The article “SMAUG v1.0 – a user-friendly muon simulator for transmission tomography of geological objects in 3D” presents a code that allows performing inversion of muon flux measurement to reconstruct the density distribution of geological objects. The contribution of this paper with the code availability is of great interest as it could be used by geophysicists and geologists interested in the method. The paper clearly details the code functioning and its limits. The paper is well structured and well written. However some passages have to be clarified. Each symbol mentioned in the equations has also to be described. Thus I recommend a minor revision for this article.

The term “tomography” is usually used in geophysics to mention 2D images, often referring to vertical cross-sections. In the case of 3D reconstruction like here, the term “imagery” should be preferred in the title and in the text of the manuscript.

Before performing inversions and even acquiring data, geoscientists need a tool to evaluate the worth of muon imagery experiment. A virtual experiment could help them also to decide how to install muon sensors. They indeed need to know: How long do they have to install the sensors to detect a priori density contrasts ? Where should they install them to best capture the density distribution ? The tool you develop and present here might offer an opportunity to answer such questions. You could add a paragraph in the conclusion mentioning that.

The paper is rather long and I find the introduction quite vague when mentioning the inversion sought parameters. The muon imagery inversion aims at supplying the sounded medium density distribution. This should be clearly mentioned. You could place Fig. 3 earlier to help you explicitly indicate which are the input data required by the muon flux crossing the sensor forward model. Then discriminate which are the parameters sought by the inversion and which are the a priori parameters given either by field observation, geological knowledge, laboratory measurements or previous experimental analysis. Then remove part of the text in section 2 and 3 to avoid repetitions.

Replace the term ch. used in reference to chapter by section and sub-section.

The paper introduce a high number of variables some of them having the same symbol. Be aware to use only once each symbol. All symbols are not defined, pay attention to describe each of them in the text. All symbols could also be introduced in a table at the beginning of the paper.

l.16: "We address the need of the geoscientific community to participate in the data analysis"
I find this sentence quite condescending… Since the years 2010 geophysicists actively took part to the development of muon imagery and played with particles’ models. By the way, you cite many of them… Geophysicists historically worked with physical models and performed inversions, one of them developed the basis of the inversion principles: Albert Tarantola… Rephrase this passage.

l. 55: repetition of "we aimed at"

Figure 1: I suggest you to rename the different plot a, b, c

L. 71: "physical parameters" be more precise and define the parameters sought by muon imagery

Figure 2: the quality of the figure has to be improved. Add to each module their inputs, outputs and how the modules interact with each other. Define also at the inversion step which are the sought parameters and which are the ones with a priori information. You could also enumerate the modules in the same order as in the text.

L. 90: "initial distribution of the lithologies" or a priori distribution…

L. 93: "to a set of parameters" → precise which ones

L. 104: "The interplay of these four submodules allows for the simulation of muon fluxes at the detector sites that are mostly located in an underground environment."
Use either the term module (I prefer this one) or submodule everywhere. Develop more precisely in the paragraph how the modules interplay.

L. 121: "As can be seen in Fig. 2, the inversion compares the simulated flux data with the measured ones. It also attempts to reduce the discrepancy between measurements and simulations by optimising the parameters in the simulation"
Inversion schemes aims at identifying the parameters of a model (or a set of modules) in order to reproduce the data observed given the a priori information available. Rewrite the sentence to be more precise.

L. 124: "As the mathematical optimization in muon tomography generally is nonlinear, one has to employ nonlinear solvers or even Monte Carlo techniques".
When working for producing a 3D block of density, the problems effectively turn non linear, a 2D tomography or else «radiography" doesn't require a MC inversion process.

L. 125: "one has to employ nonlinear solvers or even Monte Carlo techniques"
If finally you don't use such techniques, rewrite this sentence into something like → one classically employ nonlinear solvers or even Monte Carlo techniques

L. 128: "measurements from different sources"
Do you mean measurements acquired from different location ? Clarify

The introduction lacks a state of the art of the existing muon flux computation code. You only mention Geant4 and MUSIC. Without an extensive list of codes, cite the most used ones, describe their advantages and drawbacks to better highlight the supply of your code. Inversion tools to perform 3D muons imagery have also already been developed and applied, even in combination with other methods. However, the previous codes might not have been openly distributed as you do. Here are some suggested references:

- Bonnechi et al., 2015, A projective reconstruction method of underground or hidden structures using atmospheric muon absorption data, *Journal of Instrumentation*, *10*(02), P02003.
- Jourde et al., 2015, Improvement of density models of geological structures by fusion of gravity data and cosmic muon radiographies, Geosci. Instrum. Method. Data Syst. Discuss., 5, 83–116
- Niess et al., 2018, Backward Monte-Carlo applied to muon transport, Computer Physics Communications 229 (2018) 54–67
- Barnoud et al., 2019, Bayesian joint muographic and gravimetric inversion applied to volcanoes, Geophys. J. Int., 218, 2179–2194
- Lelièvre et al., 2019, Joint inversion methods with relative density offset correction for muon tomography and gravity data, with application to volcano imaging, *Geophysical Journal International*, *218*(3), 1685-1701.

L. 146: add a virgula after: "In muon tomography experiments"

Eq. 1: define: N, μ, i, sim and I

L.163: "ΔA eff,i is solely dependent on the orientation of the bin" but not on the geometry of the sensor ?

L. 169: "E cut,i describes the energy needed for a muon to enter the detector»
Doesn't it correspond to the energy required to cross the geological target and the muon sensor ? This information is indeed given later, add it here for clarity.

L. 184: "and we reinterpret E cut,i as the minimum energy that is required to traverse the matter and to be registered at the detector".
To not loose the reader, give only one definition of that term in the text so give that one earlier when first mentioning it.

Eq. 5: define x

l. 273: "Even though these algorithms suffer from possible non-uniqueness solutions"
Inverse problems addressed with a Bayesian formulation might also suffer from non-uniqueness, but they should highlight this issue while descent algorithms or locally optimising algorithms might provide a local solution without warning on the existence of other solutions.

l. 284: "density values that were measured in the lab"
Be aware that measurements in the lab correspond to an elementary volume of rock that might not be representative of the macroscale sounded with muon imagery. The weathering of rock, the presence of fractures or faults might alter the medium density. This point has to be mentioned.

l.385: "As the total material thickness is known (detector position and digital elevation models are given), the sub-space containing the thickness parameter is endowed with the same mathematical structure as the one containing the composition parameter (i.e. one sum constraint), if the cone consists of more than just one segment."
Rewrite for clarity

l. 389: "within which we a-priori possess no information about the parameters"
Which parameters? Clarify

Equations 28 and 29: add parenthesis to explicit which terms are included in the sum or product on the *i* or *j* indices.

l. 409-410: "as for our problem it merely is a nuisance parameter" "which is of no particular interest but still has to be accounted for"
I would say that the muon flux computation is the key forward model, so I don't understand what you mean with such comments. Could you specify?

Equation 31: is the i index lacking for ρ and c ?

l. 420: precise that eq. 32 is built also from eq. 12 and 25.

l. 421-424: This comment has to be considered with attention by scientists want to evaluate the interest of applying the method to their studied object. You could highlight it.

l. 434: "we retrieve $\tilde{\boldsymbol{\pi}}(\rho rock\ )$, the posterior marginal pdf for the rock density"
Be aware that $\rho rock$ might be heterogeneous in the sounded medium due to weathering processes, presence of fractures and faults… You should already mention it here and discuss it later when you present your results.

l. 478: you used earlier the Σ symbol to represent a summation, use an other symbol here.

l. 478: explicit earlier the $J(0, c2\Sigma)$ term and precise which parameter is fixed to 0.

l. 481: which parameter does *r* represent?

Fig. 4: add X and Y labels on the figure as well as the legend of the curves.

l. 535: the symbol "*r*" was used previously, maybe change the former.

l. 549: define H and k

l. 551: define Δx and Δy

l. 569: You used previously the symbol * for multiplication… maybe changed it in the previous equations

l. 588: "either from data" → from measurements?

l. 614: close the parenthesis

l. 614: "the energy loss calculations is based" → the energy loss calculations **are** based

l. 622: the error stands below 1%

Fig. 6 and 7: present here directly results for the materials you sound: ice (in dashed lines) and standard rock on the same figures.

Fusion Fig. 9 and 10 with dashed lines for the $^{22}_{11}Na$

Paragraph from l. 685: remove that paragraph that repeats what previously said.

Fusion Fig. 1 ans 11

l. 691: 2 grid pixel → clarify

l. 693: remove the sentence: "Figures 12 to 14 show the three cross-sections in detail"

paragraph from line 690: avoid writing m for metres in italic, the reader could think it represents a variable (notably as it is later used to represent the molar mass)

Fig. 12-14: Add the DEM +/- 2m error with dashed black lines to the figure

End of section 5.2: Discuss the variations between the DEM topography measurement and the topographic estimated from the measured muon flux damped to bedrock. As I mentioned earlier, the rocks sounded might be heterogeneous. As for rocks, the ice could also present some cracks, gullies, cavities… a void could also be present in between the rock upper limit and the bottom of the ice sheet. If you have prior information concerning that point, mention it. Add this discussion here.

l. 746: "In this study we have presented a model"
→ "In this study we have presented an inversion scheme"

In the conclusion, you could add a paragraph mentioning that the code you developed provide uncertainty estimates, which is very of particular interest.

l. 774: do not mix parameters and units in equations write better h0= a0+b0p (or other symbols). Then indicate that classically a0= 4900m and b0= 750mcGeV-1 and provide a reference. Then explain that you use the Nishiyama et al. (2017) suggested values.

Precise the appendix B title: “Rock parameters model”

B1 title → Density measurement

l. 781: “we constructed a density model by analysing various”
→ “we estimated the medium density by analysing various”

Fig. B1: strictly speaking a probability function integral should equal 1. Either normalize the represented values or rename the y label.

Fig. B2: add a legend with the different elements represented

B2 title → Composition of the medium

l. 863: add “the” before “following formula”

l. 879-881: divide the sentence for clarity

Fig. B3 you could remove the O plot and have 5x2 plots

l. 894: “For our example that we show”
→ “For the example shown”

l. 895: remove the lonely ending parenthesis

Equations B6 and B7: introduce all the variables in the text as well as the indices i and j

l. 910: & → and

Equation B9 and B10: introduce I and b