NEWS

NUCLEAR EMULSIONS FOR WIMP SEARCH

"SHIELDING FOR NEWS-10g"

"BACKGROUND SIMULATION"

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on behalf of the NEWS Collaboration

Summary

- Simulation results **without** the shield;
  - Environmental neutrons;
  - Cosmogenic neutrons;
  - Environmental gammas;
  - Alpha source;
  - Beta source;

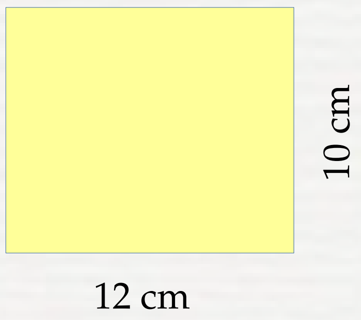
- NEWS shield idea for 10g test exposure;

- Simulation results **with** the shield;
  - Environmental neutrons;
  - Cosmogenic neutrons;
  - Environmental gammas;
  - Beta from ^{40}K;
  - Neutrons from lead;

- Time line for 1Kg exposure.

BACKGROUND SOURCES WITHOUT SHIELD

Environmental Neutrons



Density of NIT emulsion = 3.43 g cm^{-3}
Mass of 1 NIT layer ($12x10cm^2$) = 2.058 g
Flux of environmental neutrons = 8.7×10^{-7} cm^{-2} s^{-1}

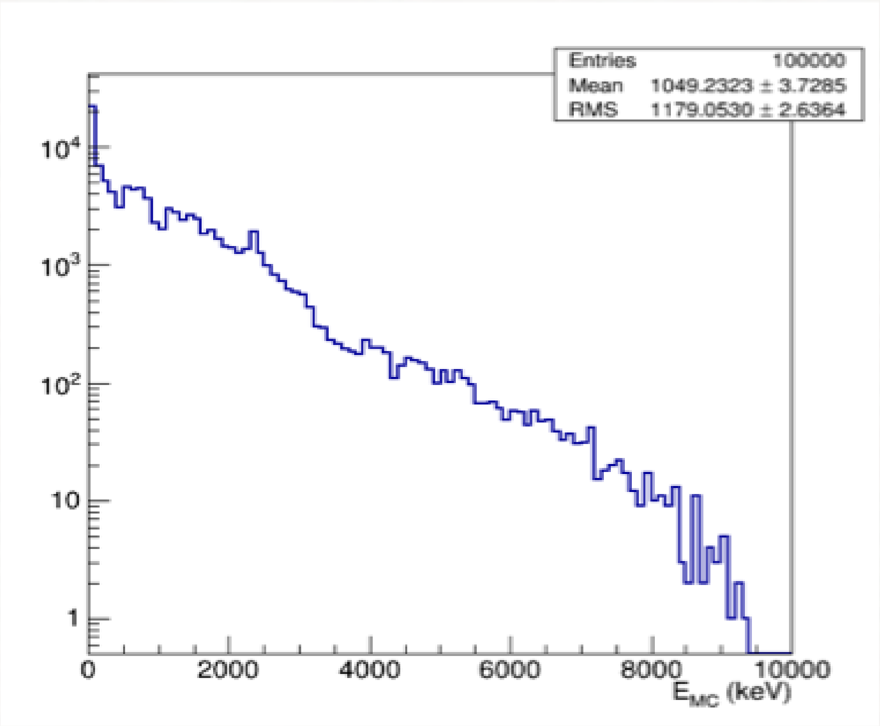
Simulation Results

No. of films	*= 45*
No. of generated events	*= 2×10^6*
Mass of Detector	*= 2.058g x 45 = 92.61g*
Exposure time	*= 1.07 month*
Total exposure	*= 98.80 g month*

NR in signal region = 4

Signal region:
0.1μm < L < 1μm

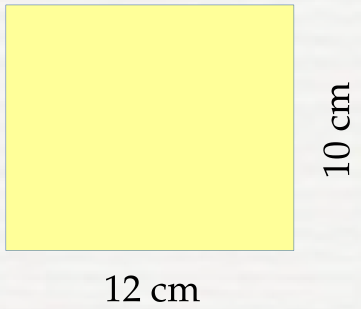
Energy spectrum



Isotropic angular distribution

Rate = Bkg events in signal region / Total exposure **= 4×10^{-2} g^{-1} $month^{-1}$**

Cosmogenic Neutrons



Density of NIT emulsion = 3.43 g cm^{-3}
Mass of 1 NIT layer (12x10cm^2) = 2.058 g
Flux of cosmogenic neutrons = 7.3 x 10^{-10} cm^{-2} s^{-1}

Simulation Results

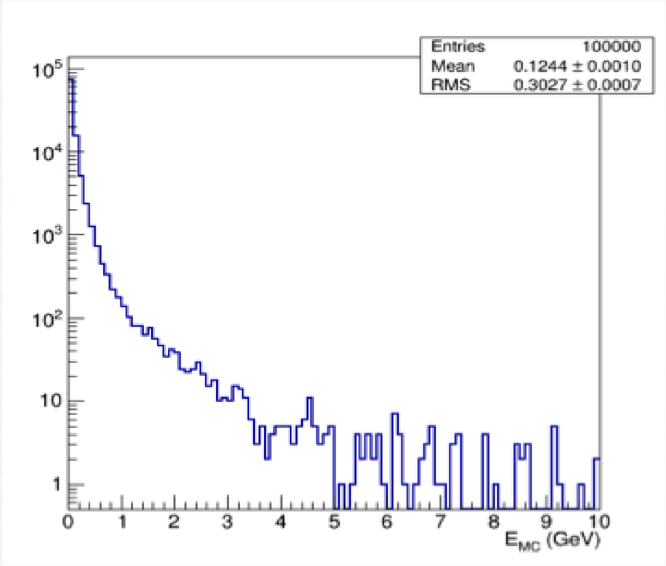
No. of films = 45
No. of generated events = 1.5 10^6
Mass of Detector = 2.058g x 45 = 92.61 g
Exposure time = 953.66 month
Total exposure = 88318 g month

NR in signal region = 0

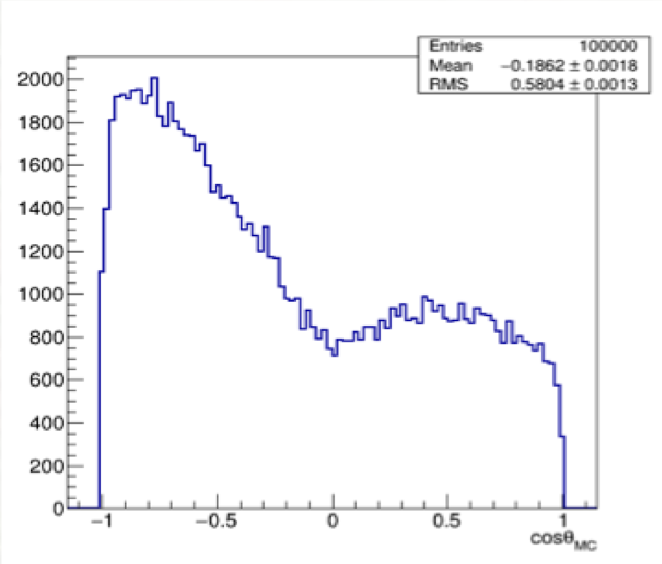
Signal region:
0.1μm < L < 1μm

Upper Limit on background rate: **2.6 x 10^{-5} g^{-1} month^{-1}**

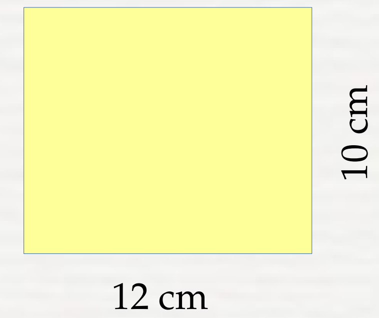
Energy spectrum



Angular distribution

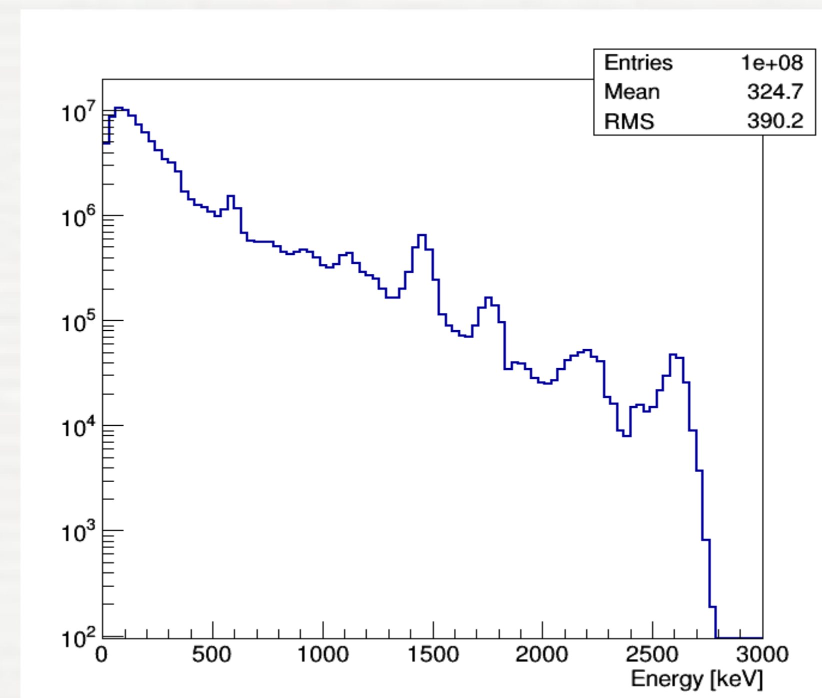


ENVIRONMENTAL GAMMAS



Density of NIT emulsion = 3.43 g cm^{-3}
Mass of 1 NIT layer (12x10cm^2) = 2.058 g
Flux of environmental gammas = 0.35 cm^{-2} s^{-1}

Energy spectrum



Isotropic angular distribution

Simulation Results

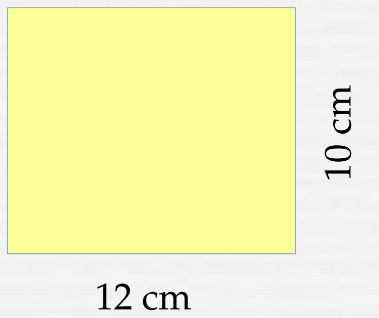
No. of films = *45*
No. of generated events = 2 x 10^7
Mass of Detector = 2.058g x 45 = 92.61 g
Exposure time = 2.18 x 10^{-6} y
Total exposure = 2 x 10^{-7} Kg year

Electrons stopped in NIT = 955

Rate = Bkg events / Total exposure = 4.7 **x 10^9 Kg^{-1} y^{-1}** = 1.6 **x 10^{-2} (10um)$^{-3}$ y^{-1}**

Factor 10 more than bkg electrons from ^{14}C = 2.5 x 10^{-3} (10um)$^{-3}$ y^{-1}

Stacking Nit Effects

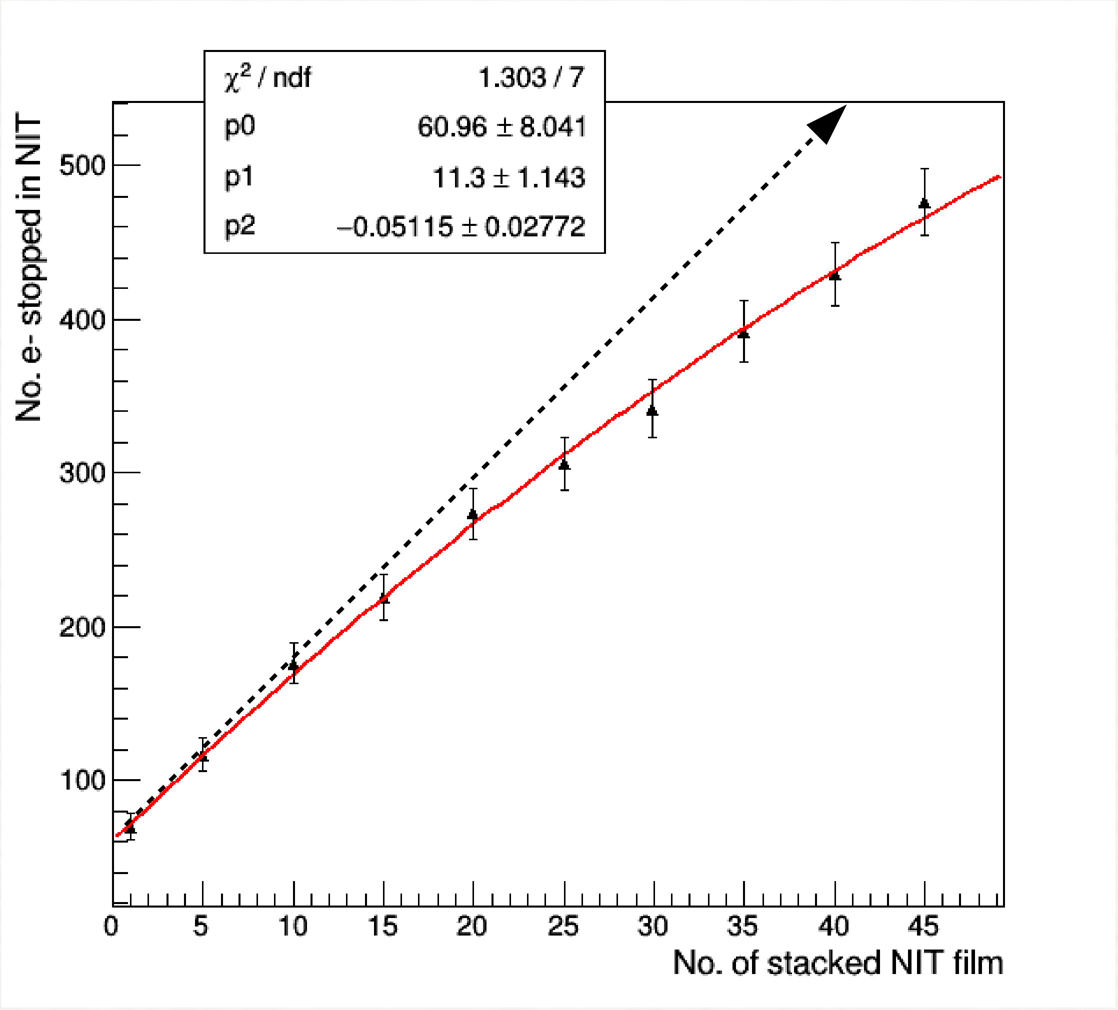


Gamma rays lose continuously their energy passing through the matter
The electron rate may not be the same in each layer of a NIT stack

1 layer

20 layers

45 layers



The background rate is lower than the expected one without pile up

ALPHA AND BETA SOURCES EXPOSURE AT LNGS

Alpha Source (^{241}Am)

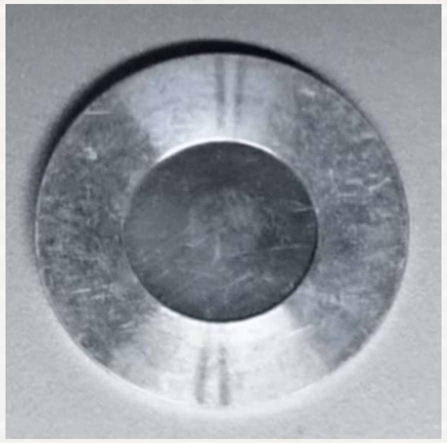
Activity = 4.3 kBq   (ε @ 99% CL: 3.1%)

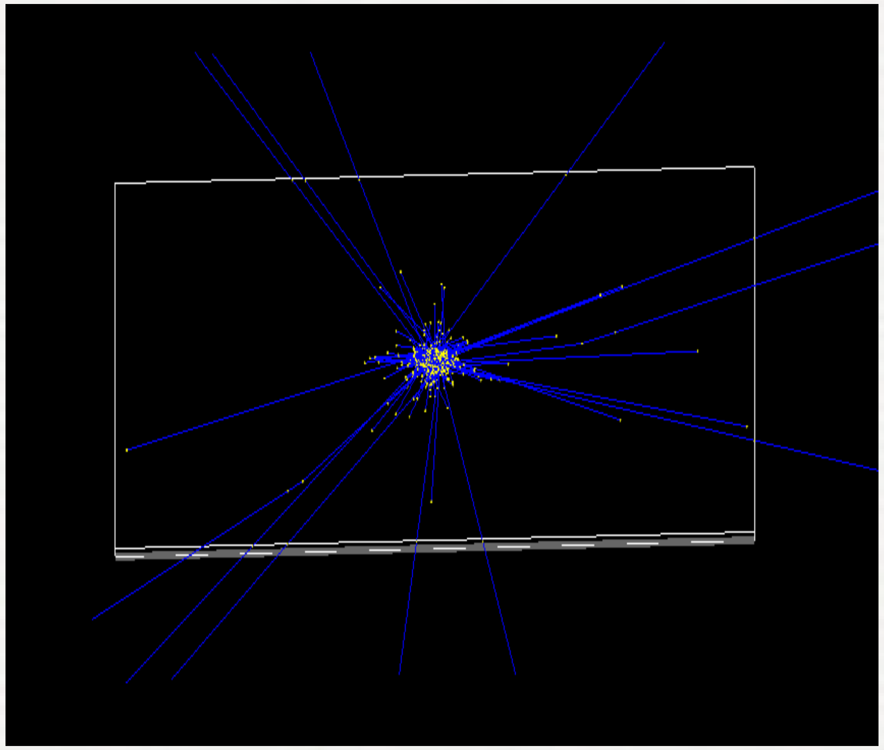
Shape: Circle
Radius: 2.5 mm
Phi: Isotropic
Theta: [0,π/2]
Energy: 5.486 MeV

Simulation Results

No. of films = 1
No. of generated events = 129000
Exposure time = 60 s
Alpha stopped in NIT = 128188

^{241}Am
Stopped in NIT = 99.4 %
Alpha density (30 s exposure) = 0.08 (10um)$^{-3}$





Beta Source (^{90}Sr)

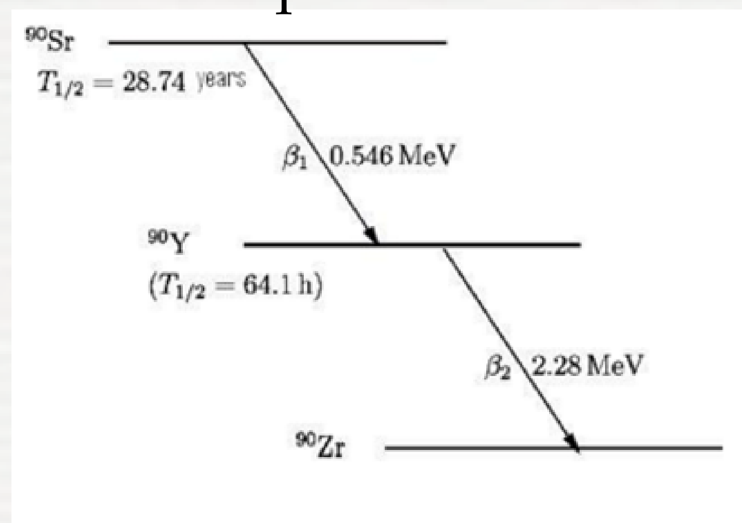
Activity = 285.59 kBq (ε: 10%)

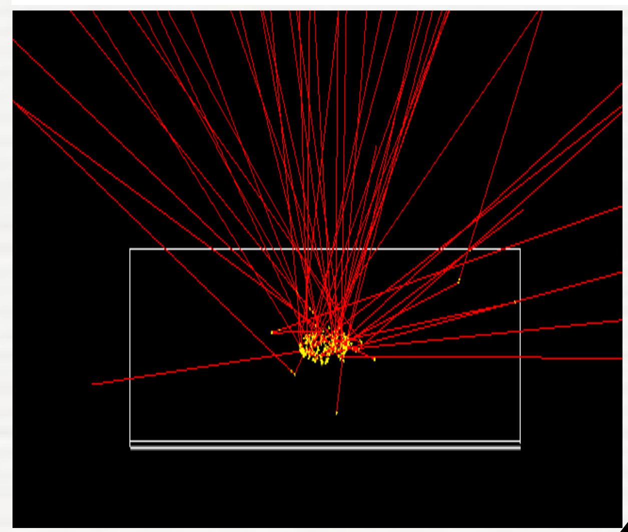
Emitters: Sr-90 and Y-90
Shape: Circle
Radius 8mm
Phi: Isotropic
Theta [0,π/2]

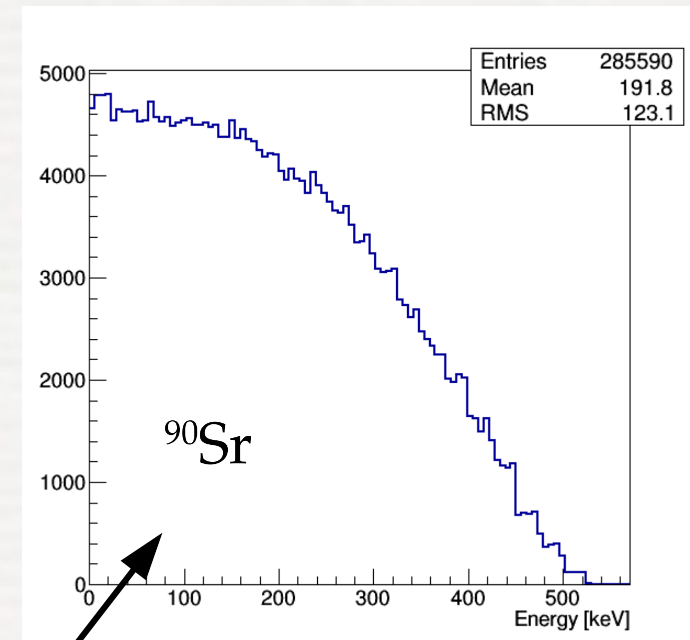
Simulation Results

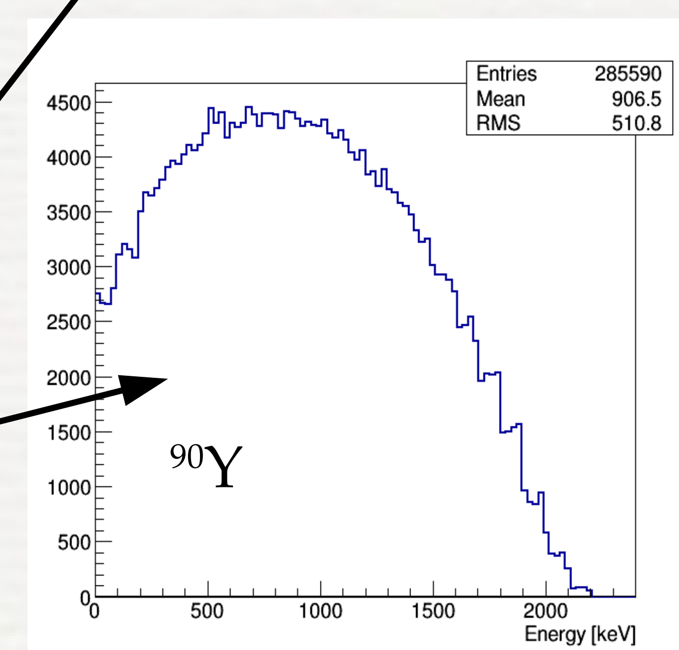
No. of films = *1*
No. of generated events = *285590*
Exposure time = *2 s*
Stopped in NIT (^{90}Sr) = 83860
Stopped in NIT (^{90}Y) = 17394

Secular equilibrium









^{90}Sr
Stopped in NIT = 29.4 %
Electron density (10min expousre)= 3.12 $(10um)^{-3}$

^{90}Y
Stopped in NIT = 6.1 %
Electron density (10min exposure)= 0.65 $(10um)^{-3}$

Energy spectra

NEWS SHIELD FOR 10g EXPOSURE

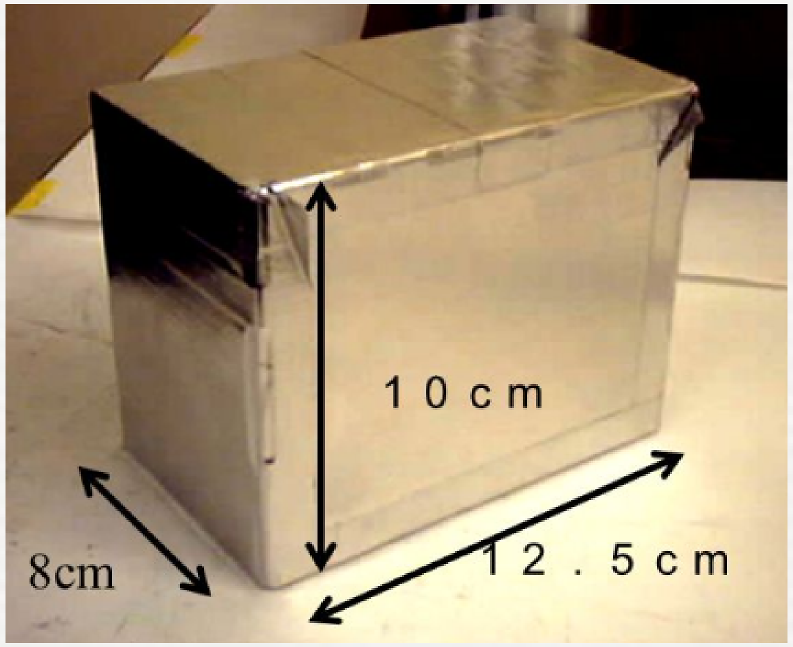
Materials Available Now

POLYETHILENE FROM DARKSIDE-10

5 Plates (XL): 2.44 x 1.22 x 0.105 m^3
50 Plates (L): 1.22 x 0.61 x 0.105 m^3 *(to verify)
5 Plates (M): 0.91 x 0.91 x 0.105 m^3
5 Plates (S): 0.61 x 0.61 x 0.105 m^3

LEAD FROM OPERA BRICKS

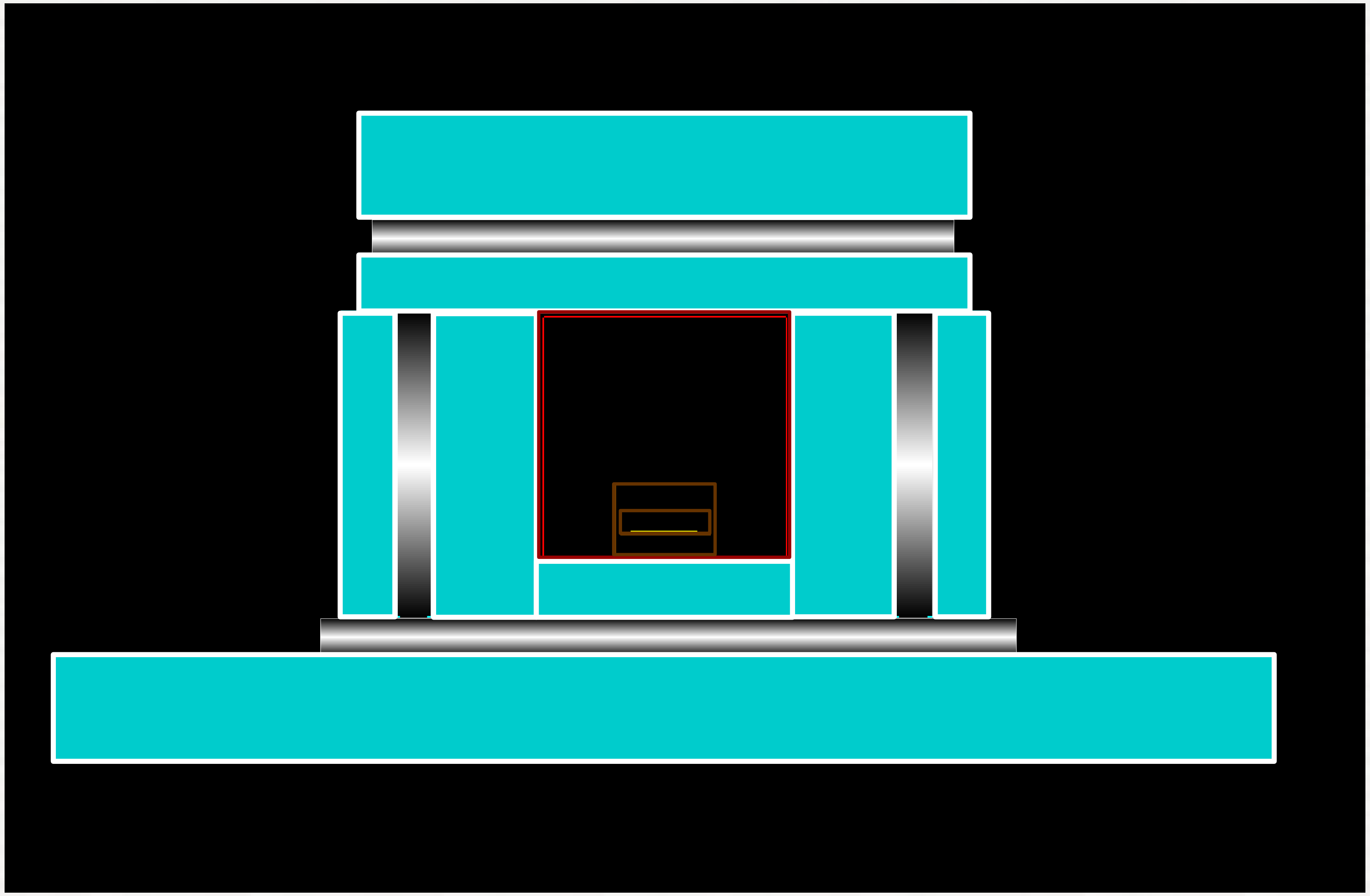
Brick Dimension: 12.8 x 10.2 x 7.9 cm^3
Lead Sheet Dimension: 12.5 x 10.2 x 0.1 cm^3



Shield For News-10g

Services Box
Cooling System
Polyethilene Plates
Opera Bricks

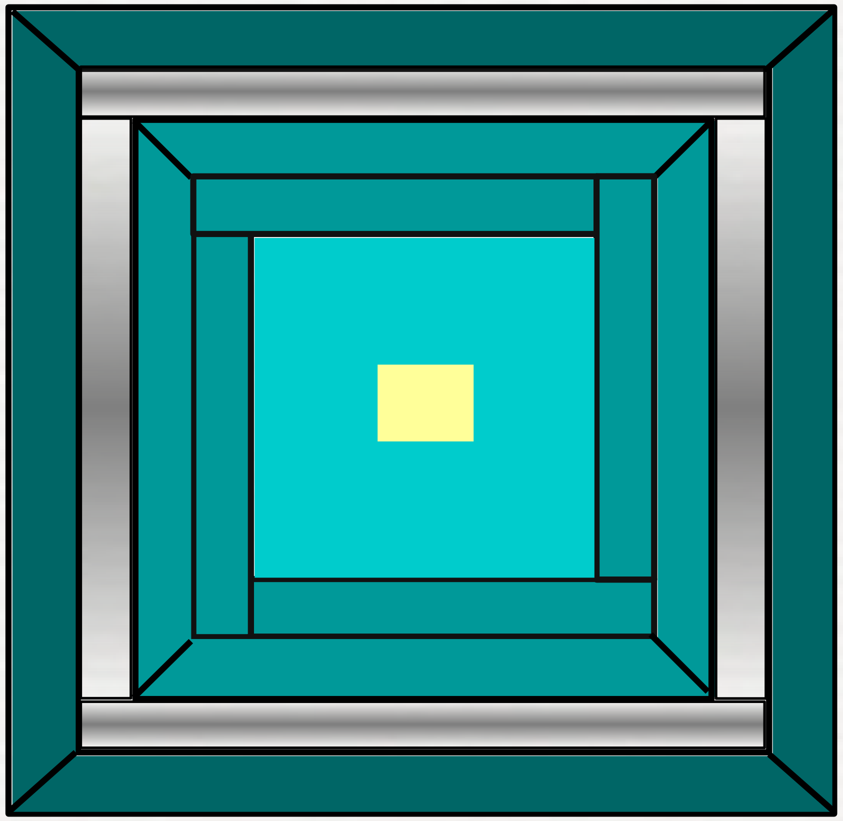
Axonometric view



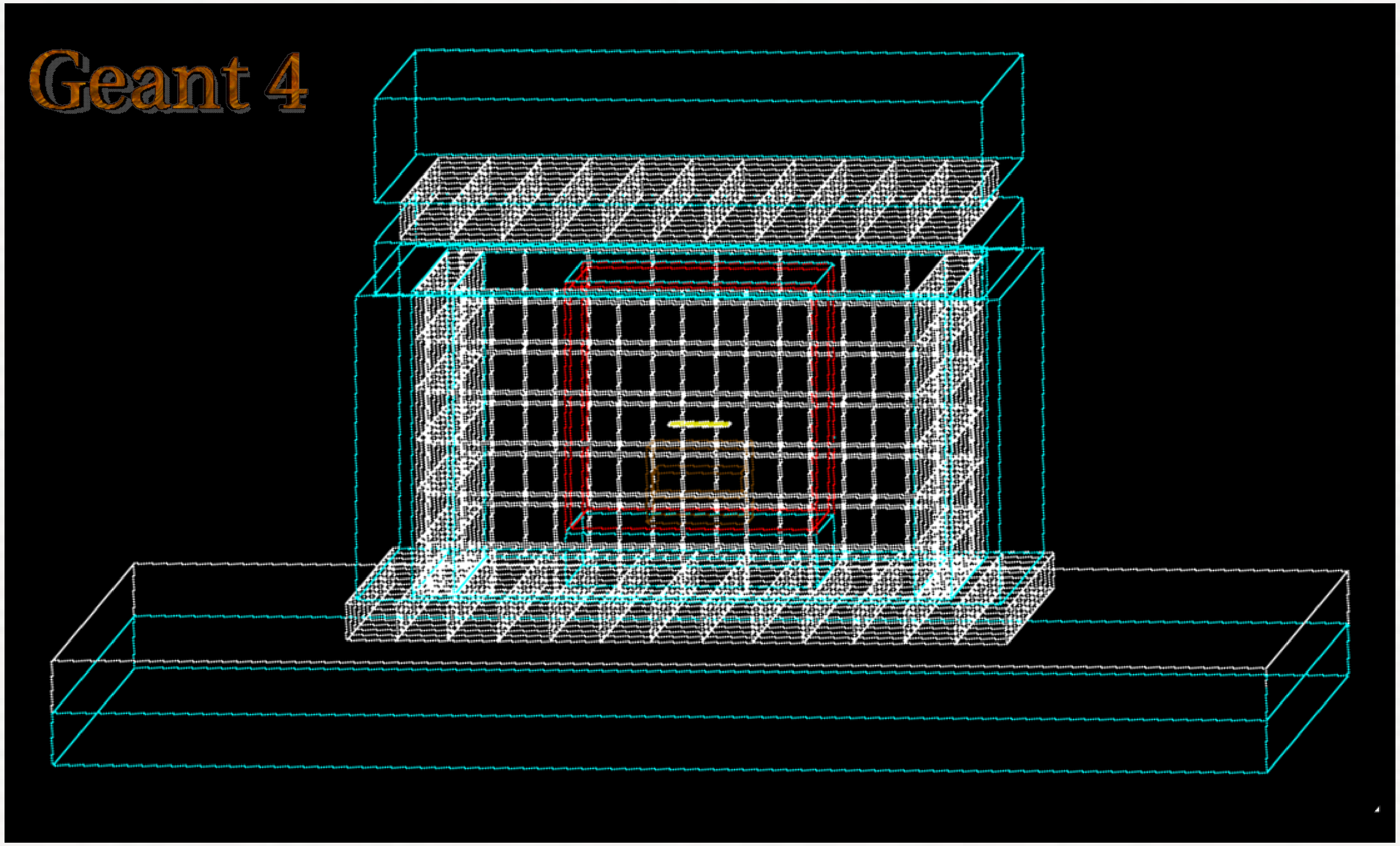
TECHNICAL DETAILS

Maximum width: 2.44 m
Maximum height: 1.28 m
Polyethilene Thickness: 31.5 cm
Lead Thickness: 5.6 cm

Top view



Shield For News-10_g

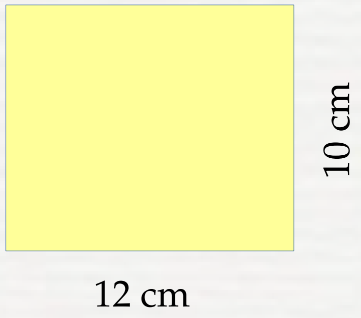


Polyethilene Plates used:
5 XL (2 cutted)
10 L
5 S (1 cutted)

Opera bricks used:
422

BACKGROUND SOURCES WITH SHIELD

ENVIRONMENTAL NEUTRONS



Density of NIT emulsion = 3.43 g cm^{-3}
Mass of 1 NIT layer (12x10cm^2) = 2.058 g
Flux of environmental neutrons = 8.7 x 10^{-7} cm^{-2} s^{-1}

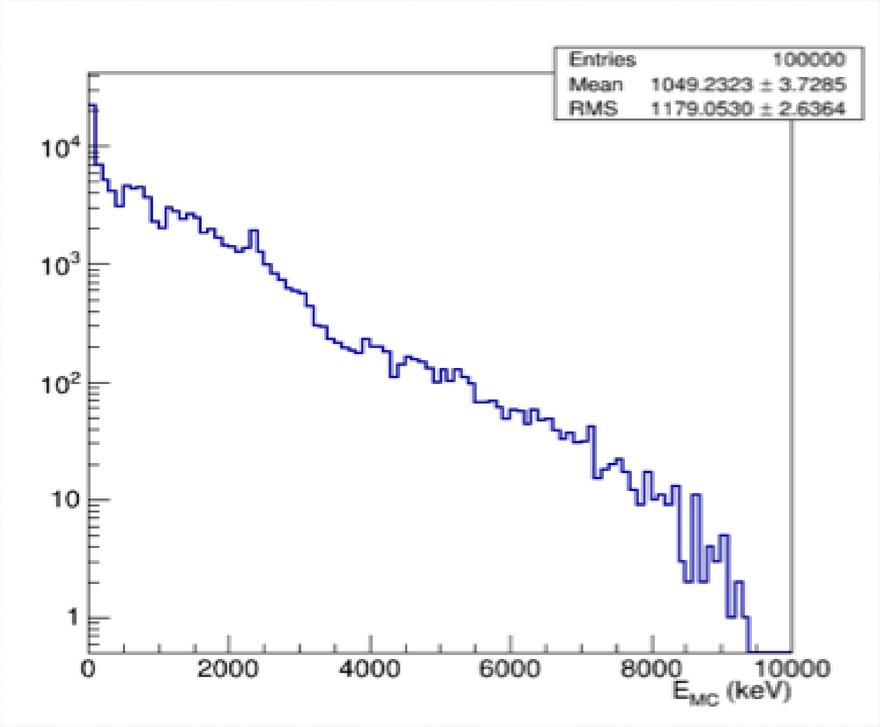
Simulation Results

No. of generated events = 10^7
Mass of Detector = 2.058g x 45 = 92.61g
Exposure time = 5.33 month
Total exposure = 494.04 g month

NR in signal region = 0

Signal region:
0.1µm < L < 1µm

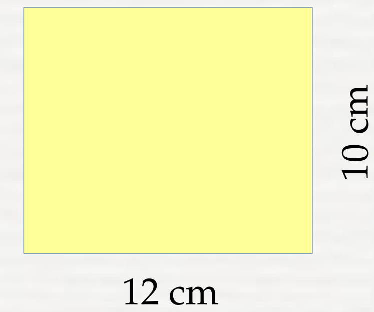
Energy spectrum



Isotropic angular distribution

Upper Limit on background rate: **4 x 10^{-3} g^{-1} $month^{-1}$** @ 90% C.L.

Cosmogenic Neutrons



Density of NIT emulsion = 3.43 g cm^{-3}
Mass of 1 NIT layer ($12x10cm^2$) = 2.058 g
Flux of cosmogenic neutrons = 7.3×10^{-10} $cm^{-2} s^{-1}$

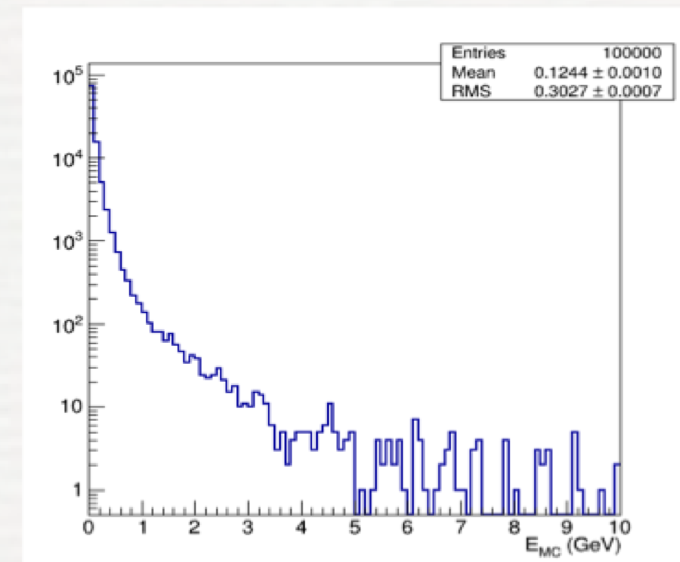
Simulation Results

No. of generated events	= *1.5* x 10^6
Mass of Detector	= 2.058g x 45 = 92.61g
Exposure time	= *953.66* month
Total exposure	= *88318* g month
NR in signal region	= 6

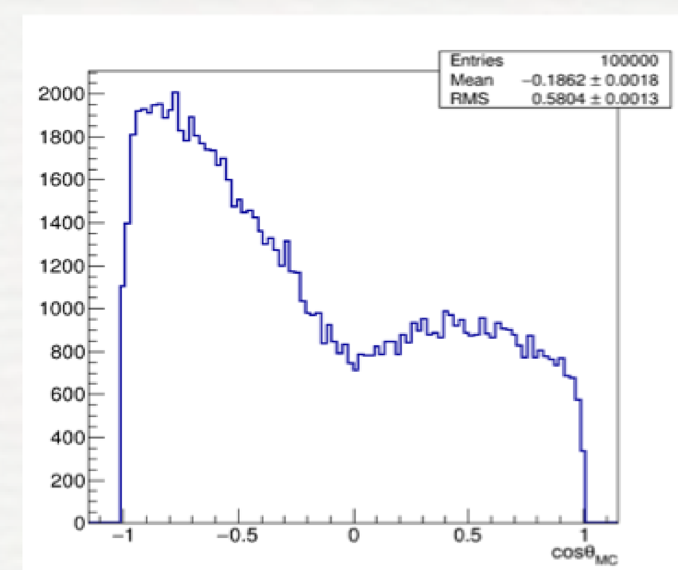
Signal region:
0.1μm < L < 1μm

Rate = Bkg events in signal region / Total exposure
= 6.8 **x 10^{-5} g^{-1} $month^{-1}$**

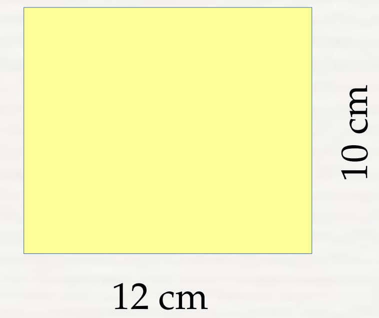
Energy spectrum



Angular distribution

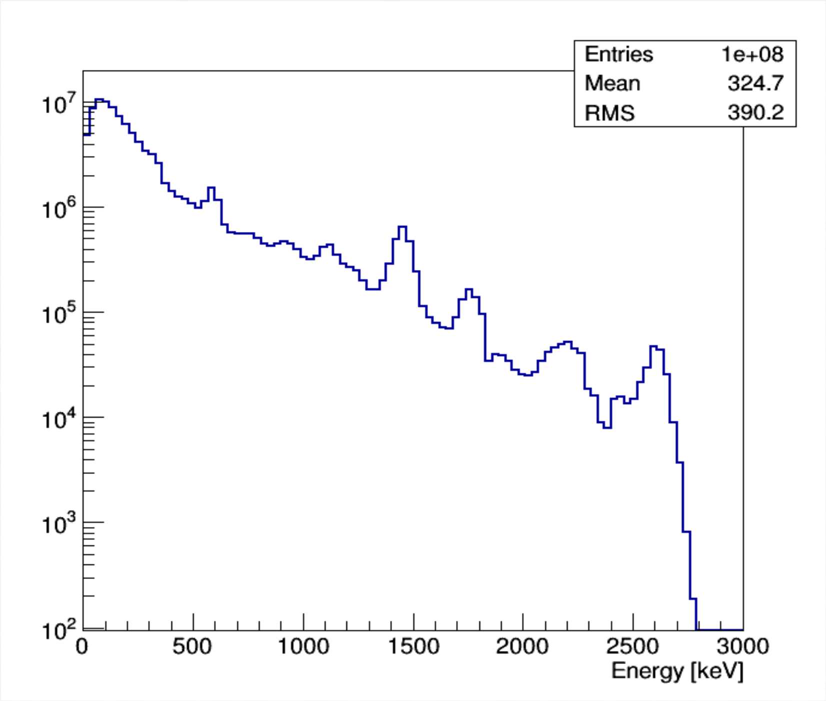


Environmental Gammas



Density of NIT emulsion = 3.43 g cm^{-3}
Mass of 1 NIT layer ($12x10cm^2$) = 2.058 g
Flux of environmental gammas = 0.35 cm^{-2} s^{-1}

Energy spectrum



Isotropic angular distribution

Simulation Results

No. generated events = 10^8
Mass of Detector = 2.058g x 45 = 92.61 g
Exposure time = 1.09 x 10^{-5} y
Total exposure = 10^{-6} Kg year

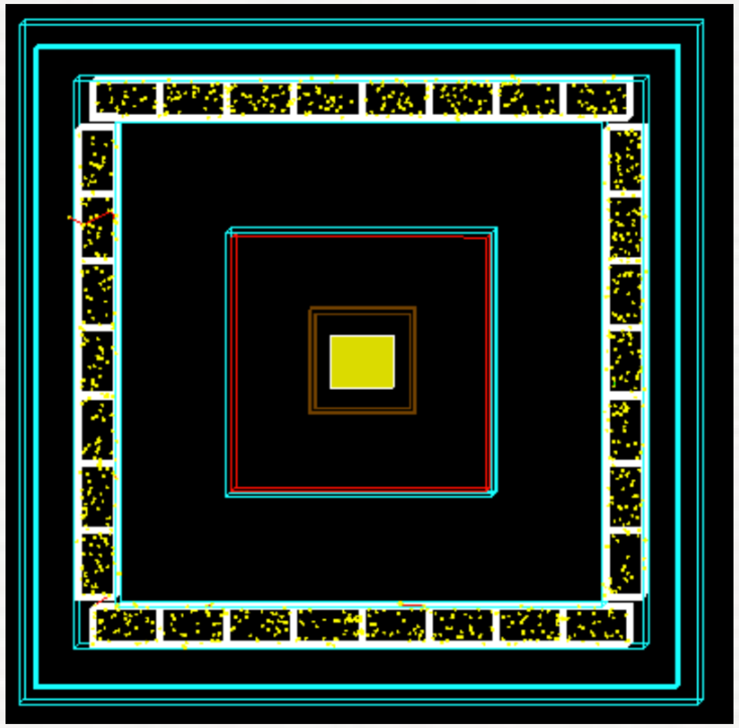
Electrons in NIT = 2

Rate = Bkg events / Total exposure = 2 x 10^6 **Kg^{-1} y^{-1} = 8 x 10^{-6} (10um)$^{-3}$ y^{-1}**

Factor 10^{-3} less than bkg electrons from ^{14}C = 2.5 x 10^{-3} (10um)$^{-3}$ y^{-1}

^{40}K From Opera Emulsion

Number of bricks used for the shield = 422
Number of opera emulsion films for each brick = 57
Mass of a film = 3 g
Fraction mass of **K** in Opera emulsion = 0.05%
Total Mass of **K** in the shield = 36.1 g
Natural abundance of **^{40}K** = 0.0117%
n(mol) in the shield = 1.08 x 10^{-4}
Number of ^{40}K nuclei in the shield = 6.50 x 10^{19}
Mean lifetime = 1.277 x 10^{10} y
Number of e^- emitted in 30 days ~ 3.8 x 10^{8}

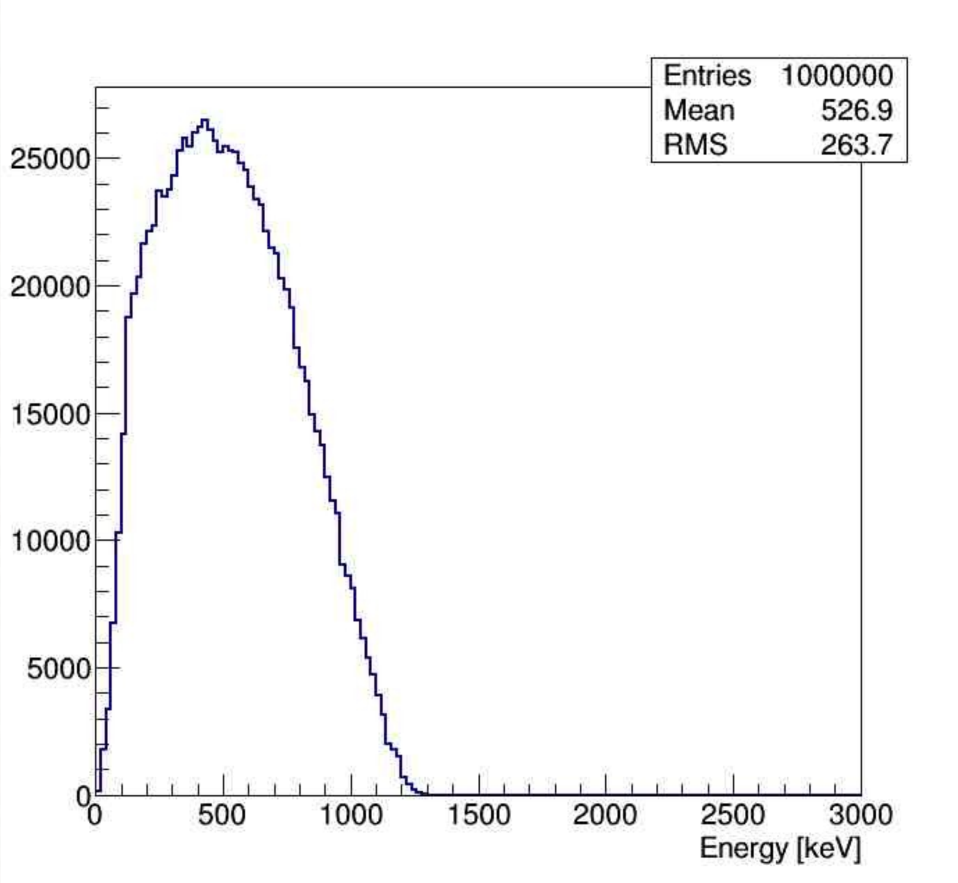


Electrons generated in the Opera films

No electrons in NIT emulsion with 10^6 electrons generated

Upper Limit on background rate:
4 x 10^{-10} (10um)$^{-3}$ y^{-1} @ 90% C.L.

Energy spectrum



NEUTRONS FROM LEAD

Decay chain: $^{210}Pb \rightarrow$ $^{210}Bi \rightarrow$ $^{210}Po \rightarrow$ ^{206}Pb (stable)

Alpha energy from ^{210}Po = 5.305 MeV

α may escape from lead and

(α , n) reaction may occur in opera emulsion

Number of bricks used for the shield = 422

Number of opera emulsion films for each brick = 57

Number of lead sheets for each brick = 56

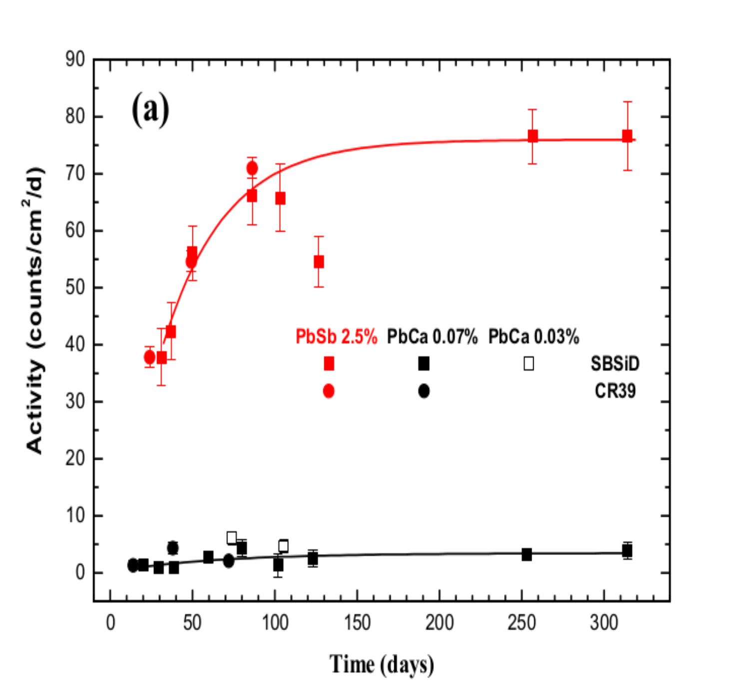
Alpha-activity from 210 Po ~ 5 cm^{-2} d^{-1} (conservative)

Surface of a lead sheet = 127.5 cm^2

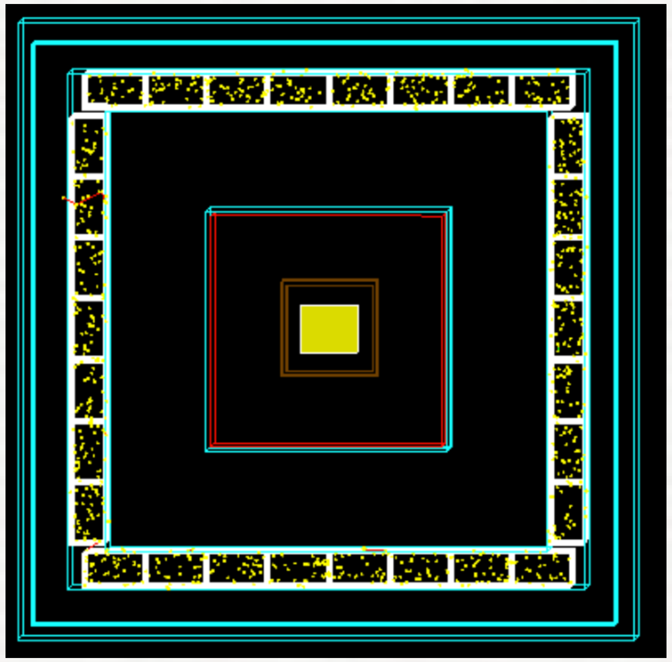
Total emulsion surface exposed in the shield = 6026160 cm^2

Number of alpha emitted in 30 days ~ 9 x 10^8

Time dependence of the alpha-activity from ^{210}Po



http://iopscience.iop.org/article/10.1088/1748-0221/3/07/P07002



No neutrons with 10^6 alpha simulated

PRELIMINARY

Alphas generated in the Opera films

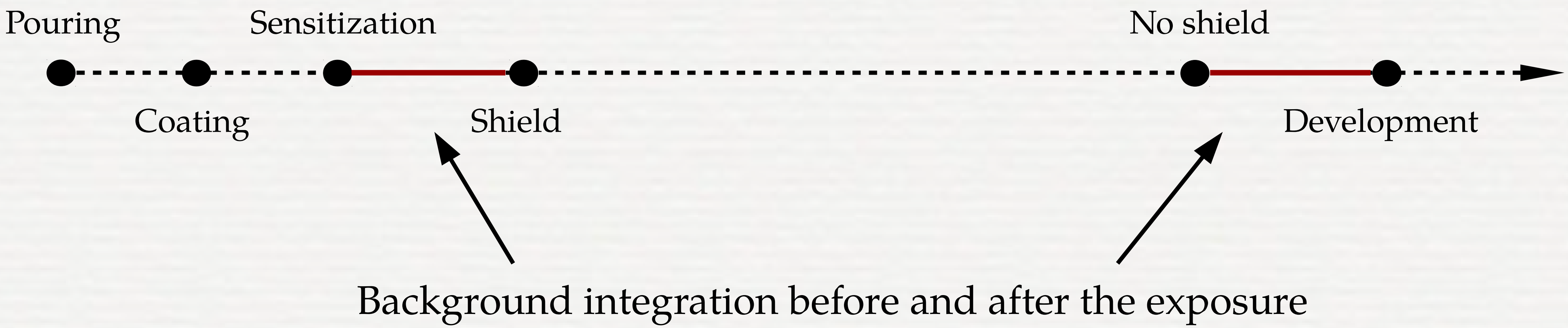
Combined with the acceptance factor O(10^3) and the rejection power for radiogenic neutron O(10^2)

↓

Upper limit on background rate: 10^{-2} g^{-1} $month^{-1}$

TIME LINE FOR 1Kg

TIME LINE FOR 1Kg EXPOSURE



HOW MUCH TIME CAN THE EMULSION STAY OUTSIDE THE SHIELD?

Development in underground laboratories:
Upper limit for background events due to environmental neutrons after 1 hour: 0.056 Kg^{-1}
Background rate due to cosmogenic neutrons after 1 hour is: 2.4×10^{-4} Kg^{-1}
Electron rate due to gamma environmental background keeps lower than ^{14}C until 57 days

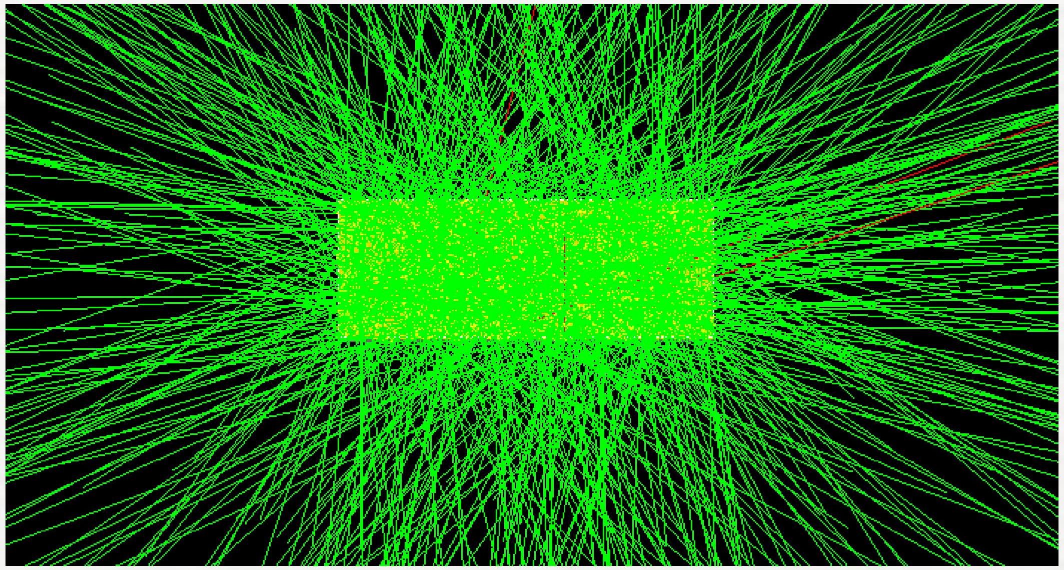
NIT may be outside the shield after sensitization and before the development just a few hours

Time Line For 1Kg

Development on surface laboratories:
Neutron yield to be evaluated

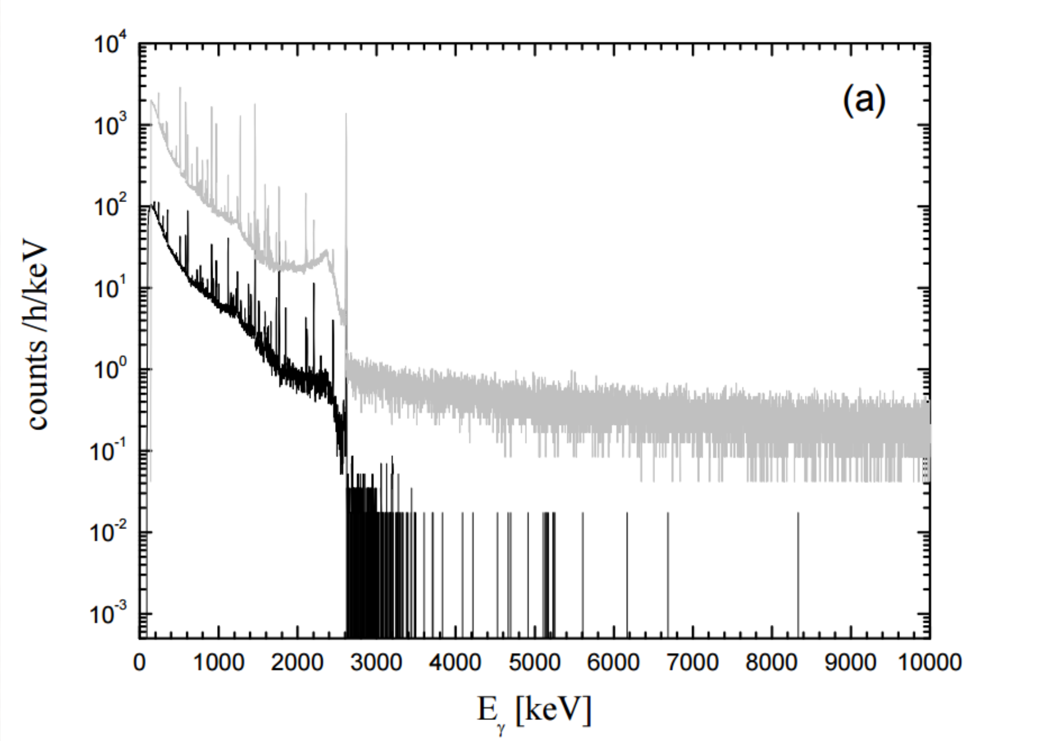
Electron rate due to gamma environmental background is 1.8 **x 10^{-3} (10um)$^{-3}$ h^{-1}**

PRELIMINARY



The rock shielding of LNGS leads in a HPGe γ-ray detector to a thousand-fold reduction in the γ-ray background signal above Eγ = 2.6 MeV

LUNA: A Laboratory for Underground Nuclear Astrophysics - Costantini, H. et al. Rept.Prog.Phys. 72 (2009) 086301 arXiv:0906.1097 [nucl-ex]



Without any protection, NIT may be transported in the surface facility for development at least in 60 min

Conclusions

- Simulation results of NIT emulsion without shield;
- Simulation results of NIT emulsion for alpha and beta test exposure;
- Simulation of detector and the shield for 10g exposure;
- Neutron background and gamma rays from environmental radioactivity and cosmic muons spallation results negligible for a 10 g exposure;

1Kg exposure: NIT may be outside the shield after sensitization and before the development just a few hours in underground laboratories.

THANK YOU

http://pos.sissa.it/archive/conferences/110/053/IDM2010_053.pdf