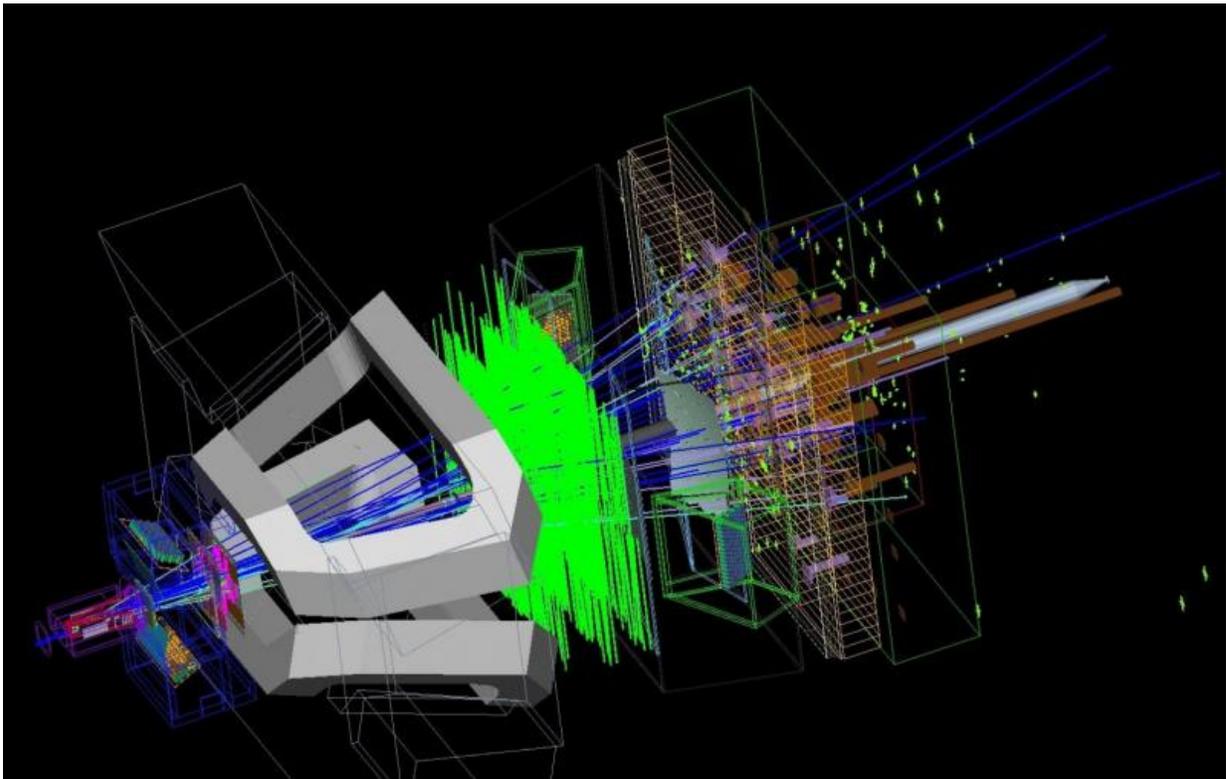


# Is this the trailer for the upcoming LHC blockbuster?

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R. Aaij et al. Angular analysis of the  $B^0 \rightarrow K^{*0} \mu^+ \mu^-$  decay using  $3 \text{ fb}^{-1}$  of integrated luminosity, *Journal of High Energy Physics* (2016). DOI: 10.1007/JHEP02(2016)104 This is a computer simulation of rare decay of Bs meson to J/psi and phi mesons in LHCb detector at CERN. Credit: CERN

In light of the latest analysis on the decay of beauty mesons, the dawn of

a 'new physics', may be approaching. An important contribution to the analysis has been made by physicists from the Institute of Nuclear Physics of the Polish Academy of Sciences (IFJ PAN).

There are some indications that physicists working at the LHC accelerator at the European Organization for Nuclear Research (CERN) near Geneva are on the verge of physics beyond the current theory describing the structure of matter. It emerges from the latest analysis of data collected by the LHCb experiment in 2011 and 2012. Physicists from the Institute of Nuclear Physics of the Polish Academy of Sciences (IFJ PAN) in Kraków, Poland, have made an important contribution to the analysis.

"To put it in terms of the cinema, where we once only had a few leaked scenes from an much-anticipated blockbuster, the LHC has finally treated fans to the first real trailer," says Prof. Mariusz Witek (IFJ PAN).

The Standard Model, a theoretical framework formulated in the 1970s, describes the structure of matter on the scale of elementary particles. Particles we now considered to be elementary play various roles. Bosons are carriers of forces; photons are related to electromagnetic interactions; eight types of gluons are responsible for strong interactions; and  $W^+$ ,  $W^-$  and  $Z^0$  bosons mediate weak interactions. Matter is formed by particles called fermions, which are divided into quarks and leptons. In the Standard Model, there are six types of quarks (down, up, strange, charm, top and bottom) and six types of leptons (electrons, muons, taons and their three corresponding neutrinos) as well as 12 antiparticles associated with them. The recently discovered Higgs boson provides all particles except the gluons and photons with mass.

"Up to now, all measurements match the predictions of the Standard Model. However, we know that the Standard Model cannot explain all

the features of the universe. It doesn't predict the masses of particles or tell us why fermions are organized in three families. How did the dominance of matter over antimatter in the universe come about? What is dark matter? Those questions remain unanswered. What's more, the force we all experience every day, gravity, isn't even included in the model," says Prof. Witek.

So far, the scientists working at the LHC have concentrated on the search for the Higgs boson (the ATLAS and CMS experiments), working out the differences between matter and antimatter (the LHCb experiment) and testing quark-gluon plasma (the ALICE experiment). Now, attention has turned to detecting new elementary particles beyond the Standard Model. The ATLAS and CMS experiments are trying to see such particles directly. However, it cannot be ruled out that the mass of the new particles is just too high to be produced at the energies of the LHC accelerator. Then the only way of discovering new physics would be to observe the influence of new particles on phenomena at lower energies. Such influence might manifest from modifying the frequency of the decay of beauty mesons or the angular distributions of their decay products.

In 2011, shortly after gathering the first large samples by the LHCb experiment, a puzzling anomaly regarding the beauty meson was noticed and announced on public site of LHCb (<http://lhcb-public.web.cern.ch/lhcb-public/>). These mesons are composed of a light quark, found in protons and neutrons that form matter, as well as a heavy beauty antiquark, which can be created in the LHC collider. The particles, made up of pairs of quark-antiquark, are unstable, so they decay rapidly.

An anomaly was observed in the decay of a B meson containing two muons among its products. Describing the final state of this decay requires up to eight parameters that define the angular distribution of

decay products—that is, at what angles they will be flying. The traditional method of determining these parameters can produce false results for the small number of such decays observed. Dr. Marcin Chrzaszcz from IFJ PAN, one of the main authors of the analysis, proposed an alternative method in which each parameter was determined independently of the others.

"My approach can be likened to determining the year when a family portrait was taken. Rather than looking at the whole picture, it is better to analyze each person individually and from that perspective try to work out the year the portrait was taken," explains Dr. Chrzaszcz.

The latest analysis is important not only for its accuracy. The results of data from 2011 have been confirmed by data from 2012. This increases the likelihood that physicists have encountered a genuine phenomenon rather than unforeseen artifact of the measurement.

"While searching for new phenomena or new particles, it is assumed that when the effect differs from prediction of a given theory by more than three standard deviations—3 sigma—that is an indication. But we cannot talk of a discovery until the rate of accuracy rises to above 5 sigma. To put it slightly differently, 5 sigma means that we have a probability of less than one to 3.5 million that random fluctuations can provide a result like that seen. At the presently observed number of such decays, the accuracy of our analysis has reached a deviation of 3.7 sigma. So we still cannot make claims of a discovery, but we certainly have an interesting clue," says Dr. Chrzaszcz.

What could be the reason for the observed effect? The most popular hypothesis among theorists is the existence of a new intermediate Z-prime boson (Z') involved in the decay of B mesons. It also explains another, slightly weaker effect observed in other decays of B mesons to measure what is called lepton universality. Still, it is not an inconceivable

explanation of the effect in the framework of the Standard Model: perhaps the theoretical calculations do not take into account some important factors affecting the decay mechanism.

The LHC has recently begun another round of colliding protons at higher energy levels, at the end of which physicists will have another batch of data to analyze. Will the new physics then become a reality?

As Prof. Witek sums it up: "Just like it is with a good movie, everybody wonders what's going to happen in the end, and nobody wants to wait for it."

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