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TITLE: The Eighth Annual Large Hadron Collider Physics Conference

Plenary VIII - Flavour Physics

DATE: 29th May 2020

NUMBER OF SPEAKERS: 10 Speakers

TRANSCRIPT STYLE: Intelligent Verbatim

FILE DURATION: 162 Minutes

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W: Okay, thank you. Thanks for the introduction. Thanks for the invitation to give this talk about the flavour theory overview. It's a pleasure to give this talk. I like to start these talks by looking broadly at the standard model. What you see on the slide is the sketch of the standard model. You can see often on T-shirts. And even so, it was the discovery that the stand arrested model is complete and we understand everything. It's actually not the case. Nearly all the terms are connected with one issue or a problem or a puzzle. And many of these puzzles and issues are things we are trying to understand and when you have these topics, of course, they are discussed in this conference here. I will focus on the talk on the flavour part of the standard model and of new physics. In the stand ad model flavour is connected to the couplings of the Higgs Boson. In some sense flavour physics in the standard model is Higgs physics. It's how it couples to the firmion and how the various masses and mixing are firmed. It's about the flavour parcels, the question of why these couplings have a peculiar structure, where it's hierarchical by the masses of the firmions spend many orders of mag any you'd and the mixing of quarks.

Beyond the stand ad model, in the field theory expansion and new physics scale squared, we get neutrino masses and all kind of additional effective interactions which describe the effects of new physics and many of these effective interactions combine with flavour and can lead to very interesting effects in low energy flavour. So the question, the two basic questions that flavour physics tries to address is on the one hand, in the context of the standard model to get an understanding of where the hierarchy of the stand ad model masses and mixing angles come from. So what sets these patterns in the sources of flavour which are the couplings. The second question is are there other sources of flavour relation beyond the stand ad model. Is there something in new physics, is there something that we can discover through low energy flavour change prog assesses? If you look at flavour changing processes. There are two classes. Charge current processes or things that change from down a type quark to an up type. We have a P quark, and a W change proportion to the metrics almost.

And then there are also flavour changing currents which arise at the loop level. We don't have a direct transition from a B quark to a transition model. We have to take a detour to the up section to do through loops. Here's an example of B to Smu transition that plays an important role later. And the relevant amplitude, suppressed by factors and small metric elements. To use those types of processes to look for new physics is following the basic ideas that one, on the one hand measures these transitions with high accuracy. So for example in the B to S mu case one can measure the rate, one can measure Angolan distribution, test lepton flavour universality. And there one calculates the observables in the standard model as precisely as possible and one compares those two things. If they agree then one can set constraints on possible new physics contributions that could enter these processes. If one finds a discrepancy between measurement and standard model prediction, we attribute it to a new physics effect and we could get information on the new physics coupling and scale that would correspond to such a discrepancy.

I think it's a very important point that I would like to stress, if you see discrepancies, we see normally in flavour observables. If the measurements in the reach agree, what you can do is establish a new scale in particle physics to get information about which new scales could be out there. And I think this is something that which cannot be overemphasised that this would have incredible implications, so having a new scale in particle physics would be really amazing. That would give us a target for exploring directly than with future colliders. So having a new scale in particle physics would be a really important thing in the future. Before going into the various anomalies that are out there, at the moment, let me give a brief summary of the metrics that we need in order to make precise standard model predictions. You all know the Wolfenstein pram tiesation. -- per amateurisation. You see the various constraints coming from all kinds of measurements which consistently intersection at the apex of the unitary triangle. Here are the latest results: They are known with pretty good precision over all the other very good agreement between all the various measurements that go into the fits, apart from subtensions which have to do with different determinations of the elements.

Overall we see agreement is very good at the level of 10% or so. One thing I would like to point out here is a recent development on the series side. That has to do with the parameter epsalomK a violation in Kaon mixing. It's hard to prediction from the series side. What I find amazing is that recently it has been found that by re-arranging the calculations that one does, one can significantly improve the predictive uncertainty in epsalomK. If we take a clever rearrange, they were able to reduce the uncertainty by a factor of three. That is now shown here. The largest part now is a parametric uncertainty. So things like particular metrics element. There's a part that is not perturbative. This uncertainty used to be much larger, factor three larger and was dominating. But these reduce that per turntive uncertainty. Now it's less than a quarter of the uncertainty, of the full uncertainty. This has important impact on this global fit of the CKM metrics. This can be illustrated in this: You see the constraint, the green band here. This is using the old theory treatment. If you use the new theory treatment you see a drastic improvement on the width of this band here.

So you get much better control over epsalomK and it has a bigger impact on the global fit of the metrics. OK, that was what I wanted to say about the CKM metrics. Now let's move to the B physics anomalies that have been around for several years. When we talk about these anomalies, they are related to decays. In order to make predictions for hadron deck yay, it needs non-perturbative input, form factors, sometimes non-factorisable effects. Those quantities are difficult to determine precisely. There's often large uncertainties which are related to those effects. One clever way to reduce or almost completely eliminate hadronic uncertainties, lepton flavour universality. The two famous classes are the RD star and RK star, ratios of branching fractions as you see here: One tests the lepton flavour universality. In charged current decays and the other in neutral current decays. Starting with RK and RK star. Here is a summary of the situation, the measurements that exist. These are the most precise and the values of RK and star are quoted here. For RK there's: All those three measurements they deviate by 2-2.5 # from the standard model prediction.

With a high precision. Expect in the standard model these ratios to be one. But the measurements are significantly lower in all those three bits. Also I wanted to mention this recently it showed a measurement of such a lepton flavour ratio in barrionic case. It has still somewhat large uncertainty. So it's compatible with the standard model which is one. But also with the lower values that are seen in RK and star. OK, so, if one interpreters all these divisions from the standard model expectation as a new physics effect, then what the standard way to analyse this effect is by doing so-called model independent physics analysis. One introduces the most general type of effective interactions that could contribute to B to S transitions and one checks which of those interactions could possibly modify RK and RK star and lead to a better agreement with the data. It turns out that this so-called semi-leptonic operators here, they are the ones which can lead to a good agreement with the observable RK and RK star. These are the coefficients, modify the B to S decays and which can lead to a series of predictions which agrees with observation.

And one example of a fit that people are doing is shown here: In principle you have several options. You can suppress the rate into muons with a combination of couplings or enhance the rate into electrons with a different combination of couplings. Depending on what you do, you get different quality of the fit but overall when you switch on these couplings you get improvement which is back to the standard model by three-and-a-half signals. There are many groups who do such type of fit and general good agreement between the results of the various groups. It's interesting that you can find new physics explanation of RK and RK star, what's more interesting, in addition to explaining RK and RK star, this type of new physics effects, they can actually also explain a large set of other discrepancies that are observed in B to S transitions. In particular if one looks at absolute branching fractions of B to s transitions one finds the measurements of those fractions don't agree with the standard model predictions very well. There are Annam Liz in the angular distributions in the B to S transitions. The P5 prime and related observers which also show some discrepancies.

If you try to explain RK and RK star with new physics and the B to Smu transition, you explain all these other anomalies out there. This turns out to be a very consistent picture of what is shown in the plot here. When you switch on the new physics effect in C9 and in C10, the blue band is the one that is preferred by RK and RK star. This orange blob here is the region preferred by the other anomalies. They're nicely compatible. It's very interesting that you can describe all of those anomalies by new physics with muons. You only need to introduce one interaction, efficient to get a good fit and you keep the final state electron standard model. That's an intriguing thing that in one new physics interaction you can explain a large set of anomalies in a consistent way simultaneously. We can ask which scale of new physics that applies and what one finds is that the scale of new physics can range from a few hundreds of Tev to around 100TeV depending on what you assume about the coupling. Depending if you assume that maybe there's loop suppression or maybe you crank the coupling up to four pi new physics has to be somewhere in this range of scales in order to be able to explain RK and RK star it gives an upper bound on where new physics has to be in order to be responsible for the anomalies.

This gives a target for further explanation and future collides. If you look for concrete model that is my favourite one, if you have seen me giving talks about the anomalies you have seen this before. The C prime gauge Boson which likes to couple to muons and has flavour changing coupling, this does exactly what it's supposed to do. It generates an effect in the C9 coefficient and it can explain the anomalies. Let me stress though that actually when we first wrote this paper there were no measurement of RK and RK star, so we proposed this model not to explain RK and RK star, we had a prediction for lepton flavour in this paper, which is pretty close to what has later been seen. Let's move onto RD and RD star. This is shown is the summary of the situation from the heavy flavour averaging group. There is some tension between the Babar measurement and the latest Pell measurement, -- Belle measurement. If you do an average of the measurements you end up with the red here. Which is something like three Sigma away from the standard model prediction. And also this anomaly now in RD and RD star has sparked out of interest and one tries to understand if they are consistent new physics explanation.

When one does the same exercise as before in the case of the B to S transition one considers all the possible effective interaction that's could contribute to these no charge current case, it would be to charge new transitions. Indeed one finds that it is possible to explain the data with new physics. In particular what turned out that rescaling the operator, the interaction that exists in the model actually lead to a very good fit of the data, somewhere in the plot, in the best fit point. But they can also find combinations of operators which lead to reasonable results for RD and RD star. Again if you ask about the scale of the new physics that could be responsible for that, you find now scales between a few hundred dread Tev. And for that you need to put the uncouplings to uncomfortably large values. EnEricically you don't expect new physics that explain RD and RD star to be a few TeV or so. That's a pretty low scale. But it is already probed directly at this, indeed model building for RD and RD star is much less trivial than for RK and RK star. You have to deal with the new states at pretty low energies. There are many constraints on new physics at TeV scales.

Model building is not triyell in that case. There are many examples of models that people constructed to explain RD and RD star. Even more they are attempts to explain all of these anomalies simultaneously. The Boson one and the neutral one and the charge currents. If do you that in a model EFT approach to the standard model effective series you can switch on two effective interactions to operators, which give a very remarkable good fit to the data, that you need one operator that tries to put new physics into RD and RD star and another which puts new physics into RK and RK star and then at the same time, you also explain all the other B to S anomalies. Everything fits together. So it's a two parameter fit of new physics which consistently describes a dozen of two to three Sigma anomalies. The fact that it works is pretty remarkable. If you try to find the completion of these effective interactions you are led to lepton quarks. They are pretty exotic objects. One would like to find some more complete description of them that's been found that the leptoquarks that are required to get this effective interactions can be embedded into extended gauge groups.

They can be remnants of extended gauge groups. So-called 4321 models that have been proposed. And we had a nice talk on Tuesday on the flavour parallel session about these models. They also attempt with RPV SUSY, where some of the superpartners of the standard model firmian can act as leptoquarks. For the rest of the talk I want to talk about rare Kaon decays. There has been some excitement in the last few months. First start with a quick review of the standard model prediction for rare Kaon decays. They can be predicted with this very high theoretical accuracy in the standard model, though these uncertainties that are shown in the standard model predictions they are almost entirely parametric. The CKM metric elements are responsible for these uncertainties. Theory uncertainties are very small in those decays. Another interesting aspect is that there is the Grossman-Nir bound that says in the standard model and in any scenario with heavy new physics there has to be this relaunch between the branching ratios. This is pretty robust bound in many new physics extensions of the standard model.

Now there are experienced NA62 and KOTO currently searching for this case. NA62 is looking for K plus. And KOTO is looking for the other one. The situation there, NA62 is starting to see events. So they expect to reach standard model activity very soon. The current recite is here: The central value is slightly below the standard model prediction. There are large uncertainties. Compatible with zero and the standard model prediction. And the bound obtained at NA62 is getting close to the standard model prediction. KOTO also saw recent events in the signal region. And they don't expect to see standard model events yet. That was a surprise. It sparked the interest of theorists. What is shown here is this number, a theorist estimation of what this could be. It's almost two orders of magnitude above the standard model prediction. Let me stress that this is not an official KOTO number. That is just a series estimate. There should be a warning here that we should take that with a grain of salt. The rest of the talk, the last few minutes that I am going to spend on this anomaly is something that is very speculative.

If you buy into that number, if you say, you take this number at face value, then it means it seems to be exceeding the standard model rate by almost two orders of magnitude and it's incompatible with the Grossman-Nir bound. You can see it here: These two numbers combined you end up here, far above the Grossman-Nir bound. What could that even mean? I mention that Grossman-Nir bound is in models, so what's going on there. It has been found already some time ago that the Grossman-Nir bound can be avoided in the presence of light new states. Because that gives the possibility to play with kinematics. The simplest example that points to Grossman-Nir bound is very simple. It's just you need to introduce a light, long lived new physics particle. You can have both K plus to. NA62 searching directly for such a process. It has a blind spot for an x particle which has a mass close to the pi on mass. It is shown here: Around here the mass of 130Mu there are no constraints. KOTO doesn't have the blind spot. It could be there is a K to pi x decay that can be seen at KOTO but not NA62.

The fact that something like that is possible, speculation from the series in the last few months about a possible new physics origin of the KOTO events, one other example that I want to mention is illustrated here: You introduce not only one new physics particle, but two. Two neutral light particles S and P. And you introduce couplings that the following two decays are possible: If the P particle is stable or long lived on the vector scales it can leave the detector and basically mimic the signature of the neutrinos and you end up in KOTO with the Kaon to pi zero pp. This corresponding chain does not exist for charged Kaon. It cannot decay into SP because S and P are electrically neutral. That example of a model where you don't need to take advantage of this blind spot of NA62. Can you just have a situation where only the Kaon to pi zero decay is open but there's no necessarily K plus to pi plus decay. This P in that case can be a natural mathematic and it can understand how this is produced. The natural thing to do is produce it through freeze in with a low reheating temperature. OK, that's all I had.

Here's my summary: Flavour physics provides an indirect way to probe new physics, complementary to direct searches. We have a few anomalies out there at the moment. The B anomalies are well established. They continue to be out there. If these B anomalies point or are explained by new physics, they point to new physics not too far above the TeV scale, depending on which anomalies you try to explain. Rare Kaon decays can probe light dark sectors. We might have seen already some first hints at the KOTO experiments. Thank you.

FC: **Thank you very much, Wolfgang. I'm sure people have questions or comments. So please raise your virtual hand. And we try to serve by first come, first base. While people - ah, there's a question. OK. Lydia.**

L: Hello. Thank you for the nice talk. I mean the usual question in those B anomalies and the models you are proposing about, I mean theory proposes solutions concerning the prime Bosons, all of the quarks, is a special prime you know, there are searches in LHC which puts them quite importantly. Is it still possible to and compatible with your models?

W: Yes, yes. Absolutely. So there are a few things that we can say about that. First of all, if I go back to this model here. If you take the most minimal setup that is required to explain the B anomalies, the only thing that this needs to do is talk to muons and bottom quarks and straight ones. The couplings can be very small. It's not guaranteed that the Z prime couples appreciably to balance quarks. The production cross-section of the Z prime can be very small. Indeed if you're only taking into account this minimal amount of couplings to explain the B anomalies the production cross-section is so small that probably not with the high luminosity you will see the C prime even if it's only a TeV or so. So, it's not guaranteed that this Z prime gets produced at the LHC. Once you embed the C prime into a more complete structure, then it is likely that it also has couplings to up and down quarks. Then as a question of how strong the constraints actually are and how much of space you can probe. But in its most minimal form, it's very hard to see that thing directly at the LFC.

L: Thank you very much.

FC: **Are there further questions? I would like to ask one about this KOTO explanation that you talked about. You mentioned at the beginning that one motivation to do flavour physics is to learn something about this peculiar structure that we observe. The big question, the origin of flavour. If this KOTO anomaly remains and I mean, stays with us, is this model,**

apparently there's an interesting link you can make. But can you learn anything about flavour from this? Or what's its connection?

W: Yeah that's a good question. People are just starting now to investigate that. So I'm not aware of any work that has been done in this direction. Given that whatever this might be, it needs to have some flavour changing couplings. It needs to be involved with flavour violations or it likely can sled light also on that problem. But I guess that needs more time and more thinking to figure out what the precise connection could be.

FC: Thank you. So, I'm not seeing any more raised hands. Anyway, I think you have the chance to ask the speaker further questions later on. So I suggest to thank the speaker if you have a clap, a button for that. Otherwise I would say we move on to the next talk by Augusto Ceccucci. I think Johannes has the slides. Hi, Augusto. You are reporting on non-LHC flavour physics results. Yes, your slides are there.

AC: Thank you. Thank you very much. Thank you for the invitation for this great opportunity. I'm not sure you're going to get the facts about the KOTO anomaly from my talk. But we can discuss. So, next slide, please. In this talk I'm not trying to be exhaustive and there are entire parts of non-LHC flavour programmes that are not conceded -- considered. Lie pions and other things. Can someone go to the next slide, please. I will ask you to change the slide. Now we are at slide two. Thank you. So there's ...

JA: This is interesting. I move the slide. Let me stop sharing and restart again.

AC: Thank you. Great! Perfect. Thank you very much. I don't have to preach to the choir telling why it is so interesting to study flavour both at the LHC and not at the LHC. As I said before this talk is not pretending to be exhaustic. The pions raise ready not discussed. I will go briefly through legacy data, the ramp up of the super B factory, the set-up of the charm factory. KOTO 62 and the mu programme. Next slide please. OK, concerning the taking as an example the complementarity that exists. And B factors. And on the left side of the slide you can see the advantages of both techniques. HRCb with a huge cross-section that allows you to have very small sensitivities. Excellent proper time resolution. Excellent single event sensitivity for final states with mu pairs. And K rare decays. You have full access to inclusive B decays. Final states neutral particles. Excellent tagging efficiency, full event reconstruction, proper time resolution and calorimetry. The next champion of the non-LHCb is the super B factory. You can monitor the progress in terms of data taking and ramp up. This picture was taken on the right-hand side now, the picture here was taken at the end of April.

So taking data. You can see the yellow line indicates the inStan continuous luminosity. -- instantaneous luminosity. What will be interesting in the future is to look to see how the data will match up with the planned increase of the luminosity. The goal of the superB factory is very ambitious in terms of luminosity. Next slide. So let me briefly show you, I have taken some results from the lake Louise conference . the other winter conference was cancelled. One very important point of a B factory is the performance of the Hadronic tagging, with full event interpretation. The full reconstruction allows you of the tagging side and makes possible to address very challenging channels. And final states between the neutrino pairs. What you see here are examples from Belle two which clearly indicate that the tagging, the full event interpretation works very nicely. You can see that classifiers can be formed to disentangle this. Depending on the purity or efficiency required for specific analysis you can make different cuts emphasising the purity or efficiency. You can see in the four plots constrained mass distributions for B pluses and zeros for different values of this classifier.

On the signal side there's a convincing distribution of inclusive decays with ironic full event interpretation on the top two plots. There's nice signals of and also concerning, so these are all plots that show thaw although the luminosity, integrated luminosity, small on this point like what was accumulated by B factories. All the elements seem to be in place to have a very great programme coming soon. And the B mixing reconstruction of B mixing you see quite a nice figure with parameters in line with the bars. Let me take the first example of where a non-LHC flavour physics takes a positive -- poster child of B factories of the time dependent CP violation, I have to go through the formulas. Please keep in mind that going from one continent to another continent, at times you have to slightly modify the notations. It's a good sign of data. There's nothing wrong with that. For instance: I would like to draw your attention to the average on the right bottom side of the slide, where you can see clearly the averages are still the best results, still come from B factories and these numbers are going to be much improved. Recent results, there was a result presented concerning time dependent CPV violation. This decay is interesting because it's a pure penguin.

It's another way of measuring and to compare with sign 251 that you get, it's a pure penguin and is CP minus one. You can see distributions for differences in energy and for the B constrained mass on the top of the slide. You see convincing CP have a lacings at the bottom. This result based on the full statistics indicates that the result is in line with the expectation of the standard model very nicely. Let's move on. Another aspect of flavour physics, which is addressed by Belle is the D zero mixing. There was a recent result concerning the measurement of ycp minus. By the mixing in the channel of K zero short omega-3 pion. And this is the first, one of the first measurements of ycp minus. The mixing of the zeros is parameterised by x and y. You see them on the formulas. In the standard model one expects X and Y in the order of ten to minus three, ten to minus two. These measurements are usually done looking at the proper distributions and referring them, you see the formula in the case of a CP state. They are made looking relatively to the Kpi proper time distribution. Basically measuring ycp minus looking at the ratio of the lifetime distributions for the K minus pi plus versus K0S omega. And the average is illuminated by. You see the measurement as well.

Why this is interesting is because of an interesting between minus or plus would indicate CP violation. Let me move to the next chapter, lepton universality. I thank you for the previous talk. Here I'm not going to describe the anomalies. I simply would like to say that leptonic decays of flavour masses can be used to determine CKM matrix elements or to test LQCD quantities. Or to test lepton universality by forming ratios comparing final states with different leptons. We have seen RD and RD star as examples. The interest of the three level ratio stems from the fact that the third lepton family is the least studied. Can you form ratios of flavour changing currents. They are interesting because electronic uncertainties drop out and beyond standard model effects can compete with the loop. I will give you a few examples. Next slide please. First example is a B plus to mu plus mu. You see the final diagrams: One is for the standard model and one is for including a charged Higgs or leptoquark. You see the formula for this type of leptonic decay. It's interesting to see that Belle is able by using very nice analysis based on classifiers shown on the right top of the plot.

You can see here that there's 2-point # evidence -- 8 evidence to say of B plus to mu, mu. That is enticing because it means that with the data from the super B factory One Show would be able to make these checks. So this is very nice. Another example I have taken from here: I have written the ratio of tau mu in the standard model. It comes to 2.67. What is shown is a nice analysis where on the tagged side there are six different Huytonic decays of the D minus, which are known on the bottom right plot. The analysis is looking at the decays. There is a measurement of 1.2 ten to minus 3 for the mu decame let's move on to the next slide please. There was an analysis made by the CLOE-2 collaboration, now the factories are nice by crashing them, you have a tagged case zero short. You can constrain the metrics. Like the initial system is completely fine in quantum numbers and kilomattics. What KLOE2 was able to do was make a measurement of the branching ratio. This is the last level to be measured. The KL were variable measured. The KS lepton was measured. What is nice you can start forming ratios here as you see at the bottom of the slide.

Comparing the product: This comparison comes up pretty close to one. Moving to the next, slide number 13. Another type of test of universality I have picked up this one from Babar. The idea is to look at the ratios of partial width which are not affected by hadronic uncertainties. This is based on data collected at epsilon three S. Then they use more data collected to continue and it's another nice check of lepton universality and the only previous result was by CLEO 2007. Let me move on now. I'm now moving to the rare K decays. We have learned everything concerning the theory from Wolfgang in the previous talk. The good point is that indeed we don't have to worry much about the theory. We really have to worry about the experiments, which for an experimenter like me is kind much a dream. So let me just move to the next slide showing you the NA62 experiment at CERN. It's looking for a very small signal. A few months ago, there was a release result based on the 2017 data. The statistics are to be analysed concerning 2018. What you see here in the void is the given that the Kaon is a small mass, the experiment is much longer rather than the transverse side.

And it is basically a I began tick canon with colour remitters and it makes sure nobody escapes except the neutrinos. What you see on the left bottom is distribution of the momentum of the charged particle. Versus the missing mass. And you can see the two boxes, the signal regions against the distribution. The K2pi pi is a so-called blind spot. You see good agreement between data in Monte Carlo concerning the distribution of this monster K2 Pi Pi background, which you must control very well in order to be able to do the measurements. So this was presented in 2019. Basically the 4.7 ten to minus 11 to 6 confidence is based on taking together the three events in 2016 data and one in the 2017 data. That corresponds to putting them together to a limit of 18.5 ten to minus 11. In the 2018 column, I have added the number, which is the expectation of standard model events as reported by recently. For the 2018 data the analysis is in progress, background figure and the box is still blind. All these experiments are done really a blind way. You see the two events here in the top plot. Inside the region 2 .

It let me now just wrap up NA62 showing you the, what has been a long story. This is a classic decay and has been addressed before, for a long time. In 87 and now in flight with NA62, and as was 62 this also helps to improve the limit on the KL Pi zero bar. The analysis of 2018 is in progress. Data taking will resume at LS2. I don't have to add anything here, I will simply say that the reason why this is very nice is this branching ratio is that being a KO minus KO bar and the lineation, the charm component drops out because it's (inaudible) that makes a very precise measurement of the height of the unitary triangle. If you will show the variant, a unique variant of CP violation in the standard model. You can see here the KTO experiment and OK, I am supposed to tell you the facts. I cannot tell you the facts really except to say that there is a robust rows Euro-sceptic upper limit published based on the 2015 data and that the analysis of data of 2016, 2019 is in progress. What I would like to emphasise is this experiment, there's really nothing coming in except a nutra particle. There is a neutrino flying out.

There is assumed to be Pi zero that nighs into photons that you not only have to detect but you have to trust to measure them precisely in order to reconstruct the decay vertex. There's not much to measure in this experiment. It's true that three events were shown but not intended to be shown as a result. But by the status report at the conference. The collaboration is making further checks before submitting for publication. I'm sure we will learn soon about those, about what's happening with KOTO. They plan to have a significant more data taken. In slide 20 I show you educated guesses for experimental prospects. This is the idea, one would like to see measurements made at 10%. And then possibly even better if one would be able to handle more (inaudible) and improve the experiment. Of course, also the KO long there are plans to further improve can KOTO upgrade and there are ideas pursued CERN trying to address the SPS. I don't need to emphasise there's a lot of room to be explored. I will be extremely brief because I'm running out of time. Concerning lepton number and flavour violations. I want to say that Babar using full statistics has been able to by two order of magnitudes on many decays.

You see them in the table. Both for these four particles and for the O2 x0 in Emu. Two order of magnitude improvement. I'd like to flash you the last part of my talk which is about muon tau ready case. There's no standard model here. Neutrino isolations you call them standard model then the prediction is ten to minus 54. You can be safe for a long time. You see here there's a strong programme going forward and there is with mu to E. So electron conversion. Then also concerning tau we see listed what the limits are. You see some of the examples of this very powerful muon programme. Which is going to take form - sorry page 24 now. It's going to be a great problem for the next decade. Which leads many eto the last slide. I'd like to say that address the compelling questions of flavour physics requires dedicated experiments are long time scales. You must insist either on the experimenter and the technique. There are novel techniques, typically at the frontier of the technology. Exploiting unique accelerator complexes. There's still data legacy data from the B factories being exploited.

For the next few years, we should watch luminosity ramp up of superKEKB towards 50atobar. And commissioning of next round of muon experiments. That extends to 2030 and beyond. Thank you very much.

FC: Thank you very much, Augusto. For this great overview of all the things you can do not at the LHC. Raise your hand if you have questions. Yes, Andreas?

A: Yes, thanks a lot. Great talk. Augusto, really very impressive. I have a question where your expert on page 16. I would like to understand how you see the prospects for the background in decay, in NA62 I seem to remember that the background levels were lower in the BNL experiments. Maybe that's wrong.

AC: No, no, I understand. The backgrounds are already lower than in NA62 the backgrounds are lower than BNL. That's not the issue. The backgrounds in NA62 are going to be further reduced because the Kaon let's say in the data analysed so far in NA62 the backgrounds related to Kaon decays in the acceptance, in the volume, were in line with the expectations. But there were additional sources of background. So-called up stream decays, so decays happening upstream than the final. So that they dominate the backgrounds and they lead to a signal background of one to one or two to one. Those can be eliminated. In the data collected from 2021, there's been a gentle resign of the upstream particle and the addition of some vision counters. With that this will sphere. But already now, the signal of a background is significantly better than the experiment.

A: Okay.

AC: The point is in the stop current experiments, one counted it was never colour what is background and not. You end up like statements like seven events, when instead it's not an event. That is a long discussion which is now gone. The point is that it's very clean inflight, once you build such an inflight experiment things are very clear.

A: Okay, so among this 1 at 3 in 2017, how much is the upstream component?

AC: It's 0.9.

A: Oh, good. Thank you. Excellent.

FC: Okay. Do we have more comments? Or questions for Augusto?

JA: I have one question. I'll raise my hand because I'm co-hosting. Sorry. About the fact checking Twitter promised us, but the KOTO events, two small questions. One thing is I understand they have not published. But

even they would publish, it doesn't look very naively it doesn't look overly significant what we see there. Then the next immediate question is what are their prospects to collect more data and is there any expectation from updated publications to learn more?

AC: Yeah, thank you. As I said before, in the case of KOTO you don't have handles. You have to assume that you've got a Pi zero, two objects coming from Pi zero and you use that to extend the vortex. You have to make checks at times, if you think you have made progress, like having identified a new source of background. At times one has to go back and take special runs, like special runs with an increased amount of neutrons to check the interactions of neutrons or different intensities. Check that the blinding effects are not in place. Because these experiments are of a high rate. They can be minded by rate so that you don't see the photons you want to mask. You have to be careful about semi-leptonic events when you have charge exchange. So I think what I can invite you to do is to go to the original presentation and there's been a pretty strong explanation put afterwards, so to say, to give you the right way to interpret those events. Of the KOTO experiment.

JA: Thank you.

AC: Also I agree with you. This is two order of magnitudes above the standard model. So there's a long way to go.

FC: Definitely, it's a very long way. I think we should move on because we are already a bit beyond time. So let's thank Augusto again for his very nice and concise overview on all the things you can do. And we move on to charm physics. I think Johannes wanted to handle this. The speaker is Maurizio Martinelli from Milano. Thank you, welcome. Please go on.

MM: OK. I will share my screen. Do you see the first slide of the talk?

JA: We see the first slide but its not full screen.

M: Now?

JA: Yes. Perfect thanks.

MM: Thank you very much for allowing me to talk about charms physics. Unfortunately this conference, it would have been a pleasure to meet all of new Paris, unfortunately we cannot. Let me start. I have to admit that I will mostly talk about charm physics at the LHCB because my talk is going to focus mostly on mixing and CPV violation and rare decays. About the direction of the experiment I think most of you know about this, but I wanted to highlight a few things important for charm physics. First of all is that not only big quarks but charm quarks are produced at the LHC even in a higher cross-section. Thanks to the very high vertexing efficiency and very good lifetime resolution, and the ip resolution we are able to detect charm quarks as well as B quarks at LHCb. There are, I will introduce you to a couple of production mechanisms that we have to produce charm decays. The first one is the so-called prompt production mechanism. Pi untagged. The two protons collide and instantly produce a star for example. It decays into the Pi and in the magenta. It's a really low momentum.

This production mechanism is particularly identified by the fact that the impact parameter of the candidate is very low. It is zero reason the resolution of the detector. Aside from this production mechanism we have the secondary decays. Also mu tagged, the zero is coming from a decay. Together with the decays through the zero and the muon we can use the sine of the muon, minus sine to tag as the zero candidate. This is the characteristic that the impact parameter is greater than zero in this Kay. We used the charge of the soft pion for the flavour candidate. By talking about CP violation in the standard model, we know the metrics are naturally introduced by the irreducible complex phase of the matrix. It has a large effect in transition involving the third generation of quarks. You can see in the elements highlighted in red in the matrix on the left. On the right you can see another way to look at it with the unitary triangle. This is very familiar to most of us. You can see all the three angles that are described in the previous talks. You can see that they are rather large angles. That's why we measure all of them.

On the other side in the decays, the unitary angle we can use the metrics - what you see below is not to scale. It's only one side of the triangle is about smaller than the other sides. That implies it's very difficult. The effects are small in charm decays. Nevertheless it's interesting to study charm decays because first of all it's the only up-type quark in which a CPV can occur. We don't have decays of the upquark and neither can we have hadronising. I wanted to show on the right that it's important to do direct searches. Narrow decays in charm. Because they could probe beyond the standard model. For example, you can see on this plot where - what is the reach in terms of new physics, energy scale. And the requirements of charm decay and the case in red and blue. Those are much higher than the direct searches that we could, that we could level at LHC or the FCCs. We are somehow complimentary in direct searches to understand the model particles. And finally, billions of cases have been ready to be started. Now the situation in charms can be split in two categories. Direct CP violation in which the processes are different between the particle or antiparticle.

Or the CP violation which is mixing in the game. Cow have it between the mixing and the decay. I will start by talking about direct CPV violation searches. And in particular I will give you the first observation on CP violation in charm that was discovered just a year ago. This was done studying the observables, which is the difference between the metrics mes you'd in the final states. It's observable from the experimental point of view to correct for detection of asymmetry of the tagging track. Or in the production of asymmetry of the D star or the B in the secondary case. So the subtraction of one asymmetry to the other one allows us to extract the cemetery we want to measure and the difference between the kk and the asymmetry. One could ask why the CPV is different to zero, this is thanks to asymmetry. We have the symmetry for this. In particular, there are many predictions that are in the ballpark of: This can be naively understood that in one diagram you have vcb and the other you have minus vus. So this is the data set to be analysed. We use the full run through data set. When analysed both the prompt decays and the secondary decays.

Can you see on the plot on the Pi untagged we started the variant mass of zero Pi candidates. In the muon tag, we studied it . it's slightly less pure and there is some contamination that you can see red here. We managed to control the backgrounds very well. You can see we recorded them with very high yields. It allowed us to reach a position of the order of ten to the minus four for both the two samples. Here are the results for the Pi untagged and mu untagged separately. We combined them with one data run. That gave a measurement, an observation of CP violation. This is the case with the 5.3 standard model deviation significance. One has to think about what is the consequence, what can we take from this? First of all, after the result there were many predictions that were made. The outcome was that in the end, standard model the CP violation in charm could be between 10 to the minus four and 10 to the minus two. What we needed and what was asked was observation in other channels which could provide nice confirmation of the effect, also help its interpretation. Furthermore the question was raised about indirect CPV violation, which is still missing.

Though it is expected 10 to the minus five and it could be sensitive to beyond the standard model effects. Indeed I want to talk now about incorrect CPV searches that we are making. The first that I wanted to talk about is the time dependent CP asymmetry. This is the measurement which is the asymmetry between the life Times. This is not only important because it's a measurement of indirect CP violation, but it enters in the measurement of ACP at a 10% level. It's important to understand how much of a direct CP violation is in that. As I mentioned before, the standard model expectation in the order of ten to minus five. At LHCb we have measured a gamma both in the prompt and in the secondary configurations. You can see in this plot the prompt sample on the left and the secondary sample on the right. The prompt sample contains only a part. It needs to be updated with the full data set. The sample on the right has the full data set. What you can see on the top is the A gamma, the effective lifetime measures. What we affect is the asymmetry is zero. Because it's a final state and there is no way we could have CP violation in there, even in new physics.

What we do is use this desire 2K Pi is a control sample to understand what are the asymmetries that are systematically introduced by our detector and to correct for them. Once we are satisfied with the 02K Pi sample we unblinded the other samples that you see on the bottom left. There you can see that unfortunately we don't have yet the statistics that determine whether CP violation is present or not. I wanted to write here a combination that is preliminary. We have a statistical answer in the order of ten to minus four. In case this can start to be interesting because in case there is any new physics beyond the standard model effect we could be able to see something in the full data set. If we are talking of facts in the other, it's ten to the mass four. Still on the CP have a lacing, I wanted to talk about a channel that is extremely useful to measure both CP violation and measured together. Sometimes called the channel in charm. In this case we have a couple of analysis approaches. One is to do a time dependent amplitude analysis. The other is an approach that we developed recently called the bin flip.

In the approach we extend the concept of the mixing measurement to multibody decays. Way wanted to study the decays versus the right side decays. Their theory treatment is particularly interesting, long sine decays sit in the upper part of the box. Here we have somehow (inaudible) the idea is to measure the ratios between the area of this plot and this other one. The problem is that in each position of the plot we have different strong phases. Therefore we need to find a way to not dilute the asymmetry that we measure. This is done by splitting the regions where the phases are similar. They are highlighted by these colours in this diagram. Then what we can do is just measuring the ratios in each of these to see if there is any mixing and CP violations. These strong phases are measured, both measuring the fifth but constrained by external pin put. As a final commentary on this technique we have a slightly degraded precision with respect to the amplitude analysis approach. But we have a significantly simplified analysis. Indeed we managed to use the round one data within a short time scale.

These are the results. We studied mixing by putting together them and plotted on the left. The initial phase and can you see the ratios. On the right, you see the study of CP violation. In this case we did the subtraction between the extraction. The field dots different types of decays. With the variables to reach a lower decay time. What this analysis brought us was the most precise measurement of x, q, p and five. This was just with the round one data set. I wanted to show you the impact on the world average that we made with this measurement. Can you see this transition? So this is a big impact. It allowed us to obtain an evidence of x being greater than zero that was still not in the previous average. For the last part of my talks I would like to talk about rare charm decays. I would start with flavour changing neutral currents. This is a promising place to search for the effects. C to U transitions at short distances are only present at loop level in the standard model. There could be new particles entering the loop that change the fractions that we measure. There is a problem, the problem is that these short distance contributions are highly CKM and GIM suppressed in the standard model.

The big problem is that those processes are dominated by long distance tree dynamics. The problem is that we are dominated by the resonances in which they are not a rich process. This also makes the theoretical description where they are, then the interpretation of the results that we can produce. In general we measured factions in the regions outside the resonances where these theoretical challenges may be a bit smaller. This is what we did for example in the: This is the rarest charm decay with the branching factor of ten to the minus seven. In this case we not only measured the branching fraction, but we studied triple product and forward backward asymmetries that were both null with the sensitivity ranging from four to 11% for Pi Pi and KK sample. This analysis was made and only part of the run through data set with a total of 5 factors. Also we proved our trigger, we expect to have a factor two better sensitivity on these channels. And we are starting further tests of the standard model suggested by theorists. And they are considering performing an amplitude analysis and lepton universality.

I wanted to show one new result that is still in preparation that will be out soon. This is about a study of rare and forbidden decays of leptons. Here we started about 25 decay channels. Some of those are just rare because they are denoted by flavour currents. And the possible branching factions are expected ten to the minus between t12 and 10 to the minus 9. Lepton flavour violation channels. Dd is decaying to an hadron, electron and muon. In this case they can be possible through neutrino mixing. The branching factor is out of reach of LHCb. Whatever we measure different from zero would be a sign of something beyond the standard model. For example, lepton flavour universality breaking. But also we are trying to measure something even more exotic like lepton number violation. These of course are expected to be zero. This is the data set. We just studied the 2016 date Cumbria set so far. We didn't have a proper trigger for this channel. But we're going to study also the reminder of the run through data set. For the selection we just move the light resonances. The re-adjust mentioned a few channels were not analysed to higher than expected background levels.

We decided to set those aside and study more carefully later. The branching fractions are measured with normalisation channels. You can see an example here. You can see it at the bottom of the slide. On the right you can see results for this analysis. What I wanted to show here is that the main challenge is to control the backgrounds from the decays from flavour decays. We misidentified either the Pi or Kaon. In which we identify as a muon or electron. This was a very complicated analysis that allowed us to improve the limits for almost all the channels that we analysed. You can see that in the stable on the left, all the results and these are summarised with the plots on the right where we improved on almost every channel. I just wanted in the last few minutes to talk about the long-term future. First of all I wanted to welcome the competition that started taking data in the beginning of 2019 and from which we expect first computation. In particular I believe that the LHCb upgrade that is being put in place starting from the round tree from which we are going to record about 15phentobar and it will have some competition, with sketches like this.

We clearly have competitions on channels with K shorts. Clearly wayward with channels and it will not be and should be upgraded to the tech. For charged Hadronic Ronic Kabuls the upgrade will be the leader in the game. If you want to have further details. I also made a comment about the upgrade two that I will talk about in the next slide. You can follow these links with some prospects for the physics upgrades. I mentioned before the upgrade two, this is a plan that we have in LHCB for around five actually. Because if I mention that the upgrade with this we one collect data at higher luminosity that we are collecting now. Then yeah, for round four we are planning to do a bit of part of the tech to complete the collection of 50 by the end -- 50 by the end of run four. During this time we will have the competition to collect about 50atoban of data by the end of 2026. Afterwards, we have an ambitious plan of using the full capabilities of LHC and record data. This would be the upgrade two for which we imagine the detector. The reward can be really exciting. Because you can see from this extrapolation for example, if you want to study the charm decay, this is what we have.

At the end of 2017 when this plot was made. Can you see the contour in blue? But with the upgrade we can reach the position as highlighted in this red contour here. So this could really tell us with extremely high precision about CP violation in there and in charms. So to summarise, LHCb has produced outstanding results in charm physics during run one and two. We still have part of the full data set to be exploited. So we expect to produce further results in the near future. For example, we have the gamma measurement which we are completing with a full data set. But also analysis with the advanced stage with the full data set. You should expect updates in the future about this. Regarding charm physics in general, of course, the discovery of CP violation in charm is a milestone. But so far it does not show deviation from standard model expectations. Though one has to, the caveat is that those already tried to get it difficult to make. Also, discovering direct CP violation and the opinion of some colleagues could shed further light into the problem because it is already HHCb we are already seeing beyond the standard model scenarios.

Future challenges, we will be collecting phentobar by 2030. It will push us to bring out our results faster. Finally, this will be an extremely challenging but very interesting project of the LHCb to produce exciting data from the detector. This will be really exciting if we manage to do that. I think that's all from me.

JA: Thanks a lot. We have time for some questions. Please raise your hands and then we can unmute. While people are trying to find the raise hand button, can you maybe say a word about the between LHCB in Be LHCB e2 in the aim of CP violation. Wow, I want to measure this in more channels and understand if it's standard model physics. Can we learn something from the interplay of the two there?

MM: Yes, for example, as I mentioned for charge hadronic channels, LHCb will lead the game. This means for example if you wanted to measure CP violation separately. Or multibody decays as well. While it is important for measuring CP violation with channels in neutral. For example, we can use further ideas from flavour to understand what the CP violation should be in the standard model and beyond for example if we measure the CP violation here for example, actually I think it's a channel in which there could be some first competition -- fierce competition between.two experiments. I think all the channels can be very important. Channels in case of 20 Pi Pi can be interesting with approaches similar to the K short Pi Pi. For the neutrals, where the Pi 0 is involved it would clearly be a winner. It could be interesting for the D02 for the decays which I didn't cover which affects the situation can be pretty large up to the percent level. The problem is that the branching faction is very small. They are tough to detect.

JA: Thanks a lot. I don't see any more questions. Let's thank Mauricio again. Unfortunately there's no clapping. The next speaker is Mark Whitehead from Bristol. He will discuss CP violation in B Hadronic Ron decays.

MW: Thanks for staying around everyone. Obviously it's (inaudible). I will tell you a bit about advances in CP violation in the B hadron system. I don't need to set the scene too much with the talks before. As we know the university is dominated by antimatter. It's a puzzle as to why that is and how to explain it all. Of course, one ingredient is CP violation, where you allow particles and antiparticles to differ. In the standard model, in the quark sector, this is encoded in the CKM matrix. We know there is a CP violation; we've seen it in quite a few places now. The question is now where is the rest of it? I mean if you look at the amount of CP violation you node to create all of the matter on the plot on the left, what we have in the standard model leaves you something like one. One galaxy. We know there must be new sources of CP violation out there. Whatever energy scale. So the effects of new particles or new interactions or a combination of both is what we're after, this new physics. I can't cover everything that's been going on since the start of CP violation. So I will cover what's been going on in the last year or so.

For more information on many of the things I'll talk about, can you see these excellent talks from the parallel session earlier today: Starting with the unitarity triangle. This is the famous triangle that comes from basically multiplying two rows or columns of the matrix together and knowing whether they should equal 1 or 0. Studies of this system, so the plot on the left gives you a precise test of the standard model. Can you see if the triangle closes. You can compare direct and indirect measurements. And when these things, if they don't agree with your sign of new physics. It's also worth mentioning that the total area of the triangle shown on the plot is proportional to the amount of cpb in the quark sector. The current state is that everything is pretty much a standard model. So then you can think OK, what do we need to improve and the two low hanging fruits at the moment are the uncertainties on gamma and alpha. You can see these are the widest bands on the plot. We've had excellent progress from LHCB in the last decade. We look forward to belle two and LHCB in future. The current status is (inaudible) by the LHCb gamma combination.

The current combination is shown on the figure here. You can see in black is the world average. It shows in the colour some contributions from individual channels. And can you see that currently our uncertainty is about 5 degrees. And completely dominated by LHCb. The LHCb progress is shown in the plot here. Can you see the uncertainties have shrunk dramatically and they will continue to do so. However there's been a couple of new measurements not included in the combinations. This is an LHCb using B0 to DK star 0 decays. This provides improvement from the B0 mode. This analysis is considering the vast array of D final states. You have two charge combinations one favoured and one suppressed. This analysis was done with the data set up to the end of 2016. Effectively this sort of measurement boils to a counting experiment. Out count the B bars and form the CP sensitive asymmetries and ratios of yield which you can then interpret in terms of gamma as a second step. A couple of examples. D to KK mode here. I should point out unfortunately this nice big peak from the BS isn't the one we measure.

We're looking at the smaller B0 peak. The BS decays are almost completely insensitive to gamma. Just due to the ratio of amplitude. You can see here, that things are consistent between the two, though you can see that B0 is slightly higher. This is a direct hint of CP violation there. Another one to flick up similar plots for the four Pi mode. The power of analysis like this comes from combining together. You measure the observables shown here from all the different channels. Don't focus much on the numbers. But can you see that they are all basically consistent with 0 at the 2 Sigma level. But when you combine the things together you see we get fair sensitivity to gamma. You can see it has the standard four fold degeneracy. The dominant, the best minimum, the dominant minimum is indeed compatible with the world average of gamma. Then another analysis that also came out even more recently is the GLS analysis. These acronyms are just the, named after the three rifts that found the approach.

We're now back to the B plus which is the golden mode. This analysis is focussing on the K Pi decay of the D. This includes the full data sample, about nine inverse fentobars. You can consider analysis in two regions in the face base. So the K star region and non-K star region. The K star region mass plots are at the bottom of the slide here. The sensitivity to gamma in this mode is less than before. We don't interpret this on its own. So the observables seen on the side of the slide here will go straight into the next LHCb gamma combination where they help constrain things further. Change in tact a bit to another angle from the triangle. This is LHCb analysis of beta D star D. Again using the full fentobars and considering the decays shown at the start and then two choices of the D decay for the D0 decay and the standard favoured three body decay of the D minus. What you want to do partly is measure the CP violation observables from the time dependent decay rates. This is one of four possible decay rate equations. I showed one and they were different by sine loops. To get to that stage you node a mass fit first.

The example of running two data sets are shown on the slide. Can you see the two bodies have a nice fit and low background and in the four body mode the D to K3 Pi the background is larger because you have, you need to add more track together to make more combinations in the so-called common background. But nevertheless you see a sharp signal peak and everything under control. When you take the signal only part of the distributions you can form your fit to the lifetime as shown in the plot on the right. The coefficients we're interested in of the decay rate equations are the terms that premultiply the cosine and sine terms which are from the mixing. There is the ff term which is a global asymmetry between the two final states. This is your direct CP violation as opposed to the stuff coming in there you -- through the Mitching. What you want to do is make -- mixing. You want a coefficient from the previous slide. The observables we're interested in are S, Delta S, C, Delta C and the (inaudible) as I mentioned. LHCb measures these to be as shown, which excludes CP conservation at ten Sigma.

These are the most precise measurements in this channel surpassing the effort from the B factories. And just the plot on the right I never get tired of looking at these beautiful plots that show you in a picture the oscillation of the B and B bar. For the two different final states. Now, staying with time dependency violation, this time we're now talking about fiS or minus two beta S as it relates to. In the unitarity you get the prediction. We are looking for something close to zero and it's also constrained very precisely. It's worth noting this is an interesting place to study because there's still room for up to 10% differences here from new physics effects. Then on the other side of the slide you can see the direct measurements. This is the status during, after running one of the LHCb. You can see it here: And the uncertainty you can see is over an order of magnitude larger than the numbers we want to compare to from CK and unitarity. This is a run two update with 2015 and 2016. Here now you're interested again in the golden mode. As you're interested in the narrow fi resonance. We have over 100,000 candidates.

You can see how pure the mass distribution is as well in the middle of the plot here. This is an independent analysis. We need to know whether we start with B0S or B0S bars. This is achieved through flavour tagging. It boils down to acb has reached a flavour tagging of around 5%. You times your 120,000 by a factor of 5%. That is the statistical power to measure the CP violation. We perform a full angular analysis including six dimensions or so. The B mass, decay time, decay time error and three decay angles. Where the decay angles are defined as the angles between things like the decay planes of the J sigh and the Fie. And we fit data samples simultaneously. The results that fall out are: Already quite close to the run one HC average. And then of course, it's also combined with run two as shown here. Further combined with the other LHCb measurements where you can see that this is the most precise in pink. But there is also some sensitivity from some of the other modes. LHCb is not the only player in the game. There's a recent update from atlas. With part of their run two data sets. Everything up to the end of 2017.

You expect, atlas has a huge signal-year-old up to half a million decays. They do pay a price in purity. It's much lower. You can see from the plot that everything seems to be pretty much under control there. The flavour tagging here is again, more difficult. Although, they are getting up to 2%. This is a promising performance. The fit generally works to the LHCb one without some of the bins and a couple of parameters are fixed and varied in systematics. We see good compatibility with measurement of fieS. The run two uncertainty is the same as from LHCb. You can see the systematic is a couple of factors higher. Nevertheless, very impressive results. It is worth measuring there is small tension in gamma S that reflects detention in the life Times. This is still to be, we'll see how this goes with more data of course. Atlas would like to combine this with their run one measurement. Can you see on the slide here what an impressive update this run two result has been moving from the blue to the green. And then combining them in the red. You see very competitive uncertainties there.

The status is somewhere through last year was to reduce the uncertainty from 0.031 from the new LHCb and atlas results reducing the uncertainty by a factor of a third. That was easy. And then, a new result to be added that hasn't been added to the nice plots yet is the spring update from 2020 for CMS. Again this is their large part of their run two data set. So up to 2017/18. So something like nearly 100 inverse semtobars. The purity is very good. I should mention here there is only something like 50,000 decays. The strategy taking by CMS was to optimise the flavour tagging efficiency rather than the pure signal yield. When everything shakes out you can see that the uncertainty on fieS is competitive to the LHCb and atlas measurements. It's worth mentioning just this flavour tagging in the range they are in the kinematic range and selection they have their flavour tagging is up to 10%. These results are in good agreement with previous measurements and the others. Again, one can combine this with the run one results. They get the very competitive results as shown on the slide. OK that was fieS and the unitarity triangles. We move to CP violation in B baryons.

There's no real differences to the mesons in most places. We're looking for this. LHCb has made a few studies about this. They've looked in two body charms decays such as PK, P Pi. It's shown on the top of the slide here. Can you see the plots are very similar meant that was a hint that we didn't see CP violation there. We consider the four body decays where you have a rich amplitude structure. You might think there's more space for CP violation to appear here. And for the lambda beta Pi mode it was seen a couple of years ago for CP violation, but it's just over the threshold. An update was needed. That came last year. At the turn of this year in fact. Over the Christmas break basically. This is now LHCb including run two up to 2017. About a factor of four in the signal yield. That gives a factor of two innocencetivity with now a signal-year-old up to 30,000 events. There's a couple of techniques used here to try and measure the CP violation. The first is the so-called triple product asymmetries where effectively what you try to do is you come up with these scalable products. They are ways to combine the momenter of the final state particles in your decays, once for the particle decay and one for the antiparticle decays.

And then can you set up asymmetries based on the sine of these things. You take the difference and the sum. You do this again independently for the particle and the antiparticle decays. The final step is to combine into asymmetry terms. So one on the left here showing for the CP violating asymmetry and another alternative which gives you the parity violating asymmetry. When you turn the handle and have a look what you get, we find that from the triple product asymmetry results CP violation is, well CP is conserved at more than 2.9 Sigma. Although parity violation is observed at 5.5 Sigma. And this is shown in these plots. Don't worry about the schemes here. Just compare whether or not the red points for CP or the blue points for parity, whether they are compatible with zero or not. On average the blue points do sit away from this line, which is why we see the parity violation. Unfortunately on average the CP seems to be consistent with 0. And one can cross-check he's results using the energy test method. I don't have time to talk about the energy test method, effectively what you're doing is using a statistical comparison of two data sets, effectively the particle and antiparticle decays using the test statistic shown on the bottom of the slide.

But the results here are just completely consistent with the triple product. We don't confirm the evidence of CP violation in these modes. I'd like to mention CP violation in three body charmless B decays. There were very exciting results back in 2014 now where huge localised CP violation is seen. This is the plot of beta three Pi decays, where this is the plot that represents the decay phase base. Can you see the Z axis, the colours represent the raw asymmetry between the particle and antiparticle decays. Can you see crazy numbers here? You're getting towards 100% CP asymmetries in the base. Quite a surprise. This generated interest, whether it could be caused by rescattering or various other ideas. But really, from the experiment side you need to, from amplitude analysis to work out what's going on . This arrived with about 20,000 candidates. So the goal is to parameterise the amplitudes in this face base contributing to the decay. This is done with the ice bar model. Where the ice bar model is really just a coherent sum of the contributing amplitudes. So the tricky part of this analysis is to model the S waves. This is a spin zero component of Pi plus, Pi minus amplitude. You have the ice bar model with additional re-scattering.

This is a new feature for this analysis. And a nice inclusion. There is the K matrix which is fairly infamous itself. And has five re-scattering couplings to various different intermediate states. And a nice thing that's come back into fashion is this quasi model independent analysis. Here you're just saying what is the magnitude and phase of the spin zero component. So you can see the plots for the magnitude of this amplitude for each of the three cases at the bottom. You can see that their CP violation in each case, blue and red, you can see the CP is violated in all of these and quantitatively there is decent agreement between the magnitudes more tricky is to get the phase motion right. Can you see that the phase motion is slightly different in the ice bar model which you would expect. It's not the most complicated model in terms of getting the phase motion correct. Nevertheless features are identifiable in all of these and the differences are taken as a systematic. There's too many results to go through. In fact they published two papers at the same time. That gives you an idea what was included.

Just to focus in on some of the obvious CP violation results. There is this quasi two body CP violation. How many we see in the region of the face base. There are large numbers. Over 40% in the F2 1270 region. And there are nice effects in the row region. Look at the integrated number for the row looking at the asymmetry you see basically nothing. But if you consider the CP asymmetry as a function of the lower half of the peak and upper half so you split the row into two bins you see huge CP asymmetries. They happen to Alex completely cancel out as you consider the resonance as a single item. This is just a nice way to show that you can miss these things if you just integrate things. This is probably coming from interference between the S wave and the row. Just to talk about the BF two region is shown on the side of the slide. On the top the mass projection. There are some small discrepancies they are covered by the systematic uncertainties and the plot to look at is the CP asymmetry. You can see CP violation here. These decay modes in combination are used to measure things about the matrix, gamma for example.

Really this is a standalone study of the CP violation in this single decay at present. So the summary is that a lot of work has been going on in CP violation and I just want to make the point that I think regardless of the outcome of these very interesting flavour anomalies going on, CP violation is and will always be an excellent precision test of the standard model and we are due to reach some truly interesting sensitivities in the coming years. We have the LHCb and LHC full run two data samples to look forward to. And the belle upgrades will be entering the game there are plenty of other CP violation topics out there that I didn't have time to talk B but just to quickly flash up one last thing before I stop talking, looking forward, this is just some projections from LHCb but including belle 2 and at also and CMS as well. You can see that the gamma combination we will be at the end of upgrade one reaching 1.5 degrees. L2 will join us at the same sort of place. Then we get to something pretty ridiculous at the end of upgrade two. These projections do include the systematics. So these should be the ultimate numbers we reach. And fieS becomes very interesting in these later dates. Thanks very much.

JA: Thanks a lot. We have time for questions.

P: Hi can you hear me?

MW: Yes.

P: I have a comment about the CP violation using the lambda decays that you show on page 23. In the previous paper publishing, they published the evidence of CP violation at the level of something more than three Sigma. There was no evidence for violation. There was the same increase by a factor of four . There is partial accommodation of course. Now they have something less than three Sigma for CP violation that they don't think is an issue. But five Sigma four the violation. I think that maybe it could be worth seeing the compatibility between the two results. Maybe running the ordinary on the new or vice versa.

MW: Yeah, okay. Thanks for the comment. I yeah I don't know much more than what you've said myself. I think it was mentioned in a talk earlier that yeah they had done some tests. But perhaps some of those numbers could be made available.

P: We discussed this morning. They performed some check on this compatibility on the two CP violation measurements. They found the agreement is at the level 2.6 Sigma. I think only three things, this was two. I think that, I don't know actually if it was the result of the CP violation in the natural. Now five and five Sigma is - of course they have more statistics can be just you to these new sensitivity and so on. It's just to check okay.

MW: Yeah, okay. I guess maybe the announcement will be done by 2018 date why in the future as well and beyond that. Yeah worth keeping in mind though.

P: Thank you.

JA: Are there any more questions? One question on the very last slide you showed, I was surprised. CMS has effective power of up to 10% why can't they be much better in fieS, what is limiting?

MW: Yeah, I'm also not 100% sure if someone from CMS is connected and wants to talk more about their projections, they're welcome to chip in. I do know that CMS will also perform their analysis using the part of the data set they haven't used yet which is the high statistics low tagging power. But obviously that should be somehow complimentary. I'm not too sure about this limiting around 22 milireps or not.

P: I can comment, if you want. Basically, 10% of tagging power you saw in the presentation of today. It's obtained by selecting a subsample of the full statistics with, it's mu enhanced. We have two mus, and an addition muon for the tagging. We select these subsample at trigger level. So it's tagging power by statistics is low.

JA: What do you know a number, a rough number of how much lower the statistics get?

P: Five times lower then we will exploit the full data set for full statistics.

JA: If you fold that in the magic 10% goes down to 2%?

P: Exactly.

JA: Now I understand the numbers better. I don't see any more questions. It's already quite late in the afternoon. Let's thank Mark with a virtual clap. Thanks a lot. Move to the last presentation of Jack Mofidi. Can you share your slides? Talking about rare B hadron decays.

JM: I should search for the preview. Quick outlook, I will give some motivations. Then I will show angular analysis B to K mu, mu. Then lepton flavour universality. The summary of the R ratio and recent results from LHCb. Then rare resonances. No newly observed decay channel. Lepton flavour violation. And rare decays eventually. Tease are recent rupts from LHCb. Moving to motivations why do we show the rare decays. In general, they are changing the current. The branching factor is low. Loops are generally involved in these decays. New physics can change the expected petrifaction for example. Other searches are looking for variation or let's say deviation from symmetries that we expect to be present. For the lepton flavour violation, which is almost impossible not to be seen violated. In general, we can search for indirect and model independent search of new physics. I'll talk about angular analysis. They are B to Smu, mu transition. You see on the top right there the formula we are looking for, interested in the efficiency, the short distance that can be calculated directly.

We analyse the coefficients and look at the B0K0 mu mu. Why do we do these searches? Again, loop diagrams are involved. The Wilson coefficients are sensitive to the new physics and especially the angular analysis we can exploit better. It's been already shown that we have this attention especially measured by LHB on the parameter leading to 3.5 Sigma deviation from the standard model. Can you see that in the plot? You should take the standard model will be just in the centre. It's clear that it's (inaudible). I'm showing the resonance for the different experiments. This is what is part done before latest part of the resonance. It's colour that we are seeing an evident discrepancy between these two and the expected values. Analysis is done for the rates as a function of Q squared. And the decay and angles of the decay products which ends up to be the sum of angular analysis coefficients and the f angular functions. We're showing now an analysis that has been carried out. They analysed this I coefficients in two ways S and P track. Both of these coefficients are dependent on the Wilson coefficients. They fit the differential decay rates as a function of Q squared.

They got a multiple number of observables out of the two bases. They analysed the run one and 2016 data. As you can see, they have more or less the same statistics. I'm showing here the K Pi mu mu mass. If I move forward, I don't go through the systematics, but it's worth mentioning that this is it arises. You can see the projection for a single. The three angles. And the visual used to disentangle the P and S. Again, you can see the single variable, the most interesting one for the mu basis, P5 prime updated with the new resonance. Combining run one and 2016 data. You see that there is still tension which is, was slightly reduced adding to the 2016 data. But the global, just local, but globally the tension is likely increased considering all the angles. If you want to see the difference between run one in red and 2016 data, blue, then look at this plot. What's nice of this plot is that they plotted what it would be the theoretical expectation if the sine and parameters shifted by minus one. And centre to here. And you see that the parameter, the curve is needed to be evaluated in points.

Another channel, this is measured by CMS. This is the B plus K plus mu mu. This single angle arises because it fits just one angle. The main variable extracted is the forward-backward asymmetry. If it is done in a mass of K mu mu and the angular variables in Q squared bins using 2020 data. The results are compatible with the standard model expectation. The asymmetry is shown in various bins. So moving to lepton flavour universality. These have been talked about by Wolfgang. So lepton flavour universality has been seen in the standard model. So seeing it will be a clear sign of BSM physics. The RK and RK star were having a lot of attention. In these blocks of the slide you can see measurements are RK, RK star and new results RPK. All of them are measured in run one plus the first of round two. For RK, they analysed the B plus, K plus, lepton, lepton channel. The idea is the ratio between the fraction of the dislocation to muons by the same channel into electrons. Experimentally it's convenient to do the double ratio. What you do is to divide this by the same branch of the same channel with the two leptons.

These cancel the statistical uncertainties. RK has been mirrored to be 0.18 above. She's 2.5 Sigmas away from expectations. Then RK star, the idea of double ratio applied to all these measurements basically. RK star has been measured to B0K0 lepton channel. O in the middle plot: Then they added this new ratio. RPK, which is Lambda into the pk channel. You can see large variation on the model. Still it's in the same direction of the previous resonances nans. -- resonance. Let's move to rare resonance. The first time X has been assessed by Belle in 2003. We don't know yet what is the nature of this particle. Whether it's a test rare Kaon quark, molecule or mixture of those with a conventional chromium state. What we did in CMS was to measure the relative BF as above: We obtained this measurement fitting by mass. You see the X resonance. Using the signal pdf in the backgrounds from this feed, we can have the S plot, we can show clearly the peak. So the ratio that we measure: It's 2.21%. If we convert this into an absolute: They are kind of in agreement. B plus is a tension. Which is not seen fully, in the charm. In the same channel decaying.

Let's move to the lepton field violation. Here the motivation is that this is possible decay in case of fought Rhoneo oscillation. But extremely small branching fractions. Sometimes we see it as a sign of something wrong or possible new physics the best measurement has been cleared out by belle. An CMS experiment tried to compete with data. But they didn't manage to better the upper limit set by Belle. At the moment everything is with the standard model. I will show what has been done at CMS for this channel. We analyse the flavour channel being the source of the signal are D and B. Then we split the sample in six categories. BDT score and mass resolution. 2016 data. We fit to the number of signal from these two sources. Can you see in this formula: Everything is normalised using this. Go through the systematic uncertainties: Six fit projections. ABC stands for mass resolution. 1, 2 tore for the BDT output. The must curve is the feet which is background only. We didn't see any Sigma and we set an upper limit. The red curve is seeing erm... ten to the minus 7. Obviously it is really improving the case we add more statistics, run two tau statistics.

The B decay into two mu. So realised the (inaudible) this is a rare, because it involves loops and it's also the helicity is suppressed. Given that we have good precise theoretical predictions it's a good candidate to search deviation from the standard model. We also measured the lifetime effect of the lifetime. In this box you see the expectations. In the boxes below you see the resonance. They didn't manage to measure it for the B0 to mu mu. They set an upper limit. This is nicely shown in the top right. It shows the evolution of this measurement in this timeline. And you see that the standard model prediction for the B0 to mu mu about to get. This shows how it has been carried out briefly. In atlas and CMS. They are quite similar analyses. Both didn't use the full run two data set. Analyses are blinded. BG main components. A third background. B decays to hadrons misidentified as muons. This is a particularly nasty background. Can you see on the plot on the right. Because it's called peaking. It peaks on basically the single region. So for the key ingredient for these analyses is to reduce as much as possible the muon misIDification to reduce this background.

This has been done using the number of it is different to experiments. But fit the dimuon mass. And the categorisation of this is different, but both of them categories output. You see fit projection for mass for the case of the most sensitive for CMS on the left and atlas on the right. It's nice to see that the peak is quite evident. In the bottom you see the contour of CMS and atlas. As I said, the results are in agreement with the standard model expectation. In this slide I'm showing the effect of the lifetime by CMS. We basically applied two methods and the denominal one is the two dimensional feed. Both the mass and lifetime observables. The two plots with the projections. In this box, there's been consistent with the standard model expectation or having just a heavy state that contributes to the decay. Last channel is the recent analysis. Again we measured fractional with a pair of electrons. The statistics is run one plus 2016/16. -- 2015/16. It's not easy to do in this these kinds of experiments. Because electrons use energy. What they did was to split the sample into three categories depending on the mass resolution it depends on the number of (inaudible) -- brem photons at the time, electrons that have been recovered.

You see the two extremes of these categories. You see that the background shapes are different. Depending on the recovered electrons. In this box you see the expectation. For this electron channel, you have orders of magnitudes lower expectation value. So it's difficult to get it with new physics contributions. There is an upper limit of four for both channels. This brings me to the conclusions. All the measurements are in agreement with the standard model. This is still an extension on the P5 parameter, which is likely this is reduced by running two data. There is a three Sigma tension of the Wilson coefficient C9. All the analysis I've shown don't use the full run two data. That means that nice development can be seen in the future. Especially for some channel where the competition of belle two. All the experiments have also shown projections that have been shown in previous slides for run three and phase two. So there is still interest in all these analyses. And that's it.

JA: Thanks a lot. We have time for some questions.

P: Maybe I start with a question and a comment. First, a question, you didn't mention CMS park data. Is there any expected date we can hope for that?

JM: We don't have results. But we are working on them.

P: Any time scale you cannot say probably?

JM: No.

P: OK. Unfortunately. I'm a bit surprised that you mention the tensions are reduced, which is correct, but I think overall, in the picture the tensions are increased. Is there yeah.

JM: If you keep the same old standard model that was used in the run one analysis, the tension would be increased not only very slightly but a bit. If you update the standard model with newer knowledge, then it's exactly as you say. You write it on the slide. But the take-home message, I would phrase it's more important than ever to get more data. And to clarify the picture. Because with the new LHCb analysis, this overall tension we see here, slightly increases in significance, it would be very important to individual measurements to show something going away or being significant.

JM: And CMS will contribute to this.

P: Yes, that's also why I asked about the park data. I would hope that we get several experiments. Looking forward to it.

JA: Are there any more questions? We're very close to dinner! (Laughter). Thanks a lot. Thanks to all the speakers of the session. It was a pleasure to do this virtually only and not the same pleasure as doing it in reality. But probably do that next year. I think that's it from the flavour plenary. Thanks to everyone and have a nice evening.

END OF TRANSCRIPT