CERN Theory Group Retreat

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fellow '15

Les Houches Centre de Physique

6 November 2015

CV

UAB

Alex Pomarol

Compositeness at the electroweak scale

CV

Higgs boson discovery!

Csaba Csaki / 3y.

Alex Pomarol

Compositeness at the electroweak scale

CV

Higgs boson discovery!

Cornell University — Founded A.D. 1865

Csaba Csaki / 3y.

Universitas Studii Paduani — MCCXXII

Andrea Wulzer / 1y.

UAB

Alex Pomarol

Compositeness at the electroweak scale

Research Interests

Physics Beyond the SM: ElectroWeak scale problem

Why are things big?

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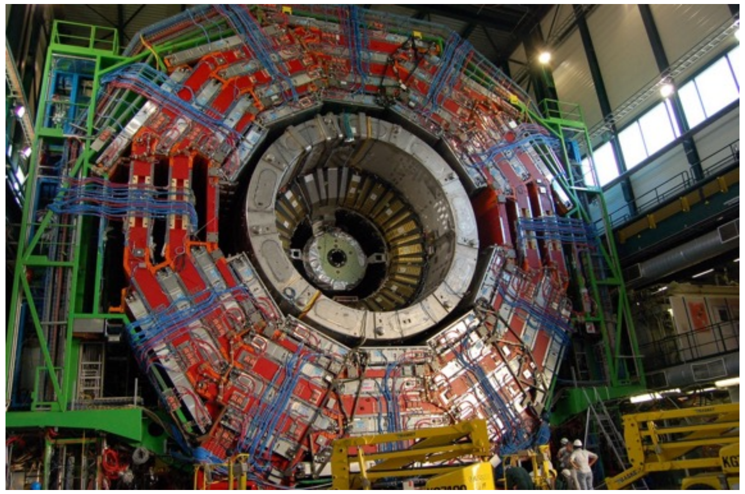
Physics Beyond the SM: ElectroWeak scale problem

Why are things big?

also motivated by other big things:
LHC phenomenology



Research Interests

Physics Beyond the SM: ElectroWeak scale problem

Why are things big?

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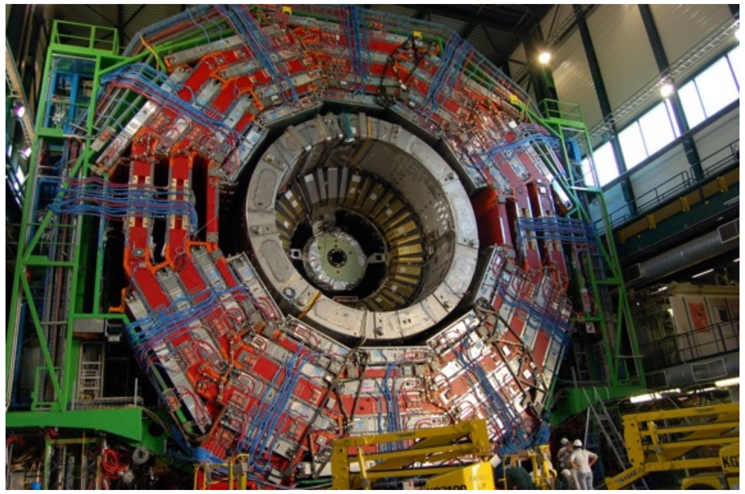
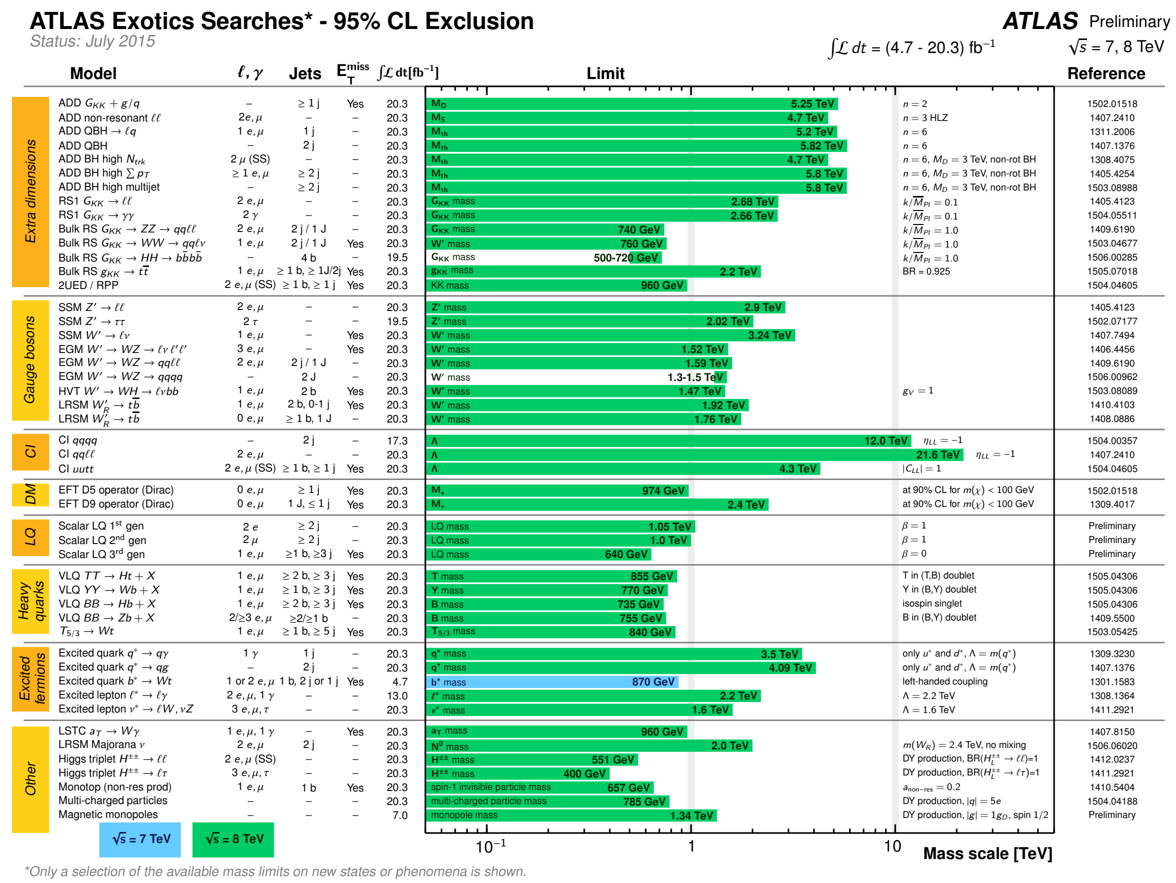


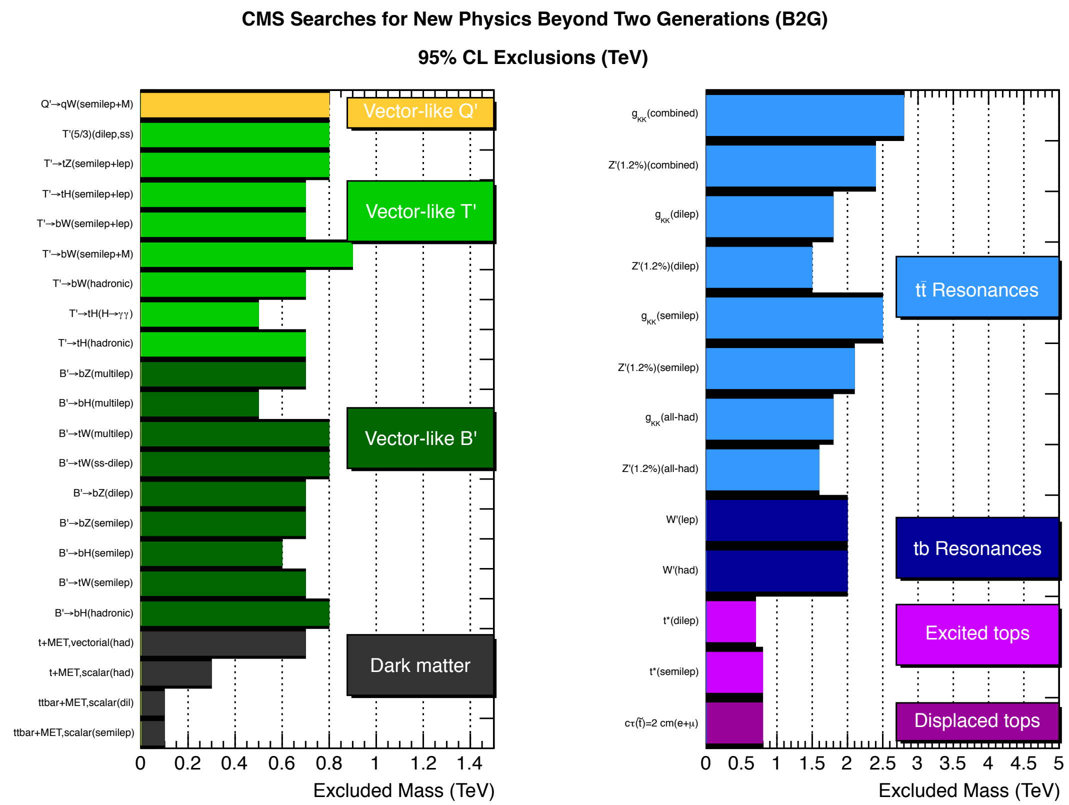
Cosmological & astrophysical spin-offs:
Why is the Universe big?
aka CC problem

LHC non-discoveries

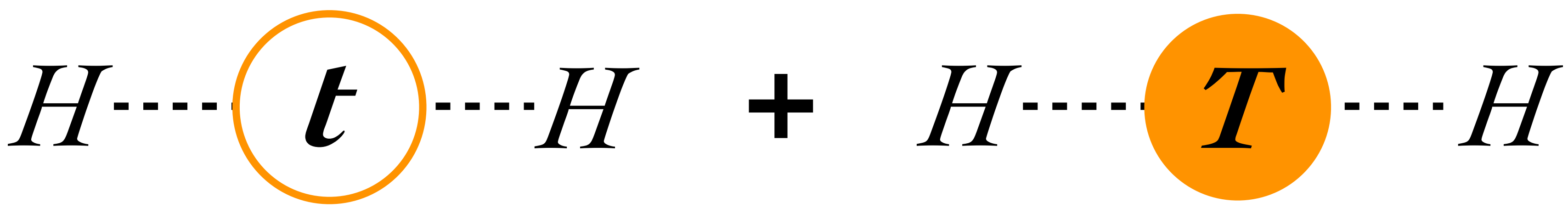


Many bounds on New Physics at the TeV scale.

LHC non-discoveries



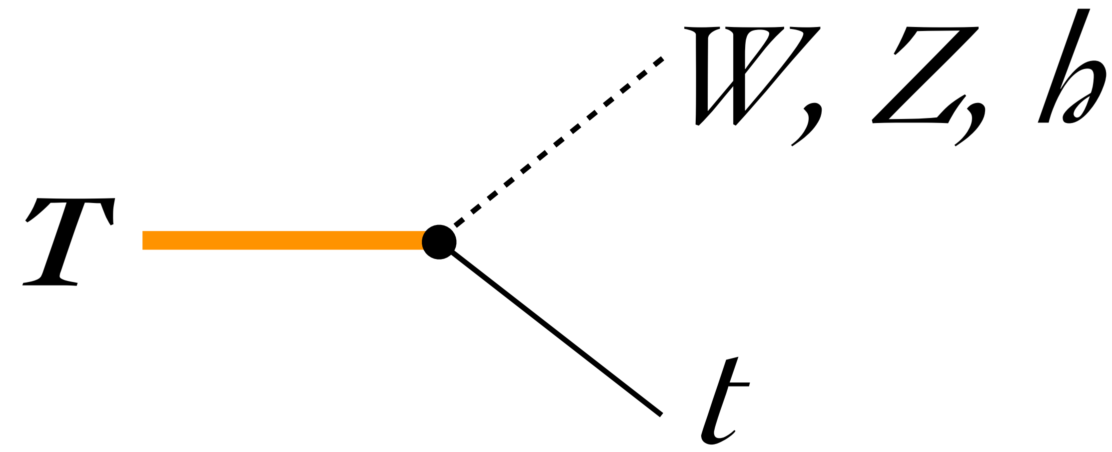
Bounds on Top partners are also significant.



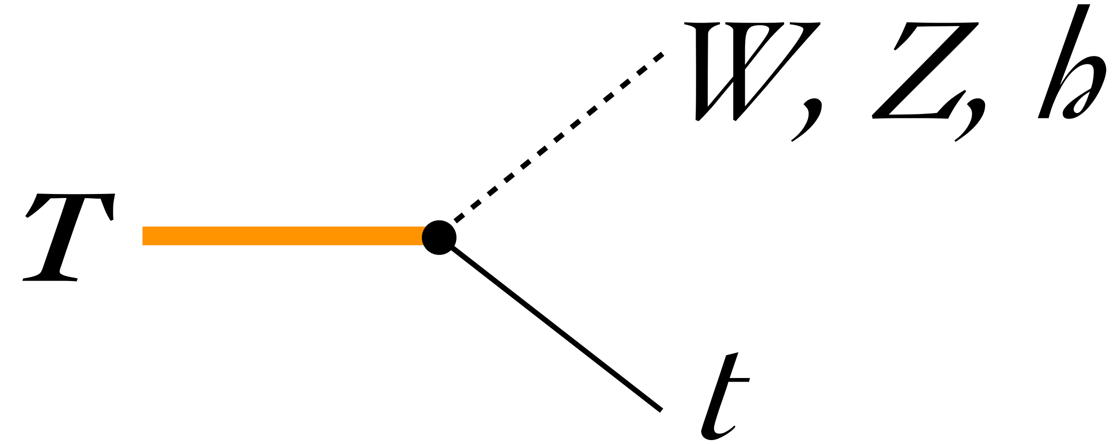
Top partners make the Higgs potential calculable: $m_H^2 \simeq \frac{3y_t^2}{8\pi^2} m_T^2$

Models where H = **pseudo Nambu-Goldstone boson** of G/H

Option 1a: Non-standard *T* decays

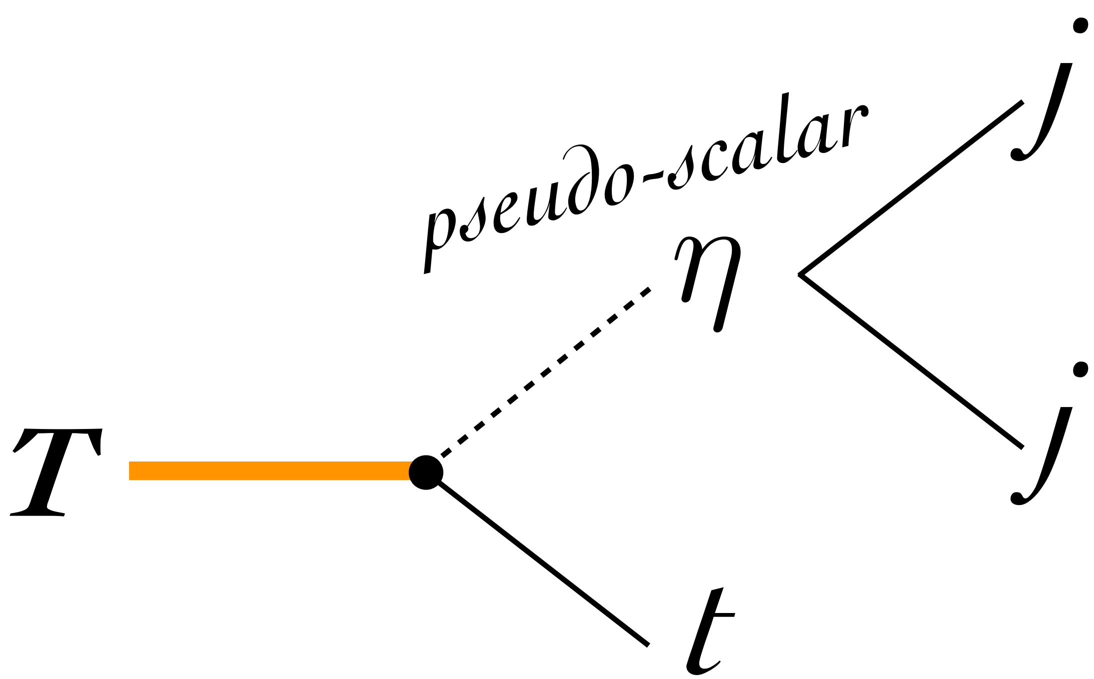


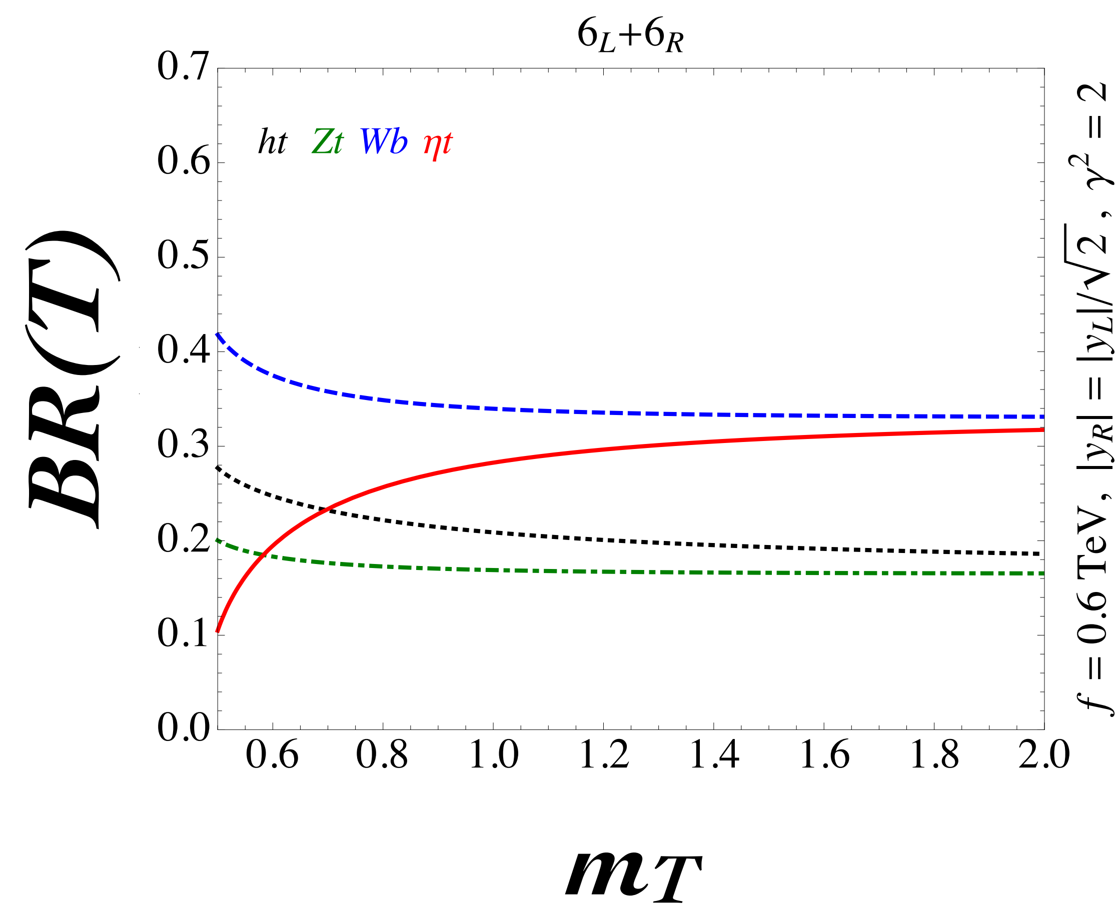
Option 1a: Non-standard T decays



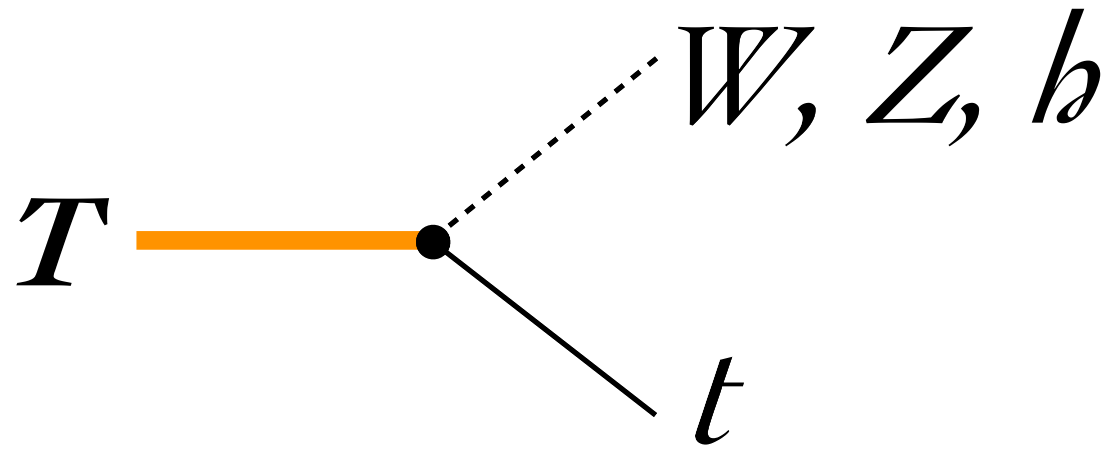
Beyond the Minimal Model: $\mathrm{SU}(4)/\mathrm{Sp}(4) \to H, \eta$

+





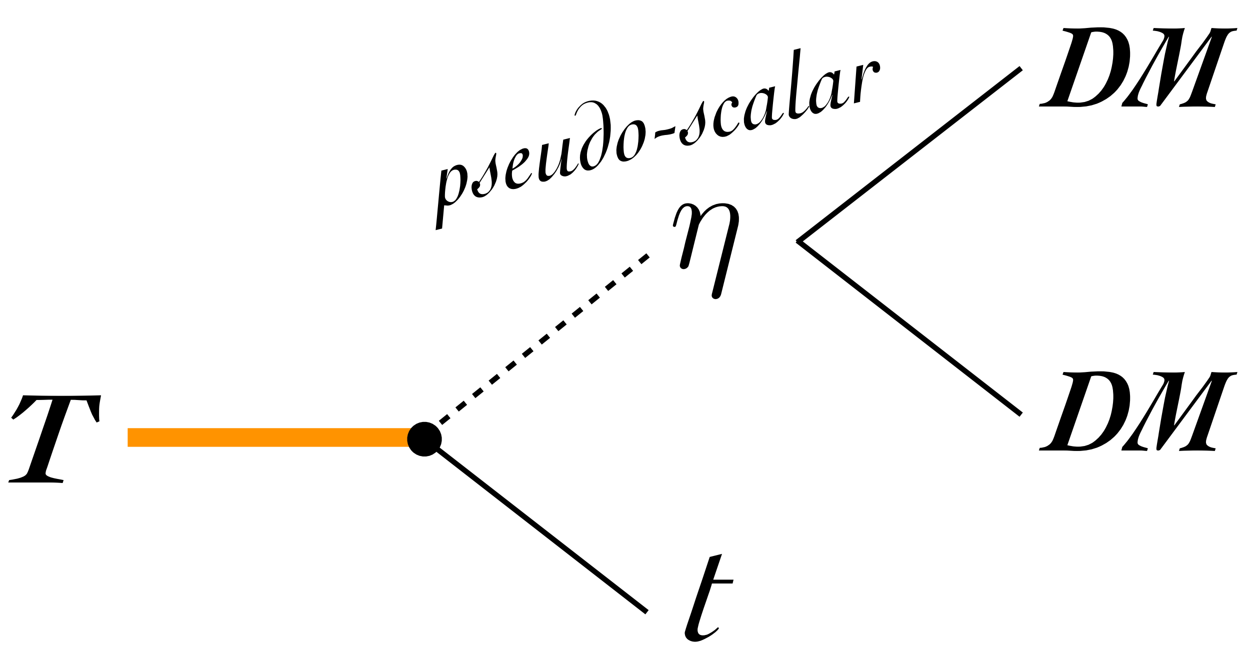
Option 1a: Non-standard T decays

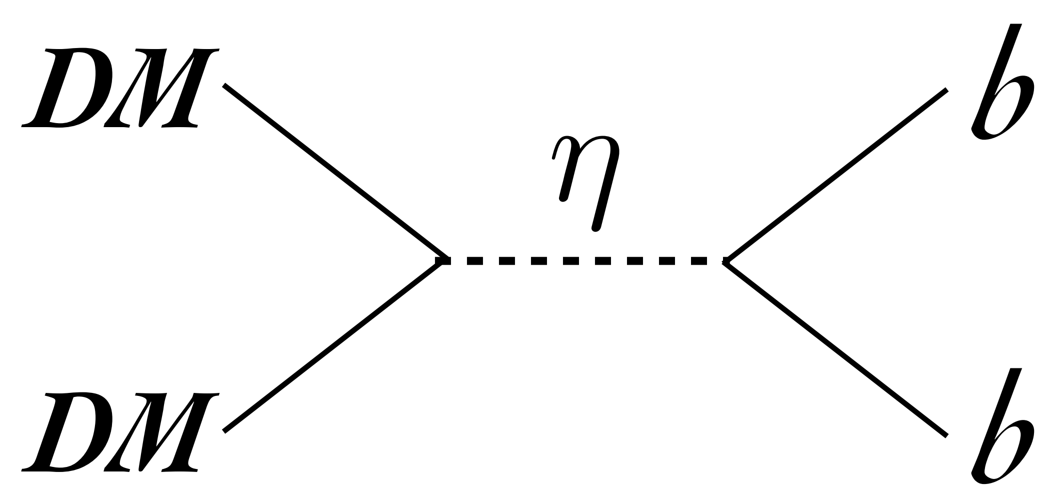


Beyond the Minimal Model: $SU(4)/Sp(4) \to H, \eta$

+

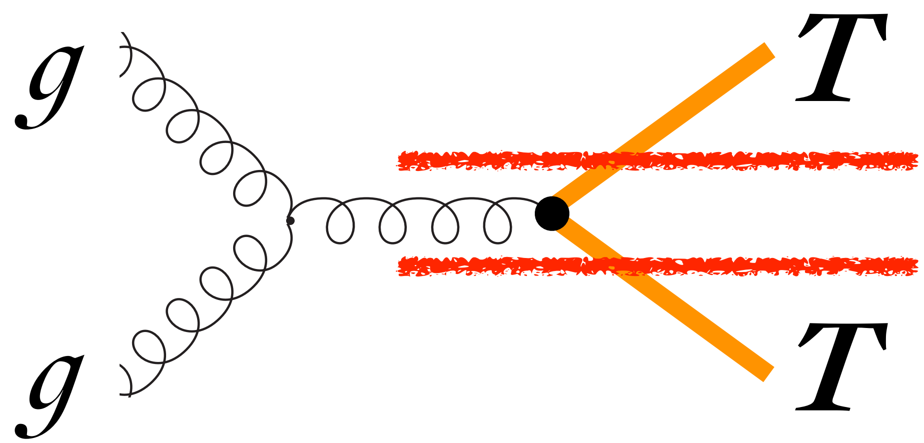
It successfully controls
relic abundance
indirect detection
direct detection





Option 1b: Twin Higgs

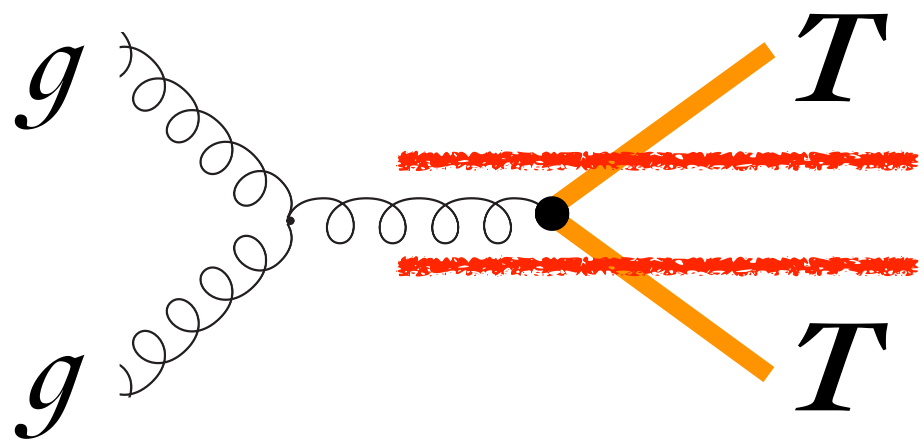
Non-colored Top partners



Normal bounds are evaded.

Option 1b: Twin Higgs

Non-colored Top partners



Normal bounds are evaded.

The exceptional model: $SO(7)/G_2$

Minimal in its symmetries and particle content.

twin top = *T* = DM | *G* = twin gluon | twin Higgs = *w* = EM charged

Novel LHC phenomenology

Option 2: EFT approach

Give up on new light particles, probe properties of SM particles.

$$\frac{ic_L^{(1)}}{m_T^2} H^\dagger D_\mu H \bar{q}_L \gamma^\mu q_L \ , \quad \frac{ic_L^{(3)}}{m_T^2} H^\dagger \sigma^i D_\mu H \bar{q}_L \gamma^\mu \sigma^i q_L \ , \quad \frac{ic_R}{m_T^2} H^\dagger D_\mu H \bar{t}_R \gamma^\mu t_R$$

$$Z_\mu \, \bar{t} \gamma^\mu \big(c^L \, g_{t_L}^{\rm SM} P_L + c^R \, g_{t_R}^{\rm SM} P_R \big) t$$

$c^L = c^R = 1$ in SM

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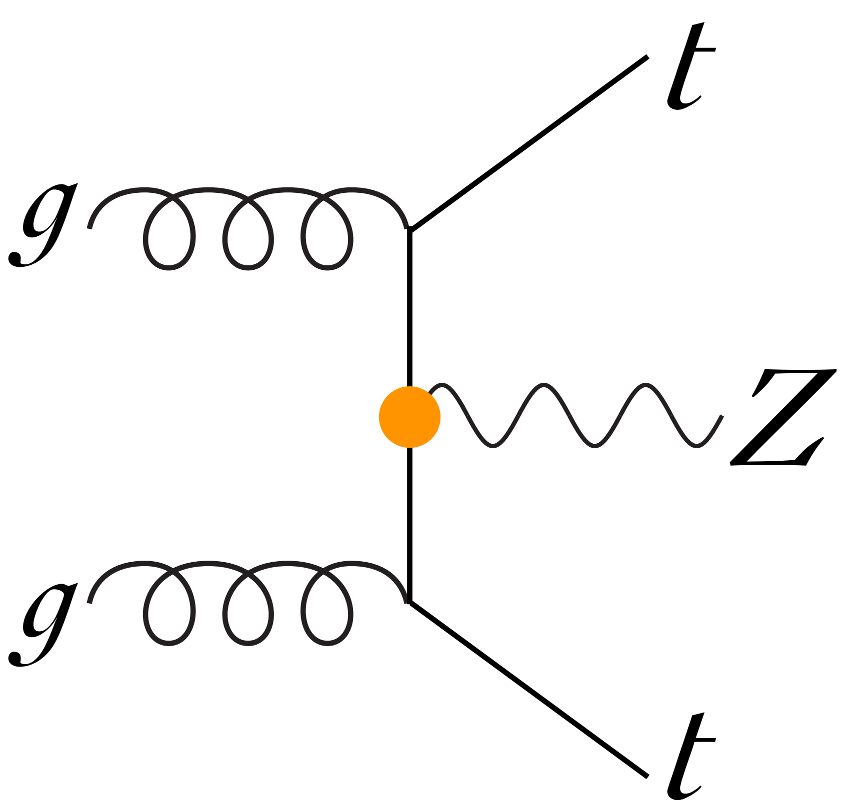
$$Z_\mu \, \bar{t} \gamma^\mu \left(c^L \, g_{t_L}^{\text{SM}} P_L + c^R \, g_{t_R}^{\text{SM}} P_R \right) t$$

$c^L = c^R = 1$ in SM

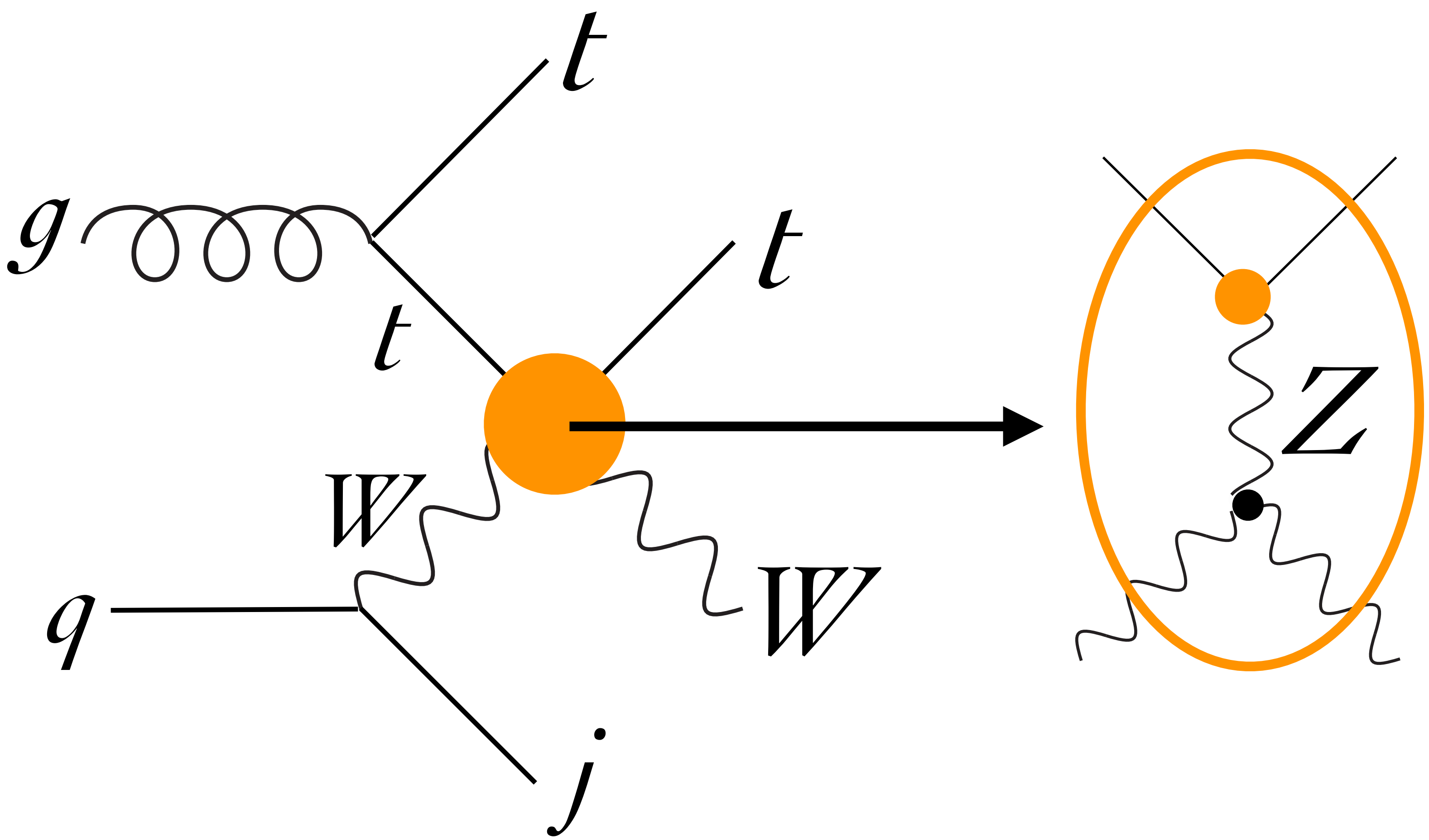


Very weak bounds form current LHC data

The LHC is not a precision machine

Option 2: EFT approach

The LHC is a high *E*nergy machine



$tW \to tW$ scattering amplitude diverges with $\boldsymbol{E}^2$

Option 2: EFT approach

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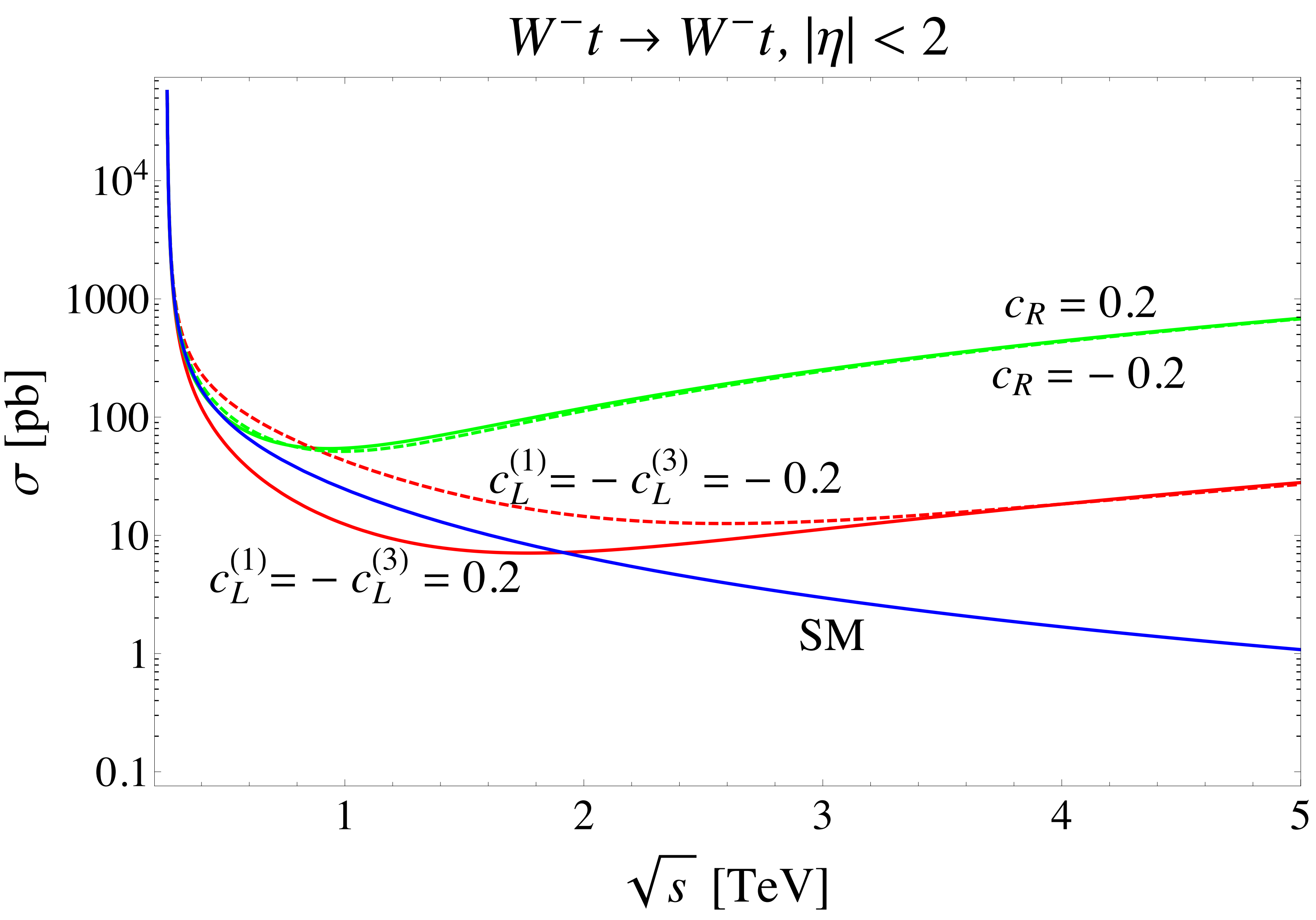
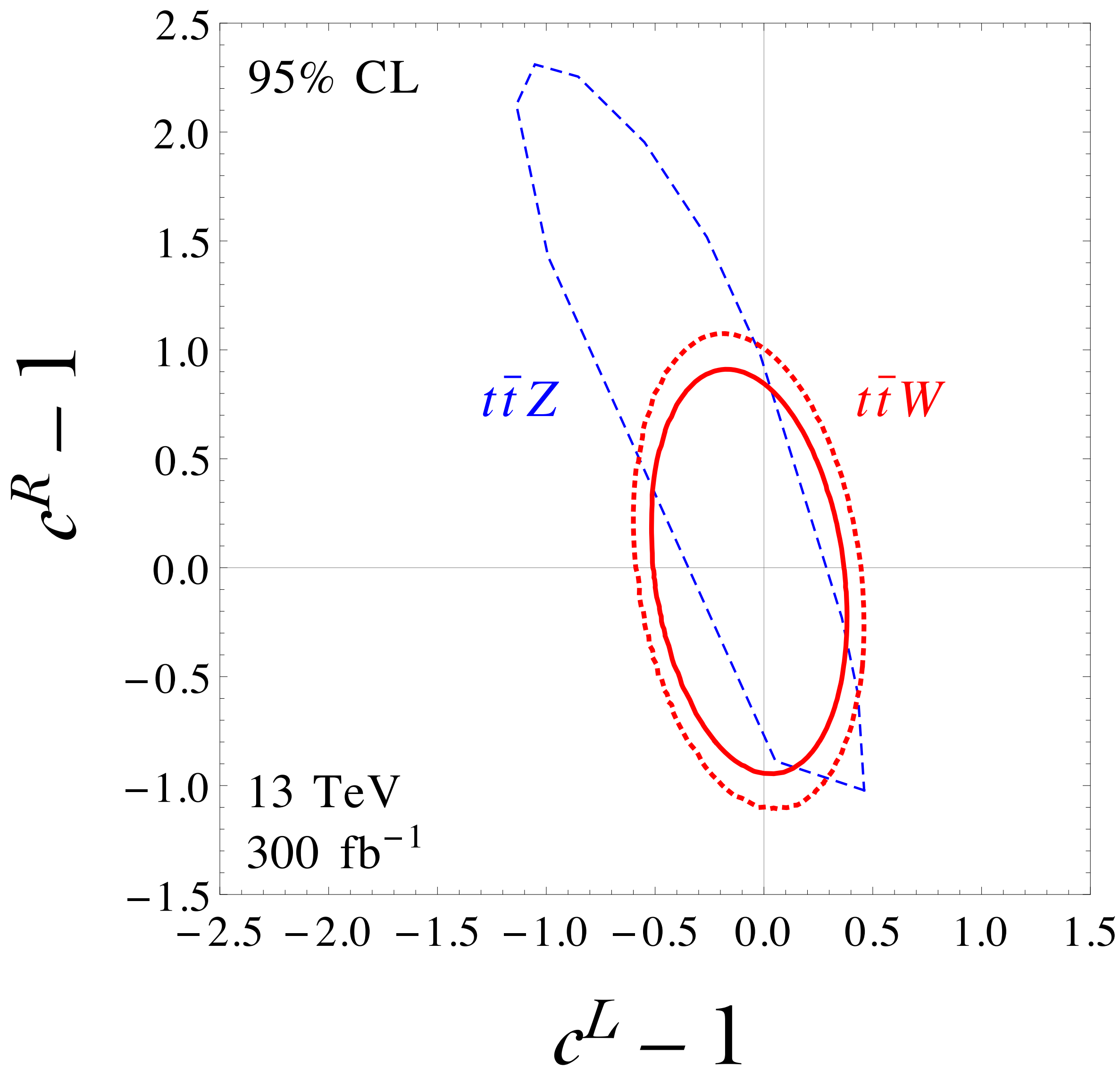
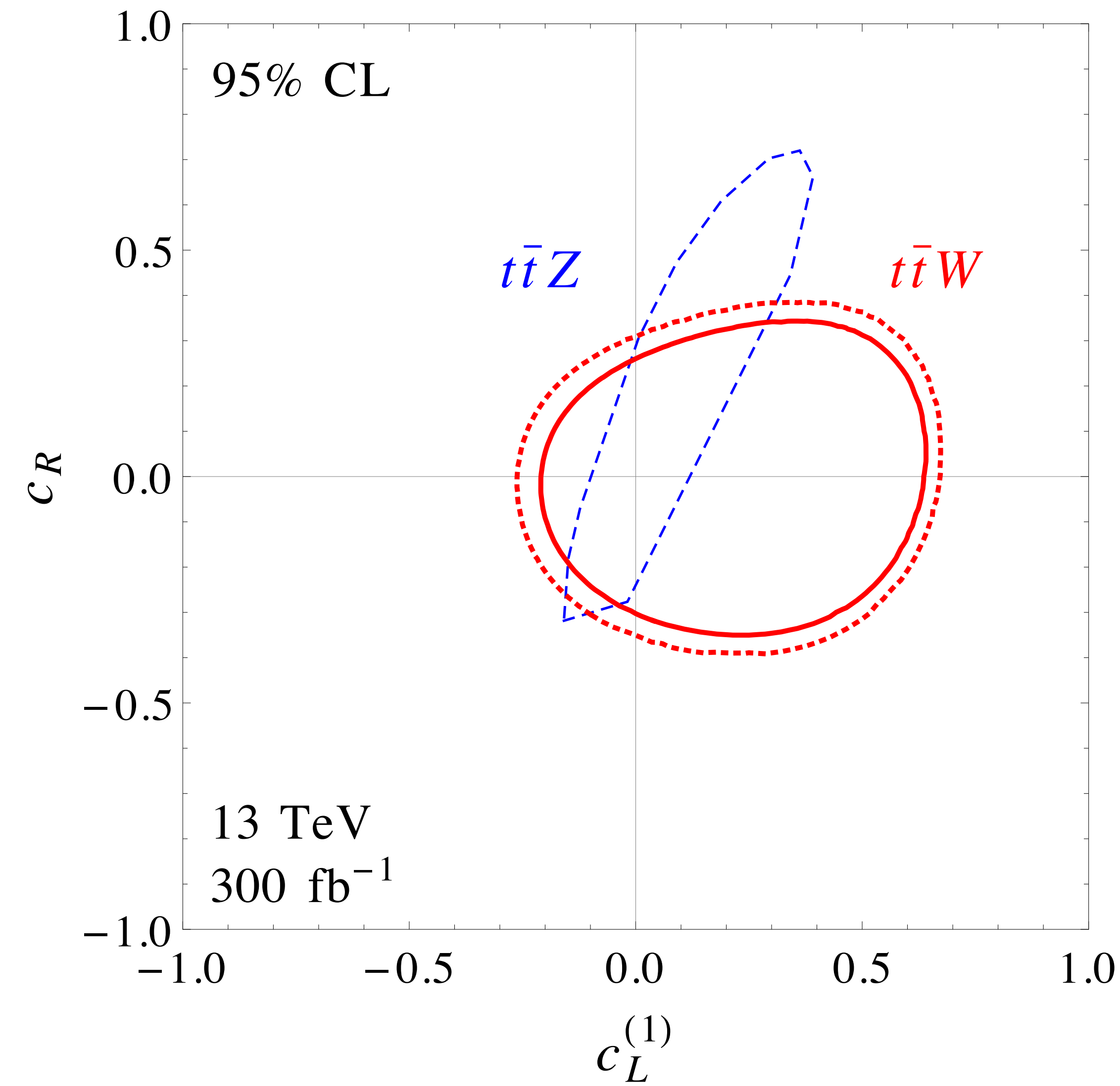


The sensitivity to non-SM top-Z couplings is enhanced.

Option 2: EFT approach



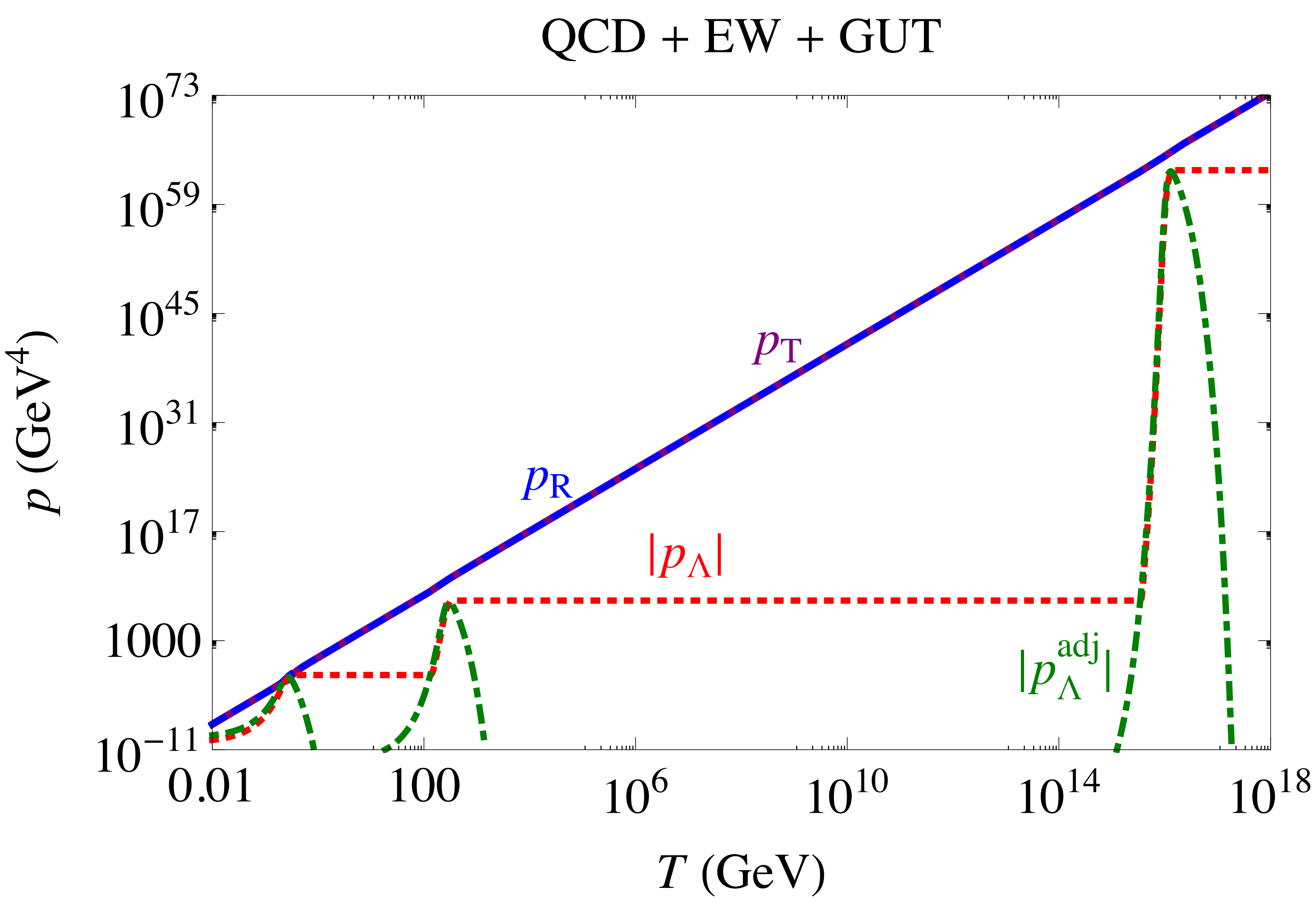


Definitely worth it.

ttZ projection from Rontsch & Schulze

Probes of Vacuum Energy

Cosmological evolution of pressure during Phase Transitions



$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{1}{3}\rho$$

$$\frac{\ddot{a}}{a} = -\frac{1}{6}(\rho + 3p)$$

The constant term in Einstein eq.'s changes during Phase Transitions.

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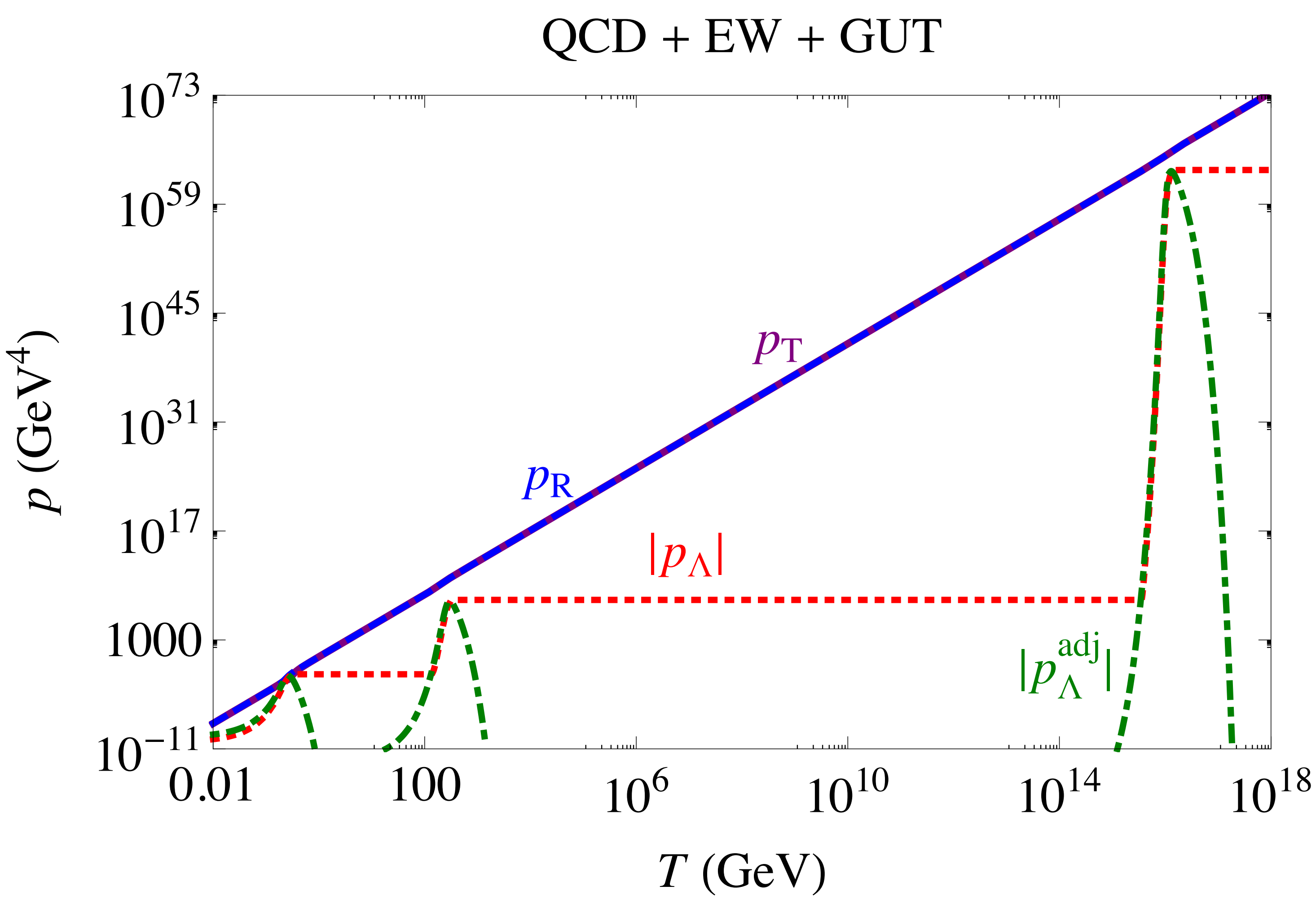

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The constant term in Einstein eq.'s changes during Phase Transitions.

How could we probe this behaviour?

Gravitational waves, neutron stars, …

Thank you and see you around