Pixel Readout Electronics - from HEP to imaging to HEP… Status, requirements, new ideas

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Outline

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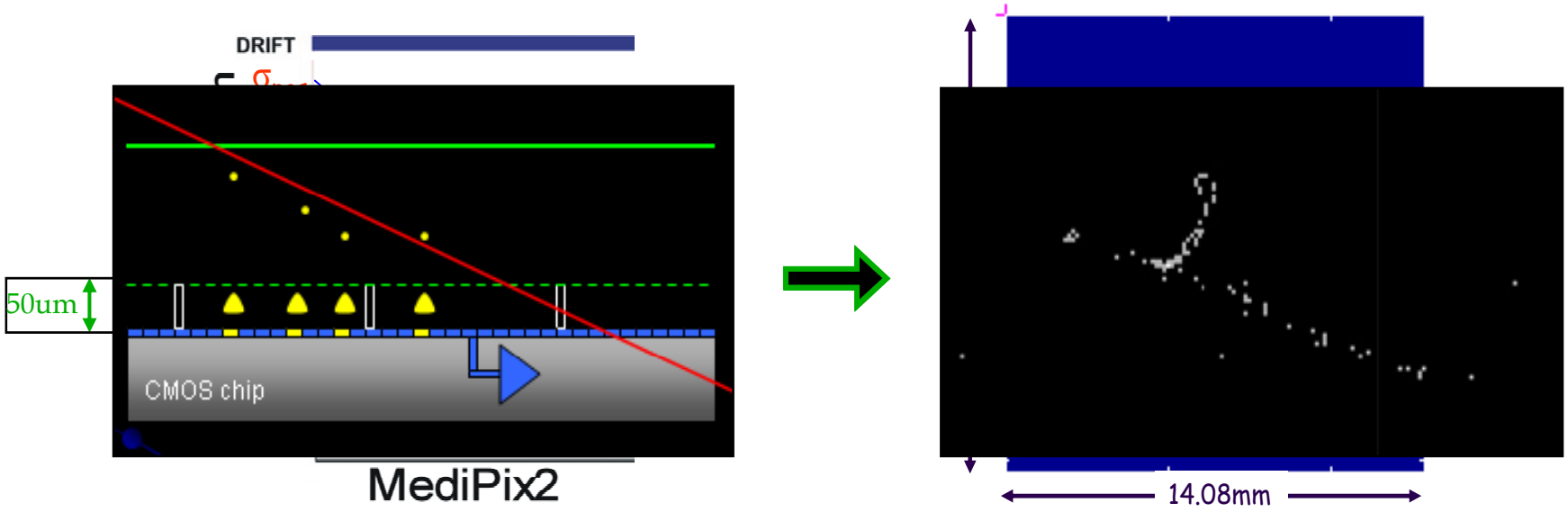
- Timepix
  - Description of circuit
  - Demonstration with Si
- Medipix3
  - Description of circuit
  - First results
- Medipix2 to Timepix to Medipix3 to … GasSiPix?
- Requirements and possibilities
- Summary and conclusions

Background

- Pixel readout developments at CERN started with LAA and then RD19 Collaboration – LHC R detector and D
- Work in RD19 was used directly by Omega, WA97 and NA57 and indirectly by Delphi
- Alice, Altas and CMS use pixel vertex detectors based on hybrid pixels. (LHCb has a RICH detector using the hybrid pixels too)
- The Medipix1 imaging chip was a direct spin off of RD19 chips
- The Medipix2 imaging chip was a separate development using the same CMOS technology (0.25μm) as Alice, Altas and CMS
- The Timepix chip (imaging and time tagging) comes directly from Medipix2

From Medipix2 to Timepix

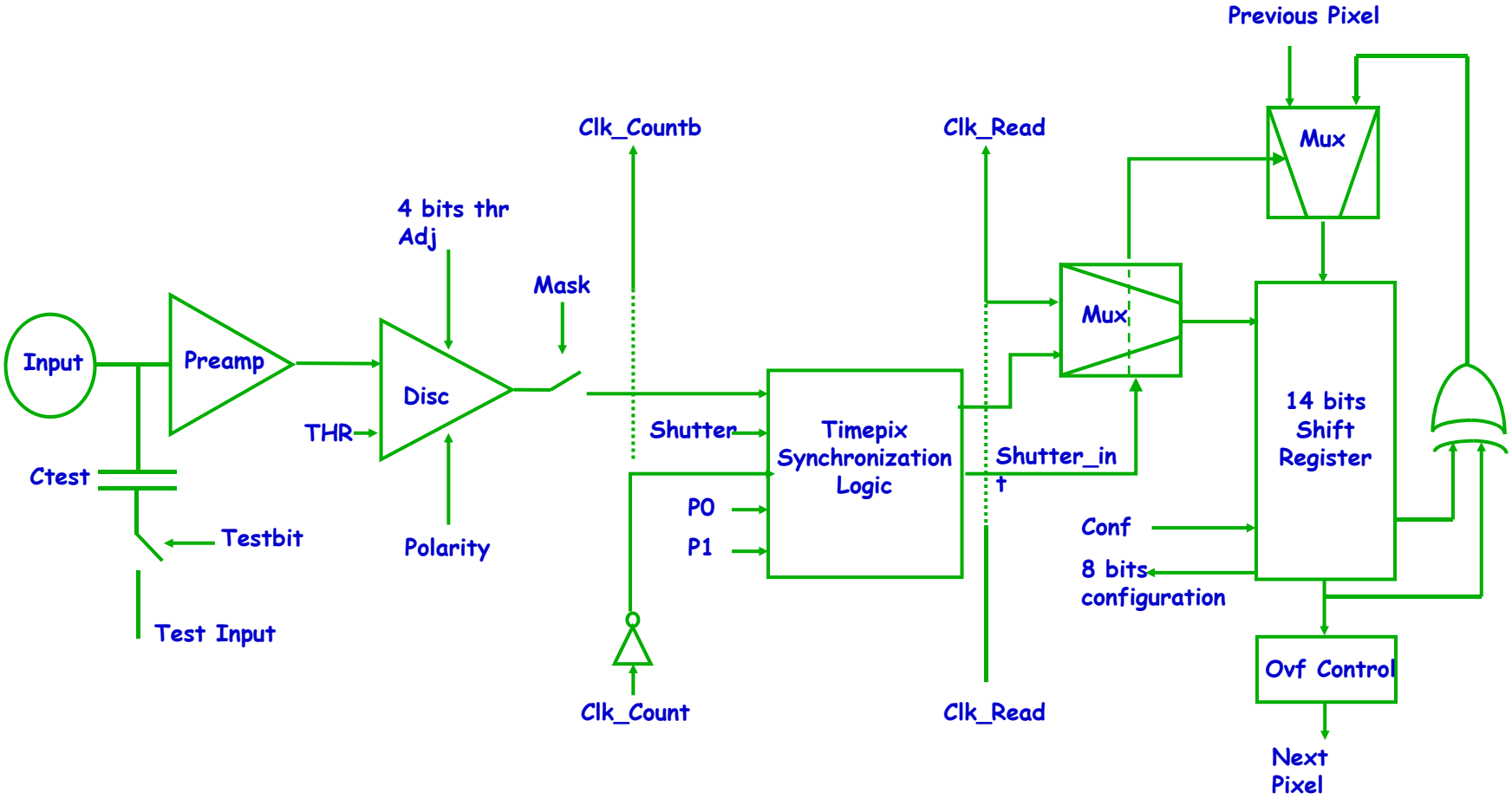
- A novel approach for the readout of a TPC at the future linear collider is to use a CMOS pixel detector combined with some kind of gas gain grid
- Using a *naked* photon counting chip Medipix2 coupled to GEMs or Micromegas demonstrated the feasibility of such approach



From Medipix2 to Timepix (contd)

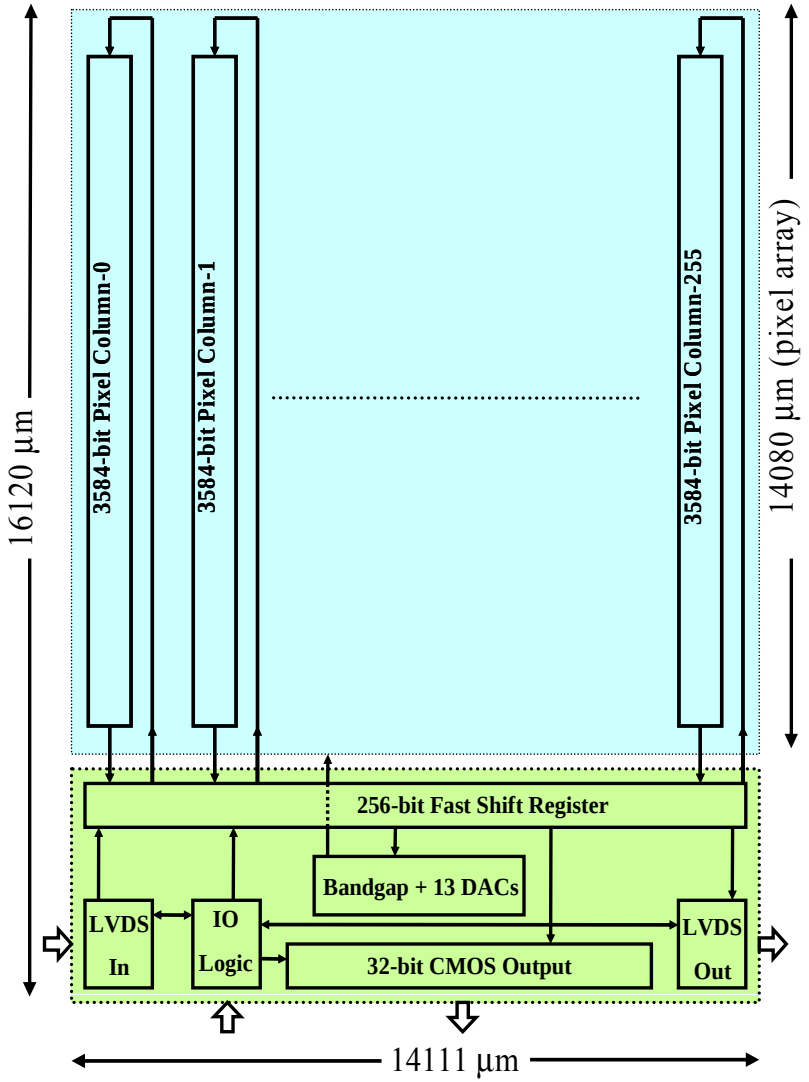
- **These experiments (by NIKHEF/Saclay, Freiburg 2004/2005) demonstrated that single electrons could be detected using a *naked* Medipix2 chip ⇒ 2D**
- **Did not provide information on the arrival time of the electron in the sensitive gas volume ⇒ 3D (position + time) !!!**
- **To further exploit this approach the Medipix2 has been redesigned to incorporate a time stamp with a tunable resolution of 100 to 10ns.**
- **Requirements:**
  - **Keep Timepix as similar as possible to Medipix2 in order to benefit from large prior effort in R/O hardware and software**
  - **Avoid major changes in pixel and/or readout logic – risk of chip failure due to poor mixed mode modeling**
  - **Eliminate 2nd threshold**
  - **Add possibility of programming pixel by pixel arrival time or TOT information**
- **This modification was supported by the JRA2/EUDET Collaboration (www.eudet.org)**

Timepix Schematic



Timepix chip architecture

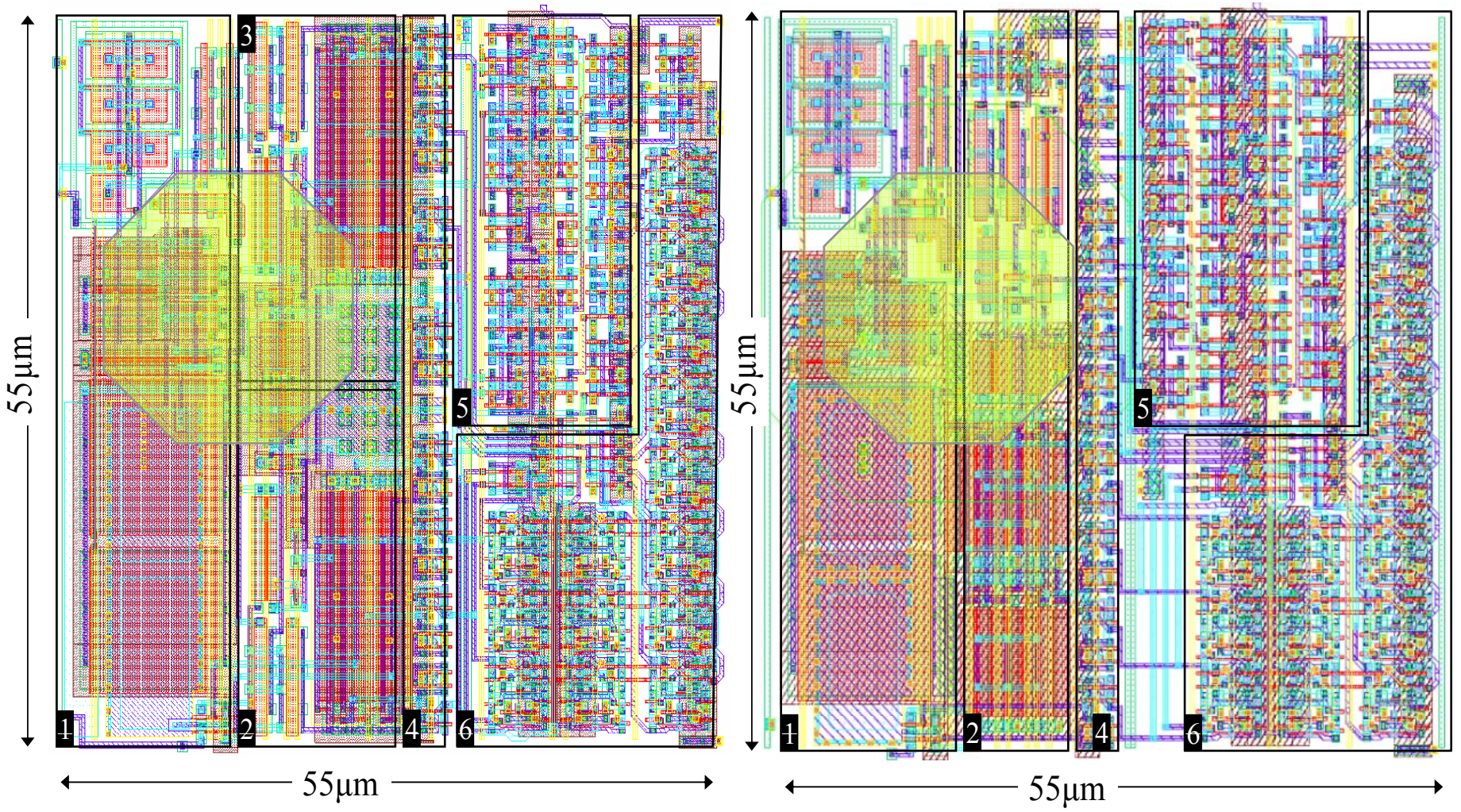
- **Chip architecture almost identical to Mpix2MXR20**
  - **M0=M1=1 and Shutter ON -> FClock used as Ref_Clk**
- **256x256 55µm square pixels**
- **Analog Power -> 440mW**
- **Digital Power (Ref_Clk=50MHz) -> 220mW**
- **Serial readout (@100MHz) -> 9.17 ms**
- **Parallel readout (@100MHz) -> 287 µs**
- **> 36M Transistors**



Timepix Layout status

Mpix2MXR20 layout

Timepix layout



Demonstration

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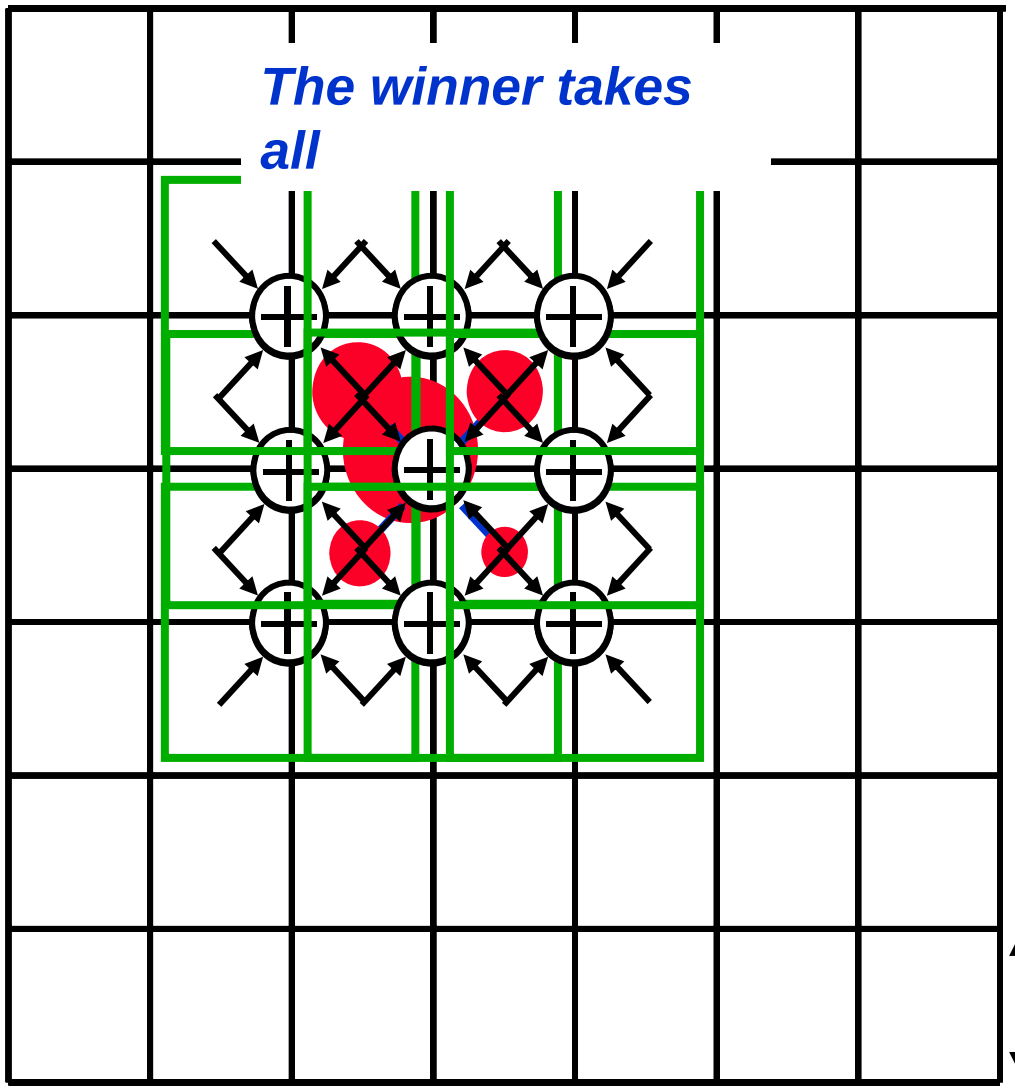
Limitations of Timepix

- Charge below threshold in shared events is lost in all modes
- Charge measurement near to threshold in TOT is imprecise
- Arrival time/TOT measurement range is limited by counter depth
- Chip is neither triggerable nor data driven
- There is no FAST-OR

Medipix3 – charge summing concept



- *The incoming charge processed is summed in every pixel cluster on an event-by-event basis*
- *The hit is assigned as a single hit*

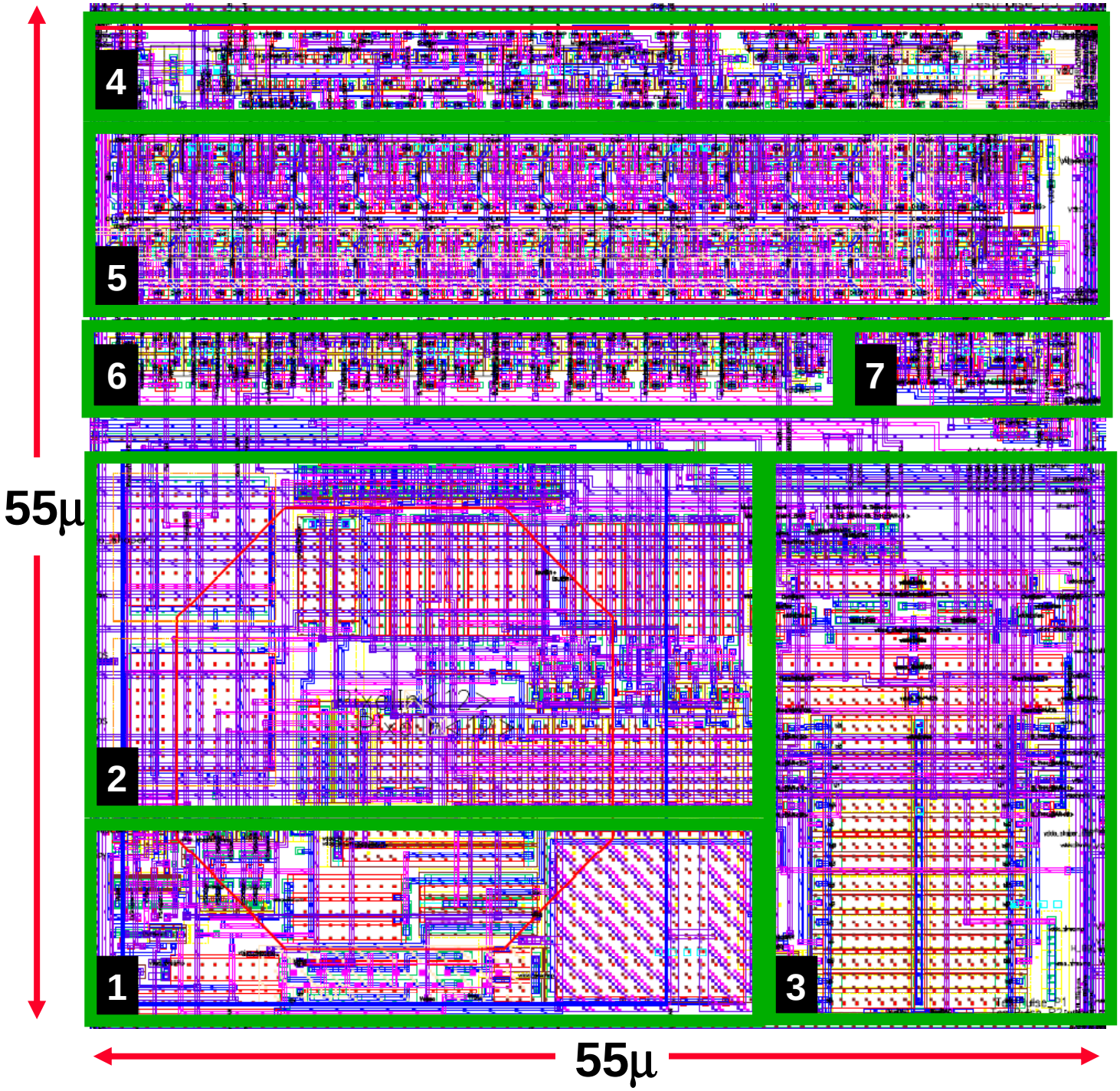
Medipix3 – pixel block diagram

BLOCK DIAGRAM PIXEL E

Input Pad
C_f
g_m
C_{test}
TestBit
Test Input
V_{fbk}
PolarityBit
GainMode
ThAdjustBit
ChSummingMode
From adjacent pixels (F, H, I)
x3
x1
x3
To adjacent pixels (A, B, D)
TH1
TH2
Disc
Disc
B_TH<0:3>
B_TH<4>
From adjacent pixels (A, B, D)
cluster common control logic + Arbitration circuitry
ModeContRW
DisablePixelCom
AdjustTHH
ModeCS_Cluster4
x2
Previous Pixel SR1
MUX
15 bits Shift Register SR1
Next Pixel SR1
To adjacent pixels (F, H, I)
Previous Pixel SR2
MUX
15 bits Shift Register SR2
Next Pixel SR2

ANALOG

DIGITAL



DIGITAL CIRCUITRY

4. Control logic (124)
5. 2x15bit counters / shift registers (480)
6. Configuration latches (152)
7. Arbitration circuits (100)

Total digital 856

ANALOG CIRCUITRY

1. Preamplifier (24)
2. Shaper (134)
3. Discriminators and Threshold Adjustment Circuits (72)

Total analog 230

Medipix3 prototype – electrical measurements summary

Front End Operating Mode	Single Pixel Mode	Charge Summing Mode
CSA Gain (C_F)	11.4mV/Ke- (C_F=14fF)	
CSA-Shaper Gain	65nA/Ke- (High Gain Mode), 30nA/Ke- (Low Gain Mode)	
Non linearity	<5% 9Ke- (High Gain Mode) , <2% 22Ke- (Low Gain Mode)	
Peaking Time	~100ns	
Return to baseline	<1μs for 4Ke- (nominal conditions), <300ns (tuning R_F)	
Electronic noise	72e^- r.m.s.	144e^- r.m.s.
Analog power dissipation	16.2μW (nominal conditions)	

Summary of present status

- The Timepix chip, although funded by EUDet, evolved from the successful Medipix2 development
- The ready availability of chips and readout systems led to the initial experiments with gas and Medipix2 and sped up enormously the exploitation of Timepix by the users
- The future Medipix3 chip is being developed to mitigate charge sharing in single photon counting. But like its predecessor Medipix2 it should provide building blocks, experience or even entire readout systems which could be reused for a future single event processing chip
- Given the length and cost of such developments it would make sense to cluster users around a single ASIC development (technology oriented development) …

Requirements for a general purpose gas and semiconductor readout chip

- Clean hit information
- Low and uniform threshold
- High spatial resolution
- Combined energy and arrival time information

GasSiPix - Front end

*** Basic idea developed together with Ruud Kluit of NIKHEF ***

- Medipix3 or GOSSIPO-2 like
  - Suitable for semiconductors and gas readout?
  - Rise time 25ns?
  - Noise 100 e^- rms?
  - Minimum threshold 750e^-?
  - Power <1W/cm^2?
- For gas detectors include spark protection and SiProt shielding
  - Which A:Si thickness?
  - How many pC should it withstand?
- Use precision time tag unit from Nikhef (GOSSIPO-2 V. Gromov) in pixel to measure arrival time
  - 1-2ns precision for Vernier counter?
  - 15-bit clock tick counter?
- Use TOT for energy measurement and/or timewalk correction if charge summing not include
  - 8-bit TOT precision?

GasSiPix - Readout

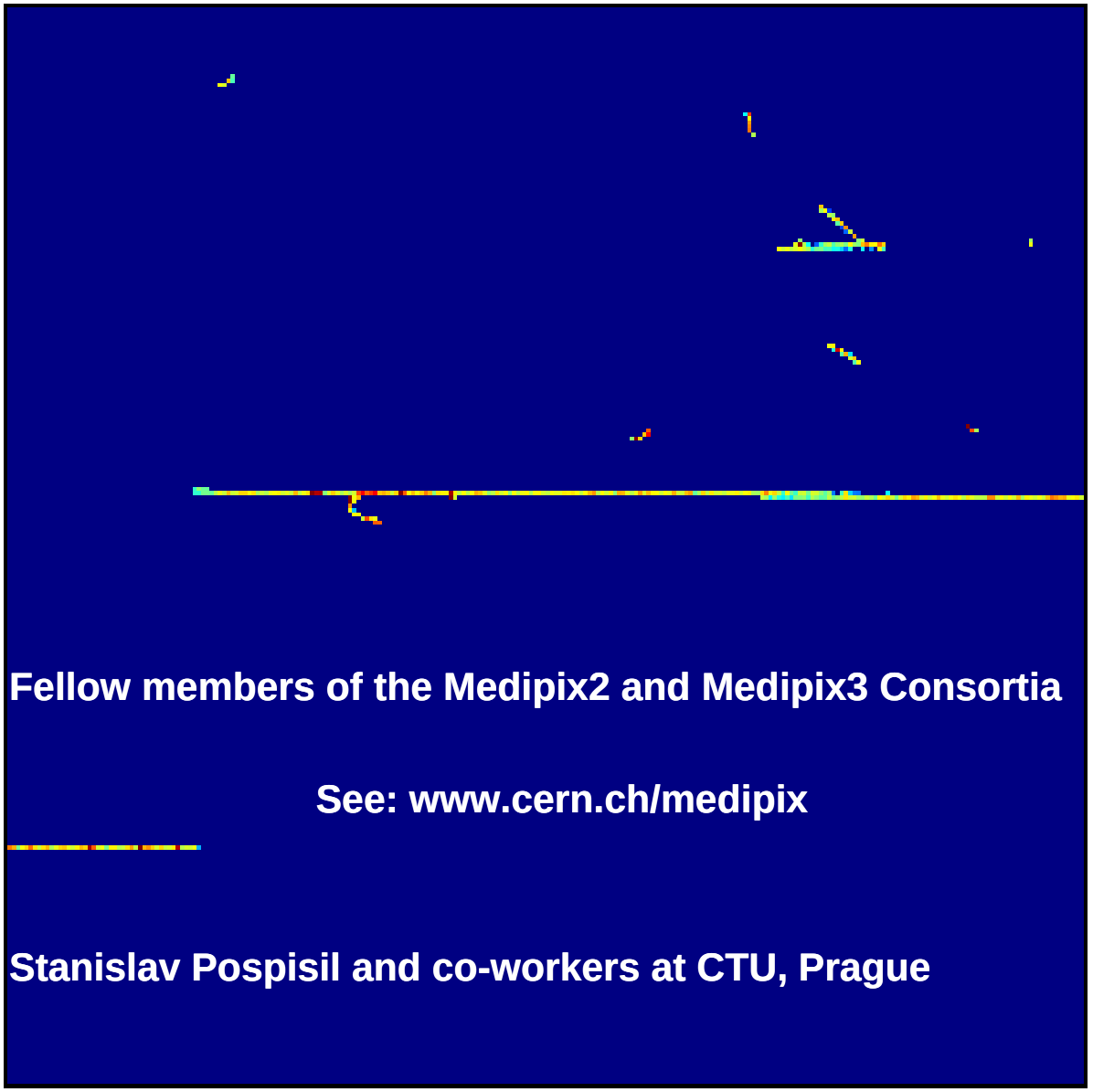
- Triggered or data initiated?
  - If triggered how/when is a pixel reset
  - Fast OR in any case?
- Hit pixels only?
- Region of interest?
- Fast serial or parallel bus?
- 4 side buttable?
- What level of rad tolerance needed (given area penalty)?

Summary and Conclusions

- Medipix2 spawned Timepix
- The synergy between imaging and HEP is evident (to me)
- Medipix3 is in full development
- GasSiPix is technically feasible (within limits)

- Collaboration with people with differing requirements requires compromises on all sides but the outcome can be rewarding for all.

Acknowledgements



Fellow members of the Medipix2 and Medipix3 Consortia

See: www.cern.ch/medipix

Stanislav Pospisil and co-workers at CTU, Prague