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WATER COSMIC DETECTOR SIMULATION

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Abstract

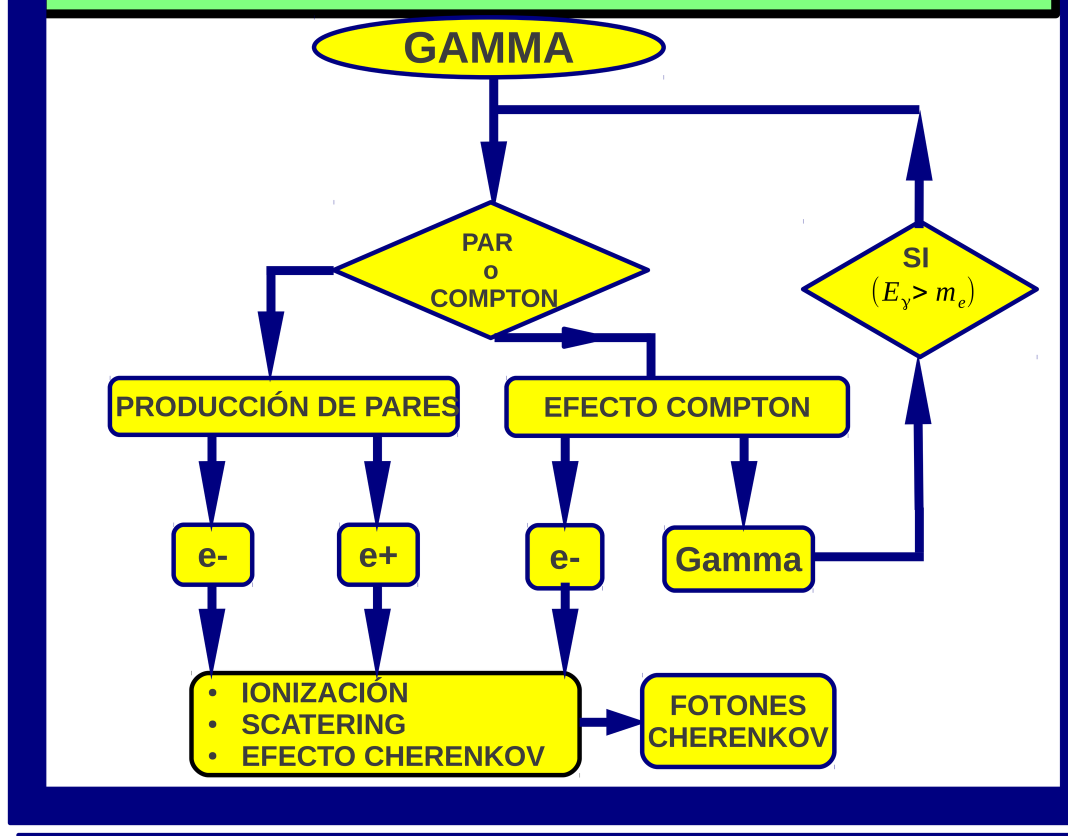
The Astrophysics Direction of CONIDA is building Water Cerenkov Detectors (WCDs) as a member of the LAGO[2] Project. Simultaneously, We are working on a Montecarlo simulation of the detectors to the electromagnetic component of the atmospherics Cosmics Rays.

The aim of this work is to use this simulation to optimize the geometric form of the WCD', and the position of the Photomultiplier (PMT) . At this moment, the simulation is being in three dimension, and relevant electromagnetic processes have been considered, such as: par creation and Compton effect.

To improve the rate of the simulation, we created and used look up tables of the relevant process..

The results of the simulation are shown in the form of pulses of photons which can be seen in the PMTs as the detector is traversed by high energy Gamma Rays.

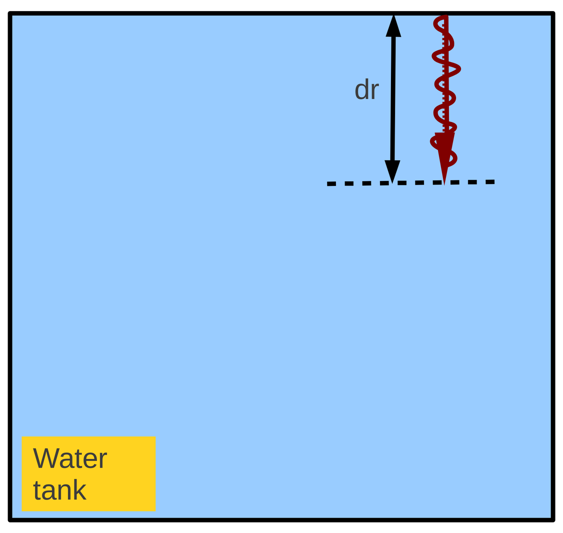
FLUX DIAGRAM OF THE PROGRAM



GAMMA RELEVANT PROCESS

DISTANCE TRAVELED FOR THE GAMMA

The distance traveled (dr) for the gamma before interaction is in function of The mean free path which depends of the gamma energy incident.



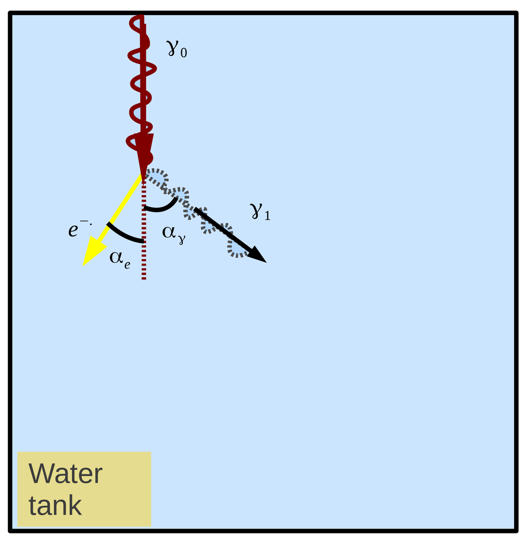
$$Prob=1-e^{-\frac{ln2}{\lambda_{mfp}}dr}$$

$$dr=\frac{-\lambda_{mfp}}{\log(2)}\log(1-random)$$

where
λ_{mfp}: mean free path
$random\in[0,1]$

COMPTON SCATTERING

Compton Scattering is an elastic colision between an incident gamma and an atomic electron in the water.



$$\alpha_{\gamma_1}=acos(1+\frac{m_e}{E_{\gamma_0}}-\frac{m_e}{E_{\gamma_0}})$$

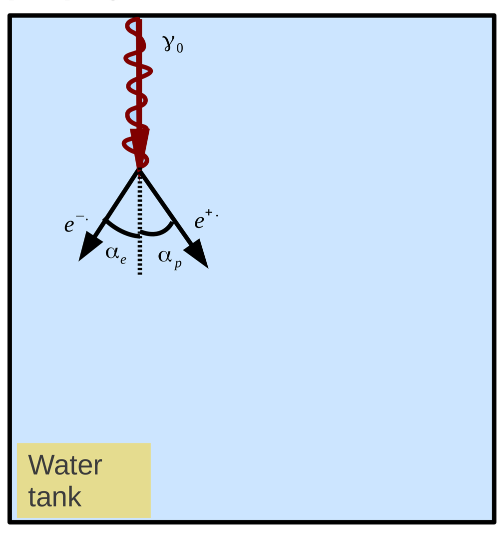
$$\alpha_e=atan(\frac{1}{(\tan(0.5\alpha_{\gamma_1})(1+E_{\gamma_0}/m_e))})$$

$$E_{\gamma_1}=E_{\gamma_0}(a-\sqrt{a^2-4})/2$$
$$E_e=E_{\gamma_0}-E_{\gamma_1}$$

where:
m_e: electron rest mass energy
$\gamma_{0,}\gamma_1$: initial, secundary gamma
$E_{\gamma_0}, E_{\gamma_1}$: initial, secondary energy of the gamma
$a=random*(2E_{\gamma_0}/m_e-m_e/2E_{\gamma_1}-2)+2$

PAIR PRODUCTION

Pair production is the interaction between an incident gamma and coulomb field of nuclei in the water, we use montecarlo for calcutation to calculate the angle of propagation of the electron for the density function.



$$\alpha_e=\sqrt{(-2\theta_{rms}*\log(\sqrt{2}\pi)*\theta_{rms}*(\Delta h))}=-\alpha_p$$

$$\theta_{rms}=\frac{m_e}{E_{\gamma_0}}\log(\frac{E_{\gamma_0}}{m_e})$$

$$\Delta h=random*h_{max}-h_{min}$$

$$h_{max}=\frac{1}{\sqrt{2\pi}*\theta_{rms}}$$

$$h_{min}=\frac{1}{\sqrt{2\pi}*\theta_{rms}}e^{-(\frac{\pi^2}{8*\theta_{rms}^2})}$$

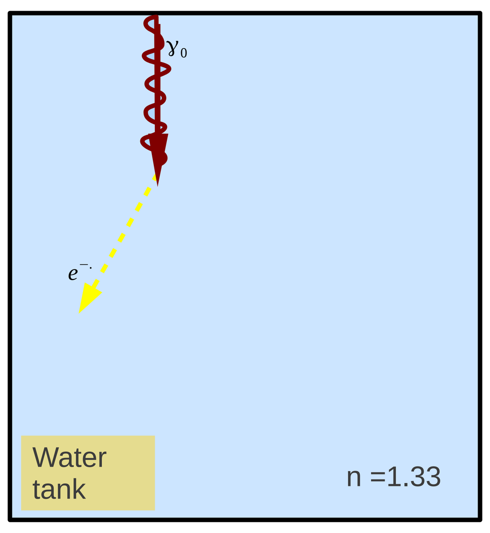
$$E_e=\frac{random*E_{\gamma_0}}{2}$$

where:
m_e: electron rest mass energy
$\gamma_{0,}$: initial gamma
E_{γ_0}: initial energy of the gamma
θ_{rms}: root mean square angle of emision

ELECTRON RELEVANT PROCESS

IONIZATION LOSSES

The charged particles propagating through matter lose energy through coulomb interaction with atomic electrons in the water. We consider as a first step, only electrons.



$$-\frac{dT}{dx}=K\frac{z}{A}\frac{1}{\beta^2}[B_0(T_e)-\ln(\frac{I}{m_e})-\frac{\delta}{2}]$$

$x<x_0;\delta=0$

$x_0<x<x_1;\delta=2\ln(\beta\gamma)+C+a(x1-x)^{m_s}$

$x_1<x;\delta=2\ln(\beta\gamma)+C$

where:

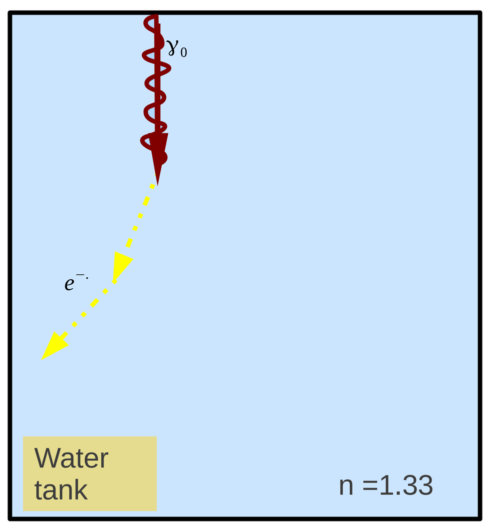
$B_0(T_e)=\ln[\frac{\tau^2(\tau+2)}{2}]+[\frac{1+\tau^2/8-(2\tau+1)ln2}{(\tau+1)^2}$

$\tau=T_e/m_e$
$I=75\,eV$: mean excitation energy
$x=\log(\beta\gamma)$
T_e: kinetic energy of the electron
δ: the density effect correction
$a=0.2065, m_s=3.0070, x_0=0.240, x_1=2.5,$
$C=-3.502$

$\gamma=\tau+1, \beta=\sqrt{(T_e^2+2*T_e)}$

SCATTERING

Charged particles propagating through matter as water are subject to deflection by many small angle scatterings, which is due to interaction with the coulomb fields.



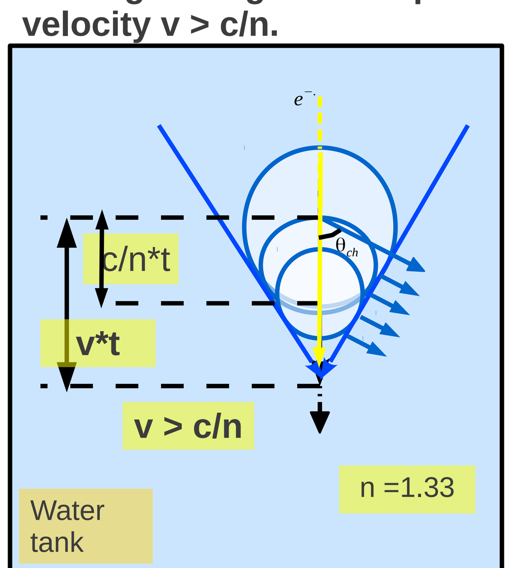
$$\alpha_{sct}=A\sqrt{(-2*\alpha_{rms}^2*\log(\sqrt{2\pi\alpha_{rms}^2}))}$$
$$A=[random*(f_{max}-f_{min})+f_{min}]$$
$$f_{max}=\frac{1}{\sqrt{2\pi*\alpha_{rms}^2}}$$
$$f_{min}=f_{max}e^{-(\frac{\pi^2}{8*\alpha_{rms}^2})}$$

$$\alpha_{rms}=\frac{13.6\text{MeV}}{\beta cp}\sqrt{\frac{\Delta x}{x_0}}[1+0.038\ln(\frac{\Delta x}{X_0})]$$

$X_0=36.1\,cm$, radiation length (RPP)
$\Delta x=0.5\,cm$

CHERENKOV RADIATION

Cherenkov ligth is produced by a charged particle moving through a transparent medium as the water with velocity v > c/n.



Cherenkov number of photons and emision angle

$$\theta_{ch}=\cos^{-1}(\frac{1}{\beta n})$$

$$N_{fot}=2\pi\alpha\Delta x(\frac{1}{\lambda_1}-\frac{1}{\lambda_2})(1-\frac{1}{\beta^2 n^2})$$

$\lambda_1=300\,nm, \lambda_2=500\,nm.$

$$\beta=\frac{\sqrt{\tau^2+2\tau}}{\tau+1}$$

where
$\beta=v/c$
n: refractive index
c: speed of ligth in vacuum
λ: wavelength
α: fine structure
$\Delta x=0.5$cm, step
$\tau=T_e/m_e$

ARRIVAL OF PHOTONS CHERENKOV TO PMT

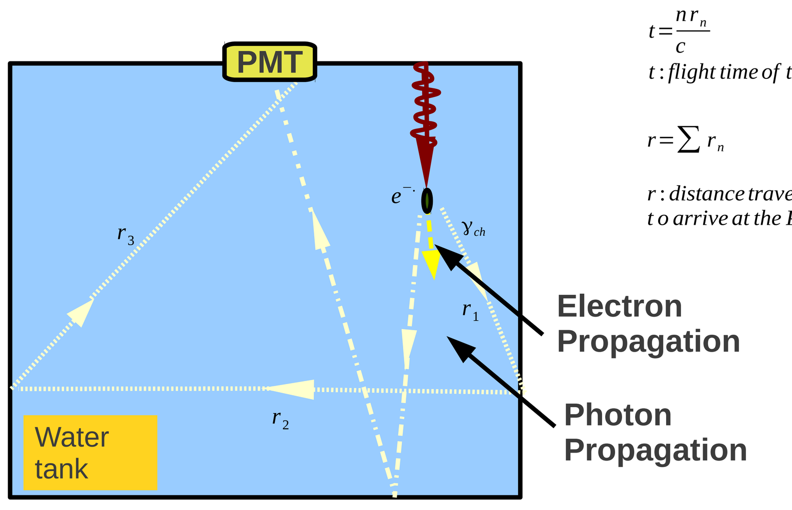
The photon produced for Cherenkov effect are scattering in the inner surface of the tank to arrived at the PMT

$$t=\frac{nr_n}{c}$$

t: flight time of the photon

$$r=\sum r_n$$

r: distance traveled by the photon to arrive at the PMT



RESULTS

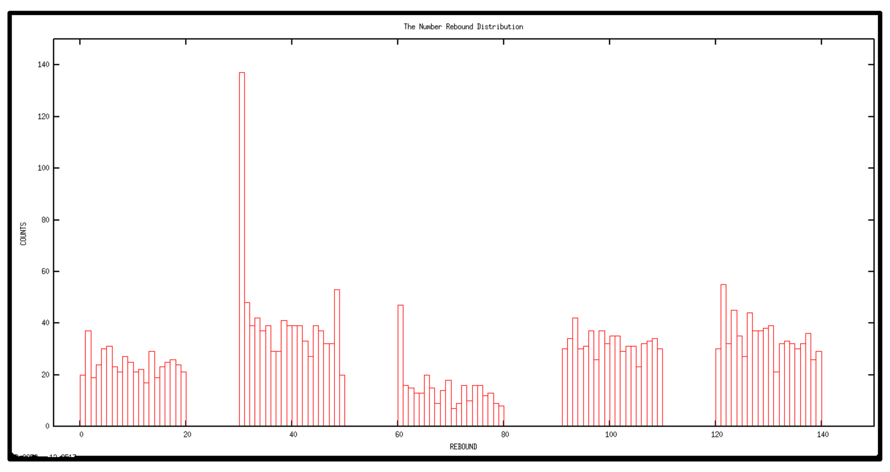


Figure 1. Histogram of number of deflexion of the Cherenkov Photons in the inner material of the tank. before their arrival to the PMT.

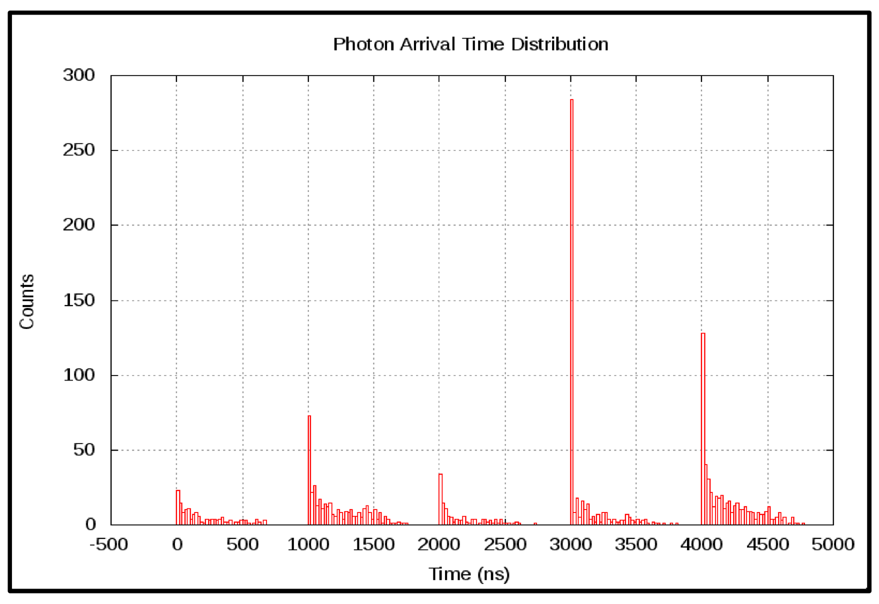


Figure 2. Histogram of the arrival time of the Cherenkov Photons to PMT.

CONCLUSIONS

•A simulation in C++ of the operation of a Cherenkov tank has been performed.

•Montecarlo methods have been applied to simulate relevant physical processes which occur in the production of photons Cherenkov.

•The time of arrival of photons to a plane fotomulltiplicador located in the top of the tank has been found.

REFERENCES

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•*Programación en C++ 5.0.* R. J. Pantiagoso Silva 2002

ACKNOWLEDGES

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