Data Analysis for a GridPix Based X-ray Detector

Micromegas meeting

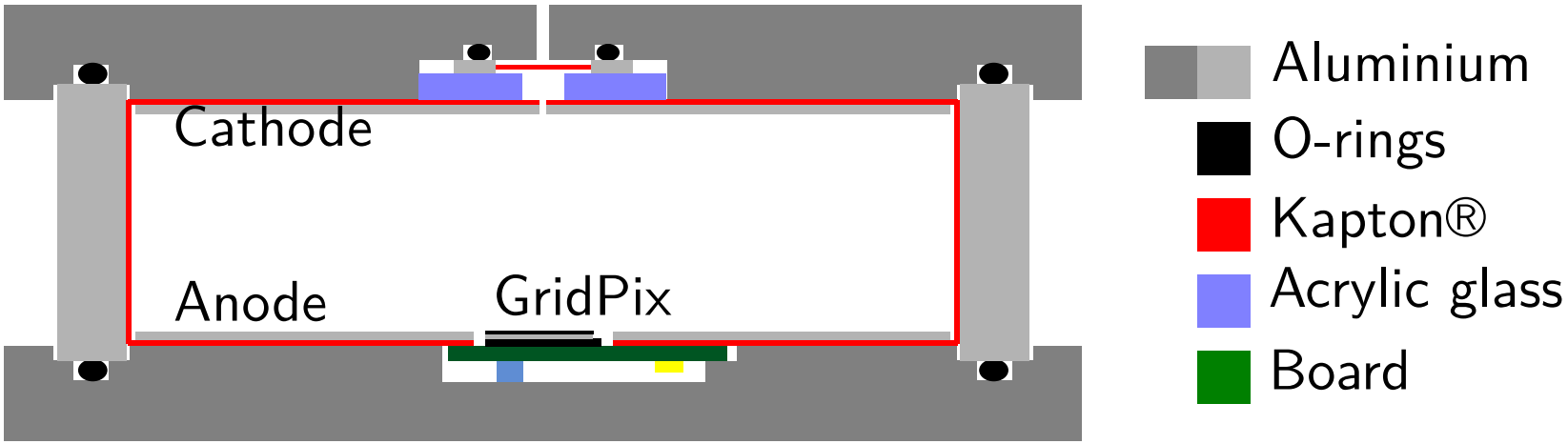
Christoph Krieger, Yevgen Bilevych, Klaus Desch, Jochen Kaminski

University of Bonn

10.01.2012

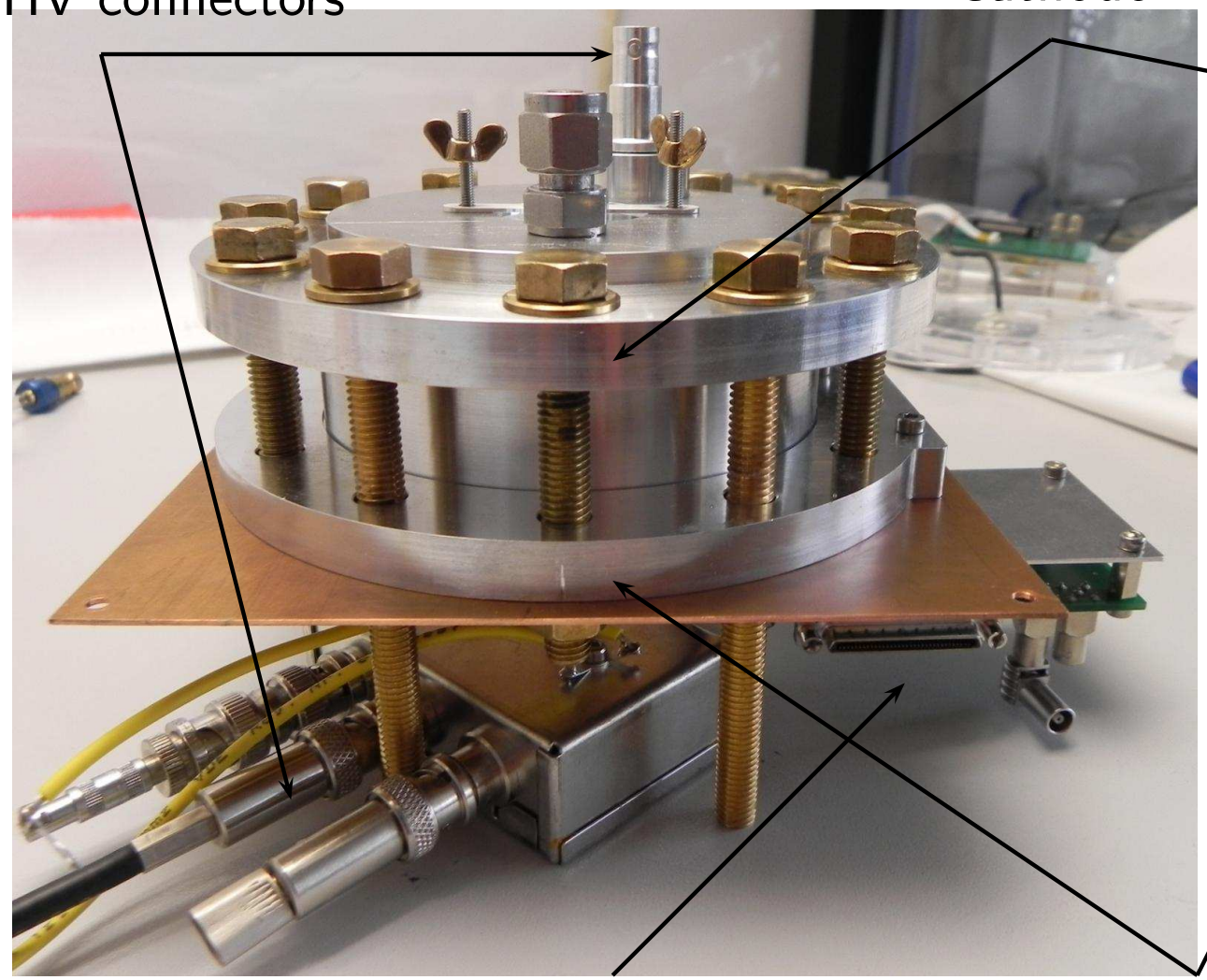
Overview

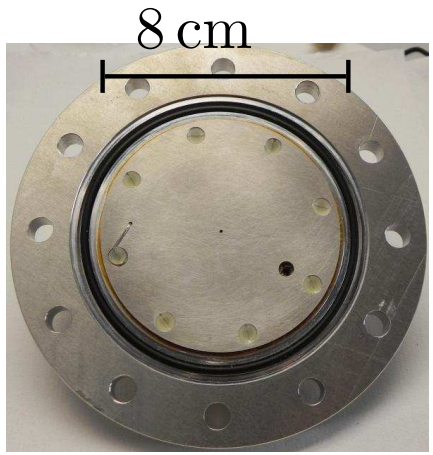
X-Ray Detector

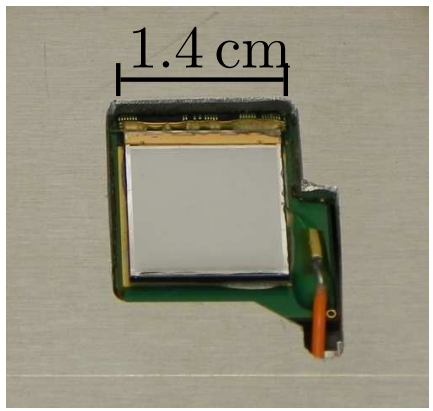


- Inner diameter $8\,\mathrm{cm}$, drift distance $2\,\mathrm{cm}$
  $\rightarrow \sim 100\,\mathrm{cm}^3$ inner volume
- Detector made of aluminium, HV isolation with Kapton® foil
- Readout and amplification: GridPix (Timepix+InGrid)
- X-ray window made of $50\,\mu\mathrm{m}$ Kapton® foil, diameter $1\,\mathrm{mm}$
- Operation with Ar/iC$_4$H$_{10}$ 95/5 at $\sim 2\,^{\mathrm{l}}/_{\mathrm{h}}$ flux and few mbar overpressure (no pressure control)

X-Ray Detector

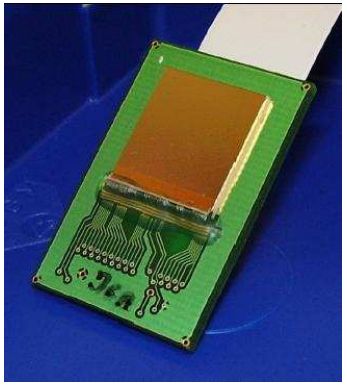


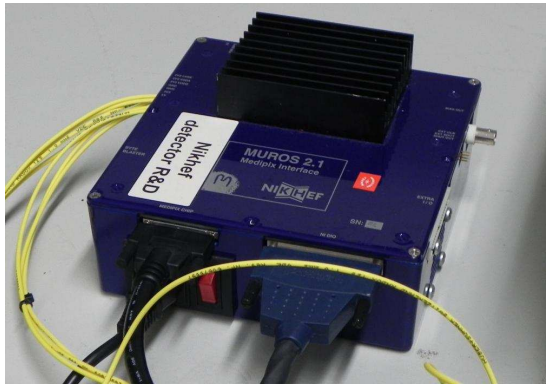




Timepix

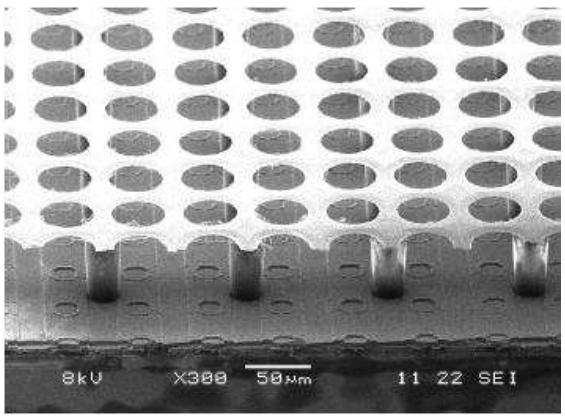
- Pixel chip: 256×256 pixels
- Pixel pitch: $55 \times 55\,\mu\mathrm{m}^2$
- Active area: $1.4 \times 1.4\,\mathrm{cm}^2$
- Charge sensitive amplifier and discriminator for each pixel
- Two modes: **ToT OR ToA**
- ENC: 90 e^-
- Threshold used: ~ 800 e^-
- Readout with **MUROS 2.1** (**M**edipix re**U**sable **R**ead**O**ut **S**ystem) developed at Nikhef
- Charge calibration with test pulses

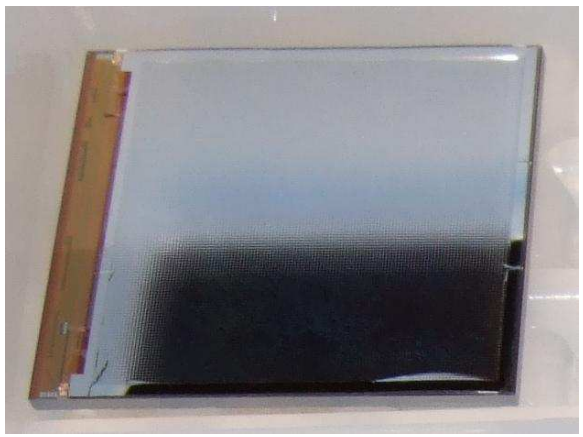


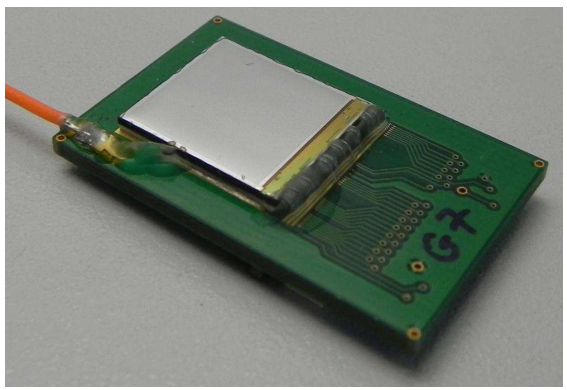


Integrated Micromegas - InGrid

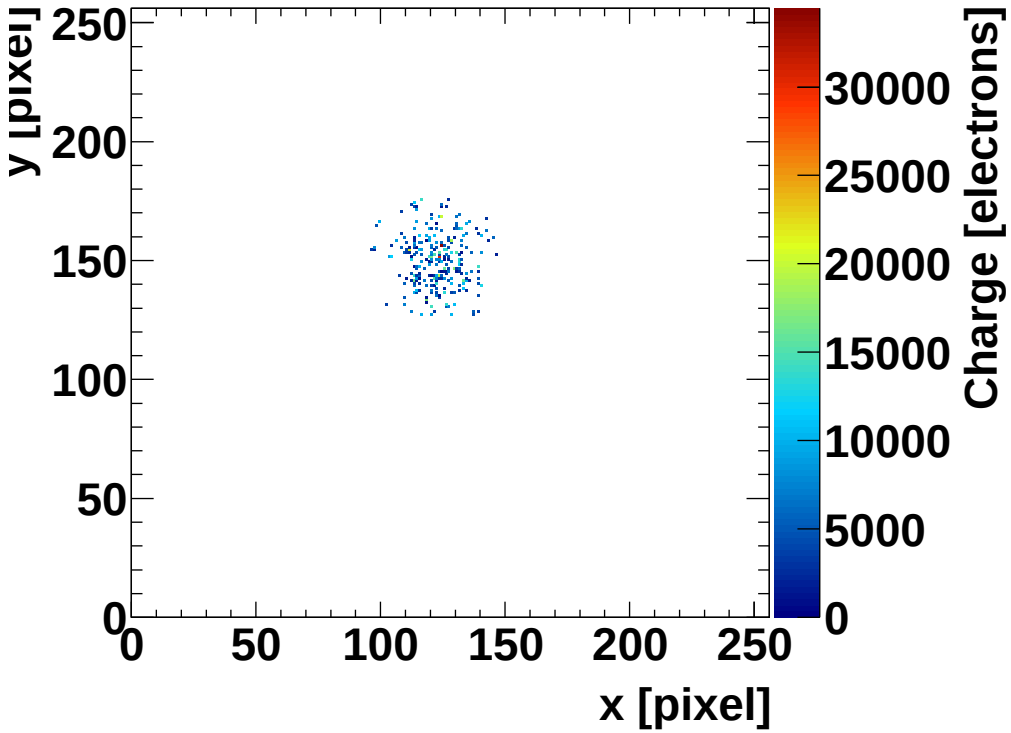
- Putting Micromegas onto Timepix with photolithographic postprocessing
- Very good alignment of grid holes with pixels
- Each charge avalanche is collected by one pixel
- Detection of single electrons possible (for gas gains $\gtrsim 5000$)
- Resistive layer (2-$8\,\mu\mathrm{m}$ Silicon Nitride) on top of Timepix to protect chip from discharges (spread charge)
- Production on chip level done at Nikhef/University of Twente
- Production on wafer level in cooperation with IZM Berlin (second GridPix wafer was delivered in November 2011)

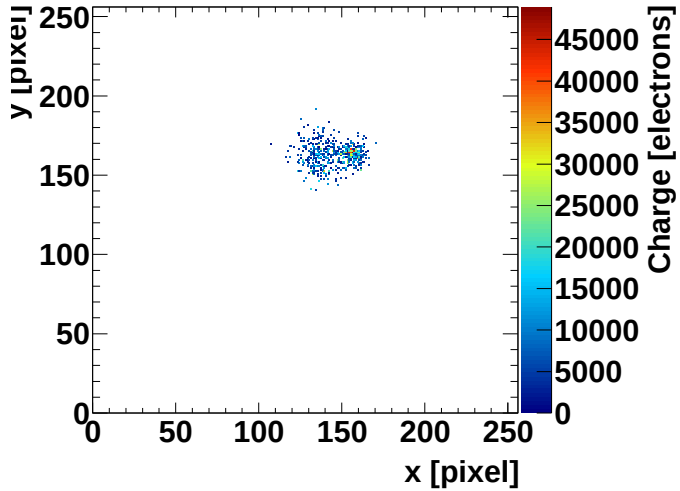


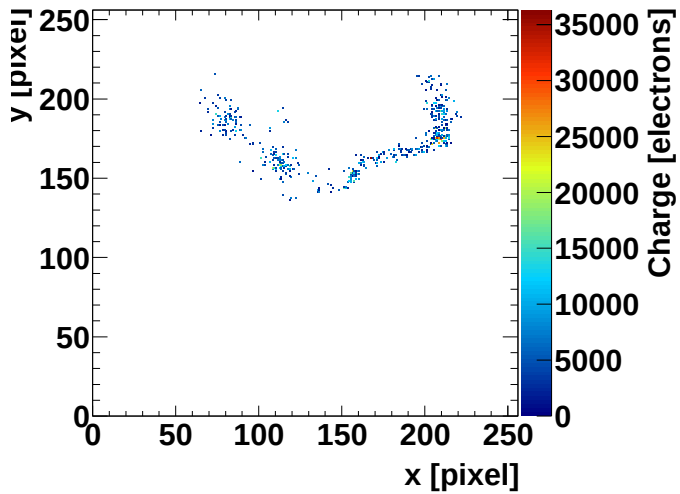




Typical X-Ray Events

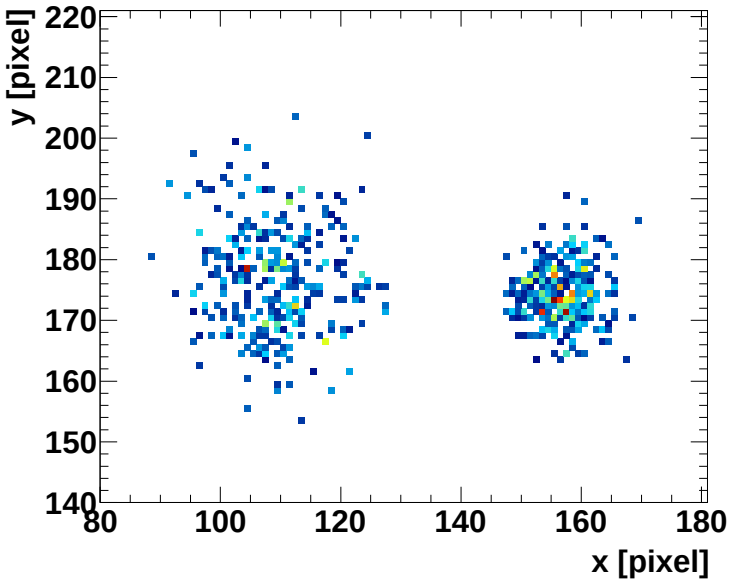


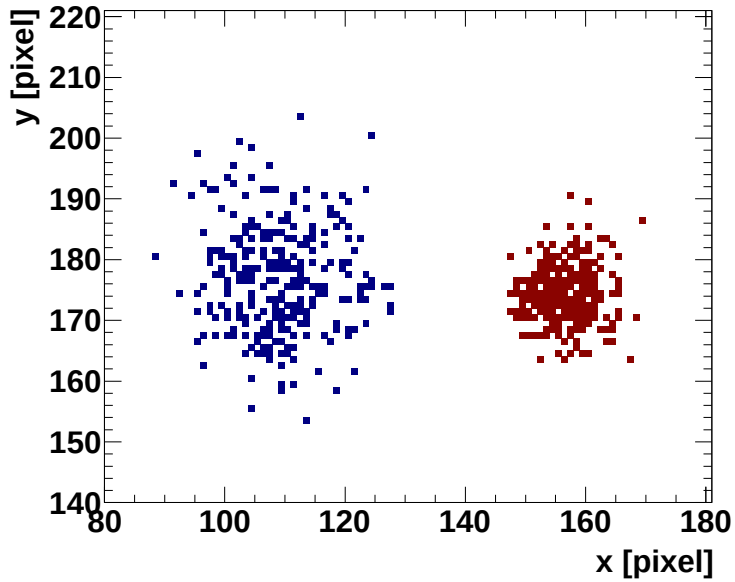




Analysis of X-Ray Events

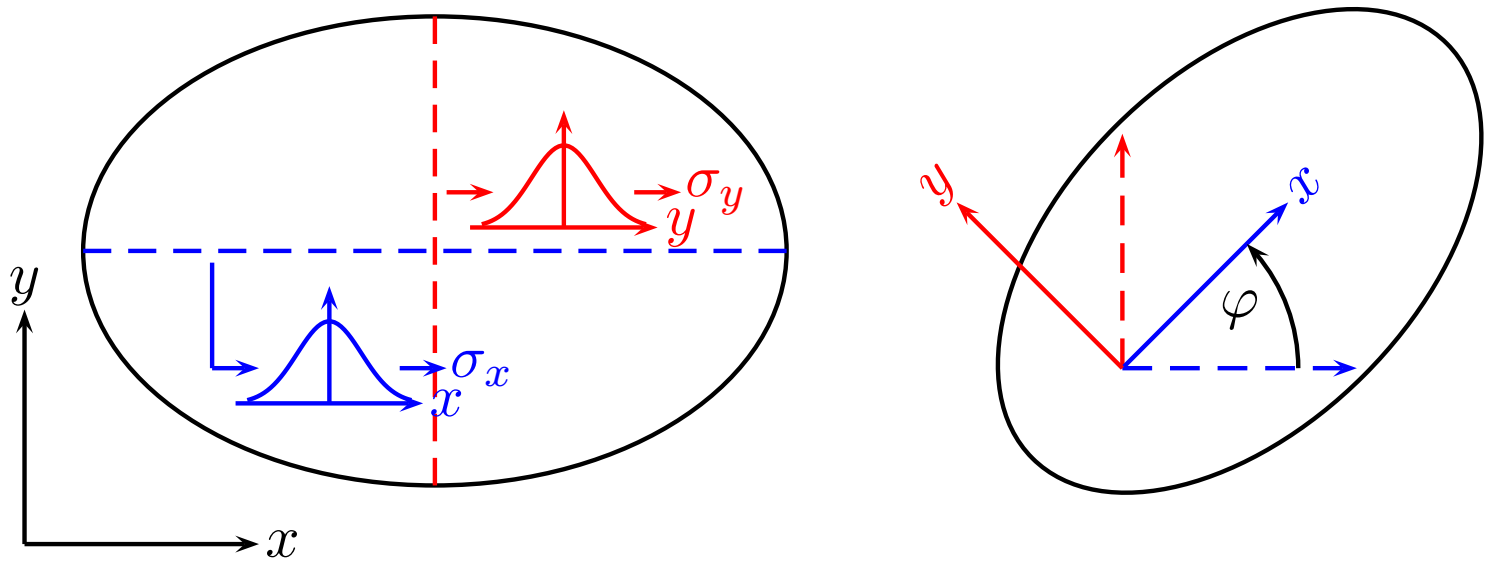
- Analysis is done within MarlinTPC framework
  Modular **A**nalysis and **R**econstruction for the **LIN**ear Collider
- Collecting all pixel of one x-ray event:
  Looking for neighbouring pixels in a square of adjustable size around every pixel
  Used settings: 10 pixels in each direction, minimum 10 pixels





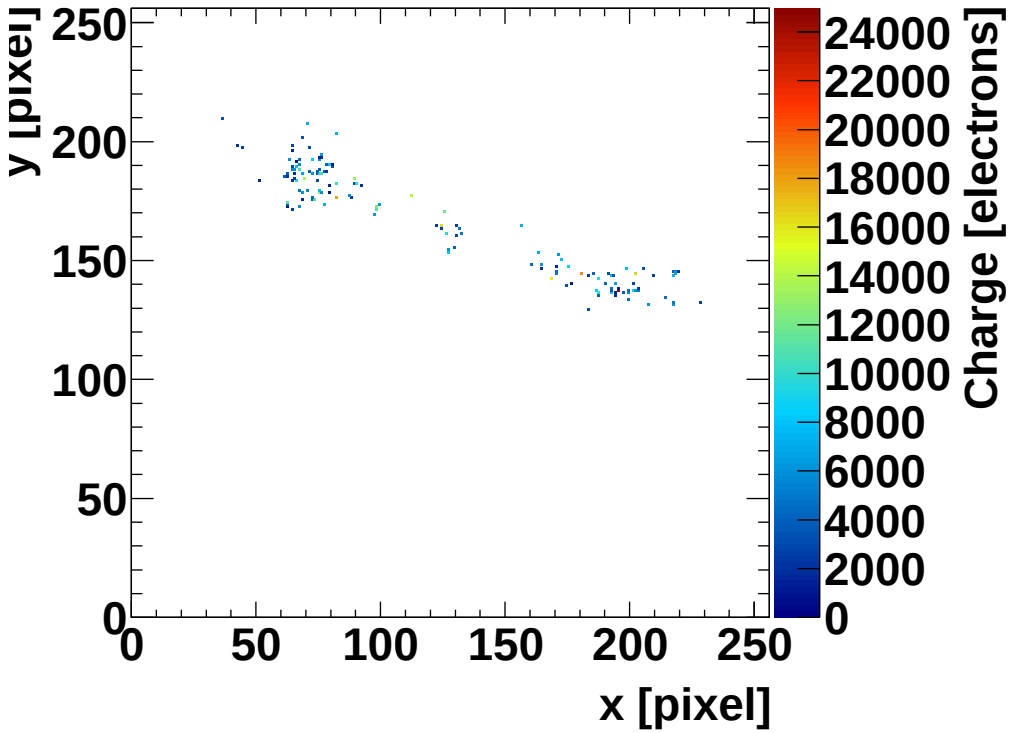
Analysis of X-Ray Events

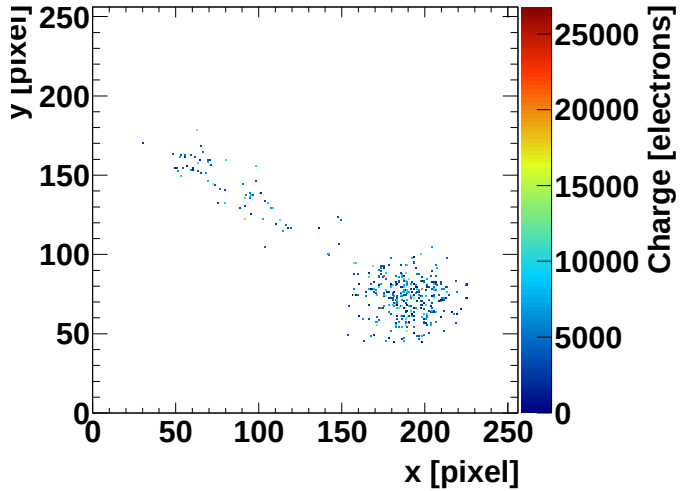
- Calculation of geometric properties:
  width σ_y, skewness, kurtosis, excentricity $= \sigma_x / \sigma_y$

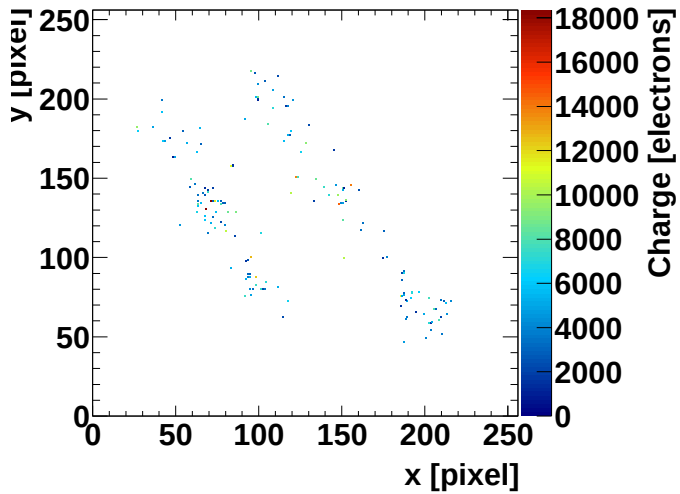


- Choose rotated coordinate system in which excentricity becomes maximal

Background Events

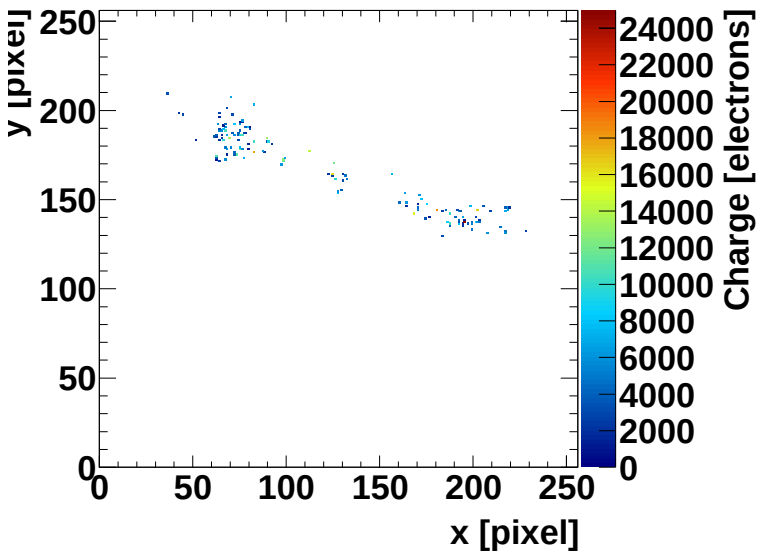


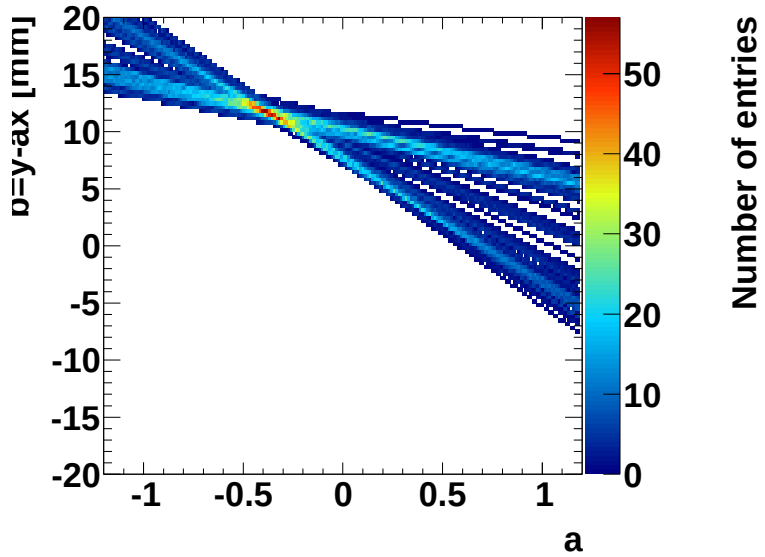




Reconstruction of Tracks in MarlinTPC

- Finding tracks $y = ax + b$ with Hough transformation $(x, y) \rightarrow (a, b)$





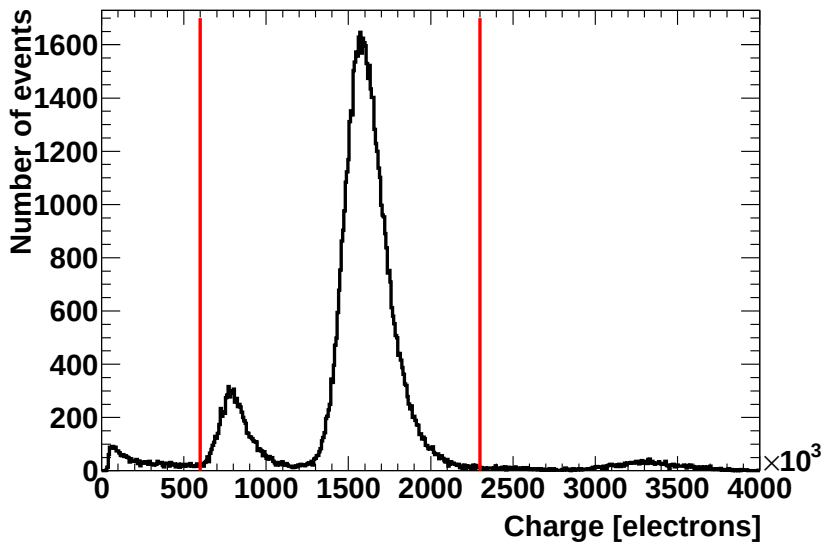
- Assign pixels within region around found track
- Determine precise track parameters with linear regression

Discrimination of Background Events

- Both, track reconstruction and x-ray algorithm for every event
- Calculate geometric properties of track and distribution of pixels assigned to it
- Separation of x-ray events and tracks by Likelihood ratio
- Likelihood ratio based on histograms from reference data sets (length of track, excentricity of track, kurtosis in track direction, number of pixels per track length, excentricity of clusters, kurtosis of clusters, number of clusters on track)

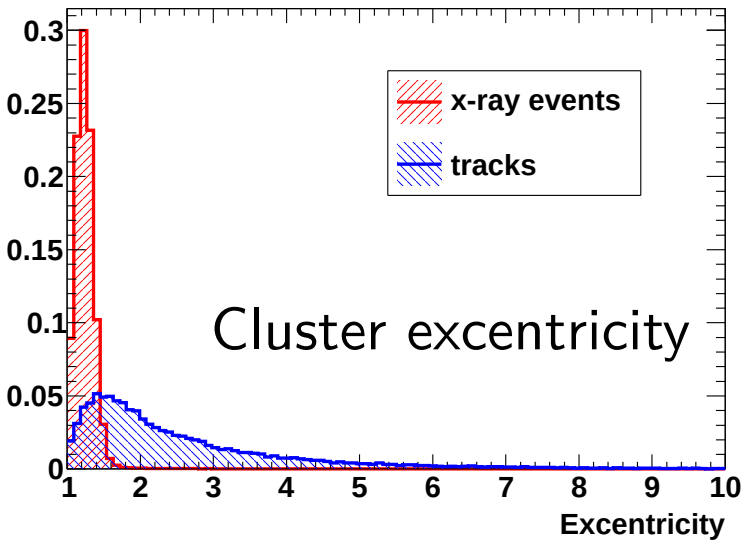
Reference Data Sets

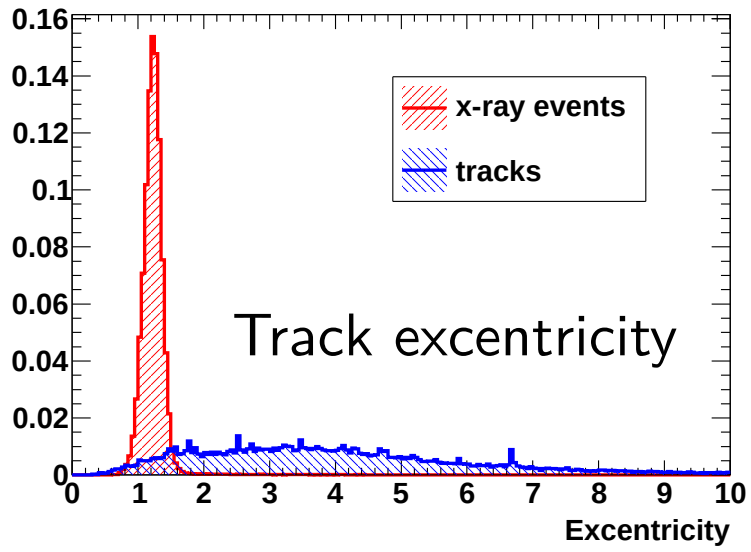
- X-ray reference
  - Run with ^{55}Fe source, short acquisition time ($20\,\mathrm{ms}$) and rate of $\sim 10\,\mathrm{Hz}$
  - Cleaning of data set: Cut on charge

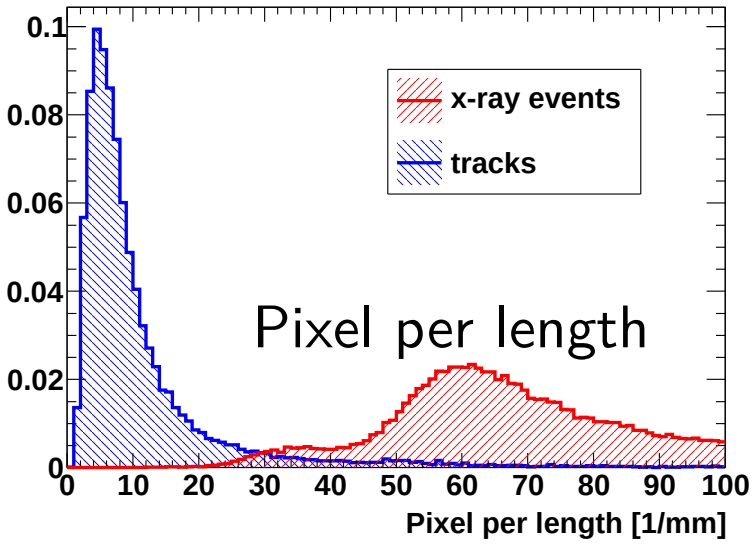


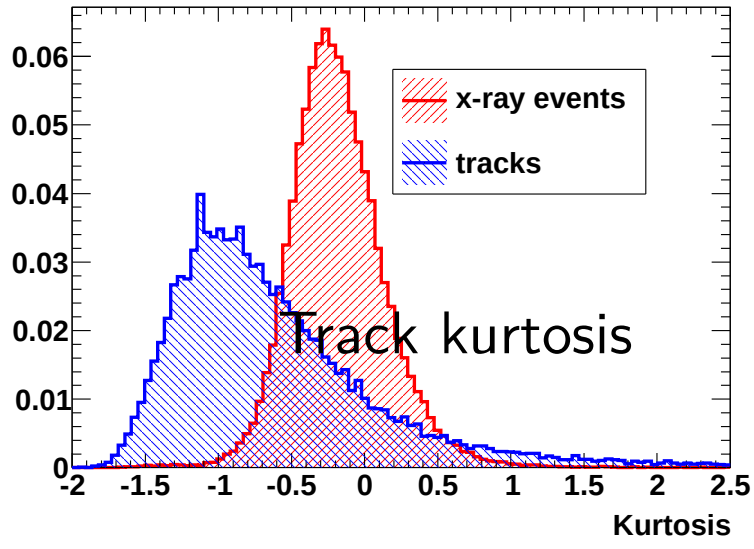
- Track reference
  - Run with full shielding

Discrimination of Background Events

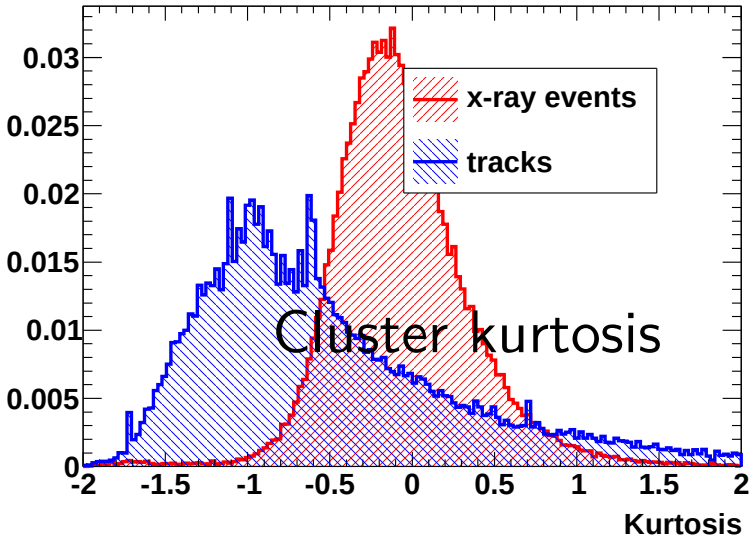


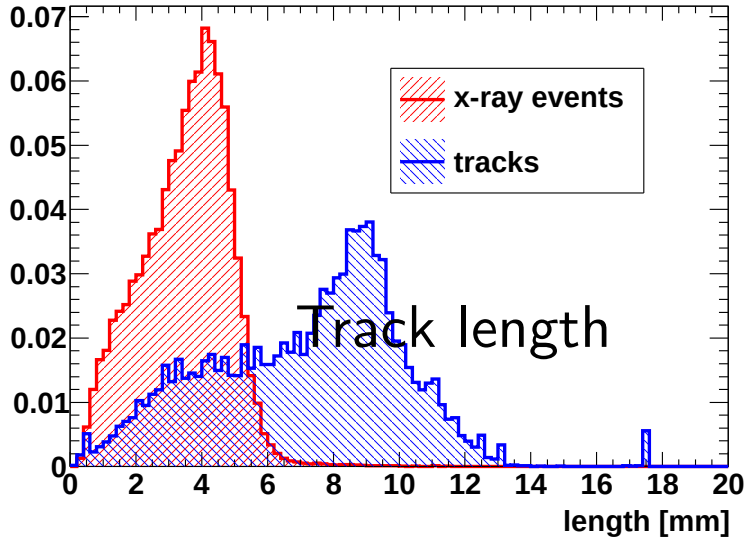


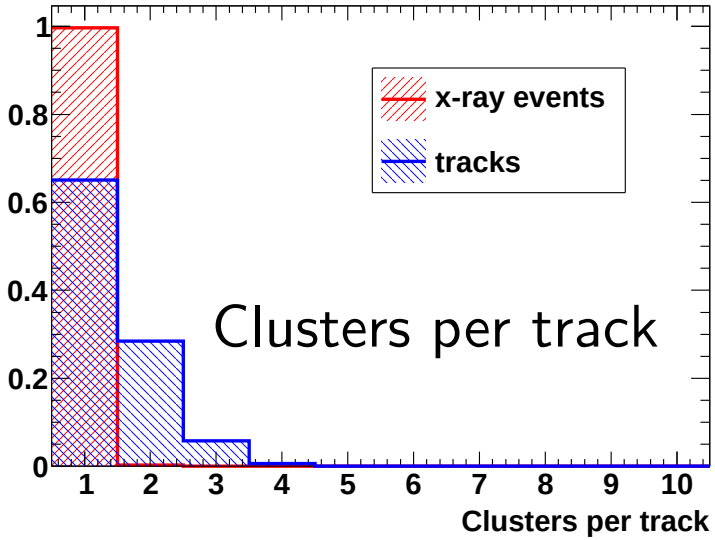




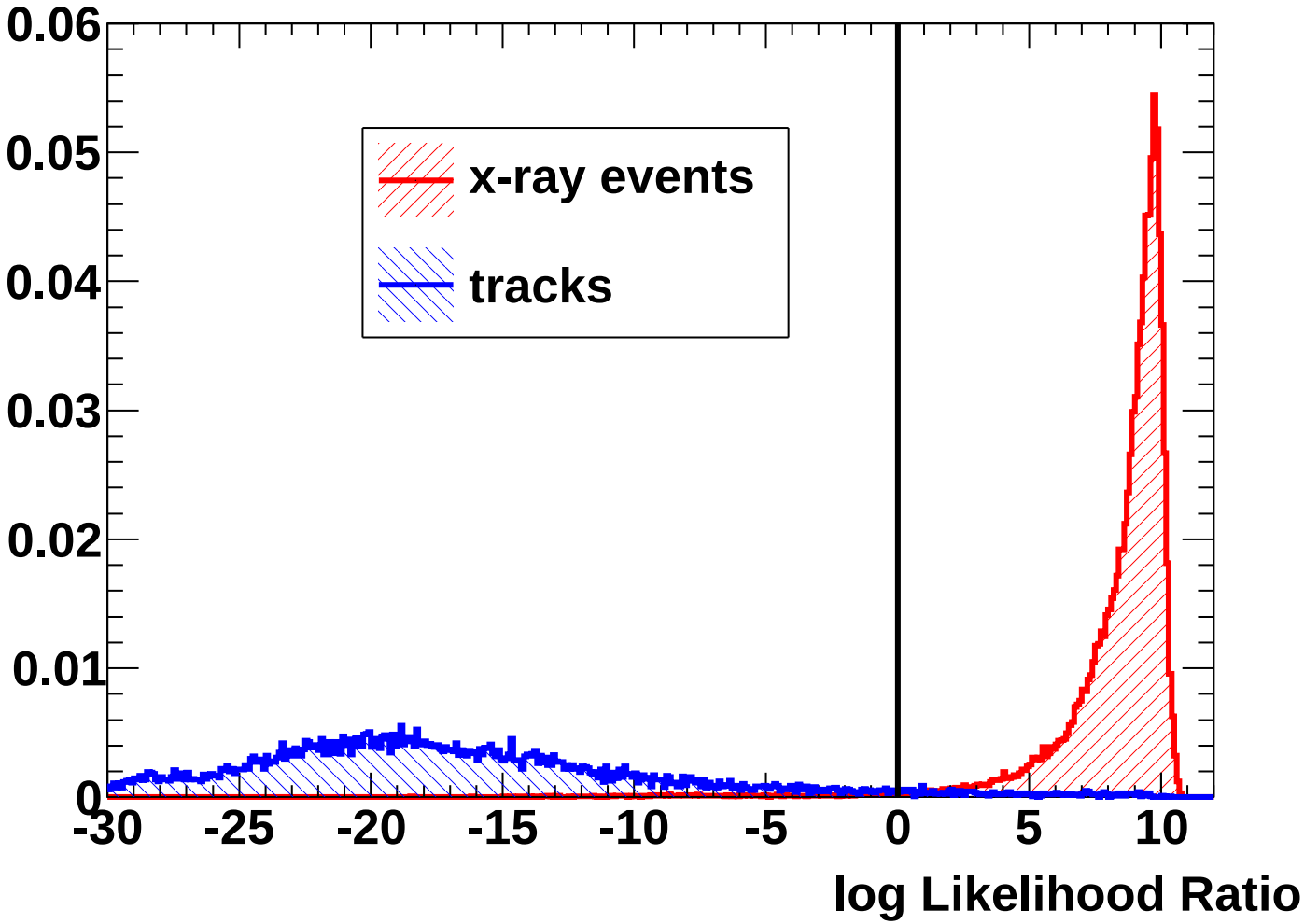
Discrimination of Background Events



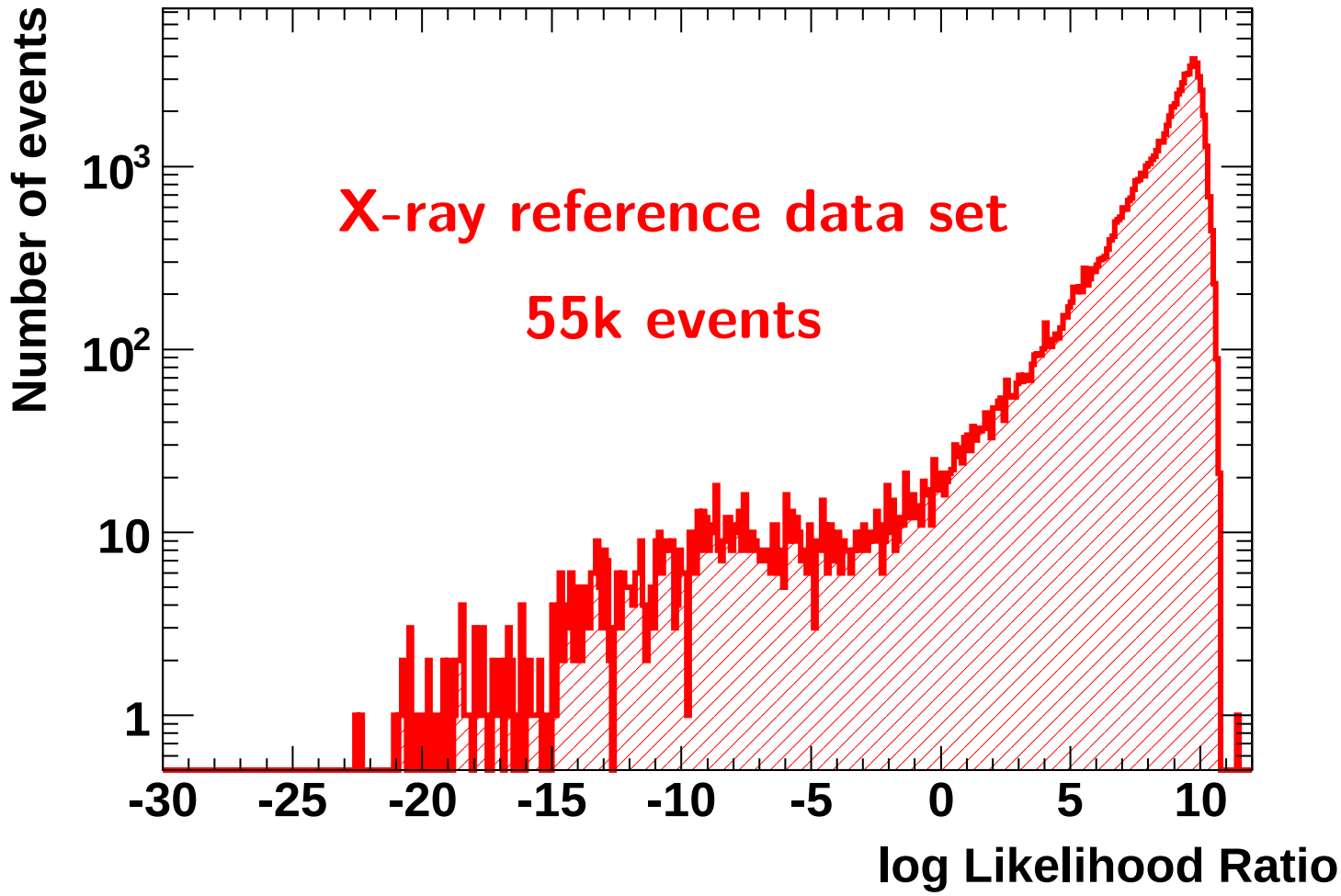




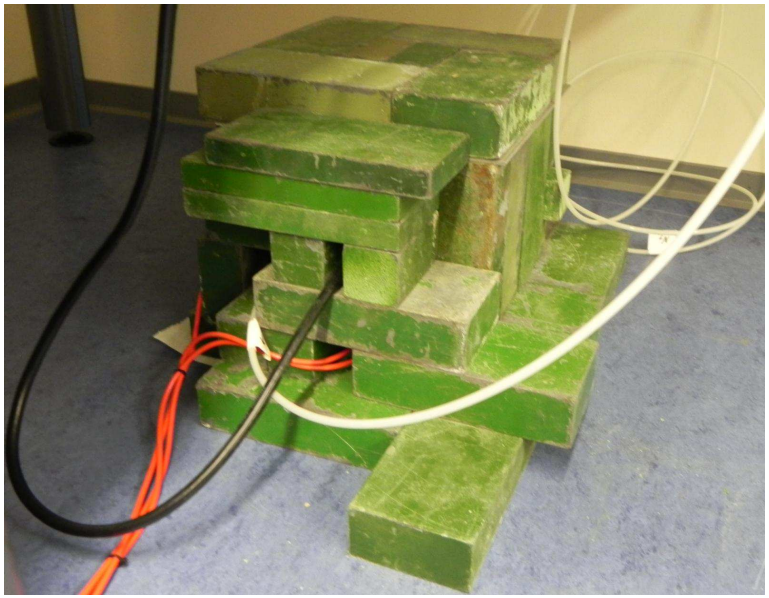
Discrimination of Background Events



Discrimination of Background Events



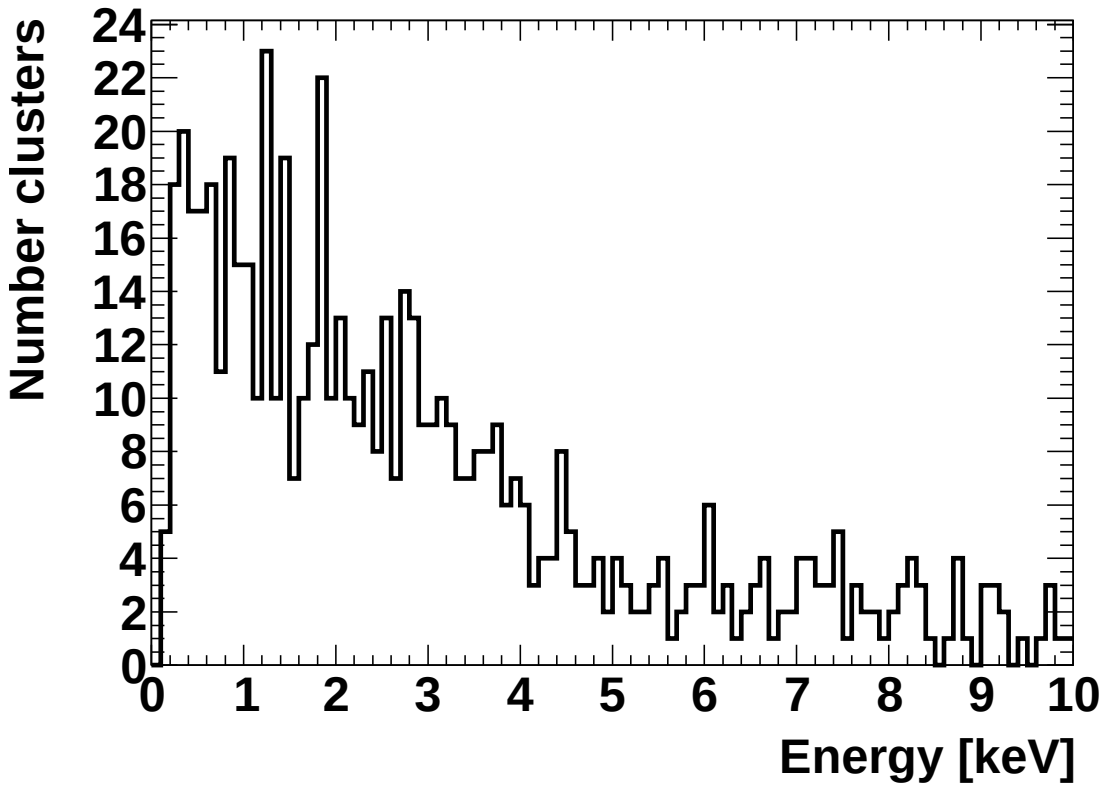
Setup for Background Measurements



- Detector shielded with copper box ($1\,\mathrm{mm}$) which can be flushed with nitrogen
- Lead shielding:
  $5\,\mathrm{cm}$ at the sides and at the bottom, $10\,\mathrm{cm}$ on the top
- Operation with Ar/iC_4H_{10} 95/5 at $350\,\mathrm{V}$
- about $500\,000 \times 1\,\mathrm{s}$ for each shielding setup
- No signal decoupled from grid yet

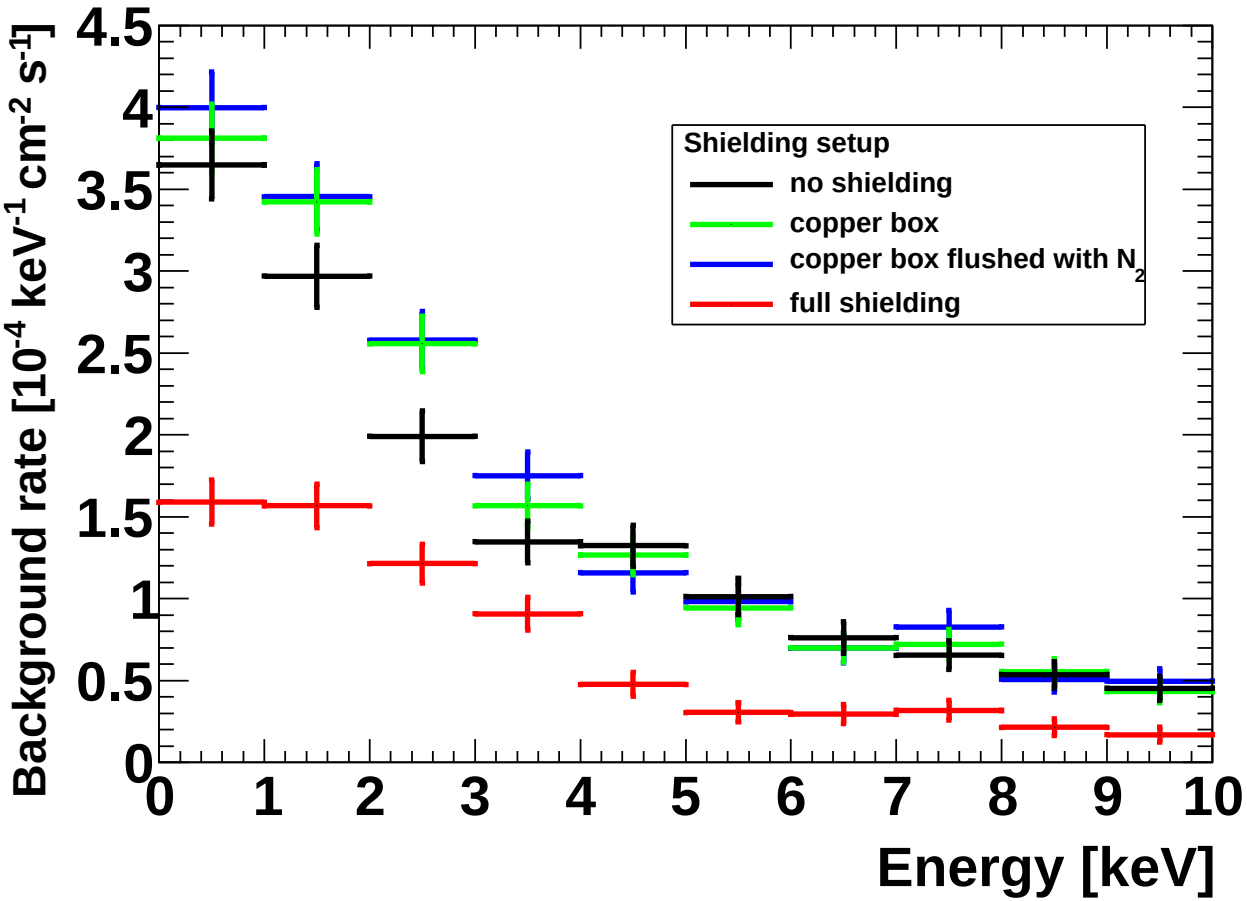
Background Measurements

- Full shielding



- Conversion from charge to energy by information from runs with ^{55}Fe source
- $520\,995$ acquisitions ($1\,\mathrm{s}$ each) $\rightarrow 37\,109$ non-empty events
- After background discrimination: 707 potential x-ray events

Background Rates



- Almost no difference in rates except for lead shielding

Conclusion and Outlook

Conclusion

- GridPix based x-ray detector successful put into operation
- Likelihood ratio based background discrimination works
- Achieved background rates are promising

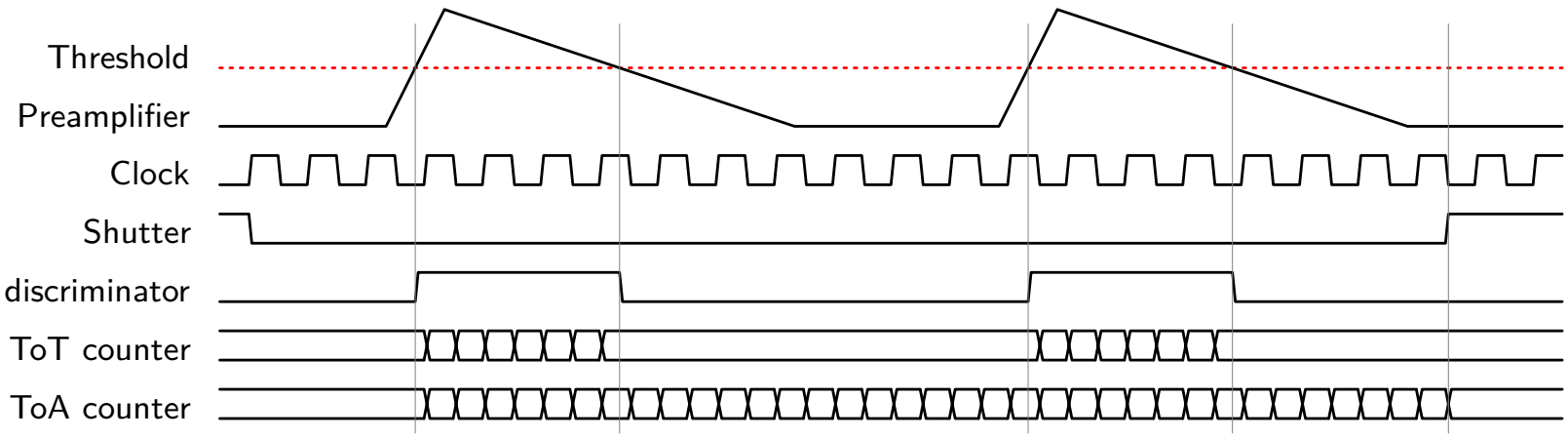
Outlook - next steps

- Decoupling signal from grid to get time information and better energy resolution
- Improve background discrimination and energy calibration

Thanks for your attention!

Backup

Timepix



- Shutter has to be 'opened' before charge arrives
- Only either ToT or ToA can be measured
- ToA possible only with Trigger and short acquisition times
- No multihit capability (charge is integrated)
- **Timepix 3** is under development and will be able to measure ToA and ToT simultaneously and recognize multihits (submission of Timepix 3 this year)

Production of InGrids

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 ($1\,\mu\mathrm{m}$)
6. Putting mask on aluminium layer (photoresist)
7. Structuring aluminum layer by etching the holes
8. Development of SU-8, cleaning of interstitials