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Confirmation of the anomaly observed at LHCb: New Physics or hadronic conspiracy?

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One of the central goals of the Large Hadron Collider (LHC), operating at CERN in Geneva, is to unravel the fundamental theory that lies Beyond the Standard Model or at least grasp some clear evidence of the existence of this theory. The study of the so called `rare' B meson (particles composed by a quark b and anti-quark d) decays is one of the most interesting portals to get access to this fundamental theory. Their natural suppression in the Standard Model (SM) convert them in a perfect tool to search for New Physics (NP), because both SM and NP can compete on the same footing offering possible clear signals.

The LHCb experiment has been designed and optimized to measure decays of B-meson and the study of rare decays is in its core program. In this respect a particularly promising rare decay is the $B^0 \to K^*\mu^+\mu^-$ where the K* decays subsequently into a Kaon and a pion particle. Already in 2013 in a breaking ground effort and going beyond traditional analysis, LHCb presented the result of the first 1fb^-1 data measurement of a complete basis of so called optimized or clean observables (P_i observables), with a large deviation found in the observable named P5'[1] that was called "the anomaly"[2].

The way Nature tells us about the presence of New Physics is by modifying certain quantities, so called Wilson coefficients showing departures from their SM predictions. These coefficients together with their associated operators govern the $B^0 \to K^*\mu^+\mu^-$ decay. However, at the same time Nature makes our life more complicated because in order to distill the information on these Wilson coefficients where NP hides one has to consider all kind of hadronic pollution (interactions of quarks with gluons described by QCD theory) to make sure that what one sees comes from New Physics and not from QCD. The idea of the optimized observables was precisely to remove automatically part of this pollution to focus more clearly on the Wilson coefficients. These observables represent a good compromise between the use of a parametrization to describe the hadronic physics of this decay and the precision in the prediction.

The EW and also the QCD Moriond conferences that are held at Lathuile are some of the most important conferences in High Energy Physics where new advances from experimental and theory side are presented. In this conference, Christoph Langenbruch presented on Friday 20th of March on behalf of the LHCb collaboration in a vibrant seminar the results of the measurement of the angular observables associated to this distribution with 3fb-1 dataset, with several interesting results, first a confirmation of the ``anomaly'' in the observable P5', one of the optimized observables of the basis. And second, and equally important the smoothness of the behaviour of this observable in the whole region of dilepton energy. Moreover, It is important to remark here that without the perseverance and cleverness of the outstanding physicists within LHCb [3] this measurement would have not been possible.

I am indebted with LHCb for allowing me a preview of the measurements a few days before the talk, incidentally the day of my birthday, to perform the analysis in the basis of optimized observables . This work was done in collaboration with Javier Virto (U. Siegen), Lars Hofer (UAB) and Sebastien Descotes-Genon (LPT, Orsay) (see also talk at Moriond QCD). I am also thankful to the organizers of the Moriond Electroweak Conference, and specially Jean-Marie Frere and Jean Orloff, for giving me the opportunity to present the theory interpretation of the new data on this important $B^o \to K^* \mu^+ \mu^-$ decay. It is important to give credit also to other people that played a central role, F. Kruger with whom in 2005 we proposed the first of this optimized observables P1 (called AT2) and D. Becirevic (LPT Orsay) that proposed the observable ATre (renamed P2 by us) that will be key in this research in the short future.

The main outcome of our analysis is that the same pattern we observed in the 2011 data, namely a deviation in one of the Wilson coefficients, so called, C9 is clearly confirmed with the new data in our global analysis with a significance above 4 sigmas. It is important to remark that compared to the 2013 analysis we have included in a systematic way different new contributions to the total theoretical error budget.

Now the final question is if this global analysis showing a 4 sigma deviation with respect to the SM hypothesis can be attributed to New Physics or to a conspiracy of hadronic effects. So what's next? It is our next goal to design a systematic method to disentangle a global effect coming from NP from a local effect originating in an hadronic effect. From the experimental point of view there is an ongoing effort to approach the measurement from other techniques that may open a new opportunity window in this search in another fundamental observable called P2. So stay tuned on this observable that can provide an internal test of the anomaly of P5' in a completely different region. The combination of the two efforts will make particularly interesting the next few months.

If the NP interpretation is clearly confirmed the next step will be what model. Already in 2013 we found that a class of existing models (Z') could explain these deviations, as long as they could accommodate other flavour data. If it is not NP it means that there is something very interesting to learn about charm or non-perturbative physics possibly, that generates a huge unknown contribution. In any case we have an exciting challenge in front of us.

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[1] The name and the observable P5' was proposed in our work JHEP 1301 (2013) 048, "Implications from clean observables for the binned analysis of $B^o \to K^* \mu^+ \mu^-$ at large-recoil"
What is the origin of this name? The answer is simple the P stands for primary observable (like the primary colors from which you get anything). 5 because it is related to the 5th term of the distribution and prime because it is an optimized version of our previous observable P5.

[2] The name ``anomaly" was first introduced in our paper Phys.Rev. D88 (2013) 7, 074002, "Understanding the $B^o \to K^* \mu^+ \mu^-$ Anomaly".

[3] Contact authors of the experimental analysis are: Nicola Serra, Konstantinos A. Petridis and Christoph Langenbruch.

* Also at the same conference after my talk another talk was presented by David Straub & collaborators that did an independent analysis showing a nice agreement with our results using different method and observables. This is an important cross check that the result does not depend much on over emphasized details.