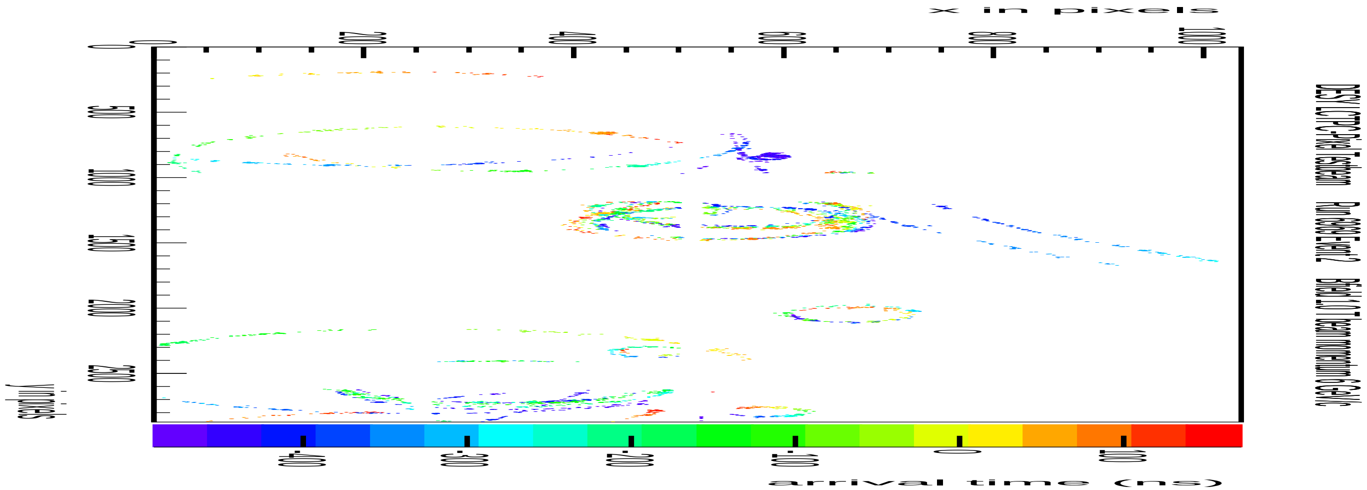
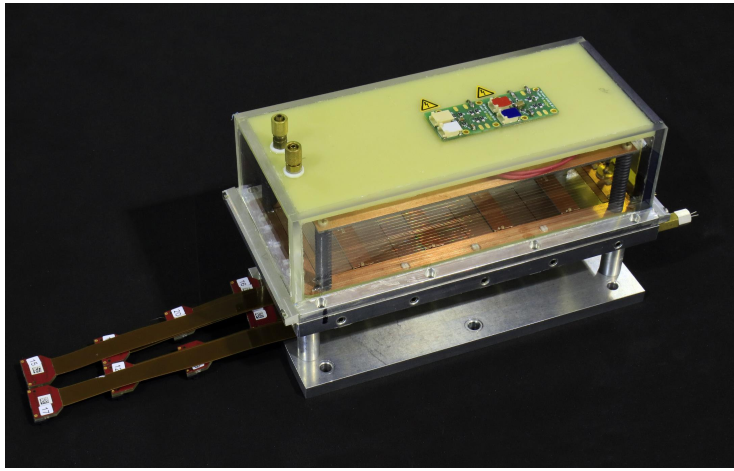
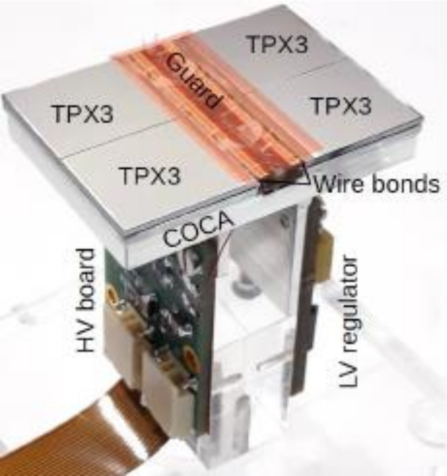




GridPix: the ultimate electron detector for TPCs



C. Ligtenberg, M. van Beuzekom, Y. Bilevych, K. Desch, H. van der Graaf, F. Hartjes, K. Heijboer, J. Kaminski, P.M. Kluit, N. van der Kolk, G. Raven, J. Timmermans

Nikhef
Physikalisches Institut, University of Bonn

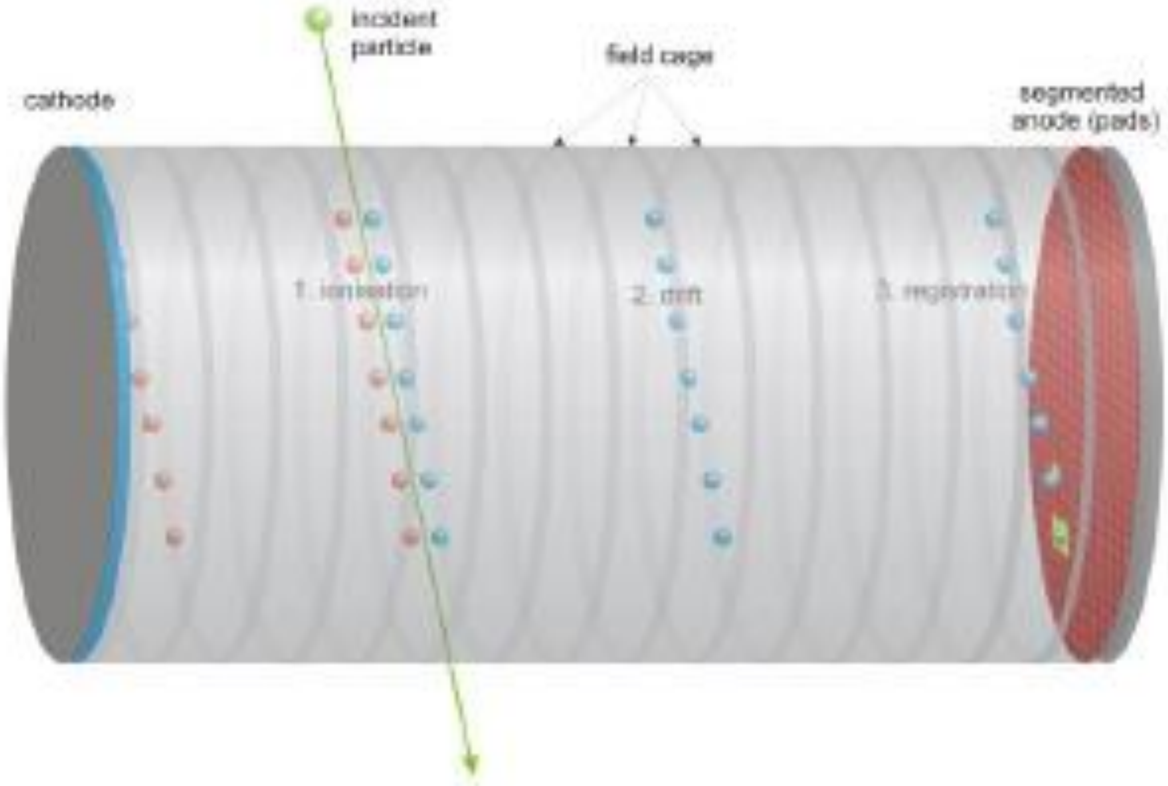
Future Lepton colliders:

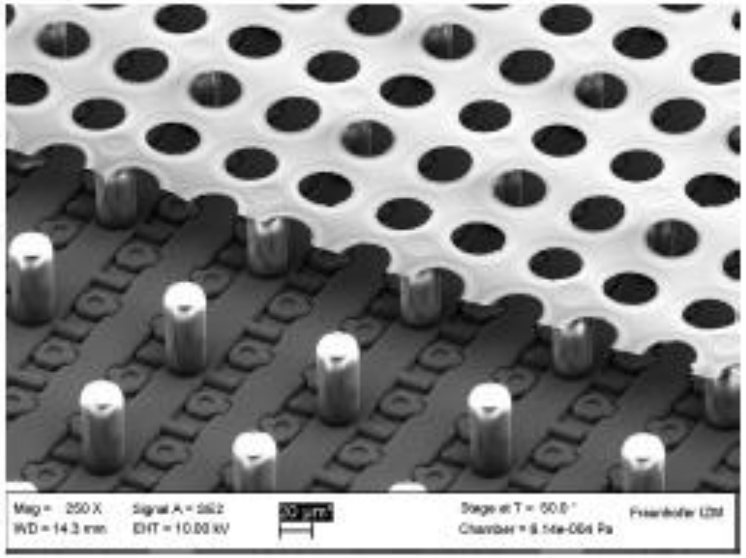
ILC ever?
CLIC ever?
CEPC Circular (China) Electron–Positron Collider

The first new experiment on any new large collider will be situated around a lepton colliding point

This experiment is likely to require a very large Time Projection Chamber (TPC):

- momentum resolution
- low scattering
- capable to handle track rate
- track separation
- track timing for trigger ID
- dE/dX measurement

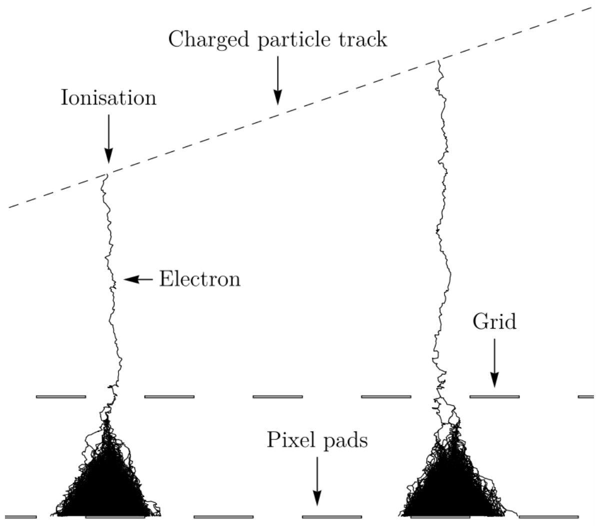


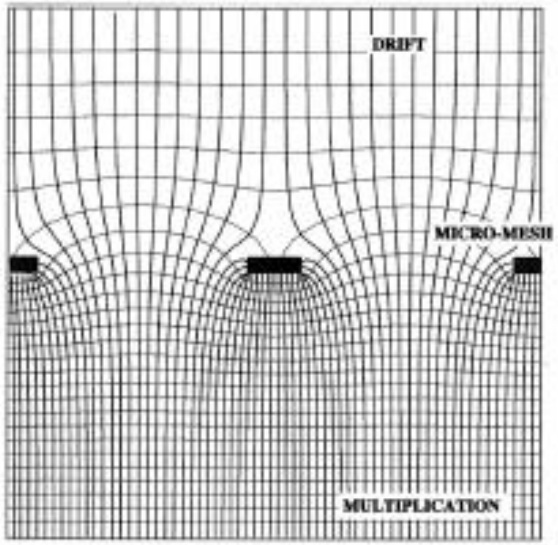


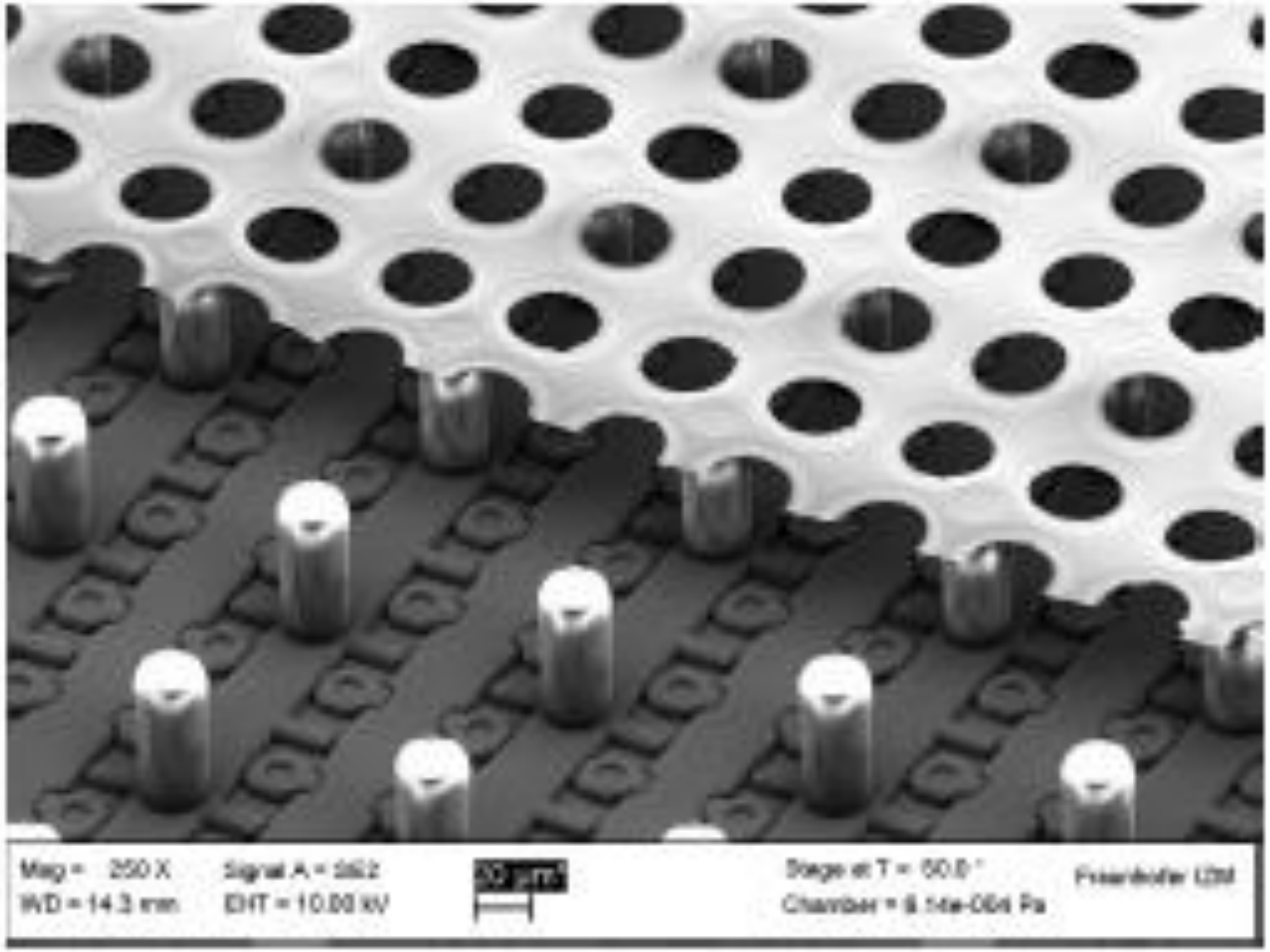
GridPIx TPC Readout:

- spark protection
- transverse spatial resolution
- spatial resolution in drift direction
- dE/dX
- track separation
- Ion back flow: Gated Grid
- Negative ion TPC

GridPix: integrated Micromegas grid onto TimePix chip.



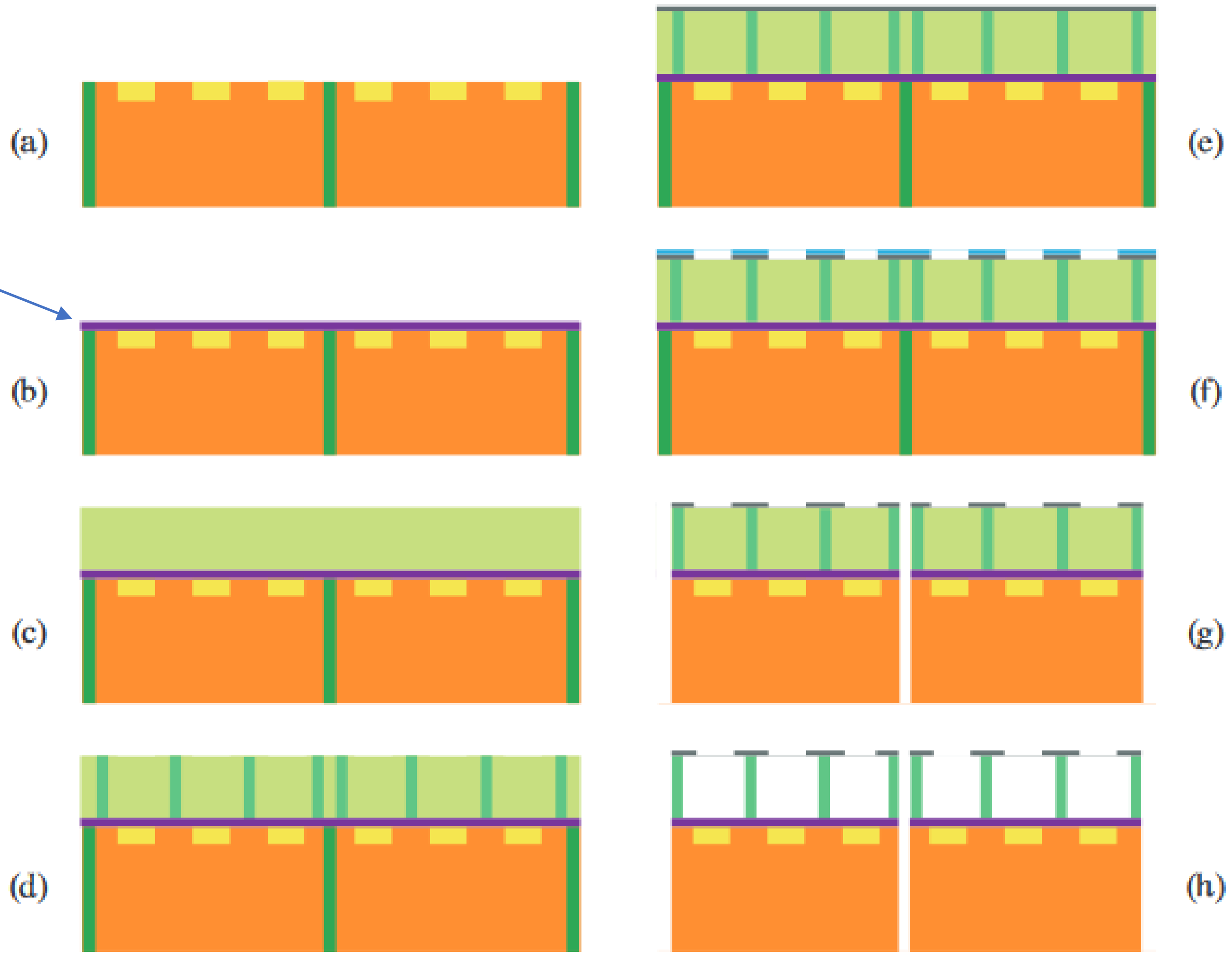




MESA+ (TU Twente), IZM-Berlin, Bonn University

Production of GridPixes: Spark protection

a) Cleaning
b) protection layer
c) SU-8 covering
d) Exposure with mask
e) Aluminium layer is deposited
f) Another layer of photoresist is applied, exposer with a mask creates a hole pattern, and the holes are chemically etched
g) The wafer is diced
h) The unexposed SU-8 is resolved



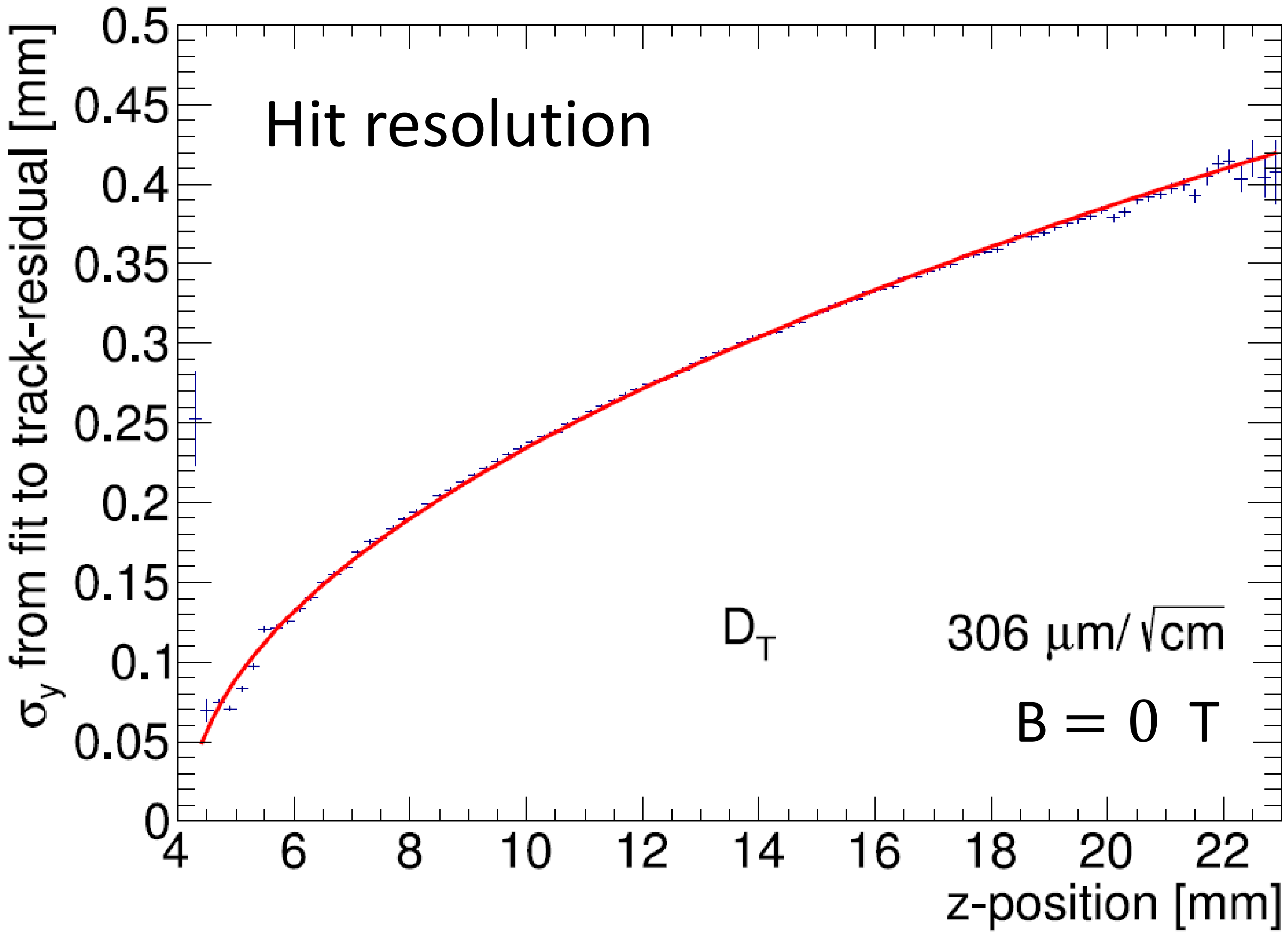
Thesis Stergios Tsigaridas, *Next Generation GridPix*

Spark protection

2003 TimePix1 chips without protection: world record breaking chips: average lifetime 45 minutes
2010 TimePix1 chip with 4 μm Silicon-rich SiliconNitride: 90% well-protected chips

2013 After very aggressive cleaning procedure: 100% well-protected chips

2020 – 2021: Operating 8-Quad module (32 chips). No chip loss, after 1000 h of HV exposure



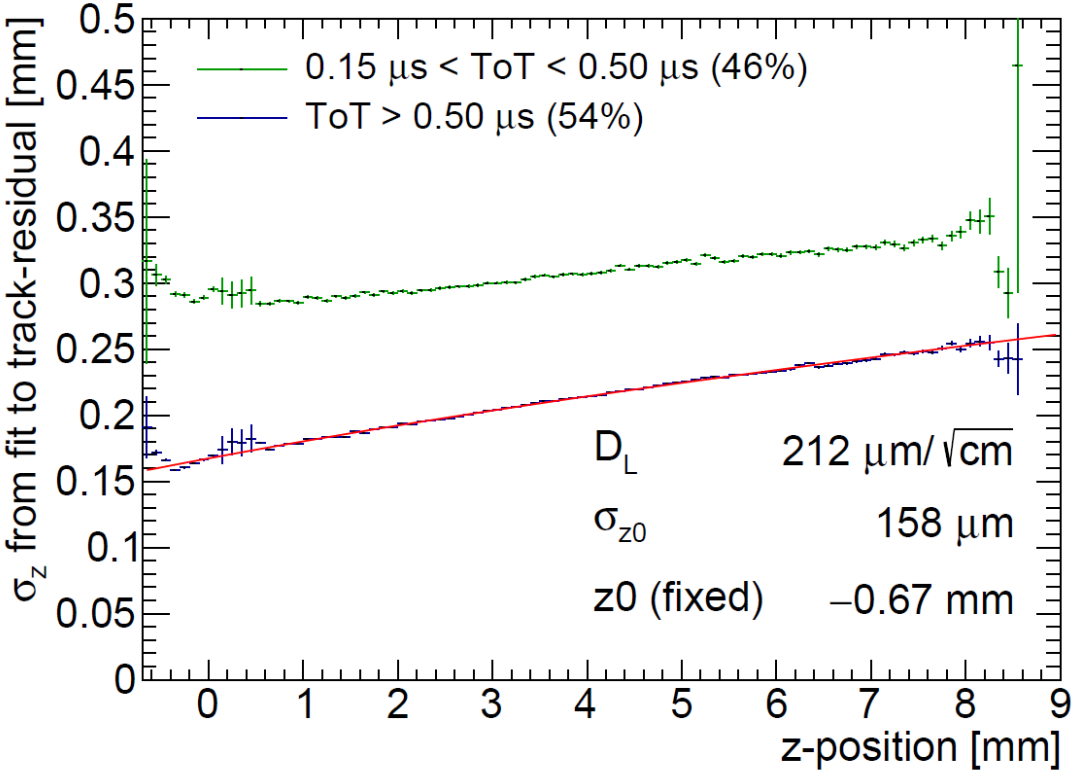
Transverse spatial resolution (X, Y)

for single electrons:

- **determined by diffusion, or**
- **for zero drift distance: pixel size (55 μm)**

This can't be better! All info from all primary electrons is extracted and processed

Hit resolution in the drift direction



Single hit resolution in drift direction

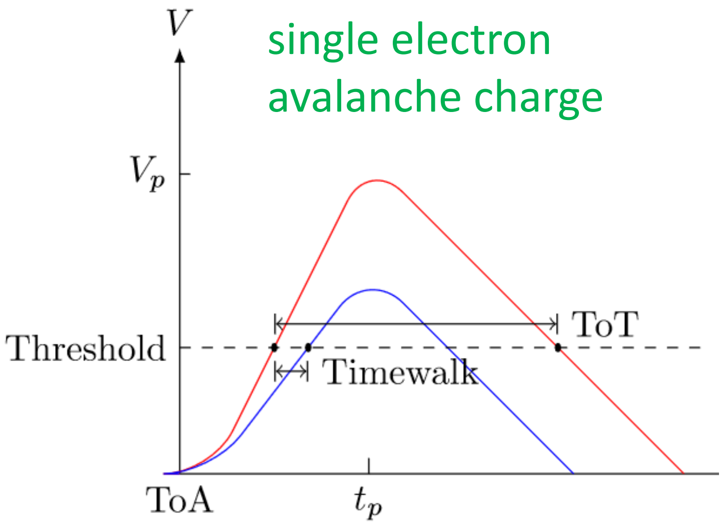
! '(= ! '() + $*((% − %0)

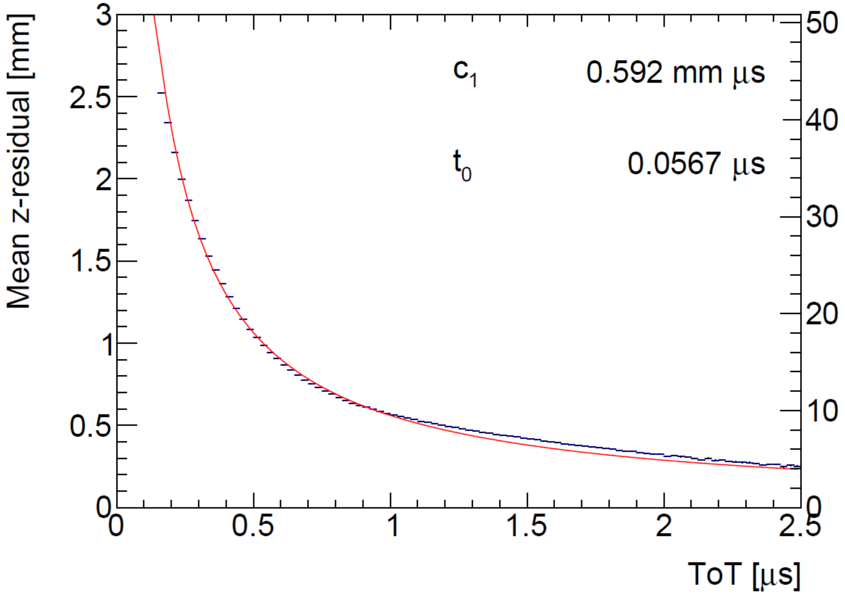
Depends on

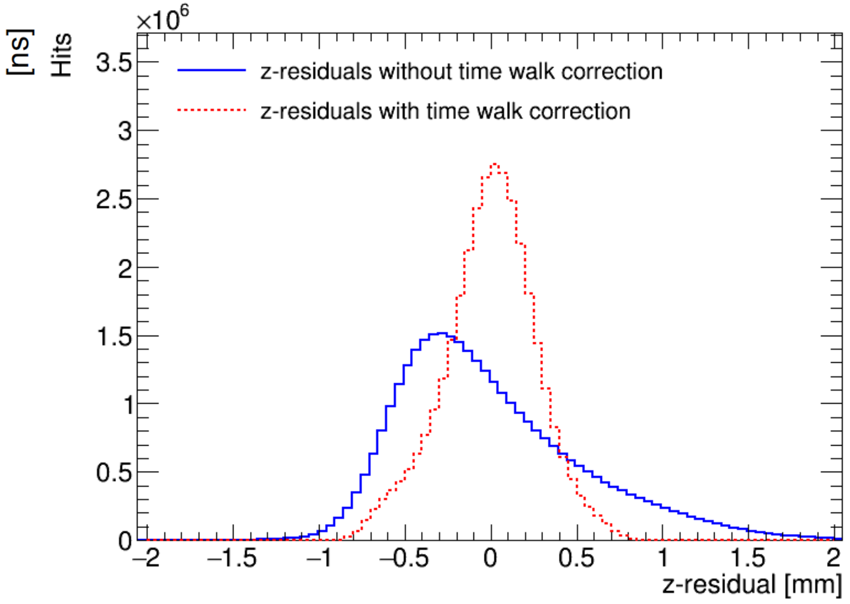
- ! ') from fit
- Diffusion $* from fit

Because of a large time walk error in hits with a low signal strength, an additional ToT cut (> 0.50 μs) was imposed

Time walk correction with the Timepix3







Time walk error: time of arrival depends on signal amplitude

Time walk can be corrected using Time over Threshold (ToT) as a measure for signal strength

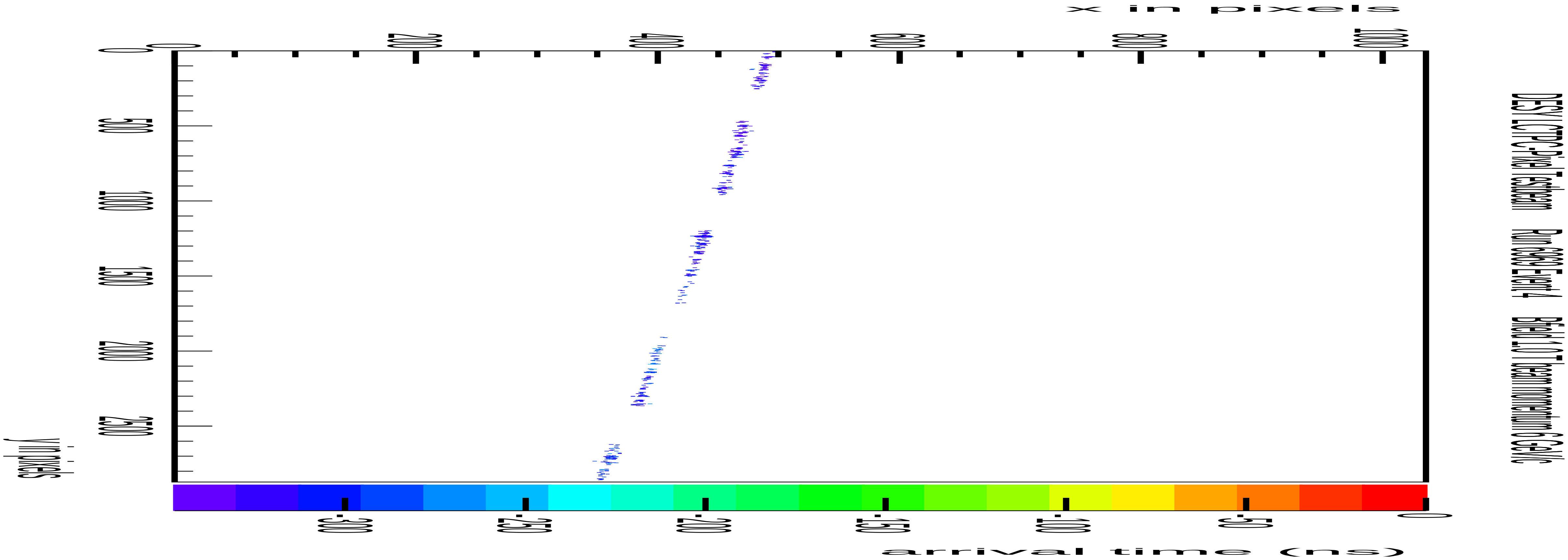
First order correction fitted and applied:

! "I mewalk = $! / (%0#" + %$) + "$

Distribution of residuals becomese more Gaussian after the time walk correction

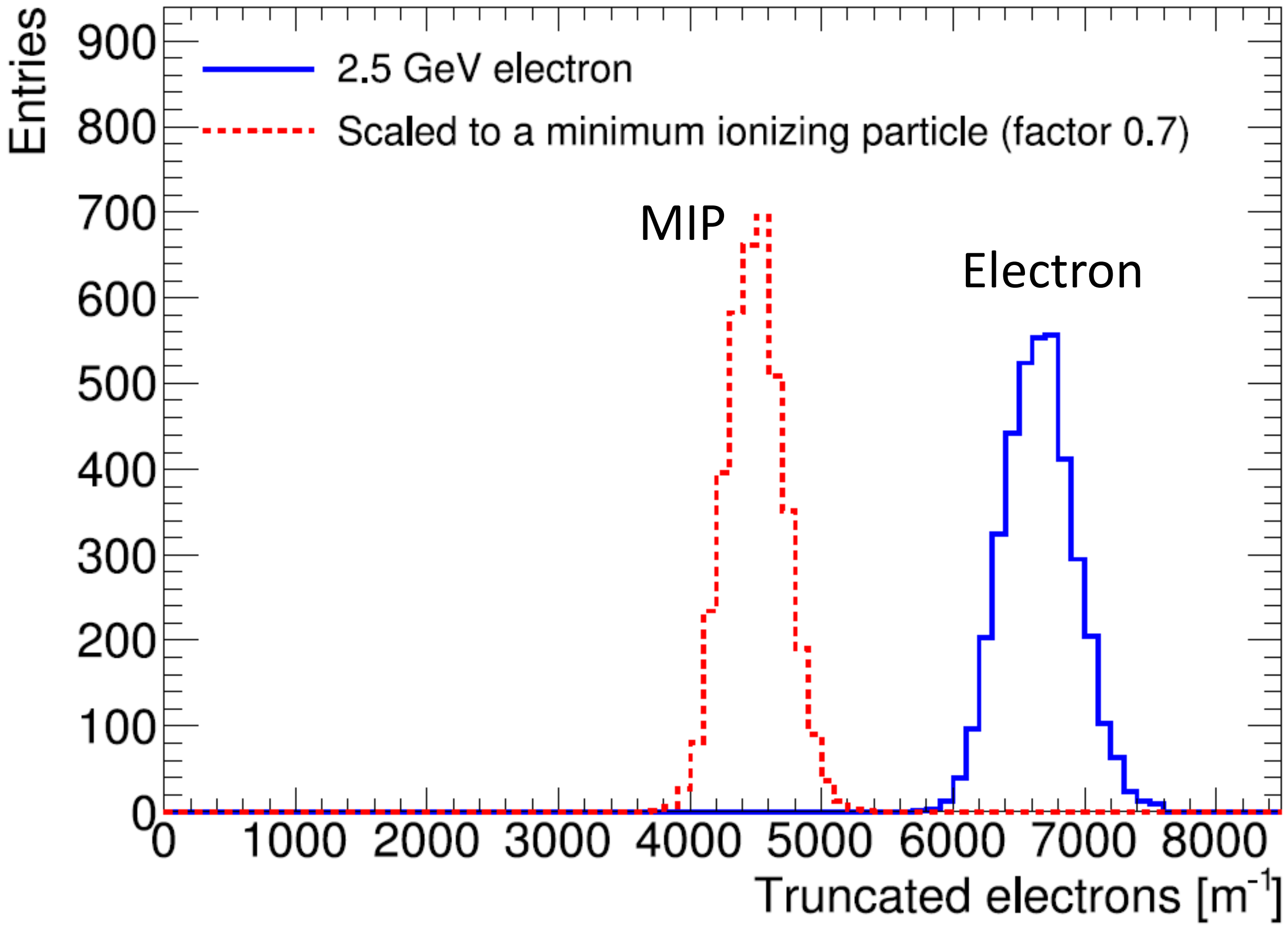
This can't be better! All info from all primary electrons is extracted and processed

dE/dX measurement

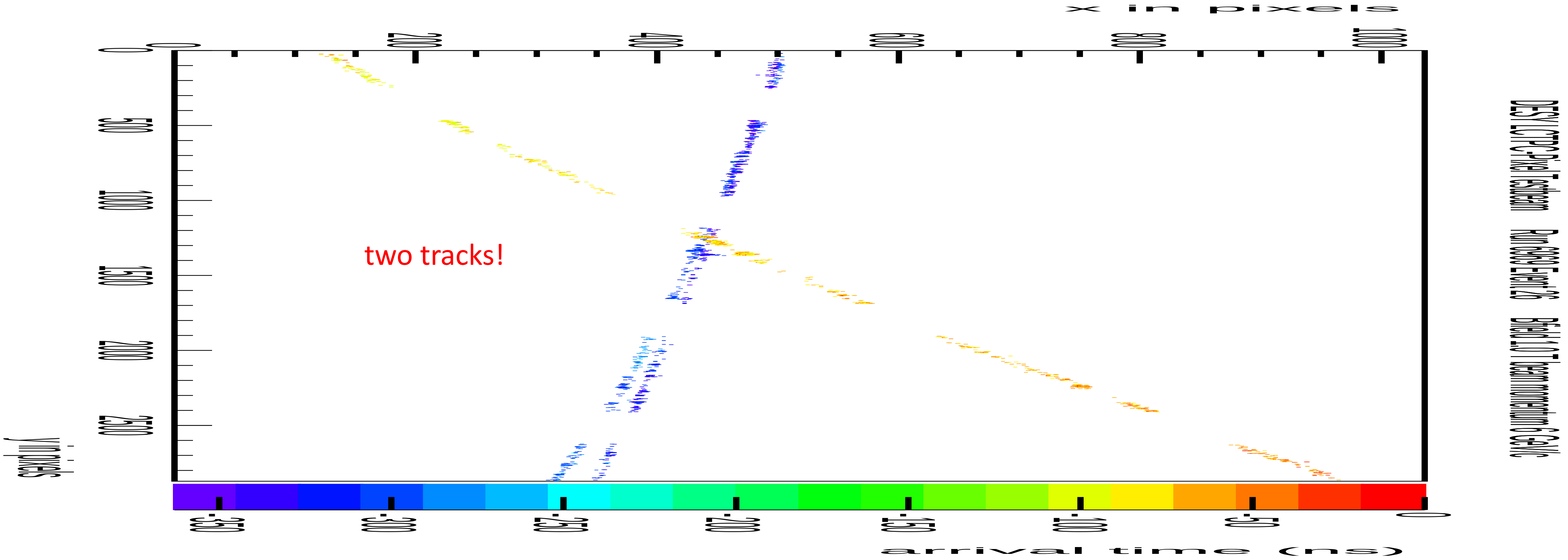


Count electrons along track:

- **count $\boldsymbol{\delta}$-ray for 1 electron**
- **apply statistical correction from**
- **distance between electrons**



Track separation



double track: contributes to track1 data until deviation is larger than to contribute to track2

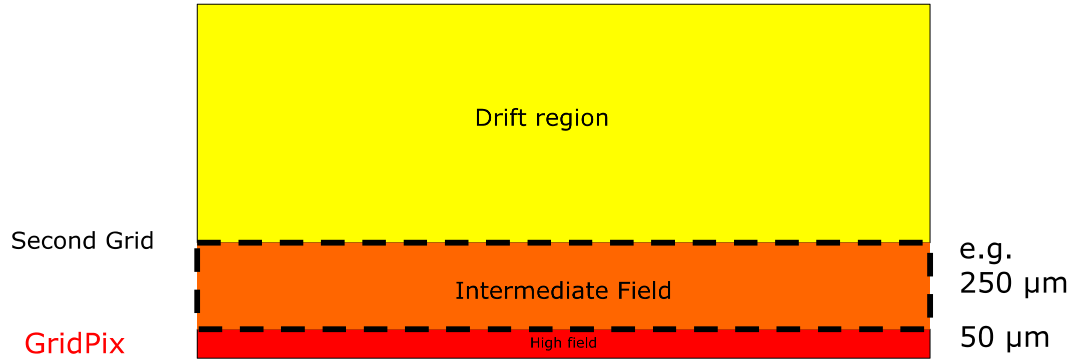
Infinite track separation power

Reducing the Ion back flow in a Pixel TPC

The Ion back flow can be reduced by adding a second grid to the device.

It is important that the holes of the grids are aligned. The Ion back flow is a function of the geometry and electric fields. Detailed simulations – validated by data - have been presented in LCTPC WP #326.

With a hole size of 25 µm an IBF of $3\ 10^{-4}$ can be achieved and the value for IBF*Gain would be 0.6. Well below the specifications.



We plan to test this idea at Nikhef

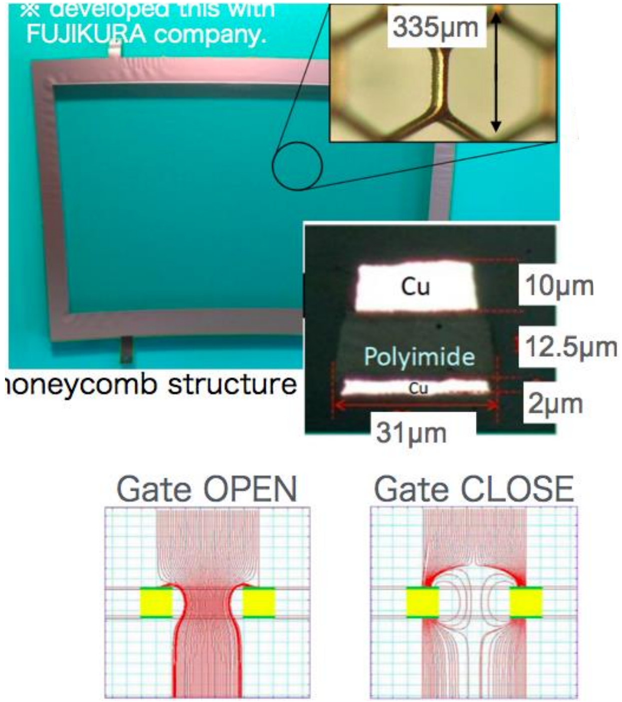
Ion backflow	Hole 30 µm	Hole 25 µm	Hole 20 µm
Top grid	2.2%	1.2%	0.7%
GridPix	5.5%	2.8%	1.7%
Total	$12\ 10^{-4}$	$3\ 10^{-4}$	$1\ 10^{-4}$
transparancy	100%	99.4%	91.7%

Reducing the Ion back flow in a (Pixel) TPC

The Ion back flow can be reduced – while running at the Z:

- By installing a gating device and closing the gate after a trigger.

E.g.the Gating GEM as developed in the contect of the ILD experiment



- LCWS19 presentation ILD gating GEM by Yumi Aoki (KEK)

Can we apply gating in Z collisions?

High luminosity CEPC L = 32-50 10^{34} $cm^{-2}s^{-1}$. Time between Z interactions 120-60 μs TPC drift takes 30 μs. So events are separated in the TPC; gating is possible.

Gate length of 20-60 μs would stop the ions in triggered mode.

Problem is that the gating will lead to dead time and a data taking efficiency at high luminosities of ∽85%-65% (for a 20 μs gate length).

Negative ion drift TPC

1. primary electron forms CS_2^- ion
2. ion drifts towards InGrid
3. electron is freed in strong avalanche field

93.6/5.0/1.4 gas mixture (by volume) of Ar/iC_4H_{10}/CS_2

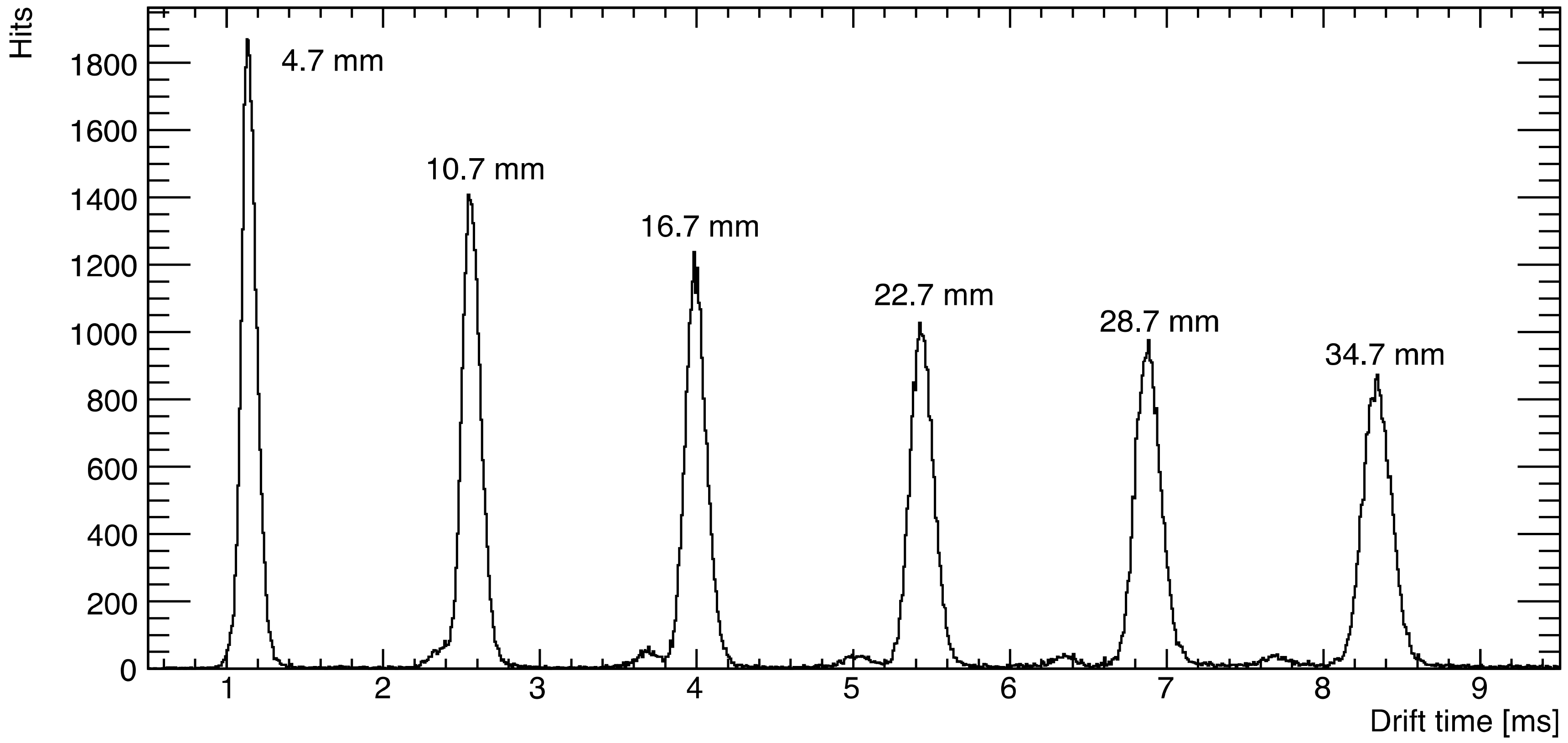
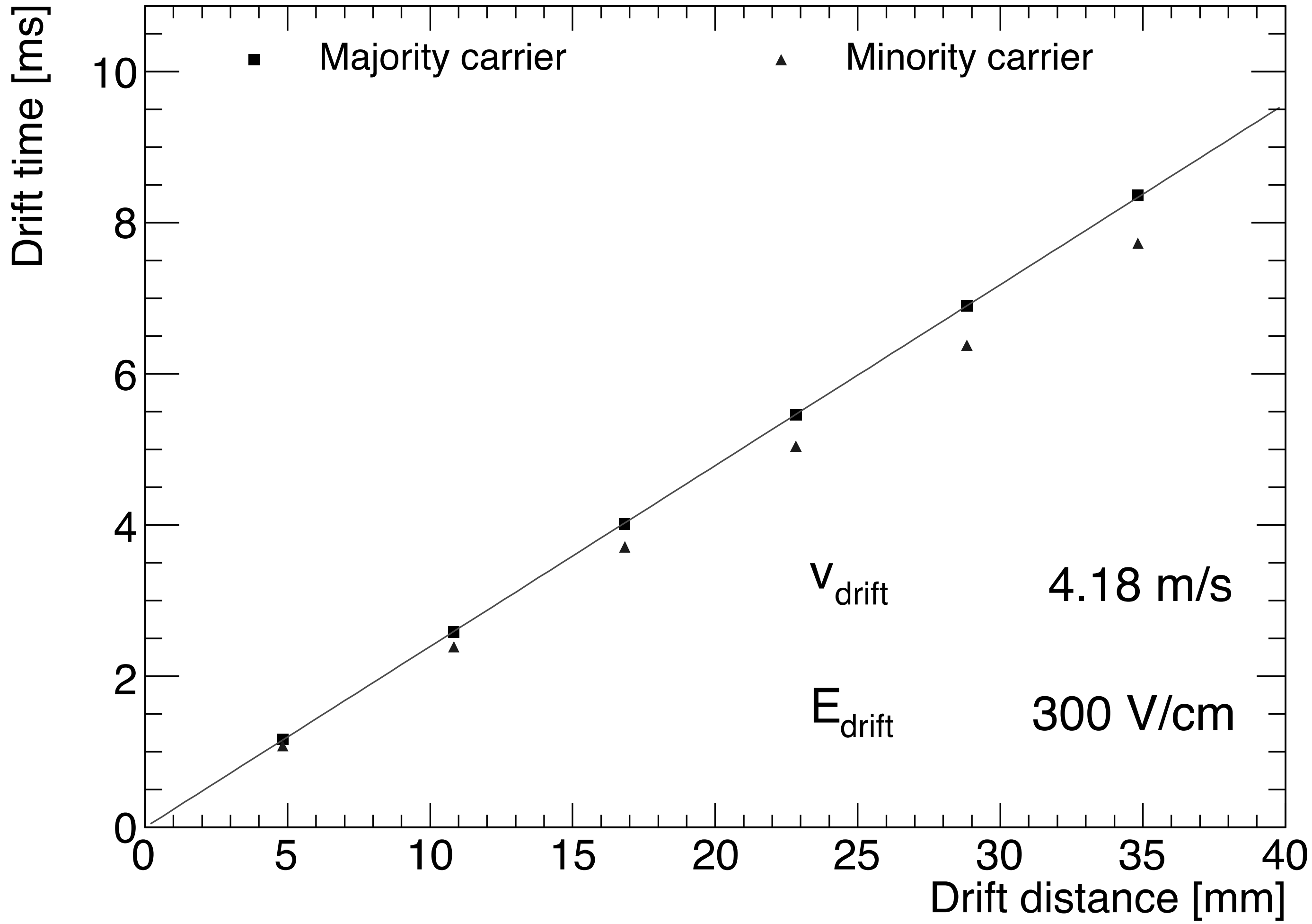


Figure 5: Drift time distribution for 400 laser pulses per z-position, annotated with the drift distance as recorded by the laser stage.

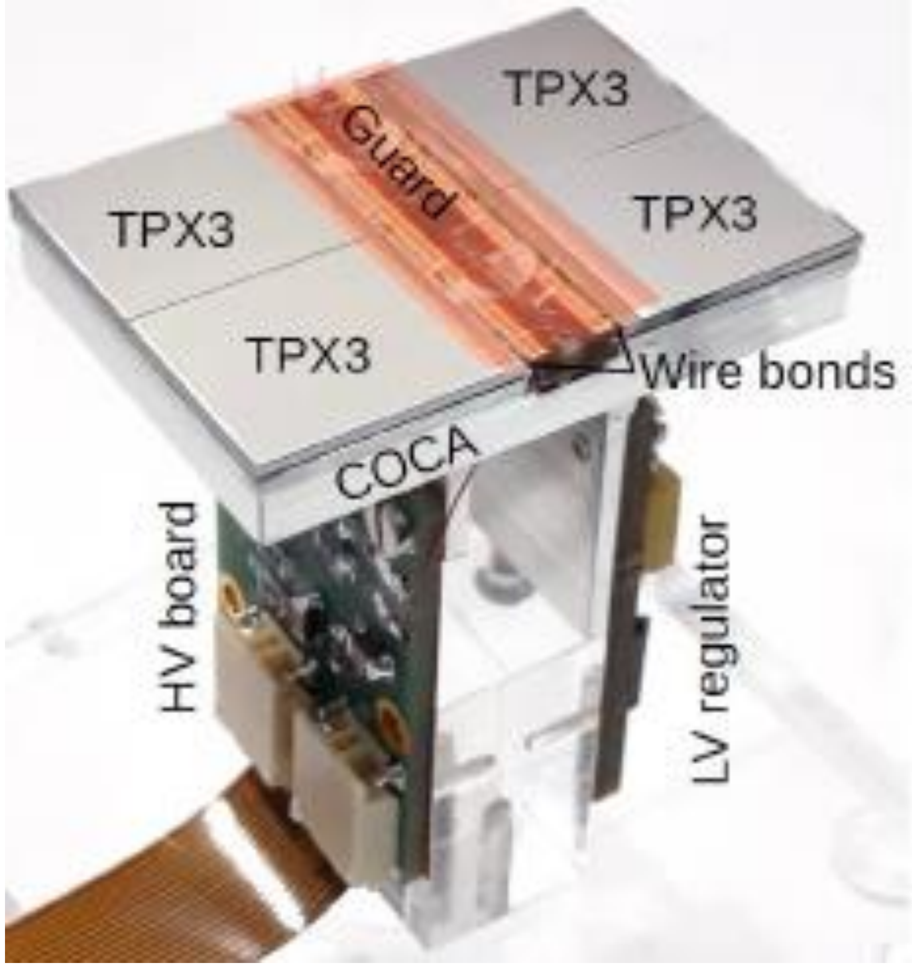


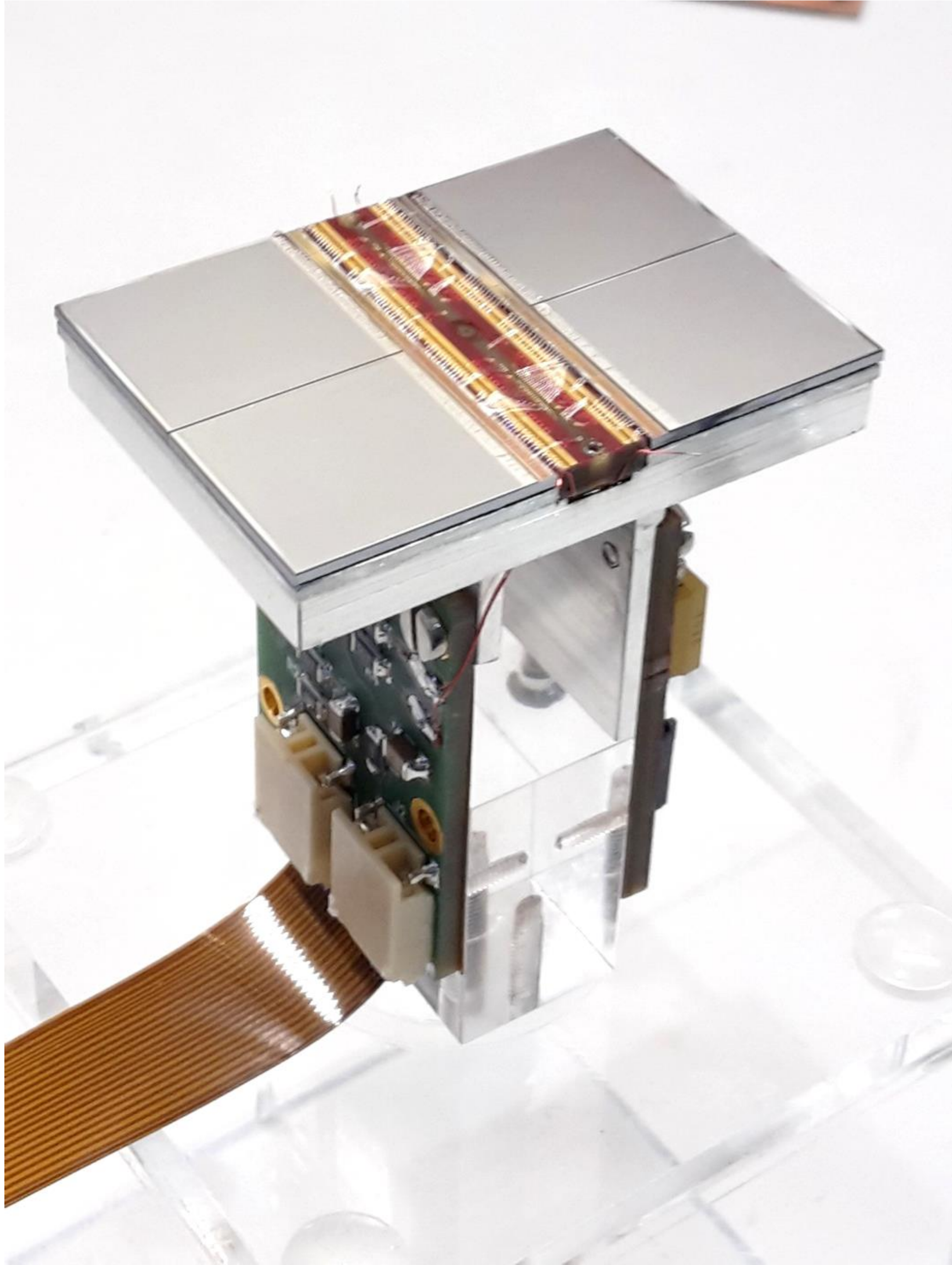
Minority carriers caused by:

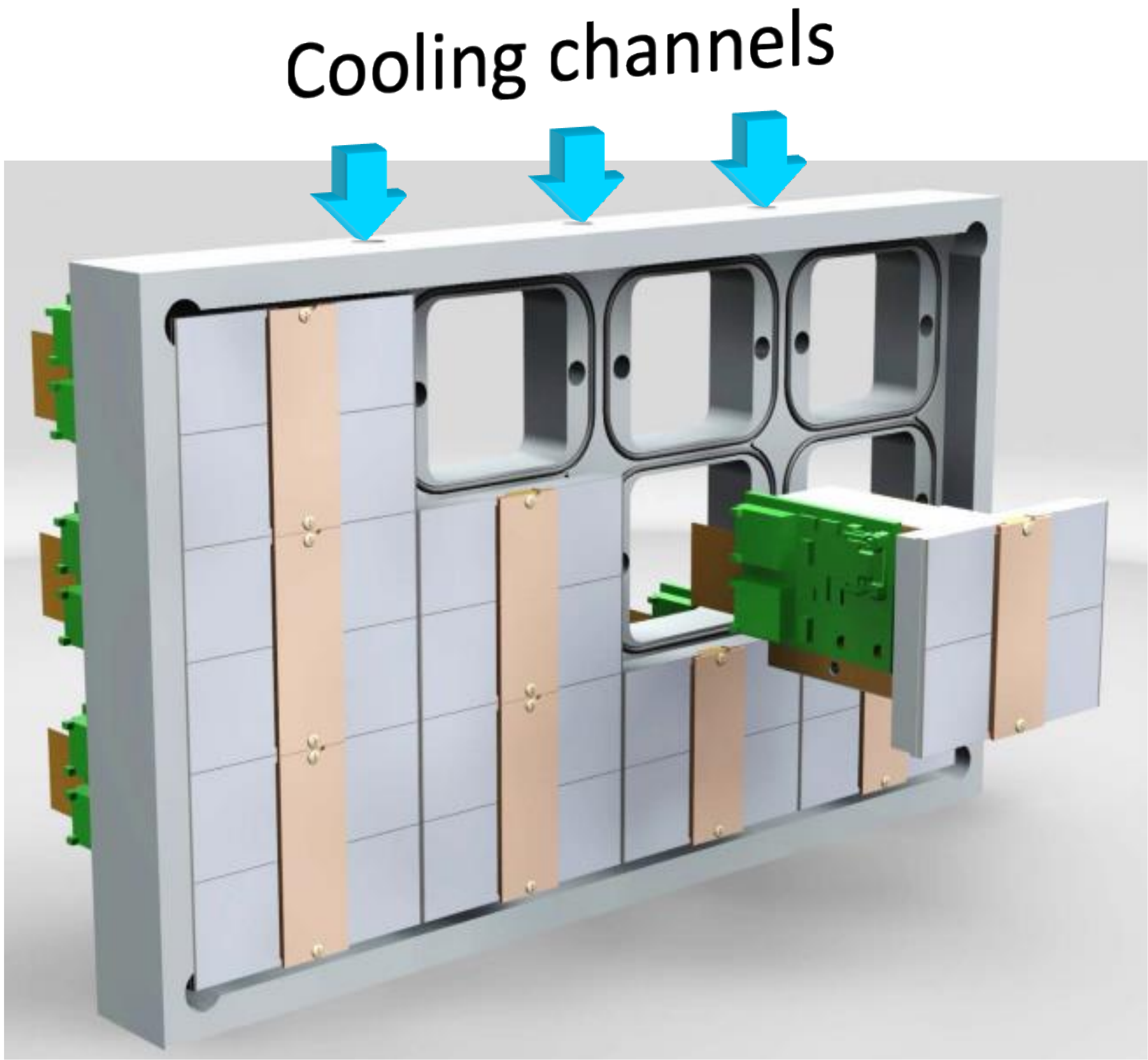
- O_2 ?
- H_2O ?

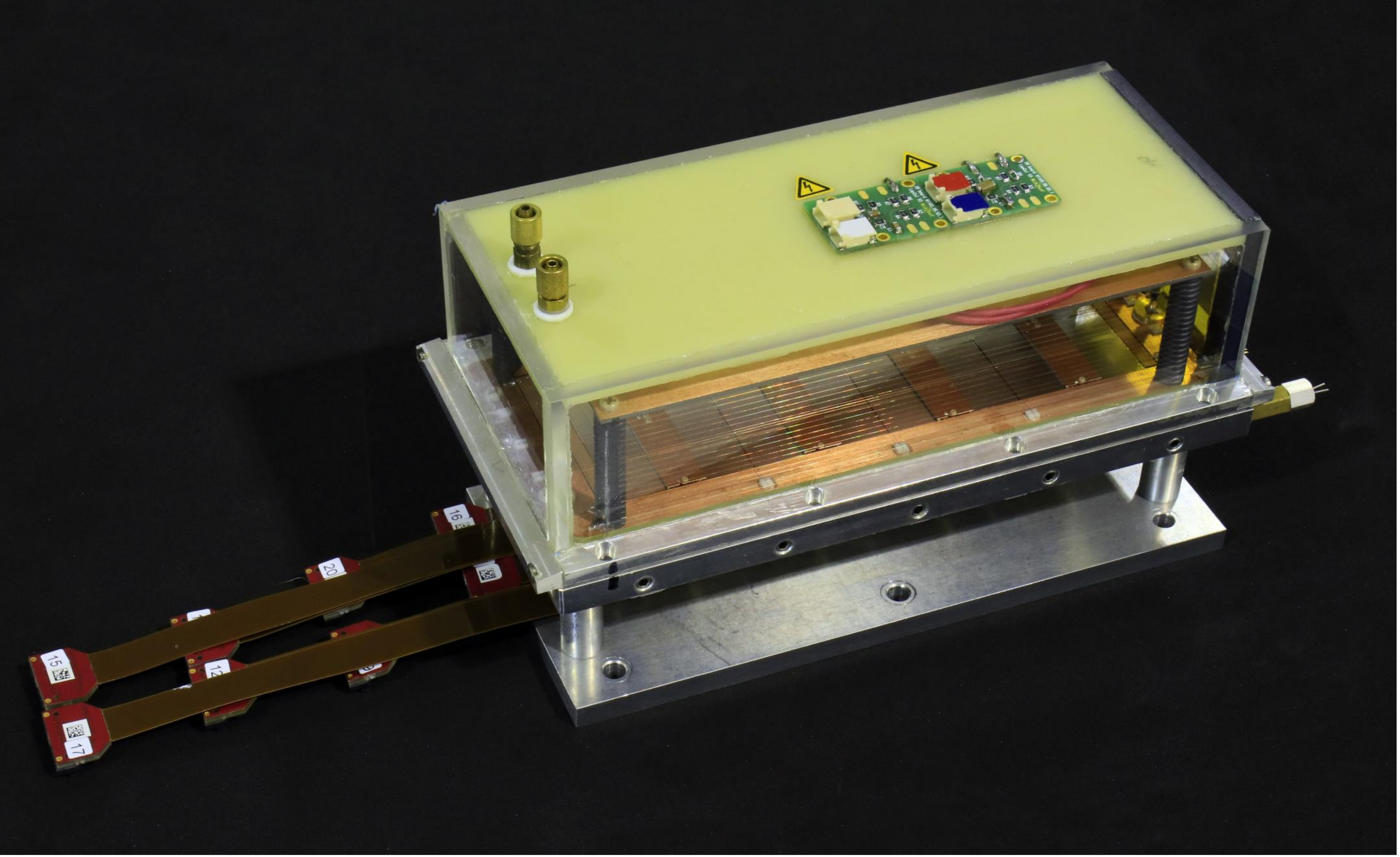
If minority track can be reconstructed, the absolute timing of the track is known!

Figure 7: Drift time as a function of the drift distance for the majority and minority carriers. The statistical error is not shown, because it is negligible compared to the systematic uncertainties.

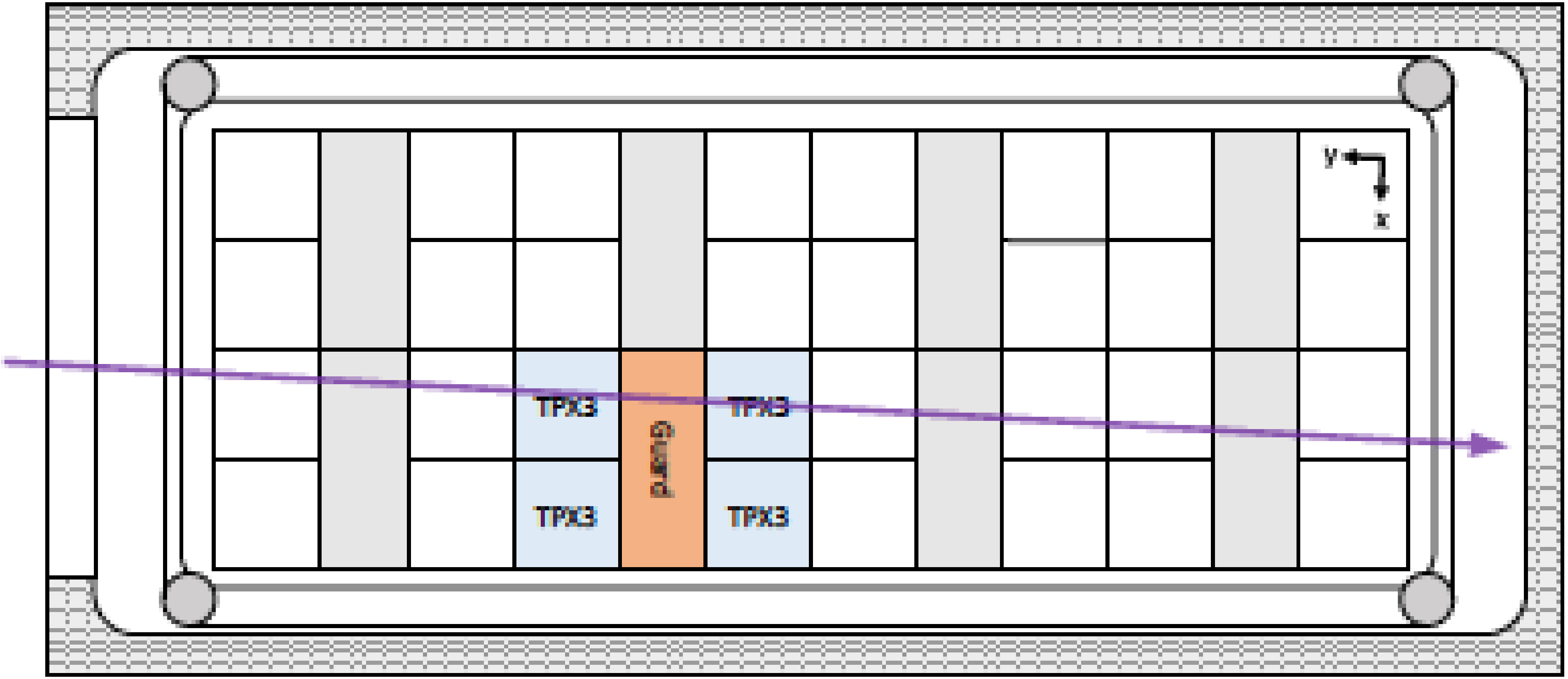

TPX3
Guard
TPX3
TPX3
TPX3
Wire bonds
COCA
HV board
LV regulator




Cooling channels

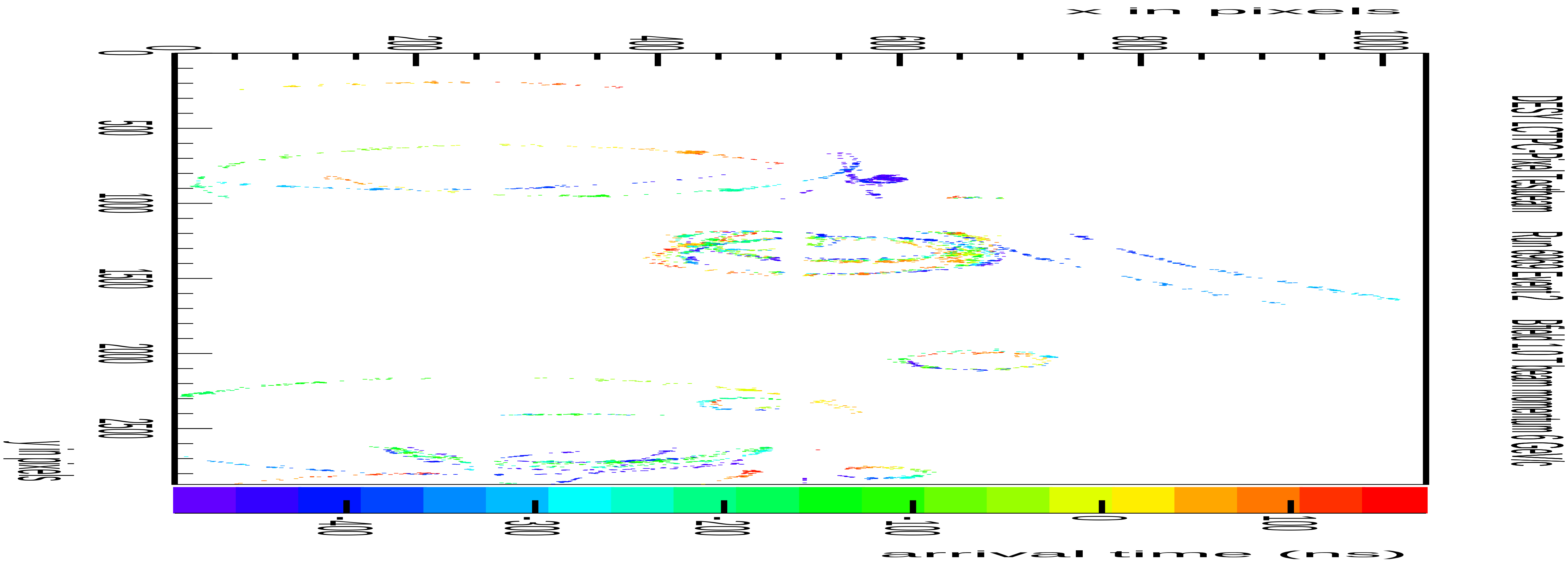


8-Quad module, containing 32 GridPix chips

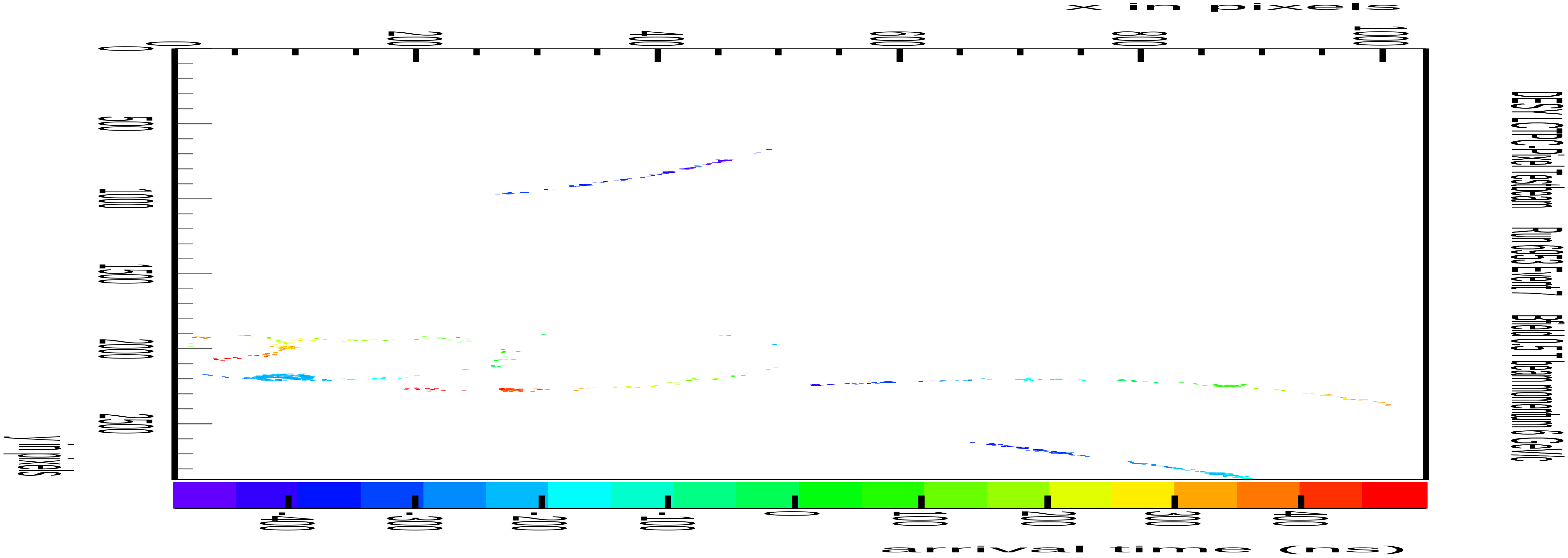


Testbeams: DESY and Else in Bonn. At Nikhef there is a N_2 UV laser set up.

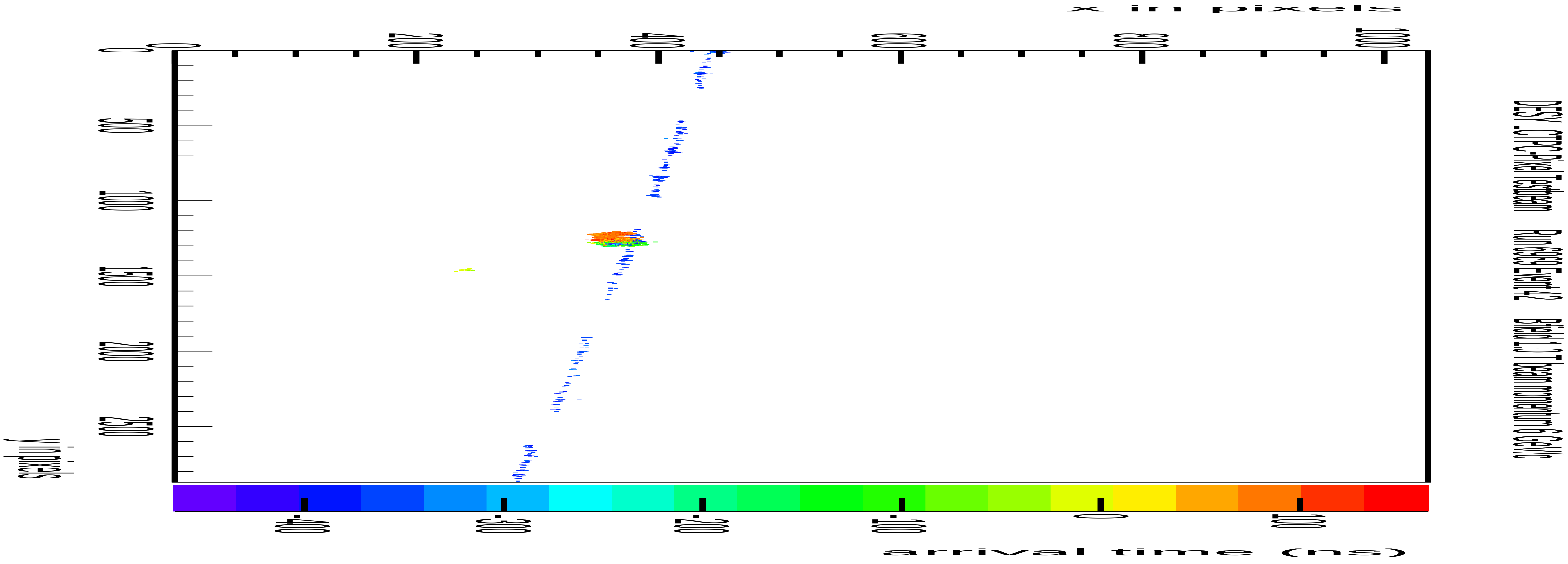
Event displays 1 T



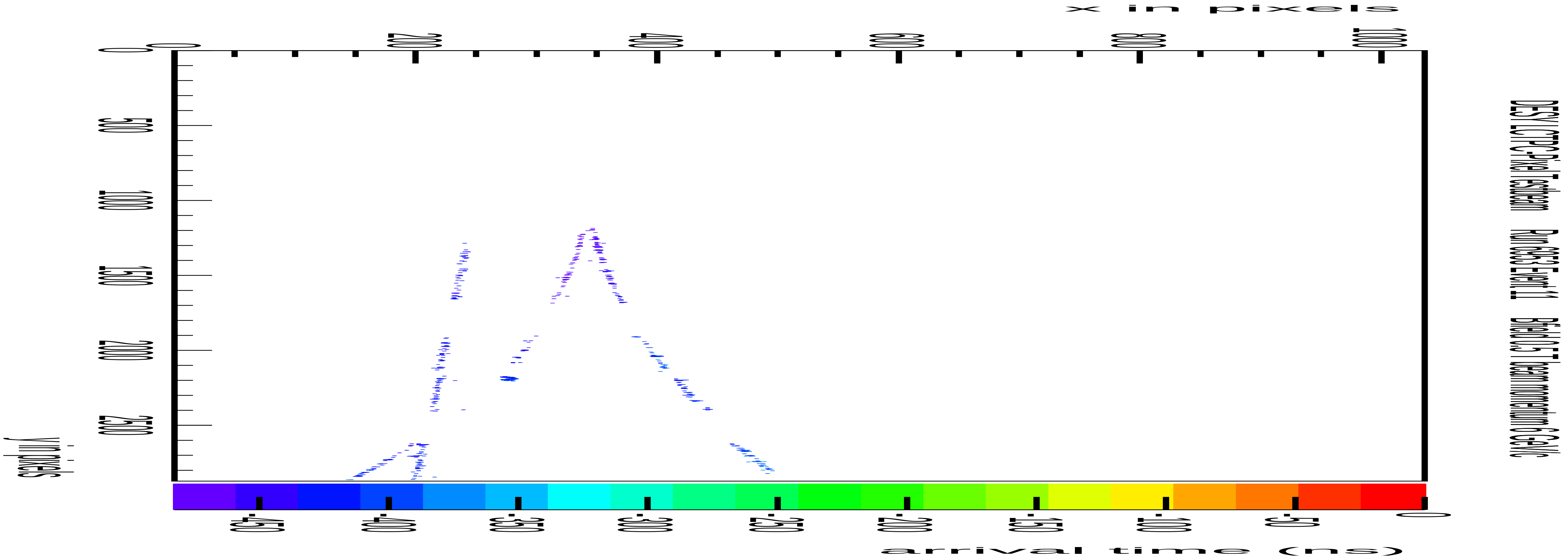
Event displays 0.5 T



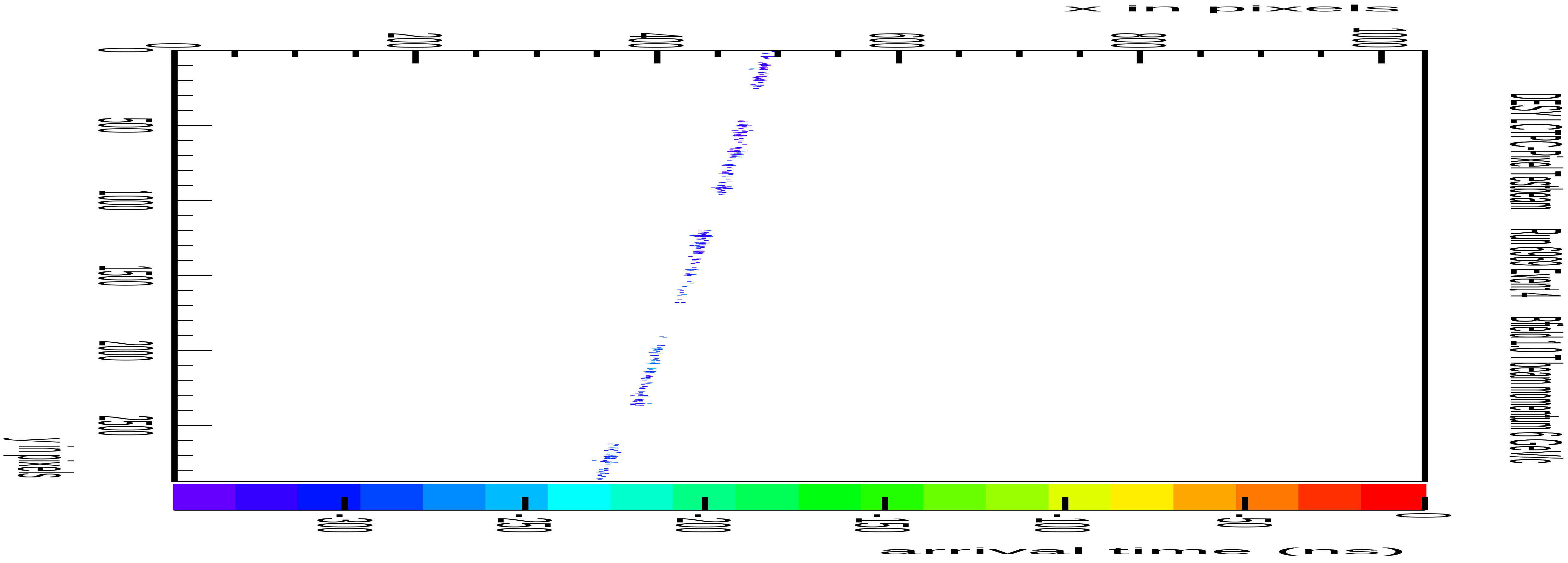
Event displays 1 T



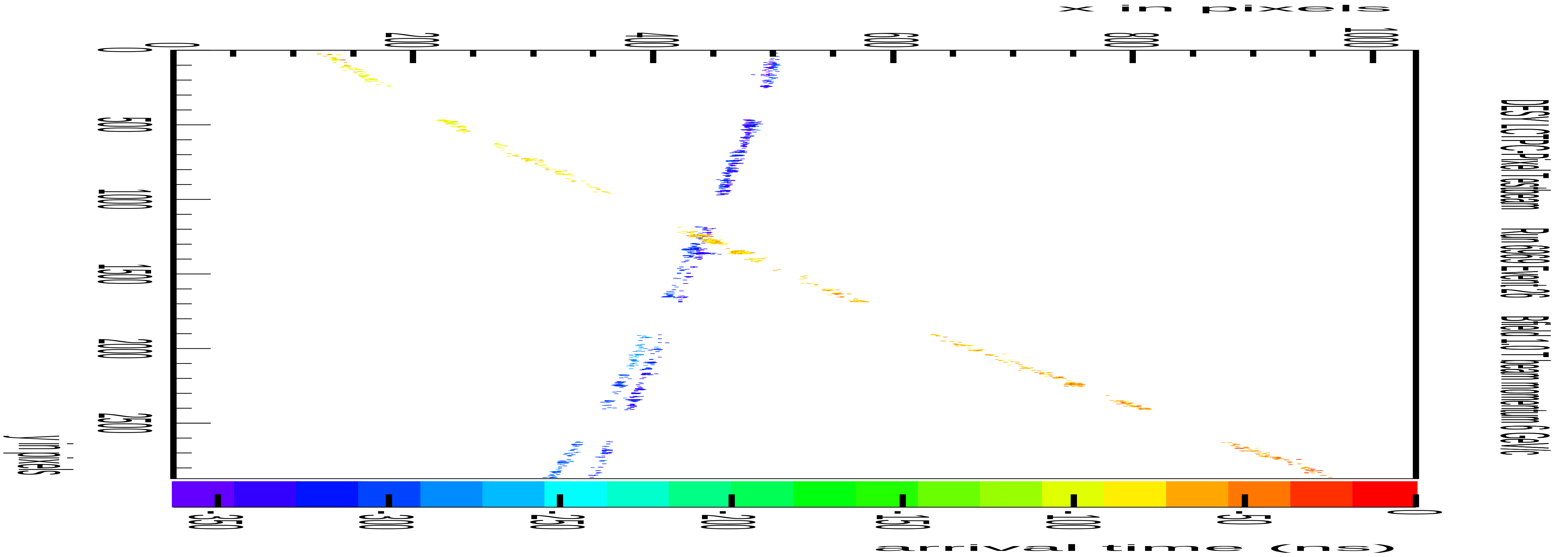
Event displays 0.5 T



Event displays 1 T



Event displays 1 T



Nikhef has pulled out of ILC collaboration
Nikhef stopped with gaseous detectors

All GridPix activity will be transported to University of Bonn (Klaus Desch et al.)

Future developments:

- **GridPix/InGrid manufacturing at new MEMS facility of Univ Bonn**
- **TPX-4 based GridPix**
- **A large TPC for** Brookhaven Electron-Ion-Collider EIC