CYGNO shielding study

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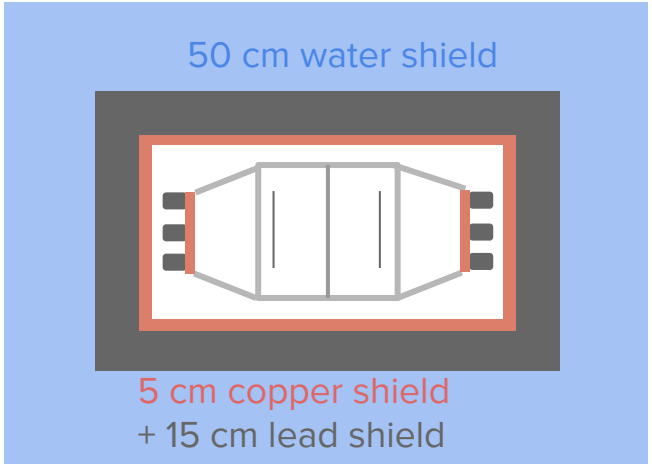
22/01/20
CYGNO simulation strategy meeting

Shielding option 2

2) 50 cm water + 15 cm Pb + 5 cm Cu

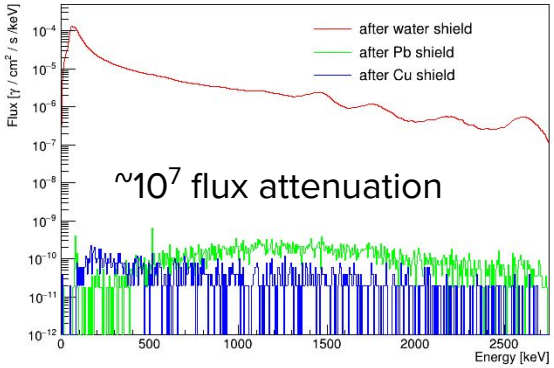


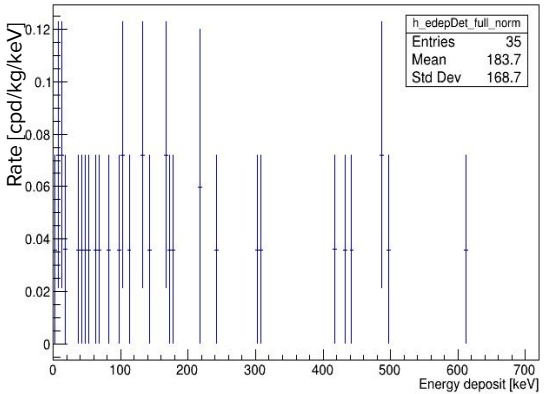
Cost of materials:

- Cu : ~25 euro/kg
- Lead : ~5 euro/kg
- PE : ~5 euro/kg

Material	Thickness [cm]	Mass [kg]	*Cost [keuro]
Water	50	16e3	-
Pb	15	42e3	210
Cu	5	9e3	225

Gamma Flux entering outermost shield 0.56 cm^{-1} s^{-1}
Gamma Flux after 50 cm water shield 0.019 cm^{-1} s^{-1}
Gamma Flux after 20 cm Pb shield 3.2 10^{-7} cm^{-1} s^{-1}
Gamma Flux after 5 cm Cu shield 1.4 10^{-7} cm^{-1} s^{-1}

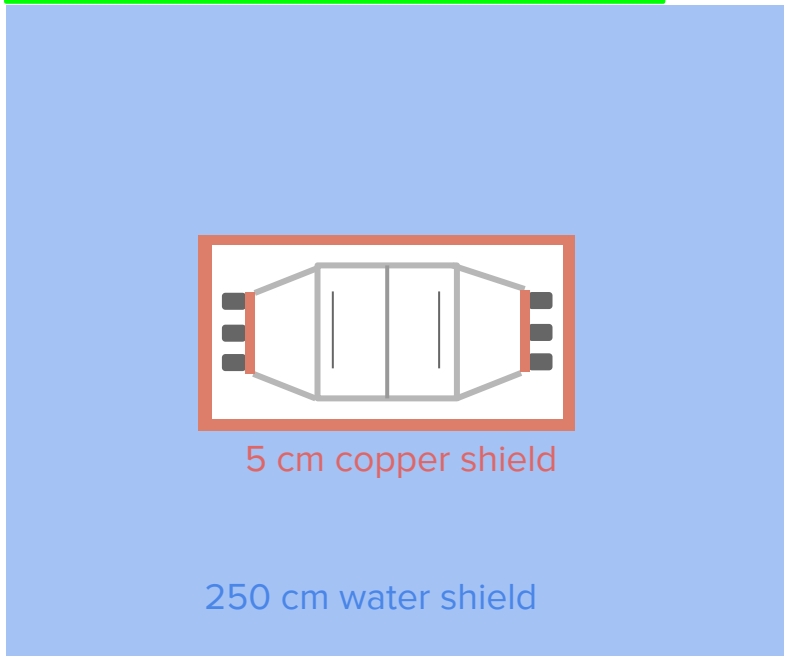




Rate [0-20] keV = 0.054 cpd/kg/keV
➔ **630 cts/yr** in CYGNO detector

Shielding option 3

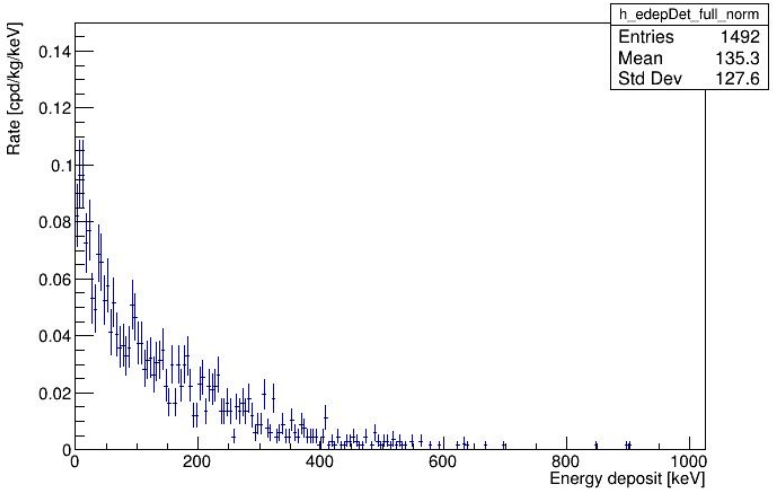
3) 250 cm water + 5 cm Cu



Cost of materials:

- Cu : ~25 euro/kg
- Lead : ~5 euro/kg
- PE : ~5 euro/kg

Volume	Material	Thickness [cm]	Mass [kg]	Cost [keuro]
Shield2	Water	250	312e3	-
Shield3	Cu	5	9e3	225

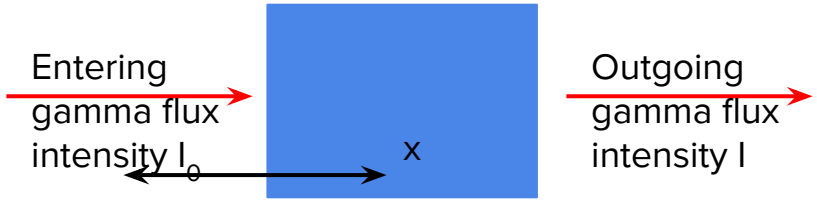


Rate [0-20] keV = 8 10^{-2} cpd/kg/keV ➔ **10^3 cts/yr** in CYGNO detector

X-rays attenuation (rough calculation)

$$I/I_o = \exp[-(\mu/\rho)x] \ .$$
$$\mu/\rho = x^{-1} \ln(I_o/I)$$

ρ material density
x=ρt "mass thickness"



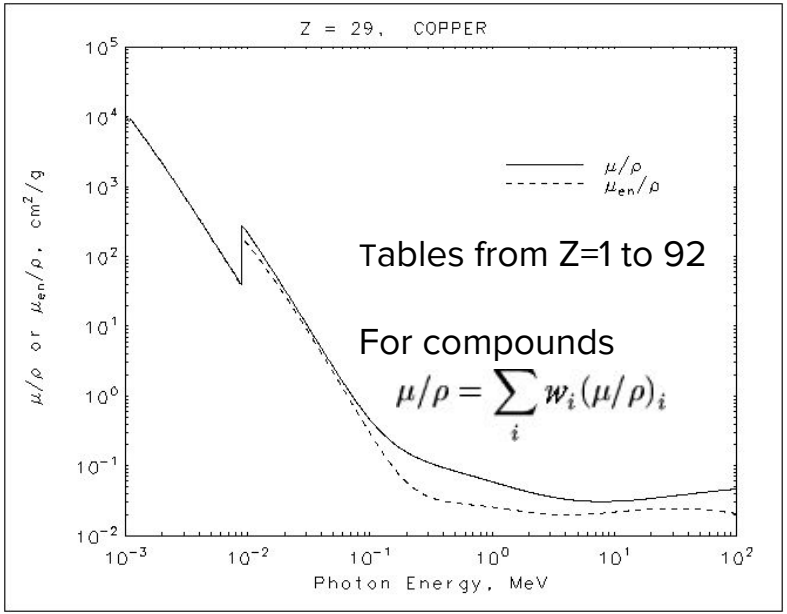
$$\mu/\rho = \sigma_{\rm tot}/uA \ .$$

u = atomic mass unit
A = relative atomic mass
σ_{tot} is the total cross section

$$\sigma_{\rm tot} = \sigma_{\rm pe} + \sigma_{\rm coh} + \sigma_{\rm incoh} + \sigma_{\rm pair} + \sigma_{\rm trip} + \sigma_{\rm ph.n.}$$

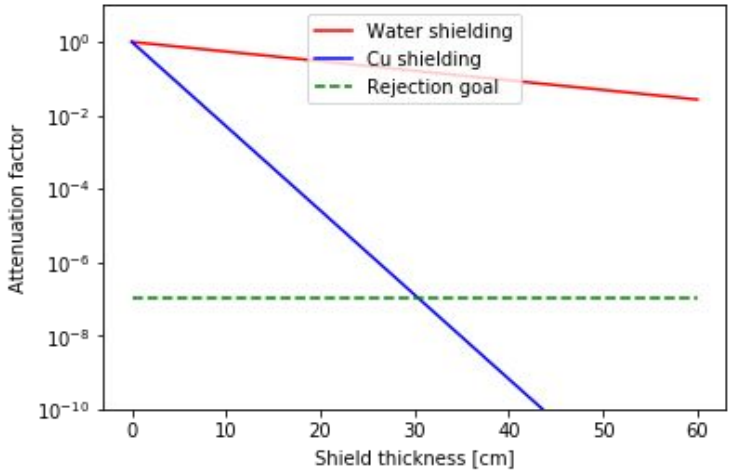
σ_{pe} atomic photoeffect xsec
σ_{coh} and σ_{incoh} coherent (Rayleigh) and incoherent (Compton) scattering xsec
σ_{pair} and σ_{trip} e+e- production xsec in the fields of the nucleus and of the atomic electrons
$\sigma_{ph.n.}$ photonuclear cross section

https://physics.nist.gov/PhysRefData/XrayMassCoef/chap2.html
https://physics.nist.gov/PhysRefData/XrayMassCoef/tab3.html



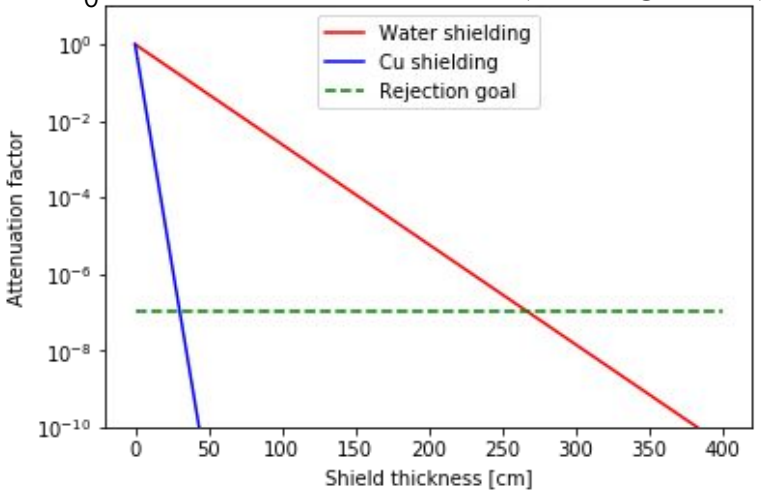
X-rays attenuation with Cu and water

I/I_0 attenuation vs thickness (1 MeV gamma)



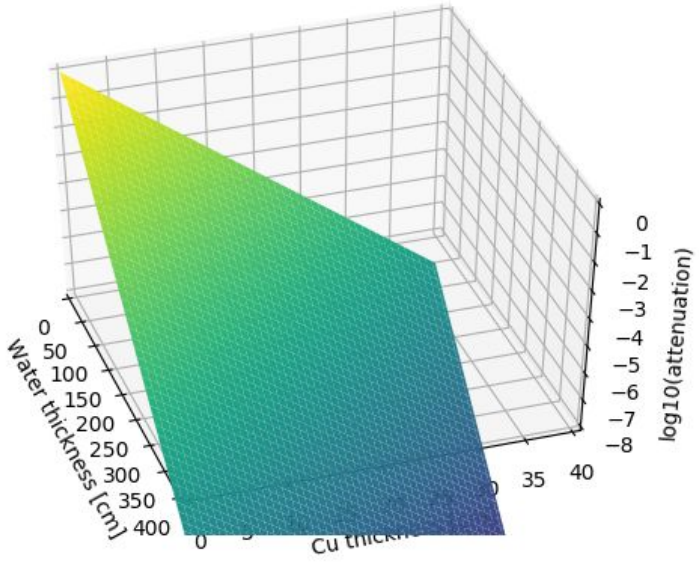
Shielding made of only copper gives an attenuation of 10^7 with thickness ~30 cm

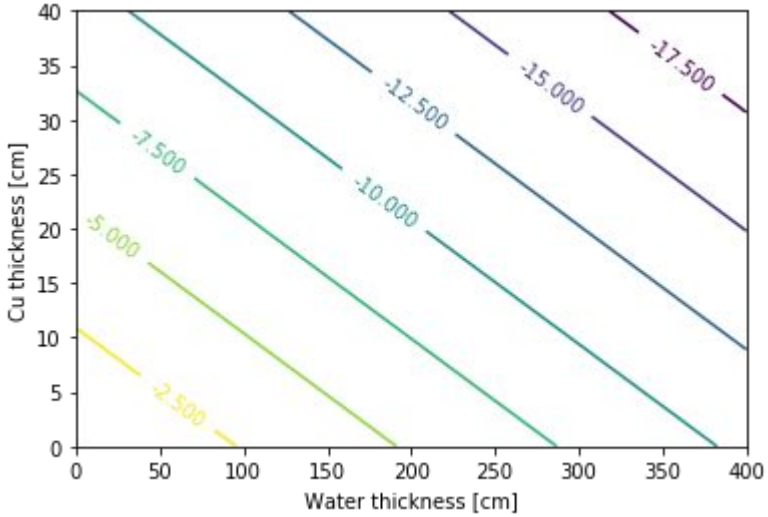
I/I_0 attenuation vs thickness (1 MeV gamma)



Shielding made of only water gives an attenuation of 10^7 with thickness ~270 cm

Combination of Cu + water

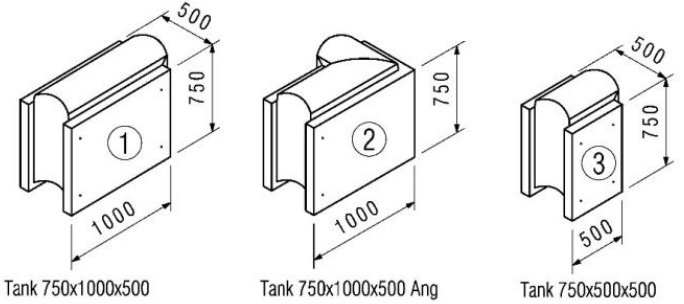


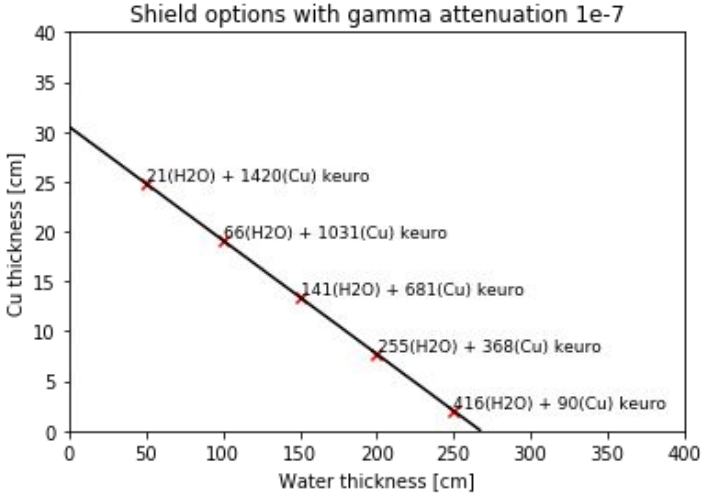


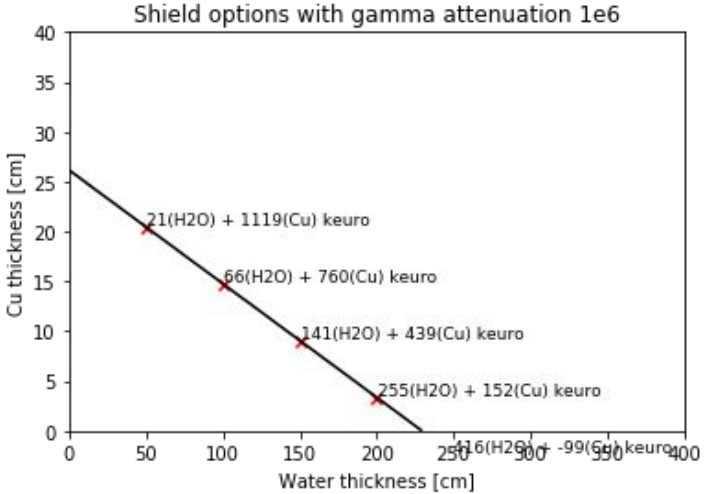
Cost optimization Cu + water

Assumptions:

- Cost of copper: 25 euro/kg
- Cost of water: ~500 euro/tank from Cesidio presentation (➔ ~1.3 euro/kg)







The Cu cost is significantly higher than water (also the modular option for water shielding), so the option with only 5 cm copper and 2-2.5 m water is the cheapest