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A Review of Recent Results from the Tevatron  
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for the CDF and D0 Collaboration

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# A Review of Recent Results from the Tevatron

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The D0 and CDF experiments have been taking data at the Run 2 of the Tevatron Collider since 2001. We present a selection of recent results, most of them obtained with an integrated luminosity of  $\simeq 1 \text{ fb}^{-1}$ . I will describe the most important facets of the physics programme and detail some results. Recent direct limits on standard model Higgs obtained at the Tevatron, and their their prospects will be also reviewed.

## 1 Introduction

The D0 and CDF experiments are two  $4\pi$  multi-purpose detectors taking data at the Tevatron Collider. Run 2 (started in 2001) is designed to provide each detector with  $4 - 8 \text{ fb}^{-1}$  of  $p\bar{p}$  collisions by the end of 2009. With respect to Tevatron Run I, the accelerator complex underwent a large upgrade which radically changed the way it operates. The interbunch distance was reduced from  $3.5\mu\text{s}$  to 392 ns, the whole  $\bar{p}$  production, cooling and stacking was revised. As a result, after a relatively long startup, the accelerator is now performing very well. The peak luminosity reached  $2.92 \cdot 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$  and is now delivering about  $40 \text{ pb}^{-1}/\text{week}$  with a record of  $45 \text{ pb}^{-1}$  in a single week. Based on the current performances, the integrated luminosity per experiment extrapolates to  $6 - 8 \text{ fb}^{-1}/\text{experiment}$  by the end of 2009.

The CDF and D0 detectors were upgraded fully to exploit the physics opportunities provided by the Tevatron. CDF completely rebuilt its tracking system (both the outer chamber and the silicon tracker), the forward calorimeter, its trigger and front end electronics and extended the muon coverage. It also added the capability to trigger on tracks at Level 1 (i.e. synchronous with the bunch crossing) and to identify and trigger on tracks displaced with respect to the primary vertex at Level 2. The silicon tracker is an important asset of its physics programme with a precision single sided layer located right on the beam pipe, five layers of double sided silicon sensors at various radii between 2.5 and 10 cm and two layers located at  $\simeq 20$  and  $\simeq 28$  cm covering  $|\eta| < 2$  and  $1 < |\eta| < 2$  respectively.

D0 changed its philosophy by becoming a full magnetic spectrometer with the addition of a 2 Tesla superconducting solenoid. It also replaced its old tracker with a new 8-layer fiber tracker which -combined with a microvertex silicon detector- provides a powerful instrument to reconstruct tracks coming from the primary vertex and offline to identify vertices due to long-lived particles. D0 also improved its acceptance for muons and upgraded the trigger system. Recently, in the shutdown of 2006, the collaboration added an extra layer of silicon sensors located right outside the beam pipe.

The detectors collect data with an efficiency of  $\simeq 90 \%$ . The small inefficiency is partly due to a deadtime coming from the trigger and Data Acquisition and partly to operational constraints. As we write  $\simeq 2.5 \text{ fb}^{-1}$  were written to tape by each experiment. However, in the following, unless otherwise indicated, I will present results obtained with  $\simeq 1 \text{ fb}^{-1}$ , less than half of the data on tape.

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## 2 Flavour Physics

Despite the large production cross section, processes involving HF remain largely buried under a large background. CDF Run 1 pioneered the identification of heavy flavour at hadron colliders by detection of secondary vertices, a powerful tool complementary to other tagging techniques. In Run 2 the experiment increased its B-physics reach by adding the capability to trigger on tracks not coming from the primary vertex (SVT). A number of  $b$  and  $c$ -related physics processes, otherwise completely buried by a large background, can therefore be selected online for further analyses. Thanks to its microvertex detector and to its large muon coverage D0 is also able to perform a number of measurements. Details can be found in [2], here I only mention a few, very interesting results.

In Spring 2005 D0 presented a limit on  $B_s$  oscillations using  $0.9 \text{ fb}^{-1}$  of  $14.9 < \Delta m_s < 21 \text{ ps}^{-1}$  at 90% C.L. With  $1 \text{ fb}^{-1}$  CDF presented (Fall 2005) a  $5 \sigma$  observation of  $B_s$  oscillations (Fig. 1) and a measurement of  $\Delta m_s = 17.77 \pm 0.10(\text{stat}) \pm 0.07(\text{syst}) \text{ ps}^{-1}$ . D0 exploits a combination of its measurement of the  $B_s \rightarrow J/\Psi\phi$  channel and of the  $B_s$  semileptonic decays together with results from the  $B$  factories and CDF  $\Delta m_s$  to obtain a measurement of  $\phi_s = 0.70^{+0.47}_{-0.39}$  [2].

CDF and D0 search for rare B decays. Thanks to SVT, CDF directly measures  $B \rightarrow hh$  decays and their  $A_{CP}$ .  $B_d, B_s$  decays to  $\mu\mu$  have tiny SM branching fractions ( $O(10^{-9})$  which are enhanced (by powers of  $\tan\beta$ ) in several SUSY models, therefore both Collaborations search for new physics through this channel. CDF has not yet updated its measurement performed with  $0.8 \text{ fb}^{-1}$ , while D0 just presented its result with the full dataset of  $2 \text{ fb}^{-1}$ . Combining the 2a (without the silicon layer on the beampipe) and 2b data they find 3 candidate events with a background of  $2.3 \pm 0.7$  and set a limit for  $B_s \rightarrow \mu\mu < 9.3(7.5) \cdot 10^{-8}$  at 95(90) % C.L. and  $B_d \rightarrow \mu\mu < 2.3(2.0) \cdot 10^{-8}$  at 95(90) % C.L. This result (which will soon be improved by adding the CDF search), sets interesting limits on many SUSY models by excluding zones in the  $\tan\beta - M_A$  plane [4]. We expect that by 2009, with  $8 \text{ fb}^{-1}$ , the Tevatron will be able to set a limit of  $\approx 2 \cdot 10^{-8}$  on the  $B_s$  decay.

state	Mass value $\pm$ stat. $\pm$ syst.
$\Sigma_B^+$	$5808^{+2.0}_{-2.3} \pm 1.7$
$\Sigma_B^-$	$5816^{+1.0}_{-1.0} \pm 1.7$
$\Sigma_B^{*+}$	$5829^{+1.6}_{-1.8} \pm 1.7$
$\Sigma_B^{*-}$	$5379^{+2.1}_{-1.9} \pm 1.7$

Table 1:  $\Sigma_B$  and  $\sigma_B^*$  masses (in  $\text{MeV}/c^2$ ).

channels [2].

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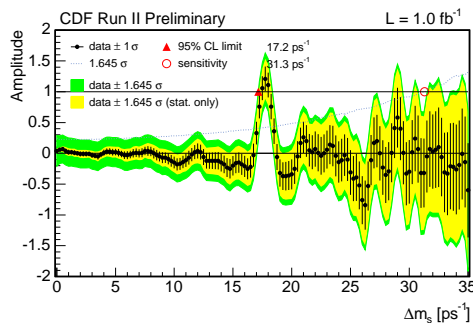


Figure 1: Amplitude scan for  $\Delta m_s$  at CDF.

Searches for rare decays of known states are complemented by the search for new states, and CDF recently presented the observation of two new  $B$  baryons:  $\Sigma_B$  and  $\Sigma_B^*$  with masses shown in table 1. Last but not least, new measurements of  $\Lambda_B$  lifetime are presented. CDF measures (exclusive states)  $1.5 \pm 0.077 \pm 0.012 \text{ ps}$  while D0 reports  $1.28 \pm 0.11 \pm 0.09 \text{ ps}$  in semileptonic decays and  $1.3 \pm 0.14 \pm 0.05 \text{ ps}$  in exclusive

### 3 QCD and jet physics

Tests of the strong interaction and measurements of jet distributions have been the bread and butter physics at the Tevatron for more than 20 years. Besides testing theoretical prediction those processes are often used to test algorithms but they also play an important role to estimate the background in rare processes and searches for new physics. This dual aspect is present in many analyses. Details can be found in the many Tevatron contributions to this Conference [3]. In the following I will only refer to a small subset.

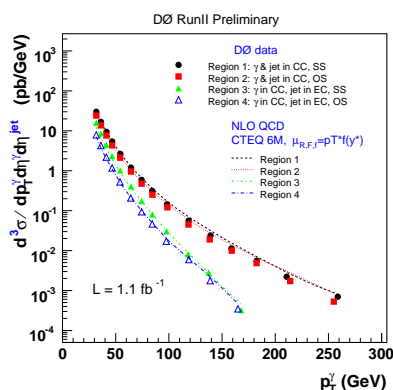


Figure 2: D0 triple differential  $\gamma - j$  cross section.

close in  $\varphi$  exhibits a clear deviation of data with respect to calculations. Even the improvement obtained by using Jimmy (a Monte Carlo describing multiple parton interactions) does not fully account for this difference, which happens in the region where gluon splitting is expected to provide a sizeable contribution to the process.

### 4 Electroweak Physics Measurements

Electroweak (EWK) processes can be used to understand better the capabilities of the detectors and to develop new tools (from trigger to analysis technique). They also often represent background for searches. With its large dataset, the Tevatron became a place where precision EWK measurements can be performed to test the SM at its boundaries.

Among the many results, I chose a few which are significant for their implications. The  $W$  and  $Z$  integral and differential cross sections provide an excellent testing ground for PDFs. NLO and NNLO calculations of the inclusive processes have been available for

Thanks to the large statistics available it is now possible to make precise measurements of associated production of jets and vector bosons ( $W$ ,  $Z$ ,  $\gamma$ ). D0 measures the triple differential cross section in the  $\gamma - jet$  process (Fig. 2) where finds a good agreement with available NLO QCD calculations. CDF finds a good agreement between its inclusive jet distribution and theoretical prediction. The difference between theory and CDF data of Run 1, has now disappeared. The large statistics, combined with the exploitation of the SVT trigger, allows CDF to study  $b\bar{b}$  correlations in a small dataset ( $\simeq 260 \text{ pb}^{-1}$ ). Existing MC do not fully describe the data, as you can see from Figure 3 where several MC are used for the comparison. The region in which the two  $b$ s are

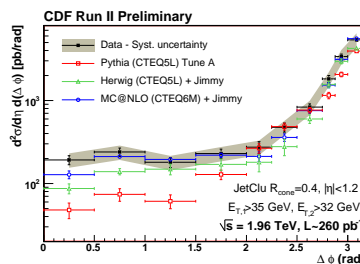


Figure 3:  $\Delta\varphi$  between two identified  $b$ s

quite some time and recently a full differential calculation at NNLO became available [7]. The large statistics collected allows CDF to present a  $d\sigma/dy$  for  $Z \rightarrow ll$  events (Figure 4). While the agreement with theory is good, this measurement -with increasing statistics- can be used to constrain PDFs. Recently CDF measured the ratio of central-to-forward cross section for  $p\bar{p} \rightarrow W + X$  with the  $W \rightarrow e\nu$  and demonstrated a sensitivity of this quantity to PDFs. This can be a promising way to study PDFs at the LHC where the  $W$  asymmetry measurement will play a less prominent role [6].

Tevatron experiments recently obtained significant results in the diboson sector. The tiny cross sections (of the order of a few pb, less than the top cross section) challenged the experimentalists' determination and ingenuity. Diboson production represents also a test bed for the detection of Higgs and indeed represents a background in several channels.

In Summer 2006 D0 presented its evidence of  $WZ$  production, with  $WZ \rightarrow l\nu l\nu$  signal at  $3.3\sigma$  level and a cross section of  $3.98^{+1.91}_{-1.53}$  pb (statistical and systematic uncertainty combined), consistent with SM expectation of  $3.7 \pm 0.1$  pb. In Winter 2007 CDF confirmed its previous evidence observing a signal of 16 events with a background of  $2.7 \pm 0.28 \pm 0.33 \pm 0.09$ . The probability of a null signal is  $< 1.5 \times 10^{-7}$  equivalent to a  $\simeq 6\sigma$  effect. The measured cross section is  $5.0^{+1.8}_{-1.6}$  pb (statistical and systematic uncertainty combined). In this case the improvement did not come from a larger dataset but rather from improved analysis technique and a larger lepton acceptance.

Another challenging process is  $ZZ \rightarrow llll$ . CDF shows a  $3\sigma$  evidence (Figure 5) and measures a cross section of  $0.75^{+0.71}_{-0.54}$  pb, compatible with the NLO prediction of  $1.4 \pm 0.1$  pb.

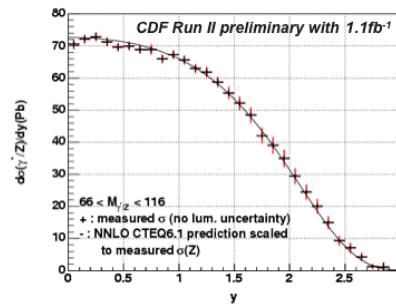


Figure 4:  $d\sigma/dy$  for  $Z\gamma^* \rightarrow ee$  CDF events.

At present the case in which one of the two bosons decays hadronically still remains unobserved.

The gauge structure of the SM finds a crucial test in the associated production of  $W\gamma$ . The destructive interference at tree level of the relevant diagrams creates a zero in the  $dN/d\cos\theta^*$  distribution at  $\cos\theta^* = \pm\frac{1}{3}$ , where  $\theta^*$  is the c.o.m. angle between the  $W$  and the incoming quarks. In our detectors we measure the charged lepton from the  $W$  decay and the sensitive variable is  $Q \cdot \Delta\eta_{l,\gamma}$  where  $Q$  is charge of the lepton. The distribution of this quantity still shows a dip at  $\approx -0.3$ . As the photon does not directly couple to the  $Z$  the interference is not present in the  $Z\gamma$  process. Both experiments measure the inclusive  $W\gamma$  and  $Z\gamma$

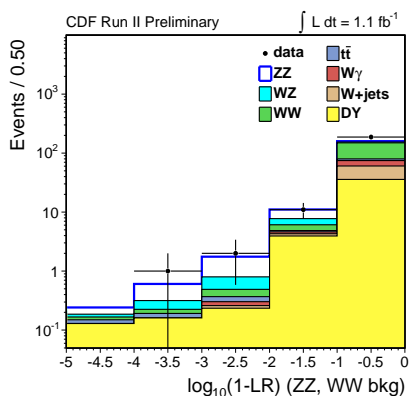


Figure 5: Log-Likelihood ratio for  $ZZ$  candidates superimposed to background.

production cross section. CDF finds  $\sigma(W\gamma) = 19.1 \pm 2.8$  pb and  $\sigma(Z\gamma) = 4.9 \pm 0.5$  pb. D0 applies a cut to the photon  $E_T$  ( $>7$  GeV) and to the transverse mass  $M(\gamma, l, \nu) > 90$  GeV and quotes  $\sigma(W\gamma) = 3.2 \pm 0.5 \pm 0.2(\text{lum})$  and  $\sigma(Z\gamma)$  of  $4.51 \pm 0.4 \pm 0.3$  pb. D0 measures the  $Q \cdot \Delta\eta$  distribution in  $900 \text{ pb}^{-1}$  and in its data there is evidence of a dip related to the destructive interference predicted by the SM (Figure 6).

In the single boson realm, the most significant contribution came from CDF which directly measured the  $W$  mass and width. The traditional way is to study the transverse mass ( $M_T = \sqrt{2 \cdot E_T^\nu \cdot E_T^l \cdot (1 - \cos\theta_{l,\nu})}$ ) distribution where  $l = e, \mu$  and neutrino transverse momentum is estimated from the transverse missing energy size and direction. The peak provides information about the  $W$  mass where the non-Gaussian tail (due to the Lorentz distribution) about the  $W$  width. In its  $M_W$  measurement CDF also fits the transverse momentum distributions of the leptons. The result is  $M_W = 80413 \pm 48 \text{ MeV}/c^2$  where statistical and systematic uncertainties contribute evenly ( $34 \text{ MeV}/c^2$  each). This is the best measurement obtained by a single experiment. As it was performed on  $200 \text{ pb}^{-1}$ , while the current sample on tape exceeds it by a factor 12, it is reasonable to expect a large reduction of the statistical error. The systematics can also be addressed with a larger statistics and a precision of  $\simeq 25 \text{ MeV}/c^2$  seems achievable. The measurement of  $\Gamma_W = 2032 \pm 71 \text{ MeV}/c^2$  (with  $350 \text{ pb}^{-1}$ ) (Fig. 7), combined with Run 1 measurements, now dominates the world average.

## 5 Top Physics

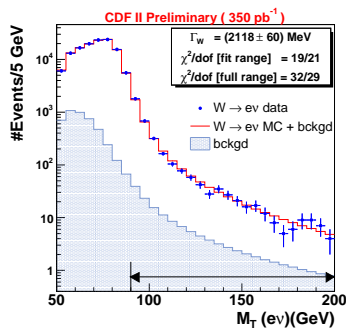


Figure 7: Fit to  $M_T$  in the  $W \rightarrow e\nu$  channel.

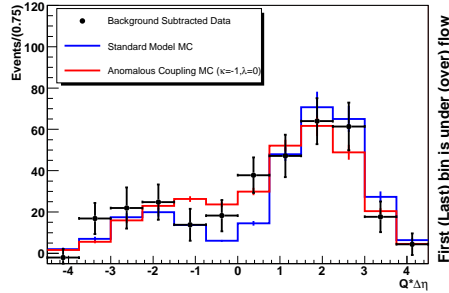


Figure 6: Signed  $\Delta\eta_{\gamma}$  distribution at D0.

Top quark production was first discovered at the Tevatron Collider in 1994-1995. Until the LHC starts it is still the only place where it can be studied and several new results are presented [9].

As the  $t \rightarrow bW \simeq 100\%$  of the times, one can classify the various decay channels according to the way the  $W$  boson decays. In this way one can measure *dilepton* channel (both  $W$ s decay into  $l\nu$ ), *lepton+jets* channel where only one of the two  $W$ s decays leptonically and finally the *all-hadronic* channel in which both  $W$ s decay hadronically. The final states contain, accordingly, one, two or no high  $P_T$  lepton. The structure of

the  $Wtb$  vertex can be directly studied in top-pair decays. Anomalous couplings (FCNC) and new physics might appear as deviation from SM expectations. The Top cross section has been measured in essentially all decay channels. A compilation of the  $t\bar{t}$  production cross section measured by CDF can be found in Fig. 8.

Some comments are in order. The dilepton channel, by far the one with least background has a BF of only  $\simeq 4.9\%$  summing together the  $ee, \mu\mu, e\mu$  channels. In order to improve statistics CDF selects events with one fully identified high- $P_T$  lepton and an isolated high  $P_T$  track. Its recent result with  $1.1 \text{ fb}^{-1}$  is  $\sigma_{dil} = 9.0 \pm 1.3(stat) \pm 0.5(sys) \pm 0.5(lum)$  pb. D0 has a comparable result with a similar data sample:  $\sigma_{dil} = 6.8^{+1.2}_{-1.1}(stat)^{+0.9}_{-0.8}(sys) \pm 0.4(lum)$  pb.

The  $l + jets$  channel has worst signal-to-background ratio, therefore, since the beginning of top physics, it has been customary to exploit the presence of two jets containing  $b$  quark. The characteristic signature due to the presence of long-lived particles is used to improve S/B. One can require one or two  $b$  tags (i.e. jets identified as containing  $b$  debris) with an efficiency that, for  $t\bar{t}$  events reaches  $\simeq 55\%$ . While both CDF and D0 are trying to improve their  $b$  tagging algorithms to increase efficiency, the overall acceptance and S/B ratio are already good enough to ensure that this channel is the most important in many top quark physics measurements. As for the cross section, the most recent result comes from D0 ( $1 \text{ fb}^{-1}$ ) and is  $\sigma_{l+j} = 8.3^{+0.6}_{-0.5}(stat)^{+0.9}_{-1.0}(sys) \pm 0.5(lum)$  pb.

In the fully hadronic channel the final state (6 jets) has a large multi-jet background to compete with. Therefore, after triggering the S/B is  $\simeq 1/1300$ . A combined neural-net based kinematic analysis and  $b$  tagging improve this ratio to  $\simeq 1/16$ . Thanks to this selection the result for the cross section is comparable to the other two channels. In  $\simeq 1 \text{ fb}^{-1}$  CDF measures:  $\sigma_{all-had} = 8.3 \pm 1.0(stat)^{+2.0}_{-1.5}(sys) \pm 0.5(lum)$  pb

With less than 50% of the dataset analyzed, the cross section measurements are reaching the level of the theoretical NLO calculations.  $\sigma_{t\bar{t}} = 6.7^{+0.7}_{-0.9}$  pb [10],  $\sigma_{t\bar{t}} = 6.8 \pm 0.6$  pb [11]. A NNLO calculation might become quite interesting, even more when the LHC comes into operation although at the moment it appears too challenging to be addressed with standard calculation procedures.

Top decays before hadronizing, therefore there are no bound states, unlike the other quarks. Therefore its mass, a fundamental quantity that combined with the  $W$  mass, provides us on insight on the Higgs sector, can be accurately measured. CDF and D0 measure  $M_{top}$  in each decay channel using several techniques. The original *template* method, where distributions from data were compared with expectations from (combined) top MC and background, is now complemented by Matrix Element (ME) and Dynamic Likelihood Method (DLM) where the intrinsic structure of the decay enters directly and helps to improve the measurement.

In table 2 we summarize the most recent results obtained with  $\approx 1 \text{ fb}^{-1}$ .

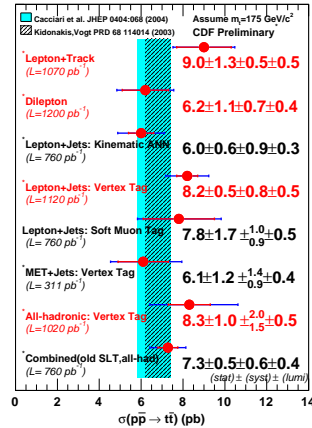


Figure 8:  $t\bar{t}$  production cross section at CDF.



All-hadronic (CDF, 943 pb <sup>-1</sup> )	171.1 ± 4.3
Dilepton (CDF, 1030 pb <sup>-1</sup> )	164.5 ± 5.6
Dilepton (D0, 1000 pb <sup>-1</sup> )	172.5 ± 8.0
Lepton+jets (CDF, 940 pb <sup>-1</sup> )	170.9 ± 2.5
Lepton+jets (D0, 900 pb <sup>-1</sup> )	170.5 ± 2.7
World Average	170.9 ± 1.8

Table 2: Best  $M_{top}$  results (in GeV/ $c^2$ ).

In previous measurements the dominant systematic effect came from the Jet Energy Scale (JES). JES indicates all the effects that -for a given measured jet energy- provide us with the information about the energy of the original parton. Both experiments are now calibrating *in situ* the JES by exploiting the constraint provided by the jets coming from the hadronic  $W$  decay. In this way the JES is included in the statistical uncertainty of the measurements and will improve with larger data sets. For example the statistical uncertainty of the CDF  $l + jets$  measurement (166 events) includes two contributions: 1.6 GeV/ $c^2$  from statistics and the remaining from JES.

With more than 2 fb<sup>-1</sup> on tape, the future of top quark measurements looks bright. The top mass will improve with the larger dataset, as the JES will be better constrained. Also, both experiments isolated a sample of  $Z \rightarrow b\bar{b}$  events that can be used to set the  $b$  specific jet energy scale. In figure 9 we show the prediction for the top mass measurement at CDF. While, for example CDF is already doing better than predicted in the TDR [12], it is difficult to establish what the asymptotic limit will be, but a precision < 1 % can be reached and the Tevatron can aim for a combined accuracy of  $\leq 1$  GeV/ $c^2$ , making this measurement a long lasting Tevatron legacy. Such an accuracy is, however, inducing both Collaborations to start addressing a number of effects that, too small to have an impact in the first measurements, can now become relevant. Moreover, a more general discussion of the meaning of the quantity measured is in order. CDF and D0, use Pythia Monte Carlo to generate top templates to which they compare data. With such an accuracy, of the order of the top natural width, one should be careful in interpreting the meaning of the measurement, in particular as we make larger use of DLM and ME methods.

The most significant recent result in terms of  $top$  production came from D0 which, for the first time, presented evidence for *single top* production. This purely EWK process proceeds through two ( $s$  and  $t$ ) channels, which have SM cross section of 0.88 and 1.98 pb respectively. While CDF sets a combined upper limit of 2.6 pb at 95 % C.L., D0 finds a

The new world average is  $M_{top} = 170.9 \pm 1.8$  GeV/ $c^2$ . While this measurement is largely dominated (about 70 %) by the results in the  $l + jets$  channel, the all-hadronic channel is acquiring a more prominent role. The systematic uncertainty in this measurement is already 2.1 GeV/ $c^2$  close to the 1.4 GeV/ $c^2$  of the lepton+jets channel.

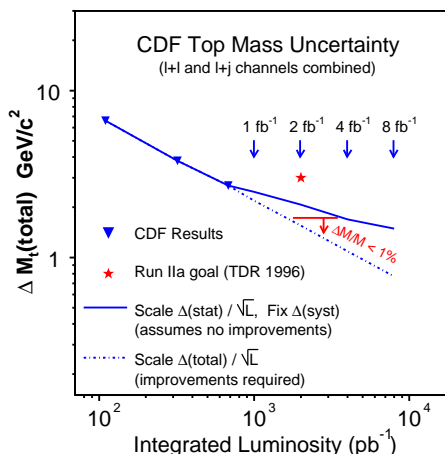


Figure 9: Prediction for  $M_{top}$  accuracy as a function of integrated luminosity.



3.4  $\sigma$  signal combining three analyses and advanced statistical techniques. The measured production cross section is  $4.9 \pm 1.4$  pb (Figure 10), as it is directly proportional to  $|V_{tb}|^2$ , D0 is able to set a direct limit  $0.68 < |V_{tb}| < 1$  at 95 % C.L.

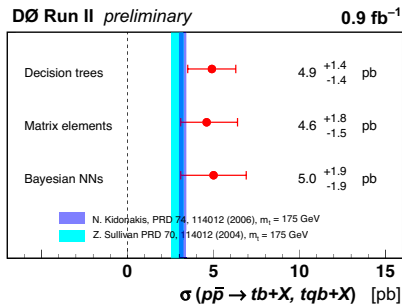


Figure 10: Evidence for single top.

end of Run 2 one might really gather (indirect) information on the  $M_{top}$  and  $M_W$  measurements.

While the indirect measurement was always seen as the major contribution of the Tevatron to Higgs hunting, in recent years the increased luminosity delivered by the accelerator pushed the two Collaborations aggressively to pursue direct Higgs searches. The experimental situation at the Tevatron has two bounds. One is the cross section. For low mass Higgs ( $< 120$  GeV/ $c^2$ ) direct production from gluon fusion is still  $\leq 1$  pb, while associated production of Higgs with  $W$  or  $Z$  boson is about an order of magnitude smaller. In this region Higgs decay  $\approx 80\%$  of the time directly into  $b\bar{b}$  pairs. The huge background due to heavy flavour jets prevents us from searching in the  $b\bar{b}$  channel while the low cross section prevents us from searching for this production mode through its rare -but almost background free- decays (like  $\gamma\gamma$ ). Therefore in this region we concentrate on the search in the  $WH$  and  $ZH$  channel where the  $W$  and  $Z$  provides a clean signature and (most) of the triggering opportunities. The Higgs decay into two  $bs$  can be exploited further to reduce the background by exploiting the  $b$ -tagging technique, as already done in  $top$  events.

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## 6 Higgs Searches

In the SM the Higgs mass is directly connected to the  $W$  and top mass, therefore precision measurements of the  $W$  and top mass mentioned above translate into a limit  $M_H < 144$  GeV/ $c^2$  at 95 % C.L. which rises to 182 GeV/ $c^2$  if one takes into account the (direct) LEP 2 limit of  $M_H > 114$  GeV/ $c^2$ . This result might imply some tension between the SM prediction and the observation, however it only appears at 1  $\sigma$  level. Figure 11 shows the 95 % C.L. contour which demonstrates how only by the

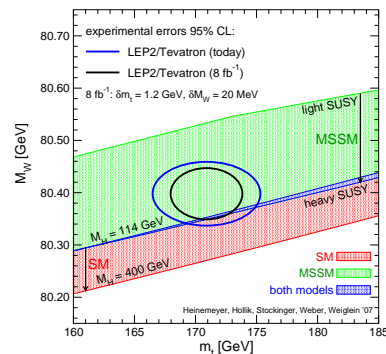


Figure 11: Constraints on SM and non-SM Higgs from indirect measurements

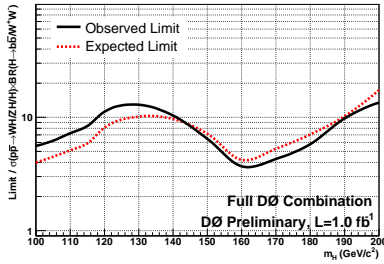


Figure 12: D0 direct Higgs limits ( $\simeq 1 \text{ fb}^{-1}$ ).

the combination of D0 results from many channels across the whole mass range of searches. The ratio 95% CL/SM is 8.4 for  $M_H = 115 \text{ GeV}/c^2$  and 3.7 for  $M_H = 160 \text{ GeV}/c^2$ . With respect to Summer 2006 more analyses were performed and new techniques were used.

CDF has not yet provided a full combination of its searches. The most recent results, all with  $\simeq 1 \text{ fb}^{-1}$  are in the  $ZH, Z \rightarrow ll, Z \rightarrow \nu\nu$  channels and in the  $H \rightarrow WW^*$  channel. In the first two searches the ratio with respect to the SM cross section is 16 (for  $M_H = 115 \text{ GeV}/c^2$ ) while for the third is 5.6 for  $M_H = 160 \text{ GeV}/c^2$  (equivalent to a cross section limit of 2.2 pb).

Unfortunately no official Tevatron combined limit is yet available and, indeed, for example, the D0 combined limit alone is already better than the previous (Summer 06) Tevatron combined. Despite that, it is clear that, even before the end of Run 2, the search for the Higgs at the Tevatron will provide useful input to the LHC experiments.

## 7 Searches for New Physics

The Tevatron is not only performing precision measurements of the SM, but is testing its frontier to check a number of theories which have been proposed as well as for any unknown possibility. It is not possible to fully present the whole set of analyses, ranging from SUSY to Extra Dimensions, Leptoquarks and more, which are, however, discussed in other contributions to this Conference [13]. Therefore I will only present a sample of recent results.

The SUSY paradigm is intensively tested, as already discussed in the flavour sector. First of all both CDF and D0 search for non-SM Higgs. As the SUSY Higgs has a large decay rate in  $\tau$  pairs, and its production can be enhanced for large  $\tan\beta$  both experiments developed a number of  $\tau$ -ID algorithms to exploit the good S/B ratio of

Recently the large data sample available opened up the opportunity to look for high mass Higgs ( $\simeq 160 \text{ GeV}/c^2$ ) directly produced by  $gg$  fusion and decaying into  $W$  pairs. By exploiting the leptonic decays of the  $W$  the background is very low and mostly due to SM processes. By increasing the acceptance as much as possible Tevatron experiments have become quite competitive.

Both D0 and CDF present results with  $1 \text{ fb}^{-1}$  in several channels. Figure 12 shows

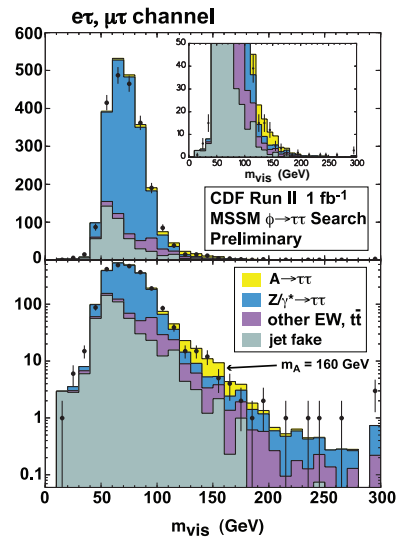


Figure 13: CDF Search for  $H \rightarrow \tau\tau$ .

the  $H \rightarrow \tau\tau$  channel. Dedicated triggers and extensive improvement of algorithms brought up the efficiency for this channel.  $\tau$  are identified through the detection of their debris in the  $\tau \rightarrow l + \nu\nu$  and the  $\tau \rightarrow$  hadronic decay. CDF searched for a discrepancy from SM expectations in the visible mass ( $m_{vis}$ ) distribution, where by  $m_{vis}$  we mean the invariant mass of the visible  $\tau$  decays and the missing  $E_T$ . In the region  $\simeq 150$  GeV/ $c^2$  a small excess of  $\simeq 2\sigma$  is visible in the channel where one of the two taus decays hadronically. Figure 13 shows a hypothetical Higgs with mass  $M_A = 150$  GeV/ $c^2$  superimposed on data. In the corresponding channel in which both  $\tau$ s decay leptonically the search does not have enough statistics to see a possible signal. D0 result does not exhibit a similar enhancement.

Another SUSY sector being tested is through the direct search for chargino and neutralino which are produced with sizeable cross sections. No signal is observed and therefore limits are set for  $M_{\chi^\pm}$  (figure 14).

Despite the large background and the small cross section, CDF performed a search for direct squark and gluino production in a sample of events containing large missing transverse energy and three jets. The negative result is converted in a limit in the  $M_{squark} - M_{gluino}$  plane (Fig. 15).

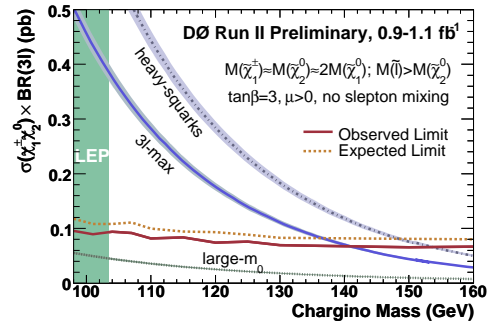


Figure 14: D0 limit for chargino production.

## 8 Conclusion

With more than  $2 \text{ fb}^{-1}$  already on tape, and the prospects of integrating between 6 and  $8 \text{ fb}^{-1}$ , the Tevatron experiments are now testing the standard model at its boundaries. The detectors are well understood and the analyses are now mature, therefore the precision study of known processes can be used to measure structure functions, test theoretical calculations and challenge measurements performed elsewhere. The measurement of  $M_W$  and  $M_{top}$  can represent an enduring legacy of the Tevatron well after the LHC starts taking data. The large datasets allow to search for new physics and for the yet undetected Higgs particle which now appears -for some mass ranges- within reach.

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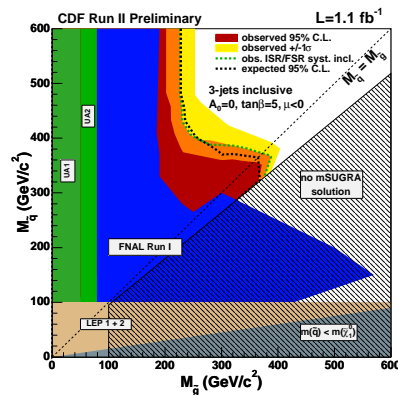


Figure 15: CDF limits in the  $M_{Squark} - M_{gluino}$  plane.

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