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Simulation of the charging process of the LISA test masses due to solar flares

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Solar flares are huge releases of magnetic energy converted to solar plasma heat and particle acceleration (mainly protons and electrons). The flare develops in a few minutes and may last several hours. The solar flare energy, peak flux, duration and rate of occurrence vary as a function of the solar activity.

In Fig. 1 the proton peak energy differential flux emitted by a strong solar flare (February 16th 1984) is compared to the best fit to the primary proton flux at solar minimum[1].

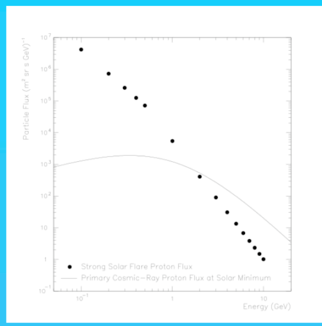


Fig. 1

We present the very preliminary results of the simulated propagation process of the solar flare energy proton peak flux through the LISA test masses. The simulation has been carried out with the FLUKA Monte Carlo program[2] in the energy range 0.1÷10 GeV. An extensive simulation of the primary and solar cosmic-ray fluxes has been also made by using the GEANT toolkit[3].

The LISA simplified apparatus geometry used for the present work is sketched in Fig. 2.

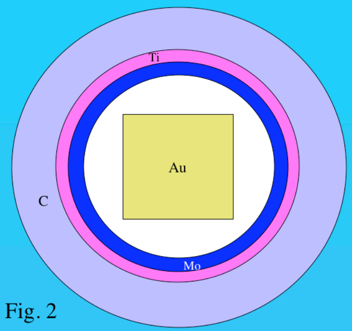


Fig. 2

The grammage and thickness of each material layer used for this simulation is reported in Table 1

	Density (g/cm^3)	Thickness (cm)	Grammage (g/cm^2)
Carbon	2.1	2.0	4.2
Titanium	4.54	0.5	2.3
Molybdenum	10.28	0.6	6.2
Gold	19.32	4.6	88.9

Table 1

While this work is too much at an early stage to estimate the actual test mass charge rate during the experiment flight, precious hints can be obtained from the comparison of the effect of the strong solar flare with respect to the steady-state proton cosmic-ray flux at solar minimum. The output of the Fluka Monte Carlo, when the input solar flare proton spectrum shown in Fig. 1 is assumed, is reported in Fig. 3.

99650 BEAM PARTICLES HANDLED - THEIR TOTAL WEIGHT WAS: 9.9650E+04
NOTE: TOTAL WEIGHT IS USED FOR NORMALISATION.

TOTAL NUMBER OF STARS GENERATED: 19919

TOTAL NUMBER OF LOW ENERGY NEUTRON INTERACTIONS GENERATED: 62095

1.9989E-01 (100.%) STARS PER BEAM PARTICLE GENERATED OUT OF WHICH
1.7822E-01 (89.2%) GENERATED BY PROTON
2.0963E-02 (10.5%) GENERATED BY NEUTRON
4.2148E-04 (0.2%) GENERATED BY PION+
2.8098E-04 (0.1%) GENERATED BY PION-

1.0437E+00 (100.%) SECONDARIES CREATED PER BEAM PARTICLE IN INELASTIC INTERACTIONS OUT OF WHICH
2.6934E-01 (25.8%) PROTON
2.5092E-01 (24.0%) PHOTON
3.6190E-01 (34.7%) NEUTRON
2.6593E-03 (0.3%) PION+
6.7235E-04 (0.1%) PION-
1.0035E-05 (0.0%) LAMBDA
1.7160E-03 (0.2%) PIZERO
1.0035E-05 (0.0%) KAONZERO
1.2865E-02 (1.2%) DEUTERON
4.5058E-03 (0.4%) 3-H
6.3522E-03 (0.6%) 3-He
1.3273E-01 (12.7%) 4-He

7.7102E-01 (100.%) SECONDARIES CREATED PER BEAM PARTICLE IN LOW ENERGY NEUTRONS INTERACTIONS OUT OF WHICH
6.2178E-01 (80.6%) NEUTRON
1.4924E-01 (19.4%) PHOTON

1.967E-01 GEV (100.%) DEPOSITED PER BEAM PARTICLE OUT OF WHICH
1.071E-01 GEV (54.4%) BY IONISATION,
5.202E-04 GEV (0.3%) BY EM-CASCADE,
1.412E-03 GEV (0.7%) BY NUCLEAR RECOILS AND HEAVY FRAGMENTS,
6.637E-05 GEV (0.0%) BY LOW ENERGY NEUTRONS,
8.251E-02 GEV (41.9%) ESCAPING THE SYSTEM,
6.179E-05 GEV (0.0%) DISCARDED,
5.086E-03 GEV (2.6%) MISSING.

Fig. 3

All z primary and secondary proton spatial distribution projected on the x-y view in the proof mass appears in Fig. 4; those of secondary electrons and positrons are reported in Figs. 5 and 6.

While electrons and positrons result uniformly distributed through the gold cube, protons accumulate at the edges because of the primary particle larger tracklength.

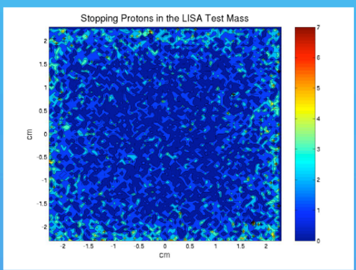


Fig. 4

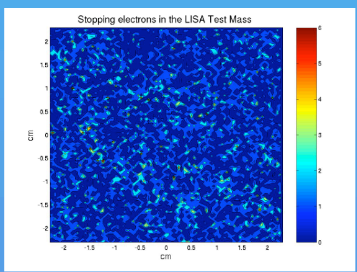


Fig. 5

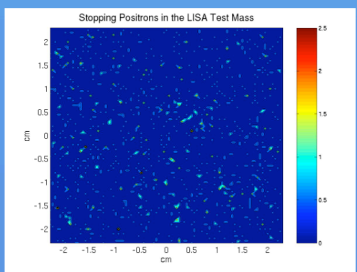
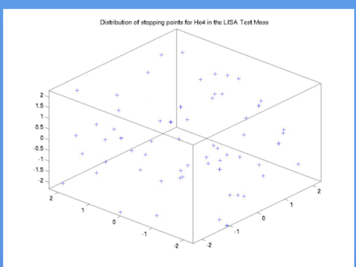


Fig. 6

In Fig. 7 is shown the 3D distribution of the stopping points of ^{4}He nuclei generated by target nuclei breaking.

In Fig. 8 the output of the Fluka Monte Carlo to the input primary spectrum at solar minimum (continuous line in Fig. 1) is reported.

Fig. 7



By comparing Figs. 3 and 8 it can be noticed that solar-flare protons lose the majority of their energy by ionization in the gold cube stopping inside. Conversely interactions overcome ionization energy losses for primary protons.

1228 BEAM PARTICLES HANDLED - THEIR TOTAL WEIGHT WAS: 1.2280E+03
NOTE: TOTAL WEIGHT IS USED FOR NORMALISATION.

TOTAL NUMBER OF STARS GENERATED: 494

TOTAL NUMBER OF LOW ENERGY NEUTRON INTERACTIONS GENERATED: 3326

4.0228E-01 (100.%) STARS PER BEAM PARTICLE GENERATED OUT OF WHICH
2.7443E-01 (68.2%) GENERATED BY PROTON
9.7720E-02 (24.3%) GENERATED BY NEUTRON
1.7915E-02 (4.5%) GENERATED BY PION+
1.2215E-02 (3.0%) GENERATED BY PION-

3.6384E+00 (100.%) SECONDARIES CREATED PER BEAM PARTICLE IN INELASTIC INTERACTIONS OUT OF WHICH
7.9479E-01 (21.8%) PROTON
7.5326E-01 (20.7%) PHOTON
1.6221E+00 (44.6%) NEUTRON
7.0847E-02 (1.9%) PION+
4.3974E-02 (1.2%) PION-
8.0619E-02 (2.2%) PIZERO
4.0717E-02 (1.1%) DEUTERON
1.0586E-02 (0.3%) 3-H
1.9544E-02 (0.5%) 3-He
2.0195E-01 (5.6%) 4-He

3.4756E+00 (100.%) SECONDARIES CREATED PER BEAM PARTICLE IN LOW ENERGY NEUTRONS INTERACTIONS OUT OF WHICH
2.6987E+00 (77.6%) NEUTRON
7.7687E-01 (22.4%) PHOTON

1.553E+00 GEV (100.%) DEPOSITED PER BEAM PARTICLE OUT OF WHICH
8.867E-02 GEV (5.7%) BY IONISATION,
1.486E-02 GEV (1.0%) BY EM-CASCADE,
3.849E-03 GEV (0.2%) BY NUCLEAR RECOILS AND HEAVY FRAGMENTS,
2.796E-04 GEV (0.0%) BY LOW ENERGY NEUTRONS,
1.425E+00 GEV (91.8%) ESCAPING THE SYSTEM,
1.326E-03 GEV (0.1%) DISCARDED,
1.885E-02 GEV (1.2%) MISSING.

Fig. 8

1 Grimani C. et al., presented at this conference and references therein
2 Fassò A, et al., HTTP://www.fluka.org
3 Araùjo H.M. et al., Class. Quantum Grav., 20, 5311, 2003