Search for heavy 4th generation quarks in final states with same-sign charged dileptons at the ATLAS experiment

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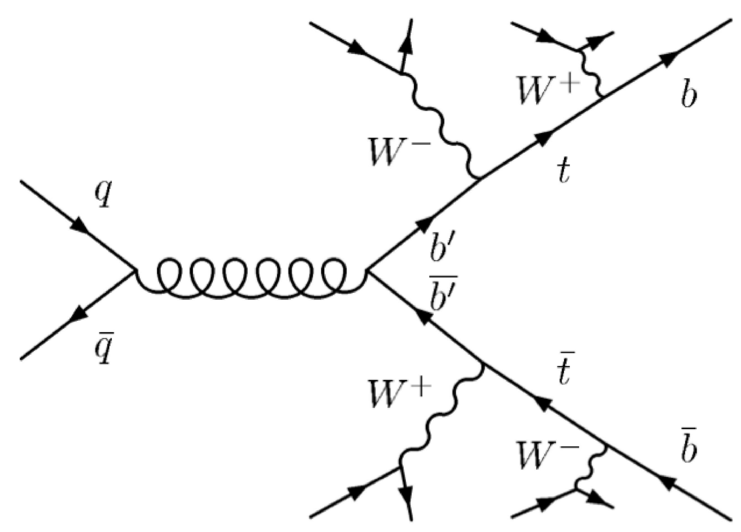
Motivation

The Standard Model (SM) of particle physics describes the elementary particles and their interactions. The fermions are grouped into families where three generations have been experimentally verified.
4th generation quarks could play an interesting role in electroweak symmetry breaking [1].
A SM with four generations has also the property to generate gauge coupling unification at a scale of order $10^{15} - 10^{16}$ GeV [2].There are also discussions in the literature if a fourth generation of quarks could play a central role in baryogenesis [3].
We look for $b'\bar{b}'$ pair production and assume the decay chain $b' \to tW \to bWW$ with a 100% branching fraction. This leads to final states with 4 W bosons (see graph below) and allows for selecting same-sign dilepton events which is a rare SM signature.

The recent discovery of a Higgs-like boson at $m = 126$ GeV excludes a sequential 4th generation with a significance of more than 5σ [4]. However, a 4th generation is still in accordance with experimental constraints when extending the Higgs sector [5]. Therefore, 4th generation searches are still of interest and the search topology with same-sign leptons is also relevant for exotic quarks searches.

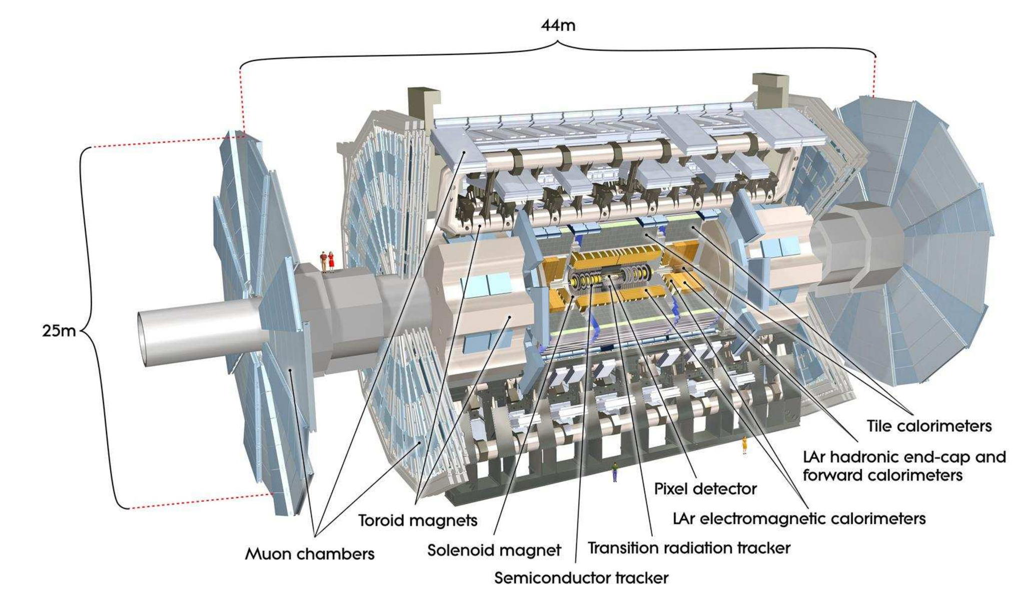


ATLAS experiment

Inner detector: Inside solenoid magnet, consists of silicon pixels, silicon strips and transition radiation tracker, provides reconstruction of charged particle tracks and vertices

Calorimeters: Electromagnetic (liquid Argon) and hadronic (iron + scintillating plastic) calorimeters, reconstruction of particle showers

Muon spectrometer: Resistive plate chambers, drift tube chambers within toroidal magnetic field



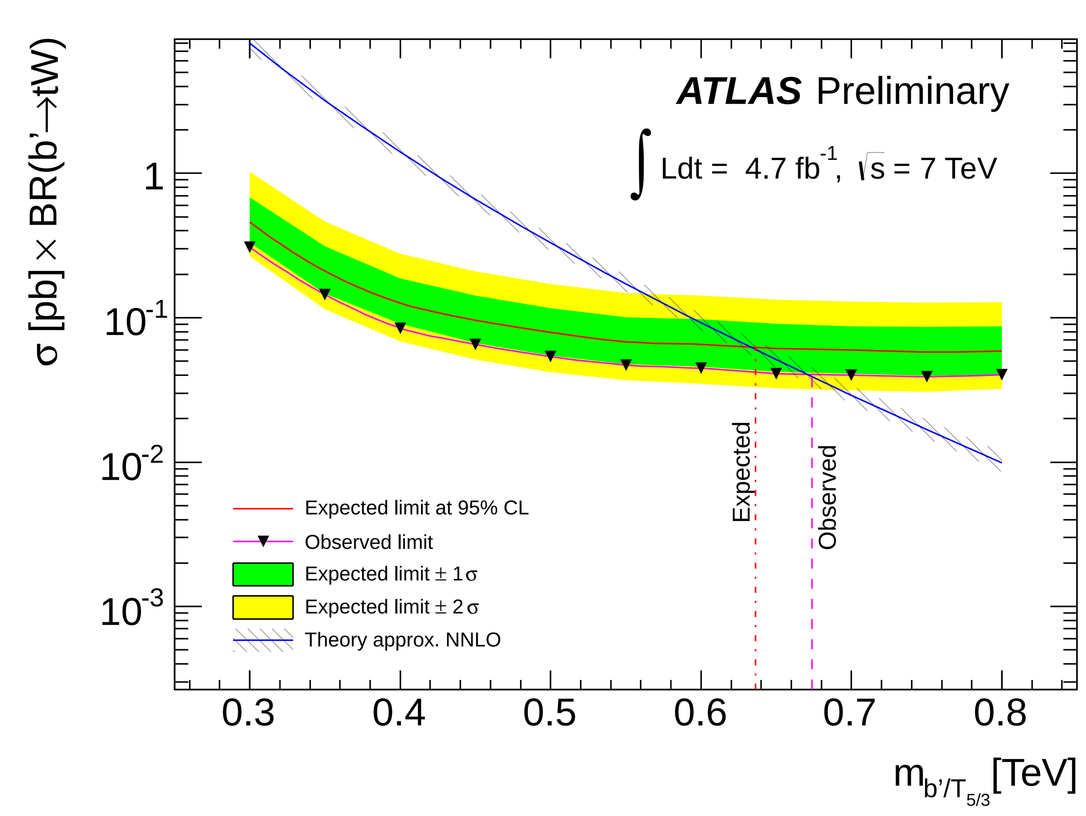
Recent Results (ATLAS-CONF-2012-130)

Our most recent result was published in 2012 as a conference note [6] using the full 2011 dataset ($\mathcal{L} \approx 4.7$ fb^{-1}) taken with ATLAS. This note contains searches of exotic signatures in final states with same-sign dileptons, namely the 4th generation b', the top partner $T_{5/3}$ and four tops production.

Selection:
There are several possible final states resulting from the production of these exotic states, but requiring at least two same-sign charged leptons is a good compromise between high branching ratio and low background. Additional requirements are at least two jets where at least one of them needs to be identified as a b-jet, large missing transverse energy $E_T^{Miss} \geq 40$ GeV and a large scalar sum of the jets and leptons transverse momenta $H_T \geq 550$ GeV.

Backgrounds:
Several background processes can contribute to the signal region of same-sign dileptons. On the one hand there are irreducible SM processes with real same-sign dileptons, namely $W^\pm Z$+jets, ZZ+jets, $W^\pm W^\pm$+2 jets, $t\bar{t} + W$+jets, $t\bar{t} + Z$+jets and $t\bar{t} + W^\pm W^\mp$. The contributions of these processes are estimated using simulated MC samples. On the other hand there are false same-sign dilepton pairs coming from charge mis-identification (ChargeMisid) and lepton mis-reconstruction (Fakes). The ChargeMisid comes from mis-reconstructed lepton charges and hard Bremsstrahlung producing trident electrons and is estimated by measuring the ChargeMisid rate within the Z-peak of di-electron events. The Fakes mainly come from hadron decays or photons mis-reconstructed as leptons and are estimated using the so called "matrix-method".

Result:
After the final event selection and comparing the data and background yields, no data excess has been observed. Therefore we have set limits on the production cross-section times branching ratio (here $b' \to tW$ with 100%) using the CL_S method, where we used the data and signal/BG estimates after simple cut and count as input. The right plot shows the expected and observed limits as a function of the b' mass. By comparing to the theoretical production cross-section we can set a limit on the b' mass of 0.67 TeV (expected: 0.64 TeV).



Expected and observed upper limits on the pair-production cross section of the b', as a function of its mass

Talks and posters

- DPG Frühjahrstagung, Karlsruhe, 03/2011: *Search for a signal of 4th generation quarks with ATLAS*
- ATLAS-D Meeting, Göttingen, 09/2011: *Search for a signal of 4th generation quarks*
- DPG Frühjahrstagung, Göttingen, 02/2012: *Search for a signal of 4th generation quarks with ATLAS*
- PLHC2012 Conference, Vancouver, 06/2012 (Poster): *4th generation searches at ATLAS*
- ATLAS-D Meeting, Wuppertal, 09/2012: *Search for exotic same-sign dilepton signatures*
- Helmholtz Alliance "Physics at the terascale" annual meeting, Hamburg, 12/2012: *Search for 4th generation quarks in same-sign dilepton final states with ATLAS*

Publications

- ATLAS Collaboration
"Inclusive search for same-sign dilepton signatures in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector", JHEP 1110 (2011) 107
- ATLAS Collaboration
"Search for same-sign top-quark production and fourth-generation down-type quarks in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector", JHEP 1204 (2012) 069
- ATLAS Collaboration
"Search for exotic same-sign dilepton signatures (b' quark, $T_{5/3}$ and four top quarks production) in 4.7 fb^{-1} of pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector", ATLAS-CONF-2012-130
- Dennis Wendland, on behalf of the ATLAS Collaboration
"4th generation searches at ATLAS", ATL-PHYS-PROC-2012-198

References

[1] B. Holdom, JHEP 0608 (2006) 076
[2] P. Hung, Phys. Rev. Lett. 80 (1998) 3000-3003
[3] W.-S. Hou, Chin. J. Phys. 47 (2009) 134
[4] O. Eberhardt et al., PRL 109, 241802 (2012)
[5] M. Chanowitz, arXiv:1212.3209
[6] ATLAS Collaboration, ATLAS-CONF-2012-130

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Profit from the GK

- Regular block courses
- Financial support for attending conferences (e.g. PLHC2012 in Vancouver, BC)

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