Istituto Nazionale di Fisica Nucleare
SEZIONE DI TORINO

Studies about the ASIC architecture: code update

Speaker: Sofia Blua (INFN – sezione Torino)

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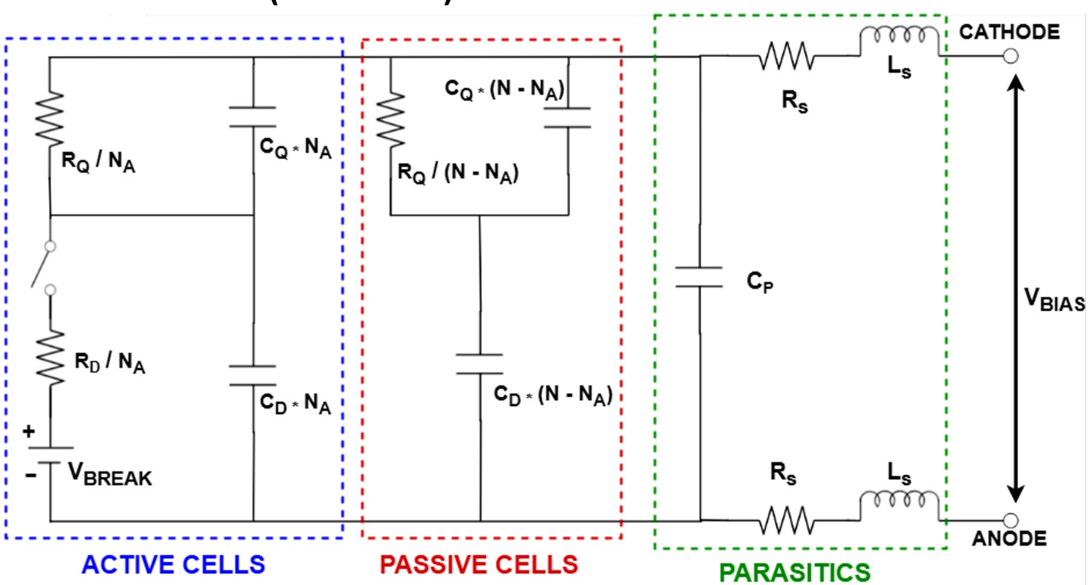
BEHAVIORAL MODEL

<u>BEHAVIORAL MODEL</u>: set of equations that capture the operation of a circuit from its terminals

<u>PURPOSE</u>: implementation of the readout front end for the analysis of different cases

INPUT SIGNAL FROM SiPM → **AMPLIFICATION** → **POLE –ZERO CANCELLATION (optional)** → **DISCRIMINATION** → **INTEGRATION**

<u>SiPM ELECTRICAL MODEL:</u> Circuit implemented in virtuoso schematic (Cadence)



Implementation through a **python code**

SiPM segmentation matters

BEHAVIORAL MODEL

PURPOSE: analysis of different cases

QUENCHING RESISTANCE

SiPM AREA		R_Q = 0.5 MΩ	R_Q = 1 MΩ	R_Q = 1.5 MΩ	R_Q = 2 MΩ
	1 x 1 mm^2				
	2 x 2 mm^2				
	3 x 3 mm^2				

TABLE OF RESULTS
FOR DIFFERENT CASES

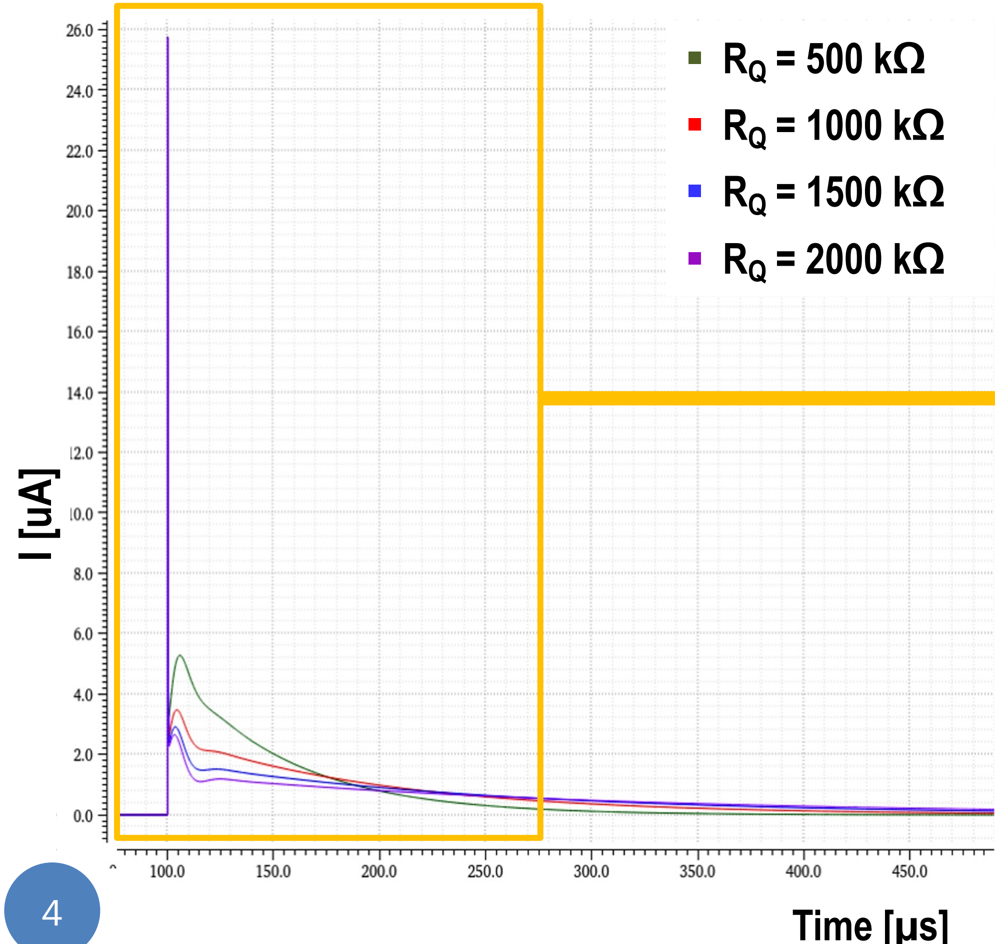
MAIN PREVIOUS QUESTIONS:

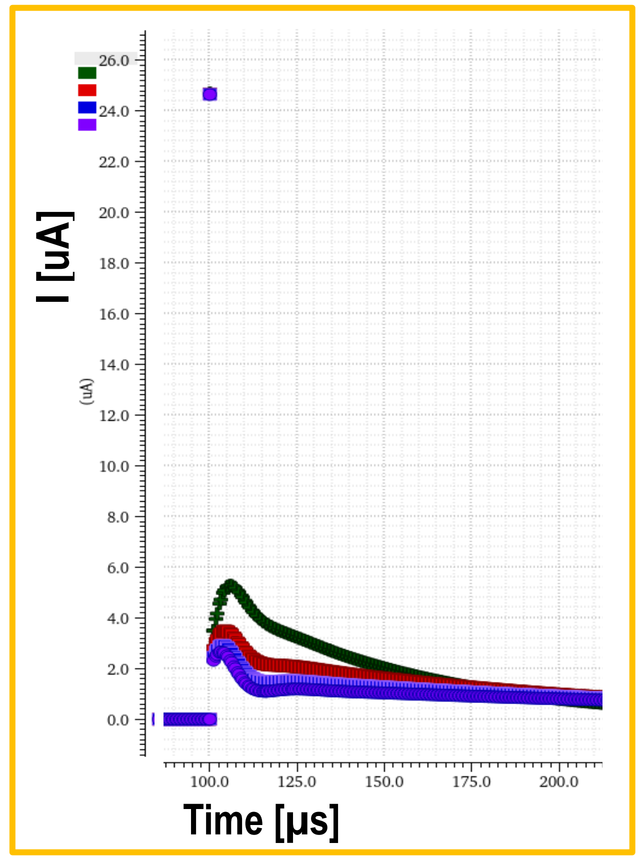
- HOW THE OUTPUT WAVEFORM HAS TO BE (ARCHITECTURE)
- HOW DISCRIMINATOR HAS TO WORK
- INTEGRATION YES OR NOT? WHICH SETTING?

BEHAVIORAL MODEL

INPUT SIGNAL FROM SiPM ELECTRICAL MODEL → **SAMPLING (bin size = 10 ps)**

Area 3x3 mm^2 (N microcells = 3584)





BEHAVIORAL MODEL

PYTHON CODE STRUCTURE: TBRChain_class.py → TBRChain_main.py

FUNCTIONS:

A. **FE_Amplification(I_1PE, time, params) :** Convolution of the sampled input signal with the amplifier transfer function T(s)

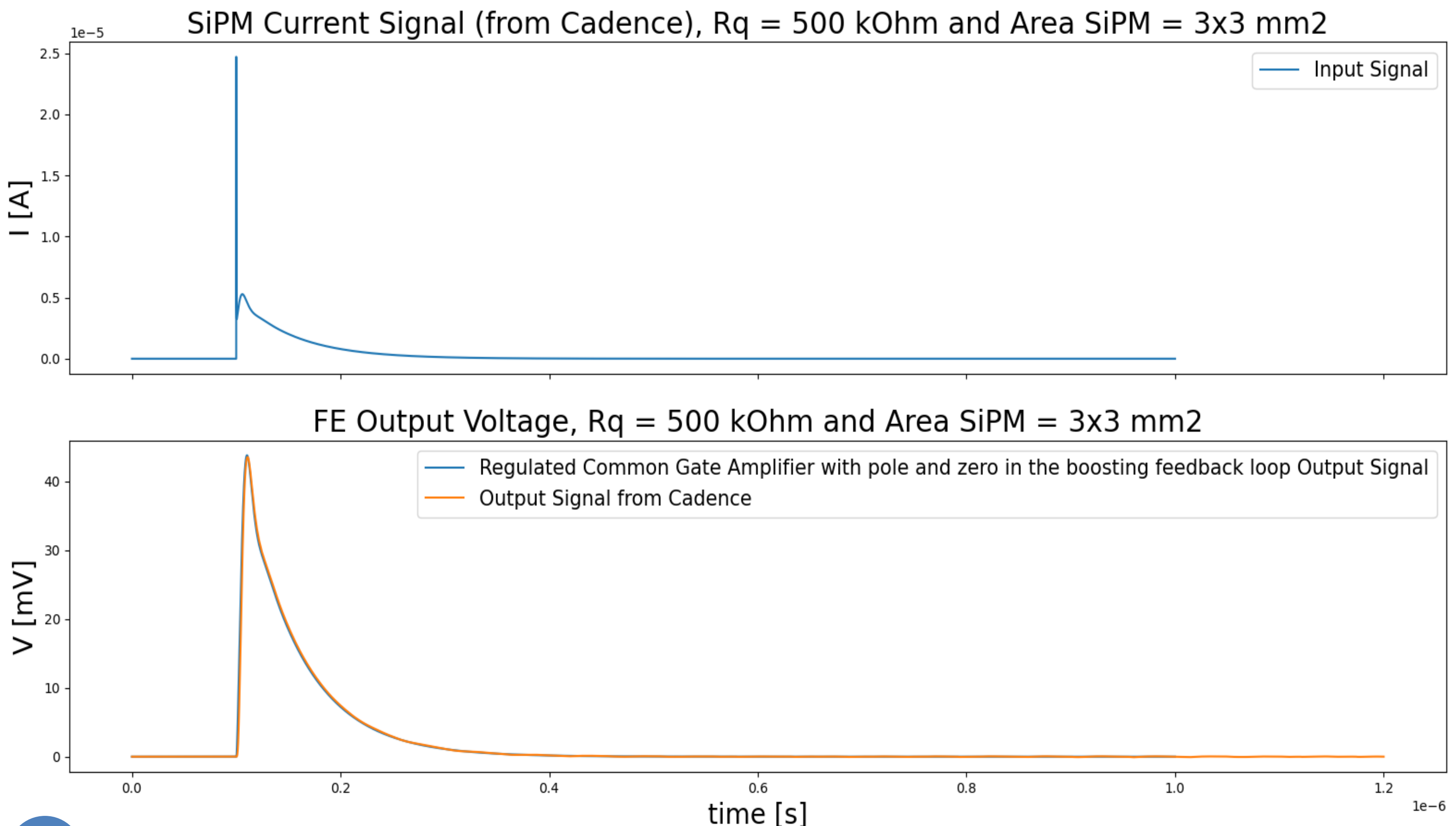
Depend on the FE Transfer Function, selected with the class inizialization

Regulated Common Gate Amplifier with pole and zero in the boosting fb loop

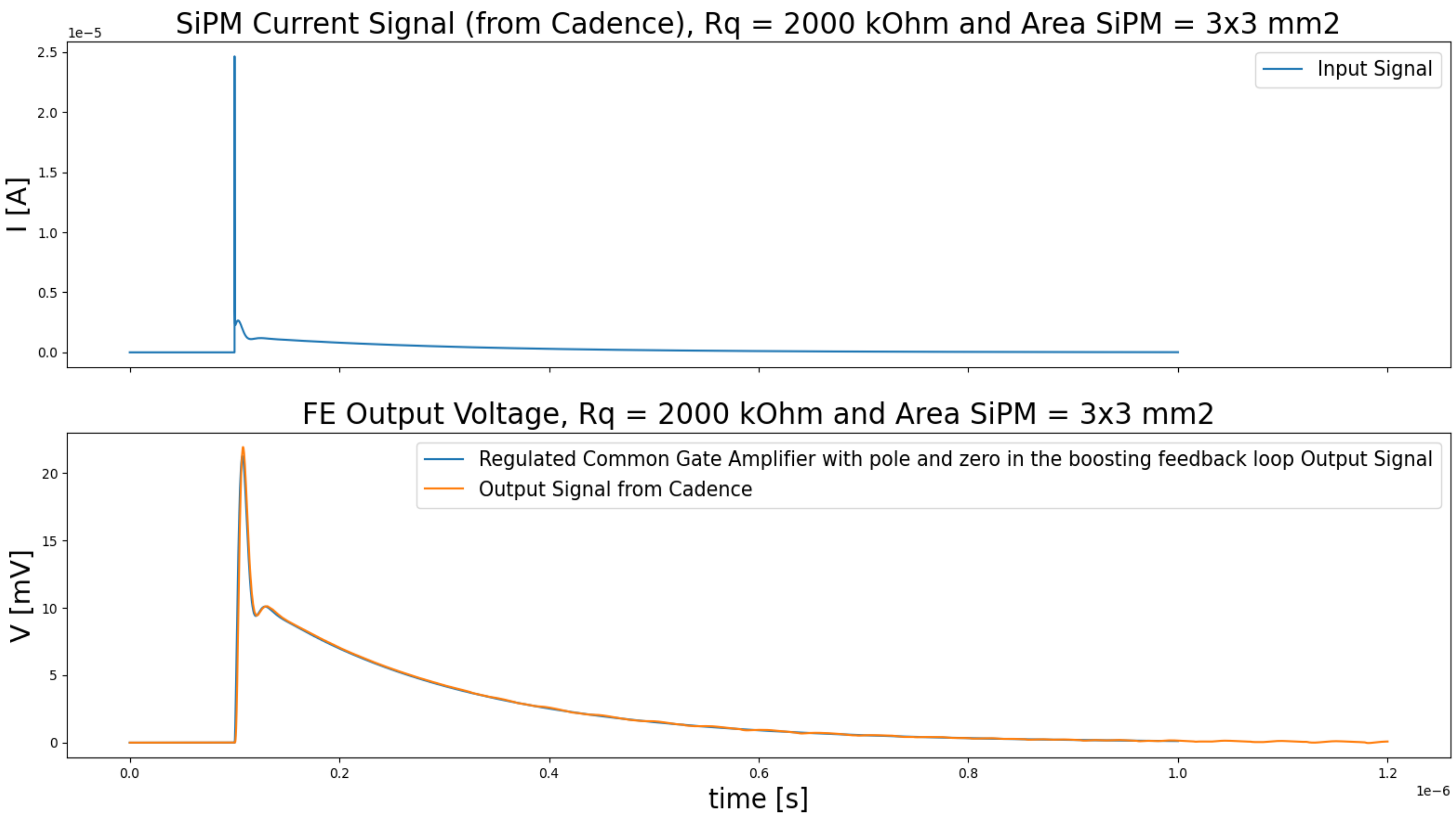
$$\frac{V_{out}}{I_{in}} = \frac{R_L gm1(A_0 - C_{gd} R_R s)}{(R_R C_T (C_{gs} + C_{gd}) s^2 + C_T s + gm1 A_0)(1 + s C_L R_L)} \cdot G$$

Based on ALCOR FE

BEHAVIORAL MODEL



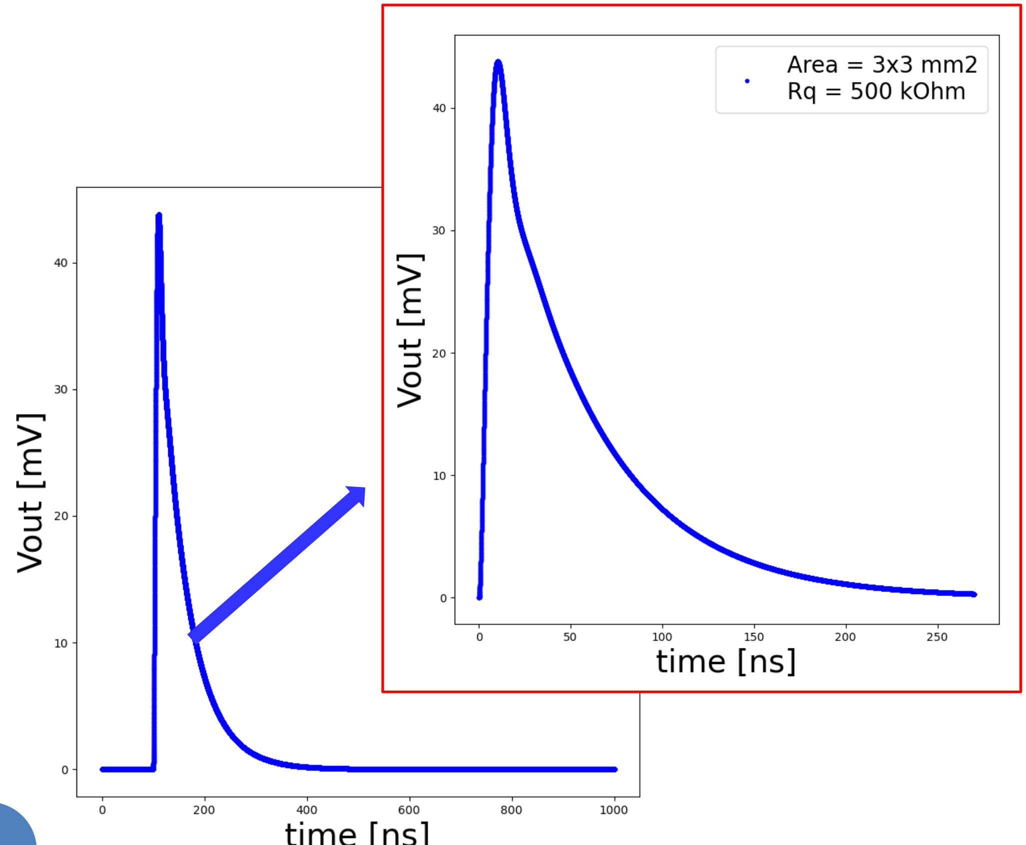
BEHAVIORAL MODEL



BEHAVIORAL MODEL

<u>FUNCTIONS:</u>

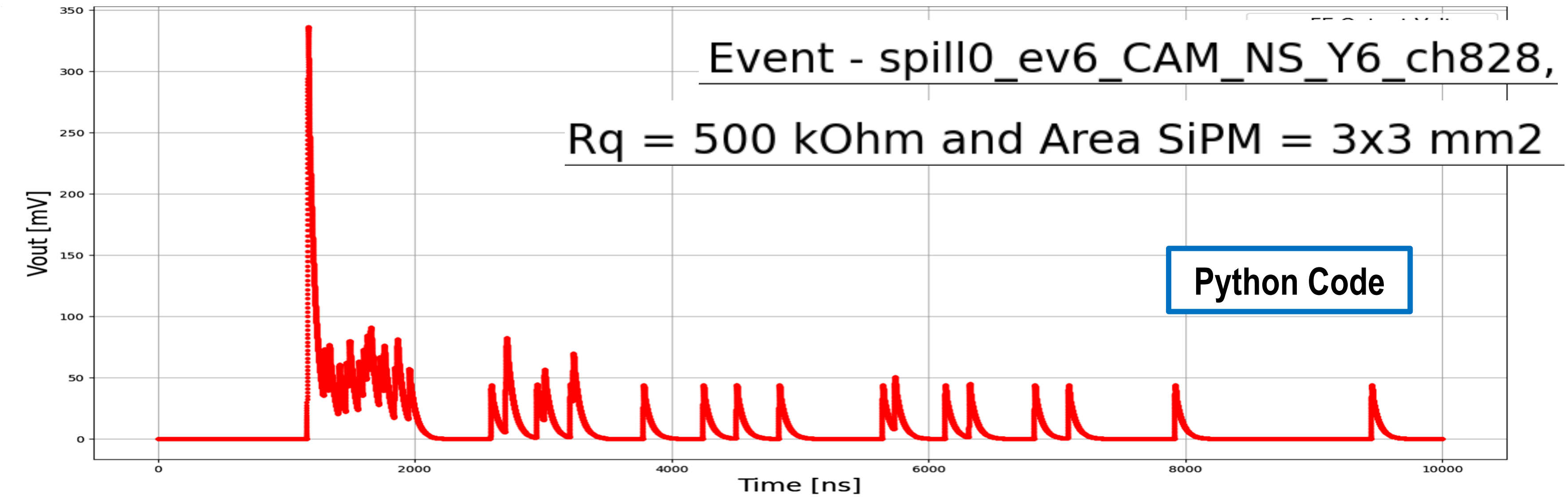
B. EventConstructor(Vout, time): Construction of a spill with a binning of **100 ps**

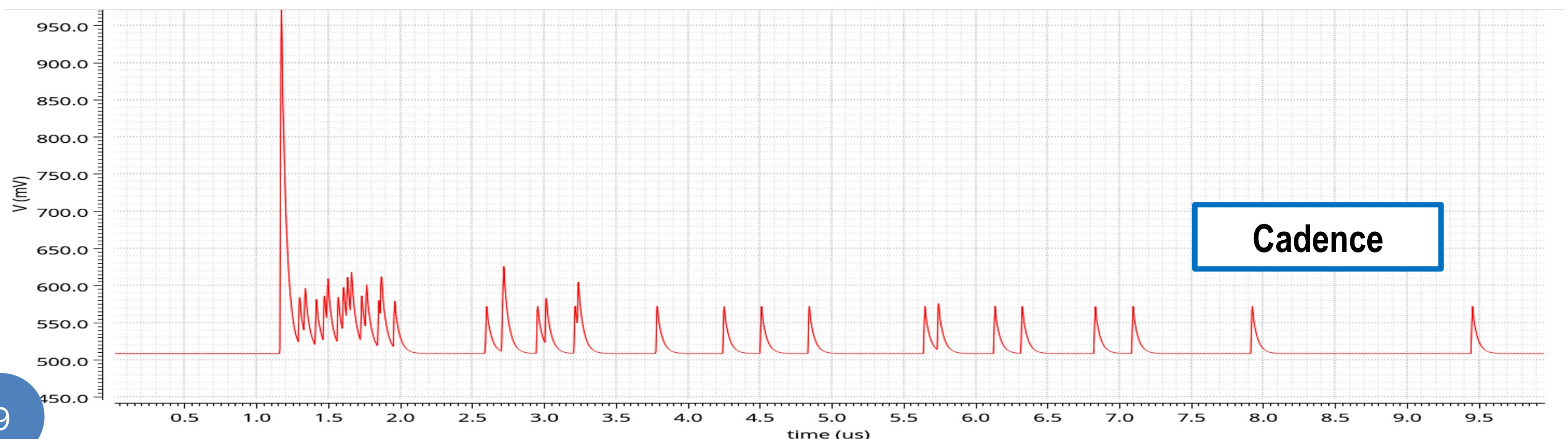


Timestamps of photon time of arrival from Montecarlo simulations (BO, GE)

BEHAVIORAL MODEL

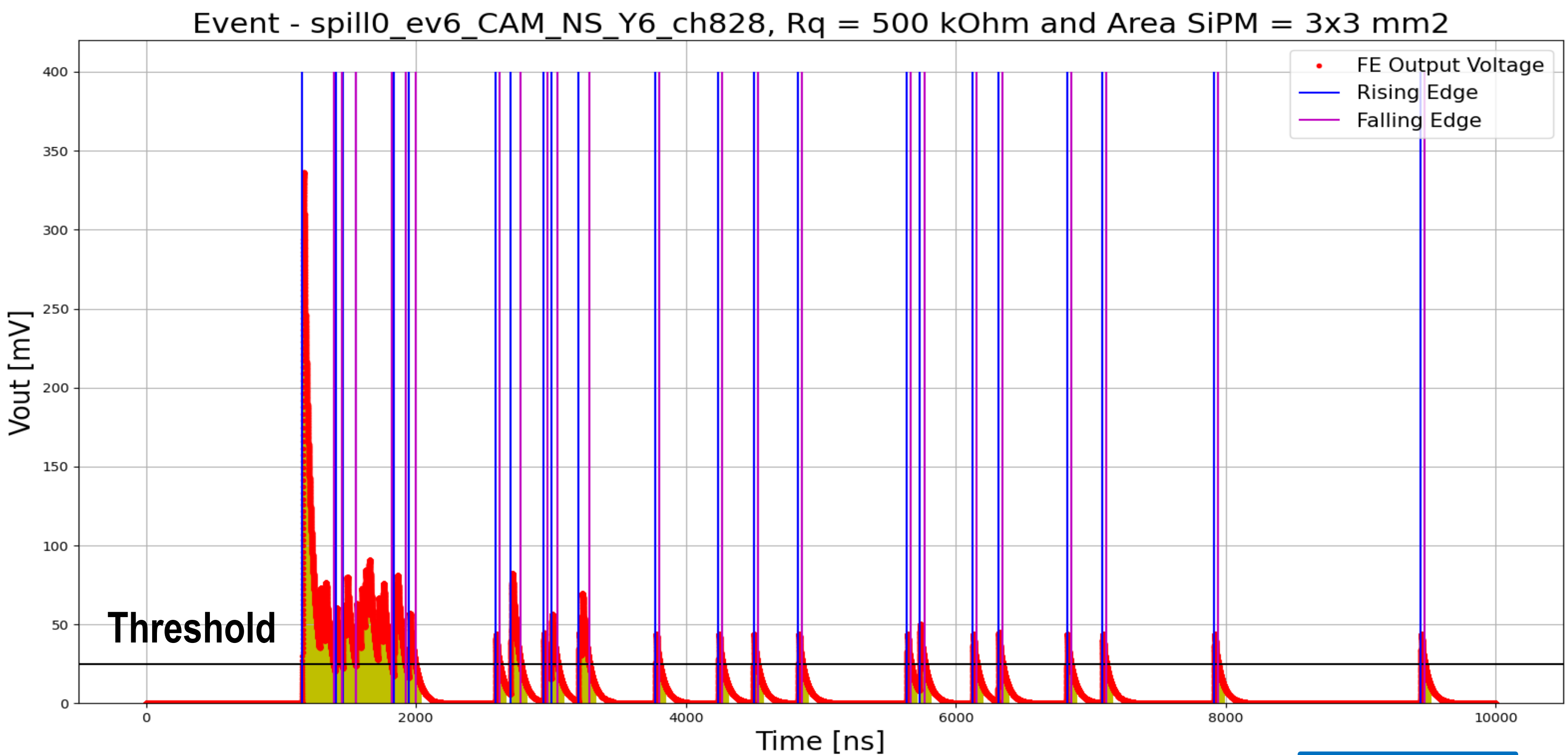
REPRODUCTION OF A SPILL USING THE PROCESSED SIGNAL





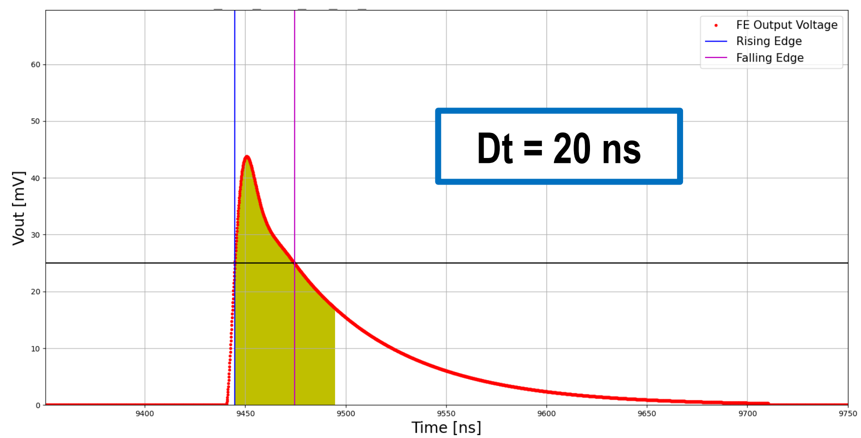
BEHAVIORAL MODEL

DISCRIMINATION AND IDEAL INTEGRATION

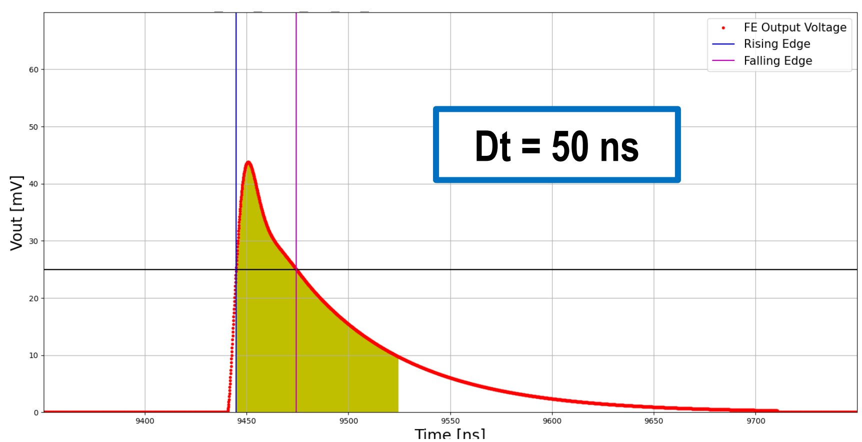


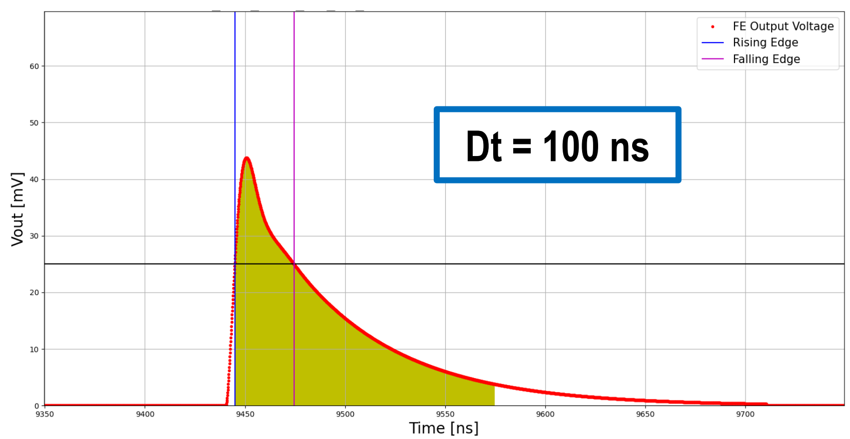
Dt = 50 ns

BEHAVIORAL MODEL



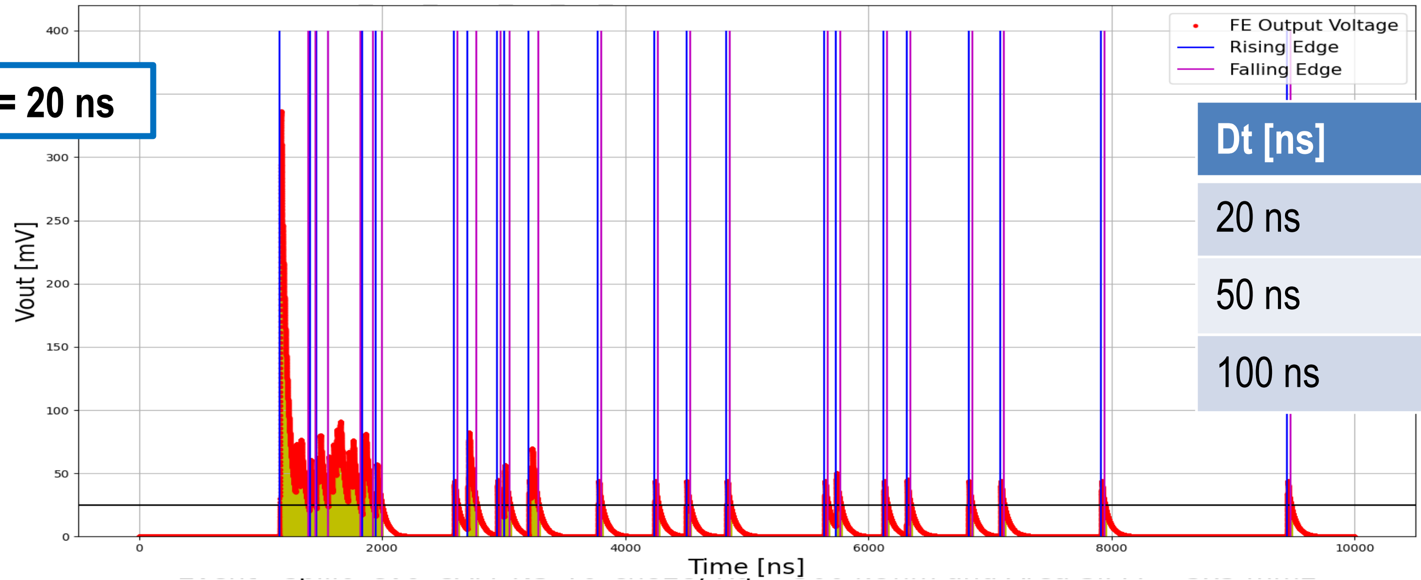
IDEAL INTEGRATION with Dead Time(Dt)





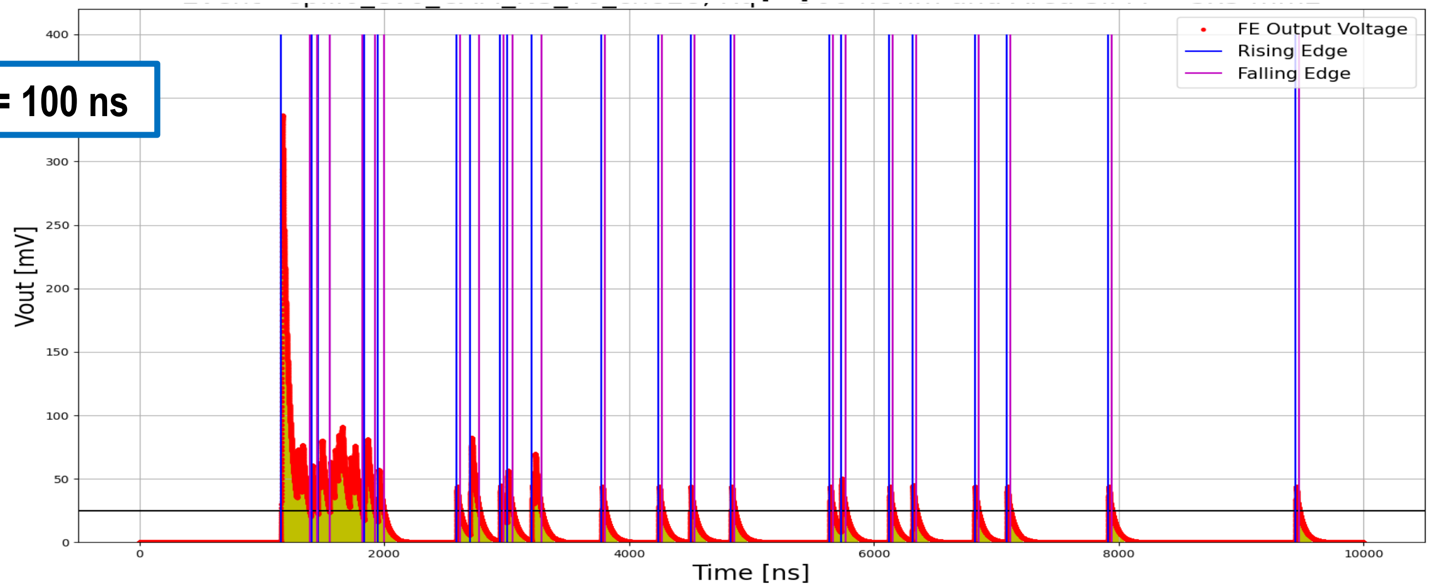
BEHAVIORAL MODEL

Dt = 20 ns



Dt [ns]	#Capacitors
20 ns	20
50 ns	17
100 ns	15

Dt = 100 ns



BEHAVIORAL MODEL

[RE; FE] ns	Area [mV*ns]
[1159.4 ; 1391.7], [1403.8;1452.2], [1459.4; 1552.0], [1555.7; 1818.2], [1838.8; 1924.3], [1949.0; 1996.2]	51243.7
[2590.1; 2619.7]	1799.6
[2702.1; 2776.4]	4466.7
[2945.3; 2975.7], [3002.8; 3049.5]	4190.6
[3205.7; 3285.2]	4209.0
[3776.4; 3806.0]	1799.6
[4241.7; 4271.3]	1799.6
[4501.2; 4530.9]	1804.0
[4833.6; 4863.2]	1799.6
[5638.1; 5667.7]	1799.6
[5731.7; 5770.6]	2222.7
[6125.1; 6154.7]	1799.6
[6314.5; 6345.8]	1869.8
[6822.4; 6852.0]	1799.6
[7085.0; 7114.7]	1803.0
[7914.1; 7943.7]	1799.6
[9444.9; 9474.5]	1799.6

NEXT STEPS

- A more realistic implementation of the integration step: the choice of the integration intervals has to be evaluated according to the photon ToA in the time scale (the SiPM matrix segmentation matters)
- Evaluation of the number of PE from the ToT and from the integrated area for the extremes Rq values to validate the integration solution
- Add the noise, based on ALCOR simulations, to the event waveform
- Investigating 1x1 mm^2 SiPM

Thank you for your attention!

BACKUP SLIDES

BEHAVIORAL MODEL

PYTHON CODE STRUCTURE

TBRChain_class.py → TBRChain_main.py

↓

FUNCTIONS:

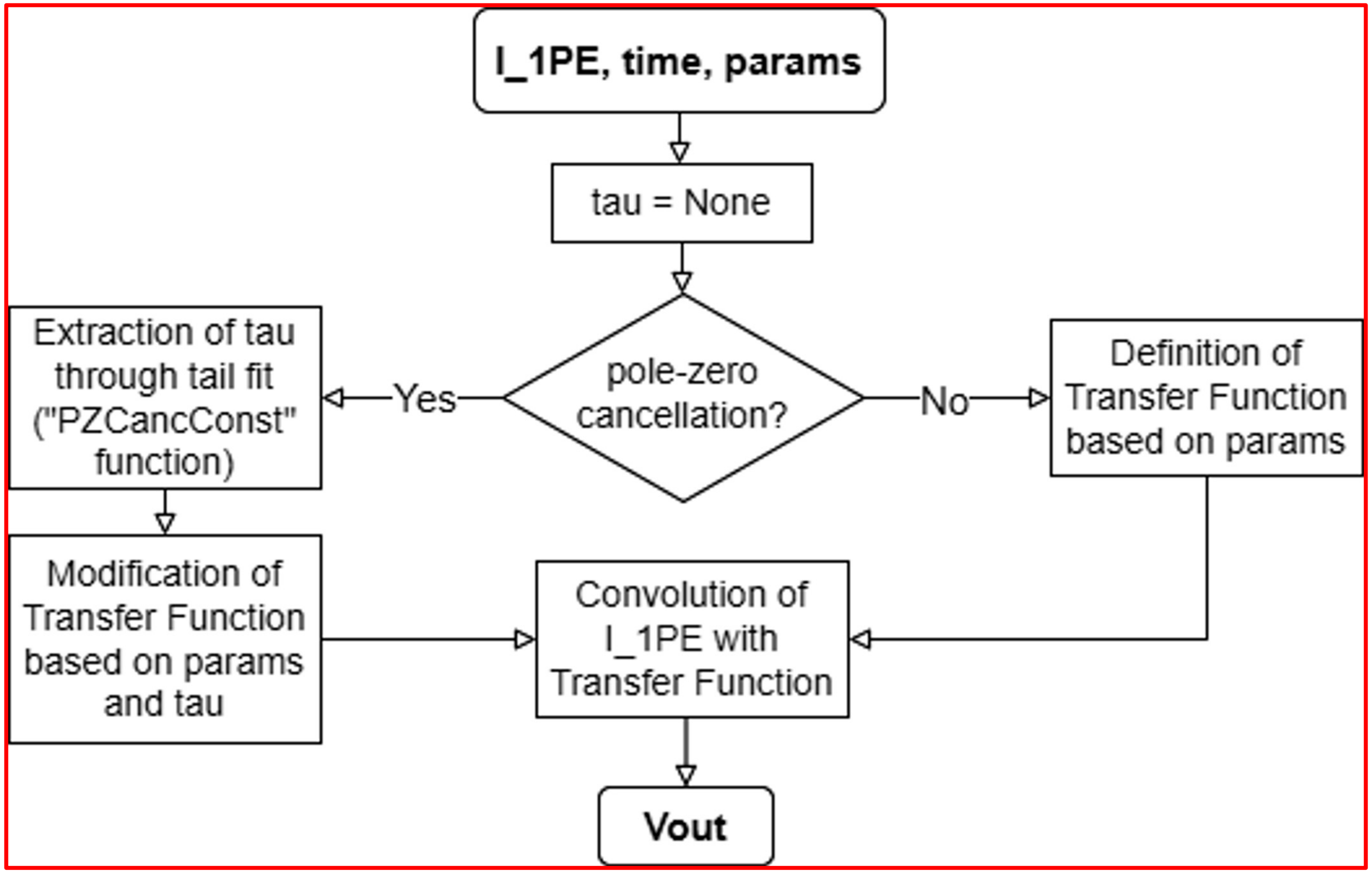
A. Convolution of the sampled input signal with the amplifier transfer function (completed)
B. Fit of the tail to provide the time constant for pole 0 cancellation (fit step completed, application of pole 0 cancellation on signal needs tuning)
C. Construction of a spill from timestamp files (completed)
D. Discrimination (with threshold and hysteresis)

BEHAVIORAL MODEL

PYTHON CODE STRUCTURE

FUNCTIONS:

A. **FE_Amplification(I_1PE, time, params)** ← **Based on function: FE_Convolution (I_1PE, time, params)**



BEHAVIORAL MODEL

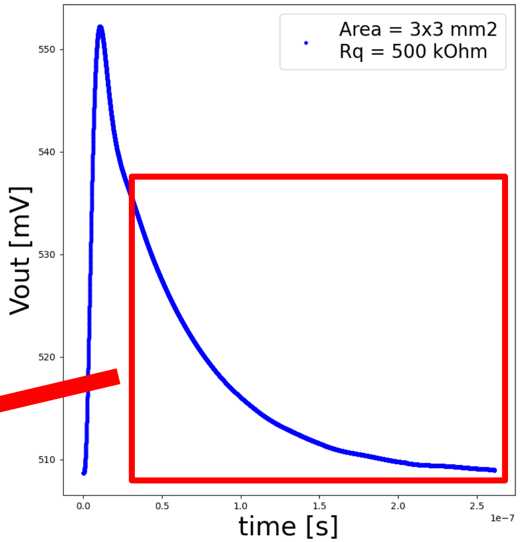
PYTHON CODE STRUCTURE

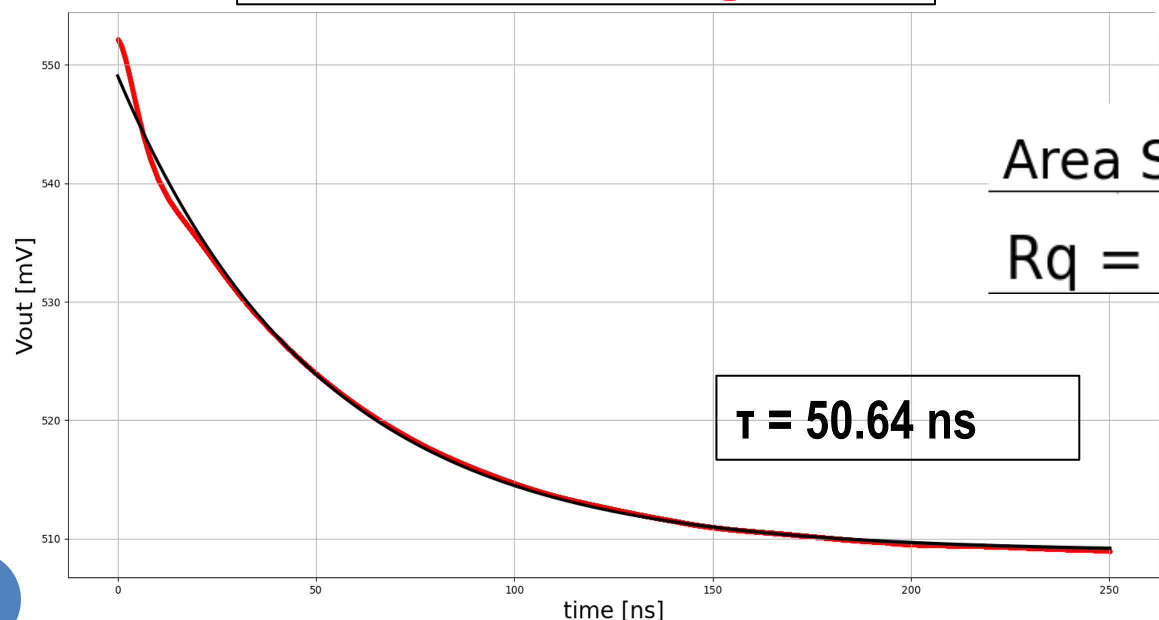
FUNCTIONS:

B. POLE-ZERO CANCELLATION: a first valutation of the pole

TailTimeConstFinder(Vout, time)

$$V_{out} = A \cdot exp\left(-\frac{t}{\tau}\right) + B$$





Area SiPM = 3x3 mm2

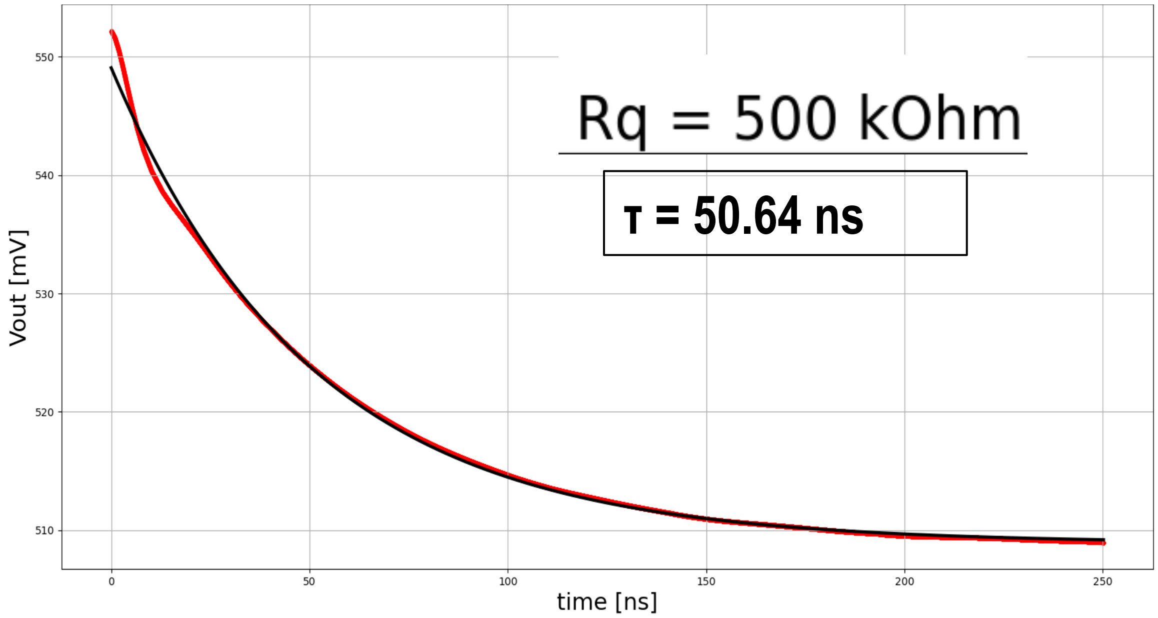
Rq = 500 kOhm

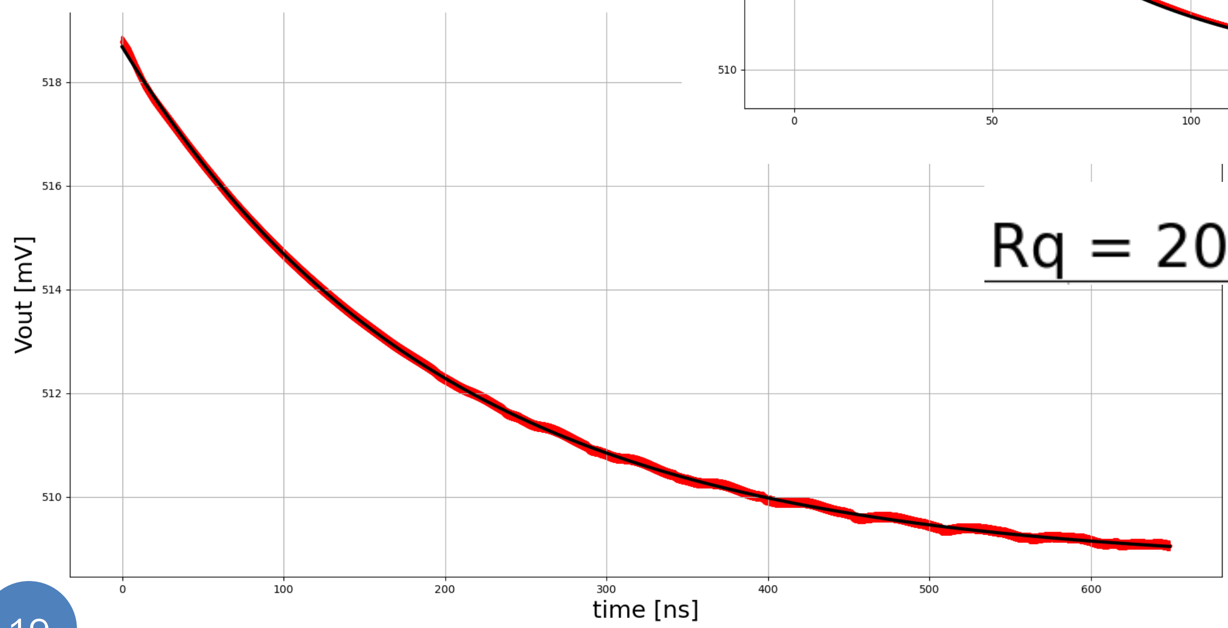
BEHAVIORAL MODEL

PYTHON CODE STRUCTURE

TailTimeConstFinder(Vout, time)

Area SiPM = 3x3 mm2





BEHAVIORAL MODEL

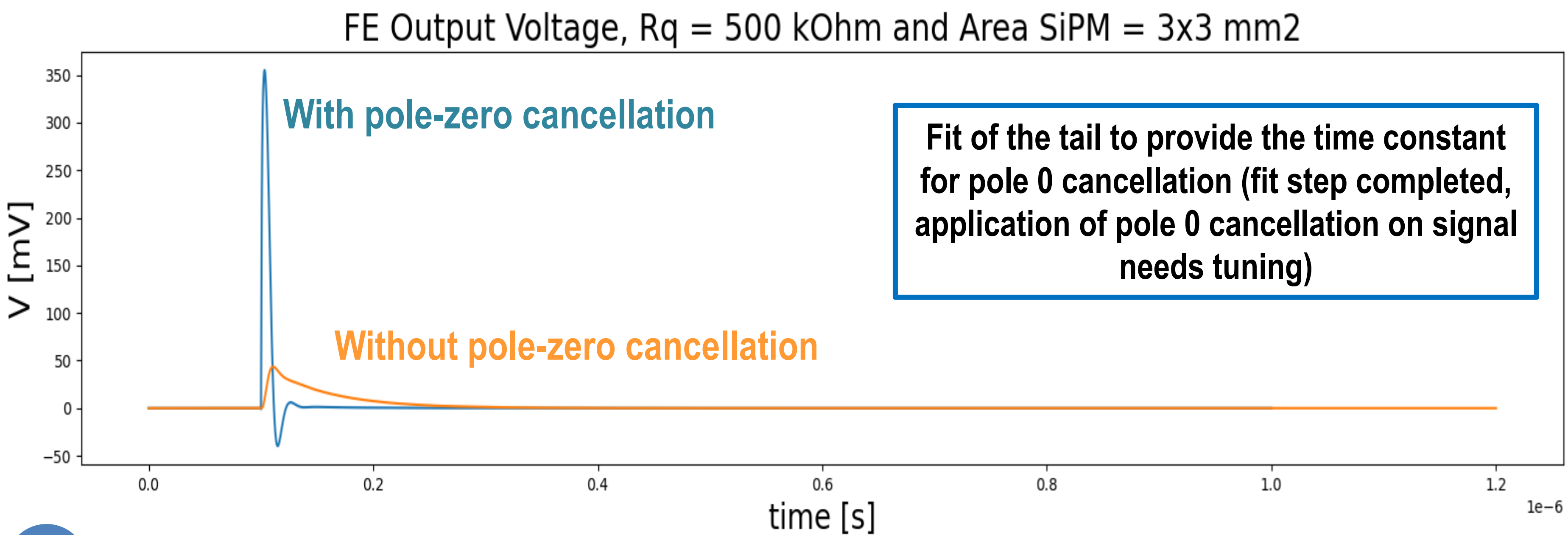
PYTHON CODE STRUCTURE

FUNCTIONS:

B. POLE-ZERO CANCELLATION: modification of the FE Transfer Function

ZeroMult(num, tau) → $$T'(s) = T(s) \cdot (1 + s\tau)$$

With: $$T(s) = \frac{num}{den}$$



BEHAVIORAL MODEL

Bode plot