SiPM timing measurements at LAL

XII SuperB Workshop
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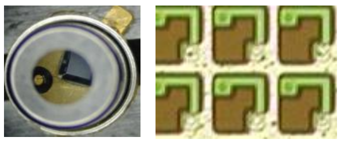
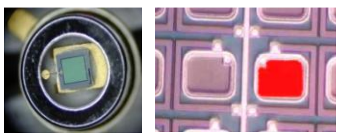
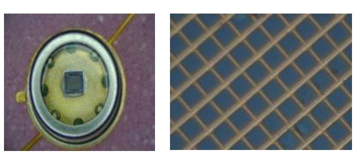
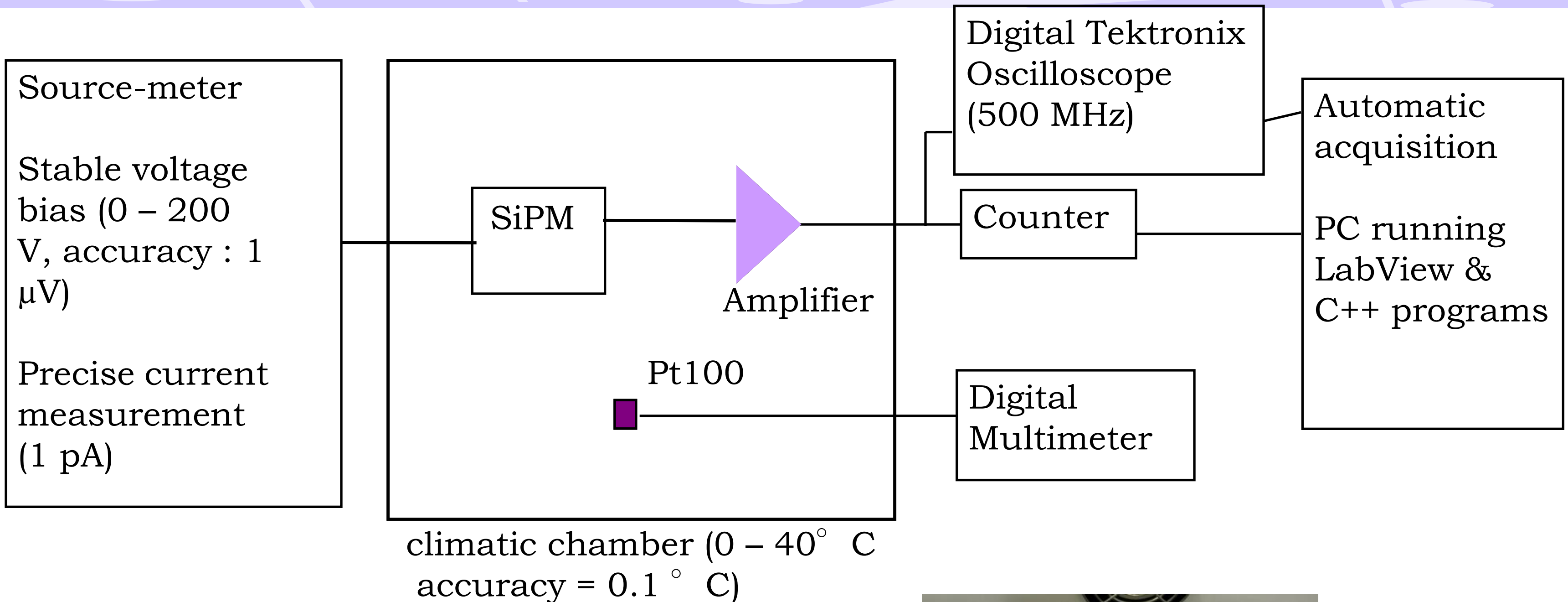
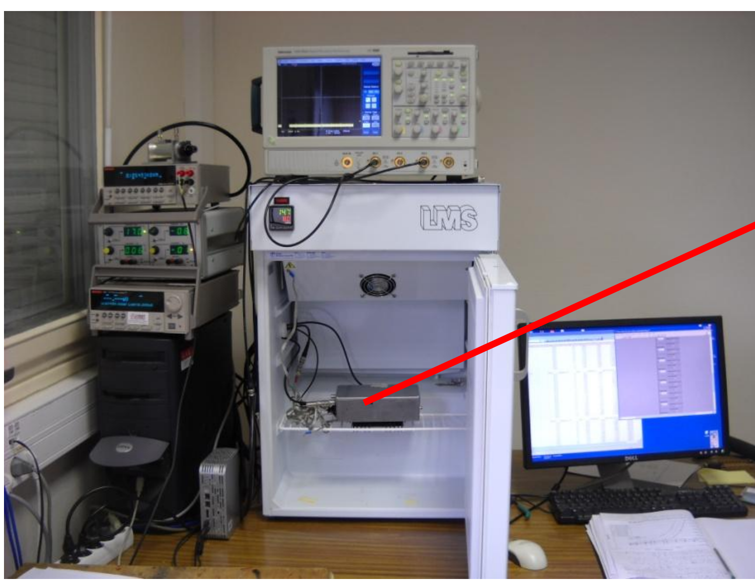
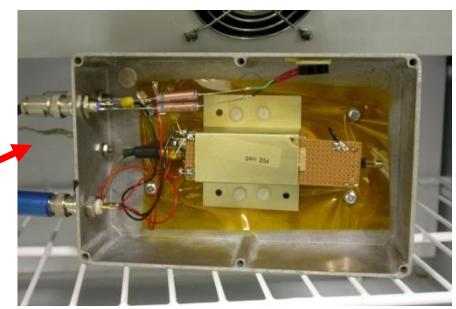
SiPMs (1 mm^2) measured at LAL

	Reference	Pixel nb	Pixel size (µm)	Fill factor (%)
F.B.K B 	**B11**	**400**	**50 x 50**	
	B13	**400**	**50 x 50**	
Hamamatsu MPPC 	**S10362-11-25**	**1600**	**25 x 25**	**31**
	S10362-11-50	**400**	**50 x 50**	**61.6**
	S10362-11-100	**100**	**100 x 100**	**78.5**
	10-50S-BK 4S	**400**	**50 x 50**	**38**
	10-100S-FS	**100**	**100 x 100**	**78**
SensL SPM 	**SPM-20**	**848**	**29 x 32**	**43**
	SPM-50	**216**	**59x 62**	**68**

Determination of the operational voltage range of the SiPMs

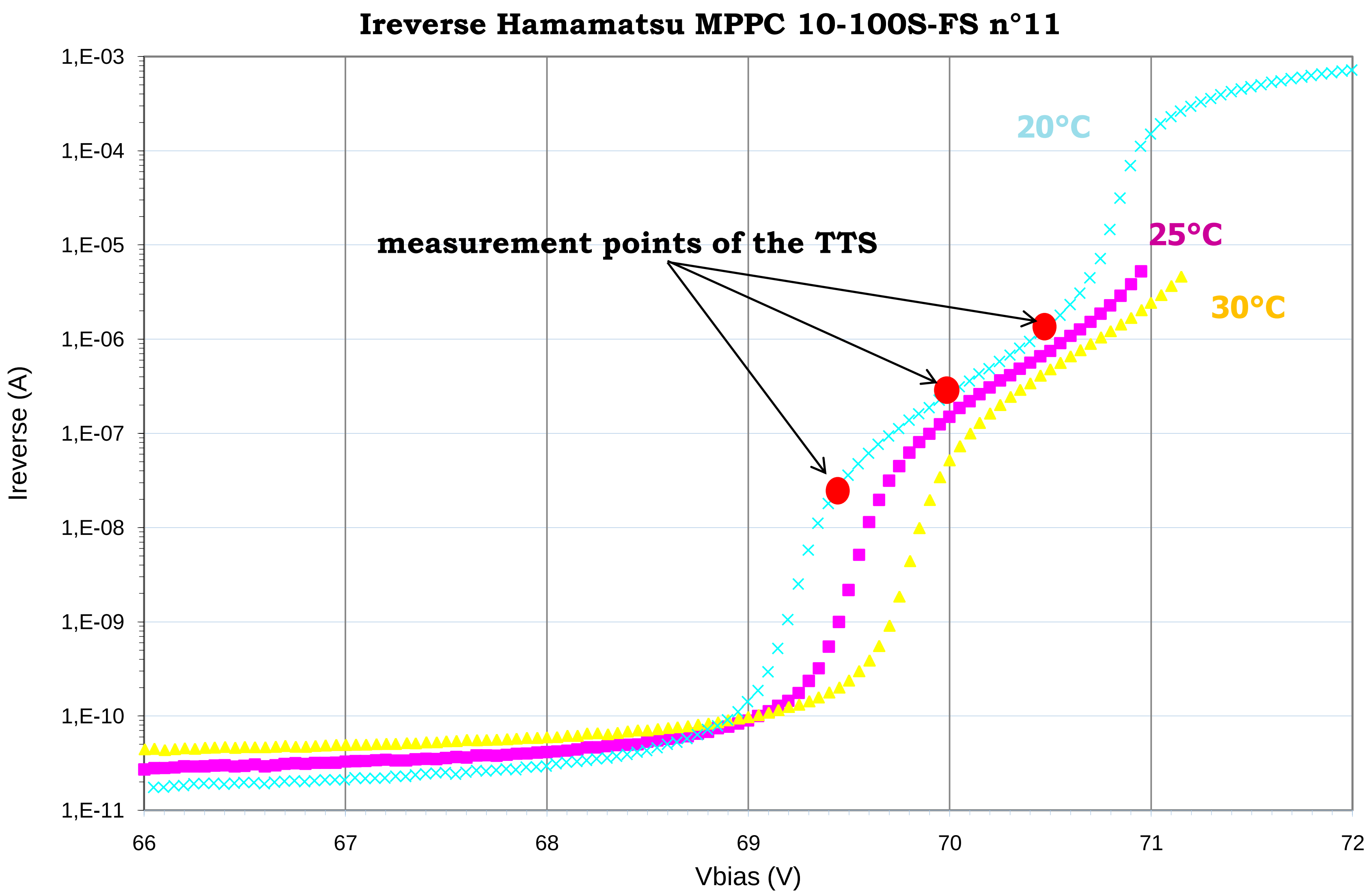






Measurements of V_{BD}, gain, DCR

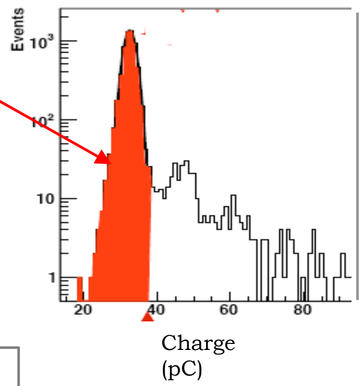
Evolution of Ireverse with the bias voltage

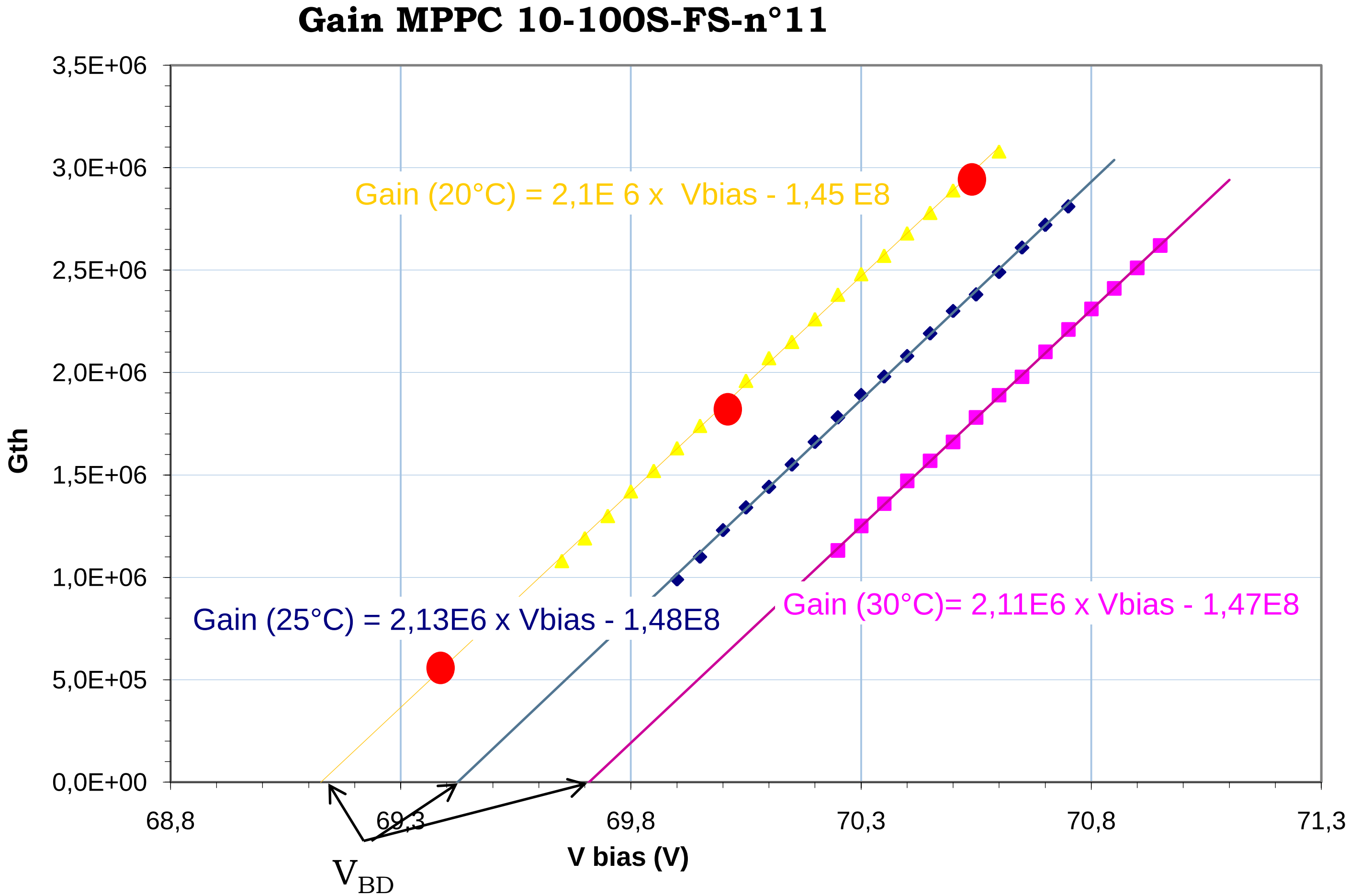


Measurement of the gain and V_{BD} (breakdown voltage)

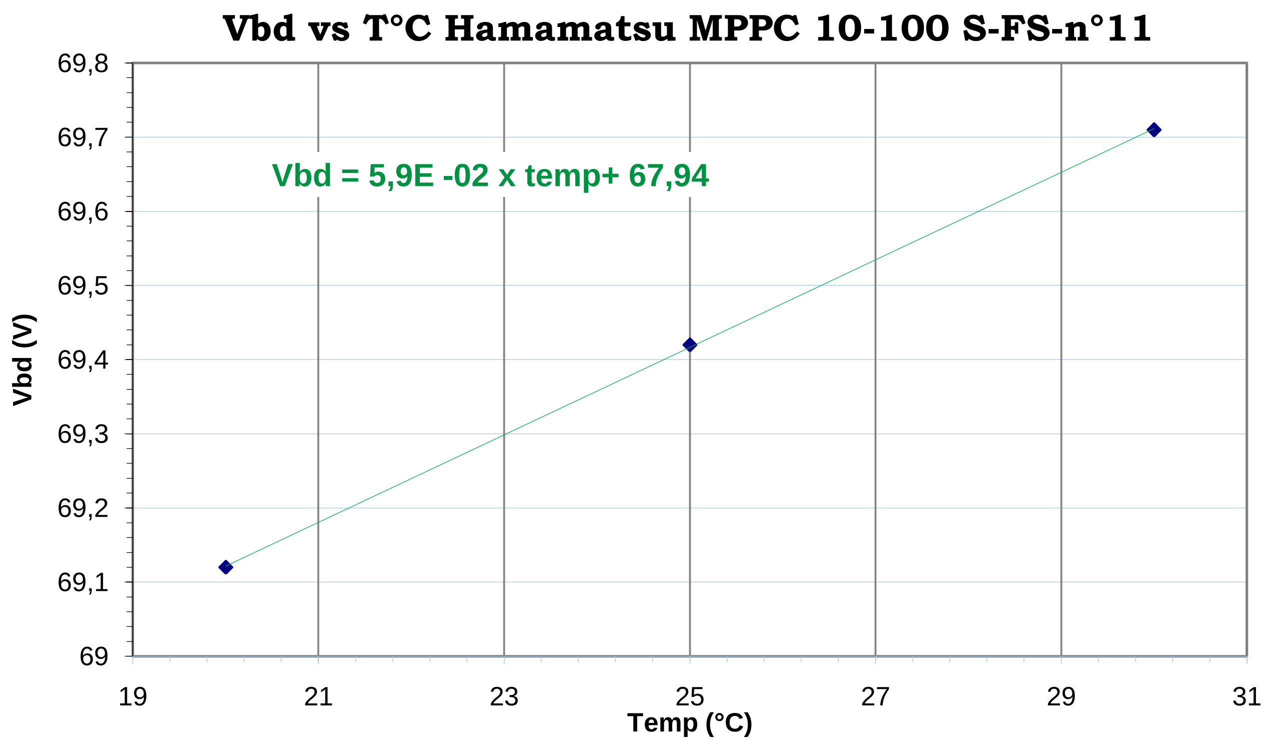
Defined as the charge developed in one pixel by a primary carrier

$$Gain = \frac{Q_{pixel}}{e} = \frac{C_{pixel} \times (Vbias - VBD)}{e}$$





Evolution of V_{BD} with temperature



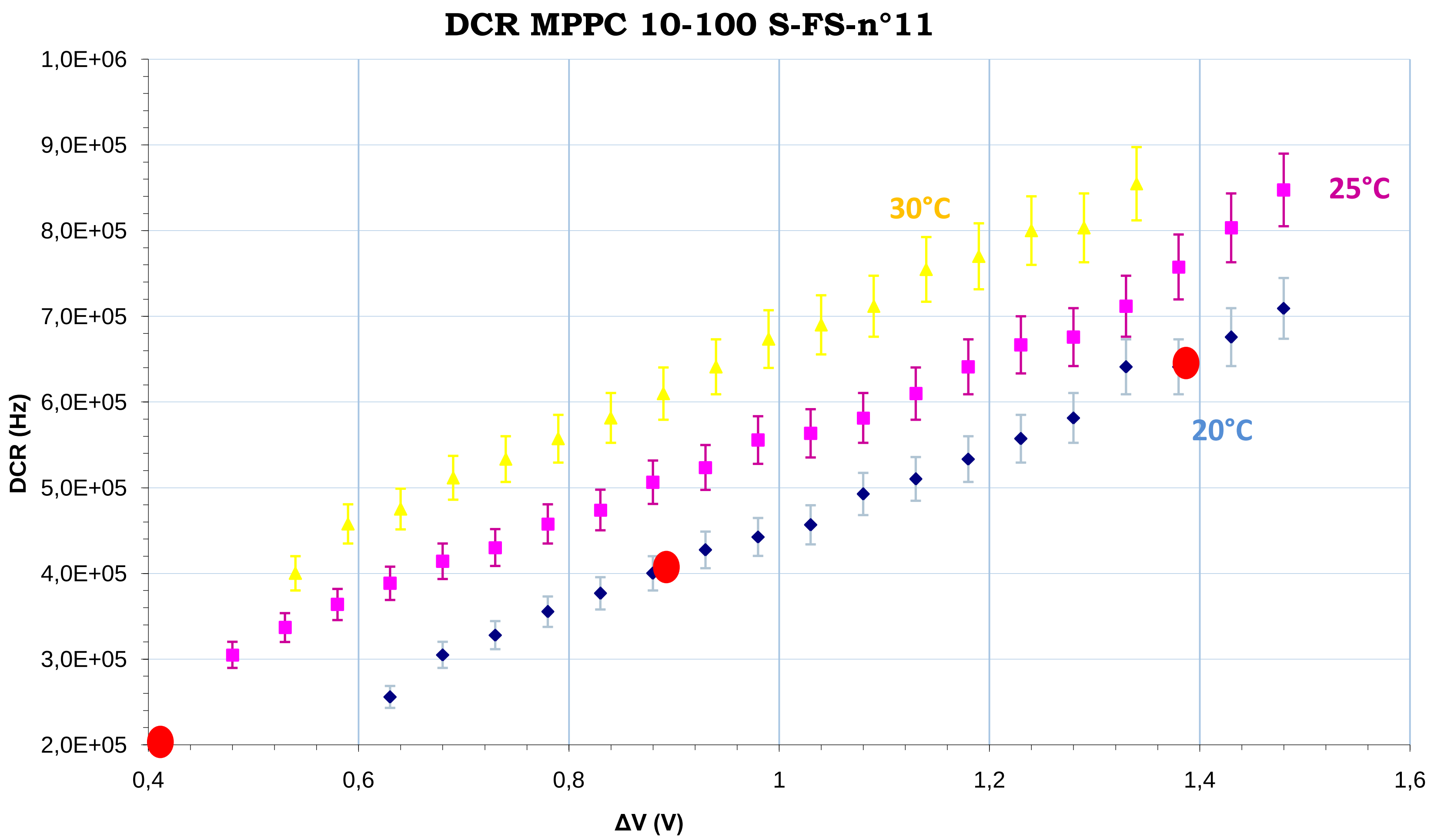
Breakdown voltage increases with the temperature

dV_{BD}/dT ~ 59 mV/°C for the MPPC 10-100 S-FS

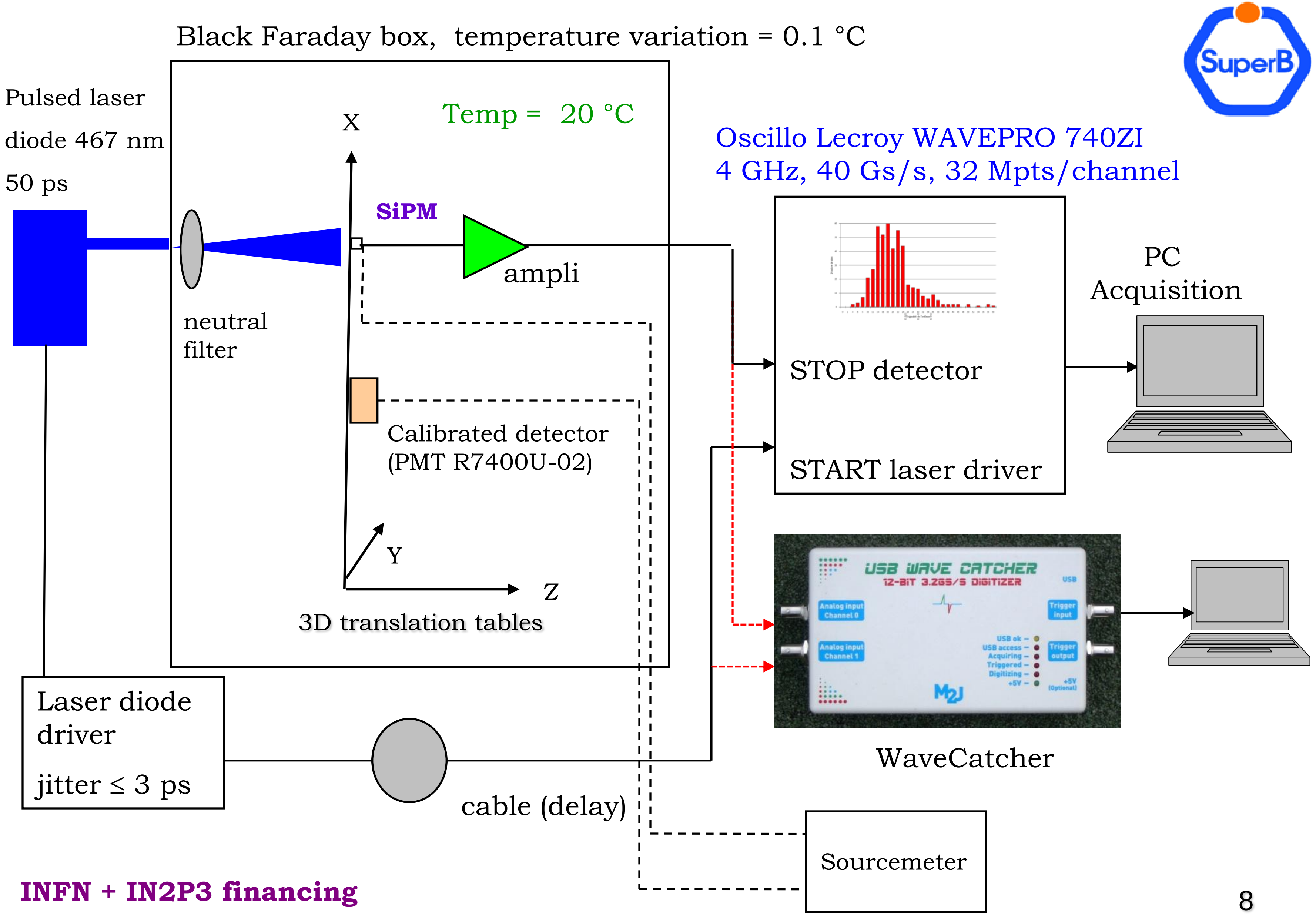
Correction of the bias voltage if the temperature changes inside the test bench to maintain a constant gain

Measurement of the Dark Count Rate

Dark noise : thermally produced avalanches. Look the same as pulses from photon



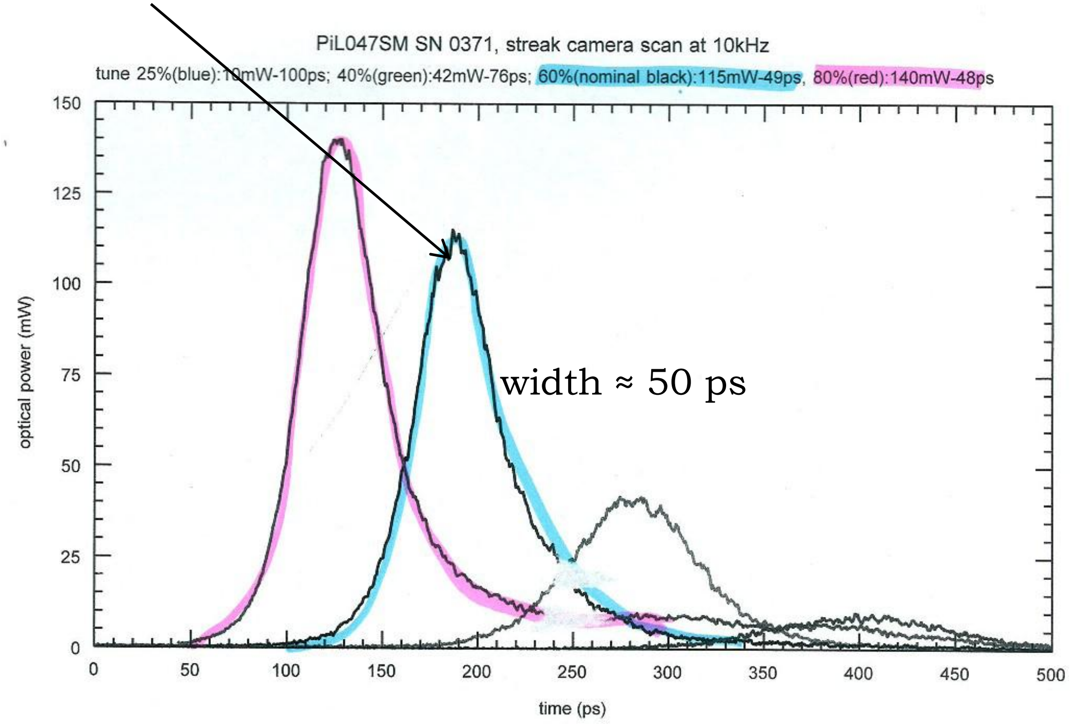
Optical test bench for the TTS measurements



INFN + IN2P3 financing

Contribution to the timing resolution of the detection chain

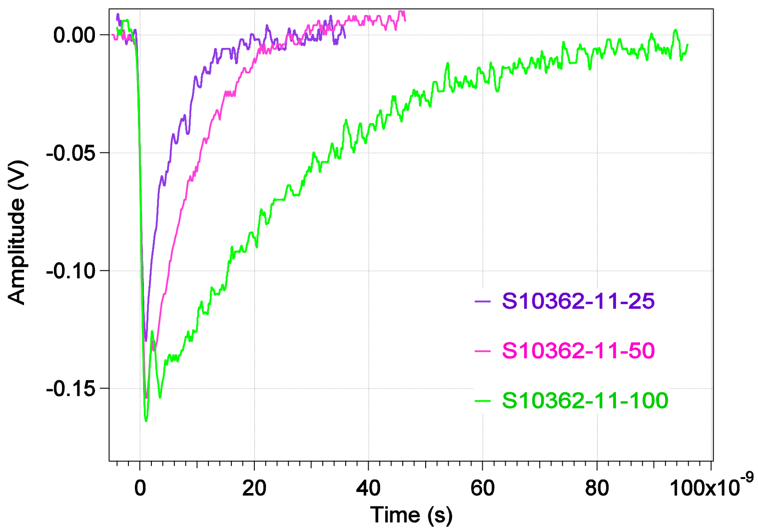
- Pilas pulsed laser diode



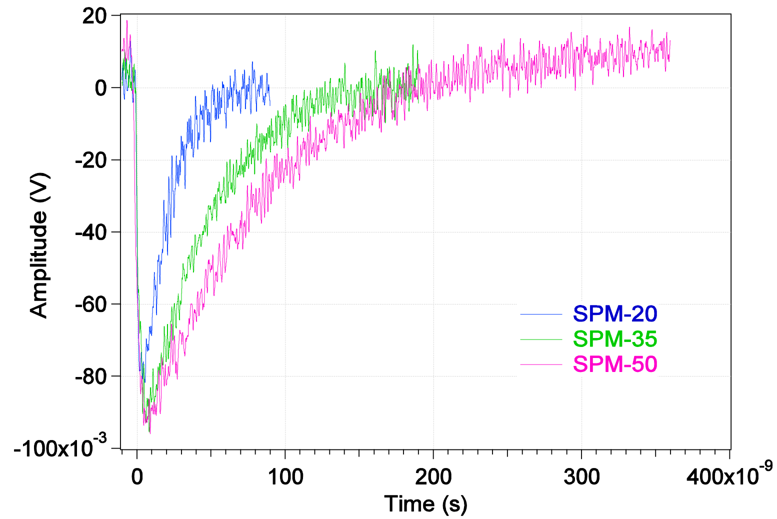
- Pilas driver : jitter ≈ 3 ps
- Timing resolution of the LECROY scope = 1 ps
- Timing resolution of the Wavecatcher = 8 ps
- Timing resolution of the SiPM ?

SiPMs signals (voltage amplifier output)

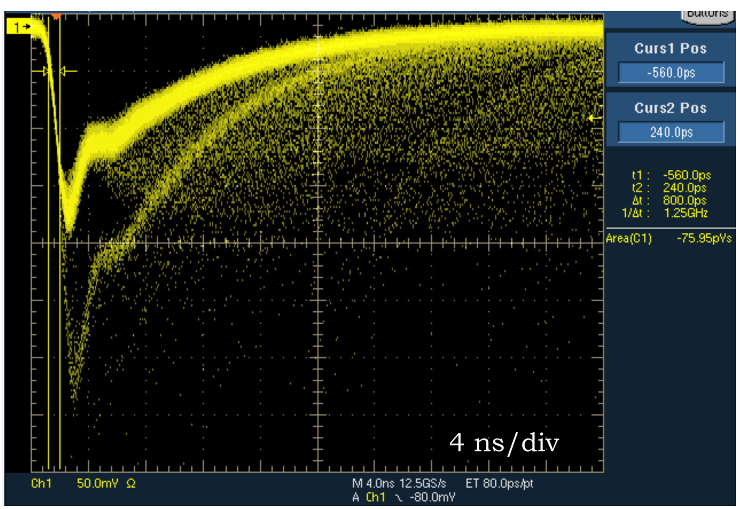
HAMAMATSU MPPC S10362-11



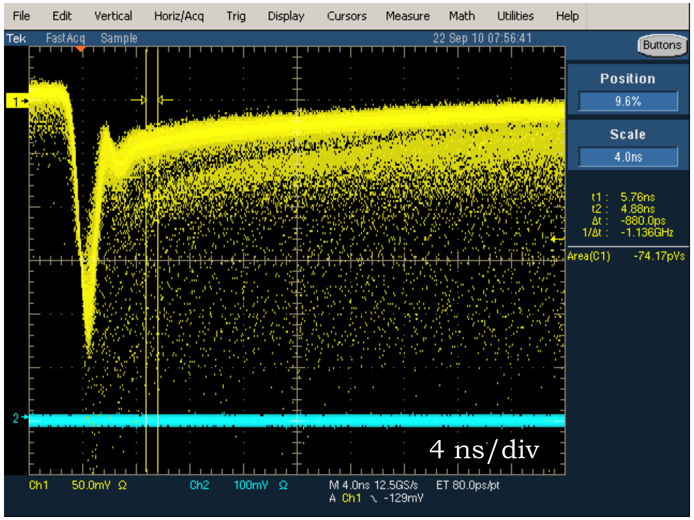
Sensl SPM



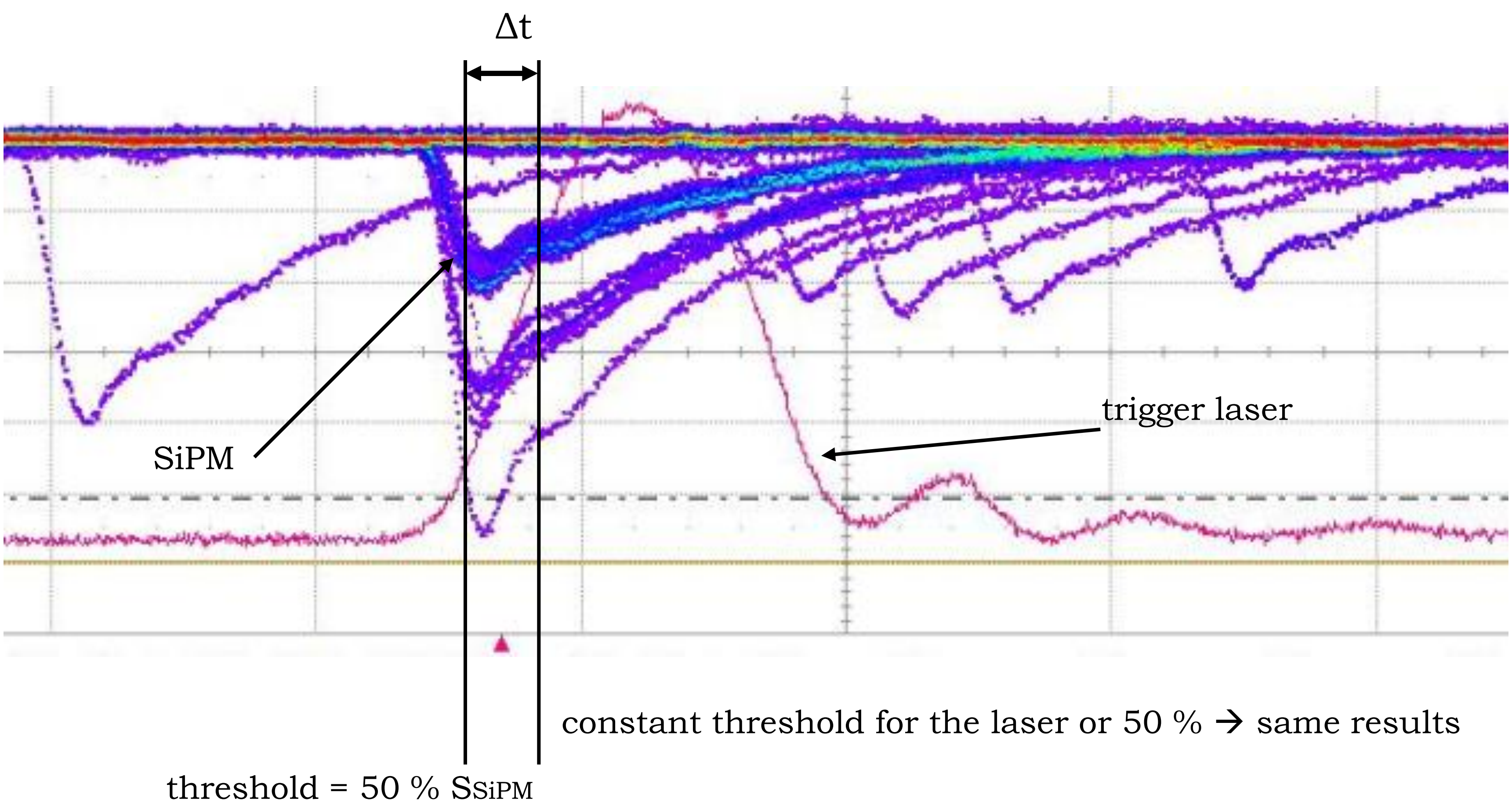
HAMAMATSU MPPC 50 μm (2009)



FBK SiPM (ref B) (2009)



Measurement principle of the SiPM timing resolution



constant threshold for the laser or 50 % → same results

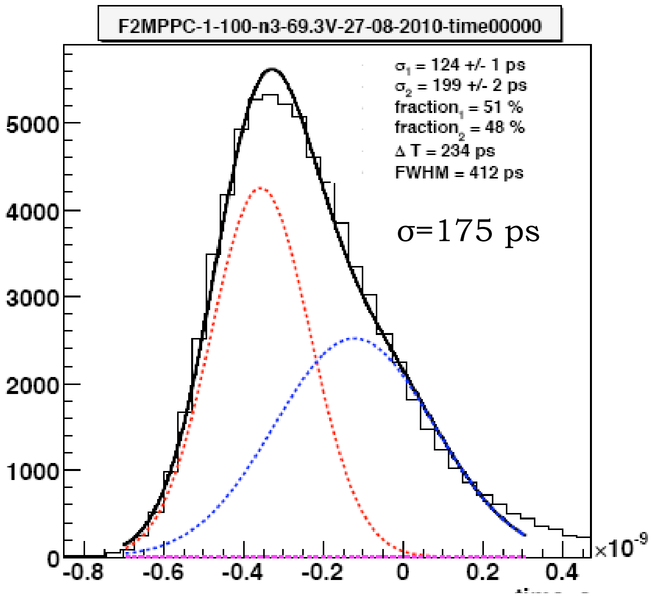
Measurement of the time between the laser and the SiPM signals → distribution of the Δt

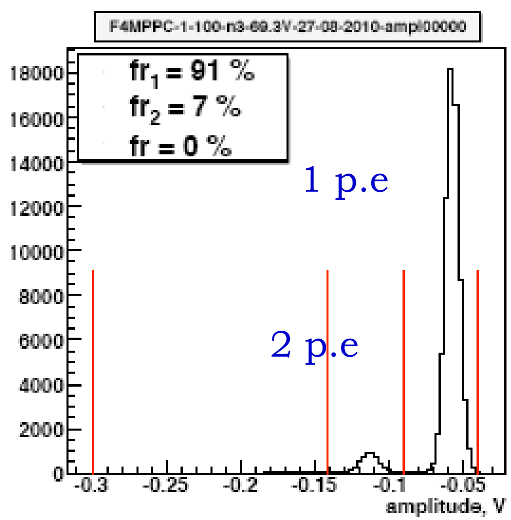
Δt and amplitude distribution of the SiPM signals

V. Puill, XIIth SuperB Project Meeting, Frascati, Sept 27-31 2010

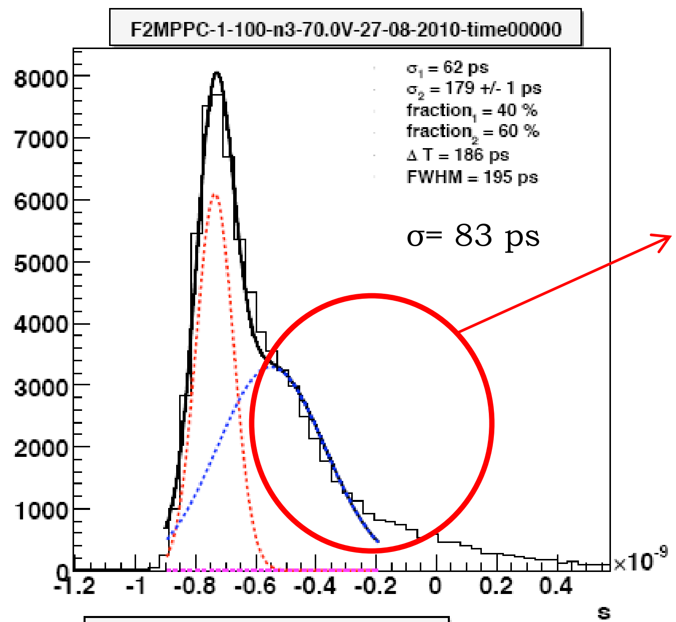
Data from LECROY oscilloscope

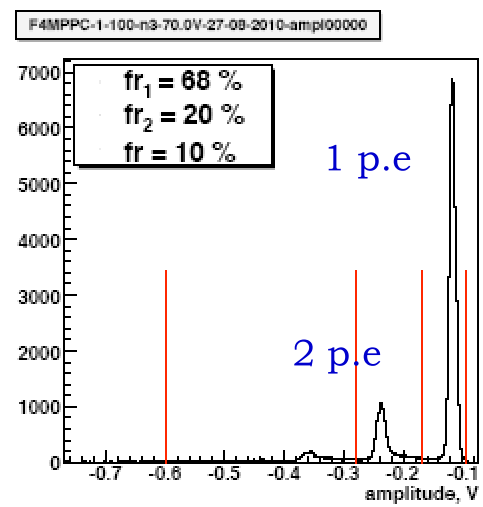
MPPC-1-100-n3-69.3V





MPPC-1-100-n3-70.0V



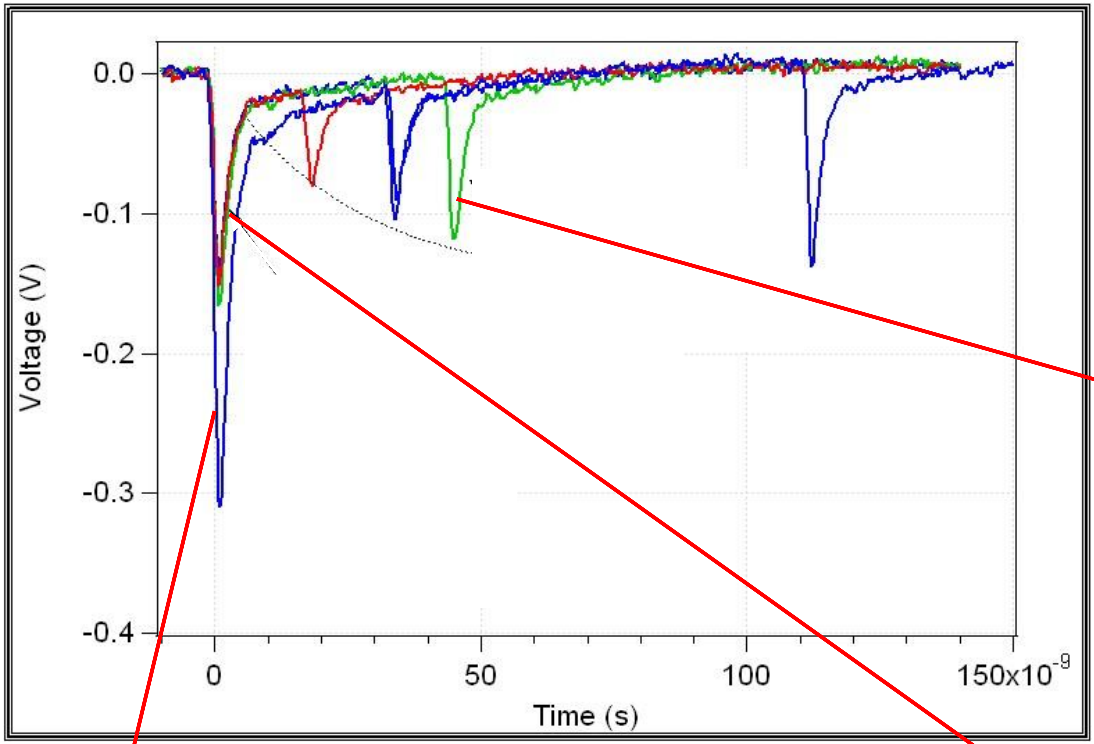


tail ↗ with Vbias

Cross-talk ?

Cross-talk definition

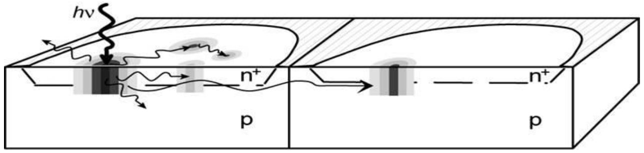
Noise : pulses triggered by non-photo-generated carriers



After-pulses

carriers trapped during the avalanche can produce delayed secondary pulses

Cross-talk



An avalanche in one pixel may produce an optical photon wich can trigger another avalanche in a neighboring pixel without delay

Dark noise

Thermally produced avalanche.
Looks the same as pulse from photon

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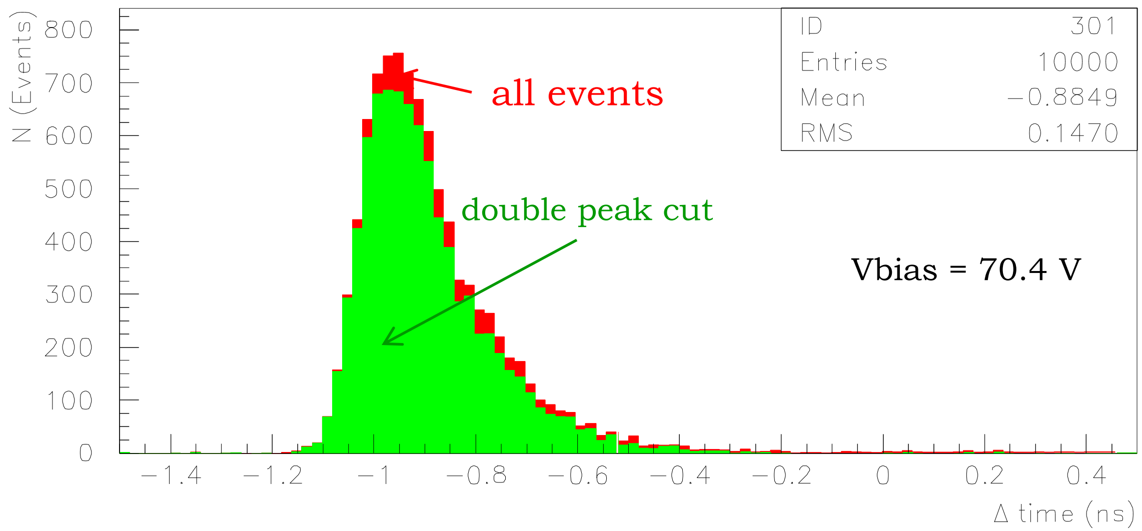
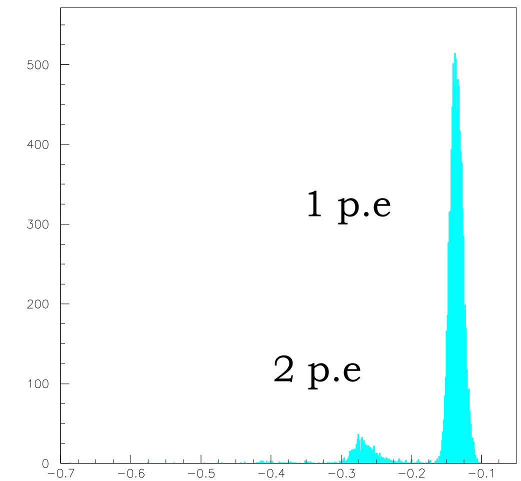
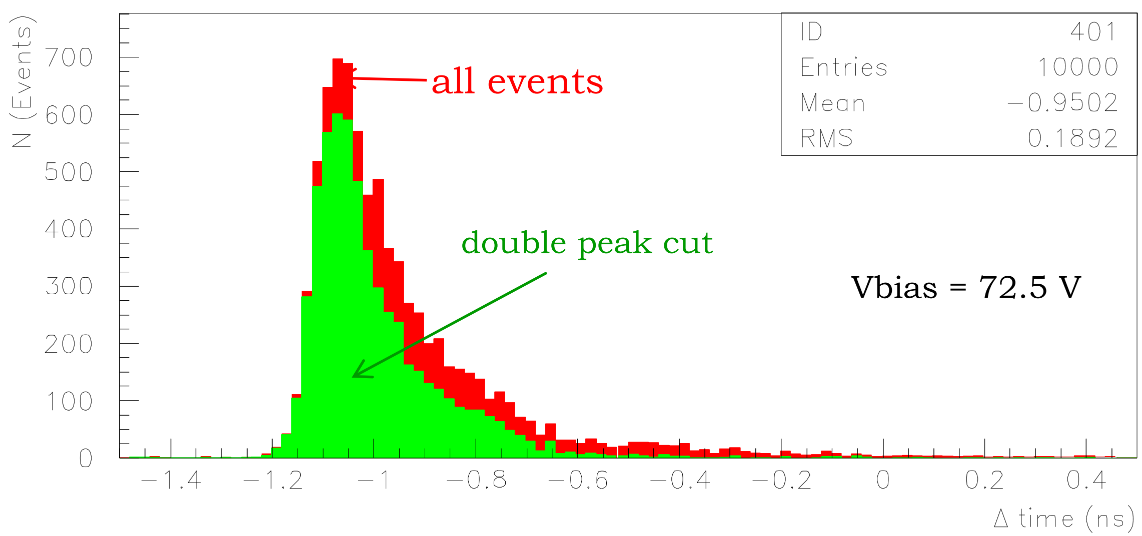
Contribution of the cross-talk to the TTS histo tail

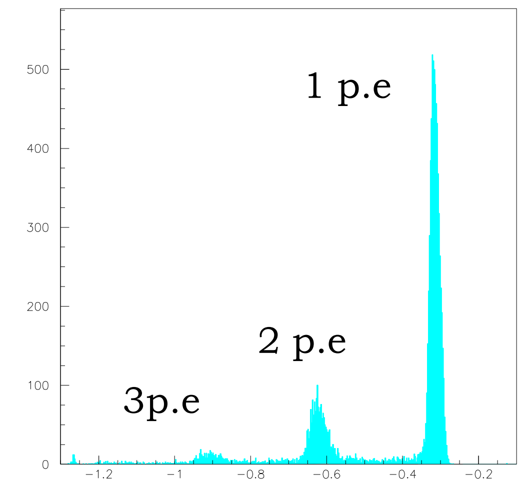
MPPC 10-50S-BK 4S



Amplitude distribution
Vbias = 70.4 V





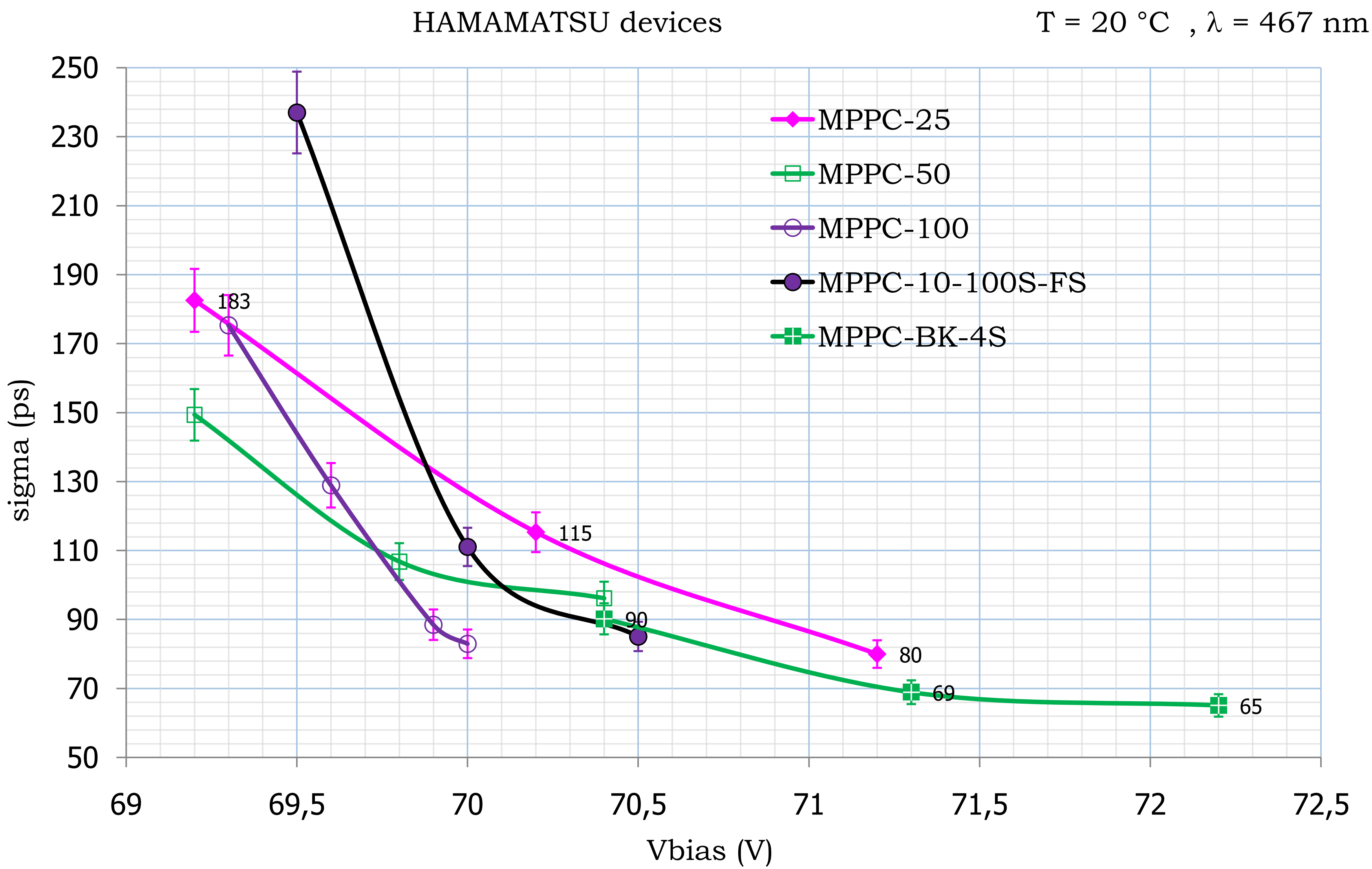


Amplitude distribution
Vbias = 72.5 V

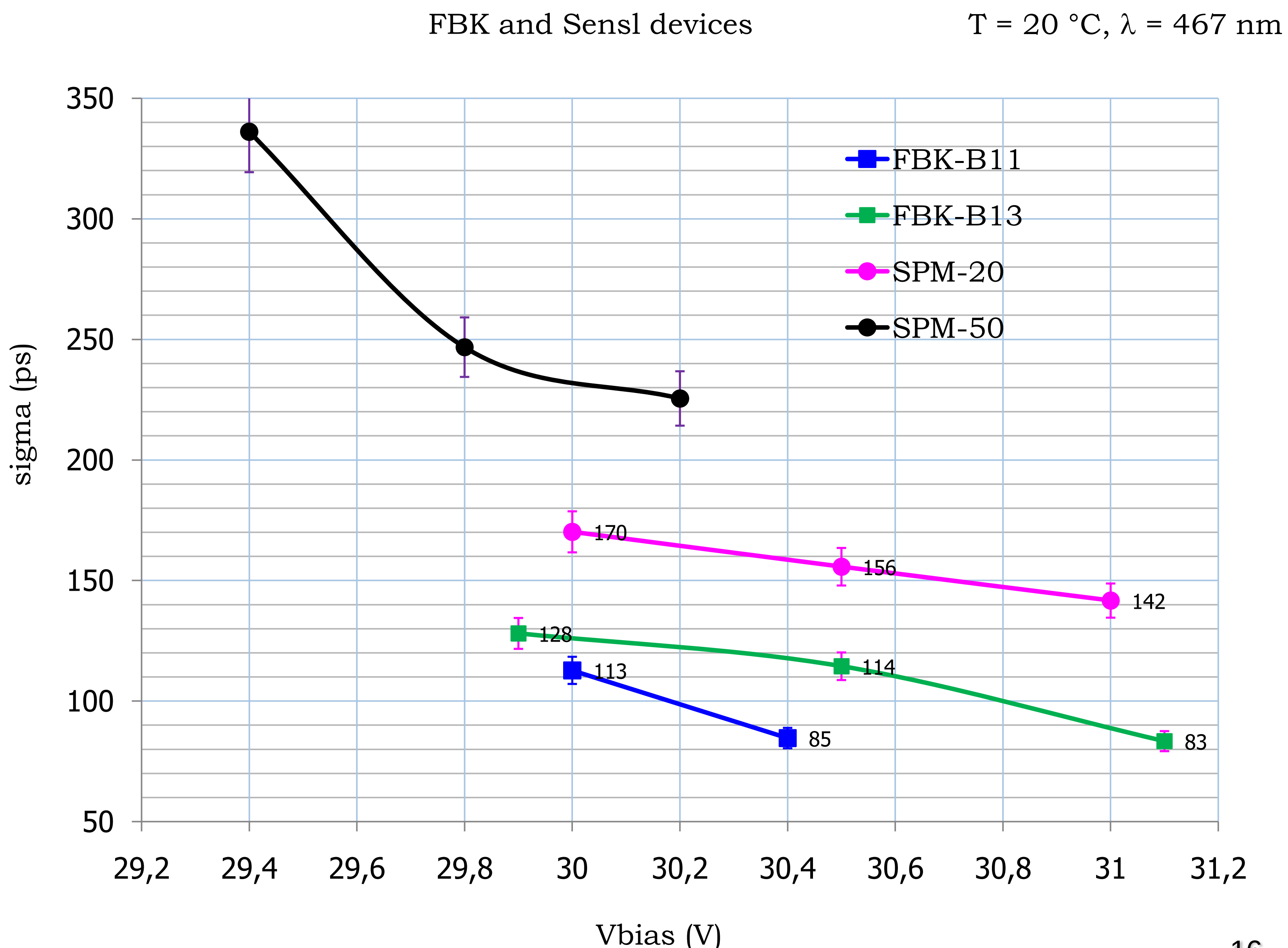
Data from Wavecatcher

→ Tail : not only due to cross-talk

Single Photo Electron Timing Resolution



Single Photo Electron Timing Resolution



Conclusion, further work

Conclusion

- 65 ps < SPTR SiPM 1 mm²< 85 ps at 20 °C, 467 nm
- SPTR measurements with the Wavecatcher and the LECROY scope in agreement (15 %)
- Tail of the TTS histo → to be undersood

Further work

★ **Measurement of the SiPM timing resolution of 9 mm² SiPM (HAMAMATSU, FBK, Sensl)**

★ **Measurement of the SiPM timing resolution in function of the :**

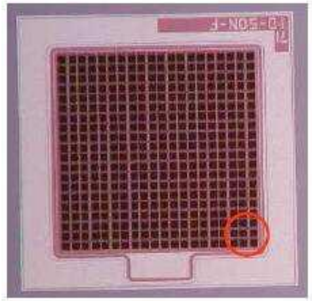
- ❖ wavelength (403 nm and 633 nm)
- ❖ simultaneous incident number of photons
- ❖ temperature

★ **Study of Burle (64 anodes) and HAMAMATSU (SL10 4 and 16 anodes) MCP-PMTs**

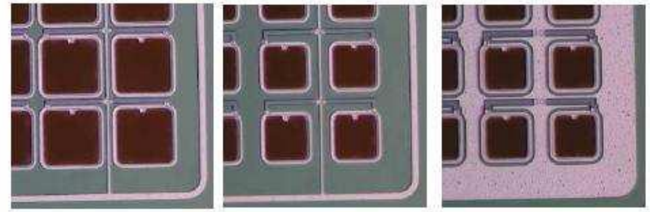
Additional slides

T = 20°C	type détecteur	Vbd (V)	V1 (V)	V2 (V)	V3 (V)
HPK	MPPC 10-50S-BK 4S n°10	69,1	70,1	70,9	71,5
DCR (Hz)	MPPC 10-50S-BK 4S n°10		2,91E+05	6,45E+05	1,18E+06
Gain th	MPPC 10-50S-BK 4S n°10		4,17E+05	7,56E+05	1,00E+06
HPK	MPPC 10-100S-FS n°11	69,12	69,5	70	70,5
DCR (Hz)	MPPC 10-100S-FS n°11		2,00E+05	4,00E+05	6,00E+05
Gain th	MPPC 10-100S-FS n°11		7,85E+05	1,85E+06	2,88E+06
HPK	S10362-11-025U-n°11	68,2	69,2	70,2	71,2
DCR (Hz)	S10362-11-025U-n°11		4,30E+04	1,08E+05	1,90E+05
Gain th	S10362-11-025U-n°11		1,28E+05	2,50E+05	3,74E+05
HPK	S10362-11-050U-n°3	68,35	69,2	69,8	70,4
DCR (Hz)	S10362-11-050U-n°3		1,53E+05	2,94E+05	4,81E+05
Gain th	S10362-11-050U-n°3		5,41E+05	9,24E+05	1,31E+06
HPK	S10362-11-100U-n°3	68,71	69,5	70	
DCR (Hz)	S10362-11-100U-n°3		1,76E+05	5,28E+05	
Gain th	S10362-11-100U-n°3		2,10E+06	3,36E+06	
FBK	FBK IRST B13	29,4	29,9	30,5	31,1
DCR (Hz)	FBK IRST B13			3,45E+06	5,87E+06
Gain th	FBK IRST B13		2,36E+05	5,19E+05	8,03E+05
FBK	FBK IRST B11	28,8	30	30,4	
DCR (Hz)	FBK IRST B11		2,95E+06	4,04E+06	
Gain th	FBK IRST B11		5,27E+05	7,18E+05	
SENSL	SensL 20µ	29,02	30	30,5	31
DCR (Hz)	SensL 20µ		7,09E+05	7,13E+05	7,61E+05
Gain th	SensL 20µ		4,53E+05	6,30E+05	8,13E+05

MPPC 50 µm « wide trace »



Quenching resistance = 130KΩ by forward IV curve

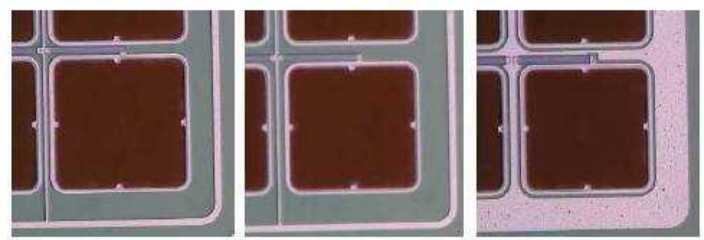


Sample name	STD	Small pixel	Wide trace
Fill factor	62 %	38 %	38 %
ΔV(Vop−Vbr) #1	1.31 V	2.02 V	2.01 V
Dark count at Vop	535 Kcps	484 Kcps	502 Kcps
Pixel capacitance (Cd) #2	90 fF	59 fF	60 fF
Stray capacitance / pixel #3	2.5 fF	11 fF	23 fF
PDE at Vop , 440nm	Not measure	Not measure	Not measure

#1 : Vop is at 7.5E05 #2 : by GAIN vs VR curve #3 : Ctotal / 400 – Cd at 25℃

MPPC 100 µm « wide trace »

Quenching resistance = 115KΩ by forward IV curve



Sample name	STD	Small pixel	Wide trace
Fill factor	78 %	72 %	72 %
ΔV(Vop−Vbr) #1	1.02 V	1.18 V	1.18 V
Dark count at Vop	1075 Kcps	1089 Kcps	1243 Kcps
Pixel capacitance (Cd) #2	373 fF	323 fF	325 fF
Stray capacitance / pixel #3	17 fF	37 fF	61 fF
PDE at Vop , 440nm	79.7 %	76.2 %	77.6 %

#1 : Vop is at 2.4E06 #2 : by GAIN vs VR curve #3 : Ctotal / 100 – Cd at 25℃