

Recent Results from CDF

Searches for New Particles Top Quark Physics

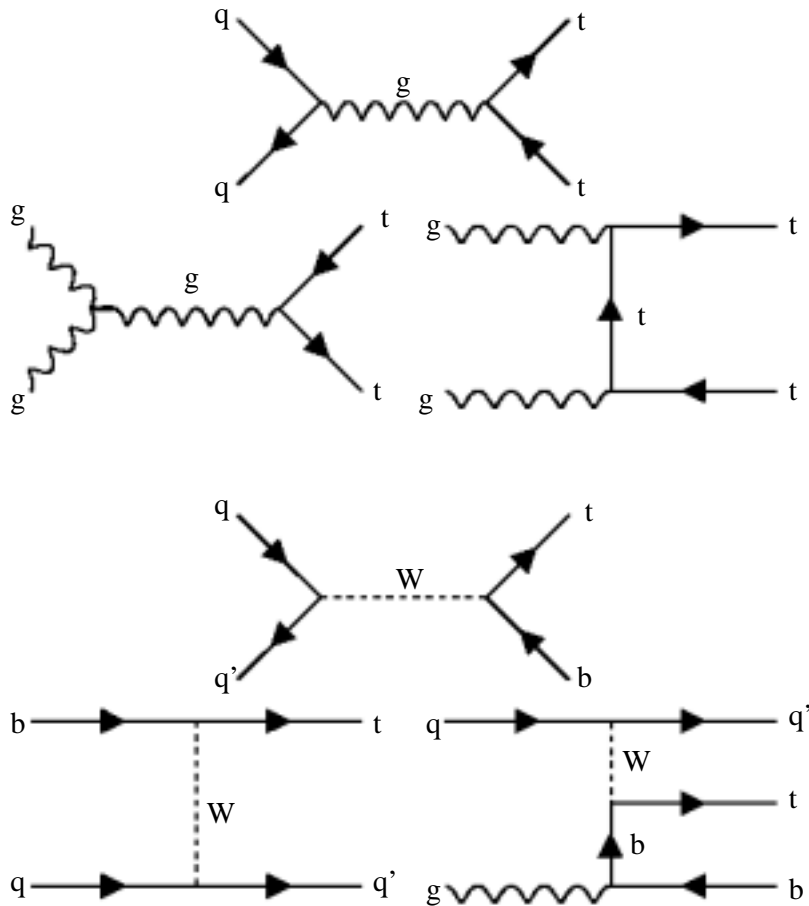
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Grant in Aid for Scientific Research on Priority Areas:
Mass Origin and Supersymmetry Physics
University of Tsukuba
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Top Quark Physics

- Tevatron has been the only place to study the top quark until LHC will start in ~ 2008
 - Discovered by CDF and D0 in 1995
- **Top mass: $175 \text{ GeV}/c^2$**
 - Why is top so heavy ?
 - Is top involved in the breaking of EW symmetry ?
 - Is it connected to any new physics ?
- **Top width: 1.4 GeV**
 - the decay time is less than hadronization scale
→ decays as a free quark
 - decay products tell us about top polarization

Top Production at the Tevatron



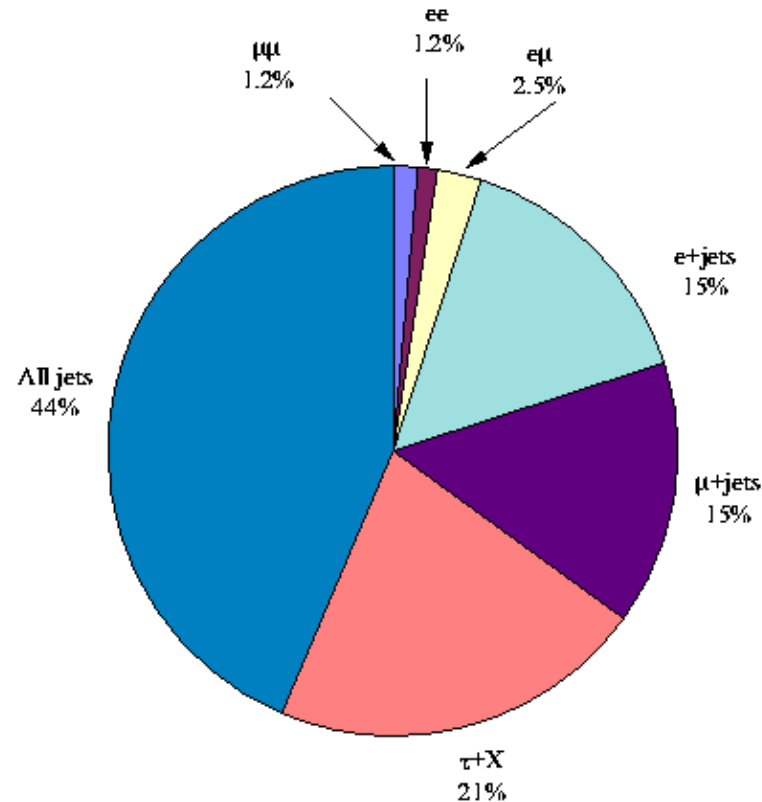
- $t\bar{t}$ pair production
 - $\sigma(t\bar{t}) \sim 5 \text{ pb}$ ($\sqrt{s} = 1.8 \text{ TeV}$)
 - $\sim 7 \text{ pb}$ ($\sqrt{s} = 1.96 \text{ TeV}$)
- $q\bar{q}$ annihilation
 - $\sim 90 \%$ ($\sqrt{s} = 1.8 \text{ TeV}$)
 - $\sim 85 \%$ ($\sqrt{s} = 1.96 \text{ TeV}$)
- gluon fusion
 - $\sim 10 \%$ ($\sqrt{s} = 1.8 \text{ TeV}$)
 - $\sim 15 \%$ ($\sqrt{s} = 1.96 \text{ TeV}$)
- single top production
 - $\sigma(t) \sim 2.4 \text{ pb}$ ($\sqrt{s} = 1.8 \text{ TeV}$)
 - $\sim 3 \text{ pb}$ ($\sqrt{s} = 1.96 \text{ TeV}$)
 - virtual $W \sim 32 \%$
 - W -gluon fusion $\sim 62 \%$

Top Quark Decay

In Standard Model, $\text{Br}(t \rightarrow W^+b) \simeq 100\%$

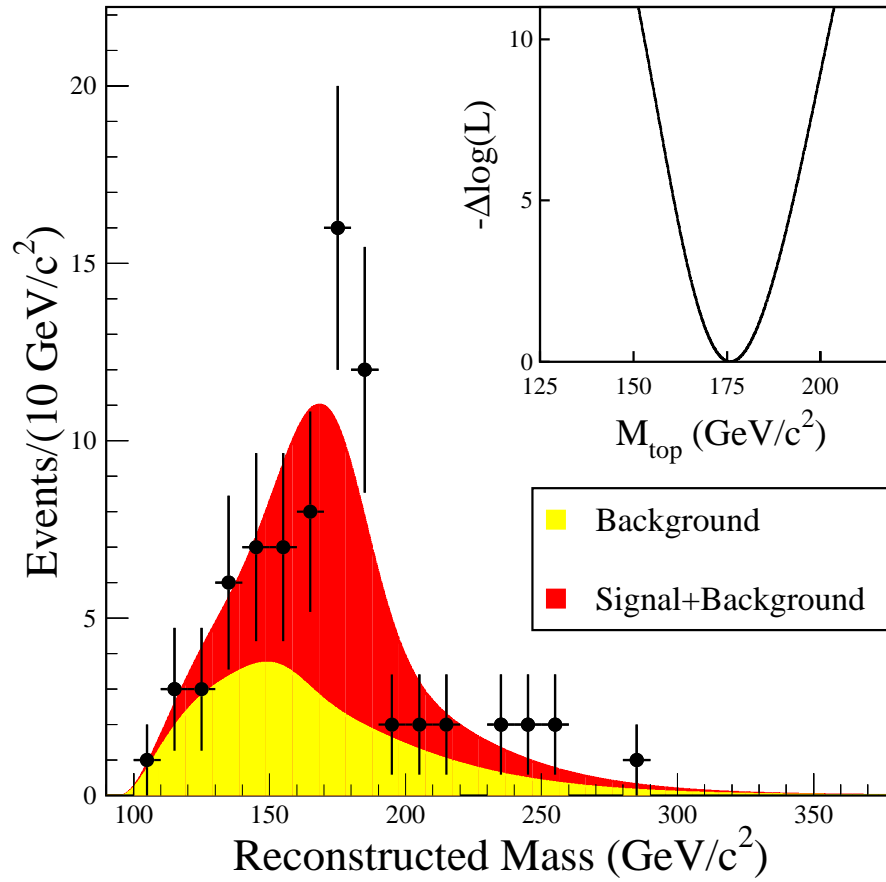
$t\bar{t}$ final states are classified according to the W decay

- Dilepton channel
($l^+\nu + l^-\nu + b\bar{b}$, 5%)
no b -tag required
- Lepton + Jets channel
($l\nu + q\bar{q}' + b\bar{b}$, 30%)
- All hadronic
($q\bar{q}' + q''\bar{q}''' + b\bar{b}$, 44%)
- ($W \rightarrow \tau\nu$)



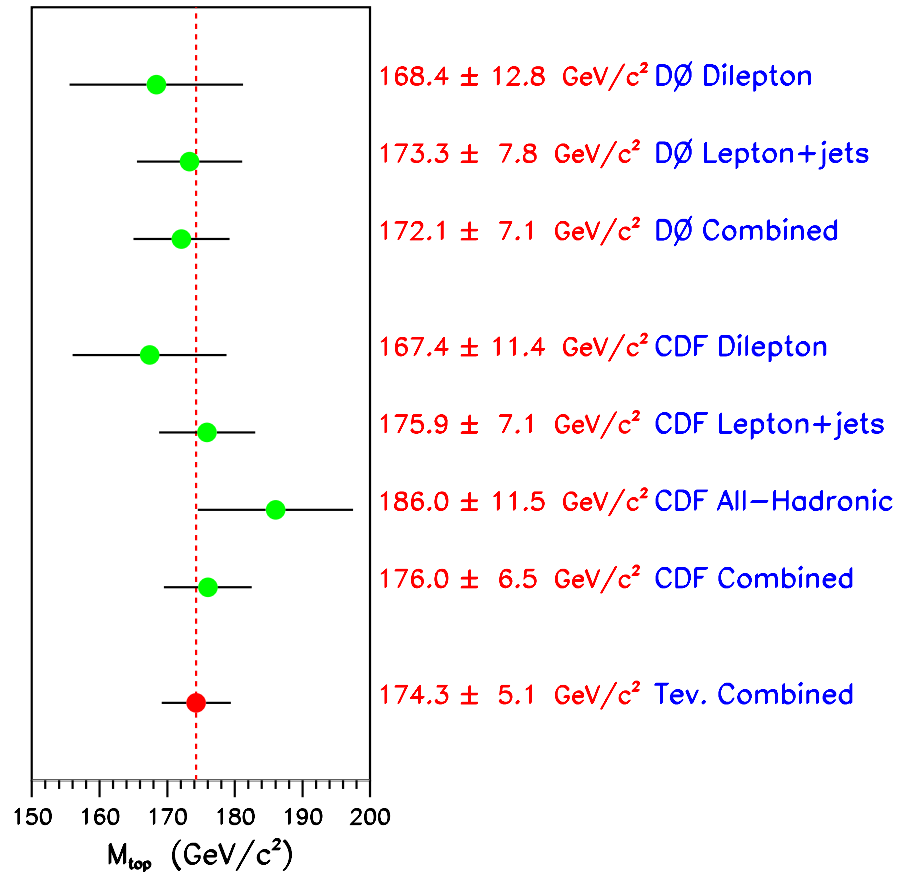
b -tagging : Soft Lepton Tag ($b \rightarrow l\nu c$), Secondary Vertex Tag

m_{top} measurements in Run 1

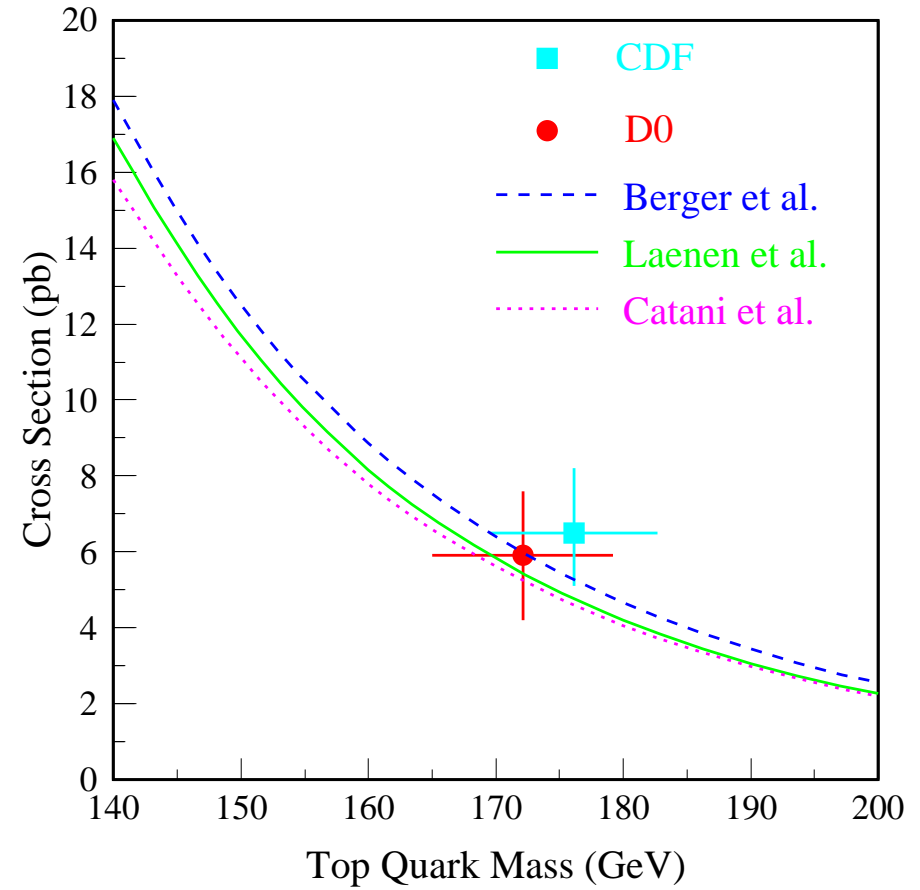
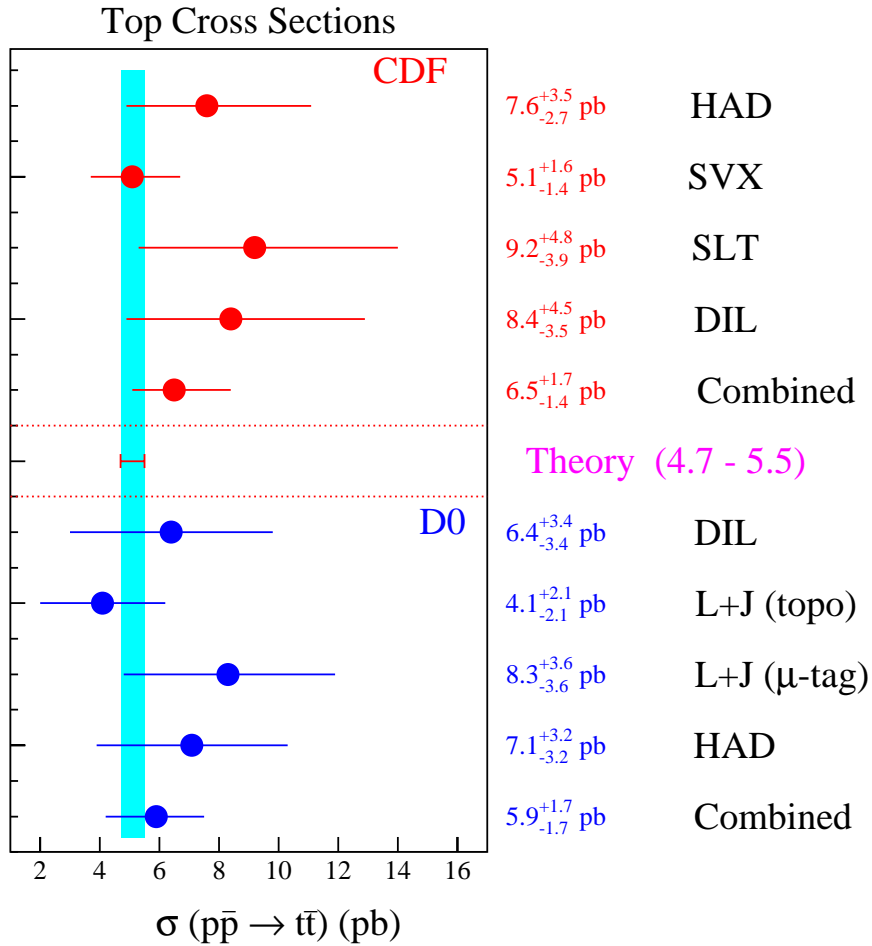


Lepton + Jets: 76 events

Tevatron Top Quark Mass Measurements



$\sigma(t\bar{t})$ results in Run 1



Single top search in Run 1

- Direct probe of V_{tb} of EW Wtb vertex

- Background for Higgs events

$$W + b + \bar{b} (W^*)$$

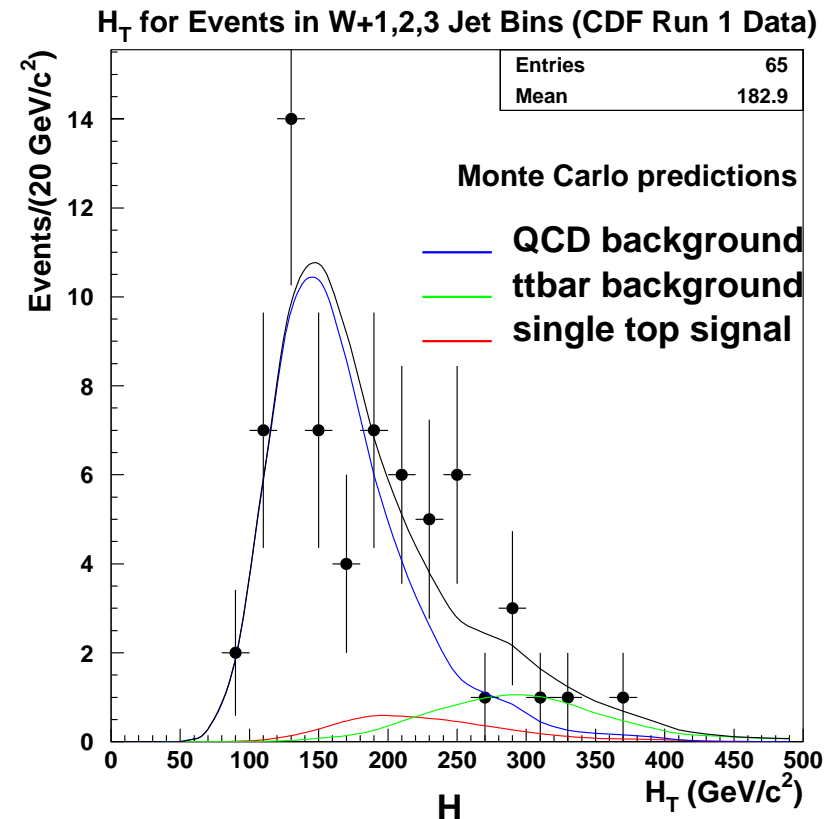
$$W + b + q (Wg \text{ fusion})$$

- Unbinned maximum likelihood fit to H_T distribution

$$(H_T \equiv |\cancel{E}_T| + |E_T(l)| + \sum |E_T(\text{all jets})|)$$

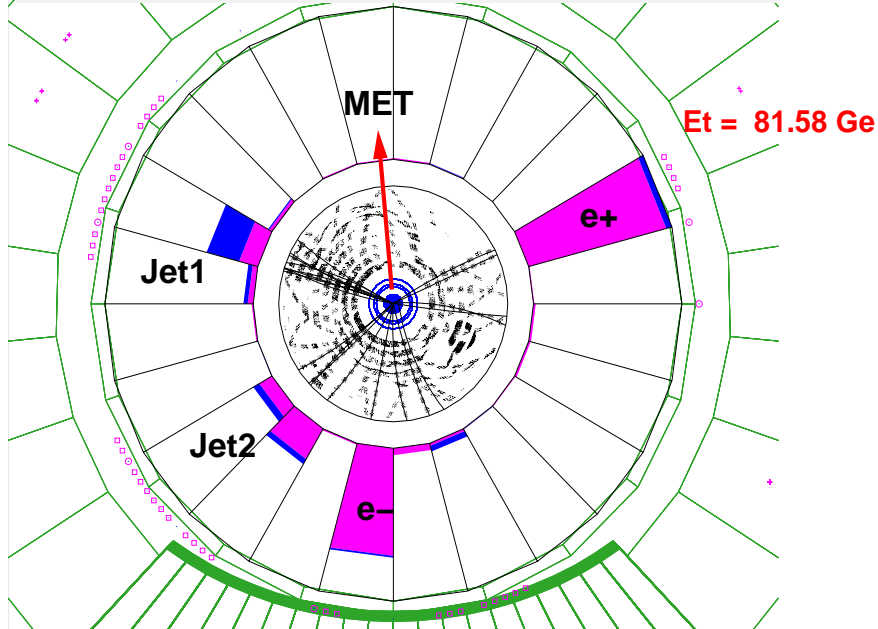
$$\rightarrow \sigma(W^* + Wg) < 14 \text{ pb}$$

- Expect **single top discovery** in Run 2 if SM is correct

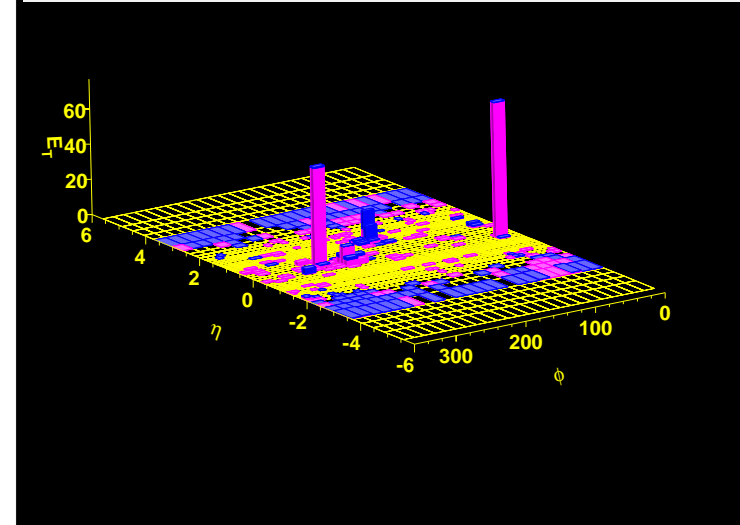








Top Dilepton Candidate in Run 2

Event : 54713 Run : 136286 EventType : DATA | Unpresc: 0,33,2,3,5,7,8,9,10,11,12,13,16,17,19,21,53,23,55,25 Presc: 0,2,8,10,12



Event : 54713 Run : 136286 EventType : DATA | Unpresc: 0,33,2,3,5,7,8,9,10,11,12,13,16,17,19,21,53,23,55,25 Presc: 0,2,8,10,12,16,25 Myron mode: 0



-  $e^+ : E_T = 73 \text{ GeV}$
-  $e^- : E_T = 56 \text{ GeV}$
-  Jet 1 : $E_T = 35 \text{ GeV}$
-  Jet 2 : $E_T = 34 \text{ GeV}$
-  MET = 43 GeV
-  $M(e^+e^-) = 118 \text{ GeV}$

$\sigma(t\bar{t})$ in Dilepton Channel in Run 2

- Measurement of the cross section is a “counting experiment”

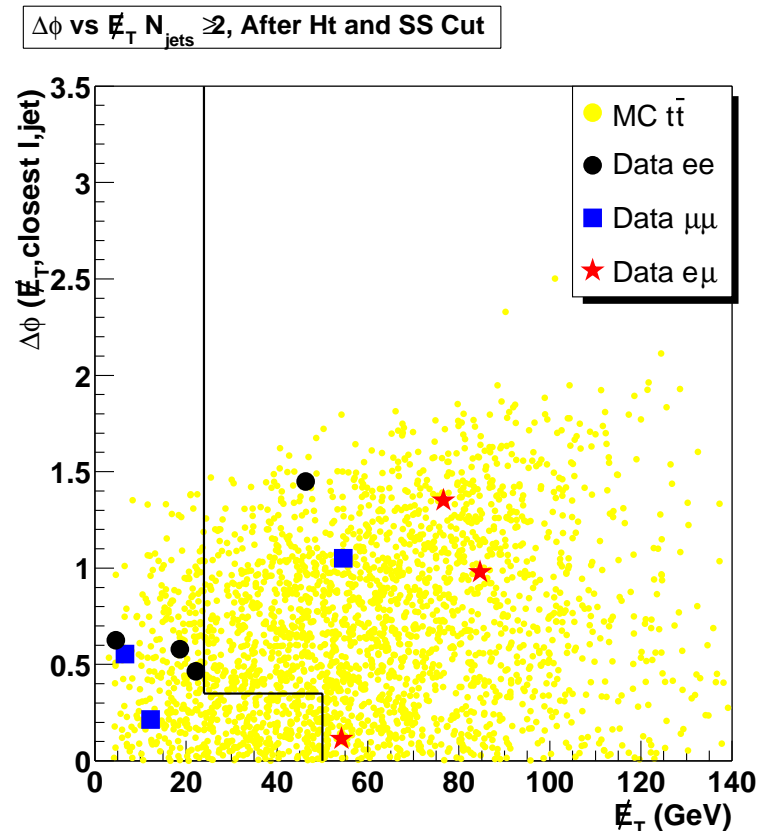
$$\sigma_{t\bar{t}} = \frac{N_{obs} - N_{bkg}}{\epsilon \cdot \int \mathcal{L}}$$

- $\int \mathcal{L} = 72 \text{ pb}^{-1}$, $N_{obs} = 5$,
 $N_{bkg} = 0.30 \pm 0.12$

Main backgrounds: WW , $Z \rightarrow \tau\tau$

- $\sigma_{t\bar{t}} = 13.2 \pm 5.9(\text{stat}) \pm 1.5(\text{syst})$

- agree with the extrapolation of Run 1 measurement: 11.0 ± 6.0



$\sigma(t\bar{t})$ in Lepton+Jets Channel in Run 2

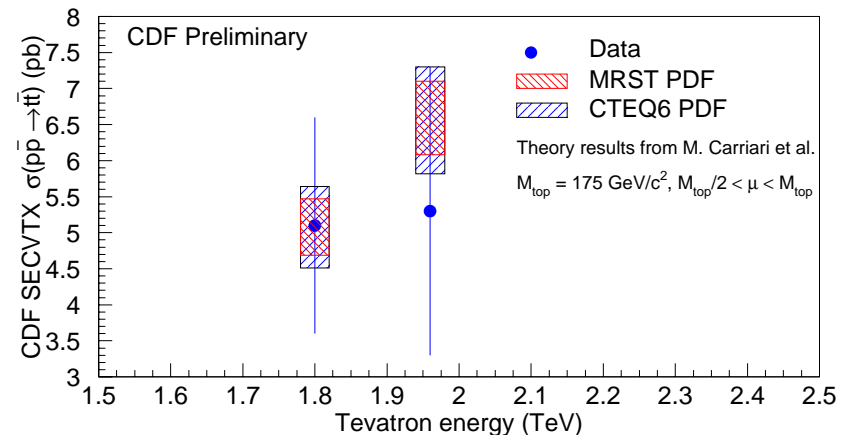
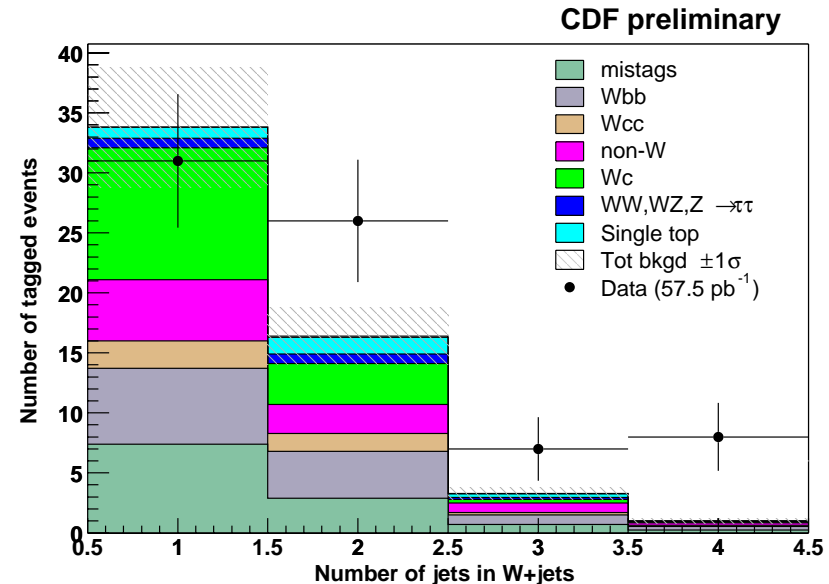
- Data taken from March 23rd to January 13th including Silicon: 57.5 pb^{-1}

- b -tagging with SecVtx

- In ≥ 3 jet bin,
 $N_{obs} = 15, N_{bkg} = 3.8$

- $\sigma_{t\bar{t}} = 5.3 \pm 1.9(\text{stat}) \pm 0.8(\text{syst})$

- good agreement with the theory prediction



Indirect Higgs Mass Constraint

With 2 fb^{-1} (Run 2a)

$\Delta M_{top} \sim 3 \text{ GeV}/c^2$

Improved b -tagging

Jet energy scale

($Z \rightarrow b\bar{b}$)

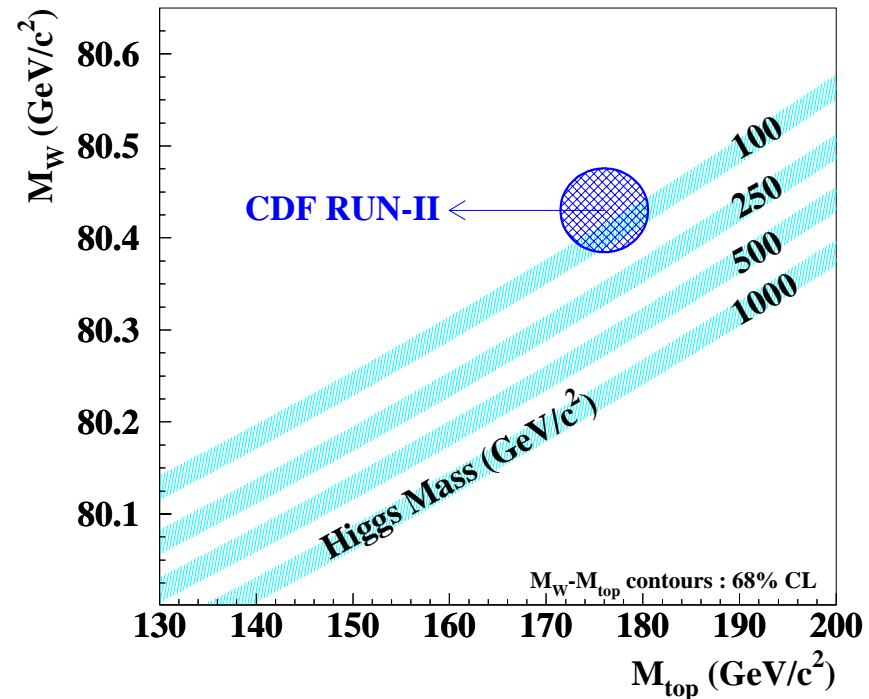
$\Delta M_W \sim 30 \sim 40 \text{ MeV}/c^2$

Systematic errors are

dominant

Constraint for Higgs mass:

$\delta M_H/M_H \sim 40 \%$



SM Higgs Search at the Tevatron

● 'Light' Higgs ($m_H < 130$ GeV/ c^2)

● $q\bar{q}' \rightarrow WH \rightarrow l\nu b\bar{b}$ ($,q\bar{q}'b\bar{b}$)

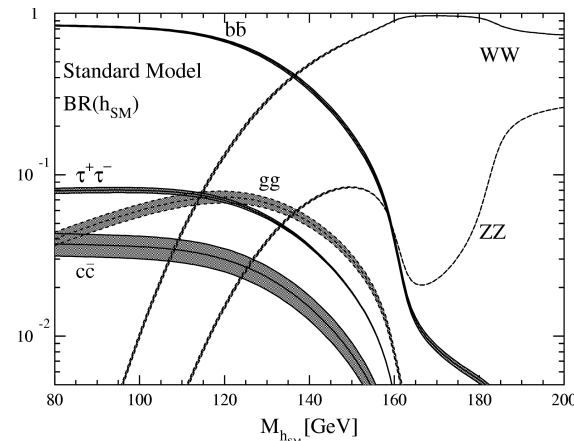
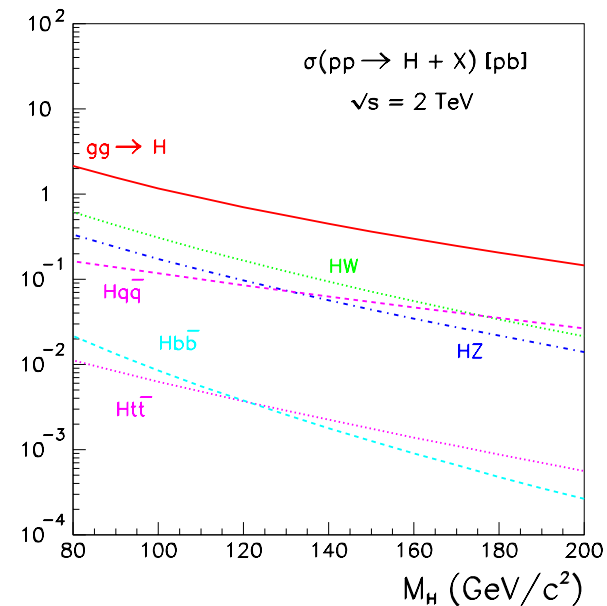
● $q\bar{q} \rightarrow ZH \rightarrow l^+l^- b\bar{b}, \nu\nu b\bar{b}$ ($,q\bar{q}b\bar{b}$)

● 'Heavy' Higgs ($130 < m_H < 180$ GeV/ c^2)

● $gg \rightarrow H \rightarrow WW \rightarrow l^+l^- \nu\bar{\nu}$

● $q\bar{q}' \rightarrow WH \rightarrow l^\pm \nu WW \rightarrow l^\pm \nu l^\pm \nu jj$

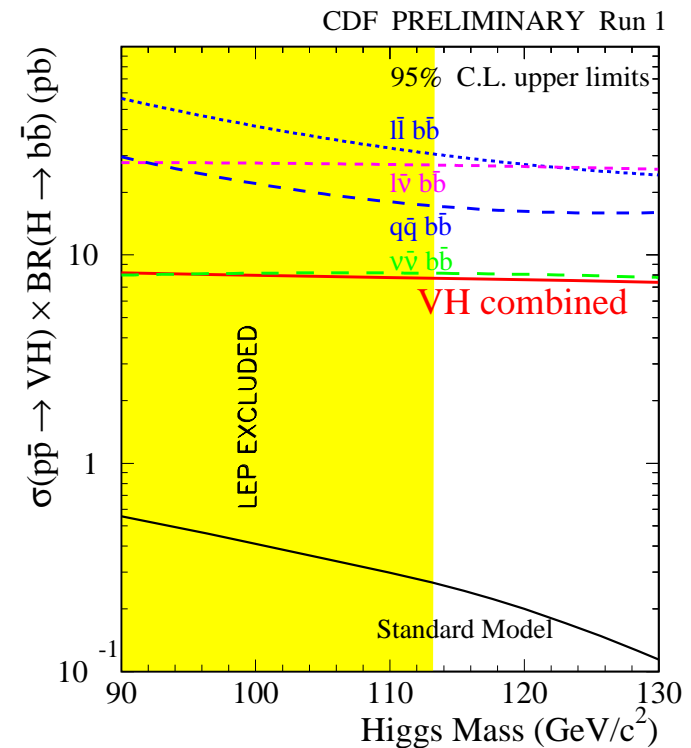
● $q\bar{q}' \rightarrow ZH \rightarrow l^\pm l^\mp WW \rightarrow l^\pm l^\mp l^\pm \nu jj$



Run 1 SM Higgs Searches

🔴 Searched for $(W, Z)H$ production in 4 channels

channel	L, pb^{-1}	N(obs)	N(bkg)
$llb\bar{b}$	106 ± 4	5	4.0 ± 1.0
$\nu\nu b\bar{b}$	87 ± 4	4	4.9 ± 0.6
$l\nu b\bar{b}$	106 ± 4	6	3.8 ± 0.7
$qqb\bar{b}$	87 ± 4	589	594 ± 30



For $m_H = 130$ GeV,

$$\sigma(p\bar{p} \rightarrow VH) * \text{Br}(H \rightarrow b\bar{b}) < 7.4 \text{ pb @ 95\% CL}$$

SM Higgs Search Projections for Run 2

● Run 2 improvements:
Luminosity, E_{cm} , B -jet trigger, B -tagging, jet energy resolution

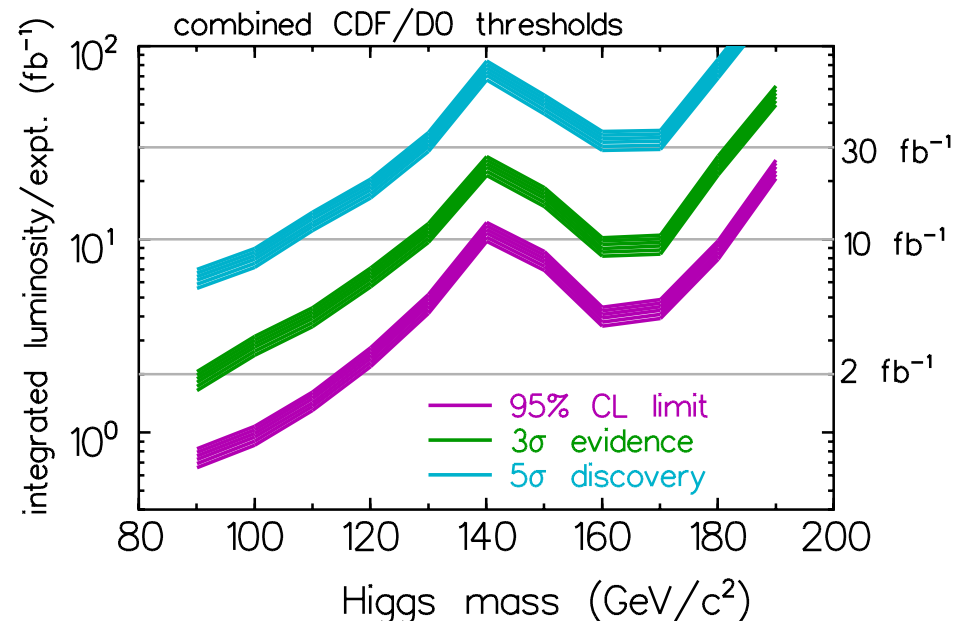
● Run 2a (2 fb^{-1})

● Exclude SM Higgs for masses up to $120 \text{ GeV}/c^2$

● Run 2b ($\sim 15 \text{ fb}^{-1}$)

● Exclude mass range up to $\sim 180 \text{ GeV}/c^2$

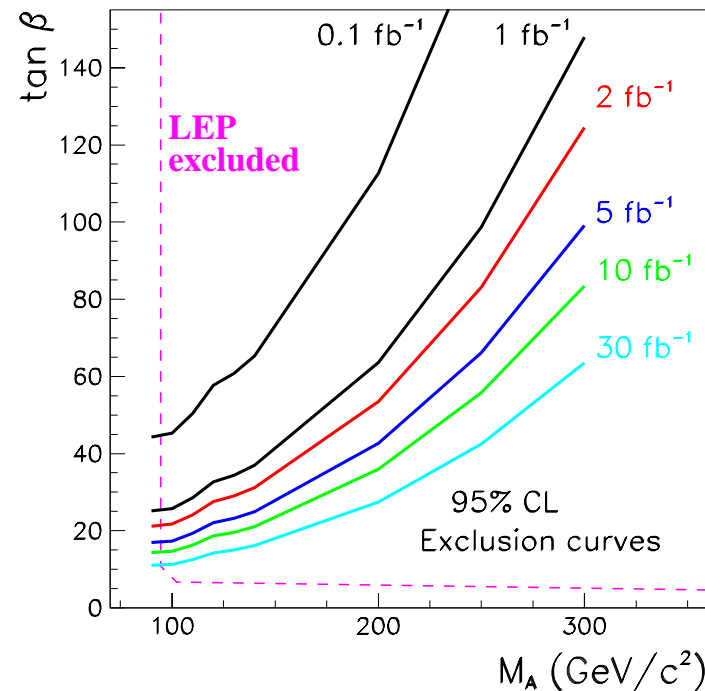
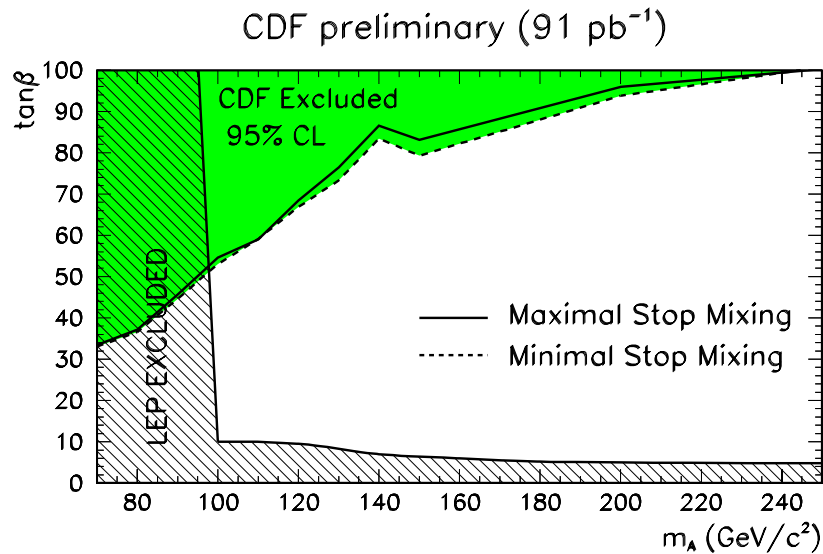
● 5σ discovery if $m_H < 120 \text{ GeV}/c^2$



Higgs Boson in MSSM

- 2 Higgs doublets
- 5 scalar particles
 - 2 neutral CP-even: h, H
 - 1 neutral CP-odd: A
 - 2 charged: H^\pm
- 2 parameters: $\tan\beta$ and M_A
- Mass constraints: $M_h < 135 \text{ GeV}$, $M_{H^\pm} > M_W$
- Signatures may be enhanced at large $\tan\beta$:
 - $\phi \text{ } bb \rightarrow bbbb$ ($\phi = h, H, \text{ or } A$)
- New signature: $t \rightarrow bH^+$, $H^+ \rightarrow \tau\nu$
- τ can be triggered in Run 2
 - $H^+ \rightarrow \tau\nu$, $\phi \rightarrow \tau\tau$

MSSM Higgs Searches



Run 1 search

- 4 jets: $E_T > 15$ GeV
- 3 b -tags
- Reconstruct $M(bb)$
- Backgrounds: dominated by QCD

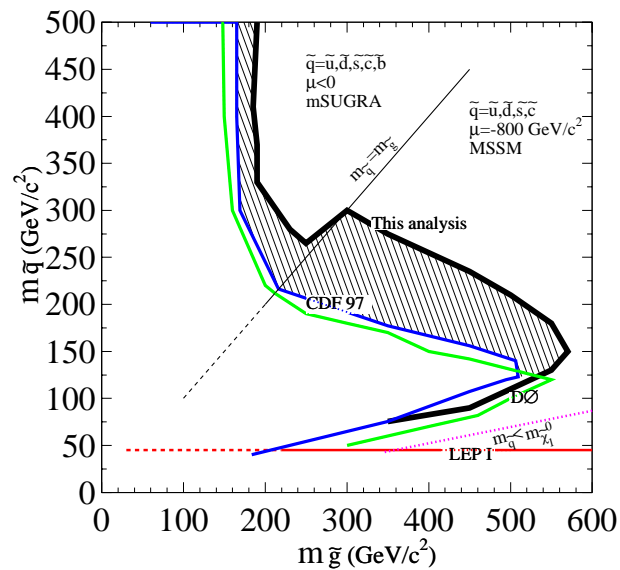
In Run 2

5 σ discovery reach @ 5 pb⁻¹:
 $M_A \leq 150$ GeV/ c^2 for tan β =40

Searches for Squarks and Gluinos

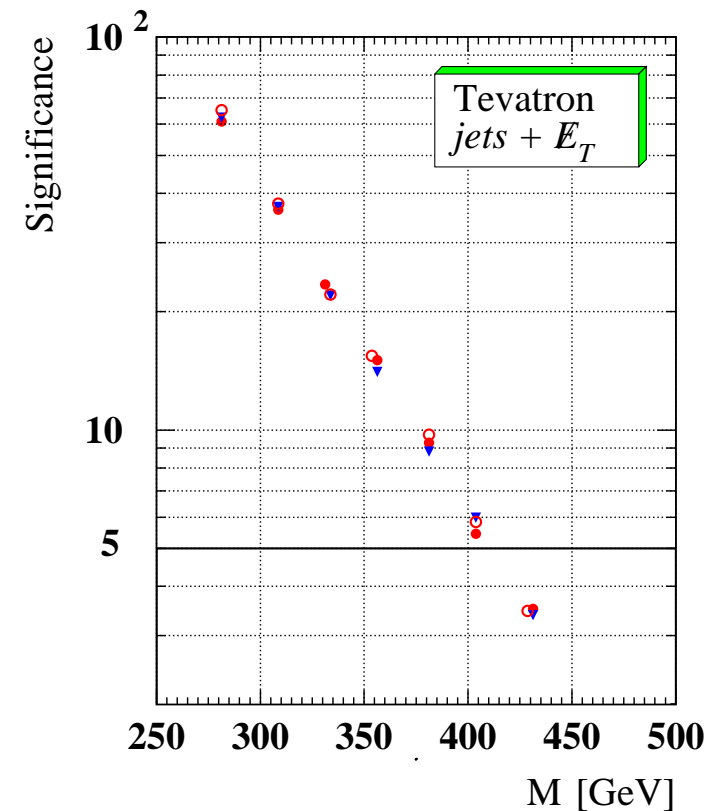
Run 1 search

- ≥ 3 jets + \cancel{E}_T events
(\cancel{E}_T originates from LSPs)
- $M_{\tilde{g}} > 190 \text{ GeV}/c^2$
- $M_{\tilde{q}} > 300 \text{ GeV}/c^2$ if $M_{\tilde{g}} \simeq M_{\tilde{q}}$



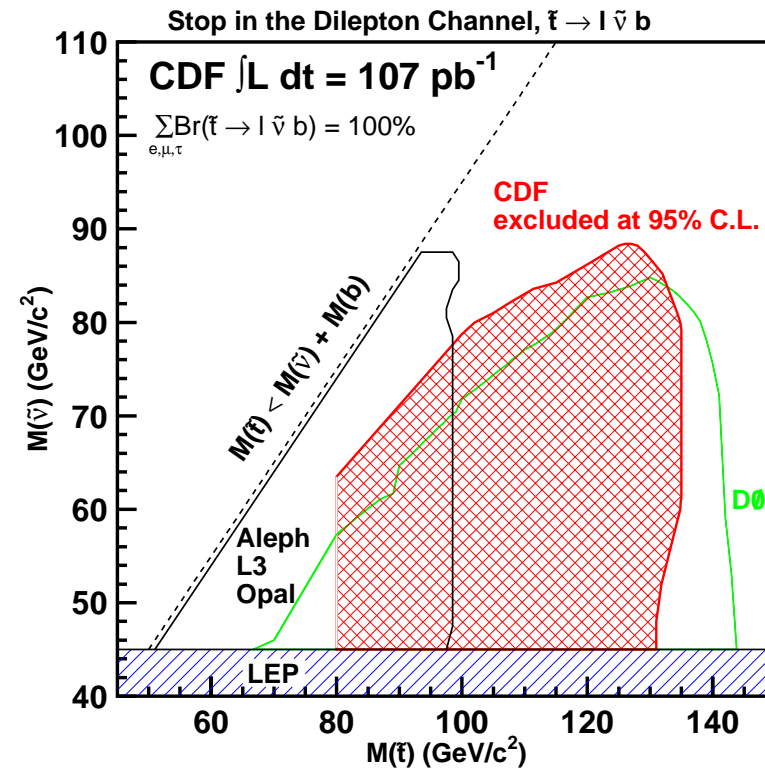
95 % CL curve ($\tan \beta = 3$)

Run 2 projection (15 fb⁻¹)



Searches for RPC stop in Run 1

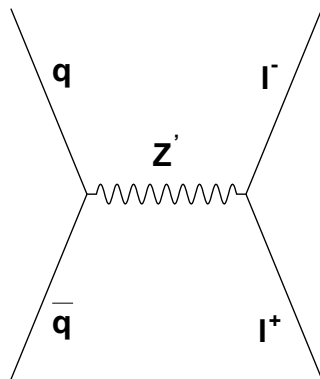
- Stop pair produced
 $(q\bar{q}, gg \rightarrow t\bar{t})$
- Assuming heavy charged sleptons
 $\sum_{l=e,\mu,\tau} \text{Br}(\tilde{t} \rightarrow bl^+\tilde{\nu}_l) = 1$
- $t\bar{t} \rightarrow l^+l^-\tilde{\nu}_l\tilde{\nu}_l\bar{b}\bar{b}$ final state
 $\rightarrow l^+l^- + \cancel{E}_T + \geq 1$ jets
- observed: 0
background:
 $1.52 \pm 0.26(\text{stat}) \pm 0.32$
(syst)



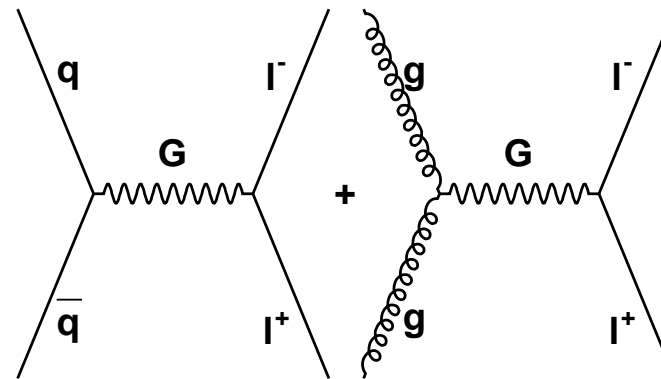
Drell-Yan Production

- Drell-Yan events can be used to search for:
 - New gauge bosons (Z')
 - Large extra Dimensions
 - quark-lepton compositeness, etc
- Expect cross section enhancement

New gauge boson

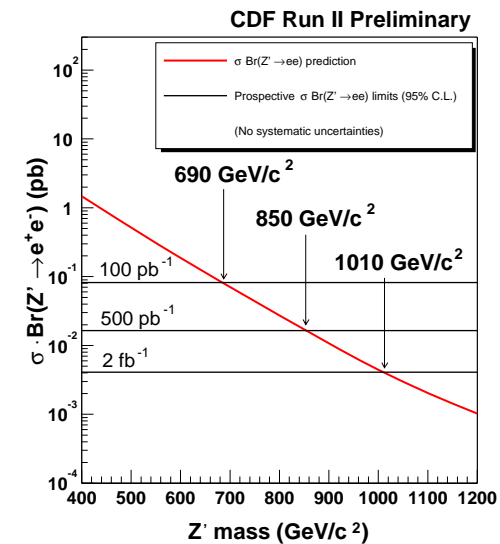
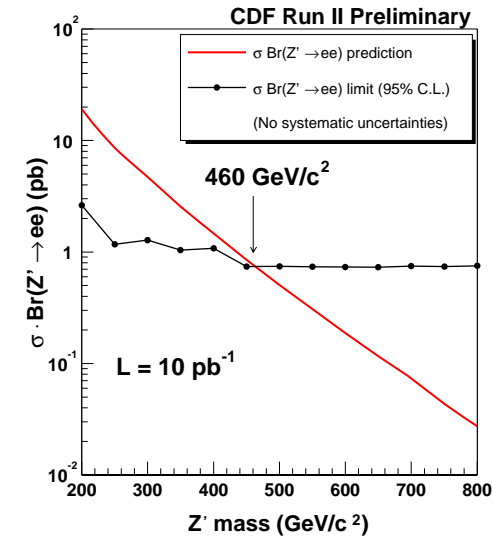


Large extra dimension



Z' Search

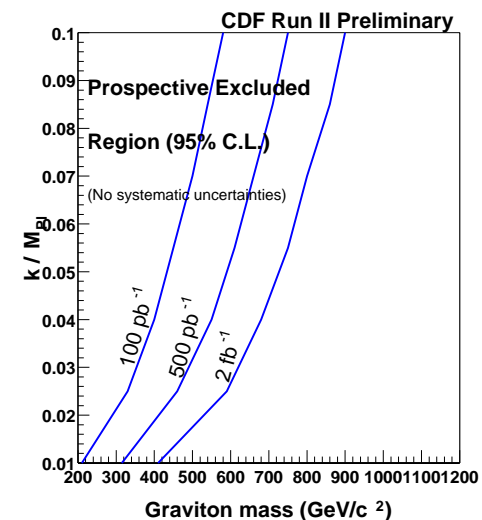
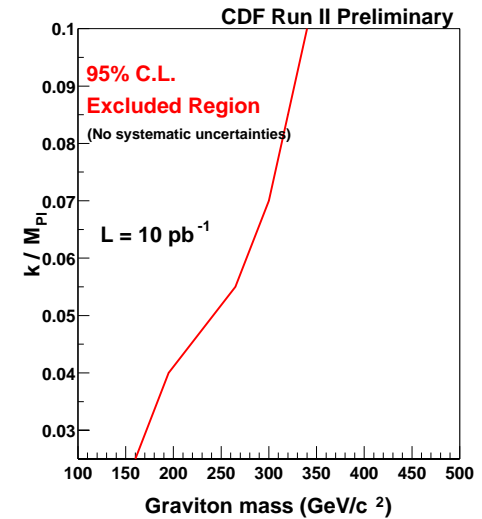
- Dielectron channel:
 $M_{Z'} > 460 \text{ GeV}/c^2$ (10 pb^{-1})
- Dimuon channel:
 $M_{Z'} > 275 \text{ GeV}/c^2$ (16 pb^{-1})
- Run 1 limit: $M_{Z'} > 690 \text{ GeV}/c^2$
from $ee + \mu\mu$ channels
- Run 2a reach: $\sim 1000 \text{ GeV}/c^2$



Large Extra Dimensions

- Randall-Sundrum graviton
 - Excited graviton in 5 dimensions
 - parameters: M_G , k/M_{pl}
 (k/M_{pl} : dimensionless coupling)

- Lower limit on RS graviton mass for 10 pb^{-1} :
 $340 \text{ GeV}/c^2$ ($k/M_{pl} = 0.1$)
 from ee channel



Summary

- Reestablished some of the basic signals
- Measured $t\bar{t}$ cross sections in Run 2
- Searches for new particles in Run 2 have already started
- More results will be released soon