

TRACE

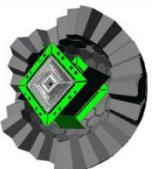


STATUS OF THE MULTICHANNEL CSP ASIC FOR THE TRACE DETECTOR ARRAY

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INFN, Milano, Italy*

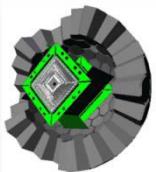




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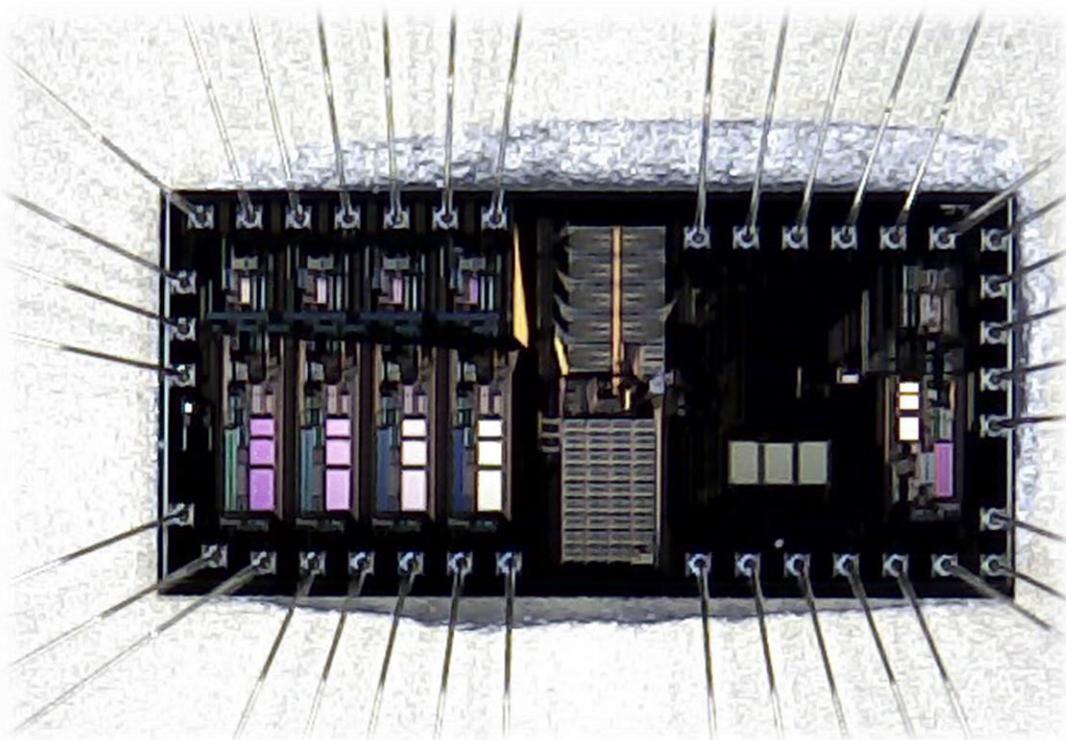
- 1.** Introduction on the new multichannel CSP ASIC
- 2.** Fast-Reset device and Time-to-Amplitude converter
- 3.** PCB development
- 4.** Conclusions and Future Perspectives

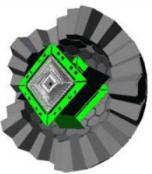


Multichannel CSP ASIC

- 4-channel CSP ASIC specifically designed for hole signals
- 1 auxiliary test channel for electron signals
- I²C engine to adjust critical parameters

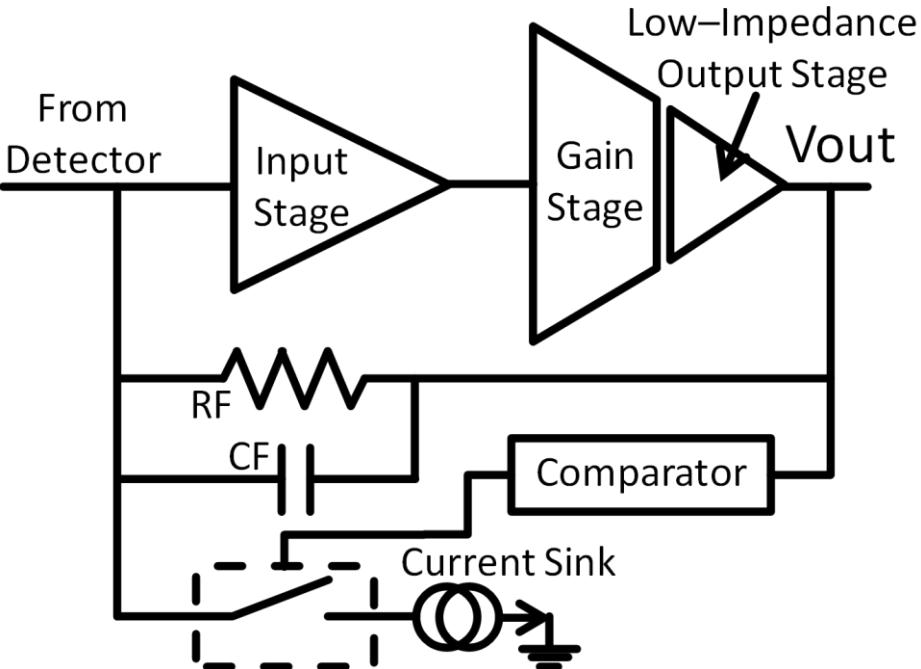
Technology:
AMS C35
Area: 5 mm²



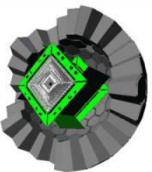


Multichannel CSP ASIC

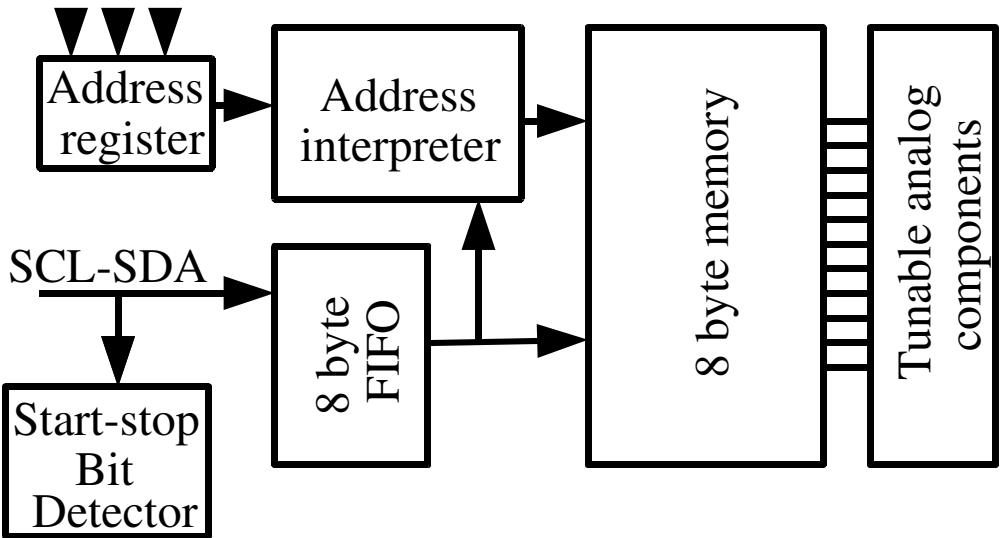
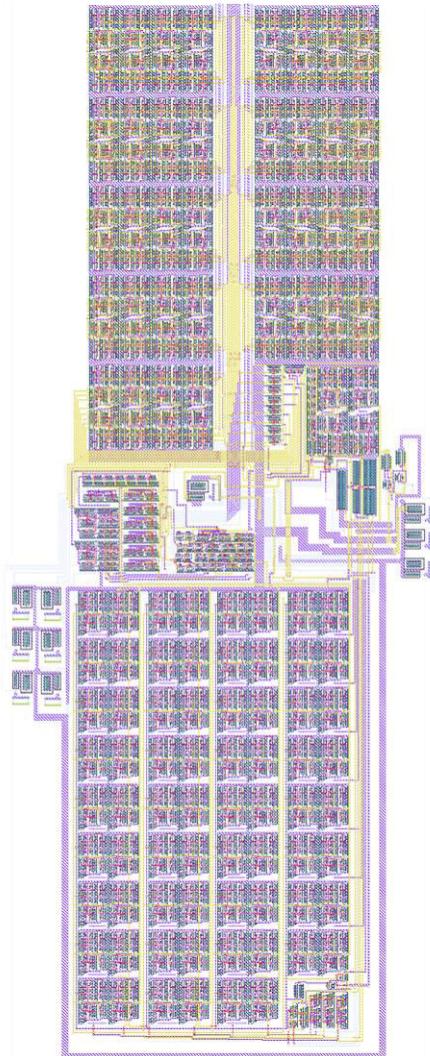
- Redesigned input stage for best speed and noise performance
- Redesigned output stage (reduced cross-over distortion, static power dissipation...)
- Fast-reset device (just to reduce dead time for the channels connected to the front pads. TOT spectroscopy for the back only)
- 10 mW / channel



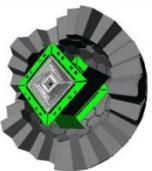
New structure used to adjust the bandwidth of the CSP, in order to achieve the best risetime possible with different detector capacitance keeping overshoot under control.



I²C engine

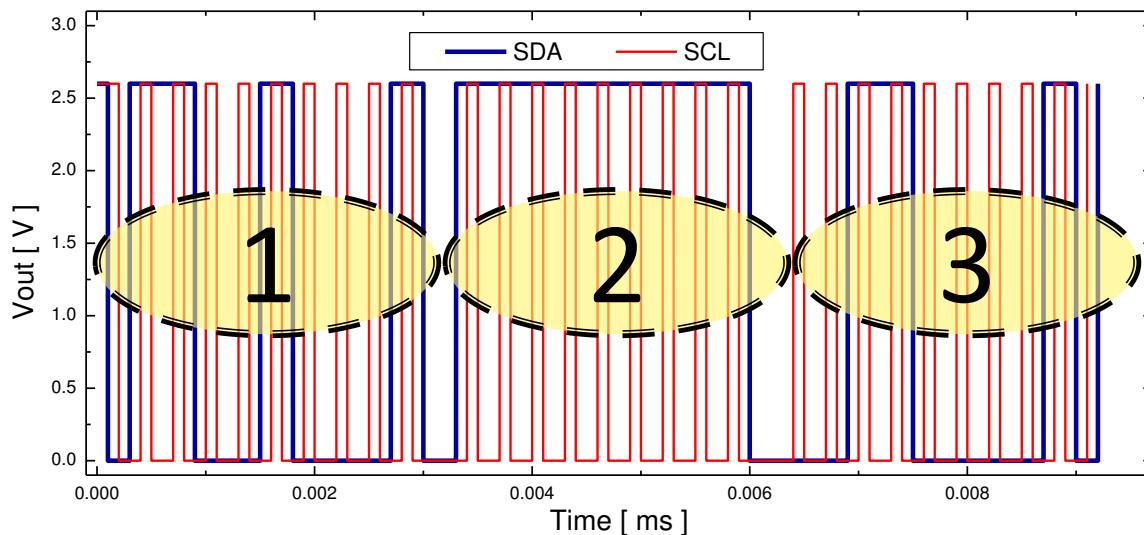
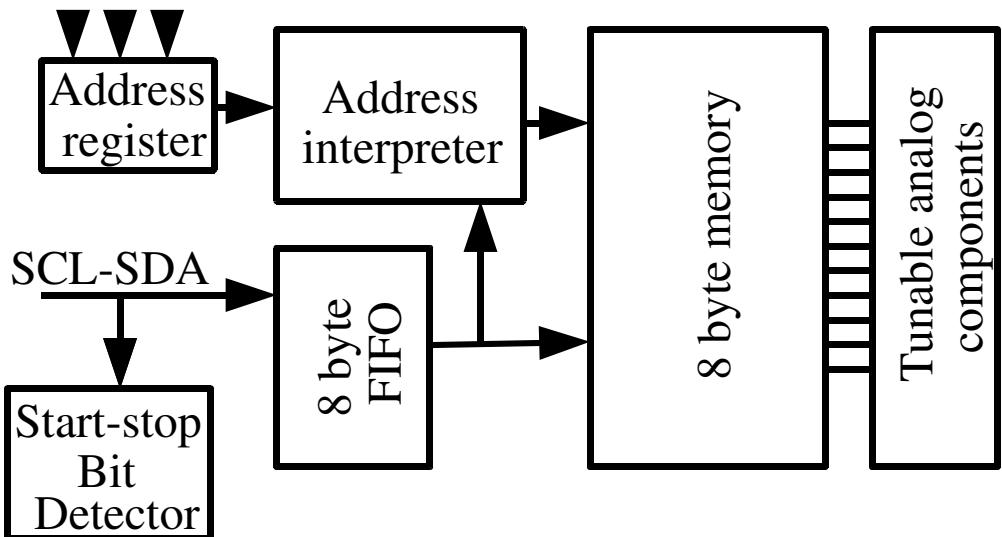


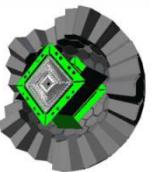
- Simple structure
- Designed to store the configuration of 8 channels on a SRAM
- Directly adjust the value of passive components through transmission gates.
- Reset function to recover immediately a predefined configuration



I²C engine

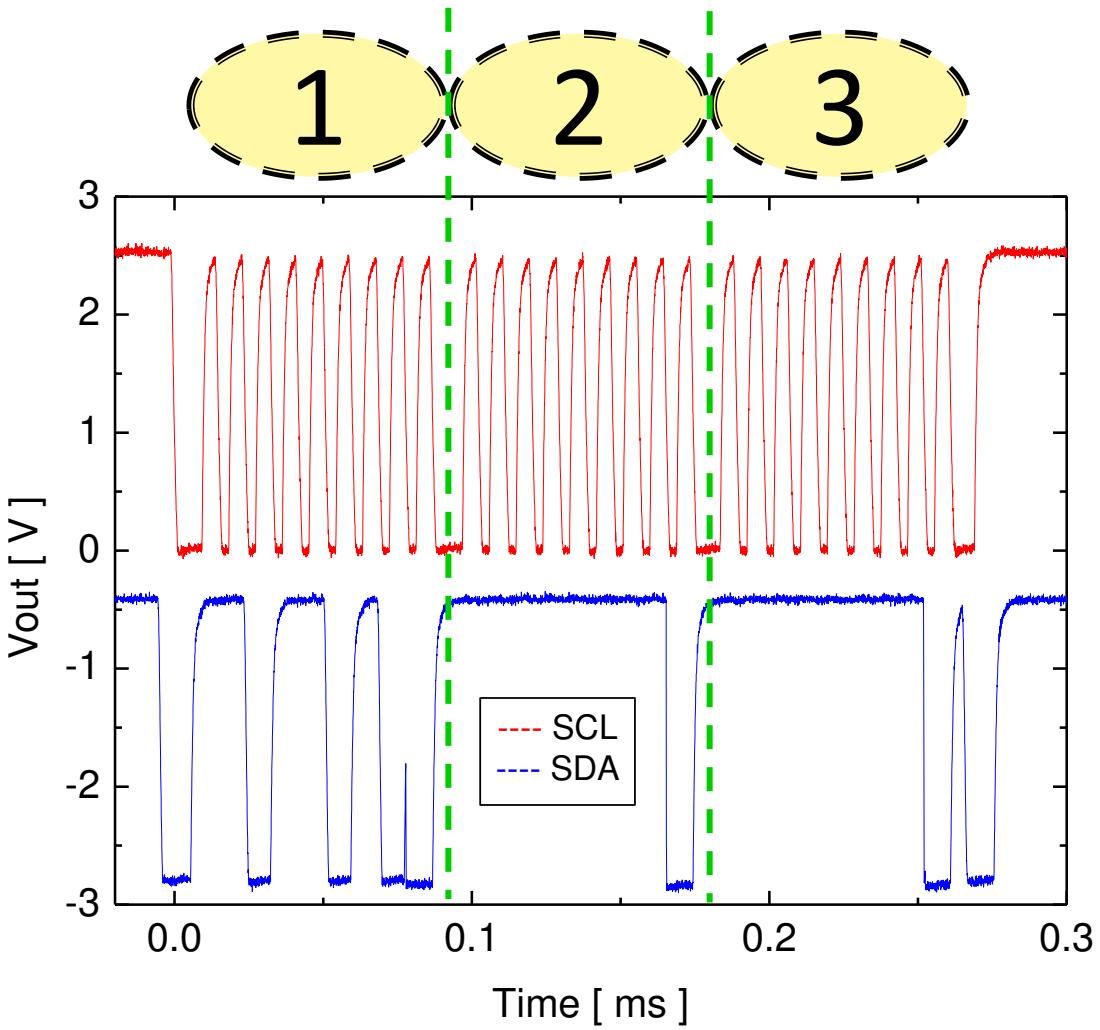
- 1 – Address of the chip
- 2 - Channels to set
- 3 – Configuration of the channels

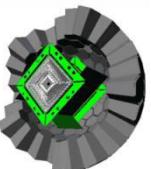




I²C engine

- 1 – Address of the chip
- 2 - Channels to set
- 3 – Configuration of the channels





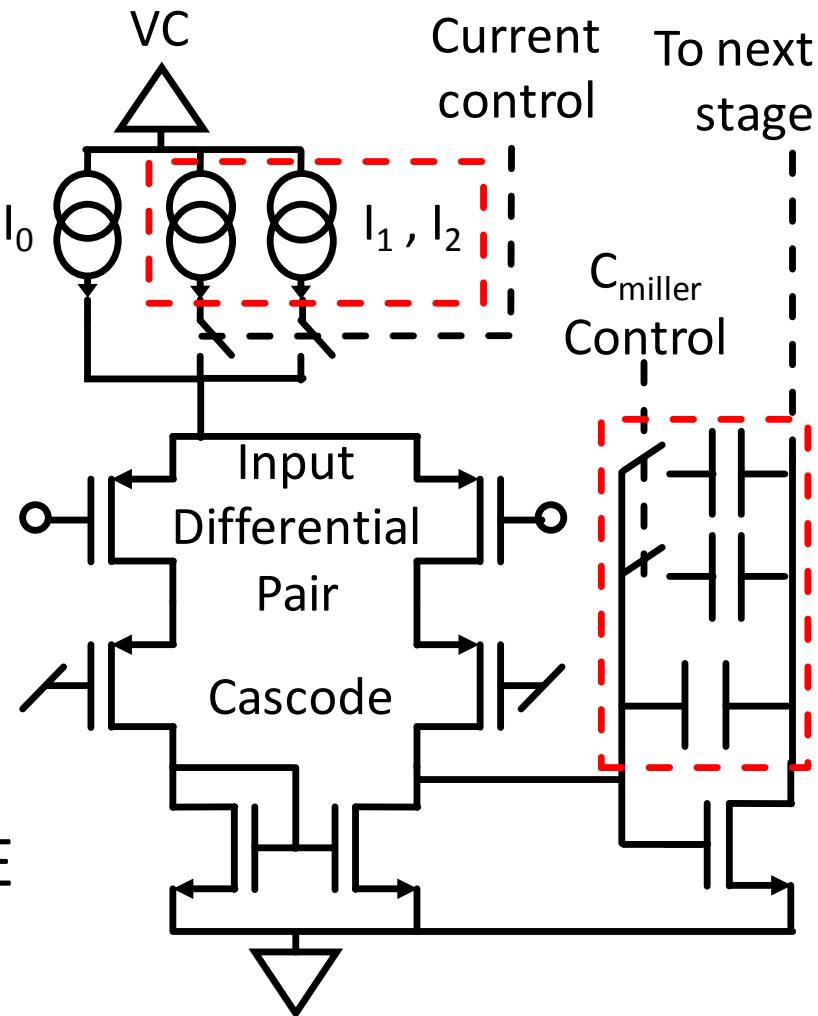
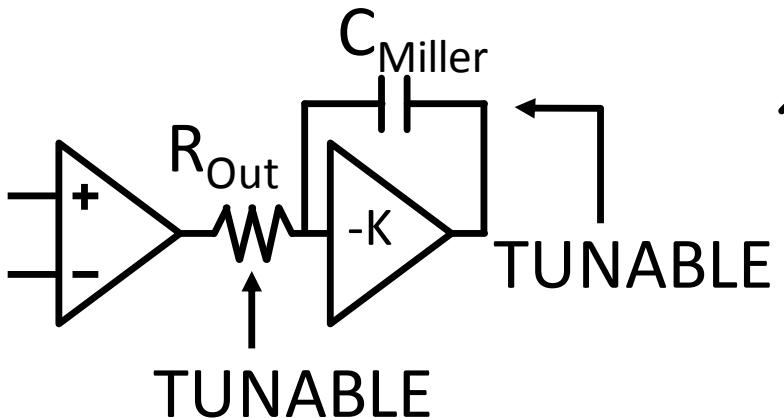
Integrated input stage

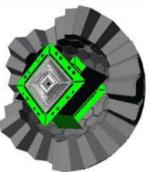


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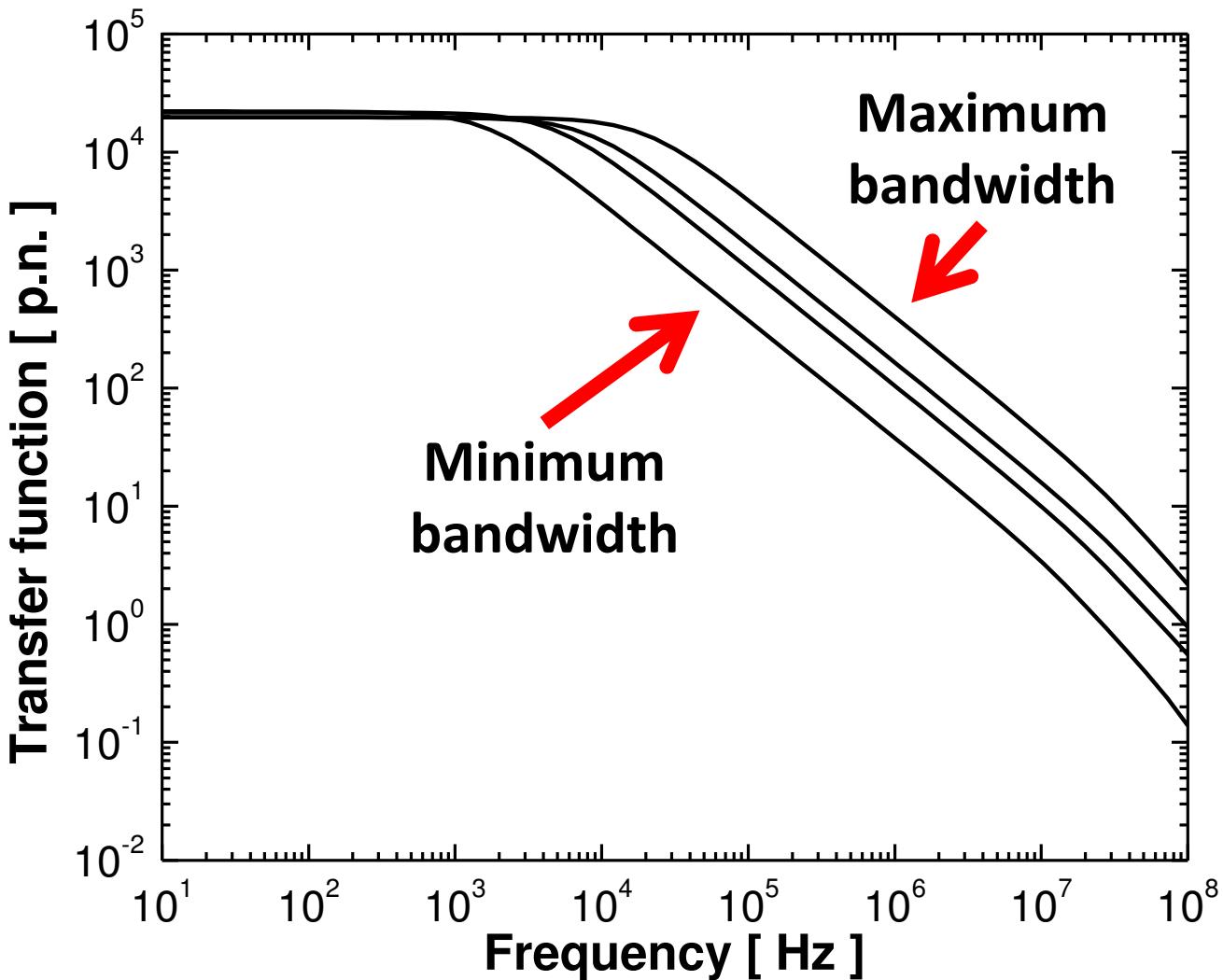
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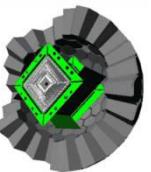
- Low noise
- Differential input
- Adjustable bandwidth with two independent controls: bias current and value of Miller capacitor



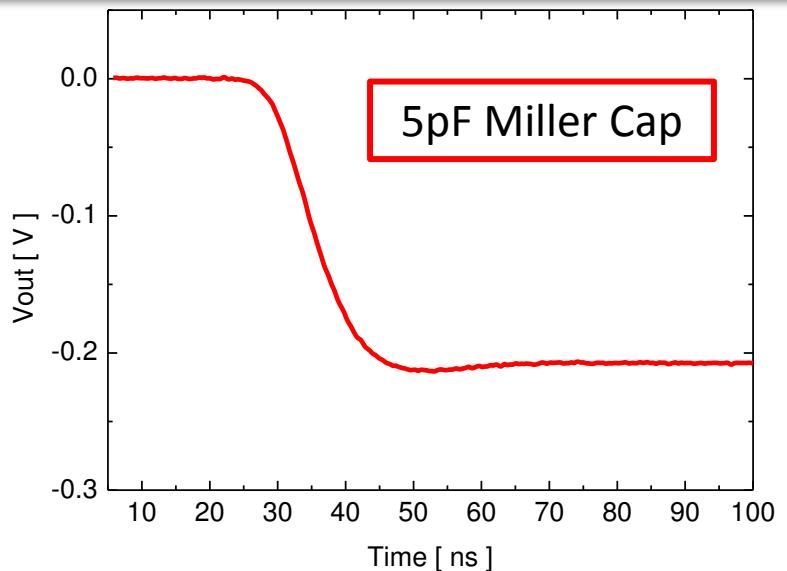


Adjustable bandwidth

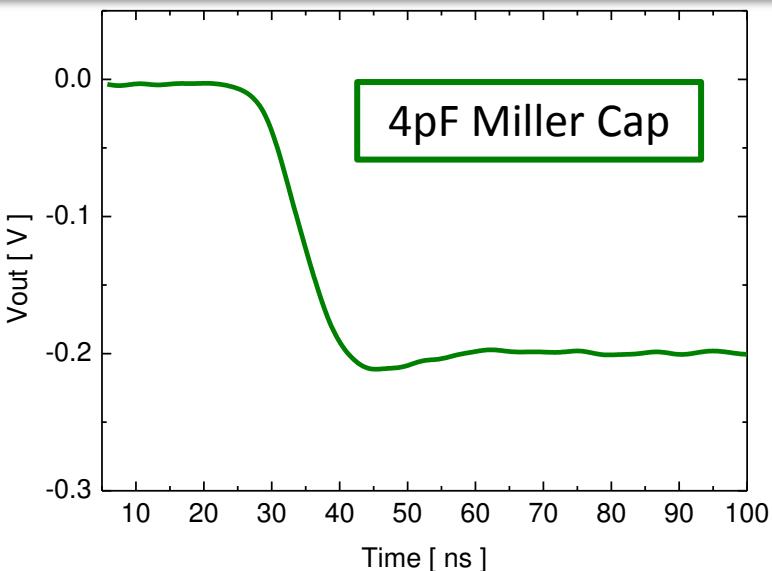




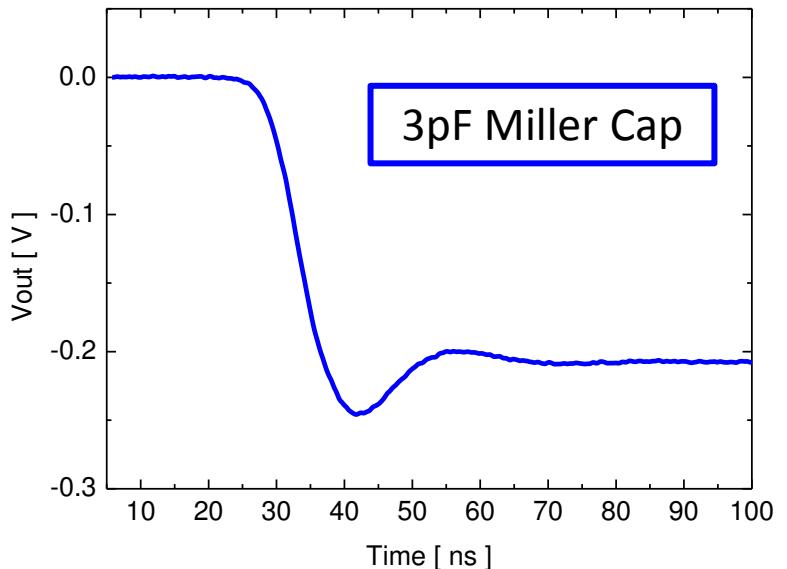
Adjustable bandwidth



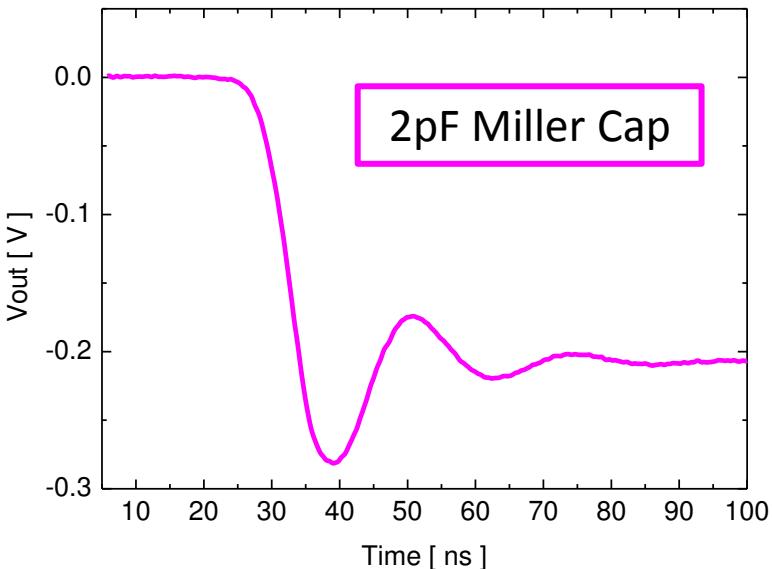
5pF Miller Cap



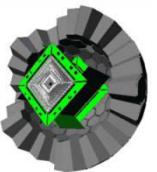
4pF Miller Cap



3pF Miller Cap



2pF Miller Cap

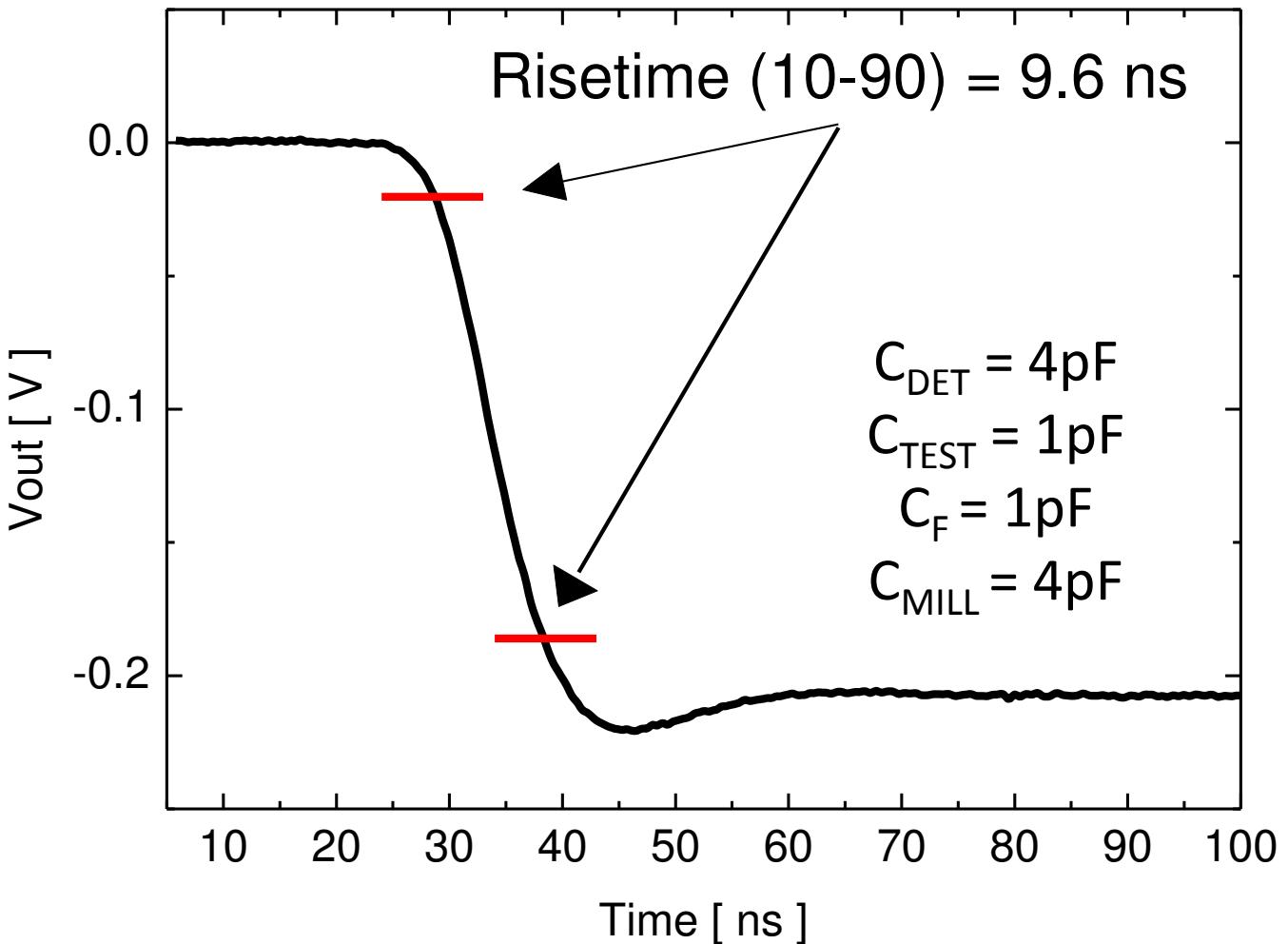


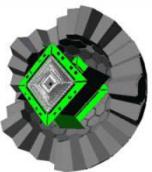
Adjustable bandwidth



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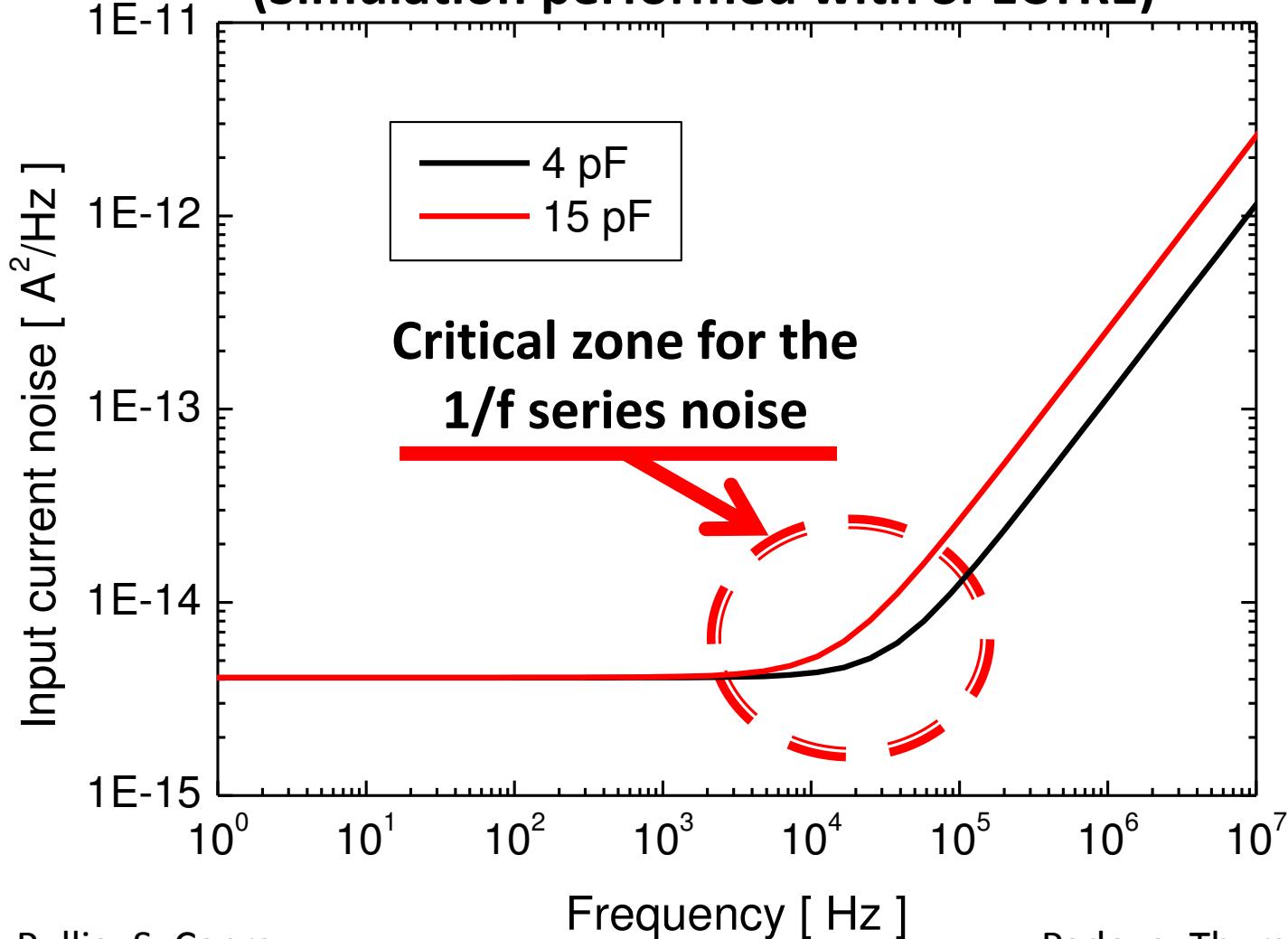
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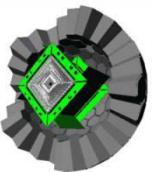




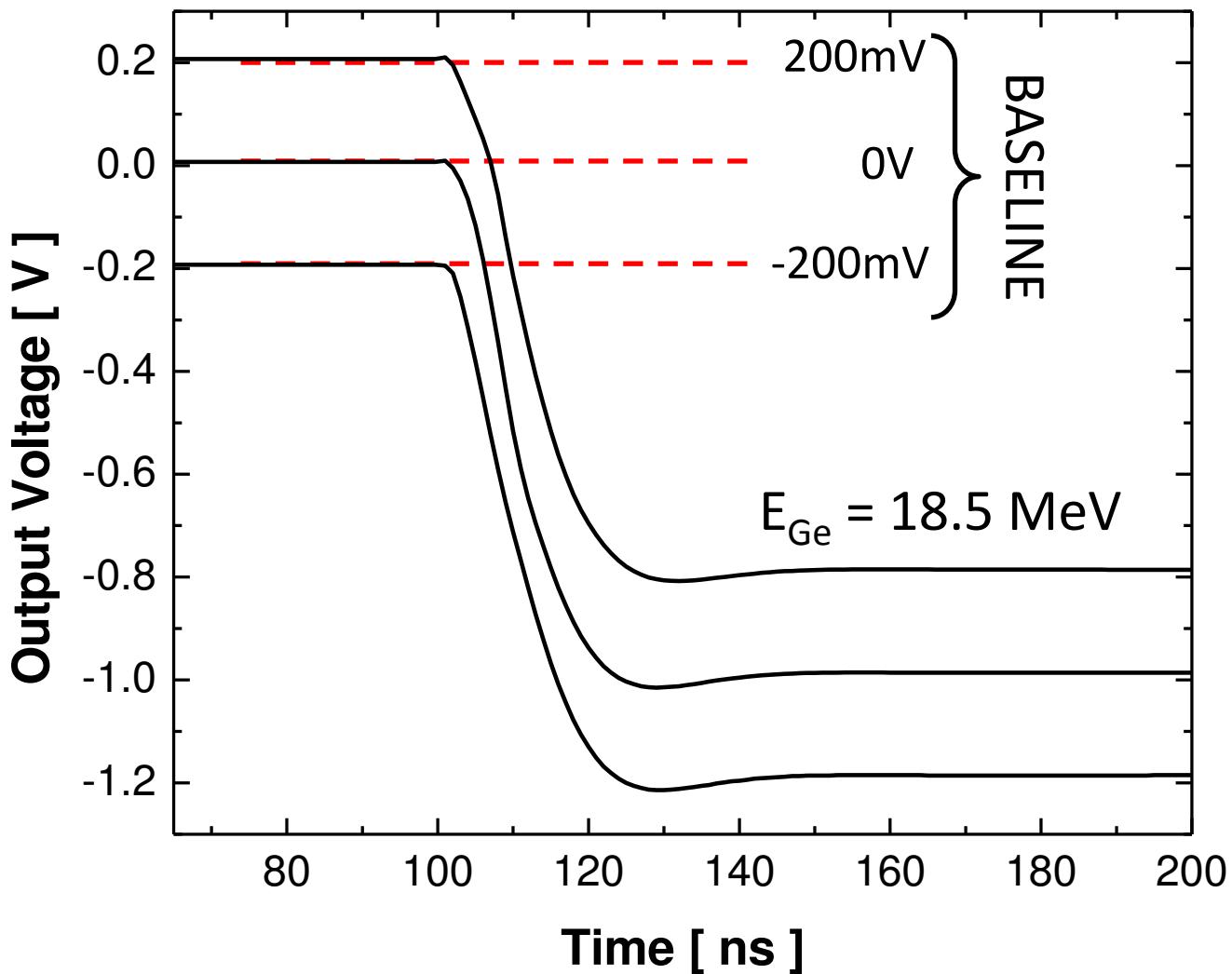
Noise performances

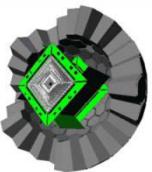
Current noise at the input for $C_{DET} = 4\text{pF}$ and 15pF
(Simulation performed with SPECTRE)





Output stage



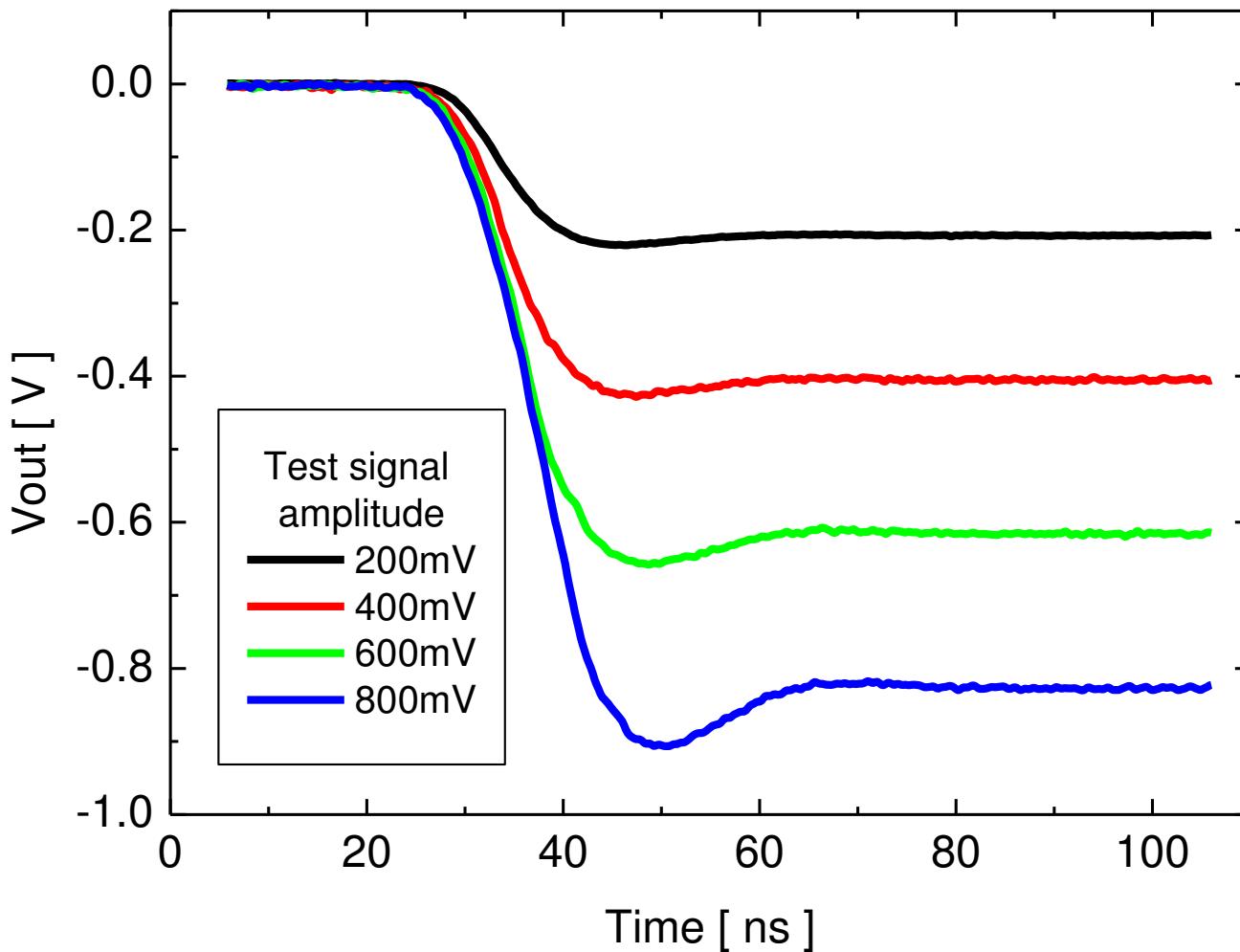


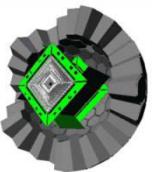
Dynamic range and linearity



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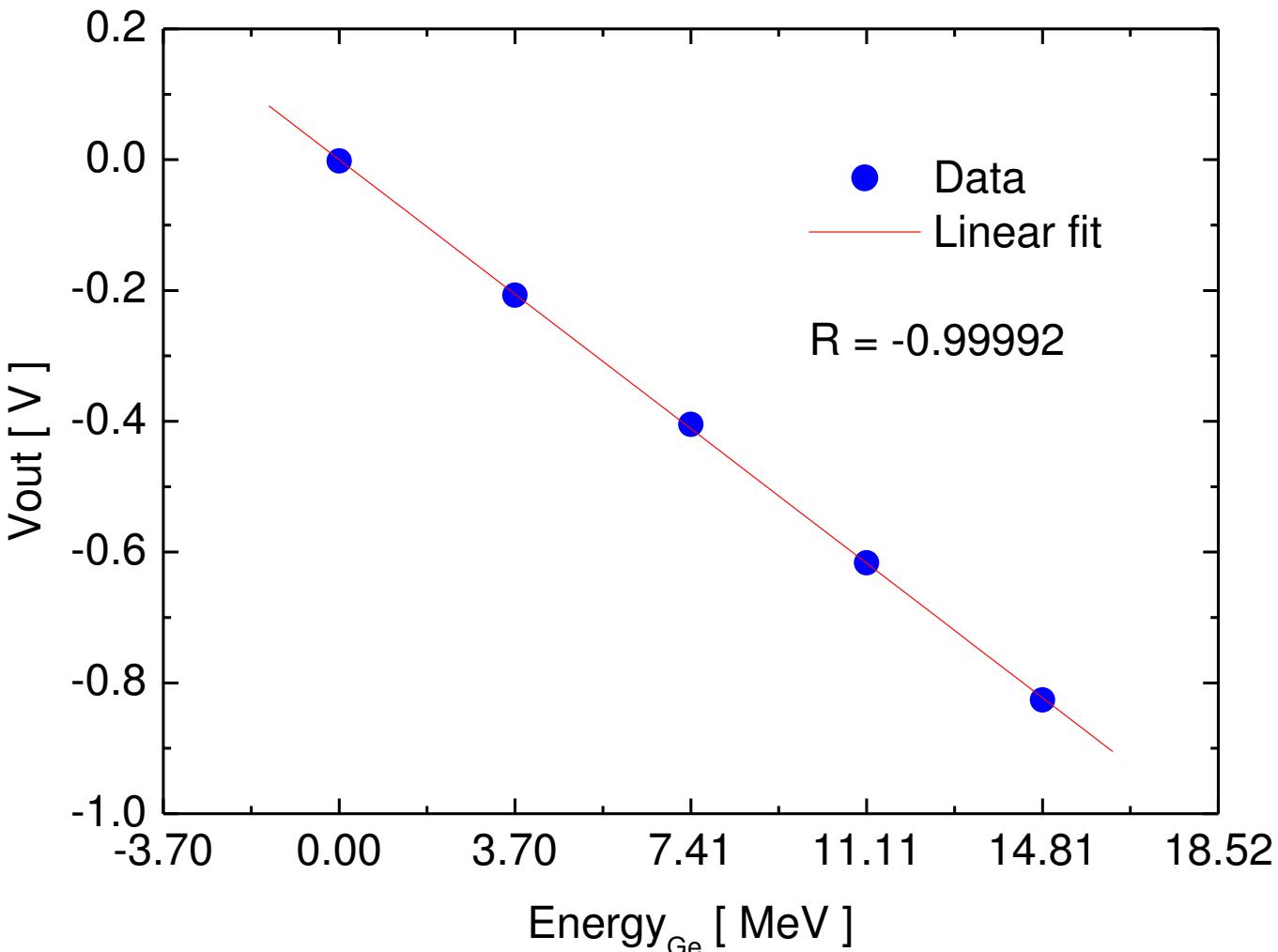


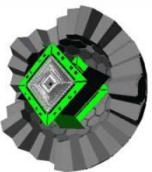
Dynamic range and linearity



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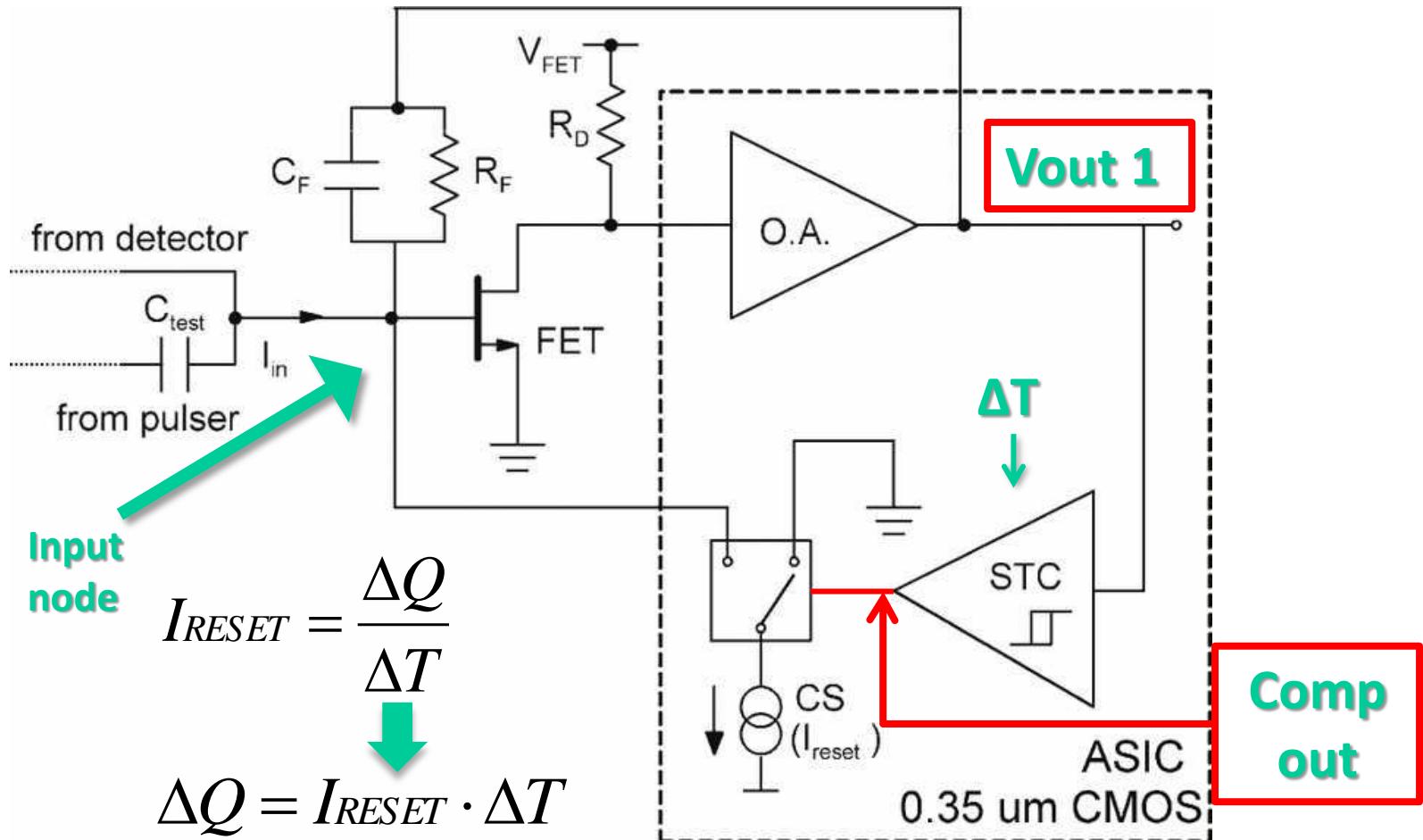


Fast-reset device

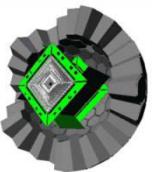


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A. Pullia, F. Zocca "Extending the Dynamic Range of a Charge-Preamplifier far Beyond its Saturation Limit: a 0.35 μm CMOS Preamplifier for Germanium Detectors" IEEE Nucl. Sci. Symp. N27-3 (2009) 1919

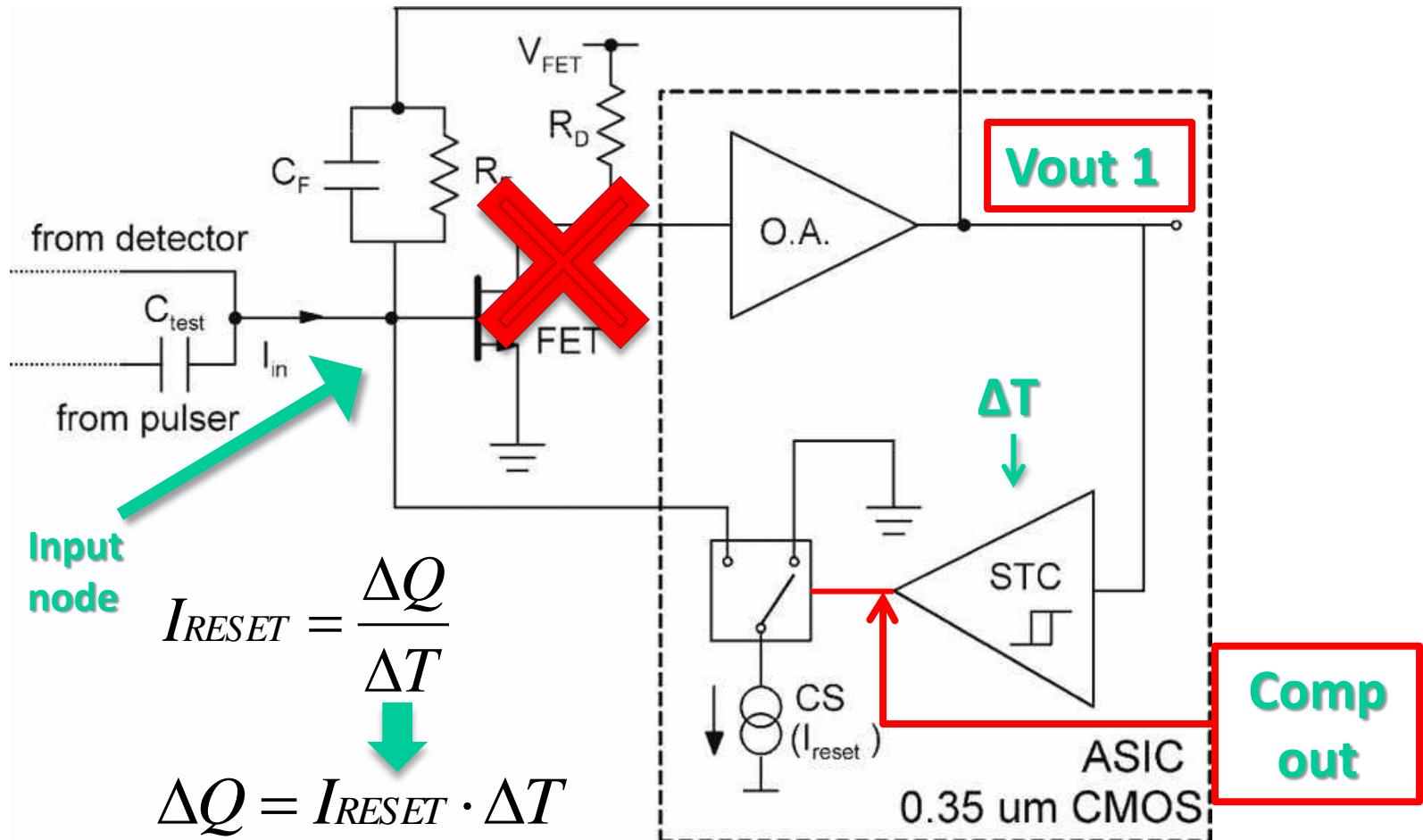


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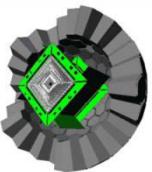


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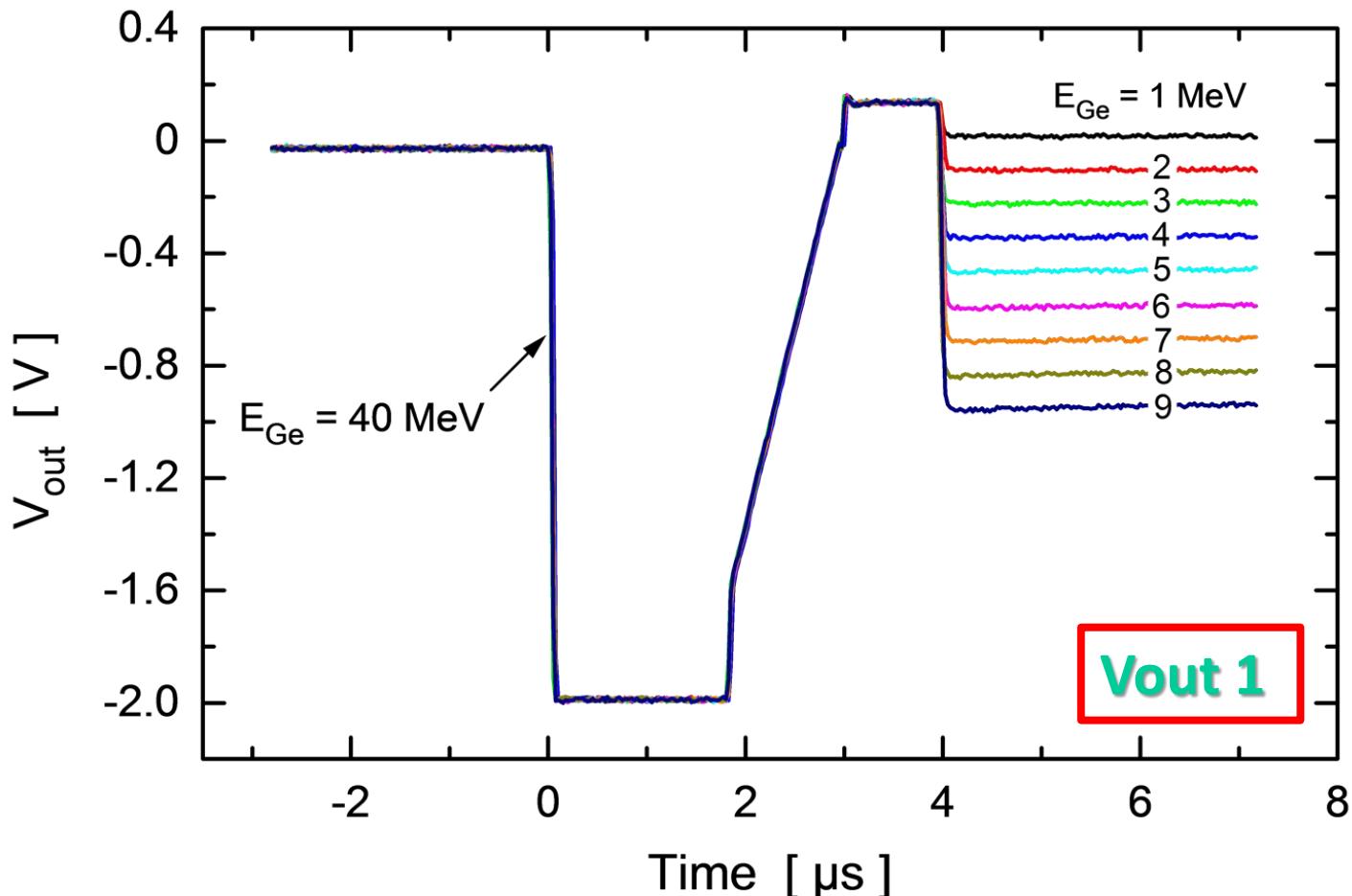


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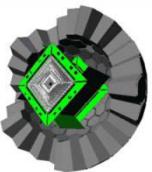


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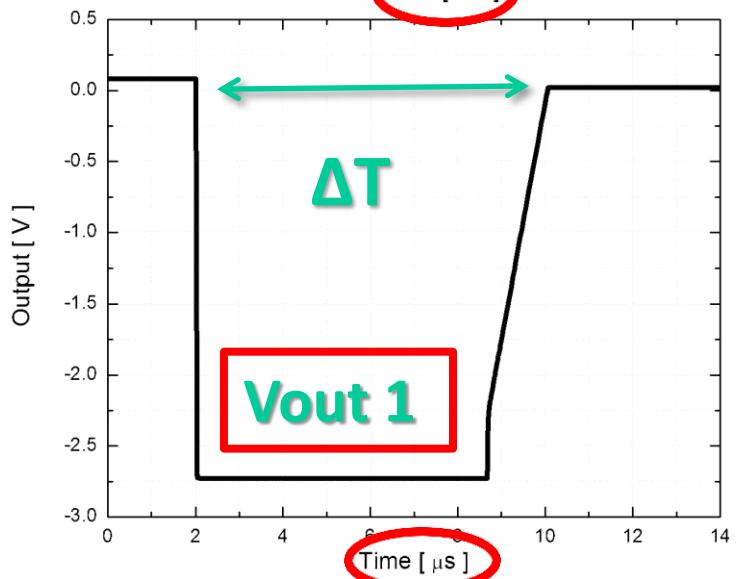
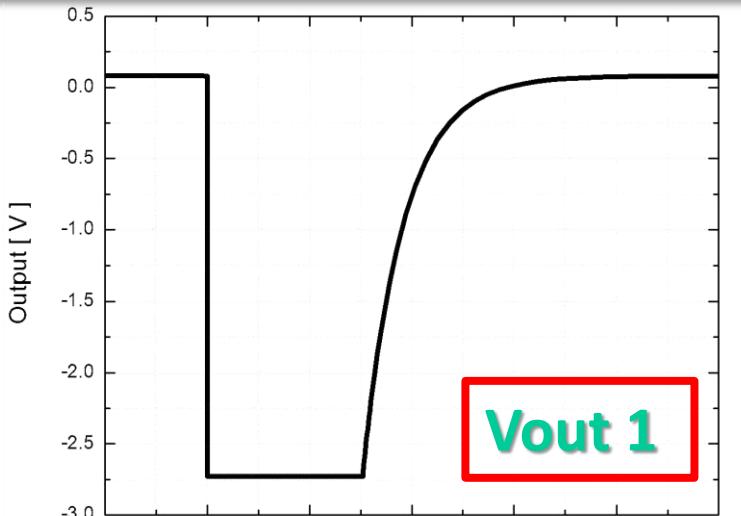
Fast-reset device



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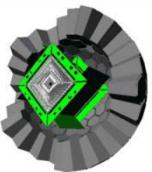
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- Minimizes the preamplifier **dead time** and prevents from the paralysis of the acquisition system in the case of extremely high background counting rates
- Allows for **charge information** even in the saturation condition
- Allows for **high-resolution energy measurements** → extending the dynamic range of photons/particles spectroscopy

$$\Delta T = \frac{Q_{TOT}}{I_{RESET}}$$



Fast-reset device

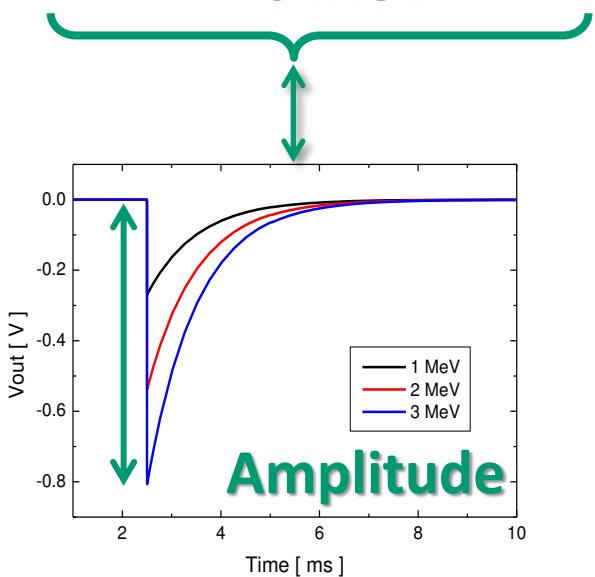


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Combining offline the information collected with the two operative modes we can reconstruct the energy spectrum over an extended range

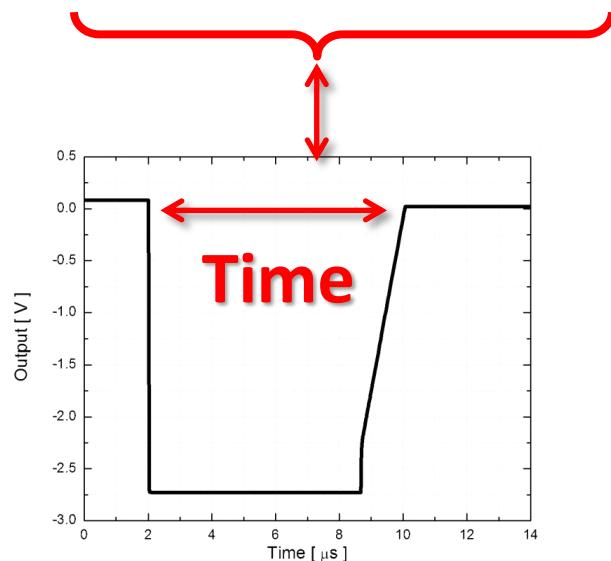
Energies under the saturation threshold

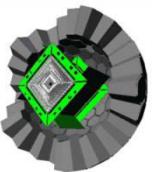
< 10 MeV



Energies over the saturation threshold

> 10 MeV





Drawbacks

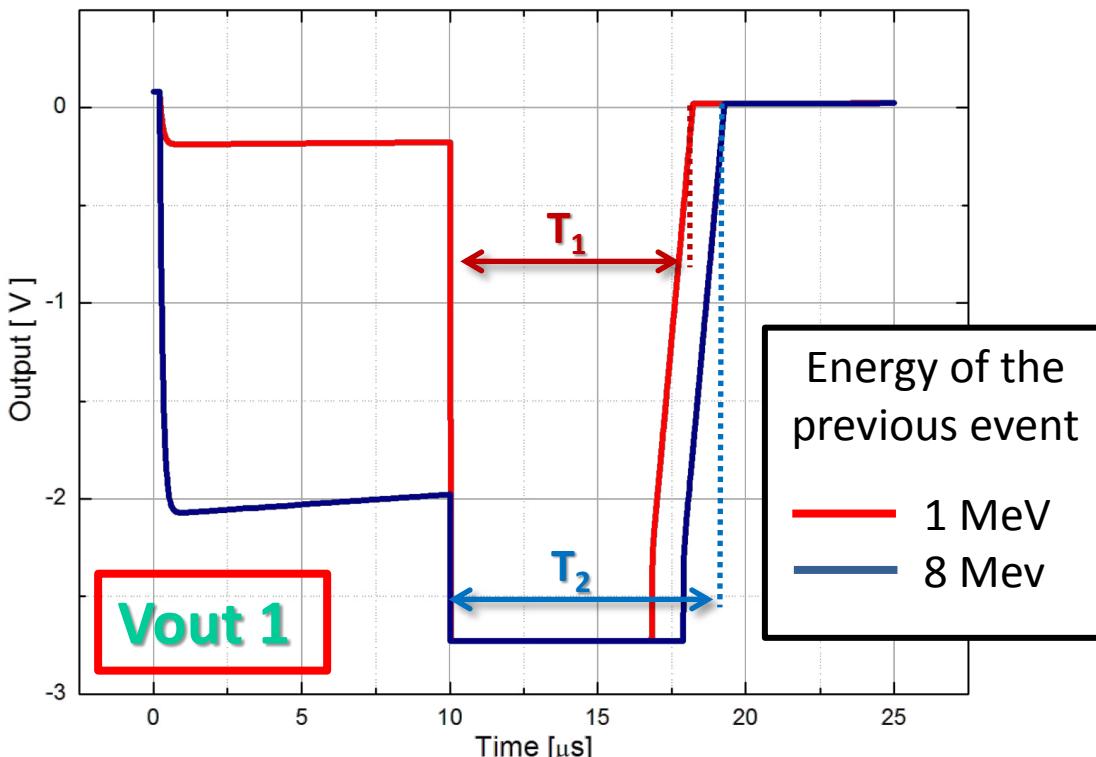


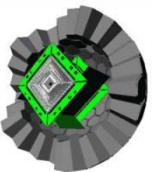
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- The digital TOT signal depends on the residual charge on C_F before the reset process
- **Need for an algorithm to correct this dependency**
- Off-line digital correction: easy to implement but expensive in computational terms





Drawbacks

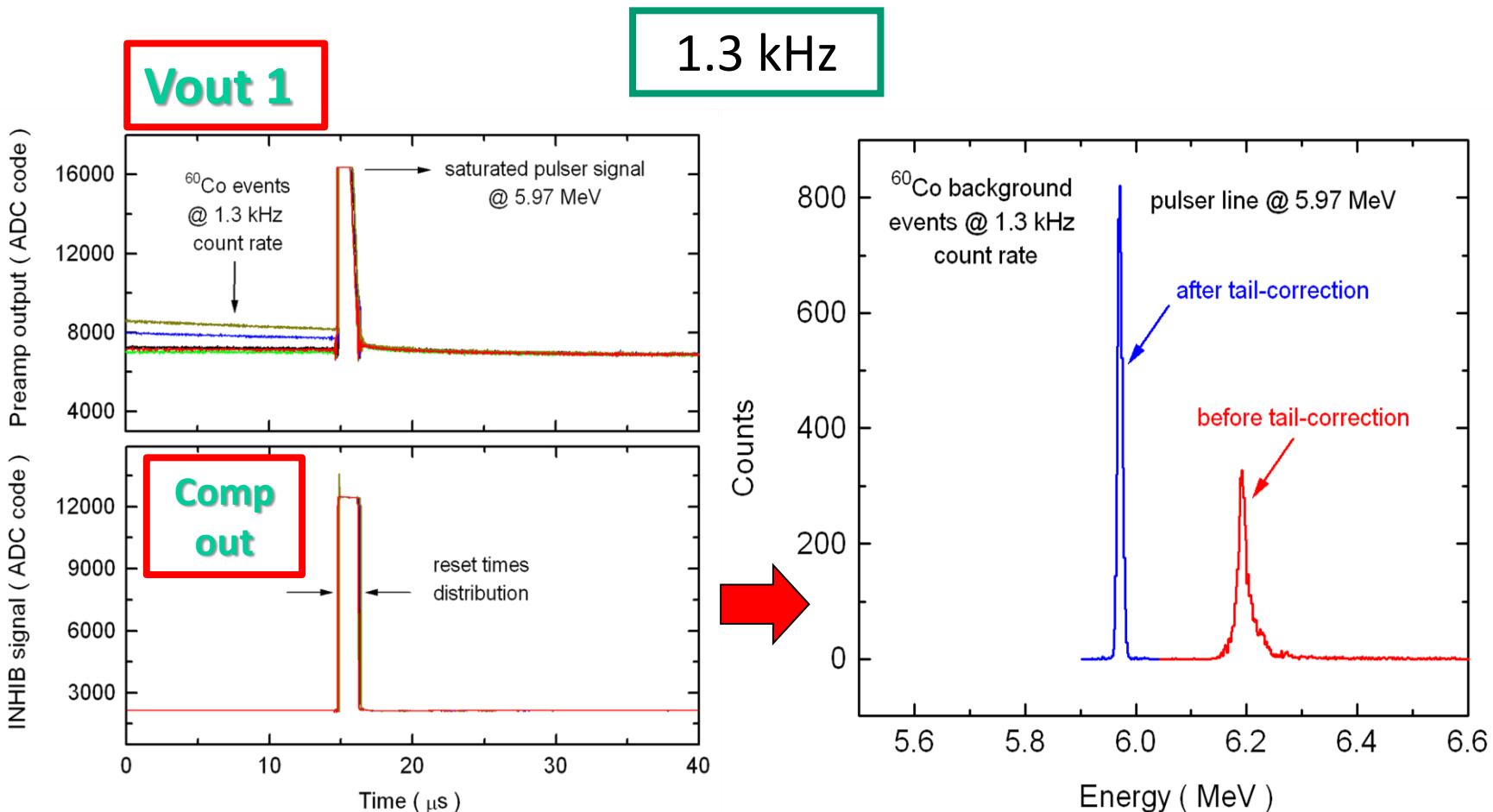


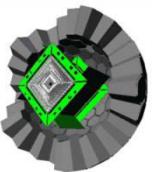
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Pile-up effects at medium counting rate





Drawbacks

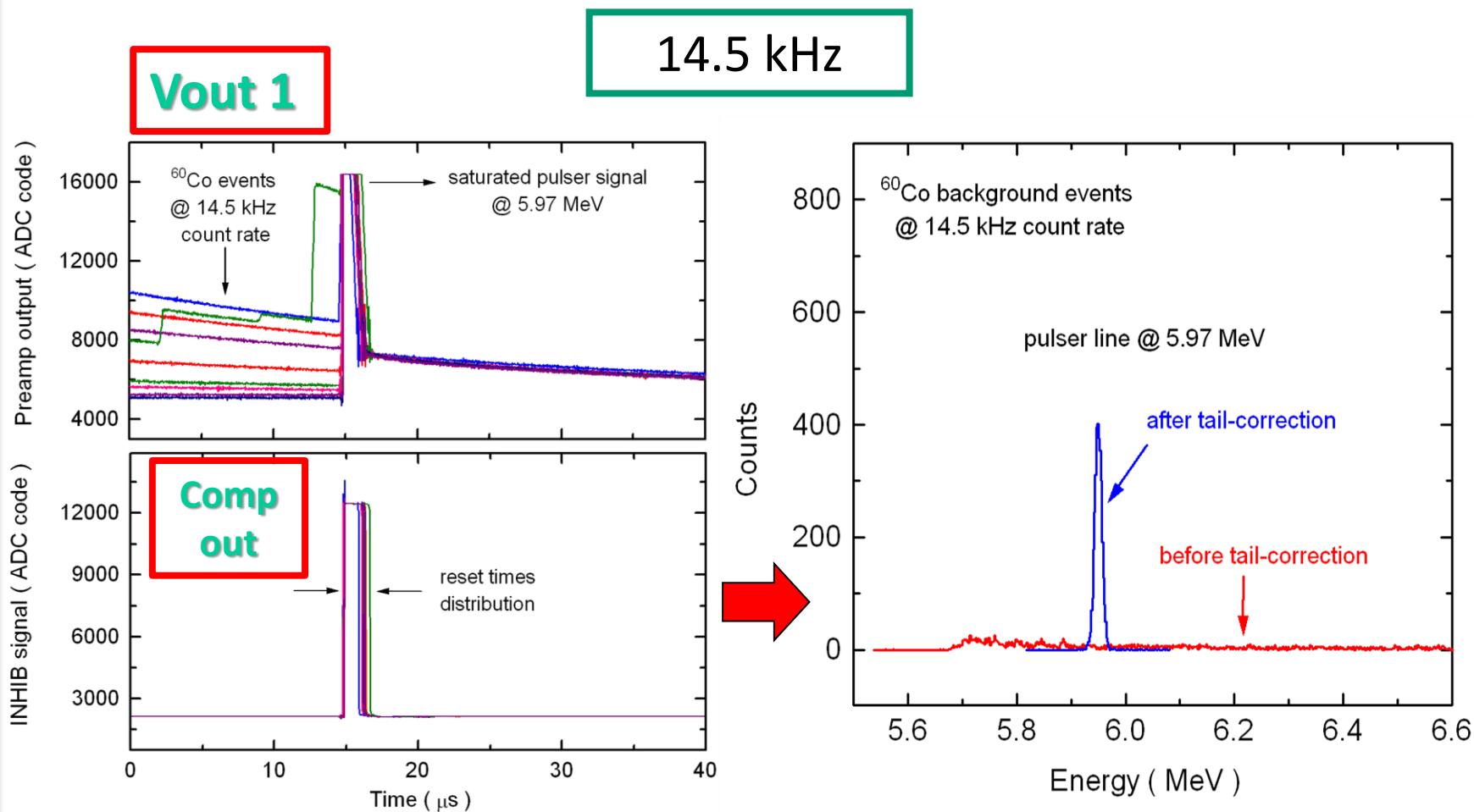


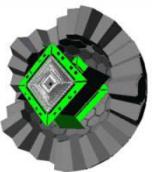
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Pile-up effects at high counting rate





TAC device

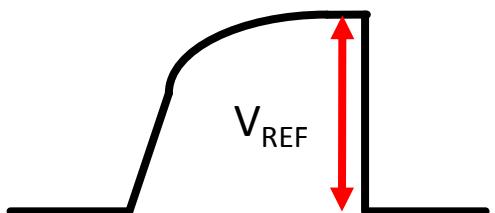


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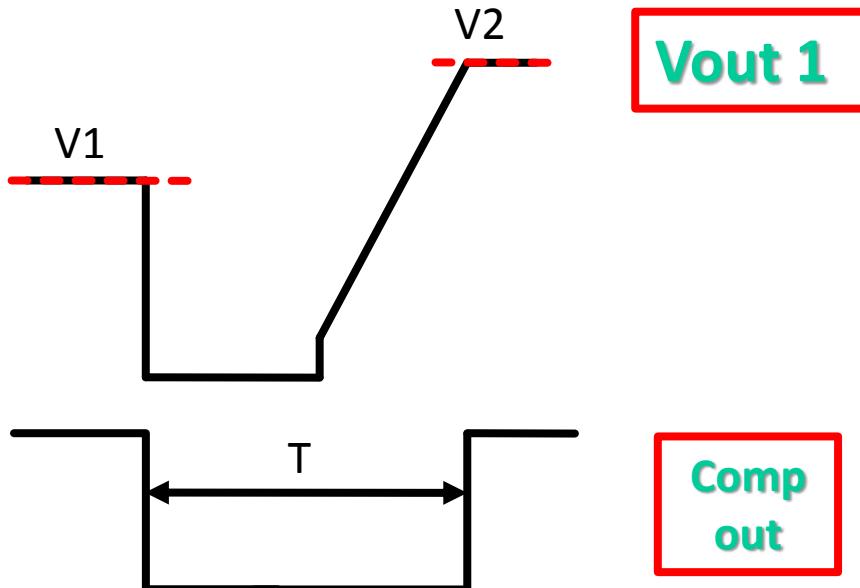
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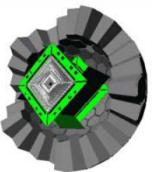
$$E_{DET} \propto V_{REF} = \alpha [kT - C_F (\langle V_2 \rangle - \langle V_1 \rangle) + c]$$

Need to generate an auxiliary signal which amplitude V_{REF} is directly proportional to the energy of the last physical event (and no longer depends on the residual charge of past events!)



Auxiliary signal Vout2



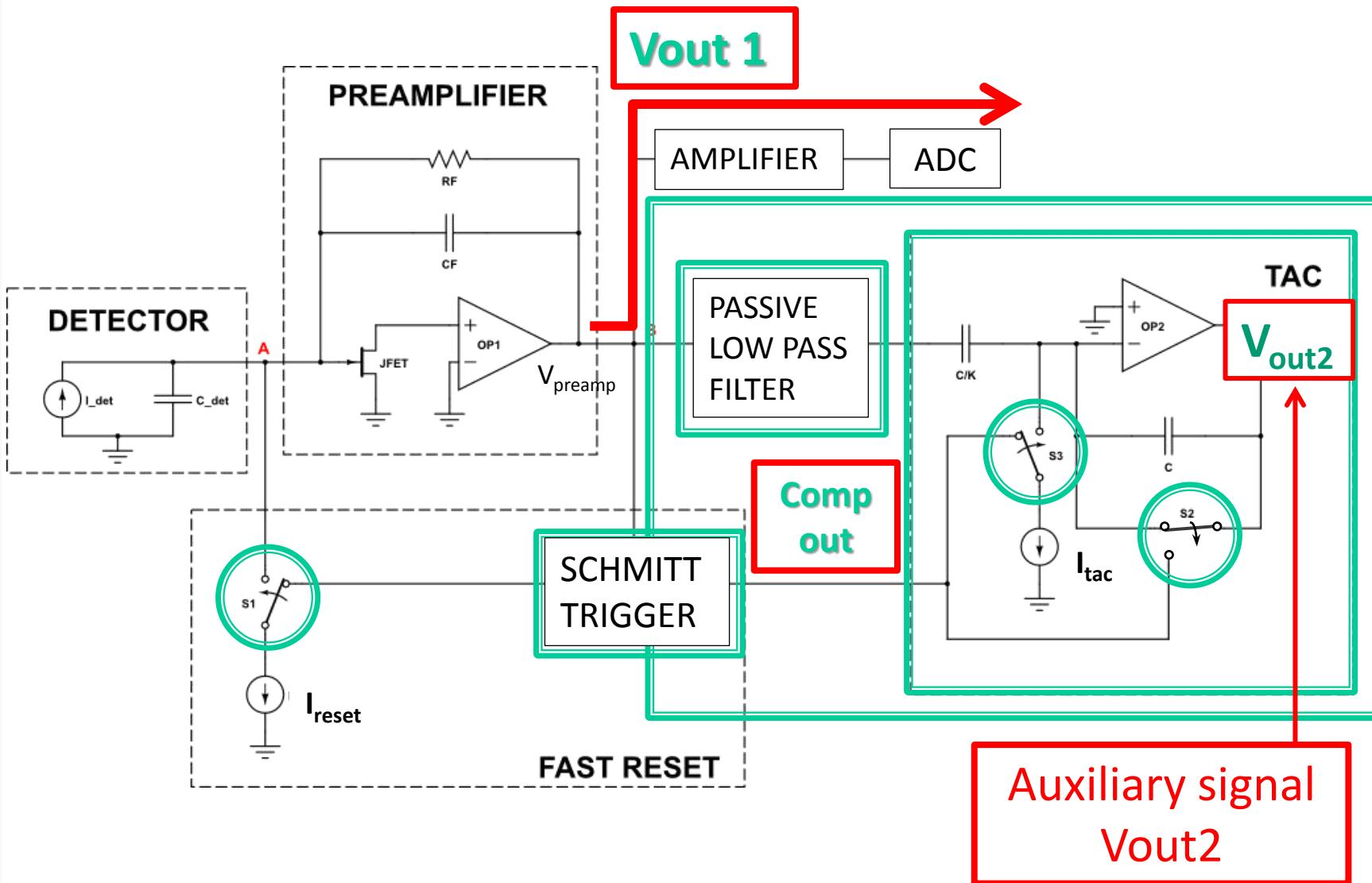


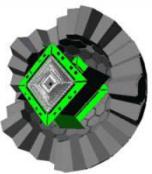
TAC device



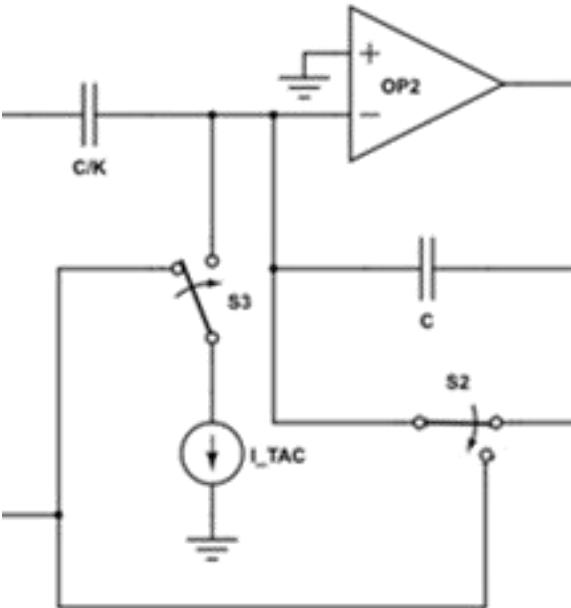
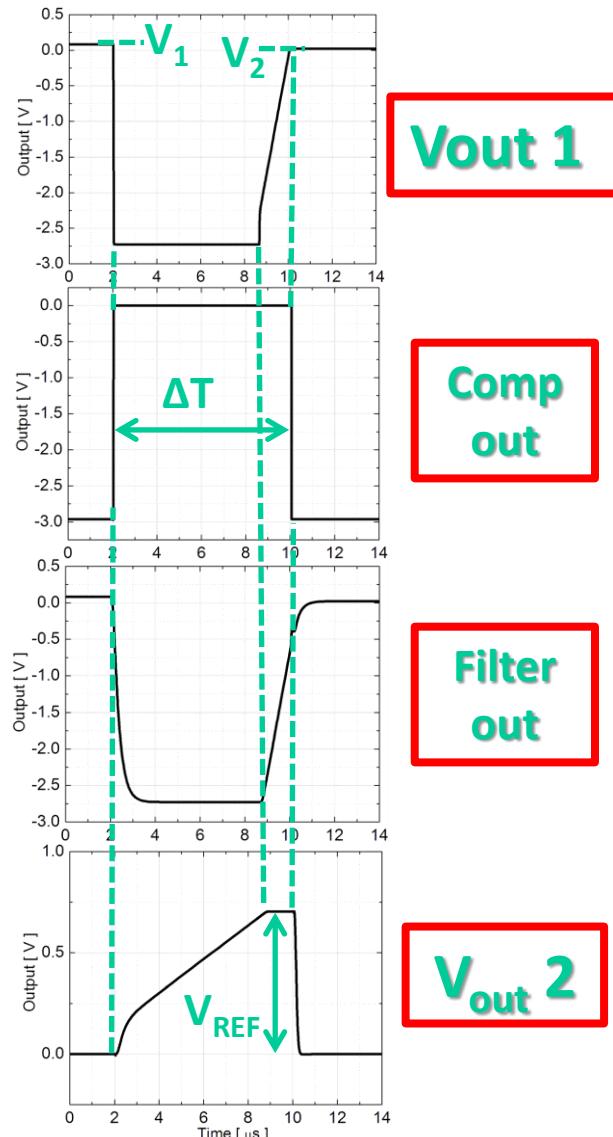
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TAC device



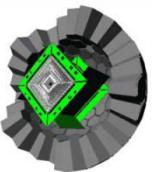
$$\frac{I_{TAC}}{C/K} = \frac{I_{RESET}}{C_F}$$

$$V_{REF} = \frac{I_{TAC} \cdot \Delta T}{C} - \frac{1}{K} (V_2 - V_1)$$

Contribute of the
 I_{TAC} current

Contribution of
The feedback

$$V_{REF} = \frac{I_{TAC}}{I_{RESET}} \cdot \frac{Q_{sat}}{C} = \frac{R_{RESET}}{R_{TAC}} \cdot \frac{Q_{sat}}{C}$$

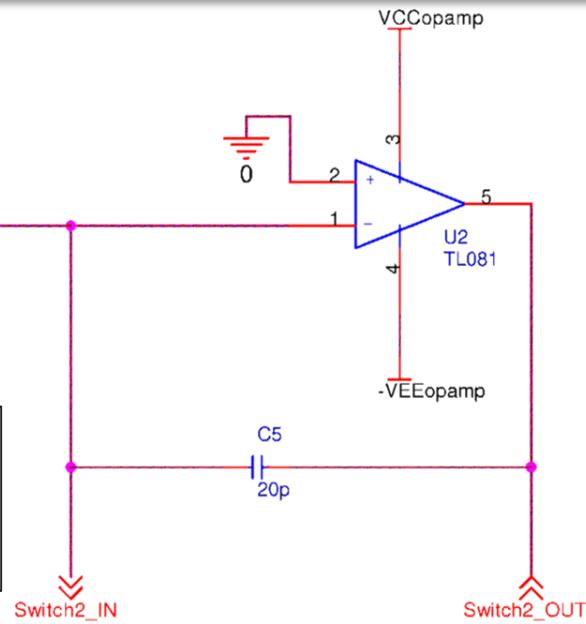
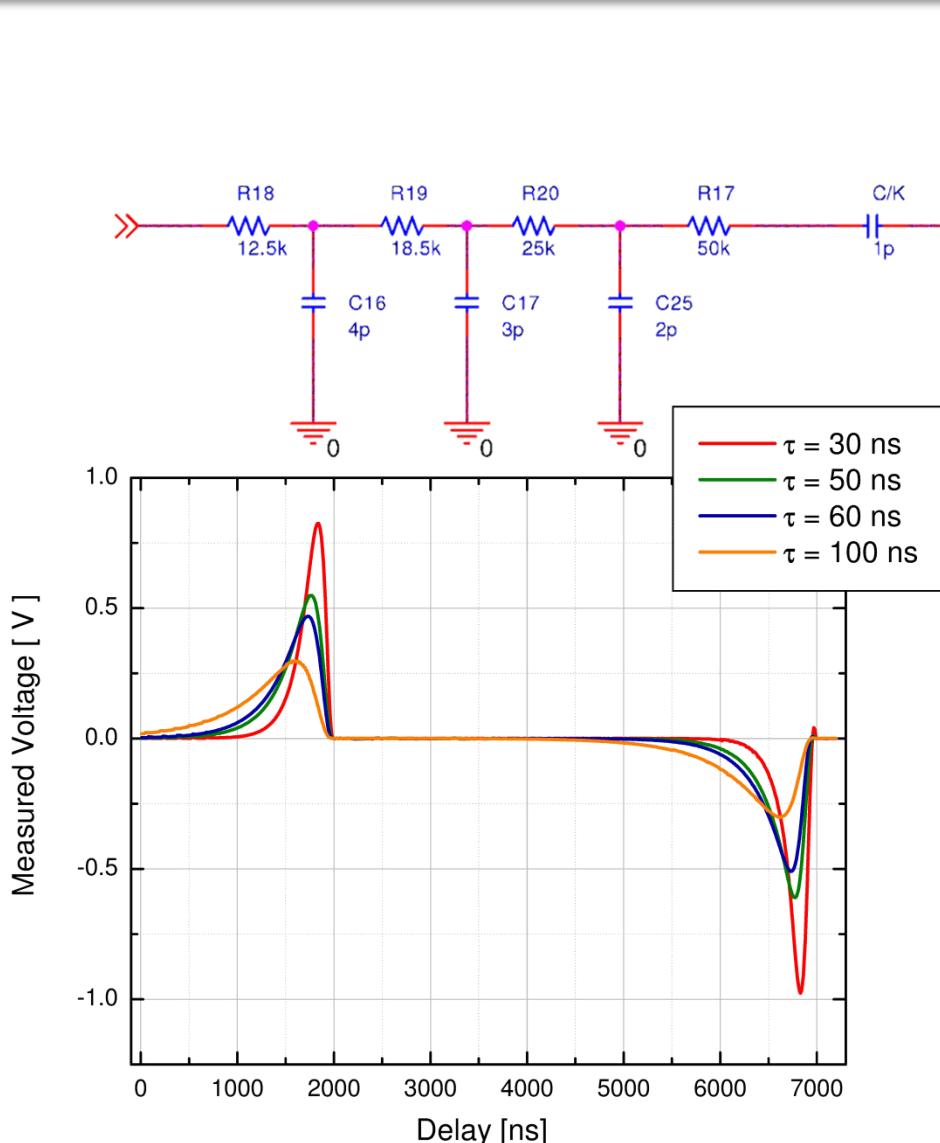


Lowpass filter

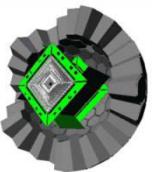


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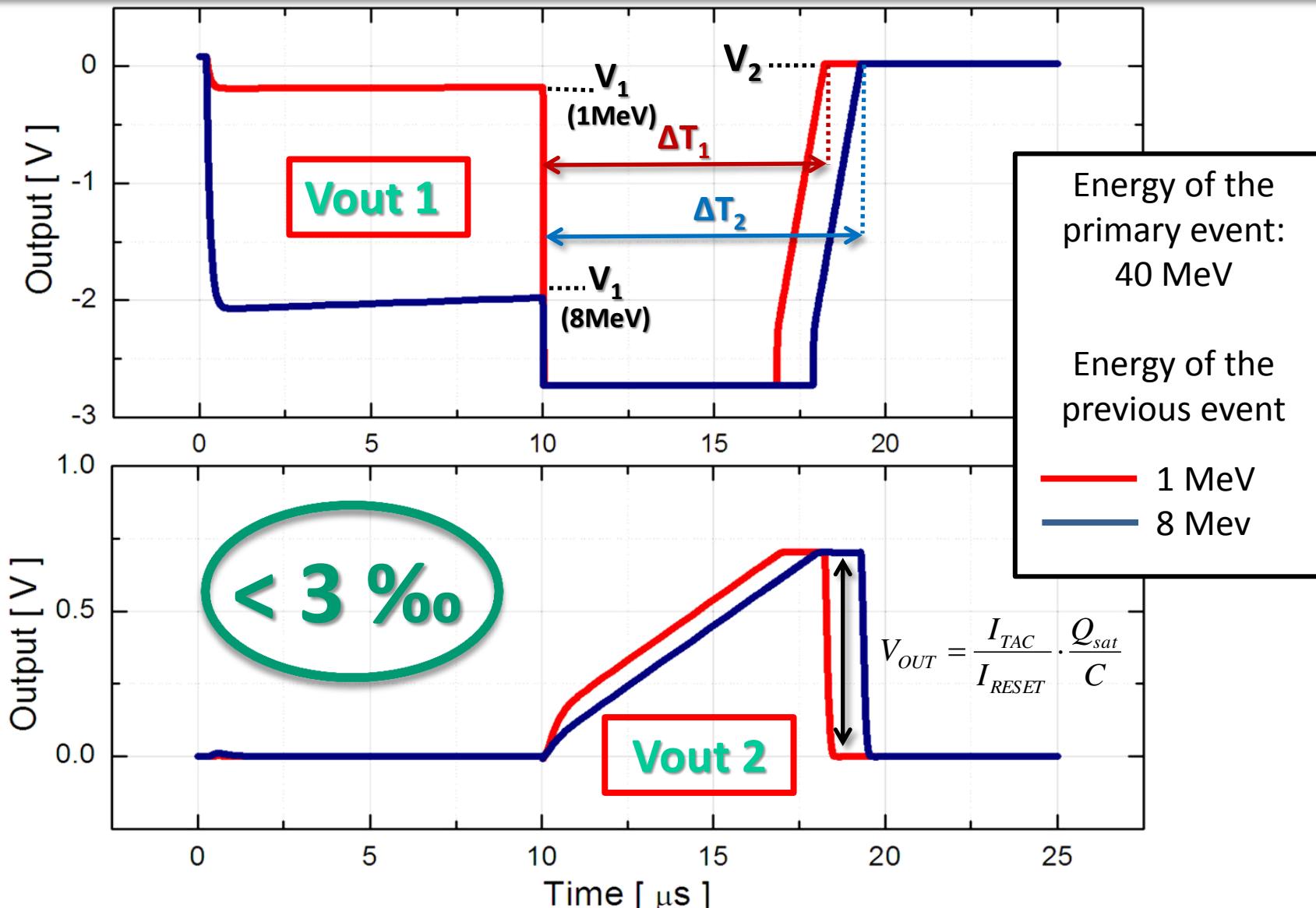
The filter applies a convolution to the function which represent the voltages V_1 and V_2 reducing the associated noise

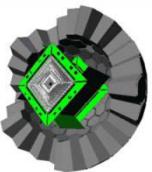


Rejection of the baseline



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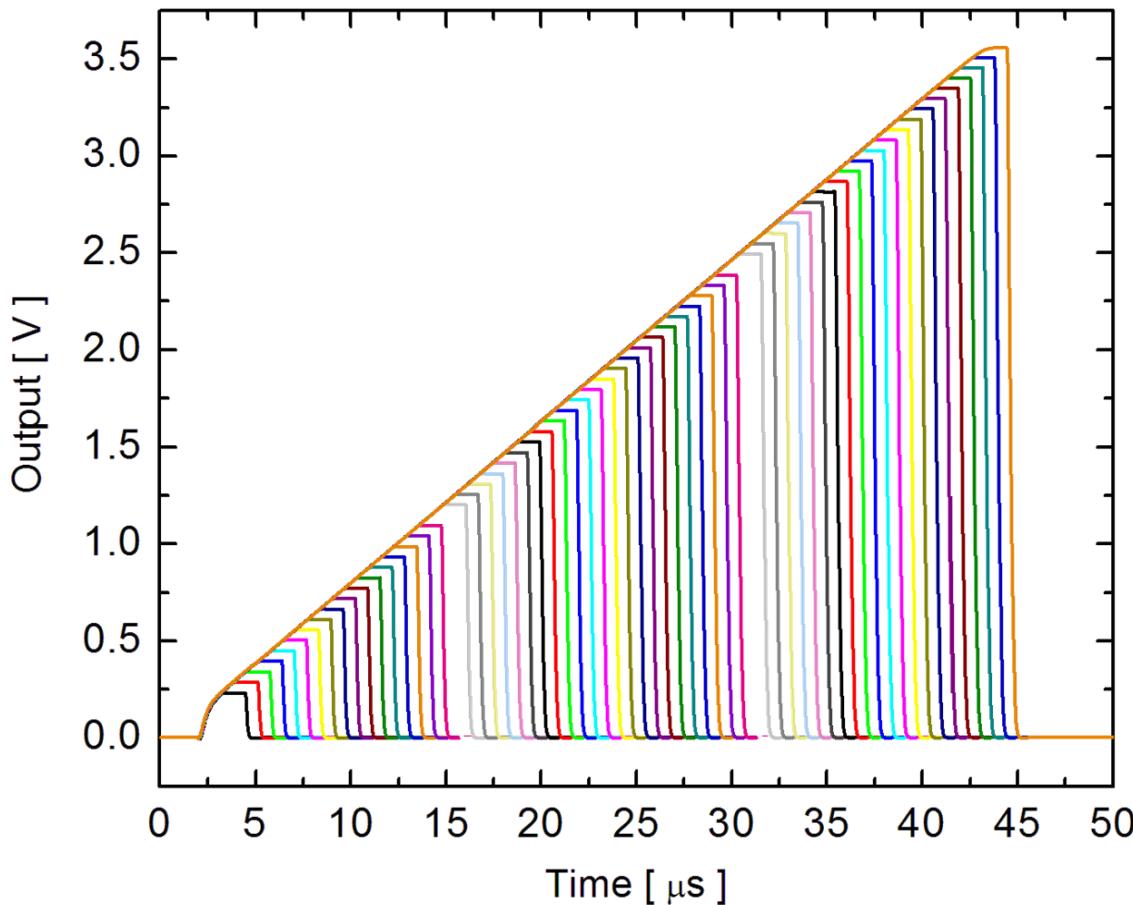


Rejection of the baseline

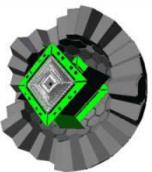


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After the time-to-amplitude conversion, we can perform amplitude spectroscopy on over-threshold signals

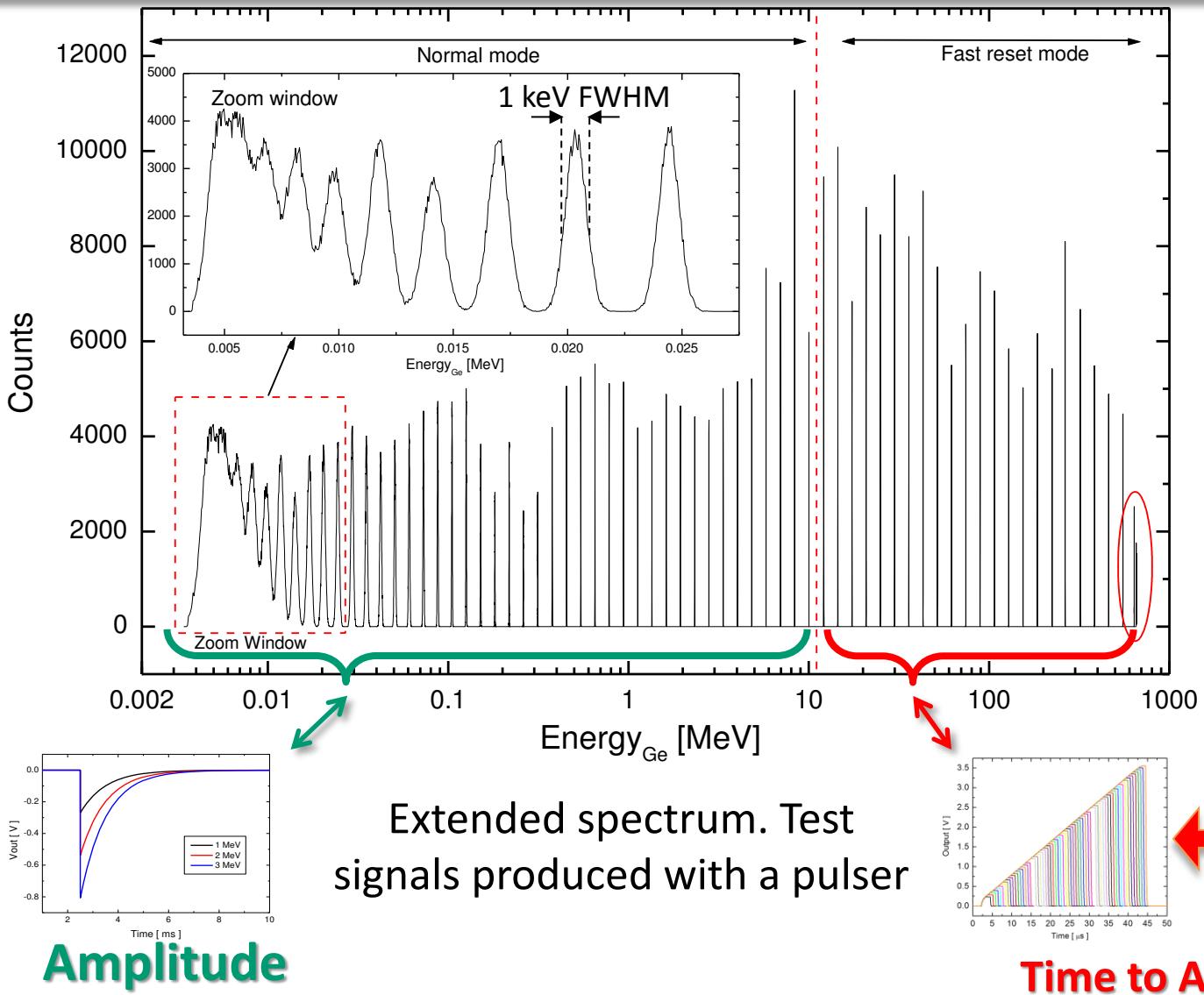


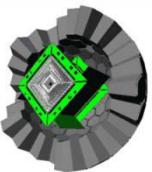
Fast-reset device



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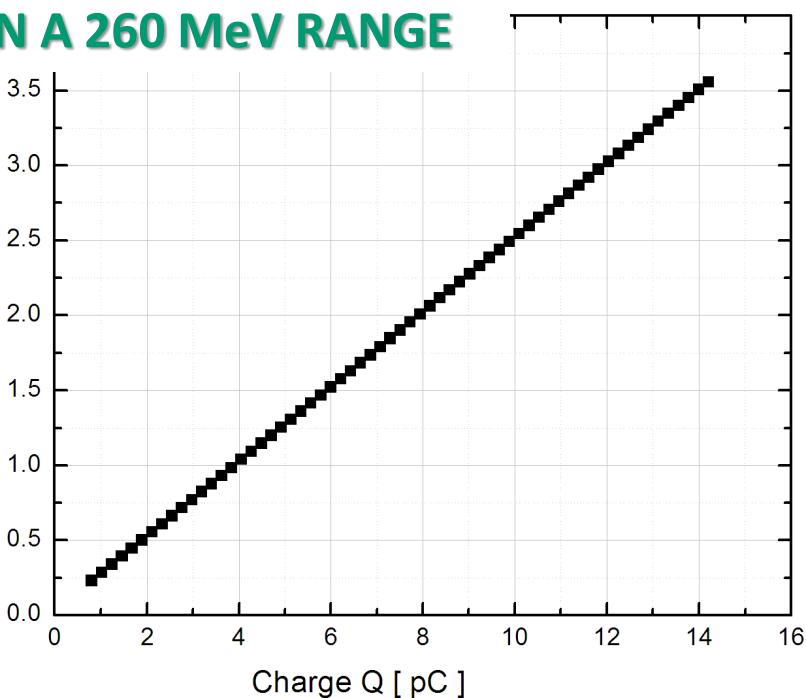
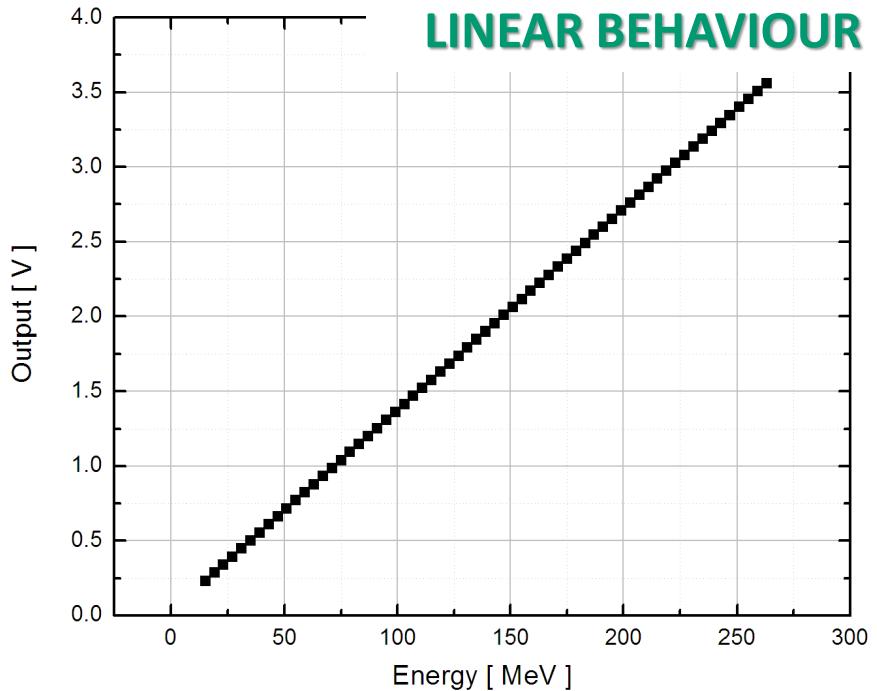




Linearity of the measurement



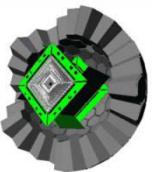
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LINEAR FIT

m	q	σ_m	σ_q	R ²
$2.489544 \cdot 10^{11}$	0.031232	$2.51 \cdot 10^7$	0.000166	0.999998

$$V_{OUT} = \frac{I_{TAC}}{I_{RESET}} \cdot \frac{Q_{sat}}{C} + OS \quad \frac{I_{TAC}}{I_{RESET} \cdot C} = \frac{1.65 \mu A}{332 nA \cdot 20 pF} = 2.48494 \cdot 10^{11} F^{-1}$$

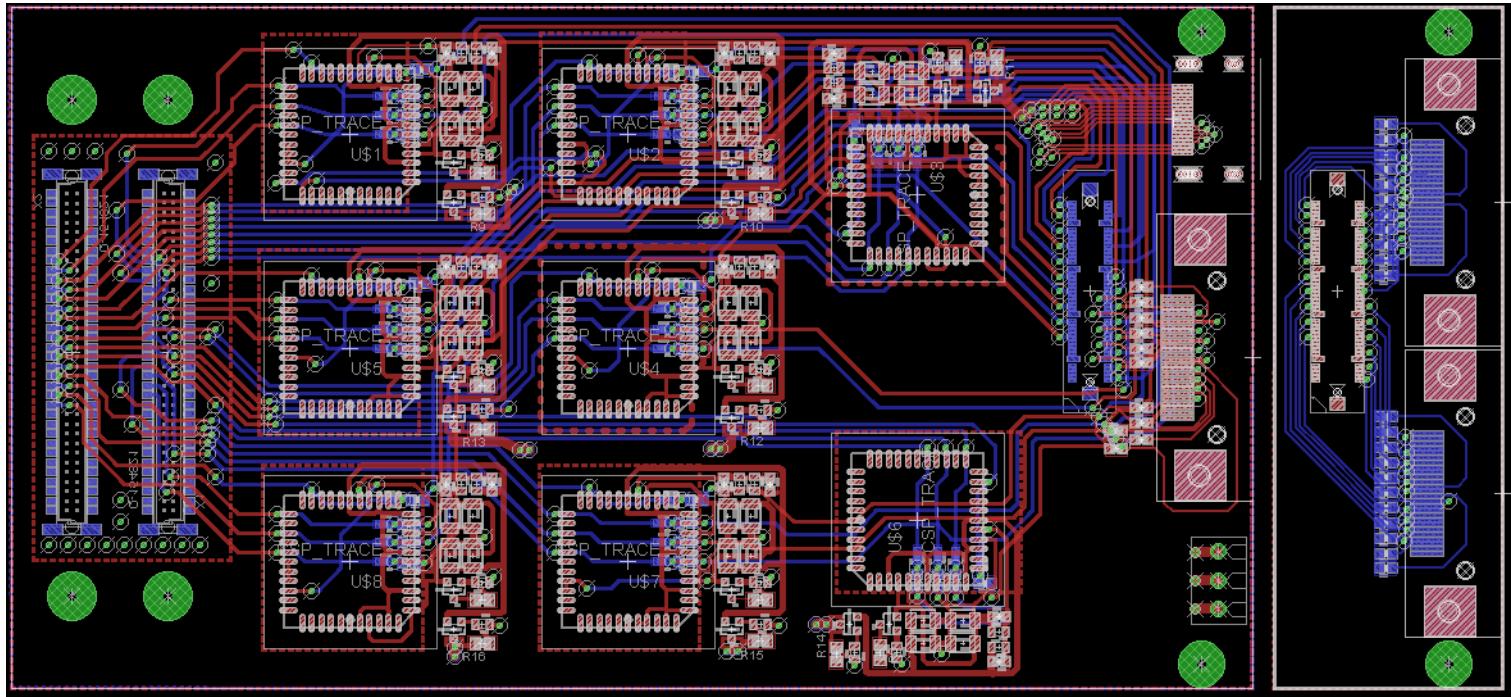


PCB design



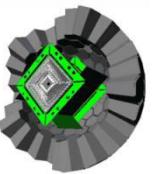
3

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- 6 layer design
- Independent power filtering for each IC
- $4 \times 8 = 32$ channels + 1
- Compatible with TRACE detector PCB
- Auxiliary board to expand connectivity

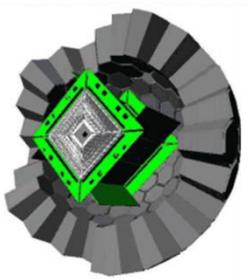
Work in progress - Ground and Power planes omitted for clarity



- Realized and tested a 4-channel prototype: more experimental results coming soon
- The TAC device proposed is able to get energy information from an event also in presence of saturation. The energy measurement is not affected by the presence of the baseline of previous events.

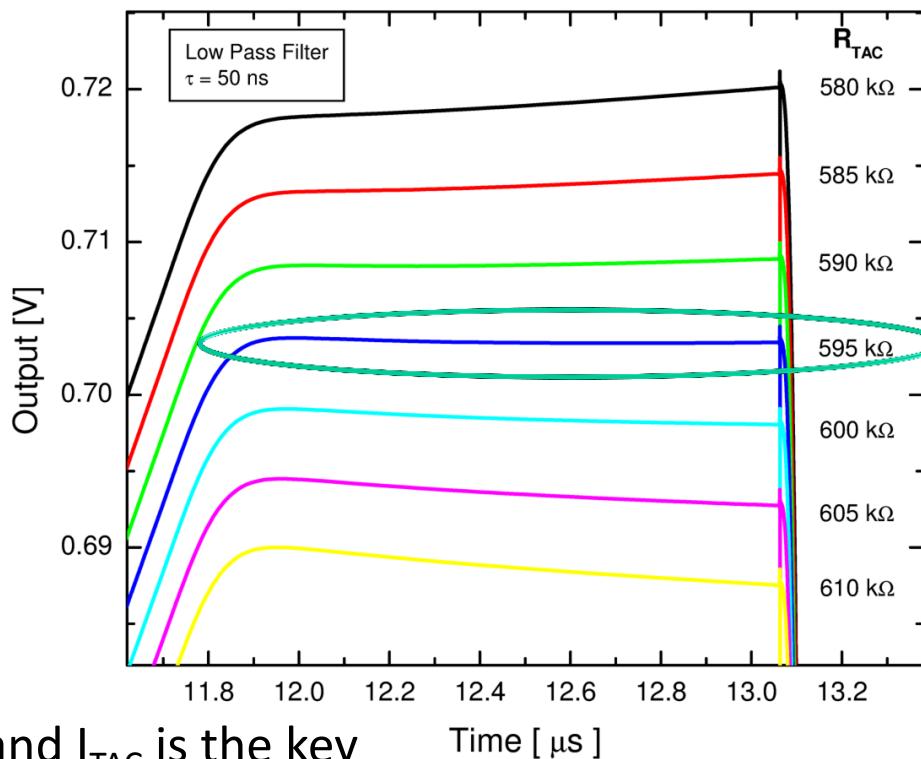
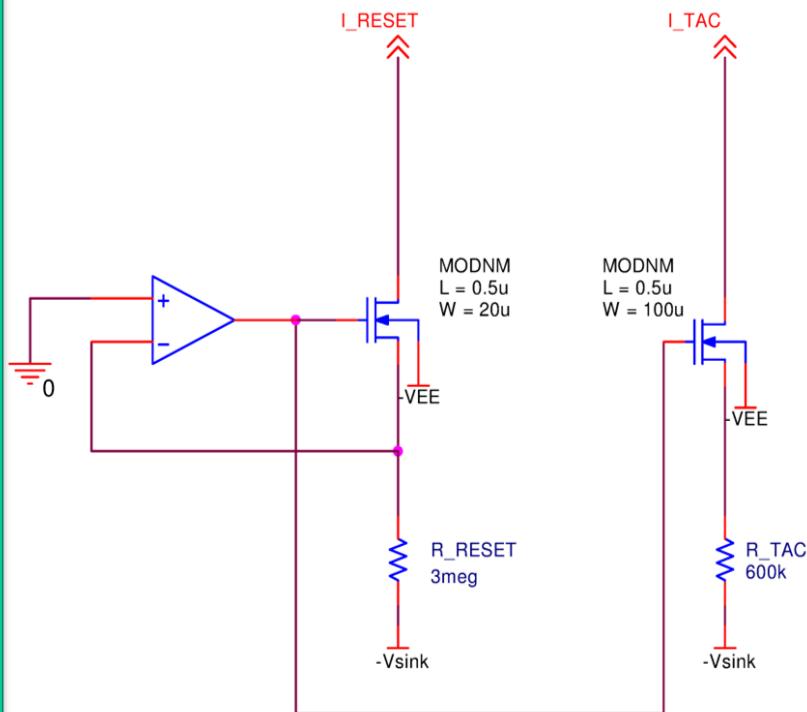
Future Perspectives

- Realize PCBs to test the existing ICs
- Noise analysis of the TAC device, layout in AMS C35 technology and post-layout simulations
- **Study the possibility to embed a shaper inside the preamplifier IC**

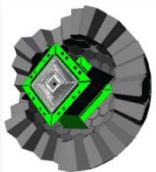


Thank you

Optimization of I_{TAC} current generator



Matching between reset current and I_{TAC} is the key to achieve the lowest derivative of the flat-top



Multichannel CSP ASIC

- 4-channel CSP ASIC specifically designed for hole signals
- 1 auxiliary test channel for electron signals
- I²C engine to adjust critical parameters

Technology:
AMS C35
Area: 5 mm²

