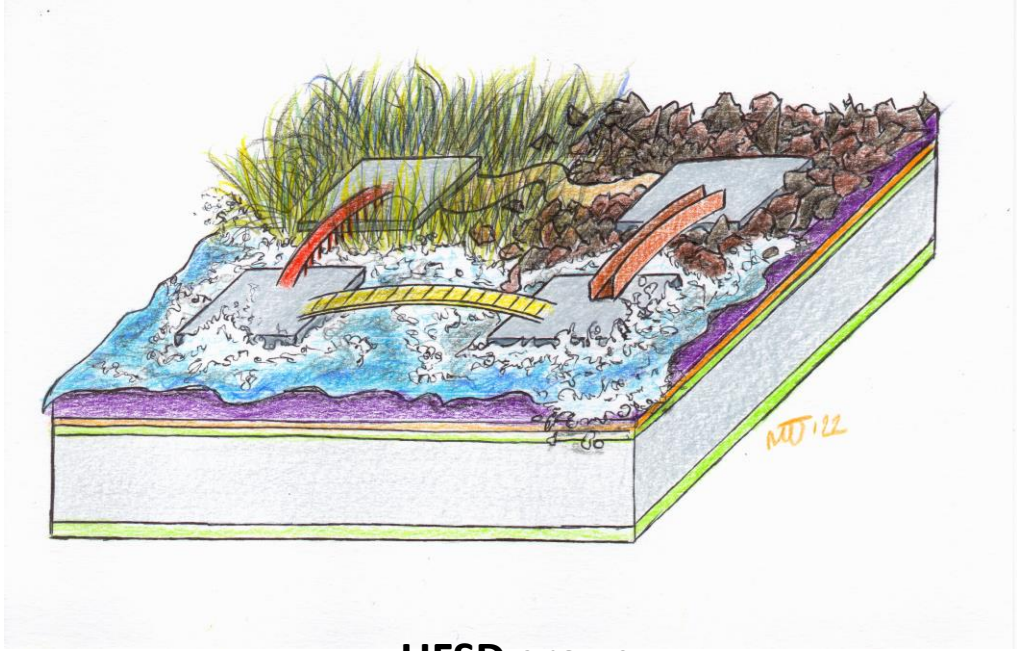
Measurements of the RSD performance at a test beam (DESY)

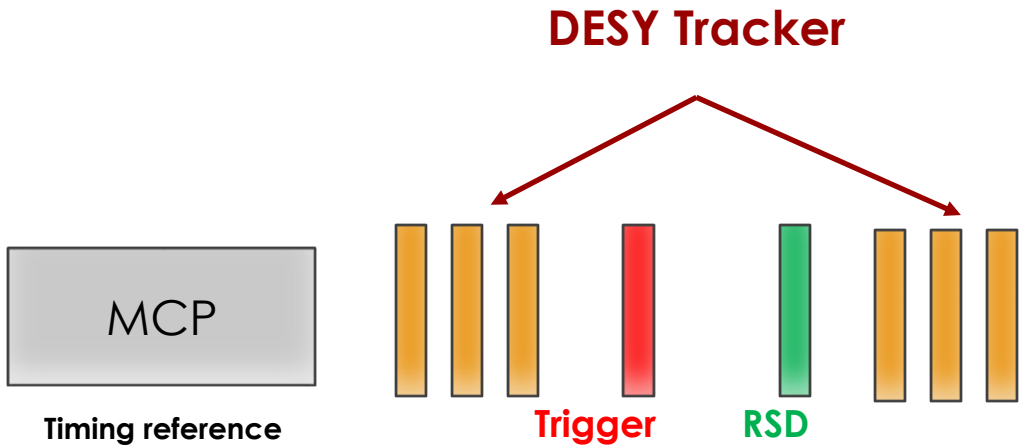


UFSD group

R. Arcidiacono; G. Borghi; M. Boscardin; **N. Cartiglia**; M. Centis Vignali; G-F Dalla Betta; M. Ferrero; F. Ficorella; L. Lanteri; L. Menzio; R. Mulargia; G. Paternoster; L. Pancheri; F. Siviero; V. Sola.

This talk is the sequel to the talk given by Roberta in Sevilla.
In her talk, you will find additional details on RSD and DC-RSD

RSD DESY test beam



Read-out scheme:

- FNAL Board +16 ch CAEN Digitizer
- FNAL Board + Oscilloscope

Goals of the test:

- Verify the performance of RSD
- Study basic properties of the DC-RSD design

DESY and EUROLabs support

The test beam facility at DESY is well organized.

The beam efficiency is ~ 100%, the support staff very present

Beam control is very easy, one user for each beam line

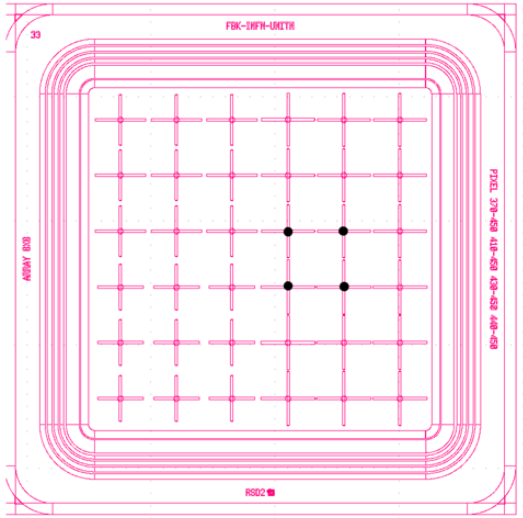
The research leading to these results has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement no. 101057511.

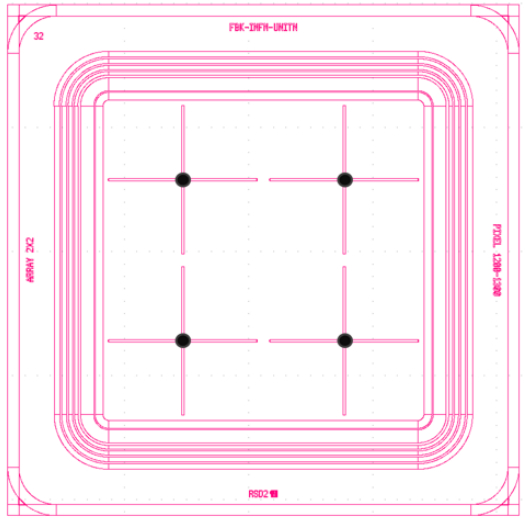
Sensors presented in this talk

FBK-RSD2, two geometries

4 electrodes, 1300 x 1300 um^2

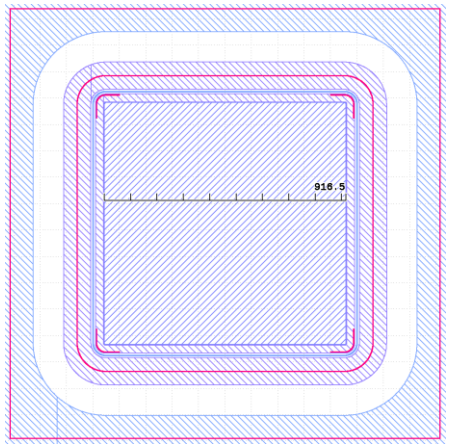
36 electrodes, 450 x 450 um^2



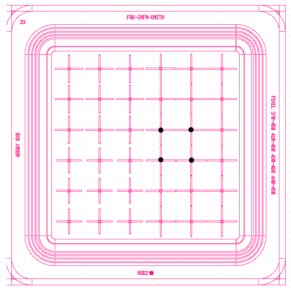


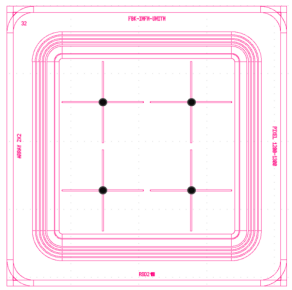
FBK-DC0 (in the ExFlu production)

4 electrodes, 900 x 900 um^2



Study of RSD2: summary of past results (TCT)

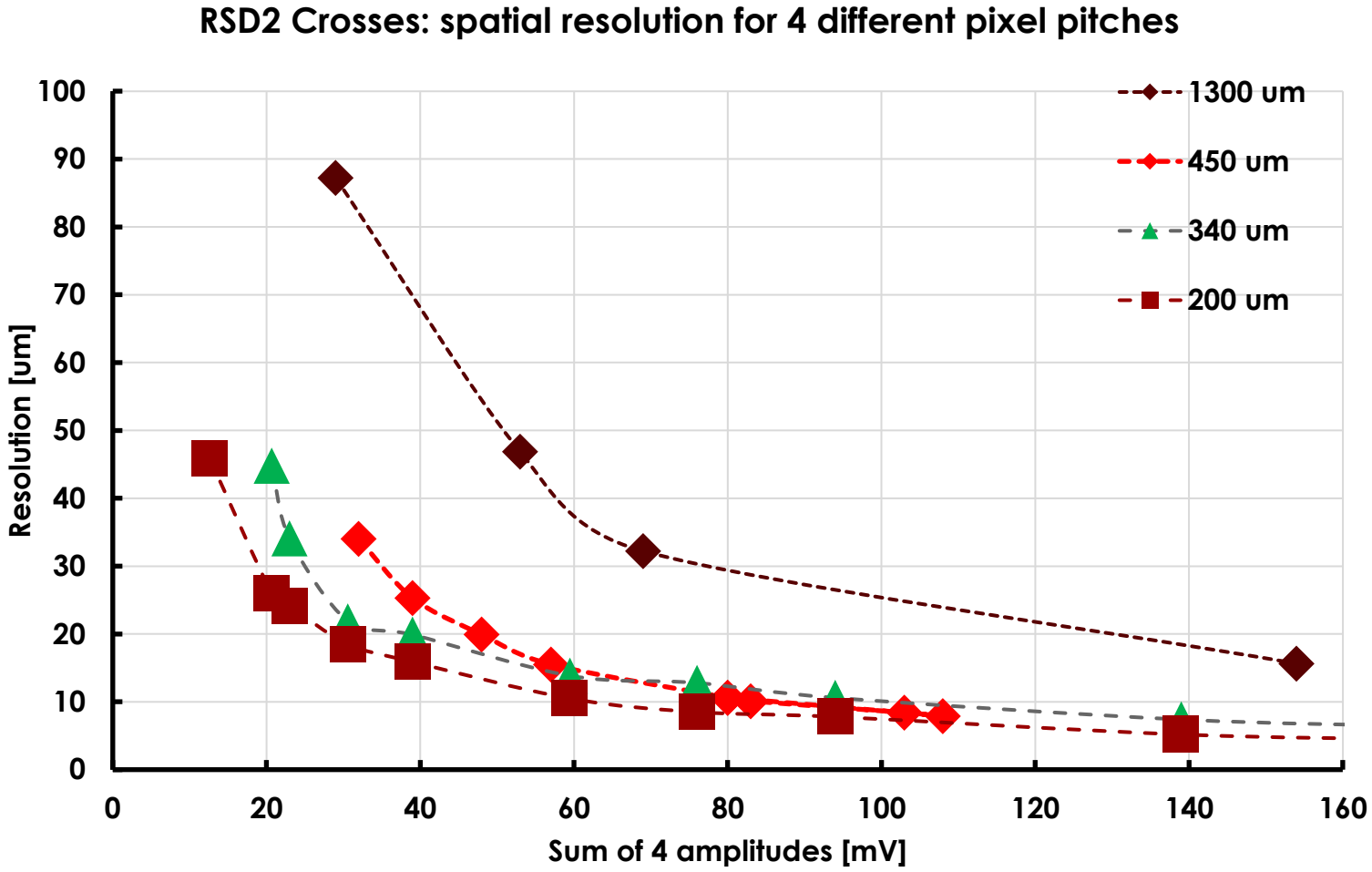




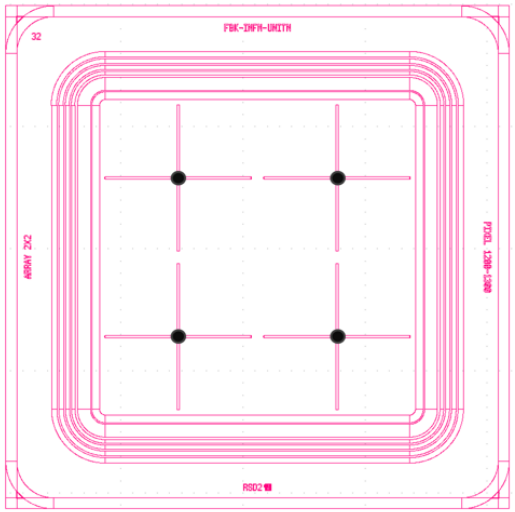
$$x_i = x_{center} + k_x \frac{pitch}{2} * \frac{Q_3 + Q_4 - (Q_1 + Q_2)}{Q_{tot}}$$

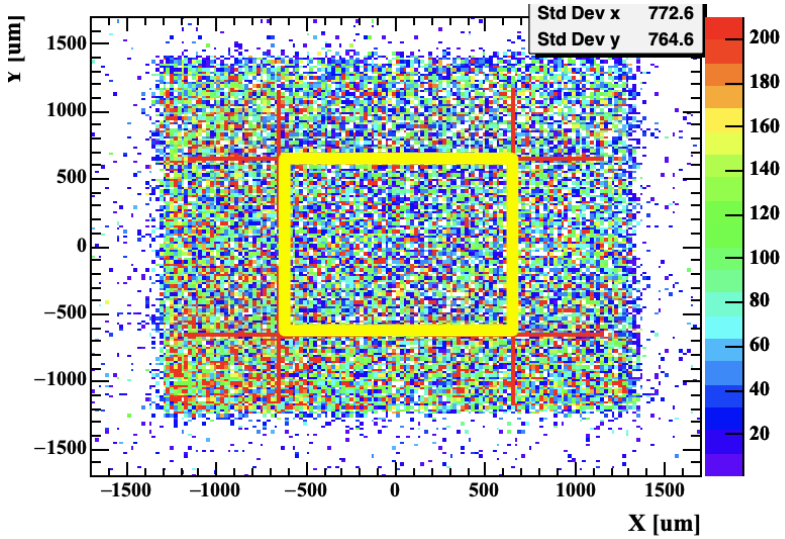
$$y_i = y_{center} + k_y \frac{pitch}{2} * \frac{Q_1 + Q_3 - (Q_2 + Q_4)}{Q_{tot}}$$

- The hit position is obtained using charge imbalance
- The resolution is defined as the difference between the laser and the reconstructed position



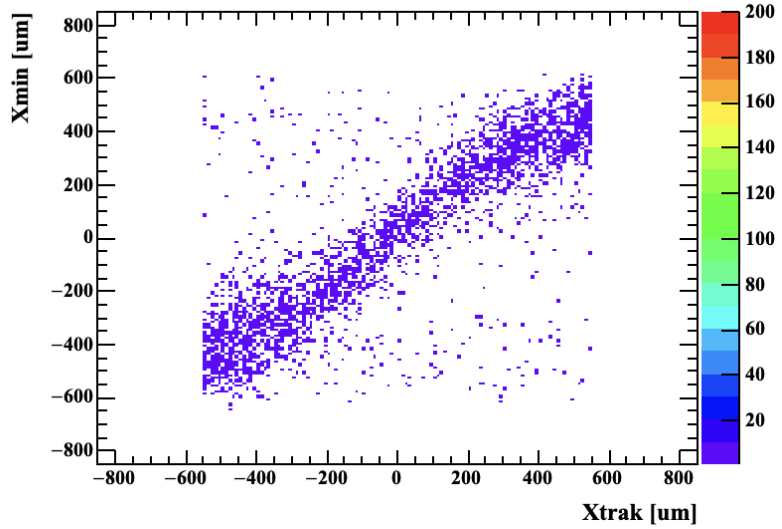
RSD2 Single pixel: 1.3 x 1.3 mm^2





Hits position (from DESY tracker) on the RSD

- An event is reconstructed if the track points to the **inside of the pixel**

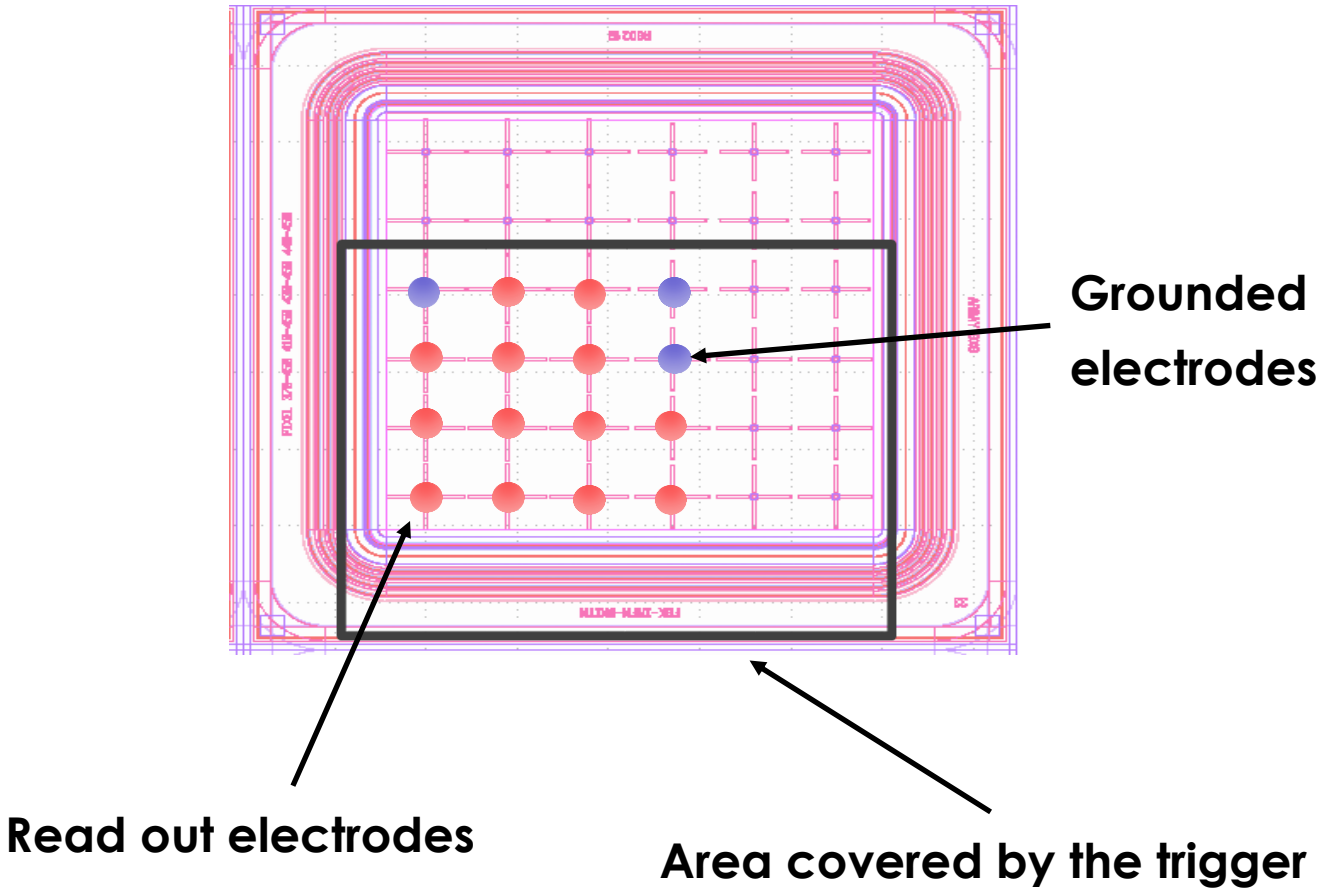


Correlation between x_tracker and x_RSD

RSD2 Multi-pixels: 450 x 450 um^2

Channels read with the 16-ch digitizer:

- 13 electrodes
- DC Contact
- Trigger DC signal
- MCP



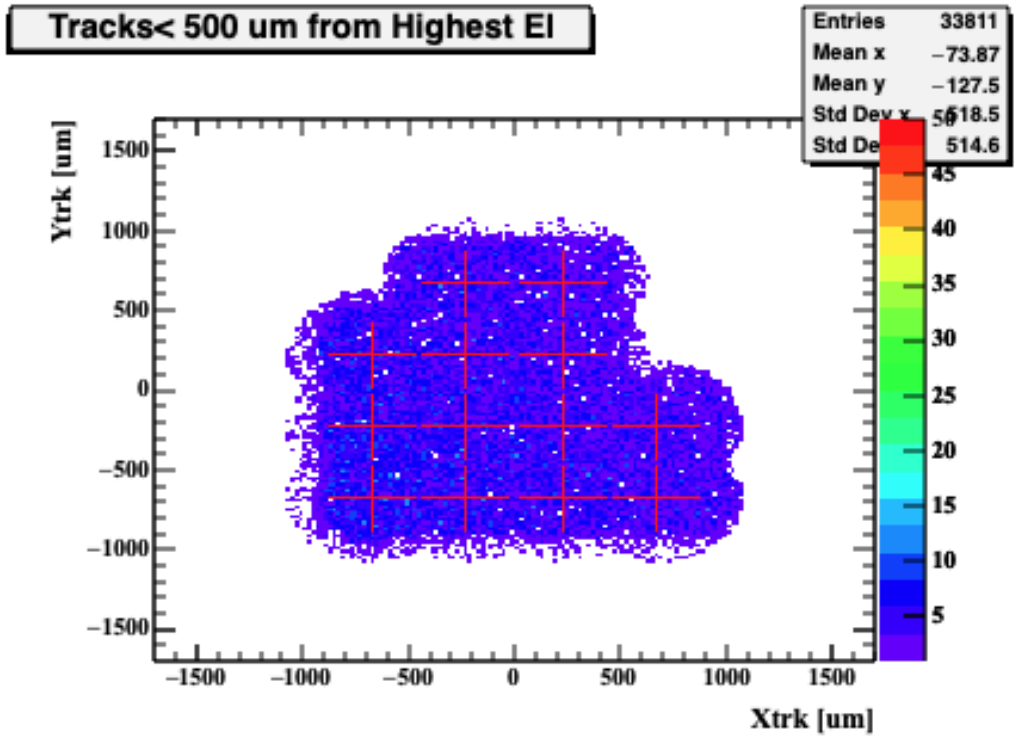
A note on data taking

We had problems in merging RSD & DESY tracker data.

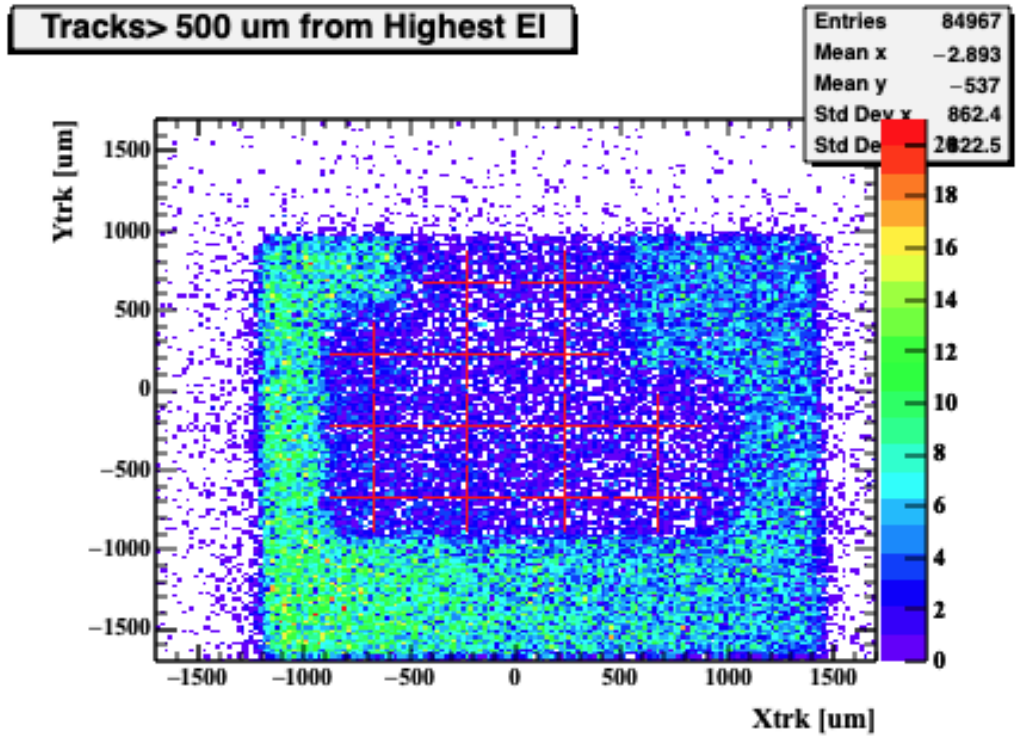
10% of the tracks point to the sensor, but the sensor has no signal

Event selection:

- A track pointing to the sensor
- The highest signal should be near the track: | **tracker – HighestEl**|**<500 um**

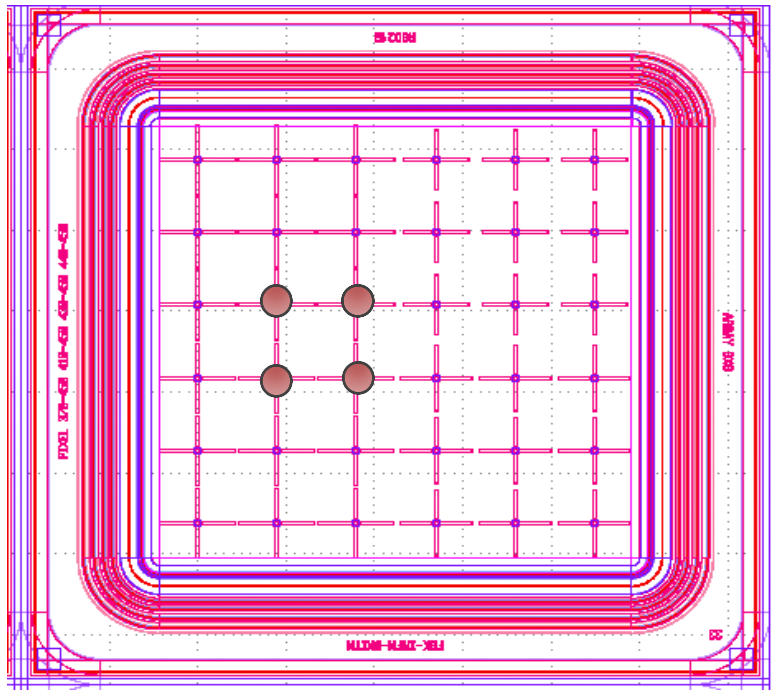


Synchronous events

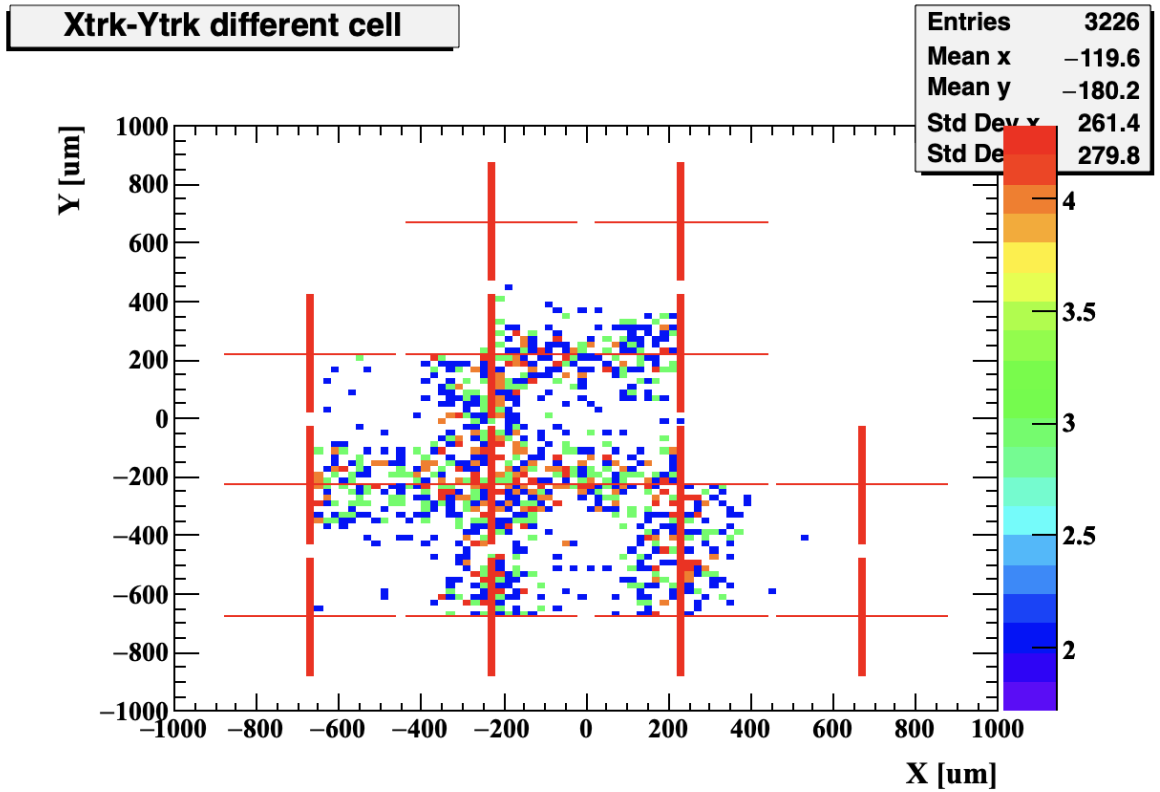


Non- Synchronous events

First reconstruction method: highest cell



- **Select the highest cell.**
- Compute the position using charge imbalance

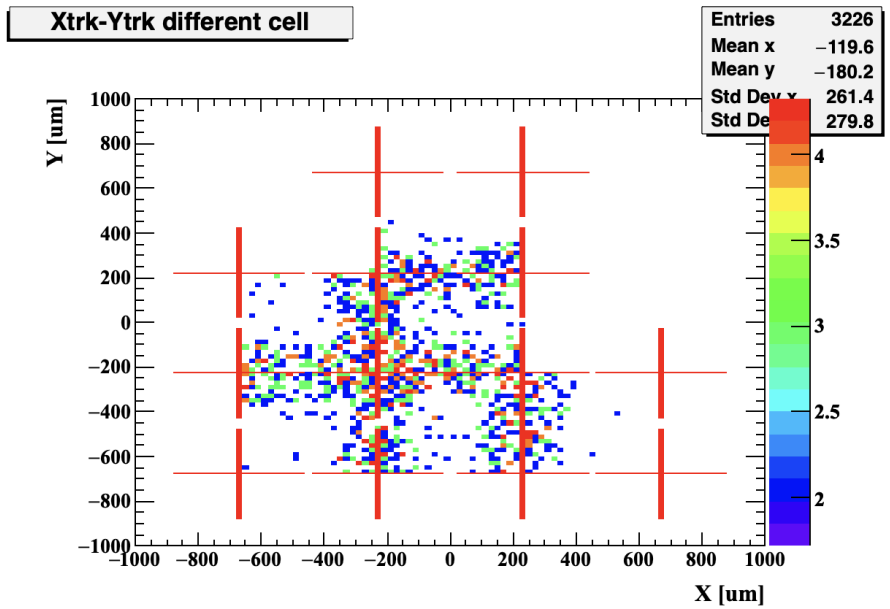


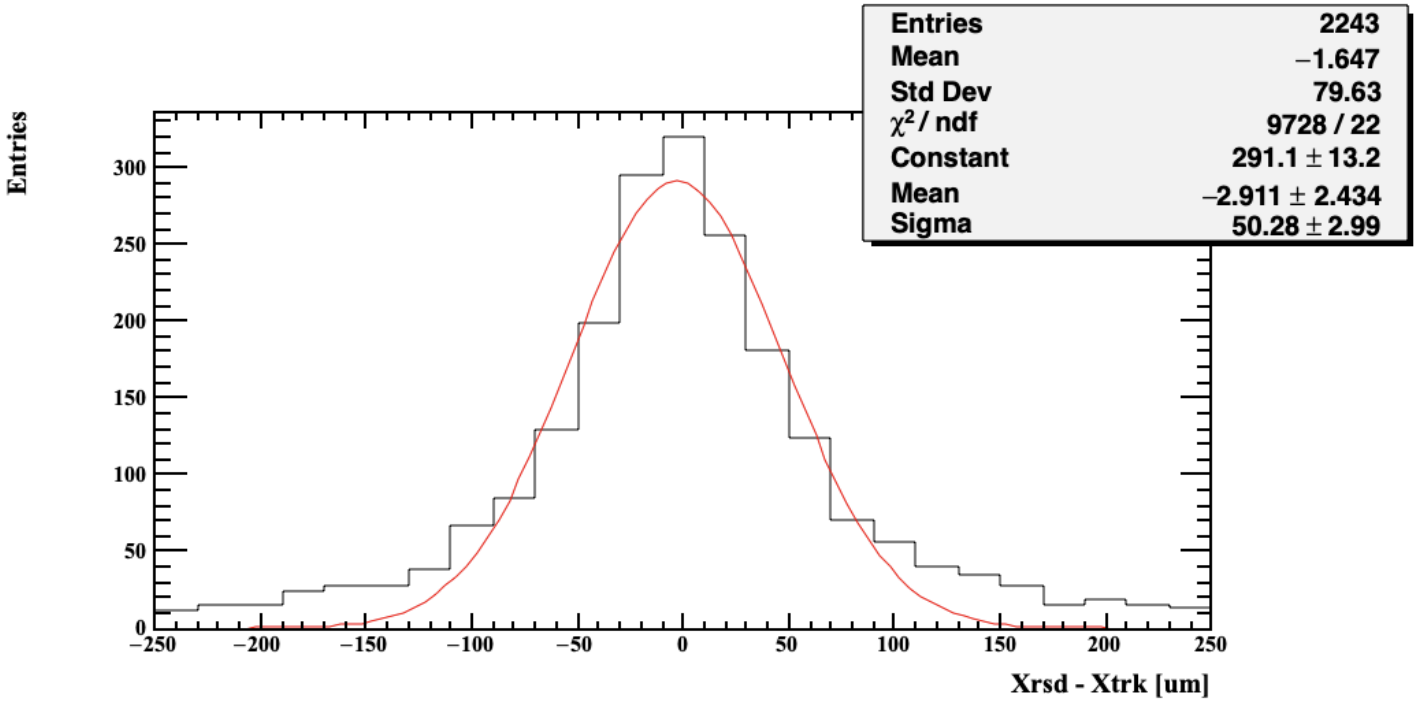
Sometimes, the cell with the highest ACSum is not the correct choice. This is due to electronic noise

The hit position (according to the tracker) is in the nearby cell

This happens ~ 15% of the times

Consequence of the wrong pixel choice

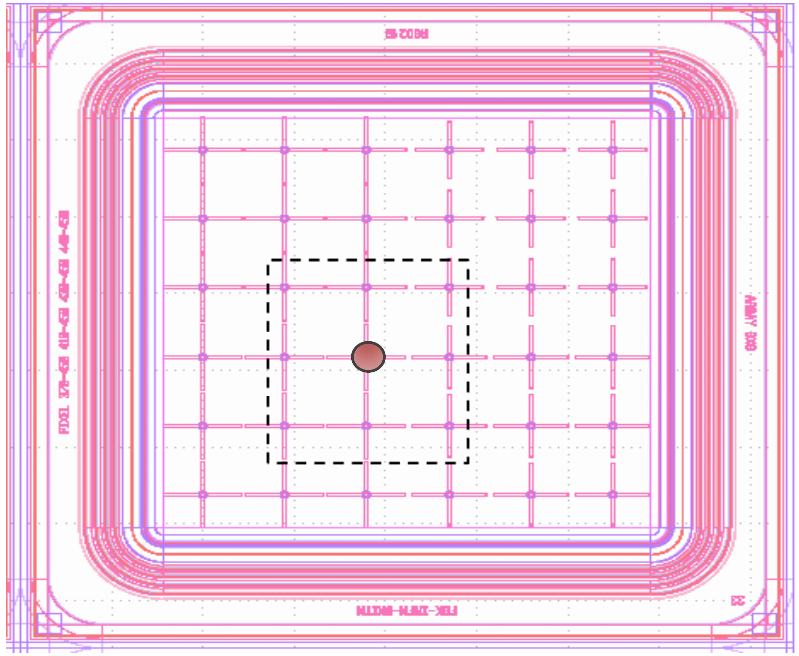




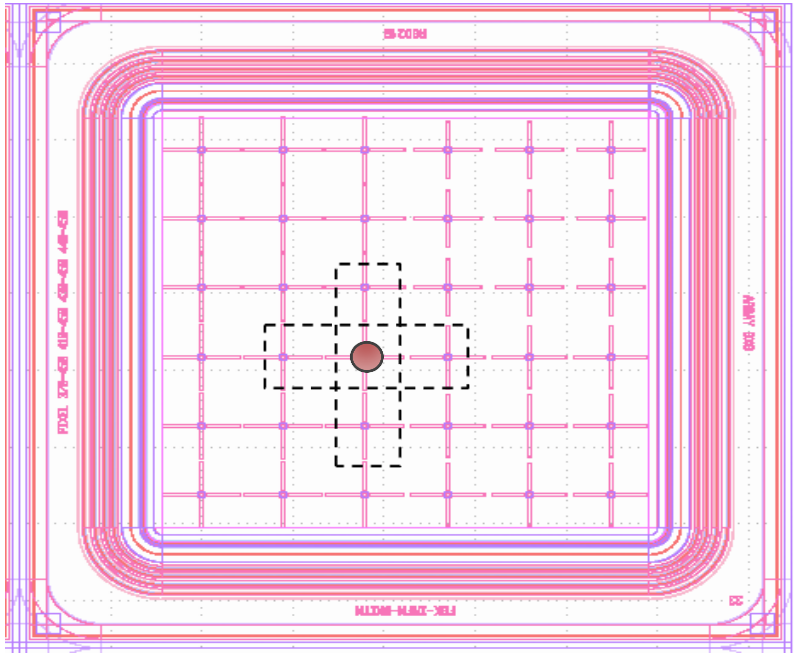
- Long tails in the resolution
- The resolution is not well described by "sigma"

Second reconstruction method: highest electrode
(as in a calorimeter)

Select the highest electrode



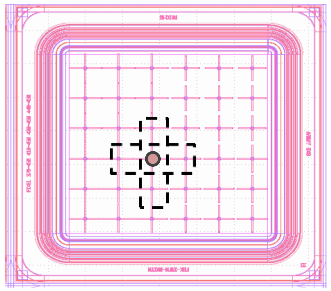
Signal-weighted centroid of
9 electrodes



Signal-weighted centroid of
5 electrodes

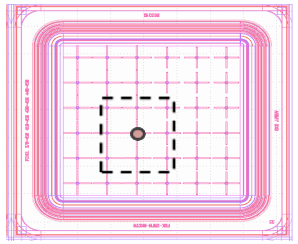
This method avoids wrong cell assignment as the definition of the highest electrode is much less problematic than the highest cell

Highest electrode



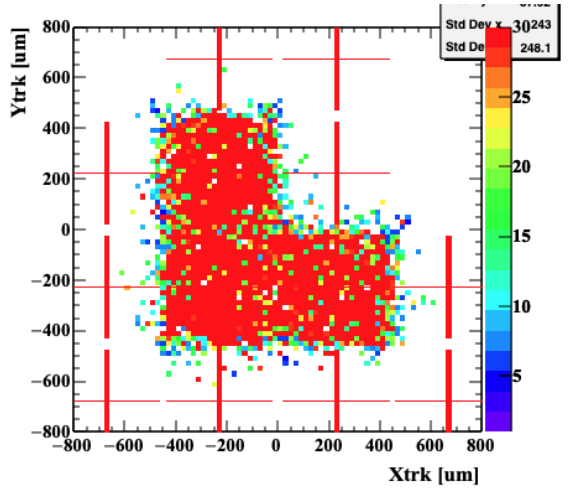
Centroid using crosses:

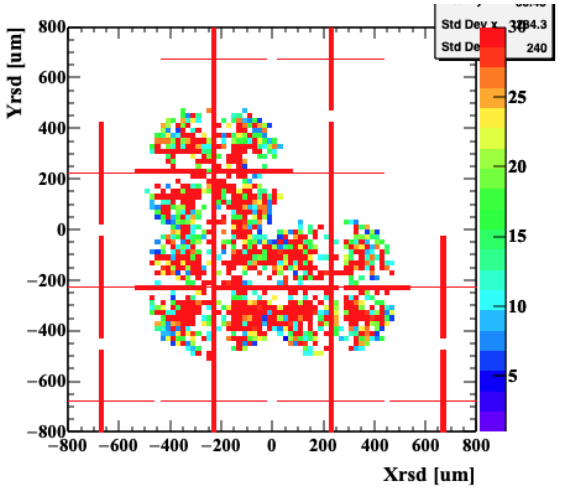
σ = 60.75 um

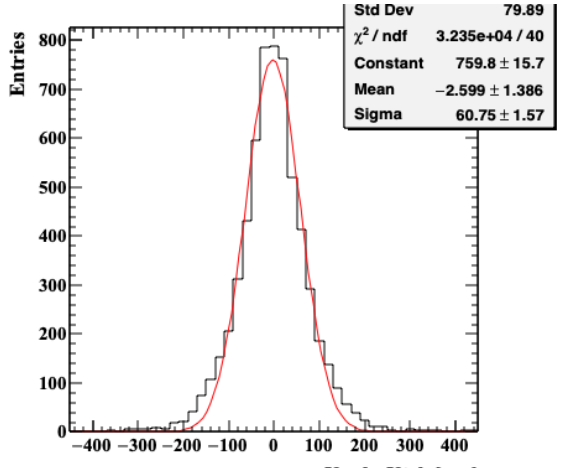


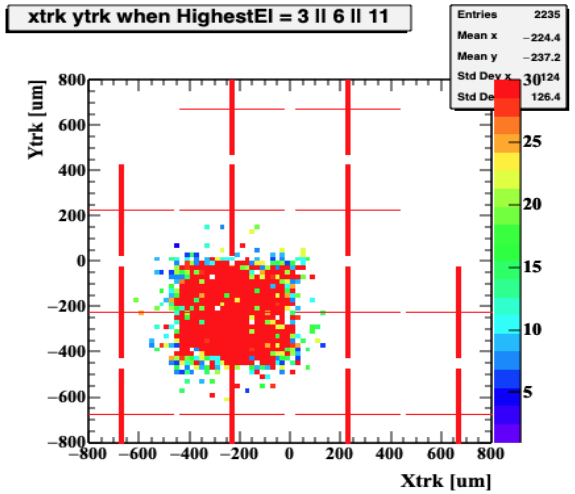
Centroid using square

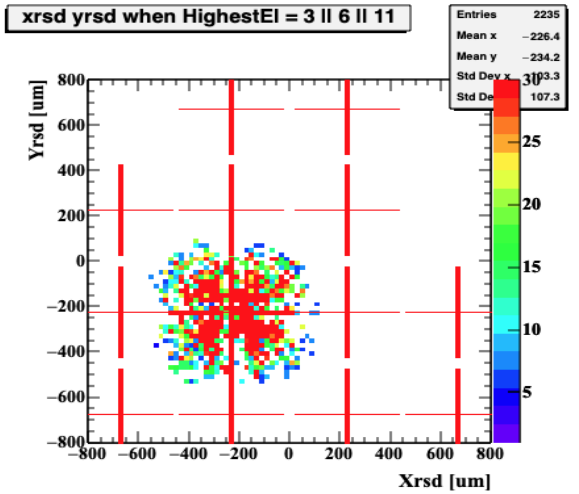
σ = 66.75 um

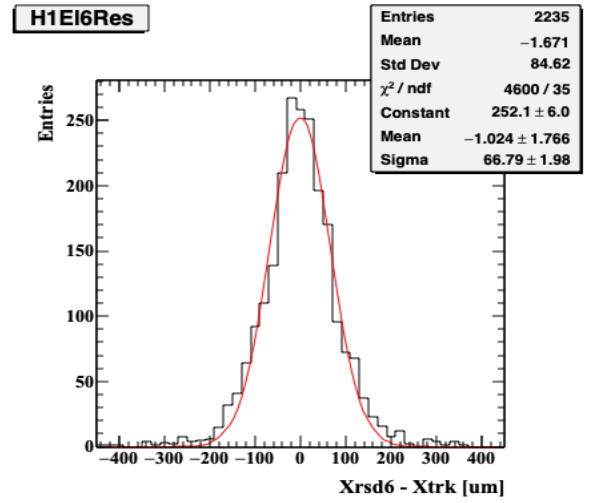






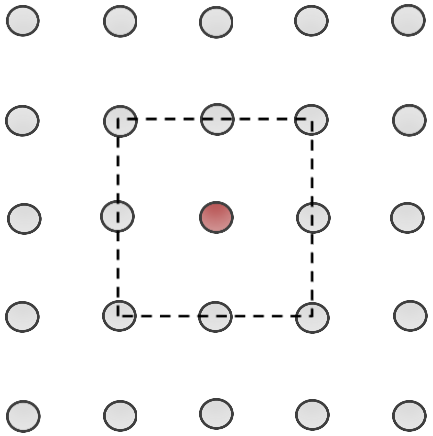




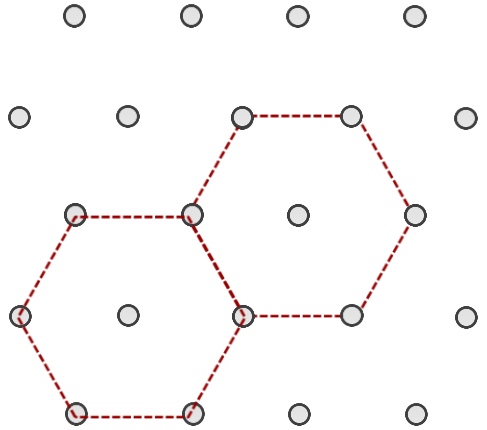


Very small tails in the resolution

Lesson learnt



Squared matrix

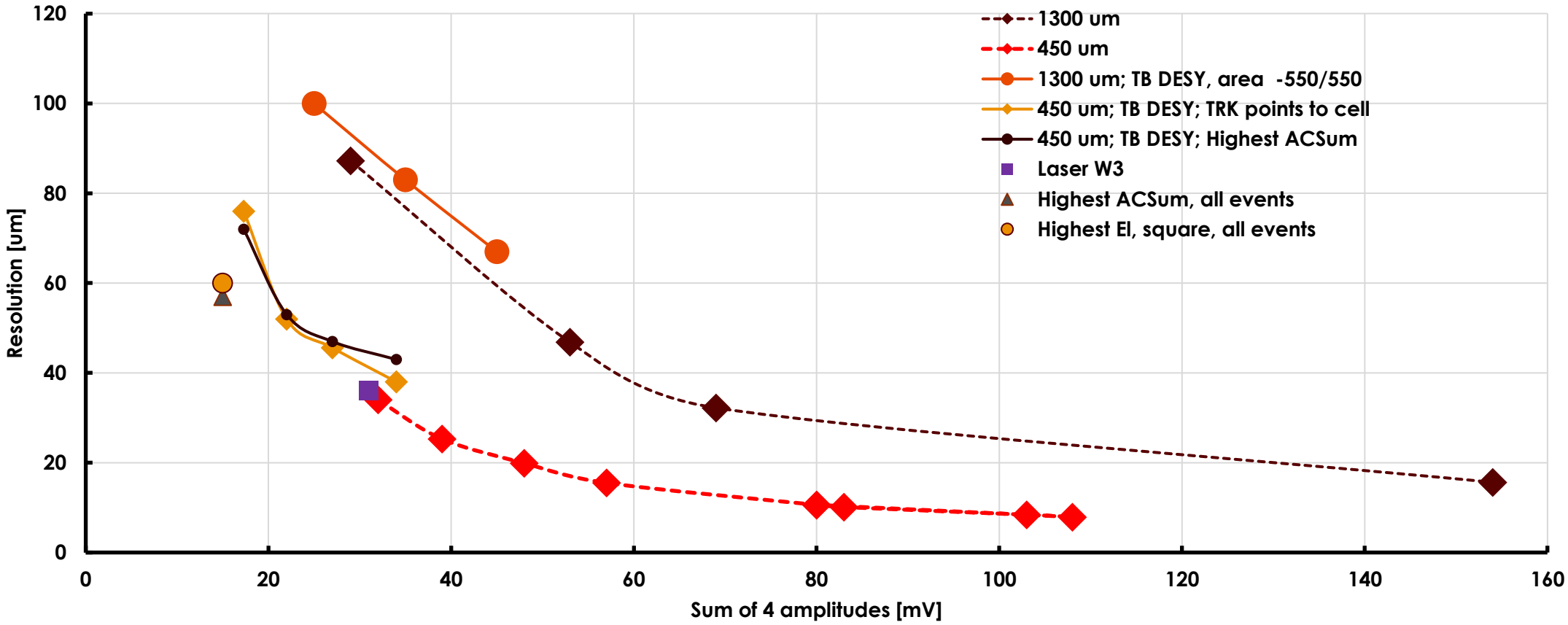


Hexagonal matrix

The “highest electrode” method looks very promising

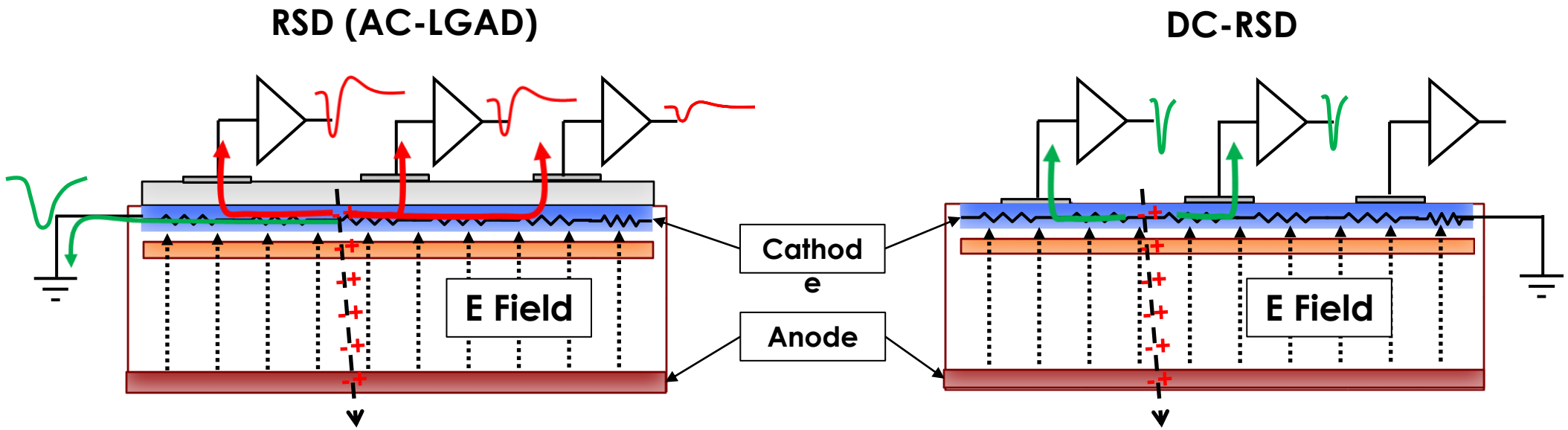
=> hexagonal matrix is an attractive design

Summary of RSD studies



- The resolution is consistent with that of the laser studies (albeit at smaller ACSum)
- Integrated spatial resolutions for Highest ACSum or HighestEI are similar.
- Signals are small! (issue connected to the latest batch of read-out boards)

RSD vs DC-RSD



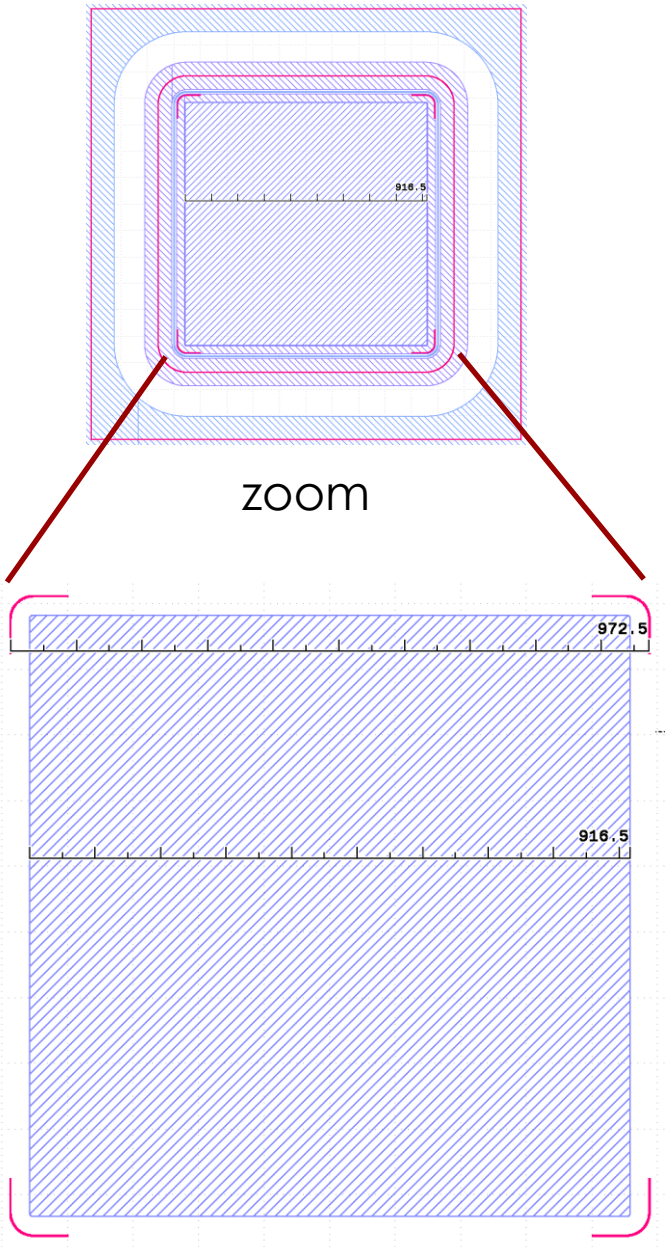
This design has been manufactured in several productions by FBK, BNL, and HPK

This design is presently under development by FBK
The main advantage of the DC-RSD design is the ability to control the signal spread

DC0 Testbeam

DC0 (prototype for DC-RSD studies)

- 4 DC contacts to the same n+ layer
  - 4 amplifiers connected to the same n+ layer
- Gain layer 916.5 um
- Distance between contacts: 972.5 um
- Sheet resistivity as for standard LGAD (not as RSD)



Test beam:

- Electron beam, 3.6 GeV
- ~270k events taken with the oscilloscope and DESY tracker
- Events collected with the MCP trigger
- MCP trigger ~ 50 mm^2
- Sensor ~ 0.8 mm^2

  ==>About 2% of good events

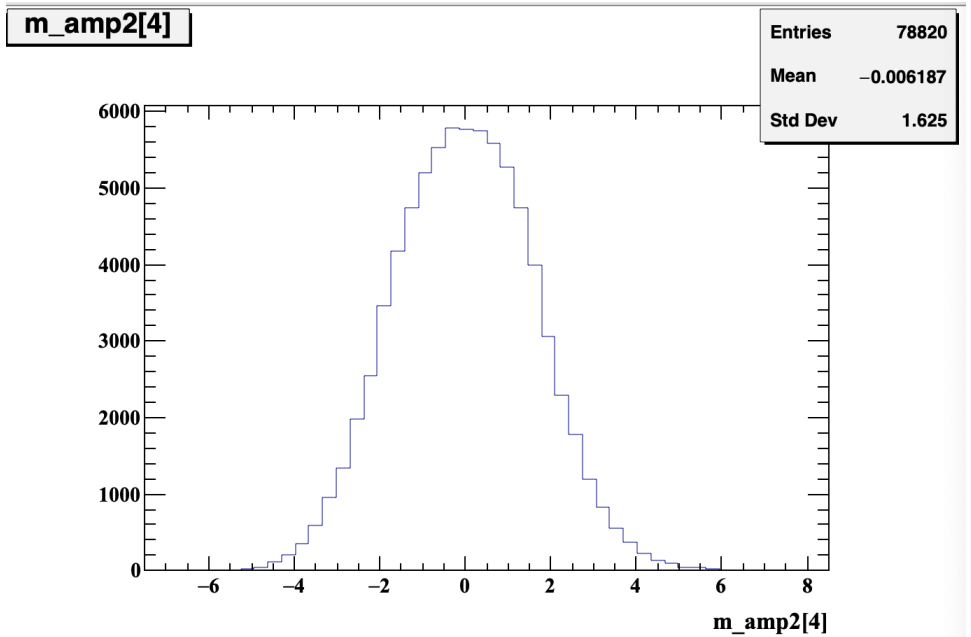
Common noise of the amplifiers

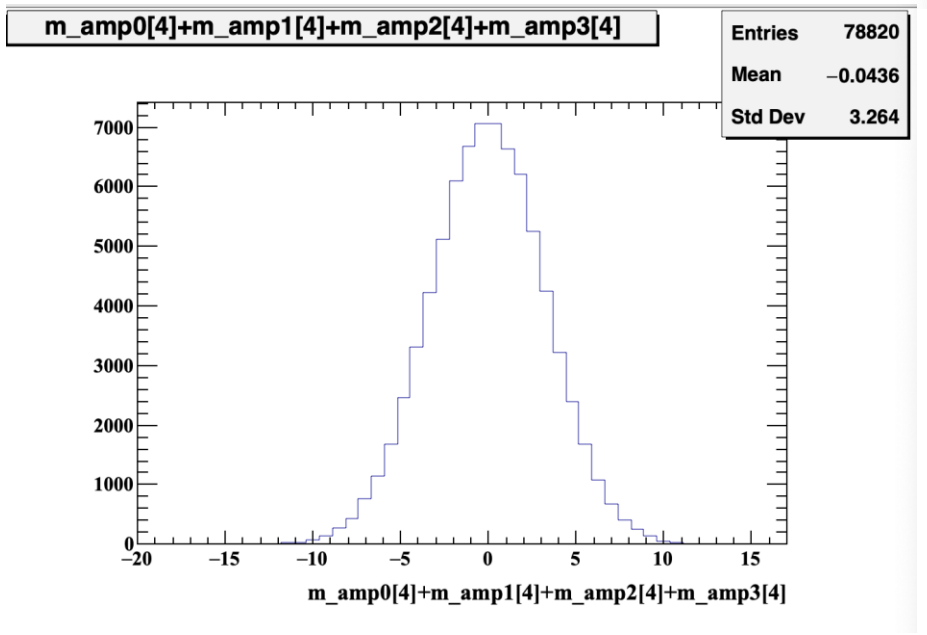
Noise:

the noise of one amplifier is = 1.62 mV

the noise of 4 amplifiers is = 3.26 mV

==> the noise is uncorrelated



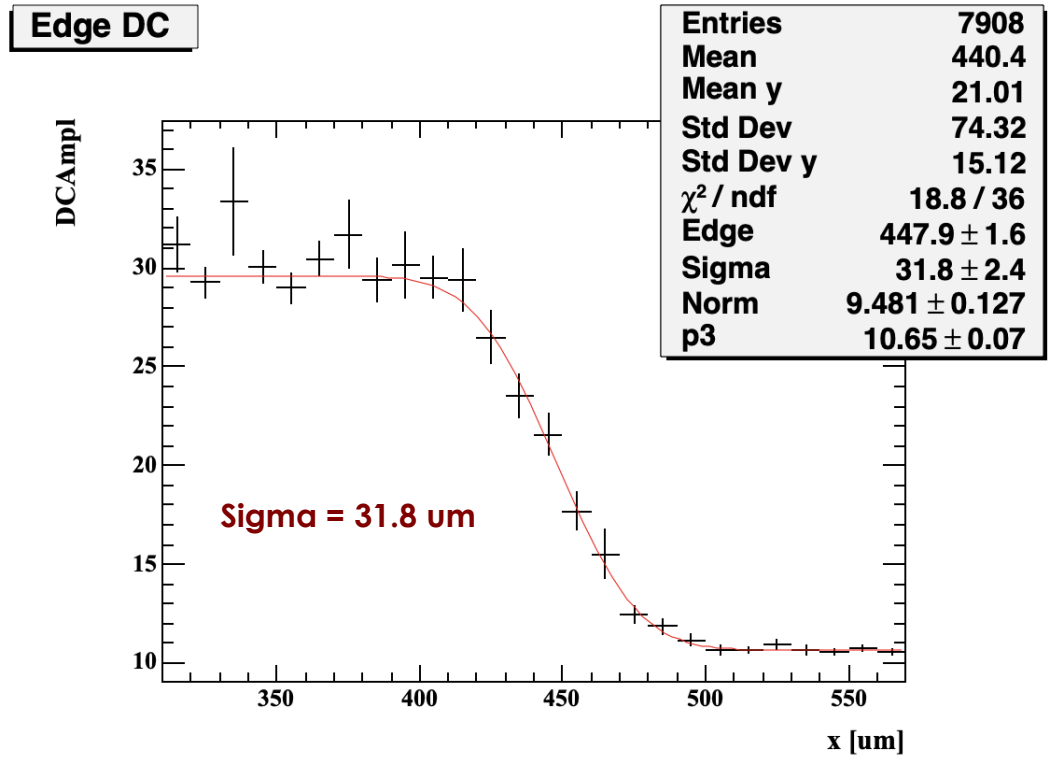


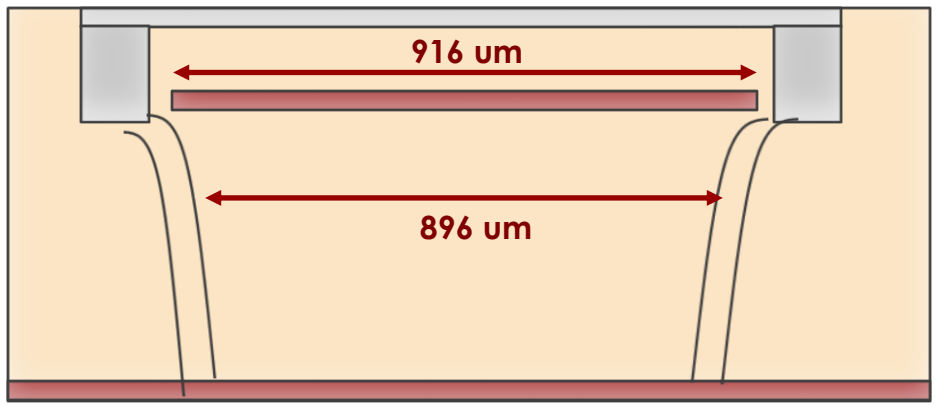
Sensors effective dimension and tracker resolution

Fitting the gain layer edge, it is possible to measure:

- **The effective sensor dimension:**
  - The edge is fitted to about 448 um
  - This is about 10 um less than the geometrical extension of the gain layer
  - This confirms the known results that the n-deep field lines expand beneath the gain implant

- **The tracker resolution:**
  - It is about 32 um.
  - This result changes slightly depending on the cut, from 26-32 um

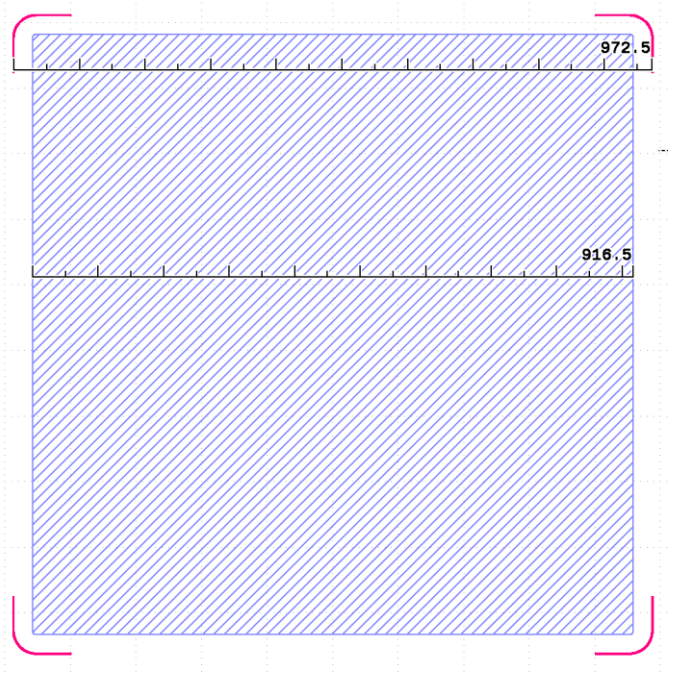




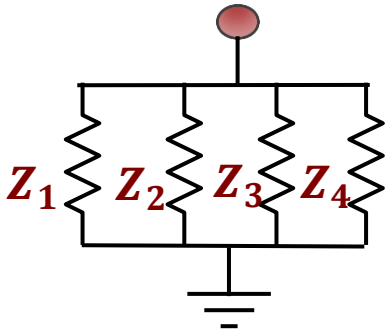
First reconstruction method: charge asymmetry

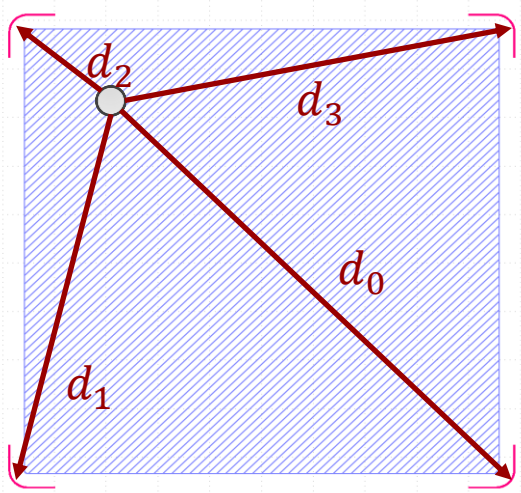
$$x_i = x_{center} + k_x \frac{pitch}{2} * \frac{Q_3 + Q_4 - (Q_1 + Q_2)}{Q_{tot}}$$

$$y_i = y_{center} + k_y \frac{pitch}{2} * \frac{Q_1 + Q_3 - (Q_2 + Q_4)}{Q_{tot}}$$



Second reconstruction method: Analytic Laws





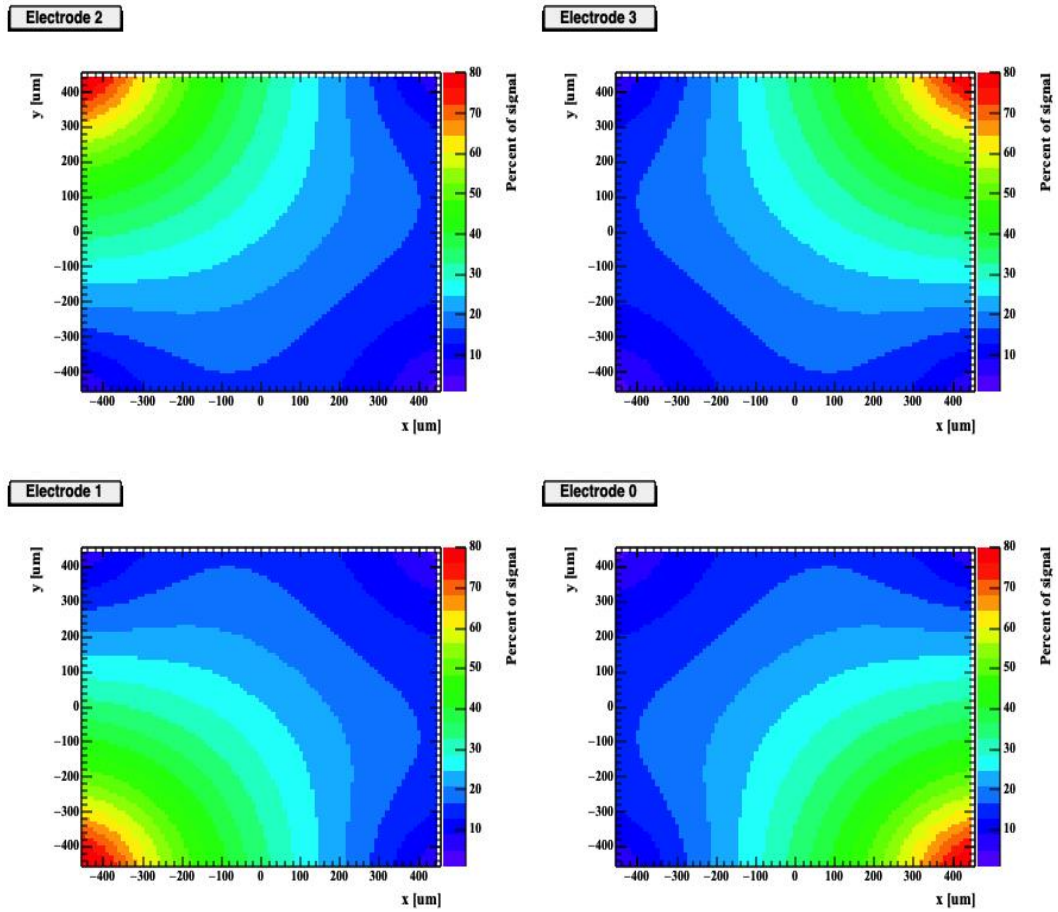
$$S_i(d_i) = \frac{\frac{1}{d_i}}{\sum_1^n \frac{1}{d_j}}$$

$$S_i(\alpha_i, d_i) = \frac{\frac{\alpha_i}{\ln(d_i)}}{\sum_1^n \frac{\alpha_j}{\ln(d_j)}}$$

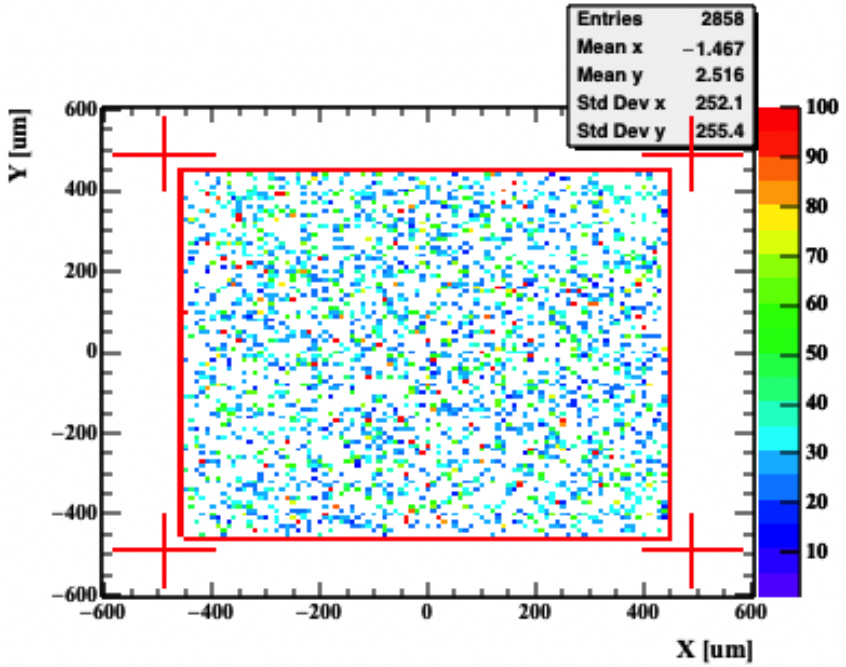
Models for the resistance:

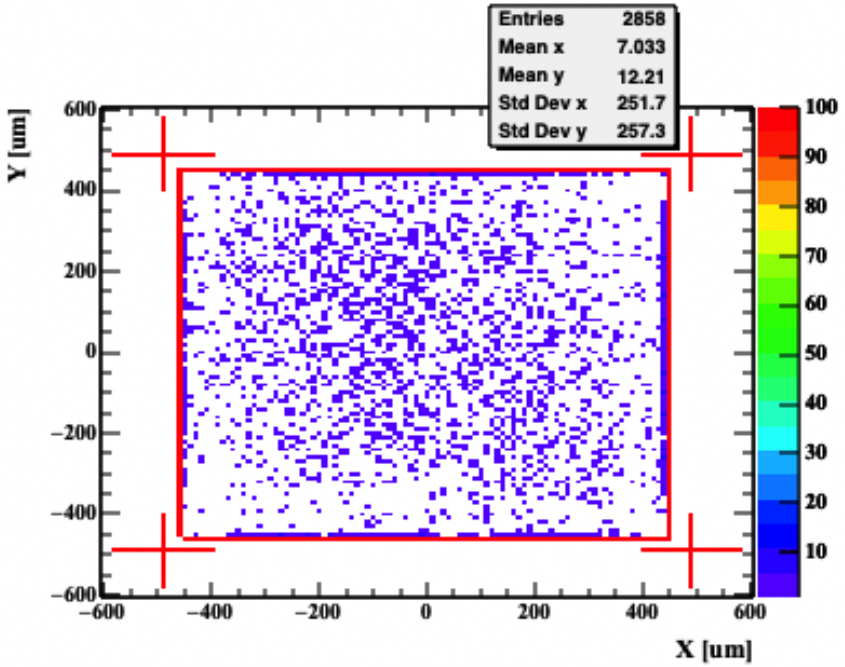
- Depends uniquely on the distance, not on the angle of the electrode
- Depends upon the angle and the log of the distance

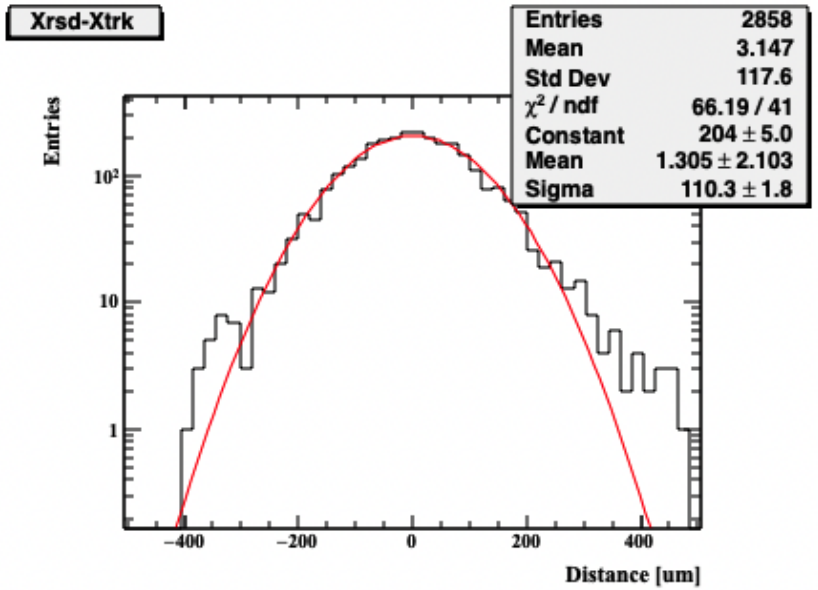
Maps of sharing for linear model

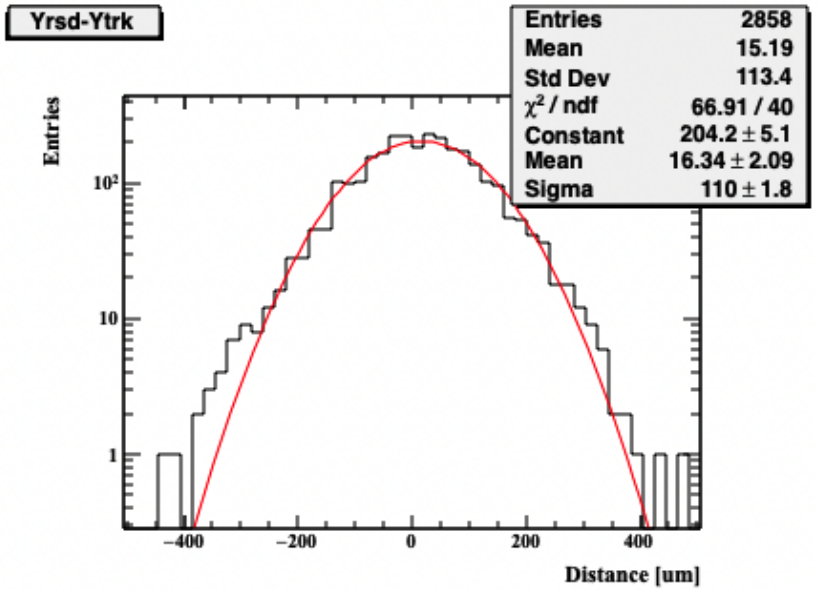


Analytic law

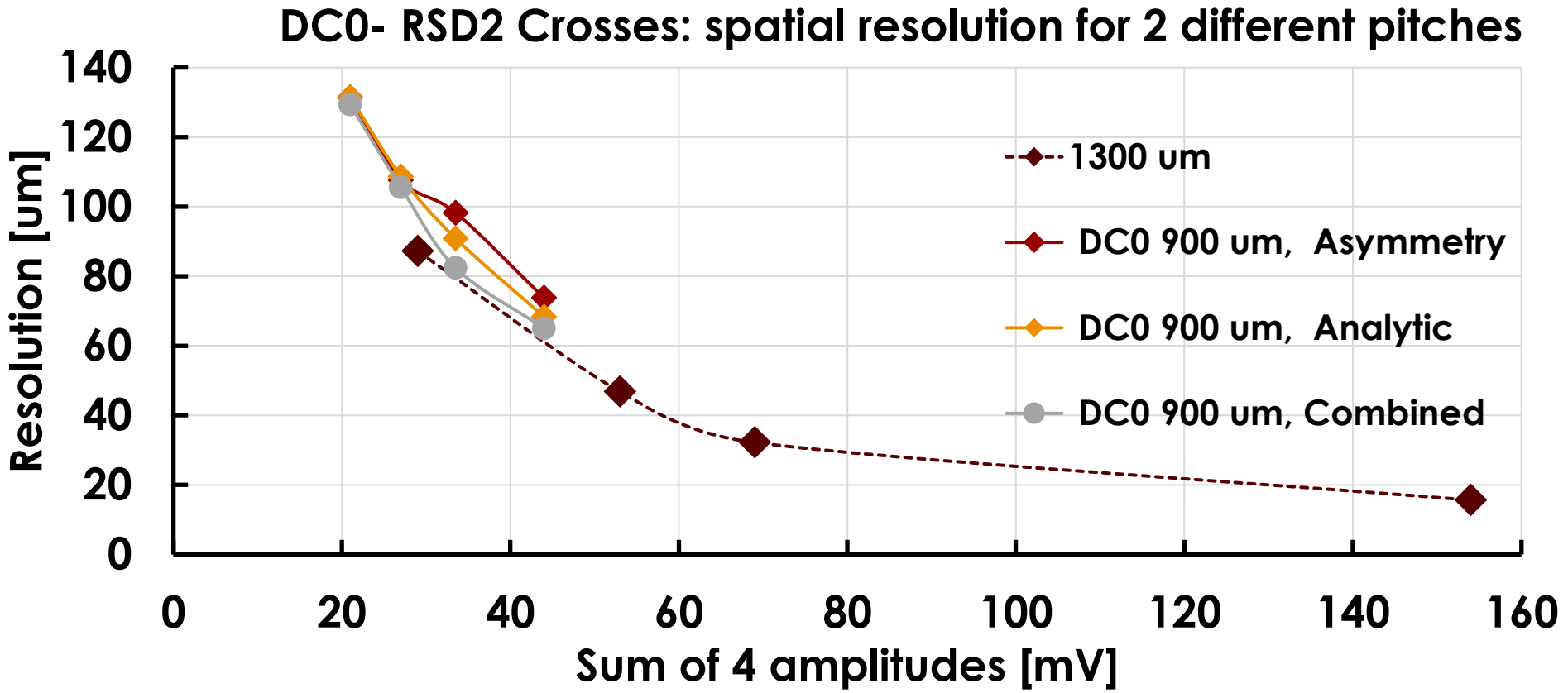






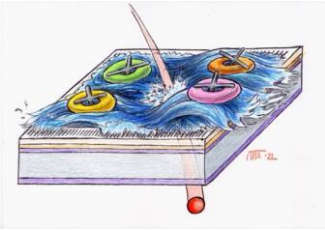


Results



- The performances of DC0 are compatible with that of RSD 1300 x 1300 um^2
- The electronic common noise, one of the main issue connected to the DC-RSD design, is absent

Acknowledgement



We kindly acknowledge the following funding agencies, collaborations:

- RD50 collaboration
- INFN - Gruppo V 4DShare project
- INFN – FBK agreement on sensor production (convenzione INFN-FBK)
- Horizon 2020, grant UFSD669529

Summary

The testbeam at DESY was succesful

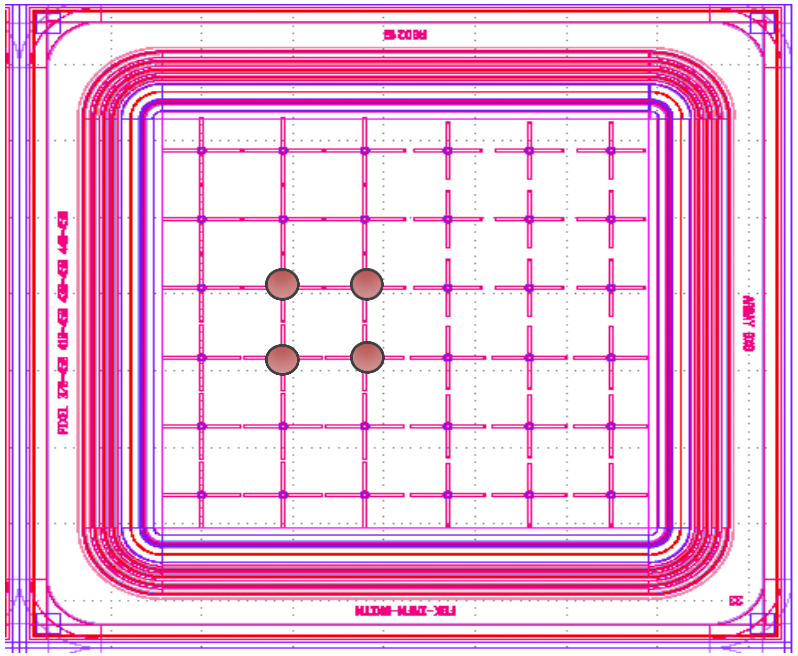
The results obtained with RSD2 sensors align with those obtained in the laboratory with the TCT.

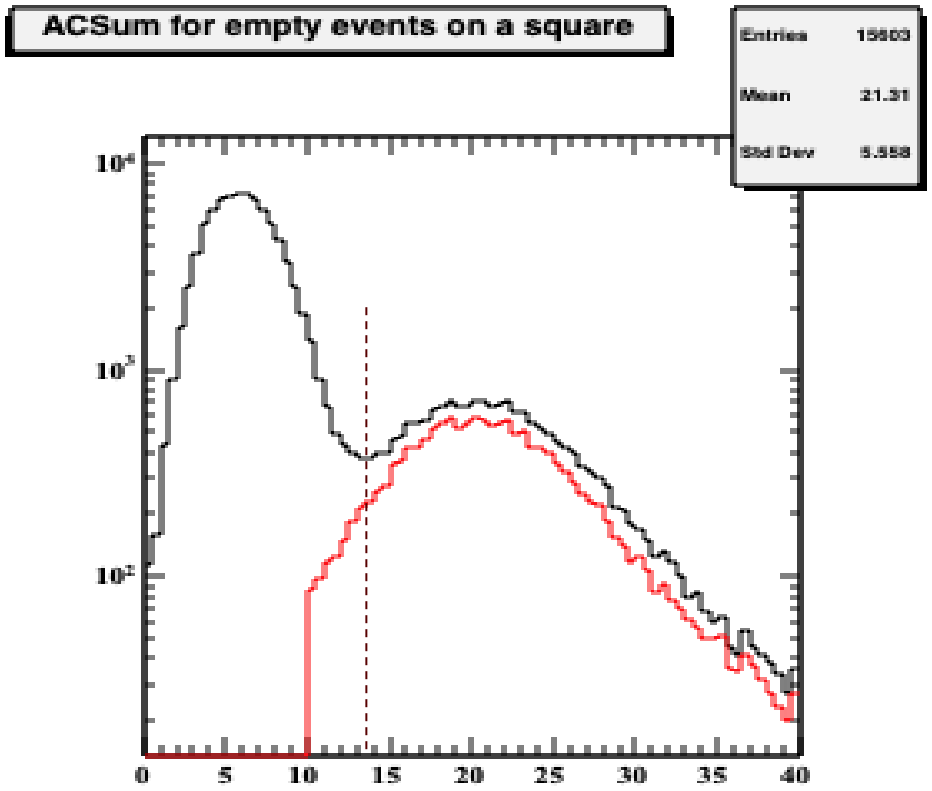
The study of ”wrong pixel assignment” was instrumental in developing an alternative reconstruction method.

The design study on DC-RSD demonstrated the absence of electronic common-noise.

Results are “less than expected” due to a “less than expected” S/N of the read-out board.

Determining the hit position using the highest ACSum





We need more gain (we don't know why the gain is low): the signal overlaps with the noise

Min ACSum = 13 mV

Inefficiency ~ 5%