Development of readout systems

Petr Burian + team/s

IEAP CTU, FEE UWB

Timepix detectors - summary

- Timepix (2006)
  - Frame based
  - 3.2Gb/s

- Timepix3 (2013)
  - Data driven
  - Frame based
  - 5Gb/s

- Timepix2 (2018)
  - Frame based
  - 3.2Gb/s
  - Low power

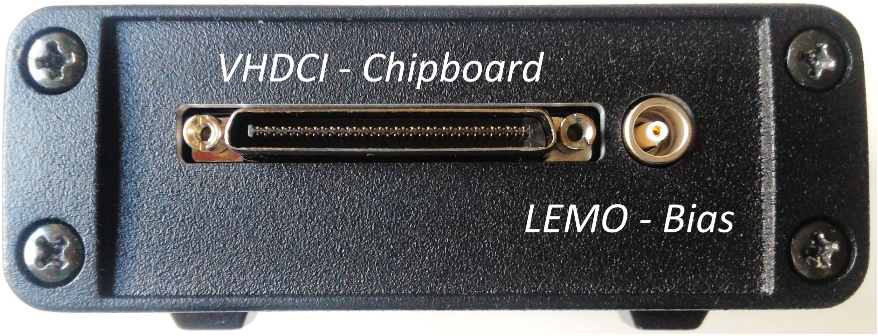
- Timepix4 (2020)
  - Data driven
  - Frame based
  - 160Gb/s

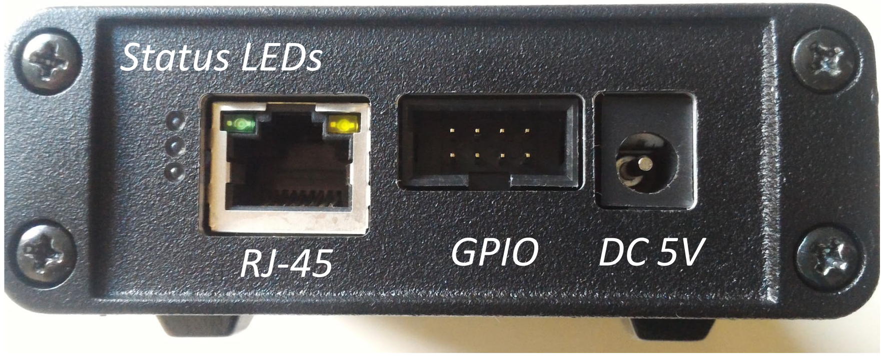
Katherine for Timepix3

- Embedded computer + interface for one Timepix3 (CERN chipboard)
- Optimized for long distance between sensor and readout
- Source of high voltage for bias – both polarities (±300V)
- Gigabit Ethernet Interface
- Long-distance access (up to 100m)
- Dimension: roughly 100x80x28

Katherine – Interfaces

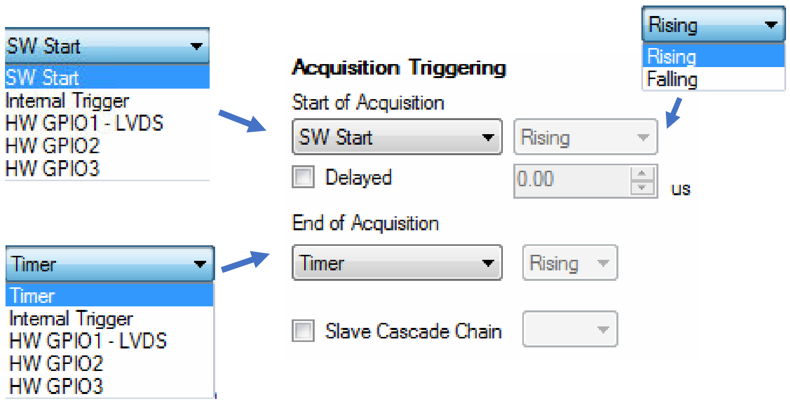
- VHDCI connector
  - Direct connection of chipboard or VHDCI extending cable
- Power supply DC 5V
- Bias voltage – LEMO connector – voltage range ±300V
- Status LED diodes (programmable by user)
- GPIO port – purpose of signals defined by control SW
  - 1x single-ended input (possible to use as external clock)
  - 1x single-ended BiDir signal
  - 1x LVDS input, 1x LVDS output

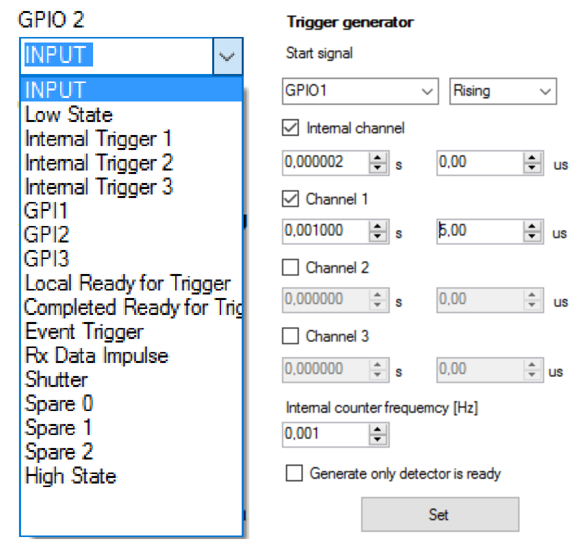




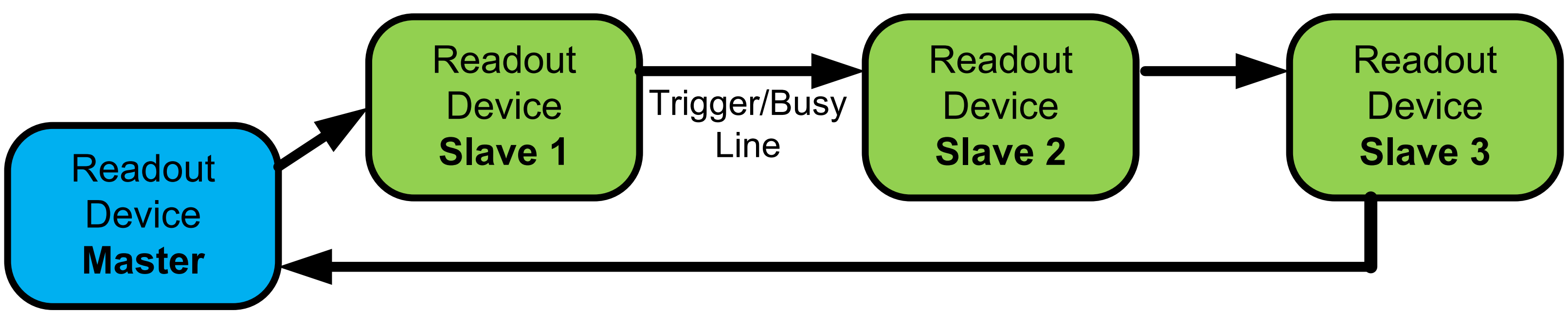
Katherine – GPIO Signals and Triggering

- Implemented internal trigger generator
- User can define the meaning of GPIO





- Triggering more detectors – cascade chain
- Common LVDS trigger/busy signal

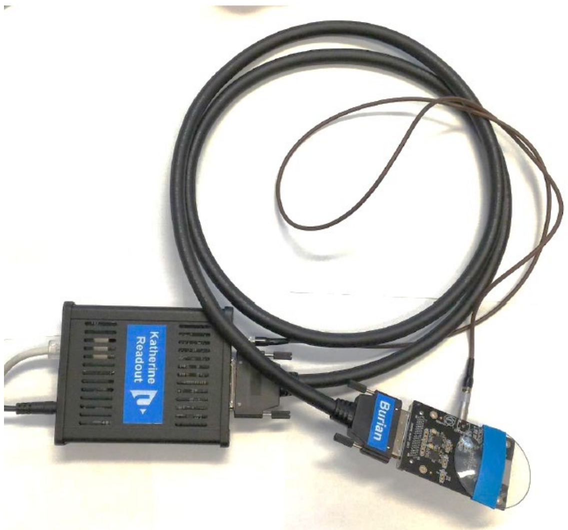


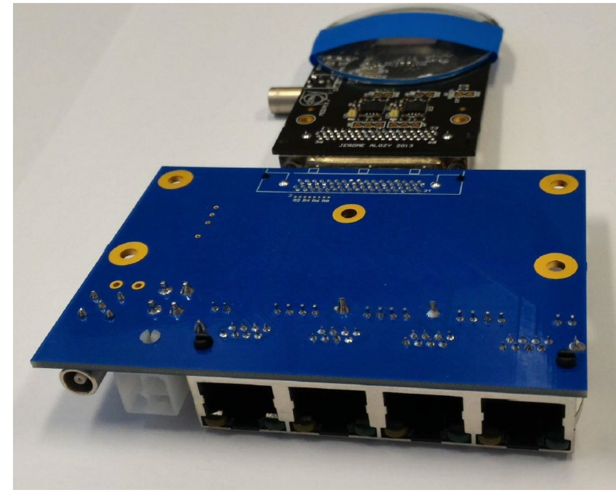
Katherine – Communication

- Communication with sensor:
  - Two “fast“ lines (2x 640Mbs)
    - Embedded clock
    - Direct connection with chipboard
    - Shorter distance via VHDCI cable (max. approx. 3.5m)
    - Hit rates: up to 20Mhit/s (but limited by Gigabit Ethernet bottle-neck)
  - Four “slow” lines (4x 160Mbs)
    - Longer distance between readout and chipboard
    - Verified: 10m VHDCI cable at 4x160Mbs rate
    - Hit rates: up to 10Mhit/s
  - Automic setting of maximal speed according to used cable during power-up sequence
- Communication with computer/server:
  - Peer-to-peer communication with computer
    (based on UDP datagrams; TCP/IP in development)
    - 36 control/status commands
  - Automatic/independent sending data to server (via SSH connection)

Katherine – Communication

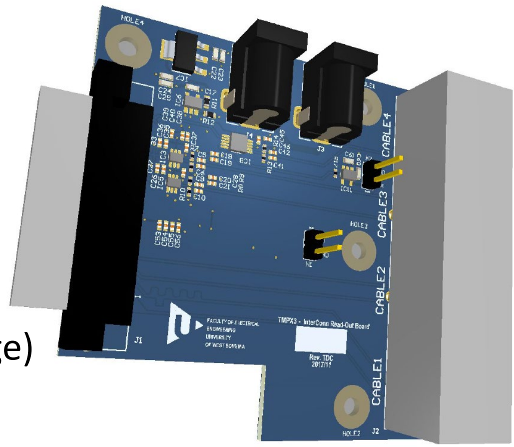
- How to connect sensor…
  - Directly (CERN chipboard)
  - Extending VHDCI cable



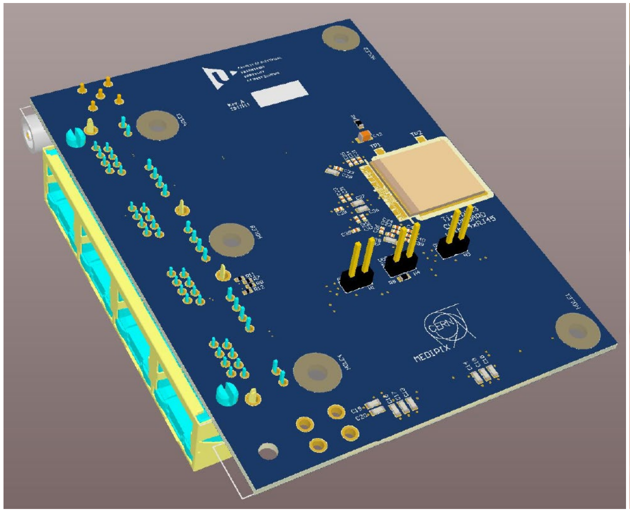


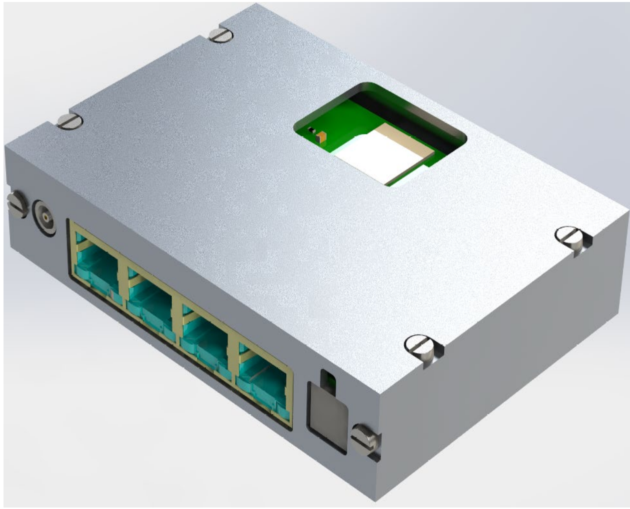
- Active or passive ethernet cabling extenders
  - Up to 100m distance between sensor and readout
  - 20m => no decreasing in speed
  - Radiation hardness solution
  - New rad. hard. chipboard

HW solution for ATLAS



- How to solve radiation hardness? By distance.
- Readout system
  - Standard ***Katherine readout for Timepix3*** with Gigabit Ethernet Interface
  - Extender for long cabling (4x Ethernet, 1 bias voltage, 1 power supply voltage)
- Chipboard
  - Newly designed chipboard appropriate for long cabling
- Tested up to 120m distance (4x 80Mbps) between sensor and readout

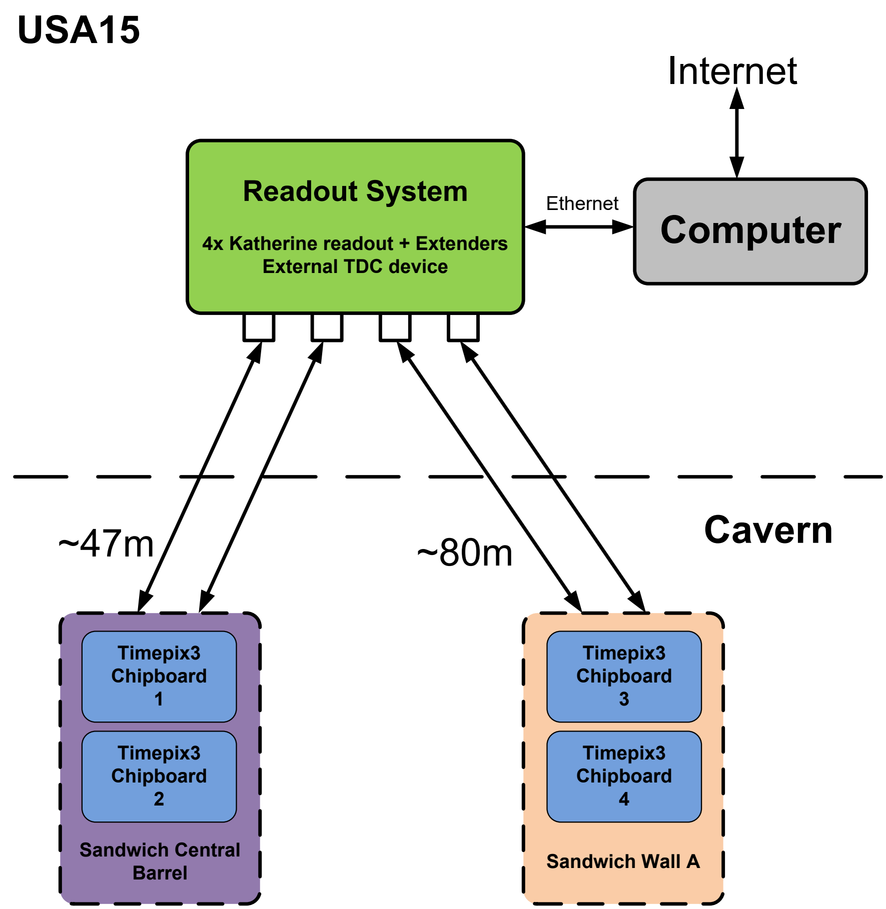




Installation - details

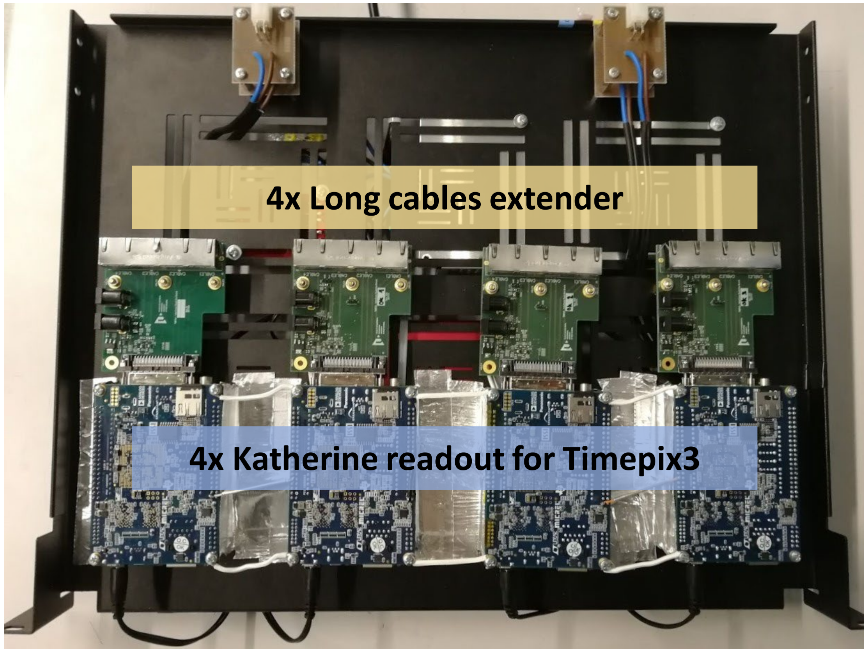
- Four Timepix3 detectors
- Used as two sandwiches (2-layer stack)
- Sensors are face-to-face oriented
- Clock data recovery (clock signal is not used)
- Delays on cables? No problem
  (setup can measure delays of signal paths)

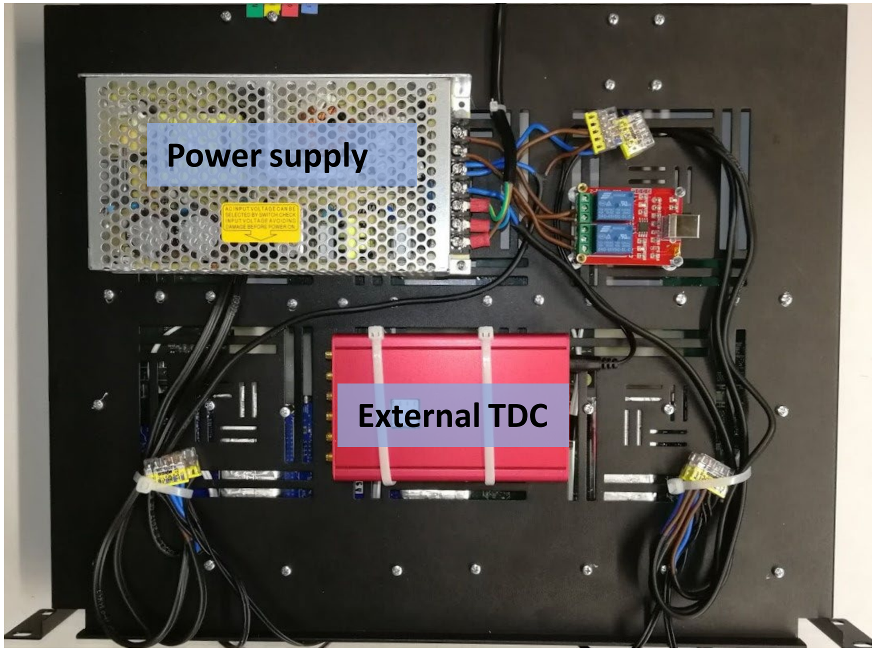
- Readout system placed in USA15 rackroom
- Distances and hit rates:
  - Central barrel ~47m (4x160Mbps, 10Mhit/s)
  - Wall A side ~80m (4x80Mbps, 5Mhit/s)
- Each of detectors can work independently



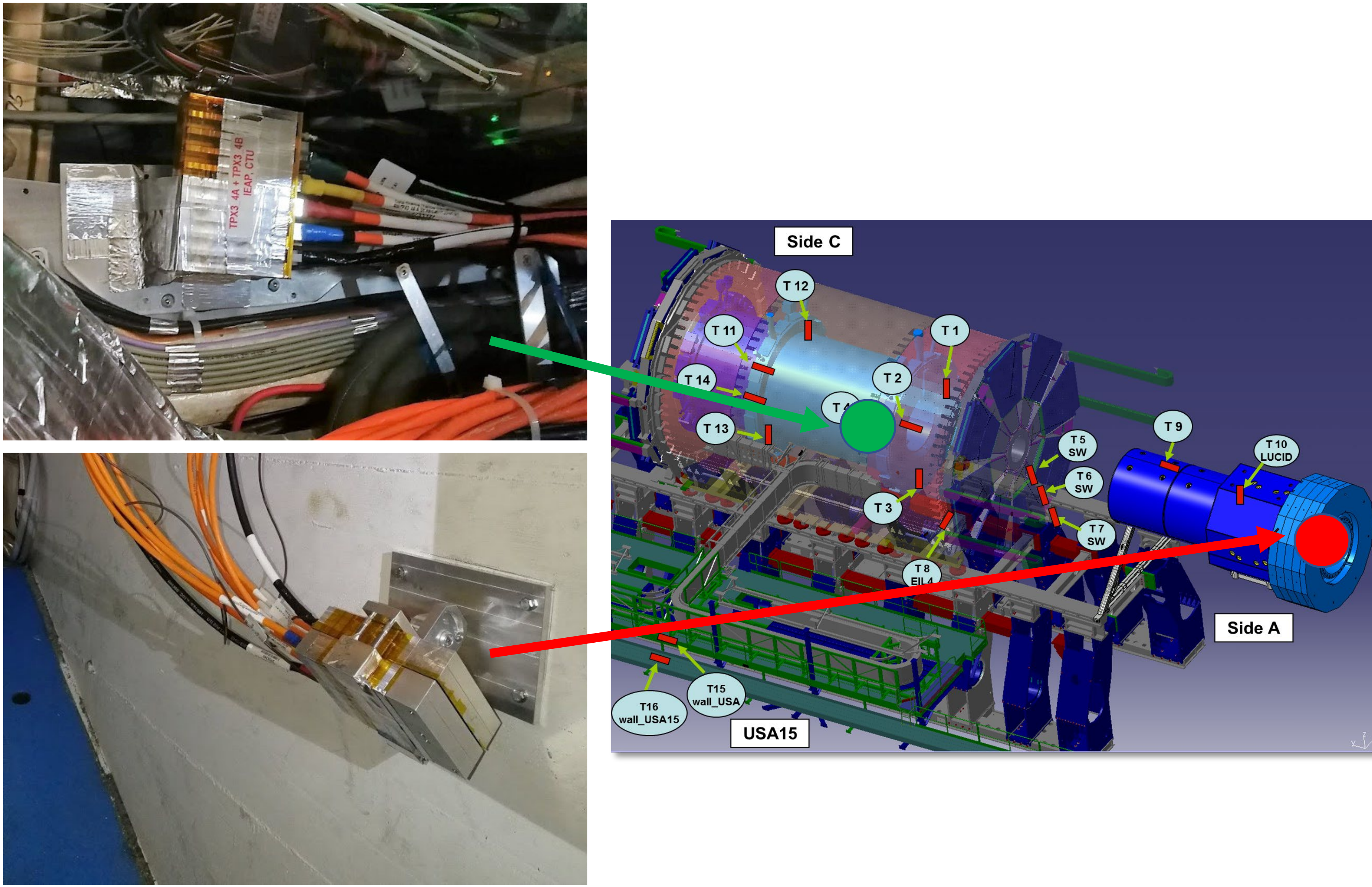
Readout system – final installation in USA15

- Everything installed in one 19“ rack shelf



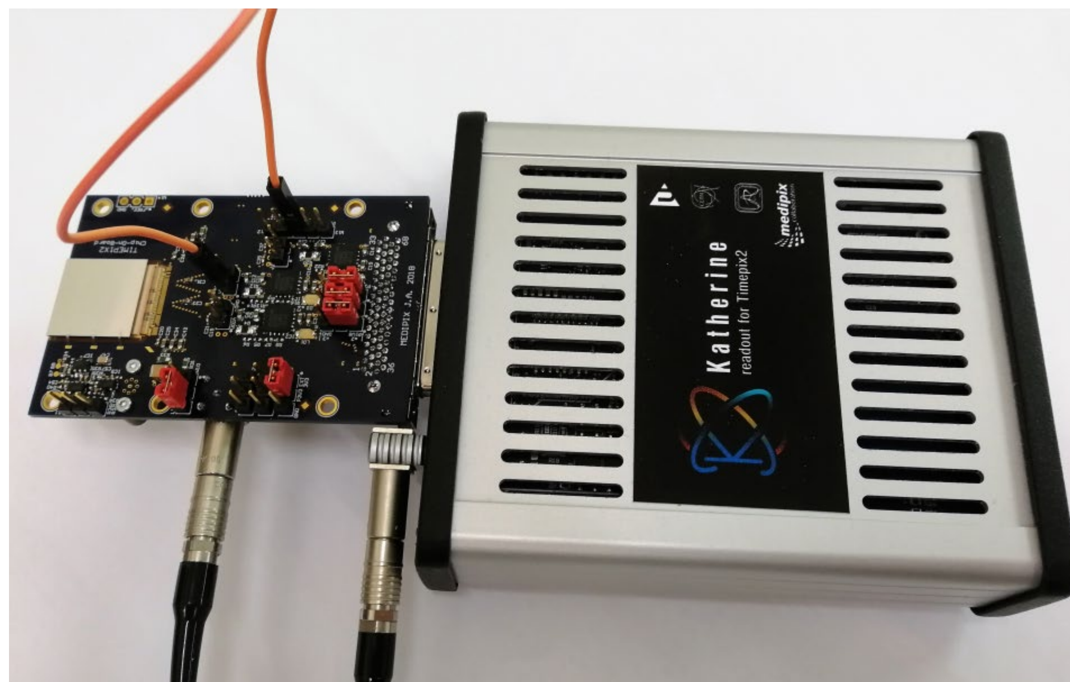


Positions of the Timepix3 sandwiches



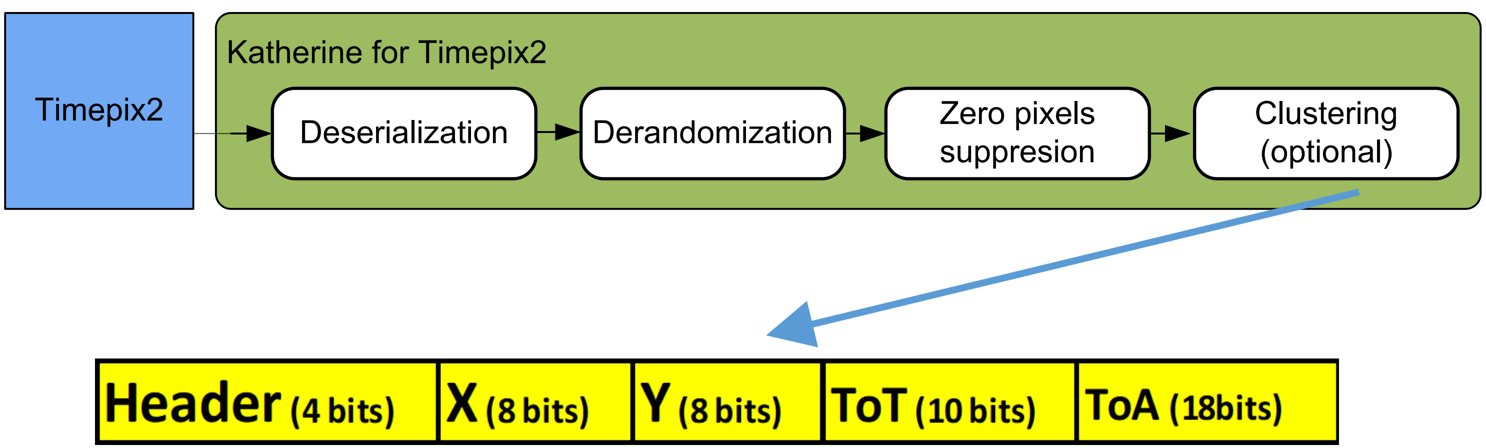
Katherine for Timepix2

- Embedded computer + interface for one Timepix2 (CERN chipboard; serial communication only)
- Source of high voltage for bias – both polarities (±300V)
- Gigabit Ethernet Interface
- Long-distance access (up to 100m)
- Dimension: 100 x 80 x 28 mm
- Power consumption measurement
- Communication based on UDP
- Optional:
    - Independent mode (via SSH)
    - Data storing to local storage (SD card)



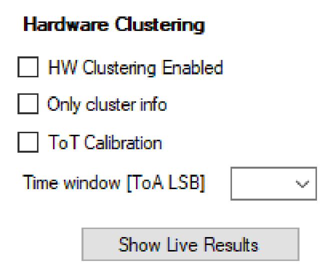
Katherine for Timepix2 – Data Pre-processing

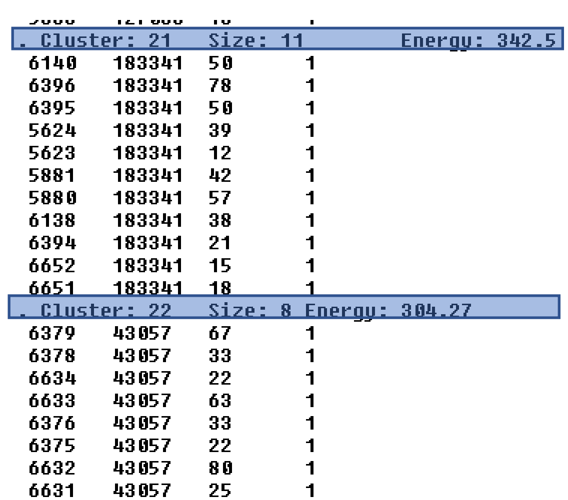
- Raw data from detector are not in straight form
  - Counter raw data – LFSR counters
  - Readout process – serialization data
- Conversion of data – commonly on SW side or in the readout device
- Katherine readout – event data format
  (only active pixels are sent – "Timepix3-like" format):



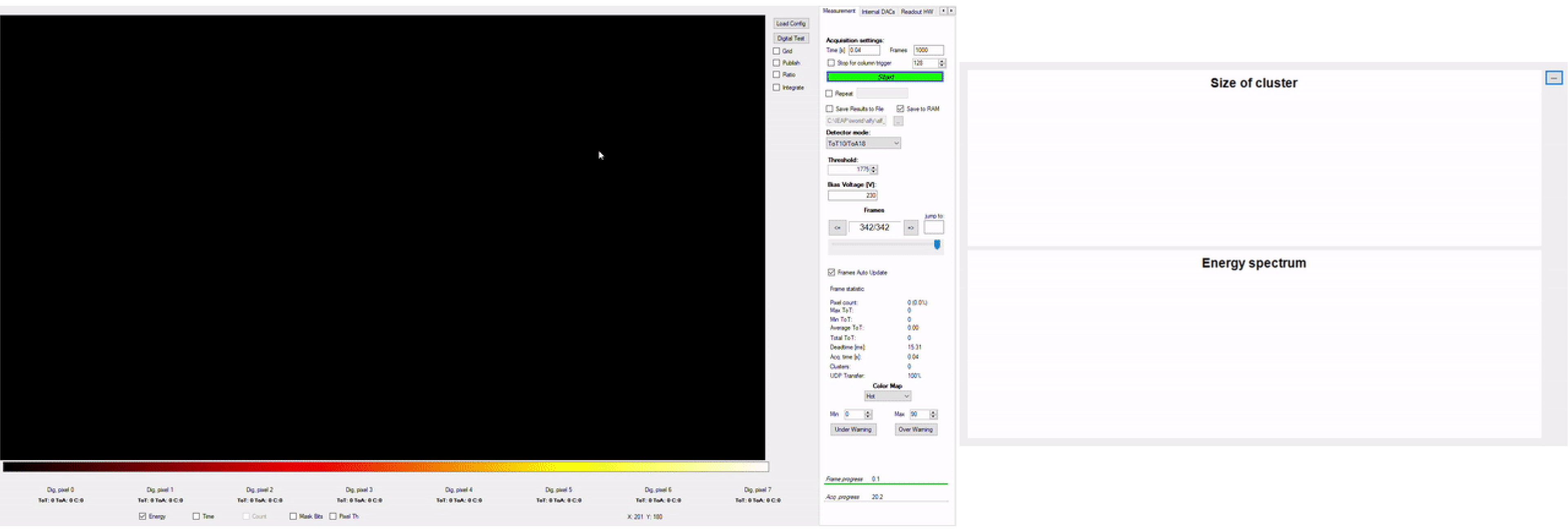
Katherine for Timepix2

- HW clustering support – clustering directly in the readout hardware
- Cluster ToT Volume calculated
- Possibility to upload calibration matrixes (per pixel ToT calibration) to the device
  → Energy of clusters





Katherine for Timepix2 – HW Clustering Support

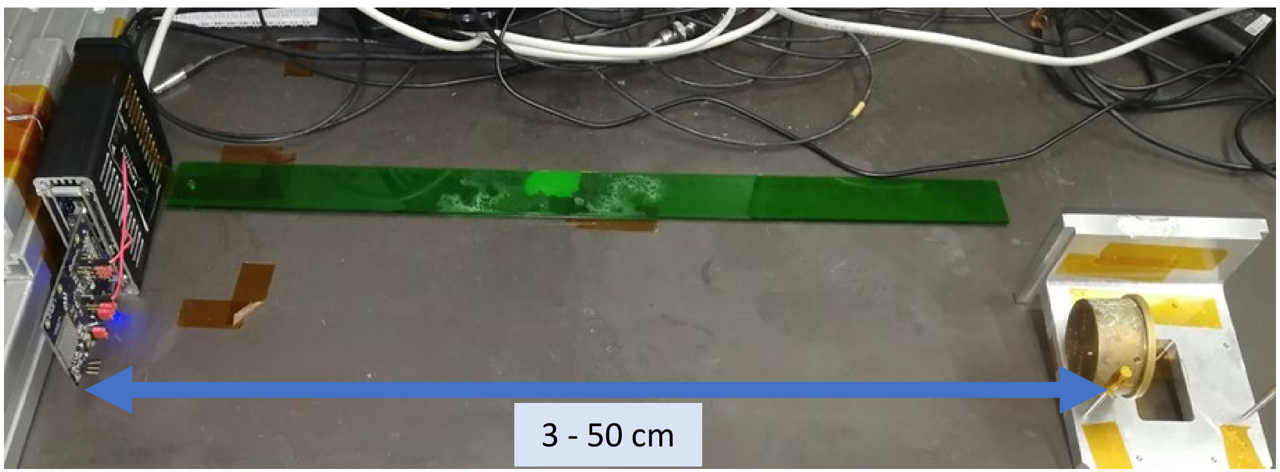


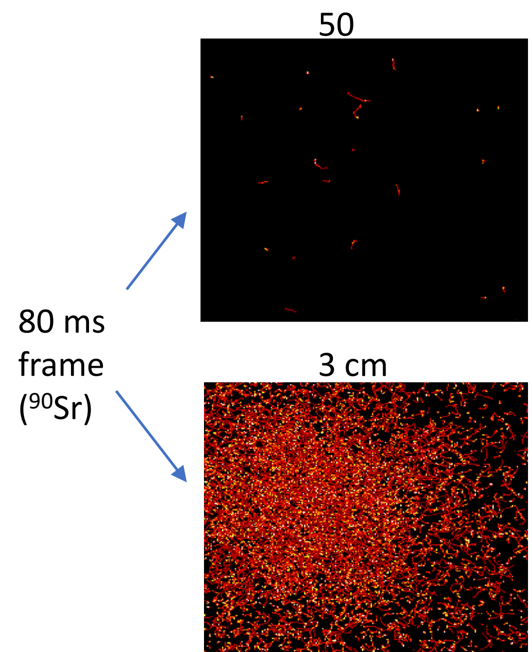
Timepix2 – Matrix Occupation Monitor

- How to set acqusition time?
  - Short frames => dead time
  - Long frames => cluster overlapping
- Mainly in changing rad. field (space…)
- Adapting algorithm of acq. time needed
- Timepix2 implements Matrix Occupation Monitor
  - Dedicated signal MATRIX_OCC goes to high active state when defined number of active columns (one pixel hit at least) is achieved
  - Readout can use it for acquisition time control
  - Currently only for simultaneous mode
- Low power systems => occupation flag as wake-up signal for a processor

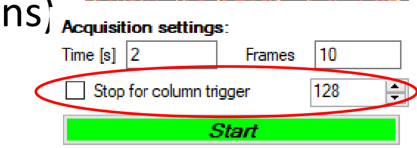
Timepix2 – Matrix Occupation Monitor

- Demonstration of the feature
- Timepix2 and ^{90}Sr and ^{241}Am movable source



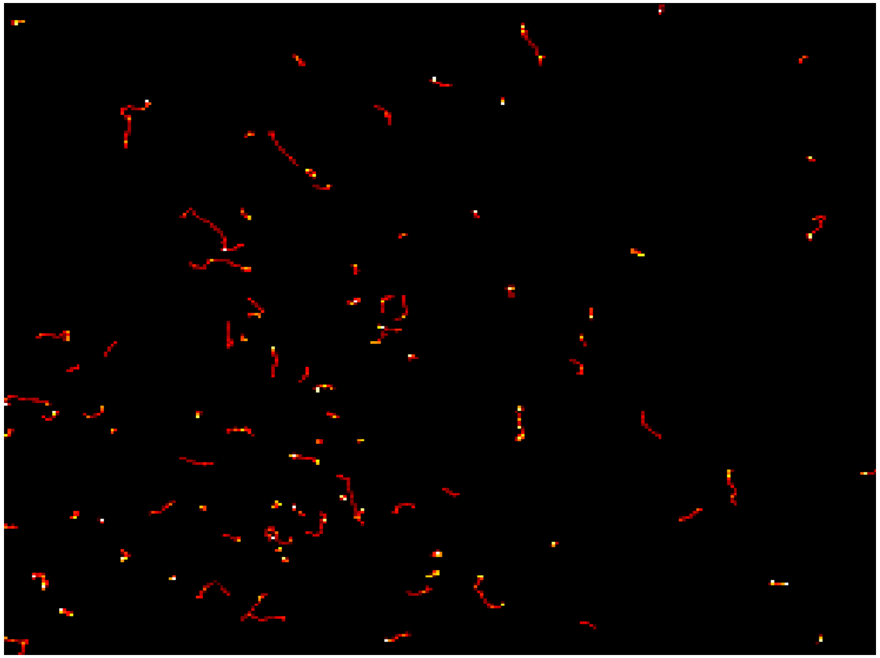


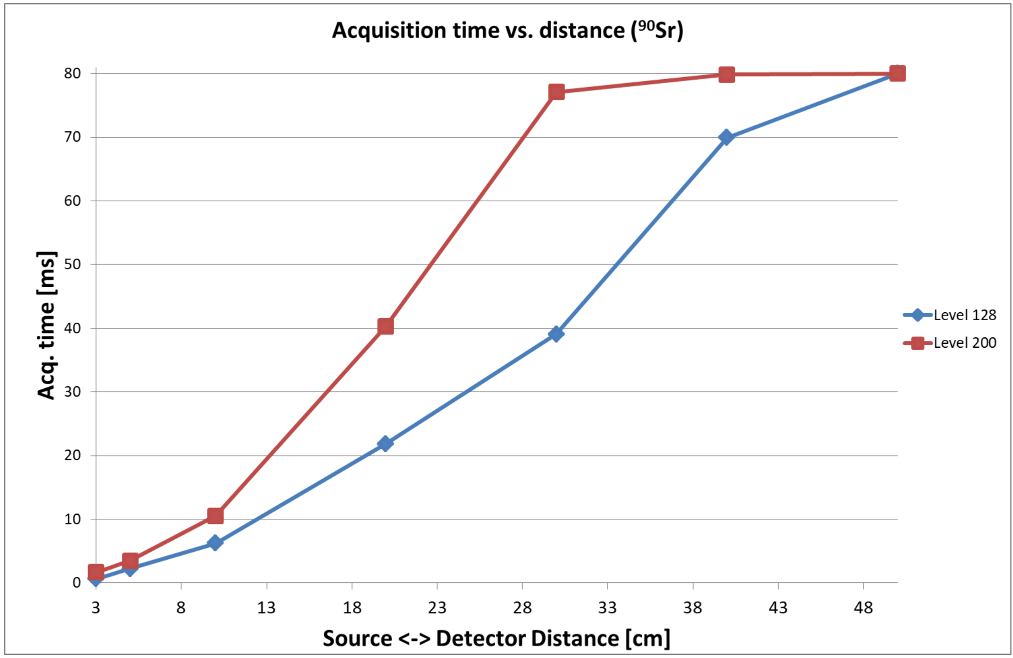
- Default acq. time (80ms) + matrix occupation monitor (128 and 200 columns)
- Readout can stop current fame
- „Automatic“ cluster overlapping reduction expected



Timepix2 – Matrix Occupation Monitor

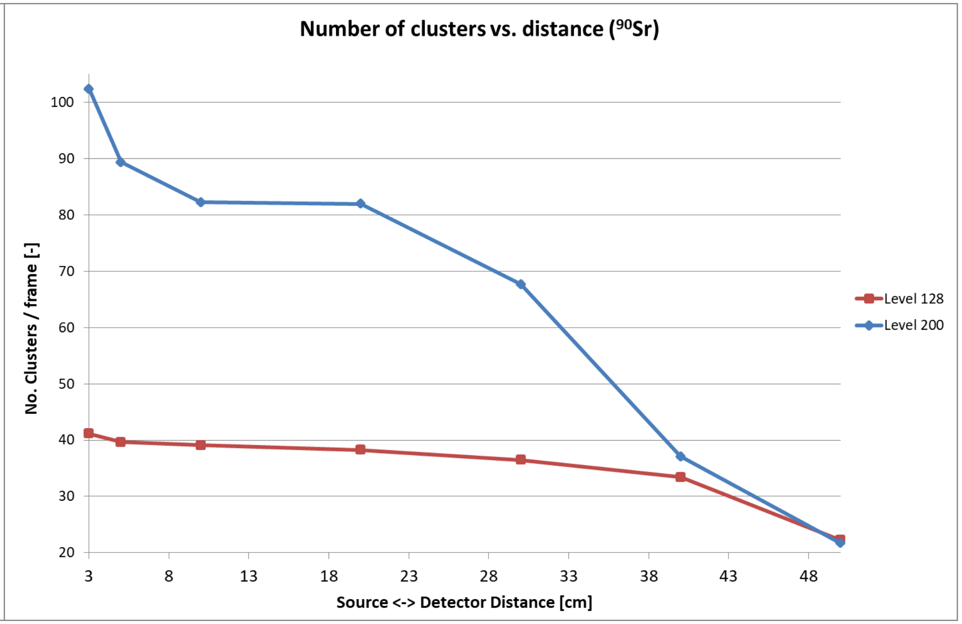
- Final distance 3cm => acq. time = 1.67773 ms





Timepix2 – Matrix Occupation Monitor

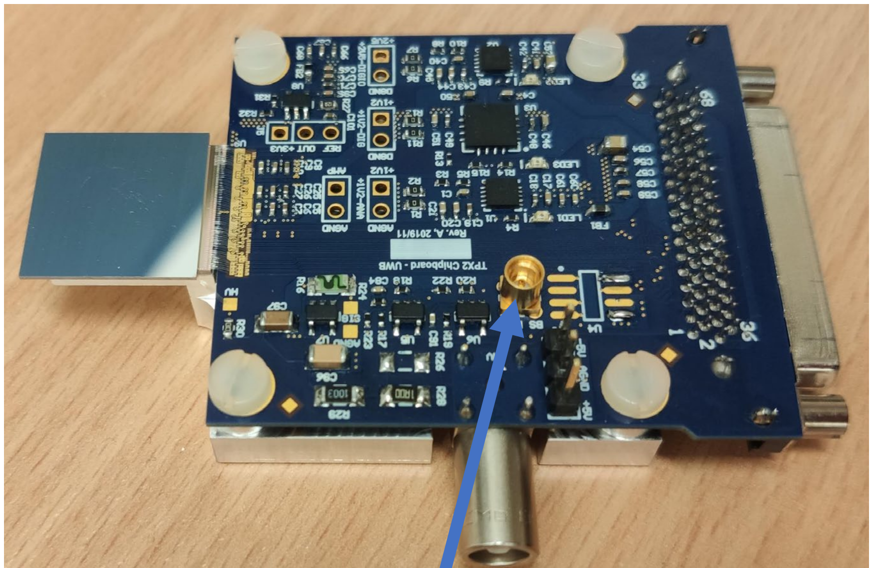
- Dependency of number of pixel hits and clusters (per frame) on detector-source distance



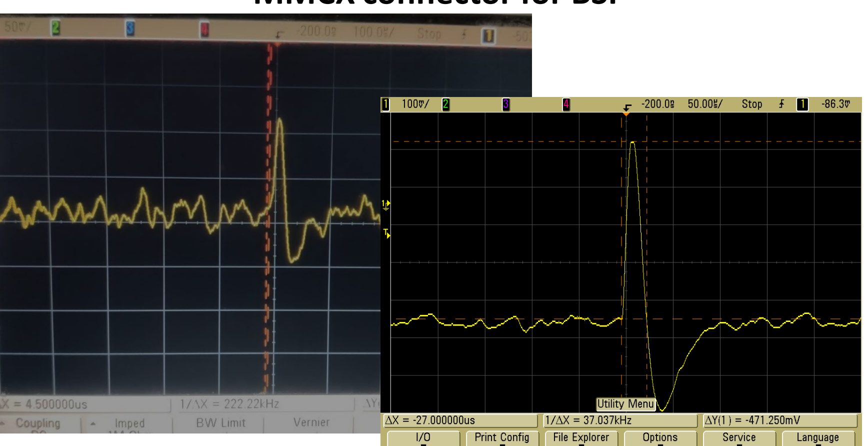
Timepix2 – Matrix Occupation Monitor

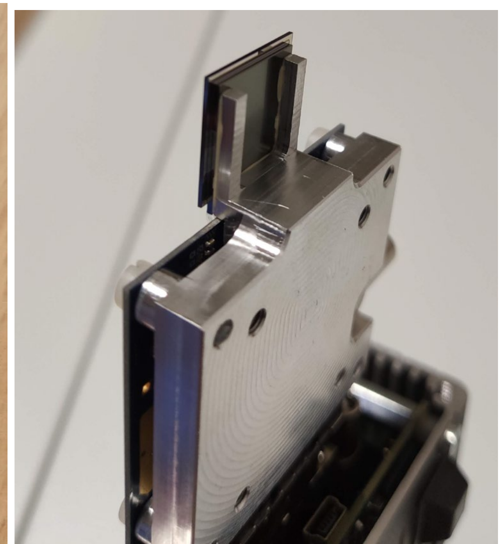
- Distance vs. dead time

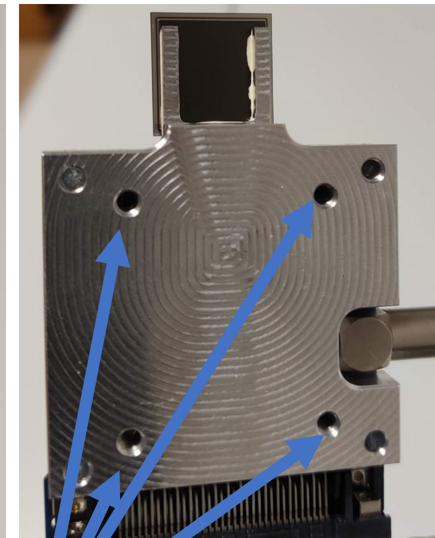
Chipboard for Timepix2

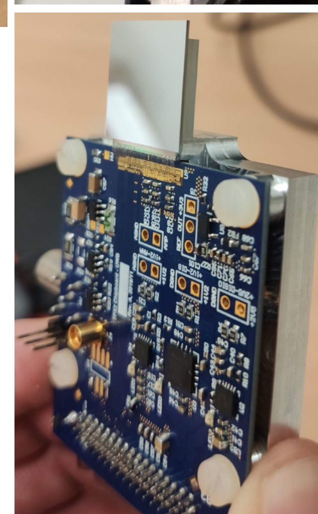


MMCX connector for BSP









Mounting holes for an external heat sink, a peltier or a fan

Dual Timepix Module for CubeSat

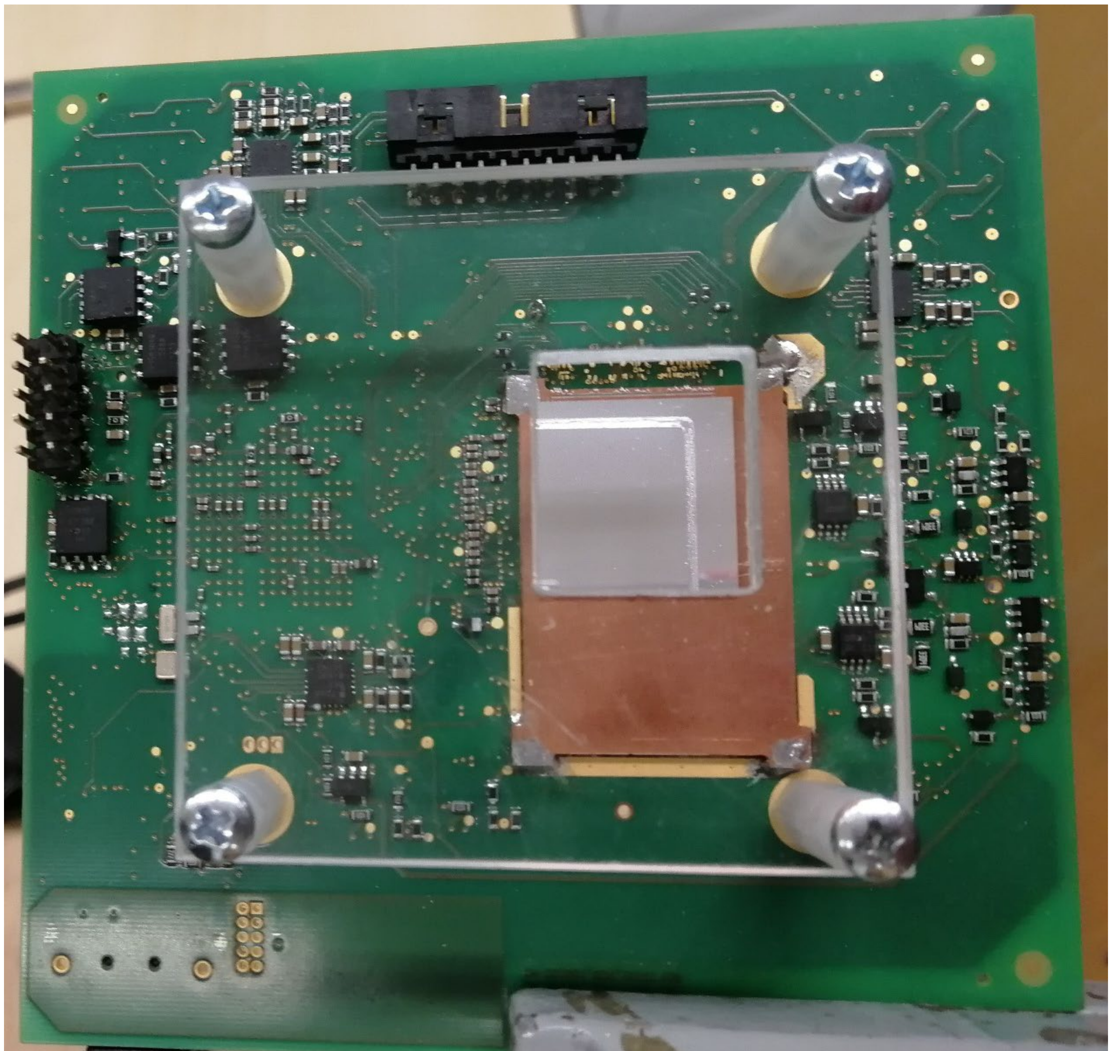
- 100mmx100mm board for mini satellite (cubesat)
- Designed for Pilsen Cube II project
- Requirements:
  - Particle telescope with Timepix
  - Radiation hardened (as much as possible)
  - Low cost (commercial components)
  - Low power
- Two bias power sources:
  - Up to +300V
  - Leakage current measurement
- Main interface:
  - Dual RS-485
- Based on SoC FPGA Microsemi Smartfusion2
- USB 2.0 Interface for equalization and calibration

Dual Timepix Module for CubeSat

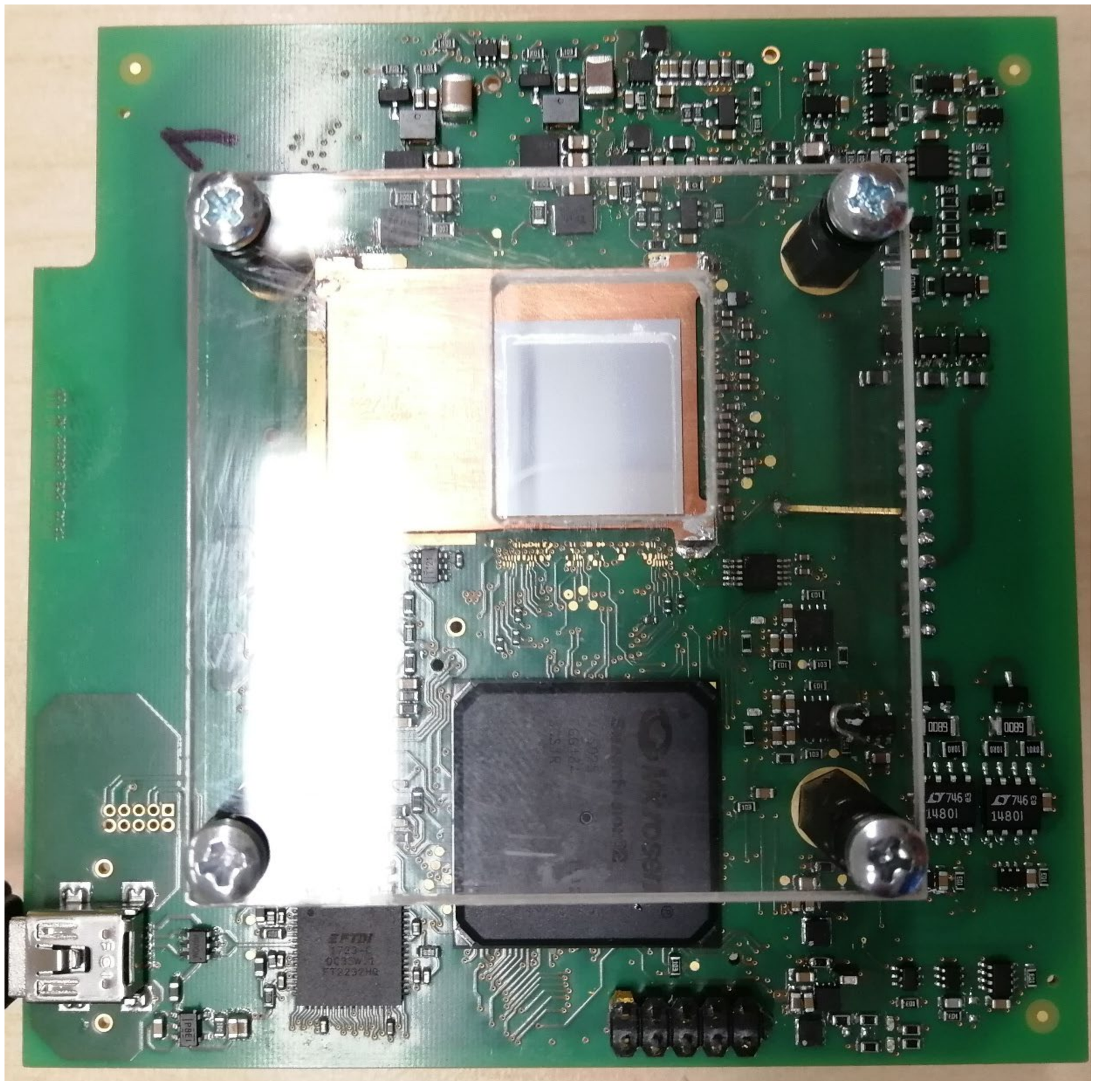
- HW watchdog
- Memories:
  - 4x 4-Mbit SPI F-RAM
- 24-channel ADC
- Temperature sensor
- Compatible with Pixelman SW
- Demonstration of on-board processing:
  - Cluster analysis
  - Spectra calculation
  - Coincidences determination

- Current status:
  - The first prototype assambled by 2x300um Si sensors on 4mm copper plate
  - Works fully via USB interface
  - Onboard processing under testing
  - Second board ready for wire-bonding of Class-A sensors

Dual Timepix Module for CubeSat



Dual Timepix Module for CubeSat



Plans…

- Quad for PAN (+Katherine upgrade)
- Tune BSP measurement on Timepix2, then adapt it for Timepix3 (Michael Holík)
- Finish setup in VDG
- ATLAS upgrade (chipboard, frontend, backend)
- Detector network for Micado project

- Challange: Low power rad. hard platform for space (Milan)

Thank you for your attention…

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