Reviewers' comments:

Reviewer #1 (Remarks to the Author):

The paper discusses an analog of the confining medium in a condensed-matter environment of NbTiN films. This system reproduces the basic features of the confinement mechanism of compact QED in two spatial dimensions, which is itself a well-understood model of color confinement in QCD. The (de)confinement reveals itself via transport properties. For example, Polyakov's string tension finds its interpretation via an experimentally observed critical voltage.

Although experimental signatures are encouraging, I have theoretical reservations that should be clarified before this work can be accepted for publication. I suggest that the authors address the following points:

.) The title of the article, "Direct probe of the interior of a meson," is misleading as the work involves no mesons, which makes a direct look to their interior impossible. I suggest changing the title.

.) The mesons are composed of quarks and anti-quarks that carry the opposite charges. The same is true for the confinement of charge-anticharge states in compact QED. However, in the authors' system, the linear confinement realizes in between the-like charged Cooper pairs and not in between the Cooper electron-electron pairs and Cooper hole-hole pairs. This observation undervalues the suggested interpretation of the result.

.) Although the authors have not stated the following, I would like to mention that the linear repulsion between the-like charges (9) is not a feature of the compact QED (one could wish to put an optional comment on this point).

Reviewer #2 (Remarks to the Author):

The manuscript presents measurements on highly controlled NbTiN films, that mimic the behavior in the interior of mesons. This is a representation of ‘t Hooft confinement mechanism, the dual superconductivity, realized in compact QED. The authors report the observation of the first direct evidence of asymptotic freedom, confinement mechanism and magnetic monopoles.
I find the manuscript very interesting, both for the topic and for its interdisciplinary nature: the findings of the paper can have impact on several fields of physics, from condensed matter to quantum chromodynamics.
The manuscript is well written and the methodology is clearly explained. Details on the experimental measurements and the preparation of the samples are provided. For all these reasons, I recommend the manuscript for publication in its present form.

Reviewer #3 (Remarks to the Author):

This manuscript describes a theory-experiment effort to probe the interior of an “electric pion” containing a pair of Cooper pair (CP)-anti Cooper pair (ACP). This is a sequel of a previous paper by some of the authors that developed the theoretical analogy between thin superconducting films close to the superconductor-insulator-transition (SIT) and high-energy physics of pions and mesons (reference [11] - Comm. Phys. 1:77, 1 (2018)). This theory invokes a new phase of matter, “the superinsulator”, in which a zero conductance state appears at finite temperatures due to formation of bound CP-ACP particles. This is based on the prediction of an equivalent particle-physics phase predicted by ‘t Hooft and implemented by Polyakov to explain confinement and asymptotic freedom.
The idea of the analogue between the SIT in condensed matter and quark mesons in high energy

physics is indeed intriguing and exciting. If it is scientifically sound it is definitely worthy of publication in a "Nature research publishing" Journal. The current manuscript however, as noted above, is not the first time the idea is presented. A previous theoretical paper by some of the authors has already been published in Communication Physics. The innovative aspect of the current manuscript is the experimental verification of the idea. Hence my report focuses on the experimental results and the degree at which they provide "the first direct evidence of asymptotic freedom". Since the "electric-pion" is a radical concept and in view of the fact that the superinsulating phase in low dimensional SC films is a heavily debated issue it is the authors responsibility to provide clear experimental evidence for their claim.

In my view, the authors present two main experimental results that provide "smoking gun" evidence that the superinsulator phase is analogous to particle-physics pions and that in this system it is possible to probe the interior of a meson. The first is the fact that for the smallest bridges of length 0.2mm, the RT curve tends to saturation rather than showing super-activated behavior at low temperatures (fig. 1) and the second is the double kink I-V curve (fig. 2).

The fact that resistance of a disordered insulator can saturate as the lateral size is reduced has a simple physical origin. If there is some characteristic localization length and the system size approaches this scale, one expects that it will not show insulating behavior (exponential resistance increase) at low T. Actually, indium oxide samples have been shown to exhibit an SIT as a function of sample length despite the fact that they are at relatively high temperatures and not in the superinsulating state (see for example: Kowal and Ovadyahu, Physica C, 468,322 (2008)). Can the authors offer more clear-cut confirmation for their interpretation? Furthermore, according to the theory one would expect real metallic behavior at these scales. How does this coincide with the fact that the resistance in this state is ~200Mohm? Shouldn't one expect metallic resistances (of the order of h/e^2 per square or less)?
The IV characteristics are of special importance. It is well known that the discontinuous I-Vs have a competing interpretation, i.e. heat imbalance due to electronic overheating. In this respect a two-kink I-V curve may indeed provide unique evidence for the asymptotic freedom interpretation since it is not naturally consistent with the overheating scenario. Nevertheless, I am not aware of any other systems and works that present such a double feature characteristic (including those of the current authors). In this manuscript only one of the two presented samples exhibits this feature and even in this sample it is seen only in the long sections and is absent in short bridges. Can the authors explain why these features are so rare? According to the meson picture shouldn't one expect the two-kink curve to be measurable for any superinsulator? What are the conditions required to resolve the two kinks and hence to probe the string tension? Why isn't Vc1 observed in other disordered superconductors such as Indium Oxide that exhibits the I-V jump? This is probably the major point of the manuscript and should be elaborated upon.
Besides the above, I did not understand the logic of the manuscript flow. The last part discusses in length the issue of the electric Meissner effect. This is a theoretical argument which is not related to the experiments presented in the manuscript and the relevance of this section to the manuscript is not clear. Is this really an integral part of the current manuscript? If so this should be made more clear.

In summary, the proposed analogy between particle physics and condensed matter is very attractive and will be of interest to a broad readership. However, before publication the authors should provide more definite proof for their data interpretation, clarify a number of points and perhaps reorganize the manuscript.

June 29, 2020
Re: COMMSPHYS-20-0268
Point-by-point reply

Reviewer #1 (Remarks to the Author):

The paper discusses an analog of the confining medium in a condensed-matter environment of NbTiN films. This system reproduces the basic features of the confinement mechanism of compact QED in two spatial dimensions, which is itself a well-understood model of color confinement in QCD. The (de)confinement reveals itself via transport properties. For example, Polyakov's string tension finds its interpretation via an experimentally observed critical voltage.

Although experimental signatures are encouraging, I have theoretical reservations that should be clarified before this work can be accepted for publication. I suggest that the authors address the following points:

Reviewer #1
.) The title of the article, "Direct probe of the interior of a meson," is misleading as the work involves no mesons, which makes a direct look to their interior impossible. I suggest changing the title.

Answer:
As the Reviewer indicates her/himself in her/his nice and succinct summary of our work, our paper offers a condensed matter analogue of the particle system described by QCD. We carefully analyzed Reviewer's suggestion. Before going to suggested title, we would like to note that there might be some confusion that we will discuss in more detail below. Namely, contrary to Reviewer #1's guess spelled out in her/his item 2, we do indeed derive the linear confinement of a charge-ANTIcharge pair, but by no means a pair of charges of the same sign. In this respect, the formation that we directly investigate is indeed a straightforward implementation of an electric meson, an electric pion to be even more precise. The essence and direct implication of our result is that since electric forces are much weaker than strong interactions, the size of this electric pion is much larger than the size of a real pion of particle physics. This makes it possible to access directly its interior and measure the asymptotic freedom phenomenon via mere experiments on the samples smaller than the pion characteristic size. We thus do feel strongly that our original title is quite appropriate. However, if the referee still feels that the reader may benefit from the more detailed specification, we would suggest changing the title to "Direct probe of the interior of an electric pion in a Cooper pair superinsulator."

Reviewer #1

.) The mesons are composed of quarks and anti-quarks that carry the opposite charges. The same is true for the confinement of charge-anticharge states in compact QED. However, in the authors' system, the linear confinement realizes in between the-like charged Cooper pairs and not in between the Cooper electron-electron pairs and Cooper hole-hole pairs. This observation undervalues the suggested interpretation of the result.

Answer:

We have to respectfully disagree at this point. In our model the confinement is realized between <u>charges and anticharges</u>. This is clearly stated in the manuscript. The sentence preceding Eq. (9) reads: "In the limit opposite to (8), the total energy U_{Eext} of the charge-anticharge pair following from (3) is…". The sentence just after Eq. (9) reads: "…where $F=2eE_{ext} - \sigma$ is the effective force pulling the charge-anticharge pair apart". In the paragraph after Eq. (5) it is written "… strings are either closed, describing pure gauge excitations (the analogues of glueballs in QCD) or open, representing Cooper pairs- anti Cooper pair dipoles (the analogues of mesons in QCD)".

The formation of a Cooper pairs-Cooper "holes" neutral plasma is a standard phenomenon and can be easily seen in the model of a granular superconductor. In the undisturbed state, each granule is neutral. However, taking a single Cooper pair from a given granule to an adjacent one immediately creates the charge –2e on this granule and leaves the "Cooper hole" with the charge +2e at the granule from which the original Cooper pair was taken. The existence of these neutral Cooper pairs-anti Cooper pairs (i.e. "+2e" and "–2e") plasma was unambiguously confirmed in our previous measurements taken on the same NbTiN films. In the publication Mironov, A.Yu. *et al*. "Charge Berezinskii-Kosterlitz-Thouless transition in superconducting NbTiN films," *Scientific Reports*, 8, 4082 (2018) (Reference [13] of our manuscript), the <u>charge</u> Berezinskii-Kosterlitz-Thouless (BKT) transition with the transition temperature corresponding to the 2e elementary charge was observed. This gives an unambiguous evidence of the neutral plasma consisting of charges of opposite signs, since in systems of charges of the like sign, repelling each other, the BKT transition is impossible. Moreover, this Ref. [13] reveals unambiguously that the attractive interactions between these charges is logarithmic, as it should be in the two-dimensional deconfined system. We reproduce this charge BKT behavior in our experiment, see Fig. 1b,c, which unambiguously evidences that the system investigated experimentally in our work hosts neutral plasma of Cooper pairs – anti-Cooper pairs.

We regret that the fact that our system hosts a neutral plasma of opposite sign charges was not articulated enough in the original version of the manuscript and hope to have now stressed it properly in the revised version.

Reviewer #1

.) Although the authors have not stated the following, I would like to mention that the linear repulsion between the-like charges (9) is not a feature of the compact QED (one could wish to put an optional comment on this point).

Answer:

As we indicated above, our formula (9) describes the attraction between charges of opposite signs, as it is straightforwardly pointed out in the text.

Reviewer #3
(Remarks to the Author):

This manuscript describes a theory-experiment effort to probe the interior of an "electric pion" containing a pair of Cooper pair (CP)-anti Cooper pair (ACP). This is a sequel of a previous paper by some of the authors that developed the theoretical analogy between thin superconducting films close to the superconductor-insulator-transition (SIT) and high-energy physics of pions and mesons (reference [11] - Comm. Phys. **1**, 77, (2018)). This theory invokes a new phase of matter, "the superinsulator", in which a zero-conductance state appears at finite temperatures due to formation of bound CP-ACP particles. This is based on the prediction of an equivalent particle-physics phase predicted by 't Hooft and implemented by Polyakov to explain confinement and asymptotic freedom.

Answer:

We thank the Reviewer for nice and succinct summary of our work and for careful reading our manuscript. His detailed thoughtful comments helped to improve our presentation.

1. Reviewer #3

The idea of the analogue between the SIT in condensed matter and quark mesons in high energy physics is indeed intriguing and exciting. If it is scientifically sound it is definitely worthy of publication in a "Nature research publishing" Journal. The current manuscript however, as noted above, is not the first time the idea is presented. A previous theoretical paper by some of the authors has already been published in Communication Physics. The innovative aspect of the current manuscript is the experimental verification of the idea. Hence my report focuses on the experimental results and the degree at which they provide "the first direct evidence of asymptotic freedom". Since the "electric-pion" is a radical concept and in view of the fact that the superinsulating phase in low dimensional SC films is a heavily debated issue it is the authors responsibility to provide clear experimental evidence for their claim.

Answer:

We are thrilled that the Reviewer finds our idea of an analogy between the SIT in condensed matter and quark mesons in high energy physics intriguing, exciting, and worthy publication in a Nature Group Journal. We are happy that the Reviewer is aware of our previous publication in Communications Physics, in which the compact QED electromagnetic response of superinsulators was derived. It became a benchmark of the theory of the SIT after which top experts of the London Prize Committee attested a gauge theory of the SIT and the superinsulating phase as a marked breakthrough of modern physics (see Communications Physics website). We are most happy that the Reviewer acknowledges the innovative character of the present manuscript, in which a theory of the electric response of a superinsulator to a dc electric field was developed and, in particular, a theory of the electric Meissner state (dual to the superconducting Meissner state) was constructed with the pioneering result that the dielectric permittivity of this state is zero. Further theoretical innovations include the derivation of the *I-V* characteristics, along with the lower and upper critical electric fields E_{c1} and E_{c2} (dual analogues of H_{c1} and H_{c2} in superconductors). And, finally, we are very pleased that the Reviewer decided to focus on the experimental results providing evidence for asymptotic freedom and the first measurement of the linear tension of Polyakov's confining strings.

2. Reviewer #3

In my view, the authors present two main experimental results that provide "smoking gun" evidence that the superinsulator phase is analogous to particle-physics pions and that in this system it is possible to probe the interior of a meson. The first is the fact that for the smallest bridges of length 0.2mm, the RT curve tends to saturation rather than showing super-activated behavior at low temperatures (fig. 1) and the second is the double kink I-V curve (fig. 2).

The fact that resistance of a disordered insulator can saturate as the lateral size is reduced has a simple physical origin. If there is some characteristic localization length and the system size approaches this scale, one expects that it will not show insulating behavior (exponential resistance increase) at low T.

Answer:

We are very pleased by this positive evaluation of our findings by the Reviewer. We would like to add here yet another novel result of prime importance: the calculation of the threshold V_{c2} given in Eq. (10) and its excellent comparison with the experiment, upper insets in Fig. 2. This calculation, based on the compact QED mapping, is the first ever, accordingly new is the comparison with the experiment.

Regarding the physical origin of the saturation, we fully agree with the insightful Reviewer's comment. Indeed, as soon as there is some characteristic localization length (of course, the Reviewer correctly understands localization in a broad sense, as a generic confinement of the charge motion) and the system size approaches this scale, one expects a change in behaviour of the resistance. However, first of all, there is no generic guarantee that the behaviour at smaller scales should be metallic, this requires a screened Coulomb potential. The behaviour at small scales could have very well been superconducting, provided the charge condensate were present. This would have corresponded to entirely different physics: a screened Coulomb interaction for out of condensate Cooper pairs vs. a superconducting order (see comments below). Secondly, the difficult issue is not to derive a change in the $R(T)$ behaviour once the existence of a typical length scale is established, but, most importantly, to actually derive how such a dynamical length scale arises. Our work identifies the "localization" mechanism as

Cooper pair confinement. The corresponding typical length is the characteristic size of the string calculated in our work and corresponds to the size of a neutral “pion” excitation.

3. Reviewer #3

Actually, indium oxide samples have been shown to exhibit a SIT as a function of sample length despite the fact that they are at relatively high temperatures and not in the superinsulating state (see for example: Kowal and Ovadyahu, Physica C, 468,322 (2008)).

Answer:

This is an excellent comment by the Reviewer, pointing out a previously published size-dependence. However, this size-dependence concerns, as the Reviewer correctly points out, the SIT. It is thus a transition between a <u>normal insulator</u>, with activated resistance and a <u>superconductor</u>, see Fig. 4b in the cited work. It is thus unfortunately unrelated to our size-dependence, which does not involve the SIT but drives a <u>superinsulator</u>, with the hyperactivated resistance, to <u>a metal, not a superconductor</u>. This means that the ground states of the short systems of short sizes in these two cases are <u>entirely different</u>, the former reflecting a superconducting order which is absent in the latter. A seemingly analogous phenomenon brought by Reviewer, does not in any way affect our result: we are not trying to explain a size-dependence of a transition between the superinsulator and the superconductor, but the transition from a superinsulating to <u>metallic behaviour</u>, in which Cooper pairs are out of condesate. However, this Reviewer’s comment is important because it actually confirms important aspects of the overall theory above the deconfinement transition. Measured in the experiment by Kowal and Ovadyahu was the sample activation energy <u>slowly growing with the sample sizes (Fig. 4a of Kowal and Ovadyahu work)</u>. Thanks to the courtesy of Zvi Ovadyahu, who provided one of the authors of the present manuscript with his data prior to publication, this dependence has been analyzed, and the log scaling of the activation energy with the sample size was found, exactly as expected in 2D systems near the SIT were charges interact according to the 2D Coulomb law. This confirmed the picture of the SIT developed by one of present authors [see M.V. Fistul, V.M. Vinokur, T.I. Baturina, Phys. Rev. Lett. **100**, 086805 (2008)].

4. Reviewer #3

Can the authors offer more clear-cut confirmation for their interpretation?

Answer:

We thank the Reviewer for this question having helped us to better formulate certain parts of the paper and improve our presentation. We summarize the important points:

(i) Above the deconfinement temperature Tdec the film conductance shows a perfect BKT scaling unambiguously evidencing the 2D Coulomb behavior (Fig. 1) in full accordance with the theory of the superinsulation.

(ii) The screening length inferred from the experimental data shows linear dependence upon the sample size in full concert with the theory.

(iii) Below the deconfinement temperature, samples allowing for electric string penetration show nonlinear *I*(*V*) characteristics in the voltage interval $V_{c1}<V<V_{c2}$ (see log-log plots in Fig. 2c) exactly as predicted by theory.

(iv) The measured values of V_{c2} are in an excellent agreement with the theoretical predictions (see upper insets in Fig. 2).

(v) Samples with short strings that cannot penetrate end-to-end show an exponential suppression of the current, with an exponent linearly dependent on sample size. This happens below a second kink Vc1 in the *I*(*V*) curves where the Meissner state of superinsulation sets in. This kink can be considered as a measurement of the electric Meissner effect.

(vi) The measured values of V_{c1} show quite fair agreement with the theoretical predictions, see the bottom inset in Fig. 2b.

5. Reviewer #3

Furthermore, according to the theory one would expect real metallic behavior at these scales. How does this coincide with the fact that the resistance in this state is ~200Mohm? Shouldn't one expect metallic resistances (of the order of h/e^2 per square or less)?

Answer:

We thank the Reviewer for this excellent question. Metallic behavior only means that the temperature dependence of the resistance saturates at low temperatures. And indeed, for example, the anomalous metal that appears as an intermediate phase between the superconductor and superinsulator at the SIT was observed to have hundreds KOhm resistance. There is absolutely no reason thus that that the anomalous metal deep in the insulating side may not saturate at even higher resistances.

6. Reviewer #3

The IV characteristics are of special importance. It is well known that the discontinuous I-Vs have a competing interpretation, i.e. heat imbalance due to electronic overheating.

Answer:

This is an excellent point. There is, indeed, a beautiful completing consideration focusing not on the nature of the high resistance state but on the shape of the *I-V* curve at the switching threshold. The electron overheating arguments help to understand how the bistability that can emerge near a dynamic deconfinement phase transition results in an observed shape of the switching I-V. Before applying, these arguments, however, one needs to establish the existence of the bistability, i.e. the presence of <u>two competing dynamic states</u>, a low-resistance state and a high-resistance state. Once bistability is established, the overheating argument contribute to explaining the precise shape of the kink *V*_c2 in the *I*(*V*) curves but it by no means explains why this kink arises and how it depends on the system size. For this, one has first to derive the existence of a high-resistance state and then one has to have a model that predicts dynamically the size-dependence of this kink. This is what we have done in the present paper. Of course, the Reviewer is completely correct that a full theory of this kink requires also to explain its shape and here the mentioned overheating argument is of great importance.

7. Reviewer #3

In this respect a two-kink I-V curve may indeed provide unique evidence for the asymptotic freedom interpretation since it is not naturally consistent with the overheating scenario.

Answer:

We are most happy to hear that the Reviewer appreciates the importance of the two-kink feature, but we would like to be more accurate at this point. The Vc1-related kink marks the formation of electric strings going from one end of the sample to the opposite one in the system and, indeed, is unrelated to any overheating effects. At the same time, the Vc2-related kink (or jump) is nothing but a kind of the dielectric breakdown, hence the description of its precise shape requires accounting for both, overheating effects and the inherent properties of the deconfinement transition.

8. Reviewer #3

Nevertheless, I am not aware of any other systems and works that present such a double feature characteristic (including those of the current authors).

Answer:

We completely agree with the Reviewer. This is a novel observation and our discovery. Had it been observed before, this would have been a discovery of some other group. We are happy that the Reviewer, who is clearly an expert in the field, confirms our priority.

9. Reviewer #3

In this manuscript only one of the two presented samples exhibits this feature and even in this sample it is seen only in the long sections and is absent in short bridges. Can the authors explain why these features are so rare? According to the meson picture shouldn't one expect the two-kink curve to be measurable for any superinsulator? What are the conditions required to resolve the two kinks and hence to probe the string tension? Why isn't Vc1 observed in other disordered superconductors such as Indium Oxide that exhibits the I-V jump? This is probably the major point of the manuscript and should be elaborated upon.

Answer:

We thank the Reviewer for these thoughtful questions. The answers to all of them are already in the text of the manuscript, but thanks to the Reviewer's insightful and constructive advice, we articulate them better in the revised version.

As we have already described above, Vc1 marks the voltage at which electric strings penetrate the system traversing it from one end to the other. That is why it is observed only in the longest bridges of the second sample. The shortest bridges are so short that at the smallest resolvable voltage, strings are already there in the sample. The "first" sample is much closer to the SIT than the second one. Since the measurements on both samples are taken at the same temperature and since the deconfinement temperature drops fast on approach to the SIT, the linear tension of the strings in the first sample is lower, accordingly, the characteristic size of the string there is longer and Vc1 gets unresolvable again. All this can be inferred from Eqs. (1), (2), and (7) of the manuscript.

In order to evaluate the conditions favoring the observation of the Vc1 kink, one has to remember that the domain of existence of the superinsulator has a dome-like shape defined by the deconfinement temperature $T_{\mathrm{dec}}(g)$ such that $T_{\mathrm{dec}}(g=g_{\mathrm{c}})=0$, where g is the parameter driving the system across the SIT and g_{c} is the critical value at which the SIT occurs. The deconfinement temperature $T_{\mathrm{dec}}(g)$ achieves the maximum at some intermediate value $g=g^*$. The conditions optimizing observation of Vc1 are:

(i) The sample is to be sufficiently long.
(ii) Take measurements far enough from the SIT. The optimal value of the SIT-driving parameter should be close to g^* where $|T–T_{\mathrm{dec}}|$ is maximal.
(iii) The temperature is to be as low as possible to maximize the linear tension of the string.

The conditions (ii) and (iii) target to make the typical size of the string as short as possible so that the electric pion could fit within the sample. In samples where the tension is small because of the closeness of the measuring temperature to the deconfinement temperature, the kink is fogged by the noise at low voltages.

10. Reviewer #3

Besides the above, I did not understand the logic of the manuscript flow. The last part discusses in length the issue of the electric Meissner effect. This is a theoretical argument which is not related to the experiments presented in the manuscript and the relevance of this section to the manuscript is not clear. Is this really an integral part of the current manuscript? If so this should be made more clear.

Answer:

We thank the Reviewer for his constructive remark. Apparently, we were not clear enough in highlighting the relevance of the electric Meissner effect for the experimental results we present. The electric Meissner effect i.e. the expulsion of the electric field from the superinsulating sample occurs at voltages below Vc1. One can thus say that the existence of the electric Meissner effect is a precondition for the emergence of the Vc1 kink. In the revised version of the manuscript we tried to better articulate this point. In the revised version of the manuscript, we describe the states in a sequence following the increase of the electric field, i.e. Meissner state, mixed state, where the electric strings form in the system, and breakdown of a superinsulation. At the same time, we defer the somewhat technically involved technical derivation of the Meissner state to the end of the paper so that the reader could better familiarize with the field theory approach.

11. Reviewer #3
In summary, the proposed analogy between particle physics and condensed matter is very attractive and will be of interest to a broad readership. However, before publication the authors should provide more definite proof for their data interpretation, clarify a number of points and perhaps reorganize the manuscript.

Answer:
We are most happy that Reviewer #3 finds that the one-to-one correspondence between quark matter and the Cooper pair ensemble in Cooper pair superinsulators is an attractive result. In our present work we offered a derivation of the electric Meissner effects at small voltages and the calculation of the *I-V* characteristics of the superinsulating state in the voltage range where electric strings form in the system. These theoretical results are new and are excellently supported by the novel experimental data. We are grateful to Reviewer for his constructive remarks and feel that the revised and structured version of our manuscript gets our message across in a more clear and articulate manner in accordance with Reviewer's advice.

REVIEWERS' COMMENTS:

Reviewer #1 (Remarks to the Author):

The authors have addressed all remarks properly; I have nothing to add. I suggest accepting the manuscript in its present form.

Reviewer #3 (Remarks to the Author):

The authors have answered all the questions in a very satisfactory manner. They have also revised the manuscript to make it more clear according to the suggestions made by the reviewers. I find the revised manuscript now worthy of publication in Communication Physics.

Point-by-point reply

REVIEWERS' COMMENTS:

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Reviewer #3 (Remarks to the Author):

The authors have answered all the questions in a very satisfactory manner. They have also revised the manuscript to make it more clear according to the suggestions made by the reviewers. I find the revised manuscript now worthy of publication in Communication Physics.

Reply: We are most happy that both Reviewers unconditionally recommend publication and like to thank them for critical reading the manuscript and constructive suggestions that helped us to improve presentation.