

## GIL: A formula for EAS longitudinal profiles

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**Abstract.** GIL stands for Greisen Linsley. It is an analytical formula with an obvious resemblance to a formula by Greisen that is well-known: Greisen's formula for average profiles of EAS due to given-energy gamma rays. GIL is not only simple mathematically, also it has the advantage of being phenomenological and model-independent: The quantity it returns is the shower size  $N(E_0, A, t)$ , where  $E_0$  and  $A$  are the energy and mass number of the primary particle, and  $t$  is the atmospheric depth in units of the radiation length. GIL resembles the Greisen formula by employing the shower age,  $s$ , as an intermediate variable; in GIL, however the role of hadronic cascades in nucleus-EAS is expressed by an altered relation between  $s$  and  $t$ . The property is retained, that the shower size is maximum for  $s = 1$ . Values of two GIL parameters are chosen to express the elongation-energy relation; i.e, the slope of the semilogarithmic dependence of

$t_{\max}$  (and  $x_{\max}$ ) on primary energy, and the intercept for  $A = 1$ . The dependence of average size on the primary mass number relies on validity of the superposition principle for average cascades. An important parameter is  $E_1$ , defined by  $N_{\max} = E_0/E_1$ . This is compatible with energy conservation (the condition, track-length integral=electromagnetic energy  $E_{EM}$ ) because some fraction of the initial energy is given to muons, neutrinos, and low-energy hadrons. An inconvenience of GIL is that some properties; i.e, EEM, the average  $t$ , and the profile width  $st$ , must be found by numerical integration rather than from closed-form expressions. But modern hand-held calculators can easily be programmed to provide, when needed, those less often used quantities.

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