Updates on Veto Simulations

BULLKID Collaboration Meeting Ferrara 1-2/07/2025

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Introduction:

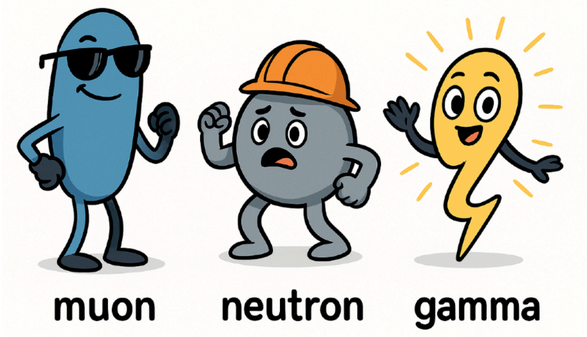
Cryogenic veto:

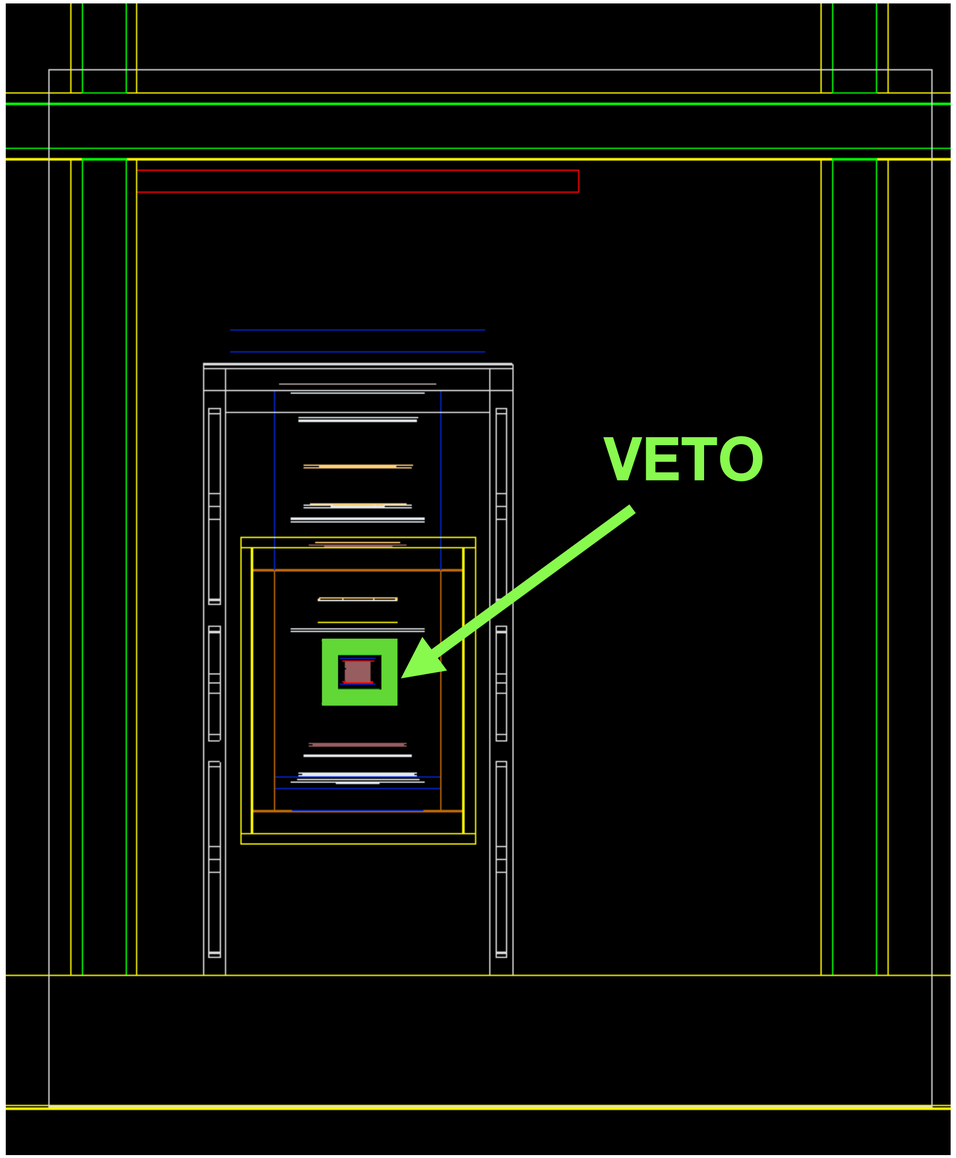
Integrate in the internal shielding system a cryogenic veto with consists of **scintillating crystals** read out by KID light detector.

Simulations:

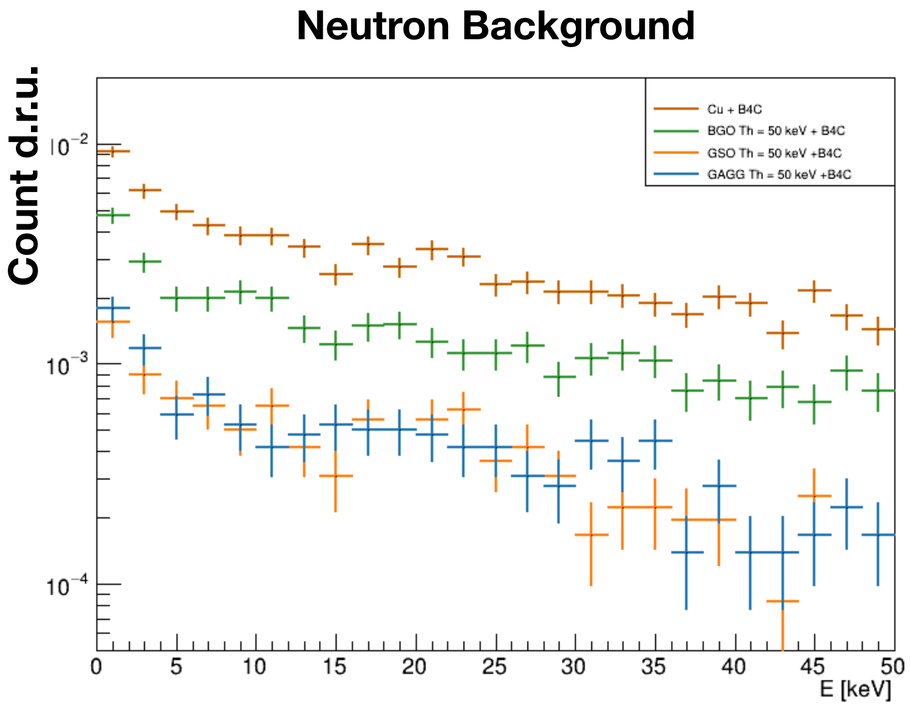
Study the effectiveness of the veto using geant 4 Simulation developed by Eric Vazquez Jaregui.

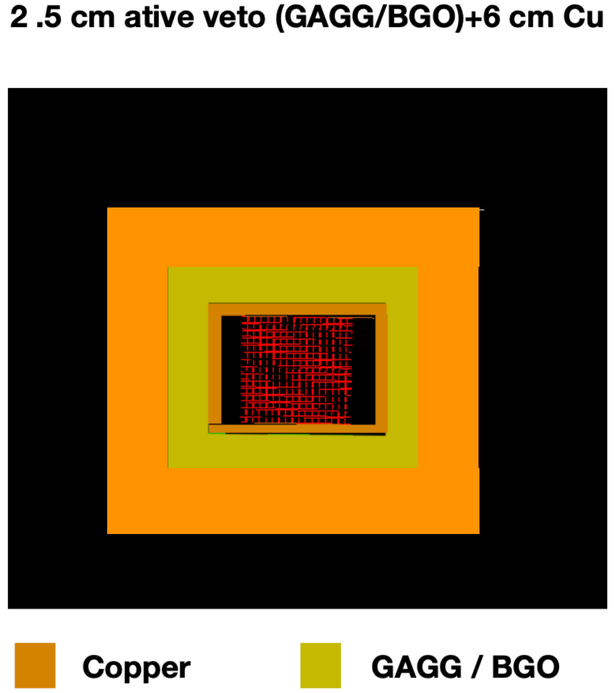
External Backgrounds:





What we have:





Neutron:

- Simulation of the baseline solution 6.5 cm Cu shield reproduce the correct background level of 10^{-2} d.r.u.
- 6.5 cm GAGG veto reduce neutron background of a factor ~ 10

Gamma:

- 6.5 cm BGO veto reduce the gamma background of a factor ~ 6

Thin veto:

- 2.5 cm veto + 6 cm Cu shield can reduce the gamma background up to a factor ~ 13

What is missing:

1. Until now simulation only **local** on my laptop:

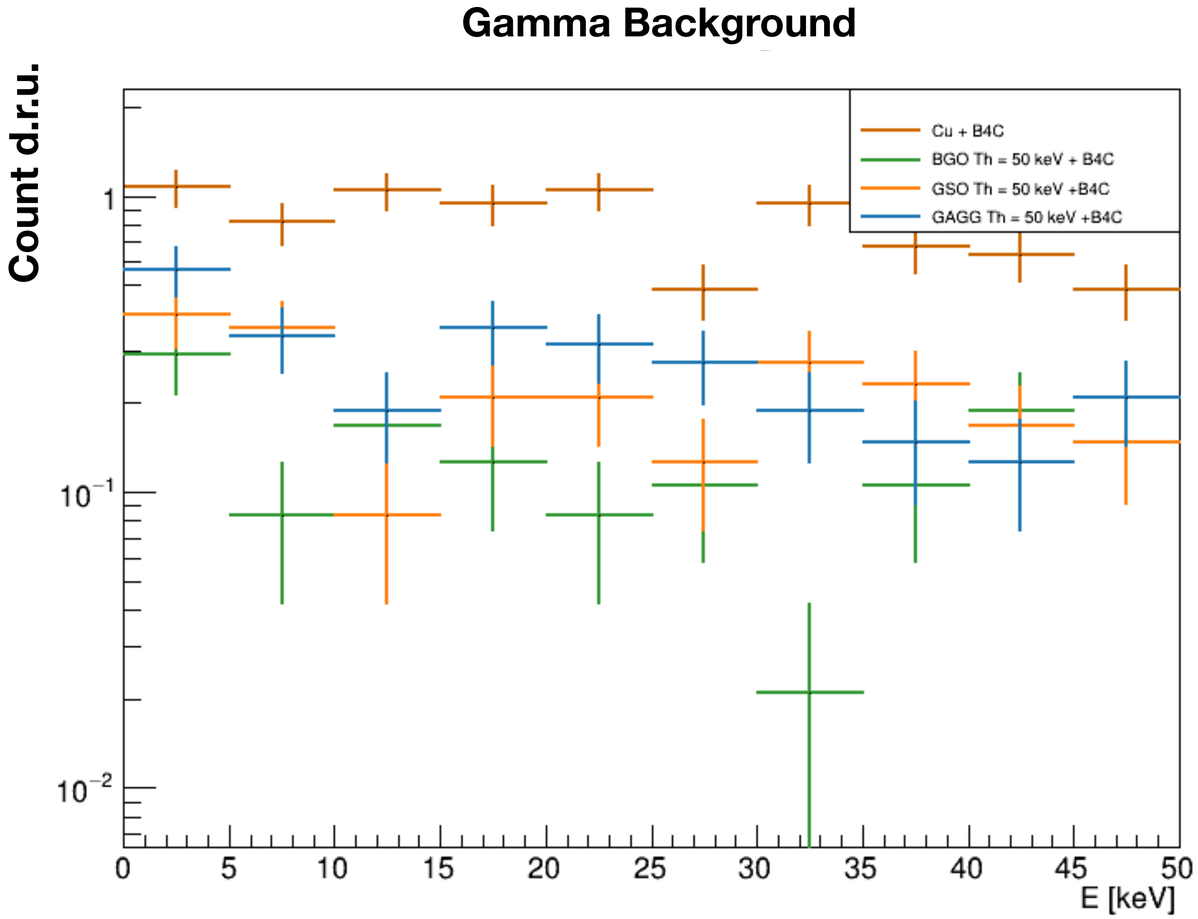
   Poor statics to evaluate gamma background.

2. **Gamma**:

   The simulation of the Cu passive shield do **not reproduce the correct background** level of $\sim 10^{-2}$ d.r.u. .

3. **External Shielding** configuration has been **updated.**

4. **Missing** simulation of **muon** background.



Finalize the simulations:

1. Increase the statistic.
2. Run simulation with **updated shielding configuration**
3. **Gamma simulations** should reproduce **correct background level** $\sim 10^{-2}$ **d.r.u.** with the **baseline configuration**.
4. Simulate **muon background**

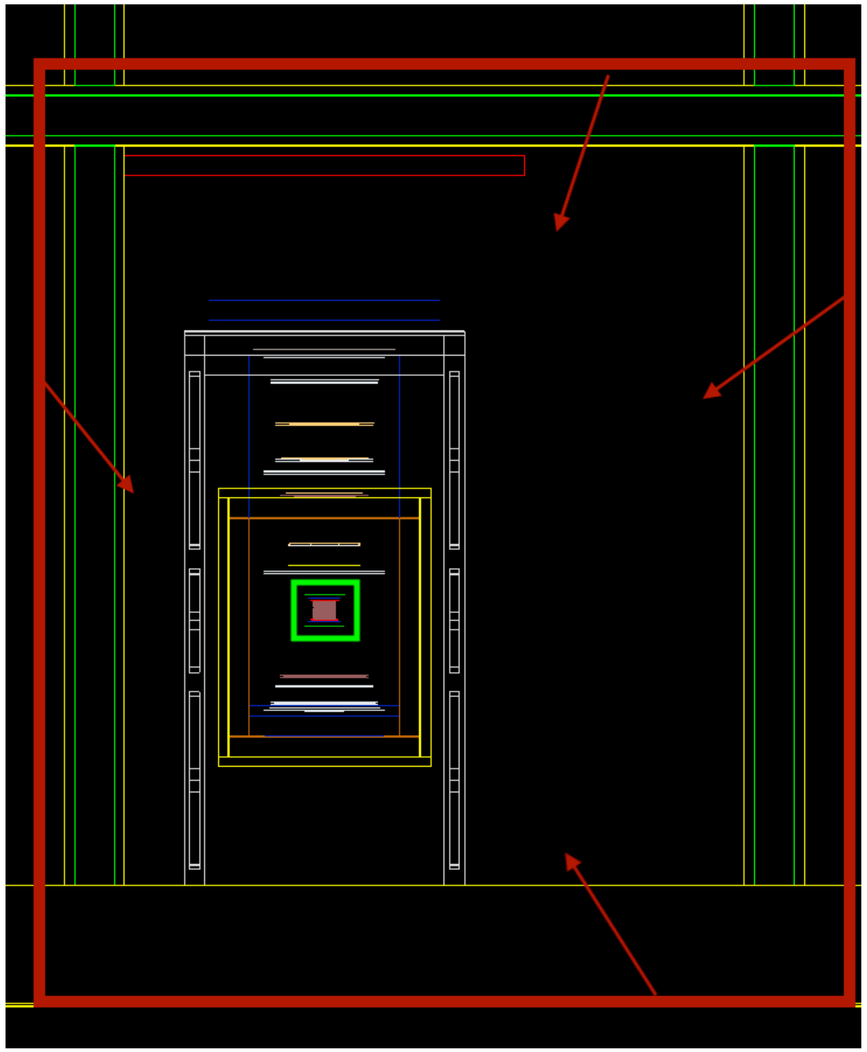
In this presentation:

1. Simulations run on **INFN pisa computing farm**
2. **Updated shielding** configuration
3. **Gamma simulation** updated
4. First simulation of **muon background**

Preliminary results

The INFN Pisa farm went down last week, so I couldn't finish the analysis.

Updated Gamma Simulation:

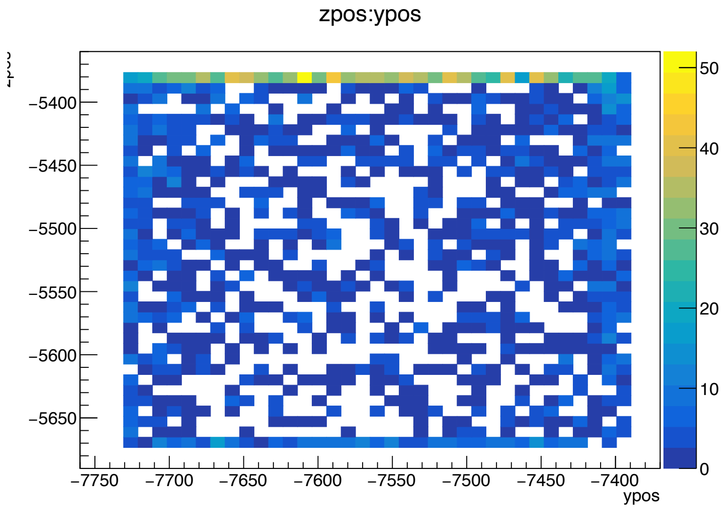


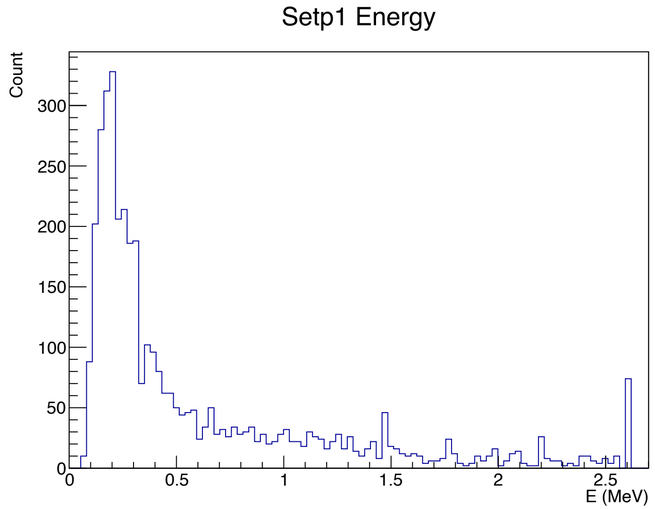
Step1:

- Primaries **energy and flux**:
  - **Belli, P., et al.** "Deep underground neutron flux measurement with large BF 3 counters." *Il Nuovo Cimento A (1971-1996)* 101.6 (1989): 959-966..
- Primaries generated from a **surface outside experimental room** with **isotropic distribution** ($\cos(\theta)$)
- Primaries gamma **collected at veto surface**.

Step2:

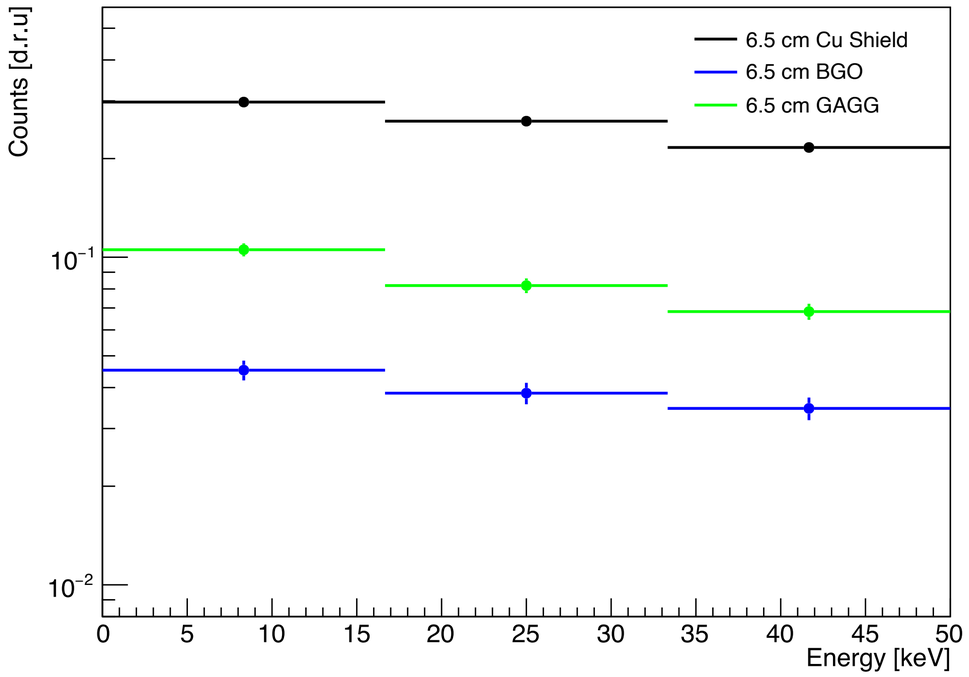
- Gamma emitted from the veto surface
- Primaries emitted accordingly with **energy, position and direction** obtained in Step1.



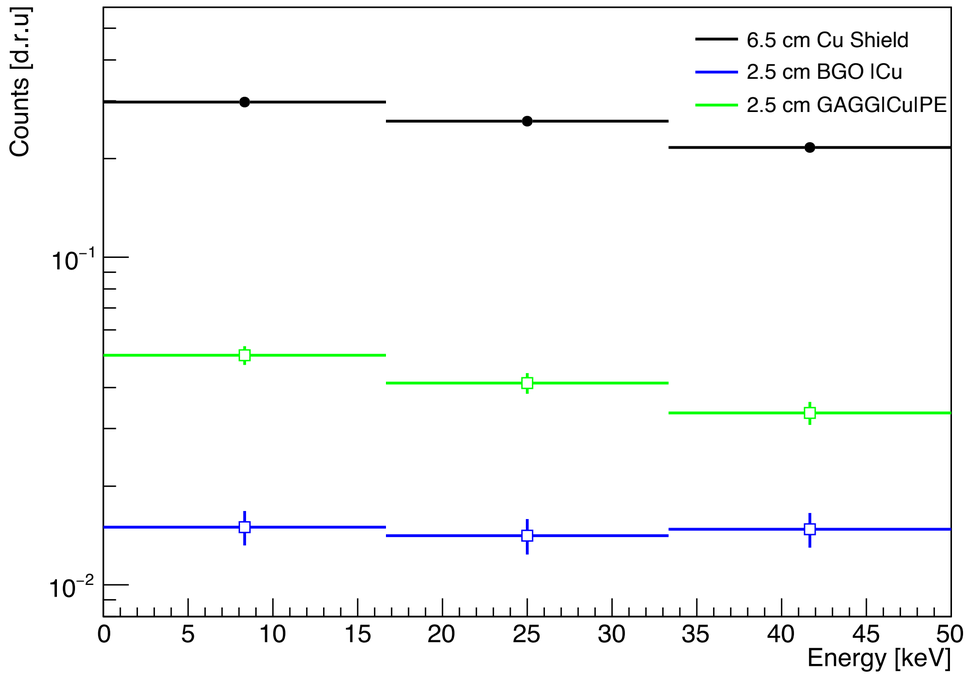


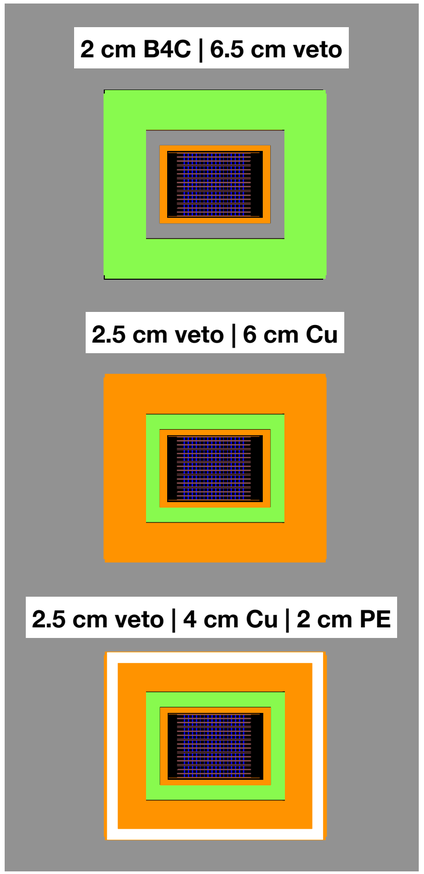
Updated Gamma Simulation:

Gamma Background 6.5 cm veto + B4C



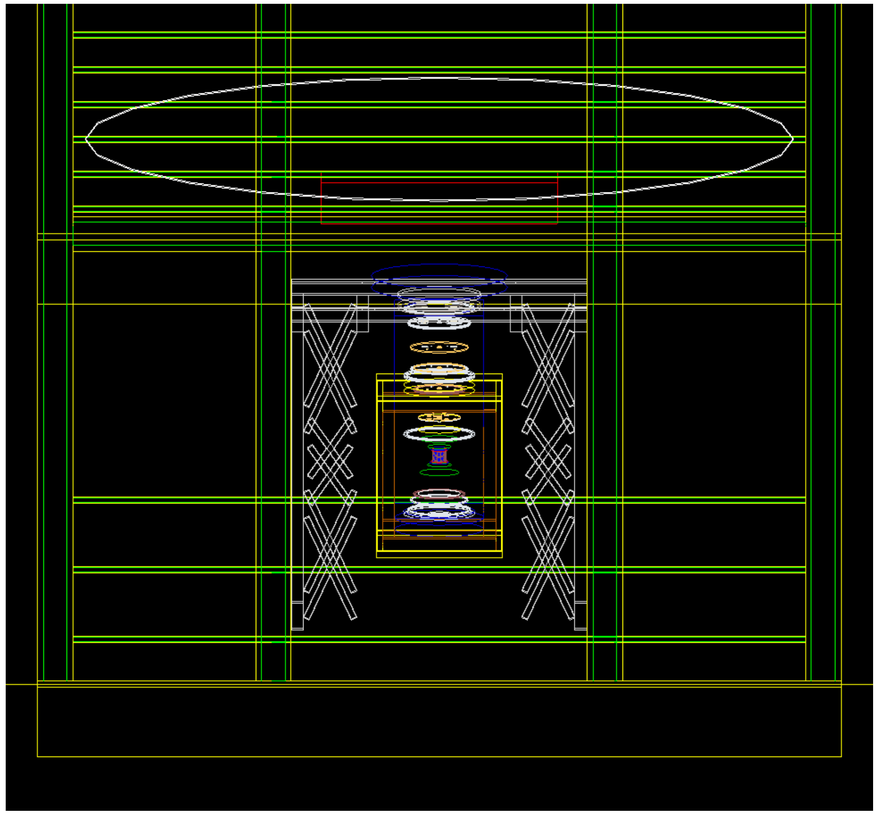
Gamma Background 2.5 cm veto + Cu/PE



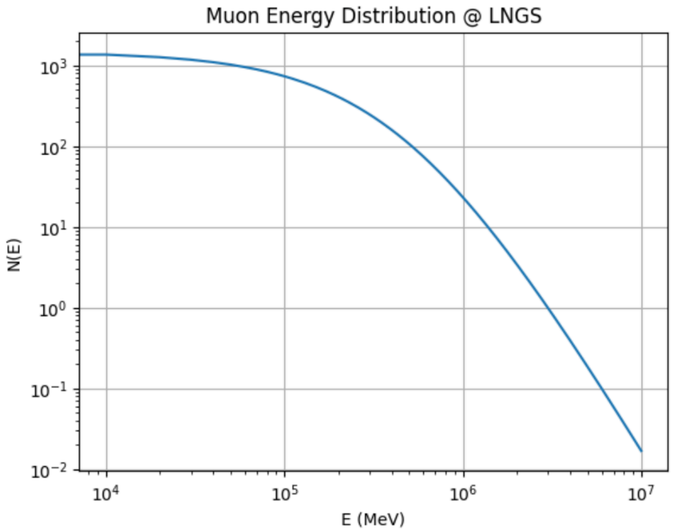


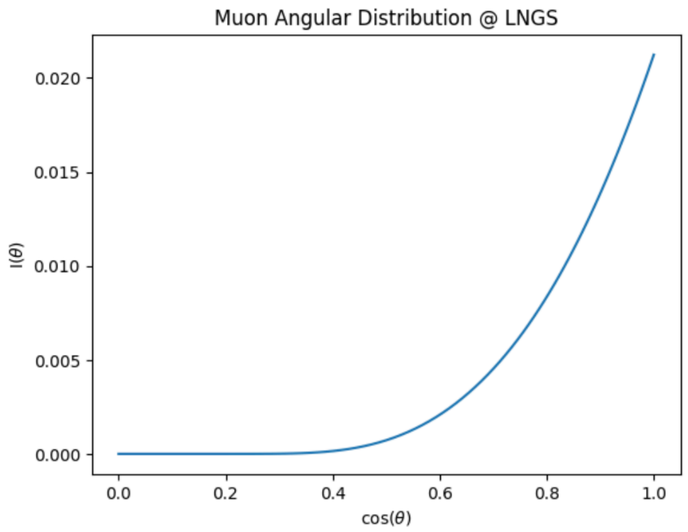
1. Simulation of Baseline Configuration **do not reproduce correct** background level: 10^{-1} **d.r.u. vs** 10^{-2} **d.r.u.**
2. Simulations of **veto** configurations **confirm previous results**.
3. Need to collect **more statistic**.

Muon Simulation:

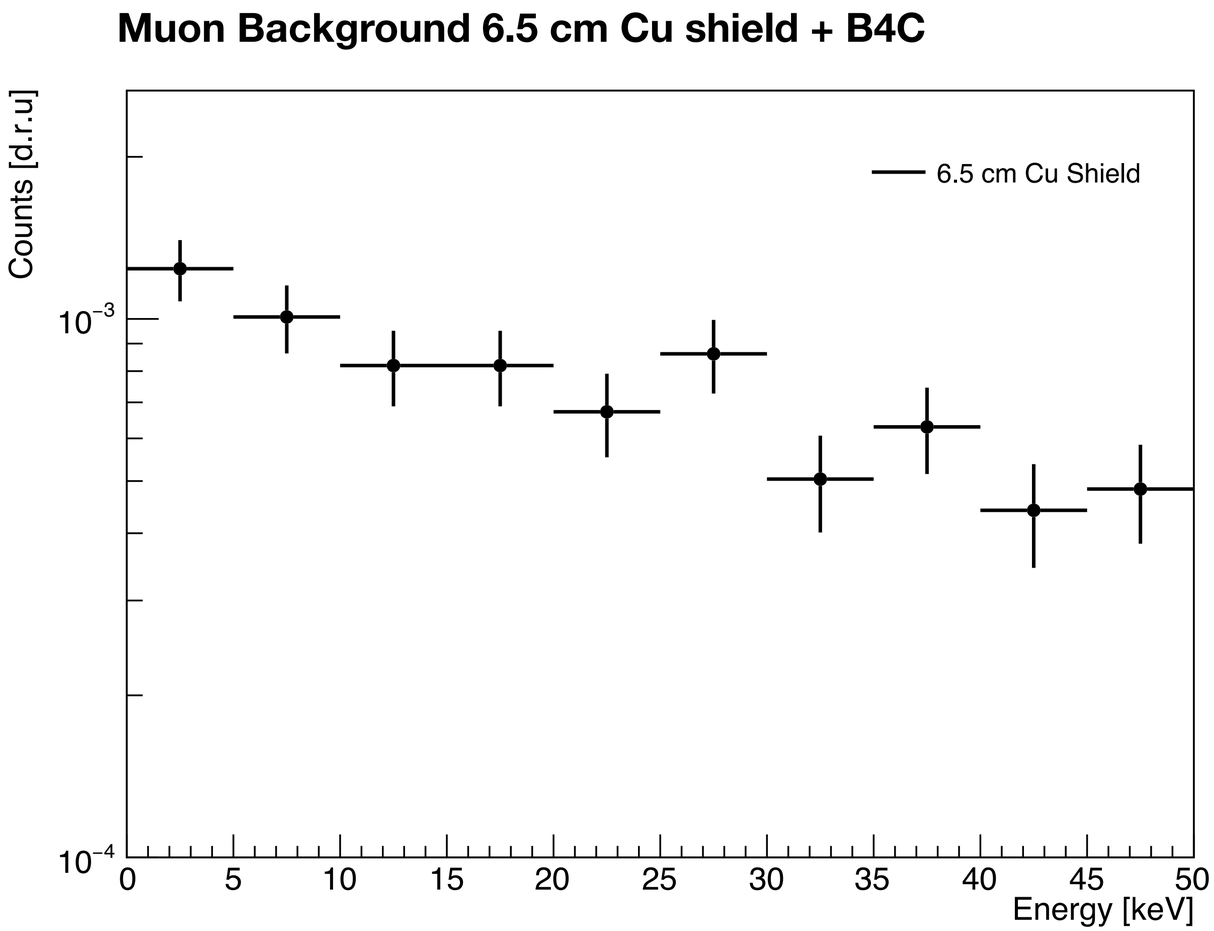


- **Total Muon Flux**:
  Ambrosio, Michelangelo, et al. "Measurement of the energy spectrum of underground muons at Gran Sasso with a transition radiation detector." Astroparticle Physics 10.1 (1999): 11-20.
- **Energy and angular distribution**:
  Mei, D-M., and A. Hime. "Muon-induced background study for underground laboratories." Physical Review D—Particles, Fields, Gravitation, and Cosmology 73.5 (2006): 053004.
- **Primaries generated from a 600 cm diameter disc above bullkid set-up.**





Muon Simulation:



1. **Only Cu shield** simulated with only $\sim 4 \times 10^2$ events.

2. Simulation of Baseline Configuration **do not reproduce** correct background level: 10^{-3} d.r.u. vs 10^{-2} d.r.u.

3. **Nice result for the veto:**

   Treating the Cu shield as active with a threshold $E_{Th} = 100$ keV, the background is zero-> **reduced at least of a factor** $> 10^2$.

Conclusions:

Finalize the simulations:

1. Run simulation on **computing farm** to increase the statistic.

   OK, it could be done in the next few weeks

2. Run simulation with **updated shielding configuration**

   OK

3. **Gamma simulations** should reproduce **correct background level** $\sim 10^{-2}$ **d.r.u.** with the **baseline configuration**.

   NO, need to check the flux normalization and other details of the simulation.

4. Simulate **muon background**

   Started but need to reproduce correct background level for the baseline configuration

Thank you for your attention

d.r.u. normalization:

Back-up

Gamma:

```
Nbins=3
nPri=8e8 # Step1 Primaries number
l1=3.20#m
l2=4.00#m
l3=4.70#m
Sgun1=((l1*l2)+(l1*l3)+(l2*l3))*2 #Gun Surface of the First Step (m^2)
Phi0=95e6 # Gamma  Flux (gamma/m^2 day)
deltaBin=50./Nbins # Bin width (keV)
nPri2=2e7 # Step2 Primaries number
nEvInt=3924 #Event in the first step.
coeff=Phi0*Sgun1*nEvInt/(nPri*0.6*deltaBin*nPri2)
```

Muon:

```
Phi0=2.58e-8 # muon/cm^2 s

Phi0=2.58e-8*(24*60*60) # muon/cm^2 day

nPri=2e7 #Primary muons number
R=300# Disc Radius (cm)
Sgun1=np.pi*(300**2) #Disc Area (cm^2)
deltaBin=50/Nbins # bin width (keV)

coeff=Phi0*Sgun1/(nPri*0.6*deltaBin)
```