SUSY 17

Towards a reconstruction of the lightest up-type squark flavour structure

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Summary

I/ INTRODUCTION

II/ A DIRECT RECONSTRUCTION METHOD

III/ A BAYESIAN APPROACH

IV/ MULTIVARIATE ANALYSIS (MVA)

IV/ CONCLUSION

MSSM

<u>Supersymmetry (SUSY)</u>

- For each degree of freedom → super-partner (same mass)

+ Standard model (SM) + A second higgs doublet

+ Softs terms : break SUSY !

MSSM

<u>Particle content</u>

- 6 quarks + 12 squarks
- 6 leptons + 12 sleptons
- Usual gauge & higgs bosons + 4 neutralinos & 4 charginos
- 8 gluons + 8 gluinos

<u>In favor</u>

- A simple viable SUSY model
- A good UV completion & coupling unification
- A dark matter candidate

<u>Disfavor</u>

- Experimental bounds
- A large number of parameters

→ *We aim to study flavor in up type squark sector*

Squark sector

The Lagrangian mass term for the up type squarks in the super-CKM basis :

$$\mathcal{L}_{m_{\tilde{u}}} = \bar{\tilde{u}} \begin{pmatrix} V_{CKM} M^2_{\tilde{Q}} V^\dagger_{CKM} + m_u^2 + D_{\tilde{u},L} & \frac{v_u}{\sqrt{2}} T_u^\dagger - m_u \frac{\mu}{\tan\beta} \\ \frac{v_u}{\sqrt{2}} T_u - m_u \frac{\mu^*}{\tan\beta} & M^2_{\tilde{U}} + m_u^2 + D_{\tilde{u},R} \end{pmatrix} \tilde{u}$$

$\tilde{u} = (\tilde{u}_L, \tilde{c}_L, \tilde{t}_L, \tilde{u}_R, \tilde{c}_R, \tilde{t}_R)$

→ Rotation matrix $R^{\tilde{u}}$ → Physical states $(\tilde{u}_1, \tilde{u}_2, \tilde{u}_3, \tilde{u}_4, \tilde{u}_5, \tilde{u}_6)$

Soft terms $M^2_{\tilde{Q}}$, $M^2_{\tilde{U}}$ and T_u

diagonal → **Minimal Flavor Violation (MFV)**

- No generation mixing
- Only flavor violation source : CKM
- No FCNC

non-diagonal → **Non Minimal Flavor Violation (NMFV)**

- Generation mixing
- FCNC possible

For our study we neglect the mixing involving first generation

Problem

We consider NMFV framework with $\tilde{c}/\tilde{t}$ mixing.

→ $\tilde{u}_1 \to t\tilde{\chi}_1^0$ and $\tilde{u}_1 \to c\tilde{\chi}_1^0$ Possible at tree level !

Problematic : How can we reconstruct the flavour structure of the lightest up-type squark ?

(I.e. find the entries $(R^{\tilde{u}})_{13}, (R^{\tilde{u}})_{16}, (R^{\tilde{u}})_{12}, (R^{\tilde{u}})_{15}$)

Direct reconstruction method

The idea : Solve a system involving observables

Variables

- $R_{c/t} = N(\tilde{u}_1 \to c\tilde{\chi}_1^0)/N(\tilde{u}_1 \to t\tilde{\chi}_1^0)$
- $R_{b/t} = N(\tilde{u}_1 \to b\tilde{\chi}_1^+)/N(\tilde{u}_1 \to t\tilde{\chi}_1^0)$
- $P_t(\tilde{u} \to t\tilde{\chi}_1^0)$ Top polarization from squark decay
- $\tan(\beta)$
- $\tilde{\chi}_1^\pm, \tilde{\chi}_1^0$ composition
- $m_{\tilde{u}_1}, m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_1^+}$

$\Rightarrow$

$$(R_{12}^{\tilde{u}}), (R_{13}^{\tilde{u}}), (R_{15}^{\tilde{u}}), (R_{16}^{\tilde{u}})$$
$$(R_{13}^{\tilde{u}}), (R_{16}^{\tilde{u}})$$
$$(R_{13}^{\tilde{u}}), (R_{16}^{\tilde{u}})$$

+ Unitarity : $(R_{12}^{\tilde{u}})^2 + (R_{13}^{\tilde{u}})^2 + (R_{15}^{\tilde{u}})^2 + (R_{16}^{\tilde{u}})^2 = 1$

Advantages

- Direct evaluation of $R^{\tilde{u}}$

Disadvantages

- Requires good precision
- Requires a lot of observables
- Does not converge all the time

Transition

A direct reconstruction should be really hard to perform in real life ...

A simpler problem : One can try to identify different categories.

In our case we choose to use the following ones, defined by their stop composition :

Categories names	***Stop composition***
MFV scharm	0% - 5%
NMFV scharm	5% - 50%
NMFV stop	50% - 95%
MFV stop	95% - 100%

In the case of categories, one can try to recognize some observables patterns and thus to statistically classify different configurations.

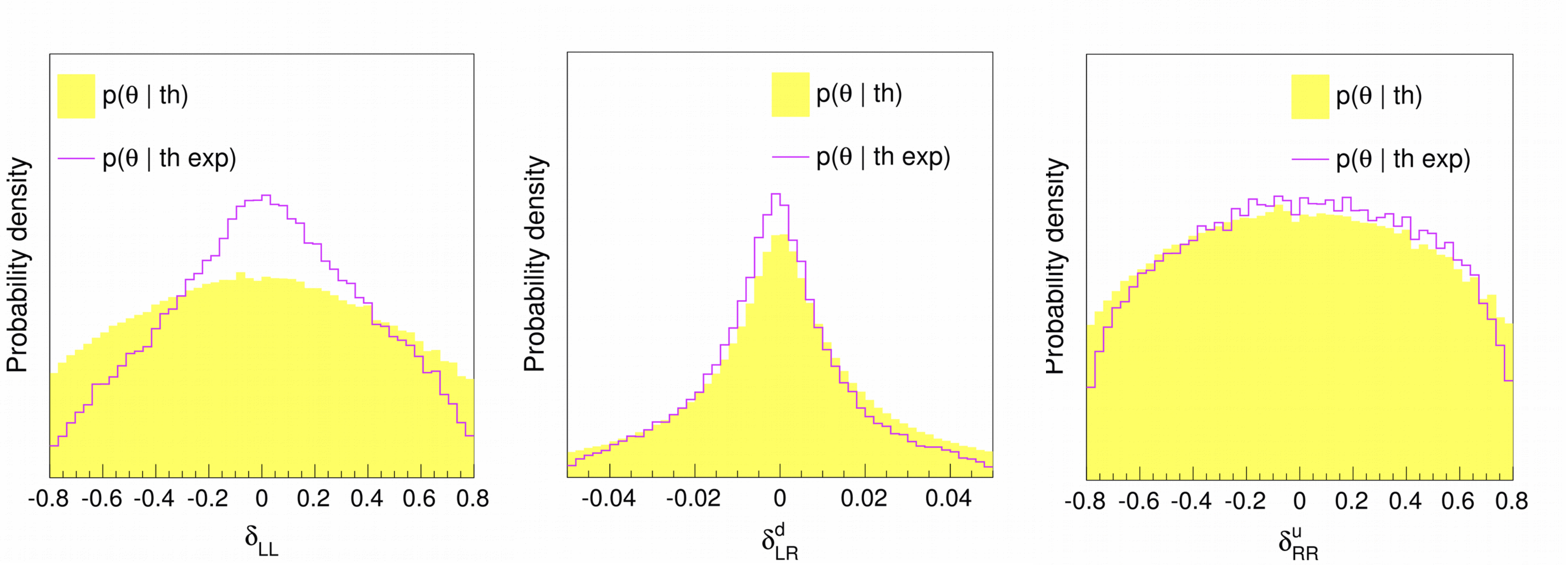
→ We need a database of scenarios

Previous study

We will use the results of the following analysis :

"General squark flavour mixing: constraints, phenomenology and benchmarks",
Karen De Causmaecker and al. *2015*

Selected results :



NB : The masses of charginos and neutralinos are highly correlated because they stem a GUT-inspired relation to reduce the number of parameters.

A Bayesian approach

A set of hypotheses to be tested

$\tilde{c}-\mathrm{MFV},\ \tilde{c}-\mathrm{NMFV},\ \tilde{t}-\mathrm{MFV},\ \tilde{t}-\mathrm{NMFV}$

New data

Data base (MCMC)

Likelihood $\mathcal{L}$

Prior π

Bayesian statistics

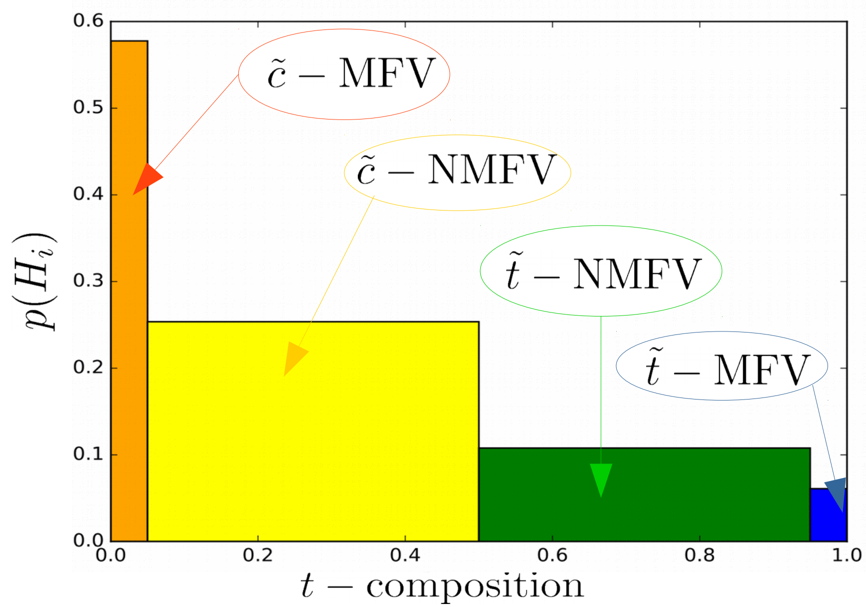
- Bayesian evidence
- Bayes factor
- ...

Comparison of the hypotheses

Variables

- $R_{c/t} = N(\tilde{u}_1 \to c\tilde{\chi}_1^0)/N(\tilde{u}_1 \to t\tilde{\chi}_1^0)$
- $R_{b/t} = N(\tilde{u}_1 \to b\tilde{\chi}_1^+)/N(\tilde{u}_1 \to t\tilde{\chi}_1^0)$
- $m_{\tilde{u}_1}, m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_1^+}$

Selected results



A test point :

$R_{c/t} = 1.24$

$\sigma_{c/t} = 5\%$

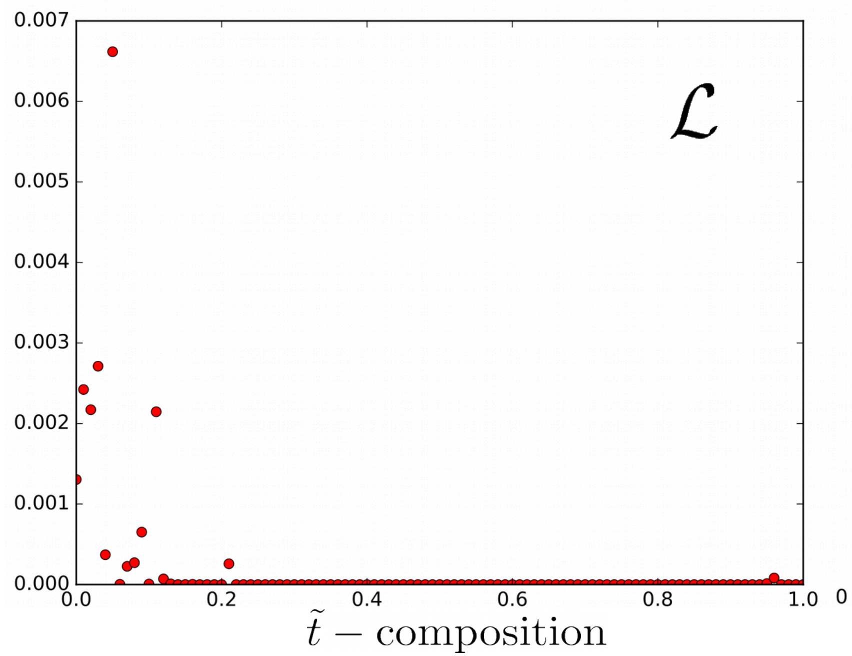
$R_{b/t} = 3.8$

$\sigma_{b/t} = 5\%$

$m_{\tilde{u}_1} = 441$

$m_{\tilde{\chi}_1^0} = 156$

$m_{\tilde{\chi}_1^+} = 162$

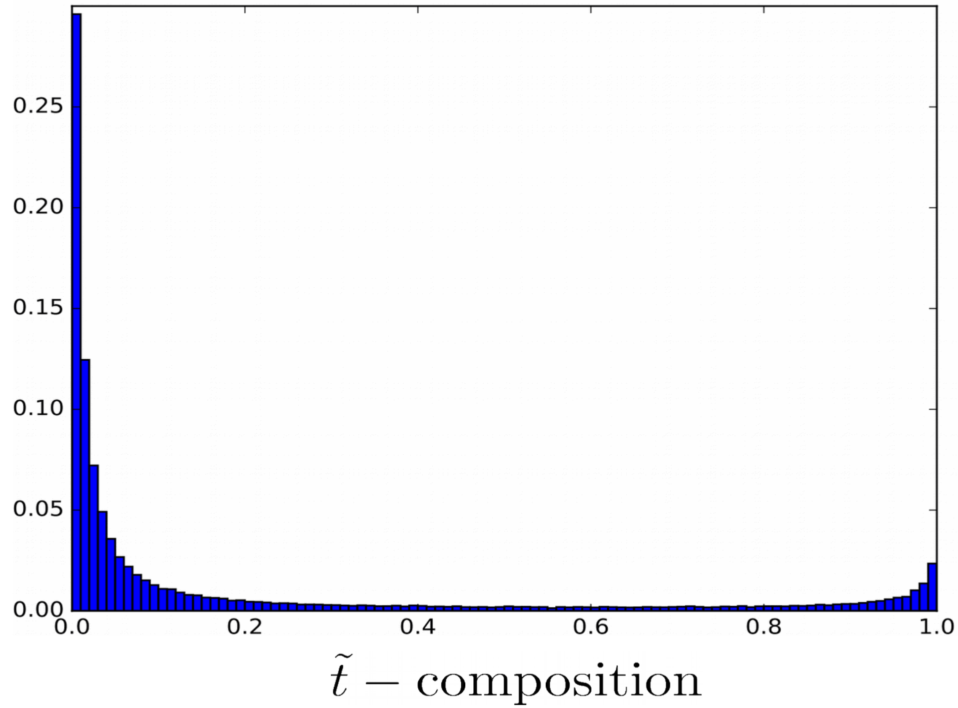


More likely :
MFV scharm

Summary of results

After several tests → Works for certain cases : MFV scharm hypothesis

It can be understood if you look at the prior distribution



But in order to have more points, we would need a lot of computational time ...

The last method : MVA classifier

Variables

- $R_{c/t} = N(\tilde{u}_1 \to c\tilde{\chi}_1^0)/N(\tilde{u}_1 \to t\tilde{\chi}_1^0)$
- $R_{b/t} = N(\tilde{u}_1 \to b\tilde{\chi}_1^+)/N(\tilde{u}_1 \to t\tilde{\chi}_1^0)$
- $m_{\tilde{u}_1}, m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_1^+}$

Training data

Classifier : MLP (neural network)

One “super” variable to classify our data

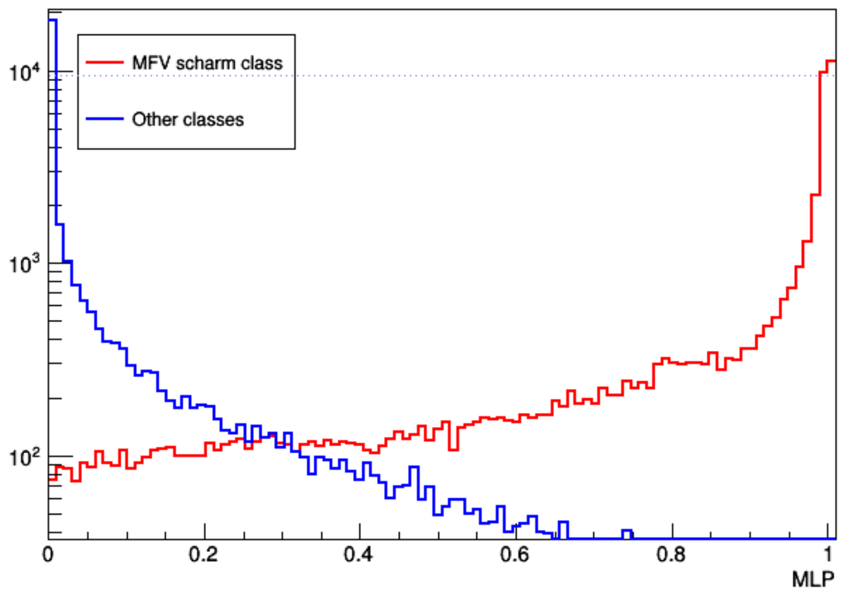
$\tilde{c} - \mathrm{MFV}$ | $\tilde{c} - \mathrm{NMFV}$ | $\tilde{t} - \mathrm{NMFV}$ | $\tilde{t} - \mathrm{MFV}$

<u>Disadvantage</u>

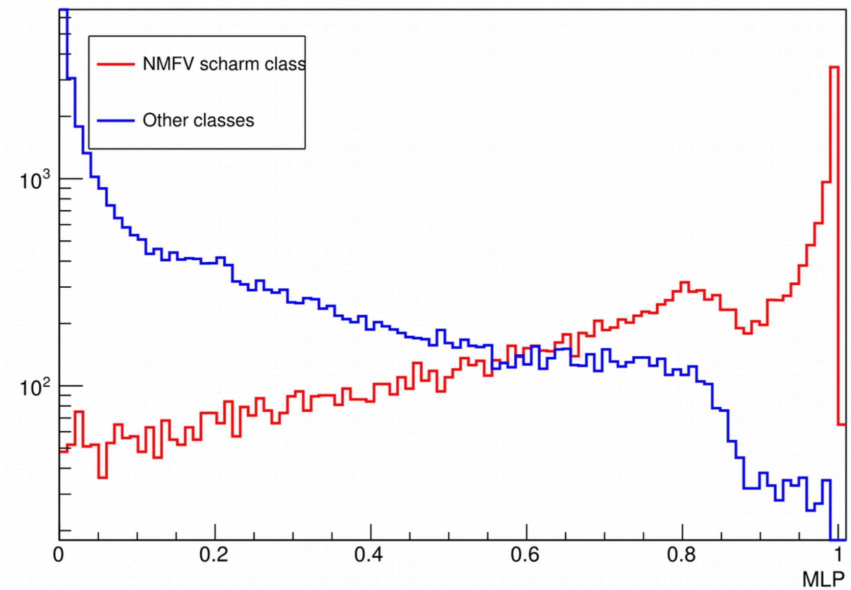
- Difficult to “really” interpret

Selected results

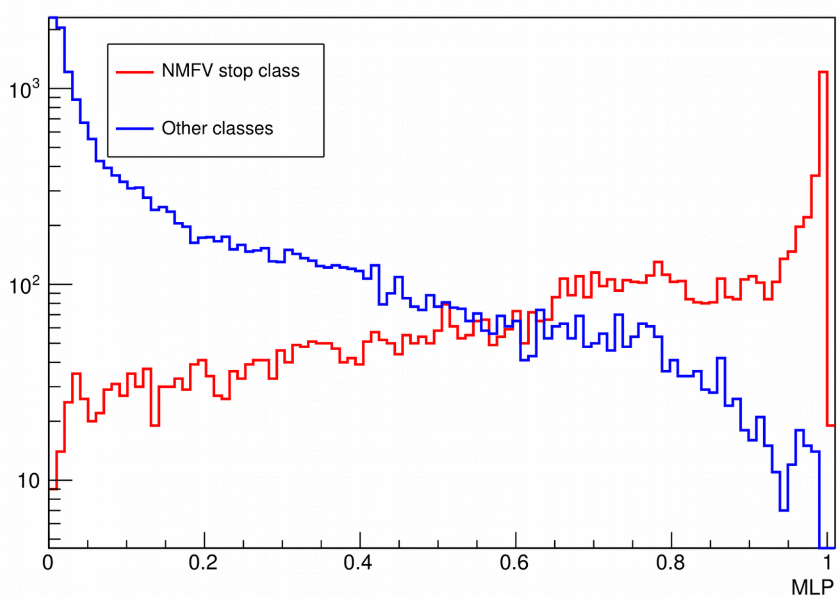
MLP response for MFV scharm



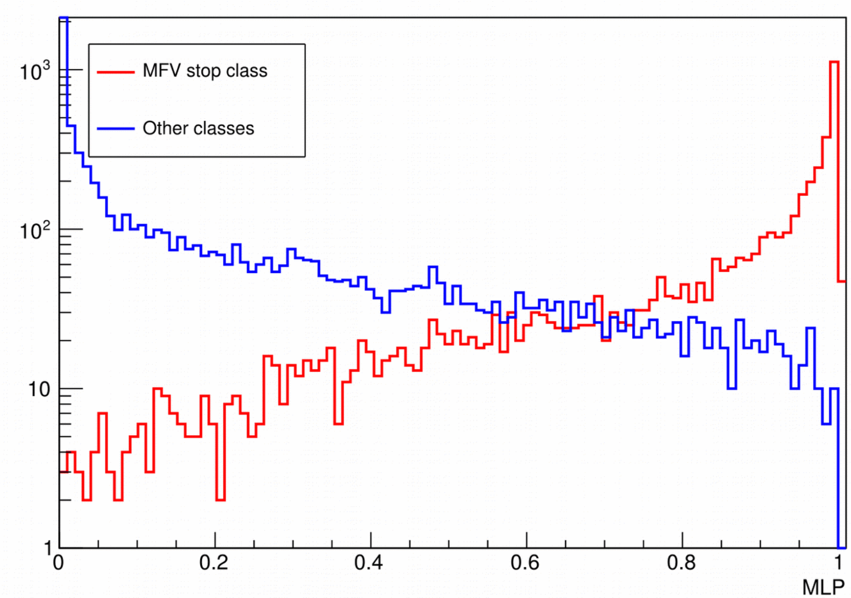
MLP response for NMFV scharm



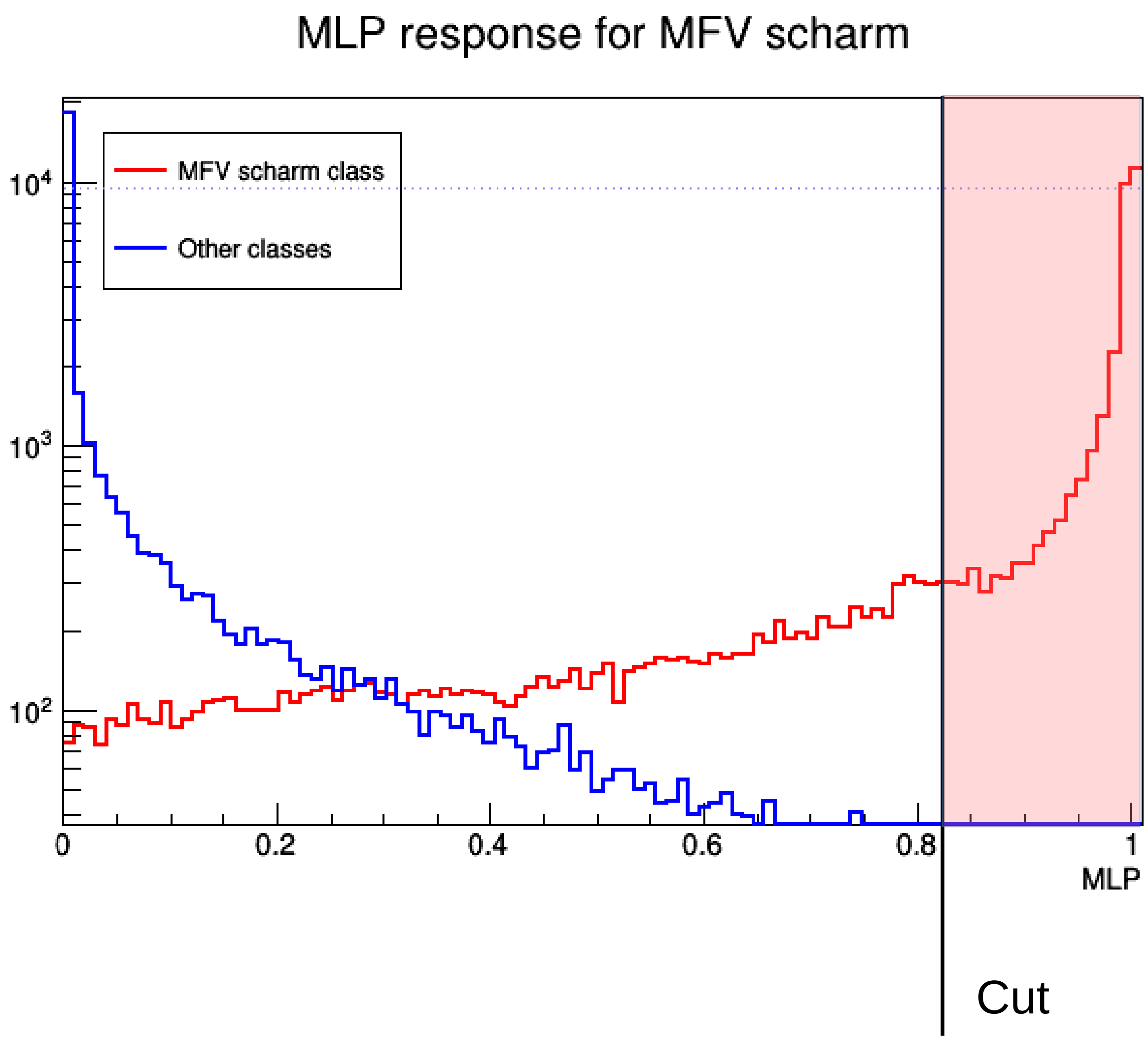
MLP response for NMFV stop



MLP response for MFV stop



Selected results

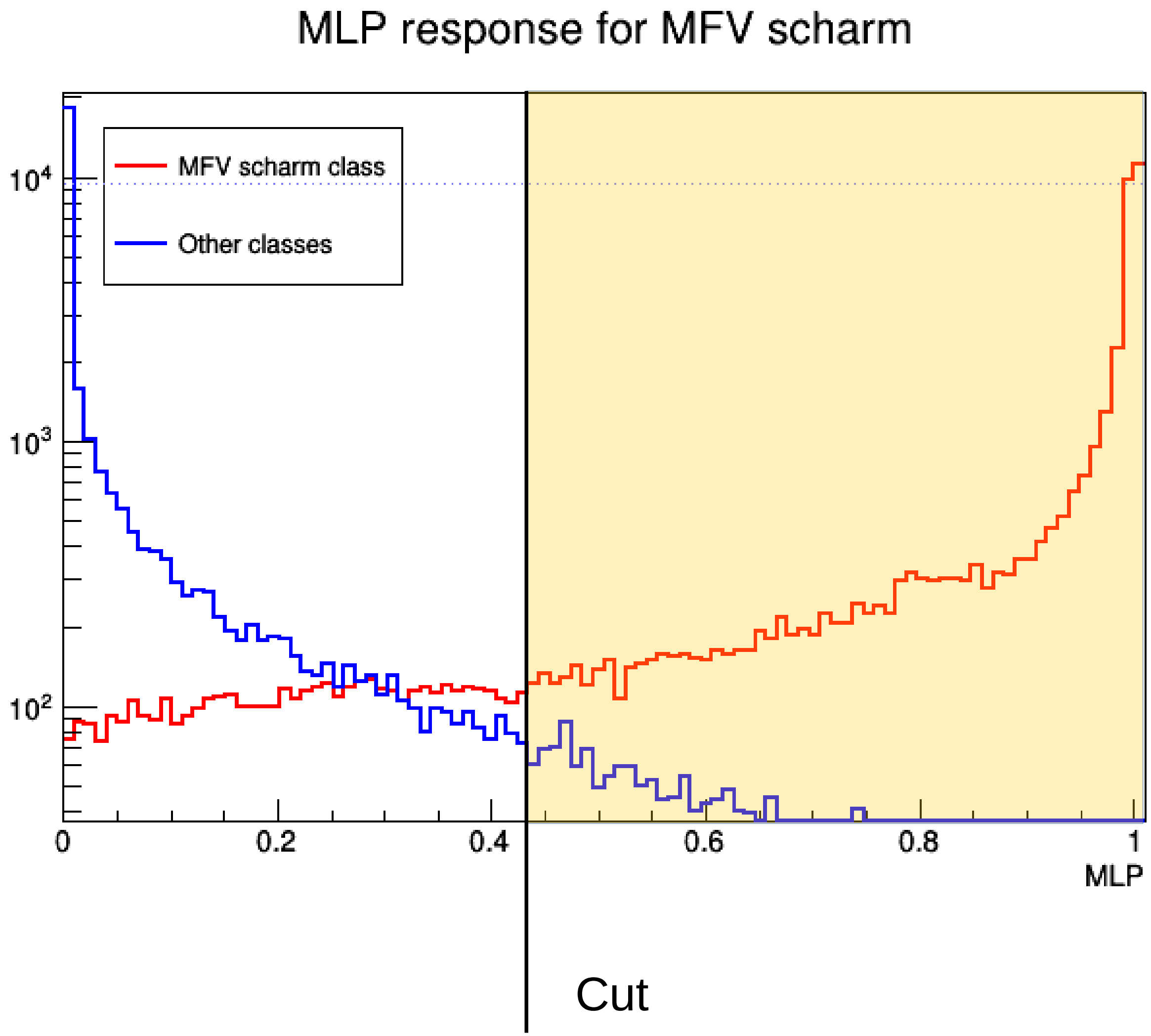


Classification characteristics

Mistaging = 1 %

Efficency = 72 %

Selected results

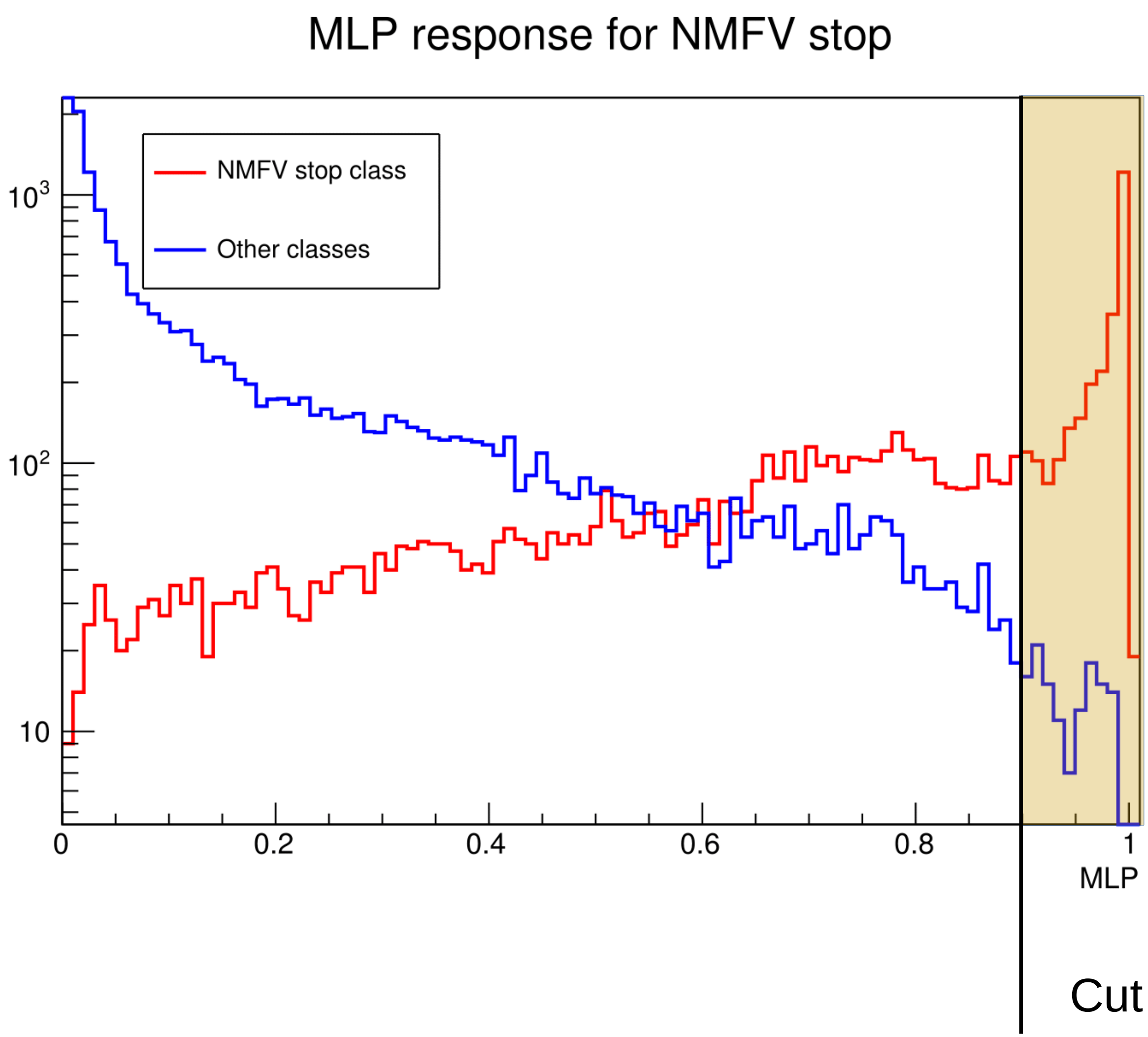


Classification characteristics

Mistaging = 5 %

Efficency = 89 %

Selected results

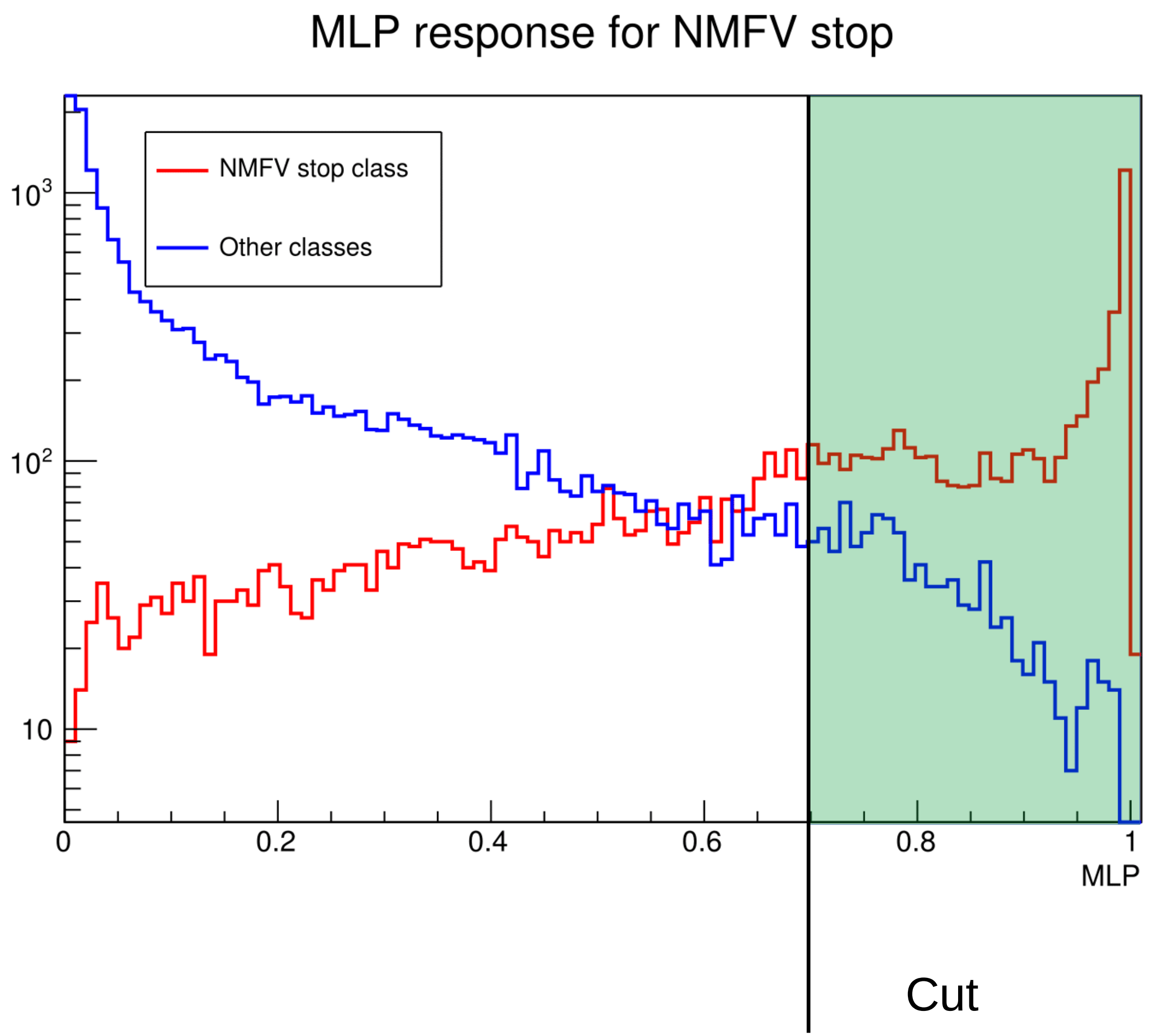


Classification characteristics

Mistaging = 5 %

Efficency = 34 %

Selected results



Classification characteristics

Mistaging = 20 %

Efficency = 57 %

Conclusion

It might be difficult to reconstruct the flavour structure of squarks at LHC … We investigated 3 different methods :

Direct reconstruction

- Gives good results

BUT

- Needs a lot of observables
- Needs a good precision

Bayesan analysis

- Would need more points

MVA

- Gives results
- Does not need so many information

BUT

- Difficult to handle uncertainties
- Difficult to understand the physics

→ The most appealing !

We are still investigating this and a lot of things can/should be done :

Better understand behaviour, new observables, custom algorithms, test with different categories etc.