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SPEAKERS

PATRIZIA AZZI: **PA**
PIERRE SAVARD: **PS**
ALEXIS KALOGEROPOULOS: A
INES OCHOA: I
ELINA: E
KEN: K
FREDERICO: F
IJC LAB: IJC

PS: **I would like to welcome everyone to the beyond the standard model plenary session 1, focusing on TeV scale physics and searches. I would like to remind all speakers to mute if you're not speaking. So our first talk will be on the experimental overview of SUSY searchers and Alexis Kalogeropoulos will be giving this talk. I hand it over to you. You have 24 minutes and I will remind you five minutes before the end.**

A: Thank you. This is the experimental SUSY overview for the ATLAs and LHCB collaborations. Why we need this. Well, we need it because simply it is one of the most promising theories we have beyond the model theories because as we know the standard model is not the final answer. SUSY has many nice features. For example, it helps solving problems and it allows for fine tuning. From the experimental point of view it is a theory because it is provides us with a plethora of possible signatures and scenarios let alone the excitement if SUSY were to be found we would be double the standard known particles. It can be provide the super partner or LSP. This will result in SUSY particles producing pairs and stable LSP would escape detection. Briefly, SUSY searches can is cat grade in the following. It benefits from the cross-section and we have already said strong limits. Then we have third generations production, which is more focused if most if not all have been from arguments and we have been able to tackle components of the top corridor. Then we have searches here and we talk about production where the main challenge is that one deals with this and very often targeting splittings.

In some cases like SUSY for direct, we have just enable to get sensitive to those models. Finally, we have long particle searches where we're interested in disappearing tracks and photons and other models which in many cases overlap with analysis. This will be covered on the plenary on Saturday which I invite you all to attend. Of course, I don't have the time to cover all of this, so today I will focus mostly on new results, but there are four parallel talks covering more details, third generation and other searches. Further, although LHCb has no recent SUSY results, we should not forget some very nice older ones. So as an experimentalist, what we do care is how to put our hands on SUSY. One of the biggest problems is that SUSY comes from relatively small cross-section compared to the standard model processes, but on the other hand, we actually expect final stage with the objects with high transmissional and any Bs as well. Over the last years, a lot of effort has been put in kinematic variables have been explored. A difficult case which you can see on the top right black is due to the presence of RPC scenario signal expecting to populate, but we expect it to have kinematic around the W mass.

Further, it is typically for the regions around the variables, sensitivity, and sometimes in many cases a further optimisation is used to get this. All in all the strategy is to suppress overwhelming background processes as much as possible and this is done with several techniques, some of this simple and some complex. We can categorise background to the resources and that means that we can have similar to the signal experimental, the same number there, et cetera, and simulation is used for the normalised and extracted from a corollary John. Then we have reducible sources, which are mainly associated to construct effects and they are estimated from data because we don't trust and validated invalidation regions. In the end the signal regions which are designed to be sensitive to the presence of signal are used to extract the signal and in the absence of significant excess, we set upper limits on the production section of the target models. Now speaking of the interpretation of models, we cannot possibly design and execute an analysis which would have many parameters like this. We have more than 100 parameters in the SUSY models.

What we do, we make some assumptions and we define simpler decay chains to a set of simplified models of super sum tree, the main characteristic is a limited number of parameters. A typical example is the production of SUSY particles. The only free parameters is the masses of the mother and the daughter particles and we connect those two. The daughter particles is, for instance, half the mother particles. We also regularly assume that the other particles are too heavy and can be decoupled. We assume that they are along the particles, in real models this is not usually the case and the practical impact is that maybe we are excluding more than we should have been excluding, it would have been considering real rather than simplified models. Now, one very important thing to remember, however, while doing a real analysis is that we have to deal with the imperfections and ageing effects which can complicate our analysis and life because we have constructed objects that can survive the analysis casts. We have invested a lot of effort understanding the detectors and that is not trivial at all.

In CMS we compile a list of events which we can exclude from the off line analysis. You can see the example at the bottom on the left, you see how problematic event in the CMS would result in fake reconstructive. On the right-hand side you can see the effect of applying those noise features on data. You see how much the data effective meant and this is very important because do not forget that the energy is a primary object for SUSY searches. Now, let's start with the analysis review. We start with Gluinos in the first and second generation. Typically we expect large and multi jets, typically search variables try to get the hydronic activity, or another variable that we will see today large mass radios where you see that the mass appears very nicely there in the tails. I start with very new CMS result. This is a new result focusing on this as you see, incorporating the next to the particle, neutral 1 are mixed states and also this analysis specifically considers small mass splitting between the Guinos and the neutral is very light. That matters because basically that results into final stage with large met along with very additional soft ports coming from the decays and contained in a single reconstructive one in a large radius.

Co-regions are defined in this for the leading and the trading set. You can see the definition of the single regions and the corollary Johns on the bottom left. The corollary Johns in the dark blue have the normalisation and the light blue is used to extract based on the assumption that they should have minimal correlation. Bottom right what you can see, it is a very nice safe peak performed on the dark blue side band regions. When we actually require the leading to lie outside and the subletting to lie inside the Z window. You can see how nicely the signal would be inside the Z mass window in the signal region. Slide 9 on the left side you see the MET on the region and the upper model excluding nicely up to 1.9 pv. Now we're going to another result. An analysis that considers also a nonzero model with a mediated top spot production, actually Baryon number violation model, that means that it can indicates strains or down bottom post. Again, it is of significance are the main handles to the background. Since we are dealing with the significance for the first time in this talk.

The significance in particular it is a variable that test this particularly hypothesis, how compatible the total meant with known interaction particles as quantifies by how much the measure made in the associated to possible measurements. This is of significance, linked to non-interacting particles. In this analysis what is very nice is that the significance has been optimised to capture the response of the other. The main background is Z through to processes. When we have B and C case, it is estimated from a low corollary John by building the significance templates because we assume that this should be mostly correlated with the MJ. On the right we can see a very nice test on the significance of the different processes populate the flow. That brings me to the results where on top left you can see the signal regions and on the bottom you see the results on this known 0 recovery model where the rates is above 1.5 for masses of 400 GB and it extends for considerably the previous result. In the right, interpretations of the simplified model on the be that as it may with recent CMS result. Both of them have about the same sensitivity excluding about 2 TEV for masses for light.

Now, another CMS result in one final stage, the experimental signature here is at the top. This analysis exploits the presence of initial state radiation Z and the main variables are as shown. A property is used in this analysis is that for typical events, which can have large multiplicities, it is correlated with the transverse, meaning that at the my MP can be estimated from MJ distribution from a low corollary John. There are several corollary Johns being in MJ and multiplicity, and the background is estimated from corollary Johns against under the assumption that MJ and MPN correlate. Correlation is taking into account by correlation factor of K which as you can see on the bottom right flow is very close. On top half of the page you can see the MJ distribution in one of the signal regions because there are more than one signal regions, and at the bottom left-hand you will see the results with the use of simplified models and 2.2 TeV are excluded for this model, which is this limited amongst the strongest limits we have. Overdoing the Gluino searches, there is limits on the masses, more than two TeV, it seems to be well excluded and we have weaker limits for mediated because we have softer products. Still this limits it above 1 DV.

On the other hand we expect to reach above 3. We go to stop searches. One can divide the base as a function of the mass difference between the strop and this, and that defines what is allowed and we can have two, three or four. Of particular interest in the top corridor where basically the difference between the stop and the Guilino there. It is very difficult to do analysis there. It is the dominant background of course. We have variables which try to distinguish potential signal against the background. For example, topness, which differentiates through to the lepton events. Of course, we have many more induced, and so on, and with all of them try to exploit the presence of extra met in signals. The particular characteristics that signal health. First I will be showing the stop pair analysis. You can see on the top left plot there, what is very nice in this analysis is the different regions optimised with different variables, but they made use of ISR sensitive variables which would help you significantly on the top corridor. Basically this this is the ratio for reference divided.

While they also used the region, they used other variables in order to have the measurement and be soft targeting techniques as well. This is a very good example where actually you need dedicated optimisation if we want to reach the difficult corners. The different standard model process dominate on different signals. Coming to the results, on the bottom half you see the interpretations as a fraction of stop, and we exclude stop masses for about 1.2 T of eV, extending by about 200 previous results, CMS has the same analysis. Although this particular result analysis was not there. Coming to yet another one lepton stop analysis result from ATLAS, this analysis employs both count and analysis for sensitivity. Typically we have many signal regions optimised after variables. Dealing now with backgrounds, among the most important measurement and sources that contribute, meaning lost lepton is when you have one of the leptons misconstructed. The top is used which quantifies how well an event can be reconstructed under the hypothesis and what is also very nice is that there is also a similar one lepton analysis which used the top for the discriminating background.

Upper limits are presented on the bottom half of the page. Coming now to a result which was also new, released this week, targeting two lepton. It considers the case. The main variables are MP2 and a variant which incorporates the multiplicity of the event. Actually, you expect them to have an end point for background events, even if you have three in the event. Of significance it is used to suppress the reconstructed particles which can be associated with interactions which is the main source of misreconstructive Met. Some more information, this follows the distribution with two degrees of freedom for events with no genuine met. The distribution of the significance in raidion and it demonstrates how background contribute, the main background for the measurements. Slide 19, that brings me to the result of this analysis. On the left you see the yields in the control and the signal regions which are focusing to extract the signal. In the absence of any significant excess results are in simplified models, one on the right, and this extends, we have the production to top in the case and this extends by about 125 DV.

Coming back to ATLAS, we have a new result which was released a couple of days ago. This is an analysis which again we found it was of significance, multiplicity. The analysis considers three and lepton stages, with different backgrounds. You can see a nice test on the top of the bottom left on the PTZ and reads radion. The depravation of one of the models which demonstrates an improvement compared to the previous result extending the results between 100 and 300. Another new ATLAS result which was released recently considers in the scenarios, given that it considers high number of jets, the main background is estimated from data. What is very nice with this analysis, it is actually that is the first analysis that is to stop, that can exclusively in the big one there. That brings to the overview slide for stop searches. You can see on the top there and the ATLAS, we have excluded stops like the 1.2 TeV. The limits are weaker along the diagonal because we have sharper objects. Collaboration incorporating more and more greater ones to increase the risks. Going to later to the searches now, they pose a challenge because of the situations that we have.

We have signatures like these and other handles. We can talk about many different scenarios like seen here, but what I want to focus on this talk is about the compressed regions. We have seen recently that people are trying to use handles like topologies and exploit the presence of ISR to increase sensitivity. A very nice example of that is this analysis for this style production looking for optimisation around ISR without going into details, the point is that you see the point which is excluded in this analysis actually sits in a region which is way beyond any sensitivity in the analysis. I think that the take home message here is that we should be smart and start using VDF and ISR techniques in order to access these compressed and difficult regions. If one wants to review the searches, we have the strongest here followed by the next case. On the right-hand side you can see the summaries. It is clear that in different corners of the page requires well established methods than just going with a good for everything model or strategy. What we expect in the future? Given the model that were suppressed, we can expect it will be very interesting because it will allow to cover a lot of the space.

The problem is that the projections have been made with certain assumptions. I think the point here is that it will get more and more attention in the future.
I hope that you have seen it is certain that both ATLAS and CMS have very rich SUSY program producing nice results. We expect more full run two results will be soon. All the likelihoods being released by ATLAS. As we prepare for round three and looking for we can benefit from not only additional lumi, but also using more target sophisticated tools, allow us to see that it will be very exciting in this period. Stick around. More will come. Thank you for your time.

PS: **Thank you for the very nice overview of SUSY searches. I will open the floor for questions. You can raise your hand. There is a feature at the bottom of your screen. If you cannot talk, you can also type your question in the chat and we can read that question. I will ask one because I was trying to figure out on slide 17 and maybe 22, but if you go to slide 17, there is on the ATLAS exclusions, you see a significant dip whereas on the CMS side, I don't know if we're comparing apples to apples, but you seem to have excluded that. Am I missing something?**

A: It has to do with specific optimisations and regions defined with Btags and so on. It has not anything to do with ATLAS or CMS detectors other than the strategy that people following different analysis.

PS: **Thank you. There was a raised hand but then it went away, so I guess you gave the answer.**

PA: **There is one that has appeared again. Don't be shy.**

PS: **Okay, Frederico, if you want to comment.**

F: Can you hear me? I think the answer was okay. I believe that the main difference in this region is the strategy that has been used in the two searches. For example, in ATLAS we relied on this result for the 3, so we lose acceptance in this region where it is wider, CMS recovers sensitivity.

PS: **Okay, thank you. I don't see other questions.**

PA: **If we still have some time, I can ask. Speaking of triggers and future, in view of run 3, given that maybe we cannot really just go forward in the mass reach but focus on the difficult regions, are there maybe new strategies that are being sought for triggers or specific things that couldn't be done now but maybe a change of priority?**

A: I could say for instance that one of the certain challenges, and we have to deal with that, is that we will have a problem with the method. The triggers there are dependent and this is something that we need if we actually needed to squeeze out more on the compressed region. I think there is already efforts optimising the figures, but also other triggers because the leptons, they have about 25 or 30 gb. We have rigorous triggers which can go lower but sometimes this is not enough. We need to go lower there.

PA: **Thank you.**

PS: **We will go to the next talk by Ines Ochoa.**

I: I will present an experimental overview of exotic searches. There is a very rich program of new physics searches at ATLAS that have been used to address questions. This program targets scenarios of new physics that can manifest itself here. This overview will cover brand new and recent results by ATLAS and CMS, for states that are generic for physics. Many of these results make use of the four sets. I want to cover resonances. Searches for them can be done on a wide range 350 GeV to 10 Tev. There are new trigger techniques to new techniques to identify at high frequencies. You can see the displays here that will be covered. On the left-hand side ATLAS candidate events. You can see clearly the three-prong structure inside each jet. On the right-hand side one that is combined with ATEV, so balanced by each jet. Going into more detail in the analysis. On page 4, the resonance search, this analysis search is an inclusive way to have where one of the jets are there or both of them are. You will see the searches is the difference between the jets and wider values will be typical in background events. There is a requirement that they are relatively close by this delta light with different cuts for different benchmarks.

The background here you can see on the right-hand side. It is from the window fitting the data directly. Here we can look at the significance of the spectrum.

There's no large enough discrepancy and exclusions are defined for several benchmarks including this one here using specifically events with two jets. For the same benchmark, we can see here, there is an experiment on the last publication. There is an improvement there due to the work on the jets. The results puts limits on cross-section limits shapes. Moving on to CMS search. CMS using the set here for searching for two jets using these wide jets which combined the jets with R equal 0.4. Reduce analysis sensitivity to final state radiation. The final is shown here on the plot. It is new methods for background estimation of 2.4 TeV. Using the control the jets is very large and the signal is small. That is shown on the plot on the right top where the signal is shown. The region with large values here is used to extract the background templates. This method has the advantage of being more sensitive to broad resonances. One of the results is shown here for the resonances and increasing widths.

So far the results shown that resonances in the range, the range relatively uncovered. This result has a lower mass region. The problem here is 3-jet events reconstructed and recorded at higher rate in compact if from. It is something that is visible because only a small portion is saved. That allows for lower PT thresholds here on the jets and a lower mass reach. You see in the end the limits shown here. This is the last highlight. This addresses four scenarios where it would be favoured for a third generation and resonances there. We have two large jets where the top ones are fully contained on one jet. We rely on information of these jets to discriminate between the candidates in the background. A new network basis with applied to the search. We end up with two signals here. The background here comes from the jet and talks about production and is fully fit for data. It is shown here on the red histograms. None of the discrepancies are highly significant. On the bottom left is a cross-section limit for a particular benchmark in how the experiments change for the datasets, highlighting the impressive results here next to the new top tagger.

Moving onto Dilepton and lepton and jets final states. These are, of course, the cleanest states and can be used for a long list of benchmarks. It shows the final state which can be an exciting reference. A couple of highlights. One is the increasing use of generator-only MC samples or fully data-driven approaches for background estimation, which is important to take into account as the sources are required. On the other hand, more data leads to better understanding of the detector. One example here is the improved treatment of the relative alignment of the sub-detectors which is critical for measuring high pt muons. On slide 9, a quick summary of both collaborations searches. Narrow and broad in range from 250 GeV to 6 TeV. You can see signal shapes over laid there. Then on the right-hand side here the results searching for narrow resonances in range from 2000 GeV to 5.5 Tev. The limits are produced in the form of a ratio for the cross-section of the new particle. It has the effect of cancelling.

Both show the channel, but we are combining these to get the limits to data on both benchmarks. Moving on to searches, non-resonant Dilepton. Search for enhanced dilepton rates for masses above 2 TeV. It can be interpreted with contact interaction in a non-resonant. It is shown here in the purple square, an extrapolation up to the signal region. The boundaries between the regions will depend on the exactly degradations. The data is shown here for the signal on the bottom. Again, with the same control regions and a few cases of the interference shown here. In the same benchmark, the lower limits are shown on the left for a combination of these channels. You will see in particular this result leads to the strongest limits for the constructive model with around the markers. To finalise the section, this is a search for excited muon or electron decaying. There are two jets here and they are excited one is producing association with another one, in the opposite sign. We're probing the energy scale and this contact interaction and that can affect the production. The backgrounds here are top players here. An simulation and invalidated into the regions.

Two signal regions are shown here. The variable here is the mass of the full system. This is shown at different scales. The results here are in the form of limits are, again, one of the most stringent and they are at large values of the exited energy scale. The result showing here for the channel with an exclusion of 5.6 dB and the assumption that it actuals the excited one. The paper presents results under different assumptions. Moving on to searches for resonances on final states. The targets here are resonances ranging from 100 Gev to multi TeV mass. The highlights here are the several movements in the algorithms that are used. They produce very large momentum. You can see a very nice illustration here of the set candidates. The other new aspect here is that it is novel analysis methods. The first result here is the search for resonances in decays to WW or WZ or ZZ. There is a reiteration of this using new strategies. Instead of targeting the candidates with their mass window and scanning the mass, a 3D like we had performed, once again the mass of each jet should be for the install, a localised resonance on the variable.

This is possible thanks to the application of this mass correlated on the top right plot comparing here signal background jets before and after the steps. In the end, CMS sees a big improvement of up to 30%, thanks in part to the fact that you're constraining the jets background directly and associated reactions. This model B is the benchmark. This is the resonance. The exclusion up to 3.8 for that. Moving on to another new result with the full run to dataset, this time an ATLAS search for resonances. The search targets are very wide. It employs different methods therefore. Here all the production mechanisms are considered. The current network is here which takes in the former momentum of some of the small events and uses that to categorise between the production methods. This, of course, takes into advantage the welfare of the jets with large mass that are typically detected with the production. It achieves a correct classification of the events. Most of the time as well as the small examination of these. These are used to optimised to maximise the reactivity. You end up windows there with tagging. They're showing here.

It has a larger signal acceptance. This is taking advantage of all the regions which are shown on the right and so taking advantage of them, we can constrain the major background with jets and doubled the jets with production. One of the regions is shown here. This is the benchmark study. Moving on to a similar final state. You can see these final states where both have been constructed at large jets. It is for the detaging is the most powerful for the Higgs. It is used to help produce the jets for the background. A big improvement here thanks to the variable jets with tagging. These are a collection of Radia and they result in a high bars. It makes a big impact. You can see on the middle part here where you see the improvement. Still at very high masses, there is still some gain to be had where only one here is used. You can see the regions here. Final state there, one tag on the top and two on the bottom. The background is estimated from the events where 0 are found and they are weighted to match the one and two tag regions with the multi-dimensional transfer factor: exclusions are presented for the model again.

Here in terms of the mass, but also shown on the left-hand side here for different mass points in terms of the coupling of resonance. Moving to the final state now, this is a Higgs resonance search. Here also new method is employed trying to identify the Higgs here, which is highly colonated and takes advantage of the structures I've just described. You can see on the top right here, this is a new algorithm. This way it combines the tracking information and uses simulation for the signal. This is used here as a discriminate variable and you see on the bottom left plot with two single events and the upper limits on the cross-section. I'm on the last side. This is the last result I wanted to cover from ATLAS, which is generic search for new resonances via anomaly detection. For the first time where all particles involved, they can all be particles. B and C are contained within the single one there region. The method is to train a new network using data to distinguish events in a particular MJJ or jet from its neighbours. So simple regions from the side. The search range is roughly here, 2.2.6.8 mass and split into six regions.

The first side band and the last side band are outside of the boundaries. New networks are trained to distinguish it. It is used individual jet markers. M1 and M2. You can see an example of the output. Here on the top right for particular similar region, so that's one marked by the green star. In this one, you can see the output is mapped into a deficiency in the M 1 and M 2 plain. In this case we injected the signal in this point. You see that the darker points, the points with the lower efficiency regions are the ones that are similar in length. The next step is to cut the output. The idea is that we're enhancing resonance, if it is there. The goal here is to do so without relying on any particular signal model simulation. Going back to this plot on the left-hand side, this is the result after cutting it to ensure 10% efficiency as you see here. There is basically no significant changes from the background prediction. You see each region here. They don't all match up because each region is on a different set of networks. One can illustrate the sensitivity of this analysis to different benchmarks and for that a few signals are injectors during the training, so that is the new network that knows what to look at. Then when applying that.

The limits are produced here on the bottom right. Here I just want to point out that this is the MA and different values for the bearers. You can see that at a that can be compared here on the search which is shown here in the grey start which has a better sensitivity than this weak search, sensitivity to the dedicated search, and this is a region with a background that makes it harder for the new network to learn how to tap the signal. One can also look at different mass points and compare the results. This is shown by the triangles here. There is a reaction here between the signal mass points where the resonance is a good fit and those where they wouldn't. That explains why the search would have a poor sensitivity here. In particular, the highlight here is that for all these bases, the method provides a very strong result. You see there a huge effort by CMS and ATLAS to cover a wide kinematic range and final states. Producing the re-interpretable limits to increase the longevity of each result. Broadening the scope of minimising direct theory biases. I would like to point out a few of these. That's it.

PS: Thank you. I will open the floor to questions. You can raise your hand at the bottom of the screen. I see one raised hand. Could you state your name, please? If you want to talk please post something in the chat. There are no questions. I will ask. Go back to your slide regarding the colour search. You explained the difference in sensitivity and at some point for the search, it over takes in sensitivity for the 80 bin. The search that you're mentioning is basic. Should we expect perhaps a neural map without labels to still do better or not?

I: In the lower mass region?

PS: Right.

I: I'm not sure. That is a distinction between those [indistinct] there isn't any substructure. I'm not sure why exactly the limits would be comparable. They are comparable, I guess.

PS: Go ahead.

E: Probably the difference is that the jet was actually applying a certain number of cuts and the efficiency is different. Here they select the efficiency of 10%. It is different. It could be different. It shows it is 10% efficiency but it could be higher.

I: There are other in the paper efficiency points or another one at 1%, yeah. I can't remember how the results compare now.

PS: Okay. Any other questions? I hand over to Patrizia.

PA: We can switch gears because now we move to a different theory side of the question. Elina, show your slides. She will discuss new models for building.

E: I will start. First of all, thank you very much to the organisers for the invitation to give this talk. Thanks for everyone logging in. It is a pleasure to tell you about review, small review of new ideas for TeV scale modelling building. There are more than enough open questions in the model that we need answers for. Some hints and some questions from the theory side like the unsolved program. This is the argument of the theory could explain. The other aspects of dark matter candidate. The matter symmetry in the universe. Hierarchy, there are no less often to build attractive models. There are many models on the market that can address one or several of these questions. The question is at which scales will the new physics show up? We might hope that at the TeV scale, but it could also be much higher or much lower. Also new physics arise or higher scales. What is our situation? In this conference we saw many impressive results of ATLAS and CMS to test many models, symmetry additional Higgs, the properties and many exotic models that are at TeV scale, 10 TeV for CMS. We haven't seen convincing evidence of new particles yet. What are the ways out of this situation?

It could be that the searches that have been performed have too strong assumptions about the models, minimal versions being tested. One could interpret different benchmarks and lift some assumptions and also just continue searching. We have seen many talks of new results in this direction. Another thing that maybe nature calls for different models that are not captured by ongoing searches. Maybe theoretical changes of paradigm like not explaining the hierarchy problem by symmetries that protect. I will try to give a little overview starting on the topic of the more known models where known it is maybe a little trend to extend the sectors and look at their roles. Then I will speak about Relaxion with framework that leads to standard signatures. Then I will discuss models that introduce new sources of regulation that will stay in the limits of the test. Clearly I cannot cover everything that is going on in the theory community, so I'm just picking some examples. I am starting with extended Higgs sectors which we have already seen beautiful results. One Higgs has been discovered. There is no reason to think it is the only one out there. It is a minimal solution.

There could be more doublets or singlets. We noted the scalar potential needs to be modified to enable first-order electroweak phase transition. More parameter space. By introducing scalar singlets, it is to interact with SM particles via the Higgs, and minimal extensions with rich phenomenology and can help with phase transition, adding to singlets to double the models. We just start with the extension, adding one singlet scalar to the potential. Scalar and adding terms for the singlet and the terms of the square and the singlet square. These terms are the two conserving terms, but they are easy to break into terms. This extension of the model and it is already well studied for different phases. The two have broken of conserved for changing the sign of the singlet. The singlet could be lighter or heavier. Even this well studied extension still has several open questions. For example, what if the two should be broken spontaneously, and there was a recent study to investigate if this standard model singlet was a spontaneous breaking.

To enhance the strengths of the transition such that it helps the barren genesis and it is not so clear because some terms that helped to modify the potential, but by taking different contributions into account, they found that one can achieve a first order of the phase transition and different scenarios like doing a transition in one step or in two steps for generating vacuum expectation values for the Higgs and for the singlet and there are different versions where the temperature is high and non-broken or if one starts in the other scenario where it is a high temperature where the symmetry is restored. It is a simple model which has rich history. How can you test this? They find that this needs to be a rally light scalar. The Higgs can be there which tests to the strongly first phase transition and test the provision at the LHC and the parameter space and self-coupling. They're a clear prediction. I will summarise in one slide one aspect of the topic. We introduce the model extension was two real singlets. There you don't really have one term of the doublet squared and singlet, and each singlet, 1 and 2. At the end you have three scalars that can all mix and generally you can describe the system. There's one, two, three, and constraints on this model. Two real singlets are contained there in the complex singlet.

There was the additional there. It is just a small extension of the simplistic extension. You can have interesting Higgs to Higgs, not only of one to two kinds, but to three kinds. This was the first part about the role of singlets to help with the phase transition and to introduce an interesting chronology. Now I will speak about the Relaxion. I'm not sure if you have heard about this T was a proposal from 2015. It adds a new scalar. It has different framework. We can look at the potential of this at five and six each. Why does it grows down a potential. It doesn't get it. It keeps rolling. It rolls slowly. At a certain point this new parameter which will also become the mass parameter for the Higgs. In crosses and becomes negative. It switches on the Higgs. It wasn't immediately at the value observed. Then it fixes the back reaction. It Wiggles in the form of a cosign. It doesn't roll straight down but wiggles. Finally, when the slope of the rolling equals the slope of the negative slope of the back reaction, it gets trapped. Then it stops. It just stops in such a way that renders the Higgs close to the observed value.

It generates an explanation for the observed Higgs without introducing partners at the top. It is just a framework and it can be different models to realise such a framework. The considering started with taking the Relaxion. It was larger than the allowed bound. You can take a copy of a strong sector. One can introduce another field which then relaxes the Relaxion mechanism. It can roll in two dimensions and there are more model realisations. In general in these pictures, you can see the potential of the Higgs. You can then introduce new particles. That's the model and the framework is general. Then it is a question of how do you stop the relaxion? The standard version is inflation. An alternative is to create friction. It becomes independent of the error of inflation and relatively recent proposal was self-stopping relaxion. It stops itself by creating relaxant and dissipating energy. Does it help you with any of these listed items? It helps to explain it. It can be dark matter, heavier dark matter or it can be light. It could be observed in halos of dark matter around the earth or sun. It can have genesis by violating CPT during its slow roll and then introducing symmetry of the variant.

It can also address the hierarchies or also found that it can address height problems in the natural matter for instance. That is one framework and there is a lot of possibilities from model building. Let's look at the phenomenology. We have the scales here. T there is the parameter. This we require to be at least a hierarchy of relief. Then there is the scale of F that describes the behaviour. Then it can be there but down to very light. There is the scale rising in the scale.

Then the interesting observation is that the point where the relaxion stops rolling and breaks CP and introducing a mixing between the scalar Higgs and relaxion. It behaviours like the standard model for singlet extension which it exists for the Higgs, called the portal where it can be messengered at dark sector. This gives a handle to search for it by mixing the Higgs. There will be more particles and it can also contribute to some processes. Let us compare what this means. You can write in general terms the scalar. This depends on the Higgs. In a general thing on the left-hand side you have seen the two breaking terms. To be more general here. On the right-hand side you see how this looks for the relaxion. It is similar when you write down the general terms for the model and then some things are given by the symmetry.

You can compare some terms are given by the framework and you see there where there was a zero and you see also if you compare them to the left-hand side, there is a cosine of five over F. If you expand it is five squared over S squared. So match on the left-hand side in terms that come there. It is then beyond this general thing. Up to 11 you can compare. The relation is linear to the singlet. How does this look? We will see in the next slide. We see the similarities, but it is not purely like a singlet extension. It is a super scalar. Here it distinguishes. Where does it actually stop? This was investigated. Would it stop at a minimum. Will it stop there? It comes to where it stops. Actually, if it stops at an earlier minimum, it is more suppressed than stopping at a later minimum. Then one can investigate which area can be covered by the relaxion in this parameter. It is a familiar way of describing the Higgs. The green region is the minimum and creating when it is a generic minimum on the grey. How can we distinguish where it comes from? If it is a light scalar, it can be found out. If it is outside, it is not a reaction in here, but here.

The relaxion can spend many, many future many frontiers. Higgs can be two relaxion. It contributes to the Higgs. From the measurements we can bound the relaxion, especially on the branching ratio to invisible or undetermined. This gives rise to tags. We need new sources because we observed this symmetry in the universe and it is insufficient, it is far from reaching the observed value. In the framework, the asymmetry is created during the transition when connected to the Higgs. You cannot make it arbitrarily large because they are from precision measurement of Higgs couplings. To sir couple event these bounds, you create this symmetry, you might need to rely to cancellations, phases or new ideas that I will review here. There was an idea by these people to have a coupling. You cover various between the bubbles, between the transition, large on the symmetric phase. It becomes very small when the EDM is measured. Another concept is to put the violation into a dark sector where it can be lounged and mediated to the visible sector. It helps to suppress the moment that has a strong bound. It comes with the future level because it needs dark sector.

Signatures that you could look for would be expressed scalars and dark matter, depending on the different model realisations. At the end I mention one framework which is not a real model. Just one dimension term of complex to cover couplings. Then you can check if you can sufficiently create sufficiently symmetry by staying in the limit and we found that this works but for the others separately not, but if you combine them, then the bottom can create more space where you have enough symmetry. It can be the case that you observe completely CP conserving signals. Zero measurement of the moment, electron or others, and a standard model like signal rates fixed to be bound and still due to cancellations of the imaginary parts of the tag covers one can still find points where you can adjust and get a symmetry. Further tests will be very important. Even more precise signal strength measurements which are for Higgs and so there are many models that I haven't talked about. I tried to give you maybe biased overview of some areas to build new models to address one or several questions. I chose here the direction I did because they're extensions which have good outcomes.

The relaxion I tried to highlight comes exotic model. If it is heavy enough, it is tested at the LHT and then collider mixing with Higgs. We don't know its mass range. It is important to check many different mass with methods with the collider range. There are very interesting models on the market. You have to be careful to make it large enough to generate symmetry, but make it small enough that you can hide behind it. There are many models on the market. There are ongoing searches. More searches for sure. It is possible to have some fine looking data. Some models achieve it. It is important to combine knowledge from Higgs precision measurement, Higgs decays, cosmology and combine different methods and so on. Thank you very much for your attention.

PA: Thank you. Thank you for a nice overview. We have a few minute to open the floor for questions. You can raise your hands. A very experimental person. Just explanation in nine where you have the experimental sensitivities. You have this generic collider. What are you referring to, which type of energy and which type of particles?

E: Going to slide 9. I think that for the FCCE, but I'm not quite sure. I will have to check in the original paper. It's about the precision measurements of the Higgs coupling. It is not about measuring the singlet itself.

PA: If it was more precision or direct search was my question.

E: Yes. One is the branch that search for the Higgs to the singlet. It occurs in many models. You can search for it by the constraints on the new physics branching ratio or directly by products of the singlets. If they decay, for example, all the combinations and so on. This will be the direct searches. It is understood, but maybe I need to check.

PA: I cannot tried to cut you because there is a question also from Ken who is the next speaker. We have a few minutes.

K: The last thing that you talked about with the genesis. You assumed that there is already a strong first order of phase transition somehow generated by some other means?

E: We don't assume that there is already, but we assume this can be separately because this cannot accommodate. Here in this one, one assumes that all new states will be heavier.

K: That was a tension there.

E: Yes. This is the assumption and the short coming of the framework, the strong assumption that you can factorise these two programs. That you can introduce a violation and then build a model to make the phase transition first order. Then it could be that the bounds, the interpretation of the bounds, will slightly change. It will be model dependent. We check how much we overshoot the symmetry. This is the factor of up to almost 10 above the observed symmetry. Even if we are order 100% uncertainty, they will be points or in the cases that we observe that the top, the bottom and the new cannot alone have enough to repeat violation. This is also far away, like 12% on the top or the bottom or a few symmetry. The qualitative observations should be robust, but it can change depending where you implement your phase transition. I should have said it from the beginning. This is the assumption to separate the two.

PA: I'm sorry, I was muted. Thank you again. That discussion was nicely introducing exactly the next presentation. Ken, you can start sharing your slides.

K: Thank you for this segue into my talk which was premeditated. I'd like to thank the organisers for the invitation and the opportunity to still carry on with this conference and really would like to compliment how nice everything has been so far. I would like to tell you a bit about progress, the status first and then progress and some perspectives on the SMEFT and, in particular, in the quest for new physics. We find ourselves sort of 10 years in, 10 years since the start of LHC run 1. No real clear sign of new physics so far, of course, and we have just seen that play out in lots of nice summaries from the first two talks in the session. I think it's fair to say that direct searches have some saturated this energy frontier capacity that we're looking forward to when we switched on. I picked the ATLAS summary plot. That was not coordinated and I probably feel bad about that, but the CMS is in the back up on the slide and this, again, just showing that the energy scale that is being probed broadly by the experiment. What can we draw from this information or at least start to speculate about the BSN?

We could say perhaps it's too weakly coupled and this is optimistic in that we have room for improvement. This is one avenue. Another one is that it is just too exotic. We haven't been looking in the right place yet. This is also very positive because it's just we're limited by our own creativity and person power and it's our job to motivate and enable these searches for new and exotic signatures. The last case is when BSN is too heavy and out of reach from the collider. That is the worst case scenario from the direct search point of view, but, of course, this moves us into the business of indirect searches. This is, of course, the reminder that direct searches are not just the only thing that we're doing with the LHC. In fact, it is all worth remembering that we have achieved the number one objective of this machine which is, of course, discovering the Higgs and we're in the midst of a very huge program of precision measurements, standard model interactions all up to the TeV scale. It is thanks to the efforts of all of us as a community internationally that the HLC can be used as a precision machine. The big question or at least one of the big questions is, of course, what is the origin of the scale.

I think one of the clear places that one can look is in the interactions among the key players in this game. By that I mean the Higgs. EW and the top. I think a very positive statement about this situation that we're this is that sort of independently of the outcome of any direct searches for new physics a big part of the LHC legacy going forward is the presigh sit of measurements governing these guys here, the sector. For the Gauge and Higgs part, we want to test all components of the field in the sense that the Goldstone modes mix together with the gauge and this is a very interesting avenue to carry on testing. On the other side we have the top which is coupled with the Higgs and has strong BSM implications. There is more reason to look into this guy.
We have really kind of reached this shift of paradigm over the last 10 years to think of direct details. This connects with the fact that we have reason to believe that new physics may well be heavy. I think the language or framework that marries these concepts of potentially heavy new physics, high energy but precision measurements is the standard model or SMEFT as it is often referred to.

Broadly speaking, it is encodes a parameter space for BSM interactions between molecules. It is a version 2 of the standard model. New physics is integrated out at a higher scale and the standard model is just the sets of operators that go up to dimension 4. Then this EFT denoted by this scum over here is this tower of operators of mass dimension. The only rules here are that we work with the building blocks and in SMEFT we have this. We respect the standard model. This is more than just a parametrisation of ignorance. It is an order by order theory that has this finite energy range. On top of that we possess this well-defined matching procedure that is improvable where one can connect concrete models of new physics to these coefficient of these different operations here. One very kind of crucial aspect of looking for the standard model is this notion of energy growth. High dimensional operators equates to energy growth. If you think about the generic insertion of some dimension 6 operators, you are expected to get types of effects on the left denoted by this green box the constant effects which are like shifts, proportional there, and they rescale standard model rates.

Rate measurements are going to be in the domain in terms of constraining these effects. These will eventually become dominated as a life time progresses. On the right, they're the new kinds of effects which can go up to the E squared in the case of dimension 6 in the standard model. These will be better and better constrained by high energy measurements and we can keep on going to higher and higher energies and we can always be in a limit where we can improve as we collect. This is a nice systematically improvable process that we can pursue. This story is complicated by the interference structure of the effects with the standard model because in order to get a cross-section you have to square this and there will be higher order. This pattern of energy growth and different SIM trees can mix this naive hierarchy of the expansion and this is coupled with the fact that operators are not stud idea in a framework. One has to approach each problem individually. The SMEFT is trying to be model independent. On top of that we don't know how this will generate. It is bottom up in nature. That really calls for a global approach.

The ultimate goal in terms of the SMEFT is this likelihood of the general SMEFT. We start small and we start with realistic subsets of measurements. Hopefully exploiting SIM trees along the way to structure the way in which we compartmentalise our parameter space. I think that the long shut down that we're this is an opportune time to take stop. There are legacy papers coming out with a dataset as we've been seeing for the last few days. It is a benchmarking and data preservation exercise which is worth doing. It takes a step back and asks the question where do we stand, how sensitive are we and where would be good to look next. There is much progress in lots of directions. It is good to have several groups working in parallel in terms of fits. I expect many papers to be coming out in the next year or so. Let me focus on a couple of interesting bits of progress in these directions. The first one I wanted to mention starting with the precision observables is this paper came out since the last edition where the full corrections to the objectables were computed. This is really the first complete NLO in SMEFT result in the sense they do all the corrections possible with all the dependents on the operators and do a statistical analysis of what the implications are.

You have ten operators in a physical basis and you only constraint eight directions. This is a well-known fact. These guys have shown that when you go to NLO, the number of operators goes up to 32. You have two additional new constraints. Before a leading order it was self-contained and the blind directions could be closed by adding Higgs. One really has to combine more measurements to actually be able to make the precise statement here. I just show here a couple of figures saying that basically the order of the corrections is something like 20/30% in terms of when you look at fitting subset, a closed subset of operators and the impact of these corrections. This is interesting progress which hopefully will percolate to the end. In terms of the combined measurements, I picked out this paper. It is not brand new, but it is quite a comprehensive combination where they use this flavour universal assumptions, which say standard way to reduce your parameter space. It was one of the early ones to include differential information in the form of the stage 1 cross-section mentions as well as other stuff. Here they just do some nice statistical stuff.

You can get the effects there and on the right you have this naive interpretation where you invert the constraint and turn it into an energy scale to have an idea of what types of scales one might access. This depends on the values that you see. In general one can see that TeVs are being potentially accessed. The real reason I picked this paper is because they take the next step where necessity map to UV models which is interesting. I show an example of two dimensional models. You can see that you can map these to UV models. The real interpretation starts here. We don't have an excuse because this is done for us. There exists a complete dictionary for all possibly models. There are much progress is going on in this direction where one can provide a similar dictionary and one week. UV interpretations involve subsets. There will be correlations between the coefficients, et cetera. When you look at the results, one should bear in mind once you plug a real model in, your constraints are likely to be better. You really need to retain the full likelihood in order to be able to do this in an agile and flexible manner.

The next thing is this recent work where this flavour assumption is reduced. I think it uses signal strength but in the end the cool thing that they did was they didn't have this universal assumption. You increase the parameter space and they did a nice interpretation in terms of the custodial triplet where you see the types of interactions are potentially being accessed which is promising. Another thing that I wanted to applaud them for was that they make the results of likelihood publicly available through this tool which is a global tool which can be found here. It is one of these very important efforts going on towards everyone coming together to go towards this false SMEFT likelihood. I wanted to flash some results in the top sector. This is not brand new but one of the important advances in this work here is that it is including NLO QCD effects. You can see that the order of sensitivity is weaker here on the right and stronger on the left. There is a clear split between the operators that are constrained here. It is statistic rich processes here. There's quite a hierarchy of sensitivity in this sector.

One other interesting thing that was done in this paper was that they assessed the impact of these terms that I mentioned in the cross-section. You can see that in some cases the blue one, which is linear only, only one of the square terms, some of the constraints disappear. You see some of them are completely dominated. This is something which needs to be looked at closely. Finally, I wanted to mention the experiments because they are really starting to get into the game. Enthusiasm for this model has percolated down strongly to the community. There are too many results to cover here. I wanted to flash results for one example here which is the measurements. I want to give a mention to the top experiment of the community which have been leading a way in this interpretation. Results when they do fit will consider slightly small parameter bases but on the other hand they have a good handle on them. It is valuable added information in terms of this ultimate goal. Fits are not that fun. It's a slog of creating data, curating the data and there are lots of gotchas. They're really a perfect kind of control to combine the data.

They're going to be included in the next generation. I find there they're a good compromise in terms of ease of interpreterability. One caveat is some model assumptions go into these. One thing was to actually study the information content in terms of being able to constrain the SMEFT. They looked at WH and compared the sensitivity to some idealised statistical ideal and were able to actually show that by making slight improvement. This is a nice back and forth going on here between the experiments and the community with regards to the cross-sections. Today if we look and say what is going on with what we know, of course we really want to make the interpretations and say what is the upshot. This is where the model independence disappears. By construction when you interpret the result there is model dependence. Especially for the validity, the implications. You have to do your constraints and check what's going on in the model. It depends on the sensitivity of the model and energy scale that you use to probe the interactions. We don't know what the new physics scale is. On one side you have this, which is arbitrary dimensionful parameter and then coupling of mass scale of new physics.

You can just imagine that if you make some constraints, it will represent itself in a line here between the coupling and the mass. You can come at it from different ways in terms of what is a valid interpretation. At some point your coupling becomes too large. It is bounded from the fact if you assume a mass scale, you better not have used data at that energy. You have this line. It is difficult to make general statements but fair to say we're probing physics. As you go to moderate to strong coupling scenarios then you're close to the energy scale. Generic new loops is challenging. Concrete models should be better constrained. As we widen the parameter space, our sensitivity should go down. That is why the motivation will be to combine top Higgs measurements. There has been a split in the sectors but these results will be hot off the press. There's a talk on Friday who may give us some results there. This is really the motivation that if we want to understand the scale, we should try and make a SMEFT fit about all the parameters that affect the particles that are most important in this sector. In fact, there are interesting processes that are measured by TTH to top production, all these things are going to be interesting to combine altogether.

Although it is unclear to what extent these two sectors will talk. We know that top measurements are important for Higgs production. I wanted to flash a few other results in various directions. One thing was in. PDFs. Can the extraction procedure absorb new physics effects? There is a lot of data being used to pin the quantities down. It shows that, indeed, there is some impact when you fix the PDFs or do a simultaneous extraction. You can actually get a better fit from the standards. There is a related issue to mention in passing that also this is often part of the determination of the strong coupling parameter. This hasn't been discussed in general. This other one is interesting where they started looking at combining high-energy data with flavour in a coherent way where even if you assume that there is no flavour violation, if you put loops of Ws in there, for example, you start to reduce this at one loop. The low-energy measurements are so sensitive, one can get complimentary information and they found five new constrained directions when they go from the SMEFT down to the experiments and found that there's really new information to be gained.

I'm interested in the impact of top data in this direction. Loop technology has been improving. Here there has been a lot of people thinking about what is the interactions in loops because these are the ones not well measured. There is a body of work here which is very interesting and finds some competitive sensitivity. There is a talk tomorrow on the TT bar 1. That is good to have a competitive sensitivity. Then we start to get parameter directions that could lead to problems. This is a slide about tools. The technology for these loops is old and there is interesting information going on. I will skip these to say we have preliminary results for these and we're going to soon have a paper out on this. The tool is public, although doesn't include this yet. Everything else, you're a SMEFT with the capacity to do process independent on the calculations. This is also especially relevant for things like these on productions of course, the leading order for the standard model is a one loop effect. Once you start modifying the guys, it is better to start including the loops once you start to look at this or the high PT region where there is a limit that might breakdown. I wanted to say something about this.

Up until now we just knew how many operators there were. Very recently two papers came out on the same day and wrote down the dimensions. That's 43,000 operators encoded in 1029 Lagrangian terms. Positivity constraints are also applicable on these operators which has been evolving fast in recent months. The last thing I wanted to talk about was how to improve with increasing statistics. High energy is something good for looking nor the SMET - for the-- for the SMEFT. High multiplicity can have growth. Things like rare top production with more final states in conjunction with weak bozons, and also for the Higgs case where you have operators that modify signal strengths, this can be tested in different ways by looking at the longitudinal Higgs and final states that probe the same operators that effect the strengths. There are some exploratory studies going on for that. The SMEFT is well established for dimension 6 side, particularly. We're extending the reach of the LEC beyond the nominal energy. The next step is to look at realistic models. There's much work to do but the tools are available. It is going to be a big part of the legacy. Let's continue to look at high energy and multiplicity and as a roadmap for the future. Thank you very much.

PA: There is not much time.

IJC: I am listening from IJC lab. Just before you mentioned the global fit, I didn't write down the slide number. You mentioned interferences which seem to make your life complicated if you could collaborate on that. Maybe I can ask my second question. Later on in slide 14 you mentioned that the interpretation that you were doing was a naive one and I was wondering if this was because you were making assumptions on the values of the couplings that you were dealing with.

K: The second answer yes, because the scales are degenerate. You can't say anything about the energy scale unless you fix the value of the coupling, so that is modelling dependent. What people do is they set a coupling to one. That is why the Y axis would correspond to. The question about interference is more involved but an important thing, perhaps the relevant slide is later on where here. Basically putting in an operator doesn't guarantee that it grows with energy. That is because it was shown that in general for any kind of scattering, which doesn't involve the longitudinal bozon, all of the dimensions do not interfere with the standard model. Somehow the structure are the kind of areas that the SMEFTs like to generate. They don't like to talk to each other. This interference where you expect the leading term in the expansion to occur is suppressed by some higher reason. Sometimes it's colour structure or something else. It is a naive expectation that the dominant effect comes and it is not always the case, especially at the LHC where there is high energy.

IJC: The absence of interference is due to the dimension of the operators?

K: In this paper they showed that for all kinds of operators it happened if you look at the structure that they generate in the particles, it doesn't match up. It just doesn't like to interfere on first principles grounds. They would prove for dimension 6 two to two. That's the limit. For two to three it is different for dimension A it is different.

IJC: The dimension but the type of process which are at stake.

K: Yes. It is a type of process. You really have to be as broad as possible and look everywhere.

IJC: Thank you.

PA: I don't see any more raised hands. Thank you for the presentation. It is very good to see all these tools coming out and also being more accessible to experimentalists. I would have questions for you but then we go too long. We thank you all the speakers of the session. This is the last talk of the afternoon. I leave the floor for some information message. Thank you again, everyone, to the speakers and the attendants.

PS: Thank you. A quick announcement in 11 minutes the session will start. You will find the zoom link for each presenter and you can go into the zoom room and discuss. There will be a second session tomorrow. Some will be today in the rooms. Others may be tomorrow. Please go to the session. Now 11 minutes for your coffee break. Thank you, everyone. See you tomorrow.

END OF TRANSCRIPT