Enabling low-power MAPS-based space trackers: a sparsified readout based on smart clock gating for the High Energy Particle Detector HEPD-02

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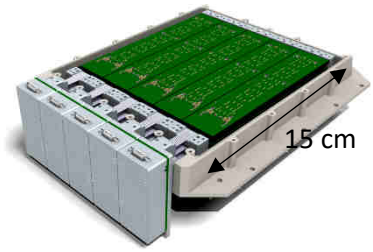
The High-Energy Particle Detector HEPD-02 is one of the payloads that will equip the China Seismo Electromagnetic Satellite (CSES-02) to be launched by the end of 2022, aimed at measuring the flux of particles trapped in the terrestrial magnetosphere through calorimetry (scintillators) and tracking measurements of electrons between 3 and 100 MeV and protons between 30 and 200 MeV.

The HEPD-02 tracker is composed of 5 turrets, each made of 3 planes or "staves" (see figure).



Each stave houses 10 ALPIDE monolithic active pixel sensors (MAPS) for a total of 150 ALPIDE sensors (80 Mpixels). The ALPIDE chip has been developed by the ALICE collaboration for the Inner Tracker System Upgrade at LHC (CERN). The use of ALPIDE in HEPD-02 constitutes the first space application of MAPS: compared to the traditional hybrid microstrip sensors employed in previous space experiments, MAPS enable higher granularity, low noise, compact assembly (with sensor and front-end circuit on the same Si substrate) with much fewer bonding interconnections. On the other hand, the satellite application imposes a strong design optimization effort in terms of power, to match the budget constraints and to allow for an adequate cooling in vacuum.

An application-specific low-power parallel readout architecture has been therefore implemented (see also figure below), by introducing several changes with respect to the one originally designed for ALICE detector at CERN.

- **ALPIDE master-slave architecture**. Each stave contains two chains of 5 chips with one master each.
- **ALPIDE master readout through serial slow-control line** (up to 40 Mbps). The ALPIDE built-in fast data transmission unit (DTU, 1.2 Gpbs) is kept permanently switched-off.
- **Minimal external control and readout electronics.** The whole tracker control and readout is managed by a single fully customized board (TDAQ).
- **Clock gating.** ALPIDE clock is normally kept off, set on only as a response to a particle trigger from the HEPD-02 scintillator system.
- **Dynamic scaling of clock frequency.** The clock frequency can be dynamically reduced in regions of the orbit where the trigger rate is significantly lower.