Brookhaven National Laboratory

Jefferson Lab

U.S. DEPARTMENT OF ENERGY

1 ČVUT ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

2 University of Glasgow

Low Q^2 Tagger DAQ

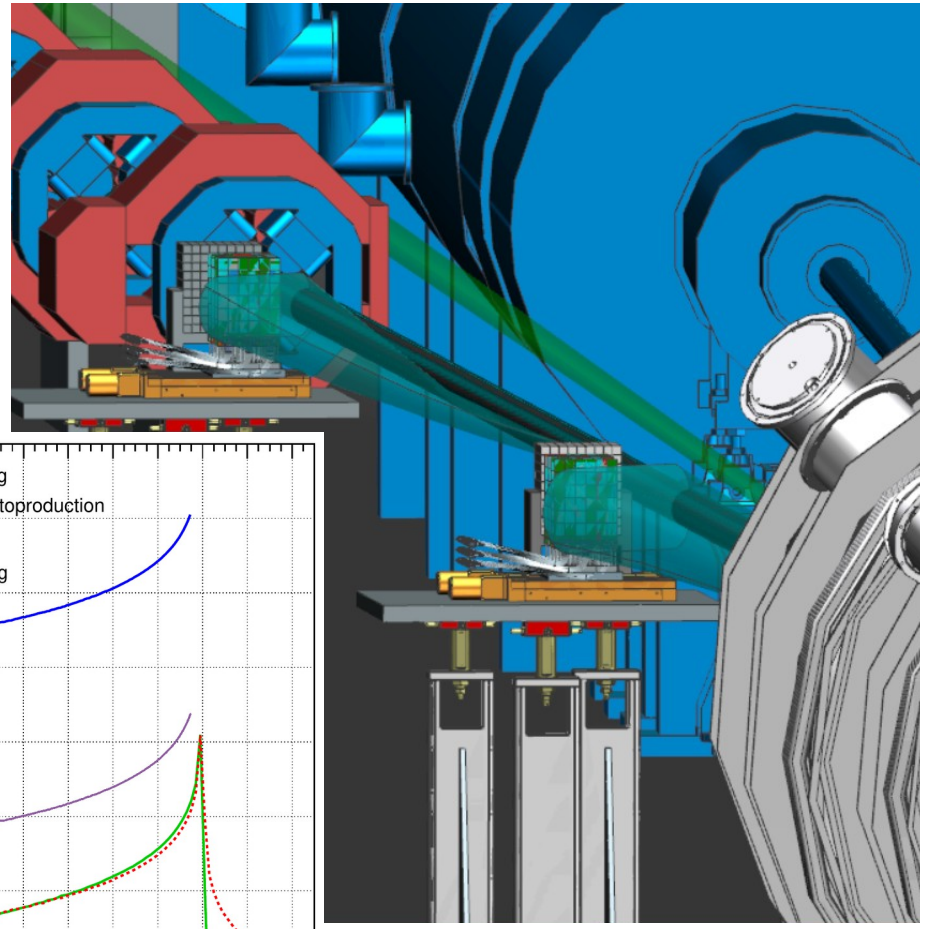
Jaroslav Adam[1], Simon Gardner[2], Derek Glazier[2], Ken Livingston[2]

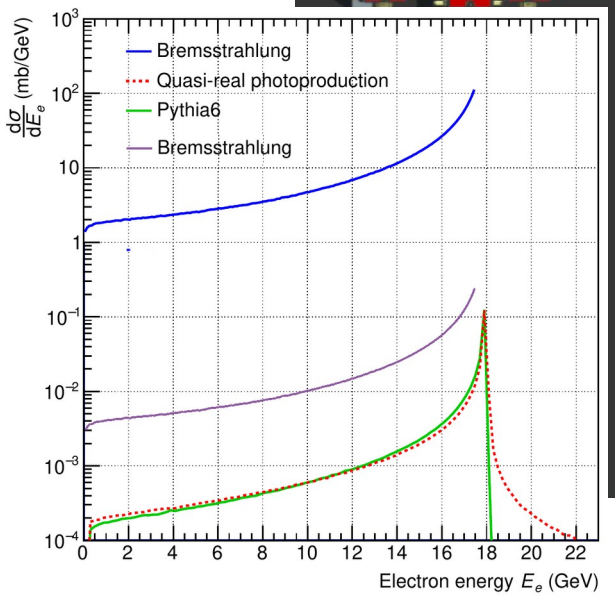
Electron-Ion Collider

Requirements

- Increase Q^2 acceptance
- Allow quasi real (Q^2~0) physics

- Very close to beamline.
  - 2 Taggers
  - Pixel based trackers
    - Rate capability and pixel resolution to identify > 10 tracks per beam bunch (brem BG)
    - $E_\sigma < 1\%$, $\theta_\sigma < 0.5$ mrad, $\Phi_\sigma < 5$ deg
  - Calorimeters
    - for calibration, alignment and monitoring of trackers, Luminosity and PS.





Requirements - Rate

- High Brem BG, Non uniform distribution.

Maximum rates

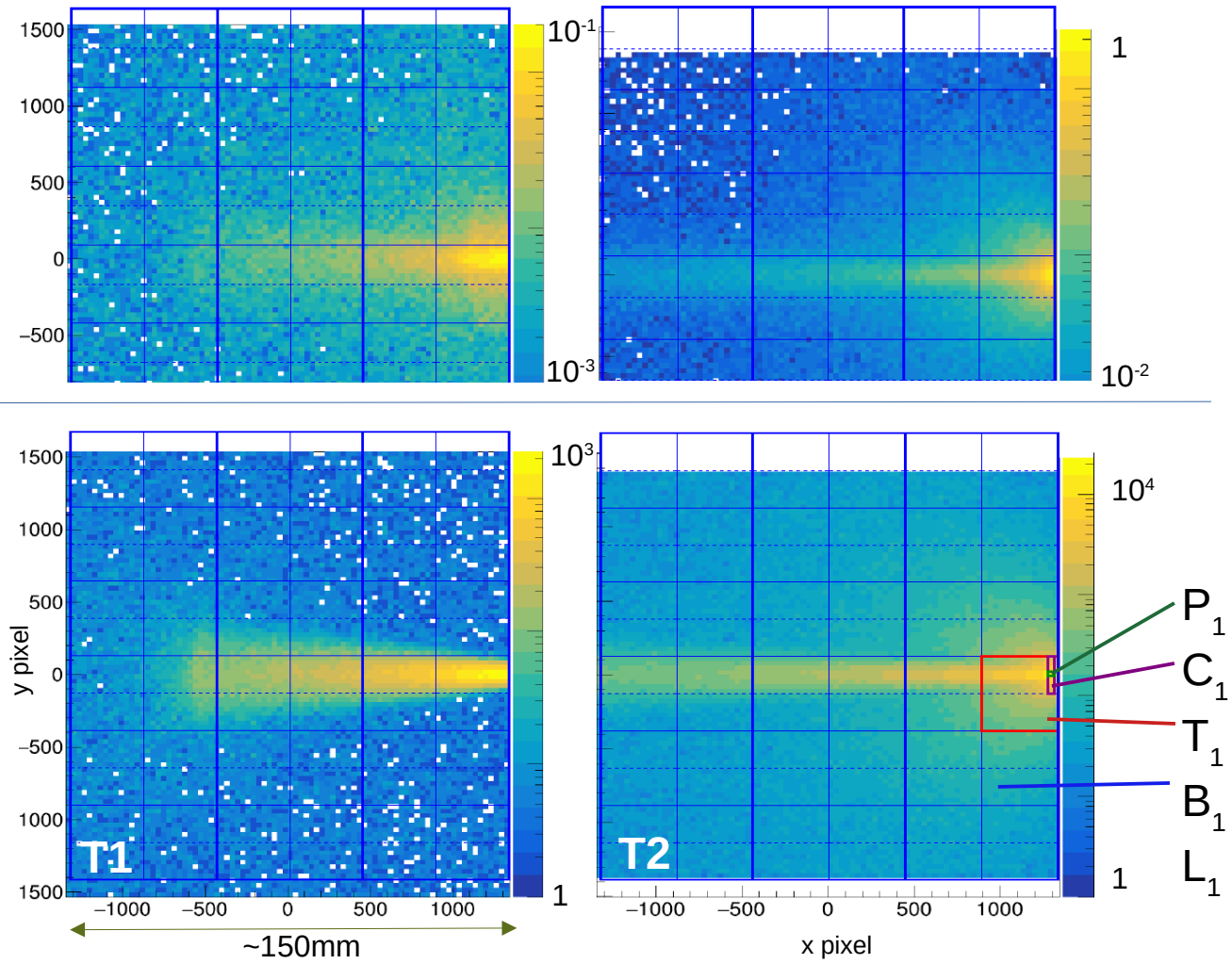
Pixel (P1)	70	kHz	
2 column (C1)	8	MHz	
Tpix4 (T1)	600	MHz	38 Gb/s
Board (B1)	1500	MHz	96 Gb/s
Layer (L1)	2500	MHz	160 Gb/s

Total integrated rates

Tagger 1	2 GHz	130 Gb/s
Tagger 2	7 GHz	480 Gb/s
Total	**9 GHz**	**600 Gb/s**

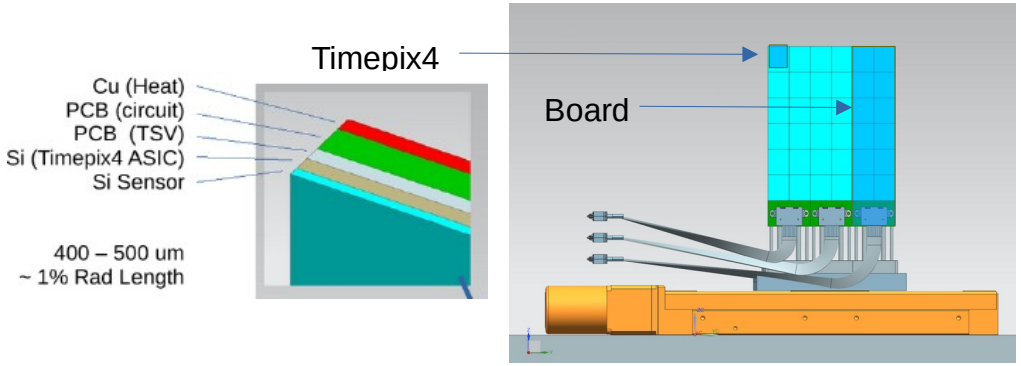
- Data buffered & filtered: need a hadron in main detector
- Trigger rate: 500 kHz: 99.4% rejection (brem only)
- Data rate (signal): 4 Gb/s
- **Data rate** (incl BG and rand sample) **<20 Gb/s** To tape

Low Q^2 tagger rates kHz / pixel. (18x275 GeV @ 10^{34} cm^{-2} s^{-1})

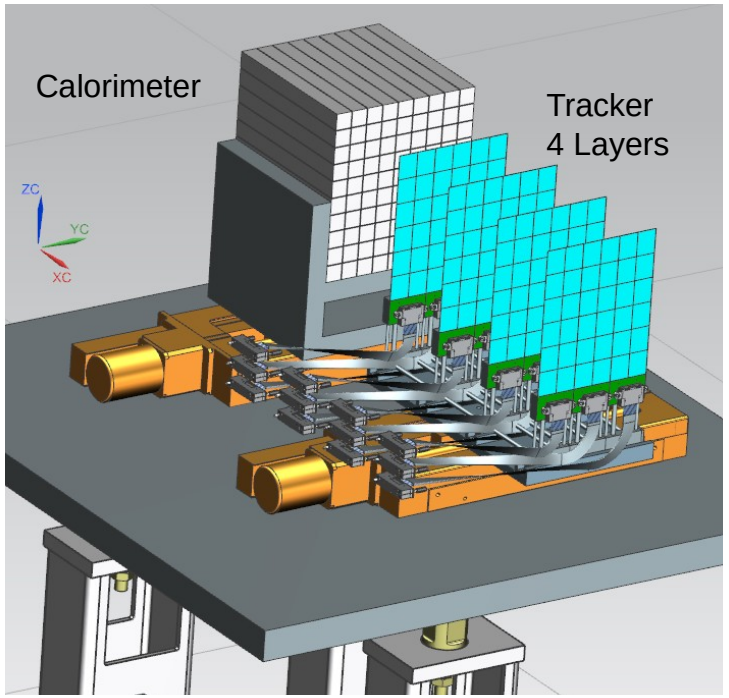


Technology

- Tracker
  - **Timepix4 Hybrid (ASIC+Si) + SPIDR4 readout.**
    - Pixels: 55x55 um. 448 x 512 pixels. Area = 6.94 cm^2
    - Individual thresholds, data driven
    - Timing: < 2 ns.
    - Rates: < 5.5 MHz per 2x256 column
  - **Layout**
    - 1 board: 6x2 Timepix4 → SPIDR4 readout.
    - 1 layer: 3 boards
    - 1 tagger: 4 layers → total of 12 boards, 144 x Timepix4
    - Documented at https://arxiv.org/abs/2305.02079



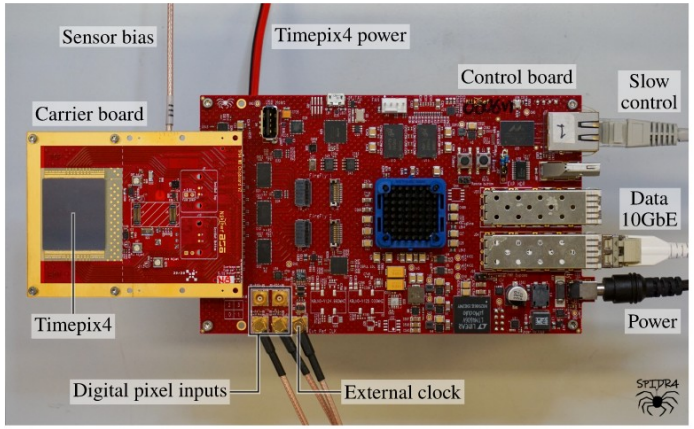
- Calorimeter
  - Scintillating Fibre Calorimeter. See Other FB Calorimeters, fECAL.
    - 18x18x18 cm cube → 900 3x3 mm Hamamatsu SiPMs

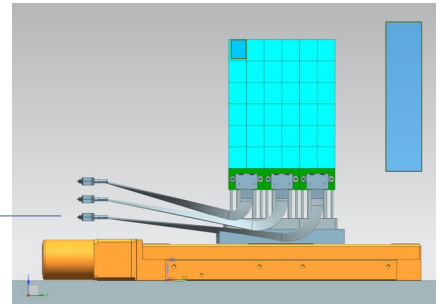


Readout and DAQ

Charge 1, 2, 5

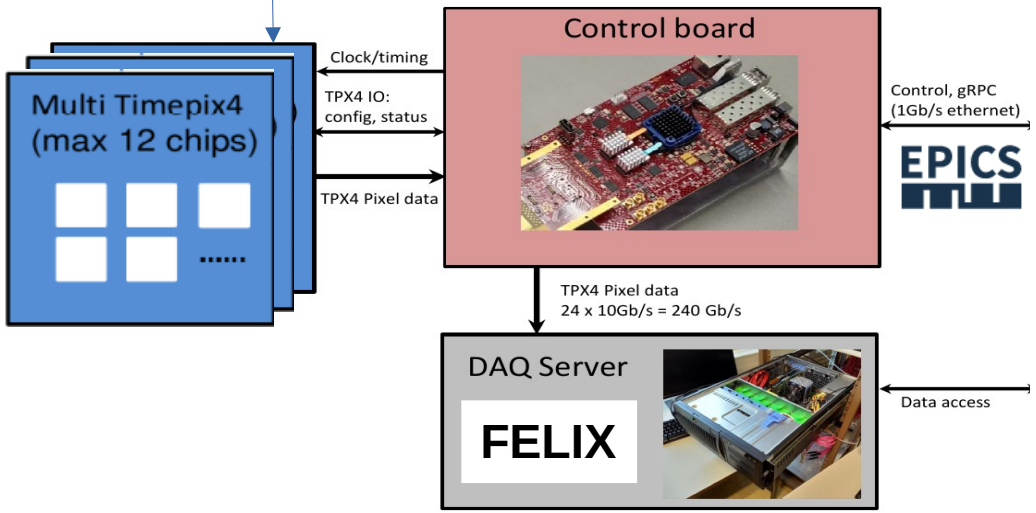
- Tracker
  - Timepix4 readout SPIDR4, NIKHEF
  - Digitization on ASIC.
  - Individual thresholds. Very low noise.
  - Control board, up to 12 Timepix4
  - Data → FELIX boards / Buffering
  - Buffered data filtered **on coincidence** with central detector





x3

SPIDR4: Multi chip, 2 x 10 Gb/s per TPX4 chip



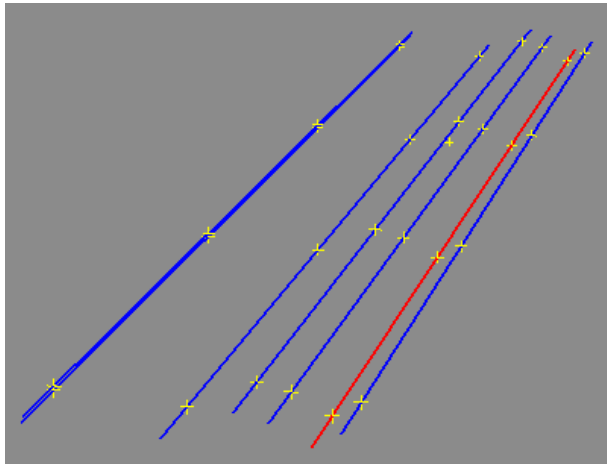
- Calorimeter
  - Fibres → SiPM → standard DAQ channels
  - 2 x 900 channels per calorimeter = 900

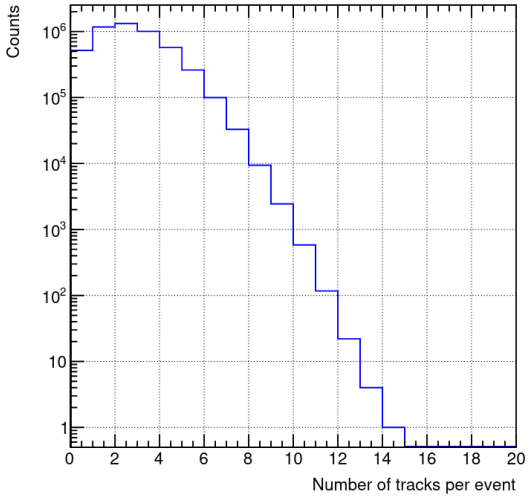
Simulation – tracking

Charge 1, 2

- Tracking
  - Can be many tracks per event, and extra clusters from noise + BG.
  - Most events are brem only.
  - Machine Learning
    - >99% efficient on mix of QR+brem

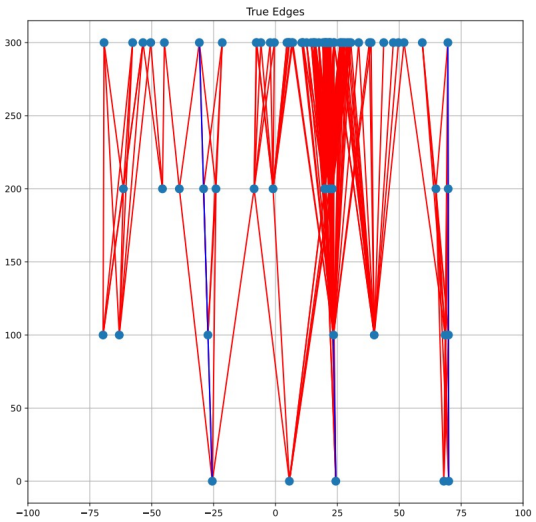
Q.R. and **Brem** events in 4 layer Tracker

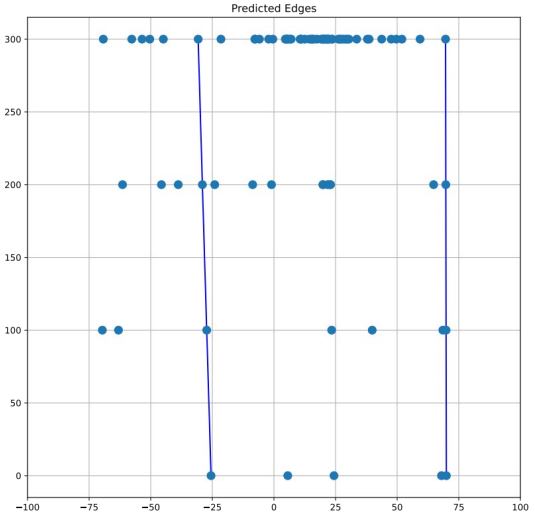


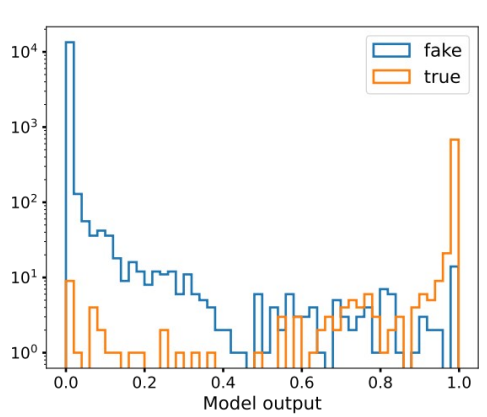


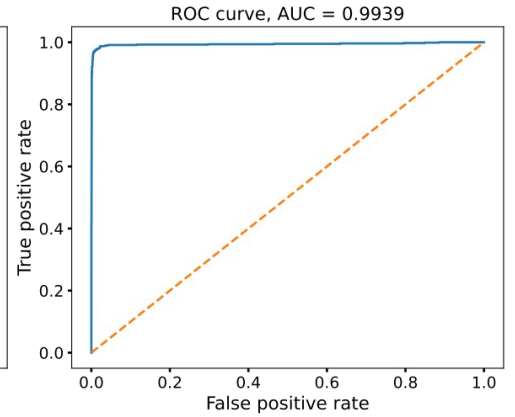
- ML + FPGA
  - Collaborating with Jlab group (generic R&D project)
    - Particle identification and tracking in real time using Machine Learning on FPGA
  - Excellent preliminary results (See backups)
    - S. Gardner: Object Condensation for Track Building in a Backward Electron Tagger at the EIC @ AI4EIC, Nov 2023, CUA, Washington D.C.

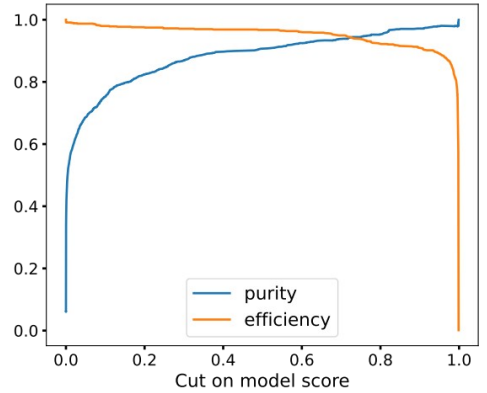
Backup slides. FPGA Machine Learning

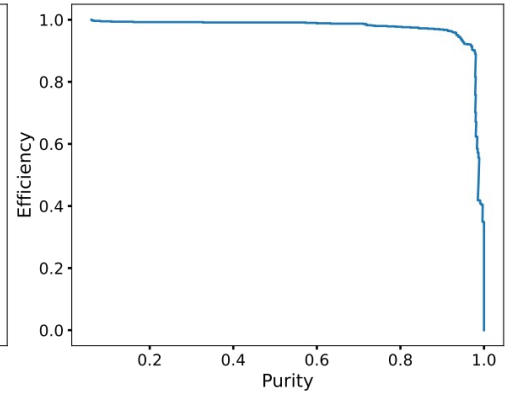












Backup slides

- Timepix4 + SPIDR4 Engineering test setup.

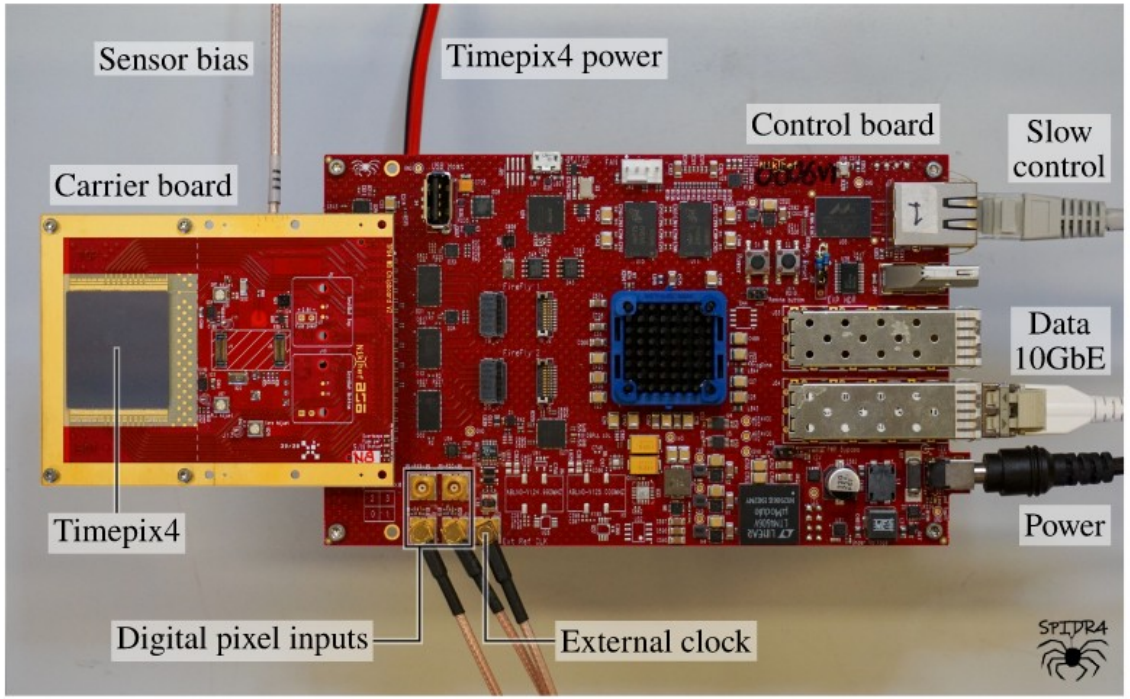
Timepix3 vs Timepix4

Timepix4: A 4-side tillable large single threshold particle detector chip with improved energy and time resolution and with high-rate imaging

			Timepix3 (2013)	Timepix4 (2019)	
Technology			130nm – 8 metal	65nm – 10 metal	
Pixel Size			55 x 55 µm	55 x 55 µm	
Pixel arrangement			3-side buttable 256 x 256	4-side buttable 512 x 448	3.5x
Sensitive area			1.98 cm²	6.94 cm²	
Readout Modes	Data driven (Tracking)	Mode	TOT and TOA		
		Event Packet	48-bit	64-bit	33%
		Max rate	0.43x10⁶ hits/mm²/s	**3.58x10⁶ hits/mm²/s**	
		Max Pix rate	1.3 KHz/pixel	**10.8 KHz/pixel**	8x
	Frame based (Imaging)	Mode	PC (10-bit) and iTOT (14-bit)	CRW: PC (8 or 16-bit)	10x
		Frame	Zero-suppressed (with pixel addr)	Full Frame (without pixel addr)	5x
		Max count rate	~0.82 x 10⁹ hits/mm²/s	~5 x 10⁹ hits/mm²/s	8x
TOT energy resolution			< 2KeV	< **1Key**	
Time resolution			1.56ns	**~200ps**	
Readout bandwidth			≤5.12Gb (8x SLVS@640 Mbps)	**≤163.84 Gbps (16x @10.24 Gbps)**	

xa 1

Xavier.llopart@cern.ch Medipix Symposium, Sept 2019



K. Heijhoff et al 2022 JINST 17 P07006