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Centro Nazionale di Ricerca in HPC,
Big Data and Quantum Computing

Exotic Quark Decay in the 331 Model: LHC Prospects and Computational Techniques

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UNIVERSITÀ
DEL SALENTO
L'Ateneo tra i due mari



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ICSC
Centro Nazionale di Ricerca in HPC,
Big Data and Quantum Computing

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Introduction

Why there are three families in the Standard Model? Need to go beyond...

331 Model(s) are a possible answers:

- $SU(3)_C \times SU(3)_L \times U(1)_X$
- Fermions are in triplets and antitriplets of $SU(3)_L$
- Generations are not treated democratically
- Anomaly cancellation and QCD asymptotic freedom constrains the number of families to three
- $SU(3)_C \times SU(3)_L \times U(1)_X \rightarrow SU(3)_C \times SU(2)_L \times U(1)_Y \rightarrow SU(3)_C \times U(1)_{em}$
- Involved scalar potential with **26 parameter (at least)**
→ **Difficulties in finding valid benchmarks**

Benchmarkcks

How to find valid benchmarks for a BSM model?

- SARAH/SPheno/HiggsBounds
- SSP automate the chain

In the case of the 331 model with 3 scalar triplets and a sextet

$M_{h_1} = 125.31$	$M_{h_2} = 6799.5$	$M_{h_3} = 10490$	$M_{h_4} = 17673$	$M_{h_5} = 17737$
$M_{Ah_1} = 10489$	$M_{Ah_2} = 17735$	$M_{H_1^{\pm\pm}} = 10572$	$M_{H_2^{\pm\pm}} = 17674$	$M_{H_3^{\pm\pm}} = 17795$
$M_{H_1^\pm} = 2566.4$	$M_{H_2^\pm} = 104900$	$M_{H_3^\pm} = 17674$	$M_{H_4^\pm} = 17736$	$M_T = 5656.9$
$M_{D_1} = 5656.9$	$M_{D_2} = 5656.9$	$M_{Y^\pm} = 1328.0$	$M_{Y^{\pm\pm}} = 1325.6$	$M_{Z'} = 4150.4$

How to do collider phenomenology (LHC, FCC)?

- MadGraph5
- MadAnalysis5

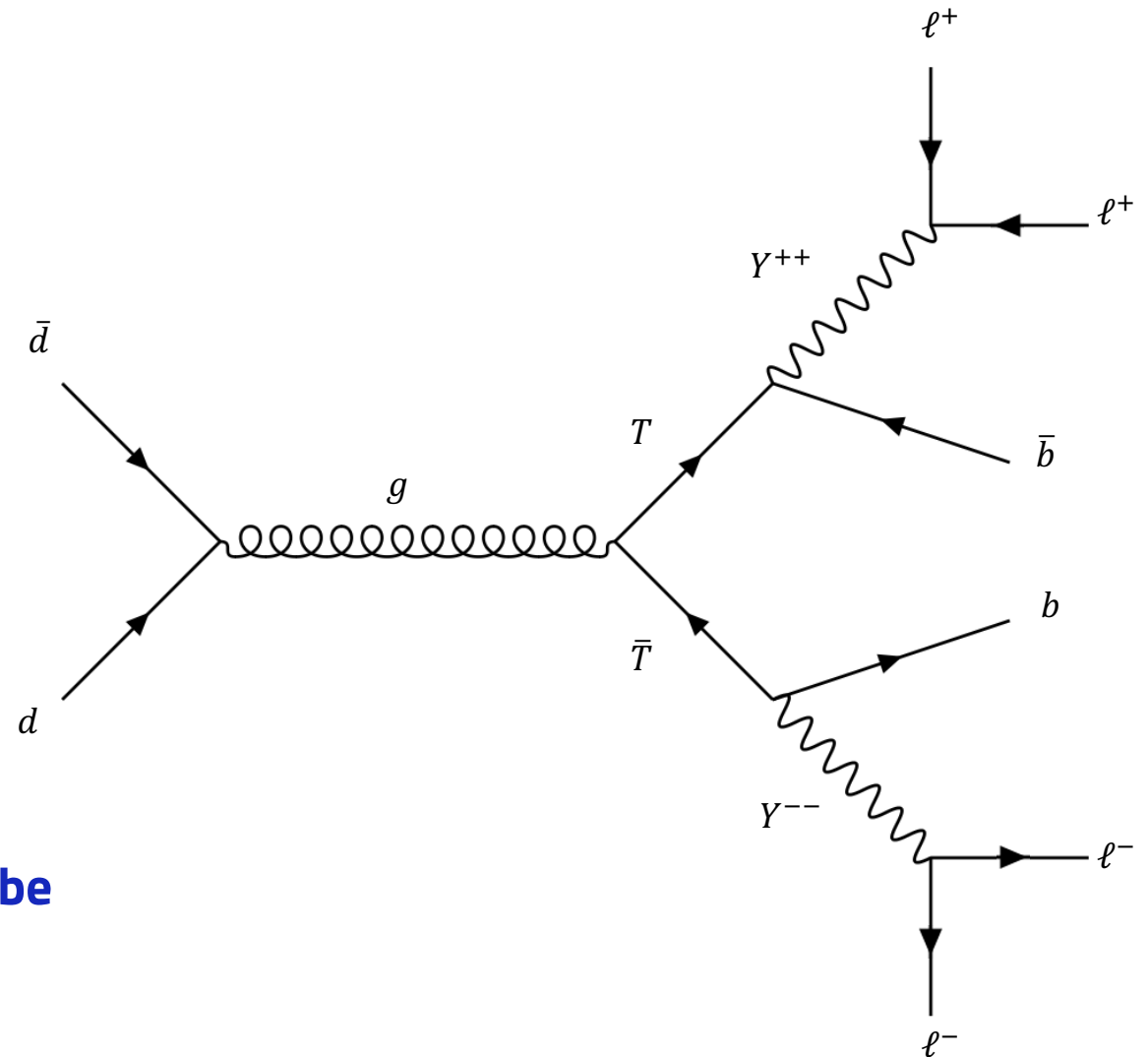
Exotic Quark Decay

The charge operator has a free parameter β
In the case of Frampton's version $\beta = \sqrt{3}$

- T has charge $\frac{5}{3}e$
- Y^{++} has charge $2e$

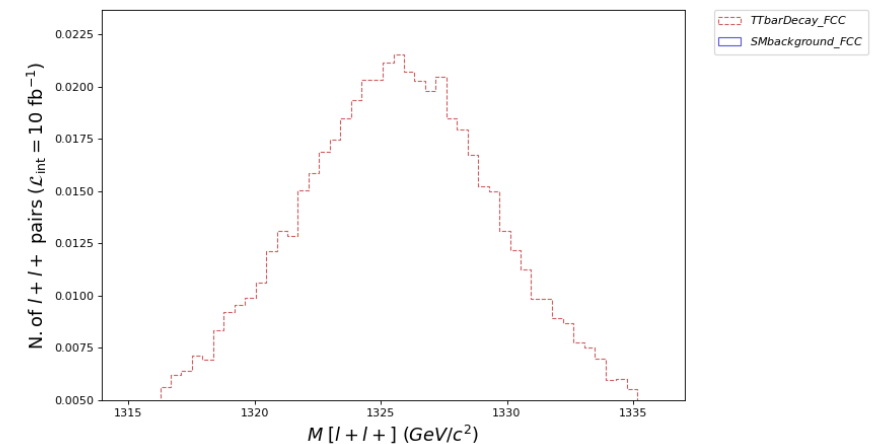
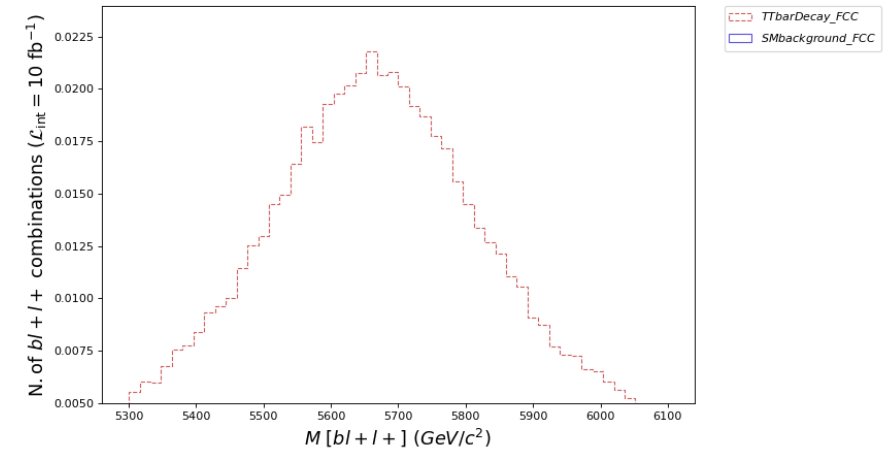
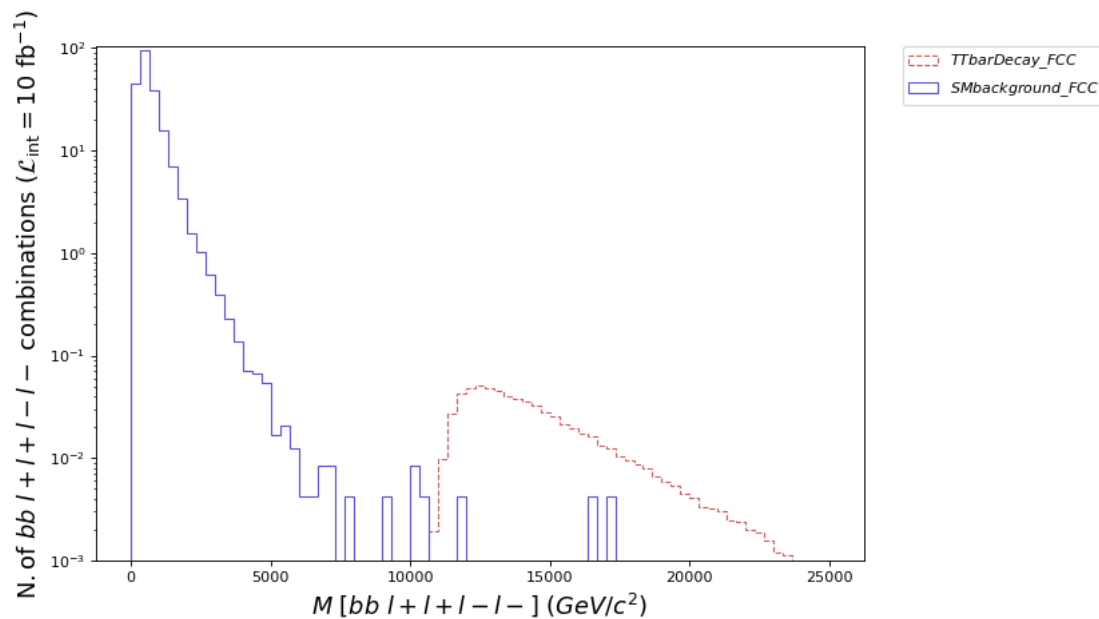
- Monte Carlo simulation
- Data Analysis

Parton Shower and Hadronization have yet to be done



Some preliminary results

- LHC $\rightarrow 2.8 * 10^{-9}$ events... the luminosity is not sufficient
- FCC $\rightarrow 3350$ events



Conclusions and future developments

Improving the benchmark search for deeper analysis of a complicated potential with many scalars and parameters

Analysis of possible first order phase transitions in BSM models with involved scalar sector like 331 Model(s):

- **Nucleation temperature**
- **Phase transition strength**
- **Rate of the phase transition**
- **Bubble wall velocity**

In order to obtain the predicted spectrum of the cosmological GW background