



Beyond the Standard Model Limits and Searches from DØ

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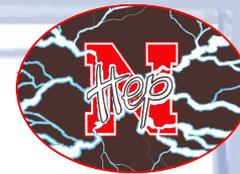
 Fermi National Accelerator Laboratory



UNIVERSITY OF
Nebraska
Lincoln



Outline

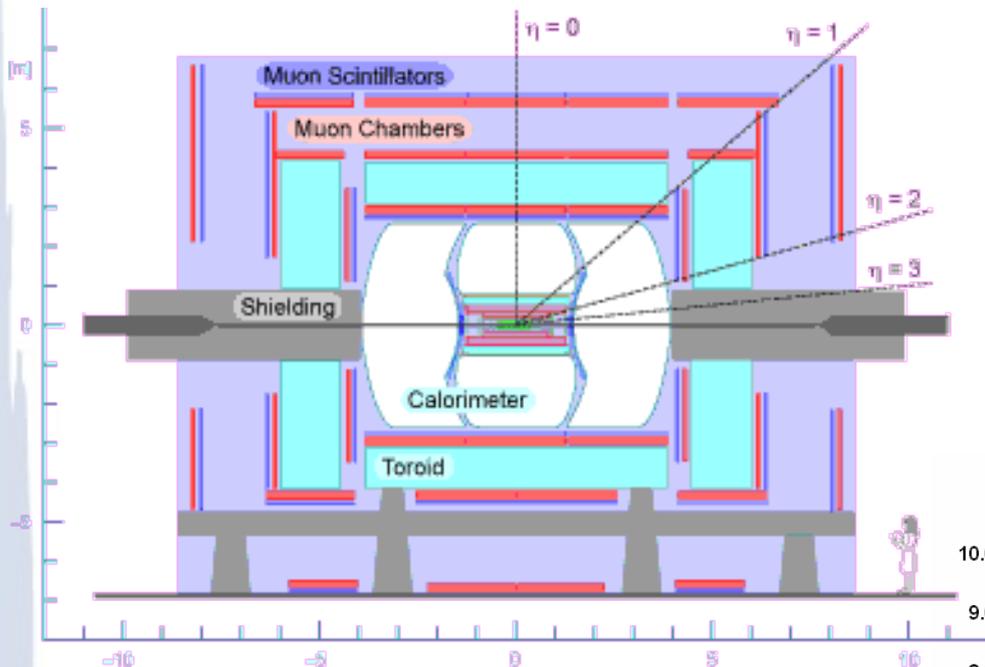
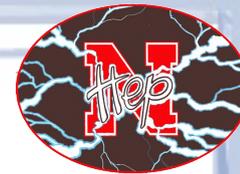


- Introduction
- Supersymmetry (SUSY) Searches
- Extra Dimensions (ED) Searches
- Searches for New Gauge Bosons
- Hidden Valley and Other Searches





The DØ Detector



Over 9 fb^{-1} delivered
 Data recorded at $\sim 90\%$ efficiency
 Results today use up to 6.3 fb^{-1}

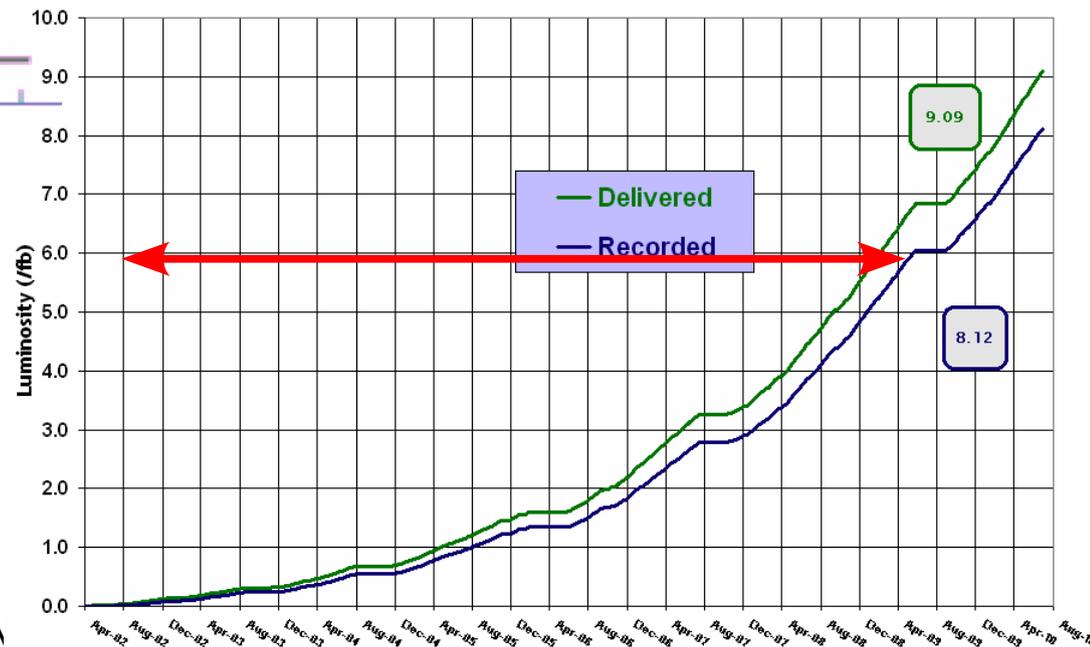
Electron acceptance: $|\eta| < 3.0$
 Muon acceptance: $|\eta| < 2.0$
 Silicon tracking: $|\eta| < 3.0$
 Calorimetry: $|\eta| < 4.2$

2T central solenoid
 10m x 10m x 17m, 5000 tons



Run II Integrated Luminosity

19 April 2002 - 18 July 2010





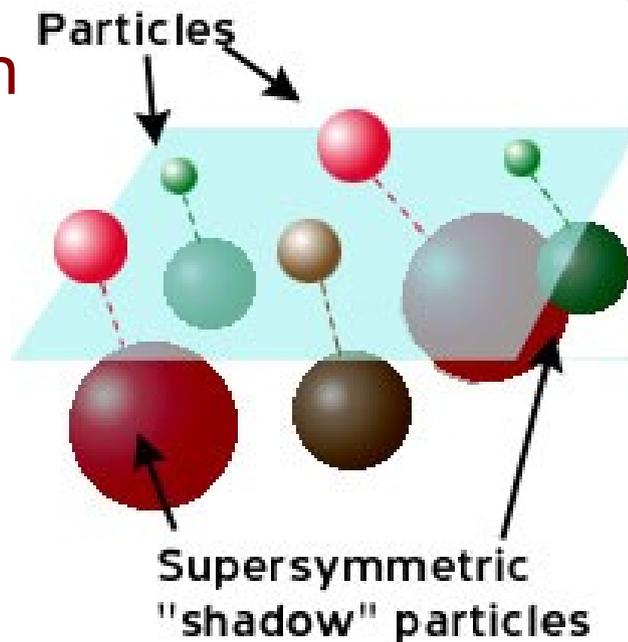
Supersymmetry Searches



An Experimentalist's View of Supersymmetry



- Supersymmetry (SUSY) predicts that each standard model particle will have a SUSY partner (differing by $\frac{1}{2}$ unit of spin)
- Must be a broken symmetry, or the “sparticles” would have the ~same mass as the SM particles (and we would have seen them by now)
- **SUSY phenomenology is driven by how SUSY is broken**
- Most generic has ~ 100 free parameters
- Much easier to work with mSUGRA (gravity-mediated), GMSB (gauge-mediated), or other SUSY breaking models with $O(5)$ free parameters
- **R-parity**



Leptons \rightarrow sleptons
Neutrinos \rightarrow sneutrinos
Quarks \rightarrow squarks
Gauge bosons \rightarrow gauginos
Higgs bosons \rightarrow higgsinos
These mix to form neutralinos and charginos.



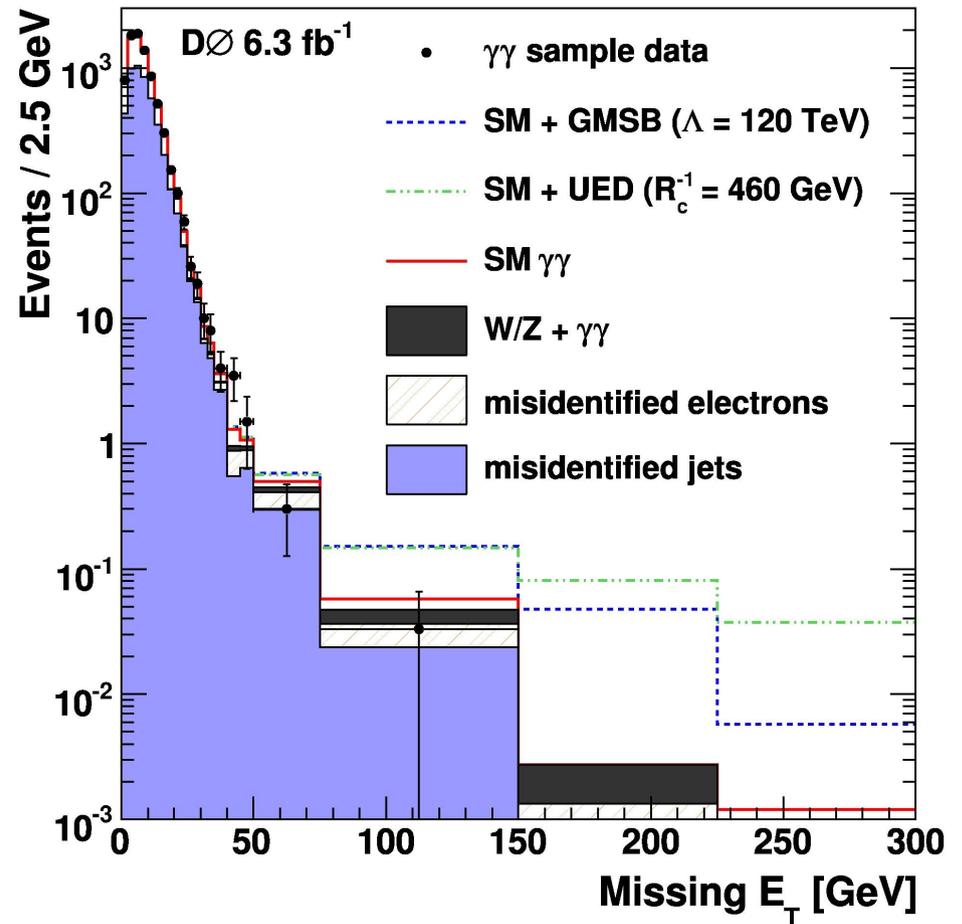
GMSB in $\gamma\gamma$ +MET (I)



6.3 fb⁻¹

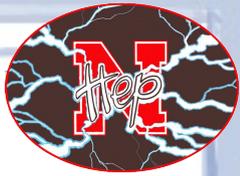
- Gravitino is LSP, lightest neutralino decays to photon + gravitino
- Signature is $\gamma\gamma$ +MET

- 2 photons above 25 GeV
- MET > 50 GeV
- Model instrumental backgrounds from data
 - MET in SM $\gamma\gamma$ from ee
 - MET in γ +jet from photon with reversed quality cuts



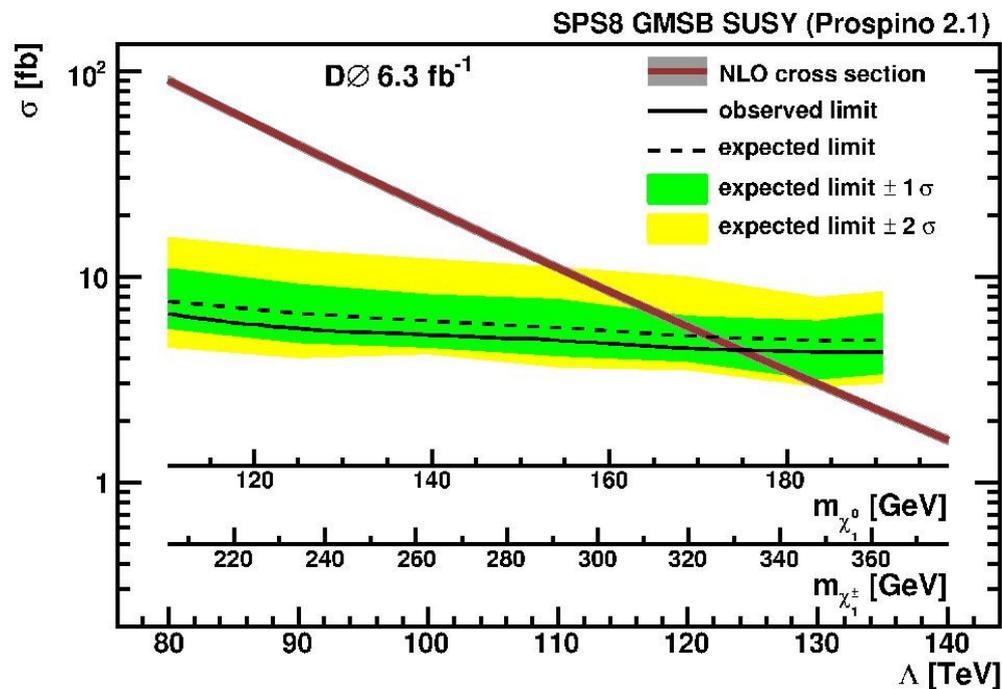


GMSB in $\gamma\gamma$ +MET (II)



6.3 fb⁻¹

- Observe 4 events, expect 6.9 ± 1.0 from background
- Set limits using MET distribution



Exclude Λ below 124 TeV, neutralinos below 175 GeV for SPS8 scenario

arXiv: 1008.2133
Submitted to PRL

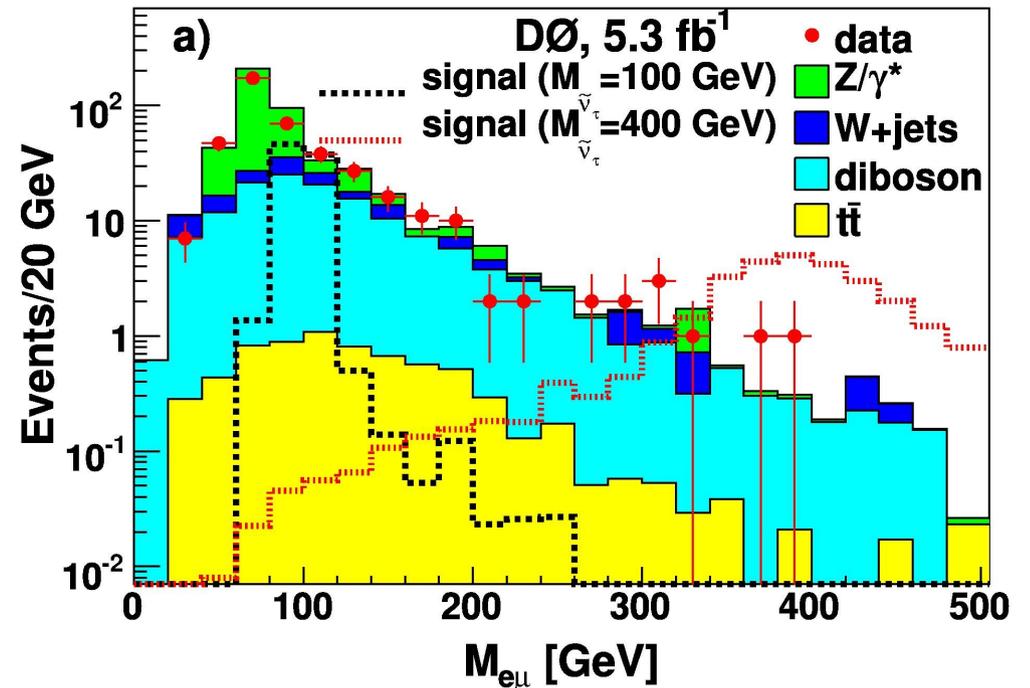
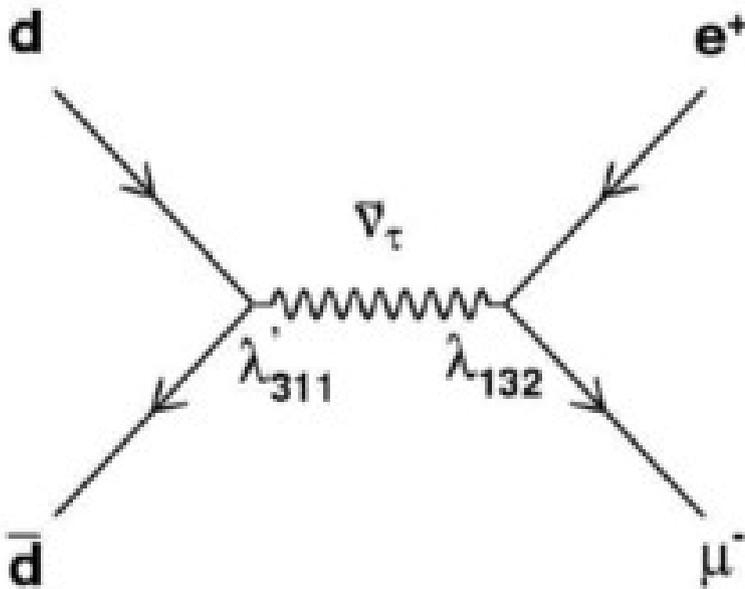


RPV Sneutrinos in $e\mu$ (I)



5.3 fb⁻¹

- RPV \Rightarrow LSP can decay
 - Various RPV couplings can lead to baryon- and lepton-number violation
- Require one electron and one muon, look for bump in invariant mass distribution





RPV Sneutrinos in $e\mu$ (II)

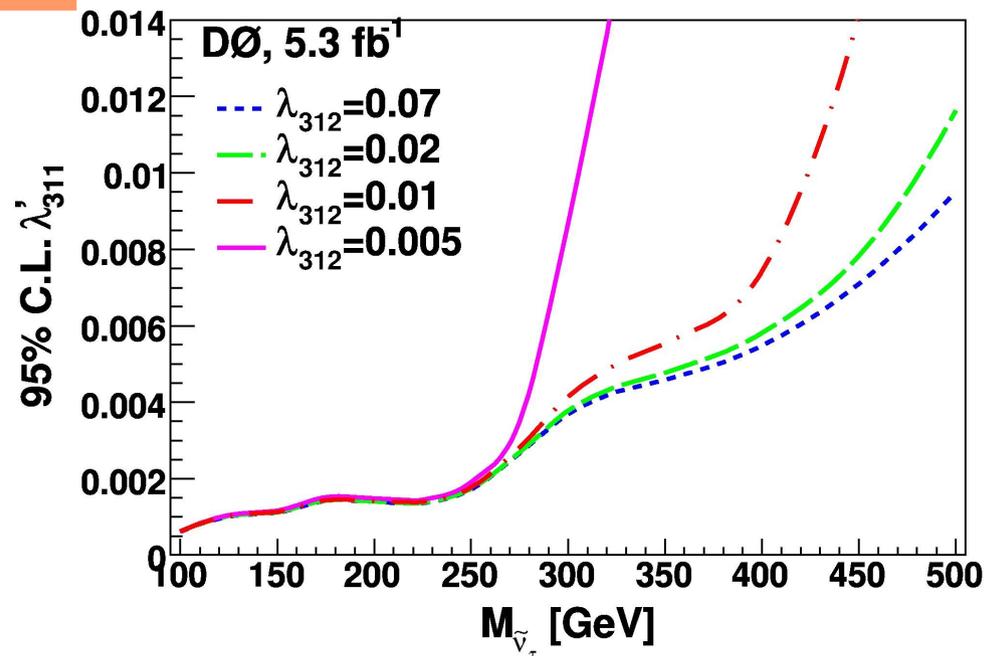
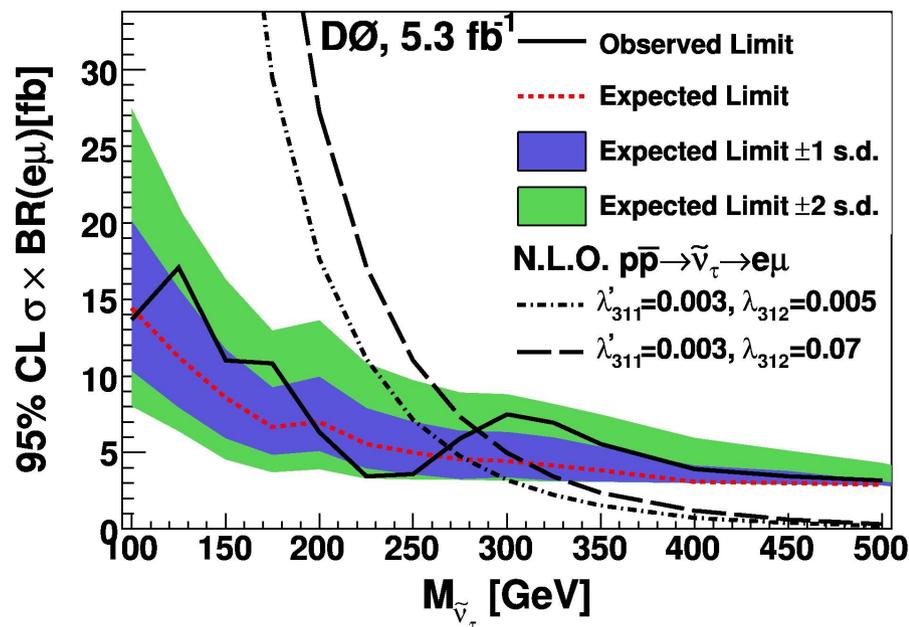


5.3 fb⁻¹

- Observe 414 events, expect 410 ± 38 background (mostly from Drell-Yan and diboson production)
- Set limits with invariant mass distribution

Exclude sneutrino below ~280 GeV (depending on RPV coupling values)

arXiv: 1007.4835
Submitted to PRL



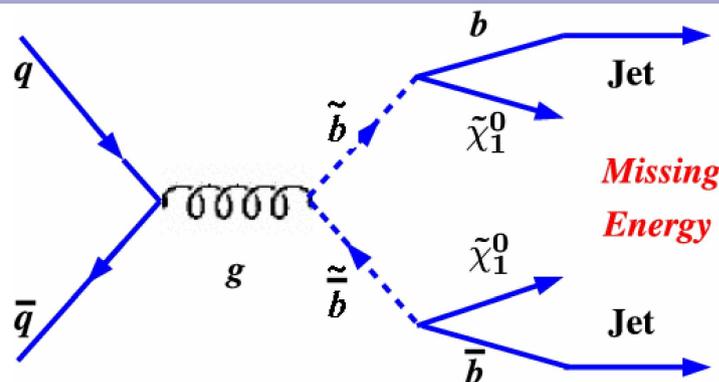


Search for Sbottom Squarks (I)

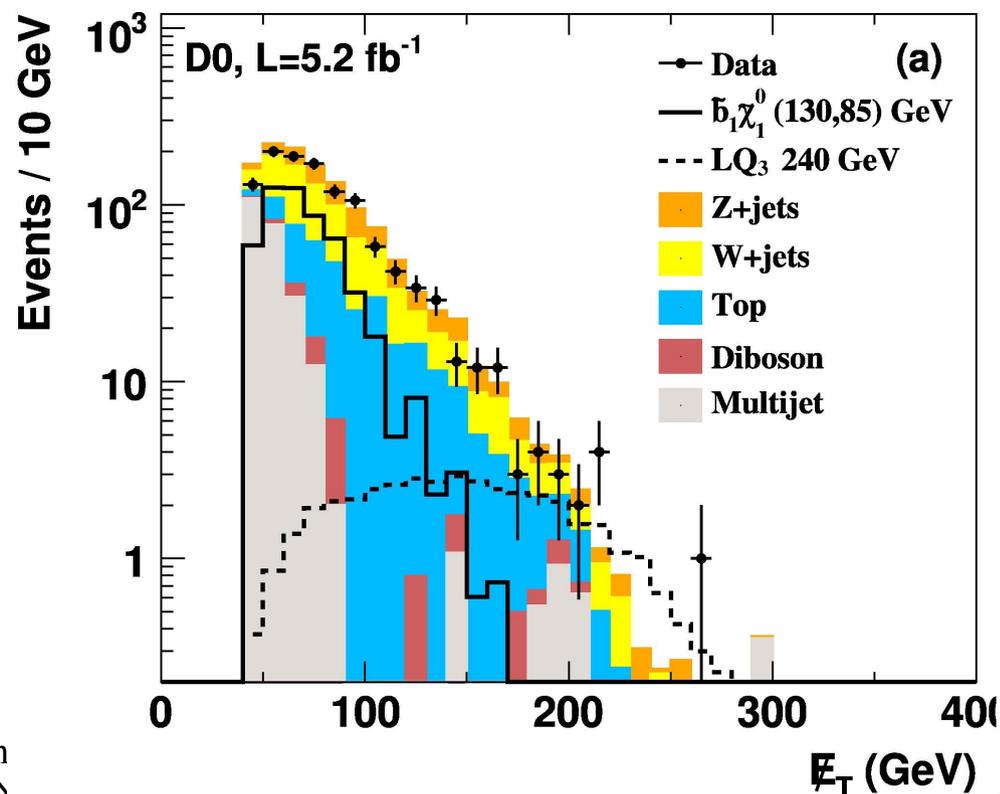


5.2 fb⁻¹

- Assume sbottom decays to b and neutralino
- Produced in pairs, so signature is bb +MET

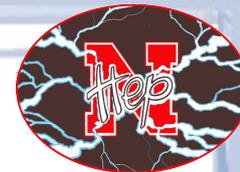


- 2 or 3 jets, one tight b -tagged, one loose
- Veto leptons (W background)
- MET > 40 GeV, MET signif > 5 (multijet)
- $(\text{jet1 } p_T + \text{jet2 } p_T) / H_T > 0.75 / 0.9$ (top)





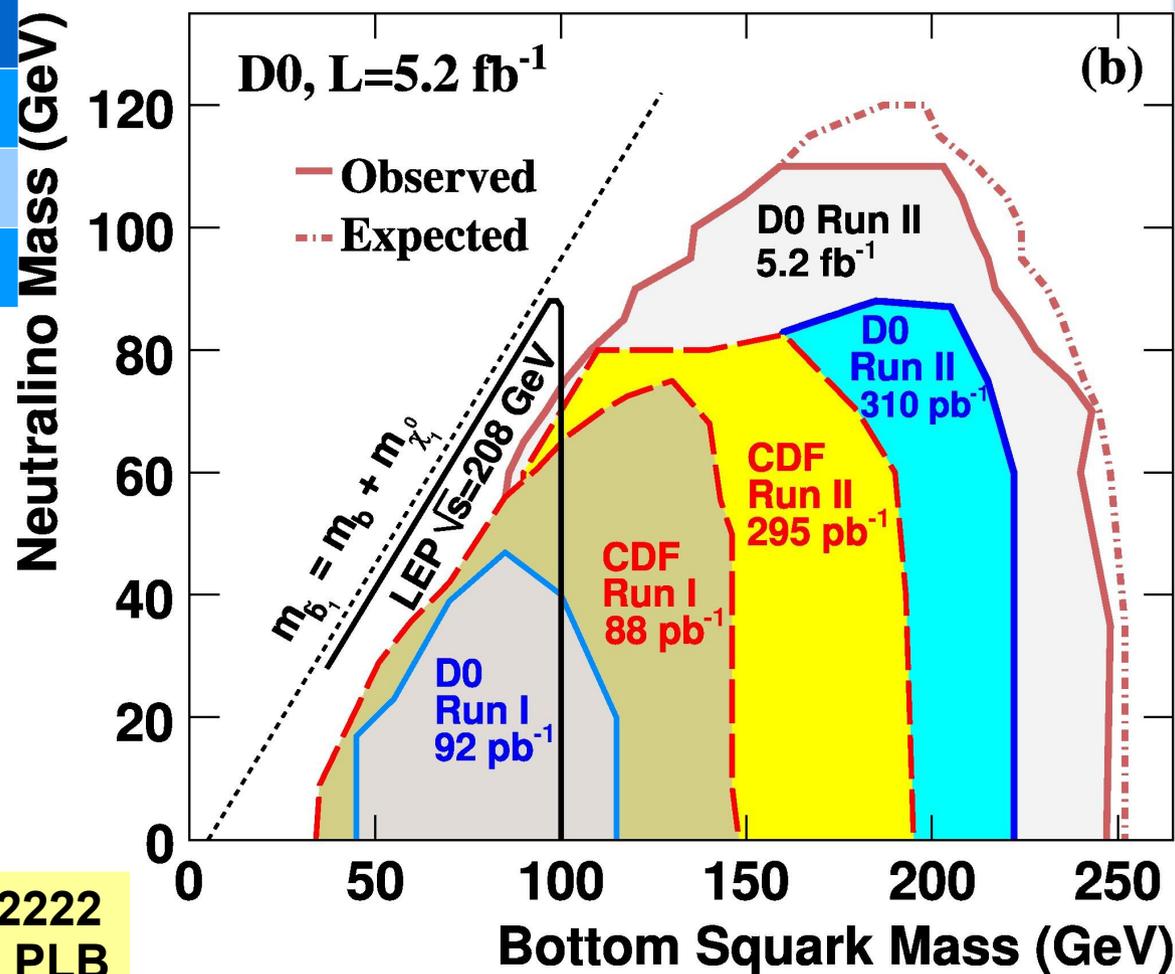
Search for Sbottom Squarks (II)



5.2 fb⁻¹

	Cut at 0.75	Cut at 0.9
Bkgd	971 ± 152	6.9 ± 1.9
Data	901	7
Signal	10.5	481

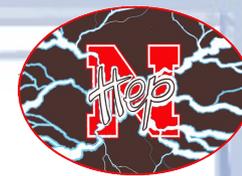
For massless neutralino, exclude sbottom with mass below 247 GeV



arXiv: 1005.2222
Accepted in PLB

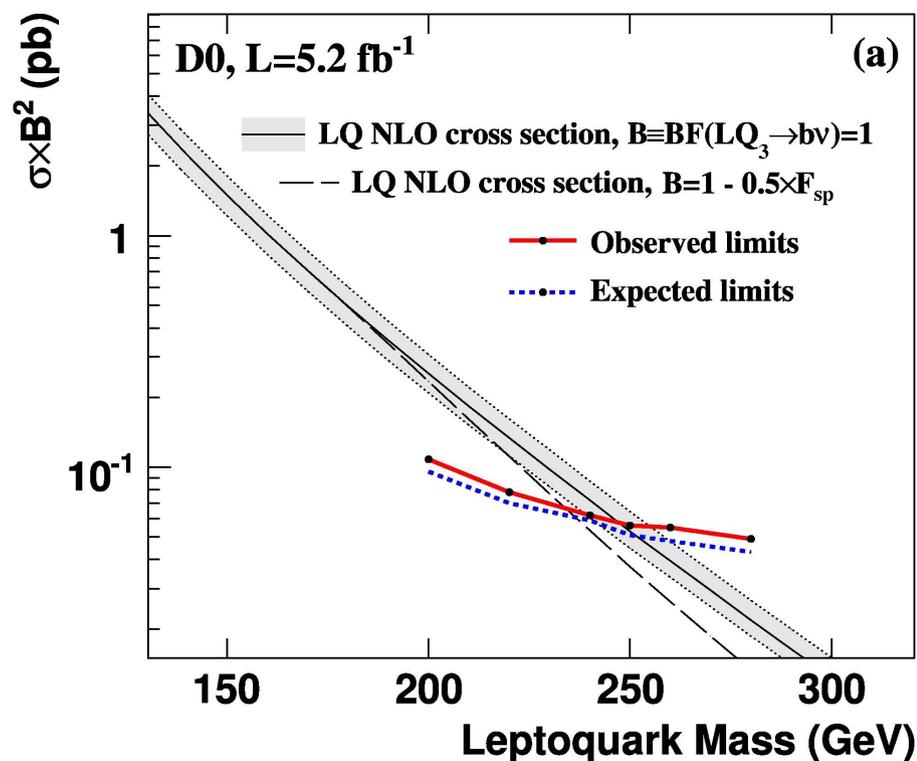


Third Generation Leptoquarks



5.2 fb⁻¹

- Interpret previous bb +MET search in terms of third generation leptoquarks
 - Charge 1/3 LQ3 decays to $b\nu$ or $t\tau$



Exclude LQ3 below 247 GeV (assuming 100% BR to $b\nu$)

arXiv: 1005.2222
Accepted in PLB



Extra Dimensions Searches



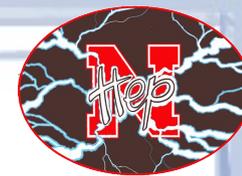
Extra Dimensions



- Can explain why gravity is so much weaker than other forces
- Particles propagating in ED have Kaluza-Klein (KK) excitations
- Randall-Sundrum (RS) models
 - SM and gravity on separate branes, only gravitons propagate between
 - Relevant parameters are curvature scale (k) and compactification radius (r_c) (equivalently M_1 and k/\overline{M}_{pl})
- Universal Extra Dimensions (UED)
 - All SM particles can propagate in extra dimensions

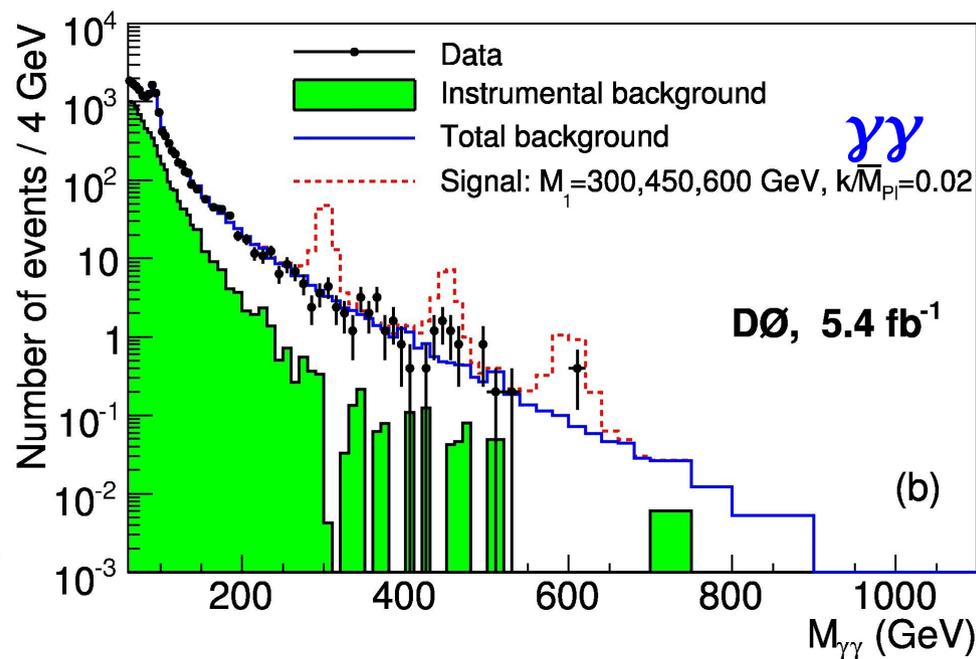
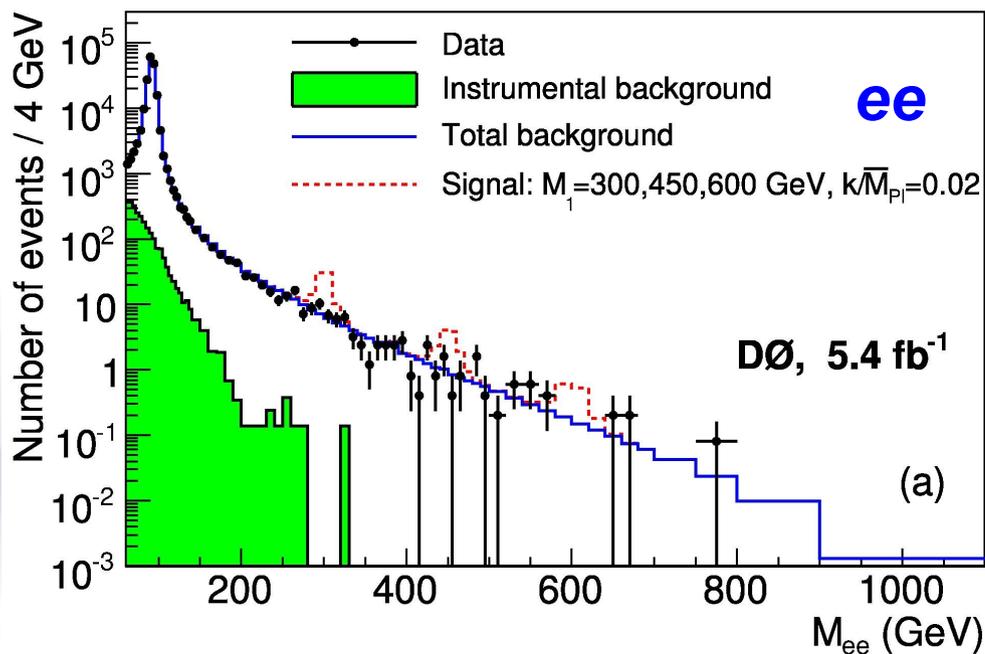


RS Gravitons in DiEM (I)



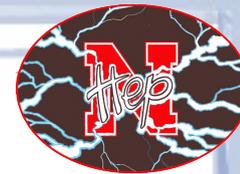
5.4 fb⁻¹

- Look for KK gravitons decaying to ee or $\gamma\gamma$
 - Treat the two channels separately
 - Diphoton BR twice as big as dielectron BR
- Require 2 photons (or electrons) above 25 GeV





RS Gravitons in DiEM (II)

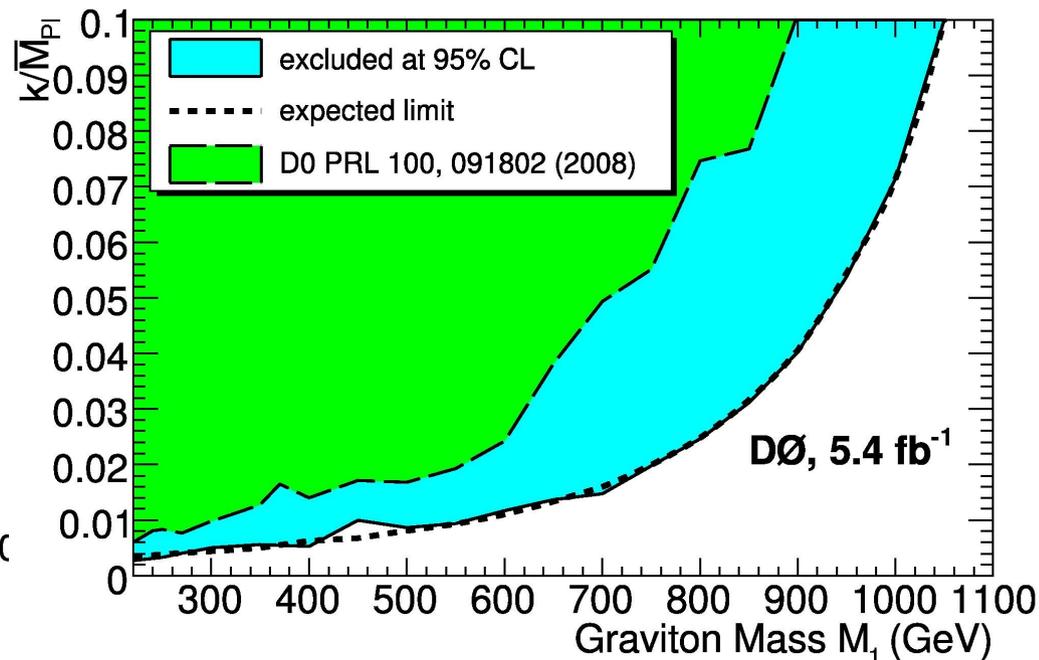
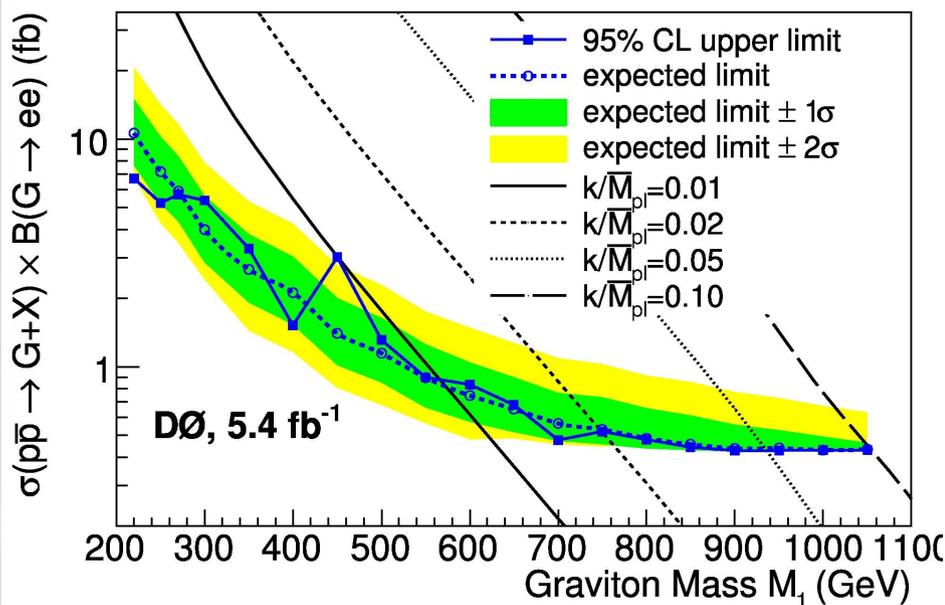


5.4 fb⁻¹

- Observation consistent with expectation
- Use invariant mass window (depending on graviton mass) to set limit

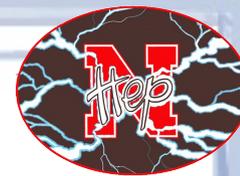
Exclude graviton below 560 (1050) GeV for k/M_{pl} of 0.01 (0.1)

PRL 104, 241802 (2010)





UED in $\gamma\gamma$ +MET

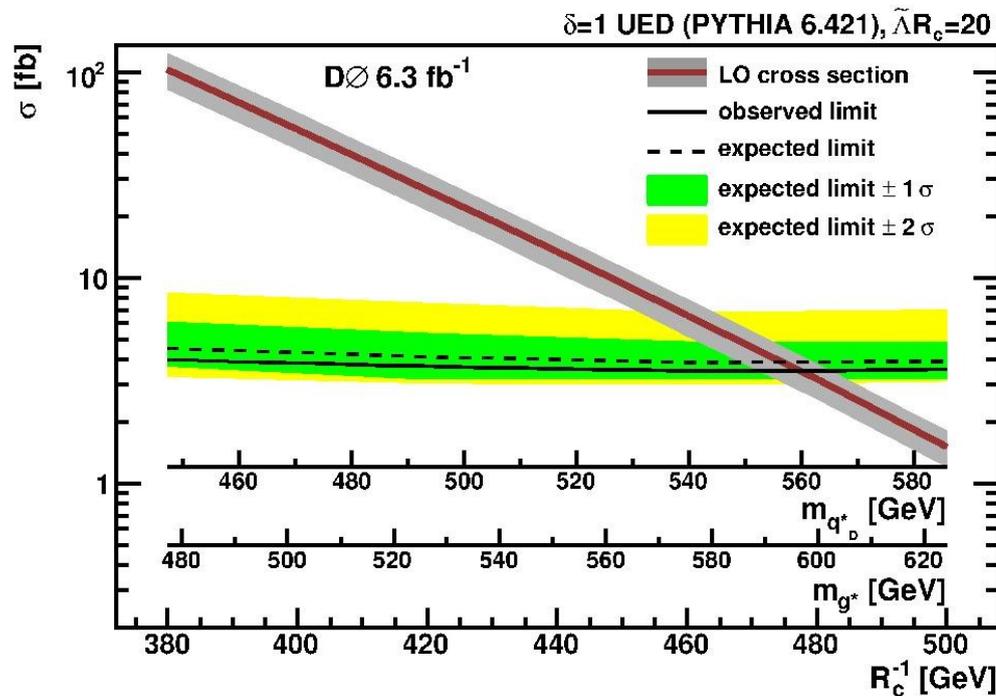


6.3 fb⁻¹

- Interpret $\gamma\gamma$ +MET search in UED model
- KK photon decays to photon and graviton

Exclude compactification radius below 477 GeV

**arXiv: 1008.2133
Submitted to PRL**





Searches for New Gauge Bosons

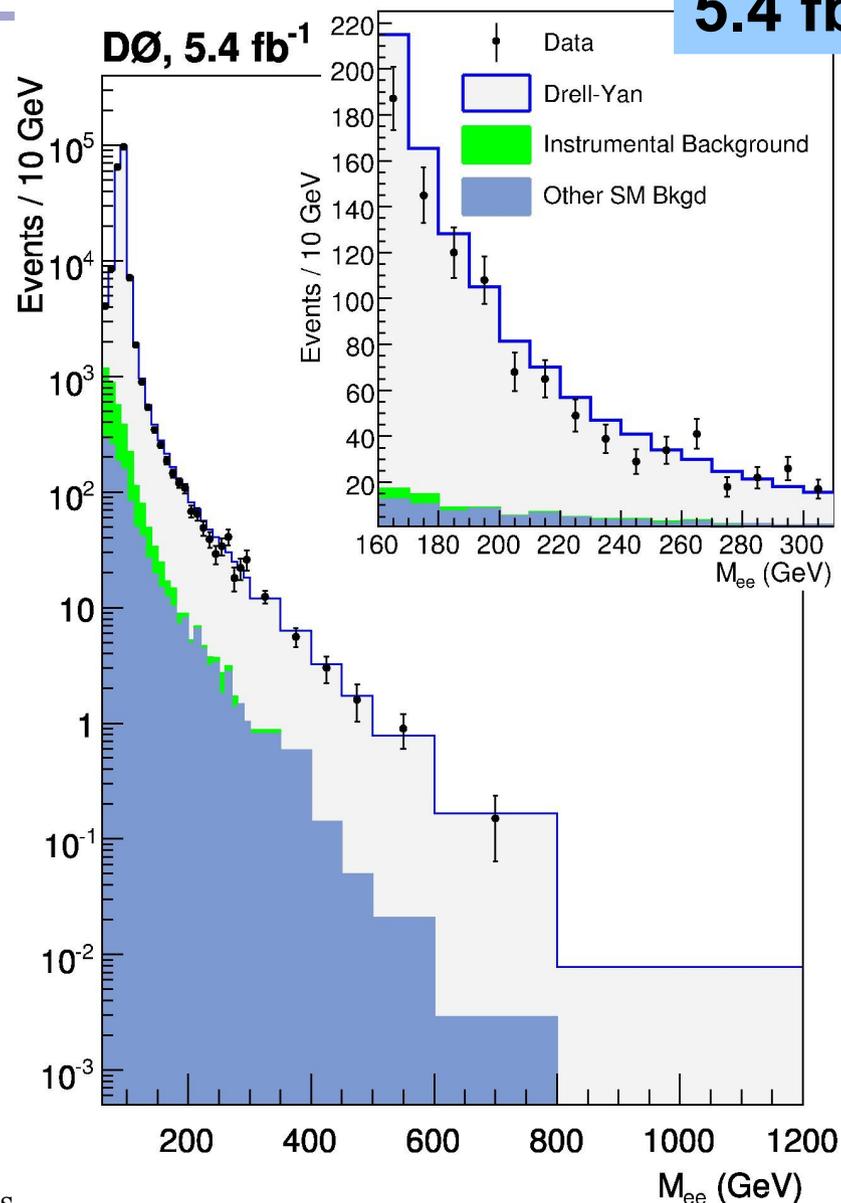


Z' in Dielectrons (I)



5.4 fb⁻¹

- Search for a new neutral gauge boson decaying to a pair of electrons
- Require two electrons (> 25 GeV) and search for bump in invariant mass spectrum





Z' in Dielectrons (II)

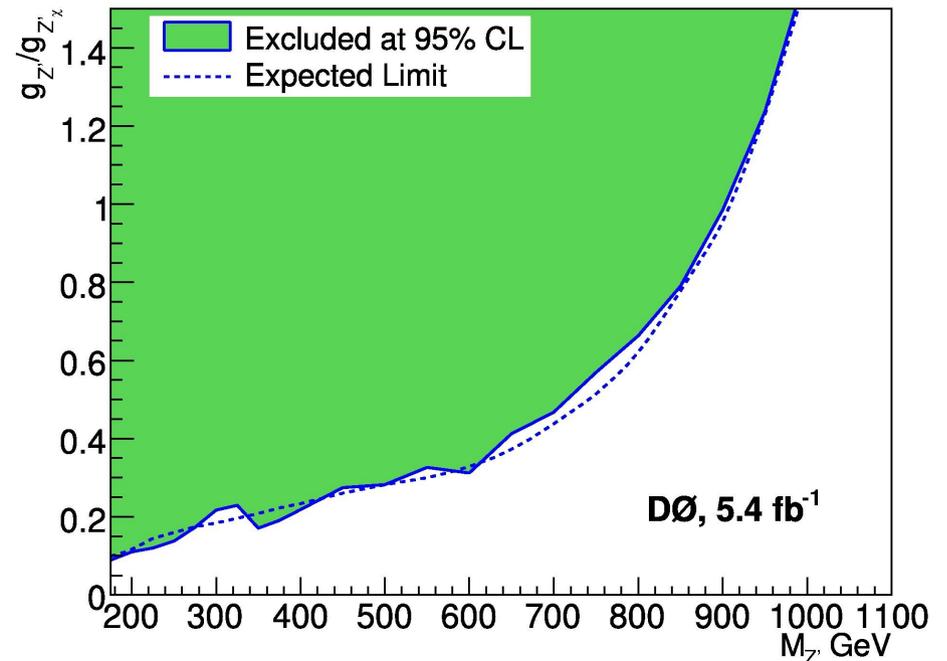
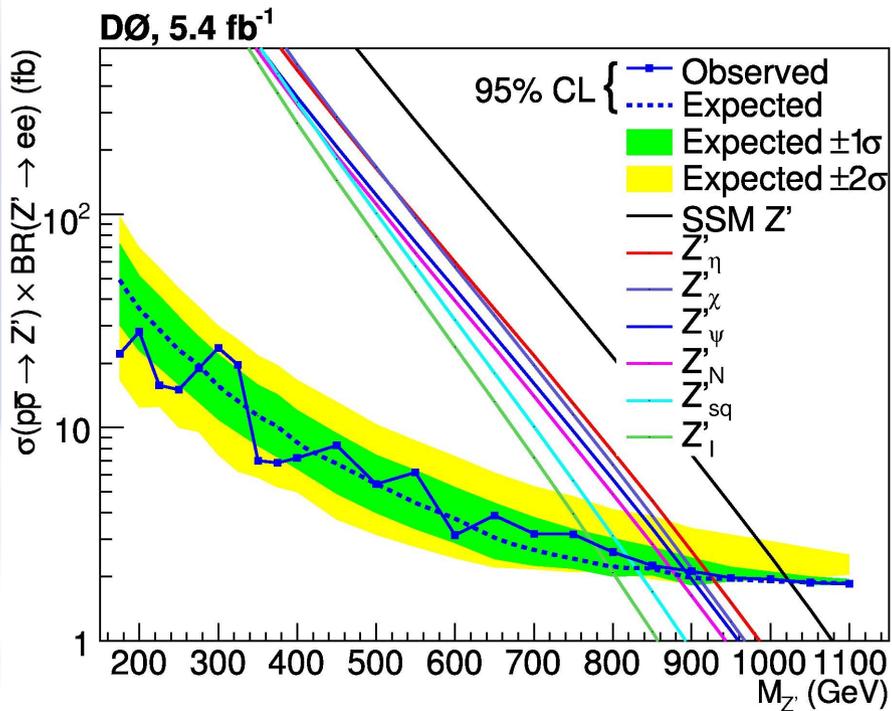


5.4 fb⁻¹

- Optimize search window based on Z' mass
 - No excess observed

Exclude SSM Z' below 1023 GeV

arXiv: 1008.2023
Submitted to PLB





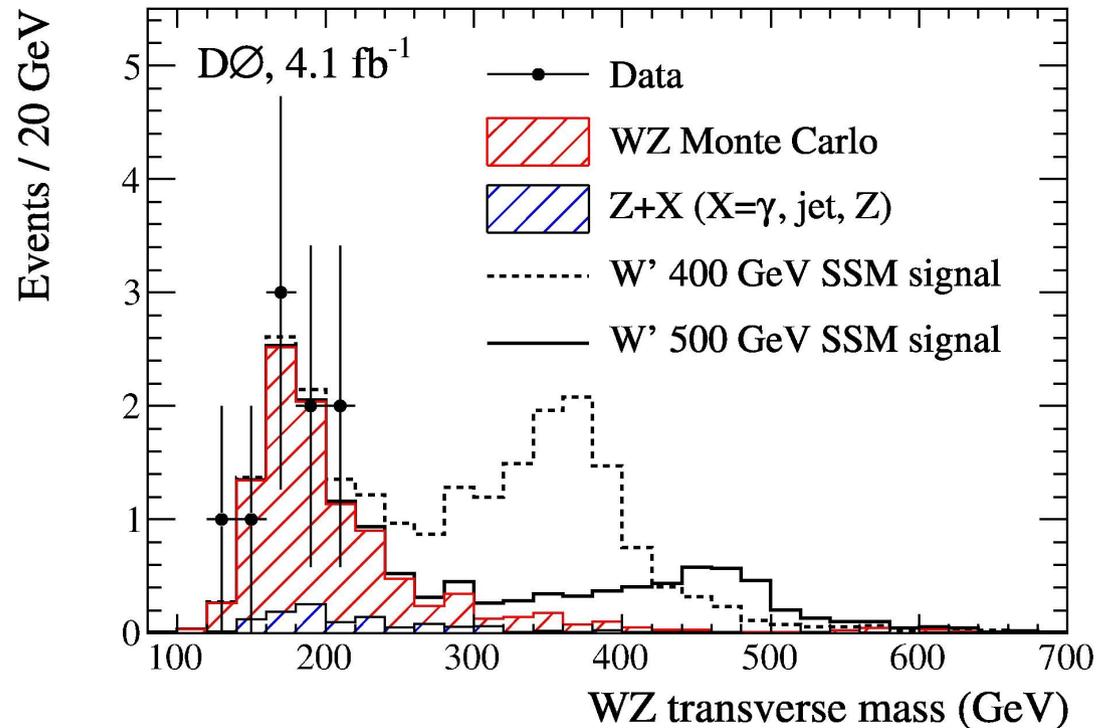
$W' \rightarrow WZ$ in Trileptons (I)



4.1 fb⁻¹

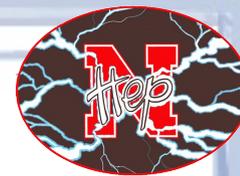
- Assume heavy W' decays to WZ , which decay to leptons
 - Signature is 3 leptons plus MET

- 3 e/μ above 20 GeV
- MET > 30 GeV
- Require a Z candidate





$W' \rightarrow WZ$ in trileptons (II)

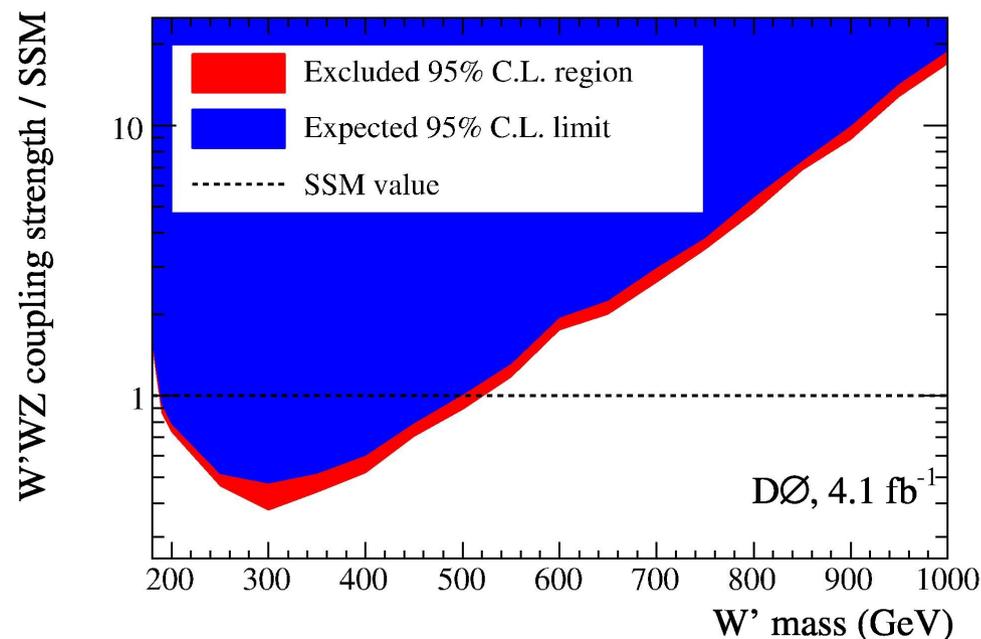
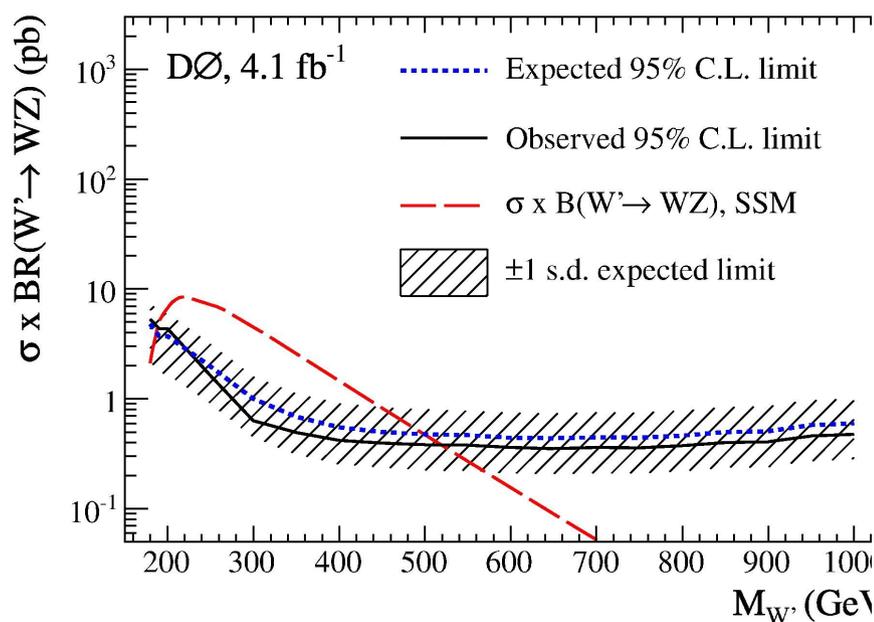


4.1 fb⁻¹

- Observe 9 events, expect 10.2 ± 1.6 from backgrounds (mostly SM WZ)

Exclude W' between 188 and 520 GeV (for simple SM extension)

PRL 104, 061801 (2010)





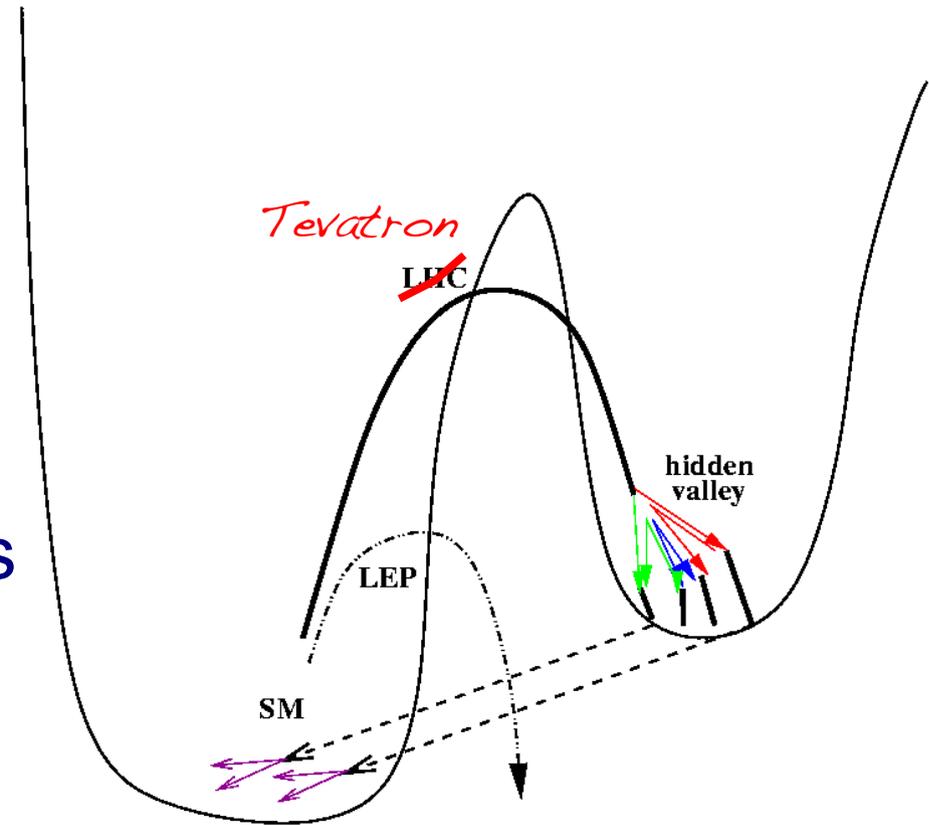
Hidden Valley and Other Searches



Hidden Valleys

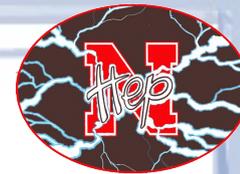


- Hidden sector very weakly coupled to SM particles
- Can directly produce HV particles, can have cascade decays to HV particles, or SM particles can mix with HV particles
- HV particles can then decay back to SM particles (often with a significant lifetime)



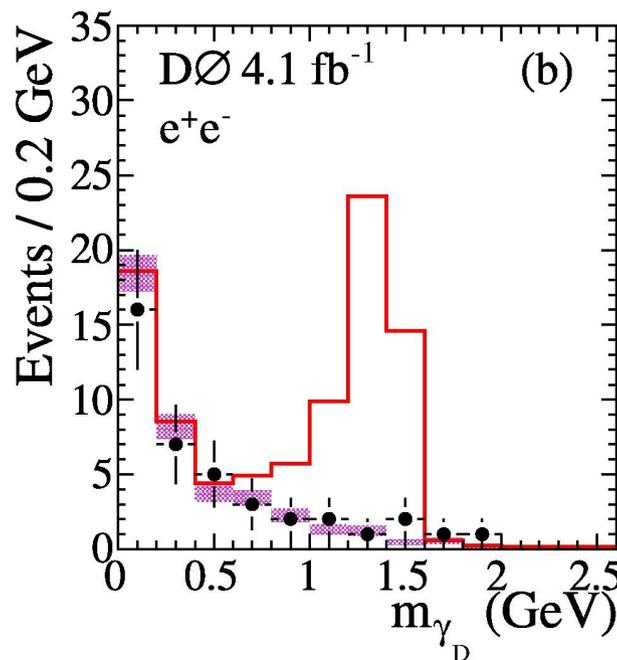
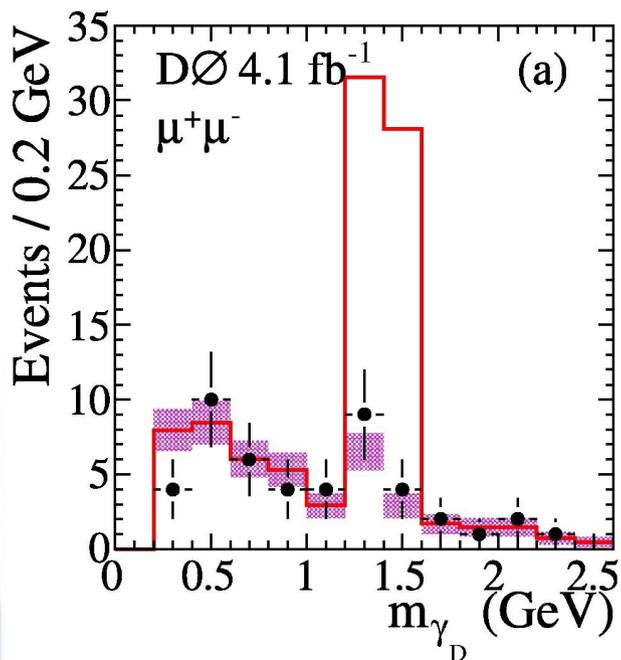
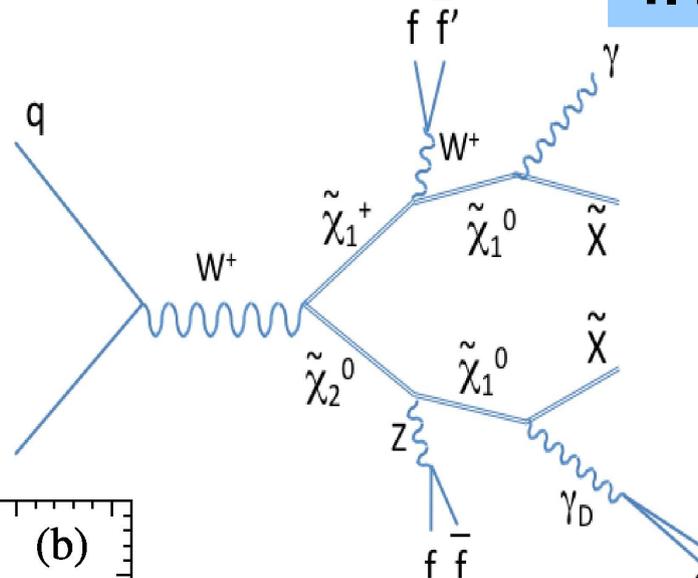


Dark Photons (I)



4.1 fb⁻¹

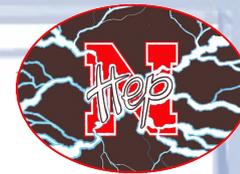
- Hidden Valley with SUSY
- Final state is photon, MET, and two (close) leptons



- Photon above 30 GeV
- MET > 20 GeV
- Two tracks above 10 (5) GeV and $\Delta R < 0.2$, matched to EM cluster or muon



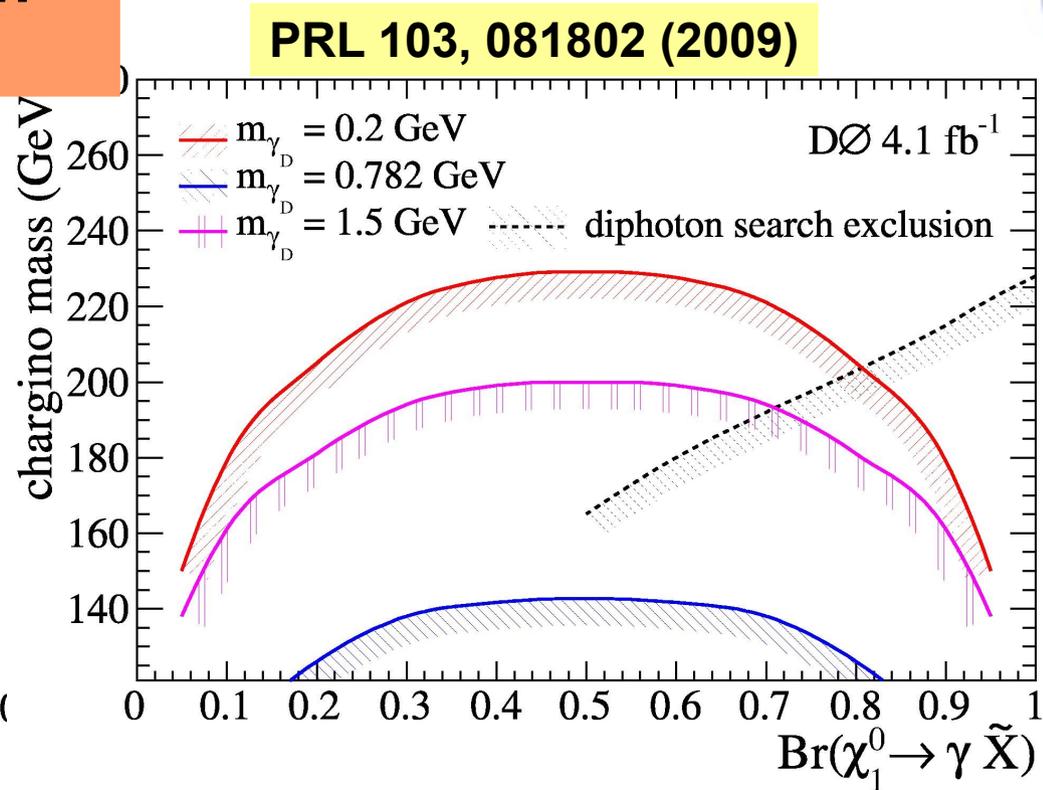
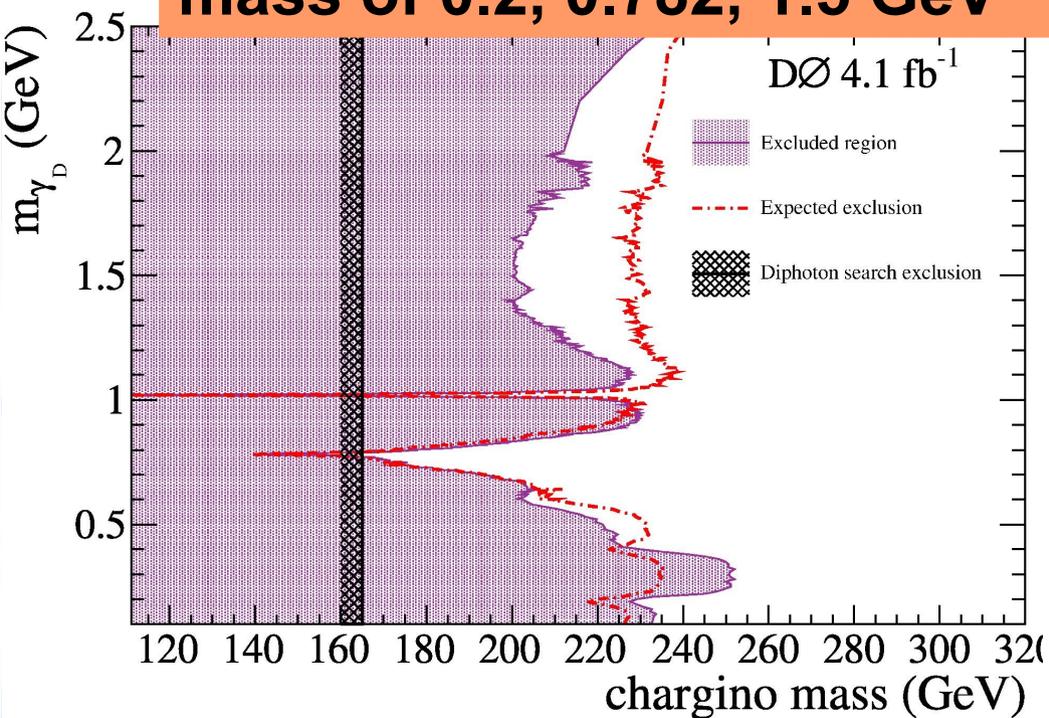
Dark Photons (II)



4.1 fb⁻¹

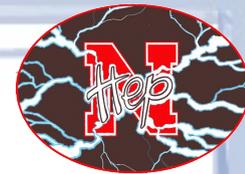
- No excess observed
- Set limit based on invariant mass distribution

Exclude chargino mass of 240, 142, 200 GeV for dark photon mass of 0.2, 0.782, 1.5 GeV



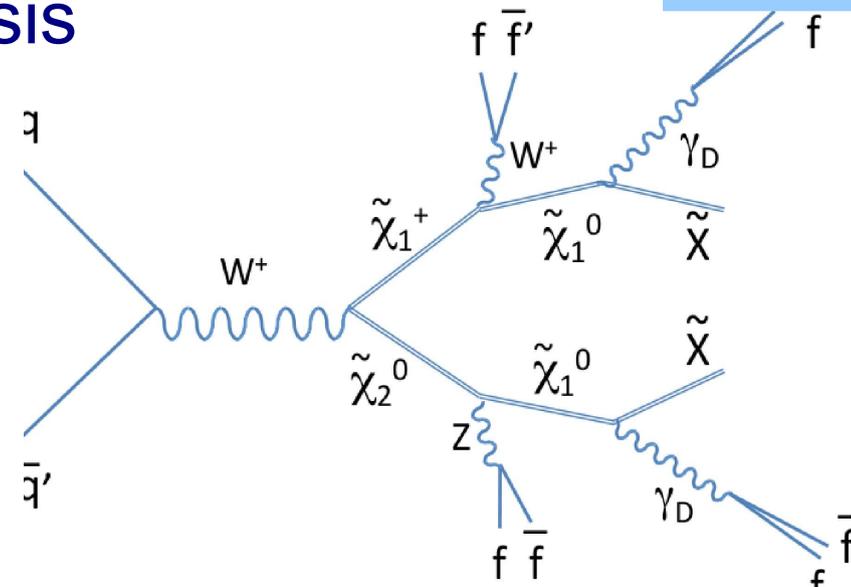
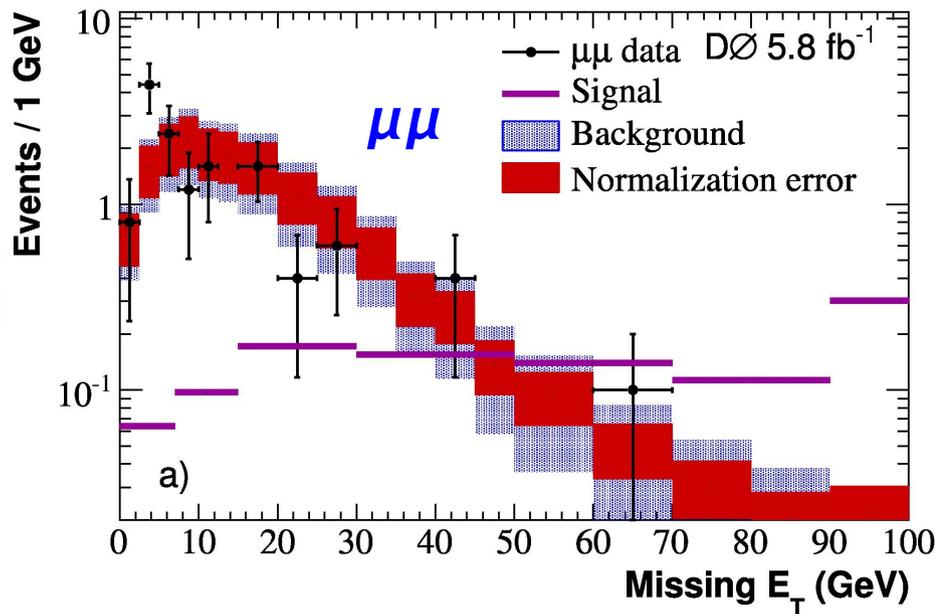


Leptonic Jets (I)

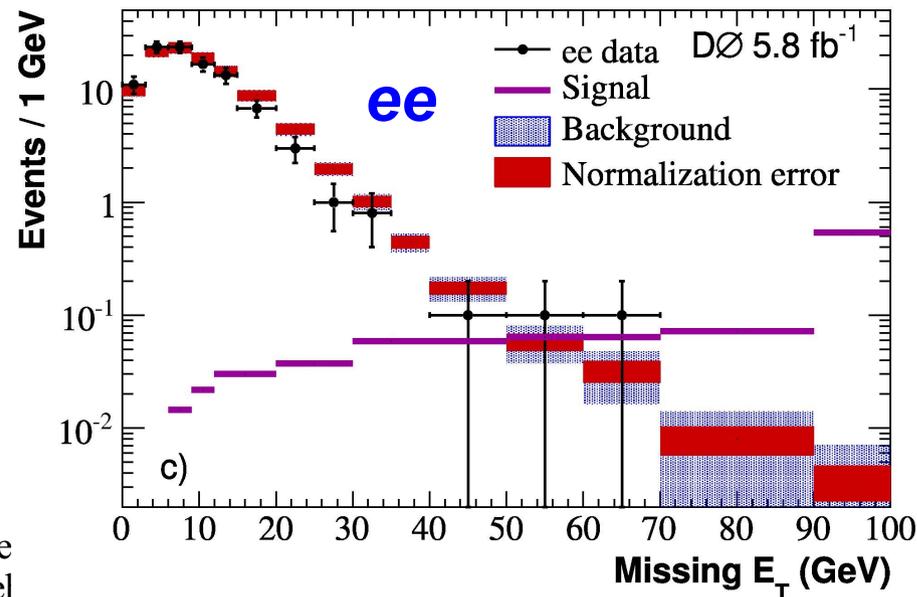


5.8 fb⁻¹

- Similar to dark photon analysis



- Look for “muon jet” or “electron jet” with multiple tracks
- Isolation
- MET > 30 GeV



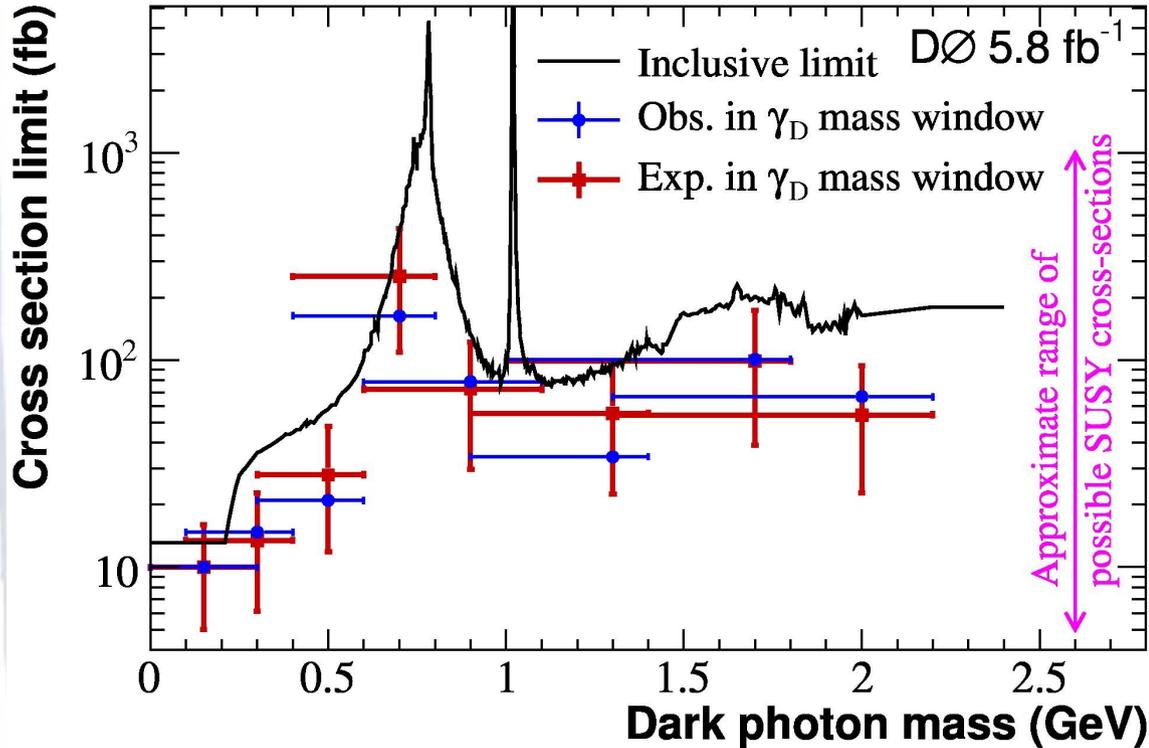


Leptonic Jets (II)



5.8 fb⁻¹

- No excess observed
- Set limits as counting experiment in 3 channels

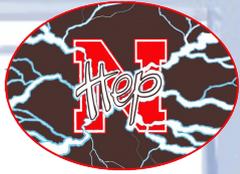


	Data	Bkgd	Signal Eff
ee	7	10.2 ± 1.7	8.9%
$e\mu$	11	17.5 ± 4.2	7.8%
$\mu\mu$	3	8.6 ± 4.5	5.8%

arXiv: 1008.3356
Submitted to PRL

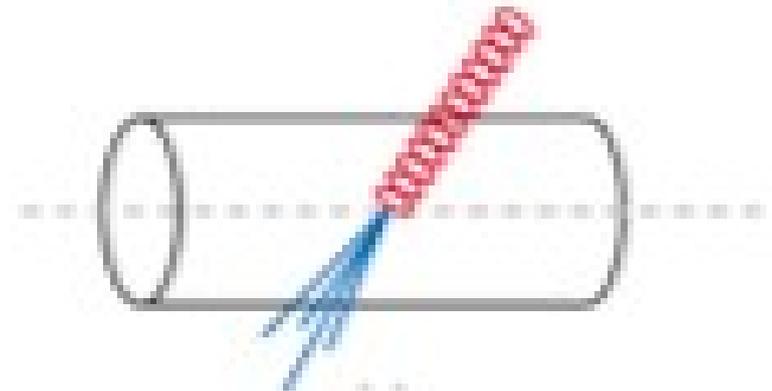
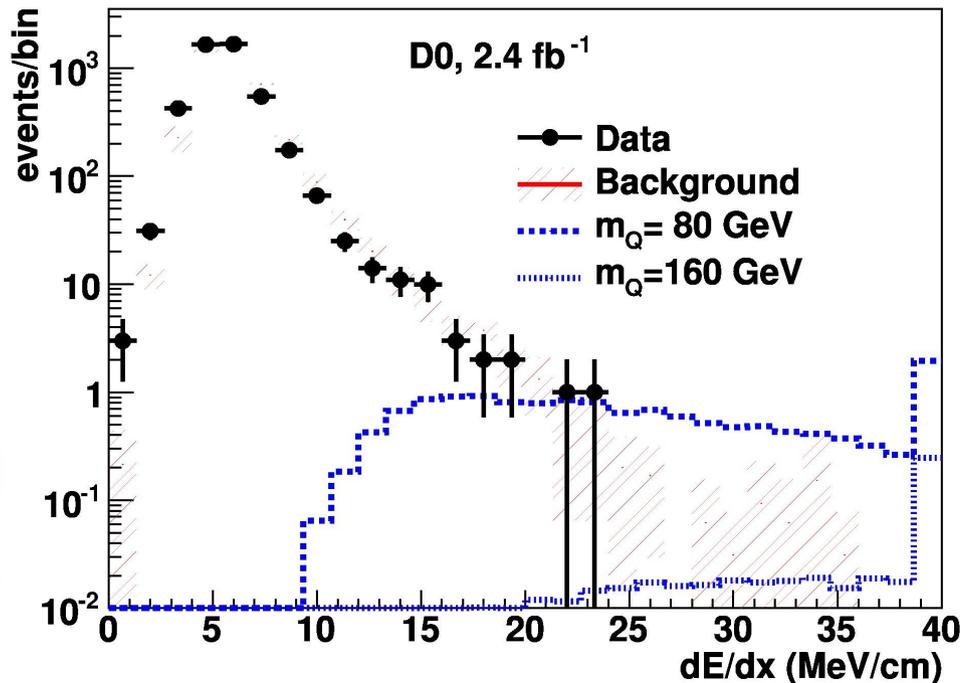


Quirks (I)



2.4 fb⁻¹

- New SU(3) gauge group with new fermions (quirks)
- Phenomenology depends on scale (Λ)
 - Probe mesoscopic scale
- Use dE/dx in inner tracker



Quirk pair with
“mesoscopic” scale



Quirks (II)



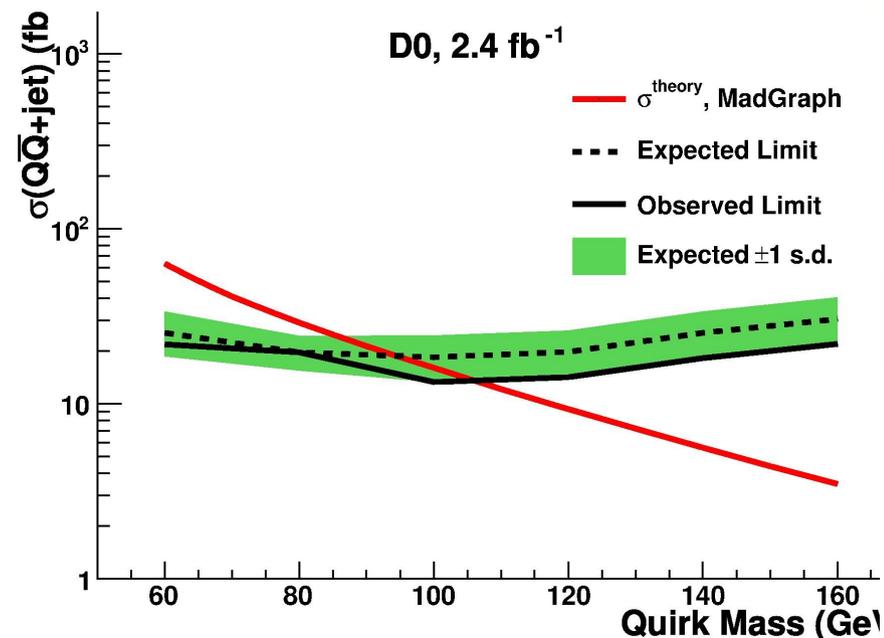
2.4 fb⁻¹

- No excess, perform counting experiment on dE/dx distribution
- Vary dE/dx threshold based on quirk mass

Exclude quirks with mass below 107 GeV

Quirk Mass (GeV)	dE/dx cut (MeV/cm)	Data	Bkgd
60	19	4	5 ± 1
80	21	2	1.9 ± 0.8
100	24	0	0.9 ± 0.4
120	24	0	0.9 ± 0.4
140	24	0	0.9 ± 0.4
160	24	0	0.9 ± 0.4

arXiv: 1008.3547
Submitted to PRL



Conclusion

- DØ continues to efficiently take data, improve analysis techniques, and explore new models
- Many more results are available (technicolor, leptoquarks, SUSY, ED, model independent, etc...)
- All public results available at
 - <http://www-d0.fnal.gov/Run2Physics/WWW/results.htm>
- Thanks to our hosts!



Backup



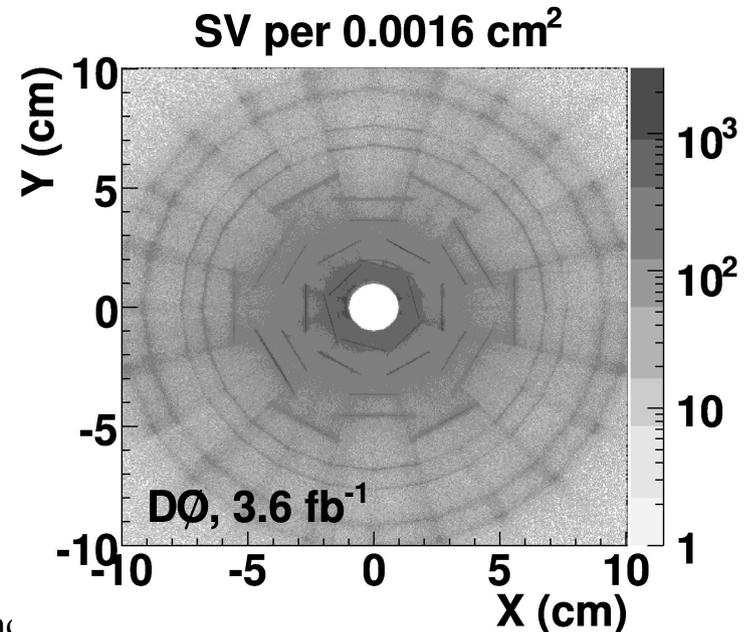
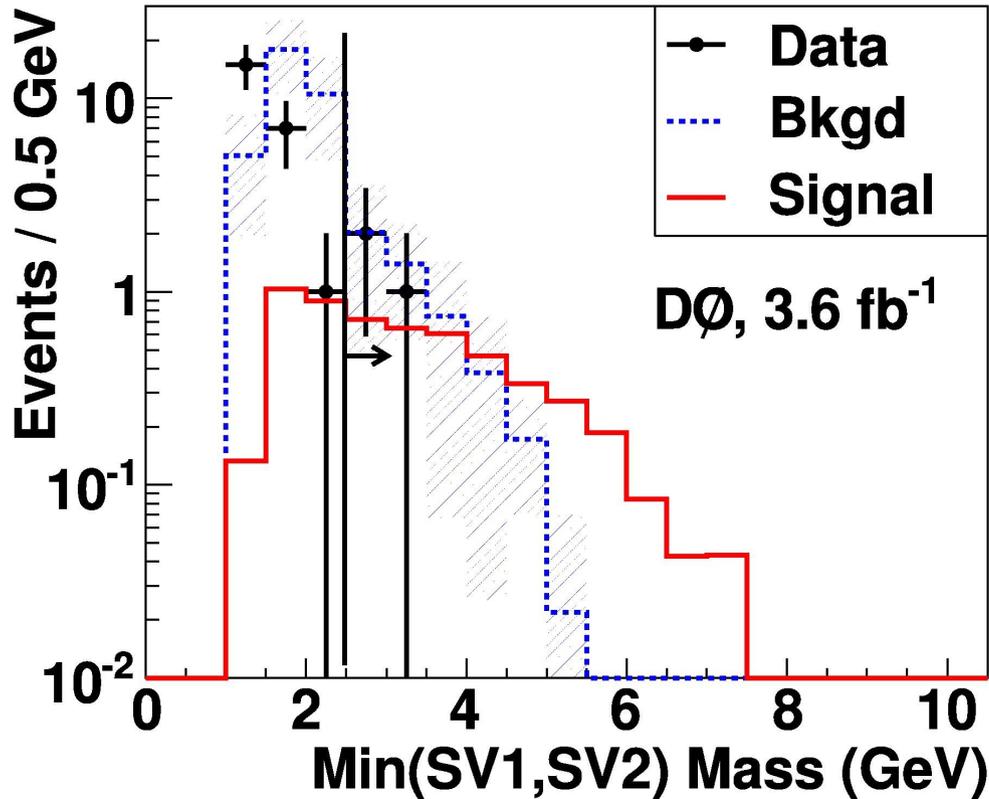
Displaced b -Jets (I)



3.6 fb⁻¹

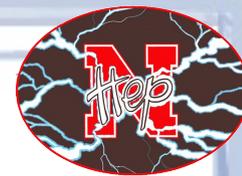
- SM Higgs mixes with HV Higgs
- SM Higgs decays to HV particle, which decays to b quarks

- 2 jets above 10 GeV, one containing a muon
 - Secondary vertex impact parameter > 1.6 cm





Displaced b -Jets (II)



3.6 fb⁻¹

- Use SV mass and collinearity to reduce background
- No excess observed

PRL 103, 071801 (2009)

