

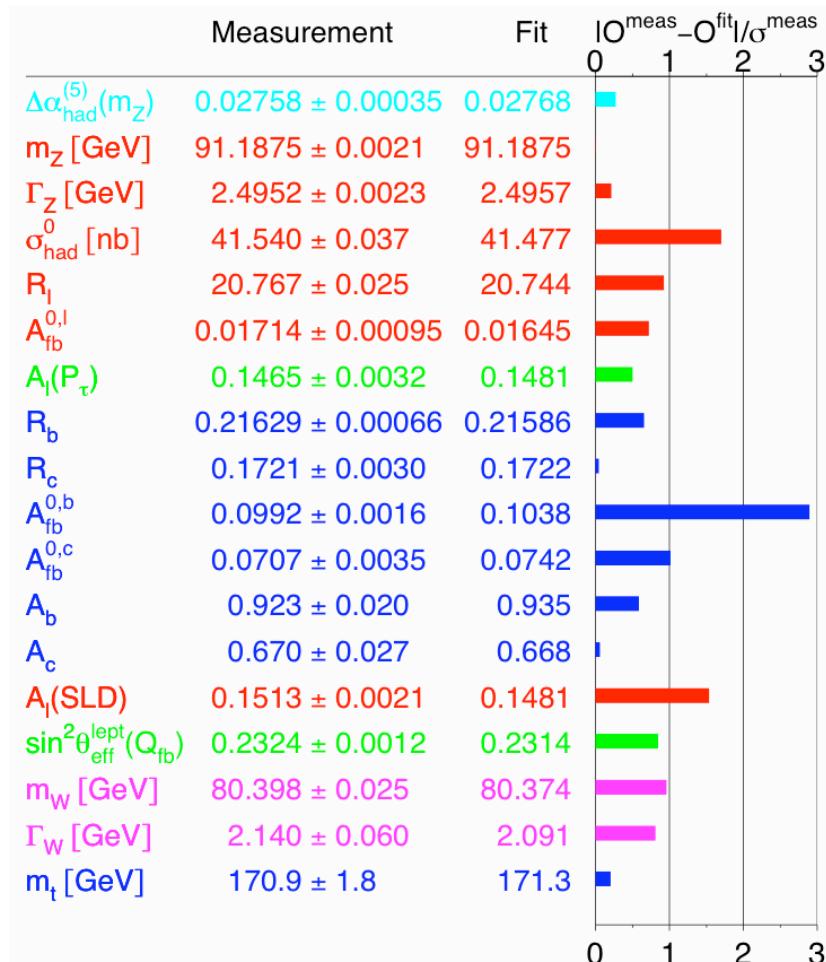


New Physics Searches at the Tevatron

Yurii Maravin (KSU)
On behalf of the CDF and DØ Collaborations



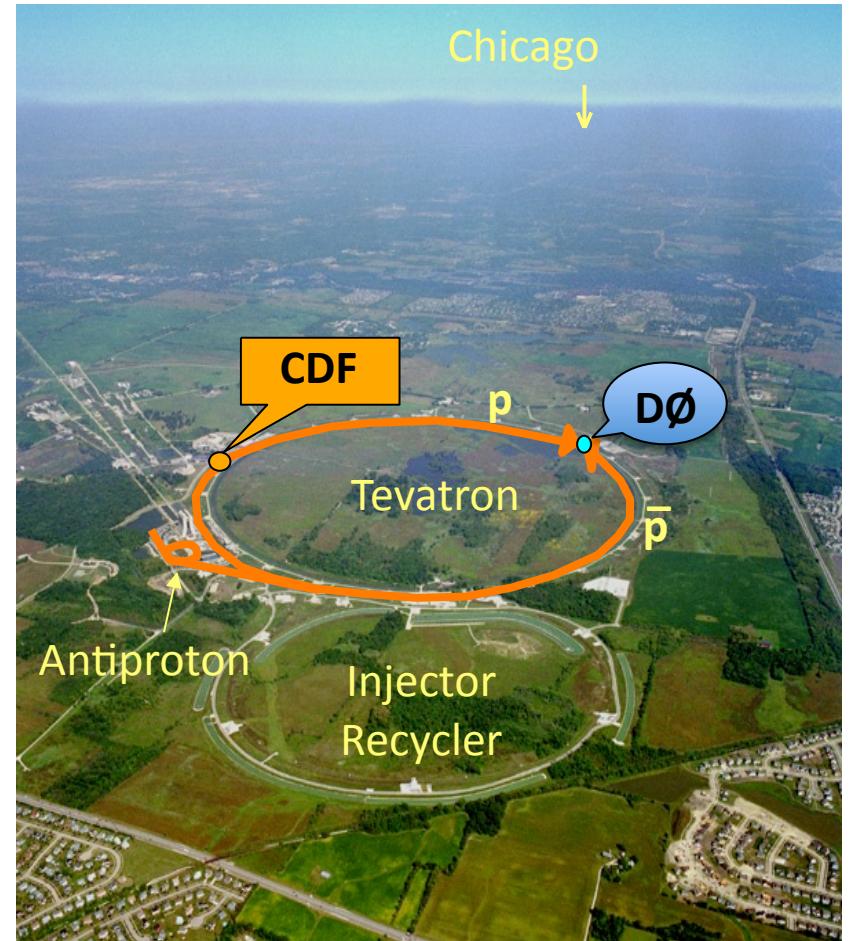
Standard model and beyond



- Excellent agreement between data and theory
 - Yet incomplete low energy approximation
 - Why 3 generations?
 - What is the mechanism of EWSB?
 - Hierarchy problem
 - Dark matter candidate
- Search for new physics would pave the path to the general theory

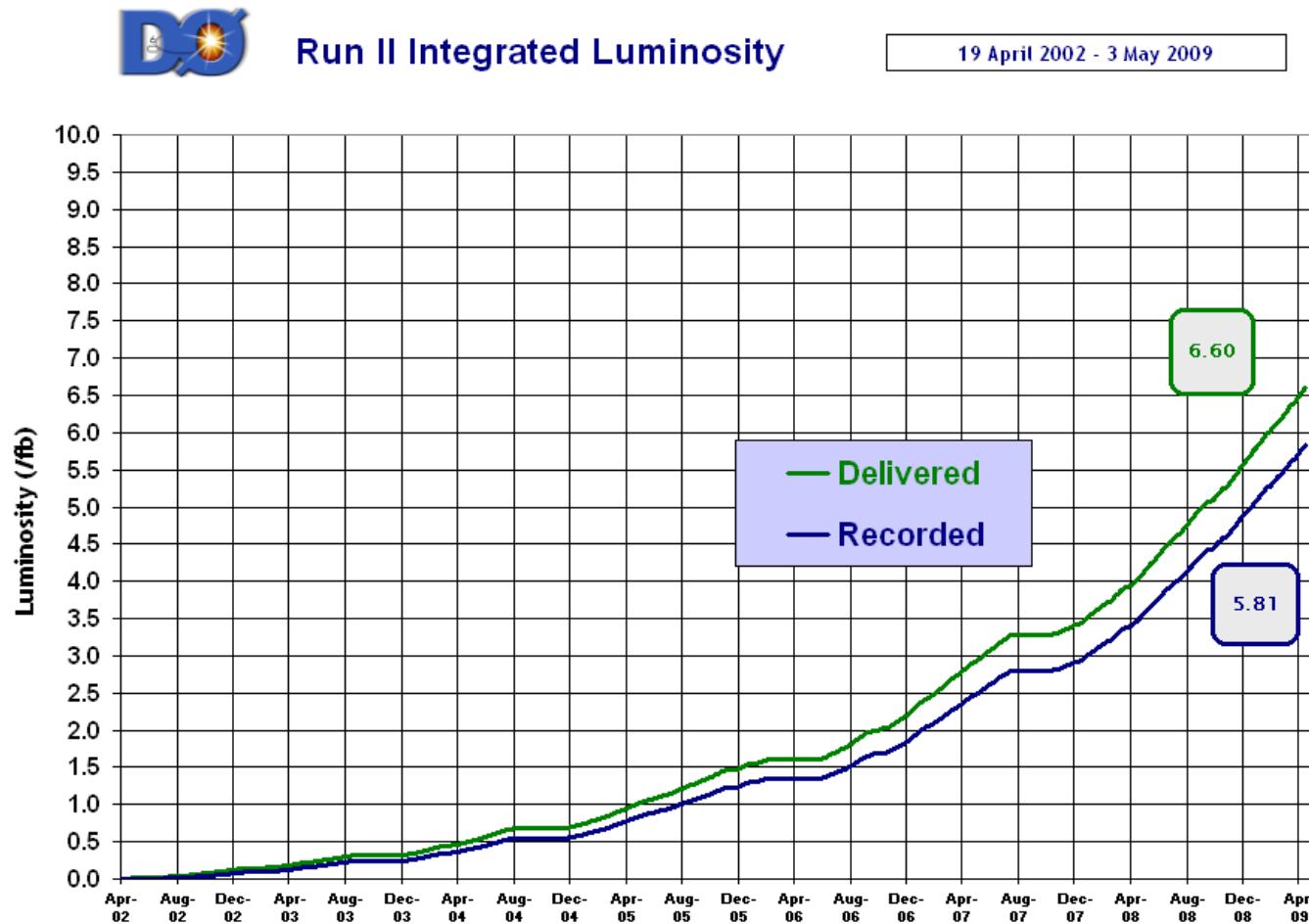
The Tevatron

- Current energy frontier
 - $p\bar{p}$ beams with 1.98 TeV
- Host of two general purpose HEP detectors: CDF and D \emptyset
- Excellent performance of both Tevatron and detectors



Tevatron performance

- More than 6 fb^{-1} delivered to both detectors

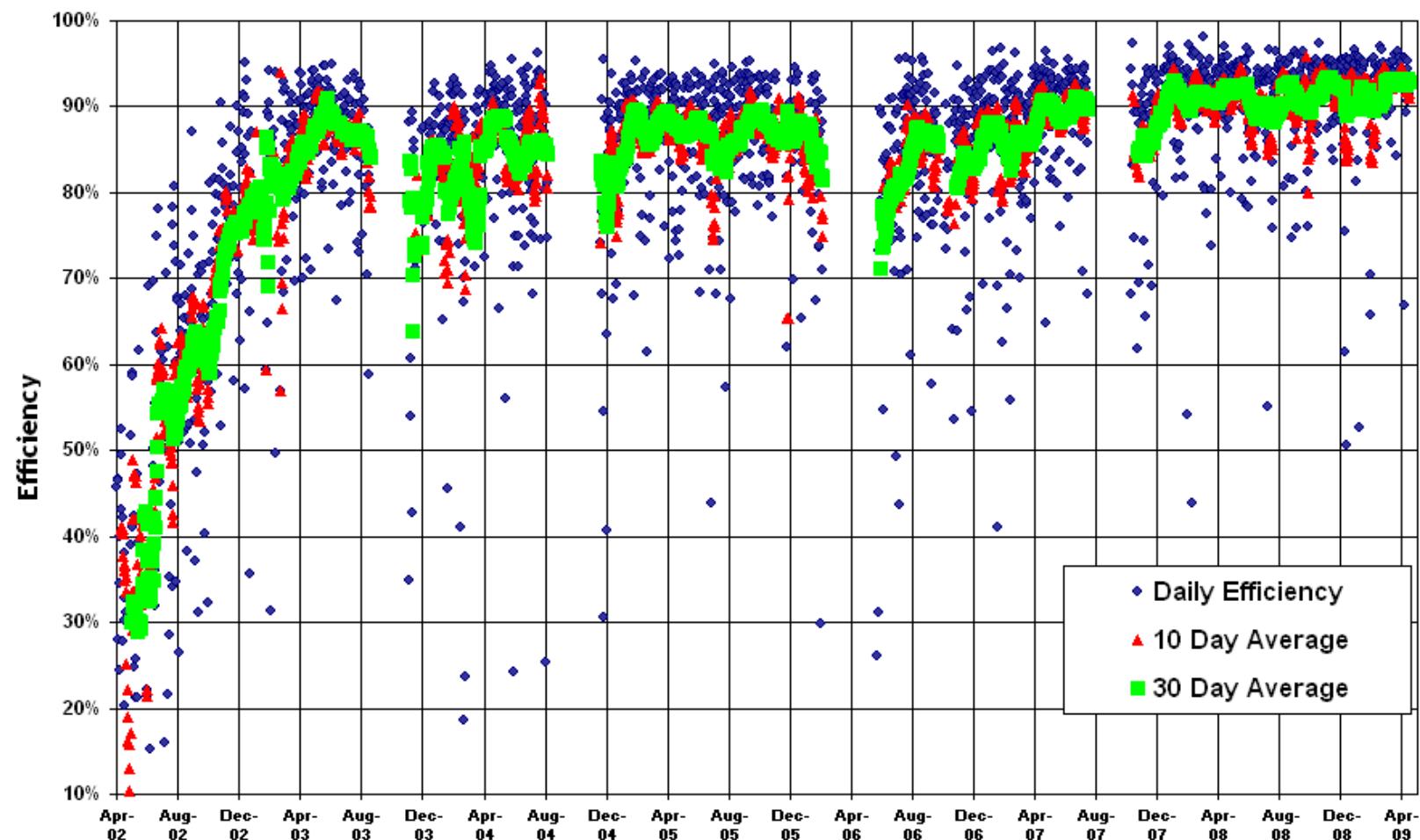


Data taking efficiency



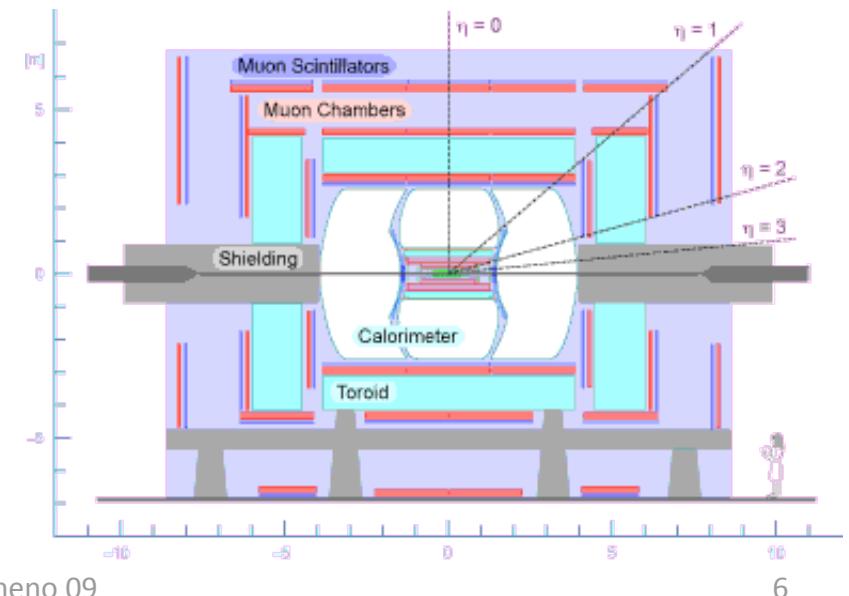
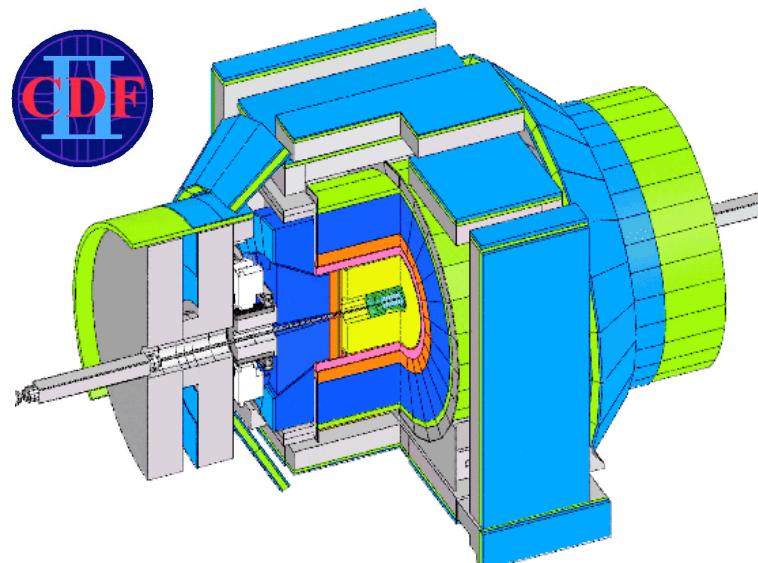
Daily Data Taking Efficiency

19 April 2002 - 3 May 2009



CDF and D \emptyset detectors

- Electrons $|\eta| < 2$
- Muons $|\eta| < 1.5$
- Silicon tracking $|\eta| < 2.0$
- Calorimetry $|\eta| < 3.6$
- Excellent tracking!
- Electrons $|\eta| < 3.0$
- Muons $|\eta| < 2.0$
- Silicon tracking $|\eta| < 3.0$
- Calorimetry $|\eta| < 4.2$
- Excellent muon system and calorimeter!



Overview of new physics searches

- Quite a lot of very interesting results!
- Will focus on the very recent ones
- For more complete overview of the results from Tevatron please see New Phenomena results web pages



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

Conveners: Monica D'Onofrio (IFAE Barcelona)
Tom Wright (U of Michigan)



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

Conveners: Todd Adams (FSU)
Arnaud Duperrin (CPPM Marseille)

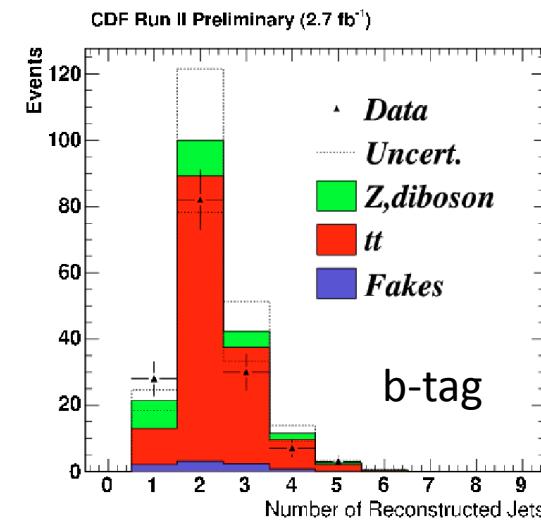
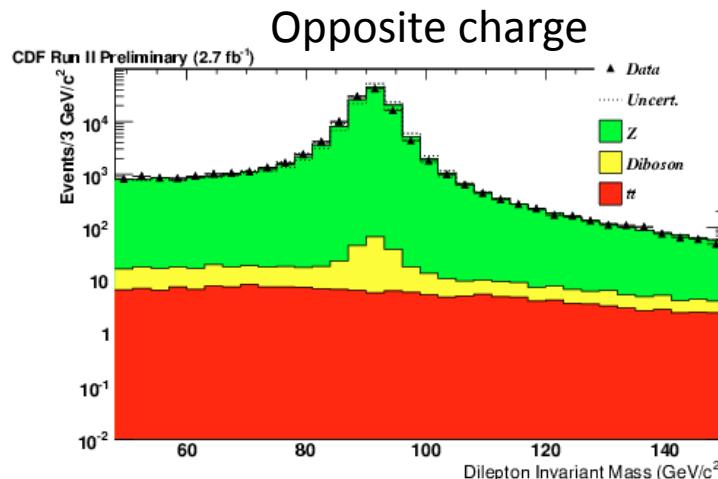


Search for b' quark

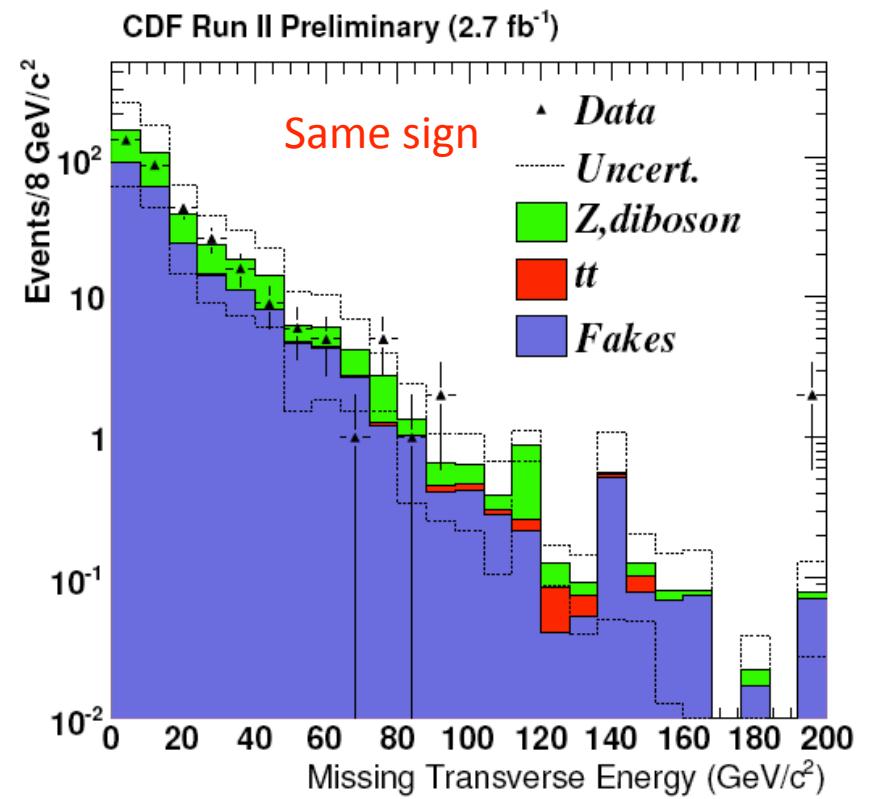
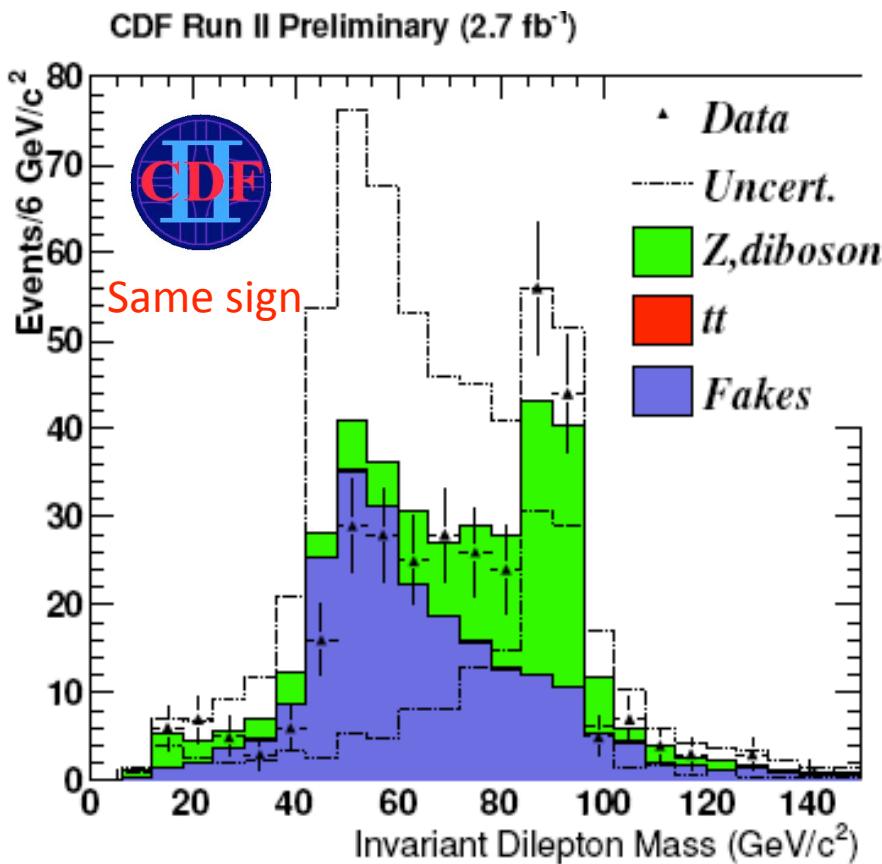


- Generic search for 4th generation b quark that also covers models predicting heavy down-type B quark and exotic $T_{5/3}$ fermion
 - Composite Higgs models
- Produced in pairs, decays to tW
 - Search in same charge lepton final state
 - Cross check with opposite charge lepton samples

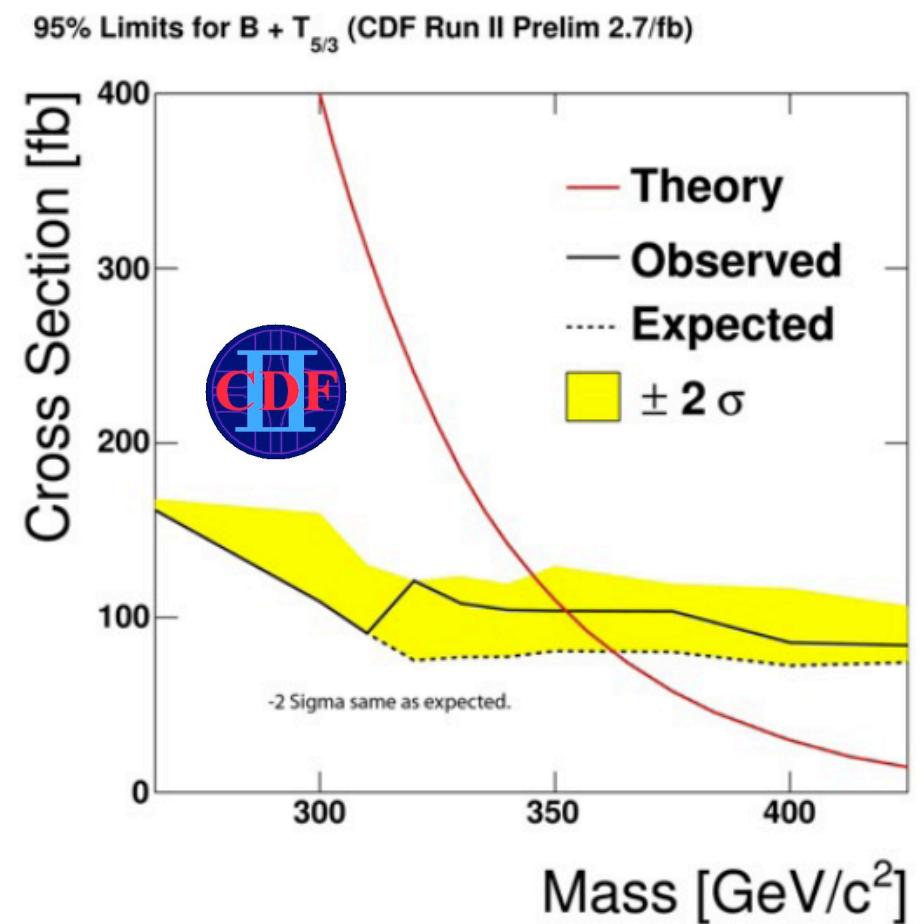
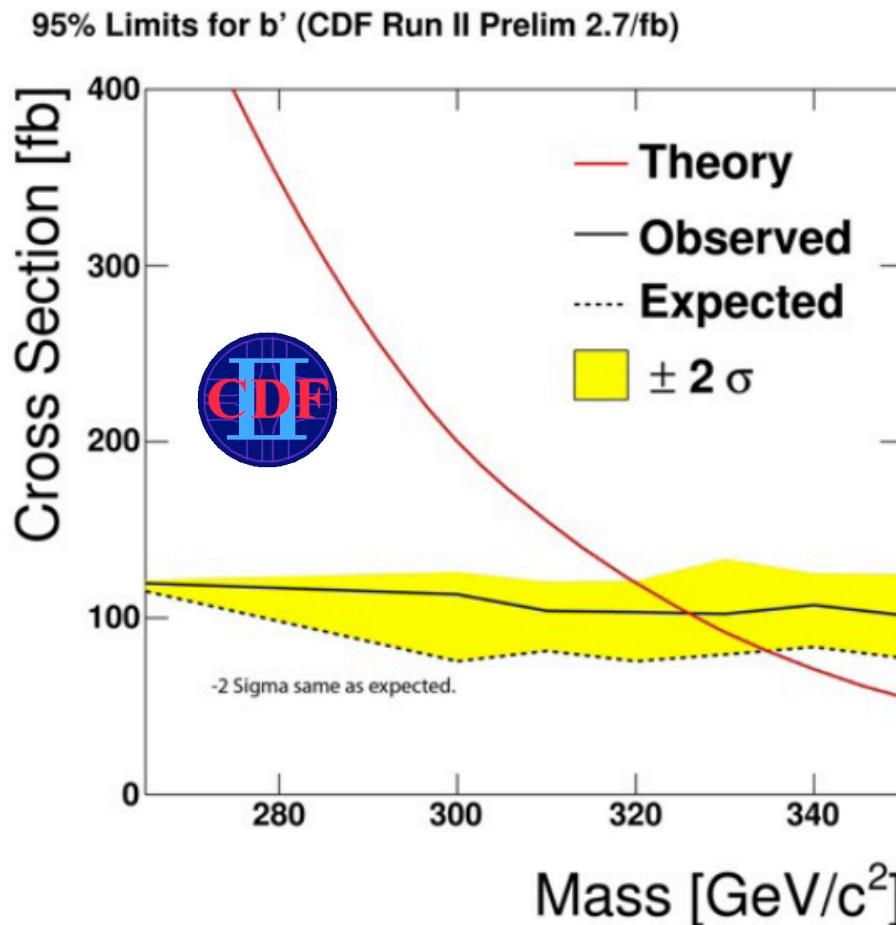
Contino & Servant arXiv:0801.1679



- Major background is Z, diboson, and processes with misidentified lepton from W+jets
 - Excellent agreement between data and SM
 - Very conservative uncertainties



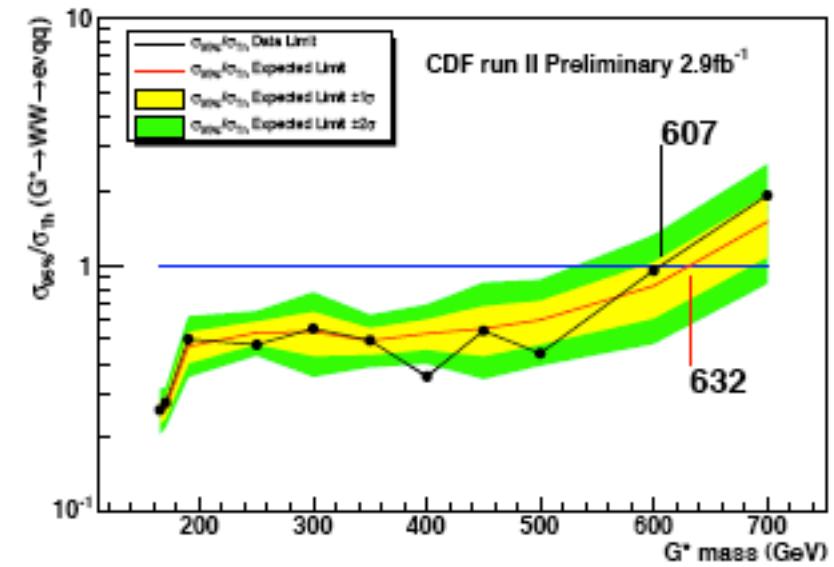
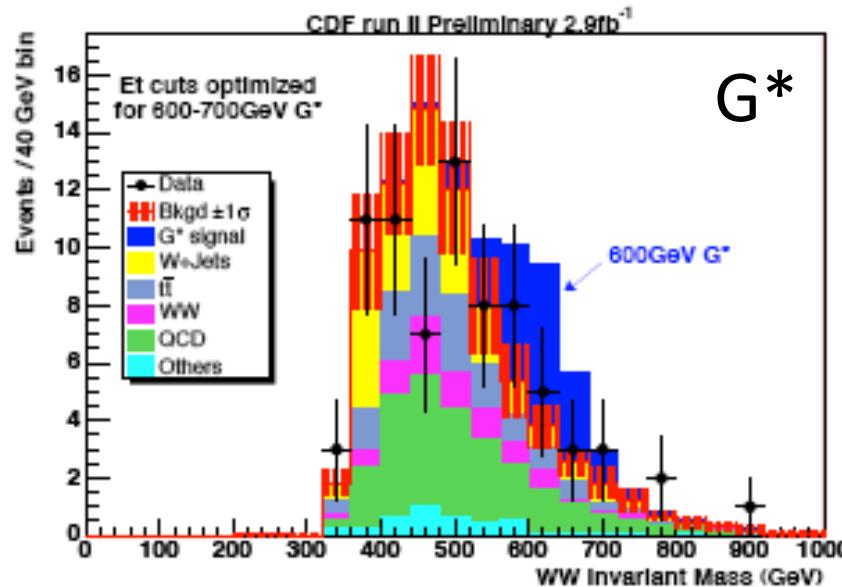
- Exclude b' with mass > 326 GeV and $B + T_{5/3}$ with mass > 352 GeV at 95% CL

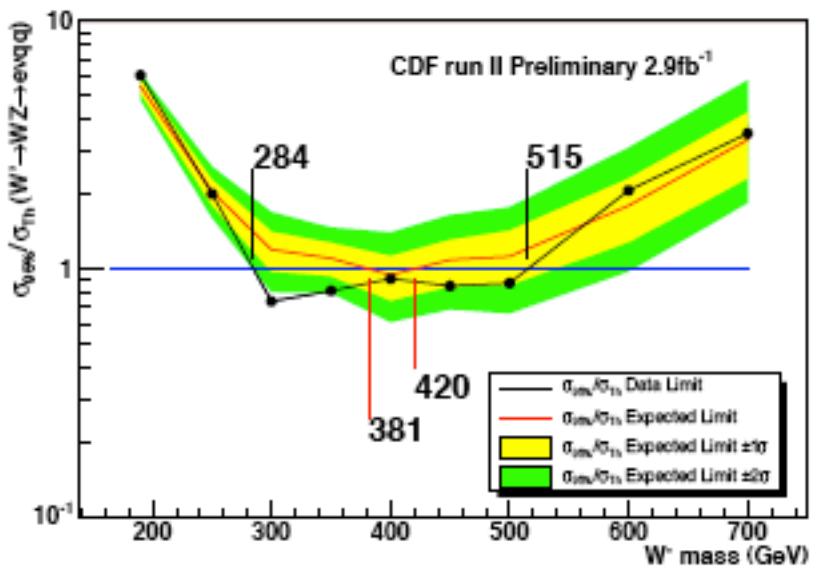
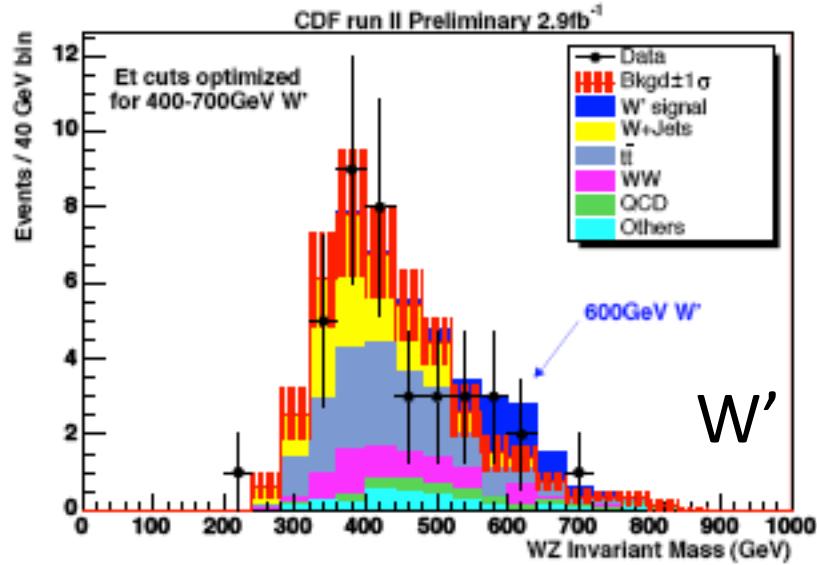
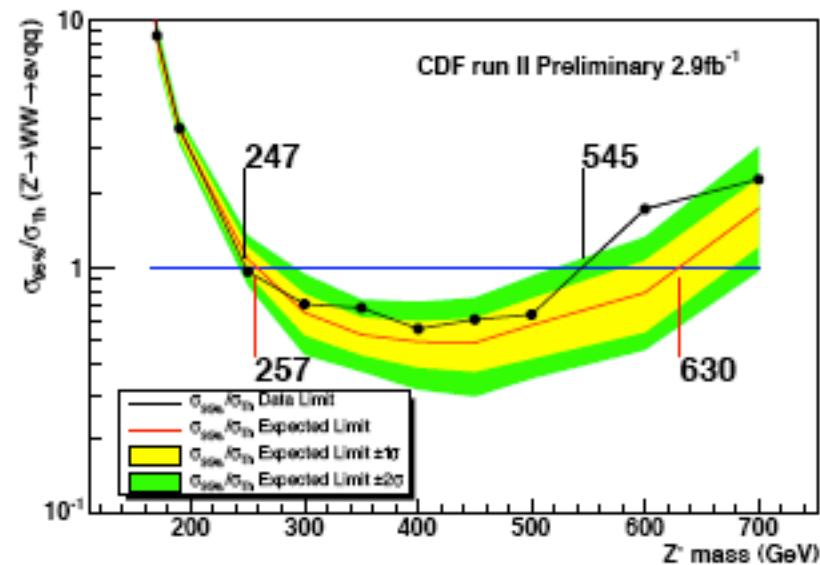
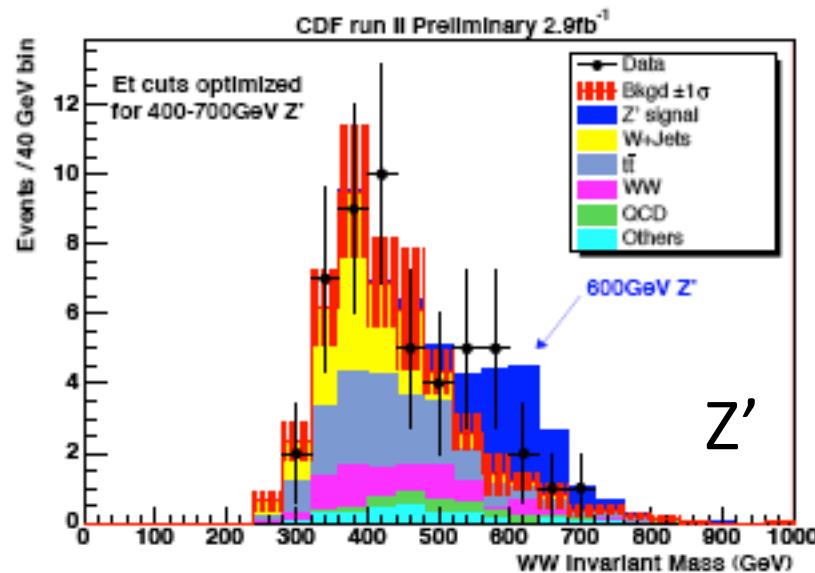




Search for WW/WZ resonances

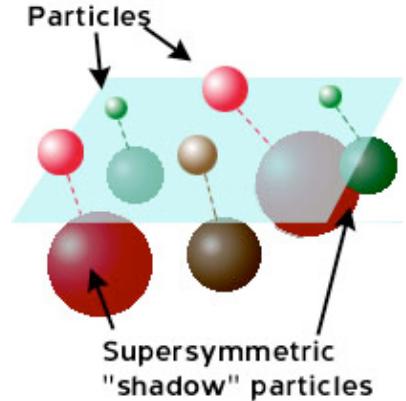
- New search for resonances in WW and WZ final state is done with 2.9 fb^{-1}
 - Sensitivity to Randal-Sundrum graviton, Z' and W'
- Use $W \rightarrow e\nu$ and $V \rightarrow jj$ decay mode
 - Highest backgrounds are $t\bar{t}$, $W+jets$, multijet



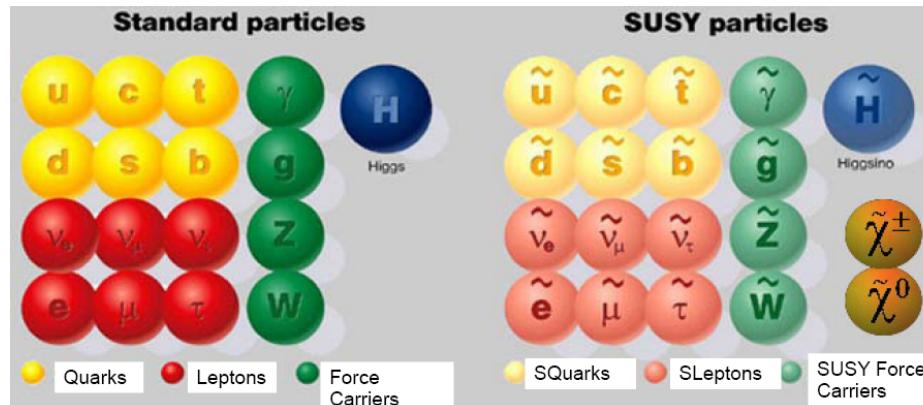


	G^+	Z'	W'
Expected Exclusion	< 632 GeV	257 - 630 GeV	381-420 GeV
Data Exclusion	< 606 GeV	247 - 545 GeV	284-515 GeV

Supersymmetry

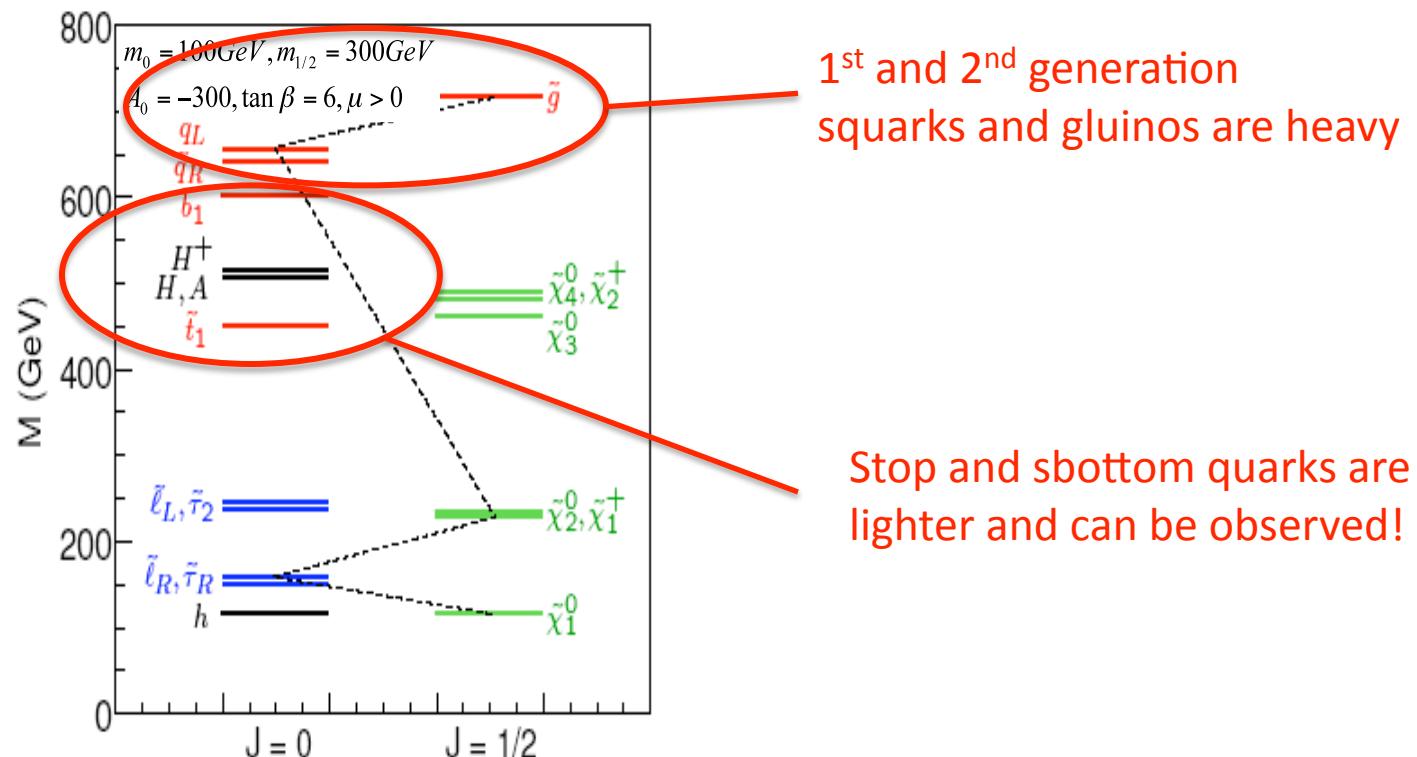


- One of the most favorite extensions of the standard model: SUSY
 - Spin-based symmetry between fermions and bosons



- 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
 - Phenomenology and search is driven by the way SUSY is broken and a particular example is usually used as a benchmark: mSUGRA (gravity-mediated)
 - *See Ray Culbertson's talk later today focusing on new gauge mediated (GMSB) results from CDF*

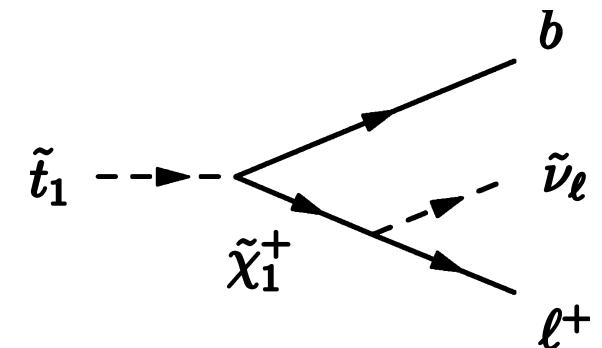


Search for stop quark

- Top quark would have two scalar partners: \tilde{t}_R , \tilde{t}_L
mixing is proportional to the mass of top
 - Potentially large mass splitting between \tilde{t}_1 and \tilde{t}_2
 - The lightest stop can be lighter than the top!

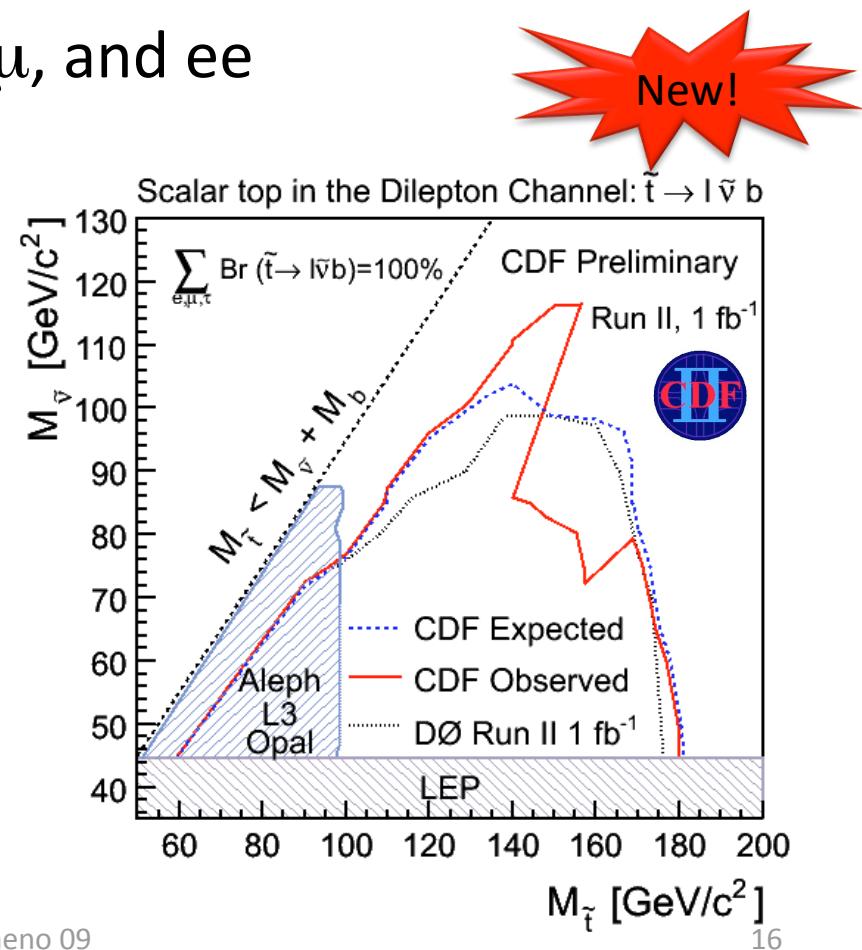
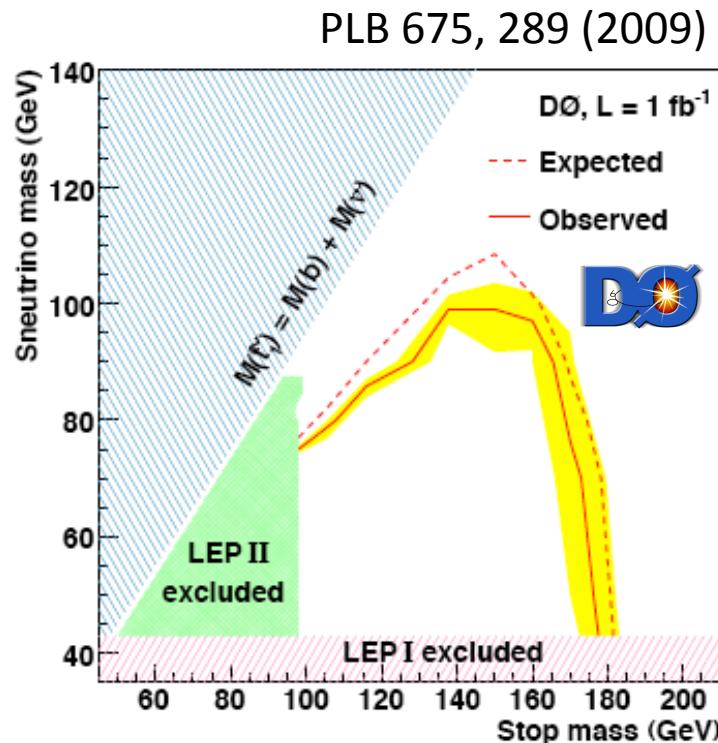
See Djouadi and Mambrini, arXiv:0011364 for more details

- The dominant decay mode is $\tilde{t}_1 \rightarrow b \tilde{\chi}_1^\pm \rightarrow bl\tilde{\nu}$
 - $\tilde{\nu}$ is invisible
- Final state signature (R-parity)
 - 2 leptons, 2 b-jets, MET
 - Main background $t\bar{t}$ production



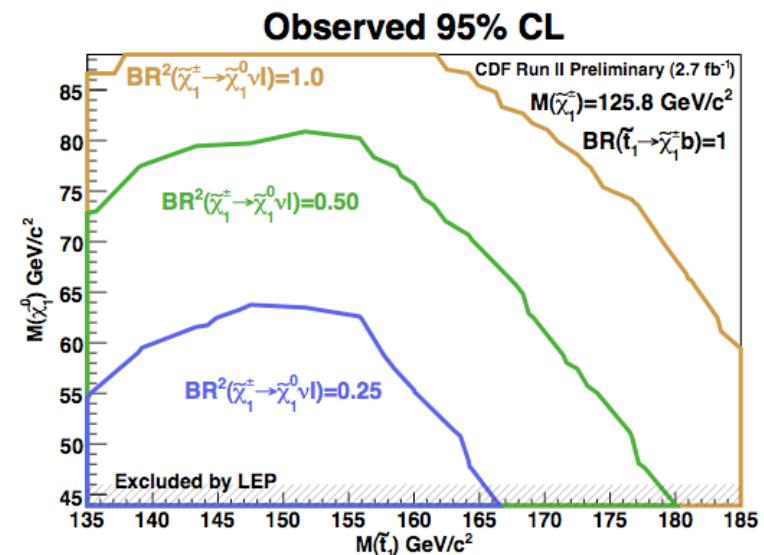
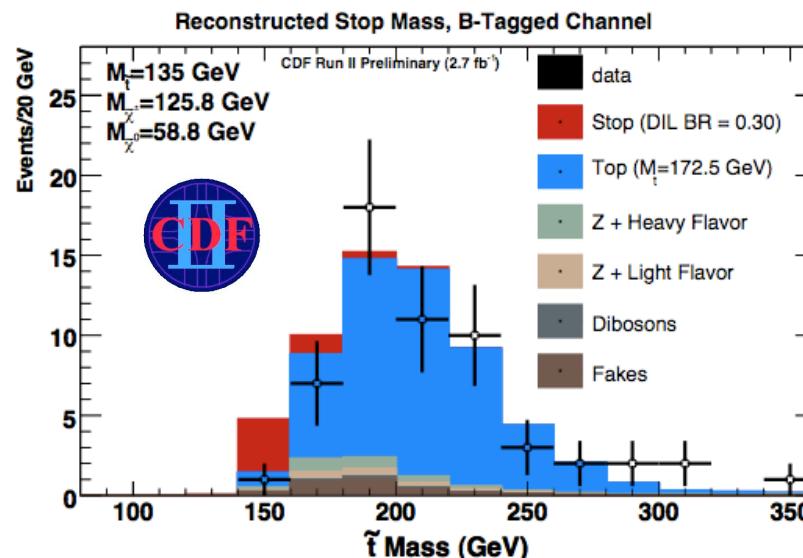
Search for stop quark

- Standard lepton and MET criteria
- Separate signal & background in bins of S_T and H_T
 - DØ: $e\mu$ and $\mu\mu$; CDF: $e\mu$, $\mu\mu$, and ee



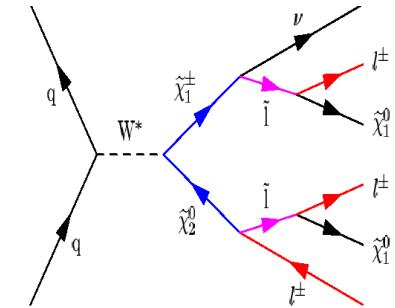
Search for stop quark

- Another CDF stop quark search assumed on-shell charginos. Various SUSY scenarios can result in different $BR(\tilde{\chi}_1^\pm \rightarrow \tilde{\chi}_1^0 \nu \ell)$
 - Use 2.7 fb^{-1} of integrated luminosity, b-tagging
 - Agreement between data and SM prediction

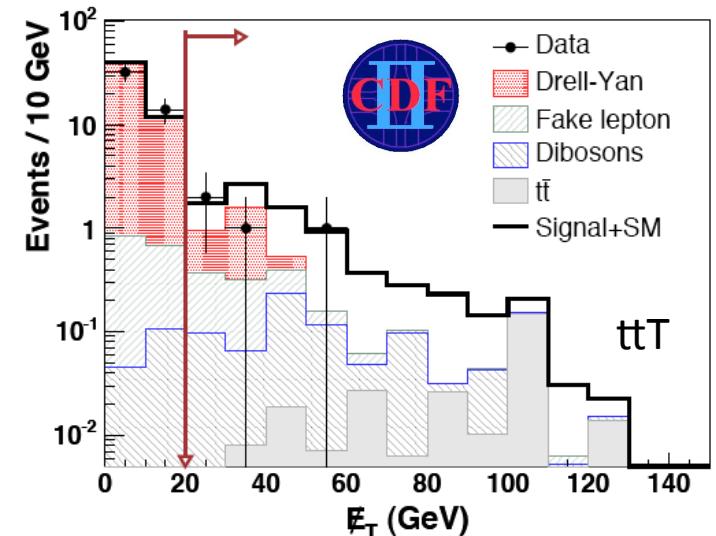




Trileptons



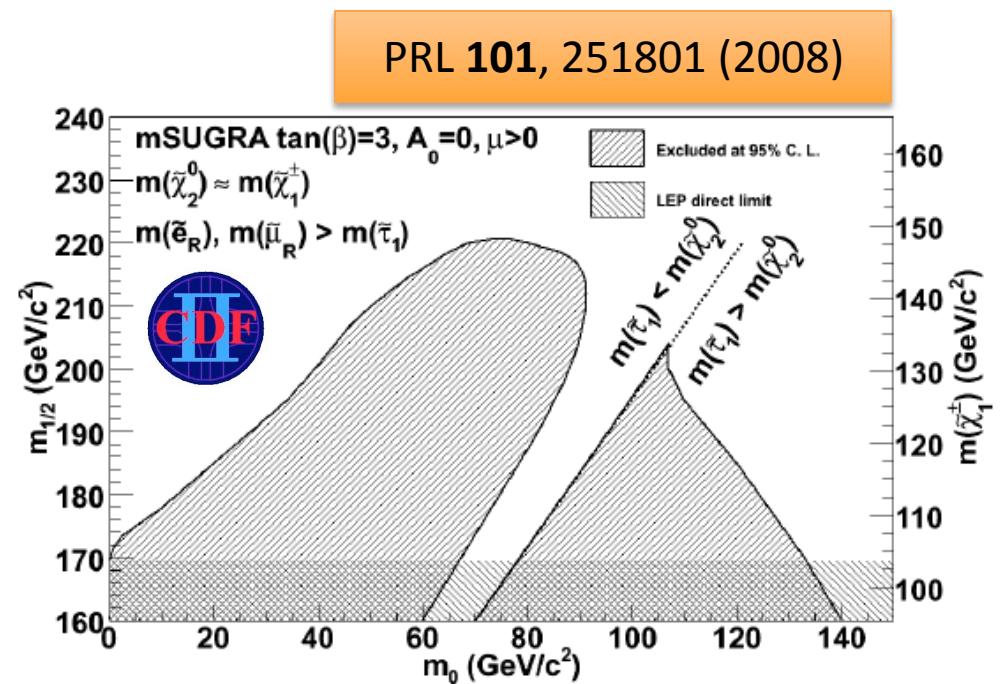
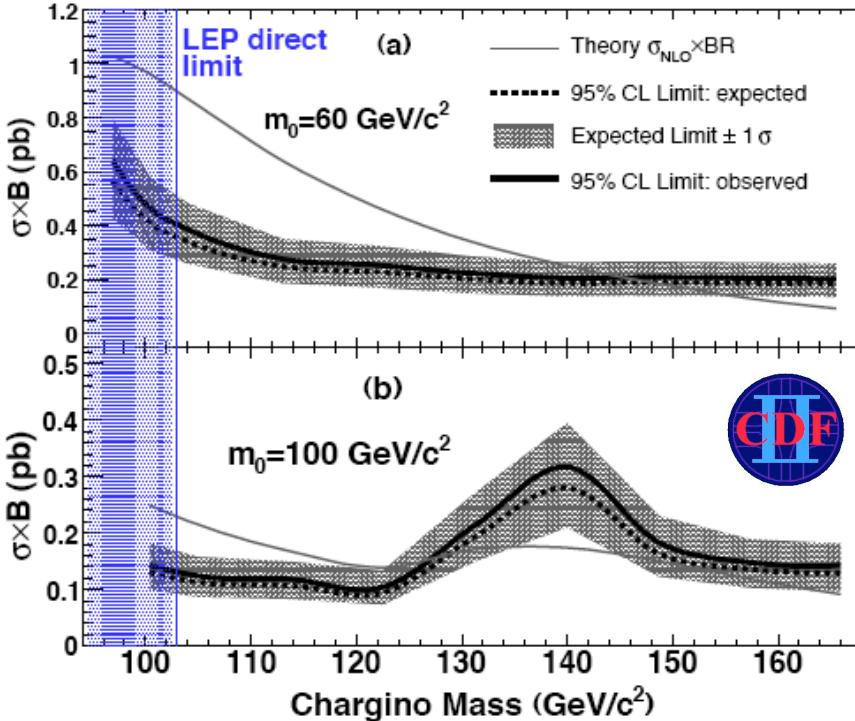
- Assuming R-parity, SUSY can manifest itself through trilepton final state + MET
 - Rare but clean experimental signature, largest background is diboson
- CDF searched for trileptons in combined five categories of leptons and tracks
 - Data agrees with SM





Trileptons

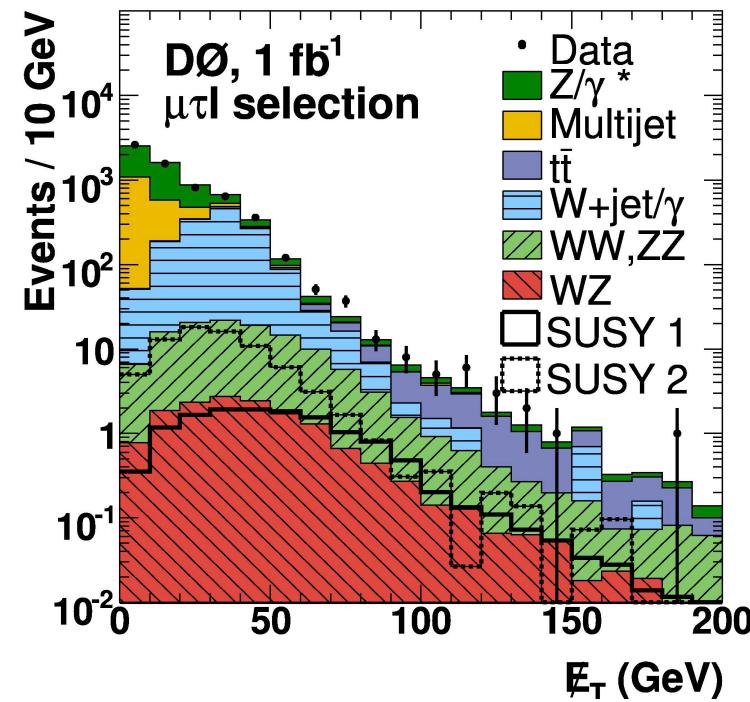
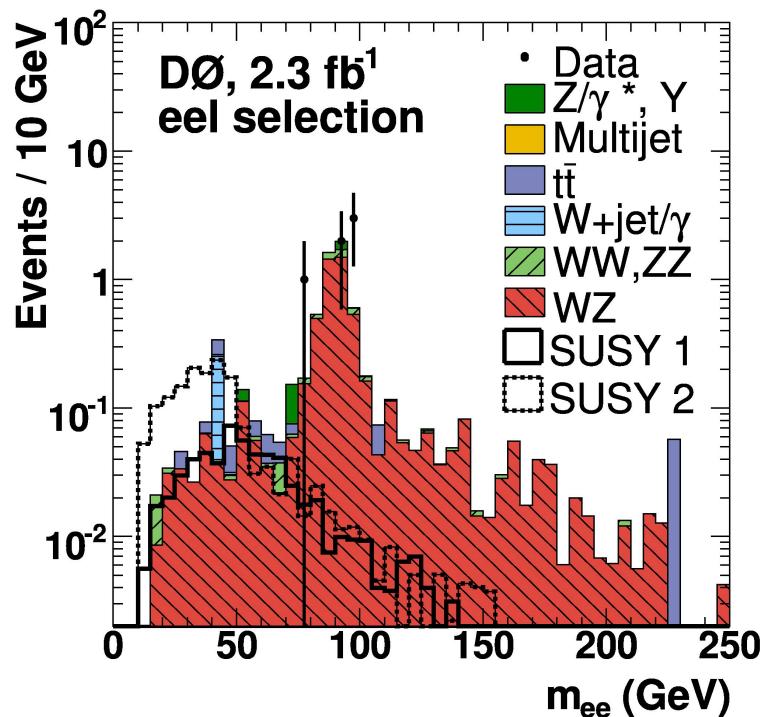
- Set limits on $m(\chi^\pm)$ and m_0 vs. $m_{1/2}$ plane (mSUGRA)
 - $m(\chi^\pm) < 147 \text{ GeV}$ for $m_0 = 60 \text{ GeV}$





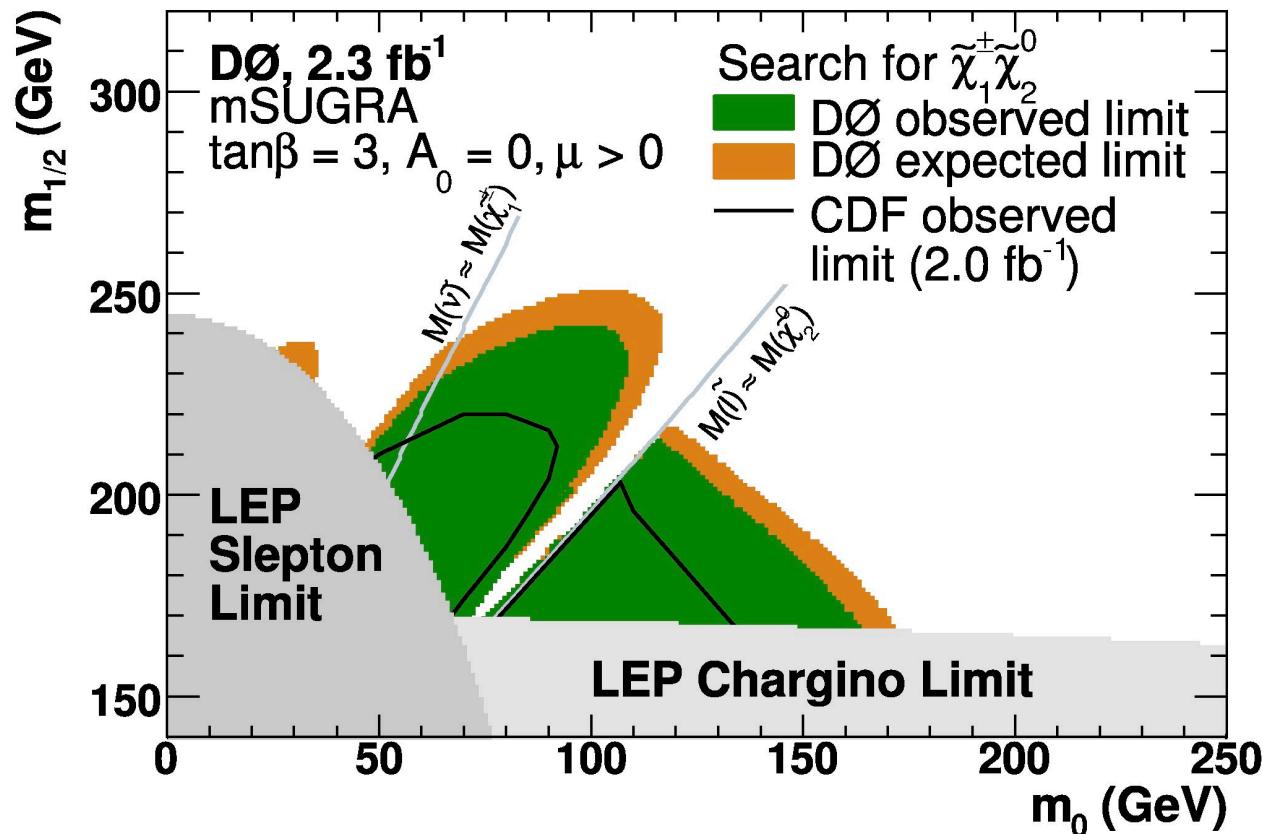
Trileptons

- Combination of $\mu\mu l$, $\mu\tau l$, $e\mu l$, $\mu\tau\tau$, and eel
 - Optimization of high- p_T and low- p_T criteria
 - Use event kinematics to separate signal from bkg



Trileptons

- Observed events are consistent with SM
 - Set limits on mass of the lightest chargino
 - m_0 vs. $m_{1/2}$ plane for mSUGRA

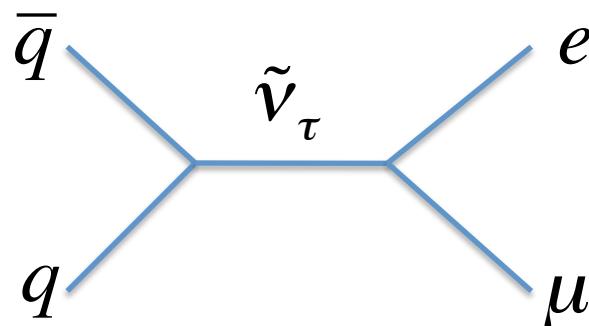




Search for $\tilde{\nu}_\tau$

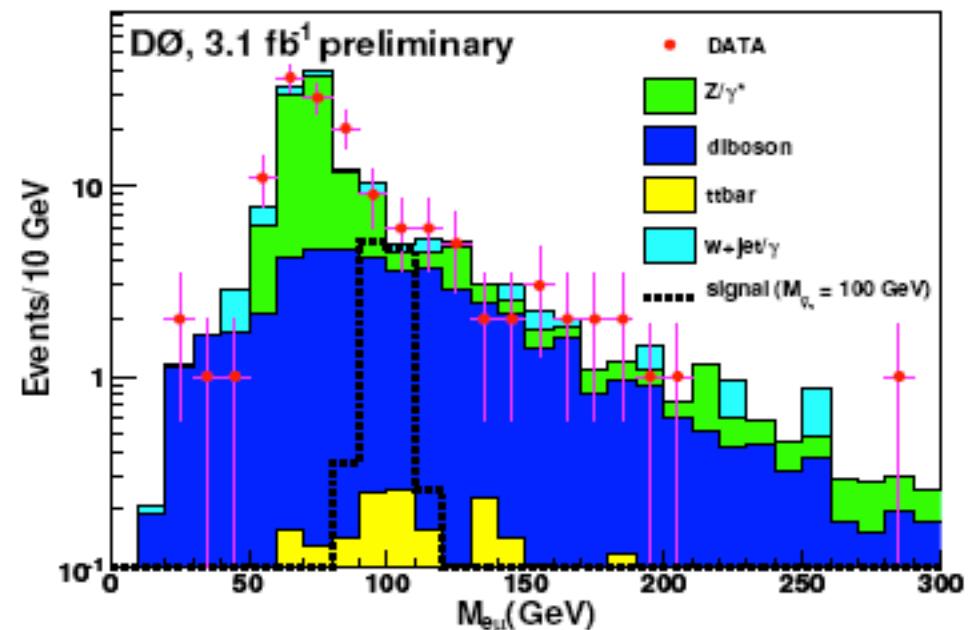


- If R-parity is not conserved, a single production of SuperPartner is possible
 - Single electron and muon final state

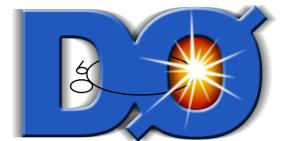


Process	No. of events
Z/γ^*	83.4 ± 6.8
diboson	46.0 ± 4.0
$t\bar{t}$ incl.	2.6 ± 0.5
$W+\text{jet}/\gamma$	12.7 ± 2.5
total background	144.9 ± 8.3
data	143

See Sun *et. al.*, hep-ph/0412205



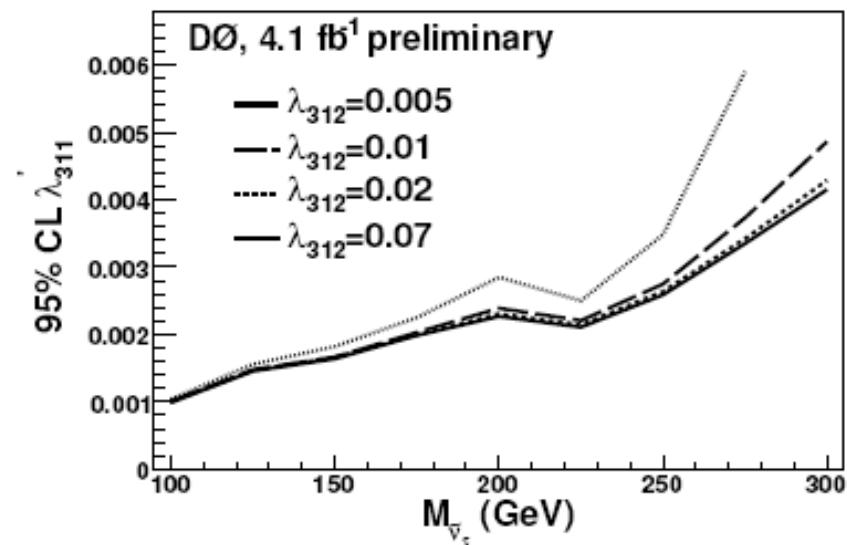
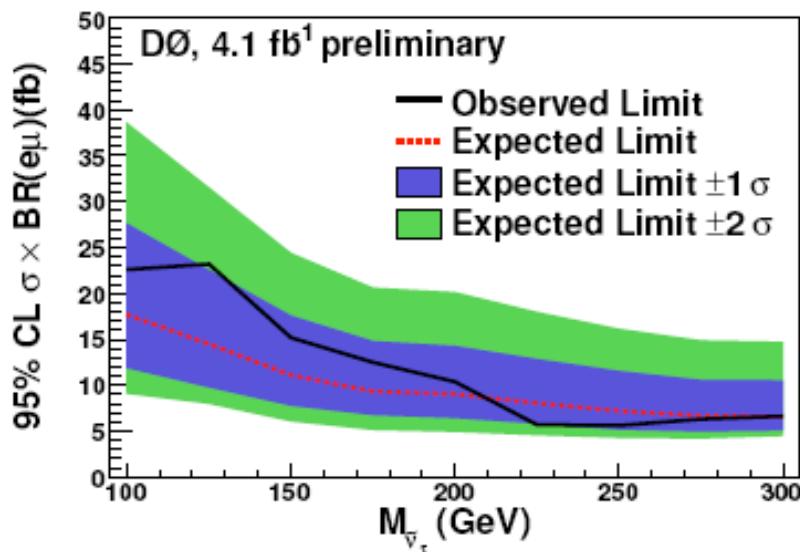
Search for $\tilde{\nu}_\tau$



- Data agrees with SM well, 95% CL limits were placed on cross-section and λ'_{311} coupling value

$$\hat{\sigma}_{e\mu} \propto (\lambda'_{311})^2 \times (\lambda_{312})^2 \cdot \frac{1}{|\hat{s} - M^2 + i\Gamma M|^2}$$

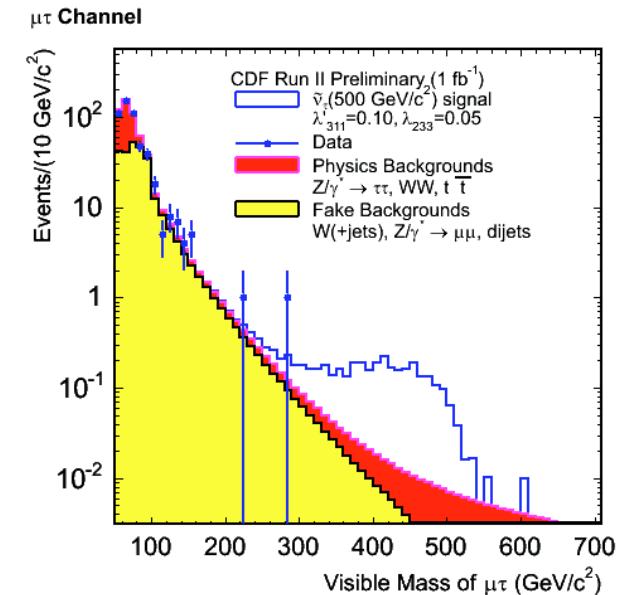
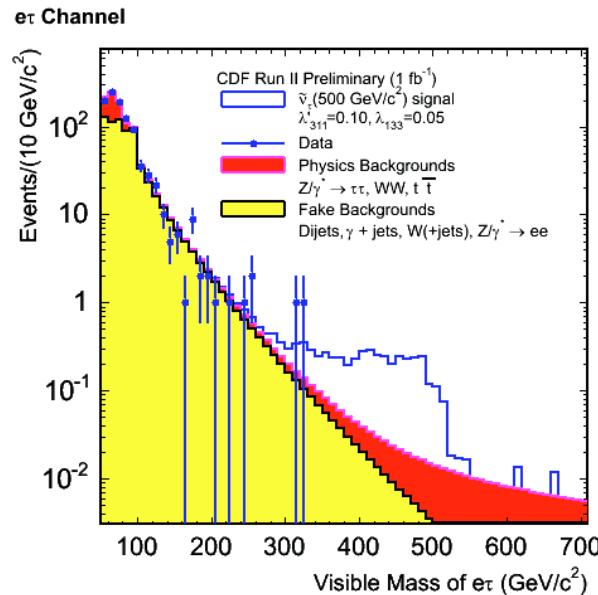
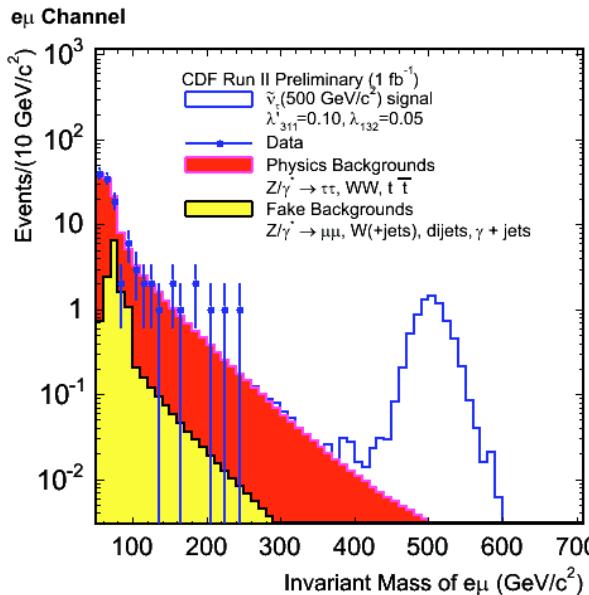
- Previous results are $\lambda'_{311} < 0.12$ and $\lambda_{312} < 0.07$





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

- CDF searches for tau sneutrino in $e\mu$, $\mu\tau$, and $e\tau$
 - Data agrees with the standard model, so limits were set on tau sneutrino production 0.018 pb ($e\mu$)



Link to cosmology

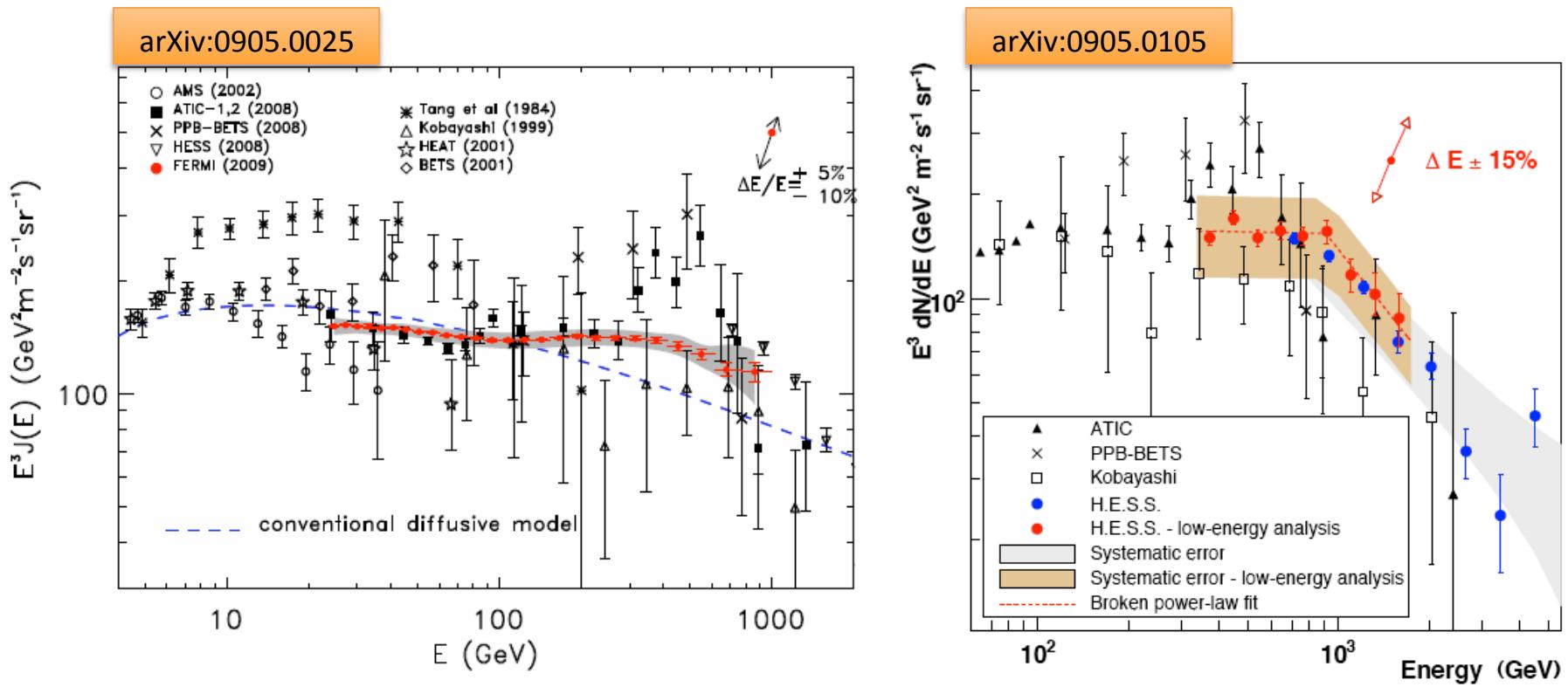




Search for SUSY Valleys

- Hidden valley (HV) models: weakly coupled sector (Strassler & Zurek)
 - Important class: SUSY in Hidden Valleys (Arkani-Hamed & Weiner)
- Motivated by recent results from PAMELA, ATIC, EGRET, FERMI-LAT, HESS
 - The excess is due to the decay of the WIMP $\sim 500\text{-}800 \text{ GeV}$

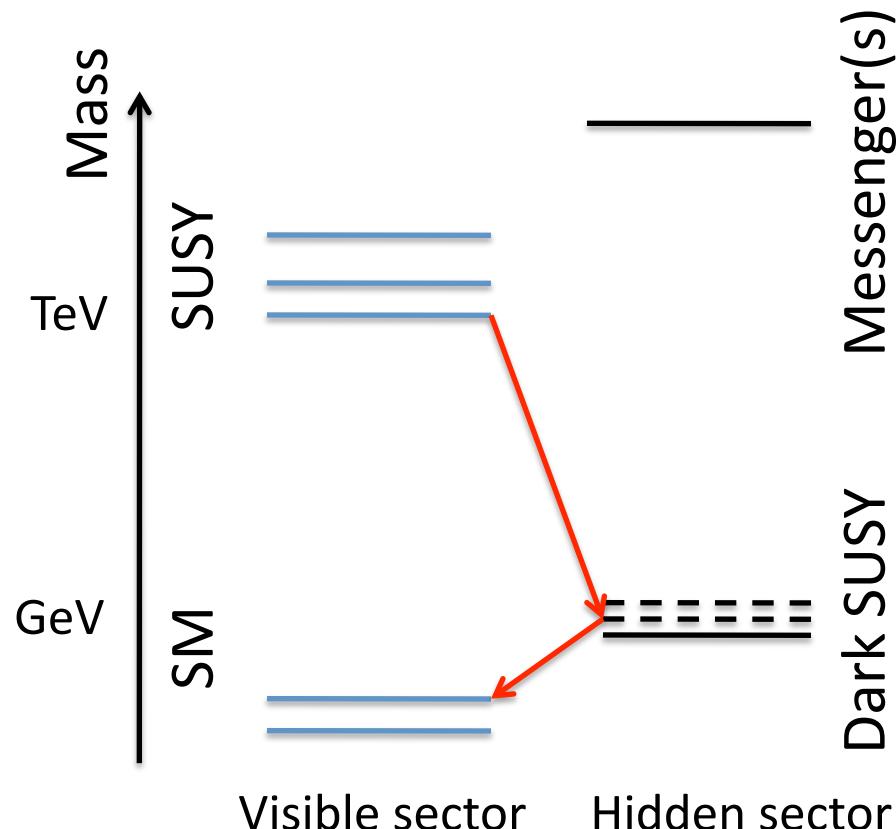
See Han *et al.*, arXiv:0712.2041
N. Arkani-Hamed *et al.* arXiv:0810.0713



SUSY with Hidden Valleys

- Many phenomenological explanations possible, one is similar to GMSB

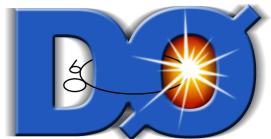
S. Thomas *et al.*



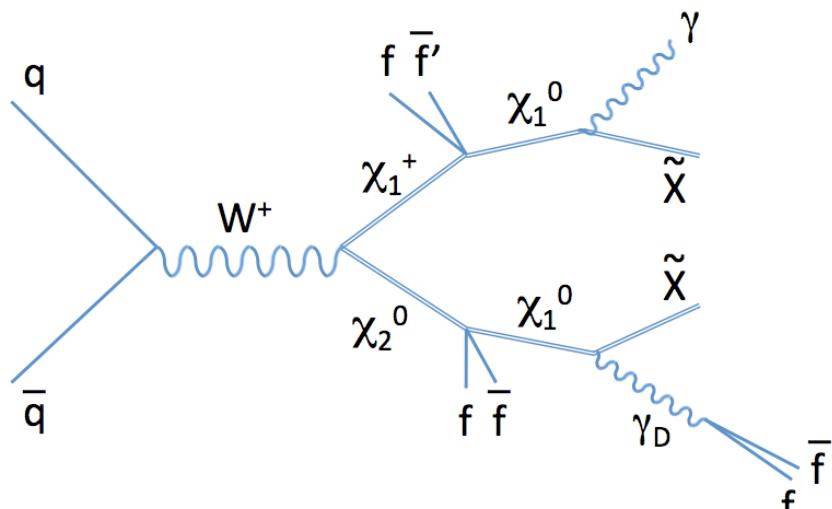
- Visible SUSY is produced
- Cascade to visible LSP
- LSP decays into hidden sector
 - Photon + dark LSP
 - Dark photon + dark LSP
- Dark LSP results in MET
- Dark photon (\sim GeV) decays into fermions



Search for SUSY Valleys



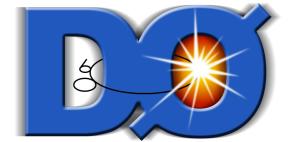
- Branching fractions of neutralino to photon and dark photon are free parameters
 - These two decays dominate available phase space
 - If branching fraction into photon is close to 100 %: the final state is indistinguishable from GMSB with neutralino NLSP



- If smaller, final state:
 - MET from \tilde{X}
 - A photon
 - A pair of spatially close leptons
- Will fail conventional isolation lepton ID!

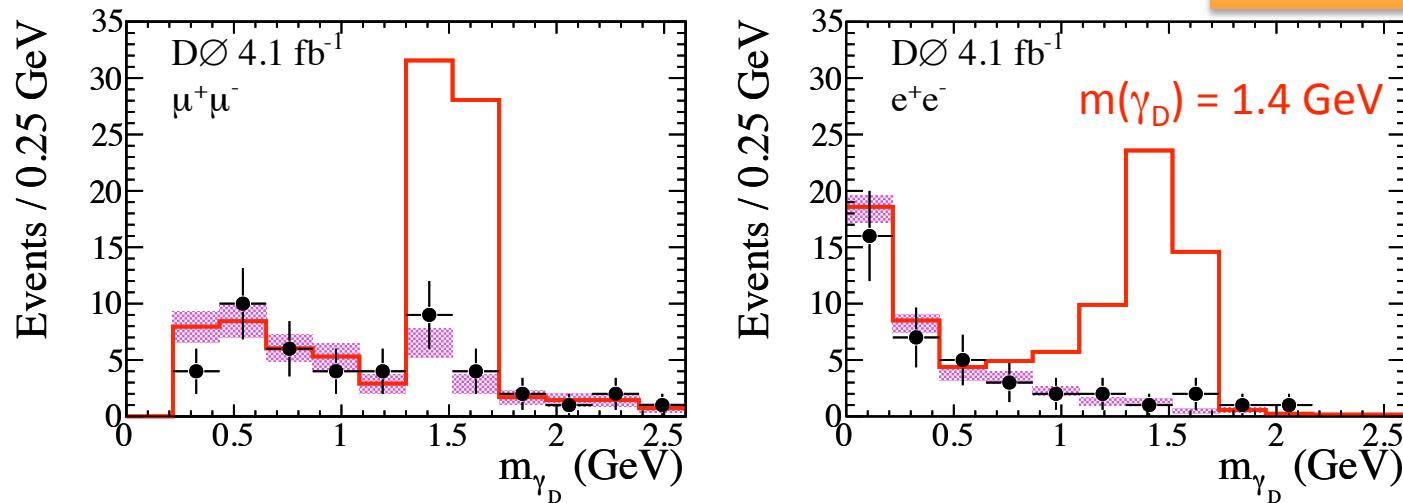
- Very distinct final state: never been investigated before!

Search for SUSY Valleys



- Estimate backgrounds from data
 - Multijet events with real/misidentified photons
 - $W \rightarrow \ell\nu$ with real/misidentified photons

arXiv:0905.1478



- Data is consistent with background
 - Use modified frequentist approach to set limits

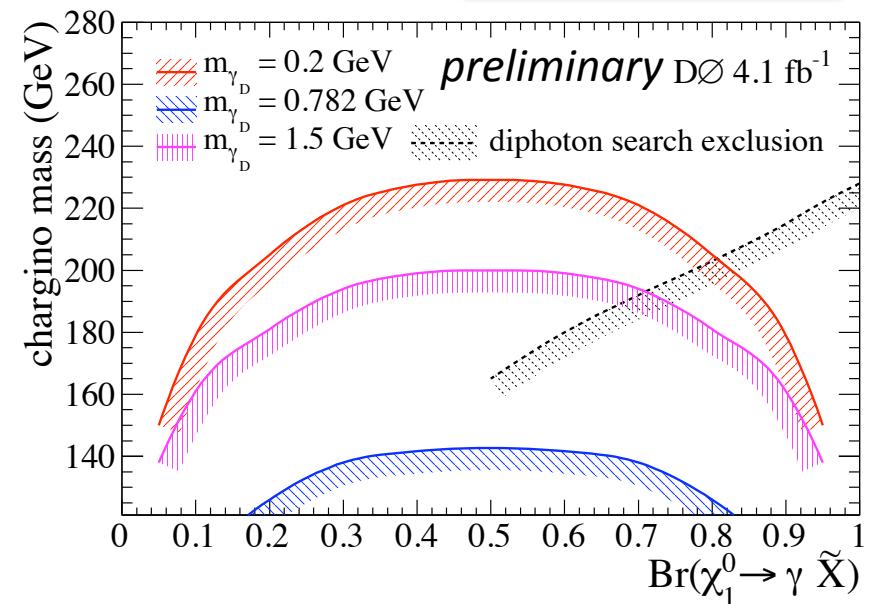
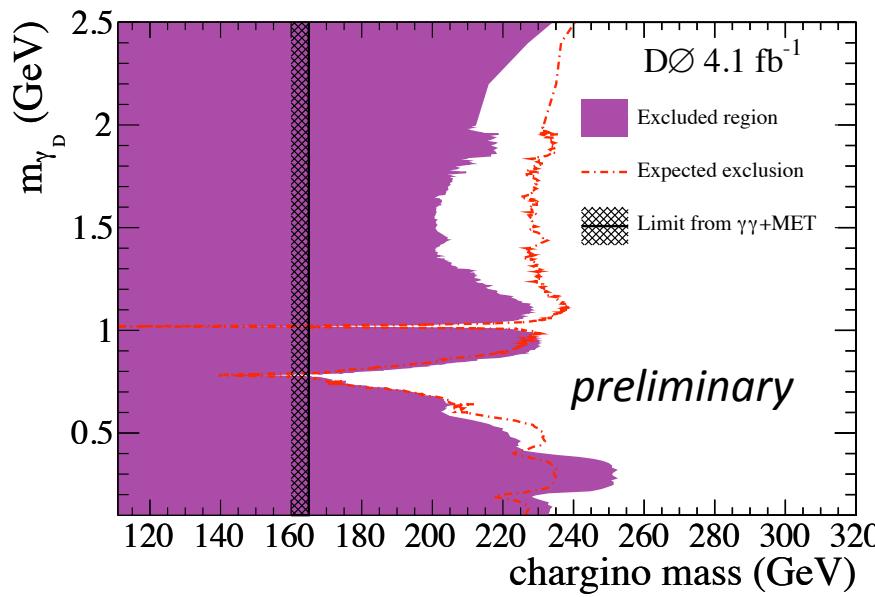
Search for SUSY Valleys



- Set limits on chargino mass as a function of the dark photon mass

– Assume $Br(\tilde{\chi}_1^0 \rightarrow \gamma_D \tilde{X}) = 0.5$

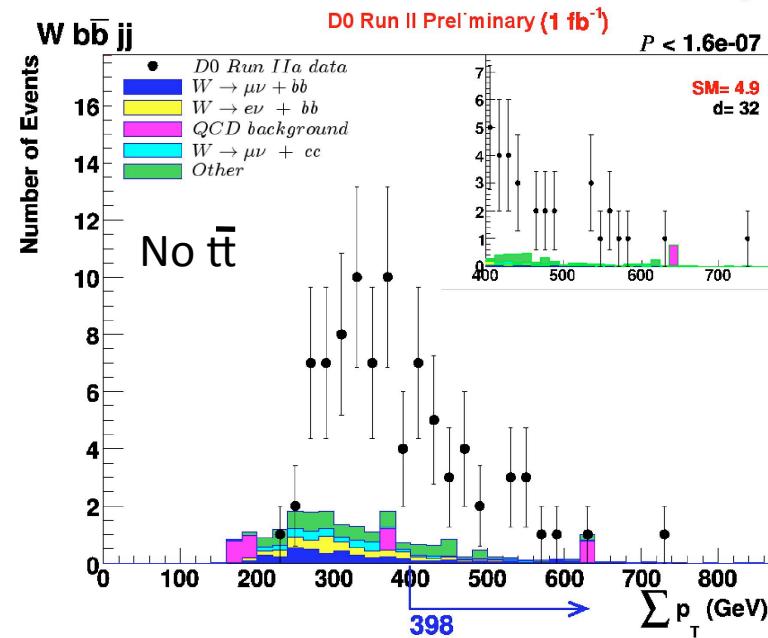
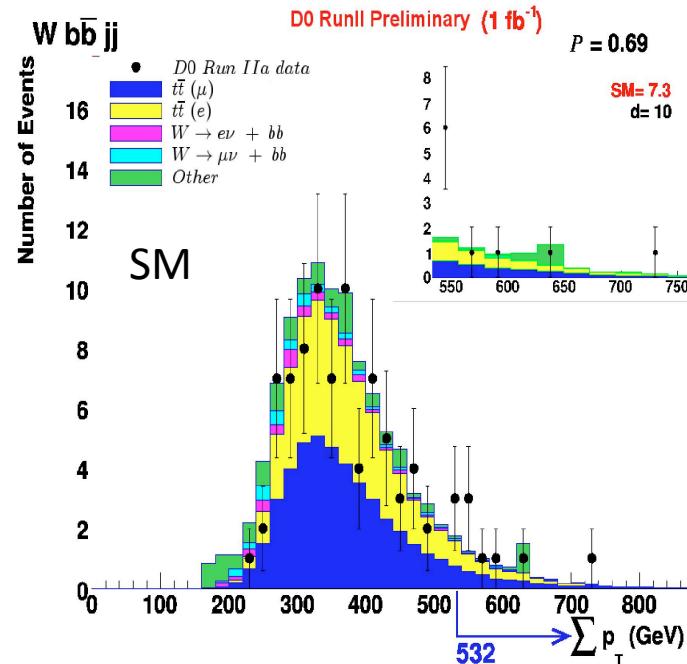
arXiv:0905.1478



Model independent searches

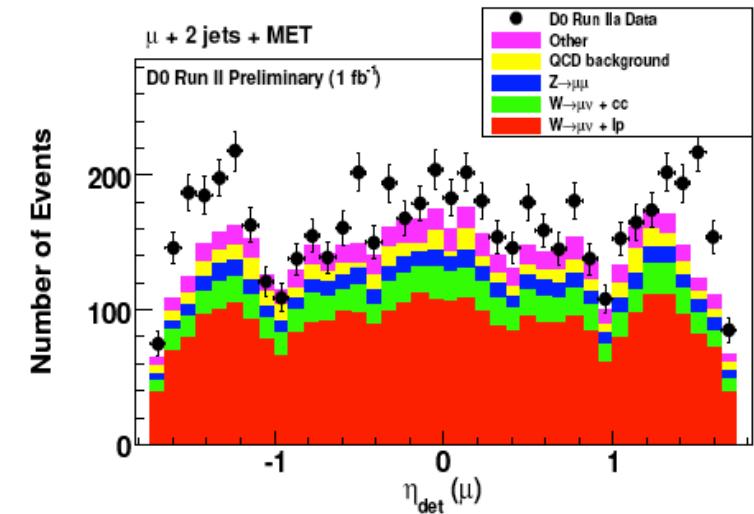
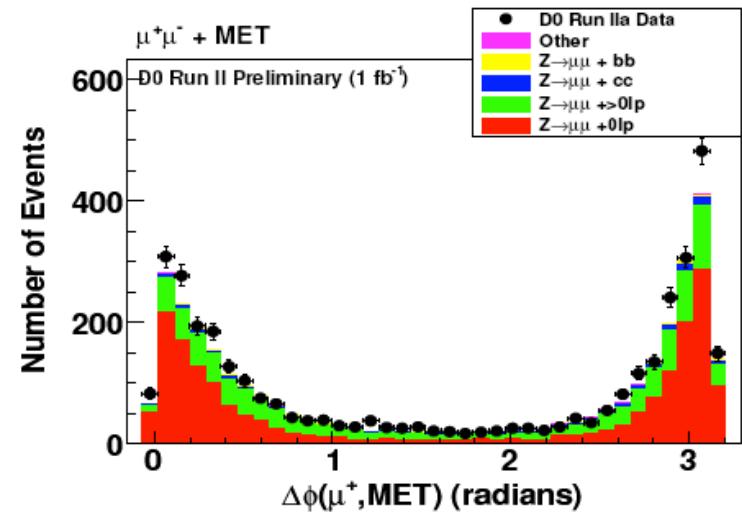


- Search for significant deviation from the SM
 - Use lepton-based final states
- Simple cross-check: remove $t\bar{t}$ from SM!



- Search in 180 distributions with high E_T leptons

- Out of 180 distributions, four exhibit significant deviations
 - $\mu + 2$ jets + MET (9.3σ)
 - $\mu + \gamma + 1$ jet + MET (6.6σ)
 - $\mu\mu + \text{MET}$ (4.4σ)
 - $\mu\mu + \gamma$ (4.1σ)
- Difficult modeling: none of these excesses are attributed to new physics
 - Trigger modeling
 - Photon mis-identification rate modeling

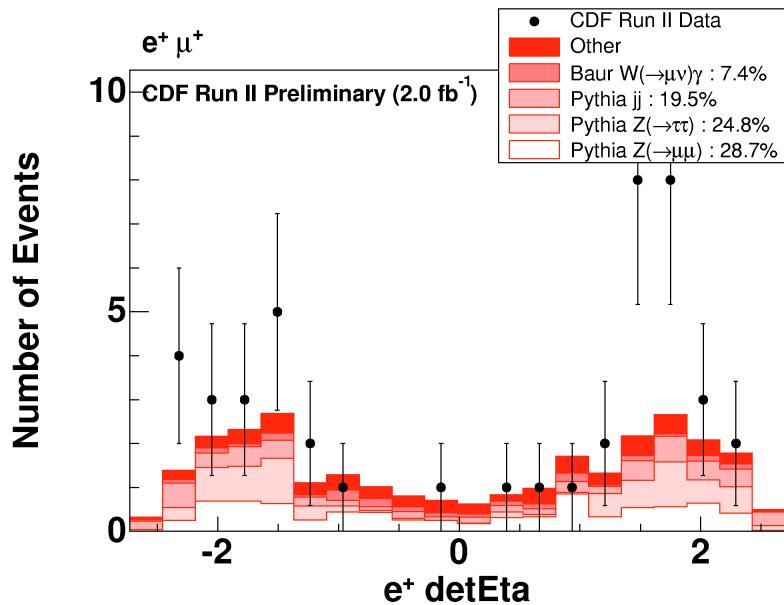


Model independent search



PRD 79, 011101 (2009)

- Use both Vista (model-independent) and Sleuth (quasi model-independent) to search for new phenomena in 2 fb^{-1}
 - No evidence for new phenomena is found
 - Some discrepancy is found but attributed to modeling



What comes next?

Prediction is very difficult, especially if it is about the future

Mark Twain, Niels Bohr, Yogi Berra

