Nuclear medical imaging techniques:

Principle:

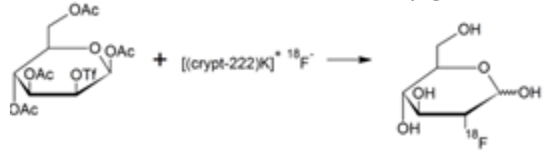
Marking

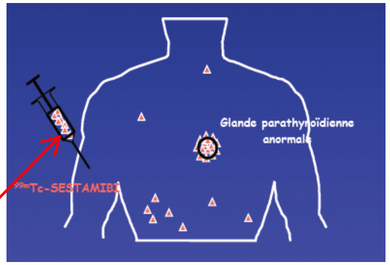
Molecule + Radioactive isotope

• ^{99m}Tc, ^{123}I, ^{201}Tl, ^{18}F, ^{11}C

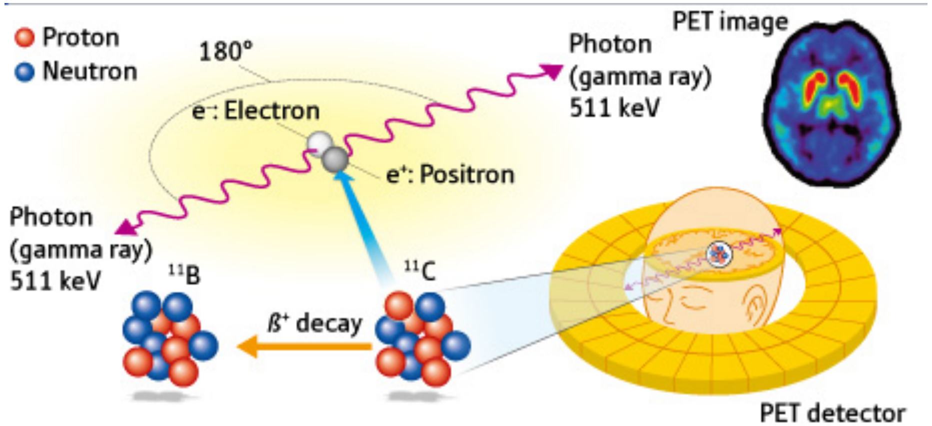
• Emitters: γ, β^+ ou β^-

Glucose -> Fludeoxyglucose





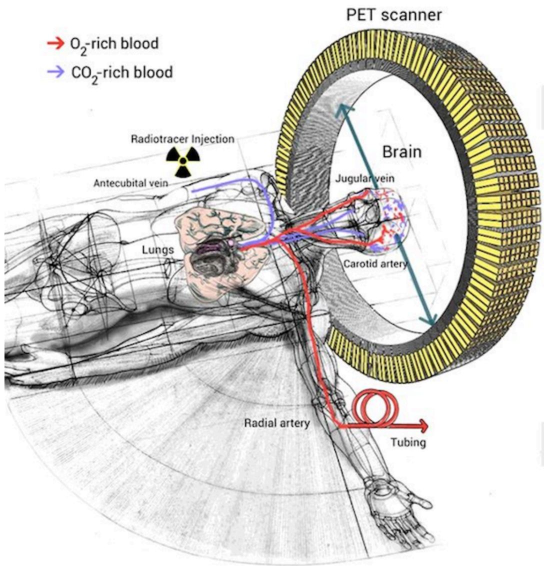
Detecting



Nuclear imaging technology γ camera, tomographs

Technologies:

Cancer diagnostic



Cancer therapy

Gamma imaging camera

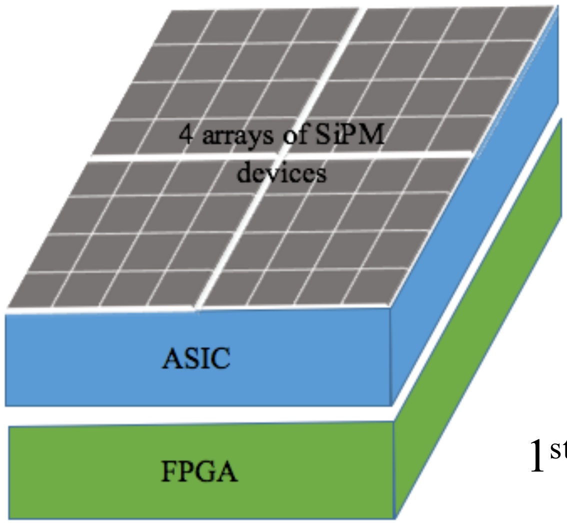
Beta probe

Beta-probe with active background rejection:

Active background rejection:

- reduction direct radioactive dose (to patient & medical personal)
- possibility to use it for tumors where gamma-ray background from the healthy organs prevent the application of traditional techniques

Detection module:



1st step to fully monolithic LEGO brick

Proposal is submitted to FET-Launchpad;
If any partner want to contribute → you are welcome!

Toward new SiPM technology

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SiPM`s failed to replace standard PMT`s in large detection surfaces experiments:

- Main limitations:
  - Dark noise
  - Poor performance of large monolithic sensor or prohibitive cost due to large number of electronics channels if area covered by tiling small detection units
- Recent developments partially address these issues:
  - Recent developments (e.g. LVR from HPK) already partially tackle the noise issue, can still be improved
  - Solution with anode in series (e.g. MEG, DarkSide) but requiring more complex bias stage or digital SiPM

Growing panel of sensors available

- Main limitation:
  - Optimization phase for electronics development (discrete) or ASIC tuning long and repetitive
  - Extended R&D phase
- Existing solution:
  - Electronic modeling of SiPM response

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The D-LIGHT FET-OPEN program intended to propose the sensor that would tackle the surface and performance not require the user to develop custom analog readout. The research lines were:

- Improve the digital sensor from Philips to tackle the noise and speed issue
- Provide compact package with 3D integration of sensor and readout electronics
- Use a scalable approach where increasing size would not necessarily means increasing electronics channel

Recently we discovered that the sensor concept was realized by a group at the University of Sherbrook:

- A 2D Proof of Principle Towards a 3D Digital SiPM in HV CMOS With Low Output Capacitance (DOI: 10.1109/TNS.2016.2582686)
  More details in the next slides

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A 2D Proof of Principle Towards a 3D Digital SiPM in HV CMOS With Low Output Capacitance (DOI: 10.1109/TNS.2016.2582686)

Every SPAD has (Exactly as planed in D-LIGHT):

- Active quenching
- Possibility to enable/disable SPAD
- **Current source**

If the goal is to implement the SPAD array and the readout in 3D fashion, the current implementation is performed with a monolithic approach (both approaches planed in D-LIGHT to) which offers poor filling factor

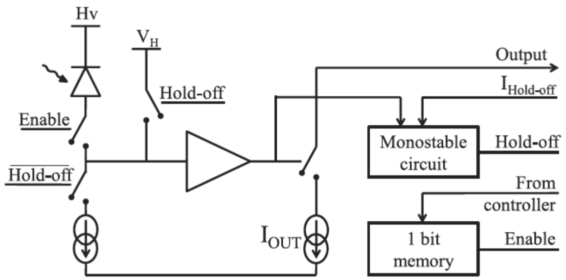

Fig. 2. Block diagram of the SPAD read-out.

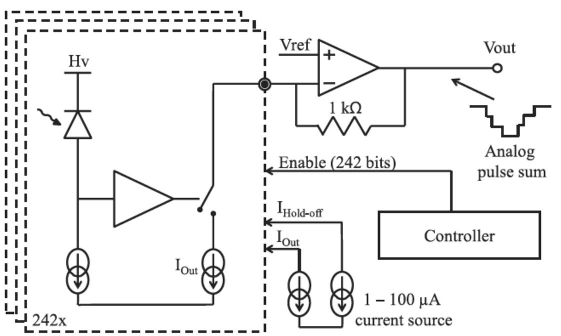

Fig. 3. Top level block diagram of the digital SiPM architecture, showing the analog sum of current pulse.

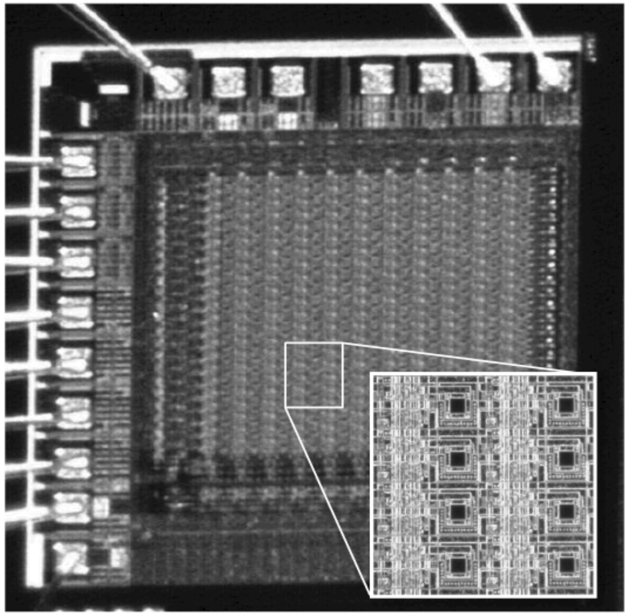

Fig. 5. Overview of the SiPM made in HV CMOS 0.8 μm with a zoom on 8 pixels of 50 $\times$ 100 μm^2.

GOAL INTEGRATION

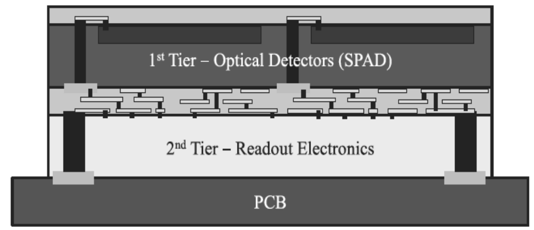

Fig. 1. Cross-section of the 3D digital SiPM. The 1st tier contains SPAD arrays with through silicon vias (TSV) and the 2nd tier contains quenching circuit arrays.

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A 2D Proof of Principle Towards a 3D Digital SiPM in HV CMOS With Low Output Capacitance (DOI: 10.1109/TNS.2016.2582686)

Advantages of the current source are:

- Fixed amplitude: lower fluctuation from avalanche to avalanche
- Variable duration: Reduction of dark count pile up, afterpulses
- Variable amplitude: Adaptable dynamic range

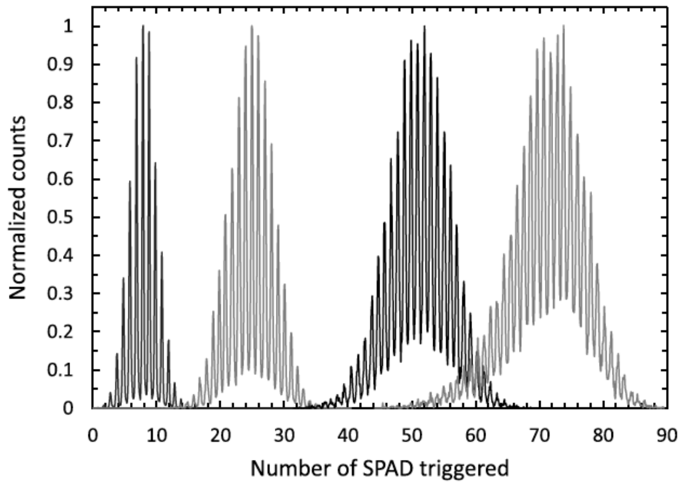

Fig. 11. Charge histogram for four different light intensities with clear steps of 0 to 90 SPADs triggered at the same time showing the single photon resolution capability of the digital SiPM.

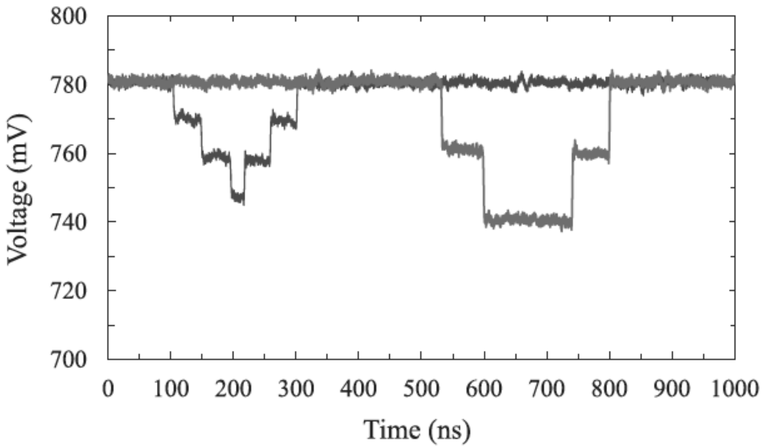

Fig. 10. Analog sum output for different current and hold-off values. In black, 3 SPADs triggered with an 11 mV response and 100 ns hold-off. In gray, 2 SPADs triggered with a 20 mV response and 200 ns hold-off.

Consequences:

- Photon counting capabilities up to high number of photons
- With the proper readout chip (e.g. SAMPIC) you can access the timing of all of them

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If we follow this path, how can we contribute the current development:

- Improve SPAD performance:
  - DCR, XT
  - PDE:
    - Micro-lenses
    - Access to better CMOS technology (currently 0.8 µm HV CMOS)
- 3D integration:
  - Contact with companies:
    - 3D plus for high yield 3D integration, e.g. WDoD
    - Silicon/Glass interposers (Planoptik, LPKF)
  - Access to machines:
    - Probe station (@ UniGe)
    - Flip-Chip machine (@ UniGe)
- Readout:
  - ASIC development
  - Interface to high performance ASICs (e.g. SAMPIC)

- Access to test facility

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