LIME background simulation summary

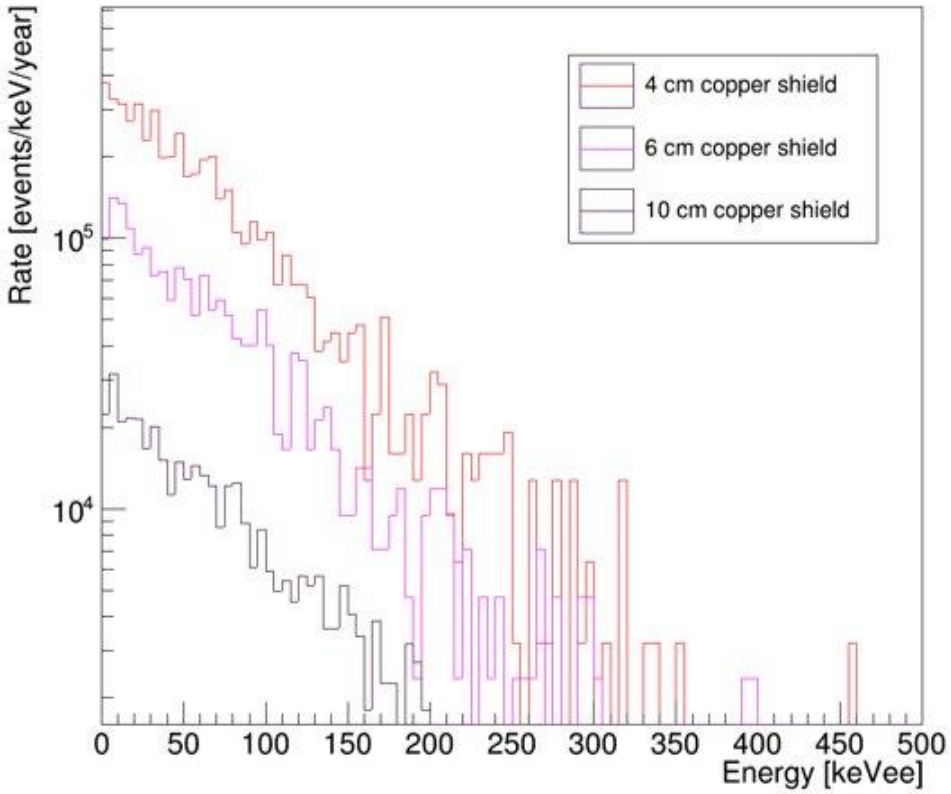
CYGNO simulation meeting – 28/11/2022

F. Di Giambattista

LIME background components

- **External background:**
  - Gamma and neutrons from the lab environment
    - Simulated with different shield thicknesses: no shield, 4cm, 6cm, 10cm of copper, 40cm water + 10cm copper
- **Internal background**:
  - Radioactivity of cathode, GEMs, field rings, resistors, acrylic box, camera body and camera lens
  - Radioactivity of the copper shielding (main contributor ^{210}Bi): simulated for 4cm, 6cm, 10cm
- Radiogenic neutrons (SOURCES4C + GEANT4)
  - (alpha,n) and spontaneous fission induced neutrons (SOURCES4C) then used as input in GEANT4
- Cosmogenic neutrons: neutrons produced by muons interacting in the detector, to be assessed; back of the envelope calculation:
  - From cross section measurements of muon spallation on different targets we can expect O(1e-3) neutrons/mu/(g/cm^3), which corresponds to 3e-10 n/s/cm^3 from our copper shielding, 16 times larger than the radiogenic neutrons flux (less then ~10 NR/yr)

External gammas



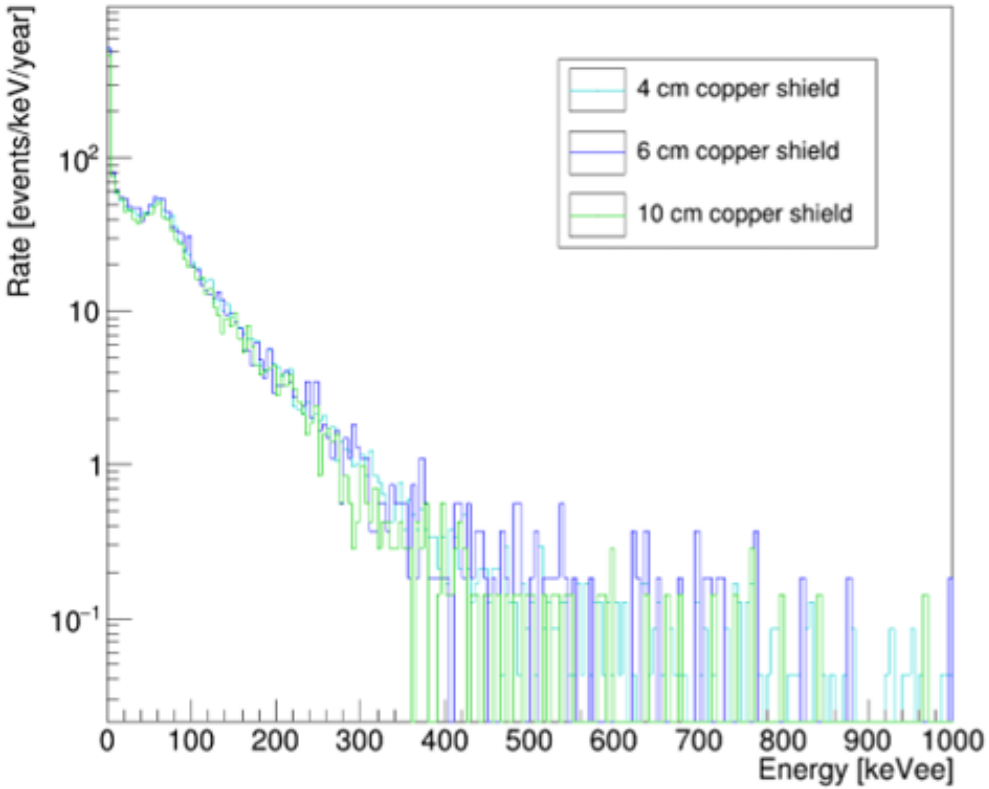
No shield:
$1.15(4)\times10^9$ ER/yr in 0-3000 keV
$1.13(4)\times10^9$ ER/yr in 1-3000 keV
$4.1(2)\times10^8$ ER/yr in 1-20 keV

4cm copper:
2.68×10^7 ER/yr in 0-3000 keV
2.64×10^7 ER/yr in 1-3000 keV
6.2×10^6 ER/yr in 1-20 keV

6cm copper:
9.56×10^6 ER/yr in 0-3000 keV
9.40×10^6 ER/yr in 1-3000 keV
2.35×10^6 ER/yr in 1-20 keV

10cm copper:
1.97×10^6 ER/yr in 0-3000 keV
1.95×10^6 ER/yr in 1-3000 keV
4.7×10^5 ER/yr in 1-20 keV

External neutrons



No shield:
1810 NR/yr in 0-3000 keV
1450 NR/yr in 1-3000 keV
350 NR/yr in 1-20 keV

4cm copper:
1020(15) NR/yr in 0-3000 keV
850 NR/yr in 1-3000 keV
410 NR/yr in 1-20 keV

6cm copper:
1190 NR/yr in 0-3000 keV
980 NR/yr in 1-3000 keV
495 NT/yr in 1-20 keV

10cm copper:
1130 NR/yr in 0-3000 keV
915 NR/yr in 1-3000 keV
550 NR/yr in 1-20 keV

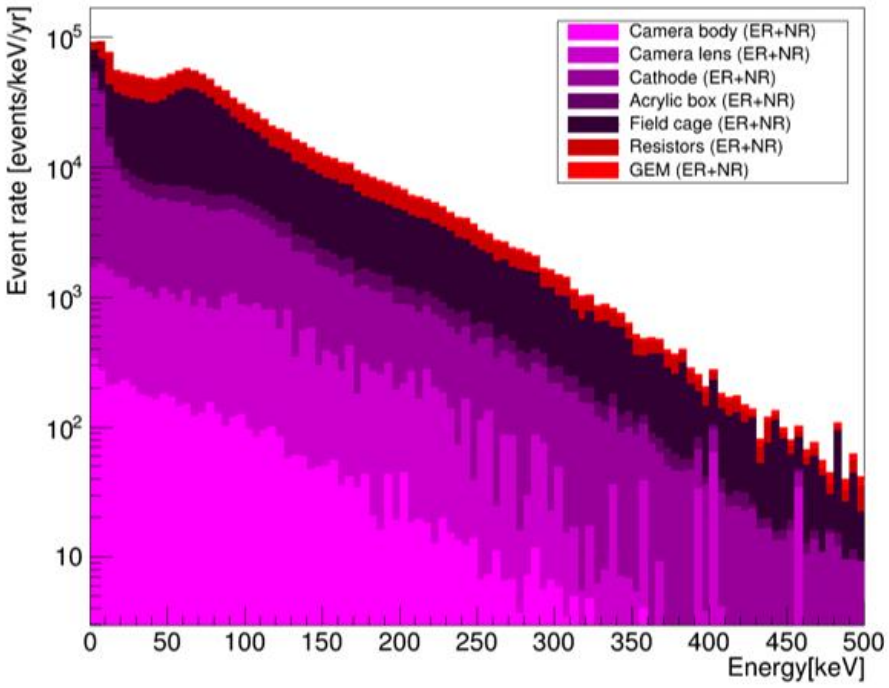
Internal background

- All main components of the detector were measured underground at LNGS by M.Laubestein
- For each isotope in the chains I simulated the induced background in the detector

	Radionuclide	FieldRings	Cathode	Resistors	GEM	Acrylic	Camera body	Camera lens
^{238}U chain	234Th	<2,10E-01	<2,10E-01	1,99E+01	1,63E-01	-	3,16E+00	4,22E+00
	234mPa	<7,70E-02	<7,70E-02	2,19E+01	-	-	-	-
	226Ra	<1,30E-03	<1,30E-03	2,16E+00	3,25E-02	<3,50E-03	8,13E-01	1,92E+00
	210Pb	-	-	5,94E+02	-	-	-	-
^{232}Th chain	228Ra	<1,10E-03	<1,10E-03	3,50E+00	<3,09E-02	<5,00E-03	9,49E-01	3,61E-01
	228Th	<1,30E-03	<1,30E-03	3,36E+00	<1,56E-02	<4,50E-03	9,49E-01	3,65E-01
^{235}U chain	235U	<1,60E-03	<1,60E-03	3,37E-01	<1,58E-02	-	1,81E-01	1,45E-01
Other	40K	<6,00E-03	<6,00E-03	<1,78E+00	<3,58E-01	<3,50E-02	8,59E-01	5,15E+01
	137Cs	<4,70E-04	<4,70E-04	<7,35E-02	<8,13E-03	-	4,07E-02	<2,67E-02
	60Co	<5,70E-04	<5,70E-04	<7,73E-03	<7,48E-03	-	<5,42E-03	<4,64E-02
	58Co	9,00E-04	9,00E-04	<3,10E-03	-	-	-	-
	Mn54	<4,30E-04	<4,30E-04	<3,27E-03	-	-	-	-
	La138	-	-	-	-	-	-	2,44E+00

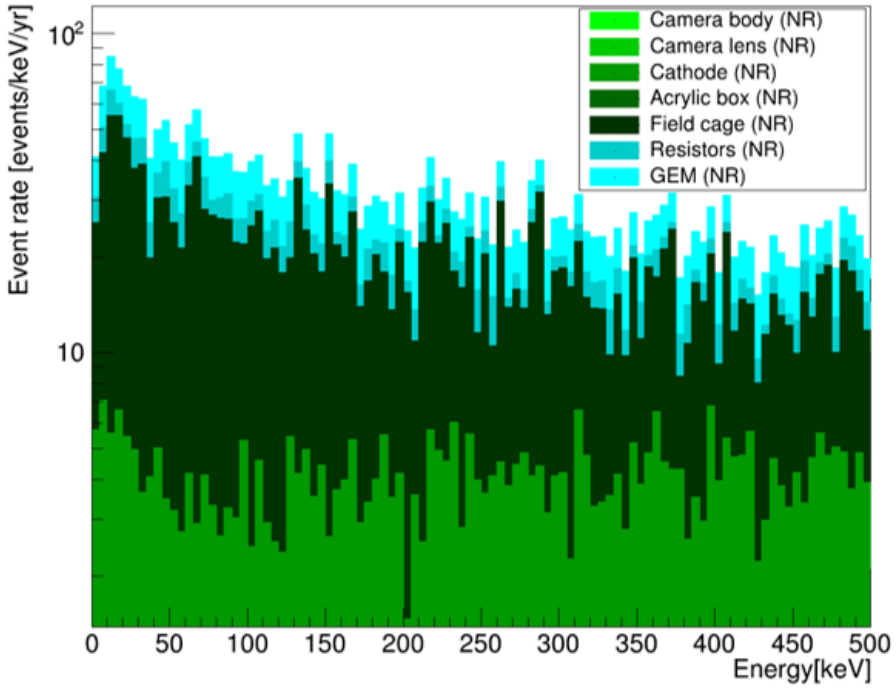
Internal background

main contributions from copper rings and cathode and resistors



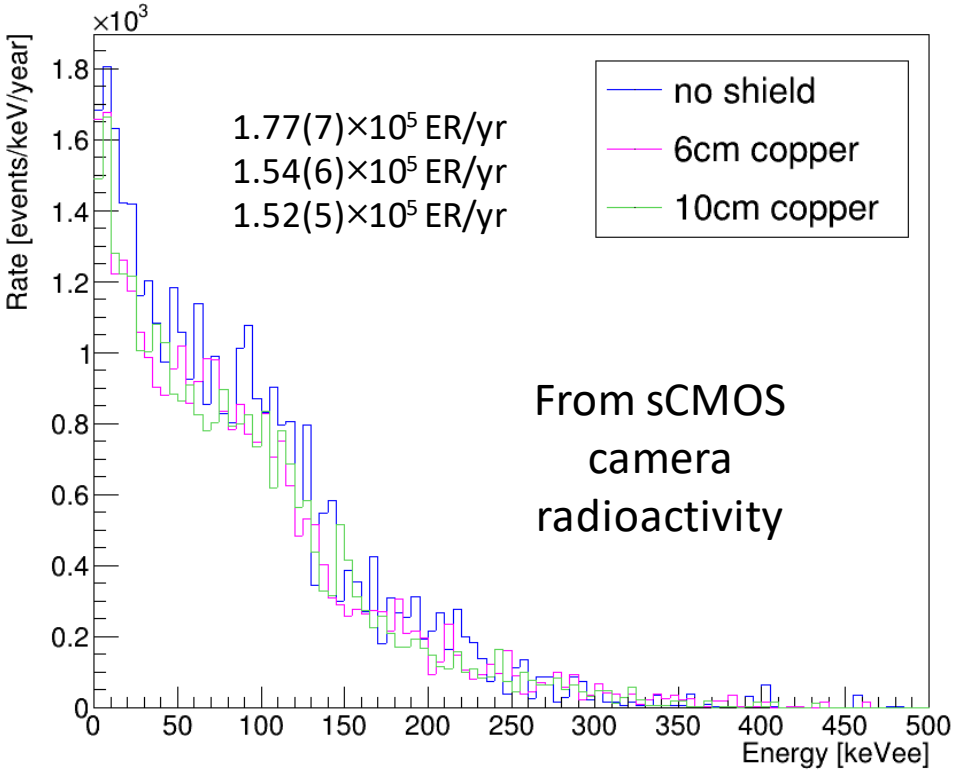
$7.403(6)\times10^{6}$ (ER+NR)/yr in 0-3000 keV
$7.317(6)\times10^{6}$ (ER+NR)/yr in 1-3000 keV
$1.534(1)\times10^{6}$ (ER+NR)/yr in 1-20 keV

main contributions from rings, cathode, resistors and GEMs

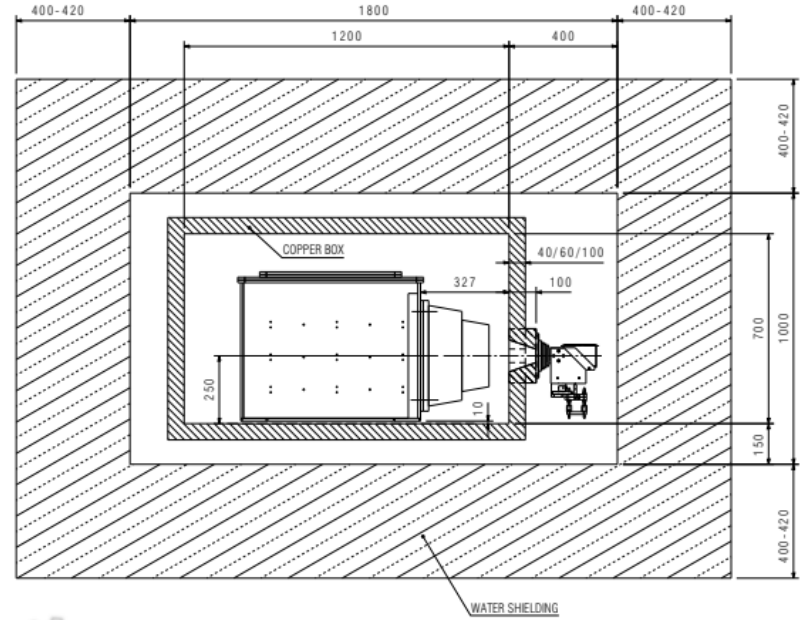


$6.11(5)\times10^{4}$ NR/yr in 0-3000 keV
$6.11(5)\times10^{4}$ NR/yr in 1-3000 keV
$1.36(2)\times10^{3}$ NR/yr in 1-20 keV

Camera background with shielding

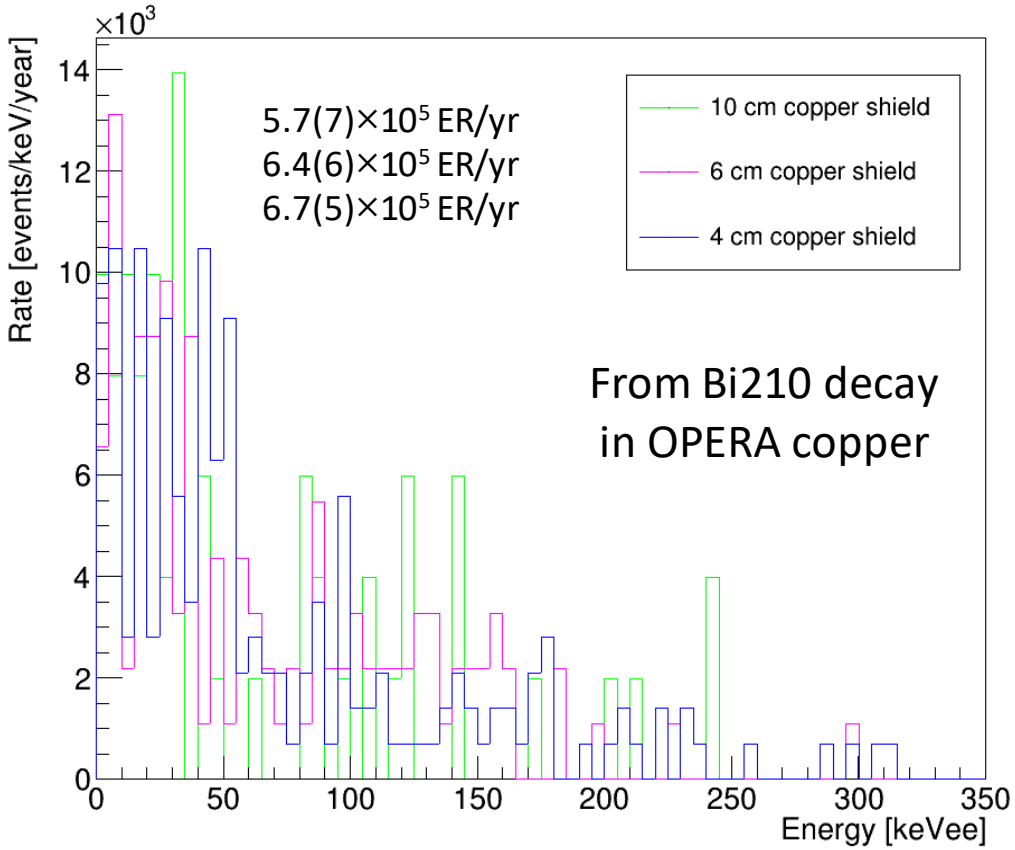


No significant difference between with or without shielding, we can not passively reduce the induced background



CESIDIO.CAPOCCIA@LNF.INFN.IT

Shield radioactivity

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rame OPERA: ICP-MS
Th [ppt] <15
U [ppt] <5

rame OPERA: HPGE
sample:        copper, magnet, OPERA
weight:        10658.4 g
live time:     2122026 s
detector:      GeMPI

radionuclide concentrations:

Th-232:
Ra-228:         < 73 microBq/kg        <==>    < 1.8 E-11 g/g
Th-228         < 64 microBq/kg         <==>    < 1.6 E-11 g/g

U-238:
Ra-226         < 0.10 mBq/kg          <==>    < 8.4 E-12 g/g
Pa-234m         < 1.9 mBq/kg          <==>    < 5.7 E-10 g/g

U-235         < 0.51 mBq/kg          <==>    < 9.0 E-10 g/g

K-40:         (0.4 +- 0.2) mBq/kg    <==>    (1.4 +- 0.7) E-8 g/g

Cs-137         < 28 microBq/kg

Co-60:         (31 +- 13) microBq/kg

Ag-108m:     (0.25 +- 0.03) mBq/kg

Bi-207:         (0.61 +- 0.06) mBq/kg

Pb-210:         (7 +- 2) Bq/kg

upper limits with k=1.645,
uncertainties are given with k=1 (approx. 68% CL);

Ra-228 from Ac-228;
Th-228 from Pb-212 & Bi-212 & Tl-208;
Ra-226 from Pb-214 & Bi-214;
U-235 from U-235 & Ra-226/Pb-214/Bi-214
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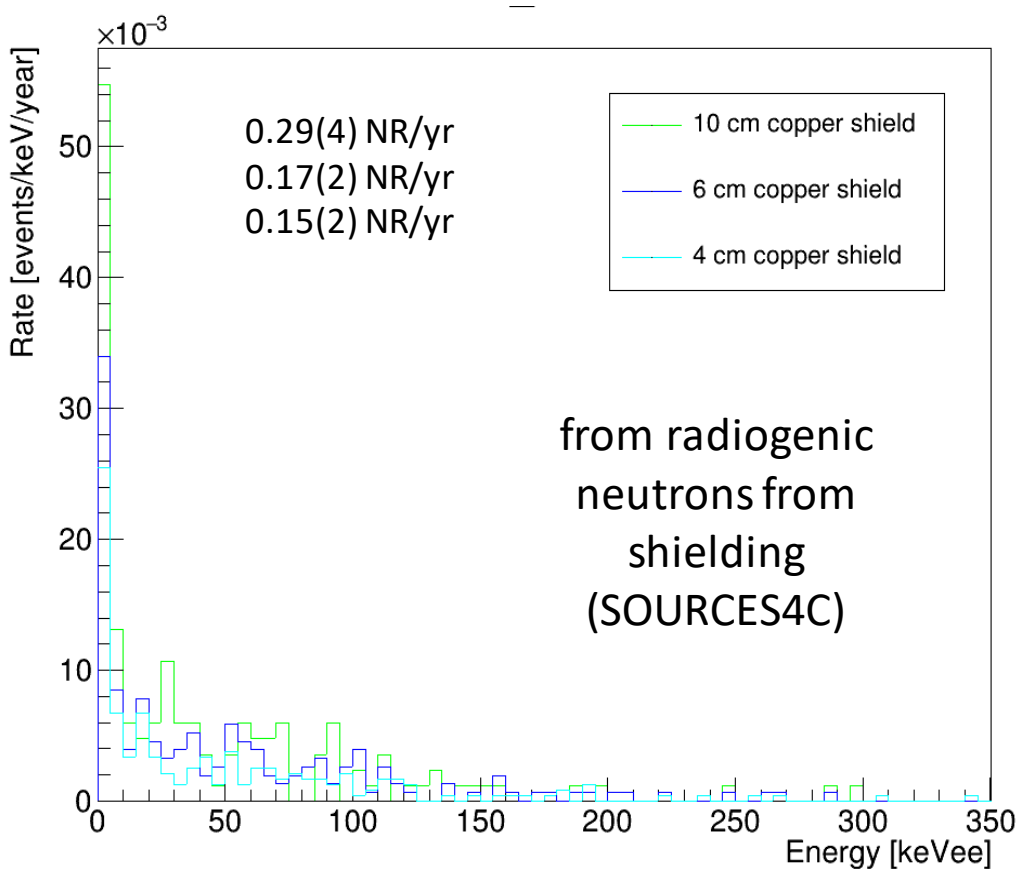
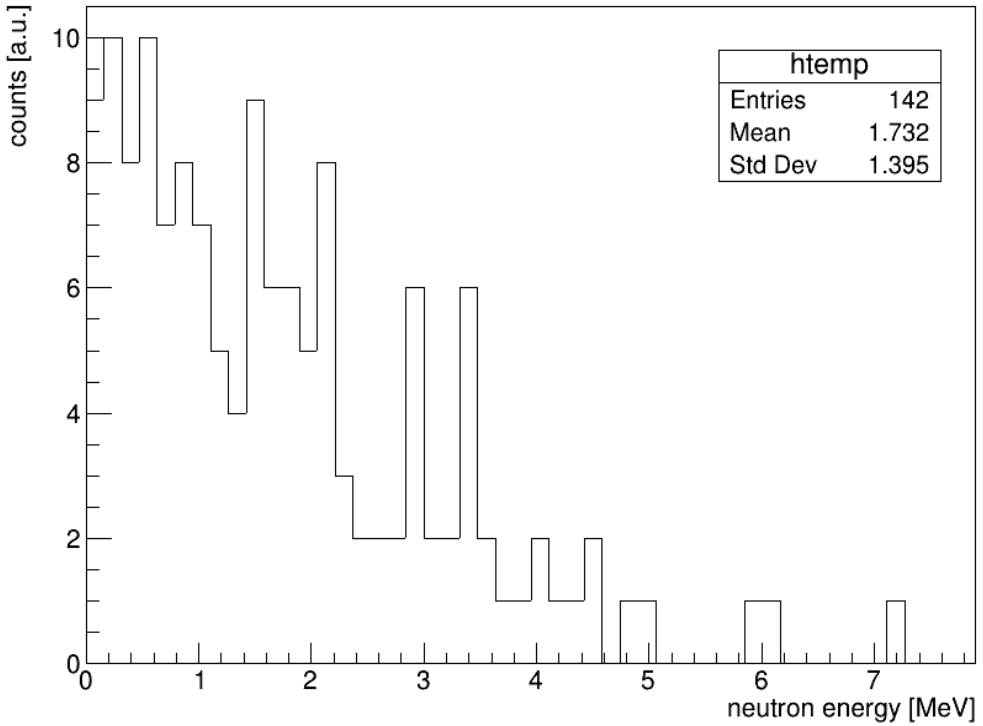
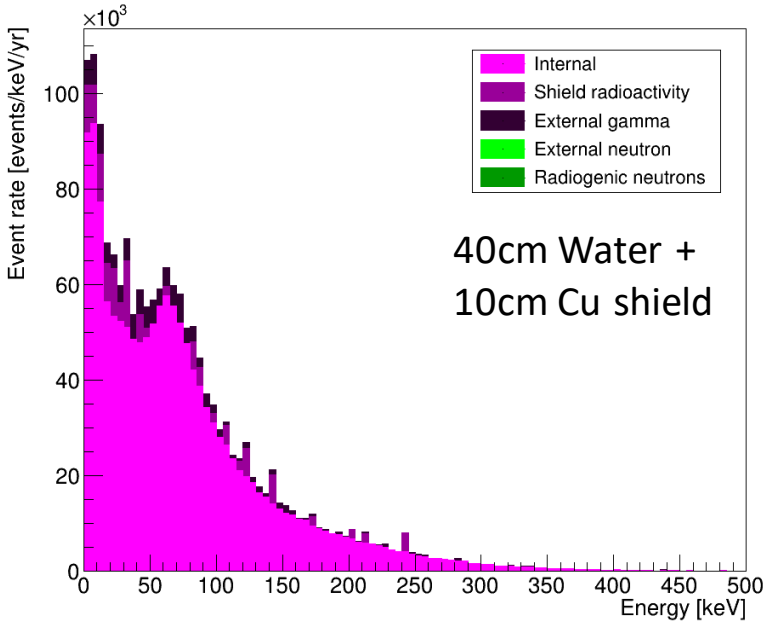
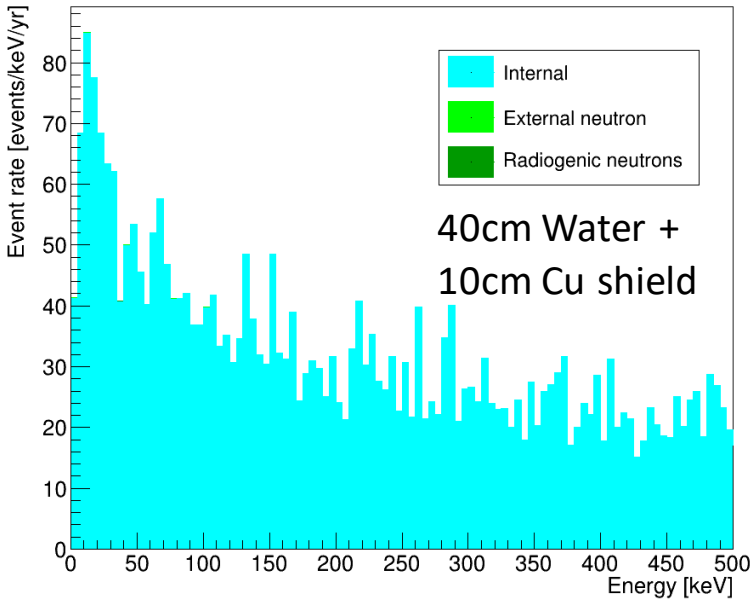
Radiogenic neutrons





Background with water shielding

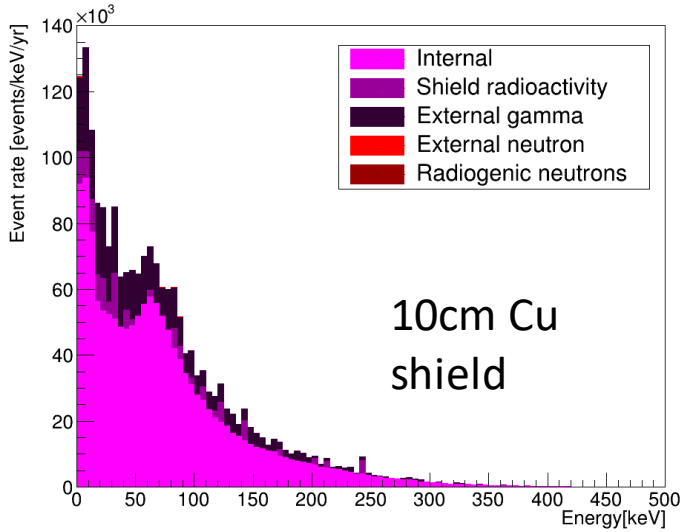


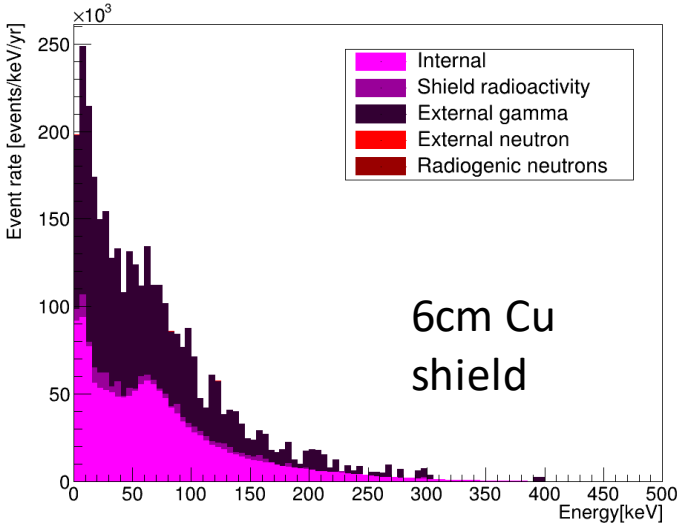


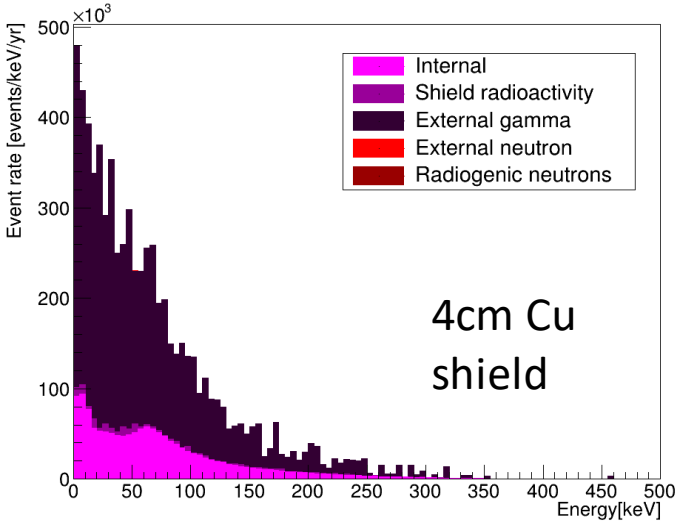
From gammas:
$5.13(1)\times10^5$ ER/yr in 0-3000 keV
5.09×10^5 ER/yr in 1-3000 keV
1.07×10^5 ER/yr in 1-20 keV

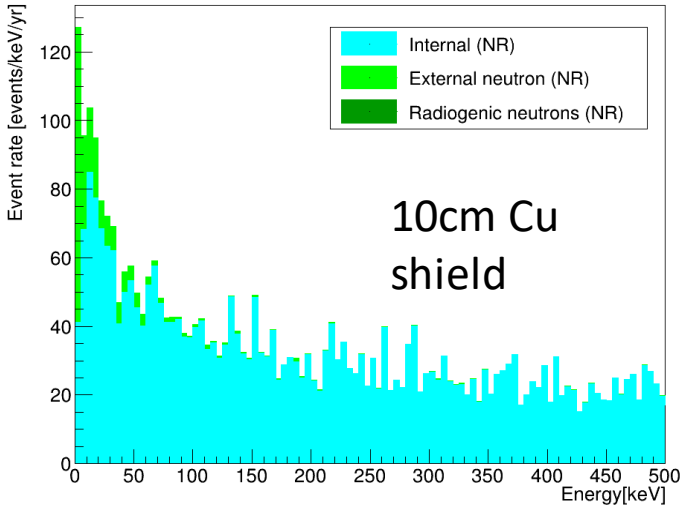
From neutrons:
2.34(1) NR/yr in 0-3000 keV
2.0 NR/yr in 1-3000 keV
0.97 NR/yr in 1-20 keV

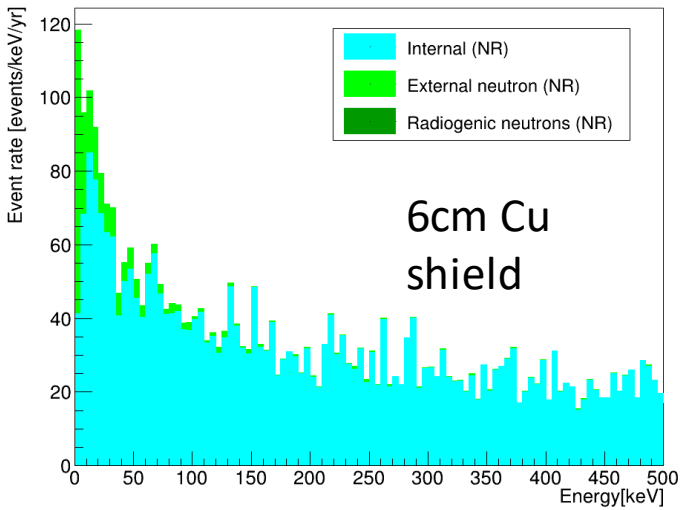
Shielding comparison

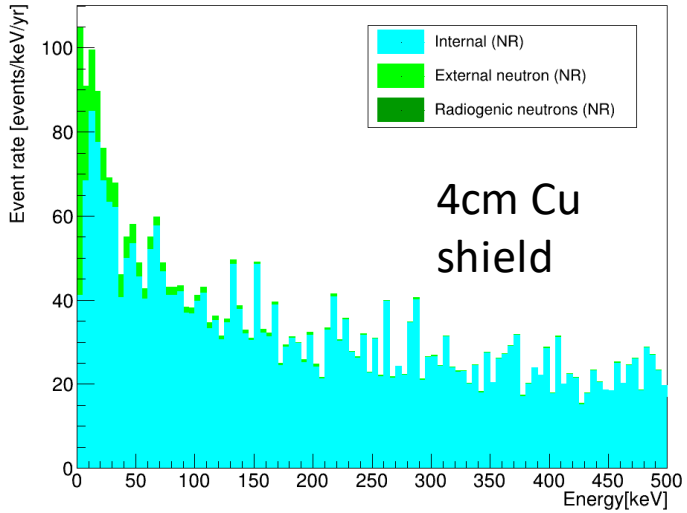




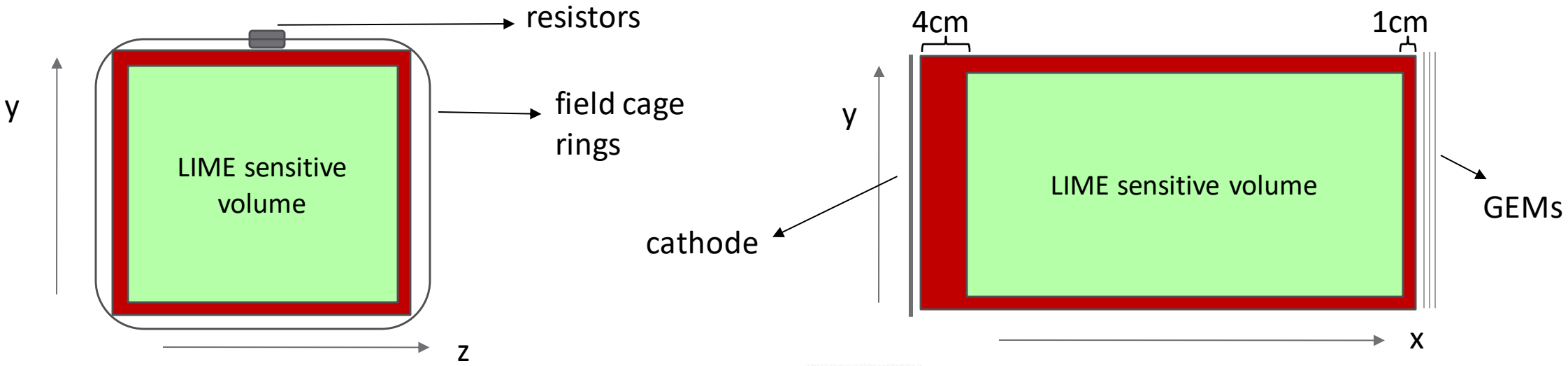




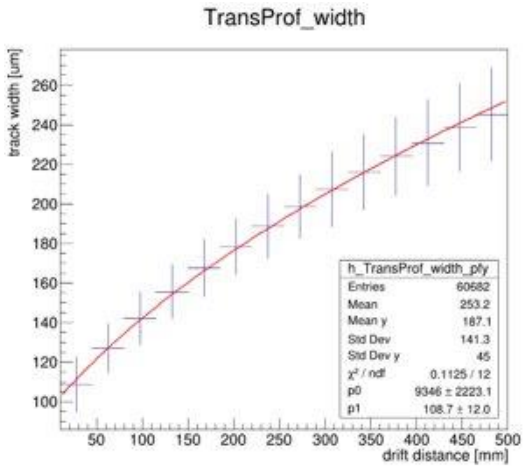


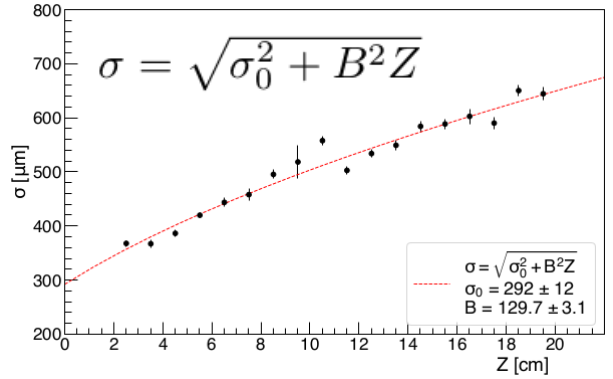


Detector fiducialization



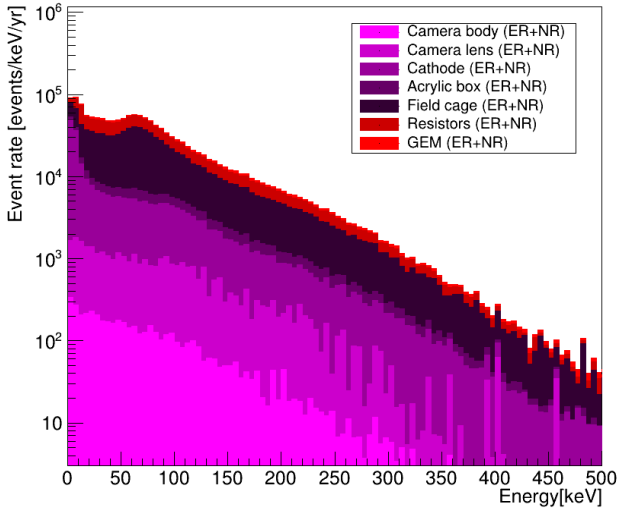
- Tracks close to the borders of the sensitive region can be excluded from analysis
- From track shape we can retrieve the distance from the GEMs (diffusion dependent on z)

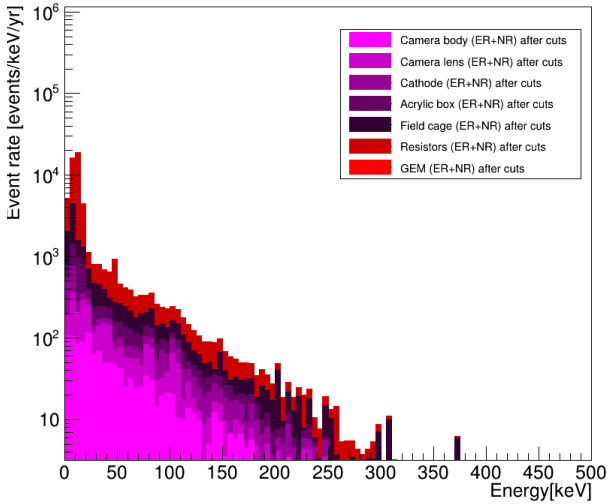




V.C. Antochi et al, NIMA 999 (2021) 165209

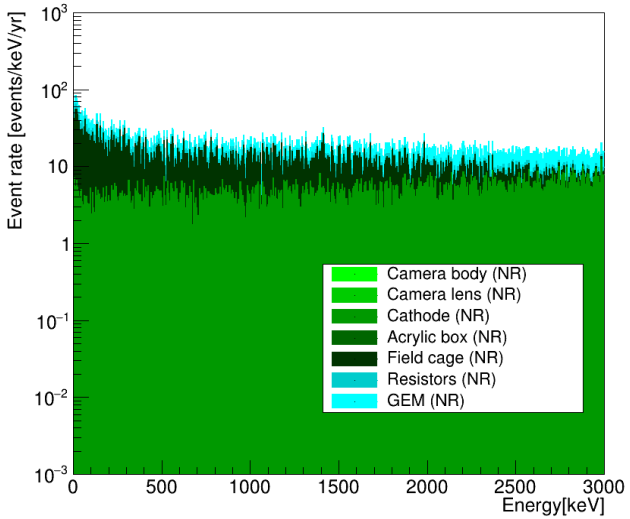
Detector fiducialization

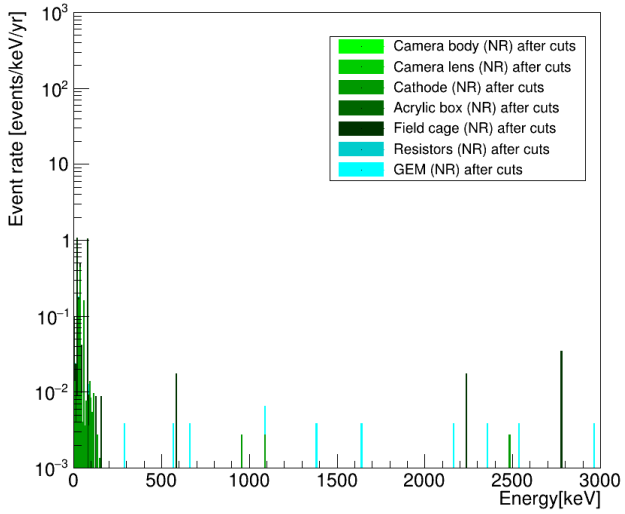




No cuts: **7.34(3)×10⁶** ER/yr
After cuts: **2.8(4)×10⁵** ER/yr

96% of events are excluded

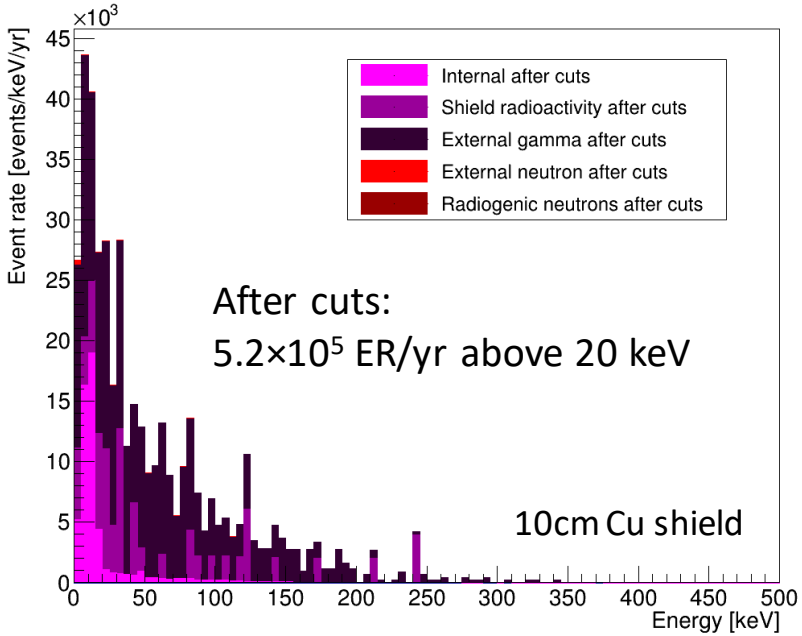


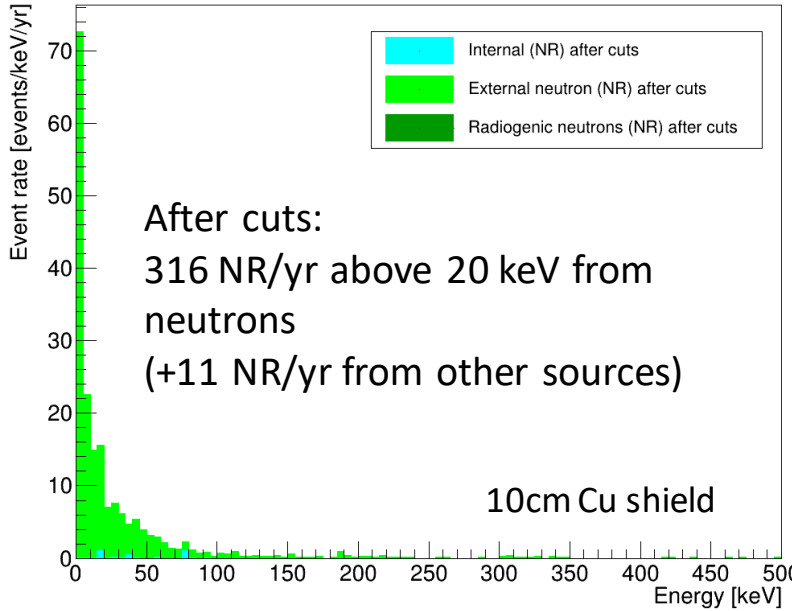


No cuts: **6.1(1)×10⁴** NR/yr
After cuts: **17(1)** NR/yr left

99.97% of events are excluded

Neutron background after cuts





Neutron flux measurement underground:

- Before cuts: **930** NR/yr above 1 keV (+**61000** background NR/yr)
- After cuts: **772** NR/yr above 1 keV (+**16** NR/yr from other sources)

- After the fiducial cuts, we expect ~105 NR induced by external neutrons above 20 keV in 4 months of data taking ("background free")

Summary table

Shielding	External		Internal		Shielding radioactivity		Total	
	ER/yr	NR/yr	ER/yr	NR/yr	ER/yr	NR/yr	ER/yr	NR/yr
No shield	1.13e9	1450	7.26e6	6.11e4	-	-	1.14e9	6.25e4
4cm copper	2.64e7	850	7.26e6	6.11e4	6.7e5	0	3.43e7	6.19e4
6cm copper	9.40e6	980	7.26e6	6.11e4	6.4e5	0	1.73e7	6.21e4
10cm copper	1.95e6	915	7.26e6	6.11e4	5.7e5	0	9.78e6	6.20e4
40cm water + 10cm copper	5.09e5	2.0	7.26e6	6.11e4	5.7e5	0	8.34e6	6.11e4

Rates refer to events >1 keV