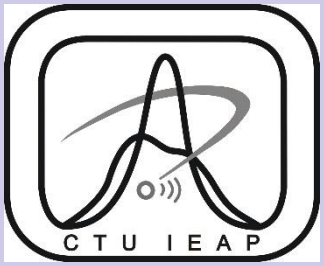

Silicon Pixel Telescope

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Overview

- Introduction
- Intrinsic background studies
- Hardware developments
- Background measurements
- Conclusion and future prospects

Silicon Pixel Telescope (SPT)

Measurement of two neutrinos double electron capture (2νEC/EC) in ^{106}Cd

$$2e + {}^{106}_{48}Cd \rightarrow {}^{106}_{46}Pd + 2\nu_e + (\gamma, X-rays) \quad Q_{EC/EC} = 2778\,keV, \quad \text{ROI:} \quad 19\,keV \le E_X \le 23\,keV$$

Signature of the process:- **2 Pd X-rays (~21 keV) in coincidence**
Main background: Cd KX-rays (~23 keV)

JINR Dubna, Russia
LSM Modane
IEAP, CTU Prague, Czech Republic
Located in the LSM underground lab, Modane, France

Overburdern: 4800 m.w.e.
Muon rate: 4 μ/m²/d
$2 \cdot 10^{-6}$n/cm²/day

What makes pixel detectors attractive for ββ ?

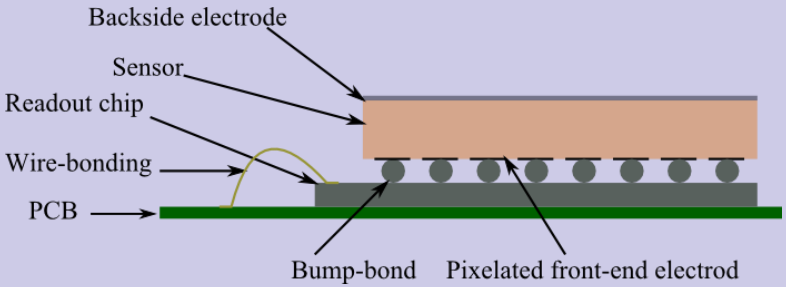
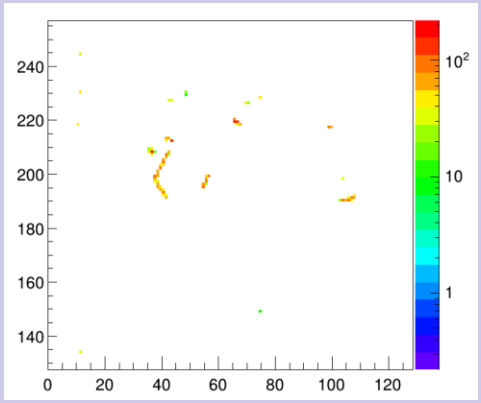


Illustration of hybrid pixel detector

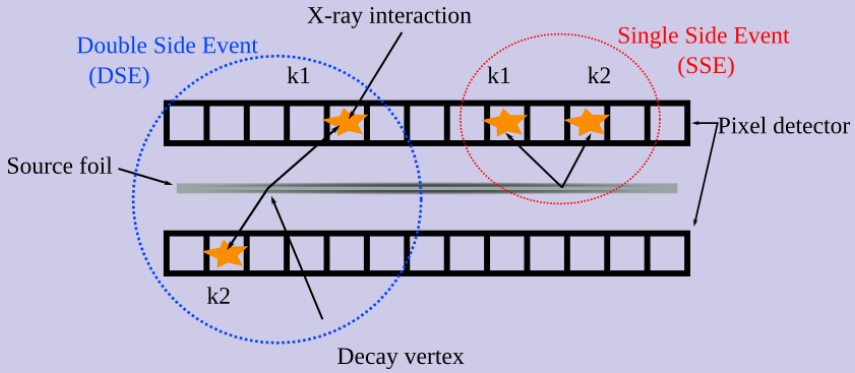
Timepix on chip-carrier PCB



A frame with coincident events acquired with Timepix pixel detector

- Timepix pixel detector from Medipix collaboration
  - Hybrid pixel detectors (possibility to have different sensor materials)
  - 256x256 pixels, 55 μm pitch.
  - Each pixel is a spectroscopic channel

- Pixel detectors can give both energy and signature of the event
- Spatial information can distinguish the coincident events in the same detector
- Both Single-Side-Events and Double-Side-Events can be utilized



SPT detection unit

Intrinsic background measurements

- Measured by low-background setup in the LSM underground lab, France
- HPGe planar detector, 150 cm^3, range 20 keV – 1.5 MeV

Single Pixel Detector (SPD)

Intrinsic contamination in Timepix pixel detector constituent materials

Material, mass and time of measurement	Radioactive Impurities (mBq/Kg)				
	^{228}Th	^{234}Th	^{40}K	^{60}Co	^{137}Cs
Bump-bond material (In), 1.1 g, 601882 s	< 245	< 3642	< 3909	< 270	< 151
Bump-bond material (Sn), 0.725 g, 593200 s	< 471	< 4141	< 3593	< 413	< 350
Readout ASIC (Si), 0.398 g, 329770 s	< 428	< 2312	< 16000	< 1300	< 716

Intrinsic contamination in PCB materials (using FR4 substrate)

Radioactive impurities (mBq/kg)					
^{228}Th	^{234}Th	^{40}K	^{228}Ra	^{210}Pb	^{226}Ra
21308 ± 648	13611 ± 891	< 2025	17660 ± 972	10693 ± 1620	14177 ± 486

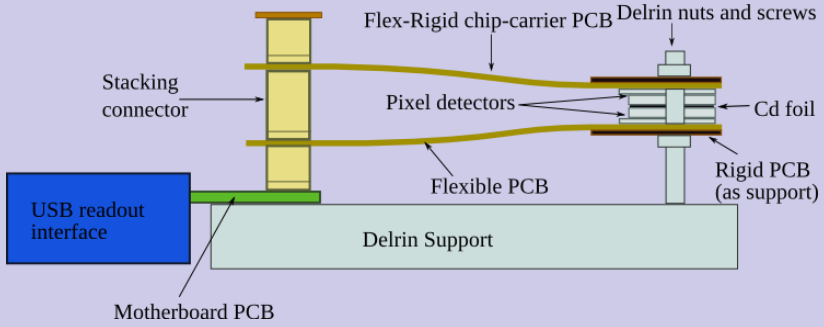
intrinsic contamination in CuFlon and Flexible PCB (mBq/kg)

PCB material	Radioactive impurities (mBq/kg)				
	^{228}Th	^{40}K	^{228}Ra	^{210}Pb	^{226}Ra
Flexible PCB	170 ± 76	< 1760	< 215	< 3200	207 ± 76
CuFlon PCB	< 16	< 280	< 39	< 134	< 16

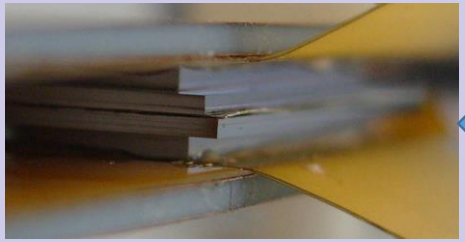
- Timepix parts (Si sensor, bump bonds, etc.) are relatively clean in terms of radio-impurities
- Standard PCB material (FR4) has significant contamination
- CuFlon and Flexible PCB were found to be the best material for low background setup
- These materials were selected for the production of coincidence prototypes

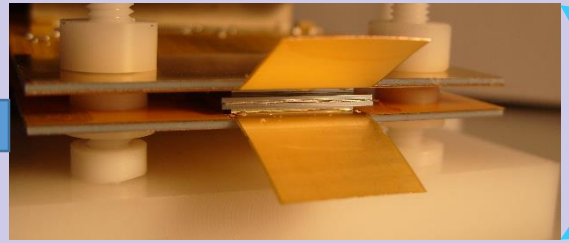
Hardware developments

- A Flex-Rigid Pixel Telescope was prepared using CuFlon and flexible PCB
- Advantage of varying the detector-foil distance
- Functional tests were performed with natural Cd foil in between.



Pixel Telescope- Flex-Rigid version





- Delrin screws nuts to fix the chip carrier boards
- Delrin support structure to hold the SPT

- Four units of Flex-rigid SPT were fabricated and installed in the underground laboratory (LSM France)
  - Two units with 500 µm Si sensors, 55 µm pitch Timepix
  - Two units with 1 mm Si sensors, 55 µm pitch Timepix

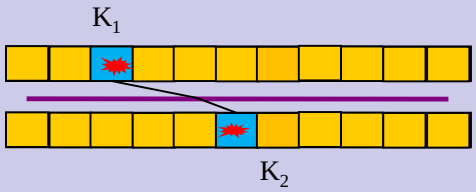
Four units of Flex-rigid SPT arranged with Delrin support structure

Background measurement results

- 8 detectors, 0.5 and 1 mm thick Si sensors
- Shielding used: 8 cm BPE, 10 cm Pb and 2 cm electrolytic copper
- Location: LSM underground laboratory

1425 h of data	All events/h	In ROI/h
Total	32.23 ± 0.15	0.81 ± 0.02
SSE with dist.	0.05 ± 0.0059	< 9.09 x 10^{-4}*
DSE	0.06 ± 0.0067	< 9.09 x 10^{-4}

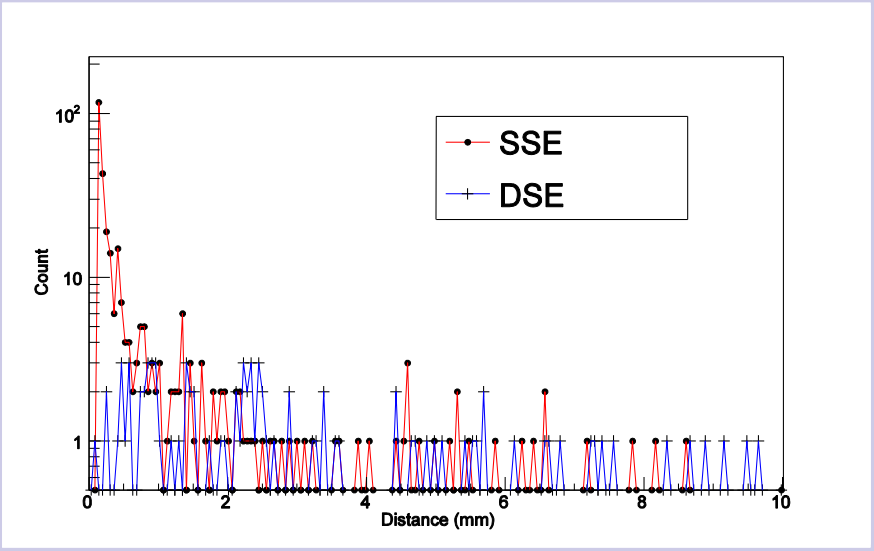
** Calculated using Feldman-Cousins method*



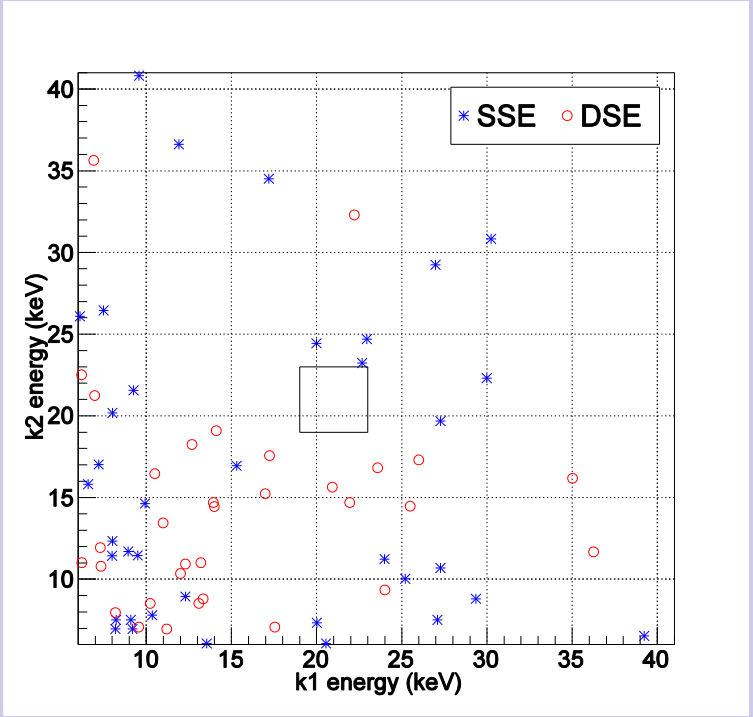
Double Side Event (DSE)

View of full shielding partially opened

- Distance between coincident events can be used as additional noise suppression criteria.



Distance distribution of SSE and DSE events



Scatter plot of SSE and DSE events from measurement with full shielding

Conclusion

- Pixel detectors for measurement of 2νEC/EC in ^{106}Cd
- Intrinsic and external radiation backgrounds studied for the setup
- Designed, implemented and optimized the Si Pixel Telescope (Flex-Rigid SPT)
- Four units of SPT prototype already installed, more on the way
- Current background levels of SPT prototype are comparable with TGV-II setup

Future prospects

- Background measurement with natural Cd foils in SPT prototype
- Increase the number of SPT units
- Finally use the enriched Cd foil in SPT for the half-life limits measurements
  (2 g of Cd enriched up to 99 % with ^{106}Cd available for SPT)

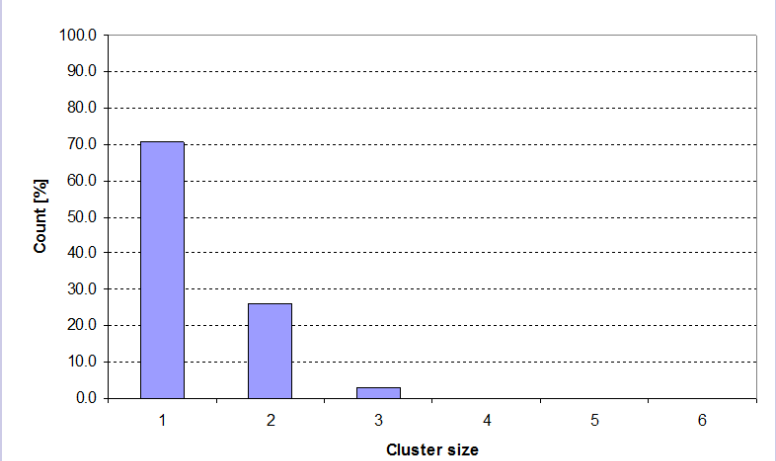
Thank you

Silicon Pixel Telescope -calculations-

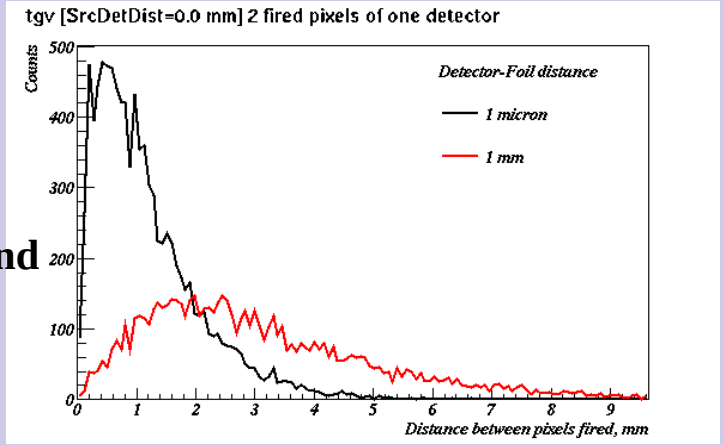
Simulations using the GEANT 4 and the DECAY0 generator.

Detector dimensions: 1.408 cm x 1.408 cm x 2 mm
Number of pixels: 256 x 256 (pixel size: 55 x 55 µm)
Detector material: Si
Source foil: 1.2 cm × 1.2 cm × 50 µm
Closely packed geometry (1 µm between foil and detector)

full efficiency for SPT = 8,54 %



The distribution of cluster sizes (numbers of fired pixels) for [19–23] keV X-rays detected by a 300 µm thick Timepix detector with pixel size of 55 µm.



Simulated distances between pixels hit by 2νEC/EC X-rays

SPT advantages:

- ❑ **Distinguishing coincident X-rays on single detector**
- ❑ **"Distance of events" information could reduce background**
- ❑ **Better identification of signature events by Cluster size**
- ❑ **Room temperature operation of detectors**

See 'P Cermak et al 2011 JINST 6 C01057' for details