Liquid xenon for medical applications

Paola Ferrario for the PETALO collaboration, DIPC-Ikerbasque

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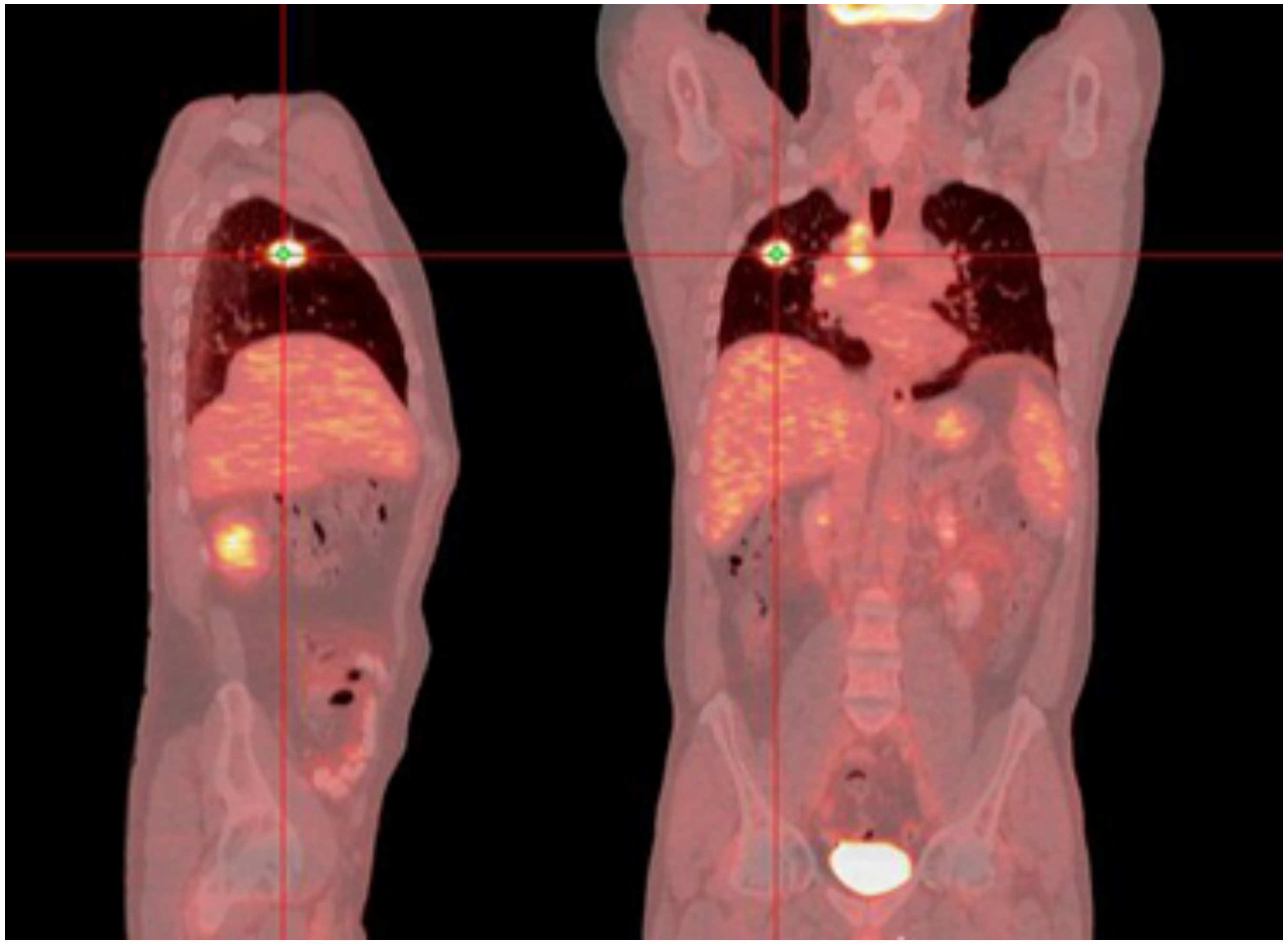
PETALO project

- Use of liquid xenon instead of scintillating crystals in Positron Emission Tomography.
- Read-out with SiPMs.
- Born within NEXT.
- Funded by ERC-StG (2018-2024).

Positron emission tomography

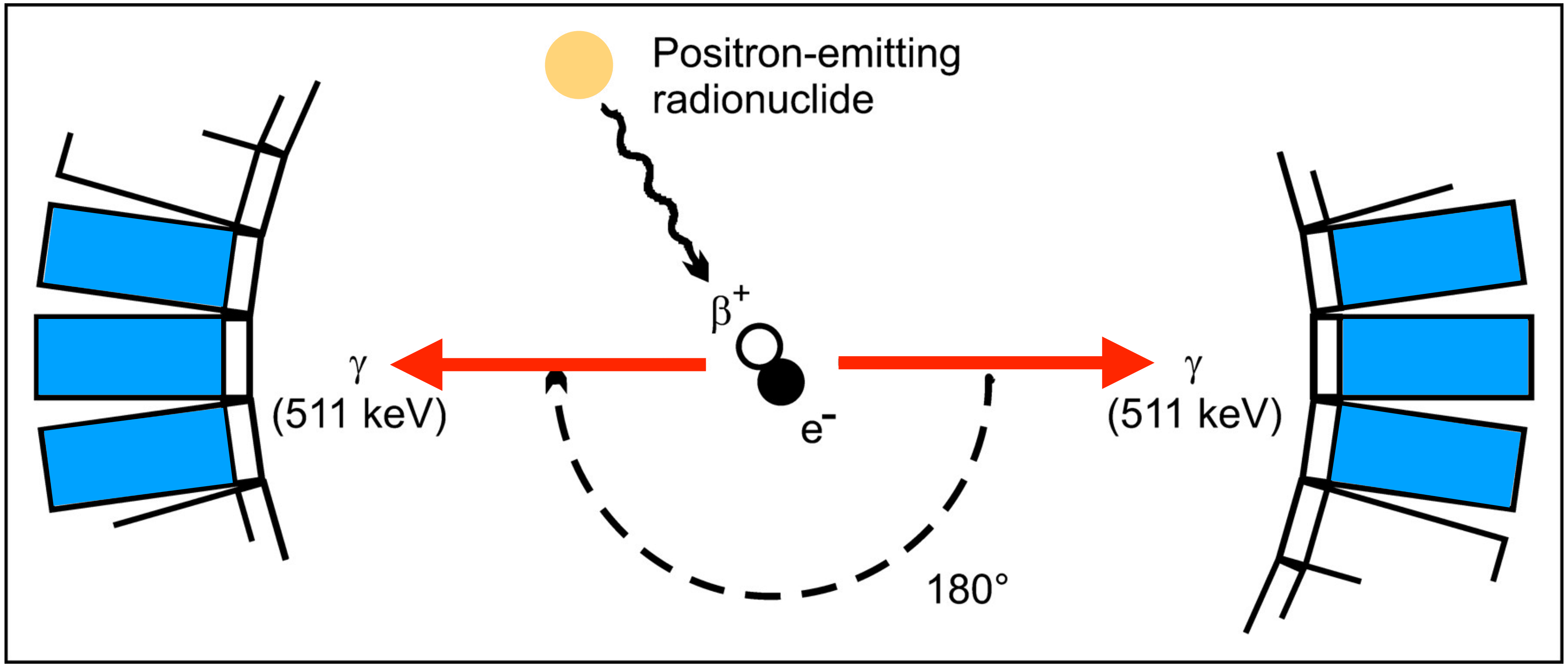
What



- PET scans shows the metabolic activity in an organ or tissue.
- High metabolism areas appear as bright spots.
- Used to detect and monitor cancer, central nervous system disorders (Alzheimer, Parkinson, epilepsy…) and cardiovascular diseases (i.e., revealing decrease of blood flow).

Positron emission tomography

How

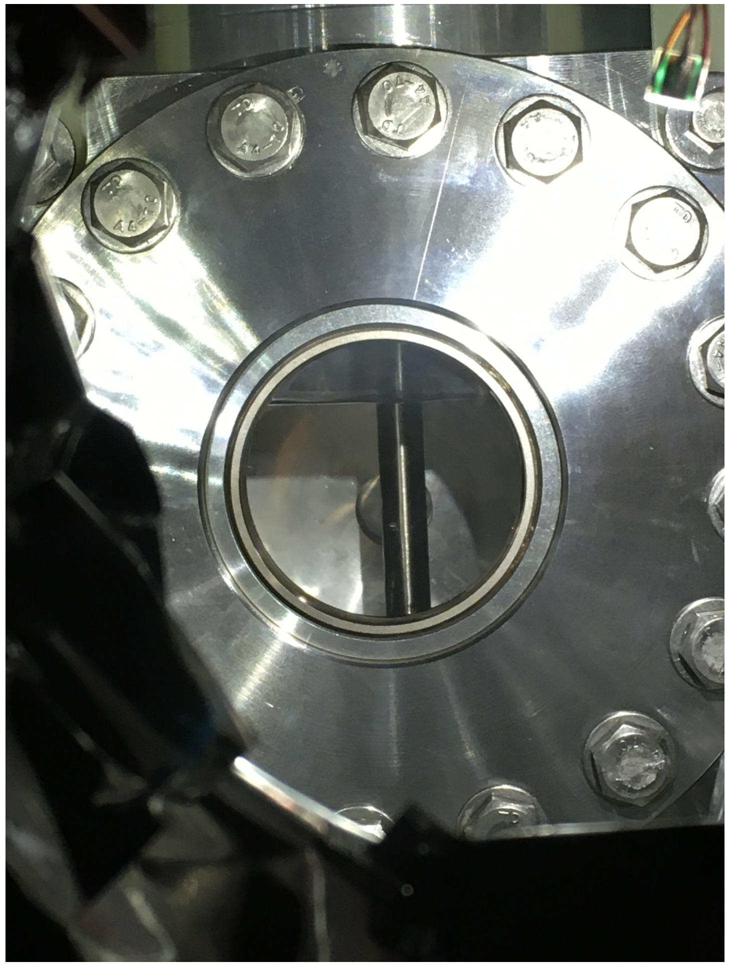


- Glucose analogue doped with β-emitter radioactive isotope.
- Positron annihilation produces two 511-keV gammas almost back-to-back.
- Gammas are detected by a ring of scintillators.
- A line of response (LOR) is identified through time coincidence of two detectors.
- Image is reconstructed crossing many LORs.

The PETALO concept

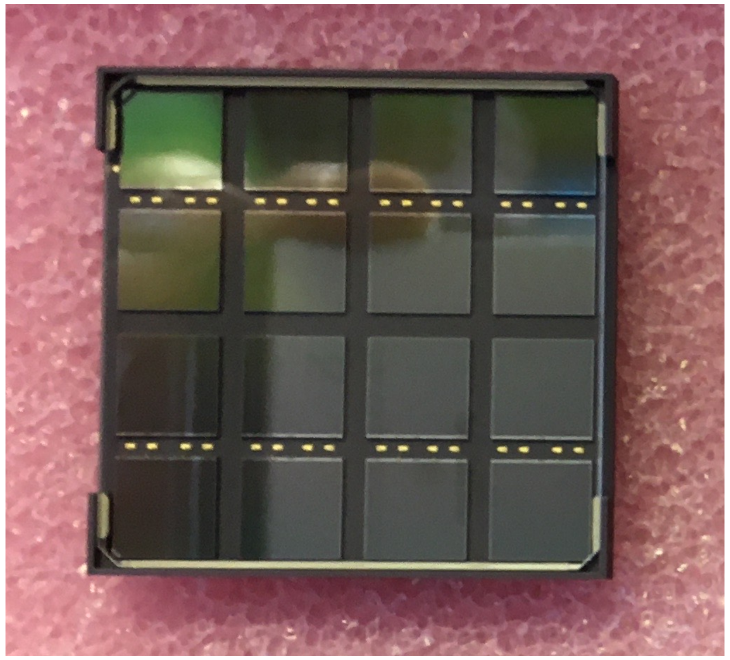
LXe

- Liquid xenon as scintillation medium.
- High yield (~30k ph/511 keV), fast time (2 ns in the fast component).
- Transparent to its own scintillation light.
- One volume compared to thousands of modules (crystals).
- Use only scintillation light (less complexity, no high voltages).

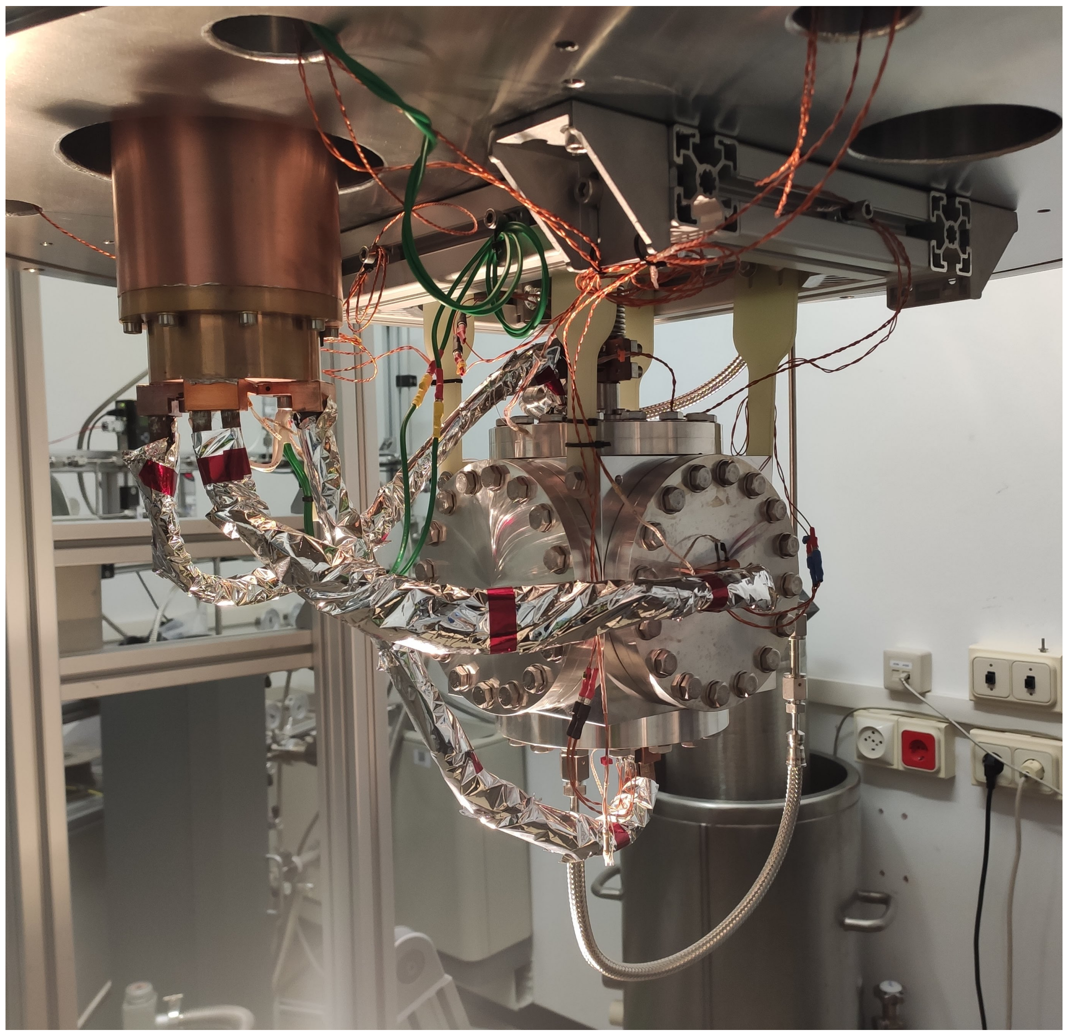


SiPMs

- Fast response, high gain.
- Almost no dark count at cryogenic temperatures.
- Compatibility with magnetic fields (NMR).



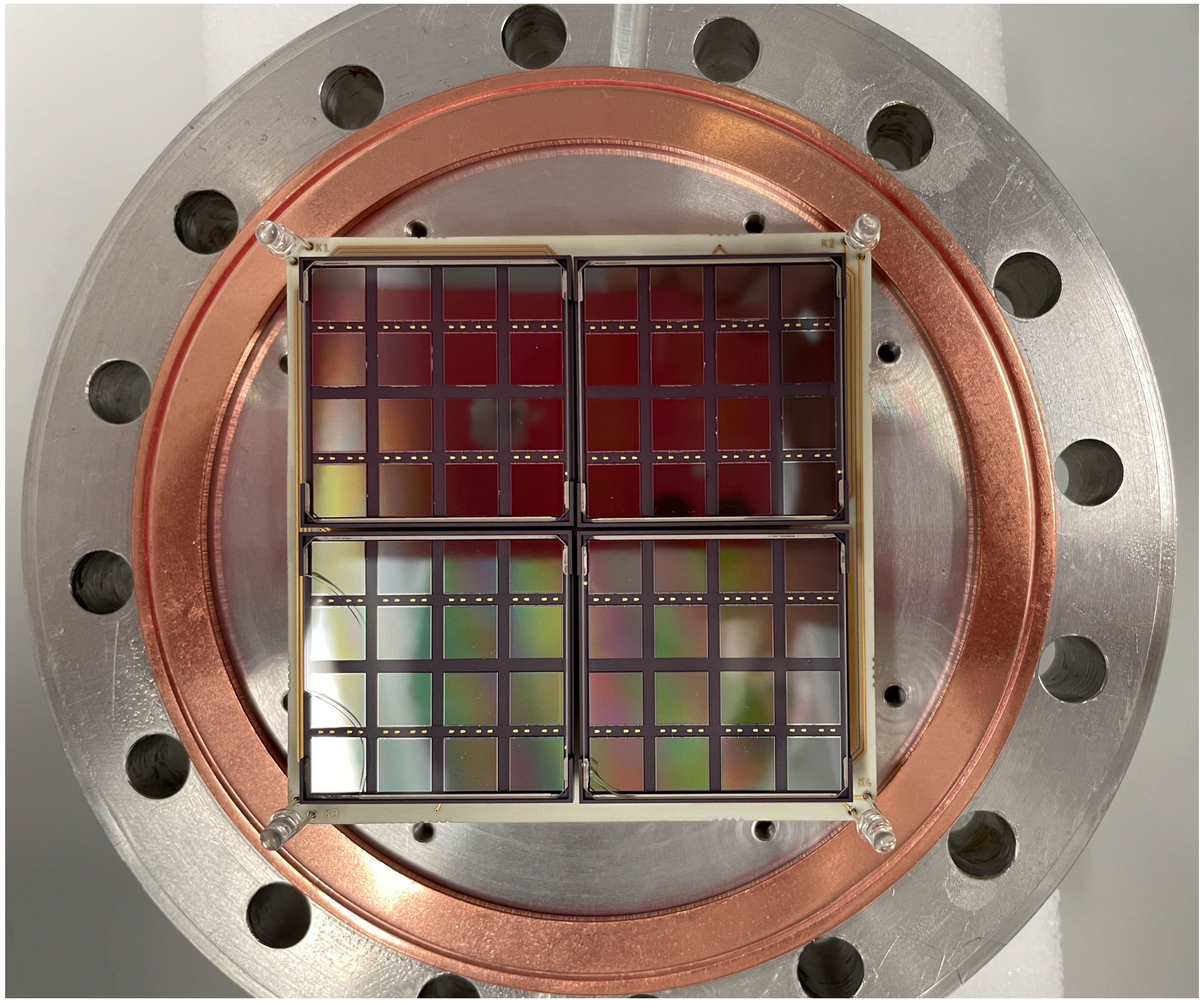
First prototype: PETit



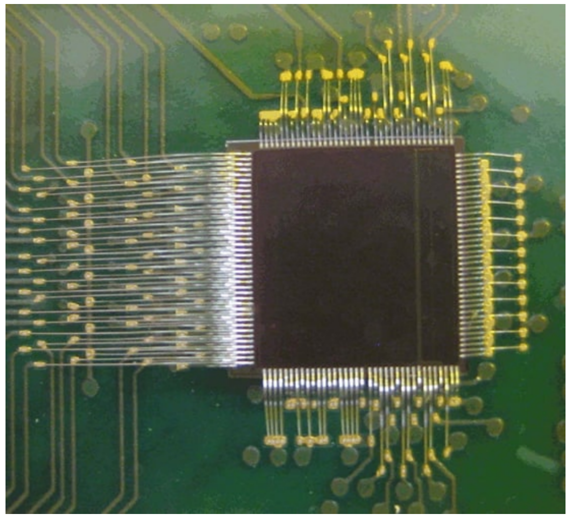
- CF-100 size aluminum cube.
- Cooled by Sumitomo CH-100 cold head, via custom-made thermal links.
- Vacuum vessel for thermal isolation.
- Gas purification from O_2, N_2 and H_2O through a hot getter.

First prototype: PETit

Photosensors



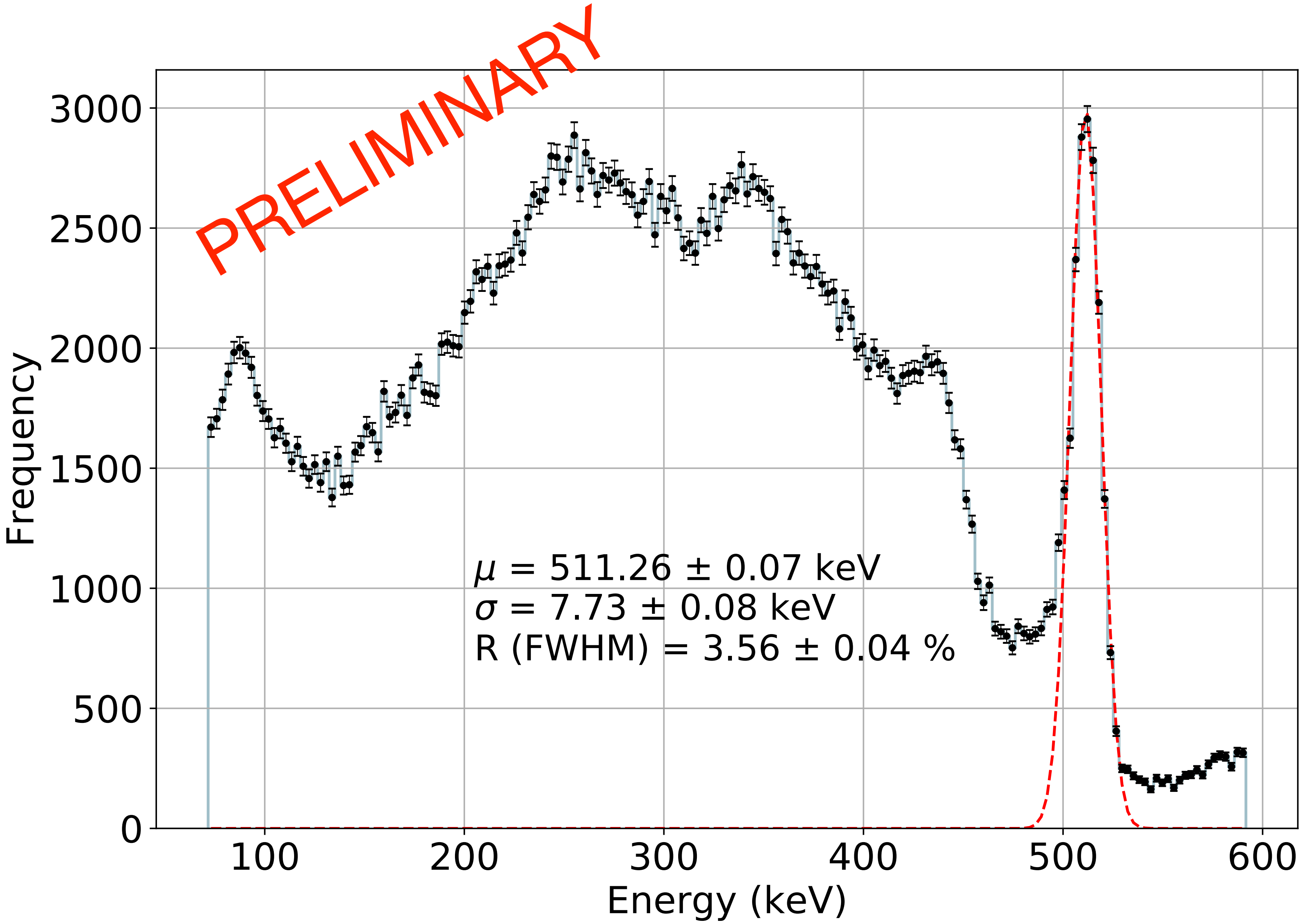
- Hamamatsu VUV-sensitive S15779, 6x6 mm2 area.
- 4 arrays of 4x4 SiPMs per side.
- Protection window made of VUV-transparent quartz.



- Signal digitized by 2 TOFPET2 ASICs from PETsys.
- Two thresholds: low for timestamp, high for charge integration.
- Fast time and high rate applications.

First results

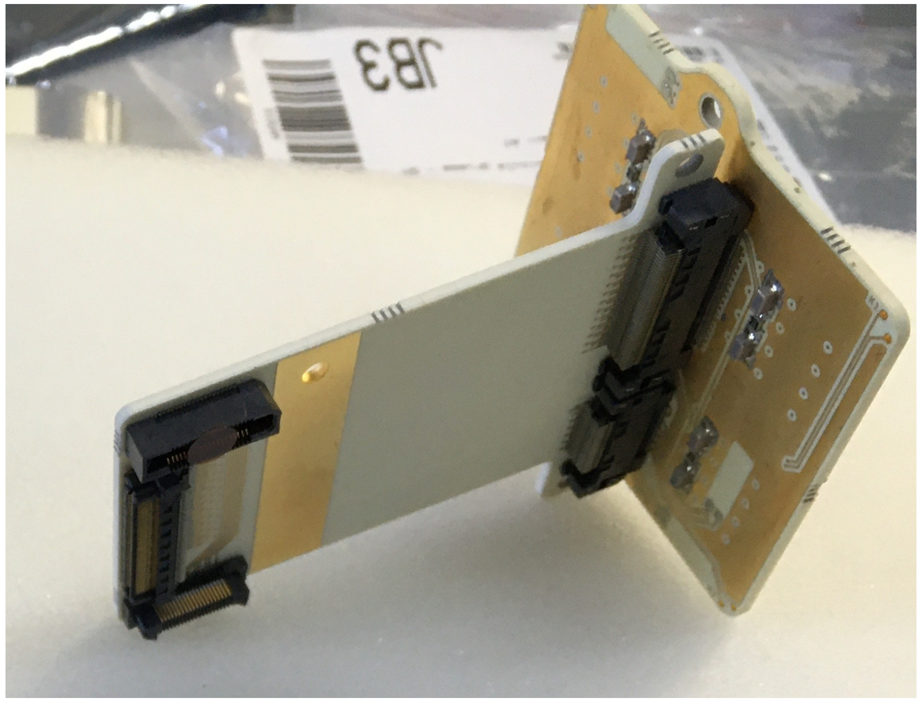
Energy resolution

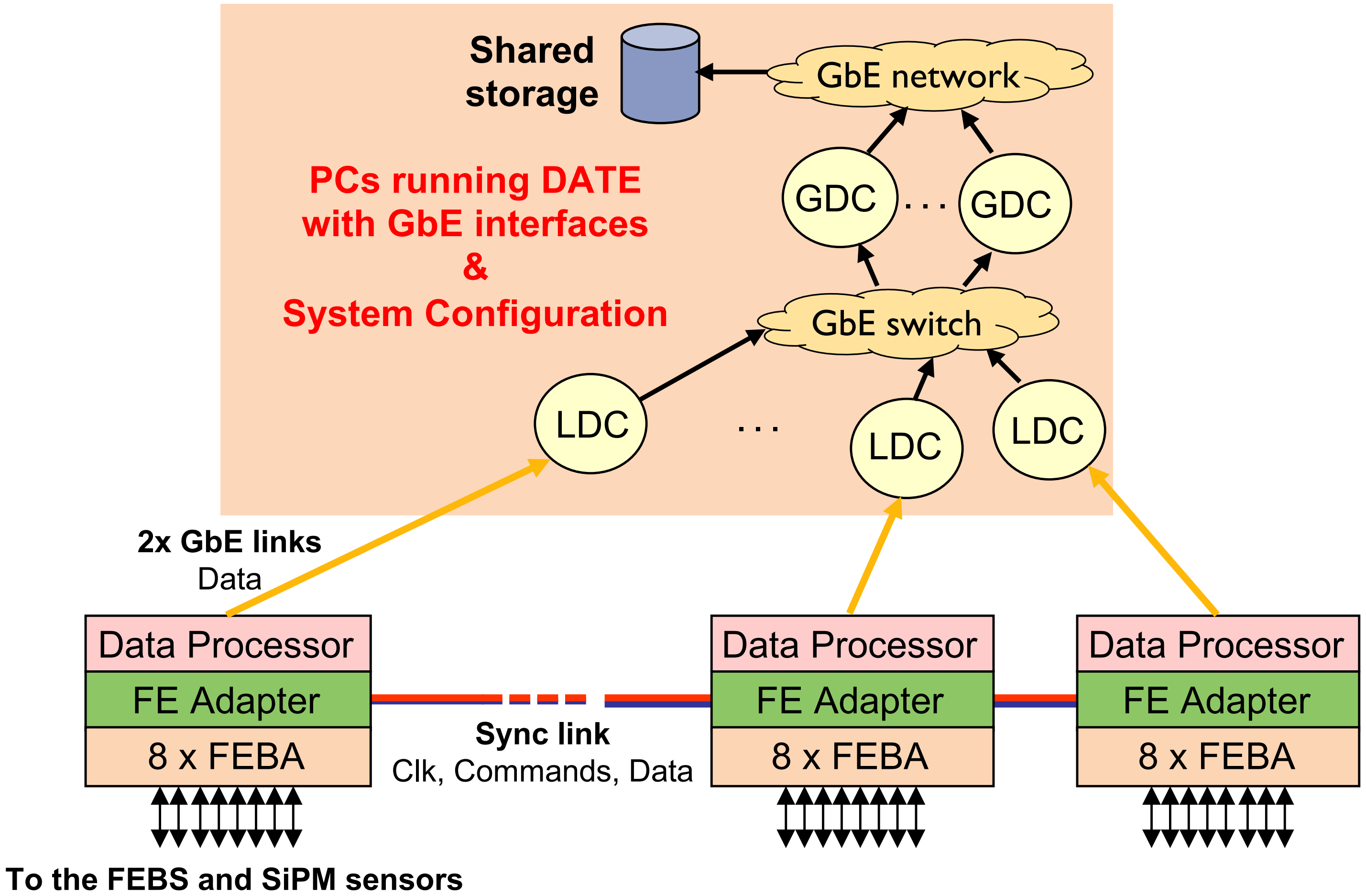


- Best resolution with scintillation only so far.
- Intrinsic, non-poissionian resolution compatible with zero.

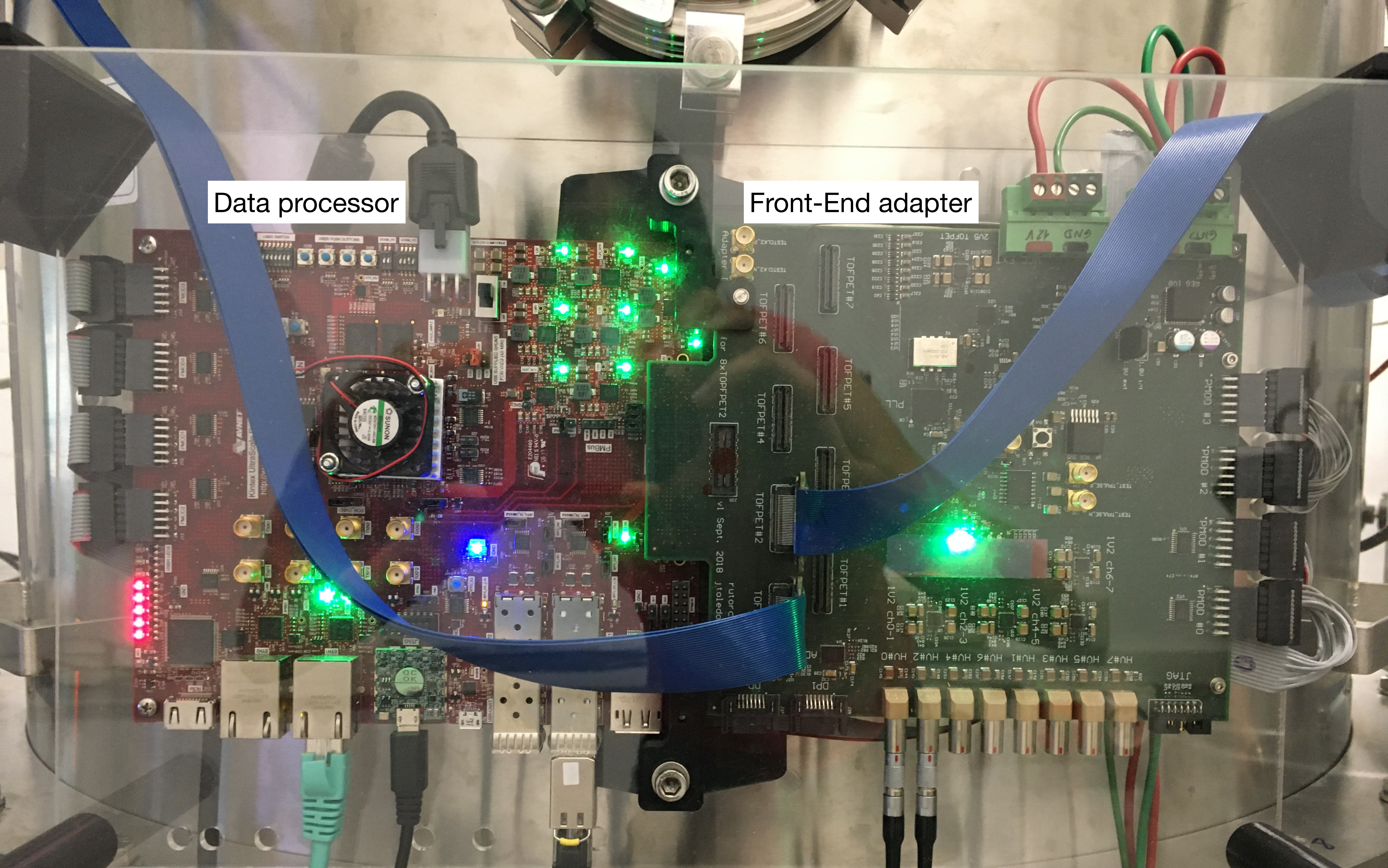
Past DRD

- **Electronic feedthroughs**: must stand high thermal stress and tightness to vacuum and liquid xenon pressure. Ceramic composite multilayer PCB + high performance cryogenic epoxy to withstand thermal cycles down to -200 C (Stycast 2580).





- **Data acquisition**: huge amount of channels and tight timing specs (synchronization of large number of ASICs). Modular scheme with synchronization over data links, easily scalable.



- Front-End adapter: ASIC calibration and reset, controls T sensors, SiPMs, clock system control and clock distribution among chips.
- Data processor (Kintex Development Boards): receives data and sends them to computer, receives TOFPET configuration and sends it to chips, responsible for clock synchronization.

DRD topics

- **Cryogenic front-end electronics**: closer to sensors, lower number of feedthroughs, better time measurement.
- **Fast electronics**: time-of-flight PET improves image quality and diagnosis capability. Time resolution is limited by sensor and electronics time jitters.
- **ASICs** with fast time, high rate, low consumption, time precision and extreme conditions functioning. In collaboration with NEXT, adding extra features.
- **Large sensor arrays**: a total-body PET requires tens of thousands of SIPMs.
- **Digital SiPMs** to reduce number of channels.

DRD topics

- **Data reduction** by adding intelligence to DAQ before data arrive to computers
- **High data rate** management.
- **Wavelength shifters** resistant to LXe.
- **High reflective materials** to enhance light collection.

People and institutions

- 3 senior physicist researchers (1.5 FTE)
- 3 senior engineer researchers (1.5 FTE)
- 1 post-doc (0.3 FTE)
- 3 engineers (1.5 FTE)
- 2 PhD students (2 FTE)
- 1 technician (0.3 FTE)

Thank you