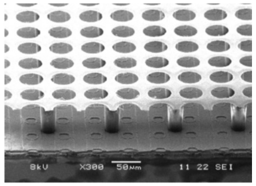

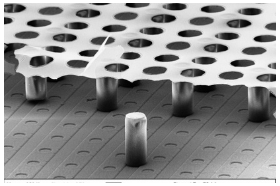

GridPix - A high resolution gaseous detector for many applications

Jochen Kaminski

University of Bonn

Joint Instrumentation Seminar
DESY
15. April 2016

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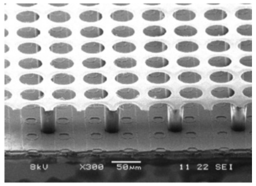

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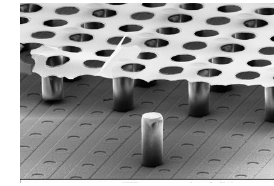

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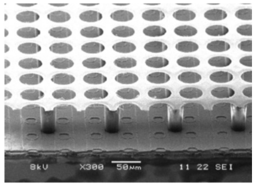
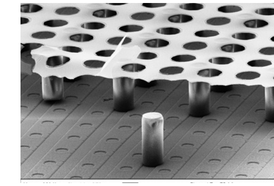
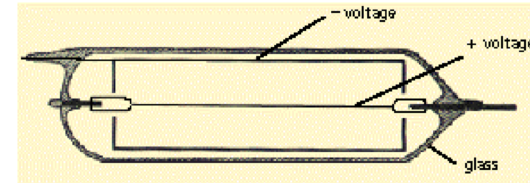


History of Gaseous Detectors



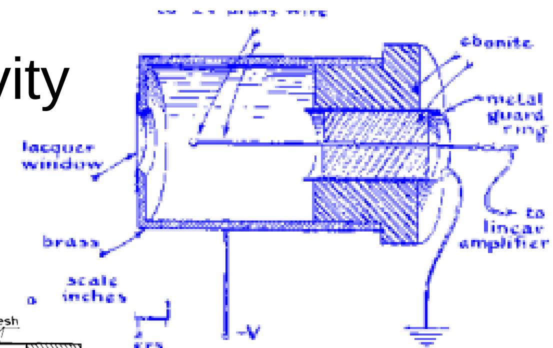
1908: First wire counter used by Rutherford

E. Rutherford and H. Geiger, Proc. Royal Soc. A81 (1908) 141



1928: Geiger-Müller Counter - single Electron sensitivity

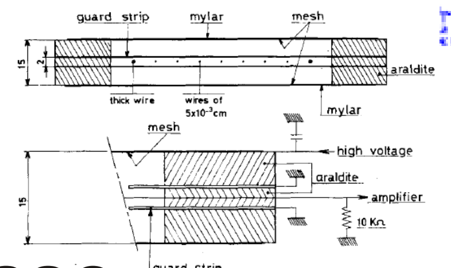
H. Geiger and W. Müller, Phys. Zeits. 29 (1928) 839



1945: Proportional tubes

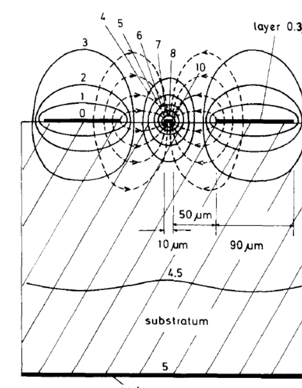
1967: Multi-wire Proportional chambers

G. Charpak, NIM 62 (1968) 262.



1988: First MPGD invented by A. Oed: MSGC

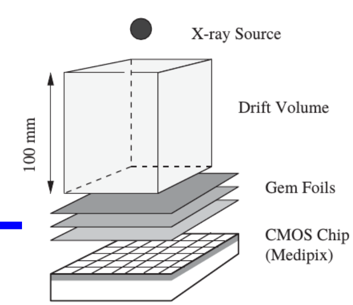
A. Oed, NIM A263 (1988) 351.

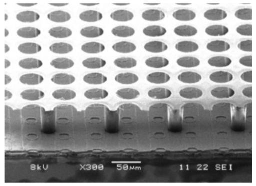


2004: ASIC-based highly pixelized Readout of MPGDs

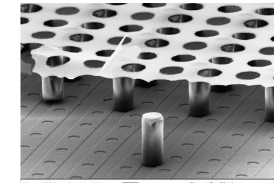
R. Bellazzini, NIM A535 (2004) 477.

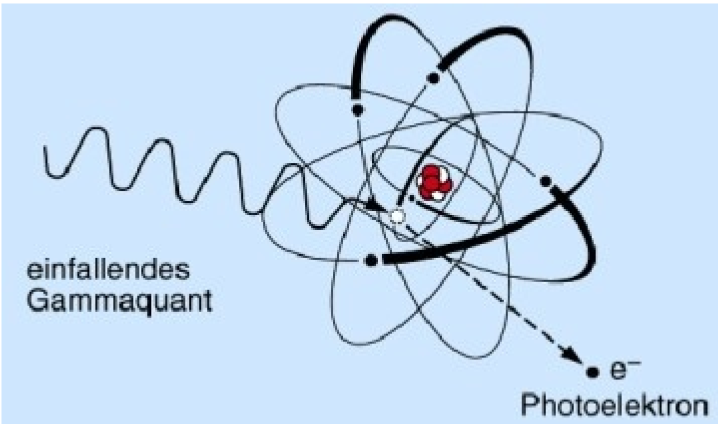
H. van der Graaf, NIM A535 (2004) 506.





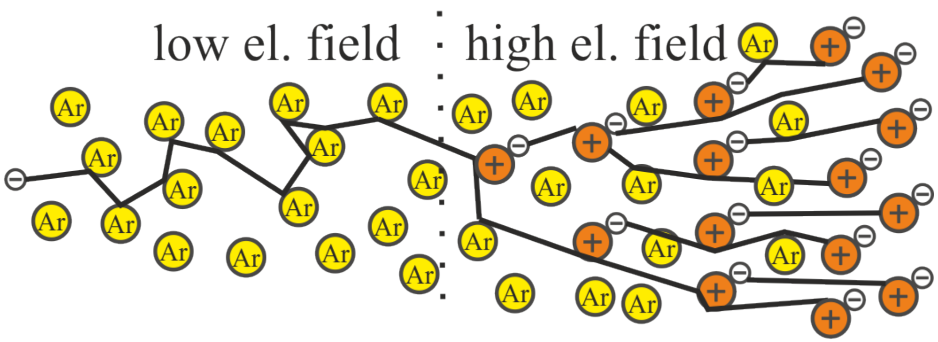
Gasfilled Detectors

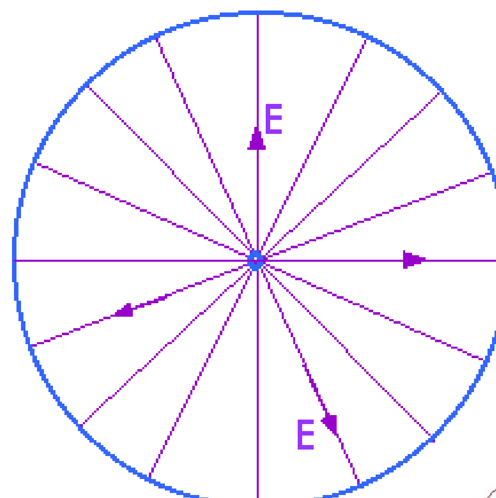


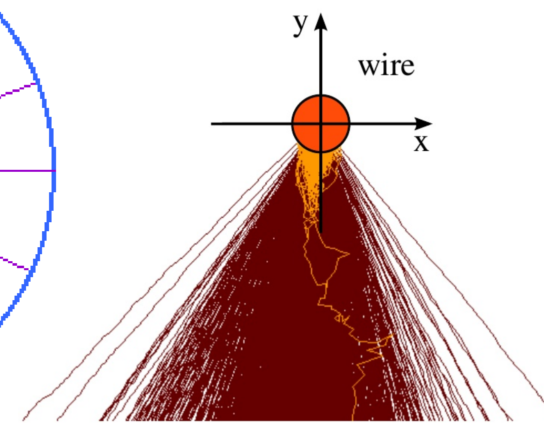


X-ray photons or high energetic charged particles ionize gas atoms. In this process electrons are ejected, which can also ionize further atoms.
=> The number of primary electrons is proportional to the deposited energy.

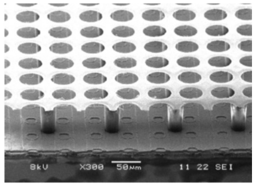
In electrical fields the free electrons drift towards the higher potential.

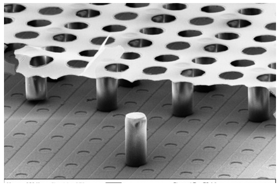






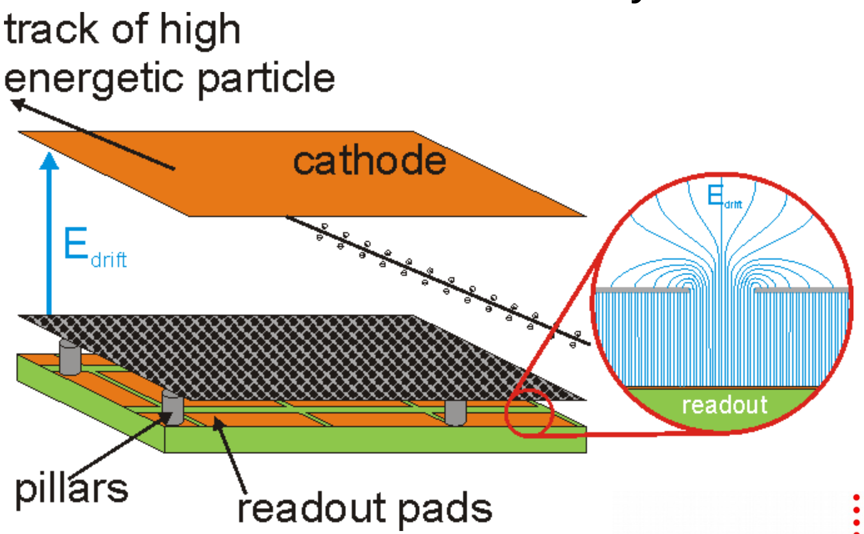
In very high electric fields the energy picked up between collisions is enough for further ionization processes => avalanche amplification



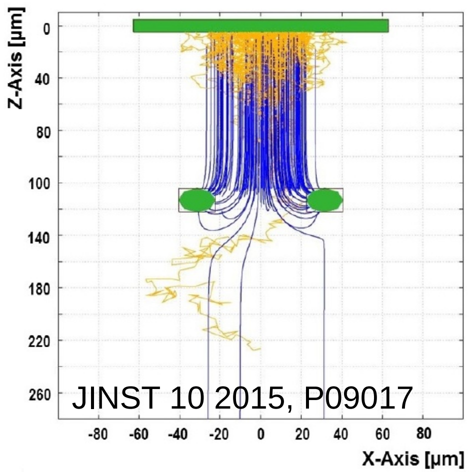


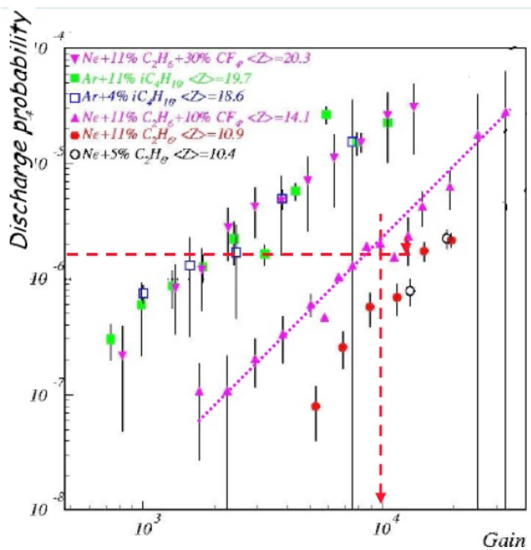
Micromegas

MM invented by Y. Giomataris, et al. (NIMA 376, p. 29-35, 1995)

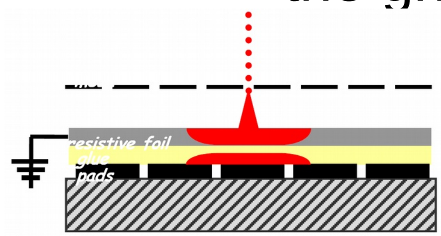


Micromegas consist of a mesh placed 20-250 µm above the readout pads. Gas amplification takes place in the gap between the grid and the pads.





Discharge probability of the tracker of COMPASS: ~10^{-6}



NIM A581(2007) 254

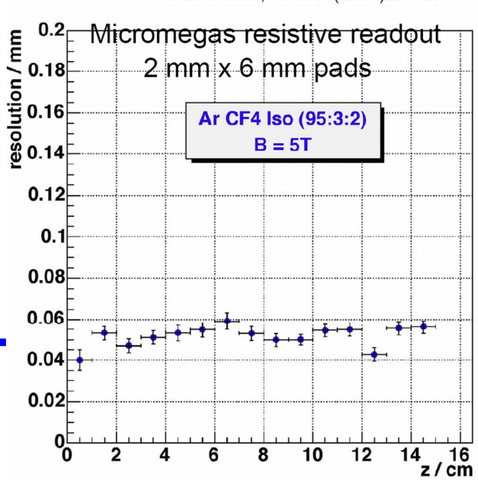
Resistive layer on pads spreads the charge

→ fewer sparks

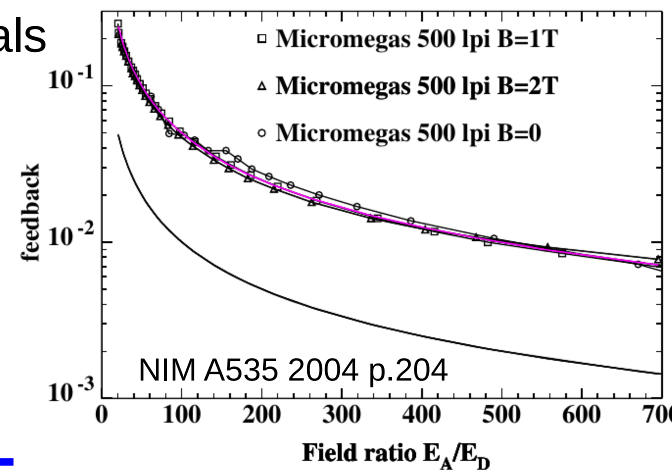
→ wider signals

B= 5 T D_T= 19 µm/√cm

M. Dixit et al., NIM581(2007)254-257



Low ion backflow



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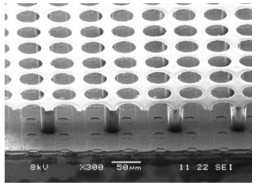

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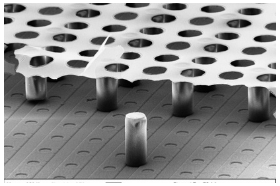

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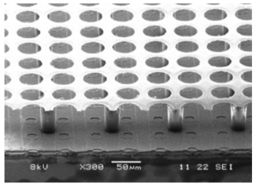
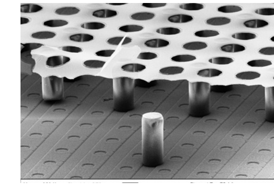
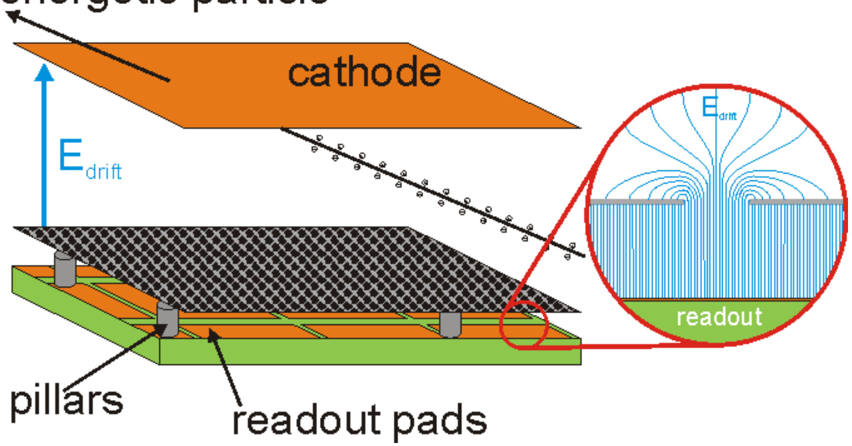


From Micromegas to GridPix





Could the spatial resolution of single electrons be improved?

$Ar:CH_4$ 90:10 → $D_t = 208\ \mu m/\sqrt{cm}$

→ $\sigma = 24\ \mu m$

Ar:iButane 95:5 → $D_t = 211\ \mu m/\sqrt{cm}$

→ $\sigma = 24\ \mu m$

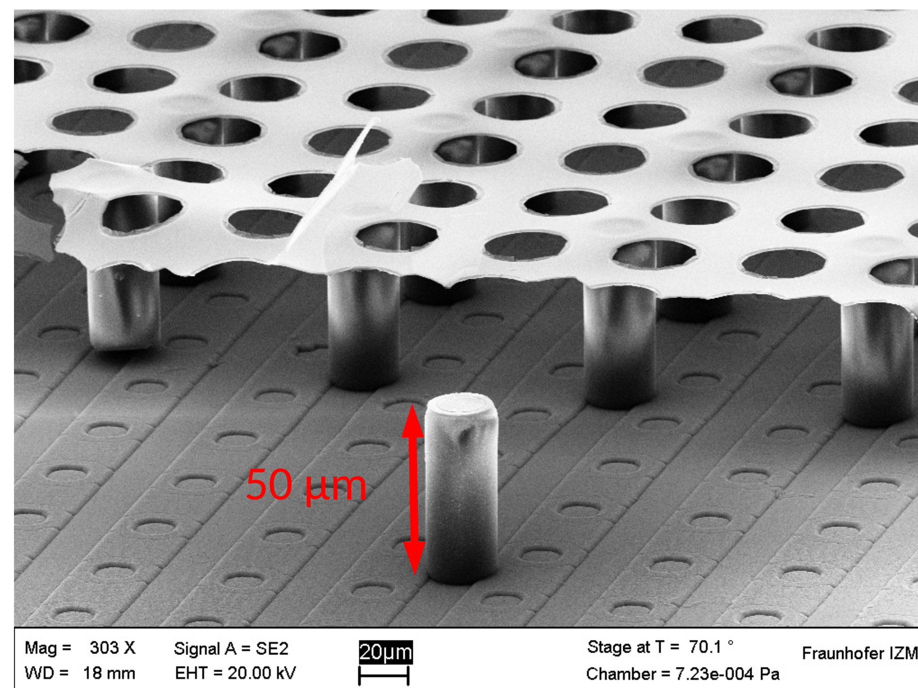
Smaller pads/pixels could result in better resolution!

The GridPix was invented at Nikhef.

Standard charge collection:

- Pads of several mm²
- Long strips (l~10 cm, pitch ~200 µm)

Instead: Bump bond pads are used as charge collection pads.



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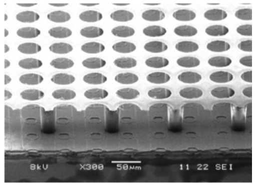
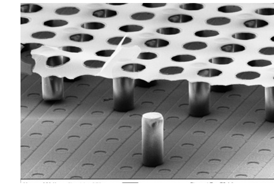


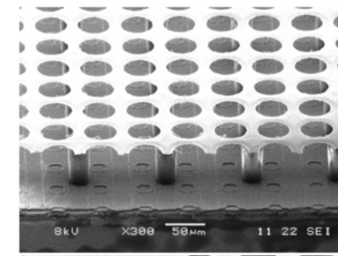
History/Nomenclature

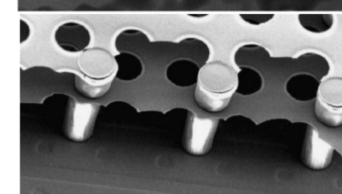


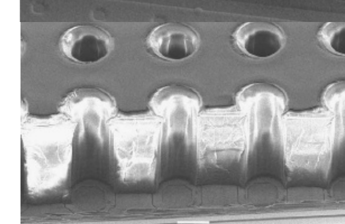
MPGDs with Pixel readout: 200 µm pad realized in PCB-technology (NIMA 513, pp. 231, 2003)

Gas Pixel Detector (GPD): single GEMand dedicated CMOS ASIC (NIMA, 566, pp. 552,2006)

Timepix / Medipix2: CMOS-ASIC designed by the Medipix collaboration, originally planned as an imaging chip for medical applications (NIMA 581, pp. 485, 2006)







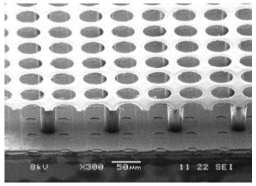
InGrid: Integrated Grid: Micromegas structure built on top of pixel chip with industrial postprocessing techniques (NIMA 556, pp. 490, 2006)

GridPix/GasPix: complete detector based on InGrids + Pixel chip including cathode, gas volume etc.

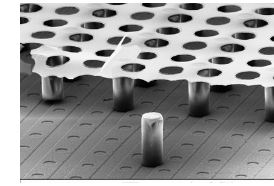
TwinGrid: two grids on top of each other (NIMA 610, pp. 644, 2009)

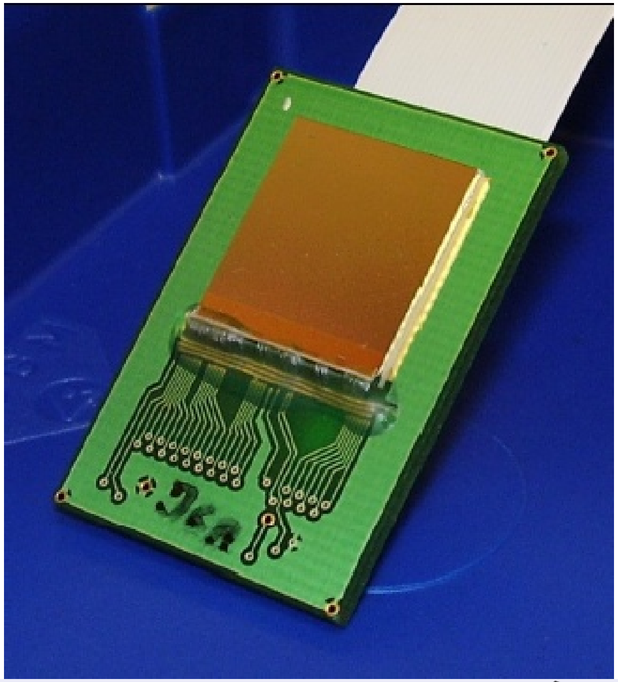
GEMGrid: Same as InGrid, but grid rests on solid layer with holes, instead of pillars (NIMA 608, pp. 96, 2009)

Gossip: Gas On Slimmed Silicon Pixels, a very thin GridPix detector with minimal material budget, e.g. 1 mm of gas gap, thinned ASIC



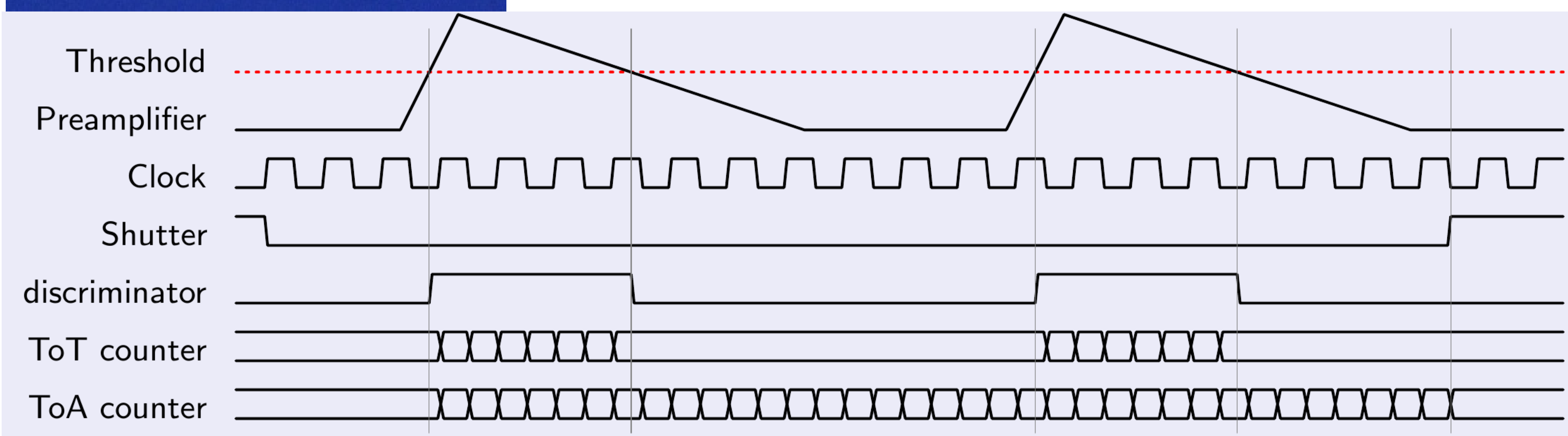
Timepix ASIC

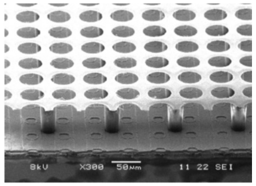




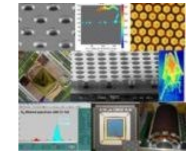
Number of pixels: 256 × 256 pixels
Pixel pitch: 55 × 55 µm²
Chip dimensions: 1.4 × 1.4 cm²
ENC: ~ 90 e⁻

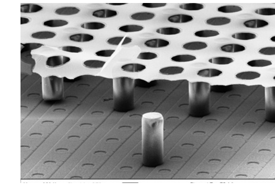
Limitations: no multi-hit capability, charge and time measurement not possible for one pixel.
Each pixel can be set to one of these modes: TOT = time over threshold (charge)
Time between hit and shutter end.





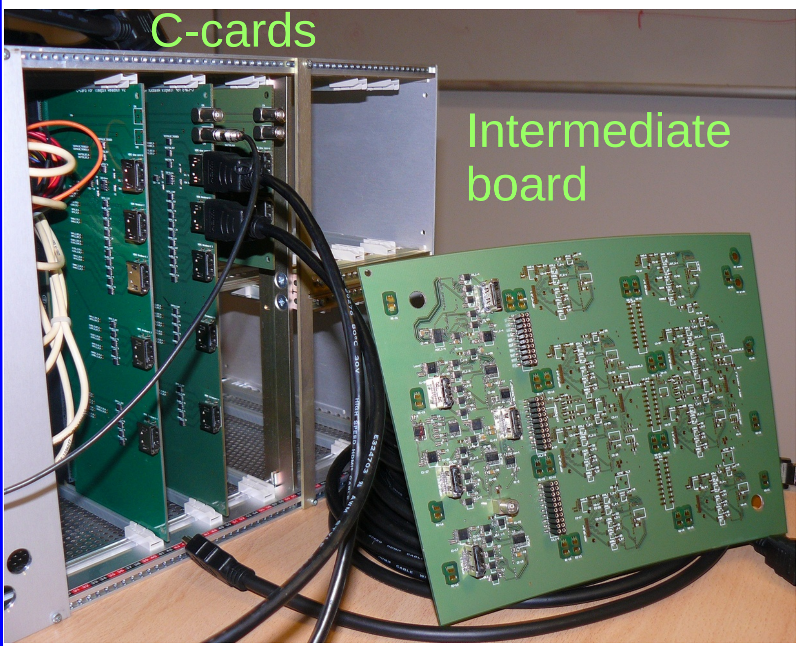
Timepix Readout

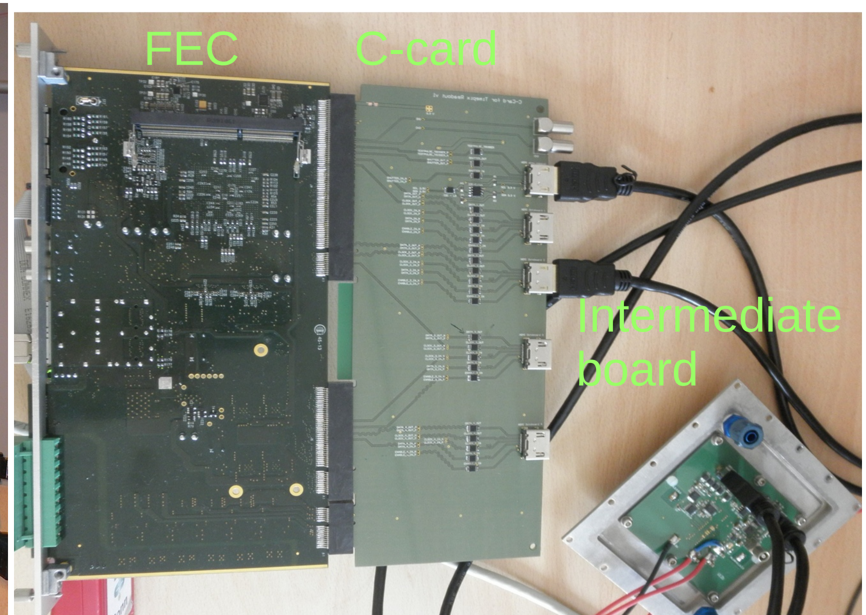




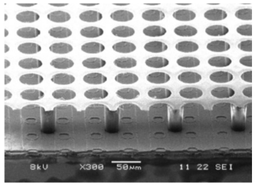
We have built a readout system based on the Scalable Readout System of RD51, because it is easy to scale, cheap and optimized for R&D.

Idea of SRS: produce flexible readout electronics, which can handle different chips (new FPGA code, chip carrier), which many groups can use.
New C-Card, intermediate board, and chip carriers were designed for Timepix.
Now up to 32 Timepix ASICs can be used per FEC/C-card.

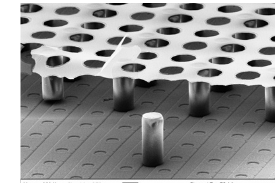




A small-size system using the same FPGA code and most of the hardware can be based on a Virtex6 evaluation board. This is used in CAST.

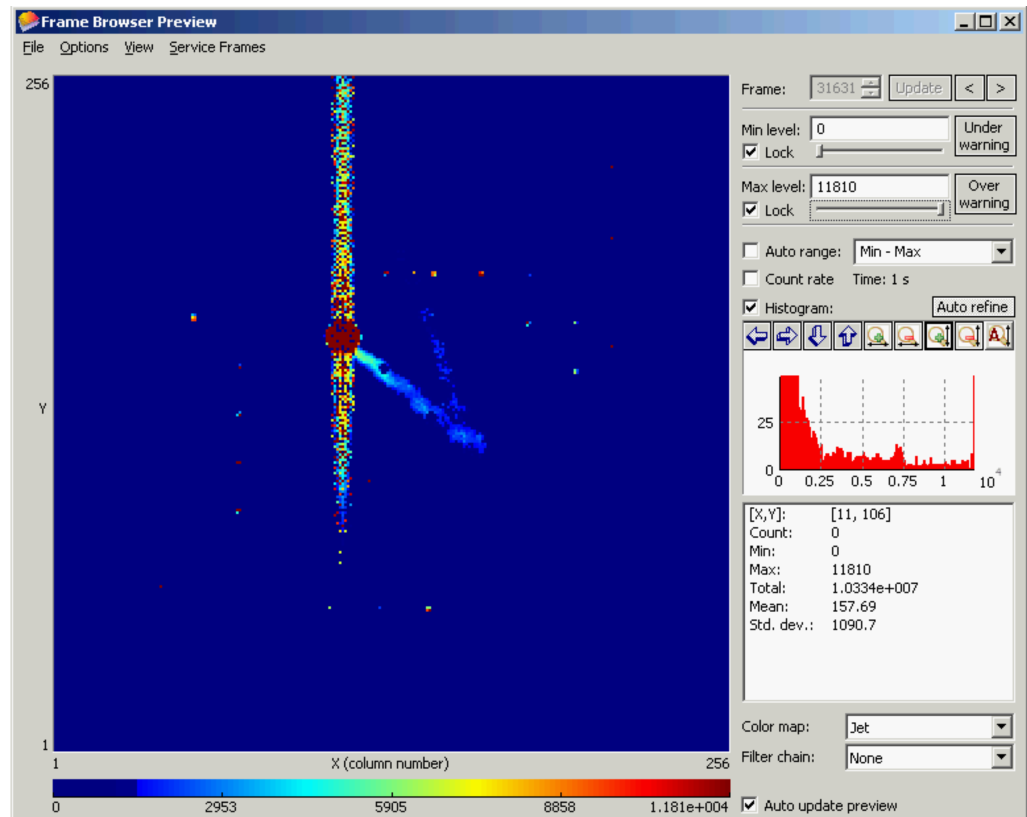


Protection Layer



Discharges triggered for example by highly ionizing particles could easily destroy the chip. The charge collected by one pixel was too high.

A protection layer is placed on the chip to disperse the charge on many pixels and thus lower the input current per pixel. Besides, the charge is removed slowly and thus quenches the discharge.

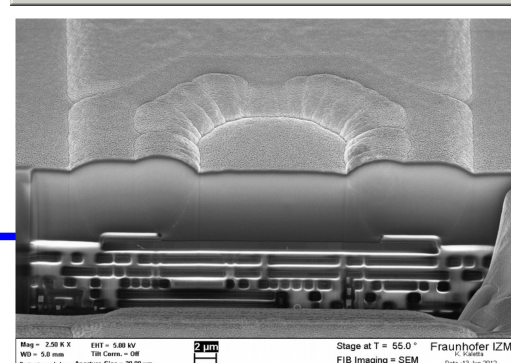


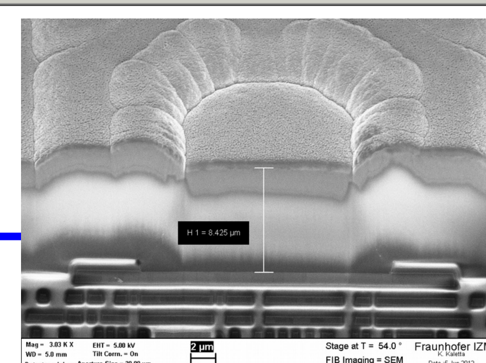
<u>high resistive material</u>

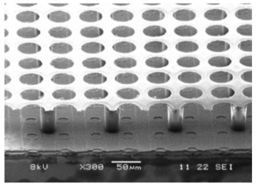
15 µm aSi:H ($\sim 10^{11}$ Ω·cm)

8 µm Si_XN_Y ($\sim 10^{14}$ Ω·cm)

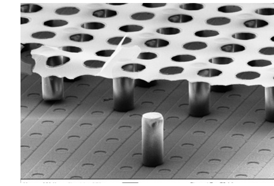
Chips survives several thousand discharges triggered by α-particles.



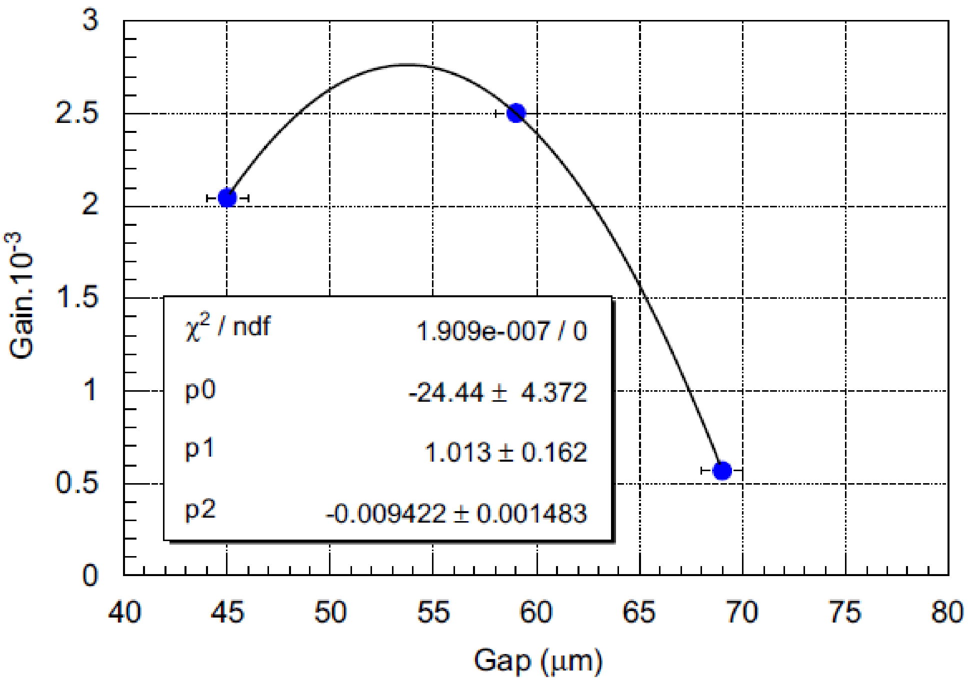




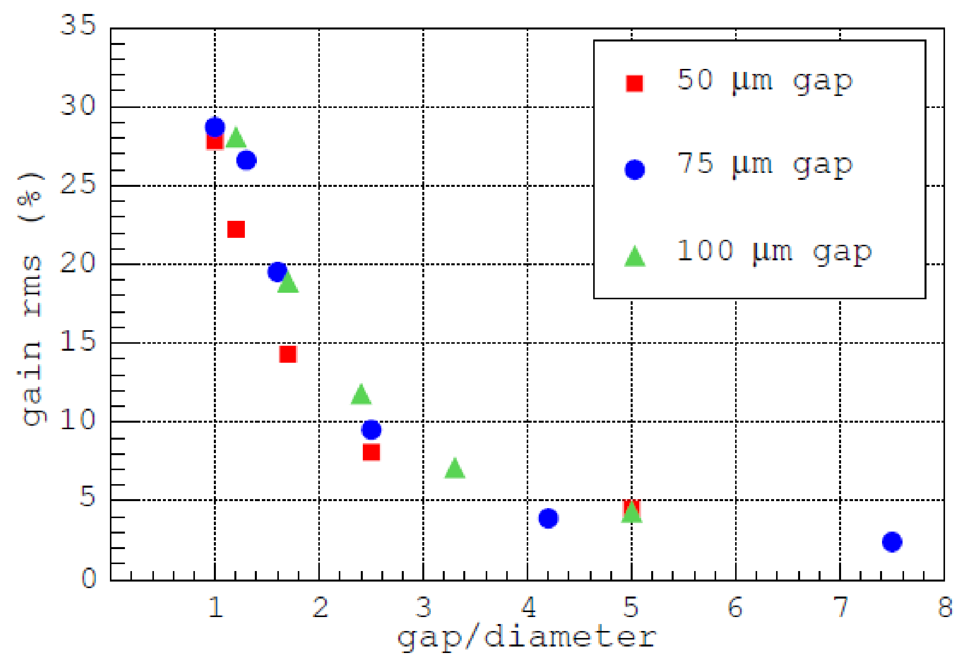
Optimization of InGrids



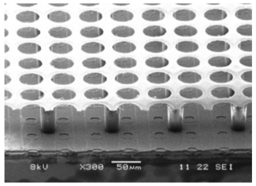
Detailed studies have been performed to optimize the layout of the structure. (NIMA 591, pp. 147, 2008, PhD. Thesis of M. Chefdeville, NIKHEF)



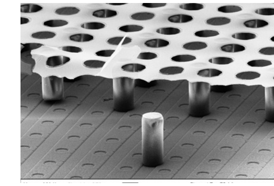
The influence of the gap size and hole diameters on gain, energy resolution, ion feedback and collection efficiency were measured.



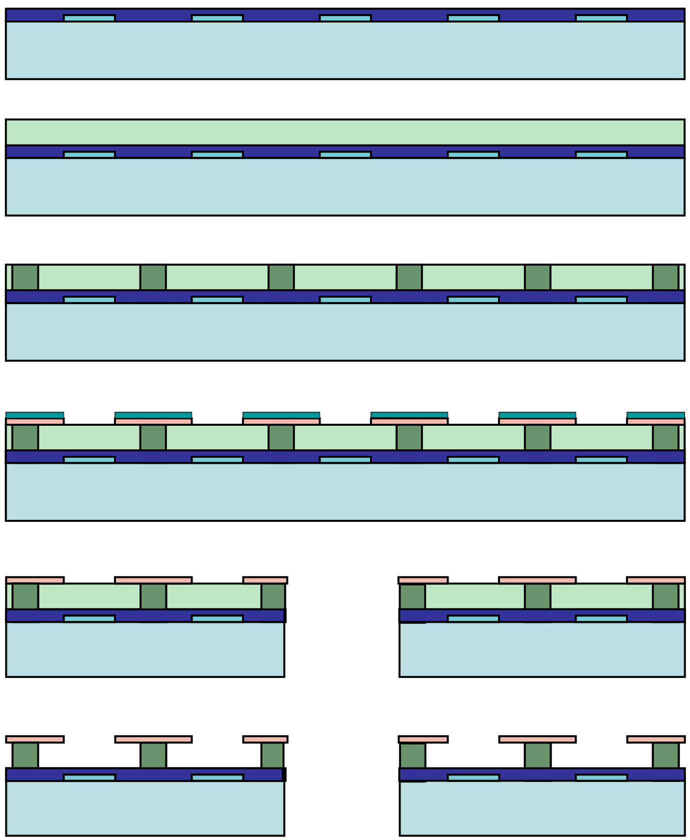
Also the layout of the supporting structures (pillars and dikes) was optimized to give the highest mechanical strength.



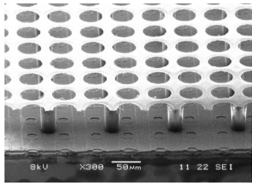
Wafer-based Production



Production at Twente was based on a 1 to 9 chips process.
This could not satisfy the increasing demands of R&D projects.
A new production was set up at the Fraunhofer Institut IZM at Berlin.
This process is wafer-based → 1 wafer (107 chips) is processed at a time.



1. Formation of Si_xN_y protection layer
2. Deposition of SU-8
3. Pillar structure formation
4. Formation of Al grid
5. Dicing of wafer
6. Development of SU-8



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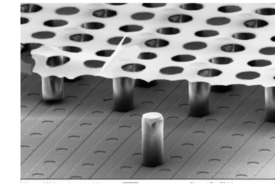
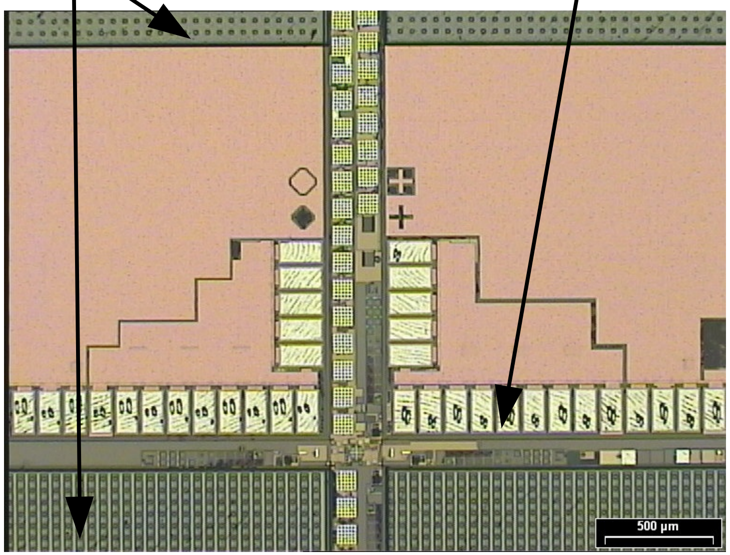


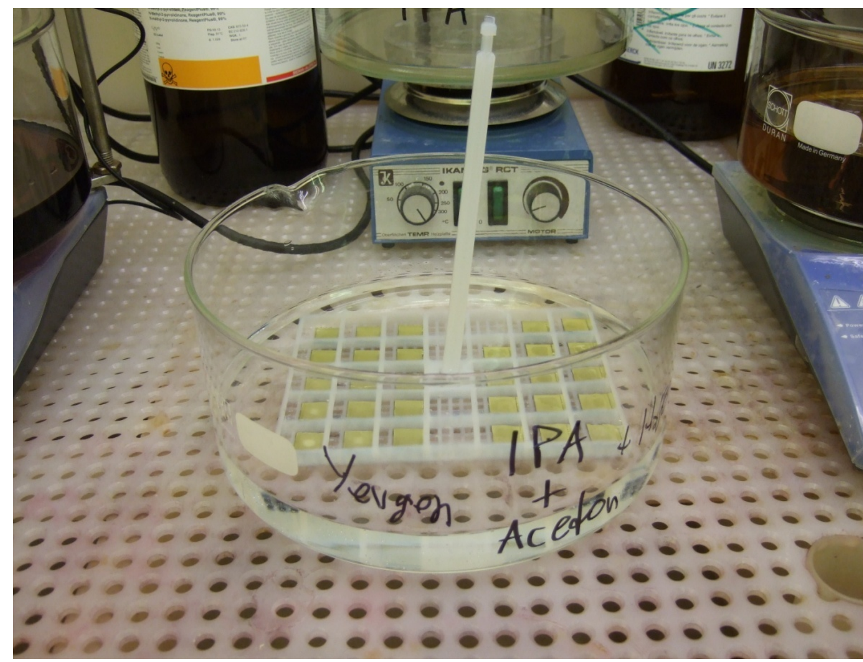
Main challenges: - Formation of layers, in particular protection layer
- Deposition of Al
- Final development of SU-8 → still chip-based

SiRN should not cover bond pads

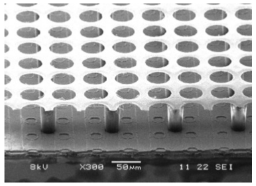


First tests: mechanical mask
→ failed due to thermal stress
<u>Better:</u> polyimide mask chem. removed

After development of pillars, the grid is too fragile for dicing

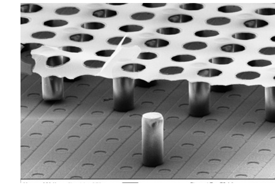


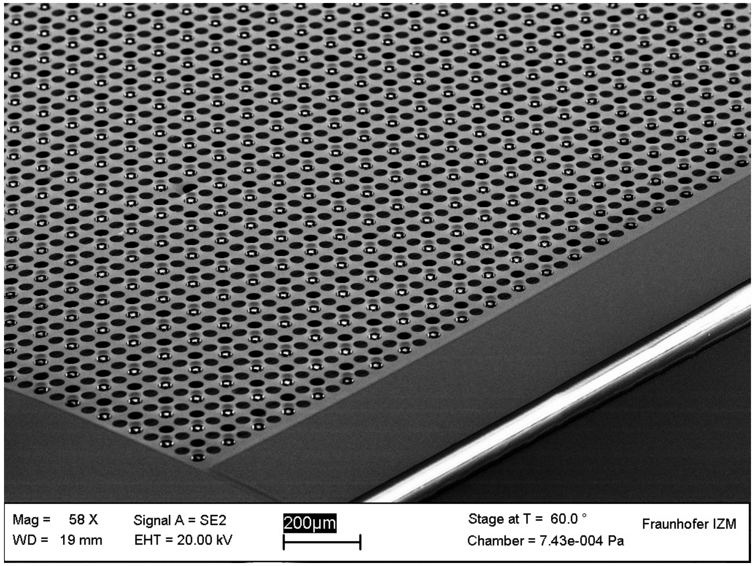
Time consuming

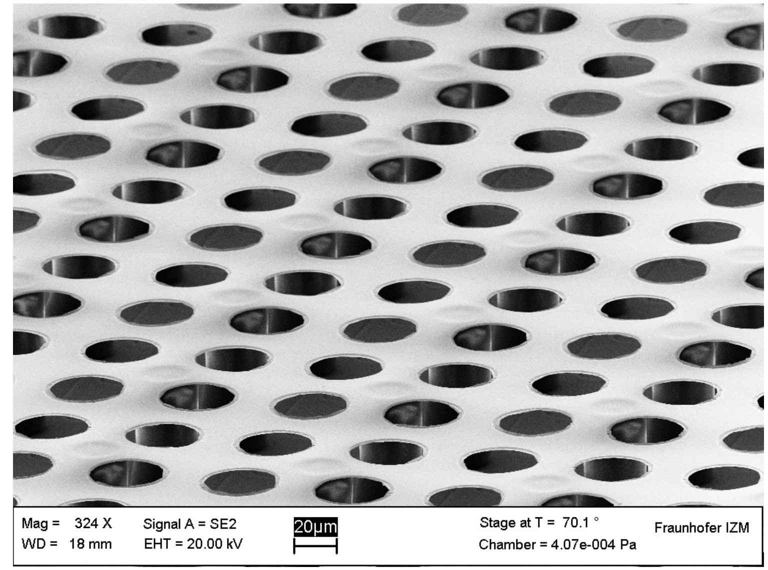


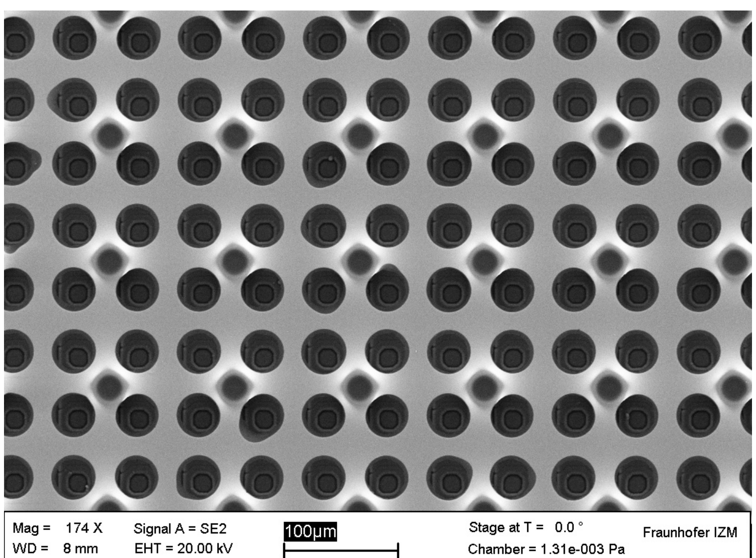
SEM Pictures

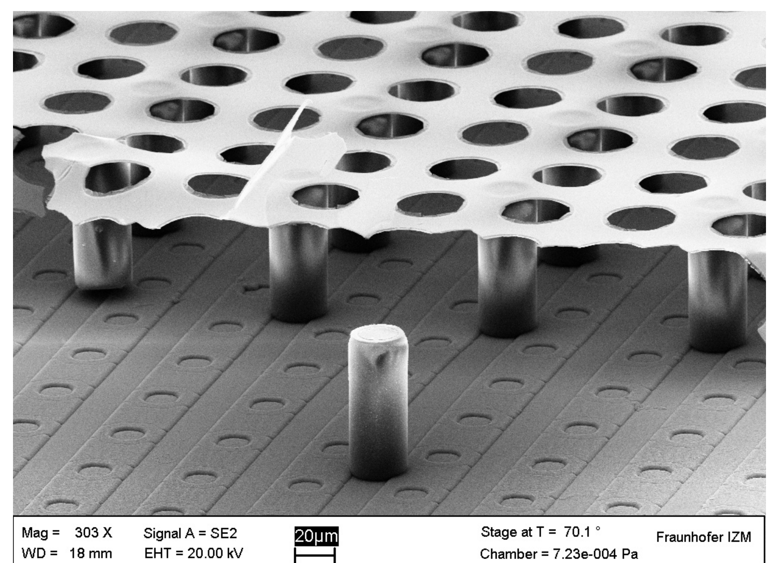
Fraunhofer IZM

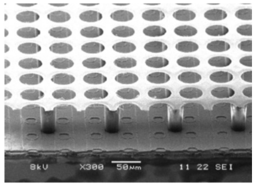




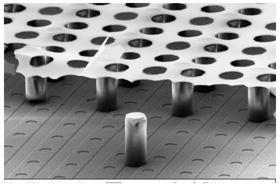








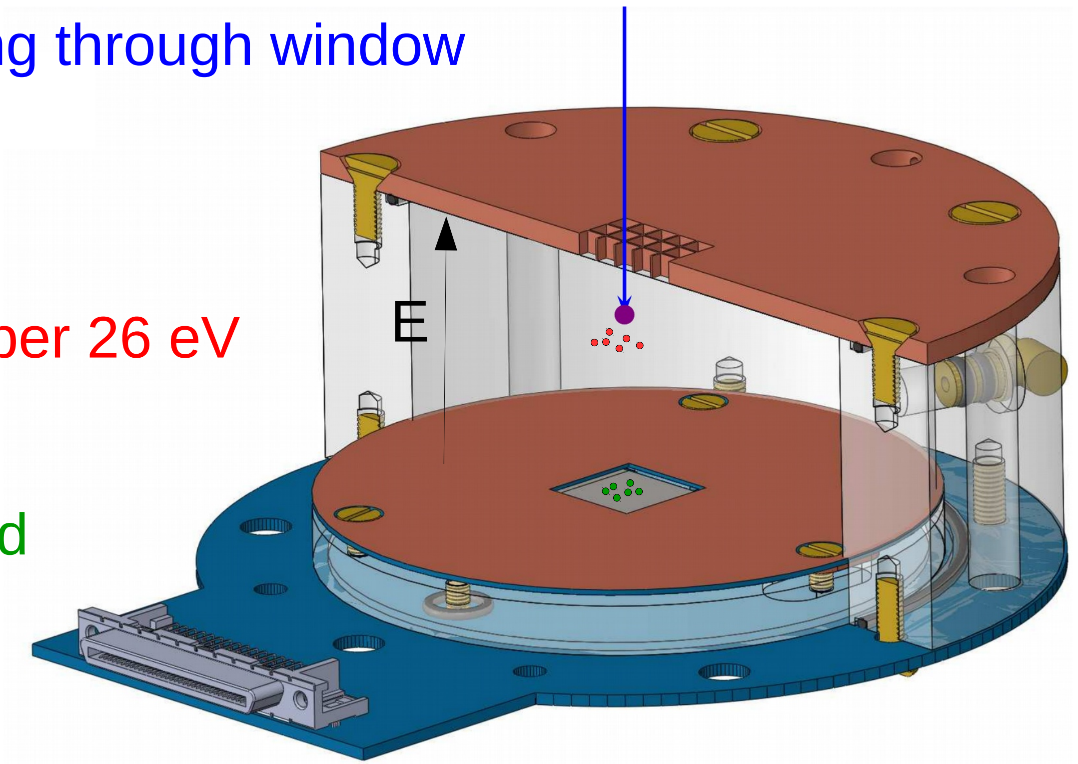
Working Principle



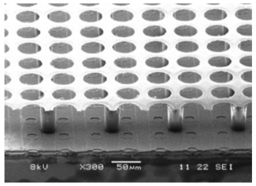
X-ray photon entering through window

Hitting a gas atom
Primary electrons 1 per 26 eV
Drift in E field

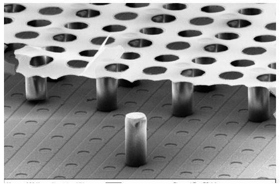
Gas amplification and
electron detection

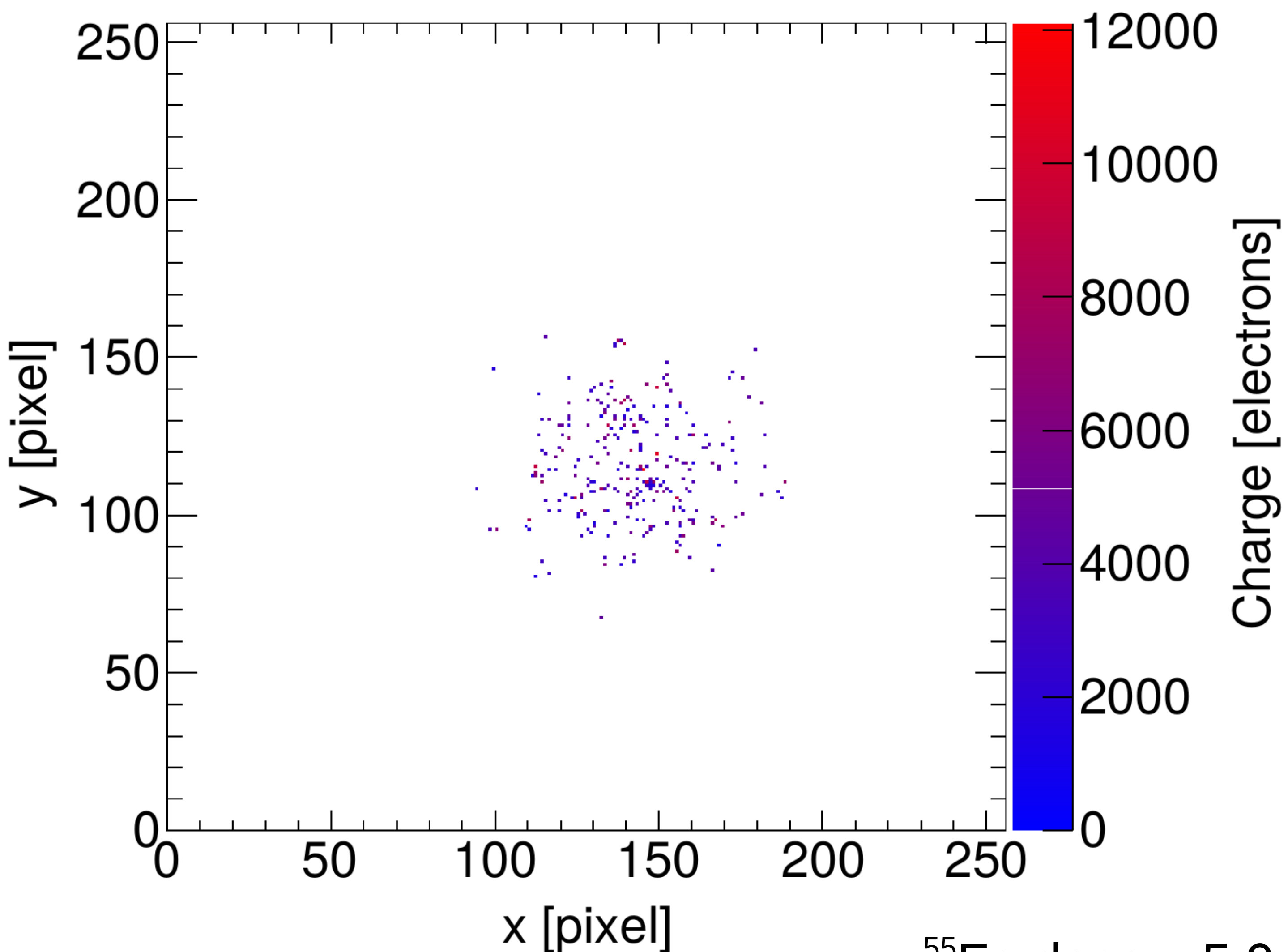


In principle photons of energy ~26 eV could be detected. But single pixels could be mistaken for noise → three pixels close by are probably enough.
But photons of 78 eV do not pass through the window.
They have to be produced internally.



1 Event

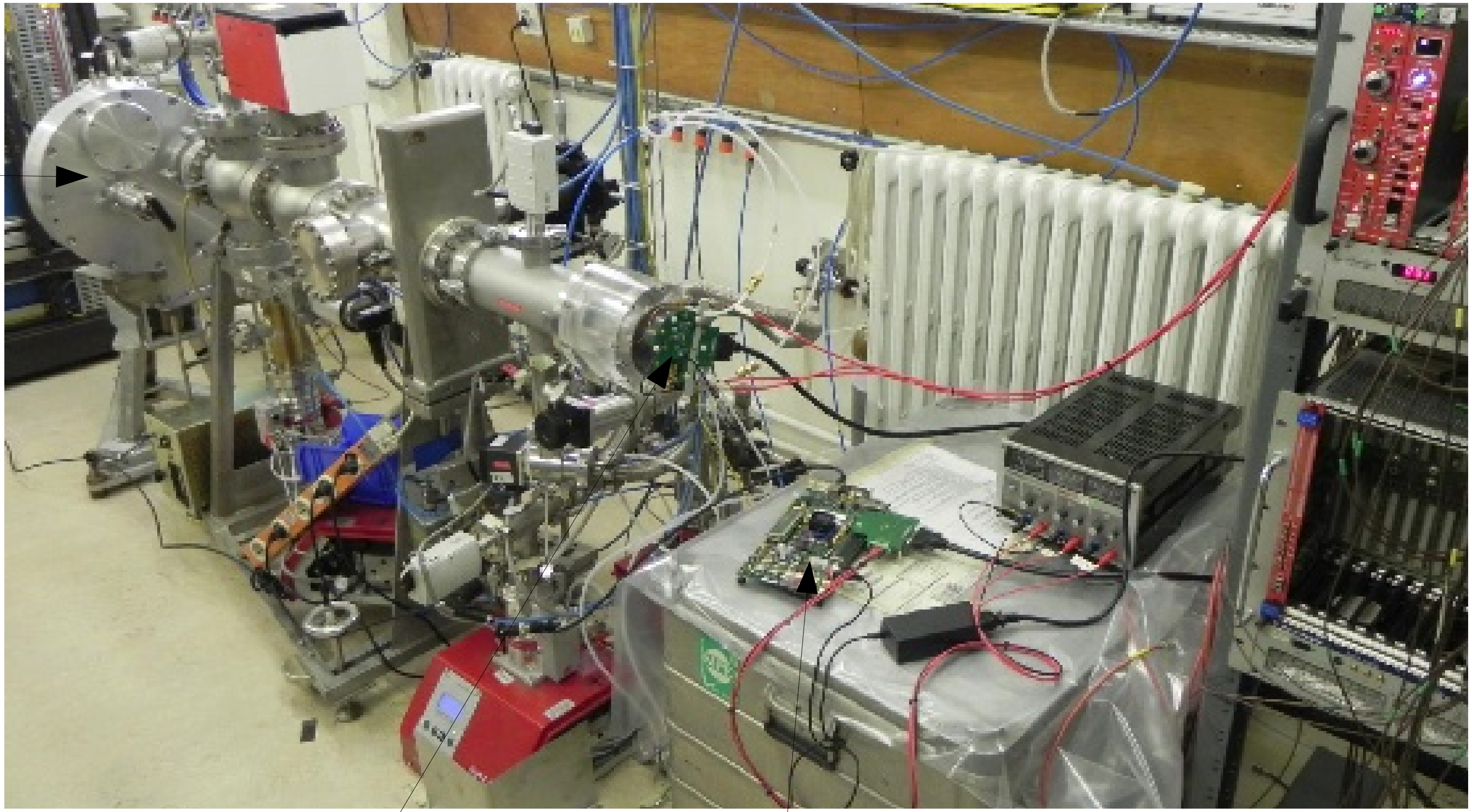




^{55}Fe decay: 5.9 keV photon
→ ~225 electrons

Tests with variable X-ray Generator

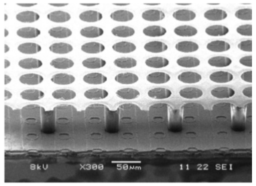
CAST Detector Lab has an X-ray tube with exchangeable targets and filter wheels. => monochromatic X-ray lines down to few hundred eV.
Vacuum system allowing for differential pumping



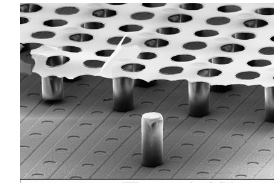
Filter wheel

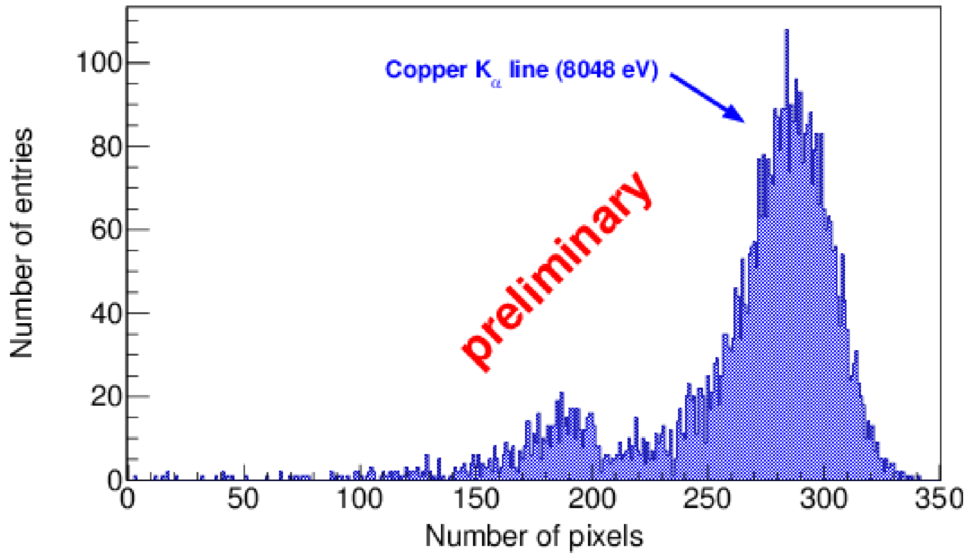
Detector

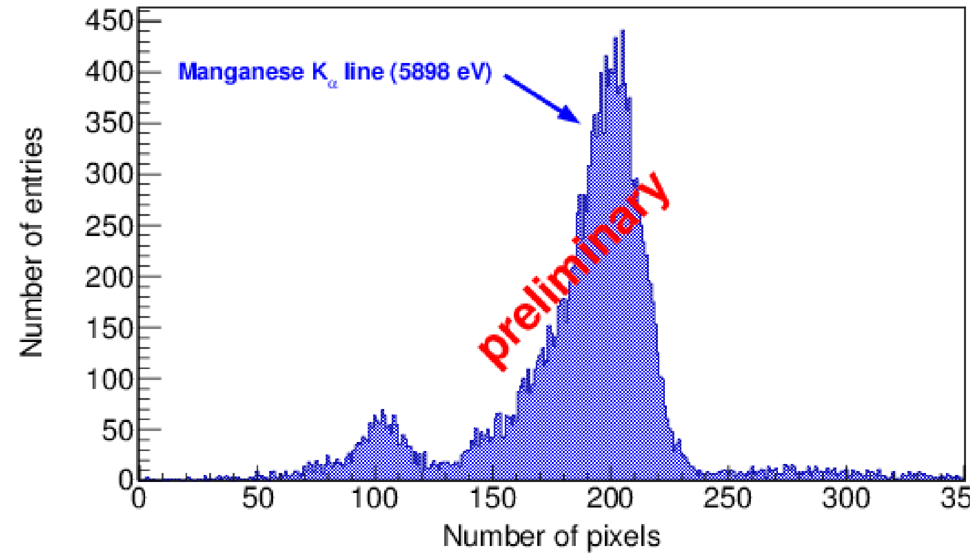
Readout system

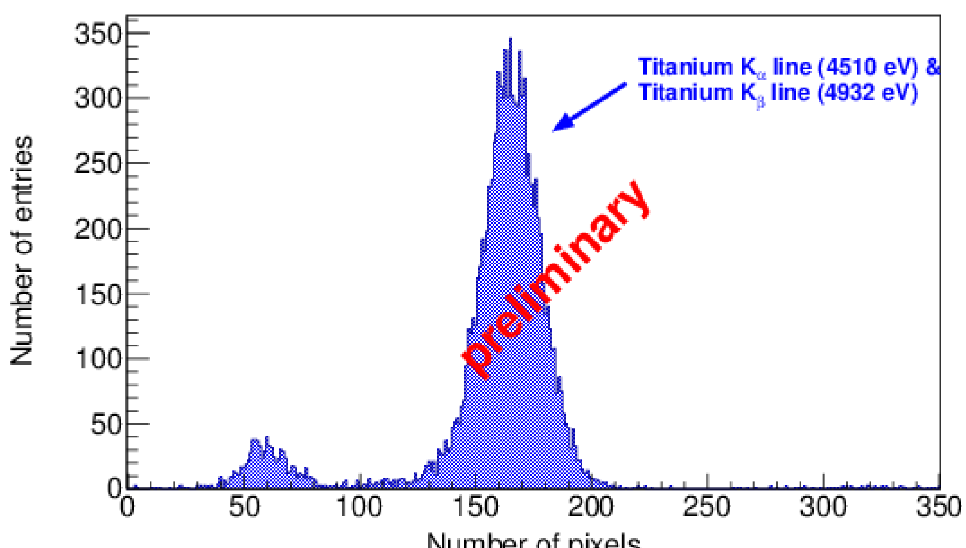


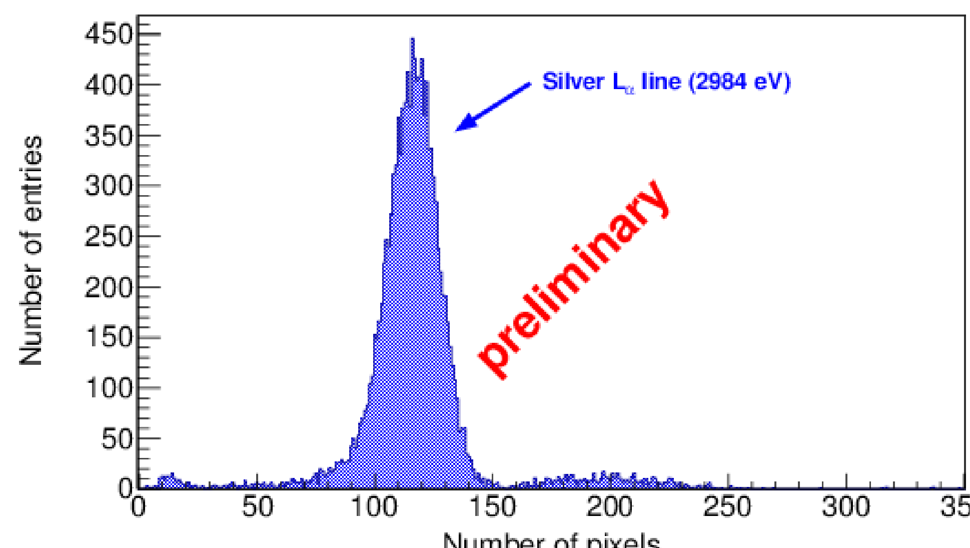
Some X-ray Lines

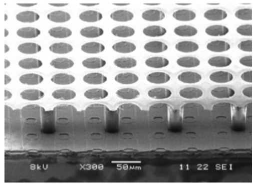




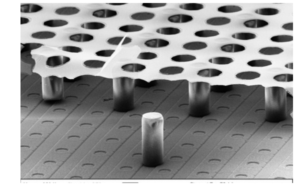


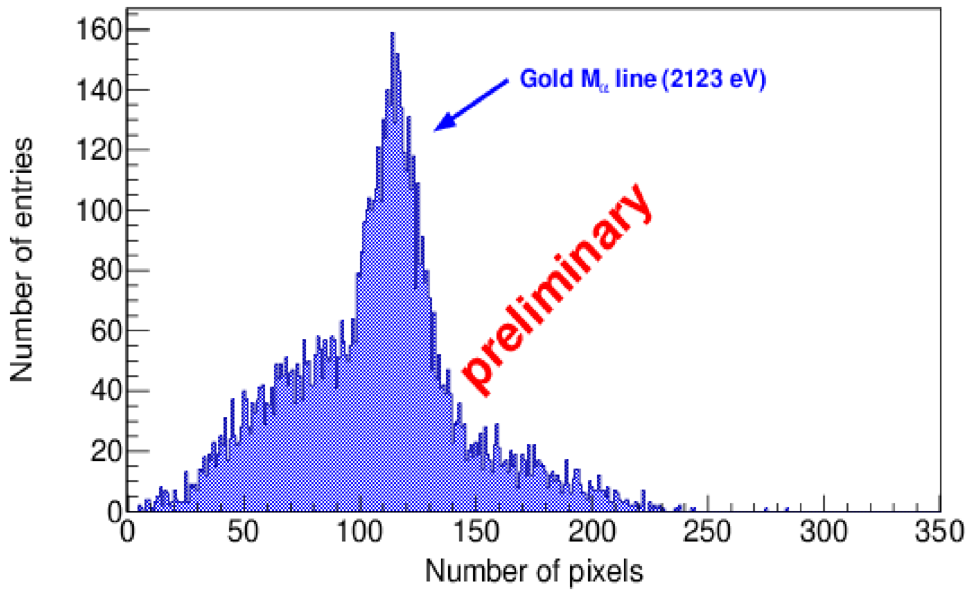


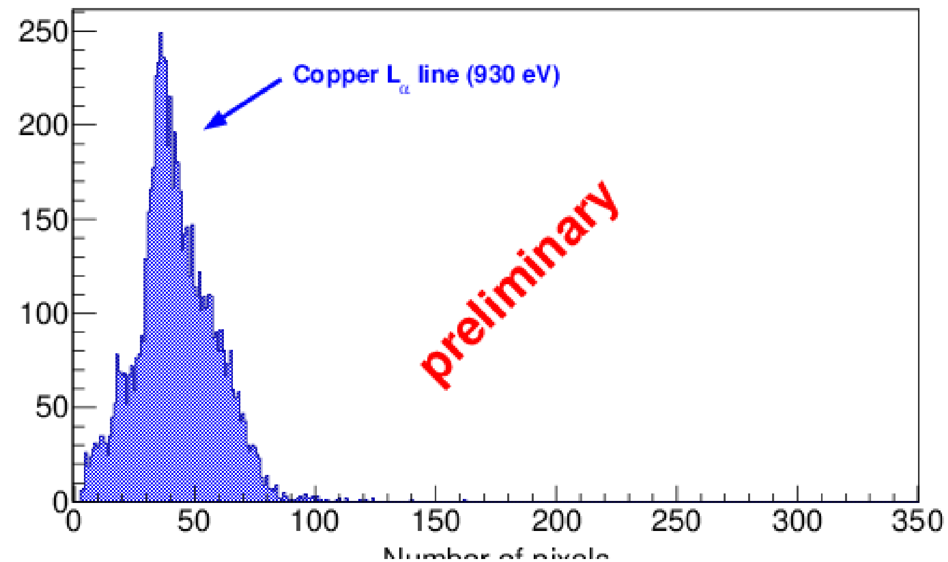


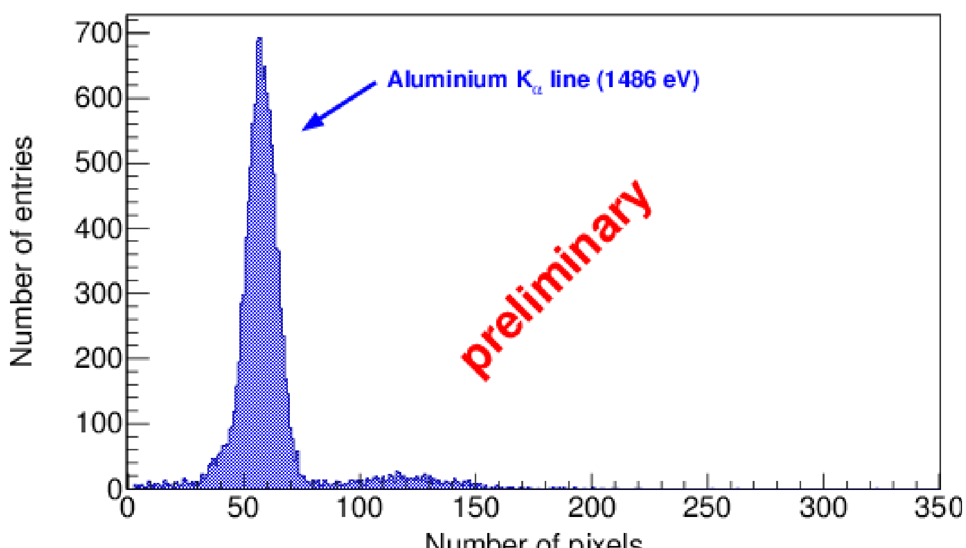


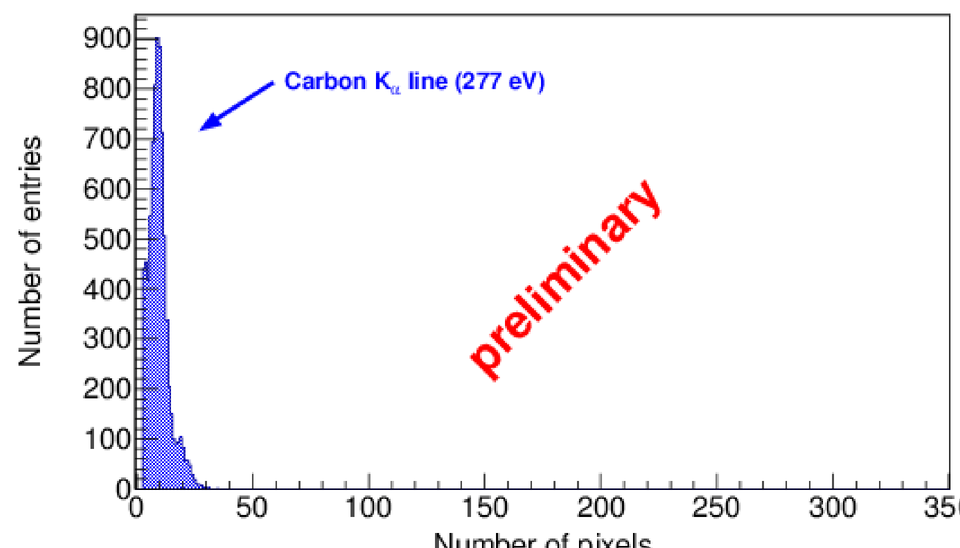
More X-ray Lines

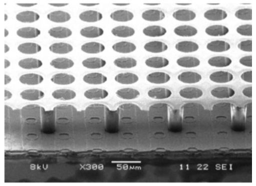




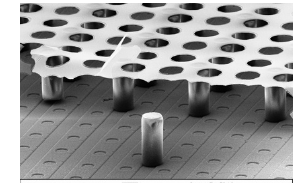




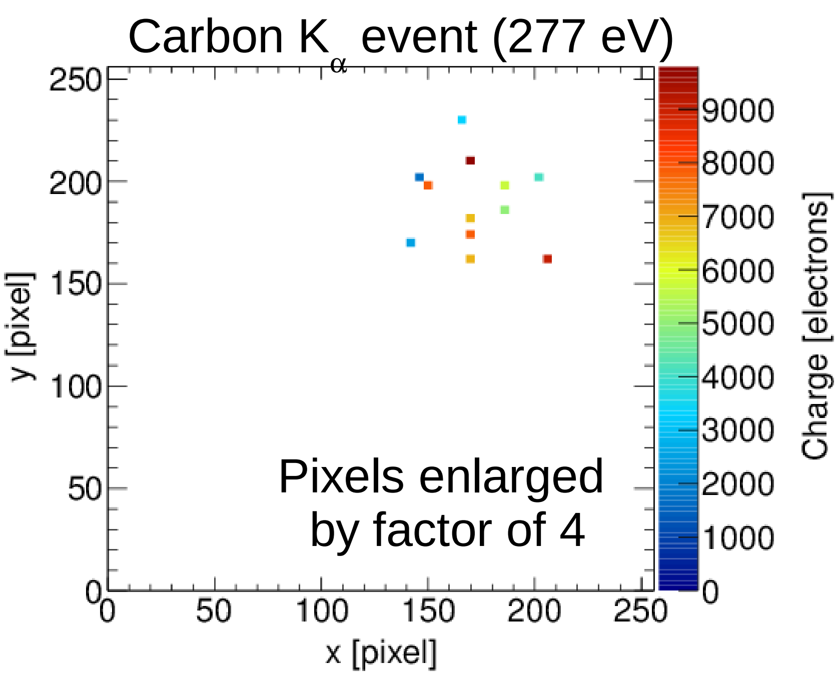


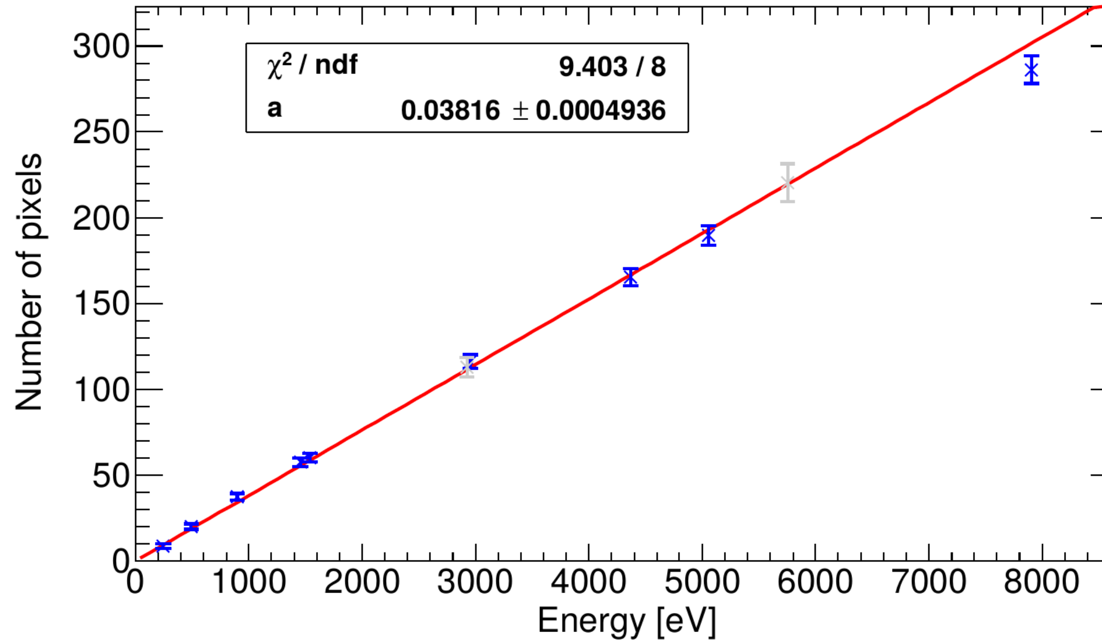


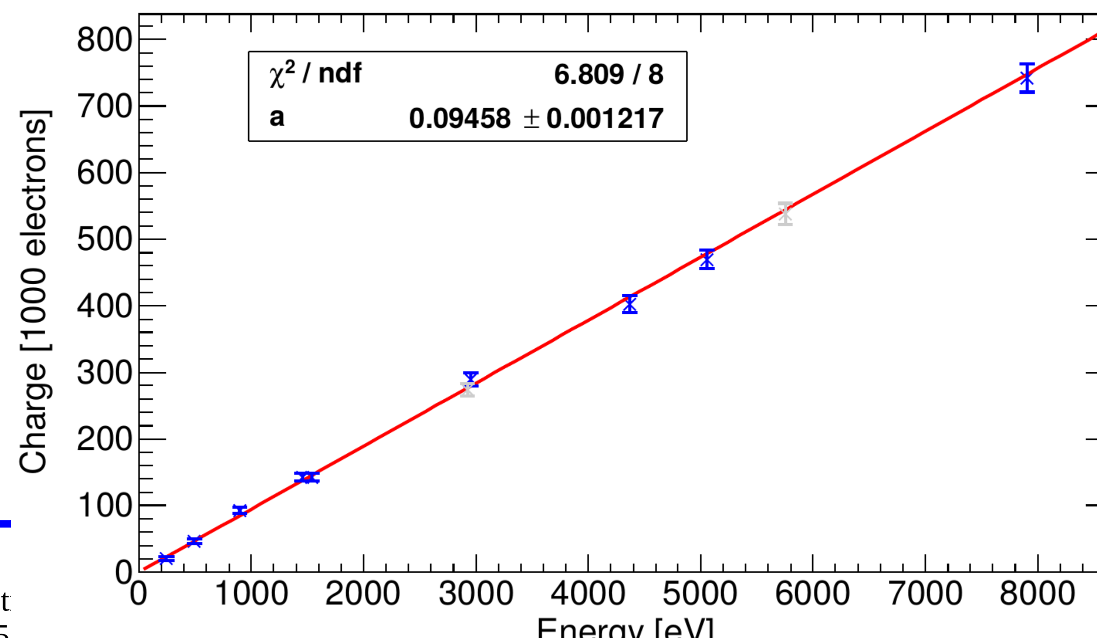
Energy Calibration



Pixel counting starts failing, if diffusion is not large enough and more than 1 electron ends upon a pixel.
Energy measurement based on collected charge still works fine.







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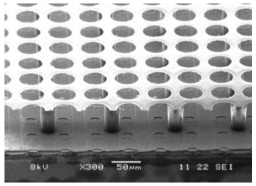
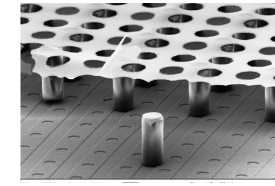
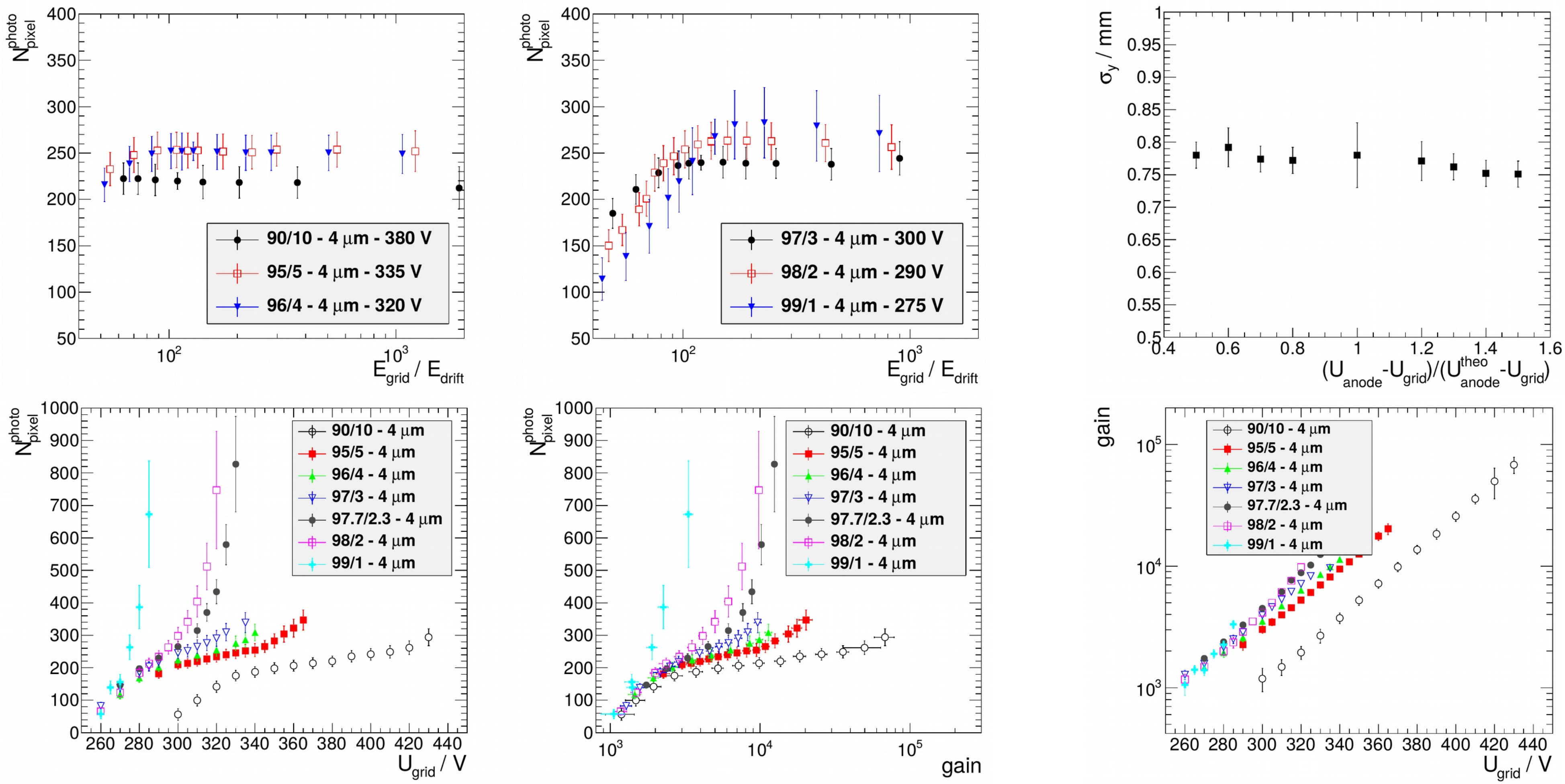
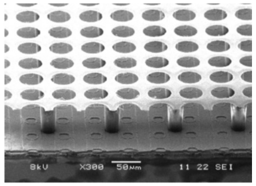


Energy Resolution

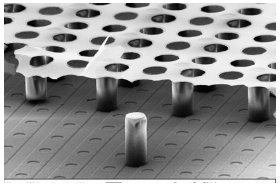


Different gas mixtures, electrical fields and gas gains were studied and good settings for the energy resolution were found.

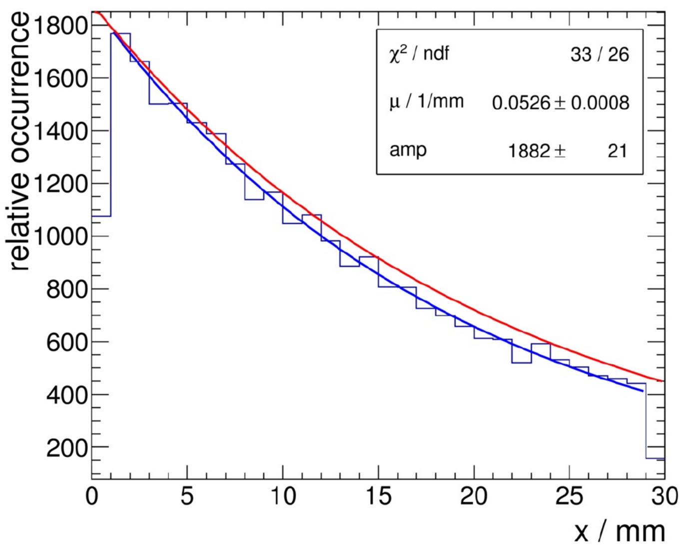


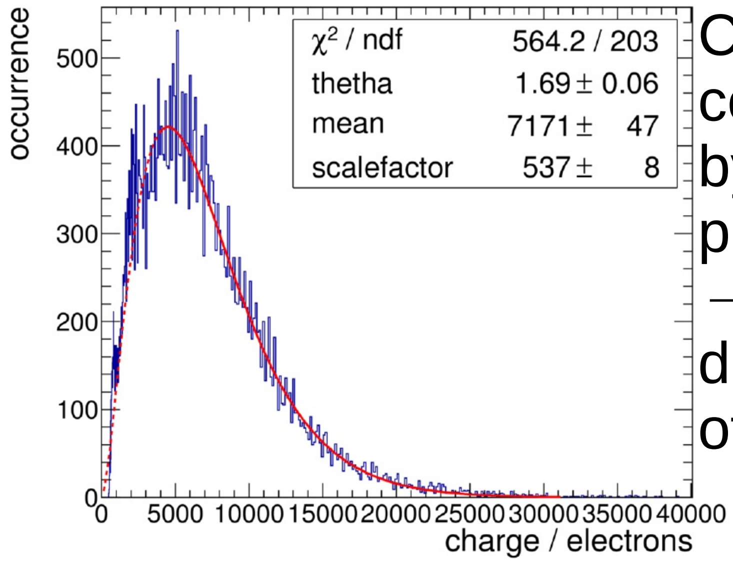


Energy Resolution



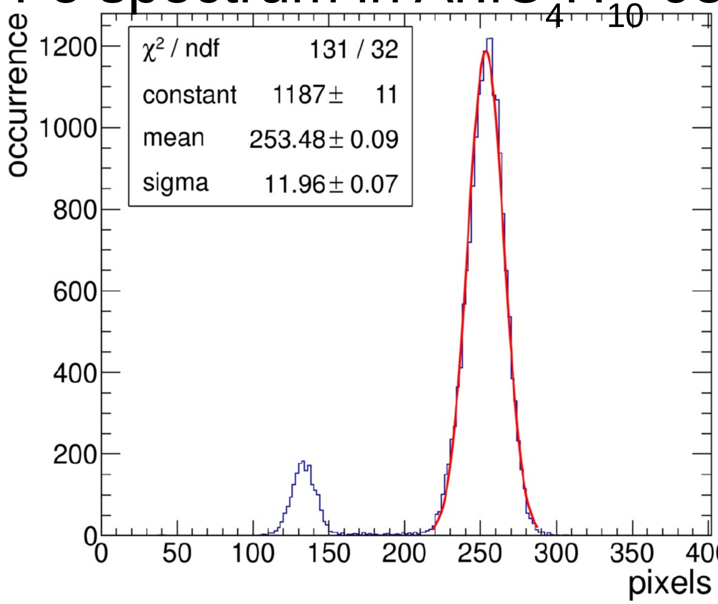
Measurement of absorption length by using cluster sizes as a measure of drift length.

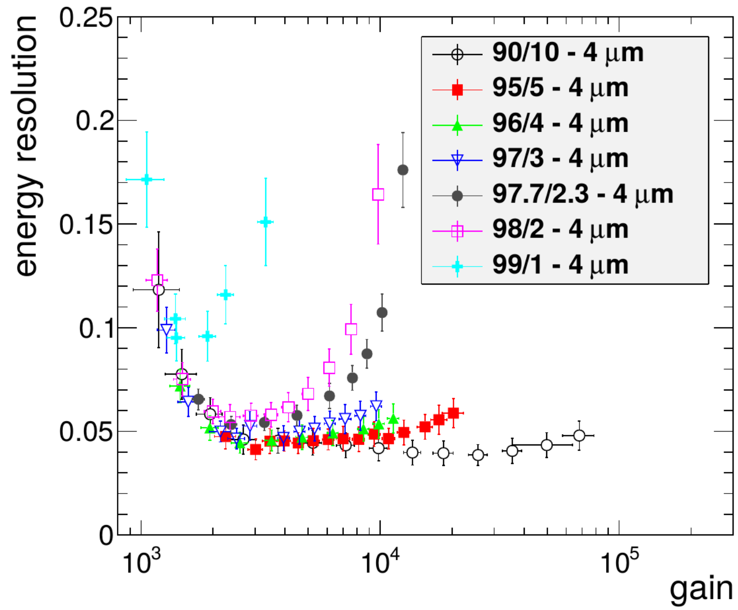




Charge collected by single pixels → Polya distribution of gas gain

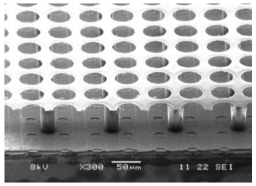
^{55}Fe spectrum in Ar:iC$_4$H$_{10}$ 95:5



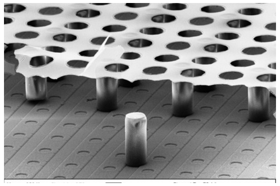


Energy resolution of 5.9 keV photons in various Ar:iC$_4$H$_{10}$ mixtures.

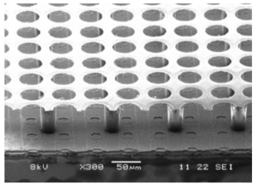
Energy resolution σ_E/E of down to 3.85 % was reached.



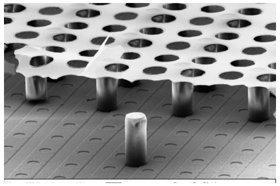
Content



- Historic Overview
- Working Principle of Gaseous Detectors
- GridPix Detectors
- X-ray Photon Detector for CAST
    - Axion search
    - CAST
    - X-ray detector for CAST
    - Performance
- TPC Readout for ILD
- Some Applications
- Summary



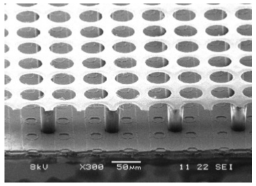
Axions



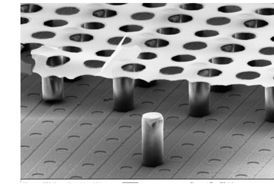
In principle the CP-violation we know from the weak force is not forbidden in the strong force. Measurements show however, that the relevant parameter which gives the strength of the violation is $\theta < 10^{-10}$ – so pretty small.
Theorists assume therefore there must be a reason why $\theta=0$ and the CP-violation is forbidden in strong interactions.

Theorists (Peccei and Quinn) introduced a scalar field, of which 3 parameters are used to explain why $\theta=0$. The fourth parameter materializes as a pseudo Nambu-Goldstone boson. (Sounds familiar?)

Since this theory cleans the Standard Model of the 'strong CP-problem' Frank Wilczek called it axion after the detergent.



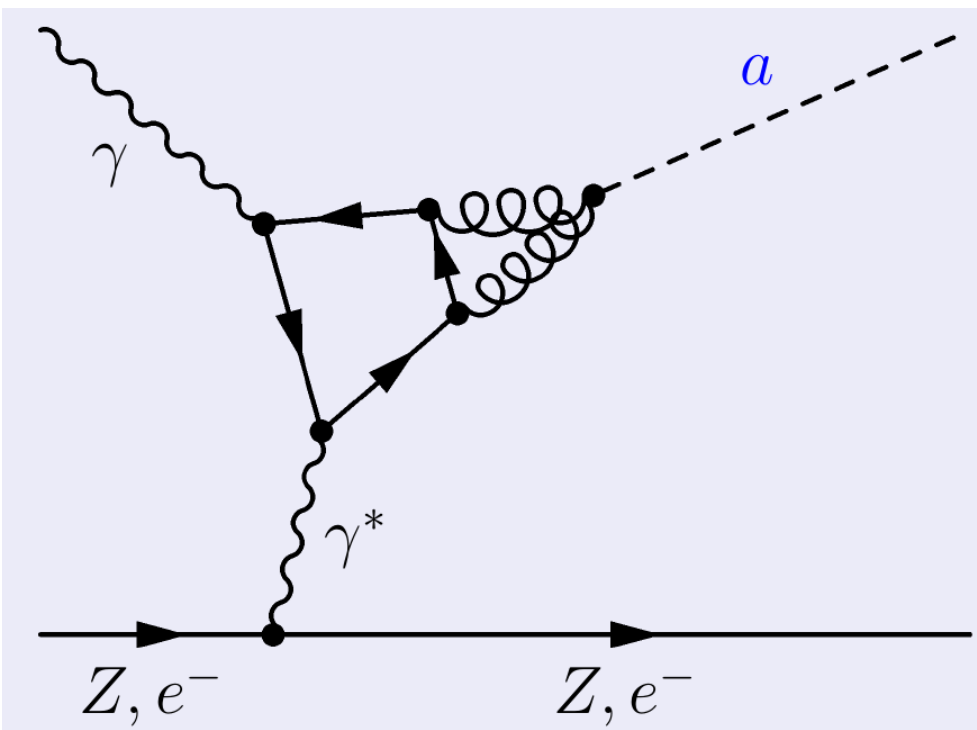
Axion Sources



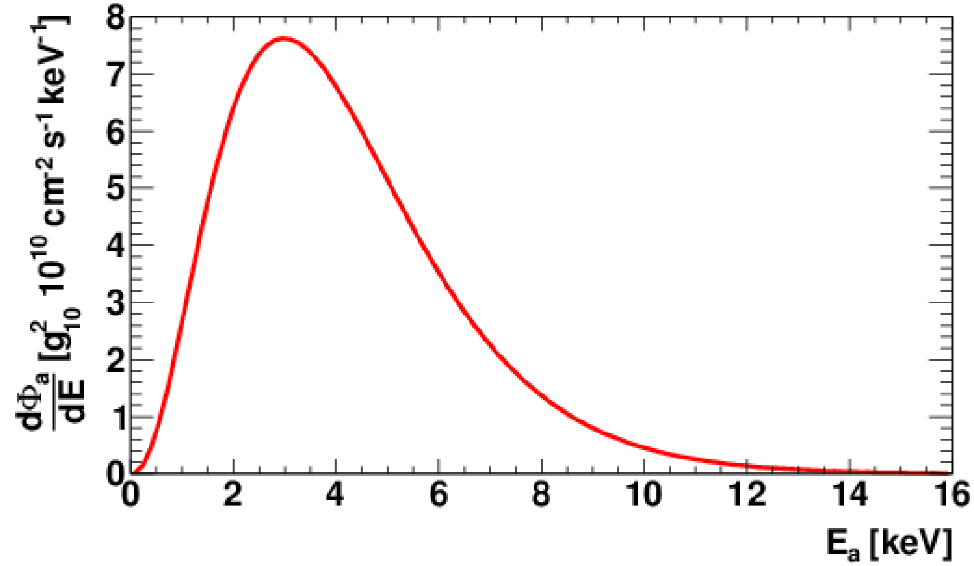
Axions can be produced for example via the Primakoff effect: A virtual photon and a real photon annihilate and form an axion via a quark loop and gluons. This process is allowed in all axion models.

One possible source of axions is therefore the interior of the Sun. There should be sufficient photons.

The axions can then escape the Sun unhindered.



The energy spectrum of the axions is determined by the temperature of the Sun's core.



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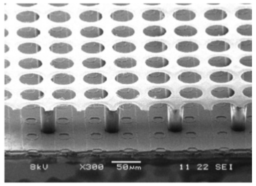
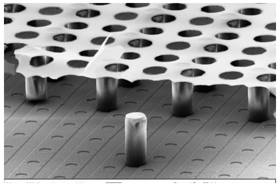
J. Kaminski
Instrumentation Seminar
15. April 2016, DESY

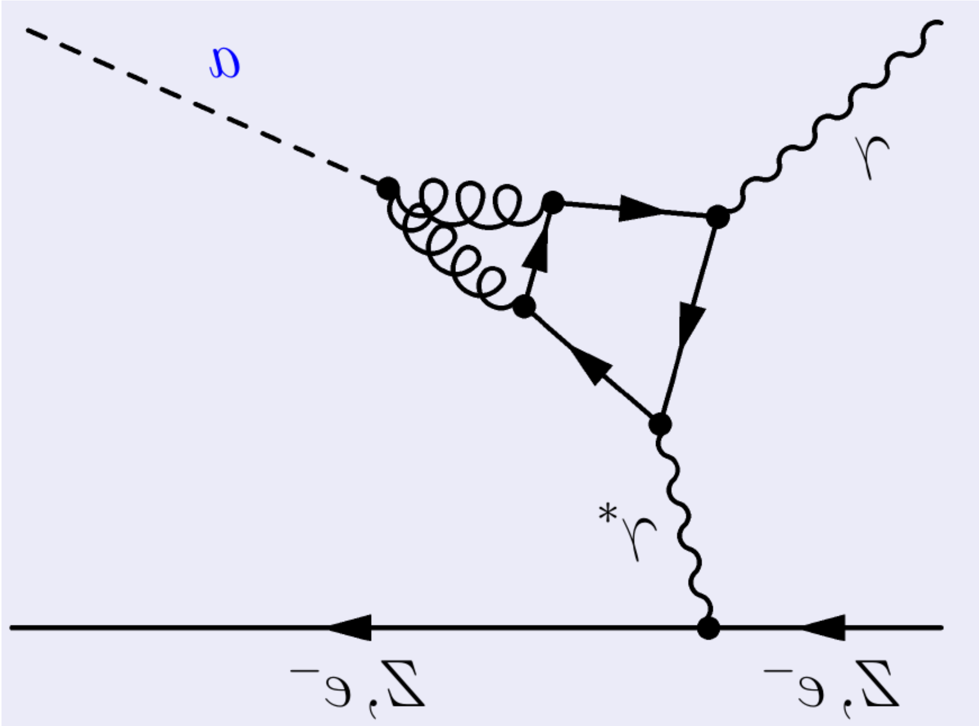


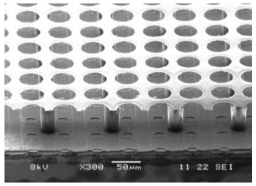
Axion Detection



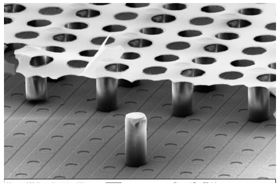
Axion detection uses the inverse Primakoff process: If an axion and a virtual photon annihilate and produce a real photon.

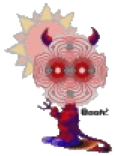
In contrast to the production, the detection must be done in (quasi) vacuum, since in matter the X-ray photons would be absorbed.
The virtual photons can be provided by a magnetic field.

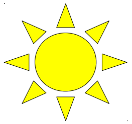




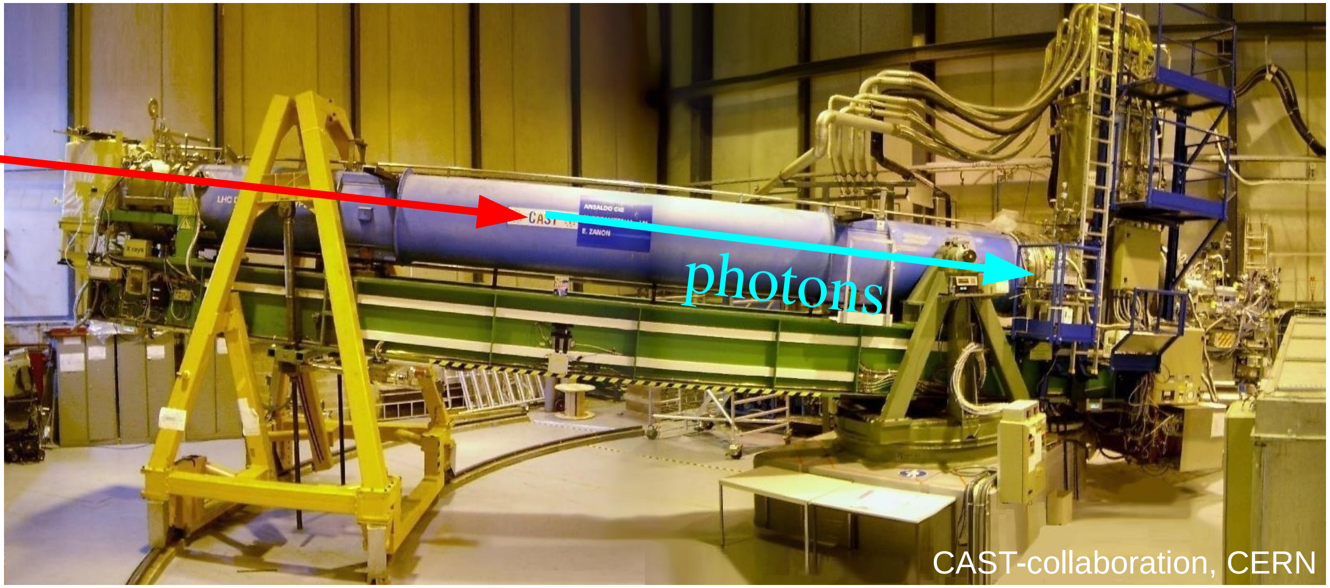
Helioscope: CAST

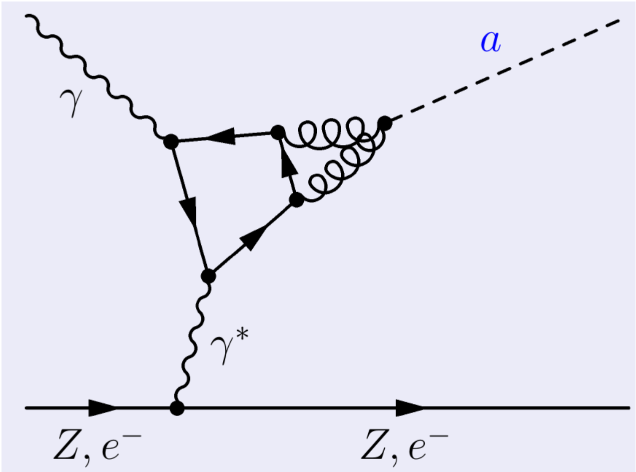






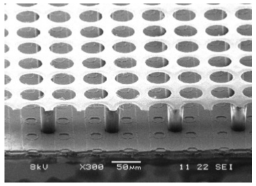
Decommissioned LHC-magnet is pointed to the sun. Axions produced in the Sun convert into X-ray photons.



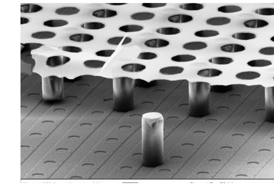


The magnet is 10 m long, weighs 20 t and is cooled down to 1.8 K.
In the aperture a magnetic flux of B = 9 T is Reached by a current of 13 kA.
The support structure weighs 40 t and can be turned vertically ~±8° and horizontally ~±40°.
Sun tracking lasts 2×1.5 h/d (Sunrise & Sunset)

https://www.facebook.com/CASTexperiment/videos?ref=page_internal



Requirement for X-ray Detector



- Detect X-rays with high efficiency.

→ Ar-mixture, 1 bar,
3 cm conversion volume

- Suppress background as much as possible

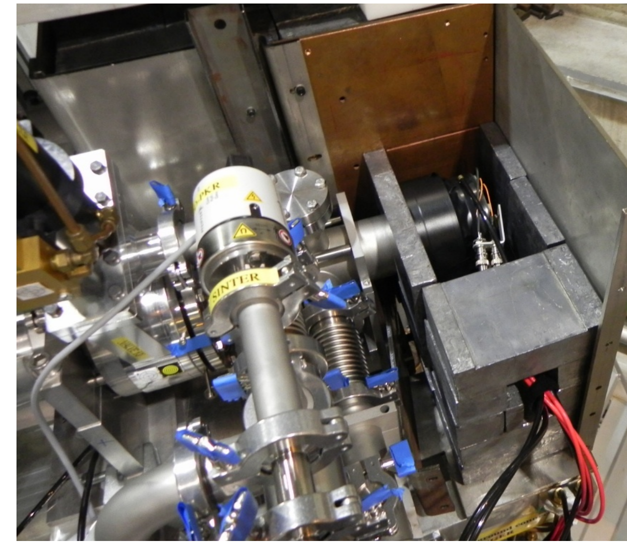
→ Radiopure material, Lead absorber,
Distinguish tracks from photons
Small area coverage and signal focusing by
X-ray telescope

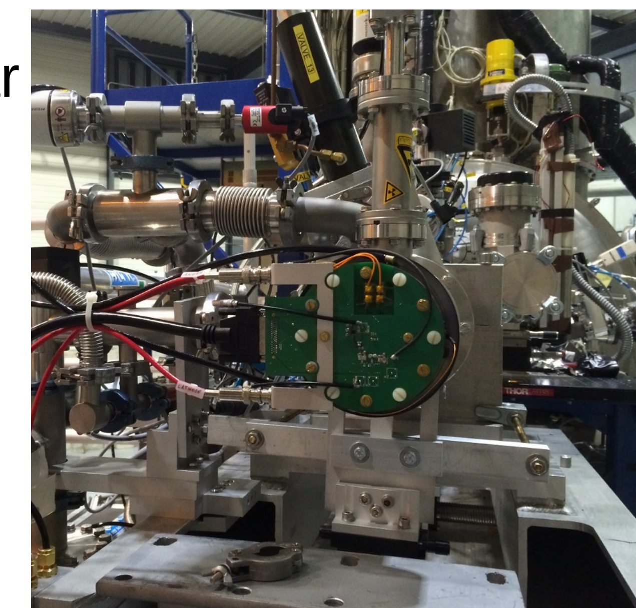
- Vacuum tightness: in the beam pipe there is a good vacuum $\sim 10^{-7}$ mbar, in the detector ~1 bar

→ Thick window

- Transparent window for low energetic X-rays

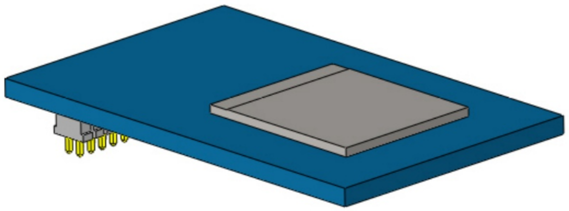
→ Thin window

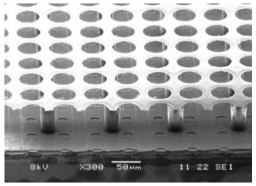




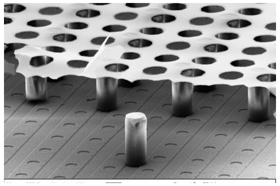
Building an X-ray Detector

Timepix with protection layer and InGrid
on a chip carrier



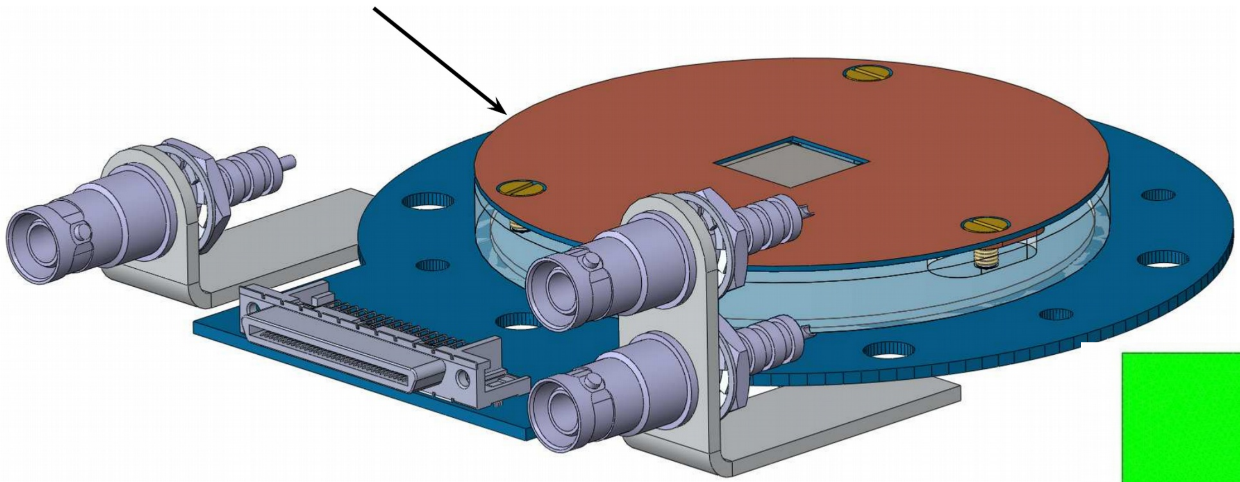


Building a Detector

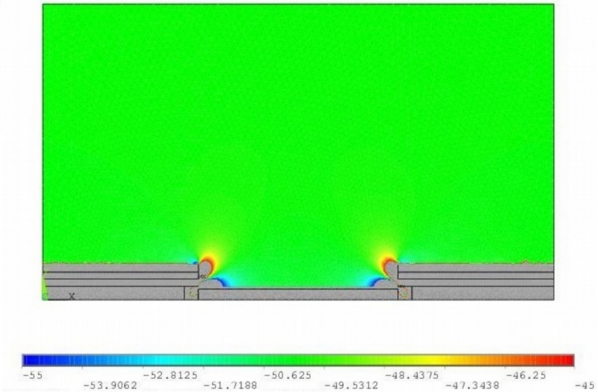


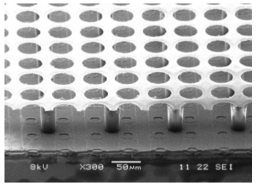
Readout module

Field shaping electrode (anode)

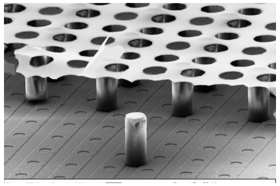


Calculation of field distortions from nominal 500 V/cm E-field.

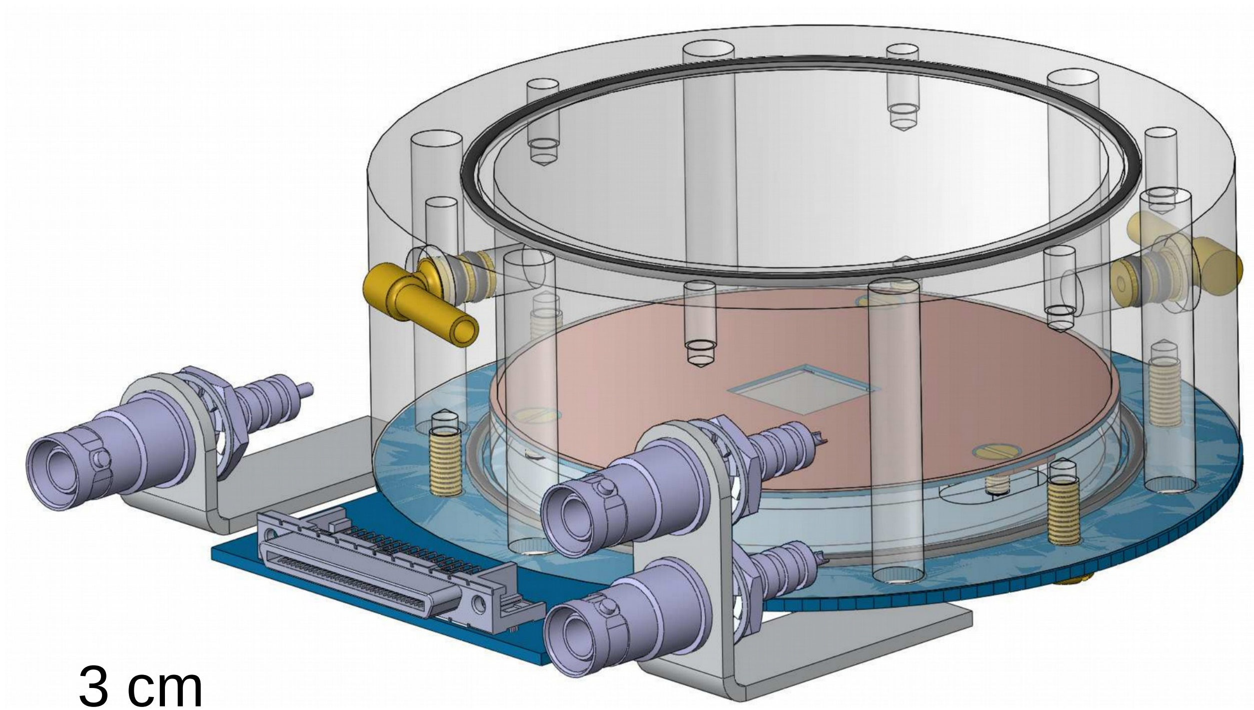




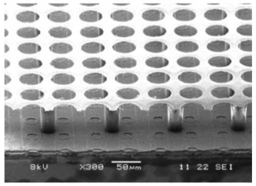
Building a Detector



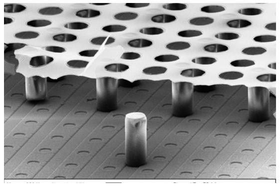
Drift volume

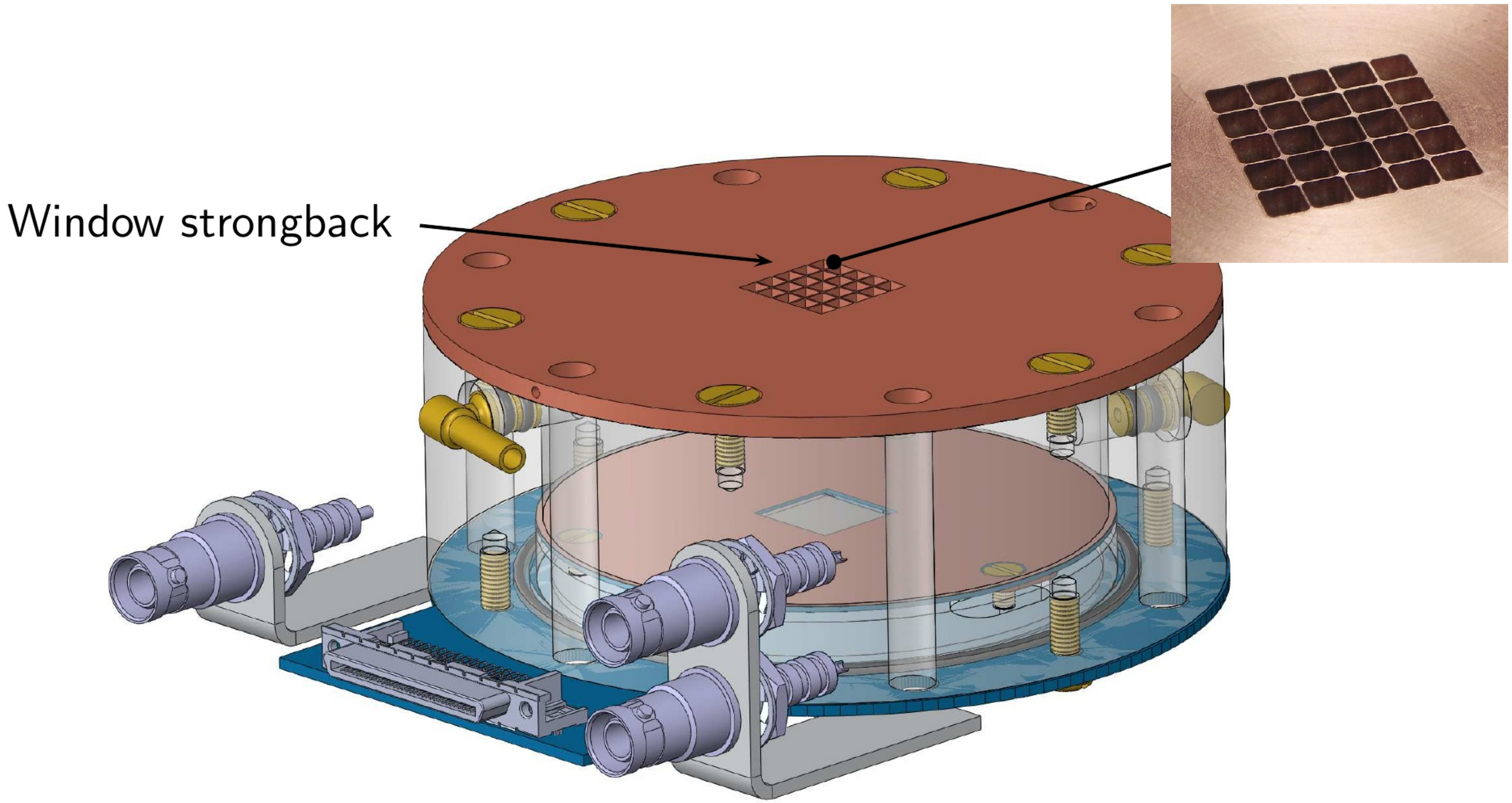


Length: 3 cm
Inner diameter: 8 cm
Electric field: 500 V/cm
Gas: Ar: iC_4H_{10} 97.7:2.3

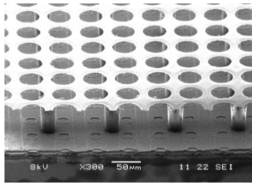


Building a Detector

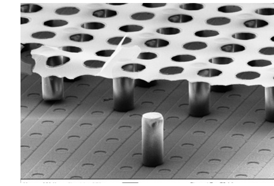


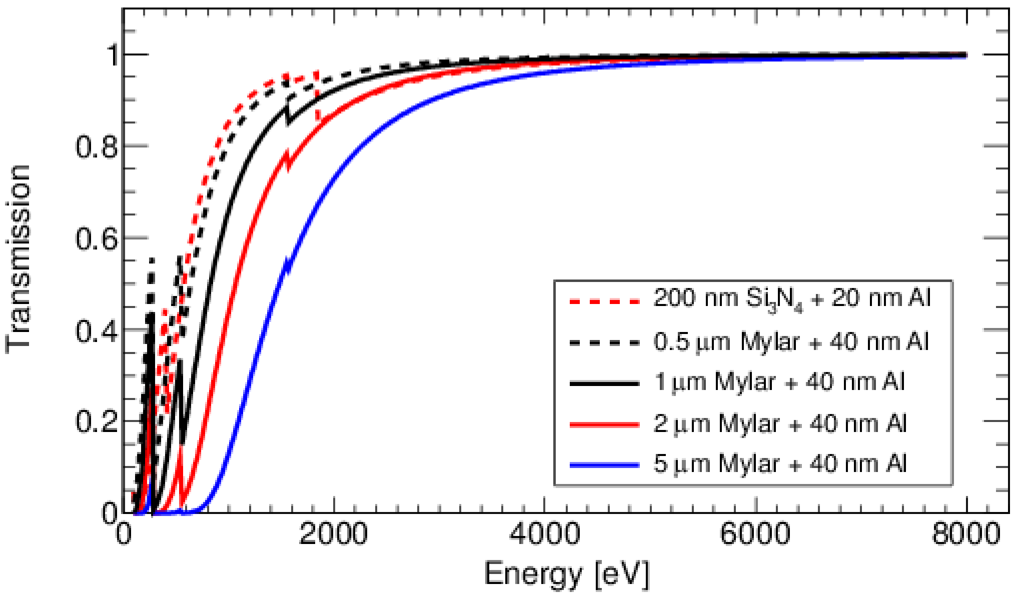


Pressure on outer side of cathode: ~10^{-5} mbar
Pressure inside detector: 1050 mbar
Window: 2 µm aluminized Mylar (with strongback)



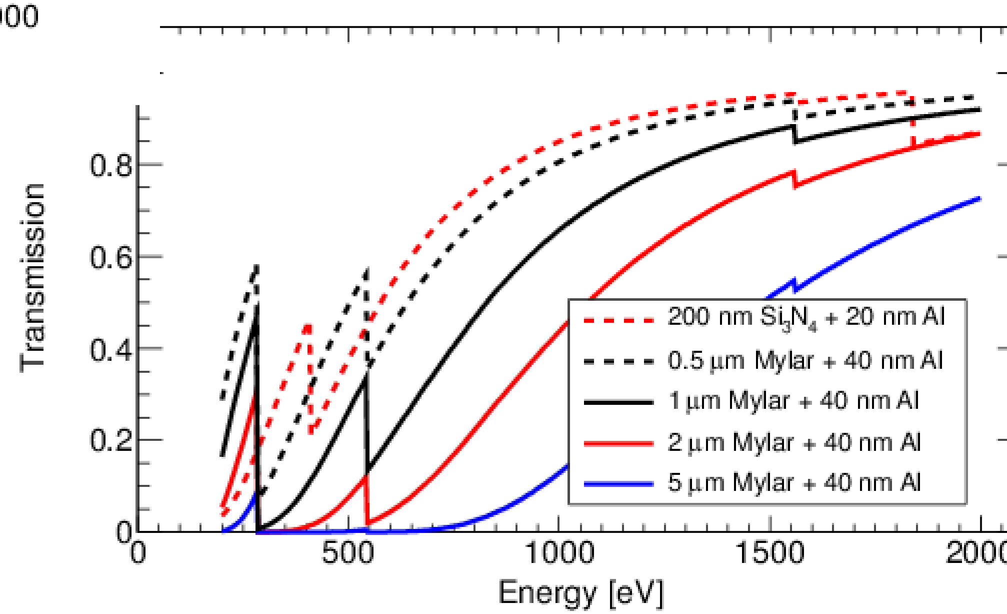
Entrance Window



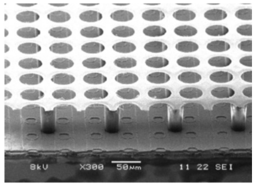


Because of the strongback, the efficiency is reduced by another factor of ~0.8.
Thinnest foil available is 2 µm aluminized Mylar. Other windows will be investigated soon.

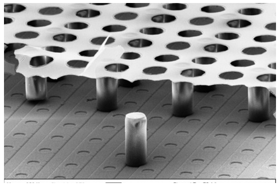
If no vacuum requirements are given, thinner windows could be used.

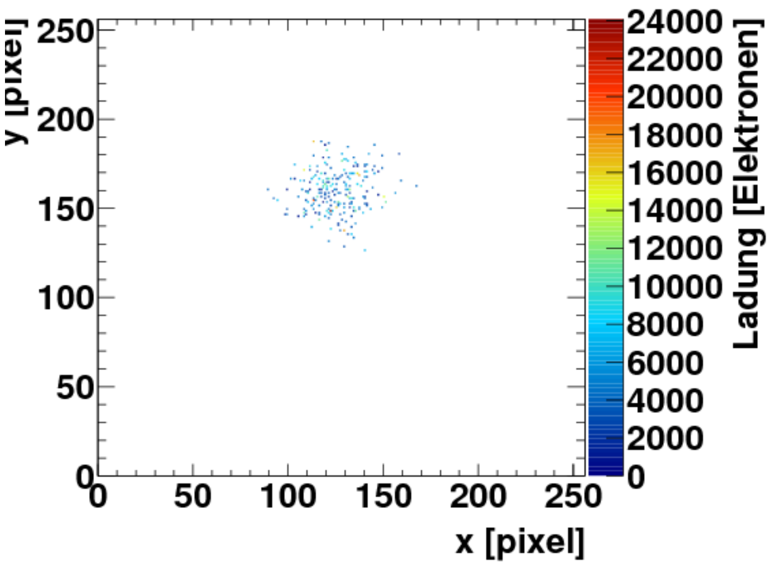


universität bonn

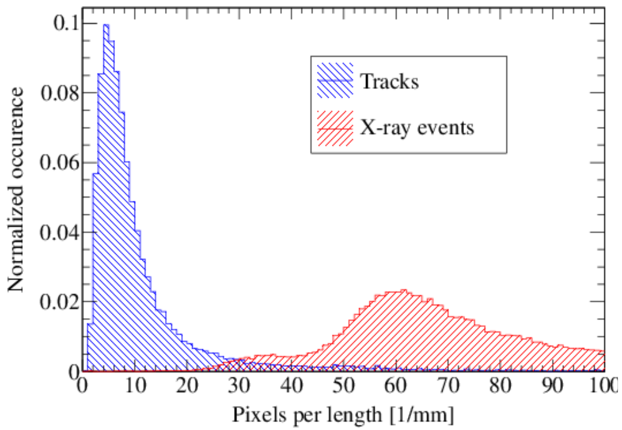


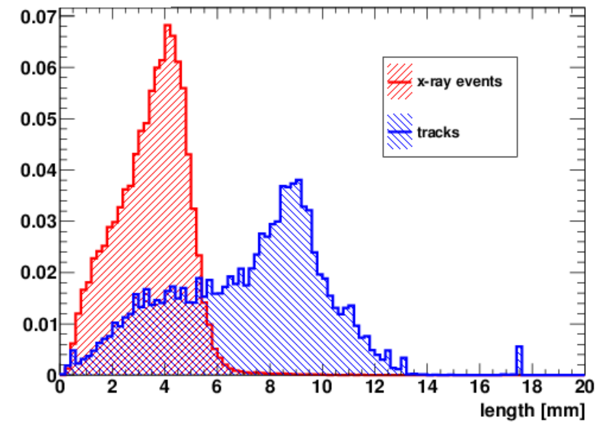
CAST Analysis

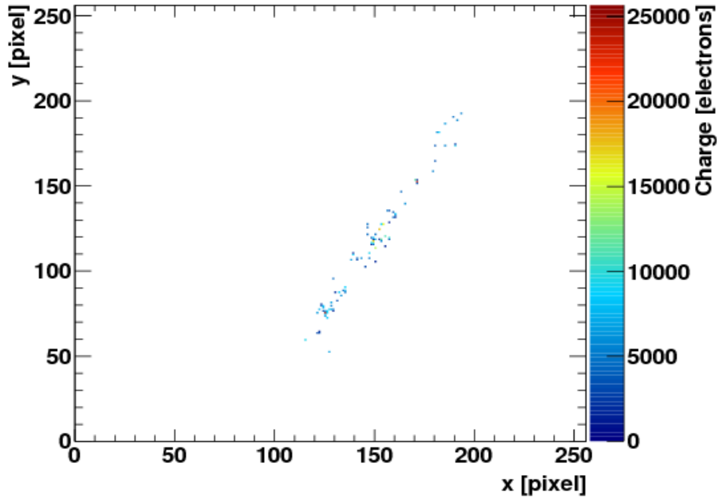


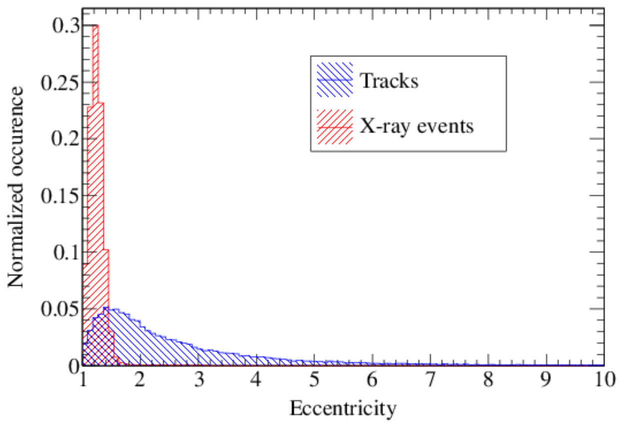


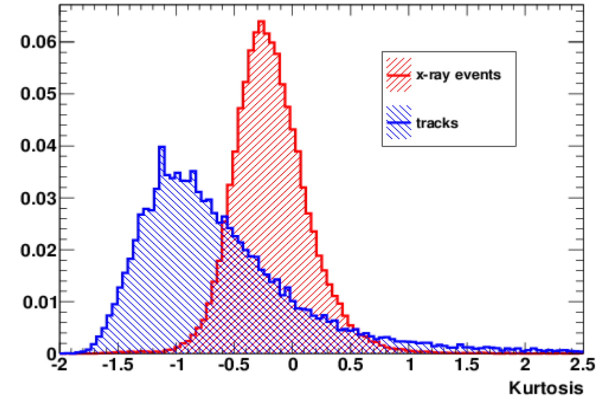
X-ray photons must be differentiated from track-like background events.
Geometric parameters are very helpful.











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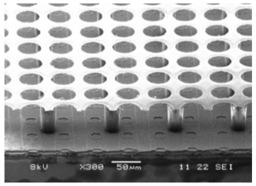
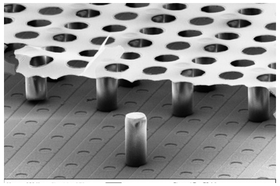


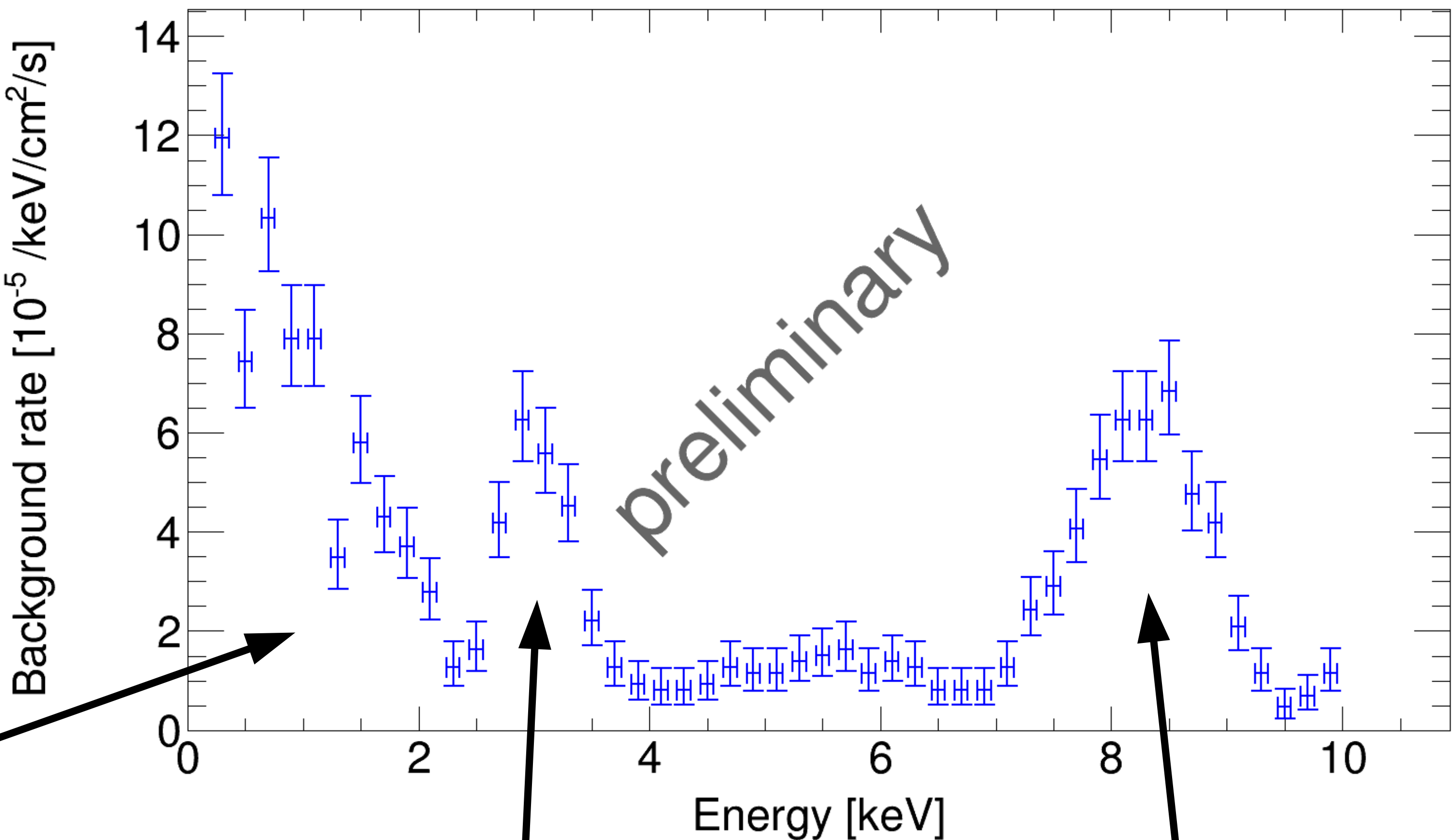
CAST Analysis

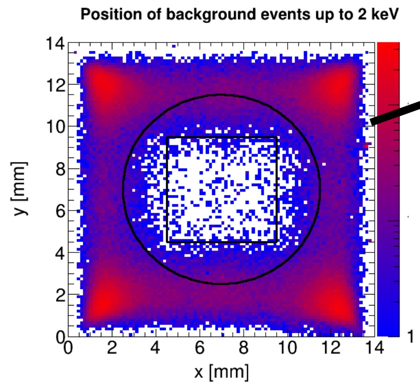


Background rejection by likelihood comparing X-ray events with data taken during run.

Interesting for chameleon search

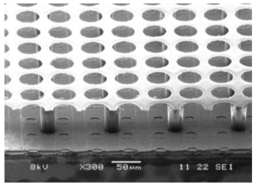
Interesting for axion search



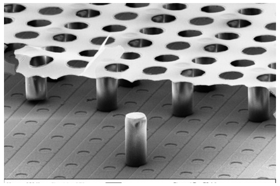


Fluorescence of Argon

Cosmic rays and fluorescence of Copper

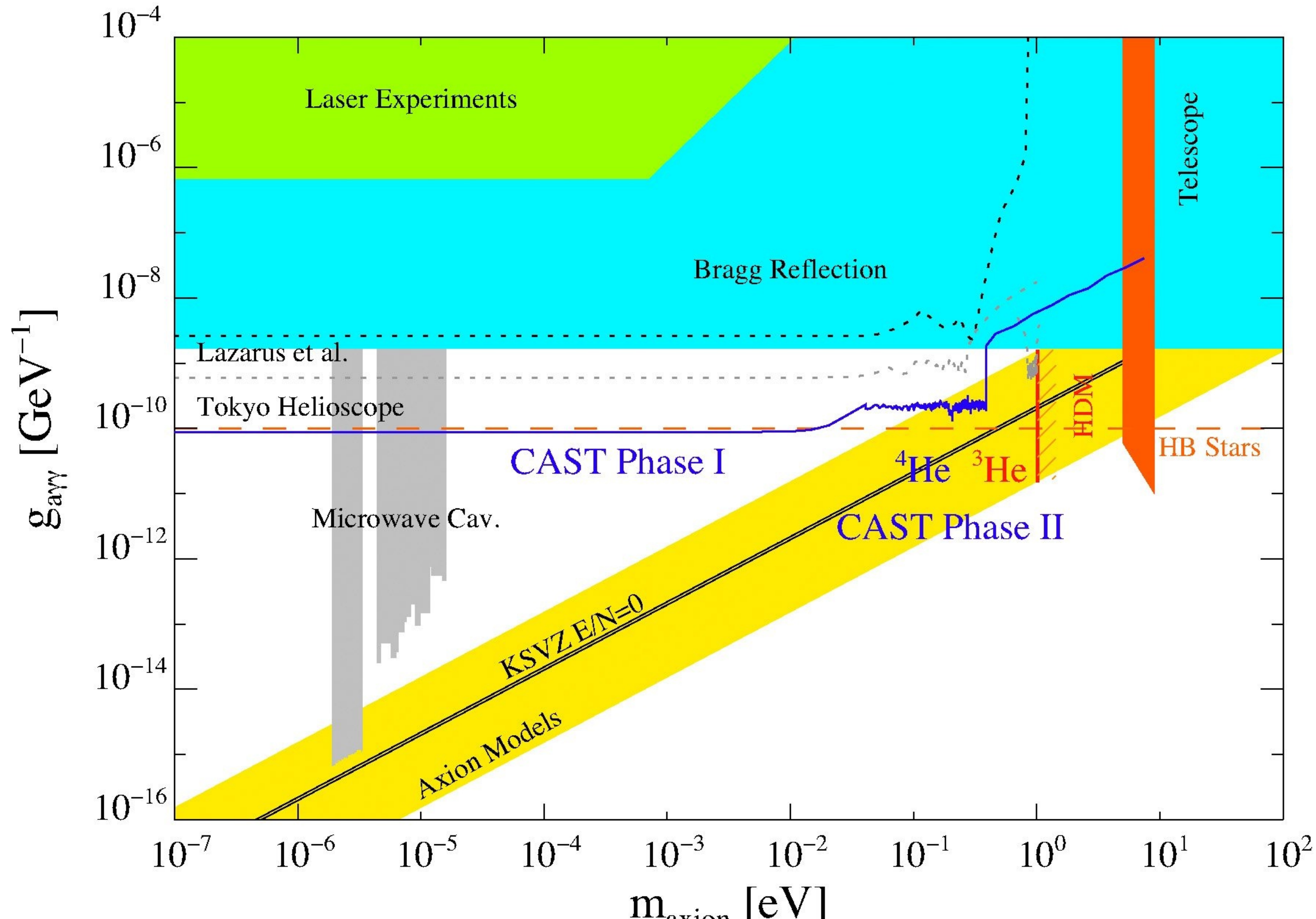


Analysis Results



Every day a detector measures the background for 21 h and observes the Sun for 1.5 h.

The two spectra are subtracted and the difference compared to the expected axion spectrum.



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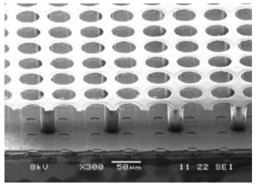
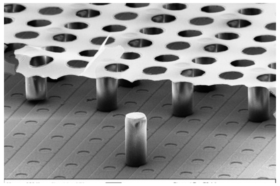


Long Term Performance

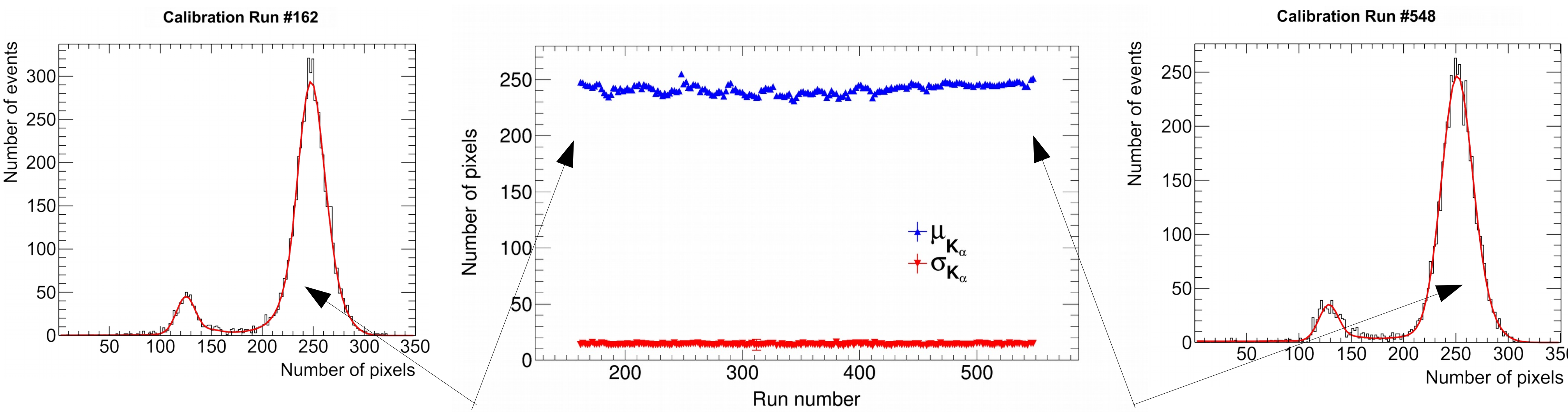


At CAST the detector takes data for 24 hours: 1.5 h looking at the Sun, 1 h calibration with ^{55}Fe, 21.5 h of background.

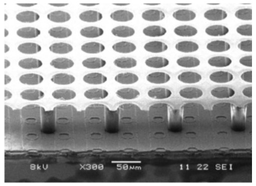
In 2014 the GridPix detector ran for ~ 30 days and then remained 6 months at the experiment.

In 2015 the GridPix detector ran for ~ 200 days.

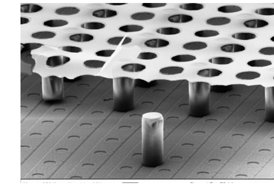
During both running periods no detector related interruptions were observed (e.g. HV trips, readout hangup,...).



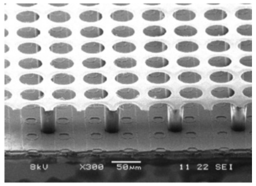
21.04.15 23.11.15



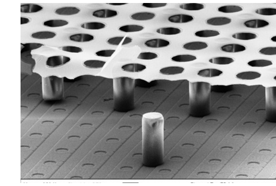
Content



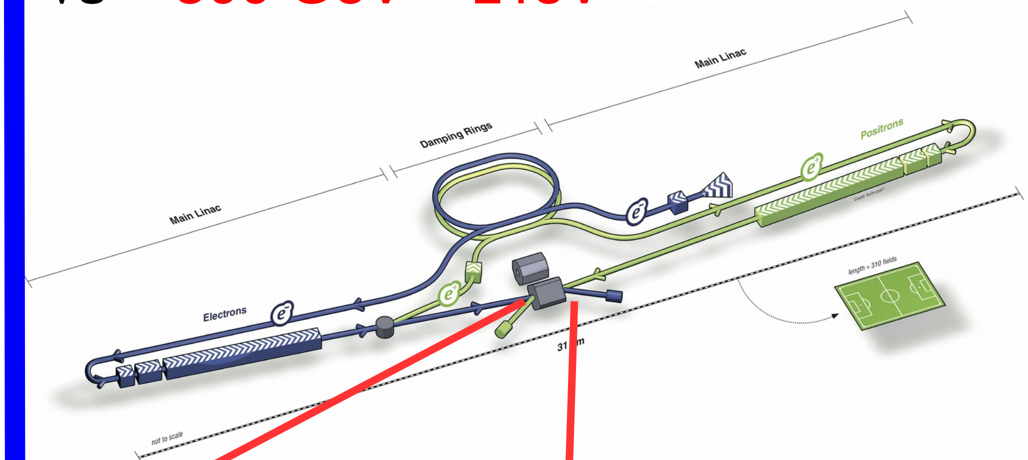
- Historic Overview
- Working Principle of Gaseous Detectors
- GridPix Detectors
- X-ray Photon Detector for CAST
- TPC Readout for ILD
  - Requiremenrs of the ILD tracker
  - Test setup of LCTPC collaboration
  - Benefits of GridPixes for ILD-TPC
  - 160 GridPix Test beam
- Some Applications
  - DICE
  - TRT Detector
  - X-ray Polarimeter
- Summary

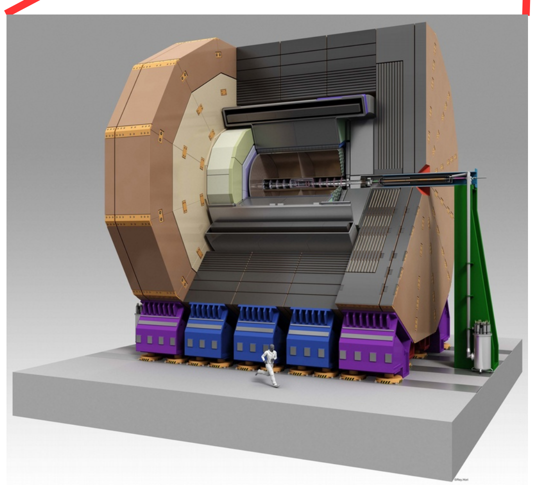


International Linear Collider



International Linear Collider (ILC) is a linear e^+e^- colliders with $\sqrt{s}$ = 500 GeV – 1TeV





International Large Detector

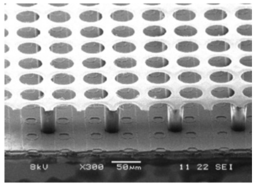
- Standard HEP detector
- TPC as main tracker

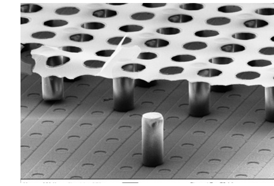
Requirements of TPC from ILC TDR vol. 4:

Parameter	
Geometrical parameters	r_{in} 329 mm, r_{out} 1808 mm, z $\pm$ 2350 mm
Solid angle coverage	up to $\cos\theta \simeq 0.98$ (10 pad rows)
TPC material budget	$\simeq 0.05$ X_0 including outer fieldcage in r
	< 0.25 X_0 for readout endcaps in z
Number of pads/timebuckets	$\simeq$ 1-2 $\times$ 10^6/1000 per endcap
Pad pitch/ no.padrows	$\simeq$ 1$\times$ 6 mm^2 for 220 padrows
σ_{point} in $r\phi$	$\simeq$ 60 μm for zero drift, $<$ 100 μm overall
σ_{point} in rz	$\simeq 0.4 - 1.4$ mm (for zero – full drift)
2-hit resolution in $r\phi$	$\simeq 2$ mm
2-hit resolution in rz	$\simeq 6$ mm
dE/dx resolution	$\simeq 5$ %
Momentum resolution at B=3.5 T	$\delta(1/p_t) \simeq 10^{-4}$/GeV/c (TPC only)

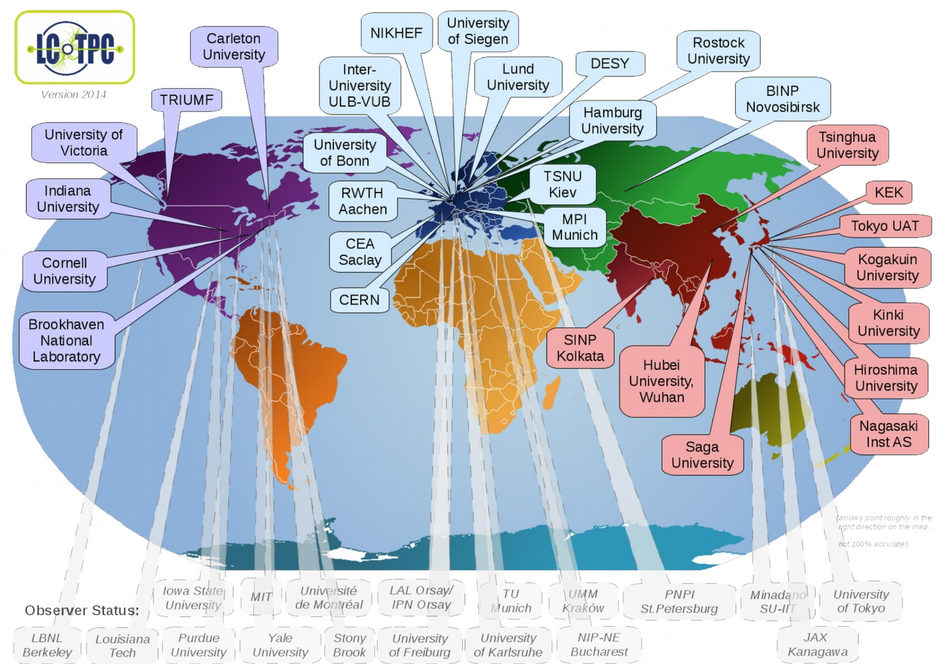
Requirements are driven by benchmark processes, in the case of ILD-TPC the most stringent one is the Higgs-recoil measurement.
For the particle flow concept also a very high efficiency of more than 99 % is required.

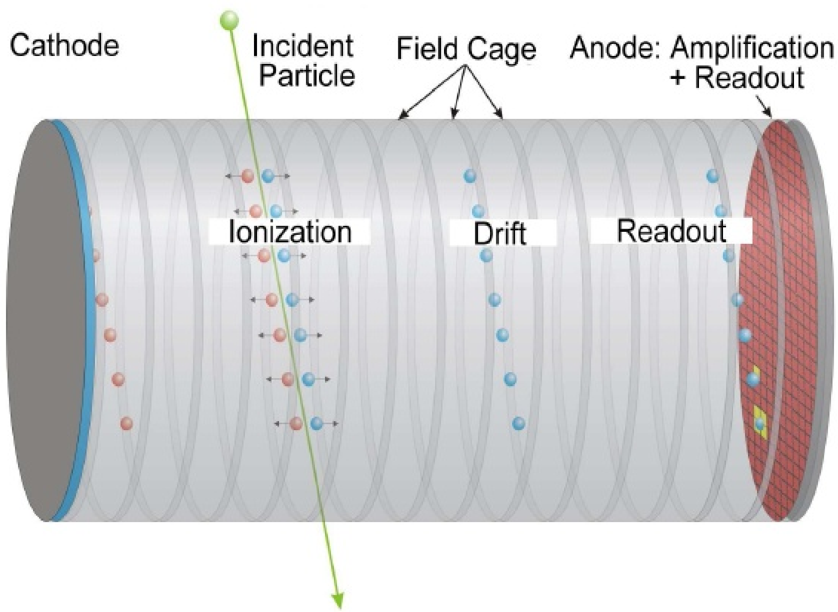
LCTPC





LCTPC-collaboration studies the MPGD detectors for the ILD-TPC:
30 Institutes from 12 countries
 + 18 institutes have an observer status

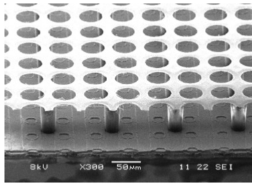




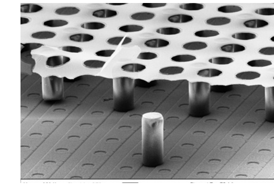
Various gas amplification stages are studied: GEMs, Micromegas, GEMs with double thickness and GridPixes.

MPGDs in TPCs

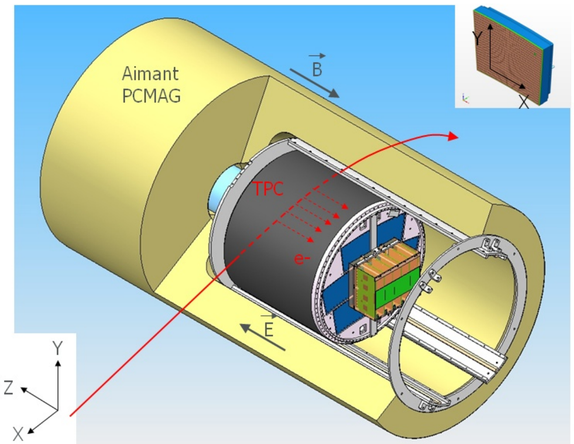
- Ion backflow can be reduced significantly
- Small pitch of gas amplification regions => strong reduction of E×B-effects
- No preference in direction => all 2 dim. readout geometries possible

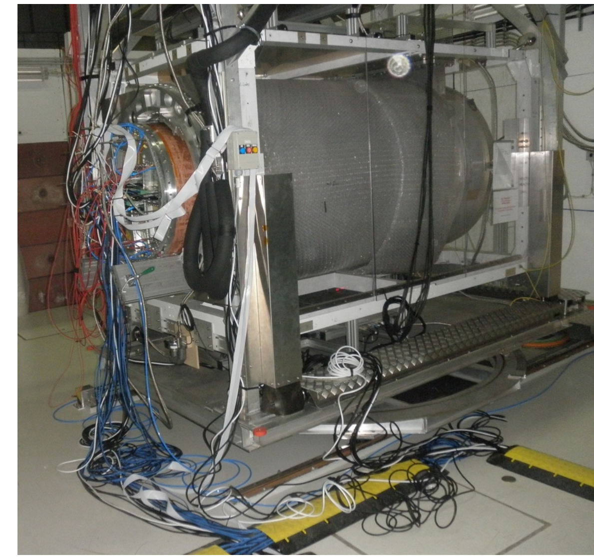


EUDET Test Fasility



Large Prototype has been built to compare different detector readouts under identical conditions and to address integration issues.





<u>Setup consists of:</u>

PCMAG: B < 1.2 T,

e^- test beam: E = 1- 6 GeV

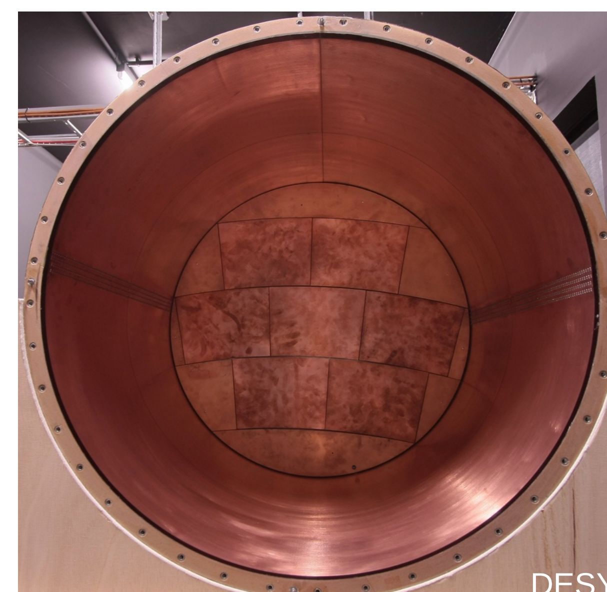
Movable support structure

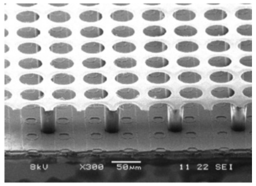
LP Field Cage Parameter:

- length = 61 cm
- inner diameter = 72 cm
- drift field: E ≈ 350 V/cm
- made of composite materials:
  - 1.24 % X_0

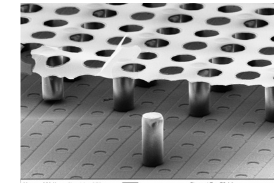
Modular End Plate

- 7 module windows,
- size ≈ 22 × 17 cm^2

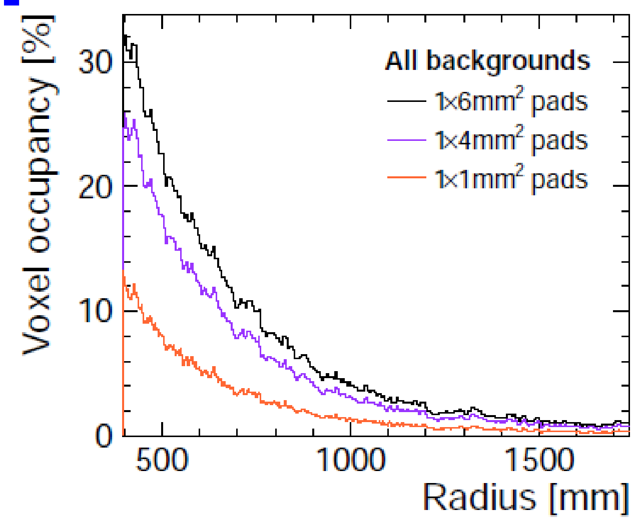


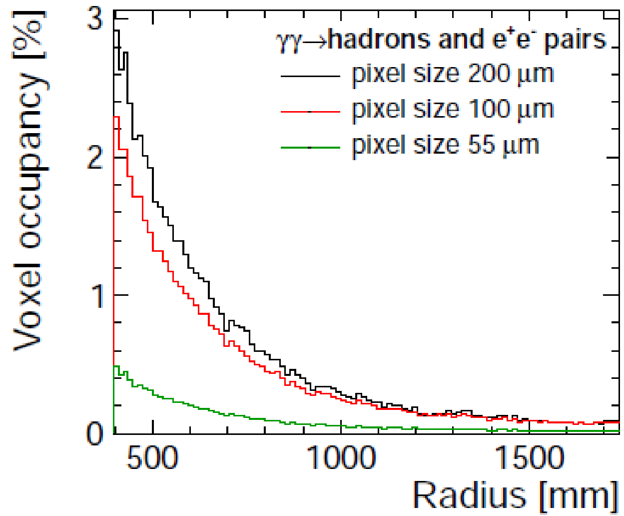


GridPix Benefits - Challenges



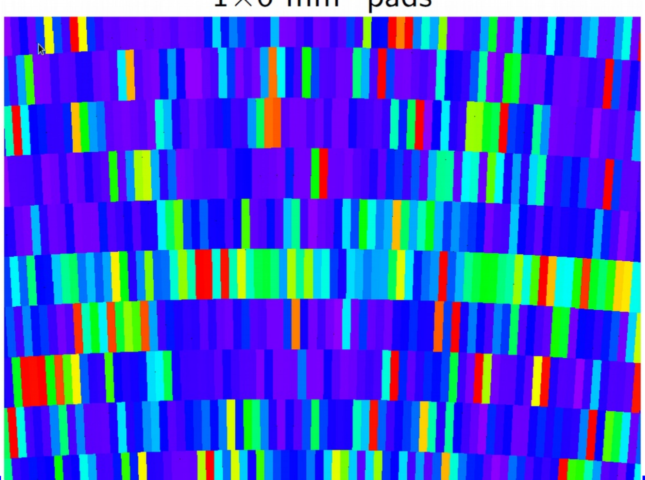
The background ($\gamma\gamma \rightarrow$ hadrons, $e^+e^- \rightarrow$ pairs/beam halo μ)
is accumulated in the TPC creating a significant occupancy
(Simulation for the CLIC detector, M. Killenberg, LCD-Note-2013-005)



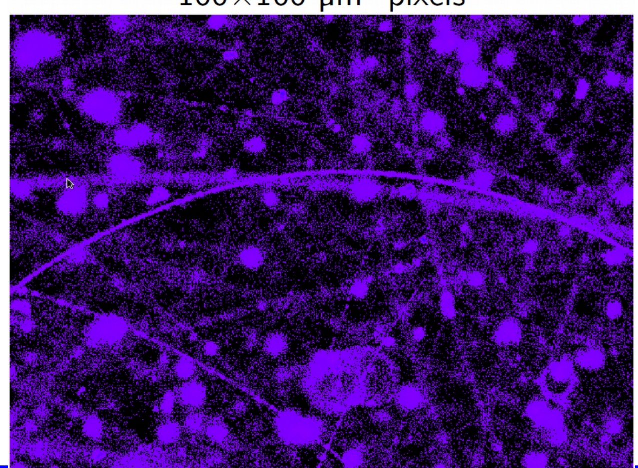


- Lower occupancy
  → better track finding
- Identification and removal of δ-rays and kinks
- Improved dE/dx, because of primary e^- counting
- Pad plane and readout electronics fully integrated

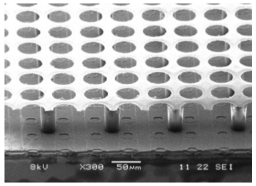
1×6 mm² pads



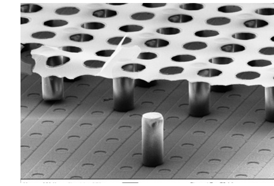
100×100 μm² pixels



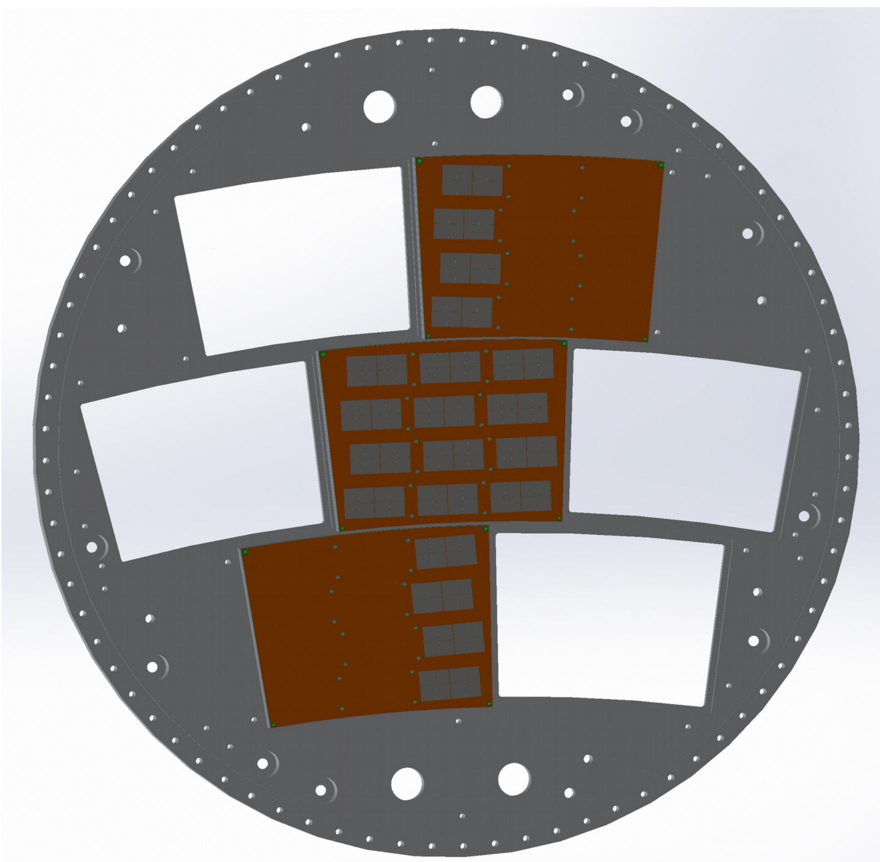
To readout the TPC
with GridPixes:
~100-120 chips/module
240 module/endcap (10 m²)
→50000-60000 GridPixes



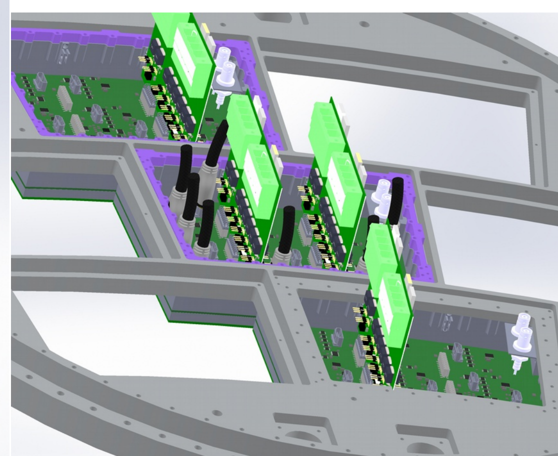
Envisioned Test Beam Setup

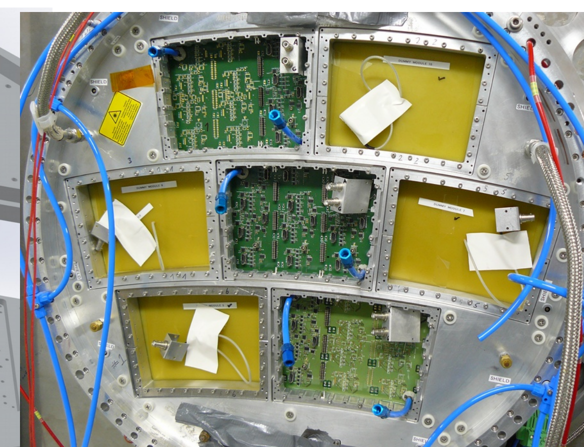


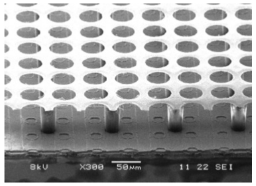
The goal foresaw an LP-module covered completely with GridPixes (~100). This goal could even be surpassed by adding two partially covered modules. In total 160 GridPixes covered an active area of 320 cm²: - central module with 96 chips (coverage 50 %)
- 2 outer modules with 32 chips each



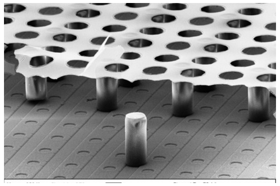
Some challenges:
- InGrid production
- Synchronized readout
- Bonding on boards
- LV distribution
- Cooling

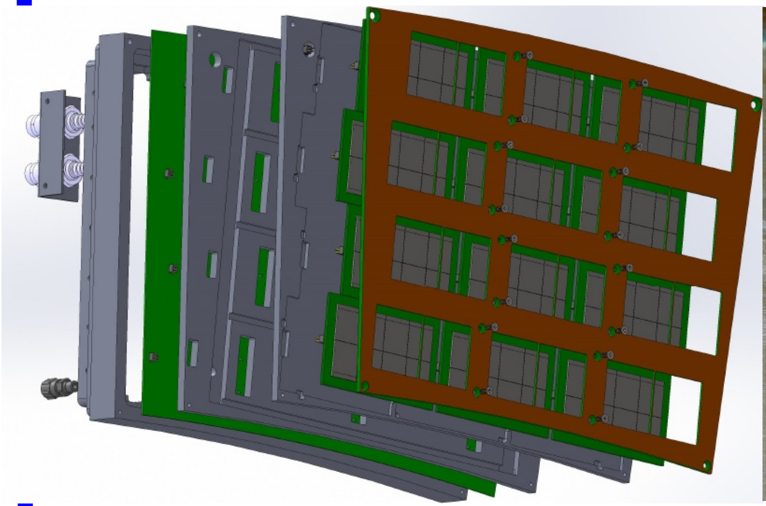


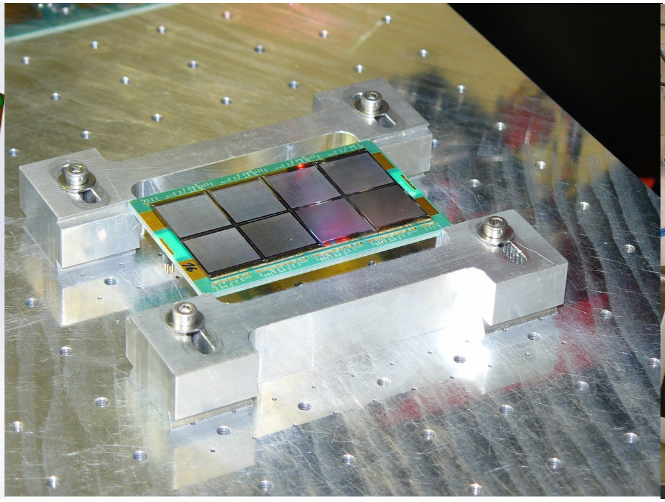


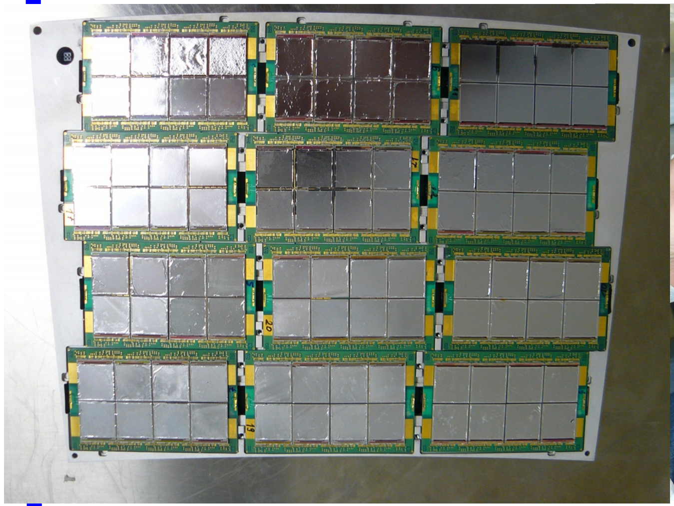


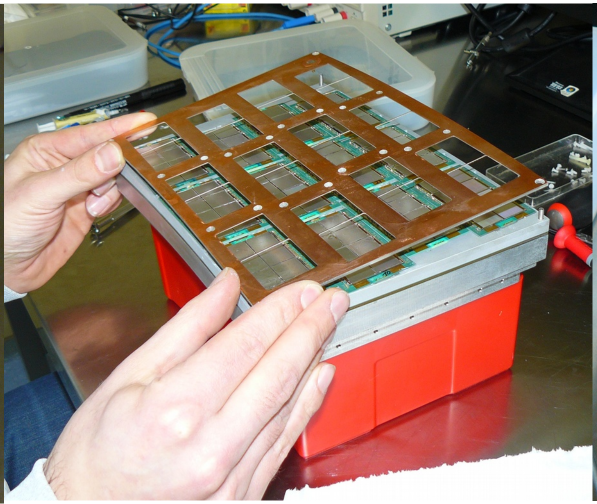
Module Production

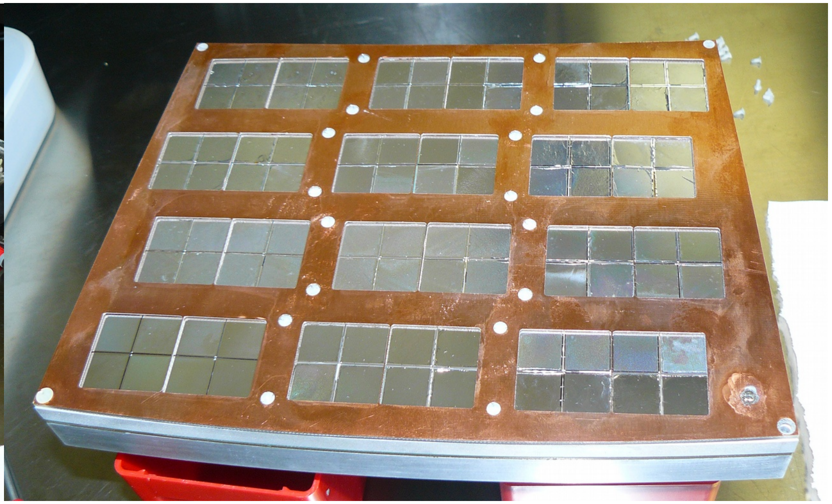




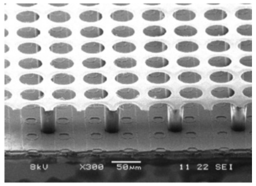




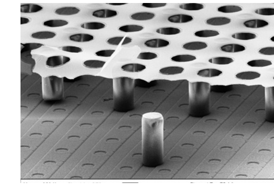




Central module



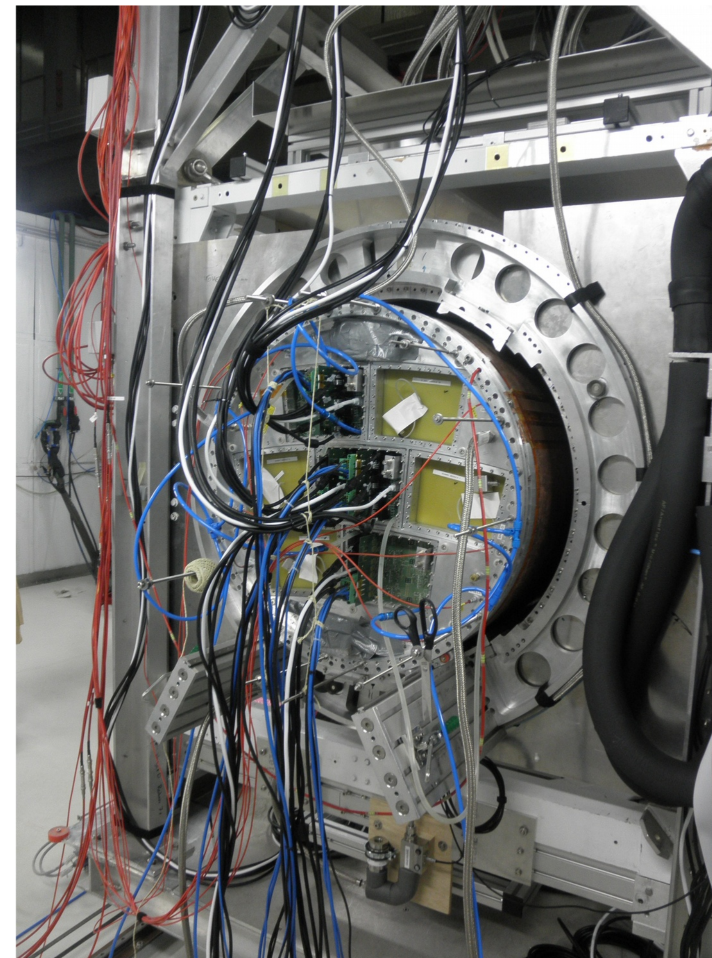
Test Beam



The test beam was a huge success. A lot of people now think, that a pixel TPC is not a crazy idea anymore, but it is realistic.
During the test beam we collected ~10^6 frames at a rate of 4.3-5.1 Hz.

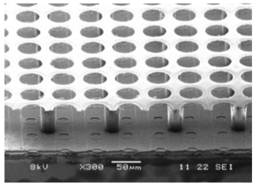
Test beam program:
– Voltage scans (gas gain)
– z-scan
– Momentum scan
– Different angles
– With and without magnetic field (B=1T)
– Two different electrical drift fields

The analysis has started.

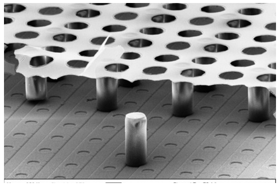


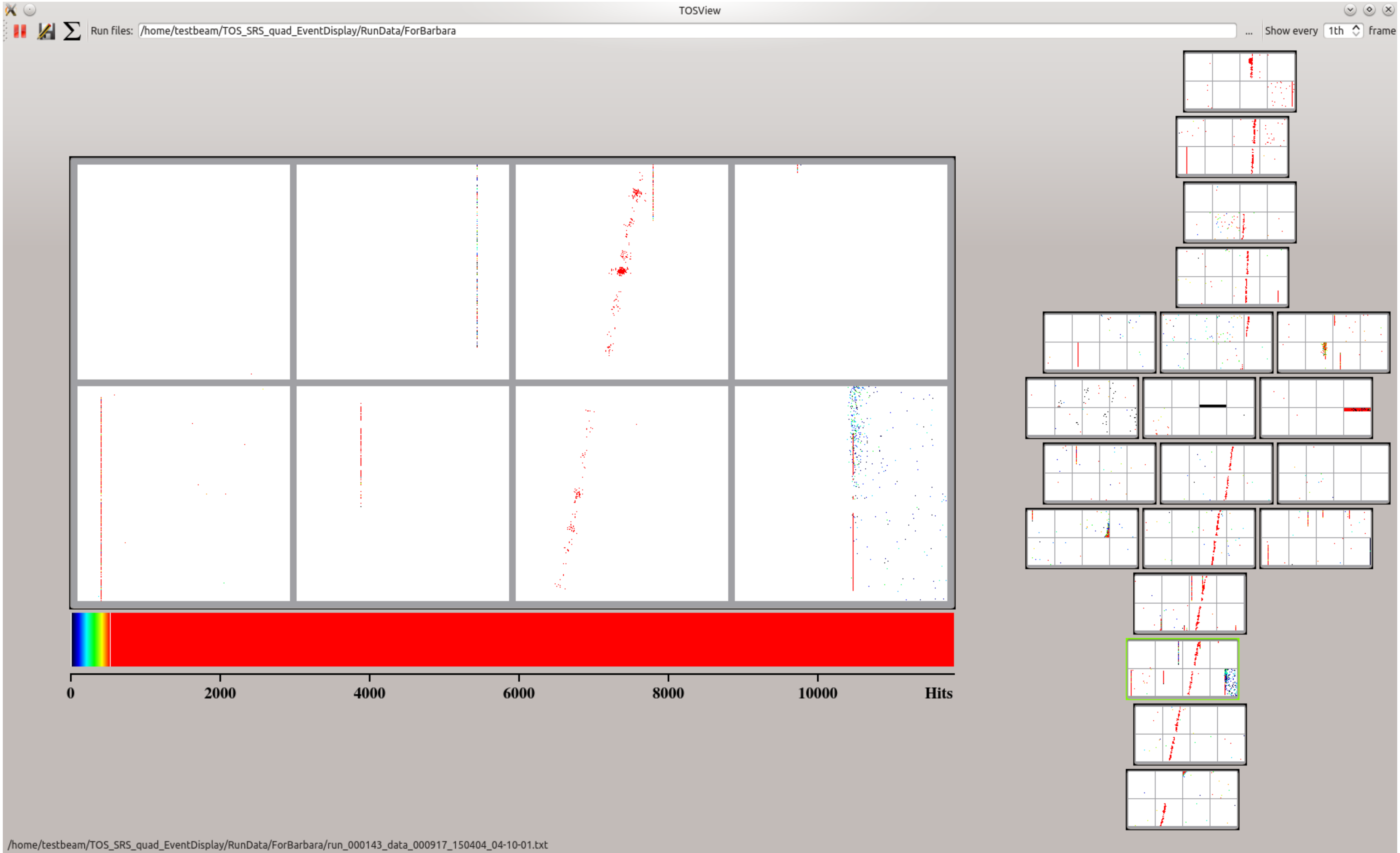
Material budget of 96 chip module (not optimized!)
- metallic frame 4.1 % X_0, cooling plate 5.9 % X_0
- 2 LV boards 2.5 % X_0, 12 Octoboards 2.9 % X_0

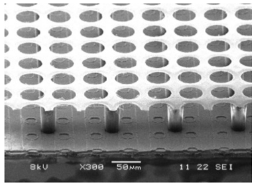
In total: 18.5 % X_0



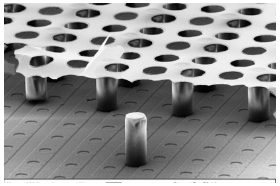
Event Picture (I)

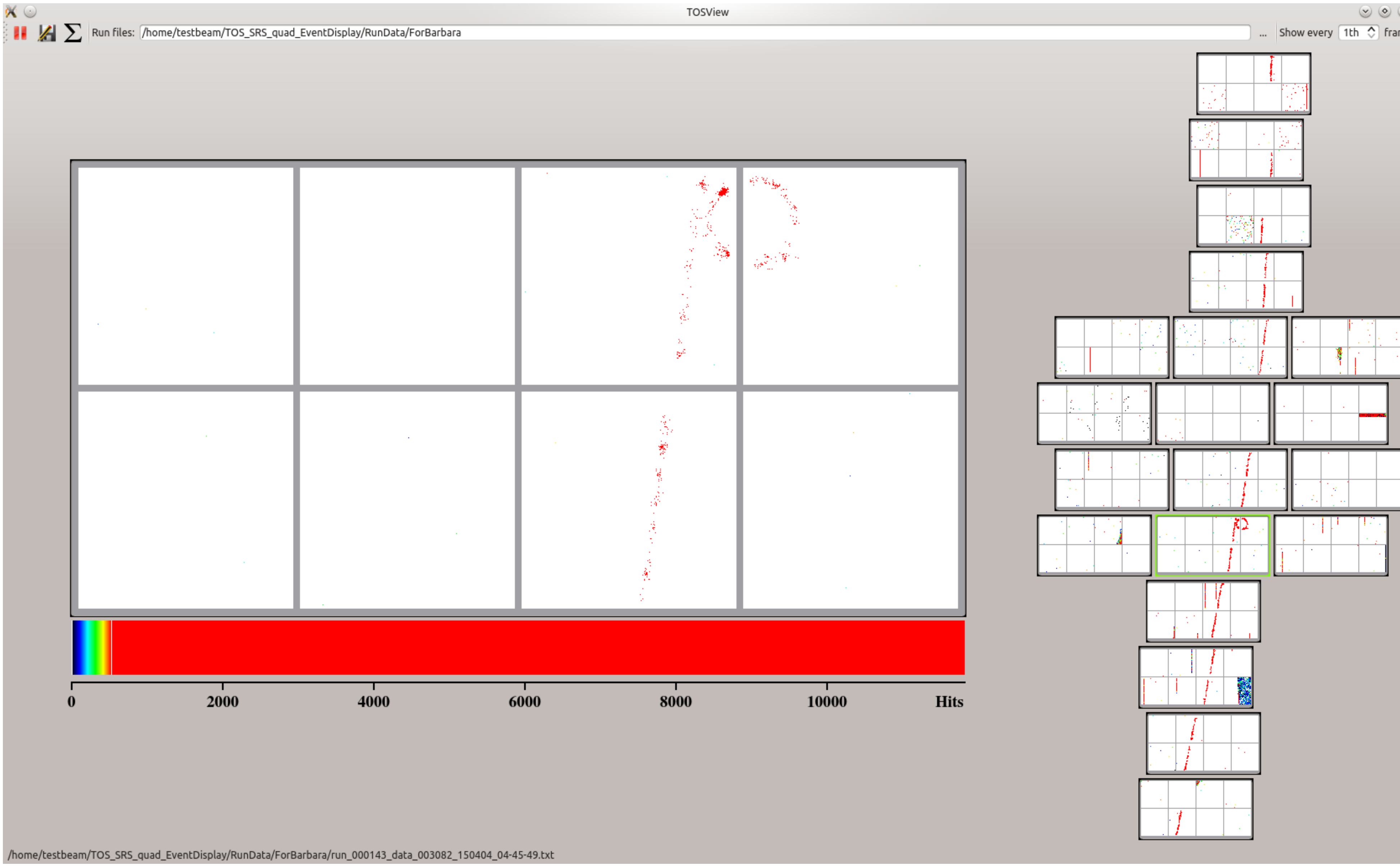


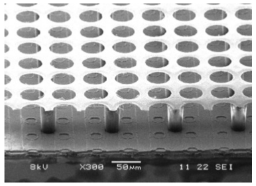




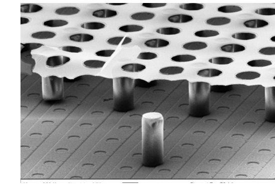
Event Picture (II)

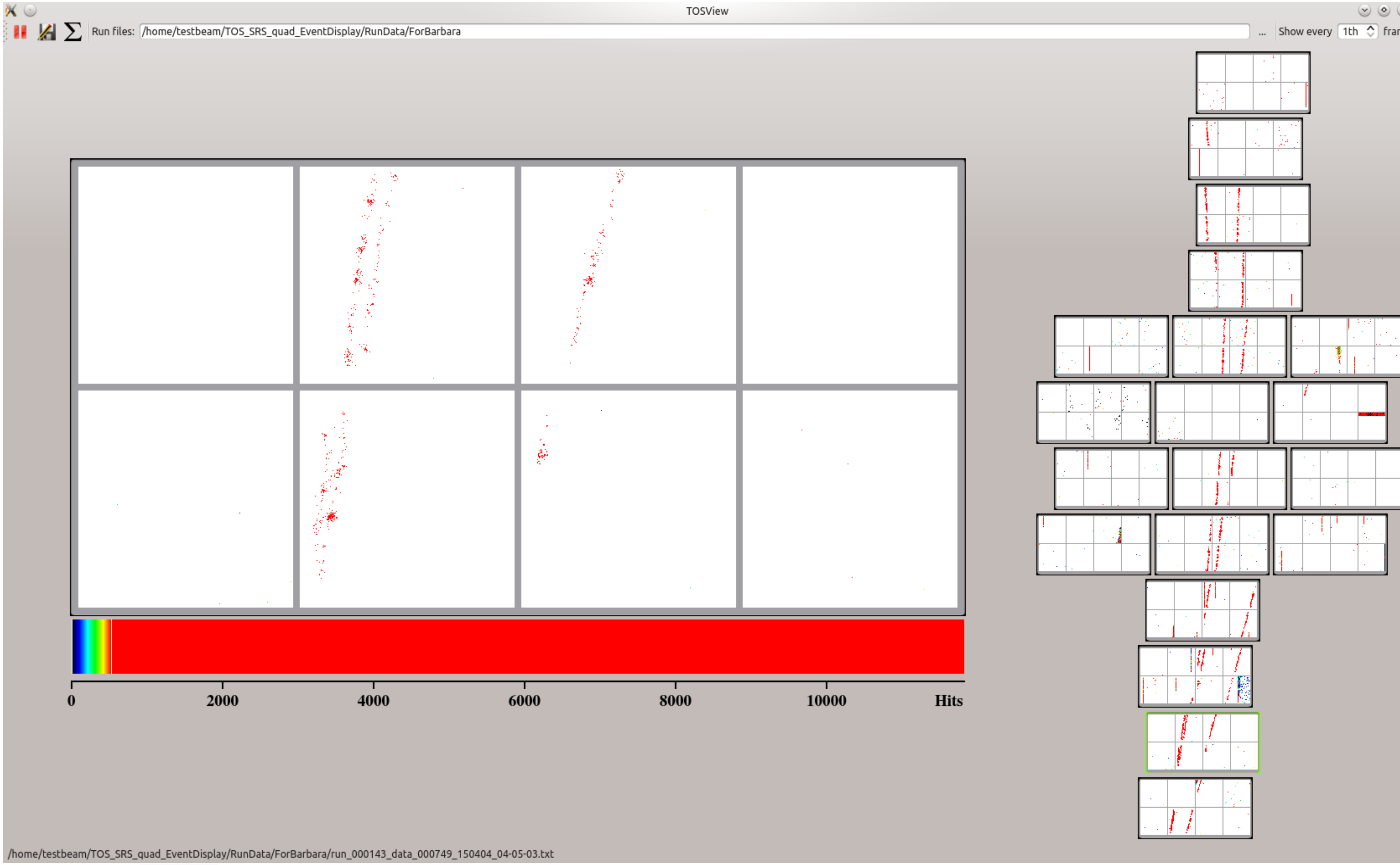






Event Picture (III)





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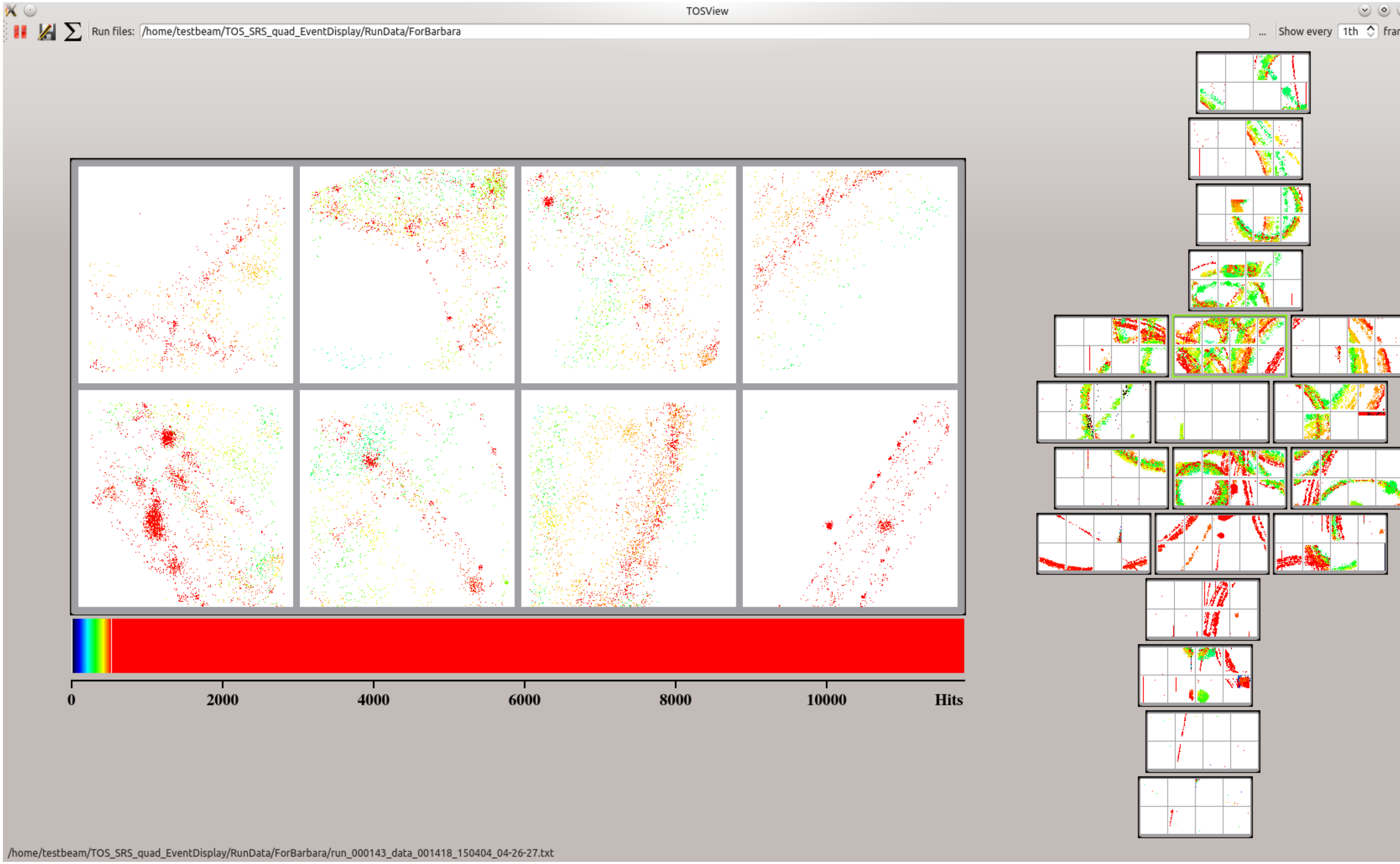
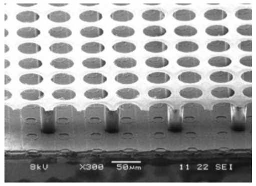
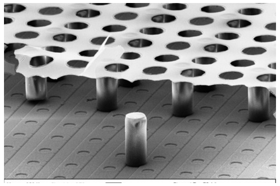
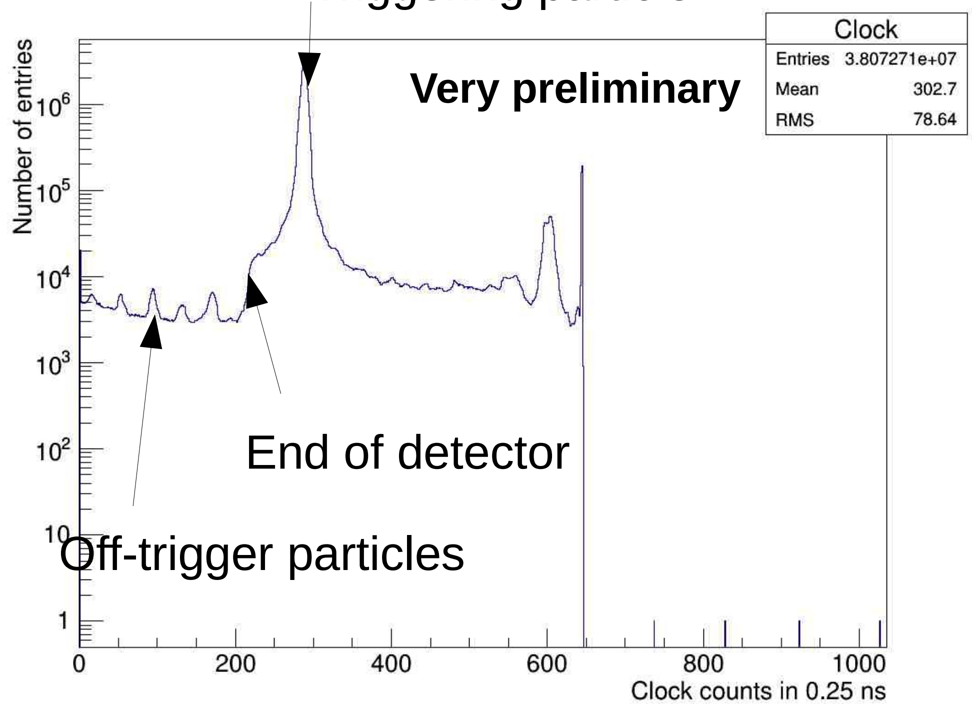
Event Picture (IV)



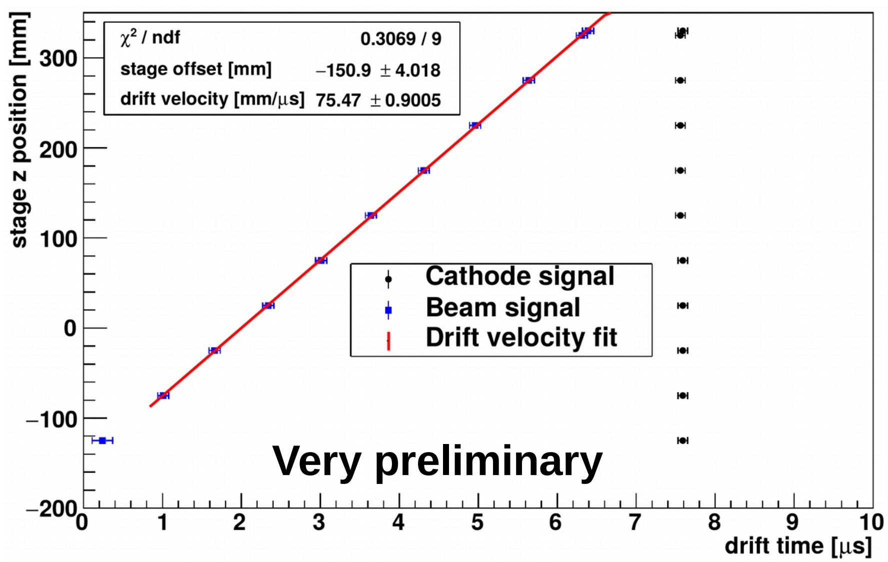


Some Results – Drift velocity



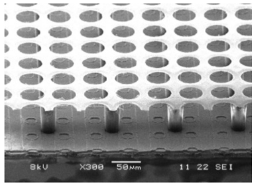


Drift velocity can be measured for triggering particle, if the beam position is known.
Also from the position of the cathode.

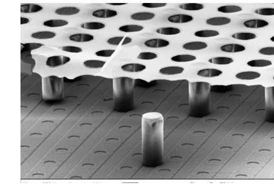


Comparison with simulation:

Condition	Simulation	Measurement
E=130 V/cm, B= 0T	5.64±0.01 cm/µs	5.50 ±0.08 cm/µs
E=230 V/cm, B= 0T	7.64±0.01 cm/µs	7.56 ±0.1 cm/µs
E=230 V/cm, B= 1T	7.64±0.01 cm/µs	7.55 ±0.09 cm/µs

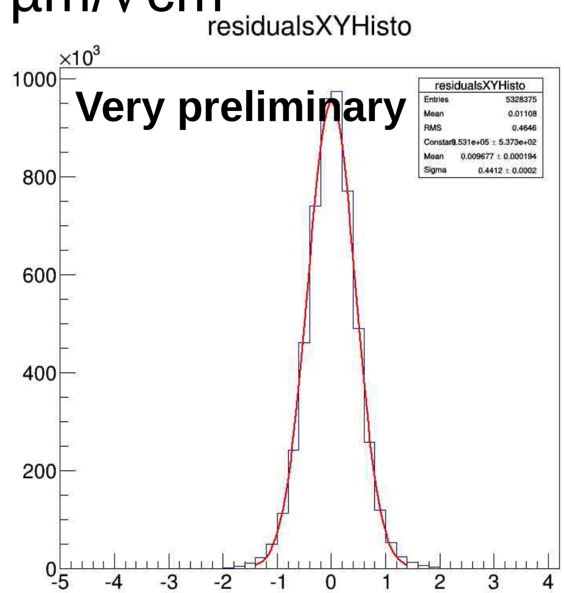


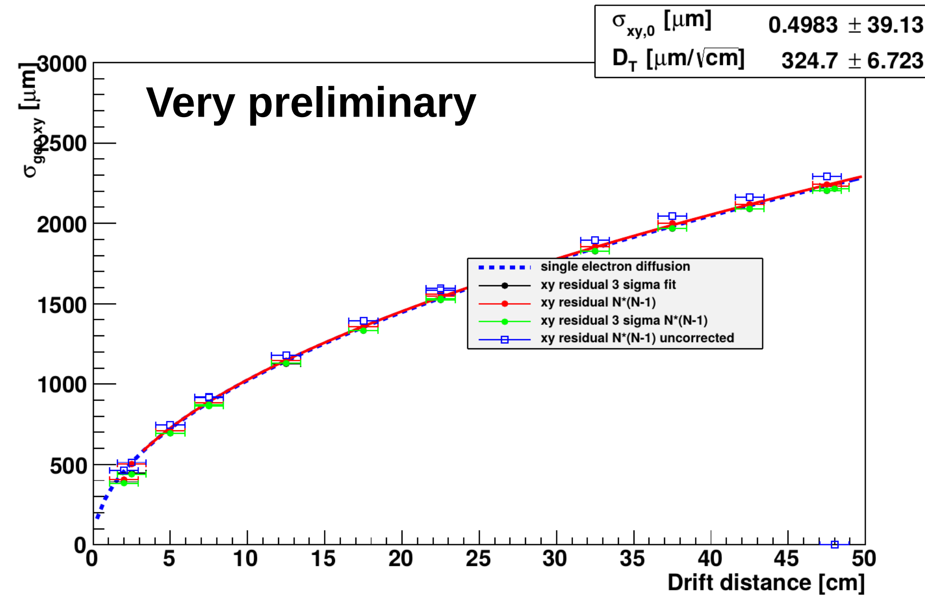
Some Results – Spatial Resolution

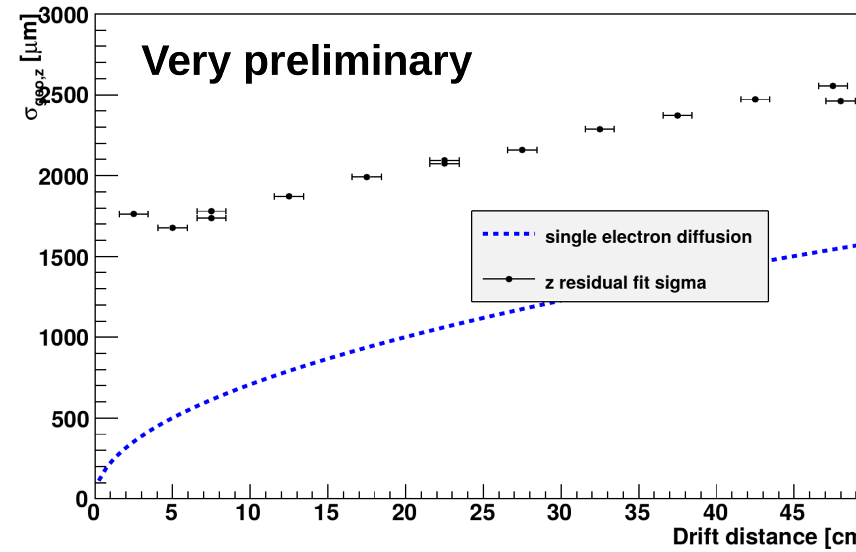


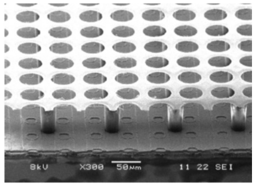
The spatial resolution is determined by calculating the residuals of single hits to fitted track. Spatial resolution follows the diffusion of single electrons.
The diffusion constant is in good Agreement with simulation
$D_{T,mes}$ = 324.7±6.7 μm/√cm and
$D_{T,sim}$ = 323.7±11 μm/√cm

Longitudinal Spatial resolution is much worse, because of many degrading effects.

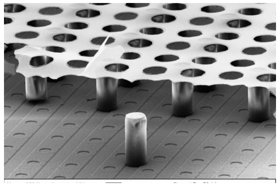




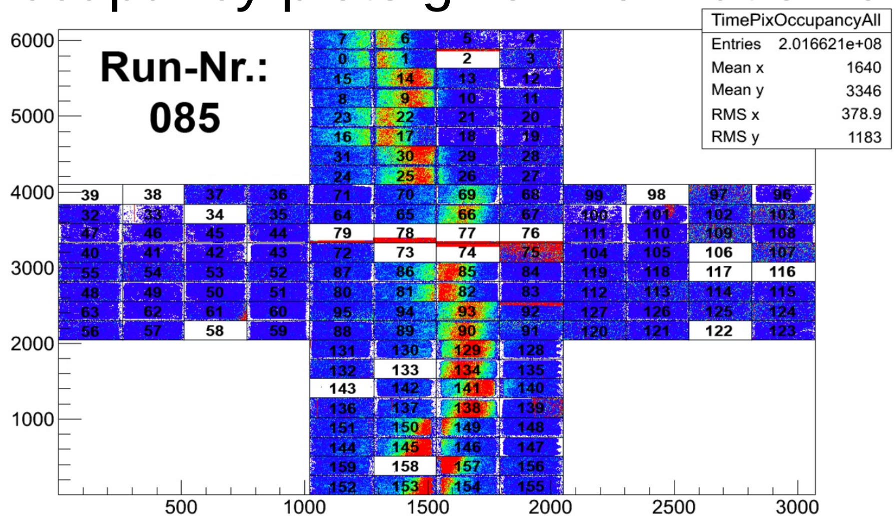


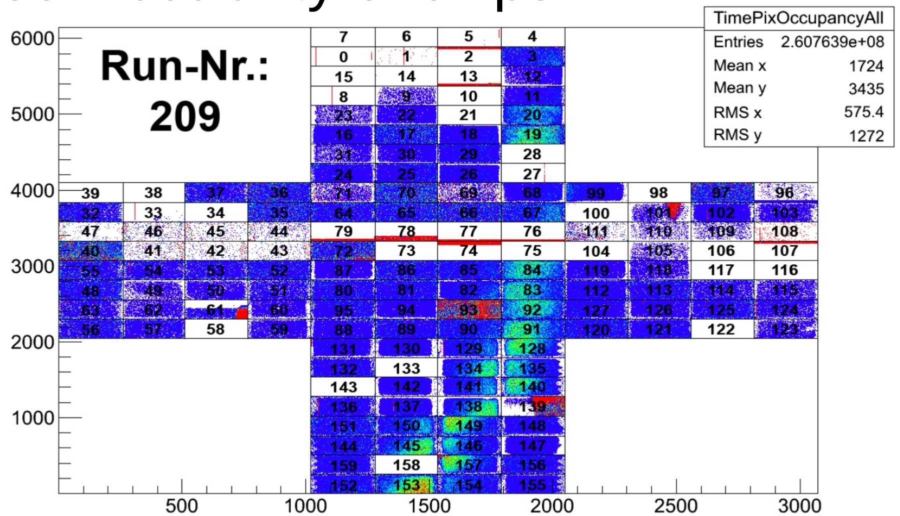


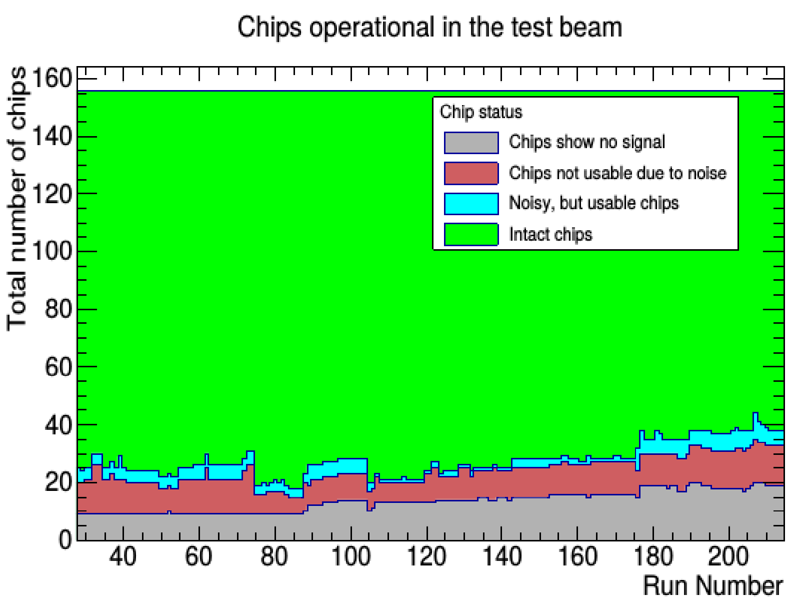
Serviceability of Chips

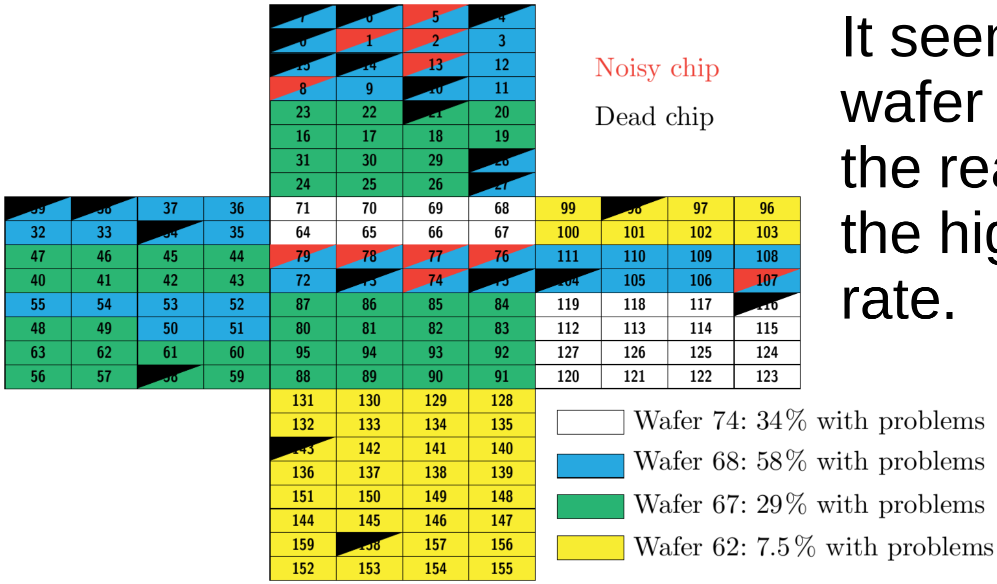


Occupancy plots give information on serviceability of chips.

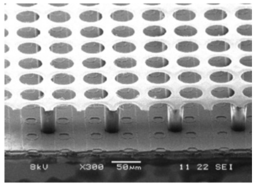




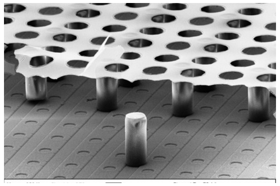




It seems one wafer is mainly the reason for the high failure rate.

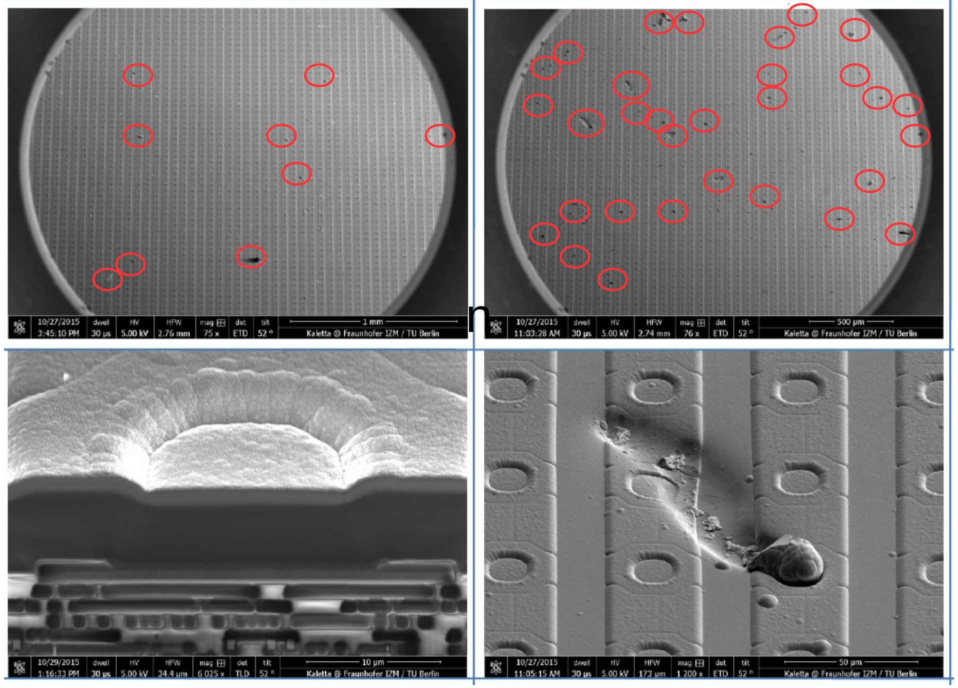


Protection Layer

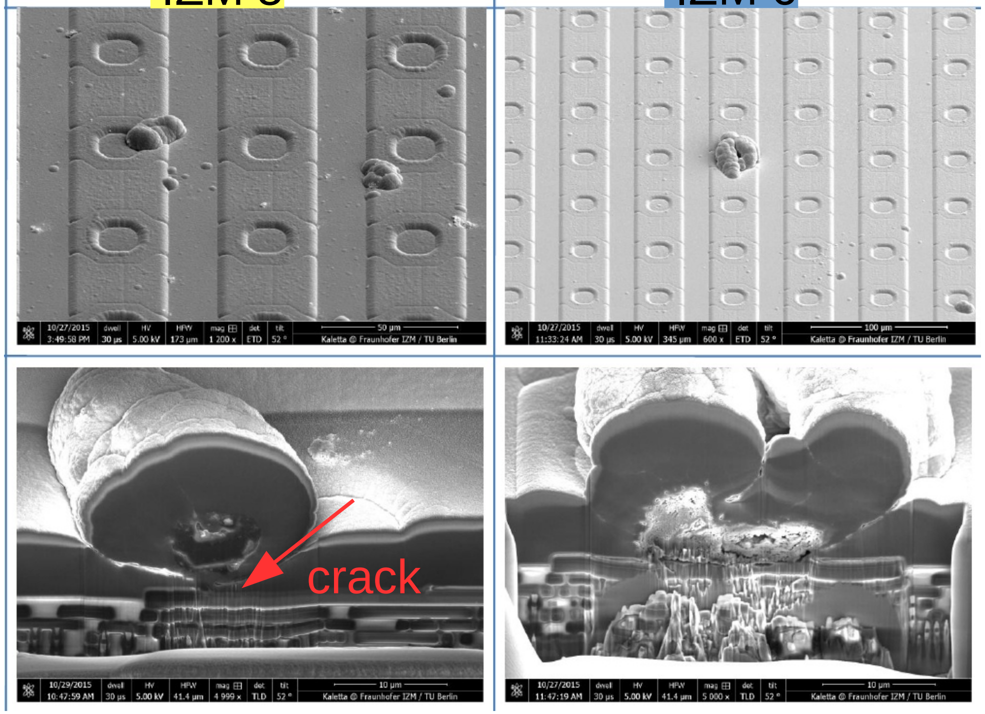


The reason is likely to be a low quality of the protection layer.

IZM 5 IZM 6



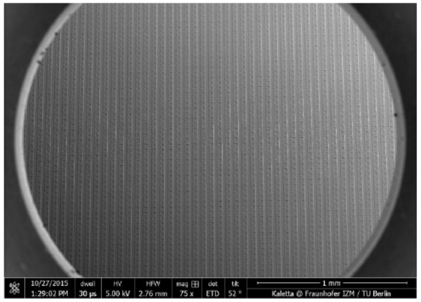
IZM 5 IZM 6

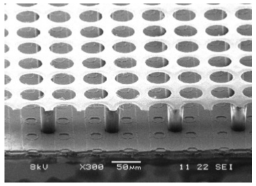


Machine depositing Si_xN_y caused defects in the protective layer during growths.

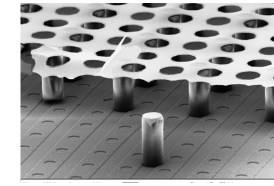
Process has been switched to a different machine.
→ SEM picture show no defects anymore
→ Have to test reliability

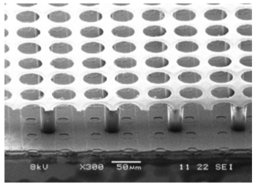
IZM-7

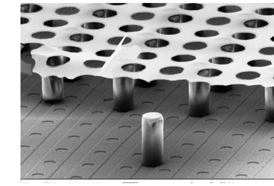




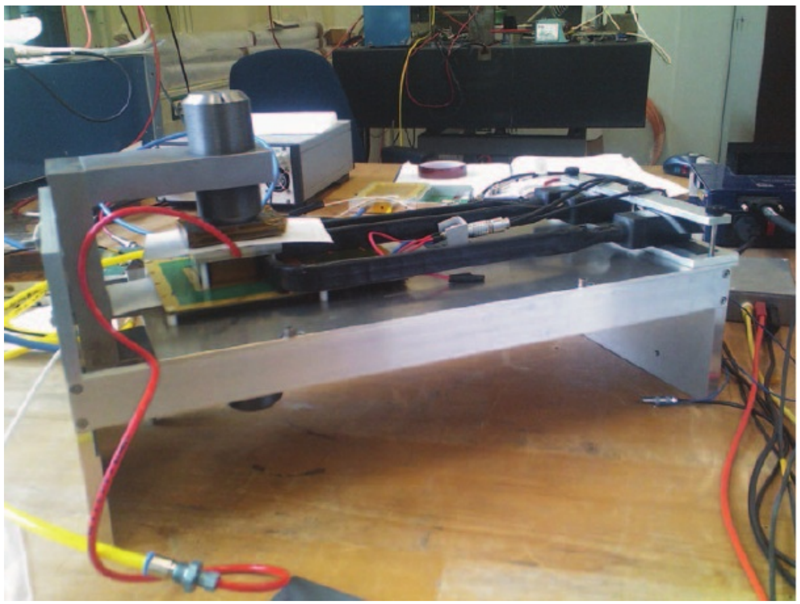
Content

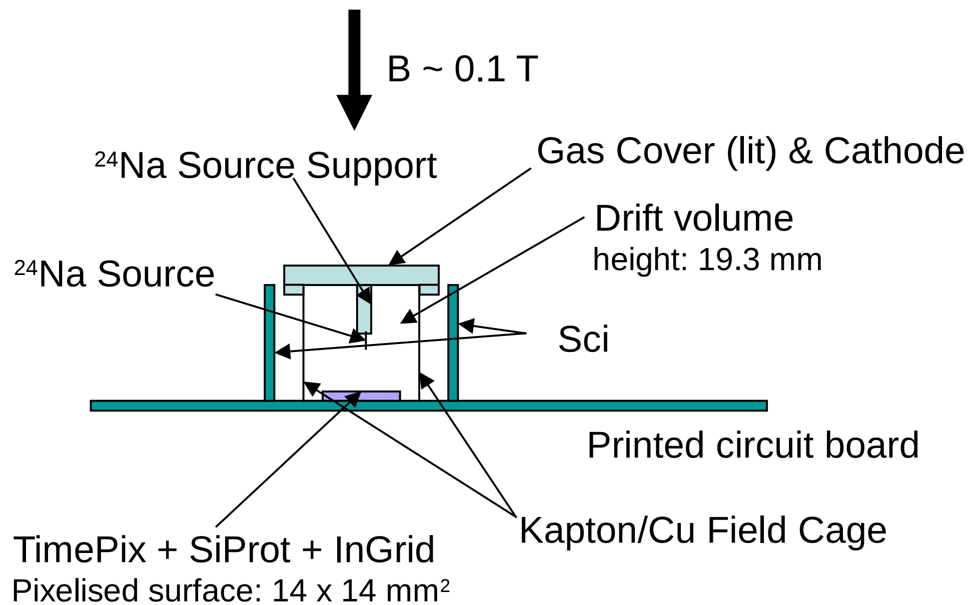






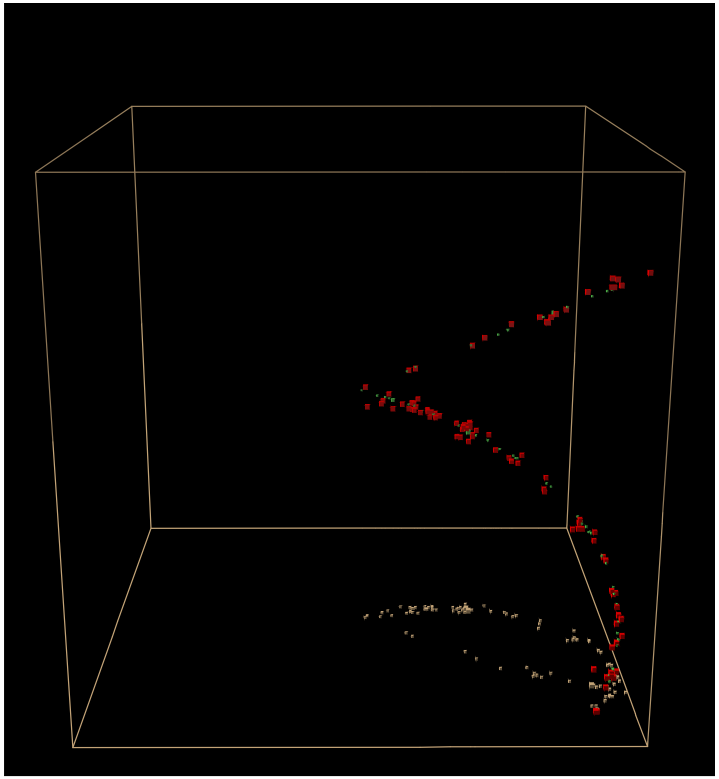
DICE
(Delft Internal Conversion Experiment)

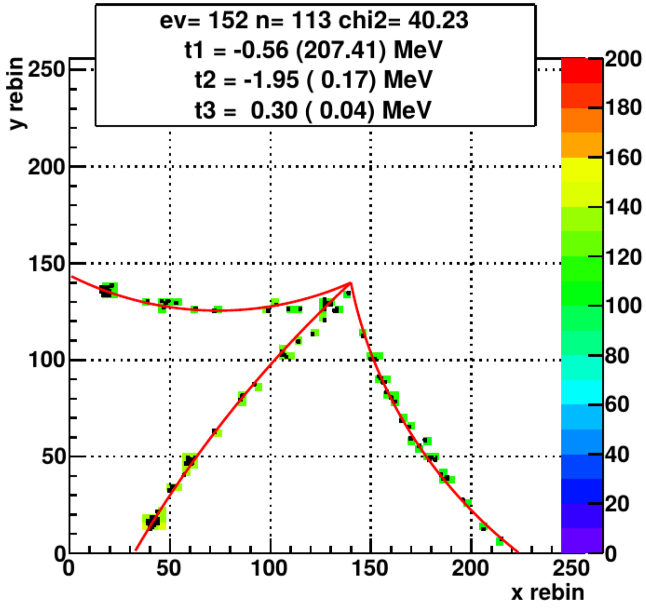


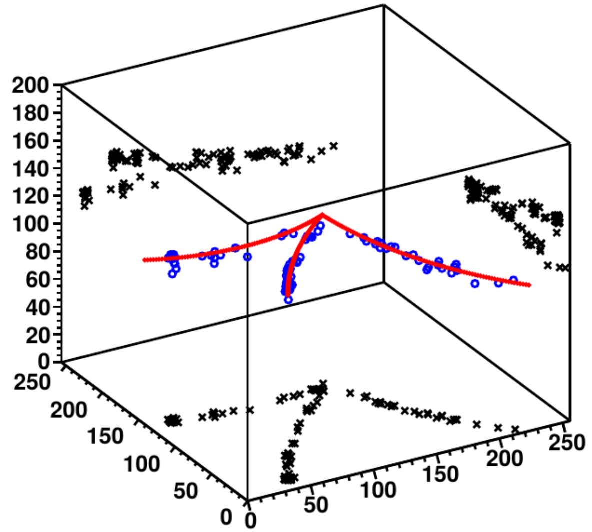


ABSTRACT: GridPix detectors are thin µTPCs, they provide an excellent vertex determination for internal radioactive sources and they have a 4π angular acceptance. GridPix detectors are ideal to study anomalies in Internal Pair Conversion signaling elusive light isoscalar neutral bosons. (2009 JINST 4 P11021)

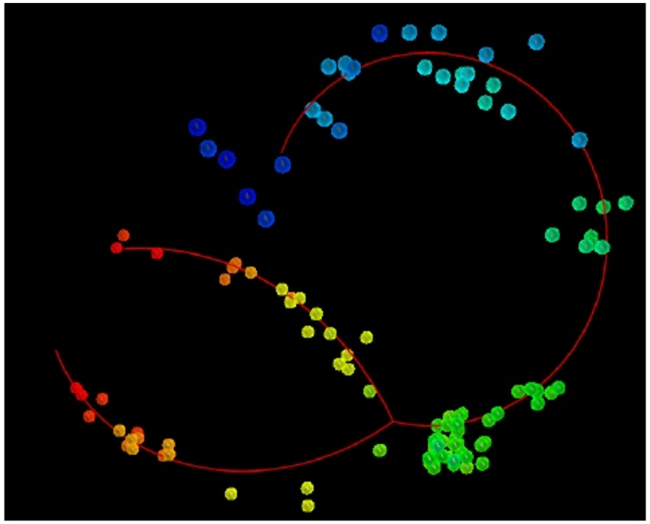
Event Pictures

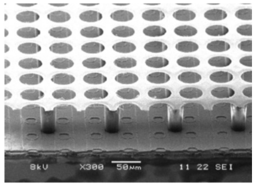




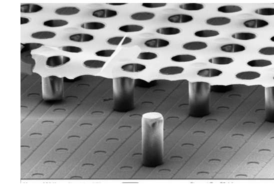


Single GridPix detector
Max. drift length: 19.3 mm
DEM:CO_2 50:50

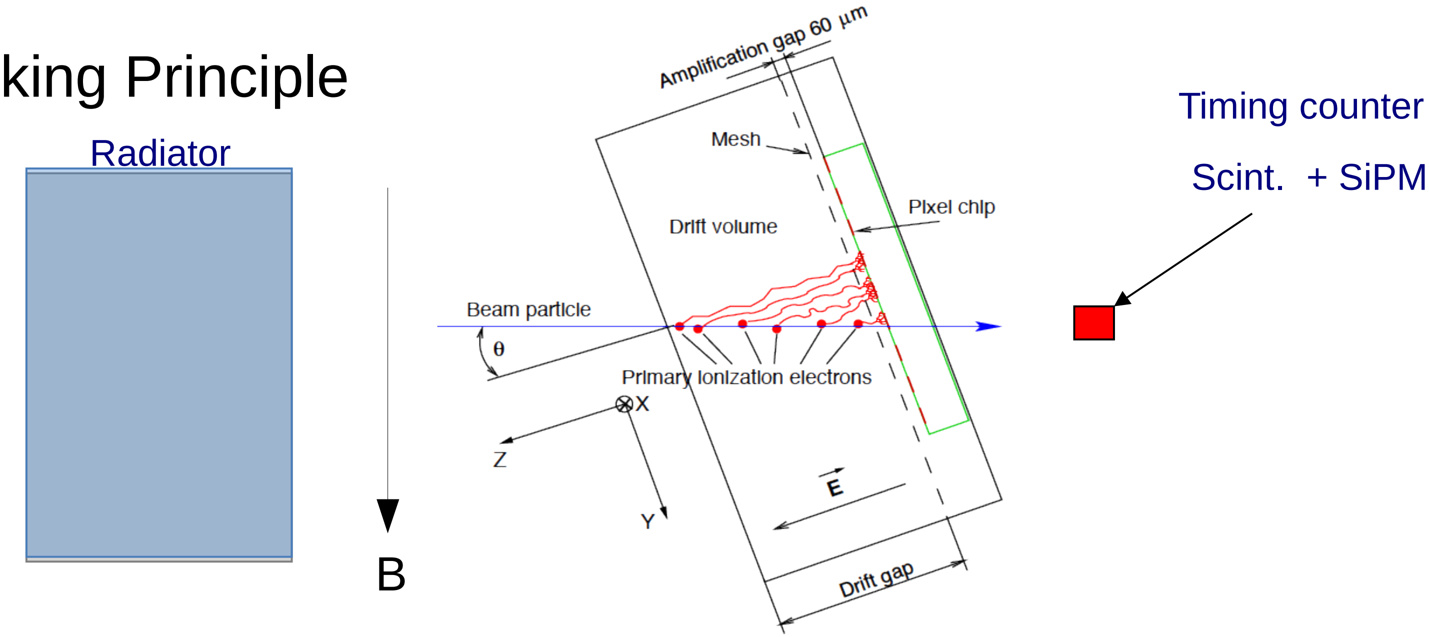




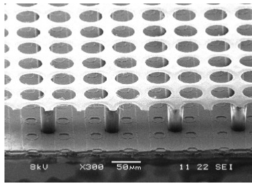
GridPix-TRT Detector



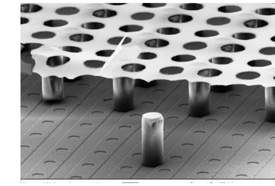
Working Principle

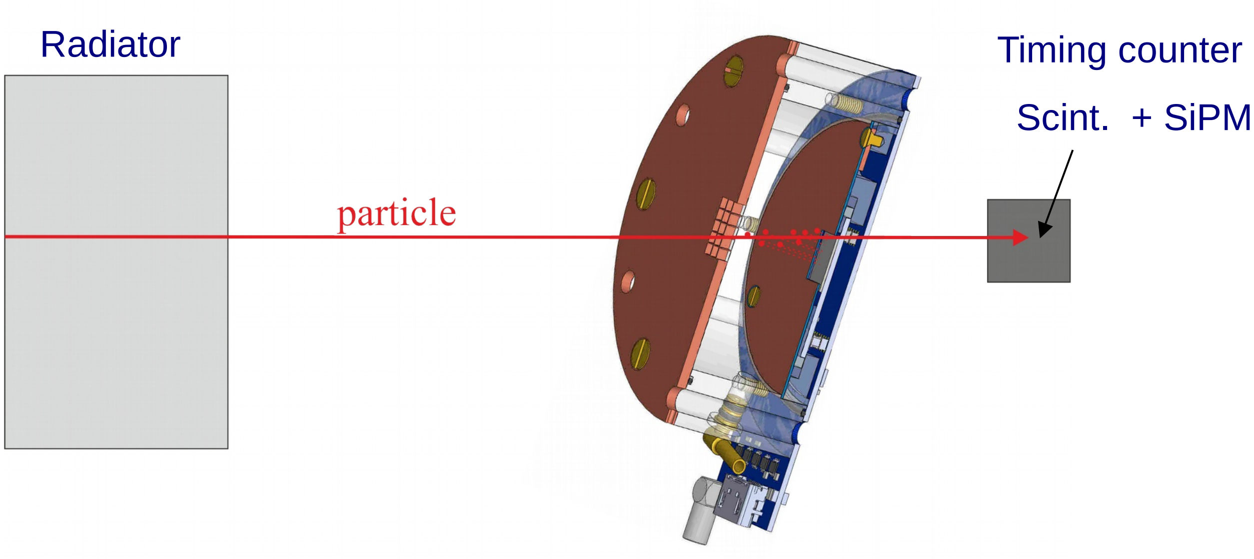


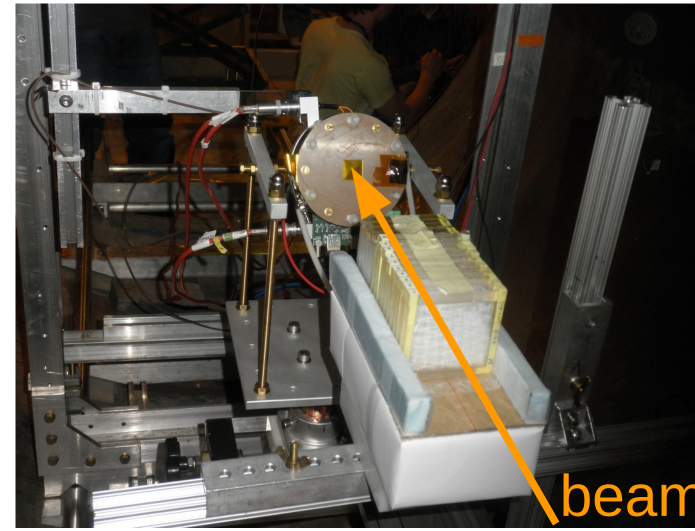
- A particle passes through the radiator and generates TR photons (or not).
- In the magnetic field (if B > 0 T), the track is bent away, the photon not.
- The particle passes through the detector perpendicular to the grid.
- Free electrons will drift to the grid (Lorentz angle, if B > 0T).
- The TR photons will convert at some depth in the drift volume of the detector.



Experimental Setup

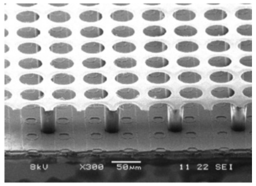




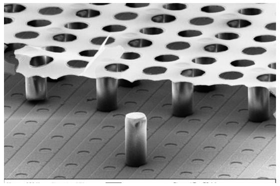


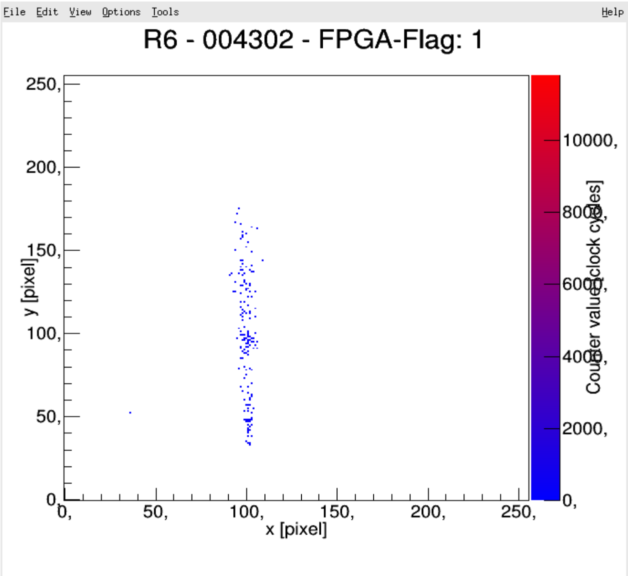
- CAST type detector (2 cm drift length)
- Gas mixtures Xe:CO_2:CF_4 80:10:10 and Kr:iC_4H_{10} 80:20
- North Area (SPS) using e^-- and π–beam
- Various radiators were used
- With and without magnetic field B=1.56 T
  → bends the track about 1 mm away from TR photons

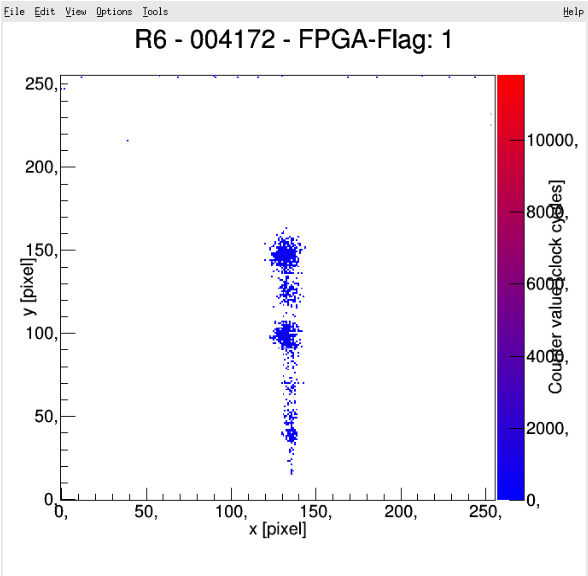
=> In total 43 runs with ~185,000 events.

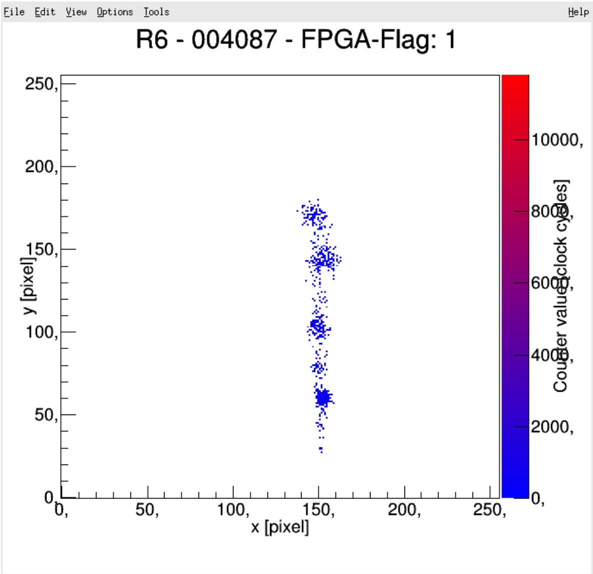


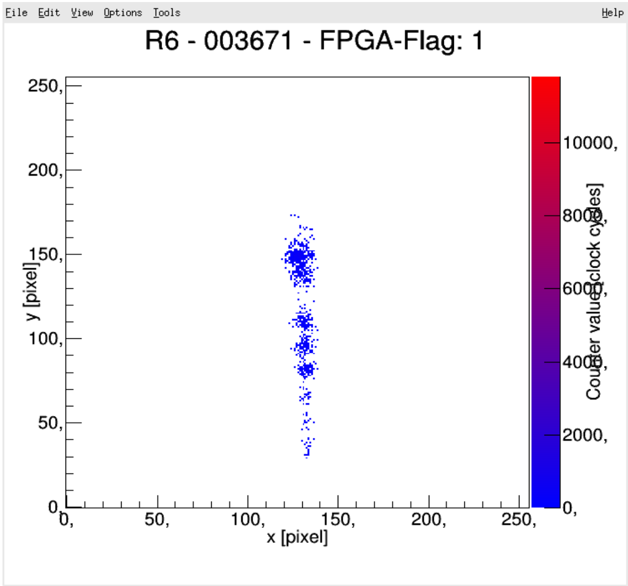
Event Pictures with B = 0 T

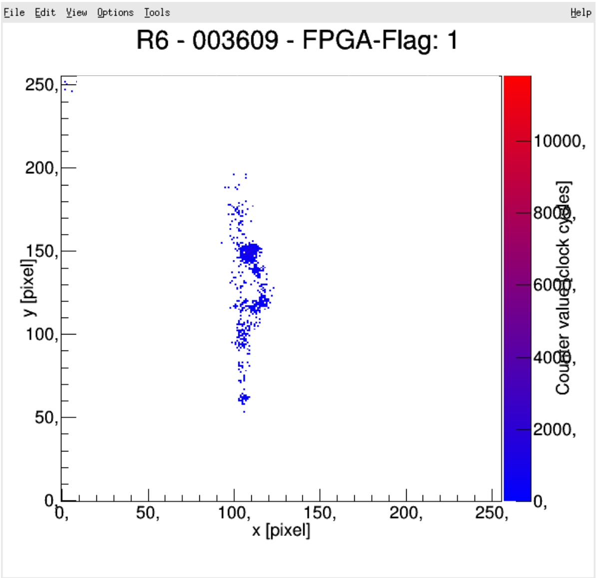


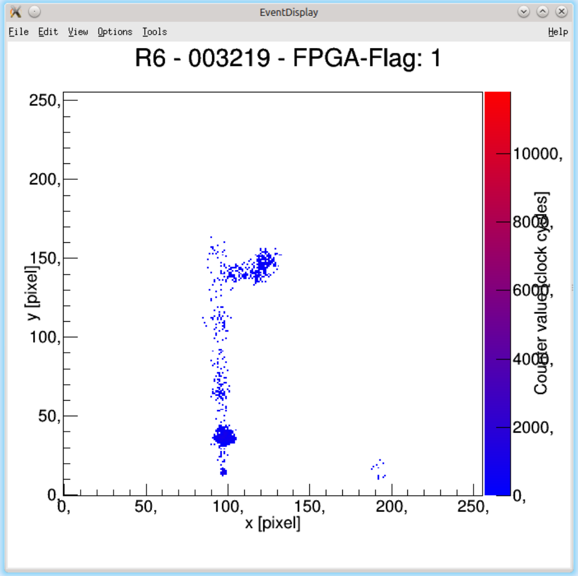


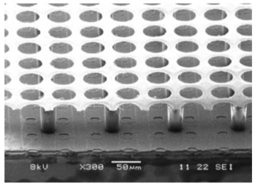




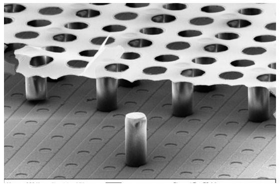


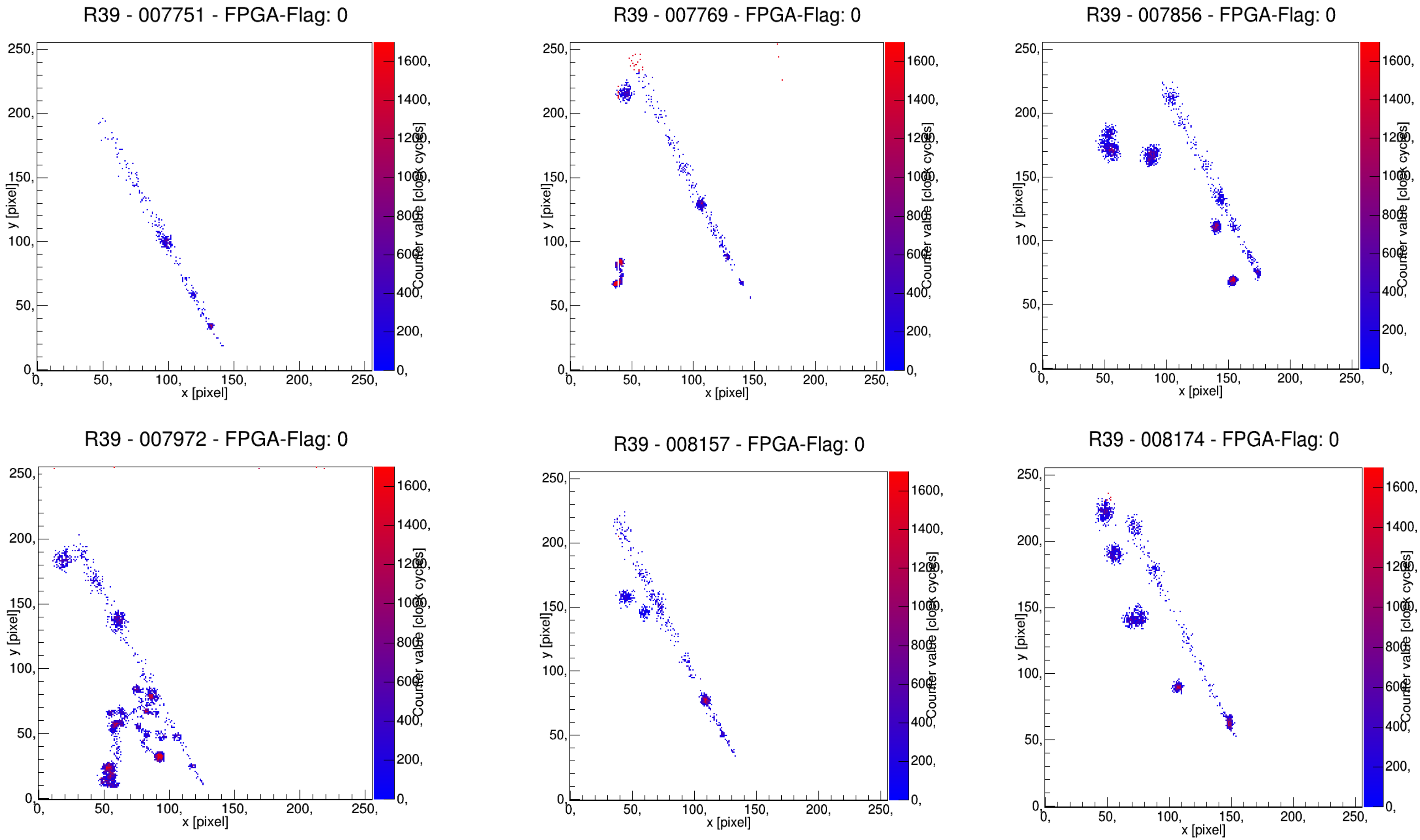






Event Pictures with B = 1.5 T





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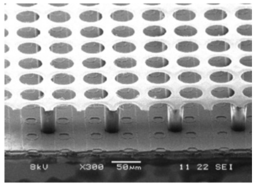
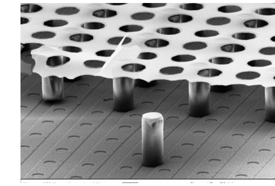
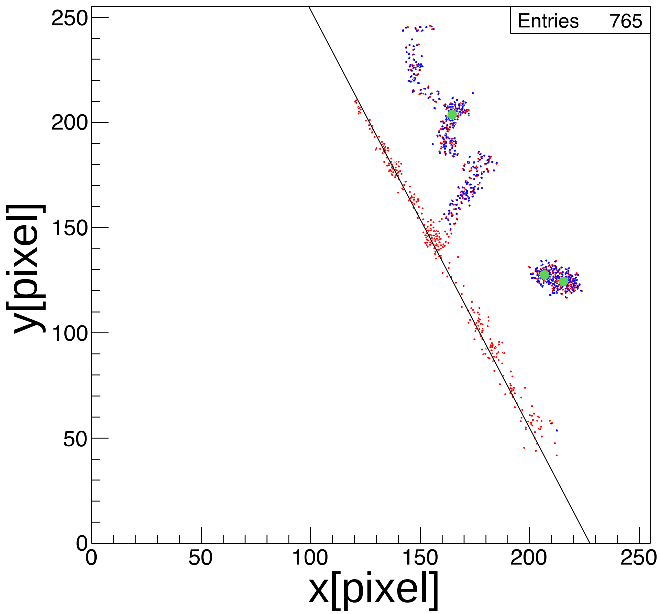
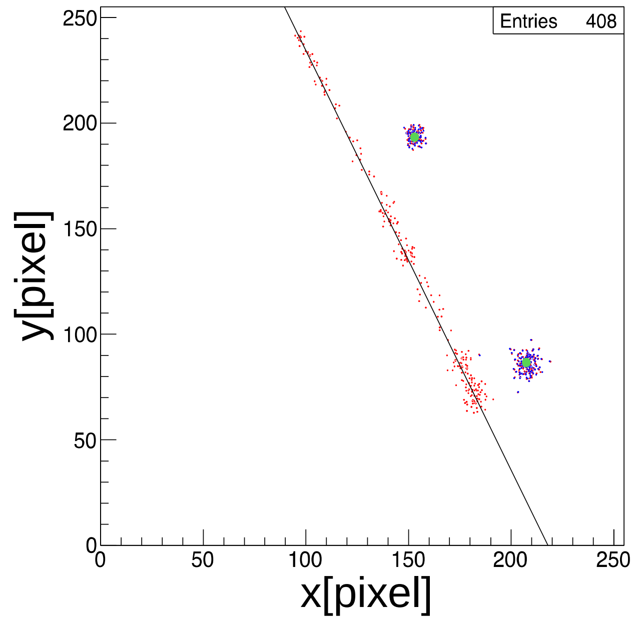
J. Kaminski
Instrumentation Seminar
15. April 2016, DESY



Results

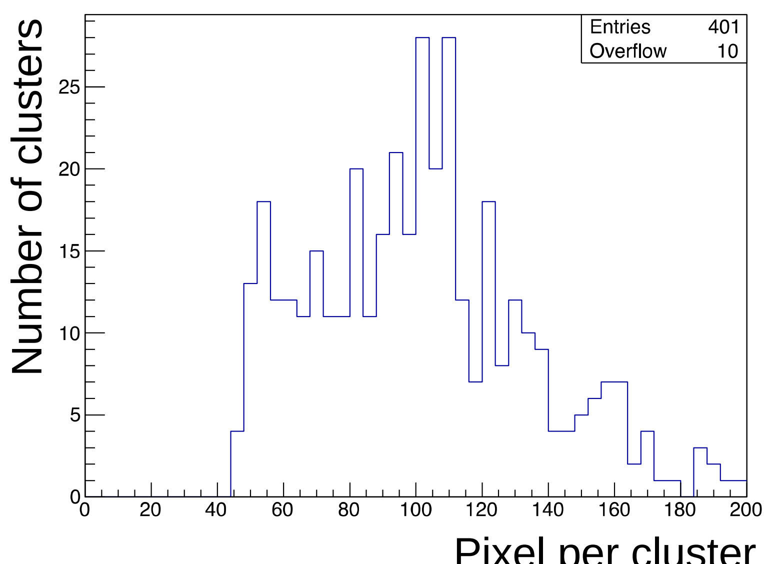


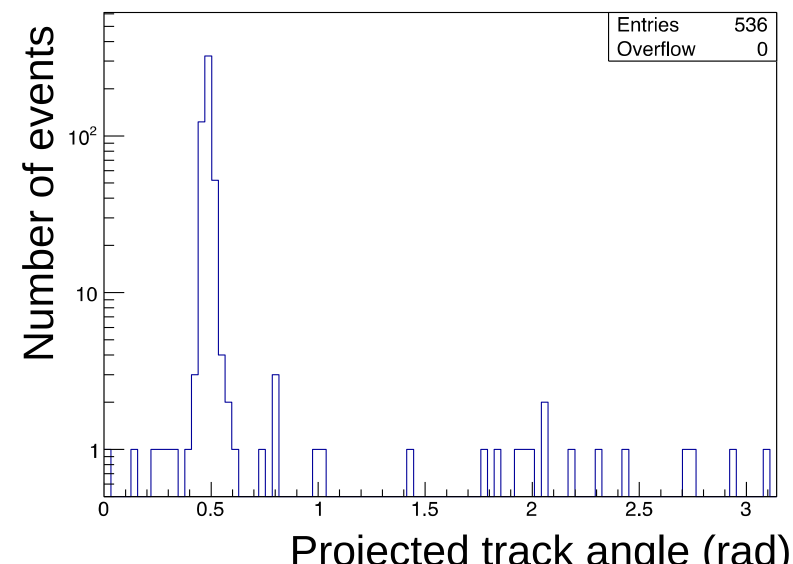


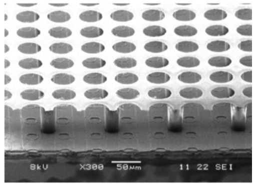


- Trackfinding – Hough transformation
- After trackfinding remove all pixels with distance to track smaller than 10 pixels
- Cluster finding classical jet-algorithm

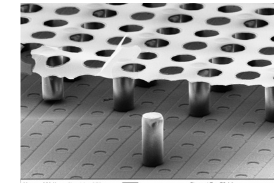
- Merge pixels until more than 8 pixels apart
- Require 44 pixels per clusters

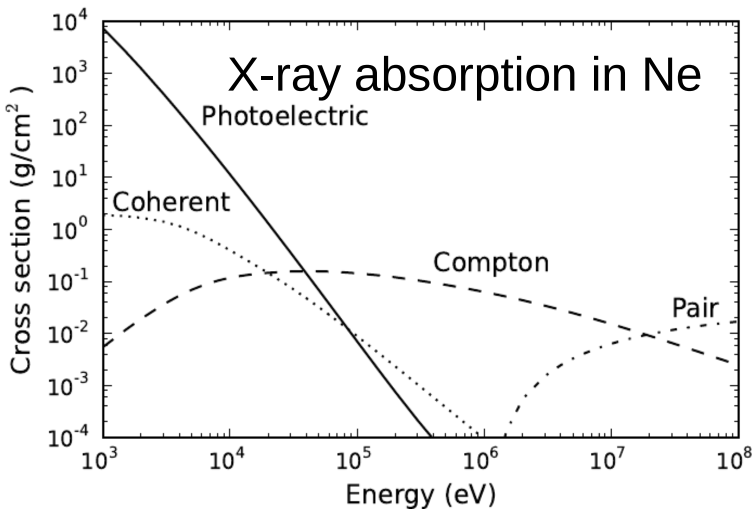




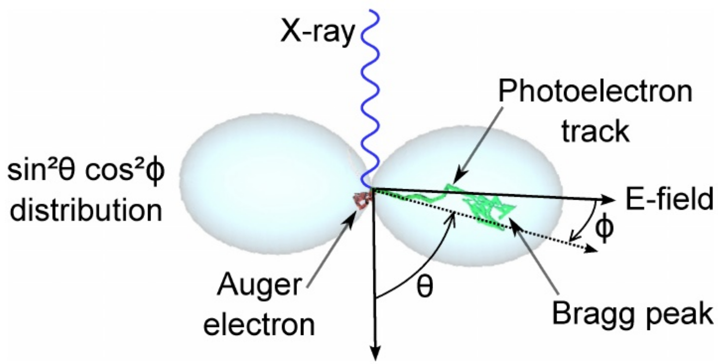


X-ray Polarimeter



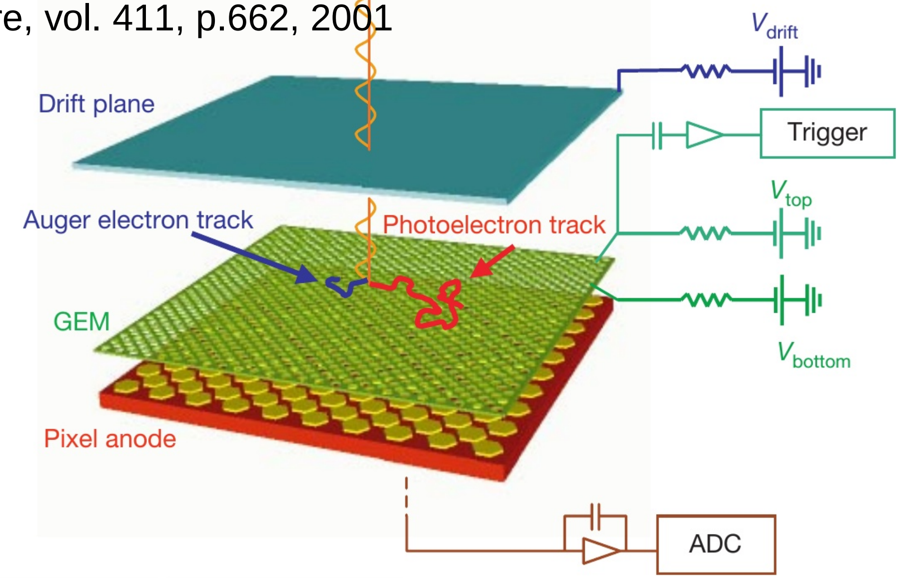


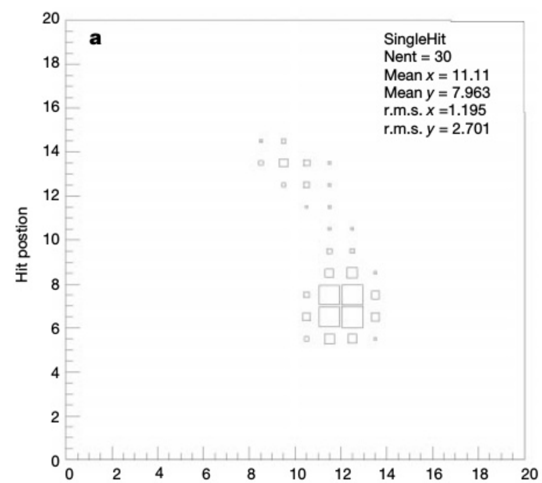
arXiv:1408.5899v3 astro-ph.IM

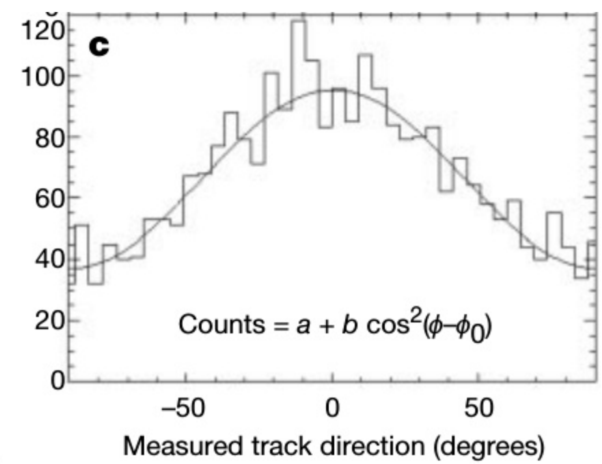


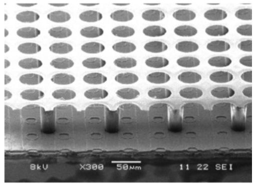
For low energies - photoelectric effect:
e^- is kicked out of an inner atomic shell
with $E_{kin} = E_\gamma - E_{bind}$
in direction of E-field of incoming wave.

Development for astrophysical observations
by E. Costa and R. Bellazzini
Nature, vol. 411, p.662, 2001

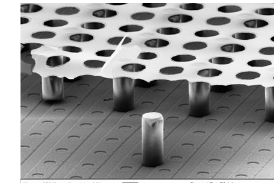






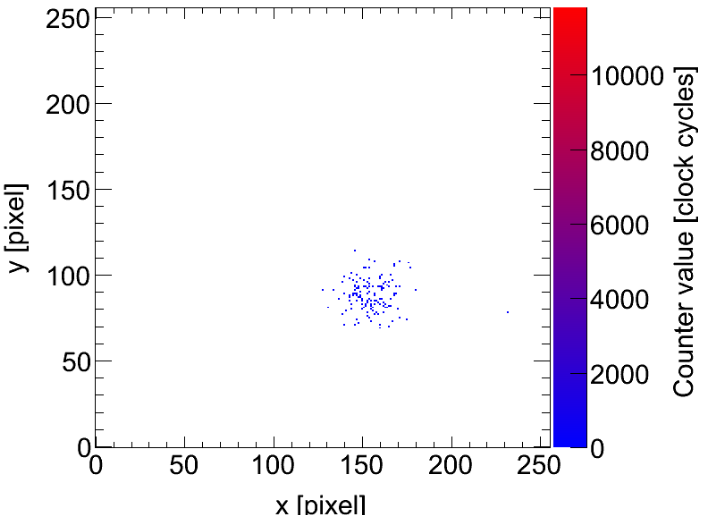


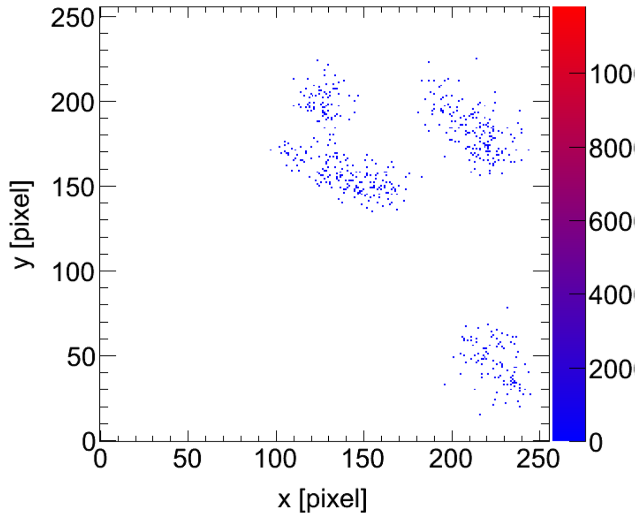
First Test with GridPix Detector

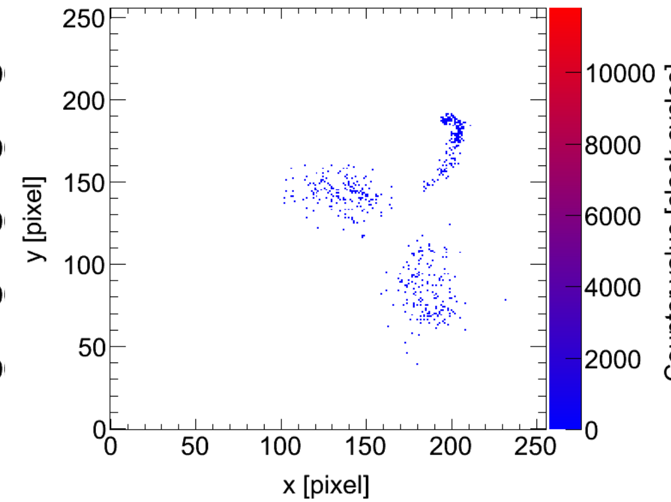


Not optimized – a fast test of 1 h with a gas mixture He: iC_4H_{10} 80:20

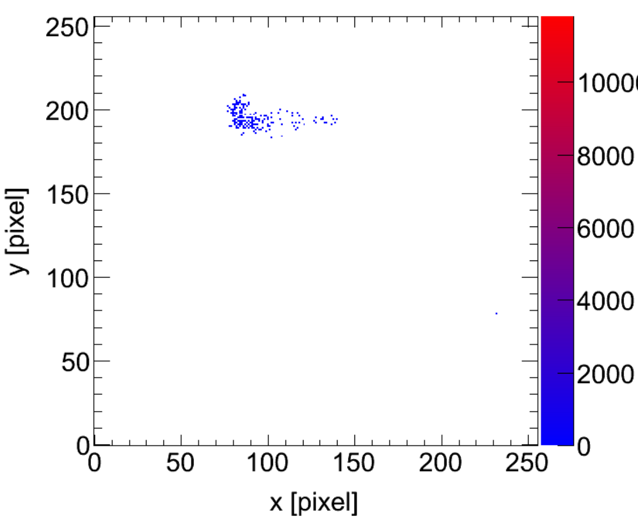
=> diffusion far too large!

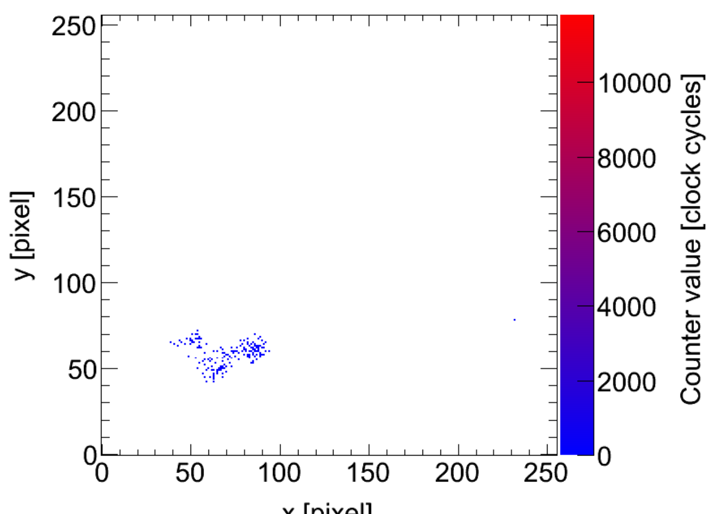


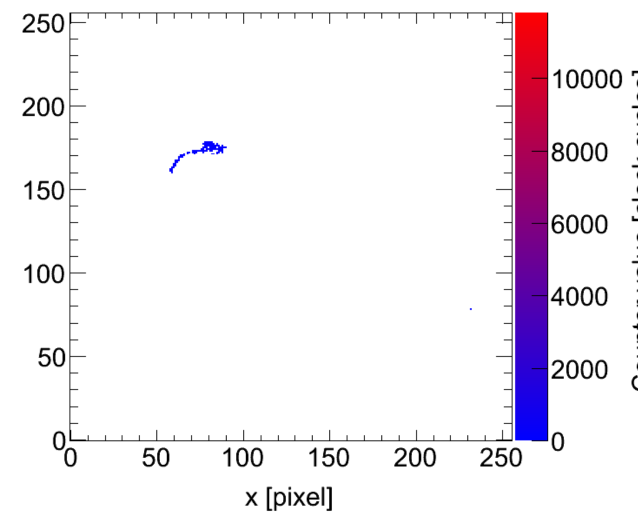


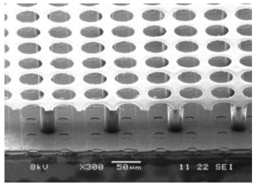


If the X-ray was absorbed deeper in the detector, the drift distance is short → less diffusion

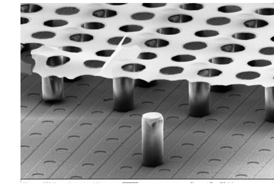


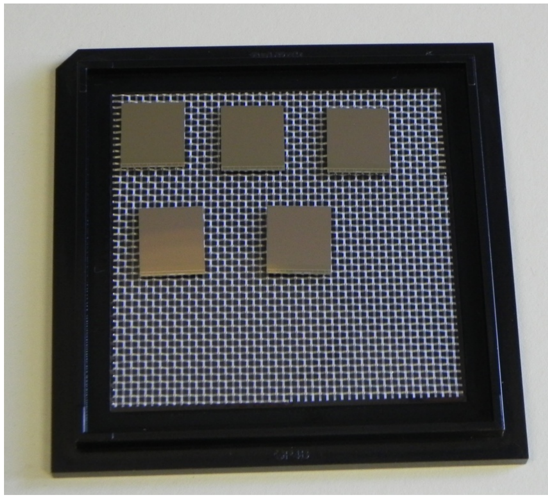






Outlook 1 - Timepix3

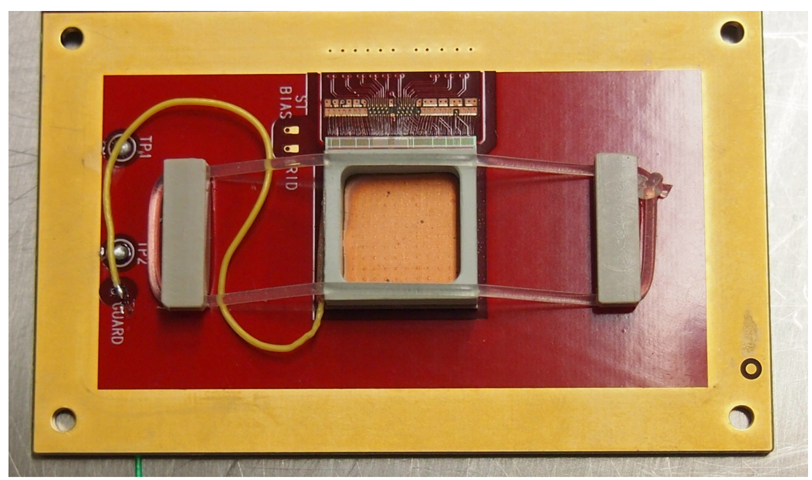


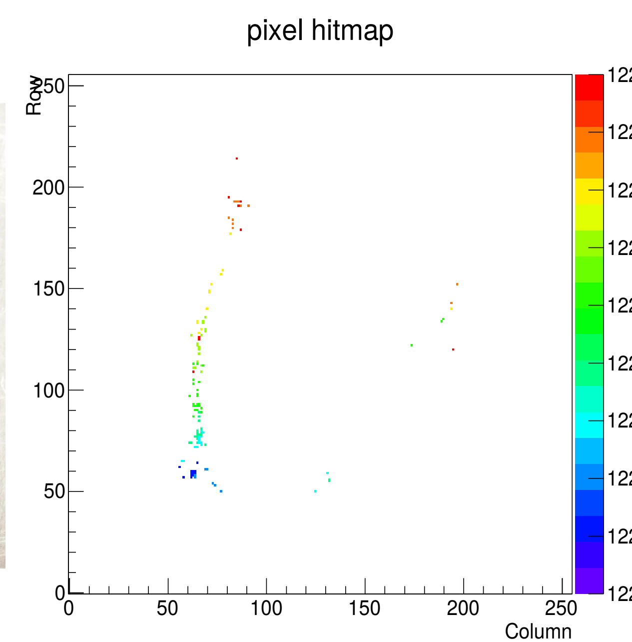


Timepix-3 has been produced. Most importantly:
- Charge and time are available for every pixel,
- Multi-hit capable,
- Very high output rate: 8×640 MHz,
- Better time resolution (~1.7 ns)

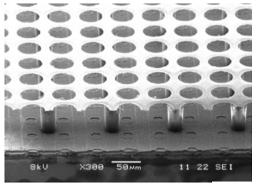
Delivered in fall 2013.
Tests have shown no problems yet.

Test with standard Micromegas
Drift gap: 8 mm
Pillar height: 50 µm
Pitch of holes: 60 µm
Gas: He:iC_4H_{10} 95:5
Source: ^{90}Sr

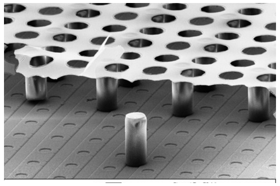


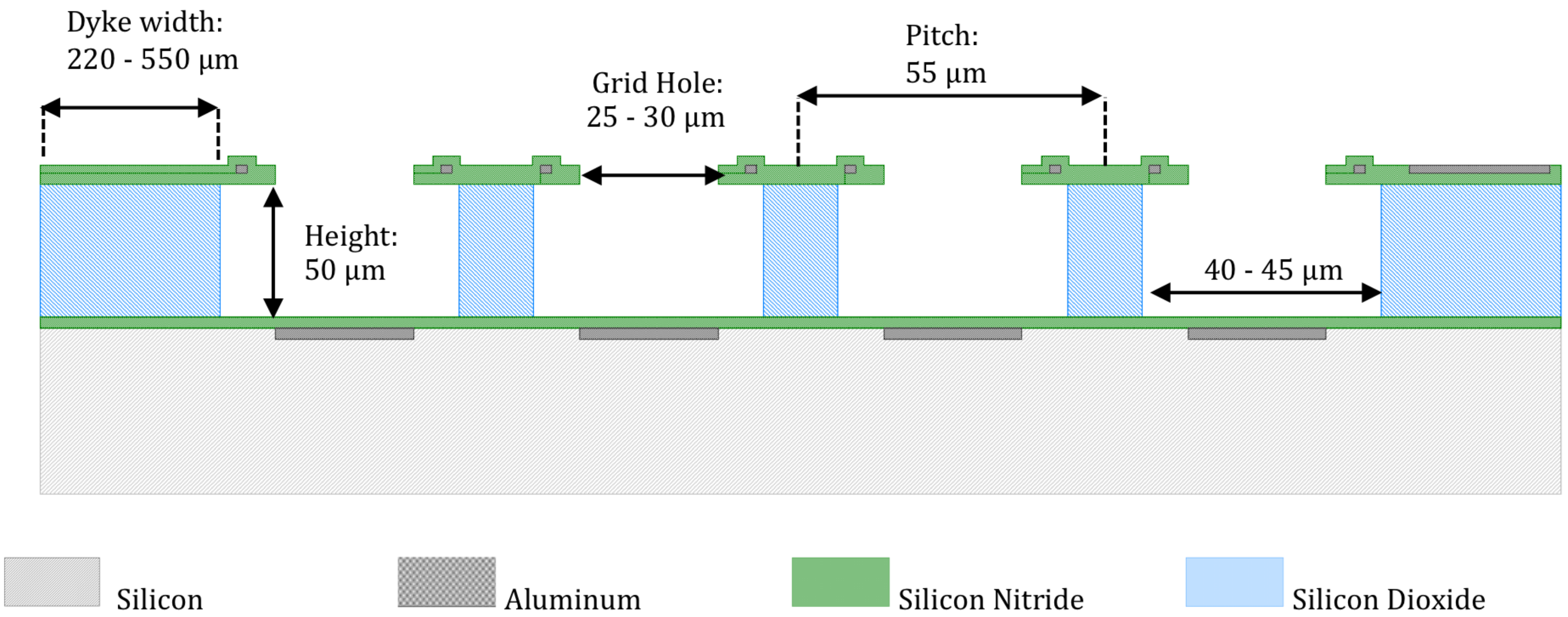


The chamber unit is read out by a SPIDR prototype.

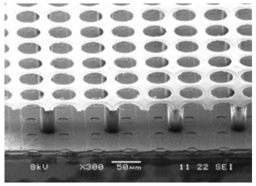


All Ceramic InGrids

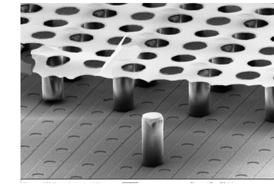




- Double discharge protection
- Equal coefficient of thermal expansion throughout GridPix:
  Needed for operating in cryogenic environments
- No outgasing: Plastics (like SU8) outgas and can not be
  used in ultra clean (cryogenic) environments
- Different pillar structures are possible.



Summary



InGrids have shown excellent performance:

- Energy resolution of σ_E/E ~ 3.85 % (at 5.9 keV)
- Spatial resolution only limited by diffusion.
- High efficiency for single electron detection.

Production techniques are well advanced, a few details have to be improved.

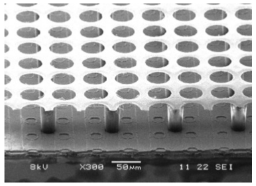
Large systems (~160 chips) have been operated with a new readout system in a test beam earlier this year.

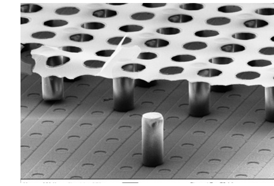
Excellent tracking properties have been demonstrated in this test beam.

Other applications like TR detection or polarimetry show encouraging first results, but need some more R&D.

Further R&D on InGrids are planned (resistive grid, all ceramic,...)

New Timepix-3 is available and shows good results.





Acknowledgment

This is of course the work of many people.
In Bonn these are:
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Christoph Krieger (CAST)
Michael Lupberger, Daniel Danilov and
Alexander Hamann (LCTPC).
and of course Klaus Desch.
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well as the electronics and mechanical workshops.