DANTE: A Digital Pulse Processor for XRF and XAS experiments

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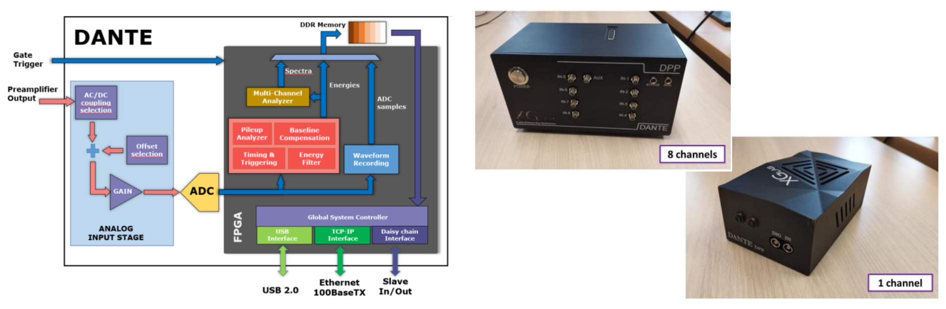
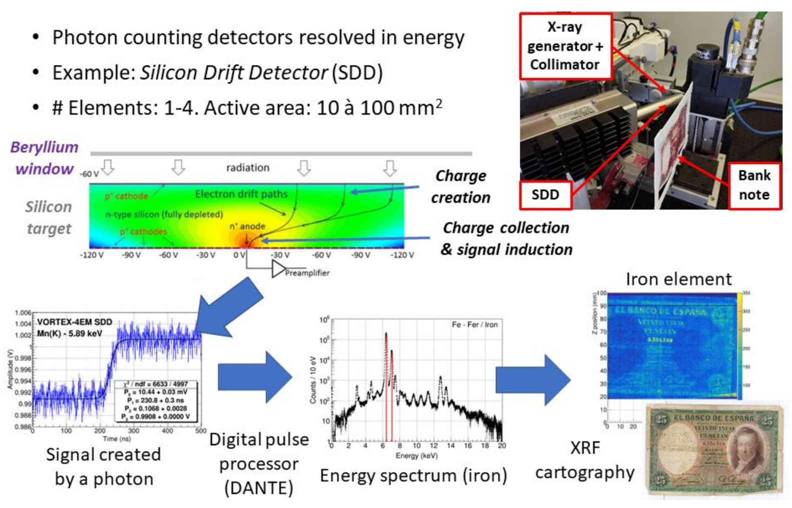
Introduction: DANTE, EDX & synchrotron

DANTE Digital Pulse Processor (DPP)

- Designed for X-ray spectroscopy applications using a fluorescence/EDX detector (SDD or germanium)
- Channels: 1, 8 or up to 32 custom version
- Controlled with a C++ based library, which also offers Python and LabView compatibility

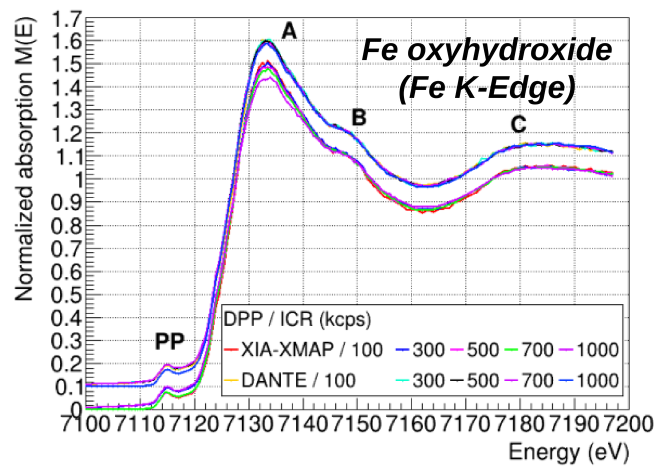


Energy Resolved Detectors (EDX)



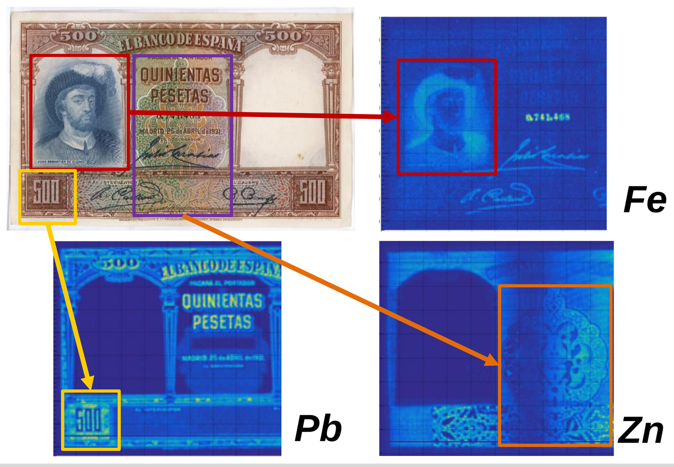
X-ray Absorption Spectroscopy (XAS)

- The absorption coefficient of a chemical element is measured as a function of the scan in energy around the ionization threshold of an element.
- The XAS spectrum provides information on:
  - **A,B:** Electronic structure of the excited atom (oxidation state & environment)
  - **C:** Interatomic distance between the excited atom & its neighbours
  - **PP:** Oxidation state of the excited atom



X-ray Fluorescence (XRF)

- Fluorescence signal of a sample is measured after an excitation by incident X-ray photons at a given energy
- The energy of the fluorescence signal depends on the element (Fe: 6.4 keV, Pb: 10.5 keV)
- Intensity is proportional to the element concentration
- Combined with a micro-beam, an element map can be collected by scanning the sample position



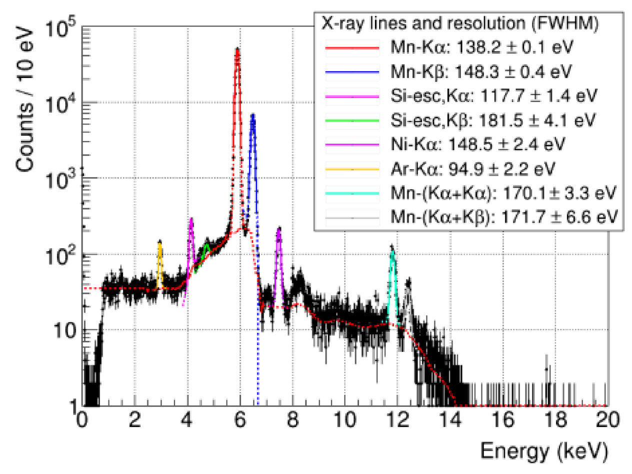
Performance with an X-ray generator source

Goals:

- DANTE DPP performance with two SDD detectors (actual & former CMOS preamplifier technology)
- Comparison with XIA-XMAP, Xspress3, XIA-FalconX DPPs

Experimental setup & procedure:

- X-ray generator source, SDD window perpendicular to beam & manganese foil target (5.9 keV X-rays) in beam at 45 degrees
- X-ray generator settings: 15 & 50 kV, 0 - 40 mA

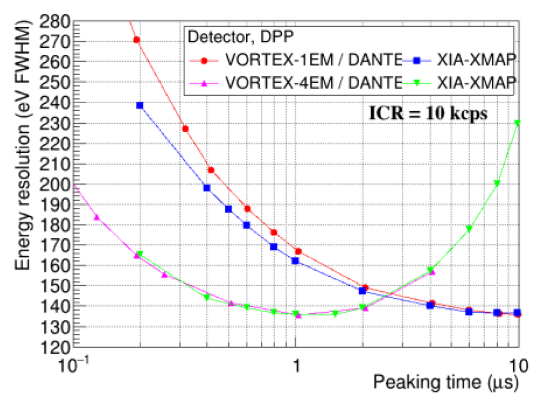


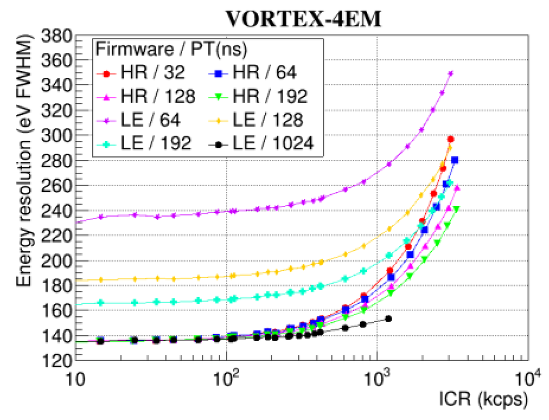
Low-Energy optimized (LE) firmware:

- **Standard trapezoidal filtering.** Energy resolution & dead time depend on PT.
- Energy resolution is stable with ICR

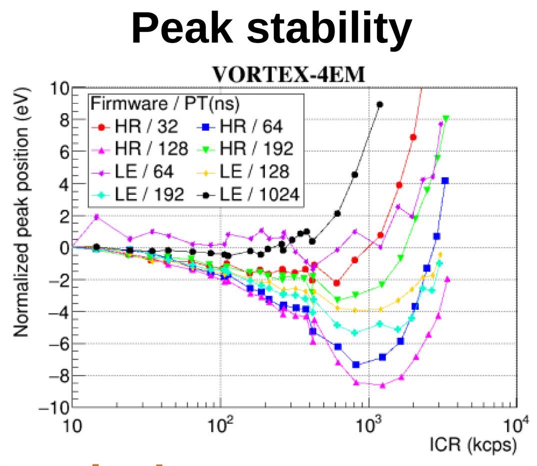
High-Rate optimized (HR) firmware:

- **Variable trapezoidal filtering**, which selects an optimum peaking time (PT) between a **min (energy resolution)** and a **max (dead time)**
- Energy resolution degrades at higher ICR

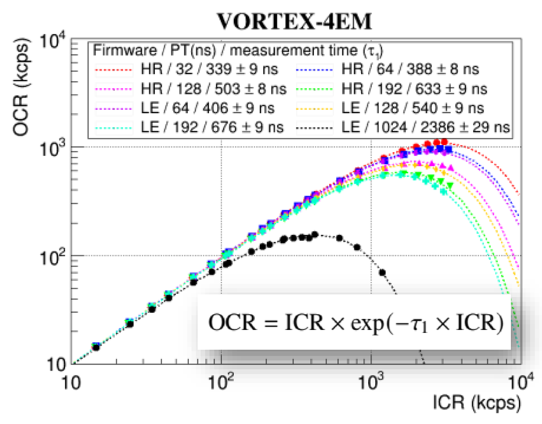




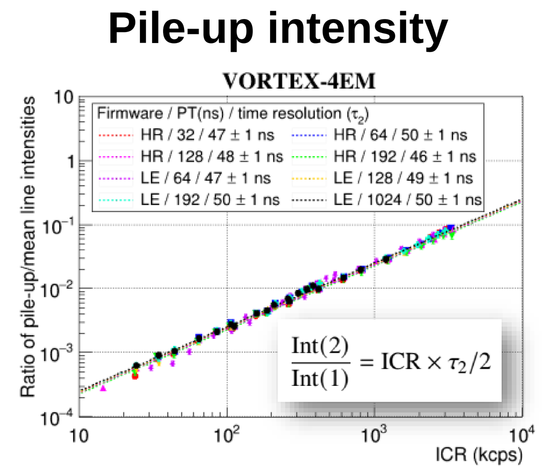
Peak stability



Dead time



Pile-up intensity



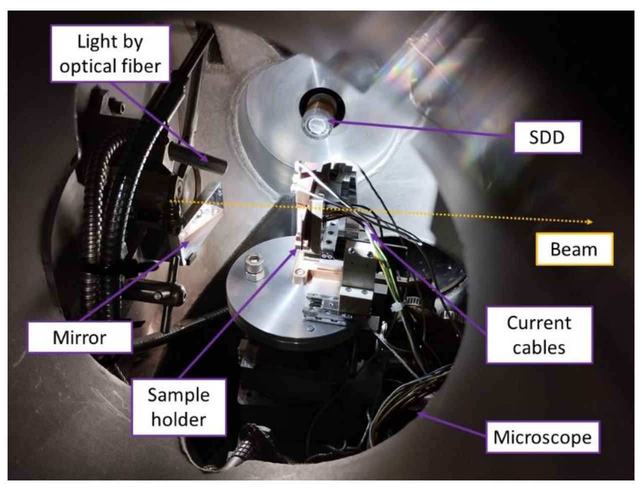
Conclusions:

- DANTE LE firmware keeps a constant energy resolution even at high rates (~1 Mcps).
- DANTE has the best-in-class pile-up rejection, i.e., pile-up peaks are less intense.
- DANTE HR firmware works at lower dead time at high rates, keeping a good energy resolution.

XRF & XAS experiments at LUCIA beamline

LUCIA beamline features:

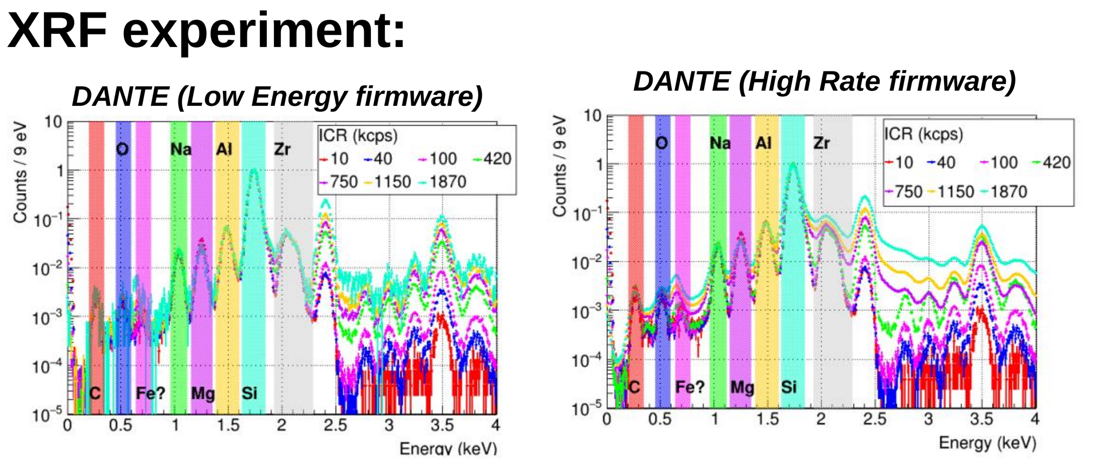
- Tender X-ray beamline (Energy range: 0.8 – 8 keV)
- Study of heterogeneous samples: chemical speciation by macro- or µ-XAS; or elementary mapping by µ-XRF



Beam experiments:

1. XRF of a home-made glass sample
   - Comparison between LE and HR firmwares of DANTE
2. XAS of a ferrihydrite sample (Iron K-edge)
   - Comparison with XIA-XMAP and FalconX DPPs

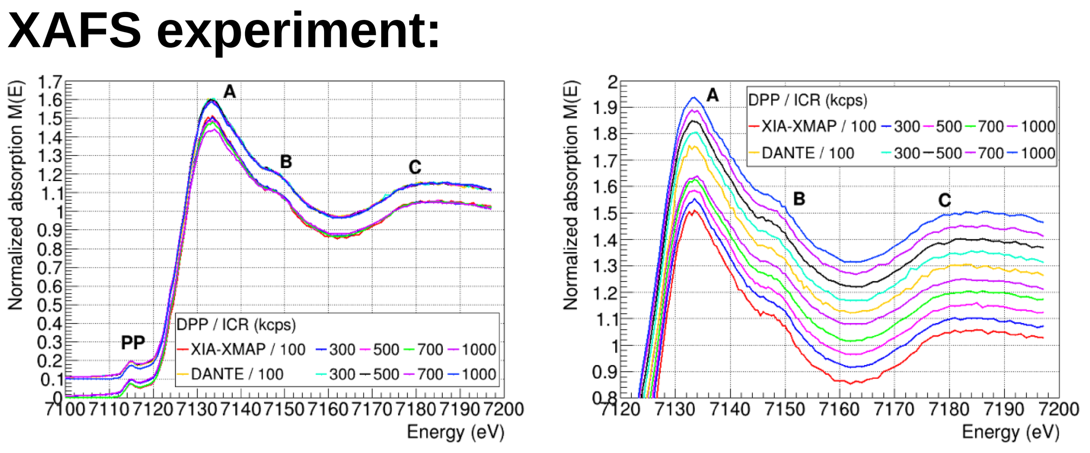
XRF experiment:



Conclusions:

- More statistics at high ICR for HR firmware spectrum than for LE one
  - HR firmware keeps dead time moderated at high ICR
- No change in shape for LE firmware at high ICR, while slight deformation for HR firmware
  - Slight degradation in energy resolution at high ICR for HR fw

XAFS experiment:



Conclusions:

- XAS spectra generated by XIA-XMAP and DANTE DPPs have similar shape and show the expected structure for ferrihydrite sample.
- For ICR of 700-1000 kcps, there is a small deformation of the main peak for XIA-XMAP spectra (0.074 units), insignificant for DANTE (0.015 units)

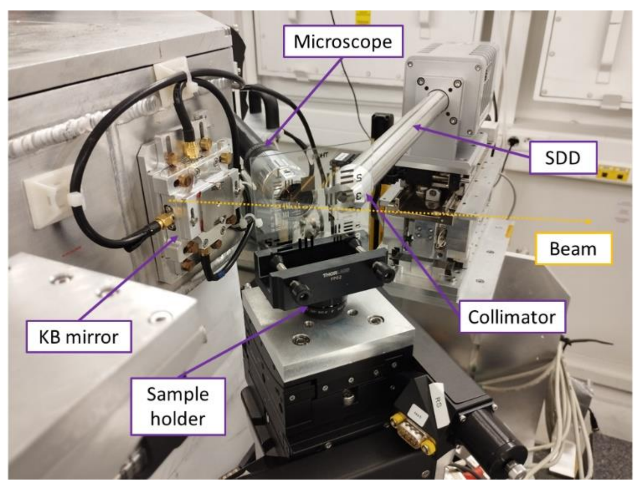
XRF cartography at PUMA beamline

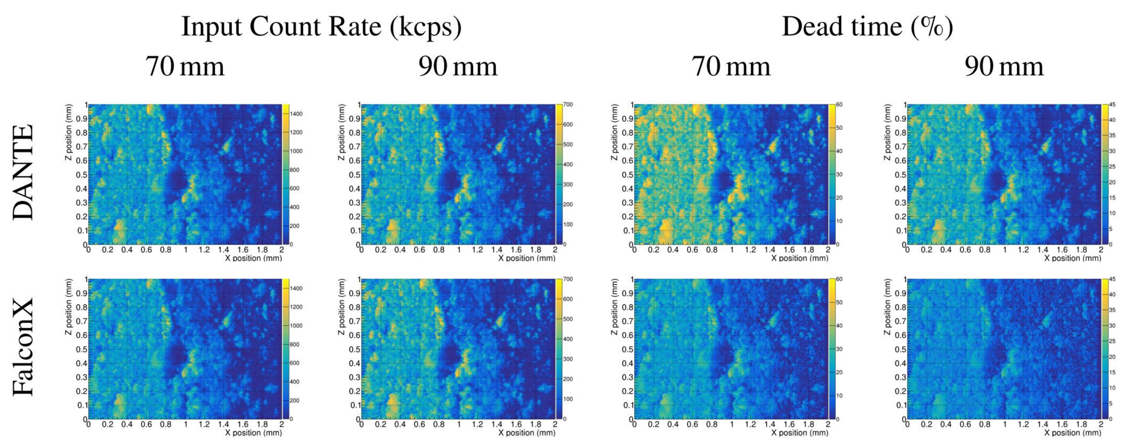
PUMA beamline features:

- Hard X-ray beamline (Energy range: 4 – 23 keV)
- Study of materials from cultural heritage

Beam experiment (µ-XRF cartography):

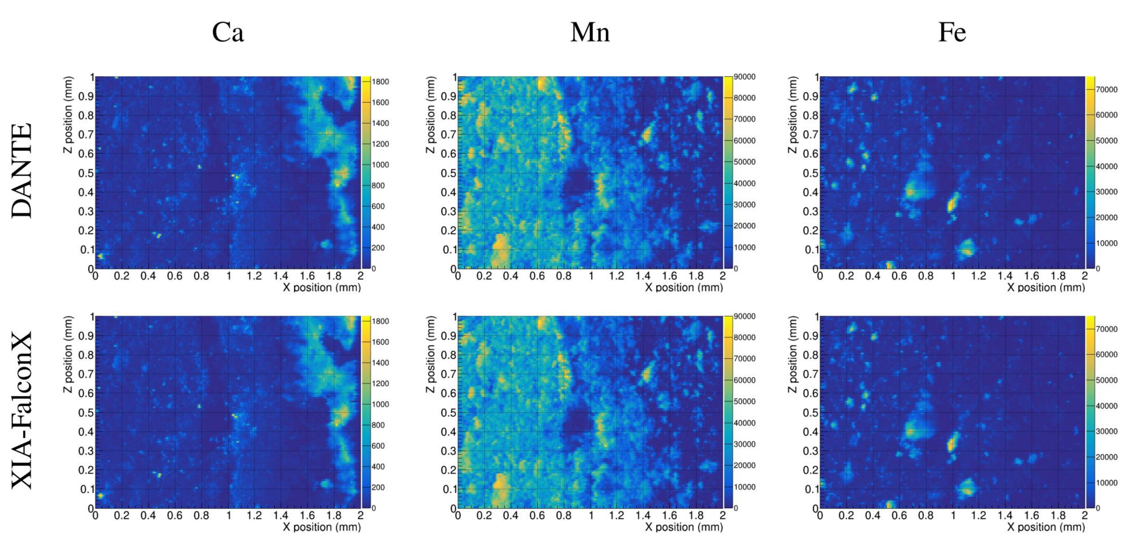
- Flyscan system & a cave stone sample
  - Comparison of DANTE DPP + HR firmware with XIA-FalconX DPP





Experimental procedure:

- Scan X/Z-axis, area: 1 mm x 2 mm, step of 10 µm, 100 ms exposure time
- Sample – SDD distance: 70 & 90 mm
- Data analysis with pyMCA software
- Normalization for DPP dead time



Conclusions:

- DANTE DPP shows ~50% higher dead time values than XIA-FalconX.
- Comparing the chemical maps of DANTE & XIA-FalconX, no clear difference in terms of ICR contrast or spatial resolution
- This fact is explained by the better energy resolution of DANTE at high ICR compared to XIA-FalconX, as previously observed in laboratory

Conclusions:

- DANTE shows excellent energy resolution & pile-up rejection power.
- DANTE has been integrated in SOLEIL TANGO control system. It can be used in step-by-step or continuous scan mode.
- DANTE has been extensively tested with an X-ray generator source and at XAS/XRF experiments at LUCIA and PUMA beamlines.
- Test results have been published in *JINST* **18** (2023) T06011
- Two optimized DANTE DPP units are available for SOLEIL beamlines at Detectors POOL (1 channel & 8 channels).
- DANTE is being tested in other SOLEIL beamlines.

Acknowledgments:

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