Searches of new physics in the final state b-τ_H-p_T^{miss}

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PPC 2022

June 7, 2022

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Standard Model of particle physics

The Standard Model of particle physics explains the interactions between the different type of particles in nature.

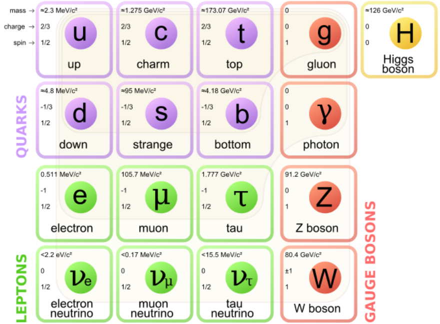
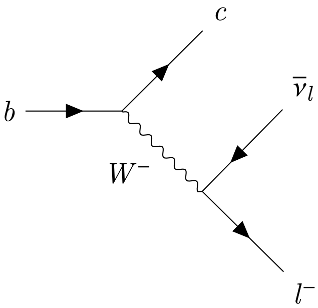


Figure: Particles in the standard model.

The $R_{D^{(*)}}$ Anomaly

But instead the relation between the decay to a τ and other charged lepton it's enhanced by roughly 30%[1].



$$R_{D^{(*)}} = \frac{\mathcal{B}(\bar{B} \to D^{(*)}\tau\bar{\nu}_\tau)}{\mathcal{B}(\bar{B} \to D^{(*)}l\bar{\nu}_l)} \quad (1)$$

[1] M. Huschle, T. Kuhr, M. Heck, P. Goldenzweig, A. Abdesselam. Measure-ment of the branching ratio of $\mathcal{B}(\bar{B} \to D^{(*)}\tau\bar{\nu}_\tau)$ relative to $\mathcal{B}(\bar{B} \to D^{(*)}l\bar{\nu}$

The Crossing Symmetry

In particle physics if an interaction like

$$A + B \to C + D \tag{2}$$

is observed, related interactions can be anticipated from the fact that any of the particles can be replaced by its antiparticle on the other side of the interaction [2].

$$\begin{aligned} A &\to \overline{B} + C + D \\ A + \overline{C} &\to \overline{B} + D \\ \overline{C} &\to \overline{A} + \overline{B} + D \\ \overline{C} + \overline{D} &\to \overline{A} + \overline{B} \end{aligned} \tag{3}$$

[2] Michael Peskin. An introduction to quantum field theory. CRC press, 2018.

Sequetial Standard Model's W'

Considering the Crossing Symmetry a alternative consideration can be made in order to explain the $R_{D^{(*)}}$

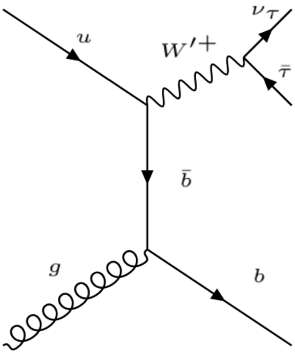


Figure: pp Collision with a final state of b, τ, ν mediated by a W'.

Effective Field Theory

In the case there is a heavier mediator that cannot be produced on-shell at the LHC, the *"Low Energy"* phenomenology can be studied as an EFT

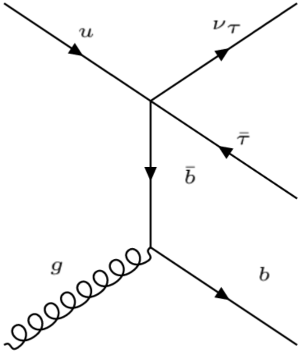


Figure: pp Collision with a final state of b, τ, ν with a punctual interaction

Leptoquark

In the case of the Leptoqurk (LQ) different models were tested. The best results came from considering a $U(1)$. Where the LQ. Couples to the up type quarks and the neutral leptons, and to the down quarks in company with the charged leptons

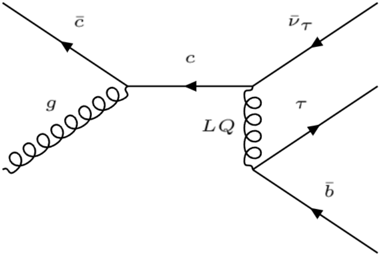


Figure: pp Collision with a final state of b, τ, ν Mediated via a LQ.

The Simulation

Different simulations were made for each signal (W', EFT and LQ) and backgrounds ($t\bar{t}$ semileptonic, Jets + $W \to \tau + \nu$ and Jets + $Z \to \tau + \bar{\tau}$). The software used were:

1. **MadGraph5** for parton simulation and cross section calculation.
2. **Pythia8** for hadronization simulation process
3. **Delphes** for detectors response emulation.

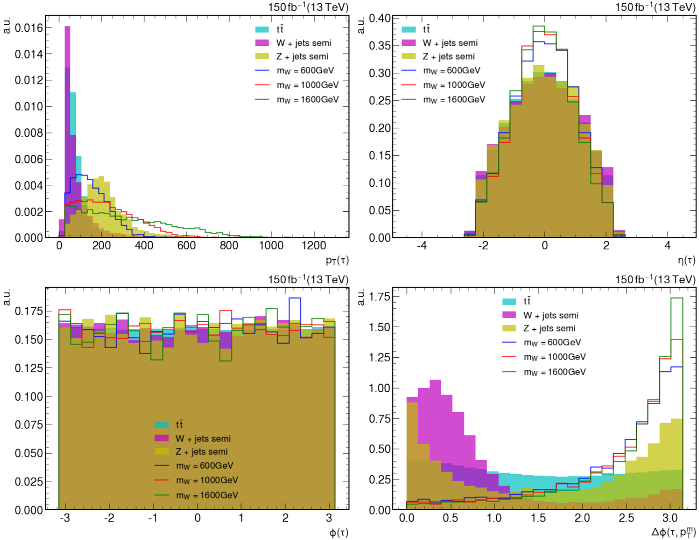
Simulation and Cross Section

Simulations' Models were made according with the reference [3].

Model	Parameters	Cross_Section(pb)
SSM	$m_{W'} = 6 \times 10^2$GeV	5.25
	$m_{W'} = 1 \times 10^3$GeV	0.45
	$m_{W'} = 1.6 \times 10^3$GeV	0.03
EFT	$\epsilon_l^{cb} = 1.0$	0.13
	$\epsilon_{sL}^{cb} = 1.0$	0.08
	$\epsilon_t^{cb} = 1.0$	0.71
LQ_U(1)	$mLQ = 1 \times 10^3$ GeV	0.02
	$mLQ = 2 \times 10^3$ GeV	3×10^{-4}
	$mLQ = 3 \times 10^3$ GeV	9.82×10^{-6}

[3] A. Greljo, J. M. Camalich, and J. D. Ruiz- Alvarez, Mono-τ signatures at the lhc constrain explanations of b-decay anomalies, Physical review letters122, 131803 (2019)

Kinematics


150 fb^{-1}(13 TeV)
a.u.
$t\bar{t}$
W + jets semi
Z + jets semi
m_W = 600GeV
m_W = 1000GeV
m_W = 1600GeV
$p_T(\tau)$
$\eta(\tau)$
$\phi(\tau)$
$\Delta\phi(\tau, p_T^{m})$

Significances

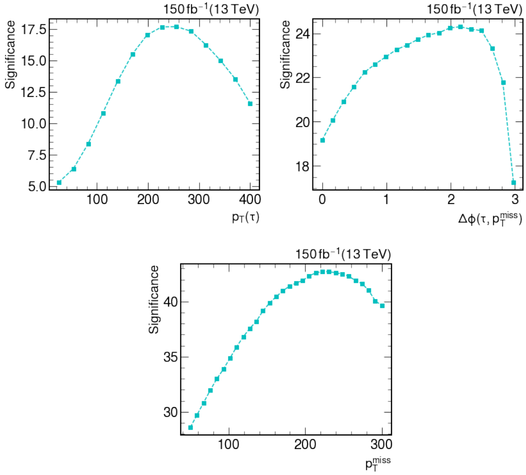


Figure: Sequential Standard Model significance curve.

Analysis parameters

In order to maximize the statistical significance

$$Z = \frac{N_s}{\sqrt{N_s + N_b}} \tag{4}$$

straight cuts are made to be above:

Parameter	SSM	EFT	$U(1)_{LQ}$
$p_T(\tau)$	250 GeV	200 GeV	300 GeV
$\lvert\Delta\phi(\tau, \mathbf{p}_T^{\text{miss}})\rvert$	2	2.0	1
p_T^{miss}	200 GeV	300 GeV	400 GeV
Reached Significance	43	6.0	7.5

Table: Parameters Table.

τ Transverse Mass(SSM)

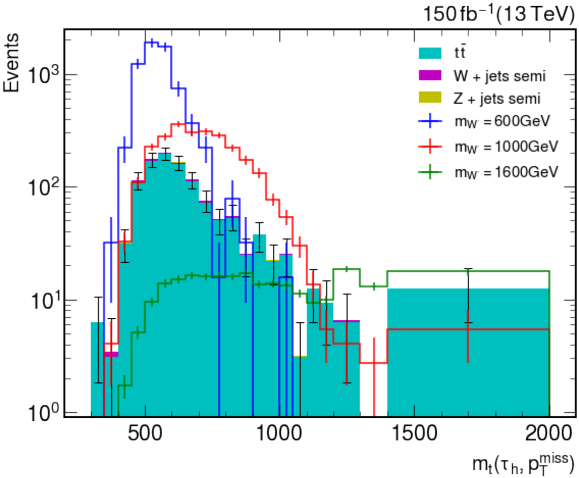


Figure: τ_h Transverse Mass

τ, b, p_T^{miss} Total Mass(EFT)

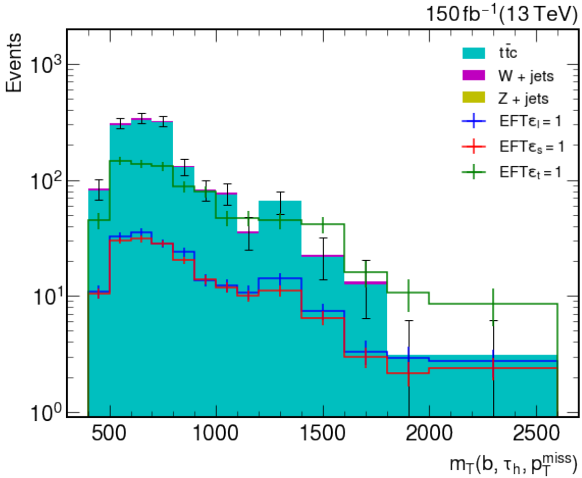


Figure: Total Mass between τ_h , b, MET

b, τ_h Invariant Mass($U(1)_{LQ}$)

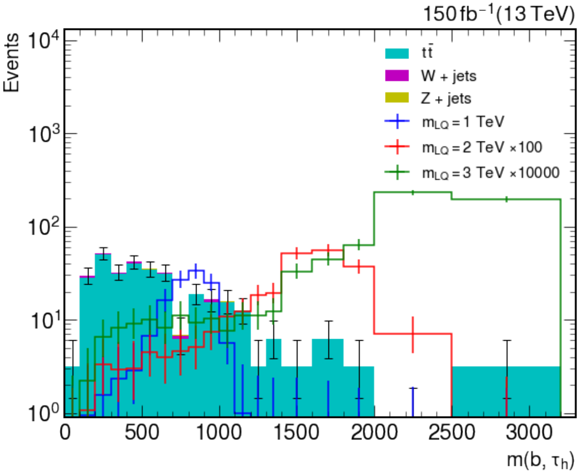


Figure: Invariant Mass between τ_h and b

SSM Significance

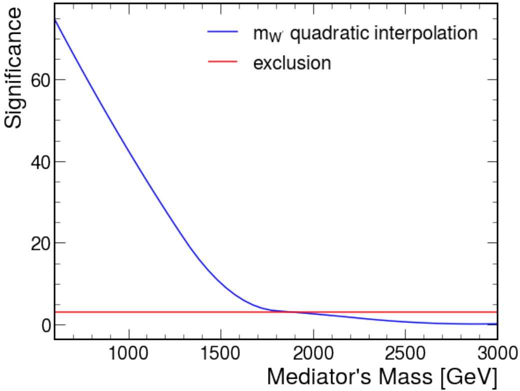


Figure: W' masses in the horizontal axis, and the Significance Z in the vertical axis. The horizontal line is the 3σ exclusion value.

LQ Significance

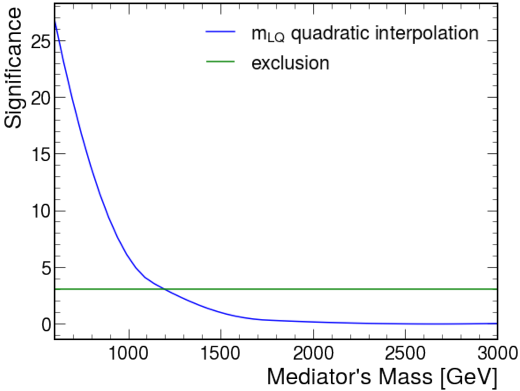


Figure: LQ masses in the horizontal axis, and the Significance Z in the vertical axis. The horizontal line is the 3σ exclusion value.

EFT Significance

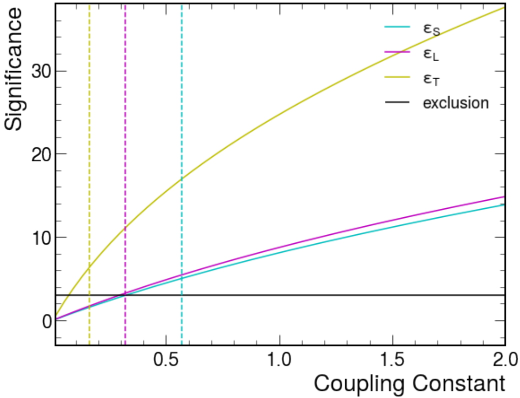


Figure: EFT value couples in the horizontal axis, and the Significance Z in the vertical axis. The horizontal line is the 3σ exclusion value.

Conclusions and projections

- The $R_{D^{(*)}}$ anomaly could be explained if there would be signals of physics BSM.
- The exclusions limits are reached for the 3 models.
- The search can be made at an experimental level in colliding experiments as CMS or ATLAS.

Thank you!