Master Thesis

Signal and background studies for scalar leptoquark pair production in the $\mathbf{t\bar{t} + 2\tau}$ channel at the ATLAS experiment

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XyZ

$2\,\mathrm{eV\,m^{-1}}$

sample	**$t\bar{t}$**		**$t\bar{t}H$**	
selection	reconstruction event yield	truth event yield	reconstruction event yield	truth event yield
≥ 2 b-jets	66878	252200	73	200
≥ 2 b-jets $+1\,\tau$	188	5923	2.5	28
≥ 2 b-jets $+2\,\tau$	0.7	49	0.2	8.2

Table 1.1: Event yield for different selections with tau leptons for the $t\bar{t}$ and the $t\bar{t}H$ Monte Carlo sample. The luminosity account for $36.1\,\mathrm{fb^{-1}}$.

sample	**$t\bar{t}$**	**$t\bar{t}H$**
selection	efficiency $\frac{\epsilon}{\%}$	efficiency $\frac{\epsilon}{\%}$
≥ 2 b-jets	26.52	36.72
≥ 2 b-jets $+1\,\tau$	3.18	8.83
≥ 2 b-jets $+2\,\tau$	1.41	2.13

Table 1.2: Efficiencies for different selections with tau leptons for the $t\bar{t}$ and the $t\bar{t}H$ Monte Carlo sample.

sample		$\mathbf{t\bar{t}}$		$\mathbf{t\bar{t}H}$	
selection	reference selection	reconstruction ratio $\frac{r}{\%}$	truth ratio $\frac{r}{\%}$	reconstruction ratio $\frac{r}{\%}$	truth ratio $\frac{r}{\%}$
≥ 2 b-jets $+1\,\tau$	≥ 2 b-jets	0.28	2.35	3.43	14.26
≥ 2 b-jets $+2\,\tau$	≥ 2 b-jets	0.0011	0.020	0.24	4.11

Table 1.3: Ratios for different selections with tau leptons for the $t\bar{t}$ and the $t\bar{t}H$ Monte Carlo sample.

sample	$\mathbf{t\bar{t}}$		$\mathbf{t\bar{t}H}$	
selection	numerator event yield	denominator event yield	numerator event yield	denominator event yield
truth matching for tau	63	13723	5590	21610
efficiency	0.46%		25.9%	
tau from H^0, $W^\pm$, Z^0	0	0	4859	11988
efficiency	-		40.5%	
tau from B-mesons	63	13722	20	7416
efficiency	0.46%		0.27%	
tau within a jet	8440	3776952	18511	20327225
efficiency	0.22%		0.091%	
tau within a b-jet	6098	2658379	2317	1208924
efficiency	0.23%		0.19%	

Table 1.4: Event yield for different selections with tau leptons for the $t\bar{t}$ and the $t\bar{t}H$ Monte Carlo sample. The luminosity account for $36.1\,\mathrm{fb}^{-1}$.

sample	$LQ_{500\,\mathrm{GeV}}$		$LQ_{1\,\mathrm{TeV}}$	
selection	numerator event yield	denominator event yield	numerator event yield	denominator event yield
truth matching for tau	2604	5362	2263	5055
efficiency	48.6%		44.8%	
tau from H^0, $W^{\pm}$, Z^0	95	340	82	461
efficiency	27.9%		17.8%	
tau from B-mesons	0	183	0	200
efficiency	0.0%		0.0%	
tau from LQ	1744	3286	1057	2022
efficiency	53.1%		52.3%	
tau within a jet	7232	55208	7011	63671
efficiency	13.1%		11.0%	
tau within a b-jet	2317	1208924	6098	2658379
efficiency	0.45%		0.23%	

Table 1.5

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Introduction

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Experimental setup for the search of scalar leptoquarks

For the search of scalar leptoquarks the ATLAS detector at the Large Hadron Collider (LHC) is used as experimental setup which will be described within this chapter. In section 3.1 the general setting of the proton-proton collider located at the CERN research center is the subject of interest. The particle detection of the resulting collision events will take place in the ATLAS detector with its different specialized components (section 3.2). Section 3.3 addresses the leptoquark pair production in proton-proton collisions.

3.1 The Large Hadron Collider

The research center CERN (Conseil Européen pour la Recherche Nucléaire) was founded in 1954 near Geneva to become a major European joint venture on elementary particle physics. In the mean time 22 member states are participating in that large-scale project with the ambition to probe the essential constitutes of nature and the fundamental forces acting between them. [1]

In the huge accelerator complex protons reach through different stages energies of 6.5 TeV and will be brought to collisions at defined interaction sites in time intervals of 25 ns. Particle detectors then register signatures of the resulting collsion events and the analysis of new created particles gives insight to the nature of elementary particle physics.
Figure 3.1 shows the different acceleration stages. Starting from the injection protons will gain as much energy as 50 MeV in the linear accelerator LINAC2 and will

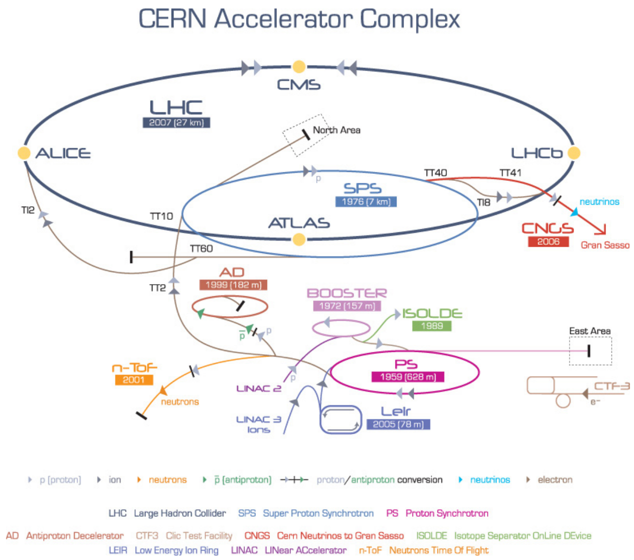

Figure 3.1: Schematic of the CERN accelerator complex with its different stages and few experiments like ATLAS located at a crossing point for protons. [2]

be further transferred to the Proton Synchrotron Booster (1.4 GeV), the Proton Synchrotron (25 GeV), the Super Proton Synchrotron (450 GeV) and finally to the LHC ring with its 26.7 km circumference. [1]
The LHC is designed as two-ring proton-proton collider. Conditions for a stable proton beam are diversely including high vacua of 10^{-10} mbar to 10^{-11} mbar and temperatures of 1.9 K for the superconducting NbTi-magnets of the accelerator. [3]

Different more experiments like ALICE[4], LHCb[5] are located at CERN due to the variety of research questions. But the subject of interest in this work lies in the high luminosity experiment ATLAS specialized for proton-proton collisions like its counterpart CMS[6].

3.2 The ATLAS detector at the LHC

3.3 Leptoquark pair production in proton-proton collisions

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