Front-end for:
Flat-Panel and
HPD with external readout

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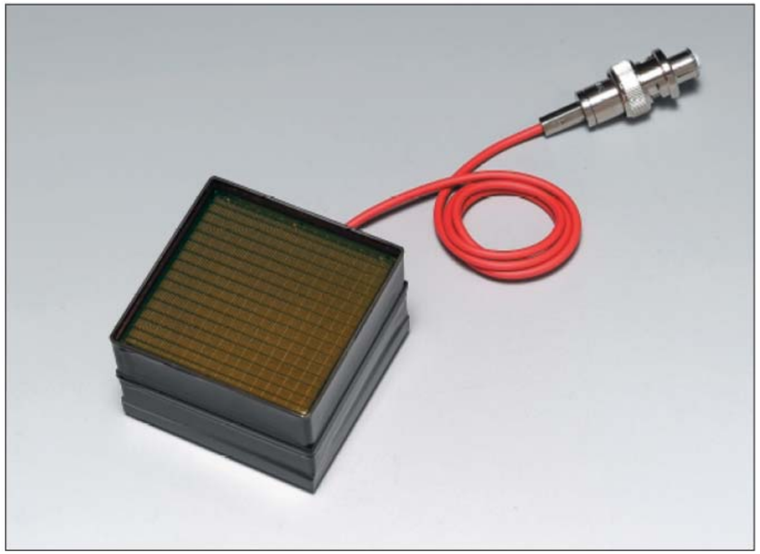
Outline

- ✓ PMT summary:
    1) H9500,
    2) R7600;
- ✓ Front-end approach;
- ✓ Front-end for PMT;
- ✓ Front-end for HPD with external readout.

1) HAMAMATSU H9500 (I)



H9500 is a 16 x 16 pixels (256 in total) having about 3 x 3 mm^2 active area per pixel.

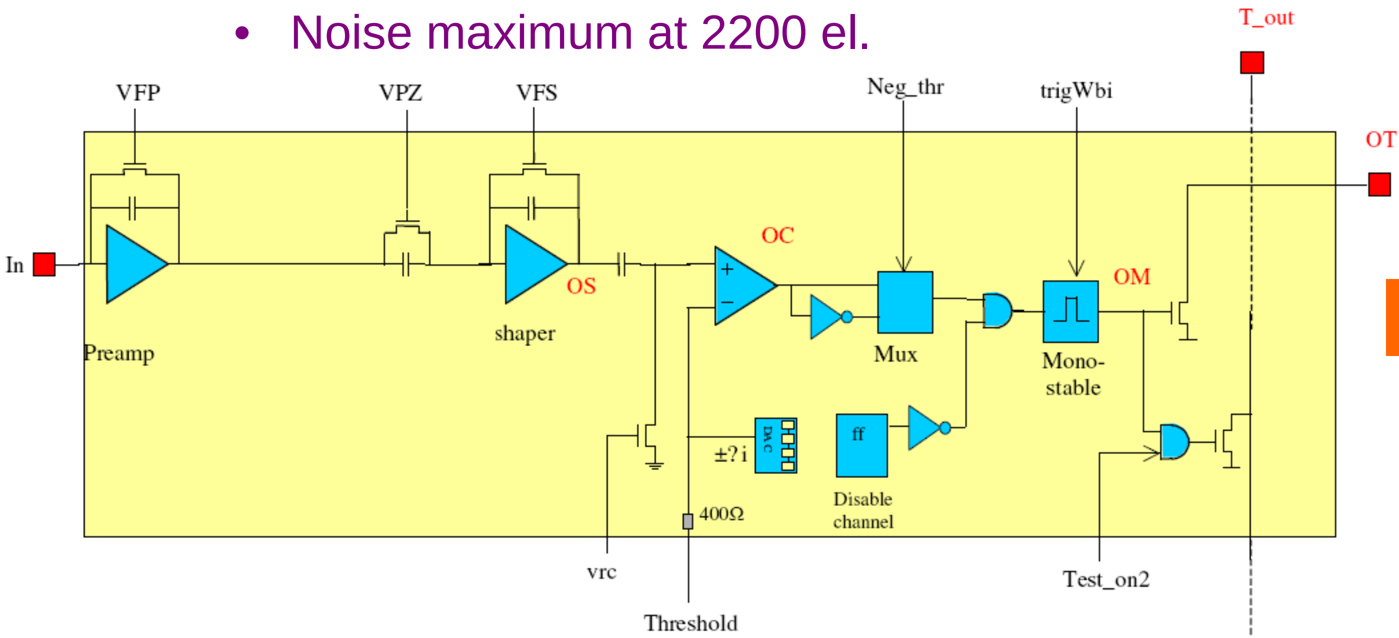
We characterized dynamic performances, noise and cross-talk.

1) HAMAMATSU H9500 (II)

For the analysis of the H9500 we used the front-end from Syracuse, originally intended for BTeV.

The main features of the VA64MaPMTv0r6 are:

- 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.

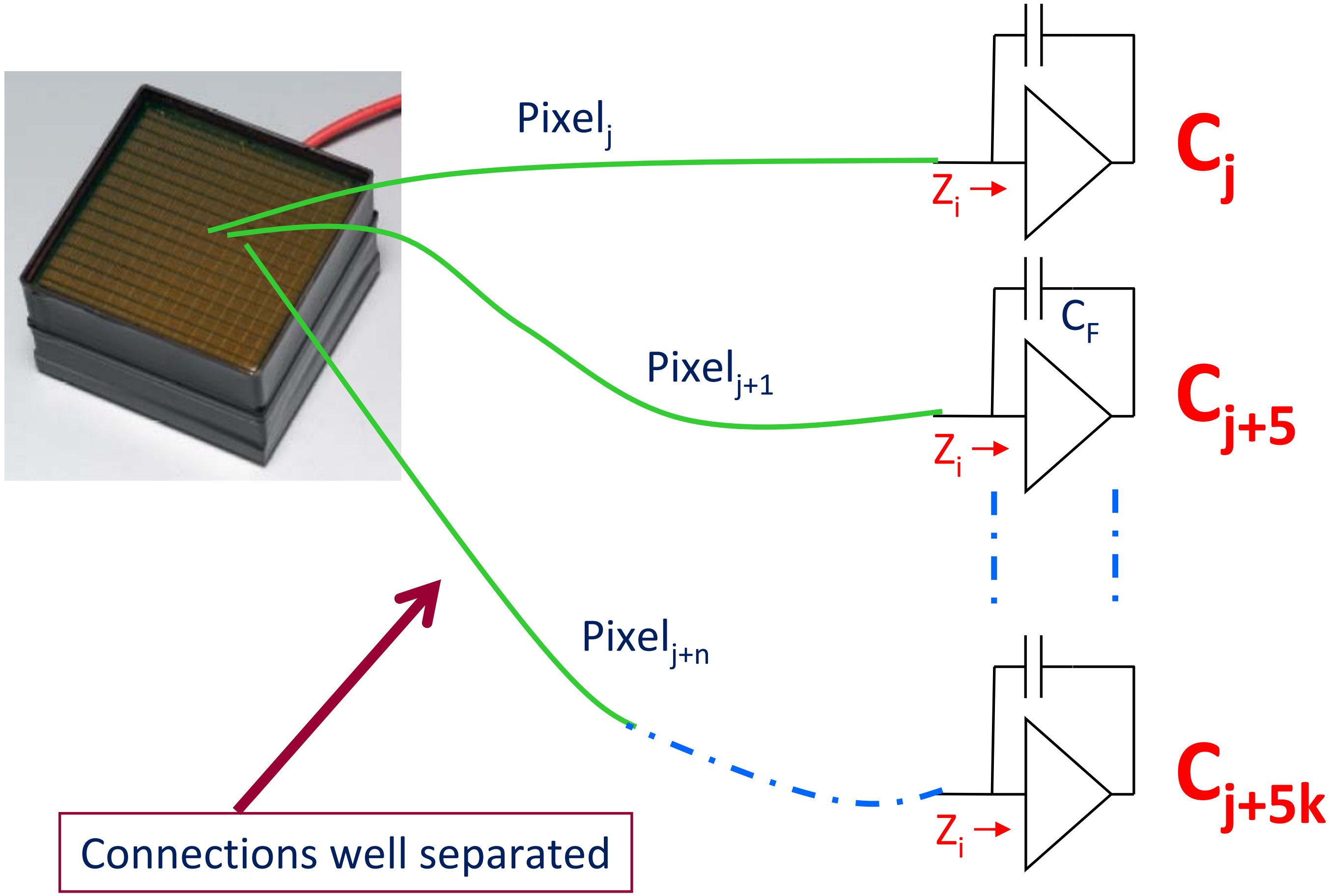


The output is digital

Figure 1: VA64MaPMT Channel Architecture.

1) HAMAMATSU H9500 (III)

We took care of the layout to avoid to add contributions from the connecting cables.

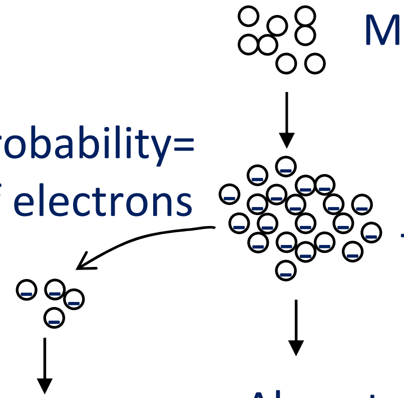


We connected one channel every 5 suppressing completely the cross-talk from the small, necessary, short flat cable.

1) HAMAMATSU H9500 (IV)

We found cross-talk that we interpreted statistically.

Signal generated from many photons



Many input Photons

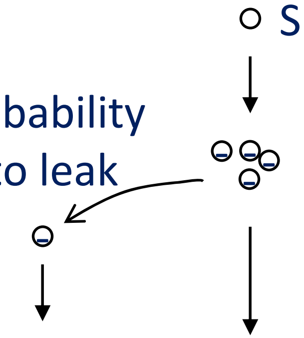
5 % Probability=
5 % of electrons
leak

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 by 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.

1) HAMAMATSU H9500 (V)

Result:

Concerning the single-photon response we expect to see cross-talk events only for a few number of event. The percentage of it equal the fraction of expected cross-talk signal expected for continuous light.

For this subject we have just submitted a paper to IEEE TNS:

Cross Talk Study to the Single Photon Response of a Flat Panel PMT for the RICH Upgrade at LHCb

C.Arnaboldi, M.Artuso, M.Calvi, E.Fanchini, C.Gotti, M.Maino, C.Matteuzzi, D.L.Perego, G.Pessina, J.C.Wang

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. An important issue for the good reconstruction of the Cherenkov rings is a negligible level of cross-talk. We have experimentally studied the cross talk from the 16×16 pixels Hamamatsu H9500 PMT. Results have shown that for the single photon signal, as expected at LHCb, the statistics tied to the small number of electrons generated at the first dynode of the PMT chain (a few units) leads to a number of cross-talk signals that are a small fraction of the fired pixel. Due to the discrete nature of the electron charge, those few cross-talk signals have amplitude that is a significant fraction of the fired pixel, which is in consequence depleted.**

to this signal at the first dynode of the multiplication chain lead to an interesting behaviour that will be described in the following sections. To do this experiment we developed a dedicated set-up, which will be detailed in the following.

II. Measurement set-up

The acquisition system adopted for this study was designed and tested for the BTeV experiment [15]. It consists in a monolithic 64 channels [16], [17] front-end chip, VA64MaPMT, developed by Ideas [18].

All the 64 analogue channels are composed by a charge sensitive preamplifier followed by a CR-RC like shaping filter

1) HAMAMATSU R7600 (I)

We had a sample of the H7600 to test.

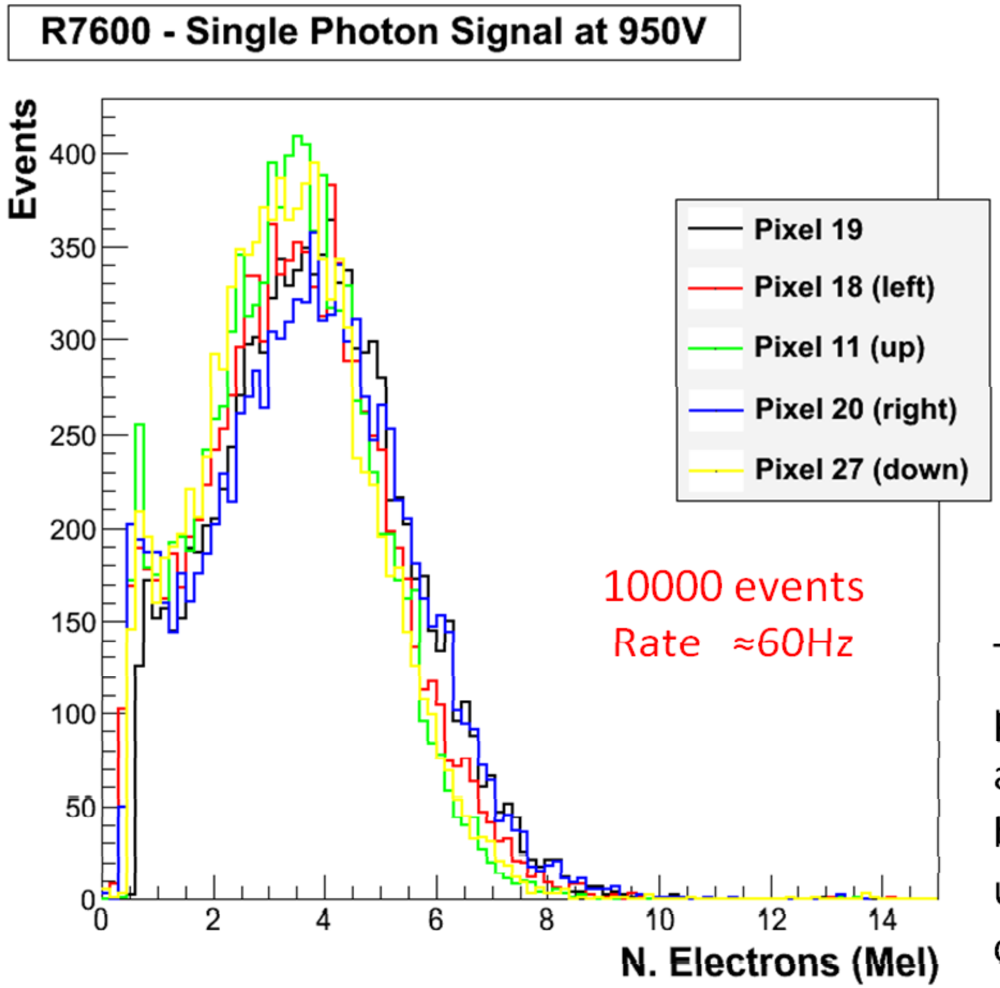
Tentative features:

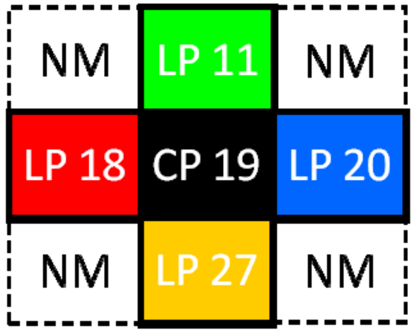
- $1.15 \times 1.15\ mm^2$ pixel area;
- 8 x 8 channels;
- 3×10^5 gain.

The bias circuit is not embedded in the device.

This way it will be possible to set the bias of the dynode chain with adjustable ratio, for the study of the cross-talk as a function of the voltage level at the first dynode.

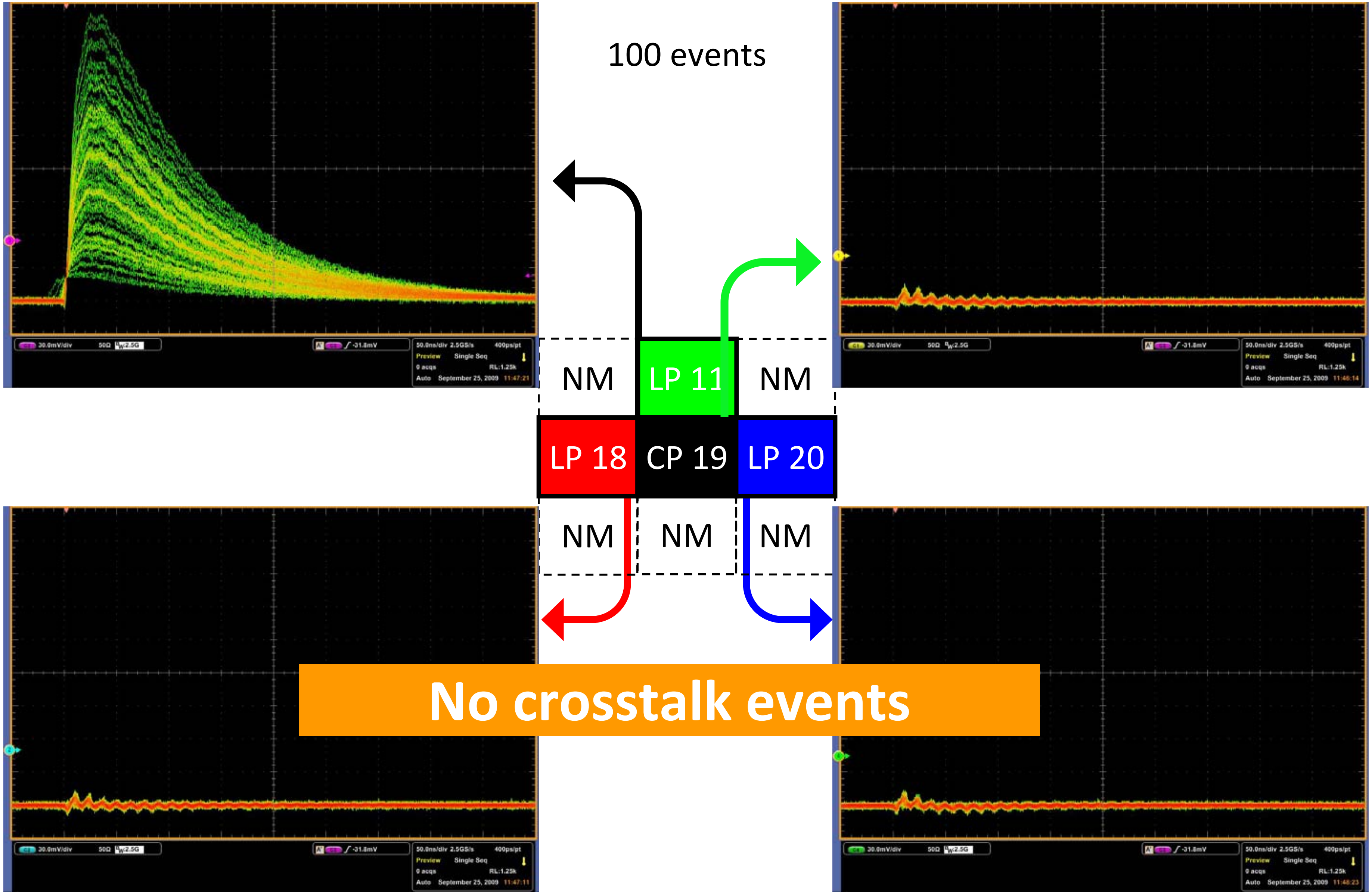
1) HAMAMATSU R7600 (II)





The calibration was done for the studied pixels by illuminating, each of them with a single fiber. This was done at 2 different biasing voltages: 850 V and 950 V. The uniformity is good within the limits of collected statistics.

1) HAMAMATSU R7600 (III)



No crosstalk events

1) HAMAMATSU R7600 (IV)

We put an order for a new R7600 (ultra-bialkali) to verify if the negligible level of cross-talk observed is not batch dependent.

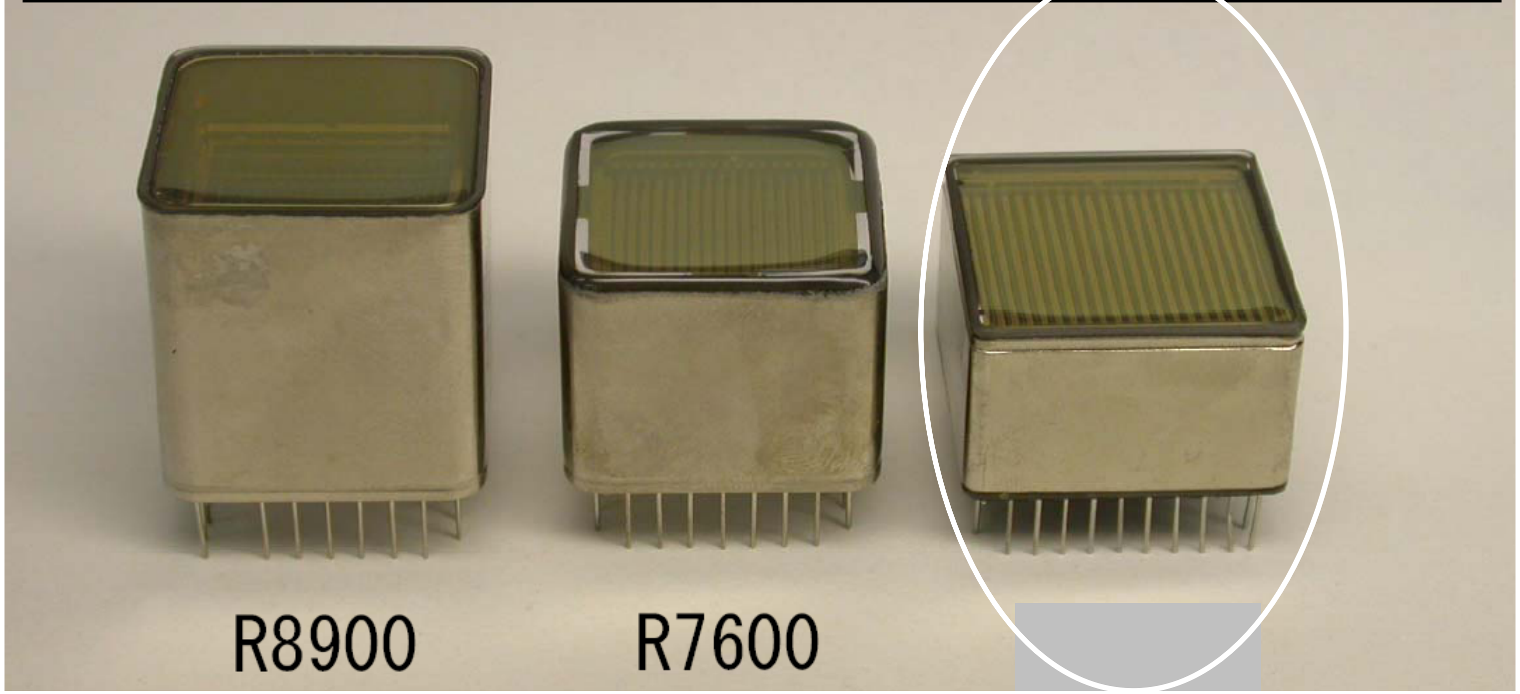
The relevant cross-talk property of the R7600 has been already observed in both:

LHCb Calorimeter;

Compass.

Near future

	R8900	R7600	
Total length	34mm	27mm	23mm
Effective area	23.5mm	18mm	23mm
CE (Simulation)	75%	80%	90%



Available soon (not known the date): small inactive border: R7600 upgrade.

The new R7600-bialkali PMT from Hamamatsu will be available within the end of march:

Front-end with commercial amplifiers (I)

PMT characterization has been done in parallel with the high-speed front-end development.

We are now working on different items.

We started with commercial high speed Operational Amplifiers and Operational Transconductance Amplifiers, OTA.

The configuration adopted were Charge and Voltage sensitive preamplifiers.

Some example results follow:

Front-end with commercial amplifiers (II)

National Semiconductor

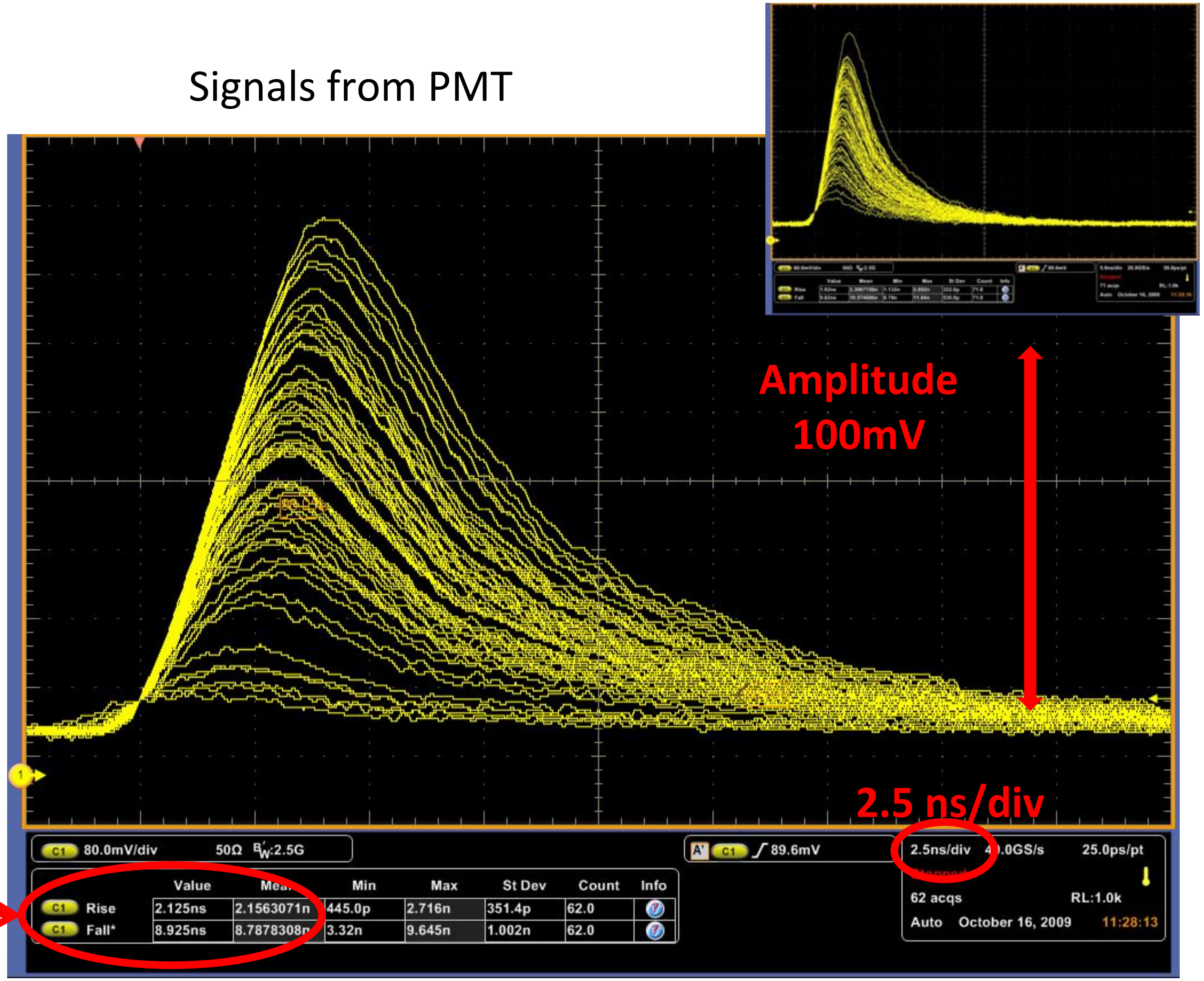
LMH6624
Gain Bandwidth 1.5GHz

Slew rate 350V/µs

Mean 62 signals
Rise Time $_{10\text{-}90\%}$ ≈ 2.2 ns

Configuration: Charge Preamplifier

Signals from PMT



Front-end with commercial amplifiers (III)

National Semiconductor

LMH6702
Bandwidth 1.7GHz

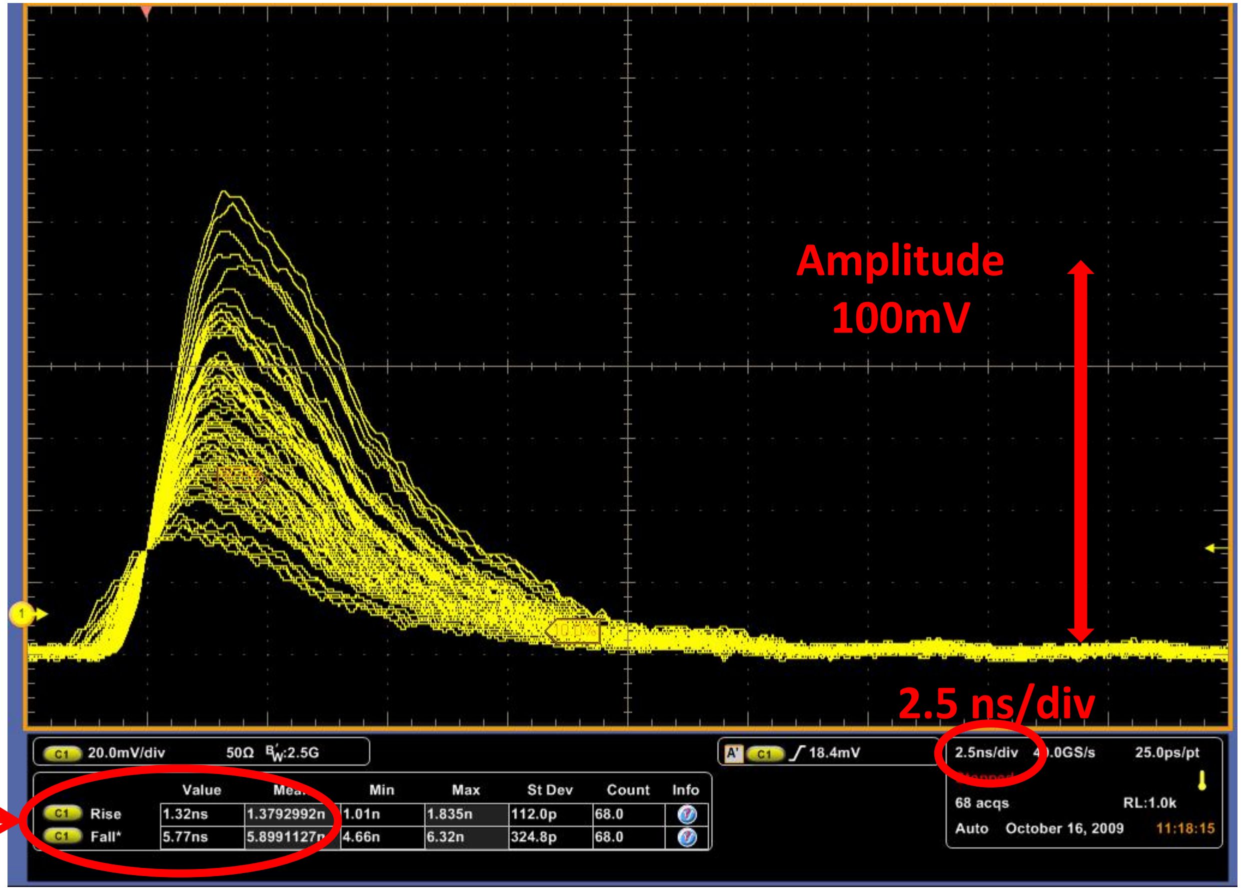
Slew rate 3100V/µs

Mean 68 signals
Rise Time $_{10\text{-}90\%}$ ≈ 1.4 ns

Configuration: Charge Preamplifier

Signals from PMT

*The same op-amp used by Edinburgh group



Front-end with commercial amplifiers (IV)

National Semiconductor

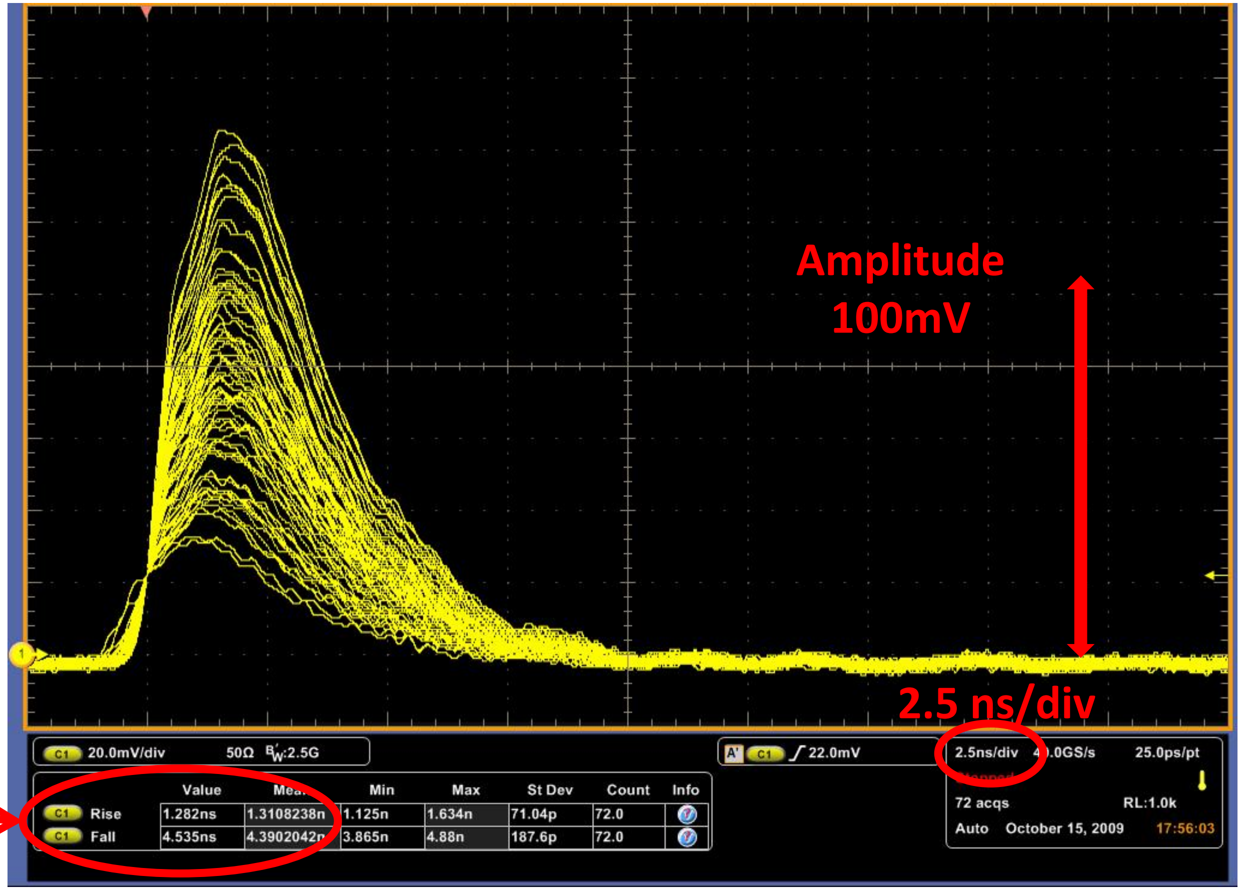
Configuration: Charge Preamplifier

Signals from PMT

LMH6703
Bandwidth 1.2GHz

Slew rate 4500V/µs

Mean 72 signals
Rise Time $_{10\text{-}90\%}$ ≈ 1.3 ns



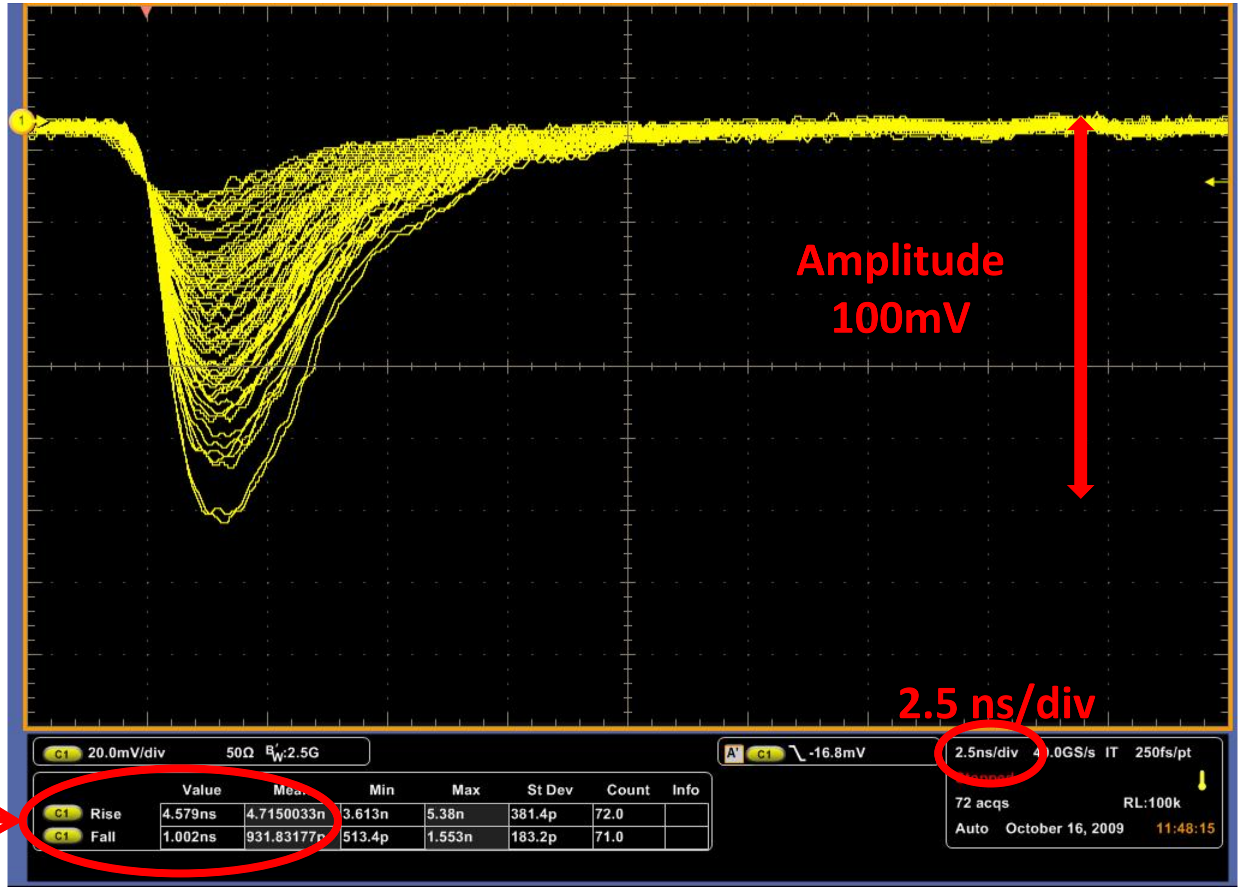
National Semiconductor

Configuration: Voltage Preamplifier

LMH6703
Bandwidth 1.2GHz

Slew rate 4500V/µs

Signals from PMT



Mean 72 signals
Rise Time $_{10\text{-}90\%}$ ≈ 1.0 ns

Front-end with commercial amplifiers (VI)

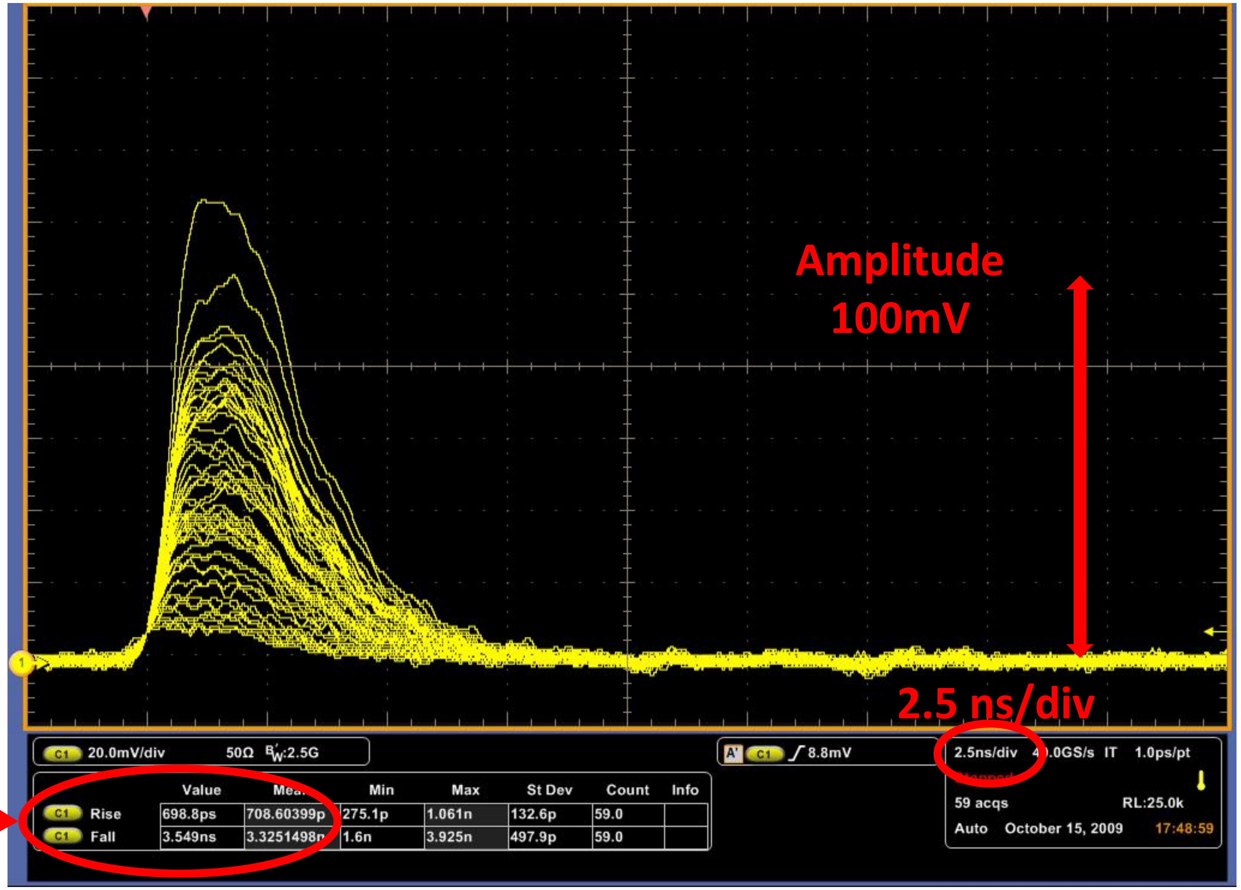
Configuration: Charge Preamplifier

Texas Instruments

OPA695
Bandwidth 1.7GHz

Slew rate 4300V/μs

Signals from PMT



Mean 59 signals
Rise Time $_{10\text{-}90\%} \approx 0.8$ ns

Front-end with commercial amplifiers (VII)

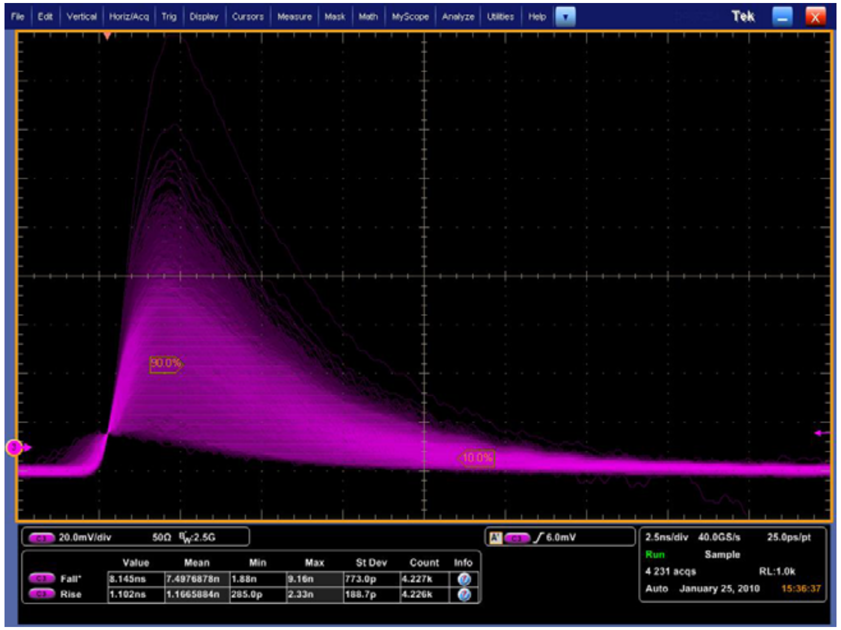
We have identified an approach for the use of Operational Transconductance Amplifiers in **C**harge **S**ensitive **P**reamplifier applications that has given excellent results:

Front-end with commercial amplifiers (VIII)

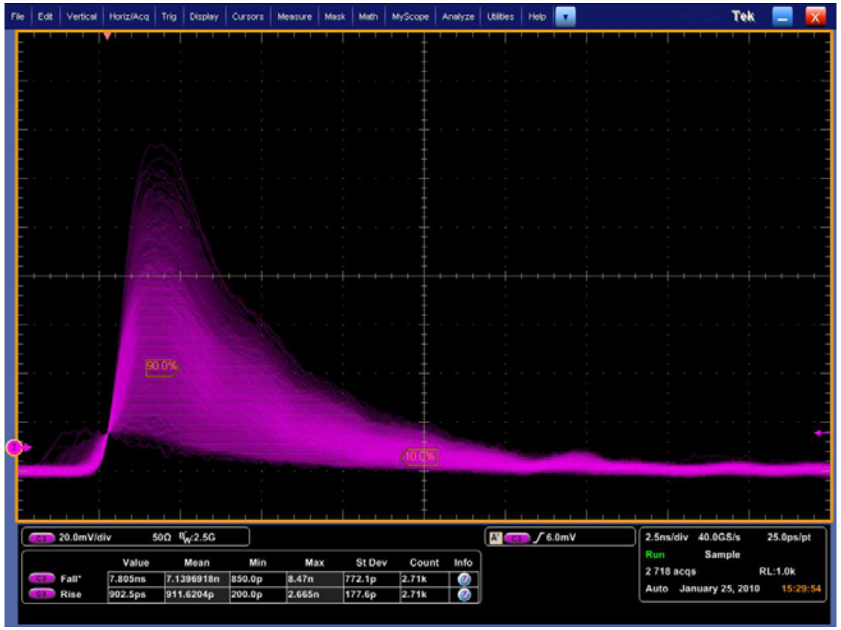
We are now able to have independent the fault time of the signal from the requirement on the stability to which the feedback resistance must satisfy in OTA applications.

LM6702 OTA in Charge Sensitive Preamplifier configuration.

Rise Time is 1.1 ns.



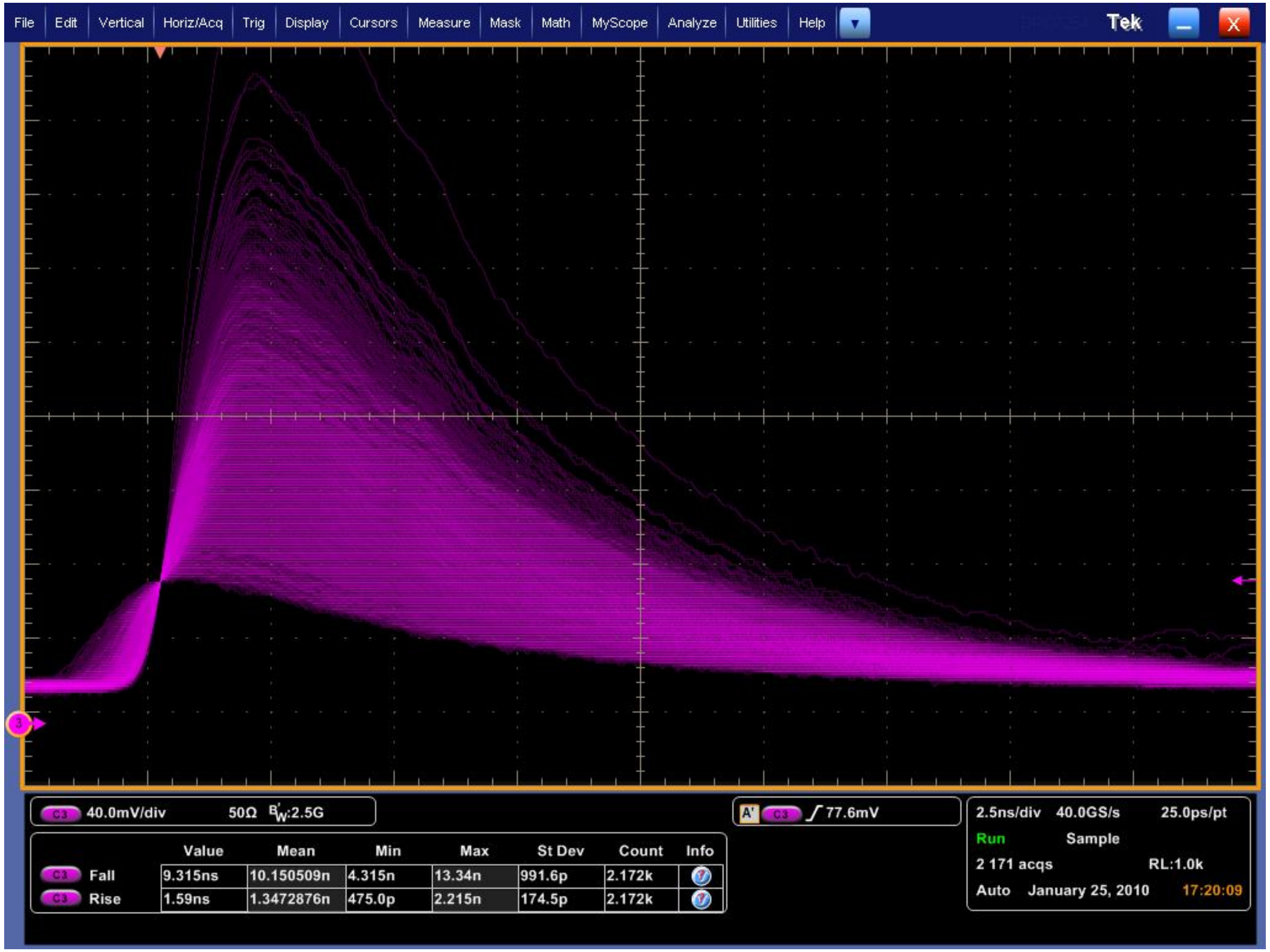
Rise Time is 0.91 ns.



Front-end with commercial amplifiers (IX)

LM6702 OTA in Charge Sensitive Preamplifier configuration.

Rise Time is 1.3 ns.



Front-end with commercial amplifiers (X)

A submission to JINST is underway:

Preprint typeset in JINST style - HYPER VERSION

Current Feedback Opamps as Fast Charge Sensitive Preamplifiers

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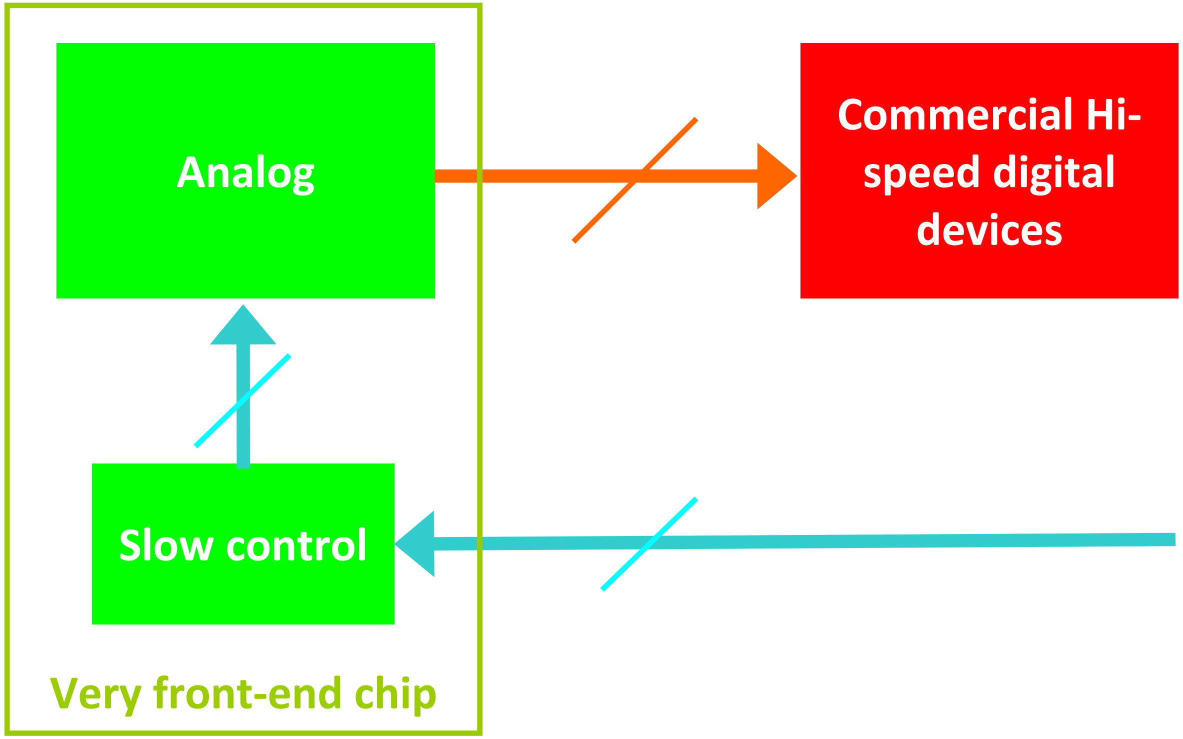
ABSTRACT: Fast charge sensitive preamplifiers were built, using current feedback operational amplifiers, in the aim to read out charge pulses from a photomultiplier tube. A simple circuit arrangement allows for very fast signals, with rise times down to 1 nanosecond. We thus provide a "recipe" to build stable and very fast charge sensitive preamplifiers from any current feedback opamp.

KEYWORDS: Current feedback operational amplifier, Charge sensitive preamplifier.

Front-end approach (I)

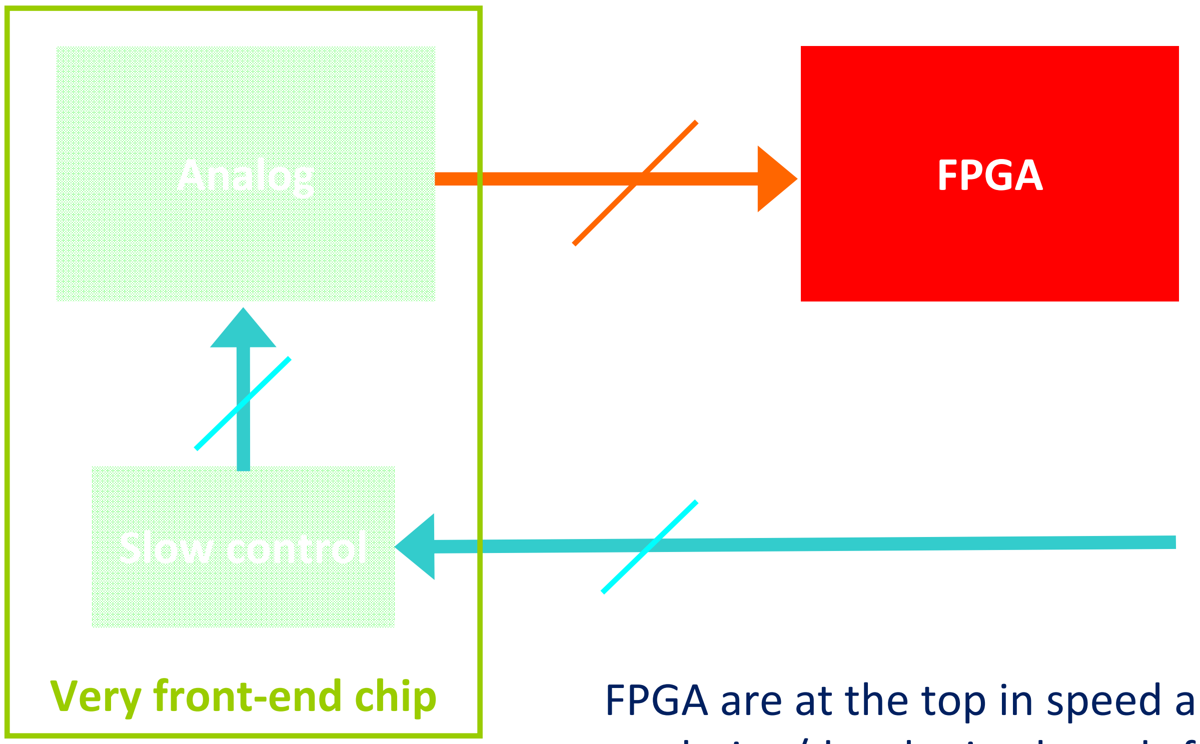
Strategy:

We suggest a separation of the analog front-end from the digital section:



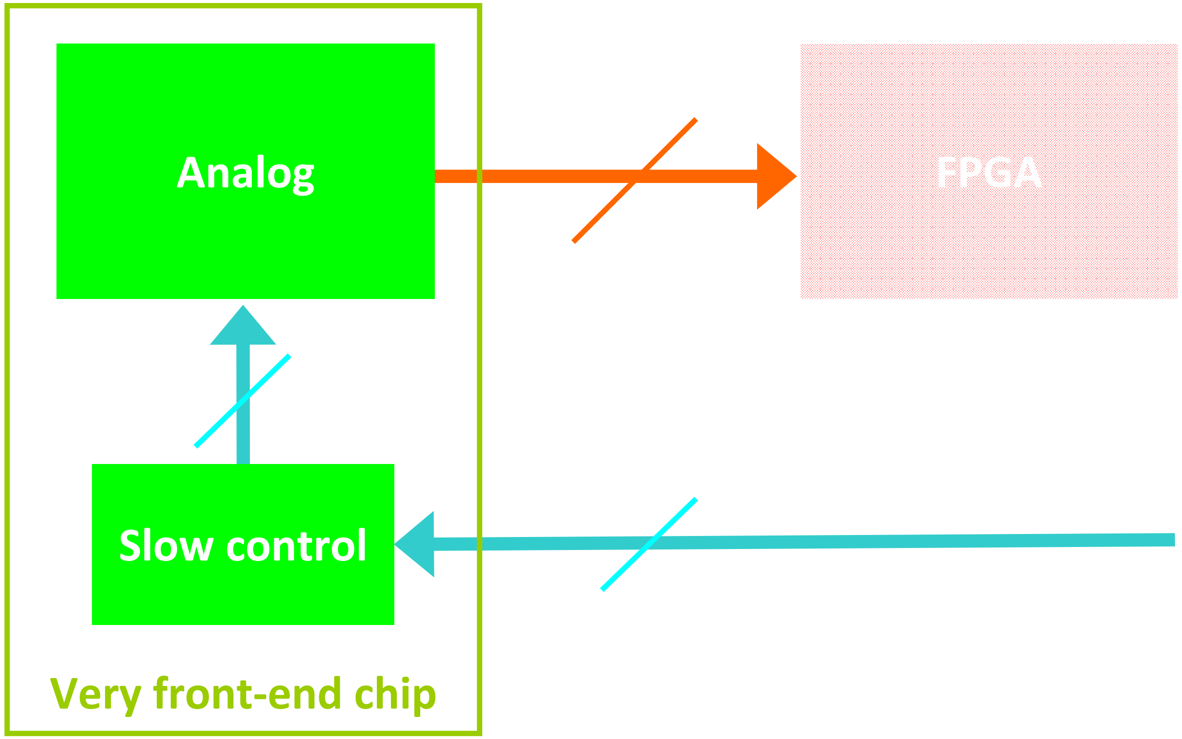
Our present effort is in the design of the Analog chip.

Front-end approach (II)



FPGA are at the top in speed and flexibility. We have emulating/developing boards from Xilinx: Spartan 3a and Spartan 6.

Front-end approach (III)



The analog front-end design follows different approaches depending on the sensor type.

The common denominator is anyway:

- Fast speed of response;
- Small power dissipation.

Front-end approach (IV)

So far we worked on both discrete and monolithic circuits, exploiting different technologies in the latter case.

Discrete devices for PMT (I)

We are developing a very simple and fast amplifier for the PMT signals.

The use of RF transistors would allow us to implement it with a multichannel PCB, allowing to study fully the performances of the R7600 and its upgrade.

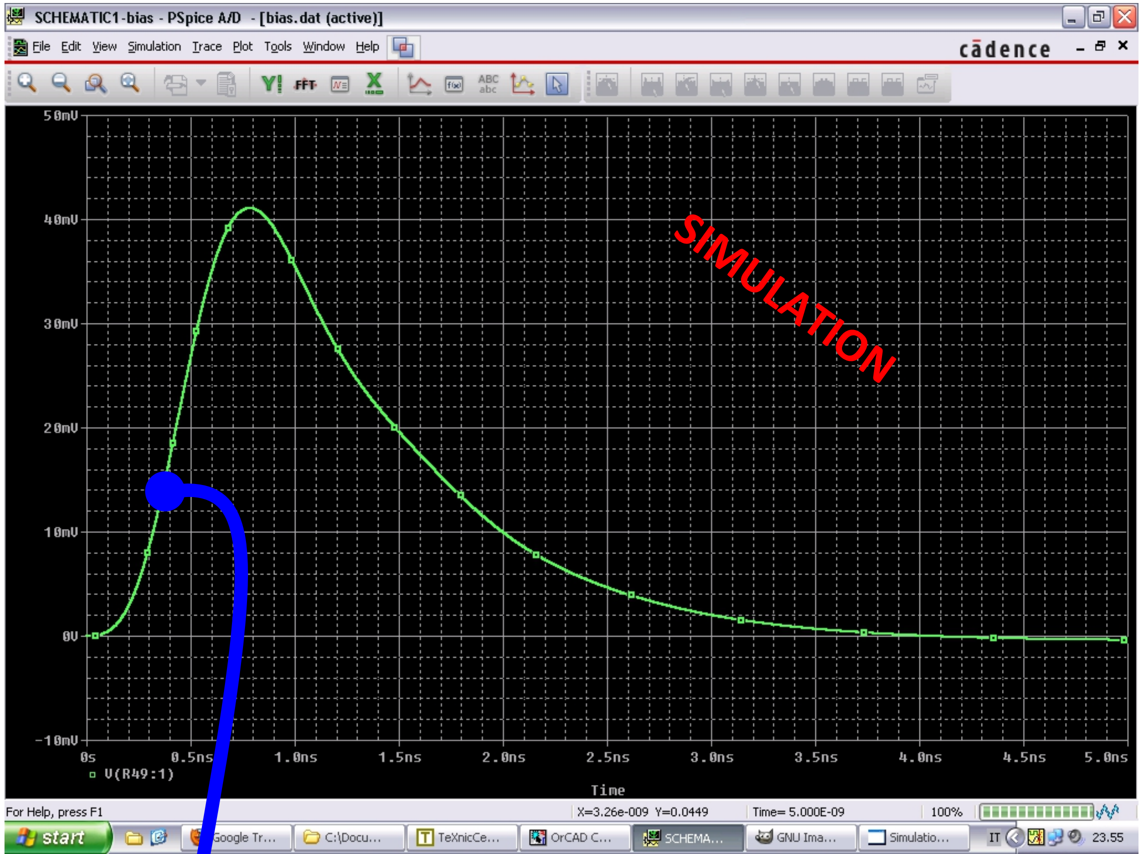
SPICE simulation is very promising.

Depending on the budget with power dissipation it can be very fast.

Operating conditions:

Input cap.: 1 pF;

Input charge: 500 kel.



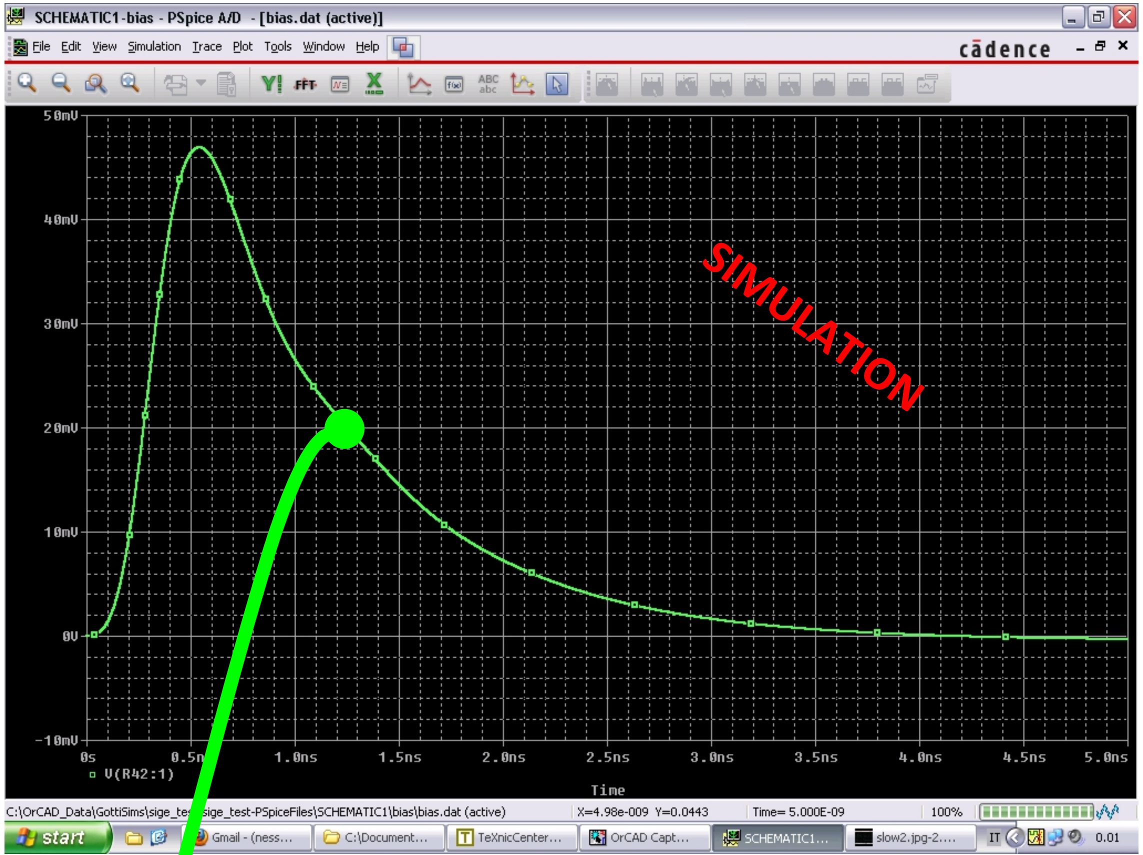
The signal has a rise-time of about 400 ps @ a power dissipation of 2 mW (980 μA of absorbing current with 2 V of power supply). The frequency bandwidth is 875 MHz.

Discrete devices for PMT (II)

Fast speed of response is an interesting result when small jitter is required.

The circuit has a small input impedance, important for negligible cross-talk.

RF transistors adopted for the simulation and next implementation are Si-Ge.



The green curve has a rise-time of about 250 ps @ 3.5 mW of power dissipation (the current consumption is 1.75 mA and the supply voltage 2 V). The frequency bandwidth is 1.4 GHz.

Monolithic solution for PMT (I)

We have support from our local STMicroelectronics that allows us to implement small test structures in some of their monolithic processes.

At present we are working with their 0.35-CMOS process on SOI, intended for medical applications.

- We have designed, simulated and lied-out a 4-channels amplifier for PMT pixels.
- The project was closed at the end of the last January.
- Test chips are expected to be available within the end of April for testing.

Monolithic solution for PMT (II)

We are starting to design a circuit solution with the **AMS 0.35 μm SiGe-BiCMOS (S35)** process with INFN funds.

It will consist in the monolithic implementation of our discrete circuit.

A fast-comparator will be designed for single-photon discrimination, to provide a digital output pattern.

Front-end for HPD with external readout (I)

The 0.35-CMOS on SOI from STMicroelectronics is interesting for HPD with external readout because it implements a N-channel JFET of recent introduction.

JFET would in principle allows smaller 1/f noise with respect to CMOS.

Low noise and small cross-talk is important for HPD since the signal is expected very small, needing a large S/N.

The adequate approach to readout the HPD seems to be the Charge sensitive Preamplifier, just as it is with the present readout.

The only remarkable different is that the external location increases the preamplifier input capacitance to 0.5 – 1 pF. A new matching is needed.

Front-end for HPD with external readout (II)

We are integrating a test chip with a 90 nm CMOS technology in TO_ASICS (INFN consortium) under another project having similar requirements to our.

End of April is the dead line of the project, while within the end of October the test chips are foreseen.

Conclusions

- A R7600 flat panel, optimized for single-photon event and small cross-talk, was done;
- Study with the front-end is in progress following different strategies.