Timepix3 Readout – current development

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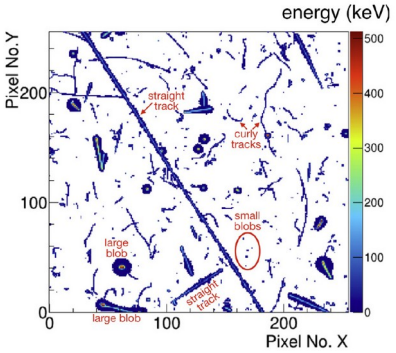
Timepix3 Module
Timepix3 is 3-side buttable. A module has 4 ASICS.

Timepix3 can deliver up to 5.12 Gb/s.
Module maximum rate = 4 x 5.12 = **20.48 Gb/s**.

The Xilinx zcu102 can handle this rate.

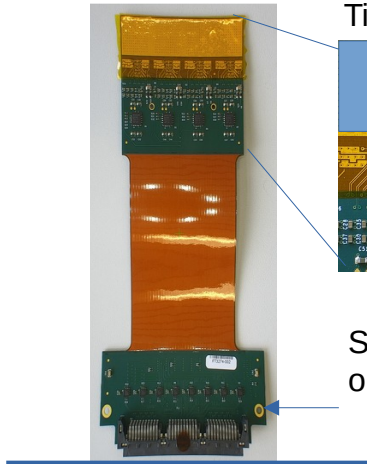
Onboard processing and data reduction.
Event selection using clustering, timing, ToT.
Initially to tested offline, then implemented on FPGA + Petalinux on Xilinx board.

Coincidences
Each Xilinx board has 16 digital I/O to select coincidences or trigger conditions.



Example of how clustering, ToT and timing can be used to eliminate background and do PID.

B. Bergmann, et al. Particle tracking and radiation field characterization with Timepix3 in ATLAS. Nucl.Instrum. Meth. A, 2020. 978:164401.



Timepix3 interface board

SAMTEC connectors
on custom PCB with TSV

Vacuum

Air

to mezzanine board
mounted on Xilinx zcu102
dev. board
(FPGA + Linux CPU)

10G link to event builder

Timepix4 design – more of the same ...

Timepix4 Module
Timepix4 is 4-side buttable. A module has 16 ASICS.

Timepix4 can deliver up to 163.84 Gb/s.
Module maximum rate = 16 x 163.84 = **2.62 Tb/s**. Ouch!

The Xilinx zcu102 design can't handle this rate.
… but something will.

Sequence for a tracker with layers of Timpix4 modules.

1. In each module.
Candidate hits associated with a track, selected on the basis of clustering, timing. FPGA + Petalinux.
For each hit the centroid, eTot and time are sent to Timepix Event Builder.

2. Event Builder.
Receives reduced info from each layer. Combines data into tracks with weights (non-trivial, potentially using GPU + Machine learning).

3. How to get the track data into the main DAQ.
Needs detailed discussion with DAQ team.

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)**	

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

Design of readout for timepix4 needs close discussion with EIC DAQ group.

Nice streaming DAQ presentation by Jin Huang, BNL
https://indico.jlab.org/event/344/contributions/10499/attachments/8253/11854/AI%20in%20StreamingDAQ.pdf

Timepix4 data readout – a very simple illustration.

Here's a tracker with 3 modules, each containing 16x512x448 = 3.7M pixels. **A total of about 10M pixels**

There are **many hits in each module** (not all shown):
from detector noise, from cosmics, sychrotron background, bremsstrahlung events and some from physics events
Even writing out the data for this where a small proportion of pixels have some sort of hit could be very expensive.

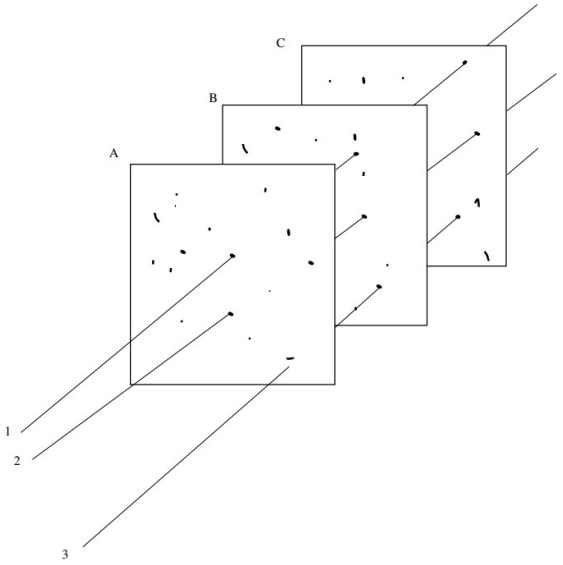
Let's assume track 1 is a physics event, 2 is a bremsstrahlung event, 3 is some sort of rescattering
The reject / accept is as follows:

In each module (A,B,C):
Accept only events with clusters that look like MIPS
from the approximate region of the interaction (ie straight through the layer).

That reduces us down to only clusters associated with tracks 1,2,3 in the figure.
The cluster information x,y,t,eTot is passed to the event builder.

In the event builder:
Cluster information 3*(x,y,t) (=**18 bytes**) to the DAQ for sorting out later.
OR
tracks constructed from the clusters in each module,
and knowledge of where the interaction region is
This would reject track 3, so tracks 2,3 (x,y,vx,vy,t) (=**20 bytes**) written to the DAQ.

In the physics analysis: Use exclusivity or kinematics to reject the brem event.



Assume 2 bytes for x,y,t (vx,vt)

Estimate of data rate for 10 tracks per 12ns pulse:
Clusters: 1s/12E-9ns * 10tracks * 18bytes = **15 Gbytes/s = 240 Gbps**

Estimate of data rate for 10 tracks at 500kHz collision rate.
Clusters: 500E3 * 10tracks * 18bytes = **0.09 Gbytes = 1.44 Gbps**