



Tevatron Searches (non-SUSY)



Aspen Winter Conference

February 2005

Stefan Grünendahl

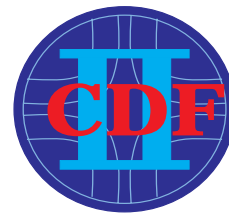
For the DØ+CDF collaborations

Outline:

- Tevatron status and luminosity projection
- DØ+CDF detector status + plans
- Recently updated searches by channel
 - Dileptons
 - Photons
 - Leptons + missing E_T
 - Jets + missing E_T
 - Other channels



Tevatron Luminosity Outlook



Tevatron

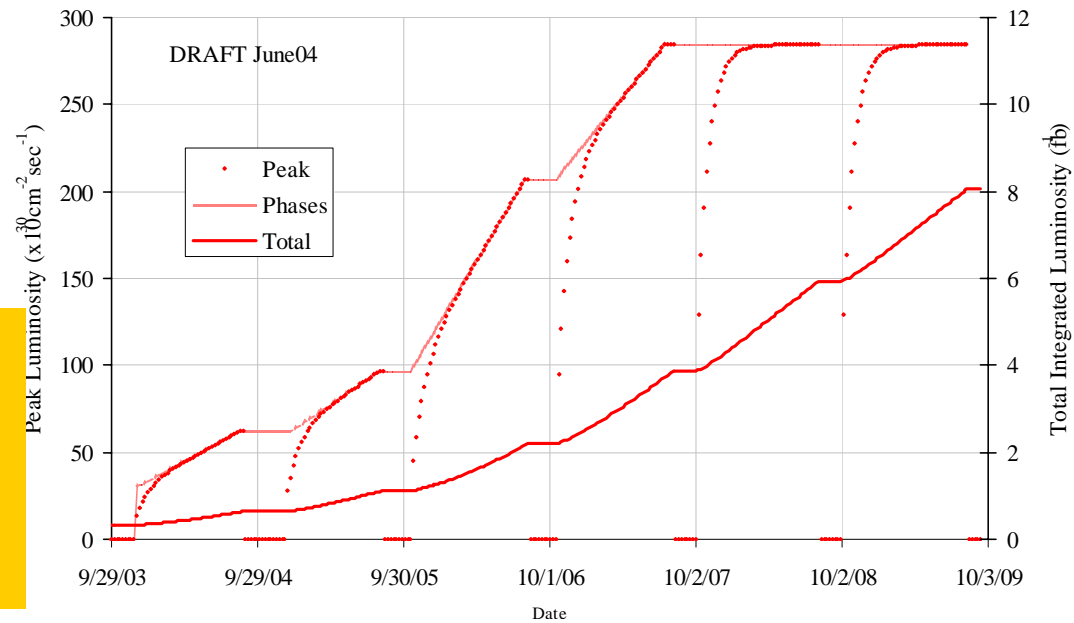
Run I: 130 pb^{-1} @ $\sqrt{s}=1.8 \text{ TeV}$

Run II: @ $\sqrt{s}=1.96 \text{ TeV}$; 0.5 fb^{-1} recorded until 2005-1-10

Current maximum instantaneous luminosity $\sim 100 \times 10^{30} \text{ cm}^{-2} \text{ s}^{-1}$

$p\bar{p}$ collider Z' reach

- 1983: 91 GeV (Z discovery)
- 1985: 180 GeV
- 1989: 218 GeV (SppS 7.4 pb^{-1} @ $\sqrt{s}=630 \text{ GeV}$)
- 1996: 690 GeV (TEV Run I 110 pb^{-1} @ $\sqrt{s}=1.8 \text{ TeV}$)
- 2004: 815 GeV (TEV Run II 200 pb^{-1} @ $\sqrt{s}=1.96 \text{ TeV}$)

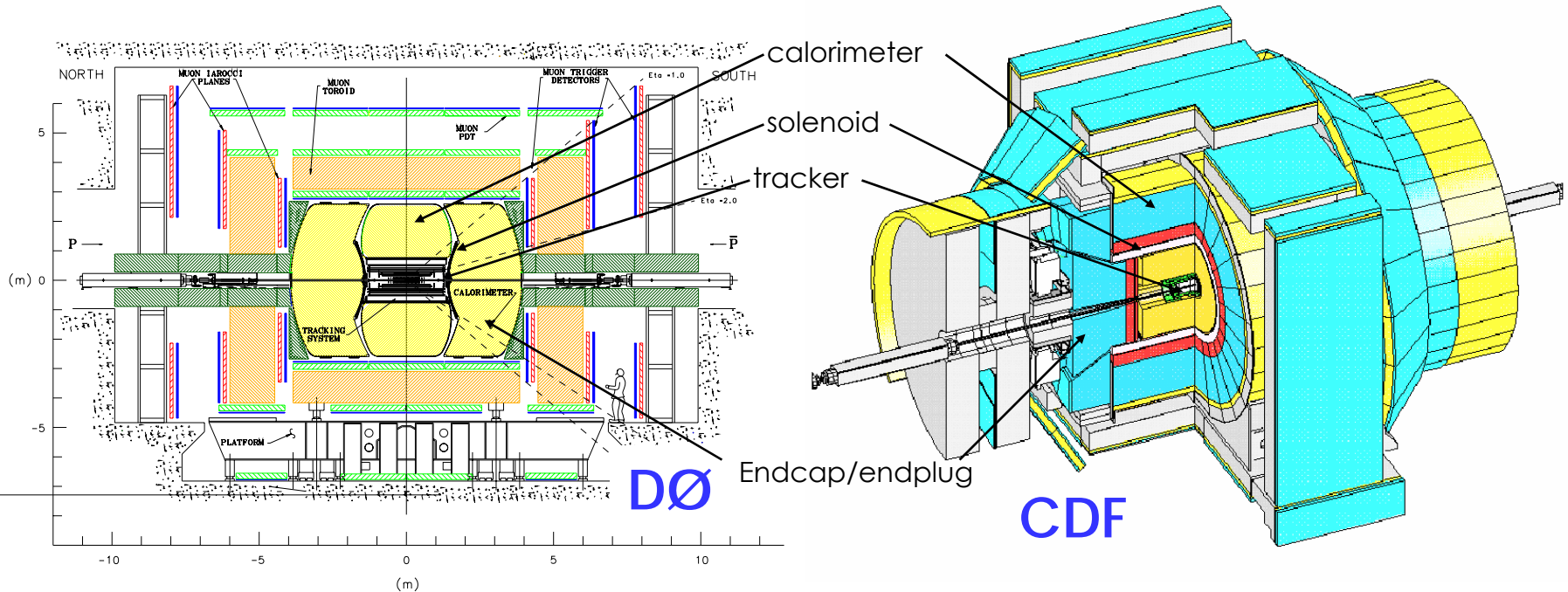




The Detectors



- Both are 4π detectors with central solenoid and silicon vertex tracker
- Differences in calorimetry, outer tracker, muon systems
- More upgrades for 2005:
 - CDF: preshower (is installed), EM timing, various trigger improvements
 - DØ: Layer 0 Silicon, Tracker readout, various trigger improvements





cross reference: search vs. signature



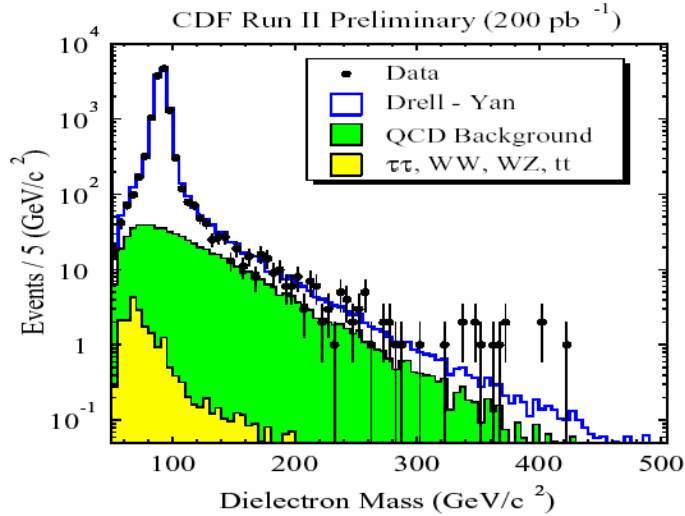
Signature marked in blue:

updated since 6/2004

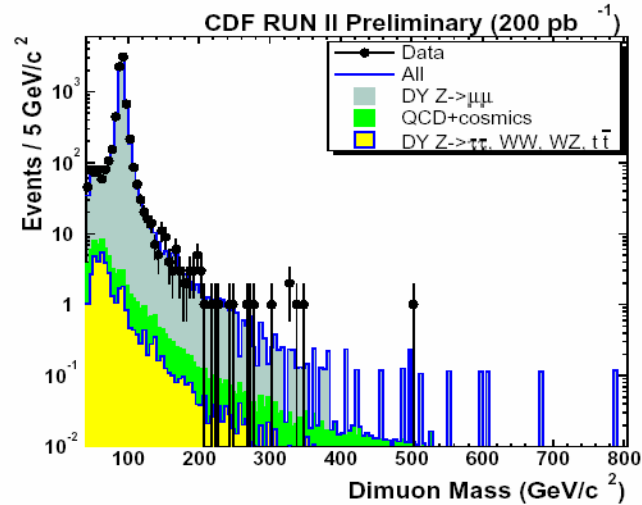
Extra Dimensions	$ee, \mu\mu, \gamma\gamma, \text{jets} + \text{MET}$
Eq compositeness	$ee, \mu\mu$
W'	$e\nu$
Z'	$ee, \mu\mu, \tau\tau$
Techni-rho	$(e\nu, \mu\nu) + bQ$ (Q=b or c)
Leptoquarks	$(ee, e\nu, \mu\mu, \mu\nu) + \text{jets}$ (combined limits), acoplanar multijets
WH	Lepton + MET + jets w/ b-tag
$H \rightarrow WW^*$	$(ee, \mu\mu) + \text{MET}$
$H \rightarrow WWW^*$	Like-sign dileptons
Stable H^{++}	Stable double-charged particle
Magnetic Monopoles	Custom trigger + tracking
Long-lived b'	Z from offset vertex



Dileptons

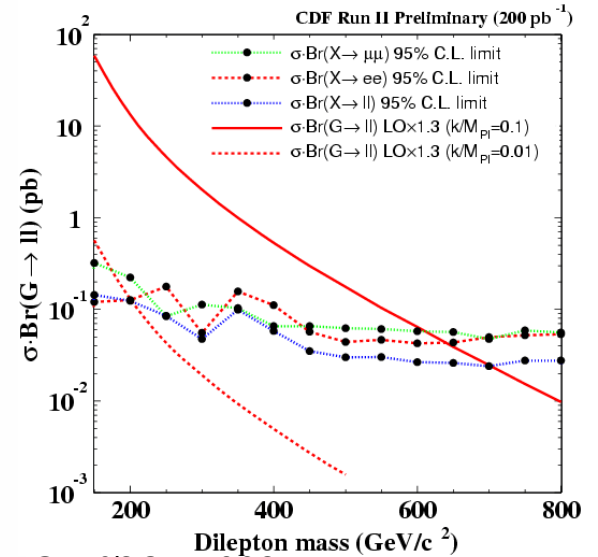
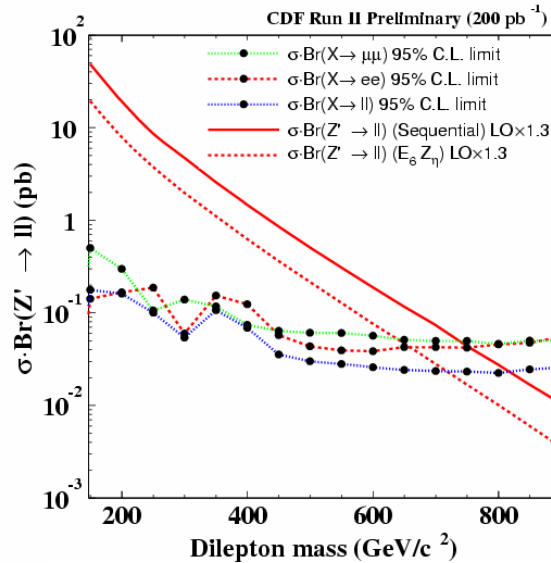
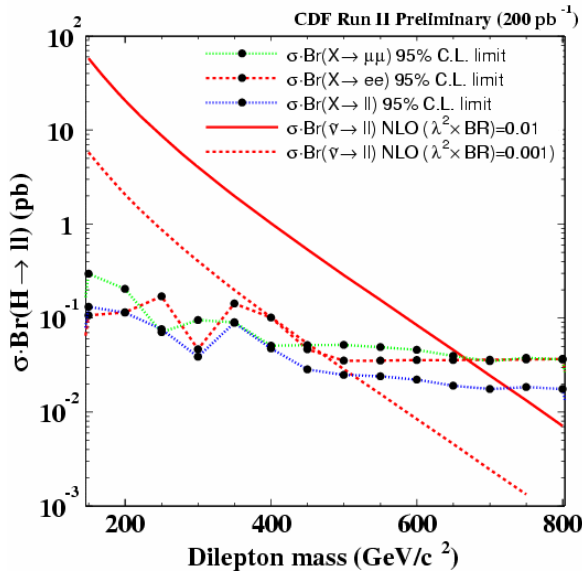


spin 0



spin 1

spin 2





dileptons: mass limits



TABLE II: Dilepton Results for E_6 Z' 's.

E ₆ Mass Limit at 95%C.L (GeV/c ²)			
Model	ee	μμ	ℓ ⁺ ℓ ⁻
Z' _{SM}	750	735	815
Z' _ψ	635	600	690
Z' _χ	620	585	670
Z' _η	655	640	715
Z' _I	575	540	610

DØ: 780 (ee, 200 pb⁻¹)
680 (μμ, 250 pb⁻¹)

650 (ee, 200 pb⁻¹)

640 (ee, 200 pb⁻¹)

680 (ee, 200 pb⁻¹)

575 (ee, 200 pb⁻¹)

TABLE IV: Dilepton Results for Techni-mesons, ρ_T, ω_T .

TC Mass Limit at 95%C.L (GeV/c ²)	
M_T	ℓ ⁺ ℓ ⁻
500	320
400	315
300	310
200	225
100	

DØ: 367/355 (m_ρ-m_π </> m_W, ee only)

DØ: 340/250 (m_ρ-m_π </> m_W ee only)

TABLE III: Dilepton Results for Littlest Higgs Z' .

Z _H Mass Limit at 95%C.L (GeV/c ²)			
cot θ	ee	μμ	ℓ ⁺ ℓ ⁻
1.0	810	805	875
0.9	785	780	850
0.7	735	715	800
0.6	700	685	765
0.5	665	640	720

TABLE V: Dilepton Results for RS Graviton.

RS Graviton Mass Limit at 95%C.L (GeV/c ²)			
k/M _{Pl}	ee	μμ	ℓ ⁺ ℓ ⁻
0.1	640	610	700
0.05	485	455	525
0.01	200	170	200

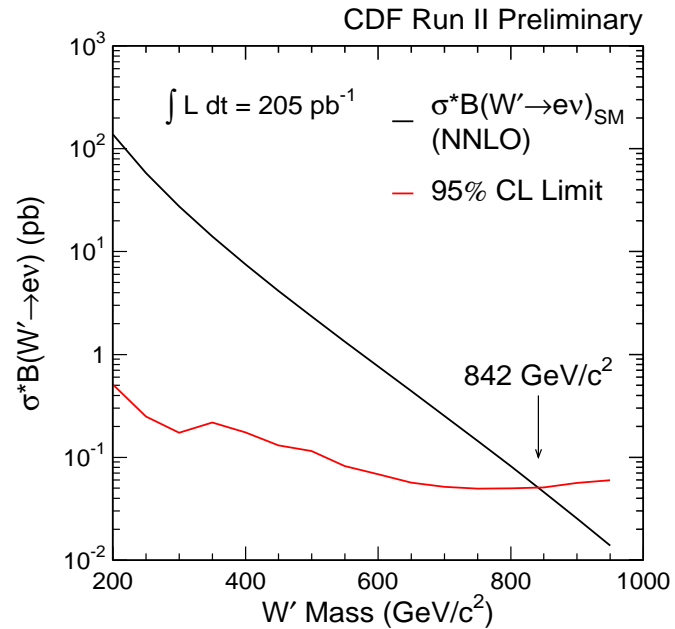
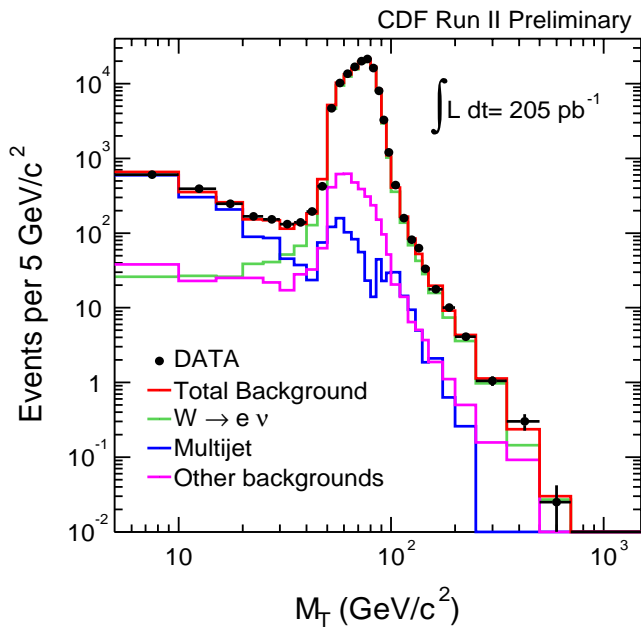
- http://www-cdf.fnal.gov/physics/exotic/r2a/20040916.dilepton_zprime/note_7286.pdf
- <http://www-d0.fnal.gov/Run2Physics/WWW/results/prelim/NP/N22/N22.pdf> DØ ee ρ_T, ω_T
- <http://www-d0.fnal.gov/Run2Physics/WWW/results/prelim/NP/N03/N03.pdf> DØ ee Z'
- <http://www-d0.fnal.gov/Run2Physics/WWW/results/prelim/NP/N20/N20.pdf> DØ μμ Z'



W'

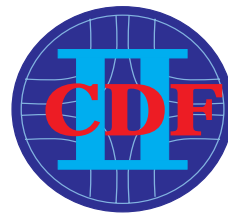


- CDF, $W \rightarrow e\nu$, based on 205 pb^{-1}
- transverse mass fit, signal = right-handed W' (V+A)
- spectrum well described by SM
- main syst. uncertainty at very high mass: electron E-scale

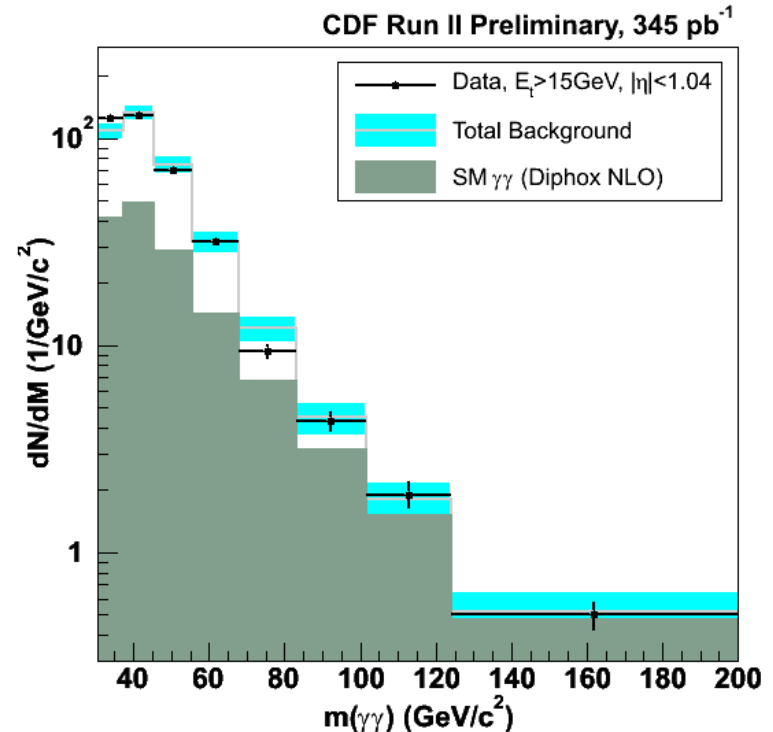
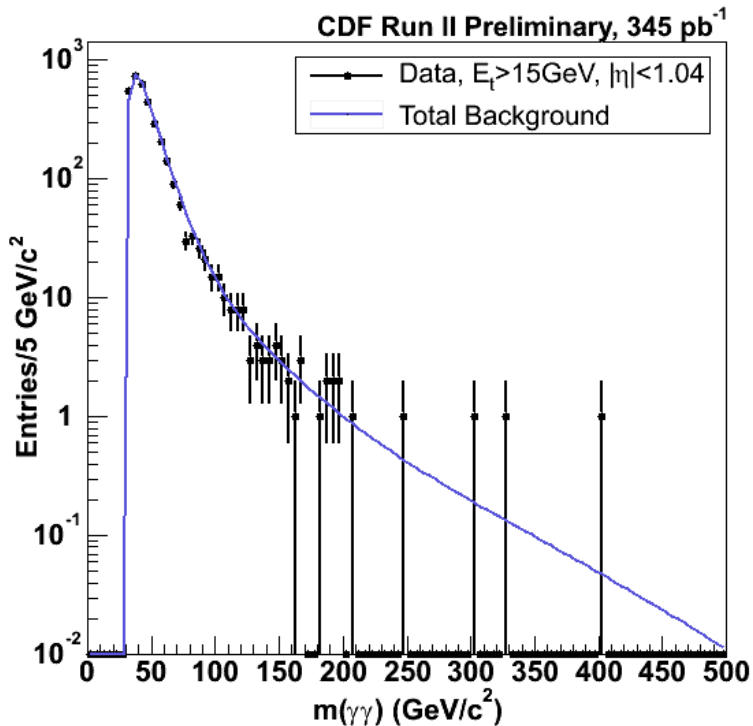




Di-photons



- Search high-mass $\gamma\gamma$ events for new physics
- Backgrounds from
 - Standard model diphoton
 - Misidentifications: γj or jj where jet gives a hard π^0
- Highest mass event: $m(\gamma\gamma) = 405 \text{ GeV}/c^2$





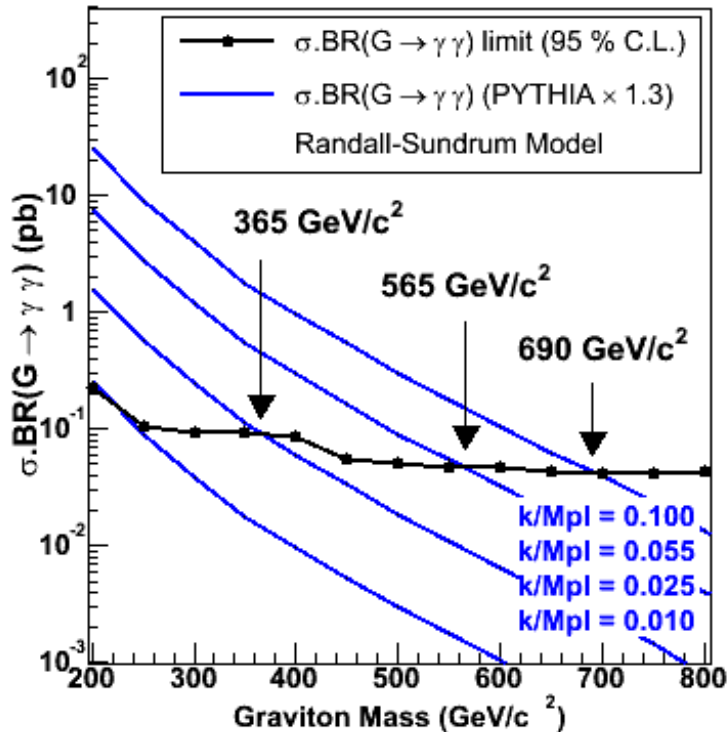
RS Graviton



Diphoton LED limit

limit on $G^{(1)}$, the first graviton excitation in the Randall-Sundrum 'warped' ED model

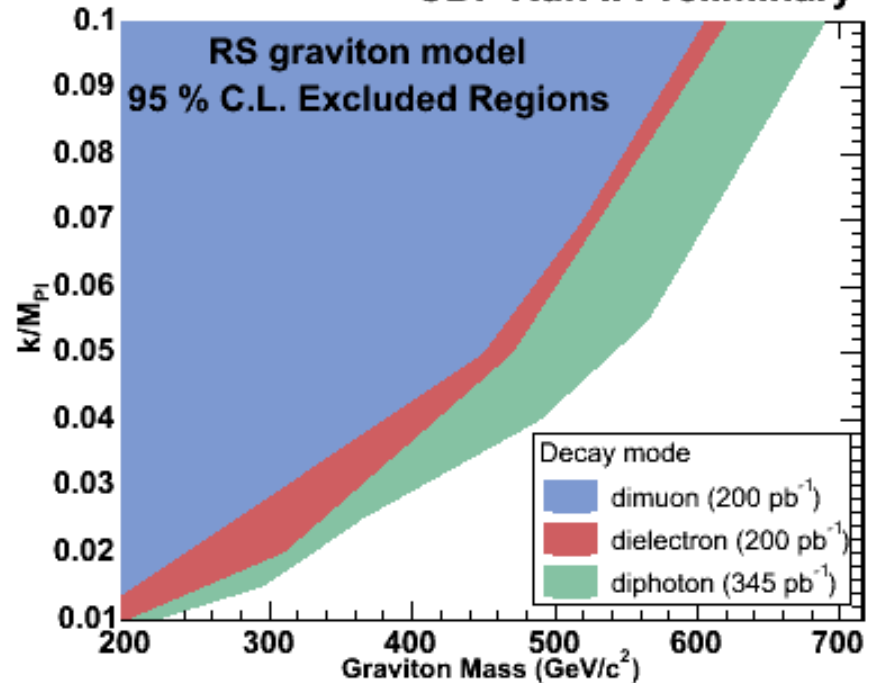
CDF Run II Preliminary (345 pb⁻¹)



Stefan Grünendahl

Combined CDF RS graviton result

CDF Run II Preliminary



Tevatron Searches @ Aspen 2005



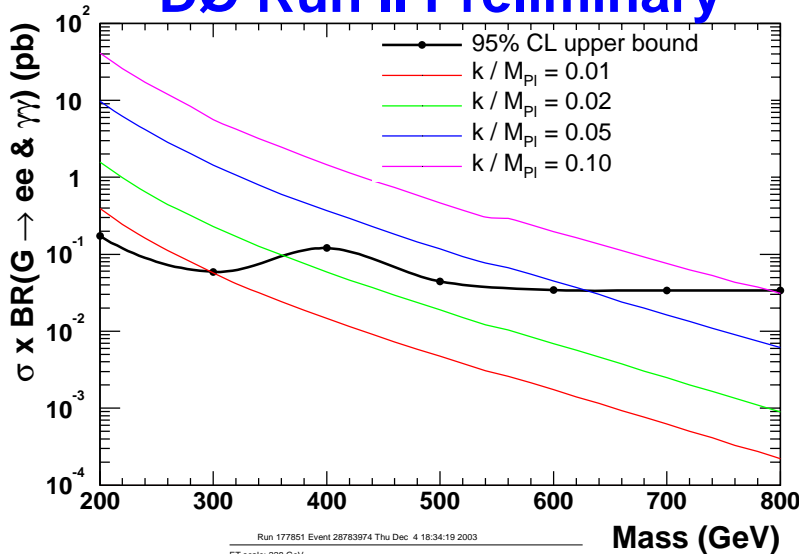
ee and $\gamma\gamma$ combined



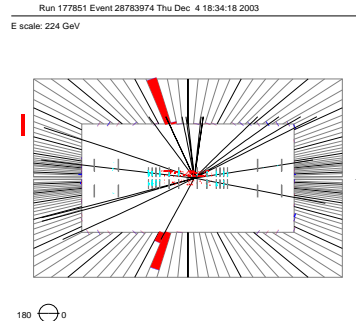
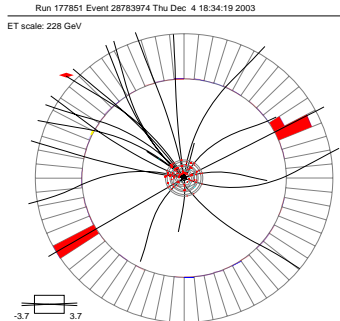
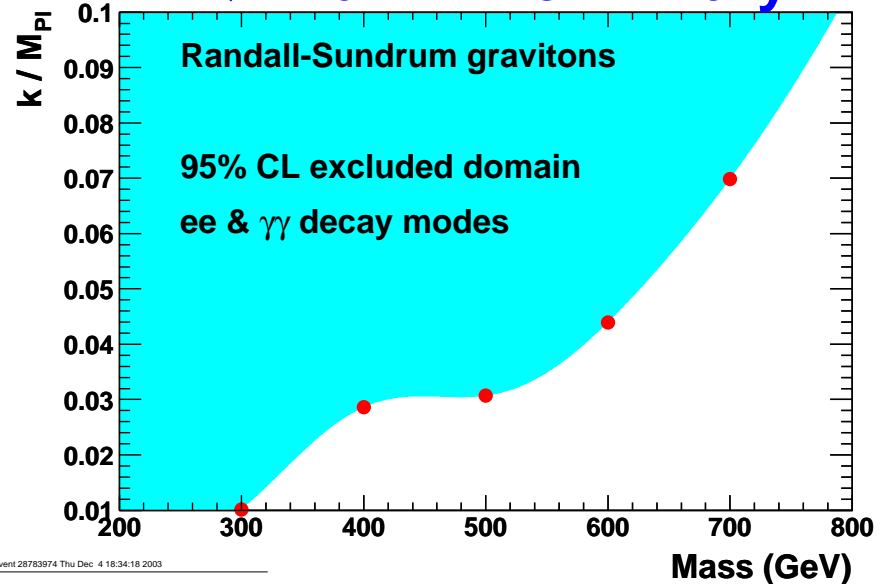
- DØ diEM search: best limit on RS-Graviton

extension of Z' analysis to set limit on $G^{(1)}$, the first graviton excitation in the Randall-Sundrum 'warped' ED model

DØ Run II Preliminary



DØ Run II Preliminary



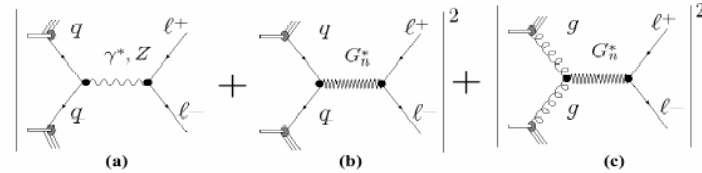
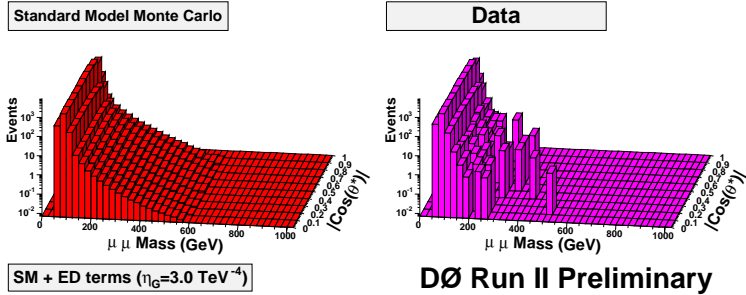
Highest-mass diEM candidate with invariant mass of 475 GeV and $\cos \theta_c$ of 0.01 (Run 177851, Event 28783974)



Large Extra Dimensions

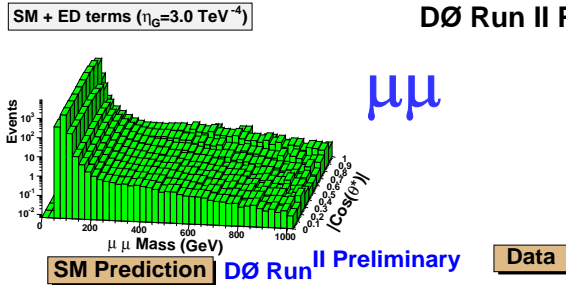


DØ: extract limit from 2d-fit mass vs $\cos(\Theta^*)$



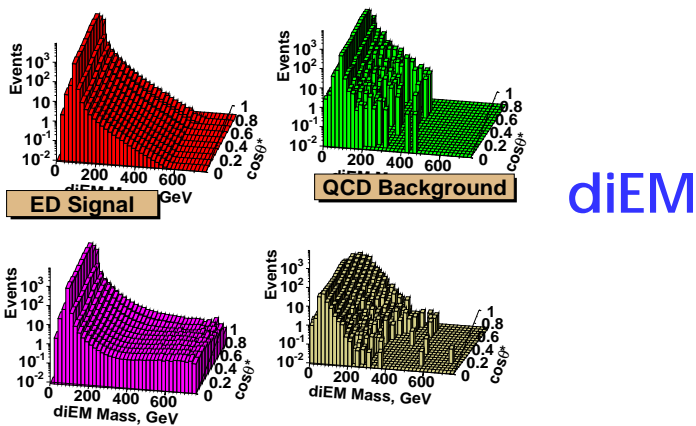
95 %CL lower limits on M_S [TeV]:

Hewett		GRW	HLZ (TeV, @95% CL)					
$\lambda = +1$	$\lambda = -1$		$n=2$	$n=3$	$n=4$	$n=5$	$n=6$	$n=7$
0.97	0.95	1.09	1.00	1.29	1.09	0.98	0.91	0.86



Hewett		GRW	HLZ (TeV, @95% CL)					
$\lambda = +1$	$\lambda = -1$		$n=2$	$n=3$	$n=4$	$n=5$	$n=6$	$n=7$
1.22	1.10	1.36	1.56	1.61	1.36	1.23	1.14	1.08
1.28	1.16	1.43	1.67	1.70	1.43	1.29	1.20	1.14
r_{max}			170 μm	1.5 nm	5.7 pm	0.2 pm	21 fm	4.2 fm

Currently best limits for $n=2$

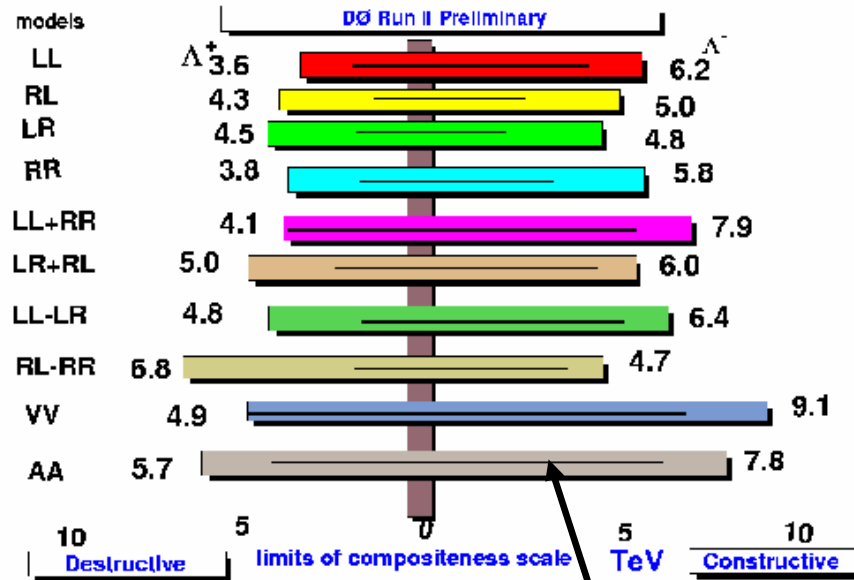
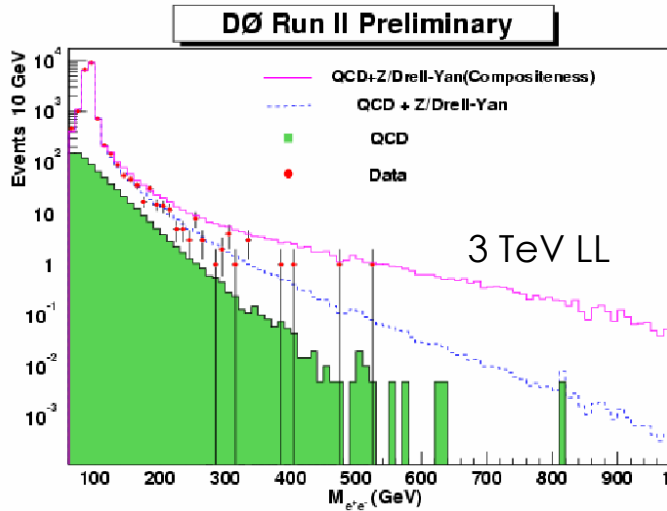




Compositeness



- DØ dielectron analysis based on 270 pb^{-1}
- Limits on compositeness scale for various models
- $\Lambda_C > 3.6 - 9.1 \text{ TeV}$

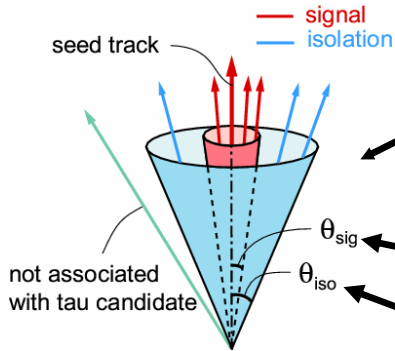


Four-fermion contact interaction interferes with SM D/Y production

Black line: Run I limit



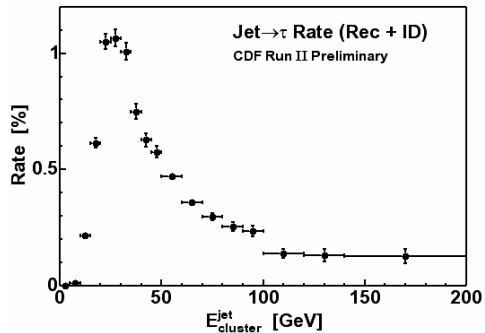
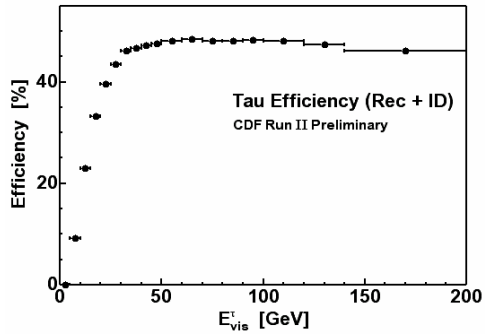
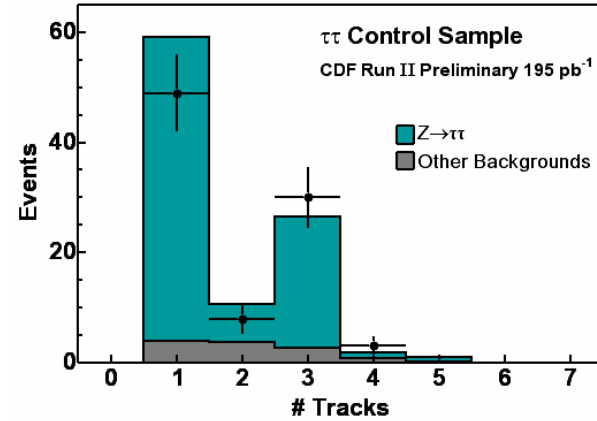
Dileptons: $\tau\tau$



τ (had) signature is a bit more complex than e or μ ; get track multiplicity right

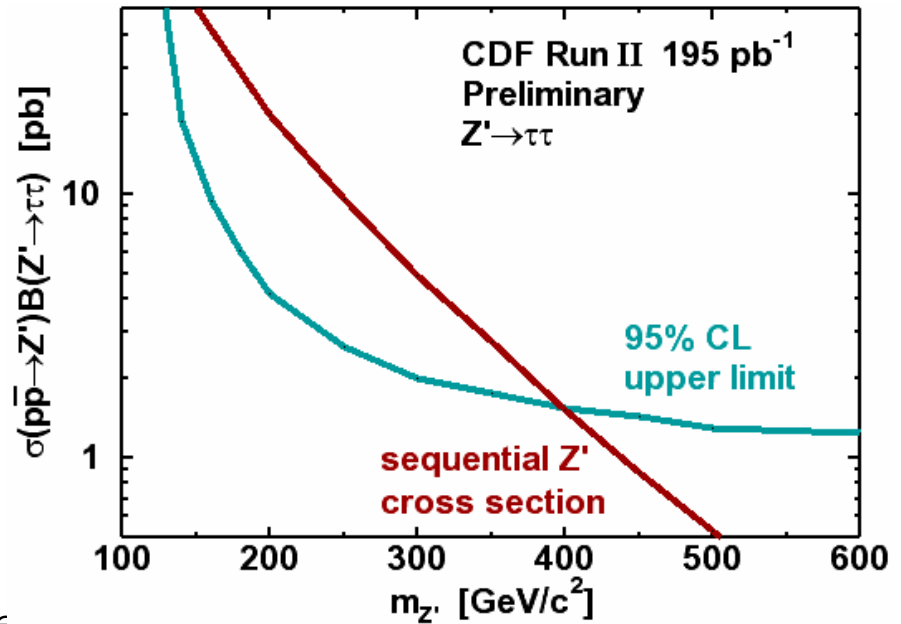
30°

5 radian/ E_{vis} [GeV] from 0.175 down to 0.05, constant above and below



Both CDF and DØ have $Z \rightarrow \tau\tau$ measurements

Z' limit





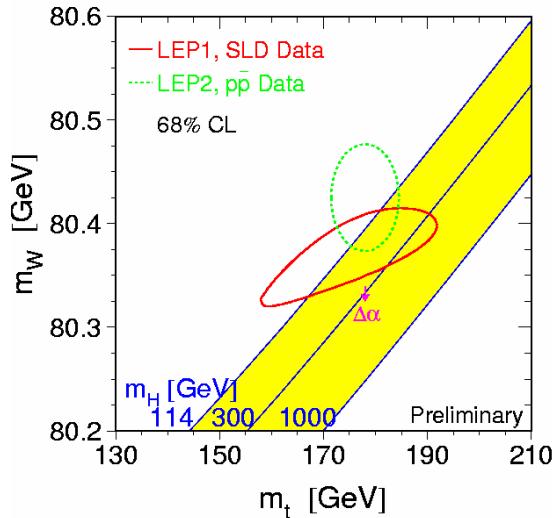
Higgs



Current status (from precision EW fits):

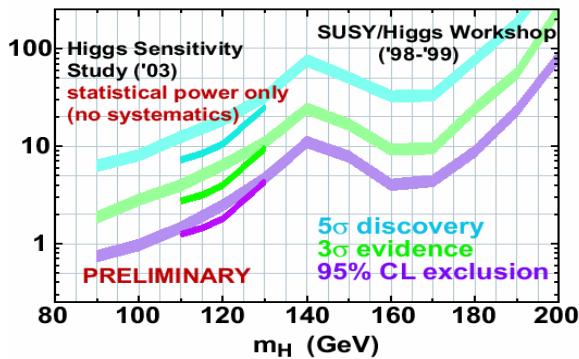
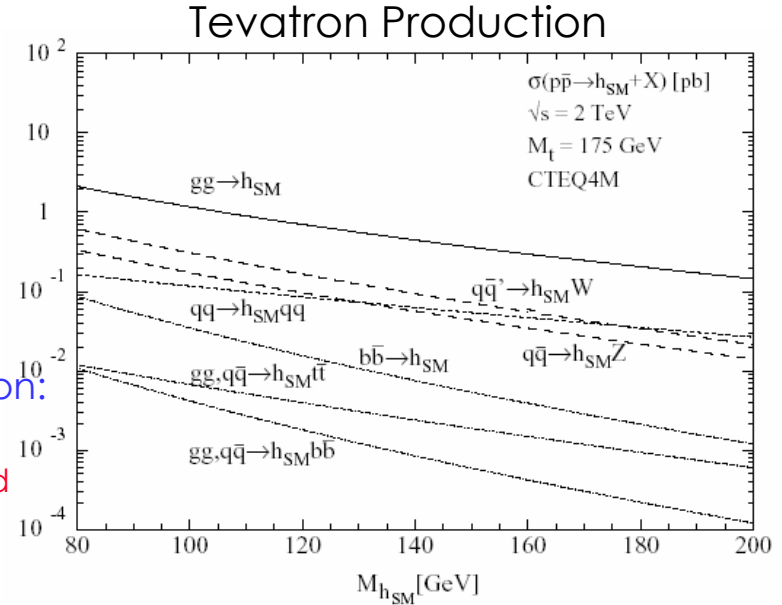
$$m_H = 114 +69 -45 \text{ GeV}$$

$$m_H < 260 \text{ GeV @ 95\% CL}$$



Production cross section:

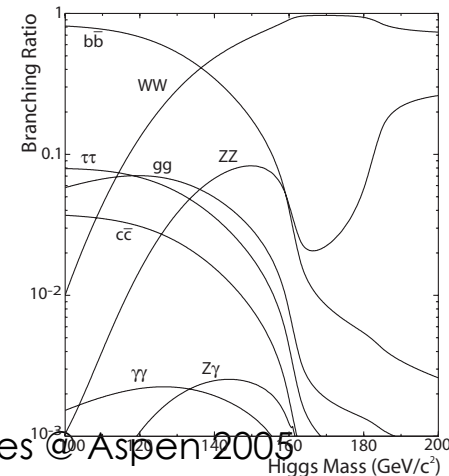
~1 pb for $gg \rightarrow H$
 ~0.1 pb for W,Z associated production



Decay modes:

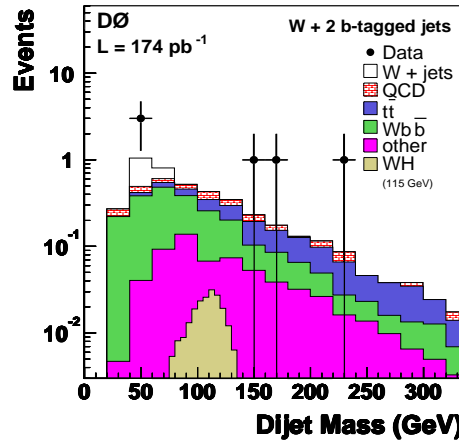
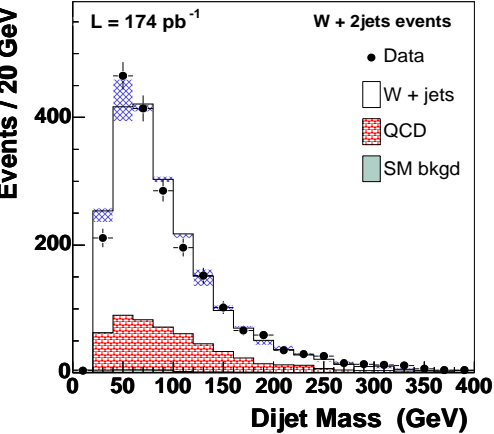
$m_H < 140 \text{ GeV} : bb$
 $\text{above } 140 \text{ GeV} : WW^*$

Higgs Decay





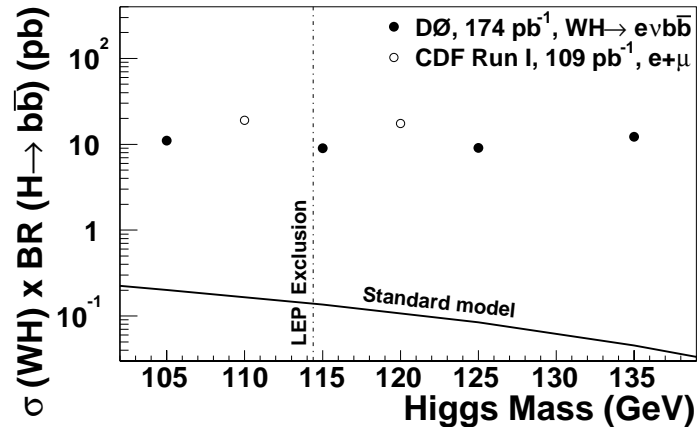
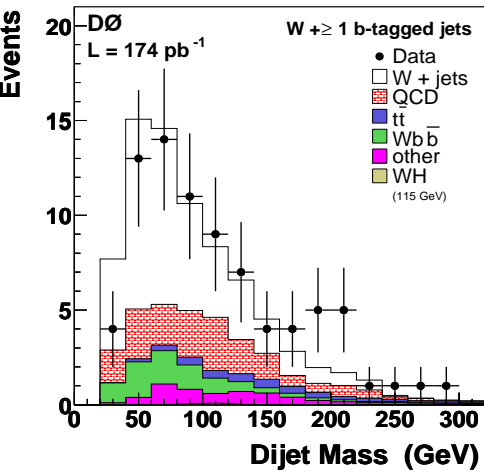
Leptons + jets: $WH \rightarrow e\nu b\bar{b}$



DØ : 6 double b-tag events in 174 pb⁻¹
 spectra well described by SM

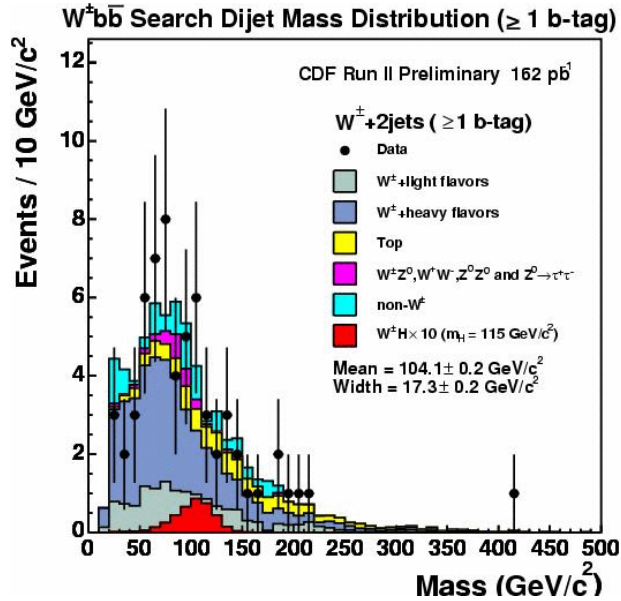
- $\sigma(Wb\bar{b}) < 6.6 \text{ pb}$ (for $P_T(b) > 20 \text{ GeV}$, $\Delta R(b\bar{b}) > 0.75$)
- $\sigma(WH) < 9.0\text{-}12.2 \text{ pb}$ (for $M_H = 105\text{-}135 \text{ GeV}$)

hep-ex/0410062

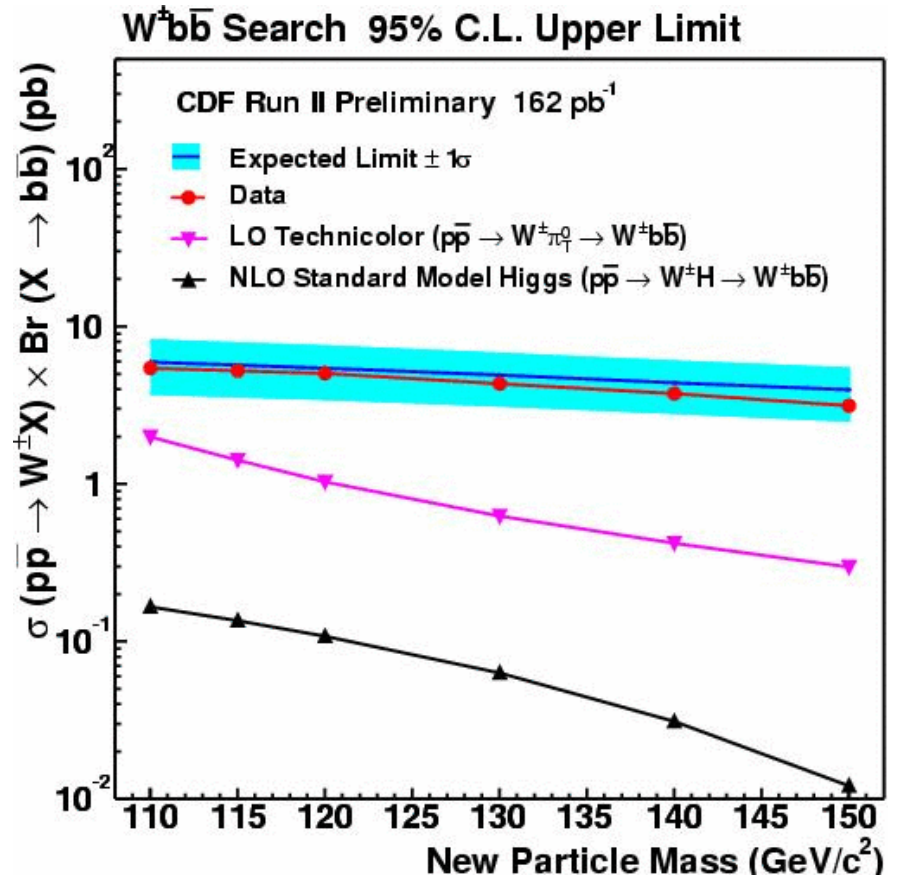




$WX \rightarrow e\nu bb, \mu\nu bb$ ($X = \text{Higgs, Techni-pion}$)

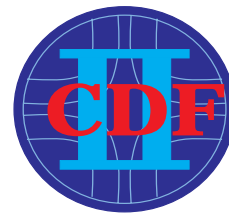


- 1-tag analysis for 162 pb⁻¹ from CDF: Higgs and Technicolor limit

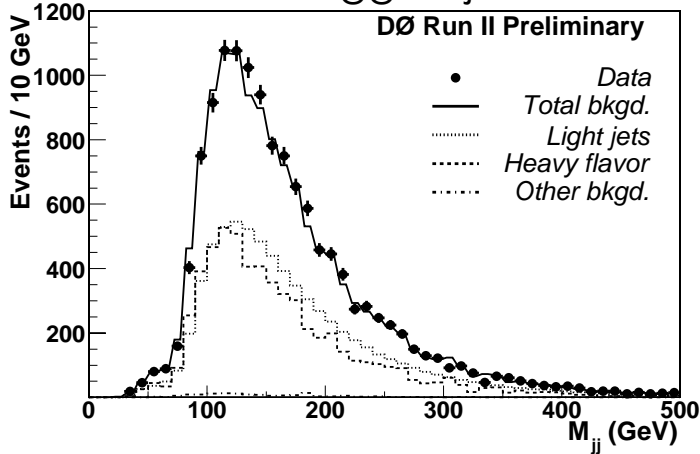




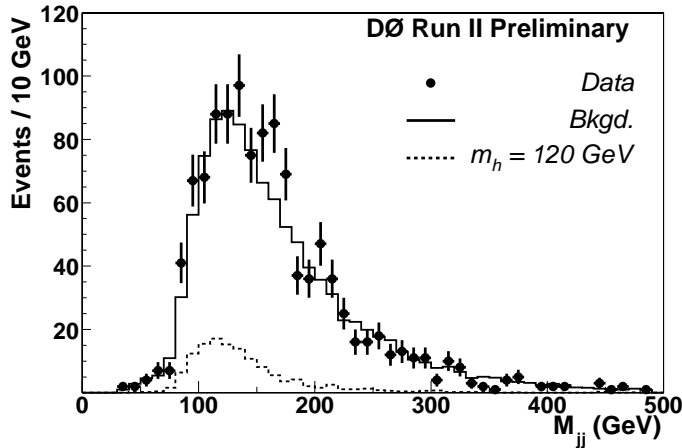
Higgs in multijets (high $\tan \beta$)



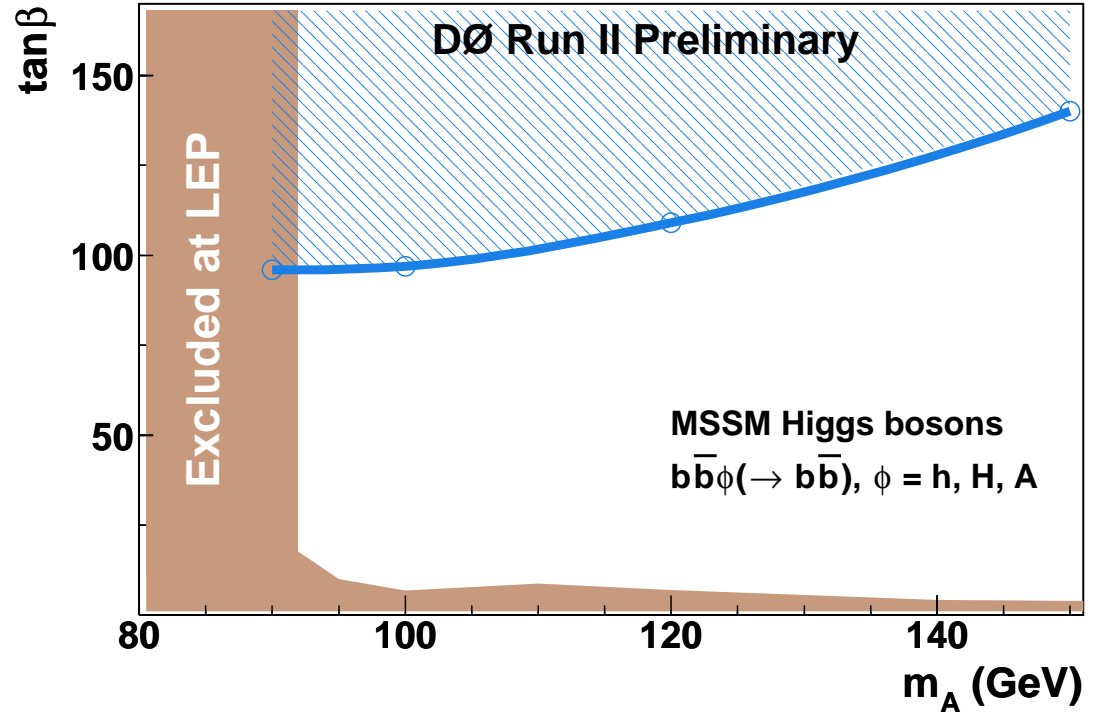
2 tagged jets



3 tagged jets

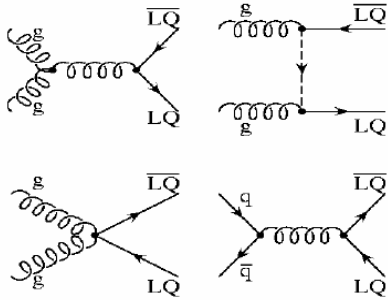


- DØ, based on 130 pb⁻¹
- Higgs produced in association with 1 or 2 b
- 3 b-tagged jets
- limits on 'down-type' Higgs in models with more than one doublet (typically MSSM Higgs)



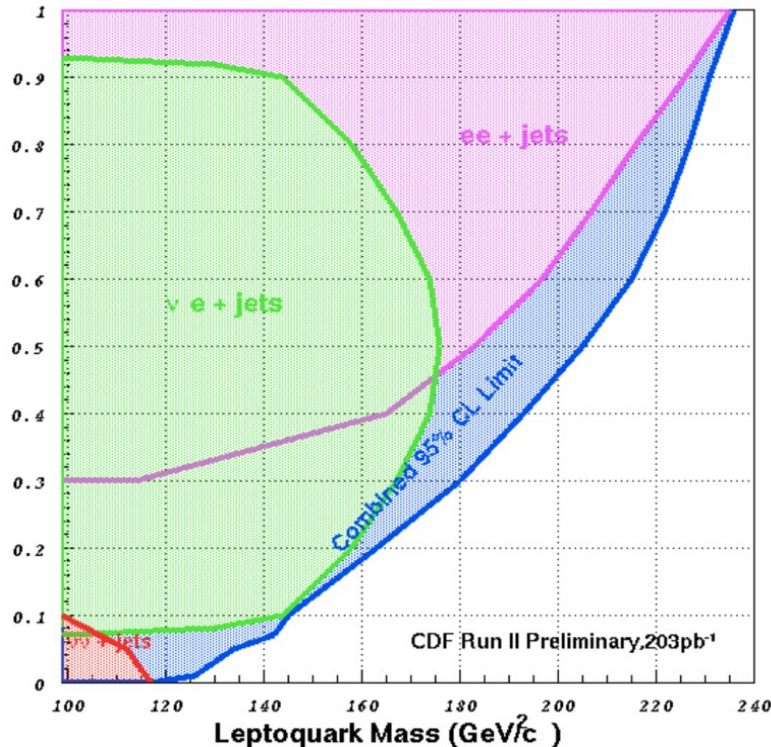


Leptoquark limits

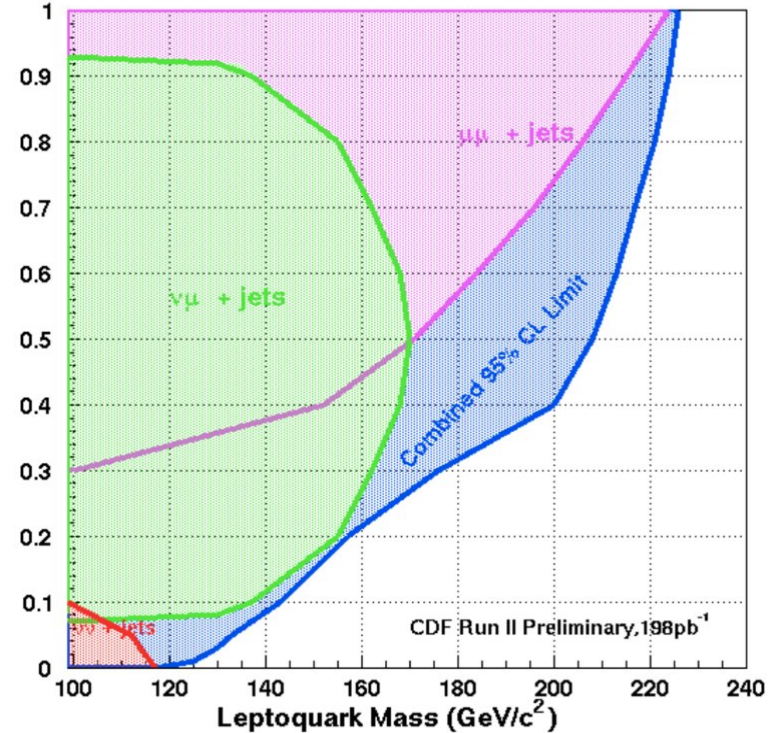


CDF: 200 pb^{-1}
 Leptons + jets, lepton + MET + jets, MET + jets combined

Search For First Generation Scalar Leptoquarks



Search For Second Generation Scalar Leptoquarks

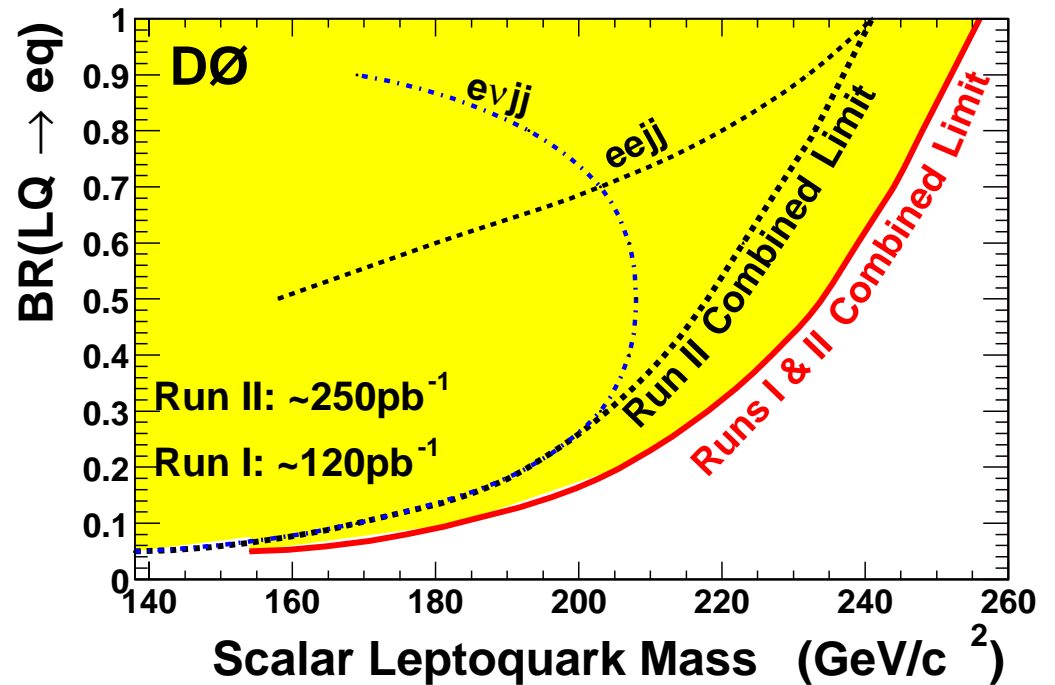
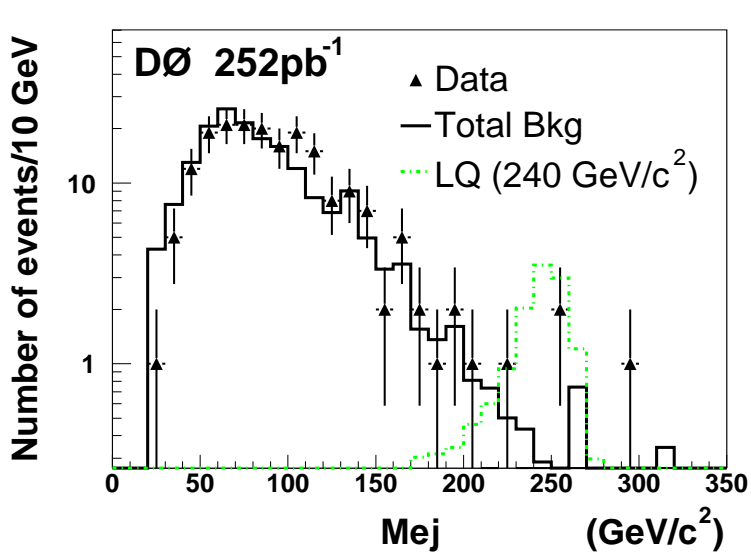




1st gen.leptoquark



- DØ: based on 252 pb⁻¹
- No excess observed
- hep-ex/0412029



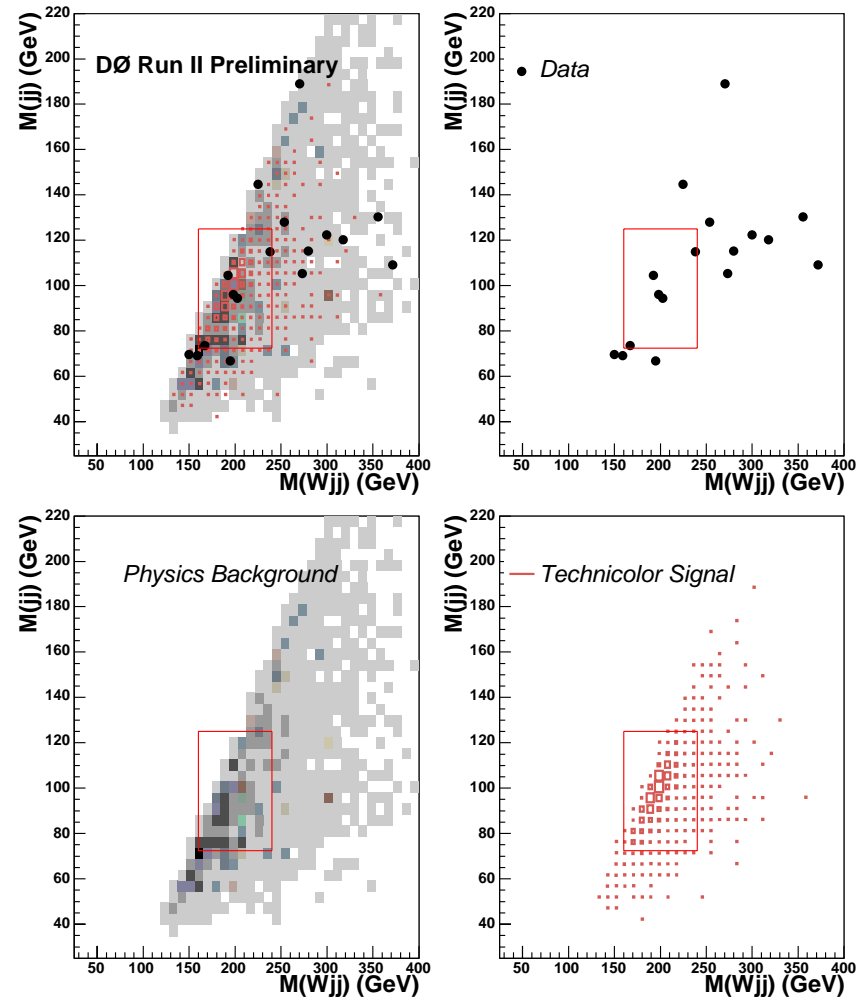


Leptons + jets: Technicolor



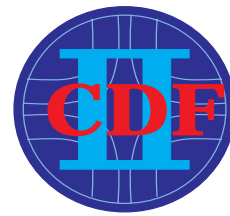
- DØ: $p_T \rightarrow (W \rightarrow ev) + (\pi_T \rightarrow bQ)$ ($Q=b,c$), based on 238 pb^{-1}
 $\Rightarrow \sigma < 6.4 \text{ pb}$ for $m(p_T)=200 \text{ GeV}$, $m(\pi_T)=105 \text{ GeV}$

Data, background and signal for the $W \rightarrow ev$ channel

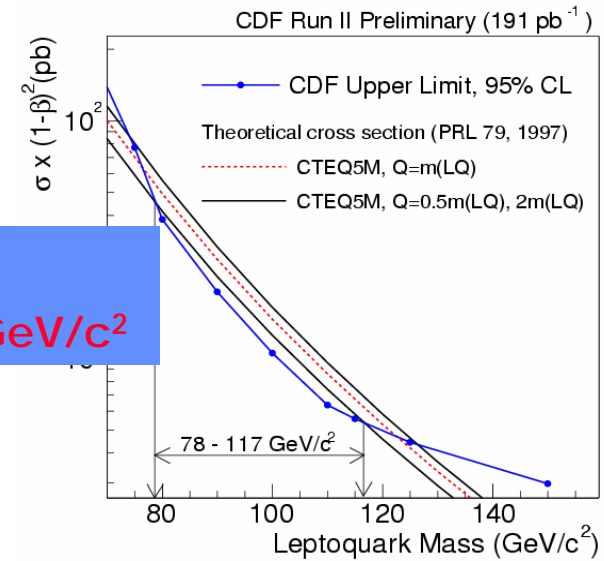
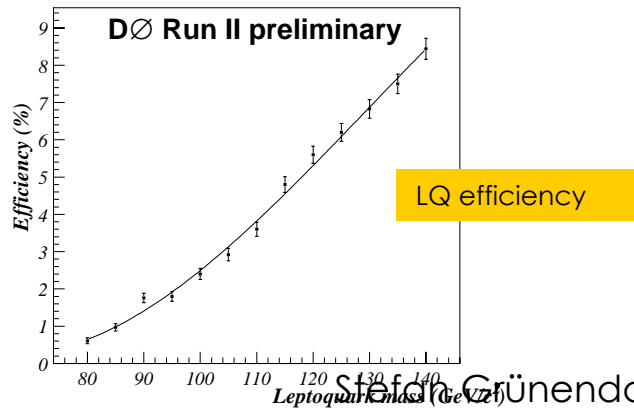
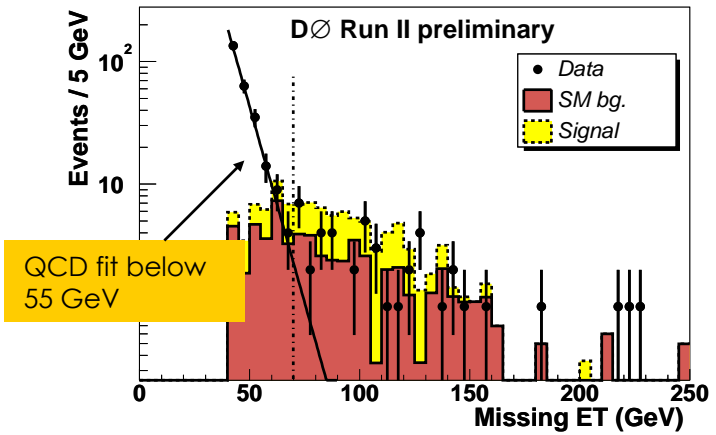
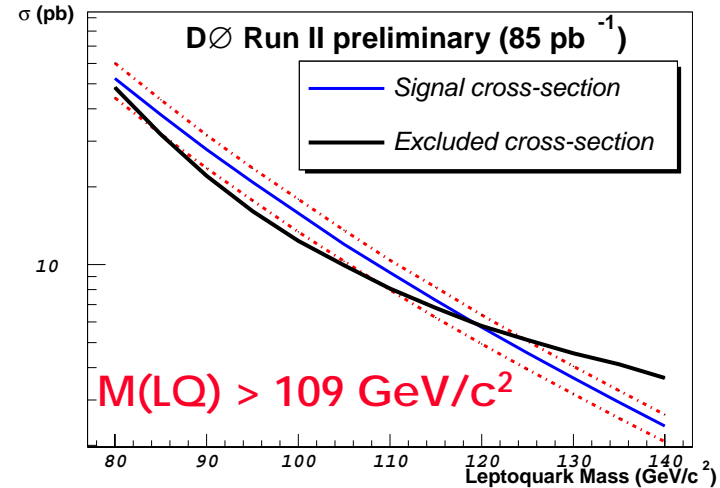




Jets + MET



- DØ leptoquark search, based on 85 pb⁻¹
- 2 jets, one central,
 - $p_T^1 > 60$ GeV/c,
 - $p_T^2 > 50$ GeV/c,
 - MET > 70 GeV,
 - $35^\circ < \Delta\Phi(\text{MET}, \text{jet}) < 165^\circ$



CDF: 191 pb⁻¹
 $M(\text{LQ}) > 117 \text{ GeV}/c^2$



Monojets



- D0 monojet search, based on 85 pb^{-1} (same trigger as LQ search)
- one central jet,
 - $p_T^1 > 150 \text{ GeV}/c$,
 - $p_T^2 < 50 \text{ GeV}/c$,
 - $p_T^{\text{em}} < 10 \text{ GeV}/c$,
 - $p_T^\mu < 10 \text{ GeV}/c$ (no isolated muon),
 - $\text{MET} > 150 \text{ GeV}$,
 - $\Delta\Phi(\text{MET}, \text{jet}) > 30^\circ$

Generator by Lykken and Matchev, based on [2]

[1] N. Arkani-Hamed, S. Dimopoulos and G. Dvali, Phys. Lett. **B 429** (1998) 263.

[2] G. Giudice, R. Rattazzi and J.D. Wells, Nucl. Phys. **B 544** (1999) 3.

Result:

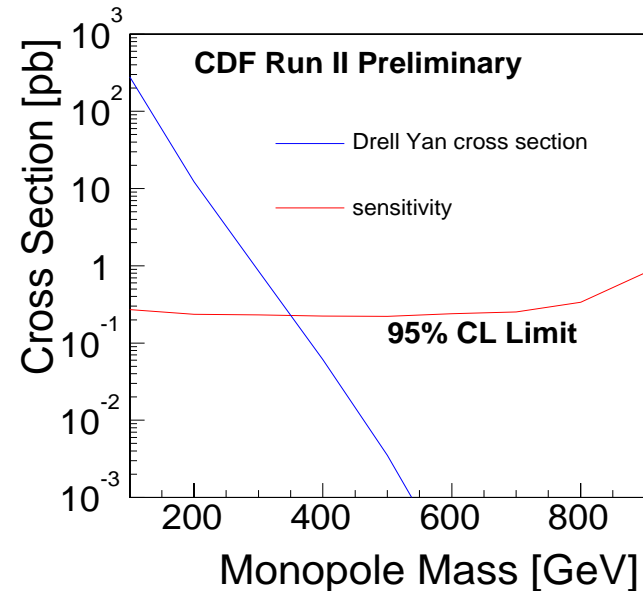
n_D	M_D lower limit (TeV)
4	0.68
5	0.67
6	0.66
7	0.68



Monopoles



- CDF search with special TOF trigger in 25 pb^{-1}
- Large magnetic charge \rightarrow heavily ionizing
- Accelerated along mag. field \rightarrow special GEANT version
- Slow moving \rightarrow late signals \rightarrow small (10%) TOF acceptance loss for 900 GeV monopoles
- Offline: Drift chamber verification via width of ionization pulse: cut far beyond standard particle range

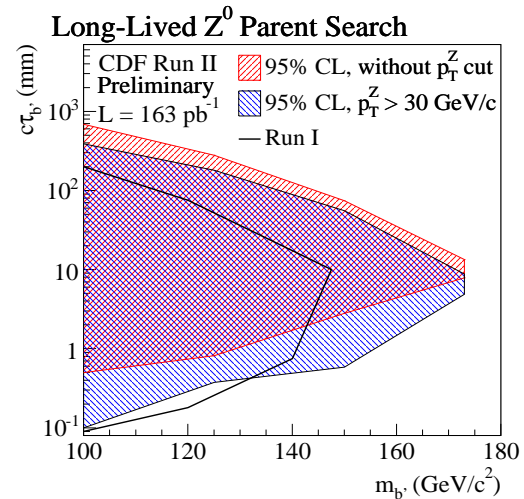
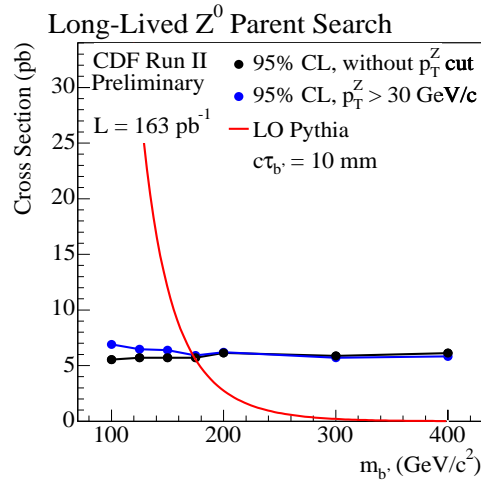
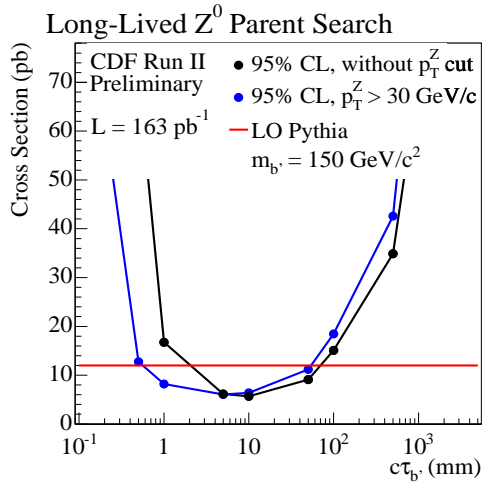
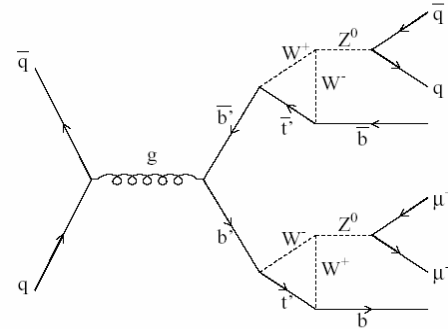




Long-lived parent of Z^0



- CDF dimuons from 163 pb^{-1}
- Parent e.g. b' with $m_{b'} < m_t$
- Search for Z from offset vertex
- Low eff * acceptance due to tracking requirement
- 5 events observed; consistent with background (1 μ -track misreconstructed)





Summary



- Current results based on 0.25 fb⁻¹
- More than 0.5 fb⁻¹ on tape
- Steady progress, not only due to more data, but also improvements in tools and methods (b –tagging, secondary vertex triggers)
- World's best limits on LQ, Z', LEDs
- Higgs: still an order of magnitude to go
- Watch for updates for the rest of the winter conferences
 - <http://www-cdf.fnal.gov/physics/exotic/exotic.html>
 - <http://www-d0.fnal.gov/Run2Physics/WWW/results.htm>

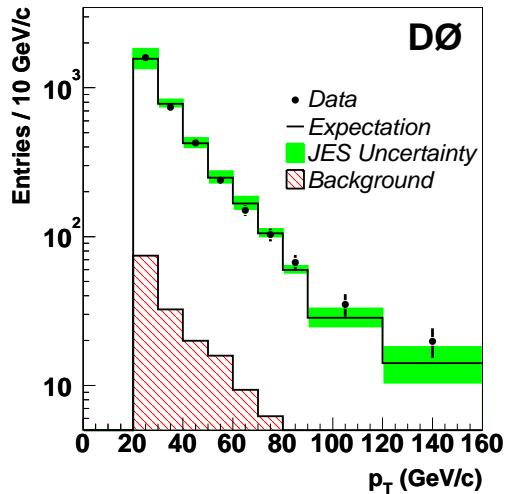




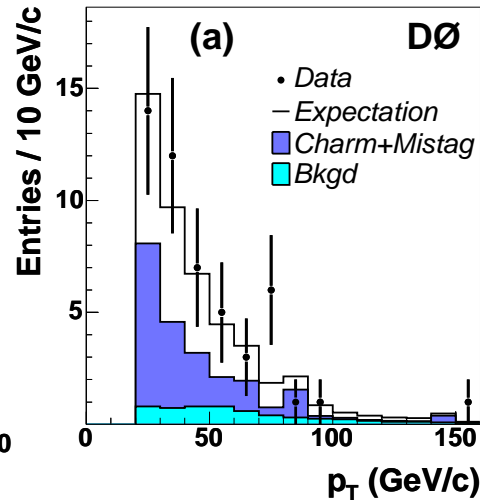
Measurement of Z+b/Z+jet



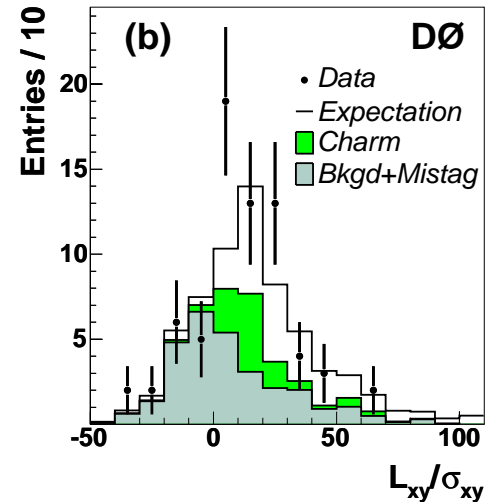
- Important check of our understanding of b-yield and systematics for searches (e.g. ZH assoc.production)



Taggable jets agree with MC within Jet Energy Scale (JES) uncertainty



PT spectrum of B-tagged jets



Transverse decay length significance of B-tagged jets

result: $\sigma(Z+b)/\sigma(Z+jet) = 0.023 \pm 0.004(\text{stat}) + 0.002 - 0.003(\text{syst})$
 agrees well with NLO prediction (CTEQ5) of 0.018 ± 0.004