# Anomalous U(1) and Asymmetry

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# Motivation

Now that LHC is up and running, we all hope that it will discover new Physics Beyond the Standard Model (BSM).
Among the different theoretical possibilities, String Theory suggests that there could be extra $U(1)s$ gauge symmetries besides the SM gauge group.
We are going to:

- show our predictions for the asymmetry in a model of this type
- show how the asymmetry can be used to impose constraints on theoretical models and to distinguish among different possibilities

# Model

Minimal Anomalous $U(1)$ extension of the MSSM (MiAUMSSM):

Gauge group: $SU(3) \times SU(2) \times U(1) \times U(1)'$

- Supersymmetry
- Effective theory (aim to describe "low-energy "scenario)
- Stückelberg mechanism
- Anomalies cancelled by the GCS mechanism $\rightarrow$ the extra $U(1)$ charges remain free
- Charge dependent phenomenology

# Asymmetry definition

The asymmetry is defined in the sequent way:

$$A = \frac{N_F - N_B}{N_F + N_B} = \frac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B}$$

Usually the F and B directions are defined with respect to the beam axis.
Its dependence on the cross section has permitted to use the asymmetry to measure couplings and quantum numbers of the SM at the LEP and at the Tevatron, where the initial state was $p^+p^-$.
For example, some of the last results obtained at the Tevatron using the asymmetry are:
$\sin^2\theta_W = 0.2309 \pm 0.0008\ (stat) \pm 0.0006\ (syst)$
$g_V^u = 0.202 \pm 0.025 \qquad g_A^u = 0.501 \pm 0.061$

# Asymmetry at the LHC

LHC initial state ($pp$) is symmetric $\rightarrow$ asymmetry is 0.
Need to cut the parameter space.
Different cuts $\rightarrow$ different definitions of asymmetry:

$$A_{\mathrm{RFB}}(Y_{f\bar{f}}^{\mathrm{cut}}) = \left.\frac{\sigma(|Y_f| > |Y_{\bar{f}}|) - \sigma(|Y_f| < |Y_{\bar{f}}|)}{\sigma(|Y_f| > |Y_{\bar{f}}|) + \sigma(|Y_f| < |Y_{\bar{f}}|)}\right|_{|Y_{f\bar{f}}|>Y_{f\bar{f}}^{cut}}$$

$$A_{\mathrm{OFB}}(p_{Z,f\bar{f}}^{\mathrm{cut}}) = \left.\frac{\sigma(|Y_f| > |Y_{\bar{f}}|) - \sigma(|Y_f| < |Y_{\bar{f}}|)}{\sigma(|Y_f| > |Y_{\bar{f}}|) + \sigma(|Y_f| < |Y_{\bar{f}}|)}\right|_{|p_{z,f\bar{f}}|>p_{Z,f\bar{f}}^{\mathrm{cut}}}$$

$$A_{\mathrm{C}}(Y_{\mathrm{C}}) = \frac{\sigma_f(|Y_f| < Y_{\mathrm{C}}) - \sigma_{\bar{f}}(|Y_{\bar{f}}| < Y_{\mathrm{C}})}{\sigma_f(|Y_f| < Y_{\mathrm{C}}) + \sigma_{\bar{f}}(|Y_{\bar{f}}| < Y_{\mathrm{C}})}$$

$$A_{\mathrm{E}}(Y_{\mathrm{C}}) = \frac{\sigma_f(Y_{\mathrm{C}} < |Y_f|) - \sigma_{\bar{f}}(Y_{\mathrm{C}} < |Y_{\bar{f}}|)}{\sigma_f(Y_{\mathrm{C}} < |Y_f|) + \sigma_{\bar{f}}(Y_{\mathrm{C}} < |Y_{\bar{f}}|)}$$

# Analysis

Framework: "on-peak "(i.e. $M_{Z'} - 3\Gamma_{Z'} < M_{e^+e^-} < M_{Z'} + 3\Gamma_{Z'}$) region.

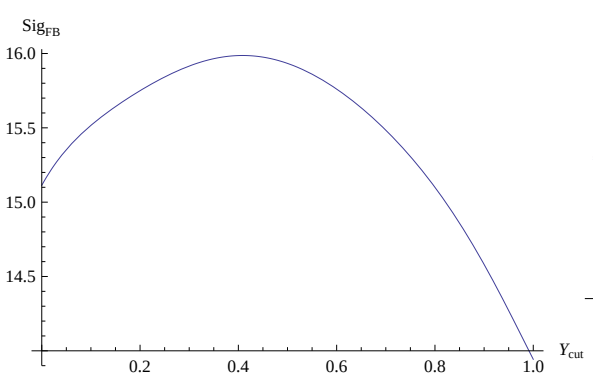
Analysis performed:

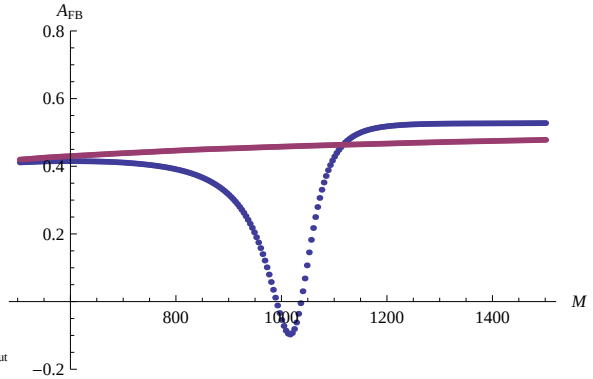
- Finding the optimal cuts maximizing the significance
- Compare the asymmetry with the MSSM
- Studying the asymmetries keeping one of the free charges fixed to 0
- Studying the asymmetries as functions of the three free charges

# Optimal cuts

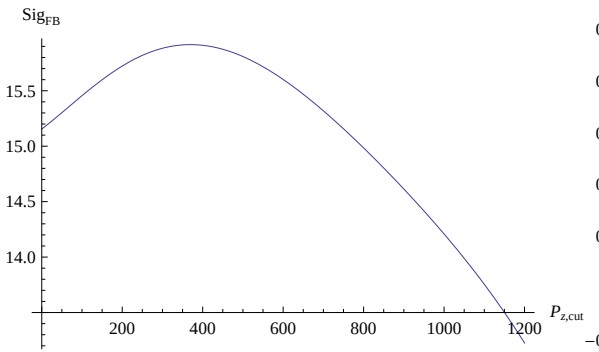
Goal: maximize the significance $Sig = A\sqrt{\mathcal{L}\ \sigma_{tot}}$.

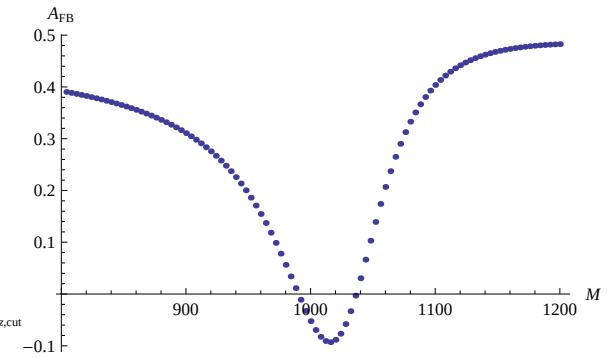
$A_{RFB}$:



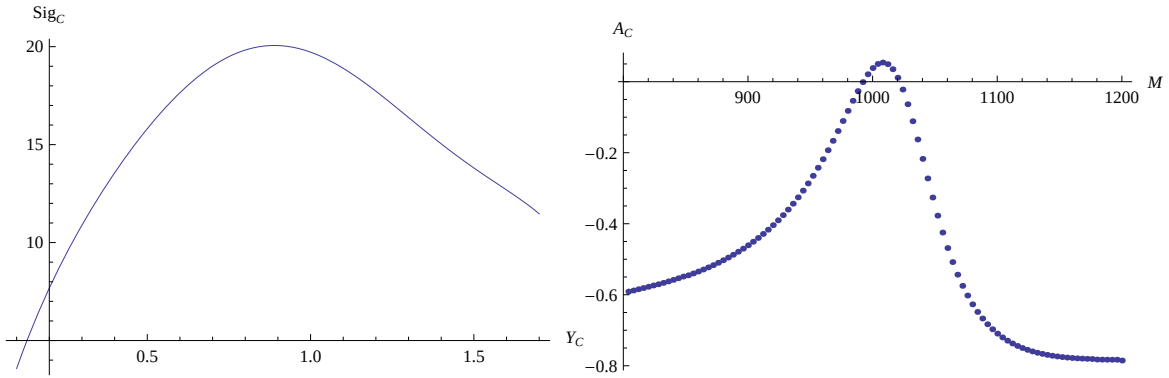

$A_O$:



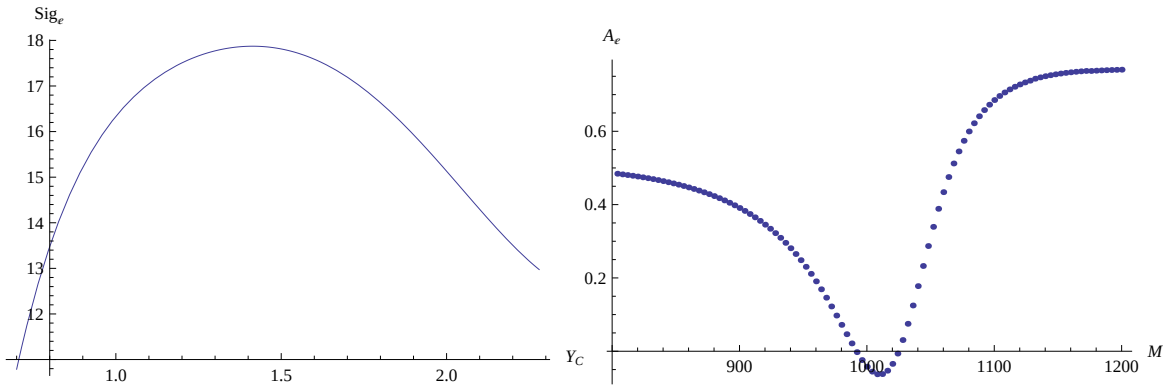



# Optimal cuts

$A_C$:

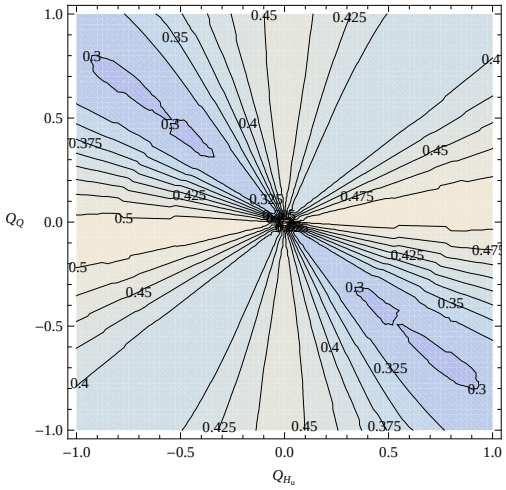



$A_E$:

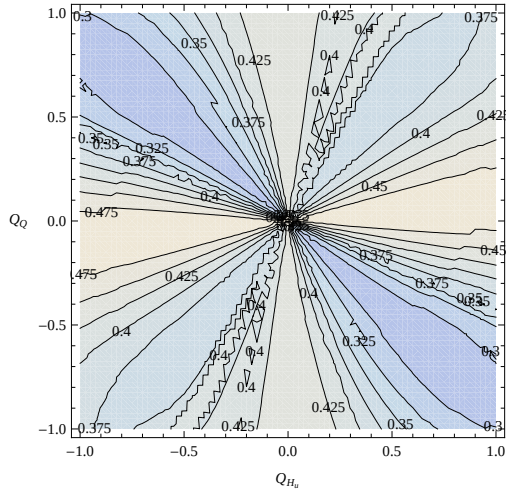


# Asymmetry with respect to 2 charges

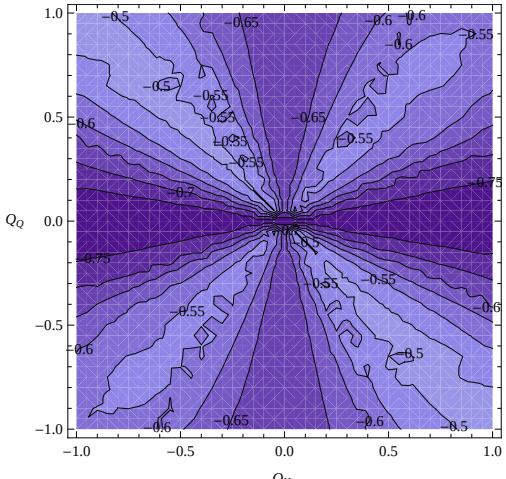
$A_{RFB}$:



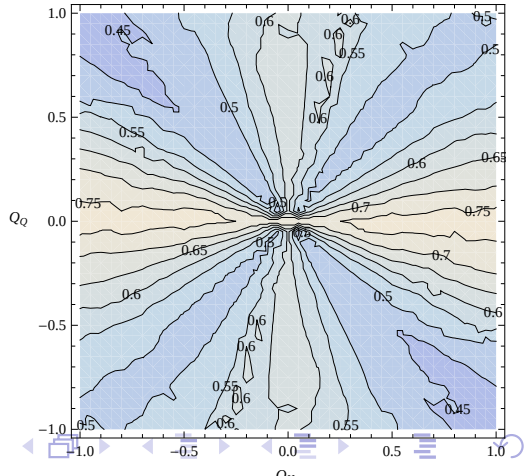

$A_O$:




$A_C$:




$A_E$:



# Asymmetries as functions of three charges

Fit of the asymmetry:

$$A = \frac{\sum_{i,j,k=0}^{n} a_{ijk} (Q_{H_u})^i (Q_Q)^j (Q_L)^k}{\sum_{i,j,k=0}^{n} b_{ijk} (Q_{H_u})^i (Q_Q)^j (Q_L)^k} \qquad n = i + j + k \leq 4$$

Fit for $-1 < Q_i < 1 \rightarrow$

| | $A_{RFB}$ | $A_O$ | $A_C$ | $A_E$ |
|---|---|---|---|---|
| $R^2$ | $0,999$ | $0,999$ | $0,999$ | $0,999$ |
| $MRE$ | 0.03 | 0.03 | 0.03 | 0.03 |

If new physics will be discovered we will have:
4 equations, 3 variables $\Rightarrow$ constraints on the charges plus consistency check

# Conclusions

- We have calculated the optimized asymmetry of the MiAUMSSM as a function of the free charges
- Given a model that aims to describe the physics beyond the SM (BSM), the asymmetry can be used to distinguish between it and other models
- If LHC reveals signals of BSM physics, the asymmetry can be used to impose constraints on the free parameter of a model