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Seasonal variations of the rate of multiple - muons in the MACRO experiment in the Gran Sasso underground laboratory

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It's well known that the rate of cosmic ray muons depends from the atmospheric temperature, and that for events with a single muon the peak of rate is in summer, in the northern hemisphere.

In 2015 the MINOS experiment, in USA, reported the seasonal modulation of the rate of cosmic ray multiple-muon events at two underground sites, the MINOS near detector and the MINOS far detector site at 2100 mwe. The peak of the seasonal rate depends from the distance between the muons. MINOS found that, for small distances between the multiple muons, the rate peaks is in the winter and that the amplitude of the modulation is smaller than in the case of a single muon. I have done a reanalysis of data of the past MACRO experiment at the Gran Sasso Laboratory (Italy) analyzing data from 1994 up to December 2010. I have found roughly similar results but with the peak rate of multiple-muon events slightly delayed respect to the peak of single muons.

This difference between MINOS and MACRO may be due to differences in the depth of the detectors and in the temperature seasonal variations in the two sites.

This results could be of interest for dark matter experiments looking to dark matter seasonal modulation due to the Earth's motion.

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