# Simulations: BULLKID-DM setup at Gran Sasso

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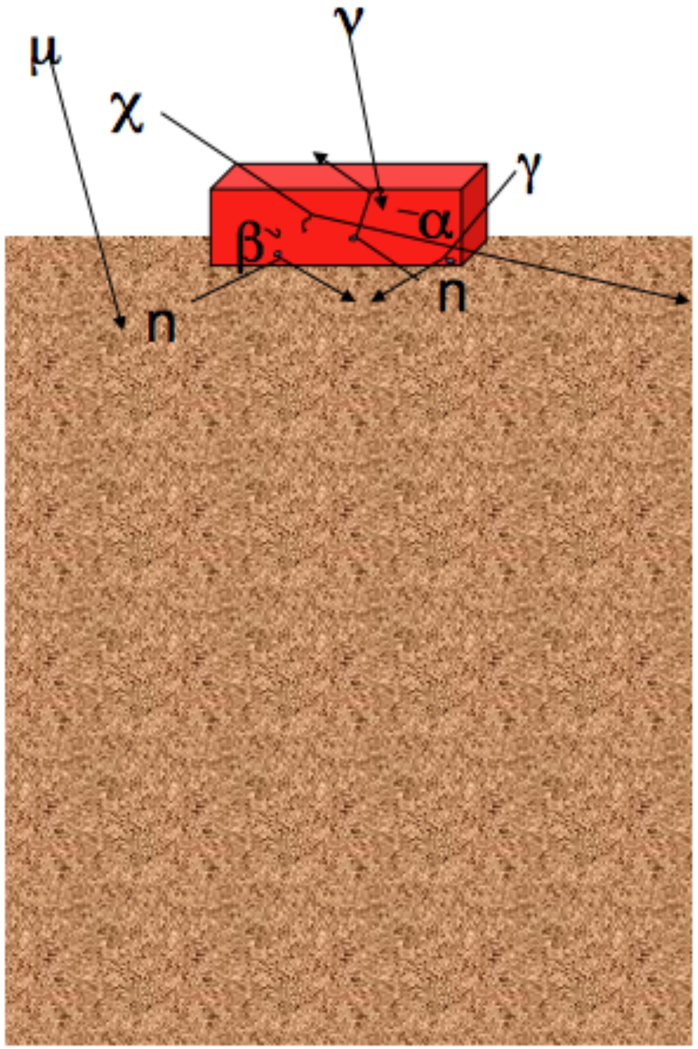
March 19, 2024

# Backgrounds, backgrounds, and backgrounds

# How to catch a WIMP

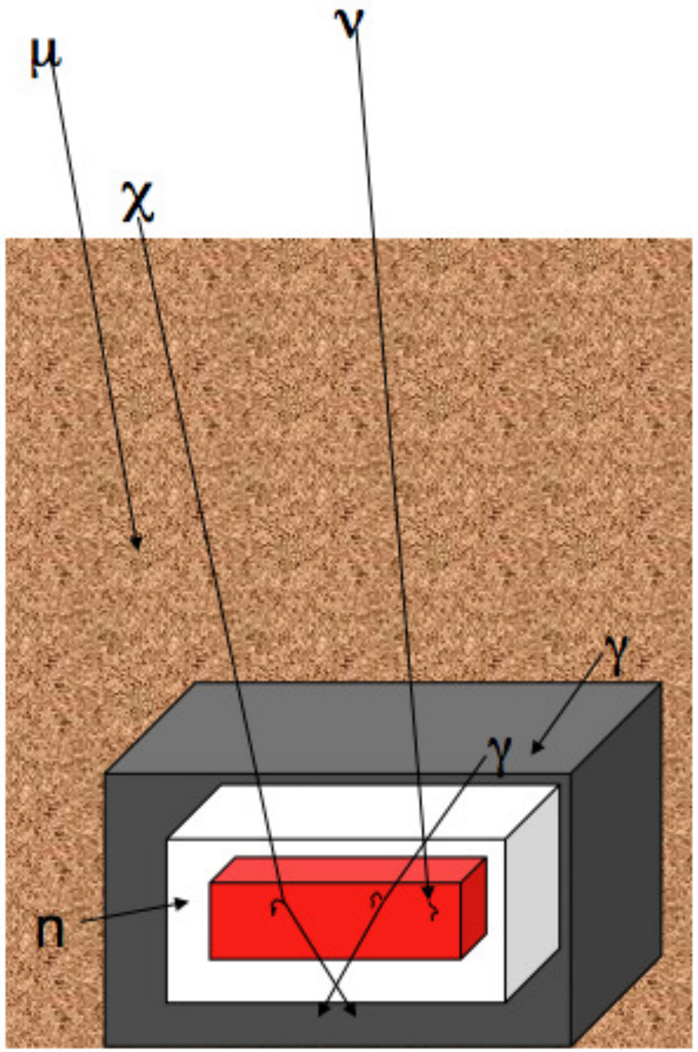
- Many backgrounds from natural radioactivity
  - Neutrons
  - Muons
  - Gammas, beta decays
  - alpha decays
  - Neutrinos




**Backgrounds:**
**($> 10^{11-12}$ events/ton/year)**

# How to catch a WIMP

- Go underground
- Shielding
- Material selection




**WIMP scatters:**
**(<1 event/ton/year)**

# BULLKID-DM setup at Gran Sasso

# Gran Sasso setup

- 616.3 g in 15 Si wafers

Wafers: 5 cm radius, 5 mm thickness

11 x 11 dices

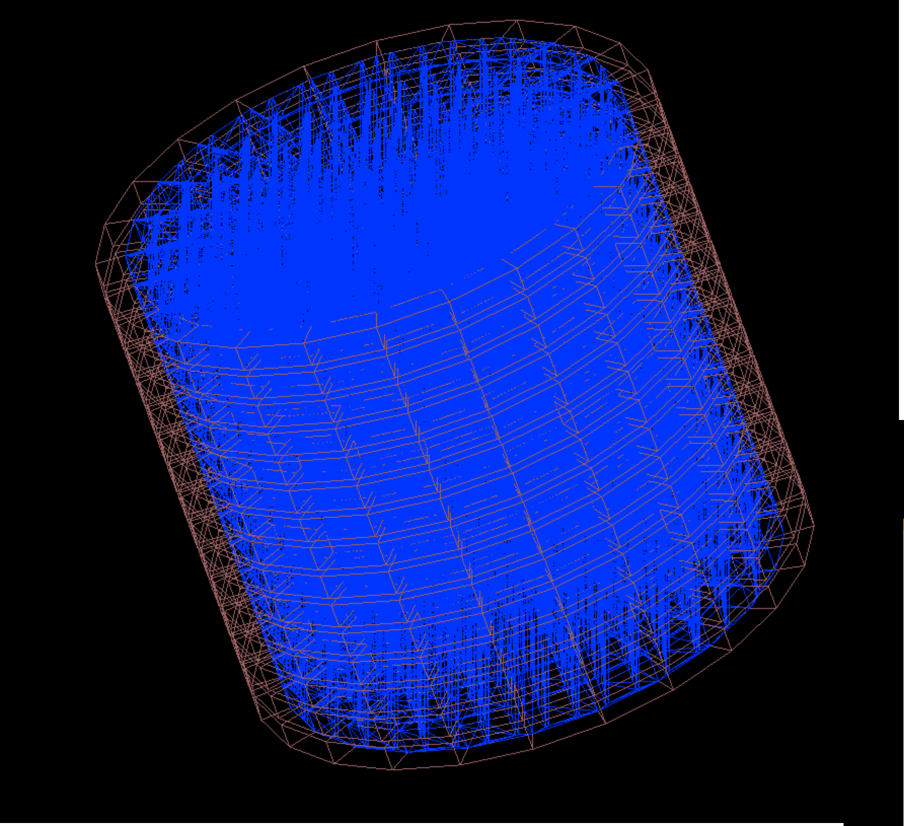
- In new Gran Sasso cryostat

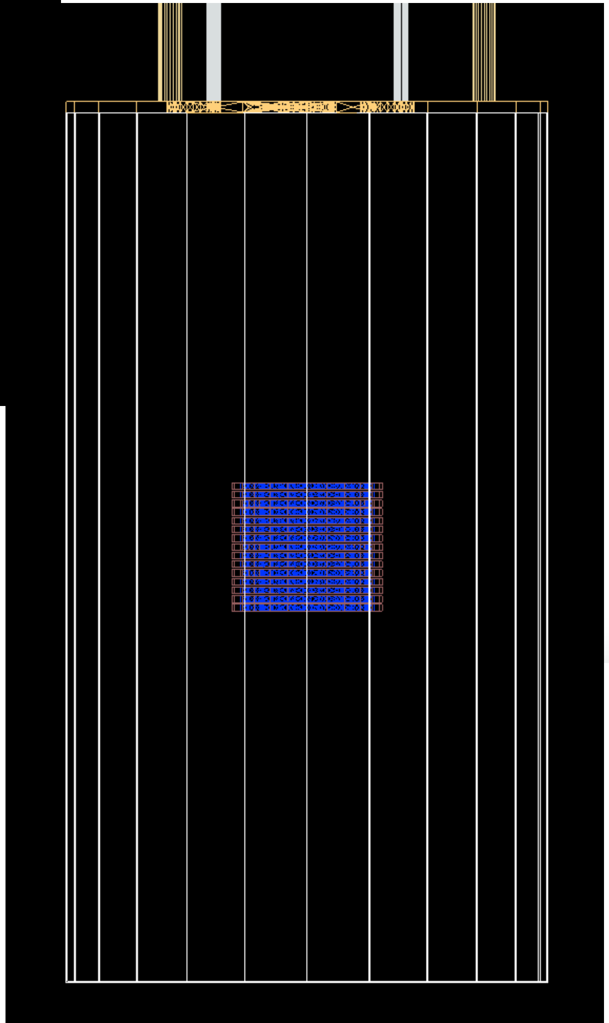
- External backgrounds:

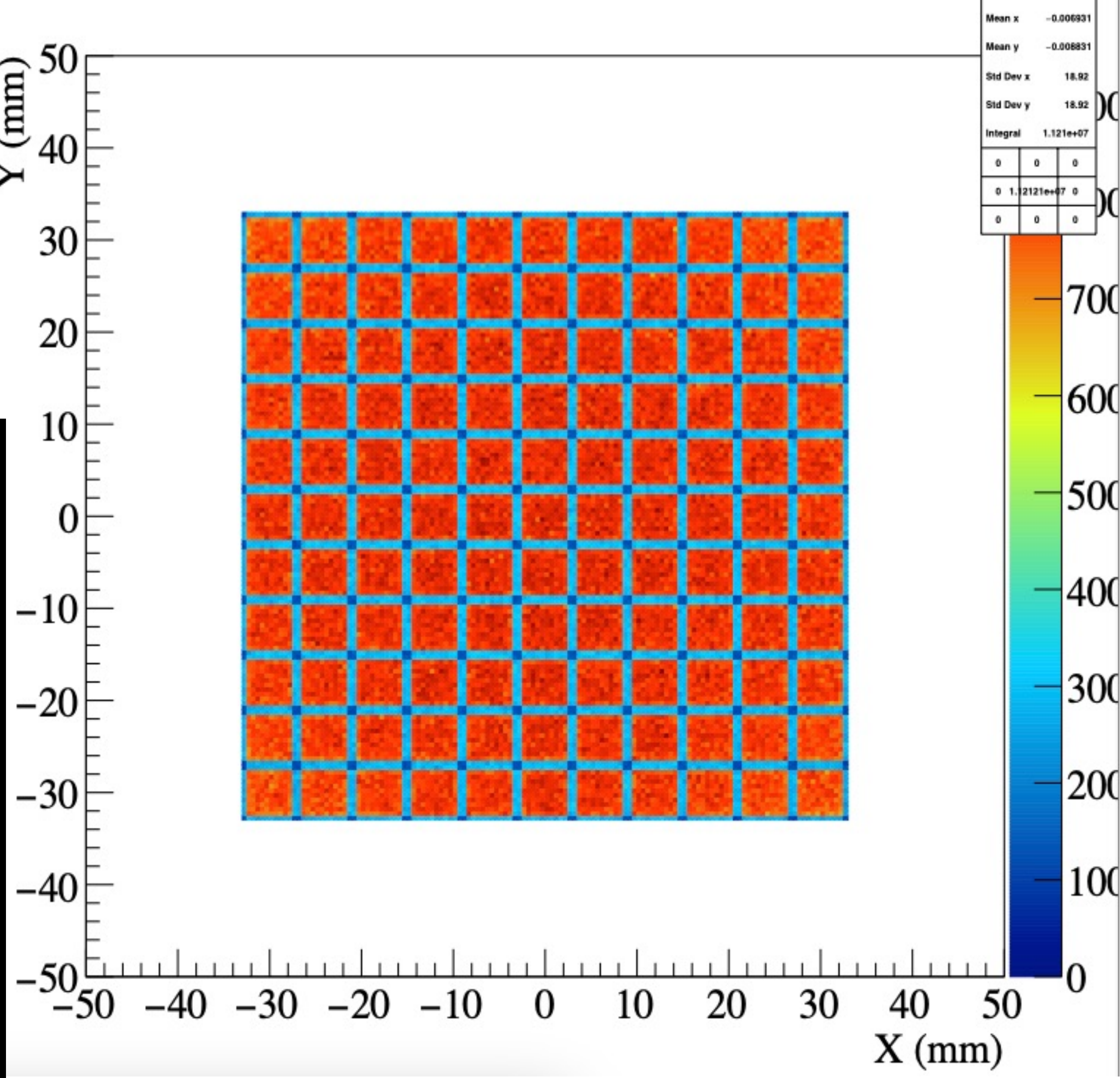
✓Gammas

✓Muons

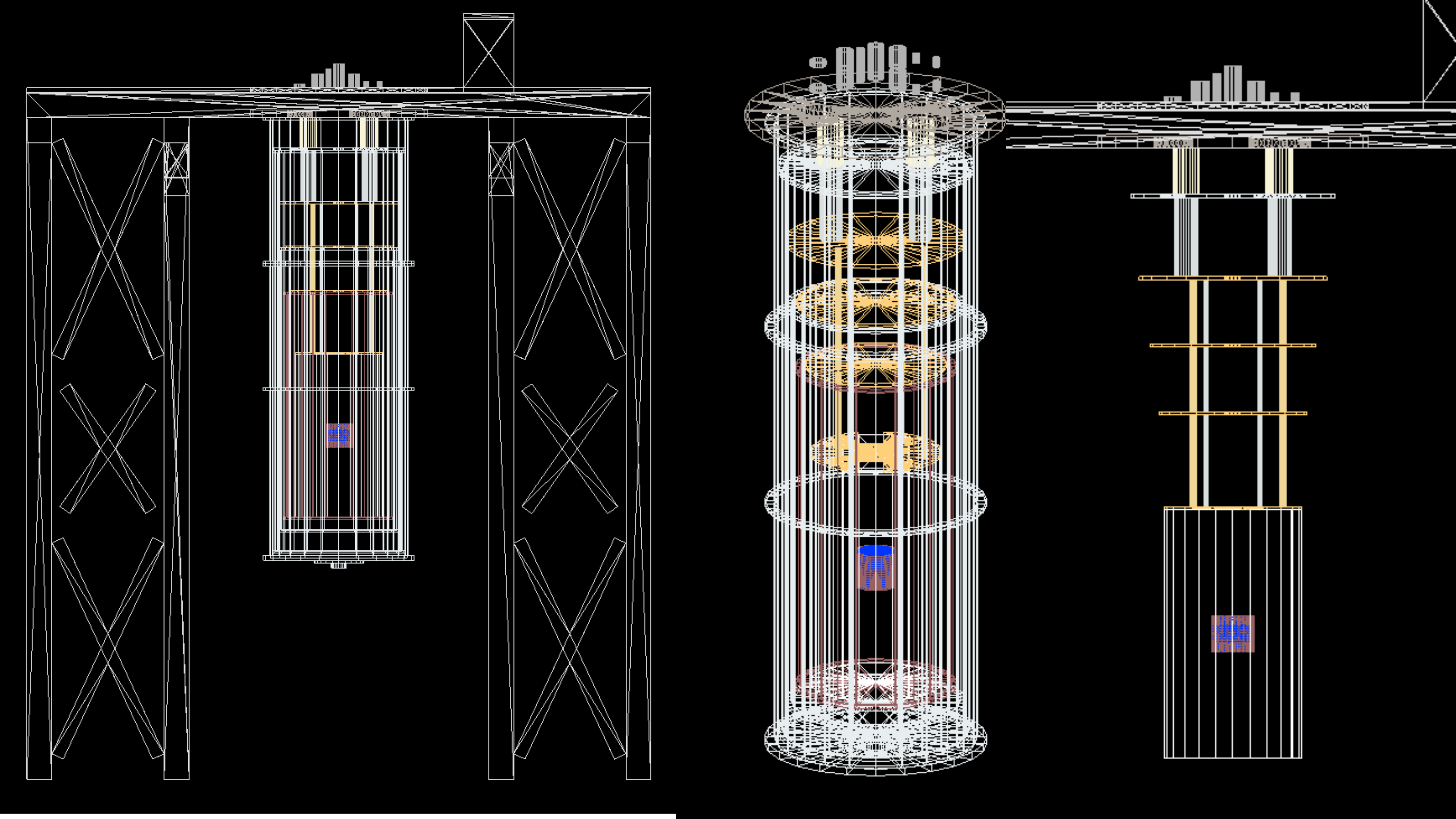
✓Neutrons

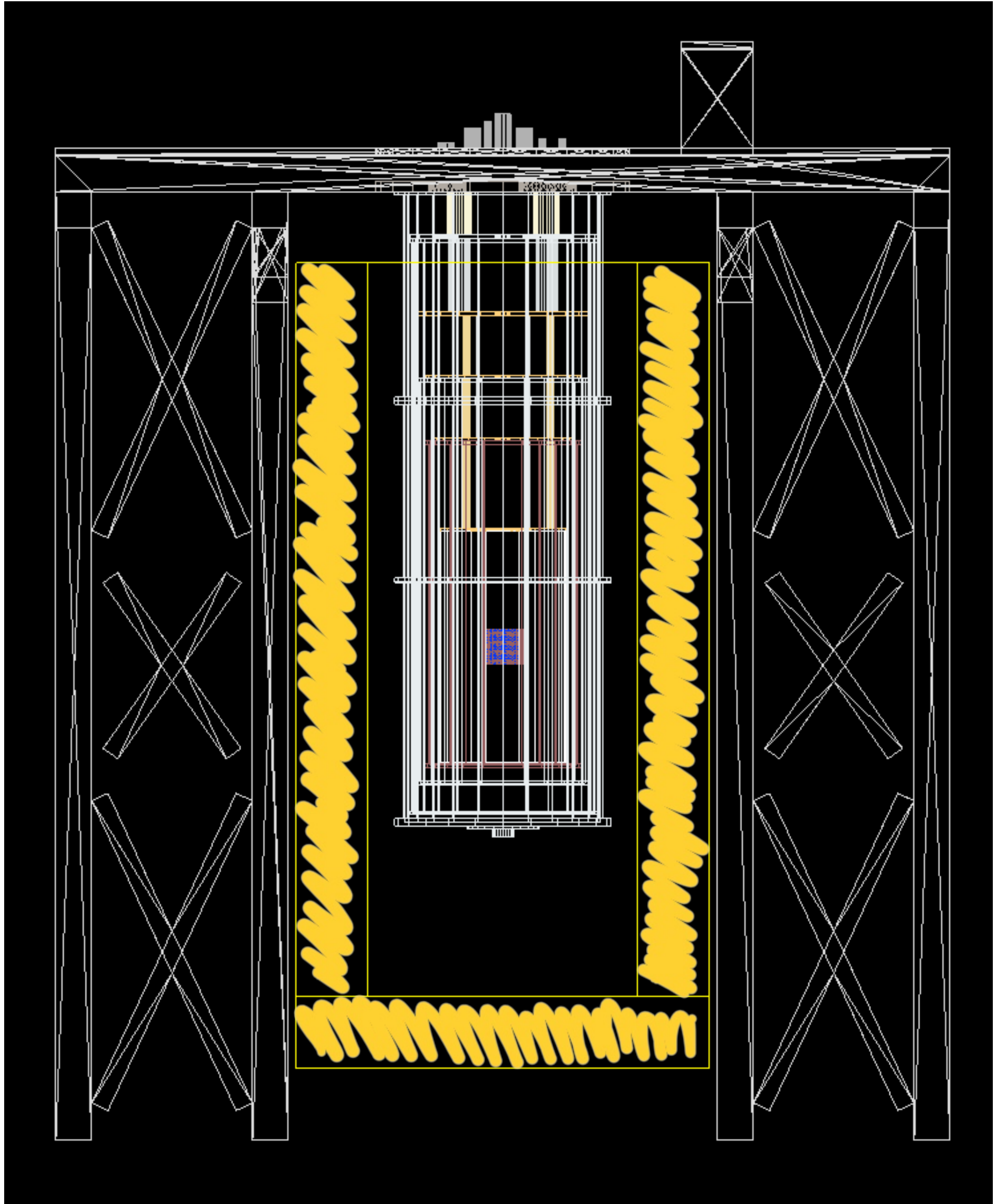
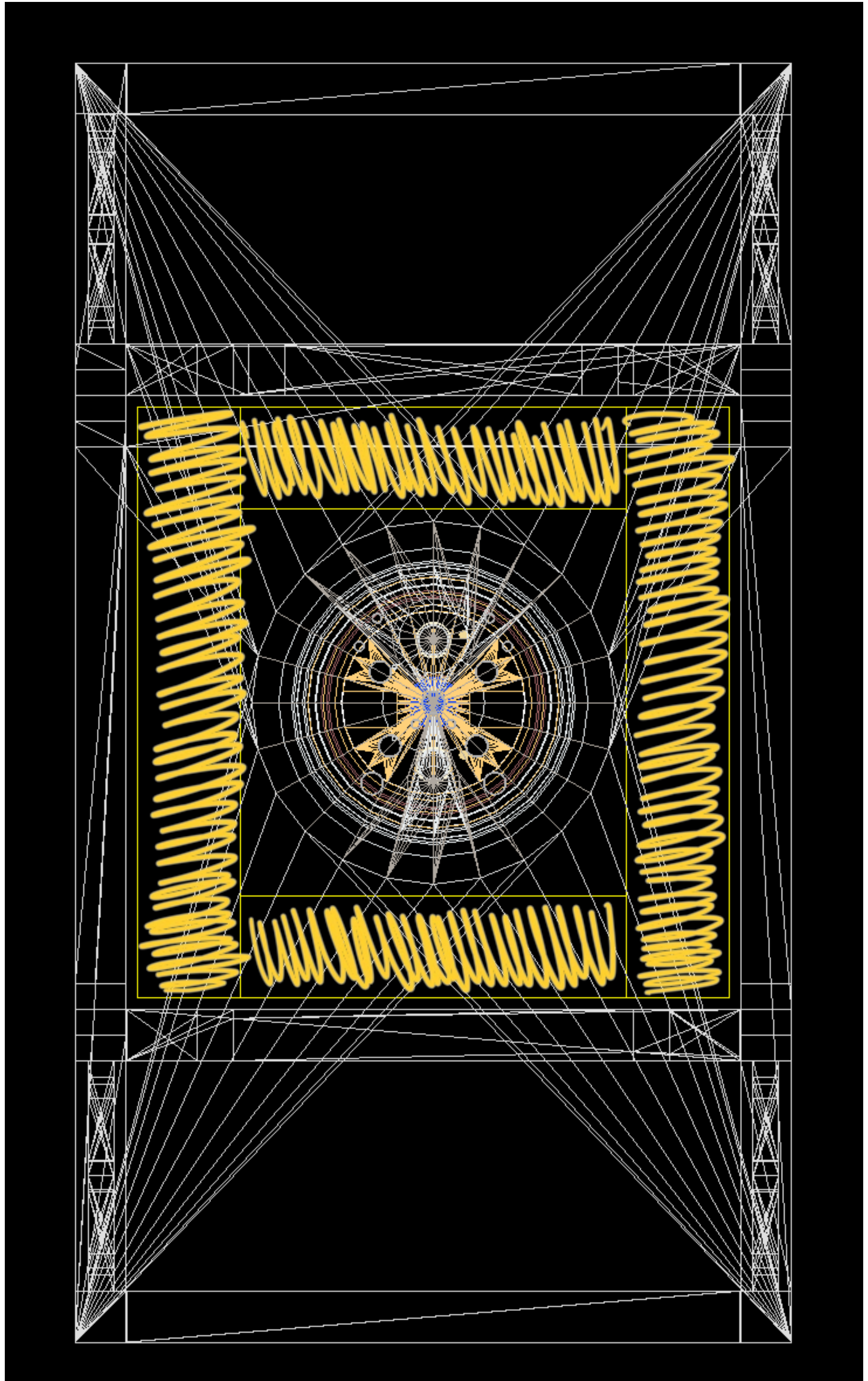







Events in the Si sensors



# Backgrounds from Monte Carlo simulations using GEANT4

# What we have now

Two GitHub repositories:

Experiment at Sapienza:

https://github.com/ericvj/BULLKID_Sapienza

Experiment at Gran Sasso:

https://github.com/ericvj/BULLKID_GranSasso ericvj / BULLKID_GranSasso

Code · Issues · Pull requests · Actions · Projects · Security · Insights · Settings

# BULLKID_GranSasso Private

Unwatch 1 · Fork 0 · Star 0

main · 1 Branch · 0 Tags · Go to file · Add file · Code

Eric Vazquez Jauregui Add PWO energy only for events in silicon to save disk space 724c1ce · 3 days ago 7 Commits

| | | |
|---|---|---|
| GranSasso | Add PWO energy only for events in silicon to save disk sp... | 3 days ago |
| Makefile | Update directories and fix errors with extra directory | last week |
| README.md | First commit with geometry at Gran Sasso | last week |
| geant4-v11.1.3.tar.gz | First commit with geometry at Gran Sasso | last week |

## README

BULLKID at Gran Sasso with GEANT4.11.1.p03

## About

Code for Monte Carlo simulations for BULLKID at Gran Sasso

Readme
Activity
0 stars
1 watching
0 forks

## Releases

No releases published
Create a new release

## Packages

No packages published
Publish your first package

## Languages

C++ 98.6% Other 1.4%

# What we have now

- How to use in one-two-three:

1. clone: gh repo clone ericvj/BULLKID_GranSasso or
   git clone git@github.com:ericvj/BULLKID_GranSasso.git
2. cd BULLKID_GranSasso
3. make

provides compilation of GEANT4 and DANAE experiment

- You need a github account, request access to GEANT code

Ready and working!

(compilation in 6 minutes and 8 sec with Apple M1 Pro)

# Backgrounds at
# Gran Sasso

# Gammas, muons, and neutrons

# Gammas

More intense gamma lines from K40, U238, and Th232 chains simulated

Underground flux:

0.729 gammas/cm^2/s

**Table 2.** Intensity of the main gamma lines ($\gamma/m^2/day$) measured in the underground Hall A of LNGS. Only lines with intensity higher than $10^6\ \gamma/m^2/day$ are listed. These are due to $^{40}K$, and to the $^{238}U$ and $^{232}Th$ chains.

| Energy [keV] | Isotope | Intensity [$\gamma/m^2/day$] |
|---|---|---|
| 238.6 | $^{212}Pb$ | $2.8 \cdot 10^6$ |
| 295.2 | $^{214}Pb$ | $3.8 \cdot 10^6$ |
| 352 | $^{214}Pb$ | $7.9 \cdot 10^6$ |
| 583 | $^{208}Tl$ | $3.0 \cdot 10^6$ |
| 609 | $^{214}Bi$ | $1.3 \cdot 10^7$ |
| 911 | $^{228}Ac$ | $3.1 \cdot 10^6$ |
| 934 | $^{214}Bi$ | $2.1 \cdot 10^6$ |
| 968 | $^{228}Ac$ | $2.1 \cdot 10^6$ |
| 1120 | $^{214}Bi$ | $6.3 \cdot 10^6$ |
| 1238 | $^{214}Bi$ | $2.8 \cdot 10^6$ |
| 1460 | $^{40}K$ | $2.9 \cdot 10^7$ |
| 1764 | $^{214}Bi$ | $8.2 \cdot 10^6$ |
| 2204 | $^{214}Bi$ | $3.1 \cdot 10^6$ |
| 2614 | $^{208}Tl$ | $7.8 \cdot 10^6$ |

# Muons

Muon energy and angular distributions from Mei and Hime

Underground flux:

$3.2 \times 10^{-8}$ muons/cm^2/s

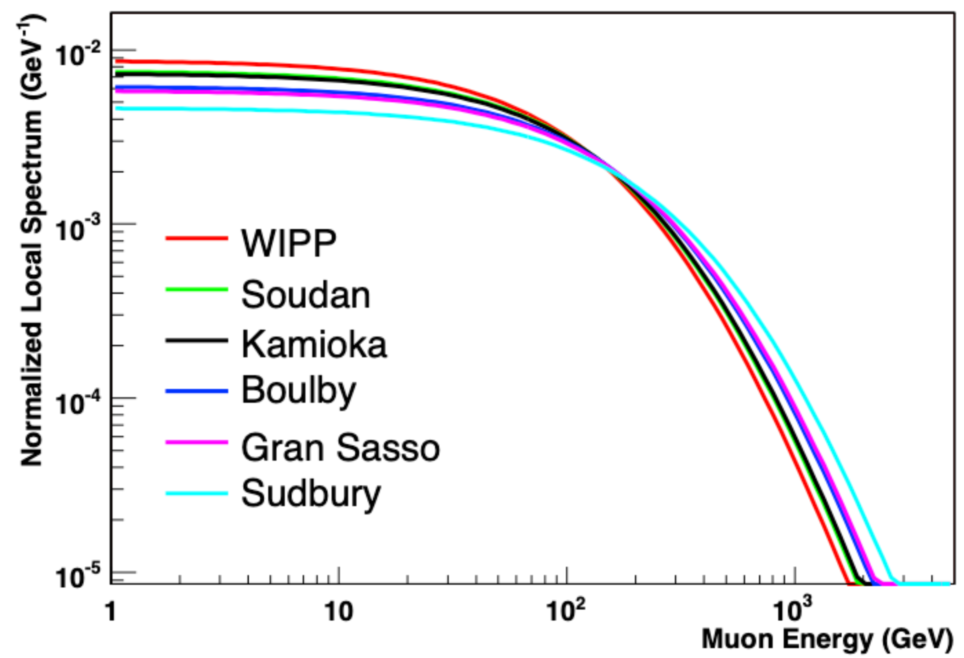



FIG. 6: The
derground sit
der the curve
for compariso

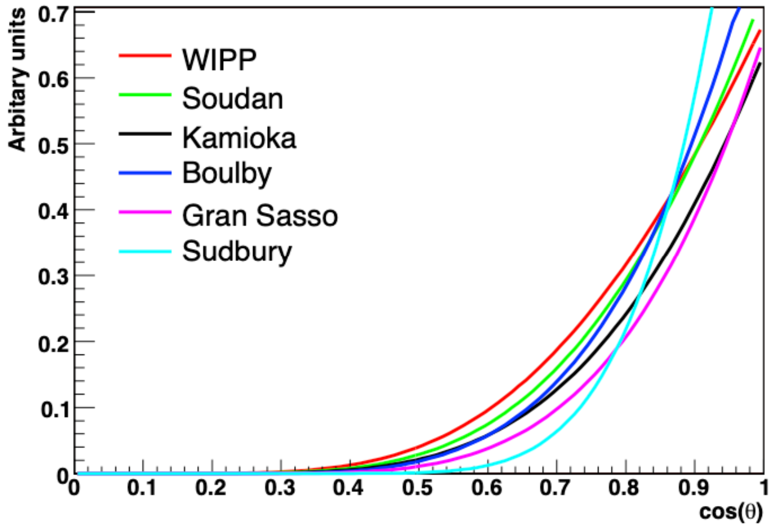


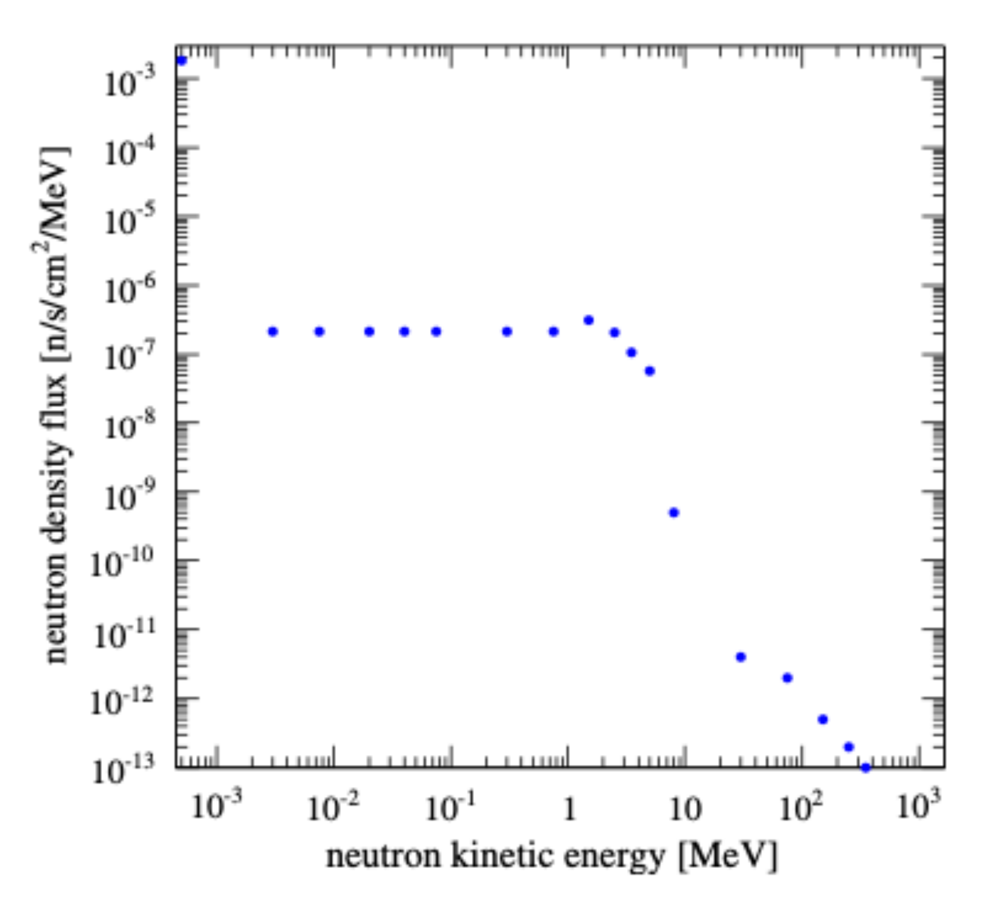

FIG. 7: The muon angular distribution local to the various underground sites based on equation (3). All curves have

# Neutrons

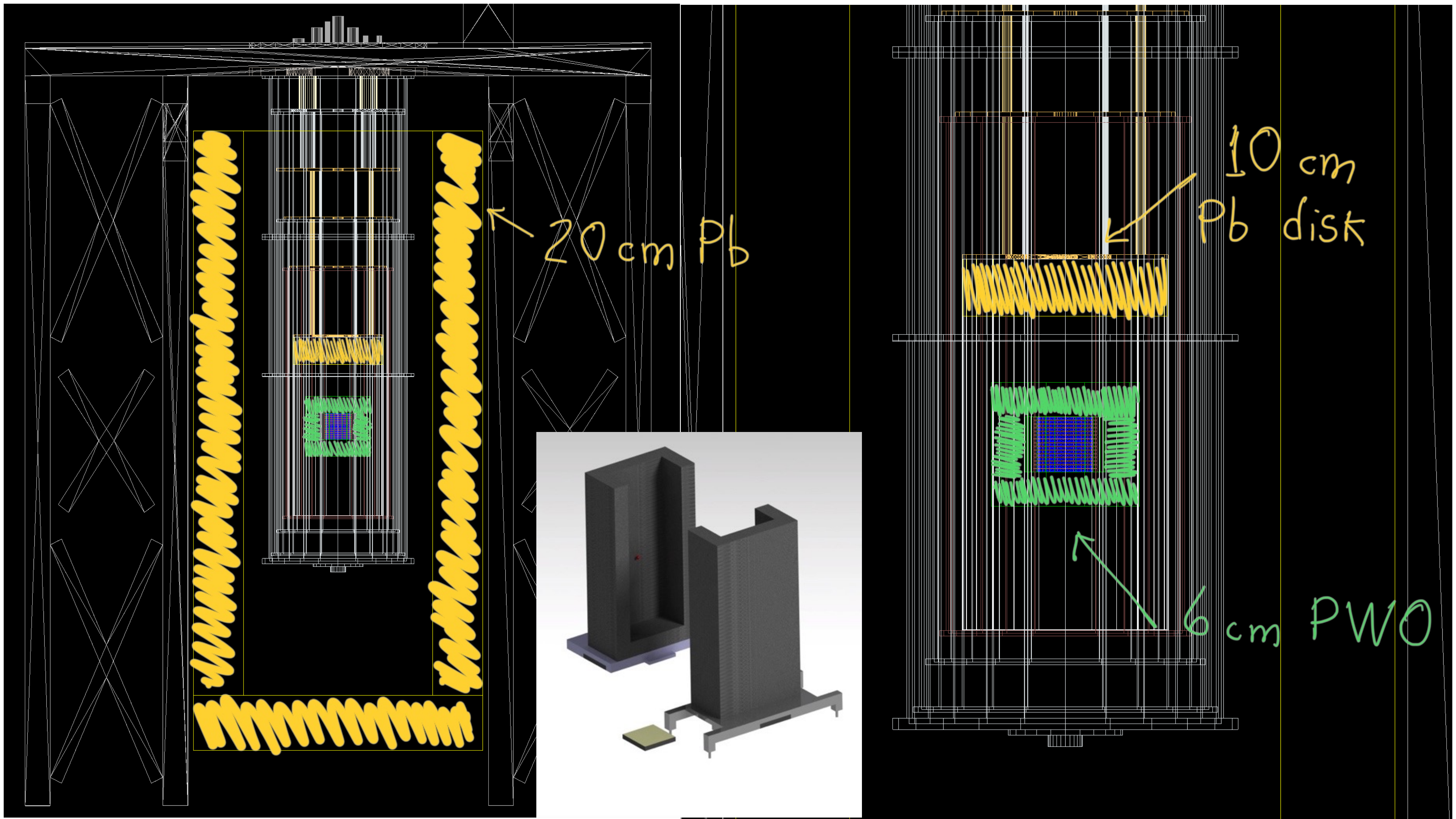
Neutron energy distribution from several sources for 3 regions:

- Thermal
- Radiogenic
- Cosmogenic

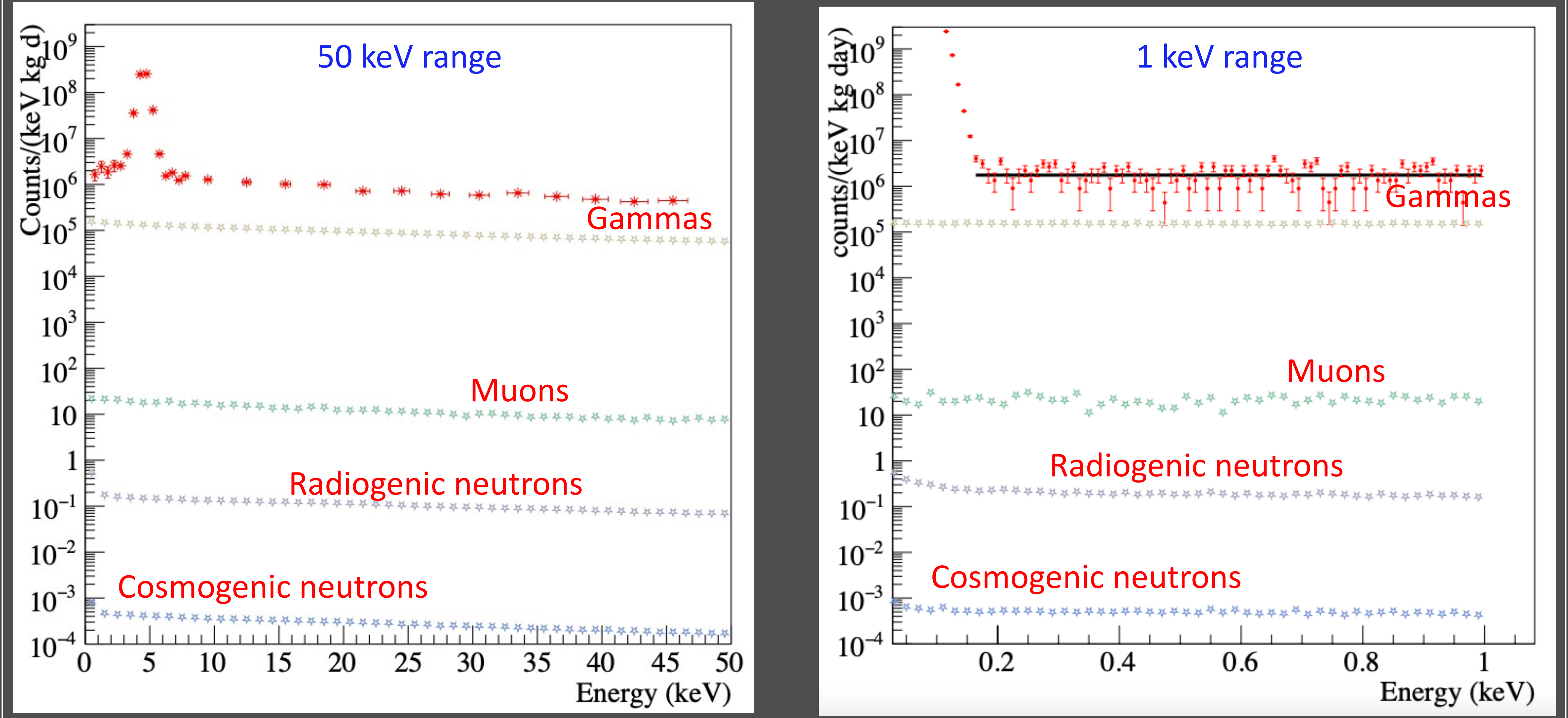
| E interval (MeV) | Neutron Flux ($10^{-6}cm^{-2}s^{-1}$) Ref. [1] | Ref. [2] | Ref. [3] | Ref. [4] | Ref. [5] | Ref. [6] |
|---|---|---|---|---|---|---|
| $10^{-3} - 0.5$ | | | | | | |
| $0.5 - 1$ | | | 0.54±0.01 | | | |
| $1 - 2.5$ | | 0.14±0.12 | (0.53±0.08) | | | |
| $2.5 - 3$ | | 0.13±0.04 | 0.27±0.14 | | | |
| $3 - 5$ | | | (0.18±0.04) | | | 2.56±0.27 |
| $5 - 10$ | | 0.15±0.04 | 0.05±0.01 (0.04±0.01) | 3.0±0.8 | 0.09±0.06 | |
| $10 - 15$ | 0.78±0.3 | $(0.4 \pm 0.4)\cdot 10^{-3}$ | $(0.6 \pm 0.2)\cdot 10^{-3}$ $((0.7 \pm 0.2)\cdot 10^{-3})$ | | | |
| $15 - 25$ | | | $(0.5 \pm 0.3)\cdot 10^{-6}$ $((0.1 \pm 0.3)\cdot 10^{-6})$ | | | |



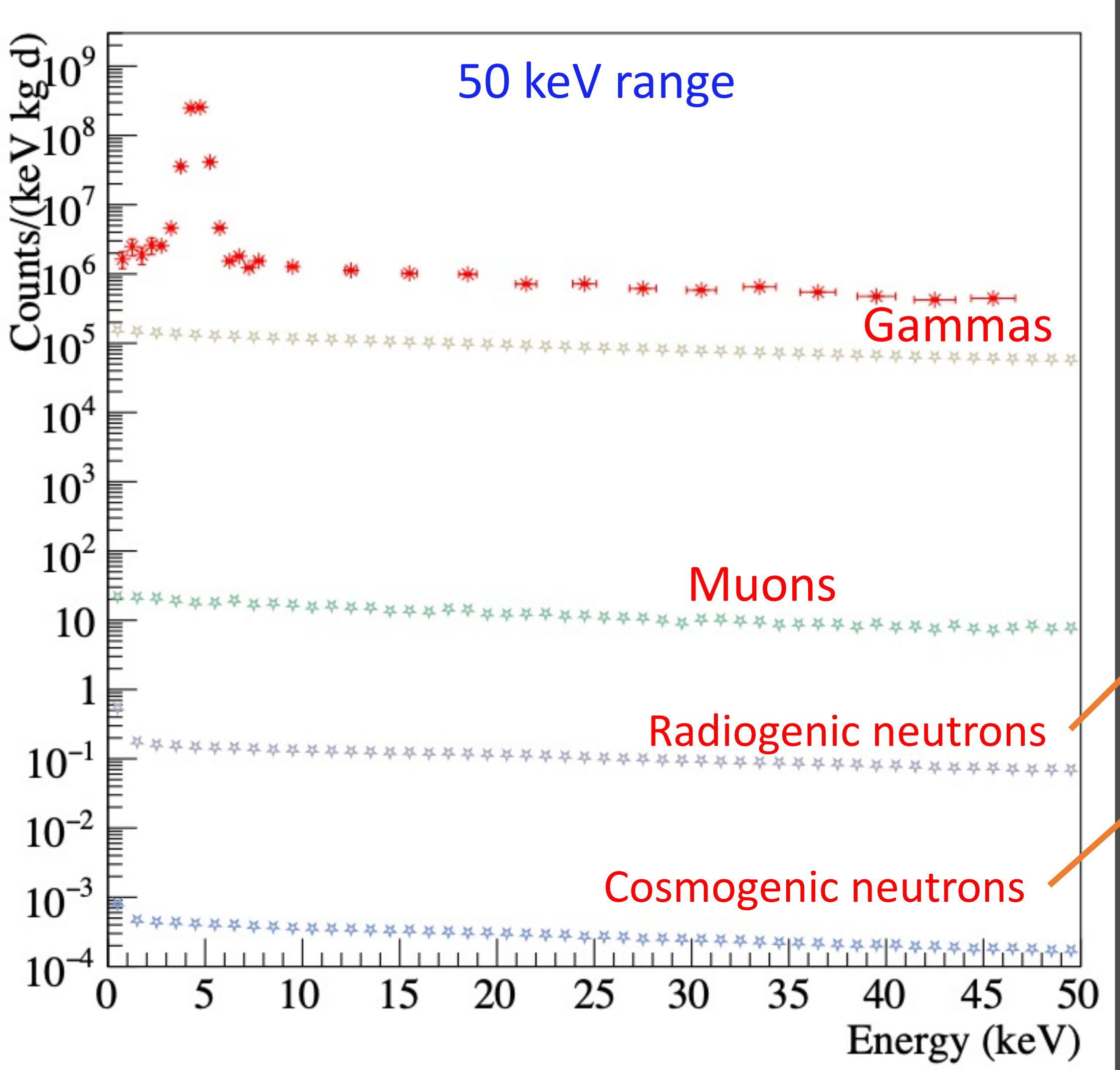
# Results: shielding and PWO veto


20 cm Pb
10 cm Pb disk
6 cm PWO

# No shielding



# All backgrounds: No shielding



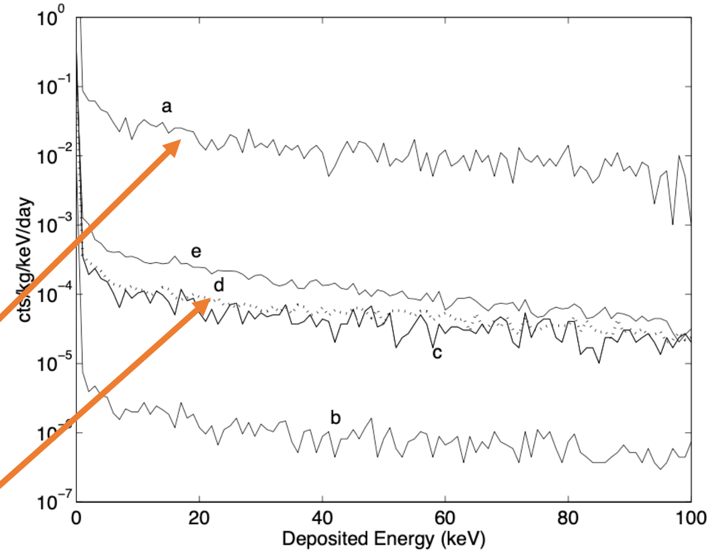
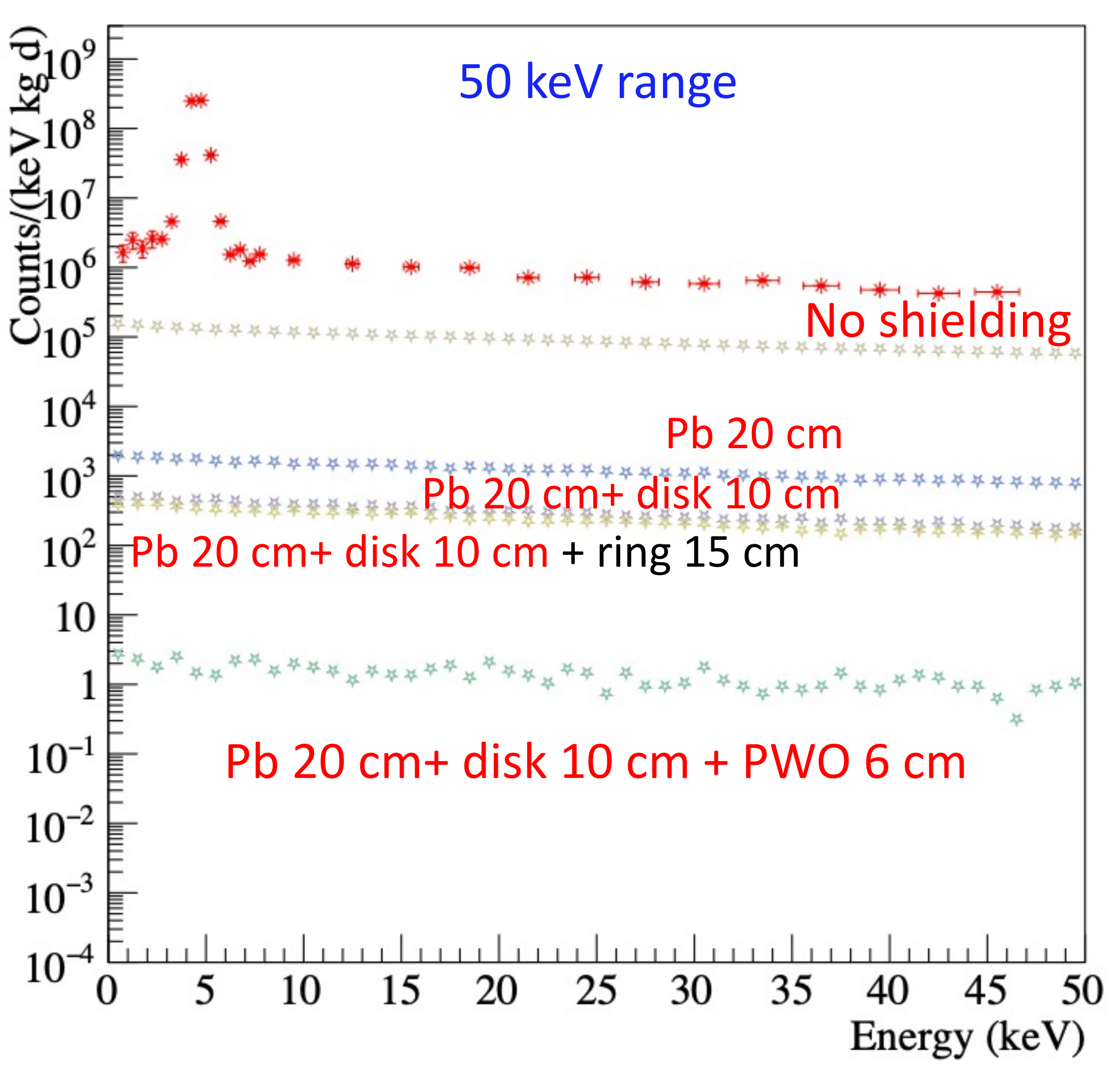
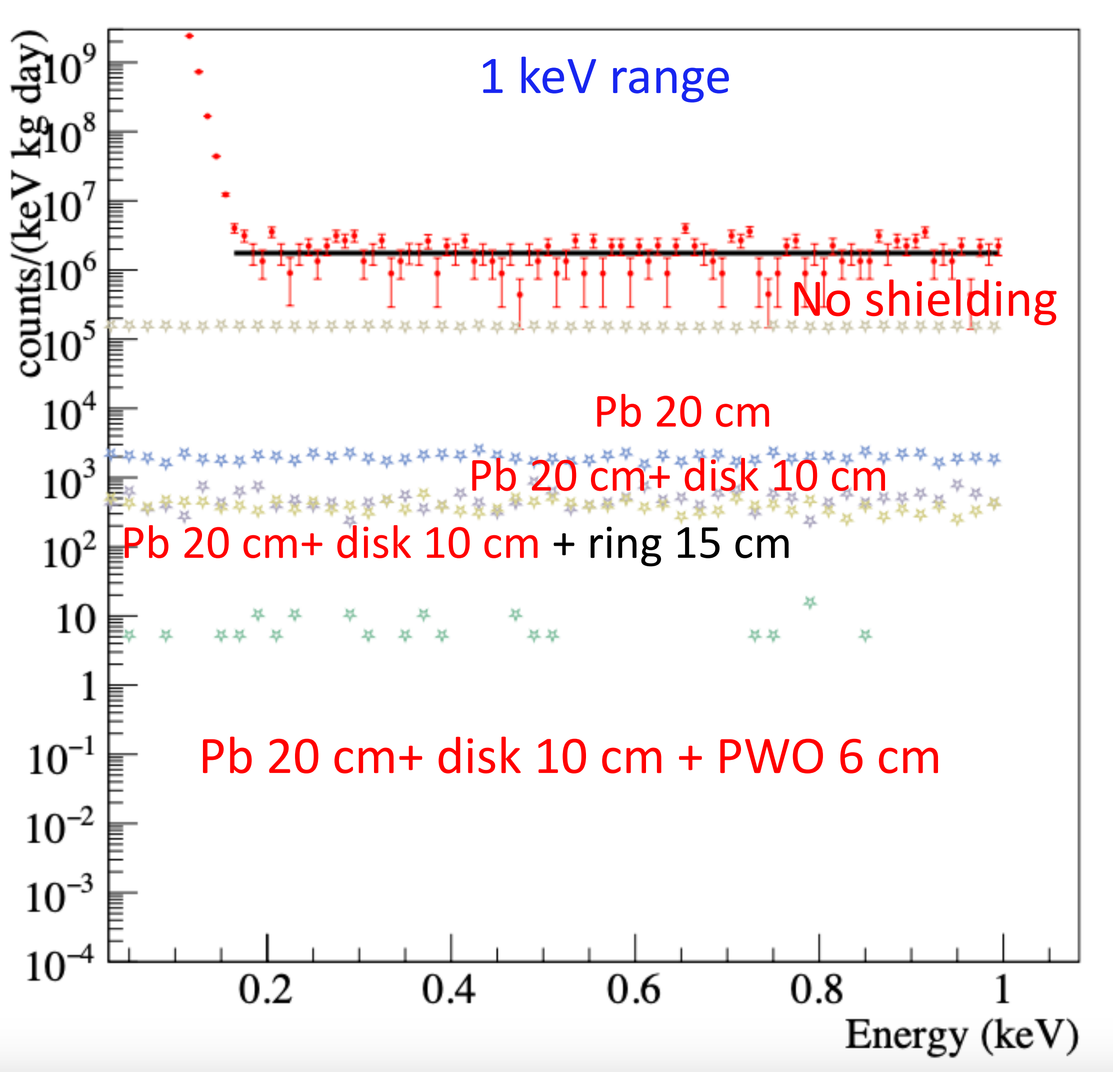




Fig. 6. Recoil spectra in a $CaWO_4$ detector induced by neutrons from different origins: (a) low energy neutrons from the rock/concrete, no neutron moderator, (b) low energy neutrons from the rock/concrete after being moderated by 50 cm polyethylene, (c) low energy neutrons from fission reactions of 0.1 ppb $^{238}U$ in the lead shield, (d) high energy neutrons induced by muons in the rock and (e) high energy neutrons induced by muons in the experimental setup.

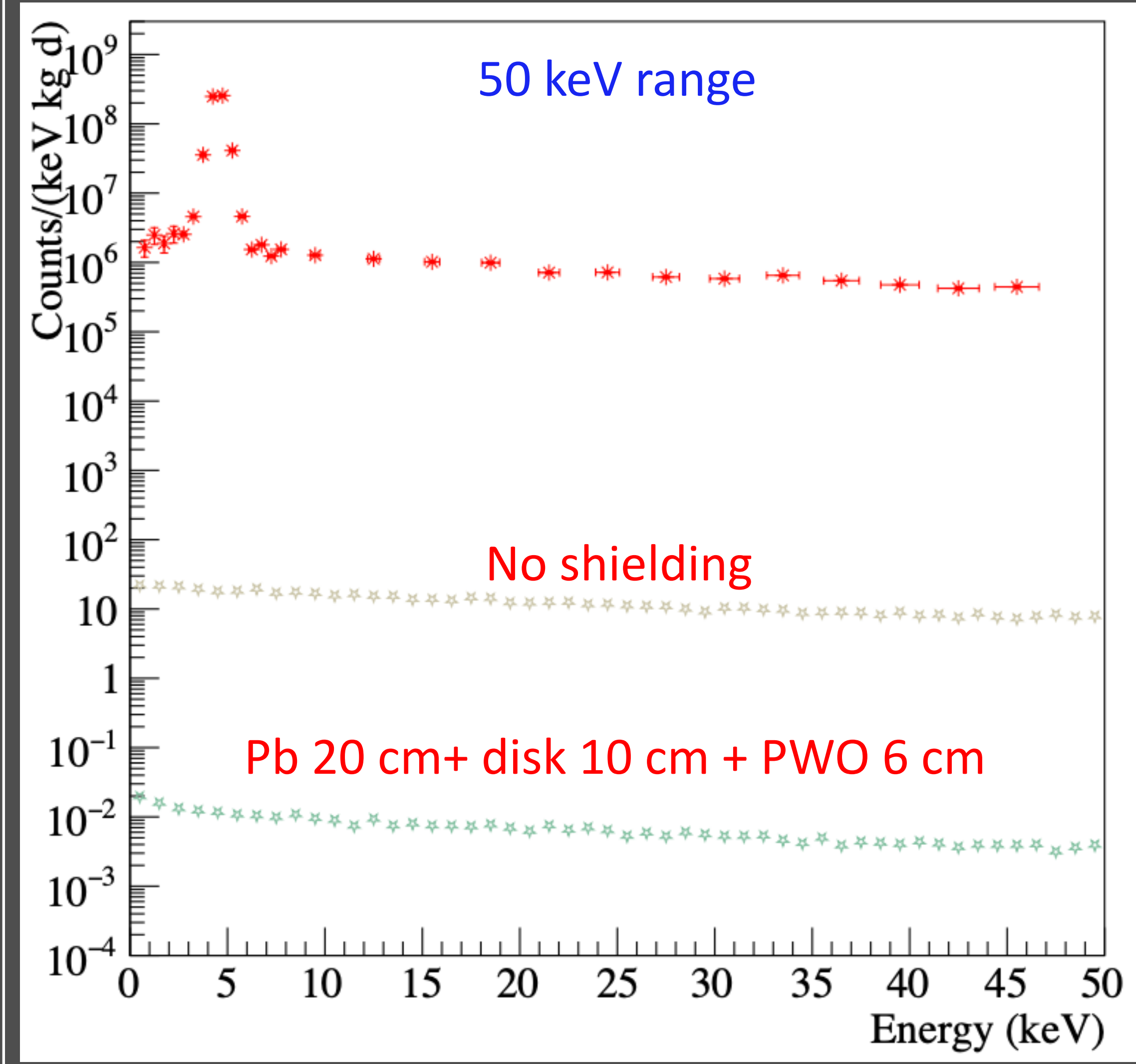
Comparison with CRESST

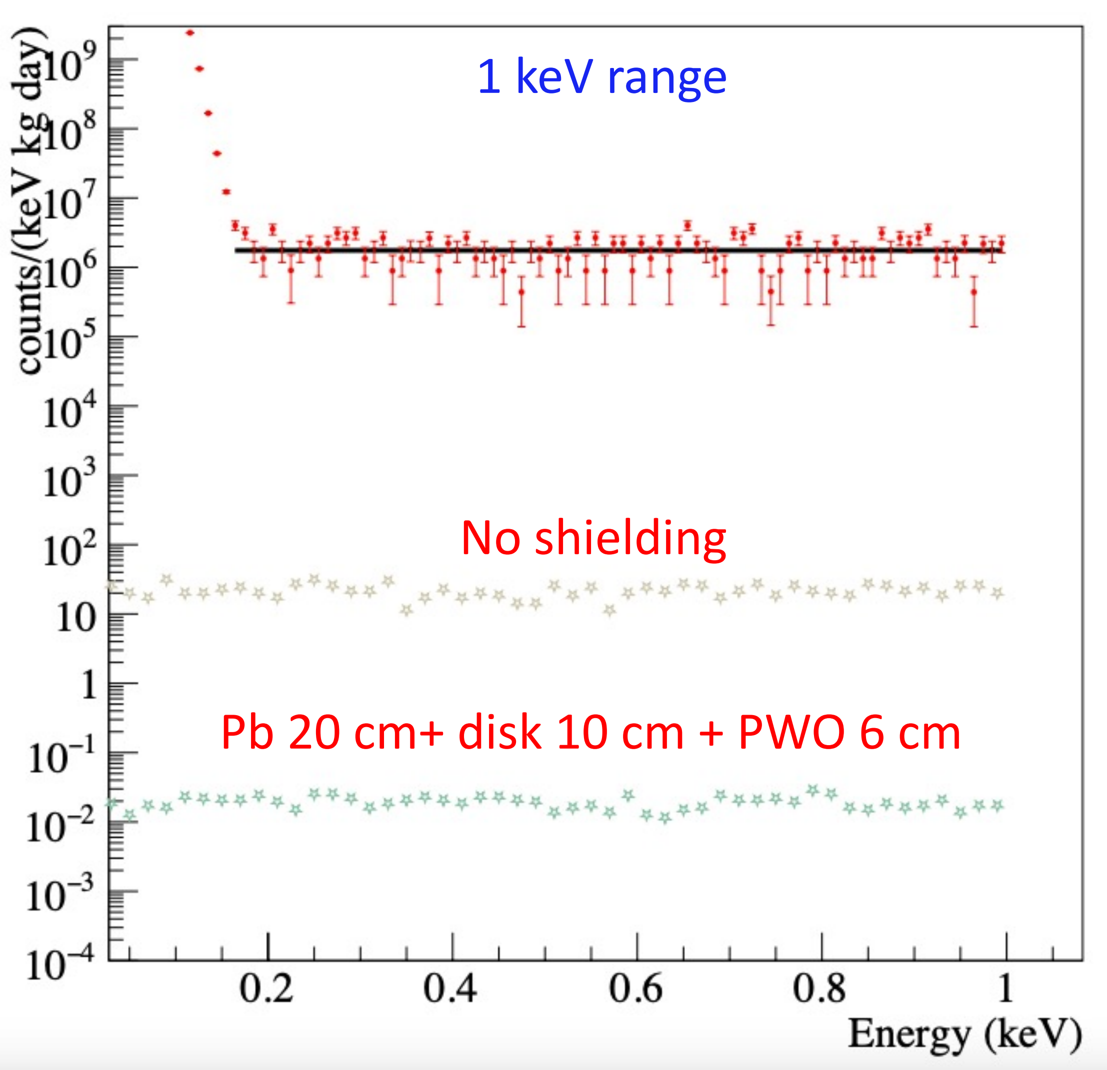
# How to reduce Gammas



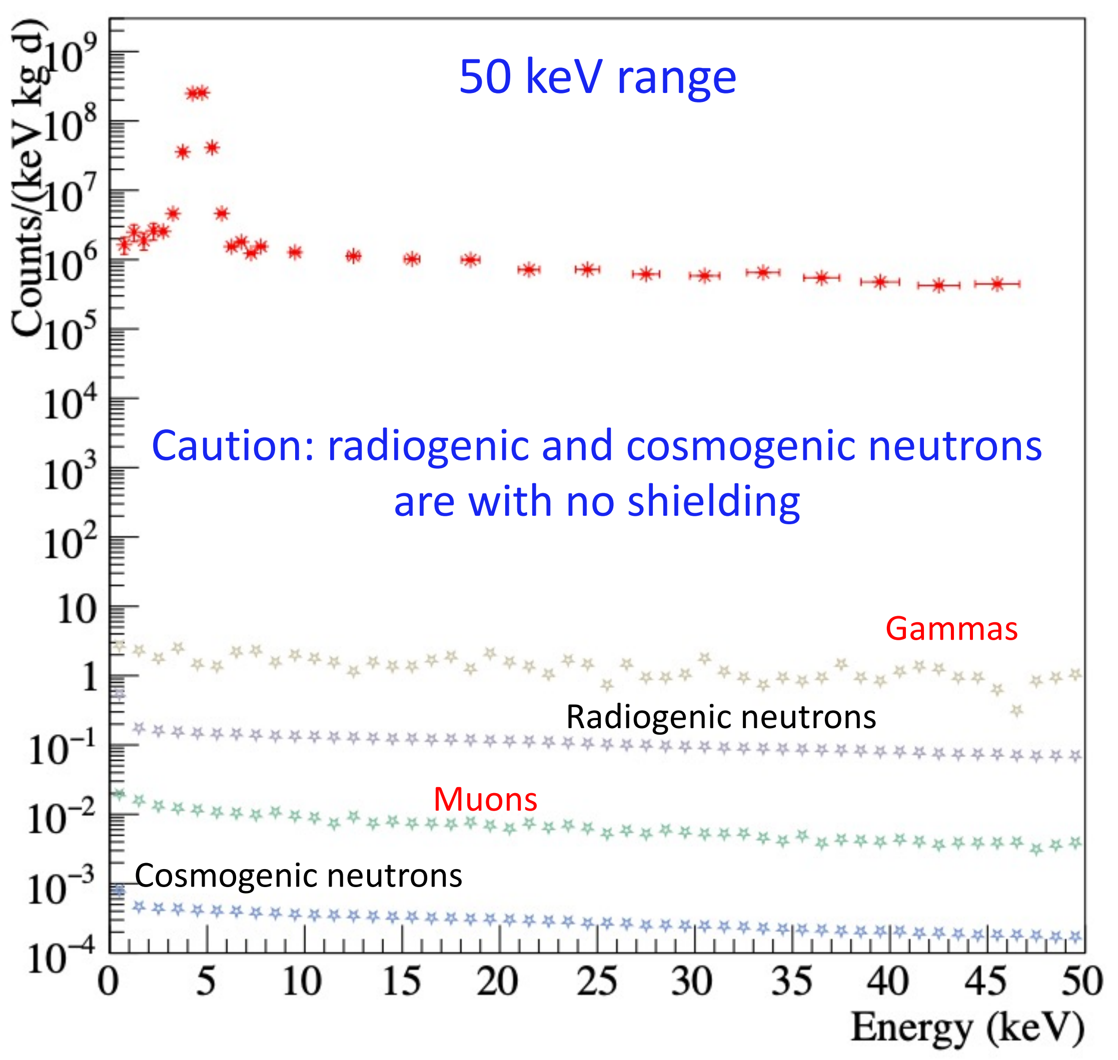



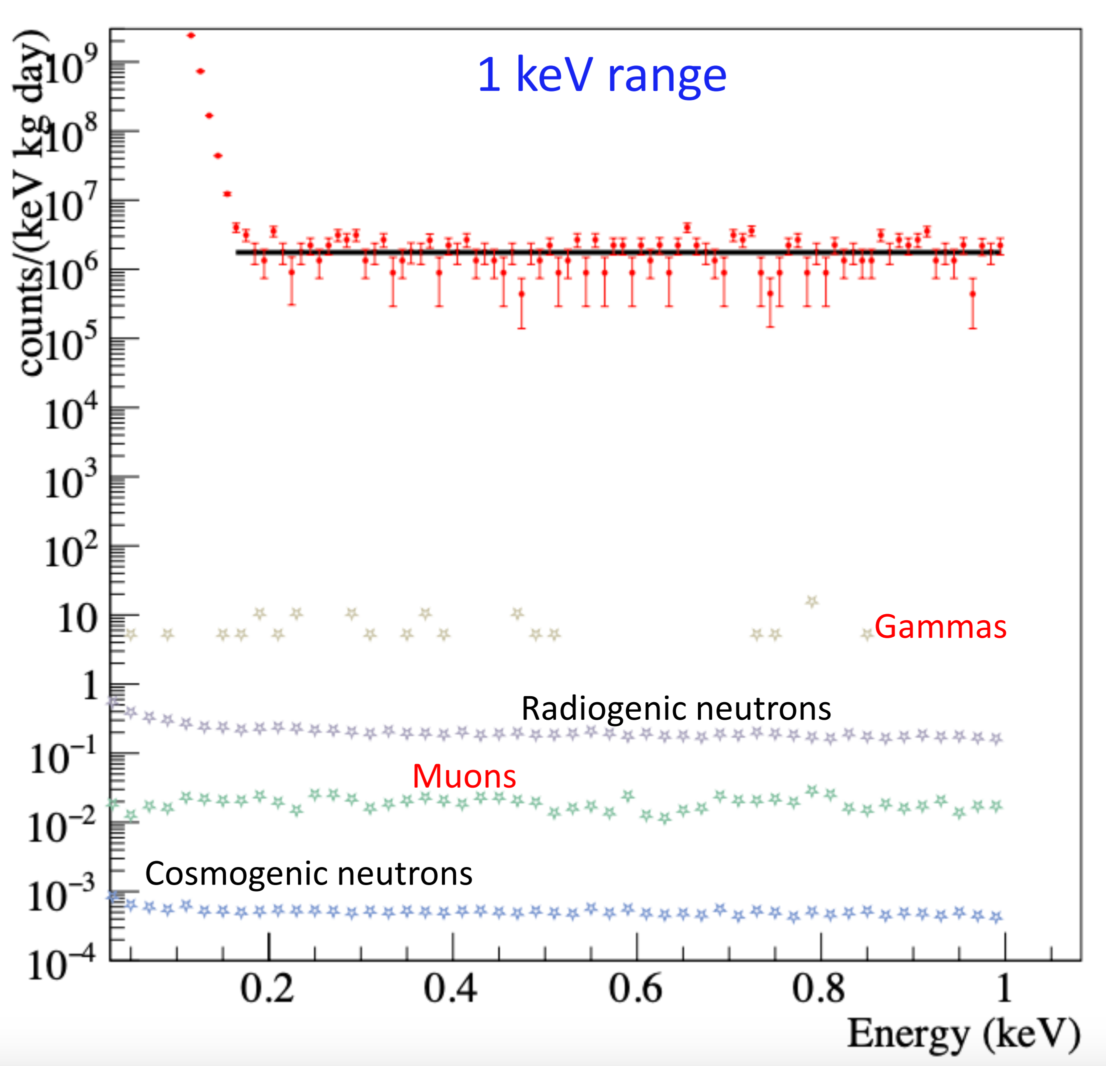
# Muons


50 keV range
No shielding
Pb 20 cm+ disk 10 cm + PWO 6 cm
Counts/(keV kg d)
Energy (keV)


1 keV range
No shielding
Pb 20 cm+ disk 10 cm + PWO 6 cm
counts/(keV kg day)
Energy (keV)

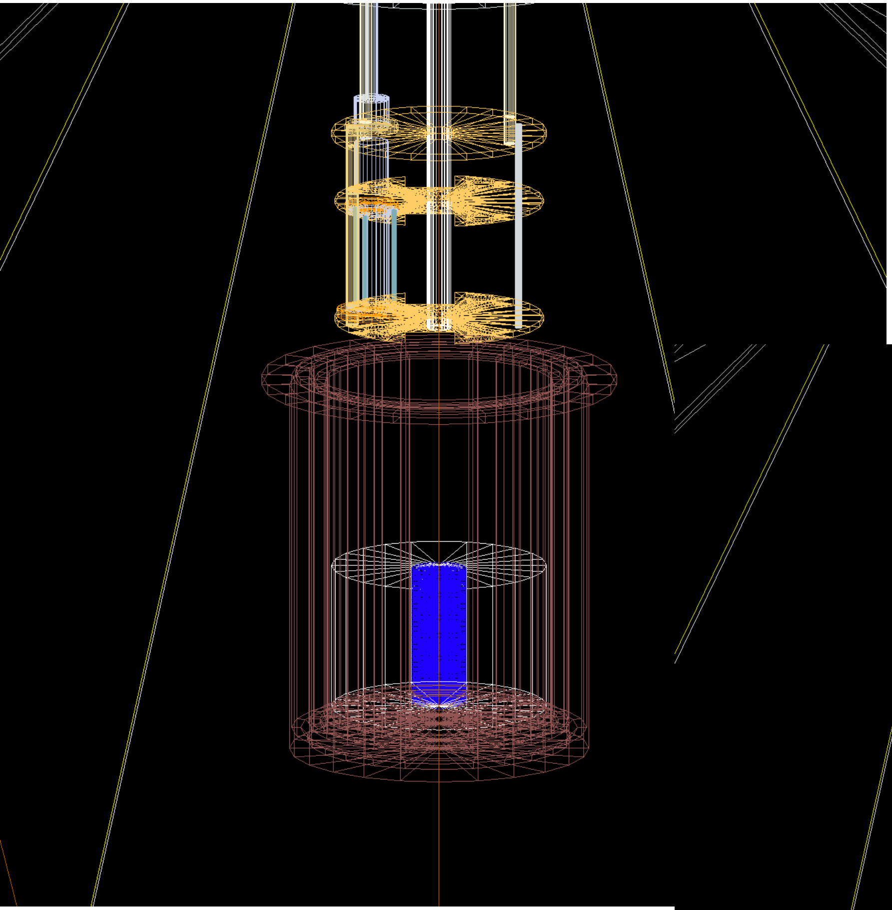
# Shielding (PWO is inactive)



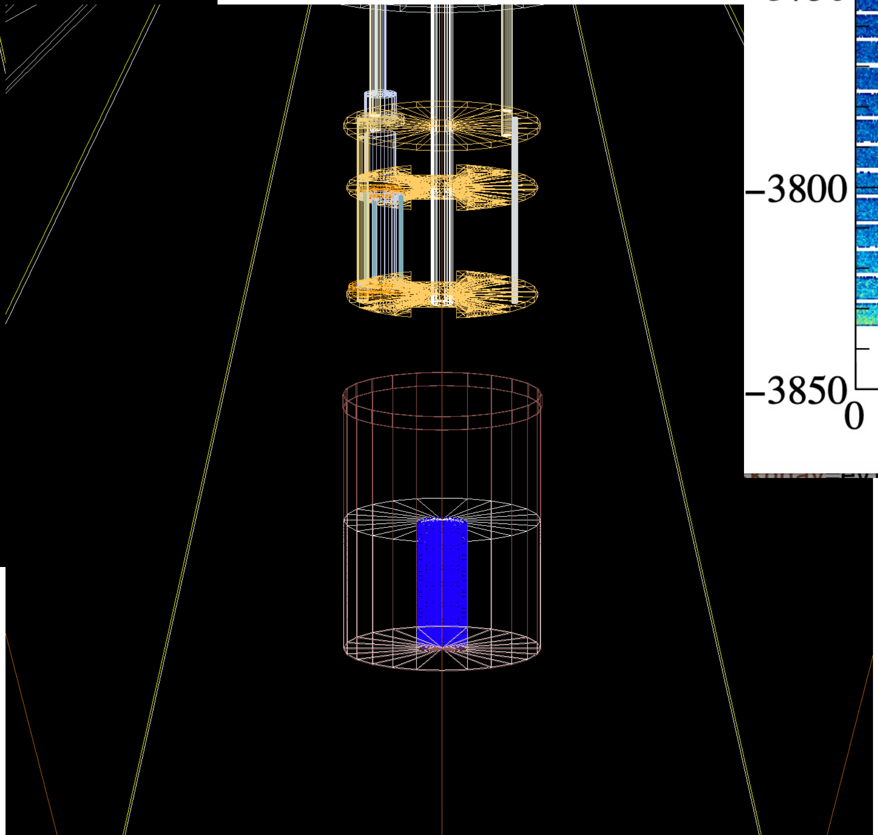



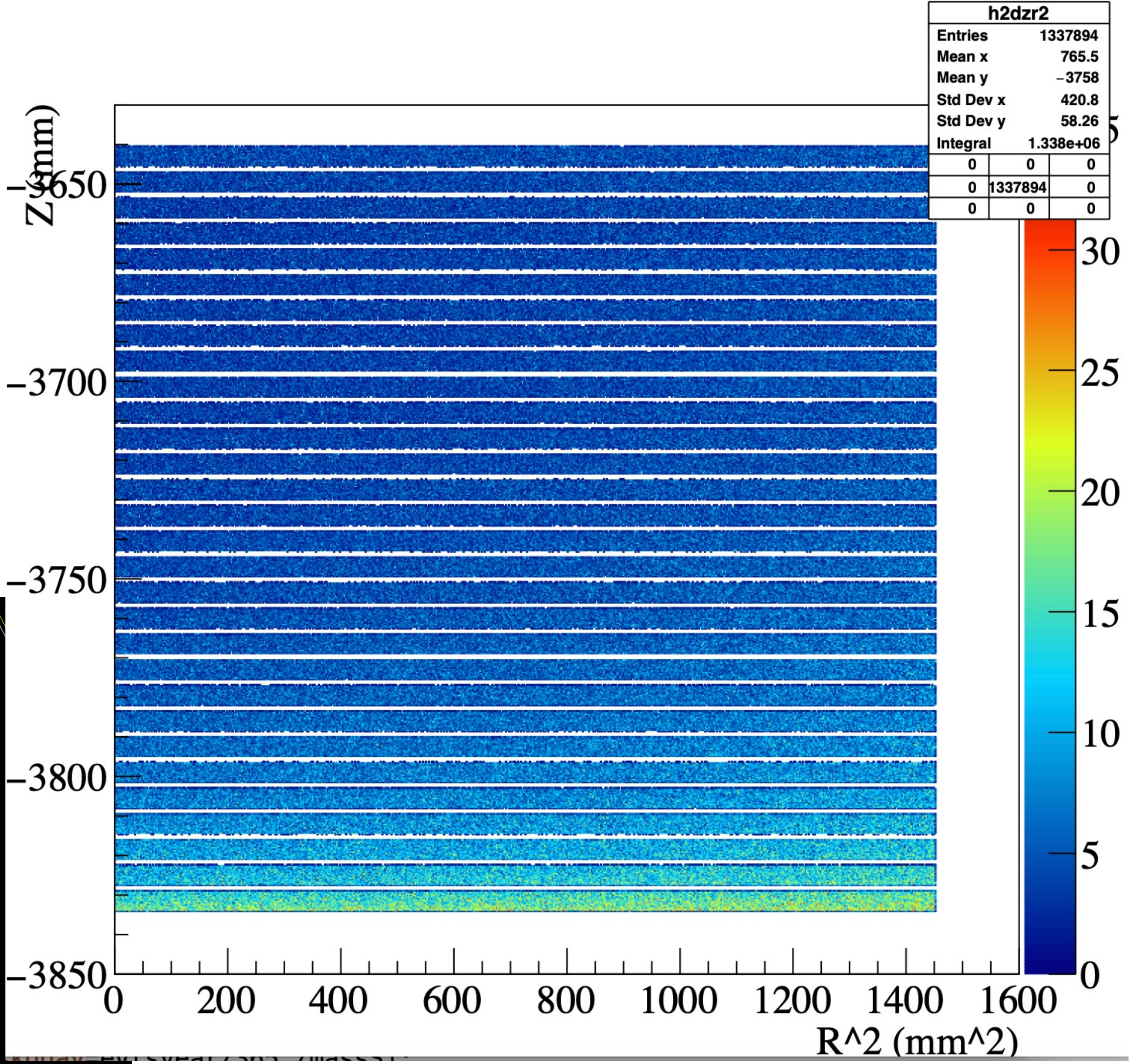
# Internal backgrounds: neutrons (two examples)

Aluminum



Copper





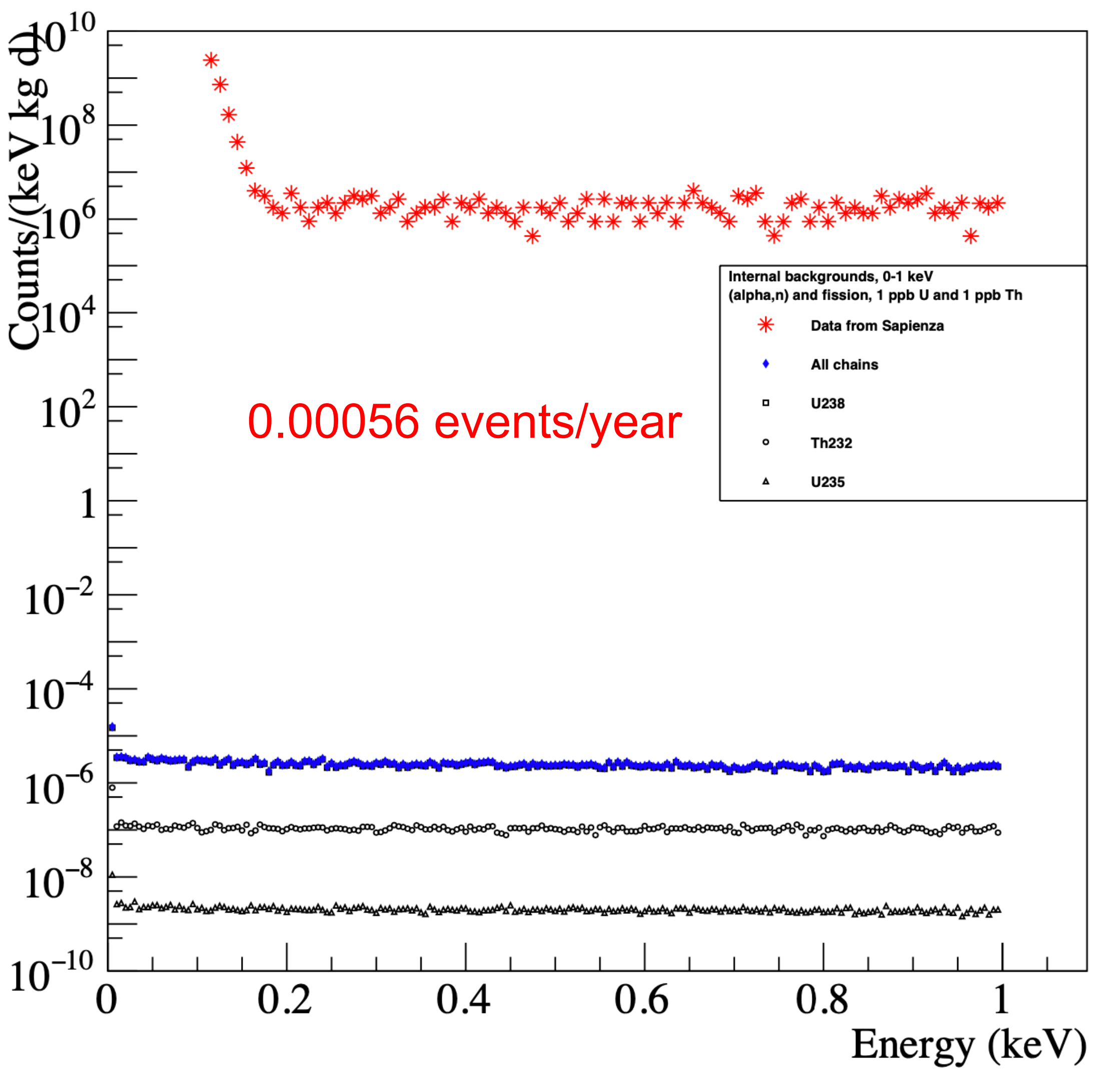

Events in the Si sensors

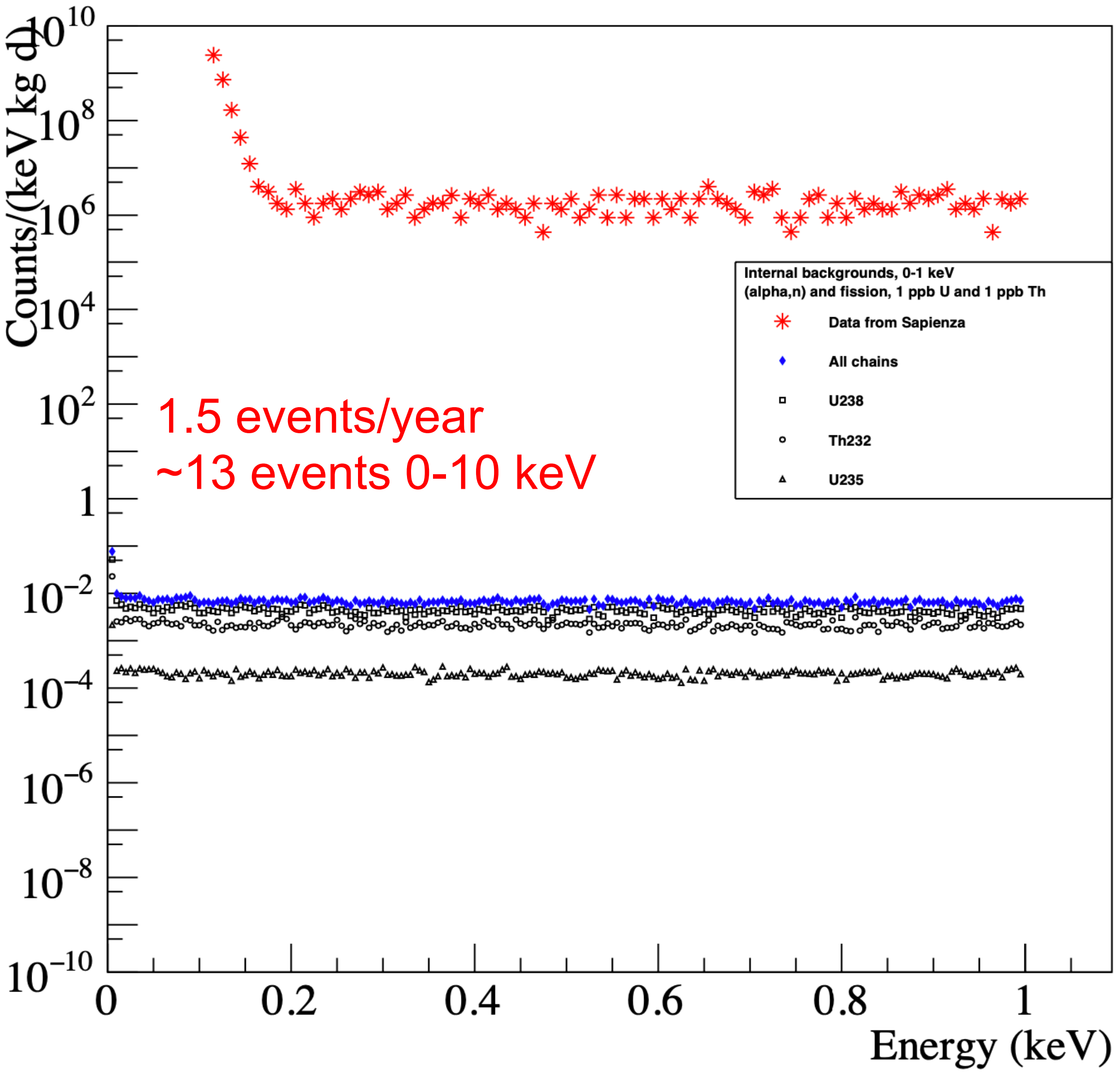
Copper, m =2.96 kg
U238 =1.415E-11 n/s/g/ppb
Th232 =7.335E-13 n/s/g/ppb

Results assuming:

- 1 ppb U, Th in Cu
- 50 ppb U, Th in Al

Aluminum, m=20.41 kg
U238 =1.647E-10 n/s/g/ppb
Th232 =8.198E-11 n/s/g/ppb



# Summary and Conclusions

- ✓ 1 event per year in the detector $\sim 1\times10^{-3}$ counts/kg/day in the ROI

- ✓Shielding design is converging for external gammas and muons

- ✓Shielding radiopurity?
- ✓Simulate neutrons with current shielding
- ✓Internal backgrounds need to be assesed
- ✓Design neutron shielding
- ✓Validate muon induced neutrons in rock, shield and detector
- ✓Active or inactive PWO?