Development of an SDD-based detection chain for the Chinese eXTP X-ray astronomy mission

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CONTEXT

The eXTP (Enchanced X-ray Timing and Polarimetry) mission

- Future X-ray astronomy satellite
- Objectives: solve fundamental physics questions especially study the behavior of ultra-dense matter and matter in strong gravity and intense electromagnetic fields.
- Means: observe various classes of compact objects (e.g. neutron stars, black holes, etc.) to study the fine temporal variations in their X-ray spectrum and polarization.

The scientific case and the payload are developed by a Sino-European Scientific Consortium led by IHEP Beijing and INAF Rome.

SFA: Spectroscopic Focussing Array

PFA: Polarimetric Focussing Array

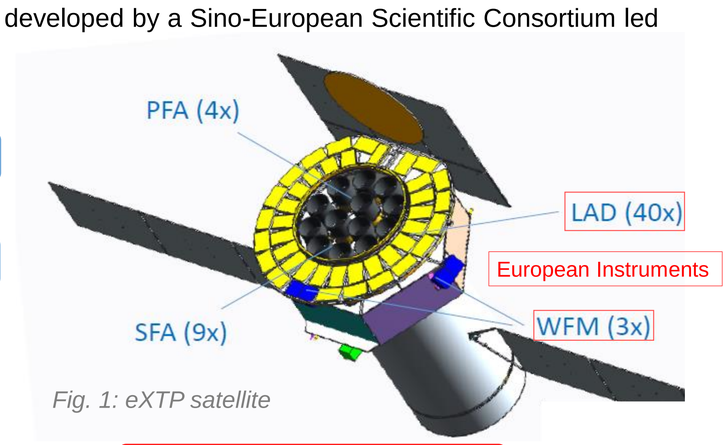


Fig. 1: eXTP satellite

LAD : Large Array Detector

40 modules
640 detectors → 143,360 measurement channels!
Optimized for spectroscopy: 960 µm anodes
Spectral resolution < 240 eV FWHM @ 6 keV

WFM : Wide Field Monitor

3 pairs of coded mask cameras
6 detection planes
Optimized for imaging: 169 µm anodes
Spectral resolution < 300 eV FWHM @ 6 keV

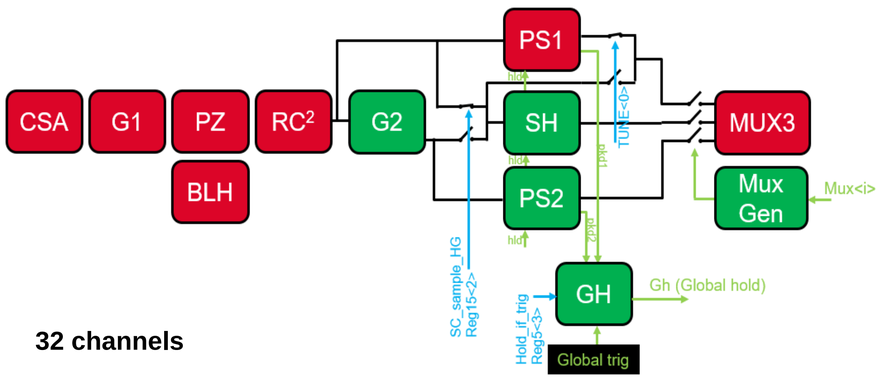
Specifications for the front-end ASIC designed by CEA-Irfu:

Dynamic range: 2-80 keV (Si) energy band for the 2 instruments.

Noise performance in Equivalent Noise Charge (ENC) :	**LAD**	**WFM**
	17 el. rms with I_{leak} = 5-7 pA	**13 el. rms for I_{leak} = 2-3 pA**

DESIGN

IDeF-X S front-end ASIC



32 channels

CSA: Charge Sensitive Amplifier
G1/G2: Gain stage
PZ: Pole Zero cancellation
BLH: Baseline Holder
PS1/PS2: Peak Stretcher
SH: Sample and Hold
GH: Global Hold

Fig. 2: In red, the legacy of IDeFX-HDBD ASIC and in green, new functions added designed by CEA-Irfu

PS2 is used for the main charge measurement on a 30 keV dynamic range.
SH is connected to G2 and is used to measure the common noise on all channels.
If one channel is hit (trigger flag) the global hold is going to be activated and the noise is sampled by all SH circuits.
The PS1 circuit is used only if the PS2 is saturated.
In this case the charge information is memorized by PS2 that has an 80 keV dynamic range.

Daughter board

Fig. 3: Electronic board with ASIC stand-alone (bottom side).

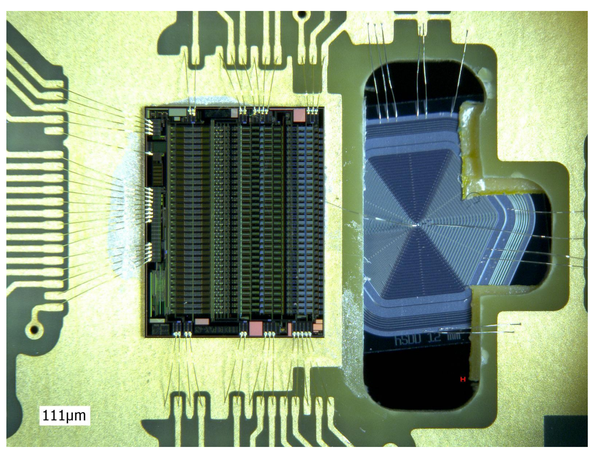
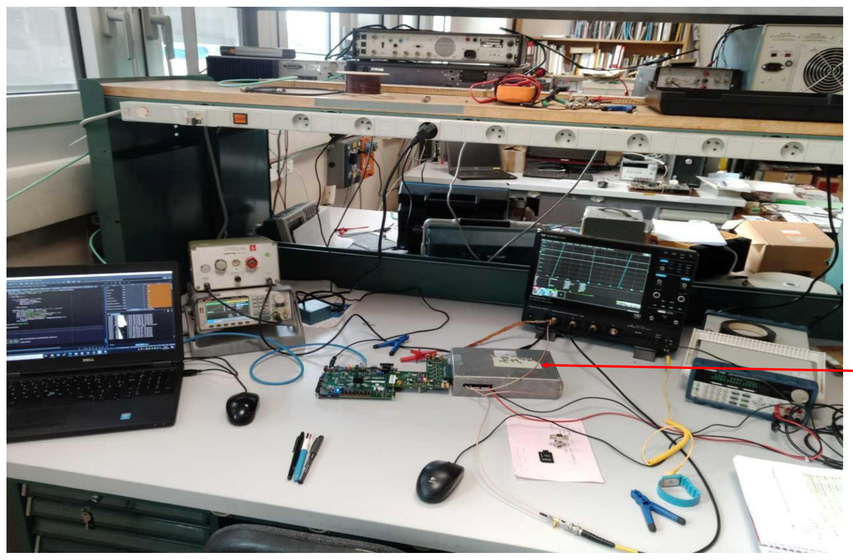


Fig. 4: Close-up of the board with the SDD glued on the top side and connected to the ASIC.

RESULTS

Electricals tests

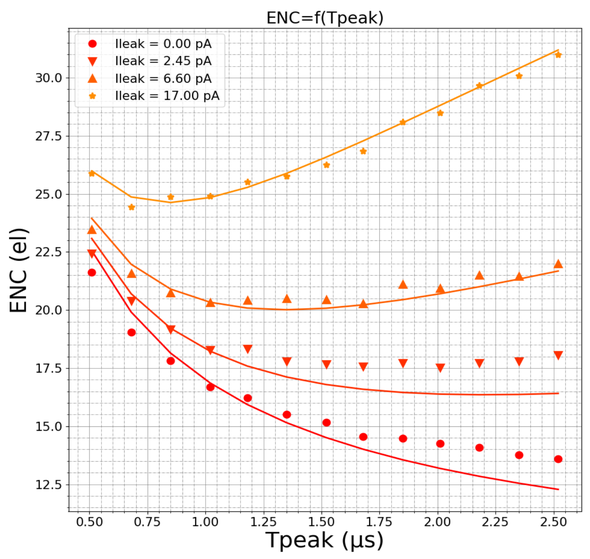


ASIC daughter board

Fig. 5: Test Setup for electrical tests

Noise model

$$ENC^2 = \frac{\alpha \times (C_{tot})^2}{T_{peak}} + \beta \times (C_{tot})^2 + \gamma \times \frac{2 \times I_{leak} \times T_{peak}}{q}$$



With:
- Tpeak: the peaking time, time from 1% to 99% of the signal
- α, β, γ: three variables extracted from measurements:
  $\alpha \times (C_{tot})^2$= 228*10^{-6} el².s^{-1}
  $\beta \times (C_{tot})^2$= 59 el²
  γ=1,53
- C_{tot} : the total capacitance
- I_{leak} the leakage current
- q is the elementary charge

Fig. 6: Noise measurements with different leakage current values and ENC modeling (average noise of all channels).

Spectroscopy

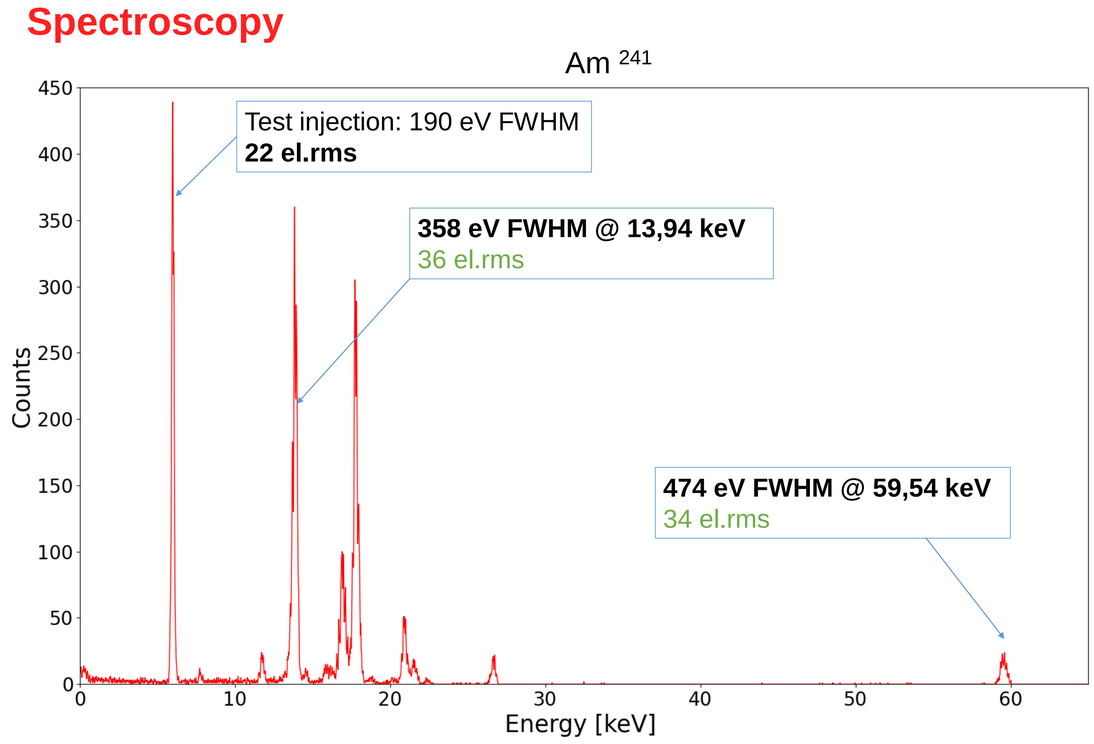


Fig. 7: Spectrum obtained by simulatenously illuminating the SDD with a ^{241}Am source and injecting a reference charge on the ASIC. Detector temperature ~35°C (leakage current around 25 pA).

CONCLUSIONS AND PERSPECTIVES

We designed a new ASIC IDeF-X S to fulfill the eXTP mission requirements for X-ray imaging spectroscopy with silicon detectors. **We demonstrated a floor noise 13 electrons rms**.
The next step is spectroscopy in a vacuum chamber to cool down the detector to decrease the leakage current. The test set-up is in preparation.

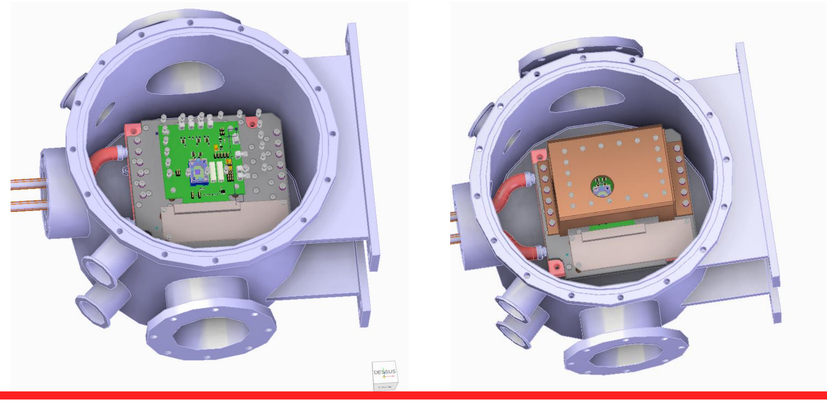


Fig. 8: 3D view of the final assembly for spectral measurements