Cross talk study to the single photon response of a flat panel PMT for the RICH upgrade at LHCb

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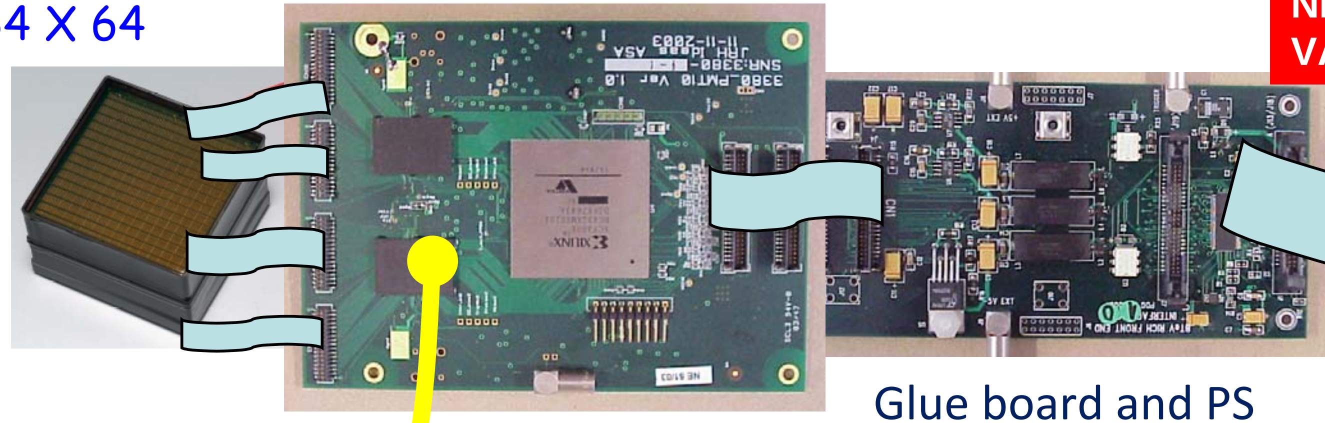
ABSTRACT

The Ring Imaging CHerenkov, RICH, detector at LHCb is now readout by Hybrid Photon Detectors. In view of its upgrade a possible option is the adoption of the flat panel Photon Multipliers Tubes, PMT. An important issue for the good determination of the rings produced in the sensitive media is a negligible level of cross talk. We have experimentally studied the cross talk from the 64×64 pixels of the H9500 PMT from Hamamatsu. Results have shown that at the single photon signal level, as expected at LHCb, the statistics applied to the small number of electrons generated at the first dynode of the PMT chain leads to a cross talk mechanism that must be interpreted in term of the percentage of the number of induced signals rather than on the amplitude of the induced signals. The threshold to suppress cross talk must be increased to a significant fraction of the single photon signal for the worst case. The number of electrons generated at the first dynode is proportional to the biasing voltage. Measurements have shown that the suppressing threshold can be lowered acting on this latter parameter.

SET-UP

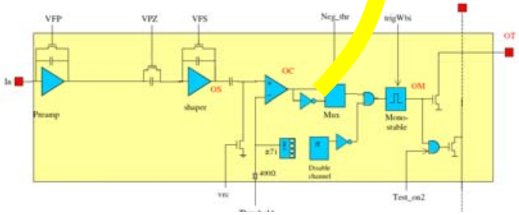
HAMAMATSU
H9500 64 X 64
pixels

NIMA V 553 p 130 134 2005
NIMA V 558 p 373 387 2006
VA64MaPMTv0r6.pdf (www.ideas.no)

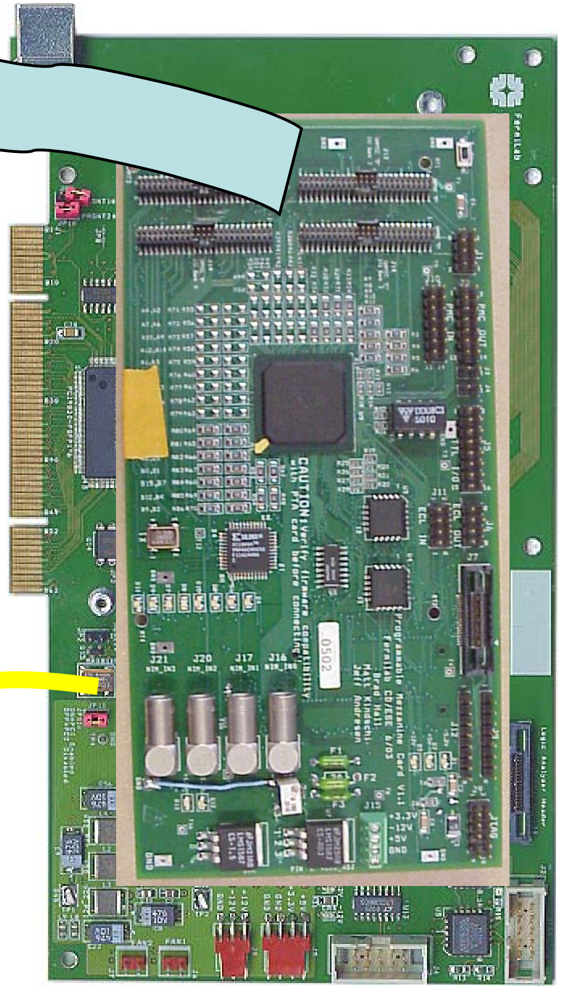


Glue board and PS

X 64

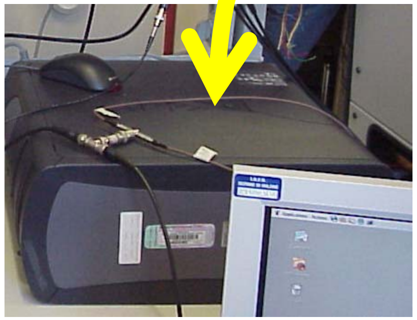


Mezzanine board and PTA



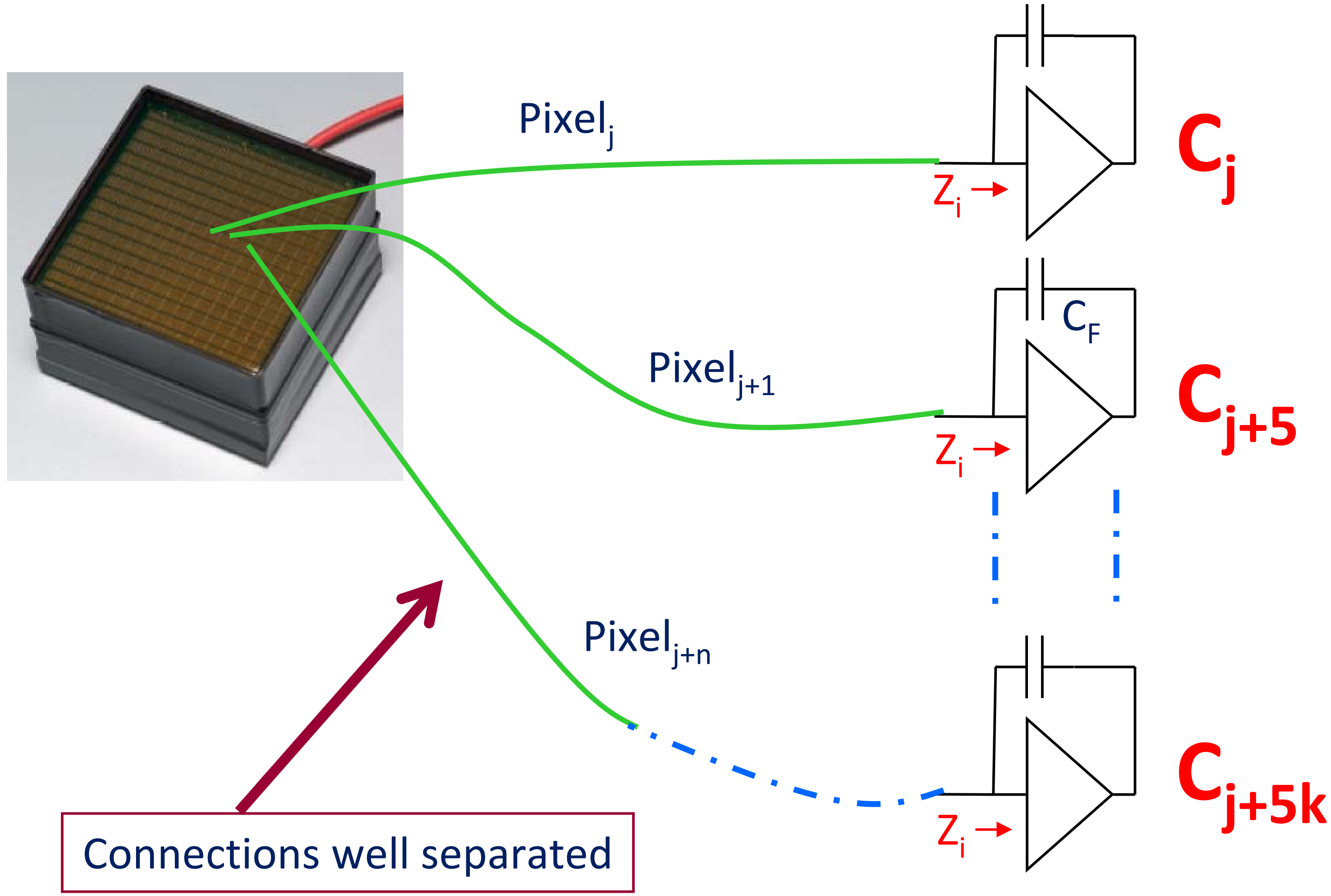
The front-end chip is the VA64MaPMTv0r6:

- 64 channels, 0.35-CMOS from Syracuse Uni. - Ideas;
- 0.32 V/Mel gain with about 70 ns CR-RC shaping time;
- Adjustable trigger threshold level, minimum at 10 fC (62 Kel);
- Noise maximum at 2200 el.

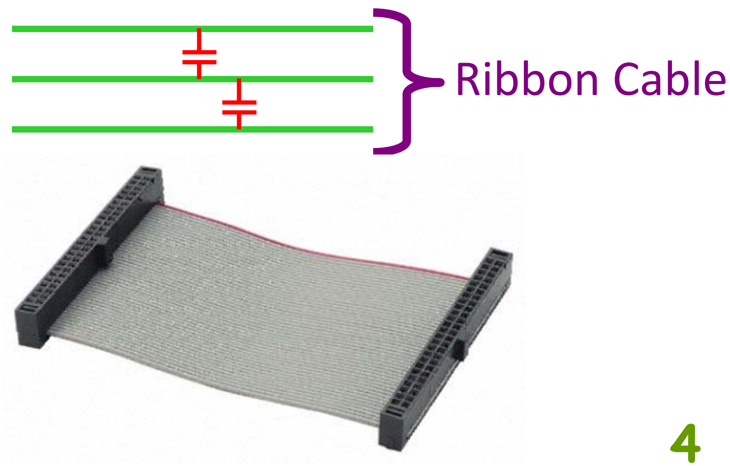


Acquisition system

Connection set-up for cross-talk study



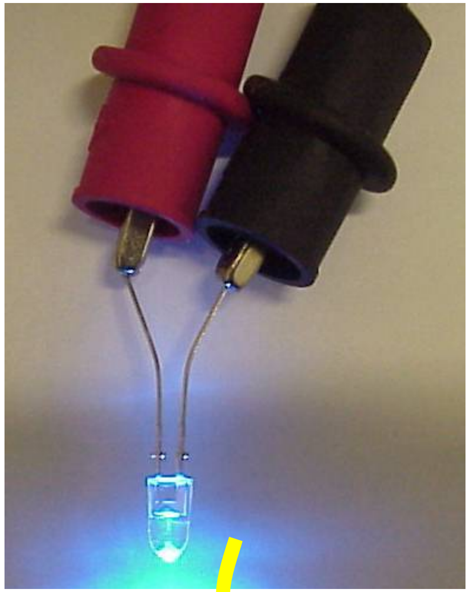
We linked one channel every 5 on the ribbon connecting cable suppressing completely the cross-talk from the small flat cable.

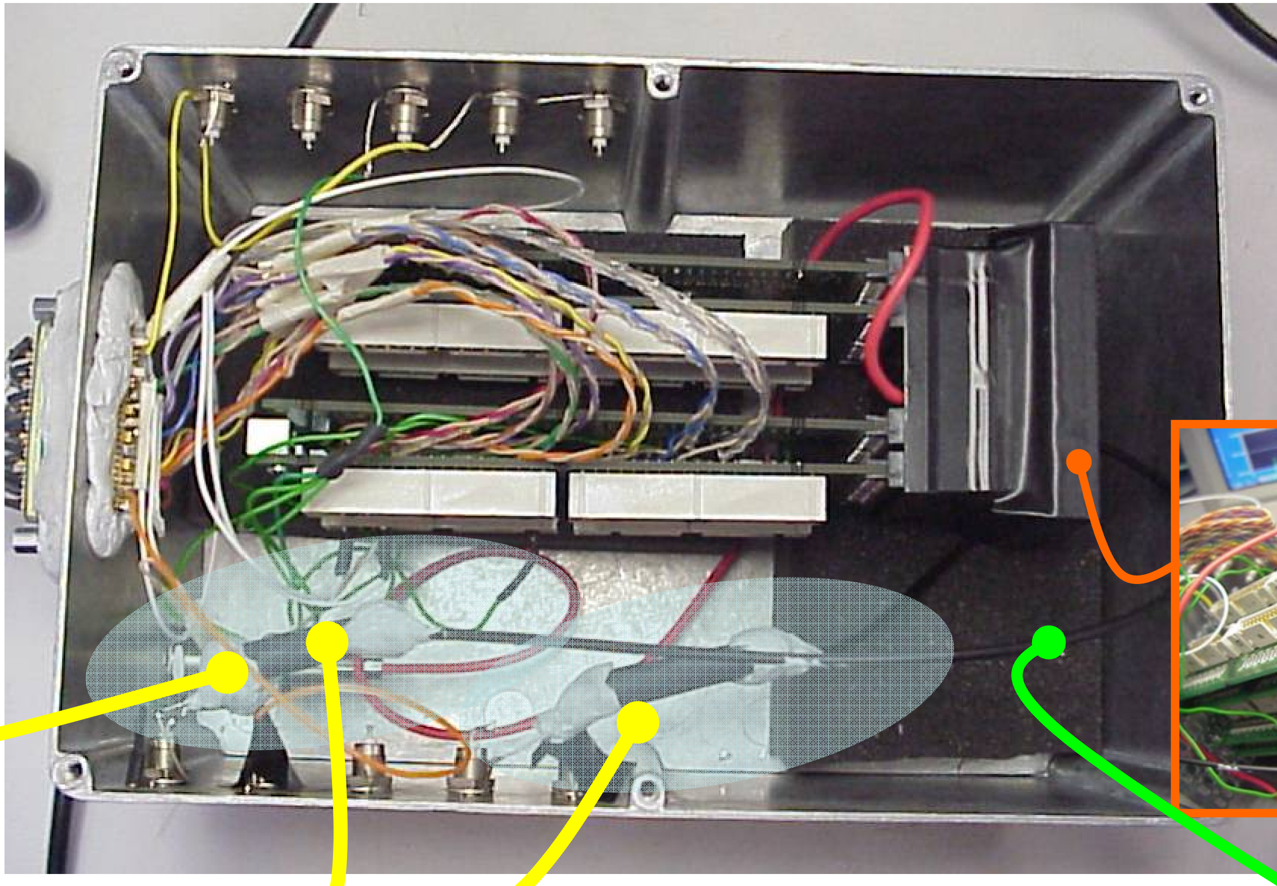


For instance in our set-up two closed channels see cross-talk coming from 10 cm flat-cable at about 2.4 Mel input charge (the level of about one photoelectron).

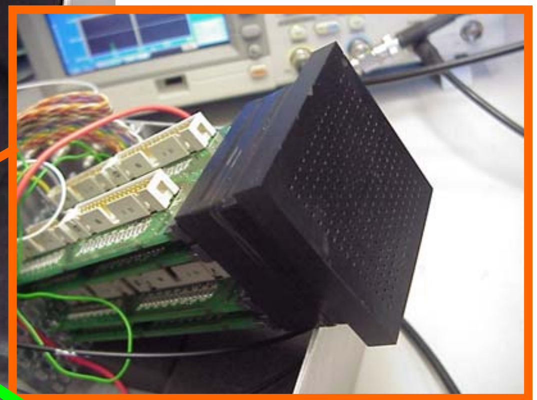
Single photon injection

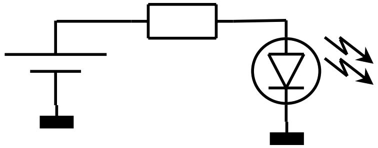
The fiber optics has been illuminated with a commercial blue-led at 470 nm wave length.





Flat Panel covered with a mask



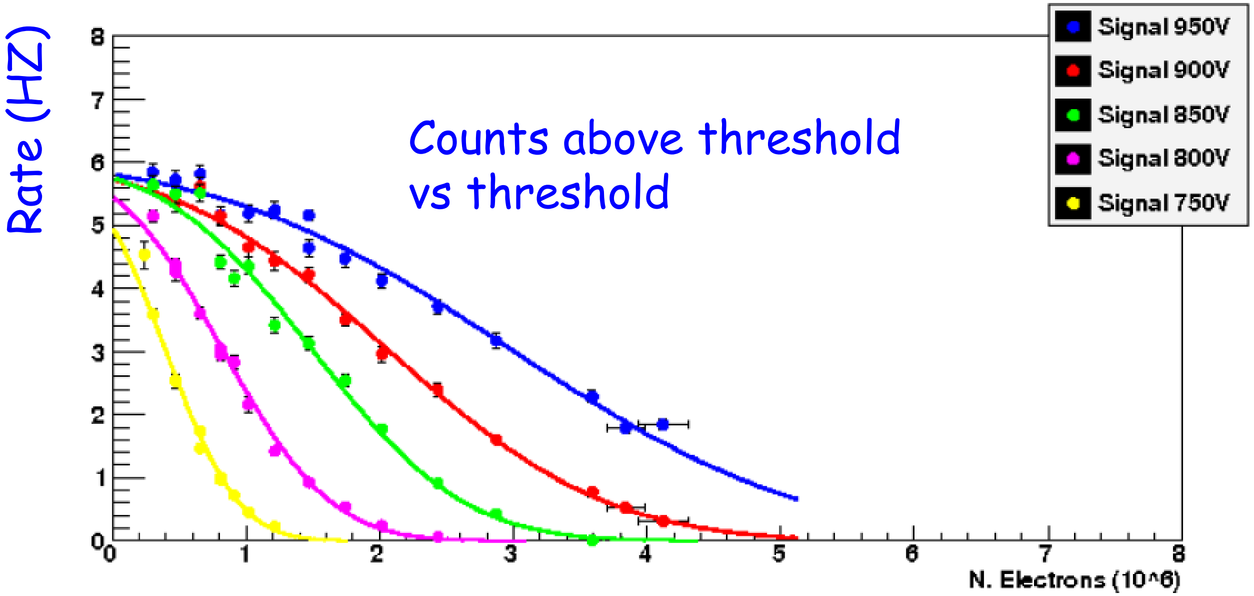


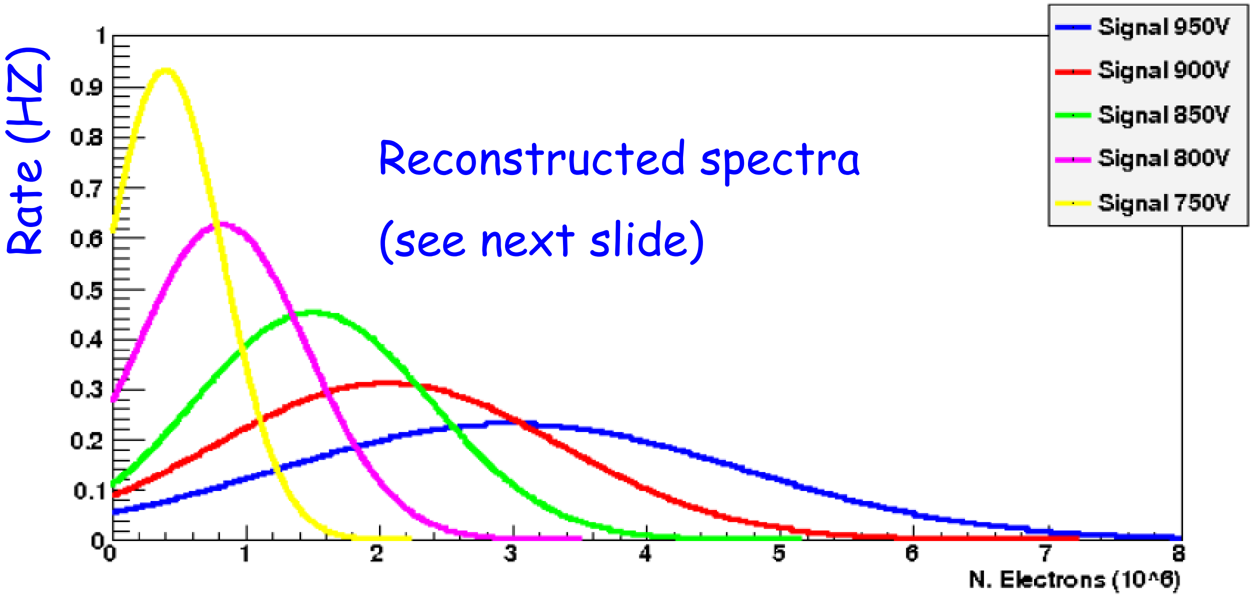
Led diodes

LEDs has been biased just above threshold and tiny coupled to an optical fiber in order to send only to one pixel, at random, a photon every second.

Optical fiber

Single photon spectra





The front-end counts the signals above threshold.

Photon spectra are collected by taking measurements at increasing thresholds.

Calibration was made by injecting a known amount of charge at the charge sensitive preamplifier input.

In the measurements shown the minimum threshold has been set just above noise.

We introduced an integral method in the measurement.

We take data changing the threshold of the preamplifier system at every measurement.
This way we construct the function:

$$F(V_{TH}) = \int_{V_{TH}}^{\infty} N(V)dv = \int_{0}^{\infty} N(V)dv - \int_{0}^{V_{TH}} N(V)dv \qquad N(V) \div e^{-\left[\left(V-V_p\right)/\sigma\right]^2}$$

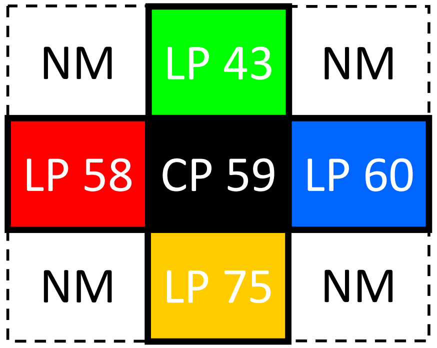
Considering that, around the peak V_p:

$$N(V) \div e^{-\left[\left(V-V_p\right)/\sigma\right]^2} \approx 1 - \frac{\left(V - V_p\right)^2}{\sigma^2}$$

We have:

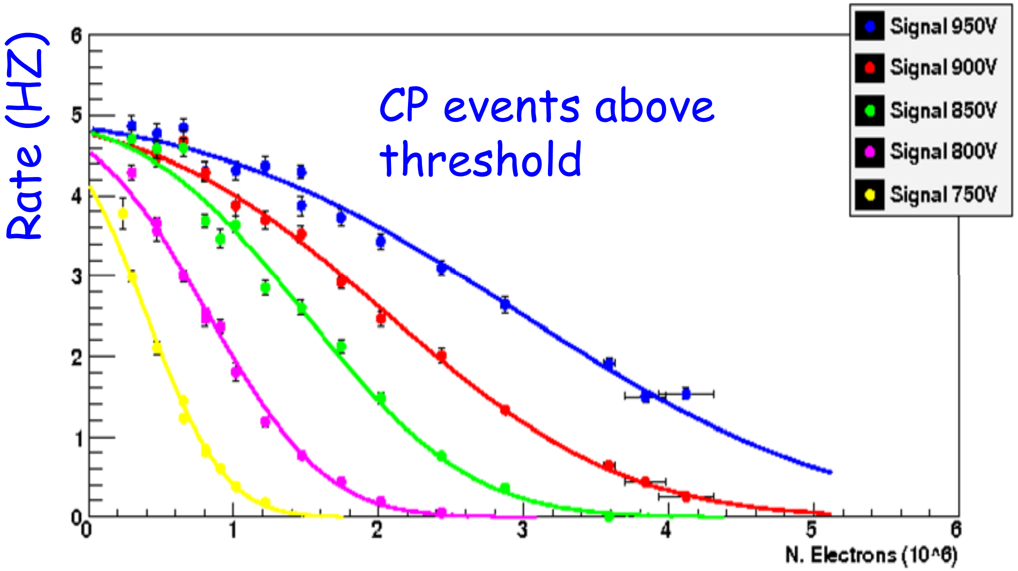
$$F(V_{TH}) = \int_{V_{TH}}^{\infty} N(V)dv = \int_{0}^{\infty} N(V)dv - V_{TH} + \frac{\left(V_{TH} - V_p\right)^3}{3\sigma^2}$$

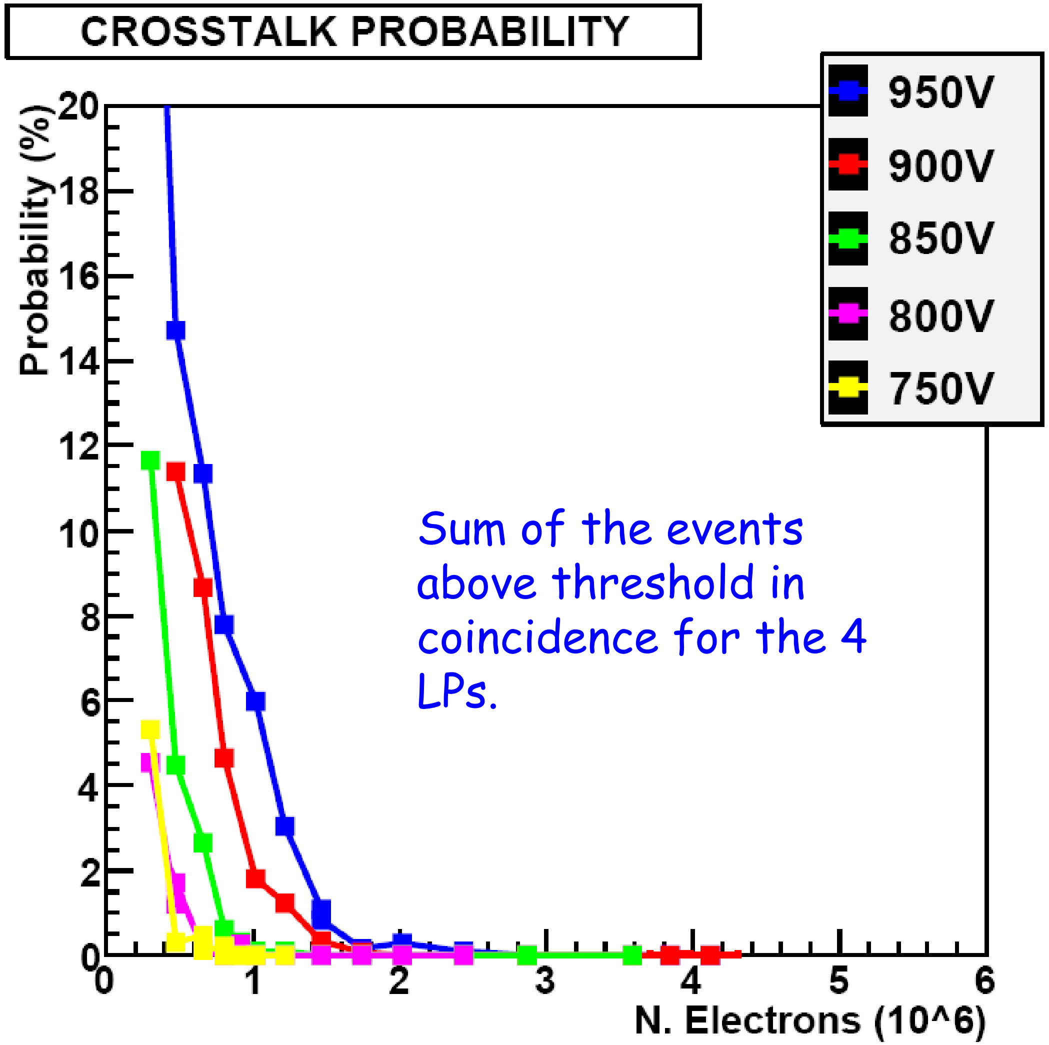
➡ We expect a linear behavior of the measured function around the peak.



A Pixel, CP, is illuminated and 4 lateral pixels, LP, are recorded only in coincidence with CP.

This way, events in the LPs have origin only from cross-talk.

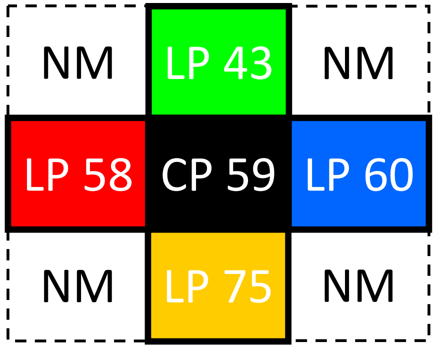


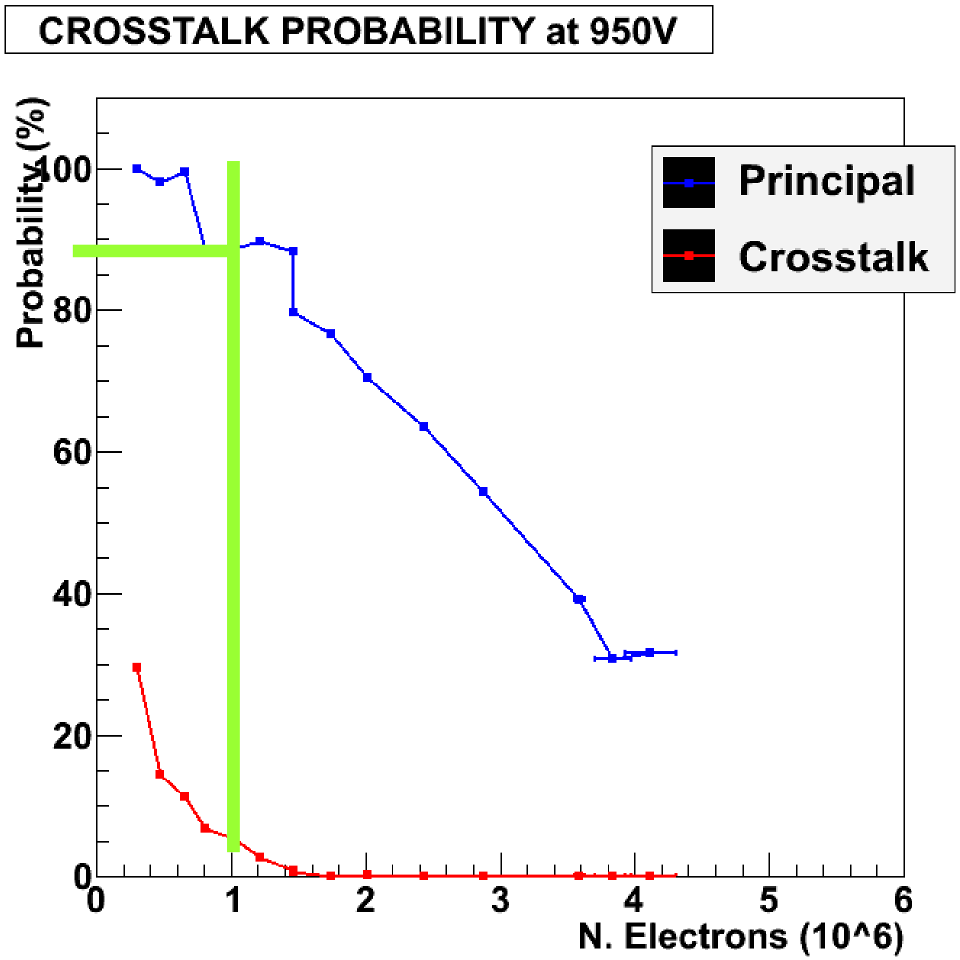


Results to single photon with H9500 say that the cross-talk level extend to large values, 20 % to 30 %.

While datasheet claims a level of 5 % for continuous light.

Cross-talk measurements (II)



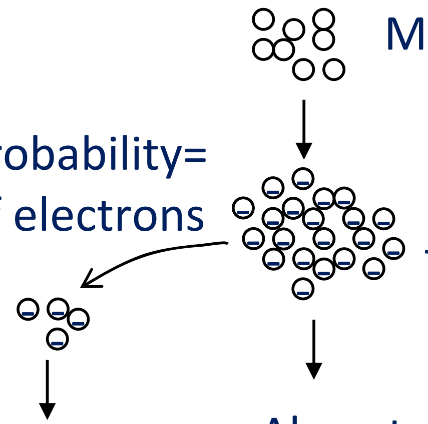


It is possible to observe that the suppression of cross-talk below 5 % needs to increase the trigger threshold that, in turn, cuts more than 10 % of genuine signals.

It is worth to consider that for only the 5 % of the signals it is expected present a cross-talk.

Interpretation of cross-talk for single photon event

Signal generated from many photons (continuous light)



Many input Photons

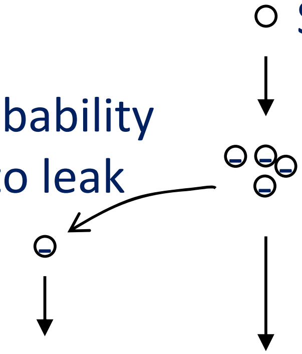
5 % Probability= 5 % of electrons leak

Many electrons at The first dynode

5 % signal Amplitude at the anode. A cross-talk signal is always present.

Almost unaffected signal at the anode

Signal generated from a single photon.



Single-Photons input

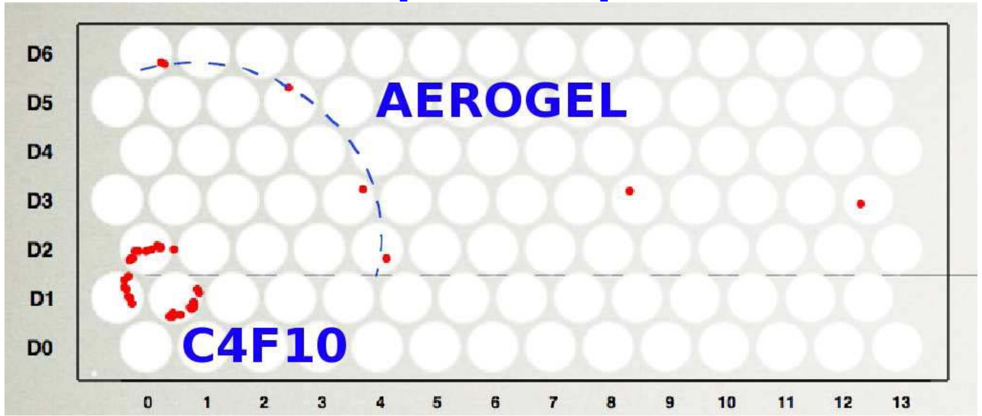
5 % Probability of 1 el to leak

Few el generated, 4 – 5.

A few number of signals, but with large fraction of the original signal.

When cross-talk happens the signal at the anode undergoes to 20 % - 30 % of amplitude reduction.

- ✓ Response to single photon from Hamamatsu H9500 presents a level of cross-talk between neighbor pixels of the order of 20 % to 30 %.
- ✓ Considering the statistics, we have that only 5 % of the pixels fired by a single photon generates such a level of cross-talk signal.
- ✓ In RICH detectors, where rings containing about 20 photons are generated from a single event, it is therefore expected one cross-talk pixel per event.



Example of a ring from a cosmic ray in RICH1 at LHCb.