On the Mechanism in Bell-test Experiments

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Abstract

This paper is about the mechanism in Bell-test experiments: why it must exist, what it is and how it is discovered.

Concerning the mechanism of Bell experiments it is said that no one has been able to open up the hood of the car and take a look at the engine. But of course that must be possible.

Why a mechanism exists

When an experiment is performed the same way time and time again under equal circumstances and conditions and it shows the same outcomes every time, then there is a pattern caused by a mechanism, even if the outcomes only concern correlations and not the outcomes of the measurements themselves. This occurs in Bell experiments. Even when we don't know or understand the mechanism, it must exist. Especially when there is a theory (Quantum Mechanics) that predicts the (probability-) outcomes. Since the probability outcomes are the same every time, they are not random and they make a pattern. If there wouldn't be a mechanism, (correlation-) outcomes from many experiments would be random and it would be pure coincidence that they make a pattern. It is hard to believe in such a coincidence and every additional experiment makes it harder to believe in.

As long as we don't know the mechanism we can call the cause of the pattern 'superdeterminism', but that only is a word to hide that we don't know the mechanism. The word suggests that a series of random coincidences can occur that yet make a pattern. It suggests that we cannot know he cause of that pattern. It doesn't explain the pattern.

Rules underlie a pattern. We have to find the rules and they must be comprehensible. The entirety of rules and circumstances define the mechanism. The mechanism can be found by a thorough analysis of the experiments.

What the mechanism is

The mechanism in Bell experiments is the division of a vector space in two sub vector spaces. The vector space is divided according to rules and depending on conditions. The rules come from the Principle of Perspective, which will be explained, and the conditions are defined by the set-up of an experiment.

The Bell experiment I have in mind is an experiment in which spin of many pairs of entangled particles is measured. No photons are involved. Entangled particles of a pair are particles with opposite (spin-) properties and they move in opposite directions along a line of motion. Once created the particles do not interact anymore. The particles of each pair are detected by detectors at either side of the source, facing each other. Each detector detects the spin of a particle at a certain setting (a direction). Spin of a particle is represented by a vector. Once a particle is created that vector has a fixed direction in space. Spin detection of a particle means that the component of the vector along

the setting of the detector is compared to that setting. If the component is in the same direction as the setting then the outcome is spin 'up' (+1). If the component is in the opposite direction in respect of the setting then the outcome is spin 'down' (-1). Spin directions of particles of an entangled pair are represented by opposite vectors. At the moment of creation of a pair these vectors are on a line through the source in a random direction. The direction of this line is totally independent of the direction of the line of motion of the particles. The vector lines of all particle pairs that are measured in one experiment, run through the source in random directions which are equally distributed in space. The opposite vectors of all pairs make a spherical vector space. This vector space is divided in two sub spaces by the settings of the detectors. One of those sub spaces contains pairs of opposite vectors (opposite spin directions) that yield combinations of equal outcomes when spin of one particle of a the pair is measured by detector A and spin of the other particle of that pair is measured by detector B. The other sub space contains pairs of opposite vectors that yield combinations of opposite spin outcomes when measured that way. Opposite spin directions of a pair of entangled particles (a pair of opposite vectors) can be considered to be one object.

The Principle of Perspective

The Principle of Perspective is as easy that children can understand it. Yet it has always been overlooked. It is about observing (or detecting, or measuring) an object from different directions. An object can be observed from all possible directions. An observer can observe an object from only one direction / only from his viewpoint. This has nothing to do with time: it is true in every case. Only by two (or more) observers an object can be observed from different directions. Then the observations are different, they are not equal. They are equivalent in the sense that they have equal value to be chosen as reference observation. But as soon as one observation is chosen to be the reference observation (from the reference direction), then the other observation is not equivalent anymore. The observations (pictures, measurement outcomes) then are not only different but also not equivalent. Those outcomes may not be compared to each other. Of course they can be compared but that would be like comparing apples to pears. This occurs in Bell inequalities. Bell inequalities describe the comparison of measurement outcomes from spin detections of pairs of entangled particles that are detected from opposite directions, as observed from one direction (the direction of the reference detector). (See fig.1). This is not allowed unless the detections have been made equal. It is not surprising that these inequalities do not represent the outcomes of Bell experiments.

Fig.1
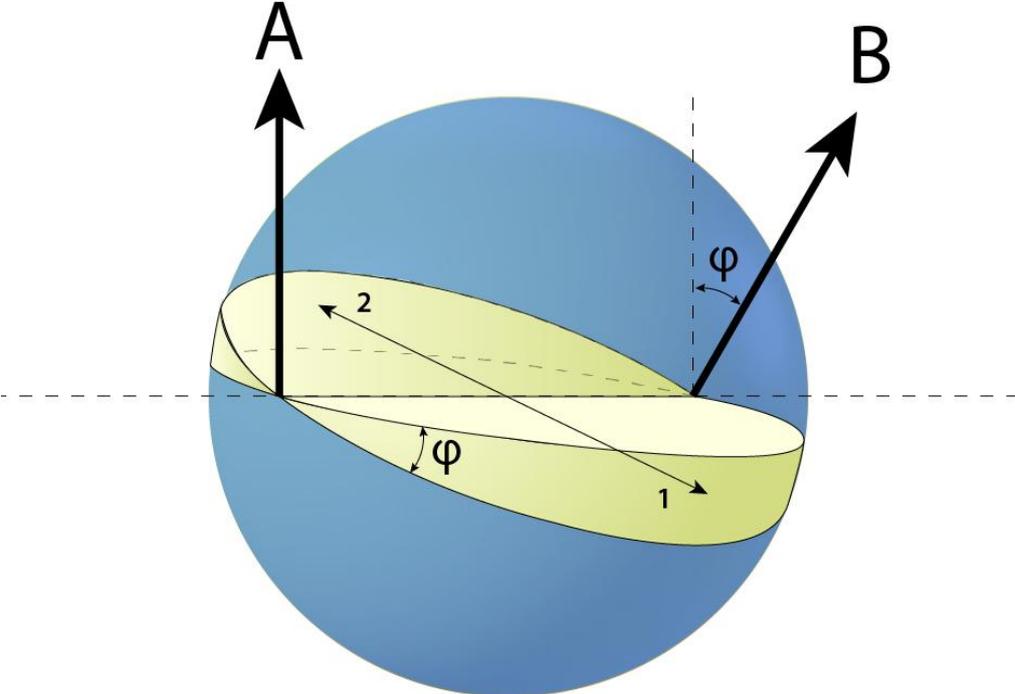
A is setting of detector A, B is setting of detector B (facing towards A), 1 is spin direction of particle 1, detected by A, and 2 is opposite spin direction of particle 2, detected by B (or vice versa).

In this figure the vectors 1 and 2 are in the yellow sub-vector space. It is easy to see that opposite vectors in this sub-space yield combinations of equal spin outcomes and opposite vectors in the blue sub-space yield combinations of opposite spin outcomes. (See fig.2).

Fig.2
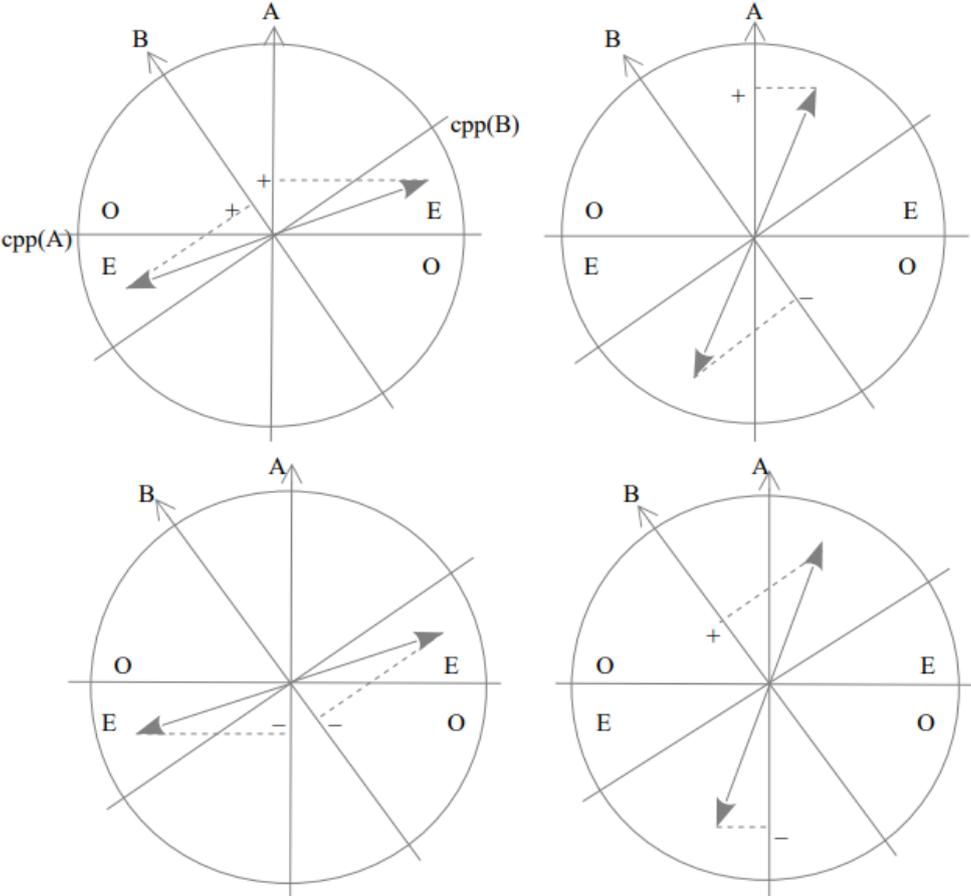
E = yellow sub-space (equal outcomes), O (and empty) = blue sub-space (opposite outcomes)

Now when the vector pairs of all particle pairs that are detected during the run of an experiment are equally distributed in the total vector space, then the number of pairs that yield a combination of equal outcomes, is proportional to the yellow space. The probability for a random pair to yield a combination of equal outcomes then is: $2\omega/2\pi$ $(= \omega/\pi)$ (yellow in diagram 1). The probability for a random pair to yield a combination of opposite outcomes then is: $(\pi - \omega)/\pi$ (blue in the diagram).
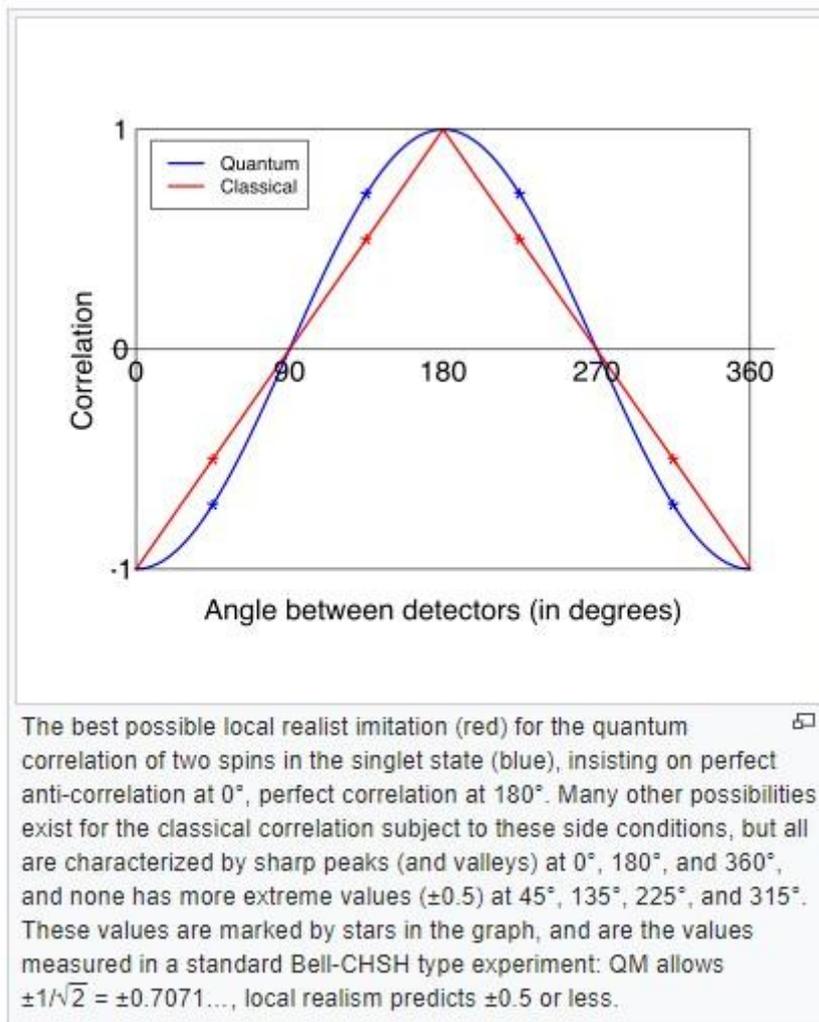
Diagram 1
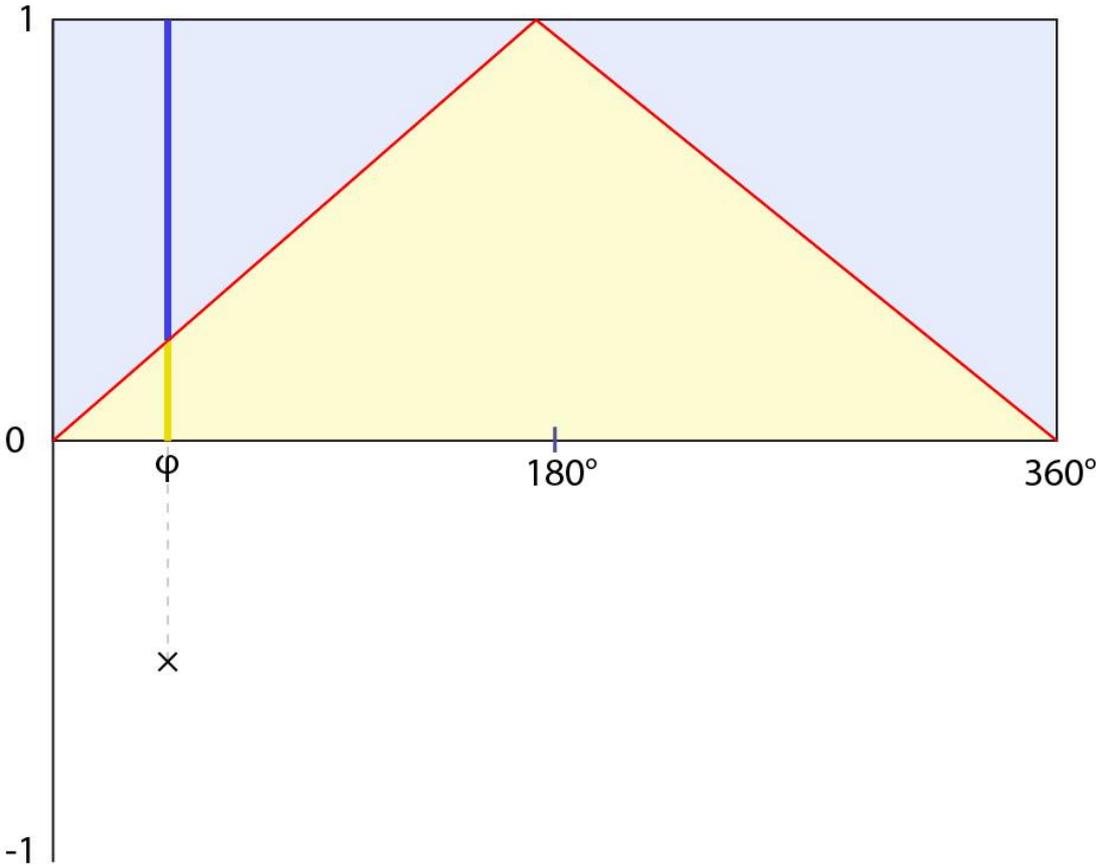
Bell's probabilities (red). Bell's probability function is valid for every arbitrary angle ɷ.

These are Bell's probabilities. Subtracting the blue line from the yellow one yields Bell's correlation for a certain angle (ɷ) between the settings of the detectors (red in the correlation diagram 2).

Diagram 2)

The best possible local realist imitation (red) for the quantum correlation of two spins in the singlet state (blue), insisting on perfect anti-correlation at 0°, perfect correlation at 180°. Many other possibilities exist for the classical correlation subject to these side conditions, but all are characterized by sharp peaks (and valleys) at 0°, 180°, and 360°, and none has more extreme values (±0.5) at 45°, 135°, 225°, and 315°. These values are marked by stars in the graph, and are the values measured in a standard Bell-CHSH type experiment: QM allows $\pm 1/\sqrt{2} = \pm 0.7071...$, local realism predicts ±0.5 or less.

Source: Wikipedia

However, since the detectors A and B do not detect in the same direction, but oppositely, the outcomes of their detections may not be compared and described as above. First the detections have to be made equal. That is easy to perform.
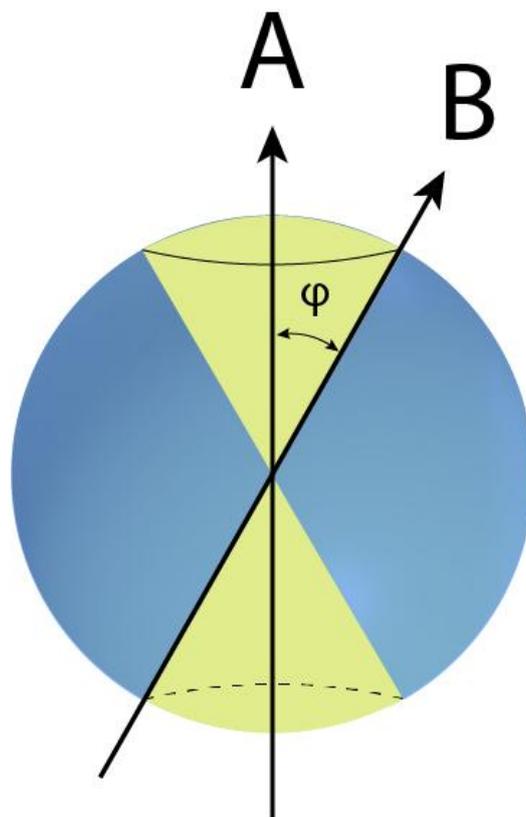
Equalizing the detections

Detections are equal when performed from one point of view. So we put detector B at the position of detector A. Of course B cannot detect particle 2 from this position, so B has to move over to the position opposite of A. We now only have to move vector 2 along with B, in the same rotation. In this way the detection of vector 2 by detector B is equal to the detection of vector 1 by detector A. Of course the, in respect of A, rotated vector is not the same as the original vector 2 in respect of A, but it indeed is the vector that is equally observed by B as the opposite vector of vector 1. This makes the detections of A and B equal. To detector B the equally detected opposite vector 2 is the rotated one, not the original one. Only the outcomes of these detections may be compared.

Comparison of the outcomes

Comparing the wrong outcomes gives a wrong correlation of course. To obtain Bell's inequalities the wrong measurement outcomes are used because the outcomes were not equally obtained. Those outcomes were described from one direction, but detected from two directions, without making the detections equal. That is not allowed.

But even comparing correct (equal) measurement outcomes doesn't tell anything about the correlation in advance. One has to know which of the pairs of entangled particles gives a combination of equal outcomes at a certain relative angle of settings of the detectors. This means that we have to know which of the pairs with their opposite vectors in what vector sub-space yield a combination of equal spin outcomes. I have to admit I found that out by trial and error, but on hindsight it is perfectly logic and comprehensible. One of the rules of the Principle of Perspective is that all rotations by the detectors in respect of themselves and in respect of the object has to be taken into account. That is in itself a comprehensible rule. This makes everything clear. The movement of the setting of one detector around the other carves out a sub-space in the spherical vector space in the shape of two cones oppositely positioned in each other's extension. (See fig.2).

Fig.2

This hourglass shaped sub-space contains all opposite vector pairs from particle pairs that yield

combinations of equal spin outcomes. The real position of these sub-spaces is found by inversing the rotations of the detectors in respect of the object. In the set-up of an experiment the detectors have to be placed perpendicular onto the line of motion of the particles in order to be able to detect the particles. Actually this means that the setting of each detector starts at the line of motion and rotates 90° in whatever direction. Inversing this rotation means that the double cone shaped sub-space gets the line of motion (which is the horizontal line through the centre of the sphere) as its central axis. In this way the pairs of entangled particles yielding a combination of equal spin outcomes, are defined. (See fig.3).

Fig.3
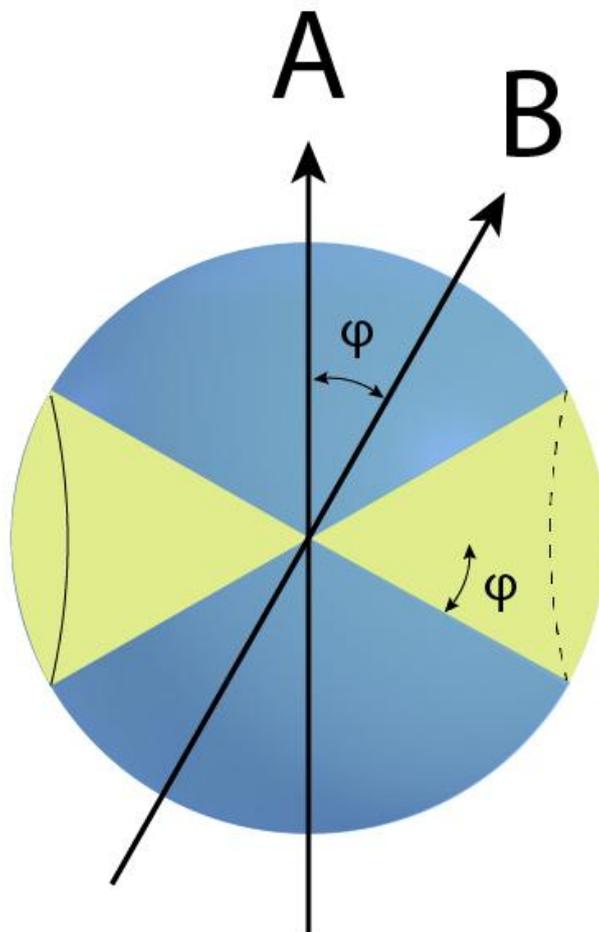
The number of the pairs having their opposite spin directions in these sub-spaces correspond exactly to QM's probabilities: $\sin^2(\phi/2)$. The ratio of the volume of the sub-space to the volume of the total vector space (a sphere) is this same number:$\sin^2(\phi/2)$. Since the opposite spin directions of all pairs of entangled particles are equally distributed in space, these numbers correspond. A computer program producing random opposite vector pairs that counts the pairs in those sub-spaces shows

exactly these numbers. (Program 3 in reference 1] calculates those numbers for ω = 0 to 360° in steps of 15°).

Having described the spin measurement outcomes as obtained from equal detections, the numbers of equal and opposite outcomes show exactly the by QM calculated correlation to the relative angle between the settings of the detectors.

Observed from one direction an opposite pair of vectors that yield a combination of equal outcomes, finds itself in the two opposite cones. Observed and equalized from two directions that pair finds itself in one of the cones.

Of course the remaining sub-space contains all opposite spin directions (vectors) of the particle pairs that yield combinations of opposite spin outcomes. The probability for a pair to belong to that sub-space is $1 - \sin^2(\omega/2) = \cos^2(\omega/2)$. (See diagram 3).

Diagram 3
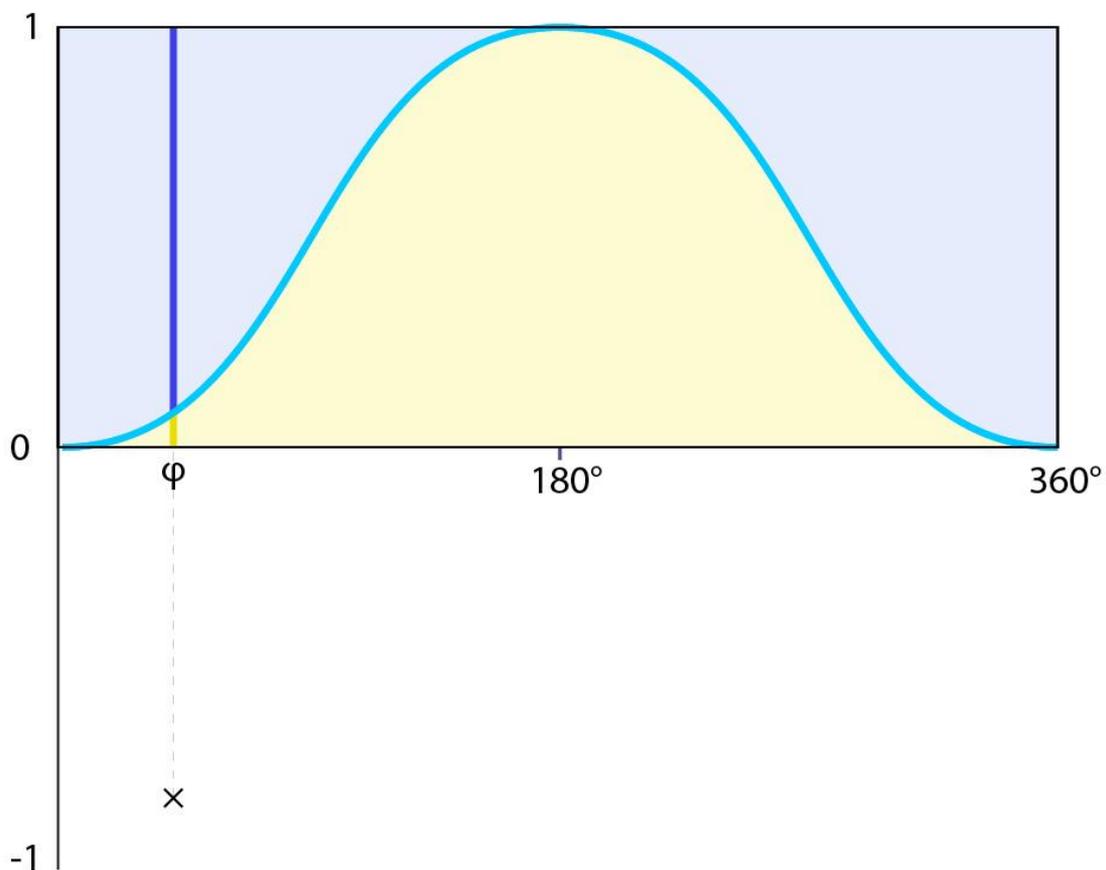
QM's probabilities. Subtracting in diagram 3 the blue line from the yellow line gives QM's correlation as represented (blue) in diagram 2. This goes for every arbitrary angle ω.

The mechanism

So this is the mechanism in Bell-test experiments: the division of a spherical vector space in two, complementary and supplementary, sub-spaces, defined by the rules of the Principle of Perspective and the conditions of the set-up of the experiment. One of the sub-spaces (yellow) contains the opposite spin directions (vectors) from particle pairs that yield equal spin outcomes, and the other (the blue one) contains the opposite spin directions from the particle pairs that yield opposite spin outcomes. The volumes of the sub-spaces in respect to the total vector space correspond to QM's probabilities for the concerning pairs that yield a certain combination of outcomes (equal or opposite).

The rules of the Principle of Perspective are:

1) One observer can observe an object from only one direction;
2) Observations of an object from different directions cannot be compared to each other unless they have been made equal;
3) Observations of an object from different directions can be made equal by taking into account all rotations of the observers in respect of each other and in respect of the object.

The mechanism is extensively explained in reference 1], including visualisations and computer programs to support the validity of the mechanism, a computer program calculating Bell's probabilities as well as computer programs calculating QM's probabilities.

Conclusion

Correlation in Bell-test experiments can be explained classically, local-real, from opposite spin of entangled particles. This explanation makes entanglement (opposite spin) totally in agreement to conservation laws. There is no interaction between entangled particles once they have been created, no supernatural or superluminal exchange between them.

Reference:

1] Gerard van der Ham;   On the Principle of Perspective   https://bell-game-challenge.vercel.app/