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Prospects for early discoveries of high mass resonances with the ATLAS experiment at the LHC

Clement HELSENS[∗†]
CEA - IRFU, Saclay
E-mail: clement.helsens@cern.ch

Many extensions of the Standard Model predict the existence of heavy resonances : grand unified theories, technicolor, extra dimensions. The discovery of a heavy resonance would open a new area in our understanding of elementary particles and their interactions. Heavy resonances are expected to appear around the TeV scale. With a center-of-mass energy of $\sqrt{s}$ = 14 TeV, the LHC will be able to search for resonances up to a mass of 5-6 TeV. To achieve the search for new heavy resonances, the ATLAS detector has been specially designed to reconstruct high p_T particles.

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∗Speaker.
†ATLAS Collaboration and ATLAS Saclay group.

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1. Motivation and current limits, ATLAS detector

Since the present limits on the Z' mass in various models are between 853 and 966 GeV from direct searches with p^+p^- colliders, the discovery of a heavy resonance is possible. The ATLAS experiment is one of the two general purpose particle detectors at the LHC. The efficiency and resolution of the sub-detectors have been determined using a Geant4 full simulation of the ATLAS detector and the event generator PYTHIA. With the first data we expect to correctly calibrate the detector and understand its performances. With the Z peak, we can obtain the performances of each sub-detector.

2. Reconstruction, Identification, Main systematic

Since background is expected to be low in high p_T dilepton pairs, we applied loose selection cuts in order to maximize the efficiency. A common event selection for both muons and electrons is: $\mid \eta \mid < 2.5$ (to be in the Inner Detector (ID) geometrical acceptance) and a lepton associated with a track in the ID. In addition, we make the following requirements. **For muons** we require $p_T > 30$ GeV and a good matching of the trajectory sections reconstructed in ID and MS. **For electrons,** the loose cuts maximizes the efficiency and the rejection of highly energetic pions and we requiere hadronic leakage and shower shape cuts. The medium cuts optimize pions rejection and require tighter criteria on the ID track quality. In the **muon spectrometer**, muon tracks are bent by the toroidal magnetic field, and the momentum is estimated from the track curvature. The design resolution of a 1 TeV muon is $\frac{\delta p_T}{p_T} = 10\%$ and increase with p_T. For electrons the energy resolution decrease with energy ($\sigma E/E = 10\%/\sqrt{E} \oplus 0.7\%$). In the dimuon channel, the alignment of the MS is the main detector effect. For dielectron, calibration and hadronic leakage are the main systematics.

3. Trigger, Event selection, Background

The goal of the trigger is to reduce the rate of events flowing through the data acquisition while maintaining a highly efficient selection for rare signal processes. For the dimuon channel, we used a single muon trigger: 1 muon with $p_T > 20$ GeV (95% efficiency). For the dielectron channel, different triggers have been proposed. The two most efficient ones were kept for dileptons analysis: 1 electron with $p_T > 60$ GeV (91% efficiency); 1 isolated electron with $p_T > 25$ GeV (80% efficiency). The Drell-Yan (DY) process constitutes an irreducible background in the search for new heavy resonances. It is by far the largest source of background. With basics selection requirements, all the other background (dijets, $t\bar{t}$, dibosons ...) are one to two order of magnitude below the DY. With 100 pb^{-1} of data, we expect to have for a 1 TeV Z'_χ after all the selection cuts, 24 events of signal ($\pm$ 50 GeV around the resonance peak), 10 of DY ($M_{\mu^+\mu^-} > 800$ GeV) for muons and 17 events of signal and 1.7 for DY ($\pm$ 4 Γ around the resonance peak $\sim$ 52 GeV) for electrons.

4. Signal extraction, Significance Results with early data

For both muons and electrons, the signal has been extracted using a parameterized fit approach (shape analysis). To separate the signal from the background, the data is fitted compared to two models: background only model and signal+background. The systematics have been treated as nuisance parameters. A log likelihood ratio has been used. For this analysis, we used a LEP Confidence Level [2] (C.L.): 1-CL$_b$ is the C.L. used for the exclusion of the null hypothesis. For the C.L. calculation we found a practical way to avoid producing large numbers of pseudo-experiments. We used an numerical method with Fourier transform [3].

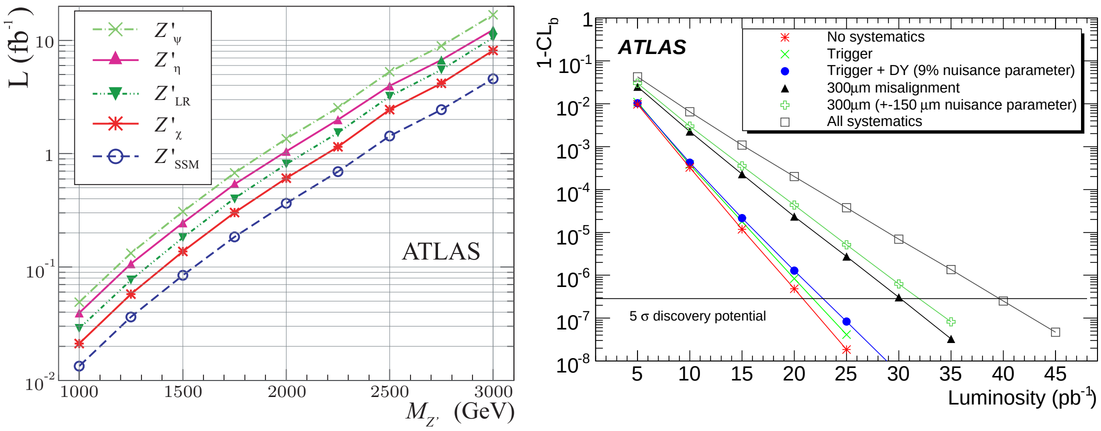

Figure 1: Figure on the left shows the required luminosity to reach 5 σ significance in the dielectron channel as a function of the mass for various Z' models. Figure on the left shows 1-CL$_b$ as a function of the luminosity for a 1 TeV Z'_χ. Considering all the systematics, a 1 TeV Z'_χ can be discovered in the dielectron channel with 20 pb^{-1} and in the dimuon channel with less than 30 pb^{-1} depending on alignment precision.

For heavy resonances ($>$ 2 TeV), the dielectron channel has a better mass resolution than muons, but the charge is better idetified with muons. The discovery could be achieve with electrons and the resonance identification with muons.

5. Conclusion

Early data will be used to gain an extensive understanding of the detector performance and its effect on the SM background. With only a few pb^{-1} of data, a 5 σ discovery particles is reasonably attainable in ATLAS in the first year of LHC running.

References

[1] ATLAS Collaboration, Expected Performance of the ATLAS Experiment, High Mass Dilepton section, Detector, Trigger and Physics, CERN-OPEN-2008-020, Geneva, 2008, to appear.

[2] Sensitivity, Exclusion and Discovery with Small Signals, Large Backgrounds, and Large Systematic Uncertainties. ***Tom Junk*** *University of Illinois at Urbana-Champaign*

[3] Analytic Confidence Level Calculations using the Likelihood Ratio and Fourier Transform. ***Hongbo Hu and Jason Nielsen*** *University of Wisconsin-Madison*