CMOS pixel sensors optimized for large ionizing dynamic

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ABSTRACT

Monolithic active pixel sensors (MAPS) are now well established as a technology for **tracking** charged particles[1], especially when **low material budget** is desirable. For such applications, sensors focus on spatial resolution and pixels with **digital output** or modest charge measurement ability are well suited. Within the European Union STRONG project focusing on experiments using hadrons, the TIIMM (**T**racking and **I**ons **I**dentifications with **M**inimal **M**aterial budget) joint research activity intends to expand **granular MAPS** capacity to energy-loss (ΔE) measurement for **ion species identification**[2].

TIIMM PROJECT

- ◆ The project targets to develop sensors for a wide signal range, covering minimum ionization particles up to heavily ionization ions, such as carbon at few 100s MeV/u.
- ◆ Technology: Tower Jazz 180nm
- ◆ Small prototypes (32 × 16 pixels)
  - TIIMM-0 has been fabricated in 2020.
  - TIIMM-1 will be submitted in Fall 2021.

PIXEL STRUCTURE

The pixel architecture is based on a charge sensitive amplifier featuring a Krummenacher feedback[3], a comparator and time-over-threshold (ToT) architecture for the signal digitization[4].

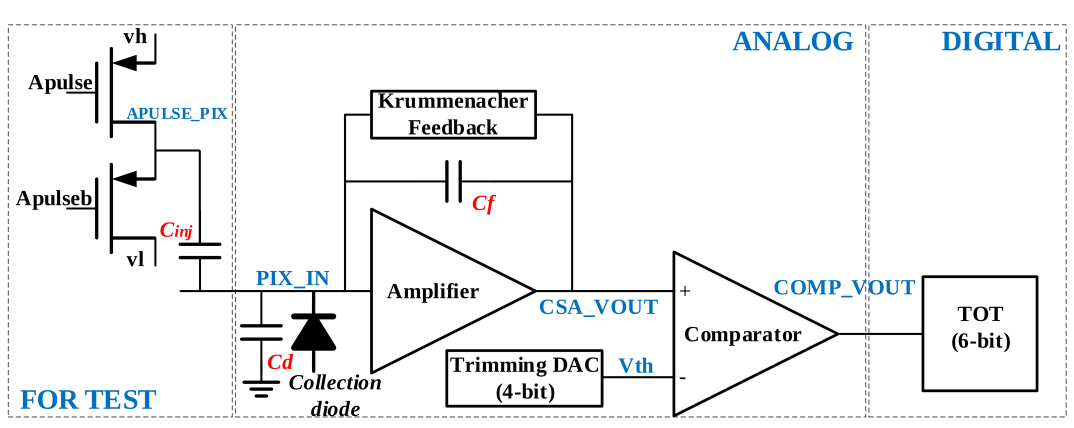

Fig.2.1 TIIMM-0 pixel structure

TIIMM-0:

- ➢ Pixel pitch: 40 µm × 40 µm
- ➢ C_f: 1fF
- ➢ ToT (6 bits)
- ➢ Trimming DAC (4 bits)
  - in-pixel offset correction.
- ➢ ENC: 42 e^- (extracted sim)

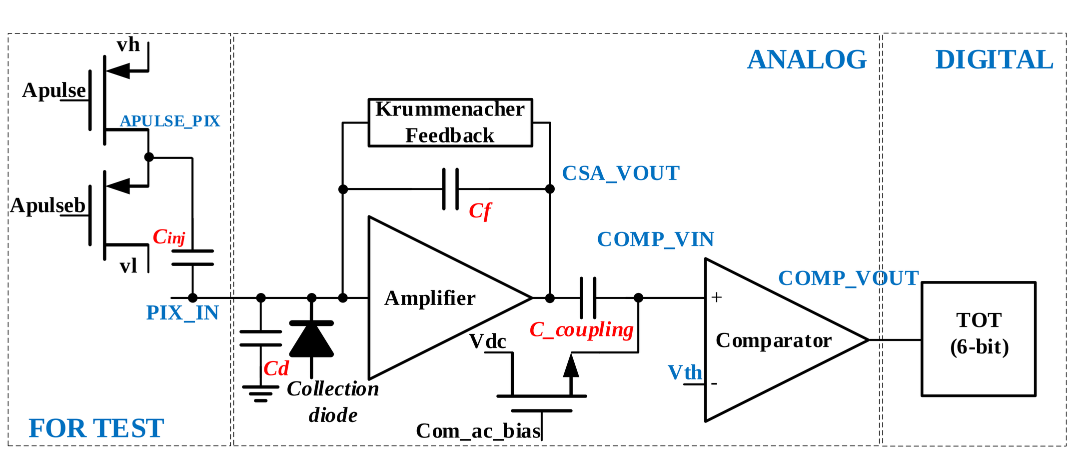

Fig.2.2 TIIMM-1 pixel structure

TIIMM-1:

- ➢ Pixel pitch: 40 µm × 41.2 µm
- ➢ C_f: 5fF
- ➢ ToT (6 bits)
- ➢ AC coupling
  - compensation of the offset of the baseline of the CSA.
- ➢ ENC: 60 e^- (extracted sim)

- The simulation shows that the spread of the baseline after the AC- coupling is decreased from 9.27 mV to 1.11 µV. (TIIMM-1, extracted sim)

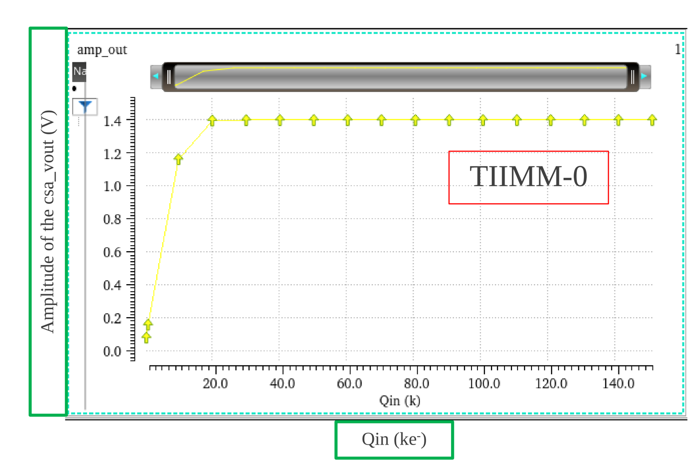

Fig.2.3 Amplitude of the CSA vs Qin (500 e^-~150 ke^-)

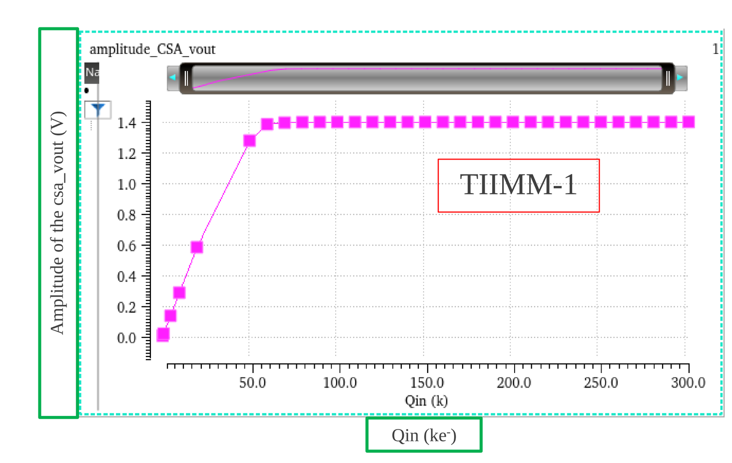

Fig.2.4 Amplitude of the CSA vs Qin (500 e^- ~300 ke^-)

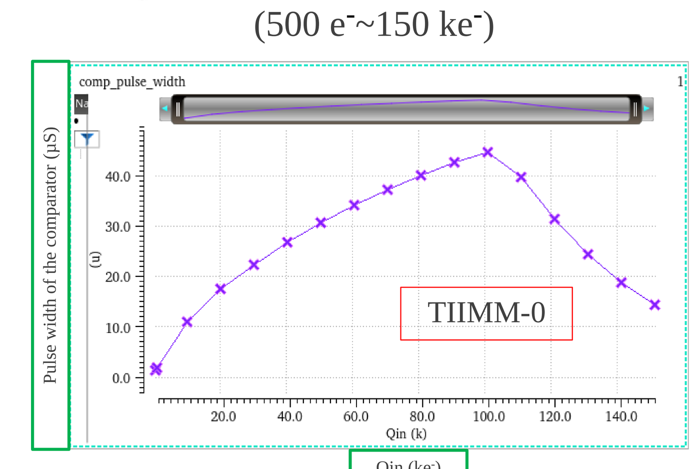

Fig.2.5 Pulse width of the comparator vs Qin (500 e^- ~150 ke^-)

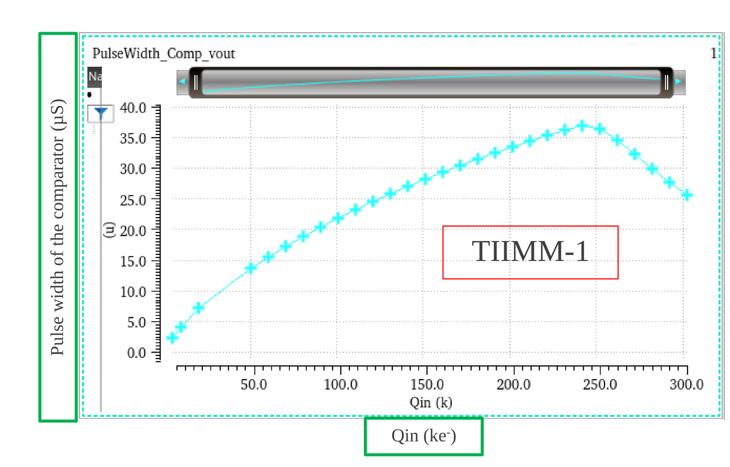

Fig.2.6 Pulse width of the comparator vs Qin (500 e^-~300 ke^-)

- The dynamic for the pulse duration is much larger than the pulse amplitude. (ToT for energy loss measurement, extracted sim)

ANALOG PIXEL DESIGN

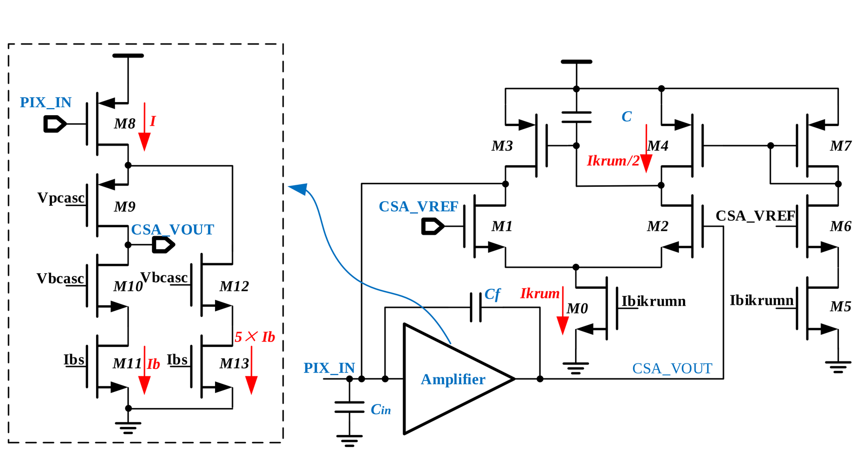

Fig.3 Schematic of CSA with the Krummenacher Feedback circuit

Pulse width of the CSA output from Monte Carlo Simulation
Pulse width spread vs Qin(500e^-~200ke^-)

TIIMM-0

Qin/ke^-	0.5	1	10	200
Mean/ns	395.8	490.1	2208	4083
Sigma/ns	85.03	115.4	749.1	840.8
Sigma/Mean	21.48%	23.55%	33.93%	20.59%

TIIMM-1

Qin/ke^-	0.5	1	10	200
Mean/ns	282.8	596.6	3818	37100
Sigma/ns	18.72	30.73	358.8	3559
Sigma/Mean	6.62%	5.15%	9.40%	9.59%

- For the pulse width of signal, the mean value and the sigma value increases with the Qin from 1ke^-, and the value of sigma/mean seems to saturate 10% in TIIMM-1 after optimization.

PRELIMINARY TEST RESULTS (TIIMM-0)

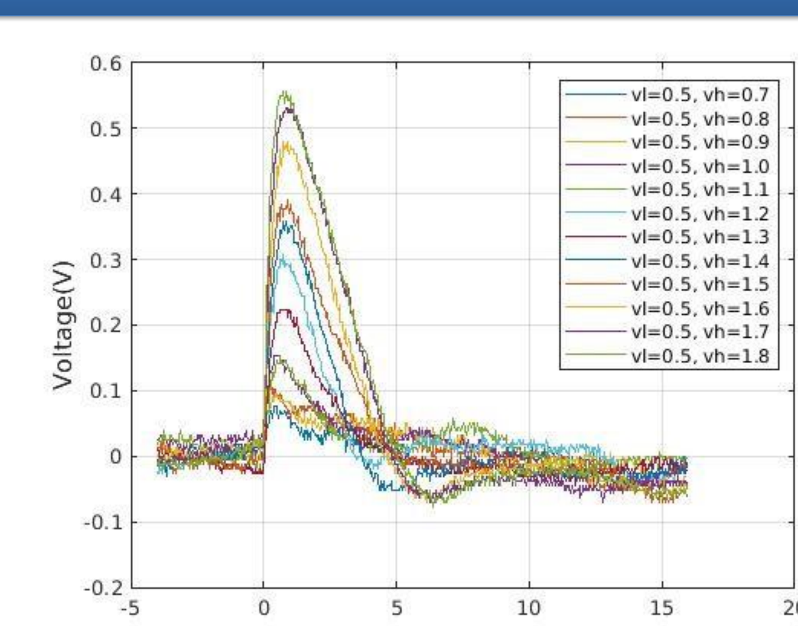

Fig.4.1 Analogue output of the CSA with different input charge.

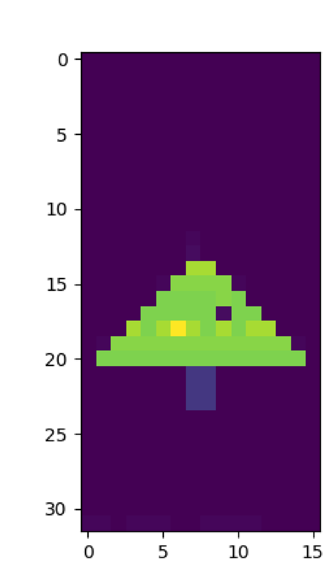

Fig.4.2 Image with digital readout test

- The pulse width increases with the input charge.
- Image created with test signals injected into the pixels.

CONCLUSION & PERSPECTIVES

- ◆ The Functionality of the ToT concept to measure the of energy loss is validated in the fabricated prototype TIIMM-0.
- ◆ Optimized design for larger dynamic (10^3) and smaller relative fluctuation of the pulse width (10%) is applied in the new prototype TIIMM-1
- ◆ The TIIMM-1 with depleted sensitive layer will be fabricated in the Q4 of 2021. And the test convolution of charge sharing & pixel dynamic will be carried out in 2022.

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