

## Now the Experiment data from NIST indicates quantum entanglement may not exist

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*This is a statistical analysis of the experimental data used in a recent paper [Lynden K. Shalm et al, Phys. Rev. Lett. 115, 250402 - Published 16 December 2015 at <http://journals.aps.org/prl/abstract/10.1103/PhysRevLett.115.250402>. The data for this analysis has been made available by the authors at [http://pml.nist.gov/belldata/belldata+processed\\_compressed+ hdf5.html](http://pml.nist.gov/belldata/belldata+processed_compressed+ hdf5.html) in hdf5 format.*

***This article is not meant in any way to comment upon the originally published findings of the experiment.***

### Abstract –

Till date, all experiments prove non-locality of entanglement based upon overall statistical correlations and thus demonstrating that Bell's inequality is violated. No detailed data analysis has been published yet. This article presents detailed data analysis of its kind and it indicates that there is a real chance that non-local entanglement may not exist. This is a huge claim by any means. But it is necessary to make such dramatic claim due to two reasons – 1) It is based upon experimental data and can be tested and verified. 2) So that the QM community makes an effort to analyze detailed data to scrutinize the locality of entanglement.

This is second experiment that gives such an indication. The first of this kind data analysis was conducted on another recent experiment data and the observation is posted at <http://vixra.org/abs/1609.0237>.

Due to large amount of data involved, experimentalists only analyze data at aggregate level and do not scrutinize the raw data in full detail. When data of this experiment was analyzed at detail level, it was observed that non-locality of entanglement can not be settled until this kind of analysis is completed on data from multiple such experiments.

The natural and prompt reaction from many may be to look for faults with this analysis without presenting the evidence that such analysis has already been completed. For curious people, observation is odd enough to be probed further. The complacent ones will look only for the faults, but those who welcome scrutiny, will challenge it with evidence and/or their own analysis at this detailed level. All sound theories welcome scrutiny and refute it with evidence.

*This article does not claim “classical mechanics” to be the solution. Quantum Mechanics predictions are correct in terms of averages. This analysis indicates that the statistical correlation percent of entanglement may be guided/balanced by some real/local mechanism rather than being independently probabilistic and spooky. It presents an intuitive mechanism that can explain statistical correlations without entanglement being non-local or entanglement being defined in a different way than it currently is.*

The scope of this article is only statistical data. Anti correlation (Bell's state, when measured in the same angle) is always true, therefore it is not statistical in nature and is left out of scope. Moreover perfect anti correlation can easily be explained as a direct consequence of conservation laws. In fact, perfect anti correlation is a big red flag to the probabilistic nature. There is no such thing as zero, or one probability. Zero or one probability would actually be a law, not probability. So, perfect anti correlation itself indicates that the outcomes of entanglement can not be probabilistic, they have to be governed by law, not probability.

***If some balancing mechanism is found to exist then (in terms of magnitude), it really operates within probabilistic limits thereby making it very difficult to differentiate it from probabilistic nature. Therefore a detailed data analysis on many such experiments is necessary to rule it in/out. In fact it would require special experiments for its independent investigation. This can also explain why the correlations have been considered probabilistic for such a long history. Therefore, this type of experimental investigation is a must in order to conclude existence/nonexistence of non-local entanglement.***

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## Experiment and Data

This paper presents a statistical analysis of the experimental data used in a recent paper [Lynden K. Shalm et al, *Phys. Rev. Lett.* 115, 250402 - Published 16 December 2015 at <http://journals.aps.org/prl/abstract/10.1103/PhysRevLett.115.250402>. You may read the full article there. I will repeat relevant information here. Data of this experiment was **recorded in sequence of actual trials** which enables proper analysis.

1. A source of entangled photons sends entangles pairs – one photon to Alice and one to Bob in form of pulsed signals.
2. Alice and Bob have detectors (polarization filters) which they can randomly set in one of the two directions. Alice’s setups can be a1 or a2 and Bob’s setups can be b1 or b2. All four setup combinations are a1b1, a1b2, a2b1, a2b2.
3. If the photon passes the filter, a click is recorded. A click is represented by a “+” which is recorded in data as a “1”. Actually the + is recorded as a pulse number but for the purpose of this analysis, all pulse numbers are considered as “1”. The pulse numbers are 1,2,4,8,16,...32768 as there are 16 pulses. As a ++ outcome, Alice and Bob get same pulse number. They rarely get different pulse numbers, but those occurrences are negligibly small and so not considered a ++ outcome. The number of such trials is so small that including or excluding them does not impact the observation. As an example, in the final run, there are 8 such trials and 20599 same pulse trials.
4. If the photon does not pass the filter, there is no click, (means no +) and is recorded as “0”.
5. The experiment sends 896532898 trials in 5 runs of 30 minutes each. This analysis combines the data sequentially making it a 2.5 hour one long run. Actually, data from 7 runs is posted on NIST site, but first two runs are discarded due to some data being way off from average. These averages are shown later from all 7 runs. Data is available at [http://pml.nist.gov/belldata/belldata+processed\\_compressed+ hdf5.html](http://pml.nist.gov/belldata/belldata+processed_compressed+ hdf5.html).
6. Each detector setup combination receives roughly one fourth trials in random fashion.
7. This article uses setup combination a1b1 to explain the observation. Number of valid trials sent to setup a1b1 is **224166820**.
8. A “++ pair” means Alice records a + and Bob records a +. A “non ++ pair” means at least one of them does not record a +.
9. Number of ++ pairs recorded in actual data for setup a1b1 is **107373**. This means on an overall basis, there are **(224166820–107373)/ 107373= 2086.74** non ++ pairs between two ++ pairs.
10. Thus the average gap between two ++ pairs is **2086.74** non ++ pairs
11. As this is a long enough run, the analysis considers QM predicted probability of getting a + at both sides, same as actual which is 1 in 2087.74, i.e. 1/2087.74.

## Definitions – (in context of setup (a1b1))

**Expected gap** – Per above #9 & #11, expected number of “non ++ pairs” between two adjacent “++ pairs” is 2086.74.

**Cumulative Expected gap** – Sum of Expected gap at any point. It is simply (2086.74) times (the number of “++ pairs”) at any point.

**Actual gap** – (Number of “non ++ pairs” before this “++ pair”) comes from the data, can be different for different “++ pairs”.

**Cumulative Actual gap** – Total of actual gap so far.

**Imbalance** – (Expected gap – actual gap). Which is = (2086.74– actual gap).

**Accumulated imbalance** – Total of imbalance so far. Or, total imbalance till this “++ pair”.

**Example calculation of cumulative imbalance** for first two ++ pairs –

In the data, first ++ outcome was found at trial number 655.

So, actual gap is 654, predicted gap is 2086.74, imbalance = 2086.74– 655 = 1432.74, cumulative imbalance = 1432.74.

Second ++ outcome was found at trial number 2818.

So, actual gap = 2818 – 655 – 1 = 2162, expected gap is 2086.74, imbalance = 2086.74 – 2162= -75.26.

**Cumulative imbalance** till this point is = (1432.74) + (-75.26) = 1357.48.

**Table 1** demonstrates example calculations of cumulative imbalance till 10th ++ pairs

**Plotting Graph – Figure 1** plots cumulative imbalance for the duration of the experiment – i.e. ~ 224166820 trials of setup a1b1.

Words “expected”, “predicted”, “average” and “overall” are all used to indicate the “Expected gap” in context of gap.

“Total imbalance”, “cumulative imbalance”, “cumulated imbalance”, “accumulated imbalance” all mean same thing.

**Observation**

1. This article first uses setup combination **a1b1** as an example to explain the observation.
2. Then this paper presents same observation in other setup combinations.
3. Even though the trend may be very subtle, what makes it interesting is that same trend is seen in all four setup combinations.
4. The trend alone may be capable of indicating something other than probability, plus similar trend in all four setup combinations at the same time, strengthens the possibility of some mechanism other than just probability.
5. This observation should be scrutinized by analyzing data of existing experiments and/or by conducting more experiments.
6. This type of analysis requires the sequence of trials to be preserved in the recorded data.

**What was analyzed?**

The paper has analyzed cumulative imbalance over the duration of experiment. Just like looking at the evolving difference between total number of heads and total number of tails in a coin toss experiment.

**Coin toss analogy -**

Supposed you tossed a coin 214000 times with eventual outcome of 50% heads and 50% tails. And suppose, throughout this experiment, total number of heads only rarely exceeded total number of tails even though final outcome is 50% heads and 50% tails. I.e. number of tails takes a lead in the beginning, and the lead keeps building up till a peak, and then the lead starts clearing and clears till the end to make the eventual outcome 50/50. But the total lead rarely swings the other way, only in the very beginning or very end.

Suppose same thing happens if you do the experiment with four coins at the same time, in parallel. In all 4 coins throughout the experiment, total number of heads rarely exceeded total number of tails.

Can you really say this experiment consists of independent trials? Actually we can not. There are two possibilities –

1. Trials are not independent and something favors number of tails first, and then number of heads to make end result even.
2. We did not conduct sufficient number of trials and were never able to see the overall excess swing the other way.

Above type of observations have been made in data of the selected experiment, and both the possibilities should call for more analysis on data of similar experiments.

**Table 1** – Example calculation of the accumulated imbalance in setup a1b1

<b>Trial Sequence where a ++ trial is seen. Setup - (a1b1)</b>	<b>(A) – (Actual Gap) please see definitions on last page</b>	<b>(B) – (Cumulative Actual Gap) = Running total of (A)</b>	<b>(C) – (Cumulative Expected Gap) = Running total at 2086.74 each line</b>	<b>(D) – (Accumulated Imbalance) = ((C) – (B))</b>
655	654	654	2086.74	1432.74
2818	2162	2816	4173.48	1357.48
4038	1219	4035	6260.22	2225.22
6819	2780	6815	8346.96	1531.96
7112	292	7107	10433.7	3326.70
7308	195	7302	12520.44	5218.44
7740	431	7733	14607.18	6874.18
8386	645	8378	16693.92	8315.92
10649	2262	10640	18780.66	8140.66
16084	5434	16074	20867.4	4793.40

**What was observed?**

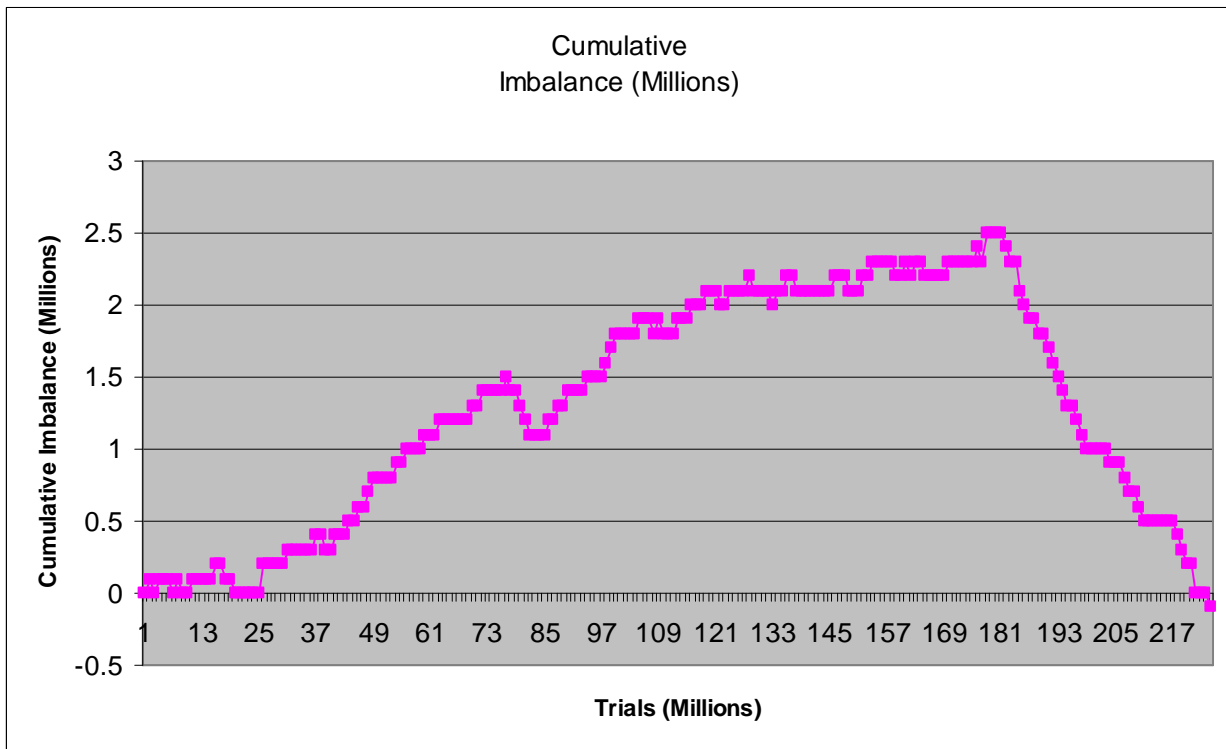
It is observed that the accumulation of imbalance has a direction for a much longer range than could be expected by a probability mechanism. Same trend observed in all four setups. The imbalance being in same direction for > 96% of experiment duration has a very low chance.

The actual average (from data) is used here therefore the curve starts at zero and winds up at zero. This is a known fact, and it should not lead readers to think that the observation is an artifact of the analysis.

If QP predictions are accurate, the predicted probability (even though it is not available), can not be significantly far from the actual average. Otherwise, the QM predictions will be in doubt.

It should also be noted that the original paper also proved Bell’s inequality by using average from actual data.

**Trend of accumulated imbalance (a1b1) trials (Total imbalance never (negligible) went below zero).  $P_{++}(a1b1) = 1/2087.74$ .**



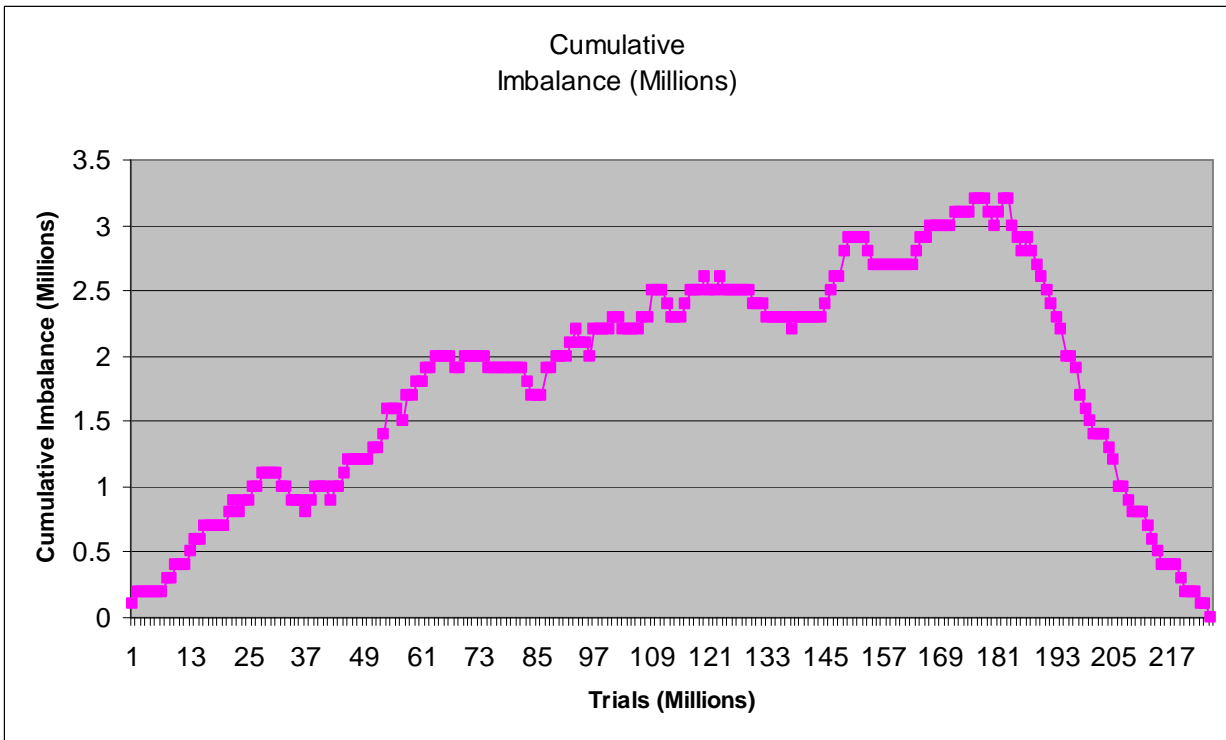
**Figure 1** – Indication that the accumulation of imbalance has an overall direction till it reaches a peak and reverses the direction at the peak. Duration in same direction is 94.88%

**5 runs of this experiment were concatenated to make it comparable with Marissa Giustina’s experiment in terms of volume. Even after concatenation, the number of a1b1 trials in this experiment is ~1/4<sup>th</sup> of that in the other experiment. But the probability of ++ in this experiment is 3 times that of the other experiment, therefore, in terms of total outcomes, the two experiments are comparable. Total number of ++ outcomes in the two experiments is 107373 and 141439 respectively, which are comparable in order of magnitude. If we take a single run from this experiment, that has ~20000 ++ outcomes which is not comparable in volume and is not large enough to show the observation.**

$P_{++}$  ratio between the two experiments =  $6191/2087 = 2.966$

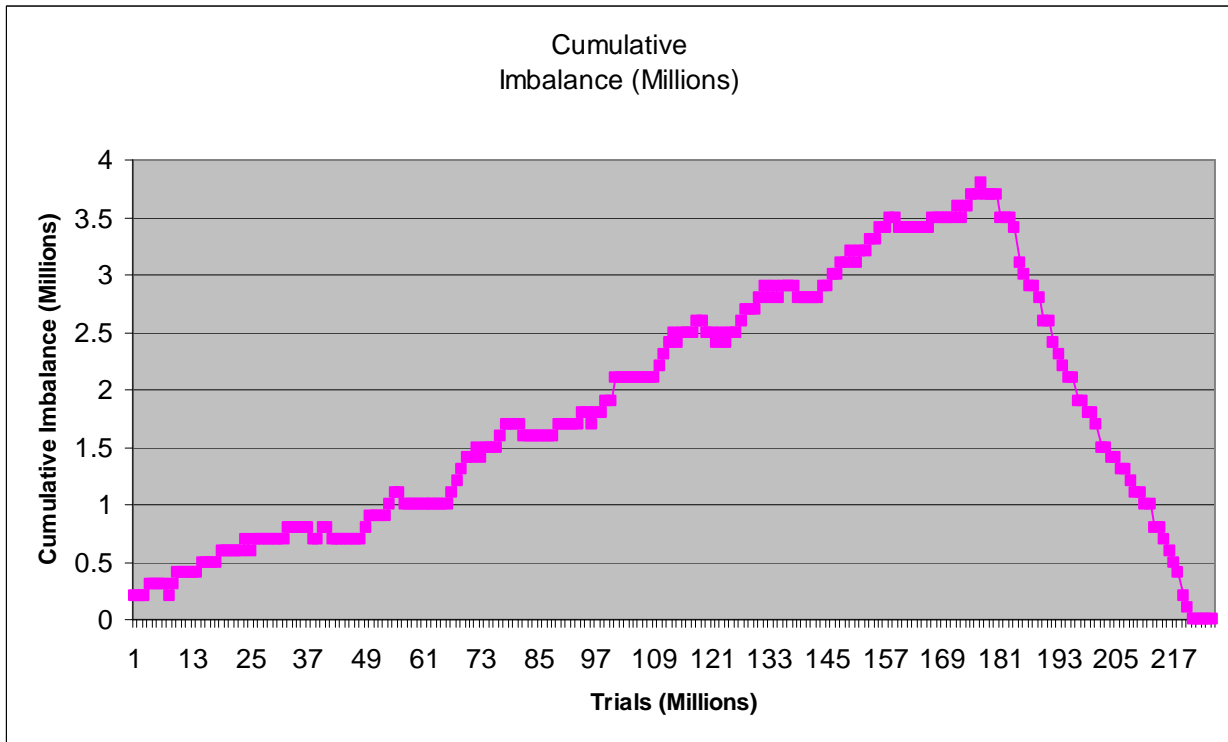
Total ++ trials ratio between the two experiments =  $224166329/ 875683790 = .2559$

Trend of accumulated imbalance (a1b2) trials (Total imbalance never (negligible) went below zero).  $P+0(a1b2) = 1/4517.04$



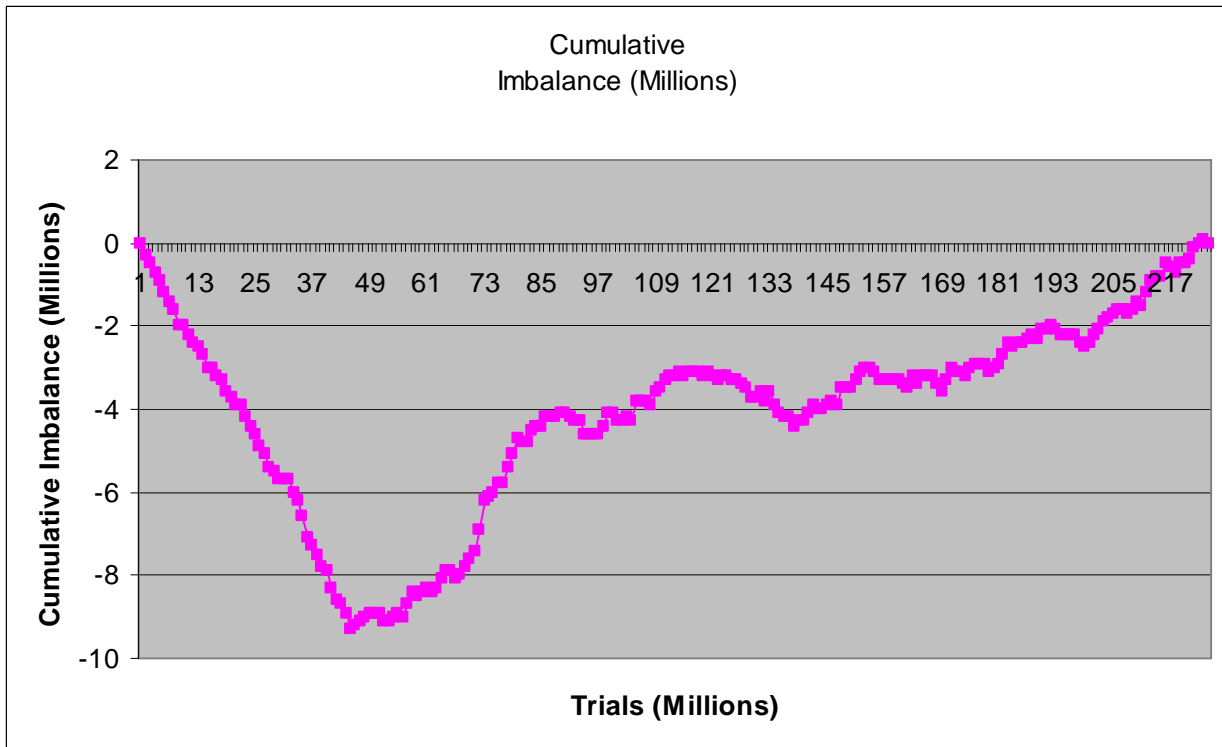
**Figure 2** – Indication that the accumulation of imbalance has an overall direction till it reaches a peak and reverses the direction at the peak. Duration in same direction is 99.84%

Trend of accumulated imbalance (a2b1) trials (Total imbalance never (negligible) went below zero).  $P0+(a2b1) = 1/4326.74$



**Figure 3** – Indication that the accumulation of imbalance has an overall direction till it reaches a peak and reverses the direction at the peak. Duration in same direction is 98.28%

Trend of accumulated imbalance (a2b2) trials (Total imbalance never (negligible) went below zero).  $P_{++}(a2b2) = 1/26642.07$



**Figure 4** – Indication that the accumulation of imbalance has an overall direction till it reaches a peak and reverses the direction at the peak. Duration in same direction is 99.65%

**Points to be noted -**

1. Graphs show most or all accumulated balance in just one direction.
2. Even though the peak accumulation of bias is within 4% in terms of average, but it is a consistent build-up in all 4 setups and, it can be just strong enough to tilt the balance at the time. Up to 4% percent imbalance accumulation may not be large enough to differentiate from probabilistic distribution, but the consistent direction of cumulated imbalance in all 4 setups is something that would be hard to expect from a truly probabilistic outcome. Probabilistic curves should cross on both sides few times.
3. The possibility of dependent data is not ruled out. Dependent data itself can mean imbalance (or memory) in some form or other.
4. If the trials are found to be (inter-pair) dependent, then dependency itself means imbalance (or memory) in some form or other. So, in that case Bell's inequality should not apply to entanglement correlations. Because in that case, the imbalance steers the averages towards QM predicted value and violation of Bell's inequality is no surprise.

### Simplifying “entanglement” by separating anti correlation and statistical correlation

1. Whole confusion is created by mixing two things and then applying Bell’s inequality on the mix.
2. To understand this, two things need to be separated first – “Bell’s state perfect anti correlation” and “Statistical correlation”.
3. **Bell’s state perfect anti correlation** - This is a direct consequence of conservation laws. Meaning the two particles will have opposite spin in order to conserve angular momentum. They will have opposite spin irrespective of when and where they are measured. This is just like two shoes of a pair being examined at different places. It can not be probabilistic because probability never guaranties an outcome. Anti correlation is a guaranteed outcome, so has to be enforced by a law and not by probability. Hence, it is enforced by conservation law in the form of kind of hidden variables. No communication is necessary, let alone faster than light! Anti correlation has nothing to do with Bell’s inequality.
4. **Statistical correlation** - This is a game of averages and is totally different from anti correlation. It is guided by nature over a period of time by balancing for example, angular momentum. To solve the statistical correlation part of puzzle, the data analysis presented in this paper needs to be used to further scrutinize the locality of entanglement. In this case too, FTL is not necessary. Sub c speeds are sufficient to guide the statistical correlation over the duration of experiment. This is basically conservation laws working over a period of time rather than working instantaneously. So much effort is spent on proving non-locality between particles of same pair. This effort may not be necessary at all. Because, previous measurements can influence subsequent measurements without need of any FTL. This is what needs to be probed.
5. With this partition of anti correlation and statistical correlation, and further’s data analysis, there are good chances that locality of entanglement will be proved.

### Conclusion(s)

1. The observation is very subtle, but due to unidirectional bias **consistent in all four setup combinations**, it indicates a possibility of tilting bias over time. Further research and analysis can help rule in/out any mechanism other than independent probability.
2. The distribution on first look does appear amazingly similar to that of an independent probability, but all four setups having bias in same direction, at majority of the time and then clearing the bias, should call for probing of independence vs. dependence of trials in data from similar experiments.
3. The magnitude of the cumulative imbalance is likely not beyond probabilistic limits. *And that may be the reason that experimentalists never suspected it as anything other than probabilistic. The small magnitude of imbalance can give impression of probabilistic behavior to anyone who does not pay attention to the direction of the imbalance.* Percent durations of the experiment for which the cumulative imbalance stayed in one direction are 94.88, 99.84, 98.28, & 99.65 respectively setups a1b1, a1b2, a2b1 & a2b2. This could be difficult to explain in terms of probability.
4. Until this kind of analysis is not completed on multiple experiments, non-locality of entanglement will remain in doubt.
5. Suspect is some kind of balancing mechanism that guides the experiment over its duration, in order to conserve angular momentum (for example, in case of spin) over duration of experiment.

### References:

1. <http://journals.aps.org/prl/abstract/10.1103/PhysRevLett.115.250402> - NIST experiment from which the data was used for this data distribution analysis.

### Contributions:

1. I sincerely thank Dr. Krister Shalm, & Sae Woo Nam *for making the experimental data available* for this analysis in the form of hdf5 files along with some notes/readme/data key as well as providing help in how to interpret the data.
2. Special thanks to Vijayan Thanasekaran – Helped by writing a base C++ program to extract data from the binary (created from hdf5) data file into a text file for further analysis.



Averages from 7 different runs:

<b>Criteria for all files =&gt; All trials, No stop</b>	11	Alice != 0 & Bob != 0 & Alice == Bob
	12	Alice != 0 & Bob == 0
	21	Alice == 0 & Bob != 0
	22	Alice != 0 & Bob != 0 & Alice == Bob

File Name	Setting	#of Trials	Clicks	Average (actual)	Comments
20150918_03_43	11	26789179	12591	2127.65	<b>Discarded</b> see <b>Red</b> values are way off
20150918_03_43	12	26775145	5759	4649.27	
20150918_03_43	21	26768994	6093	4393.40	
20150918_03_43	22	26776276	<b>152</b>	<b>176159.71</b>	
20150918_19_45	11	45674302	21974	2078.56	<b>Discarded</b> see <b>Red</b> values are way off
20150918_19_45	12	45681090	10170	4491.75	
20150918_19_45	21	45641424	10772	4237.04	
20150918_19_45	22	45663035	<b>330</b>	<b>138372.83</b>	

File Name	Setting	#of Trials	Clicks	Average (actual)	Comments
20150918_21_15	11	44679233	21647	2063.99	Selected for analysis
20150918_21_15	12	44686255	10125	4413.46	
20150918_21_15	21	44678266	10484	4261.57	
20150918_21_15	22	44659286	1321	33807.18	
20150918_22_20	11	44767955	21850	2048.88	Selected for analysis
20150918_22_20	12	44754487	10111	4426.32	
20150918_22_20	21	44739349	10578	4229.47	
20150918_22_20	22	44739767	1879	23810.41	
20150918_23_55	11	44699512	21789	2051.47	Selected for analysis
20150918_23_55	12	44712421	9958	4490.10	
20150918_23_55	21	44694021	10595	4218.41	
20150918_23_55	22	44695375	1675	26683.81	
20150919_00_25	11	44469638	21488	2069.51	Selected for analysis
20150919_00_25	12	44473907	10035	4431.88	
20150919_00_25	21	44463137	10485	4240.64	
20150919_00_25	22	44459074	1707	26045.15	
20150919_02_31	11	45550482	20599	2211.30	Selected for analysis
20150919_02_31	12	45544623	9399	4845.69	
20150919_02_31	21	45533203	9654	4716.51	
20150919_02_31	22	45532907	1829	24894.97	
<b>Above 5 files concatenated in sequence as if it was one big run of 2.5 hours</b>					
201509_ALL_CONCAT	11	224166820	107373	2087.74	Above 5 files concatenated in sequence
201509_ALL_CONCAT	12	224171693	49628	4517.04	
201509_ALL_CONCAT	21	224107976	51796	4326.74	
201509_ALL_CONCAT	22	224086409	8411	26642.07	