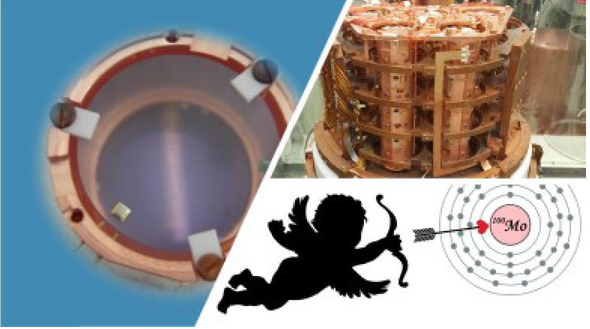


CUPID-Mo inauguration

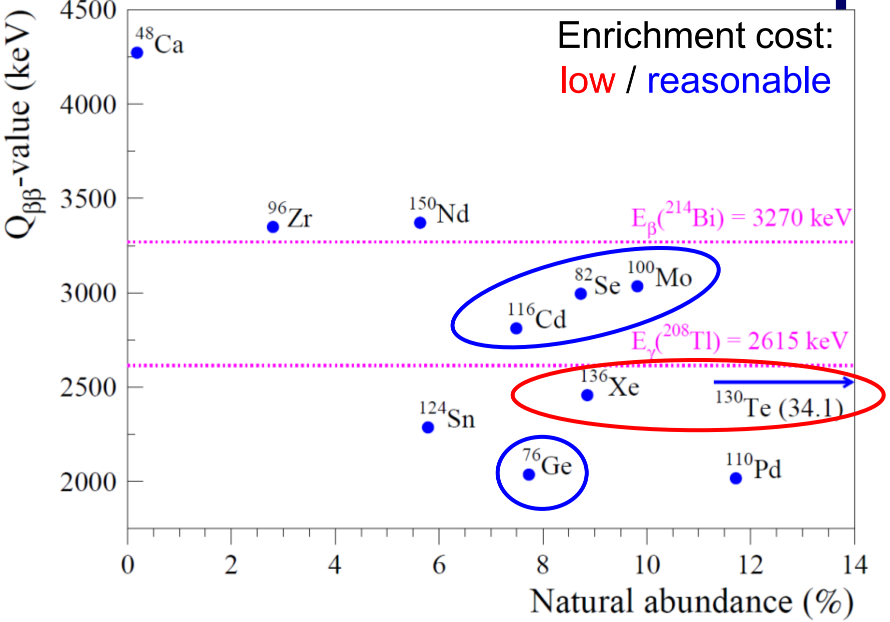
Fourneaux (France)

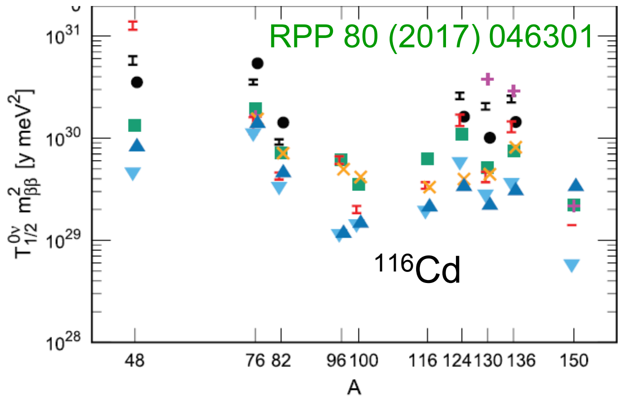
11-12 December 2019

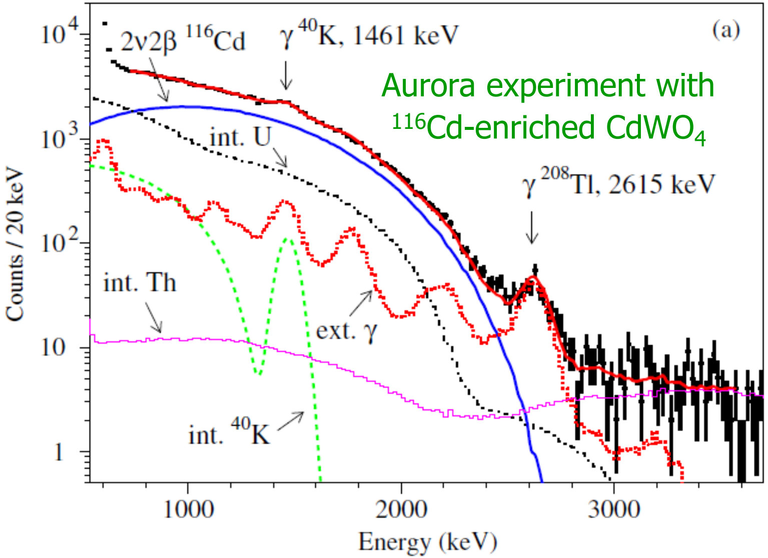
$^{116}CdWO_4$ scintillating bolometers at Modane and Canfranc

D.V. Poda (CSNSM, CNRS/IN2P3) **for D. Helis** (CEA, IRFU)

^{116}Cd as a 2β decay isotope







^{116}Cd	Aurora experiment @LNGS (Italy) PRD 98 (2018) 092007	
	Exposure (kg×yr)	**Half-life** (yr)
2ν2β	3.56	= 2.630(11) × 10^{19}
0ν2β	4.68	> 2.2 × 10^{23}

^{113}Cd issue of Cd-containing 0ν2β detectors

Issue: 12.23% of ^{113}Cd is in natural cadmium

Long-lived radioisotope (Q_β = 324 keV, $T_{1/2}$ = 8×10^{15} yr)

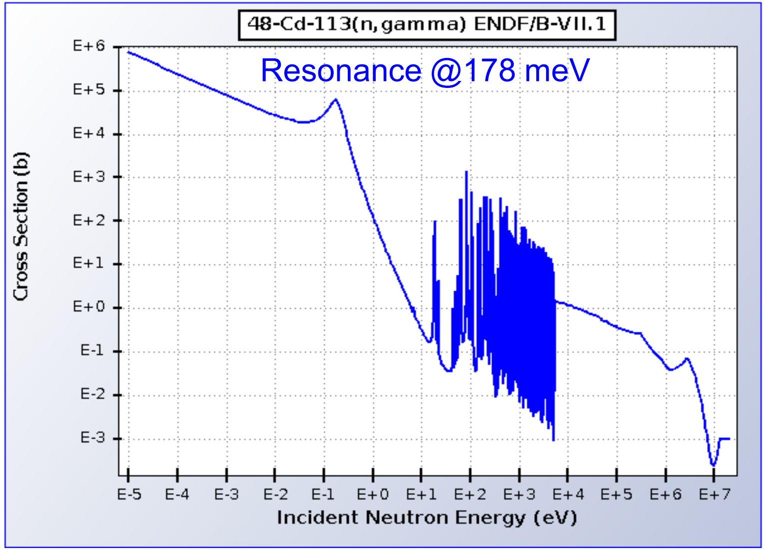
⇒ 0.45 Bq of ^{113}Cd in 100-cm^3 $CdWO_4$

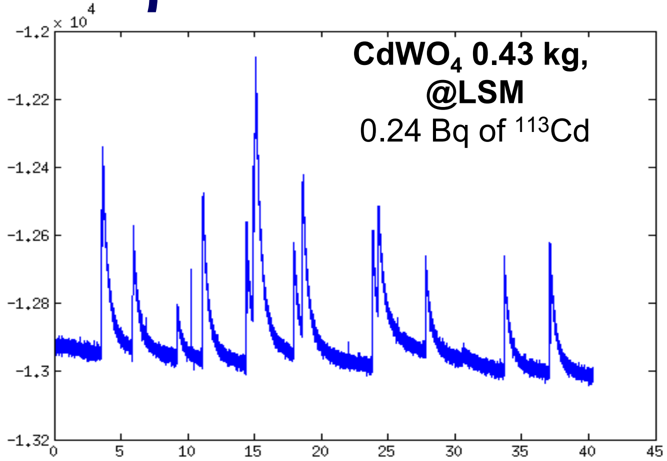
⇒ Strong pile-up issue for bolometers

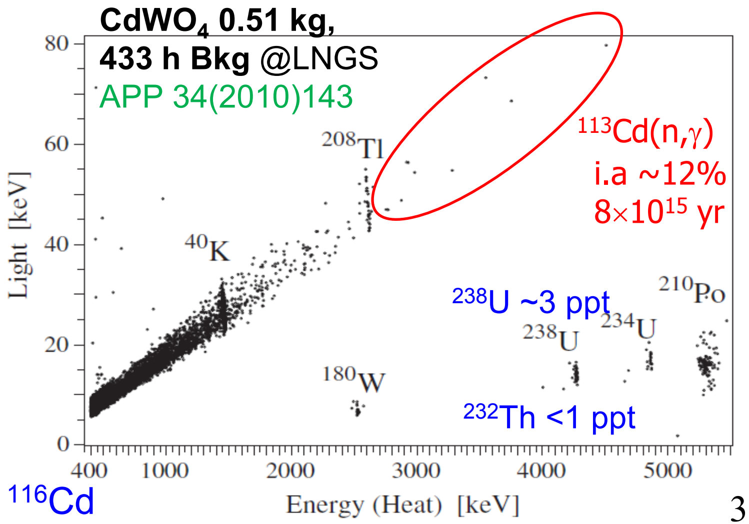
Huge thermal neutron capture cross section

~20 kb for thermal neutron capture via (n,γ)

⇒ ~23% γ's are emitted with (2.81-9.04) MeV

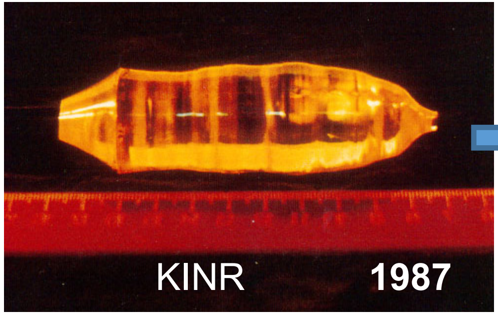






Solution: ~100% enrichment in ^{116}Cd

History of enriched cadmium tungstate scintillators

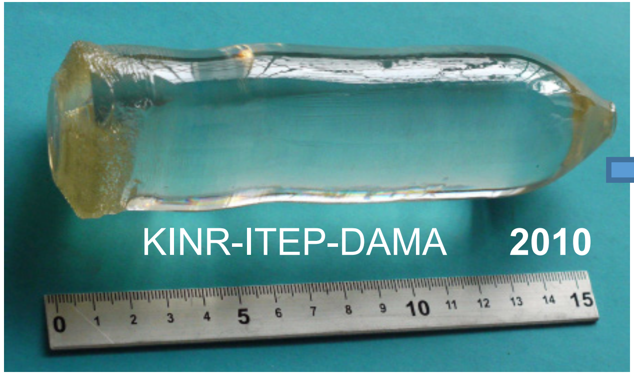


$^{116}CdWO_4$ (0.51 kg, **83%** ^{116}Cd)
Phys. Lett. B 334 (1995) 72

Solotvina experiment
$^{116}CdWO_4$ (0.33 kg)
$T_{1/2} > 1.7 \times 10^{23}$ yr @90% CL

Phys. Rec. C 68 (2003) 035501

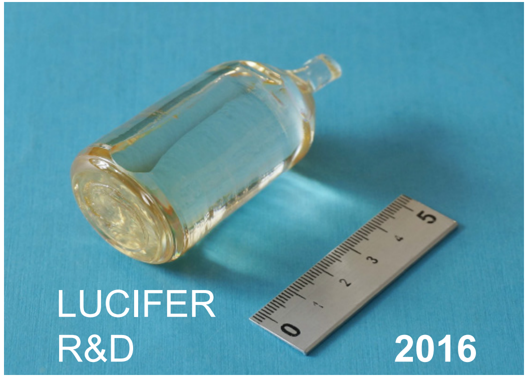
$^{106}CdWO_4$ (0.22 kg, **66.4%** ^{106}Cd)
Nucl. Instrum. Meth. A 615 (2010) 301



$^{116}CdWO_4$ (1.9 kg, **82%** ^{116}Cd)
JINST 6 (2011) P08011

Aurora experiment
$^{116}CdWO_4$ (1.16 kg)
$T_{1/2} > 2.2 \times 10^{23}$ yr @90% CL

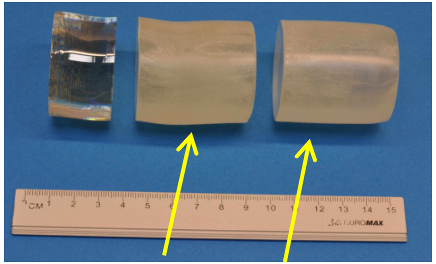
Phys. Rec. C 68 (2003) 035501

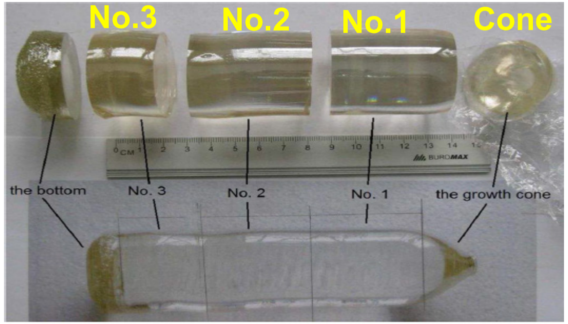


$^{116}CdWO_4$ (0.41 kg, **~99%** ^{116}Cd)
JINST 12 (2017) C08011

Radiopurity of $^{116}CdWO_4$ scintillators

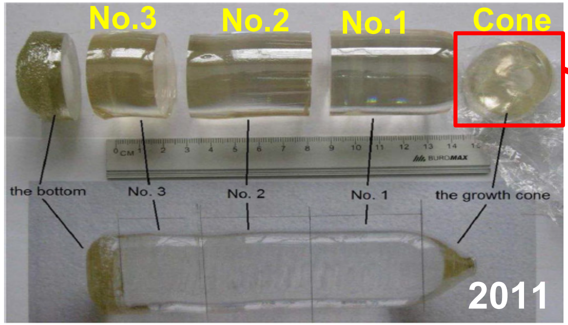
Atomic number	Enriched ^{116}Cd	Natural cadmium [3]
106	0.11 ± 0.01	1.25 ± 0.06
108	0.10 ± 0.01	0.89 ± 0.03
110	1.80 ± 0.05	12.49 ± 0.18
111	2.00 ± 0.05	12.80 ± 0.12
112	4.35 ± 0.04	24.13 ± 0.21
113	2.14 ± 0.06	12.22 ± 0.12
114	7.30 ± 0.06	28.73 ± 0.42
116	82.2 ± 0.1	7.49 ± 0.18





Chain	Nuclide	Activity (mBq/kg)	
		$^{116}CdWO_4$ 580 g + 582 g JINST 6, P08011 (2011)	$CdWO_4$ 433 g PRC 76, 064603 (2007)
^{232}Th	**^{232}Th**	0.061(2)	≤ 0.026
	^{228}Th	0.022(3)	0.008(4)
^{235}U	^{227}Ac	≤ 0.002	0.014(9)
^{238}U	**^{238}U**	0.59(7)	≤ 0.045
	^{234}U	0.64(7)	
	^{230}Th	0.11(22)	≤ 0.018
	^{226}Ra	≤ 0.01	≤ 0.018
	^{210}Po	0.6(1)	≤ 0.063
Total α activity		2.23(2)	0.26(4)
	^{113}Cd	**100(10)**	**558(4)**
	^{113m}Cd	**460(20)**	**≤ 3.4**
Expected rate (Hz)		**0.32**	**0.24**

First bolometric test of $^{116}CdWO_4$ scintillator

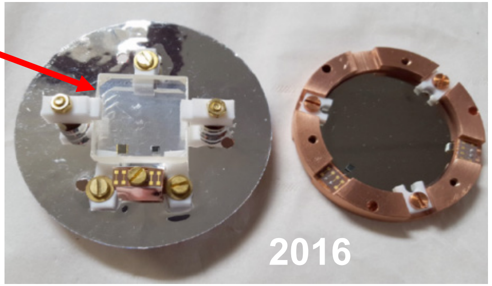


$^{116}CdWO_4$ ~ 1.9 kg

JINST 6(2011)P08011

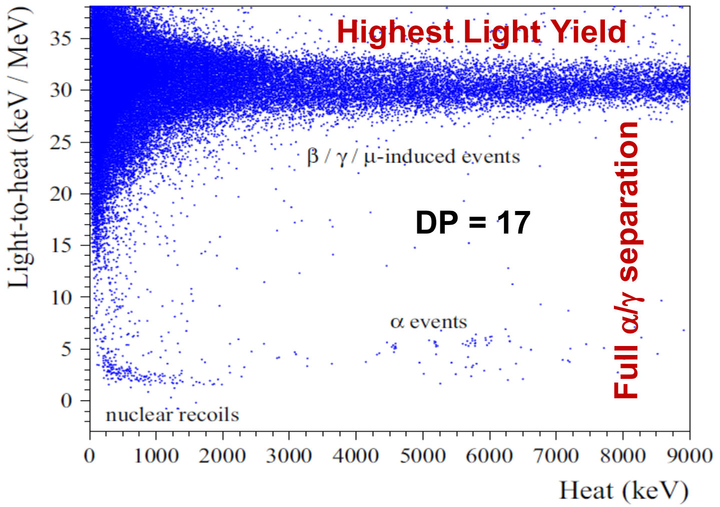
EPJWC 65(2014)01005

Bolometric test @ CSNSM (Orsay)

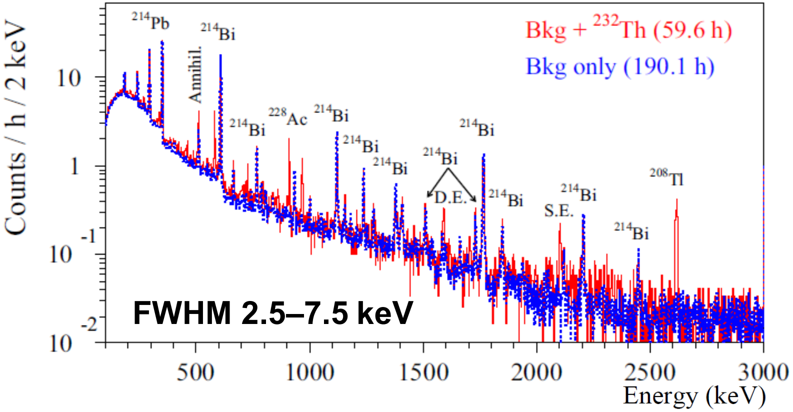


$^{116}CdWO_4$ (cone), 34 g

EPJC 76(2016)487



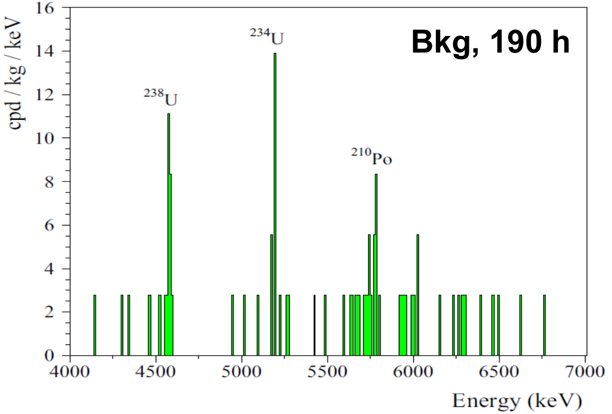
High energy resolution



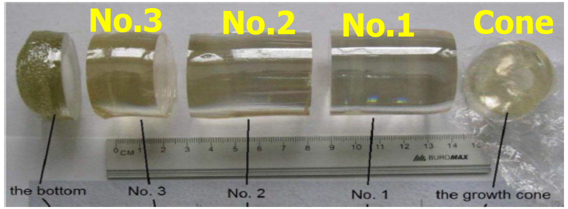
High radiopurity, segregation of U/Th

see also NIMA 833(2016)77

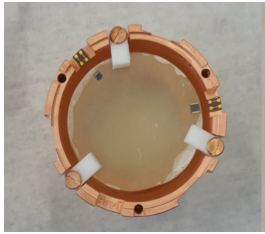
Nuclide	mBq/kg	
	Cone	No. 1
^{228}Th	≤ 0.07	0.031(3)
^{238}U	0.3(1)	0.5(2)
^{210}Po	0.23(8)	0.6(2)

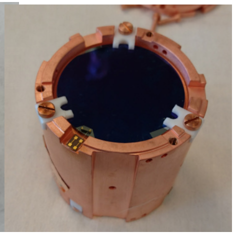


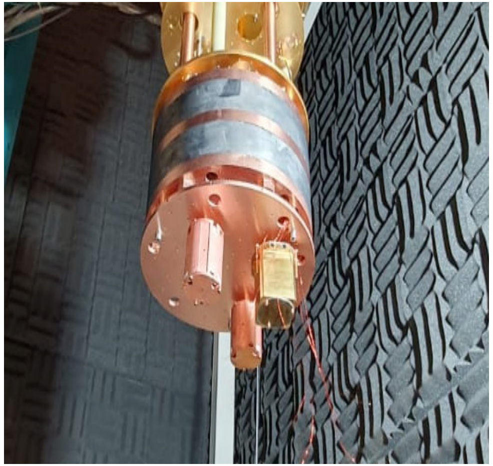
Large volume $^{116}CdWO_4$ scintillating bolometers



@LSM (France)	@LSC (Spain)
$^{116}CdWO_4$ No. 1 ∅45×47 mm **580 g**	**$^{116}CdWO_4$ No. 2** ∅45×47 mm **582 g**
Ge LD ∅44×0.17 mm SiO coated	**Ge LD** ∅44×0.17 mm SiO coated
EDELWEISS Suspended tower @20.7 mK *	**CROSS** No suspension @10.0 mK
Jan., 2019 - now	April – July, 2019

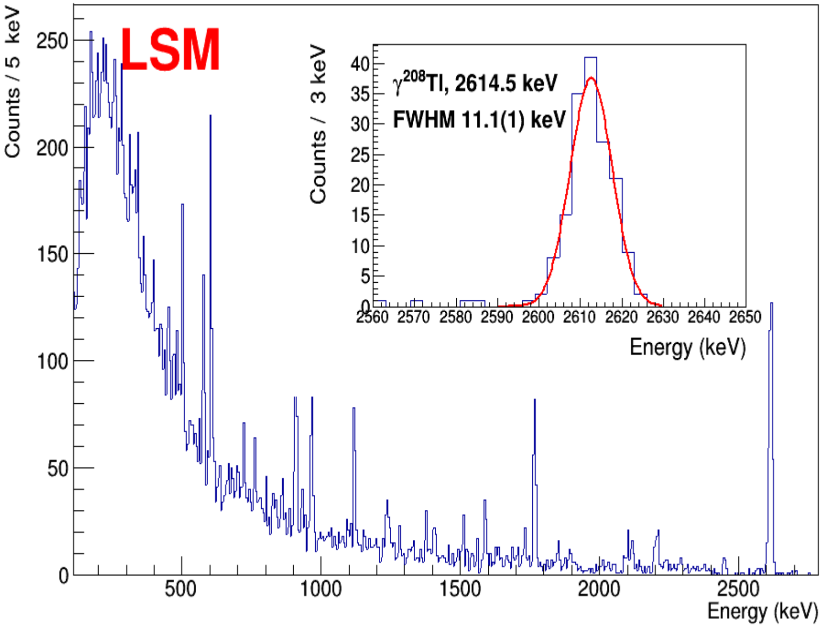


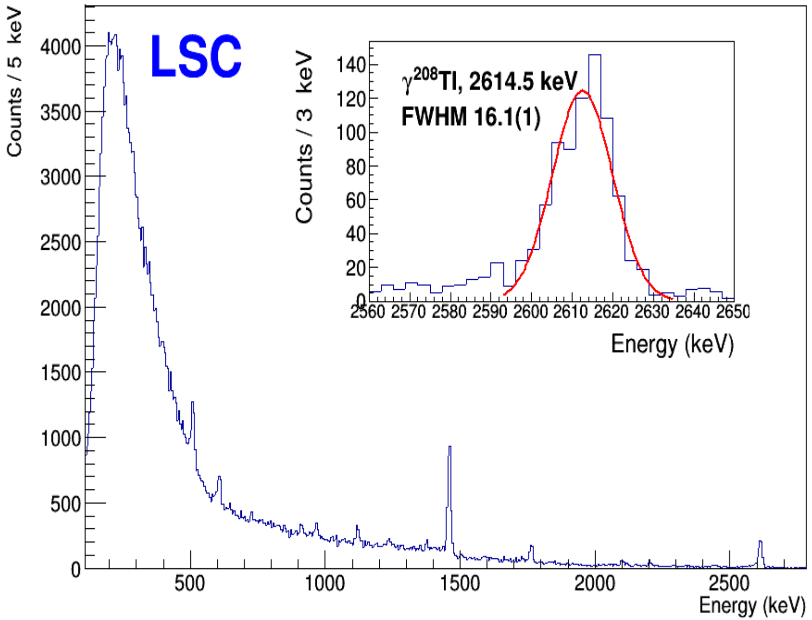




D. Helis @LTD-18, to apear in JLTP

Performance of $^{116}CdWO_4$ scint. bolometers

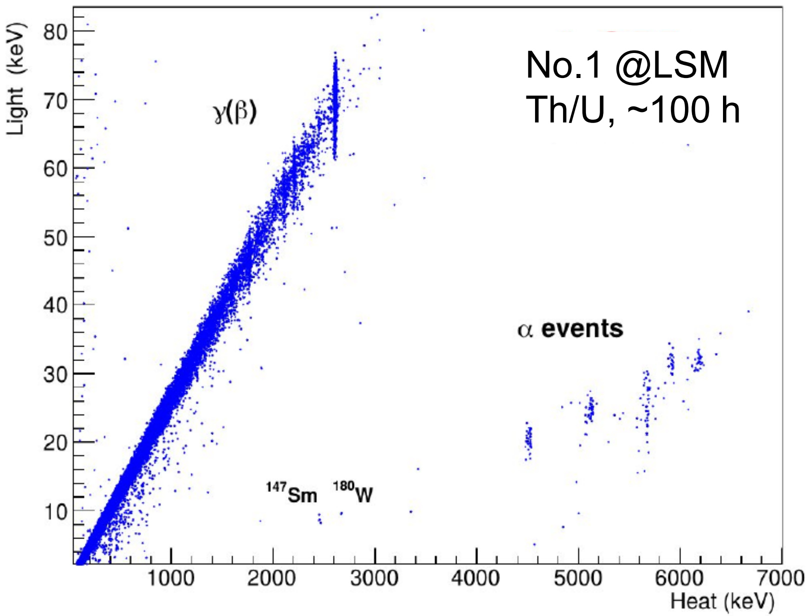


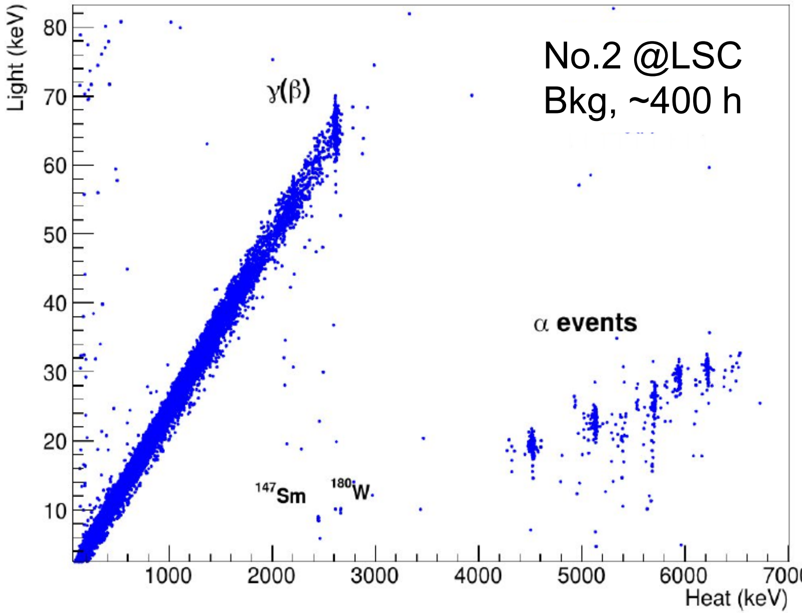


Performance	$^{116}CdWO_4$ No. 1 LSM @20.7 mK	$^{116}CdWO_4$ No. 2 LSC @10.0 mK
Signal (nV/keV)	29	36
Noise FWHM (keV)	**2.3**	**10**
FWHM (keV) @2615 keV	**11**	**16**

D. Helis @LTD-18, to apear in JLTP

Performance of $^{116}CdWO_4$ scint. bolometers



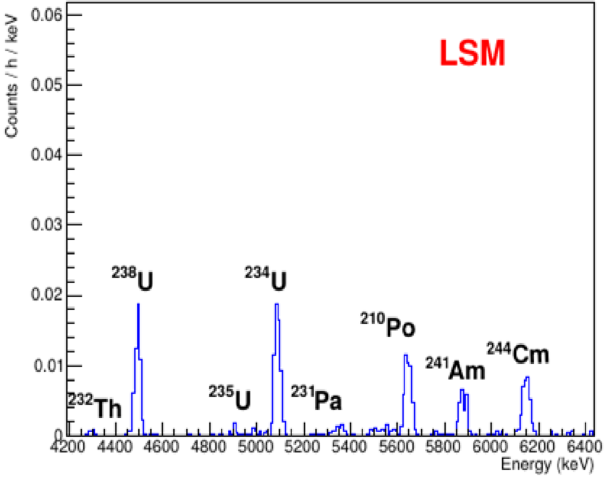


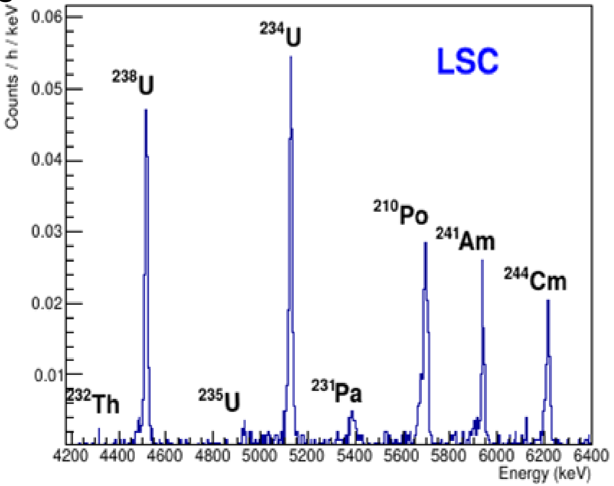
Detector	LD signal (μV/keV)	LD noise FWHM (keV)		$LY_{\alpha/\gamma(\beta)}$ (keV/MeV)	QF_{α}	$DP_{\alpha/\gamma(\beta)}$
$^{116}CdWO_4$ No. 1 LSM @20.7 mK	0.72	**0.15**		**27**	0.15	**19**
$^{116}CdWO_4$ No. 2 LSC @10.0 mK	1.1	**0.36**		**25**	0.15	**21**

D. Helis @LTD-18, to apear in JLTP

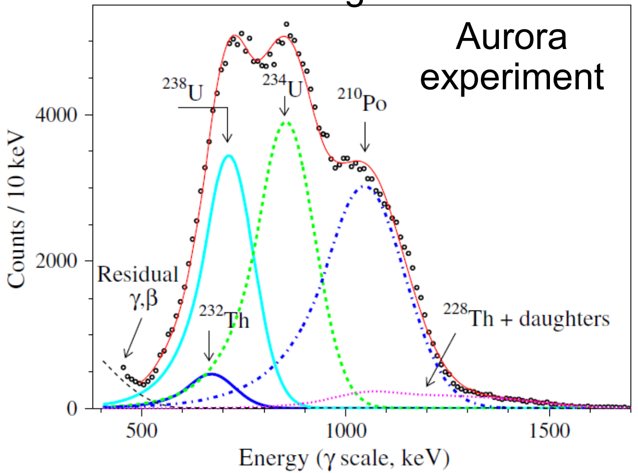
Radiopurity of $^{116}CdWO_4$ crystals

Scintillating bolometes





Scintillating counters

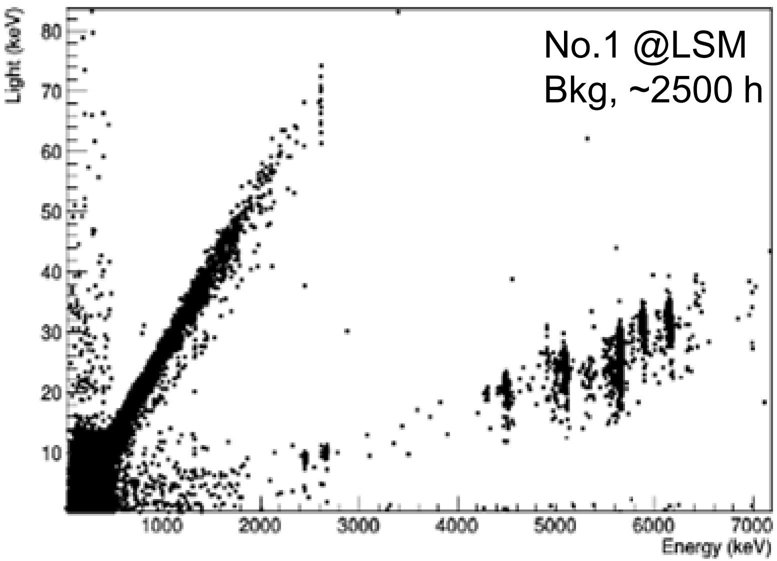


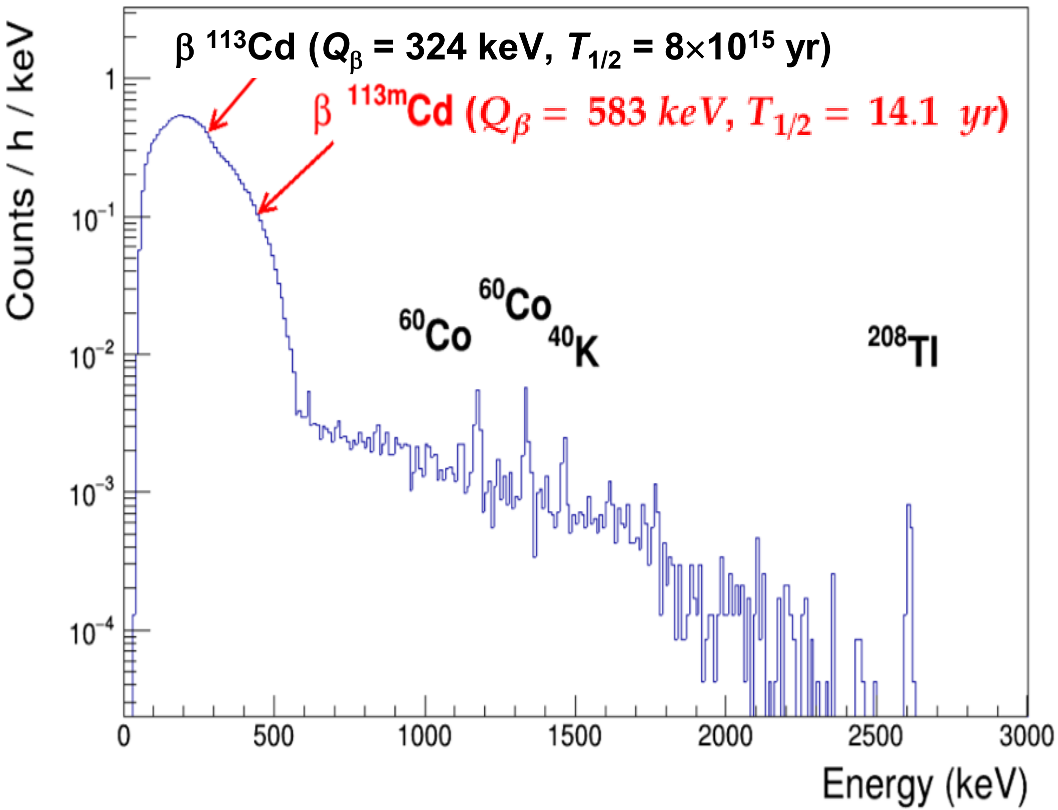
PRD 98 (2018) 092007

D. Helis @LTD-18, to apear in JLTP

Chain	Nuclide	Activity (mBq/kg)				
		No. 1 at LSM	No. 2 at LSC	Present work Weighted mean	Present work Combined value	Aurora [15]
	^{147}Sm	0.018(3)	0.019(5)	0.018(3)	0.018(2)	
	^{180}W	0.009(2)	0.010(4)	0.009(2)	0.009(2)	
	^{241}Am	0.12(1)	0.24(2)	0.14(1)	0.18(1)	
	^{244}Cm	0.19(2)	0.24(1)	0.23(1)	0.21(1)	
^{232}Th	^{232}Th	0.010(4)	0.013(4)	0.012(3)	0.011(2)	0.07(2)
^{238}U	^{238}U	0.29(2)	0.53(3)	0.36(2)	0.41(2)	0.58(4)
	^{234}U	0.32(6)	0.48(3)	0.45(3)	0.40(3)	0.60(1)
	^{210}Po	0.27(2)	0.34(2)	0.305(14)	0.30(1)	0.70(4)
^{235}U	^{235}U	0.021(2)	0.038(8)	0.022(2)	0.029(4)	
	^{231}Pa	0.037(6)	0.067(9)	0.046(5)	0.052(5)	

Sensitivity to the ^{116}Cd $0\nu2\beta$ decay



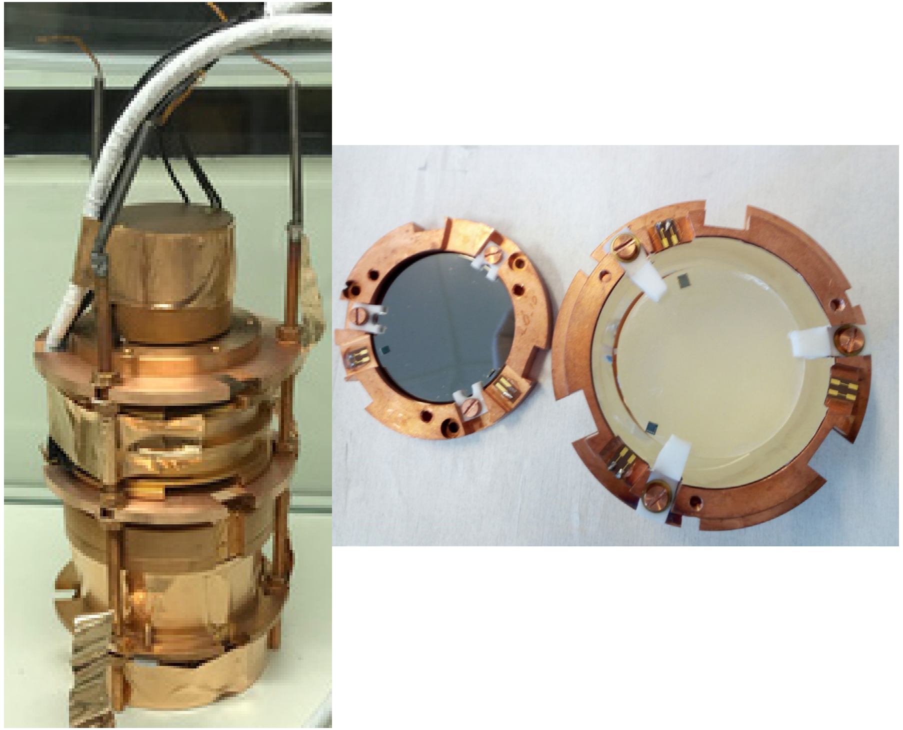


- **No events @ ROI** ($Q_{\beta\beta}$ = 2813 keV)
- **BI < 0.02 cts/yr/kg/keV** @ 90% C.L. considering the 2650-3350 keV range
- **lim $T_{1/2}$ ~ 5×10^{22} yr** @ 90% C.L. (0.165 kg×yr), ~5x lower than the Aurora limit
  Aurora: $T_{1/2} \geq$ 2.2×10^{23} yr @ 90% C.L. (4.68 kg×yr) [PRD 98 (2018) 092007]

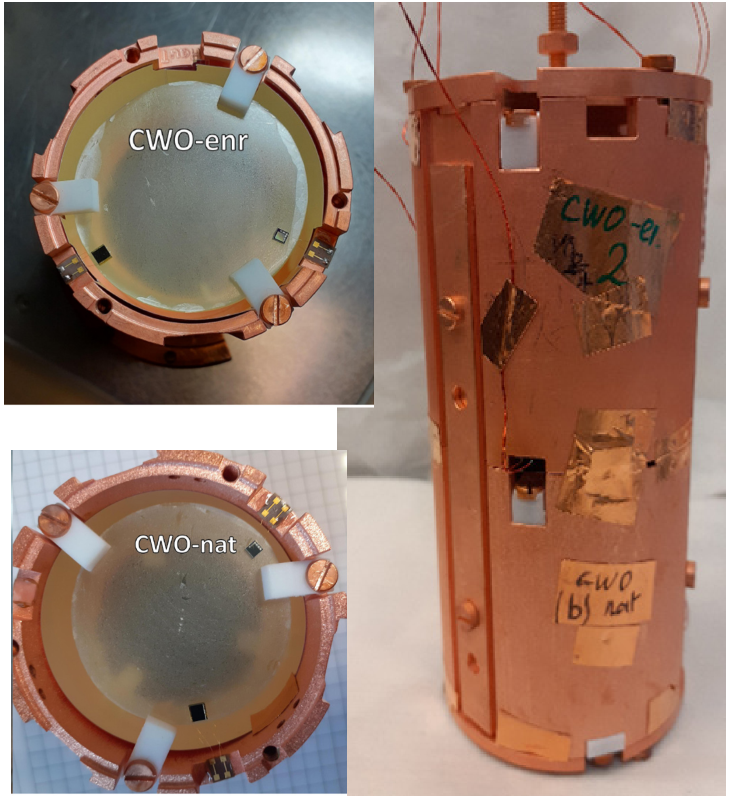
$^{116}CdWO_4$ scintillating bolometers: prospects

- Collect as long as possible data of large-mass $^{116}CdWO_4$ scintillating bolometes

Continue $^{116}CdWO_4$ No. 1 data taking at LSM
(together with CUPID-Mo & EDELWEISS)



Use $^{116}CdWO_4$ No. 2 as a reference detector at LSC



Summary

- First bolometric tests of large volume $^{116}CdWO_4$ crystals (75 cm^3) have been succesfuly performed at LSM (France) and LSC (Spain)

- Both $^{116}CdWO_4$ scintillating bolometers show high performance, efficient particle ID and high radiopurity. The existing information about the crystals radioactive contamination has been improved

- Longer data taking at LSM demonstrates a «zero-Bkg» approach. The present sensitivity to the ^{116}Cd $0\nu2\beta$ decay, lim $T_{1/2} \sim 5\times10^{22}$ yr, is ~5x lower than the most stringen limit set in the Aurora experiment, but we are limited by a modest exposure (0.17 kg×yr vs. 4.7 kg×yr)

- Both detectors are in operation to improve the sensitivity to ^{116}Cd 2β