

Dear Michael, thank you very much for your review of our paper draft. Below I have collected my responses to your comments and suggestions. Any suggestion which was implemented and needs no further discussion is shown with strikethrough font. My responses are shown in red. Thanks again.

Dear Jesse, Tom, all,

I am commenting on version "2019-07-22-lamkpublication\_v4" of your paper. This paper describes nicely the motivation (first time that this is measured), the used method and analysis, and the results together with a discussion on its implications. Especially the analysis and method part is discussed in quite some technical detail, which might be needed for this analysis (sometimes I was wondering if all details are needed, but that is of course up to you and the IRC). In addition, I had the impression that the very last paragraph (emission asymmetry) seems to be added later during the writing process. It is not (or at least not very clear) in the initial motivation and in my opinion also missing in the abstract and summary. I think one could work a bit to better integrate it in the whole text (especially since most of the appendix adds even more details to that specific part).

I have a few general questions and comments here and more minor ones in the attached pdf (also there you might find some non-editorial ones, I hope that is OK with you):

- ~~In the introduction there is twice an outlook to the results that are presented later on (if I am not wrong). I would not do it at this stage and focus on existing measurements (none?) and theoretical expectations.~~

I have removed an explicit description of the results from the study in the introduction.

- Very often I had the impression that colloquial terms are used. Not being a native speaker I might be wrong, so please feel free to ignore my comment if you think that it is not applicable.

I have tried to take some of the colloquial language out of the paper, and will keep this in mind when preparing and reviewing future drafts.

- ~~When introducing the used nomenclature (L71-73) I think it would be good to be more explicit: "LambdaK for all LambdaK combinations", "AK+ for AK+ @ AbarK-", "AK- for AK- @ AbarK+", "AK0S for ...". I was a bit confused at this stage.~~

- "Daughter/mother": these terms are used very often and while we do not have a strict guidelines in ALICE on that I personally would like to suggest to use a gender neutral form, e.g. "decay products" and "decaying particle" or something similar.

The term "daughter" is pretty standard when discussing the decay of a V0 (I do not believe I use "mother" in the draft). Inserting something like "decay products" in place of "daughter" makes the language feel somewhat cumbersome. To make the language gender neutral, I could use "child" in

place of “daughter”, but again the latter is more common in the literature. So, for now, I will keep the term “daughter” in the draft.

- Figures: I had the impression that many different styles are used. Additionally, there are more detailed comments to the figures below. But this could be worked on during the collaboration round or after in my opinion.

I have adjusted the figures according to most of your suggestions, but likely refinement will need to continue throughout the next rounds.

As usual, please feel free to contact me, if something is not clear.

Best regards,  
Michael

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Non-editorial (so you don’t need to address them if you feel this is beyond my task here ;) ):

- Averaging/central value: in the systematic uncertainty section you write that you average the data points over all systematic variations. I am wondering, how do you average the stat. uncertainty? Since this is non-trivial, I guess this was discussed with the IRC.

The statistical uncertainty is taken from the data obtained using the final cut values. So, the statistical error bars are not affected at all by the systematic study. Doing otherwise would seem to mix the statistical and systematic error bars, but if this is the correct method I can include it in my procedure.

- Systematic uncertainties, selection criteria: do you vary all parameters (table 5) at the same time and build one uncertainty from it? Or do you vary line by line and do a quadratic sum? The latter would be probably an overestimation in my opinion, since correlations would not be taken into account.

I’m not sure I fully understand the question, but I think our method is closer to the vary all situation than the line by line one. For example, for the systematic uncertainty on the data points themselves, the following is employed. We create a correlation function separately for each different cut and parameter value. Taking the LamK0 system as an example, this means we form 33 correlation functions (11 cuts varied, 3 values for each cut). We then average all of these correlation functions and calculate the standard deviations, which are then used as the systematic uncertainty on the final correlation function.

- Systematic uncertainties, other contributions: perhaps I missed it, but how do you treat uncertainties in two-track cuts (~L160), the normalization range (~L180), the BG normalization (L324) and other sources of uncertainties to the  $\lambda_{ij}$  (or do you assume there are none except the tau? I would assume that there should be uncertainties on the values in Table 4)?

The two-track cuts are included in Table 5, as the variation of  $\delta_r$ .

The normalization range is not included in the systematics, as it affects only the normalization parameters in the fit.

The BG normalization is also not varied for the systematics, although the form of the background fit function is varied.

We assume that the variation of tau handles the main systematic contribution to the  $\lambda_{ij}$ . Such a variation changes the primary contribution to the correlation function, which has the most effect on the final result.

I can include these additional systematic contributions (normalization, BG normalization,  $\lambda_{ij}$ ) if desired or necessary.

General:

- I used the guidelines (<https://twiki.cern.ch/twiki/bin/view/ALICE/GuidelineEditing>) for my review. I am listing here things that I found in this draft, but better to check again.

- Avoid using physics slang such as "cuts", "cut tuning", etc. Use precise terms; "obtain" instead of "get", "require" instead of "cut on", "selection criteria" instead of "cuts", etc.

- Avoid footnotes; they tend to drift onto wrong page. If the information is needed, why not having it in the text?

All footnotes have been removed.

- ~~"Pb-Pb" --> "Pb--Pb"~~

- ~~In the guidelines we suggest "space--time" (evolution) instead of "space-time", but I am not sure, which one is correct.~~

- ~~Assuming that you use American spelling: In American English, the rule is to use a comma before and after "i.e." and "e.g.".~~

- ~~Only capitalize the first word and proper nouns of section and subsection headings unless the publisher requires otherwise~~

- ~~Avoid ":" before the equation (in particular when it interrupts the flow of the sentences)~~

- ~~I think "bin" is a rather technical term, which I would substitute: "centrality bins" --> "centrality percentile ranges" for example.~~

- I didn't really check on the tenses, but you might want to check again the guidelines on the tense: <https://twiki.cern.ch/twiki/bin/viewauth/ALICE/GuidelineEditing#Tense>

I'm not certain which tense should be used in all situations. The guidelines are not terribly descriptive. Looking at some other ALICE papers, the tenses used are not always consistent. I will try to determine these rules in more detail, and to refine the draft. For now, I will leave the tenses mostly as they are.

Title:

- Usually we try sentences not to start with a symbol. Not sure if this applies to titles as well.

I'm not sure either. For now, I will keep the title as is.

Abstract:

- L6/7: Repeating "measurements": perhaps one can be replaced  
"measurements" → "results"
- L8: the "from" in "from ALICE at the LHC" sounds a bit strange to me. Does it refer to "measurements from"?  
"from" → "recorded by"

Text:

- L24: "~~two (or many)-particle~~" --> "two-(or many-) particle"
- L27-29: "Current femtosopic studies are able to extract the size, shape, and orientation of the pair emission regions, as well as offering estimations of the total time to reach kinetic decoupling and the suddenness of particle emission." --> Would be good to add a (or several) reference(s) to that statement (perhaps a recent femto summary paper?)
- L29-31: "~~Non-identical particle analyses additionally allow for the measurement of the space-time separation of the single particle source emitting regions.~~" --> Reference
- L31-32: "~~The momentum and species dependence of femtosopic measurements affirm the collective nature of the hot and dense matter created in heavy-ion collisions.~~" --> Reference
- L37-38: "~~The femtosopic signal demonstrates that the strong interaction acts...~~" --> Is this a result of this paper? Or of another work? If the latter, then reference is missing. If the first, then it would probably good to point that out.
- L43: "(anti)" --> "(anti-)"? If yes, then twice  
The guidelines show "antibaryon" instead of "anti-baryon", so it seems antidown would be the correct nomenclature here, but I am also not certain.
- L45: "select regimes" --> "selected regimes"?  
I believe select is appropriate here, as I was trying to convey that the weak coupling regimes are special. In any case, I'm not entirely certain, so I have removed "select" completely as it is not really needed (i.e. "... except in select regimes of weak coupling" → "...except in the regime of weak coupling")
- L46/47: repeated "measurements"
- L51: as above, "as observed in the AK+ system" refers to this measurement?  
Yes, this refers to this measurement.
- L56: the "from" in "from ALICE at the LHC" --> see above
- L62: "~~two particle~~" --> "two-particle"
- L72: Assuming that you use American spelling: In American English,

the rule is to use a comma before and after "i.e." and "e.g." -->  
in this case only one after is needed (since you write it in  
brackets). The later occurrences should be treated accordingly.

- L73: " $\Lambda K^0 S$ ,  $\Lambda K^+ \oplus \Lambda K^-$  is simply  $\Lambda K^+$ " --> I do not quite  
understand, for " $\Lambda K^+ \oplus \Lambda K^-$ " you write " $\Lambda K^+$ ", but what about " $\Lambda K^0 S$ "?

All cases now written for clarity

- L75: "dataset" --> "data set"?

I believe either is correct. In any case, this has been removed in the new version of the sentence.

- L75: ~~"The dataset analyzed is from"~~ --> sounds strange to me,  
perhaps reformulate?

- L77: ~~"The events were classified according to their centrality"~~ --  
> I think one should mention the word "percentiles" somewhere.

- L78: "z-position" --> "z position"?

z also now in italics

- L86: ~~"pT"~~ --> ~~"transverse momentum pT"~~ (or was it introduced  
before?)

- L88/89: ~~"Time-of-Flight (TOF)"~~ --> ~~"Time-Of-Flight (TOF)"~~

- L92: ~~"time-of-flight"~~ --> ~~"time of flight"~~? Not sure?

- L93: " $N_\sigma$ " --> " $n_\sigma$ "? To be checked in other ALICE papers. If you  
change it, make sure it is done in the full text.

I have seen both  $N_\sigma$  and  $n_\sigma$ . For now, I will keep it as  $N_\sigma$  (since, for instance, the number of events is  
typically expressed as  $N_{ev}$ ).

- L99: ~~Don't start a sentence with a symbol.~~

- L99: What do you mean with "track detection"? Tracking is done  
with TPC only I thought. Or you mean that tracks were also matched  
to the TOF?

I meant particle identification, not track detection, for which only the TPC was used. The text has been  
changed accordingly.

- L100: ~~"secondaries"~~ --> ~~"secondary particles"~~ (not sure if  
~~"secondaries"~~ is slang)

- Table 1: Caption has to be put above, perhaps there could be put a  
few more words to it, e.g. "Charged kaon ( $K^\pm$ ) selection criteria"

- L113: ~~Don't start a sentence with a symbol.~~

- L117: Why "point of closest approach", but "distance-of-closest-  
approach"? Is there a reason to have "-" in one and none in the  
other case?

No. Hyphens removed.

- L127: ~~Avoid footnotes; they tend to drift onto wrong page.~~ If the

information is needed, why not having it in the text?

OK. It was suggested by the IRC that I place this information in a footnote. I believe this information is needed, and I understand how footnotes can be troublesome, so I have instead included it in the text.

- L130-137: Fix enumerations according to guidelines: "Lists: Capitalize and punctuate lists if the items are sentences. If the items are one or a couple of words, one uses commas after the item and a full stop after the last one - if it ends the sentence started before the list itself. If the items are longer than that, use sentences."

I'm still not really sure what the correct formatting is here. Items 1 and 3 in the list are not long enough to be sentences, but item 2 is. For now, I will include commas after items 1 and 2, and a full stop after item 3. I will also remove "The" at the beginning of item 2, since now it is not to be considered a full, standalone, sentence. Please advise further if you believe this is not correct.

- L144: "Figure" --> "Fig.~" ("Figure" only at the beginning of a sentence)
- Table 2/3: see comment table 1
- Table 2/3: Daughter Cuts --> not capitalized, in general: why some words are written capital in the table and others not? I would have them all non-capitalized...
- Equation 1: the ingredients to that formula are not defined.
- L174: "term is contained the particle interaction information" --> "term the particle interaction information is contained"
- L178, 180: Don't start a sentence with a symbol.
- L186: "binned both in primary vertex location (2 cm bin width) and in centrality (5% bin width), and only events within a given bin are mixed; i.e. only events of like centrality and of like primary vertex location are mixed." --> Instead of using rather technical terms such as binning etc. it would probably enough to say that "only events of like centrality (within 5%) and of like primary vertex location (within 2 cm) are mixed." or similar.
- L191: "statistics" --> see guidelines: "Statistics" refers to a field of mathematics. Avoid the jargon use of "statistics" as a substitute for "data": "With more data (not "higher statistics") we could measure the Higgs boson mass." Use "improve the statistical precision" rather than "improve the statistics".
- L191: "kT-dependences" --> "kT dependences"?

- L191-192: "are comparable, so an integrated analysis is acceptable." --> where do you show this? If later, then why not bringing the statement only later?

This is not explicitly shown, so the language has been changed from "are comparable" to "should be comparable". This sentence was suggested to be added by the IRC.

- Eq. 4: comma missing after equation
- Eq. 5: I think this equation needs to be split into two lines
- Eq. 5: comma missing after equation

- L218: is "fake" colloquial?

I believe this is the commonly used expression. I will keep it for now.

- L219-220: Commas needed around "whose members originate as daughters from resonances "

Including such commas would suggest that "those pairs" refers to the fake pairs from the previous sentence, which they do not. I have removed "Those" from the beginning of the sentence, to make it clearer that I am not talking about fake pairs.

- Eq. 6: I would have a "with" before the  $\lambda_{ij}$  (perhaps start a new equation)

- Eq. 6: comma missing after equation

- Eq. 7: comma missing after equation

- L252-261: I think it would help to write out somewhere the reaction between  $\lambda_{ij}$  and  $N_{ij}$ . I was confused when reading this paragraph (probably reflected in the following comments, some of them might be rather naive for that reason).

The IRC felt such an equation was redundant. Your confusion probably means that I have not done a sufficient job explaining the procedure. I do also agree that an equation would be helpful, and have added such an equation back into the text.

- L254: "in the experimental sample" --> I am not sure I understand correctly, is this taken from experiment or from real data?

We are trying to estimate the numbers in the experimental sample using simulation, as this information is not available from the real data. However, I can see how this is confusing, and have removed the word "experimental" from the sentence.

- L256: "MC HIJING data" --> sound strange to me. Perhaps simply "HIJING simulations"?

- L257: "which have been run through GEANT to simulate the detector response" --> sounds colloquial to me, please reformulate.

- L261: What is the number of  $\Lambda_K$  pairs?  $N_{ij}$ ? I thought this would be the number of  $ij$  pairs?

This is the number of  $\Lambda_K$  pairs originating from source  $ij$ . I have added this piece of information to clear up the confusion.

- L263: sound very colloquial to me: "in the eyes of...", "particle born from..."

- L277: "hodgepodge" --> colloquial?

"hodgepodge" → "mixture"

- L278: Use passive instead of "we"/"our". That is not a strict rule though...

- Table 4: caption above table

- Table 4: don't start with a symbol

- L294: "generated with MC HIJING data" --> see earlier comment

- L302: "which" --> ", which"

- L305: "~~is due primarily to~~" --> "~~is primarily due to~~"?

- L305: what about other sources? Not necessarily to be added to the text but for my own information...

Typically, the other candidates for non-femtoscopic backgrounds are mini-jets and momentum conservation effects, but in Pb-Pb collisions the elliptic flow is the main contributor.

- L306: "event-plane angles" --> this term is not defined before, also I would write "event plane"

I changed "event-plane angles" to "event planes". Does event plane need to be defined, or is it part of the basic dictionary for nuclear physicists?

- L306: avoid footnotes, see earlier comment (also in the footnote there is the symbol for the event plane that is not introduced)

This footnote was added in anticipation of readers wondering if such a technique could eliminate the background. However, this piece of information probably isn't vital, so the footnote has been removed.

- L307/308: "~~intermediate-k\*~~" and "~~low-k\*~~" without "-" in my opinion.

- L308: "but a clean view of it" --> colloquial?

Maybe, but the term "clean" somewhat best describes the situation. Outside of the the femtoscopic signal, we are able to gain a view of just the background, without any contamination from the femtoscopic signal. I have changed the language of "clean" → "isolated", but I welcome any suggestions for a better descriptor.

- L314: remove "~~(open triangles)~~", "~~(closed circles)~~", "~~(dashed curves)~~", and "~~(solid curves)~~": I am not sure if this detail is needed in the text itself, it is enough to have it in the caption and/or legend in my opinion.

- Equation 9,10: comma missing after equation

- L321-322: "before use with the experimental data" --> is this correct english?

This is correct English. Here "use" is a noun, not a verb. However, I have changed "use" → "application" to avoid any confusion for non-native speakers.

- L331: "~~This rotation rids the pairs of any femtoscopic correlation~~" --> I was not aware of the term "to rid sth", but I trust you here as native speakers.

- L339: "~~between all analyses~~" --> A relationship can only be "between" two things. For three or more things, use "among". Check also other occasions of "between"...

- L341: Why not adding the "N" once more after "normalization parameter", just to be clear.

- L335-341: I am wondering, why alpha and beta from the background are not mentioned here? They are extracted for each pair and centrality separately, I guess?



The background is not mentioned here because it is not really part of the correlation function, but rather a correction to the correlation function. I can try to clarify this further in the text if you think it is confusing.

- Equation 11: comma missing after equation
- L361 and following: "errors" --> "uncertainties"

- L361-362: "To quantify the systematic errors on the data, all correlation functions built using all varied cut values were bin-by-bin averaged, and the resulting variance of each bin was taken as the systematic error" --> I do not understand what was done here, probably needs reformulation. I think it would help to start with the fact that selection criteria were varied to estimate the systematic uncertainties and then you can explain the detail of which value was taken as central and which as uncertainty...

Hopefully this is less confusing now, but I can reformulate further if it is still too confusing.

- Table 5: caption above table, don't start with a symbol.
- Table 5: See comment in guidelines on "systematics": "Systematics" is not an English word. Use "systematic uncertainty" or "systematic bias" instead.
- L380: "between the different AK charge" --> see comment above for "between"
- L385: "represent statistical errors, while boxes represent systematic errors" --> I would move this information to the caption.
- L385-388: also the details on the style of lines could be moved to the caption, in the text I would just mention what is shown (but w/o its representation on the figure).
- L390: "30-50%" --> "30--50%"
- Caption Fig.3: I would at least add a short description of what the lines are. And also mention systematic uncertainties.
- L410: reformulate "vs."
- L412: "Figure" --> "Fig.~" (see comment above)
- L412: reformulate "vs."
- L413: "centralities" --> "centrality ranges"

- L414: avoid footnotes, see earlier comment

I have taken the information out of the footnote and placed it in the text. A precise definition of the pair transverse mass for non-identical particles is difficult to find in the literature, which is why I have included this piece of information in the text. However, this can be omitted if you think it is unnecessary.

- L429 and 432/433: "out", "side", "long" not introduced, or do you consider it clear from mentioning "LCMS"?

Added brief description of coordinate basis

- L438: "to the second moments " --> probably it is just me that doesn't understand the connection, but how do we measure the second moments?

The femtoscopic radii that analyses quote is actually the second moment of the emission function. With identical particle analyses, this is the only piece of information accessible. I have tried to make this more clear in the text.

- L444 and later: Also "C00", "C11" etc. are not introduced
- L444: "1D" --> "one-dimensional"

- L437-452: this paragraph seems somehow "added on top". Since it contains a lot of extra information, I think it should be extended a bit with a short intro and definitions (see above). Also the results of this section are not mentioned in the summary or the abstract, aren't they?

The main focus of this study is the extraction of the scattering parameters, which is why this information was suggested to be left out of the introduction. However, this larger than naively expected radii, and emission asymmetry, are mentioned at the end of the abstract and in the summary. Please let me know if you think further emphasis needs to be placed on this aspect of the study.

The purpose of the paragraph L437-452 is to help justify the claim made in the previous paragraph (L422-436), where we state that a non-zero separation can inflate the radii. The paragraph L437-452 demonstrates that the experimental data support the Lambda and Kaon single particle sources being separated in space-time.

I have attempted to reformulate these two paragraphs a bit, but please let me know if further work needs to be done.

- ~~Caption Fig. 6: Don't start with symbol~~
- ~~Caption Fig. 6: "1D" --> "one-dimensional"~~
- ~~Caption Fig. 6: "a non-zero value reveals the asymmetry" --> "."~~  
missing?
- ~~Table 6: caption above table~~
- ~~Table 6: "(sys.)" --> "(syst.)"~~
- Table 6: somehow the style of table 6 looks different than the other tables in the paper, but perhaps I am wrong.

I will work to make all tables and figures more cohesive.

Appendix:

- L555-556: "rid the correlation functions of the non-femtoscopic background" --> see comment above

This is correct English, but please let me know if you still think it is best to re-word

- L563: "Figure" --> "Fig.~"
- L564: "does a very good job" --> colloquial? I would rather write that the CF is 1 in regions, where no femto signal is expected?
- L566: I am wondering, where this appendix B is referenced in the text (except in the introductory summary)? If it is not referenced, then I would remove the appendix.

This appendix is mentioned once. I feel that it may be unnecessary, but the IRC suggested we keep it for now. I am happy to remove it, if you feel that is best.

- Eq. B1: comma after equation
- Eq. B1 (and later in the text): should the "C" not be roman (it stands for Coulomb and is therefore not a variable)?
- L572: Don't start a sentence with a symbol
- L574: Don't start a sentence with a symbol
- Eq. B2: comma after equation
- L575: "where, the" --> "where the"
- Eq. B3: "." after equation
- Eq. B4: "." after equation
- Caption Fig. A1: Don't start a sentence with a symbol
- Caption Fig. A1: "centralities" --> "centrality intervals"
- L582: "Fig." --> "Figure " (in the beginning of sentences, elsewhere "Fig. ")
- L588: "one dimension" --> "one-dimensional"
- L588/589: as commented in the main text the "spherical harmonic decomposition" is not introduced anywhere.
- L605: Remove ")" after Figure number.
- Caption Fig. C3: Don't start a sentence with a symbol
- Caption Fig. C3: "centrality bin" --> "centrality interval"

## References

- "et al." not in italics
- [8]: "The alice experiment at the cern lhc" --> Why everything non-capital?
- [8]: Why there is this extra link here? This is not there for other references.
- [15]: journal etc. missing
- [17]: why not citing the latest version? <https://journals.aps.org/prd/abstract/10.1103/PhysRevD.98.030001>
- [30]: missing information (links etc.)

Figures (could also be done during or after Collaboration review):

I have implemented many of the suggested changes, and will continue to work to make all of the figures and tables feel more uniform. I have not implemented the suggestion to add the systematic uncertainties in the legend. I typically have not seen this done within femtoscopy paper, and it somewhat clutters the figures. I have added methods in my plotting functions to include these in the legends if need be, but I would rather keep them out if possible.

- check again the guidelines on figures ([https://twiki.cern.ch/twiki/bin/viewauth/ALICE/GuidelineEditing#Figures\\_and\\_Tables](https://twiki.cern.ch/twiki/bin/viewauth/ALICE/GuidelineEditing#Figures_and_Tables))
- "Clearly indicate the subfigures with (a) (b), (left) (right) etc. in the caption." (from guidelines): While this is done in the

current draft, I was wondering if it would help to actually add (a), (b),... in some of the figures (especially if they have 6 panels) to make the description simpler. But of course, i leave it up to you.

- Be sure to label both axes of a plot and include the units. Give the binning of one-dimensional histograms in the y axis label, e.g. "Events/ 50 MeV"
- Try to make the figures with a uniform style and size throughout the paper (they seem all to have a different style, especially 5,6,C2,C3)
- Avoid use of triangles in figures
- XX--YY% instead of XX-YY% (en-dash instead of dash as in the text)

- Fig 2:
  - ~~remove "preliminary"~~
  - systematic uncertainties not in the legend
  - ~~fit not in legend~~

- Fig 3:
  - ~~remove "preliminary"~~
  - ~~data points not in the legend~~
  - systematic uncertainties not in the legend
  - fit not in legend

The fit is in the legend of the top left panel.

- Fig 4:
  - ~~remove "preliminary"~~
  - systematic uncertainties not in the legend
  - ~~I am wondering, if one should write the reference directly into the legend (as this is usually done in other ALICE papers), this would make also the additional substitution obsolete ([A] = [2] etc.)~~
  - ~~Suppress the horizontal lines at the end of the error bars~~

- Fig 5:
  - systematic uncertainties not in the legend

- Fig 6:
  - ~~add "ALICE" and collision system~~
  - ~~add legend with data and systematic uncertainties~~

- Fig C1:
  - systematic uncertainties not in the legend
  - the large brackets in the fit formula look very strange

Removed

- ~~"N" in "dN" italic, "t" in "Delta t\*" italic~~
- ~~are these observables ( $\tau^*$  and  $t^*$ ) explained actually in the text?~~

- Fig C2:

-- legend missing: what are the symbols, what is the line? Somewhere should be written Terminator on the text

- Fig C3:

-- systematic uncertainties not in the legend

-- light green and magenta shouldn't be used (invisible in projections)

Made colors darker for now