CAEN Electronic Instrumentation

Tools for Discovery

Digital acquisition systems for neutron tubes and solid-state detectors

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2021 ISOLDE WORKSHOP AND USER MEETING

Summary

New developments on digital data acquisition chain for solid-state detectors

- 1429 preamplifiers
- 2745 digitizer with settable gain

The NUMEN experiment

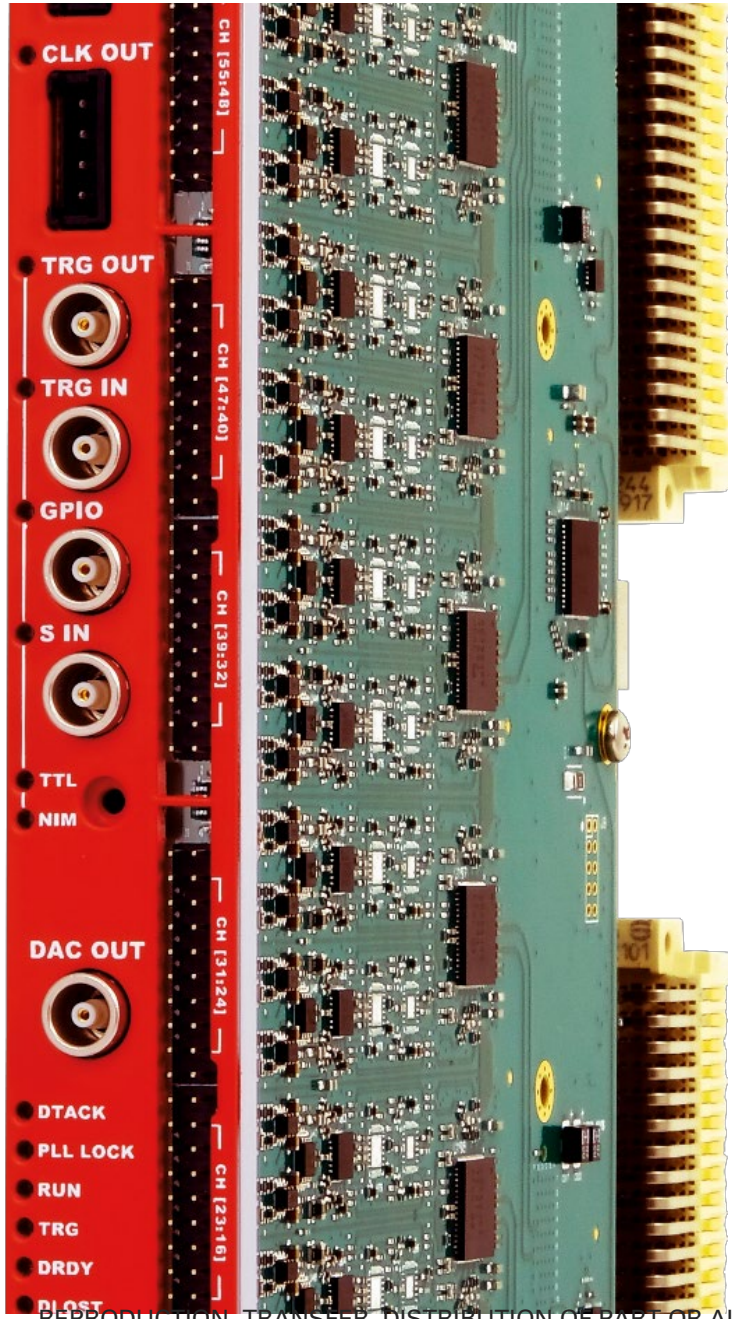
New developments on digital data acquisition chain for ^{3}He tubes

- 1421 preamplifiers
- 7771 digitizer

The active/passive neutron detection system of the MICADO project

The A1429

- 64 ch highly integrated charge preamplifier
- 5 keV energy resolution
- Differential output 4 Vpp
- Good for multi-strip silicon detectors as well as for multi-channel detectors with common bias
- Low power consumption
- Two LEMO Bias inputs, (0 to 31 and 32 to 63)
- Available in different sensitivities: 20, 45, 90, 200, 400 mV / MeV.
- Micro-coax cable assembly (up to 3m) for inputs



The 2745 digitizer

The 2745 CAEN digitizers

Adjustable gain (SW selectable)

- From 0 to 40 dB (x100), from 4 Vpp down to 40 mV FSR

64 channel, 125 MS/s, 16 - bit waveform digitizer

High channel density spectroscopy

Good fit for highly segmented solid-state detectors.

Open FPGA: SCI-Compiler tool for beginners or advanced firmware template

Four 40-pin, 2 mm header connectors with DIFF or SE inputs

1 GbE, **10 GbE**, **USB 3.0** and CONET 2.0 (optional) connectivity

Common Trigger (waveforms) or Individual Self-trigger modes

DPP options: PHA, QDC, PSD, CFD

Advanced Waveform Readout modes: ZLE, DAW

Readout interfaces

10 Gb Ethernet: Bandwidth = ~280 MB/s

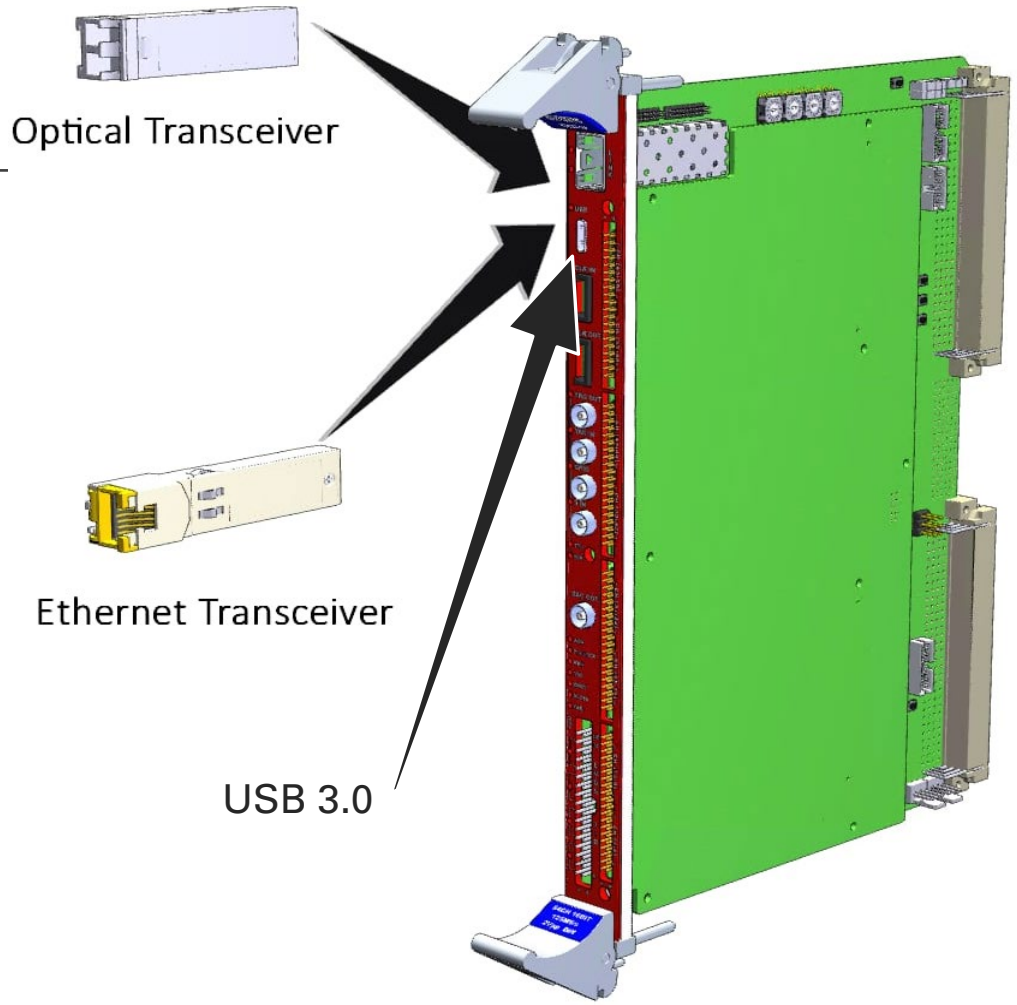
1 Gb Ethernet: Bandwidth = ~100 MB/s

USB 3.0: Bandwidth = ~280 MB/s

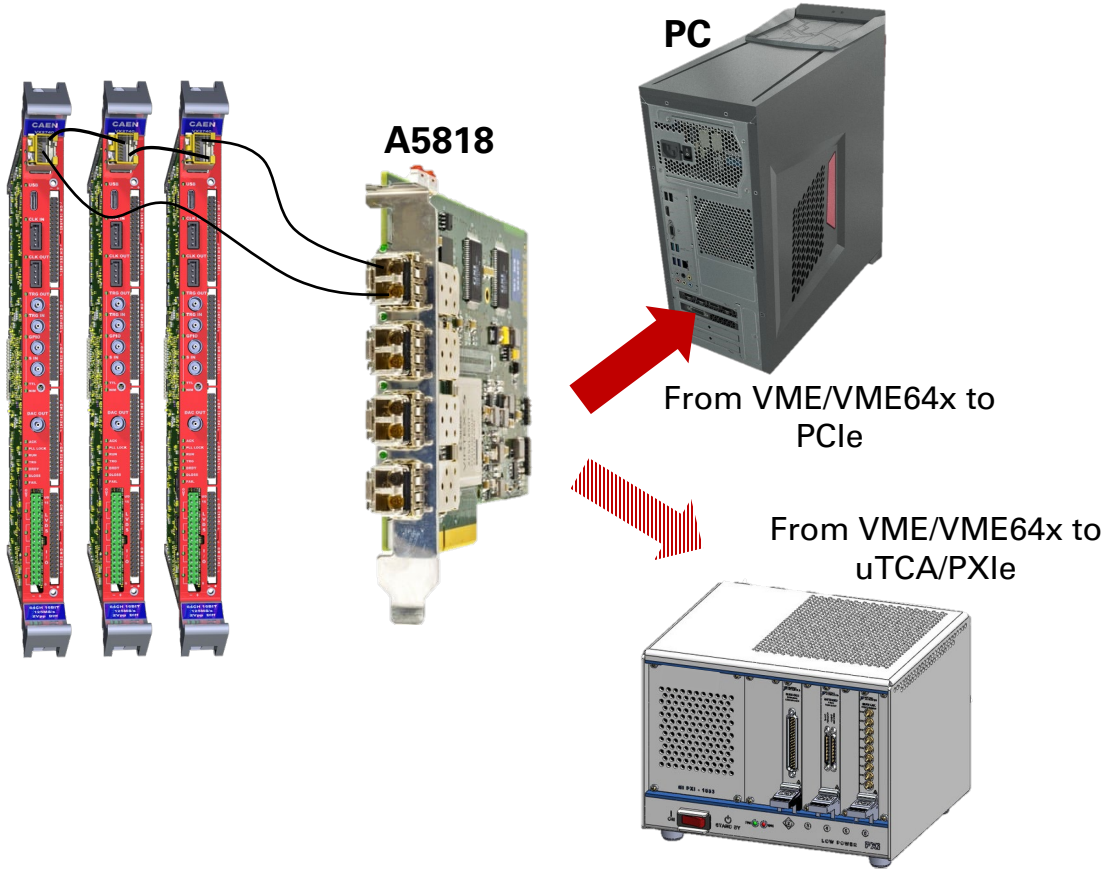
USB 2.0: Bandwidth = ~30 MB/s

PCIe: via optical links, daisy chainable. Aggregate Bandwidth = ~320 MB/s

VME: legacy from the past… being dismissed



CONET2/PCIe readout



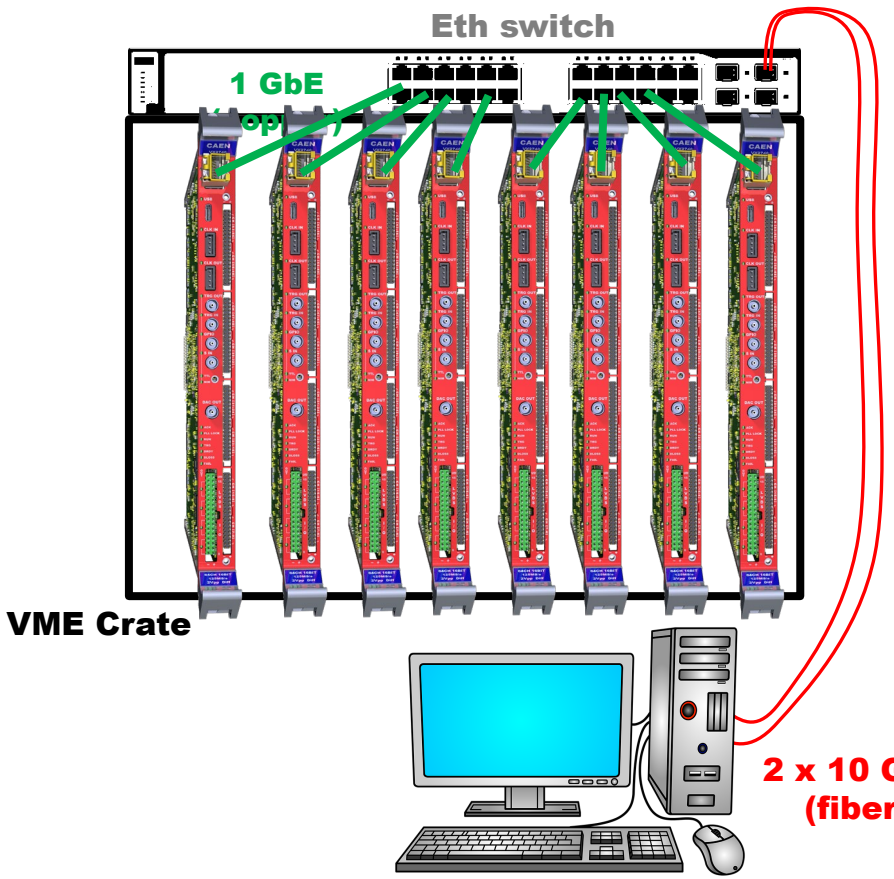
Backplane free policy: VME is kept for power only

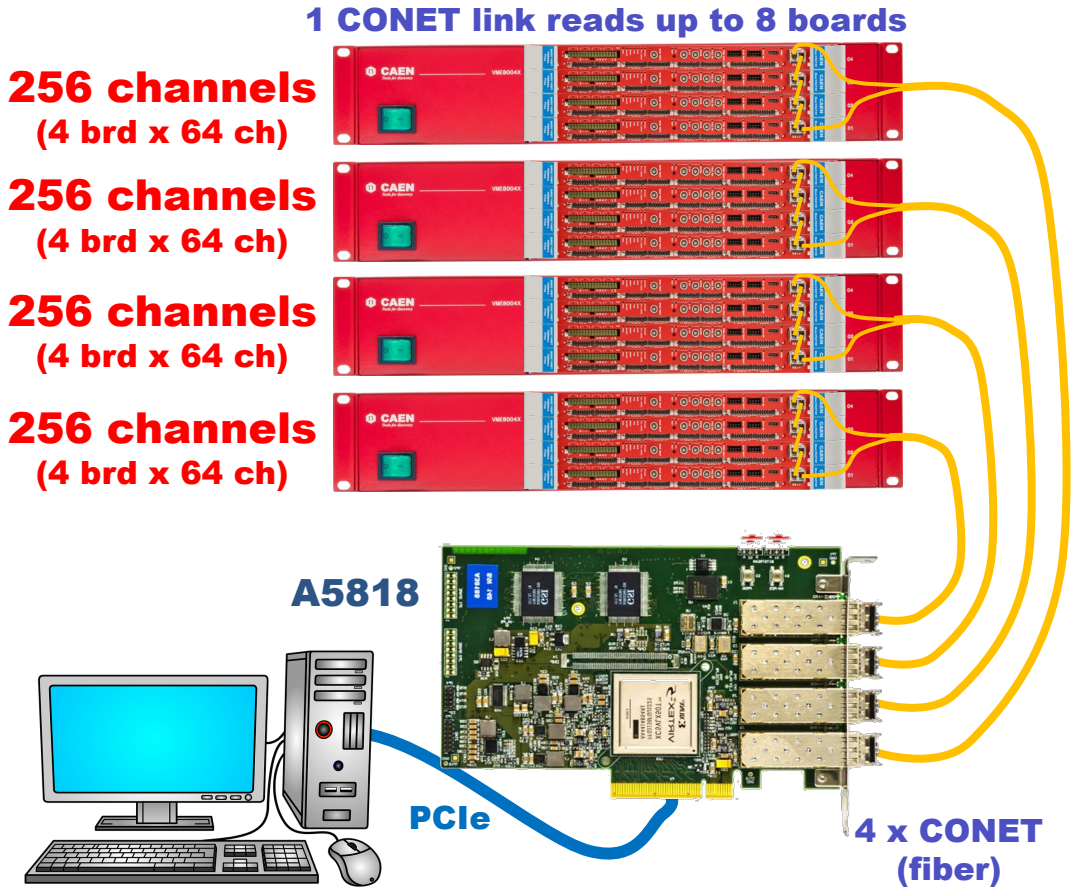
Arrangement in Desktop form factor

easily

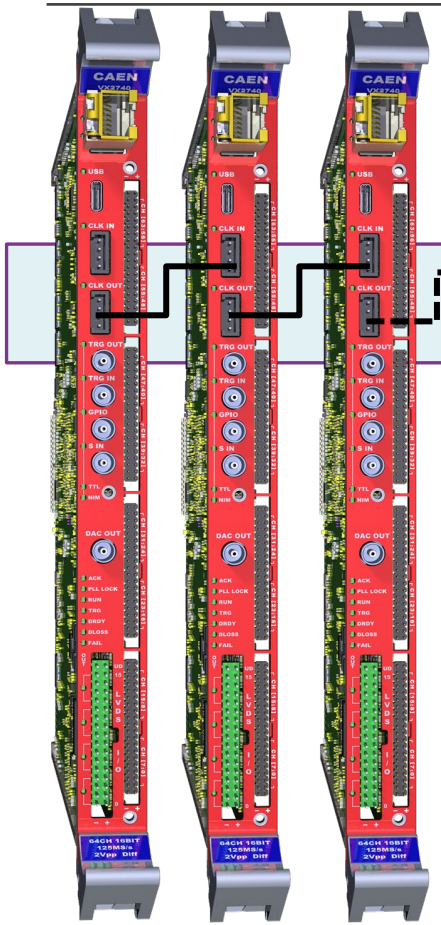
A5818 into PCIe slot, but possibility of expansion to uTCA/PXIe

Multiboard Readout – Ethernet vs. CONET2





Digitizers Synchronization



Synchronization of a CAEN Digitizer multiboard system

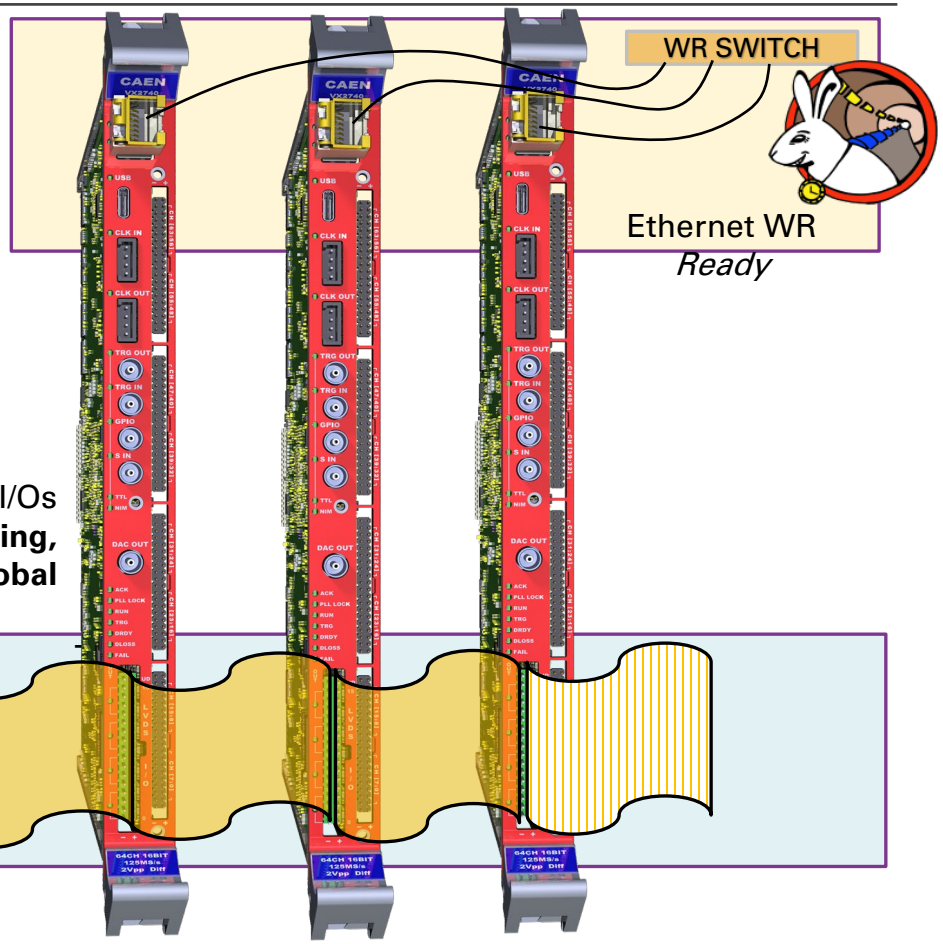
CLK+SYNC

Clock and Sync distributed over a single cable –

Alternatively over the **VME backplane** user-defined pins

Synchronization with external systems

Additional LVDS I/Os for **trigger sharing, busy , veto** and **global timestamp**



Model	# channels	MS/s	# bit	Applications
x2740	64	125	16	64 MCAs for high channel density spectroscopy Good fit for Neutrino and Dark Matter experiment
x2745	64	125	16	Variable gain input stage Designed for Si detectors readout
x2725/x2730	32	250/500	14	Medium-fast detectors Sub-ns timing combined with high energy resolution Optimal trade off between cost and performances
x2751	16	1000	14	Ultra-fast detectors (diamond, MPCs, SiPMs) with ps timing applications Potential upgrade to 2.5 GS/s
x2724	32	125	16	Spectroscopy & MCA Advanced Front-End (gain, shaping, AC/DC coupling …) Semiconductor detector (HPGe, Clover, SDD ,…) Typically connected to charge Sensitive Preamplifier

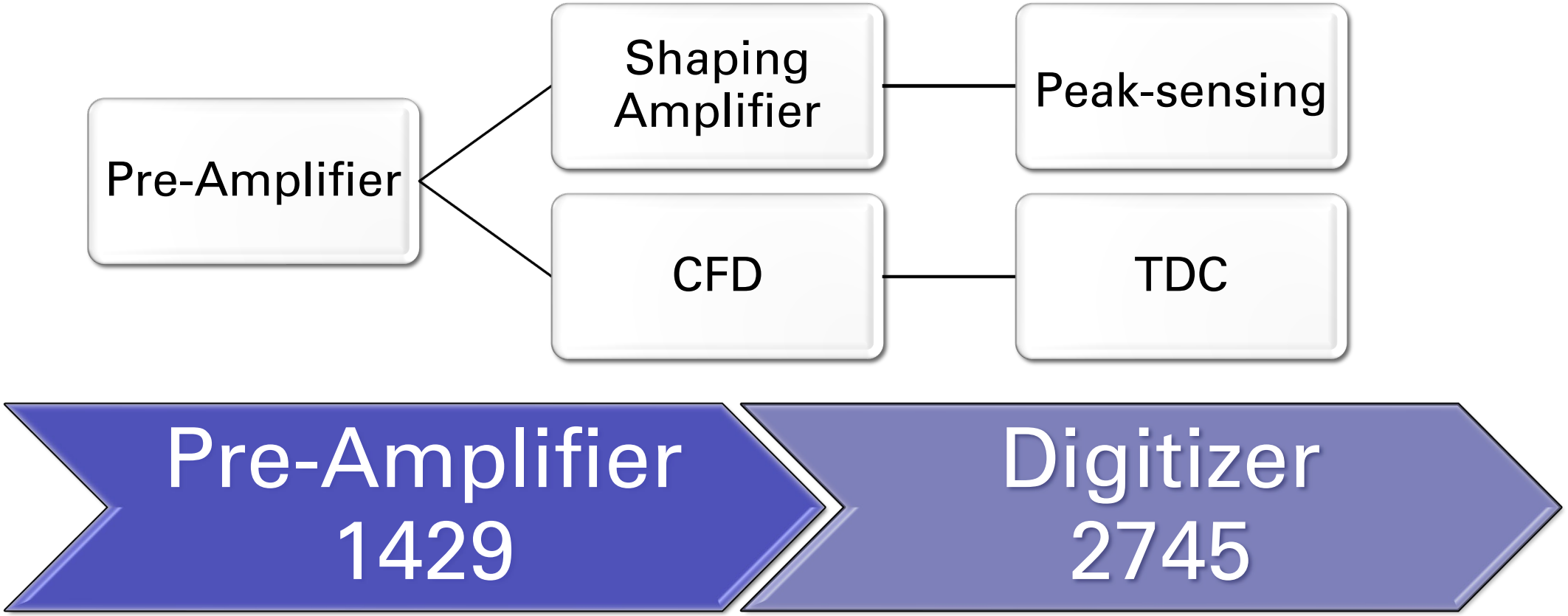
Birdseye view – what's coming

Acquisition Modes

	62.5 MS/s	100/125 MS/s	250 MS/s	500 MS/s	1000 MS/s	> 1000 MS/s	Description
Scope	●	●	●	●	●	●	Oscilloscope mode, all channels triggered simultaneously
PHA	●	●	●	●	●	●	Spectroscopy with Charge Preamps and PMTs
PSD	●	●	●	●	●	●	Neutron/Gamma/Alpha discriminations with Scintillators
TDC	●	●	●	●	●	●	Digital CFD or LED, Resolution < 1 ns (<100 ps with 500/1000 MS/s)
QDC	●	●	●	●	●	●	Self-gated charge integrator
ZLE/DAW	●	●	●	●	●	●	Waveform fragments (zero suppression, adaptive acquisition window)
Open FPGA	●	●	●	●	●	●	User defined Algorithms and Output Data Content

● Ready ● Coming soon ● Not Available

The digital acquisition chain vs analog



The digital acquisition chain vs analog

The digital acquisition chain has many advantages over the old analog one:

- Less module to be configured (and purchased).
- Denser solution, space saved by less modules and more channels per module.
- Less cables.
- Overall easier setup and shorter configuration time, for a smoother data taking.
- Digitizer allows exhaustive and complete data recording with only one acquisition chain: PHA returns Energy, Timing and Pulse Shape at once.

NUMEN

3D sketch of the NUMEN multidetector to be installed on the MAGNEX spectrometer [1]:

a) the new scattering chamber,

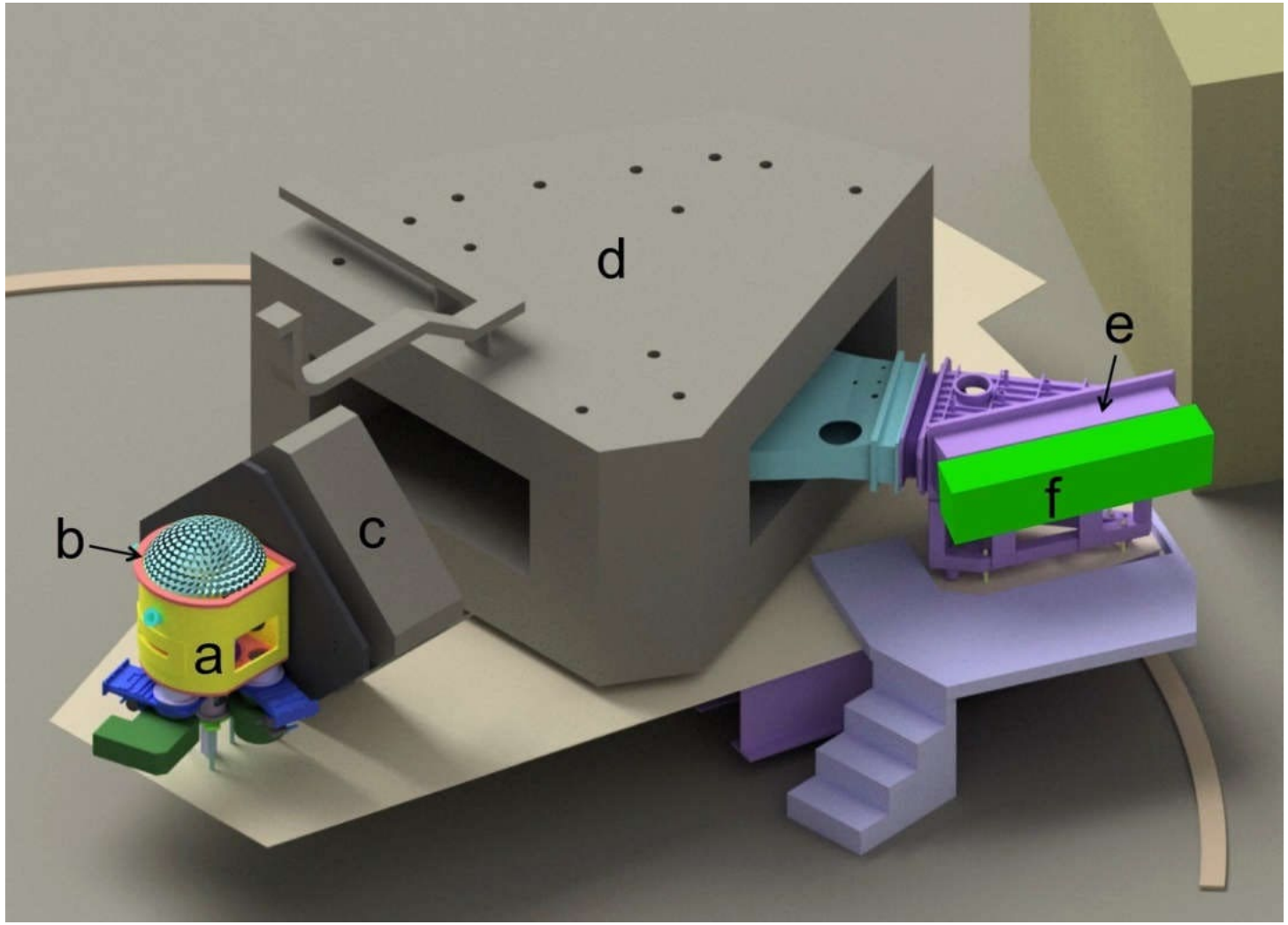
b) the gamma detector array,

c) the input quadrupole,

d) the magnet,

e) the focal plane gas tracker detector,

f) the particle identification detector.

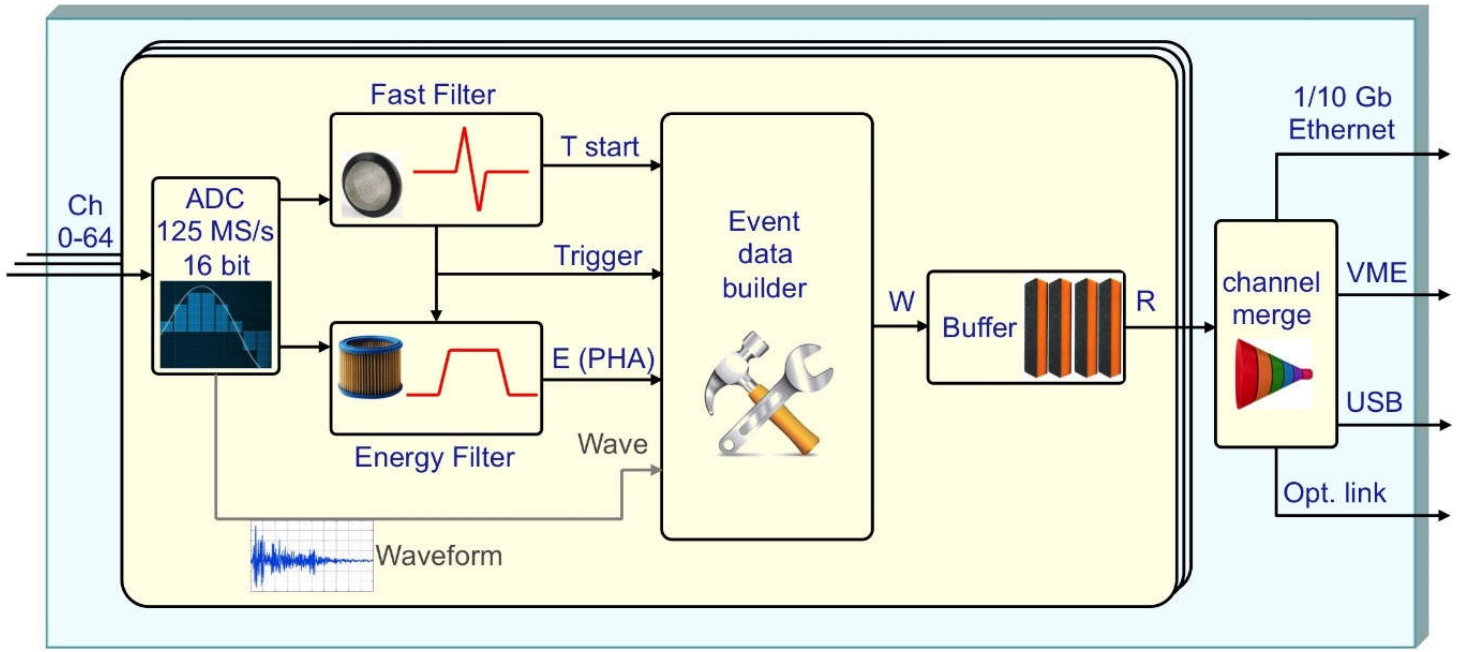


[1] Finocchiaro, Paolo et al. for the Numen Collaboration. **The NUMEN Heavy Ion Multidetector for a Complementary Approach to the Neutrinoless Double Beta Decay**. Universe. 6. 129. DOI:10.3390/universe6090129.

NUMEN

Benefits for the experiment:

- uniform front end and readout hardware architecture;
- reduction and simplification of the spares;
- programmable signal handling algorithm, tailorable to each detector type;
- very good energy resolution, 16-bit conversion;
- very good timing capabilities, in 8-ps steps;
- pile-up detection and tagging;
- high data throughput, nominally up to 10 Gbit/s;
- cost reduction due to purchasing only one model for all the detector subsystems.



Block scheme of the VX2740 digitizer operational features.

Neutron measurements and MICADO

^{3}He tubes

MICADO is an EU funded project, it comprises of several partners from private sector and academia.

CAEN Tools for Discovery

orano

DE LA RECHERCHE À L'INDUSTRIE cea

X-RAY IMAGING EUROPE

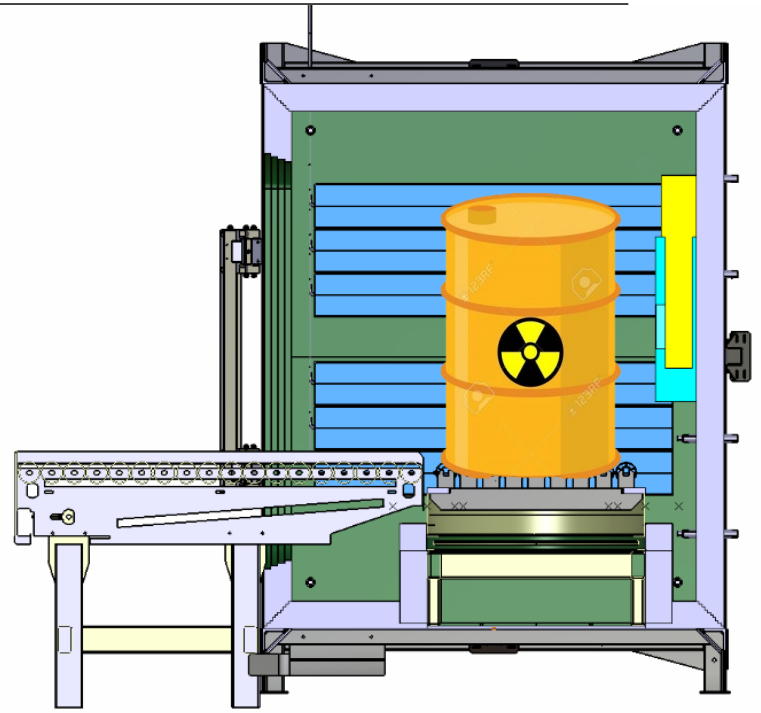
CTU CZECH TECHNICAL UNIVERSITY IN PRAGUE

ENEA Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile

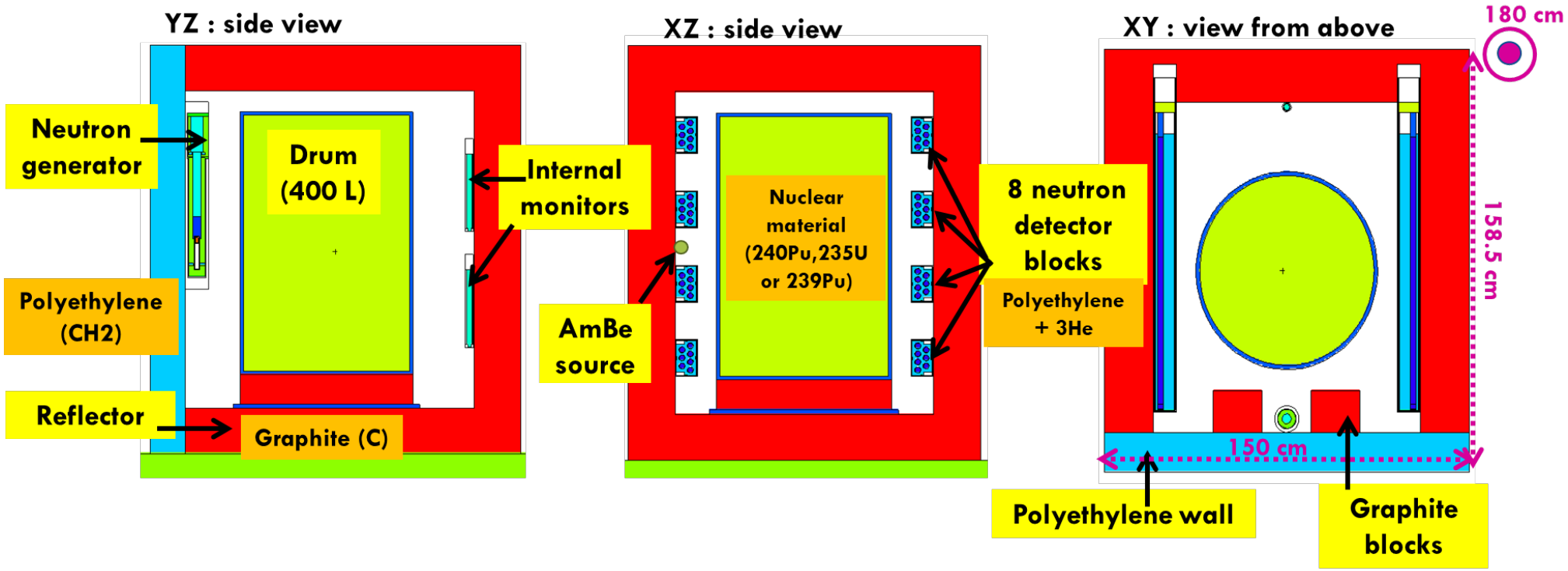
INFN

sck cen

SOGIN



Enclosure studied to contain a waste drum and perform both active and passive measurements with minimal background.



Passive/active neutron system

New A1421 pre-amplifier

- Designed for neutron counting
  - ^{3}He or Boron coated tubes
- Pre-amplifier with a 1 ms decay time
- 700 ns shaper
- 28 V/pC gain
- Embedded discriminator
- HN connector for HV
- Bias +/- 6V

Dedicated electronics for neutron system

- Neutron Pulse Train Recorder (NPTR)
- 32 independent channels
- Time-stamped list of TTL pulses
- 10ns pulse pairs resolution
- Complete information on neutron counting
- Able to characterize nuclear material in passive mode and in active nuclear material interrogation.

Customization for MICADO

The R7771 is designed for both active and passive neutron measurements, in MICADO the rate for active measurements is so high that the list mode cannot sustain the data rate, therefore the multi-channel scalar (MCS) mode is used, so that only relevant data is extracted from the module and sent to the acquisition system computer.

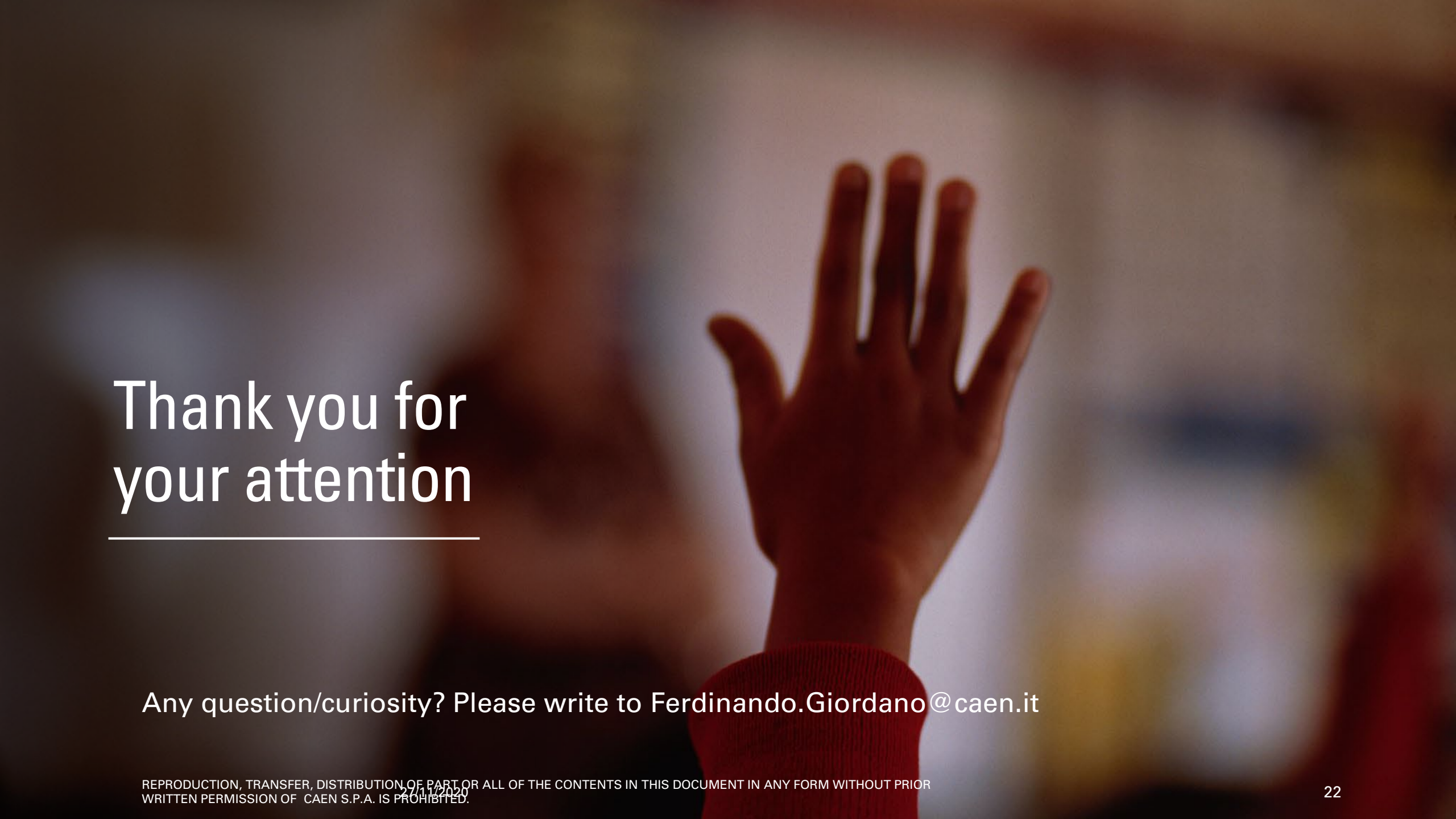
In MICADO we want to investigate the amount of actines present in a waste drum, thanks to a dedicated software this operation can be sone directly by the R7771 (given the matrix information about the drum is known), which can return directly the quantities of uranium and plutonium inside the waste.

Conclusion

CAEN is always developing it acquisition systems, while maintaining its lead for power supplies. Unfortunately, in this talk I did not cover our new R&D for power supplies, specifically those for hostile environment (the new EASY6000 family), if you have any question do not hesitate to ask.

The new digitizer family is expanding, giving more options to experimentalist for high performance acquisition systems, at the same time trying to simplify as much as possible the setup time while keeping maximum flexibility (thanks for dedicated FW, Open-FPGA, and COMPASS).

New solutions are also being developed in the contest of funded EU projects, thanks to collaborations with the research centers and universities all around Europe.



Thank you for your attention

Any question/curiosity? Please write to Ferdinando.Giordano@caen.it