

INTRINSIC RADIOACTIVITY OF PHOTOELECTRONICS

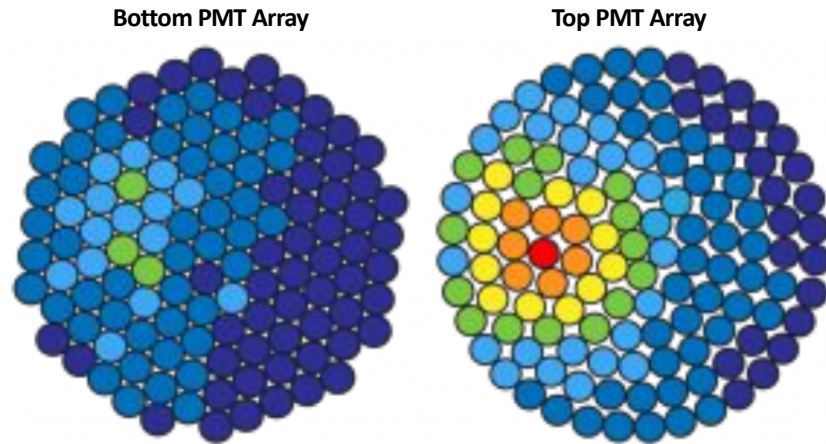
Ludovico Luzzi (CIEMAT)

- XENONnT
- LUX - ZEPLIN (LZ)
- DARKSIDE - 50
- DARKSIDE - 20K

Strategy and comments

- Comparison of intrinsic U and Th activity in photoelectronics measured for different experiments with noble liquids
- U and Th produce background due to (α, n) reactions and γ emission
- Because of breaking of secular equilibrium in U decay chain we split it in 3 parts
- Only we measure the bottom part of the U chain
- Hard to compare different experiments because of no systematic assays for U chain
- The comparison is coherent for the Th chain

XENONnT



The XENONnT Time Projection Chamber, Arianna Rocchetti, Albert-Ludwigs-Universität Freiburg 17 – 06 - 2018

	²³⁸ U up (mBq/unit)	²³⁸ U mid (mBq/unit)	²³⁸ U low (mBq/unit)*	²³² Th (mBq/unit)
PMT tube + bases *	1,05E+01	9,13E-01	-	1,53E+00

Projected WIMP Sensitivity of the XENONnT Dark Matter Experiment, XENON Collaboration, 17 November 2020

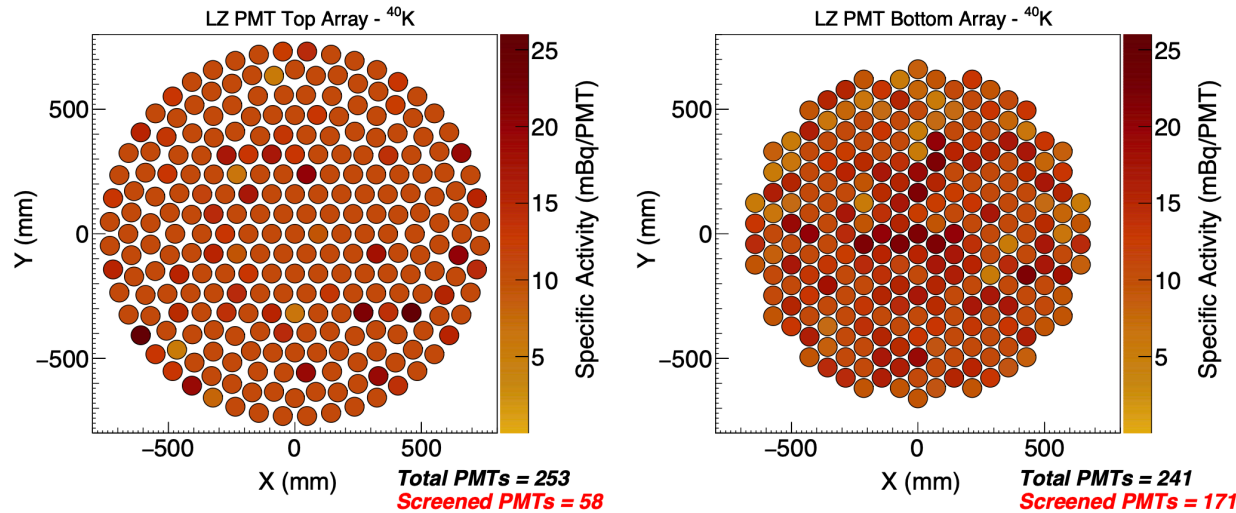
* Only this value reported in XENON documentation

** U low not measured

3" R11410-21 Hamamatsu PMT

#PMT	494
#PMT TOP	253
#PMT BOTTOM	241
Diameter Tot	7,6 cm
Diameter eff	6,4 cm
Tot single PMT surface	45,36 cm ²
Eff single PMT surface	32,17 cm ²
Single PMT squared area	57,76 cm ²
Diameter TPC base	1,3 m
Tot area TPC base	1,33 m ²
Average QE	0,34

LUX – ZEPLIN



The LUX-ZEPLIN (LZ) radioactivity and cleanliness control programs, LZ Collaboration, 6 September 2020

	²³⁸ U up (mBq/unit)	²³⁸ U mid (mBq/unit)	²³⁸ U low (mBq/unit)*	²³² Th (mBq/unit)
PMT tube	1,33E+01	5,96E-01	8,80E-02	1,14E+00
PMT base	1,29E+00	3,91E-01	3,83E+01	3,01E-01
Total detector	1,46E+01	9,87E-01	3,84E+01	1,44E+00

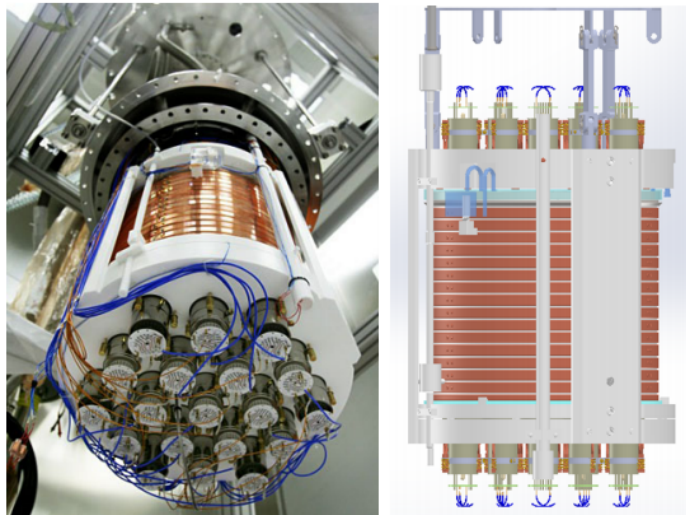
The LUX-ZEPLIN (LZ) Technical Design Report, LZ Collaboration, 27 March 2017

* U low derived from ²¹⁰Pb measurements: only 2 PMT tubes components and all bases components

3" R11410-20 Hamamatsu PMT

#PMT	494
#PMT TOP	247
#PMT BOTTOM	247
Diameter Tot	7,6 cm
Diameter eff	6,4 cm
Tot single PMT surface	45,36 cm ²
Eff single PMT surface	32,17 cm ²
Single PMT squared area	57,76 cm ²
Diameter TPC base	1,5 m
Tot area TPC base	1,77 m ²
Average QE	0,31

DS-50



Dark Matter Direct Detection with DarkSide-50: Analysis of Early Data, Laura Marini, Master Thesis, Università degli Studi "Roma Tre" A.Y. 2012 - 2013

	²³⁸ U up (mBq/unit)	²³⁸ U mid (mBq/unit)	²³⁸ U low (mBq/unit)*	²³² Th (mBq/unit)
PMT tube	2,80E-04	1,82E+01	-	1,20E+01
PMT base	1,30E+02	1,61E+01	-	4,96E+00
Total detector	1,30E+02	3,43E+01	-	1,70E+01

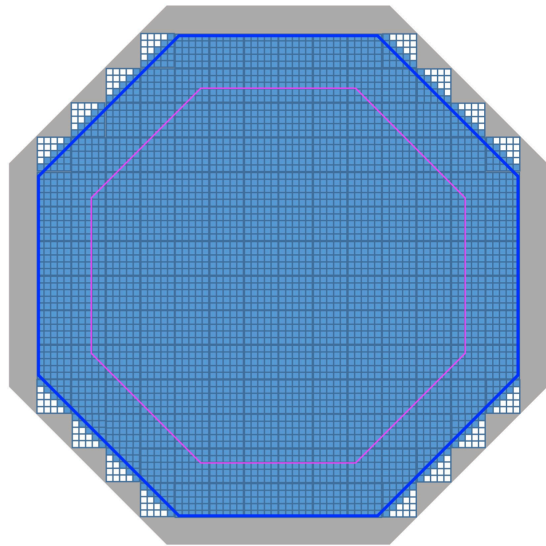
Persephone DataBase, 10 August 2016

* U low not measured

3" R11065 Hamamatsu PMT

#PMT	38
#PMT TOP	19
#PMT BOTTOM	19
Diameter Tot	7,6 cm
Diameter eff	6,4 cm
Tot single PMT surface	45,36 cm ²
Eff single PMT surface	32,17 cm ²
Single PMT squared area	57,76 cm ²
Diameter TPC base	36 cm
Tot area TPC base	0,10 m ²
Average QE	0,33

DS - 20K



DarkSide-20k Technical Design Report, The Global Argon Dark Matter Collaboration, 21 January 2020

FBK SiPM	
#PDM	8400
#PDM TOP	4200
#PDM BOTTOM	4200
Tot single PDM surface	25 cm ²
Eff single PDM surface	24 cm ²
Average QE	0,45

	²³⁸ U up (mBq/unit)	²³⁸ U mid (mBq/unit)	²³⁸ U low (mBq/unit)	²³² Th (mBq/unit)
SiPM tiles	2,15E+00	6,23E-01	4,05E+00	6,32E-01
Front End Board	9,60E-01	1,62E+00	1,79E+01	2,22E-01
Mother Board	3,96E-02	1,92E-01	1,92E+00	1,20E-03
Finger Module	1,05E-01	4,24E-01	1,70E+00	1,41E-02
Steering Module	6,38E-01	3,91E-01	1,91E+00	5,36E-02
Optical Module	8,97E-02	1,90E-01	2,27E+01	3,85E-02
Total	3,98E+00	3,44E+00	5,01E+01	9,62E-01

- **Not included most of cables and optic fiber**

SUMMARY (intrinsic efficiency)

- Activity normalized by single unit effective area

	²³⁸ U up (mBq/cm ²)	²³⁸ U mid (mBq/cm ²)	²³⁸ U low (mBq/cm ²)	²³² Th (mBq/cm ²)
PDM DS-20k	1,59E-01	1,38E-01	2,01E+00	3,85E-02
R11410-20 PMT (LZ)	4,54E-01	3,07E-02	1,19E+00	4,47E-02
R11410-21 PMT (XENONnT)	3,27E-01	2,84E-02	-	4,75E-02
R11065 PMT (DS-50)	4,05E+00	1,07E+00	-	5,27E-01

- Activity normalized by single unit effective area and QE

	²³⁸ U up (mBq/cm ²)	²³⁸ U mid (mBq/cm ²)	²³⁸ U low (mBq/cm ²)	²³² Th (mBq/cm ²)
PDM DS-20k	3,54E-01	3,06E-01	4,46E+00	8,55E-02
R11410-20 PMT (LZ)	1,47E+00	9,90E-02	3,85E+00	1,44E-01
R11410-21 PMT (XENONnT)	9,62E-01	8,35E-02	-	1,40E-01
R11065 PMT (DS-50)	1,23E+01	3,23E+00	-	1,60E+00

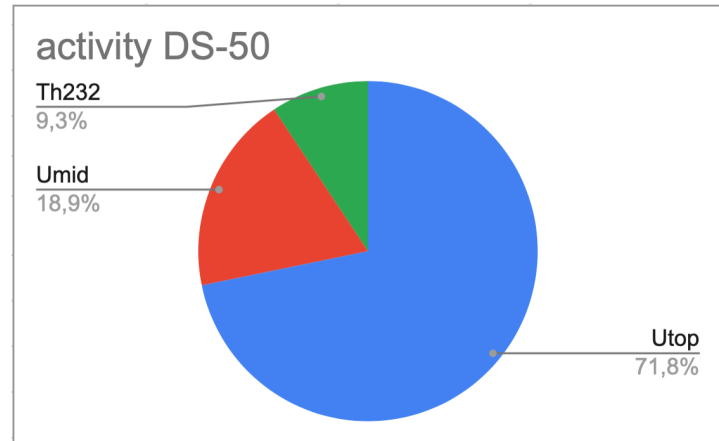
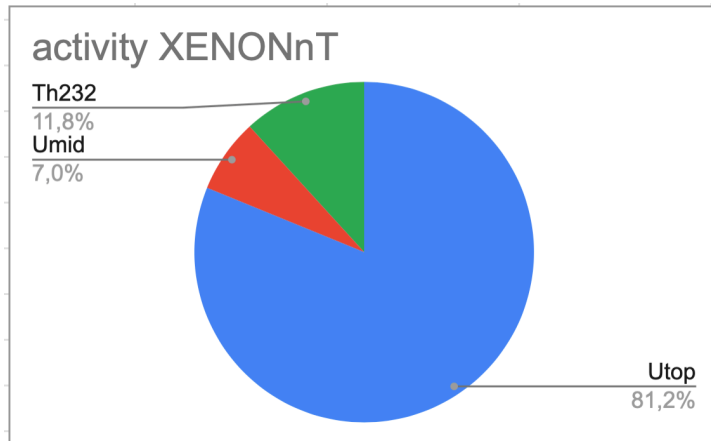
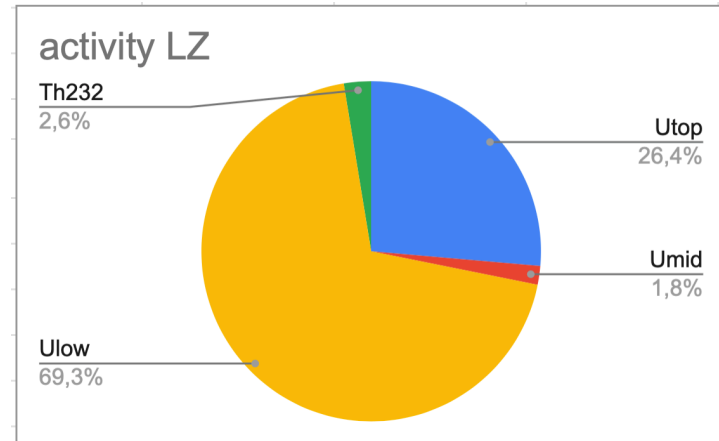
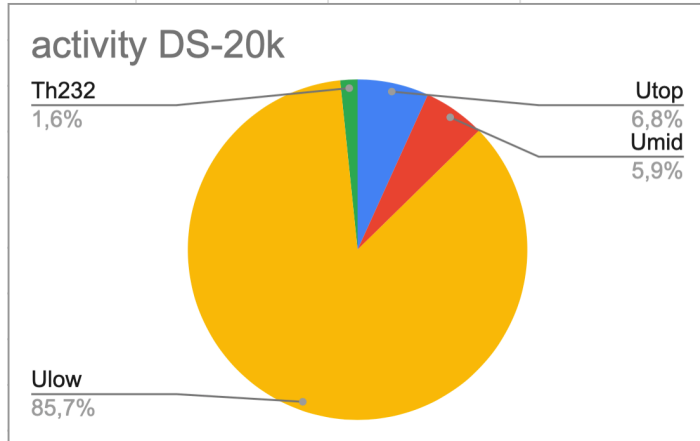
SUMMARY (geometric efficiency)

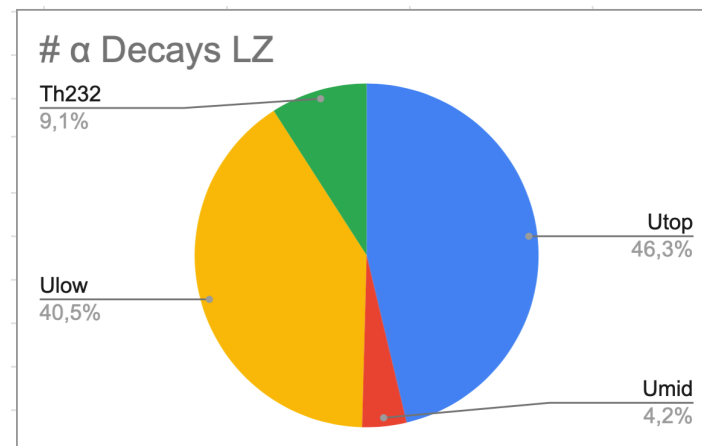
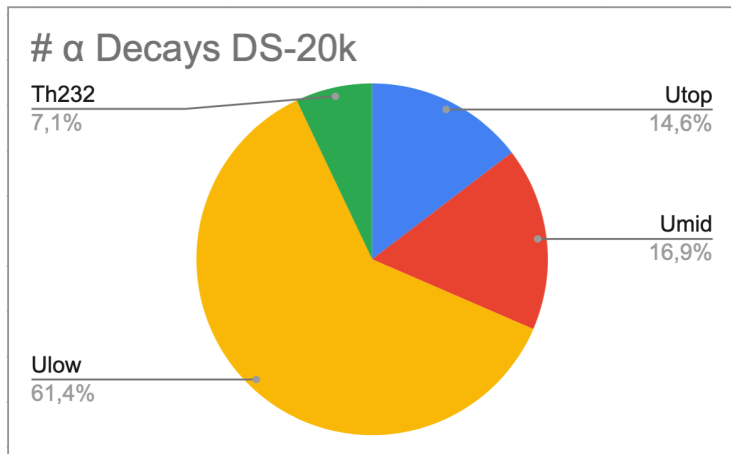
- Activity normalized by single unit effective area, QE and **shape factor** (coverage factor)

	Shape Factor	²³⁸ U up (mBq/cm ²)	²³⁸ U mid (mBq/cm ²)	²³⁸ U low (mBq/cm ²)	²³² Th (mBq/cm ²)
PDM DS-20k	0,96	3,68E-01	3,19E-01	4,64E+00	8,91E-02
R11410-20 PMT (LZ)	0,45	3,26E+00	2,20E-01	8,56E+00	3,20E-01
R11410-21 PMT (XENONnT)	0,61	1,57E+00	1,36E-01	-	2,28E-01
R11065 PMT (DS-50)	0,60	2,05E+01	5,38E+00	-	2,66E+00

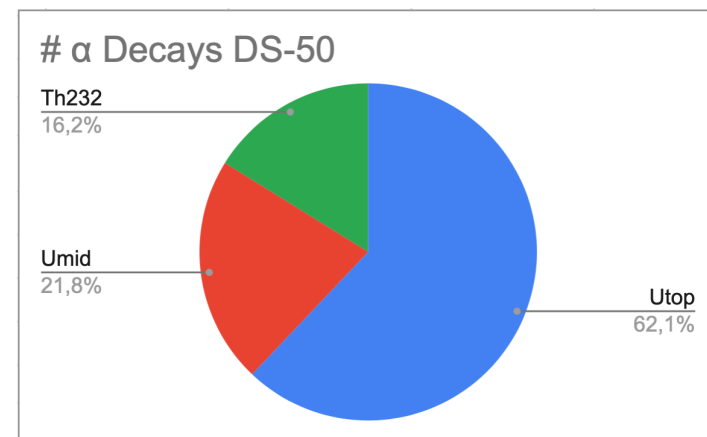
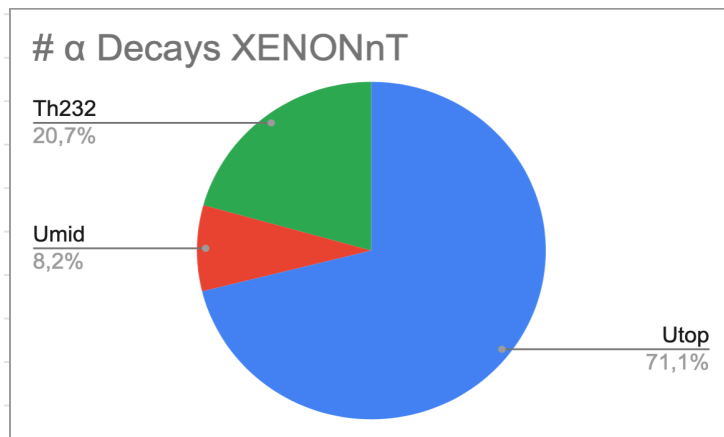
**PDMs: Activity/(QE* eff area* $\frac{\text{eff area}}{\text{tot area}}$)

**PMTs: Activity/(QE* eff area* # PMTs of a plane* $\frac{\text{eff area}}{\text{area TPC base}}$)

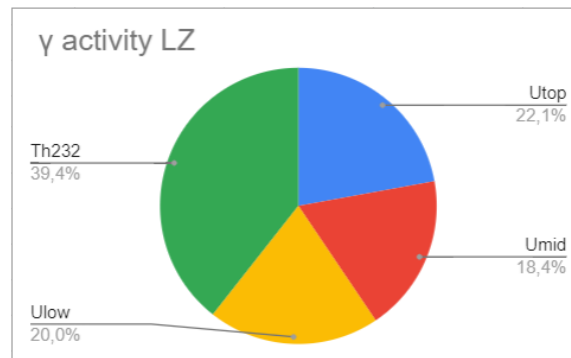
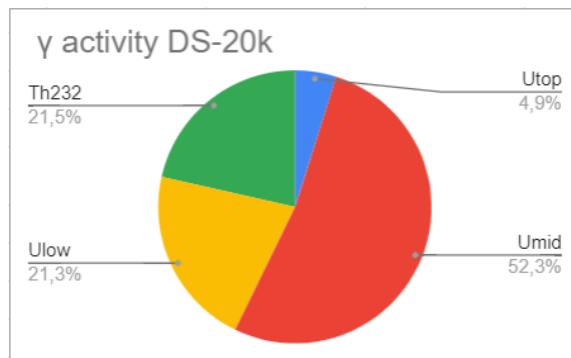




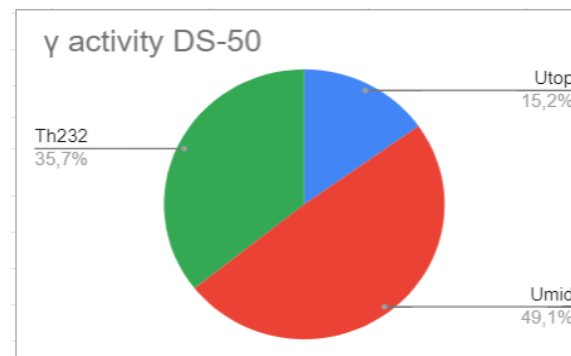
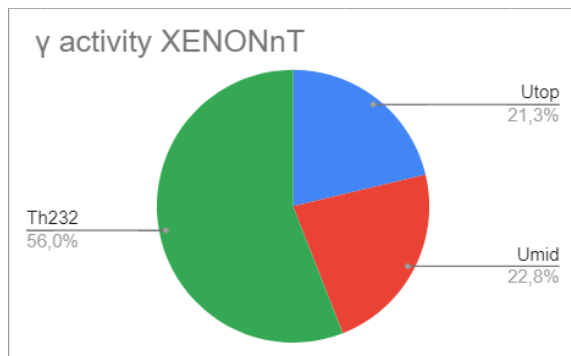
Isotope	# α Decays
U top	3
U mid	4
U bot	1
Th	6



γ activity	^{238}U up (mBq/cm ²)	^{238}U mid (mBq/cm ²)	^{238}U low (mBq/cm ²)	^{232}Th (mBq/cm ²)
PDM DS-20k	4,27E-02	4,56E-01	1,86E-01	1,87E-01
R11410-20 PMT (LZ)	3,78E-01	3,15E-01	3,42E-01	6,73E-01
R11410-21 PMT (XENONnT)	1,82E-01	1,95E-01	-	4,79E-01
R11065 PMT (DS-50)	2,37E+00	7,70E+00	-	5,59E+00



Isotope	γ scaling factor
U top	0.116
U middle	1.43
U bottom	0.04
Th	2.1



CONCLUSIONS

- The activity of the **top** ^{238}U chain for PDMs in DS-20k is ~ 9 times $<$ LZ, ~ 4 times $<$ XENONnT and ~ 55 times $<$ DS-50
- The activity of the **middle** ^{238}U chain for PDMs in DS-20k ~ 1.5 times $>$ LZ, ~ 2.3 times $>$ XENONnT and ~ 17 times $<$ DS-50
- The activity of the **bottom** ^{238}U chain for PDMs in DS-20k ~ 2 times $<$ LZ and we can't say anything about the others
- The activity of ^{232}Th chain in DS-20k is ~ 3.5 times $<$ LZ, ~ 2.5 times $<$ XENONnT and ~ 30 times $<$ DS-50