Photon collection time simulation and comparison with laboratory data

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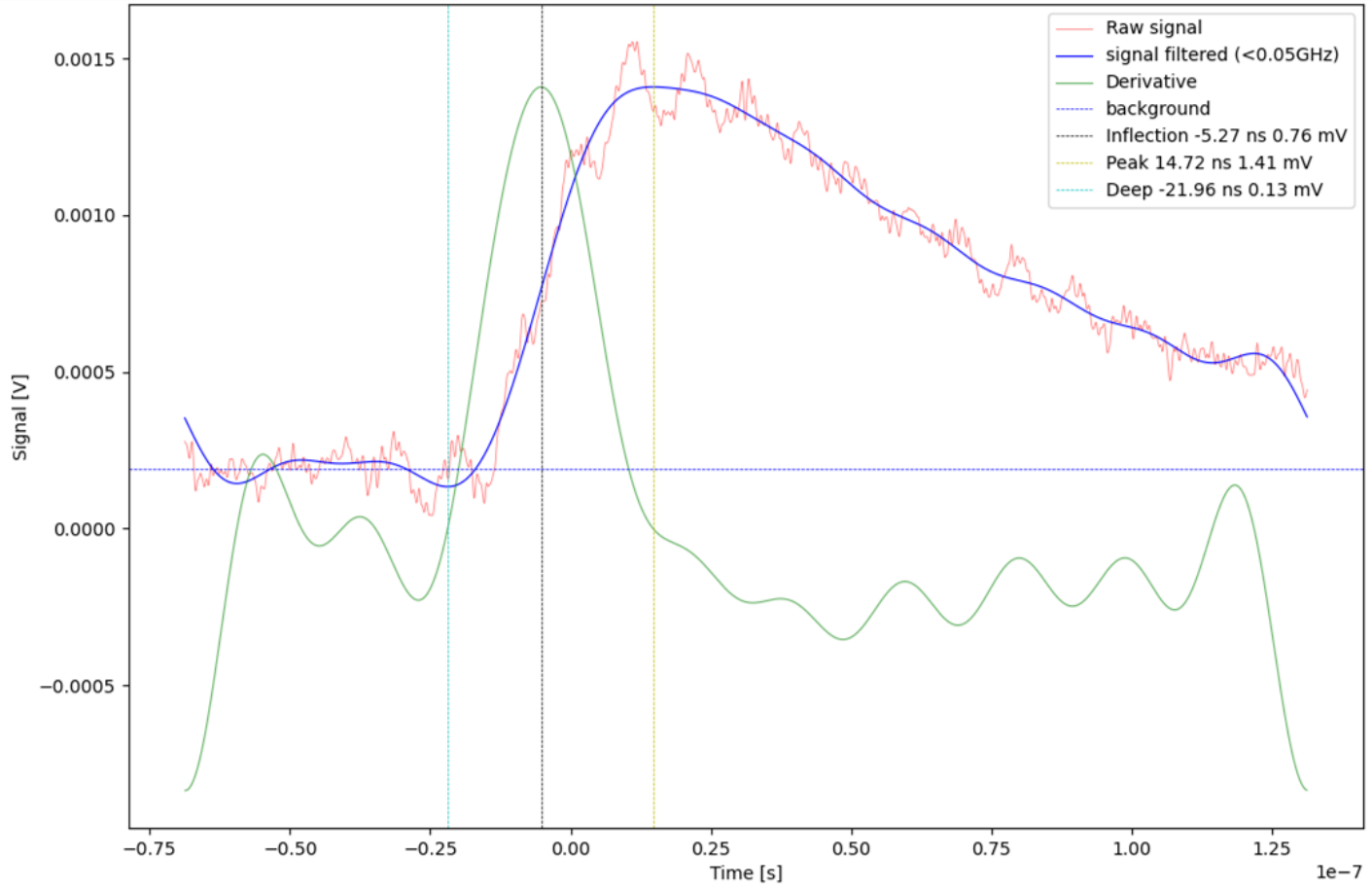
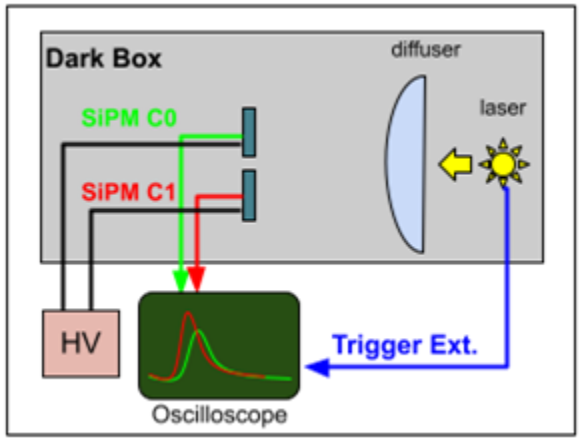
Time sampling: Analysis with derivative

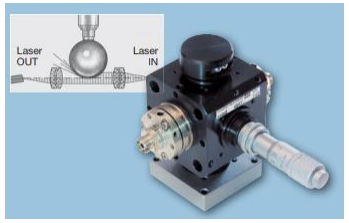


- Raw signal: Waveform was acquired with the Oscilloscope
- Signal filtered: Waveform was filtered with Low-pass filter **<50MHz**
- Derivative: The filtered waveform was analyzed in its first derivative
- Inflection**:** Time was sample in the peak of the derivative; the inflection point of the signal (this value is very close to the **50%** of the Signal amplitude)
- Peak: Is the first peak of the filtered function after the inflection
- Deep: Is the first deep of the filtered function before the inflection

Lab Tests: Laser SetUp



Laser PiLas
Tune 50%
Pulsed 20 Hz
Diffuser thorlabs ED1-S50_MD
Attenuation with pinhole 2.5 mm
Distance from device ~20 cm
Fiber QSMJ-3A3S-400-3/125-3-1
Length 1 m



Configuration 1)
- C0 -> 1 X SiPM AdvanSid nuv 1x1 mm^2
- C1 -> 1 X SiPM AdvanSid nuv 1x1 mm^2
- DAQ: Oscilloscope R&S 6GHz 20GS
- Trigger: External from laser
- HV: 30.50 V (+2.5 OV)

Configuration 2)
- C0 -> 1 X SiPM AdvanSid nuv 3x3 mm^2
- C1 -> 1 X SiPM AdvanSid nuv 3x3 mm^2
- DAQ: Oscilloscope R&S 6GHz 20GS
- Trigger: External from laser
- HV: 30.50 V (+2.5 OV)

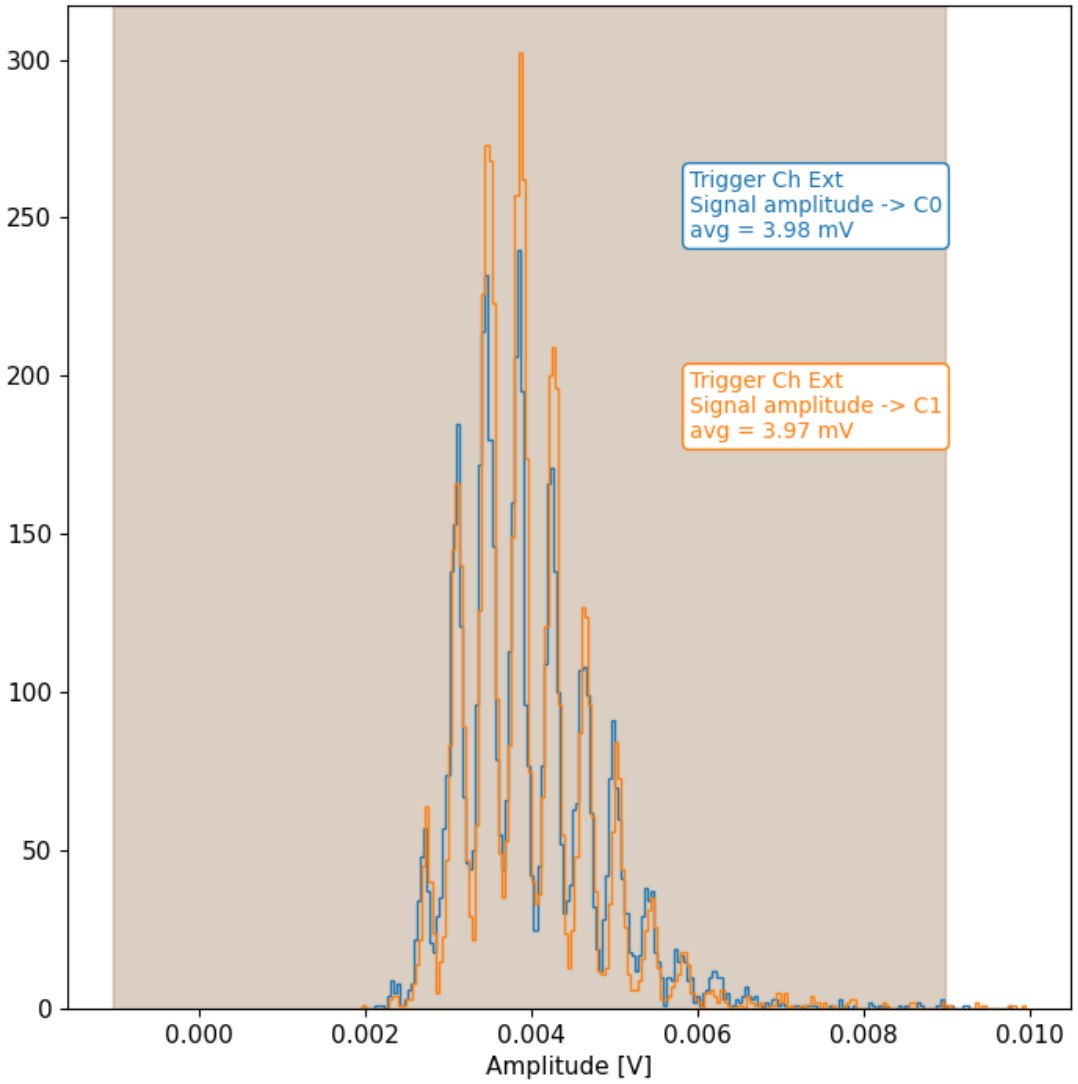
Configuration 3)
- C0 -> 3 X SiPM 3x3 mm^2 Hamamatsu OR S14160-1315 (Long pcb)
- C1 -> 3 X SiPM 1x1 mm^2 Hamamatsu OR S14160-3015 (Long pcb)
- DAQ: Oscilloscope LeCroy 1GHz 20GS
- Trigger: External from laser
- HV: 42.00 V (+4 OV)

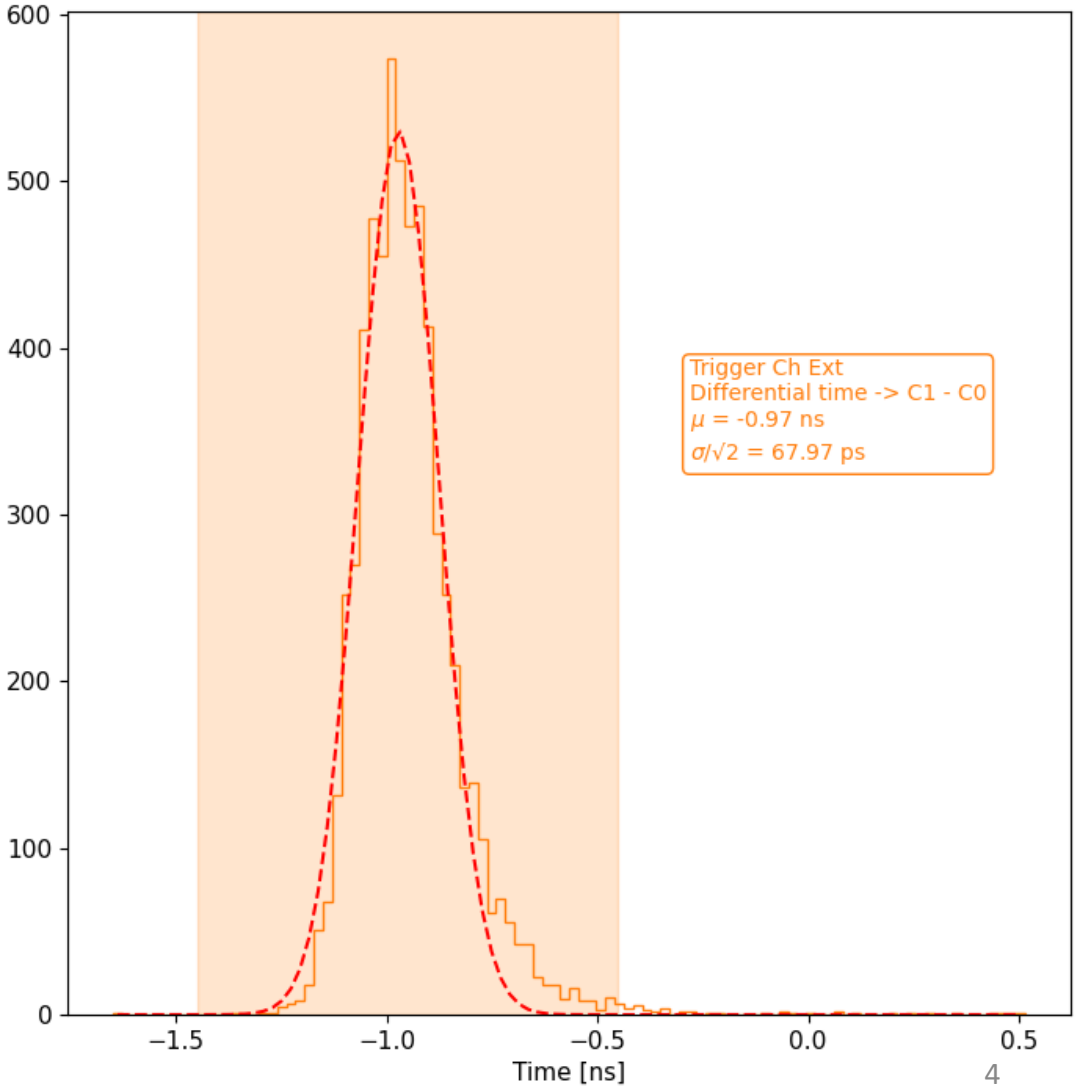
Lab Tests: Laser SetUp -> AdvanSiD 1x1 mm^2

- Laser Source SiPM AdvanSiD 1x1 nuv - 30.5 HV - Amplitude distribution

- Laser Source SiPM AdvanSiD 1x1 nuv - 30.5 HV - Inflection position

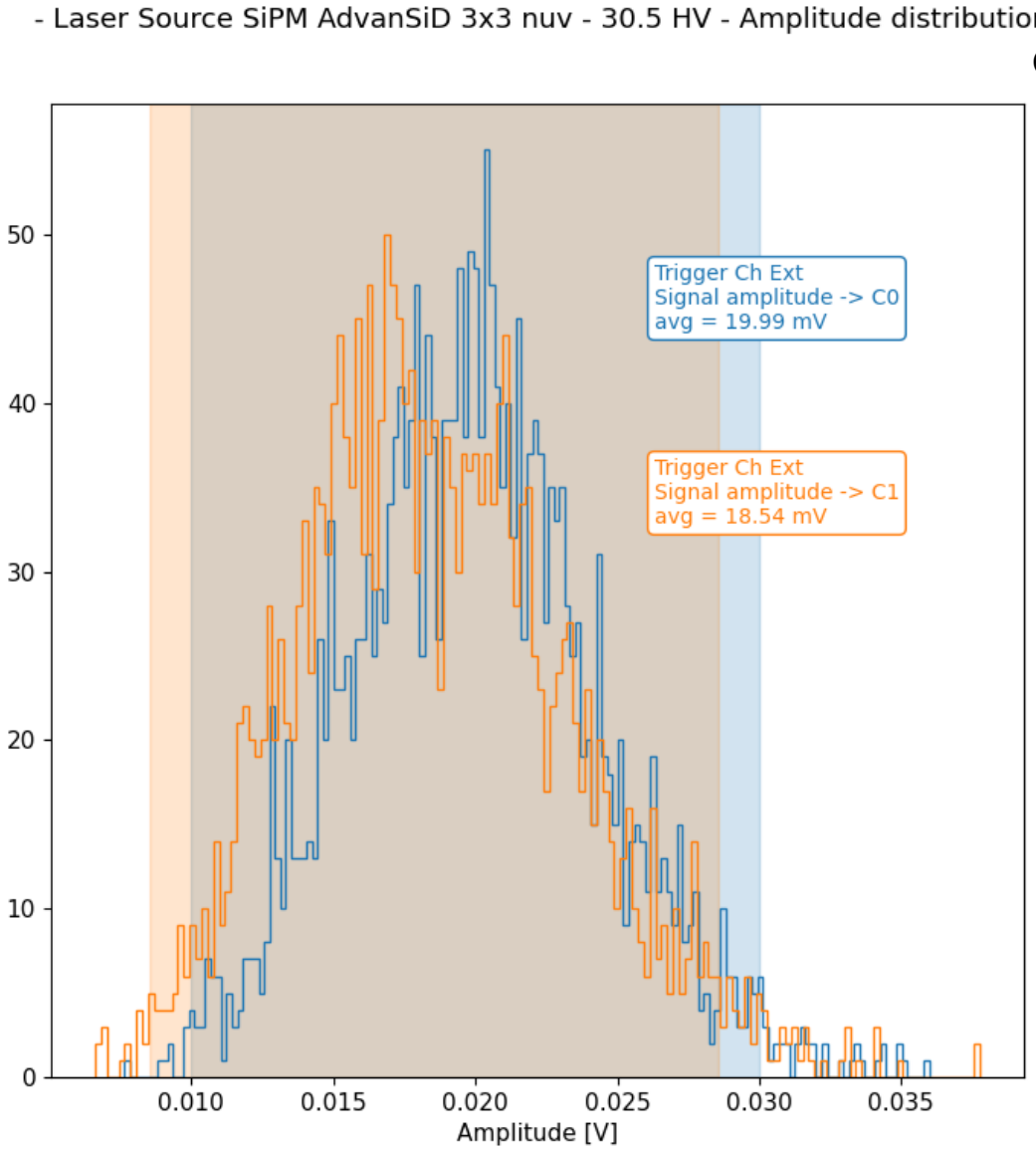
Configuration 1

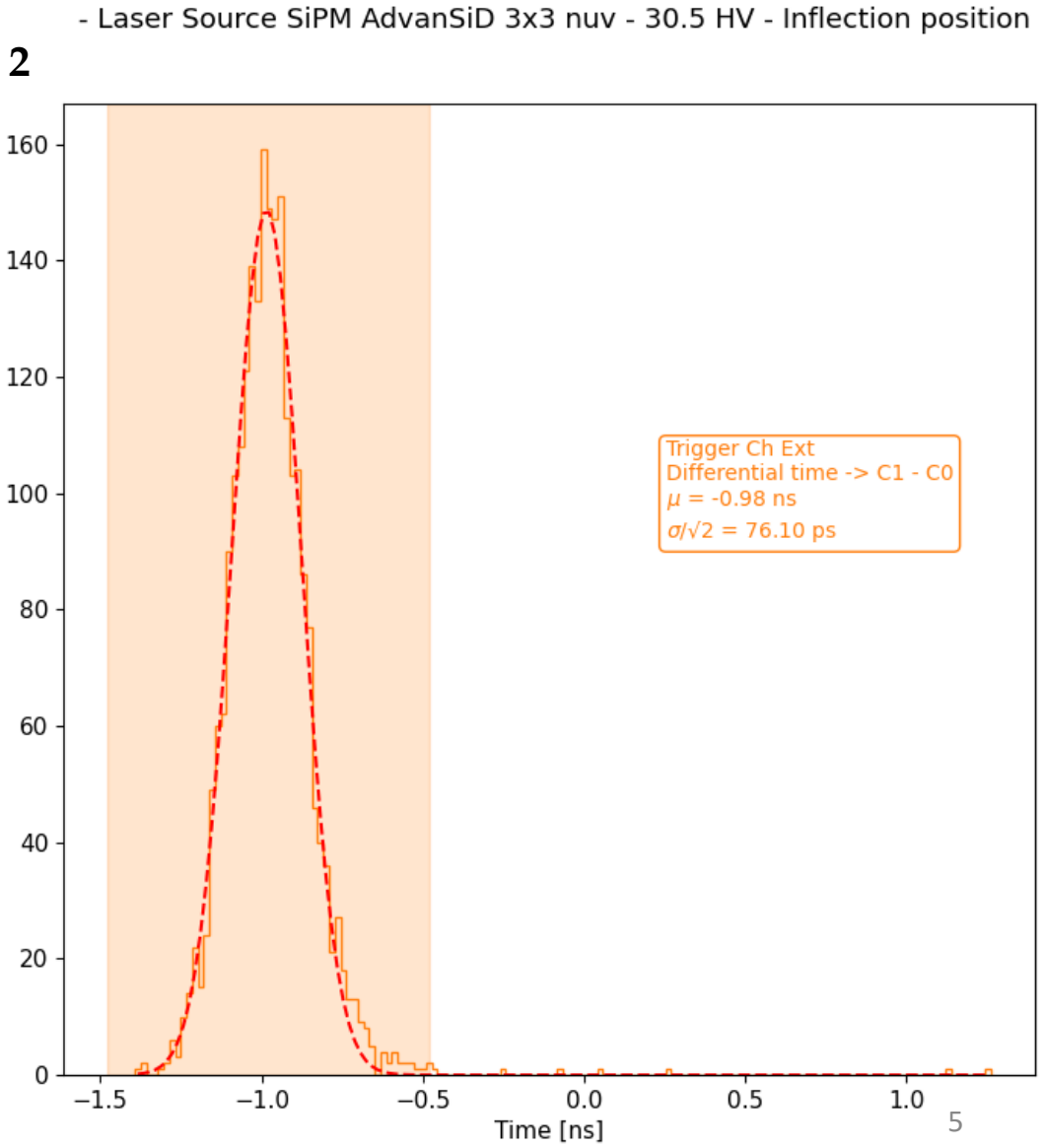




Lab Tests: Laser SetUp -> AdvanSiD 3x3 mm^2

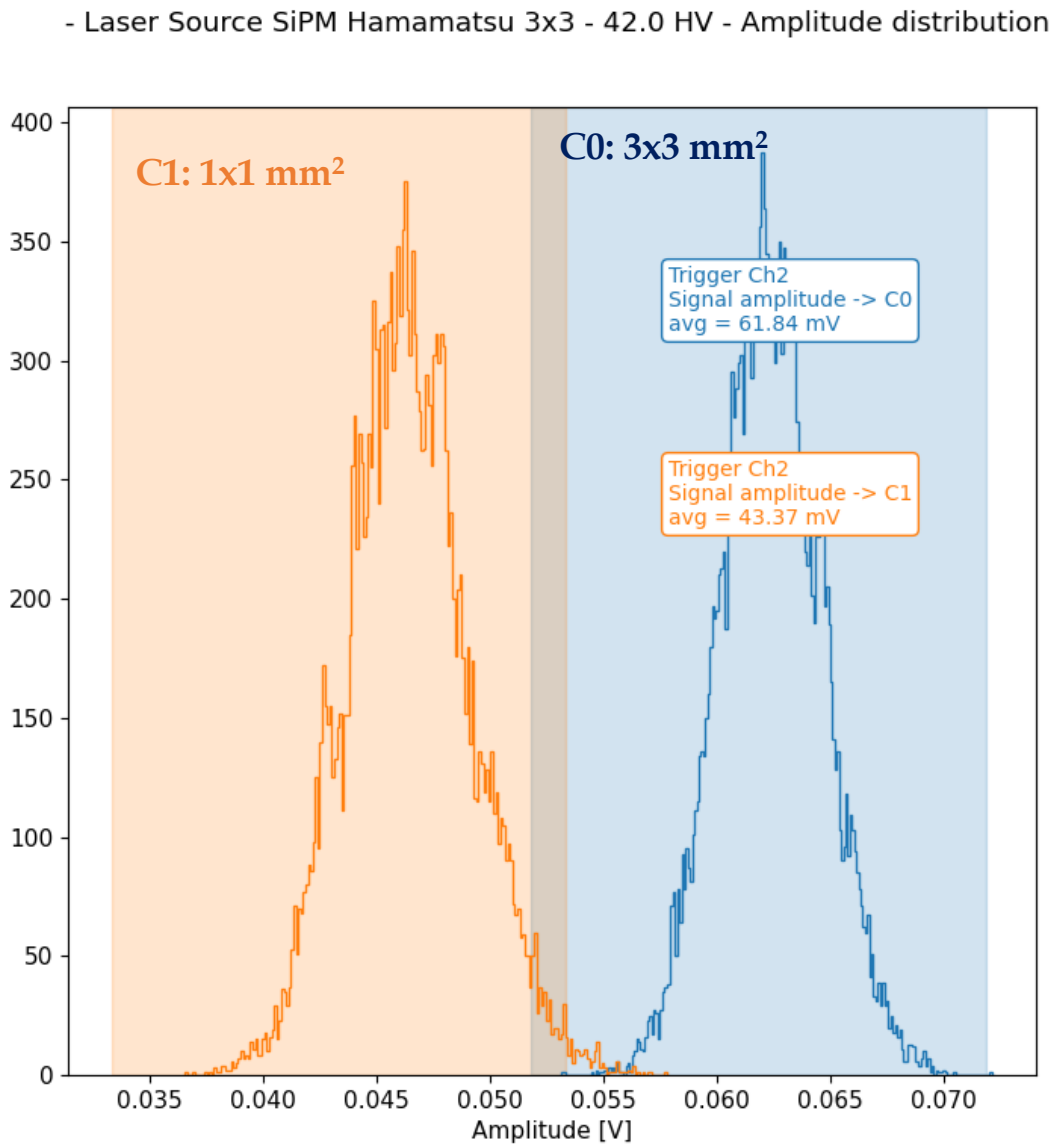
Configuration 2

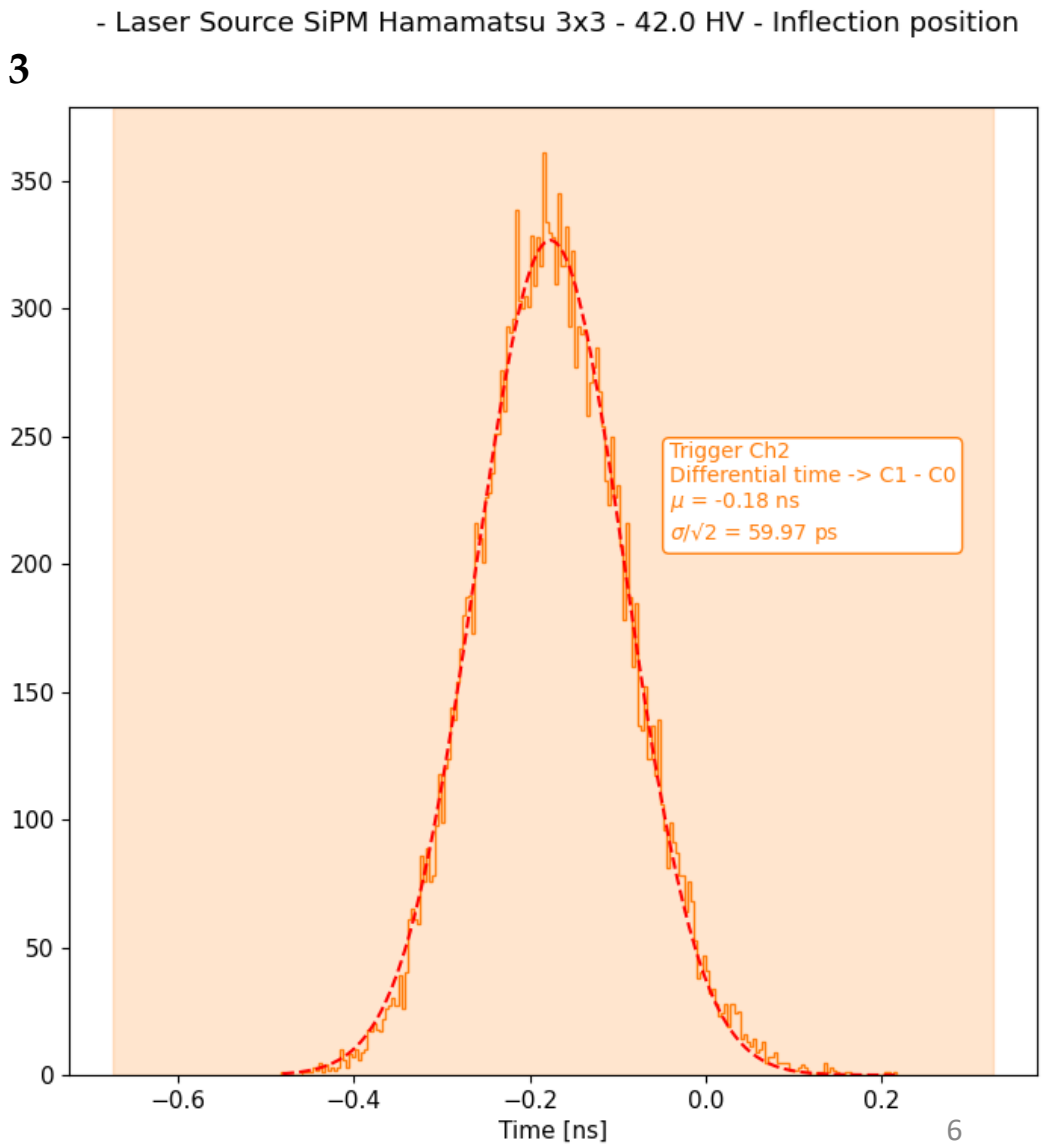




Lab Tests: Laser SetUp -> Hamamatsu pcb 3x 1x1 mm^2 and 3x 3x3 mm^2

Configuration 3

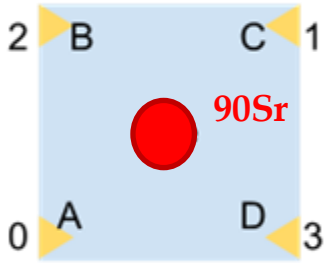




Lab Tests: Results for laser configuration

Source	SiPM	Size	HV	$\sigma/\sqrt{2}$ [ps]
Laser	AdvanSiD	1 X 1x1 mm^2	30.50	68
Laser	AdvanSiD	1 X 3x3 mm^2	30.50	76
Laser	Hamamatsu	3 X 1x1 mm^2 Vs 3 X 3x3 mm^2	42.00	60

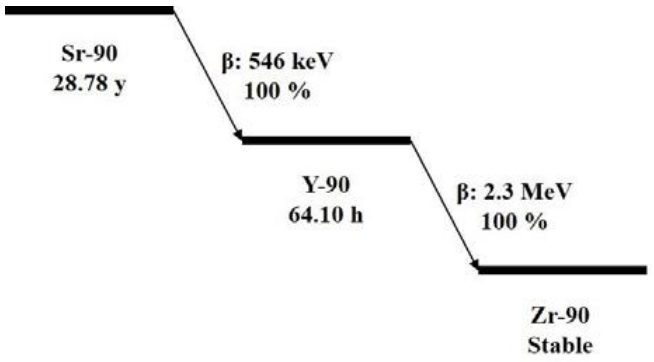
Lab Tests: 90Sr SetUp



Configuration 4)

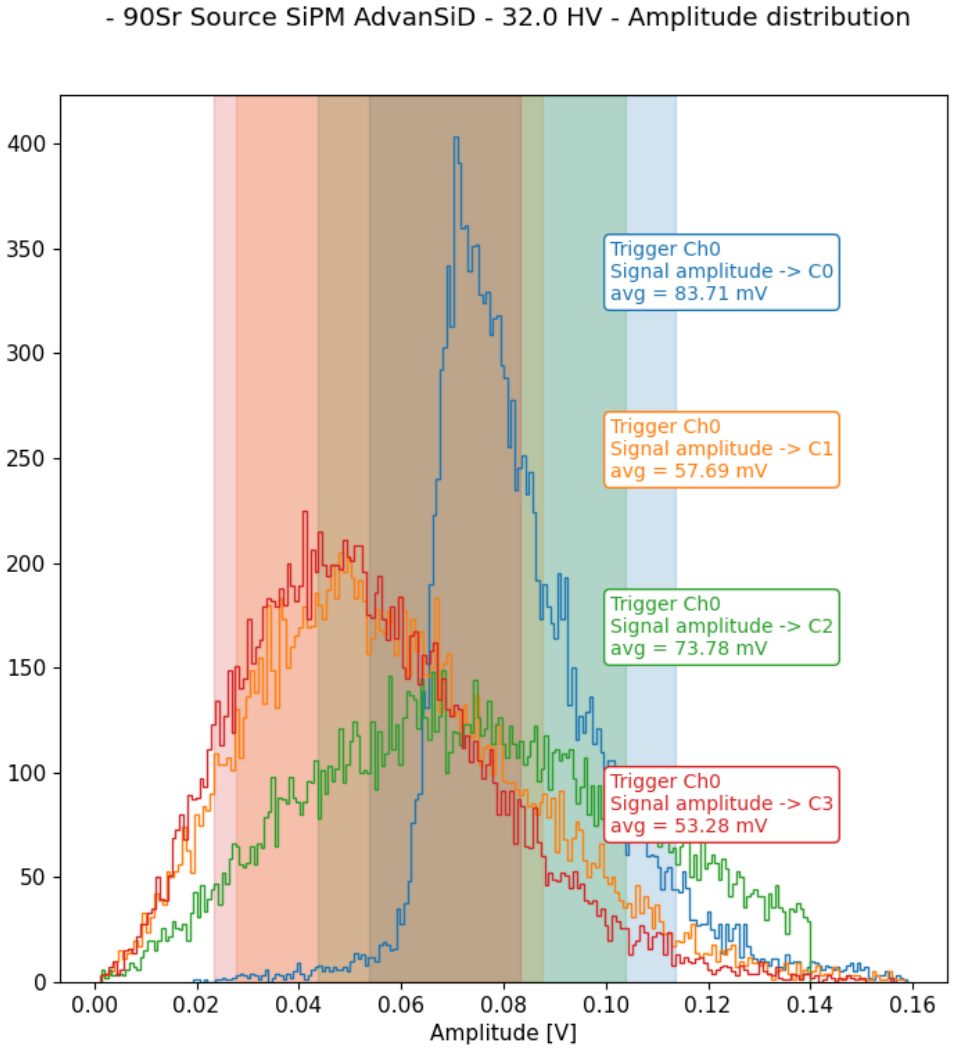
C0 -> 1 X SiPM AdvanSiD nuv 3x3 mm^2
C1 -> 1 X SiPM AdvanSiD nuv 3x3 mm^2
C2 -> 1 X SiPM AdvanSiD nuv 3x3 mm^2
C3 -> 1 X SiPM AdvanSiD nuv 3x3 mm^2
DAQ: Oscilloscope LeCroy 1GHz 20GS
Trigger: C0 (Threshold 67mV)
HV: 32.00 V (+4 OV)

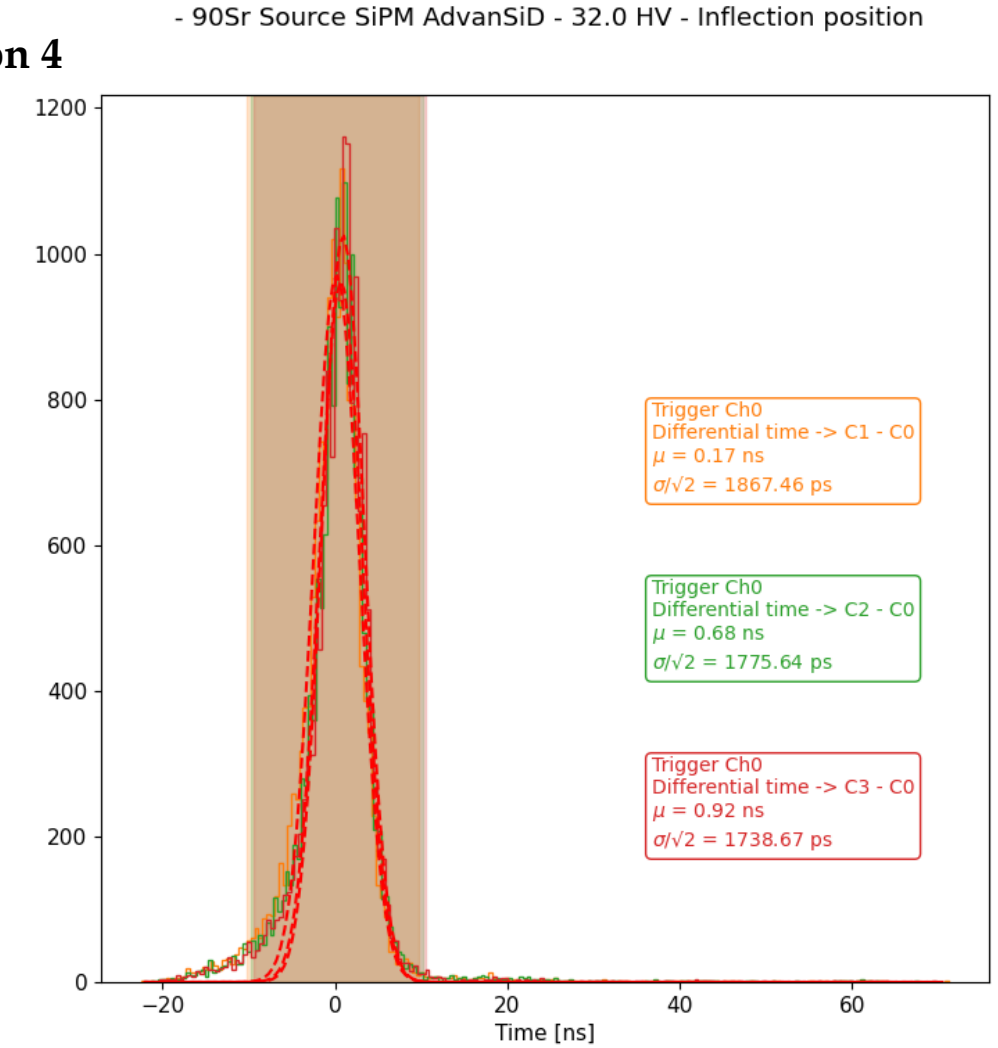
90Sr Source
2 MBq



Lab Tests: 90Sr SetUp -> Advansid 3x3 mm^2

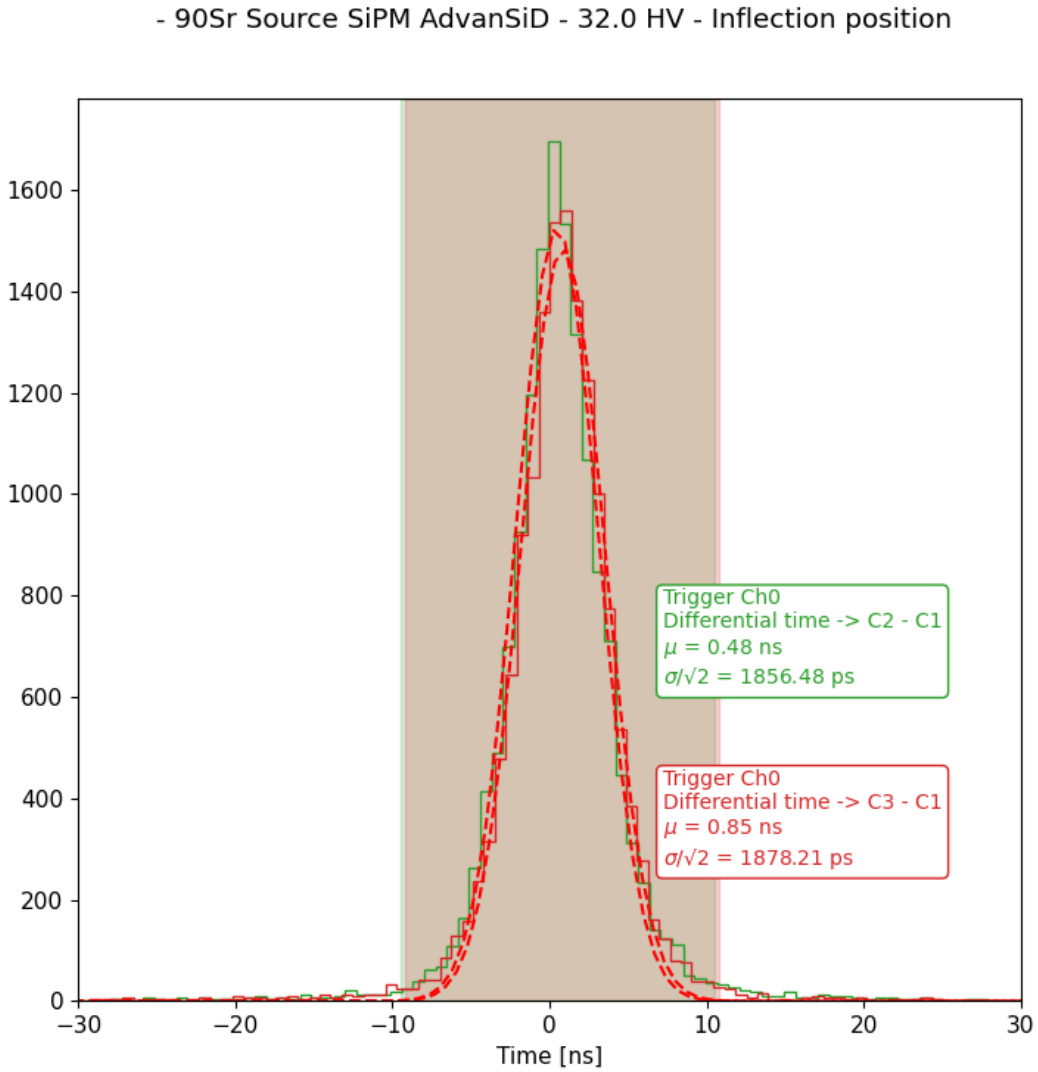
Configuration 4

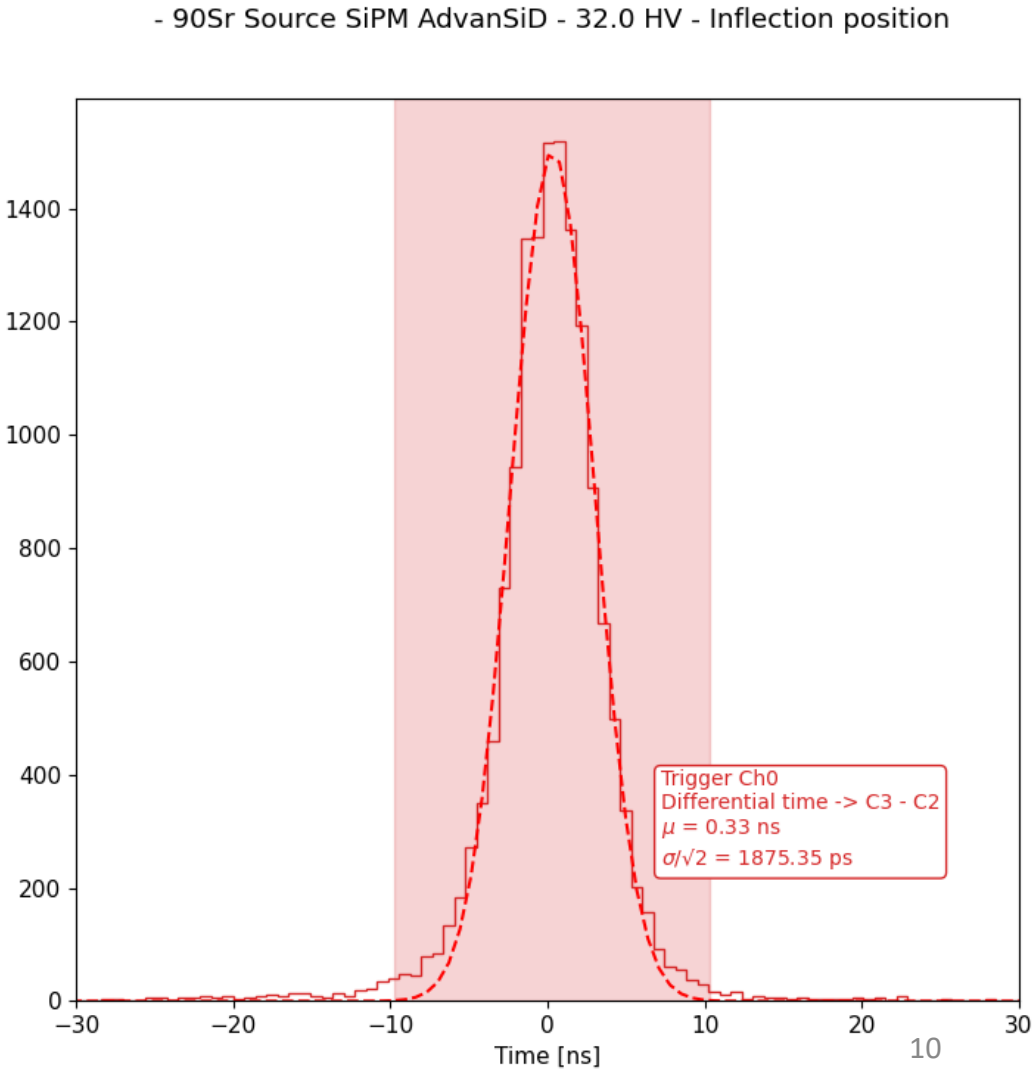




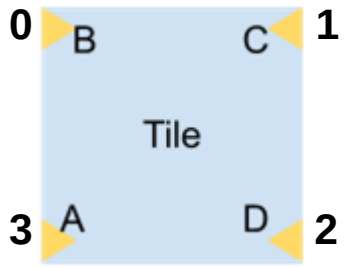
Lab Tests: 90Sr SetUp -> Advansid 3x3 mm^2

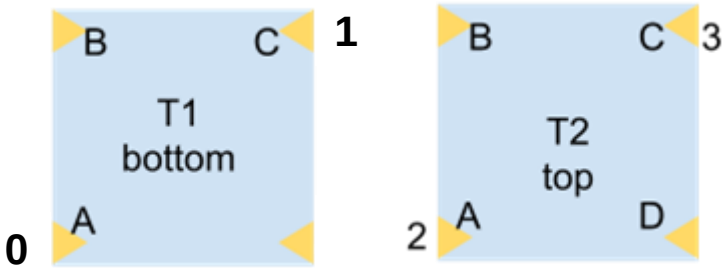
Configuration 4





Lab Tests: CR SetUp





Configuration 5)

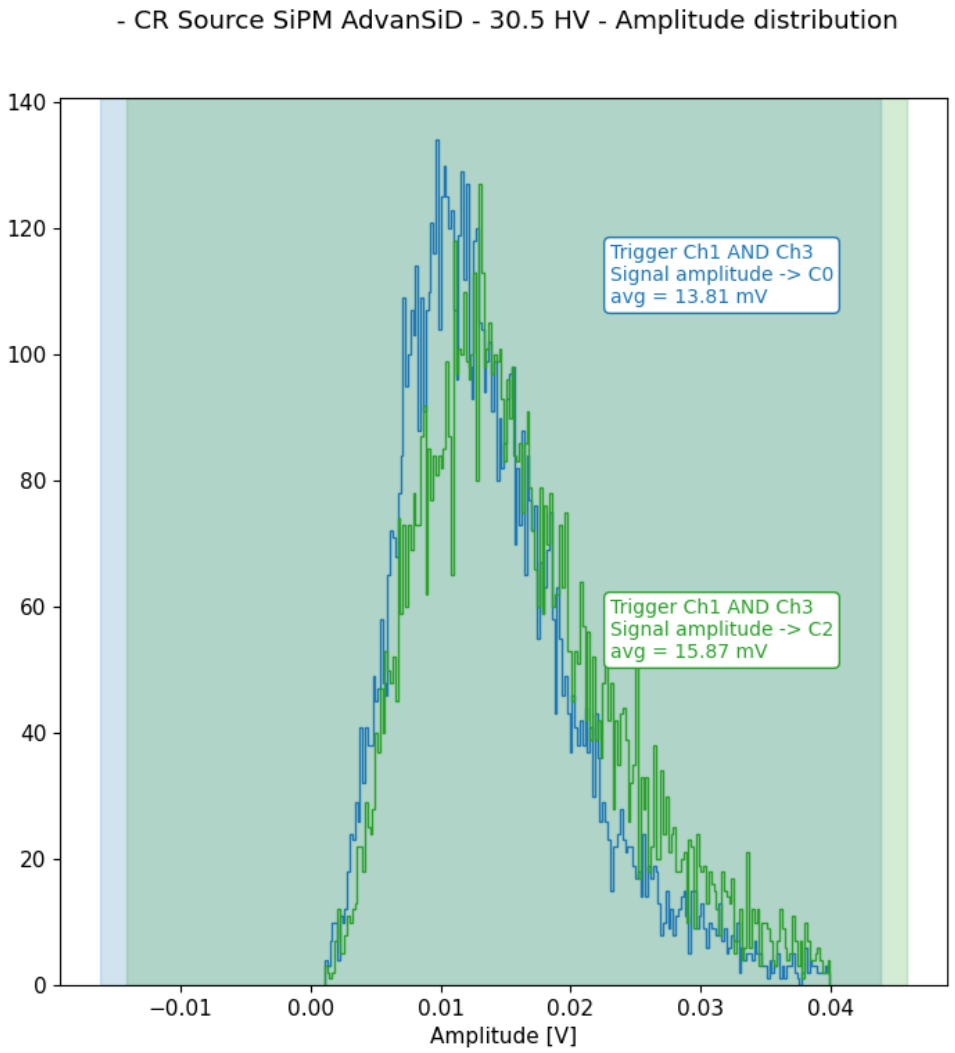
C0 -> 1 X SiPM AdvanSiD nuv 3x3 mm^2
C1 -> 1 X SiPM AdvanSiD nuv 3x3 mm^2
C2 -> 1 X SiPM AdvanSiD nuv 3x3 mm^2
C3 -> 1 X SiPM AdvanSiD nuv 3x3 mm^2
DAQ: Oscilloscope R&S 6GHz 20GS
Trigger: C1 AND C3 (NIM)
HV: 30.50 V (+2.5 OV)

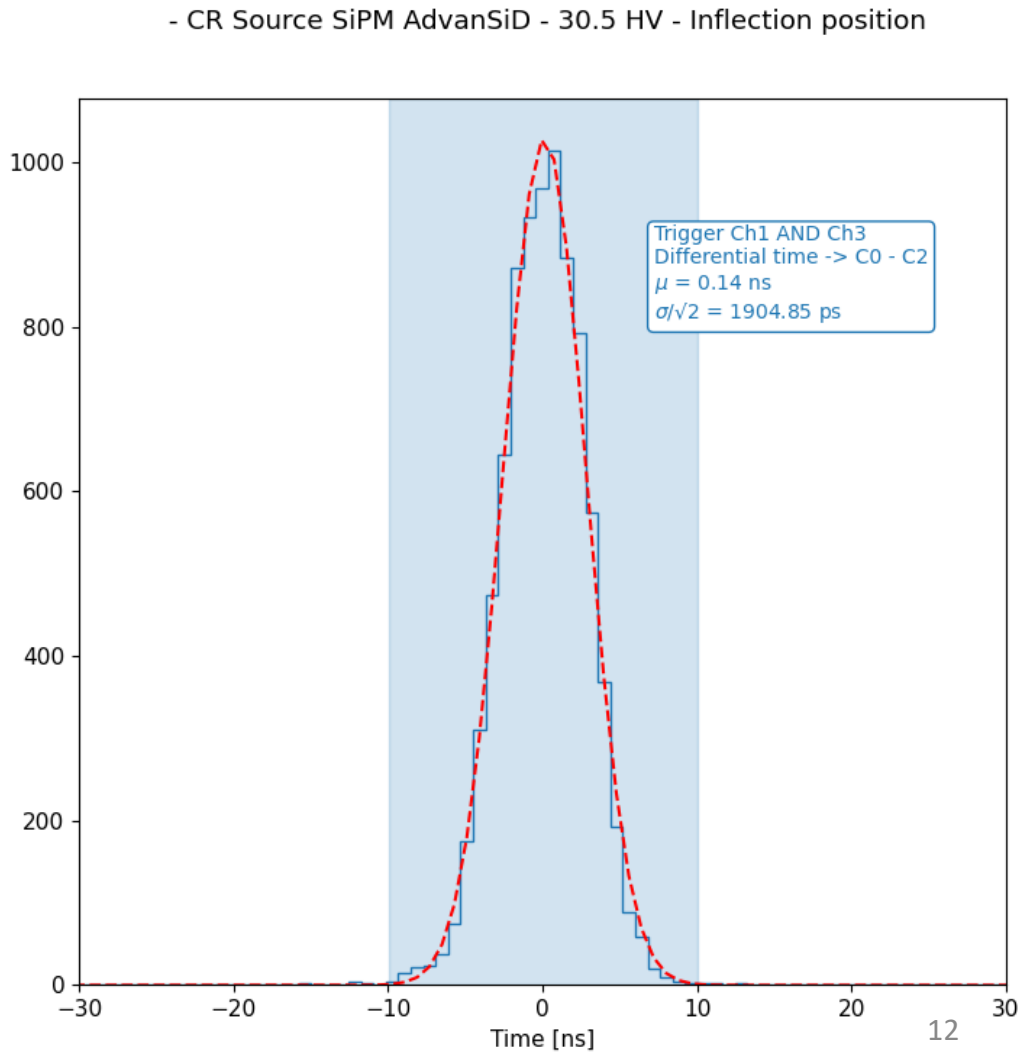
Configuration 6)

C0 -> 3 X SiPM 3x3 mm^2 Hamamatsu OR S14160-1315 (Long pcb)
C1 -> 3 X SiPM 3x3 mm^2 Hamamatsu OR S14160-1315 (Long pcb)
C2 -> 3 X SiPM 3x3 mm^2 Hamamatsu OR S14160-1315 (Long pcb)
C3 -> 3 X SiPM 3x3 mm^2 Hamamatsu OR S14160-1315 (Long pcb)
DAQ: Oscilloscope LeCroy 1GHz 20GS
Trigger: C0 AND C1 (Threshold 0.8 mV)
HV: 42.24 V (+4.24 OV)

Lab Tests: CR SetUp -> Advansid 3x3 mm^2

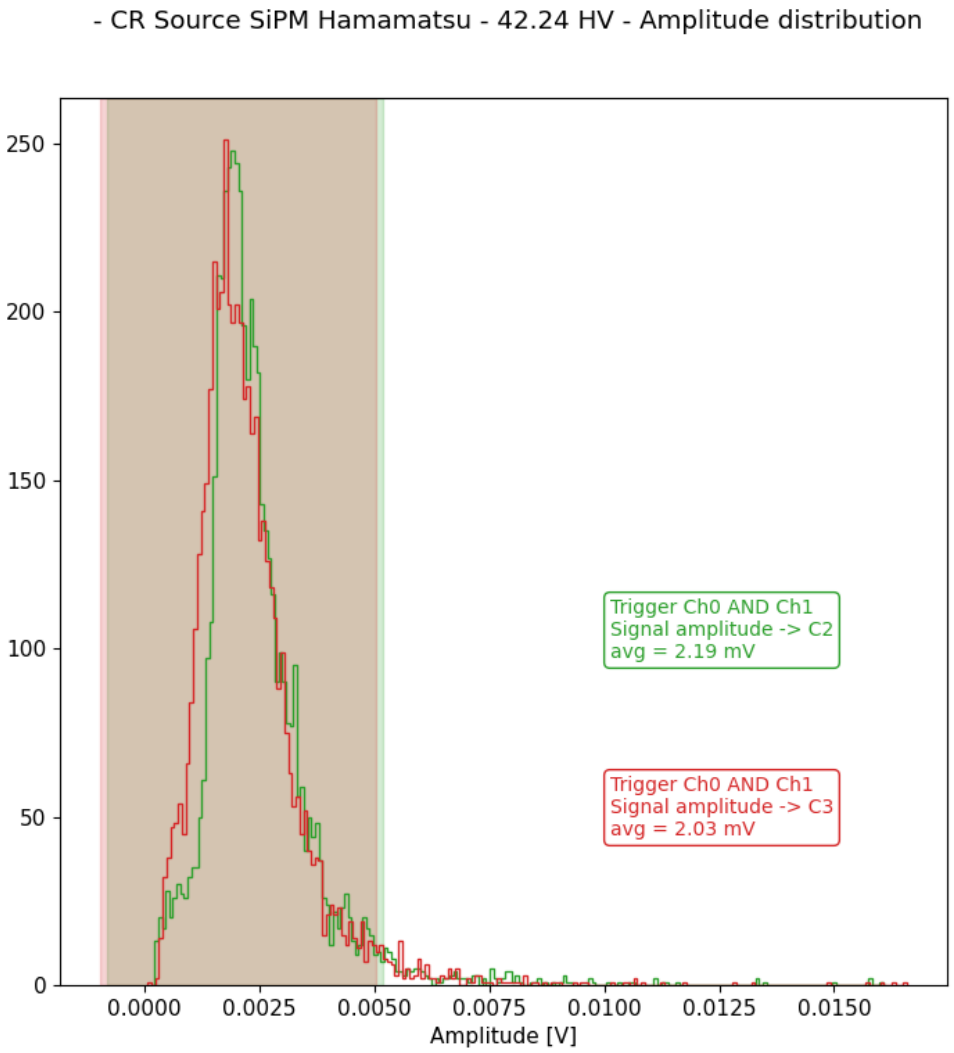
Configuration 5

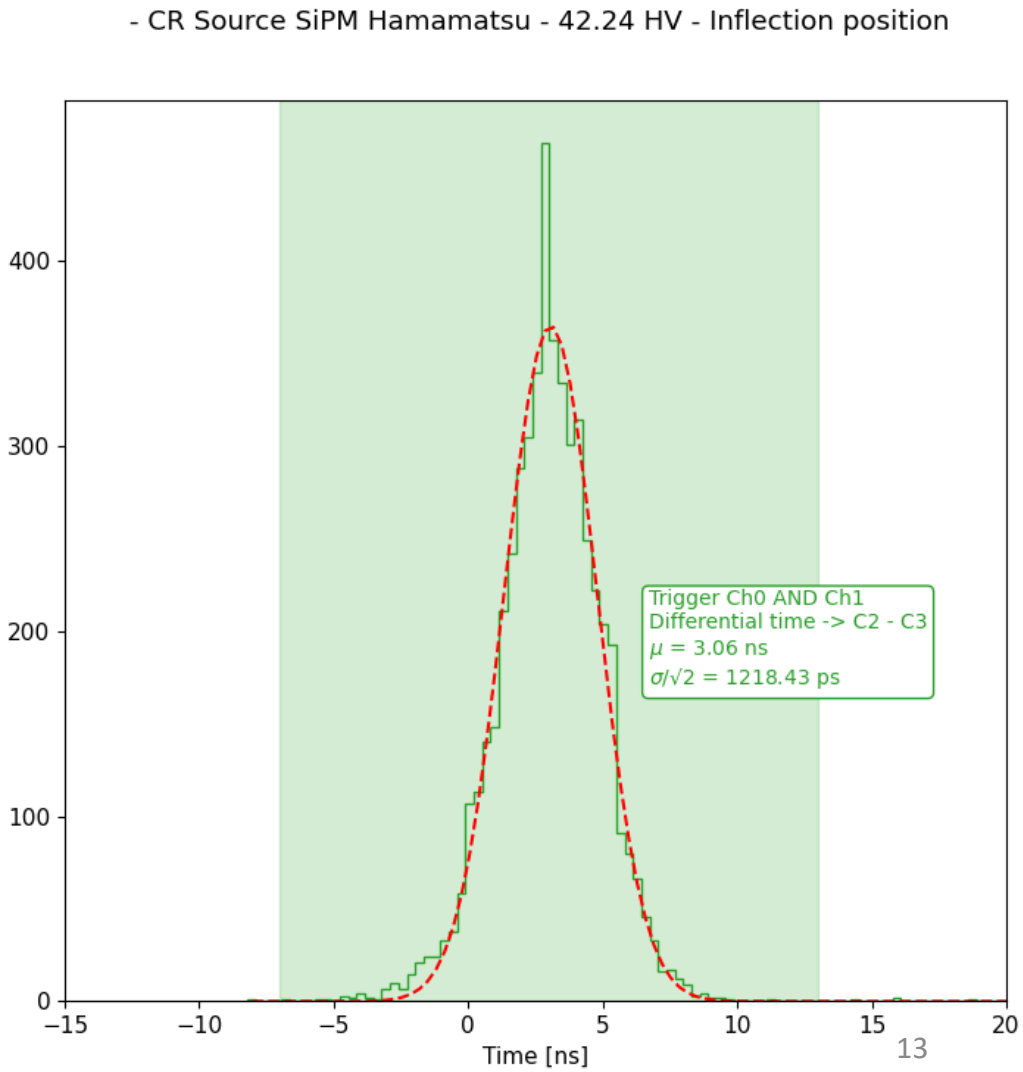




Lab Tests: CR SetUp -> Hamamatsu 3x3 mm^2

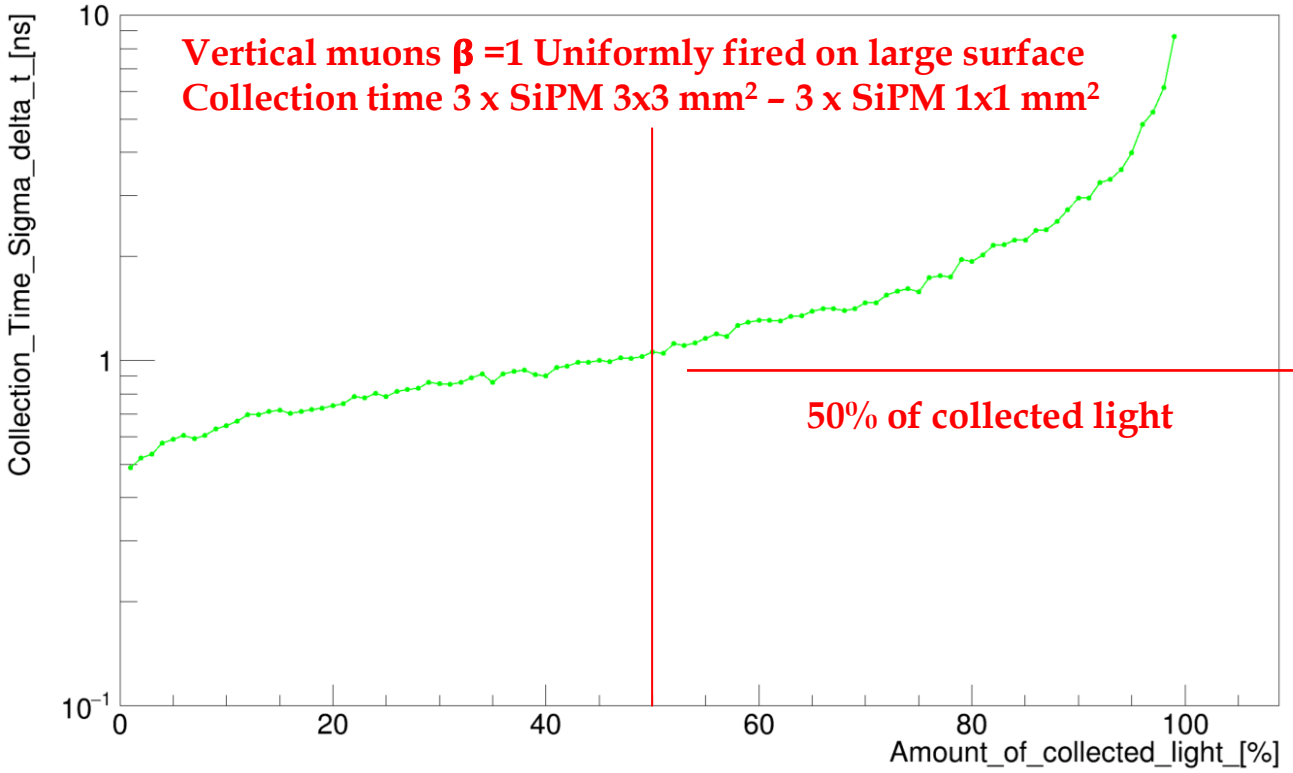
Configuration 6

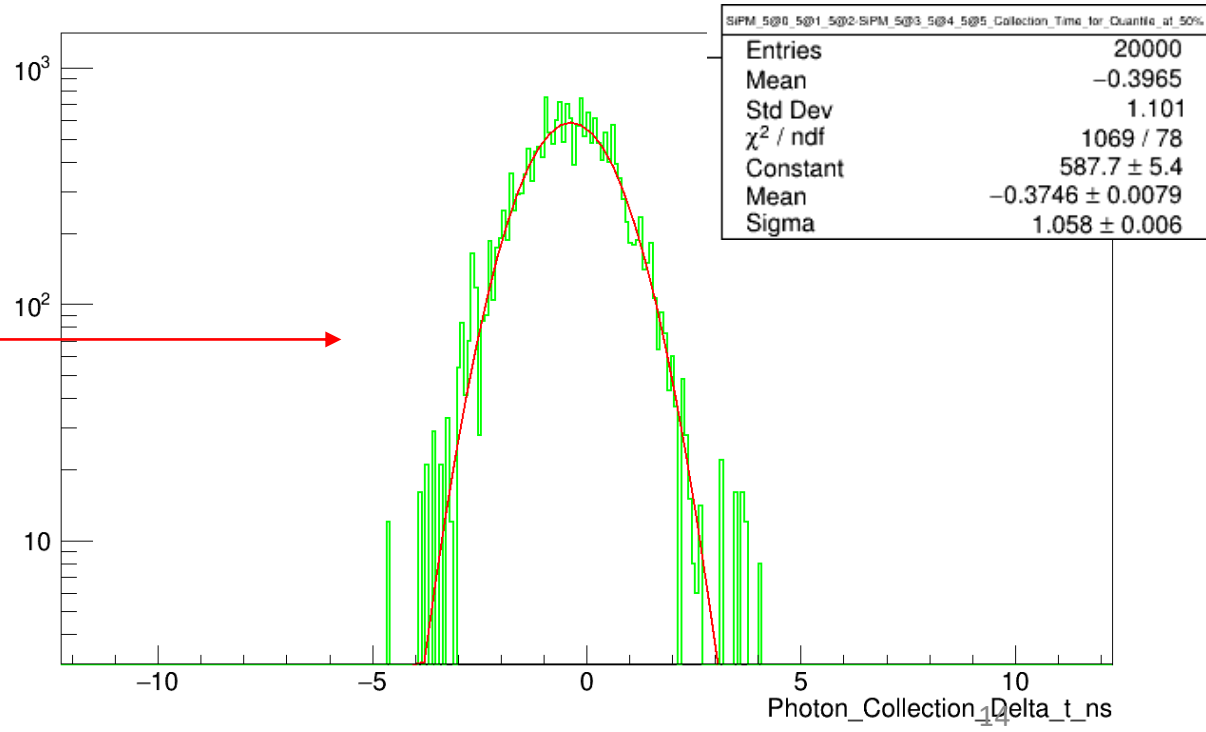




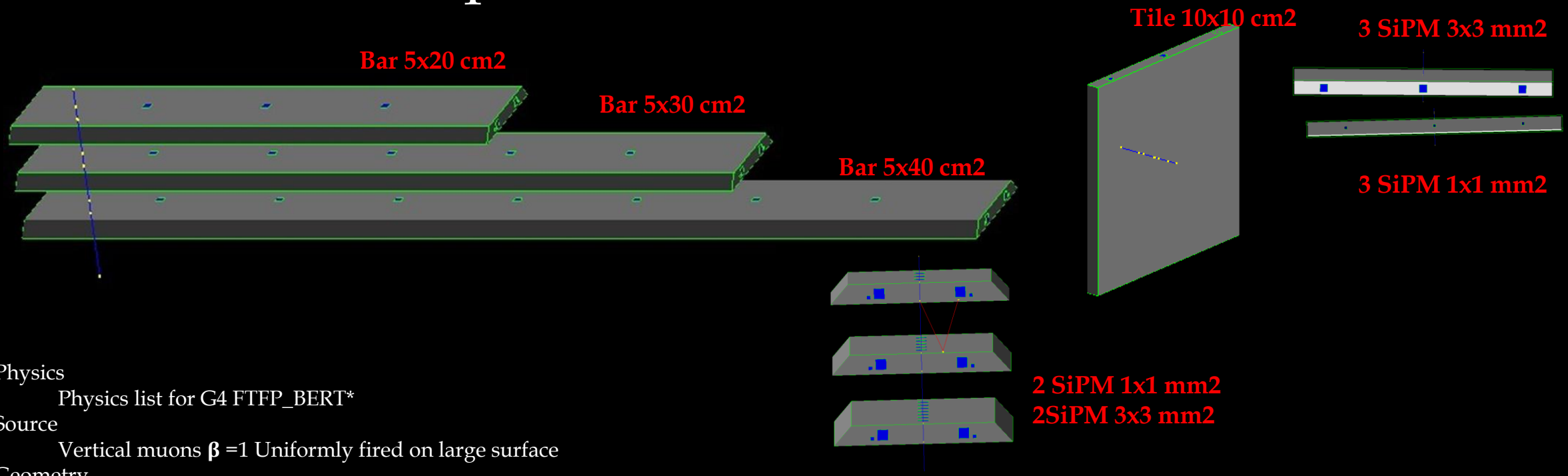
Lab Tests: Results

Source	SiPM	Size	HV	$\sigma/\sqrt{2}$ [ps]
Laser	AdvanSiD	1 X 1x1 mm^2	30.50	68
Laser	AdvanSiD	1 X 3x3 mm^2	30.50	76
Laser	Hamamatsu	3 X 1x1 mm^2 Vs 3 X 3x3 mm^2	42.00	60
90Sr	AdvanSiD	1 X 3x3 mm^2	32.00	1870
CR	AdvanSiD	1 X 3x3 mm^2	30.50	1941
CR	Hamamatsu	3 X 3x3 mm^2	42.24	1235
Mu+	Simulation	3 X 1x1 mm^2 Vs 3 X 3x3 mm^2		748





Simulation SetUp



Physics

Physics list for G4 FTFP_BERT*

Source

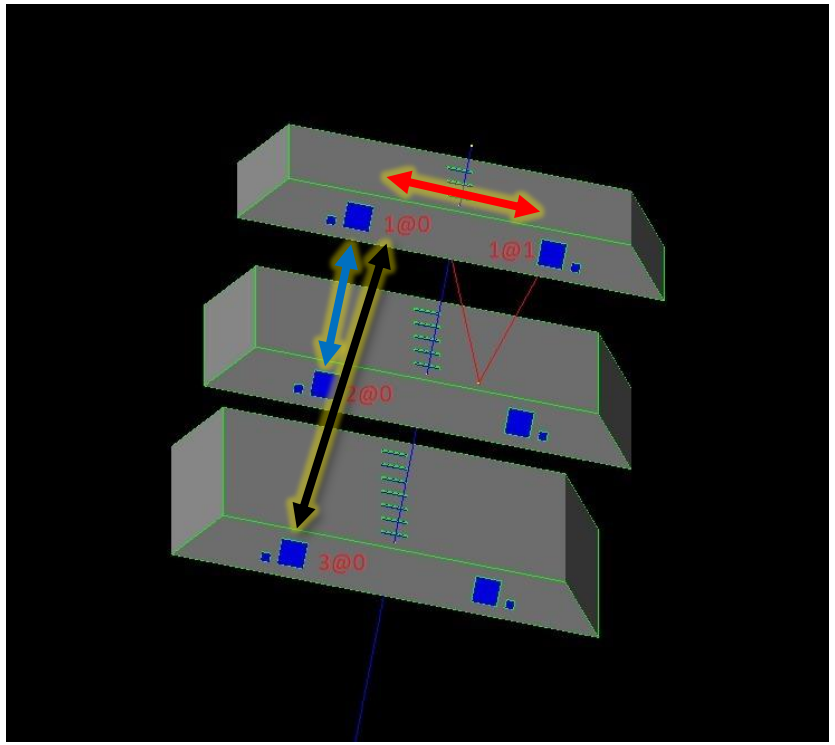
Vertical muons **β** =1 Uniformly fired on large surface

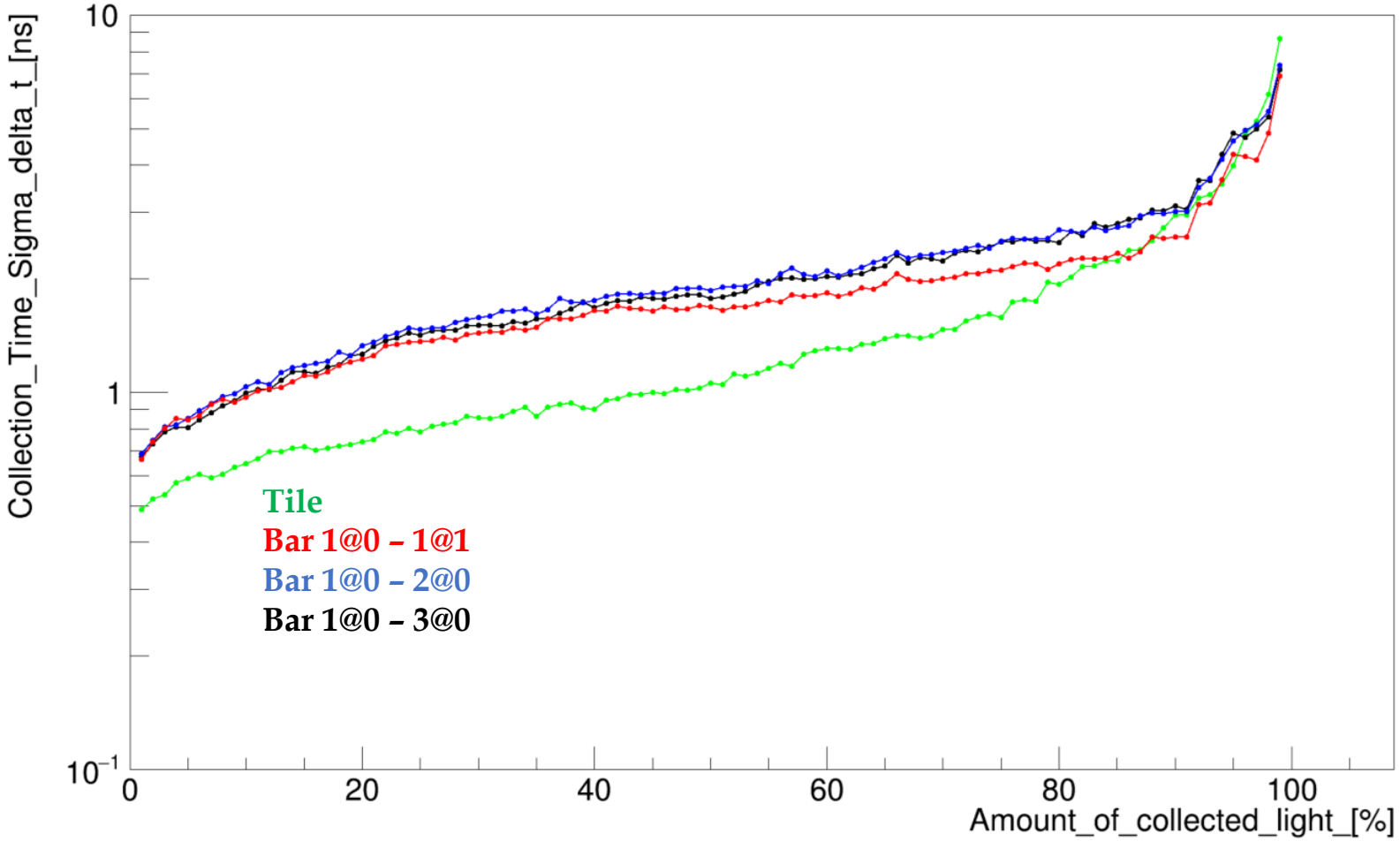
Geometry

1) Tile 10x10x0.5 cm3 -> 3 SiPM 3x3 mm2 on Top + 3 SiPM 1x1 mm2 on Bottom
2) Bar A 5x20x0.5 cm3 -> 4 SiPM on large side + 8 SiPM (4 3x3 and 4 1x1) on small sides (4SiPM for each side)
3) Bar B 5x30x0.5 cm3 -> 6 SiPM on large side + 8 SiPM (4 3x3 and 4 1x1) on small sides (4SiPM for each side)
4) Bar C 5x40x0.5 cm3 -> 8 SiPM on large side + 8 SiPM (4 3x3 and 4 1x1) on small sides (4SiPM for each side)

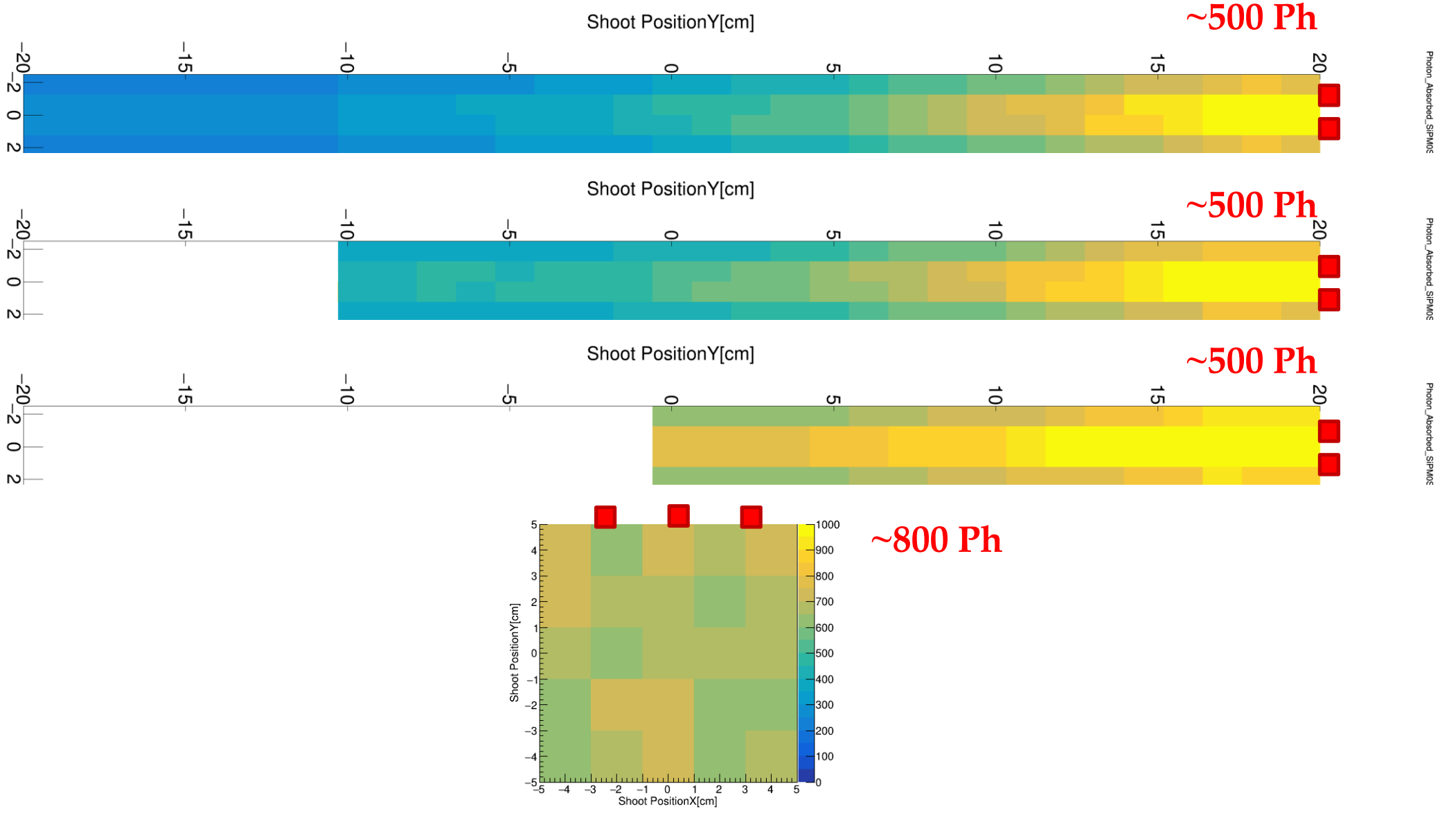
http://geant4-userdoc.web.cern.ch/geant4-userdoc/UsersGuides/PhysicsListGuide/html/reference_PL/FTFP_BERT.html#ftfp-bert

Simulation timing results

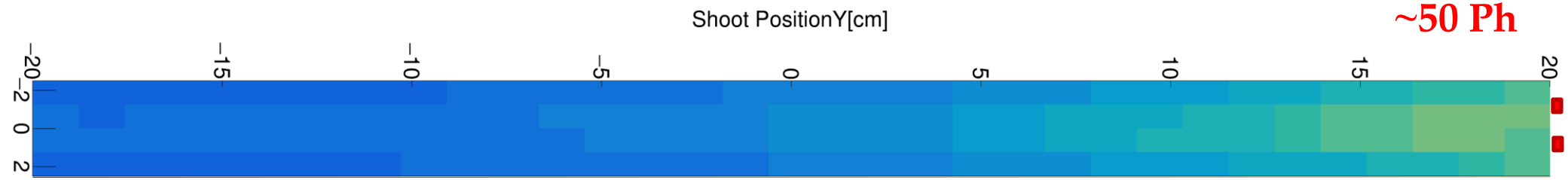




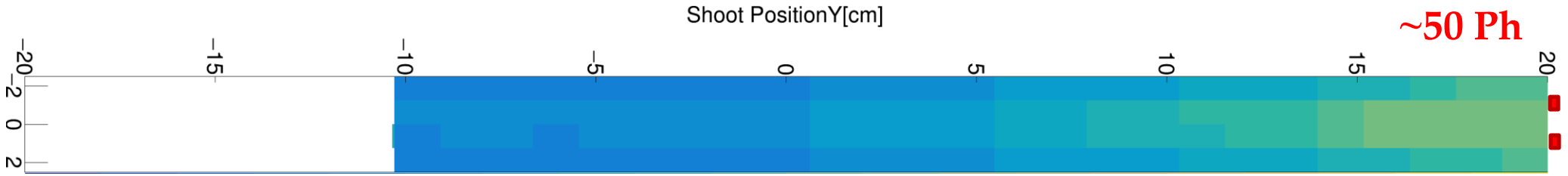
Photon collected: Large SiPM



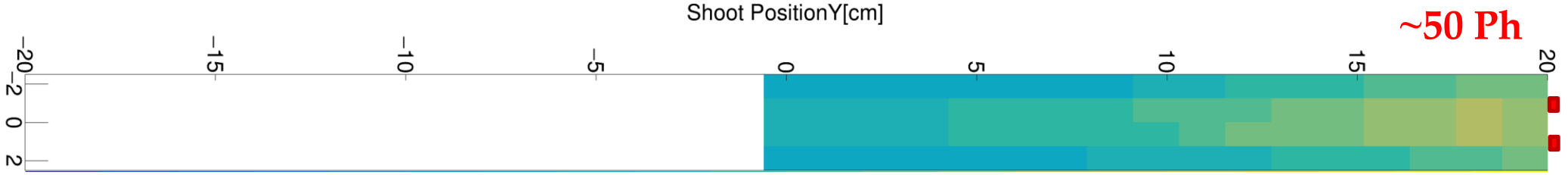
Photon collected: Small SiPM



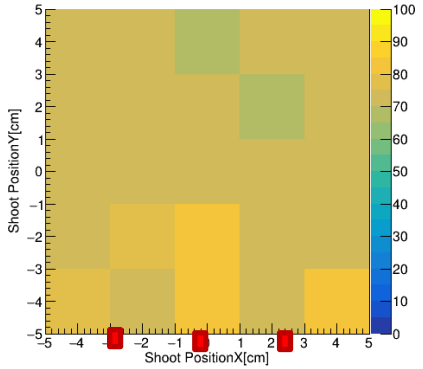
~50 Ph



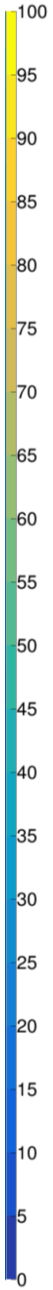
~50 Ph



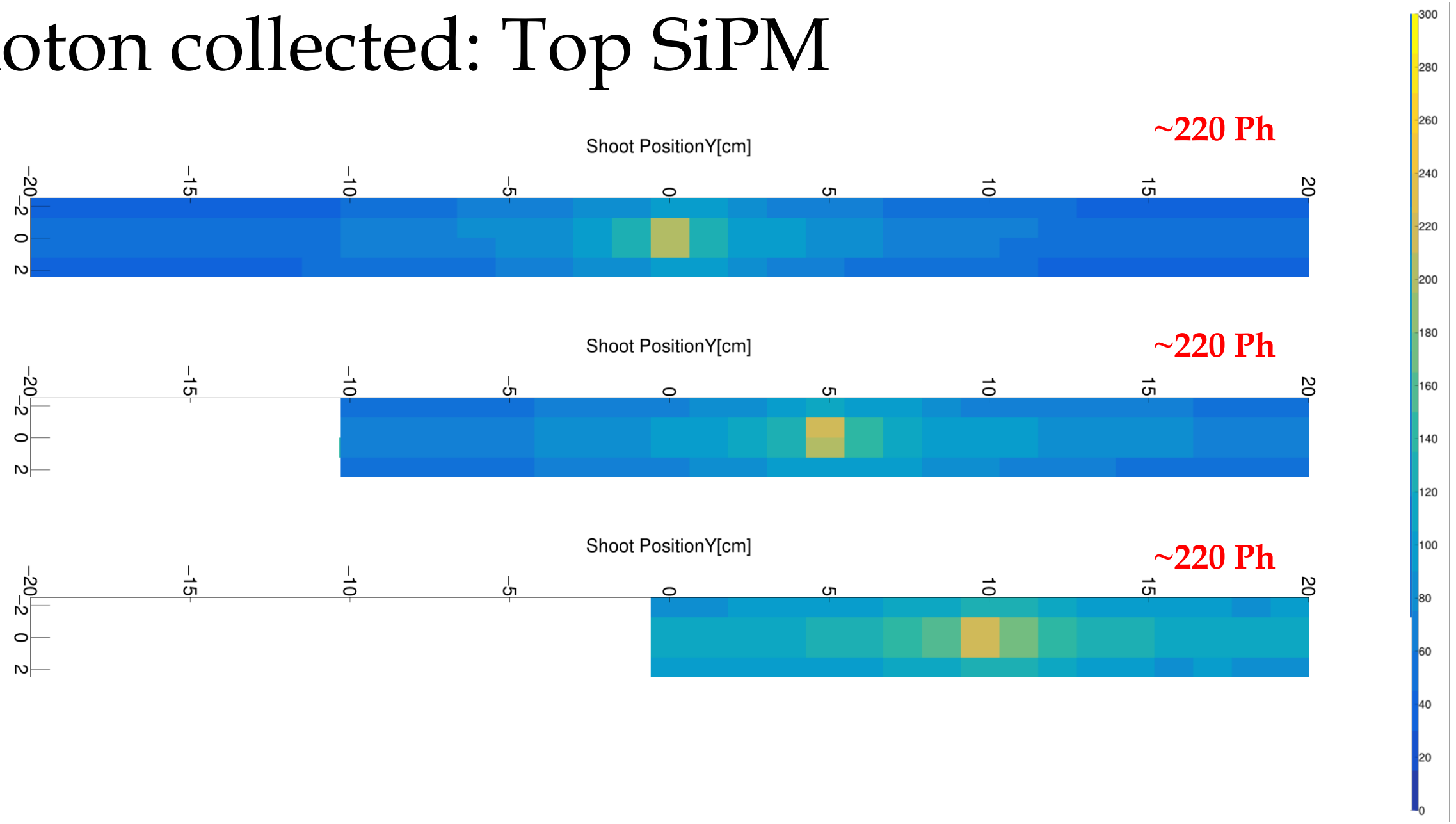
~50 Ph



~80 Ph

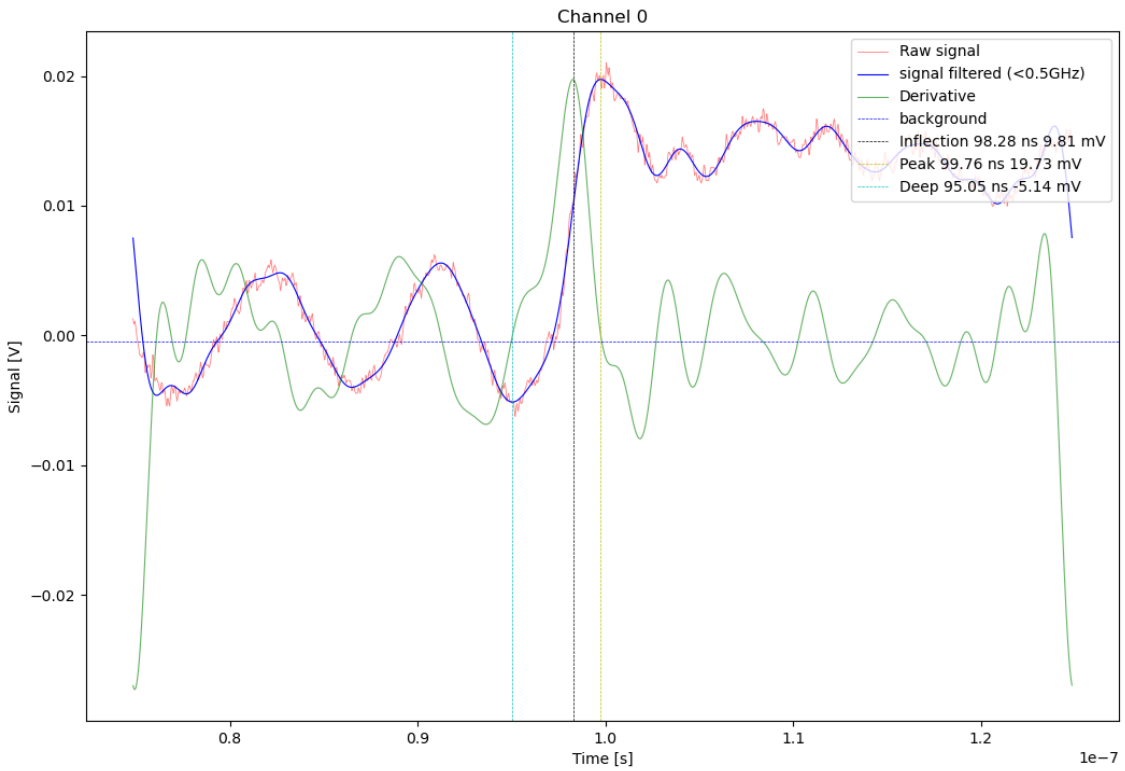


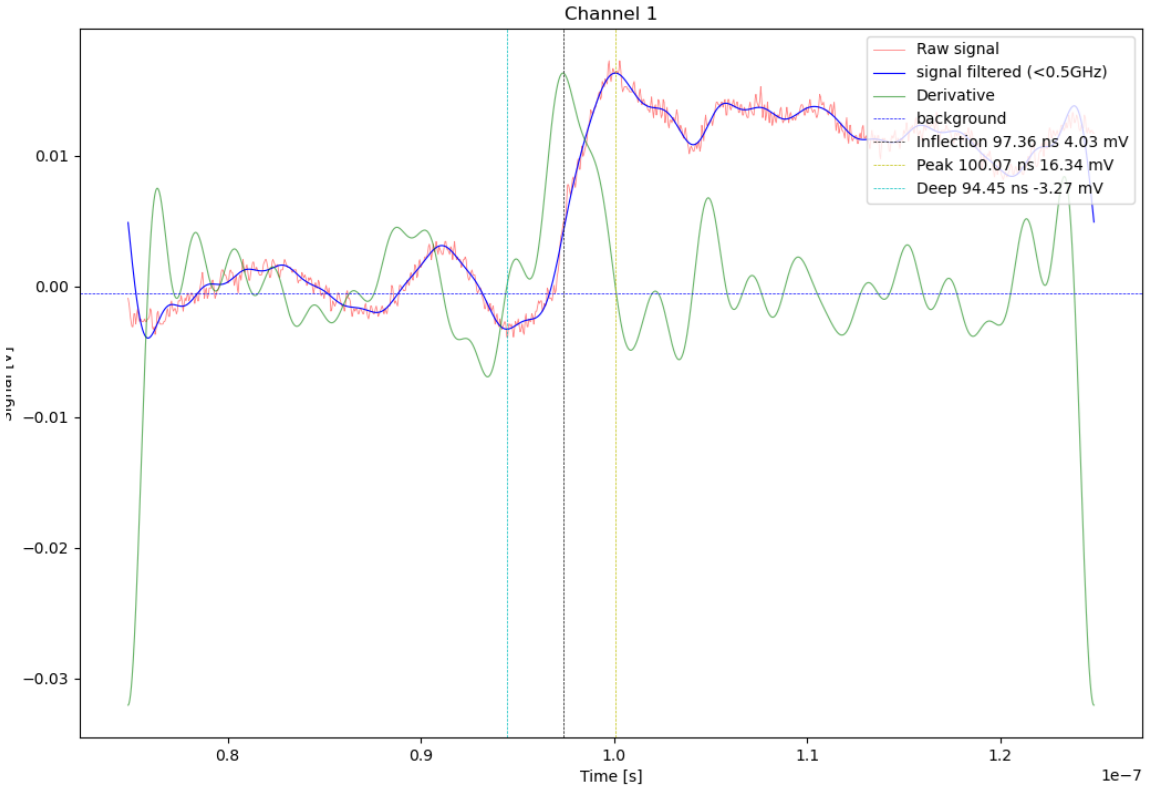
Photon collected: Top SiPM



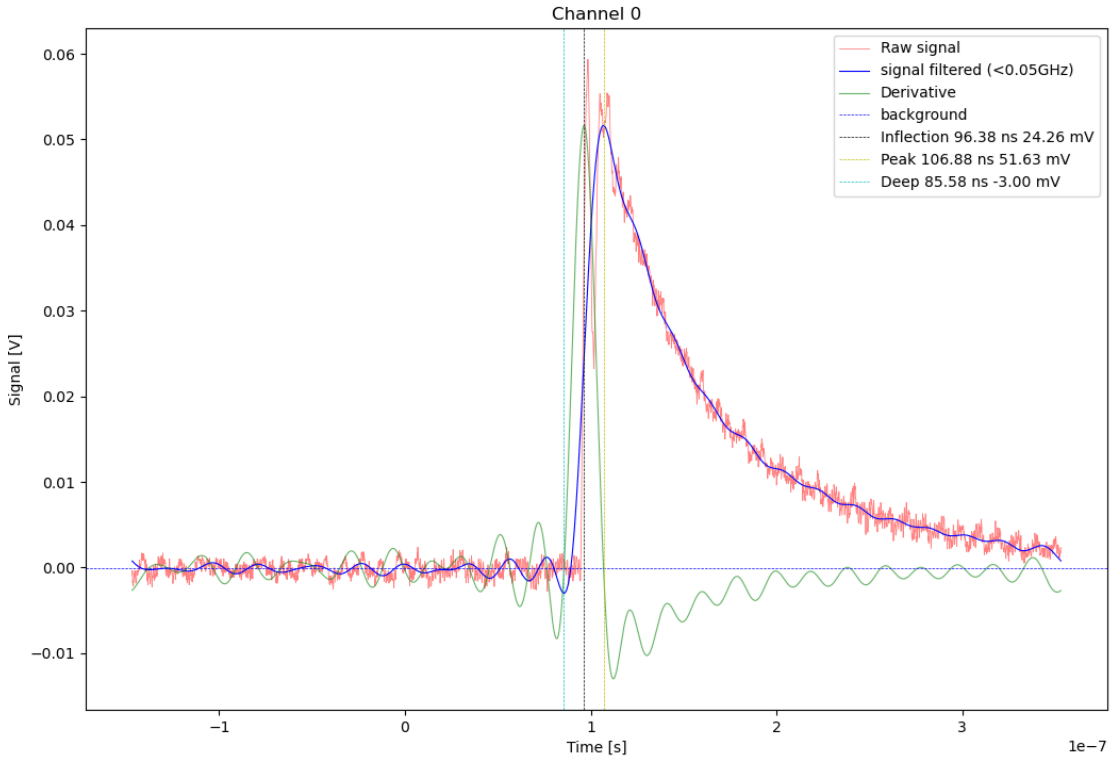
BackUp Slides

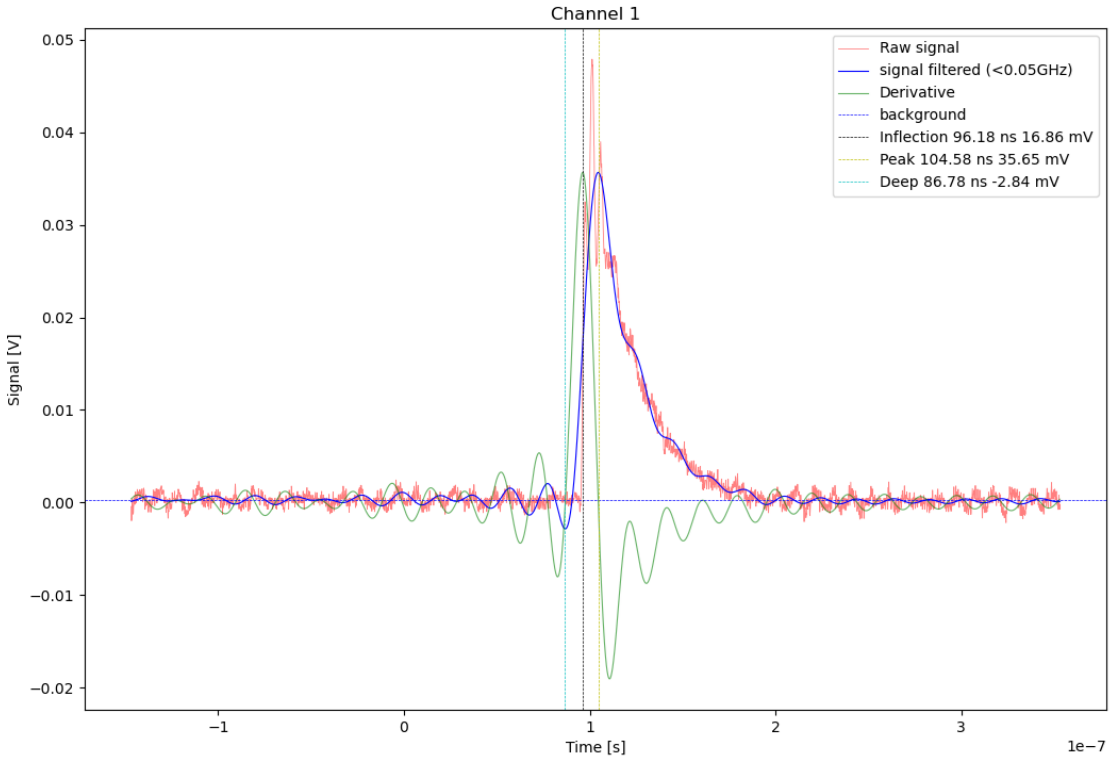
Waveform: Laser SiPM AdvanSiD



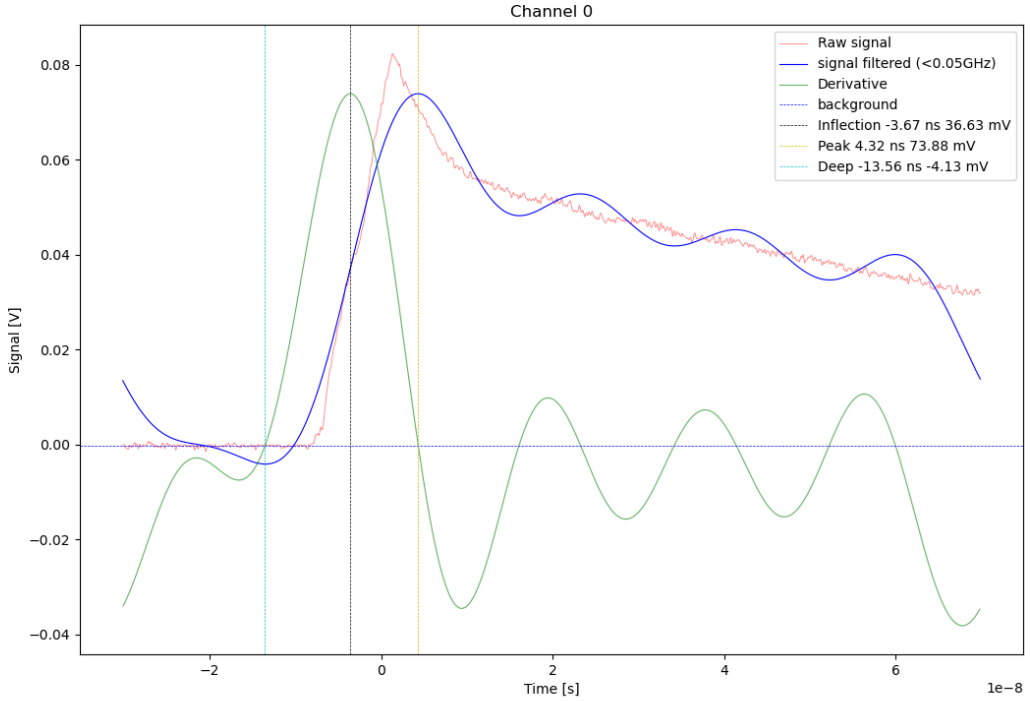


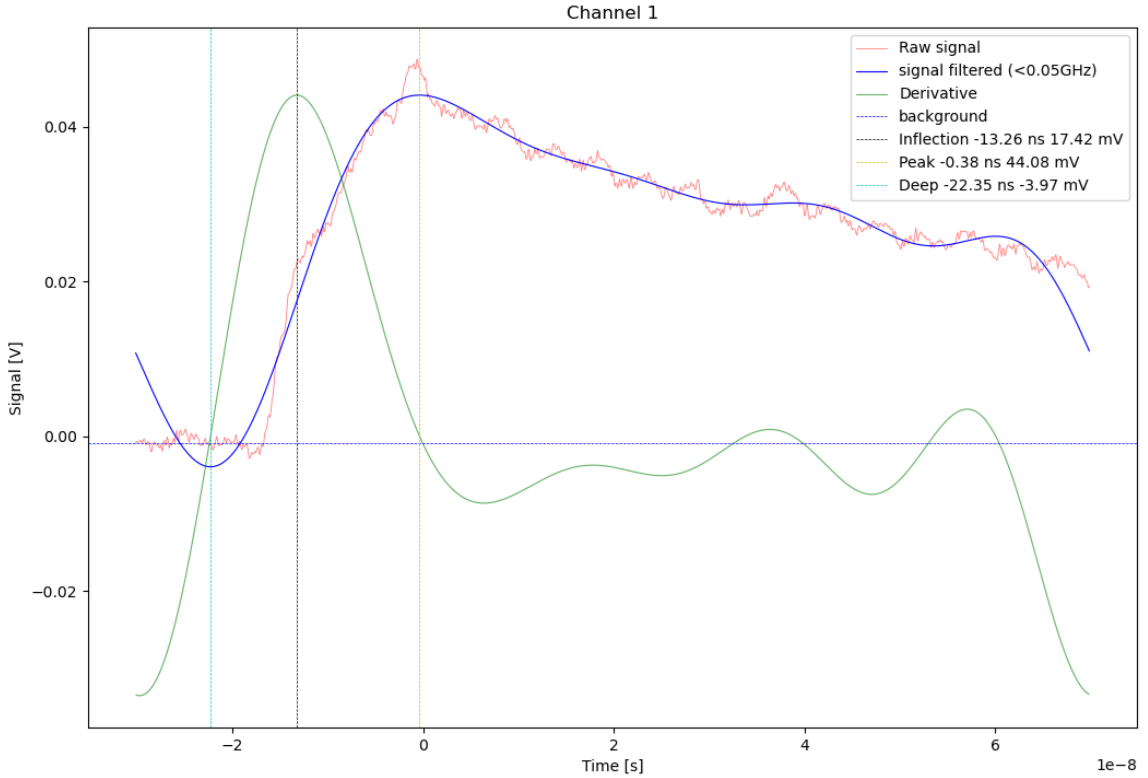
Waveform: Laser Hamamatsu



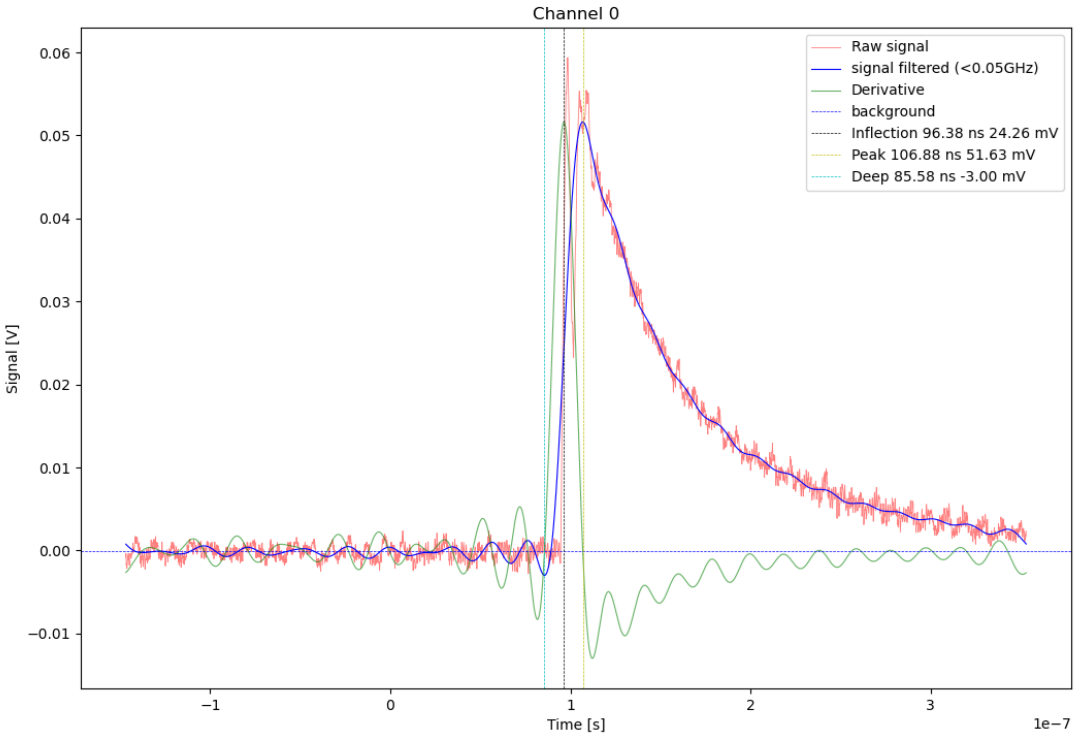


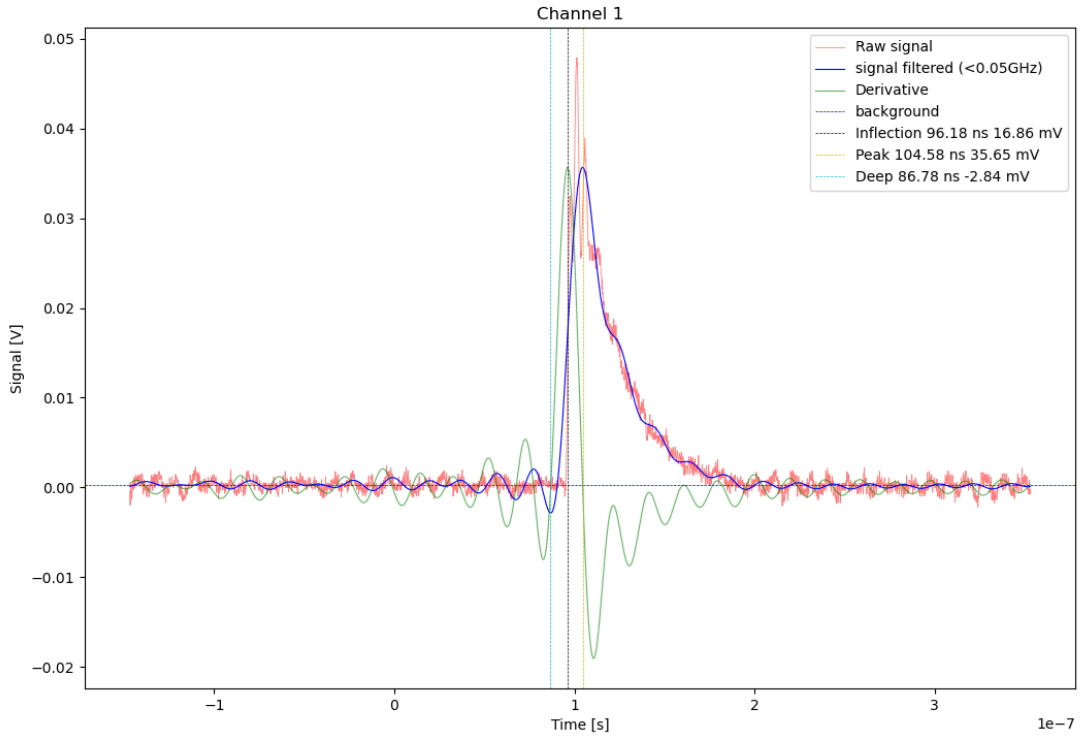
Waveform: 90Sr SiPM AdvanSiD



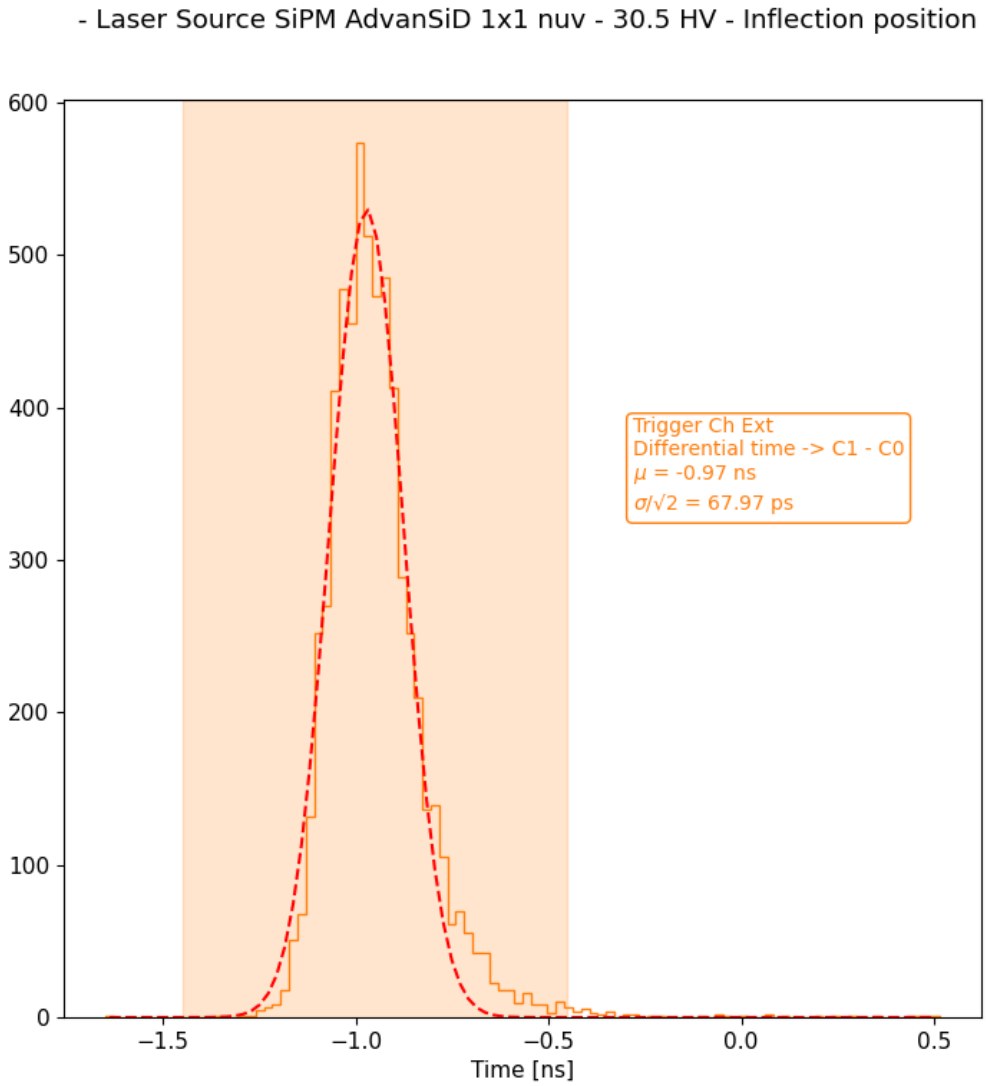


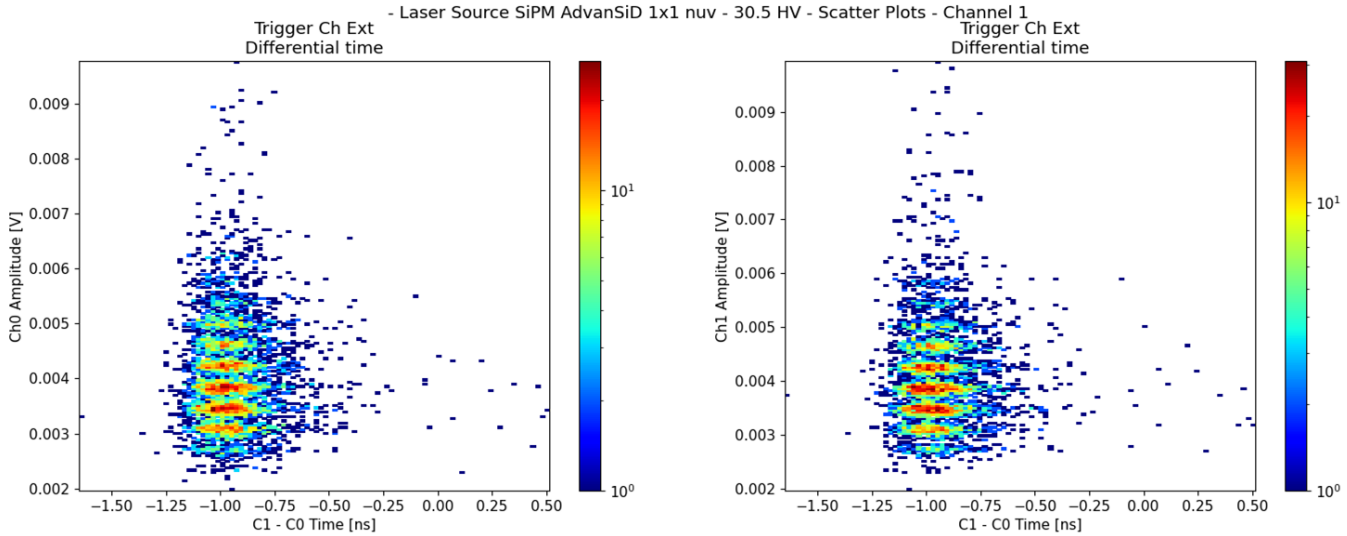
Waveform: CR SiPM Hamamtsu



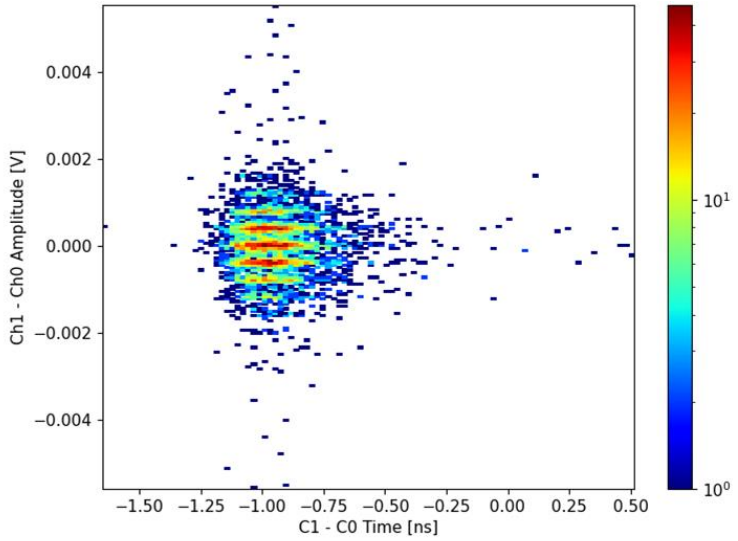


Lab Tests: Laser SetUp -> Advansid 1x1 mm^2

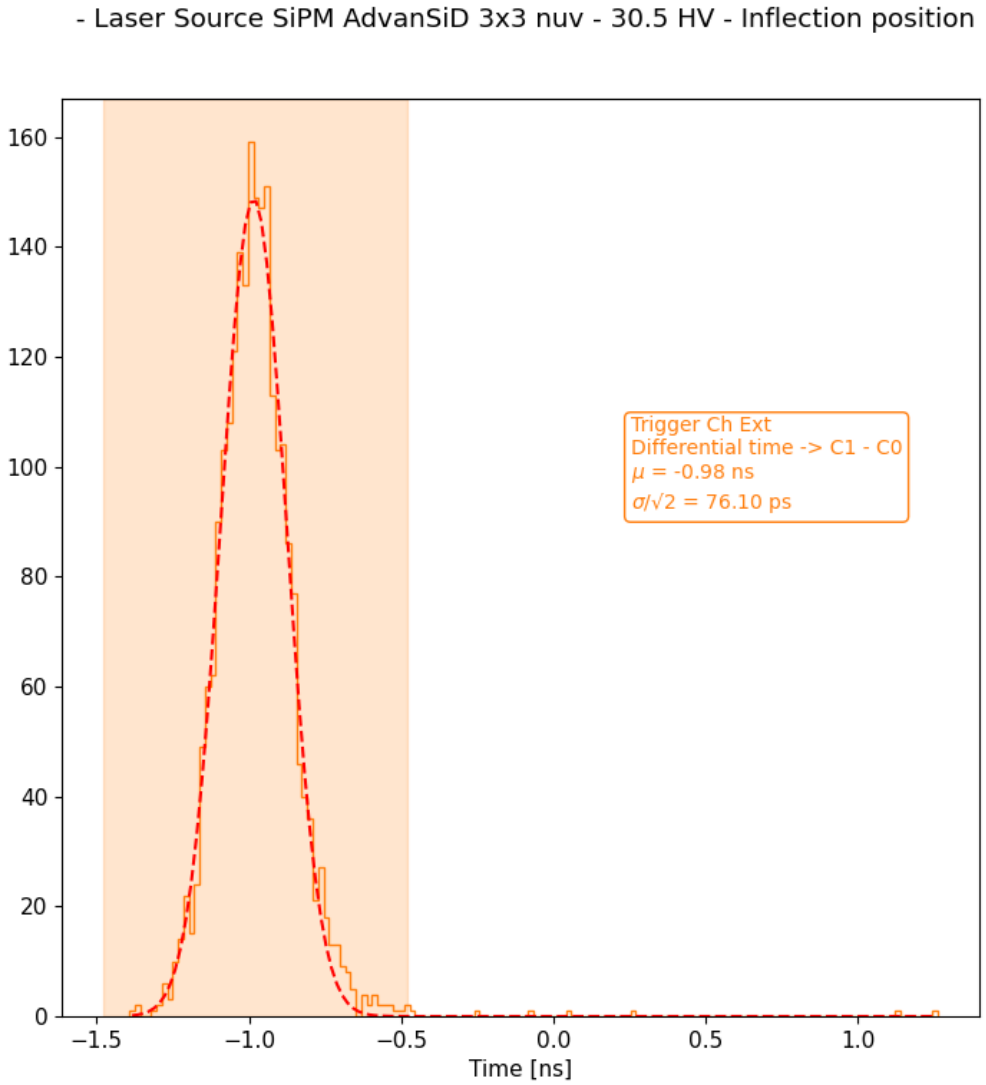


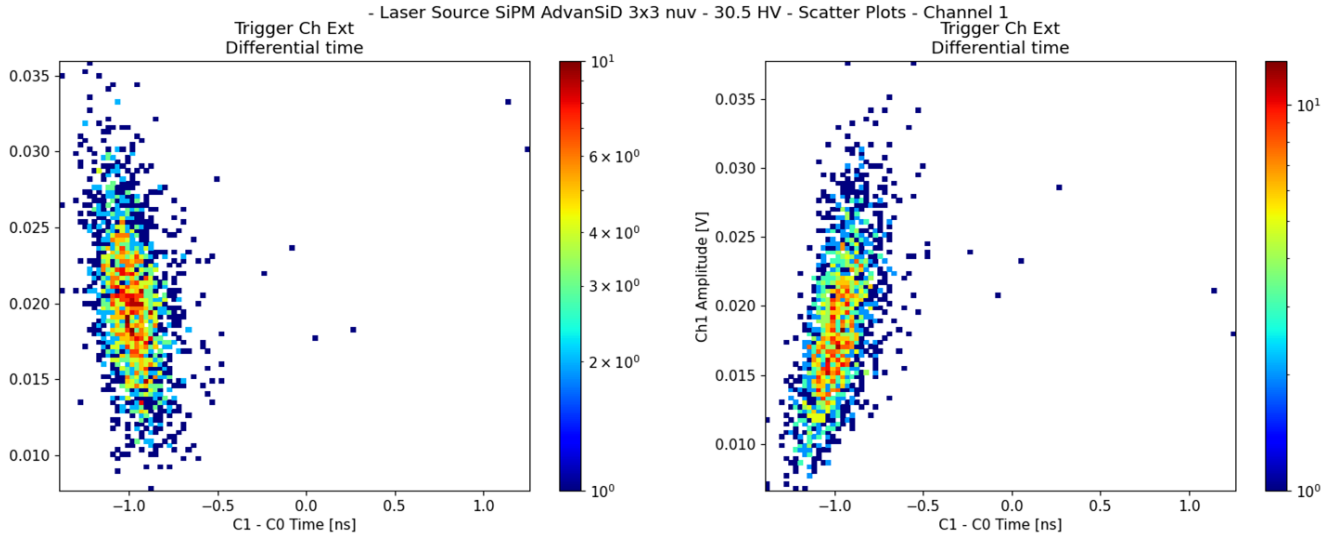


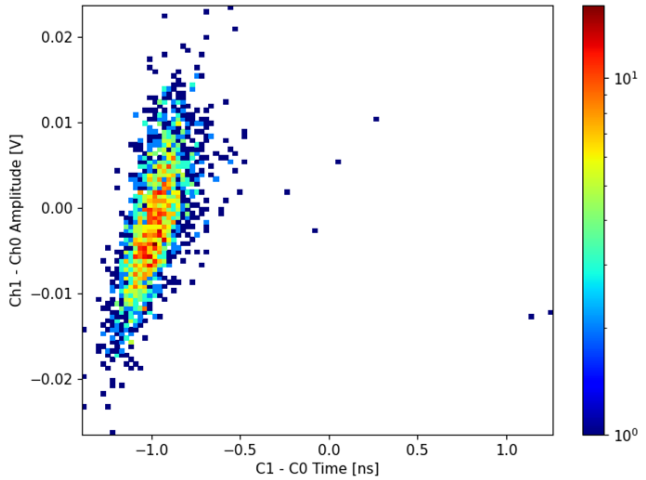
Config. 1



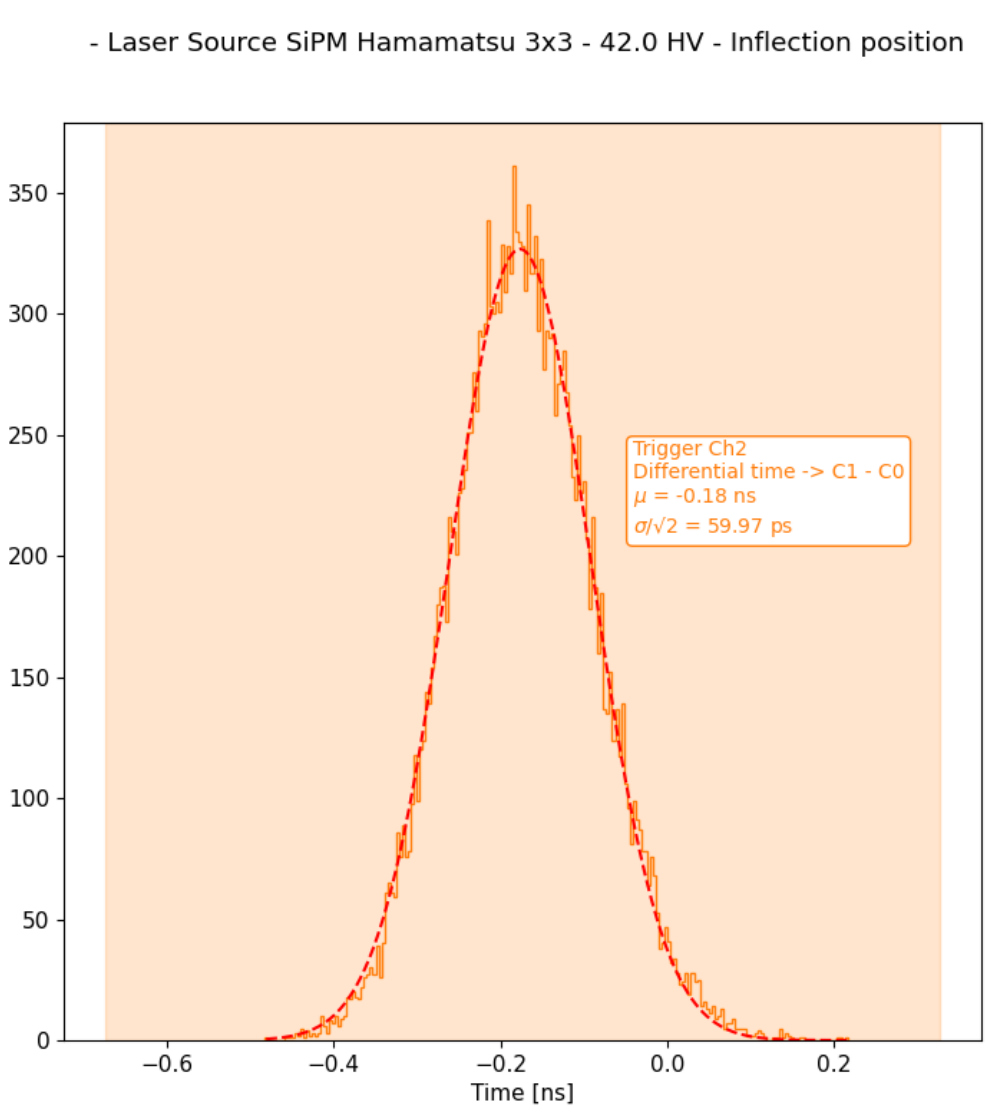
Lab Tests: Laser SetUp -> Advansid 3x3 mm^2

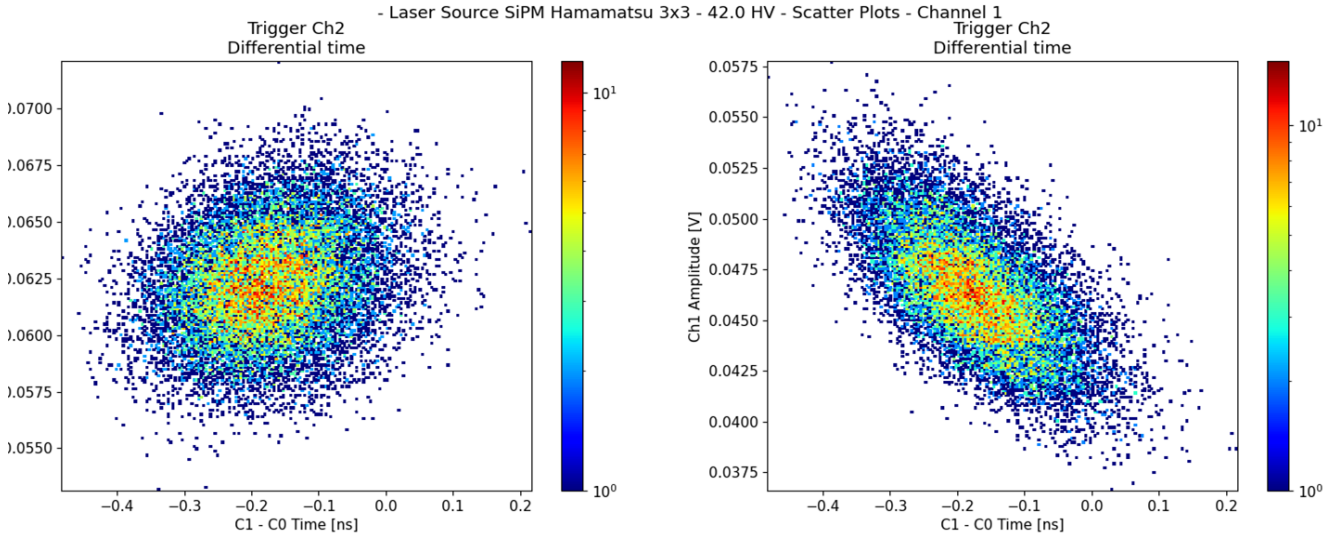


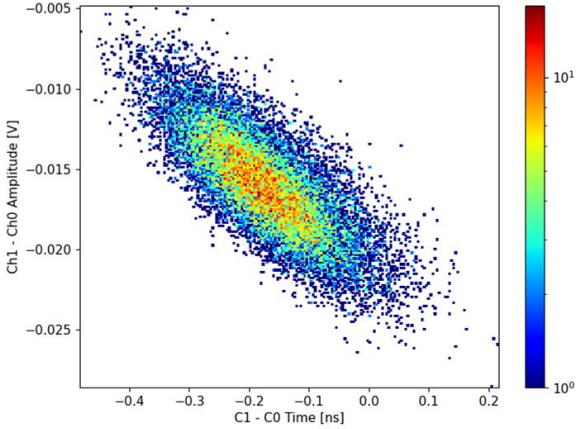




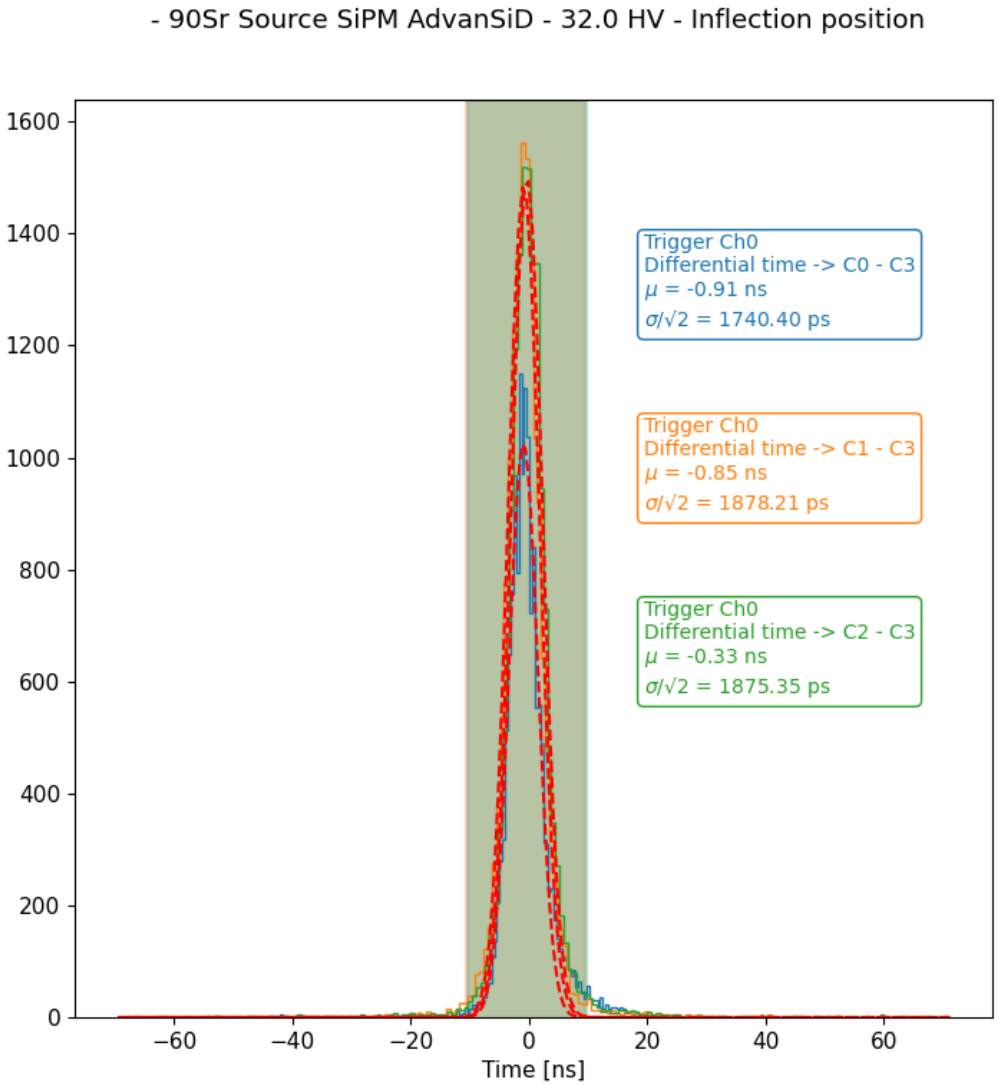
Lab Tests: Laser SetUp -> Hamamatsu pcb 1x1 mm^2 and 3x3 mm^2

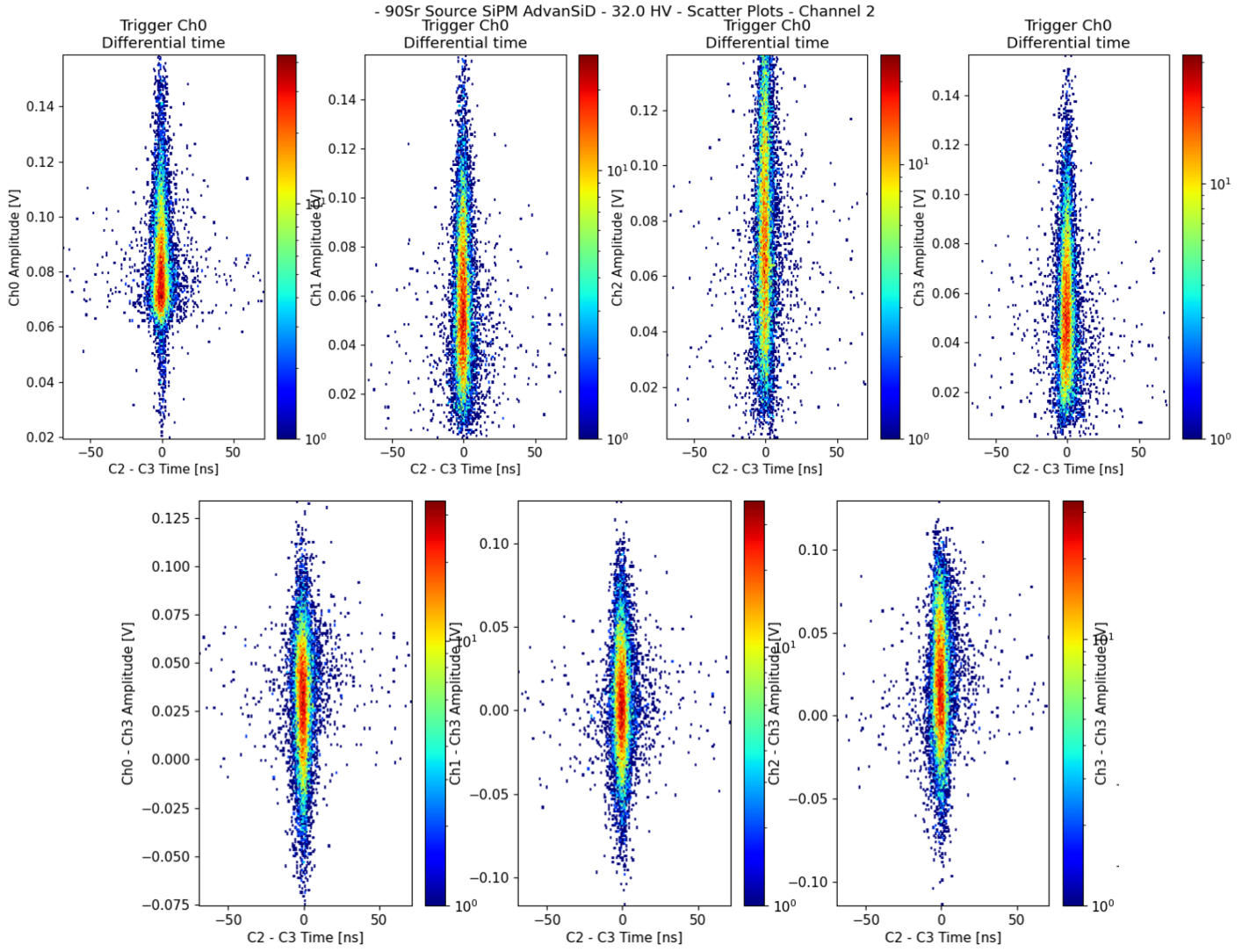




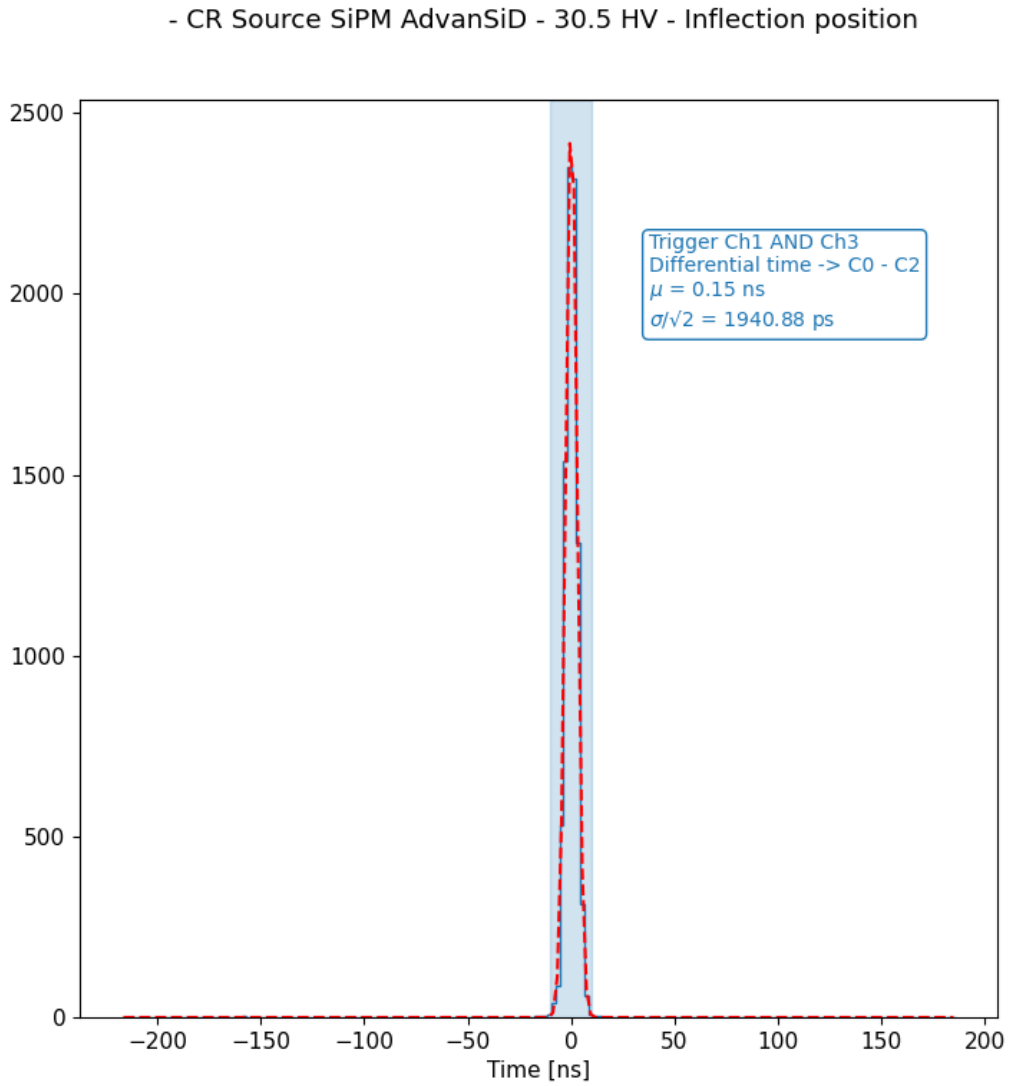


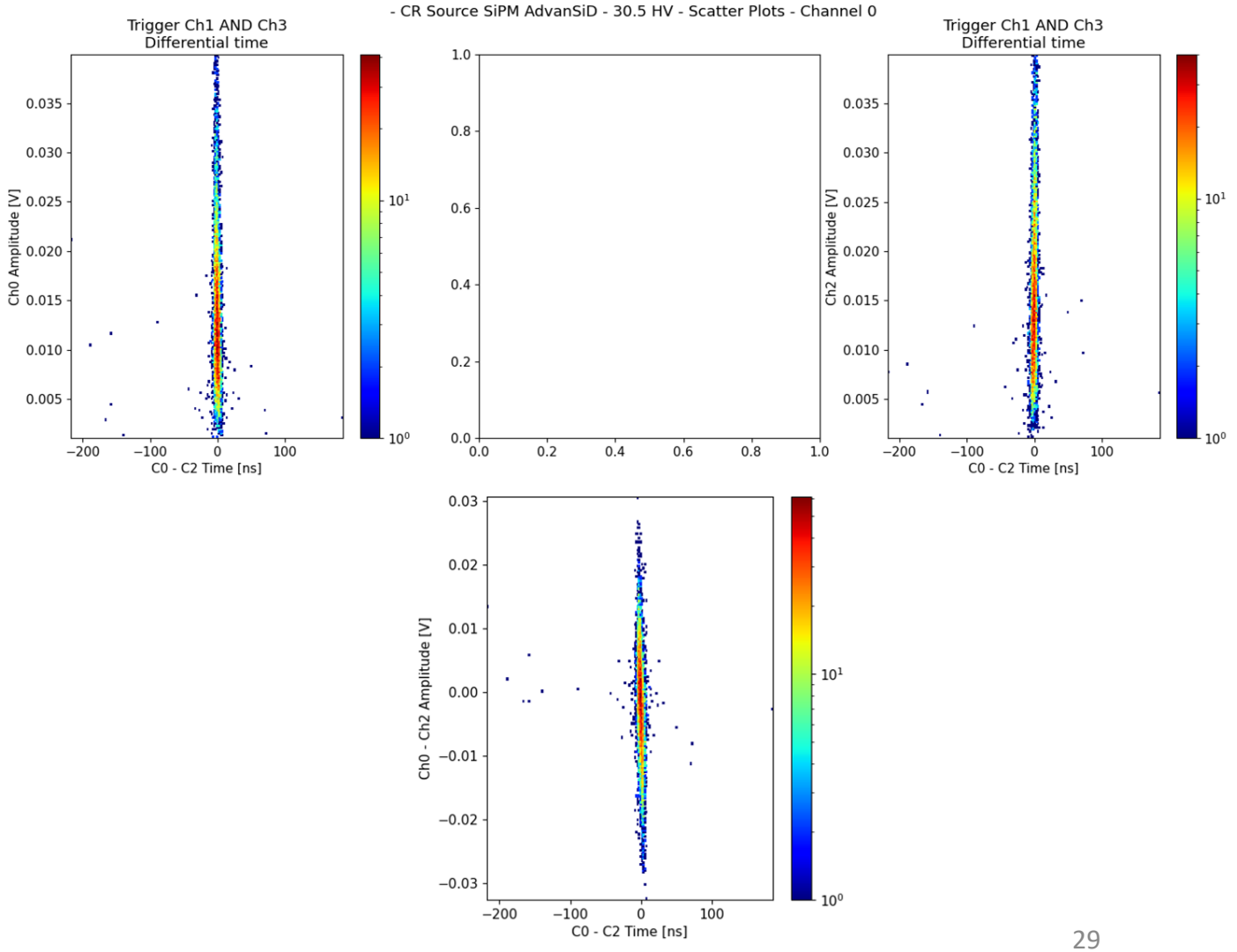
Lab Tests: 90Sr SetUp -> Advansid 3x3 mm^2



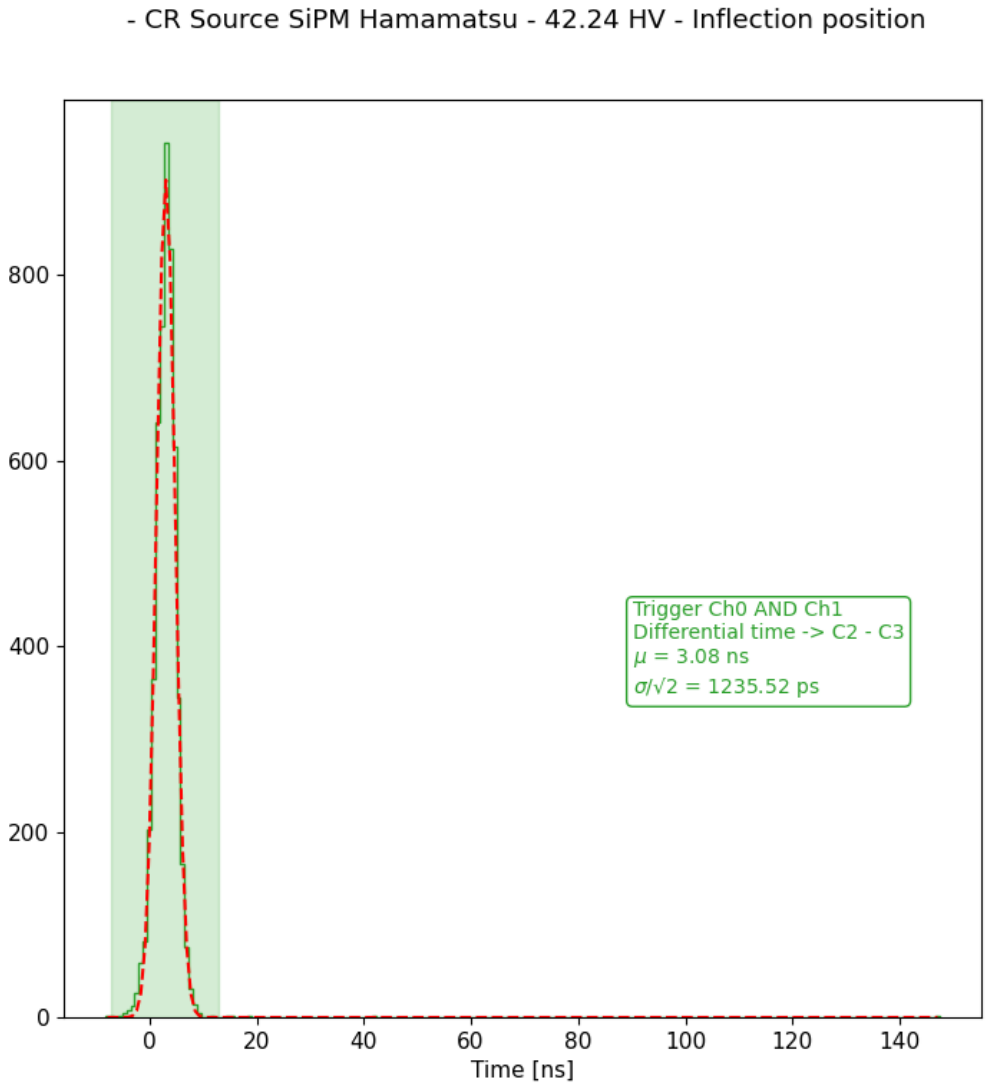


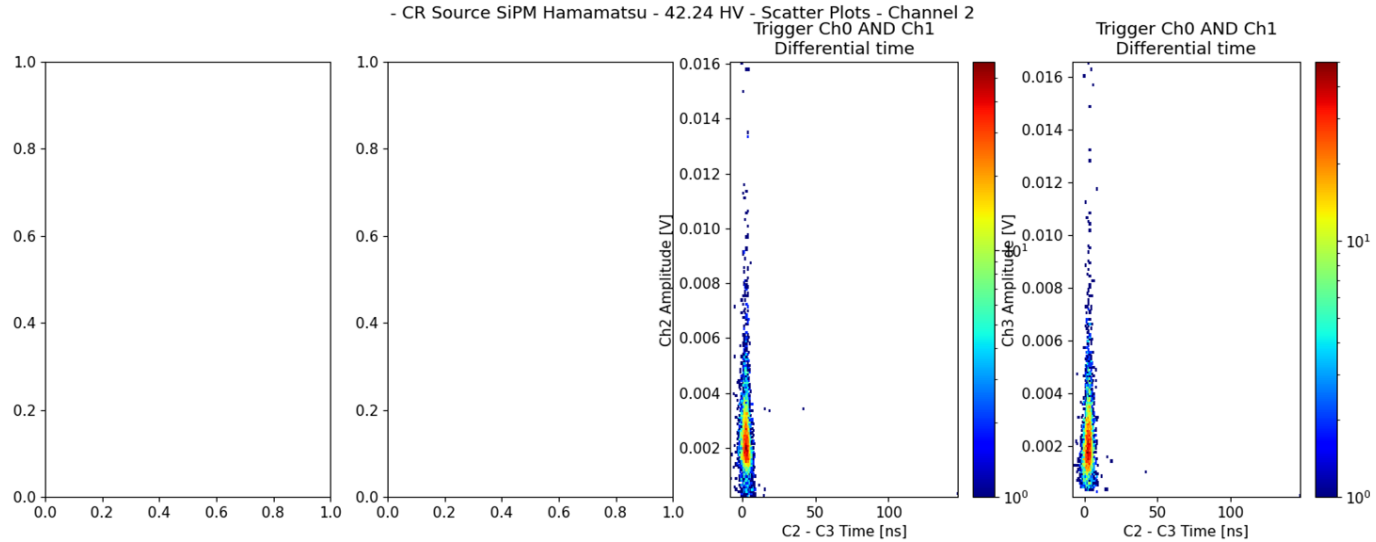
Lab Tests: CR SetUp -> Advansid 3x3 mm^2

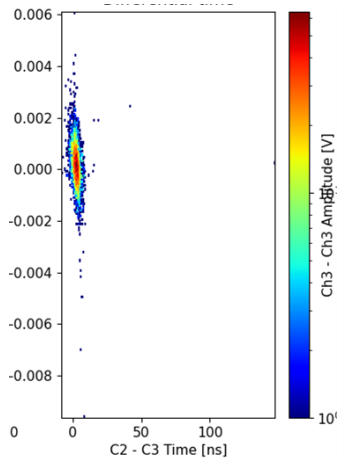




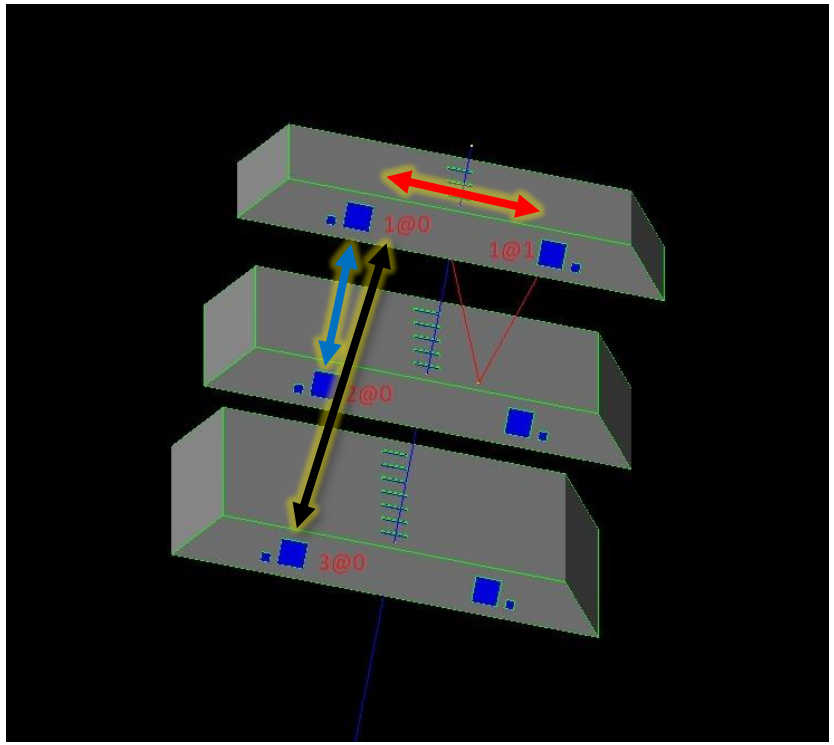
Lab Tests: CR SetUp -> Hamamatsu 3x3 mm^2

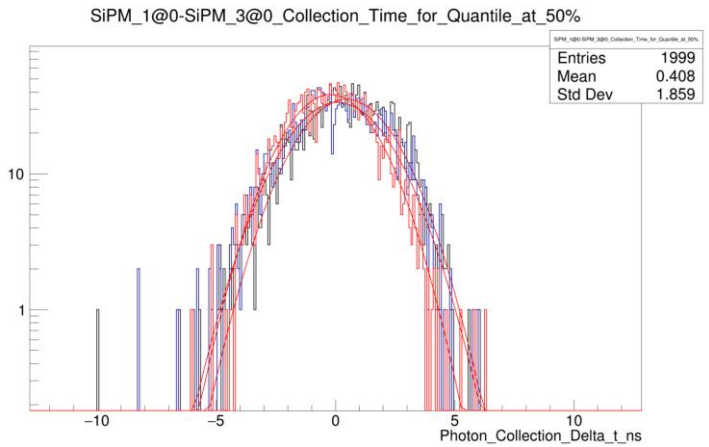


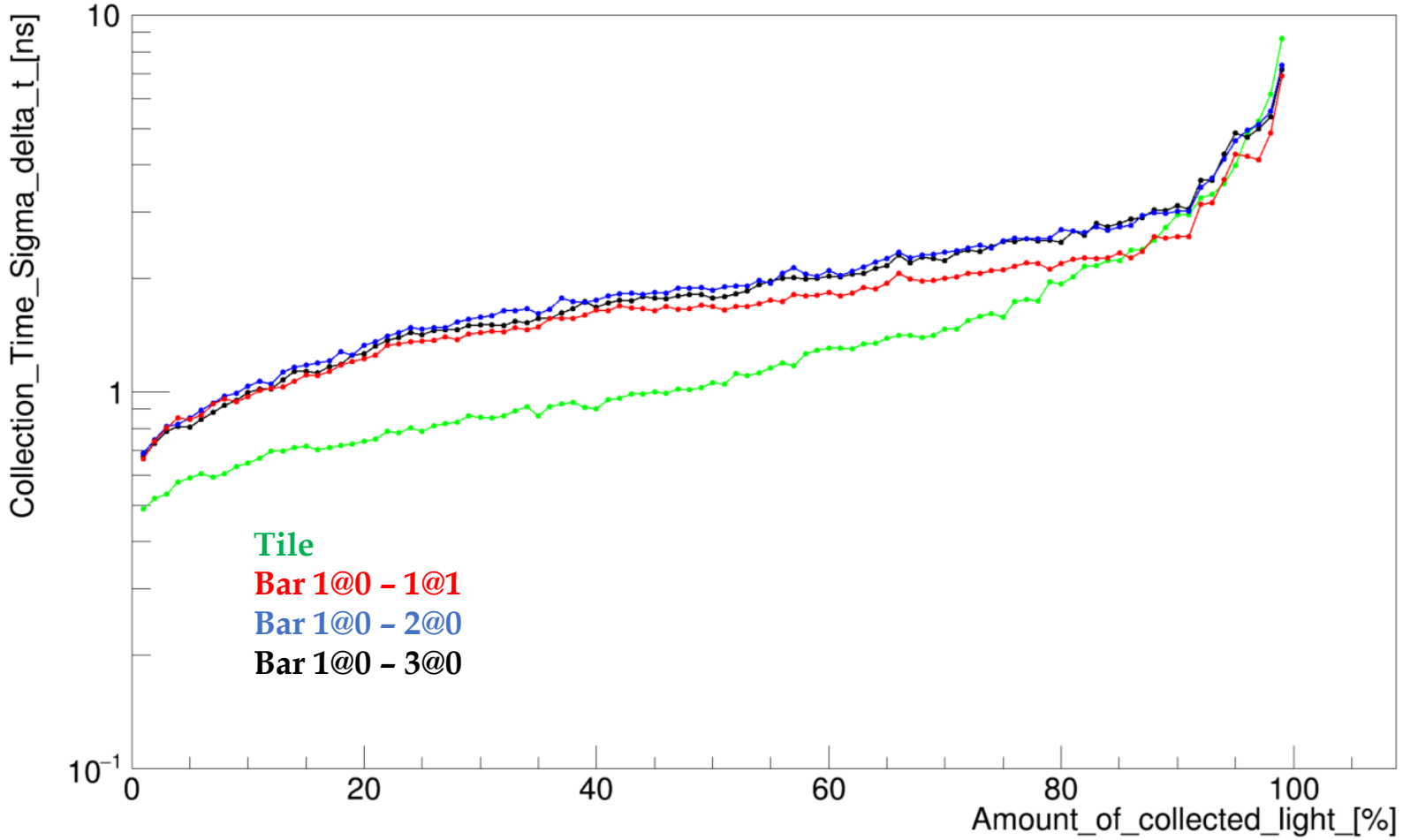




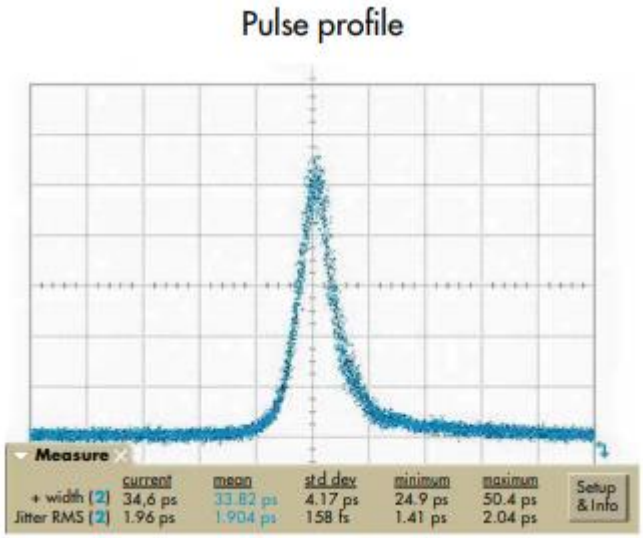
Simulation timing results







Lab Tests: Laser SetUp



Laser PiLas
Tune 50%
Pulsed 20 Hz
Diffuser thorlabs ED1-S50_MD
Attenuation with pinhole 2.5 mm
Distance from device ~20 cm

Laser specifications	PiLas
Center wavelength[1]	**375 nm – 2 µm**
Pulse Duration[2]	20 ps – 150 ps
Pulse peak power[3]	10 mW – 1 W
Pulse energy[4]	1 – 50 pJ
Av. output power at 100 MHz	0.5 – 2 mW
Pulse repetition rate	pulse-on-demand – 120 MHz
Beam quality	$M^2 < 1.1$, TEM_{00}
Polarization Ext. Ratio	> 20 dB
Timing jitter[5]	< 3 ps (rms)
Laser output	free-space or fiber output (PM, SM, MM)
Environmental	
Warm-up time	< 10 minutes
Operation temperature	15 °C – 35 °C
Storage temperature	-20 °C – 65 °C
On/Off cycles	> 10000
Mechanical	
Size laser head	97 x 31 x 147 mm³
Weight laser head	0.45 kg
Size OEM control unit[6]	168 x 129 x 33 mm³
Weight OEM control unit	0.7 kg
Size stand-alone control unit	235 x 88 x 326 mm³
Weight stand-alone control unit	2.5 kg
Electrical	
Power supply	12 VDC/3 A or 100 – 264 VAC, 47 – 63 Hz
Power consumption	< 30 W
Cooling	
Laser system	air cooled

[1] All commercially available laser diode wavelengths in this range
[2] Depending on laser head model, pulse duration up to 5 ns possible
[3] Depending on laser head model
[4] Depending on laser head model and pulse duration
[5] Not for DFB/DBR lasers
[6] Other OEM versions available