PROCEEDINGS

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ElectroWeak Symmetry Breaking in Tevatron Run II

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ABSTRACT: The Tevatron Run II will provide CDF and D0 with a large dataset of ppbar interactions collected at $\sqrt{s} = 2$TeV. We discuss the opportunity for the two experiments to improve understanding of electroweak and top physics in the first years of data taking (Run IIa) in view of the upgrades of the detector themeselves. We also discuss the perspectives for an Higgs discovery at the Tevatron in view of the Run IIb data taking period which willdeliver an additional 13 fb^{-1} to each detector.

1. Run II of the Tevatron Collider

The successful Run I of the Tevatron in 1992-1996 lead to the upgrade of the accelerator complex. The new run, started in March 2001, is known as Run II and is expected to collect 2 fb^{-1} in a first phase (Run IIa) and, after another set of improvements to machine and detectors, gather additional 13 fb^{-1} in what is known as Run IIb. The net results of the upgrades are an increase in energy (from $\sqrt{s}$ =1.8 to 2 TeV) and in instantaneous luminosity (from a typical 10^{31} in Run I up to $10^{32}\text{cm}^{-2}\text{s}^{-1}$). The average number of interactions per crossing is kept low by decreasing the inter bunch distance from 3.5 μs of Run I down to 396 ns and will eventually become 132 ns.

In order to match the technical challenges posed by those changes, as well as to exploit the physics capabilities of the Tevatron, both CDF and D0 underwent a series of upgrades [1, 2]. Here we just mention a few of them, which are of special interest to the electroweak physics. CDF completely rebuilt its front-end electronics and DAQ system to match the 132 ns interbunch. The trigger was also completely rebuilt, online tracking for hight P_t tracks was moved to the first level trigger, while a new special set of processors, providing the experiment with a second level trigger on tracks displaced from the primary vertex (the Silicon Vertex Tracker) was built. Finally the whole tracking system was completely rebuilt. It is now made of a new silicon tracker (7 layers providing space points for

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$|\eta| < 2$ at $2 \leq R \leq 28$cm) and a new central drift chamber with a stronger 3D reconstruction capability. Just to mention a few figures, this system will allow tracking up to $|\eta| < 2$ (therefore doubling the Run I coverage), and will increase the b tagging efficiency in top events to 65 % per jet. D0 upgrade was even more substantial as a solenoid, providing a 2 T magnetic field, was added. Futhermore the tracking system was rebuilt with a silicon vertex detector and a fiber tracker to fully exploit this new situation (figure 1). Again, trigger, front end and DAQ were rebuilt to cope with the decreased bunch spacing. In the end the two experiments will have similar performances in terms of hermeticity and tracking capabilities.

To put things in perspectives, the overall acceptance for W,Z events will be doubled and for events containing a vector boson pair is tripled.

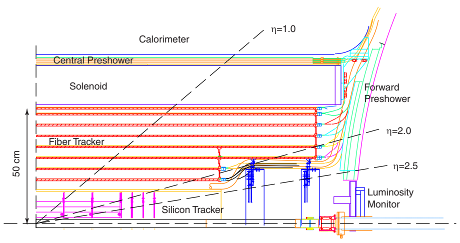

Figure 1: D0 upgrade

2. Gauge Boson Physics

Run IIa with its 2 fb^{-1} of data, will provide each experiment with over $3{\times}10^6$ W's (e and μ channel), therefore allowing a precise determination of many EW parameters. One of the most important results will be a better determination of the W mass. In Run I CDF measured M_W with an accuracy of 79 MeV, and D0 final accuracy was 84 MeV, bringing the total uncertainty for this measurement (Tevatron only) at $\simeq$ 60 MeV, with statistical and systematics on equal footing. However most of the systematic uncertainty depend upon the size of control samples, therefore will greatly benefit from the large data set. As an example we show (table 1) the contributions scaling with luminosity for the CDF W$\rightarrow \mu\nu$ measurement.

Source	**uncert.** *(MeV/c^2)*
`Fit statistics`	*100*
`Momentum scale`	*85*
`Recoil model`	*35*
`Background`	*25*
`Mom.resolution`	*20*
`Selection bias`	*18*

Table 1: M_W uncertainties [5]'

The biggest component (momentum scale) is obtained by fitting all the l^+l^- invariant mass spectrum, while W asymmetry is used to constrain PDF and the Z P_t spectrum is the input to the W P_t spectrum. With 2 fb^{-1} we expect to reduce the overall uncertainty to 40 MeV/c^2, with 30 MeV/c^2 as a possible target.

The study of W and Z couplings will benefit from the wider acceptances and the new features of the two detectors. The anomalous couplings in the ZV (V=Z,γ) vertex are parameterized in terms of h_{30} and h_{40}. Any value different from zero of those couplings would signal new physics. In Run I D0 set a 95 % C.L.limit to h_{40} at about 0.3 and in Run IIa we expect to reach a limit to better than 0.03 by using several hundreds of reconstructed Zγ $\rightarrow ee(\mu\mu)\gamma$ events and a few $ZZ \rightarrow 4l$ detected. In the W sector we expect to collect about 100 events WW $\rightarrow l\nu l\nu$ and about 30 events WZ $\rightarrow lll\nu$. Scaling from Run I analysis, we expect to set limit to anomalous couplings (parameterized as Δk and λ to $-0.12 < \Delta k < 0.18$ (for λ =0) and $|\lambda| < 0.09$ for $\Delta k = 0$. One of the most important checks of the SM still to be performed, is the detection of the *zero amplitude* in the W$\gamma \rightarrow \gamma l\nu$

process. Due to specific SM cancellations, a dip appears in the angular distribution of the final states (l,γ). CDF saw hints of this effect in Run I and we expect to collect about 3000 $W\gamma \rightarrow l\nu\gamma$ in Run IIa, therefore being able to isolate this process.

3. Top Physics in Run II

Right after the discovery of the top quark, both experiments swiftly moved on to measure its properties (cross section, mass and couplings). Some of those measurements were already systematic-limited at the end of Run I. We expect most of those systematics to scale with statistics as they are determined by the size of control samples and therefore studies of the sixth quark will greatly benefit from the increase of luminosity and in c.o.m. energy. Raising the energy from $\sqrt{s}$ = 1.8 to 2 TeV, the production cross section increases by 40%, as the gg scattering acquires a more prominent role (this will eventually become the dominant process at the LHC).

Table 2 shows the number of top events expected in 2 fb^{-1} per experiment. To put things in perspectives, CDF collected 9 candidates dilepton events in Run I, and 76 were used in the l+4j sample (the most important one to determine M_{top}) to reconstruct the top mass. The larger statistics will be obtained thanks to a wider acceptance and better tracking capability. The improved b-tagging efficiency (for example at D0 ϵ_b will be about 50 % for b-jets with P_t >40 GeV/c) will greatly improve, besides the determination of M_{top}, the measurement of the cross section and the study of the Wtb vertex.

Channel	**CDF/D0**
`Dilepton(e,`μ`)`	*155*
`Dilepton(`τ`)`	*19*
`lepton+` $\geq$ `3jets`	*1520*
`lepton+` $\geq$ `4 jets`	*1200*
`lepton+` $\geq$ `3jets+1btag`	*990*
`lepton+` $\geq$ `3jets+2btag`	240

Table 2: Yield of $t\bar{t}$ events in 2fb^{-1}

The measurement of M_{top} is dominated by systematics, with the biggest one being the jet energy scale. The best way to tackle this problem is to identify a signal on which calibrate the energy scale. In Run I CDF was able to reconstruct a $W \rightarrow jj$ peak in its tiny $t\bar{t}$ double b-tagged sample and to detect the $Z \rightarrow b\bar{b}$ signal in its dijet sample. The experiment plans to do even better in Run II by using a dedicated trigger to select $Z \rightarrow b\bar{b}$ events. In this way the two vector bosons will be used to set the jet energy scale and to check b-specific corrections. Given that, we expect the uncertainty to be reduced by a factor 2 (see table 3 for CDF estimates of expected systematics in Run IIa). Together with the precise determination this will set stringent limit on the Higgs mass (see figure 2).

Source	**GeV/c^2**
`Jet En. scale`	*4.4(2.2)*
`ISR and FSR`	*1.8(1.0)*
`background`	*1.3(0.5)*
`b-tag bias`	*0.4*
`PDF`	*0.3*
`Total`	4.9(2.5)

Table 3: CDF determination of M_{top}, systematics in 2 fb^{-1}. In parenthesis Run I results.

Another topic in top physics which will be explored in Run II is the precision determination of the top cross section, which is currently a $\simeq$ 25% measurement and which will be determined to better than 10% at the end of Run IIa. The comparison data to Monte

Carlo will greatly improve with the availability of larger samples of b tagged events and with the wider acceptance.

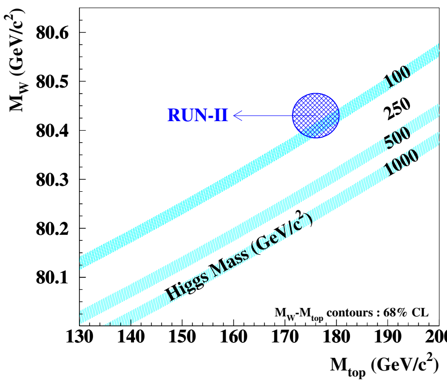

Figure 2: SM Higgs as a function of M_W and M_{top}. Run IIa (2 fb^{-1}), one experiment only.

Studies of the Wtb vertex in Run I were performed at CDF. Both top helicity and ratio of branching fractions $R = \frac{t \to Wb}{t \to Wq} = \frac{|V_{tb}|^2}{|V_{tb}|^2+|V_{td}|^2+|V_{ts}|^2}$ were measured [3]. CDF measurement of R to 26 % allowed an indirect determination of the CKM matrix element $|V_{tb}|$ to $\simeq 15\%$. In Run II we expect to reduce the uncertainty on R to 6 % with a corresponding uncertainty on $|V_{tb}|$ to about 3%. A direct determination of $|V_{tb}|$ (15% accuracy) can be obtained by identification of the single top production process, which however stands as an elusive process. The understading of forward tracking and tagging will play a decisive role in this search.

4. Higgs Searches in Run II

Over the last two years a lot of efforts were dedicated to better understand the chances to detect a SM Higgs particle at the Tevatron. Emphasis was set on the low mass (< 130 GeV/c^2) region, where the Higgs decays almost completely in $b\bar{b}$ pairs.

Although (figure 3) the dominant production process is the direct production through gg fusion, the large QCD background renders this channel unfeasible. It is more promising the associate production VH ($V = W, Z$), where a leptonic decay of the V would provide a clean trigger and bring to a favourable S/B ratio. A detailed study, based on a mix of Monte Carlo paremeterization, Run I data analysis and comparison with detailed simulation of the CDF and D0 detector, was performed in the last three years. It is not possible here to describe all the studies performed[4], the summary is provided in tables 4 and 5 where the event yield in 15 fb^{-1} is shown for the WH and ZH case. It is, however, best recollecting here that *all*, but the single top, background processes were already seen or measured in Run I. Therefore the calculation of the signal includes all known effects. The studies of the "high mass" region focused on the $gg \to H \to W^*W^* \to l^+l^-\nu\nu$ channel where the price paid for the low cross section is offset by the very small background. An additional step was to add the associate production of H and W or Z $p\bar{p} \to W(Z)H \to l^{\pm}l^{\pm}jjX$. By vetoing on b-tagged jets (produced in $t\bar{t}$ events), the backgrounds are reduced to a

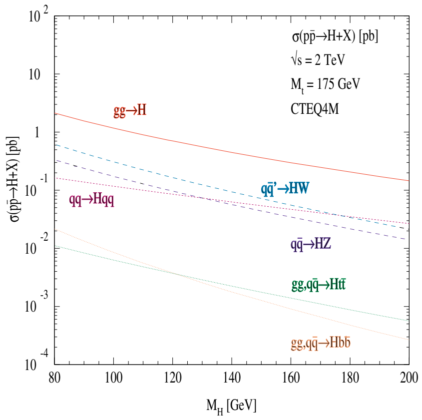

Figure 3: SM Higgs production

M_H (GeV/c^2)	110	120	130
Signal	*75*	*60*	*45*
$Wb\bar{b}$	*435*	*375*	*285*
WZ	*90*	*60*	*30*
$t\bar{t}$	*225*	*300*	*330*
single top	*105*	*135*	*135*
S/$\sqrt{B}$	2.6	2.0	1.6

Table 4: Low mass Higgs, WH channel

M_H (GeV/c^2)	110	120	130
Signal	*69*	*46*	*31*
$Zb\bar{b}$	*84*	*69*	*52.*
$Wb\bar{b}$	*100*	*81*	*63*
ZZ	*43.5*	*3*	*0.0*
$t\bar{t}$	*70.5*	*64.5*	*52.5*
single top	*79.5*	*70.5*	*57.*
S/$\sqrt{B}$	2.4	2.0	1.5

Table 5: Low mass Higgs, ZH channel

manageable level. The final outcome of these studies is shown in figure 4. The 95 % C.L. limit as well as the 3σ and 5σ discovery curves are shown as a function of the Higgs mass and of the integrated luminosity. The two experiments have been combined. There is a window of opportunity in the low and intermediate Higgs mass region, if the Tevatron can provide an integrated luminosity in excess of 10-15 fb^{-1} before the start of the LHC.

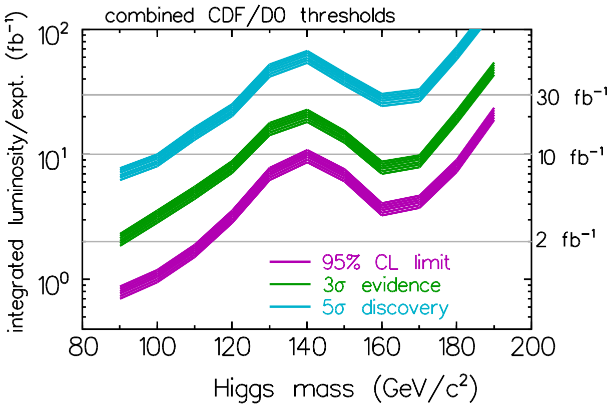

Figure 4: SM Higgs expectations at the Tevatron

In order to do so the Beams Division of Fermilab initiated an intensive R&D program to demonstrate the technical feasibility of delivering about 4 fb^{-1} per year. At the same time both CDF and D0 started an intensive period of studies to understand which parts of their detectors need to replace in order to survive luminosities more than 7 times larger than originally planned for.

5. Conclusion

In the next years of Run II we expect to gather more than 2 fb^{-1} per experiment. Thanks to the very large statistics precise determinations of the masses of the top quark and of the W vector boson are possible. This will allow to set stringent limit on the Higgs mass. Furthermore, if the Tevatron collider will be upgraded to deliver $\simeq$ 4 fb^{-1} per year, there is a chance to isolate the Higgs particle if its mass is low enough.

References

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