3. On *P*-noninvariant wave equation for spin 1/2 particle with anomalous magnetic moment, interaction with external fields / V.V. Kisel, V.A. Pletyukhov, E.M. Ovsiyuk, V.M. Red'kov.

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FIRST RESULTS ON PRECISION CONSTRAINTS ON CHARGED BOSON MIXING FROM DIBOSON PRODUCTION SEARCHES WITH ATLAS AT LHC AT 13 TEV

Introduction

Many new physics (NP) scenarios beyond the Standard Model (SM) [1], including superstring and left-right-symmetric models, predict the existence of new neutral and charged gauge bosons, which might be light enough to be accessible at current and/or future colliders [2]. The search for these new neutral Z' and charged W' gauge bosons is an important aspect of the experimental physics program of high-energy colliders. In this note we concentrate on the latter one while the former one has been studied recently in [3]. A W' boson, if lighter than about 5 TeV, could be discovered at the LHC with 13 TeV in dilepton process $pp \to W' \to \nu\, l + X$ ($l = e, \mu$).

After the discovery of W' boson at the LHC via the dilepton process, some diagnostics of its couplings and W-W' mixing needs to be performed in order to identify the underlying theoretical framework. In this paper we investigate the implications of the ATLAS data [4] in the diboson production channel

$$pp \to W' \to WZ + X \qquad (1)$$

to probe the W' boson that arises, e.g. in a popular model with extended gauge sector proposed in [5] and called as Sequential Standard Model (SSM). The presented analysis is based on pp collision data at a center-of-mass energy 13 TeV, collected by the ATLAS (36.1 fb^{-1}) experiment at the LHC. In particular, the data is used to probe the W-W'mixing.

1. Resonant production cross section

In many extended gauge models, while the couplings to fermions are not much different from those of the SM, the W'WZ coupling is substantially suppressed with respect to that of the SM. In fact, in the SSM the W-W' mixing factor ξ can be written as $\xi = C \cdot (M_W / W_{W'})^2$ where C the coupling strength scaling factor. We will set cross section limits on such W' as a function of the mass $M_{W'}$ and ξ.

The cross section for the narrow W' state production and subsequent decay into a WZ pair needed in order to estimate the expected number of W' events can be written as

$$\sigma^{W'}(pp \to W\,Z + X) = \int dM \int dy \int dz \, \frac{d\sigma^{W'}}{dMdydz}, \quad (2)$$

where integration has been done over the relevant fiducial phase space. The number of signal (W') events for a narrow W' resonance state can be written as follows

$$N^{W'} = L \cdot \varepsilon \cdot \sigma^{W'}(pp \to WZ + X) \equiv L \cdot \varepsilon \cdot A_{WZ} \cdot \sigma(pp \to W') \times Br(W' \to WZ). \quad (3)$$

Here, L denotes the integrated luminosity, and the overall kinematic and geometric acceptance times trigger, reconstruction and selection efficiencies, $\varepsilon \cdot A_{WZ}$, is defined as the number of signal events passing the full event selection divided by the number of generated events. Finally, $\sigma(pp \to W') \times Br(W' \to WZ)$ is the (theoretical) total production cross section times branching ratio extrapolated to the total phase space. In the calculation of the total width $\Gamma_{W'}$ we included the following SM final states: $W' \to \nu\, l, q\, q', W\, Z$. For the large W' masses there is an enhancement that cancels the suppression due to tiny W-W' mixing parameter ξ as can be seen from the expression for the partial width of decay channel $W' \to W\,Z$ [5]:

$$\Gamma_{W'}^{WZ} = \frac{\alpha}{48} \cot^2\theta_W M_{W'} \frac{M_{W'}^4}{M_Z^2 M_W^2} \left[\left(1 - \frac{M_Z^2 - M_W^2}{M_{W'}^2} \right)^2 - 4 \frac{M_W^2}{M_{W'}^2} \right]^{3/2} \left[1 + 10 \left(\frac{M_W^2 + M_Z^2}{M_{W'}^2} \right) + \frac{M_W^4 + M_Z^4 + 10 M_W^2 M_Z^2}{M_{W'}^4} \right]$$

For a fixed mixing factor ξ and at large $M_{W'}$ where $\Gamma_{W'}^{ZW}$ dominates over contribution induced by the fermion channels, the total width increases very rapidly with the mass $M_{W'}$ because of the quintic dependence on the W' mass. In this case, the WZ mode becomes dominant and $Br(W' \to WZ) \to 1$, while the fermionic decay channels are increasingly suppressed as demonstrated in Figure 1.

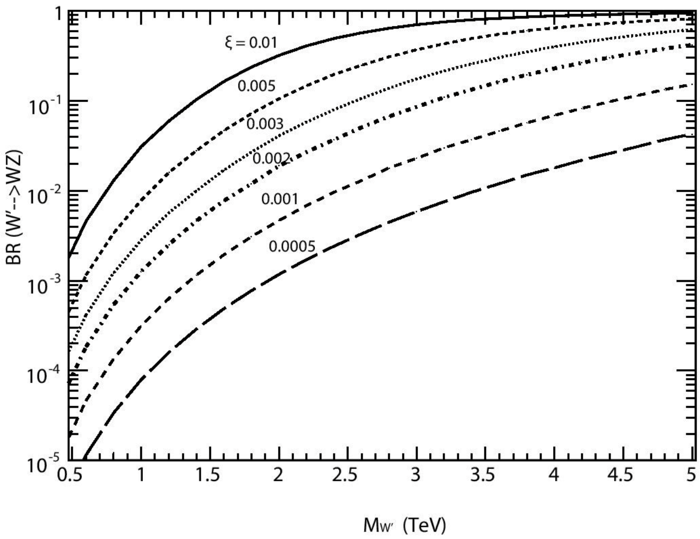

Figure 1 – Branching fraction $Br(W'\to W\,Z)$ vs $M_{W'}$ for SSM. Labels attached to the curves correspond to an array of values of mixing factor ξ ranging over the set {0,0005, 0,001, 0,002, 0,003, 0,005, 0,01}

Further contributions of decays involving Higgs and/or gauge bosons and supersymmetric partners (including sfermions), which are not accounted for $\Gamma_{W'}$, could increase $\Gamma_{W'}$ by a model-dependent amount, as large as 50% .

2. Numerical analysis and concluding remarks

Here, we are making an analysis, employing the most recent measurements of diboson processes provided by the experimental collaboration ATLAS. In particular, for W' we compute the LHC W' production cross-section multiplied by the branching ratio into WZ bosons, $\sigma(pp\to W')\times Br(W'\to WZ)$ as a function of two parameters $(M_{W'},\xi)$, and compare it with the limits established by the ATLAS experiment [4] analyzed the WZ production in process (1) through the semileptonic and hadronic final states. Figure 2 shows the observed and expected 95% C.L. upper limits on the production cross section times the branching fraction for $W'\to W\,Z$ as a function of W' mass. The data analyzed comprises pp collisions at 13 TeV, recorded by the ATLAS (36.1 fb^{-1}) detector at the LHC [4]. Also shown are theoretical production cross sections, $\sigma(pp\to W')\times Br(W'\to WZ)$, for W', calculated from PYTHIA 6.409 adapted for such kind of analysis.

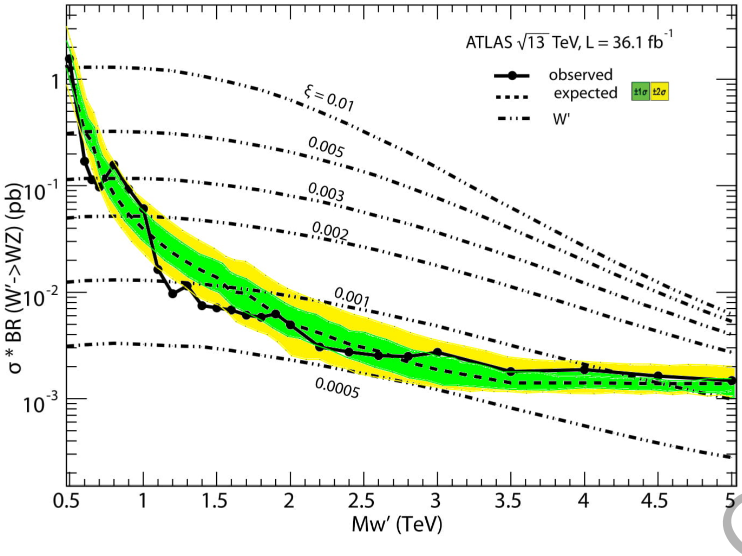

Figure 2 – Observed and expected 95% C.L. upper limits on the production cross section times the branching fraction for $W' \to WZ$ as a function of W' mass. Theoretical production cross sections $\sigma(pp \to W') \times Br(W' \to WZ)$ are calculated from PYTHIA 6,409, and given by dash-dotted curves

Higher-order QCD corrections for the SM and W' boson cases were estimated using a K-factor. The intersection points of the expected (and observed) upper limits on the production cross section with these theoretical cross sections for various ξ give the corresponding lower bounds on $(M_{W'}, \xi)$ displayed in Figure 3.

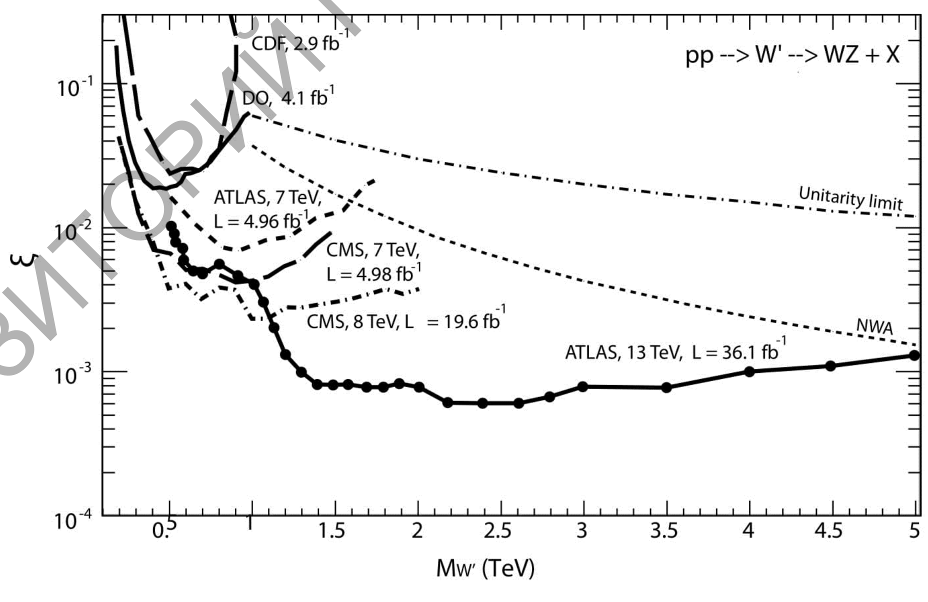

Figure 3 – W' exclusion regions in the two-dimensional plane of $(M_{W'}, \xi)$ obtained from CDF and D0 collaborations at Tevatron and LHC data at different energies and luminosities.
Also, unitarity and narrow width approximation (NWA) constraints are displayed

In Figure 3, we collect limits on the W’ parameters, starting with the Tevatron studies of diboson WZ pair production. Interestingly, Figure 3 shows that at heavy W’ masses, the limits on ξ obtained from the ATLAS diboson resonance production data at the LHC at 13 TeV are much stronger than those derived from the global analysis of the precision electroweak data which yields $|\xi|<0.01$.

In conclusion, the current paper presents an analysis of W-W’ mixing in the process of WZ production. The analysis is based on pp collision data at a centre-of-mass energy of 13 TeV, collected by the ATLAS experiment at the LHC.

We analyze the popular SSM model and determine limits on its mass of W’ as well as on the W-W' mixing (angle) factor ξ. We present the W’ exclusion region in the ($M_{W'}, \xi$) plane for the first time by using these data. The exclusion limits represent a large improvement over previously published results obtained at the Tevatron, and also over precision electroweak data as well as results obtained from proton-proton collisions at the LHC at 7 TeV and 8 TeV. These are the most stringent exclusion limits to date on the ($M_{W'}, \xi$) plane. Further improvement on the constraining of this mixing can be achieved from the analysis of data which will be collected at higher luminosity at Run III and HL-LHC options.

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