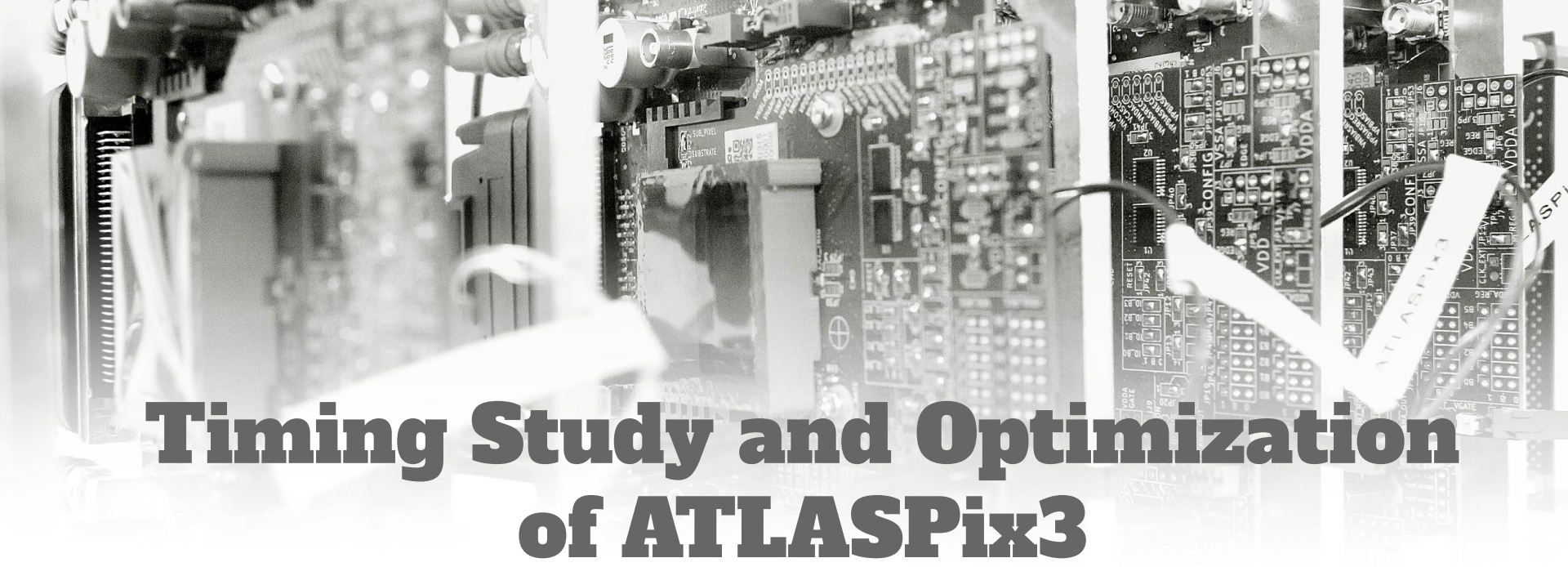

Timing Study and Optimization of ATLASPix3 a full-scale HV-MAPS Prototype

UNIVERSITÄT HEIDELBERG
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Bundesministerium für Bildung und Forschung

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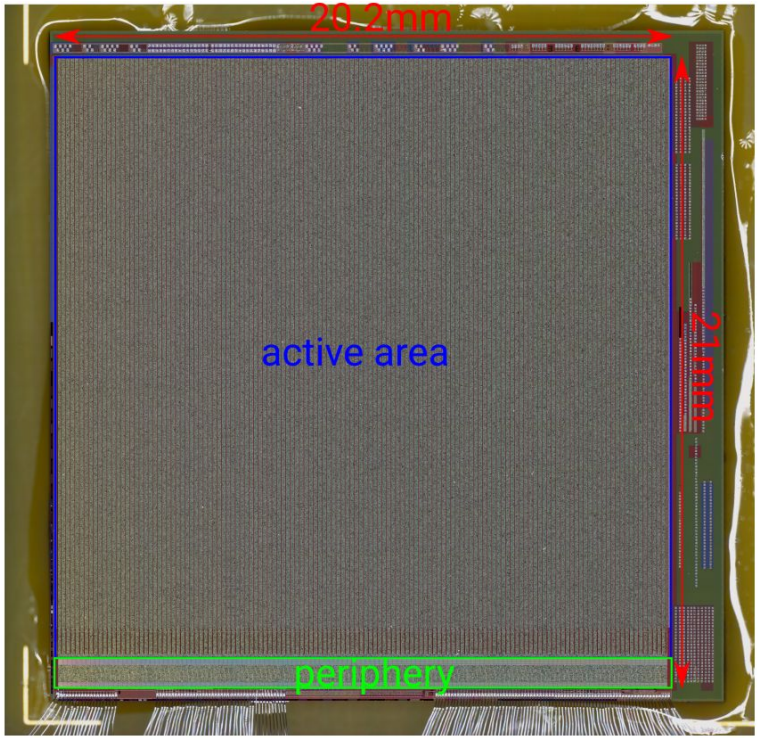
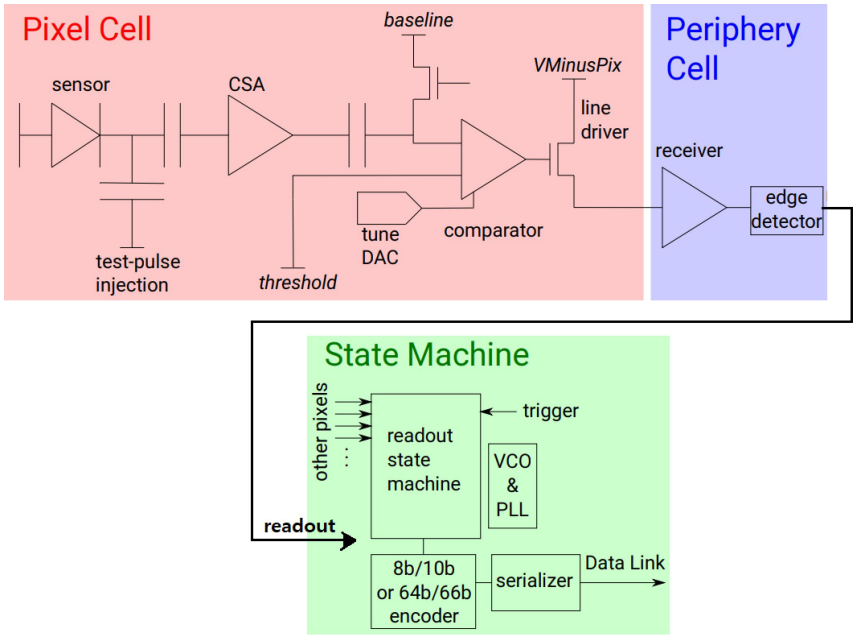
Dohun Kim
Universität Heidelberg
T 64.9 Session

ATLASPix3



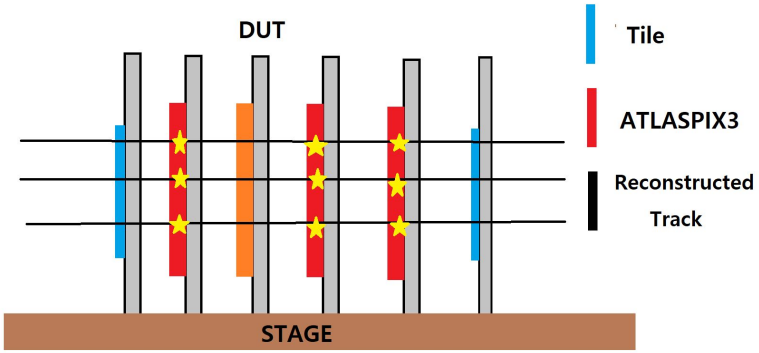
- Motivated by ATLAS upgrade
  - developed by ATLAS HV-MAPS collaboration
  - designed by Prof. Ivan Peric
- A full scale HV-MAPS prototype
  - implemented in an 180 nm HV-CMOS by TSI
  - substrate resistivity of 200 Ωcm
  - wafer thinned to 100 µm
  - a pixel size of 150 µm x 50 µm
  - the pixel matrix 132 column x 372 row
  - in-pixel comparator

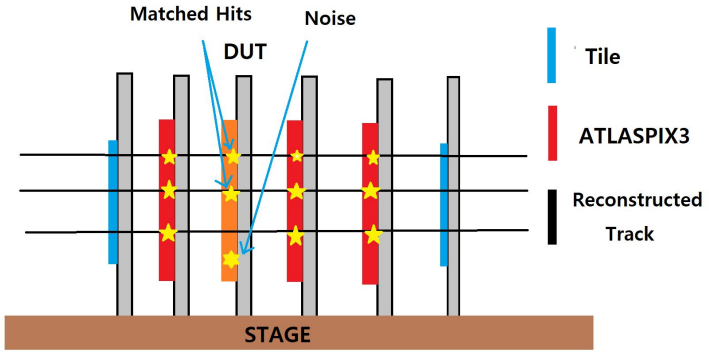
Pixel & Periphery Cell



- Signal inputs
  - artificial injection signal
  - collected charges in the sensor diode
- Charge Sensitive Amplifier (CSA)
- In-pixel NMOS-comparator
- Signals are driven to periphery by the line driver
- Periphery
  - signal is digitized by edge detector
- State machine
  - hits are encoded by 8b/10b encoder and serialized
  - send out data via a 1.25Gb/s LVDS Link

Efficiency



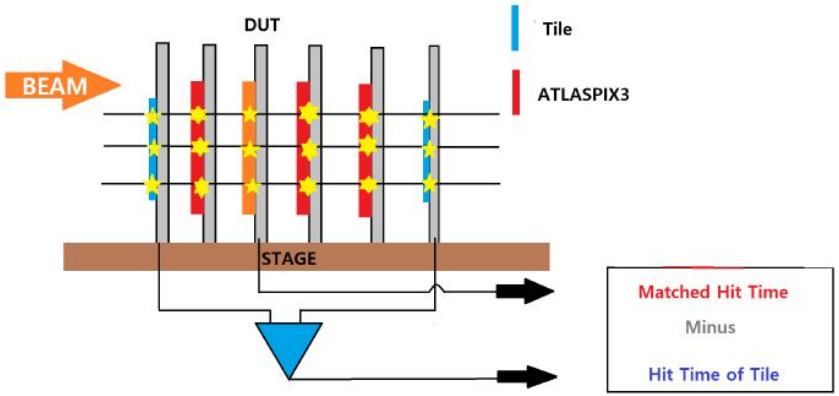


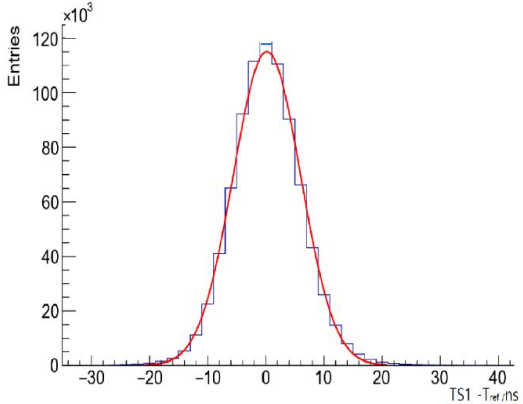
- Beam telescope
  - consist of 3 reference layers, device under test (DUT) layer and two scintillating tiles as time reference
  - measured track efficiency and noise
  - T 64.1 D.M. Immig : A Very Large HV-MAPS Tracking Telescope
- Efficiency
  - linear fit using hits in reference layers
  - reconstructed tracks are compared to hits in DUT layer
    - If matched : count as matched hit
    - If not matched : count as noise
  - definition of efficiency

$$\epsilon = N_{\text{tracks associated with a hit}} / N_{\text{total tracks}}$$

  - Noise
    - electric noise, scattering and inefficiency of telescope etc.

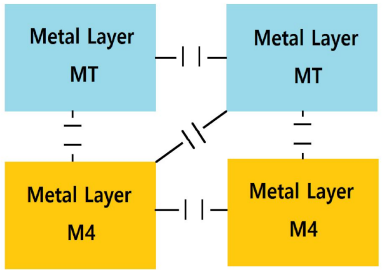
Time Resolution



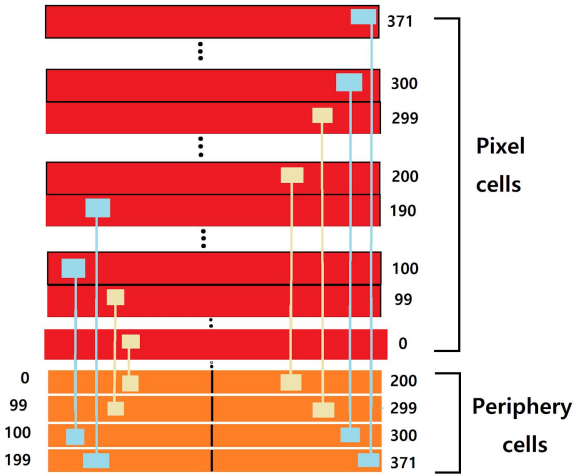


- Time resolution
  - time difference distribution = $TS1_{DUT}$ - T_{ref}
  - time difference distribution => Gaussian
  - uncertainty sigma σ from Gaussian fit
    - σ = time resolution

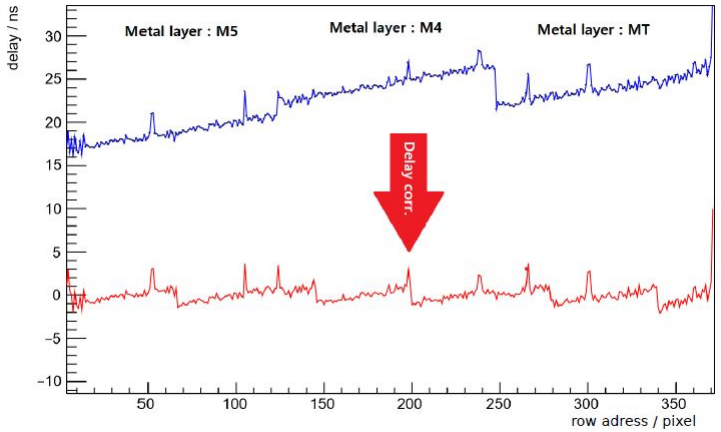
Line Delay



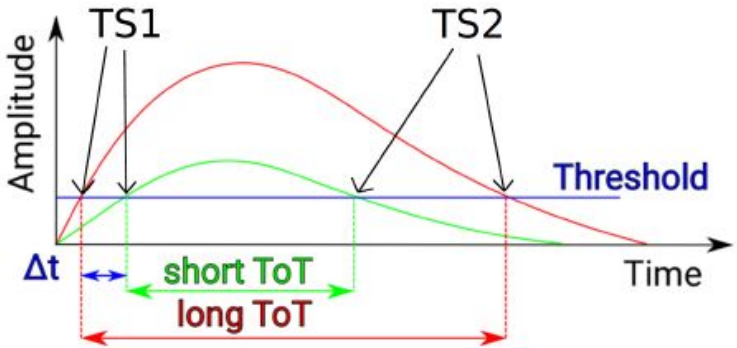
Cross section of metal Layers



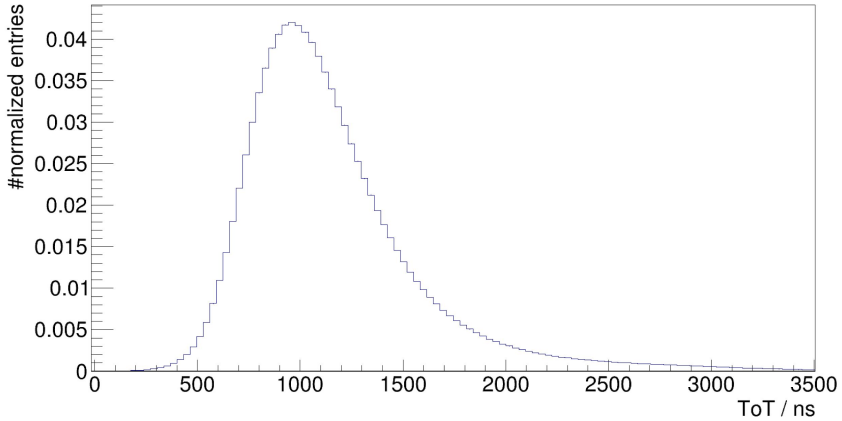
- Delay
  - capacitive couplings of the used metal layers causes delay
  - small difference length of metal layers at periphery cells.
  - three metal layers (M 4,5,T) for signal line routing

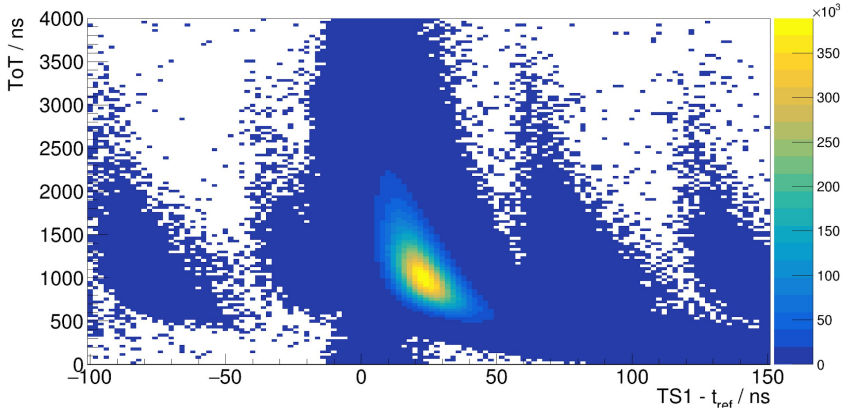


Time Walk Correction

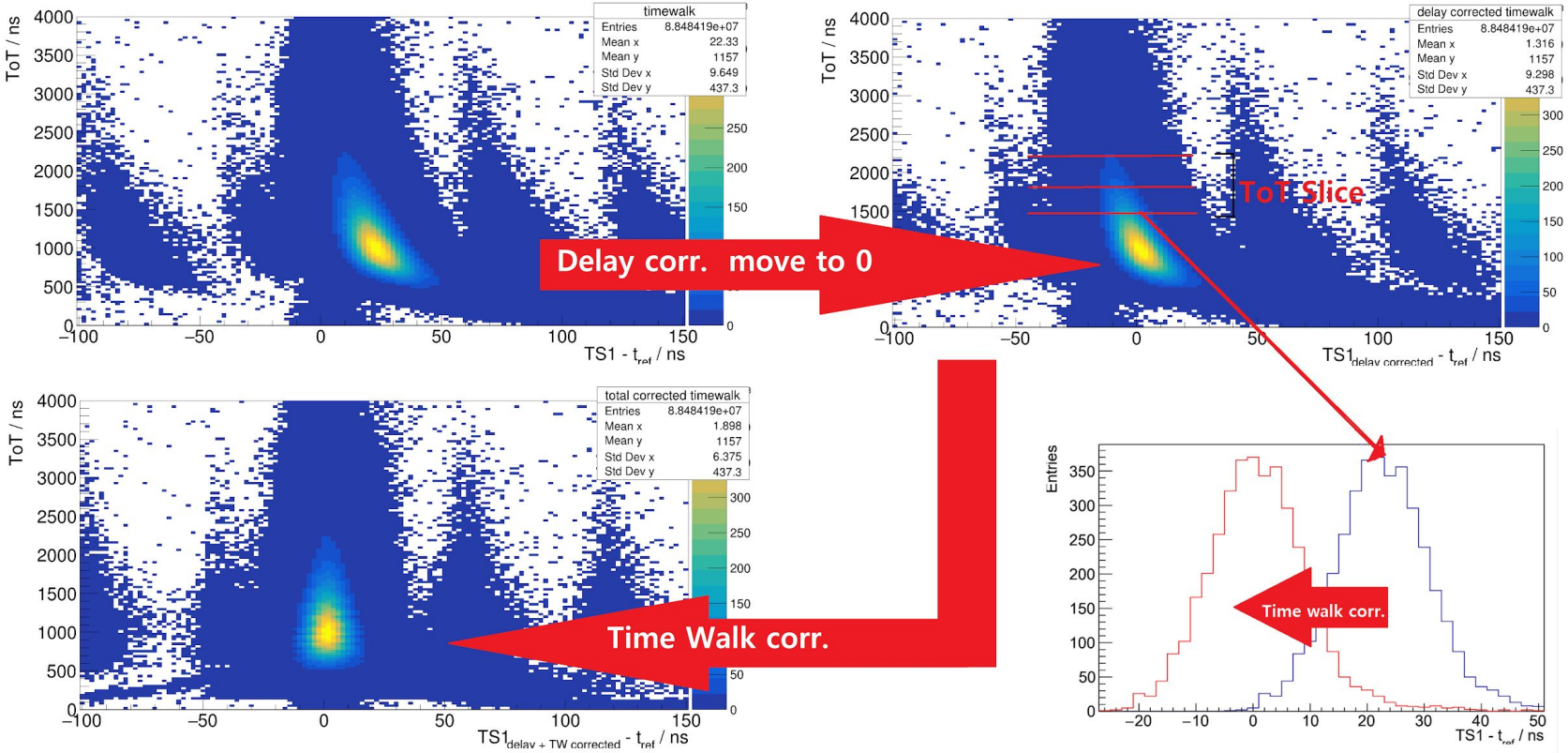


- Time over Threshold (ToT)
  - the time difference between two timestamps by one signal pulse
    - ToT = TS1 - TS2
  - ToT depends on the deposited charges
    - Landau distribution
  - Δt latency : different signal amplitudes
    - correction : time walk correction

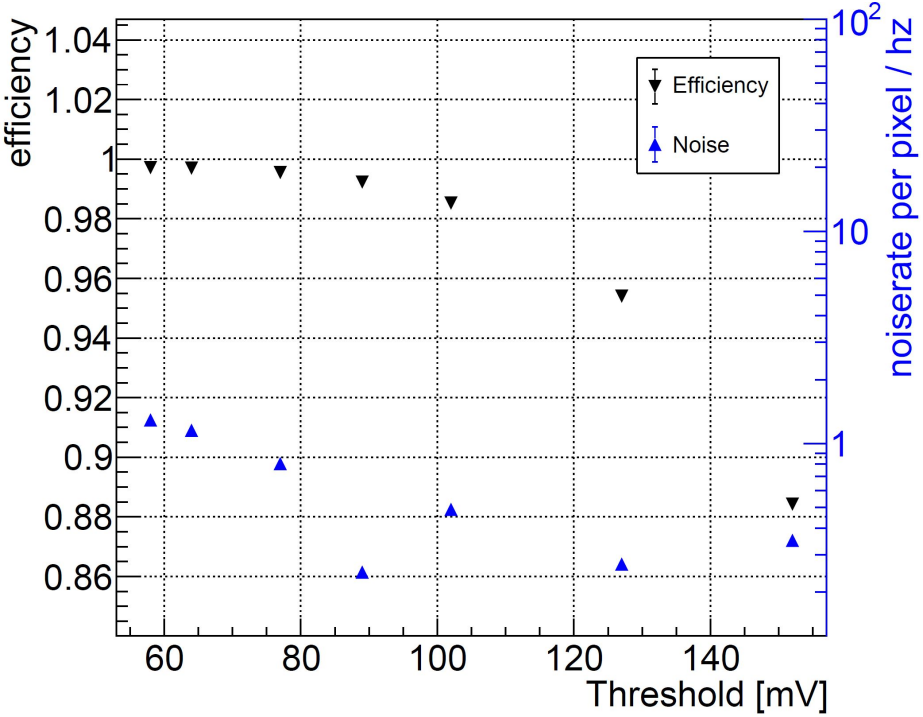




Time Walk Correction



Efficiency at PSI & Power Consumption

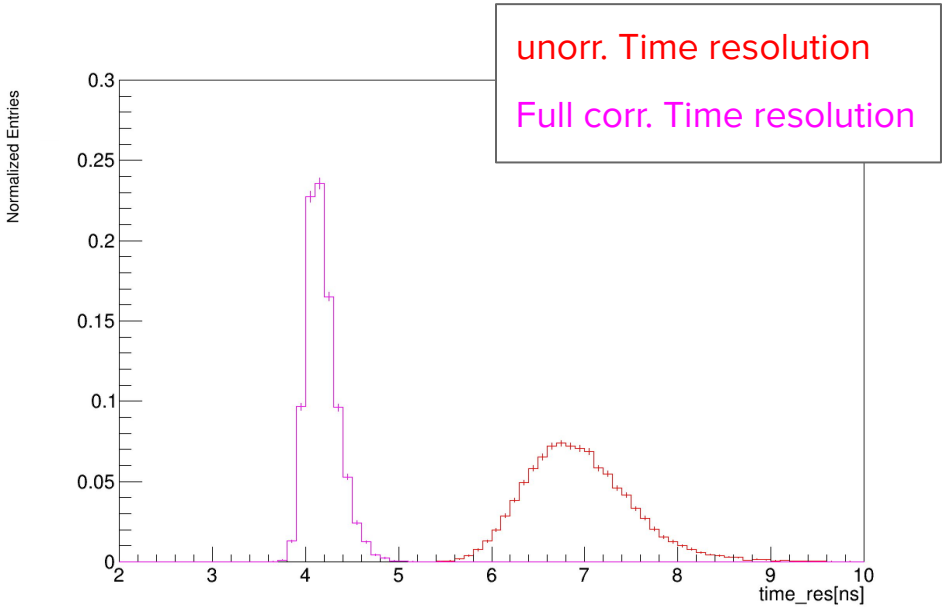


- Efficiency
  - over 99% with threshold level smaller than ~90mV
  - noise rate < 2Hz/pixel
- Power consumption

current [mA]	Power [mW]	Power/surface [mW/cm^2]
~400	~630	~140

[L. Mandok, Bachelor Thesis]

Time Resolution for Single Pixels at PSI



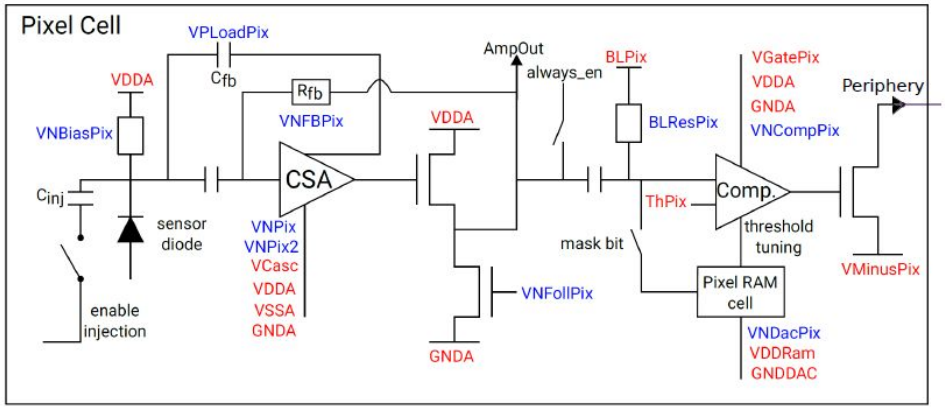
- Time resolution for single pixels

Correction	Time resolution [ns]
uncorrected	6.7 ± 0.5
Full corrected	4.1 ± 0.1

Summary

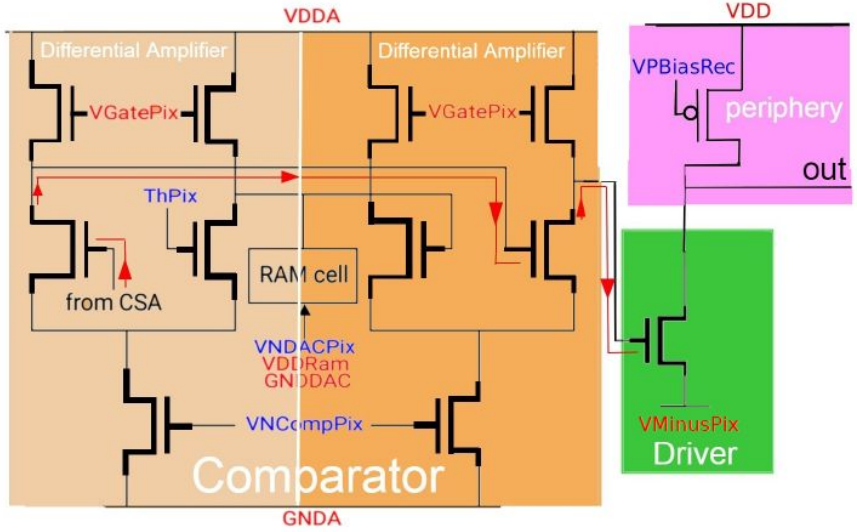
- Time resolution with a optimized configuration
  - high efficiency : > 99 %
  - time resolution for single pixels
    - uncorrected : (6.7 ± 0.5) ns
    - full corrected : (4.1 ± 0.1) ns
- The result is not enough for upgraded LHC
  - requirement : 99% efficiency in the time frame of 25 ns with a sigma of 5 ns
  - requires in-pixel-correction
- However,
  - Mighty Pixel for LHCb is based on ATLASPix3
    - T 14.8 A.M. Gonzalez : CAD Simulation and Testbeam characterization studies of High-Voltage Monolithic Active Pixel Sensors
  - ATLASPix3.1 submitted

Backup : Pixel Cell - CSA



- CSA
  - VNPix is current source for CSA
  - VPLoadPix is the feedback capacity
  - VNFBPix is the feedback resistivity which discharges the capacity
  - VNFollPix is source follower, which stabilizes feedback process
- The DC components of the amplified signals are removed by the baseline
  - BLPix is adjustable level
  - BLResPix acts as a high-pass filter

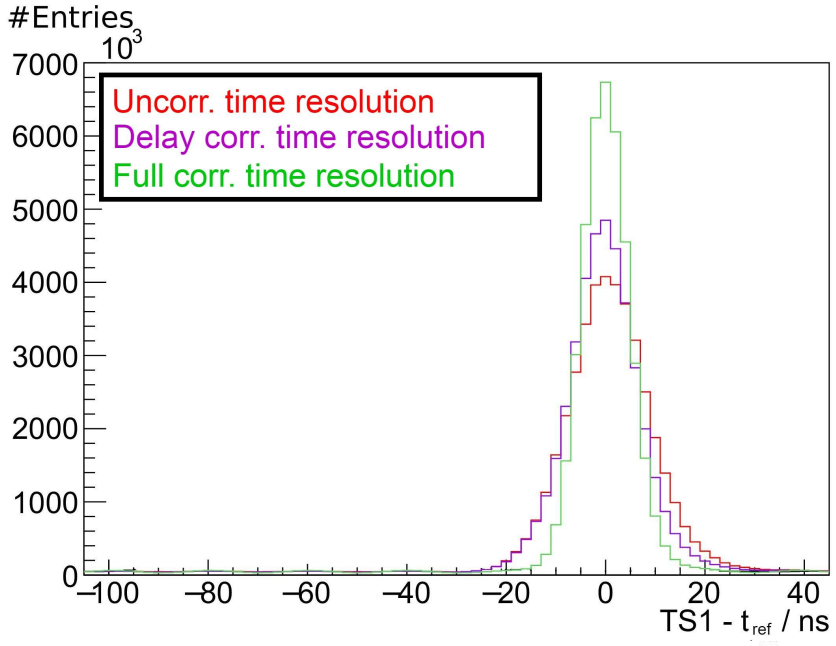
Backup : Pixel Cell - Comparator



$$V_{\text{line\_signal}} \approx \text{VDD} - \text{VMinusPix}$$

- NMOS comparator
  - two differential amplifier stages
  - VNCompPix is a current source
  - ThPix is threshold level
  - VGatePix : self-aligned gates for certain type of high speed circuits in order to limit current flow and to act as a load
- Line driver
  - The voltage amplitude of line signal is defined by VDD and VMinusPix
  - The signal is sent to periphery

Backup : Time Resolution for Sensor at PSI



- Efficiency
  - 99.6 % with noise rate 1.9 Hz/pixel
- Time resolution for the sensor
  - defined error of time resolution
    - variance of 10 times measurement with different fit ranges

Correction	Time resolution [ns]
uncorrected	8.0 ± 0.1
Delay	7.5 ± 0.1
Full	5.1 ± 0.1

VNPix	VNFBPix	VNCompPix	VGatePix	VNLoadPix	VNFollPix	HV	VMinusPix
0x12	0xa	0x2a	2.08 V	0xa	0x7	-60 V	700 mV