Time distributions of electromagnetic and hadronic components in giant EAS

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Abstract

From our databank of giant air showers produced by 4D simulation with CORSIKA, we have derived the time distributions for photons, electrons, muons, charged hadrons and neutrons. Those distributions are compared at different distances from the shower core up to 2 km for proton and iron induced cascades.

The average arrival time at different distances can help the reconstruction of the axis position and we present some cases of axis determination at 20 m from the actual location in the case of AUGER experiment.

1. Electromagnetic component

Taking the advantage of the 4D-simulation carried with CORSIKA, we have derived the arrival time distributions of the different particles in fixed bands of distances, 550 to 650 m, 900 to 1100 m and 1450 to 1750 m.

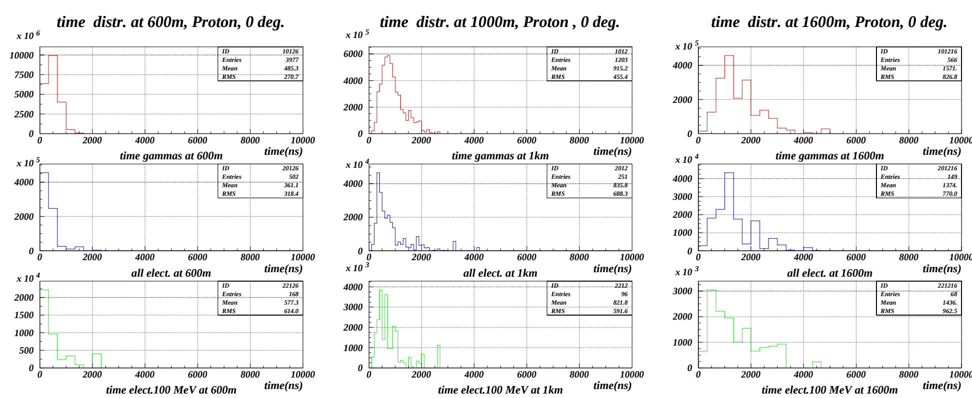

Fig. 1. time distributions near 600 m, 1000 m and 1600 m from axis, primary proton 10^{20} eV, for photons, electrons and electrons above 100 MeV (from top)

The average arrival times τ are listed on Table 1. for the different particles and distances. The average situation for proton primary is shown on Fig. 1. and iron primary around the 3 same distances from axis on fig. 2.

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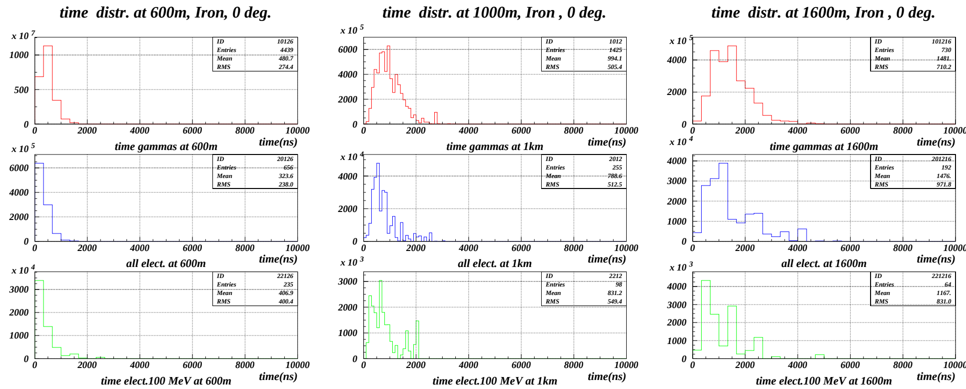

Fig. 2. time distributions near 600 m, 1000 m and 1600 m from axis, primary iron 10^{20} eV, for photons, electrons and electrons above 100 MeV (from top)

2. Muons, hadrons and neutrons

A general leptonic synchronism is observed with comparable mean arrival times for electrons and muons (larger than 25-30% for photons).

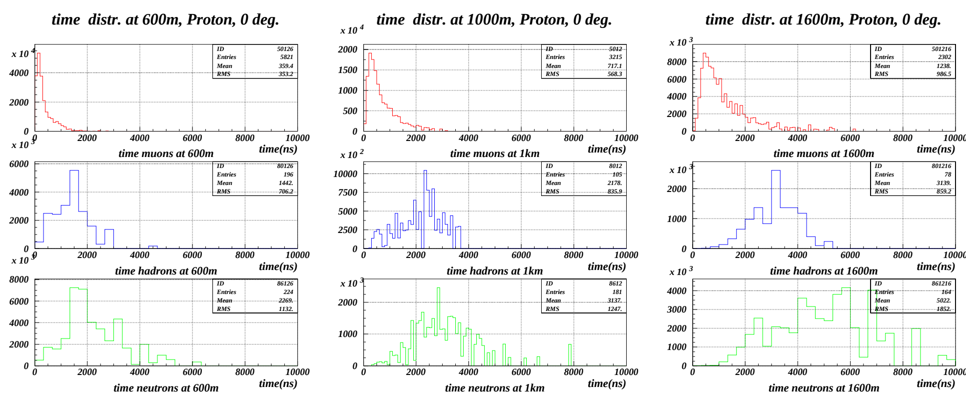

Fig. 3. time distributions near 600 m, 1000 m and 1600 m from axis, primary proton 10^{20} eV, respectively for muons, hadrons and neutrons above 300 MeV (from the top) .

Neutrons with energies above 300 MeV are arriving around 5 μs at 1600m from axis. The width of the corresponding pulses are larger for muons than for electrons inside a radiius of 1 km. For near vertical showers, it appears that the time distribution cannot be used for the discrimination between primaries, protons and heavy nuclei; the delayed signals can however be useful to distinguish photons primaries from nuclei (absence of delayed component from hadrons or muons at lage distance and typical shorter time distribution via LPM effect).

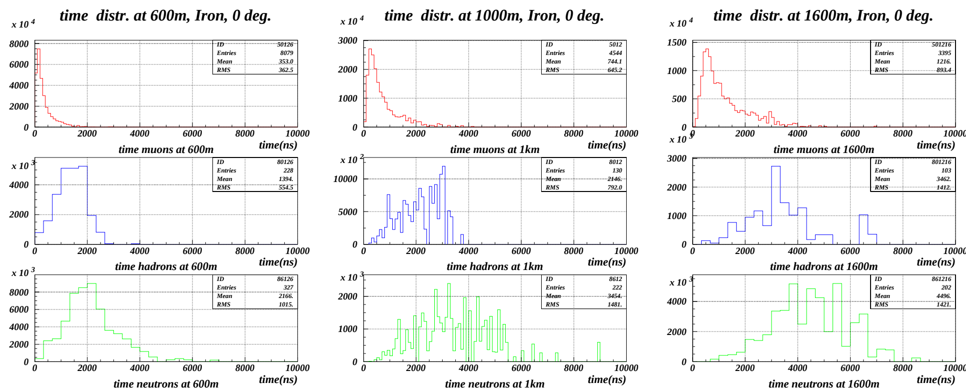

Fig. 4. time distributions near 600, 1000 m, and 1600 m from axis, primary Iron 10^{20} eV, respectively muons, hadrons and neutrons above 300 MeV (from the top) .

Table 1. Average arrival times (in ns) for the different particles at 600, 1000 and 1500 m from axis.

	τ_γ	τ_e	τ_μ	τ_h	τ_n	σ_γ	σ_e	σ_μ	σ_h	σ_n
r=600 m, prim.p	483	361	359	1440	2270	483	361	359	1440	2270
r=600 m, prim. Fe	480	323	353	1394	2166	275	238	362	554	1015
r=1000 m, prim.p	915	821	717	2178	3137	455	688	568	836	1247
r=1000 m, prim. Fe	992	788	744	2146	3454	505	512	645	792	1481
r=1600 m, prim.p	1571	1374	1238	3139	5022	826	770	986	859	1852
r=1600 m, prim. Fe	1480	1476	1216	3462	4496	710	971	893	1412	1421

3. Time structure of the shower front

Average time of arrival component at different distances compared with Linley dispersion at different distances.

The respective r.m.s. standard deviations are reproduced on Table **??** and can be compared to the mean arrival time τ. At 600 m, they are comparable to τ for photons, electrons and muons, about one half for hadrons and muons. At 1600 m from the axis, they are respectively about 70% and 40%. Electrons, photons and muons are approximately synchronous. The value of τ for hadrons and neutrons is about 3 times larger. This circumstance suggests the existence of one delayed signal, with a large spread for proton and iron initiated showers. As seen from Table 1., there are no chance to distinguish proton and iron primaries by time measurements in near vertical showers. On the opposite, the delayed signal will be systematically missing in photon initated showers, as well as in showers rejuvenated after muon bremsstrahlung or initated after a high energy neutrino interaction.

According to the probabilities in regard of the low densities of hadrons and neutrons to pass simultaneously out of the field of the different tanks, or to cross without visible effect, it can be roughly estimated that 20% proton showers can have a signature by delayed hadronic signal.

The thickness of the electron shower front σ(r) (Fig. 5.) increases with distance according to

$$\sigma(r) = 2.6(1 + \frac{r}{25.})^{1.4} \qquad (1)$$

as derived from our simulation with CORSIKA for near vertical showers. Those values, up to 2000 m, are in agreement with the adaptation of Linsleys's previous estimation [4] adapted for AGASA [7]. The original experimental measurements values are closed from the simulation Fig. 5.

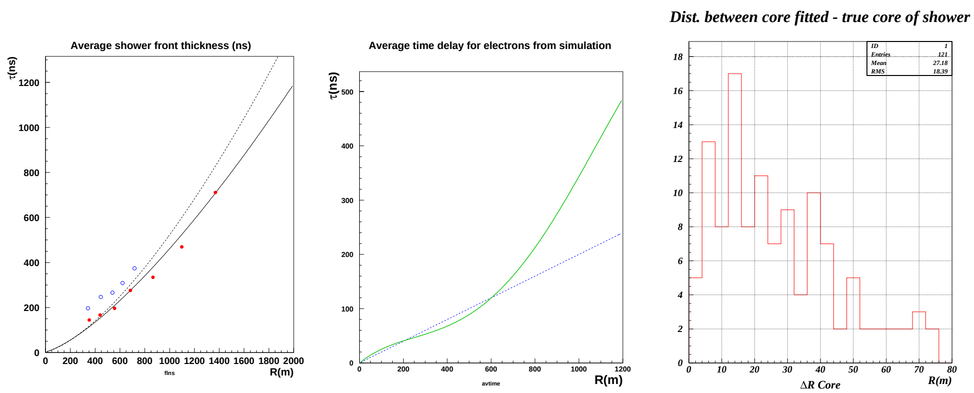

Fig. 5. Left: Average shower front thickness (ns). Our simulation with CORSIKA (solid line) is compared to the experimental data of Akeno exended to 20 km^2 [5] and Akeno [3] (average from 10 EAS). Primary particle is a proton with energy 10^{11} GeV. The adaptation of Linsley's prediction to AGASA (dahed line) corresponds to showers up to zenith angle of 40^o . Middle: Average time delay for electrons from our simulation (solid line) compared to the data of [6] (dashed) . Right: Core reconstruced using time delay, error on the core: near 30 m

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4. References

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