On fluctuations of tank-signal

Samvel Ter-Antonyan (*Southern University, Baton Rouge*)

1. Fluctuations of the number of shower particles n passing through a detector with area A in a time interval Δt at a given average particle density $<n>$ have to be **Poisson by definition**.

In the case of **ICETOP tanks** we deal with the **effective** number of shower particles via the total number of photoelectrons S (signal) produced by Cherenkov light proportional to the length of the shower particle trajectory in the tank. Number of photoelectrons (S) are evaluated from known parameterizations of GEANT tank-simulated data depending on particle id (γ,e,μ) and corresponding energy. The effective number of particles in the tank (n) is estimated by the VEM-signal normalization: $n = S/$ VEM.

What are the expected fluctuations of the number of shower particles (in units of VEM) passing through the tank ?

According to statement 1 above, if $<n>$ is the average and σ is the standard deviation of a random $n = S/$ VEM and the VEM-signal is constant for a given tank, then

$$\frac{\sigma}{<n>} \cong \sigma[Ln(n)] \cong \frac{1}{\sqrt{S/VEM}}$$

Instead of a discrete Poisson distribution that deals with integer variables one can use continuous Gamma or Log-Normal distributions satisfying only the condition of Poisson distribution: $\sigma^2 = <n>$. The test of this statement are presented in Fig.1.

Different shower particles and corresponding energy spectra, different lengths of trajectories in the tank and fluctuations of Cherenkov light can only increase the fluctuations but never decrease them.

Poisson fluctuations are reduced for large number of detected shower particles ($n >> 10$) where the Cherenkov light and particle trajectory fluctuations begin to dominate.

2. Is there R-dependence of fluctuations or does the detector know where the shower axis is?

Observed R-dependence of tank-signal fluctuations cannot be real and has an artificial origin due to strong dependence of energy spectra of shower particles on the distance from the shower core, whereas the VEM signal remains constant. It means that the shower particles from the core region having larger energies will produce greater average tank-signal (S) and corresponding $n = S/$ VEM, and will shift the $\sigma[Ln(n)]$ dependence to the right region imitating larger fluctuations. The observed parallel shift of $\sigma[Ln(n), R]$ is well seen from Shahid, and my ring simulation results.

Outlook

Fluctuations of detected shower particles have to be Poisson regardless of distance from the shower core. Poisson processes for tank-signal fluctuations can be described by both Gamma and Log-Normal distributions. The Gamma distribution is more preferable.

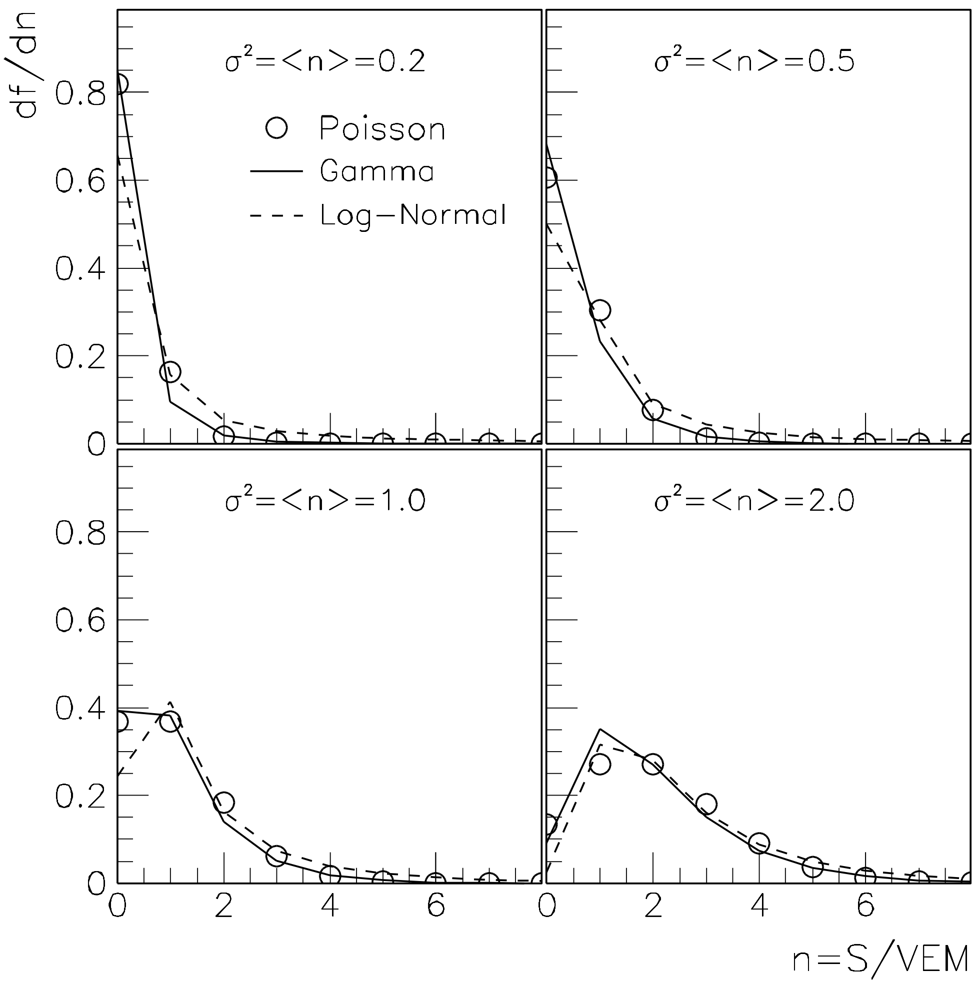

Fig. 1 Poisson distributions (symbols) for different $\boldsymbol{\sigma^2} = < n >$. It is seen, that both the Gamma (solid lines) and Log-Normal (dashed lines) distributions can well describe the Poisson process.

***Appendix*:** Gamma distribution for Poisson process:

$$\frac{df}{dx} = \frac{x^{\alpha-1}e^{-x}}{\Gamma(\alpha)}$$

where $< \boldsymbol{x} > = \sigma^2 = \alpha$.

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