HELLENIC REPUBLIC
National and Kapodistrian University of Athens
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DMAPS for measuring energy depositions and tracks of Galactic Cosmic Ray and Solar Energetic Particles

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DMAPS for measuring energetic particles in space

- DMAPS a “spin-in” from High Energy Physics
- Energetic particles in space environment:

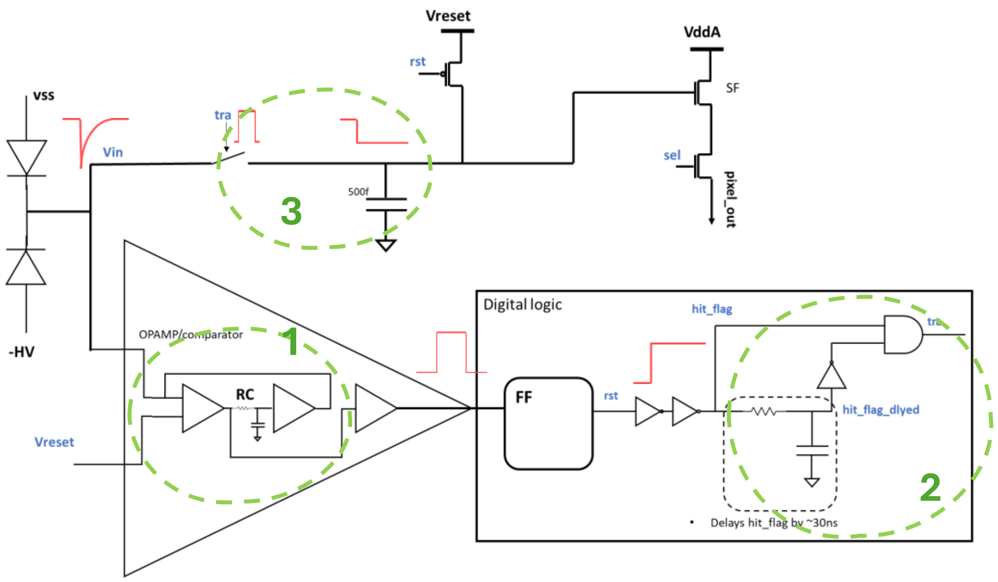
➢ Have a range of energy depositions on Si from keV to tens of MeV (not only minimum ionizing particles)

➢ For ions energy deposition is not only along the track of the particle: It has rich spatial structure

➢ The hit rate can be from 2 to 4 $cm^{-2}\cdot s^{-1}$ (GCR) to $55\cdot 10^{7}$ $cm^{-2}\cdot s^{-1}$

Power consumption minimization is obligatory.

Low gain pixel design covers 40 fC – 9 pC

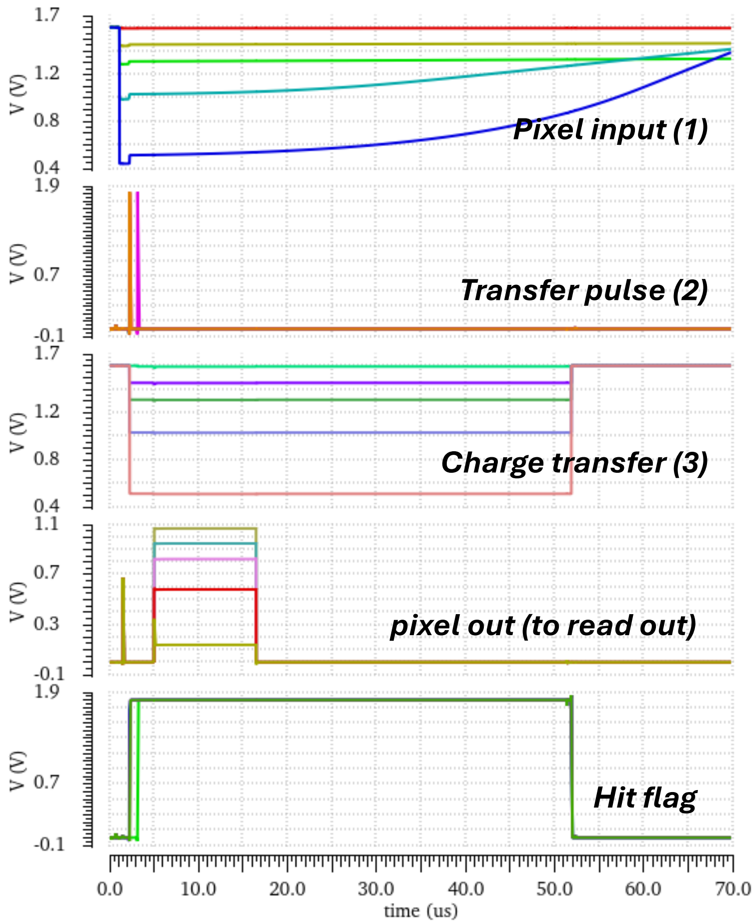


When charge Q_{in} hits the pixel:

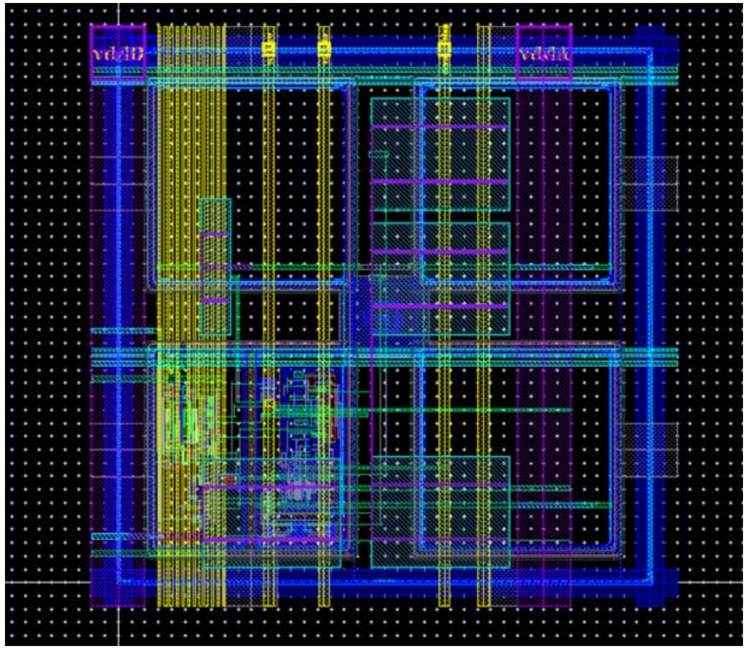
- Vin drops abruptly and is slowly returned to Vreset by OPAMP loop[1]
- Comparator flips: rst transistor is turned off and hit_flag signal is raised
- tra signal is generated locally as shown[2]
- Charge is transferred to a 500f capacitor[3]

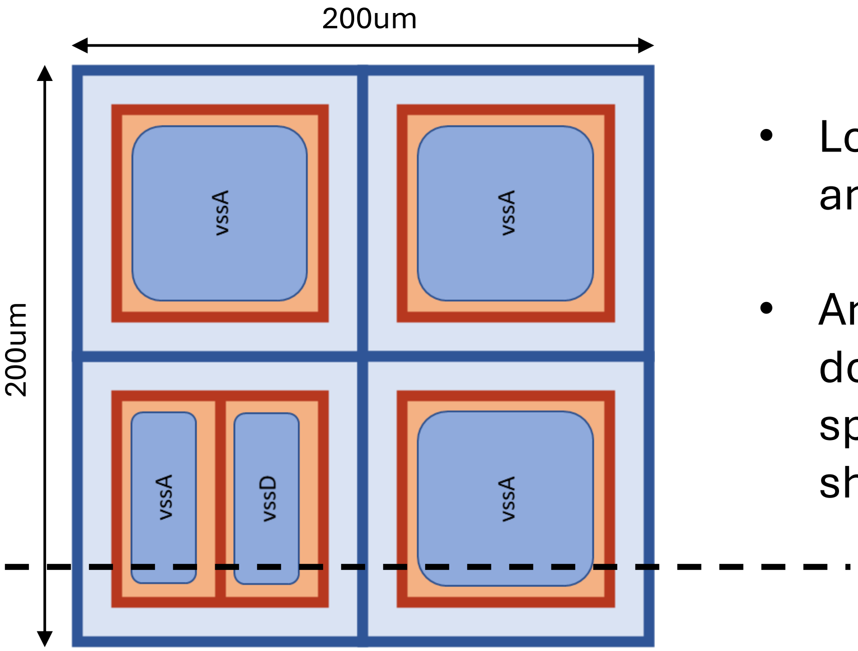
idle power consumption ≈ 35nA

Low gain pixel transient response to Q_{in} = 50fC, 1pC ,2pC ,4pC ,8pC

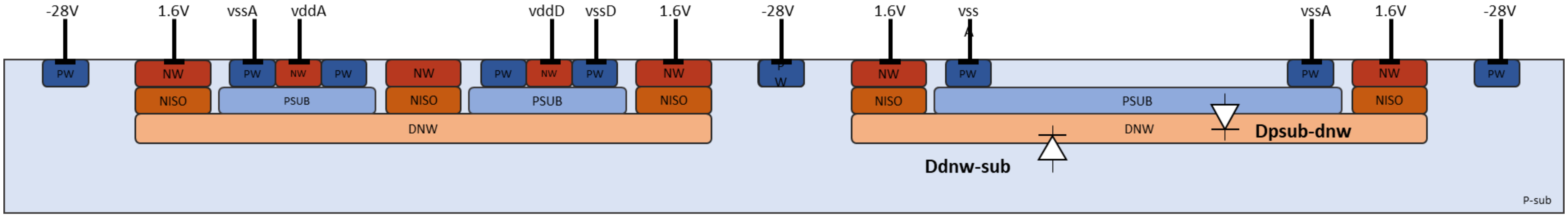


Low gain pixel layout





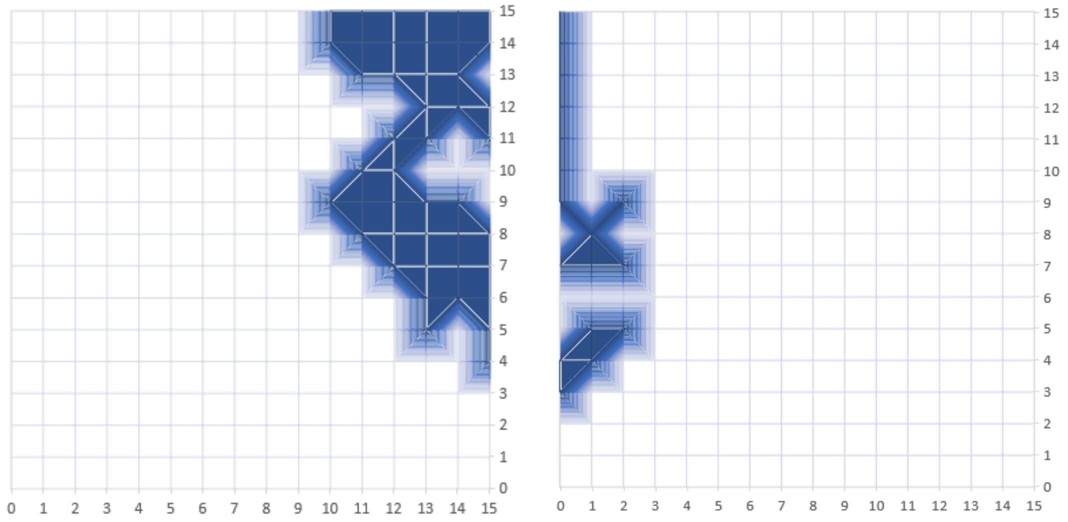
- Low gain pixel top view and cross-section
- Analog and digital supply domains are isolated by splitting the DNW as shown below



vssA = 0V, vddA = 1.8V
vssD = 0V, vddD = 1.8V

Low gain sensor response to light:

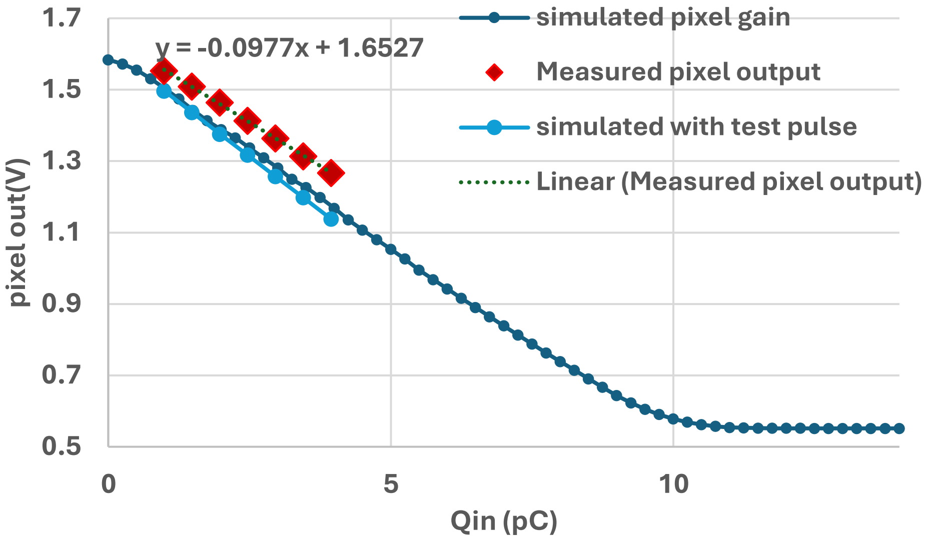
- Illuminating the sensor with a diffused laser locally from the top
- Filtering false hits from the pixel array



Laser positioned at the ***top-right*** *corner of the array*

Laser positioned at the ***top-left*** *corner of the array*

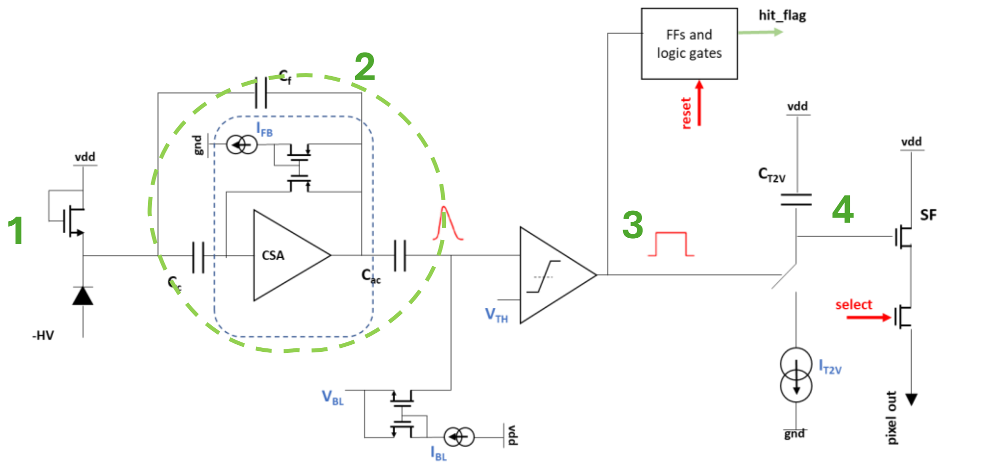
Low pixel gain



Simulated pixel gain	109 mV/pC
Measured pixel gain	98 mV/pC

- $Q_{in} = \Delta V_{in} \cdot C_{test} \cdot \frac{C_{det}}{C_{det}+C_{test}}$
- Good agreement with simulation results
- Deviation possibly due to C_{in} value being different from what simulation predicts

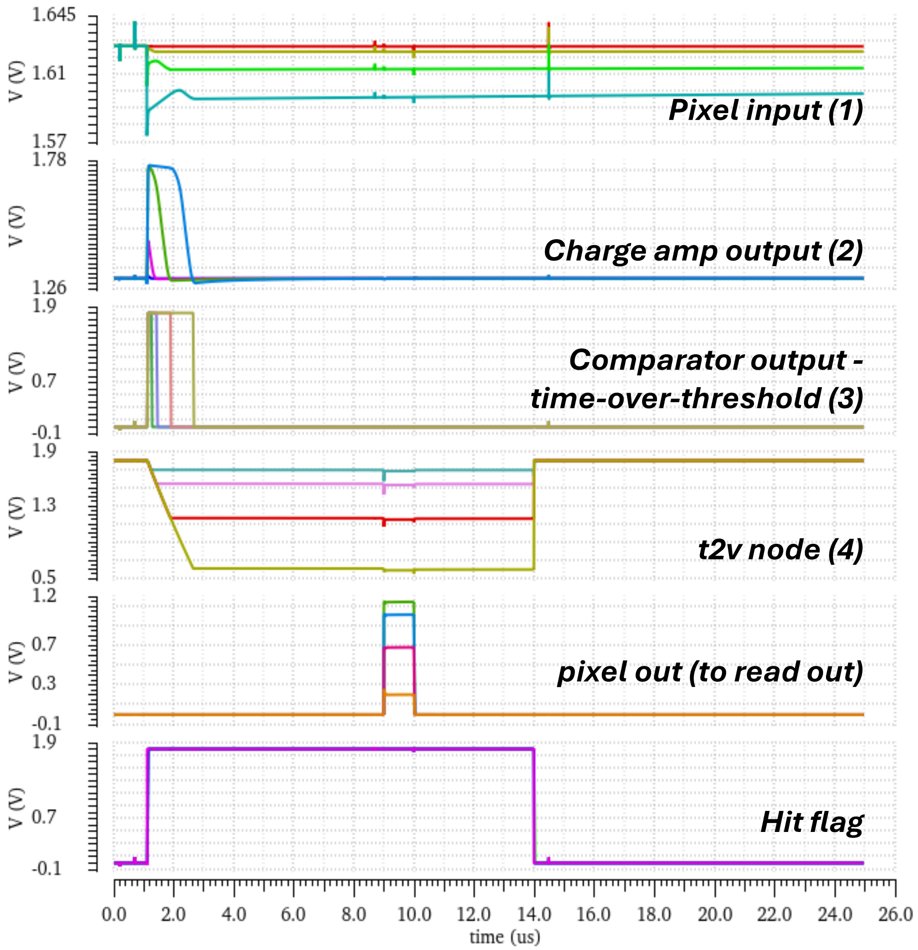
High gain pixel design covers 0.5 fC – 50 fC



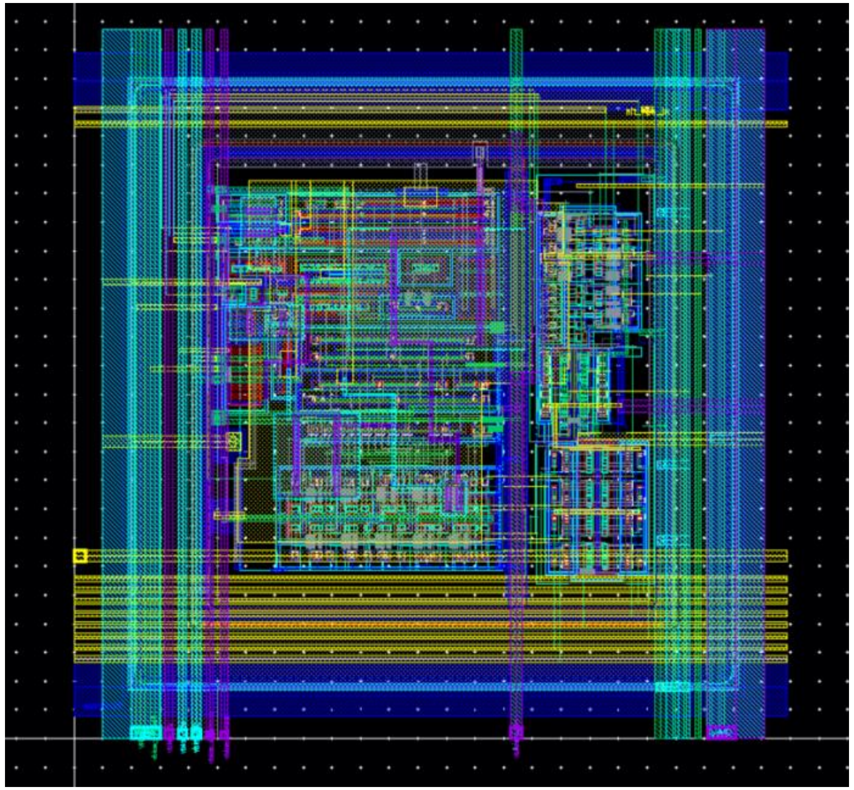
- Diode connected nmos for DNW bias[1]
- Cc decouples CSA from leakage path
- CSA to integrate input charge over feedback capacitor C_f[2]
- CSA output compared against threshold voltage to produce time-over-threshold pulse[3]
- Comparator decoupled from CSA to allow for trimming of V_{TH}
- Comparator output used to charge C_{T2V} for time to voltage conversion[4]
- Same readout as the low gain pixel

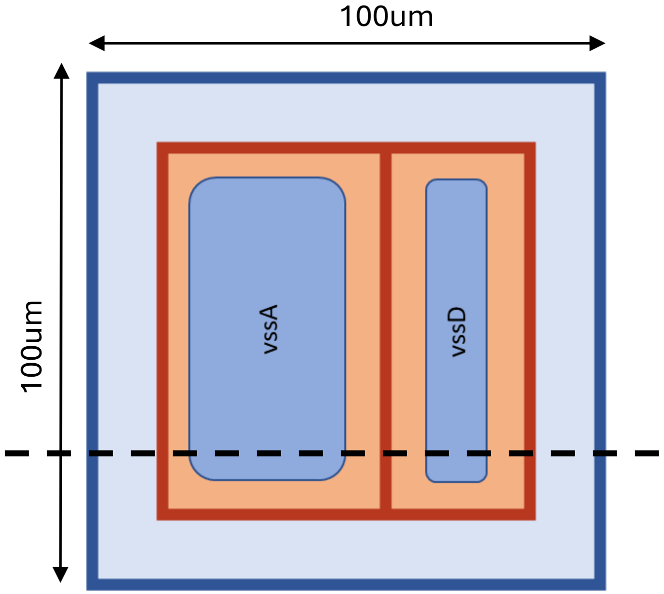
idle power consumption ≈ 7.5uA

High gain pixel transient response to Q_{in} = 0.5fC, 5fC ,20fC ,45fC

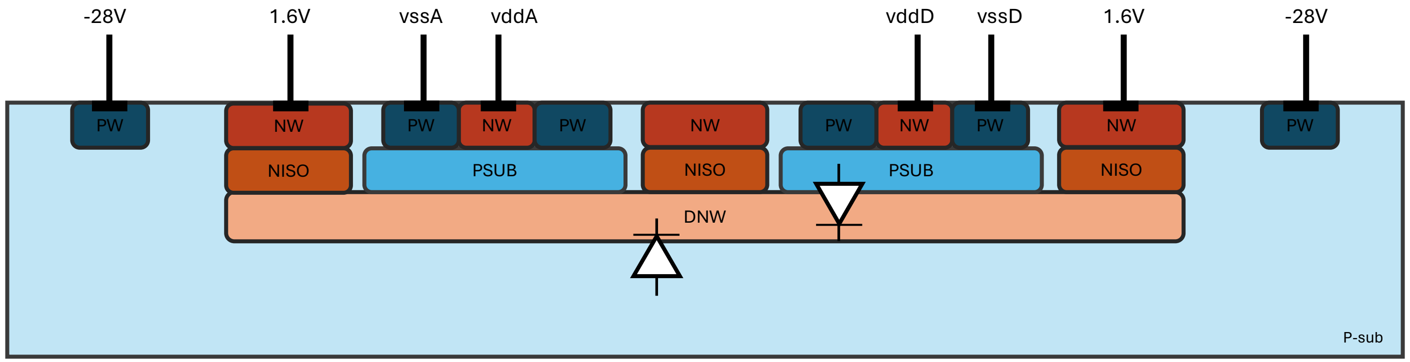


High gain pixel layout





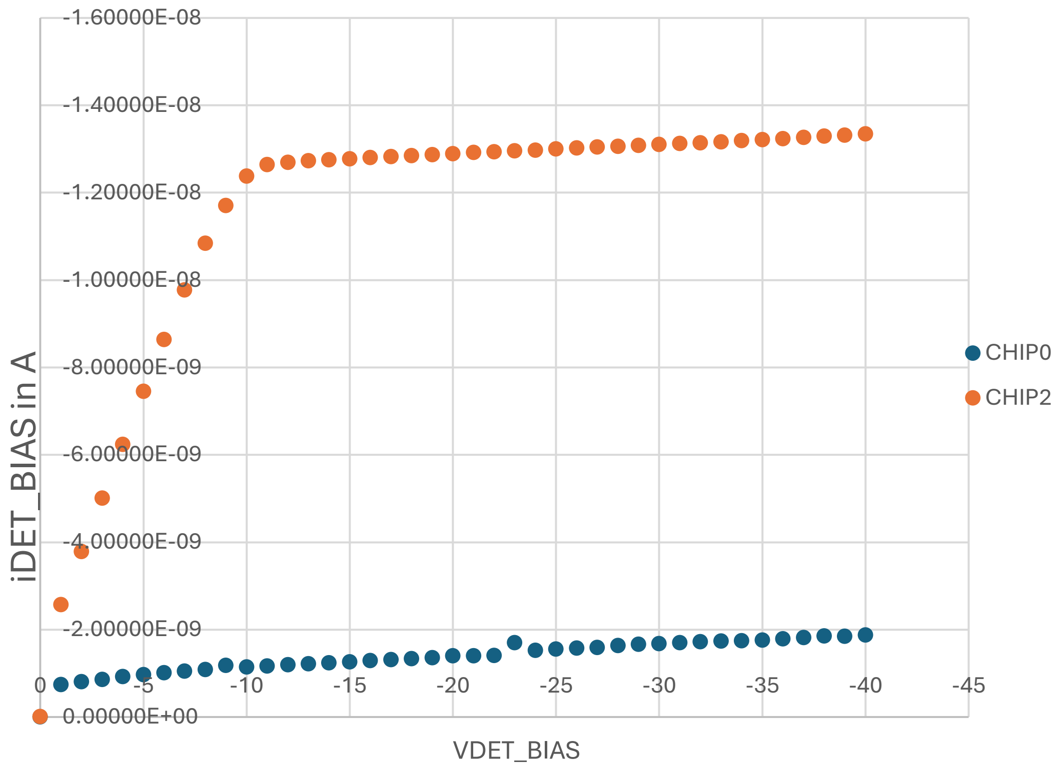
- Input capacitance at ~0.74pF
- Analog and digital supply domains are isolated by splitting the DNW



vssA = 0V, vddA = 1.8V
vssD = 0V, vddD = 1.8V

High gain sensor characterization very first measurements (to be continued)

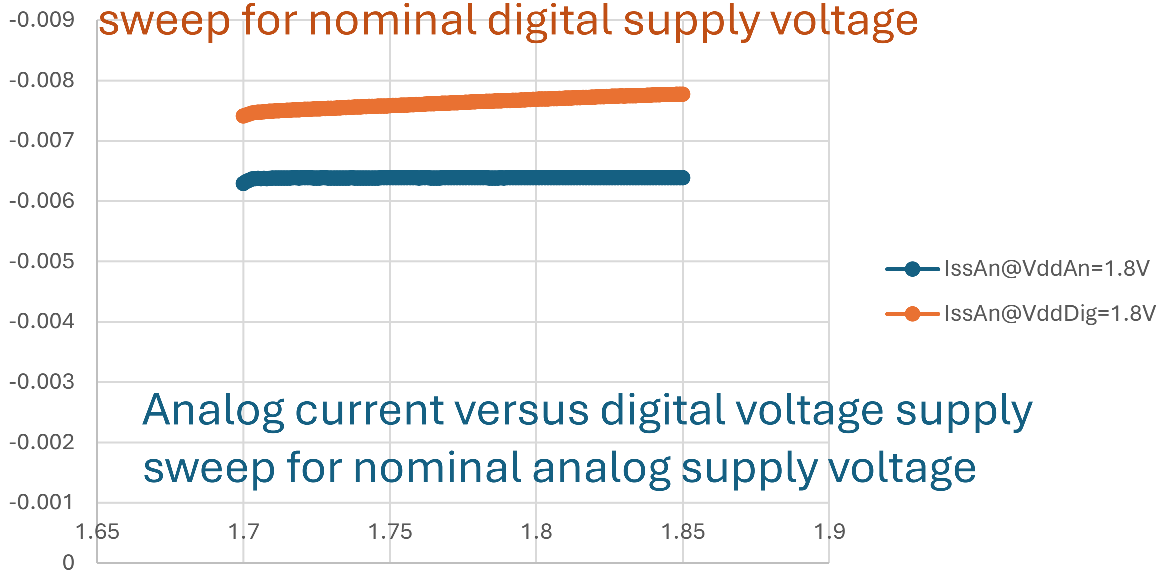
Leakage current



Conclusion: No breakdown occurs for up to -40 V bias

“sanity checks”

Analog current versus analog voltage supply sweep for nominal digital supply voltage



Analog current versus digital voltage supply sweep for nominal analog supply voltage

No leakage between analog and digital supply domain

DMAPS Specifications

	LOW GAIN PIXEL	HIGH GAIN PIXEL
Pixel size	200x200 um^2	100x100 um^2
Charge range	40fC - 9pC	0.5fC -50fC
Gain	109 mV/pC	17.5 mV/fC (Q_{in}>3fC) 120 mV/fC (Q_{in}<3fC)
Idle power consumption	35nA/pixel	7.5uA/pixel
Noise charge	1.5fC	200aC
Digitization	Embedded SAR ADC 11 bits @ 10 MHz	
Communication	SPI @ 10 MHz	
Readout mode	Only hit pixels/all pixels/specific pixel	

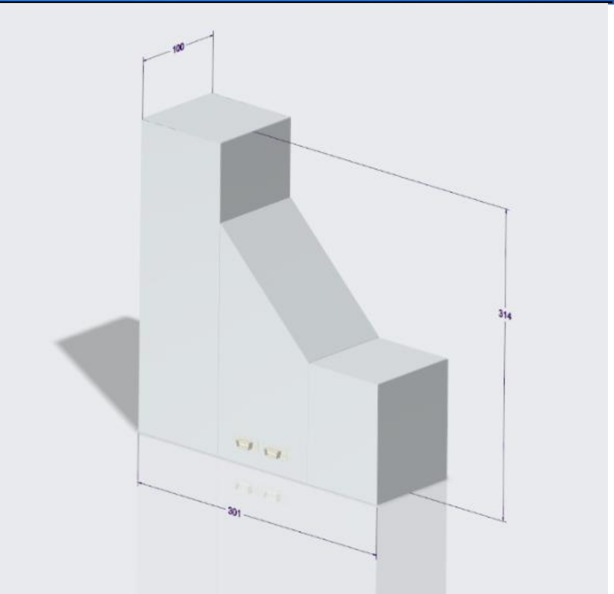
No charge amplifier !
idle power consumption ≈ 35nA @ 1.8 V = 63 nW/pixel
For 16 cm^2 covered by 40000 pixels
idle power consumption = 2.52 mW
A very low power figure !!!

idle power consumption ≈ 7.5uA @ 1.8 V = 13.5 μW / pixel
For 16 cm^2 covered by 160000 pixels
Idle power consumption = 2.16 W
High power consumption!

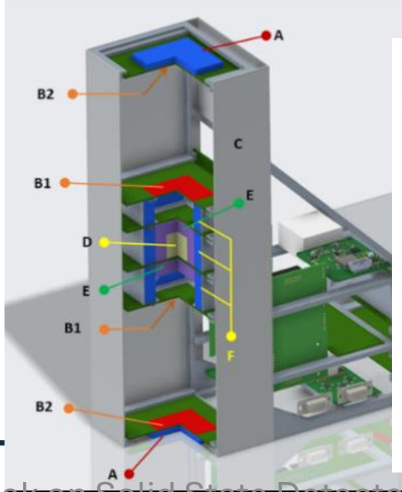
- Low gain and High gain sensors combined cover a dynamic range from 0.5fC to 9pC
- Common top-level architecture and read-out circuitry for the two sensors

LURAD: Comprehensive radiation monitor package for lunar mission

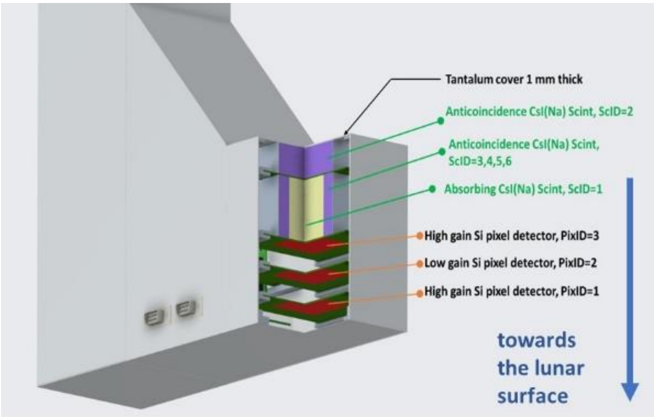
Measurement capabilities:
▪ *Protons and ions spectra in the energy range from 40 MeV/u up to 2 GeV/u*
▪ *Discriminate GCR particle species with atomic number from Z=1 up to Z=26*
▪ *Electrons spectrum in the energy range from < 1MeV up to 20 MeV*
▪ *gamma photons spectrum in the energy range from 100 keV up to 10 MeV*
▪ *Neutrons spectra in the energy range from 100 keV to 300 MeV.*
▪ *Lineal energy spectra, dose, dose equivalent, quality factor*
Mass 3 kg
Power: 17 W Power Bus: 28V
Interfaces: Spacewire, MIL-STD-1553



Dimensions in mm

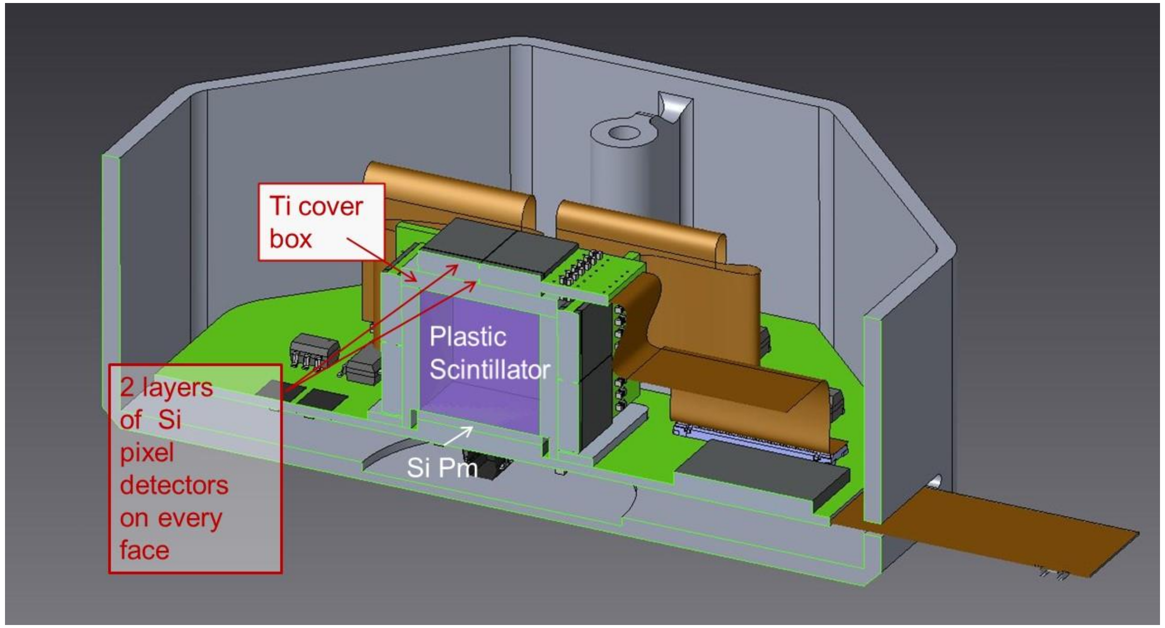


A. EJ232Q Fast Scintillator (50x50x5 mm³)
B. Silicon active pixel detectors
   - B1 (low-gain): 200 x 200 μm², 40000 pixels
   - B2 (high-gain): 100 x 100 μm², 160000 pixels
C. Aluminum cover
D. Cubic plastic Scintillator (EJ200)
E. Crystalline scintillator CsI(Na)
F. EJ200 Plastic scintillator anticoincidence detector



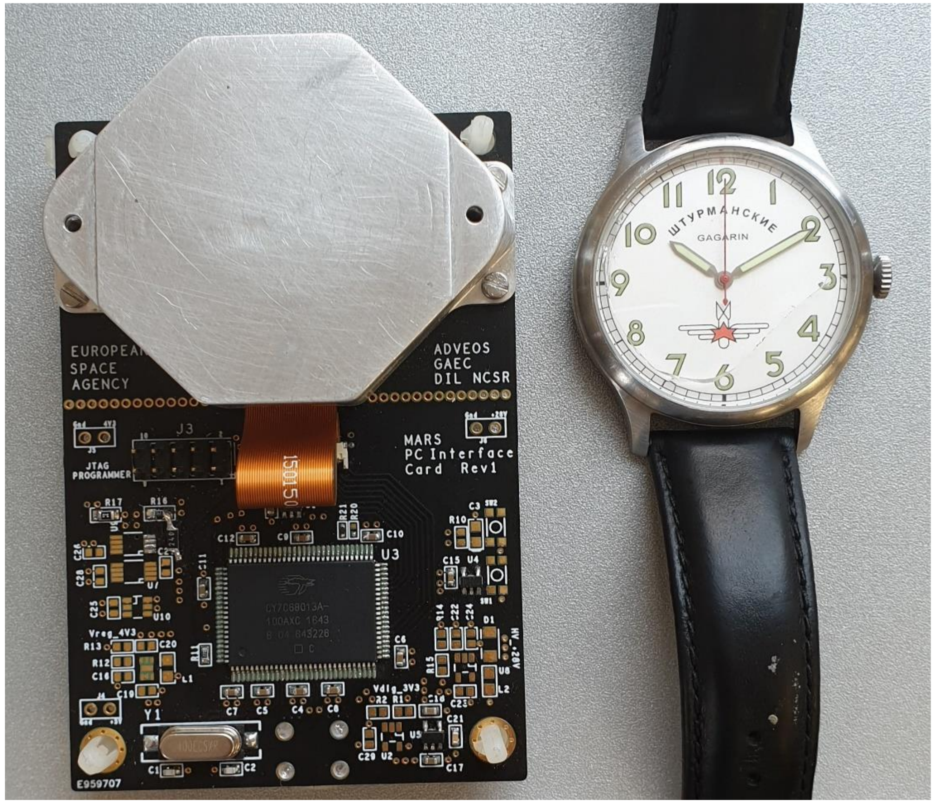
Astronaut exposure in mixed radiation fields in space

MIDAS Detector



(excerpt from ICRP publication 123)

Quantities to be measured are radiation fluence rates, the energy distributions of different types of particles, and linear energy transfer (LET) distributions.



A collaborative effort




National and Kapodistrian UNIVERSITY OF ATHENS




ADVEOS
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DEMOKRITOS

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- 4000119598/17/NL/LF “Highly miniaturized ASIC Radiation Monitor”
- 4000133574/21/NL/CRS “Comprehensive Radiation Monitor Package for Lunar Mission”

Thank you