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 Waveform and Analysis

- Results:
  3D Time resolution before and after irradiation for 285μm thick sensor.
  σ_{wf} behaviour for high voltages
  Last results

3D Pixel Sensor – CNM production

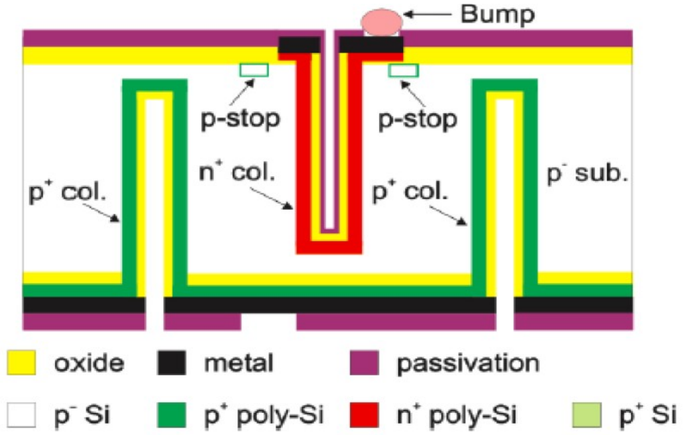
Features:

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

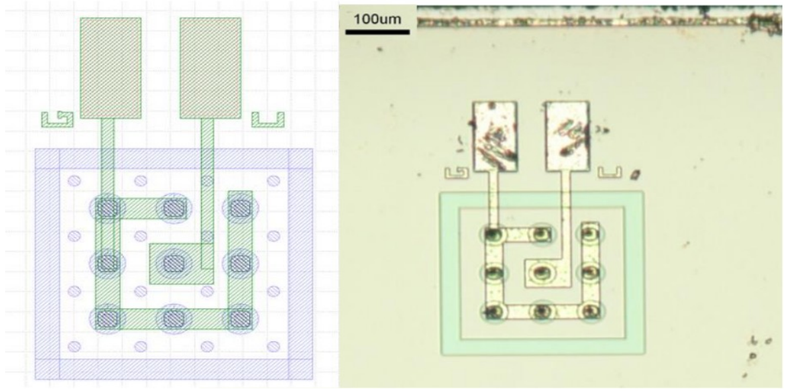
Radiation doses:

1) Irradiated @ $8x10^{14}$ 1Mev n_{eq}/cm^2
2) Irradiated @ $2.3x10^{15}$ 1Mev n_{eq}/cm^2
3) Irradiated @ $4.8x10^{15}$ 1Mev n_{eq}/cm^2

Schematic Cross Section

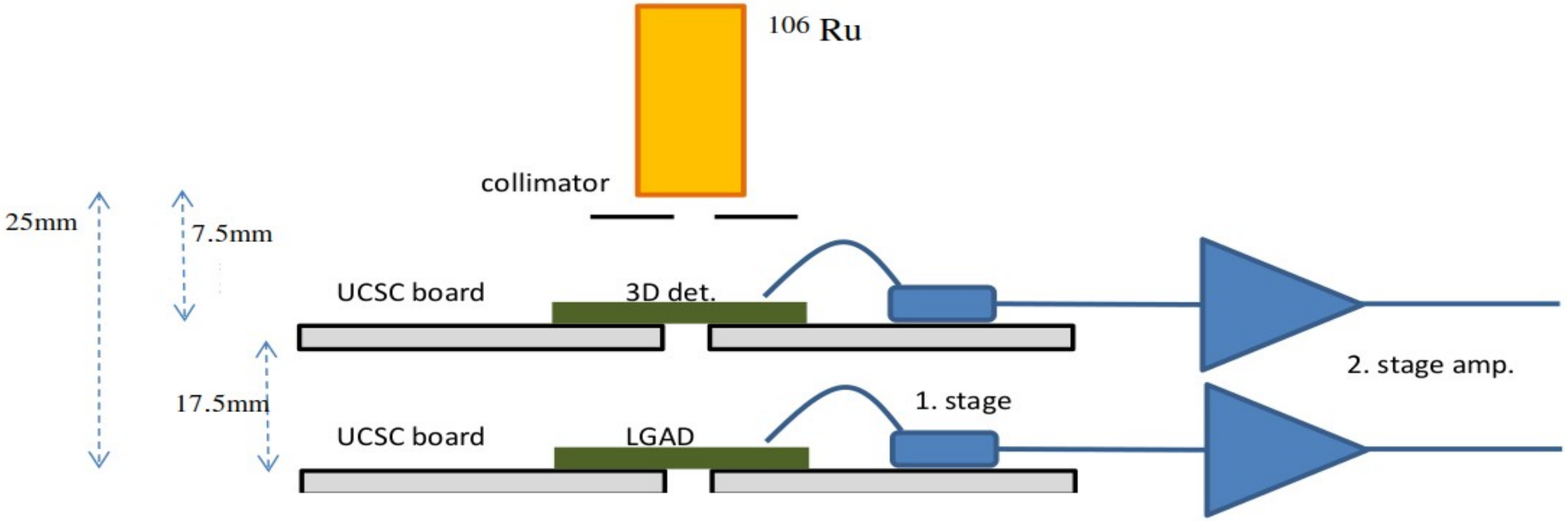


Design of a single cell structure



arXiv:1901.02538

Experimental Setup

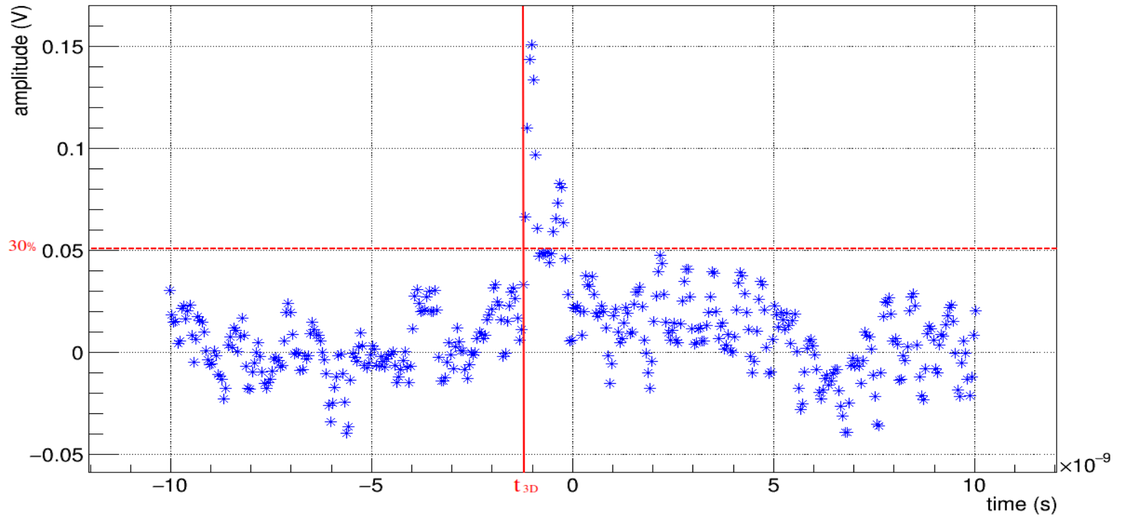


Signals in coincidence are analyzed

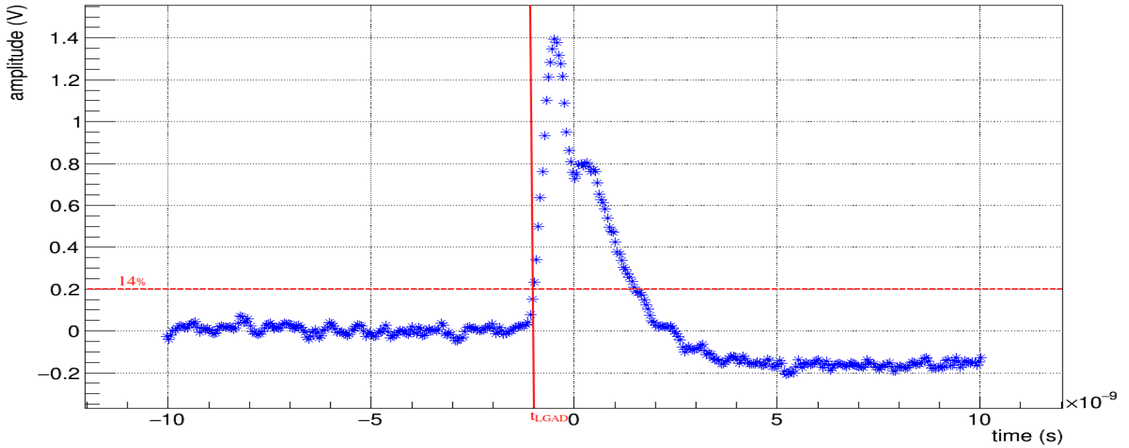
Source: ^{106}Ru
Board: Preamplified UCSC
LGAD: HPK50C - high gain 50 um thick (1 mm diameter)
Time resolution 39 ps (20°C) and 36 ps (-20°C)
2.stage amp: 4GHz
Readout: Waverunner 8404M oscilloscope 4GHz

3D Waveform and analysis – σ_{3D}

3D Waveform

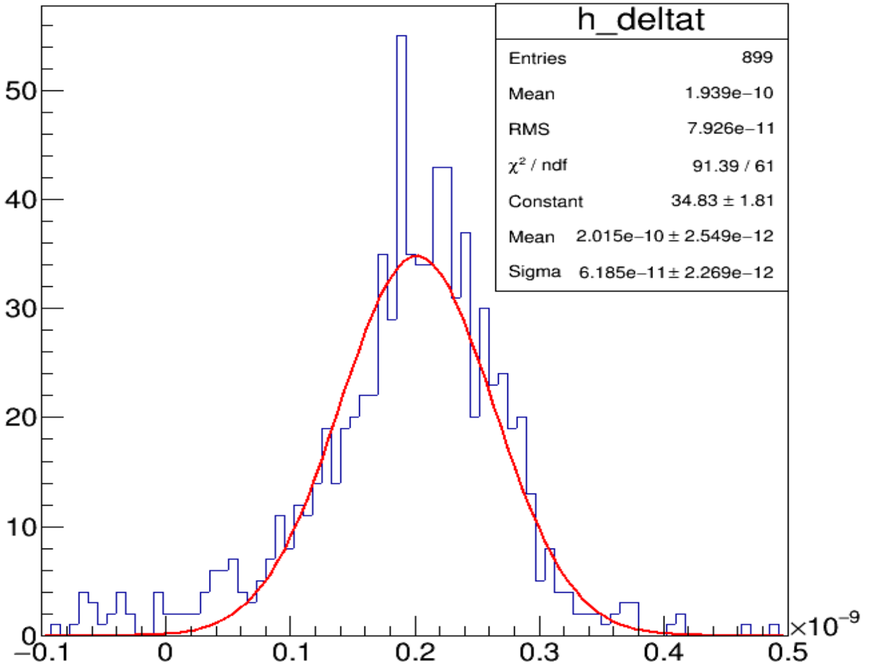


LGAD Waveform



CFD method

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



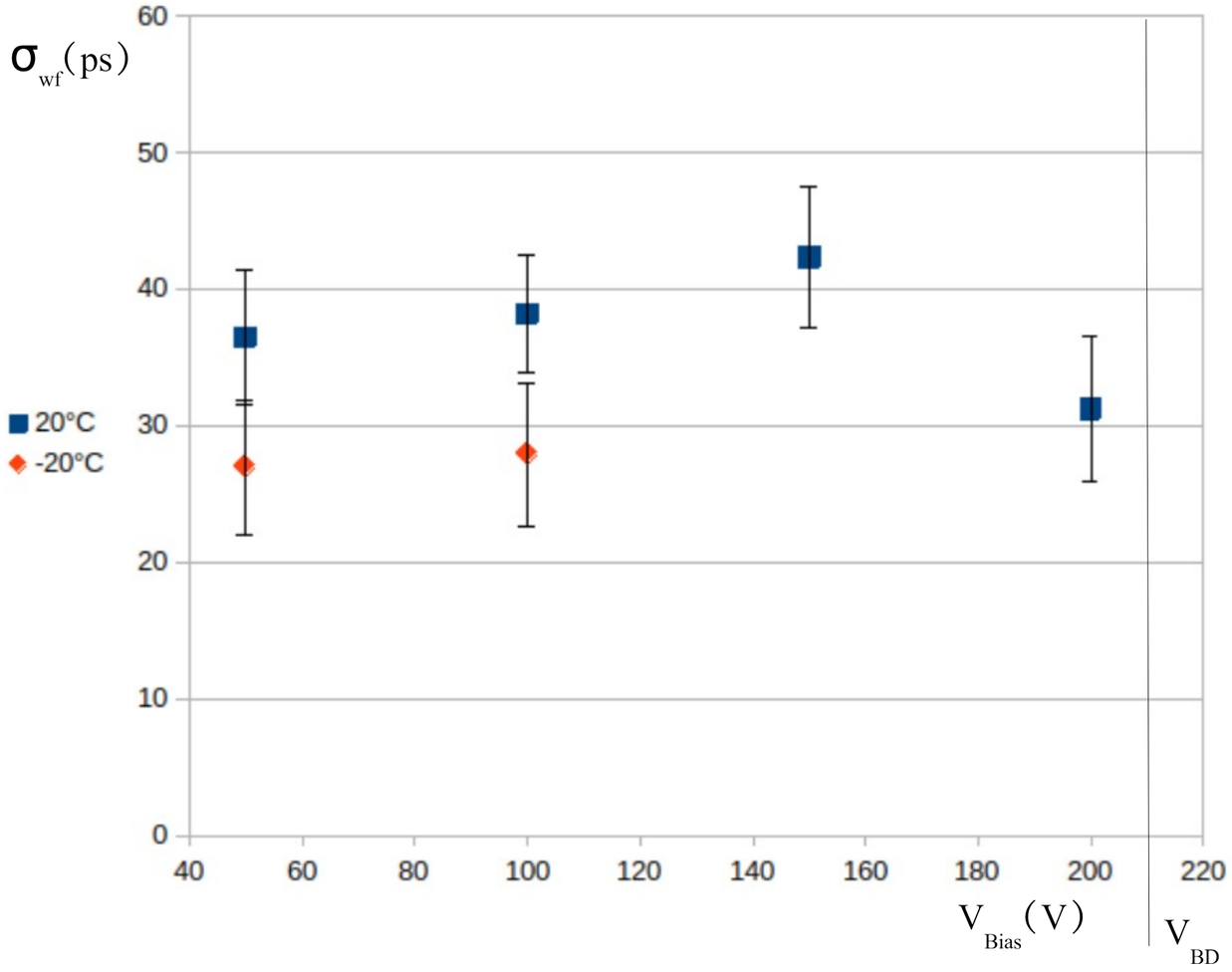
Fit on Δt to obtain: $\sigma_t = (\sigma^2_{LGAD} + \sigma^2_{3D})^{1/2}$

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

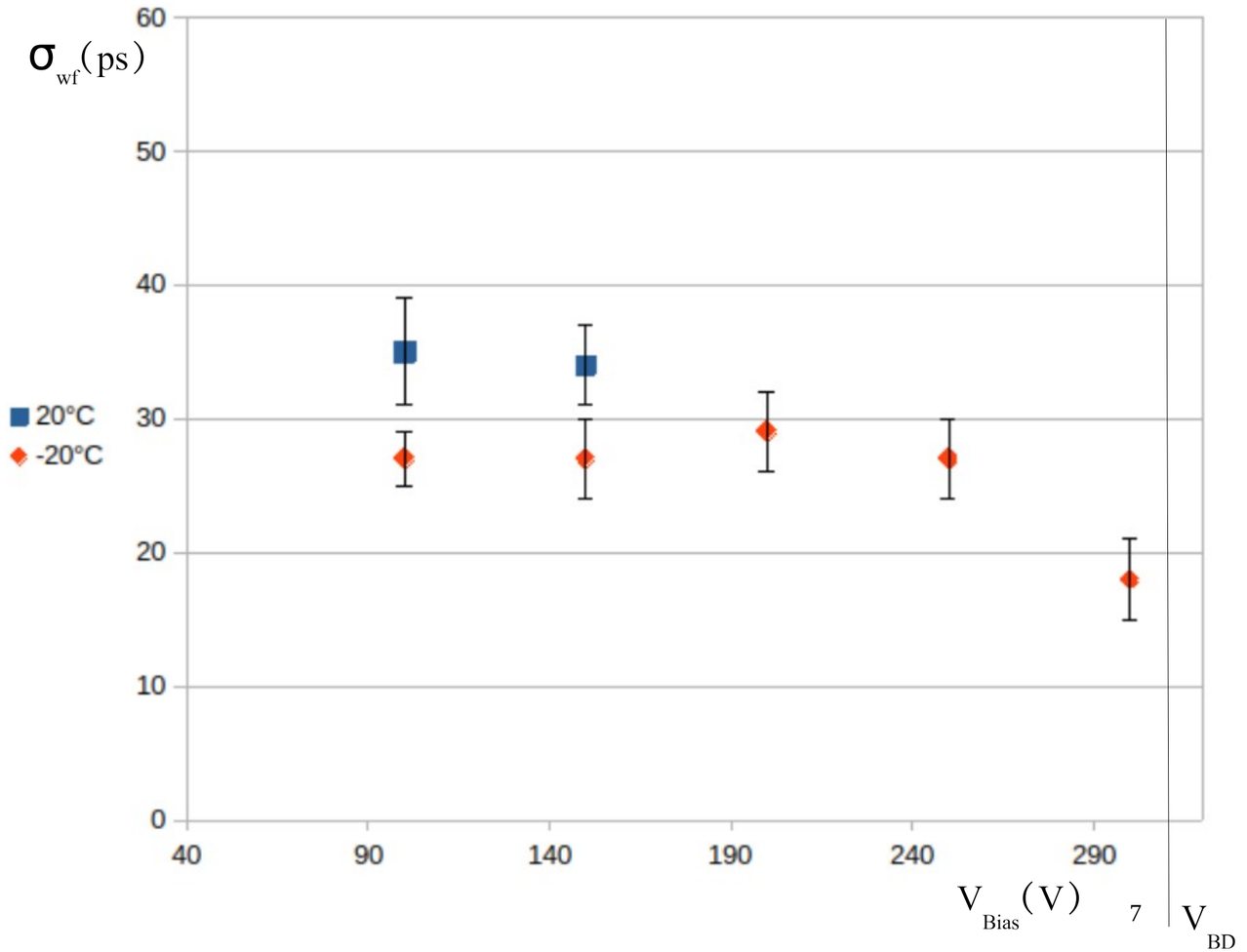
Results

σ_{wf} behaviour for high voltages

Not irradiated

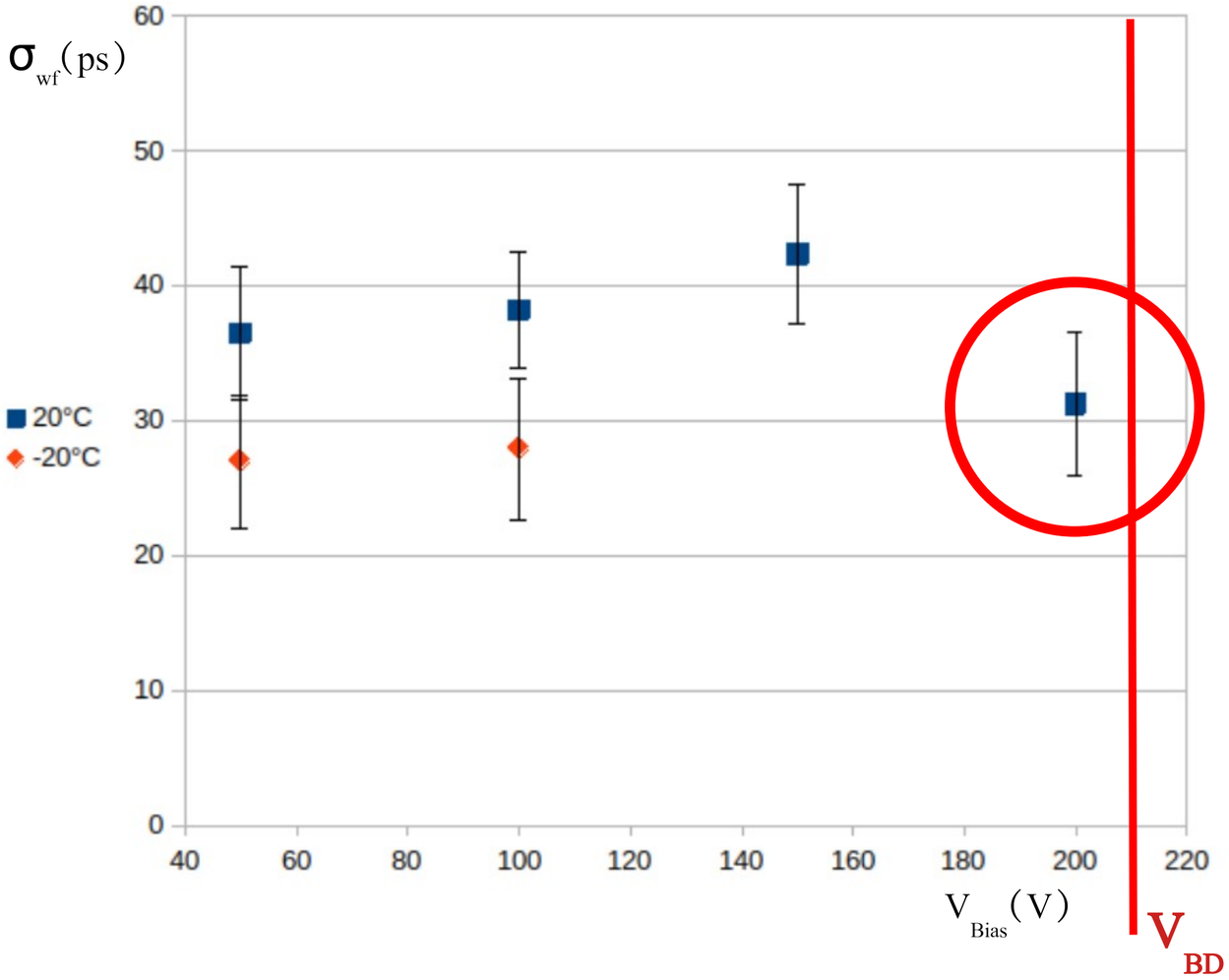


Irradiated @ 2.3×10^{15} 1Mev n_{eq}/cm^2

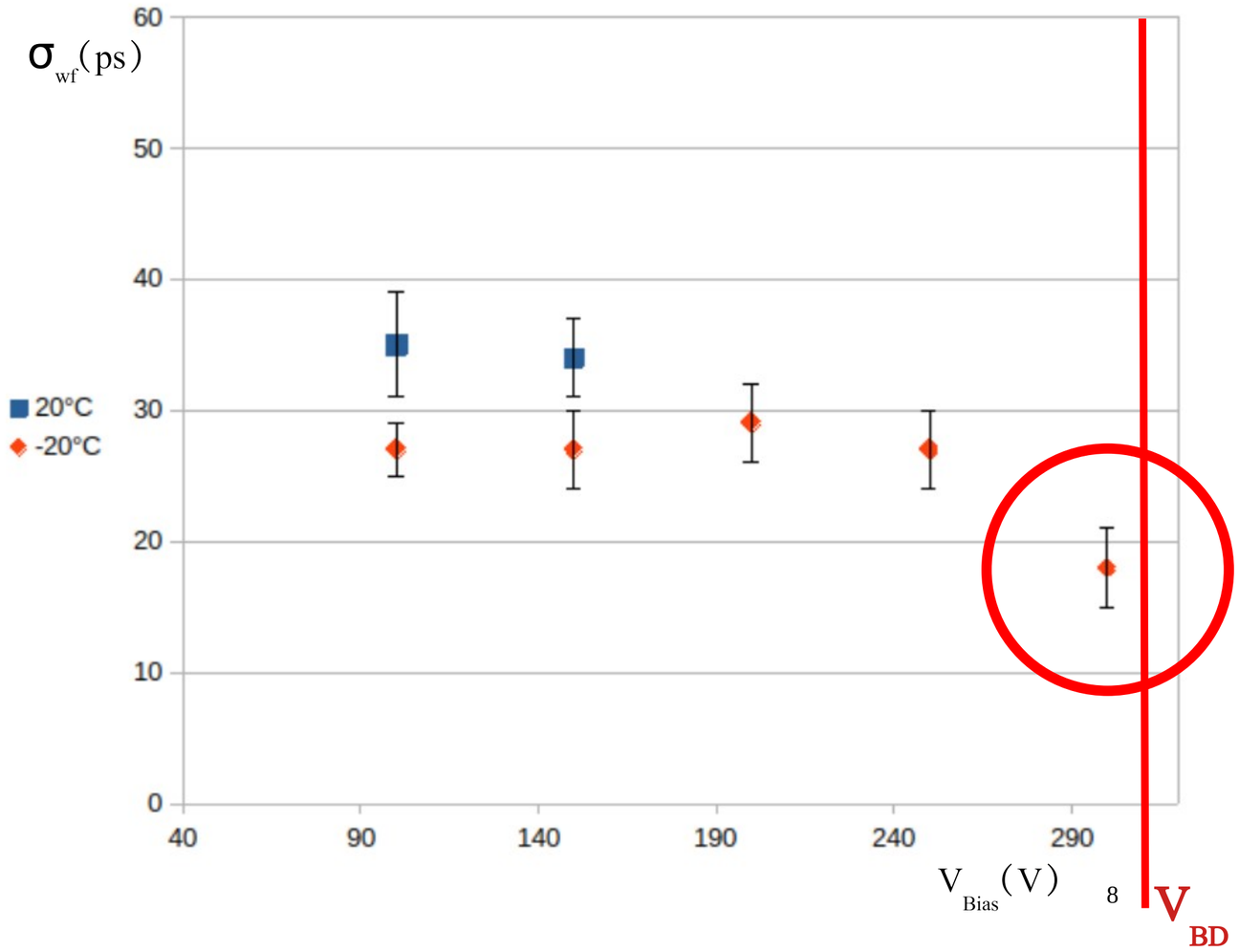


σ_{wf} behaviour for high voltages

Not irradiated

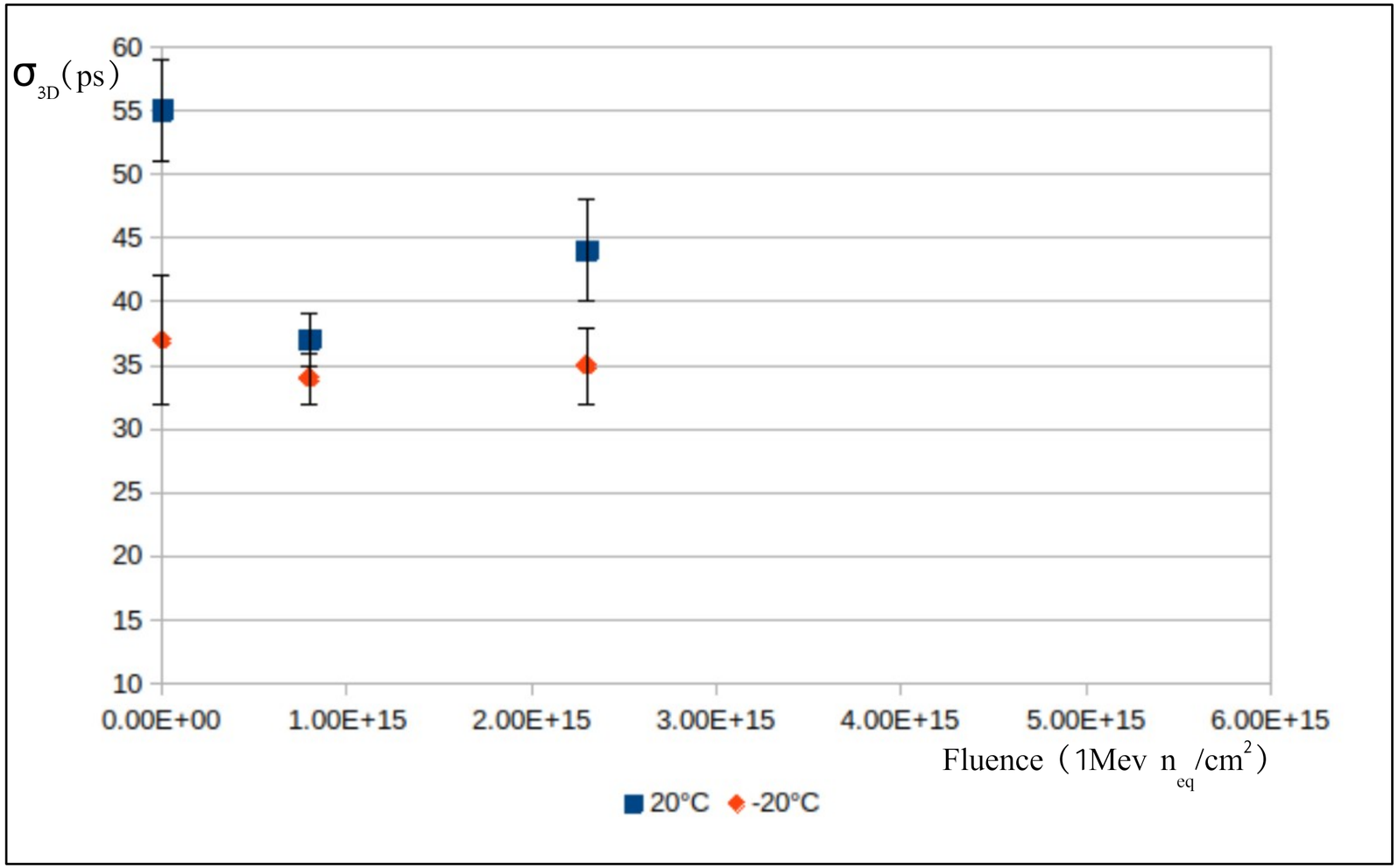


Irradiated @ 2.3×10^{15} 1Mev n_{eq}/cm^2



3D time resolution before and after neutron irradiation

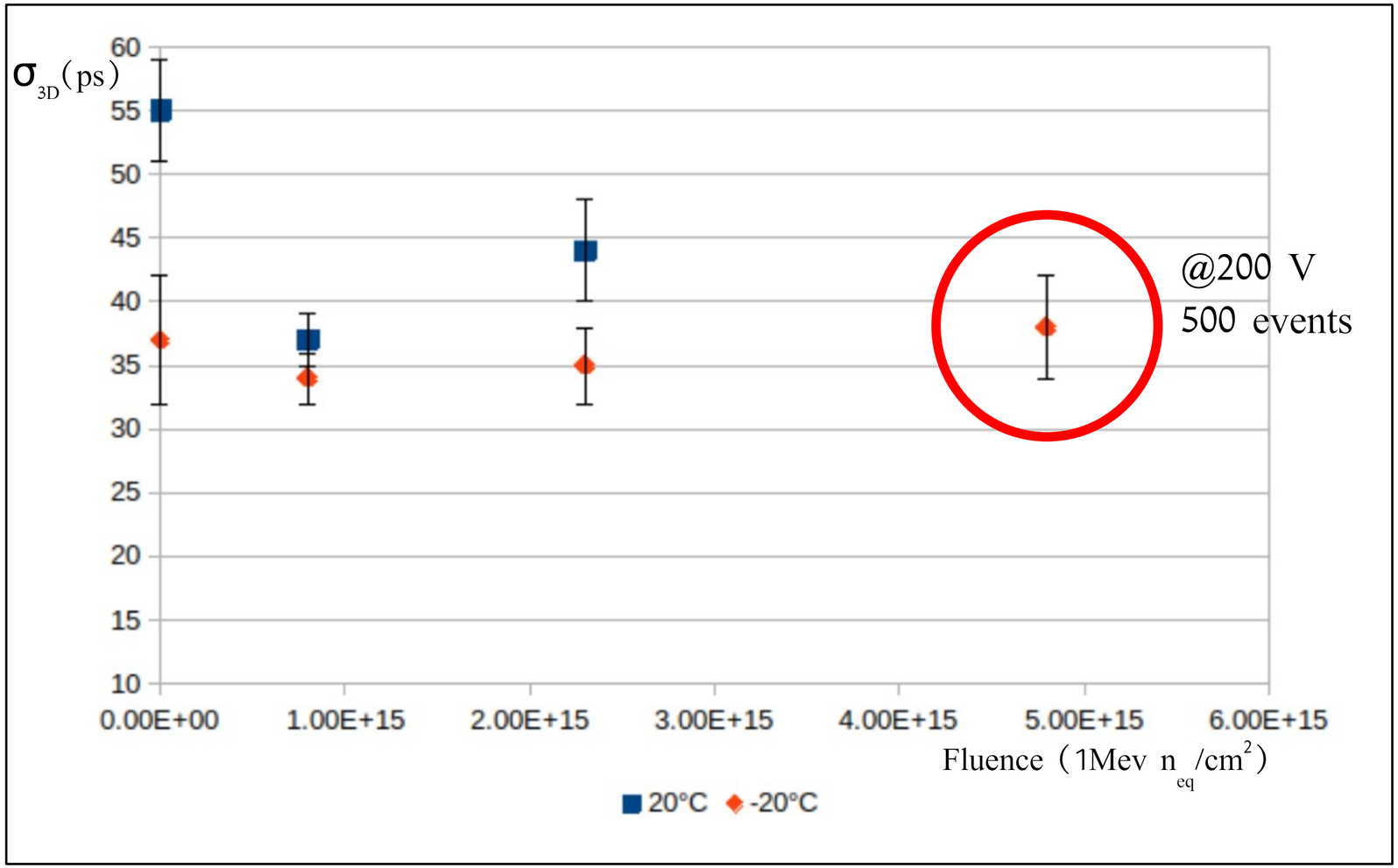
Irradiated at 8.0×10^{14} 1Mev n_{eq}/cm^2 2.3×10^{15} 1Mev n_{eq}/cm^2



@ 100 V

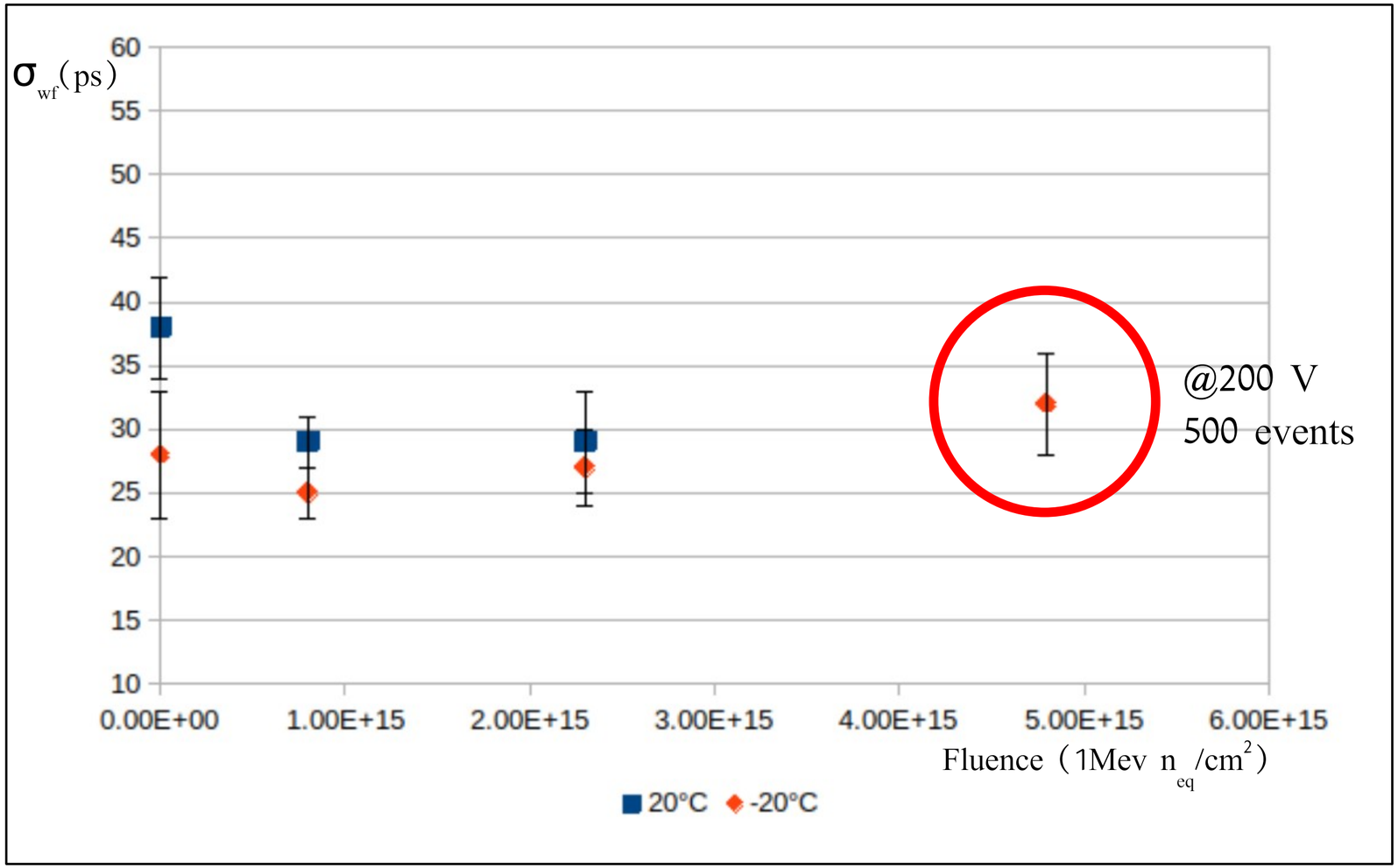
3D time resolution before and after neutron irradiation

Irradiated at 8.0×10^{14} 1Mev n_{eq}/cm^2 2.3×10^{15} 1Mev n_{eq}/cm^2 at 4.8×10^{15} 1Mev n_{eq}/cm^2 at Ljubjiana



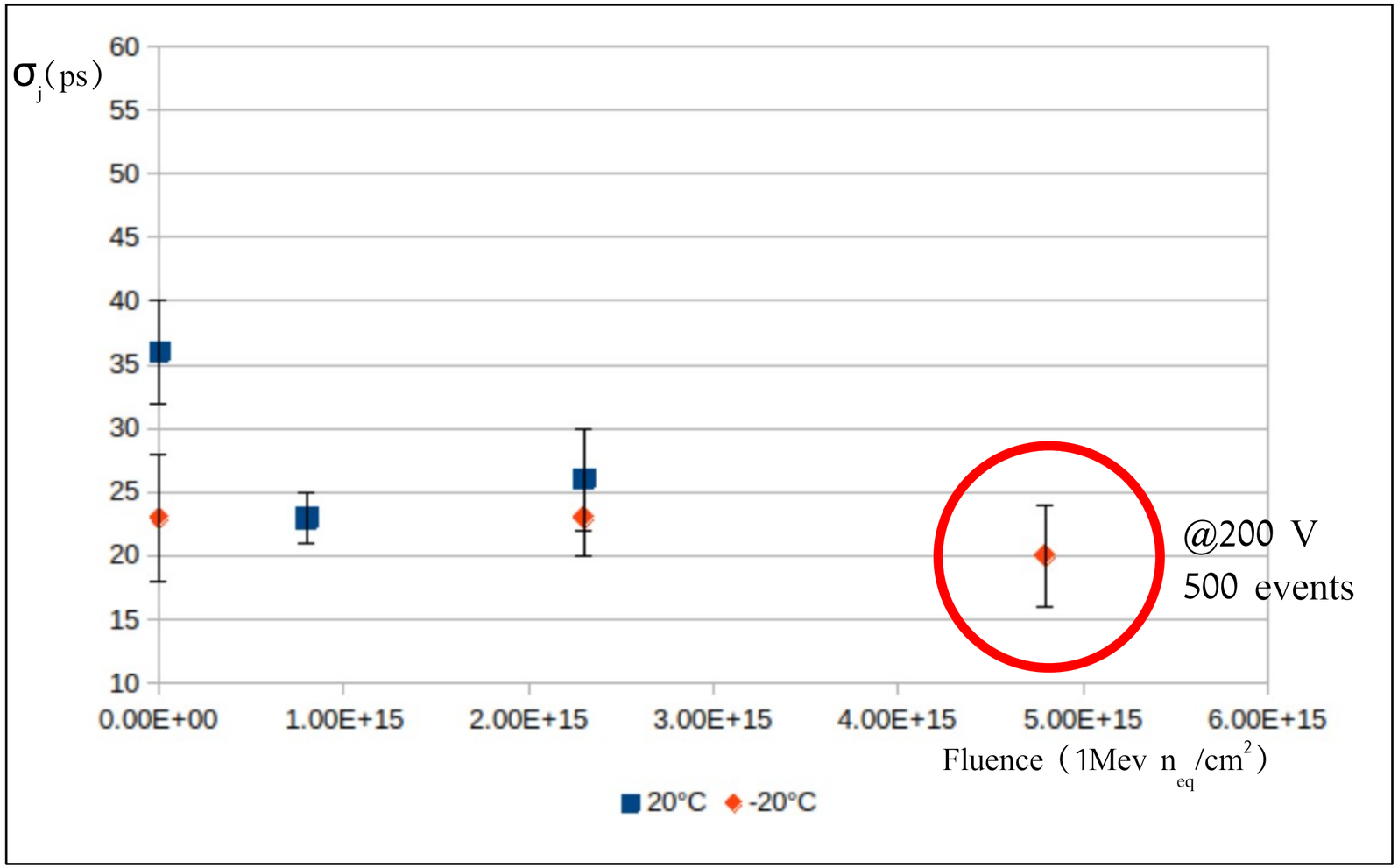
3D time resolution – σ_{wf} contribution before and after neutron irradiation

Irradiated at 8.0×10^{14} 1Mev n_{eq}/cm^2 2.3×10^{15} 1Mev n_{eq}/cm^2 at 4.8×10^{15} 1Mev n_{eq}/cm^2 at Ljubjiana



3D time resolution – σ_j contribution before and after neutron irradiation

Irradiated at 8.0×10^{14} 1Mev n_{eq}/cm^2 2.3×10^{15} 1Mev n_{eq}/cm^2 at 4.8×10^{15} 1Mev n_{eq}/cm^2 at Ljubjiana



Conclusions

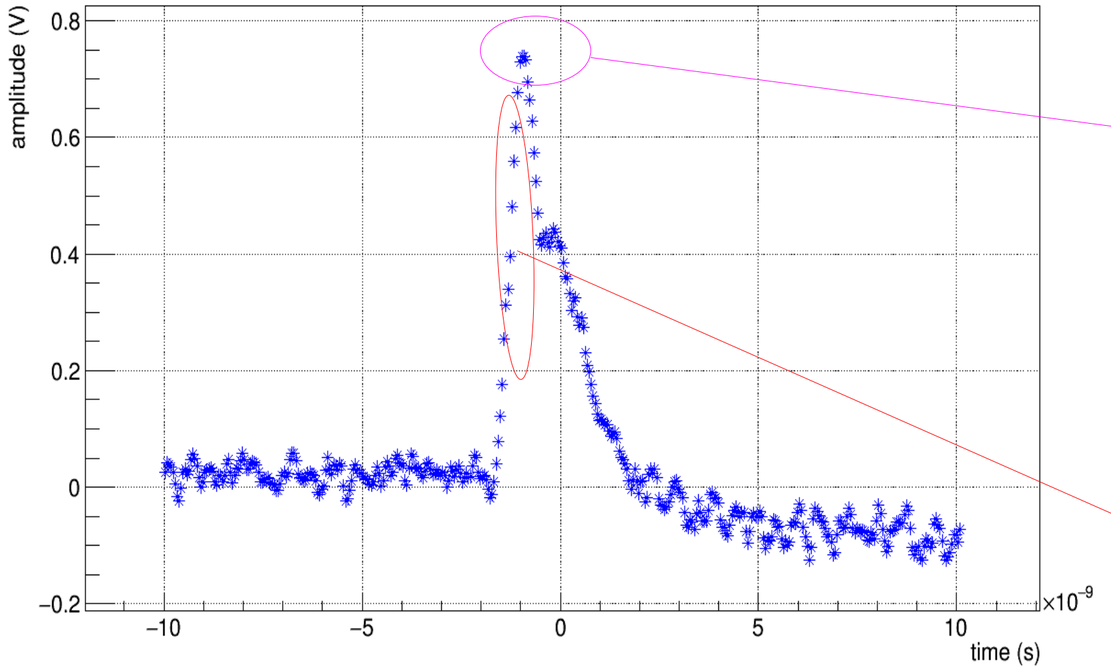
- We measured data for 3D detector with thickness of 285 μm at different V_B at 20°C and -20°C
  - Considerable drop close to V_{BD}
- After n irradiation at $8x10^{14}$ 1MeV n_{eq}/cm^2 at $2.3x10^{15}$ 1Mev n_{eq}/cm^2 and then at $4.8x10^{15}$ 1Mev n_{eq}/cm^2
  - stable for -20°C

Next steps:

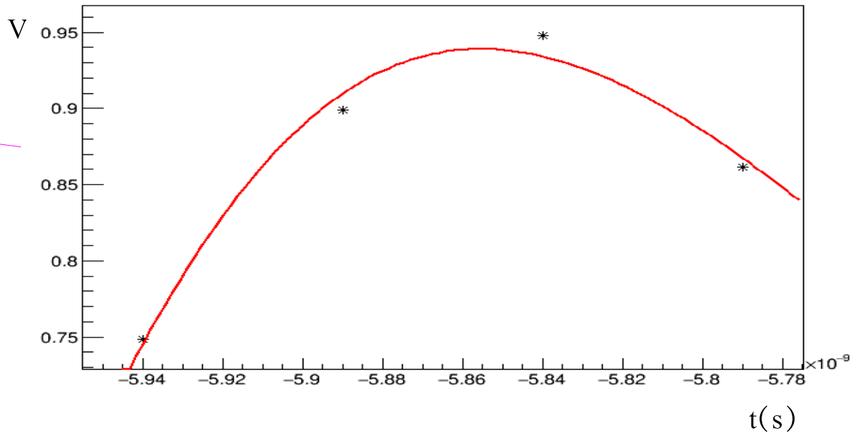
- Redo the measurments increasing the radiation dose

Backup - Analysis

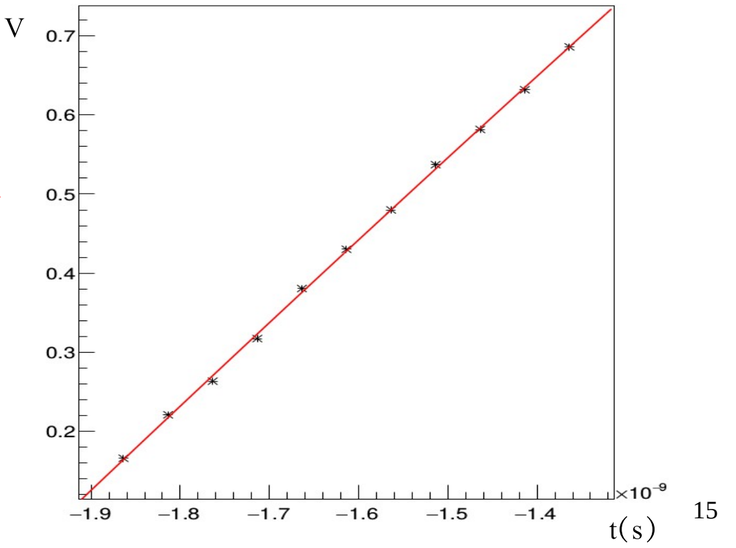
LGAD Waveform Analysis



3)

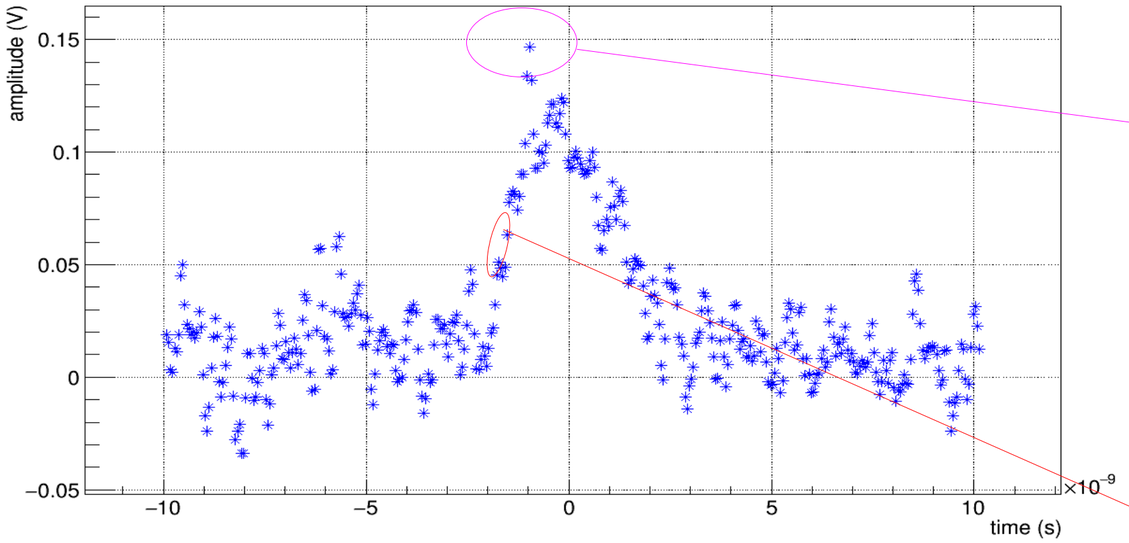


4)

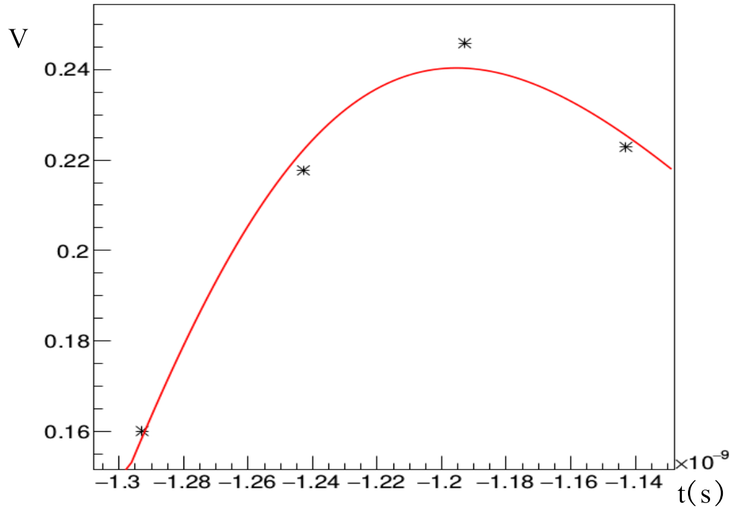


1) Noise estimation: gaus fit on the first 100 pt. (5 ns)
2) Offset correction
3) Landau fit around the maximum value in amplitude (4 pt.) and extrapolation of t_{MAX}
4) Landau fit (11 pt.) on the waveform rising
5) Extrapolation of t^{*}_{LGAD}

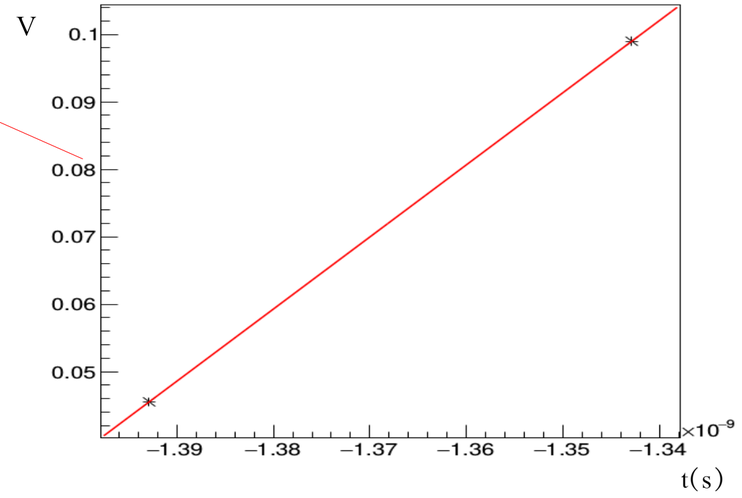
3D Waveform analysis



3)



4)

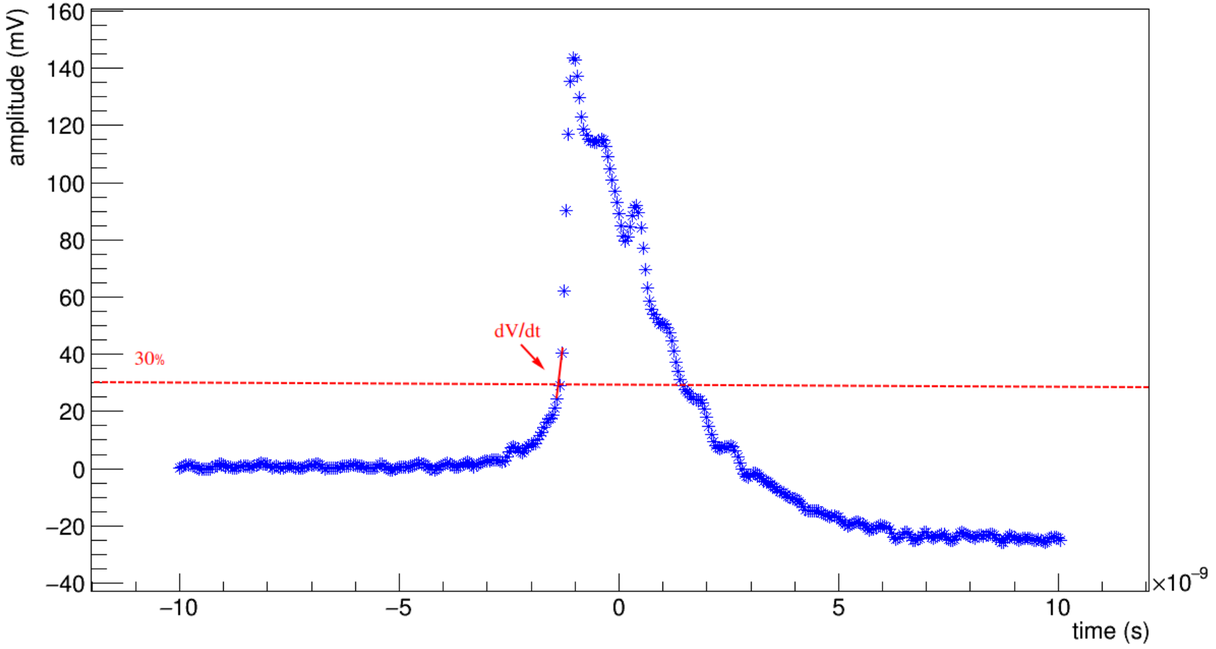


1) Noise estimation: gaus fit on the first 100 pt. (5 ns)
2) Offset correction
3) Landau fit around the maximum value in amplitude (4 pt.)
and extrapolation of t_{MAX}
4) Linear fit (2 pt.) with the first point which crosses the threshold and the previous one
5) Extrapolation of t^{*}_{3D}

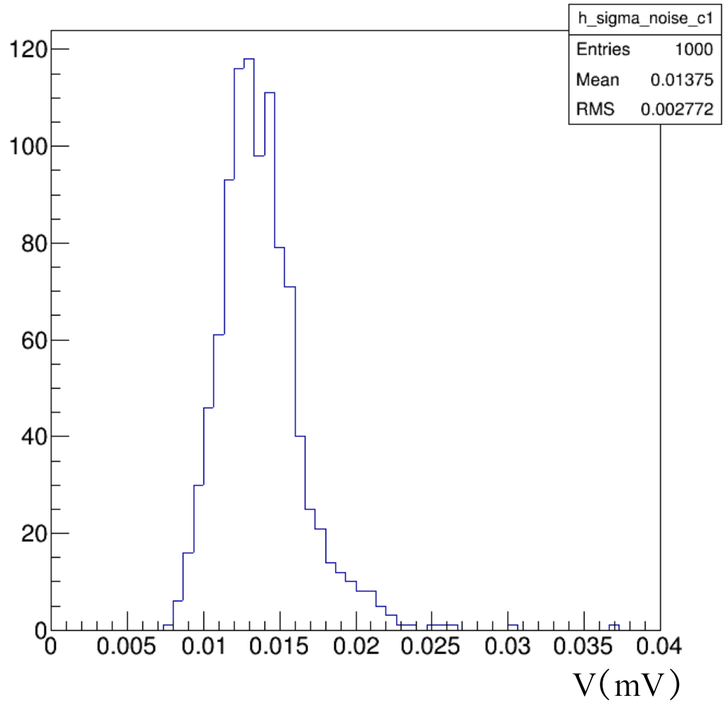
3D Waveform and analysis – σ_j

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

1000 averaged waveforms



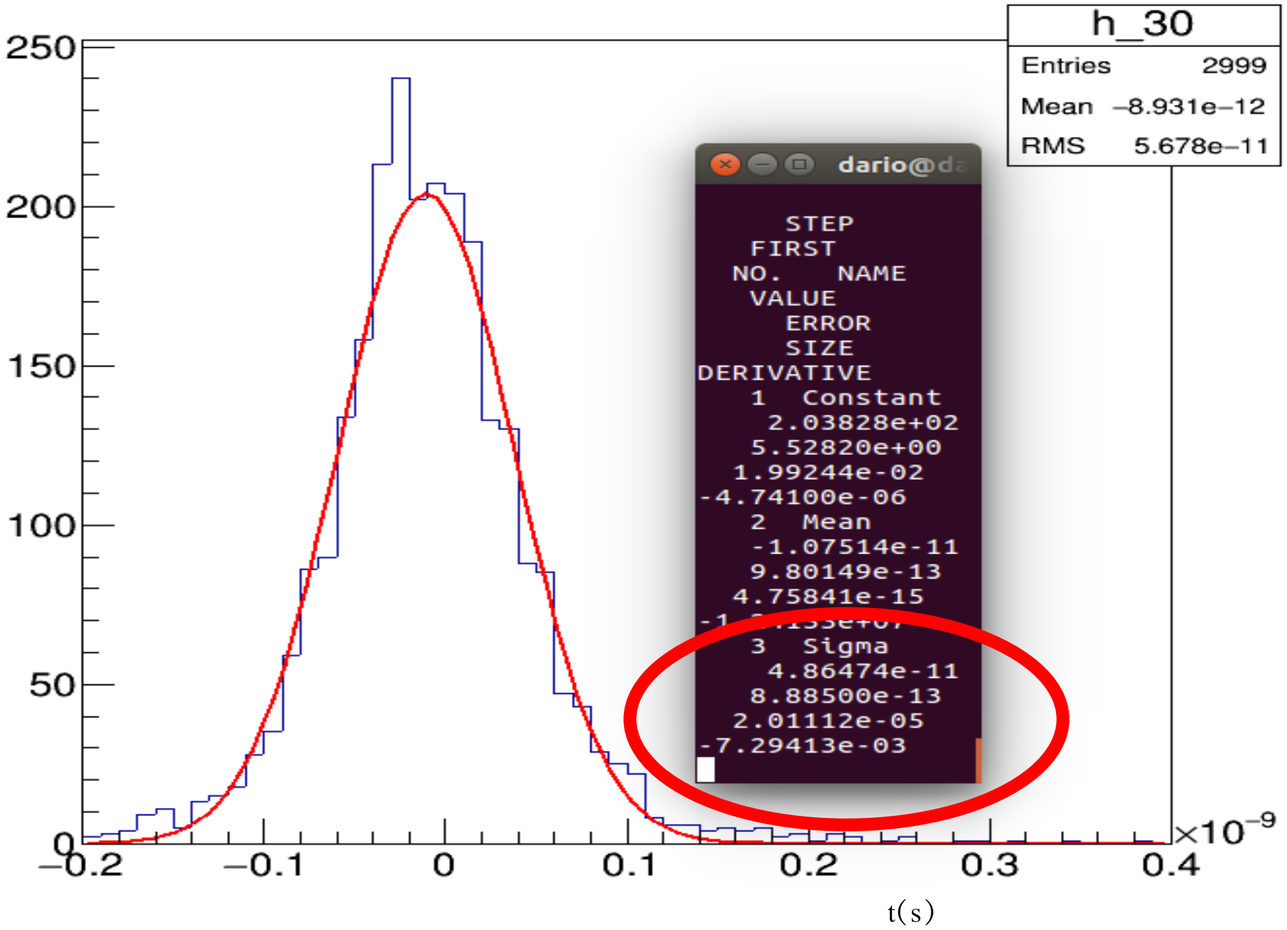
RMS of the noise



Noise:

RMS of the noise evaluated on the first 100 points of the single waveform.

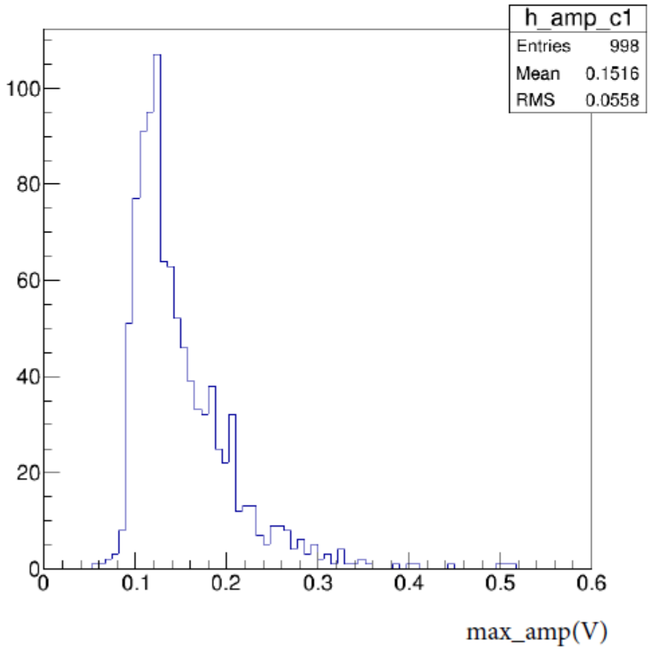
LGAD-LGAD time resolution



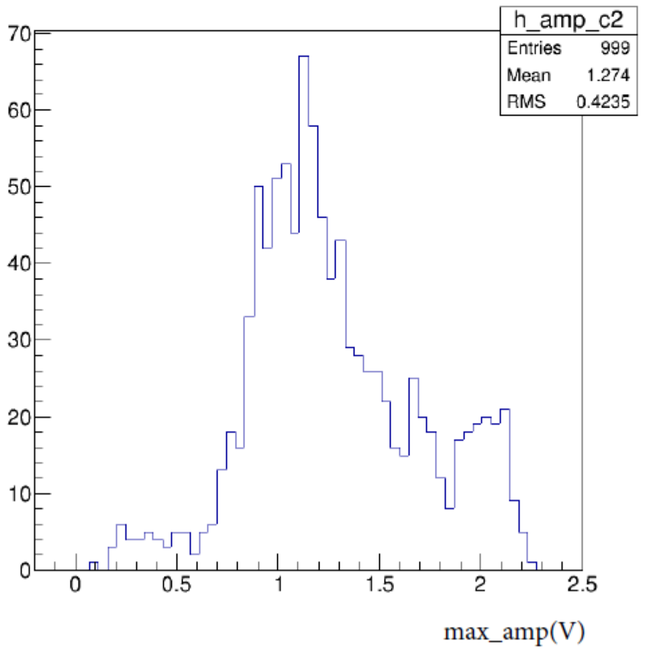
-20 C cfd 14% - σ_{TOT}

Thickness: 285 μm T:-20°C Vbias:300V Radiation dose: 2.3e15 1MeV N_{eq}/cm^2

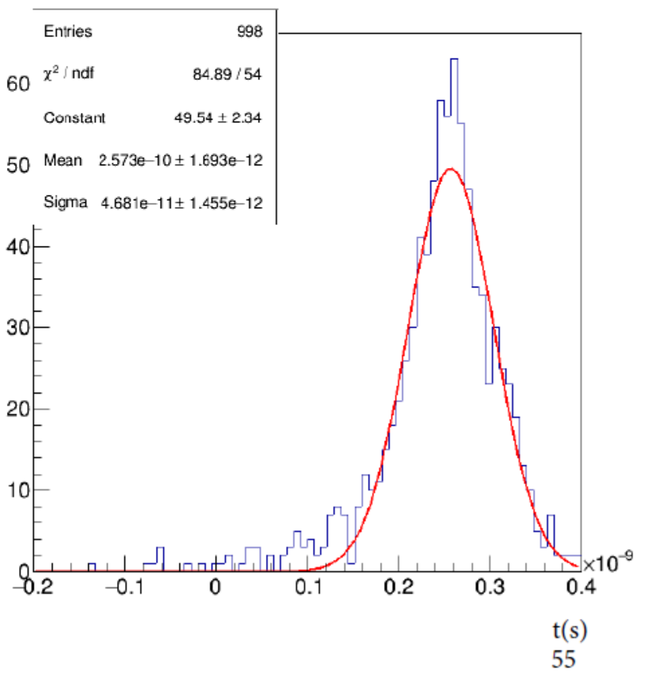
3D



LGAD



$\Delta t=t_{LGAD}-t_{3D}$



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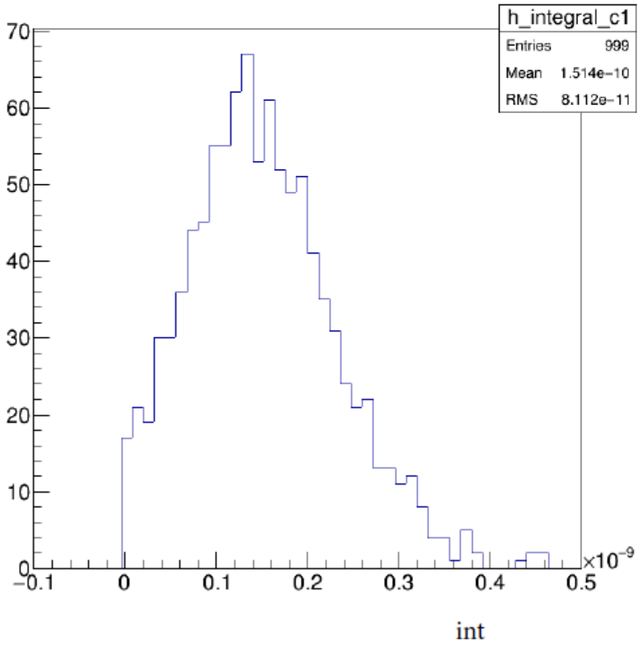
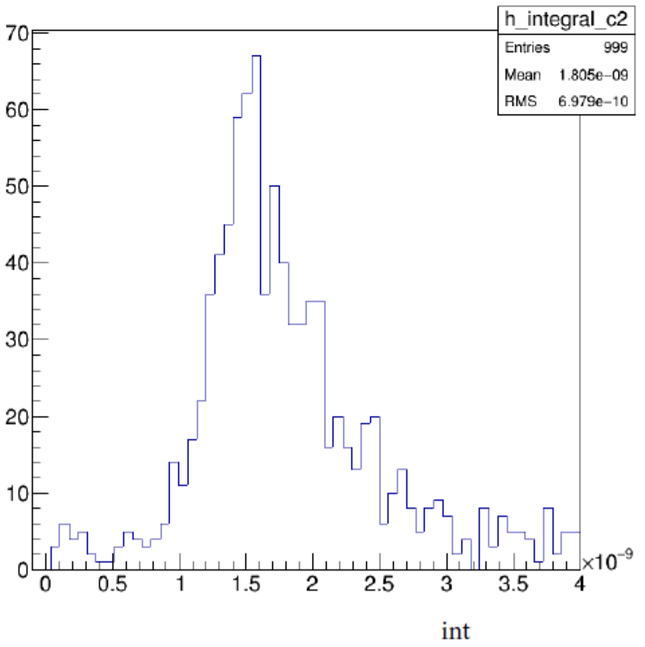
Thickness: 285 μm T:-20°C Vbias:300V Radiation dose: 2.3e15 1MeV N_{eq}/cm^2

3D

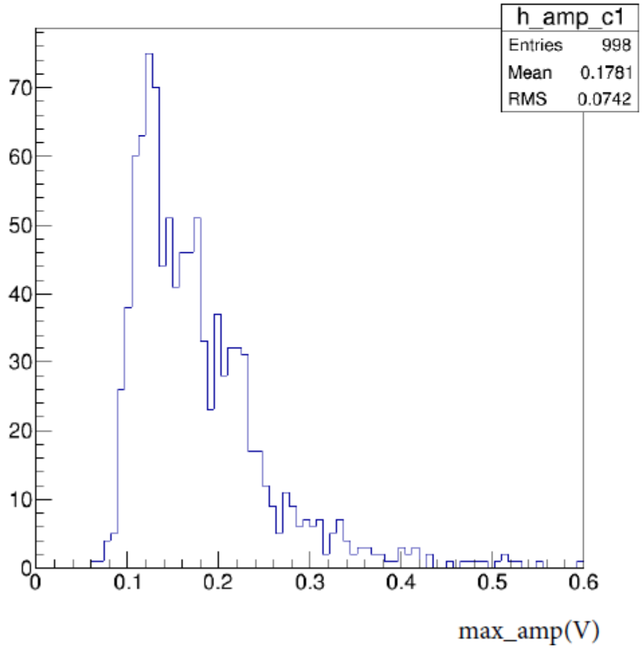


LGAD

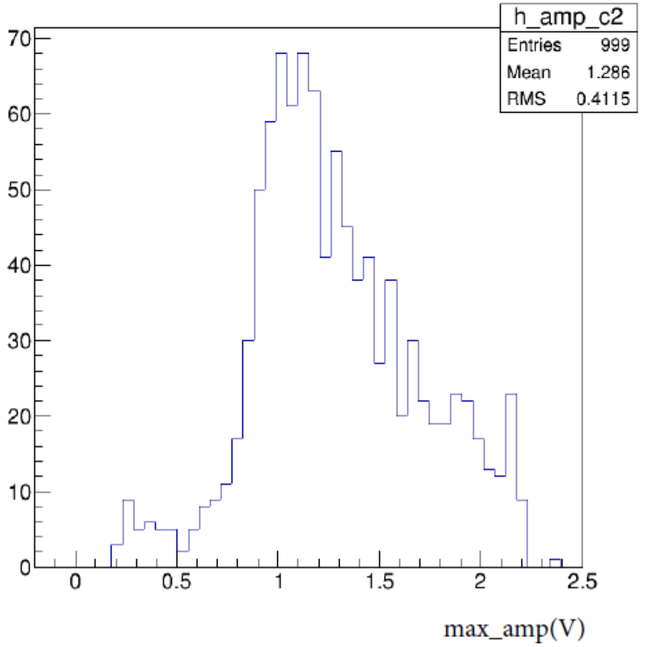


Thickness: 285 μm T:-20°C Vbias:100V Radiation dose: 2.3e15 1MeV N_{eq}/cm^2

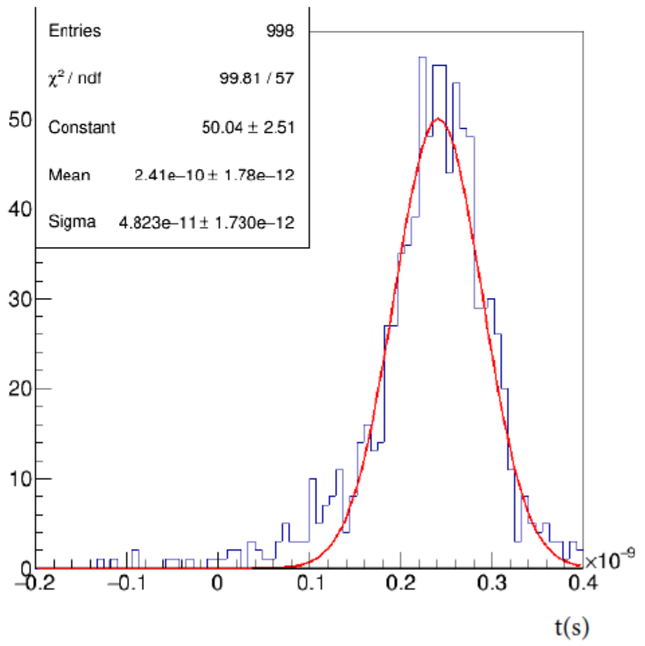
3D



LGAD

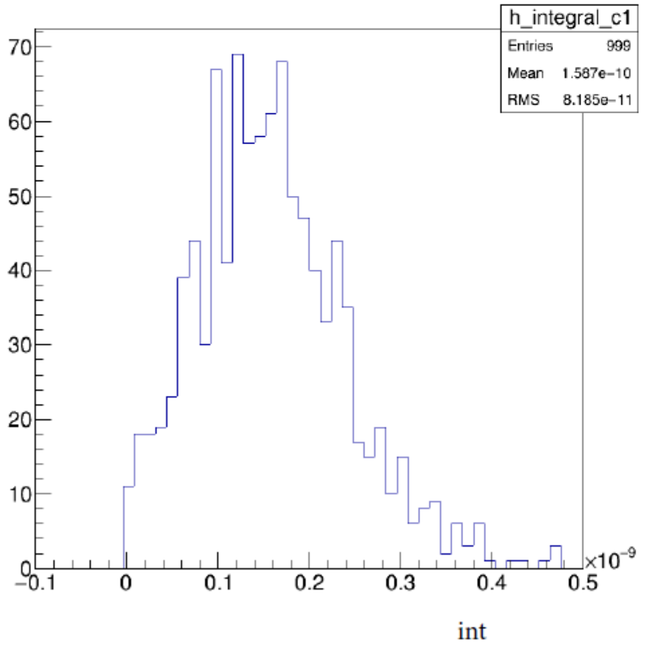


$\Delta t=t_{LGAD}-t_{3D}$

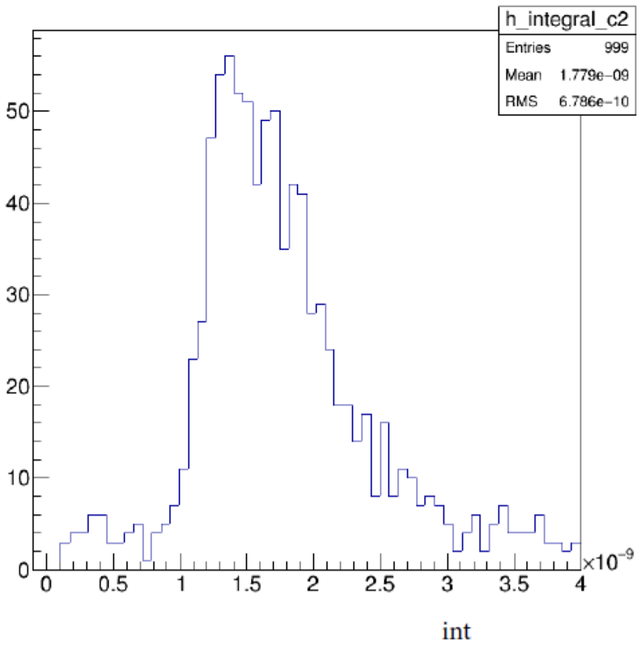


Thickness: 285 μm T:-20°C Vbias:100V Radiation dose: 2.3e15 1MeV N_{eq}/cm^2

3D



LGAD



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

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

+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