Present and future activities in LSM
(2nd LSM Extension WORKSHOP, Oct.16, 2009)

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(1) **TGV experiment** – measurement of 2νEC/EC decay of ^{106}Cd

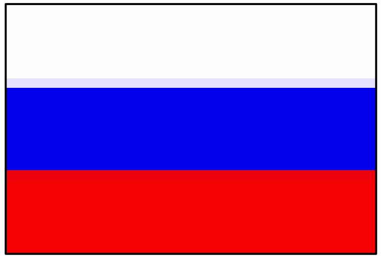
(2) **R&D of pixel detection technique** – in ββ decay

(3) **HPGe (600 cm^3)** – ultra low background measurements, special modes of ββ decay (excited, 0νEC/EC)

(4) **Single Events Effect studies** – comparative testing of electronic chips

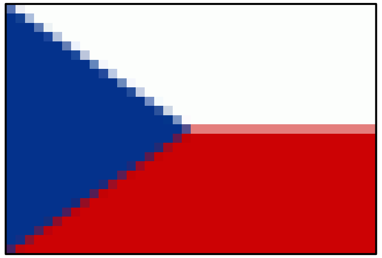
TGV Collaboration

JINR Dubna: V.B. Brudanin, V.G. Egorov, A.A. Klimenka, N.I. Rukhadze, V.G. Sandukovski, Yu.A. Shitov, V.V. Timkin, Ts. Vylov, D.R. Zinatulina

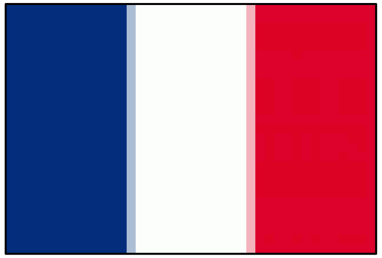


IEAP CTU: P. Čermák, F. Mamedov, I. Štekl

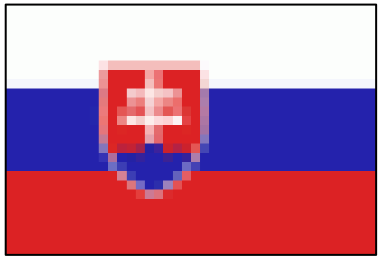
NPI CAS: A. Kovalík (on leave at JINR)



CSNSM, Orsay: Ch. Briançon

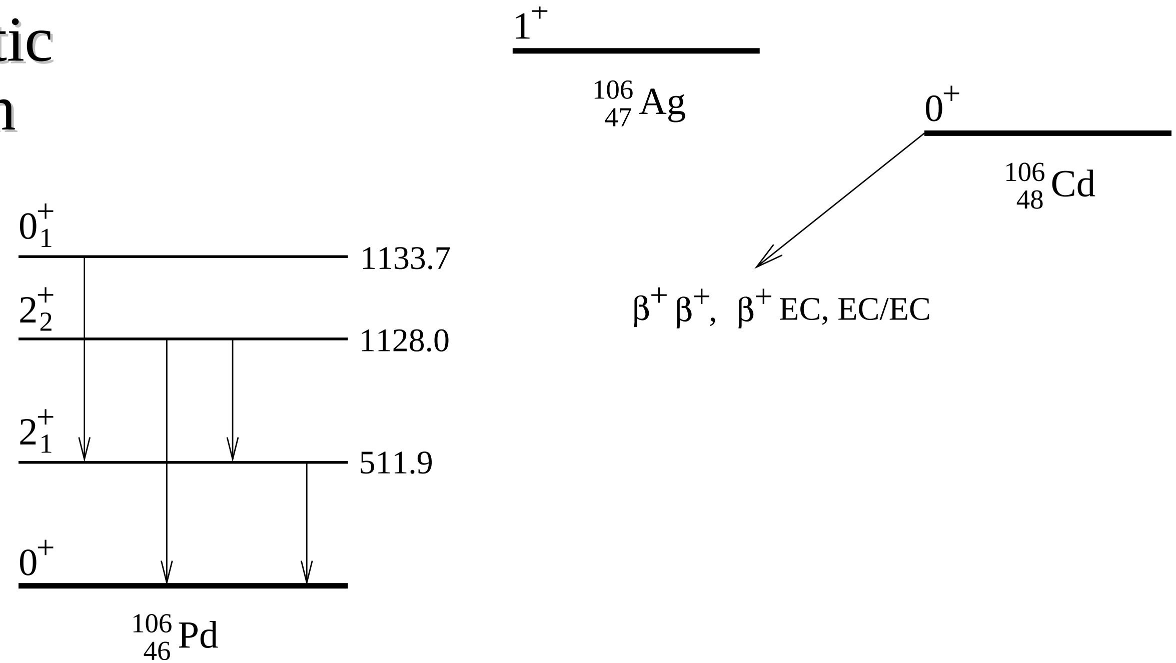


Comenius University: F. Šimkovic



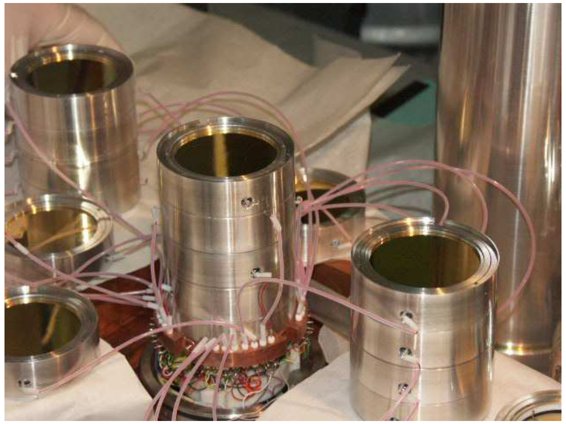
- TGV I (1994-2000): 2νββ ^{48}Ca, $T_{1/2} = 4.2 \times 10^{19}$ y
- TGV II (2000 – ...): to investigate ββ processes in ^{106}Cd (to focus on 2νEC/EC channel, g.s. → g.s.)

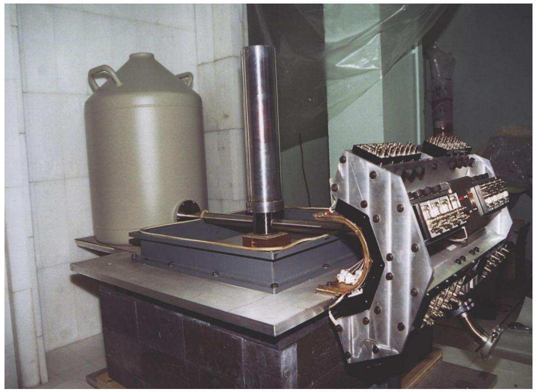
Observables = 2 characteristic X-rays from de-excitation of ^{106}Pd shell

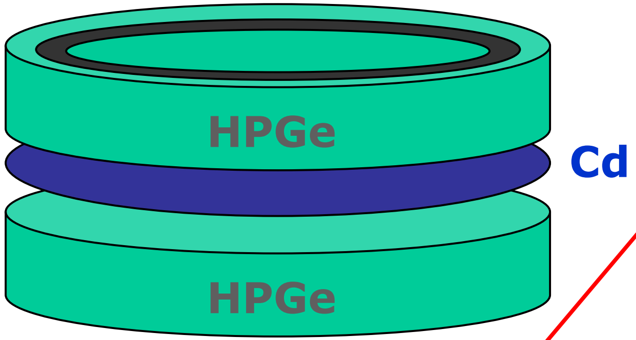


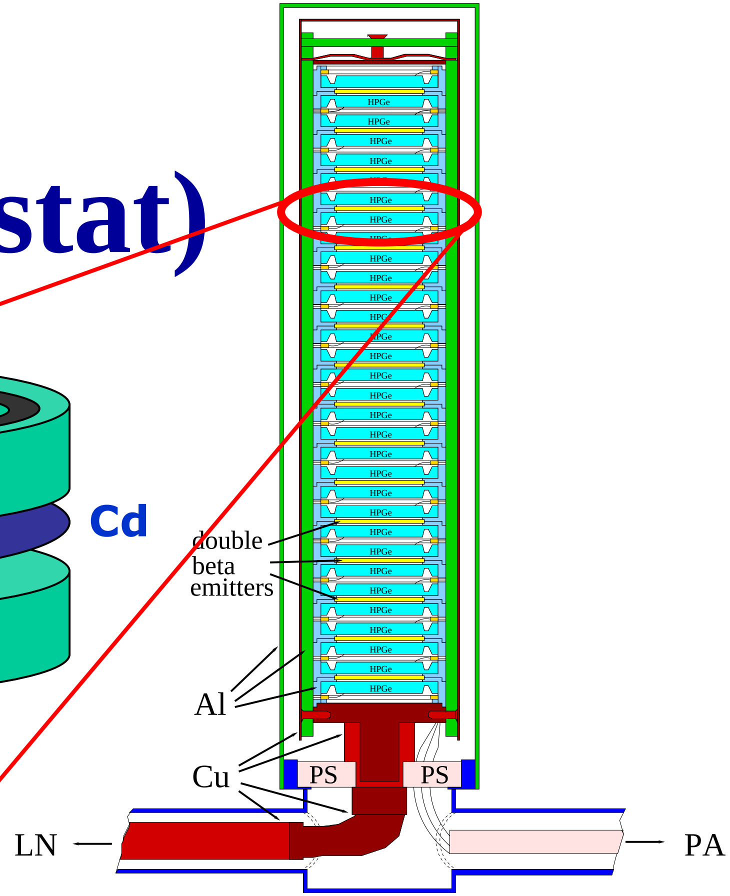
2νEC/EC: $$2e + {}^{106}_{48}Cd \rightarrow {}^{106}_{46}Pd + 2\nu_e + (\gamma, X-rays)$$

TGV II (cryostat)



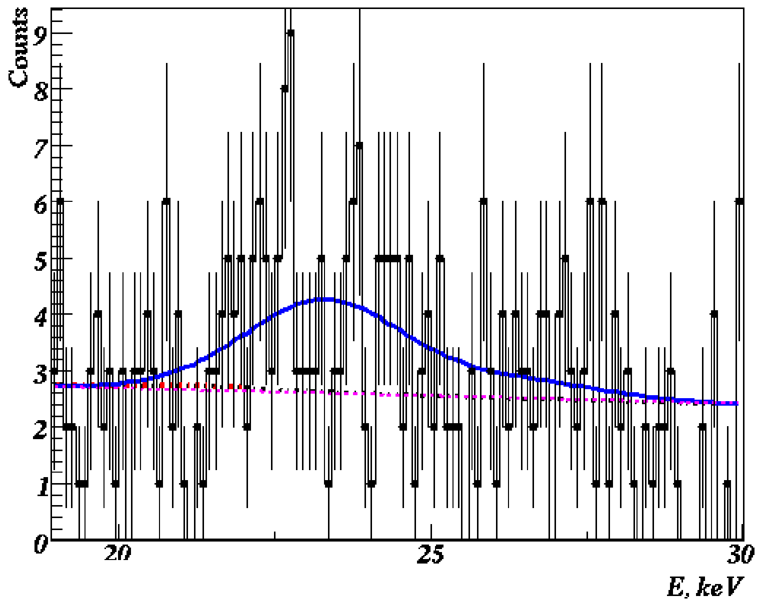


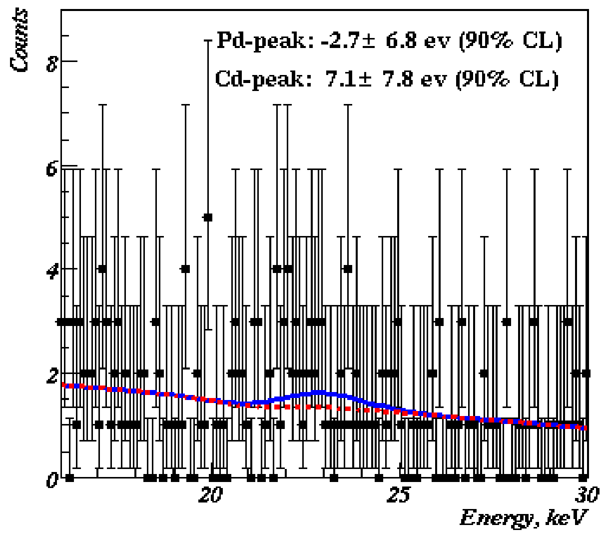




- 32 HPGe planar detectors ø60 mm x 6 mm (active area 2040mm^2)
- Total mass of samples: 10 - 25 g
- E-threshold: $\approx$ 10 keV
- Samples: 12x ^{106}Cd foils (~10g)

- Phase I (1 year): **$T_{1/2}(^{106}Cd\ 2\nu EC/EC\ (g.s.)) > 2.6 \times 10^{20}$ years**
- Phase II (1 year): **$T_{1/2}(^{106}Cd\ 2\nu EC/EC\ (g.s.)) > 3.6 \times 10^{20}$ years**





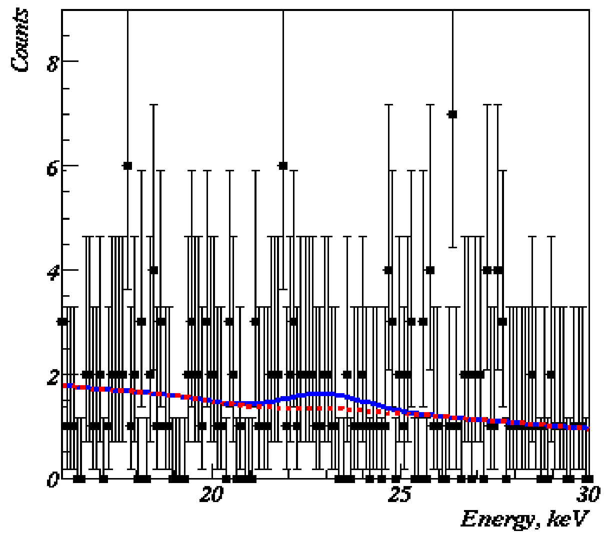


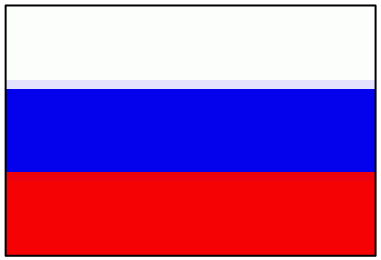
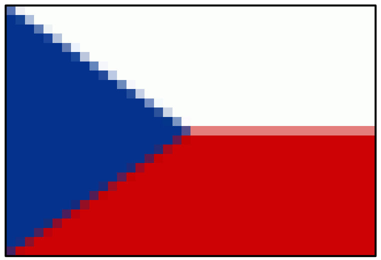
Table 2
A comparison of measured lower bound for the 2νEC/EC decay half-life (in years) of ^{106}Cd for ground state to ground state transition with calculated half-lives of different nuclear structure approaches. QRPA - quasiparticle random phase approximation, RQRPA - renormalized QRPA, SQRPA - selfconsistent QRPA, PHFB - projected Hartre-Fock-Bogoliubov model, SSDH - single state dominance hypothesis, WS - Woods Saxon single particle energies (s.p.e.), AWS - adjusted WS s.p.e., s.b. (l.b) - small (large) basis of single particle states.

Experiment		Phenomenology		Theory			
$T_{1/2}^{2\nu ECEC}$	Ref.	$T_{1/2}^{2\nu ECEC}$	Ref.	$T_{1/2}^{2\nu ECEC}$		Method	Ref.
				$g_A = 1.0$	$g_A = 1.25$		
$> 5.8\ 10^{17}$	(29)	$> 5.3\ 10^{21}$	(30)	$4.2\ 10^{21}$	$1.7\ 10^{21}$	SU(4)	(19)
$> 3.6\ 10^{20}$	p.w.	$> 4.4\ 10^{21}$	(11)	$2.5\ 10^{22}$	$9.7\ 10^{21}$	PHFB	(10)
				$2.2\ 10^{21}$	$8.7\ 10^{20}$	QRPA	(12)
				$1.5\ 10^{20}$	$6.1\ 10^{19}$	QRPA	(13)
				$2.3\ 10^{20}$	$9.0\ 10^{19}$	QRPA (WS)	(14)
				$2.6\ 10^{20}$	$1.1\ 10^{20}$	QRPA (AWS)	(14)
				$5.5\ 10^{21}$	$2.3\ 10^{21}$	QRPA (WS)	(16)
				$3.0\ 10^{20}$	$1.2\ 10^{20}$	QRPA (AWS)	(16)
				$5.3\ 10^{20}$	$2.1\ 10^{20}$	RQRPA (WS)	(17)
				$5.1\ 10^{20}$	$2.0\ 10^{20}$	RQRPA (AWS)	(17)
				$5.0\ 10^{20}$	$2.0\ 10^{20}$	SQRPA (s.b.)	(18)
				$6.6\ 10^{20}$	$2.6\ 10^{20}$	SQRPA (l.b.)	(18)

Pixel detectors in double beta decay

COBRA, TGV collaborations

MEDIPIX collaboration

Approaches to double beta studies

GERDA	SuperNEMO	CUORE	COBRA	TGV II
Detector = source	Tracking + scintillator	Low-temp. detector	Semiconductor + segmentation	Setup based on semiconductor detectors

Pixel R&D projects

COBRA extension

- Segmented CdTe pixel detectors (enriched Cd)
- Signature = two tracks of electrons from one pixel, Bragg curve
- Particle identification / rejection (alpha, electrons, photons)

TGV III (EC/EC)

- Si pixel detectors in coincidence mode
- Thin foil of enriched isotope
- Signature = two hitted pixels with X-rays of precise energy
- Efficiency (factor 2x comparing with TGV II)
- Particle identification (alpha, electrons)

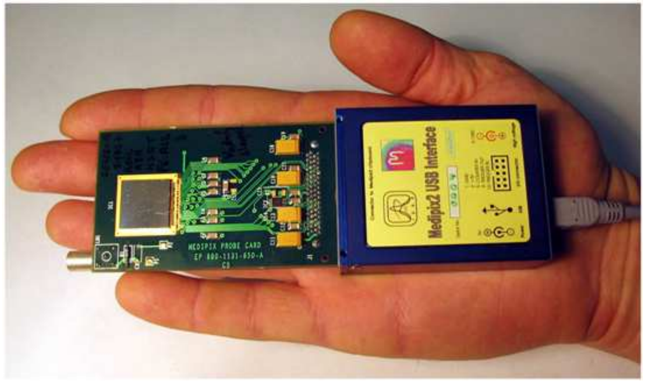
Intensive R&D studies:

1) Coincidence mode
2) Dimension of detector and pixel (charge sharing, quality of track)
3) Optimal readout chip – energy and time of registered particle in every pixel
4) Design of detector, selection of materials – low background.

Timepix detector (Medipix collaboration)

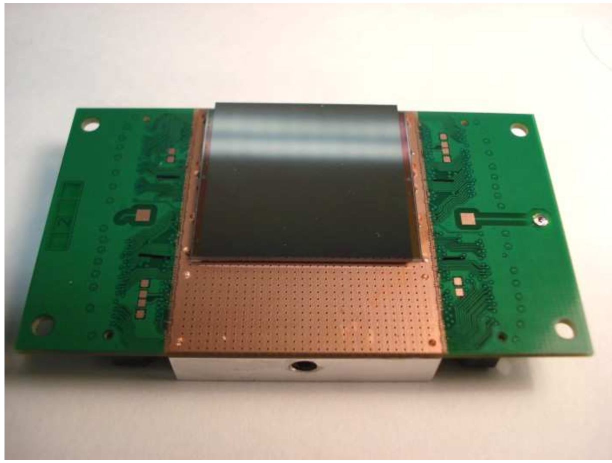
- CdTe (COBRA) and Si (TGV) timepix detectors
- Prague Medipix group => experience, access to the technology

- **thickness 300μm and 1mm**
- **256x256 pixels matrix**
- **55μm, 110μm pitch**
- **1.4 × 1.4 cm² (single, quad, hexa)**
- **handy setup (USB interface + laptop)**



Chipboard + USB readout interface

- To get acquainted with the technology
- To test of spectroscopic capabilities, calibration
- To compare materials for the sensor production (Si vs. CdTe)
- To evaluate the potential of such device for ββ measurements (intrinsic background) – in LSM

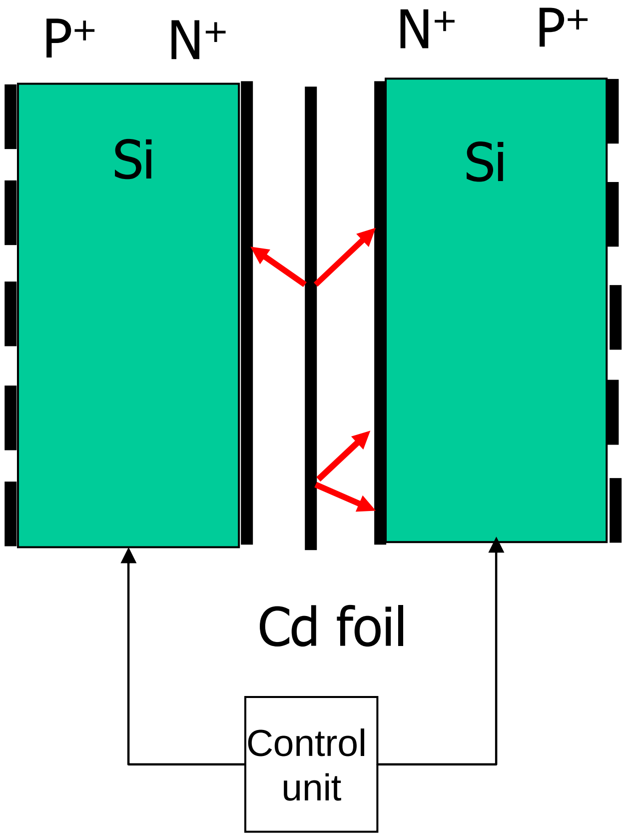


HEXA chipboard with 4 sensor bonded

Pixel detectors in double beta decay (EC/EC decay)

- to investigate EC/EC processes in ^{106}Cd (to focus on g.s. to g.s. channel) using Timepix detectors in coincidence mode
- observables:

  2 characteristic X-rays from de-excitation of ^{106}Pd shell



Advantages:

- better efficiency comparing with TGV II (factor 2)
- information about energy + position of registrated X-ray
- track recognition (background vs. signal)
- much less material needed (lower background)
- measurement under room temperature (easy access)

Summary of MC simulations for TGV research:

(efficiency for TGV II detector = 5.5%)

For 40 μm Cd foil, 1 mm Si Timepix, 256x256 pixels – efficiency = 9%

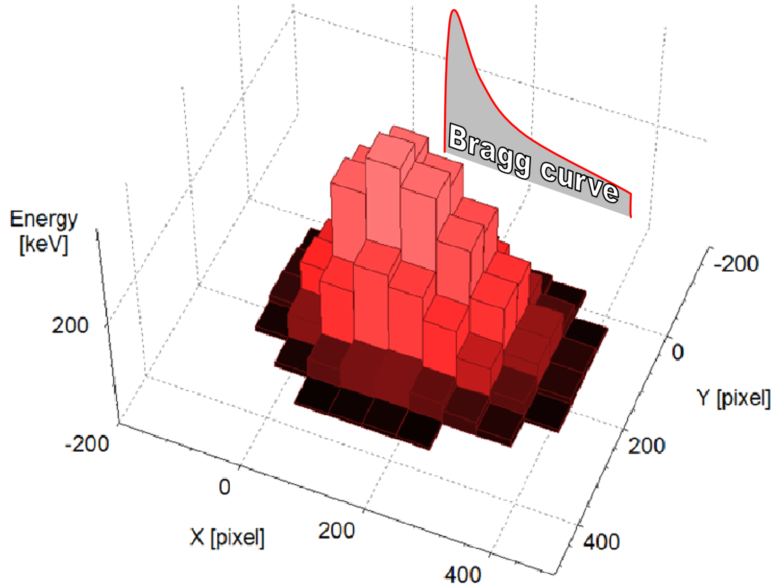
a) Change dimension of pixel (from 256x256 to 64x64) – efficiency = 9.6%

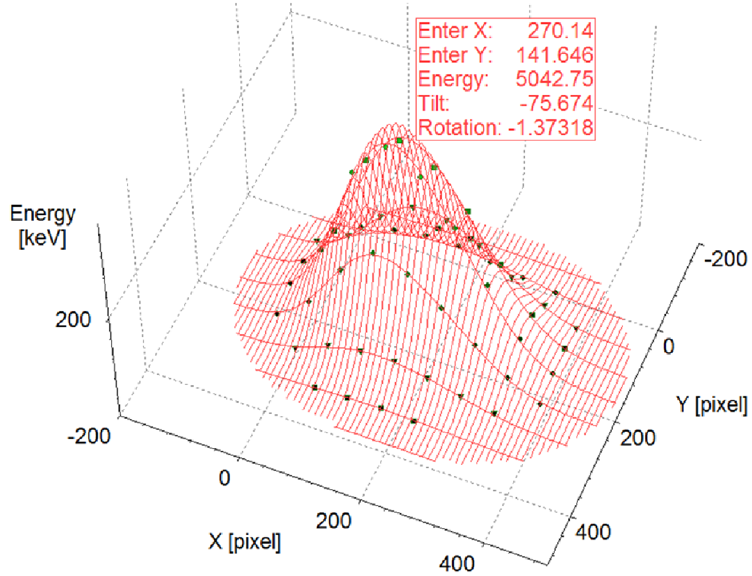
b) Changing thickness of TimePix Si detector

   from 1 mm to 2 mm – efficiency = 11.2% (factor 2)
   from 1 mm to 5 mm – efficiency = 16.2% (factor 2.9)

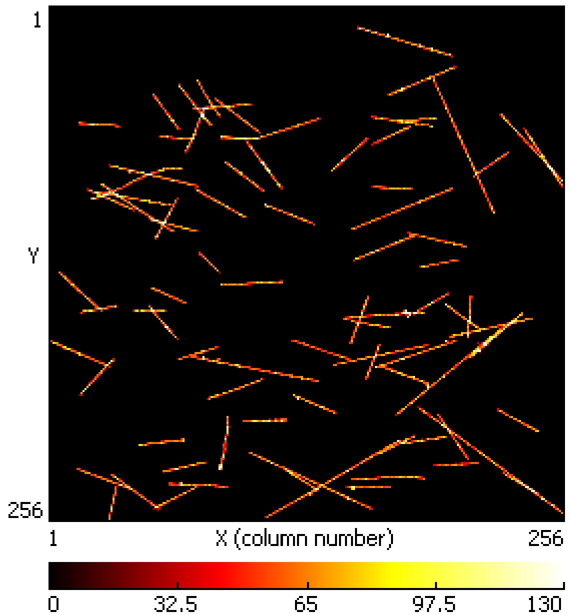
Protons in Si

Brag curve

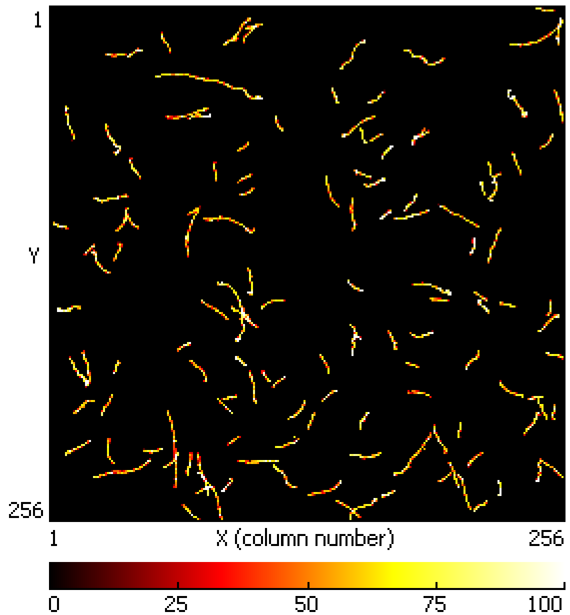




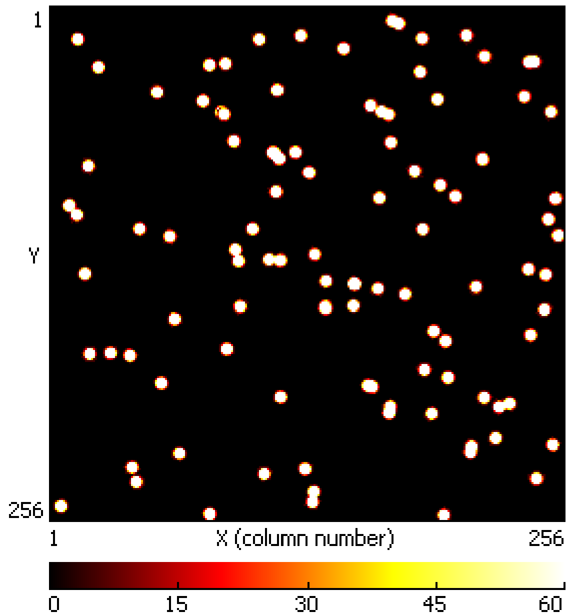
muons



electrons



alphas



Future plans:

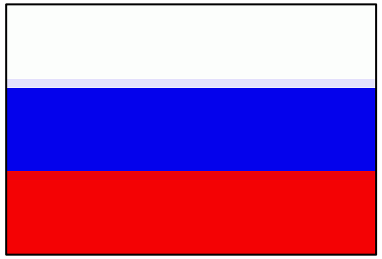
1) TGV II – measurement in LSM up to 2010

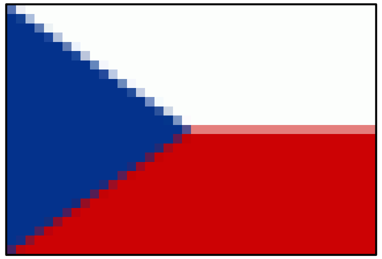
2) Pixel detector R&D in ββ decay – Si and CdTe timepix detectors, selection of low background materials; development of coincidence mode; back-side pulse; first prototype – testing and background measurements; schedule: 2 years (2010, 2011).

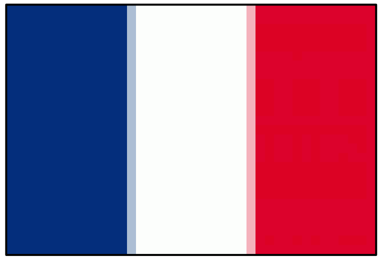
3) TGV III – measurement of EC/EC decay by Si pixel detectors;
   schedule: 4 years (2012-2015)
   needed infrastructure: antiradon facility, Pb shielding.

HPGe detector (600 cm^3)

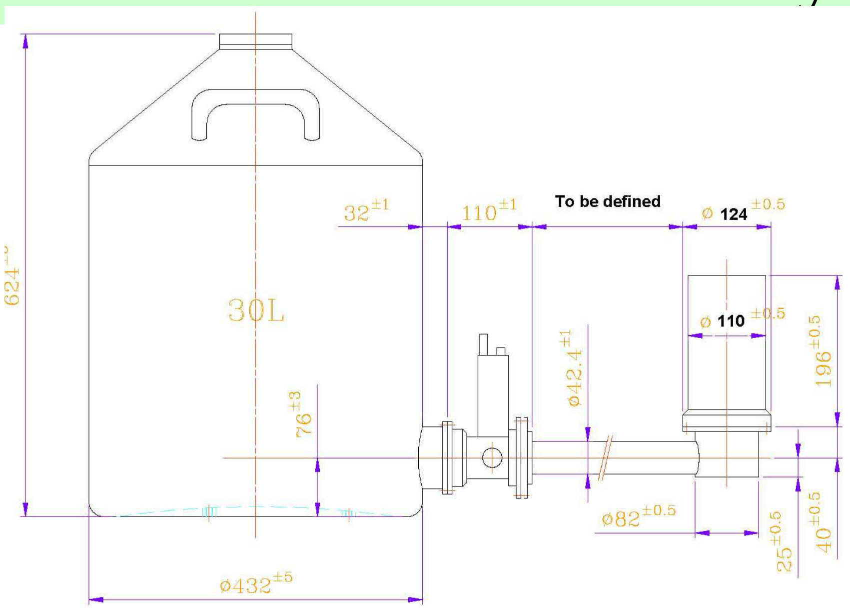
JINR Dubna, IEAP CTU, LSM







- ultra low background measurements (SuperNEMO - material selection);
- Measurement of ββ decay (excited states, 0νEC/EC);
- produced by Canberra;
- installation in LSM – July 2010.



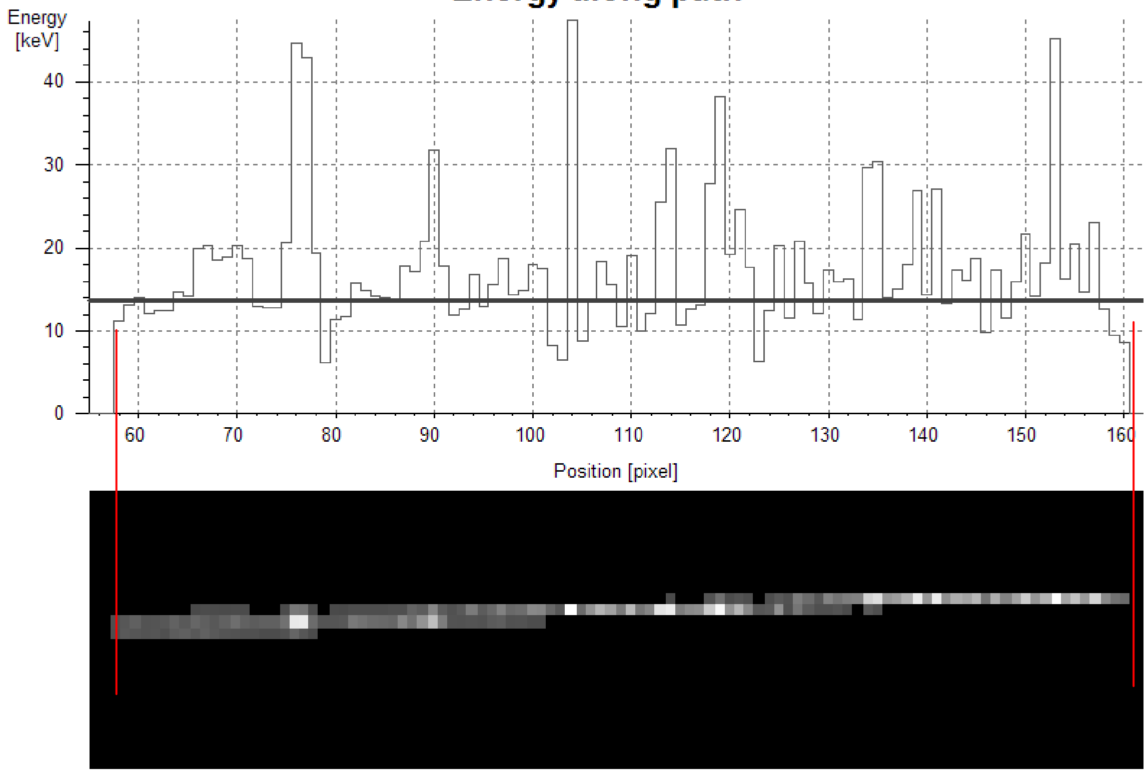
- long-term running in LSM
- antiradon facility, Pb shield

Single event effects comparative studies

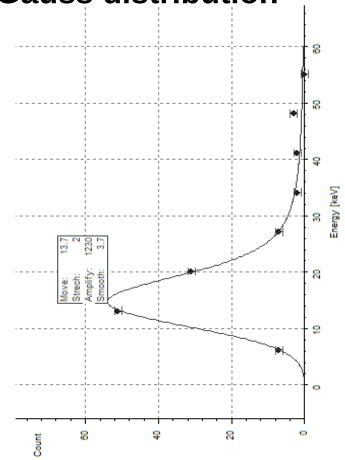
IEAP CTU, Medipix collaboration

- Influence of protons to functionality of electronic circuits (FPGA, memory);
- High altitude, ground earth lab, underground laboratory;
- Pixel detector + tested circuit;
- Flight direction of proton => region influenced by proton;
- Installation in LSM – 2010-2011, long-term measurement.

Tracks of MIP particles – cosmic muons

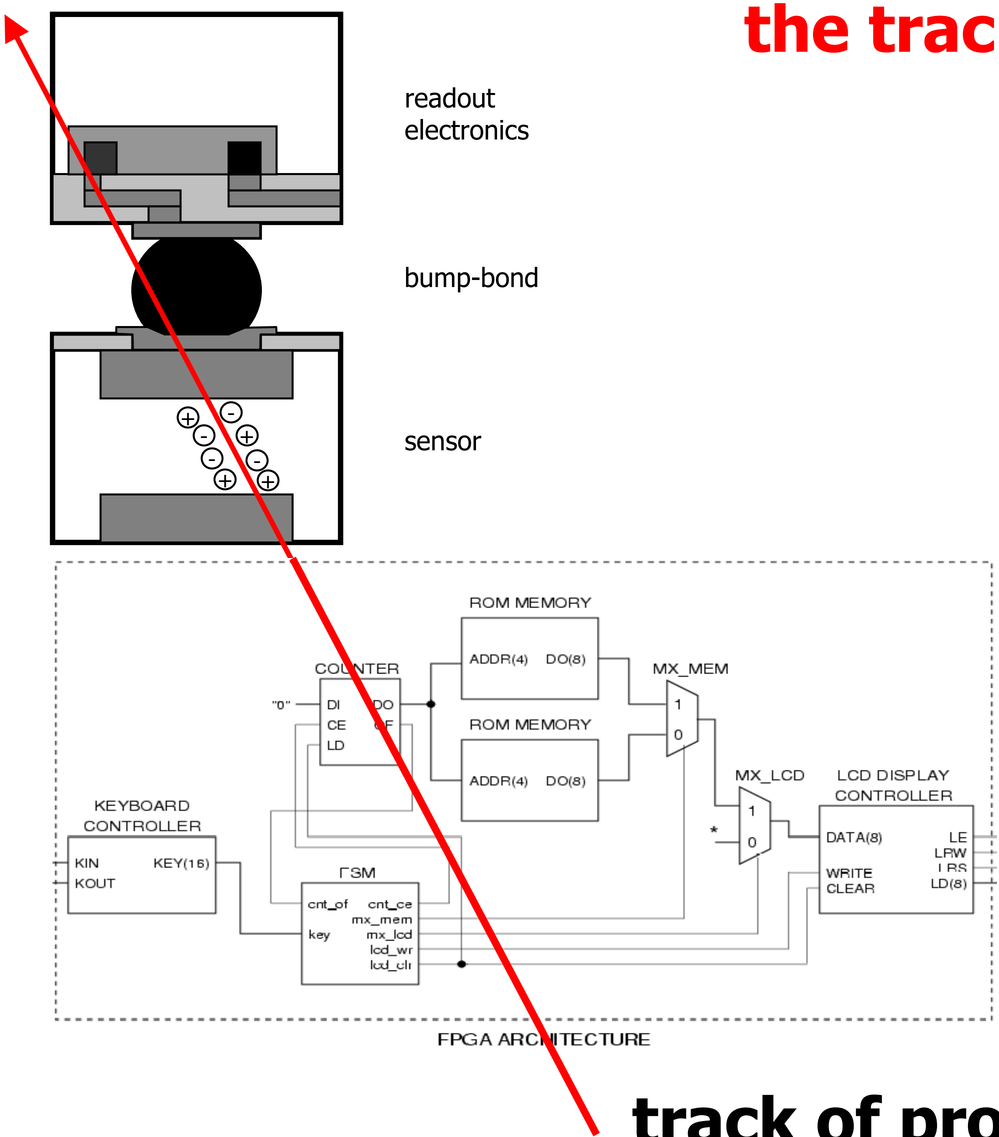


Energy distribution fit by convolution of Landau and Gauss distribution



3D-visuallization of muon track in silicon detector recorded by TimePix device.
X- and Y-coordinates are determined with a precision of about 100 nm.

Spatial resolution of the track < 500 nm



electronic circuit

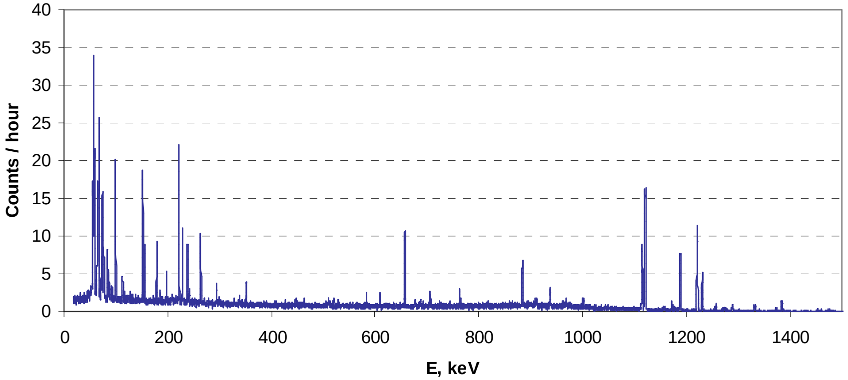
track of proton

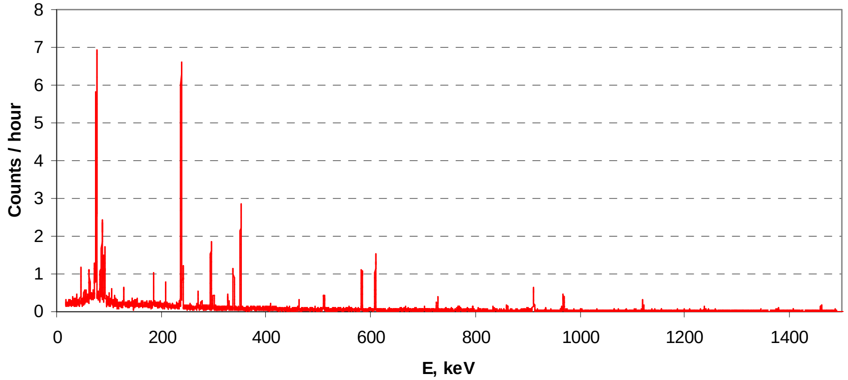
Thank you very much for your attention

Background slides

Intrinsic background in Timepix

- Measured by low-background setup in Modane lab
- HPGe planar detector “Mafalda” , 150cm^3, range 20keV – 1.5MeV





Chipboard with Si detector

8396.2 ev. / hour

Th-228: (165 ± 10) mBq
K-40: (117 ± 28) mBq

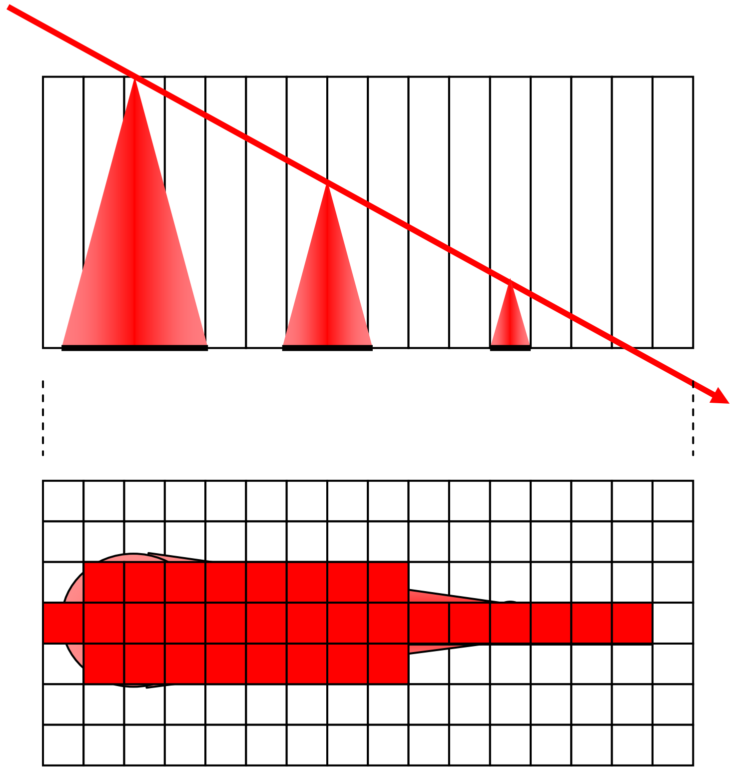
Co-60: (60 ± 21) mBq
Ta-182: (2065 ± 82) mBq
Ag-110m: (483 ± 15) mBq

Chipboard with CdTe detector

803.7 ev. / hour

Th-228: (156 ± 10) mBq
K-40: (122 ± 14) mBq

Tracks of MIP particles



- Ionization by MIP particles doesn't depend on depth and follows Landau distribution
- Charge sharing effect is more significant if charge is generated near the surface

⇒Charge sharing brings more information in tracking mode. By analyzing such a muon track one can determine X- and Y-coordinates with a precision on submicron level.