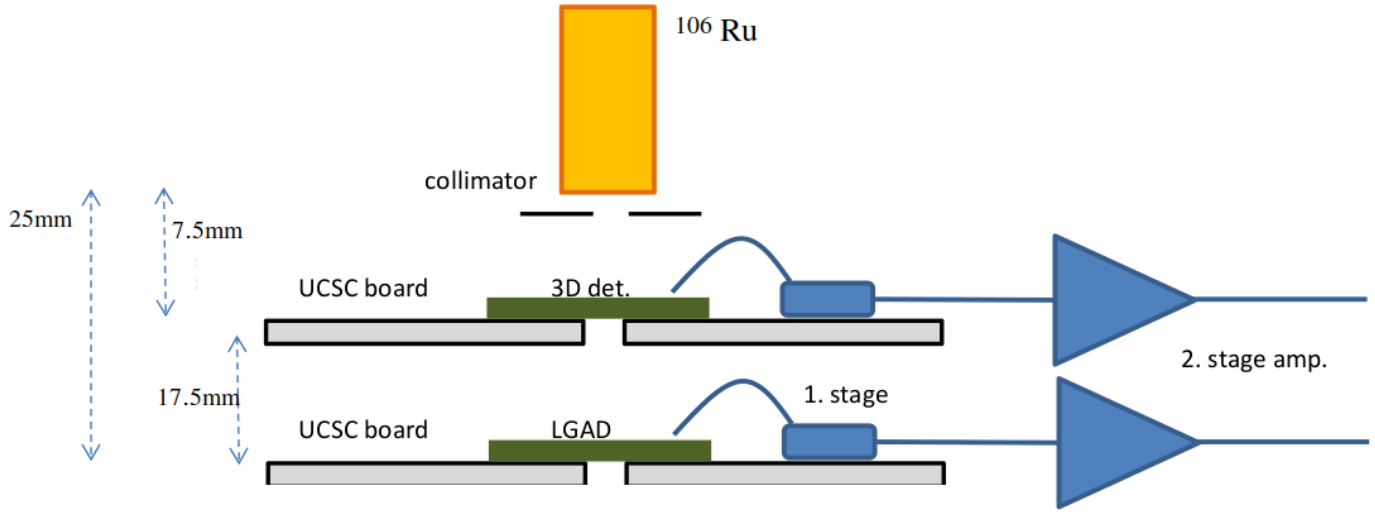


Design of a single cell structure



arXiv:1901.02538

Experimental Setup



Signa

Source: ^{106}Ru

Board: Preamplified UCSC

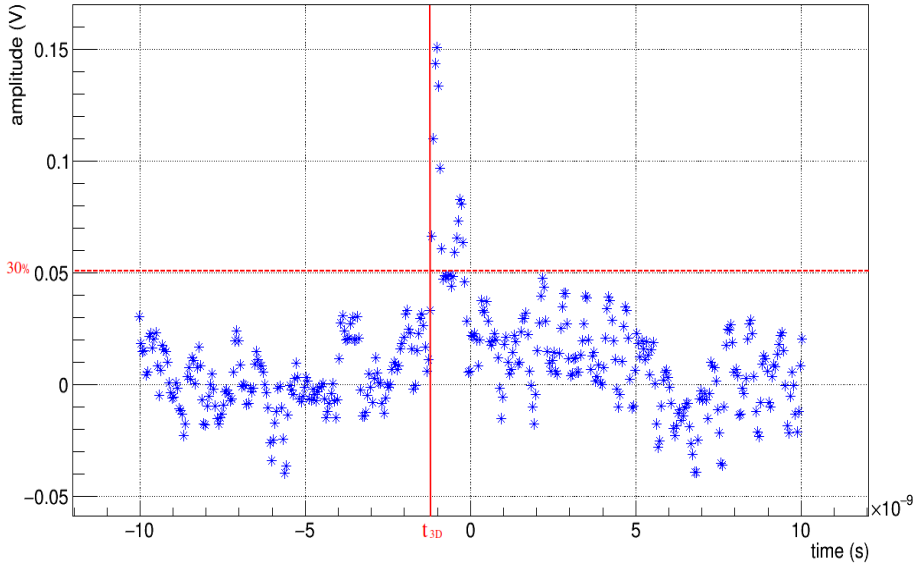
LGAD: HPK50C - high gain 50 um thick (1 mm diameter)
Time resolution 39 ps (20°C) and 36 ps (-20°C)

2.stage amp: 4GHz

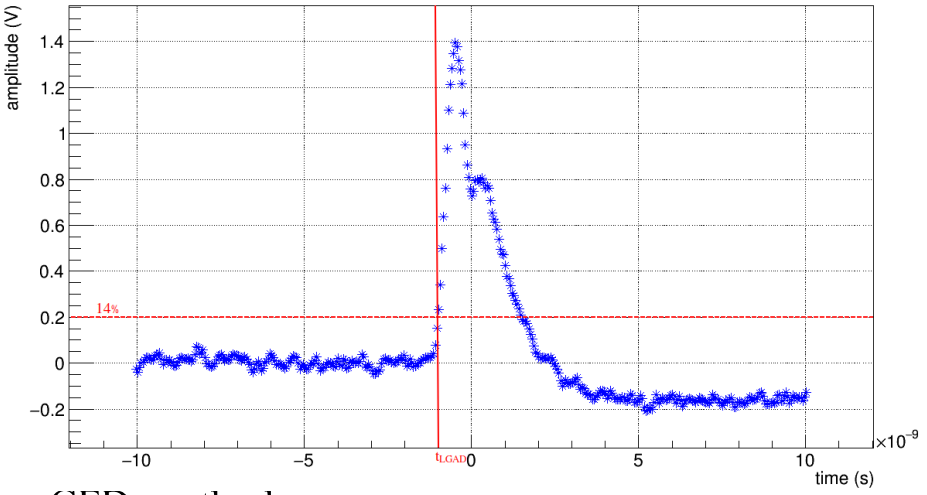
Readout: Waverunner 8404M oscilloscope 4GHz

3D Waveform and analysis

3D Waveform

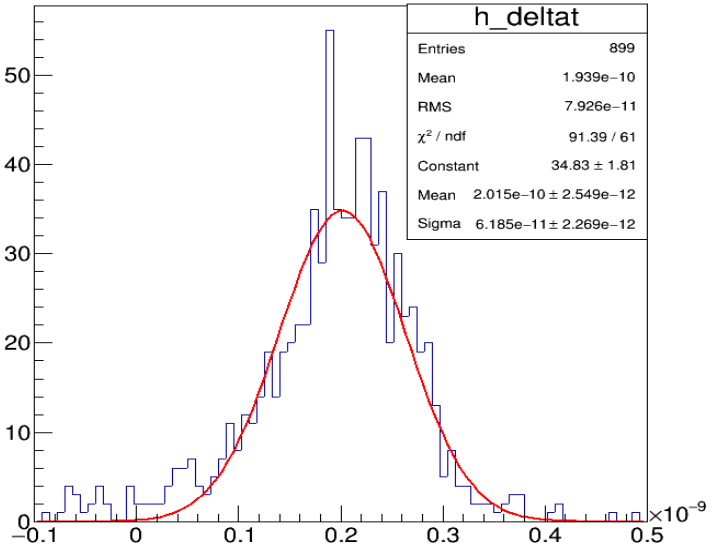


LGAD Waveform



CFD method

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



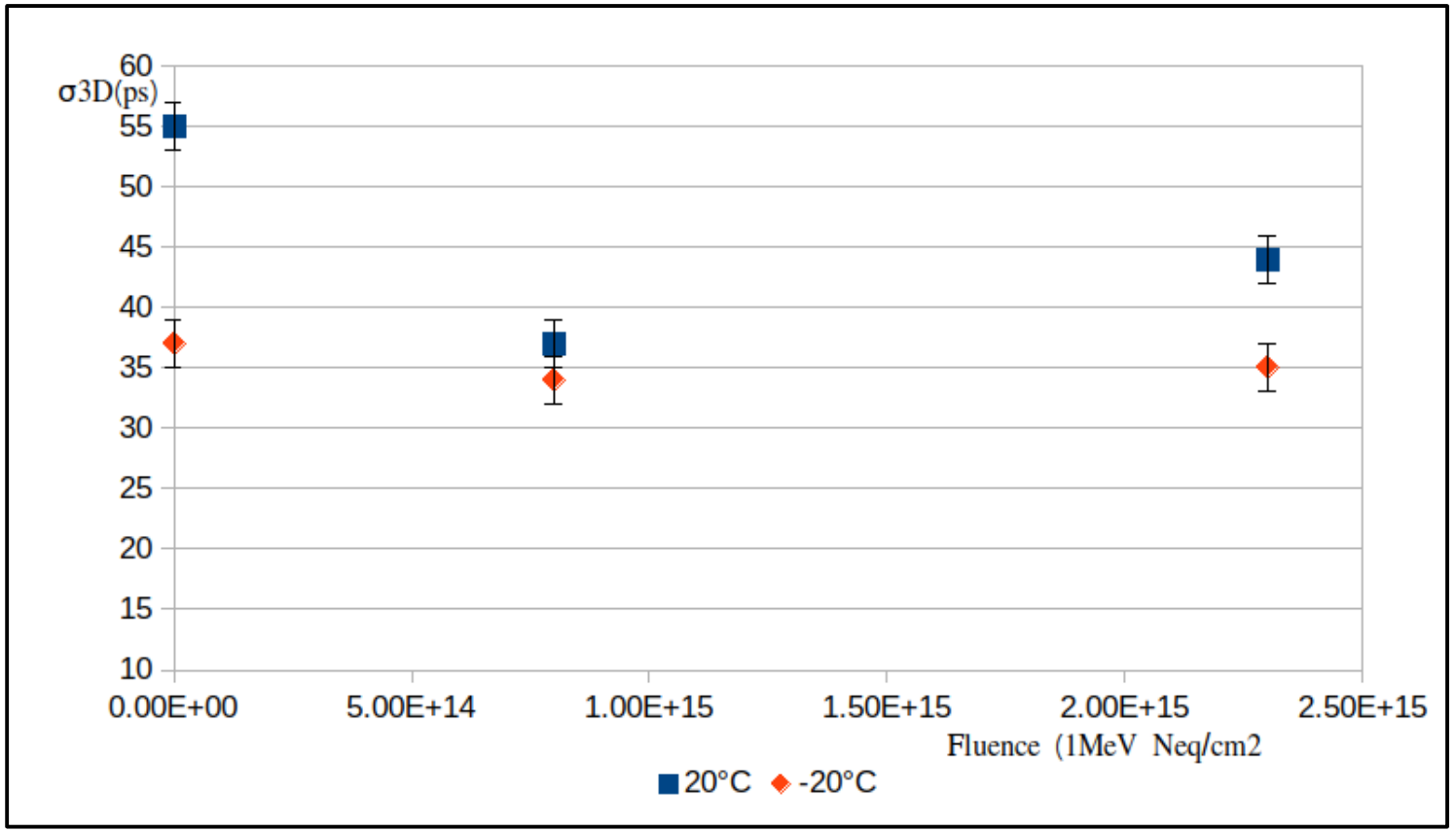
Fit on Δt to obtain: $\sigma_t = (\sigma^2_{LGAD} + \sigma^2_{3D})^{1/2}$

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

3D time resolution before and after neutron irradiation at 20°C and -20°C

Annealed 60 min at 80°C

Irradiated at $8x10^{14}$ 1Mev n_{eq}/cm^2 and then at $2.3x10^{15}$ 1Mev n_{eq}/cm^2 at Ljubjiana

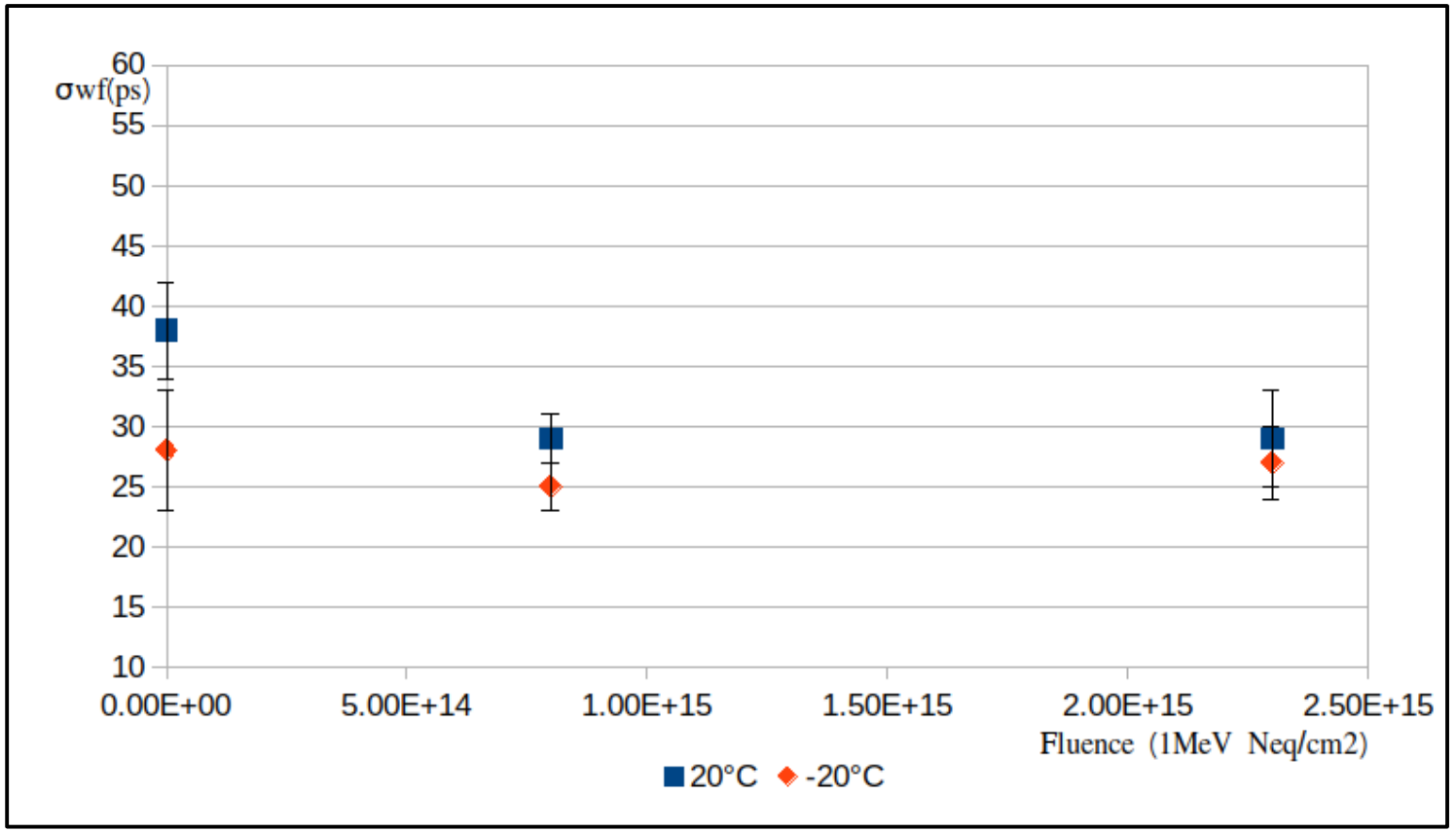


@ 100 V

3D time resolution before and after neutron irradiation at 20°C and -20°C

Annealed 60 min at 80°C

Irradiated at $8x10^{14}$ 1Mev n_{eq}/cm^2 and then at $2.3x10^{15}$ 1Mev n_{eq}/cm^2 at Ljubjiana

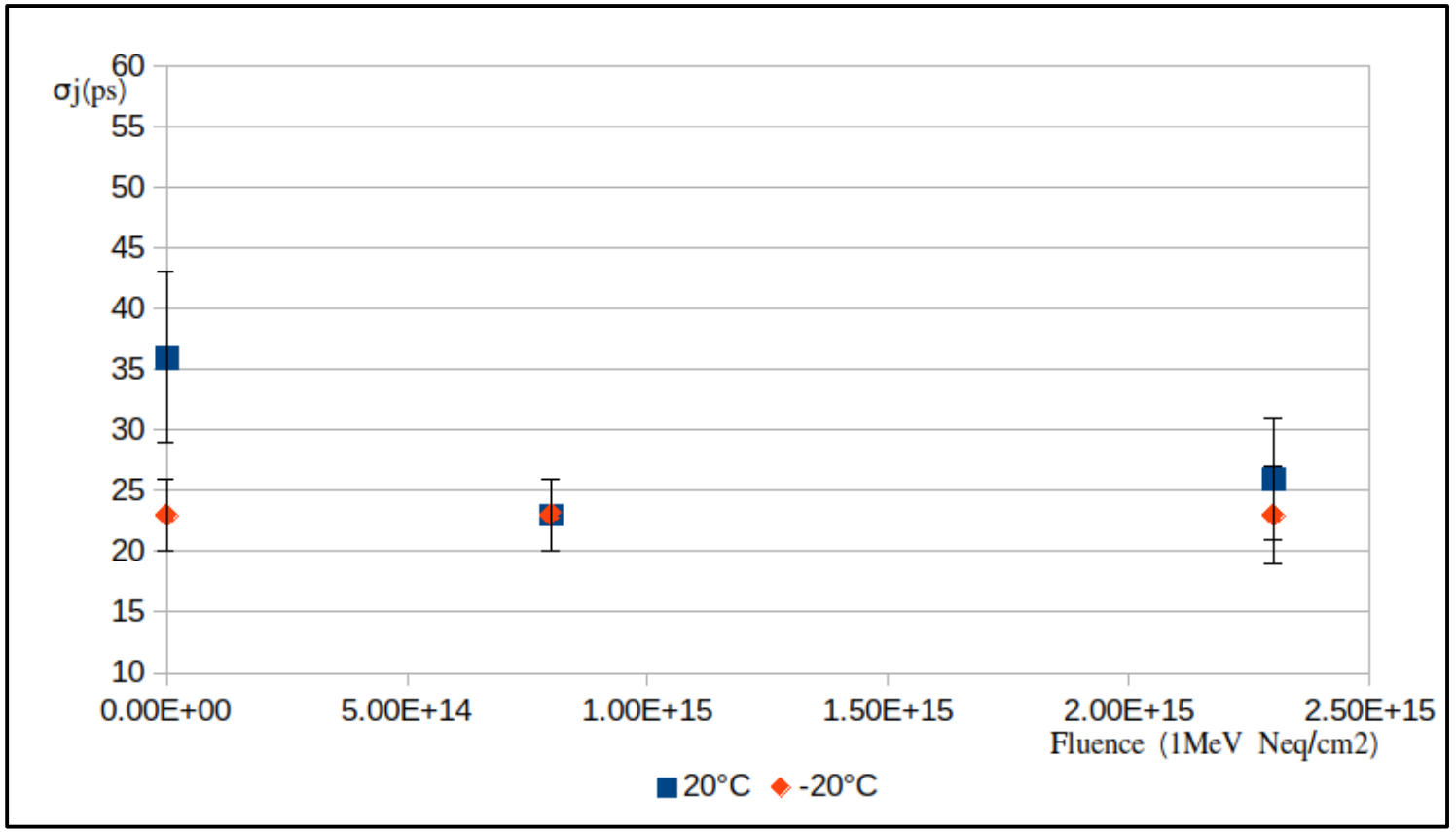


@ 100 V

3D time resolution before and after neutron irradiation at 20°C and -20°C

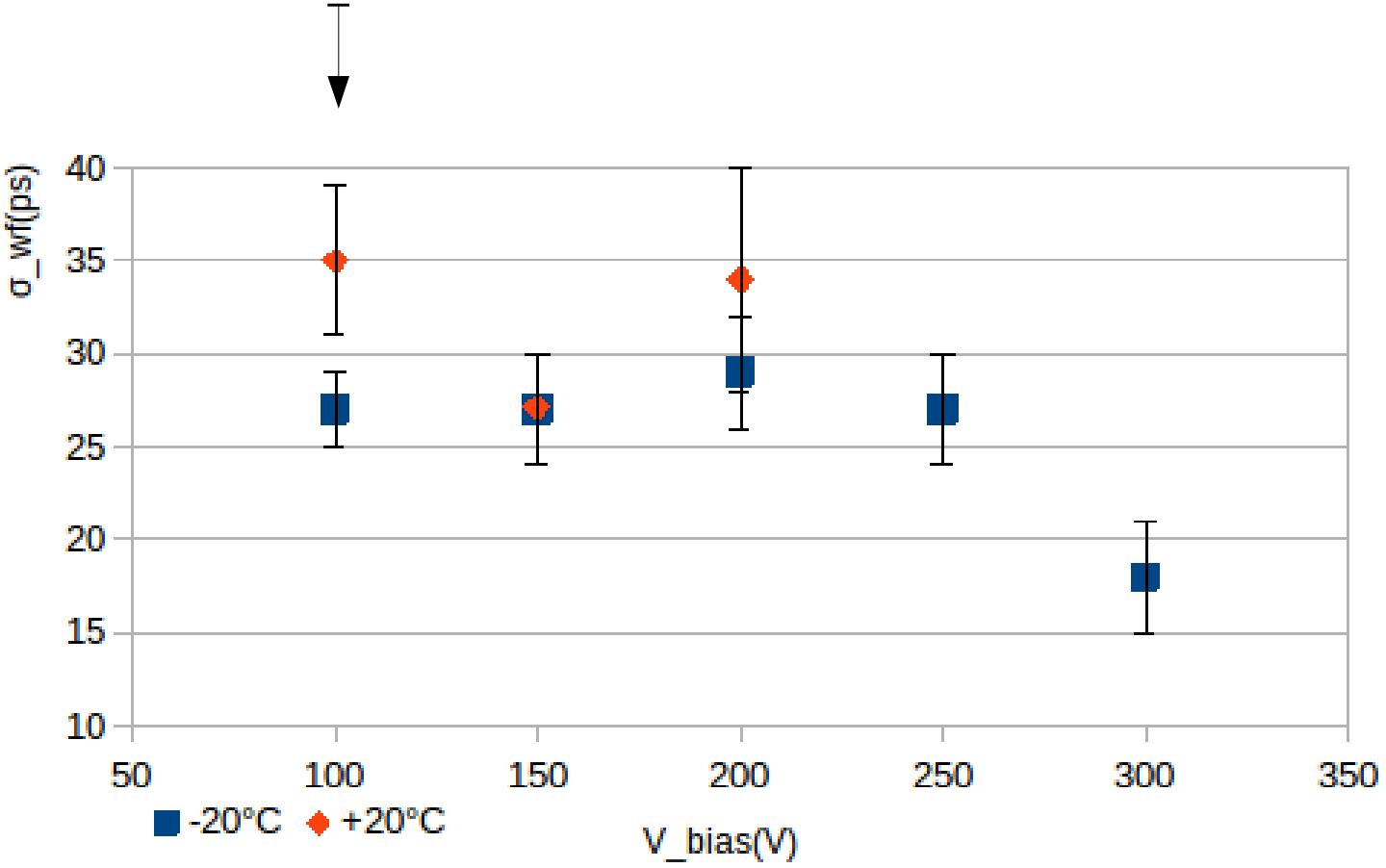
Annealed 60 min at 80°C

Irradiated at $8x10^{14}$ 1Mev n_{eq}/cm^2 and then at $2.3x10^{15}$ 1Mev n_{eq}/cm^2 at Ljubjiana



@ 100 V

3D time resolution after neutron irradiation at 2.3×10^{15} 1Mev n_{eq}/cm^2 20°C and −20°C



3D time resolution before and after neutron irradiation at 20°C and -20°C at 100V

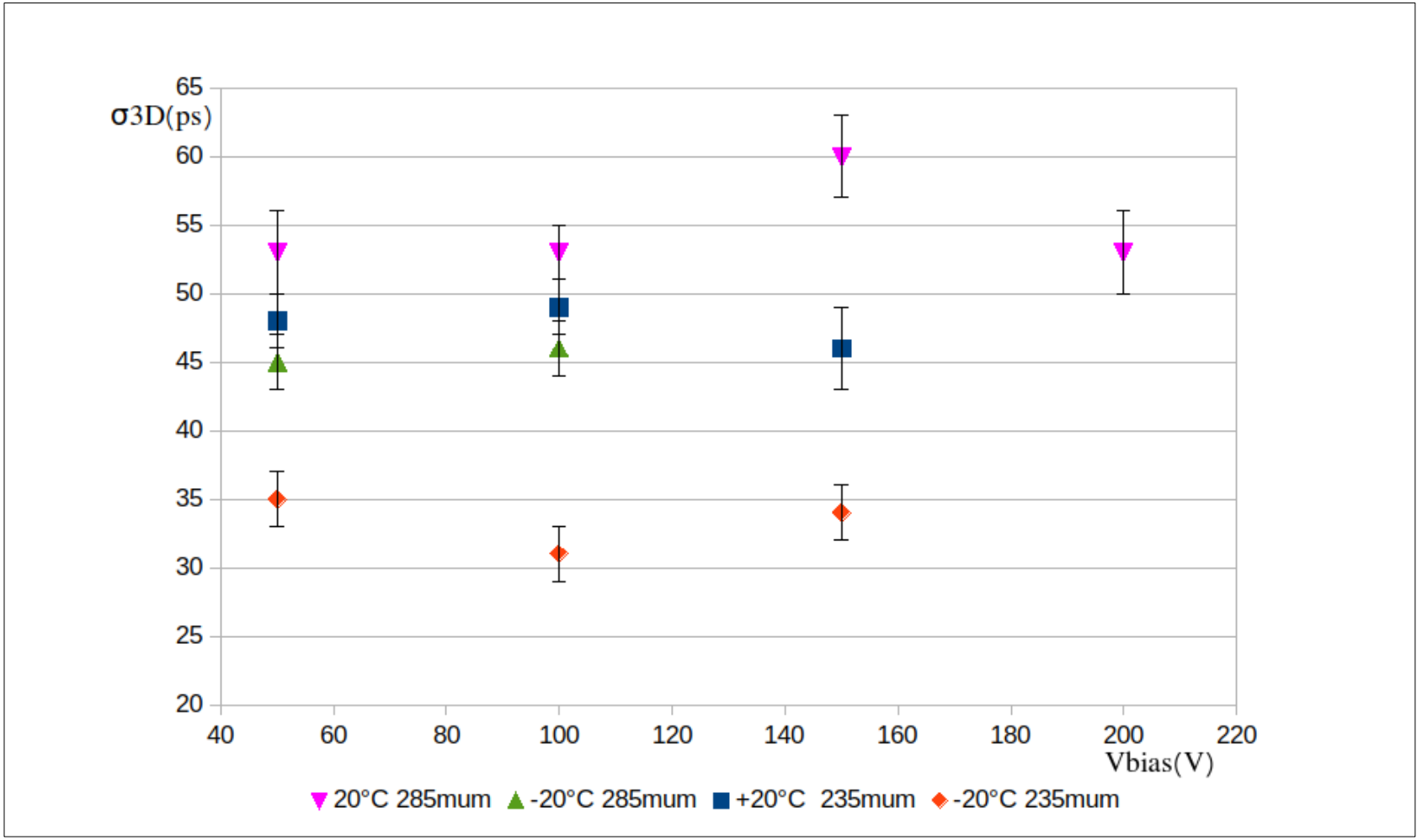
Annealed 60 min at 80°C

Irradiated at 8×10^{14} 1Mev n_{eq}/cm^2 and then at 2.3×10^{15} 1Mev n_{eq}/cm^2 at Ljubjiana

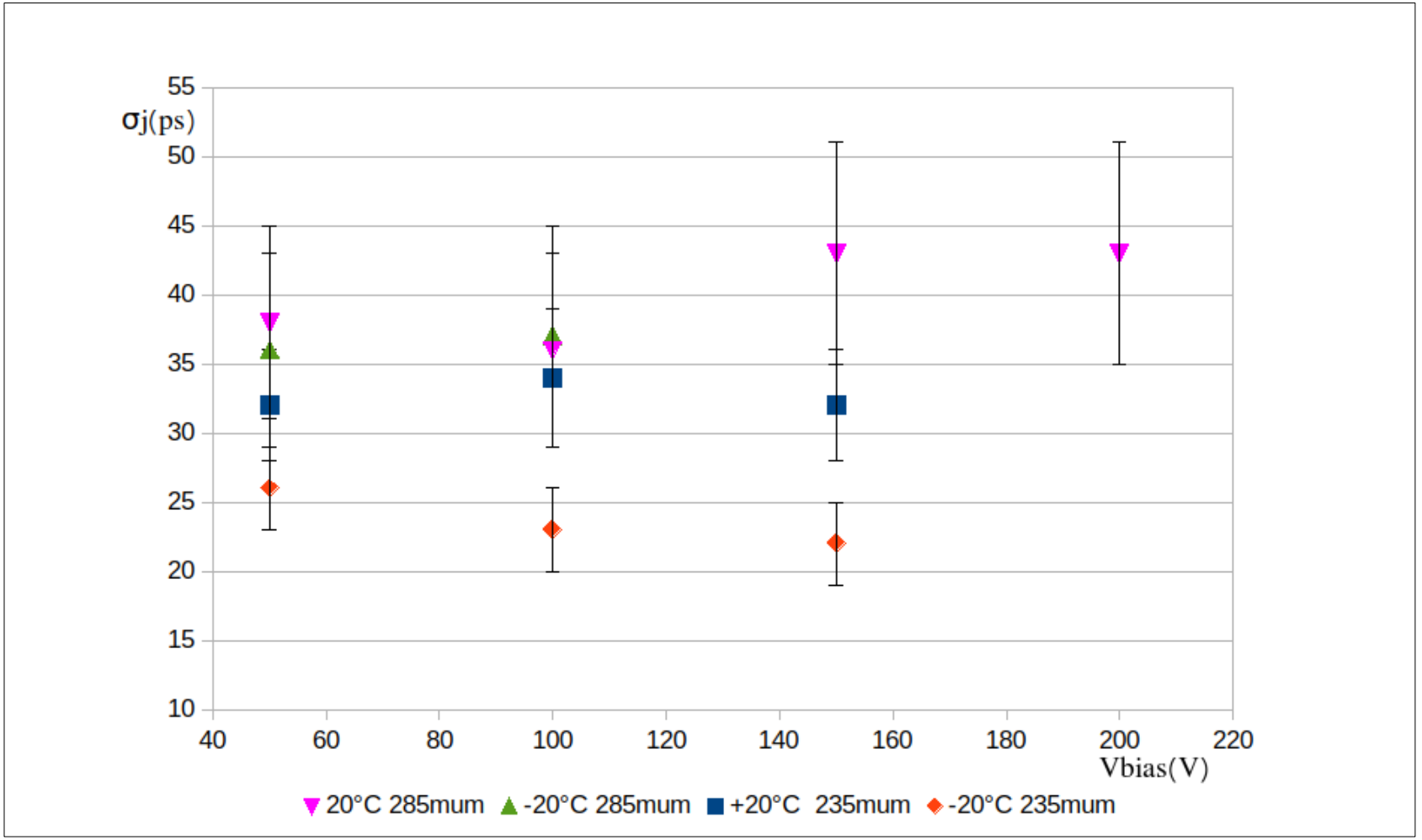
+20°	σ_{3D} (ps)	σ_j (ps)	$\sigma_w f$ (ps)
not irradiated	53±2	36±7	38±4
8e14 MeV n_{eq}/cm^2	37±2	23±3	29±2
2.3e15 MeV n_{eq}/cm^2	44±2	26±5	29±3
-20°	σ_{3D} (ps)	σ_j (ps)	$\sigma_w f$ (ps)
not irradiated	37±2	23±3	28±5
8e14 MeV n_{eq}/cm^2	34±2	23±3	34±2
2.3e15 MeV n_{eq}/cm^2	35±2	23±4	27±3

3D time resolution with 235 μm thick pixel sensor

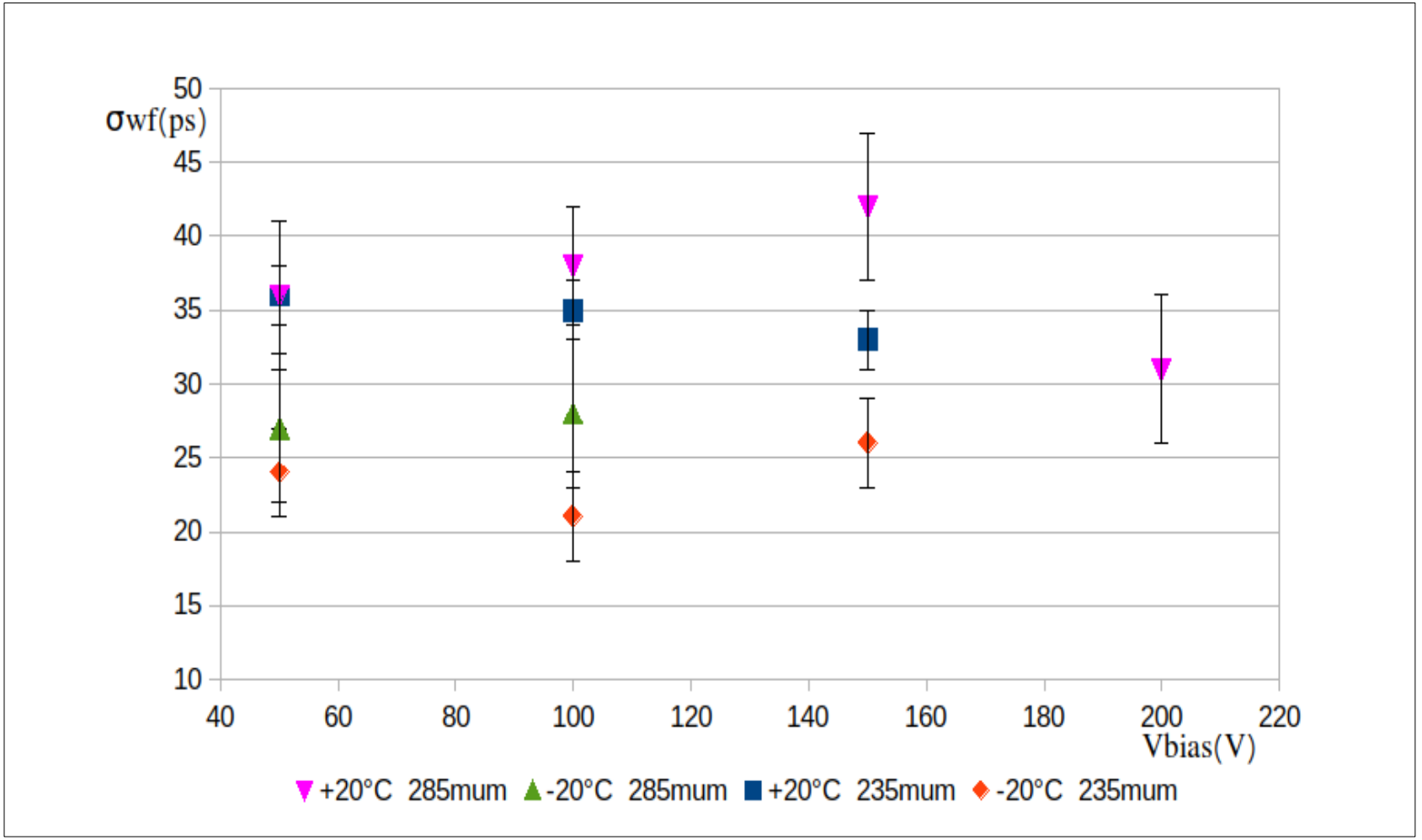
3D time resolution 235 μm thickness at 20°C and -20°C



3D time resolution 235 μm thickness at 20°C and -20°C



3D time resolution 235 μm thickness at 20°C and -20°C



Conclusions

- We measured data for 3D detector with thickness of 285 μm at 50,100,150,200 V_B at 20°C and -20°C. At 100 V_B time resolution is around 40 ps for 20°C and 30 ps for -20°C
  - Slight rise up to 150V and then a considerable drop at 20°C
- After n irradiation of $8x10^{14}$ 1MeV n_{eq}/cm^2 and then of $2.3x10^{15}$ 1Mev n_{eq}/cm^2
  - decrease in both σ_{wf} and σ_j for 20°C
  - stable for -20°C
- We measured data for 3D detector with thickness of 235 μm and it was possible to notice a decrease in σ_j

Next step:

- Redo the measurments increasing the radiation dose

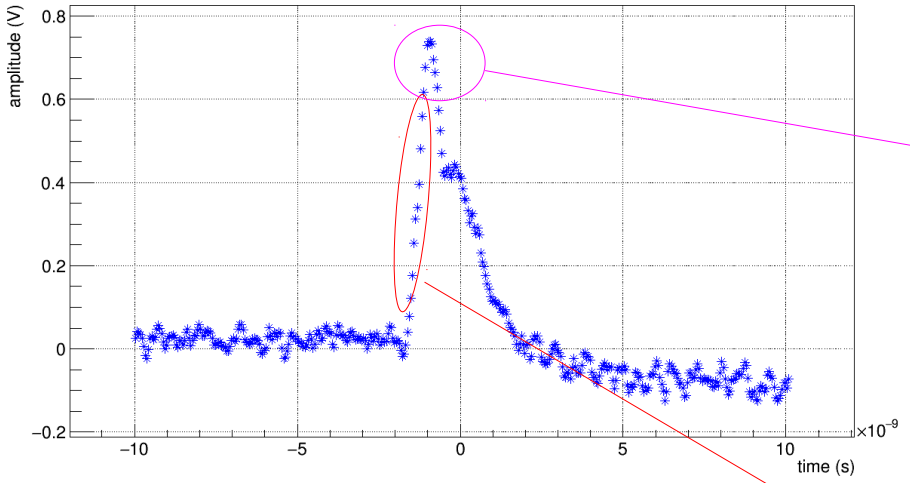
Backup

Jitter $\sigma_{j,3D}$

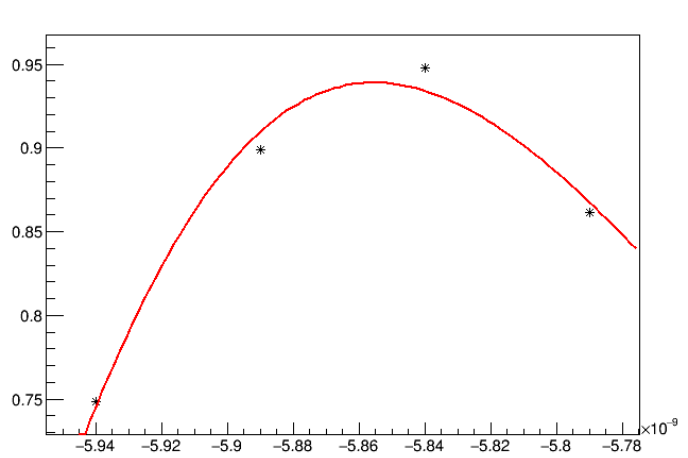
$\sigma^2_{3D} = \sigma^2_{j,3D} + \sigma^2_{tw}$ $\quad$ $\sigma^2_{tw} \sim \sigma^2_{wf}$ $\quad$ $\sigma^2_{wf} \approx \sigma^2_{3D} - \sigma^2_{j,3D}$ $\quad$ $\sigma^2_{j,3D} = N/(dV/dt)$

50 V	CFD(%)	N (mV)	dV/dt (mV/ps)	$\sigma_{j,3D}$(ps)
20 °C	30	16±3	4,2±0,3	38±8
-20 °C	40	16±3	3,9±0,2	41±8

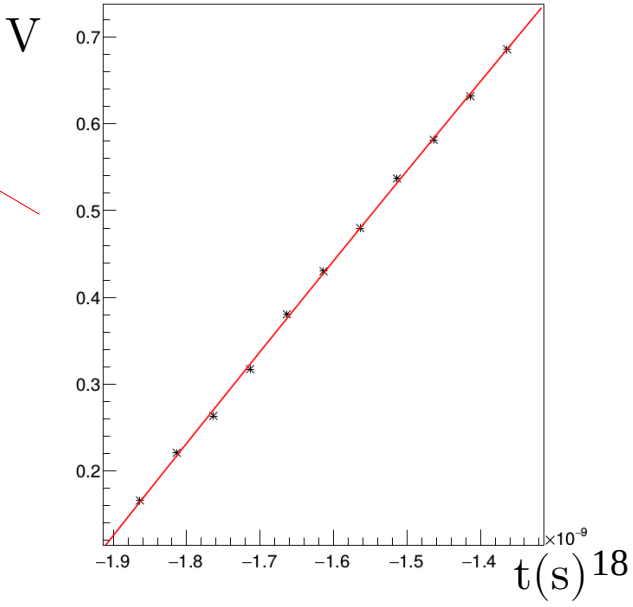
LGAD Waveform Analysis



3)



4)



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

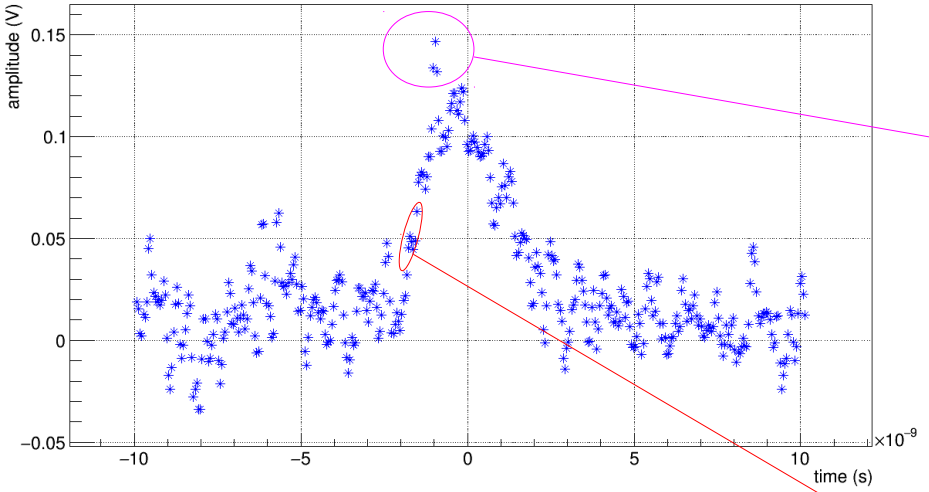
2) Offset correction

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



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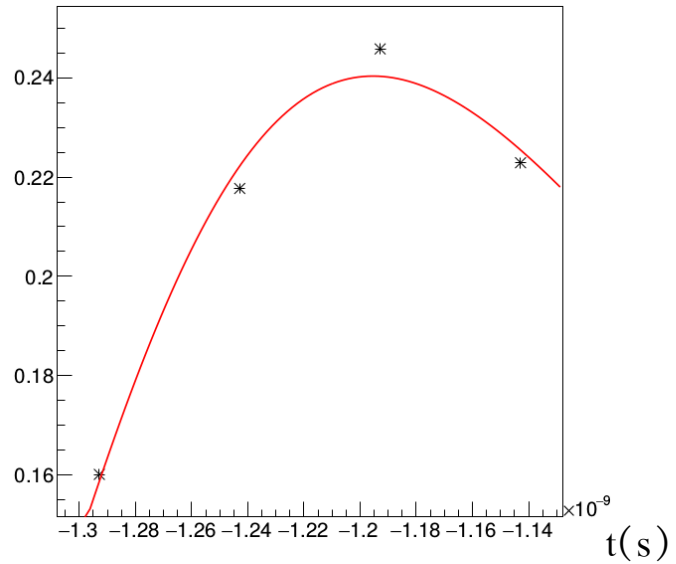


1) Noise estimation: gaus fit on the first 100 pt. (5 ns)

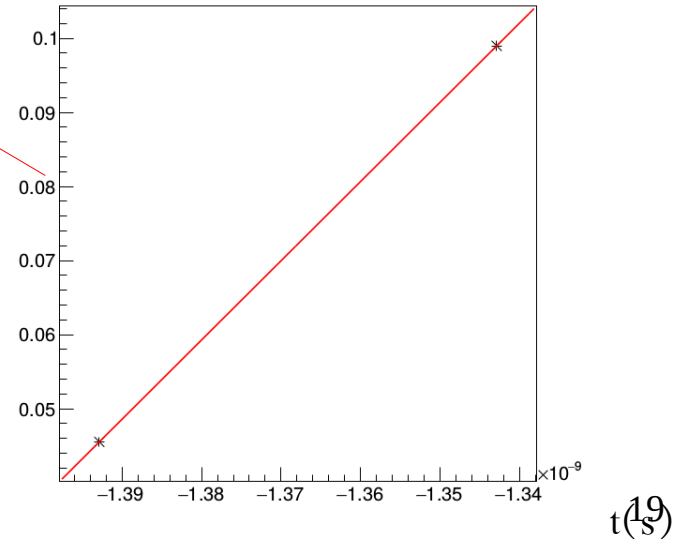
2) Offset correction

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

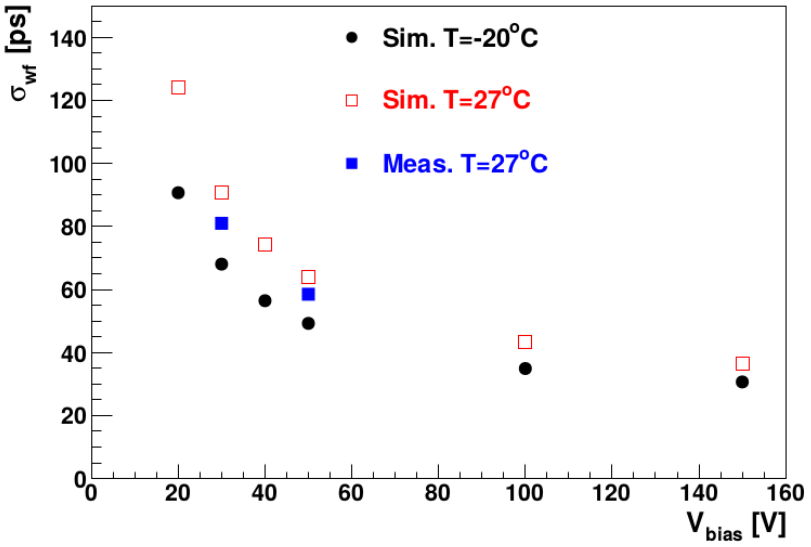
5) Extrapolation of t^{*}_{3D}

4)



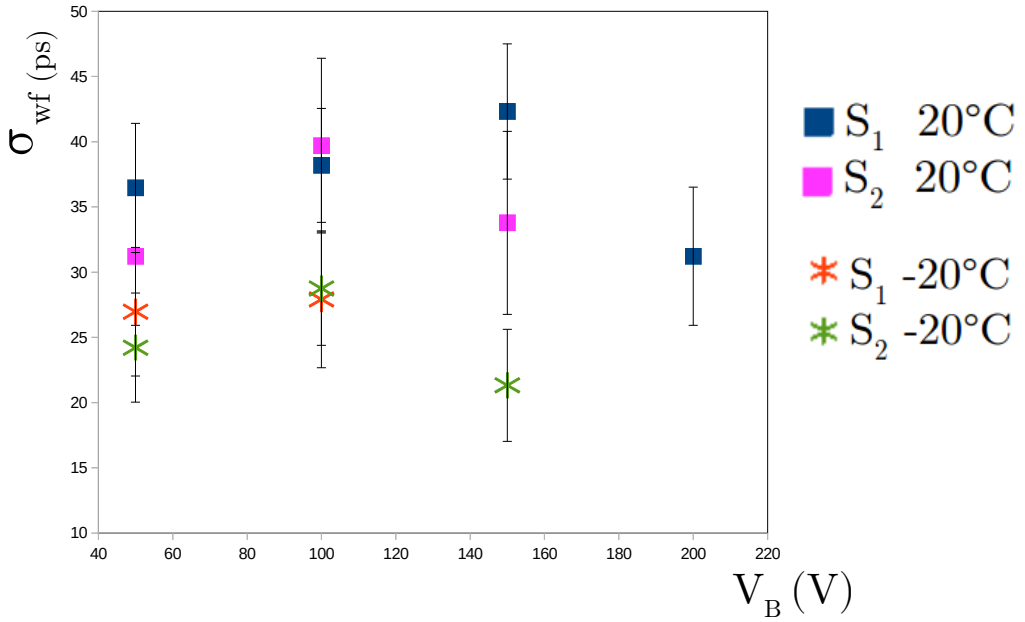
3D Time resolution measurement and simulation

Sim. And previous measurements



arXiv:1901.02538

Measurements 2019



3D V_{BD}

	0	8e14	2.3e15	
285 mum	170	230	320	