Status of the Monte Carlo Simulation

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Overview

- Development by the Munich group since 2005
- Object orientated C++ Program
- Based on the GEANT4 framework (currently used version 4.9.3.p01)
- Interface to the GENIE framework for the simulation of high energy ν-events ($\mathrm{E} > 100\,\mathrm{MeV}$)
- Command-line user interface
- Data analysis with ROOT

Physics of the Simulation

Predefined GEANT4 physics list QGSP-BERT-HP

- Electromagnetic interactions
- Gamma-nuclear und muon-nuclear interactions
- Hadronic interactions ranging from the eV to the GeV scale

Optical model

- Scintillation light emission
- Photon scattering
- Photon absorption

Scintillation Model

- Photo emission process is described by a sum of N exponential decays (components)

$$F(t) = \sum_i N_i e^{-\frac{t}{\tau_i}}$$

- Number of decay components adjustable
- Quenching of the scintillation light modelled by the Birks formula

$$\frac{dL}{dx} = \frac{A\frac{dE}{dx}}{1 + k_b\frac{dE}{dx}}$$

- Particle dependent k_b factors

Scattering Models

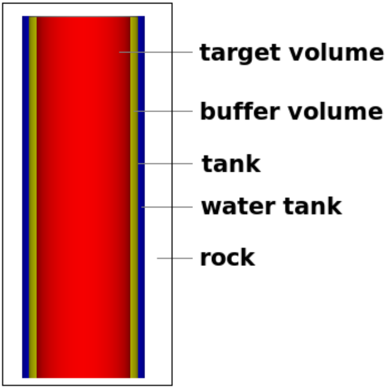
Rayleigh scattering

- GEANT4 model
- Adjustable scattering lenght

Absorption and reemission process

- Developed by the Munich group
- Delayed emission, modeled by an exponential decay with $\tau = 1.2\,ns$
- Isotropic emission

Simulated detector geometry



Buffer and target volume is either LAB or PXE

Material Properties (LAB)

Parameter	Value
$\tau_1(e^-)$	4.6 ns
$\tau_2(e^-)$	18 ns
$\tau_3(e^-)$	156 ns
$k_b(e^-)$	$0.15\ \frac{\mathrm{mm}}{\mathrm{MeV}}$
$k_b(p)$	$0.12\ \frac{\mathrm{mm}}{\mathrm{MeV}}$
$k_b(\alpha)$	$0.11\ \frac{\mathrm{mm}}{\mathrm{MeV}}$
absorption length	20 m
rayleigh scattering length	40 m
absorption/reemission length	60 m
refractive index	1.484

Photon Detection

- PMTs are simulated as simple photosentive volumes
- Quantum efficiency (QE) is set to 1 $\Rightarrow$ light yield reduced to $2 \cdot 10^3/MeV$ to compensate the higher QE

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- Reduction of the computation time by a factor of 5
- Simulation of $13 \cdot 10^3$ SuperKamiokande type PMTs instead of 8 inch PMTs to save computation time
- Option to use whole steel tank as a photosentive volume with an adjusted light yield to further reduce computation time

Winston Cones

- Winston cones can be attached to the PMTs
- Only photons with an angle relative to the surface normal of less than a certain critical angle are detected
- Size of the simulated PMTs stays the same

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- Light yield needs to be adjusted

Simulated PMT Performance

- Time jitter (time uncertainty for a photon hit)
- Dark counts (PMT counts in no correlation to a photon hit)
- Afterpulses (additional pulses that are correlated to a photon hit)
- Latepulses (photons that are detected with a time delay)

DAQ

- Results will be saved to a root file (TTree format)
- Two options for the DAQ
  - Save every photon hit for further analysis
  - Only save the visible energy of event and a root histogram of the pulse shape
- Monte-Carlo truth will be saved for ν-events that were generated with the GENIE interface

Simulation of High Energy ν-events $(\mathrm{E} > 100\,\mathrm{MeV})$

- Simulation of the ν-events with Genie (www.genie-mc.org)
- Use the generated root file as an input file for the LENA simulation
- ν-events will be selected randomly from the input file
- All stable final particles ($\tau > 1\,ps$) are tracked
- Different cuts can be set in the LENA simulation on the neutrino energy, the interaction type (CC,NC), the interaction point and many more

Conclusions

- Full detector simulation based on widely used frameworks (GEANT4, ROOT)
- Complete optical model, including scattering, quenching and a realistic scintillation model
- Inclusion of several PMT properties that can influence the measurement like dark counts, afterpulses and latepulses
- Interface to the GENIE Neutrino Monte Carlo Generator

Open Tasks

- Include wavelength dependent effects (the simulation is ready for this, but certain values still needs to be measured)
- Simulation of the detector electronics
- Additional complex event generators are needed for supernova neutrinos, geoneutrinos and solar neutrinos

Distribution and Development of the Code

- The code is hosted by a version control system (subversion; subversion.apache.org)
- At the moment the subversion server can only be reached inside the TUM intranet

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- Proposal: The code should be hosted by a subversion server that can be accessed through the internet, so that everyone from the Collaboration can get the latest version and can contribute to the further development
- Who is responsible for this task (setting up the server costs time and money!)???