JSirene: A program to simulate the detector response

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November 19, 2021

Abstract

The JSirene program can be used to simulate the detector response to muons and showers. A brief description of its functionality and some guidelines for running it are presented.

1 Introduction

The JSirene program can be used to simulate the detector response to muons, taus and showers. It uses tabulated values of the probability density function (PDF) of the arrival time of light and the interpolation methods that are part of the Jpp - JTools package [2]. PDFs can be calculated using the formalism of PDFs introduced in reference [1]. PDFs produced in other ways can be used as well. In the following, a brief description of the functionality JSirene and some guidelines for running it are presented. First, any existing hits are removed before processing the event. Muons are propagated from a given starting position (e.g. the neutrino interaction vertex) to the border of a cylinder surrounding the instrumented volume. In the first step, the energy loss of the muon is taken from reference [3]. No simulation of light from the muon or showers is made. Therefore, a margin is introduced between the surface of this cylinder and the positions of the photo-multiplier tubes (PMTs). This margin corresponds to the maximal dynamic range of the PDFs. Inside the cylinder, the muon is propagated using the energy loss according reference [4]. The light from a muon includes that of a minimum ionising particle (MIP), δ-rays and Bremsstrahlung showers. A tau is simulated as-is (i.e. the length of the tau should *a priori* be specified). The light from a tau includes that of a MIP and δ-rays. Note that the production of δ-rays depends on the mass of the particle. Light from any other particle shower (except neutrinos) is separately simulated. In this, it is assumed that the light produced by hadronic showers is identical to that produced by Electro-Magnetic showers. This assumption is reasonable because the hadronic interaction length and the radiation length of water are similar. In JSirene there is a possibility to weigh the light yield from the various particles according to their type. At present, the relative weights of e^-, e^+, π_0 and γ are set to 1. The weights of π^- and π^+ are energy dependent and taken from reference [6].

2 JSirene

The JSirene program uses various command line options. The list of command line options includes:

option	parameter
-f	input file name
-o	output file name
-a	detector geometry file
-F	file descriptor
-n	number of events
-d	debug level

The input format could be ASCII (so-called '.evt' file) or ROOT. A ROOT formatted input file should contain a standard ROOT tree of Monte Carlo events (i.e. data structure Evt). The output file is in ROOT format. The detector geometry file should be an ASCII formatted file (a so-called '.det' or '.detx' file). The debug level allows to specify the amount of text output (-d0 will disable all printing).

The file descriptor refers to the naming of files containing the data of the cumulative density functions (CDFs). The file descriptor should contain the wild card character %. The list of file names is then obtained by replacing the wild card character % by 1, 2, 5, 6, 13, and 14. The corresponding files should contain the data of the CDFs of direct light from a muon, scattered light from a muon, direct light from δ-rays, scattered light from δ-rays, direct light from an Electro-Magnetic shower and scattered light from an Electro-Magnetic shower, respectively. The list of parameters internally used in JSirene includes:

parameter	default	meaning
Ecut_GeV	0.1	minimal energy for generation of light from shower
Emin_GeV	1.0	minimal energy of muon for shower generation
Dmin_m	0.1	minimal distance for positioning
Tmax_ns	0.1	maximal time between hits on same PMT to be merged
Nmax_npe	max	maximal number of photo-electrons

The value of each parameter can be set on the command line using the syntax:

```
JSirene -@"<name>=<value>[;<name>=<value>]"
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In this, <name> refers to the name of a parameter and <value> to the set value. For each parameter a default value is set (max refers to the maximal value of the corresponding data type int).

3 Auxiliaries

Tabulated values of the PDFs can be produced with the JMakePDF, JMakePDG, JMakeCDF, and JMakeCDG applications [5]. The characteristics of the PMT, such as the photo-cathode area, the quantum efficiency and the angular acceptance are included. The angular distribution of the light scattering, the scattering length and absorption length are also included. The characteristics of the PMT and the optical properties of the water are described by standalone methods which are organised in a simple include file called Antares.hh and KM3NeT.hh for Antares and KM3NeT, respectively. The tabulated values of the PDFs include direct light and single-scattered light.

An auxiliary script JMakePDF.sh is available that can be used to swiftly produce all tables of the probability density functions and the cumulative density functions. The list of command line options includes:

option	parameter
-W	working directory for PDF and CDF tables
-P	create PDF tables
-M	merge PDF tables
-C	convert PDF tables to CDF tables
-c	clean PDF tables
-d	debug level

The options -P and -C can be used to produce all tabulated data of the PDFs and CDFs, respectively. The first may take some time (couple of hours) the latter is very fast. The option -W is required for each step. Obviously, the provided value should be the same for each step.

References

[1] ANTARES-SOFT-2010-002, M. de Jong.

[2] ANTARES-SOFT-2011-003, M. de Jong.

[3] Proceedings of ICRC 2001, "Precise parametrizations of muon energy losses in water", S. Klimushin, E. Bugaev and I. Sokalski.

[4] P. Kooijman private communications.

[5] ANTARES-SOFT-2011-004, M. de Jong.

[6] "Investigation of the One-Particle Approximation in the ANTARES simulation package KM3", Mona Dentler, Bachelorarbeit Erlangen Centre for Astroparticle Physics, Friedrich-Alexander-Universität, Erlangen-Nürnberg.