REal Time Image REconstruction for 3-γ Xenon camera

LabSTICC ARCAD
LaTIM
Subatech
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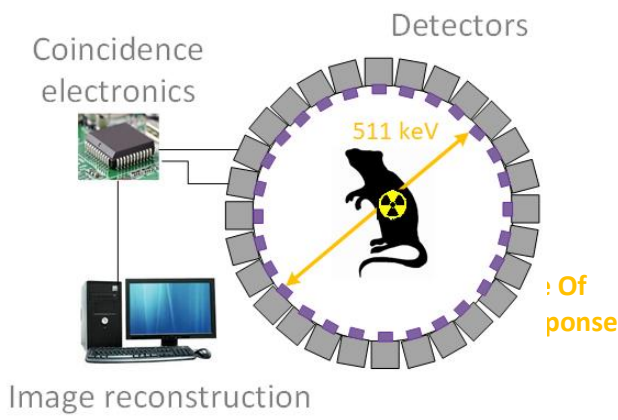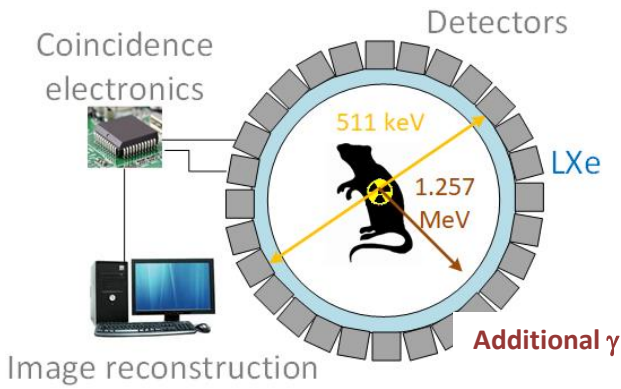D. Thers/ E. Morteau
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Nuclear medical imaging context

- Main tool: Positron Emission Tomography (PET)
- Injection of **radioactive tracer** [18]F (fluorooxyglucose).
- Nuclear disintegrations create 511keV back-to-back gamma photons detected by **scintillation**.
- Push to **reduce injected dose** of radiotracer
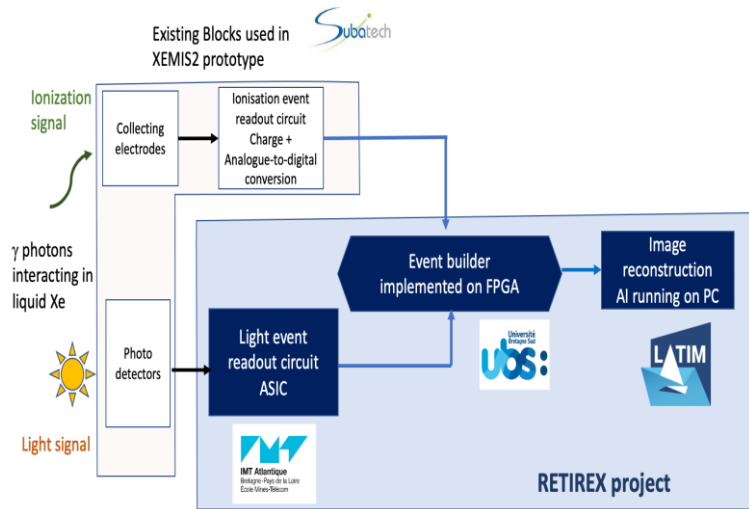- Image quality = f(injected dose, duration)

Coincidence electronics
Detectors
511 keV

Image reconstruction

Not compatible with routine clinical usage

New imaging tool: 3-γ Xenon camera by Subatech

- Use of a (β+, γ) emitter, e.g. Scandium 44 ([44]Sc).
- **3 γ photons = Additional spatial information**
- **Fewer disintegration needed**
- Scintillator: **liquid Xenon** (Lxe).
- **Reduce the injected radiotracer dose**
- **Reduce acquisition times**
- **Localise accurately the disintegration**
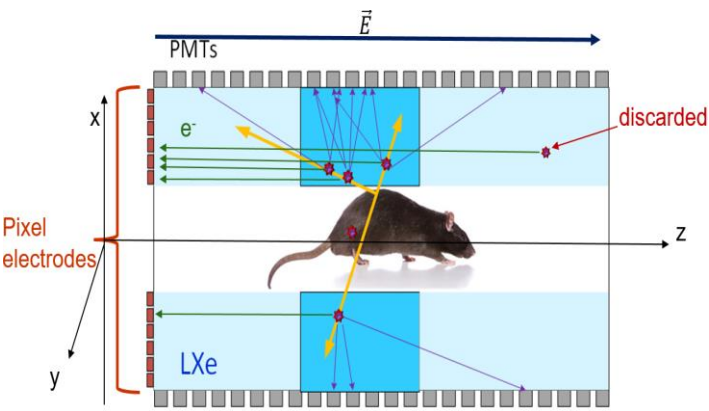- **Achieve real-time dynamic quantitative imaging**

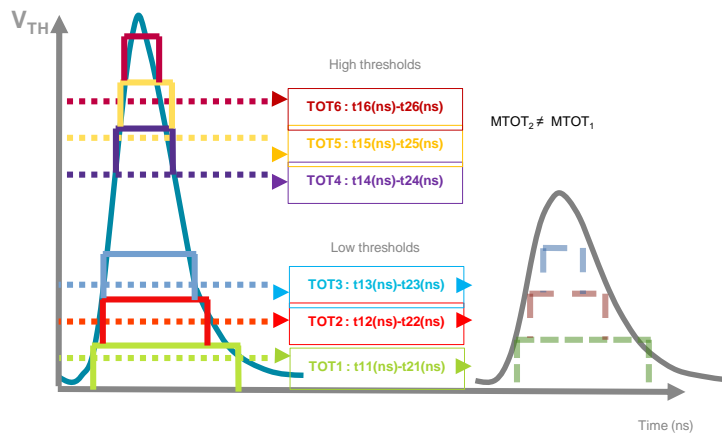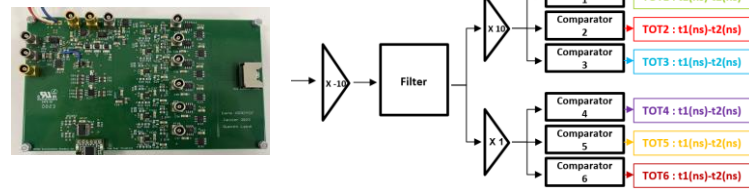Coincidence electronics
Detectors
511 keV
1.257 MeV
LXe

Image reconstruction
Additional γ

RETIREX works

Existing Blocks used in XEMIS2 prototype

Ionization signal
Collecting electrodes
Ionisation event readout circuit Charge + Analogue-to-digital conversion

γ photons interacting in liquid Xe
Photo detectors
Light event readout circuit ASIC

Light signal

Event builder implemented on FPGA
Image reconstruction AI running on PC

RETIREX project

Light-read out circuit

- Use to trigger measurements
- Use to reduce volume of interest

PMTs
$\vec{E}$
x
e⁻
discarded
Pixel electrodes
z
y
LXe

- TOT not good for counting > 10 photoelectrons
- Need to count up to 200 photoelectrons

High thresholds
TOT6 : t16(ns)-t26(ns)
TOT5 : t15(ns)-t25(ns)
TOT4 : t14(ns)-t24(ns)
$MTOT_2 \neq MTOT_1$

Low thresholds
TOT3 : t13(ns)-t23(ns)
TOT2 : t12(ns)-t22(ns)
TOT1 : t11(ns)-t21(ns)
Time (ns)

- 1st prototype

Comparator 1 — TOT1 : t1(ns)-t2(ns)
Comparator 2 — TOT2 : t1(ns)-t2(ns)
Comparator 3 — TOT3 : t1(ns)-t2(ns)
Comparator 4 — TOT4 : t1(ns)-t2(ns)
Comparator 5 — TOT5 : t1(ns)-t2(ns)
Comparator 6 — TOT6 : t1(ns)-t2(ns)

- 1st measurements
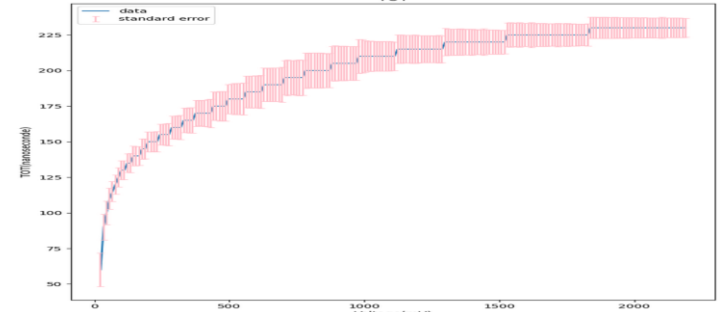
Event builder

- Combines data from PUs & PMs
- Implement event filtering

PU
PM
LVDS Inputs
Merging & Ordering
Filtering
Ethernet Gigabit link (10/20G)
Server
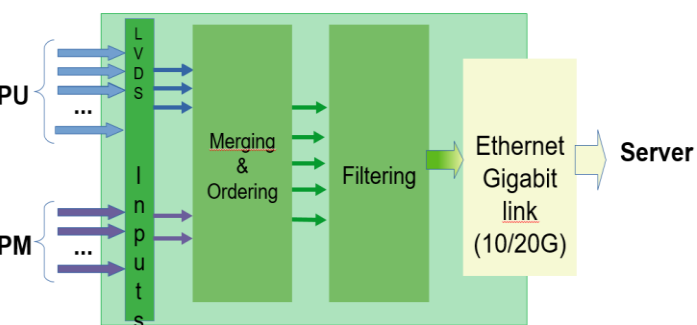
Output protocole (Payload)

PU Number	Xtract	Chanel	Strength	Time	PM Number	Strength

70 bits

Image reconstruction

Use AI software to estimate annihilation point coordinate

LOR
1st GNN
2nd GNN
Ordered interactions
Estimated emission point coordinates
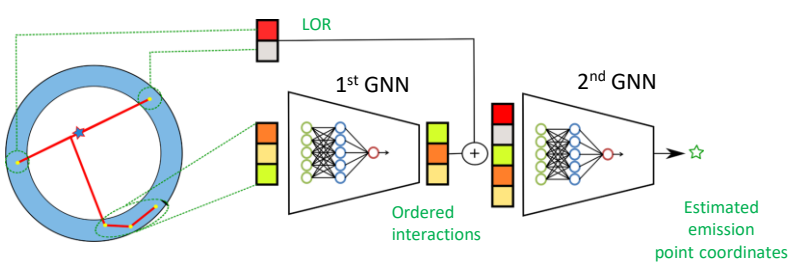
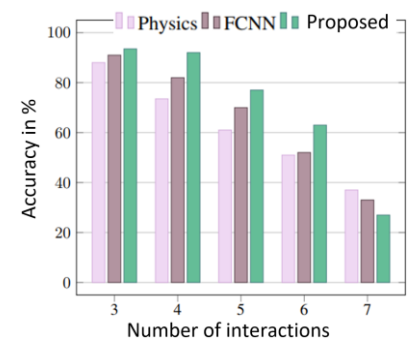| Method	Path classification (FCNN)	Edge Classification (GNN)
Complexity	N!	N (N-1)

Accuracy coordinates estimate vs actual)

Physics FCNN Proposed
Accuracy in %
Number of interactions

Image comparison (CASToR)

PET-TOF
3-γ