Pixel Detectors in Double Beta Decay

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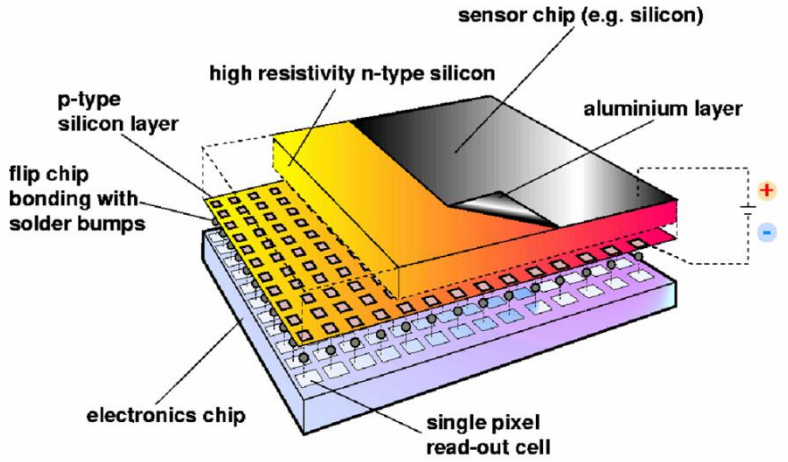
Overview

- Pixel Detectors
- Experiments Involved
- Pixel Telescope
- Background Measurements
- Conclusion

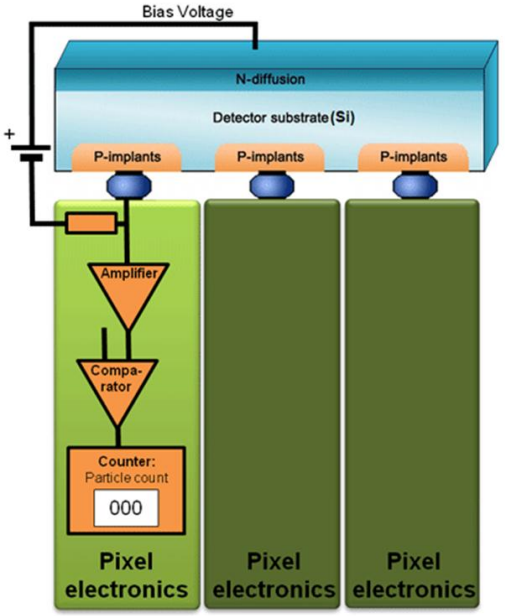
Hybrid Pixel Detector Timepix

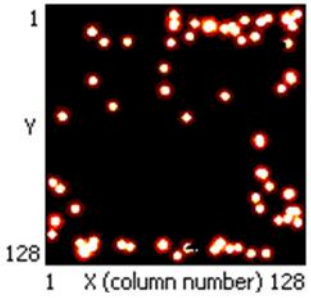
- Hybrid pixel detectors have sensor and readout in separate modules
- Bump-bonding of sensor on to the readout ASIC
- Possibility to have different sensors

- Timepix (derived from medipix2 chip) from Medipix collaboration
- 256x256 pixels, 55 µm pitch.
- Operation modes
  - Single photon counting (Medipix)
  - Time of arrival (Timepix)
  - Energy measurements (TOT)

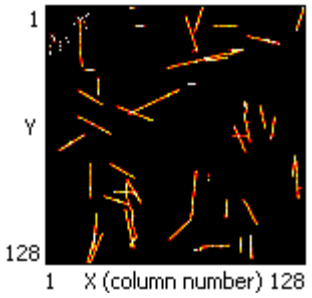


Timepix detector

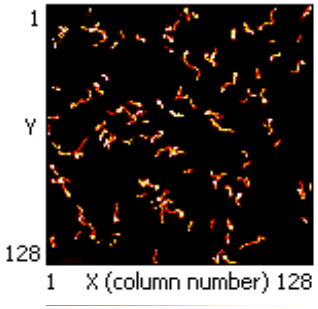




Alpha



Muon



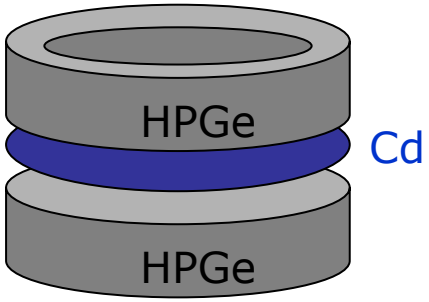
Electron

Experiment Silicon Pixel Telescope (SPT)

- **TGV III experiment (Location: LSM Modane)**
- **Measurement of 2nEC/EC (g.s. to g.s) in ^{106}Cd**

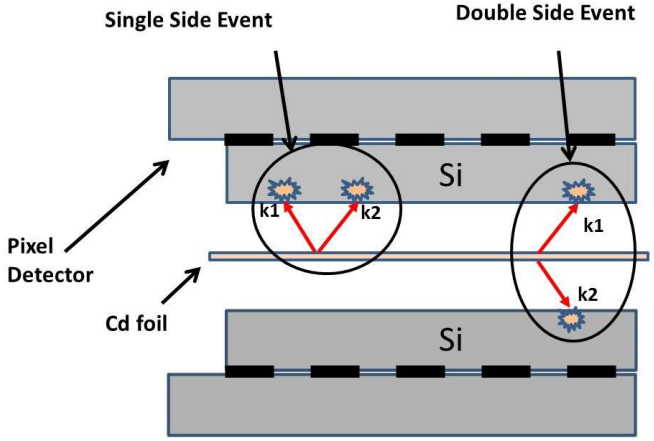
$$2e + {}^{106}_{48}Cd \rightarrow {}^{106}_{46}Pd + 2\nu_e + (\gamma, X-rays)$$

$$Q_{EC/EC} = 2778\,keV, \quad \text{ROI}: \quad 19\,keV \le E_X \le 23\,keV$$



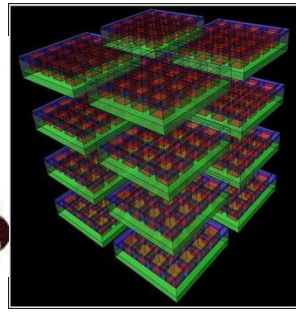
TGV II detector idea

- **Signature of the process:- 2 X-rays (21 keV) in coincidence**
- **Majority of above signature events will form Single Side Events (SSE) and Double Side Events (DSE)**
- **SSE occurs when both event deposit on same side**
- **DSE occurs when events deposit on opposite side**



SPT idea

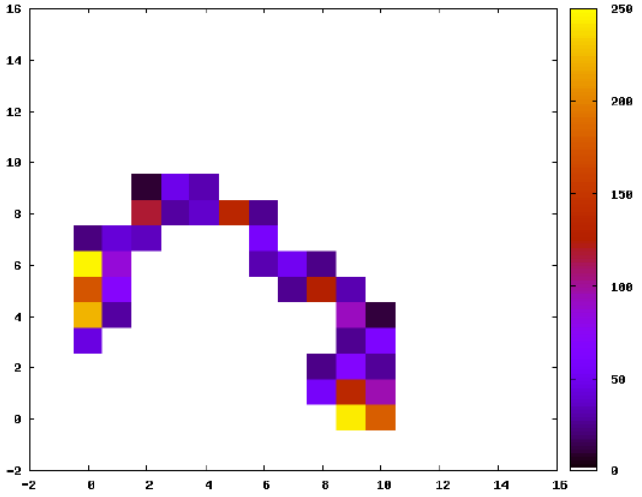
Experiment COBRA



- **Measurement of Neutrinoless Double Beta Decay**
- **Large array of CZT semiconductor detectors planned**
- **Out of 35 double beta isotopes, nine in CZT**
- **Operation in room temperature**
- **Source = Detector concept**
- **Main focus on ^{116}Cd, $Q(\beta^-\beta^-) = 2813.5 \pm 0.13$ KeV**
- **Signature of the process:- Peak at $Q_{(\beta^-\beta^-)}$ in double beta spectrum**
- **Location: LNGS, Italy**

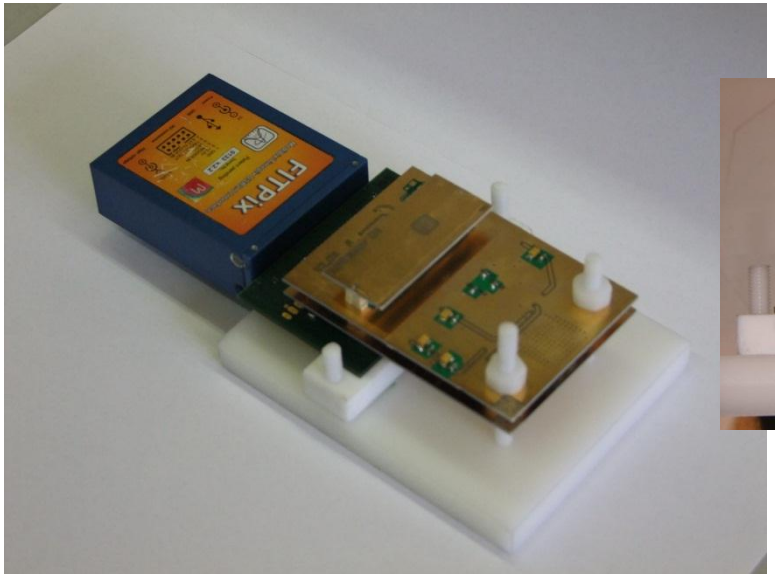
Isotope	nat. ab. (%)	Q (keV)	Decay Mode
^{70}Zn	0.62	1001	$\beta-\beta-$
^{114}Cd	28.7	534	$\beta-\beta-$
^{116}Cd	7.5	2813	$\beta-\beta-$
^{128}Te	31.7	868	$\beta-\beta-$
^{130}Te	33.8	2529	$\beta-\beta-$
^{64}Zn	48.6	1096	$\beta+$/EC
^{106}Cd	1.21	2771	$\beta+\beta+$
^{108}Cd	0.9	231	EC/EC
^{120}Te	0.1	1722	$\beta+$/EC

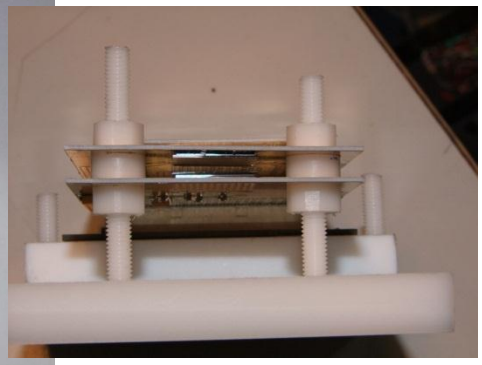
ββ isotopes in CZT



Simulated 0νββ electron track in 110 µm pitch pixel detector

Pixel Telescope





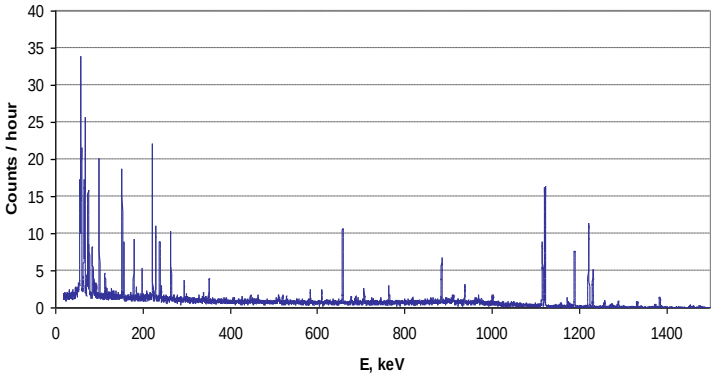
SPT setup on CuFlon PCB

Measurement setup with
5 cm lead shielding

- First Prototype of SPT in low intrinsic PCB (CuFlon) ready
- The prototype (two detectors face to face) taking underground measurements in LSM.
- CdTe Pixel Telescope expected to install in LNGS soon.

Intrinsic Background Measurements

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



Intrinsic background from SPD

Single Pixel Detector (SPD)

Contributions per unit (comparison of samples and Si module) [mBq/unit]:

	Bunb-Bonding (In+Sn)	Readout chip	Empty PCB	Si module
^{228}Th	< 10^{-8}	< 0.2	263 ± 8	187 ± 11
^{234}Th	< 10^{-6}	< 0.9	168 ± 11	123 ± 10
^{40}K	< 10^{-7}	< 6.2	< 25	117 ± 28

Intrinsic background for different PCB materials

Intrinsic background measurement results for different PCB materials. All numbers are in mBq/kg. FR4 is the general PCB substrate. The adhesive mentioned here is for the fabrication of flexible PCB, and coverlay is the solder mask used for flexible PCB. CuFlon is a 100% Teflon based PCB substrate.

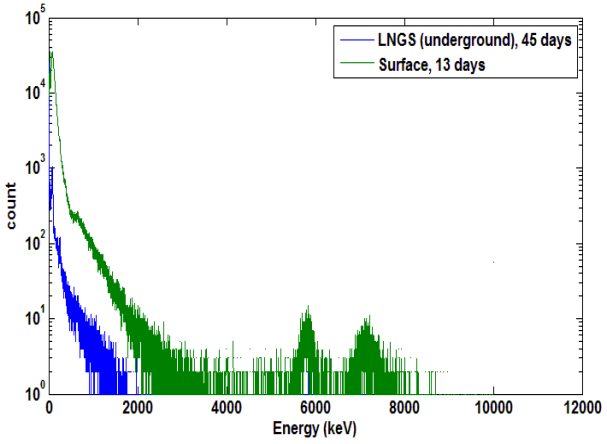
PCB material	^{226}Ra	^{210}Pb	^{228}Ra	^{228}Th	^{40}K
FR4	14259 ± 486	10692 ± 160	17658 ± 972	21303 ± 648	<2025
Cu foil	< 126	< 4500	< 293	<146	595 ± 315
Flexible PCB	207 ± 76	< 3200	< 215	170 ± 76	< 1760
Adhesive	< 556	< 16000	< 1400	< 1400	< 9000
Coverlay	< 1500	< 40000	< 3500	< 3500	< 28000
CuFlon	< 16	< 134	< 39	< 16	< 280

Background Measurements with CdTe detector (110 µm pitch, 1 mm thickness)

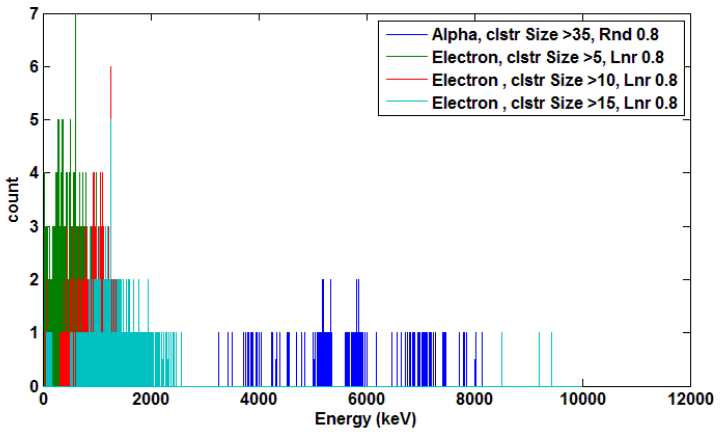
Surface (IEAP Prague) and Underground (LNGS Italy)

Results of background measurements, surface vs. LNGS. All numbers are normalized to one day of measurement, with 90% confidence level. Number of electrons in the region of interest (ROI) is negligible in underground data. The region of interest is taken in the range (2.5-3) MeV.

Data set	Alphas		Electrons	
	Total	ROI	Total	ROI
Underground (LNGS), with N_2 flushing	3.9 ± 0.5	< 0.05	20.0 ± 1.1	$0.02^{+0.08}_{-0.02}$
Underground (LNGS), without N_2 flushing	43.5 ± 3.3	< 0.22	22.1 ± 2.3	$0.09^{+0.31}_{-0.08}$
Surface (IEAP, Prague), without N_2 flushing	406.0 ± 9.2	$0.15^{+0.30}_{-0.12}$	2740.0 ± 23.9	37.00 ± 2.78



CdTe SPD background measurements



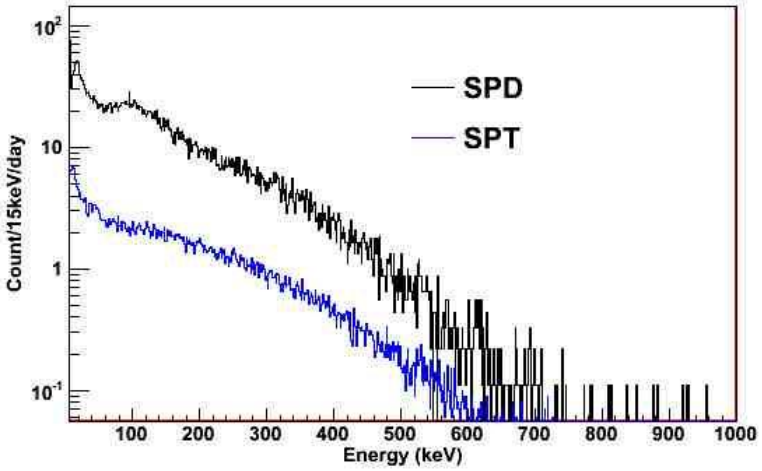
Spectra after cluster classifications

Background Measurements with Si detectors (55 µm pitch, 300 µm thickness)

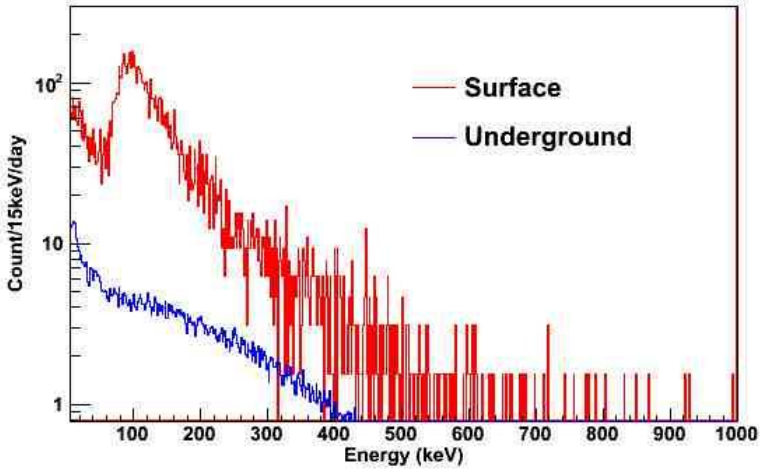
Surface (IEAP Prague) and Underground (LSM, Modane, France)

Statistics from background measurements. Events in the region of interest (19-23 keV) are given in brackets

Dataset	Cluster/h	SSE/h	DSE/h
SPT surface, shielded	428.3 (7.4)	1.10 (0.20)	8.8 (0.06)
SPD, underground, shielded (single det.)	152.9 (4.6)	2.2 (0.23)	NA
SPT, underground, shielded (two detectors)	45.8 (1.0)	0.19 (0.0036)	0.54 (0.0062)



Comparision of full spectra, SPT vs. SPD



SPT measurements, surface Vs Underground

Conclusions

- Pixel detectors seems to be a good option for ββ experiments.
- More studies are necessary
- Optimization of pixel pitch and sensor thickness
- Intrinsic background reduction.
- Possibility of large setup

THANK YOU

- References

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