The stop on top

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INTRODUCTION

Supersymmetric partners of the top quark have been sought since the top quark has been discovered at the Tevatron. The searches are more easily performed in scenarios where the mass splitting between the top and the stop is large and where differences in kinematics are striking. The region in which top and stop are almost degenerate in mass is more difficult to explore experimentally as the final state kinematics are very similar, apart from angular-related distributions which reflect the spin/parity difference between the two particles. Usually the searches are performed looking for deviations on the measured top-quark pair production cross section with respect to the standard model prediction, or looking to simple variables such as the difference in the azimuthal angle between two leptons produced after top quark decays. In this project we explored and combined different variables starting from a full reconstruction of the top pair kinematics. As a starting point we mimic the reconstruction adopted in [1] and compare the standard model (SM) expectations to those of a generic SUSY model.

EVENT SELECTION

We started by selecting eμ or same-flavour (ee/$\mu\mu$) events with at least 2 b-tagged jets and attempted to peform a reconstruction of the top-anti-top kinematics. The method employed is described in detail in [2]. As there is an ambiguity in assigning each lepton to each b-tagged jet to form a top quark decay and as there are two neutrinos expected in the event and only one constraint from the missing transverse energy, there can be up to 8 solutions per event. The solutions can be ranked according to the invariant mass of the $t\bar{t}$ system. Given that the gluon PDFs (Parton Distribution Function) are steeply falling in x we expect that the most probable value for the production of the $t\bar{t}$ system is at rest, thus we pick the solution which yields the lowest M$(t,\bar{t})$.

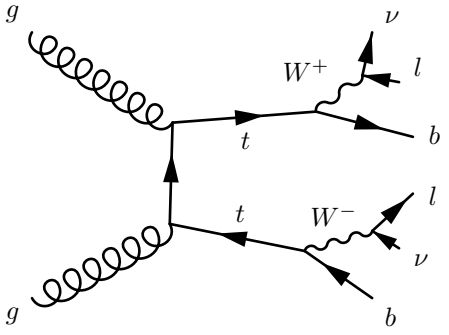

Fig.1 SM - top pair production

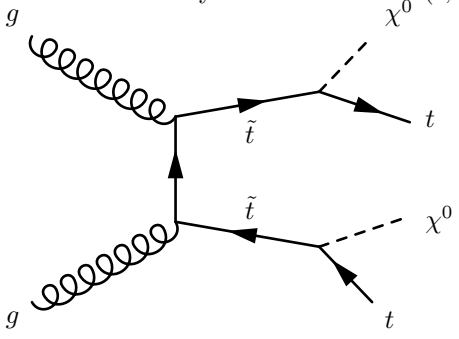

Fig.2 SUSY - contribution to top pair production in association with a pair of neutralinos

CHOOSING VARIABLES

With a full reconstructed system we plotted variables related to angles of the leptons or b-jets in the top quark rest frames from where they come.

After looking at histograms for different variables we observed the one that shows different character from standard model that is $cos\theta_{b_1} * cos\theta_{b_2}$ where θ_{b_1} and θ_{b_2} are azimuthal angle of final state b-jets.

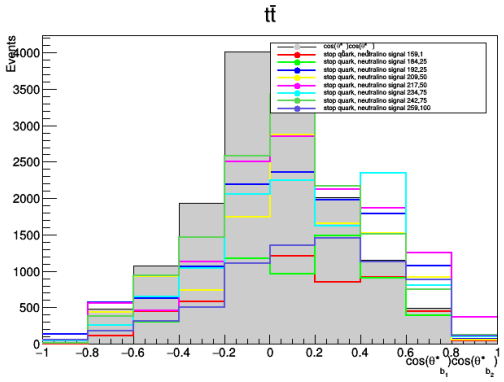

Fig.3 Distribution of the product of the b-jet angles in the top rest frame for SM tt and different SUSY scenarios.

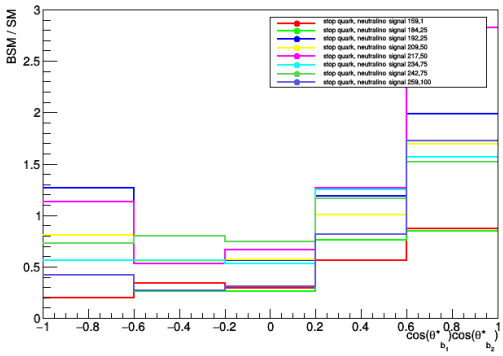

Fig.4 Ratio of the SUSY to SM predictions

From Fig.3 we can see tha this variable is asymmetric for stop production and symmetric for SM $t\bar{t}$. The expected asymmetry at reconstruction level is shown in Fig.5.

The efficiency is almost the same for SM and SUSY simulation (Fig.6). Thus we did not consider events failing reconstruction in a separate category.

	Asymmetry
SM	0.006 ± 0.003
m_{stop}, m_{LSP}	
159, 1	0.201 ± 0.008
184, 25	0.278 ± 0.007
192, 25	0.227 ± 0.005
209, 50	0.292 ± 0.006
217, 50	0.284 ± 0.005
234, 75	0.274 ± 0.006
242, 75	0.195 ± 0.005
259,100	0.317 ± 0.006

Fig.5 Asymmetry in the $cos\theta_{b1}cos\theta_{b2}$ distribution for SM and SUSY scenarios.

Reconstruction Efficiency	
SM	0.94
m_{stop}, m_{LSP}	
159, 1	0.95
184, 25	0.94
192, 25	0.94
209, 50	0.93
217, 50	0.94
234, 75	0.92
242, 75	0.92
259,100	0.94

Fig.6 Top kinematkics reconstruction efficiency for SM and SUSY scenarios.

Data/MC comparisons

We can see from Fig.7 and Fig.8 that there is a fair agreement of Data and MC simulation for our chosen variable $cos\theta_{b_1} * cos\theta_{b_2}$ in both channels.

Overall there is a fair agreement between data and predictions for all variables.

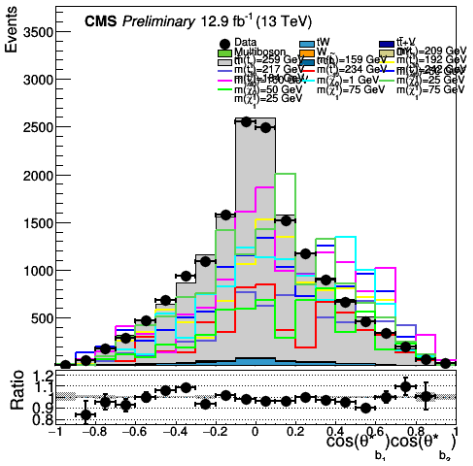

Fig.7 $e\mu$ channel

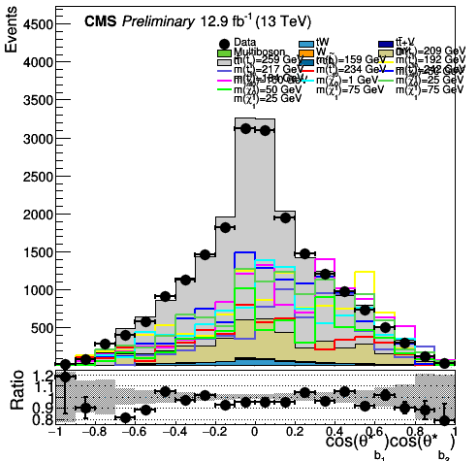

Fig.8 ll channel

EVALUATING SIGNAL STRENGTH

We used Higgs Combination Tool to project expected limits on SUSY contribution and derived signal strength "r" ($\sigma_{95\%CL}/\sigma_{th}$) values for each stop, neutralino mass signal that we were looking at.

In the analysis we included systematic uncertainties such as: B-tagging, theory cross-section for all backgrounds, luminosity and MC statistics bin by bin uncertainties.

In the area where value of r is less than 1 we expect to exclude with 95% CL mass region of the $\tilde{t}$ squark, in particular masses lower than 220-230 GeV.

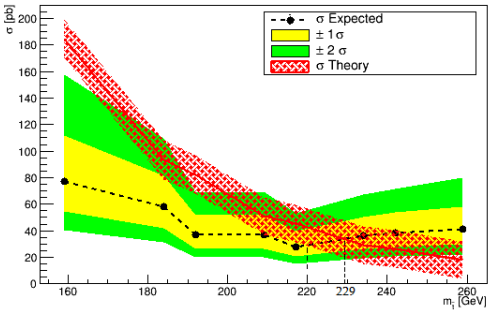

Fig.3 Stop pair production cross section

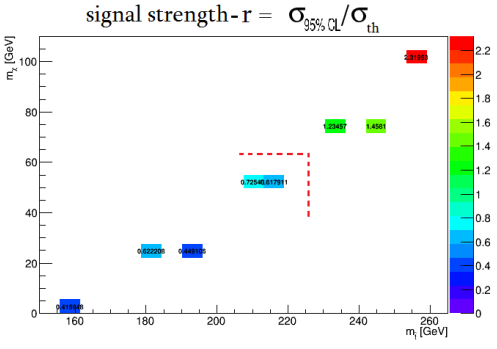

Fig.4 m_{stop}, m_{LSP} plane

CONCLUSIONS

A preliminary study using polarization variables has been performed during my stay at CERN:
• Reproduced results from [1] at 13 TeV (reconstruction level).
• Re-casted in a search for compressed SUSY contributions to the top quark sector.
Amongst all the variables studied the b angle in the top rest frame seems a promising variable.
After a statistical analysis we expect to exclude mstop $<$ 220-230 GeV at the 95% CL.
Further improvements may be foreseen in a more mature version of this analysis by:
• optimizing kinematics cuts.
• categorizing and choosing variables depending on how soft the events are.

REFERENCES

[1] CMS Collaboration, "Measurements of $t\bar{t}$ spin correlations and top quark polarization using dilepton final states in pp collisions at $\sqrt{s} = 8$ TeV", Phys. Rev. D 93 (2016) 052007.
[2] arXiv:1305.1878v2 [hep-ph]