Draft for PAR  
  
Hello everyone, I'm Chengxin, and I’ll be presenting PAR on behalf of EWK di-tau group today.

So Let's start it.

Our analysis focus on two scenarios:

Frist, C1C1/C1N2 via stau, where the final state contains 2tau+MET+ initial state radiation (ISR)

Second, direct stau production, with final state with 2tau+MET, we include ISR and inclusive channel here, previous result please check this paper. In the used analysis, no significance shows in compressed region, so this analysis will focus on these regions. This work can help explain the observed excess in the Muon g-2 experiment and the measurement of dark matter relic density. The requirement of ISR is crucial because it boost the SUSY system and improve the sensitivity in the compressed region.  
For more details, refer to the Glance Analysis entry or internal note with these links  
  
Now, let’s move on to the preparation before analysis. The Ntuples we use are produced by the MelAnalysis framework with DAOD PHYS, and the p-tags we used are listed here.

Our dataset includes full Run 2 data + partial Run 3 data. For electroweak processes, we use the samples shown in the table on the right. And additionally, we have top-quark and Higgs samples—the full lists for these are available at the links provided.  
  
The signal grid we use is displayed on this page. Left plot shows the C1C1/C1N2 ISR signal, with chargino 1 (C1) or neutralino 2 (N2) mass ranging from 100 GeV to 400 GeV, and the neutralino 1 (N1) mass from 0 GeV to 370 GeV. middle plot displays the direct stau ISR signal, applying a filter of leading jet ​pt >50 GeV. Here, the stau mass ranges from 90 GeV to 200 GeV, with a mass splitting between 10 GeV and 60 GeV. Right plot: Presents the direct stau inclusive channel signal, using a filter of lepton ​pt >20 GeV. The stau mass spans 90 GeV to 700 GeV, while the N1 mass covers 0 GeV to 500 GeV. The reference point used in ML are pointed out with red-circle.  
  
About the object definition show in this table, the baseline lepton definitions following the recommendations of EWK combination group except the tau pt in the baseline decrease from 20GeV to 15GeV and tau id in baseline is VeryLoose. The full configuration includes in these 2 links.  
  
For Overlap removal, we follow the SUSYTools recommendation with tau overlap removal. The detail about the strategy for overlap removal show in this table.  
  
About trigger we use show in this page, in high MET region of stau, we use MET trigger, and for low region, we use single-lep trigger, and for C1C1/C1N2 ISR, we all use MET trigger.

Ok, that's all the preparation before the analysis. Now, let's move to Direct stau analysis, we search include had-had and lep-had channel.

Now Let's talk about the SR definition for HH channel, first, our pre-selection requires: at least two OS medium taus, No leptons, b-jet veto to suppress top backgrounds, MET trigger and MET > 200GeV to keep trigger efficiency at plateau, and an invariant mass cut to reduce Z+jets. For the SR, we trained a neural network using reference point, the detail about training process already put in the backup, and the full DNN output distribution is shown in the left figure, we define our signal region with a DNN score cut at 0.7, the right figure shows the binned SR results, the combined significance reaches 2.22, as shown in the bottom table, the dominate bkg is fake and VV process, the fake tau mainly comes from W+jets and partial Top, we use fake factor method to estimate, and real tau comes from Z+jets, Top, VV, we scaled them with dedicated CRs and validate them with VRs.

Now let me explain our strategy for fake background estimation. we define two types of regions to calculate fake factor. one called CR which have similar selection with LH channel, and the other one is SR which have similar selection with HH channel. I know the name use here is quite weird. For each region, we categorize taus based on their ID status: 'ID' refers to taus passing the medium identification, while 'Anti-ID' refers to those passing only the VeryLoose criteria but failing medium. And we also use SS region to orthogonal with SR in LH channel. The illustration for fake factor please sees the right one figure. For fake calculation, we employ a three-dimensional binning scheme. For prongness, we separate tau into 1-prong and 3-prong. For tau eta, we split that into two bins based on barrel and endcap and we also split barrel bin into two bins to apply in 1-prong. And about tau pt bin, we use auto-binning algorithm. The result shows in the right bottom two figures and the legend corresponds to the specific bin definitions.

Here is the score distribution and some kinematic distribution that used in the training after data-driven and more data/MC can find in the backup. we can see that the agreement of MC and data here looks good.

Besides the SR, we define control regions (CRs) and validation regions (VRs), each targeting specific dominant processes—such as fake, Z+jets, VV, and Top. The selection for these regions is quite similar just change to different score and different range, the below figures show the distribution of these scores and lowerpad shows the MC modeling for these region. This table summarizes the performance of our background predictions across these regions. Key metrics include purity and data over MC. The Fake VR shows excellent agreement (Data/Bkg = 0.97) and high purity (96%), confirming our fake factor method. The Z CR/VR and VV VR exhibit slight over-prediction (ratios ~1.05–1.07), but that is acceptable.

Now we can turn to the LH channel. while similar in approach to HH channel. In pre-selection for LH channel, we change to >= 1 medium taus, and require 1 base lepton, 1 signal lepton. and additional kinematic variables to suppress background before training. Like before, we trained a DNN model (distribution shown left) and defined our SR with a DNN score > 0.7. The combined significance for this region is 0.79, and more detail about events yields shows in the below table, last row shows the significance for each bin.

For bkg estimation, which is similar with HH channel, we define dedicated CRs and VRs in LH channel. The region definitions follow the same method, as shown in this table, the lowerpad in the below figures show our MC modeling performance. From the purity and MC modeling, it shows better performance compared with HH channel and we even have additions CR for di-boson here.

After all regions are well defined, we evaluate the whole signal grid with this model, the result shows with sensitivity map, and for the all-signal point with 30% flat systematic uncertainty. as you can see the left figure is HH channel, and the right figure is combined one which follow the same trend with HH channel, since HH channel derived the main sensitivity for direct stau ISR channel, even for the stau mass equal 180 GeV, its significance still quite good.

Next is Direct stau with single-lep trigger, it only has LH channel. The selection is quite similar with direct stau ISR except reverse the MET cut to make them orthogonal. And here requires more kinematic variable to cut bkg. SR defined by DNN score with reference points. And SR are binned by NJets as show in the left bottom table. The whole distribution of DNN for these two SRs show in the top figures, and here we also define CR and VR by signal score. The below figures show the binned SR and as you can see, main sensitivity is derived from 1J channel.  
  
This table shows the CR and VR definition in 1J channel, for the CR, it split into e-channel and muon-channel to make comparison. The purity for these regions all quite good. One more thing need to be mentioned that the fake is from MC not from data-driven, but it will be replaced by data-driven. The next two pages show the score distribution, and the agreement for these scores are quite good.  
  
And then for the 0J channel, we only define the Fake CR and Z CR since the VV and top are minor background. the selection for these region shows in the table and below figures also show the distribution of these scores.

after defining the CR and VR in 1J channel and 0J channel, we have background only fit analysis as show in this slide. For 1J channel, the norm factor for fake only have 0.7 but it needs to be improved by data-driven method. The VRs all have slightly overprediction, but they are all under 2-sigma. And combined and separated show the consistent result which provide the cross-validation.

For 0J channel, there is large 3 sigma overestimation for fake and further investigation need for data-driven and Z+jets in here have good agreement.  
  
we also have search in exclusion fit, as you can see the figure in the right one, all the signal grid are with 20% shape systematic, and you can see the reference point is pointed out with arrow. And its exclusion CLs is 0.41.

At Last, the Fake estimation for this channel also ongoing and we can see some preliminary results. The process of the Fake factor is quite similar with what I just discussed before except here calculate the FF separate in W+jets and Top. And the right figures show the result comparison between MC fake and data-driven fake. For OS channel, high tau pt perform the better agreement but for SS channel, it still worse and it's under investigation.

Besides the NN method to define SR, we also have a search with Cut&Count method to define the SR. The left one table shows the pre-selection for HH channel. And that's similar with I just mention before. The middle one table shows the result after Cut&Count, and right one figure shows how we binned the SR into 4 parts. The variable we use here is transverse of tau1 and MET and transverse of tau2 and MET, and the distribution for these variables display in the below figures.

We can see more details in this page, left table shows the events yields and significance for each bin and right one figure shows the sensitivity map for the signal grid. The map shows the same trend with NN result, these two methods perform a cross validation to our result which is great.

For the LH channel, that's the same. Here we use number of Jets and tau pt as orthogonal variable to split the SR into 4 binned SRs.

The result for these 4 SRs shows in the left one table and the sensitivity map only involve SR1 result.  
  
To estimate the bkg in the SR, here we also define the CRs and VRs. as you can see, we define Top CR and Z CR in HH channel by MT2(70) Cut. W+jets CR and VV CR are defined in LH channel and LL channel respectively. besides we also have three VRs region which close to SR and orthogonal with CR by transverse of tau1 and MET cut. clearer and detail information about the SR, CR and VR can check this table. That's all for the Direct stau scenario.   
  
Now we can move to the C1C1/C1N2 ISR search, First is C1C1ISR search, the preselection we ue here is the same with Direct stau and add pt jet cut to select ISR, the SR are optimized by BDT method with reference point, figure of merit to evaluate the result is combined significance with 30% flat systemic uncertainty and for the training, we use 5fold cross-validation to avoid overfit. The best performance model shows in the below table.

SR are defined by applying the BDT score cut at 0.9 both HH and LH channel. And we can see the binned SR in the right one figure, the combined significance for SR is 3.32. more detail about these bins can be found in the below table. For the significance in signal grid, we use sensitivity map to show the result, as you can see the black dash line label the 1.64 in significance, we can see that the low mass C1 have better performance in significance.

For LH channel, they are the same, and the combined significance for SR is 5.36.  
  
Besides the SR, we also define some CRs and VRs in LH channel, the selection for them show in the table, and the second column in selection shows how these regions are orthogonal, as you can see the Top CR/VR have 10% disagreement in data/MC but for ZCR/VR this ratio is close to 1 which is good. And now the preliminary result only for run2 sample, but it will expand to run2+partial run3 sample later.  
  
Then Let's move to C1N2 analysis, we use the same way to optimize the SR, the pre-selection is the same and the process of hyperparameter tune show in the bottom table, we use penalty function to balance the AUC and overfit in the training.

The score distribution show in the left one figure and in HH channel we define the SR with BDT score cut at 0.8, the Binned SR show in the right one figure and details for each bin are listed in the below table, last row shows the significance for each bin, the combined the significance for binned SR is 7.56.

Here also shows the distribution after data-driven, we use the same way to estimate the fake with direct stau, more data/MC after data-driven please check the backup.

For CRs and VRs, the detail for the selection shows in the table, and the crucial variable that marked in the blue box, their distribution list in the below figures. For the TopCR and ZCR/VR, the data/MC have about 10% disagreement which is acceptable. And the Fake VR have a good agreement in data and MC.  
  
Now, we can move to the LH channel, the process in the LH channel is quite similar, and we apply a BDT cut at 0.91 which because Zn is large than 2 at score = 0.91, and the right figure shows the binned SR, the combined significance is 4.9 which is lower than the HH channel.

The CRs and VRs definition are also similar with HH channel, expect change some vars to define, and they are pointed out with bule box, the distribution for them can see in the below figures, the agreement in Top still has 10% disagreement, the purity for these region is higher than HH channel. And data/MC is better in ZCR/VR compare with HH channel.

And at Last, the sensitivity for signal grid shows in this page, the 1.64 line are label with black line. The gap comes from the interpolation algorithm, and sensitivity map results only in run2 data, but it will be updated to full run2 + partial run3 data. And That's all.

Let's summary that what we have now, in the Direct stau, SR are investigate with DNN and preliminary CRs/VRs already prepared. The fake is estimated by Fake Factor method, also, include the expected sensitivity map. For inclusive channel, it includes the preliminary result in bkg onlyfit and expected CLs. and for C1C1/C1N2, we use BDT approach to define the SRs both in HH and LH channel, the fake is estimated by FF method, and provide run2 sensitivity map which will expand to run2+partial run3.  
  
next step, we need to finalize CRs/VRs for all scenarios, like add data-driven to replace MC fake, and add systematics studies to our analysis. For now, we only have preliminary result about CLs in Direct stau inclusive channel, so we need to start to prepare the interpretation for expected limit with uncertainty, and last thing is about the internal note, it needs to be prepared for the EB request. more detail about our analysis can found in the backup. So, that's all from my side, Thanks!