TECHNISCHE UNIVERSITÄT DRESDEN

Institute of particle and nuclear physics

Exploration of Pixelated CdZnTe Detectors for Double Beta Decay Searches within the COBRA Experiment

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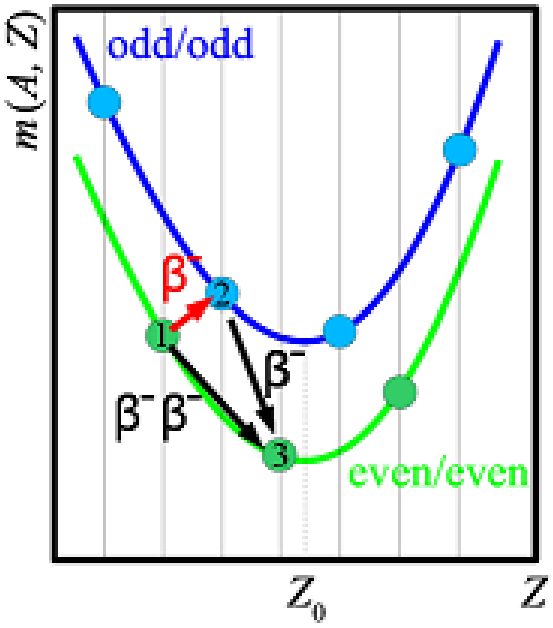
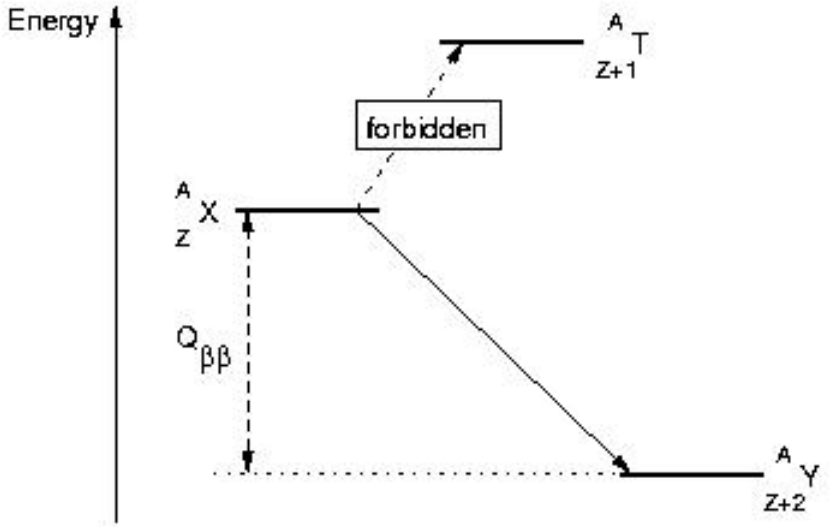
Outline

- short introduction – double beta decay
- the COBRA experiment
- pixel detector activities

Double Beta Decay

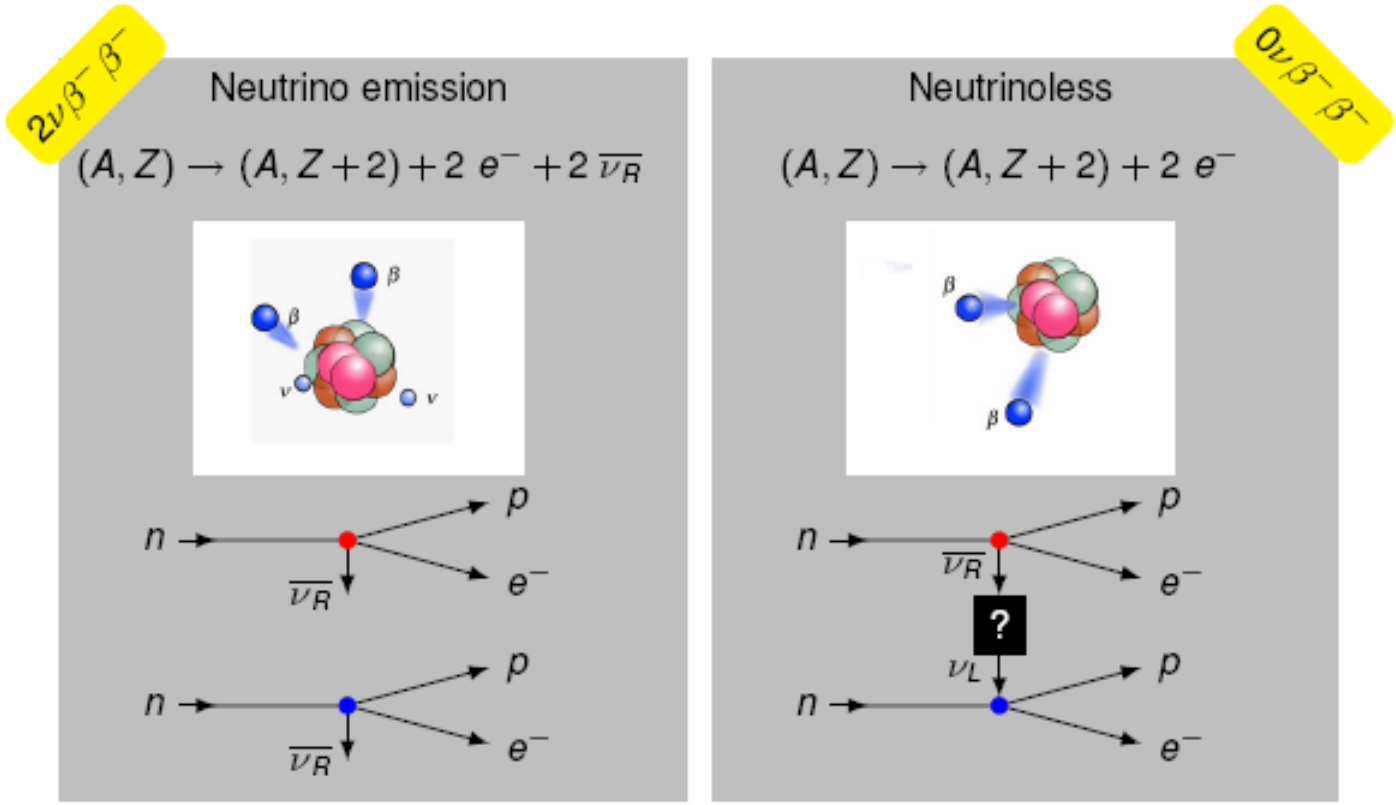
- rare and sponteanous second order process





- 35 nuclids are able to decay under $\beta\,\beta$ - decay

Double Beta Decay

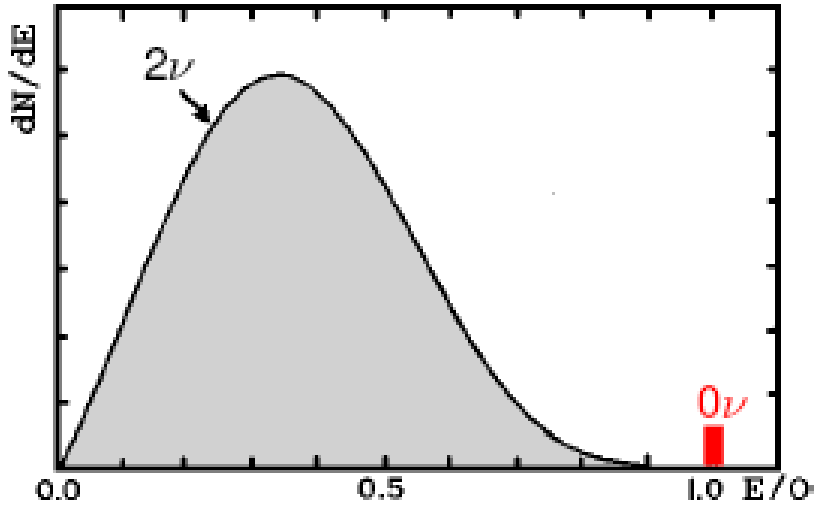


- energetically competing processes
- theoretical $2\upsilon\beta\beta$ 10^6 – 10^7 times more often than $0\upsilon\beta\beta$
- $2\upsilon\beta\beta$: $T_{1/2} > 10^{17}$ a

Neutrinoless Double Beta Decay

- not allowed in SM, $\Delta L=2$
- possible in many theoretical models beyond the SM
- presence of $0\upsilon\beta\beta$
  - fundamental neutrino character (Majorana or Dirac)
  - absolute neutrino masses $T_{1/2}^{0\nu} \sim (\langle m_{ee} \rangle / m_e)^2$

sum energy spectrum of both electrons



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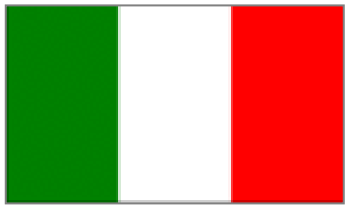
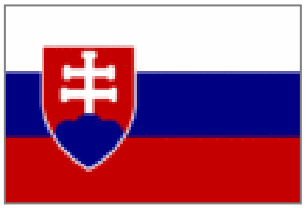
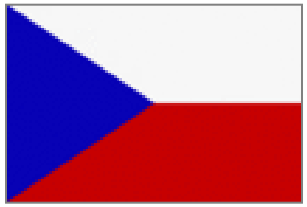
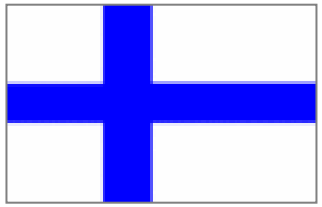
- the COBRA experiment
- pixel detector activities

COBRA Collaboration






TU Dortmund, TU Dresden, FMF Freiburg*, Uni Hamburg, Uni Erlangen-Nürnberg*

Laboratori Nazionali del Gran Sasso (LNGS), Uni Jykvaskyla

TU Prague*, JINR Dubna, University of Bratislava

Washington University St. Louis, University of La Plata

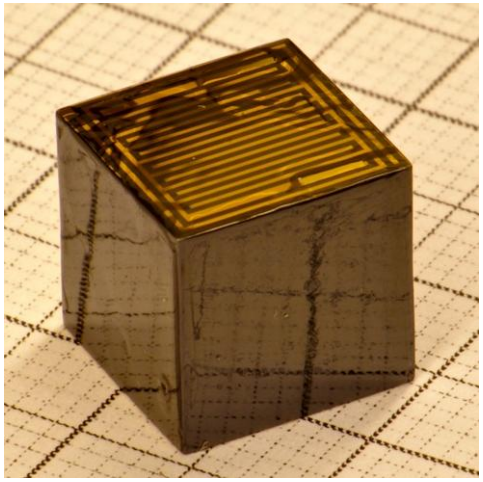
* Medipix-Collaboration members

The COBRA Experiment

What is COBRA?

Cadmium-Zinc-Telluride 0-neutrino double-Beta Research Apparatus

- searching for rare decays, especially $0\nu\beta\beta$ with CdZnTe-semiconductor detectors
- source = detector
- 2 concepts:
  - coplanar grid detector
  - pixelated detectors



The COBRA Experiment

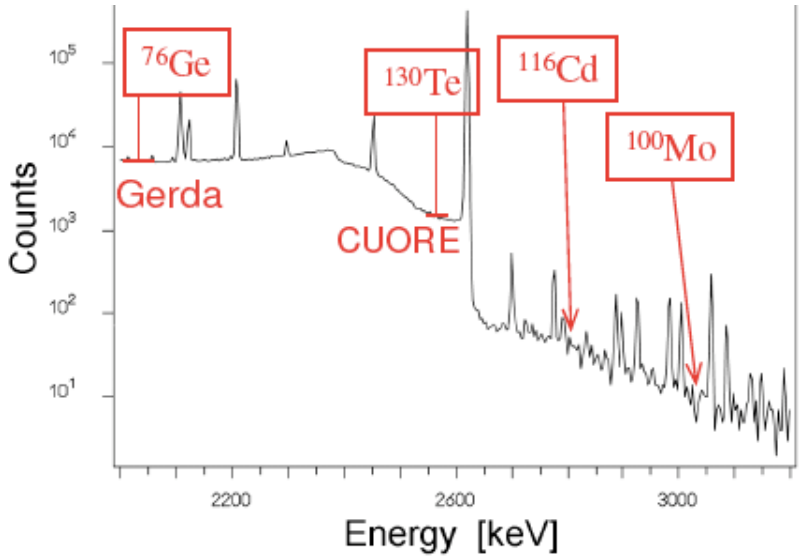
- expected halflife: $T_{1/2} > 10^{25}$ a of $0\upsilon\beta\beta$ - decay

  if $T_{1/2} = 10^{26-27}$ a $\rightarrow 10^{26-27}$ atoms $\rightarrow$ 1 event/a

  $\rightarrow$ needed mass CdZnTe: 100 kg

- ^{116}Cd: Q-value: 2809 keV

  $\rightarrow$ above high energy photon background

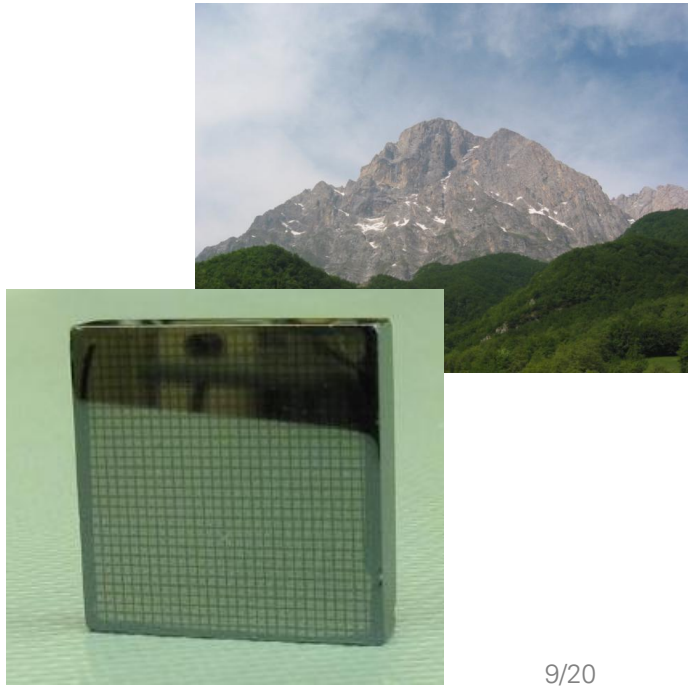


COBRA and Background

- background from: (high energy photons), muons, alphas, betas, neutrons, radioisotopes produced by cosmic radiation

→ it is all about background reduction!!

- experiment located at LNGS, Italy
- complex shielding
- lowbackground optimization
- pixelated CdZnTe detectors
  - efficient energy measurement
  - tracking
  - particle identification



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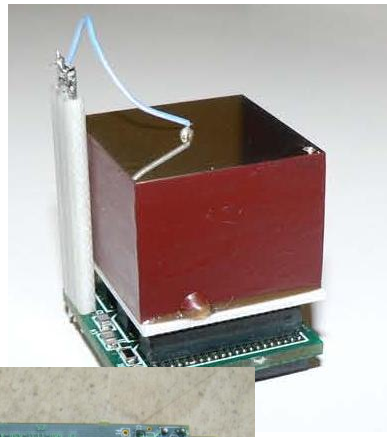
Pixeldetector Activities

- particle identification (α, β, γ, μ) offers the possibility to identify $\beta\beta$ – decays

- available pixelsystems:
  - large volume Polaris system
  - Timepix system



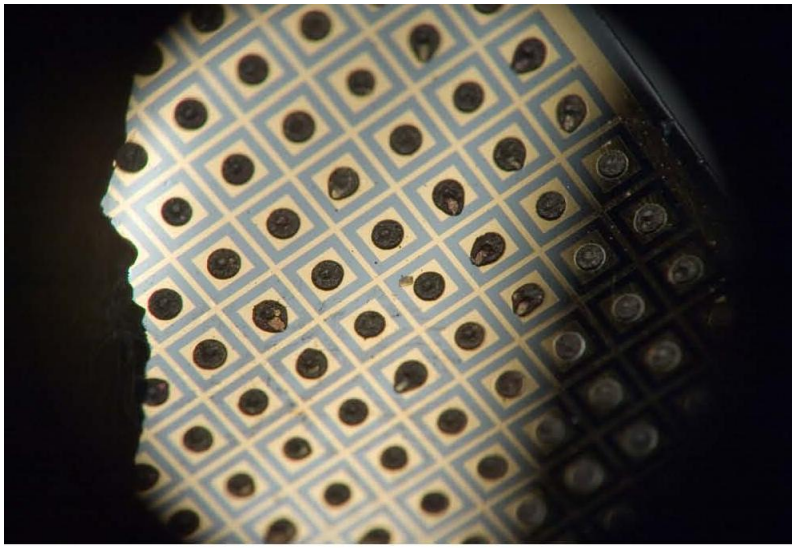
Large Volume System Polaris

prototype from Zhong He, University of Michigan

- CdZnTe, 2*2*1,5 cm^3 , 36 g
- 11*11 pixel, drifttime measurement offers 3D hit information
- energy resolution: 2 % at 662 keV

BUT:

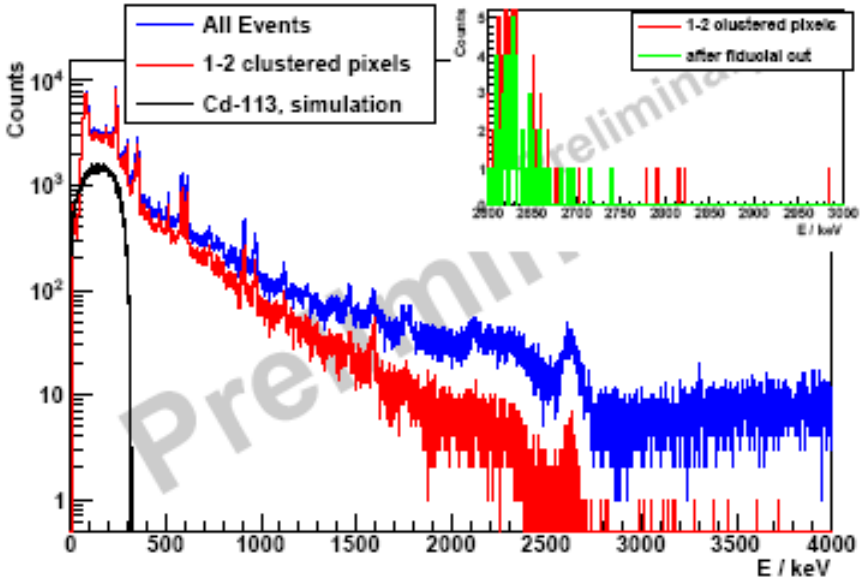
- no lowbackground optimization
- pixel too large for particle identification via tracking



→ background analysis

Large Volume System Polaris

- data: > 4,3 kg d
- analysis:
  - 1 or 2 pixel hits
    → low background,
    but also low effiency for
    $0\upsilon\ \beta\beta$ – detection (29%)
  - edge pixel neglected



- results:
  - 0 events in 125 days in the interesting energy region after fiducial cut
  - preliminary $T_{1/2} > 10^{20}$ a – very promising

  → efficient background suppression and coincidence analysis

Timepix Detectors

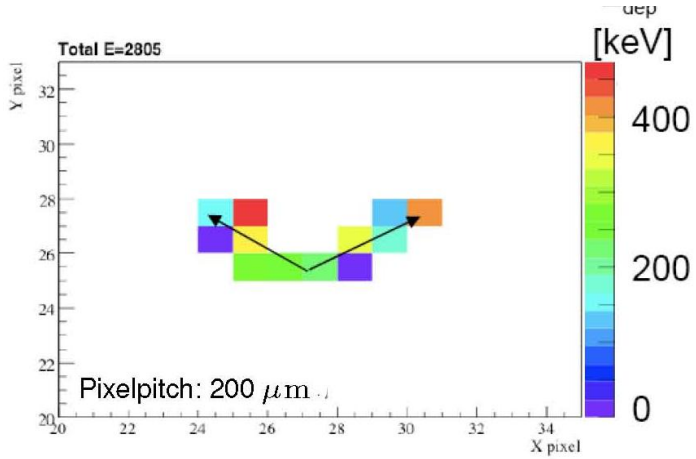
- developed by Medipix 2 Collaboration (www.medipix.cern.ch)
- 1,4 * 1,4 cm^2 sensor
- adjustable energy threshold (THL)

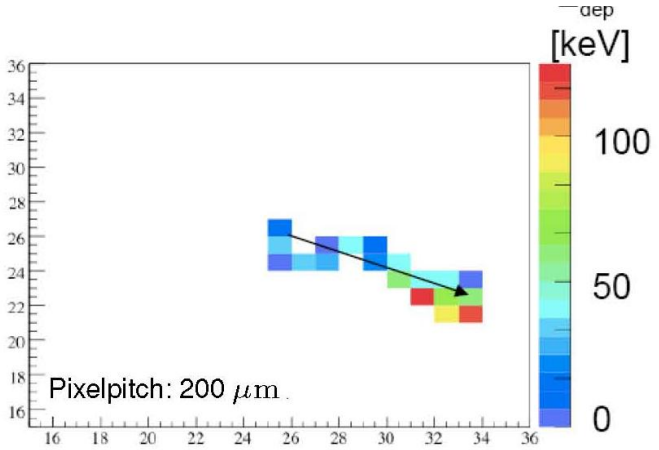
- Si – 256 * 256 pixel
- 300 μm thick
- 55 μm pitch,
- energy resolution about 13% at 59.6 keV (^{241}Am)

- CdTe – 128 * 128 pixel
- 1 mm thick
- 110 μm pitch
- energy resolution about 11% at 59.6 keV (^{241}Am) 7% at 662 keV (^{137}Cs)

Timepix Detector - Simulations

Simulation of signal and background for CdTe





signal: $0\upsilon\beta\beta$ from ^{116}Cd

background: 3 MeV β^-

- typical ranges in CdTe: 0,7 – 1,5 mm
- dangerous source of background : β^- from ^{214}Bi with 3,3 Mev endpoint energy

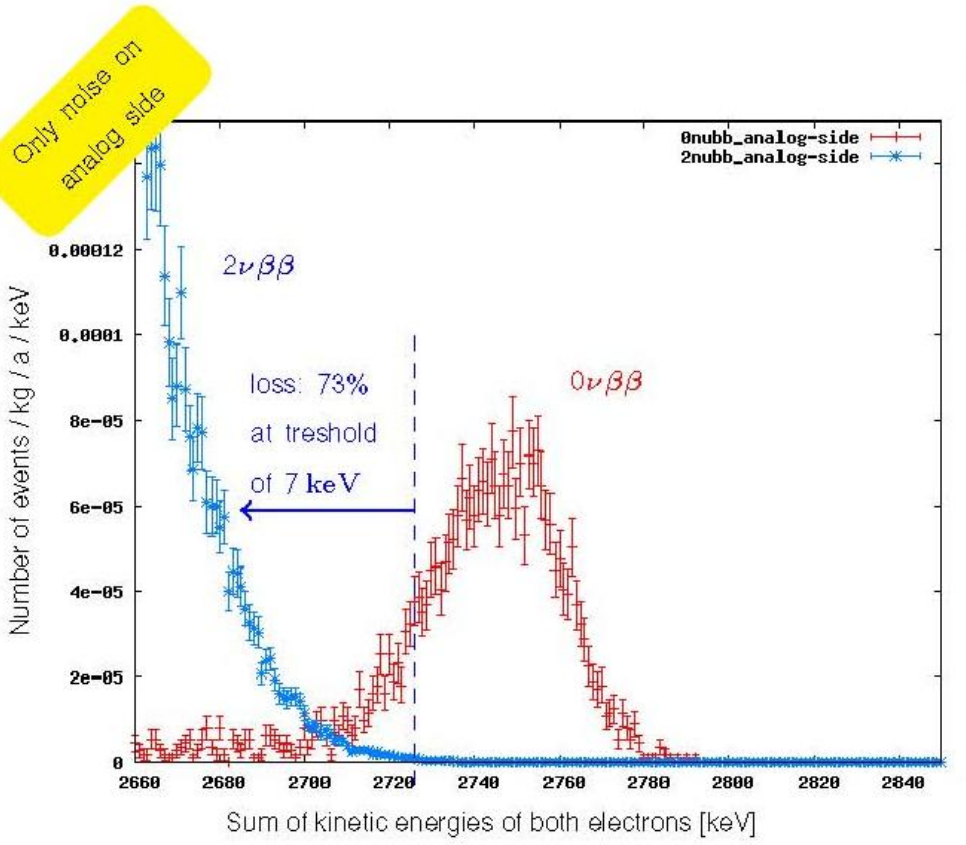
Timepix Detector - Simulations

simulation of $0\upsilon\beta\beta$ and $2\upsilon\beta\beta$ of 1,6 mm thick CdTe sensor

- only analog side of pixel electronic

- pixelpitch 110 μm
- 700 V bias voltage
- noise: 400 e^- rms
- threshold: 7 keV:

$$\frac{\Delta E_{FWHM}}{E} = 1{,}3\%$$



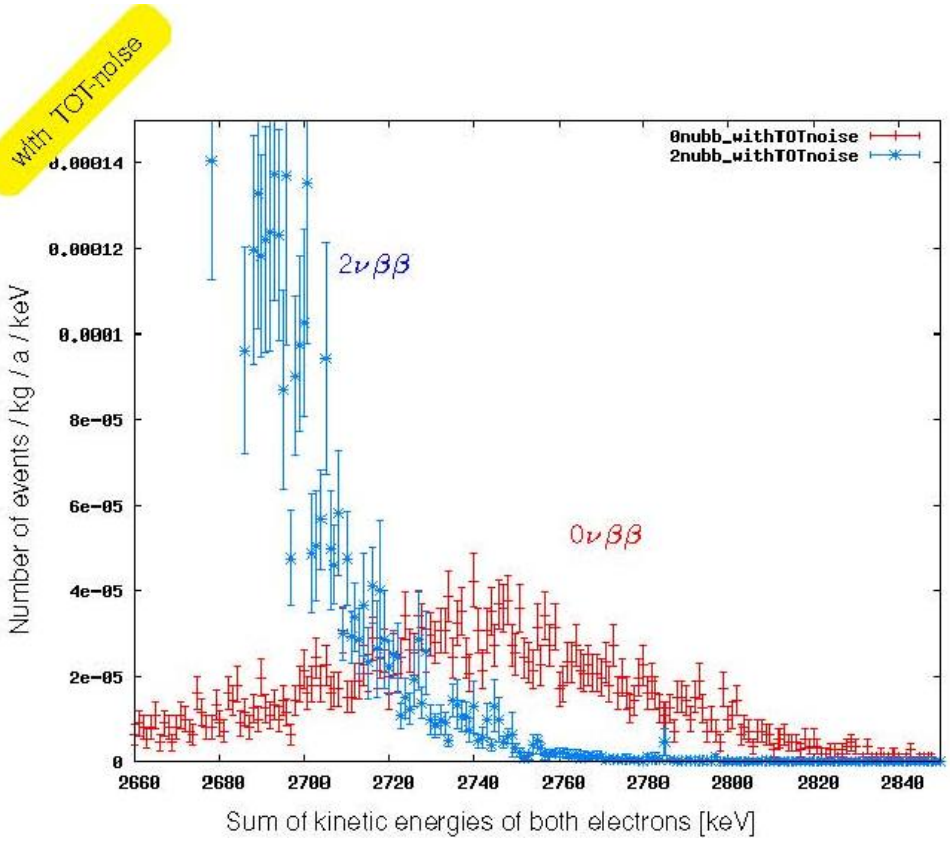
Timepix Detector - Simulations

simulation of $0\nu\beta\beta$ and $2\nu\beta\beta$ of 1,6 mm thick CdTe sensor

- with analog and digital side of pixel electronic
- threshold: 7 keV:

$$\frac{\Delta E_{FWHM}}{E} = 3{,}3\%$$

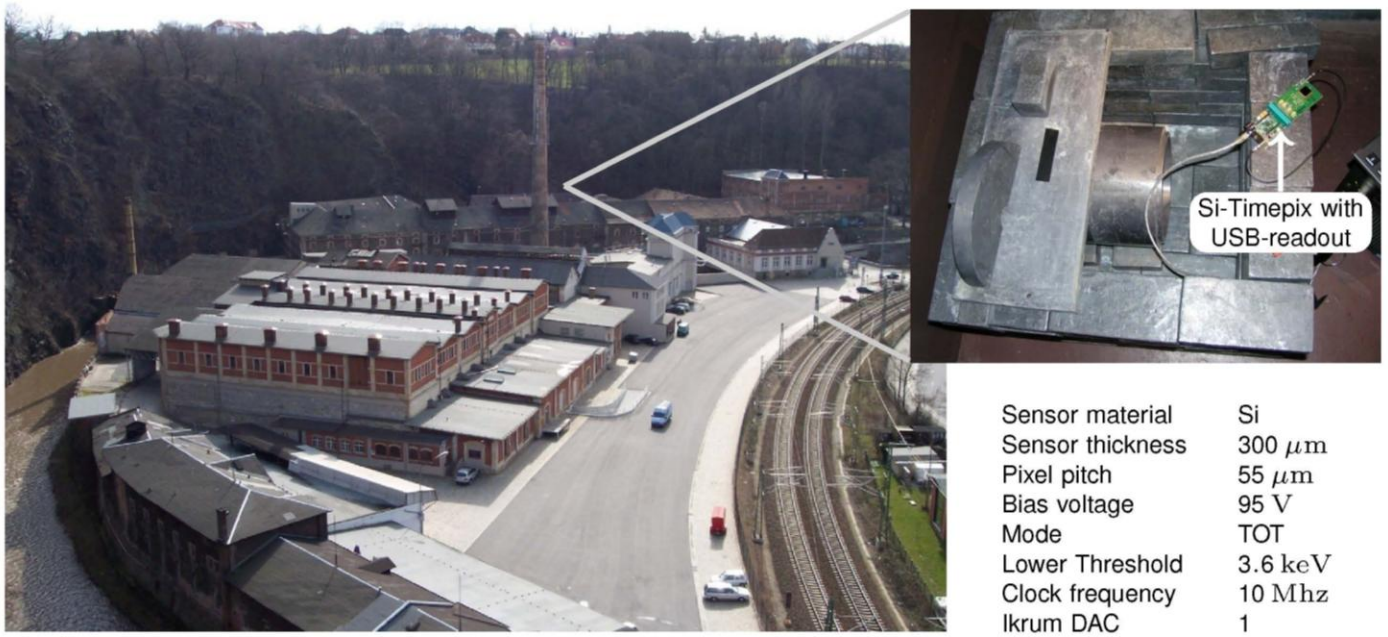
- optimization possible:
  - sensor thickness
  - face –to-face



Timepix Dectectors

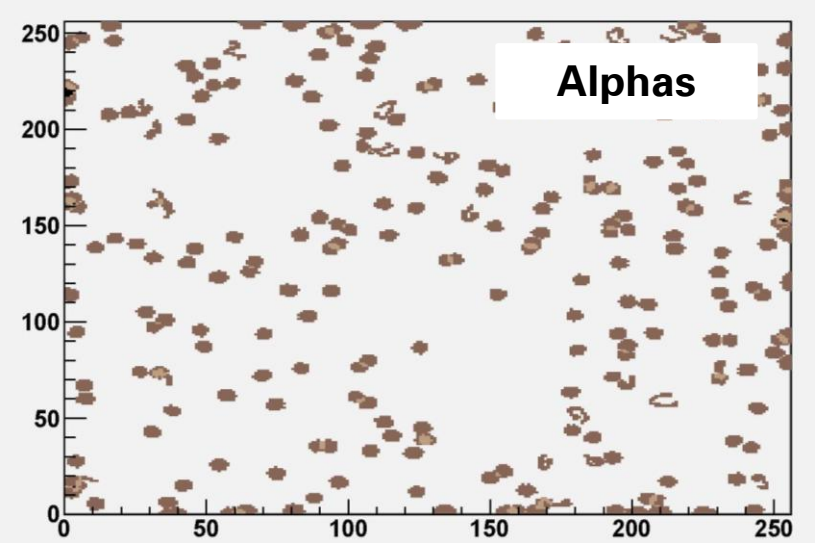
background measurements in an Underground Lab

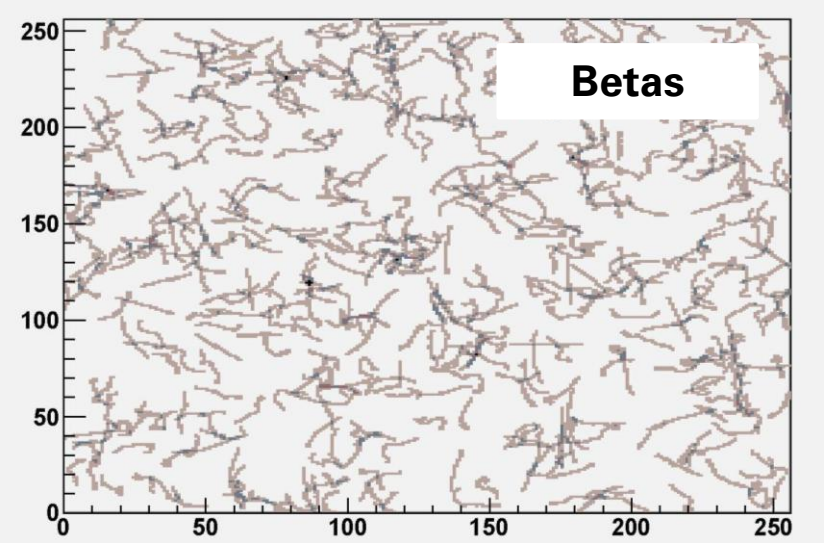
- Si-Timepix detector in Felsenkeller Laboratory in Dresden since 09/2009

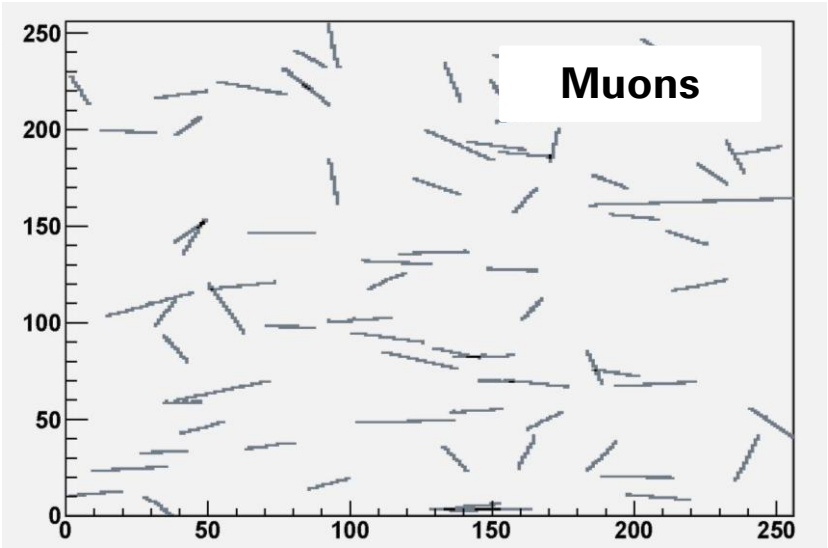


Sensor material	Si
Sensor thickness	300 μm
Pixel pitch	55 μm
Bias voltage	95 V
Mode	TOT
Lower Threshold	3.6 keV
Clock frequency	10 Mhz
Ikrum DAC	1
Frametime	1 s

Timepix Detectors





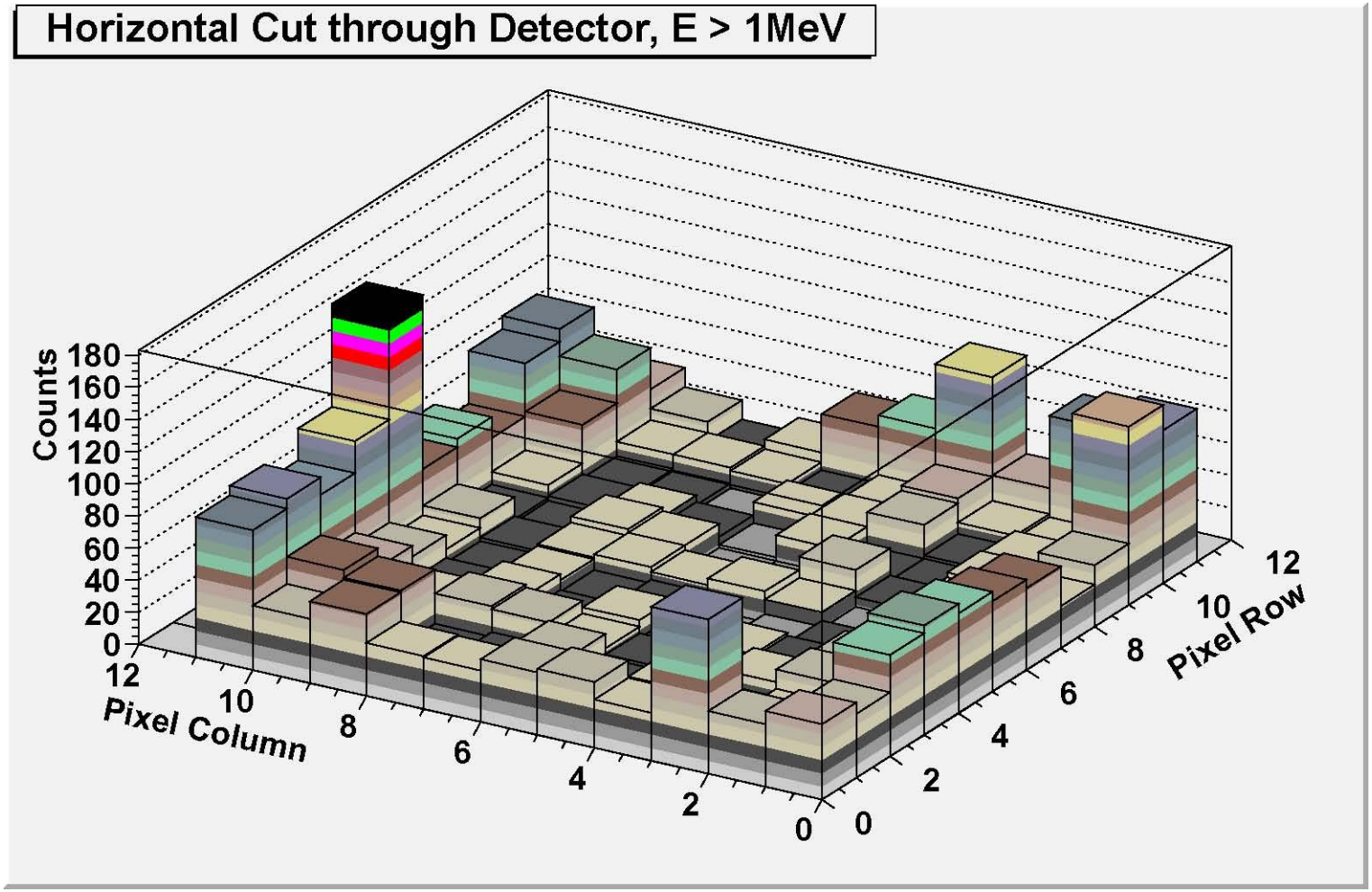


Conclusion

- energy resolution of pixelated detectors has to be improved to distinguish $0\upsilon\beta\beta$ and $2\upsilon\beta\beta$ – events
- due to electron loss in thin detectors → development of thicker pixel sensors together with our collaboration partners
- first time for pixelated detection module to run under low background conditions– but intrinsic contamination of the asic materials is still too high

  → field of severe requirements and high potential in developing new techniques and materials to run pixel devices under low background conditions

BUT: the energy sensitive tracking capabilities are a promising technology for the $0\upsilon\beta\beta$ –decay search


Horizontal Cut through Detector, E > 1MeV
Counts
180
160
140
120
100
80
60
40
20
0
Pixel Column
12
10
8
6
4
2
0
Pixel Row
0
2
4
6
8
10
12