Long Symmetric Cumulant paper : 2nd IRC review

We would like to thank all IRC members for the prompt reviews on the paper draft as well as for many great suggestions. The replies to all IRC comments and an outline of the changes made in the updated version of the manuscript are provided below:

Paper draft location :

Reviewed version :

<https://aliceinfo.cern.ch/ArtSubmission/sites/aliceinfo.cern.ch.ArtSubmission/files/draft/djkim/2016-Dec-08-paper_draft-longSC_v4.3.pdf>

New version:

**Reviwer : Alice Ohlson**

Two general suggestions/comments:

- Like I wrote in my previous comments, be very careful about stating

that a value is increasing when it's actually getting more negative

(i.e. decreasing!) or about saying that something more negative is

"larger" than something less negative.  The strength of the

anticorrelation may be increasing (larger), but the actual numerical

values are decreasing (smaller).  I notice this in line 229 but I think

it happens elsewhere too.

R : We changed to “Both NSC(3,2) and NSC(4,3) are getting more anticorrelated toward peripheral collisions with the similar magnitude.”

And remove “and a monotonic increase is observed” in line 227.

- I suggest defining a quantity p\_T^{min} at line 231 so that you can

then use it throughout this paragraph were applicable. For example, in

line 234 you can write 0.2 < pTmin < 0.7 to be more clear.  Also you can

change the legends in Fig. 2 to say e.g. pTmin = 0.8 GeV/c instead of

0.8 < pt < 5 GeV/c (this will reduce the text on the figure).

R : good suggestion, we modified the text and figures accordingly.

* line 81: magnitude -> magnitudes
* R : done
* line 82: is sensitive -> are sensitive
* R : done
* line 109: alone are -> alone is
* R : done
* line 116: of heavy-ion -> of the heavy-ion
* R : done
* line 149 (and perhaps elsewhere): pseudo-rapidity -> pseudorapidity
* R : done, only here
* line 153: taken for -> included in
* R : done
* line 192: correct for -> avoid
* R : done

- lines 193-194: I suggest "resolution, a hybrid track selection

utilizing SPD hits and/or ITS refit tracks combined with TPC information

was used."

R : done

* line 195: The systematic -> A systematic
* R : done
* line 199: and it is -> and is
* R : done
* Fig. 1 caption: Systematical -> Systematic
* R : done
* line 241: NSC(m,n) -> NSC(4,2)
* R : done

- lines 260 and 315 (and perhaps elsewhere): initial condition ->

initial conditions

R : done and found one more place, fixed now.

* line 305: remove "observable"
* R : done
* line 308: to model the initial stages -> in models
* R : done
* line 309: use -> measurement
* R : done
* line 310: The better -> Better
* R : done

- Figs. 3, 4, and 5 need a bit more work on the plotting, some ticks

labels are cut off, points cover up 10^-6, the exponents along the axis

change, and parm->param in the legends.  Also, all the text needs to be made larger.

R : parm->param fixed, we have improved the figures as you suggested.

* line 355: As it can -> As can
* R : done
* line 355: for "param1" -> for the "param1"
* R : done
* line 355: latex ''->``
* R : done

- line 356: from the hadronic to the QGP phase occurs at the lowest

temperature, around 150 MeV

R : done

- line 357: characterized by a moderate slope in eta/s(T) which

decreases (increases) in the hadronic

R : done

* line 358: with the parameters for -> in
* R : done
* line 358: of phase -> of the phase

R : done

* line 359: latex ``->''

R : done

* line 359: already with -> by
* R : done
* line 359: measurement -> measurements
* R : done
* line 361: remove "the transition towards"
* R : done
* line 363: the data -> the anticorrelation in the data
* R : done
* line 364: a failure of constant -> the failure of a constant
* R : done
* line 370: quite clear -> clear
* R : done
* line 386: Except for the
* R : done
* line 392: a AMPT -> an AMPT
* R : done
* line 412: "for NSC(3,2) there is no pt dependence in the centrality"
* R : done
* line 413: seen for -> observed in
* R : done
* line 414: or the centrality increase -> or centrality increases
* R : done
* lines 415 and 417: Fig. 8 and Fig. 9 -> Figs. 8 and 9
* R : done
* Figs. 8 and 9 captions: cut -> cuts, are ->is
* R : done
* line 420: magnitude of the data for both -> magnitudes of both
* R : done
* line 425: remove "from the data"
* R : done
* line 430: In case -> In the case
* R : done
* line 434: with two -> with the two
* R : done
* line 435: parameterizations -> parameterizations of eta/s(T)
* R : done
* line 435: magnitude -> result
* R : done
* line 436: centralities -> centrality range
* R : done
* line 436: underestimate in -> underestimate it in
* R : done
* line 436: add comma after "However"
* R : done
* lines 437-438: calculations between -> results for the
* R : done
* lines 438-439: between two parameterizations are -> between the two are
* R : done
* line 439: in 10-20% where -> in the 10-20% centrality range where
* R : done
* line 445: correlation -> correlations
* R : done
* line 448: the non-flow -> non-flow
* R : done
* line 449: free from -> independent of
* R : done

- The sentences at liens 466-467 and 470-472 say almost the same thing,

so I suggest incorporating the first one into the second.

R : done

**Reviewer : Sudhir Raniwala**

Here are some suggestions. Some of these may reflect my ignorance. Please take what you like.

1. In general, define once and for all that in the present work, SC(m,n) is considered as higher order if m + n >= 7, and lower order if m+n <= 6.

R : In L209-210 they are defined clearly. Probably this math is not needed.

2. Do we want to write $\eta/s(T)$ or $\frac{\eta}{s}(T)$ ?. The former indicates that entropy (alone) is temperature dependent.

R : We used this in the short paper [40] and the theory paper [30] used this convention. Since it was defined clearly, we think the current form is ok.

In addition to minor edit comments, some comments are interspersed in the following, and may be of greater relevance.

Line 17: and the temperature dependence 🡪 and to the temperature dependence

R : we think the current version is ok.

Line 19: Correlations between the magnitudes of v2, v3 and v4 🡪 Correlations of v2 with v3 and v4

R : we think the current version is ok.

Line 31: has been 🡪 was / is (In general, ‘has been’ and ‘have been’ are not good in a science paper, imho).

R : done

Line 41: close to that limit 🡪 close to the lower bound.

R : we think the current version is ok.

Line 41-42: We can remove the sentence ‘This may have....goals’.

R : OK.

Line 58: Remove the word ‘respective’.

R : we think it is fine with “respective”.

Lines 61-63: This appears to be too much blah blah. What is the extent of variation of eta/S with temperature? How does this variation affect vn values? A more specific statement may help.

R : We don’t think so. This statement shows where we are in our field. That is why this paper is important. Our short SC paper was addressing eta/s(T) for the first time based on the experimental data.

Also based on the cited paper which studied the effect of eta/s, there is x 2 difference on eta/s value based on vn comparisons to the data by using different initial conditions.

A large uncertainty on IC and corresponding eta/s varies by x2, Refs. [4,24,25].

Line 78-79: “Therefore, the higher .....harmonics” 🡪 The nature of the (non)linear response will manifest itself as correlations of higher harmonics( n > 3) with lower order harmonics.

R : We think the current version is ok.

Line 86: parts of 🡪 features of , or aspects of

R : We think the current version is ok.

Line 99: explained 🡪 detailed

R : We think the current version is ok.

Line 104: What remains..... 🡪 It is imperative to discern the temperature dependence of eta/S of the QGP.

R : We think the current version is ok.

Line 105-106: were studied in [] 🡪 were studied in reference []

R : conflict with llya’s comments. We will leave it as it is.

Line 107: has just been 🡪 was recently

R : done

Line 107: Can remove “in Ref”

R : we keep “in” as 105 but remove “Ref”

Line 108: remove “only”

R : we think we can keep it.

Line 114: remove the word “development”. “Therefore their “ 🡪 Their

R : We think the current version is ok.

Line 114-118: Needs to be rephrased. Am sorry I can not give a good suggestion.

R : We think the current version is ok.

Lines 128-134: There is something that I am missing, as also mentioned earlier. NSC are SC divided by mean-squares of vm and vn. SC contains <vm^2> and <vn^2>. The language conveys that if we do NOT leave a gap while calculating SC, it is OK, but it is necessary while calculating NSC. So the second term in SC will have a different value with and without the eta-gap. What am I missing here ?

R : Yes, you are right but that effect is rather small and assigned as a systematic uncertainty.

Line 138-139: “The observed centrality ......... “. Let me consider a limiting (extreme) scenario. The model is ‘useless’,and is not able to reproduce any feature of the data. Then eta/S or its temeperature dependece become completely irrelevant. This was one of the concerns that I had expressed earlier, the goodness of the model to explain the distribution of v\_n.

R : We are not sure what you mean by the goodness of the model. The models cited here have their own limitations. Good description of vn in various models can’t guarantee that they are correct and rather we have found that vn themselves couldn’t constrain model parameters. These facts are described in the introduction with the references. That was why SC has been quite interesting and we did observe clear separations of the model parameters. Once we understand model parameters better, vn description in the model will also be improved.

Line 173: How come systematic uncertainty on different data points show such ‘uniform’ behaviour. Are we considering the maximum systematic error here?

R : do you mean why we are adding them in quadrature ?

Line 176-178: There will be an auto-correlation effect here. The magnitude of fluctuation is related to the multiplicity. And if the track multiplicity is used for centrality determination, then it will bias the systematic error.

R : This is what we studied and assigned as a systematic error.

Line 193-193: Known to ALICE, but may require elaboration for the general reader.

R : We have rephrased to " resolution, a hybrid track selection

utilizing SPD hits and/or ITS refit tracks combined with TPC information

was used.” Based also on Alice’s suggestion.

Line 211-213: What is being said here, please, in reference to Fig. 1.

Suggestion: For all centralities, data for SC(m,n) shows a negative correlation if m – n =1 and a positive correlation if m – n > = 2.

R : we think the current version is ok.

Lines 221-224: I have missed the relevance. What is the issue? What is being said, really?

R : We are describing what we observed.

Line 225-226: linear or non-linear is irrelavant because centrality interval is a more of a convenience. Linear and non-linear would make more sense if the figure is plotted as a function of N\_part of impact parameter. Please rephrase.

R : We are not sure why N\_part is better here. We are just describing the observed centrality dependence.

Line 242 -244: Can I conclude that the results are ‘insensitive to pT of particles’ or claim that the results are robust against changes of pT.

R : There is an expectation that the pT spectra would change at the freeze-out from hydrodynamic calculations. Also see L245-247. As you said, there is no hint of changes pT\_min up to 0.7GeV/c but we start to see the changes >0.8 GeV/c.

Lines up to 247: The SCs change with pT because vn change with pT and therefore it is important to see whether the model reproduces the pT dependence of vn. This is another reason in support of the earlier question about necessity of model reproducing the gross features.

R : similar answer from us as Line 138-139.

Line 259-261 ‘ and given initial conditions later’.....? Please rephrase.

R : We think the current version is ok.

Line 271-272: “ ...non-vanishing initial local flow velocities.....”. What is the relevance with the present work?

R : We describe the initial conditions (IC) of AMPT which has a different implementation than the other IC. This should be stated clearly because it could effect the results and their implications.

Line 274-276: Is there an eperimental evidence to support that the process of thermalisation has started, but equilibrium has not been reached?

R : Not at all. A very strong assumption in hydrodynamic models is that the local equilibrium should be achieved.

Line 276-277: The AMPT addresses such non-equilibrim many body dynamics with includes both initial partonic....

R : We think the current version is ok.

Line 294: Missed the emphasis here....are we saying that lower radial flow is able to reproduce the charged particle flow, but not able to reproduce the identified particle flow results?

R : No, it says disagreement “is responsible for the quantitative disagreement [82].”

Line 304-305: “This observation......density” – How? Why ? What ?

R : The disagreement between the models and the data will help models improved.

Line 335-336: Obviously I do not understand this. How can difference in individual results explain the difference in correlations ?

R : This came from the relation between SC and NSC via <vm^2><vn^2>.

Line 338: Remove “the”.

R : done

A general comment for section 6.1: One needs to read it multiple times to derivee the conclusion on what observables and what experimetnal results validate show which physical properties? Before writing the text, it may help to make a table (or an n-dim matrix in one’s mind) to make the statements and conclusions crisp.

R : We tried to summarize them in L395-410. We think it is ok. We don’t want to overdo it. The disagreements between the models and the data are quite visible with SC observables, which tells us that the results can help to constrain model parameters.

Which parameters and how much …. ? We can’t solve it by ourselves at this moment; we leave these kinds of works to theorists.

Line 346: “give better constraints” 🡪 further constrain

R : We think the current version is ok.

Line 355-356: Please rephrase.

R : we have rephrased it to “As can be seen in Fig.~1 from Ref.~\cite{Niemi:2015qia}, for ``param1'' parameterization the phase transition from the hadronic to the QGP phase occurs at the lowest temperature, around 150~MeV. This parameterization is also characterized by a moderate slope in $\eta/s(T)$ which decreases (increases) in the hadronic (QGP) phase.”

See the Alice’s comment.

Line 411: You may want to change the title considering that we are restricting to v2 –v3 and v2-v4, these are lower order as per the proposed defintion of m+n < = 6. Also, since v3-v4 is not being discussed, the present title may mislead.

R : This is what llya suggested. We think this is ok.

It may be good to reduce the blah blah in the following:

Line 466-467: Can we specify what contraint?

R : this is combined to Line 470-472

Line 470-472: Which specific properties of the model?

R : the initial conditions and $\eta/s(T)$ being said.

**Reviewer : Ilya Selyuzhenkov**

https://twiki.cern.ch/twiki/pub/ALICE/PtDependentStandardCandles/longSC\_v5.0.pdf

l7

The correlations between event-by-event fluctuations of anisotropic flow harmonic amplitudes

->

The amplitude correlations between event-by-event fluctuations of anisotropic flow harmonics

R : We think the current version is ok.

l12

flow), as well as the transverse ... are presented

->

flow) is presented. The transverse ... is also reported.

R : done

l18

favored regardless of initial conditions and the AMPT initial condition

->

favored independent of specific choice of initial conditions in the models. The calculations with the AMPT initial conditions

R : done, yields to yield accordingly.

l20

This might be an indication of possible viscous corrections to

->

This might reflect viscous effect in

R : We think the current version is ok.

l21

Question: Why only "at hadronic freeze-out"? Why not during the whole evolution? I think it is better not to limit these effects to freeze-out.

R : This is based on the reference [21] ??

l23

the results presented here

->

the presented results

R : done

l28

"collective and anisotropic flow" - anisotropic flow is also "collective" effect, so "and" does not read well here. Suggest rephrasing:

This matter exhibits strong collective and anisotropic flow in the plane transverse to the beam direction, which is driven by anisotropic pressure gradients, resulting in more particles emitted in the direction of the largest gradients.

->

The matter produced in a heavy-ion collision exhibits strong collective radial expansion. Due to anisotropic pressure gradients in the plane transverse to the beam direction, more particles emitted in the direction of the largest gradients which result in anisotropic transverse flow.

R : We removed “collective”.

l31

This has been predicted

->

The measurements are well described

R : done

l32

These calculations also demonstrated that the .. is close

->

The experimental data favor the .. to be close

R : We think the current version is ok.

l35

For instance, one

->

One

R : done

l41

Remove "This may have important implications for other fundamental physics goals" - This generic sentence adds zero information to the paper.

R : done

l45

is traditionally

->

is nowadays

R : done

l45-56

Ref. [14]-[15] does not introduce the notion of vn having corresponding Psi\_n => Add more recent references where it is discussed.

R : ??

l59

Difficulties in extracting η/s in heavy-ion collisions can be attributed mostly to the fact that it ... for comparison

->

Until recently, the difficulties in extracting η/s in heavy-ion collisions were attributed mostly to the fact that extracted value ... in calculations

R : we think the current version is ok.

l61

Viscous effects also reduce ... elliptic

->

Viscous effects reduce ... anisotropic

R : done

l61

Viscous effects also reduce the magnitude of the elliptic flow.

->

This sentence does not belong here. It either need to be extended or removed.

R : we think the current version is ok.

l62

Furthermore, the magnitude of η/s used in hydrodynamic calculations should be considered as an average over the temperature evolution of the expanding fireball as it is known that η/s depends on temperature.

->

It is now understood that the temperature dependence of the of η/s should be considered in the hydrodynamic calculations.

R : we think the current version is ok.

l64-66

"Therefore, both the temperature dependence of η/s and the relative contributions from the partonic and hadronic phases should be understood better to quantify the η/s of the QGP."

This is a repetition of the previous two sentences and can be removed

R : we think the current version is ok.

l67

An important input to the hydrodynamic model simulations is the initial distribution, ... which is ... the probability distribution

-> This is again about initial conditions which was introduce earlier, no need to repeat

->

The initial distribution ... is ... the distribution

R : we think the current version is ok.

l 69

This initial energy density profile can be quantified by calculating the distribution of the spatial eccentricities

->

It is quantified by the spatial eccentricities

R : we think the current version is ok.

l73-74

There is experimental and theoretical evidence

->

There is an evidence

R : we think the current version is ok.

l76-83 Have you synchronized this discussion with the outcome of the discussion with PC+IRC for related paper on non-linear response (You Zhou is its PC chair)?

I think it is important to write this part such that it reflects the fact that both linear and non-linear terms are misleading and in reality both have non-linear contributions.

R : we think the current version is ok. Yes, we are aware of it (DongJo is one of PC of that paper). l76-83 is correct “Harmonic v4 and higher order flow coefficients can arise from initial anisotropies in the same harmonic” by definition. Confusion has arrived while we decomposed it w.r.t v2 and v3. Also it was not stated clearly in the current paper draft. Also it was known that hydrodynamics is a non-linear theory and the linear term in that paper contains non-linear contribution but they should be small. There are assumptions given in that paper clearly.

l84

Hence, studies of the higher order (n > 3) to lower order (v 2 or v 3 ) harmonic correlations

->

Studies of the higher correlation between higher order (n > 3) and lower order (v2 or v3) harmonics

R : done , studies of the correlations between higher order ($n>3$) and lower order ($v\_2$ or $v\_3$) harmonics

l85-86

viscous correction to the momentum distribution at hadronic freeze-out

->

Same question as in the abstract> Why only "at hadronic freeze-out", not during the whole evolution?

R :

l87

Recently, the ALICE Collaboration measured for the first time the Symmetric 2-harmonic 4-particle Cumulants (SC), new multiparticle observables which quantify the relationship between event-by-event fluctuations of two different flow harmonics [40]

->

The first results for a new multiparticle observables which quantify the relationship between event-by-event fluctuations of two different flow harmonics, the so-called Symmetric 2-harmonic 4-particle Cumulants (SC), were recently reported by the ALICE Collaboration [40].

R : done

l94

higher order Fourier harmonics

->

higher order harmonics

R : done

l96

We also include extensive comparisons ... calculations.

->

We also present a systematic comparison ... calculations.

R : done

l100

theoretical calculations. Various theoretical models

->

model calculations. Various models

R : done

l103-124

This is basically a repetition of what was written in the introduction. I see no reason to repeat the messages which were just discussed.

I suggest to:

(a) merge this part with the text in the introduction at l87 and start Sec. 2 right from the definition of SC observables (l125), i.e.

R : we think the current version is ok.

The SC observables are defined as

->

The Symmetric 2-harmonic 4-particle Cumulants (SC) are defined as

(b) merge Sec 2 and Sec 1, and move "outline" i.e. l94-l101 after lines 143.

R :

l128

cumulants reflect

->

cumulants has an advantage that it reflect

R : we think the current version is ok.

l132

For the two

->

For the product of

R : we think the current version is ok.

l136

However, the

->

It was found that the

R : done

l139

indicating clearly that

-> (either indicating or clearly shows, but not a mix of two)

indicating that

R : done

Fig. 1 caption

Systematic errors

->

Systematic uncertainties

R : done

l127

However, unlike ... The NSC(4,3) magnitude...

->

Unlike ... This demonstrates the advantage of using the normalized SC observables in which the correlation strength between flow harmonics is not hindered by the differences in magnitudes of different flow harmonics. The NSC(4,3) magnitude...

R : done

l220

Fig. 1b

-> should the brackets be added here and in other places?

Fig. 1(b)

R : done

l230

we systematically vary

->

gradually change

R : done

l232

Various minimum pT cuts from 0.2 to 1.5 GeV/c are applied

->

The minimum pT cut is varied in the range from 0.2 to 1.5 GeV/c for values of pT = 0.2, 0.8, 0.9, 1.0, 1.2, and 1.5.

Question: do we really need so many steps shown in Fig. 2? Maybe it is enough to have them all shown in Figs. 8-9

R : we think the current version is ok and these show all the data points we have. In this way it is much clear to show both SC and NSC. Also p\_T dependence can be seen clearly. Figs.8-9 show only NSC.

l237

dependence of the vn values

->

dependence of the individual flow harmonics <vn>.

R : done

l244-245

These observations are strikingly different from pT dependence of the individual flow harmonics...

->

Actually I do not completely agree with this assessment. Can this be due to increase in non-flow correlations at high pT? The published sigma\_vn/vn are obtained with VZERO event plane (much larger eta gap).

It would be good to provide an explanation for why this is happening.

R : non-flow correlation should be included in the systematic error. Also we tested with lowering pT\_max we still see the same trend. Hydrodynamic model calculations also show the similar trend. We didn’t know if this trend can be seen in the hydro until we receive the hydro result.