Calibration of single-photon detectors using correlated photons from spontaneous parametric down-conversion

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ABSTRACT

Experimental particle physicists rely on accurately calibrated detectors so that they can properly interpret the results of their experiments. Most detector calibration methods depend on some outside standard in order to determine absolute efficiency, but there is a method that relies on correlated pairs in order to calibrate detectors without any outside standards. Through a quantum-optical process called spontaneous parametric down-conversion, photons from a high-intensity laser (called pump photons) are sent through a nonlinear crystal and are split into two down-converted photons (called the signal and idler photons). Due to the conservation of energy and momentum, the down-converted photons are highly correlated in momentum and energy; in other words, if you measure the energy, momentum of one of the photons (the signal), you know immediately the energy and momentum of the other photon (the idler). Absolute calibration of a detector *A* can be accomplished by aligning two detectors, *A* and *B*, so that they each pick up an entangled photon. When detector *B* picks up a trigger photon, there is a guarantee that the idler photon will hit detector *A*. So if detector *B* registers a photon, then the experimenter looks to see if detector *A* registers a photon as well at the same time (a coincident photon count). Thus the photon detection efficiency *A* is found by dividing the number of coincident counts by the number of single photon counts by *B*. A metrology lab that utilizes correlated photons from spontaneous parametric down-conversion to calibrate photodetectors was put together at Fermilab. The lab was made specifically to calibrate silicon photomultipliers, a new kind of photodetector device with a broad range of applications in modern particle physics experiments. In addition to the alignment of the optical equipment in the lab, the necessary software was written and tested and an experimental protocol was devised in order to efficiently calibrate silicon photomultipliers purchased by experimenters at Fermilab.