3) Reply to Referee 3

The application of the muon radiography in Mars is extremely interesting, and this paper should be published. My main comments are related to the lack of detector details and the need for more detailed consideration of the different atmospheres and very different constraints for working in a space mission. The only descriptions of the possible muon telescope are found in the bibliography. I recommend to add a section describing in more detail the proposed detector. The authors mention low power (5 to 6 W) but I see in the references large solar panels. It's not clear what the consumption from each component is. Also, in the abstract (line 830.8) they mention a ten meter scale resolution when in the cited papers the resolution is an order of magnitude larger. Maybe the detector has a very different design, and can achieve a better resolution, but gain there are no details. (In the Tanaka et al papers, the typical space resolution is 100 m.)

> *We would like to thank the referee for his detailed reading and support for publication. The authors considered expanding the paper to include a detailed detector design, however, the trade-off space between science objectives, detector design (types, size, power, weight, cost) and performance demands a very detailed study including a full GEANT4 simulation which we hope to complete in the future. This paper's hope is to convince the reader of the feasibility of the technique for Mars Geology.*

One general point that is important to clarify is the energy range of interest. In Fig 2 they should muons up to 10 TeV (which is puzzling), but in Fig 3b the energy of the primary protons is up to 20 GeV. Then are the fluxes in Table 1 integrated in energy?

> *All the geological objects of interest will be of thickness greater than 50 meters demanding muons with ~20 GeV or more but these objects will have edges where the softer muons will play an important imaging role. Fig3b is for muons from 1-20 GeV for muons from 20 GeV and upwards the rate is ~ > 10 times larger. A comment has been added to Figure 3b caption.*
>
> *The flux's in Table 1 are integrated in energy and the text on page 6 line 9 has been modified to clarify this.*

I'm also confused in Fig 3a as for why it goes up to 120 km in height. In Fig 3b is the flux of protons integrated in solid angle? I mean, these are muons per incident proton of a given energy, but for what incoming directions? It should be done for a fixed range in zenith angle (very inclined protons), but it's not explained. I understand the direct relationship, but I'm used to see atmospheric depth in grams per square cm, and not in hPa. (For example in the caption of Fig 3a, in line 833.18, etc.)

> *Fig 3a is used to give the reader a feel for the similarity and differences in Mars and Earths atmospheric pressure over the entire profile. Fig 3b is for zenth angles from -90 to +90 degrees. The caption has been modified to include this point.*

In line 832.29 The sentence "Muons interact only weakly with matter" is wrong. I understand what they're trying to mean, but they should rephrase it.

> *Fixed.*

In line 833.26 it's mentioned 5 or 6 layers of detectors. The telescopes used in the bibliography are made with four layers of scintillators. This is another example where a description of the detector would help. (Another one is line 834.5 where lead plates are mentioned.)

> *Yes, it is possible that we may need a "U and V" layer to assist in the removal of the horizontal background. Optimum detector design will require a full GEANT4 simulation.*

The other important considerations is working in Mars. In line 833.9 they mention a shorter integration time. Given the measurements presented in the cited bibliography, this correspond to two weeks. Is this reasonable for a Mars mission? How does the detector design change to adapt to even shorter integration times?

> *A two-week integration time is reasonable for typical rover traverses on Mars; MSL, MERA and B had much longer stay overs than this. So even as a secondary instrument valuable internal density information of the surrounding terrain can be extracted. Of course, for focused science objectives the instrument and rover transverse will be optimized.*

In line 833.11 they mention "A large fraction of primaries at the surface" and it's not clear whether this is from Geant simulations or from where? It should be possible to run these simulations, and even to carry out experiments in balloons. There is also the issue of proton background. This should be easily simulated.

> *Yes, the estimation of hadronic background was estimated using Earth cosmic ray data but the Mars muon production rate were from a detailed 2007 Monte Carlo study [Tanka (2007)]. To clarify this point line 14 on page 3 was modified and a reference was added [Barringer et. al. (2012)] in line 8 on page 6. We also agree that a full simulation is straightforward but the trade-off space is quite large and should be part of a larger study. Text has been added at the bottom of page 7 to explain this is detail.*

It is not clear that the proposed methods can be implemented. The measurements from pure atmosphere and from a direction going through several hundreds of meters of rock will have very different ratios of protons to muons, for example. In line 835,7 they mention "weak" pointing requirements. It is not clear what this means.

> *Weak pointing requirements refers to the target to detector alignment not the track resolution or more importantly the triggering directionality.*

In relation to this point, in line 836.2 they use a "roving" detector from the bibliography. The cited paper did not use a roving system, but two fixed telescopes. I did not find in the bibliography examples of a roving system. I think that it is important to demonstrate this capability. It should be straightforward to make a test with an existing telescope. My guess is that a roving system would be trickier than the combination of two fixed detectors.

> *The cited paper for the roving system was in error, the reference has been fixed.*

In line 839.19 they mention a detector with a reduced size. This should be demonstrated on Earth beforehand. (As the shorter integration time.)

> *We agreed.*