

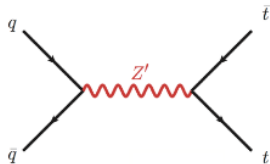
# A search for $t\bar{t}$ resonances in the lepton plus jets final state with ATLAS

March 22, 2022

# Beyond the Standard Model

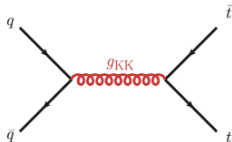
- **Changing symmetries**

- connection to EW Symmetry Breaking ?
- SM based on  $SU(3) \times SU(2) \times U(1)$  → Belong to a larger symmetry group ?
  - $SO(10)$ ,  $E_6$ ,  $E_7$ , GUT theories
- Breaking  $\Rightarrow$  new symmetries remain  $\Rightarrow$  additional gauge bosons predicted
  - $W', Z'$



- **New Dimension**

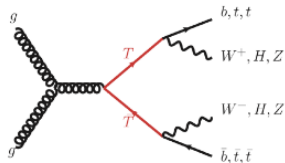
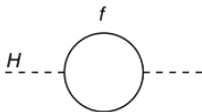
- Explain mass hierarchy, scale hierarchy
- Constraints extra-dimensions compactified
  - Warped extra-dimensions (Randall-Sundrum)
- Randall-Sundrum Kaluza-Klein excitations



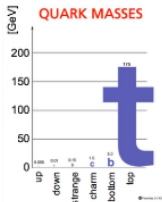
# Beyond the Standard Model

- **Top quark partners**

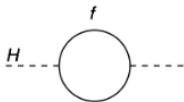
- New Physics at higher scale  $\Rightarrow$  Large radiative corrections to Higgs.
  - Need to cancel.
- Reduction of these corrections: top quark's partners (e.g stop, vector-like partners...)



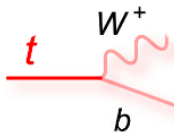
# Top quark: probe for New Physics?



**Distinctive properties**  
(mass,  $y_t$ , ...)



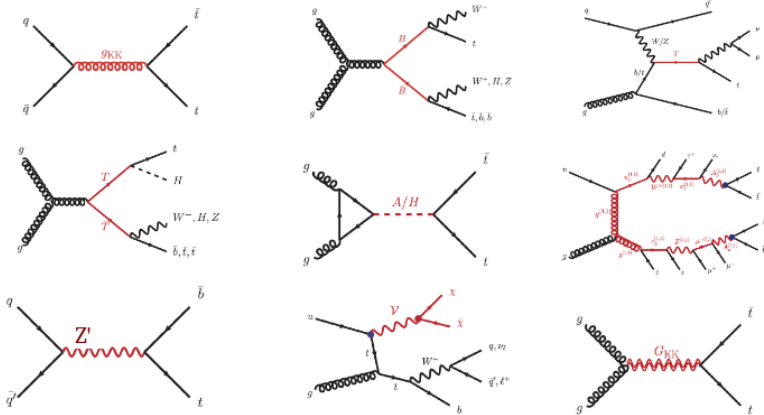
**Leading** radiative corrections  
to Higgs mass



**Unique experimental signature**

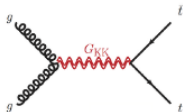
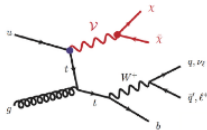
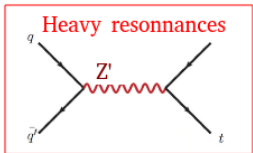
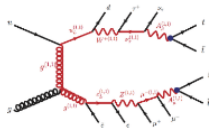
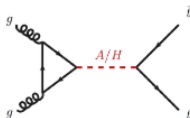
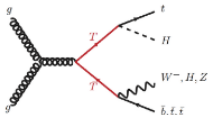
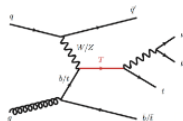
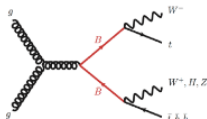
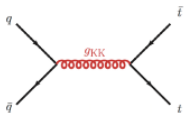
# Top quark: probe for New Physics?

- Large coupling expected to BSM sector in several models



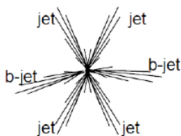
# Top quark: probe for New Physics?

- Large coupling expected to BSM sector in several models



# Top events and final states: experimental signatures

## Depends on decay of W bosons

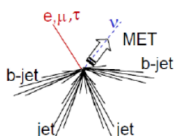


### All hadronic

BR ~ 46 %

**Major** backgrounds:

- QCD multi-jet

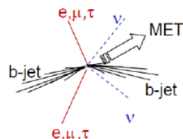


### Lepton + jets

BR ~ 44 %

Major backgrounds:

- W + jets
- Single top



### Dilepton

BR ~ 10 %

**Main background**  
*(highly reducible):*

- Z + jets

# LHC and luminosity

- This talk covers searches for these new physics models using data from proton-proton collisions recorded by the **ATLAS** experiment at a center-of-mass energy of **13 TeV** collected during the LHC **Run 2 (2015-2018)** (**139 fb<sup>-1</sup>**)



# Resonances searches

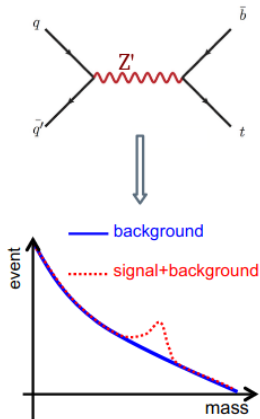
- New heavy leptophobic gauge bosons ( $Z'$ ,  $W'$ ,  $g_{KK}$ , ...)
  - Several models probed (e.g. extra-dimension, SSM, Dark Matter)
  - Charge conservation: decays to  $t\bar{t}$  or  $b\bar{b}$

- **Strategy**

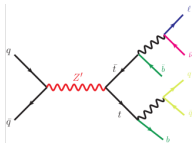
- Continuously falling background
- New Physics  $\rightarrow$  bump on invariant mass spectrum

- **Key aspects**

- Identification of boosted and resolved objects
- Reconstruction of invariant mass

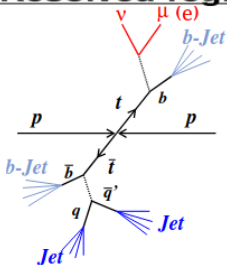


# Signal Topology



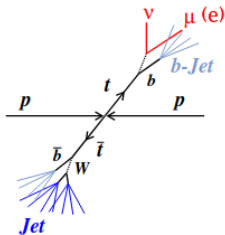
Going from SM  $t\bar{t}$  to high-mass BSM  $t\bar{t}$   
 $e(\mu)+\text{jets}$  topology:

## Resolved regime



Low top  $p_T$

## Boosted regime

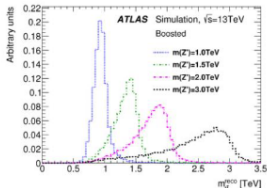
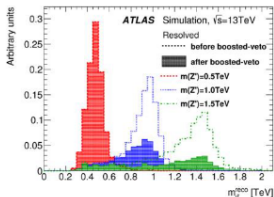


High top  $p_T$

One electron (muon), missing transverse energy ( $E_T^{miss}$ ), jets.  
 But: high top quark  $p_T$  leads to small  $\Delta R$  between decay products  
 not always  $\rightarrow$  4 reconstructed jets

# Event Reconstruction

- **Resolved Selection:**  
use  $\chi^2$  minimization algorithm to select the best assignment of jets to the semileptonically decaying of top quarks
- **Boosted Selection:**  
no ambiguity in jet assignment



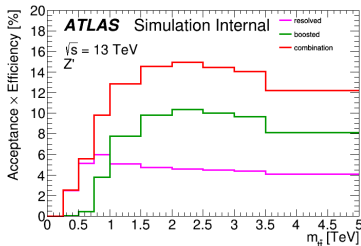
# Event Selection

## Boosted Selection:

- Leptonic top :  $\geq 1$  R = 0.4 jet close to the lepton (jsel)
  - $\Delta R(jsel, l) < 1.5$
- Hadronic top:  $\geq 1$  large-R jet away from the leptonic top
  - $\Delta R(JET, jse) > 1.5$  and  $\Delta\phi > 2.3$
  - $\geq 1$  tagged track jet

## Resolved Selection:

- $\geq 4$  small R jets with :
- $P_t > 25\text{GeV}$
- $\geq 1$  tagged track jet
- jets assignment to W and top:  $\log_{10}(\chi^2) < 0.9$



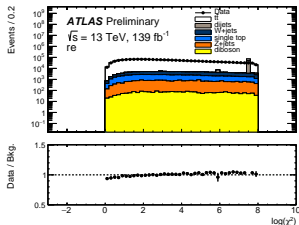
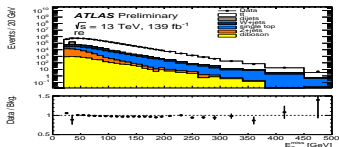
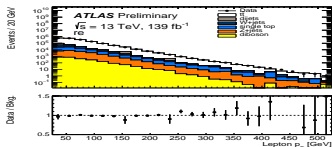
# MC sample

- **SM  $t\bar{t}$**   $\rightarrow$  largest background.
- **W+jets**
- **Multi-jets**
- **Single top, Z+jets, Diboson**

# Resolved top-antitop system reconstruction

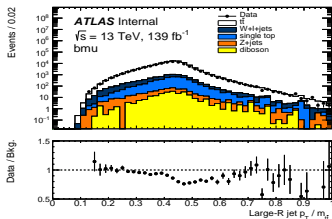
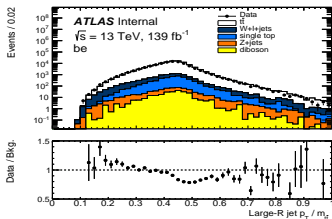
- Choose jets with minimum  $\chi^2$  for the  $t\bar{t}$  mass reconstruction.  
Parameters extracted from truth-matched events.

$$\chi^2 = \left(\frac{m_{jj} - m_W}{\sigma_W}\right)^2 + \left(\frac{m_{j\bar{j}b} - m_{jj} - m_{th-W}}{\sigma_{th-W}}\right)^2 + \left(\frac{m_{j\ell\nu} - m_{t\bar{t}}}{\sigma_{t\bar{t}}}\right)^2 + \left[\frac{(p_{T,j\bar{j}b} - p_{T,j\ell\nu} - (p_{T,th} - p_{T,t}))}{\sigma_{p_{T,th} - p_{T,t}}}\right]^2$$



# Boosted top-antitop system reconstruction

- Hadronic top Mass estimate from the large-R jet.



# Summary

- Searching for  $t\bar{t}$  resonances in the lepton plus jets decay channel has been carried out with the ATLAS experiment at the LHC, with a luminosity of  $139 \text{ fb}^{-1}$  and a center-of-mass energy of 13 TeV.
- Two ways for reconstructing the event: **resolved + boosted**.