Physics > Instrumentation and Detectors

Simulation of large photomultipliers for experiments in astroparticle physics

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We have developed an accurate simulation model of the large 9 inch photomultiplier tubes (PMT) used in water-Cherenkov detectors of cosmic-ray induced extensive air-showers. This work was carried out as part of the development of the Offline simulation software for the Pierre Auger Observatory surface array, but our findings may be relevant also for other astrophysics experiments that employ similar large PMTs. The implementation is realistic in terms of geometrical dimensions, optical processes at various surfaces, thin-film treatment of the photocathode, and photon reflections on the inner structure of the PMT. With the quantum efficiency obtained for this advanced model we have calibrated a much simpler and a more rudimentary model of the PMT which is more practical for massive simulation productions. We show that the quantum efficiency declared by manufactures of the PMTs is usually determined under conditions substantially different from those relevant for the particular experiment and thus requires careful (re) interpretation when applied to the experimental data or when used in simulations. In principle, the effective quantum efficiency could vary depending on the optical characteristics of individual events.

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