SIMULATION OF SOLAR NEUTRON FLUX IN THE EARTH'S ATMOSPHERE

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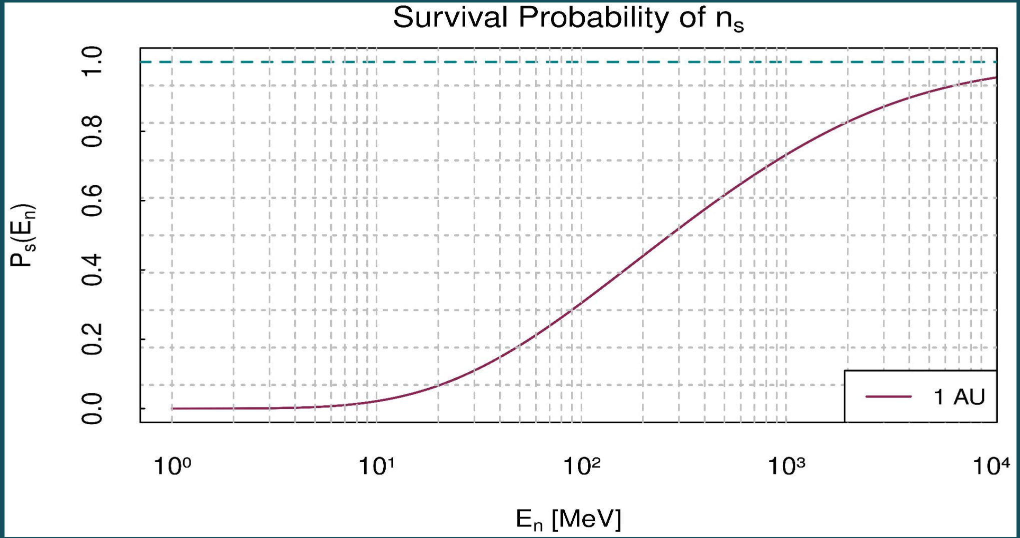
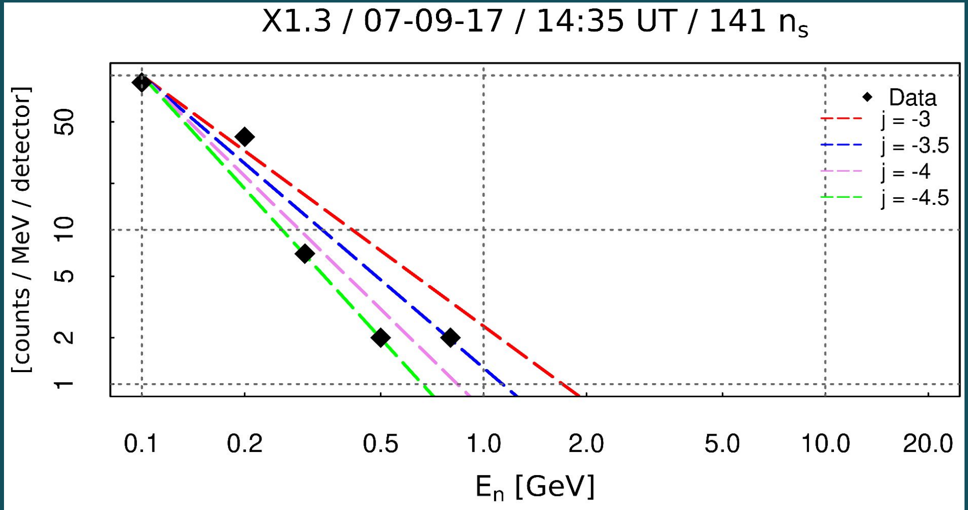
SOLAR NEUTRONS AND THE EARTH'S ATMOSPHERE

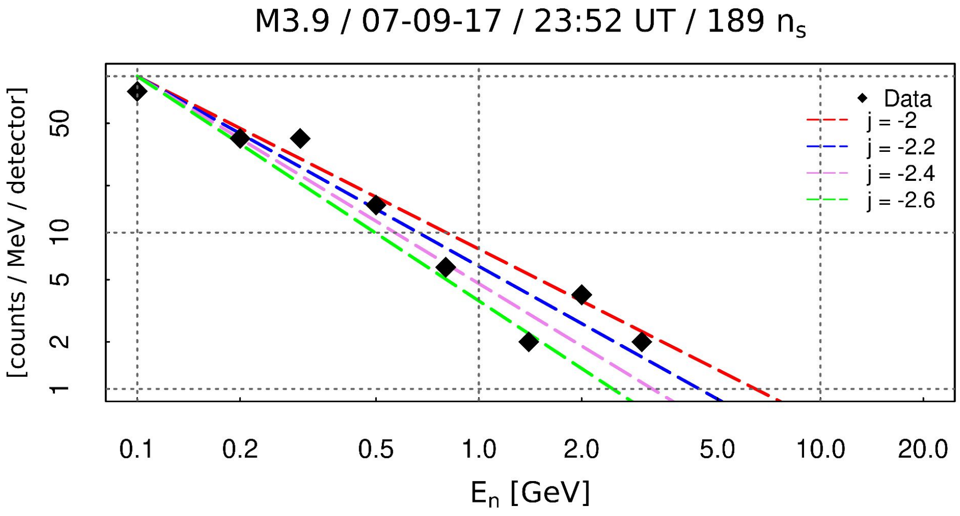


- ❖ Produced by nuclear reactions induced by collisions of protons (p^+) and He nuclei, accelerated at the reconnection site of magnetic field lines after a solar flare.

- ❖ Relativistic n_s released from the Sun may reach 1 AU, according to their survival probability (P_s), which is a function of n_s energy (E_n).

- ❖ The n_s flux is scattered at the Earth's atmosphere. Based on the n_s zenith angle (θ_i), such flux attenuation will become significant. Also, some of this collisions are able to start air showers.



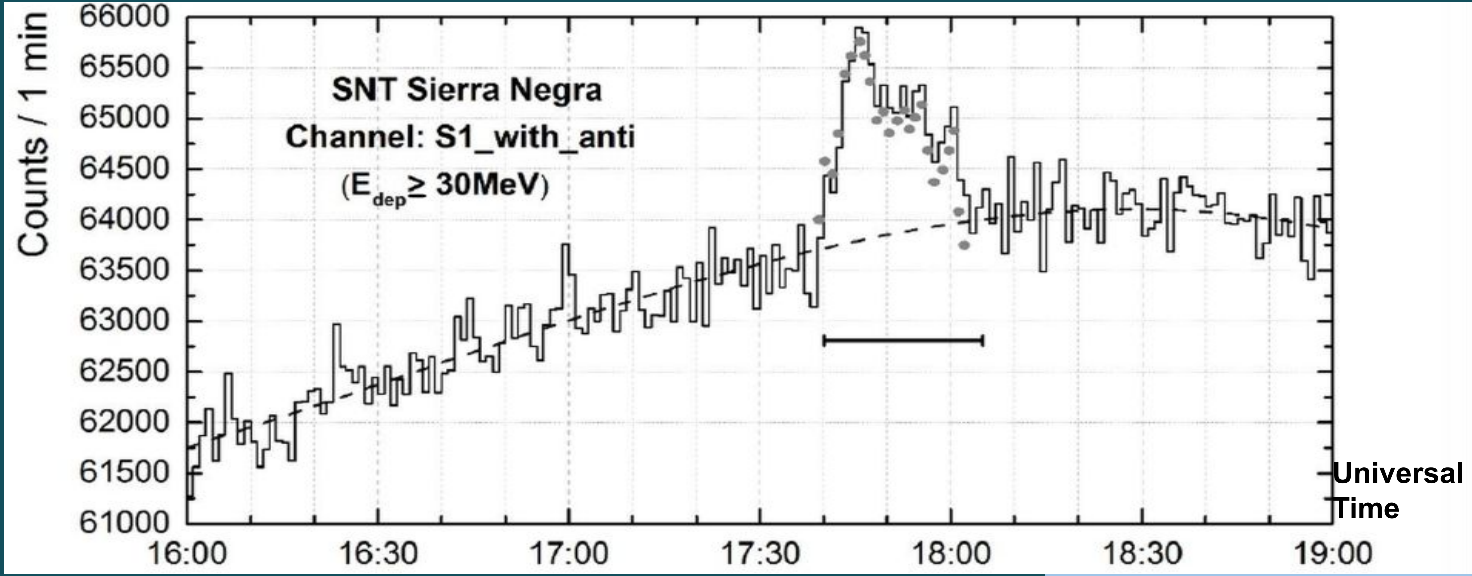


Simulation of solar neutron flux with CORSIKA

CORSIKA: widely used tool to perform cosmic rays simulations.
FLUKA: low energy interaction model.
Main input parameters are:

- ❖ Observation level: Sierra Negra volcano (SN) in Mexico.
- ❖ Spectrum (j):
  - ➢ X1.3 and M3.9 flares: from FIB SEDA-AP, calculated j=3.5 and j=2.6, respectively.
  - ➢ X17 flare: j=3.
- ❖ Energy interval:
  - ➢ X1.3 flare: E_n= 0.1-0.8 GeV.
  - ➢ M3.9 flare: E_n= 0.1-3 GeV.
  - ➢ X17 flareE_n= 0.1-20 GeV.
- ❖ Primary flux (F):
  - ➢ X1.3 and M3.9 flares: sum of the total events.

SIMULATION OF SOLAR NEUTRON FLUX WITH CORSIKA

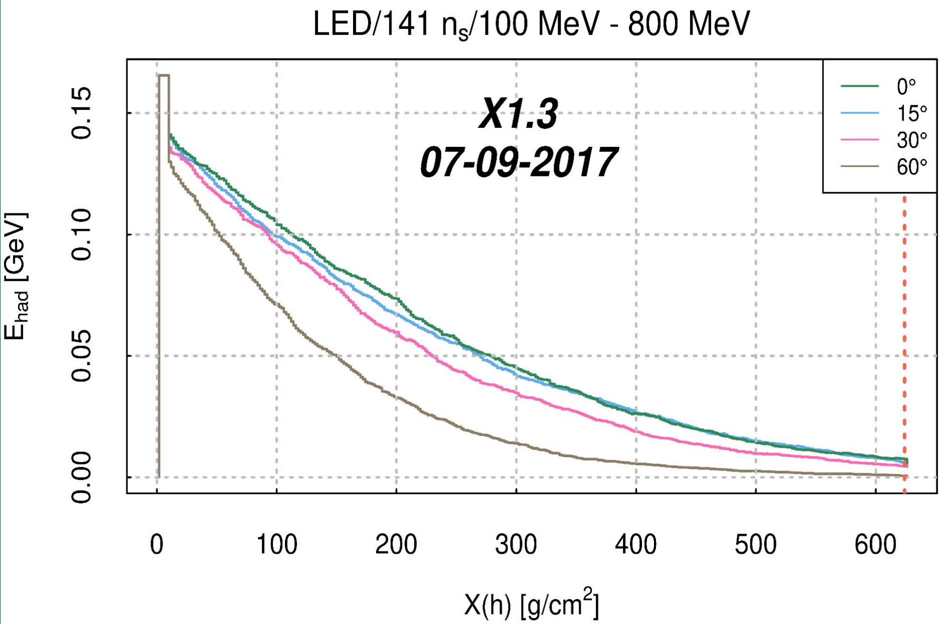


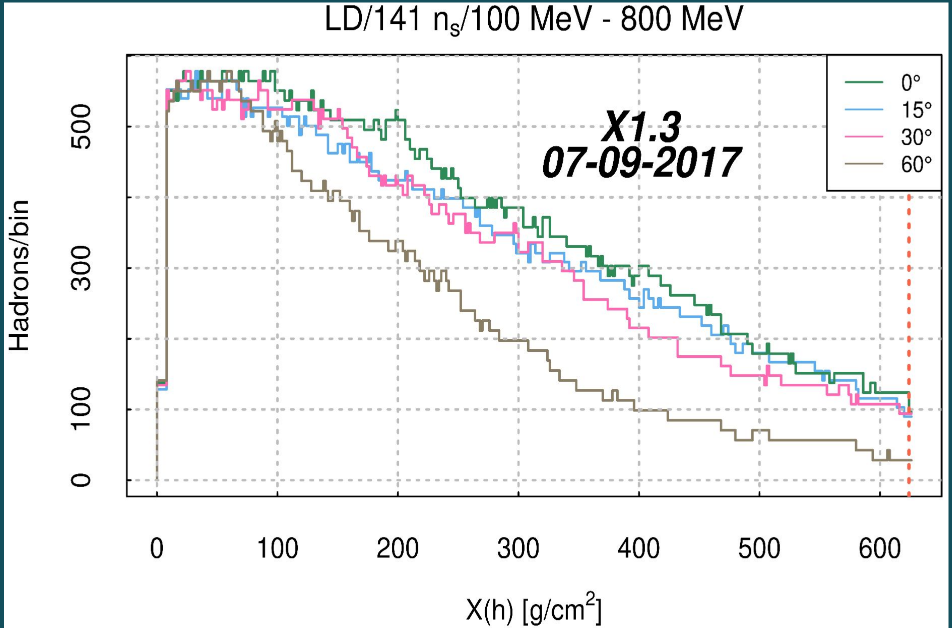
Taken from González, et al. (2015).

❖ X17 flare: we used the counting enhancement (ΔN) of the S1_with_anti channel of the SNT-SN, its effective area (S), detection efficiency (ε) and energy interval per time bin (ΔE), according to:

$$\mathbf{F = \Delta N / (S * \Delta E * \varepsilon)} \qquad \mathbf{(1)}$$

RESULTS AND DISCUSSION

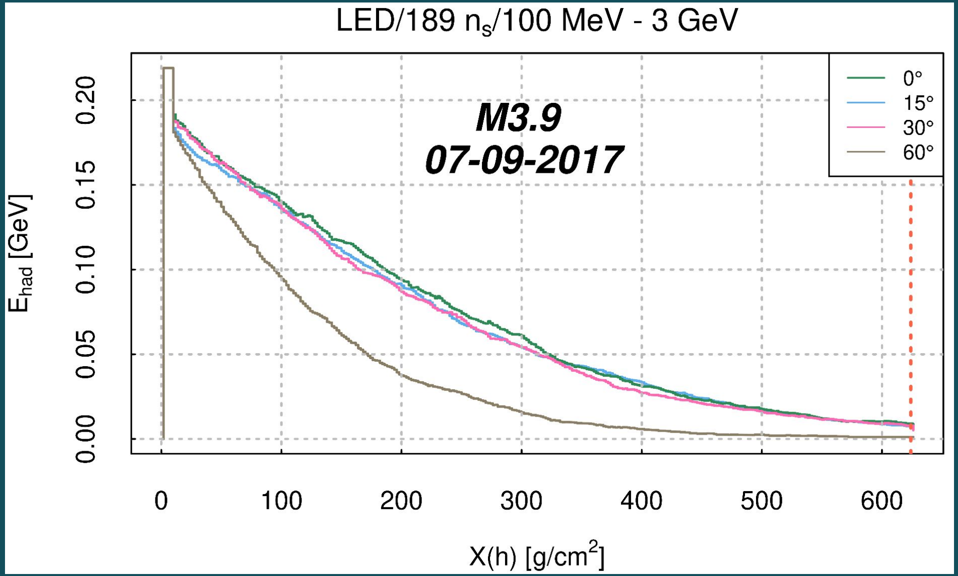


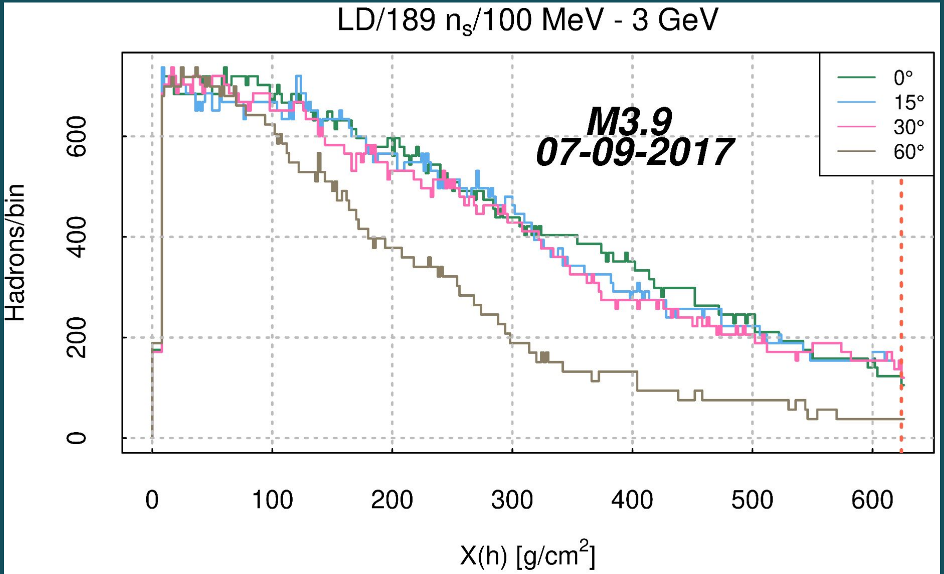


- ❖ Longitudinal Energy Distribution (LED); shows the flux average energy variations. The peak corresponds to the first interaction, followed by an exponential decrease.

- ❖ Longitudinal Distribution (LD); shows an average of the flux variations due to attenuation and air shower generation.

RESULTS AND DISCUSSION





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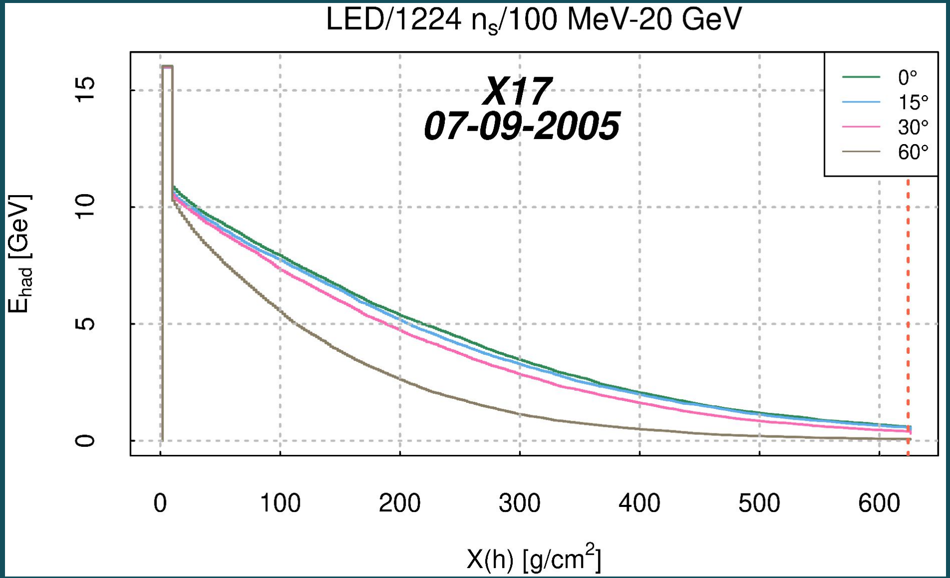

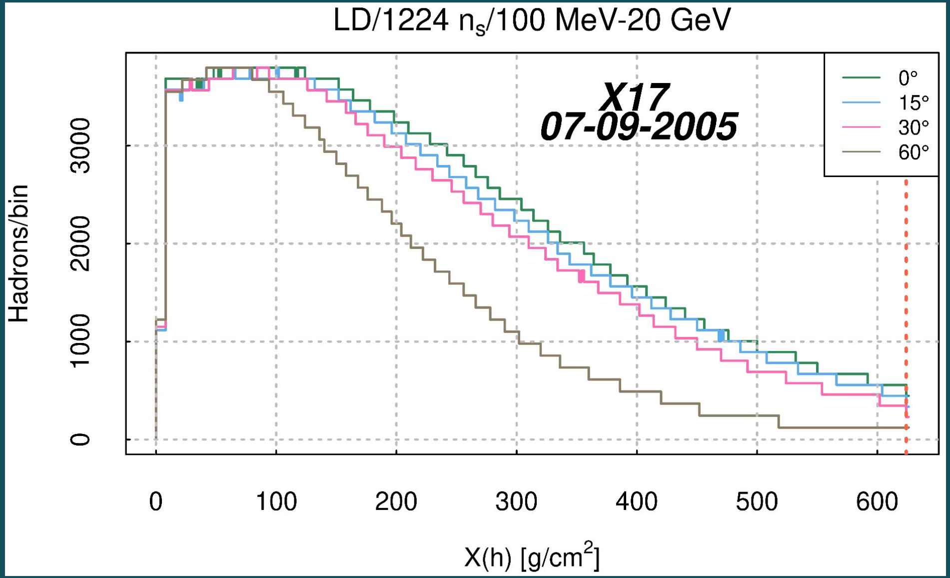

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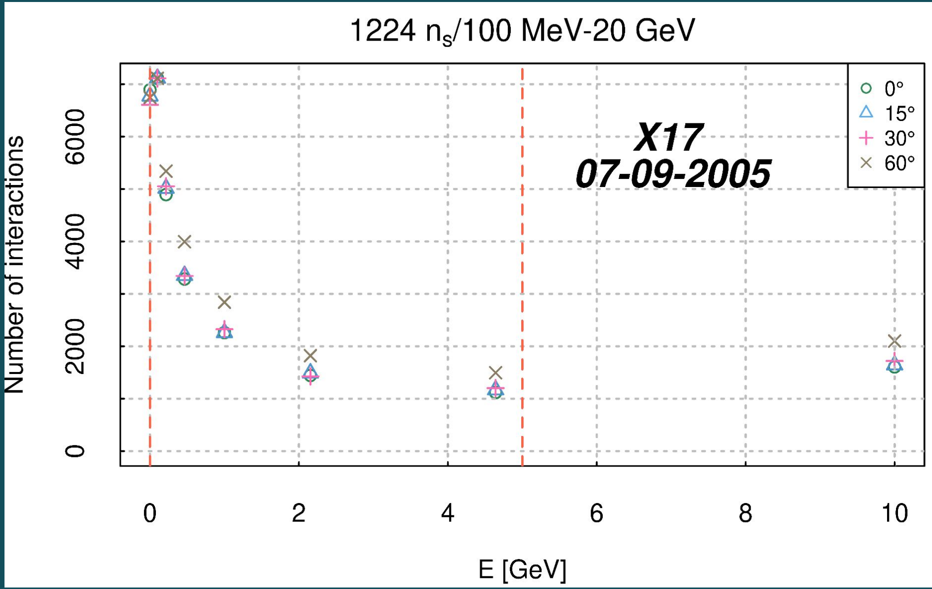

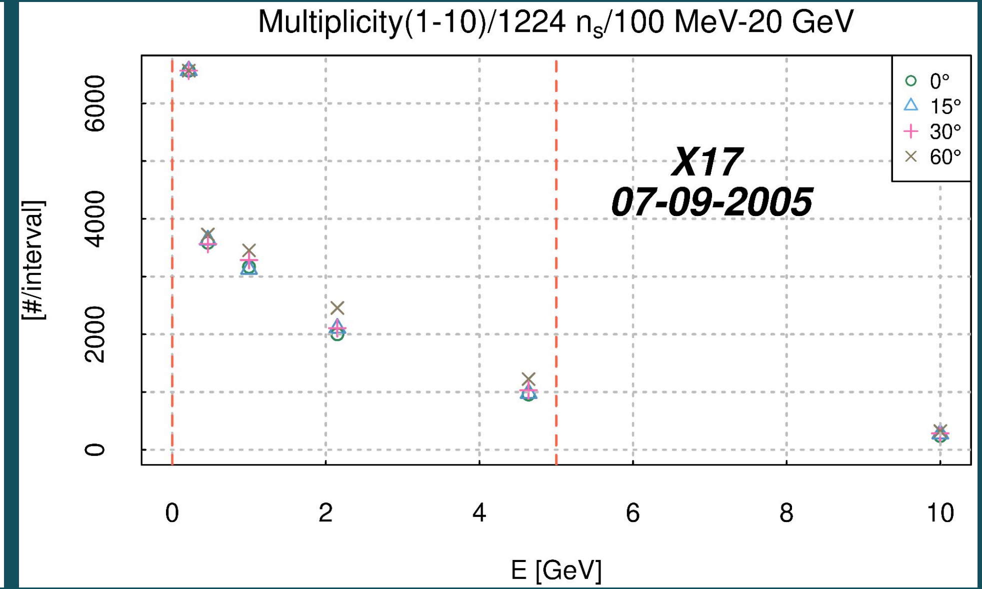

- Interactions and multiplicity for the X17 flare: ~86-89% of interactions and ~93-97% of particle production, take place in a energy (E) range attributed to secondary particles..
- Percentage of n_s that reach the SNT-SN without starting a particle shower
- This is consistent with the n_s detection for the X17 flare of September 07, 2005.

RESULTS AND DISCUSSION

- ❖ Results evaluation: we plotted data (5 min counting rate) from the S1_with_anti channel of the SNT-SN for September 07, 2017 and fitted the background as a third order polynomial, we also calculated a significance of ±3σ.
- ❖ No increment, associated with the n_s released by the X1.3 or M3.9 flares, is observed.

CONCLUSIONS

- According to our simulations, atmospheric attenuation and energy dissipation of n_s are more significant for higher θ_i. The collisions of n_s decreased the E_n by ~ one order of magnitude at the STN-SN level.

- Only secondary n arrived at the SNT-SN for the X1.3 and M3.9 flares. This is consistent with SNT-SN data, since no enhancement was observed.

- We estimated that ~11-14% of the initial n_s, associated with the X17 flare, reached the SNT-SN. Thus, our results are a theoretical confirmation of the n_s detection of 07-09-2005.