Recent results on the searches for double beta decay processes with scintillators and pure samples

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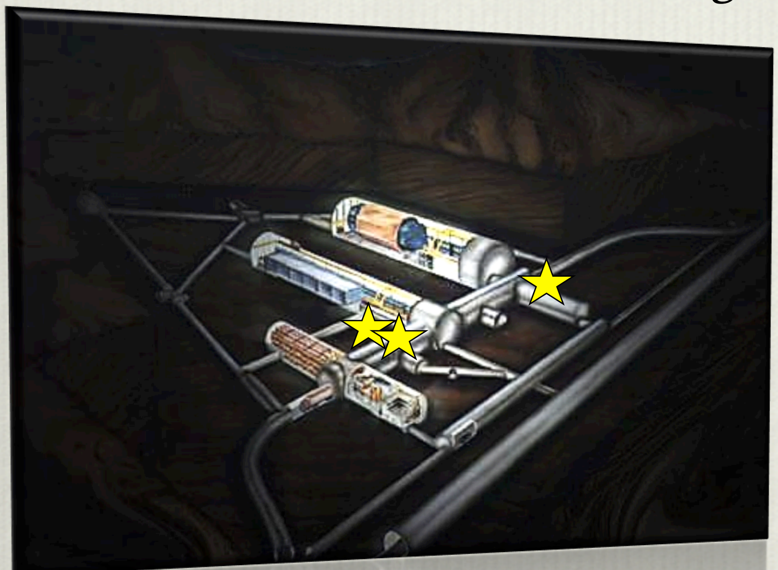
Lomonosov Conf.
Moscow (Ru), August 21-28, 2013

DAMA project

The DAMA project was proposed to develop and to exploit low background scintillator in order to investigate rare processes



- ❖ DAMA/LIBRA (DAMA/NaI)
- ❖ DAMA/LXe
- ❖ DAMA/R&D
- ❖ DAMA/Crys
- ❖ DAMA/Ge and Ge facility (STELLA)

Collaboration:

Roma Tor Vergata, Roma La Sapienza, LNGS, IHEP/Beijing

+ by-products and small scale expts.: INR-Kiev

+ in LNGS: Chemistry Lab and Ge facility (STELLA)

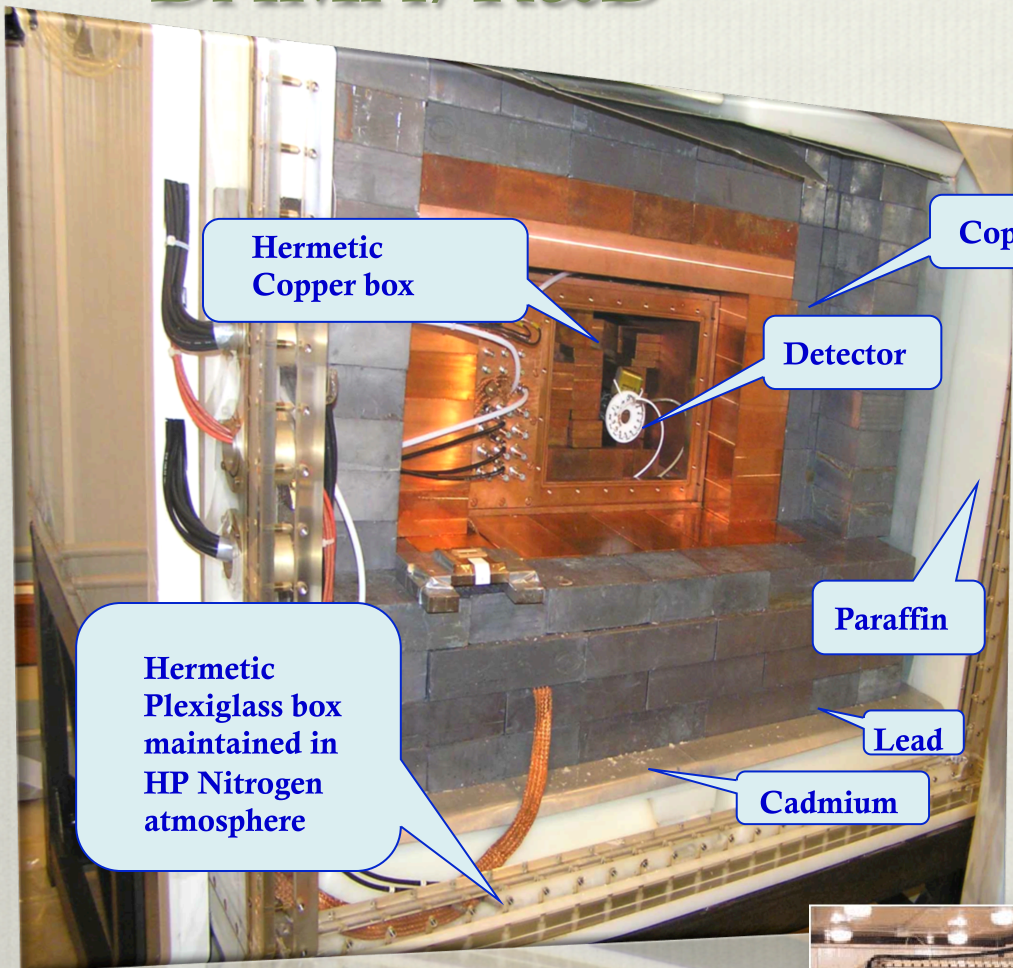
+ some activities: JINR-Dubna Russia, ITEP-Moscow Russia, Nikolaev Institute of Inorganic Chemistry - Novosibirsk Russia, Institute of Physics and Technology- Kharkiv Russia, University of Jyvaskyla Finland, IIT-Ropar India

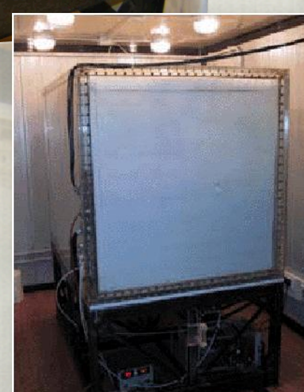
+ neutron meas.: ENEA-Frascati

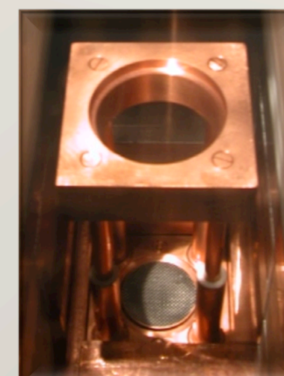
Web Site: http://people.roma2.infn.it/dama

DAMA/R&D

DAMA/Ge and STELLA







Materiale	^{238}U (ppb)	^{232}Th (ppb)	^{nat}K (ppm)
Cu	< 0.5	< 1	< 0.6
Pb boliden	< 8	< 0.03	< 0.06
Pb boliden2	< 3.6	< 0.027	< 0.06
Polish Pb	< 7.4	< 0.042	< 0.03
Polietilene	< 0.3	< 0.7	< 2
Plexiglass	< 0.64	< 27.2	< 3.3

Physics in DAMA/R&D and LNGS Ge facility

- Dark Matter with CaF2(Eu)
- Solar Axions
- **2β decay in various isotopes**
- First observations of rare α decays (^{190}Pt, ^{151}Eu)
- highly forbidden β decay
- Cluster decay
- CNC decay

- $2\beta^- 2\nu$ observed for several nuclides
- in the field experiments mainly on $2\beta^-$ ($T_{1/2}$ ~10^{23}-10^{25} yr)
- $2\beta^+$ decay:
  - 34 candidates for 2ε,
  - 22 also for $\varepsilon\beta^+$, 6 also for $2\beta^+$
- $2\beta^+ 2\nu$ not observed yet (indication ^{130}Ba in geoch. exp.)($T_{1/2}$ ~10^{18}-10^{21} y)

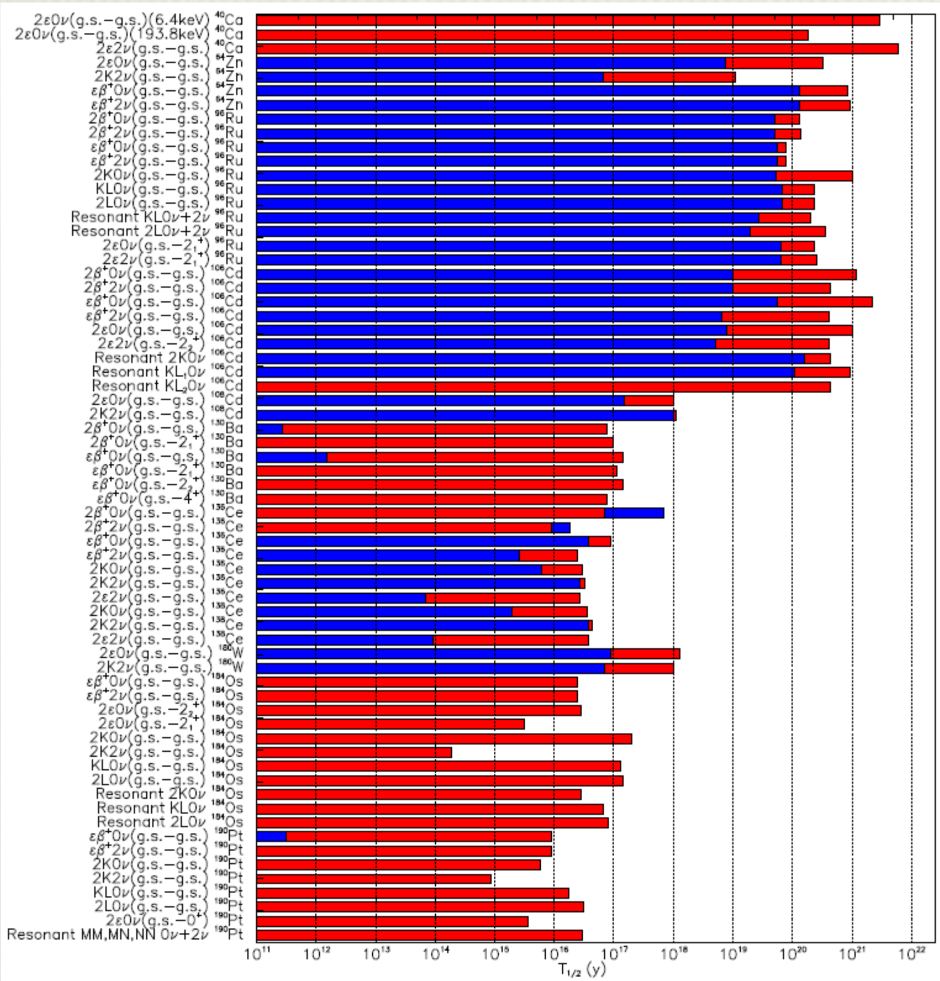
2ε and $\varepsilon\beta^+$ important: observation of 0ν mode could help to distinguish between the mechanisms of neutrinoless 2β decay (non-zero neutrino mass or right-handed admixtures in weak interactions)

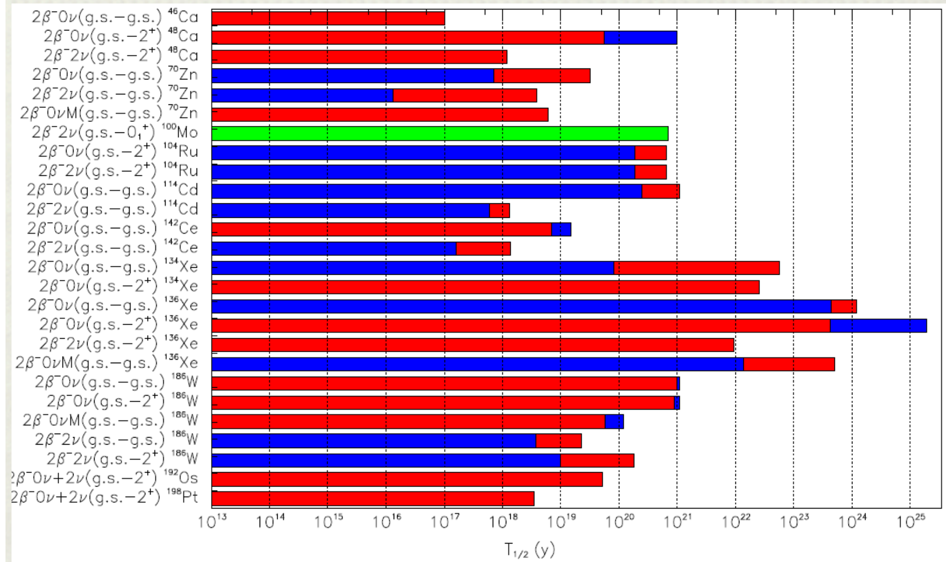
DAMA focus on search for $2\beta^+$ decay

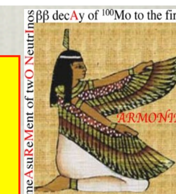
AP7(1997)73, N.Cim.A110(1997)189, NPB563(1999)97, AP10(1999)115, NPA705(2002)29, NIMA498(2003)352, NIMA525(2004)535, NIMA555(2005)270, UJP51(2006)1037, NPA789(2007)15, PRC76(2007)064603, PLB658(2008)193, EPJA36(2008)167, NPA824(2009)101, NPA826(2009)256, JPG:NPP38 (2011)115107, JPG: NPP38(2011)015103, PRC85(2012)044610, JINST6(2011)P08011, PRC85(2012)044610

NIMA572(2007)734, NPA806(2008)388, EPJA42(2009)171, NPA824(2009)101, NIMA607(2009) 573, NIMA846(2010)143, NIMA615(2010)301, NPA846 (2010)143, EPJA47(2011)91, NPA859(2011)126, PRC83(2011)034603, NIMA626-7(2011)31, PLB711(2012)41, NIMA670(2012)10, NIMA704(2013)40, EPJC73(2013)2276, EPJA49(2013)24, PRC87(2013) 034607

Summary of searches for ββ decay modes (partial list)







ARMONIA: New observation (green) of $2\nu2\beta^-$ $^{100}Mo \rightarrow ^{100}Ru$ (g.s.$\rightarrow 0_1^+$) decay

NPA846 (2010)143

AURORA: New observation of $2\nu2\beta^-$ ^{116}Cd decay

NPAE2012

$T_{1/2}$ experimental limits by DAMA (in red) and previous ones (in blue). All the limits are at 90% C.L. except for $0\nu2\beta^+$ in ^{136}Ce and $2\beta^-0\nu$ in ^{142}Ce at 68% C.L.. In green observed!

- Many competitive limits obtained on lifetime of $2\beta^+$, $\varepsilon\beta^+$ and 2ε processes (^{40}Ca, ^{64}Zn, ^{96}Ru, ^{106}Cd, ^{108}Cd, ^{130}Ba, ^{136}Ce, ^{138}Ce, ^{180}W, ^{190}Pt, …)
- First searches for resonant 2β decays in some isotopes

Many publications on detectors developments and results
Many future measurements in preparation

Summary of the results presented in this talk

- ✓ Search for 2β decay of ^{96}Ru and ^{104}Ru

DAMA/Ge and STELLA

- ✓ Status and perspectives of $ZnWO_4$ crystal scintillators on the search for 2β in Zn and W
- ✓ Status and perspectives of $^{106}CdWO_4$ crystal scintillators on the search for 2β in ^{106}Cd
- ✓ Status and perspectives of $^{116}CdWO_4$ crystal scintillators on the search for 2β in ^{116}Cd

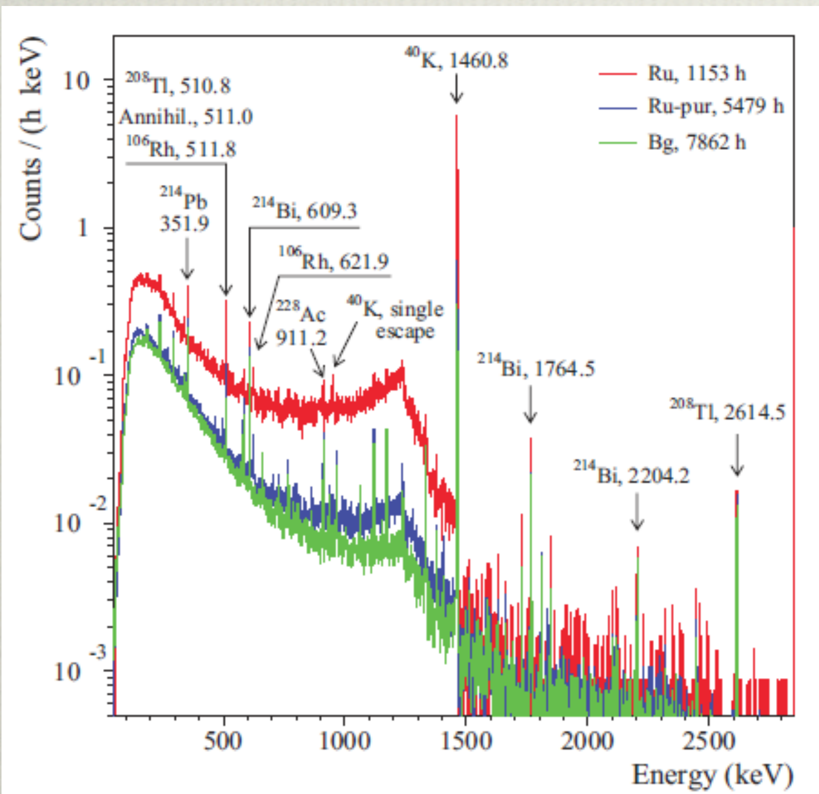
DAMA/RD and STELLA

Search for 2β decays of ^{96}Ru and ^{104}Ru by ultra-low background HP Ge γ spectrometry

EPJA42(2009)171
PRC87(2013) 034607

- ^{96}Ru potentially $2\beta^+$ active nuclei, $\delta \sim 5.54\%$, $Q_{2\beta}$=2718 keV
- Resonant "0ν2ε-capture" possible (energy-release = energy of exited level daughter's nuclei), that can arise possibility of decay (up to 10^6)
- Favourable theorethical $T_{1/2}$:
  2ν2ε - (4.7-39)×10^{20} yr, 2νεβ+ − (2.0−23)×10^{21} yr (g.s.→g.s.),
  J. Suhonen, PRC 86 (2012) 024301

Possible processes:
$2\beta^+$ – g.s.
$\varepsilon\beta^+$– g.s., 778 keV
2ε – up to 2713 keV



Stage 1

- Preliminary results EPJA, $2\beta^+/\varepsilon\beta^+/2\varepsilon$ (0ν+2ν) in ^{96}Ru
- Further measurements over 2162 h with a 473 g sample
- Preliminary limits on 2β in ^{96}Ru: $T_{1/2} \approx 10^{18-19}$ y

Stage 2

- Purification from ^{40}K with electron beam melting method (10 times decrease of ^{40}K)
- Increased mass of Ru sample (**720 g**)
- T=5479 h in **Ge-Mult set-up** (4 x 225 cm^3)
- Sensitivity:

$T_{1/2} \approx 10^{20-21}$ y for ^{96}Ru
$T_{1/2} \approx 10^{20}$ y for ^{104}Ru ($2\beta^-$)

Previous limits improved

$T^{2k0\nu}_{1/2} > 1.0 \times 10^{21}$ yr (90%C.L.) in ^{96}Ru

$T^{resKL0\nu}_{1/2} > 2.0 \times 10^{20}$ yr (90%C.L.) in ^{96}Ru

New measurement with purified sample with higher mass

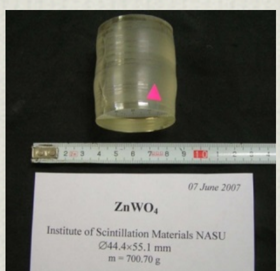
$ZnWO_4$ crystal scintillators

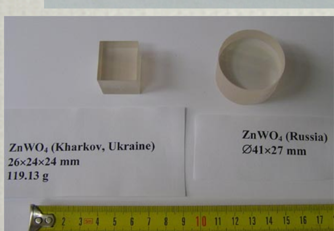
- Development of low background $ZnWO_4$ crystal scintillators with large volume and high scintillation properties is important to investigate double beta decay modes in Zn and W isotopes with source=detector approach

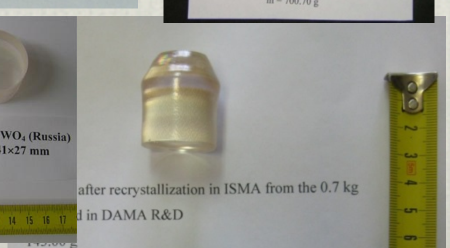
Transition	Energy release ($Q_{\beta\beta}$) (keV) [26]	Isotopic abundance (%) [27]	Decay channels	Number of mother nuclei in 100 g of $ZnWO_4$ crystal
$^{64}Zn \rightarrow {}^{64}Ni$	1095.7(0.7)	49.17(75)	2ε, $\varepsilon\beta^+$	9.45×10^{22}
$^{70}Zn \rightarrow {}^{70}Ge$	998.5(2.2)	0.61(10)	$2\beta^-$	1.17×10^{21}
$^{180}W \rightarrow {}^{180}Hf$	144(4)	0.12(1)	2ε	2.31×10^{20}
$^{186}W \rightarrow {}^{186}Os$	489.9(1.4)	28.43(19)	$2\beta^-$	5.47×10^{22}

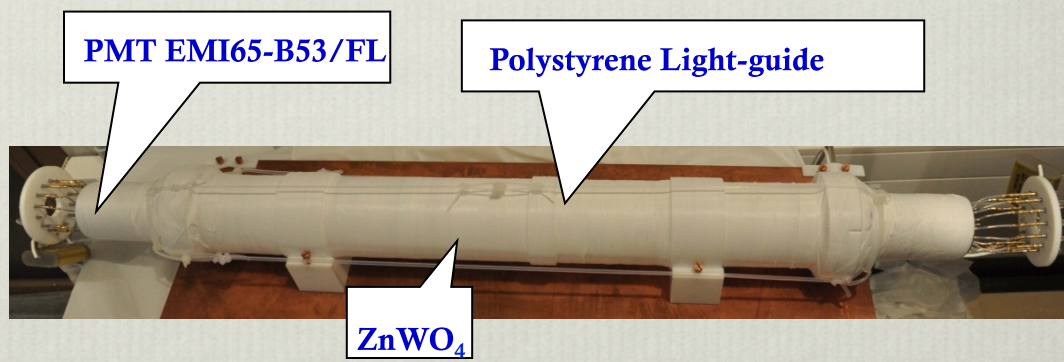
PLB658(2008)193
NPA826(2009)256
NIMA626-627(2011)31
JP38(2011)115107

- Various detectors with mass **0.1-0.7 kg** realized by exploiting different materials and techniques
- Crystal inside a cavity (filled up with high-pure silicon oil) ϕ 47 x 59 mm in central part of a polystyrene light-guide 66 mm in diameter and 312 mm in length.





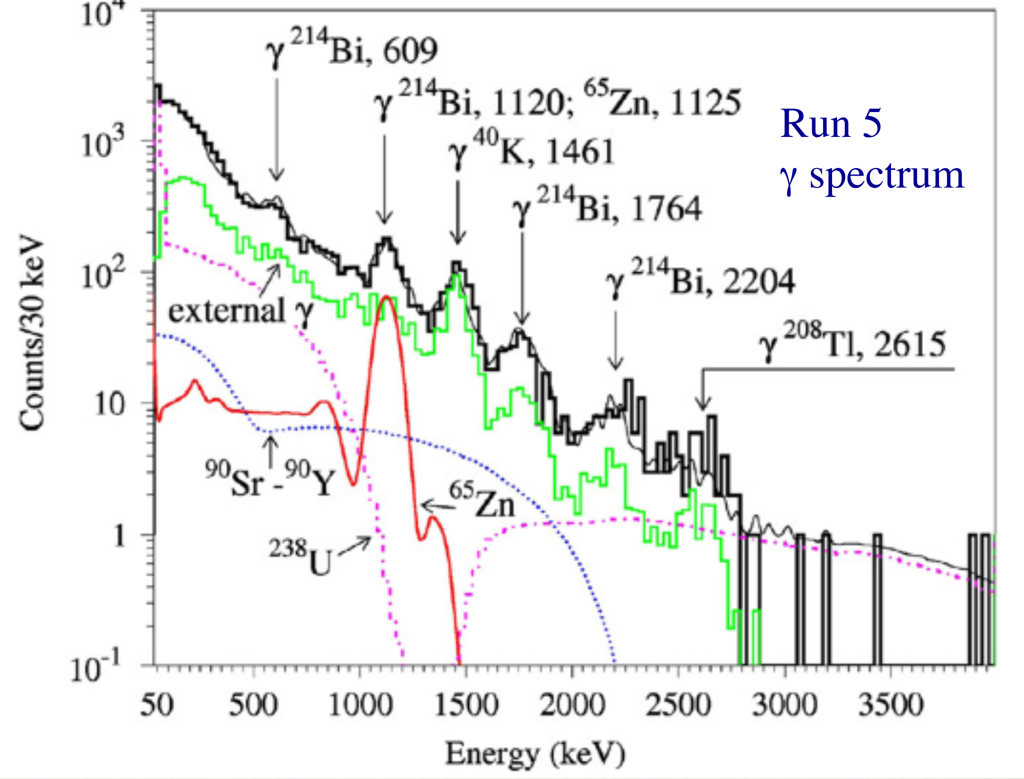




Summary of the measurements with $ZnWO_4$ crystal scintillators

Run	Crystal	Mass (g)	T (h)
1	ZWO-1 (ISMA)	117	2906
2	ZWO-2 (ISMA)	699	2130
3	ZWO-3 (ISMA)	141	994
4	ZWO-4 (NIIC)	239	834
5			4305

NIMA 626(2011)31



Run	Crystal	Background (cpd/kg/keV) 0.2-0.4 MeV	0.8-1.0 MeV	2.0-2.9 MeV
1	ZWO-1 (ISMA)	1.71(2)	0.25(1)	0.0072(7)
2	ZWO-2 (ISMA)	1.07(1)	0.149(3)	0.0072(4)
3	ZWO-3 (ISMA)	1.54(4)	0.208(13)	0.0049(10)
4	ZWO-4 (NIIC)	2.38(4)	0.464(17)	0.0112(12)
5		1.06(1)	0.418(7)	0.0049(4)

α at level of 0.2 -2 mBq/kg

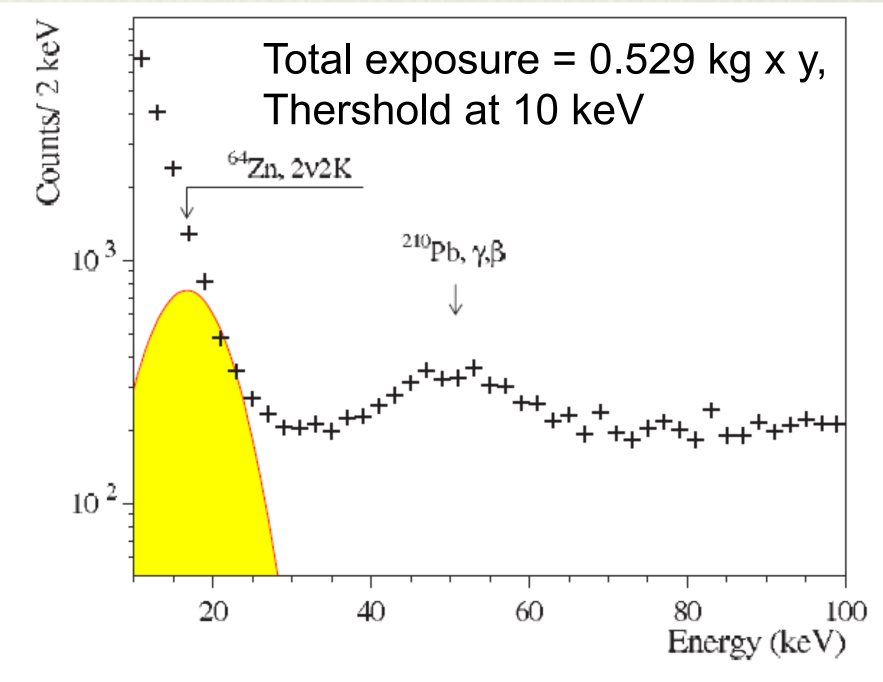
$\beta\beta$ decay modes in Zn and W isotopes with (0.1 – 0.7 kg) low background $ZnWO_4$

J. Phys. G: Nucl. Part. Phys. 38 (2011) 115107

Improved (up to 2 orders of magnitude) limits on the $\beta\beta$ decay modes of ^{64}Zn, ^{70}Zn, ^{180}W and ^{186}W:

$$T_{1/2} \sim \mathbf{10^{18} - 10^{21}\ yr}$$

up to now only 5 nuclides (^{40}Ca, ^{78}Kr, ^{112}Sn, ^{120}Te and ^{106}Cd) over 34 candidates to 2ε, $\varepsilon\beta^+$, $2\beta^+$ processes have been studied at this level of sensitivity in direct search experiments



1) A possible positive hint of the (2ν+0ν)ECβ$^+$ decay in ^{64}Zn with $T_{1/2}$ = (1.1 ± 0.9) × 10^{19} yr [I. Bikit et al., Appl. Radiat. Isot. 46(1995)455] excluded

2) the 0ν2EC capture in ^{180}W is of particular interest due to the possibility of the resonant process;

3) the rare α decay of the ^{180}W with $T_{1/2} = (1.3^{+0.6}_{-0.5}) \times 10^{18}$ yr observed and new limit on the $T_{1/2}$ of the α transition of the ^{183}W to the metastable level $1/2^-$ at 375 keV of ^{179}Hf has been set:

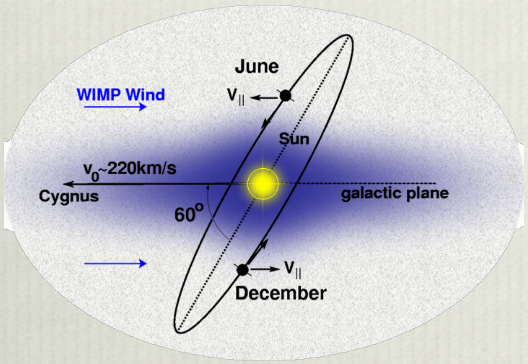
$$T_{1/2} = 6.7 \times 10^{20}\ \text{yr.}$$

Further developments, new detectors … towards suitable mass fragmented set-up

The ADAMO project: Study of the directionality approach with $ZnWO4$ anisotropic detectors

Eur. Phys. J. C 73 (2013) 2276

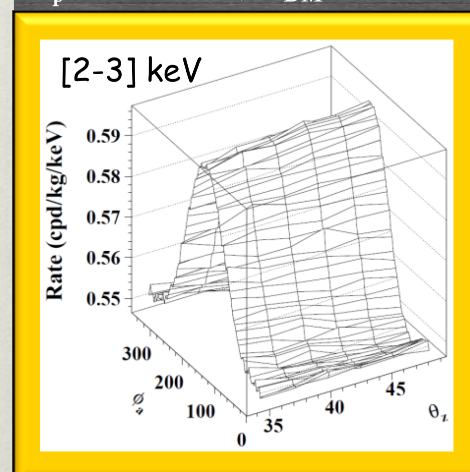
Directionality: study of the correlation between the Earth motion in the galactic rest frame and the arrival direction of those Dark Matter (DM) candidates inducing just nuclear recoils



- Nuclear recoils would be strongly correlated with the DM impinging direction
- This effect can be pointed out through the study of the variation in the response of **anisotropic scintillation detectors** during sidereal day

- **light output** and **pulse shape** of **$ZnWO_4$** depend on the direction of the impinging particles with respect to the crystal axes
- These **anisotropic features** provide two independent ways to exploit directionality, overcoming the difficulties of TPC detectors due to the very short track of recoils

$\sigma_p = 5\times10^{-5}$ pb, m_{DM}= 50 GeV



Example (for a given model framework) of the expected counting rate as a function of the detector velocity direction

Complementary information to those by DAMA/LIBRA for some aspects

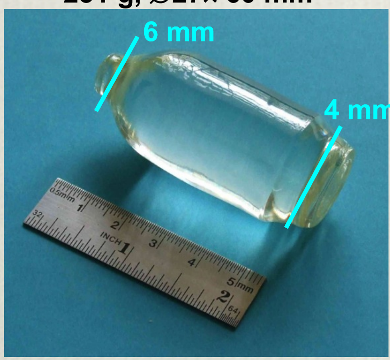
Development of enriched $^{106}CdWO_4$ to search for 2β decay of ^{106}Cd in DAMA/R&D

NIMA651(2010)301
PRC85(2012)044610

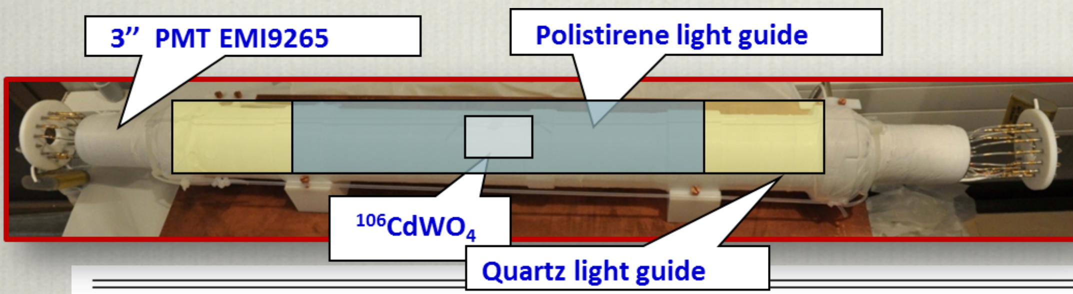
- **66% enriched ^{106}CdWO4** crystal scintillator (215 g), **2.66×10^{23}** nuclei of ^{106}Cd developed
- **2nd** enriched $CdWO_4$ crystal **ever produced**

265 g of initial powder

231 g, ∅27× 60 mm



216 g, ∅27× 50 mm



^{106}Cd promising for $2\beta^+$:

1) δ =(1.25 ± 0.06)%; possibile enrichment up to 100%;
2) $Q_{2\beta}$= (2770±7) keV; $2\beta^+$, $\varepsilon\beta^+$ and 2ε decay modes possible with favourable theoretical mean lives (resonant processes possible)

	$^{106}CdWO_4$ [1]	$^{116}CdWO_4$ [2]
Attenuation length @ 480 nm	(60 ± 7) cm *	(31 ± 5) cm
FWHM (CWO on PMT) @ 662 keV of ^{137}Cs @ 2615 keV of ^{208}Tl	 10.0% 8.4% **	 10.1% 6.7% (5.6% **)
Enrichment (Isotopic abundance in ^{nat}Cd)	66.4% of ^{106}Cd (1.25%)	82.2% of ^{116}Cd (7.49%)

* – Never reported for $CdWO_4$
** – FWHM that was reached in 2β experiment

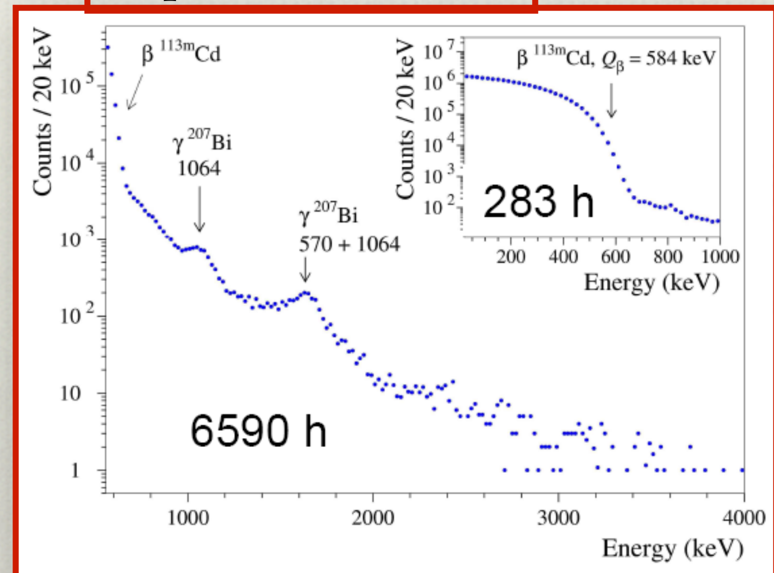
[1] NIMA615(2010)301 [2] JInst6(2011)P08011

Data taking periods

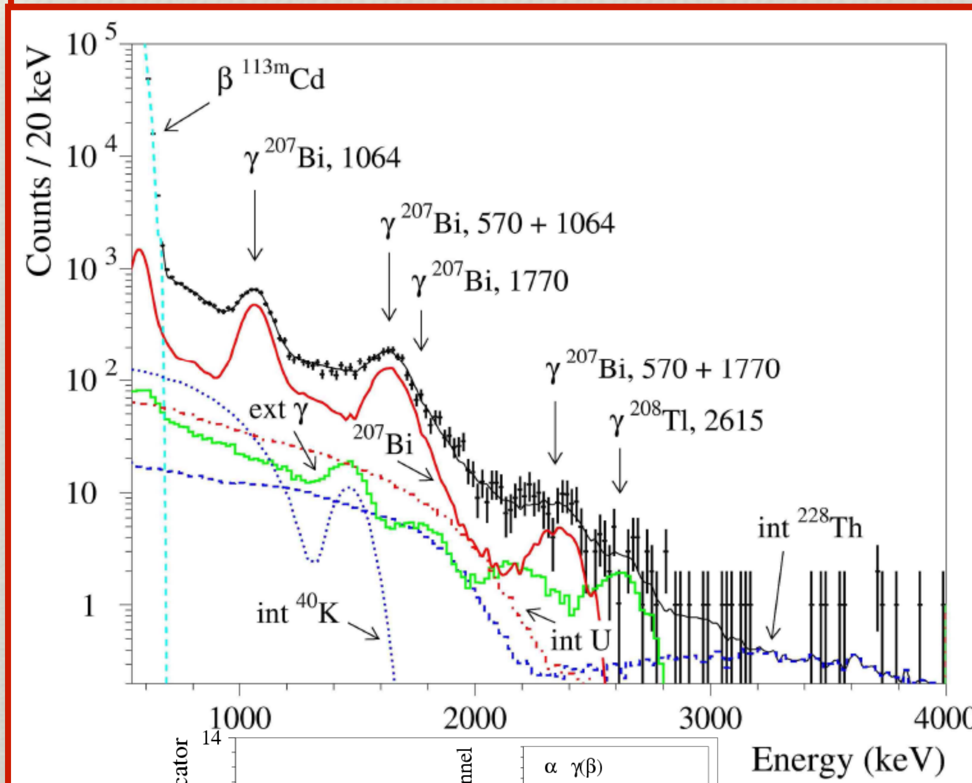
Run No.	t(h)	ΔE(MeV)	BG [counts/(yr × keV × kg)] in energy interval		
			0.8–1.0 MeV	2.0–2.9 MeV	3.0–4.0 MeV
1	283	0.05–4.0	474(18)	2.6(6)	0.4(3)
2	2864	0.40–1.8	453(11)	–	–
3	6307	0.57–4.0	412(4)	2.3(1)	0.33(4)

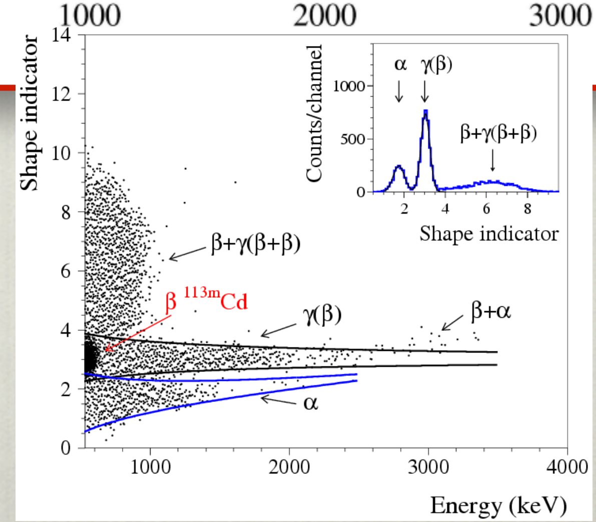
Search for 2 β decay in ^{106}Cd

Experimental data



Distribution of the γ/β events selected by PSD





Contamination level in $^{106}CdWO_4$ (mBq/Kg)

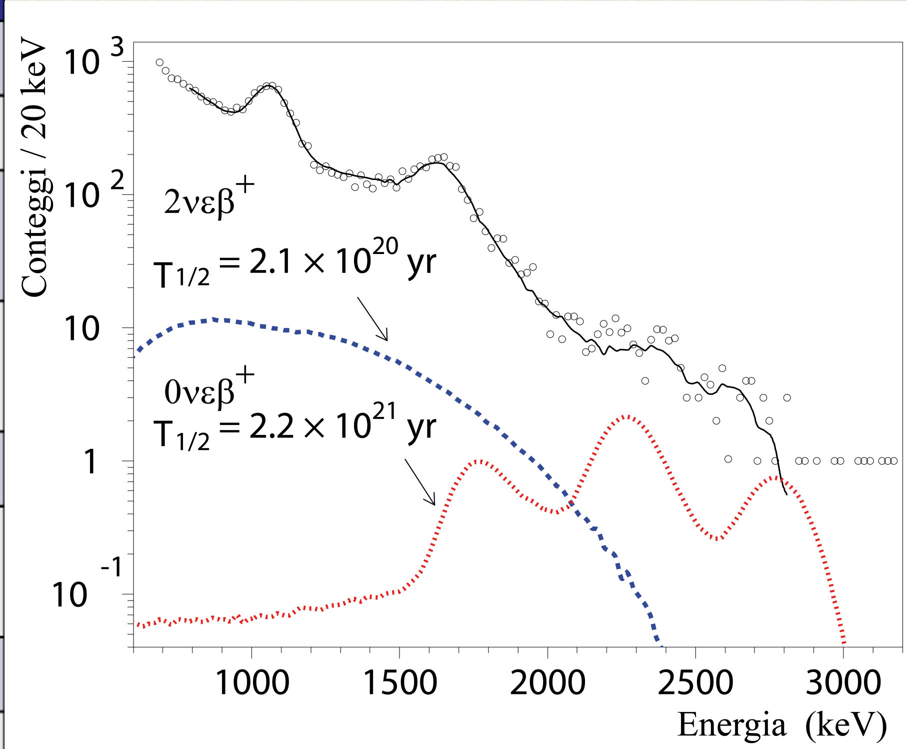
^{207}Bi	<0.7
^{113m}Cd	$116 \cdot 10^3$
^{232}Th	< 0.07
^{228}Th	0.042(4)
^{238}U	<0.6
^{226}Ra	0.012(3)
^{40}K	<1.4

Limits on $T_{1/2}$ of some 2β decay modes in ^{106}Cd

Phys. Rev. C 85 (2012) 044610

Decay channel	Decay mode	Energy level of ^{106}Pd [keV]	$T_{1/2}$ [yr] (90% CL)
2ε	2ν	1128 (2^+)	$>4.1 \cdot 10^{20}$
	0ν	g.s.	$>1.0 \cdot 10^{21}$
		512 (2^+)	$>5.1 \cdot 10^{20}$
		1128 (2^+)	$>3.1 \cdot 10^{20}$
$\varepsilon\beta^+$	2ν	g.s.	$>2.1 \cdot 10^{20}$
		512 (2^+)	$>1.1 \cdot 10^{20}$
	0ν	g.s.	$>2.2 \cdot 10^{21}$
		512 (2^+)	$>1.3 \cdot 10^{21}$
$2\beta^+$	2ν	g.s.	$>4.3 \cdot 10^{20}$
	0ν	g.s	$>1.2 \cdot 10^{21}$

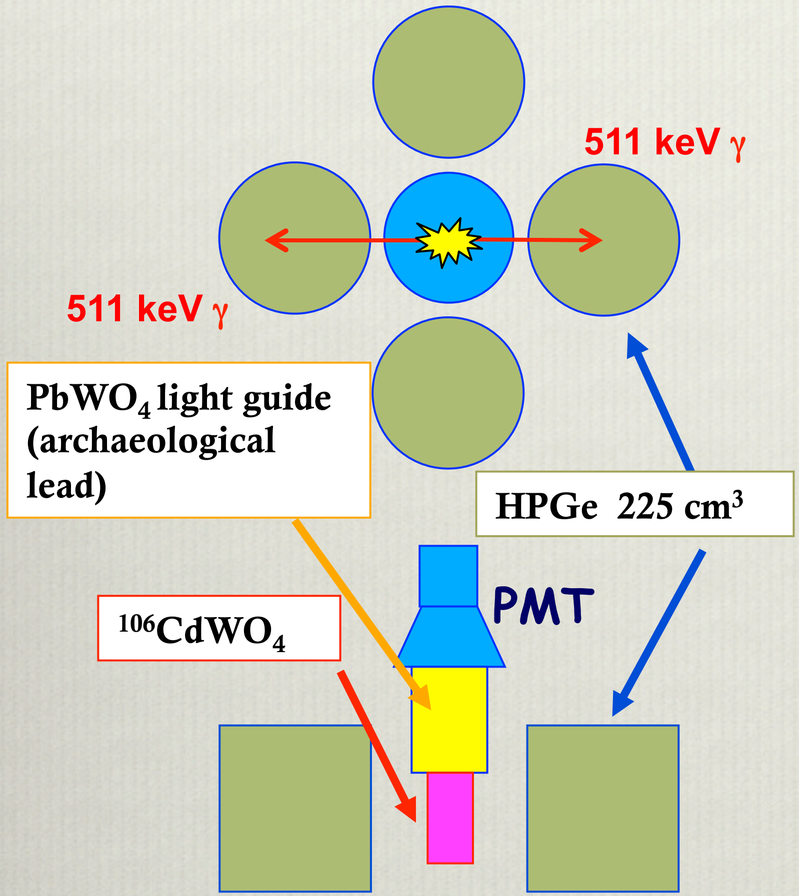
Example of fit to determine the limit on $T_{1/2}$



$T_{1/2}$ (2β, $^{106}Cd \rightarrow {}^{106}Pd$) ≥ 10^{19-21} yr

27 new results for 2β ^{106}Cd, 9 of them for the first time

New measurement with $^{106}CdWO_4$ in GeMulti



- $^{106}CdWO_4$ in coincidence / anticoincidence with 4-crystals HPGe detector (GeMulti)
- Registration efficiency ~ (3–8)%
- Expected background ~ few counts/yr

Sensitivity to $2\nu\varepsilon\beta^+$ and $2\beta^+$ in ^{106}Cd:

$T_{1/2} \sim 10^{20}$ - 10^{21} yr

Theory: **$2\nu2K$: 10^{20} - 5×10^{21} yr,**
$2\nu\varepsilon\beta^+$: 8×10^{20} - 4×10^{22} yr

In data taking since December 2012

Further step: production of $^{106}CdWO_4$ from the ^{106}Cd depleted in ^{113}Cd to remove ^{113m}Cd

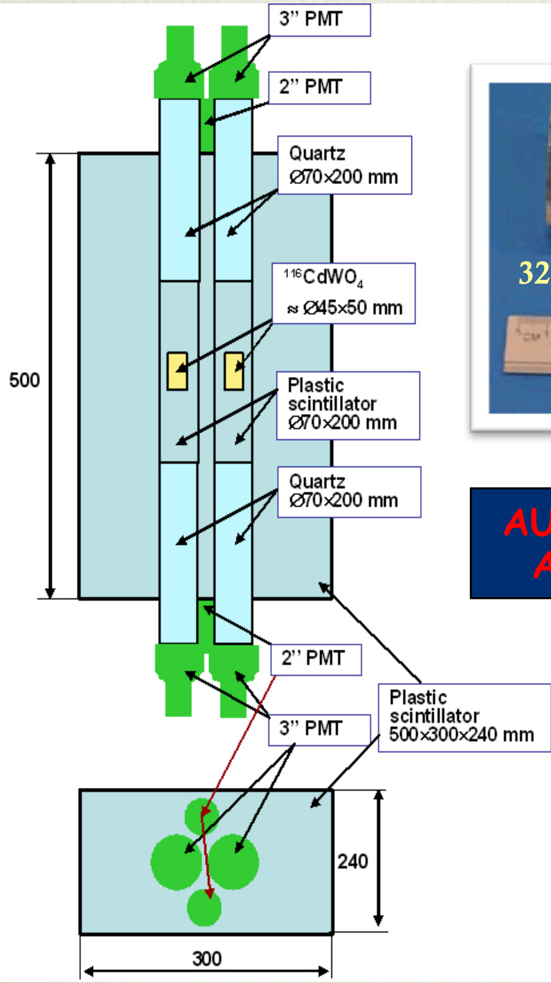
Future and general perspectives:

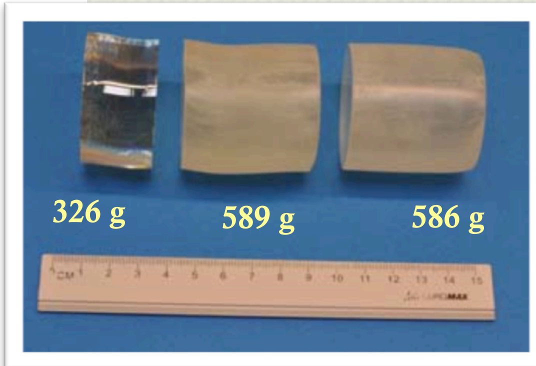
increase mass, running time, enrichment, … reasonable goal

Developments of ^{116}CdWO4 and investigation of 2β decay in ^{116}Cd with DAMA/R&D

Coll. DAMA+INR-Kiev+NIIC+ITEP-Moscow+ JSC NeoChem

JINST 06 (2011)P08011
Proc. NPAE2012, (2013) 353
Rad. Meas., in press





AURORA set-up
At stage 1,2

In data taking

Schema of **AURORA** set-up (stage 1,2):

- **2 ^{116}CdWO$_4$ crystal** 4.5 × 5 cm
- ultra-low background PMTs
- **plastic scintillator with cavity** (to place ^{116}CdWO$_4$)194 mm lenght + 200 mm high purity quartz
- ^{116}CdWO$_4$ surrounded by **active shield** made of plastic scintillator of large volume (500 × 300 × 240 mm), viewed by four low background 2" PMTs.
- **complete 4π active shield** of the main (^{116}CdWO$_4$) detectors provided

This measurement will also improve aspects of the low background techniques and can act as a pilot for next larger mass experiment

AURORA: search for 2β decay of ^{116}Cd with ^{116}CdWO4

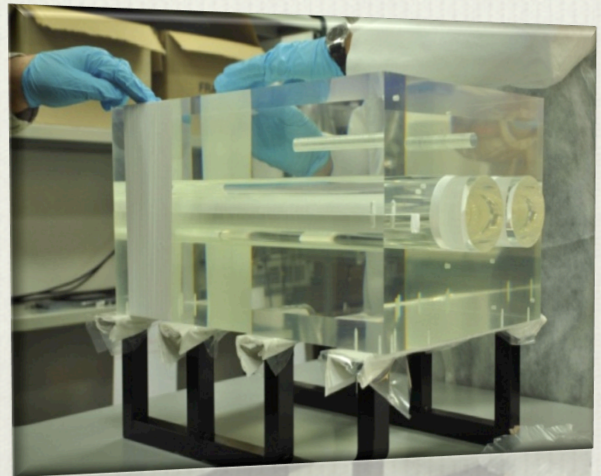
Absolute isotopic composition of Cd

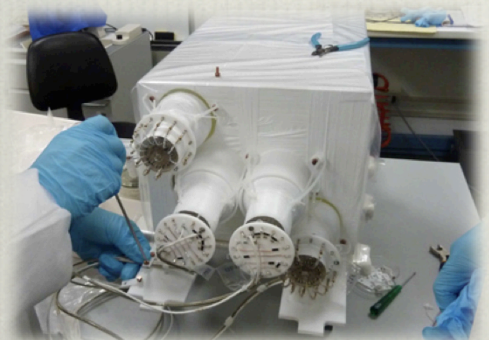
ICP-MS analysis

	Atomic number	Isotopic composition of Cd, %	
		Natural Cd [1]	Enriched ^{116}Cd
2β	106	1.25(6)	0.11(1)
2β	108	0.89(3)	0.10(1)
	110	12.49(18)	1.80(5)
	111	12.80(12)	2.00(5)
	112	24.13(21)	4.35(4)
β	113	12.22(12)	2.14(6)
2β	114	28.73(42)	7.30(6)
2β	116	7.49(18)	82.2(1)

[1] M. Berglund and M.E. Wieser, Pure Appl. Chem. 83 (2011) 397.

JINST 06 (2011)P08011



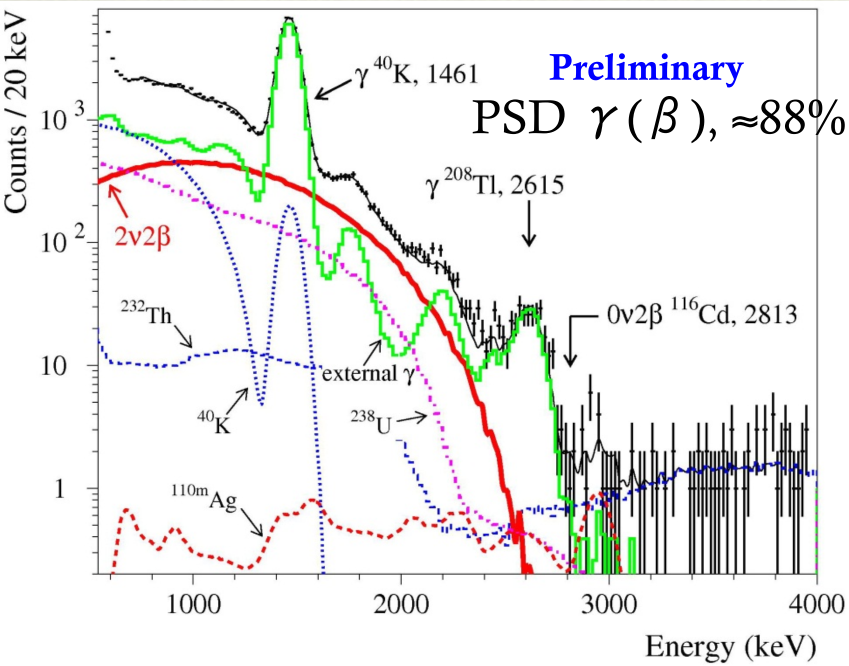


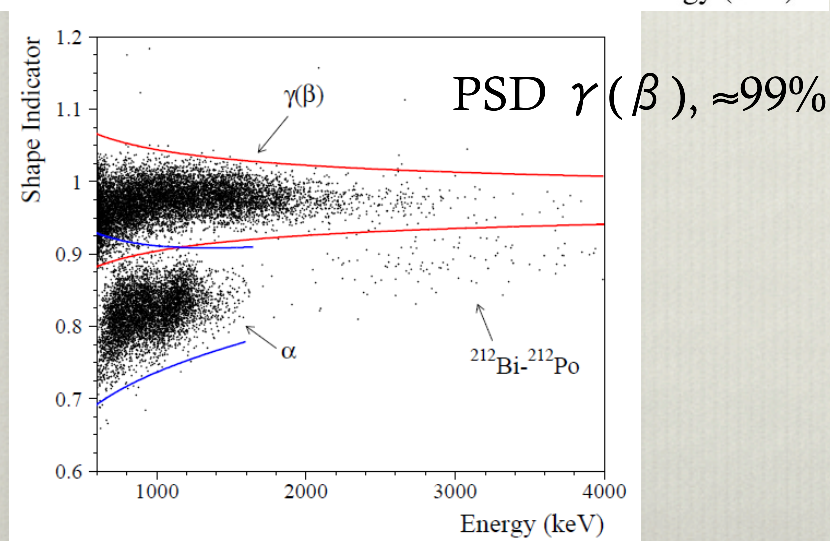
Stage	Mass(g)	Livetime (h)	Some Features
1	586.2 589.3	1727	Detector: Veto covered by PTFE; Light-guides covered by PTFE; LS –"LS-221" (ISMA, Kharkiv). DAQ: Sampling rate 20 MS/s; low level threshold ≈ 50 keV.
2	579.8 582.4	2512	Detector: Veto covered by Tyvek; Light-guides covered by Mylar; LS –Ultima gold liquid scintillator.
3		8552	DAQ: Sampling rate 50 MS/s; low level threshold ≈ 300 keV.
4	579.8 582.4	5557 running	Detector: Plastic veto removed; additional OFHC low radioactive Cu added

Further improvements in preparation

Radioactive contamination of $^{116}CdWO_4$ crystals (stage 2)

Background $^{116}CdWO_4$ (stage 2)





Source	Activity in $^{116}CdWO_4$, mBq/kg			
	No.1	No.2	^{116}CWO [1]	^{106}CWO [2]
^{232}Th	≤ 0.08 [b]	≤ 0.08 [b]	0.053(9) [b]	≤ 0.07 [b]
^{228}Ra	≤ 0.2 [a]	≤ 0.2 [a]	≤ 0.004 [a]	–
^{228}Th	0.032(2) [c]	0.054(3) [c]	0.039(2) [c]	0.042(4) [c]
^{227}Ac	≤ 0.002 [c]	≤ 0.002 [c]	≤ 0.01 [c]	–
$^{238+234}$U	≤ 0.4 [b]	≤ 0.6 [b]	≤ 0.6 [b]	≤ 0.6 [b]
^{230}Th	≤ 0.06 [b]	≤ 0.05 [b]	≤ 0.5 [b]	≤ 0.4 [b]
^{226}Ra	≤ 0.005 [b]	≤ 0.005 [b]	≤ 0.004 [b]	0.012(3) [b]
^{210}Po	≤ 0.4 [b]	≤ 0.6 [b]	≤ 0.4 [b]	≤ 0.2 [b]
Σ α	2.1(2) [b]	2.9(3) [b]	1.4(1) [b]	2.1(2) [b]
^{40}K	≤ 0.9 [a]	≤ 0.9 [a]	0.3(1) [a]	≤ 1.4 [a]
^{90}Sr-^{90}Y	≤ 0.1 [a]	≤ 0.1 [a]	≤ 0.2 [a]	≤ 0.3 [a]
^{110m}Ag	0.12(4) [a]	0.12(4) [a]	–	≤ 0.06 [a]
^{113}Cd	100(10) [d]	100(10) [d]	91(5) [a]	182 [d]
^{113m}Cd	460(20) [d]	460(20) [d]	1.1(1) [a]	116(4)×10^3 [a]
^{137}Cs	≤ 0.3 [a]	≤ 0.05 [a]	0.43(6) [a]	–

[a] Fit of background spectra; [b] Pulse shape discrimination;
[c] Time-amplitude analysis; [d] ICP-MS analysis

[1] F.A. Danevich et al., PRC 68 (2003) 035501.

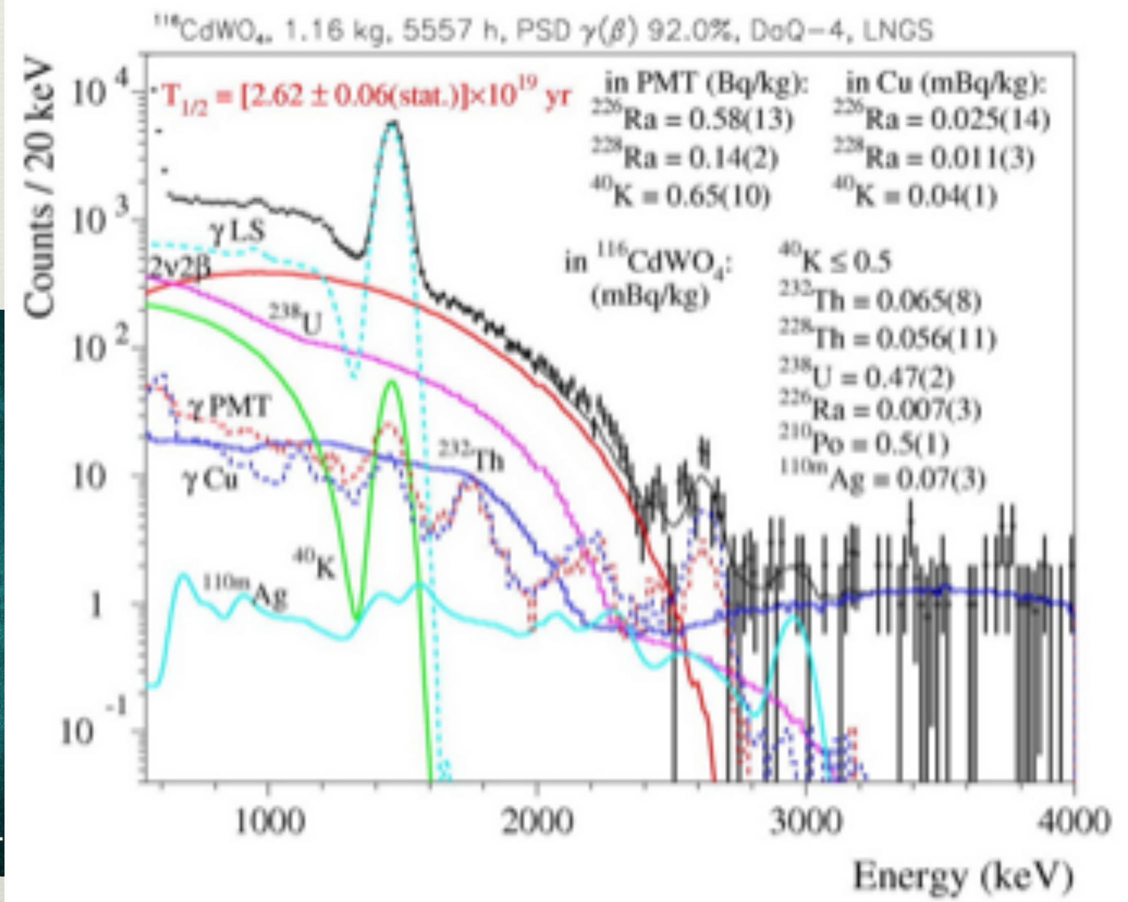
[2] P. Belli et al., PRC 85 (2012) 044610

$2\upsilon 2\beta$ decay of ^{116}Cd

- Radioactive contamination of the similar PMTs was measured in [1]

- U/Th in ^{116}CdWO4 were bounded according to PSD and T-A results

Stage 4 - preliminary



[1] R. Bernabei et al., JINST 7 (2012) P03009.

Half-life on $2\nu 2\beta$ decay of ^{116}Cd (g.s→g.s.)

Experimental $T_{1/2}$, 10^{19} yr		
Present work	Previous results	
2.6 ± 0.06(stat.) ± 0.3(syst.)	$2.6^{+0.9}_{-0.5}$	[1]
	2.9 ± 0.06(stat.) $^{+0.4}_{-0.3}$(syst.)	[2]
	3.75 ± 0.35(stat.) ± 0.21(syst.)	[3]
	2.88 ± 0.04(stat.) ± 0.16(syst.)	[4]
	2.8 ± 0.2 [world average value]	[5]

[1] H. Ejiri et al., J. Phys. Soc. Japan 64 (1995) 339.
[2] F.A. Danevich et al., Phys. Lett. B 344 (1995) 72; Phys. Rev. C 68 (2003) 035501.
[3] R. Arnold et al., JETP Lett. 61 (1995) 170; Z. Phys. C 72 (1996) 239.
[4] V.I. Tretyak on behalf of the NEMO-3 collaboration, AIP Conf. Proc. 1417 (2011) 125.
[5] A.S. Barabash, Phys. Rev. C 81 (2010) 035501.

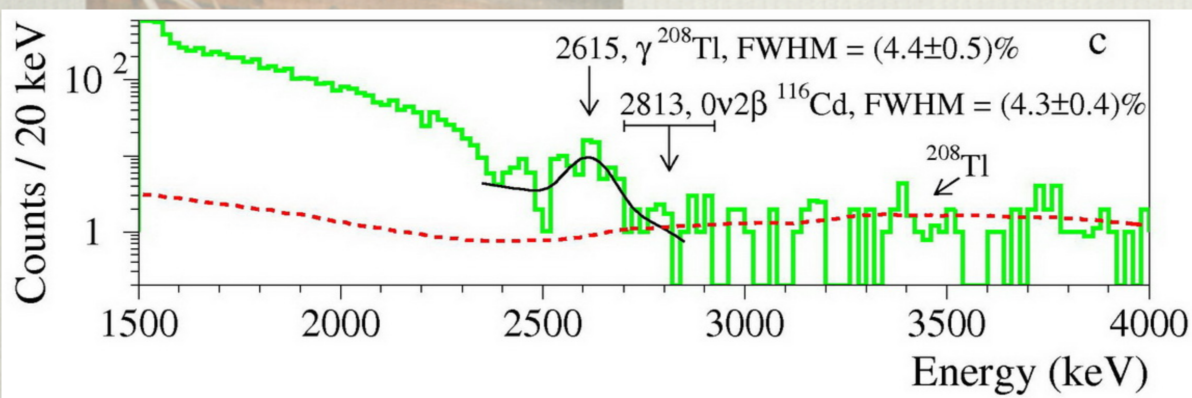
$2\upsilon 2\beta$ decay of ^{116}Cd:
$T_{1/2}$ =(2.6±0.06(stat.)±0.3(syst.))×10^{19} yr

AURORA experiment with $^{116}CdWO_4$: stage 4

5557 h, DAMA/R&D set-up, LNGS (Italy)

Two $^{116}CdWO_4$ crystals ≈0.58 kg each; enriched in ^{116}Cd to 82.2(1)%

$Q_{2\beta}$ (^{116}Cd)=2813.50(13) keV



Rate @ 2.7–2.9 MeV: 0.14(3) cnts/(keV×kg×yr)

Main contribution: internal ^{208}Tl, ^{110m}Ag; external ^{208}Tl (PMT+Cu)

sensitivity of the experiment in accordance with G.J.Feldman and R.D.Cousins [Phys. Rev. D 57(1998)3873] = 7×10^{22} yr (90% CL)

Estimated sensitivity over 5 yr of measurements (subject to reduce the background by a factor 2-10):

$T_{1/2}$ ~ (0.5–1.5)×10^{24} yr
$\langle m_\nu \rangle$ ~ (0.4–1.4) eV

Conclusions

- Continue efforts to develop new/improved crystal scintillators for low background physics
- Effectiveness of the low background scintillation technique for the search of rare processes proved
- Many rare processes investigated with high sensitivity in DAMA/R&D and DAMA/Ge and LNGS STELLA facility
- Sensitivity for $2\beta^+$ decay at level of 10^{21} yr
- Experiments on 2β decay of ^{106}Cd and ^{116}Cd running/under-improvement
- Other new measurement in preparation and/or foreseen (Gd, Nd, Ru, SrI, etc.)