Truth analysis of Vector-like leptons simulations in ATLAS

Iker Vea Llàdser, Judita Mamuzic, Imma Riu

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Institut de Física d'Altes Energies

EXCELENCIA SEVERO OCHOA

BIST Barcelona Institute of Science and Technology

ATLAS EXPERIMENT

VLL 4321 model

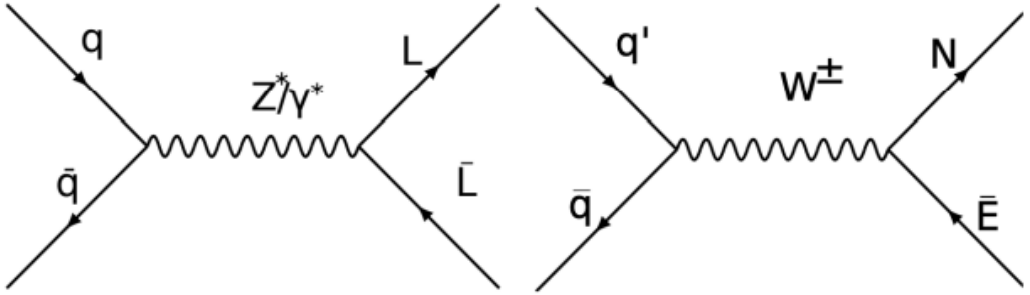
- It is an UV-complete model
- Extends the SM gauge groups to a SU(4) x SU(3)' x SU(2) x U(1) ' model
- Motivated by the B-anomalies
- Gives a possible explanation for these flavour-nonuniversal results.

arxiv.org/abs/1708.08450

Vector-like leptons

❖ VLLs come in doublets with one charged (E) and one neutral (N).

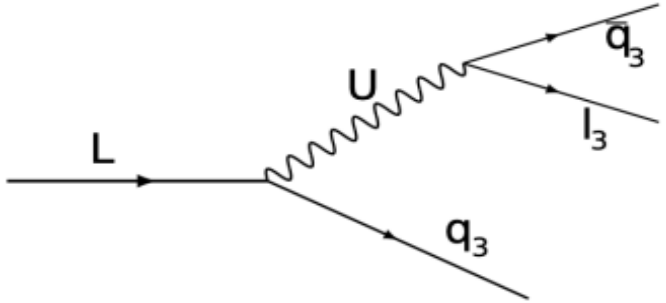
❖ They can be produced via electroweak production through their couplings to SM W and Z bosons or through interactions with a new Z' boson in the 4321 model



*L represents either the neutral or charged VLL

❖ VLLs decays

- via an intermediate leptoquark, U, to two quarks and one lepton
- decays are expected to be almost entirely to third generation fermions



VLL analysis procedure

- We are using the VLL 4321 model

- We set the charge of the VLL and using MC we generate different samples for different production modes and masses

- The CMS released a similar study of VLLs, therefore, we plan an analysis to be consistent with the theoretical model assumed by CMS and be able to compare the results after our research

CMS analysis

❖ **The analysis** selection driven by the highly flavour asymmetric final states produced in the VLL decays

- They search for pairs of VLLs by selecting events with high b-jet multiplicity

- These events are categorized by the number of (hadronically-decaying) **τ** leptons

- CMS latest analysis ignores the production of EE and NN via Z'

- The τ multiplicity categories and the decay modes of the different VLL pairs that contribute to each category

tau multiplicity	production + decay mode	final state
0 τ	EE $\rightarrow$ b(tν_τ)b(tν_τ)	4b + 4j + 2ν_τ
	EN $\rightarrow$ b(tν_τ)t(tν_τ)	4b + 6j + 2ν_τ
	NN $\rightarrow$ t(tν_τ)t(tν_τ)	4b + 8j + 2ν_τ
1 τ	EE $\rightarrow$ b(bτ)b(tν_τ)	4b + 2j + τ + ν_τ
	EN $\rightarrow$ b(tν_τ)t(bτ)	4b + 4j + τ + ν_τ
	EN $\rightarrow$ b(bτ)t(tν_τ)	4b + 4j + τ + ν_τ
	NN $\rightarrow$ t(bτ)t(tν_τ)	4b + 6j + τ + ν_τ
2 τ	EE $\rightarrow$ b(bτ)b(bτ)	4b + 2τ
	EN $\rightarrow$ b(bτ)t(bτ)	4b + 2j + 2τ
	NN $\rightarrow$ t(bτ)t(bτ)	4b + 4j + 2τ

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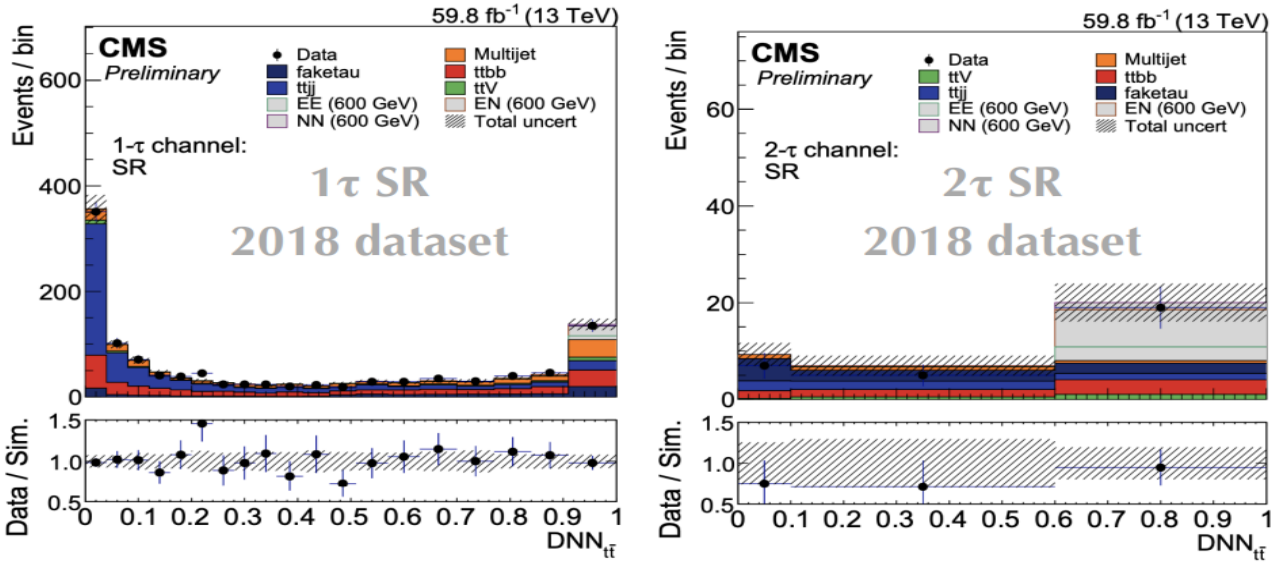
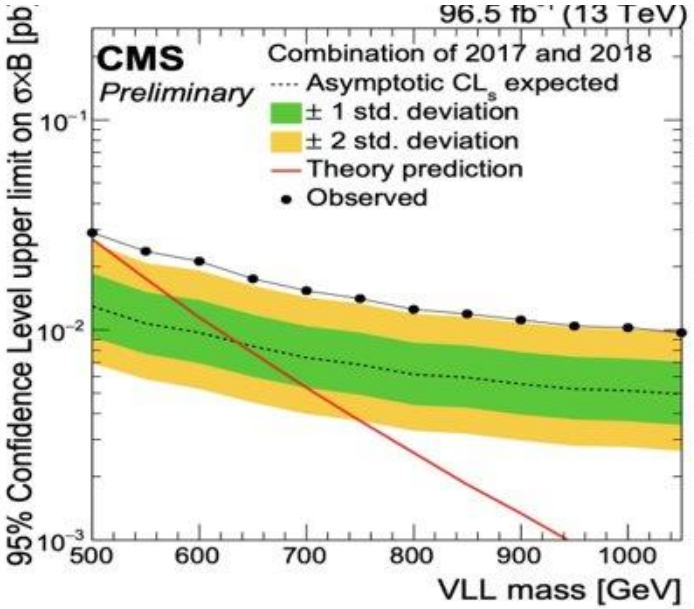
CMS results

- Excess observed in the 1-τ and 2-τ regions are consistent among each other

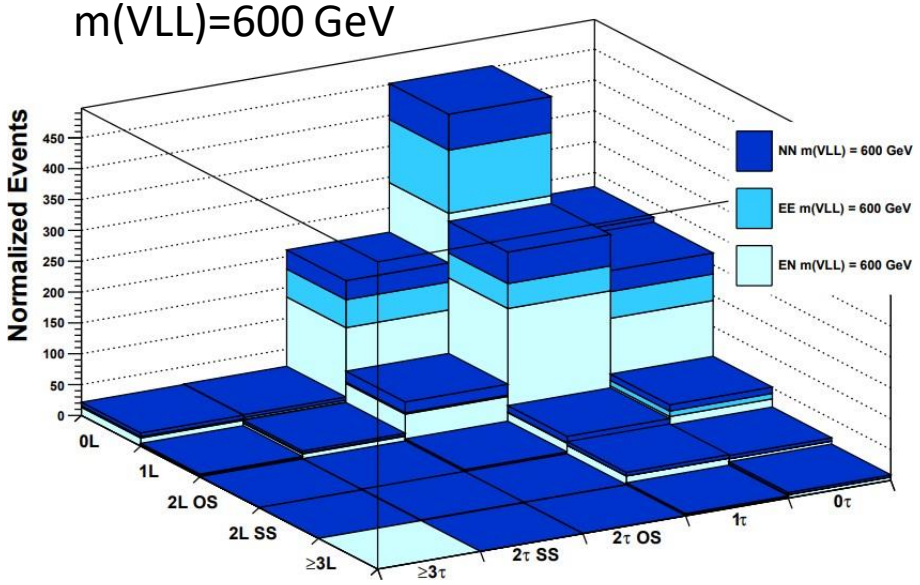


- 2.8σ obs tension above SM @ 600 GeV VLL mass

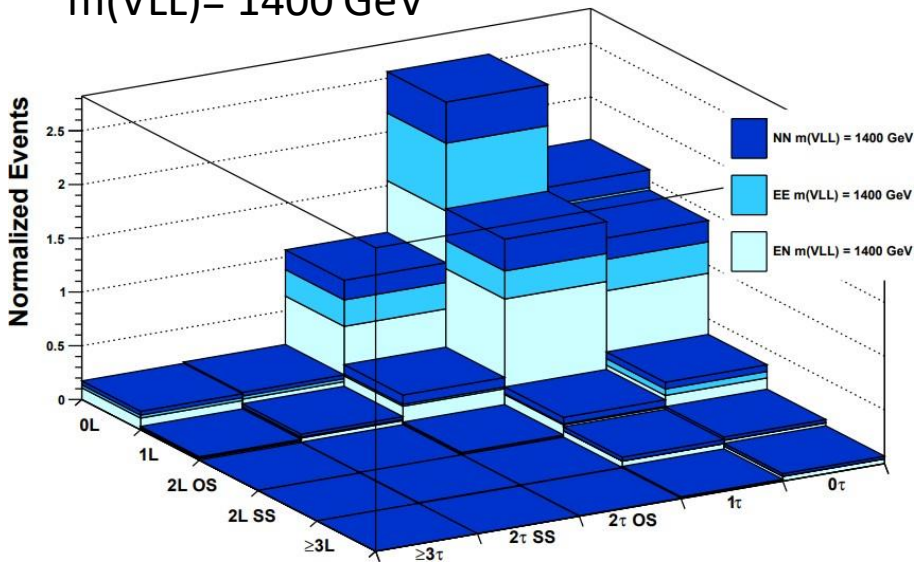


RESULTS: Yields per category of variuos VLL samples

m(VLL)=600 GeV



m(VLL)= 1400 GeV

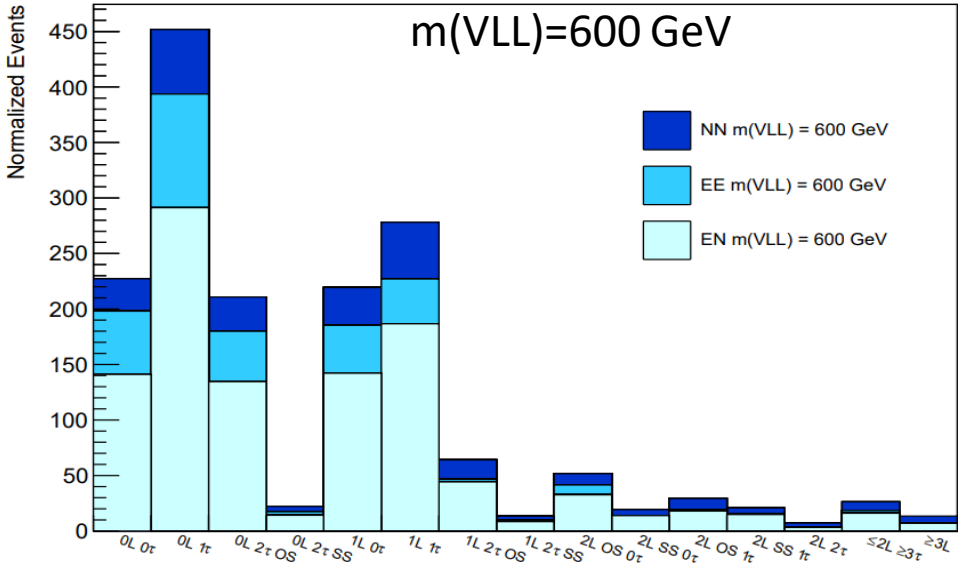


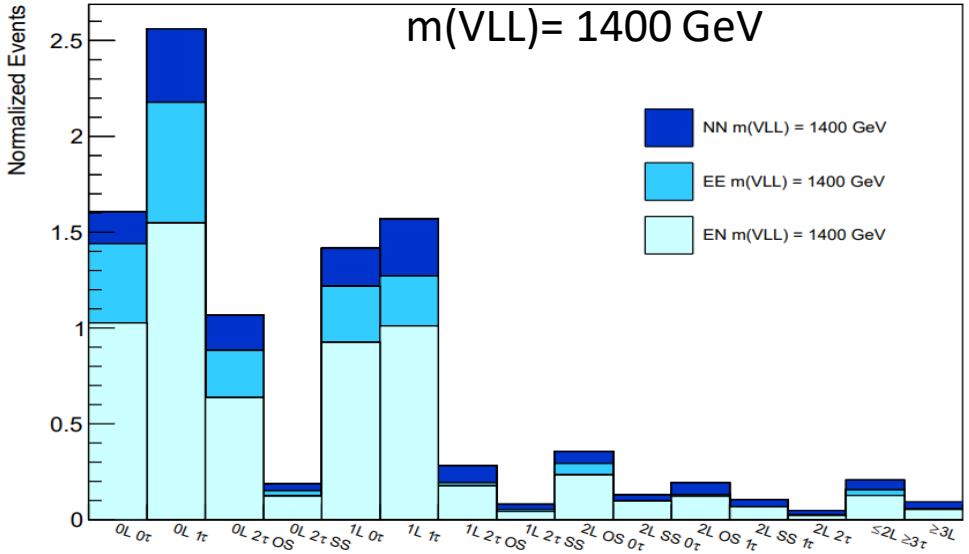
We want to look into signal populating the tau and lepton channel categories

We created productions with mUμ = 3.5 TeV, gU = 3, $\beta_R^{b\tau} = 0$

- The most populated categories are those with low number of Leptons and Taus
- In order to see that properly we represent those histograms in 1D

RESULTS: Yields per category of variuos VLL samples





We created productions with mUμ = 3.5 TeV, gU = 3, $\beta_R^{b\tau} = 0$

- As expected, the biggest production contribution comes from the EN production and yields reduce with cross section
- The distribution of normalized events per category is similar between masses

RESULTS: VLL MC samples with different parameters

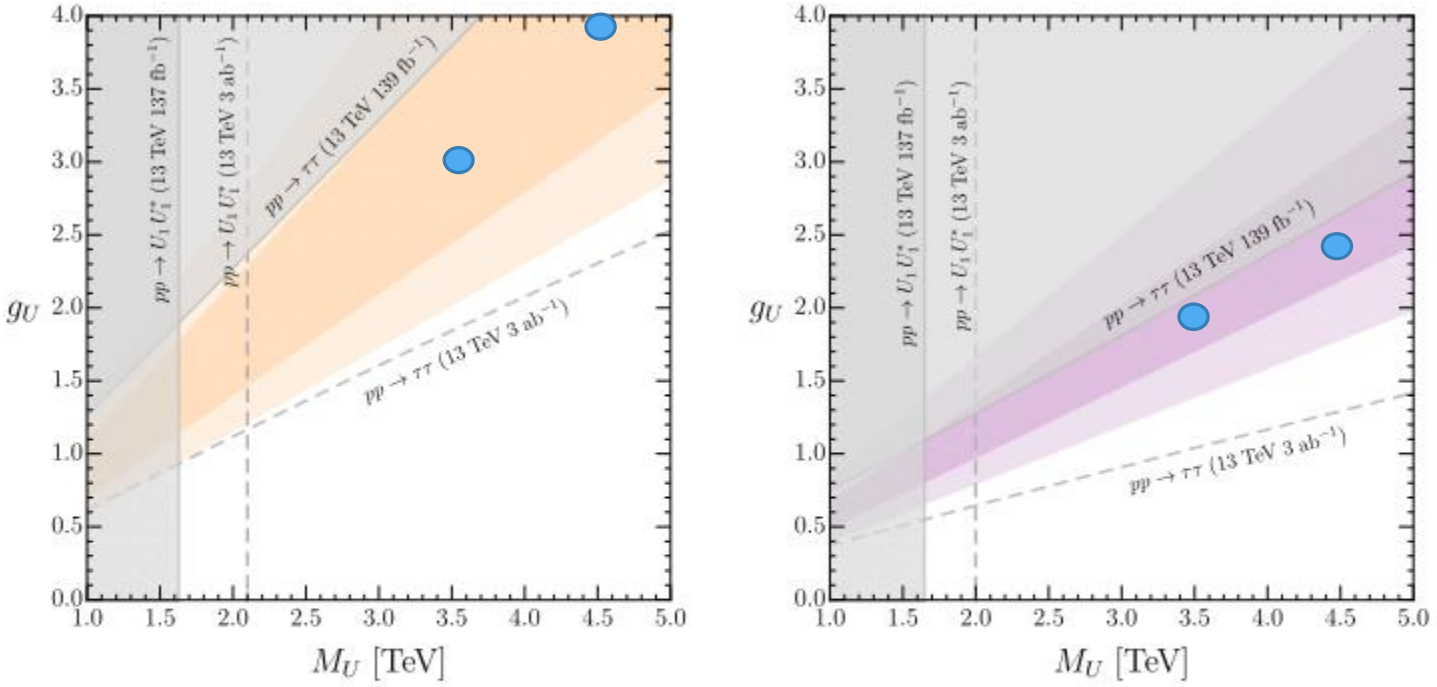
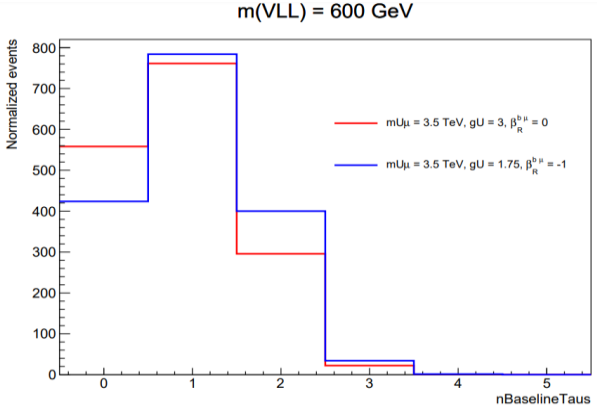


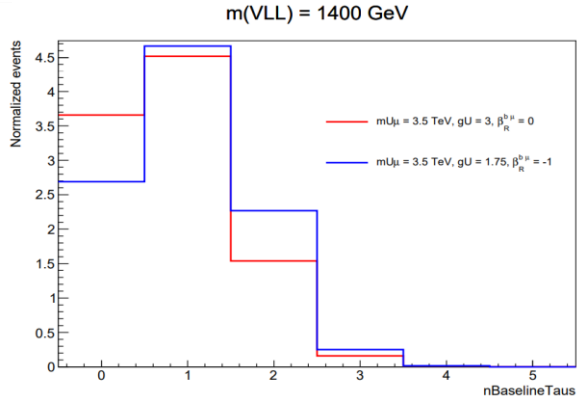
Figure 7. LHC constraints for the U_1 vector leptoquark for the benchmark scenarios with $\beta_R^{b\tau} = 0$ (left) and $\beta_R^{b\tau} = -1$ (right). The 1σ and 2σ regions obtained from the fit to low-energy data are also shown.

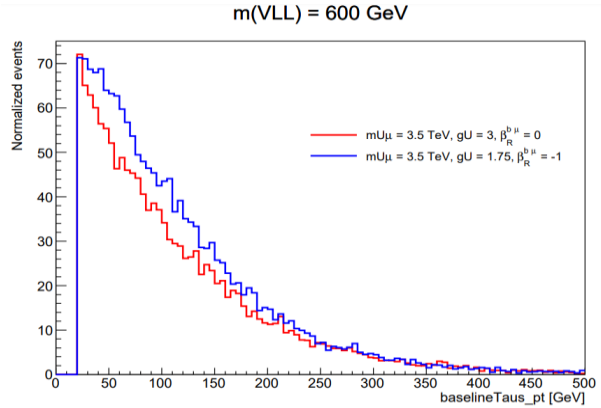
- To check the effect of mUμ in order to avoid additional studies
- Check varying Uμ mass, needs to be done together with changing the gU coupling.
- $\beta_R^{b\tau}$ is coupling of Uμ to third generation

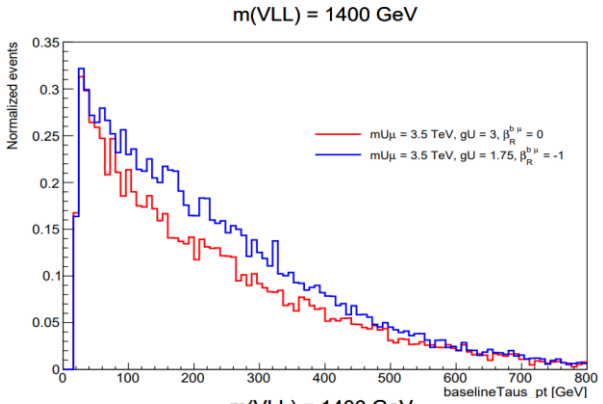
link.springer.com/content/pdf/10.1007/JHEP08(2021)050.pdf

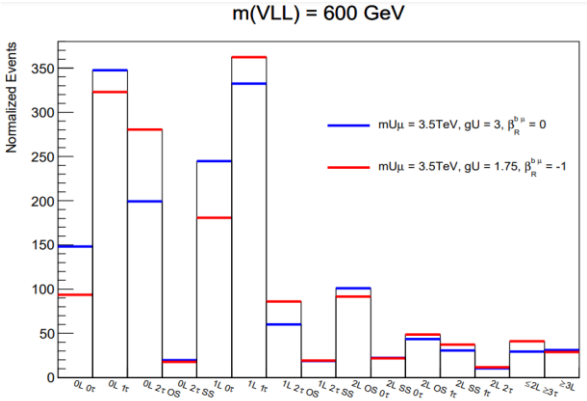
RESULTS: VLL MC samples with different parameters

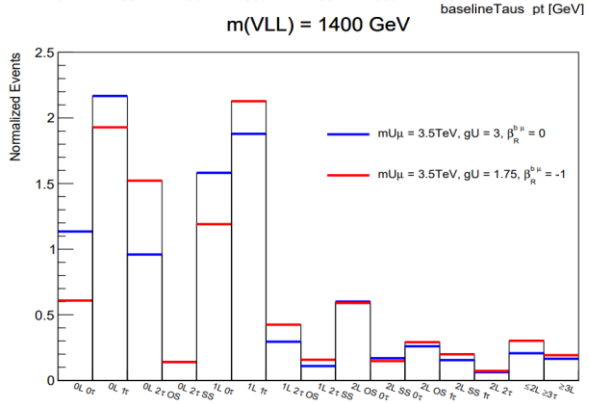










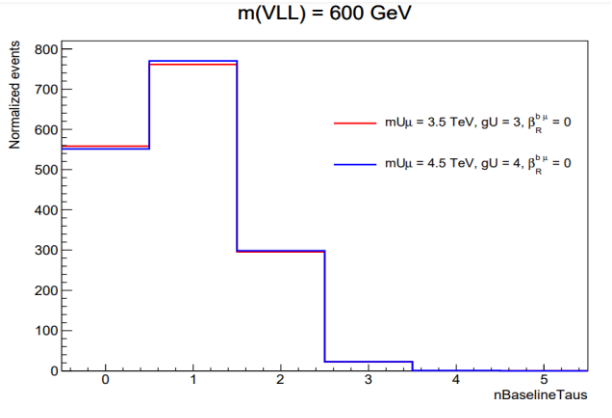


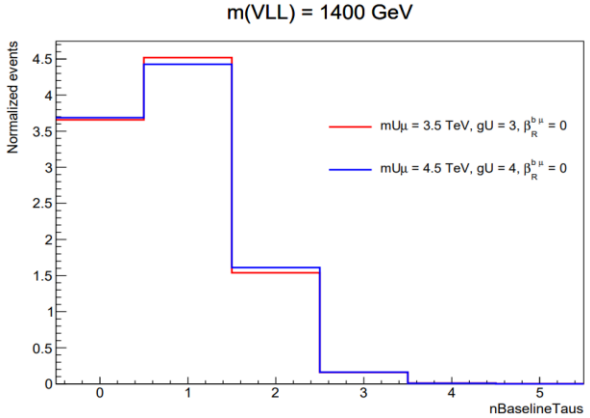
Plots of the normalized
EE+EN+NN distributions

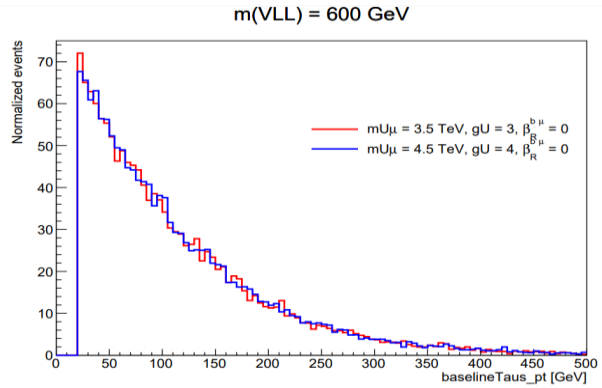
We compare productions with mUμ = 3.5 TeV, gU = 3, $\boldsymbol{\beta_R^{b\tau} = 0}$
and mUμ = 3.5 TeV, gU = 1.75, $\boldsymbol{\beta_R^{b\tau} = -1}$

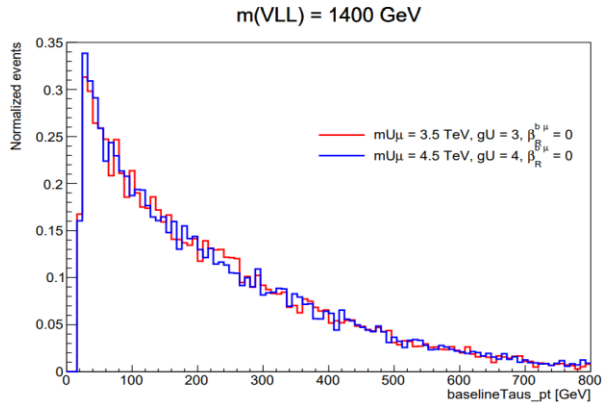
- For different $\beta_R^{b\tau}$ we clearly see an increase of the number of Taus
- Differences between them are quite independent of the VLL mass
- Multiplicity, kinematics and category selection plots are slightly different.

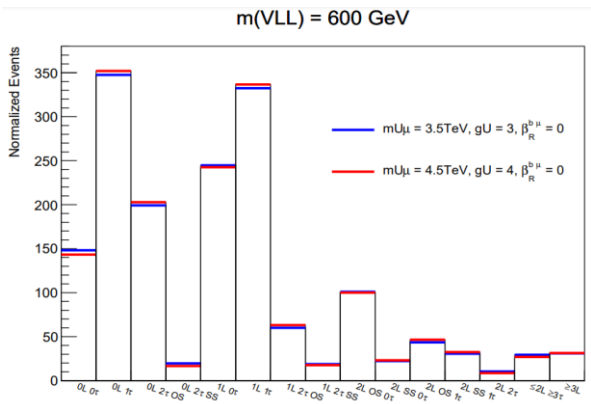
RESULTS: VLL MC samples with different parameters

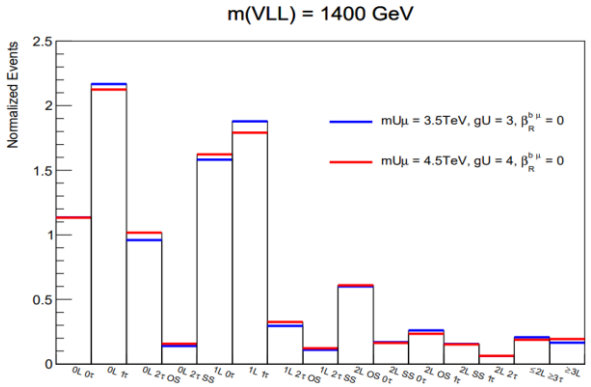










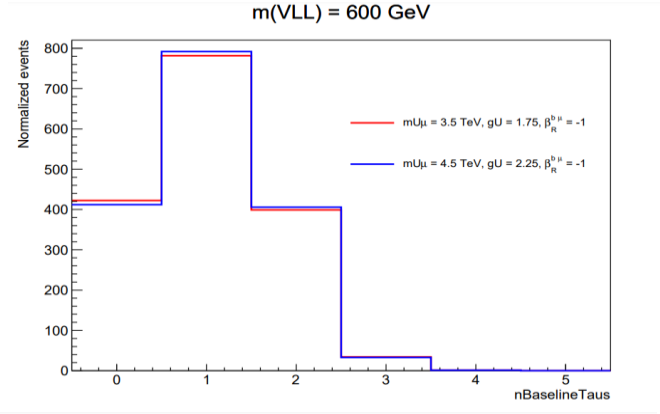


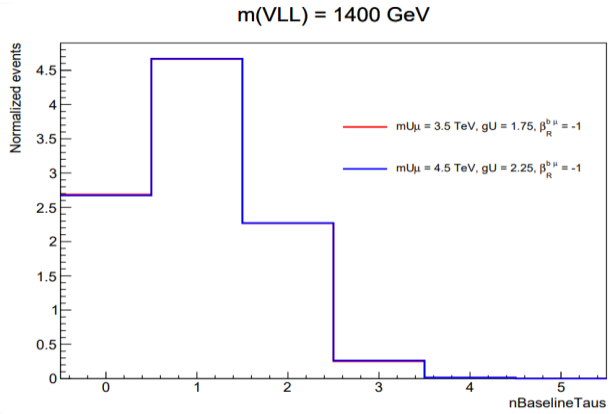
Plots of the normalized
EE+EN+NN distributions

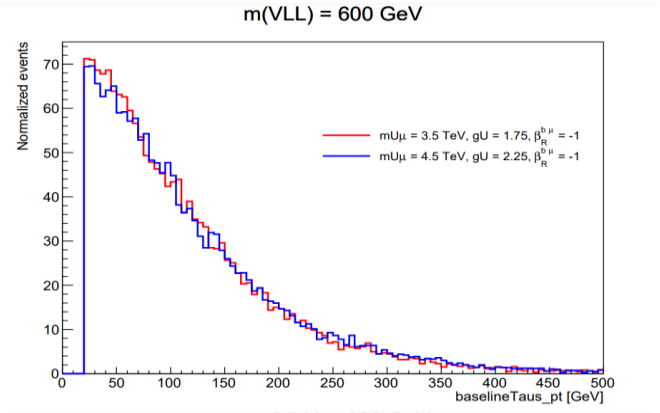
We compare productions with **mUμ = 3.5 TeV**, gU = 3, $\beta_R^{b\tau} = 0$
and **mUμ = 4.5 TeV**, gU = 4, $\beta_R^{b\tau} = 0$

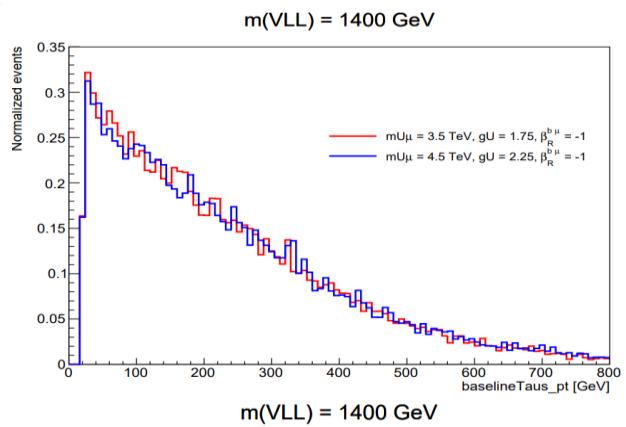
- They are almost identical. mUμ doesn't cause a significant change
- Multiplicities, kinematics and category selection plots are unchanged.

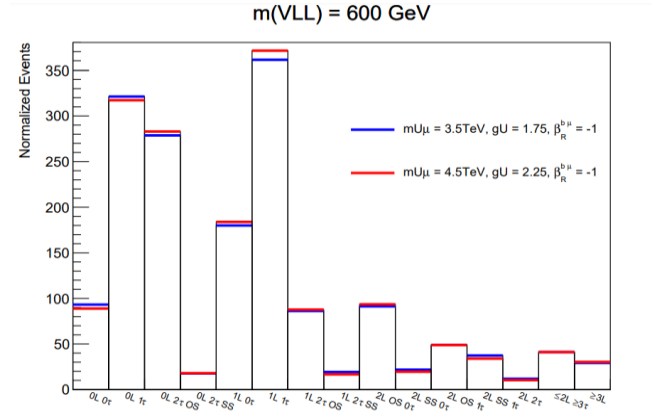
RESULTS: VLL MC samples with different parameters

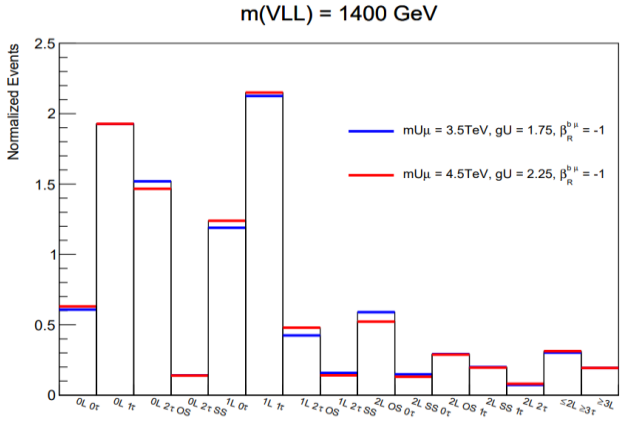












Plots of the normalized
EE+EN+NN distributions

We compare productions with **mUμ = 3.5 TeV**, gU = 1.75, $\beta_R^{b\tau}$ = -1 and **mUμ = 4.5 TeV**, gU = 2.25, $\beta_R^{b\tau}$ = -1

- They are almost identical. Uμ doesn't cause a significant change
- Multiplicities, kinematics and category selection plots are unchanged.

Summary and plans

- The distribution of normalized events per category is similar between masses
- The biggest production contribution comes from the EN production
- Varying mUμ doesn't cause a significant change.
- As expected, for different $\beta_R^{b\tau}$ we clearly see an increase of the number of Taus.

Analysis is currently ongoing in IFAE using all MC samples and reconstructed objects.
In the near future we plan to see if the comparison study can be performed using BR re-weighting