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M_W MEASUREMENT AT THE TEVATRON WITH HIGH LUMINOSITY ¹

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Abstract

We present an alternate method to measure M_W at the Tevatron with high luminosity from a direct comparison of the W and Z distributions.

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Currently, the mass of the W -boson (M_W) is measured at the Tevatron from the transverse mass distribution (M_T). At higher luminosity, the uncertainty is expected to scale with the inverse of the square root of the integrated luminosity, as most of the systematic uncertainties are controlled by data samples. However, a recent study [1] has shown that the increase in the number of interactions per crossing (I_C) will substantially degrade the uncertainty in the reconstruction of the transverse energy of the neutrino ($P_{T\nu}$), and therefore the uncertainty with which M_W can be extracted. In Table 1, we reproduce the expected uncertainty calculated in that study at $1fb^{-1}$ ($I_C = 3$) and $10fb^{-1}$ ($I_C = 9$). Note that no detector upgrades were considered for that analysis. For comparison, we use as a benchmark the current CDF uncertainty of $180MeV/c^2$ at about $20pb^{-1}$ simply scaled with the luminosity, see Table 1. The uncertainties at $1fb^{-1}$ and $10fb^{-1}$ are about 2 and 4 times worse than our benchmark, and are dominated by the systematic uncertainty. It would be interesting to have a method that is dominated by statistical uncertainty. The total uncertainty should be compared to the expected uncertainty at LEP II of $40MeV/c^2$ for the 4 detectors combined. Note also that the TeV33 committee report [2] suggests a target of $30fb^{-1}$ by the end of 2006, with a goal of $\Delta M_W = 15MeV/c^2$. Recently [3], the prospect to measure M_W at the LHC was investigated, and no problems that would prevent a very precise determination were uncovered.

One possible solution to the multiple interactions per crossing problem is to divide the data sample into subsamples corresponding to fixed I_C and to study the effect [4]. Another solution would be to lower the bunch spacing, in order to reduce I_C . However, this would require detector upgrades beyond what is currently planned. Finally, observables that do not depend on $P_{T\nu}$, like the momentum (P_l) or the transverse momentum (P_{Tl}) of the charged lepton, could be used. In this short contribution we concentrate on this latter solution.

First, let us consider P_l . A few years ago, a study was performed during the Madison-Argonne workshop [5], and it was concluded that the total uncertainty using this observable is about 1.5 times worse than our benchmark. It is reasonable to assume that for this observable the uncertainty will scale normally to higher luminosity, such that this method could provide a better measurement

ΔM_W	$\int Ldt = 1fb^{-1}, I_C = 3$	$\int Ldt = 10fb^{-1}, I_C = 9$
statistical	29	17
systematic	42	23
total	51	29
Benchmark	25	7.9

Table 1: *Projected uncertainty on M_W , along with our benchmark, in MeV/c^2 , per experiment. The e and μ channels are both included.*

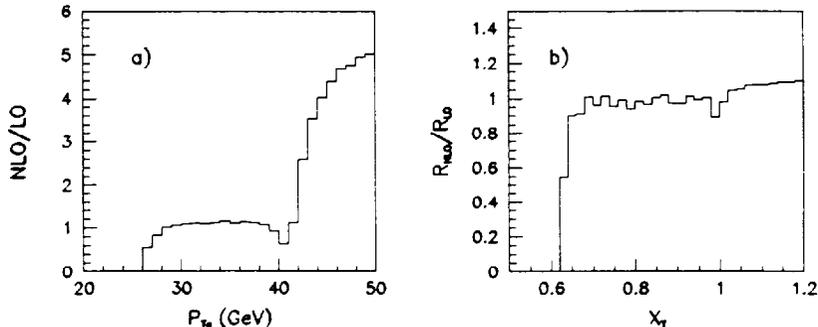


Figure 1: W production. a) Ratio of NLO over LO cross sections as a function of P_{T_e} . b) Ratio of NLO over LO R as a function of X_T .

than using the M_T distribution. This analysis should be repeated as it is not clear if all the uncertainties were accounted for.

Let us now turn to P_{T_l} . In Fig. 1a, we present for W production the ratio of the QCD next-to-leading order (NLO) calculation over the leading order (LO) calculation as a function of P_{T_e} . As can be seen, there are large corrections in the region of interest, around $M_W/2$. As a result, the perturbative expansion can not be trusted, these large corrections need to be resummed. Here, we want to suggest an alternative to resummation by considering the ratio of W over Z distributions. The basic idea is that the large corrections are universal and cancel in the ratio. The P_{T_l} -distributions of the W and Z peak at different places, at about half the vector boson mass (M_V), such that the first step is to consider scaled variables: $X_T = P_{T_l}/(M_V/2)$. The X_T -distributions have also large QCD corrections. We define R as the ratio of the W over Z X_T -distributions. The ratio of NLO over LO of R is presented in Fig. 1 b. As can be seen, the corrections are small and of the order of 10-20 % which indicates that the perturbative expansion for this observable is well behaved. The mass dependence mainly enters when the P_{T_l} distribution is transformed into the X_T distribution, and M_W can be measured by fitting the ratio R .

The limitation of the method is that it depends on the Z statistics which is about 5 times smaller than the W (considering that both the electron and the positron can be used in the Z case). Therefore, a statistical uncertainty about $2(\sim \sqrt{5})$ times worse than our benchmark can be expected. Note that the method still depends on the P_{T_ν} for the identification of the W , but this dependence can be reduced by imposing a cut on P_{T_l} bigger than on P_{T_ν} .

There are several advantages to the method. First, it only uses the NLO QCD calculation (the NNLO could be used if it becomes available), there is no need for any resummation. Second, M_W is directly measured with respect to M_Z which has been measured very precisely at LEP. Finally, because of the use of the ratio, the systematic uncertainty is expected to be small. Only the

systematic effects that are different for the W and Z should contribute, like the isolation criteria of the 2nd electron in the Z case, or some of the backgrounds. Considering a small systematic uncertainty, overall the ratio method should give an uncertainty on M_W smaller than 2 times worse than our benchmark. Therefore, it has the potential to do better than the conventional transverse mass method. Finally note that the ratio method can be used with any other observables, like M_T itself or P_T .

In conclusion, at this point there is no clear winner at high luminosity between the different observables to measure M_W , and the direct comparison of W and Z distribution seems very promising.

References

- [1] The TeV-2000 Group Report, Fermilab-Pub-96/082.
- [2] see the TEV33 Committee Report Executive Summary, <http://www-theory.fnal.gov/tev33.ps>.
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- [4] B. Carither at the TEV33 Workshop, Fermilab, Illinois, May 1996.
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