

# Beyond the Standard model

M. Schmaltz, Boston U.

# Murayama LP 2003



TC-TC composite Higgs  
bosonic TC  
hypercolor  
supercolor  
techni-GIM  
extended TC

NOT YET THOUGHT OF

effective SUSY  
SUSY  
NMSM  
MSSM  
R  
anomalous

THOUGHT OF

NOT YET

pseudo 2<sup>nd</sup> 3<sup>rd</sup> 4<sup>th</sup> 5<sup>th</sup> 6<sup>th</sup> gen

6th gen  
5th gen  
4th gen

lepto squark

sterile  $\nu$

heavy Majorana

vector-like family

fractionally charged

milli-charged

anomalous  
X  
Y  
mono-pole

NOT YET THOUGHT OF

triple Higgs  
general 2HDSM  
spontaneous CP  
Type 2  
Type I

shadow matter

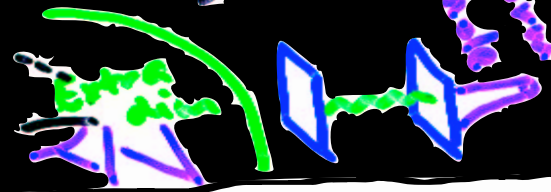
mirror symmetry

Majorana  
axion  
families  
NGB

Weinberg's 3HD  
superweak  
milli-weak

intelligence  
K-essence  
composite W, Z

later  
G



2 sources of inspiration for  
model building:

A. problems of the standard model  
hierarchy, flavor, CP, ...

B. anomalies in data  
“ambulance chasing”

# 2 examples

A. Little Higgs

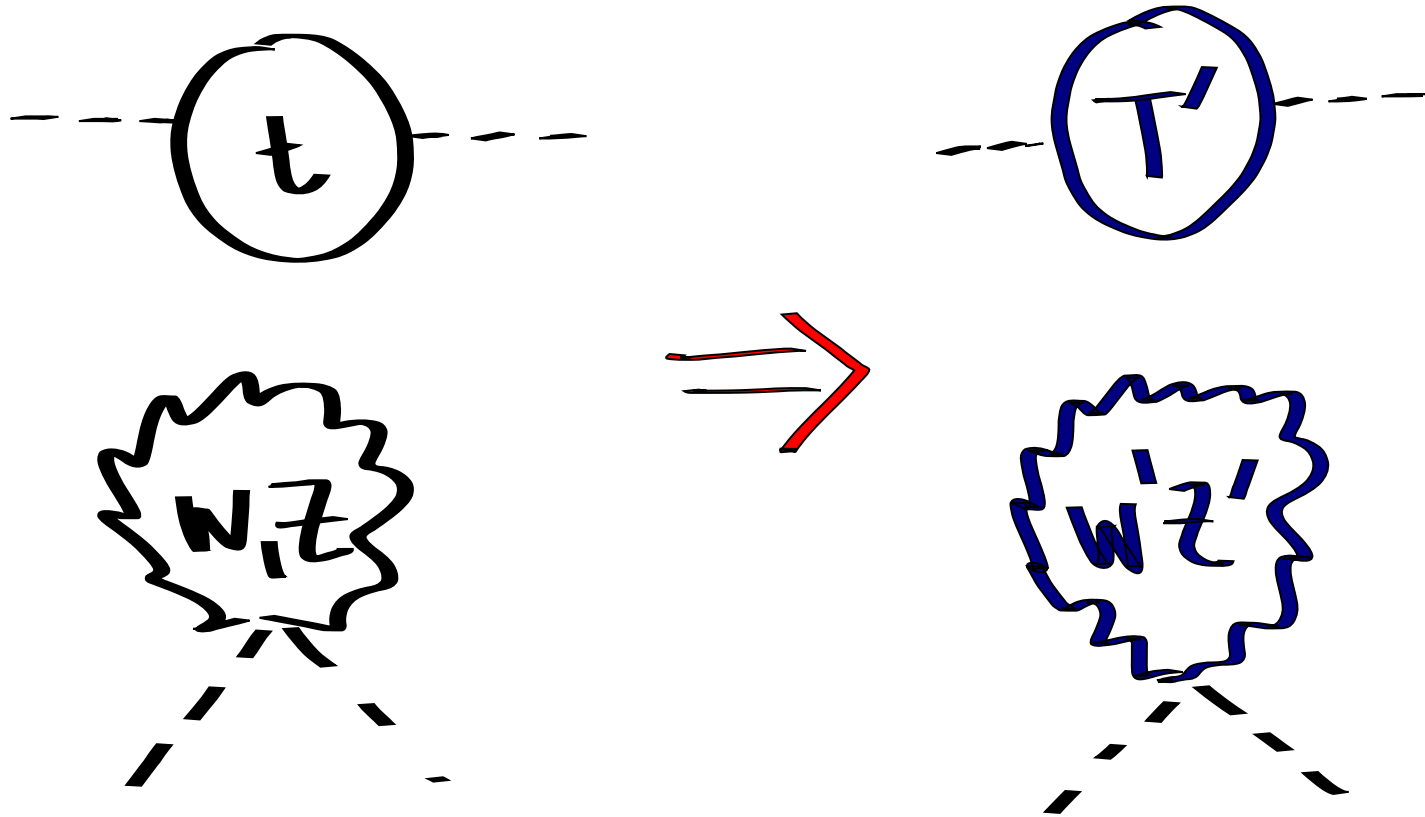
B.  $t\bar{t}$  asymmetry  $\rightarrow$  axigluons

# A. Little Higgs motivation

$m_{\text{Higgs}}$  in SM is UV sensitive, unnatural to be small



# Little Higgs "Partners"



cancel the divergences  $m_H^2 \sim \frac{g^2}{16\pi^2} M_{\text{partner}}^2$

# Example: Littlest Higgs

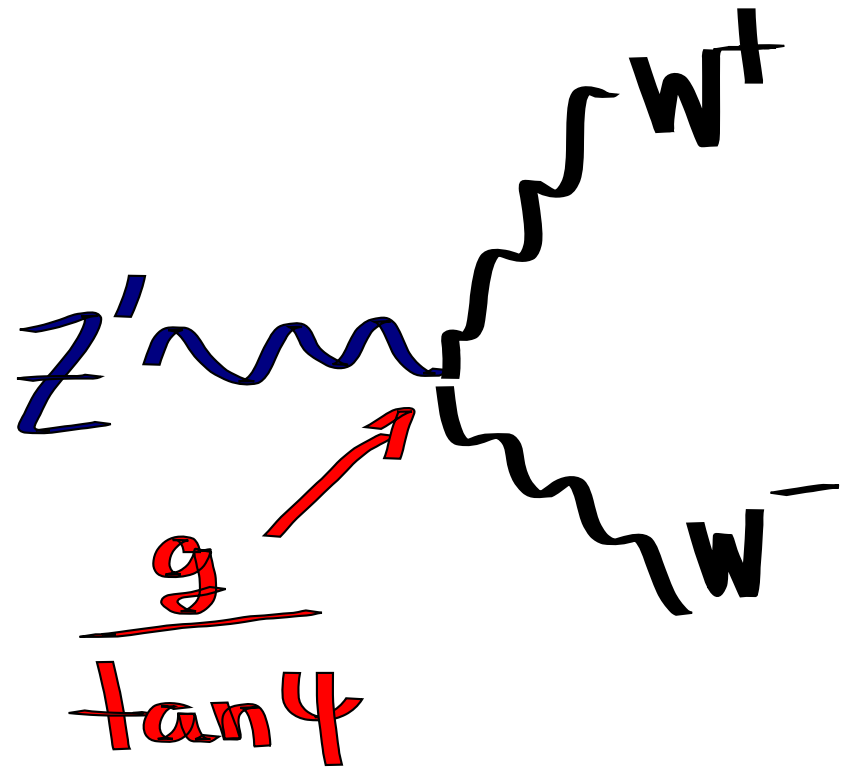
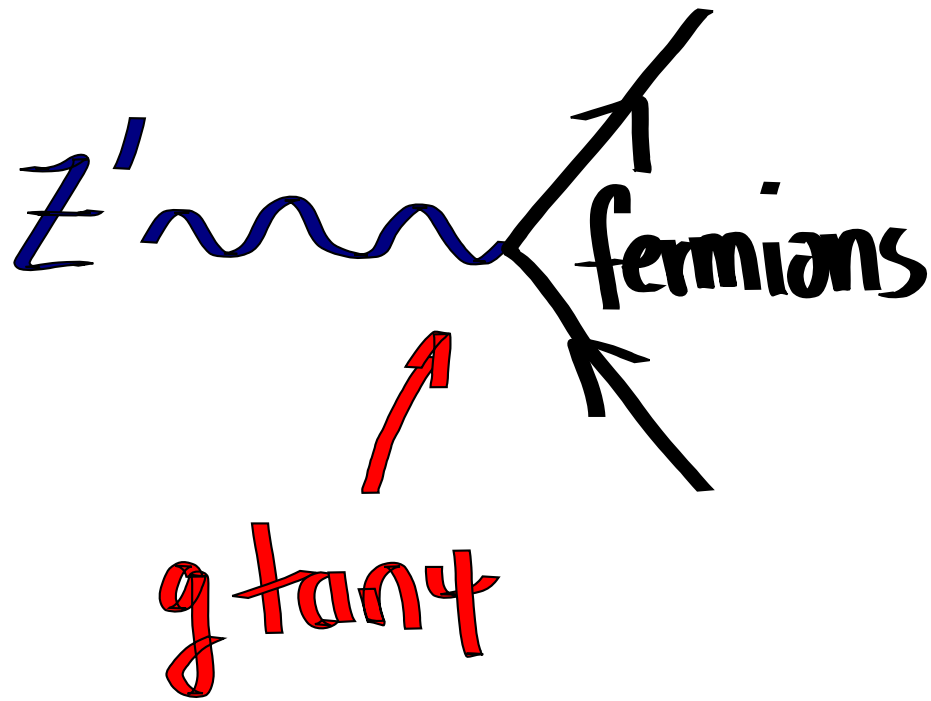
precision EW  
constraints

$$M_{Z'} = \frac{\sqrt{2}g}{\sin 2\alpha} f \sim 1.5 \text{ TeV}$$

$$M_{T'} = 2\lambda_{\text{top}} f \sim 2.5 \text{ TeV}$$



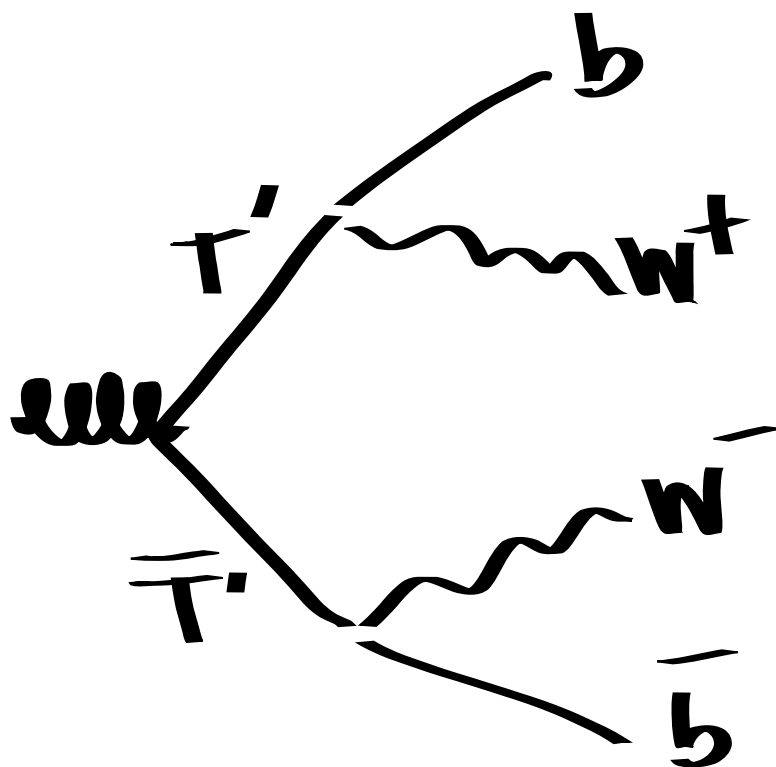
$Z'$  at LHC:



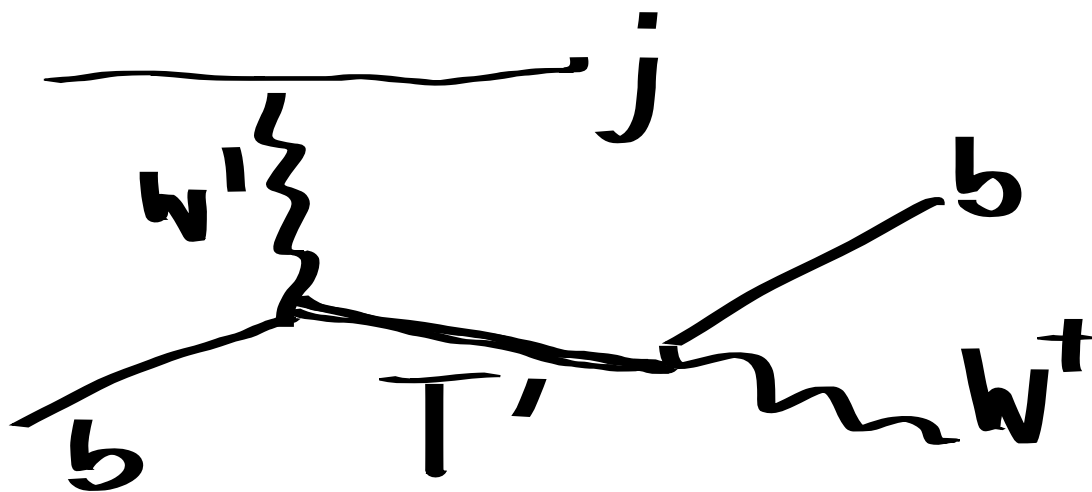
$\tan \psi \lesssim 0.5 \implies Z' \rightarrow W^+ W^-$  dominates  
requires  $100 \text{ fb}^{-1}$   $m > 440 \text{ GeV}$  (CMS)

# $T'$ at LHC

- QCD production



- Single  $T'$



# $T'$ at LHC

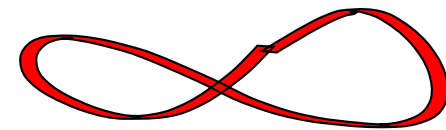
- Similar to 4<sup>th</sup> gen  $\Rightarrow M \gtrsim 400-500$  GeV

7 TeV study in progress :  
Godfrey  
Kalyniak  
Gregoire  
Martin

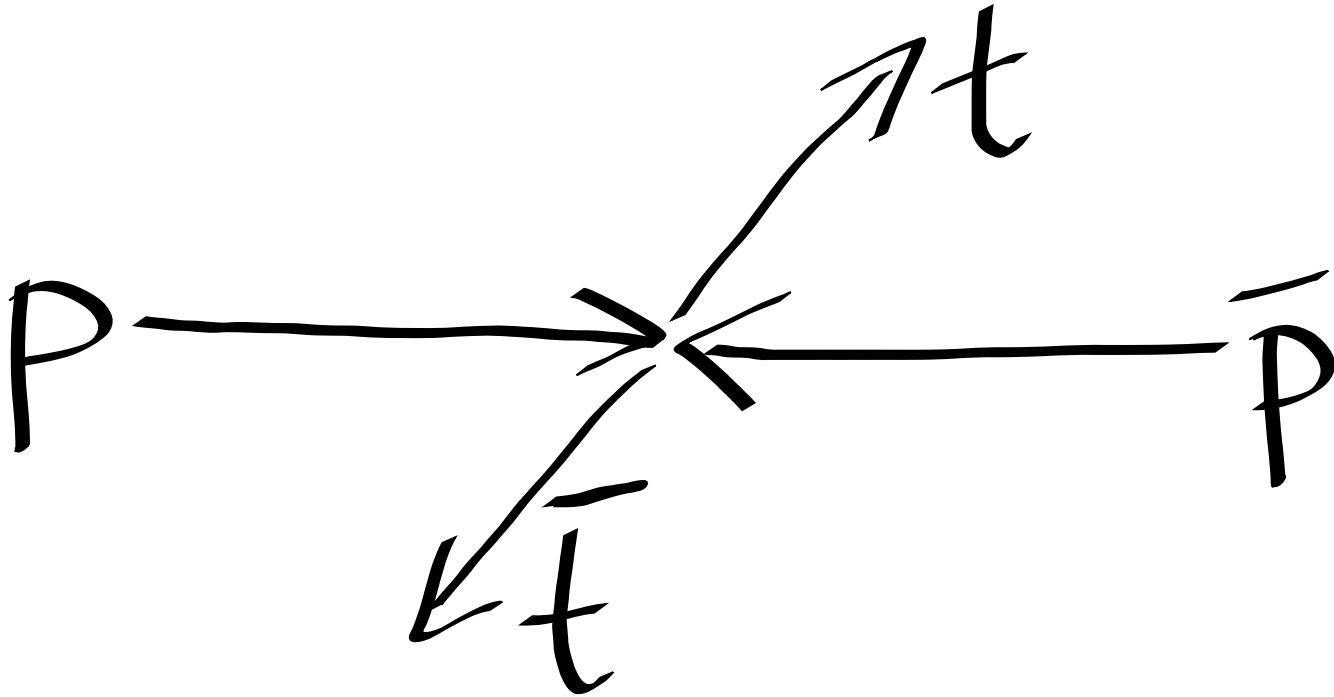
Little Higgs is trickier

than SUSY ...

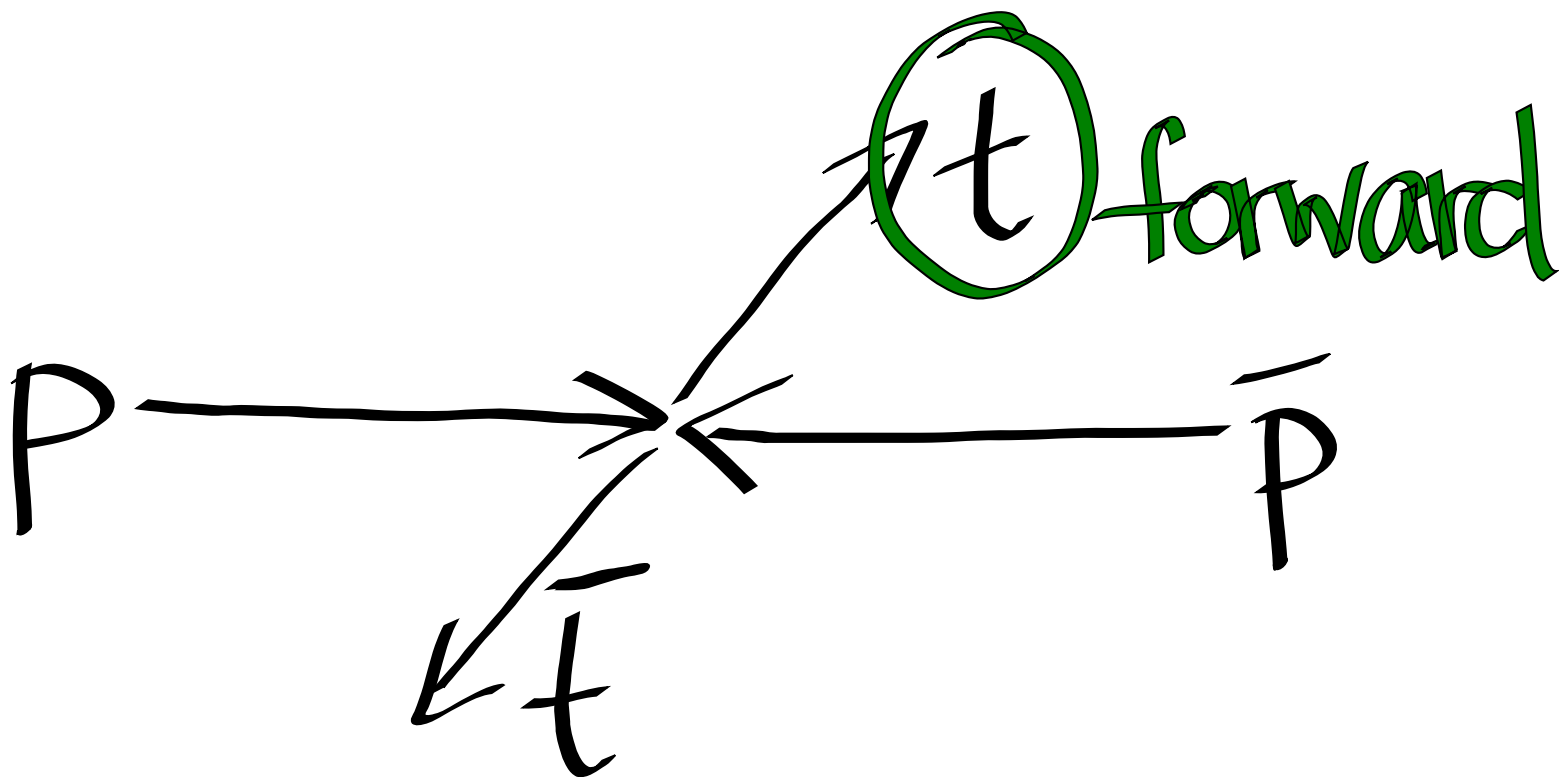
LHC starting to compete with  
precision EW



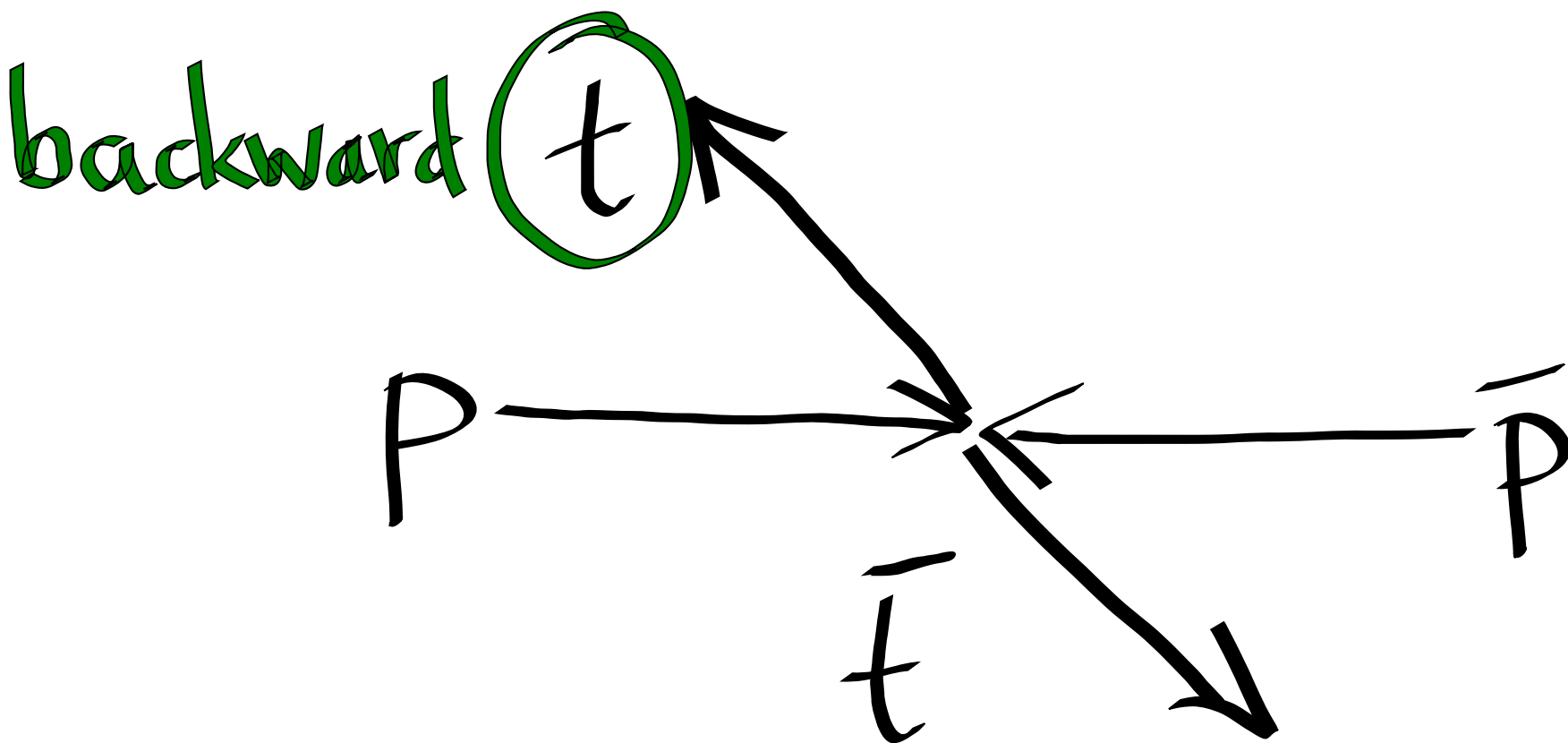
$t\bar{t}$  asymmetry

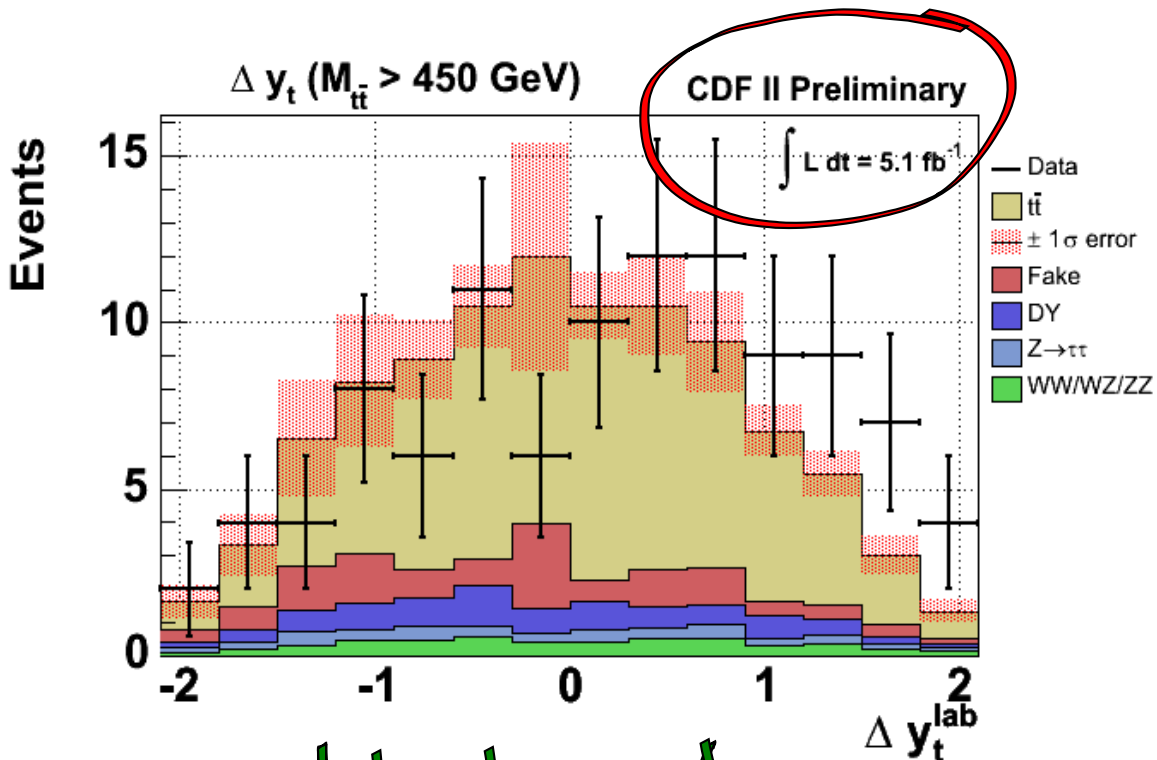


$t\bar{t}$  asymmetry



$t\bar{t}$  asymmetry

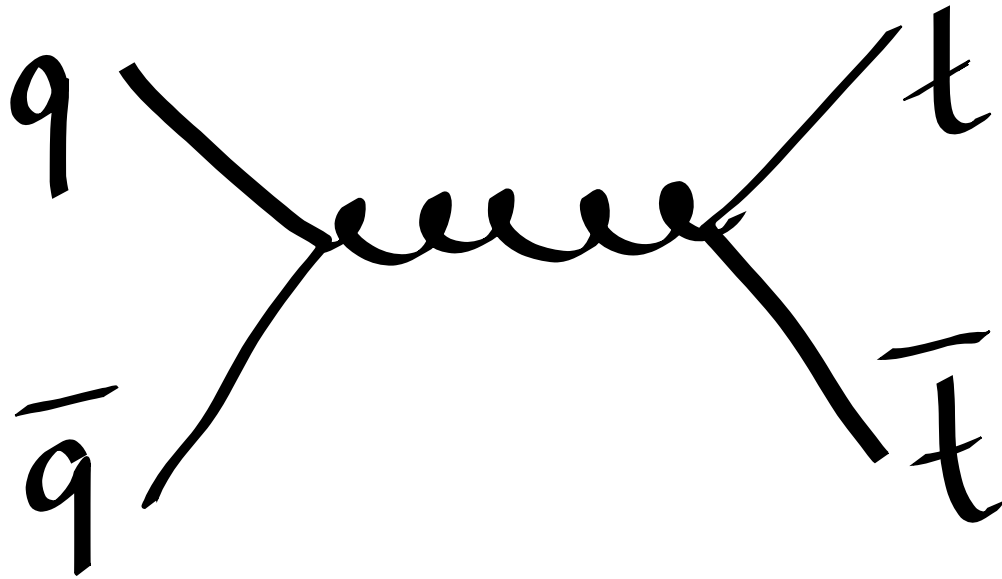




dilepton  $A_{t\bar{t}} \sim 20\%$

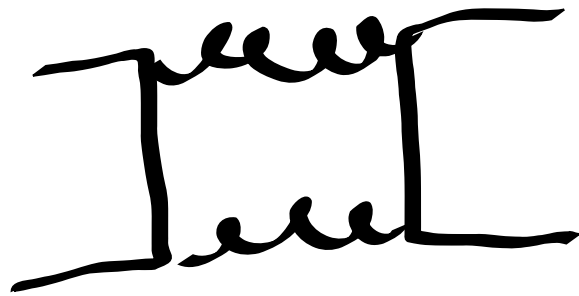


# Standard Model



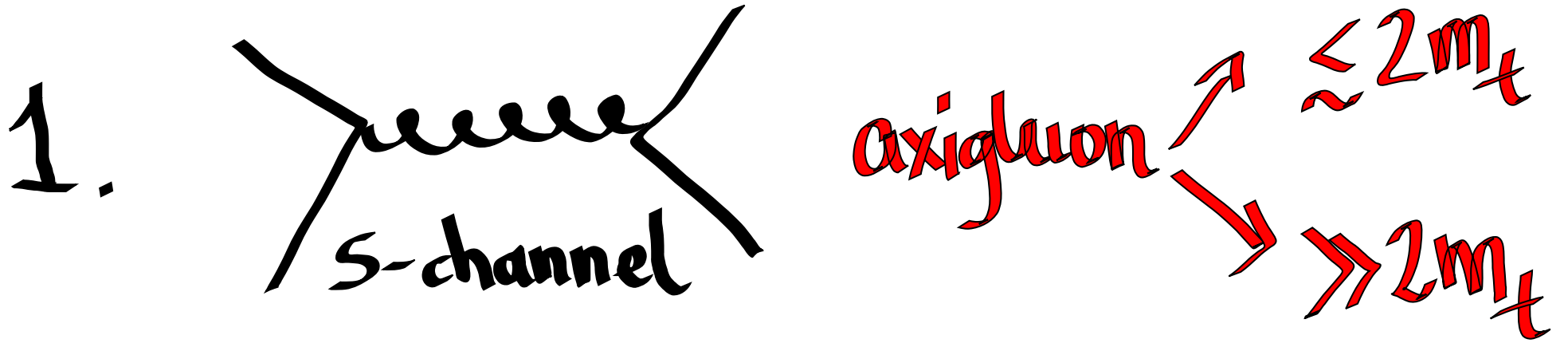
symmetric

NLO:

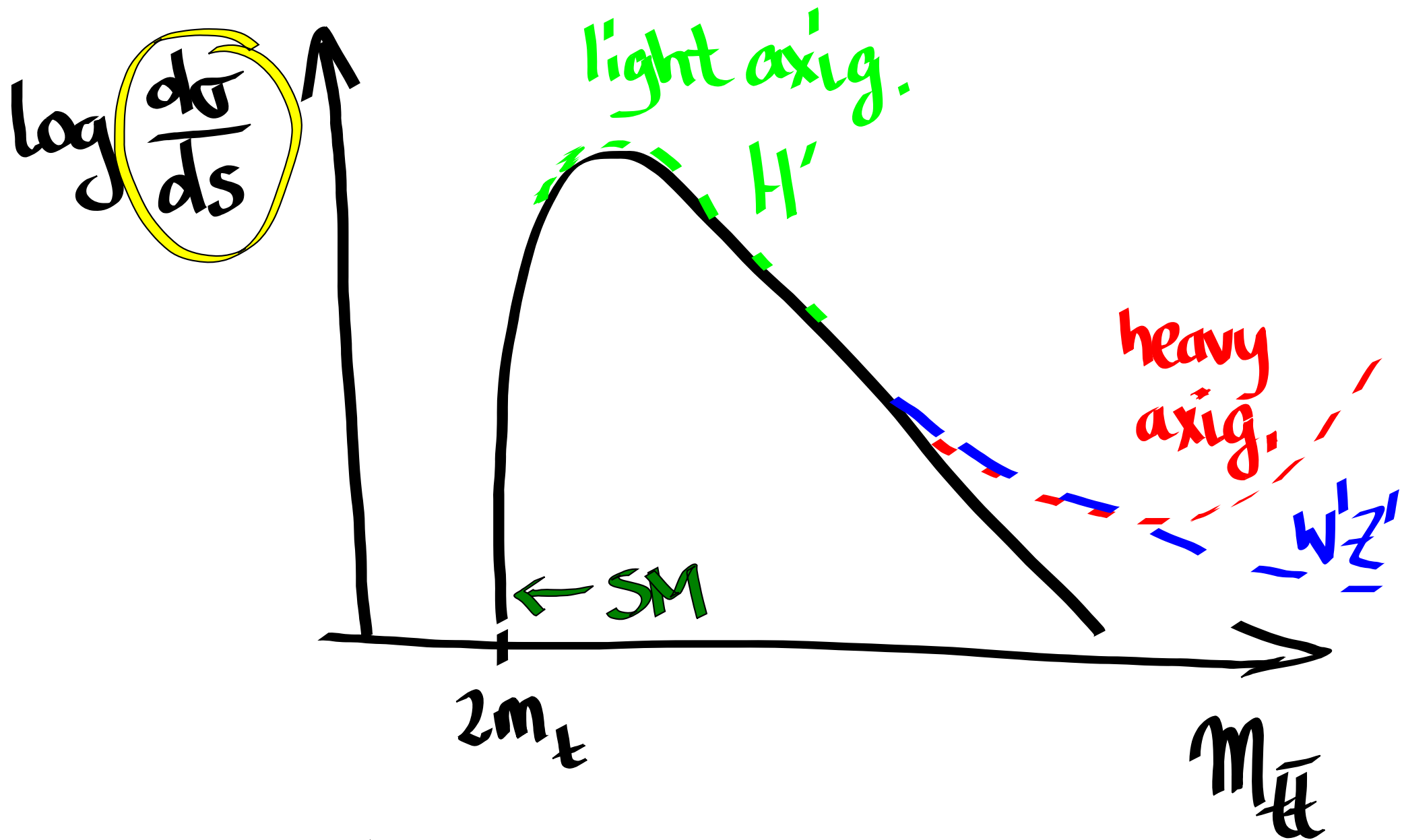


a-symmetric  
few %

# New physics

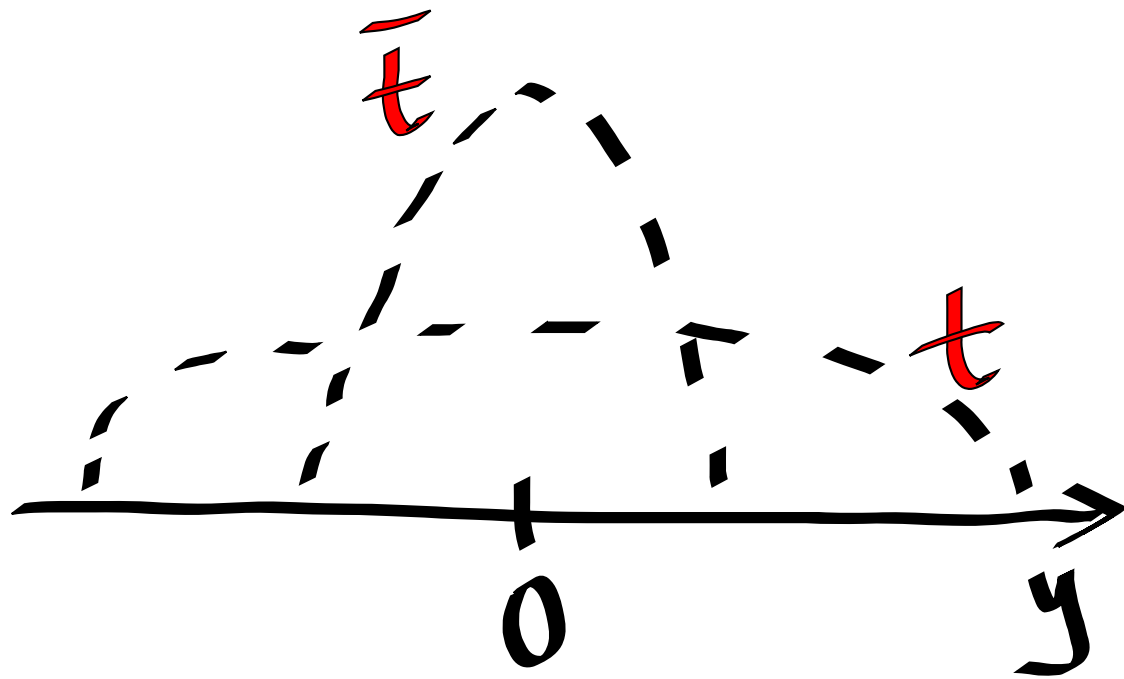


all fit "reasonably" well:  $A_{tt}, \sigma_{tt}$



ATLAS/CMS: "soon"

# Asymmetry at LHC?



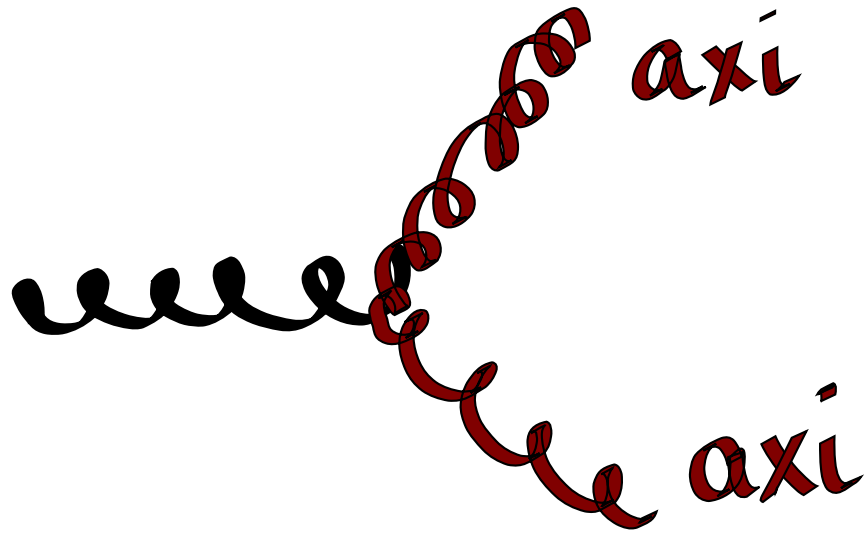
SM:  $\sim 1\%$

NP:  $\sim 3-8\%$

ATLAS :  $\ominus 2 \pm 2 \pm 2\%$   $\sim 1 \text{fb}^{-1}$   
CMS

# Light axigluon production @ LHC

100 - 450 GeV



$$\sigma_{450} \sim 20 \text{ pb}$$

what is the signature?

# Axigluon pair decay

recon-  
struct {

4 jets

6 jets

ATLAS prelim,  $36 \text{ pb}^{-1}$   
 $m \geq 200 \text{ GeV}$

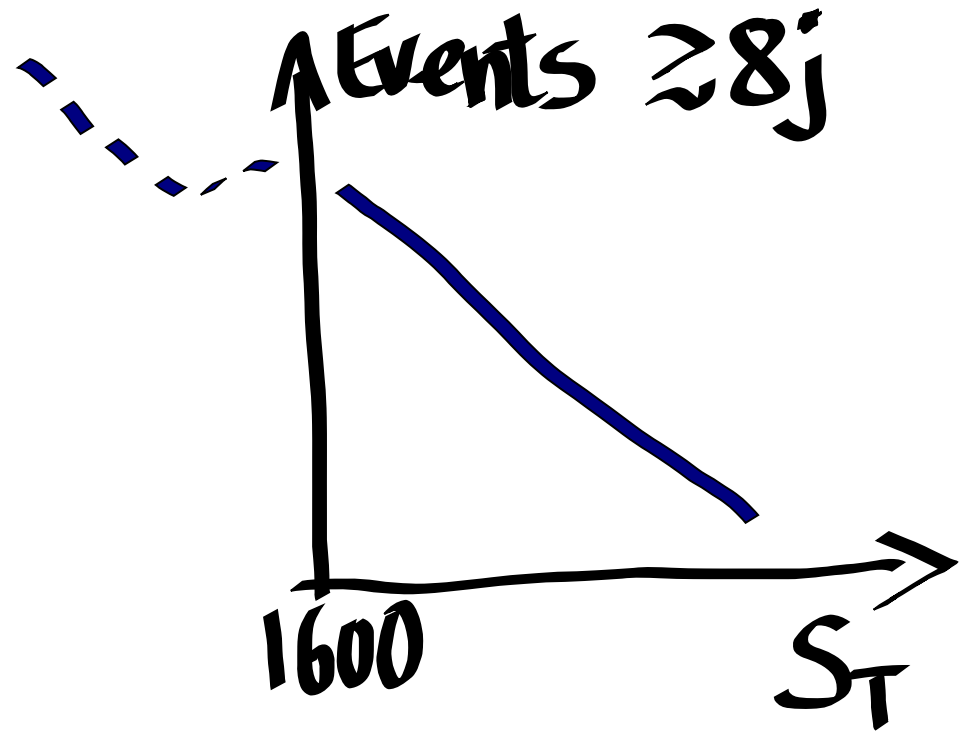
CMS  $35 \text{ pb}^{-1}$   
 $180 < m < 280 \text{ GeV}$

(>2 $\sigma$  excess @ 380 GeV)

# Axigluon pair decay

“black holes” {  
8 jets  
12 jets

CMS  $1.1 \text{ fb}^{-1}$



Light axiguan enthusiasts:

Marques-Tovares, M.S.

Aguilar-Saavedra, Perez-Victoria

Barceló, Carmona, Masip, Santiago

Falkowski, Shelto



TC-TC composite Higgs  
bosonic TC  
hypercolor  
supercolor  
techni-GIM  
extended TC

NOT YET THOUGHT OF

effective SUSY  
SUSY  
NMSM  
MSSM  
NR  
annihilated SM

THOUGHT OF

NOT YET

pseudo 2<sup>nd</sup> 3<sup>rd</sup> 4<sup>th</sup> 5<sup>th</sup> 6<sup>th</sup> gen

6th gen  
5th gen  
4th gen

lepto squark

sterile  $\nu$

heavy Majorana

vector-like family

fractionally charged

milli-charged

asignee  
X  
Y  
mono-pole

NOT YET THOUGHT OF

triple Higgs  
general 2HDSM  
spontaneous CP  
Type 2  
Type I

shadow matter

mirror symmetry

Majorana  
axion  
families  
NGB

Weinberg's 3HD  
superweak  
milli-weak

intelligence  
K-essence  
Composite W, Z

later  
G

