Intrinsic XRF correction in CdTe Timepix3 spectral detectors

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Outline

• Timepix/Timepix3 detectors at DTU

• Hybrid Pixel detectors
  – Limitations: due to intrinsic XRF

• Timepix3
  – Timepix3 vs Timepix
  – XRF correction in Timepix3

• Results of XRF corrections
  – 57 Co spectrum: original vs XRF corrected

• Summary
Timepix/Timepix3 detectors at DTU

- Custom built setups for spectral imaging and diffraction
- Timepix and Timepix3 Si and CdTe detectors:
  - In-house TOT calibration at 25 °C
Timepix/Timepix3 detectors at DTU

- Custom built setups for spectral imaging and diffraction
- Timepix and Timepix3 Si and CdTe detectors:
  - In-house TOT calibration
  - Subpixel Resolution with Timepix3
  - Intrinsic XRF suppression
  - Phase contrast imaging with Timepix3

![Pixel Diagram](chart.png)
Timepix/Timepix3 detectors at DTU

- Custom built setups for spectral imaging and diffraction
- Timepix and Timepix3 Si and CdTe detectors:
  - In-house TOT calibration
  - Subpixel Resolution with Timepix3
  - Intrinsic XRF suppression
  - Phase contrast imaging with Timepix3

Tomorrow at 9.00 [66] “Low dose single shot two-dimensional phase contrast imaging”, Erik Schou Dreier, Niels Bohr Institute, U. of Copenhagen
Hybrid Pixel detectors

Limitations in HPDs:

- Intrinsic fluorescence => partial charge deposition
- Charge diffusion => charge sharing

- Absorption efficiency
- Fluctuations in the number of generated e-/h+ pairs
- Charge trapping, Leakage current, electronic noise, pileup
Hybrid Pixel detectors

Limitations of HPDs:
- Intrinsic fluorescence => partial charge deposition
- Charge diffusion => charge sharing

- Energy transfer to an orbital e
- e is ejected with $h \cdot E_{\text{incident}} - E_{\text{binding}}$
- The vacancy is promptly filled with e from other shells
- Fluorescence yield in CdTe is 80%

- Energy range: 3-100 keV
- Pixel size: 55 µm

<table>
<thead>
<tr>
<th>Substance</th>
<th>$Z$</th>
<th>$\kappa_1$ [keV]</th>
<th>$\kappa_2$ [keV]</th>
<th>Mean free path $\kappa_1$ [$\mu$m]</th>
<th>Mean free path $\kappa_2$ [$\mu$m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cd</td>
<td>48</td>
<td>23.17</td>
<td>22.984</td>
<td>113.2</td>
<td>110.7</td>
</tr>
<tr>
<td>Te</td>
<td>52</td>
<td>27.44</td>
<td>27.202</td>
<td>59.32</td>
<td>57.85</td>
</tr>
</tbody>
</table>
Hybrid Pixel detectors

Limitations of HPDs:
- Intrinsic fluorescence => partial charge deposition
- Charge diffusion => charge sharing

Charge diffusion leading to pixel clusters

1 mm CdTe
# Timepix3 vs Timepix

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Timepix ASIC</th>
<th>Timepix3 ASIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pixel pitch</td>
<td>55 µm</td>
<td>55 µm (can achieve sub-pixel resolution of 14 µm)</td>
</tr>
<tr>
<td>Pixel matrix</td>
<td>256 × 256</td>
<td>256 × 256</td>
</tr>
<tr>
<td>Sensitive area</td>
<td>14 mm × 14 mm</td>
<td>14 mm × 14 mm</td>
</tr>
<tr>
<td>Detection modes</td>
<td>• Energy</td>
<td>• Arrival Time and Energy</td>
</tr>
<tr>
<td></td>
<td>• Arrival Time</td>
<td>• Arrival Time</td>
</tr>
<tr>
<td></td>
<td>• Counts</td>
<td>• Counts +integrated Energy</td>
</tr>
<tr>
<td>Readout mode</td>
<td>Frame based (1700 fps)</td>
<td>• Frame based (1700 fps)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Data driven (40 Mcts/s)</td>
</tr>
<tr>
<td>Time Resolution</td>
<td>Up to 10 ns</td>
<td>1.56 ns</td>
</tr>
</tbody>
</table>
Results

$57\text{Co} + \text{Pb}$ Spectrum

Counts

Energy (keV)
Results

57Co + Pb Spectrum

- 75 keV-escape
- Ka\(_1\), Ka\(_2\) of pb: 75 keV
- Kb\(_1\) of Pb: 85 keV
- 57Co: 122 keV
- 122 keV- escape
- 57Co: 136 keV

Ka\(_1\), Ka\(_2\), Kb\(_1\) of CdTe
Results

57Co + Pb Spectrum

- 75 keV-escape
- Ka₁, Ka₂ of pb: 75 keV
- Ka₁, Ka₂, Kb₁ of CdTe
- Kb₁ of Pb : 85 keV
- 57Co: 122 keV
- 122 keV- escape
- 57Co: 136 keV
Results

E = 15-40 keV
Time = 15 ns
Space = 100 pixels

57Co + Pb Spectrum

Counts

Energy (keV)

×10^4

CdTe Fluorescence suppressed

Escape peaks suppressed

Original
XRF corrected
Results

E=15-40 keV
Time= 15 ns
Space= 100 pixels

57Co + Pb Spectrum

Counts

Energy (keV)

57Co + Pb peaks recovered

Original
XRF corrected
Summary

- Advapix-Timepix3 is a new hybrid pixel detector produced by ADVACAM:
  - Simultaneous Energy and arrival time measurements up to 40
  - Unambiguous one-by-one photon detection
  - Advapix-Timepix3 XRF correction algorithm can significantly reduce spectrum distortions due to intrinsic XRF
Thank you

Questions ?
Timepix3 vs Timepix

Timepix:

- Either **TOT** (Time-Over-Threshold mode: Energy) or **TOA** (Time-of-Arrival) measurements.
- **TOT measurement mode:** a second particle strike on the same pixel while the shutter is open results in integrated TOT.
- **Frame-based readout mode (up to 1700 fps):** Pixel matrix is insensitive during readout.

Timepix3:

- Simultaneous **TOT** and **TOA** measurements to identify pixel clusters and fluorescence events.
- Data driven readout (**up to 40 Mcts/s**): when a pixel is hit, it immediately initiates the sending of its data off-chip. => no dead-time. 475 ns to clear digital information from a pixel.