Design and preliminary results of the Timepix chip

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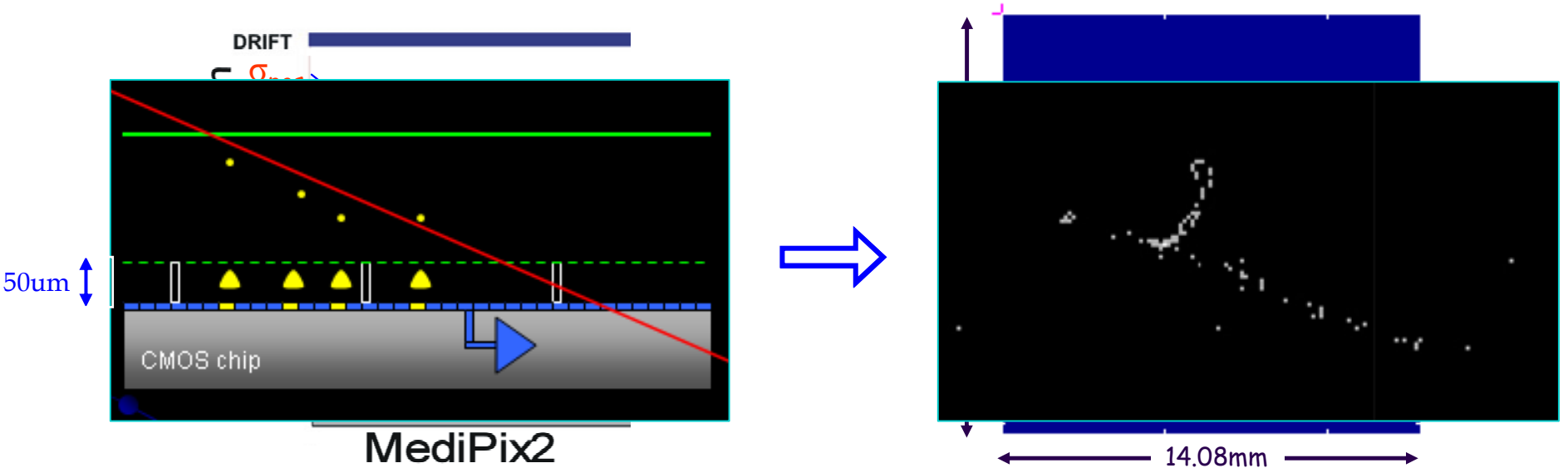
From Medipix to Timepix

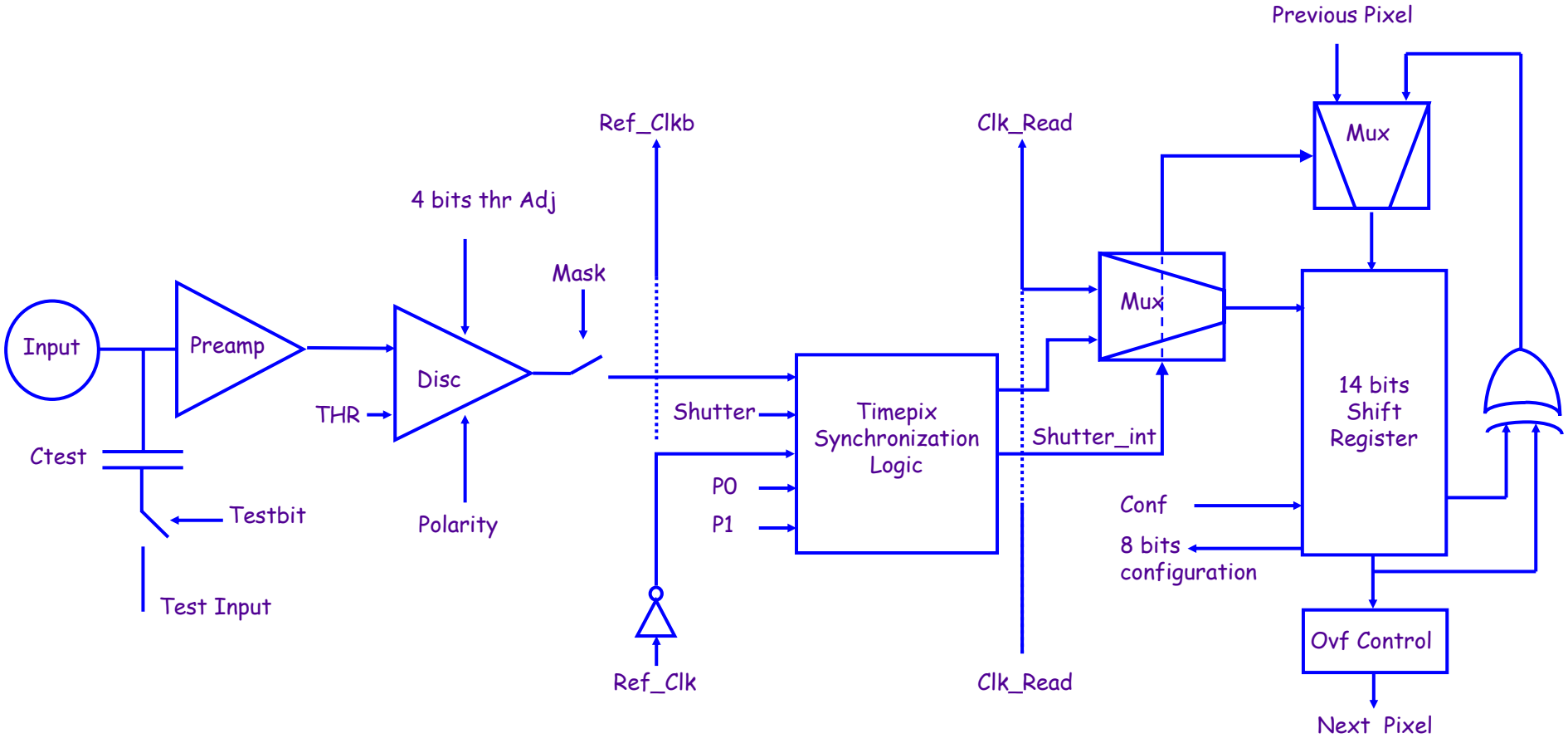
- A novel approach for the readout of a TPC at the future linear collider is to use a CMOS pixel detector combined with some kind of gas gain grid
- Using a *naked* photon counting chip Medipix2 coupled to GEMs or Micromegas demonstrated the feasibility of such approach



Motivation: Medipix → Timepix

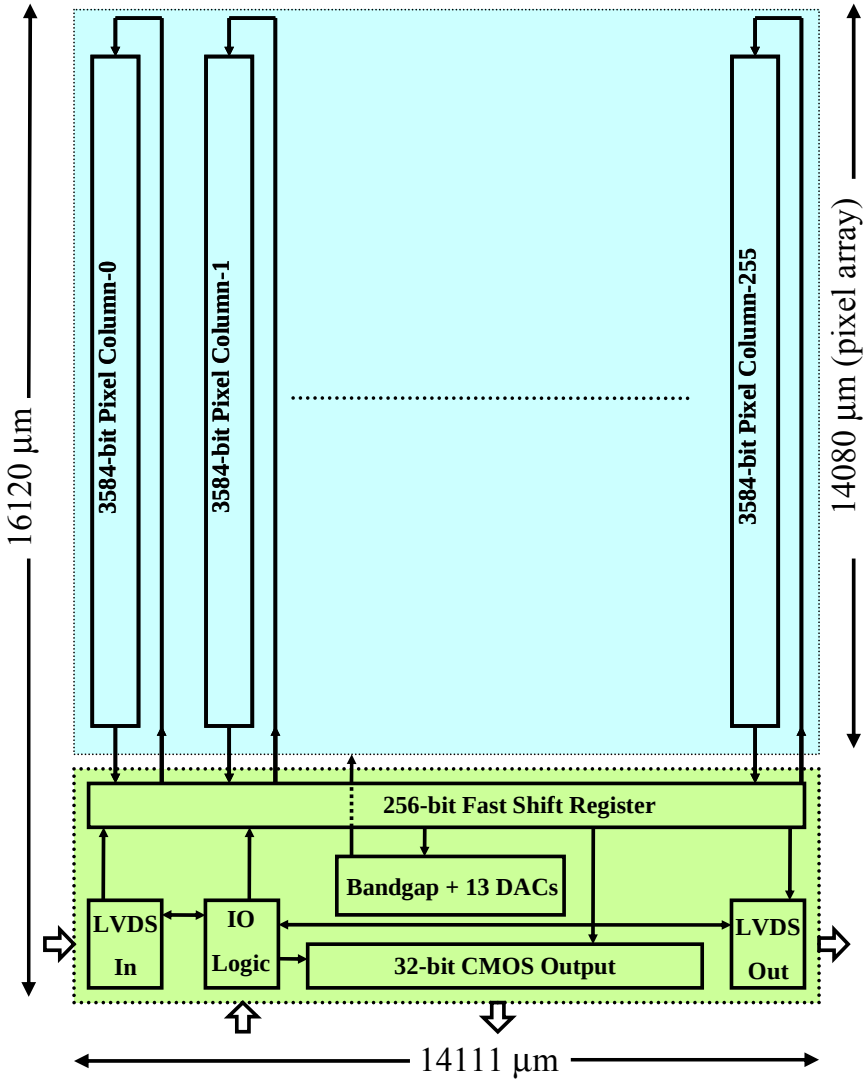
- These experiments (by NIKHEF/Saclay, Freiburg 2004/2005) demonstrated that single electrons could be detected using a *naked* Medipix2 chip ⇒ 2D
- Did not provide information on the arrival time of the electron in the sensitive gas volume ⇒ 3D (position + time) !!!
- To further exploit this approach the Medipix2 is being 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 modelling
  - Eliminate 2nd threshold
  - Add possibility of programming pixel by pixel arrival time or TOT information
- This modification is supported by the JRA2/EUDET Collaboration (www.eudet.org)

Timepix Schematic



Timepix chip architecture

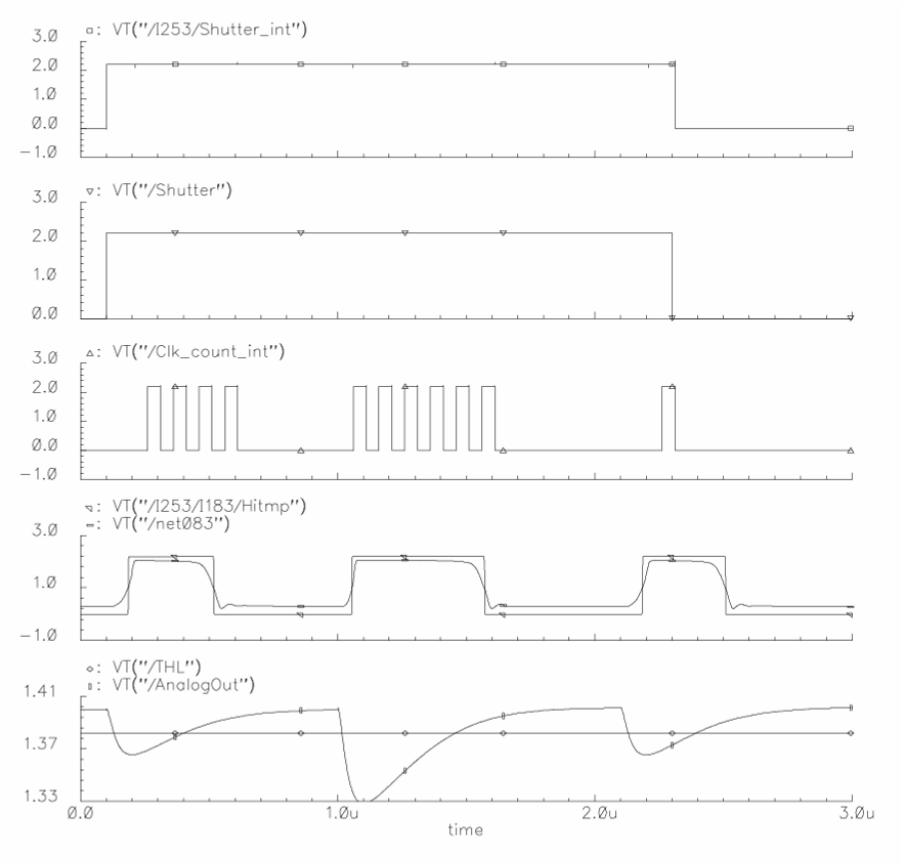
- IBM 0.25µm
- Chip architecture almost identical to Mpix2MXR20
  - M0=M1=1 and Shutter ON -> FClock used as Ref_Clk
- 256x256 55µm square pixels
- Analog Power -> 440mW
- Digital Power (Ref_Clk=50MHz) -> 220mW
- Serial readout (@100MHz) -> 9.17 ms
- Parallel readout (@100MHz) -> 287 µs
- > 36M Transistors



Timepix Synchronization Logic control

- Each pixel can be configured independently in 5 different modes
- Minimized power consumption in stand-by (no hit)

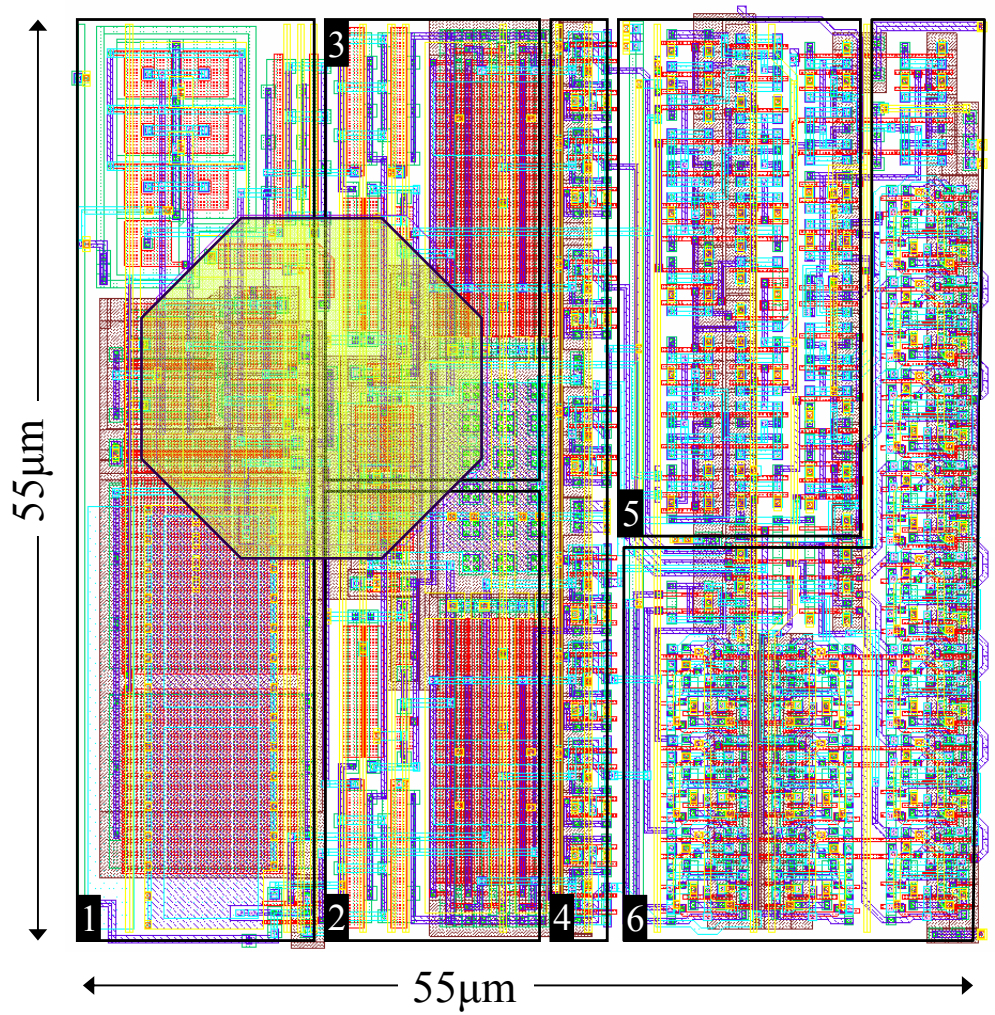
Mask	P1	P0	Mode
0	0	0	Masked
0	0	1	Masked
0	1	0	Masked
0	1	1	Masked
1	0	0	Medipix
1	0	1	TOT
1	1	0	Timepix-1hit
1	1	1	Timepix



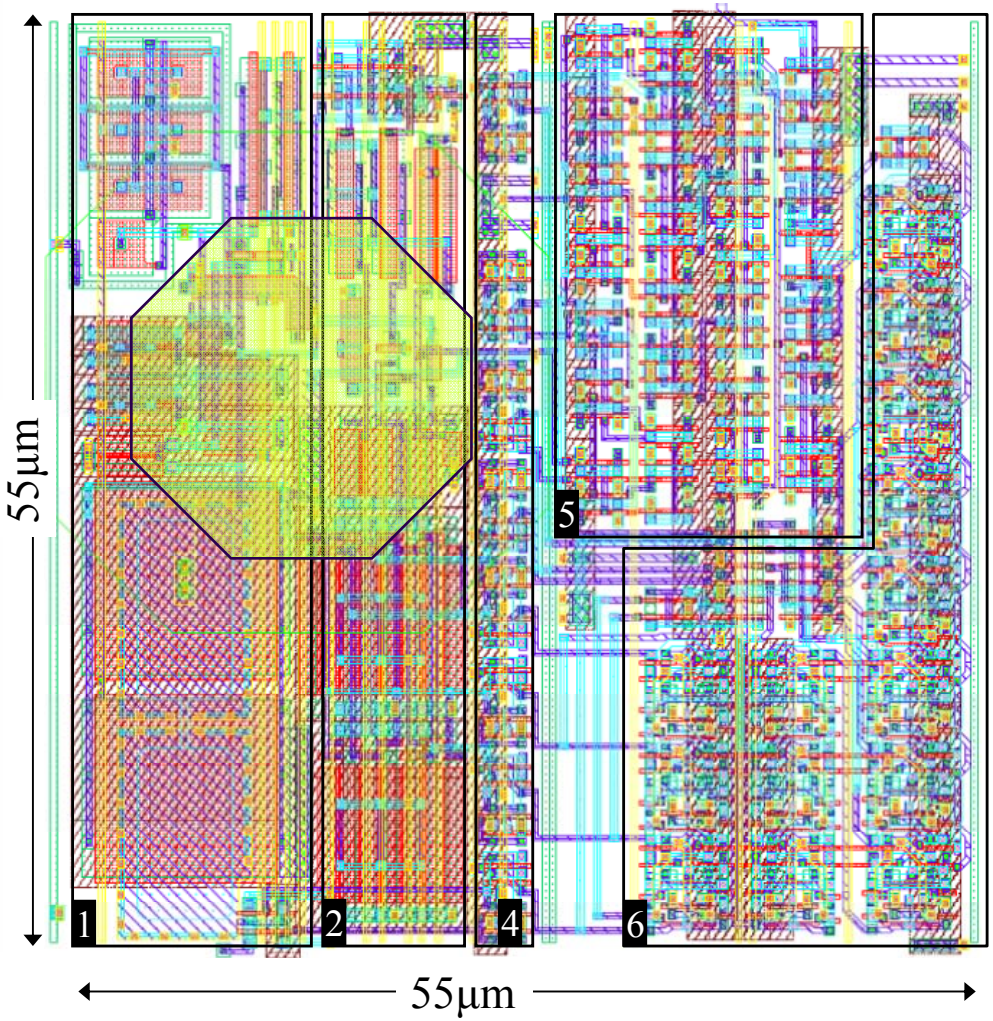
Timepix Mode
TOT Mode
Medipix Mode

Timepix Layout status

Mpix2MXR20 layout



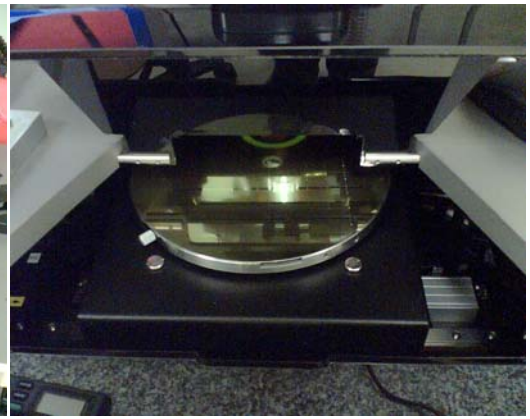
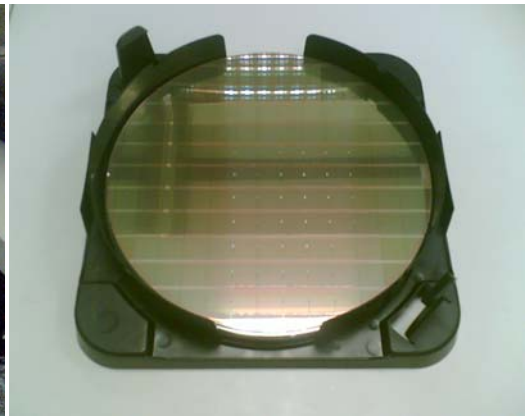
Timepix layout



Timepix measurements

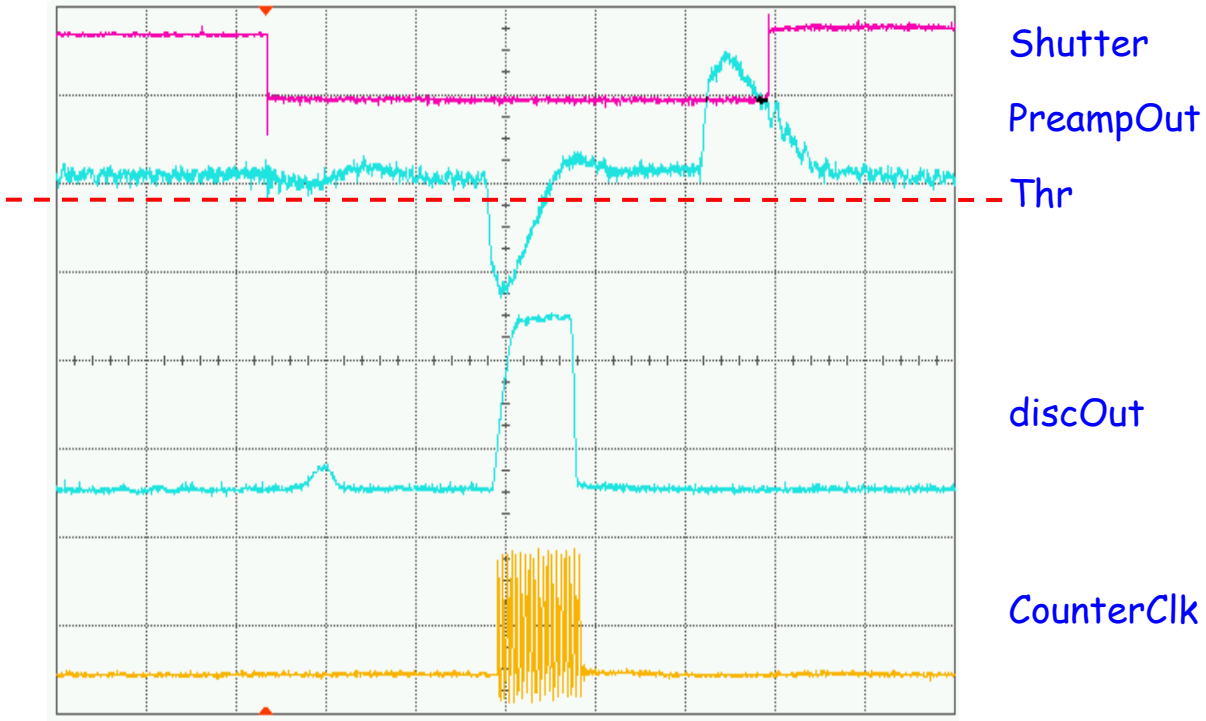
- Chip was submitted to foundry on the beginning of July
- 12 wafers arrived at CERN 2nd week of September
- Modifications in the Medipix readout system (~1 week):
  - "Timepix-Medisoft" version of the software
  - MUROS2 firm update (thanks to Hans Verkoojen, Nikhef)
- Preliminary Timepix characterization has been done on-wafer using the Medipix2 probe card in the DSF clean room facility at CERN



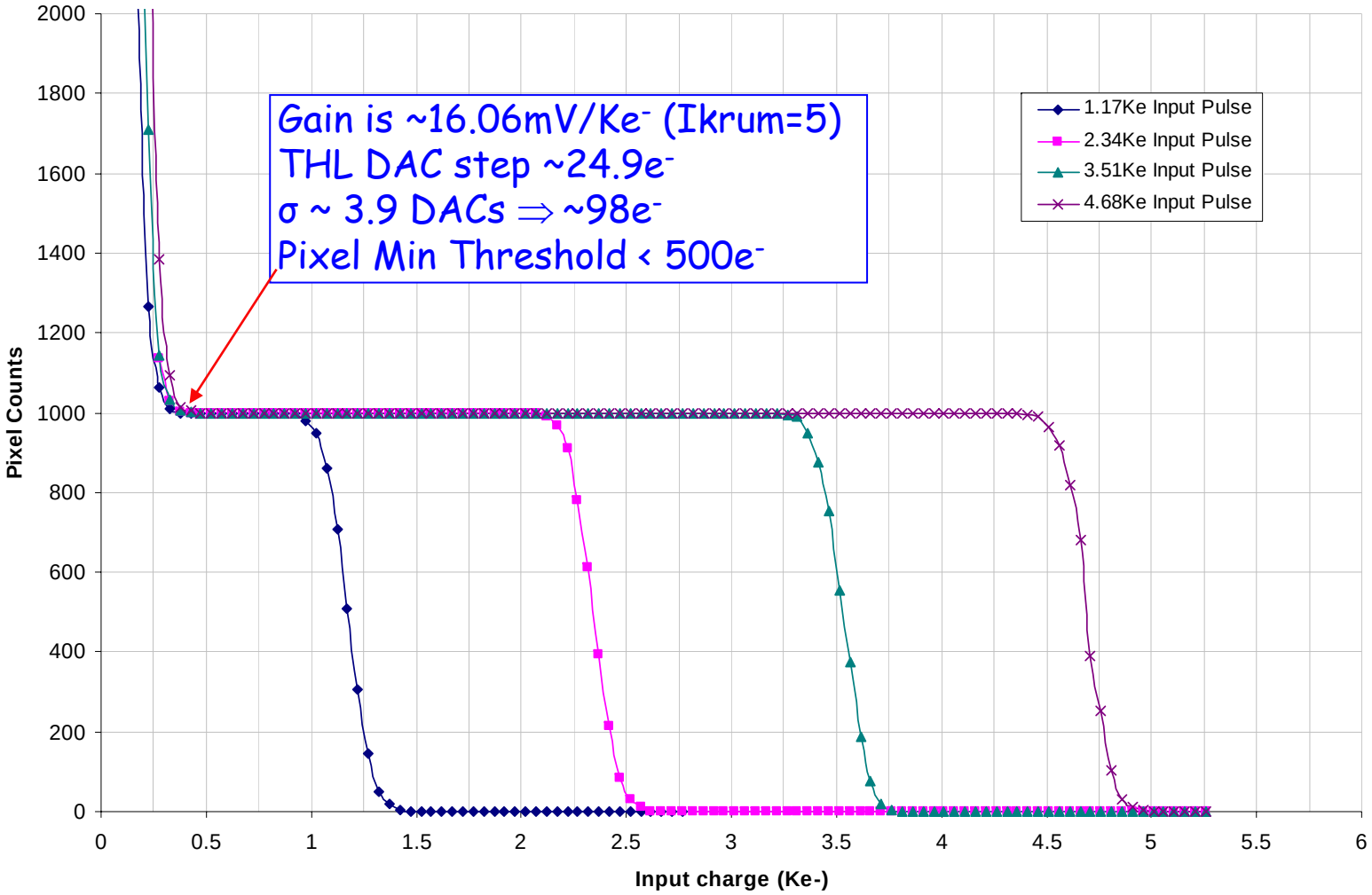



Pixel measurements

- From the 2 test pixels [120:121,0] one can measure the preampOut, discOut, internal Ref_Clk and the counter clock
- State Machine of the counter Modes (P0, P1) work as expected
- No visible coupling of the Ref_Clk signal into the analog signals (preampOut and discOut)

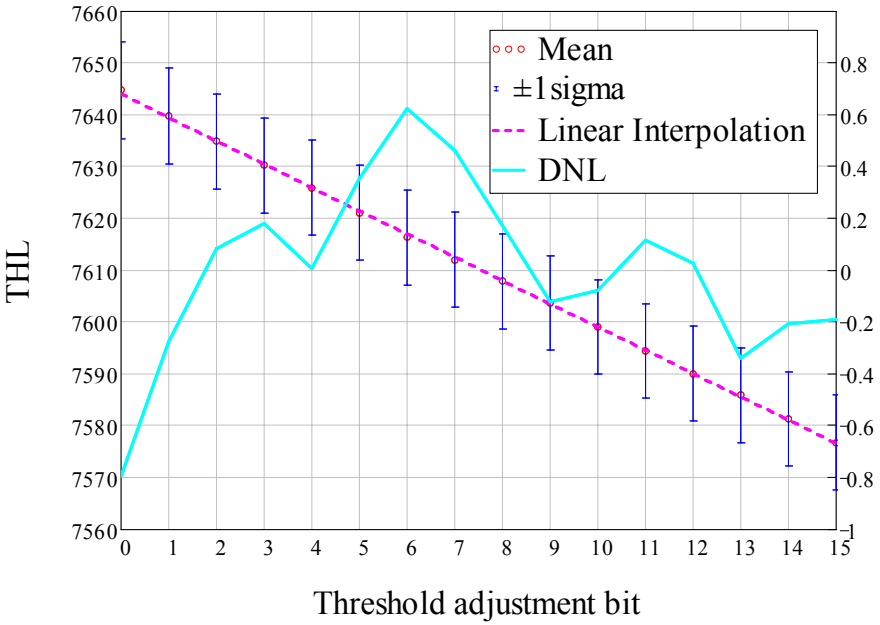


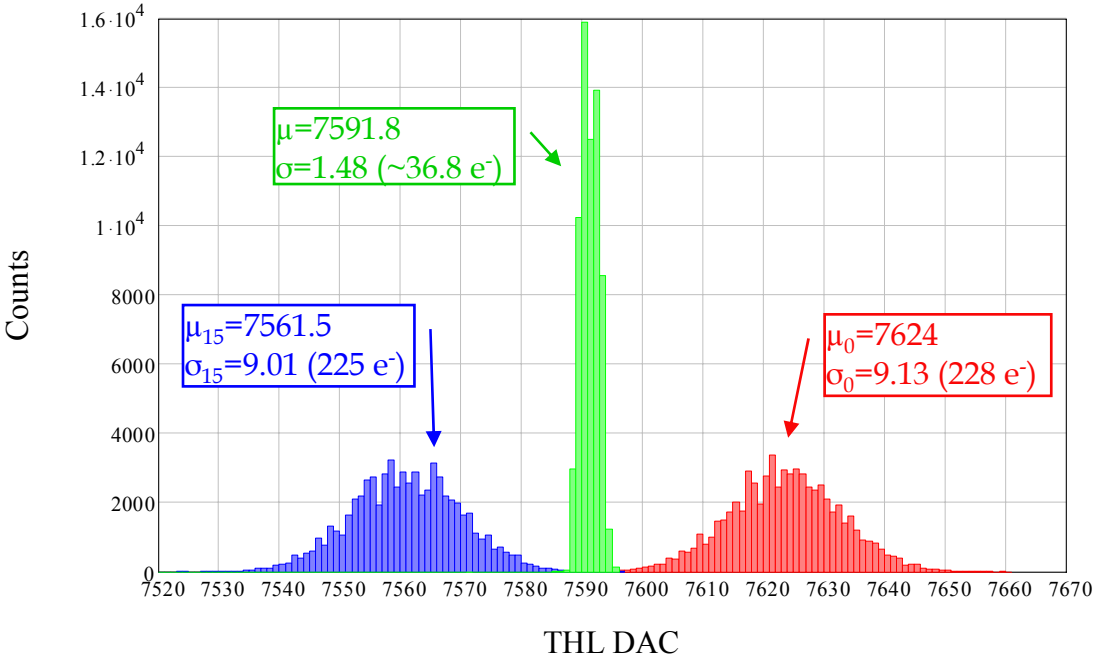
TestPulse on 1 pixel (Medipix Mode) Ikrum=5



Timepix equalization (I)

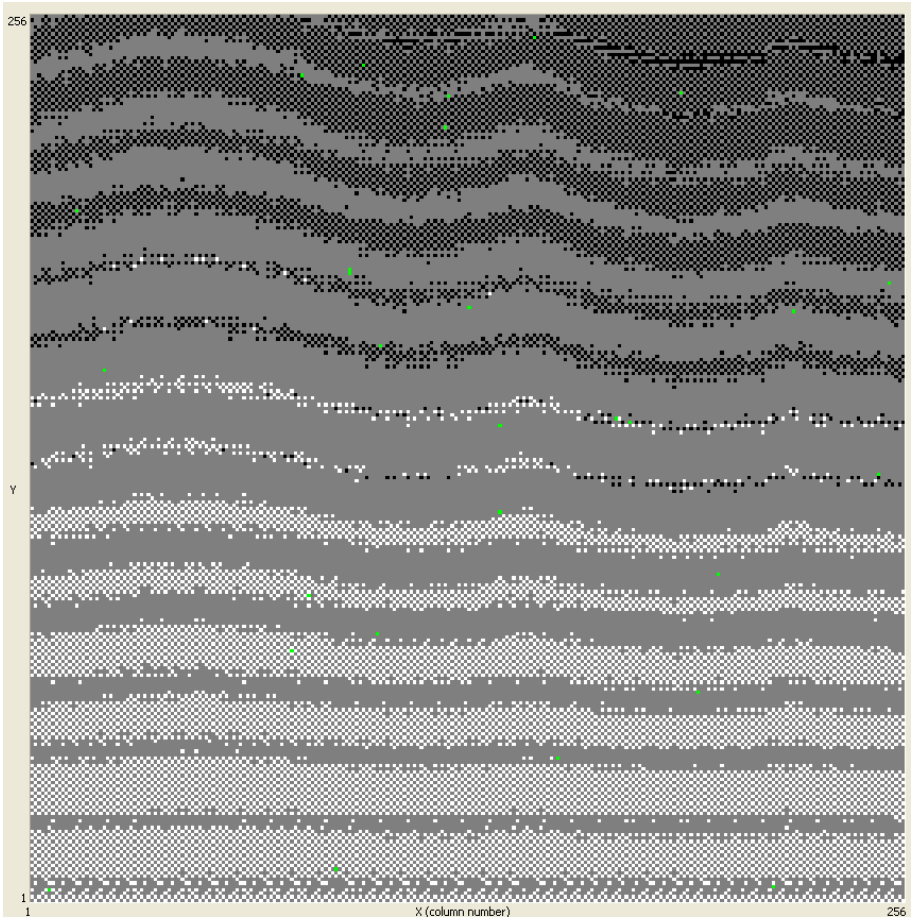
- Equalization using the noise as trigger and Medipix Mode (P0=P1=0)
- The measured DNL of the 4-bit DAC is < 1THL DAC -> Interpolation in the equalization can be used





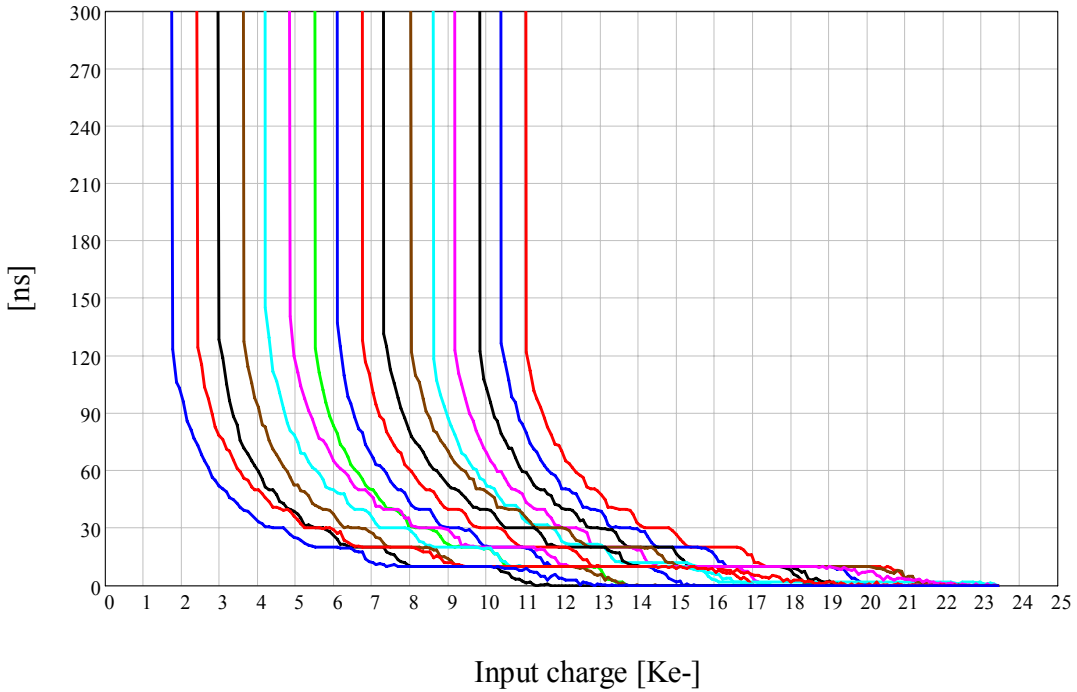
Timepix mode (shutter time)

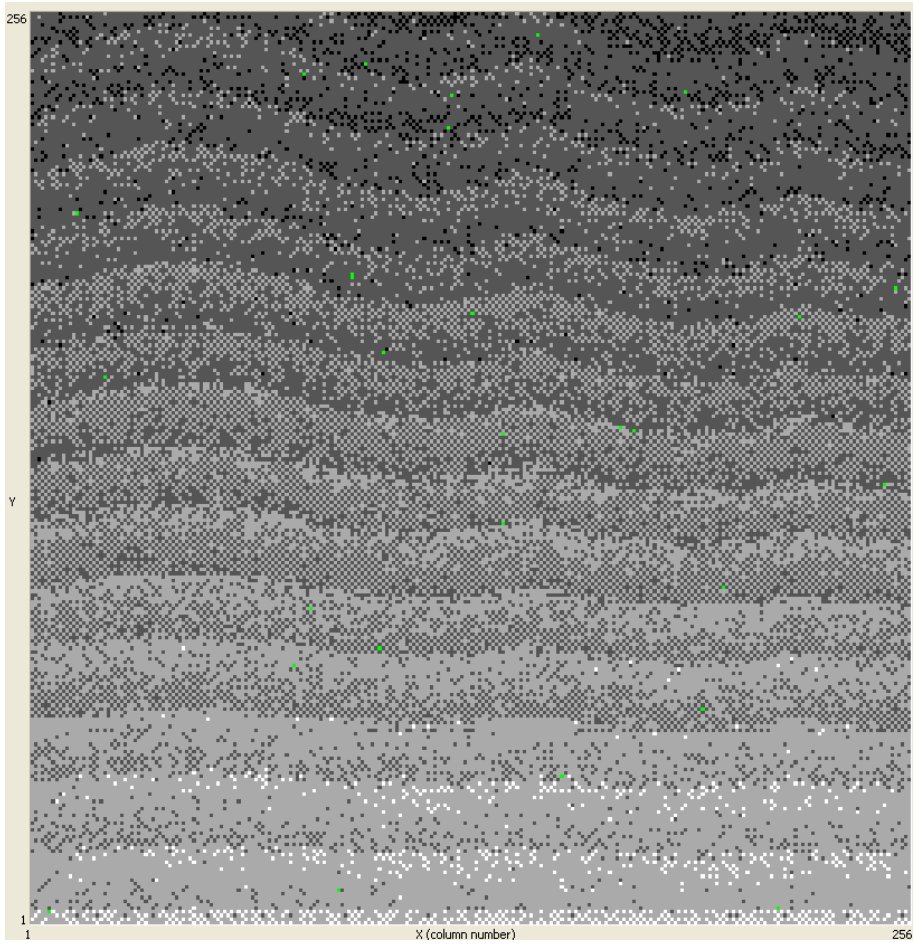
- Opening the shutter with all the pixels in Timepix mode and in wrong polarity the shutter length can be measured.
- In this example Ref_Clk=71MHz -> Shutter opened 2032 ±1 clk = 28.619 μs ± 14.08 ns
- Horizontal waves correspond to the VDD/VSS IO Pads distribution…
- Ref_clk to Shutter synchronization is lost as the Ref_clk is buffered in each pixel -> Top down effect due to the way the Shutter is generated (NxRef_clk)



Timepix mode

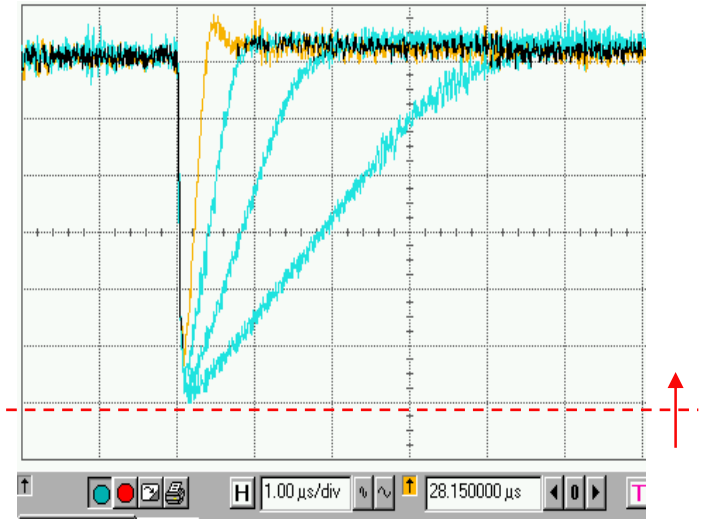
- Injection of 30Ke input pulse at Thr~=1Ke$^-$ -> 1019.5 ±1.5 clk = 14.359 μs ± 21.12 ns -> Test Pulse delay seen as an increase of the error time
- Pixel time-walk [(Thr+1Ke$^-$) -> ∞] is ~ 60ns at nominal settings

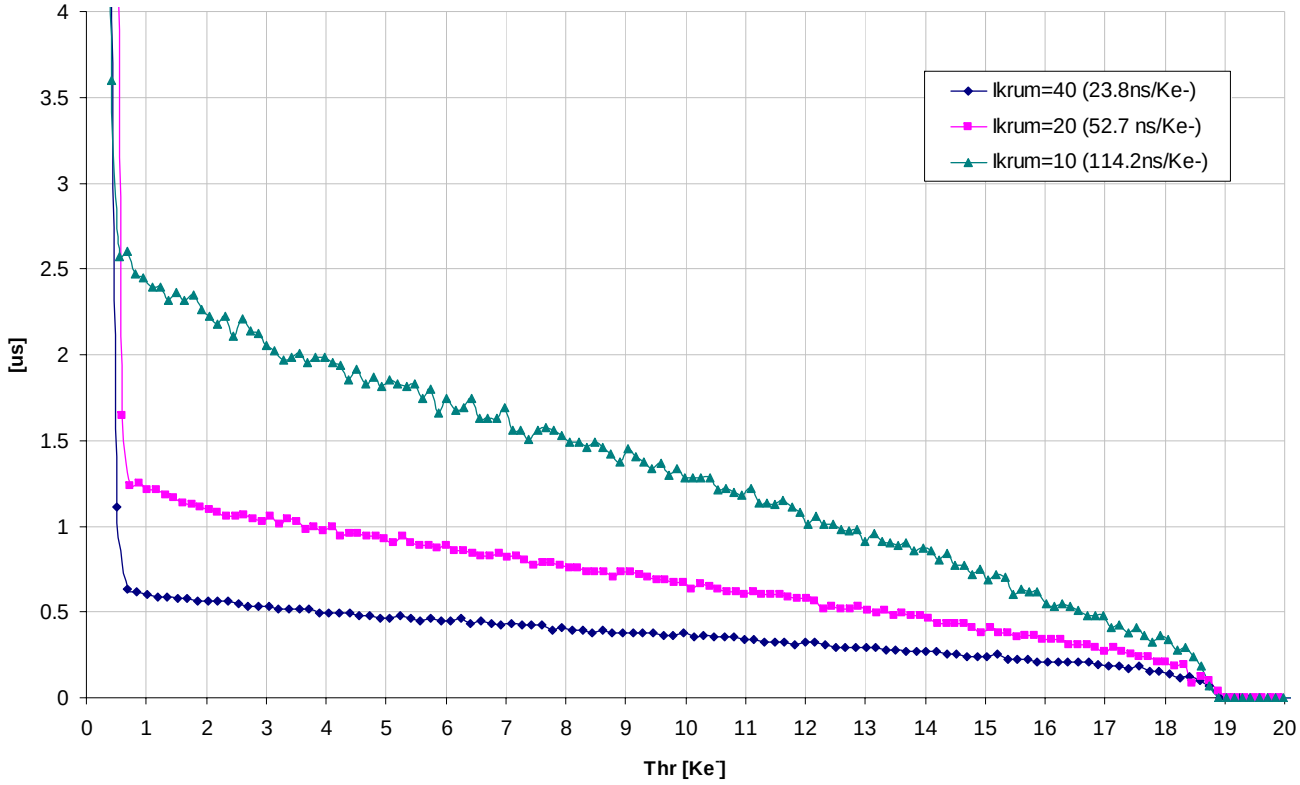




TOT on single pixel

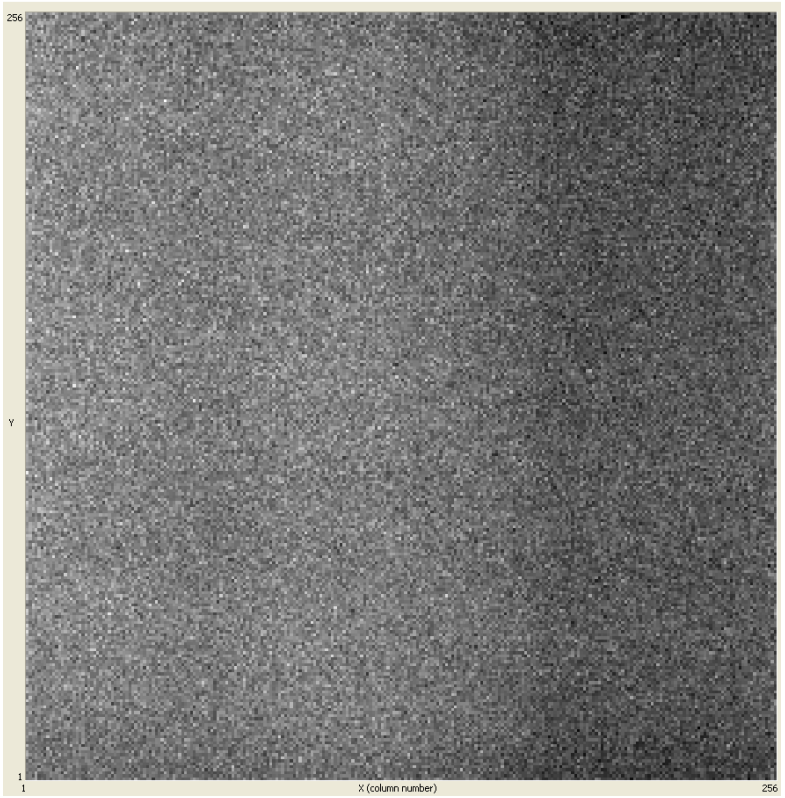
- TOT gain is a function of Ikrum DAC setting
- Ref_Clk=71.1MHz

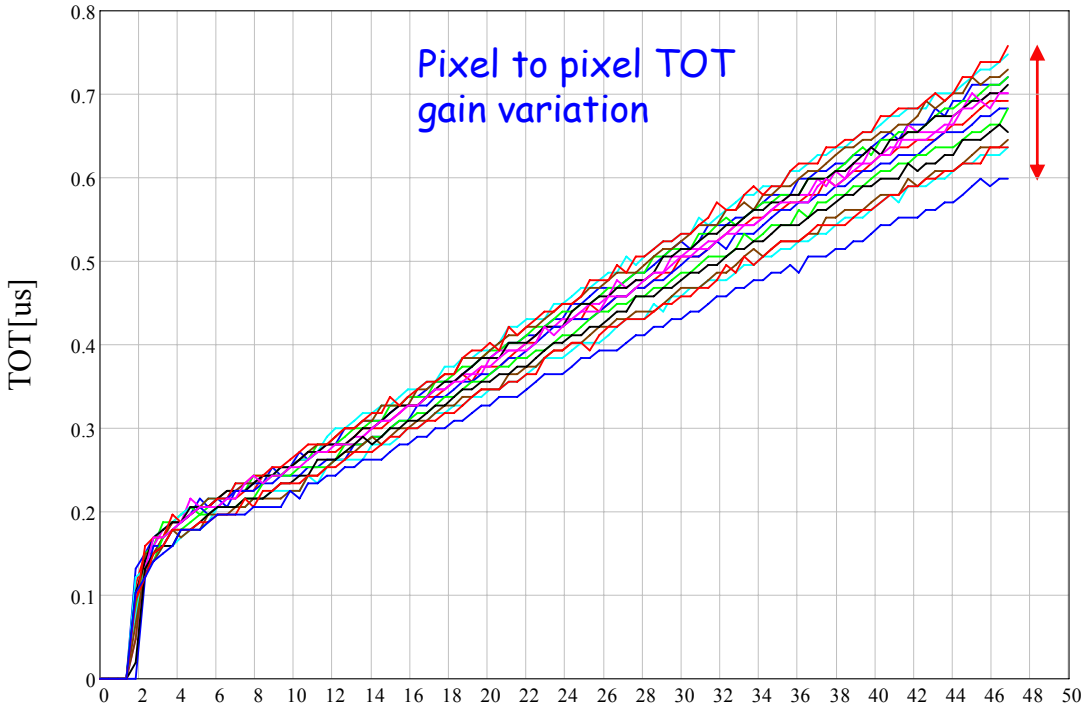




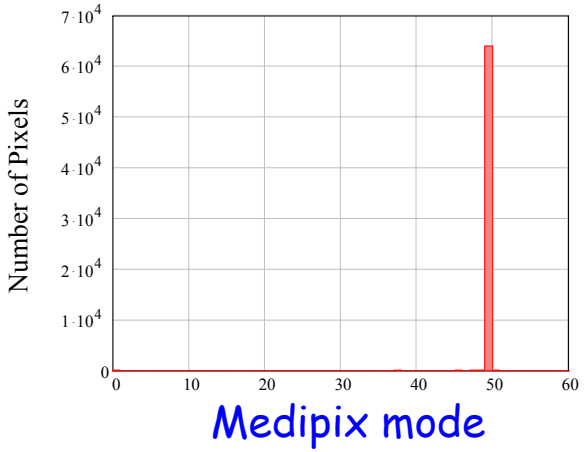
Pixel to pixel TOT gain variation

- Pixel to pixel TOT gain variation observed due to non uniform power supply distribution (measured at the IO chip pads)
- This artifact can be corrected by and improved power distribution at the PCB level and/or with a correction mask due to the good TOT gain linearity

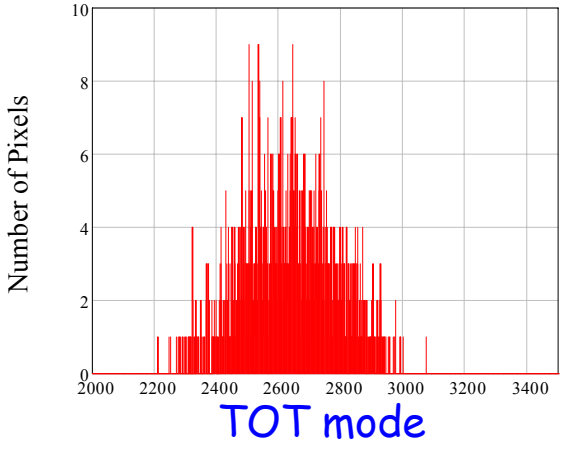




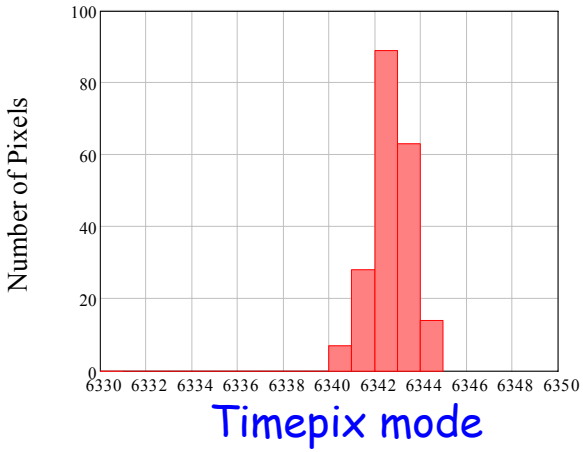
All pixel modes simultaneously (I)



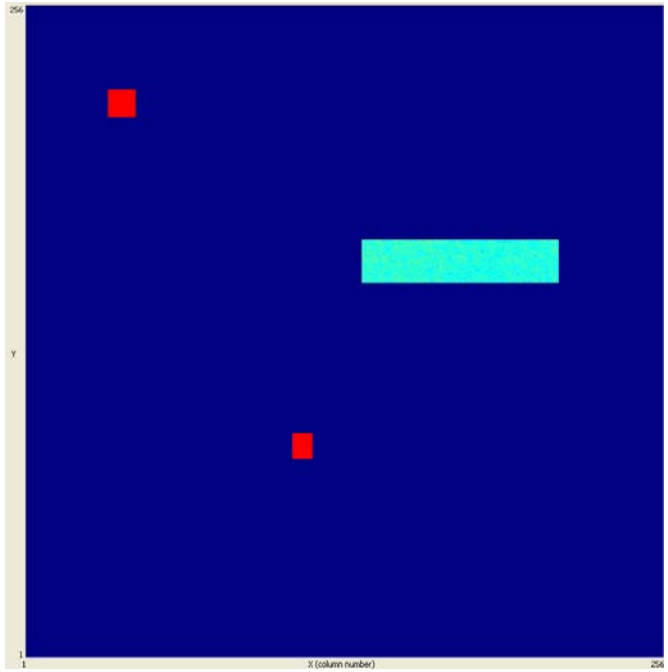
Medipix mode



TOT mode

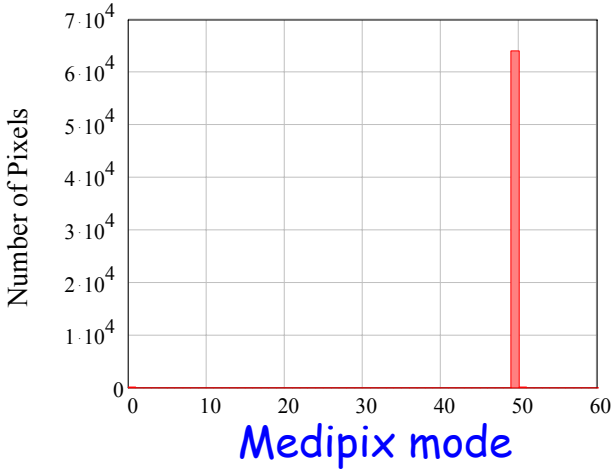


Timepix mode

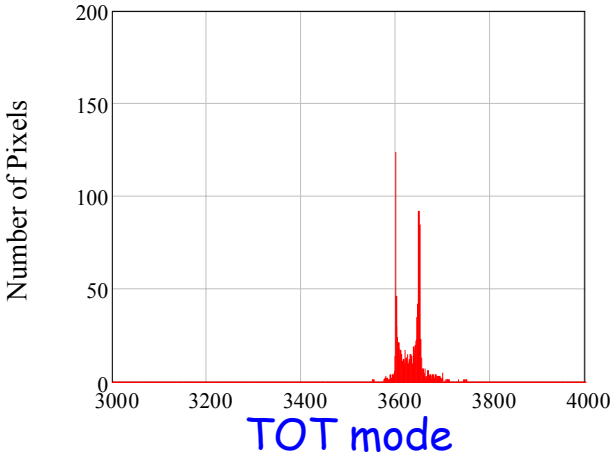


- Threshold set ~1Ke-
- 50 Test pulses of 1.5Ke-
- Ref_Clk=71.1 MHz

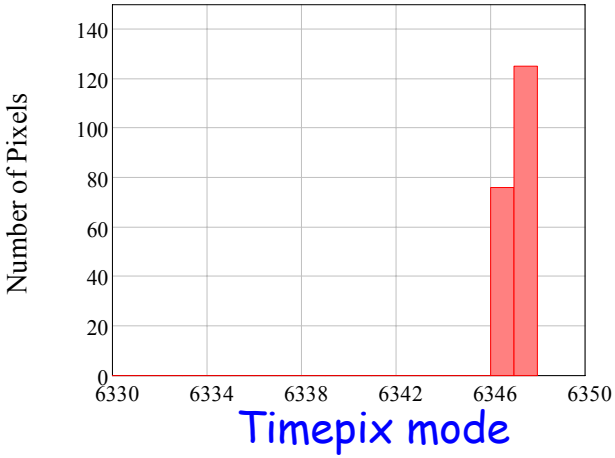
All pixel modes simultaneously (II)



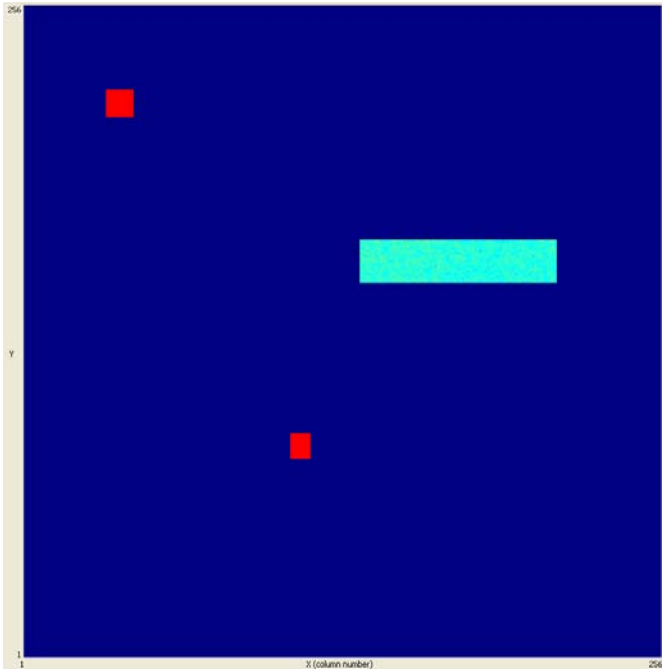
Medipix mode



TOT mode



Timepix mode



- Threshold set ~1Ke$^-$
- 50 Test pulses of 30Ke$^-$
- Ref_Clk=71.1 MHz

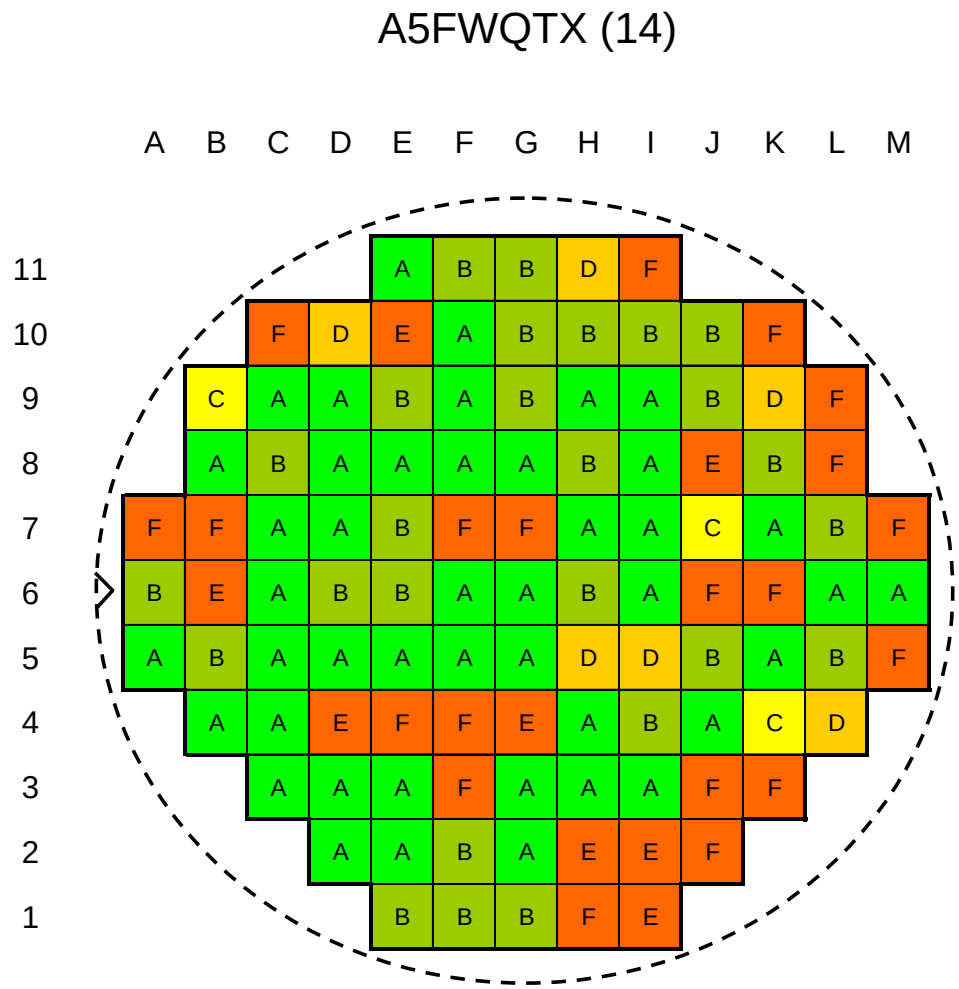
Timepix wafer map

- **Yield:**

A (No dead Column)	44	41.1%
B (1 dead column)	26	24.3%
C (up to 2 dead cols)	3	2.8%
D, E, F (Bad chips)	34	31.8%
TOTAL	107	100%

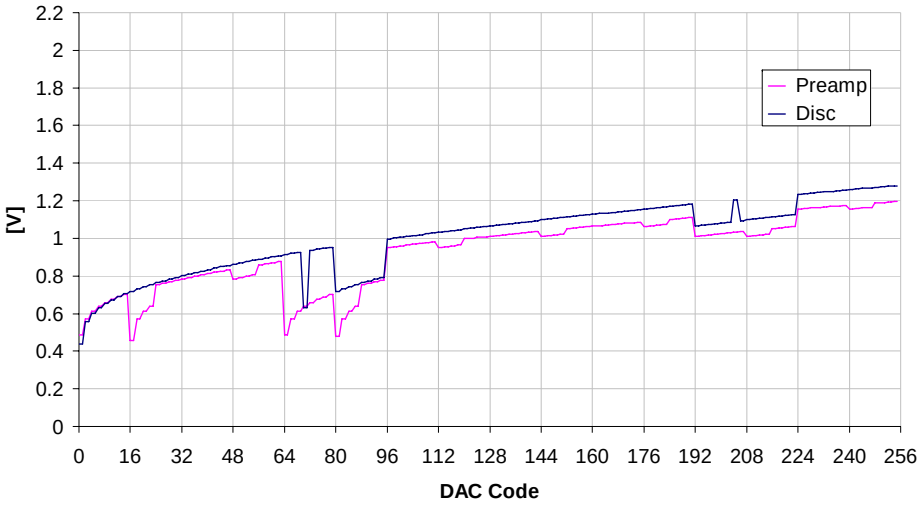
- **Test includes for each chip:**
  - **Digital Test**
    - Chip ID
    - Write/Read matrix test
  - **Analog Test:**
    - DACs scan
    - Tespulse Test (Medipix and TOT)

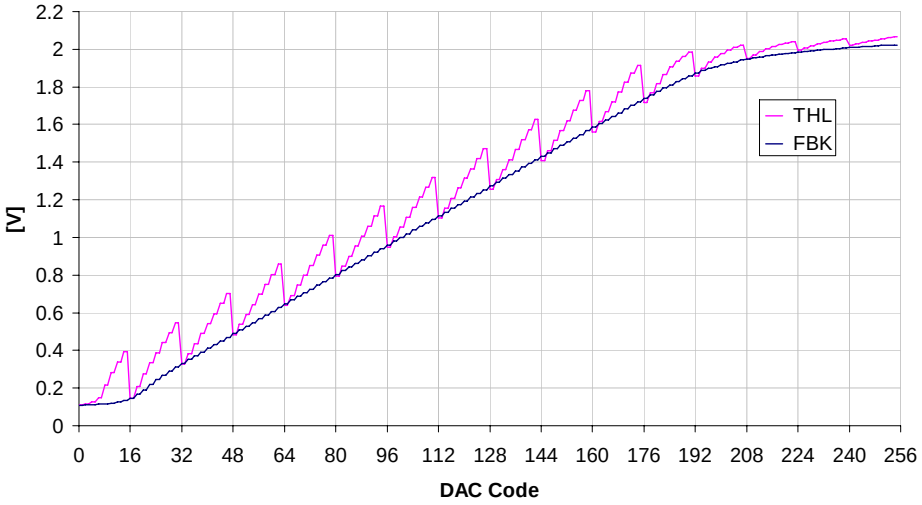
- **Wafer is being diced and first mounted chips will be available soon (~2/3 weeks)**



Timepix DACs

- Some DACs show a non-monotonic curve
- Non- Monotonic DACs are:
  - Preamp
  - Disc
  - BufferA
  - BufferB
- Problem may be related to the latching of the DACs register
- The midrange value (code 01111111=127) is always stable (1 complete wafer)
- These DACs are unchanged under normal operating conditions





Summary, Conclusions and Future plans

- The new on-pixel state machine works as designed providing 3 different pixel operating modes (Timepix, TOT and Medipix)
- Minimum threshold is not affected because of the running clock (Ref_clk) and it is even lower (<700e^-) than Mpix2MXR20 chip.
- At chip level the Timepix and TOT mode might need some extra correction for non-uniformity.
- Some DACs show a non-monotonic behaviour. Threshold DACs are not affected. Further investigations to be done.
- 1/12 wafers has been tested. First diced chips to be received in ~2 weeks.
- Pixelman (official Medipix software) needs Timepix update → ~1 month
- Muros2.1 upgrade/check for external shutter trigger → ~1/2 weeks
- Testbeam: Timepix coupled to GEMs will be used in a test beam in DESY on the beginning of November.