1) Reply to Referee 1

This paper is very interesting and I quite liked it. The technique has been used on earth successfully for many years and has produced many beautiful results. This is obtained by comparing the muon flux behind a geological structure with the unobscured muon rate. The application of this technique on Mars for me has to face a major problem, which the authors have already tried to answer but needs perhaps more clarifications: the different, and much smaller, thickness of the Mars atmosphere with respect to the earth. On earth the atmosphere acts as a natural filter of cosmic rays reaching the surface of the planet to produce an almost pure muon flux with negligible background. On Mars on the other hand there will be roughly 200 times more p's compared to muons for vertical cosmic rays, so a factor of at least 10ˆ4 suppression of p's has to be provided at the detector level. It is true that for inclined muons the p/muon ratio may decrease to about a factor of ten, still a substantial background reduction is needed if one wants to be sensitive to percent variations in detected muon flux. Is this feasible? and, is it feasible with a negligible increase in detector mass? Also it would in general be nice to have more details of the possible detector the authors have in mind (e.g. surface, granularity, redundancy), even if the detection techniques may evolve somewhat by the time of the mission.

> *The authors would like to thank the referee for the detailed reading of the paper and we are pleased that it was liked.*
>
> *The referee is concerned due to the 200 times more vertical protons (to muons) and the needed background suppression. These protons, in addition, to producing direct charge particle background tracks in the detector can interact hadronically with the detector, target and surrounding environment creating charged secondary's that could cause unwanted background. The needed background suppression can be obtained by simply using the target as a filter: demanding good tracking directionality. Increased background suppression can be obtained by simply increasing the detector segmentation, tracking planes, timing constrains and if needed using additional detectors such as calorimeters. This would allow for deeper tomography or functionality in more difficult background environments. But as the referee alludes to, there is a price both in power and mass trade-offs. Increase timing and segmentation normally means (using plastic scintillation detectors) increased power and mass unless silicon drift (or strip) detectors are used but these come at higher cost. On Mars for spatial resolutions of ~100 meters, density resolutions of ~5 % at depths of <~1km the technique is feasible, however, the authors feel that detailed detector design, performance, cost… (… surface, granularity, redundancy) should be part of a larger study, which employs a full GEANT Monte Carlo simulation of the detector and cosmic ray interaction with the target and the resulting impact to science objectives.*
>
> *On page 7 lines 7,8 and 9 were modified to clarify this point.*

Comment (in addition to the one already posted):
Table 1. The vertical muon and proton fluxes are presumably integrated over energy. How does the relative flux change with increasing energy?

> *The proton flux follows the well-known Gaisser power law and the muon flux (as measured on earth) is also a power law but with a larger slope (~alpha + 1).*
>
> *Added Gaisser reference on page 4, line 4 and Greider on page 4 line 14-15,*

Fig. 3b at P849. The muon production rate per incident proton is shown for primary energies between 1 and 20 GeV. It would be interesting to see what happens to this rate also at much higher energies, since muons which penetrate and traverse a geophysical structure must have energies of at least several *hundreds of GeV. In fact, according to Tanaka (2007), the muon production rate/proton seems to get larger at higher energies.*

Yes , in fact, Tanka et. al. [Icarus 191 (2007)] show that at a Mars pressure of 10 hPa for primaries above 20 Gev the muon to production ratio is a factor of ten larger than 1-20 Gev primaries. The Fig 3 caption has been modified to clarify this point.

Suggested references to be added to the text

P831 L22 I suggest that there should be a reference for the composition of primary cosmic rays, perhaps Gaisser (1990). The same, or another specific, reference is needed for the discussion of the muon flux on Earth's surface (P832 L14-23).

Done, added Gaisser reference lon page 4, line 4 and Grieder et al on page 4 line 14-15,

P832 L24 Perhaps a reference is needed for the atmospheres of Mars and Titan.

Added a reference for each, Gierash and Flaser on L24.

P835 L18-24 The reference Tanaka et al. (2010) doesn't deal with Mt. Omuro, imaged with a moving detector and short exposures, but rather describes the tomography of the Asama volcano, realised with just two fixed detectors and long exposure times (one to three months). The only reference I could find to the Mt. Omuro test is H.K.M. Tanaka, Volume slicing with multi-directional muon radiography (talk presented at the "International Workshop on "Muon and Neutrino Radiography 2012"

Yes, the reference given was incorrect. This has been corrected.

P840 L21-23 Perhaps a reference is needed for the Mars Exploration Laboratory.

Added a reference, Grotzinger et. al.

P851 Fig. 5 caption. The source of the different images should be referred to.

The attribution of the individual images in Figure 5 can be found in the figure caption where the missions responsible for the images are mentioned.

P853 Perhaps a reference for MOLA is needed.

A reference, Smith et. al., was added in Fig 7 caption.

Problems with references. The following references are not quoted in the text :

They references below were either removed or added back in the text at the appropriate place.

Agostinelli et al. (2003) : Added
Anderson et al. (1990) : Removed
Barr et al. (2006) : Removed
Connerney et al. (2005) : Removed
Coustenis and Taylor (1999) : Removed
Formisano et al. (2004) :Removed
Gaisser (1990) : Added