

Measurement of W and Z properties at the Tevatron

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The very large sample of proton-antiproton data collected at the Tevatron at $\sqrt{s} = 1.96$ TeV, allows the two full purpose experiment CDF and D0 to study in detail the properties of W and Z bosons and to exploit them to study high-energy interactions.

The very large samples of vector bosons allow also accurate measurement of S.M. parameters which help constrain models of new physics. Last but not least, the W mass, related to the EWSB sector, can help in the long lasting search for the Higgs particle.

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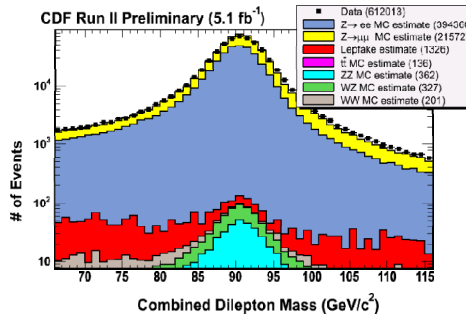


Figure 1: Invariant mass of dilepton pairs, CDF results in 5 fb^{-1} .

1. Introduction

The Tevatron Collider is successfully providing the two experiments CDF and D0 with a wealth of data in $p\bar{p}$ -collisions. At this time the typical initial instantaneous luminosity is in excess of $3.5 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$, with record above $4 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$. Since the start of Run II, the delivered luminosity as reached 9 fb^{-1} , with more than 7 stored to tape. The results discussed here use a range of acquired luminosity between 3 and 5 fb^{-1} .

The yield of W and Z decaying into leptonic channels is in the nb and fraction of nb region, therefore each of the two experiments has already collected more than 600K Z 's decaying in either e or μ channel (see Fig. 1), and ten times more W 's. In Fig. 1 we show the dilepton sample collected by CDF, it is note the little background. Those large samples allow the detailed study of the production of gauge bosons, providing helpful insights on the properties of the bosons themselves as well as on the parton distributions of the incoming hadrons.

2. Parton Distribution Functions

One of the most traditional ways to measure p.d.f. in hadron collisions is through measurement of charge asymmetry in W boson decays. Positrons (electrons) tend to remember the original $W^{+(-)}$ direction and therefore, despite the missing neutrino P_z constitutes an estimator of their direction which is, in turn, related to the valence quark distribution in protons and pbars. The very large data set provides the possibility to measure A_W in differential lepton E_T bins. Recent studies have shown some inconsistencies with recent p.d.f. fits [1]. CDF and D0 data agree with each other and MC@NLO Monte Carlo describe their distribution better than RESBOS (see Fig. 2).

A less traditional way to constrain p.d.f. is by measuring $d\sigma(Z)/dy$ distribution in $Z \rightarrow ee$ events. Thanks to the large statistics, this direct measurement of Z rapidity allows a comparison with p.d.f. over a large rapidity range (see Fig. 3).

Recent p.d.f., which includes Tevatron results, show a good agreement over the whole range. While HERA results on F_2 constrain u quark valence distribution, new CDF result constrains the d valence quark at large x [2].

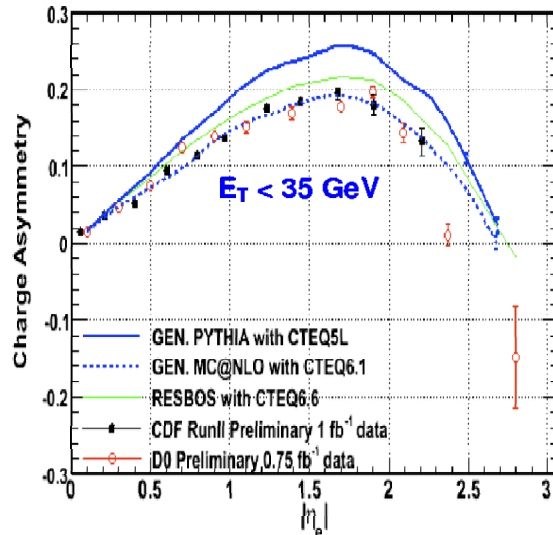


Figure 2: W asymmetry, D0 and CDF results compared with different MCs.

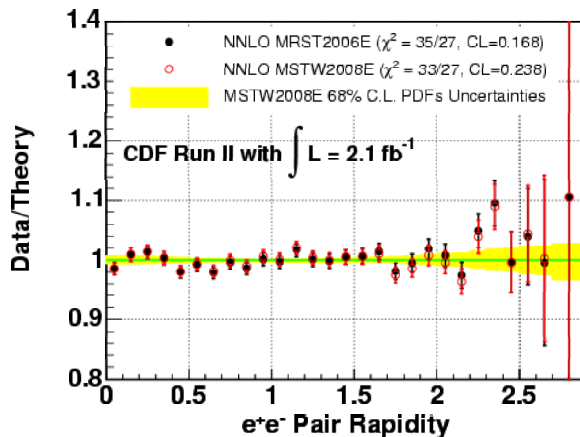


Figure 3: CDF data. $d\sigma/dy$ for $Z \rightarrow ee$ compared to NNLO predictions.

3. Precision Measurements and Hints of New Physics

It is well known that precision measurements of SM parameters can be used to look for hints/signal of new physics. This path was extensively exploited at LEP to set a number of important limits on many scenarios of new physics. The very large sample of vector bosons collected at the Tevatron, and the deep understanding of the detector behavior, allows CDF to set very interesting limits. We studied Drell-Yan dielectron pairs in the region $|\eta| < 2.8$ in 4.1 fb^{-1} selecting a total of approximately 200K events with $50 < M_{ee} < 600 \text{ GeV}/c^2$ with very little background contamination.

The forward-backward asymmetry in Z events is sensitive to the couplings to quark and leptons and could also signal the existence of a sequential Z' . In order to measure the true A_{FB} from the measured one, we developed a response matrix as a function of the reconstructed dielectron mass.

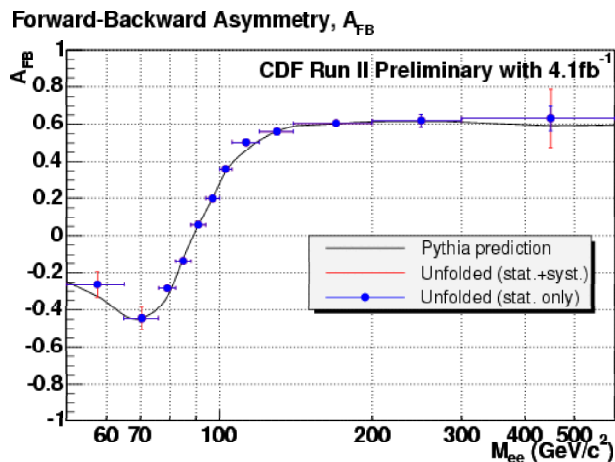


Figure 4: $Z A_{FB}$ after unfolding, compared to Pythia prediction.

In Fig. 4 we show the asymmetry after unfolding, compared to Pythia predictions which shows excellent agreements with data.

From this measurement it is possible to extract $\sin^2\theta_W$. With 1 fb^{-1} D0 obtained an accuracy of 0.002. We expect to extract $\sin^2\theta_W$ with an accuracy of 0.0007 and project that with 8 fb^{-1} (approximately already on tape while we write), the Tevatron only accuracy would match the current WA accuracy.

Another interesting channel to look for new physics is the search for W rare decays. The decay $W \rightarrow \gamma\pi$ is strongly depressed in the SM, with expectation in the range $10^{-6} \div 10^{-8}$. While this channel might eventually be very interesting at the LHC, it can be enhanced by new physics processes, therefore becoming visible at the Tevatron. CDF searched in the $M_{\pi\gamma}$ invariant mass but sees no bump in the spectrum of 206 candidate events (in 4.3 fb^{-1}). With 219 background events, we set a 95 % C.L. limit $BR(W \rightarrow \pi\gamma)/BR(W \rightarrow e\nu) < 6.4 \times 10^{-5}$.

Thanks to the Lorentzian shape of the resonance, the spectrum of the W transverse mass can be used as an estimator of the W width. By fitting the tail ($M_T > 100 \text{ GeV}/c^2$) both D0 and CDF accurately measure this quantity. CDF in 350 pb^{-1} obtains: $2.032 \pm 0.045(\text{stat}) \pm 0.053(\text{syst.}) \text{ GeV}/c^2$; D0 in 1 fb^{-1} measures: $2.028 \pm 0.038(\text{stat}) \pm 0.061(\text{syst.}) \text{ GeV}/c^2$. The Tevatron average [3] of $2.046 \pm 0.049 \text{ GeV}/c^2$ drives the overall accuracy of the WA: $2.085 \pm 0.042 \text{ GeV}/c^2$ and brings Γ_W close to the S.M. expectation (see Fig. 5).

4. The W mass

The W mass is an important parameter of the S.M. Besides, being linked (together with M_{Top} to the Higgs mass, it sheds light on the EWSB mechanism.

In order to match the current accuracy on M_{Top} , which reached $1.3 \text{ GeV}/c^2$, ΔM_W of $8 \text{ MeV}/c^2$ (current is 23) should be reached. It is a formidable experimental challenge and can be one of the most enduring heritages of the Tevatron. D0 has recently published [4] its measurement obtained with 1 fb^{-1} in the $W \rightarrow e\nu$ channel, $M_W = 80.401 \pm 0.021(\text{stat}) \pm 0.038(\text{syst}) \text{ GeV}/c^2$.

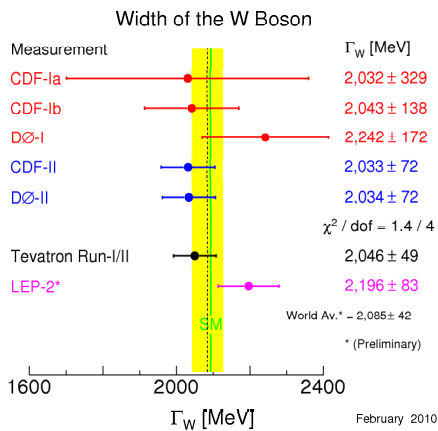


Figure 5: Compilation of recent Γ_W results.

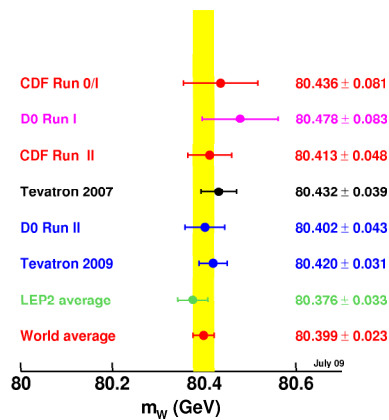


Figure 6: M_W measurements and World Average.

CDF has not yet updated its result (0.2 fb^{-1} , $M_W = 80.413 \pm 0.034(\text{stat}) \pm 0.034(\text{syst}) \text{ GeV}/c^2$ in the e and μ channels combined [5]. However the 2009 Tevatron combination (see Fig. 6) has an accuracy of $31 \text{ MeV}/c^2$ [6]. (better than the LEP average of four experiments of $33 \text{ MeV}/c^2$). With more than 7 fb^{-1} data on tape per experiment, there is room for improvement and, in perspective, to reach an accuracy of better than $20 \text{ MeV}/c^2$ per experiment. At the moment, with the most recent results on M_{Top} and M_W , $M_{Higgs} < 157 \text{ GeV}/c^2$ at 95 % C.L. (indirect limits only) [7].

5. Conclusion

With more than 7 fb^{-1} per experiment on tape, the Tevatron is an excellent place to measure the vector boson properties with great accuracy. The two experiments look forward to provide LHC with information on the Higgs sector not only in their direct searches, but also with indirect measurements of S.M. parameters.

References

- [1] H. Schellmann, These Proceedings.
- [2] M. Lancaster, to appear in Proceedings of the Lake Louise Winter Institute 2010.
- [3] CDF and DØ Collaboration, arXiv:1003.2826.
- [4] DØ Collaboration, PRL 103, 141801 (2008).
- [5] CDF Collaboration, PRL 99, 151801 (2007).
- [6] CDF and DØ Collaboration, arXiv:0908.1374.
- [7] EWK Working Group, arXiv:0911.2604.