

A cost and energy efficient data acquisition architecture for pixel detectors in mobile applications using embedded multi-core processors

Oliver Keller^{1,2} (oliver.michael.keller@cern.ch),
Sascha Schmeling¹, Andreas Müller², Mathieu Benoit²

¹CERN, ²Université de Genève

- Motivation
- Hardware overview
- Bias supply
- User interface
- Physics experiments



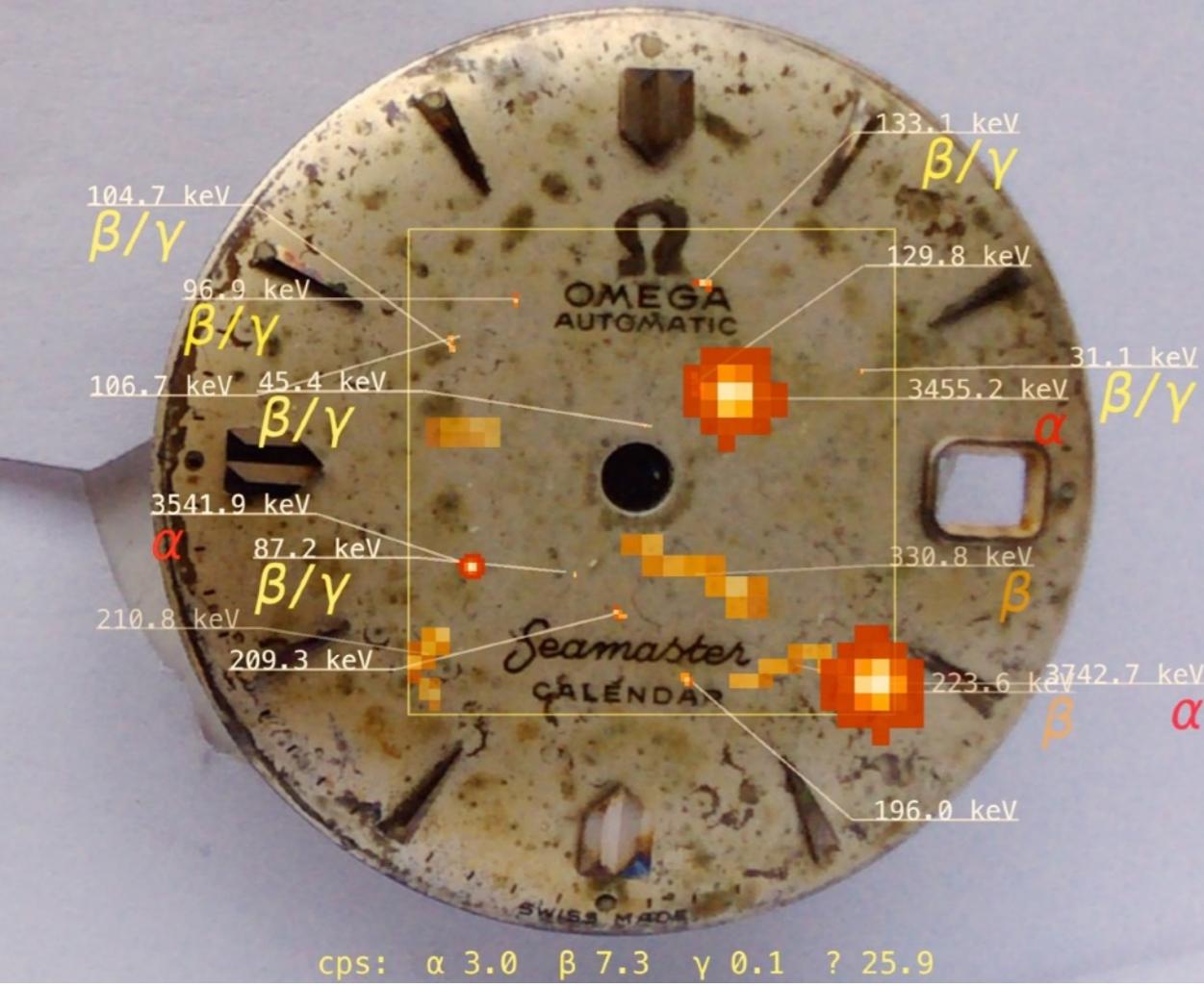
**UNIVERSITÉ
DE GENÈVE**
FACULTÉ DES SCIENCES



S'Cool LAB at CERN

- half-day workshops for high-school students
- working groups with teachers and students, 2-3 weeks
- several MX-10s (Timepix1), X-ray machines, DIY cloud chambers ...
- needs: adequate user interface for educational purposes; software-guided experiments

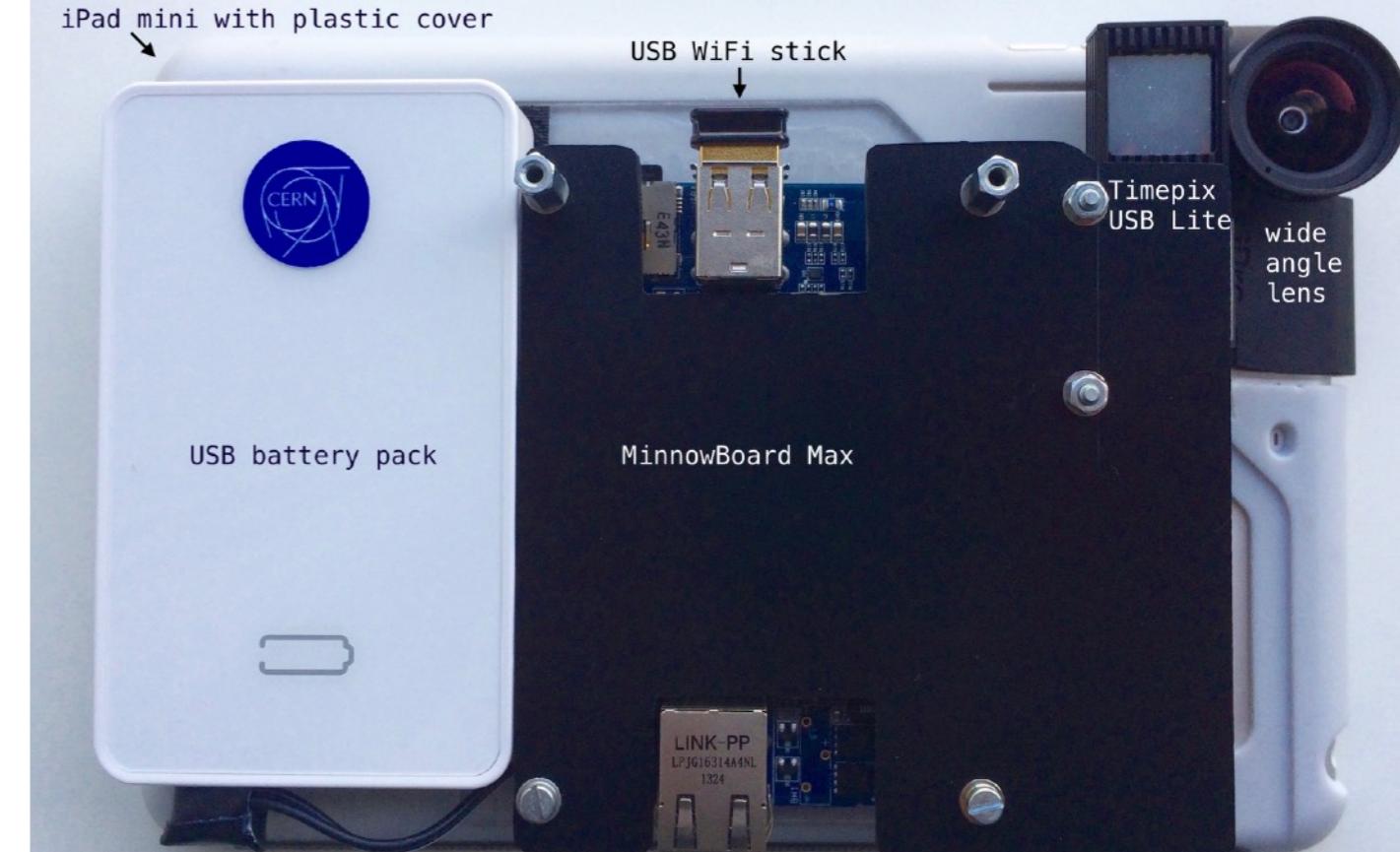




iPadPix—A novel educational tool to visualise radioactivity measured by a hybrid pixel detector

PIXEL 2016

O. Keller, S. Schmeling, A. Müller and M. Benoit
 2016 JINST 11 C11032



Goals of the architecture

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- portable & flexible, 3 main use cases:
 - in the lab over wired ethernet, browser GUI via local server
 - standalone, recording to SD card, battery powered
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- using Timepix3:
 - energy range: 3 keV - 8 MeV (per cluster)
 - event based mode, 40 Mb/s - 80 Mb/s (5.12 Gbit/s max.)

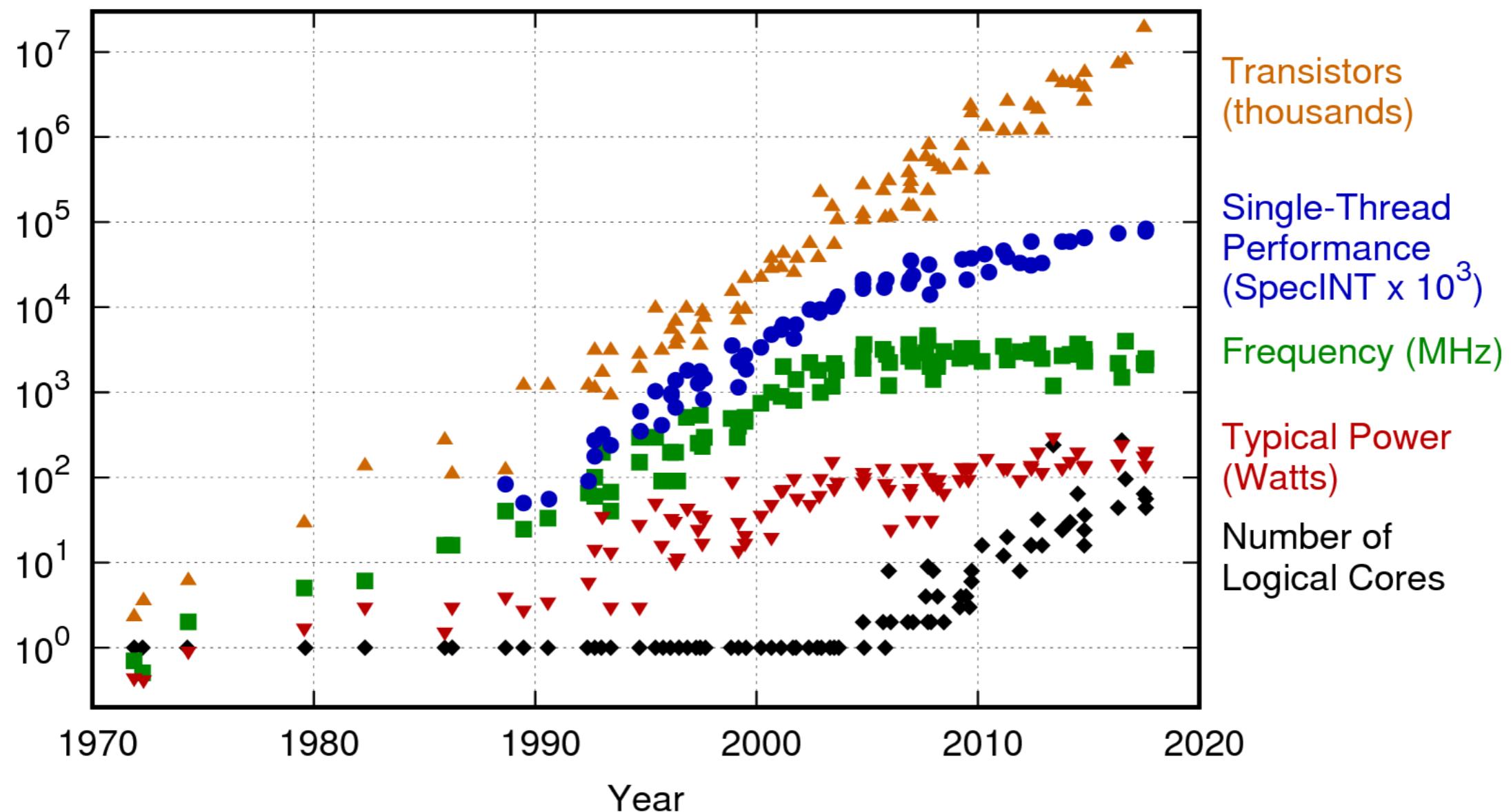
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« Timepix = HEP detector in a nutshell »

Processor Evolution

42 Years of Microprocessor Trend Data



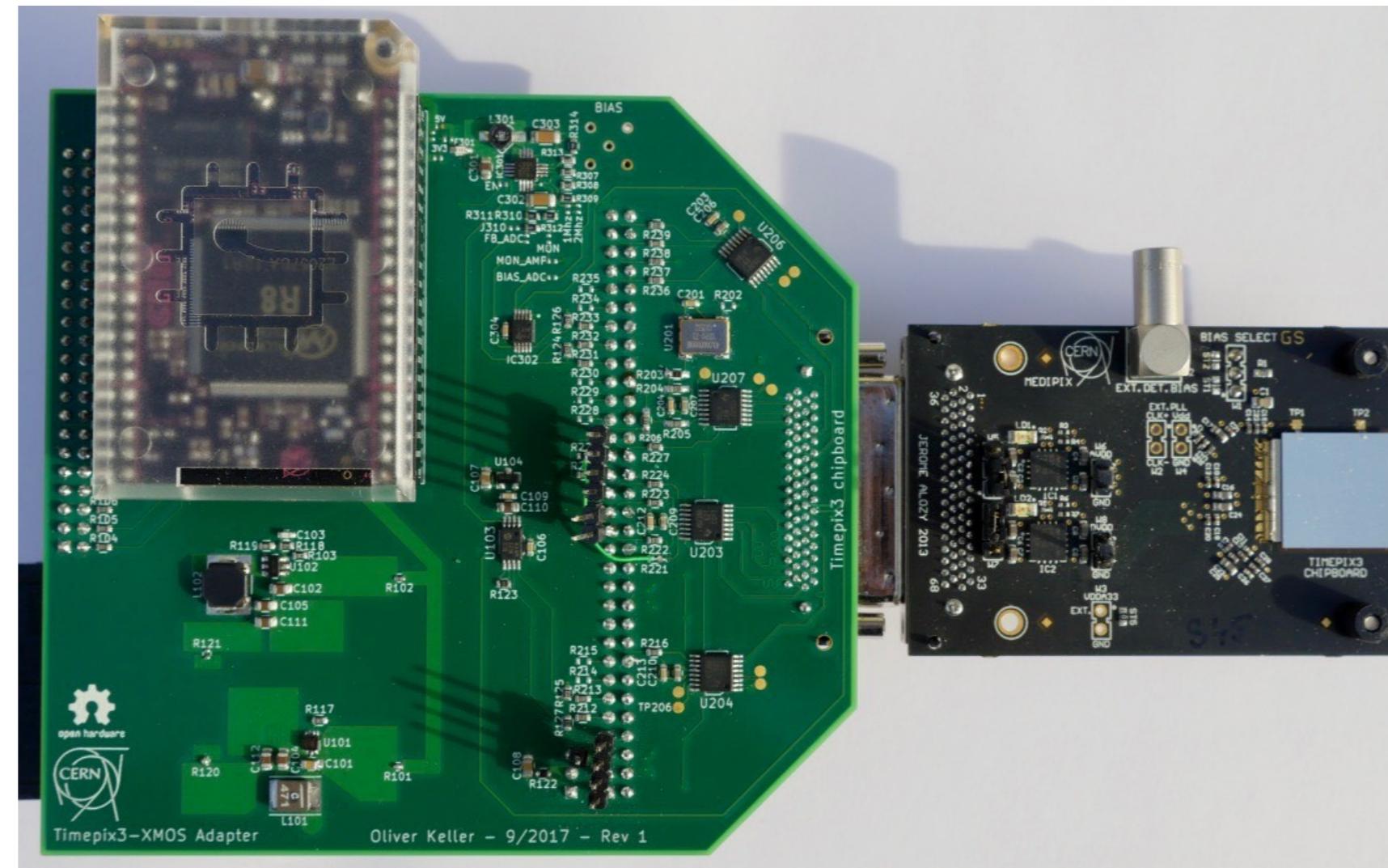
Original data up to the year 2010 collected and plotted by M. Horowitz, F. Labonte, O. Shacham, K. Olukotun, L. Hammond, and C. Batten
New plot and data collected for 2010-2017 by K. Rupp

www.karlrupp.net

Hardware Design

1st revision, adapter built around XMOS eXplorer evaluation board:

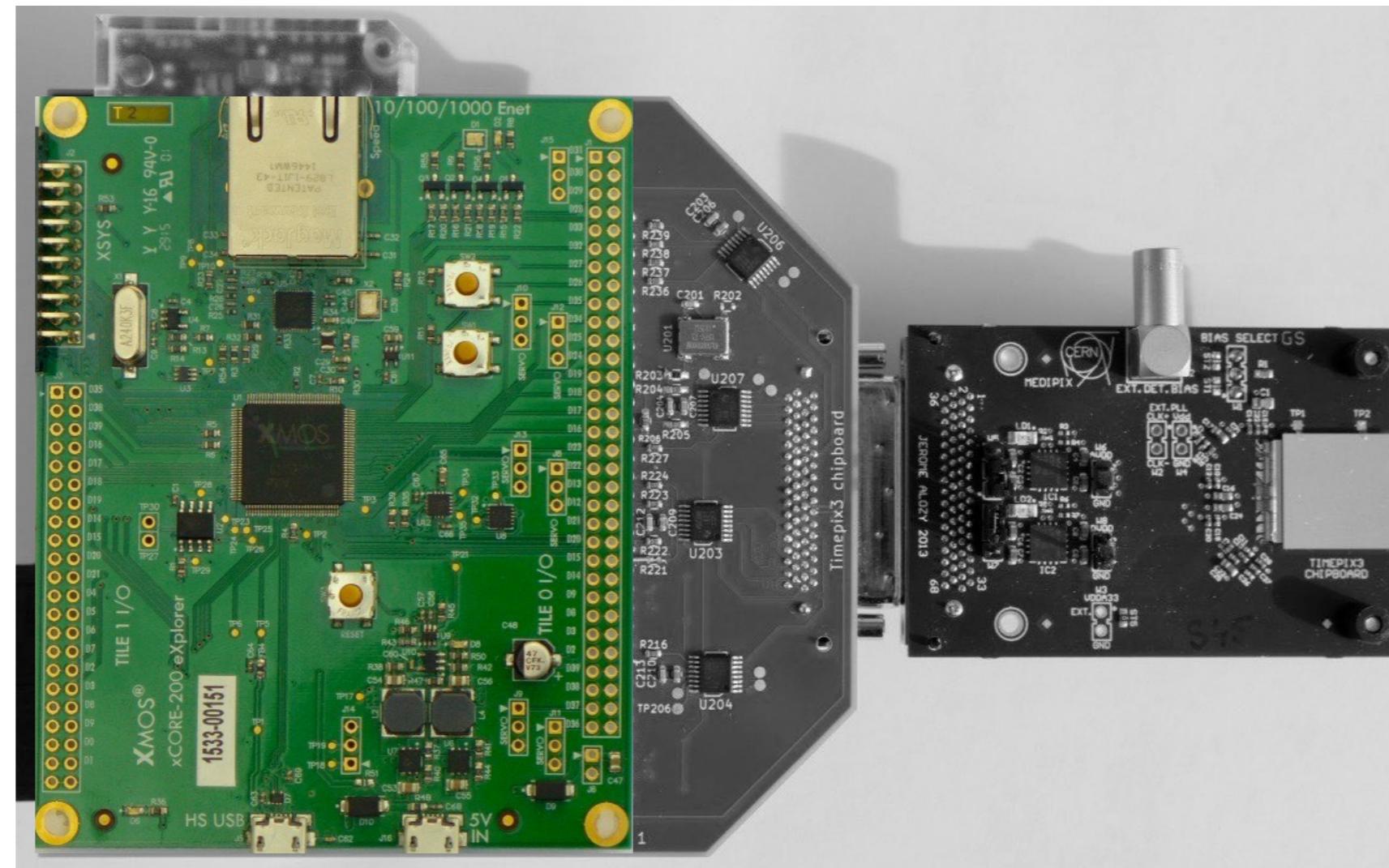
- SLVS transceivers,
40-80 Mbps
- bias supply 0 - 60 V
I/V monitor
- Gigabit Ethernet
- schematic & layout
in KiCAD
- 4 layer board
- TODO: new chipboard & much smaller, integrated base board
- will be released under CERN's open hardware license



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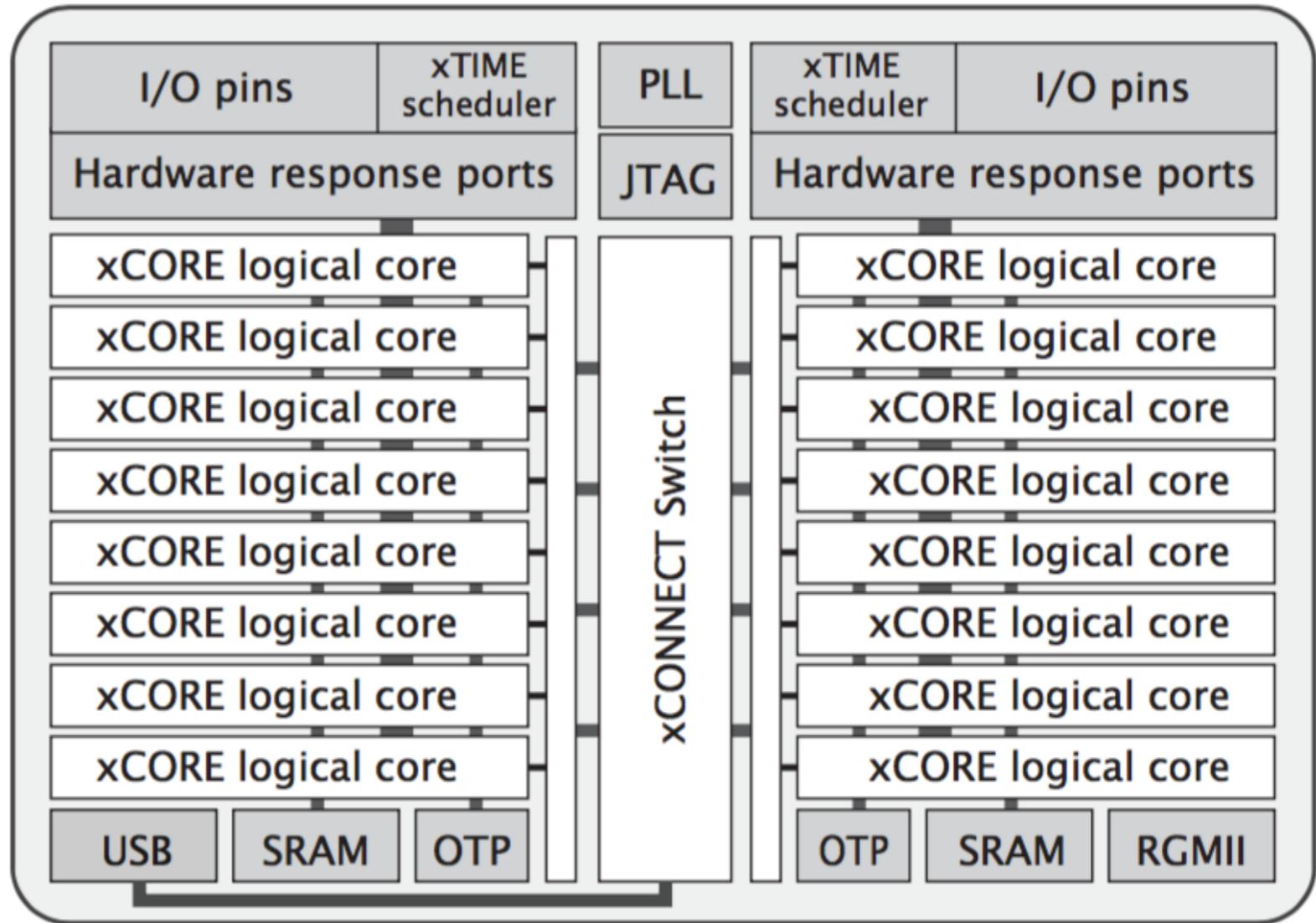
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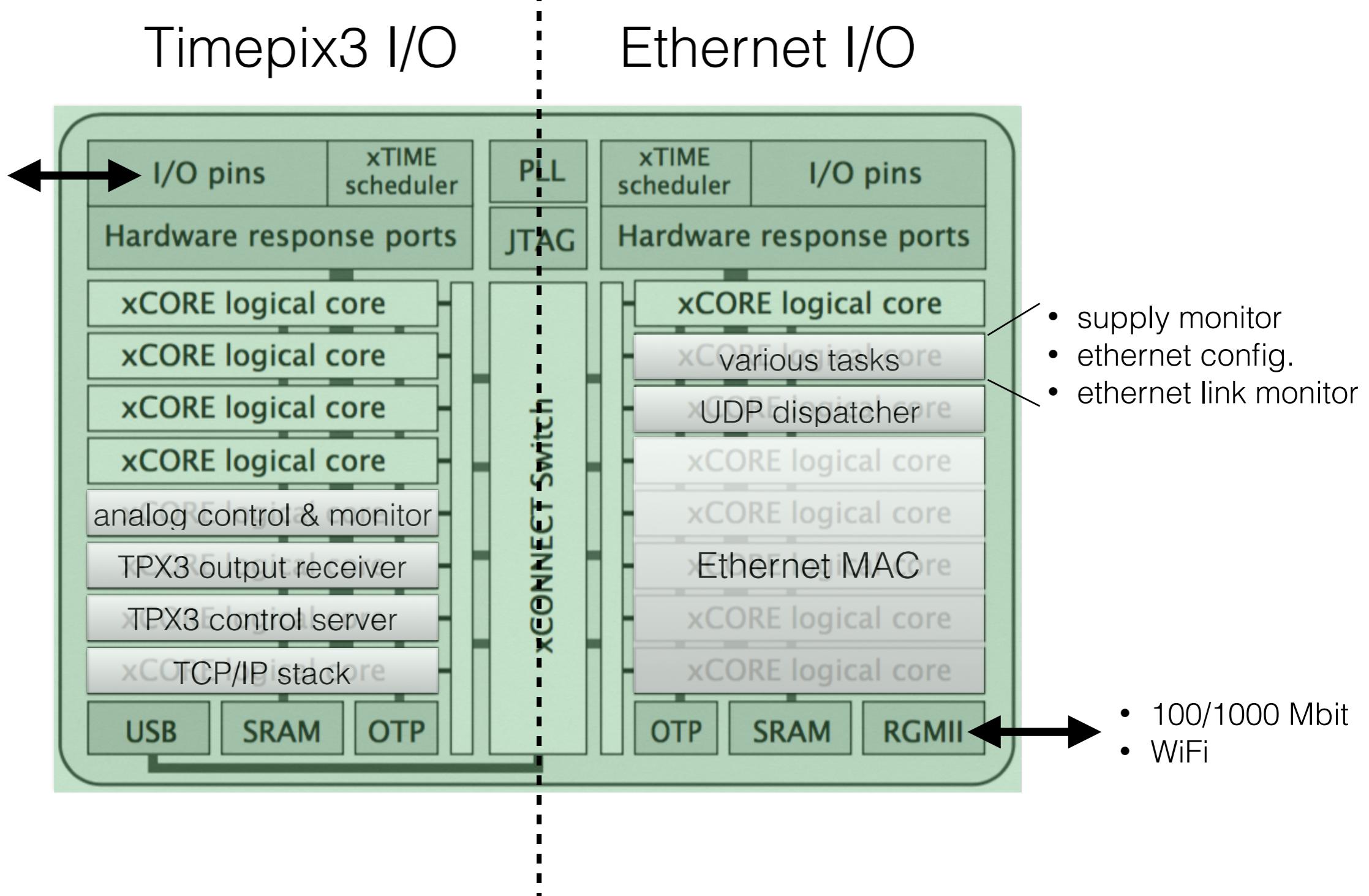


Processor Overview

- XMOS embedded multi-core processor
- xCore-200 series:
32-Bit, 512 KB RAM
2000 MIPS, 2x500 Mhz
- flexible I/O, xLinks
- deterministic operation
- XE216 chip: ~1 Watt
- XC, C/C++, many libraries on github.com/xmos => fast dev. cycles
- on-board clustering and classification is possible



Task Distribution



FPGA Comparison

	XMOS XE 216	FPGA
voltages	2	≥ 4
power	1 Watt	5 - 10 Watt
chip package	TQFP (2 tiles) BGA (4 tiles)	BGA only
price in single quantities	14 Eur (100 p.: 8.8 Eur)	50 - 100 Eur Altera Cyclone IV Xilinx Spartan 6

other interesting multi-cores/many-cores:

- Tilera (gone)
- Adapteva Parallelia
- Parallax Propeller
- RISC-V

Power Measurements

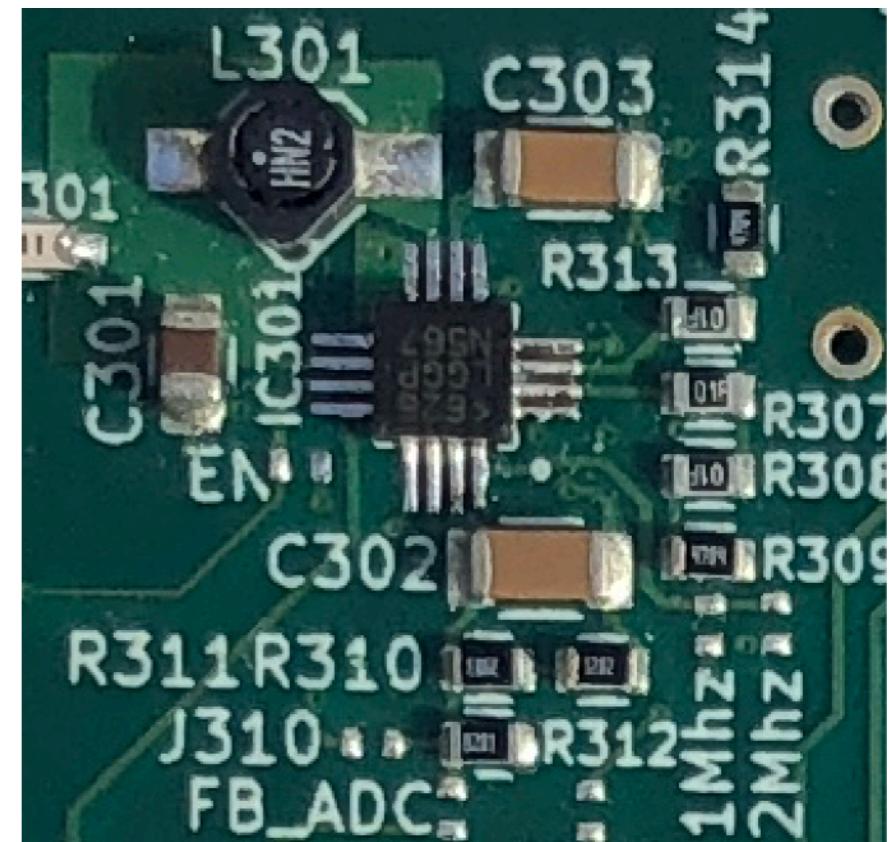
preliminary

- Timepix3 active
DataDriven mode
2.5 W
- Timepix3 idle (shutter off)
2 W
- Readout only
1.25 W
(including several active but unused parts)

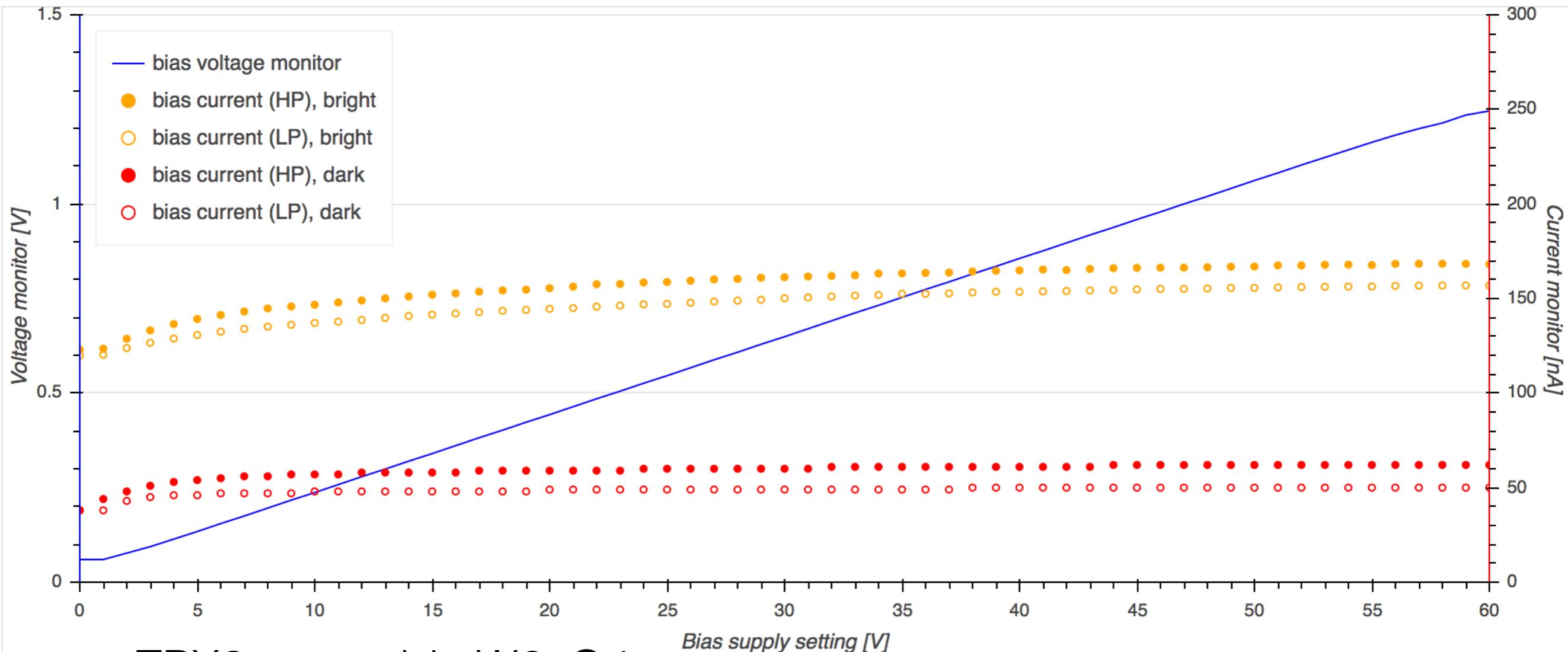


Bias Supply

- 300 µm p-on-n silicon sensor
- safe bias supply for learning places
- IEC 61010-1: Safety requirements for electrical equipment (...) in lab use
=> 70 V DC, 2 mA continuous, dry location
- 1-2 cm² board space
- LT 3905, APD control IC, 65 V max., designed for 3 µA - 3 mA loads
 - 3x3 mm² SMD package, allows tiny biasing circuit
 - internal current mirror
 - adapted for 1 mV/nA, range: 1 nA - 2000 nA, 1 nA resolution
 - c.f. Mihaly Vadai, CERN-THESES-2017-370



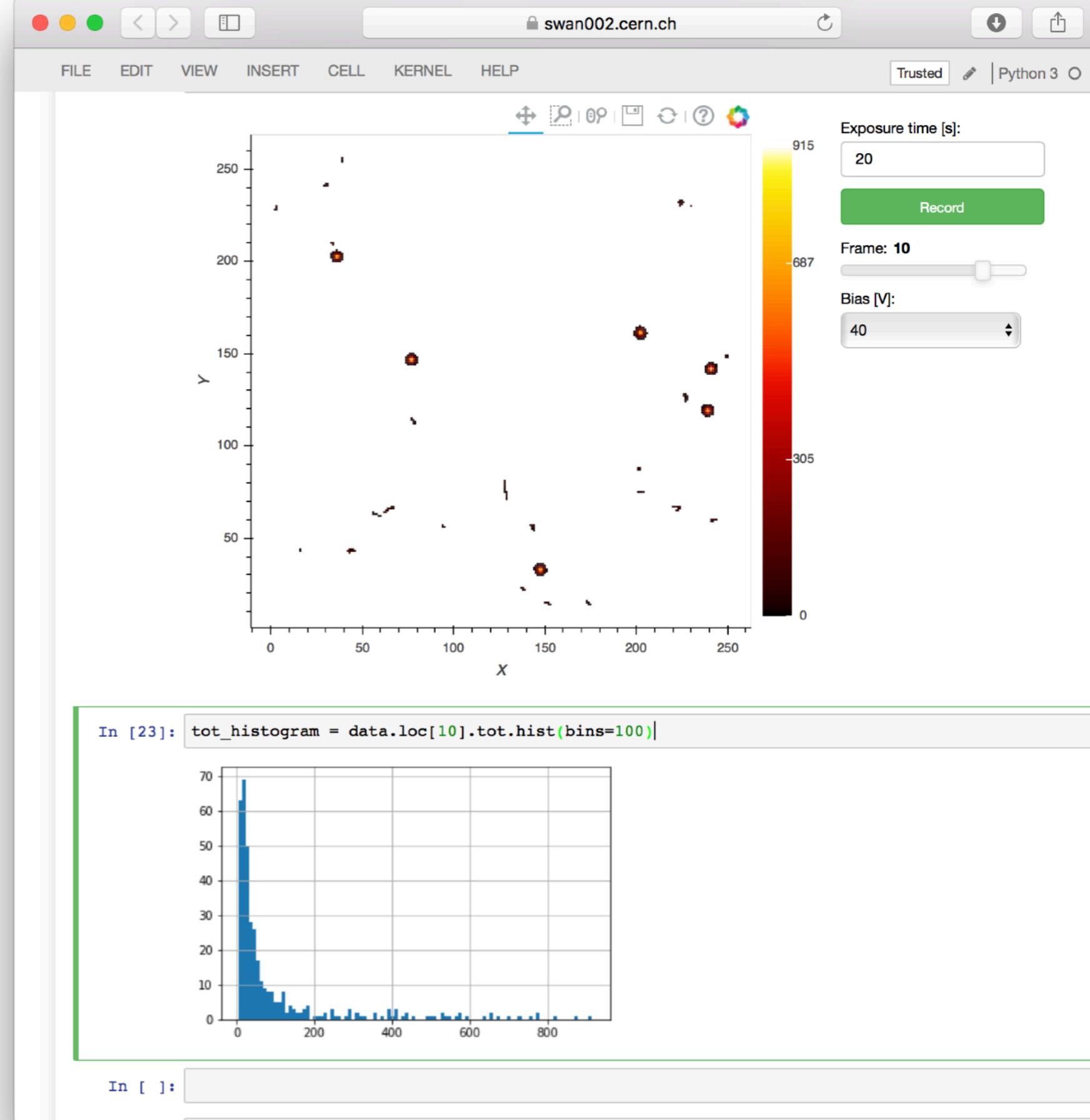
Bias measurements



- TPX3 assembly W2_G4
- voltage monitor via converter feedback (blue, left axis)
- two pairs of current measurements (red/orange, right axis)
 - nominal and low power settings
 - under bright office lights and in the dark
- a nice way to monitor sensor health

GUI

- Development ongoing,
M.Sc. thesis of Irtaza Syed
- Jupyter Notebook based:
customised workflows
for interactive & on-line
data analysis in real-time
powered by Python
- Data transfer via
TCP/websockets,
clusters in AVRO binary
format (c.f. iPadPix)

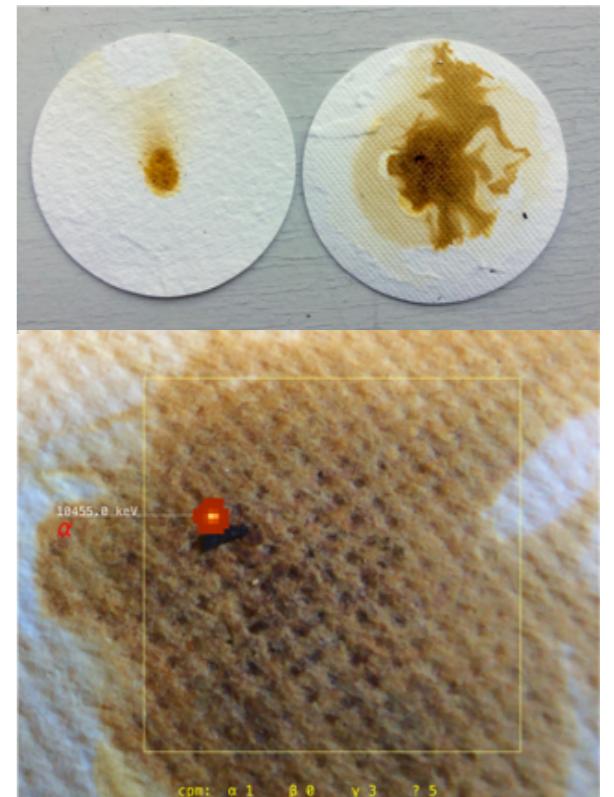
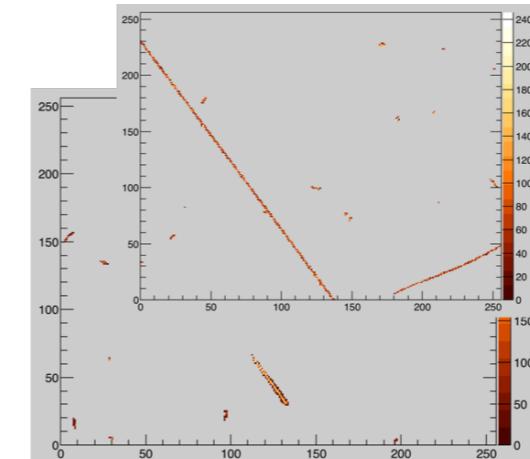
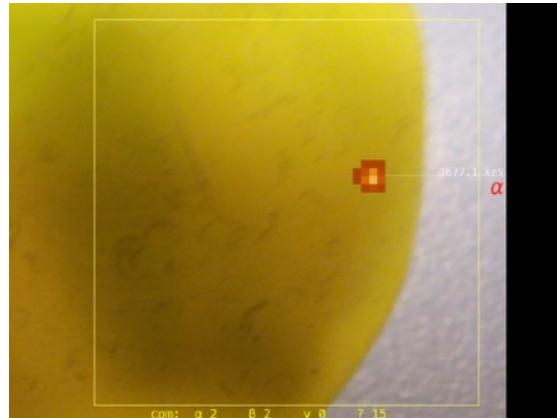


Experiments

Towards inquiry-based learning, indoors & outdoors

Sensitivity and ability to discern particles allows exploration of

- Environmental radioactivity and every-day objects (U&Th, Rn, K40)
- Cosmic rays, Landau distribution with muons
- Bragg peak from heavy ionising particles recorded on airplanes
- Deflection of particles in magnetic fields
- Rutherford scattering of alphas
- Bremsstrahlung of old cathode ray tubes



Summary

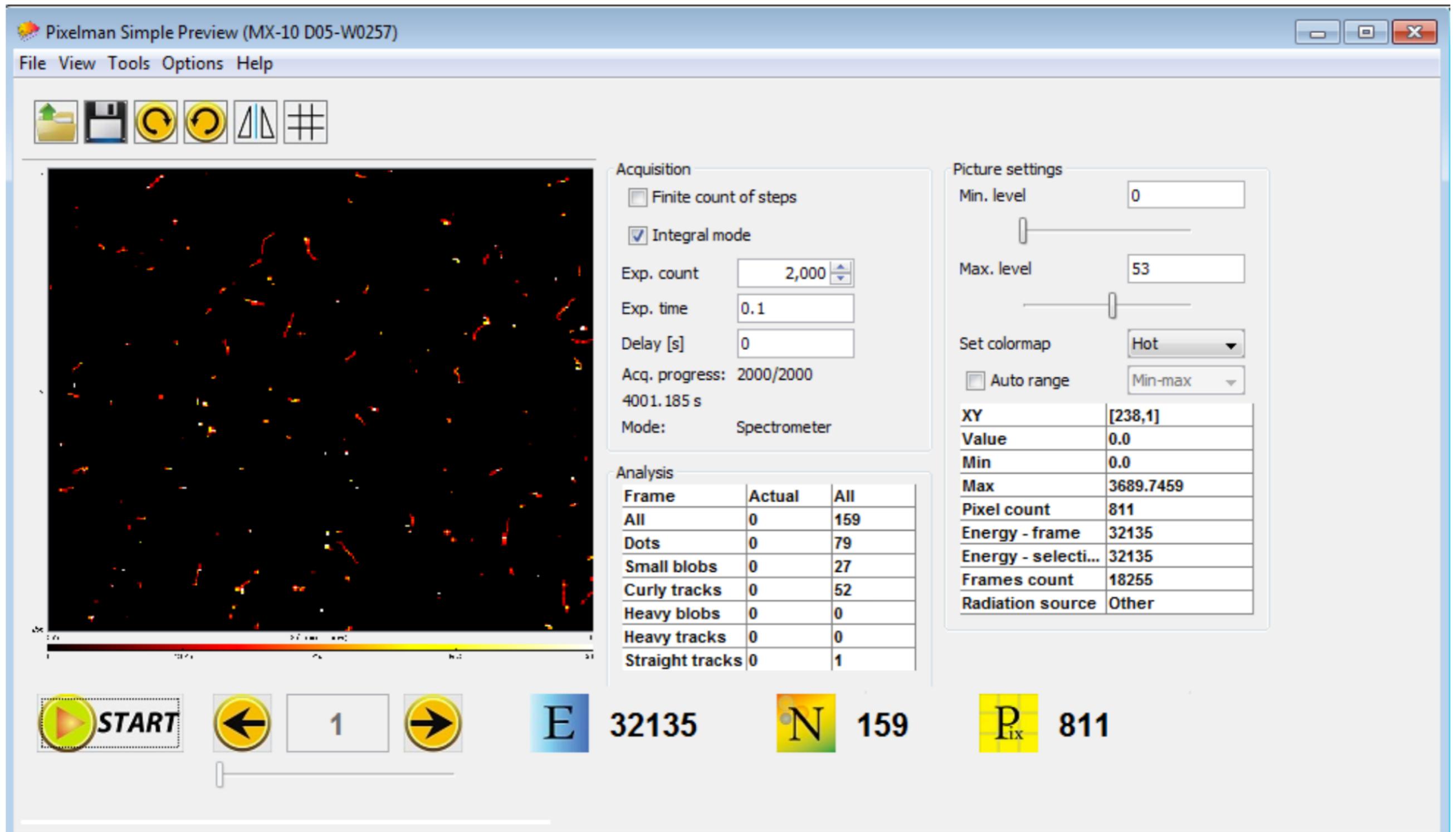
- portable Timepix3 detector architecture, completely open design
- low power consumption, more compact revision 2 in the pipeline
- first hybrid pixel platform based on embedded multi-core processors instead of complex FPGAs => rapid development cycles
- making pixel detectors available as promising tool for particle physics outreach
- towards a streamlined user experience, enabling novel experiments for physics education and citizen science, close to the state-of-art



Thank you!

BACKUP

Screenshot from MX-10 ‘particle camera’, Jablotron



“Learning Particle Physics Using Timepix-Based Pixel Detectors at CERN S’Cool LAB” (2015)
scool.web.cern.ch

Example: reading a serial bit stream on a XMOS processor

```
on tile[0]: in buffered port:32 TPX3_DataOut = XS1_PORT_1H; // 32 bit deserialiser input
streaming chan packets;                                     // channel output to next xCore (UDP conn.)
int input, word;
short symbol, byte;
select {
    case TPX3_DataOut when pinseq(1) :> input @ t:      //wait for rising edge
        TPX3_DataOut @ t + 81 :> input;                  //timed input for correct bit alignment
    while(1){
        word = (input << carry_bits ) | last_word ;
        symbol = (word          & 0b1111111111);      //get first 10 bits
        byte = map10b8b[symbol];                         //map 10 bit symbols to 8 bit
        if(byte != 0xFFFF) {                            //valid 8 bits?
            packets <: (unsigned char) byte;           //pass on to next xCore
        }
        // [...] get next 10 bits
        // [...] get next 10 bits
        // [...] track carry_bits, save remainder in last_word, 1 extra word every 5th input
        TPX3_DataOut :> input;                         //input next 32 bits
    }
}
```