TimePix-2

a new and fast general-purpose MPGD readout pixel chip

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MPGD/RD-51 Workshop
Nikhef, Amsterdam The Netherlands
April 16, 2008

A short reminder…..

2004: TimePix: concept; modified Medipix-2

2006: Start of EUDET: money (≈ 300 k€) found

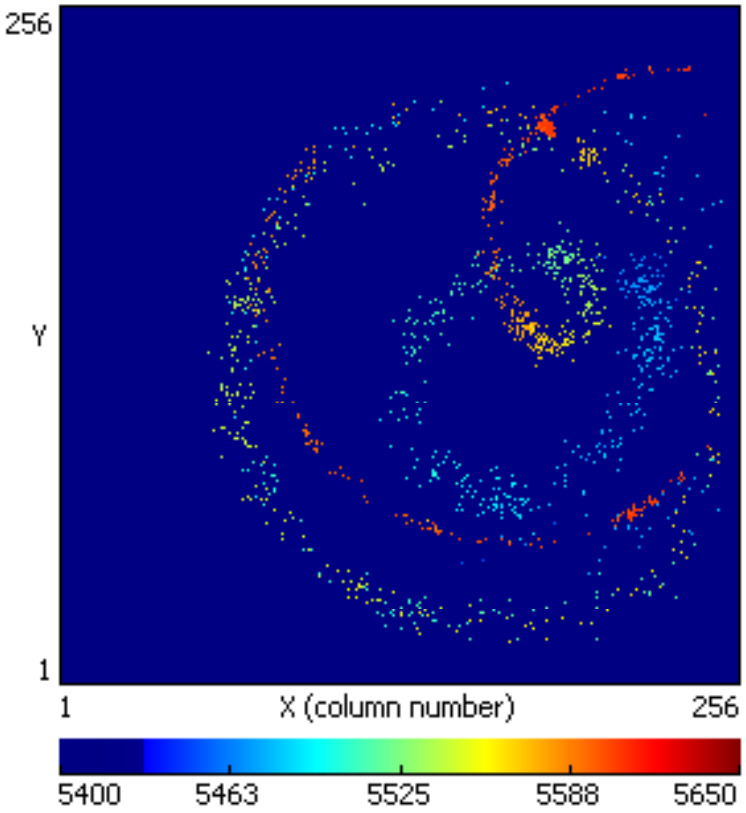
2006: TimePix operational (first submit, including TOT),
and available

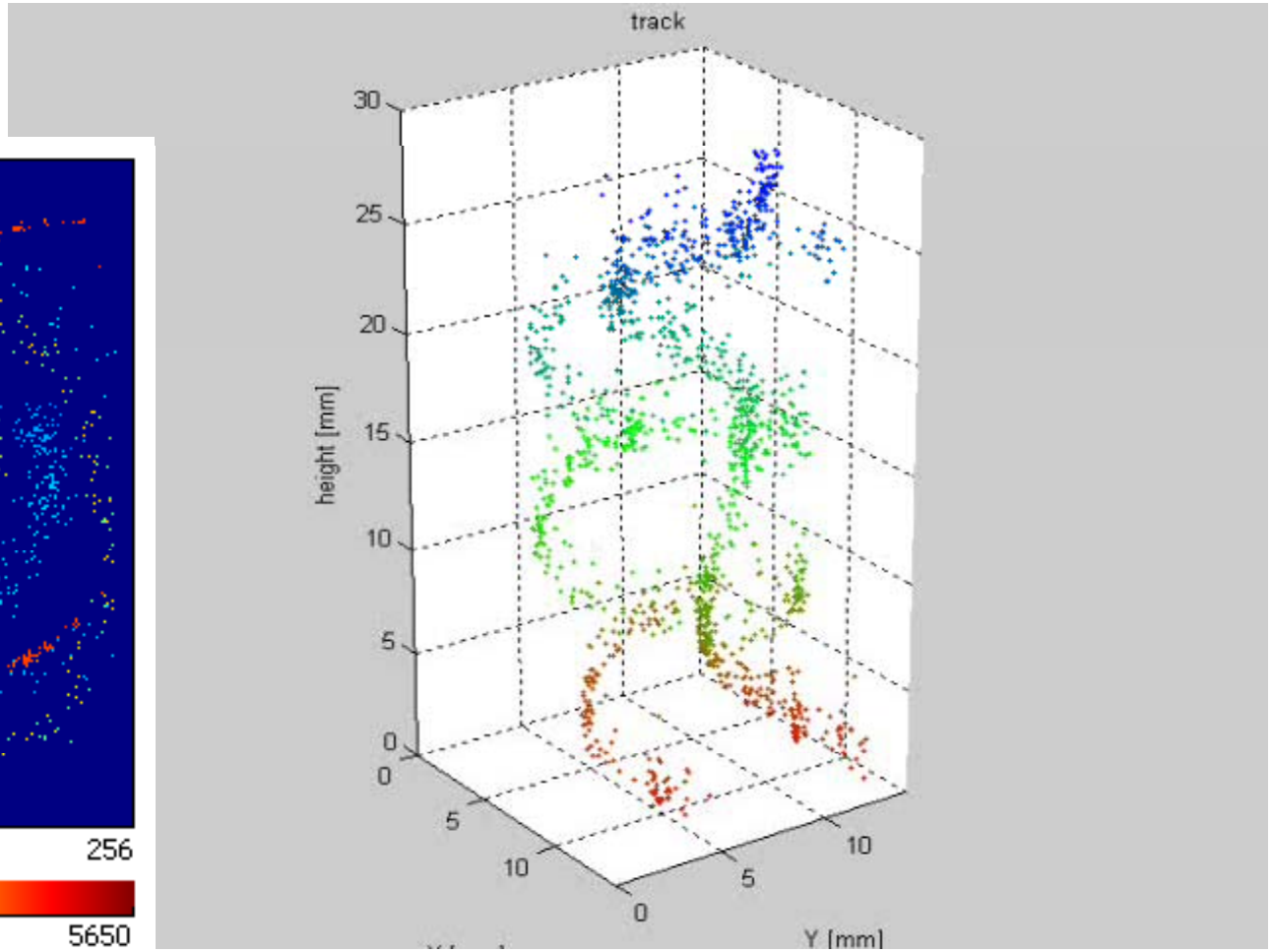
2007: TimePix in use by several R & D groups

2008: order of 48 TimePix wafers (+24 wafers for Medipix coll.)

And how it works……

B = 0.2 T





A 5 cm^3 TPC (two electron tracks from ^{90}Sr source)

Present limitations of the TimePix chip

- Low event rate due to frame-based readout architecture

- Problematic zero-drift time measurement:
  triggered shutter is too late; no fast clear

- Time resolution 'only' ≥10 ns bins (σ ~ 3 ns), and
  limited TOT (pulseheight) resolution;
  'large' time slewing

- ~~(Lowest threshold not determined by preamp noise)~~

- Non-standard readout electronics ((USB)Muros)

In addition:

- Preamp not optimized for MPGD pixels (noise, power)

Gossipo-1:

•130 nm technology

• fast, low noise, low power preamp, matching extremely low (10 - 30 fF) source capacity: 60 e- inp. eq.; 2 μW/pixel

• no digital feedback (triple well tech.): threshold 5 x 60 e- = 300 e- possible

Gossipo-2:

•130 nm technology

• TDC per pixel: 1 ns RMS time resolution

• Analog part as Gossipo-1. Threshold determined by preamp noise, while 100 MHz clock on pixel is running!

Definition of TimePix-2 version -1

Basics

- Name: first thing to agree upon
- Goal: general-purpose pixel chip for the time-resolved readout of (single) primary electrons from a gas-filled drift space.

  - The granularity is adequate to detect single electrons from MIP tracks with an acceptable occupancy.

  - With its time resolution, all 3D position information of the single electrons is made available, only limited by diffusion during drift.
- Users: all future tracking detectors (TPCs, Gossip, large-area drift chambers).
- Interested groups: Nikhef, Bonn, Saclay, Freiburg, Eudet, ATLAS, CERN

Definition of TimePix-2 (cont'd)

- Technology: 130 nm IBM
- Radiation hardness: no (surface claiming) precautions: TimePix-2 will not be applied in SLHC environments. Known radiation softness should be avoided
- Dimensions
  - 256 x 256 pixels: history Medipix/TimePix
  - 128 x 128 pixels: pixels too large for low single-electron occupancy
  - 512 x 512 pixels only useful for future ILC high-precision tracker
  - pixel area: 14 mm x 14 mm.

    May be larger in future versions: 25 mm x 25 mm, in combination with 512 x 512 pixels

So for TimePix-2: - 256 x 256 pixels
- pixel pitch: 55 µm x 55 µm

Definition of TimePix-2 (cont'd)

- Input Pad
  - surface: 15 µm x 15 µm (as in Gossipo-2)?
  - Coaxial geometry (as in Gossipo-2)
  - integration of feedback C
- Preamplifier
  - No bias current circuitry
  - As in Gossipo-2
  - Matching the low source capacity of 10 fF
- Shaper
  - Time constants: as in Gossipo-2 but:
    - Take in account (high resolution) TOT slewing correction
    - Single electron follows Polya distribution instead of exponential 'decay'
    - Take into account fast GEM signals and fast (30 µm gap) InGrid signals
- Discriminator: improved version of discriminator in Gossipo-2 (?)

Pixel functionality

- Clock distributed to all pixels: 40 MHz
- 'TDC' time measurement: 15 bins in 25 ns

  Oscillator f=15/25 ns = 600 MHz (central freq.)

  TDC data:4 bits
- TOT data: max. value ~ 200 ns. This corresponds to 7 bits;

  so provide 8 bits. Optional: use only 6 bits to be read out, possibly the most significant bits (or the least significant bits)
- Beam Cross ID (BX): max. drift length = 2000 mm

  max. drifttime = 40 μs → 1600 BX's

  (or full bunch train = 1 ms → 40000 BX's)

  Need 11 bits (or 16 bits)

  Total of 23 (or even 28) bits

- Pixel data is generated independent of the readout DAQ
- Instead of a shutter there should be 'pixels enable', common for all pixels

DAQ

• Hit pixel data (18 bits?) is stored per pixel, adapting for future SLHC applications

• For Gossip close to SLHC beam pipe memory is required for two events in order to limit occupancy.
For TimePix-2 we propose one event memory per pixel.

• Readout: a total readout of hit pixels should be possible.
The much faster readout of hit pixel with a specific BX should be possible as well.

Towards sLHC @ ATLAS

- Assume 40MHz BC => inner layer will get **500M tracks/cm^2**
- For 55x55um pixel => **hit rate/pixel = 150kHz**
- Raw data : pixel ID (16b) + Drift time (8b) + TOT (4b) = 24b/pixel
  total **raw data => 230Gb/s.**
- Triggered data : L1 rate 100kHz, 120 pixel/cm^2 have data:
  total **triggered data => 580Mb/s** (5.8us @ 1Gb/s)
- Local memory / pixel , no column memory :

  1 per pixel: occupied L1 latency(2.5us) + readout (5.8μs): **lose 20%**

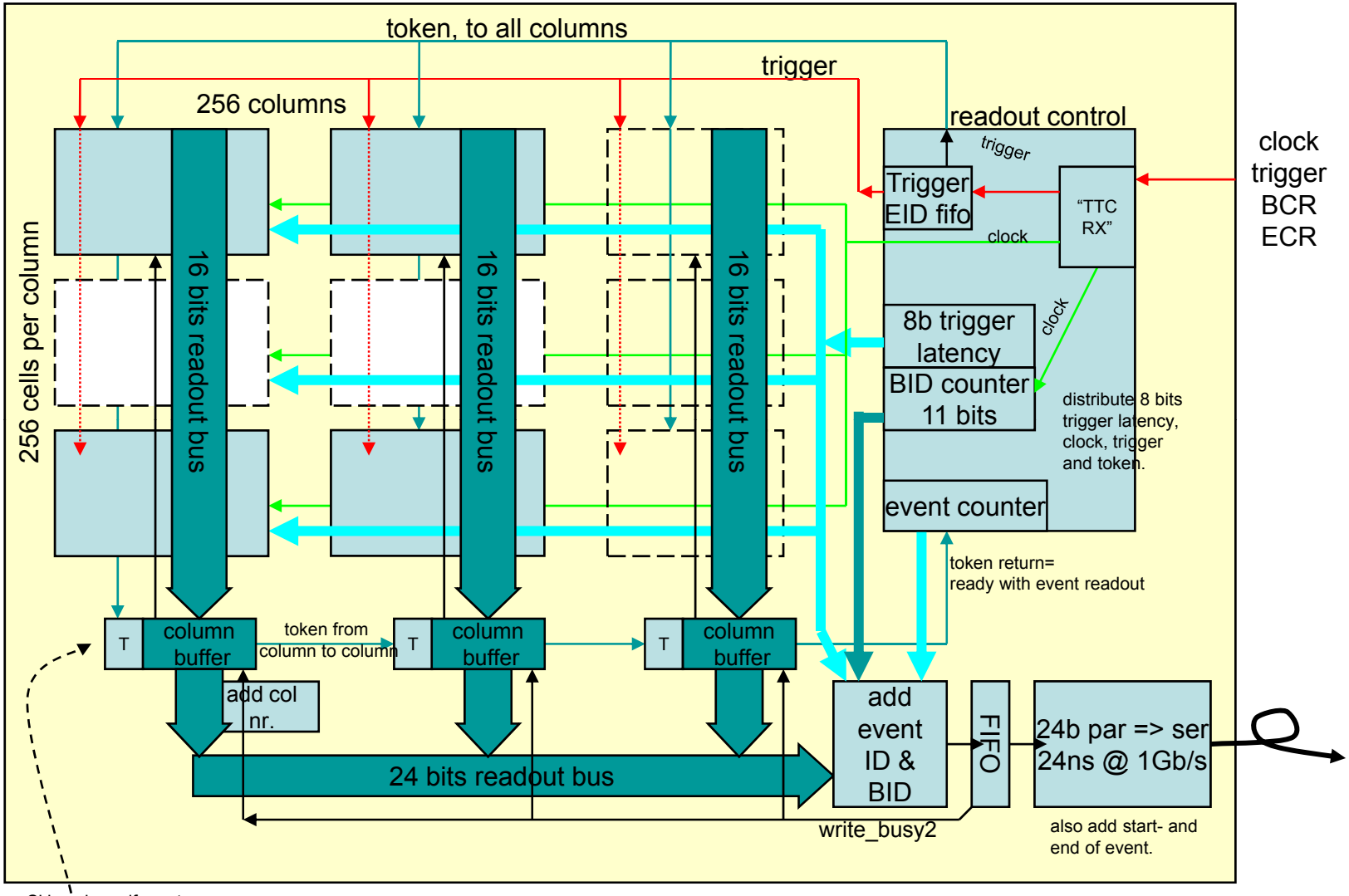
  2 per pixel: occupied L1 latency(2.5us) + readout (5.8μs): **lose 5%**

- *Local memory / pixel with fast readout to column buffers:*

  1 per pixel: occupied L1 latency(2.5us) + readout (50ns): **lose 2.9%**

  2 per pixel:** occupied L1 latency(2.5us) + readout (50ns): **lose 0.24%

Chip level readout



•Skip column if empty
•pixel to column hand-shake with write-busy1
•column buffer to link FIFO hand-shake with write-busy2
•until previous column ready

@Token the pixel cell copies its triggered data in the column buffer.
Readout starts automatic after token comes out of first column.
Asynchronous process, speed determined by serial data link (busy as handshake)
This means the pixel cell and column buffer readout faster then 40MHz.

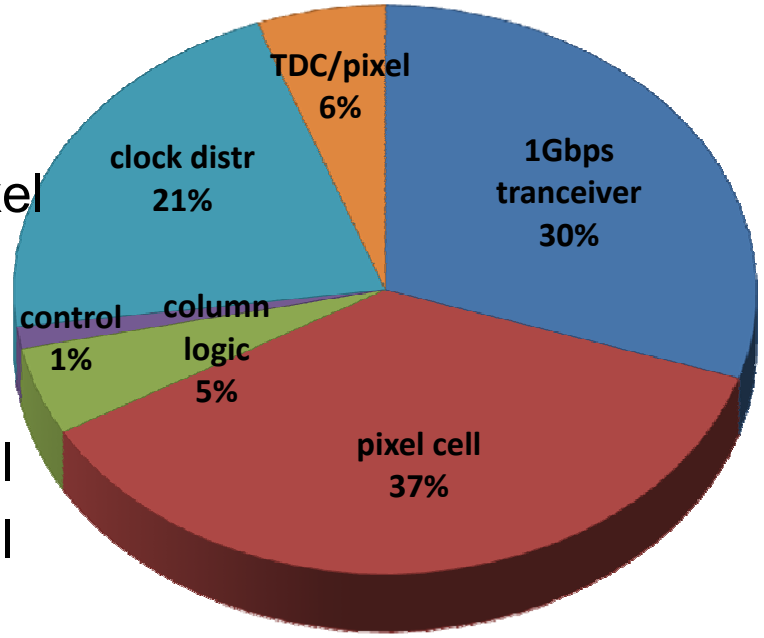
Power budget

Assume total power density: **200mW/cm²**

Sensor chip size: **2 cm²**

Power on chip:

- digital:
  TDC/pixel: (as in gossipo2) 0.34µW/pixel
  column logic 20mW
  control functions 5mW
  data transmitter (1Gb/s) 120mW
- clock distribution (40MHz) 1.3µW/pixel
- power "left" for **analog** 2.2µW/pixel
  Vdd=1.2V : **1.85 µA per pixel.**



(logic power estimate based on 1.2Vdd & capacitance switching of bus lines & DFF's)

Some final thoughts…

- Follow-up of Medipix-3?
- Realisation requires:
- money for submit of engineering run (≈250 k€)
- Chip Design Manpower: CERN, Bonn, Saclay, Nikhef
- Timepath: -- Owner? Project leader?
  -- Definition
  − which multi-project wafer test submits are required?

Required for starting TimePix-2
- expression of interest of a larger-than-critical group size
- outlook on money (FP7 !?): new searches for $$~~€€€~~YY