The Timepix3 telescope

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Telescopes & Testbeams Workshop DESY 2014





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Motivation			
Upgrade of the	LHCb detector		LHCb accepta
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Upgrade of the	Vertex Locator		
 strips → pix Velopix silico 200 µm sens Timepix3: pr 	els on pixel detector sor on 200 μm ASIC rototype for Velopix	State Land	Aller.
 Testbeams for characteriza entre efficient 	or sensor & ASIC tion up tests		

efficiency tests

Introduction

- high fluence irradiation($\sim 10^{16} n_{eq}/cm^2$) high rate tests (80 Mhits/s)



The telescope

The Timepix3 detector

Epilogue

The telescope

Hybrid pixel operation

What is it

- Hybrid pixel detector: sensor-readout separately processed
- 256 x 256 square pixels of 55 μm size
- measures
 - Position (x, y)
 - Time of Arrival
 - Time over Threshold





Principles of operation

- Sensor is a reversed biased *p-n* junction
- charged particle ionizes the sensor
- e⁻/holes drift to the readout
- readout processes the collected charge

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Sensors for LHCb Velo Upgrade			

Sensor characteristics

- 200 µm thick (exploring other thicknesses too)
- 400-450 μm wide guard rings
- n-on-p (n-on-n)
- Radiation hard up to $\sim 10^{16} \ n_{eq}/cm^2$
- Non-homogeneous irradiation (factor 40 difference between tip and other end)
- 8.5 tracks per bunch crossing hit rate: average (peak) 600 (900) Mhits/s
- Vendors
 - Micron
 - Hamamatsu



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Timepix3 predecessor of Velopix

- Velopix early next year
- use Timepix3 for sensor characterisation programme

Timepix3 specs

- 130 nm CMOS technology
- Maximum hit rate 40 Mhits/s/cm²
- Simultaneously 18-bit ToA and 10-bit ToT
 - Time resolution of 1.55 ns
 - ToA range 400 μs
 - ToT in 10-bits with configurable resolution
- Dead time per pixel is charge depended (typical 800 ns)
- Zero suppressed data driven readout





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SPIDR Readout			



- Single chips up to quads
- 10 Gbps Ethernet link
 - 1 Timepix3 chip at full speed: 6 Gbps/s
- Prototype SPIDR with Xilinx VC707 board
- Dedicated PCB (compact SPIDR) available later this year

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First results with silicon on a Timepix3 chip



figures taken from Massimiliano De Gaspari's talk in TIPP 2014

chip is working very well
 plan to use it in the beam telescope

Telescopes & Testbeams Workshop

The Timepix3 telescope





The telescope

Results with the Timepix Telescope

Efficiency at the last pixels of Active-edge sensors



Results with heavily irradiated Medipix3's



In many analyses performed, more data would be beneficial

The telescope ○○○●○○○○

Additional telescope elements

- 2 scintillators for time-stamps for other LHCb users
- Cooling for the DUT
 - peltier elements
 - maybe CO₂ cooling
- Mechanics
 - similar to existing telescope mechanics (rotation & translation stages etc.)

DAQ

- raw data stored locally on DAQ PC's
 - 600 MByte/sec per DAQ PC
- separate DAQ stream (copy) for online monitoring (DQM) ("look" at a sample of data)





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Data Flow			



monitoring for high rate data raw data offline reads data from DAQ PC slow control

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Software environment

Readout philosophy: when a pixel is hit ..

- a data-packet with address, time and charge information is sent
- DAQ PCs will continuously record the stream of pixel packets

reconstruction software relies on timestamps

Project "Kepler"

- based on LHCb software framework
- used in LHCb collaboration
- Distinguish between events (e.g hit, cluster, track) and tools (e.g. fit)
- algorithms in C++, python configurables, xml description of detectors



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Online Software

Data Quality Monitor (DQM) GUI

- standalone .cpp using ROOT and Qt libraries
- online check of data quality on sample of data
- "basic" plots of hitmaps, correlations etc.



courtesy of Daniel Martin Saunders (Bristol) 🗇 🛛 🖛 💷 🖉 🔍

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Offline Software			

Software chain

- Time re-ordering of data
- Clustering
- Track Finding (Pattern Recognition)
 - Look in a volume (cylinder) for best fitted track
 - Least squares fit performed
- Additional Track Fitting
 - Kalman-Filter for low energy beams
- timestamped tracks will be provided for "external" users

Alignment

- aligning on residuals
- implement also Millipede

Software already running

- "fake" raw data
- MC data based on Gaussian, Landaus etc.



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Summary			

LHCb upgrade

- Velo group actively working of pixel for the LHCb upgrade (2018/2019)
- In view of this: making a new telescope
- Telescope to characterize new ASICS & sensors
 - Telescope will also be used by other LHCb group (non VELO)

The Timepix3 telescope

- New telescope under construction based on Timepix3 ASIC
- Online & offline software developed in paralled with hardware
- Active area 2 cm²
- 2 μm resolution at >100 GeVbeam
- Smaller radiation length by a factor 6
- Higher data rate by a factor 1,000 (10 Mtracks/s)

The telescope

Testbeam periods in 2014

- July in PS
 - First tests of Hardware & Software
- October in SPS
 - First 3×1 assemblies
- December in SPS (Fermilab?)
 - Irradiated DUT's

Exiting times ahead!



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