

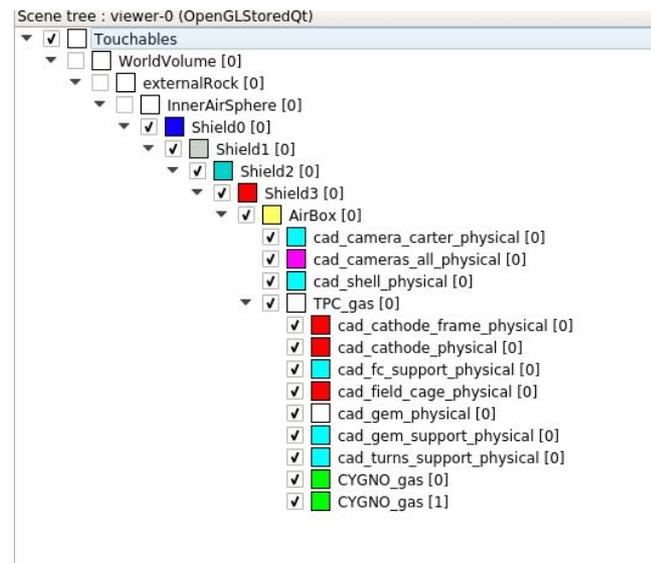
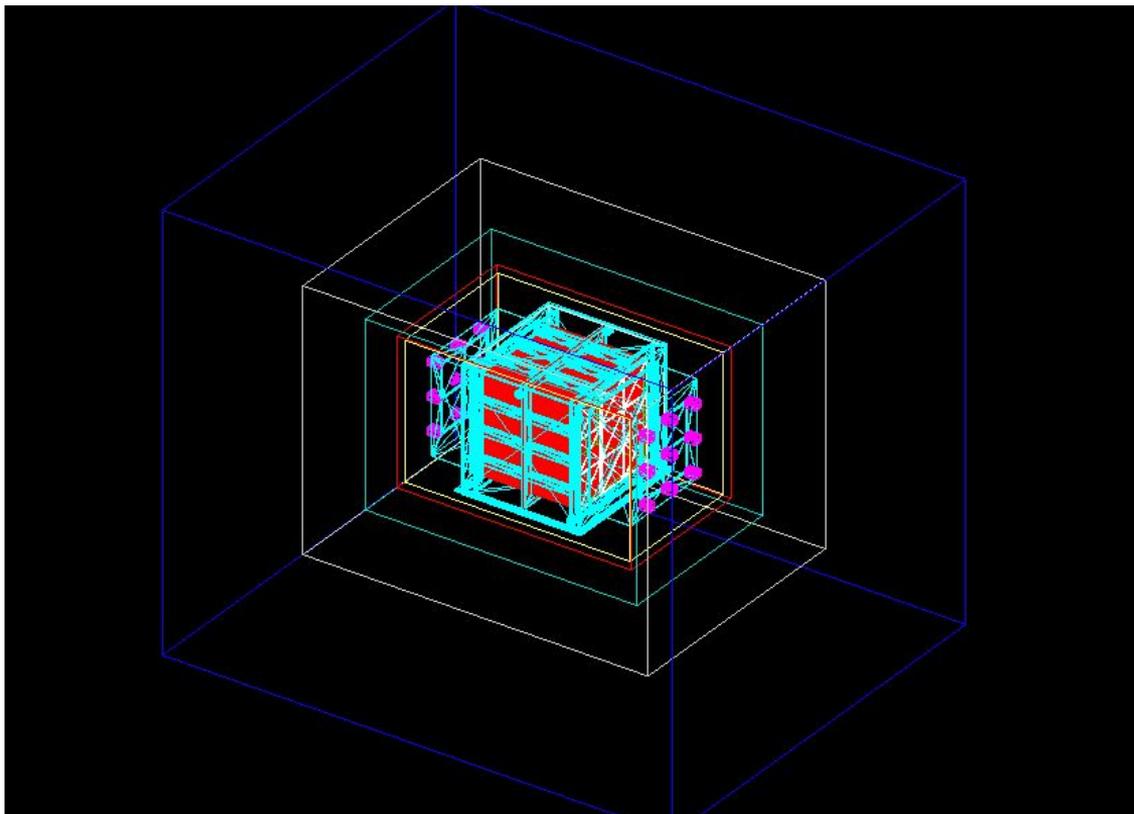
# Update CYGNO simulation

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Giulia D'Imperio

CYGNO meeting 19/07/19

# Geometry



Changes wrt last update

- Dimensions of the AirBox  
 $1.45 \times 1.45 \times 2.45 \text{ m}^3$
- Fiducial volume inside the field cage

# Shielding options

1. no shielding (for reference)
2. “DRIFT-like”: 50 cm water + 5 cm Cu
3. 50 cm water + 5 mm Cu
4. 50 cm water
5. 50 cm PE
- ... work in progress
6. 50 cm water + 5 cm Pb + 5 cm Cu
7. 50 cm water + 10 cm Pb + 2 cm Cu
8. 50 cm water + 5 cm Cu + 2 cm Steel (should be similar to the case of vessel made of steel)

# Table of shielding materials

Cost of materials:

- Cu : ~25 euro/kg
- Lead : ~5 euro/kg
- PE : ~5 euro/kg

50 cm water + 5 cm Cu

Volume	Material	Thickness [cm]	Mass [kg]	Cost [keuro]
Shield2	Water	50	16e3	-
Shield3	Cu	5	8.7e3	217.5

50 cm water + 5 mm Cu

Volume	Material	Thickness [cm]	Mass [kg]	Cost [keuro]
Shield2	Water	50	16e3	-
Shield3	Cu	0.05	830	20.75

50 cm water + 10 cm Pb + 2 cm Cu

Volume	Material	Thickness [cm]	Mass [kg]	Cost [keuro]
Shield1	Water	50	19e3	-
Shield2	Pb	10	24e3	120
Shield3	Cu	2	3.3e3	82.5

50 cm water + 5 cm Pb + 5 cm Cu

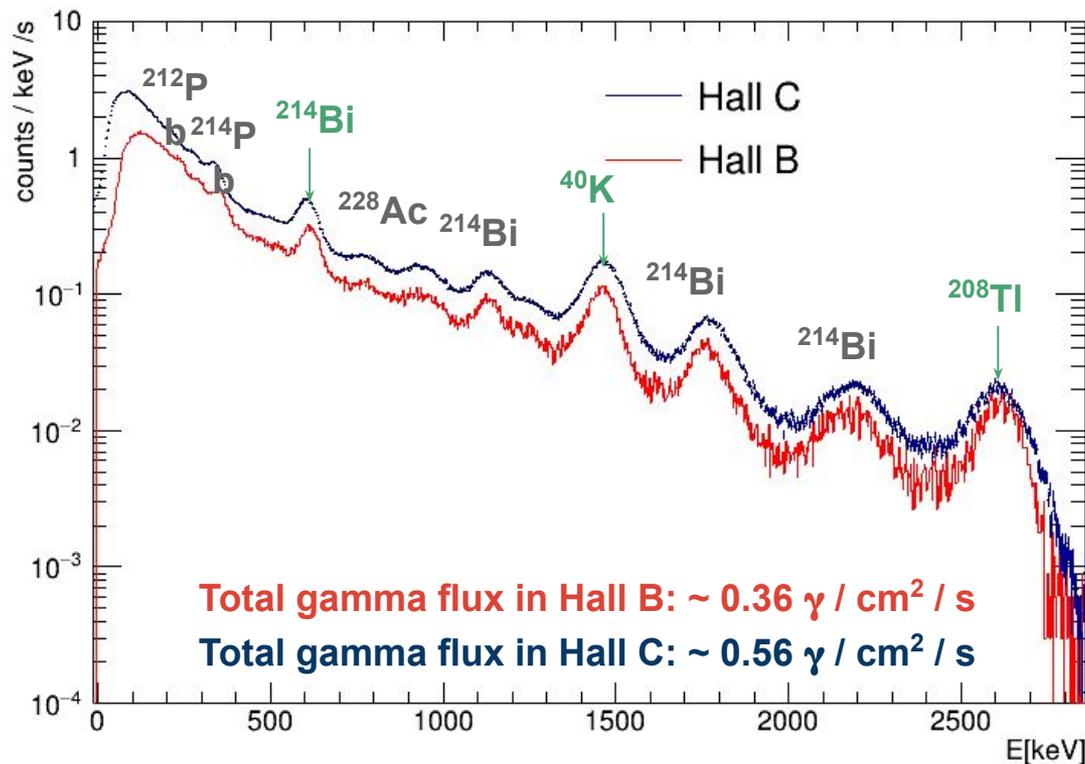
Volume	Material	Thickness [cm]	Mass [kg]	Cost [keuro]
Shield1	Water	50	16e3	-
Shield2	Pb	5	12e3	60
Shield3	Cu	5	8.7e3	217.5

only PE

Volume	Material	Thickness [cm]	Mass [kg]	Cost [keuro]
Shield3	PE	50	15e3	75

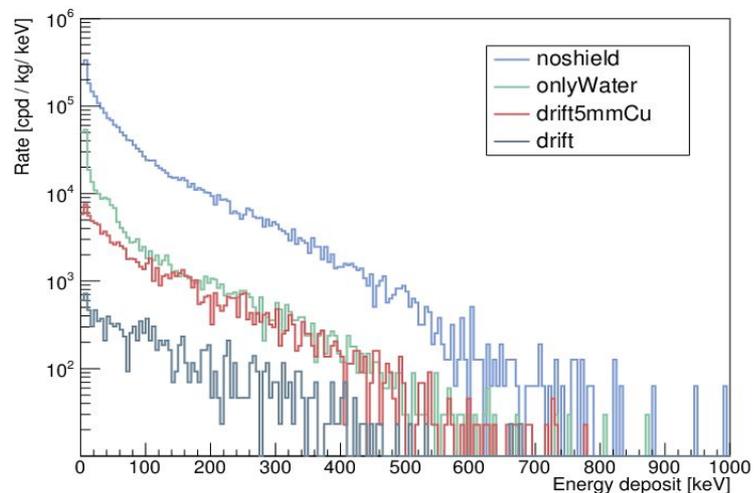
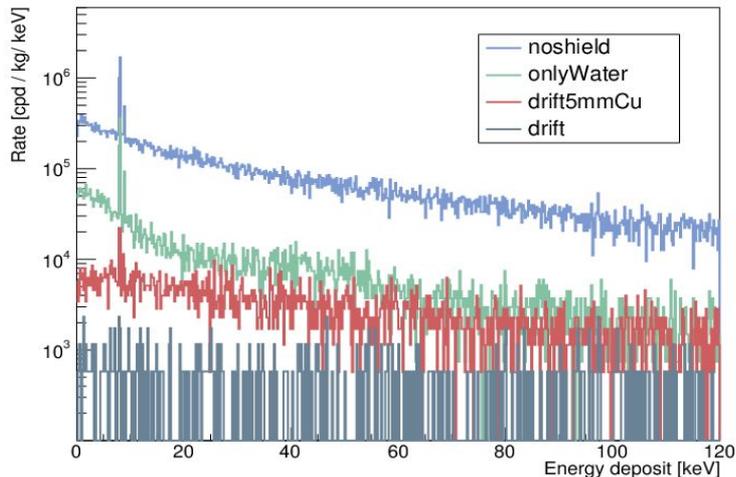
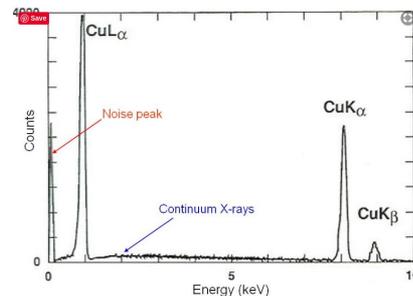
# Input gamma flux

- gamma from spherical surface
- isotropic direction
- energy spectrum from SABRE measurements
- integrated flux 0.56 gamma/cm<sup>2</sup>/s



# Expected background from external gamma

- Energy deposit in the CYGNO fiducial volume with different shielding options
- Normalized in counts/day/kg/keV
- Lines around 8-9 keV are Cu re-emission x-rays
- Expected rate in [0.20] keV for “drift” option is  $\sim 600$  cpd/kg/keV  
→  $\sim 6 \cdot 10^6$  counts/year

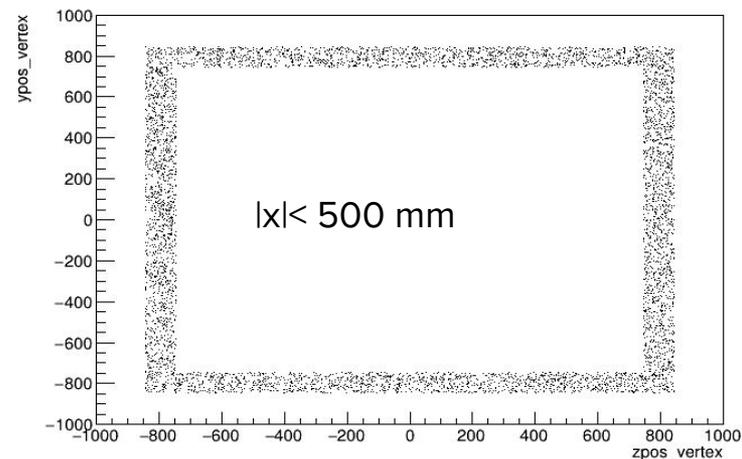
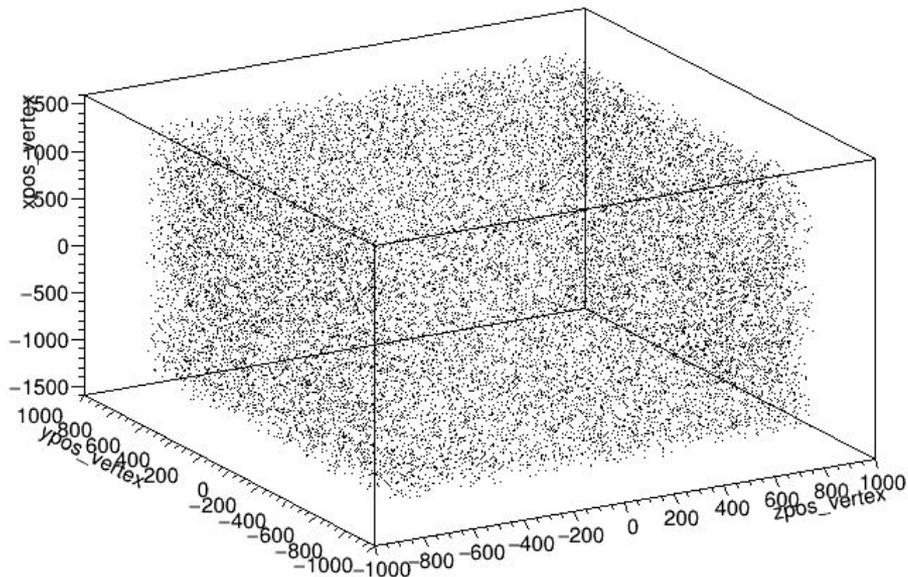


# Work in progress

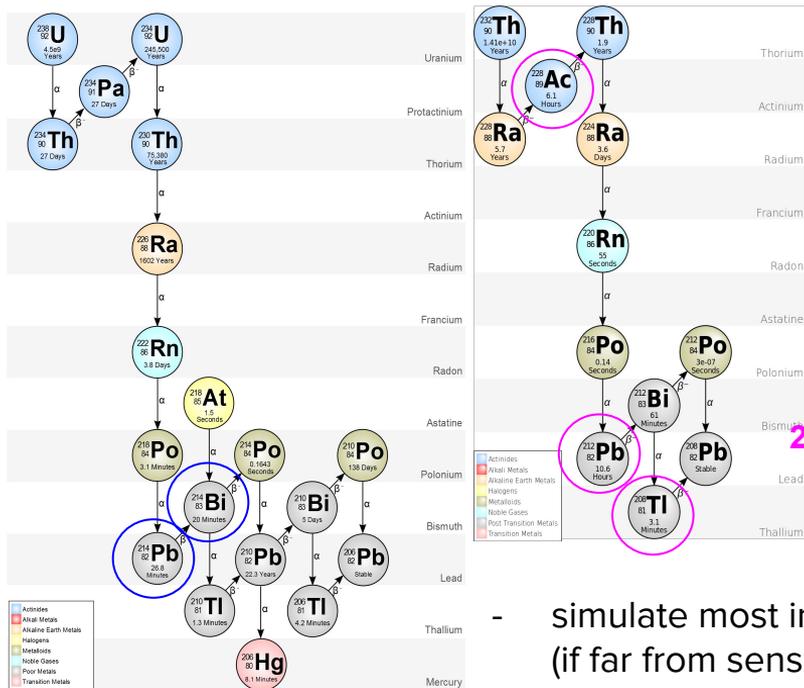
- Shielding of Pb+Cu (5+5, 10+2)
- Shielding of Cu and stainless steel (or replace acrylic box with steel vessel+acrylic )
- Simulation of radioactivity:
  - Pb of the shielding, check that radioactivity  $\ll$  external background
  - cameras with a copper shielding
    - need to be implemented in the Geant4 geometry
  - other internal background, starting from the parts close to sensitive volume
- Technical limitations:
  - Rome farm very inefficient,  $<50\%$  jobs successful → need babysitting
  - add shielding thickness → need more than  $10^{10}$  evts, 270B/evt → ~some TB
  - 1 TB left on the disk

# Simulation of radioactive decay in Pb shielding

Distribution of nuclei positions



# Simulation of radioactive decays



$^{40}\text{K}$

$^{238}\text{U}$ :

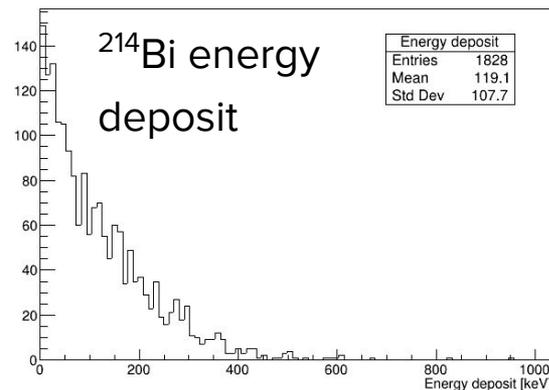
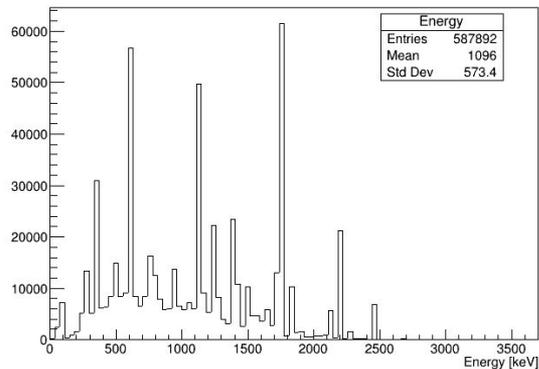
$^{214}\text{Bi}$   
 $^{214}\text{Pb}$

$^{232}\text{Th}$ :

$^{208}\text{Tl}$   
 $^{228}\text{Ac}$   
 $^{212}\text{Pb}$

- simulate most intense gamma emitters (if far from sensitive volume)
- simulate all the isotopes in the chain (if close to sensitive volume)
- normalize to the activity

example:  $^{214}\text{Bi}$  spectrum



# Radioactivity of materials

#	Material,Supplier	Method	Unit	<sup>238</sup> U	<sup>226</sup> Ra	<sup>232</sup> Th	<sup>228</sup> Th	<sup>235</sup> U	<sup>40</sup> K	<sup>60</sup> Co	<sup>137</sup> Cs
1	Pb, Mifer	GDMS	mBq/kg	0.33		0.10			1.2		
2	OFE Cu, Luvata	GDMS	mBq/kg	<0.012		<0.0041			0.061		
3	ETP Cu, Sanmetal	GDMS	mBq/kg	<0.062		<0.020					
4	ETP Cu, Sanmetal	Ge Oroel	mBq/kg	<27	<1.0	<1.1	<0.76	<0.56	<3.1	0.24±0.05	<0.29
5	PFA tube, Emtecnik	Ge Paquito	mBq/m	<31	<0.58	<0.53	<0.34	<0.29	<2.6	<0.16	<0.18
6	PTFE tube, Tecnyfluor	Ge Paquito	mBq/m	<19	<0.48	<0.54	<0.41	<0.26	<2.5	<0.14	<0.17
7	Kapton-Cu PCB, LabCircuits	Ge Paquito	μBq/cm <sup>2</sup>	<42	<1.3	<1.1	<0.66	<0.41	<4.0	<0.24	<0.28
8	Epoxy Hysol, Henkel	Ge Paquito	mBq/kg	<273	<16	<20	<16		<83	<4.2	<4.5
9	SM5D resistor, Finechem	Ge Paquito	mBq/pc	0.4±0.2	0.022±0.007	<0.023	<0.016	0.012±0.005	0.17±0.07	<0.005	<0.005
10	Mylar, Goodfellow	Ge Paquito	μBq/cm <sup>2</sup>	<29	<0.59	<0.80	<0.36	<0.29	<3.3	<0.18	<0.21
11	Nylon (3D printer), CNM	Ge Latuca	mBq/kg	<436	<9.2	<11	<3.4	<2.6	<29	<1.0	<1.2
12	Nylon (3D printer), CNM	ICPMS	mBq/kg	36		2.9					
13	Teflon, Sanmetal	ICPMS	mBq/kg	<0.062		<0.041					
14	Extruded PTFE, Gore	ICPMS	mBq/kg	<0.124		<0.041					
15	Gold connectors, Fujipoly	Ge Paquito	mBq/pc	<25	4.45±0.65	1.15±0.35	0.80±0.19		7.3±2.6	<0.1	<0.4
16	Silver connectors, Fujipoly	Ge Paquito	mBq/pc	<55	5.68±0.81	6.1±1.1	6.17±0.72		12.2±3.8	<0.3	<0.3
17	Carbon connectors, Fujipoly	Ge Paquito	mBq/pc	14.5±6.0	2.77±0.38	1.17±0.23	1.14±0.14		7.5±2.3	<0.1	<0.1
18	Final Gold connectors, Fujipoly	Ge Paquito	mBq/pc	<12	2.80±0.38	0.49±0.10	0.58±0.09		5.3±1.6	<0.08	<0.07
19	Kapton connectors, Samtec	Ge Paquito	mBq/pc	<3.6	<0.065	<0.072	<0.040	0.043±0.015	<0.32	<0.020	<0.021
20	Flat cable, Somacis	Ge Paquito	mBq/pc	<14	0.44±0.12	<0.33	<0.19	<0.19	1.8±0.7	<0.09	<0.10
21	Teflon cable, Druflon	Ge Paquito	mBq/kg	<104	<2.2	<3.7	< 1.7	<1.4	21.6±7.4	<0.7	<0.8
22	Coaxial cable, Axon	Ge Paquito	mBq/kg	<650	<24	<15	<9.9	<7.9	163±55	<4.3	<5.1
23	Electronic board, CEA	Ge Paquito	Bq/kg	94±38	41.4±5.6	59±10	53.6±7.4		19.5±6.1	<0.67	<1.1
24	AGET chips, CEA	Ge Paquito	mBq/pc	<8.7	0.48±0.07	0.16±0.06	0.47±0.09		0.83±0.29	<0.04	<0.04
25	Ceramic AGET chips, CEA	Ge Paquito	mBq/unit	(0.64±0.24)10 <sup>3</sup>	539±94	116±20	113±21		43±14	<2.2	
26	Classical micromegas, CAST	Ge Paquito	μBq/cm <sup>2</sup>	<40		4.6±1.6		<6.2	<46	<3.1	
27	Microbulk MM, CAST	Ge Paquito	μBq/cm <sup>2</sup>	26±14		<9.3		<14	57±25	<3.1	
28	Kapton-Cu foil, CERN	Ge Paquito	μBq/cm <sup>2</sup>	<11		<4.6		<3.1	<7.7	<1.6	
29	Cu-kapton-Cu foil, CERN	Ge Paquito	μBq/cm <sup>2</sup>	<11		<4.6		<3.1	<7.7	<1.6	
30	Microbulk MM, CERN	Ge Latuca	μBq/cm <sup>2</sup>	<49	<0.70	<1.2	<0.35	<0.22	<2.3	<0.14	<0.13
31	Micromegas GEM, CERN	Ge Oroel	μBq/cm <sup>2</sup>	<5.2	<0.10	<0.22	<0.08	<0.03	3.45±0.40	<0.02	<0.02
32	Micromegas GEM 1 <sup>st</sup> cleaning	Ge Oroel	μBq/cm <sup>2</sup>	7.41±0.81	<0.21	0.19±0.05	<0.11	0.36±0.04	0.84±0.16	<0.02	<0.03
33	Micromegas GEM 2 <sup>nd</sup> cleaning	Ge Oroel	μBq/cm <sup>2</sup>	7.87±0.89	<0.17	0.14±0.04	0.07±0.02	0.36±0.04	0.81±0.15	<0.03	<0.02
34	Pyralux, Saclay	Ge Paquito	μBq/cm <sup>2</sup>	<19	<0.61	<0.63	<0.72	<0.19	4.6±1.9	<0.10	<0.14
35	Isotac adhesive, 3M	Ge Paquito	μBq/cm <sup>2</sup>	<18	<0.45	<0.43	<0.22	<0.18	<2.3	<0.10	<0.14
36	Stainless steel mesh	Ge Paquito	μBq/cm <sup>2</sup>	<53	<1.5	<1.7	<0.9	<0.6	<8.7	<0.3	<0.5
37	Micromegas, CNM	Ge Paquito	μBq/cm <sup>2</sup>	<462	<10	<11	<6.3	<4.5	<61	<3.8	<3.7
#	Material,Supplier	Method	Unit		<sup>214</sup> Bi	<sup>208</sup> Tl					
38	Microbulk MM, CAST	BiPo-3	μBq/cm <sup>2</sup>		<0.134	<0.035					
39	Cu-kapton-Cu foil, CERN	BiPo-3	μBq/cm <sup>2</sup>		<0.141	<0.012					
40	Microbulk MM, CERN	BiPo-3	μBq/cm <sup>2</sup>		<0.045	<0.014					
41	Kapton-epoxy foil, CERN	BiPo-3	μBq/cm <sup>2</sup>		<0.033	<0.008					
42	Pyralux foil, Saclay	BiPo-3	μBq/cm <sup>2</sup>		<0.032	<0.013					

From T-REX screening campaign

<http://arxiv.org/abs/1812.04519v1>

# Radioactivity of cameras

- Radioactivity of cameras measured @LNGS
- implement in geometry cameras in 2(3) parts: body, objective (shielding)

sample: camera, Hamamatsu, orca-flash4.0,  
2.1275 kg, CYGNO

Th-232:  
Ra-228: (2.1 +- 0.2) Bq/pc  
Th-228: (2.1 +- 0.1) Bq/pc

U-238:  
Ra-226 (1.8 +- 0.1) Bq/pc  
Pa-234m (7 +- 2) Bq/pc

U-235: (0.4 +- 0.1) Bq/pc

K-40: (1.9 +- 0.3) Bq/pc

Cs-137: (0.09 +- 0.03) Bq/pc

Co-60: < 0.012 Bq/pc

sample: objective of Hamamatsu orcaflash4.0,  
213.5 g (with plastic cap), CYGNO

Th-232:  
Ra-228: (0.077 +- 0.009) Bq/pc  
Th-228: (0.078 +- 0.006) Bq/pc

U-238:  
Ra-226 (0.41 +- 0.02) Bq/pc  
Pa-234m (0.9 +- 0.3) Bq/pc

U-235: (0.031 +- 0.008) Bq/pc

K-40: (11 +- 1) Bq/pc

Cs-137: < 0.0057 Bq/pc

Co-60: < 0.0099 Bq/pc

La-138: (0.52 +- 0.04) Bq/pc

# Summary

- Fix shielding geometry so that external gamma bkg  $\ll$  internal
  - need estimate also internal background
  - evaluate first the most radioactive parts (cameras), and parts close to the sensitive volume
- Reference number: total bkg goal for Cygnus  $<10^4$  evt/yr @  $E < 10$  keV
  - assuming discrimination power  $\sim 10^4$  in this energy region
- work in progress:
  - more efficient external gamma simulation
  - implement the geometry of cameras+shielding in Geant4
  - simulation of radioactive decays + analysis