Extra Gauge Bosons - Search for Z' at ATLAS

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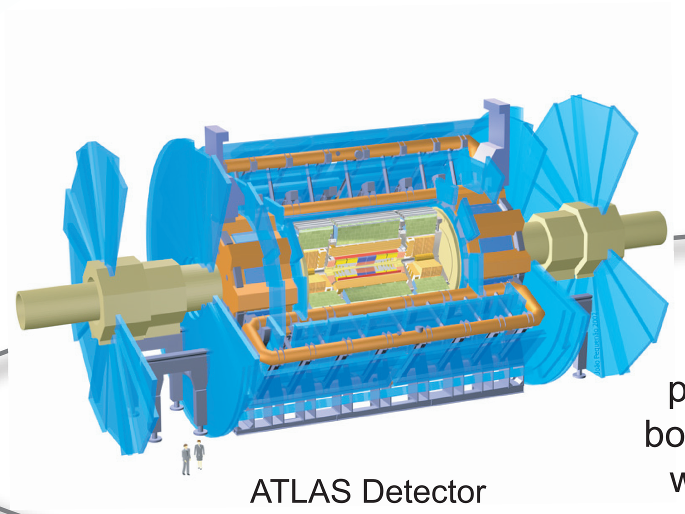
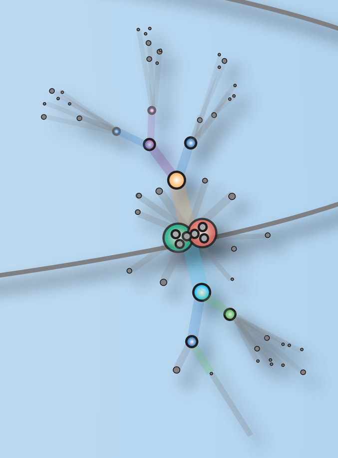
On behalf of the ATLAS Exotics Group



LHC

Within the next few years the ATLAS detector will be ready for the first series of physic runs. In this light an update on Z' physics will be presented which will summarise the possibilities of Z' detection at both low and design luminosity. The first effort will be to investigate the Z' boson characteristics and to evaluate the discrimination possibilities between the various Z' models. Here we present Atlfast simulations of Z' decay to leptons, as well as a first discussion of full simulation results. The possibilities to study forward-backward asymmetries and Z' parameters (decay width, cross-section), both off- and on-peak resonance will be treated.

Physics Process

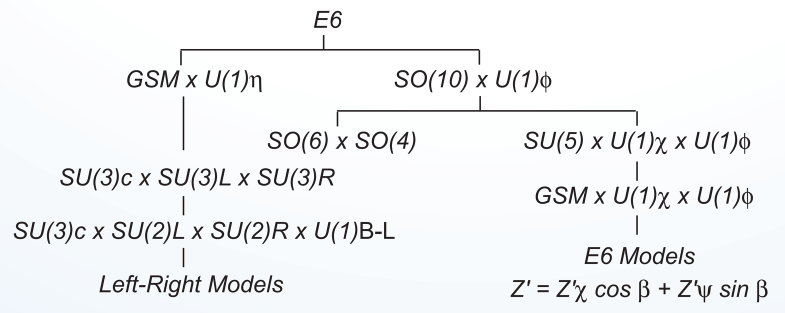


-7 TeV proton

7 TeV proton

Existence of Extra Neutral Gauge Bosons

Grand Unified Theories aims to explain the physics present at energies higher than the SM range. Many of the GUT theories (supersymmetry, superstring, left-right symmetric models) predict the existence of a heavy neutral gauge bosons.

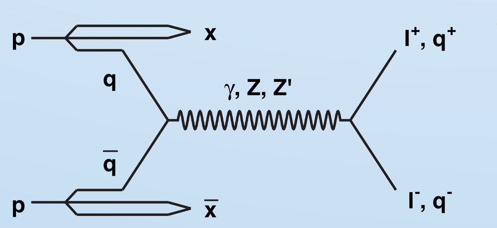


The following Z' models have been studied by ATLAS. SSM (Sequential Standard Model) assumes the Z' to be identical with Z_0 just with higher mass and is used as a reference model:

E6 models:	*Other models:*
$\chi \to \beta = 0$	LR models
$\Psi \to \beta = \pi/2$	Kaluza-Klein
$\eta \to \beta = -\arctan(5/3)^{1/2}$	SSM

Z' - Production channels

Z' are produced by the quark antiquark fusion (1) and detected by their decay to pairs of leptons (Drell-Yan process). Other possible decay modes for new neutral gauge bosons are decays to dijets, pairs of SM bosons and leptonic W^+ decay modes (rare decay (2) or associate production (3)). In this study we have looked at (1) only.



1) $q\bar{q} \to \gamma, Z^0, Z' \to l^+l^-$

2) $q\bar{q} \to Z' \to f_1 \bar{f}_2 V_{Z,W}$

3) $q\bar{q} \to Z' V_{Z,W}, Z' \to l^+l^-$

The couplings of Z' to leptons are given by the following two formulas, where the first shows the couplings for the E6 models and the second for the Left-Right models:

$$g_{Z'} J^{\mu}_{Z'} Z'_{\mu} = \frac{e}{c_W} \sum_f \gamma^{\mu} \left[\frac{1-\gamma_5}{2} g_L^{fZ'} + \frac{1+\gamma_5}{2} g_R^{fZ'} \right]$$

$$J^{\mu}_{LR} = \alpha_{LR} J^{\mu}_{3R} - (1 \lhd 2\alpha_{LR}) J^{\mu}_{B-L} \quad \text{with} \quad \alpha_{LR} = \sqrt{(c_W^2 g_R^2 \lhd s_W^2 g_L^2) - 1}$$

	E6		LR	
Couplings	a'f	v'f	a'f	v'f
v	$\frac{3cos\beta}{\sqrt{40}} + \frac{sin\beta}{\sqrt{24}}$	$\frac{3cos\beta}{\sqrt{40}} + \frac{sin\beta}{\sqrt{24}}$	$\frac{1}{2\alpha}$	$\frac{1}{2\alpha}$
e	$\frac{cos\beta}{\sqrt{10}} + \frac{sin\beta}{\sqrt{6}}$	$\frac{2cos\beta}{\sqrt{10}}$	$\frac{\alpha}{2}$	$\frac{1}{\alpha} - \frac{\alpha}{2}$
u	$-\frac{cos\beta}{\sqrt{10}} + \frac{sin\beta}{\sqrt{6}}$	0	$-\frac{\alpha}{2}$	$-\frac{1}{3\alpha} + \frac{\alpha}{2}$
d	$\frac{cos\beta}{\sqrt{10}} + \frac{sin\beta}{\sqrt{6}}$	$\frac{2cos\beta}{\sqrt{10}}$	$-\frac{1}{3\alpha} - \frac{\alpha}{2}$	

Table 1: Vector and Axial vector couplings of Z' [4]

Simulation Tools and Criterias

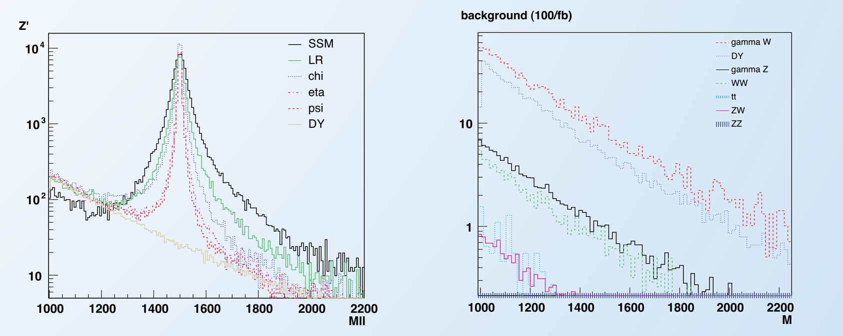
Fast simulation is performed using Pythia 6224.f and ROOT 3.10, full Simulation is based on GEANT3 detector simulation. The trigger conditions depends on the beam luminosity:

Luminosity:	*low: $2x10^{33}$ $cm^{-2}s^{-1}$*	*design: 10^{34} $cm^{-2}s^{-1}$*	
electrons:	e25i, 2e15i	e30i, 2e20i	$\lvert\eta\rvert < 2.5$
muons:	μ20i, 2μ10	μ20i, 2μ10	$\lvert\eta\rvert < 2.$

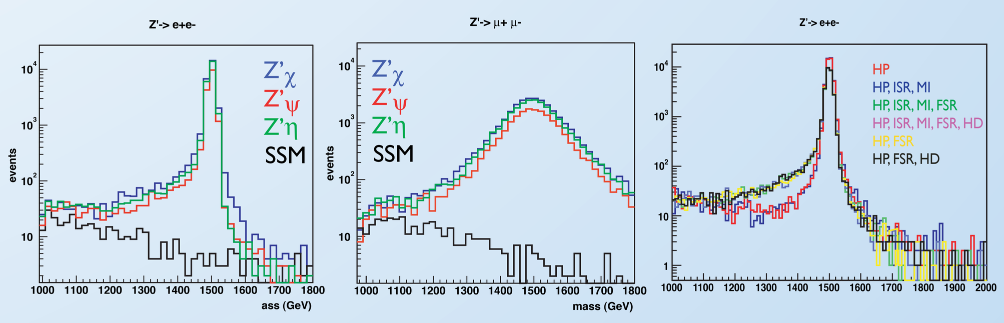
2e25i: two isolated electrons with Et > 25 GeV

Z' Reach - Signal and Background

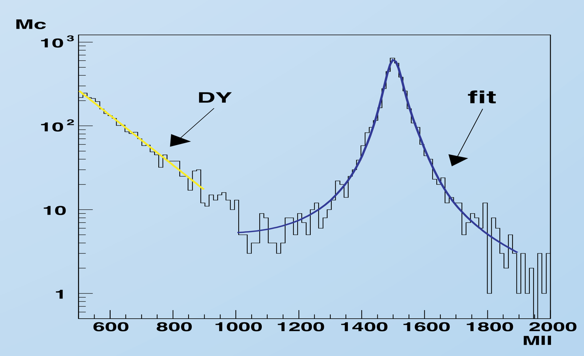
The main Standard Model process contributing to the background, and interfering with the signal is Drell-Yan production via an intermediate γ and Z^0. Other possible, but negligible background sources are leptons from γW, γZ, ZZ, ZW, WW and tt production.



Generation level (Pythia): Left hand plot shows Z'-> e+e- at a mass of mass 1.5 TeV for different models. Right hand plot shows the corresponding background @ 100 fb^{-1}.



Atlfast simulation: Z' mass at 1.5 TeV @ 100 fb^{-1}. The left plot shows Z' –> e+e-, the middle plot shows Z' –> μ+μ–, and the right picture shows the influence of Final State Radiation (FSR), and the Initial State Radiation (ISR) and Hadronisation (HD). HP stands for the Hard Process and MI for Multiple Interaction.



Full Simulation: Z'–> e+e- for a Z' mass at 1.5 TeV @ 100 fb^{-1}

Cross section

The cross section for Z' is given by the following formula:

$$\frac{d\hat{\sigma}}{d\cos\theta^*}(q\bar{q} \to \gamma, Z, Z' \to \ell^+\ell^-) = \frac{1}{9}\frac{\pi\alpha^2}{2\hat{s}}\left[(1+\cos^2\theta^*)Q_1 + 2\cos\theta^* Q_3\right]$$

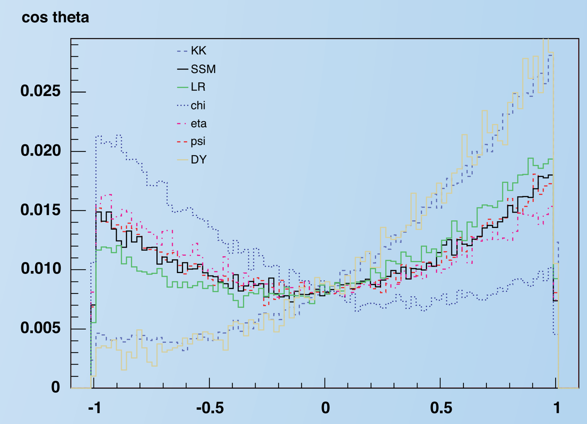
where Q's are charges defined in terms of helicity amplitudes and θ* the angle between the lepton direction and the quark direction in the Z' centre of mass frame.

Model Discrimination using Asymmetry

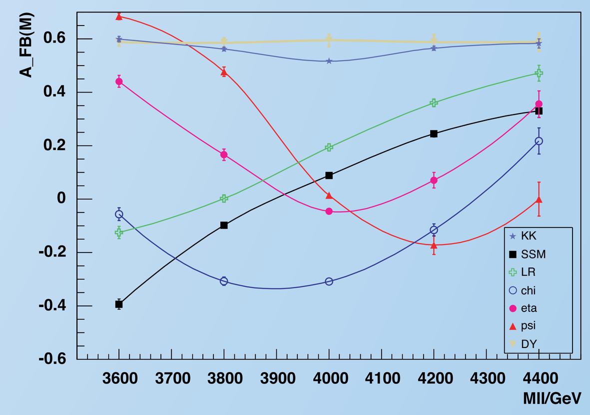
Models differ by the coupling constants which affect the decay width of Z' and result in a Forward-Backward asymmetry in the angular distribution of θ*. The asymmetry ($A^l{}_{FB}$) is given by the following formula:

$$d\sigma/d\cos\theta^* \propto 3/8\,(1+\cos^2\theta^*) + A^l{}_{FB} \cos\theta^*$$

Both the decay width and the asymmetry permit to distinguish between models. According to [3] the off-Peak analysis is a valuable tool to detect Z'. When comparing the number of positive θ* with the number of negative θ* for the on-peak mass as well as for masses off peak the models show differences which will be measurable in the ATLAS detector.



Example of forward-backward asymmetry for different Z' models at a mass of 1.5 TeV - generation level.



Forward Backward asymmetry for the off-peak region for different models. Z' mass at 4 TeV- *generation level.*

Z' - Reach in ATLAS (preliminary)

Direct searches from Tevatron show a lower limit of 690 GeV (CDF) or 670 GeV (D0). Indirect measurements from LEP derived from electroweak fits, is of around 1 TeV. If a Z' is lighter than 1 TeV, it should be detected at the Tevatron (Run II).

Based on fast and full simulation studies, it will be possible to observe Z' decaying to electrons up to 5 TeV if SM couplings apply, with an integrated luminosity of 100 fb^{-1}. In the case of muon decay the mass reach is ~4 TeV.

Conclusion

The simple and clean signal will allow the search of a heavy neutral gauge boson to be efficiently performed, even in early ATLAS data acquisition runs. It will also be possible to distinguish between models by examining the width and amplitude of the resonance and the forward-backward asymmetry both on- and off-peak.

Acknowledgements

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References

[1] ATLAS High-Level Trigger Data Acquisition and Controls, CERN/LHCC/2003-022, June 2003

[2] Neutral current interference in the TeV region: The experimental sensitivity at the CERN LHC
Michael Dittmar,
Phys.Rev. D, Vol 55, 1997

[3] Z' studies at the LHC: an update,
M. Dittmar, A. Nicollerat, A. Djouadi,
ETHZ-IPP PR-2003-01

[4] The Phenomenology of Extra Neutral Gauge Bosons
A. Leike
Phys. Reports 317, 143-250, 1999

[5] Discovery and Identification of Extra Gauge Bosons
M. Cvetic and S. Godfrey
hep-ph/9504216, 1995

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