Background Simulations

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GOAL: background index < 10^{-3} counts/(keV kg y)
→ proof of principle &
no background event for 100 kg y statistics!

Background sources considered so far

- external background from primodial decay chains (^{232}Th)
- external neutron background
- muons (no simulations, veto foreseen in vessel design)

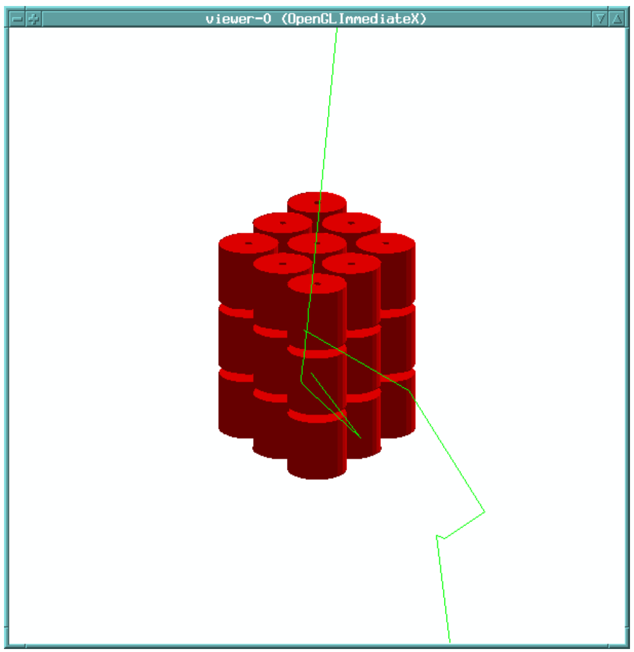
- internal background (to Ge diode) from ^{68}Ge
- internal background from ^{60}Co

Background Simulations: ^{208}Tl (2.615 MeV γ)

Large Flux in Gran Sasso ~ 1.4×10^7 /(d m^2) → major impact on tank design

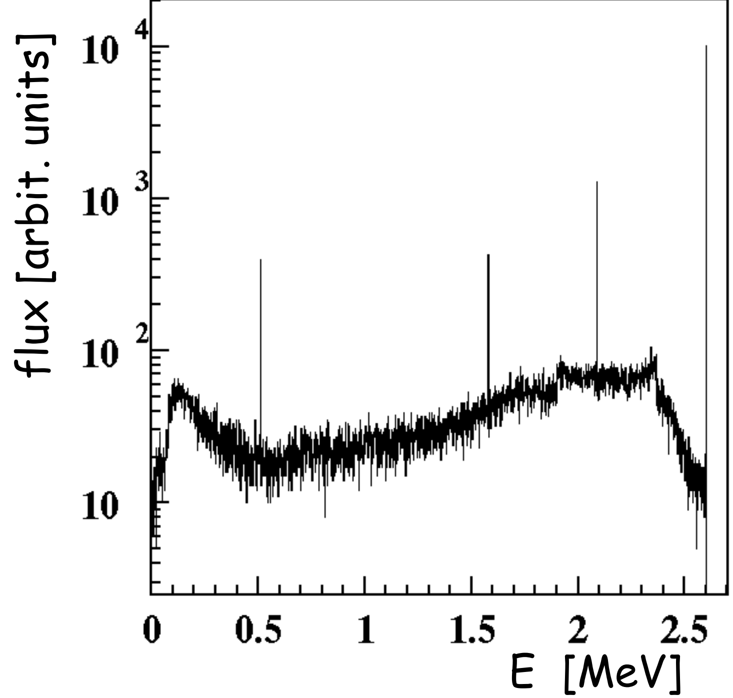
3 methods to estimate shielding of liquid nitrogen, liquid argon, lead, ... :

o Geant4 simulation: setup = 27 diodes in large tank of liquid gas



2kg, 0.7 mm dead layer (p typ),
12 mm spacing between diodes

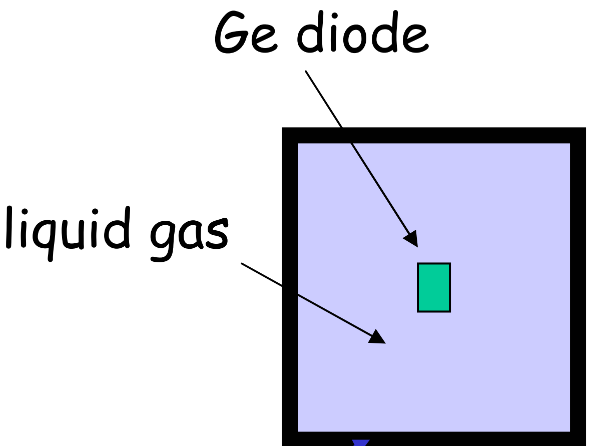
max Energy deposited in a single crystal
shielding = 1 m of liquid argon



o standalone Monte Carlo: compton scat., pair production, photo effect

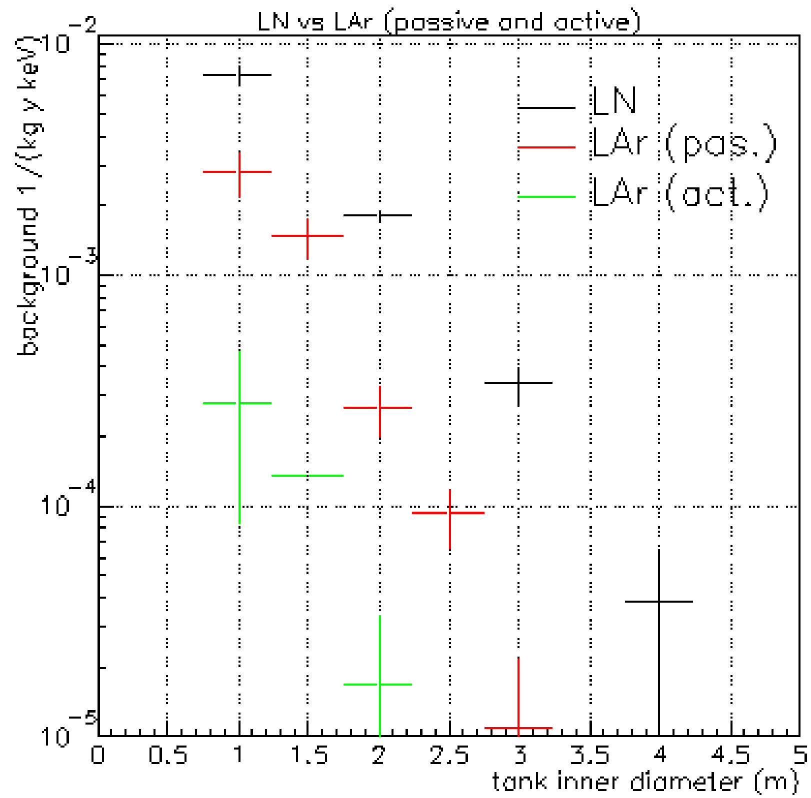
setup = single crystal in vessel, author = Stefan Schönert
output cross check with Geant4, speed ~ 30 faster than Geant4

Example: shielding with lead



lead as shield against concrete but with intrinsic activity of 30 μBq/kg of ^{208}Tl

background index for different tank sizes



o calculation (author = Gerd Heusser)

start with a measured $\frac{\text{peak (2.615 MeV)}}{\text{compton (2.0 - 2.08 MeV)}}$ ratio

& detection efficiency (using ^{228}Th source)

use the measured (surface) activity of concrete, …

extrapolate to different shieldings by scaling the ^{208}Tl line according to the absorption coefficient in different materials

example: shielding against intrinsic lead activity of 30 μBq/kg

→ surface activity $= 30 \cdot 10^{-6} \frac{Bq}{kg} \bullet 11 \frac{g}{cm^3} \bullet 2.07 cm = 6.8 \cdot 10^{-7} \frac{Bq}{cm^2}$

measurement input = 5×10^{-3} cm^2/(keV kg)

shielding by 150 cm LN_2 → bkg index = 10^{-3}/(keV kg y) (absorption coeff = 0.03/cm)

note: the P/C ratio becomes smaller with larger shielding thickness

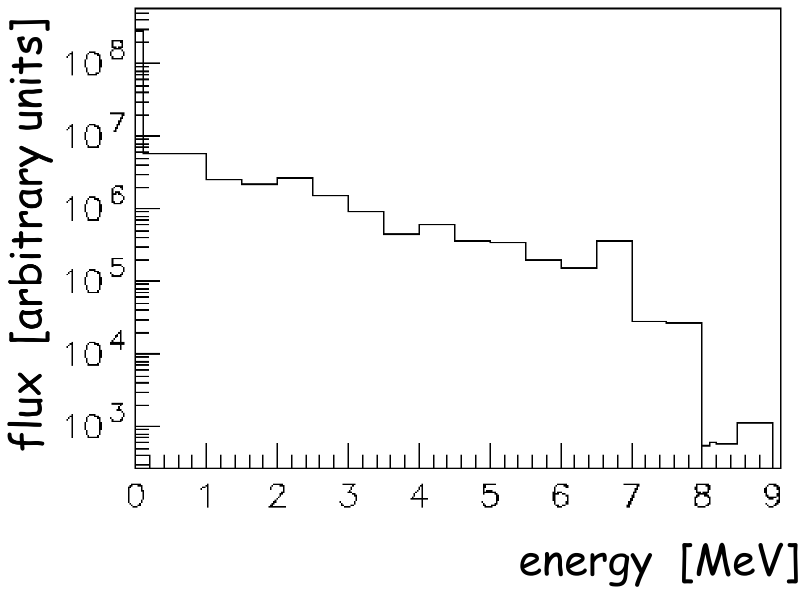
→ ~ 4x larger bkg for larger shielding, taken into account

within factor ~2 all methods predict same background index

Background Simulations: neutrons

source = fission of ^{238}U and (α,n) reactions in concrete/rock
(reference: H.Wulandari et al, hep-ex/0401032)

simulated neutron energy spectrum



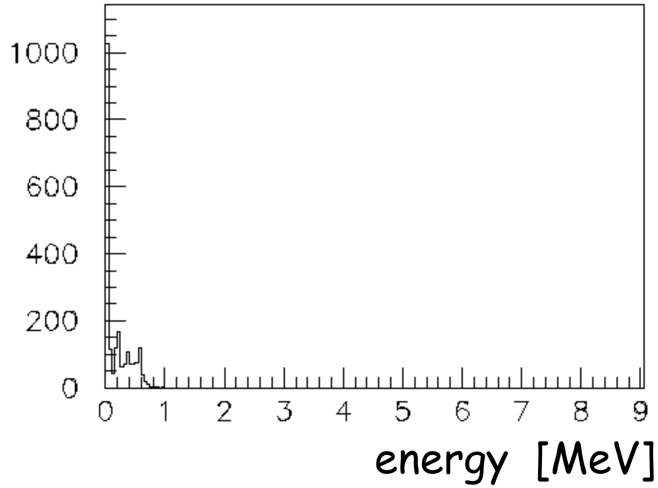
measurements for coarse E intervals and total flux agree with simulation

above 9 MeV: muon induced neutrons (spallation, electro-mag & hadr shower) neutron energies up to GeV, flux small NOT YET SIMULATED!!!

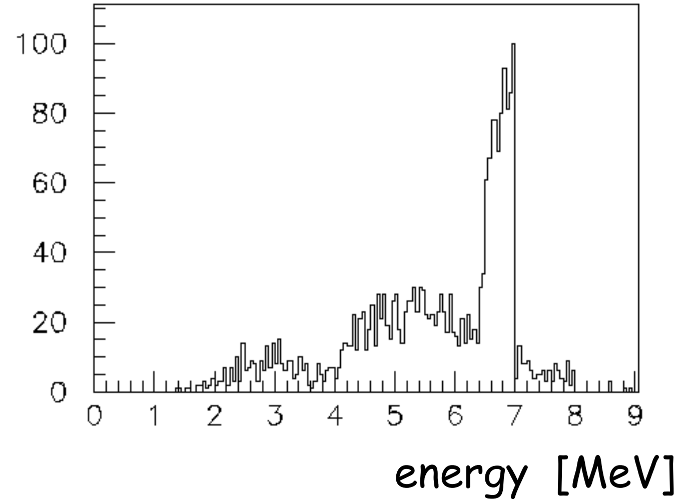
Geant4: elastic, (n,n´γ), (n,γ), (n,p), (n,pγ), ... interactions simulated
input = measured/interpolated cross sections from data base

setup: 27 diodes, r=3.5 m liquid argon, 40 cm polyethylen moderator

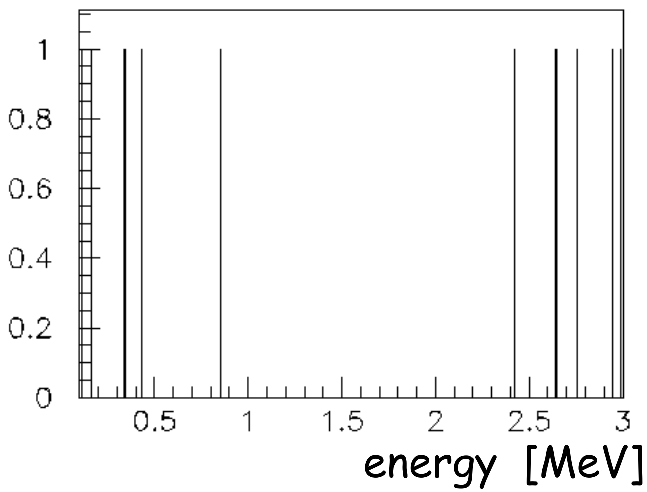
neutron energy
after 3m Ar & 40 cm PE



initial energy of those neutrons



energy deposition in Ge diodes



statistics ~ 2x annual flux

→ 40 cm of PE is more than enough

for nitrogen bkg is even smaller

Background Simulation: ^{68}Ge

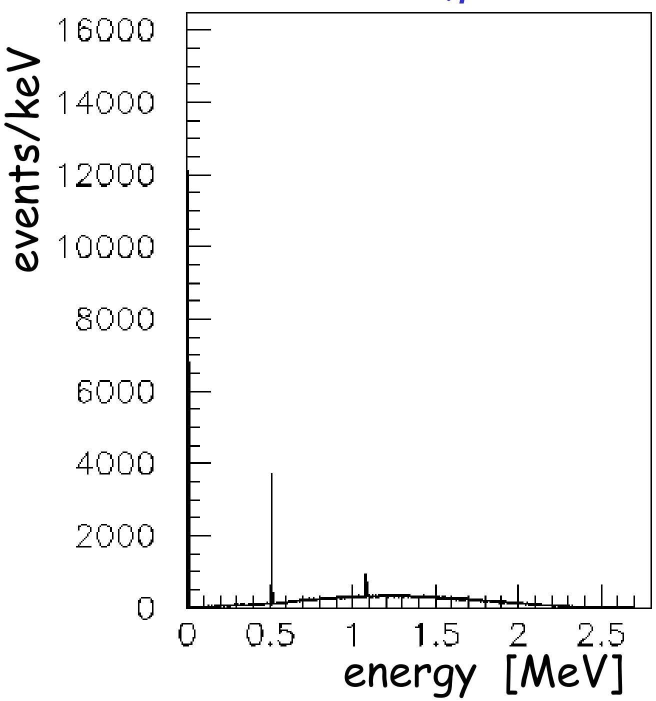
^{68}Ge is produced by spallation, rate ~ 1 atom/(kg d) for ^{76}Ge

reference: F.T.Avignone et al., Nucl Phys B (Proc Suppl) 28A (1992) 280.

→ saturation activity ~ 400 atoms/kg, after 3 years ~ 25 ^{68}Ge/kg, 15 decay in following year

decay chain: $$^{68}Ge \xrightarrow[\text{K shell 10.3 keV}]{EC, T_{1/2} \sim 270 d} {}^{68}Ga \xrightarrow[\text{Q=2.9 MeV}]{EC, \beta^+, T_{1/2} \sim 68 \min} {}^{68}Zn$$

energy deposition in diode from EC,β^+ of ^{68}Ga



~1/5000 decays E deposition close to $Q_{\beta\beta}$ in 1 keV bin

background index ~ 3×10^{-3} cnt/(keV kg y)

note: similar MC done for Genius 1.5×10^{-6}/(keV kg y)

possible additional background rejection:

- anti-coincidence of Ge detectors (rej up to 2.5)
- anti-coincidence of Ge segments, 4 axial segments (rej ~ 4)
- pulse shape analysis
- time analysis of decay chain (rej ~ 5)

in total: bkg < 10^{-4} cnt/(keV kg y) possible

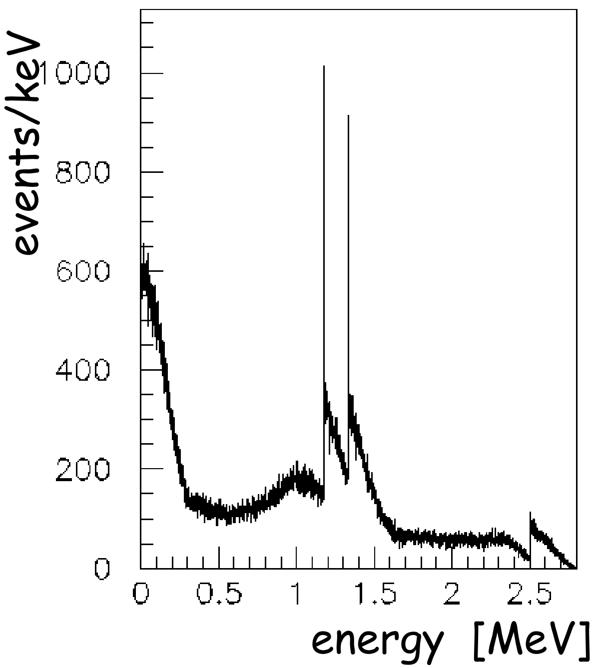
Background Simulation: ^{60}Co

^{60}Co is produced by spallation, rate ~ 4 atoms/(kg d)

reference: F.T.Avignone et al., Nucl Phys B (Proc Suppl) 28A (1992) 280.

if detectors are fabricated underground only 10 days of activation possible (?)
after 10 days → 40 ^{60}Co/kg → 5.4 decays/(kg y), $T_{1/2}$ = 5.3 y

energy deposition in diode from β^- of ^{60}Co



~1/6000 decays E deposition close to $Q_{\beta\beta}$ in 1 keV bin

background index ~ 0.9×10^{-3} cnt/(keV kg y)

note: similar MC done for Genius 3×10^{-5}/(keV kg y)

possible additional background rejection:

- anti-coincidence of Ge detectors (rej up to 6)
- anti-coincidence of Ge segments (rej ~ 5)
- pulse shape analysis

in total: bkg < 10^{-4} cnt/(keV kg y) possible

Summary

calculation of shielding against external ^{208}Tl decay γ straight forward
→ for vessel design and bkg index see talk of K.T.Knöpfle

neutron from fission & (α,n) can be shielded effectively with ~ 30 cm PE
high energy muon induced neutrons still need to be studied

muon veto is required, neccessary efficiency not yet studied

internal background will be dominant
→ eventuallly underground detector fabrication is needed
detector segmentation is needed for bkg index < 10^{-3} cnts/(keV kg y)

what is the intrinsic background of existing ^{76}Ge detectors?