ATHENA XIFU warm front-end electronics evolution

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The ATHENA space observatory

ATHENA will be the next generation X-ray space observatory. The **X-ray integral field unit (X-IFU)** is ATHENA's cryogenic spectro imager observing the sky with thousands of superconducting micro-calorimeters. The detectors are based on transition edge sensors (TES) in time-division multiplexing (TDM).

XIFU's warm front-end electronics (WFEE)

XIFU's **WFEE** provides **low-noise biasing** current for the detectors (transition edge sensors) and the cold electronics (two SQUID stages) as well as **low-noise amplification** of the SQUIDs output signals. The WFEE is based on the **AwaXe** application specific integrated circuit (**ASIC**) family.

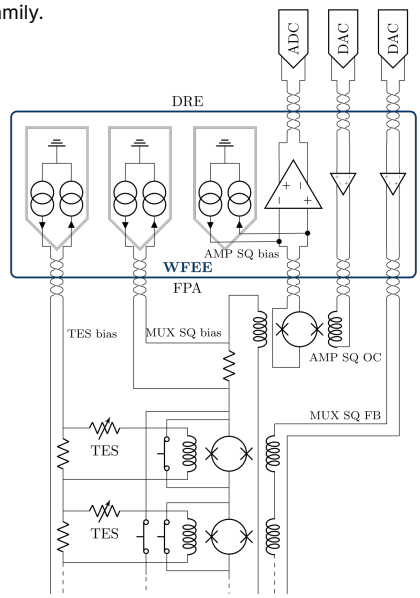

Fig 1. Simplified schematic of an XIFU TDM column readout

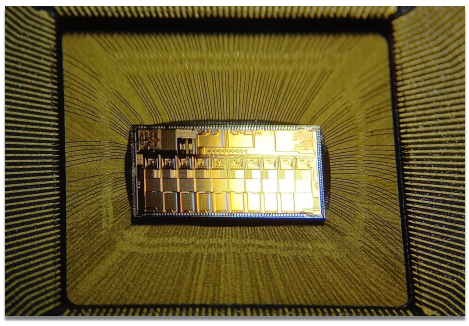

Fig 2. AwaXe_v3 in a CQFP208 package.

Beyond the WFEE Demonstrator model (DM)

Two **WFEE DMs** delivered to CNES and SRON were integrated for validation of X-IFU's readout chain performance. The DMs were based on the **AwaXe_v3** (Fig 2.) designed in AMS 350 nm BiCMOS technology.

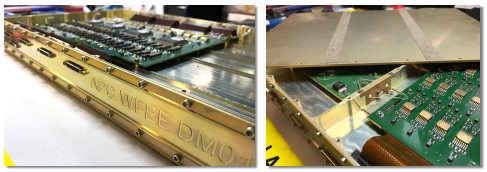

Fig 3. WFEE **DM1** delivered to CNES.

ASIC technology evolution

To anticipate the end of the **AMS BiCMOS 350 nm** node, the WFEE engineering model (EM) was migrated to the **ST 130 nm BiCMOS** technology. Several ASICs were produced and validated, including upgraded **10-bit DACs**, **LNAs with input offset compensation,** a new **two-level addressed I²C** protocol, and **triple modular redundancy (TMR)** output registers. **TID and SEE** tests demonstrated good radiation tolerance.

However, **significant discrepancies** between simulations and measurements, as well as ASIC-to-ASIC variations, were observed. In particular, the **1/f noise, nonlinearity** (INL) and temperature dependence of the current DACs, and the **LNA bandwidth,** could not be reproduced by simulations. Significant chip-to-chip DAC INL and range variations were also measured.

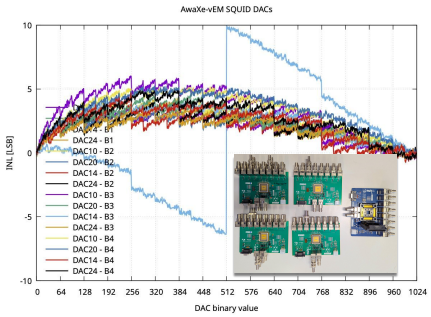

Fig 4. AwaXe_vEM DACs INL. Inlay: test boards.

ASIC packaging

For reliability requirements, the **wire bond length must remain below 100 times the wire diameter**.

Custom ceramic flat package with **reduced cavity size** to shorten bond lengths was developed.

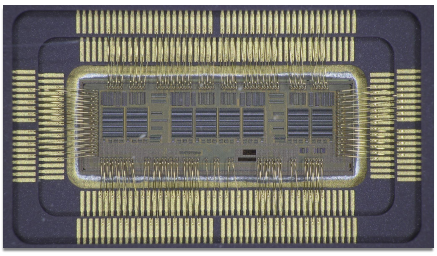

Fig 5. AwaXe_vEM in **custom CQFP256 package**.

AwaXe_TLH - the last hope

A last **AMS BiCMOS 350 nm** run was used to send a new design, the **AwaXe_TLH** with LNA and DACs in independent chips:

- **Improved flexibility** for potential updates
- **Easier to package** due to fewer number of I/O
- Potentially **flight compatible**

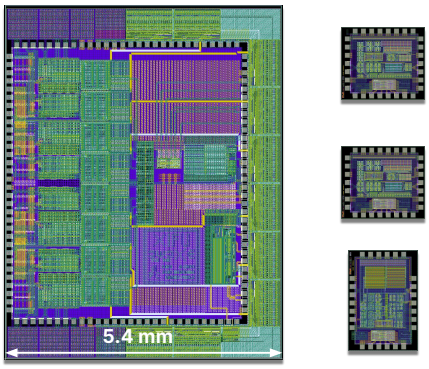

Fig 6. The four AwaXe_TLH ASICs layout. Left: TLHDACs ASIC including 8 slow DACs and I2C communication. Right: The 3 TLHLNA versions.

The AwaXe_TLH ASICs feature:

- Tested **analog performance** (based on DM)
- **Symmetric power supply**
- Improved communication protocol
- LNA design redundancy (3 versions)

Towards the WFEE EM

- Size optimization of the electronics boards
- Evolution of the thermo-mechanical design
- Space-qualified components choice
- Validation of the AwaXe_TLH early 2027

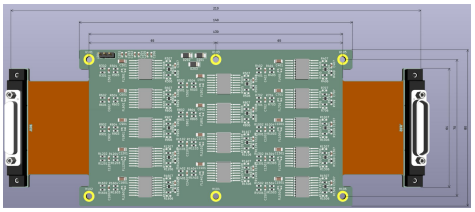

Fig 7. Size-optimized RAS board for WFEE EM

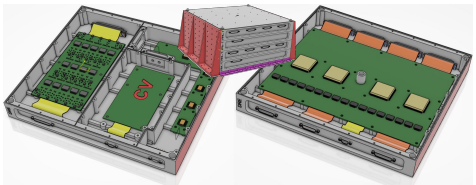

Fig 8. Evolution of the WFEE EM mechanical box

Conclusions

- WFEE **DM performance validation** in X-IFU readout chain.
- New **flight-compatible** ASICs, **AwaXe_TLH**, sent in fabrication.
- WFEE **EM PCBs** design and **optimization** started.
- **Thermo-mechanical design** evolution, compatible with the mission redefinition

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