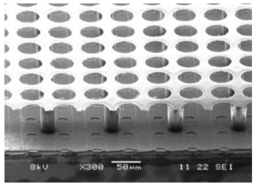

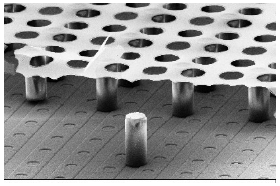

GridPix as a candidate for the future of CAST

C. Krieger, J. Kaminski, Y. Bilevych,
T. Krautscheid, K. Desch

University of Bonn

6th TPC-Symposium
Paris
17. - 19. December 2012

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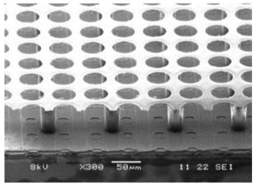
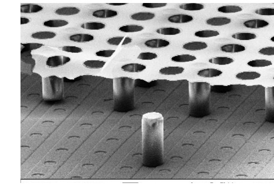
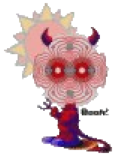
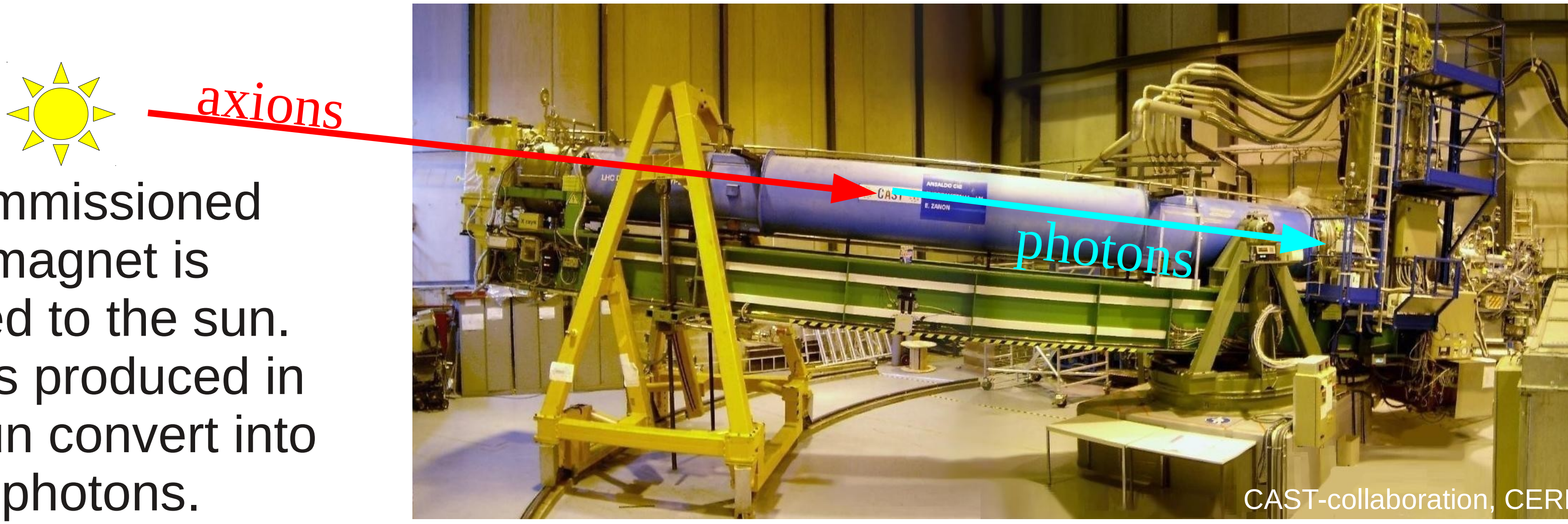


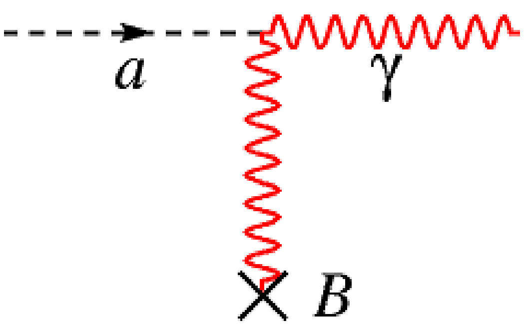
Axion Search with CAST





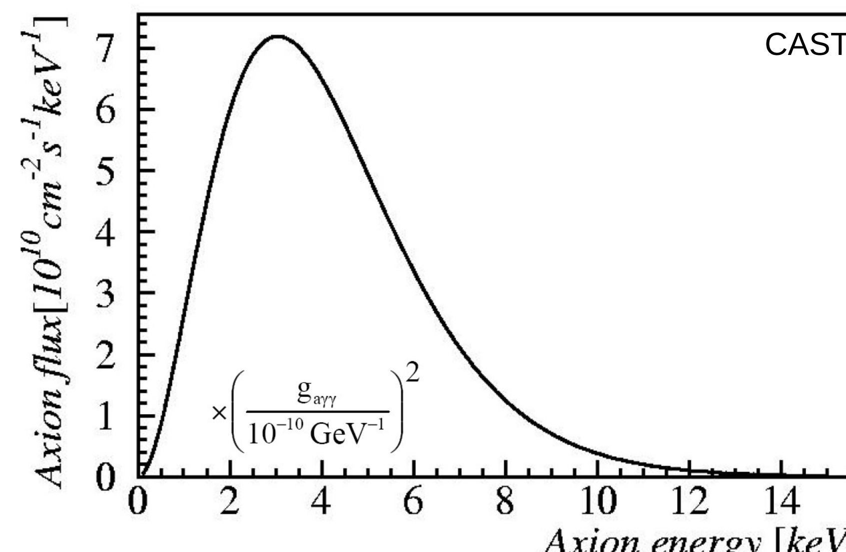


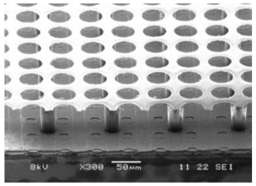
Decommissioned LHC-magnet is pointed to the sun. Axions produced in the sun convert into X-ray photons.

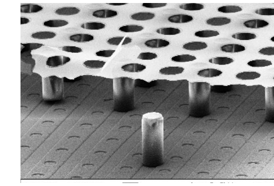


Detect X-ray photons with high efficiency.

→ Gaseous detectors (Micromegas) with Ar-mixture at 1-2 bar over-pressure (and 1 CCD).

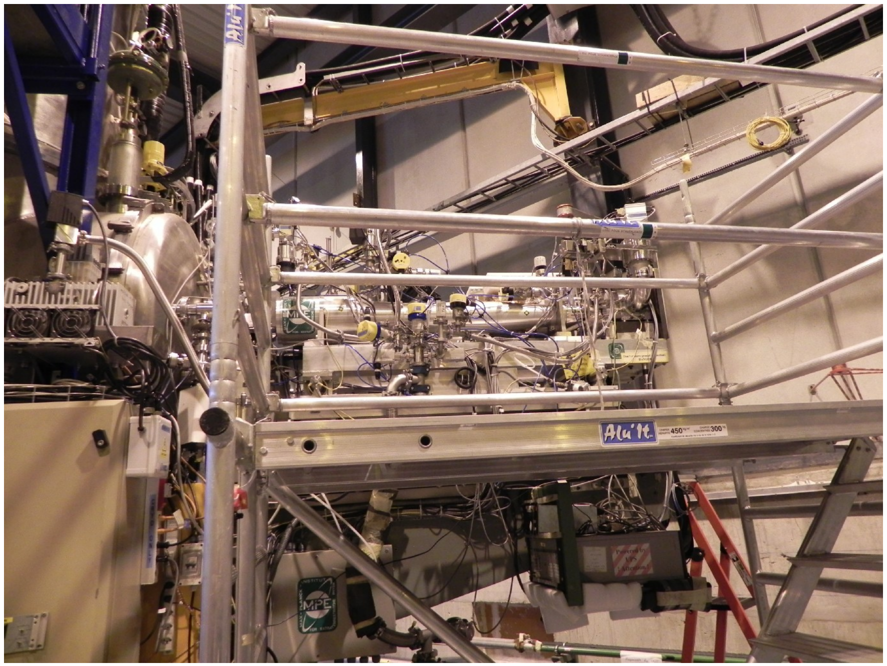






Reduction in Background

Suppress background as much as possible to increase signal significance



Spare X-ray telescope from ABRIXAS space mission

- 27 nested gold coated nickel shells
- focal length 1.7 m
- 35% transmission
- diameter 43 mm (magnet)
- focused to 3 mm diameter

=> background reduced by factor 200 by reducing area and concentrating signal on smaller area

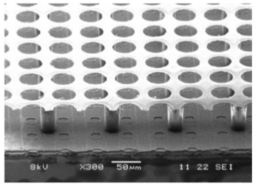
Several layers of shielding to reduce background

Better reconstruction of the events

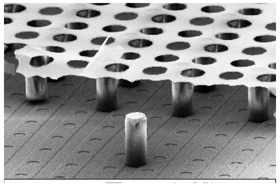
→ improve energy and spatial resolution of detector

Micromegas have a very good intrinsic resolution, but it is often limited by large readout pads.

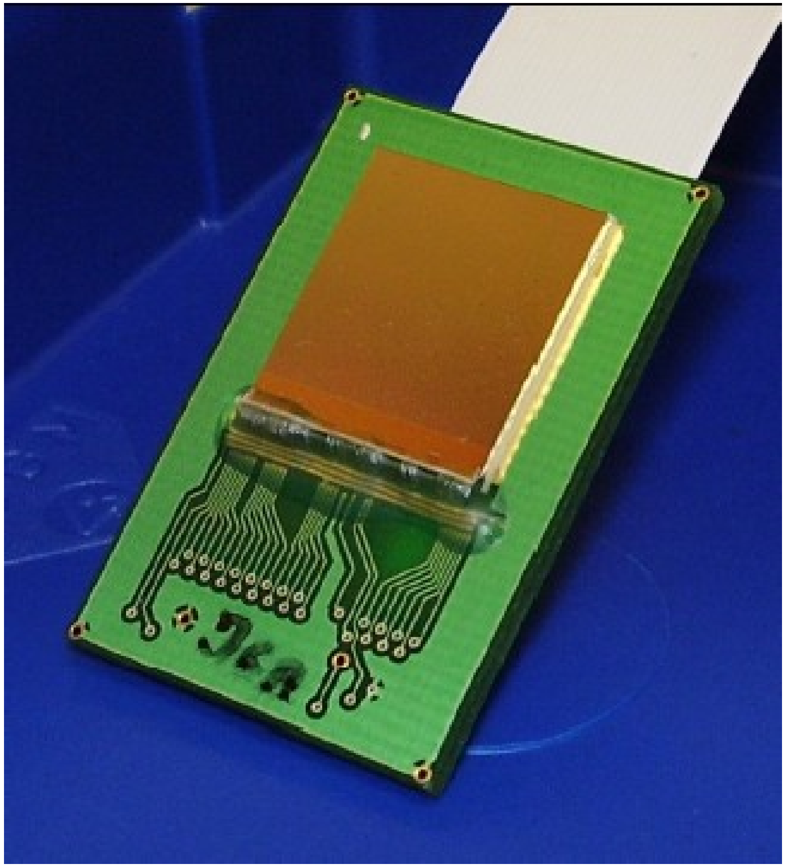
=> Decrease pad size to improve detector resolution.



Timepix Chip



Timepix chip (1st version) derived from MediPix-2



Available for tests since Nov. 2006

Number of pixel: 256 × 256 pixel
Pixel pitch: 55 × 55 µm²
Chip dimensions: 1.4 × 1.4 cm²
ENC: ~ 90 e^-

Each pixel can be set to one of these modes:

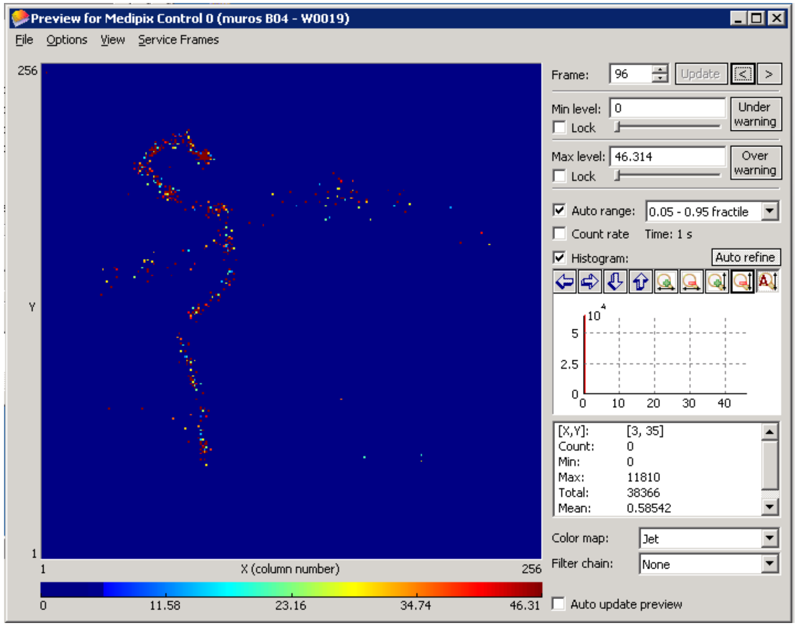
- Hit counting
- TOT = time over threshold
  gives integrated charge
- Time between hit and shutter end
- Hit/no-hit

<u>Limitations:</u> no multi-hit capability, charge and time measurement not possible for one pixel

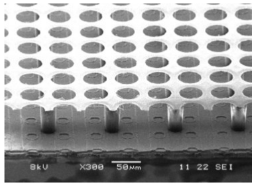
The successor Timepix-3 is being designed and will be submitted soon.

Timepix Readout

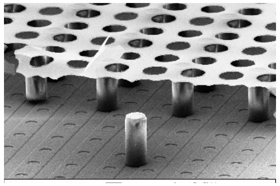
MUROS 2.1 designed at NIKHEF - not in production anymore



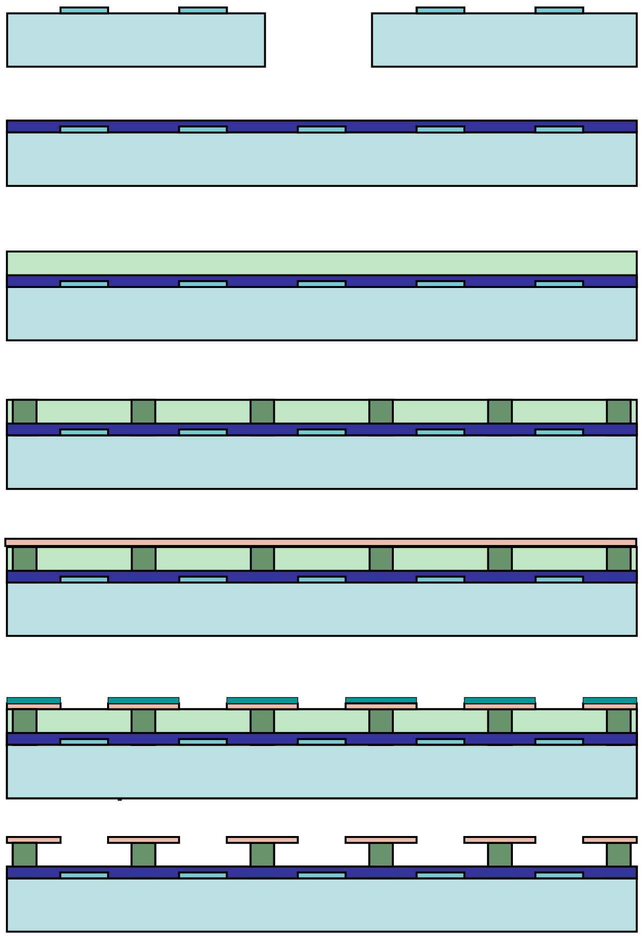
Data acquisition was operated by the Pixelman software developed at the TU Prague.



Production of InGrids

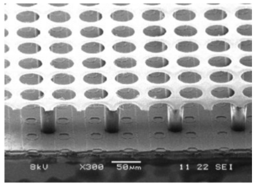


The production of InGrids was pioneered by the University of Twente/MESA+.

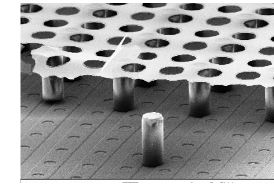


1. Dicing of Wafer
2. Formation of Si_xN_y protection layer
3. Deposition of SU-8
4. Pillars-like structure formation
5. Deposition of thin Al layer
6. Formation of Al grid
7. Development of SU-8

Grid holes aligned with the readout pads.



Protection Layer



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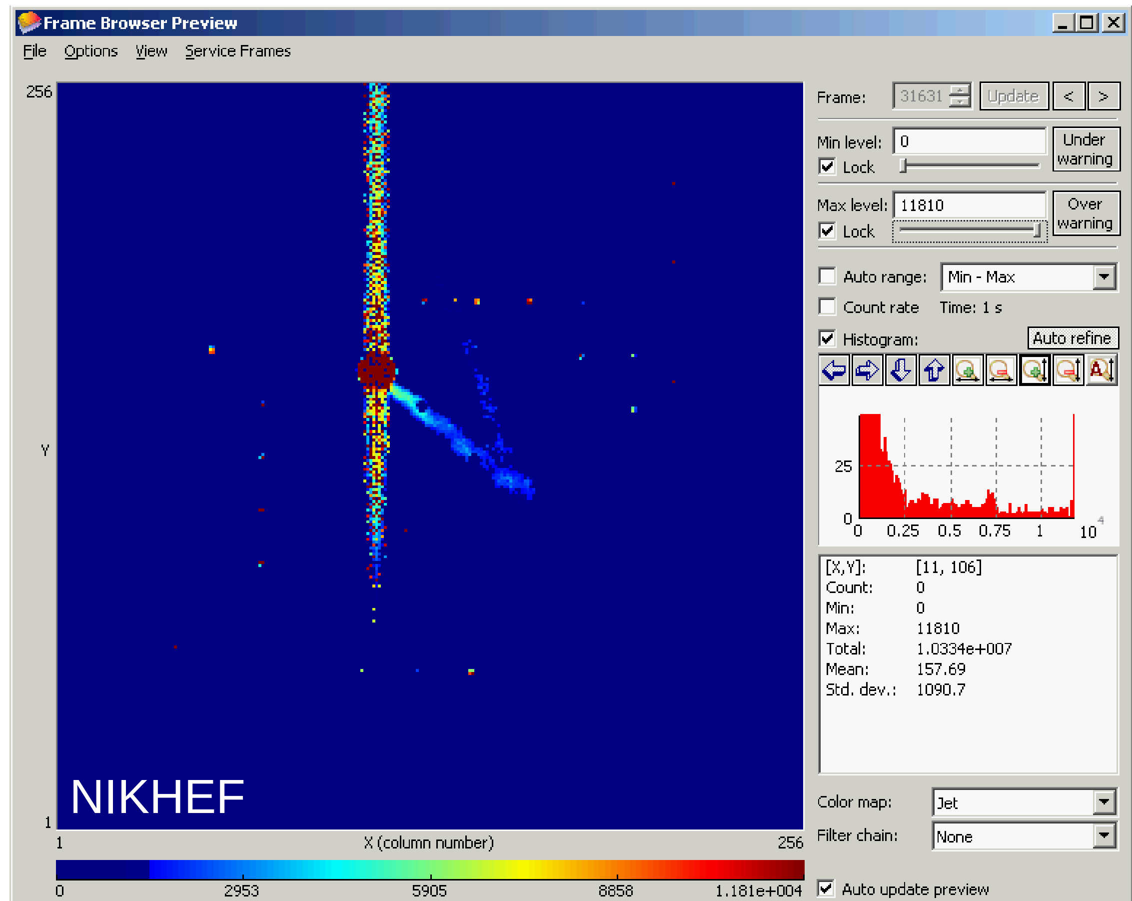
Discharge triggered for example by highly ionizing particles could easily destroy the the chip. The charge collected by one pixel was too high.

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



high resistive material

15 µm aSi:H (~10^{11} Ω·cm)

8 µm Si_XN_Y (~10^{14} Ω·cm)

Chips survives several thousand discharges triggered by αs.

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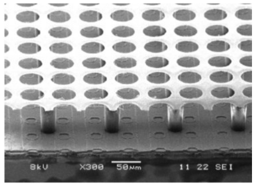
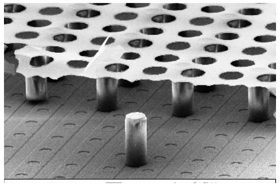
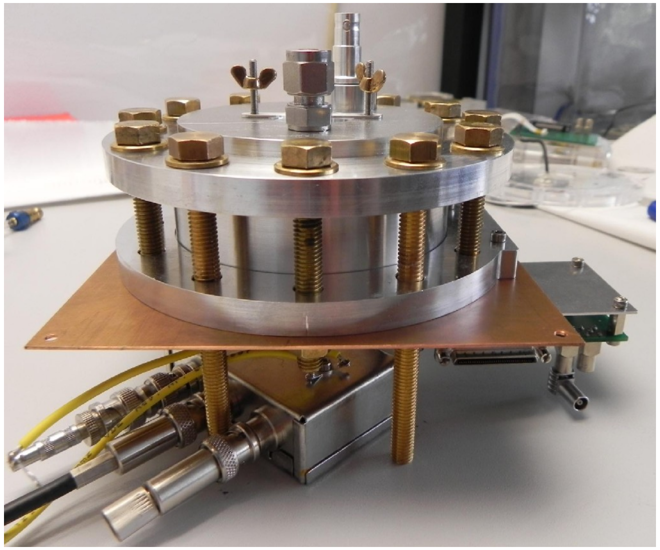
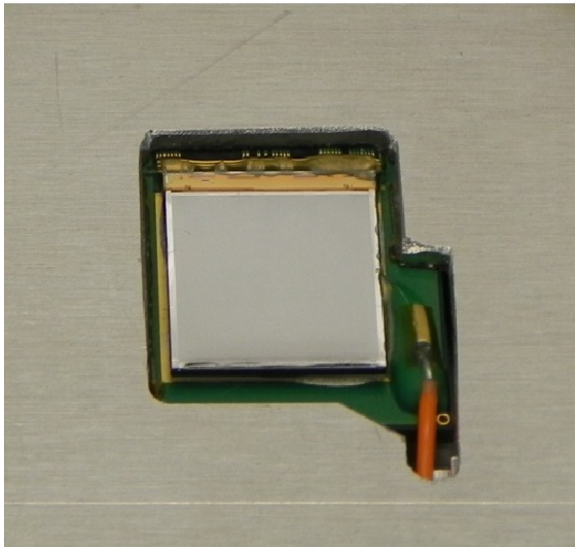
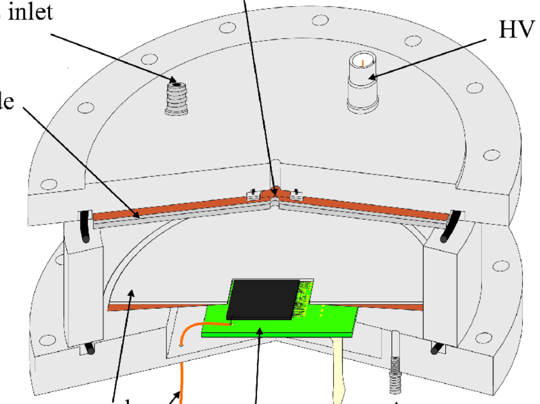


First GridPix Detector

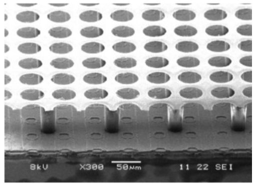




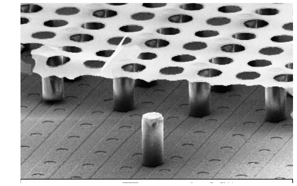


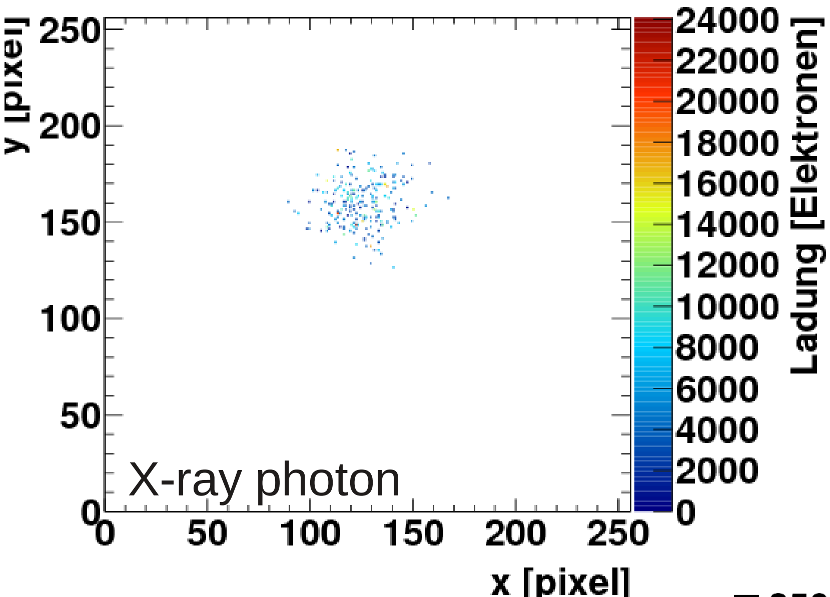


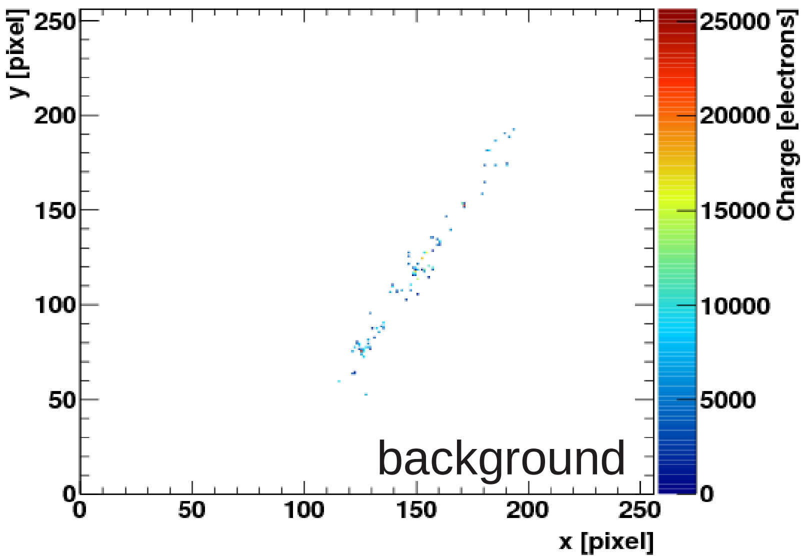
- Inner diameter 8 cm, maximum drift distance 2 cm
- Detector made of aluminum, insulation with Kapton®-foil
- Read out by one InGrid
- Entrance window diameter 1 mm, covered with 50 µm Kapton-foil
- Gas mixture Ar/iC_4H_{10} 95/5 (flux 2 l/h) only a few mbar over-pressure

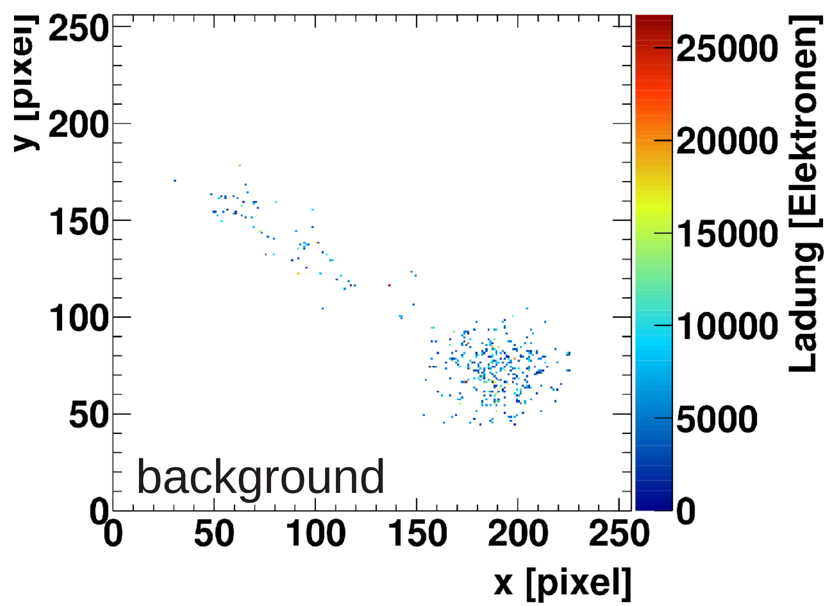


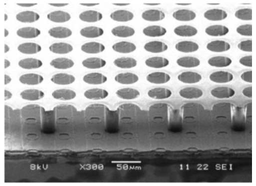
Example Events

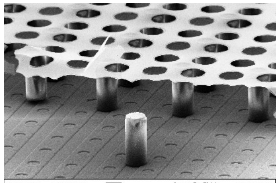










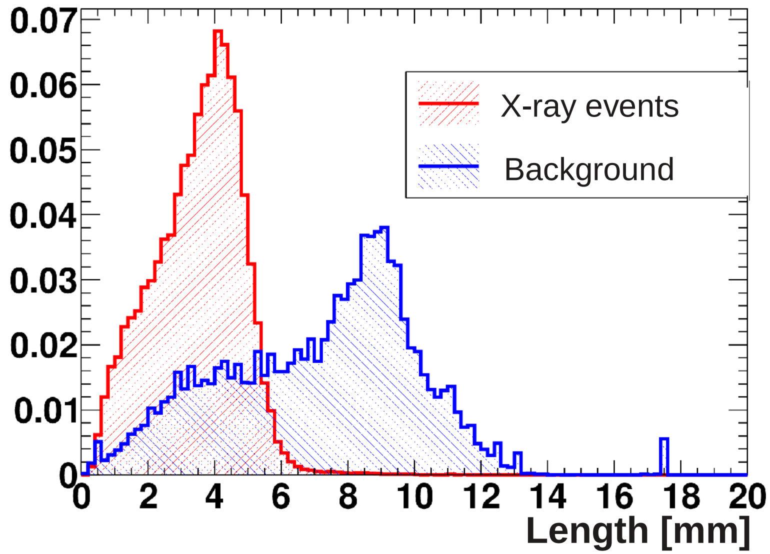


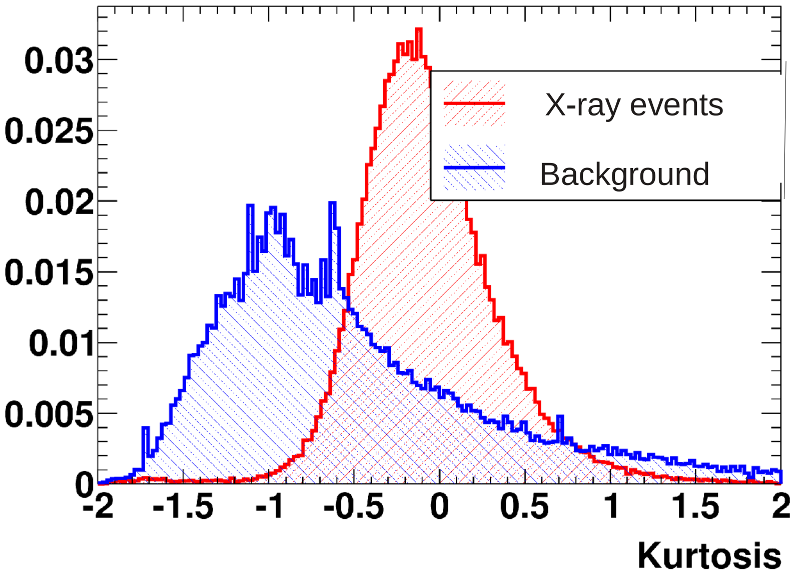
Analysis

Event shapes are reconstructed under the assumption being either a track or an X-ray photon.

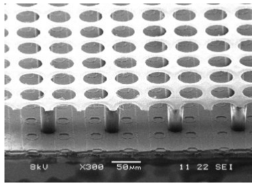
Event shapes are determined under both assumptions for each event. (e.g. widths and higher central moments along the longest and shorted axes)

The values are then compared to sample distributions for both hypothesis:

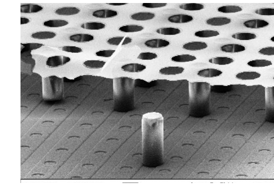


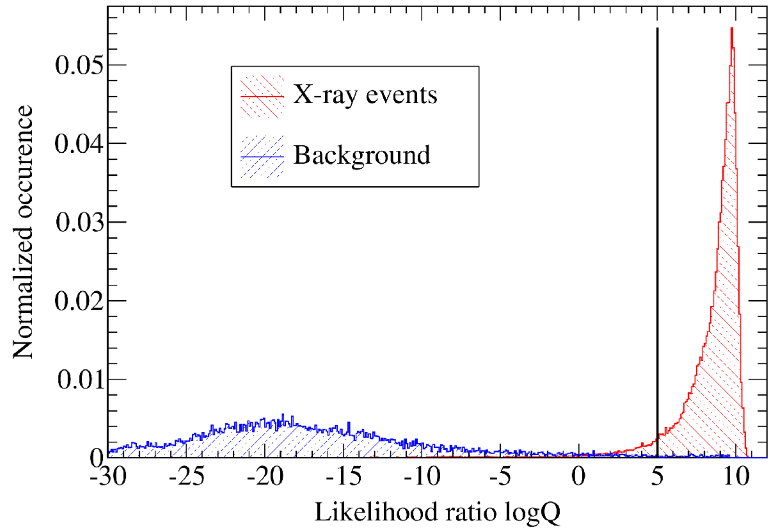


A likelihood ratio based on 6 observables is used to make an event-by-event decision.

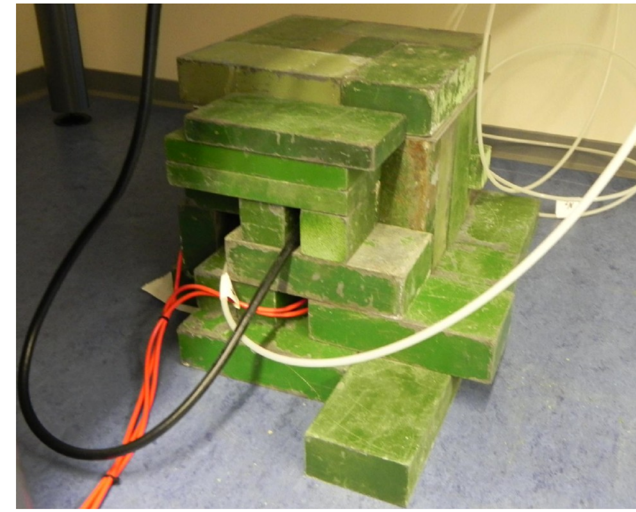


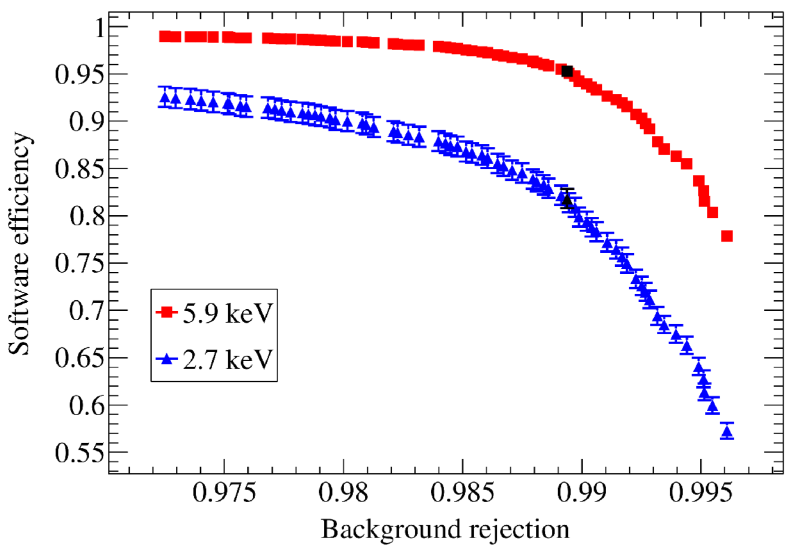
Background Reduction

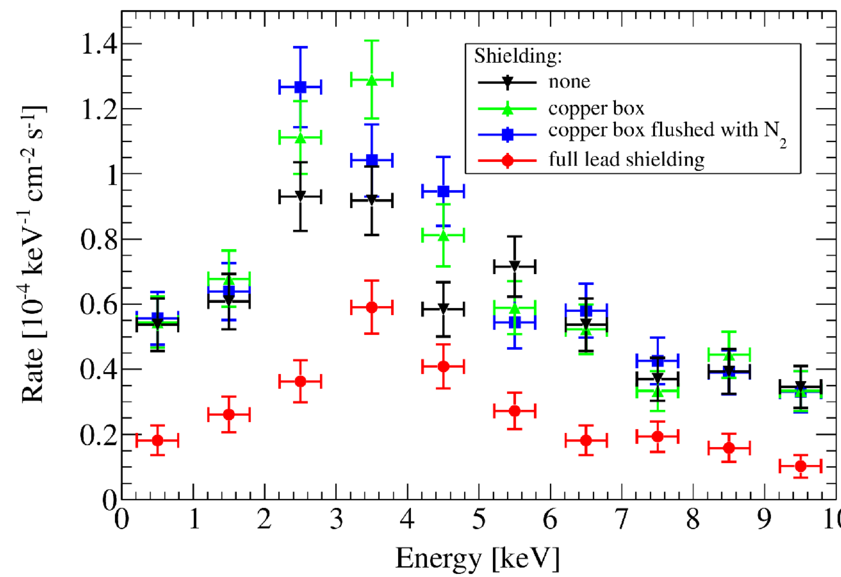


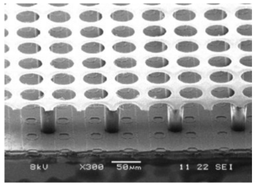


Lead shielding and likelihood ratio algorithm suppress background down to 10^{-5} keVcm^{-2}s^{-1}

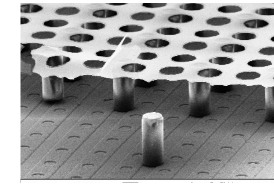








Further Work



<u>In progress</u>

Design of new detector –
compatible with other Micromegas detectors

Production of new InGrids

New electronics

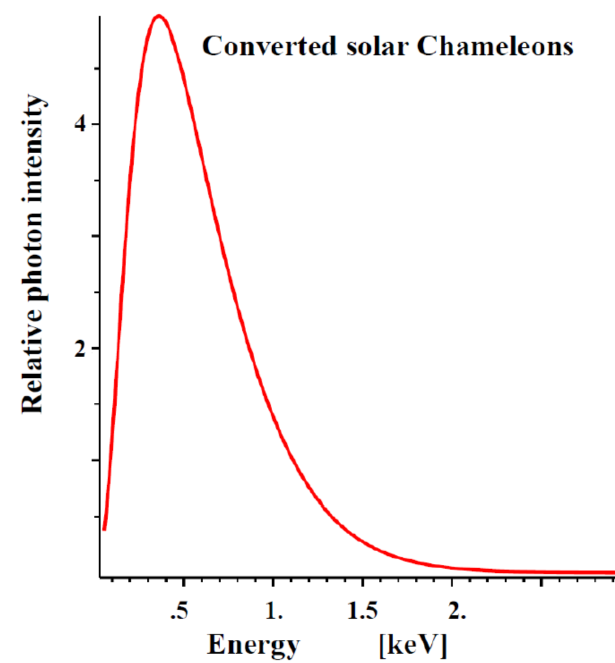
Entrance windows with maximal transmission

<u>In close future</u>

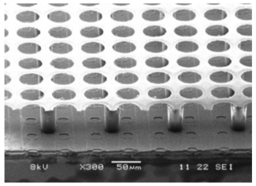
Connection to telescope

Study of the lower detection limit
for searches of chameleons
(software efficiency of reconstruction and
entrance window transmission)

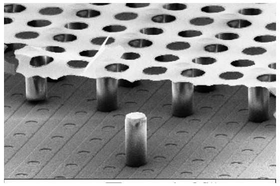
Decouple grid signal and sample with FADC
→ further reduction of background

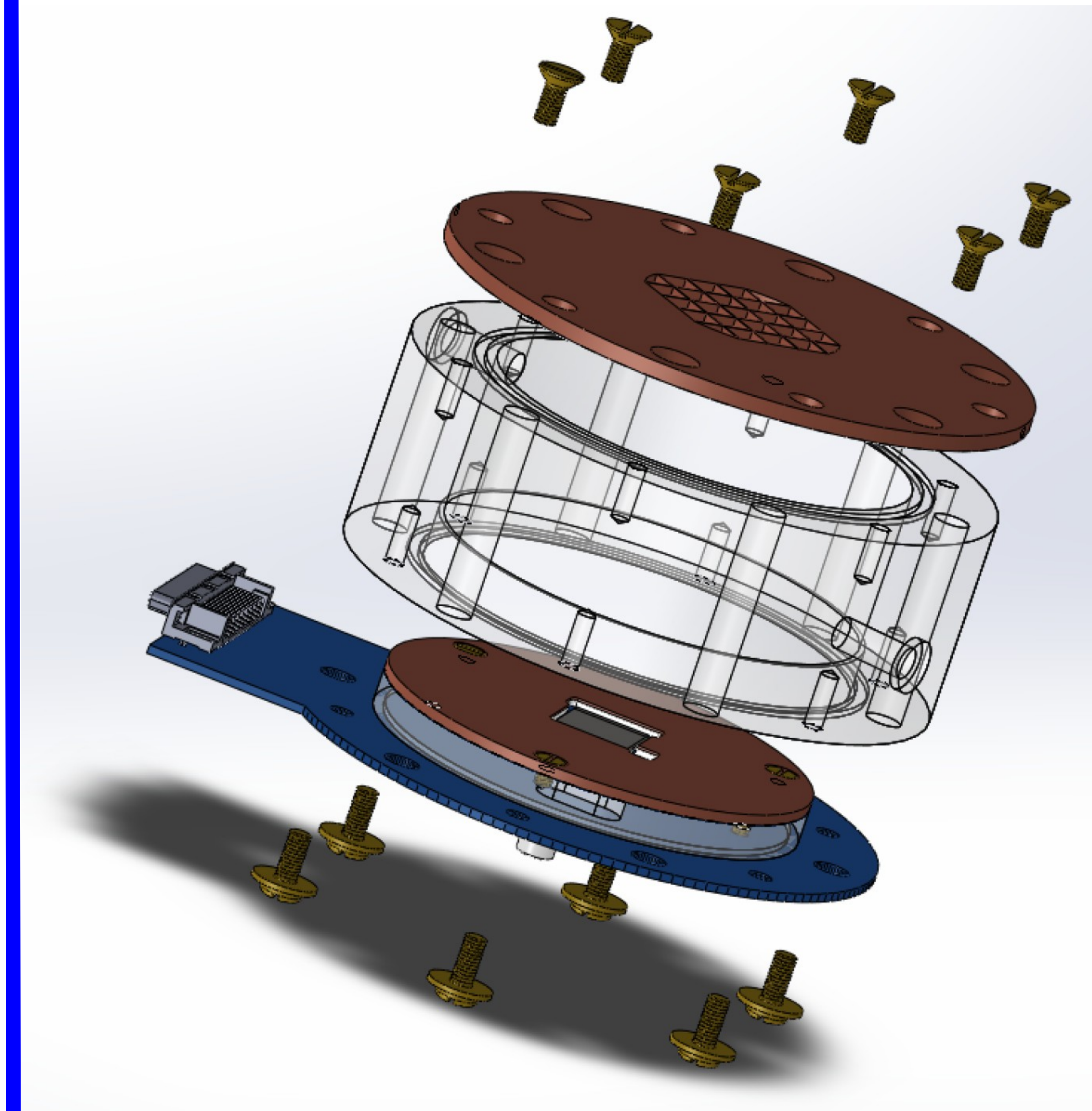


CAST report SPSC-107



Design of new Detector





Removed all of the aluminum.

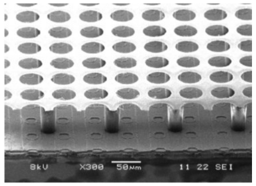
Detector is made of acrylic glass and copper.

All connection compatible with CAST.

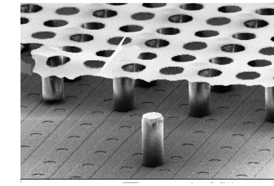
Larger entrance window with strongback (optical transparency ~ 90%).

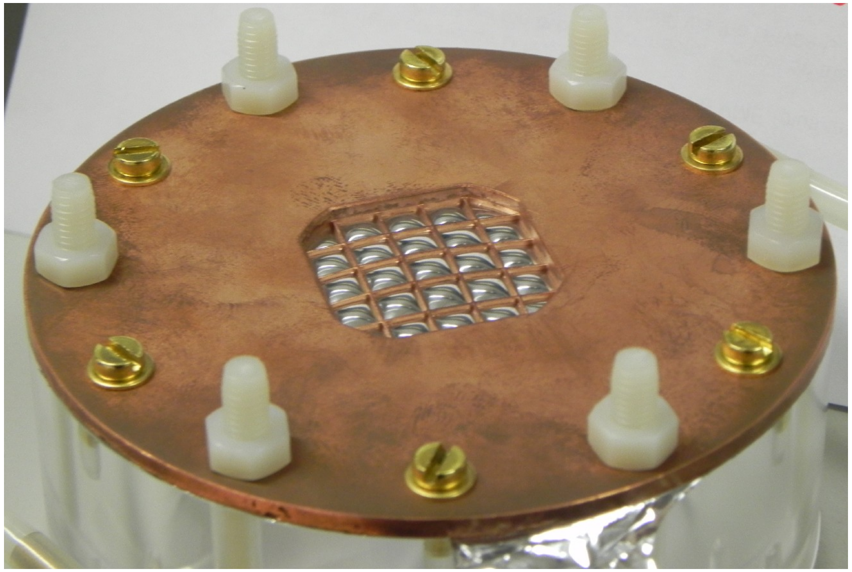
2 drift cylinders (2-3 cm drift distance).

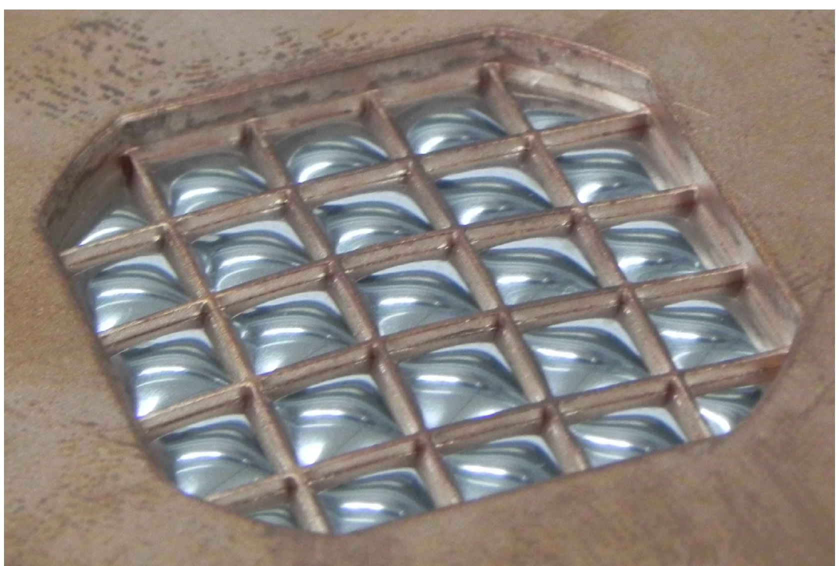
Detector design follows closely current Micromegas detectors.



Entrance Windows

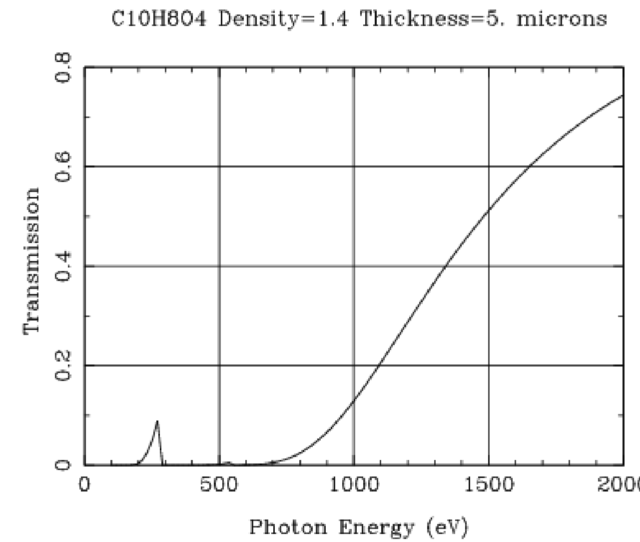


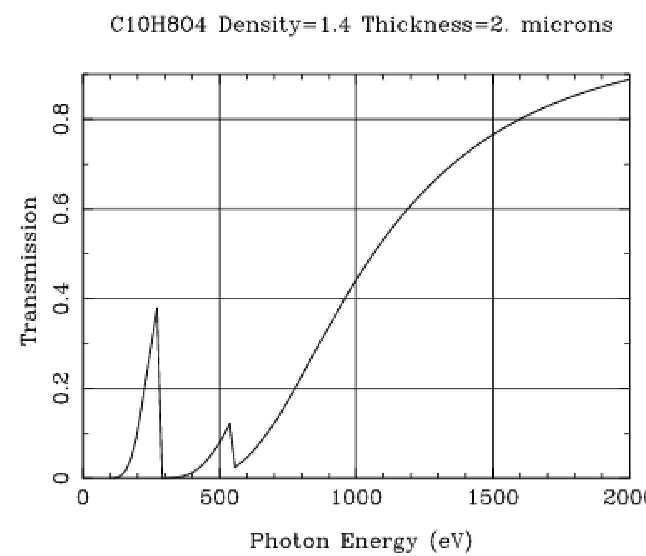


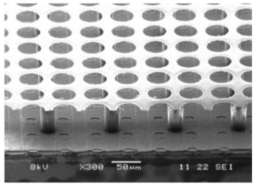


Several strongbacks have been produced to test different windows.
First test with a 5 µm Mylar-foil
→ stood an over-pressure of 1.5 bar

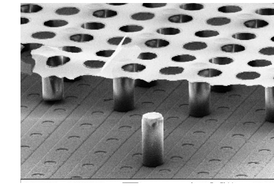
Transmission not good enough.
Next test with a 2 µm Mylar-foil.



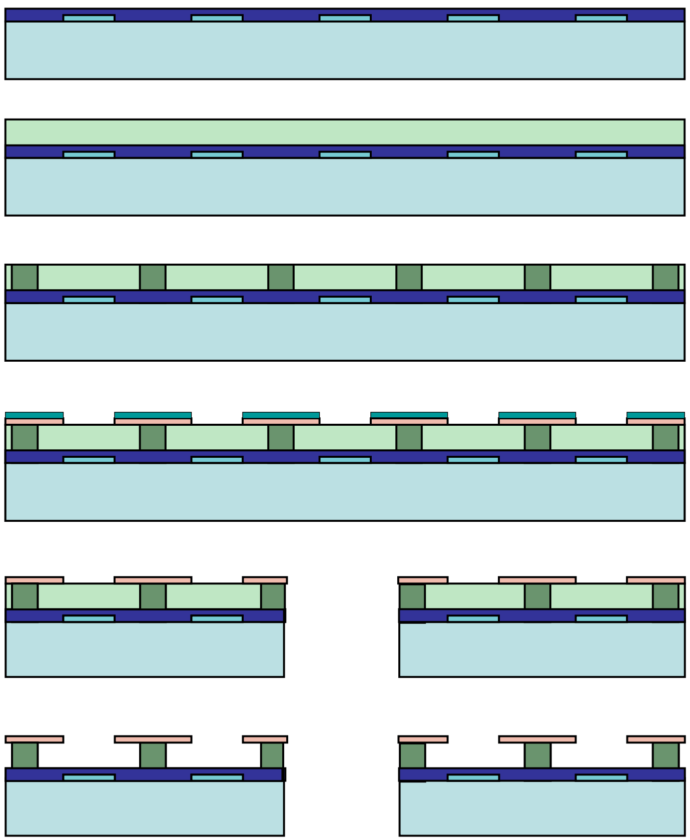




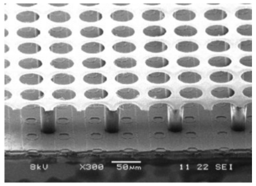
Wafer-based Production



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

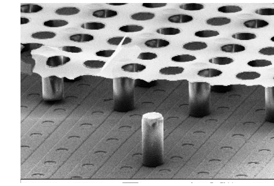


1. Formation of Si_xN_y protection layer
2. Deposition of SU-8
3. Pillar structure formation
4. Formation of Al grid
5. Dicing of Wafer
6. Development of SU-8



Wafer-based Production

Fraunhofer IZM



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

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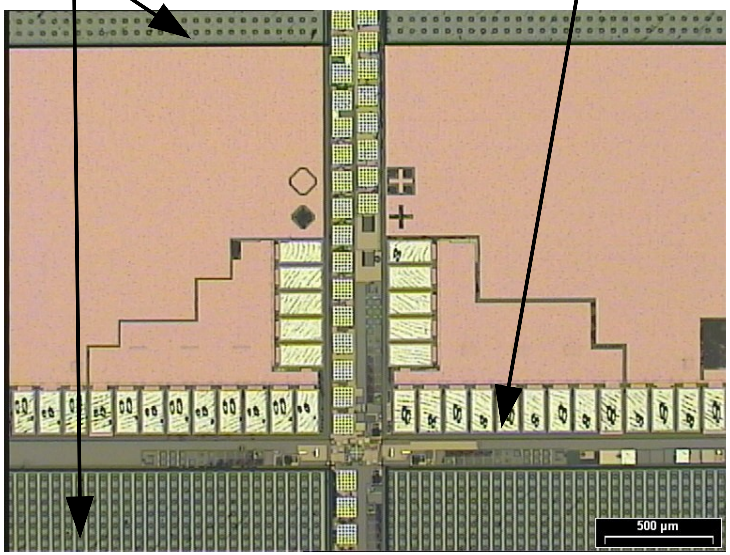
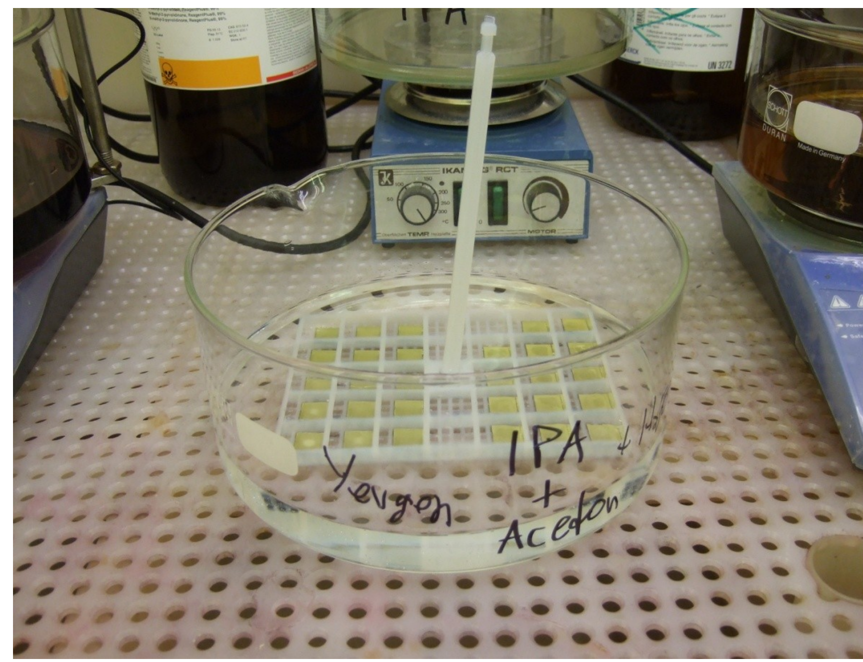
SiRN should not cover bond pads



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

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

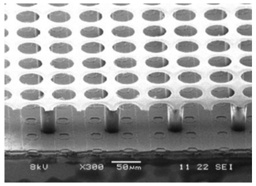


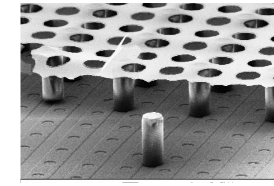
Time consuming

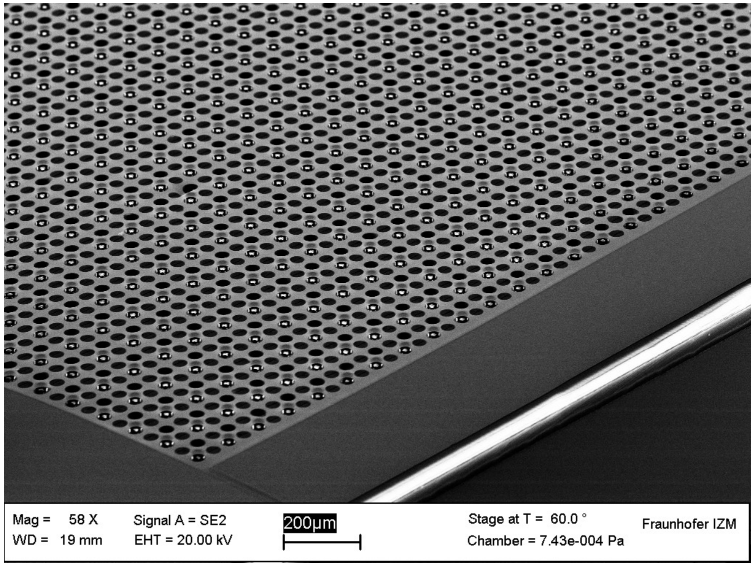
universität bonn

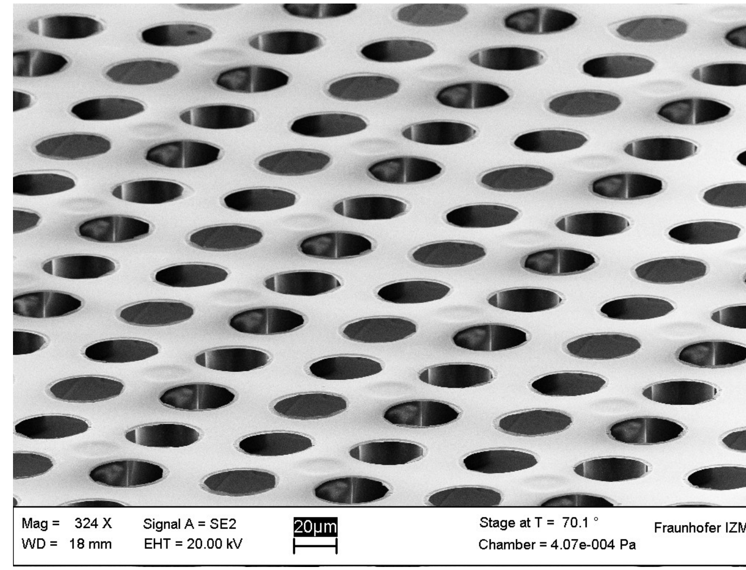
SEM Pictures

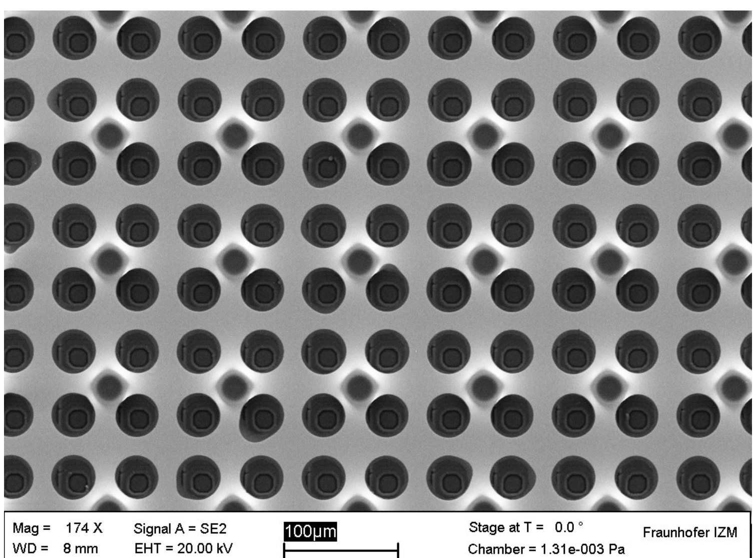
Fraunhofer IZM

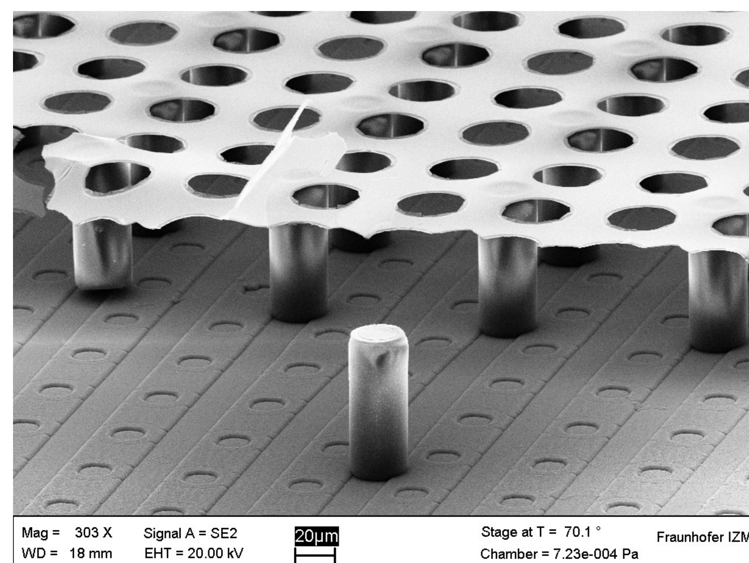


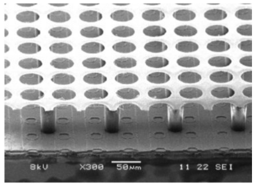




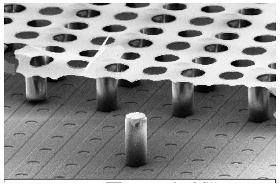




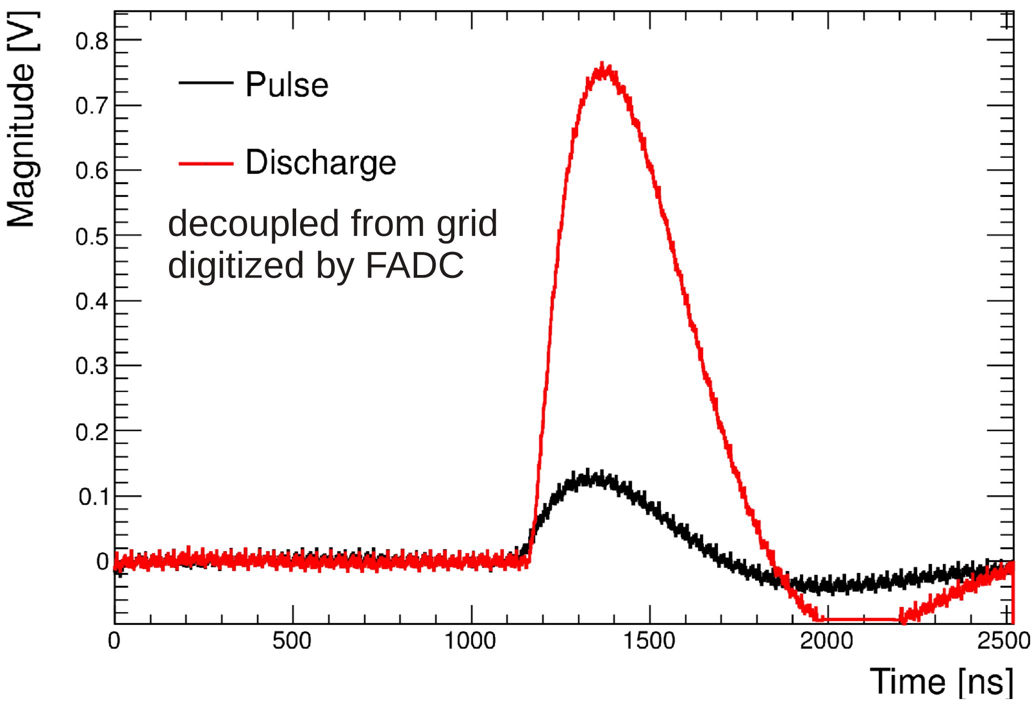


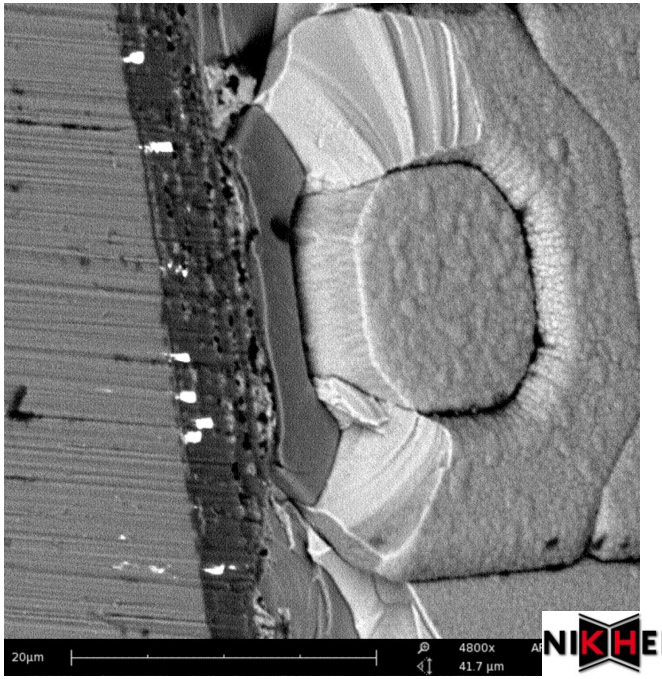


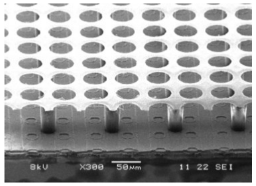
Performance



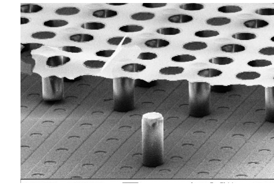
1. batch (10/2011): Problems with resistive layer and Al-grid
2. batch: InGrids worked well, good energy resolution (σ_E/E~7%)
 (12/2011) Resistive layer proved vulnerable (chips died after 2 weeks)
3. batch: Chips survived many thousand X-ray-induced sparks
 (9/2012) But 7 out of 10 chips died in a hadronic test beam at CERN
4. batch: In preparation, 4 wafers with different resistive layer thicknesses

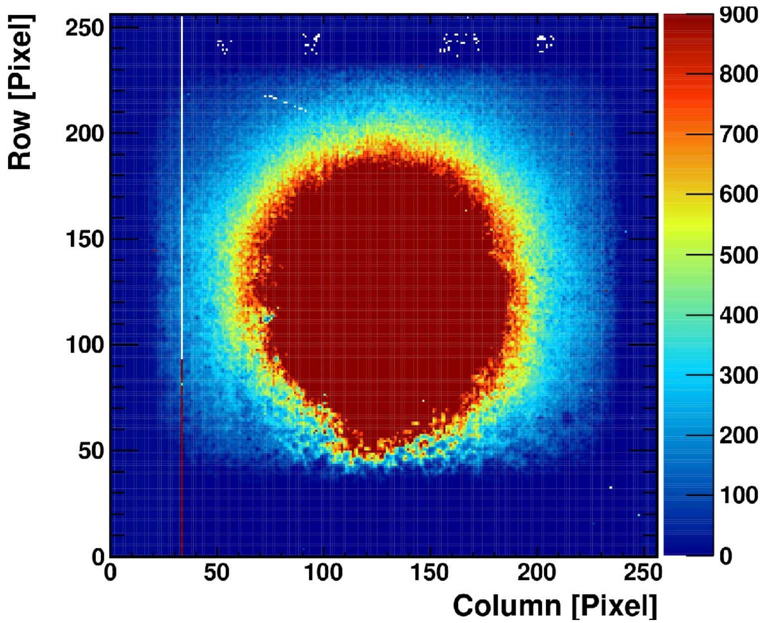






Some Results from the 3. Batch





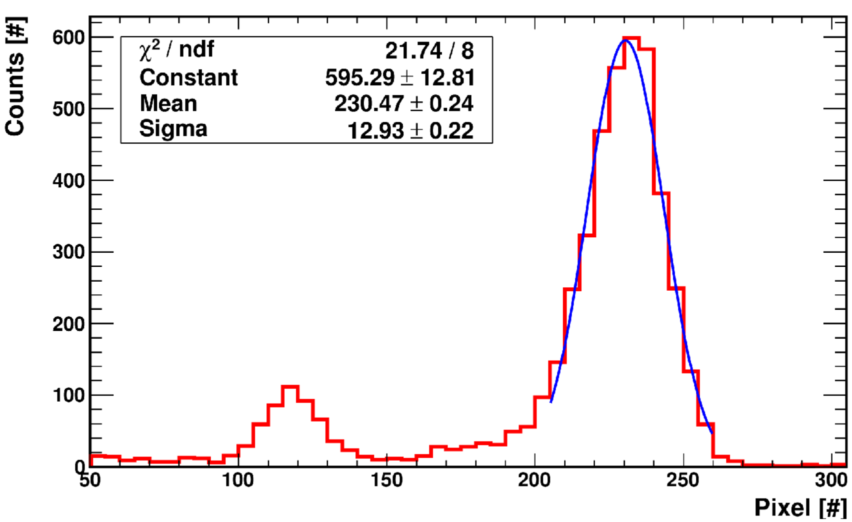
Occupancy plot shows very few closed holes

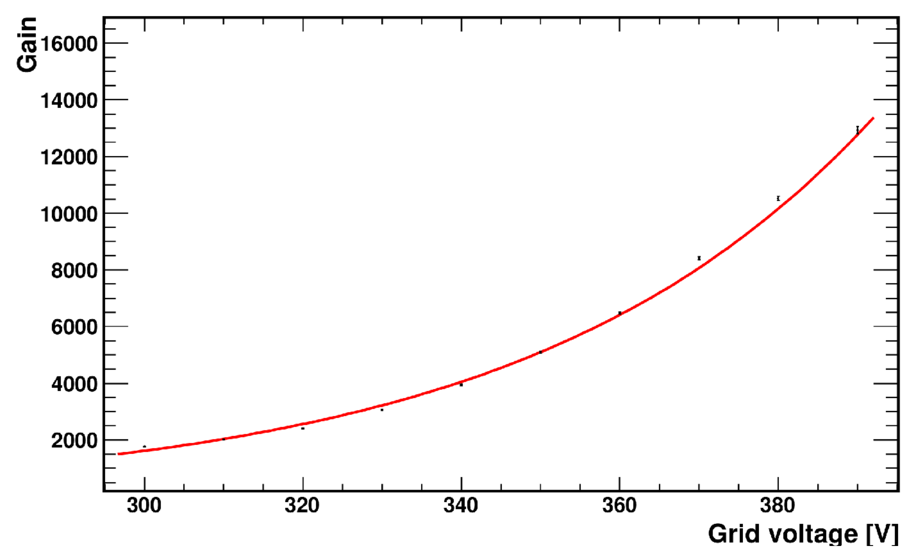
Energy resolution is similarly good as before:

σ_E/E=5.5 % for the pixel spectrum

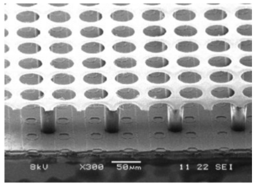
σ_E/E=7.2 % for charge spectrum

Voltages of 450 V could be applied to grid
→ chip not destroyed.

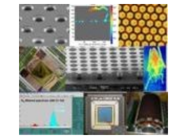


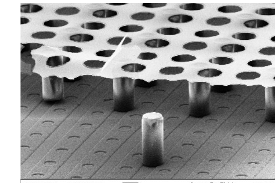


universitätbonn



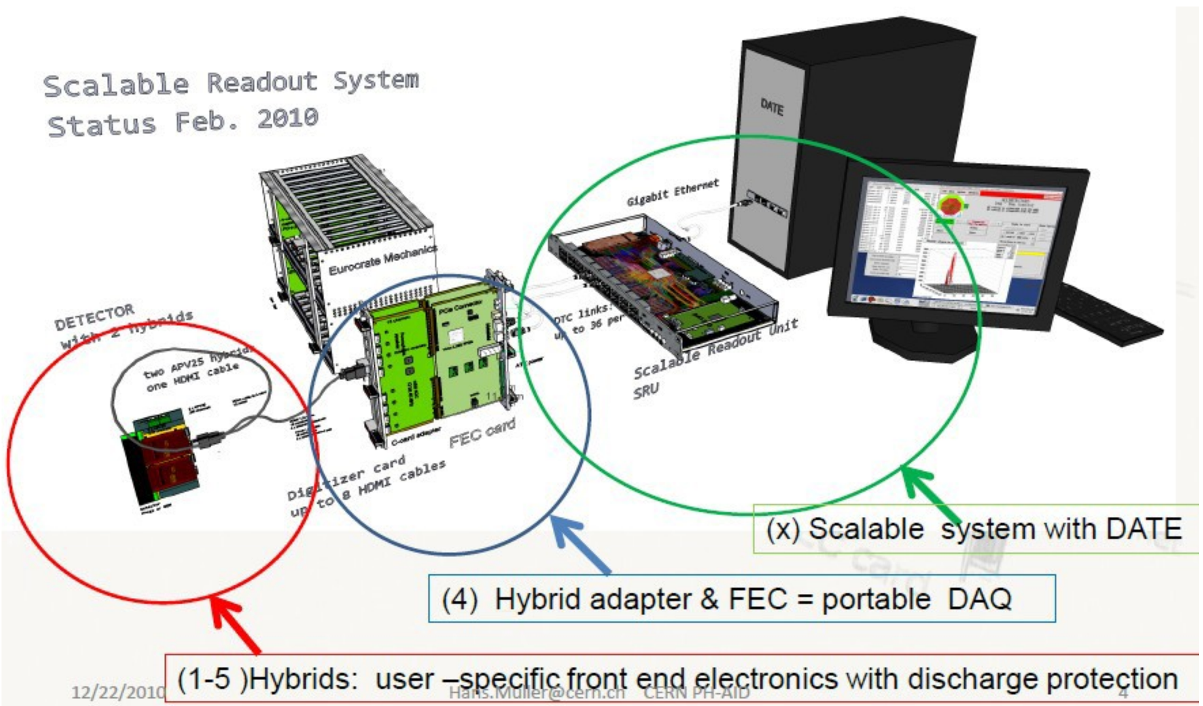
Timepix readout with SRS



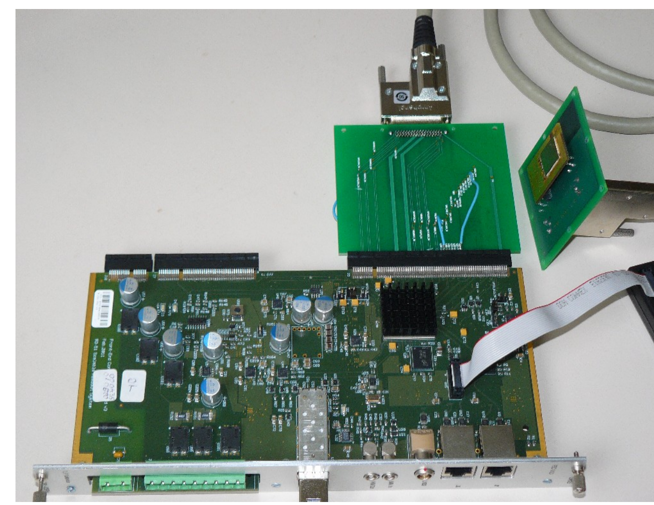


The Scalable Readout System is designed by the RD51 collaboration with CERN as a main developer.

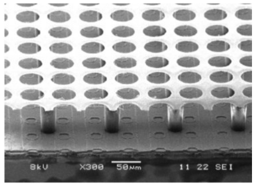
Idea: produce a flexible readout electronics, which can handle different chips (new FPGA code, chip carrier), which many groups can use.



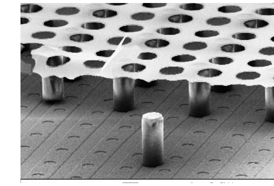
U. Bonn and U. Mainz are developing a readout for the Timepix chip



Operation has been demonstrated for a single and is being extended to multi-chip boards. A readout system based on this development will be used in CAST.



Summary and Outlook



GridPix detector shows an excellent performance:

Energy resolution of $\sigma_E/E \sim 5\ \%$ (at 5.9 keV)

Event shape analysis very effective in suppressing background.
Further optimization is planned.
Study of entrance window transmission has started.

Installation in CAST is planned for June 2013.

Production techniques of InGrids are well advanced, but resistive layer may have to be optimized a bit.

New readout system optimized for large systems and flexibility has been developed.

New Timepix-3 should be available next year and will be used as soon as possible.