Simulations for BULLKID-DM

January 15th 2025

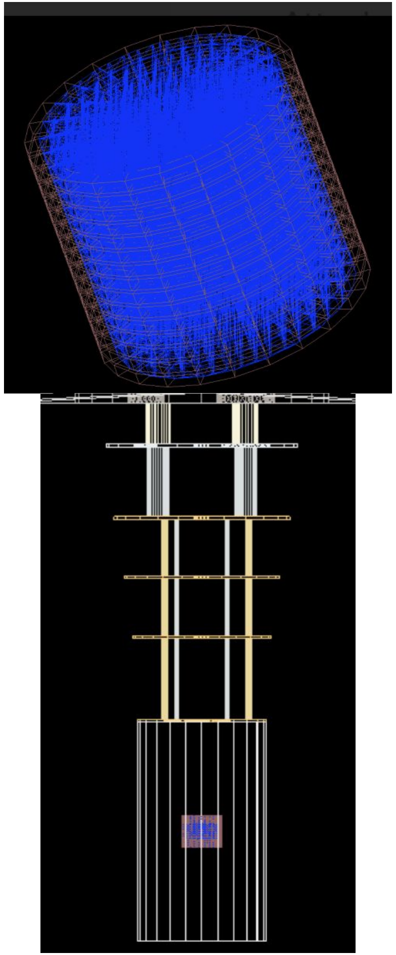
Backgrounds

- Cosmogenic - shielded by rock of LNGS
- Radiogenic - come from the ^{238}U, ^{232}Th and ^{40}K decay chains
- Internal - come from components and materials used in the experimental setup

- Monte Carlo simulations in Geant4 are being done to estimate the contribution of the background for gammas, the main background for BULLKID
  - gamma energy in the hall (https://doi.org/10.1140/epja/i2009-10805-7)
  - radionuclide in Lead (OPERA_Pb.txt)

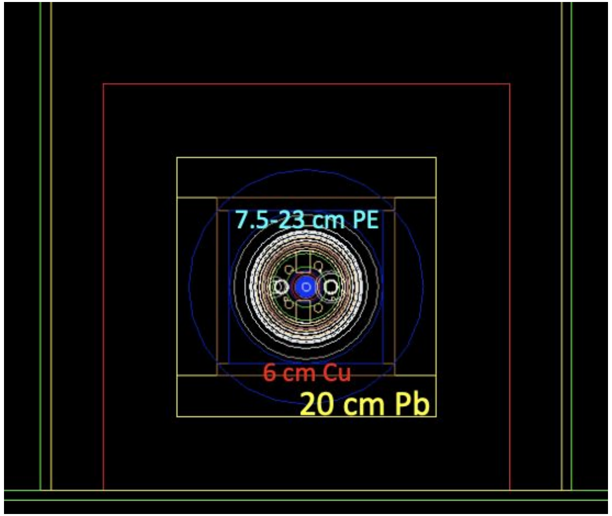
Gran Sasso setup

- 617.37 g in 15 Si wafers
    - Wafers:
        - radius 5 cm
        - thickness 5 mm
- Gran Sasso cryostat
- Room temperature and cold shielding

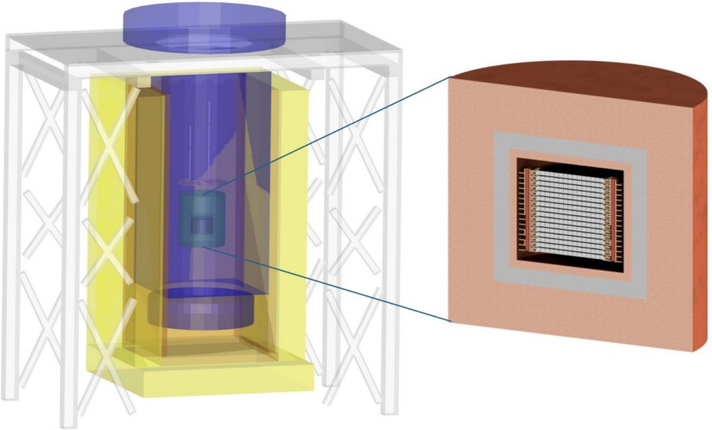


Shielding

- Room temperature shielding
  - Lead
  - Copper
  - Polyethylene
- Cold shielding
  - Copper
  - B_4C



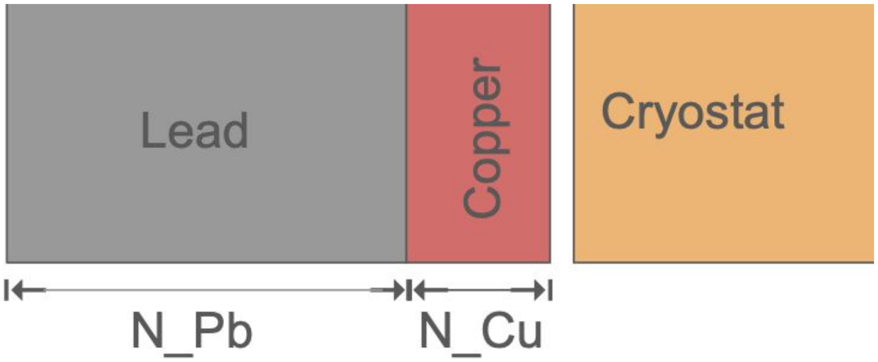
Nominal shielding



Backgrounds for room temperature shielding

- Simulations per gamma energy in the Hall
- Simulations per radionuclide in Lead

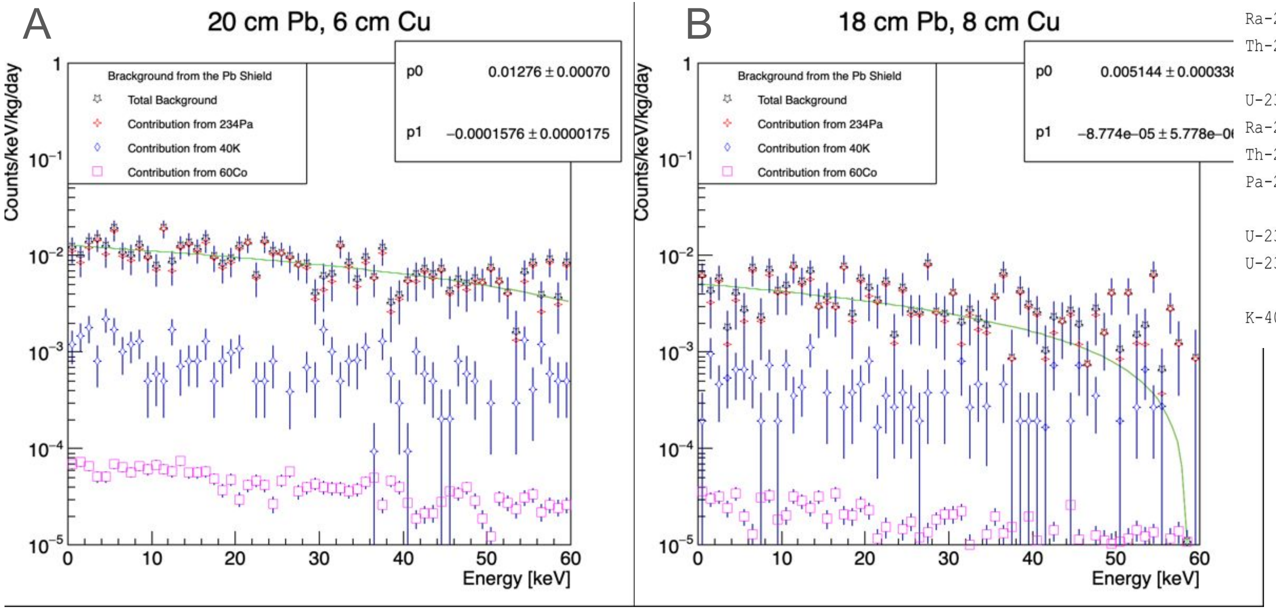
Isotope	Energy [keV]	Intensity [γ/m^2/day]
^{208}Tl	2614	7.8×10^6
^{214}Bi	2204	3.1×10^6
^{214}Bi	1764	8.2×10^6
^{40}K	1460	2.9×10^7
^{214}Bi	1238	2.8×10^6
^{214}Bi	1120	6.3×10^6
^{228}Ac	968	2.1×10^6



C. Bucci et al., *Eur. Phys. J. A* **41**, 155–168 (2009)

Backgrounds for room temperature shielding (Lead block)

- Two examples

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sample:         39 lead sheets OPERA
weight:         5.4149 kg
live time:              1424949 s
detector:               GeCris

radionuclide concentrations:

Th-232:
Ra-228:         < 0.18 mBq/kg           <==>    < 4.4 E-11 g/g
Th-228:         < 0.46 mBq/kg           <==>    < 1.1 E-10 g/g

U-238:
Ra-226          < 0.12 mBq/kg           <==>    < 9.6 E-12 g/g
Th-234          < 2.5 mBq/kg            <==>    < 2.0 E-10 g/g
Pa-234m         < 8.0 mBq/kg            <==>    < 6.5 E-10 g/g

U-235:
U-235:          < 6.7 mBq/kg            <==>    < 1.2 E-8 g/g

K-40:           < 1.8 mBq/kg            <==>    < 5.9 E-8 g/g
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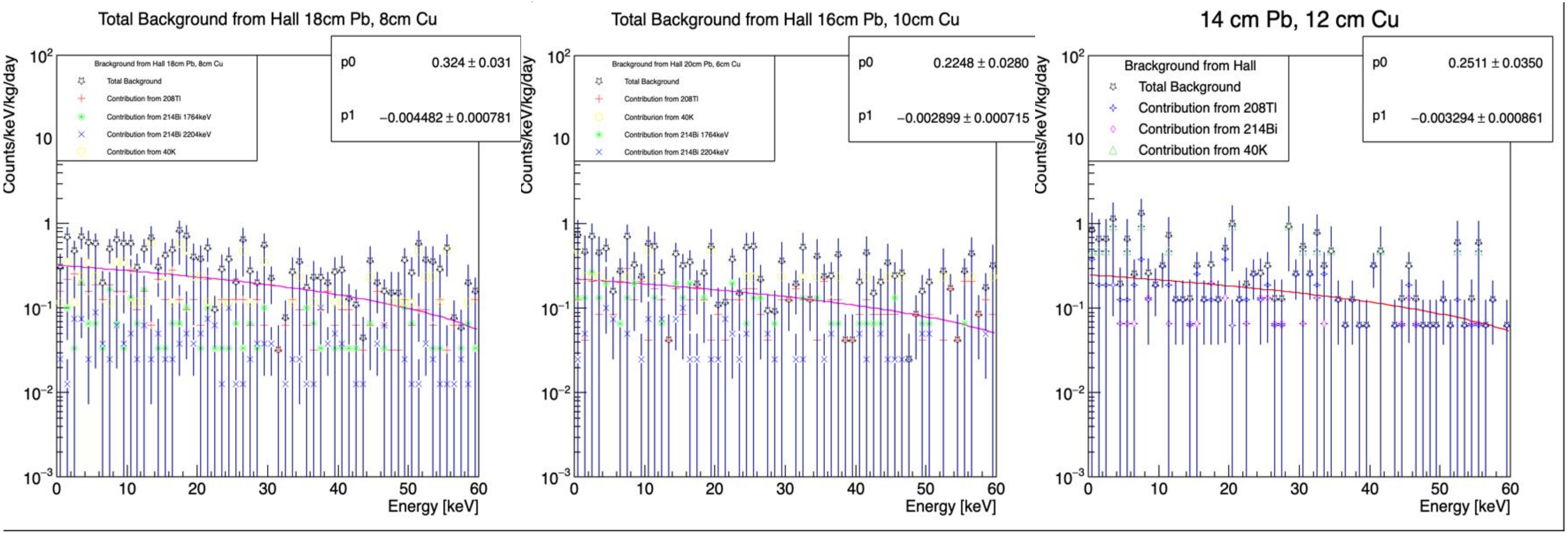
A	1E-2
B	5E-3

Backgrounds for room temperature shielding (Hall)

- Three examples of different dimensions for the Lead and Copper shielding
- We could use no Lead!



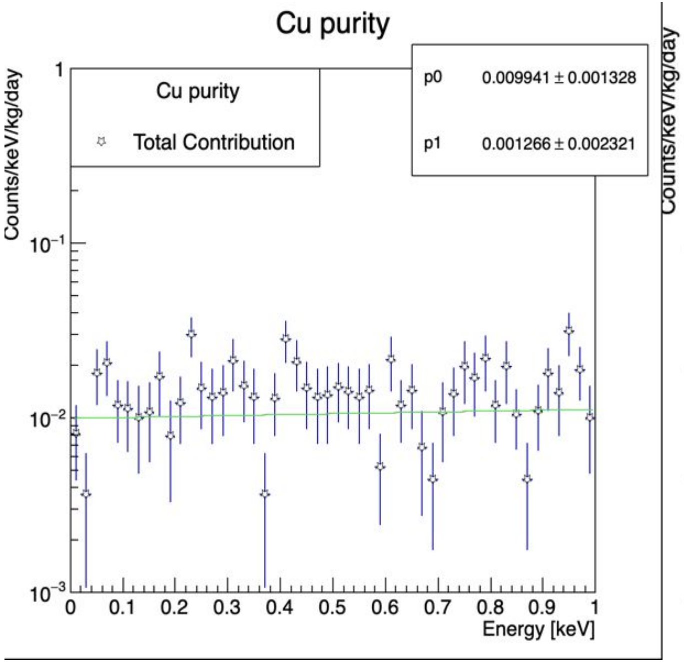
Backgrounds for room temperature shielding

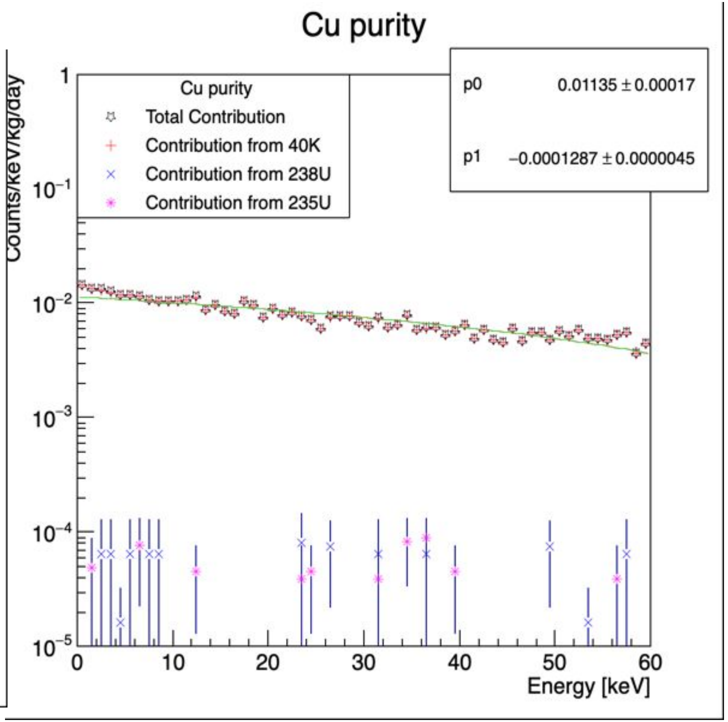
- How much Lead and Copper?

Lead thickness [cm]	Lead mass [T]	Copper thickness [cm]	Copper mass [T]
20	23.68	6	3.9
18	21.65	8	5.36
16	19.54	10	6.91
14	17.36	12	8.55
12	15.1	14	10.28
0	0	26	22.01

Copper Purity: assuming 6 cm of Cu thickness

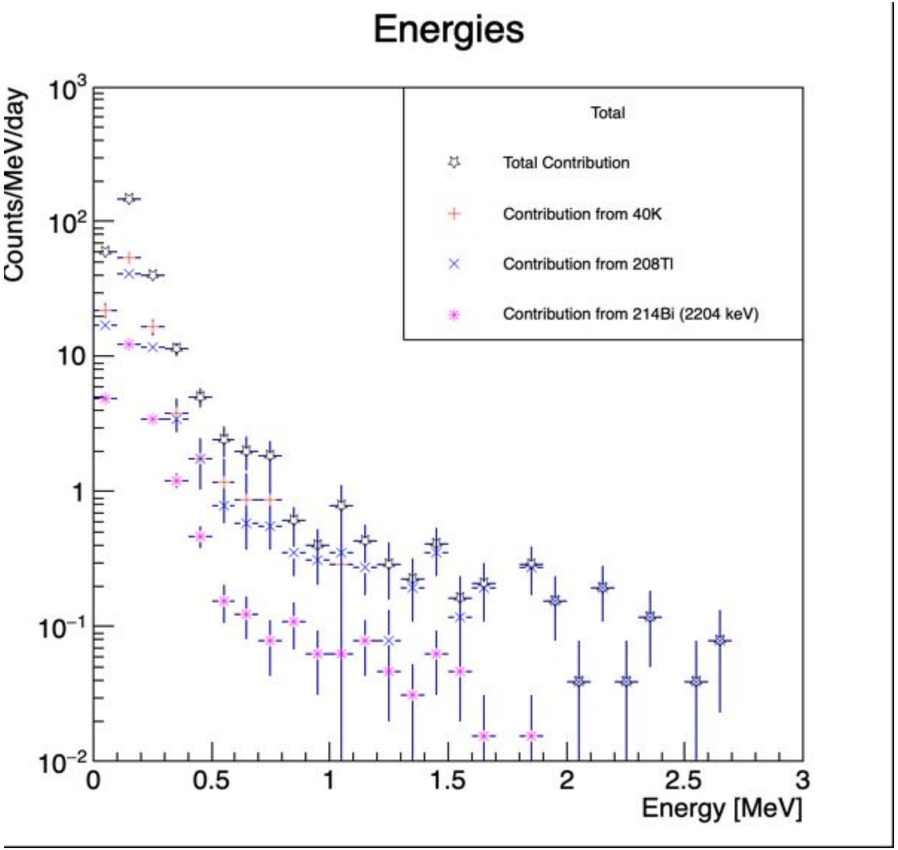
- ^{40}K < 1.4 mBq/kg
- ^{238}U ≤ 10 mBq/kg
- ^{235}U ≤ 6 mBq/kg





Gran Sasso is requesting information about energies above BULLKID ROI, so simulations were also done up to 3 MeV

- 20 cm Pb
- 6 cm Cu



Conclusions and next steps

- Room temperature shielding can be only Copper or Copper and Lead
- Background to at least 10^{-2} dru, the upper limit for Lead thickness is 18 cm
- Limits for the presence of ^{40}K, ^{238}U and ^{235}U in the high purity Copper (for ^{232}Th more simulations are needed)
    - $^{40}K < 1.4$ mBq/kg
    - $^{238}U \leq 10$ mBq/kg
    - $^{235}U \leq 6$ mBq/kg
- Next: optimize height for the room temperature shielding
- Working on simulations for cold shielding