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Using W-charge asymmetry to measure W-production

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Summary. — The W-boson production at the LHC results in an excess of positive over negative lepton candidates. In the framework of the top pair cross section measurement at the ATLAS experiment with $35\,\text{pb}^{-1}$, a new data-driven method based on this charge asymmetry has been implemented to estimate the W-production in association with jets. An overview of the asymmetry is initially presented and the data-driven method is then explained in details. The W-charge asymmetry technique results in a good evaluation of the W-production but suffers from a high statistical uncertainty, which can be reduced when the LHC collects more data.

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1. – Introduction

The W-boson production at proton-proton colliders (such as the LHC) is charge asymmetric due to the different PDFs of the u-quark and d-quark in protons. The charge asymmetry ratio r can be defined as:

$$r \equiv \frac{\sigma(pp \to W^+)}{\sigma(pp \to W^-)}\,. \tag{1}$$

The W-charge asymmetry can be used to calculate the W-boson production at the LHC, with satisfactory accuracy, in the context of the exclusive W+jets cross section measurement or for studing it as a background process to other signals. In any analysis which looks for leptons in the final state, one can thus count the number of selected events that contain positively (D^+) and negatively (D^-) charged leptons, and measure the total number of expected $W^\pm$ ($N_{W^\pm}$) with the following formula:

$$N_{W^+} + N_{W^-} = \frac{r_{MC}+1}{r_{MC}-1}(D^+ - D^-)_{DATA}, \tag{2}$$

where r_{MC} is the rate in eq. (1) computed by means of Monte Carlo (MC) programs. This is a versatile method that can be applied with any set of cuts, and remains accurate as long as all the other background processes are charge symmetric (or the asymmetry is small with respect to the one under study).

Table I. – *Estimated number of W+jet events using W-charge asymmetry and W/Z methods for $\mathcal{L} = 35\,\mathrm{pb}^{-1}$ and $\sqrt{s} = 7\,\mathrm{TeV}$ and their associated statistical error. Uncertainties are mainly due to the Jet Energy Scale (JES), Parton Density Functions (PDF) and MC generators.*

	W^+/W^- (electron)	W^+/W^- (muon)	W/Z (electron)	W/Z (muon)
JES (%)	3.6	3.6		
PDF (%)	6.3	6.2		
MC generator (%)	5.3	3.2		
Total systematics (%)	9.0	7.8	12.3	10.4
Statistical (%)	33.2	27.0	21.0	17.0
Total W+jets bkg	240 ± 80	380 ± 110	160 ± 40	310 ± 60

2. – W+jets background estimation for the $t\bar{t}$ cross section measurement

The W-charge asymmetry method described above has been used to estimate the W+jets background contribution to the $t\bar{t}$ cross section measurement at the ATLAS experiment, in the single lepton plus jets channel. The simplest analysis for the $t\bar{t}$ cross section measurement is a cut and count method which does not use b-tagging. The cross section can be defined as:

$$\sigma_{t\bar{t}} = \frac{N_{sig}}{\mathcal{L} \times \epsilon} = \frac{N_{obs} - N_{bkg}}{\mathcal{L} \times \epsilon}, \tag{3}$$

where N_{obs} and N_{bkg} are the number of events which survive the selections observed from data and estimated by data-driven techniques or MC, $\mathcal{L}$ is the integrated luminosity and ϵ the selection efficiency. The main process which contributes to N_{bkg} is the W+jets production, which can be estimated using the ratio r_{MC} known from MC and eq. (2). Table I lists the obtained results for an integrated luminosity of $35\,\mathrm{pb}^{-1}$ and a center of mass energy $\sqrt{s} = 7\,\mathrm{TeV}$, with the associated uncertainties. Here a different method based on the W/Z ratio is shown for comparison [1]. As one can observe, the W-charge asymmetry method results in a better systematics uncertainty but also in a higher statistical error. Having chosen the right method to apply for the W+jets background estimate, the $t\bar{t}$ cross section can thus be measured using eq. (3). With the simple counting analysis this gives $\sigma_{t\bar{t}} = 154 \pm 11(\mathrm{stat.})^{+48}_{-43}(\mathrm{syst.}) \pm 5(\mathrm{lumi})\,\mathrm{pb}$ [1].

3. – Conclusions

The W-charge asymmetry method is a powerful data-driven technique to estimate the W+jets background process for the $t\bar{t}$ cross section measurement, but it suffers from a high statistical error. For this reason, at the final stage, the method based on the W/Z ratio has been preferred in order to measure $\sigma_{t\bar{t}}$. But with a larger integrated luminosity (starting with $350\,\mathrm{pb}^{-1}$) the statistical error of the two methods becomes comparable, and the W-charge asymmetry technique, having a smaller systematics uncertainty, results in a precise measurement of the W+jets production at the LHC.

REFERENCES

[1] The ATLAS Collaboration, ATLAS-CONF-2011-023.