R&D of InGrid Detectors for IAXO

3rd General IAXO Meeting
Saclay

Christoph Krieger, Yevgen Bilevych, Klaus Desch,
Jochen Kaminski, Thorsten Krautscheid, Michael Lupberger

University of Bonn

21.06.2012

Outline

Introduction

What is an InGrid?

- Integrated Micromegas fabricated by photolithographic postprocessing
- Can be put on top of a pixel chip, e.g. Timepix ASIC

Why putting a pixelchip below a Micromegas?

- Micromegas detectors show very good performance
  e.g. very low background rates in case of CAST Micromegas
- Readout structures do not match the granularity of the gas amplification stage: relatively large pads/strips
- Matching readout and gas amplification granularity could improve performance

Motivation

Possible Benefits of Micromegas with Pixelized Readout

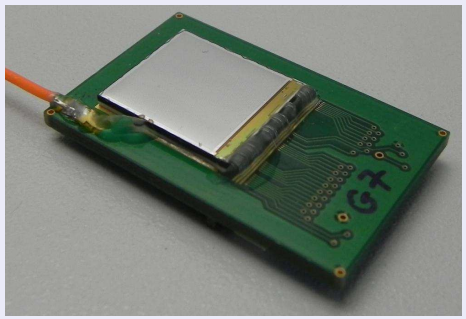
- In case of high single electron efficiency:
  Detection/Resolution of single electrons possible
- High spatial resolution can be exploited for event shape analysis (may be used for background rejection)
- Photon energy measurement in principle by counting electrons (w-value of gas mixture: 1 e^- corresponds to roughly $30\,\mathrm{eV}$)
- Low treshold should be possible: about $300\,\mathrm{eV}$ (10 electrons)
- Data read out at the pixel chip is purely digital

Timepix ASIC

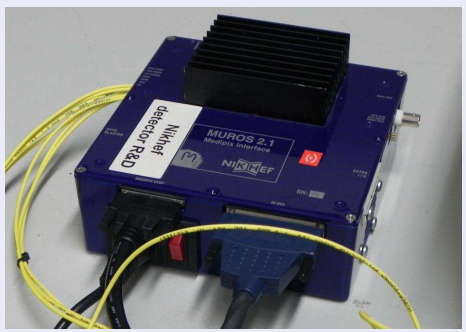
Facts

- 256×256 pixels, $55 \times 55\,\mu\mathrm{m}^2$ pitch
- $1.4 \times 1.4\,\mathrm{cm}^2$ active area
- Charge sensitive amplifier and discriminator in each pixel, $90\,e$ ENC
- Two modes: **Charge** or **Time**

Carrier board



MUROS 2.1

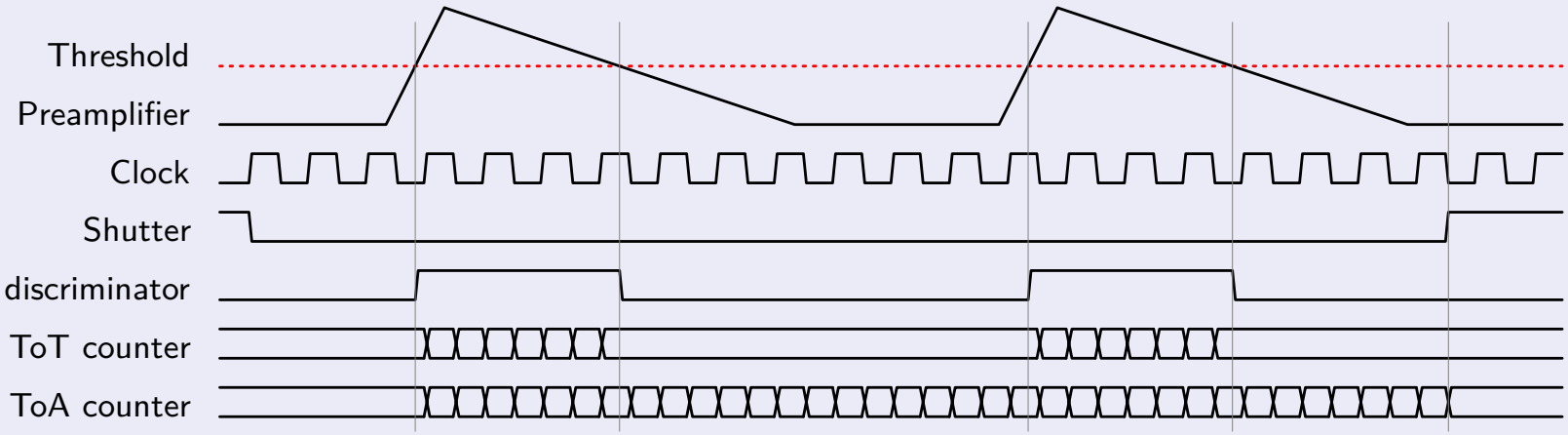


Readout

- Readout with **MUROS 2.1**
  Medipix re**U**sable **R**ead**O**ut **S**ystem developed at NIKHEF
- Acquisition and control: `Pixelman`

Timepix ASIC

Timing Diagram



Timepix 3

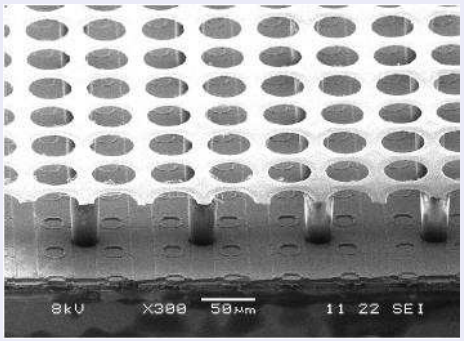
- Is under development and will be submitted this year
- Will be able to recognize multihits and to measure ToT and ToA simultaneously
- Will allow data driven readout

InGrid - Integrated Micromegas

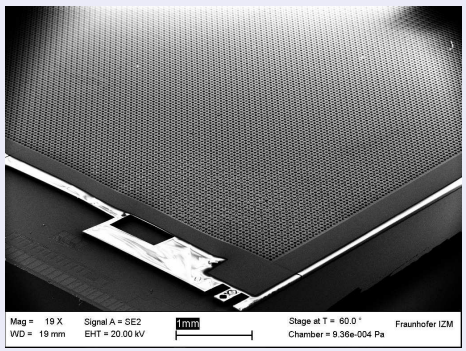
Micromegas on top of Timepix ASIC

- Fabrication by means of photolithographic postprocessing
- Very good alignment of grid and pixels
- Each avalanche is collected on one pixel
- Detection of single electrons possible

InGrid - SEM



Timepix + InGrid



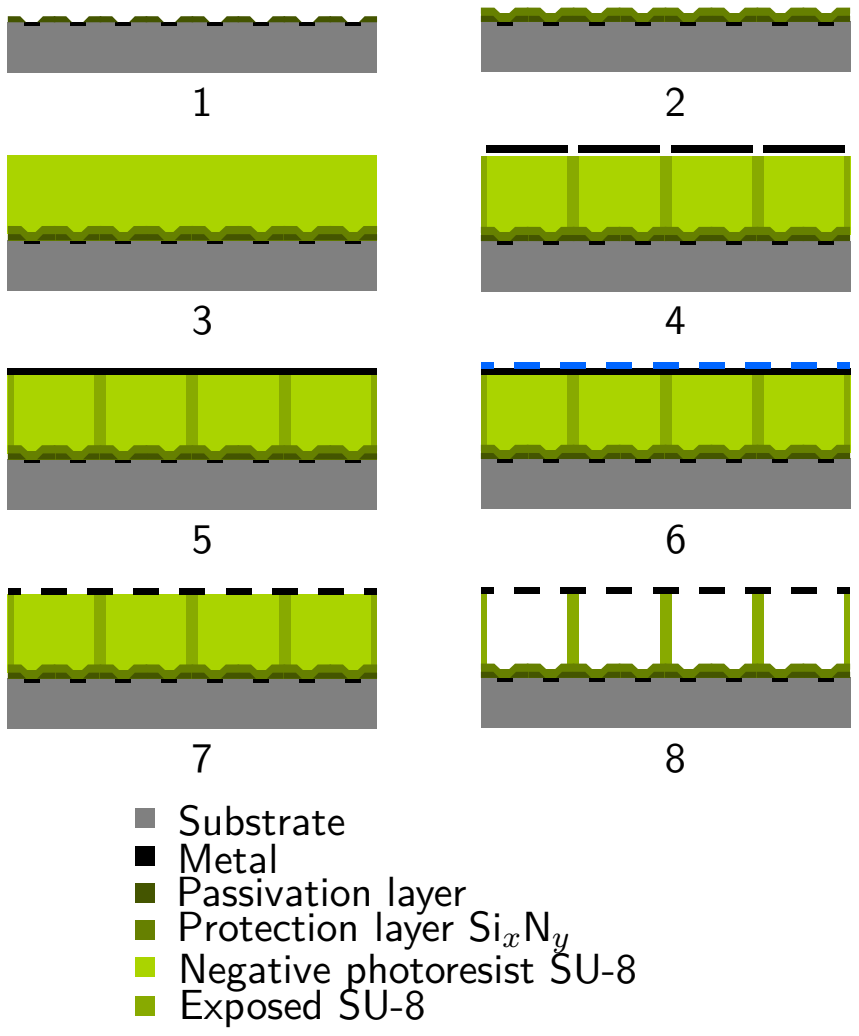
Protection layer

- Timepix was not designed to survive discharges: must protect electronics!
- Resistive layer (2-$8\,\mu\mathrm{m}$ silicon nitride) to spread charge in case of discharge

Fabrication of an InGrid

Fabrication steps

1. Starting with bare Timepix
2. Deposition of protection layer ($8\,\mu\mathrm{m}$ Si_xN_y)
3. Deposition of negative photoresist SU-8 ($50\,\mu\mathrm{m}$)
4. Exposure of SU-8
5. Sputtering aluminium
6. Putting mask on aluminium layer (photoresist)
7. Structuring aluminum layer
8. Development of SU-8, cleaning of interistitials

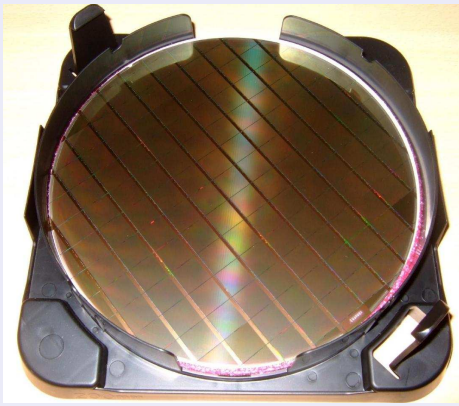


Wafer Scale InGrid Production

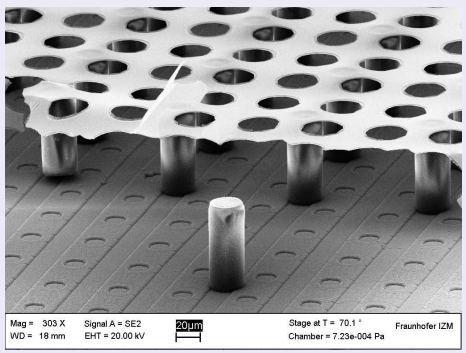
InGrid fabrication

- Fabrication steps take about one week
- Single and few chip processing: NIKHEF / Mesa+ (Twente)
- Wafer processing (~ 100 chips at once): in cooperation with IZM Berlin

Timepix wafer



IZM InGrid - SEM

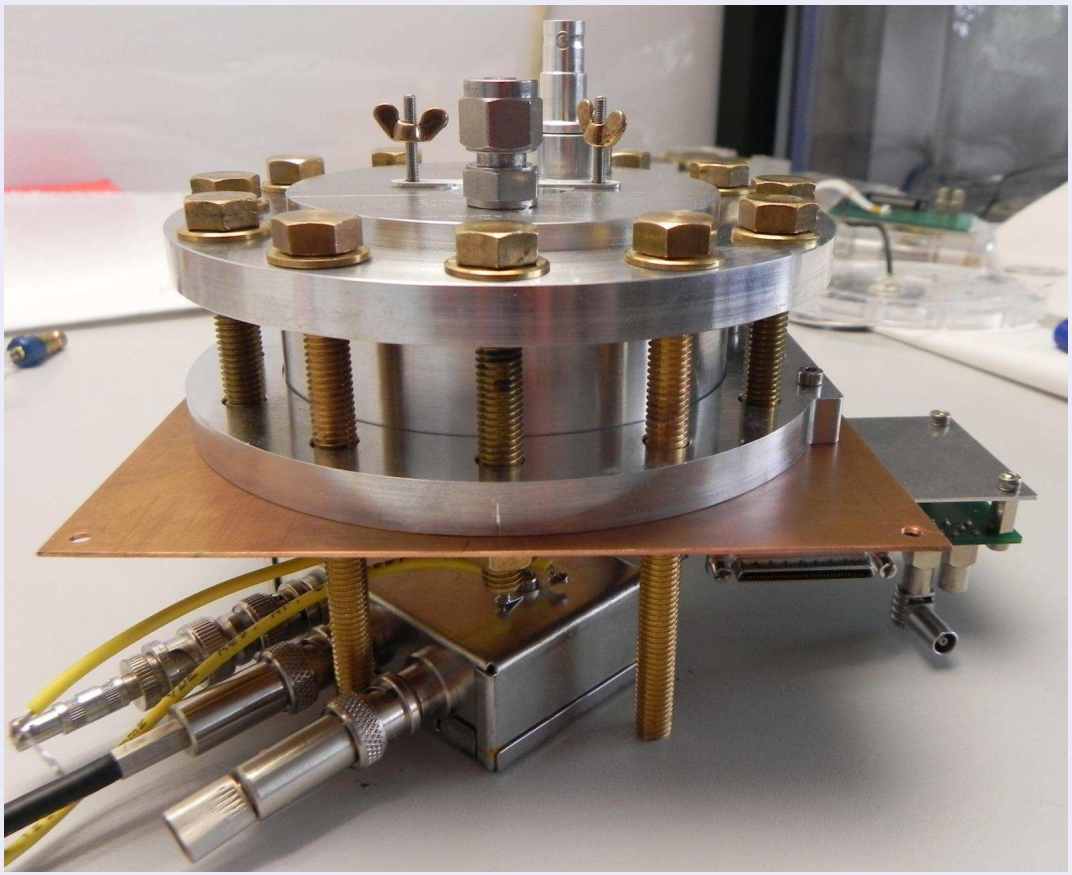


Results of wafer processing

- Structures of IZM InGrids look and behave good (similar to Twente InGrids)
- Still some optimization needed

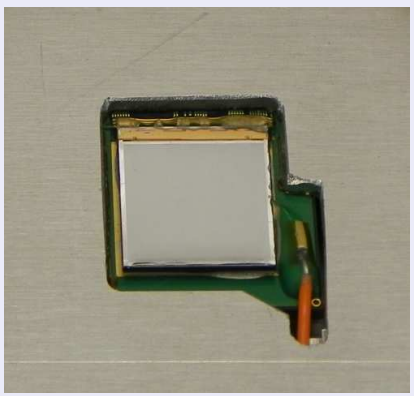
Prototype Detector

X-ray detector



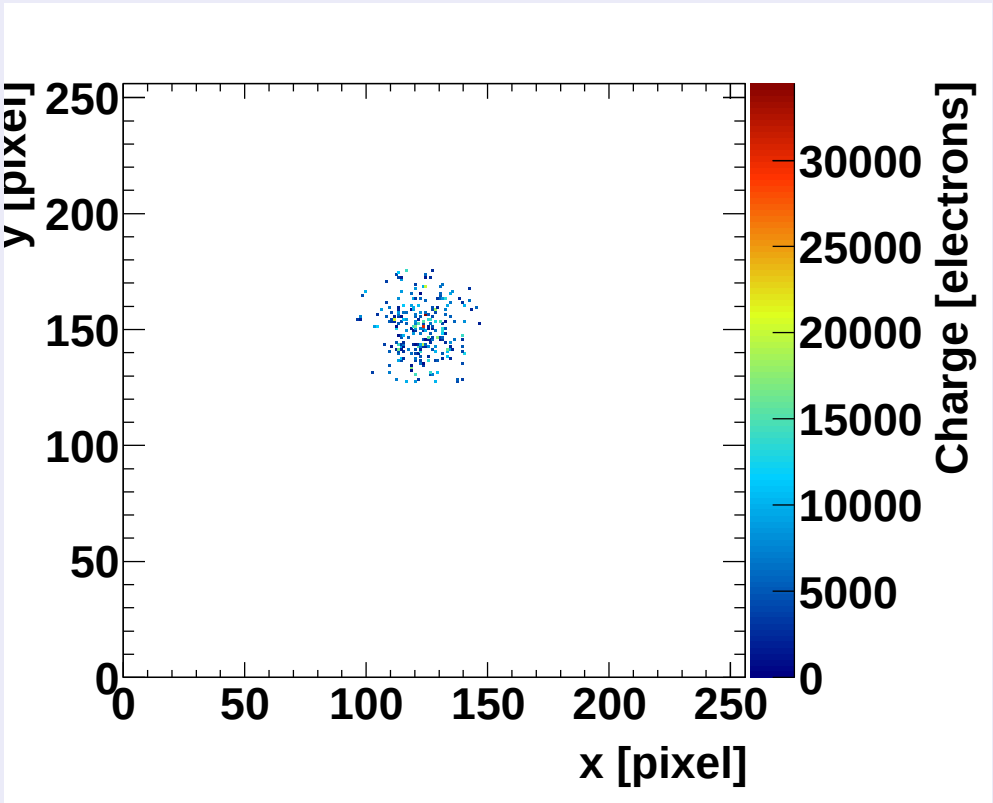
Cathode

Anode

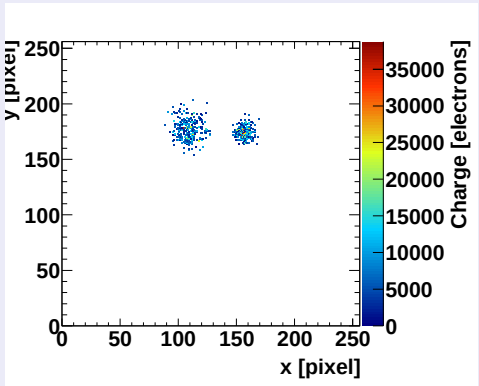


Typical X-ray Events

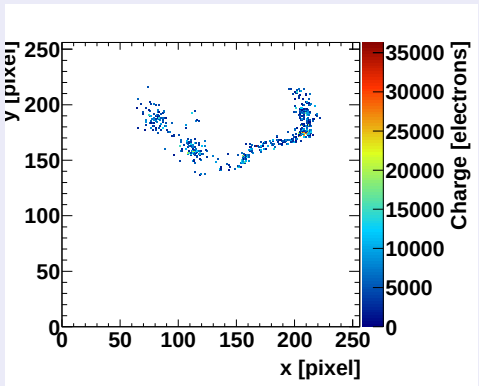
X-ray event



Double event

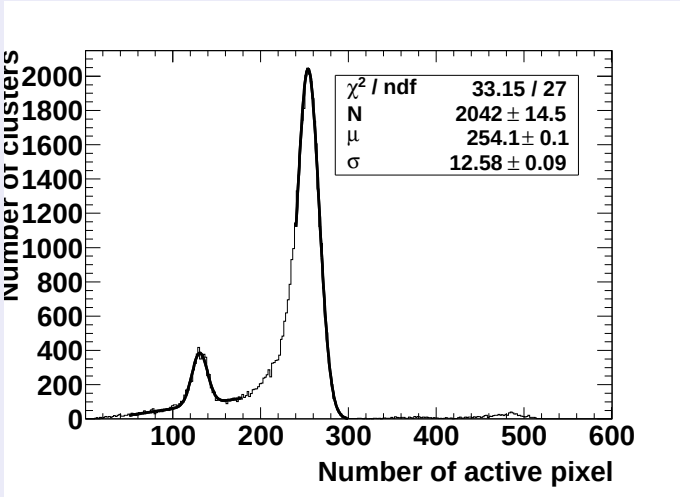


Background event

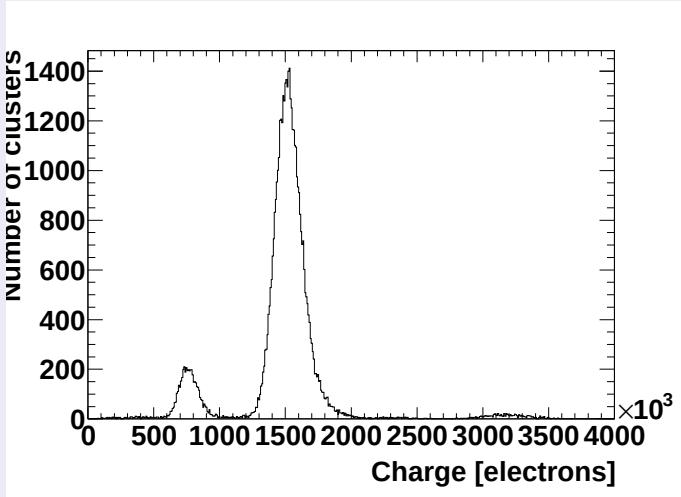


Energy Resolution

Spectrum - Pixels



Spectrum - Charge



Energy resolution

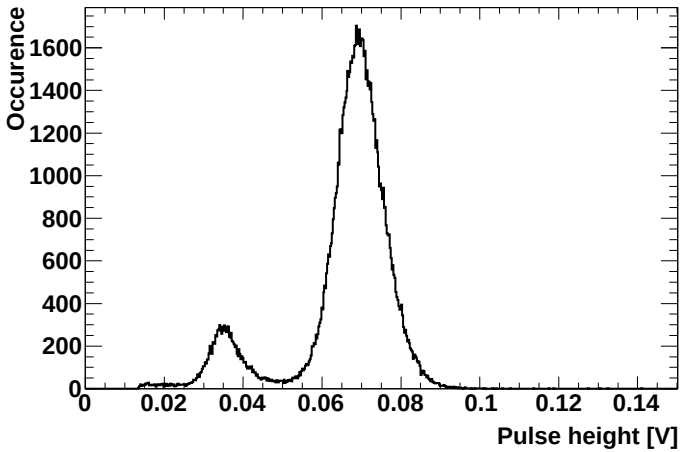
- Energy resolution: $\sigma_N/N \approx 5\,\%$ at $5.9\,\mathrm{keV}$
  Chromium foil to suppress $6.5\,\mathrm{keV}$ line of $^{55}\mathrm{Fe}$
- Charge spectrum: $\sim 6.6\,\%$ energy resolution
- Gas gain ~ 6500 at $350\,\mathrm{V}$

Decoupling of the Grid Signal

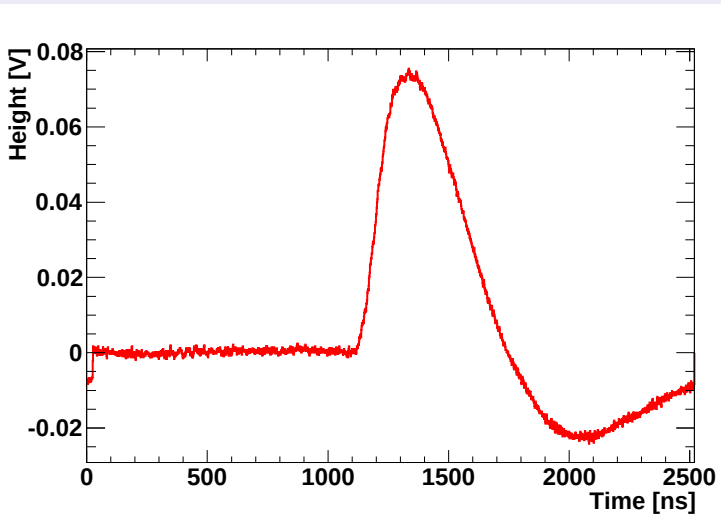
Recording

- ALEPH preamplifier
- CAEN FADC 12-bit 2 GHz

Spectrum - Grid



Grid signal

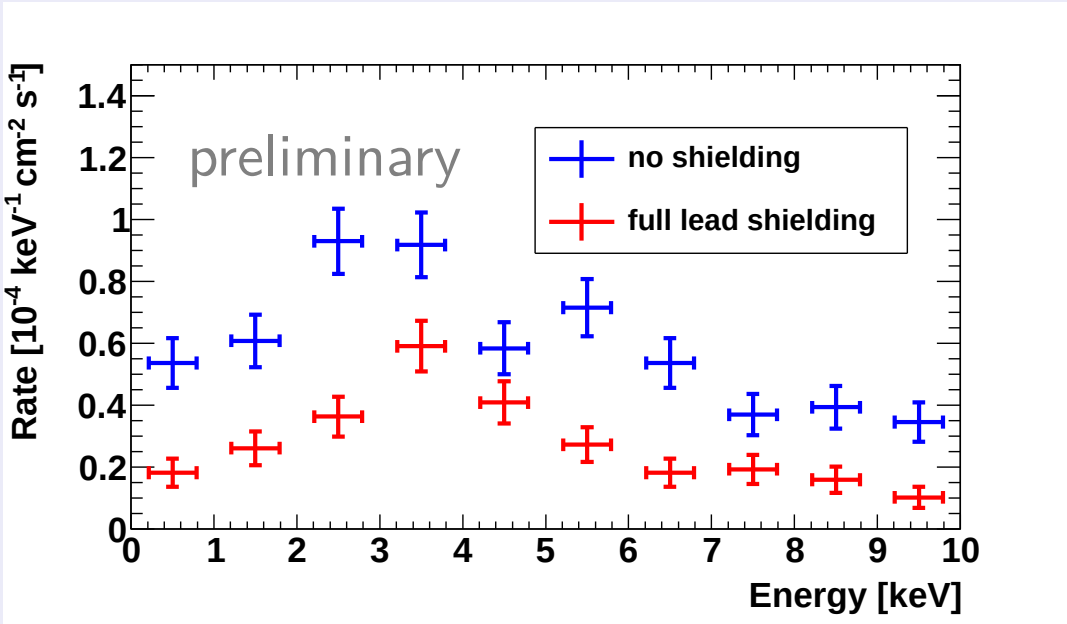


Energy resolution

- $\sigma_E/E \approx 8\,\%$ at $5.9\,\mathrm{keV}$

Background Rates

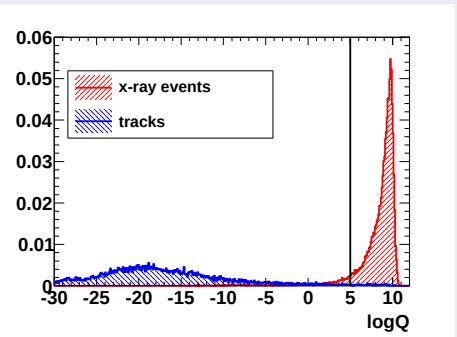
After Likelihood-Ratio based discrimination



- Reduction should be possible by improvement of algorithm

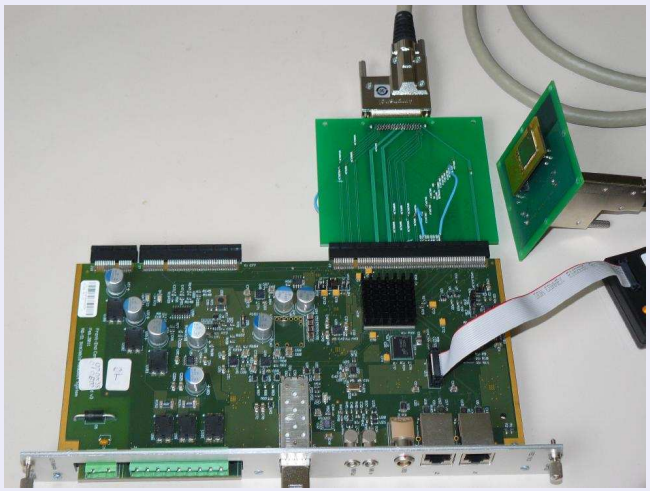
Lead shielding

Likelihood-Ratio



New Readout System

Prototype readout



Development of new Timepix readout

- Based on Scalable Readout System (FPGA-based, very flexible system)
- Will be much faster than MUROS
- Usage of grid signal as kind of trigger should be possible

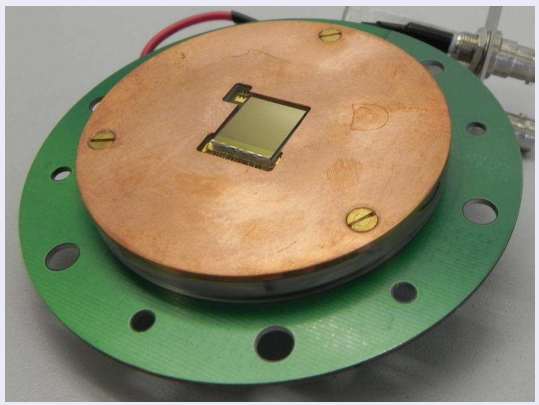
Benefits of 'triggered' readout

- 'Close' shutter some time after trigger signal from grid
- By operating the pixels in Time mode longitudinal shape of electron cloud can be analyzed

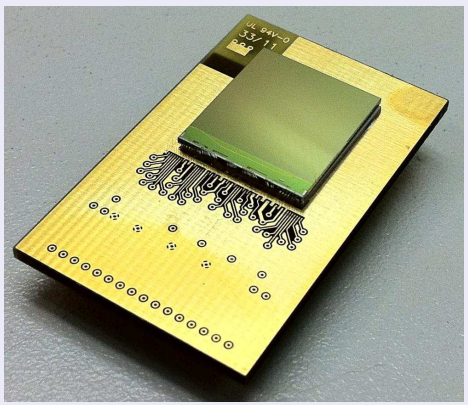
New Detector Design

Drift volume

Readout block



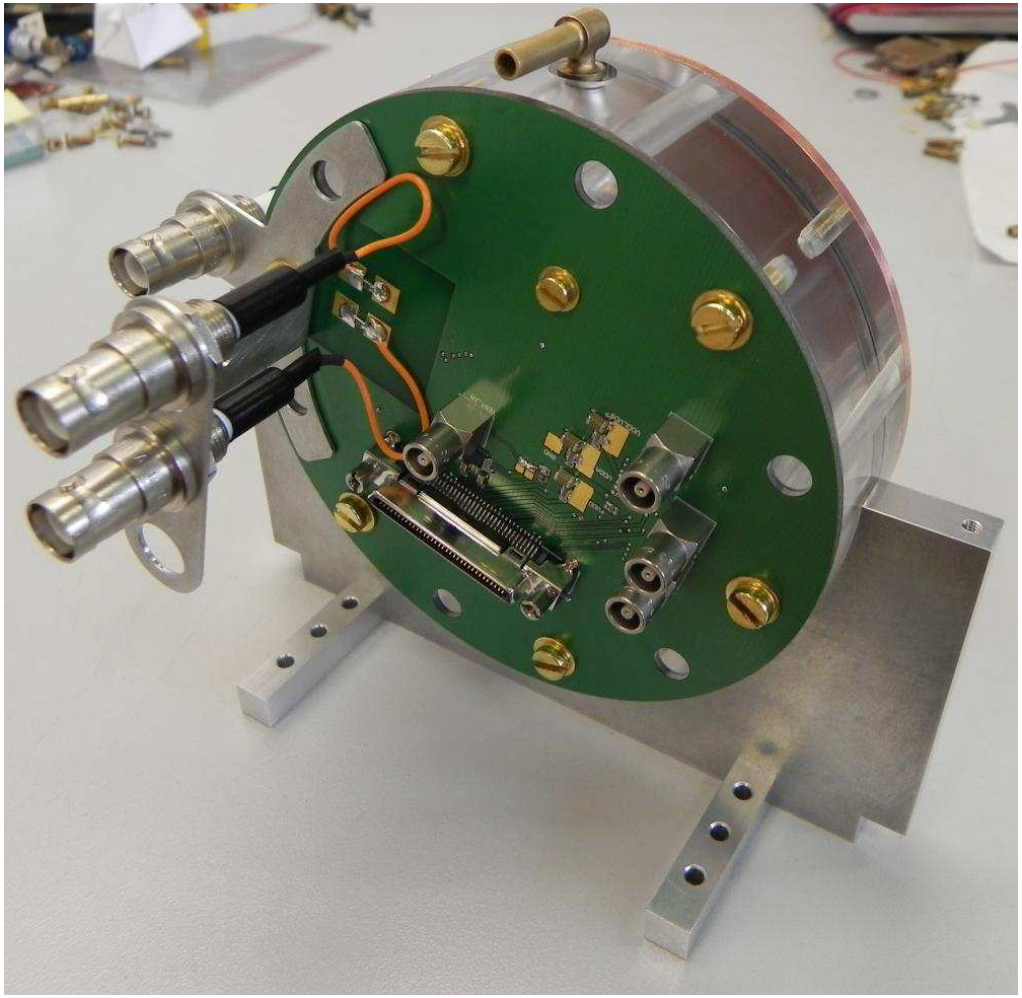
Carrier board

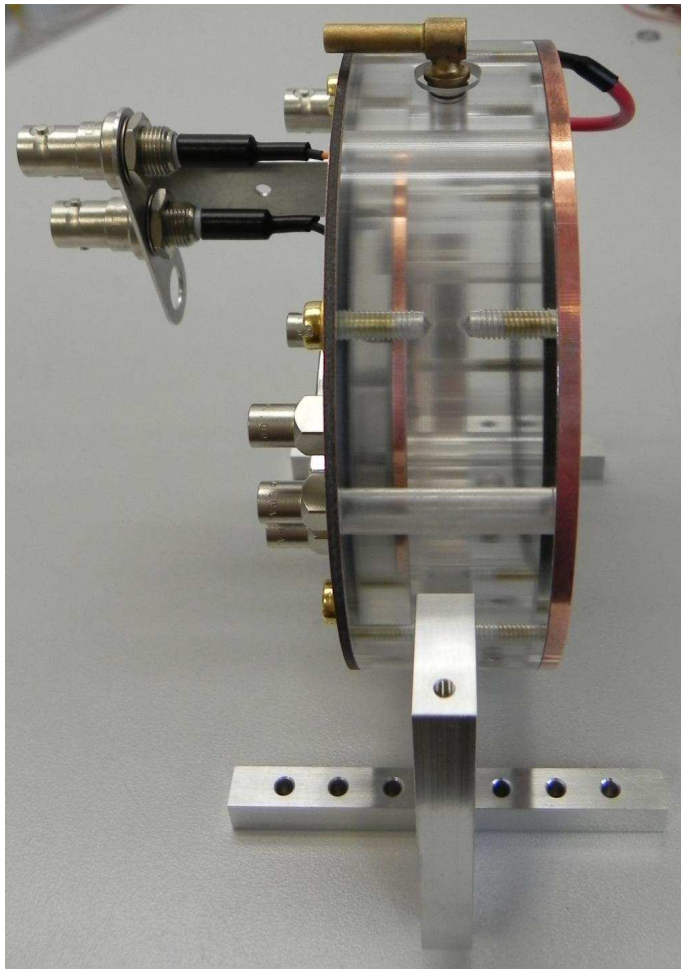


Changes in design

- New design based on the CAST Micromegas
  $\rightarrow$ mechanical CAST compatibility
- Plexiglas instead of aluminium
- New carrier and intermediate boards (HV connection from downside, HV feedthroughs, plug and socket connection)

New Detector Design





Conclusion & Outlook

Conclusion

- InGrid based detector was successfully put into operation
- Good energy resolution could be achieved
- Reached background rates are promising
- Work is ongoing: e.g. readout system, new detector design

Outlook

- Determination of low energy threshold
- Grid signal as 'trigger', record of grid signal
- Improvement of background rejection algorithm
- Test data-taking at CAST (area) towards end of the year

Thanks for your attention!