SIMULATIONS AND CALIBRATIONS OF THE MARS SURVEYOR 2001 GAMMA-RAY SPECTROMETER PERFORMANCES. O. Gasnault, C. d'Uston, H. Barthe and Veyan J.F., CESR (Toulouse, France. Olivier.Gasnault@cesr.fr).

Introduction: Like every wavelengths of the electromagnetic spectrum, the gamma-ray astronomy brings pieces of information in the knowledge of the universe. It is a space science which deal with a low photon intensity and with a high background level. Nevertheless the results of LUNA and APOLLO missions, as well as theoretical works and simulations show the power of this method for planetary surface investigations. Gamma-ray spectroscopy provide information on the abundance of major elements in the first tens of centimeters below the surface [1]. Mainly, it allows to measure the abundance of H, O, Mg, Al, Si, S, Ni, Cl, K, Ca, Fe, Th and U.

Today several planetary missions combine high energy gamma ray detectors and neutron spectrometers to explore the surface composition of the Moon with at present LUNAR PROSPECTOR [2] then later with SELENE [3] in 2003, of Mars with MARS SURVEYOR 2001 [4], of the asteroid Eros with NEAR [5] in 2000 and possibly of a comet with DS4-CHAMPOLLION mission.

The development of such detectors requires the use of computer simulation to characterize the performances of the instrument in the space next to its target. We have developped such a numerical code and applied it to the gamma-ray spectrometer (GRS) of MARS SURVEYOR 2001 (MS'01) spacecraft which is planed to map the Martian surface in 2002.

Gamma Physics in the Vicinity of Mars:

Origin of planetary gamma-rays: Whenever a planetary atmosphere is thin, a lot of neutrons are generated by nuclear interactions between high energy galactic cosmic rays (87% of protons with energy of 0.1-10 GeV) and the surface material nuclei [6]. These neutrons excite nuclei by various processes depending on their energy (diffusions, captures...) Excited nuclei de-excite by emitting gamma-rays promptly with energies typical of the excited nucleus. The intensity of these gamma-ray lines reveals the number of nucleus which can emit them. Then the gamma-ray spectrum is a signature of the abundance of the major elements in the soil. It is also possible to measure gamma-ray emitted during the decay of radioactive elements such as K, Th and U for natural ones. Galactic cosmic rays produce radioactive elements too, but their study is more difficult because the emission is delayed.

Computer simulation rationale: Computer simulations are used to evaluate the detector performances in the vicinity of the planet. Detection efficiencies could be calibrated in the laboratory, but simulations will be favourably used to complete these few measurements. With the computer model, it is also possible to simulate the background level in the detector due to cosmic irradiation and to the Martian gamma continuum. Then expected sensitivities to the elemental composition of the soil for a particular GRS could be calculated.

GEANT tool: GEANT [7] is a system of numerical codes to simulate high energy processes within any experimental setup; it is provided by CERN (Geneva, Switzerland). The GEANT program, based on Monte Carlo methods, simulates the passage of elementary particles and photons, the production of secondaries and their transport through matter. With these codes we are able to evaluate the detection efficiencies and the backgrounds of the MS'01 GRS; we are also able to

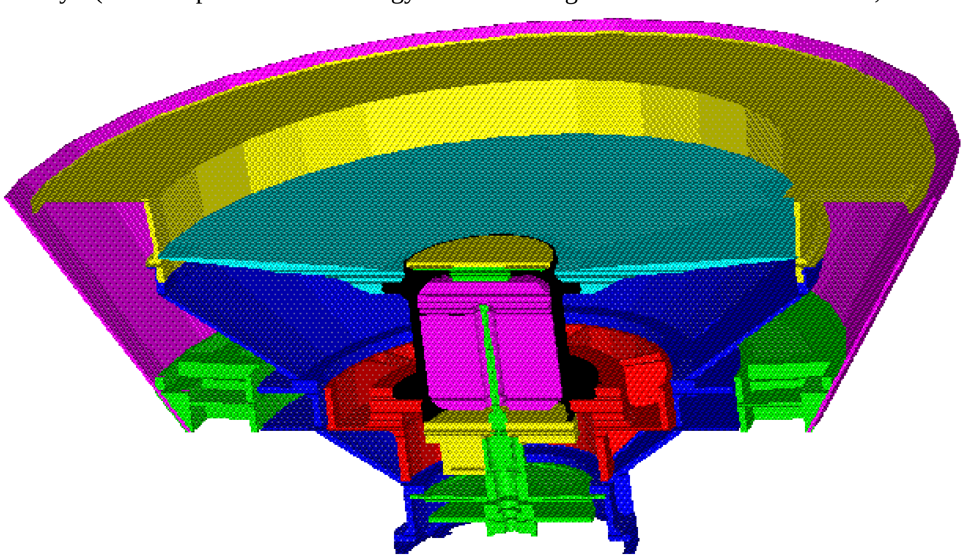

Figure 1. *Computer model of the gamma-ray spectrometer for MARS SURVEYOR 2001 mission with its cooler.*

estimate its sensitivities to Martian gamma-ray lines.

Mars Surveyor 2001 gamma ray spectrometer: The MS'01 scientific payload is designed to carry global mineralogical and morphological investigation throughly. Onboard there will be one GRS and several neutron detectors for the first time since the lost of MARS OBSERVER instruments in 1993. The CESR (Toulouse, France) is responsible for doing preparatory simulations of the GRS. The results about detection efficiencies are presented here.

This GRS is based on a high resolution semiconductor detector made of a high purity germanium (HPGe) crystal (6,7cm*6,7cm) cooled at 80 K. For the first time the canister of the crystal is made of titanium instead of aluminum to allow for a clean measurement of aluminum lines from Martian surface.

Figure 1 shows the GEANT model of the MS'01 GRS in its passive cooler (flight configuration). At the center there is the coaxial HPGe crystal surrounded by its titanium canister in black.

Simulated Efficiencies and Calibrations: As a first step, which is not the configuration shown on Figure 1, the first constructed models of MS'01 GRS detector with its titanium canister were calibrated in a variable temperature cryostat (VTC) at CESR. These calibrations consist in measuring calibrated gamma-ray sources such as ^{60}Co, ^{137}Cs and ^{152}Eu at 50 cm from the crystal to get lines at 121.54 keV, 244.58 keV, 344.2 keV, 411.08 keV, 443.97 keV, 661.81 keV, 778.99 keV, 964.16 keV, 1.09 MeV, 1.11 MeV, 1.17 MeV, 1.33 MeV and 1.41 MeV. This experiment was numerically simulated to evaluate the efficiency of these units in function of the energy and in function of the angle between crystal axis and source position.

Here efficiency is defined as the ratio between the count per second in the detector and the source rate (γ/s) in the solid angle corresponding to the crystal seen from the source.

Figure 2 is comparison of the detection efficiencies that have been calculated as a function of the energy and the

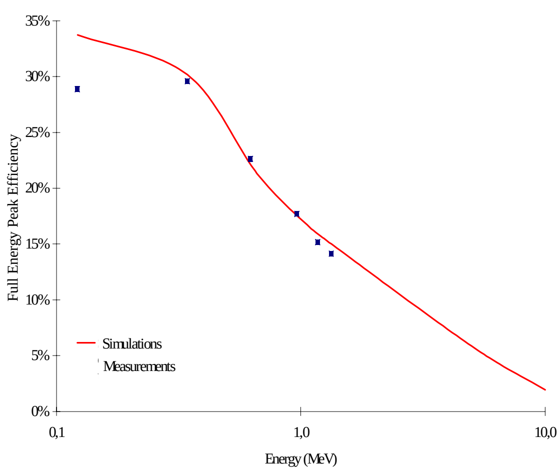

Figure 2. *Simulated (line) and measured (dots) efficiencies of MS'01 GRS in VTC as a function of energy.*

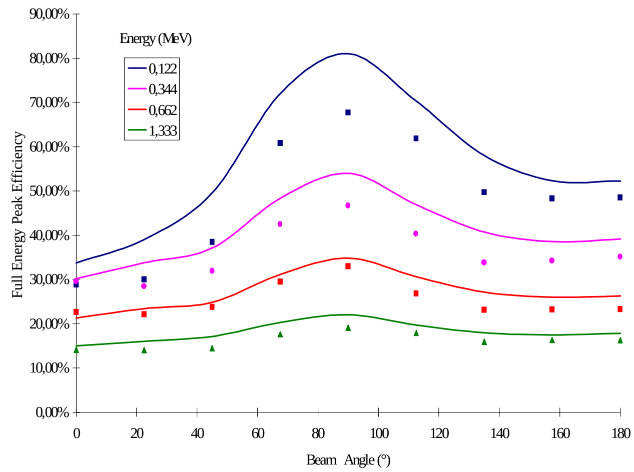

Figure 3. *Simulated and measured efficiencies of MS'01 GRS in VTC as a function of the γ-ray source position for few energies. Lines are simulation results; Dots are measurements.*

measurements in the laboratory. Figure 3 shows measurement and simulated results of the efficiencies function of the incident gamma-ray beam angle.

Differences between measurements and simulations are currently observed [8, 9] with an excess of simulation forecasts. They could be explained either by the approximation of little pieces in the computer model for lower energies, either by a imperfect charge collection in HPGe of type n. A detailed study of this problem in the case of the GRS of Integral spacecraft was made in reference [10]. Once the difference is known in function of energy, a numerical correction could be easily done in the simulations.

Conclusion: We have developed a numerical code using GEANT tool from CERN which can simulate the performances of the gamma-ray spectrometer of the MARS SURVEYOR 2001 mission. The calculated efficiencies are consistent with calibration measurements. This simulation tool will be useful to complete the calibrations, to evaluate and understand the background in the gamma-ray detector in the vicinity of Mars and then to contribute to a better data processing.

Such code could be adapted for every gamma-ray detector to make the same kind of work, for example with SELENE or DS4- CHAMPOLLION.

References:

[1] Evans L.G. et al. (1993) Remote Geoch. Analysis: El. and Mine. Composit. *C.M. Pieters and P.J. Englert (ed.), Cambridge Univ. Press, New York*, 167. [2] Binder A.B. (1998) *Science, 281*, 1475. [3] Hasebe N. et al. (1999) *LPS XXX, Abstract #1171* (CD-ROM). [4] Boynton W.V. et al. (1999) *LPS XXX, Abstract #1991* (CD-ROM). [5] Cheng A.F. et al. (1997) *JGR, 102, E10*, 23695. [6] Feldman W.C. (1993) *same book as [1]*, 213. [7] Brun R. et al. (1994) *Program Library Long Writeup, W5013, CERN*. [8] Rogers D.W.O. (1982) *Nucl. Inst. Meth., 199*, 531. [9] Moss C.E. and Streetman J.R. (1990) *Nucl. Inst. Meth., A299*, 98. [10] Kandel B. (1998) Thesis, *Université Paul Sabatier, Toulouse III, France*.