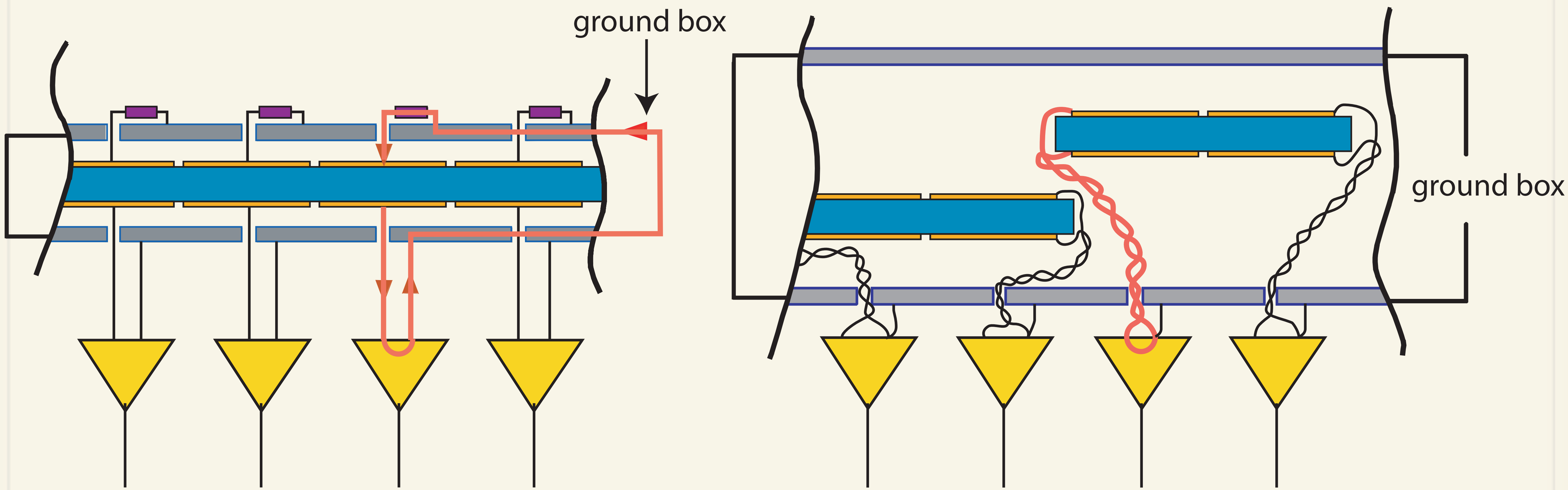
Systematic study of the latest Hamamatsu MPPCs readout with NINO ASIC

Crispin Williams
CERN & INFN -Bologna

outline

- The focus of this presentation will be on fast timing
- Recap from some techniques we learned from building the ALICE TOF
- Results from the latest generation of MPPCs

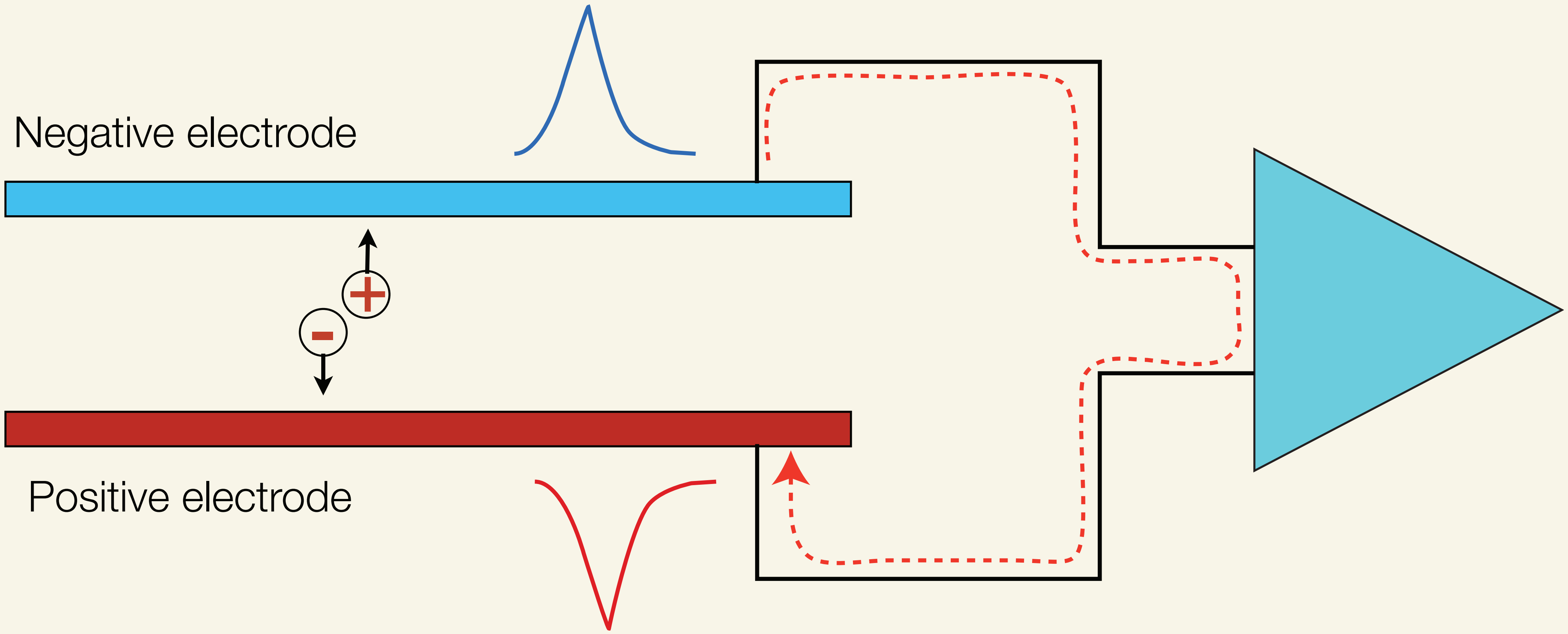
We learned from R&D for ALICE ToF:
Big reduction in noise if care is taken with the signal return



The signal is induced on the anode and cathode pickup pads - current flows from anode pad through amplifier and returns to cathode pad. The strip design allows the use of a transmission line (twisted pair cable) to connect this 'signal generator' to the amplifier - otherwise return path is via the outside grounding box (therefore sensitive to all the noise in the ground). In reality this is a key ingredient to substantially reducing the noise and improving the time resolution

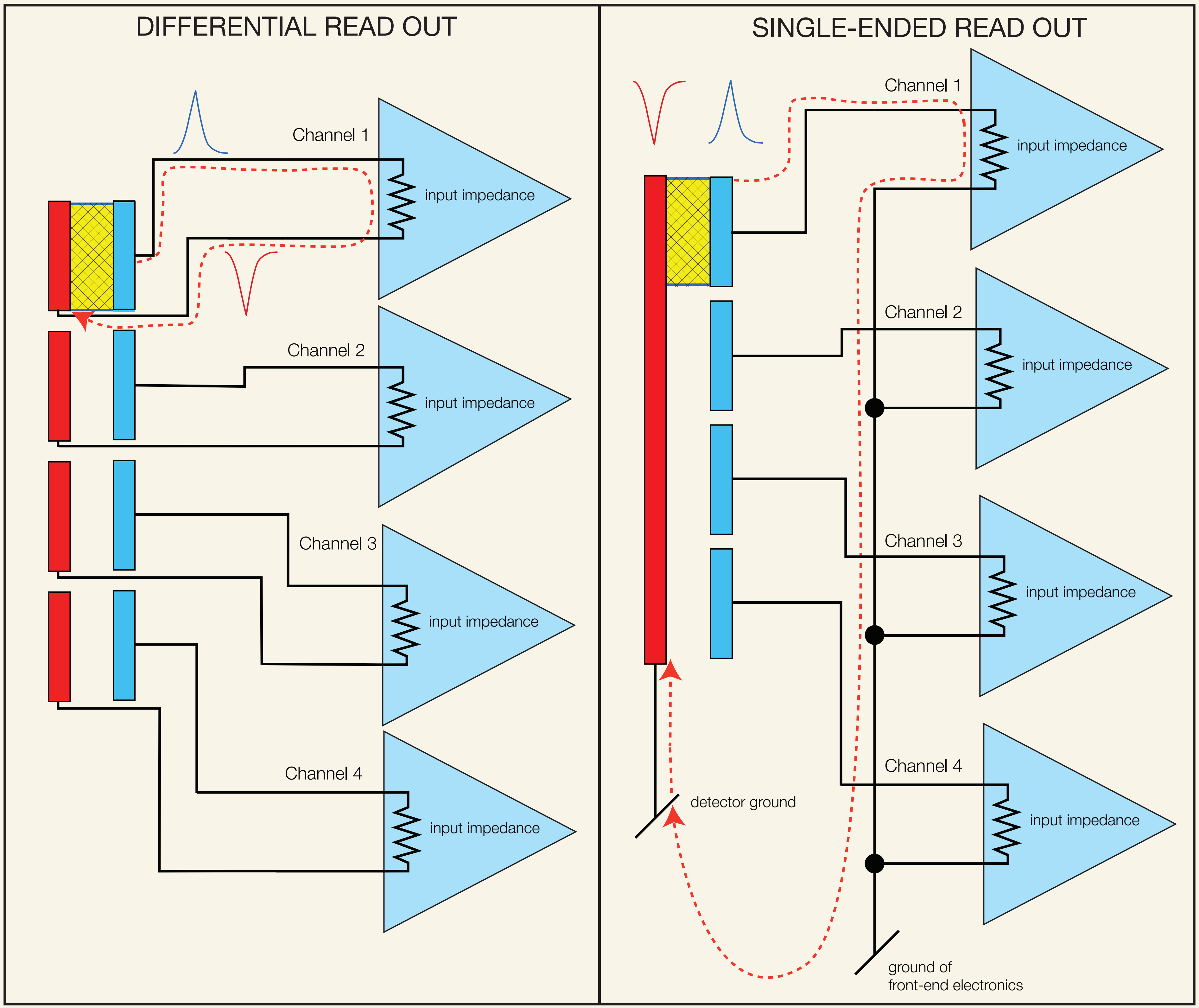
If you want to get better than 50 ps time resolution - must use differential readout - must have access to anode and cathode readout pads

All signals produced by movement of charge between pickup electrodes

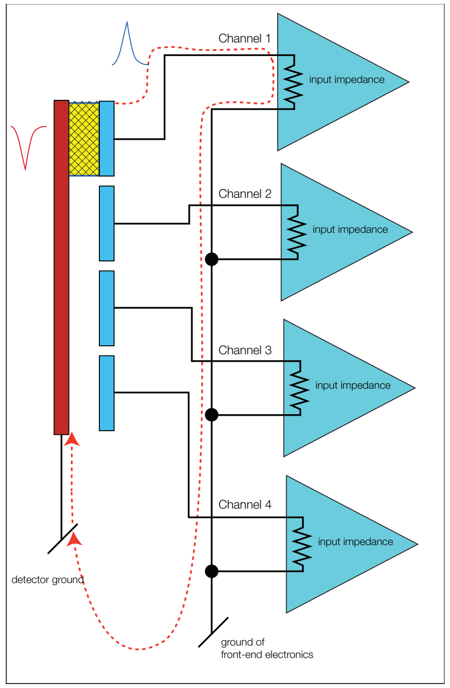


This is true of all detectors: SiPM/SPADS, MCP…….

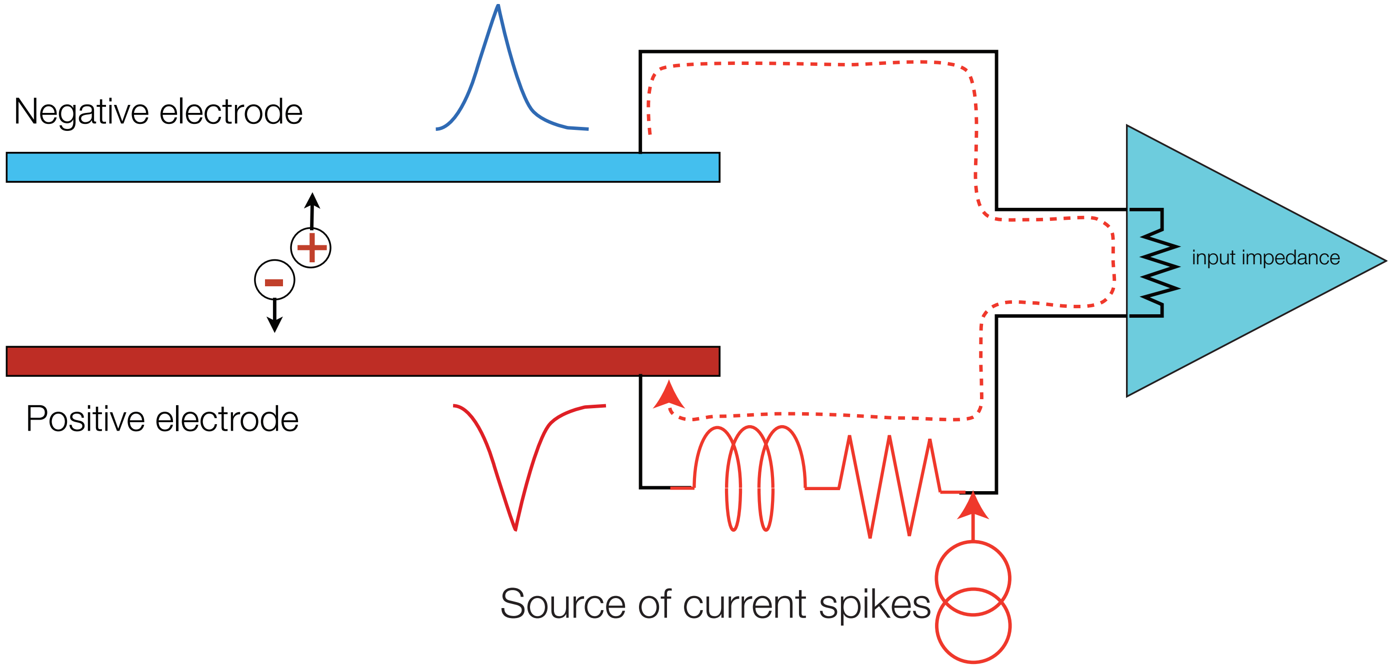
Single ended vs Differential



single-ended has a common electrode: this injects current spikes into the neighbours

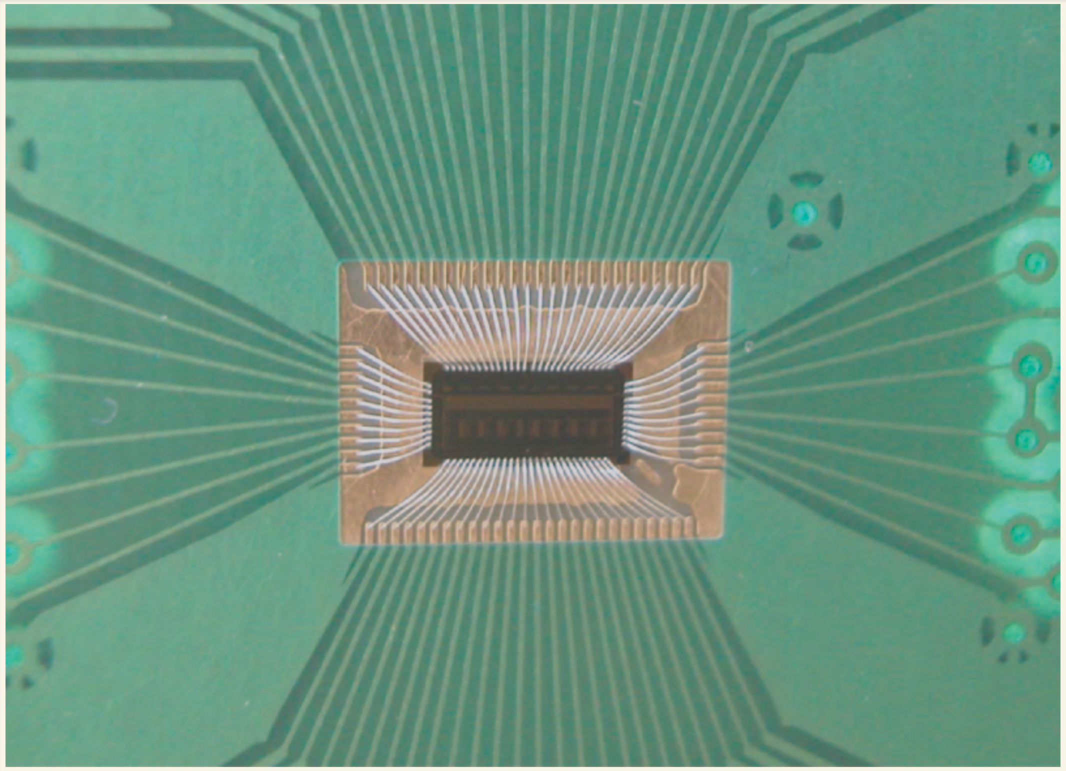


Take care of the signal return
(i.e.do not add extra resistance and inductance)

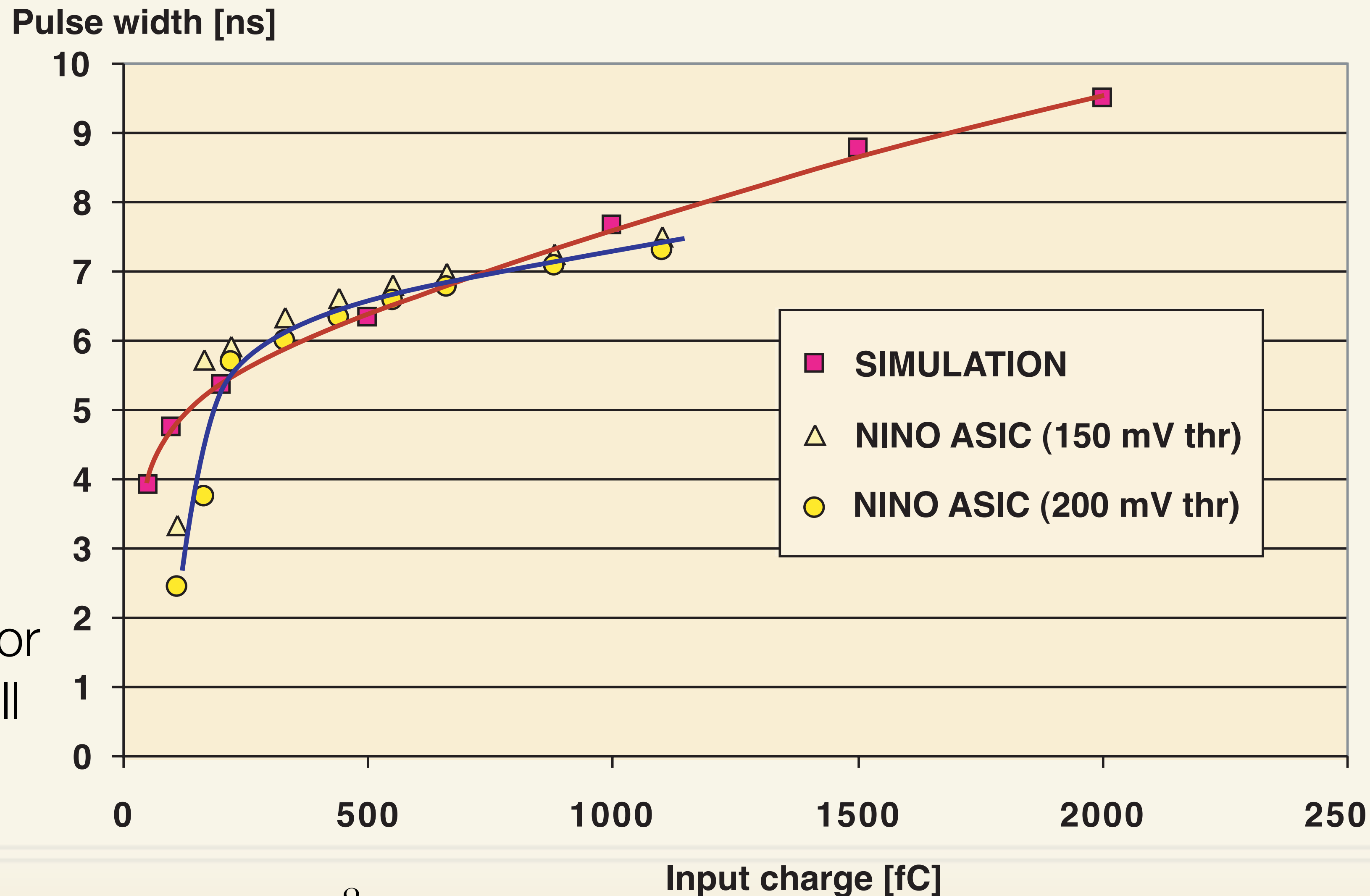


Also from the ALICE TOF Time-over-Threshold technique used extensively

- ALICE TOF: many colleagues wanted to install an ADC on each channel to measure charge
- however HPTDC measures time of all edges - so the pulse width can be measured



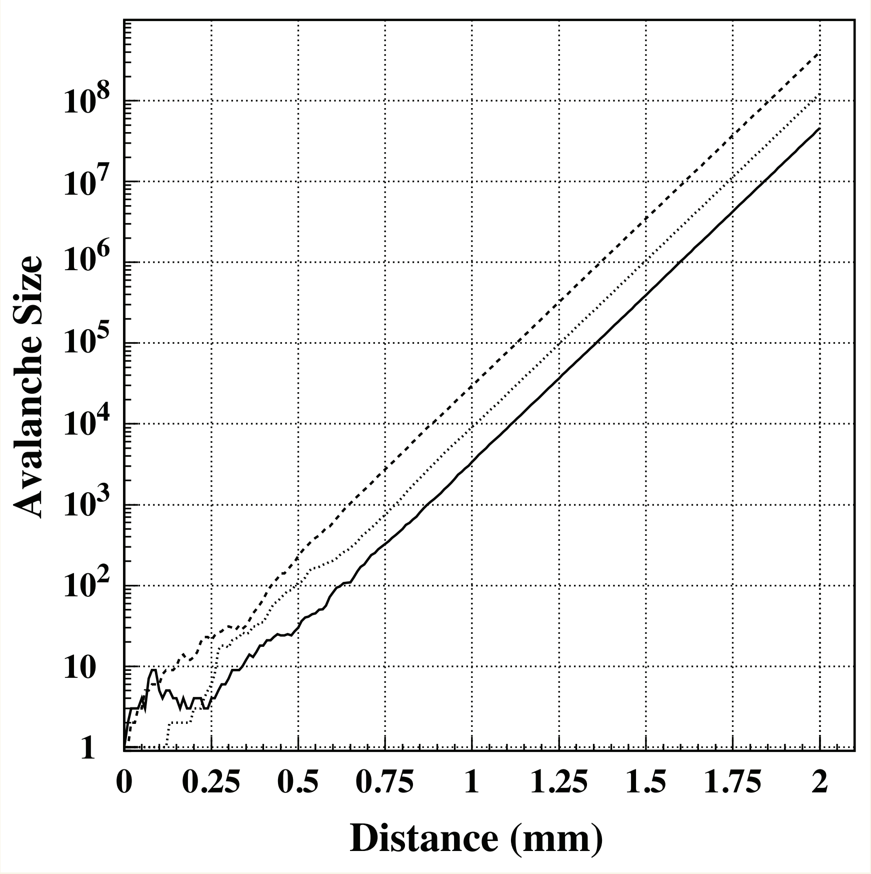
NINO asic : encode input charge into pulse width



Even though NINO designed for MRPC : it works extremely well with SiPMs

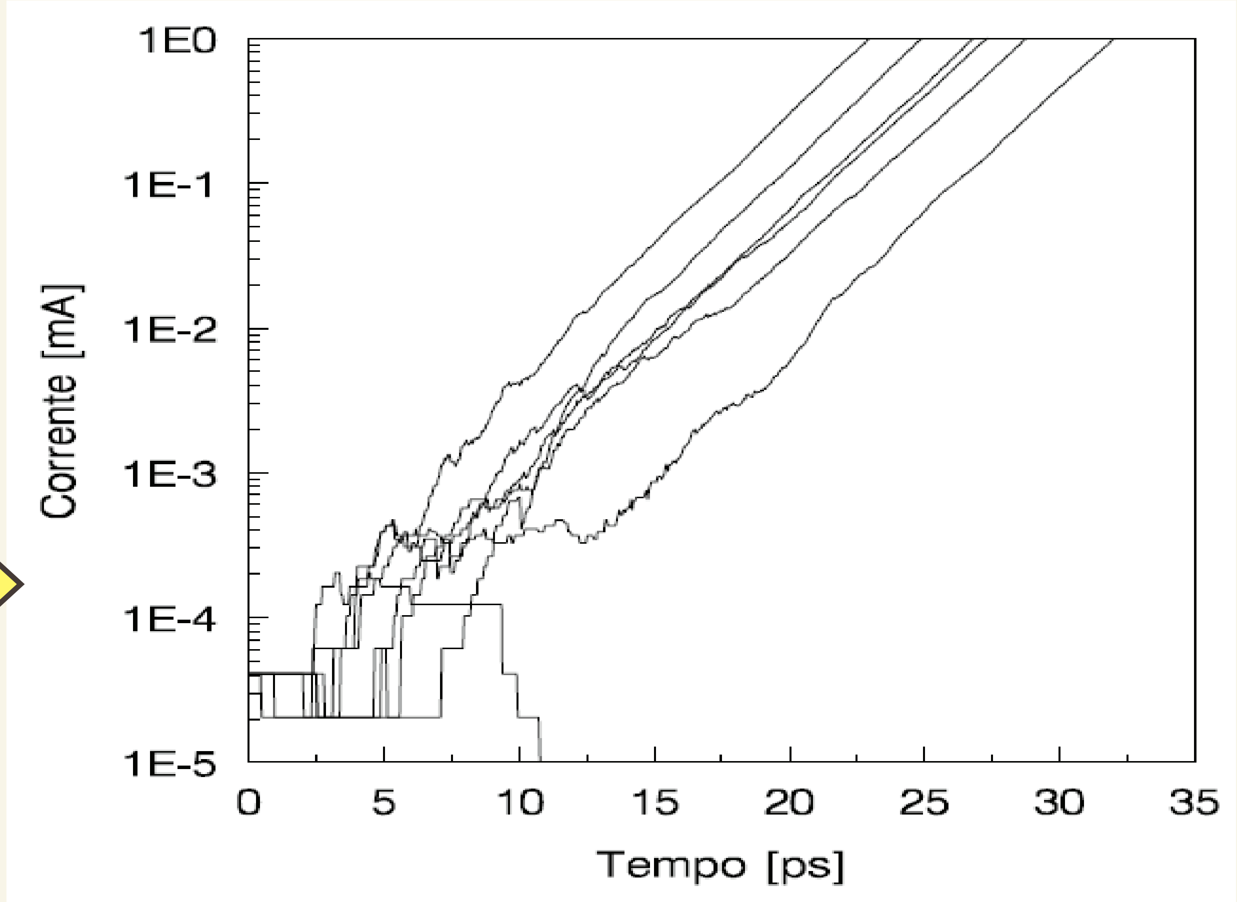
Time Development of avalanches

Detector physics and simulation of resistive plate chambers
Werner Riegler*, Christian Lippmann, Rob Veenhof NIMA 500 (2003) 144–162



Development of avalanche in 2 mm gap RPC

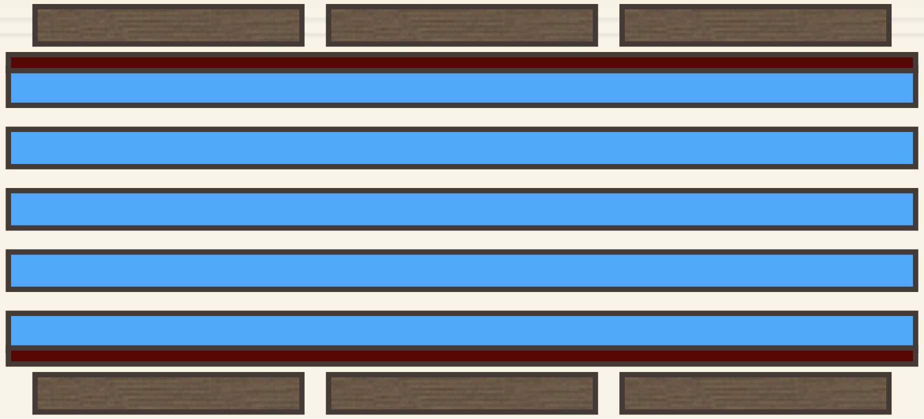
A. Spinelli Ph.D thesis (1996)



Development of avalanche in Silicon PM

In both cases the timing jitter is created during early development of avalanche

Multigap RPC

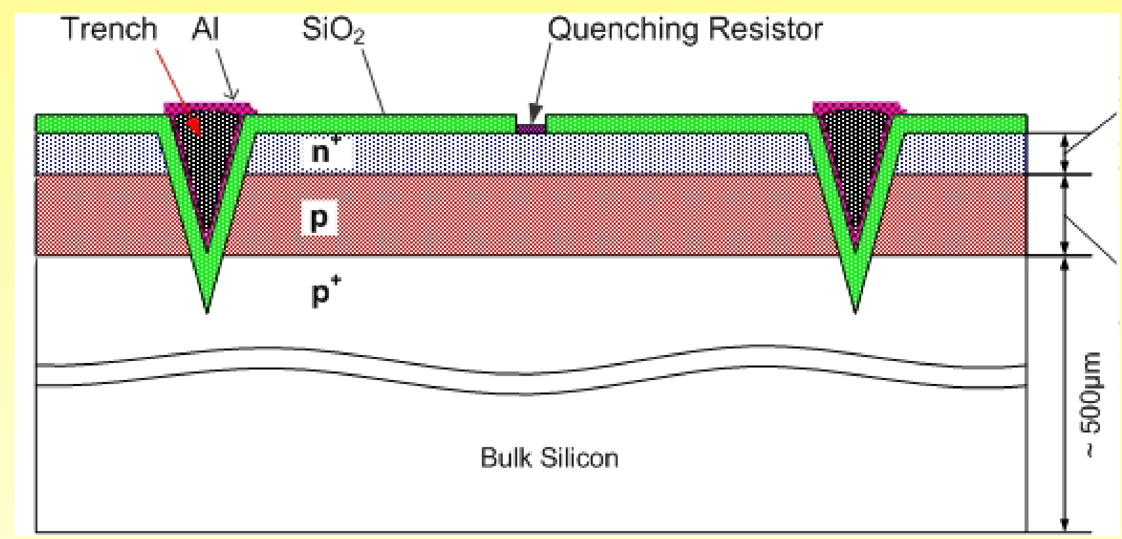


Electric field uniform : no cell boundaries

Electric field will be modified around edges of each cell (especially with trenches). This will introduce extra time jitter.

Optical cross-talk reduction

Solution: optically separate cells trenches



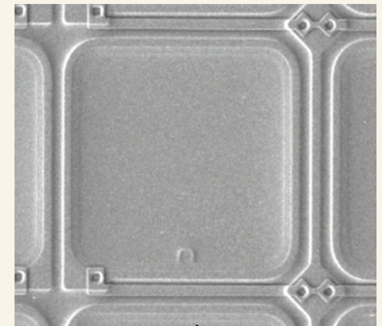
(D. McNally, G-APD workshop, GSI, Feb. 2009)

To reduce optical cross-talk CPTA /Photonique was the first to introduce trenches separating neighbouring pixels

CERN, SiPM workshop, 16.02.2011 *Y. Musienko (Iouri.Musienko@cern.ch)* 21

presented by Yuri Musienko in 2011

50 micron SPADS

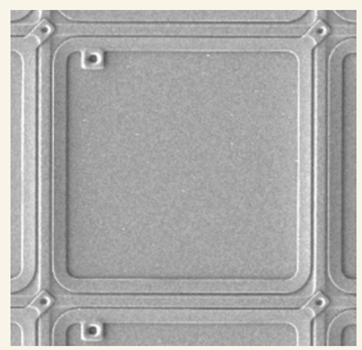


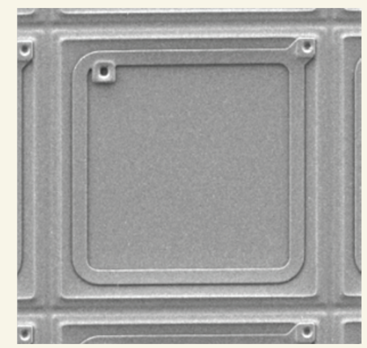
CONVENTION TYPE

HIGH FILL FACTOR TYPE

LOW CROSS TALK TYPE (WITH TRENCHES)

Polysilicate resistor replaced by transparent metal film



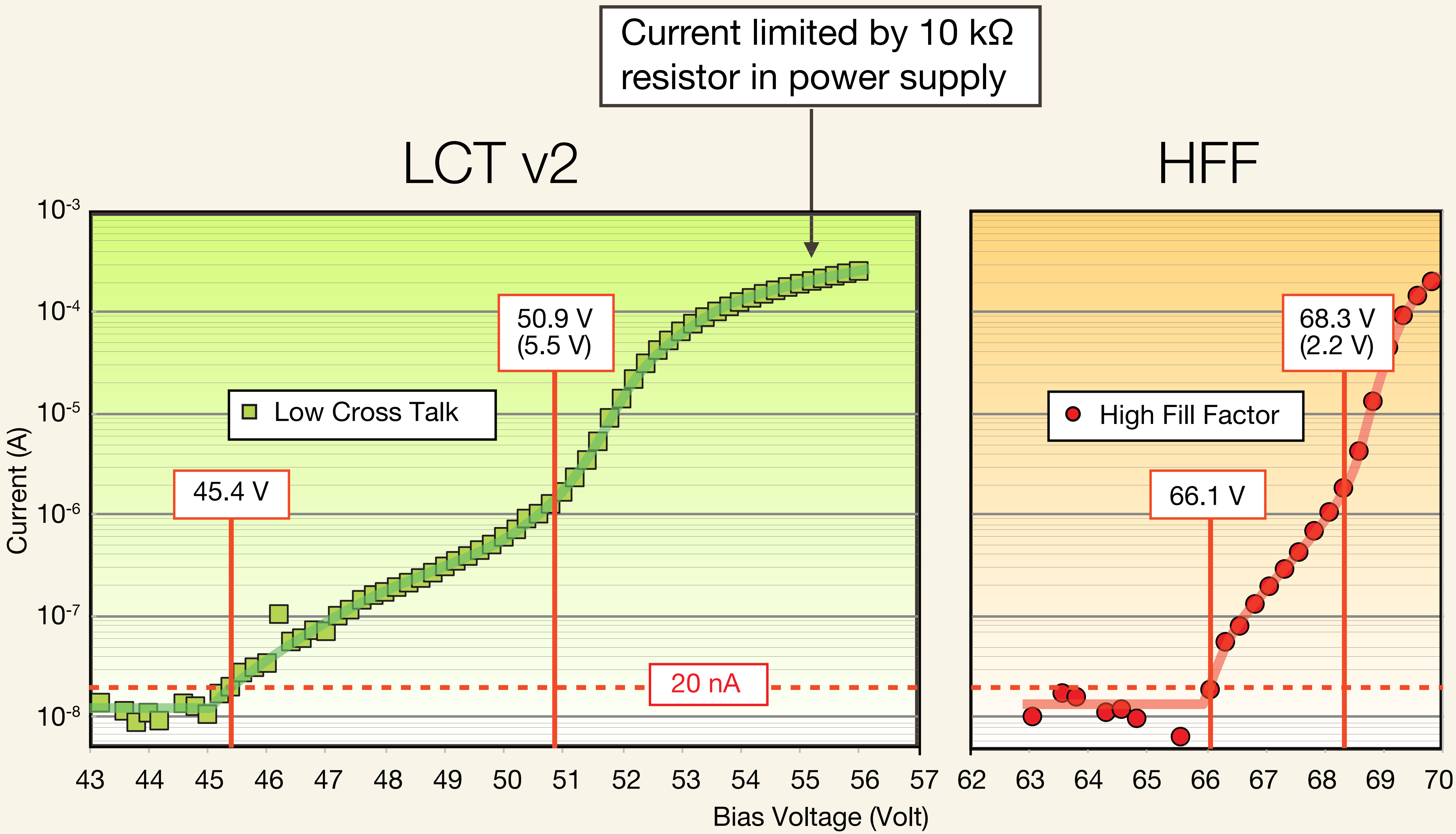


Trenches added to inhibit cross talk

3 x 3 mm^2 device

MPPC Type	SPAD size	Fill factor	Overvoltage for $1.5.10^6$ gain	C_{Total}	Crosstalk at $1.5.10^6$ gain	Dark Counts at $1.5.10^6$ gain
HFF-MPPC	50 µm	81%	2.6 V	320 pF	50%	2 MHz
LCT-MPPC	50 µm	60%	2.2 V	320 pF	12%	200 kHz

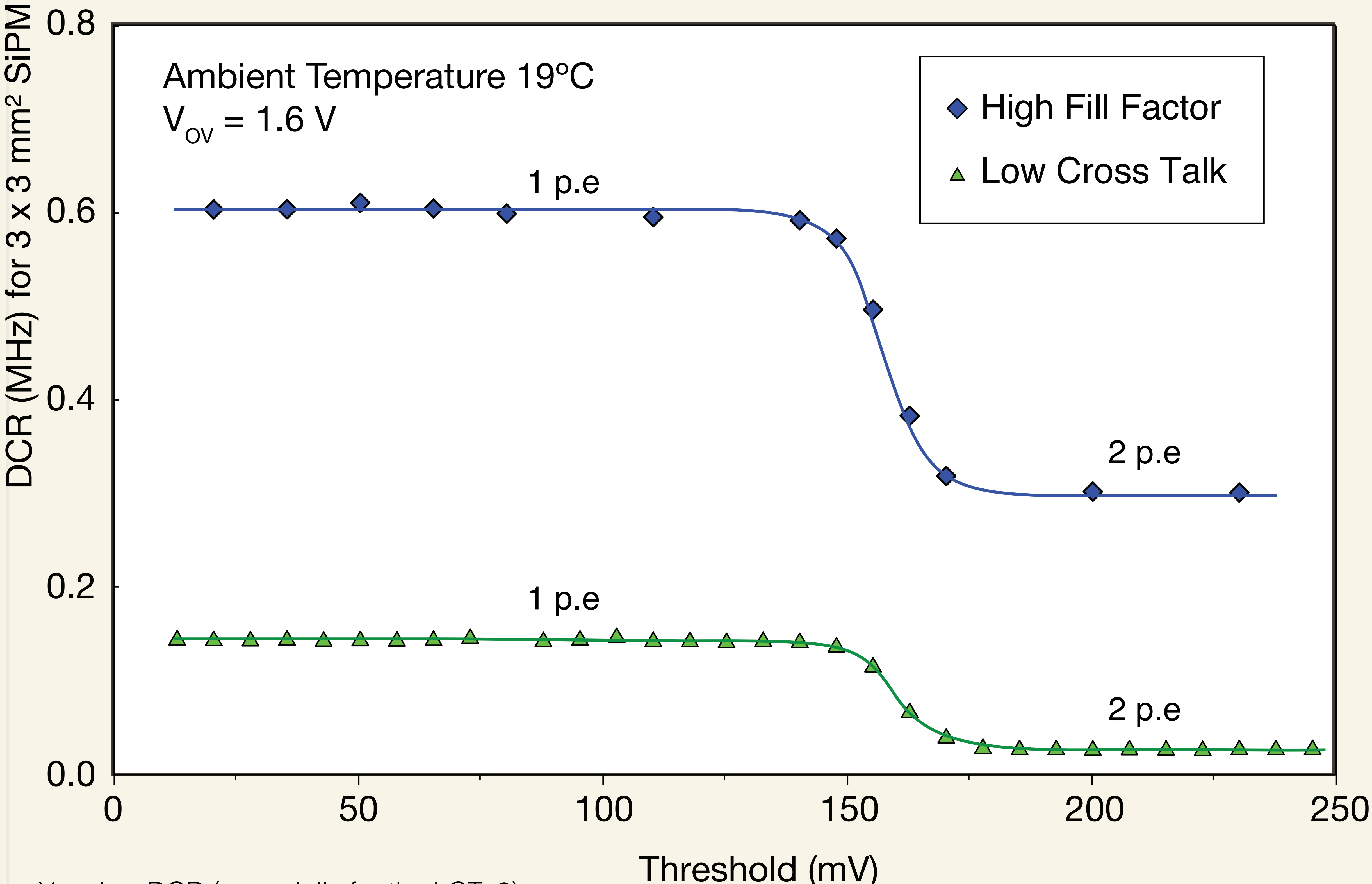
I-V curves



Very extended working voltage for the LCT MPPC

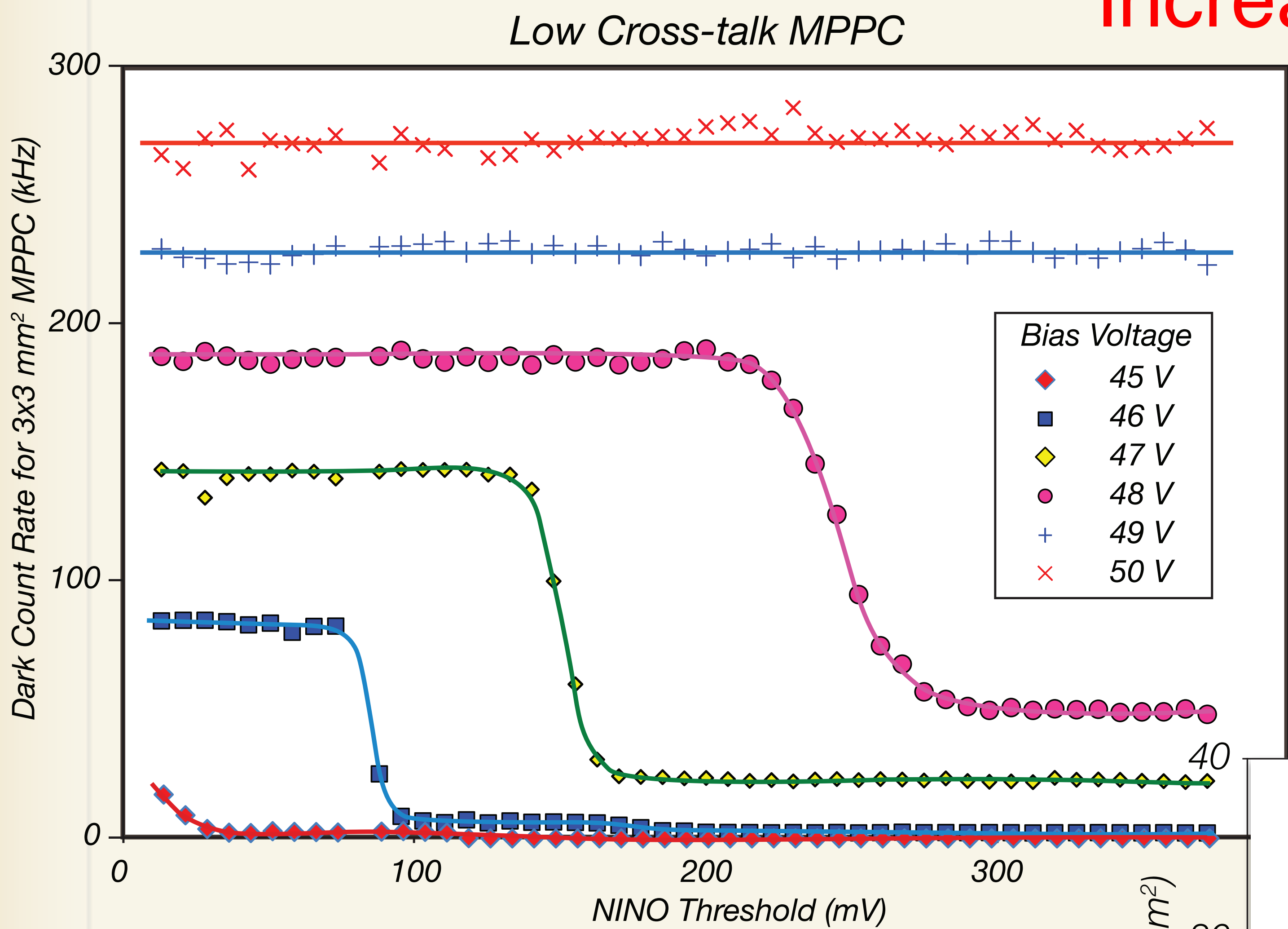
Crispin.Williams@cern.ch

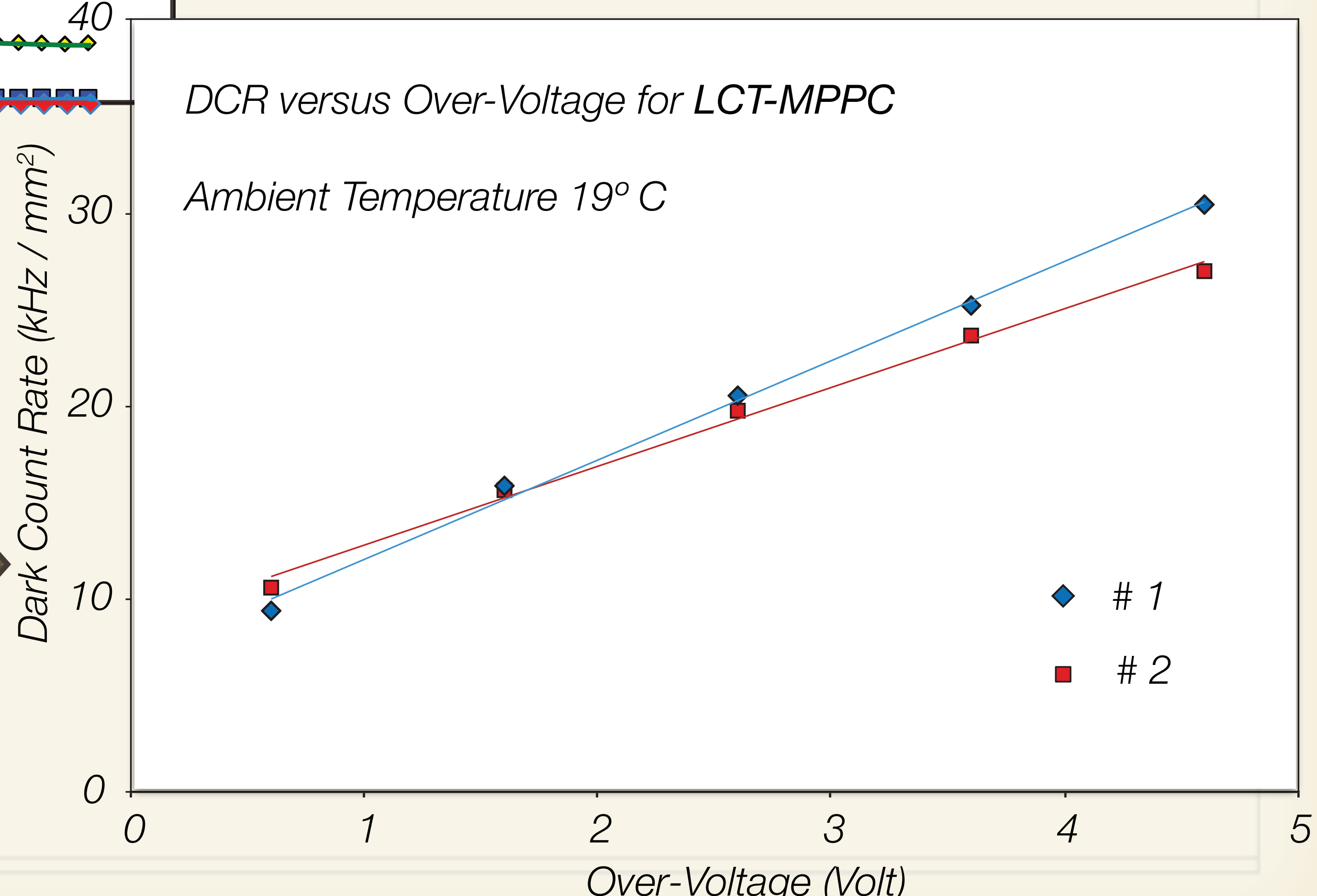
DCR versus threshold of NINO ASIC



- Very low DCR (especially for the LCTv2)
- also look at sharpness of step between 1 and 2 p.e (good uniformity and low noise)
- big reduction in crosstalk for LCT (as expected)

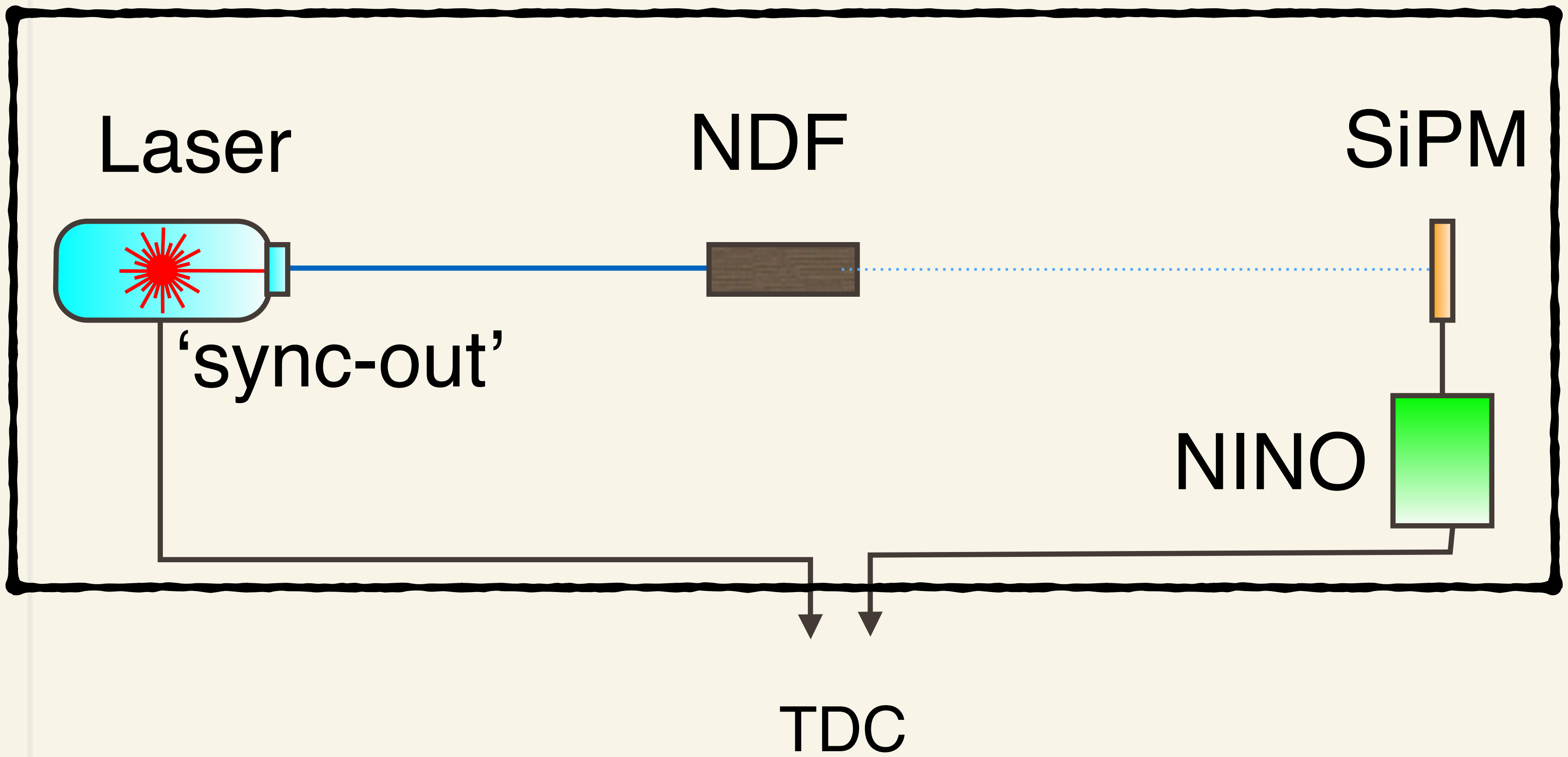
Increasing the bias Voltage……..

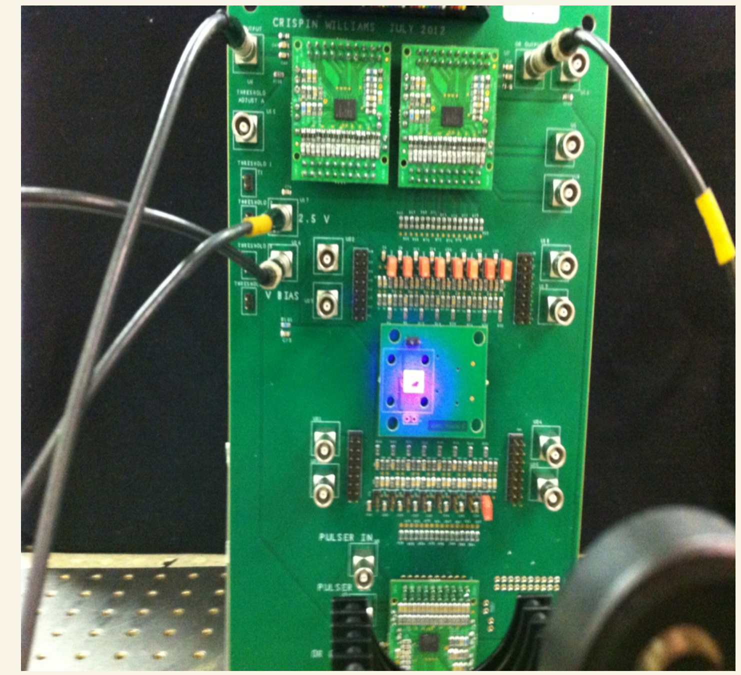


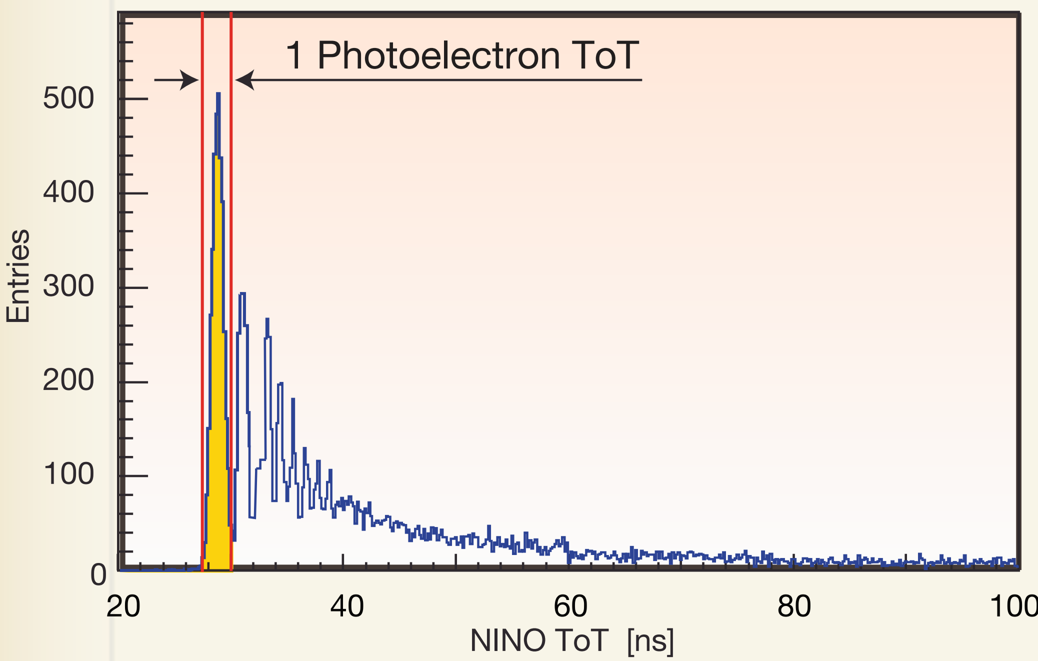


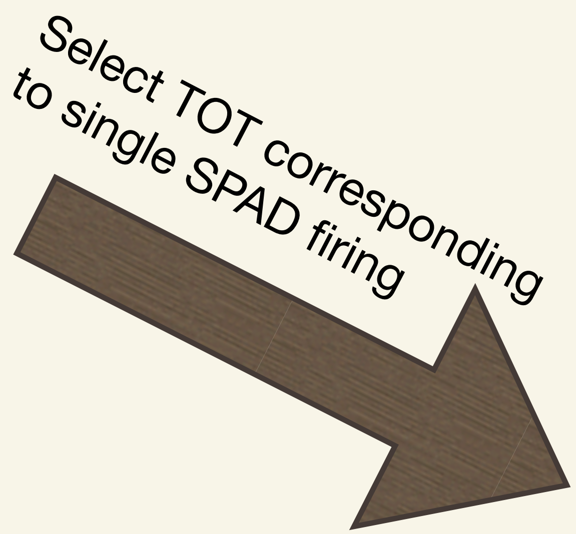
~ 30 kHz/mm² at ~ 5 V above breakdown

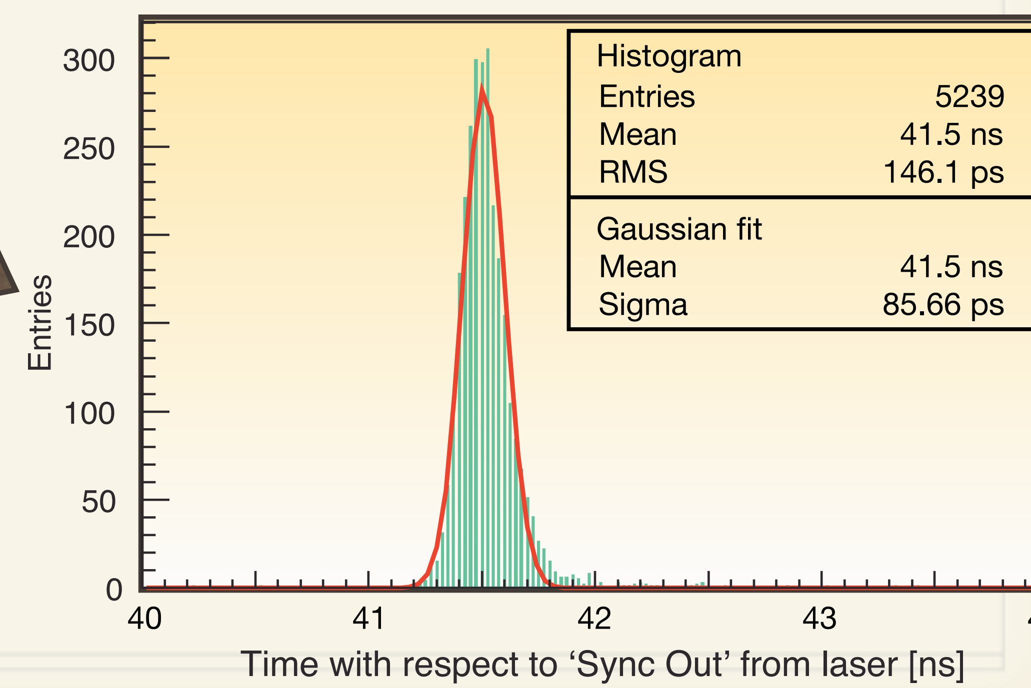
Single Photon Time Resolution





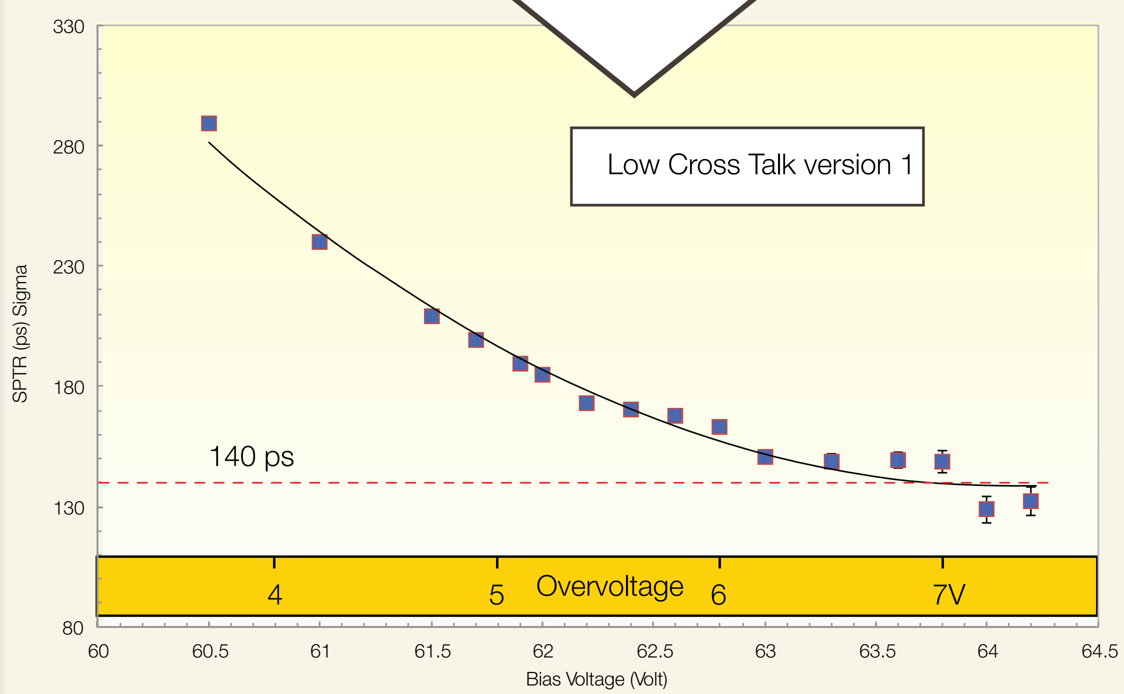


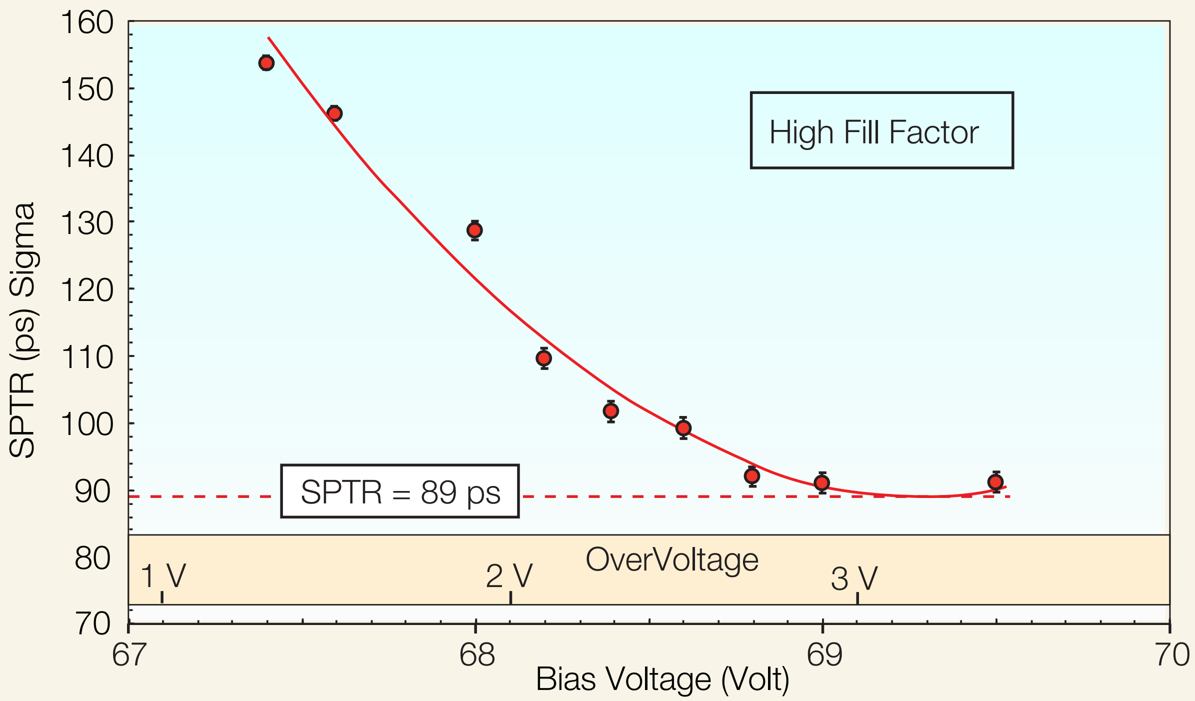


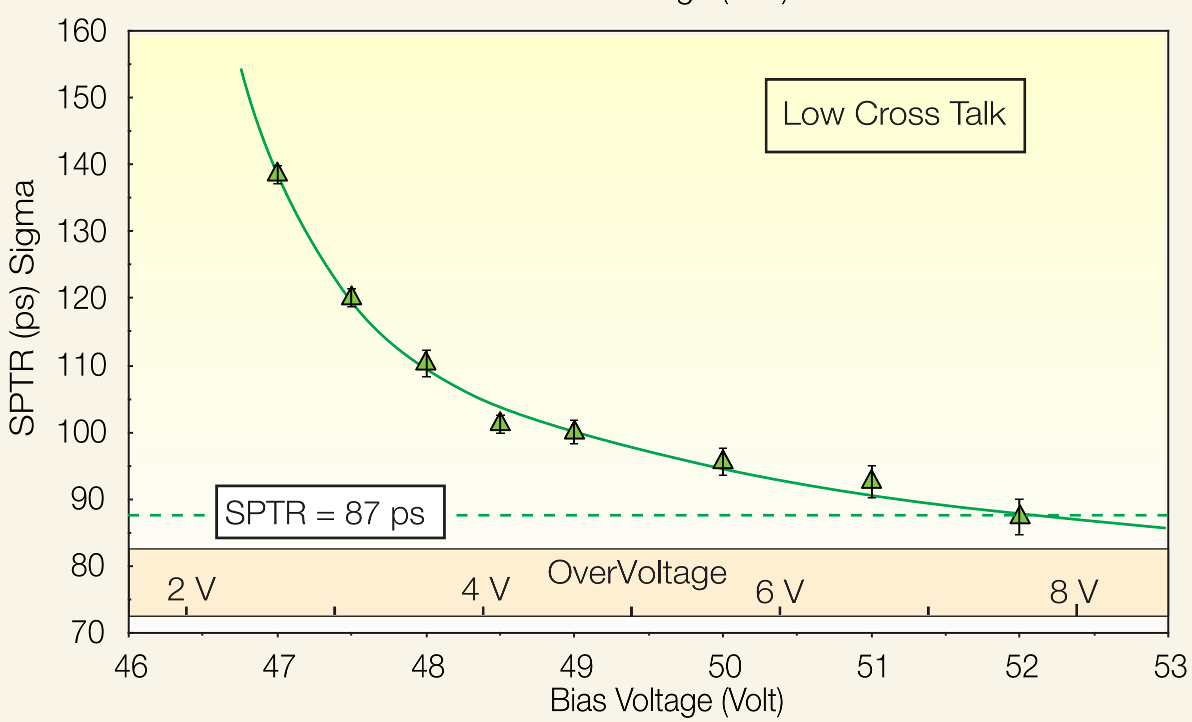


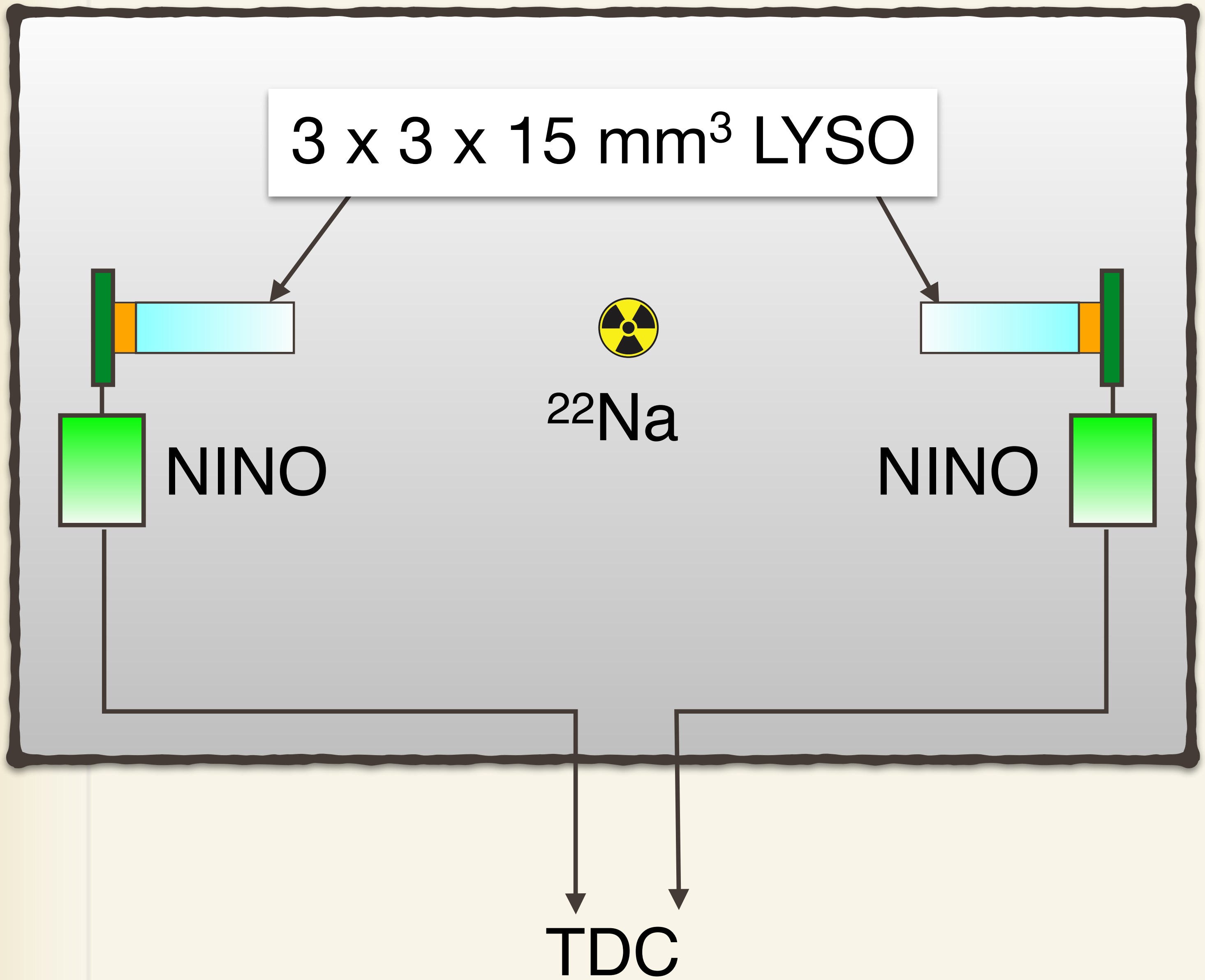
Single Photon Time Resolution

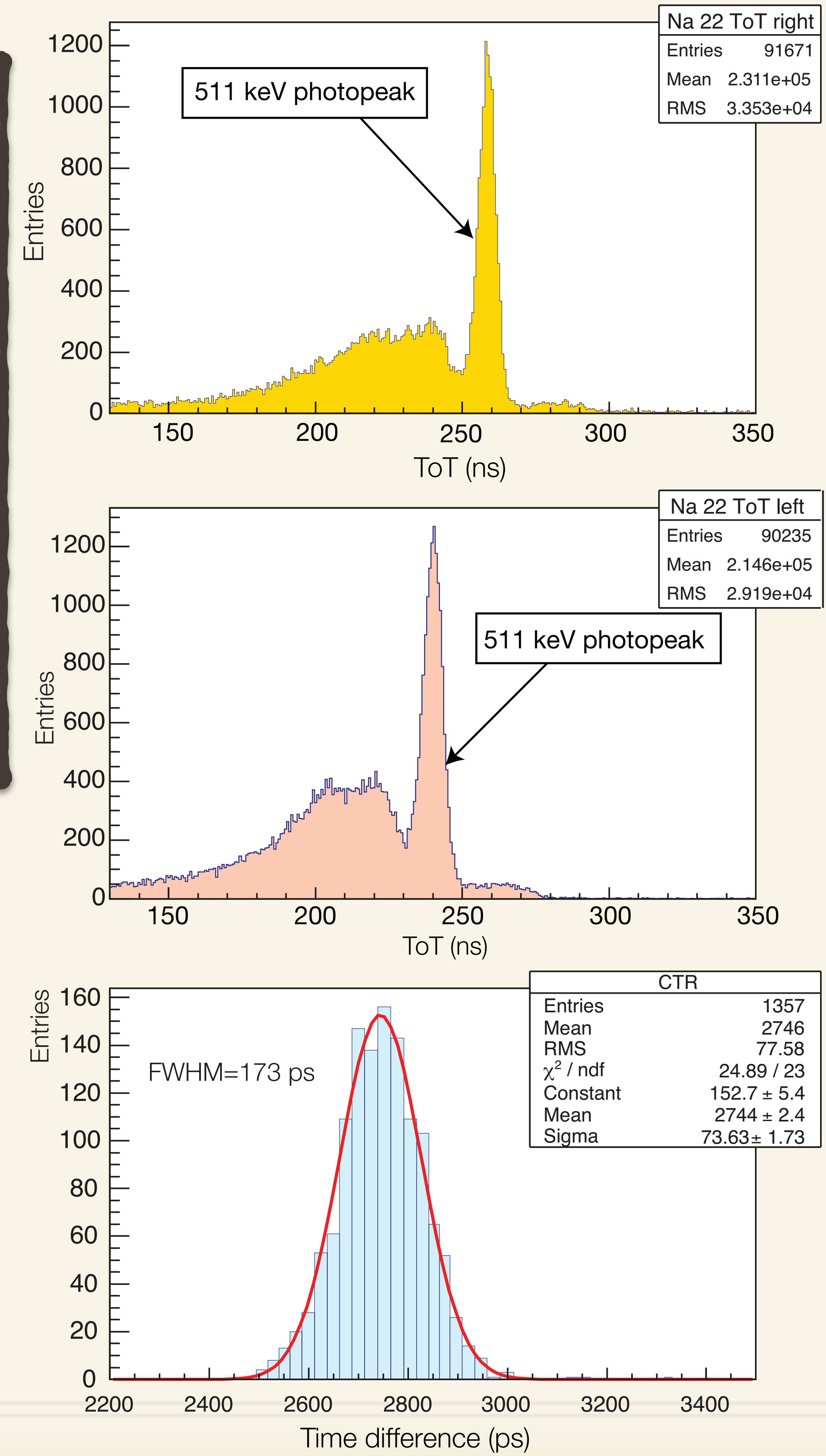
Significant degraded SPTR with first version of LCT MPPC (maybe edge effects around each SPAD??)







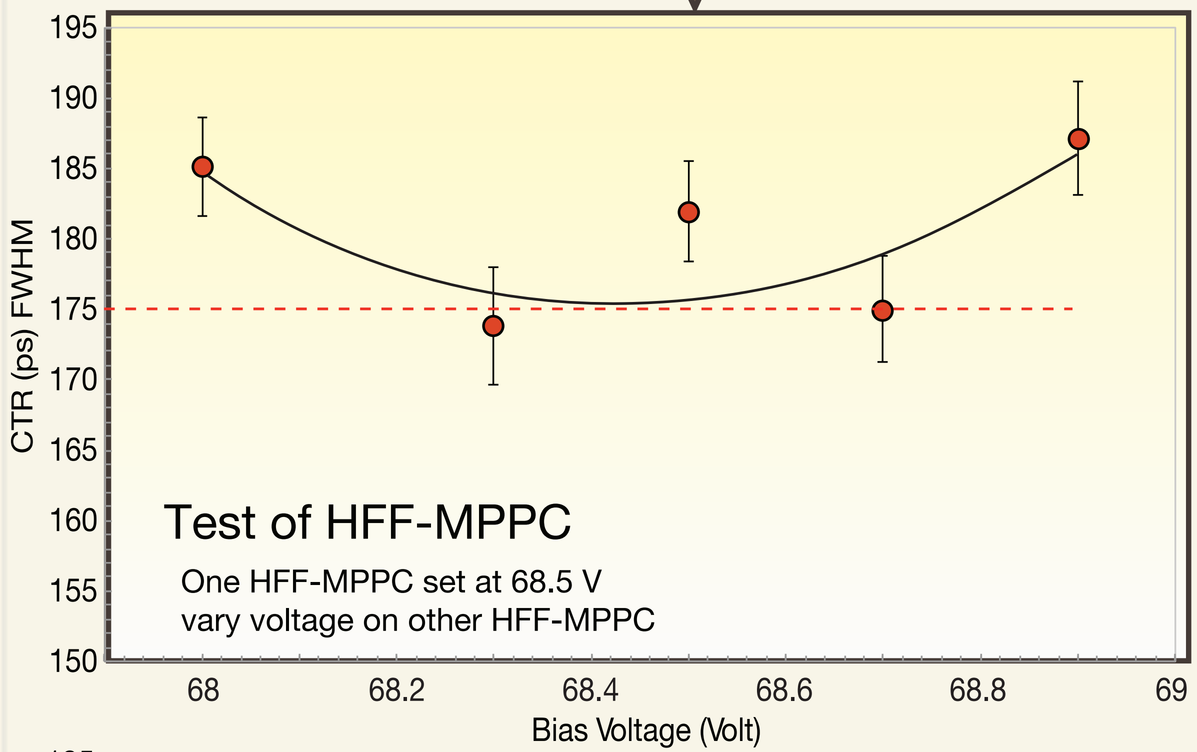


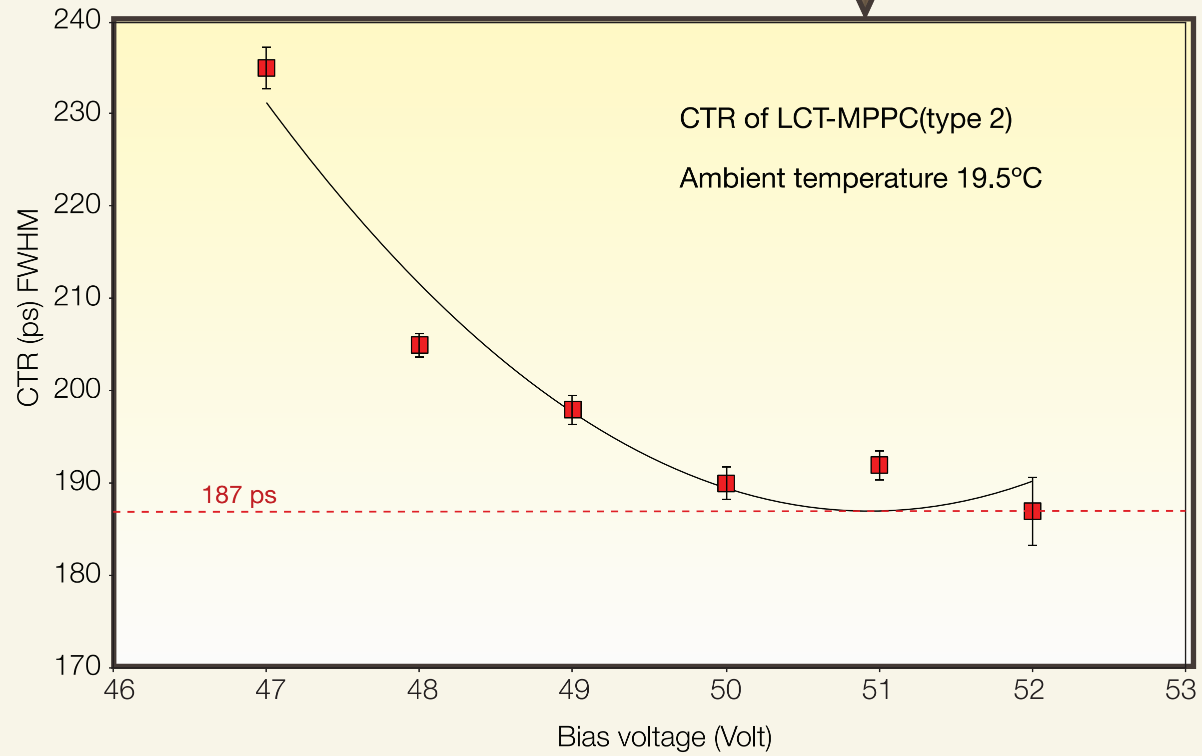


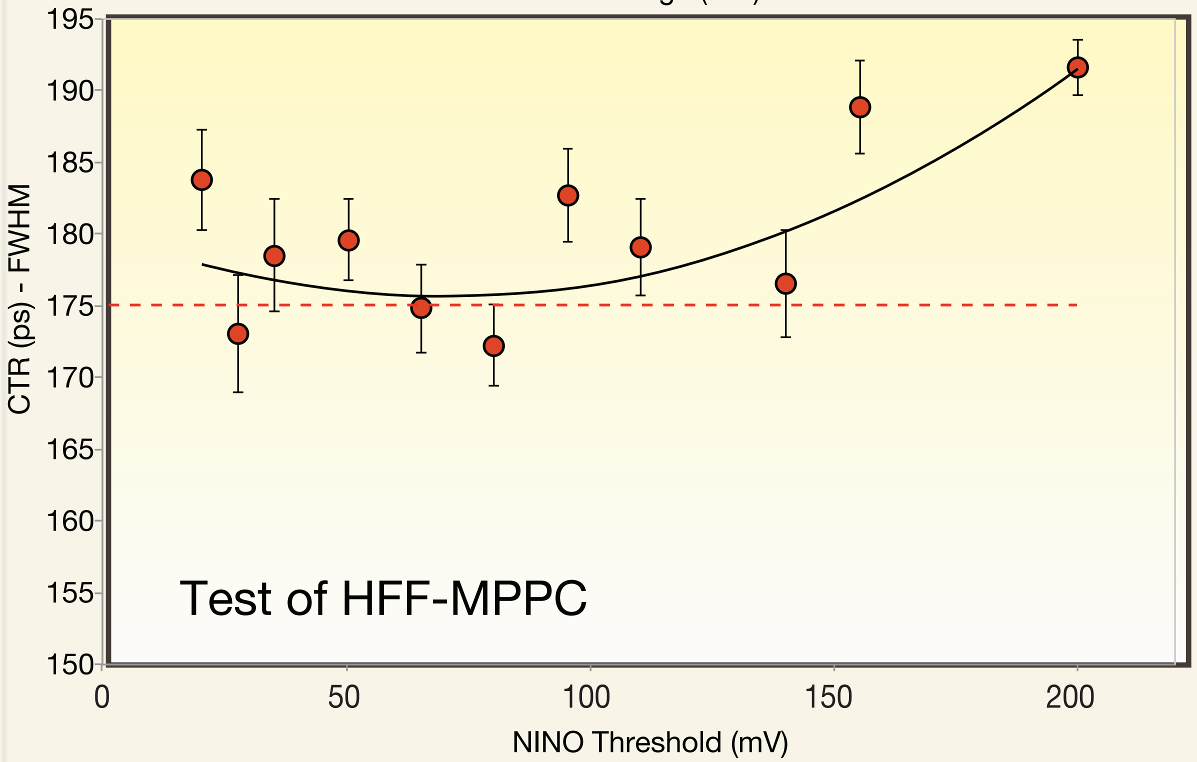
Note: Lab tests will give optimistic CTR

2.4 V overvoltage

6.6 V overvoltage







With 3 x 3 x 15 mm^3 LYSO crystals

High Fill Factor :175 ps FWHM (2.4 V overvoltage)
Low Cross Talk :187 ps FWHM (6.6 V overvoltage)
scaling from HFF to LCT using fill factor :

$$175 * \sqrt{(80/60)} = 202 \text{ ps}$$

Conclusions

- Exceptionally low Dark count rate with Hamamatsu MPPCs fabricated with 'Trenches'.
- Lower Cross-talk with 'Trenches' : and LCT can be operated at higher over-voltages.
- Quenching resistor made from metallic film (instead of polysilicate) allows very high Fill Factors (80 % without trenches 60 % with trenches) and a corresponding increase of photon detection efficiency.
- Coincidence Time Resolution of 175 ps with "large" crystals (15 x 3 x 3 mm^3).
- Note: best timing derived from first arriving photoelectrons : need high photon detection efficiency to detect these first p.e.
- NINO asic has differential inputs: essential to reduce electronic crosstalk (extra noise… extra time jitter) between cells:

  this is the route to excellent timing.

Crispin.Williams@cern.ch