LIME background simulation

CYGNO general meeting – 3/06/2021

F. Di Giambattista

LIME background rate calculation

- Simulation of LIME external background underground at LNGS (gamma and neutron external flux)
- Internal background was already *partially* simulated – we assume a rate of 0.5-1×10^5 events/yr
- Different shielding configurations:
  - No shield (air)
  - 5cm Cu
  - 10cm Cu / 5cm Pb + 5cm Cu
  - 40cm water + 10cm Cu / 40cm water + 5cm Pb + 5cm Cu
- Motivation:
  - To assess the best shielding configuration for underground operation (Lead vs Copper)
  - To verify the feasibility of the use of the new camera acquisition mode for the DAQ

5cm Cu vs no shield

- **No shield**

External gammas (0.56 cm^{-2} s^{-1})
(ER): (9.4±0.3)×10^{8} events/yr (total)
(ER): (3.5±0.2)×10^{8} events/yr (0-20 keV)

External neutrons (2.7×10^{-6} cm^{-2} s^{-1})
(ER+NR): (4088±130) events/yr (total)
(ER+NR): (2616±105) events/yr (0-20 keV)
(Only NR): (1480±80) events/yr (total)
(Only NR): (460±50) events/yr (0-20 keV)

- **5cm copper**

External gammas (0.56 cm^{-2} s^{-1})
(ER): (5.1±0.7)×10^{7} events/yr (total)
(ER): (1.6±0.4)×10^{7} events/yr (0-20 keV)

External neutrons (2.7×10^{-6} cm^{-2} s^{-1})
(ER+NR): (7180±170) events/yr (total)
(ER+NR): (3180±110) events/yr (0-20 keV)
(Only NR): (1300±70) events/yr (total)
(Only NR): (680±50) events/yr (0-20 keV)

5cm (Pb/Cu) + 5cm Cu

- **10cm copper**

External gammas (0.56 cm^{-2} s^{-1})
(ER): (4.05±0.07)×10^6 events/yr (total)
(ER): (8.0±0.3)×10^5 events/yr (0-20 keV)

External neutrons (2.7×10^{-6} cm^{-2} s^{-1})
(ER+NR): (2850±45) events/yr (total)
(ER+NR): (1590±30) events/yr (0-20 keV)
(Only NR): (895±20) events/yr (total)
(Only NR): (509±15) events/yr (0-20 keV)

With Cu: **8.0×10^5 ER/yr** (0-20keV)
With Pb: **2.3×10^5 ER/yr** (0-20keV)
Internal background:
0.5-1.0×10^5 ER/yr (0-20keV)

- **5cm lead + 5cm copper**

External gammas (0.56 cm^{-2} s^{-1})
(ER): (1.15±0.05)×10^6 events/yr (total)
(ER): (2.1±0.2)×10^5 events/yr (0-20 keV)

External neutrons (2.7×10^{-6} cm^{-2} s^{-1})
(ER+NR): (6000±160) events/yr (total)
(ER+NR): (2610±104) events/yr (0-20 keV)
(Only NR): (1180±70) events/yr (total)
(Only NR): (580±50) events/yr (0-20 keV)

Radioactivity from 210Bi*:
(ER): (6.6±0.5)×10^4 events/yr (total)
(ER): (2.1±0.3)×10^4 events/yr (0-20 keV)

OPERA lead: *(80Bq/kg×5658.7kg of lead = 452693 Bq)

40cm Water + 5cm (Pb/Cu) + 5cm Cu

- **40cm water + 10cm copper**

External gammas (0.56 cm^{-2} s^{-1})
(ER): (4.2±0.2)×10^5 events/yr (total)
(ER): (9.1±1.0)×10^4 events/yr (0-20 keV)

External neutrons (2.7×10^{-6} cm^{-2} s^{-1})
(ER+NR): (18.5±1.0) events/yr (total)
(ER+NR): (5.3±0.5) events/yr (0-20 keV)
(Only NR): (1.9±0.2) events/yr (total)
(Only NR): (1.1±0.1) events/yr (0-20 keV)

With Cu: **9.1×10^4 ER/yr** (0-20keV)
With Pb: **3.7×10^4 ER/yr** (0-20keV)
Internal background:
0.5-1.0×10^5 ER/yr (0-20keV)

- **40cm water + 5cm lead + 5cm copper**

External gammas (0.56 cm^{-2} s^{-1})
(ER): (1.5±0.2)×10^5 events/yr (total)
(ER): (1.6±0.7)×10^4 events/yr (0-20 keV)

External neutrons (2.7×10^{-6} cm^{-2} s^{-1})
(ER+NR): (13.2±0.2) events/yr (total)
(ER+NR): (5.6±0.1) events/yr (0-20 keV)
(Only NR): (2.73±0.07) events/yr (total)
(Only NR): (1.50±0.05) events/yr (0-20 keV)

Radioactivity from 210Bi*:
(ER): (6.6±0.5)×10^4 events/yr (total)
(ER): (2.1±0.3)×10^4 events/yr (0-20 keV)

OPERA lead: *(80Bq/kg×5658.7kg of lead = 452693 Bq)

40cm Water + 5cm Pb + 5cm Cu

Giulia did a cross-check on my simulation of this shielding configuration and found a bug – now it's fixed

CYGNO-MC-Analysis run on Giulia's sim:

- Equivalent time of this simulation:
  t_eq = 0.116643 days
  Flux after 40cm water: 0.0407 $cm^{-2}s^{-1}$
  (ER): 1.4 x 10^5 evts/yr (total)
  (ER): (2.8 +/- 0.9) x 10^4 evts/yr (0-20) keV

- **40cm water + 5cm lead + 5cm copper**

External gammas (0.56 cm^{-2} s^{-1})
Time equivalent **0.112269 days**
Flux after 40cm of water: 0.04075 $cm^{-2}s^{-1}$
(ER): $(1.5\pm0.2)\times10^5$ events/yr (total)
(ER): $(1.6\pm0.7)\times10^4$ events/yr (0-20 keV)

The results are consistent

40cm Water + 5cm (Pb/Cu) + 5cm Cu

- **40cm water + 10cm copper**

External gammas (0.56 cm^{-2} s^{-1})
(ER): $(4.2\pm0.2)\times10^5$ events/yr (total)
(ER): $(9.1\pm1.0)\times10^4$ events/yr (0-20 keV)

External neutrons (2.7×10^{-6} cm^{-2} s^{-1})
(ER+NR): (18.5±1.0) events/yr (total)
(ER+NR): (5.3±0.5) events/yr (0-20 keV)
(Only NR): (1.9±0.2) events/yr (total)
(Only NR): (1.1±0.1) events/yr (0-20 keV)

With Cu: **9.1×10^4 ER/yr** (0-20keV)
With Pb: **9.6×10^4 ER/yr** (0-20keV)
Internal background:
$0.5\text{-}1.0\times10^5$ ER/yr (0-20keV)

- **40cm water + 5cm lead + 5cm copper**

External gammas (0.56 cm^{-2} s^{-1})
(ER): $(1.5\pm0.2)\times10^5$ events/yr (total)
(ER): $(1.6\pm0.7)\times10^4$ events/yr (0-20 keV)

External neutrons (2.7×10^{-6} cm^{-2} s^{-1})
(ER+NR): (13.2±0.2) events/yr (total)
(ER+NR): (5.6±0.1) events/yr (0-20 keV)
(Only NR): (2.73±0.07) events/yr (total)
(Only NR): (1.50±0.05) events/yr (0-20 keV)

Radioactivity from 210Bi*:
(ER): $(2.5\pm0.2)\times10^5$ events/yr (total)
(ER): $(8\pm1)\times10^4$ events/yr (0-20 keV)

***(300Bq/kg×5658.7kg of lead = 1697610 Bq)**

Summary

*Internal background (ER) is set to 1×10^{5} ER/yr = 0.00317 ER/s
**Internal background (NR) is set to 282 NR/yr = 8.9×10^{-6} NR/s

Shielding	Rate (external)				Total rate (ext + int)	
	[ER/s]	[ER/yr]	[NR/s]	[NR/yr]	[ER+NR/s]	[ER+NR/yr]
No shield	28.9	9×10^{8}	4.7×10^{-5}	1480	**28.9**	**9×10^{8}**
5cm Cu	1.6	5×10^{7}	4.1×10^{-5}	1300	**1.6**	**5×10^{7}**
10cm Cu	0.13	4×10^{6}	2.8×10^{-5}	895	**0.13**	**4.1×10^{6}**
5cm Pb+5cm Cu	0.039	1.2×10^{6}	3.7×10^{-5}	1180	**0.042**	**1.3×10^{6}**
40cm water+10cm Cu	0.013	4×10^{5}	6.0×10^{-8}	1.9	**0.016**	**5×10^{5}**
40cm water+5cm Pb+5cm Cu	0.007	2×10^{5}	8.7×10^{-8}	2.7	**0.01**	**3×10^{5}**

**calculated in 0-20 keV – total rate could be higher*
***from CYGNO simulations, scaled to 1/18*

Conclusions

- The (OPERA) **lead** shield seems to lead to a lower background rate (unlike the case of CYGNO, where radioactivity is more significant)
  - With *higher* radioactivity lead, the background rate can reach the same order of magnitude obtained with copper (same order of the internal background, 10^5 events/yr)
- The event rate without shielding is 30 events/second, down to 1-2 events/second with 5cm copper, and lower than 1 event/second with any other additional shielding
- *To do*: full internal background simulation, including the field cage resistors