



Searches for Physics beyond the Standard Model

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on behalf of the D0 and CDF collaborations

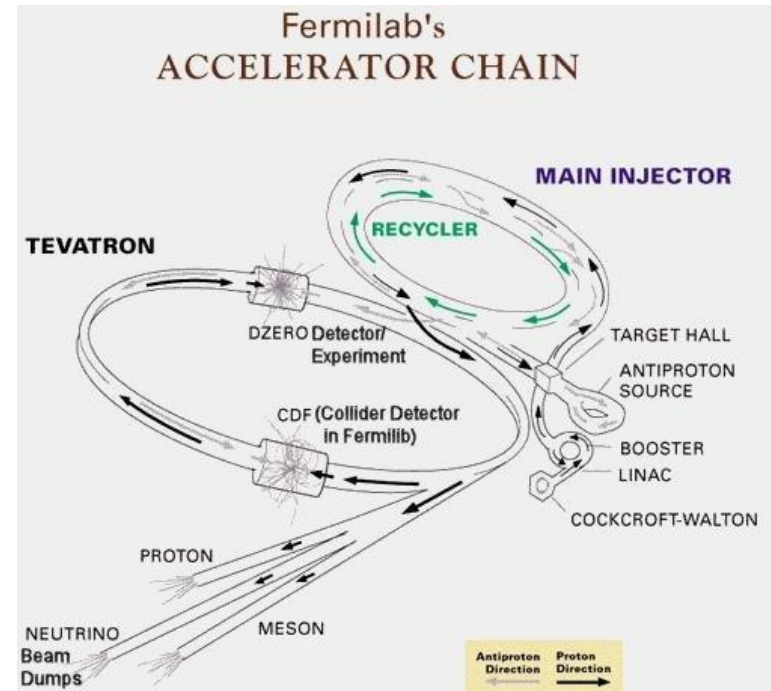


Tevatron collider

$p\bar{p}$ collider which provides the highest energy at present: 1.96 TeV

Hosts two multi-purpose HEP detectors: D0 and CDF

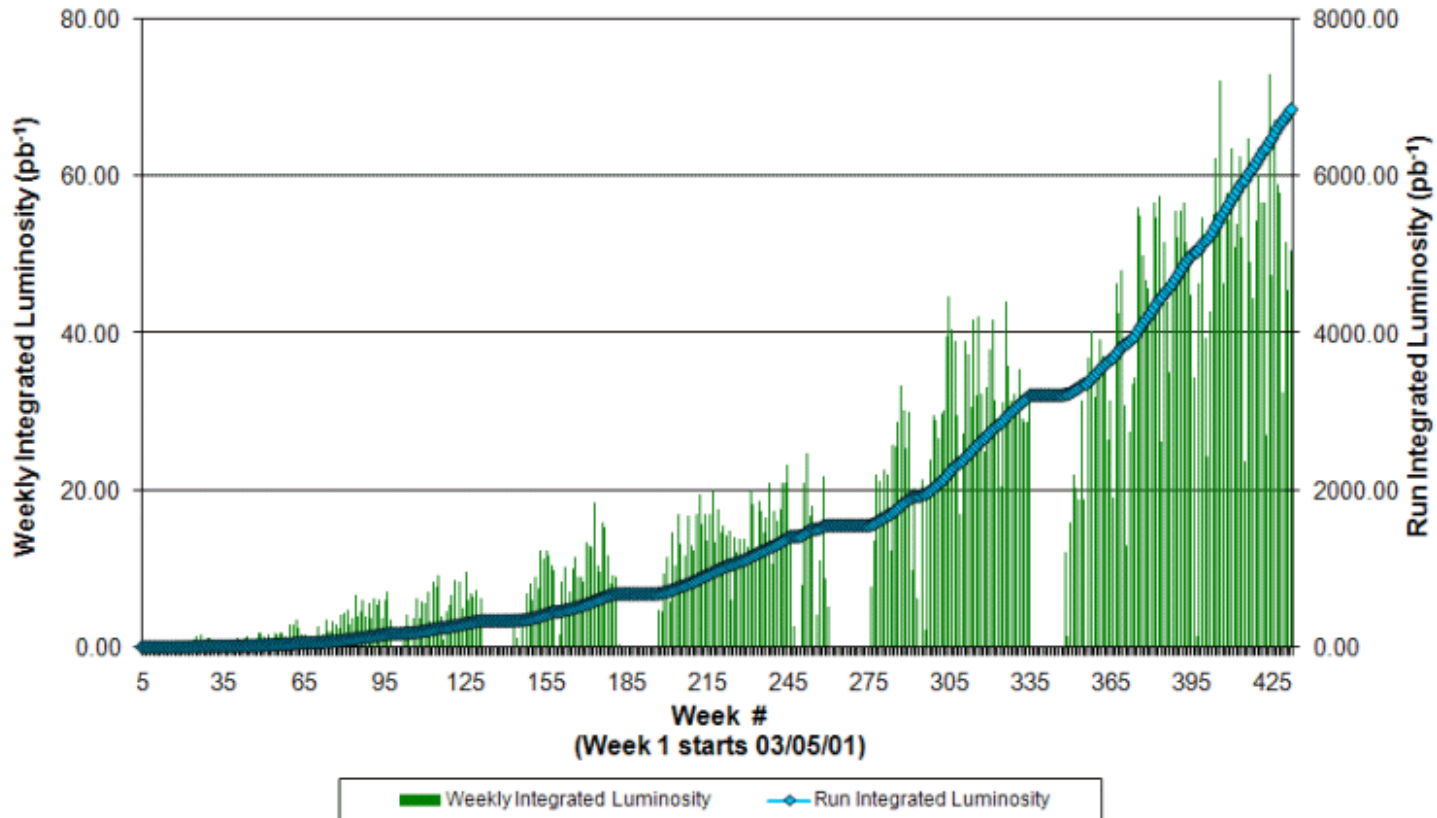
Operates with excellent performance



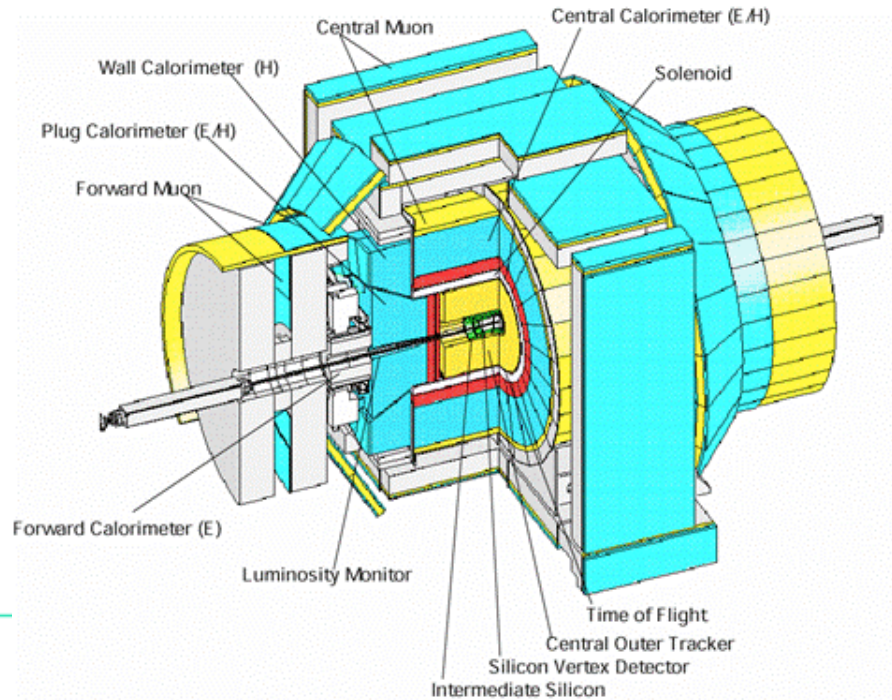
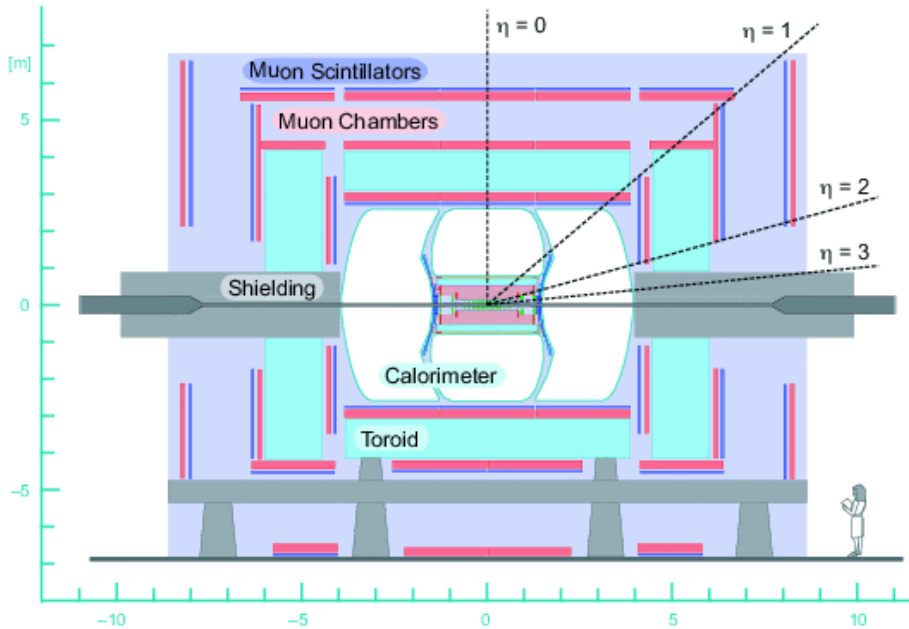
Run II Data

Since the beginning of Run II The Tevatron has delivered $\sim 7 \text{ fb}^{-1}$ of integrated luminosity **and growing!**

Collider Run II Integrated Luminosity



D0 and CDF detectors



Typical acceptance values for the detectors:

D0

Muons	$ \eta < 2$
Electrons	$ \eta < 3$
Silicon tracker	$ \eta < 3$

CDF

Muons	$ \eta < 2$
Electrons	$ \eta < 1.5$
Silicon tracker	$ \eta < 2$

New physics searches

-A lot of interesting results!

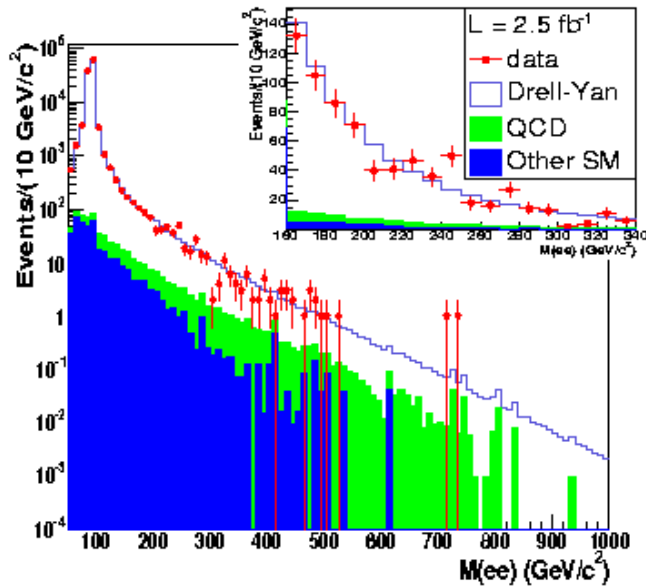
- Total number of published results is ~80!
- This review will focus on the latest results
- The detailed information about the results and publications can be found at:
<http://www-cdf.fnal.gov/physics/exotic/exotic.html> (CDF)
<http://www-d0.fnal.gov/Run2Physics/np> (D0)

High mass resonances

- High mass resonances are sensitive to new physics
 Z' , Randall-Sundrum graviton
- Two recent CDF searches using ee and $\mu\mu$ final states with 2.5 and 2.3 fb^{-1} respectively.
 ee : Phys. Rev. Lett. 102, 031801 (2009),
 $\mu\mu$: Phys. Rev. Lett. 102, 091805 (2009).

ee inv. mass

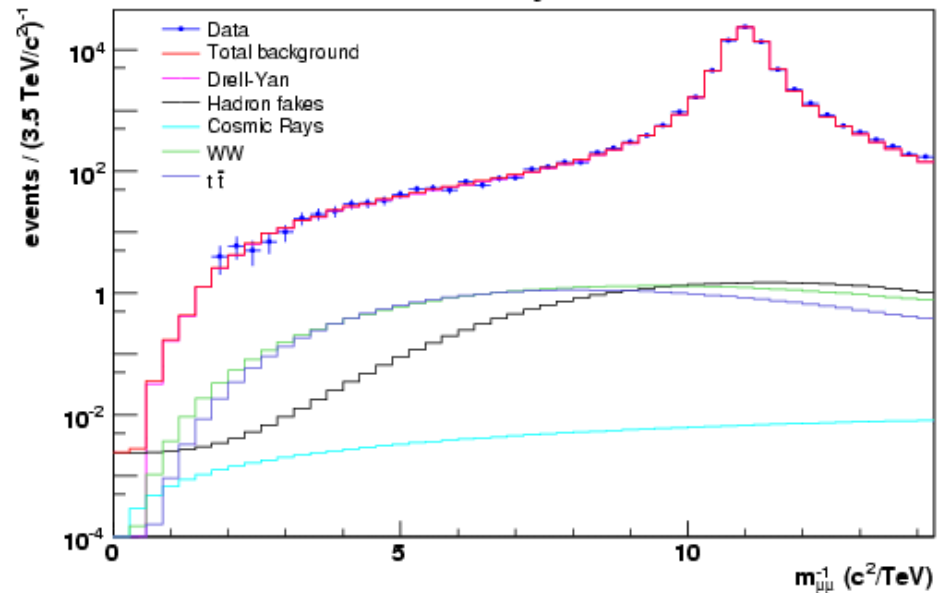
CDF Run II Preliminary



$\mu\mu$ inv. mass⁻¹

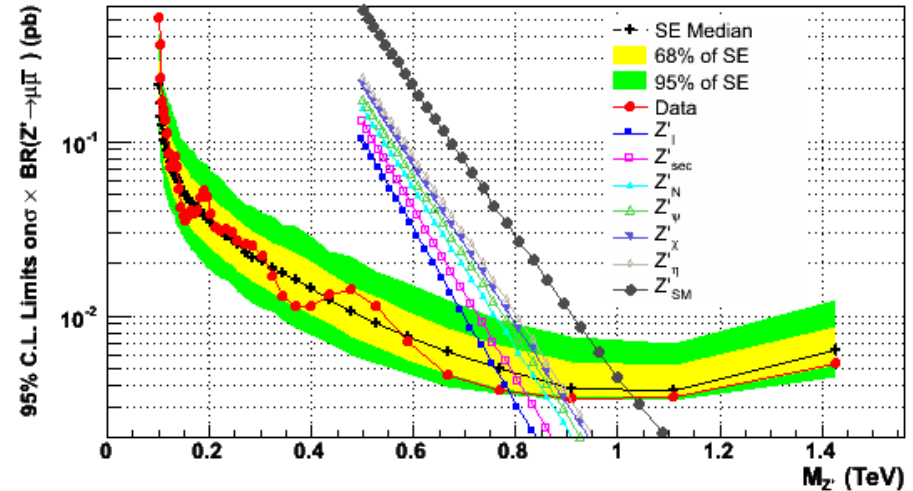
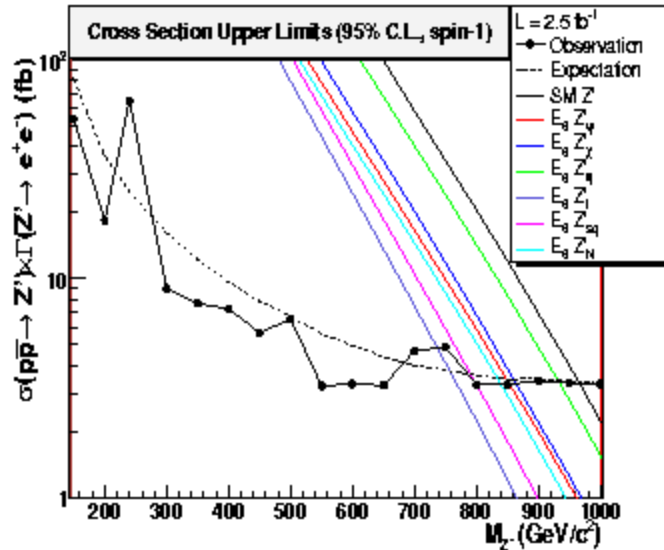
CDF II preliminary

$\int L dt = 2.3 \text{ fb}^{-1}$



High mass resonances

CDF Run II Preliminary



Spin 1: SM coupling $Z' < 966 \text{ GeV}$ (ee) and $< 1030 \text{ GeV}$ ($\mu\mu$) excluded;

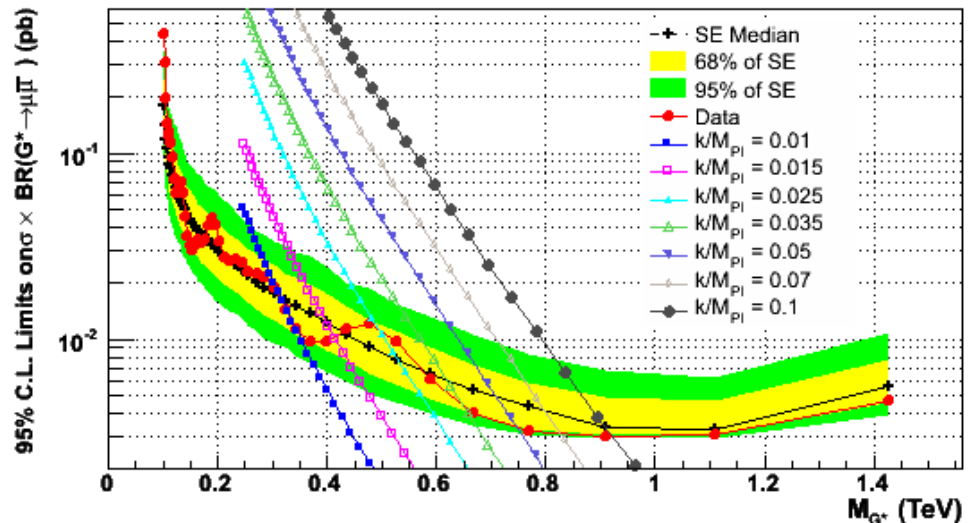
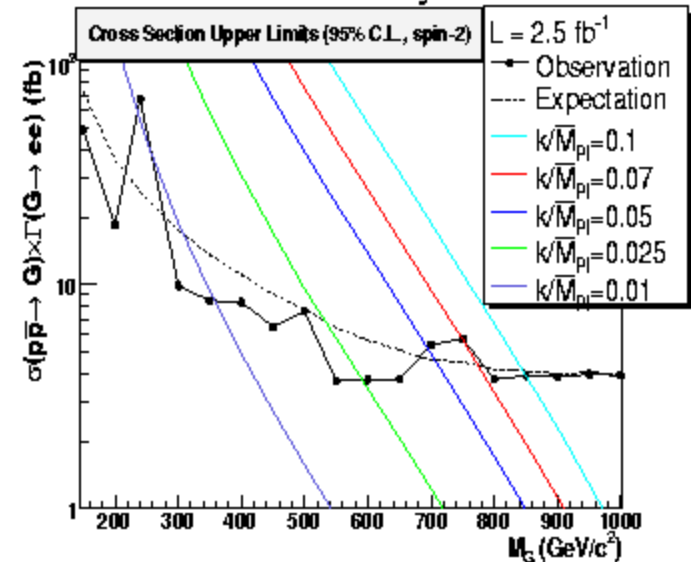
Randall-Sundrum Gravitons

5th extra dimension with warped geometry;
 Gravity is localized on brane other than SM
 KK excitation have spacing of order of TeV

Signature: narrow high masses resonances
 Two model parameters: Mass and coupling (k/M_{pl})

Latest CDF results in $\mu\mu$ and ee excludes $M < 921$ GeV
 and $M < 850$ GeV respectively
 (for $k/M_{pl}=0.1$)

CDF Run II Preliminary



Search for b' quark

Search for 4th generation b quark

- covers the models predicting heavy down-type quark and exotic $T_{5/3}$ fermion

Produced in pairs

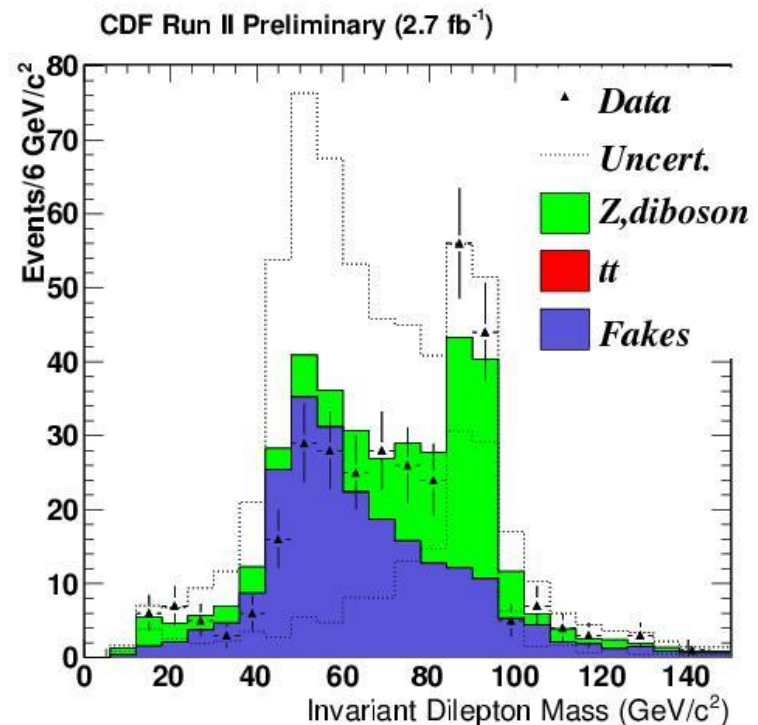
Decays to tW



- Same sign lepton final state
- Major background is Z , di-boson, and processes with misidentified lepton from W +jets

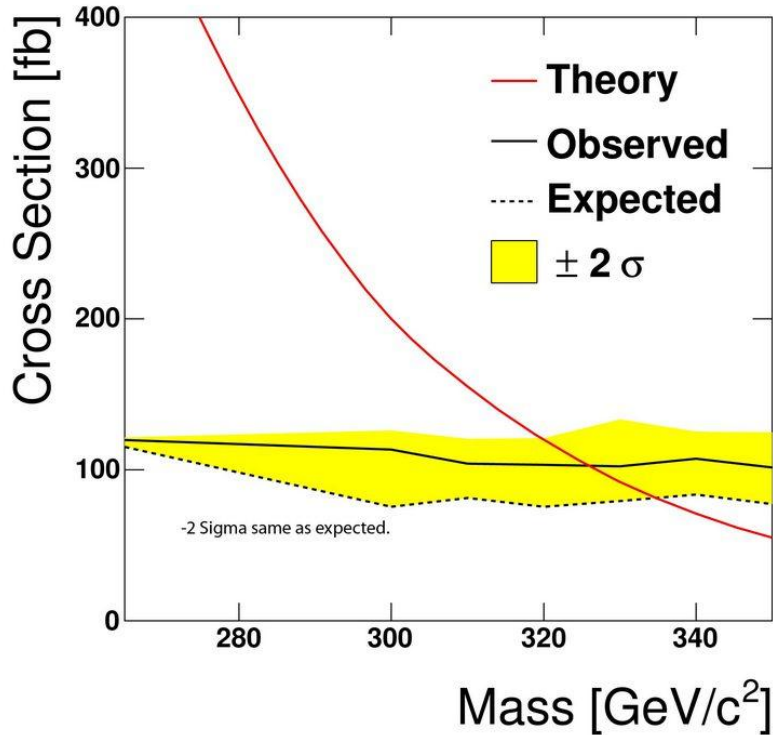
Good agreement between data and Standard Model

CDF
2.7 fb⁻¹

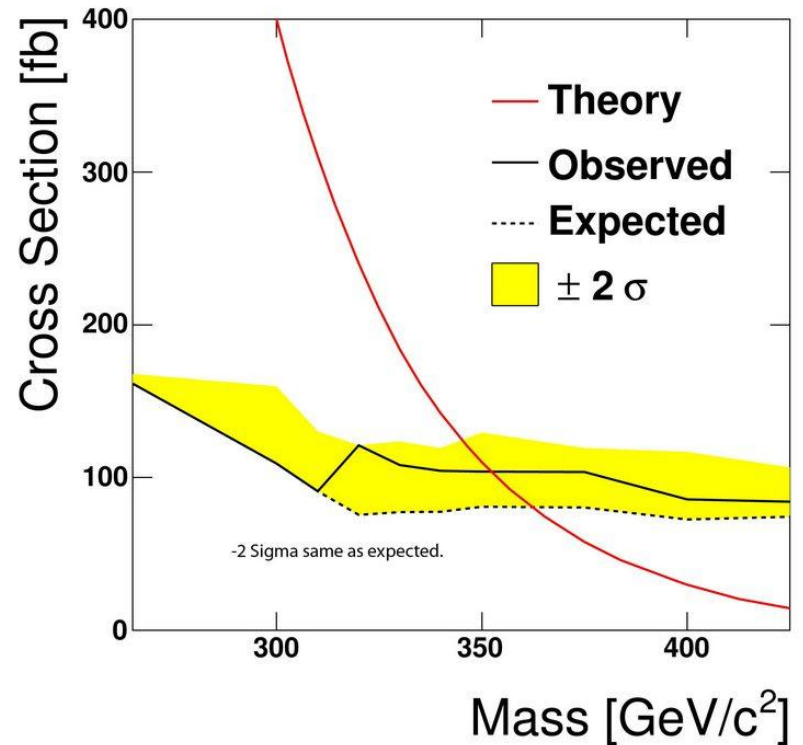


Search for b' quark

95% Limits for b' (CDF Run II Prelim 2.7/fb)



95% Limits for $B + T_{5/3}$ (CDF Run II Prelim 2.7/fb)



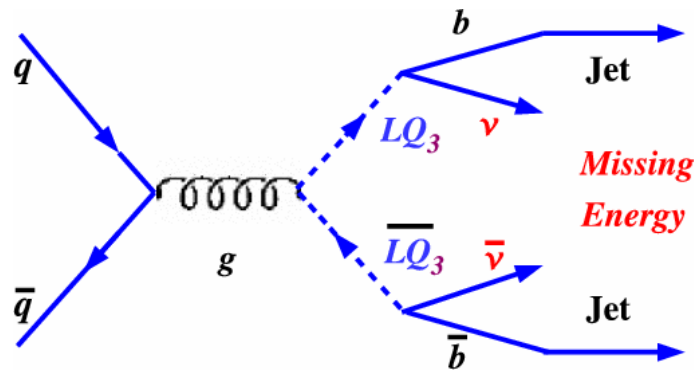
b' mass < 326 GeV and $b'+T_{5/3}$ mass < 352 GeV excluded at 95% CL

Leptoquarks

Leptoquarks are exotic particles that have color, electric charge, lepton and baryon numbers and appear in extended gauge theories and composite models.

- exist in various extensions of Standard Model;
- would come in 3 different generations corresponding to the three quark and lepton generations;
- can be either scalar or vector particles.

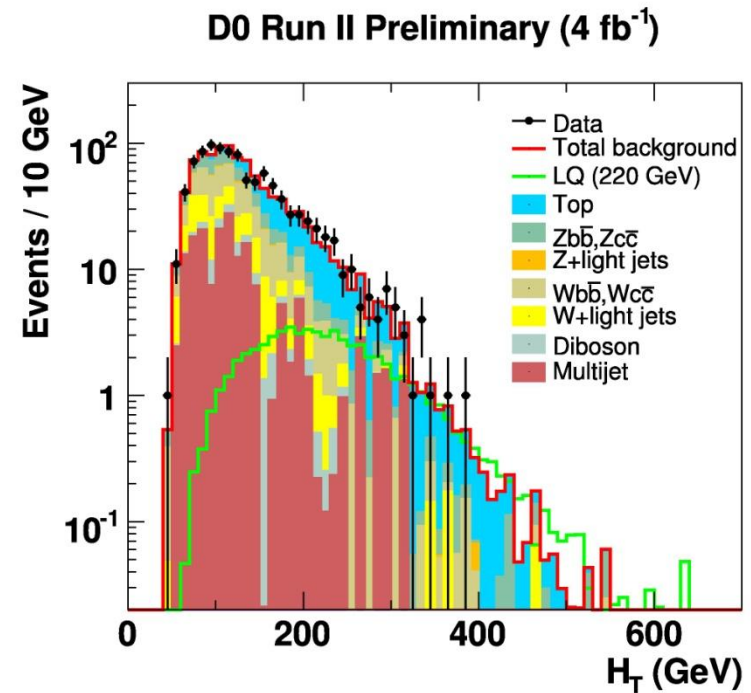
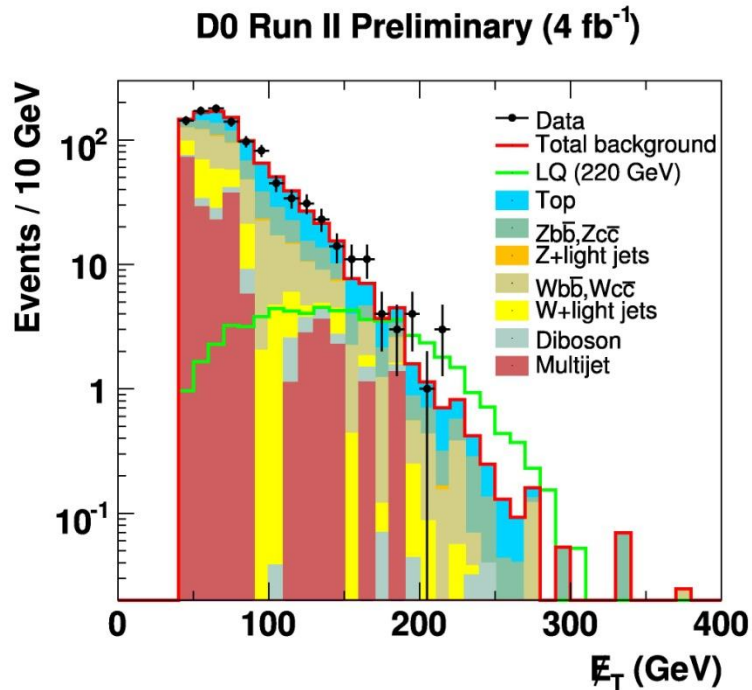
At the Tevatron, leptoquarks pairs would be produced mainly through $q\bar{q}$ annihilation or gg fusion with identical leading order production cross sections.



Leptoquarks

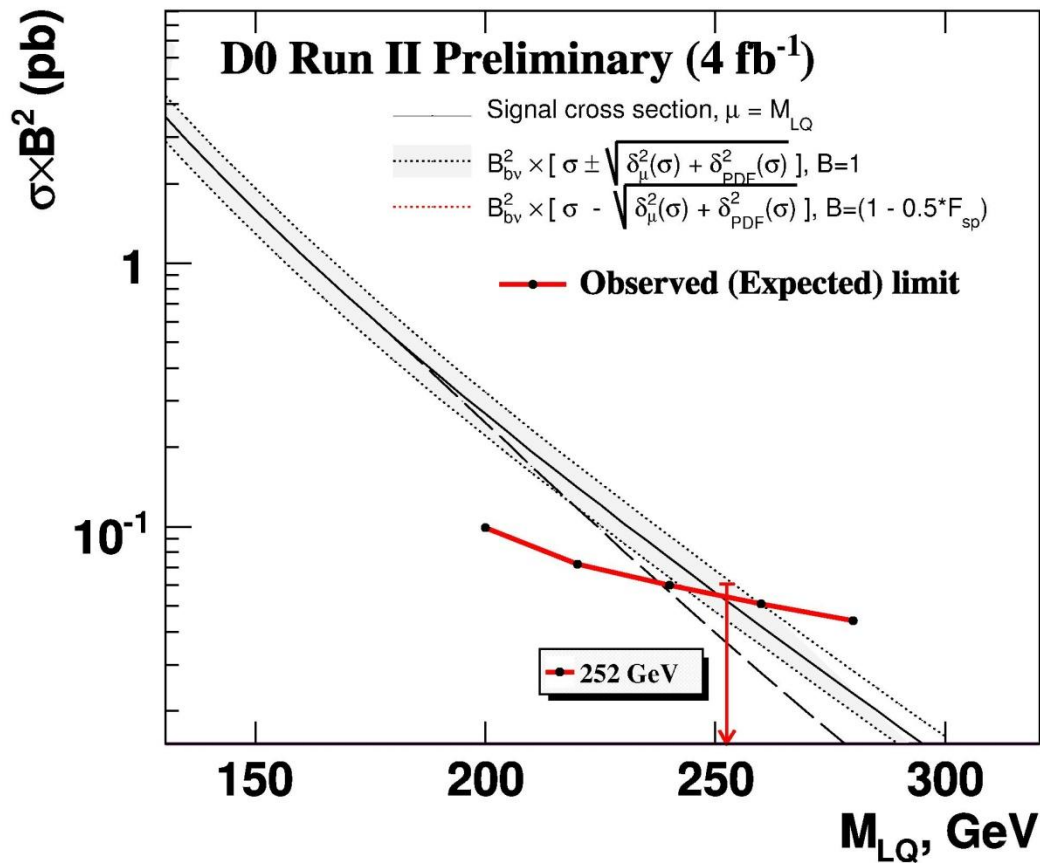
D0. <http://www-d0.fnal.gov/Run2Physics/WWW/results/prelim/NP/N68/> - 4 fb⁻¹

Search for final state with missing ET from neutrinos and two acoplanar b-jets from leptoquark. b-tagging is used to reduce SM background



Leptoquarks

3 events remain in the data compared to an expected $3.2 \pm 0.3 \pm 0.6$ events from background processes. New cross section limit is set.



Large Extra Dimensions (LED)

Possible solution to hierarchy problem

Arkani-Hamed, Dimopoulos, Dvali model (ADD)

- gravity propagates to n extra spatial dimensions;
- gives massive stable Kaluza-Klein gravitons G_{KK} ;
- can explain why gravity is weak: $1/G \sim M_{Pl}^2 \sim M_D^{n+2} R^n$

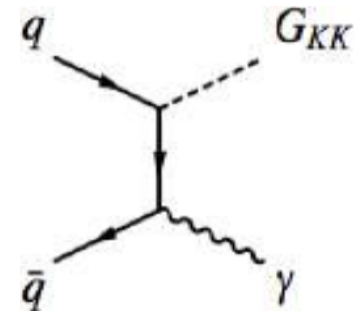
Signatures:

Real graviton

- high E_T single photon + missing E_T
- monojet + missing E_T

Virtual graviton

- high mass pair resonance: $ee, \mu\mu, \gamma\gamma$

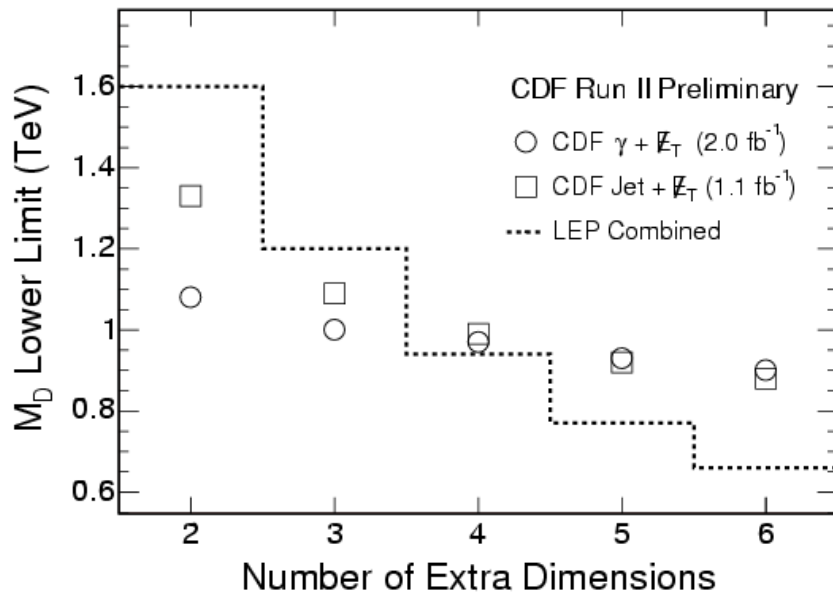
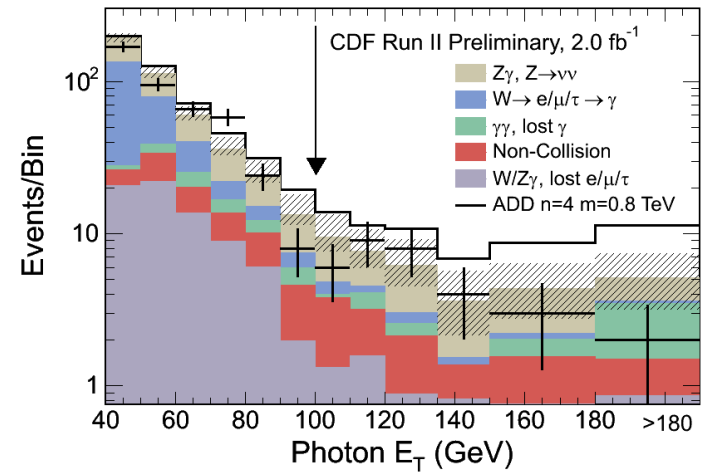
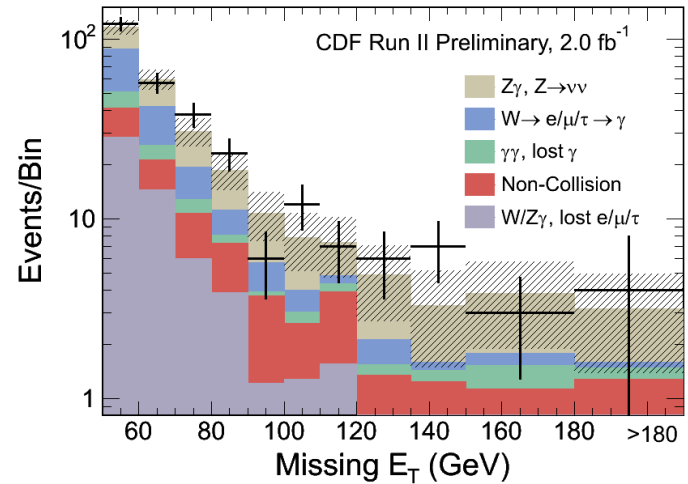


LED $\gamma + \text{MET}$

CDF
2 fb⁻¹

CDF. PRL 101:181602 (2008)

Data selection:
 Photon $E_T > 50$ GeV;
 Missing $E_T > 50$ GeV;
 No jets with $E_T > 15$ GeV;
 No tracks with $P_T > 10$ GeV



LED γ + MET

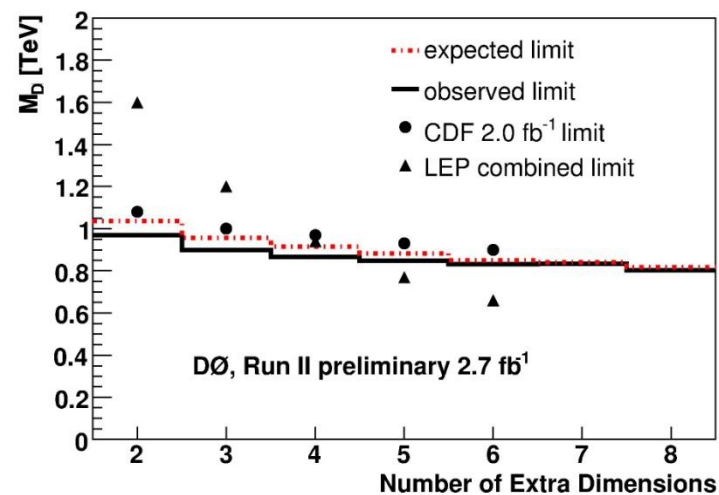
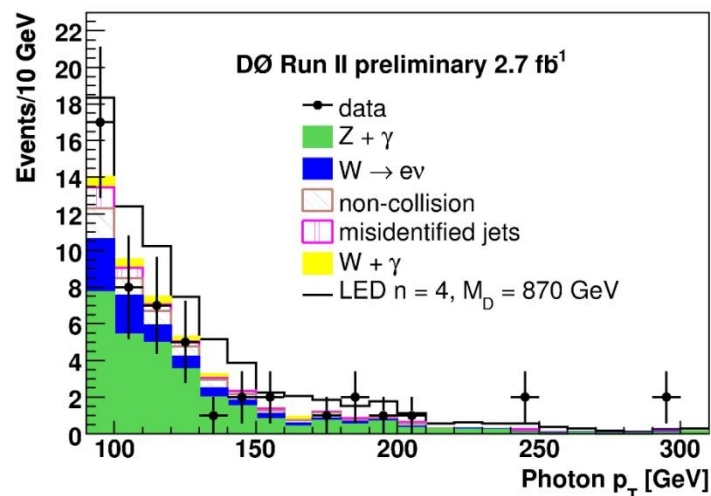
D0
2.7 fb⁻¹

D0. <http://www-d0.fnal.gov/Run2Physics/WWW/results/prelim/NP/N63/N63.pdf>

Data selection:

- Photon $E_T > 90$ GeV;
- Missing $E_T > 70$ GeV;
- No jets with $E_T > 15$ GeV;
- No tracks with $P_T > 10$ GeV
- EM shower points to PV

At 95% CL the limits on the fundamental mass scale M_D are set from 970 GeV to 816 GeV for two to eight extra dimensions

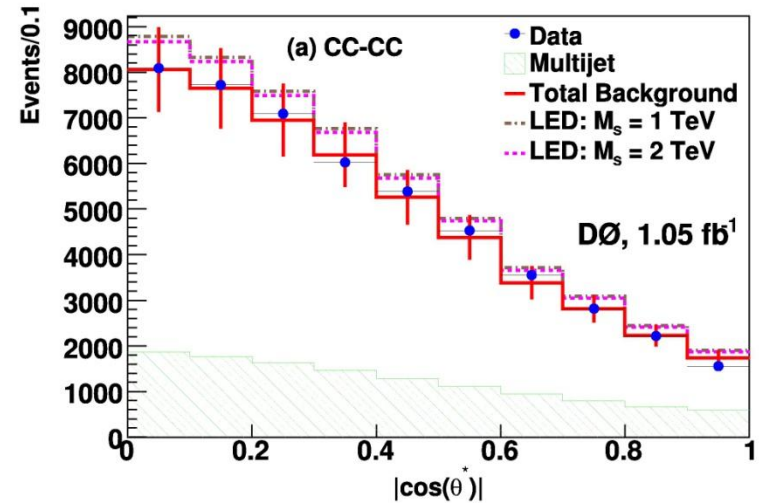
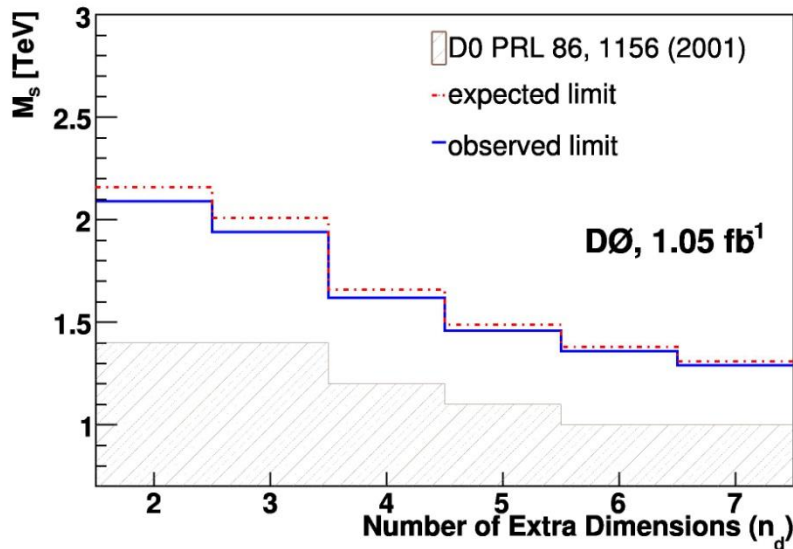
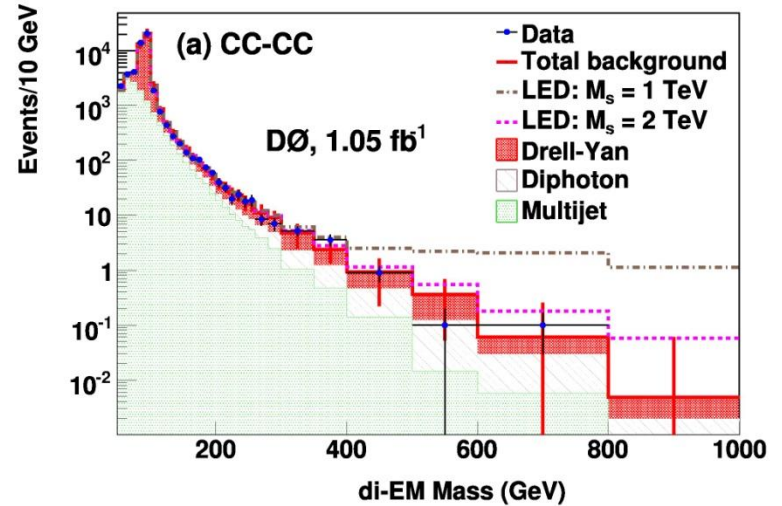


LED $\gamma\gamma/ee$

D0
1.1 fb⁻¹

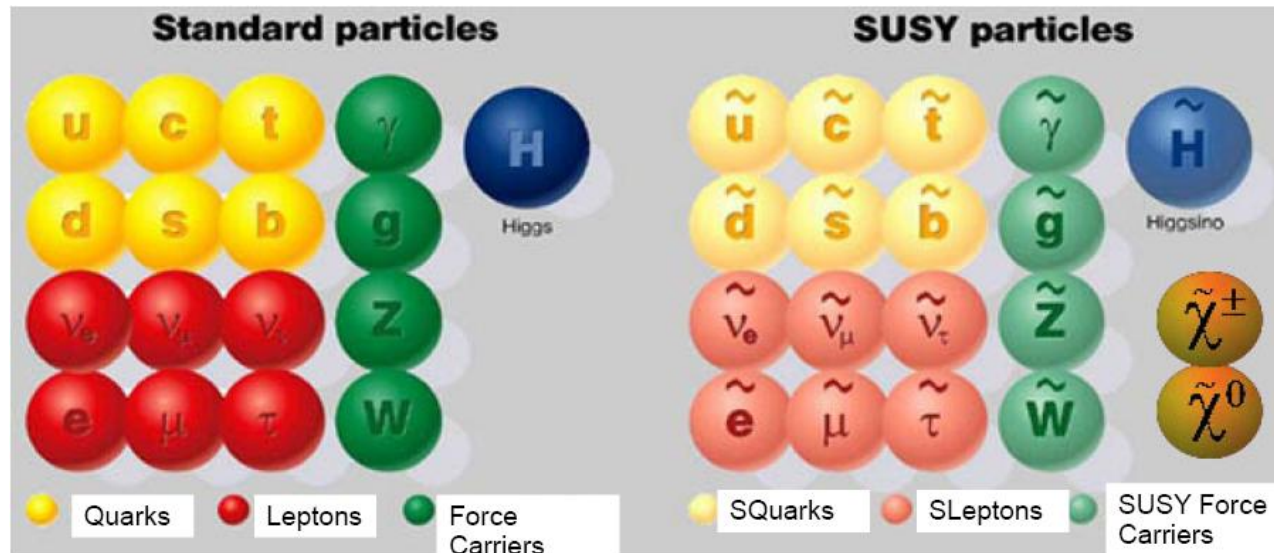
D0. PRL 102:051601 (2008)

- Combine ee and $\gamma\gamma$ channels to maximize sensitivity
- 2D-fit in mass and $\cos \theta^*$
- assume $BR(G_{KK} \rightarrow \gamma\gamma)/BR(G_{KK} \rightarrow ee) = 2$



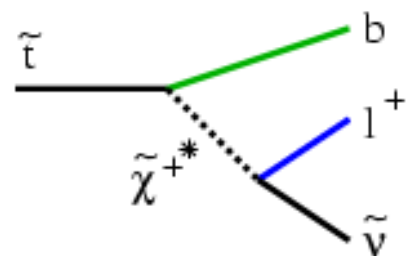
SuperSymmetry searches

- Spin-based symmetry between fermions and bosons
- Can be a solution to many outstanding problems
 - Provides a natural solution to the hierarchy problem
 - Allows to unify gauge couplings at GUT scale
 - Provides a dark matter candidate ($R = (-1)^{3(B-L)+2s}$)
 - No SuperPartners are seen: SUSY is broken



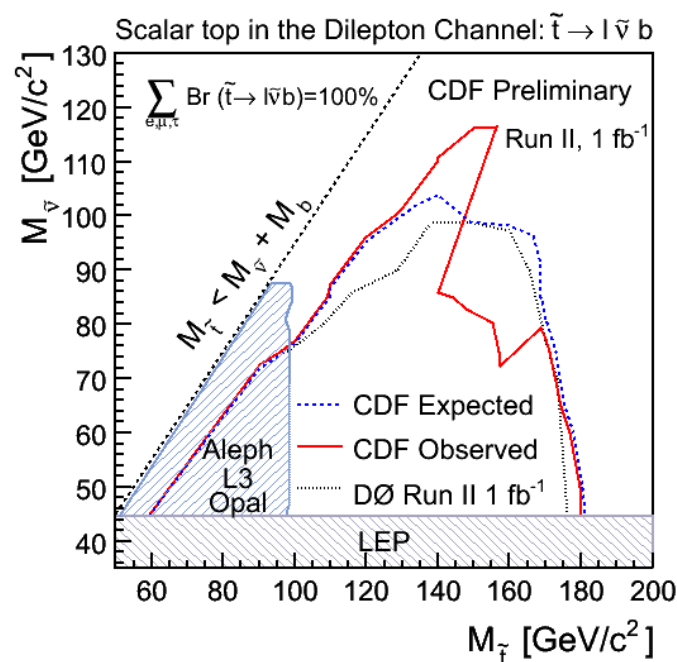
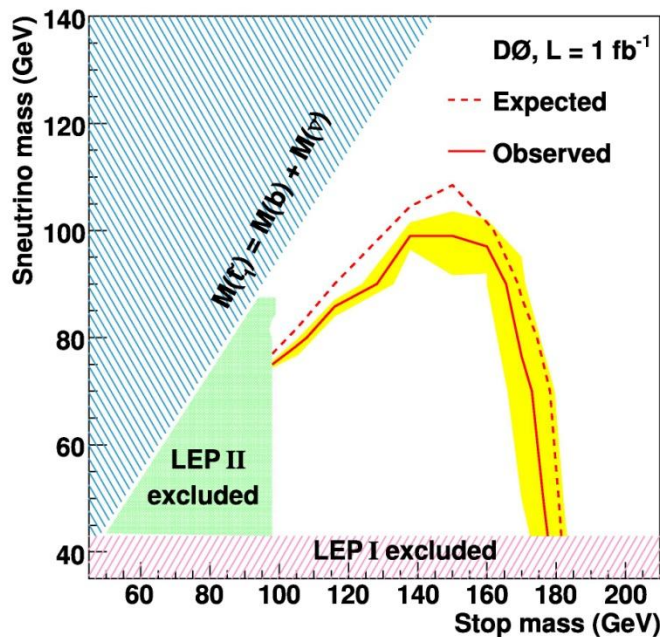
Stop searches

- Lightest stop might be lighter than top quark, it leads to interesting decay modes
- Final state signature (R-parity): 2 leptons, 2 b-jets, MET
Main background $t\bar{t}$ production
- Challenge can be potentially soft jets (leptons)



D0. PLB 675, 289 (2009) $e\mu, \mu\mu$

CDF. http://www-cdf.fnal.gov/physics/exotic/r2a/20090319.stop_dilepton/cdf9775_stop_in_dilep_pub.pdf $e\mu, \mu\mu, ee$



Stop searches

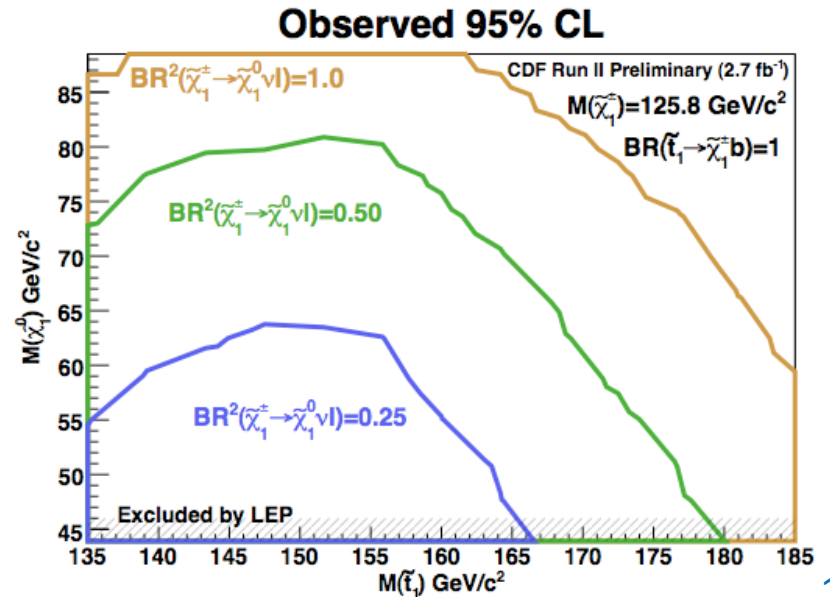
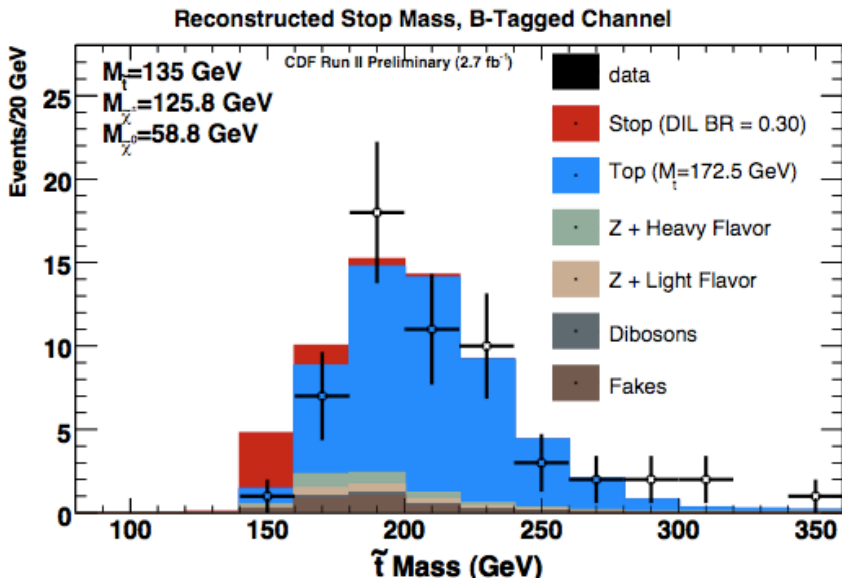
CDF
2.7 fb⁻¹

CDF. http://www-cdf.fnal.gov/physics/new/top/2008/tprop/Stop/images2_7InvFb_may20_09/stopDilPublicNote_may20_09.pdf

$\tilde{\chi}_1^0$ is the LSP ← WMAP data
 $m_{\tilde{t}_1} \lesssim m_t$ ← Electroweak Baryogenesis
 $m_{\tilde{\chi}_1^+} < m_{\tilde{t}_1} - m_b$ ← C. Balazs, M. Carena, C. Wagner, PRD 70 (2004) 015007
 - A possibility, otherwise $\tilde{t}_1 \rightarrow c\tilde{\chi}_{1,2}^0$

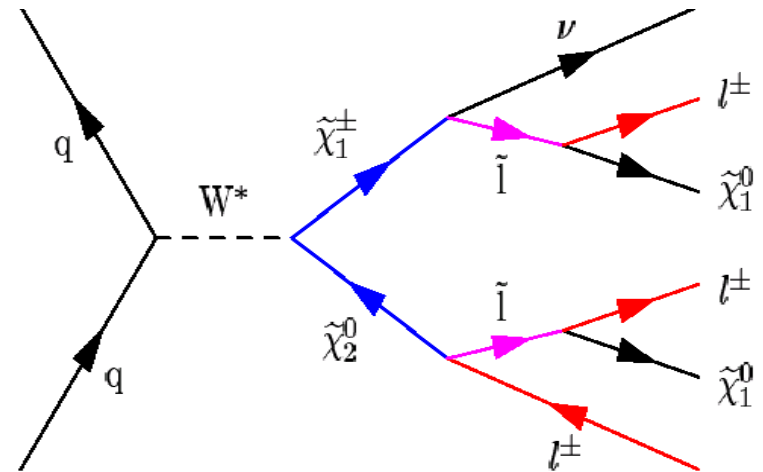
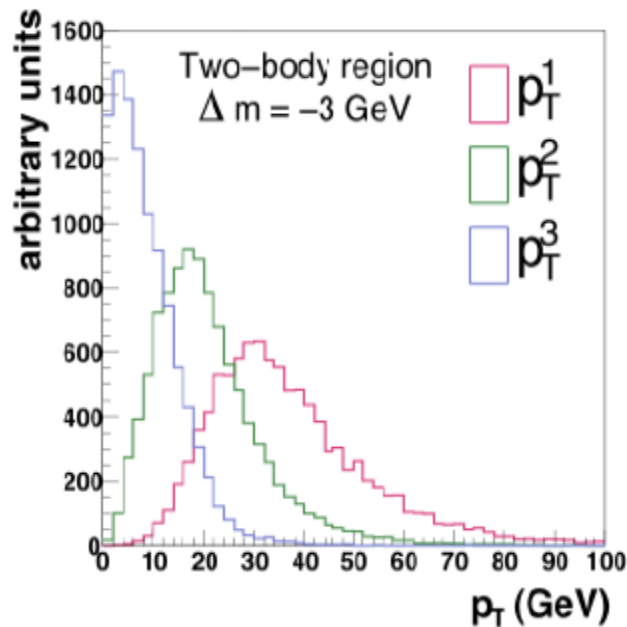
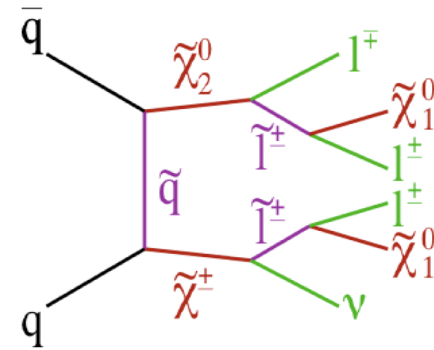
$$\tilde{t}_1 \rightarrow b\tilde{\chi}_1^\pm \rightarrow b\tilde{\chi}_1^0 W^\pm(*) \rightarrow b\tilde{\chi}_1^0 l\nu$$

- b-tagging is used
- Good agreement between data and SM is observed.



Trileptons

- Assuming R-parity supersymmetry can be discovered in trilepton final state and missing ET
- Clean signature
- Largest source of background are diboson processes
- Leptons can be soft and depend on Δm



Trileptons

CDF. http://www-cdf.fnal.gov/physics/exotic/r2a/20090521.trilepton_3fb/cdf9817_susy_trilep_pub.pdf - 3.2 fb⁻¹

D0. <http://www-d0.fnal.gov/Run2Physics/WWW/results/final/NP/N09A/N09A.pdf> - 2.3 fb⁻¹

CDF			D0		
<ul style="list-style-type: none"> • 5 categories of leptons and tracks combinations • p_T thresholds 5-20 GeV • MET > 20 GeV 			<ul style="list-style-type: none"> • Combination of $\mu\mu$, $\mu\tau$, $e\mu$, $\mu\tau$, and $e\tau$ • Optimization of high-p_T and low-p_T criteria • MET > 20 GeV 		
	Background	Data		Background	Data
Trilepton	1.5±0.2	1	Low- p_T	5.4±0.6	9
Lepton+Track	9.4±1.4	6	High- p_T	3.3±0.4	4

No evidence for SUSY is observed

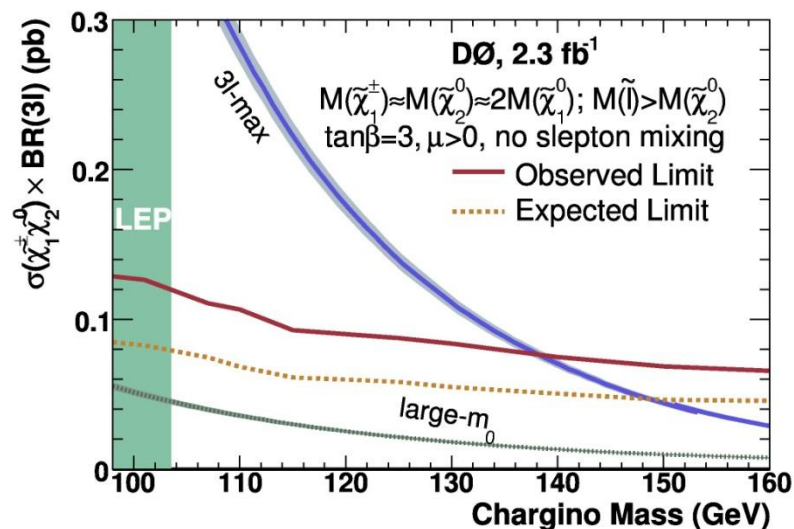
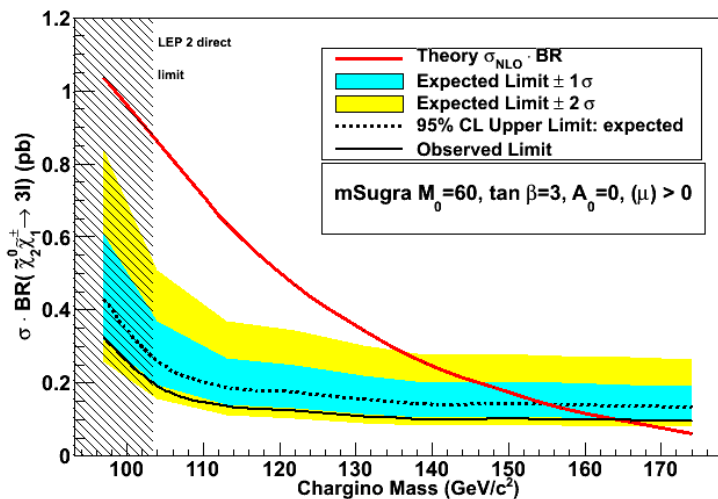
Trileptons

CDF

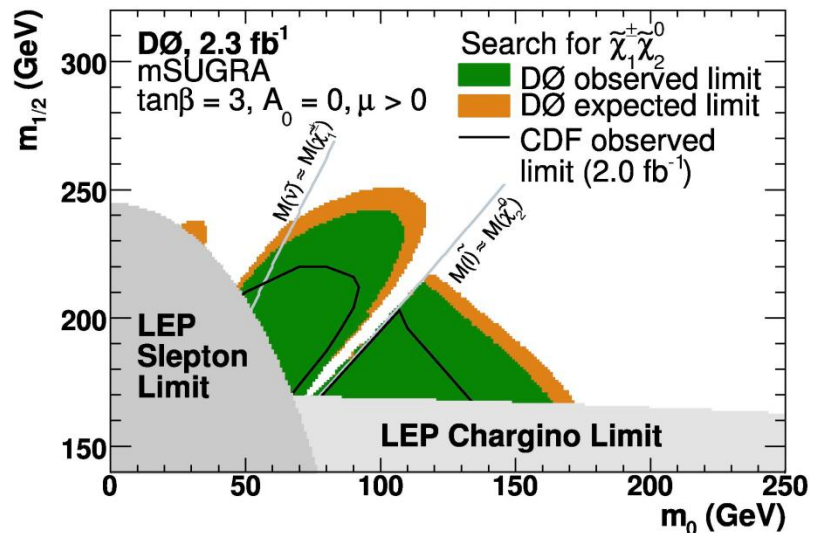
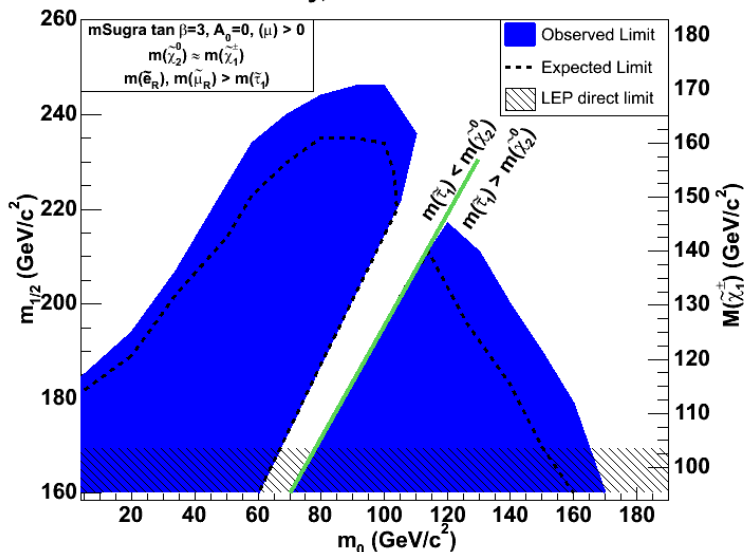
DØ

New limits are set

CDF Run II Preliminary, 3.2 fb⁻¹

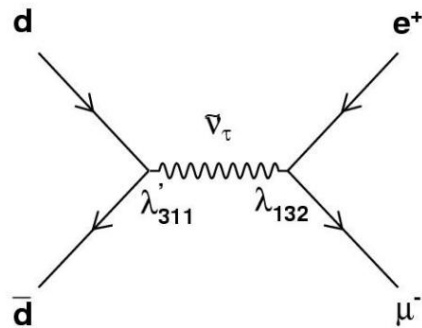


CDF Run II Preliminary, 3.2 fb⁻¹



Search for $\tilde{\nu}_\tau$

If R-parity is not conserved then single production of super partner is possible



Search for isolated high p_T lepton pairs

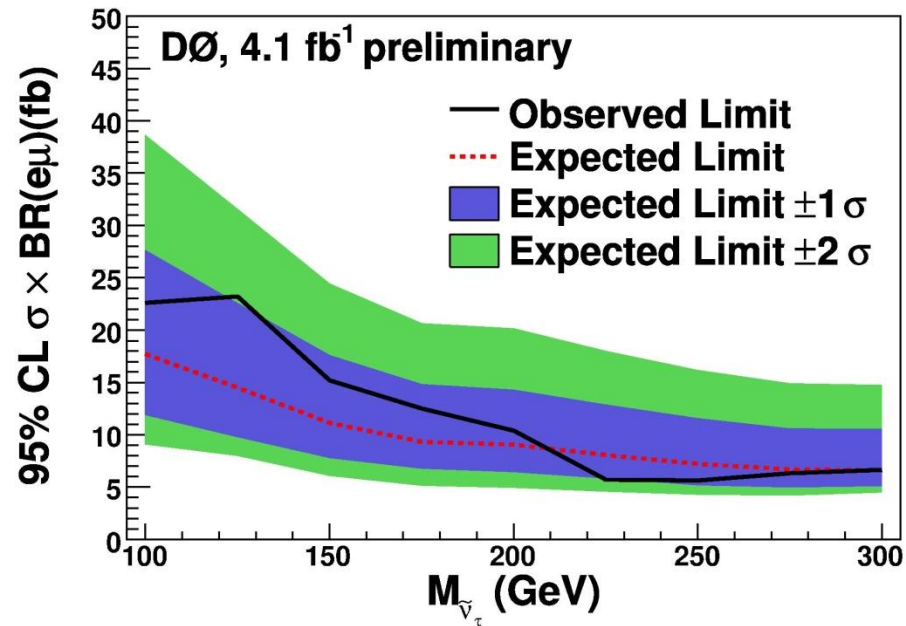
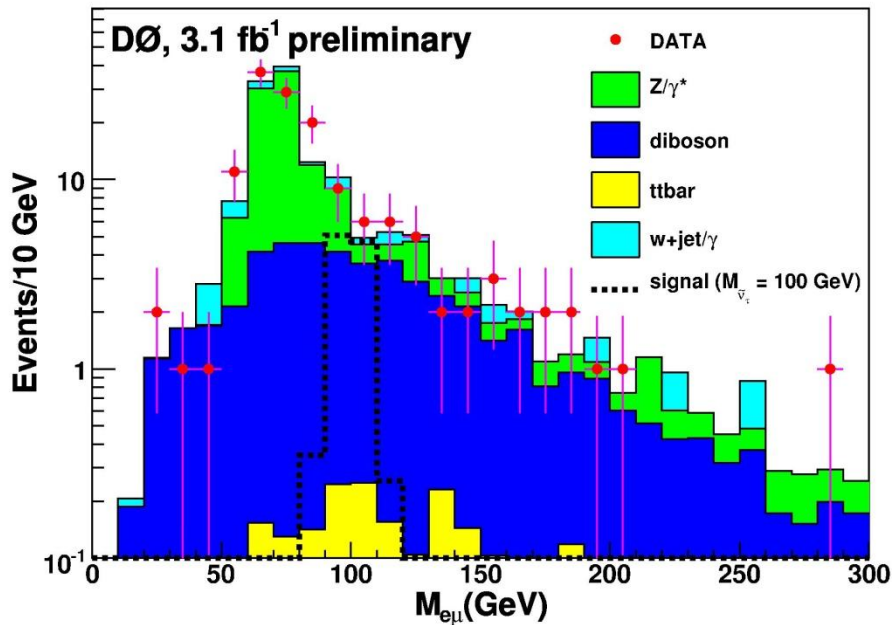
Assume $\tilde{\nu}_\tau$ is LSP

Assume all RPV couplings are zero except $\lambda'_{311}, \lambda_{321} = \lambda_{312}$

Latest D0 result uses 4.1 fb^{-1} data

Search for $\tilde{\nu}_\tau$

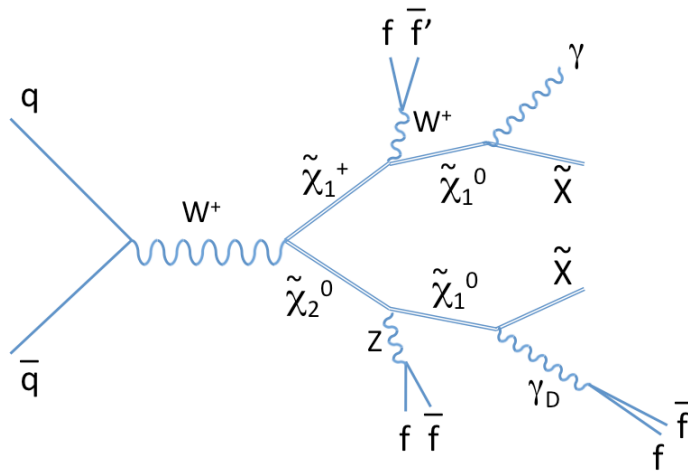
DØ. <http://www-d0.fnal.gov/Run2Physics/WWW/results/prelim/NP/N64/N64.pdf> - 4.1 fb⁻¹



SUSY with Hidden Valleys

SUSY with Hidden Valleys is important class of Hidden Valleys models

- Motivated by recent results from PAMELA, ATIC, EGRET, HESS, Fermi/LAT
- Many phenomenological problems can be explained
- If R-parity is conserved superpartners are produced in pairs and decay to the SM particles and the lightest superpartner



Very distinct final state which never was explored:

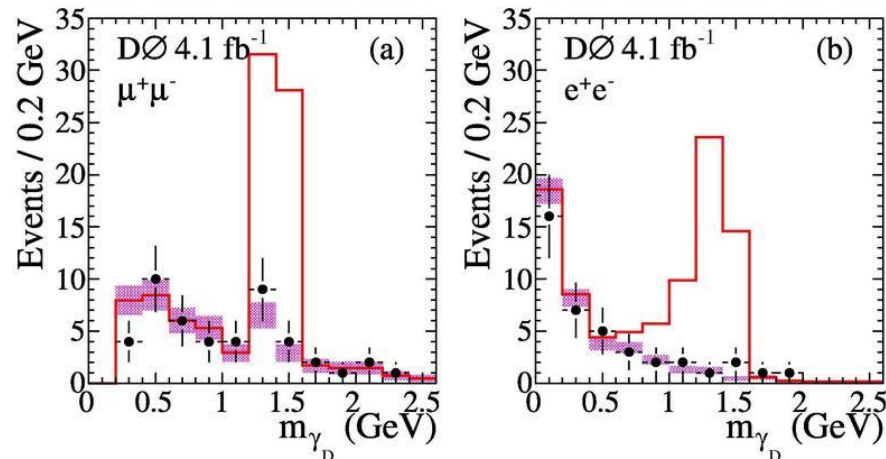
- Missing E_T (from darkino)
- Photon
- Two spatially close leptons

SUSY with Hidden Valleys

D0. PRL 103, 081802 (2009) - 4.1 fb⁻¹

Major sources of background are:

- QCD events with real or fake photons and mismeasured MET. These contain jets or photon conversions faking the dark photon
- $W \rightarrow l\nu$ plus real or fake photon. The dark photon is faked by an accidental overlap of a high p_T track with the lepton

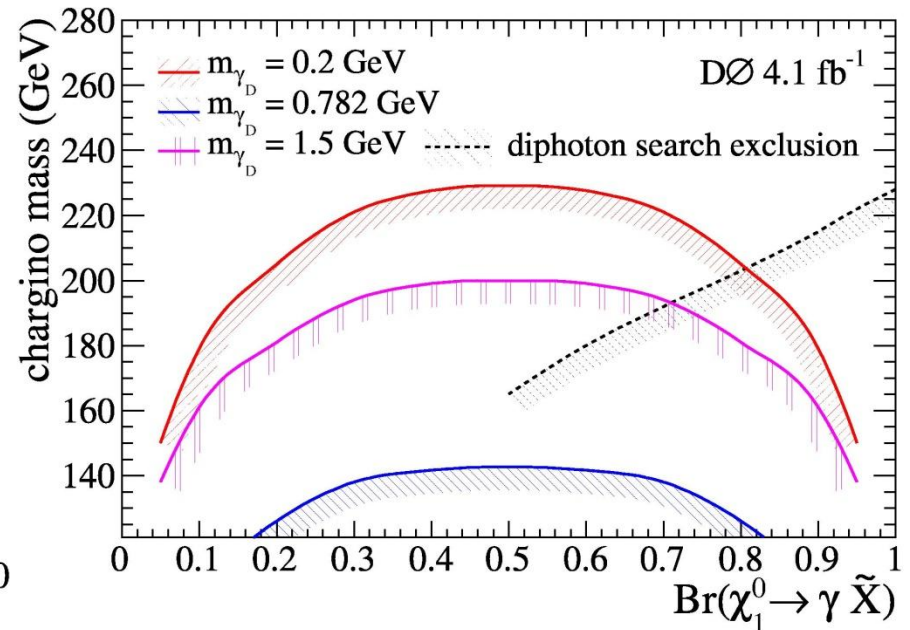
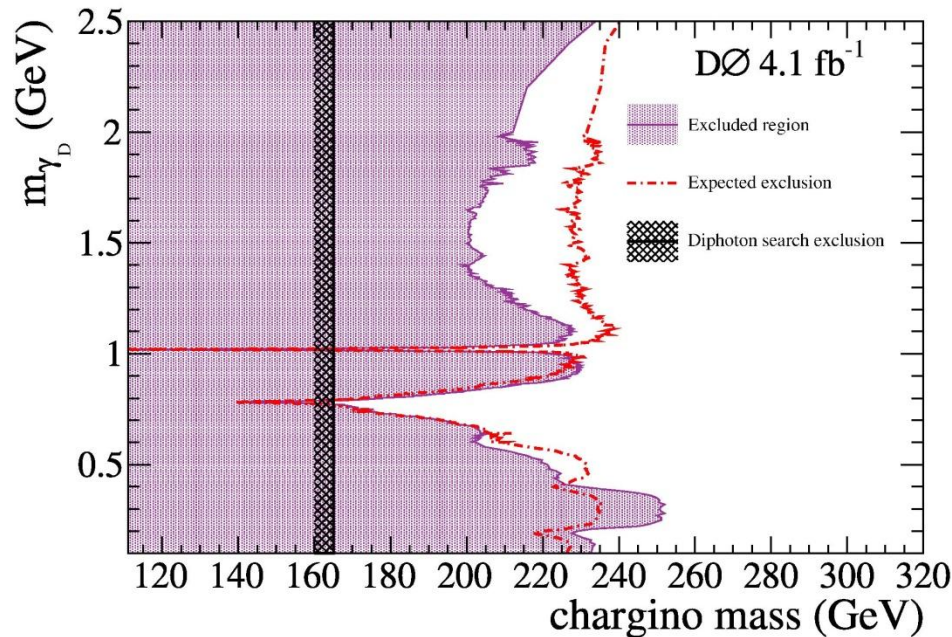


The data is consistent with background.

SUSY with Hidden Valleys

-No evidence for dark photon events is found;

For dark photon masses of 0.2, 0.782, and 1.5 GeV chargino masses of 230, 142, and 200 GeV, respectively, are excluded.



Summary

It's a very good time to make high energy physics searches at Tevatron!

- $\sim 7 \text{ fb}^{-1}$ of integrated luminosity (and growing!);
- well understood detectors;
- powerful analysis tools;

Most of presented results use 1-4 fb^{-1} datasets

- with growing integrated luminosity there can be many promising updates

There are a lot of interesting results which are not covered in this talk

Please check web pages:

<http://www-cdf.fnal.gov/physics/exotic/exotic.html> (CDF)

<http://www-d0.fnal.gov/Run2Physics/np> (D0)