Test beam results

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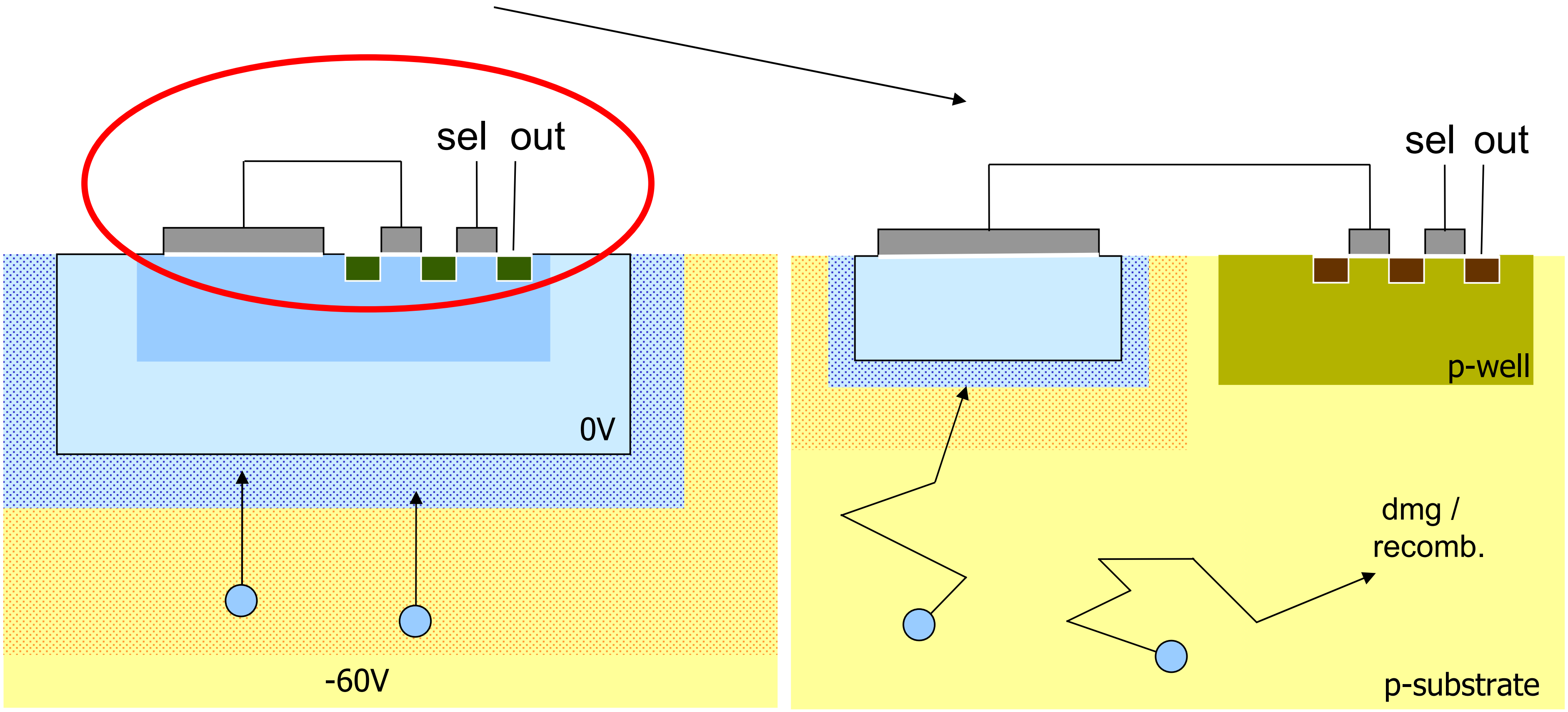
This work draws on preliminary results of a research project
commissioned by the Landesstiftung Baden-Württemberg

Outline

- Quick sensor info
- Measurements
- Results
- "Theories"

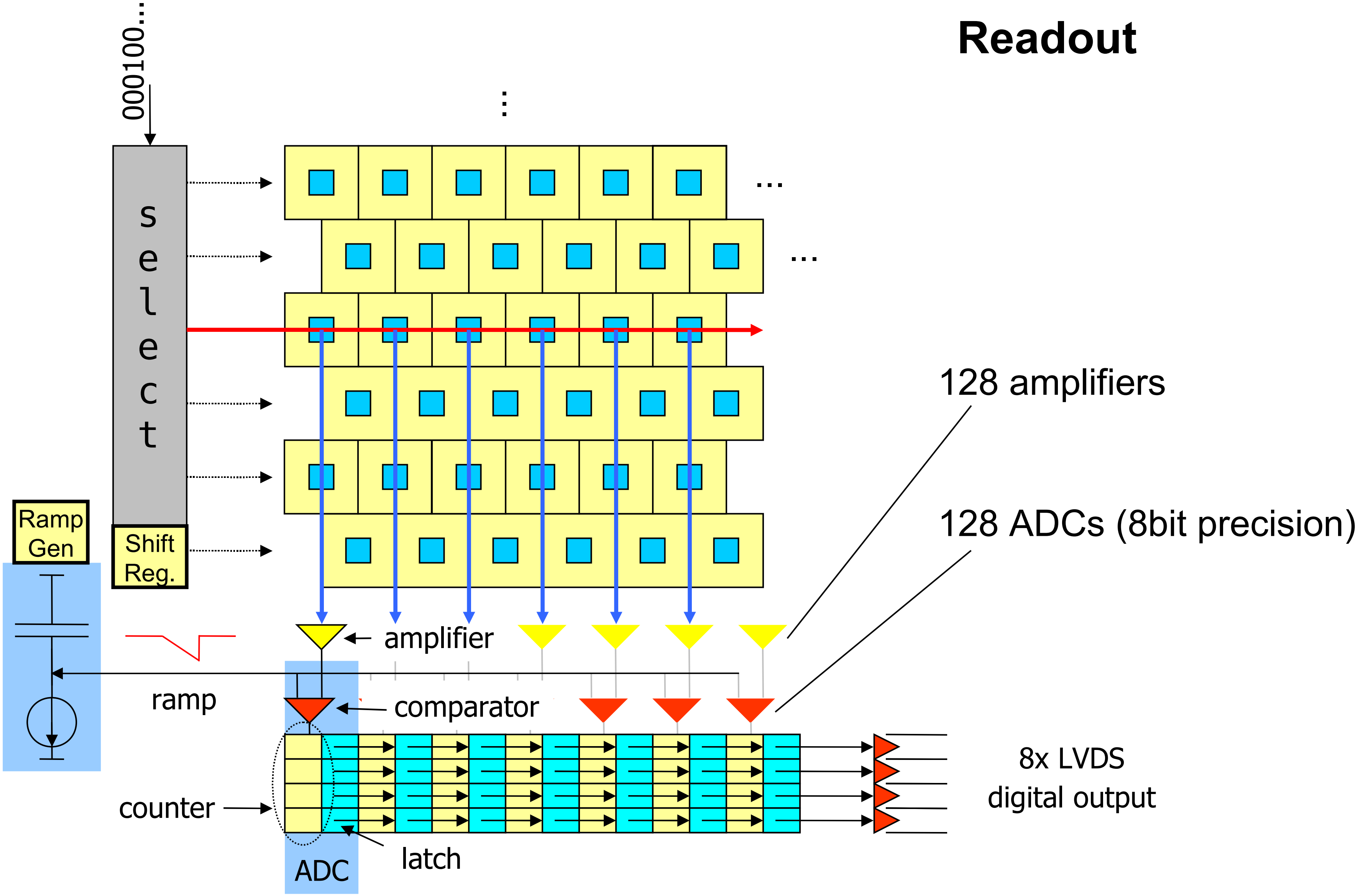
- **compared to a native monolithic sensor chip**



- charges collected by **drift** (rather than diffusion)
- higher **radiation tolerance**
- **pmos** intrinsically more radiation tolerant

cannot place another n-well

Readout



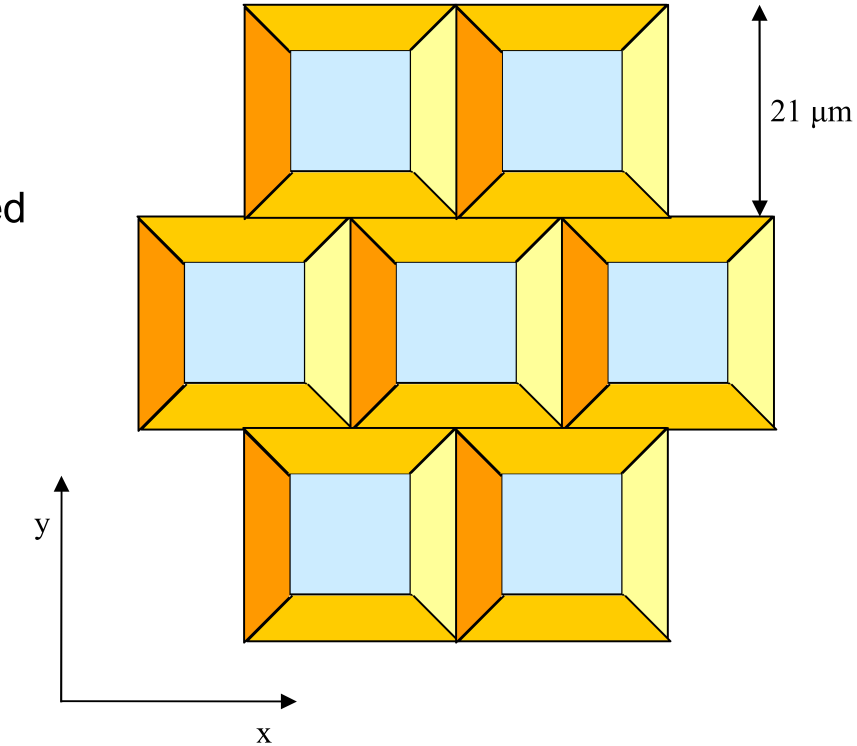
000100...
select
Shift Reg.
Ramp Gen
ramp
amplifier
comparator
counter
latch
ADC
128 amplifiers
128 ADCs (8bit precision)
8x LVDS digital output

HVPix Chip – What's important?

- *Monolithic pixel detector* in high voltage CMOS technology
  ☺ possibly better radiation tolerance, quick readout
  ☹ larger detector capacitance (10fF)

- 128x128 pixel-matrix, pixel size 21x21μm^2

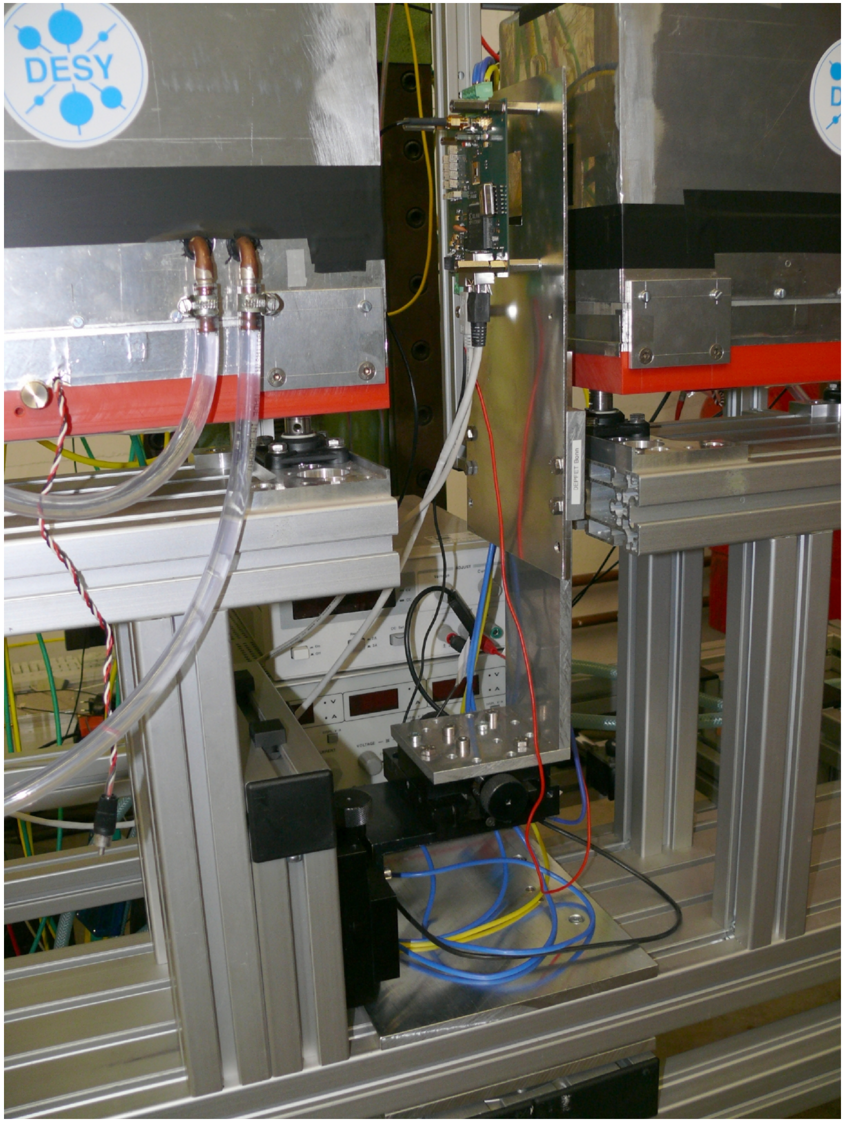
- **bricked pixel structure**
  7 instead of 9 pixels!
  additional software logic required



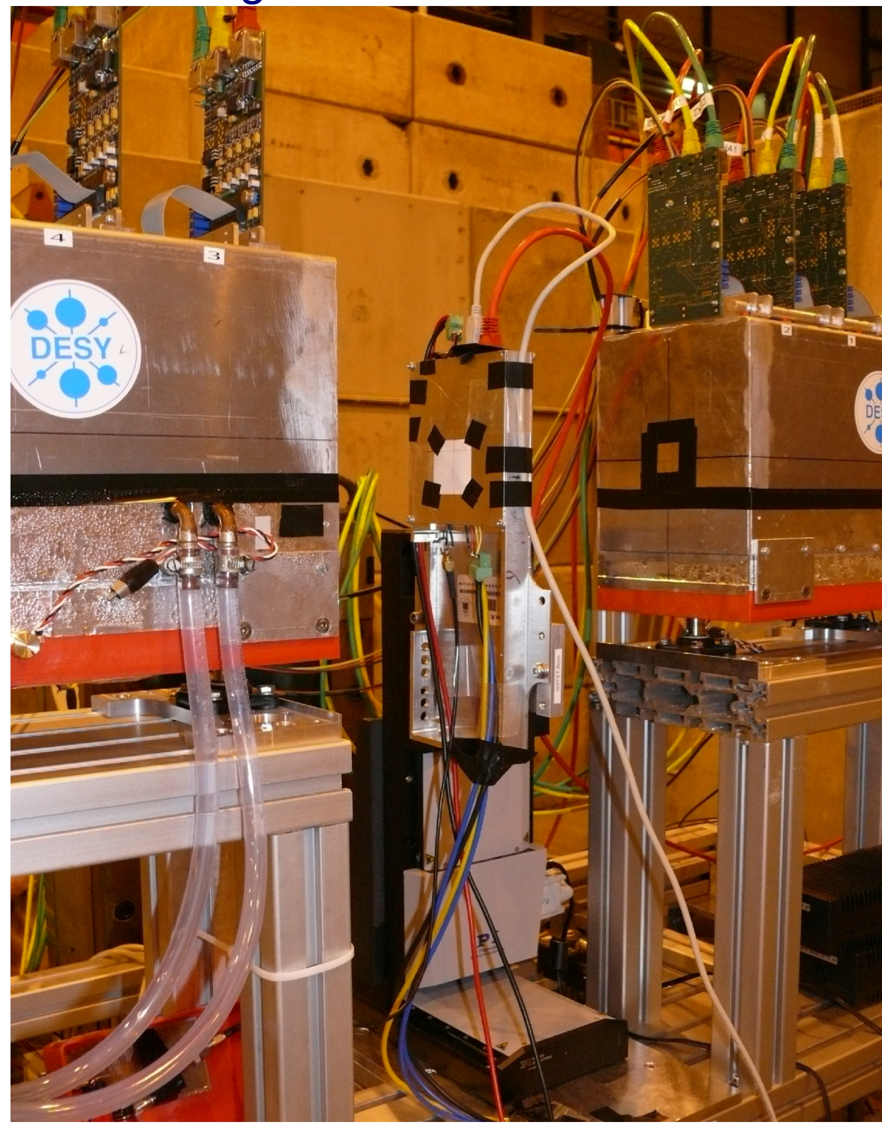
Basic Measurements

DESY vs CERN setup

manual alignment a lot easier this time!

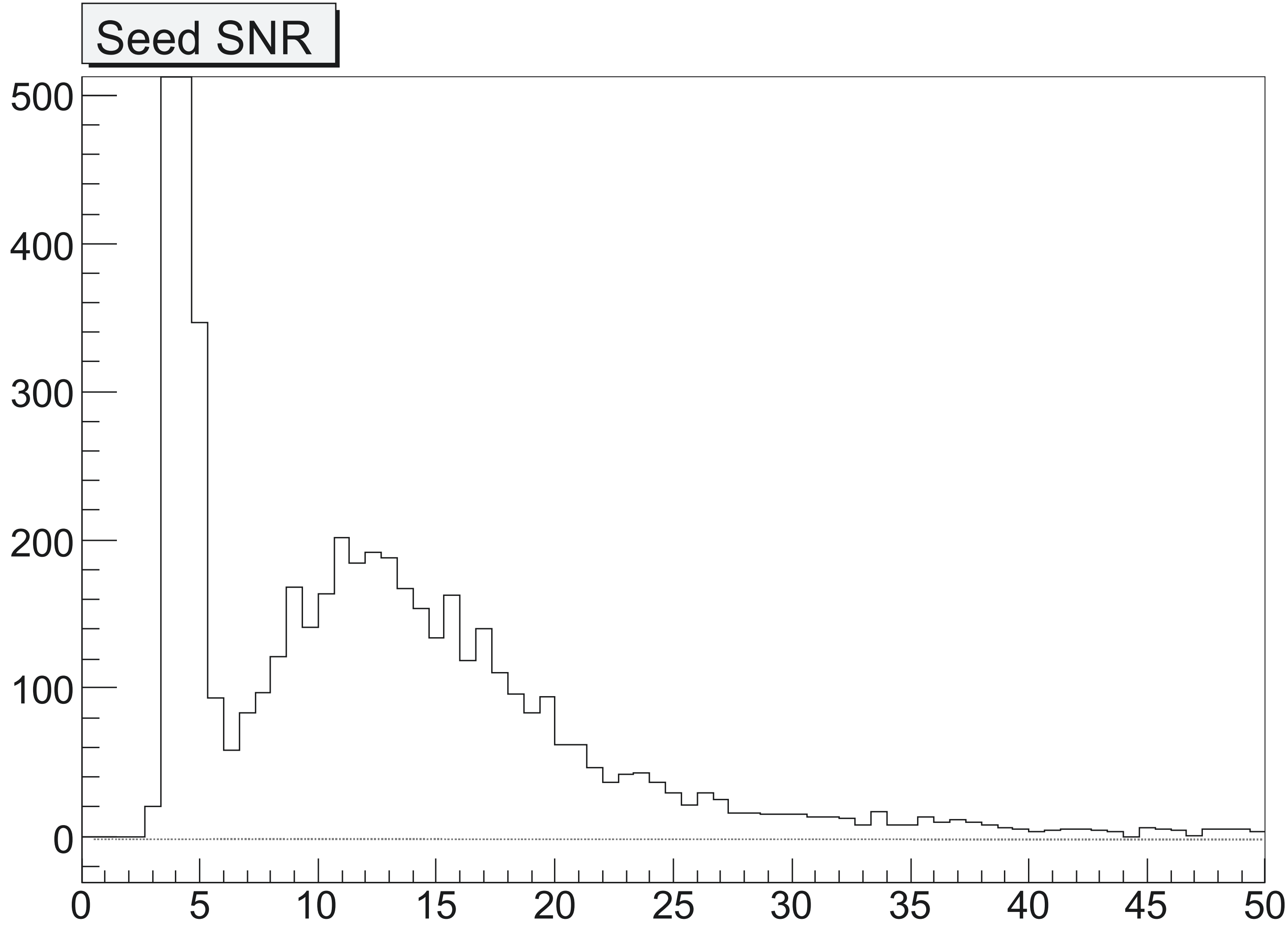


DESY

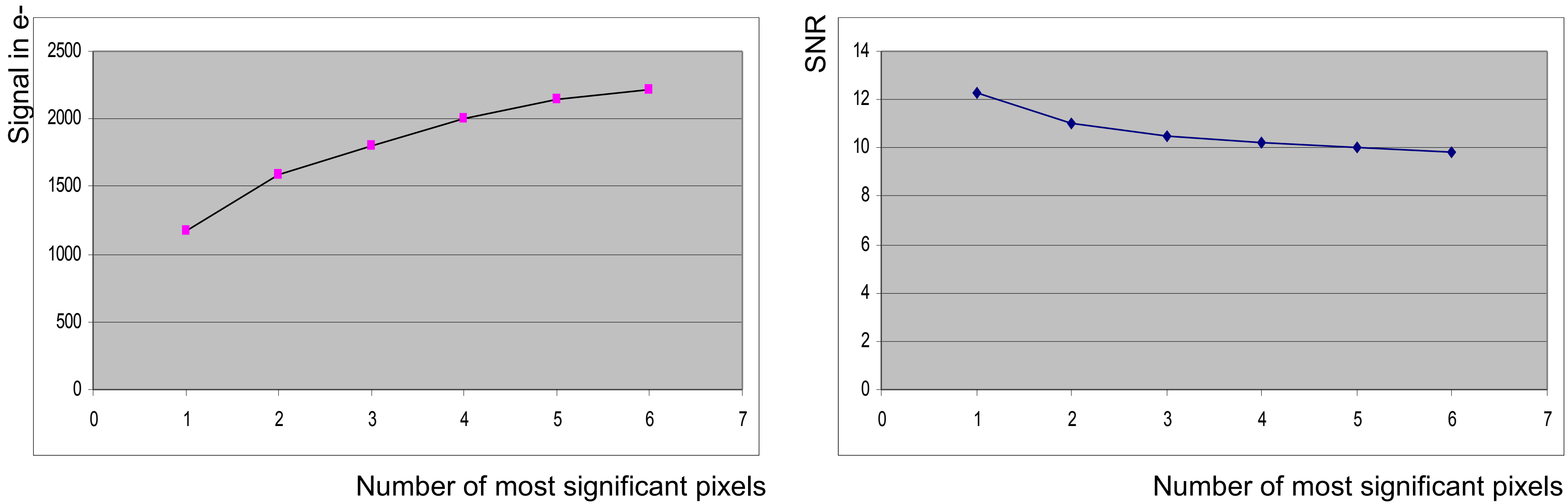


CERN

HVPix Seed-Pixel S/N Ratio

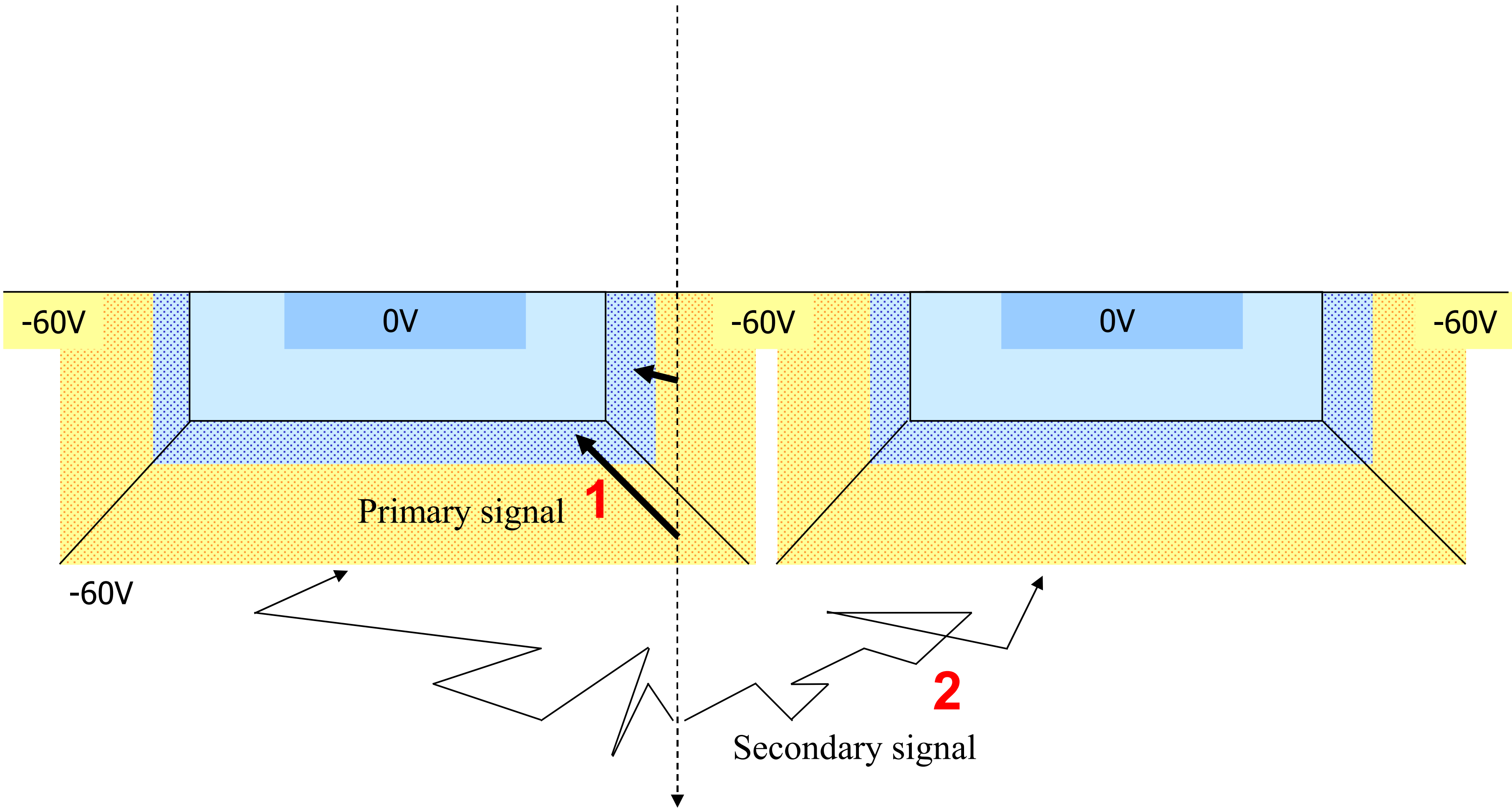


Telescope: ~13.5

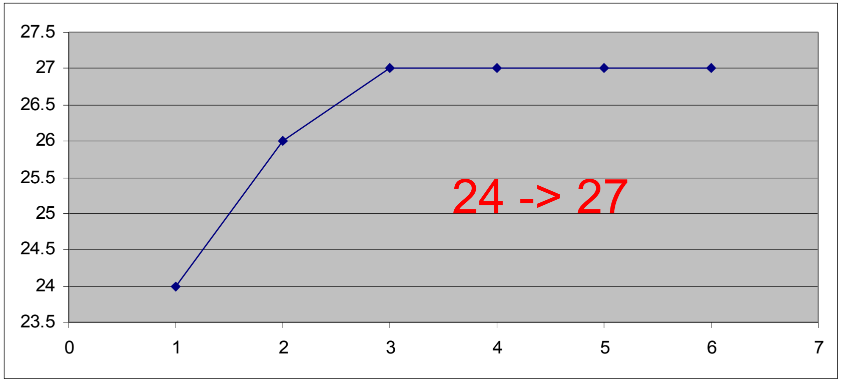


- **non-linear increase in signal** -> limited charge sharing
- **signal offset** -> two kinds of signal sources!

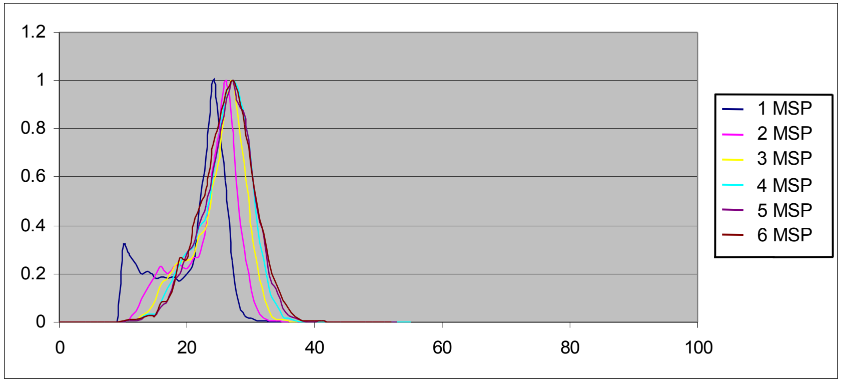
- SNR drops: 12.3 (single pixel) to 9.8 (6-pixel cluster).
- -> we apply our cluster cut to clusterSNR(3MSP)


-60V
0V
-60V
0V
-60V
1
Primary signal
-60V
2
Secondary signal

Calibration with: Fe-55



Signal in ADC cnts vs number of MSP

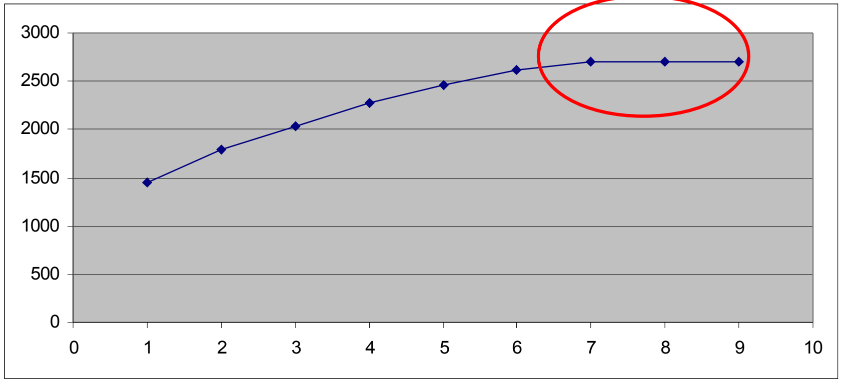


Signal (ADC cnts)

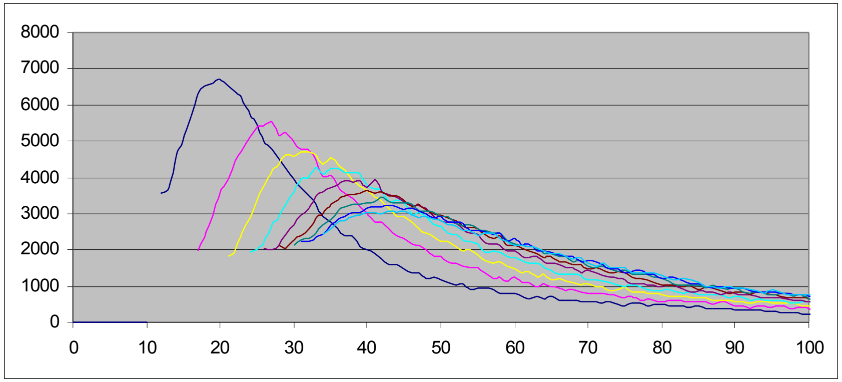
- absorbed in seed pixel

Trying to estimate charge sharing:

Co-60



Signal in e- vs number of MSP



Signal (ADC cnts)

- Higher-energetic source: 7MSP imposes a limit!
  7-Pixel-Cluster is good enough!
- Similar signal peaks -> Confirms TB measurements.

Analysis
Results

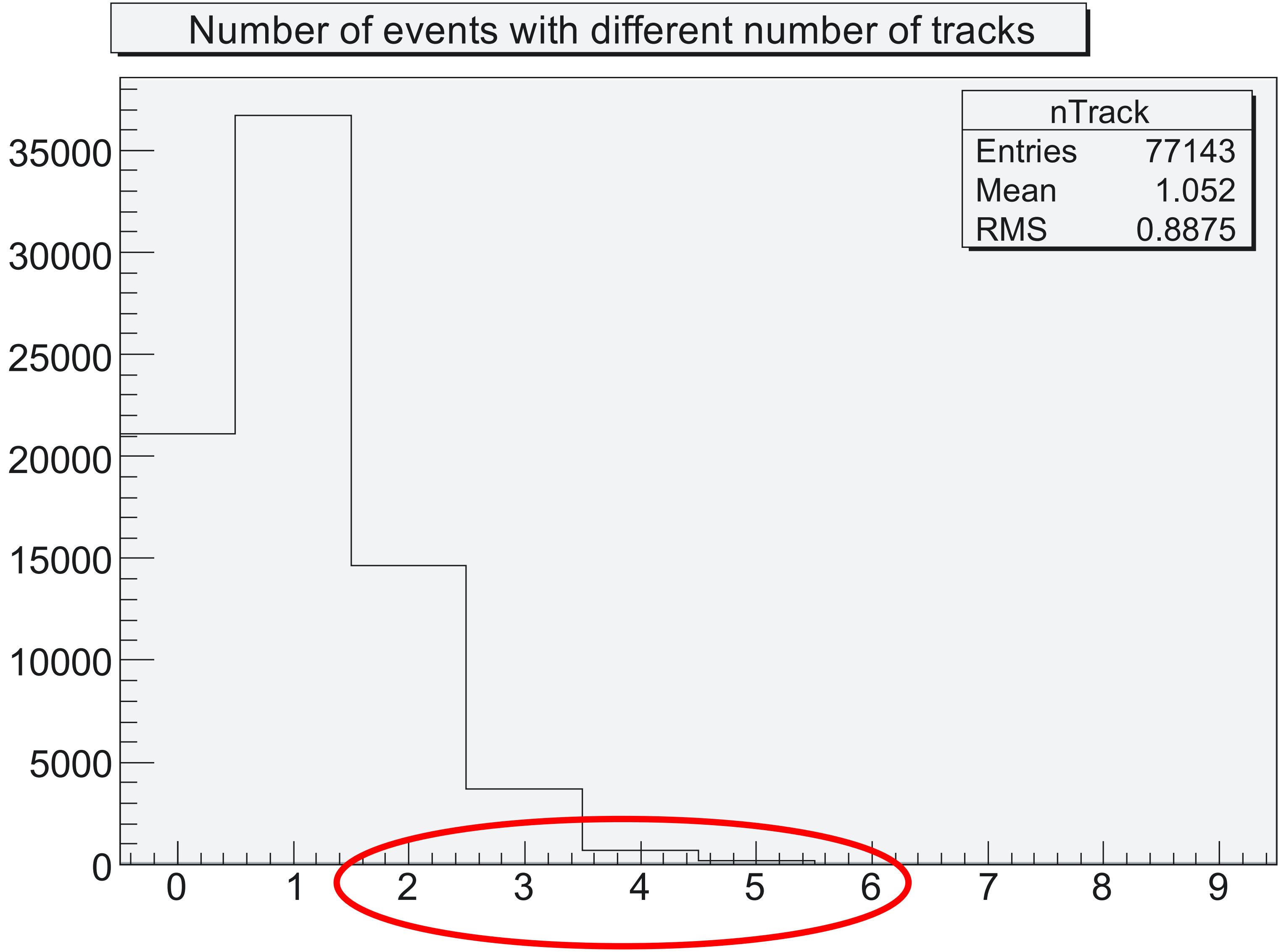
Efficiency: 82%

Efficiency: 82%   =(

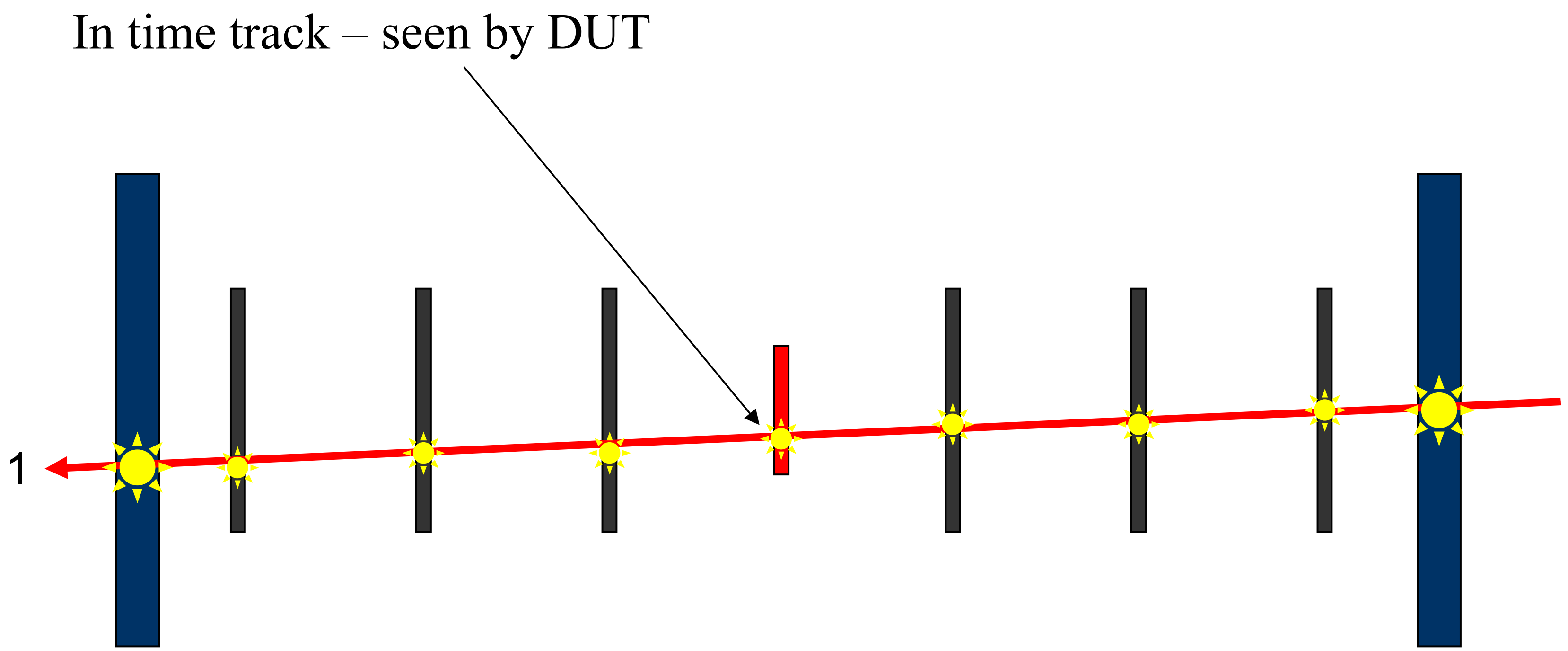
We examined the possible in-noise-hits:
Very low cluster cuts -> still not more than 83% !

Where could they be?
-> Theories!!

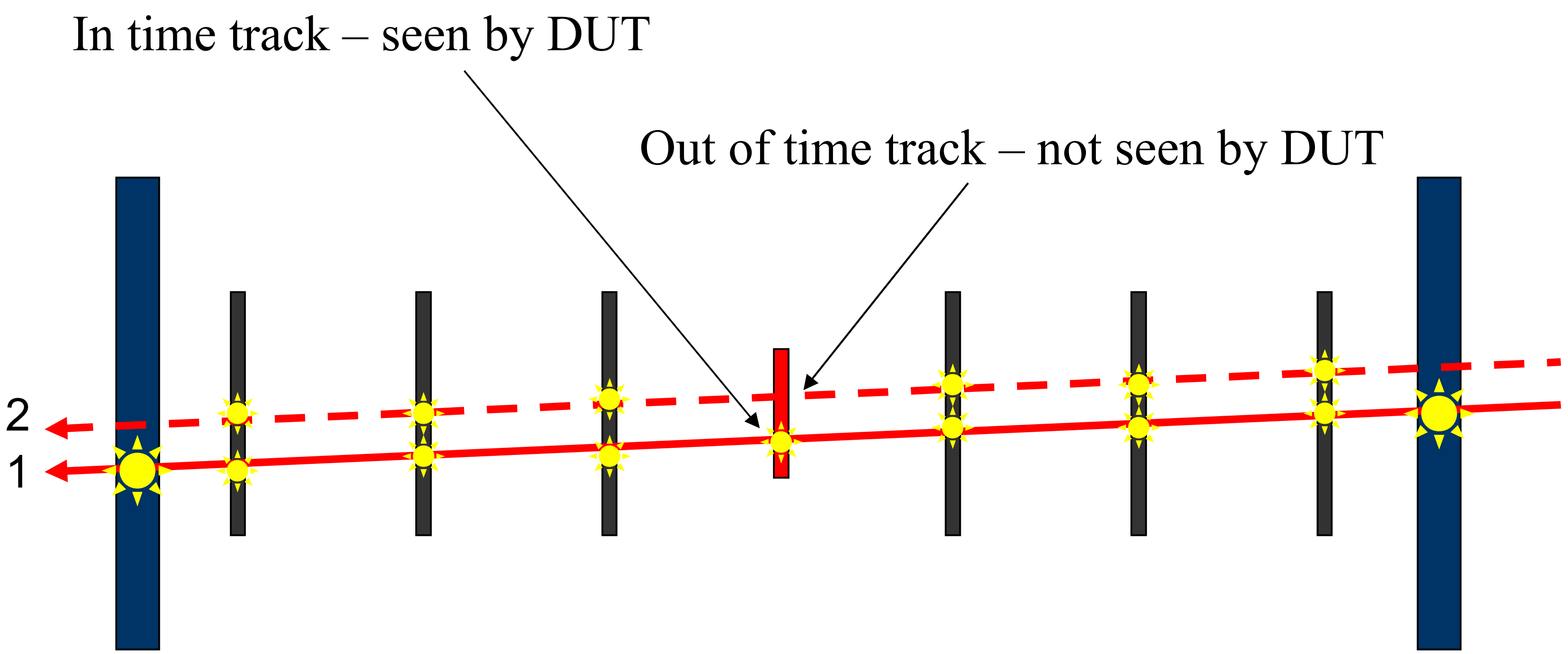
Double track events and integration time



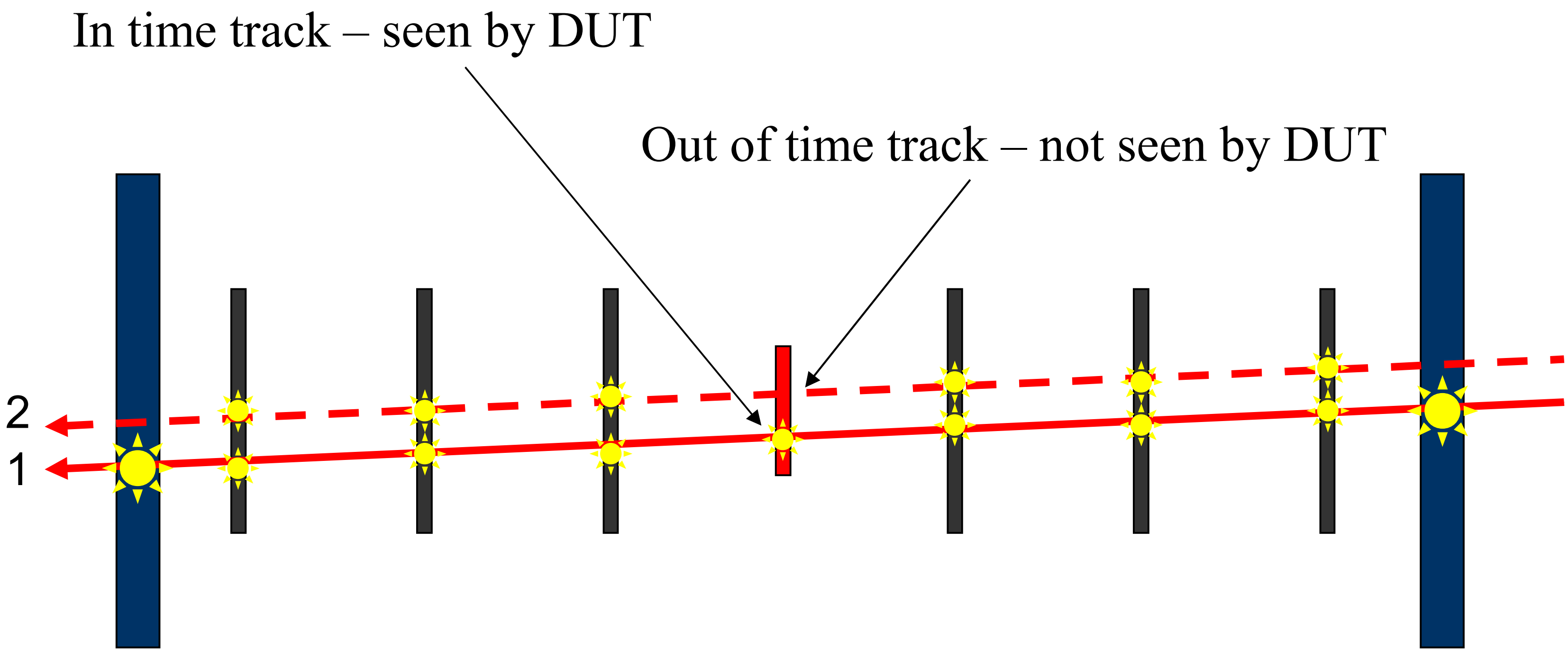
Double track event



Double track event

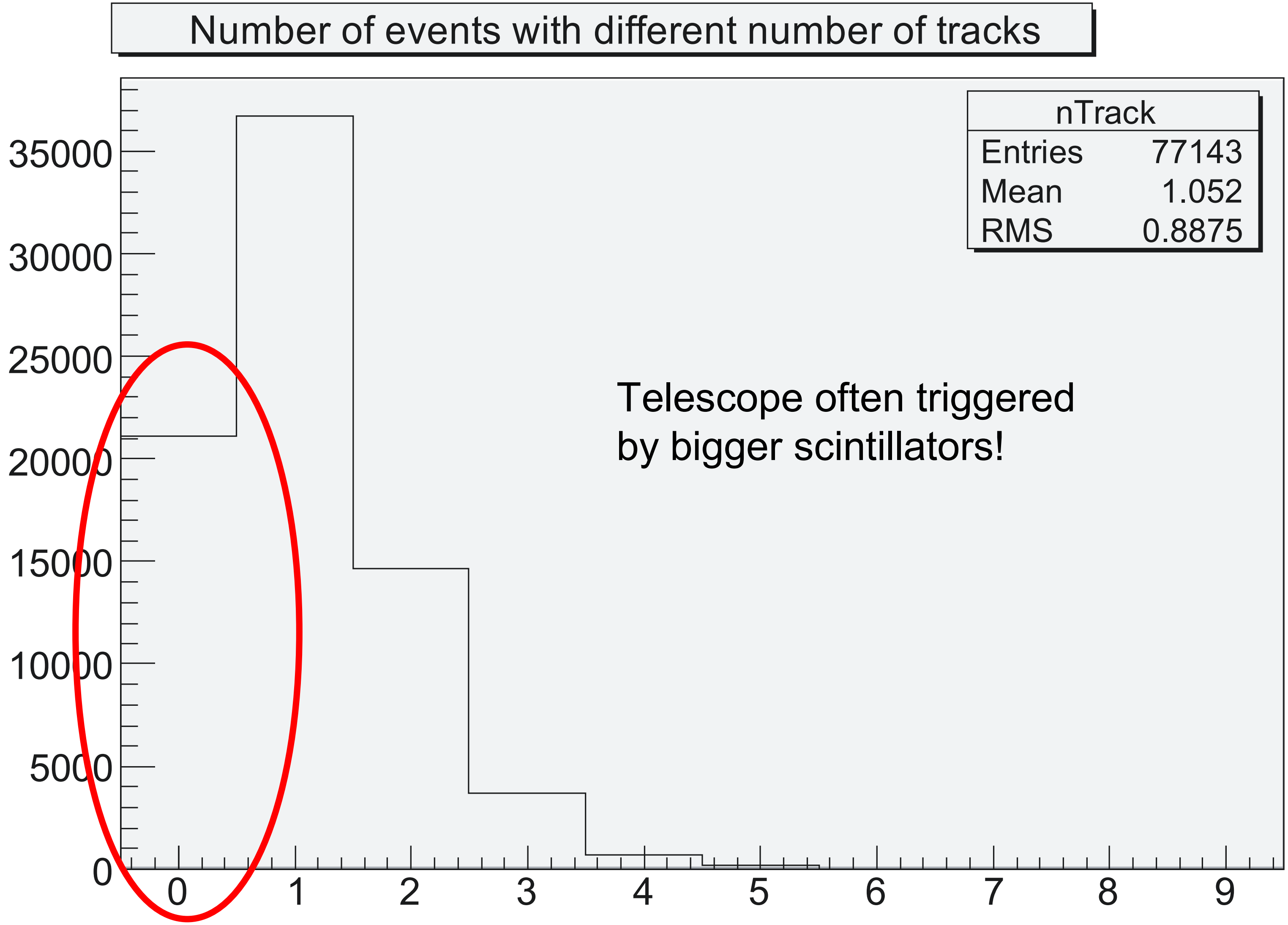


Double track event



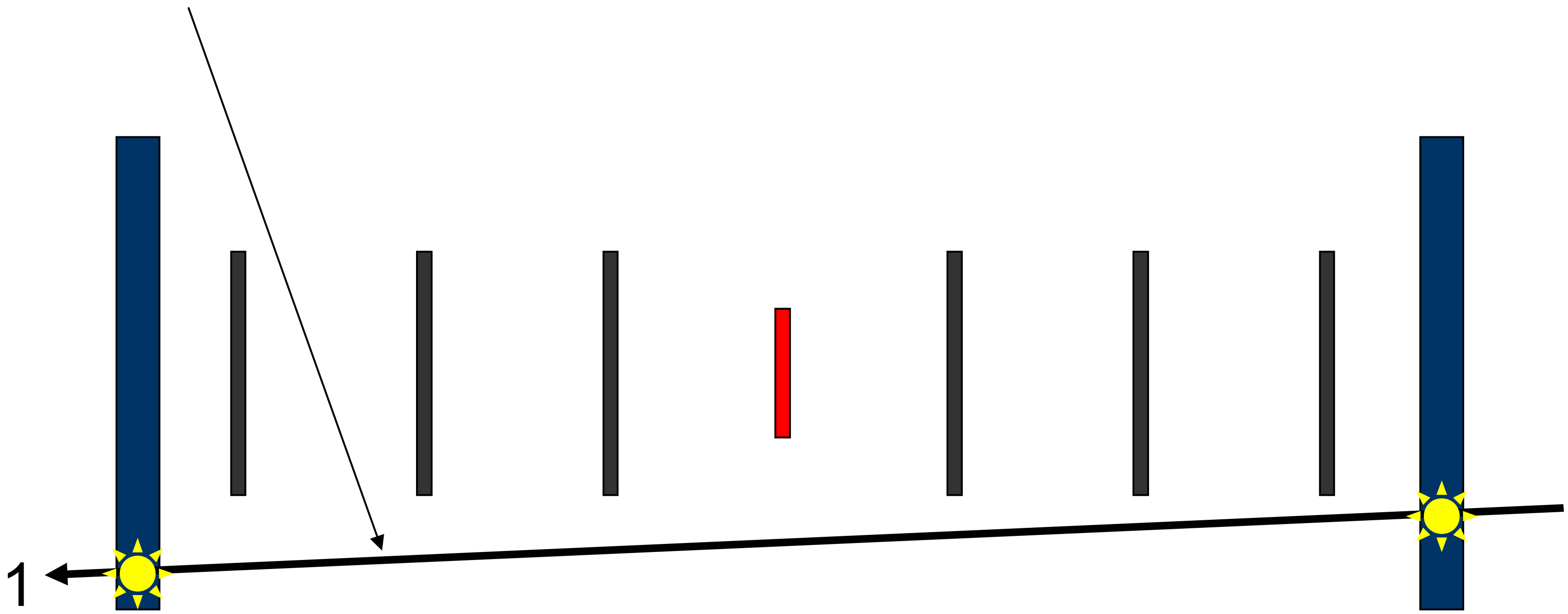
- Neglecting all multiple-track-events: efficiency goes from 72% to 82% !

Next idea: Double track event seen as a single track event??

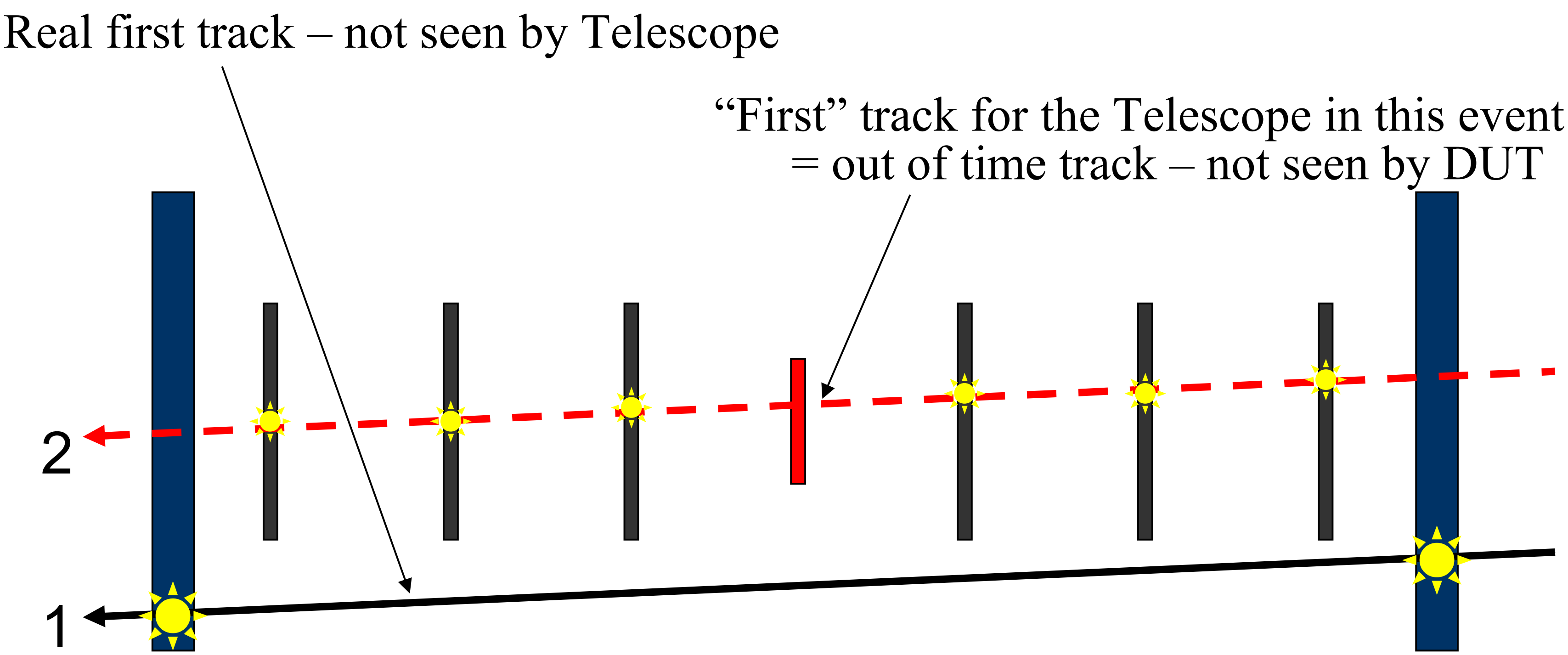


Double track event seen as a single track event

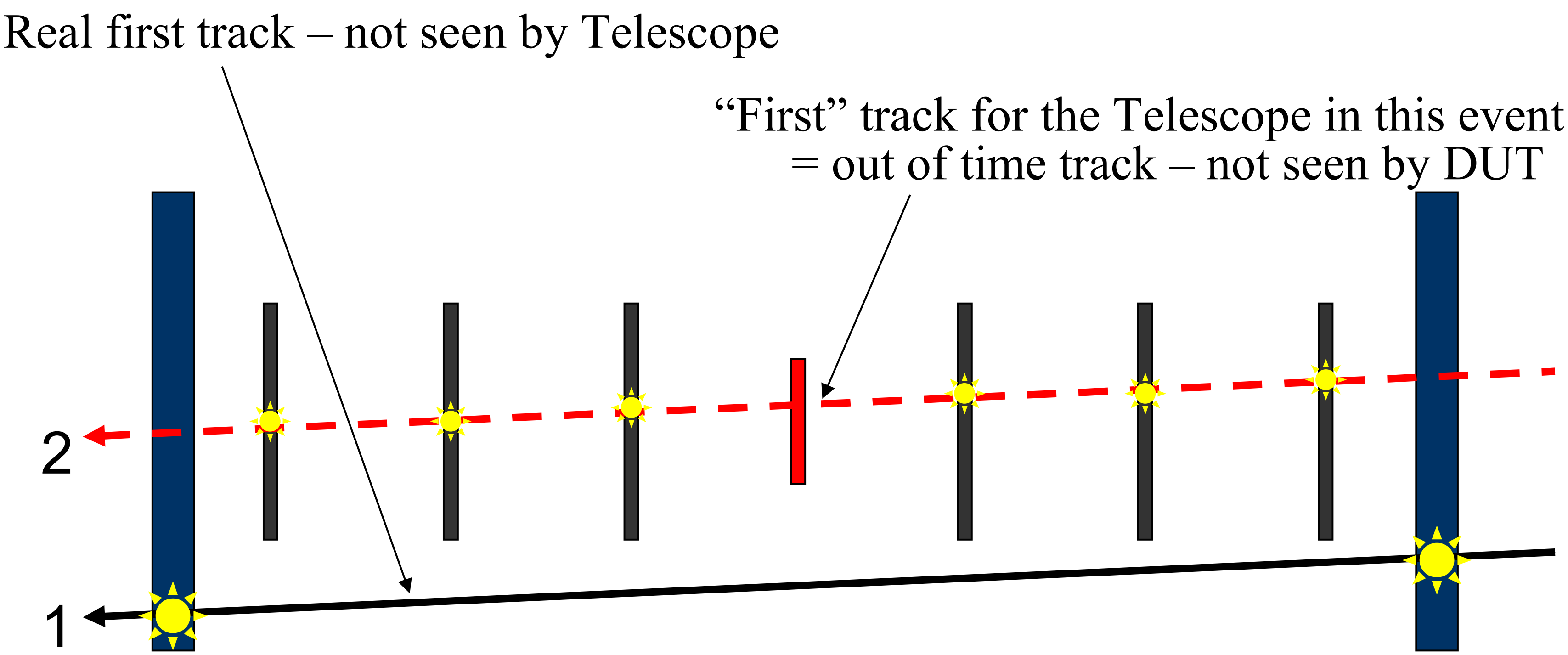
Real first track – not seen by Telescope



Double track event seen as a single track event



Double track event seen as a single track event



Is this our lost efficiency?
Do other groups with a fast readout reach 100% ?

Efficiency Conclusion

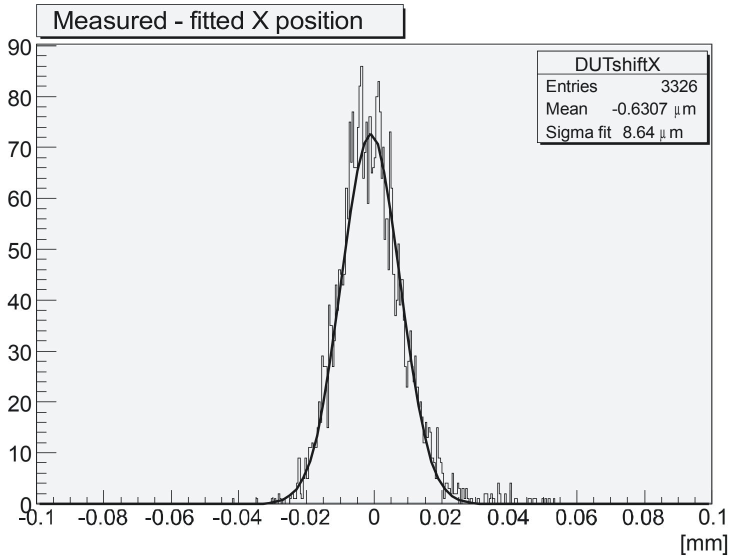
- Efficiency lower than 100% probably due to timing issues
  - Readout of telescope and DUT are not synchronous
  - DUT integration (readout) time 164 μs
  - Telescope integration time = ?
  - Large cluster and track multiplicity in telescope
  - multiple tracks in telescope due to high beam intensity and long integration time
  - Small cluster multiplicity in DUT due to shorter integration time

- Some “out of time” particles hit the telescope after the trigger moment (during the readout) – the particles are not seen by the DUT due to wrong timing
- Neglecting of all multiple track events increases efficiency from 72% to 82%

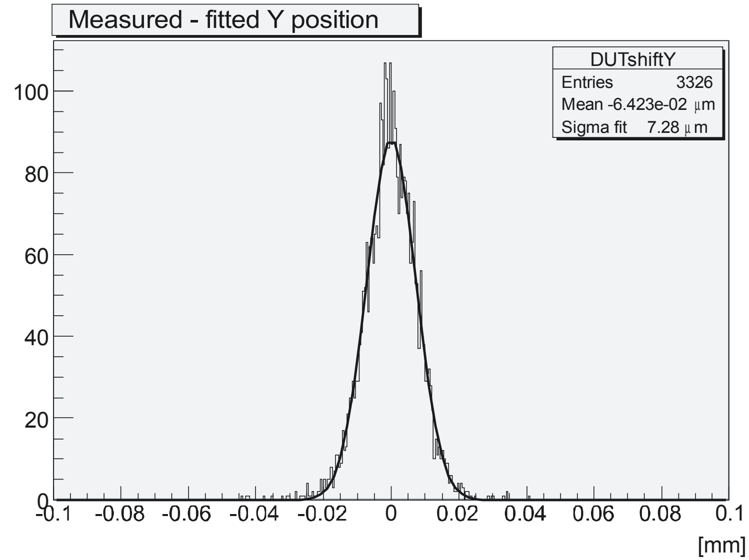
- Problem: scintillator area is bigger than telescope area: some out of time tracks are seen as single tracks by telescope. If we were able to filter these out of time tracks too, we would probably measure a better efficiency.

Spatial resolution

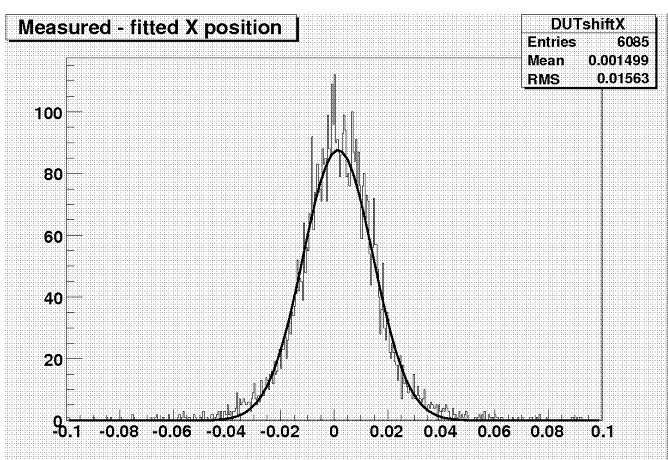
Sigma residual X: 8.6 µm

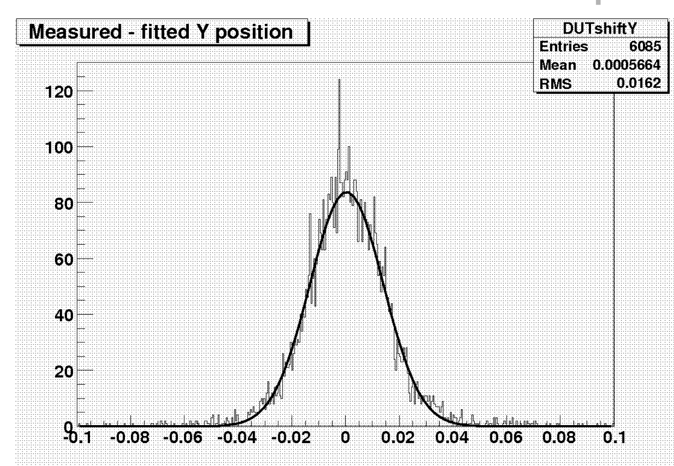


Sigma residual Y: 7.3 µm



DESY said: X: 13.2 µm Y: 13.7 µm

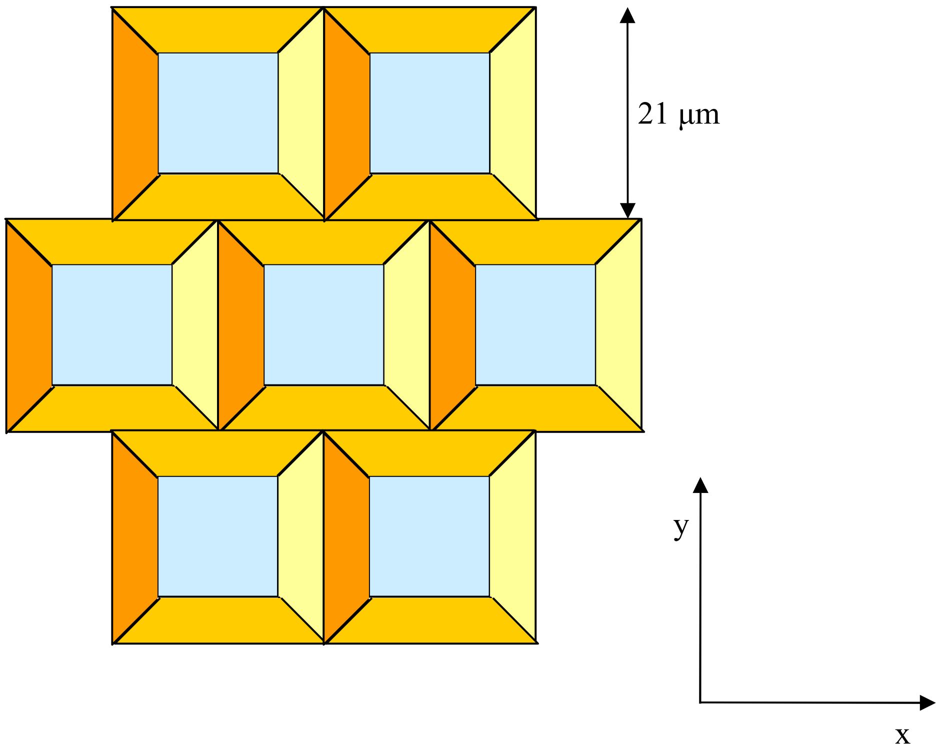




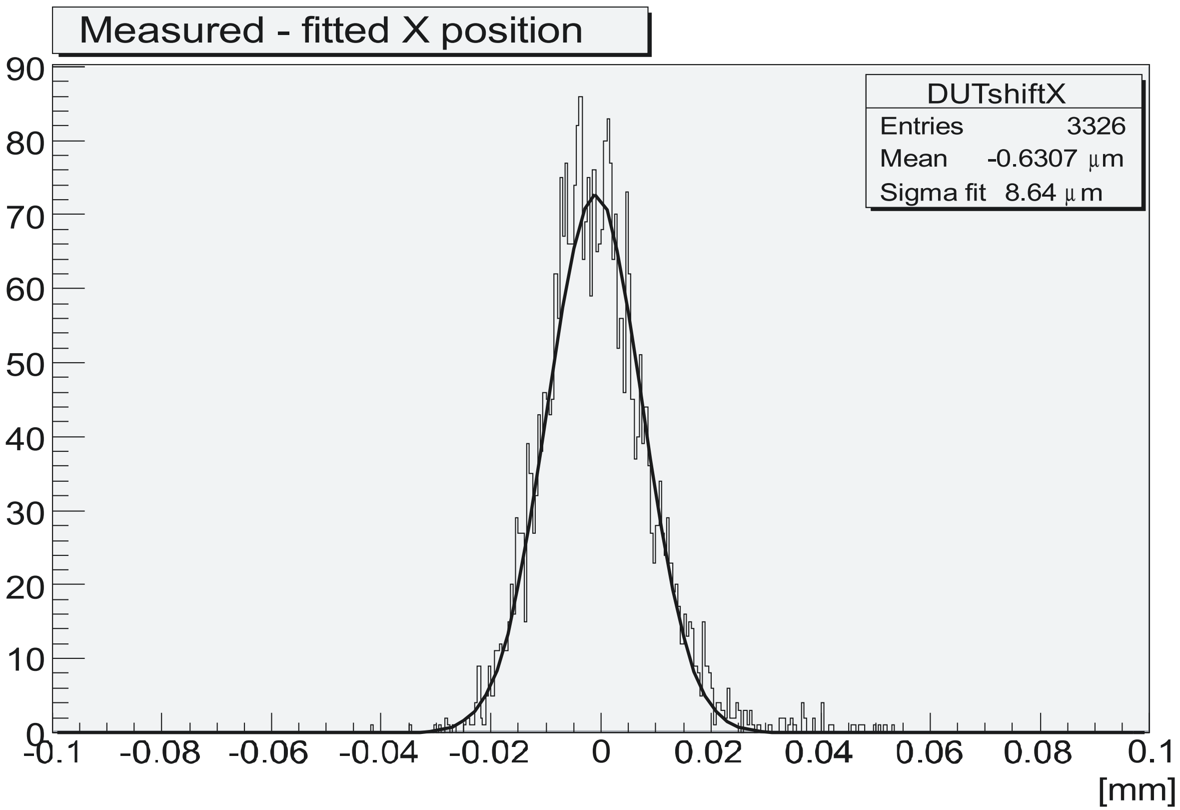
Spatial resolution:

Sigma residual X: 8.6 µm
Sigma residual Y: 7.3 µm

.... =(expected 6 µm or less!

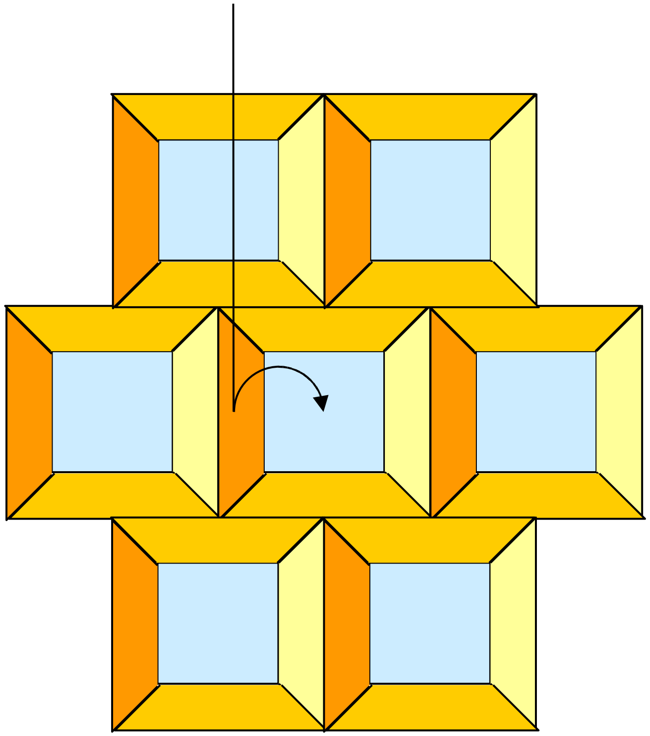


Questions!



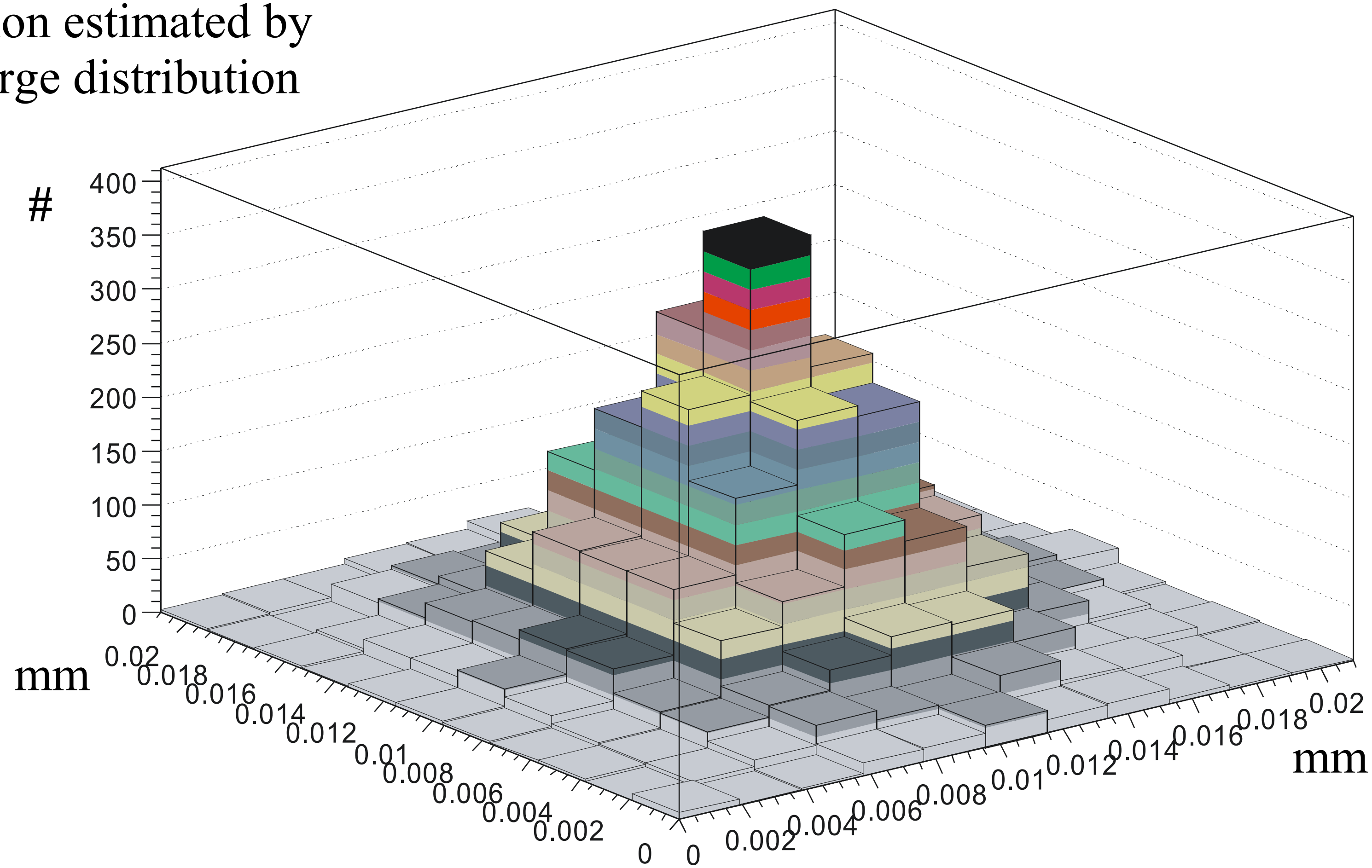
- How is it possible to have larger residual than pixel pitch? Which we do, sometimes.
- We would assume a <u>different</u> pixel to be hit. But our **COG Shift** is very small normally.
- Does the COG correction (ETA) work?

COG Shift due to primary signal



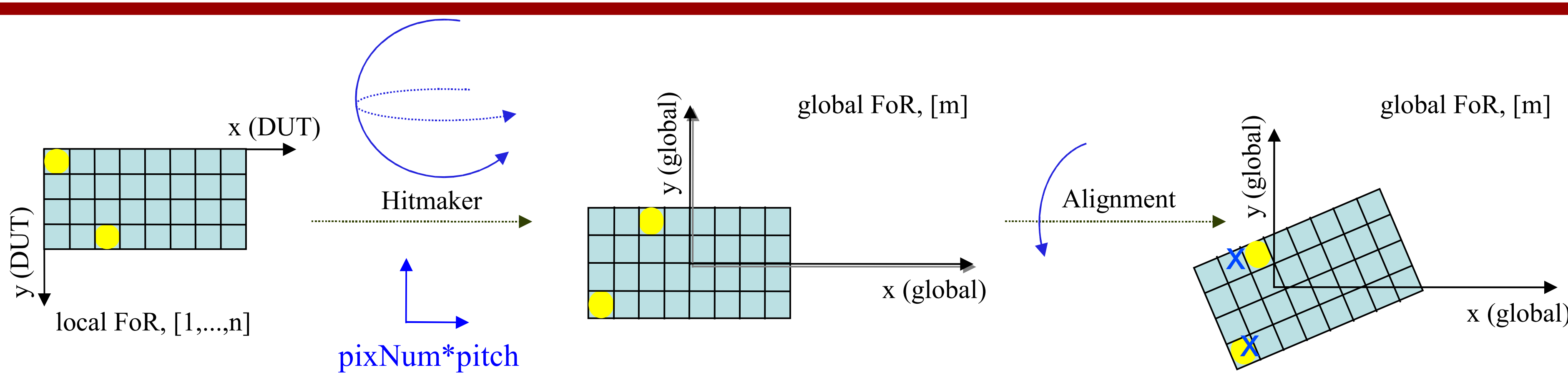
- drift leads to primary signal
- not shared between pixels
- radiation hardness (strong field, fast collection) costs us charge sharing
- call for ETA! (does it really work?)

hit position estimated by
DUT charge distribution

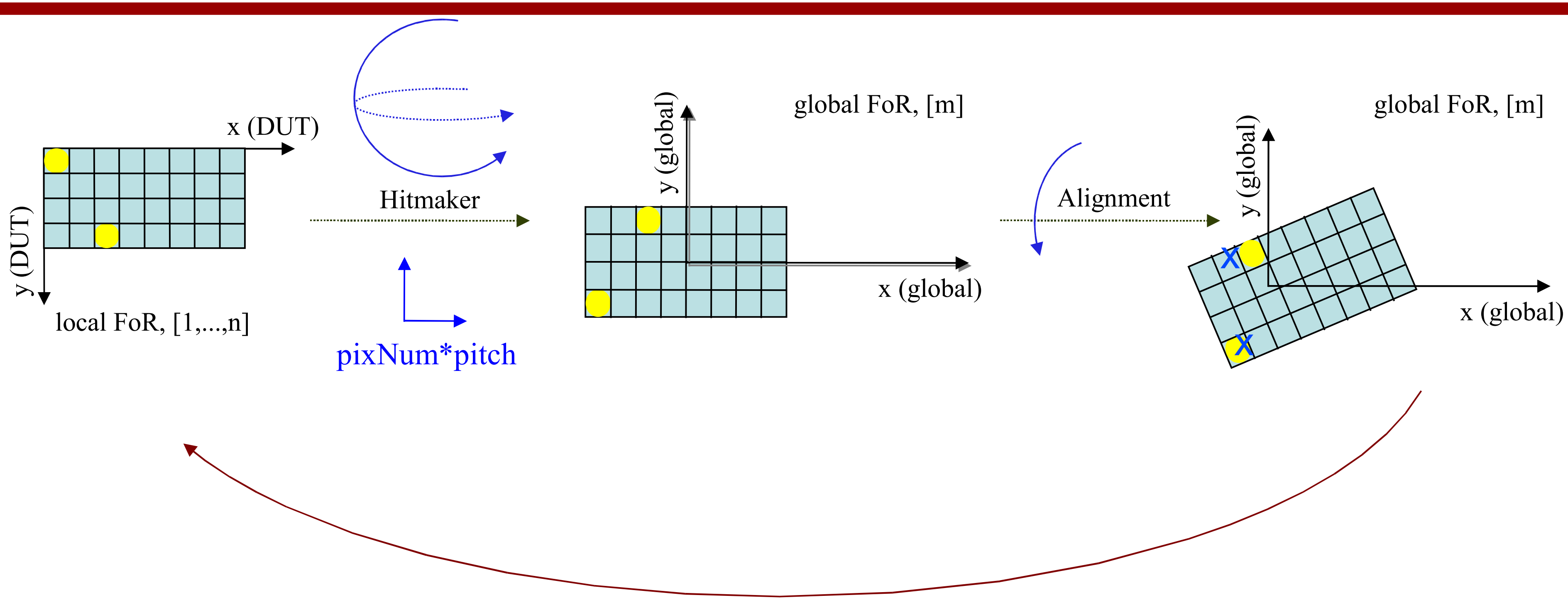


- COG Shift 0.5 almost never to be seen

→ primary signal very prominent!

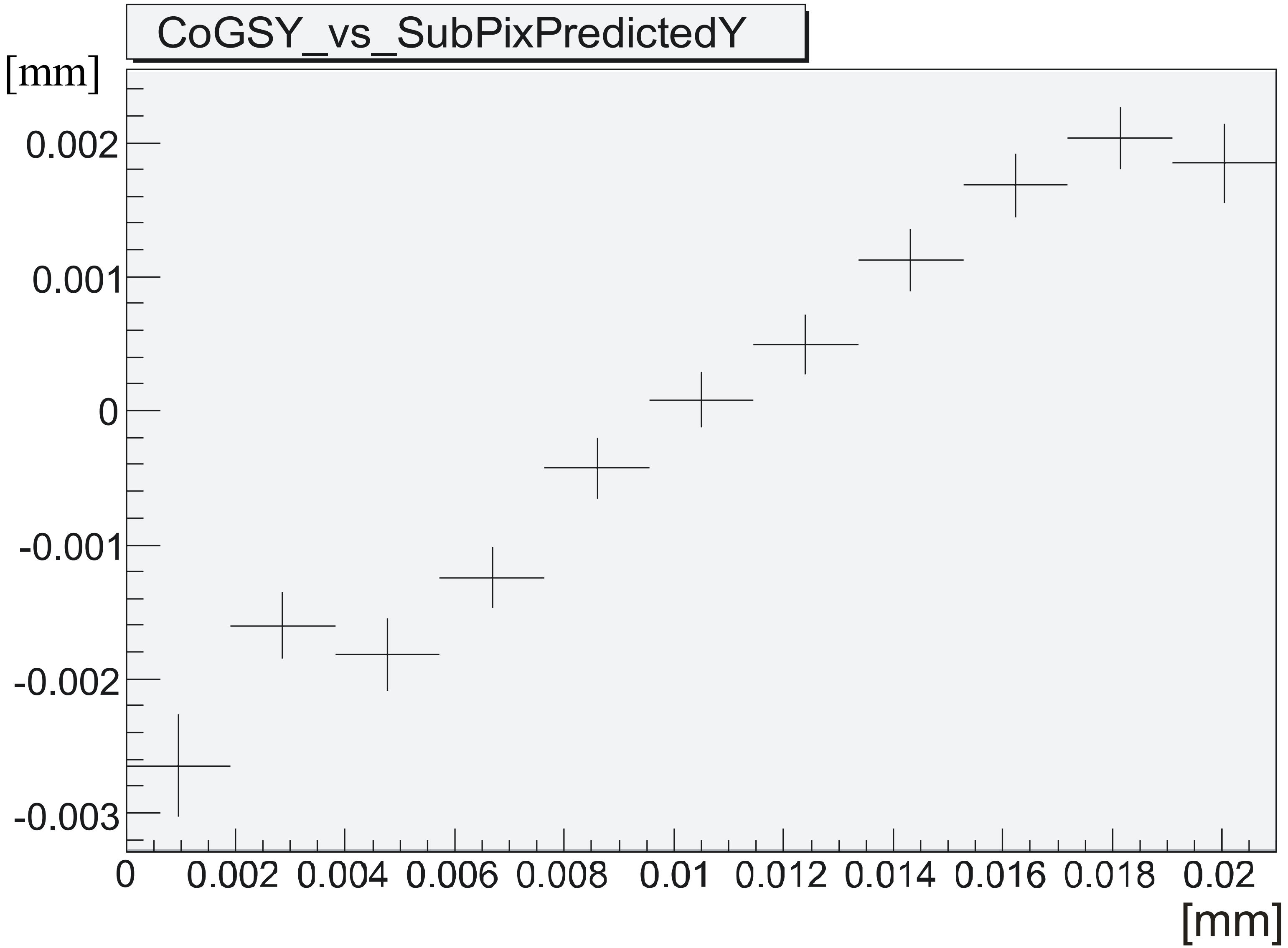

x (DUT)
y (DUT)
local FoR, [1,...,n]
Hitmaker
pixNum*pitch
y (global)
global FoR, [m]
x (global)
Alignment
y (global)
global FoR, [m]
x (global)

In-pixel measurements – back-propagation



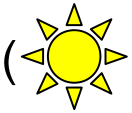
'back-propagation'
of fitted hits
→ hit pixels' **numbers** and **sub-pixel** hit location

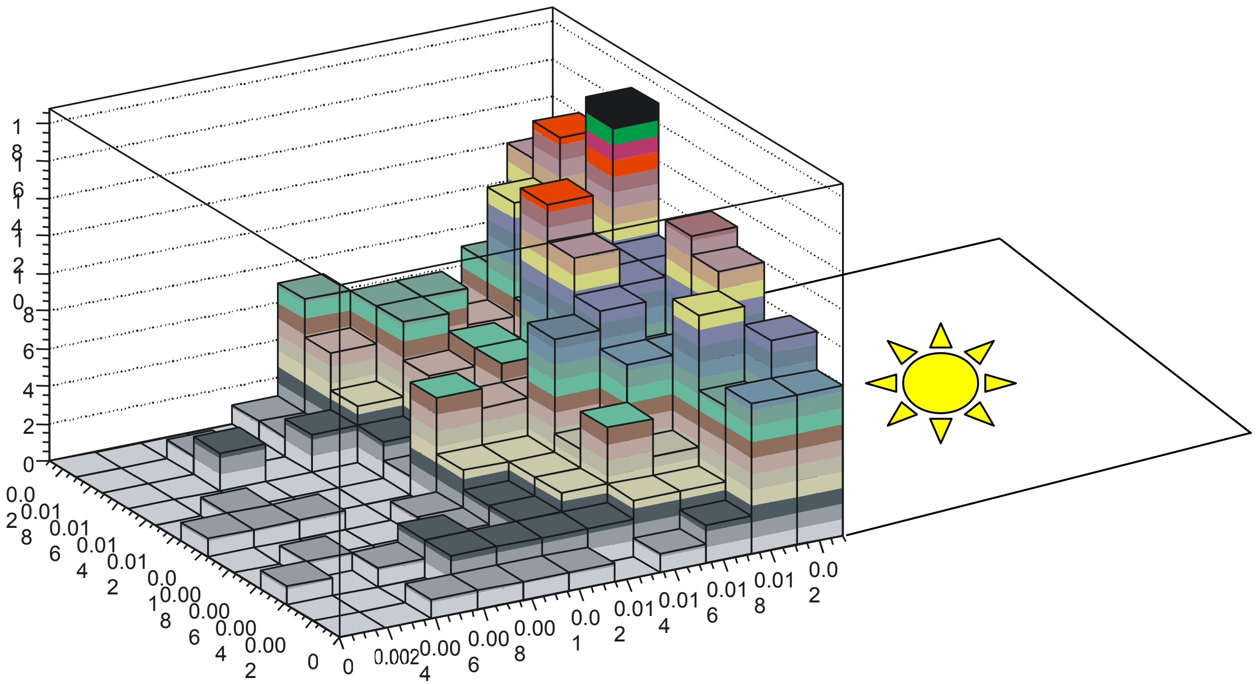
Y COG Shift by DUT vs in-pixel hit coordinate Y



(This plot without ETA. But wit ETA not much better)

Investigate Matched Hits with large Residuals!

Measured hit () appears to the right of fitted (predicted) hit:



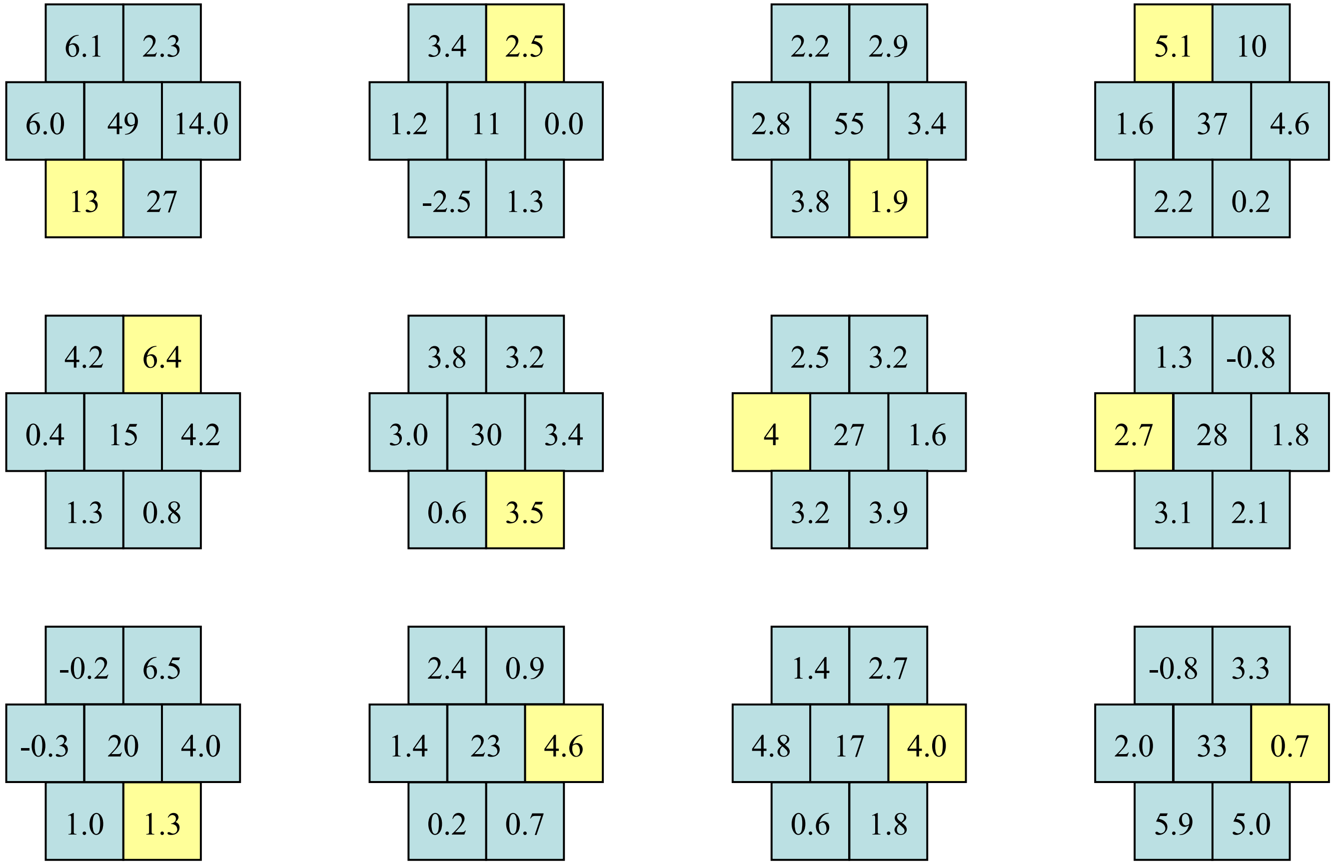
Where was the predicted-hit-pixel hit?

Very often near the corresponding pixel boundary…

(at least that is what the telescope predicts)

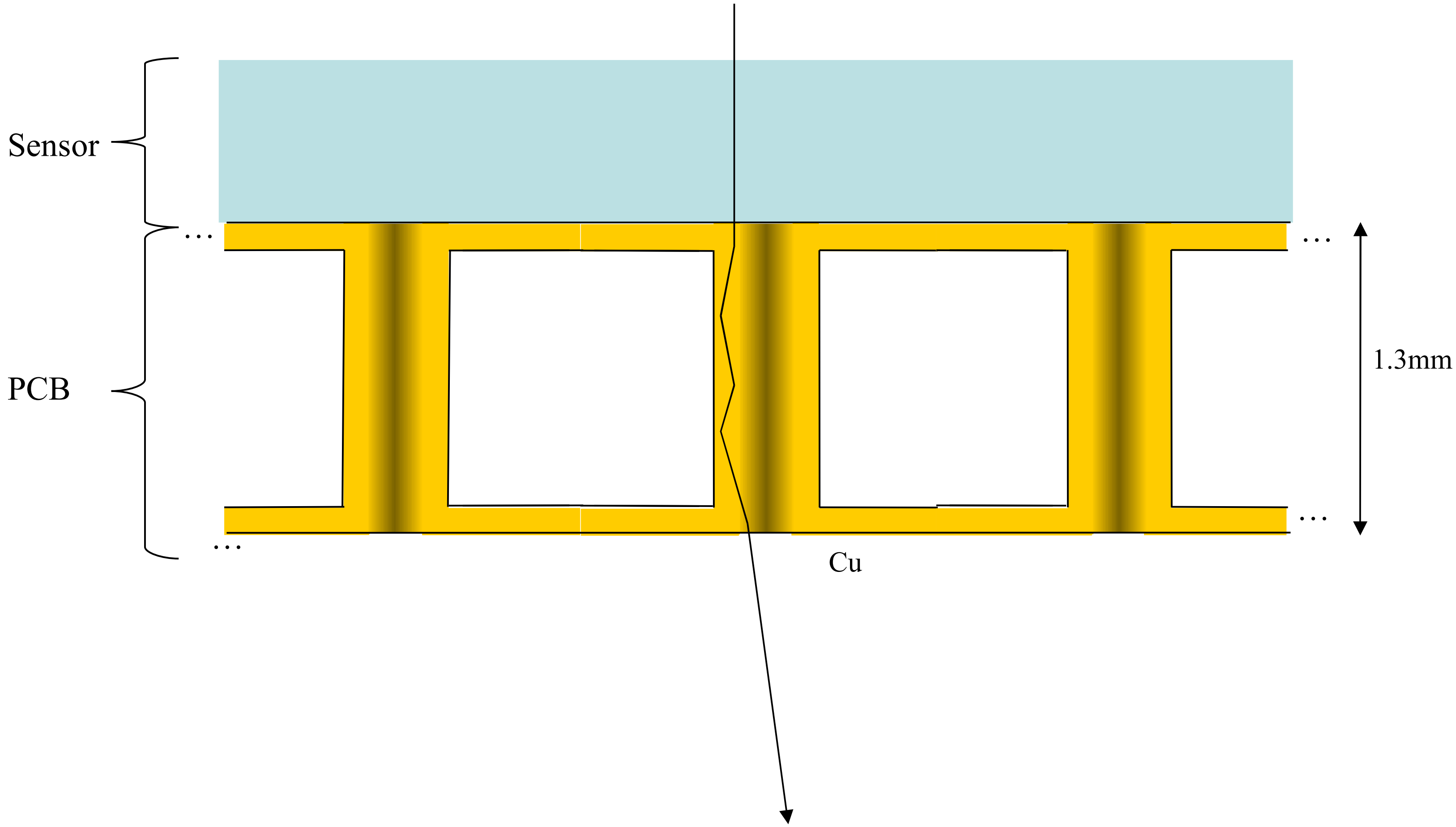
What do WE see in that case though??

Seed pixel – fitted point mismatch (clusters and their pixel S/N)



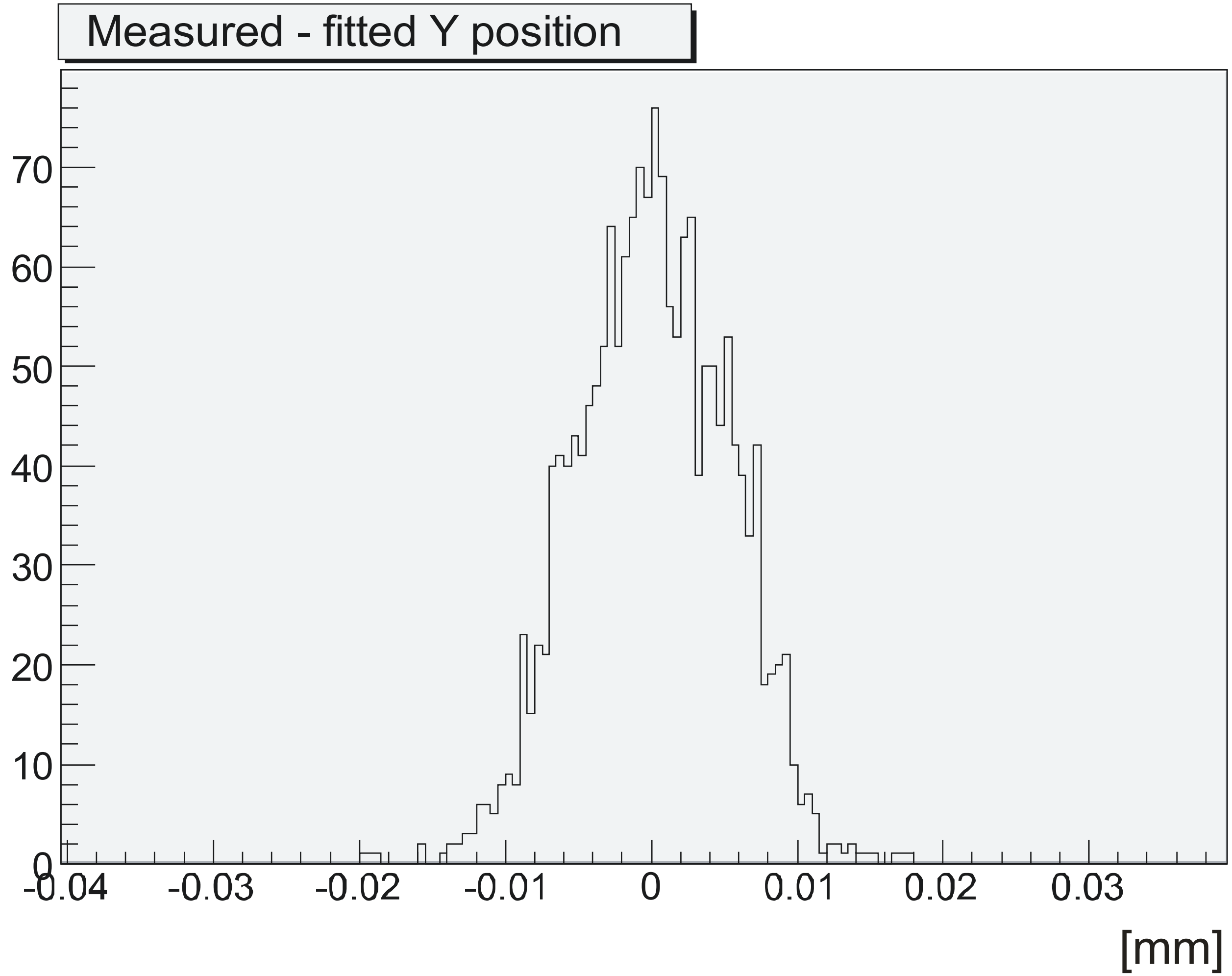
- In case of mismatching hit-pixel: Amplitude is always very high.
  How could we have predicted wrong? Electronic noise is a lot less!
- Did the prediction go wrong?? -> Slower particles – higher signal – more MS???

- The mismatch could to be caused by mechanical instability? (DESY: vibrations? CERN xy-table moved over time?)
- OR: Multiple scattering on PCB vias?? (Are there slower particles, which are more prone to that?)



Spatial resolution when fitted point and seed pixel match

- Assume there really is an error ...
  And those matches with [fitted pixel != measured pixel] could be disregarded…
- Residual could be reduced to nearly sigma 4 μm!
  (Even though in-pixel there is still an error of +/- 21um possible!)



Summary

[all results at the same cluster S/N cut and fitter residual cut]

Efficiency:	82% (does not increase even when going to high-noise clusters!)
Spatial resolution:	
Sigma residual X:	8.6 µm
Sigma residual Y:	7.3 µm
Purity:	72%

Thank you!

BACKUP SLIDES

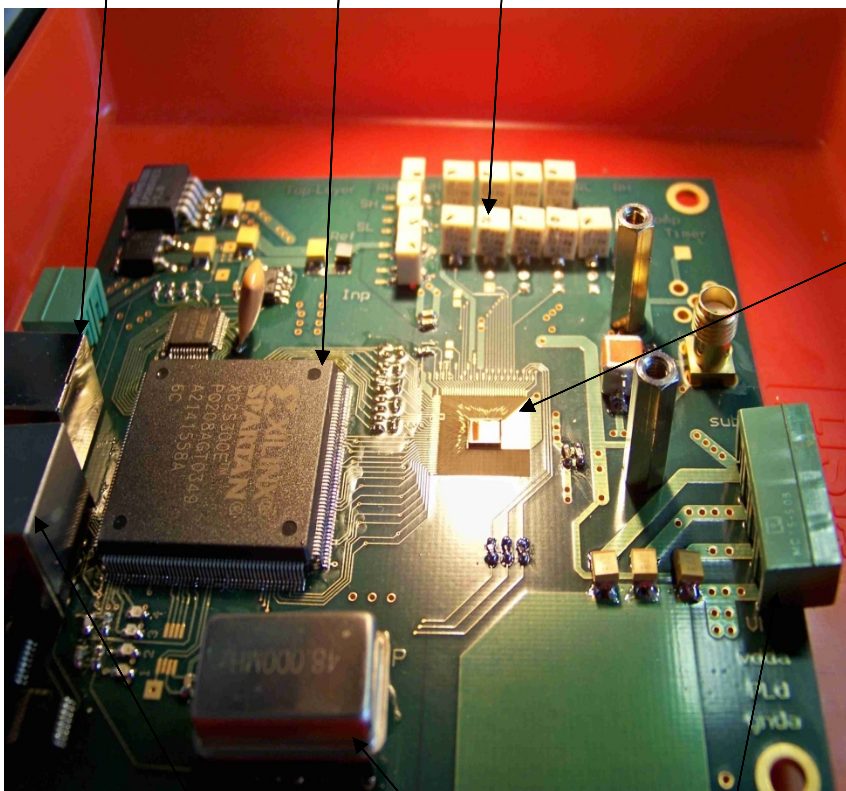
Results

- Efficiency: 82%
- Purity: 72%
- Sigma X-residual 8.6 µm
- Sigma Y-residual 7.3 µm
- S/N ratio seed: 12
- S/N ratio cluster (6 pixels): 10

It's this guy's fault...

(Warning! Ugly picture ahead)

It's this guy's fault...


USB
FPGA
Bias voltages
Trigger
100MHz
Power

Chip Overview 1

- A large monolithic particle pixel-detector implemented as **system on a chip** in a **high-voltage 0.35 µm CMOS technology** will be presented
- The detector uses high-voltage **n-well/p-substrate diodes** as pixel-sensors
- The diodes can be **reversely biased with up to 60 V**
- In this way **depleted zones of about 10 µm thickness are formed**, where the signal charges can be collected by **drift**
- Due to fast charge collection in the strong electric-field zones, a higher **radiation tolerance** of the sensor is expected than in the case of the standard MAPS detectors
- The readout is based on a source follower with one select- and *two* reset-transistors
- Due to embedding of the pixel-readout electronics inside the collecting electrodes (n-wells) there are no insensitive zones within the pixel matrix

Chip Overview 2

- The detector chip contains a **128x128 matrix** consisting of pixels of **21x21 μm^2 –size**
- The diode voltages of one selected pixel-row are received at the bottom of the matrix by 128 switched-capacitor amplifiers
- After amplification, the signal voltages are processed by **128 8-bit single-slope ADCs** also placed **on the chip**
- The readout electronics are designed to allow the readout of the **full matrix in nearly 50 μs**
- Only one selected pixel-row conducts DC current and has the **power consumption** of about **8 mW**
- The **power consumption** of the bottom-of-column readout circuits, including 128 switched-capacitor amplifiers and 128 ADCs, is **42mW**
- All analogue parts of the chip are implemented using **radiation-hard layout** techniques
- The pixel-electronics itself are implemented **using only PMOS transistors** that are intrinsically radiation-tolerant