# Physics Beyond the Standard Model & the $t\bar{t}$ asymmetry

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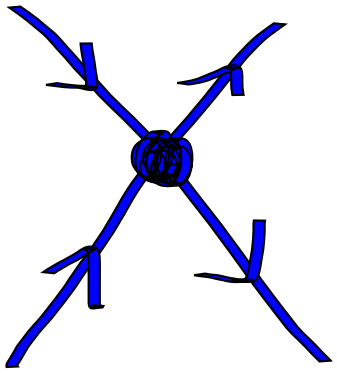
today: Motivation, what is so interesting about tops?

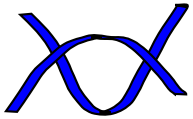
tomorrow: $t\bar{t}$ asymmetry & New Physics

# Fermi's weak interactions



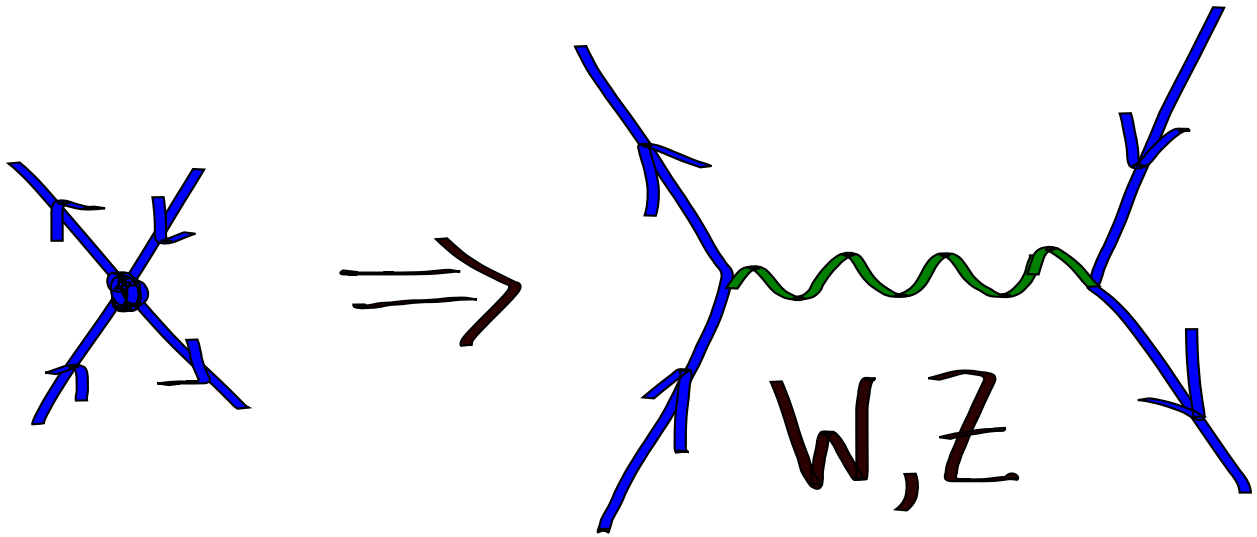
$$\sim \frac{E^2}{(250\,\mathrm{GeV})^2}$$

strong coupling $E \sim 250\,\mathrm{GeV}\,\frac{4\pi}{N_f N_c}$



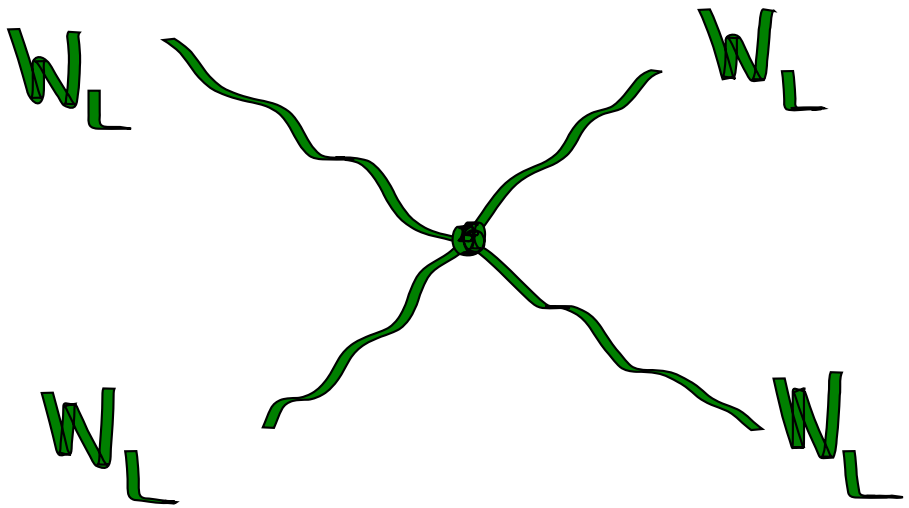
incomplete $\Rightarrow$ New Physics $\lesssim$ TeV

# 1980's: CERN $S\bar{p}pS$



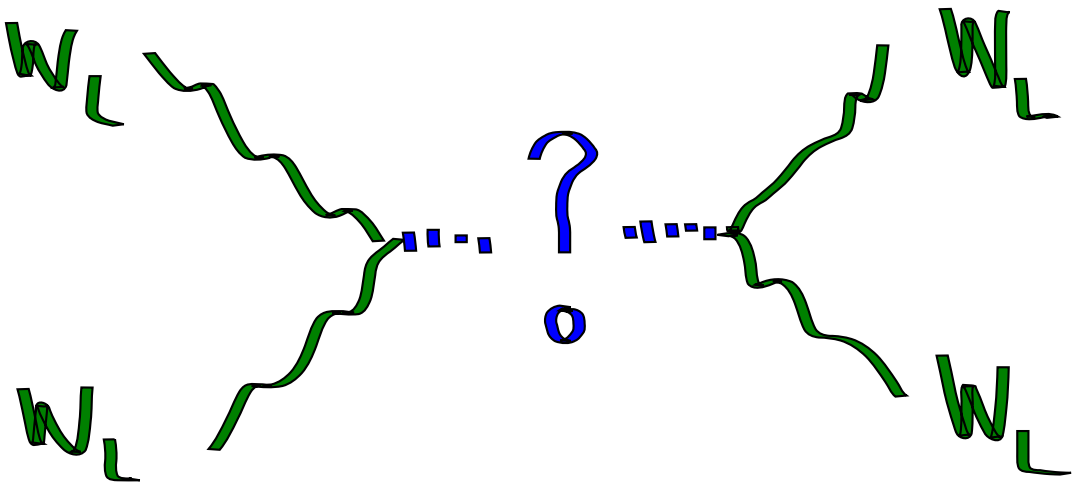

W, Z = "New Physics" at 100 GeV

... still incomplete !



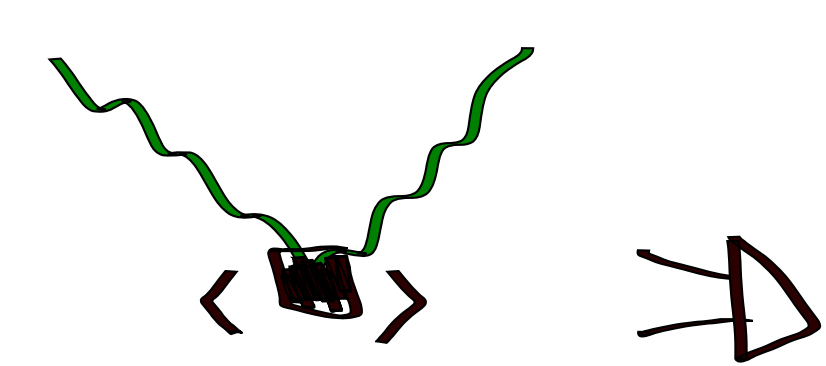

strong coupling : $E \sim 250\,\text{GeV}\frac{4\pi}{\hbar} \sim \text{TeV}$

# 2010's CERN LHC

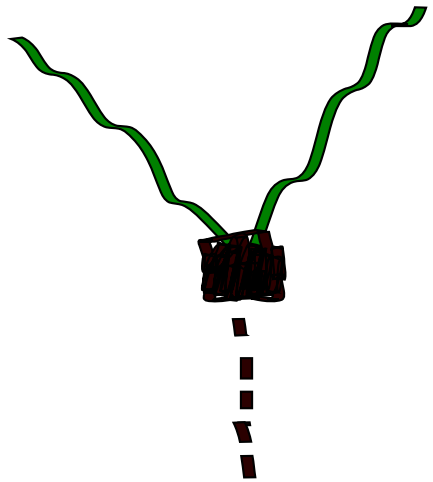



What New Physics unitarizes WW scattering ?

# Hint: W, Z masses break EW symmetry



Condensate

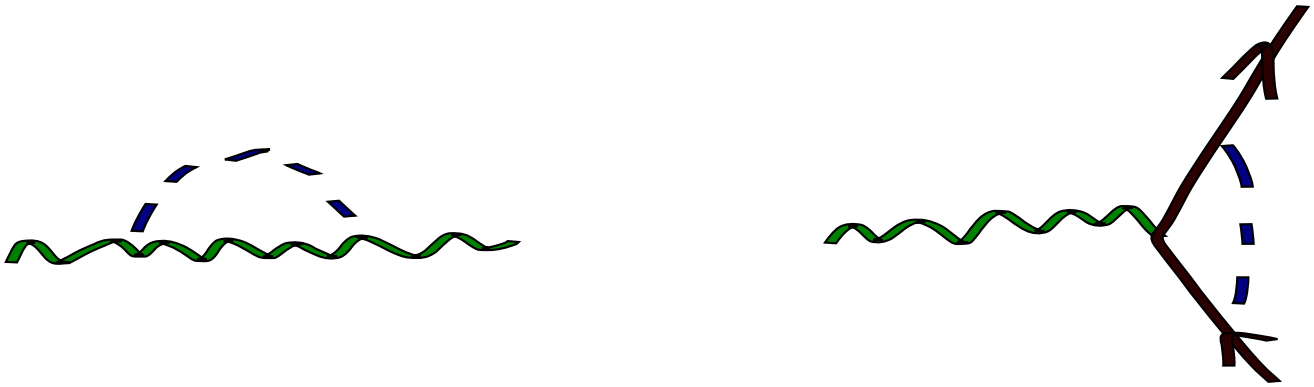


"Condenson"

excitation of condensate

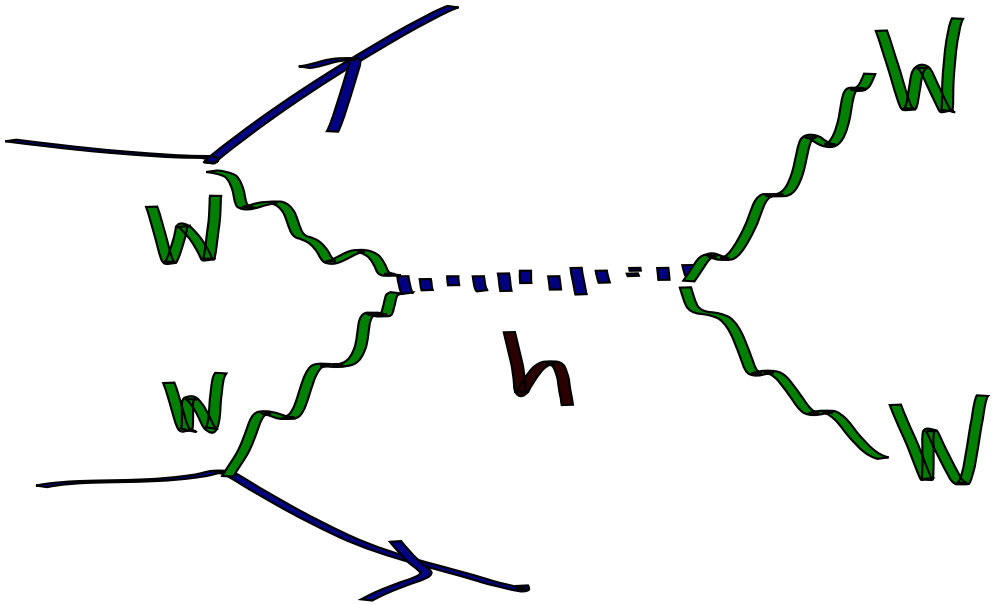
# 1990's LEP & SLC :

Higgs is the simplest condenson consistent with precision data

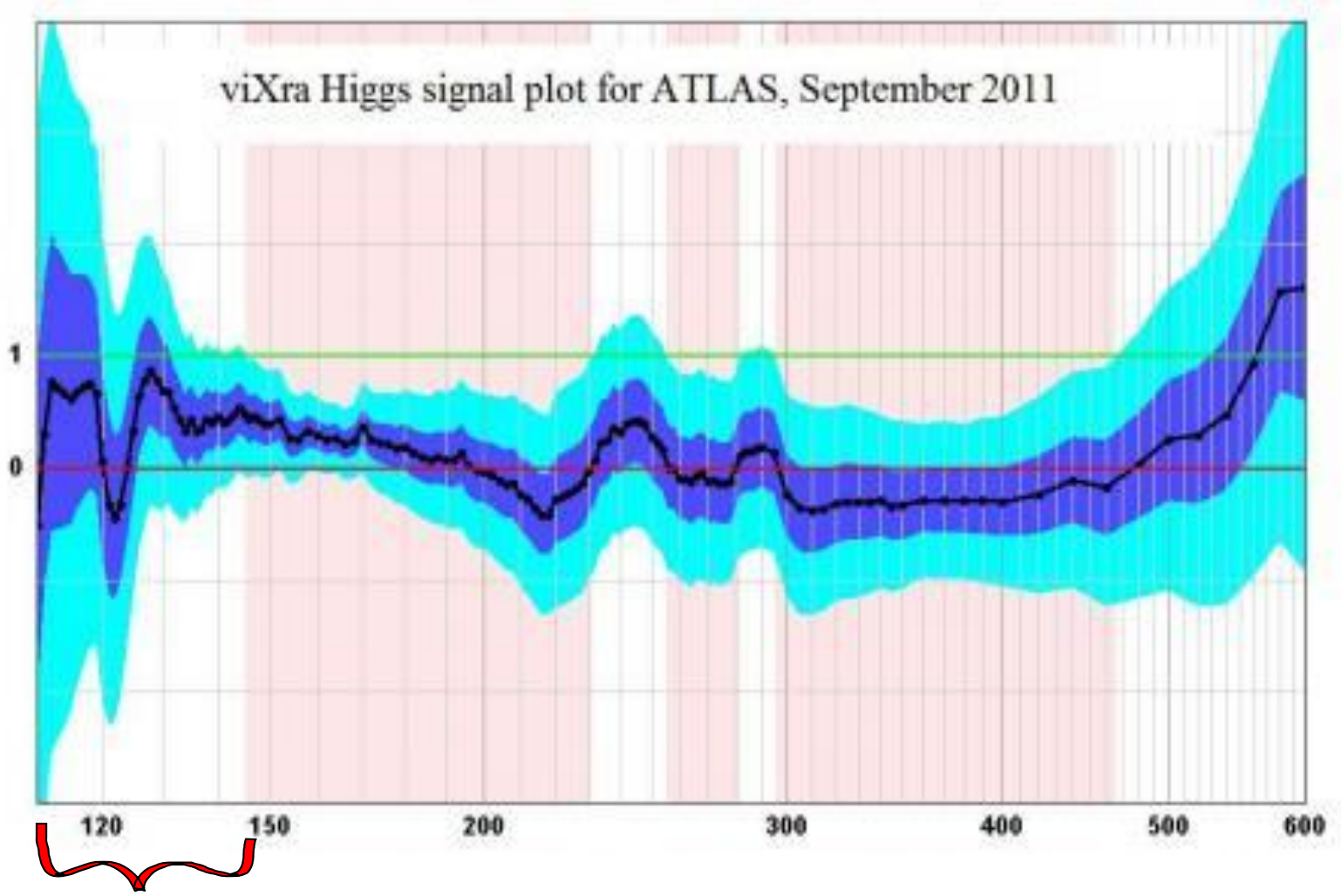


$m_h \lesssim 200$ GeV

expect light Higgs @ LHC

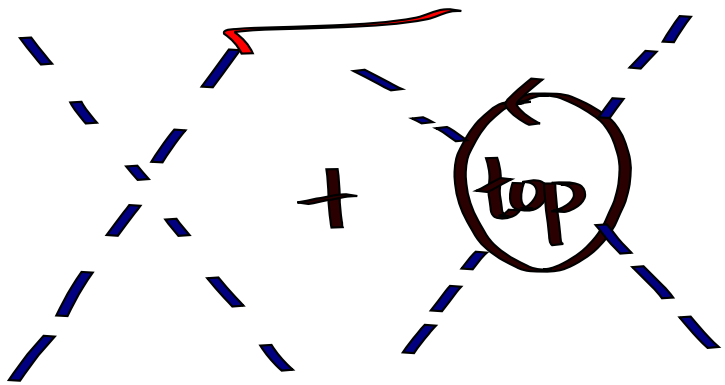


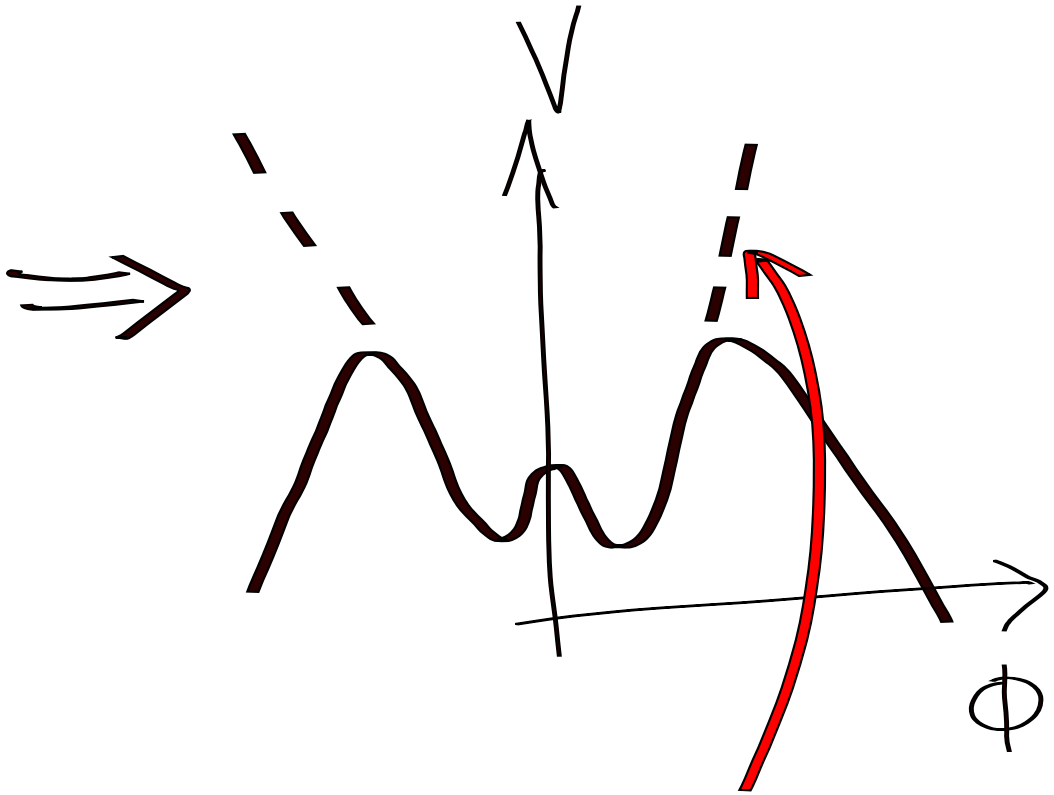
# Vixra Higgs signal plot ATLAS




$m_h \sim 115 - 145$ GeV

# still not complete!




negative at

$$\log \frac{E}{\text{TeV}} > 1$$

New physics needed

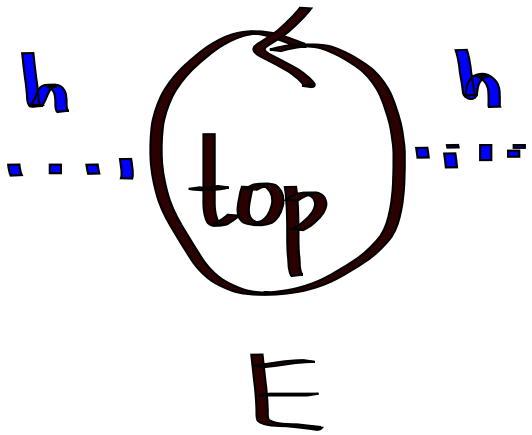
# a more immediate problem: Naturalness

$$m_h^2 |\phi|^2$$

not protected by any symmetries

$\Longrightarrow$ dimensional analysis: $m_h \gtrsim m_{NP}$

More concretely---




$$\Rightarrow \delta m_h^2 \sim \frac{\lambda_t^2}{16\pi^2} E^2$$

Naturalness requires new physics before $\delta m_h^2$ gets too big.

numerically


$$m_h^2 - 6\frac{\lambda_t^2}{16\pi^2}\Lambda_t^2 + \frac{9}{4}\frac{g^2}{16\pi^2}\Lambda_W^2 + \frac{\lambda_h}{16\pi^2}\Lambda_h^2 \sim (100\,\text{GeV})^2$$

$\lesssim$ 10% tuning requires

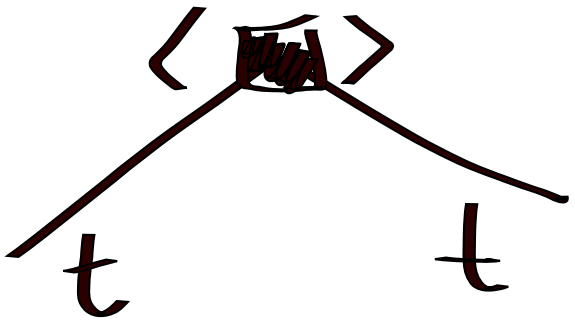
$\Lambda_t \lesssim 2\,\text{TeV}$ $\quad \Lambda_W \lesssim 5\,\text{TeV}$ $\quad \Lambda_h \lesssim 10\,\text{TeV}$

# Fazit:

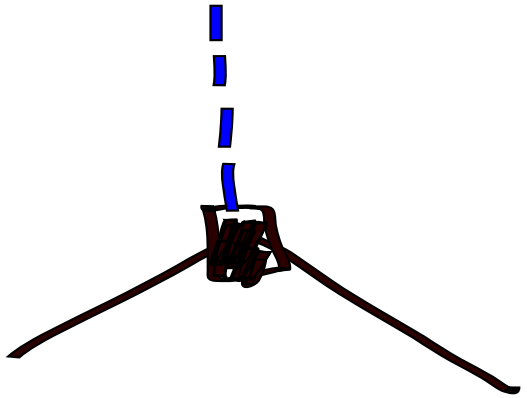
Naturalness of Higgs potential in SM requires new physics related to top

$\lesssim 2$ TeV

# What if there is no Higgs?

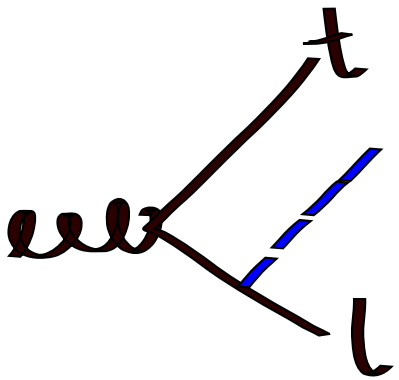



largest mass



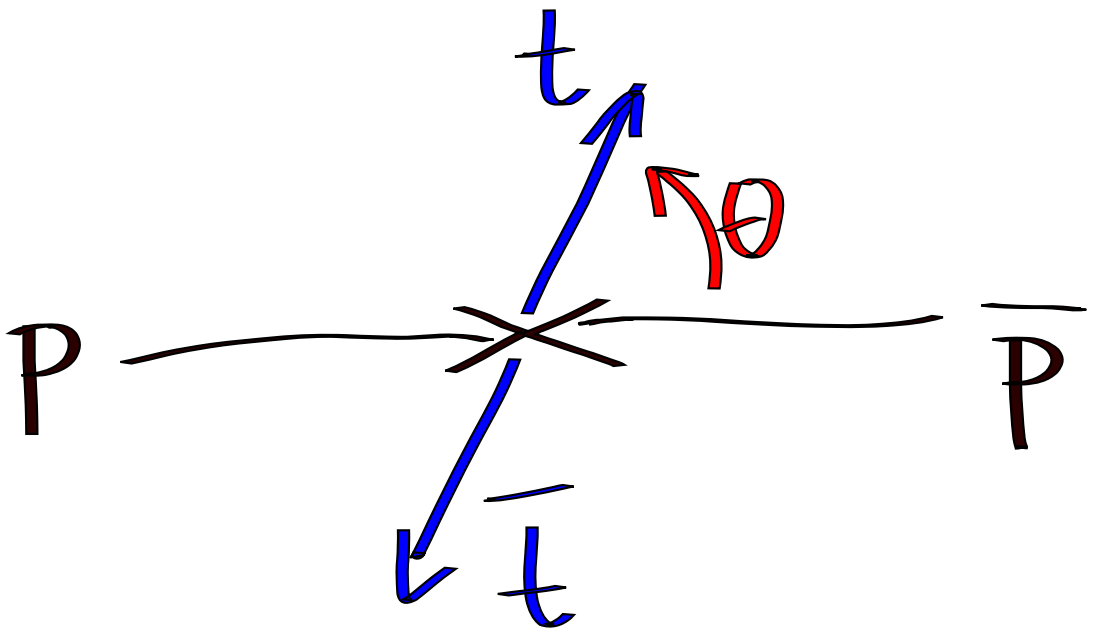
strongest coupling to condenson

# top physics good place to look for NP

1. top partners e.g. susy, LH, RS, ...
2. condenson 

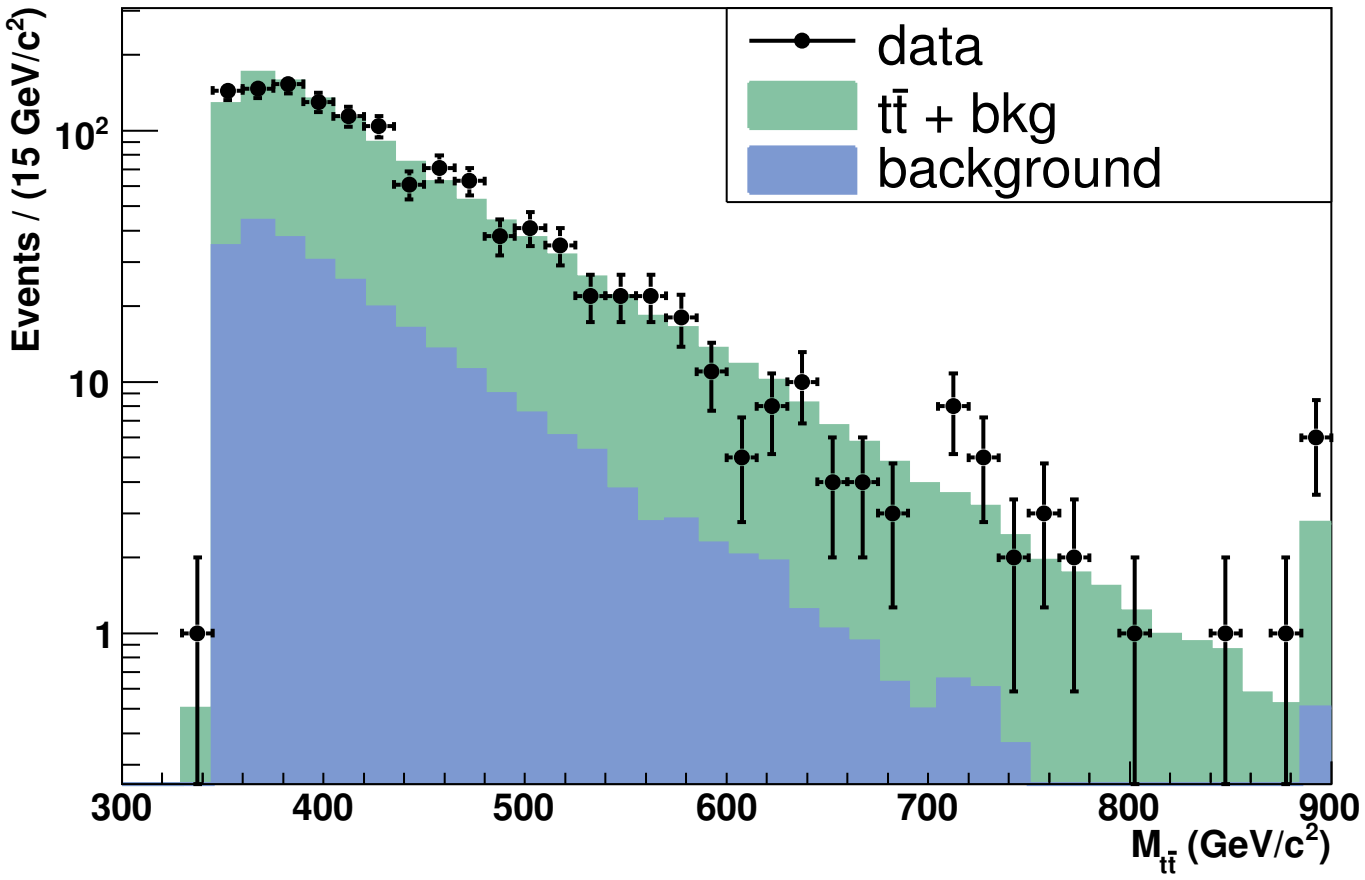
3. unusual top couplings

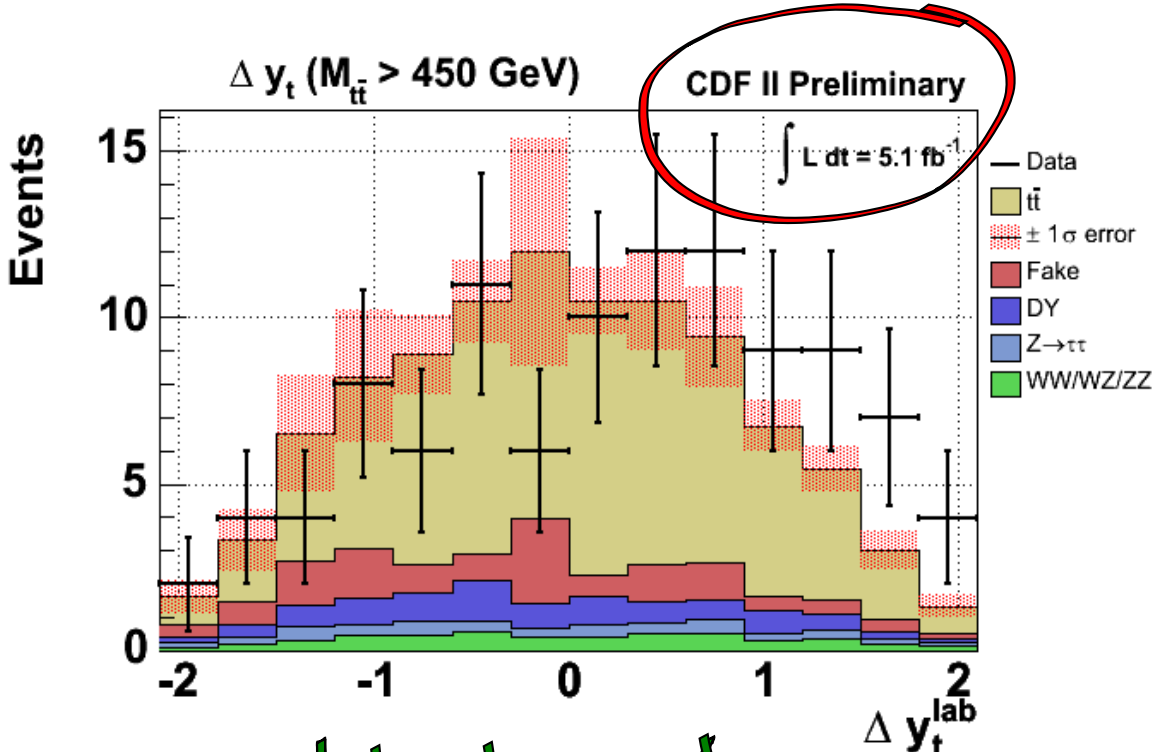
# Let's take a look at tops




$$\frac{d\sigma}{dE_{cm}} \qquad \frac{d\sigma}{d\cos\theta}$$

# CDF $t\bar{t}$ cross section






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