

Search for New Physics Beyond SM at Tevatron

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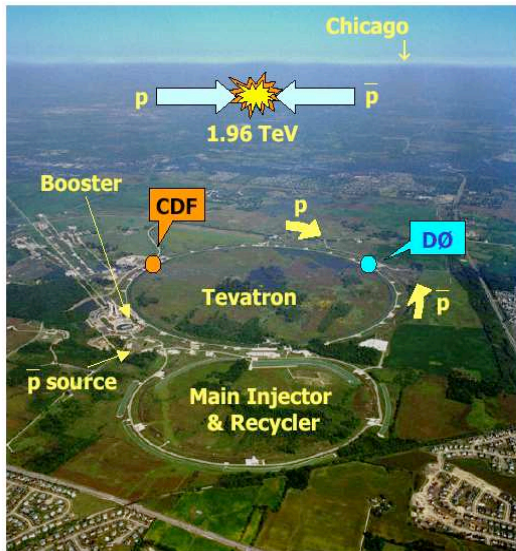
University of California, Irvine

For the CDF and D0 Collaborations

Kruger 2010 Workshop

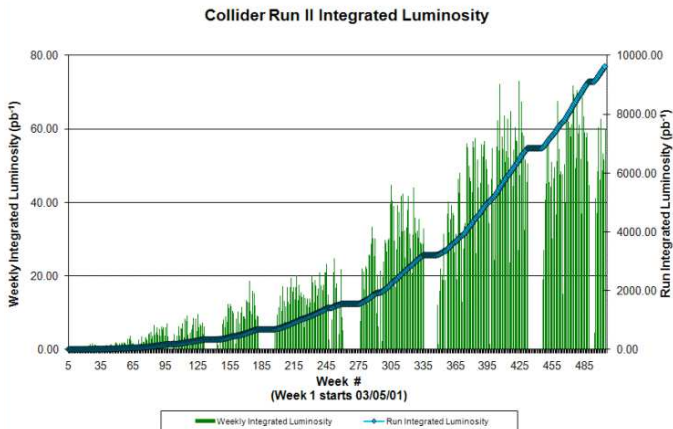
- Introduction
 - Tevatron Status
 - CDF and D0 Detectors
- Search for New Physics Beyond SM
- QCD study at Tevatron
- Conclusion

Tevatron – W, Z and Top Factory



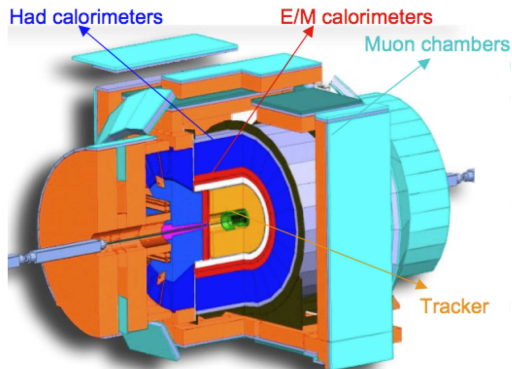
Tevatron Status

- $p \bar{p}$ collision at 1.96 TeV
- Peak luminosity exceeded $400 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$
- Total luminosity delivered: $\sim 10 \text{ fb}^{-1}$
- Recorded luminosity: $\sim 9 \text{ fb}^{-1}$ per experiment



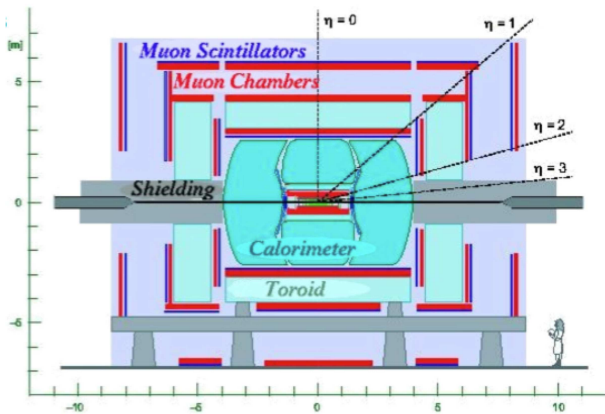
CDF Detector

- Central silicon and drift tracking
- Lead/Steel + scintillator calorimeter
- Outer muon chambers
- Magnetic field of 1.4 Tesla

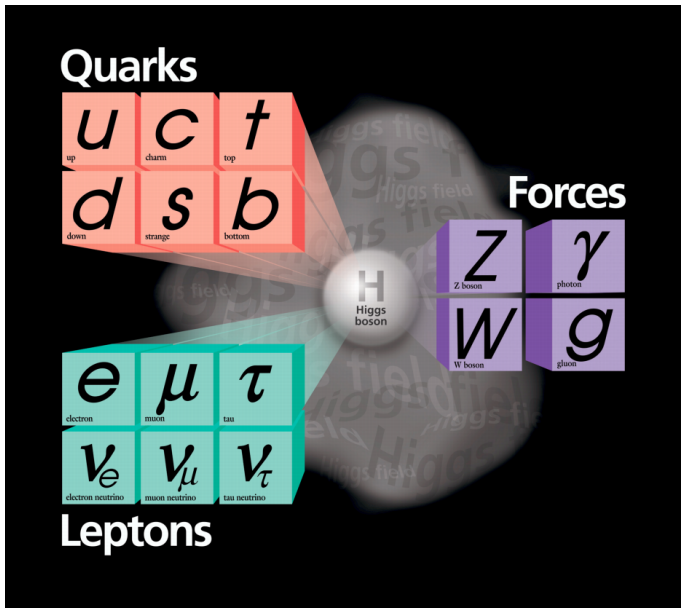


D0 Detector

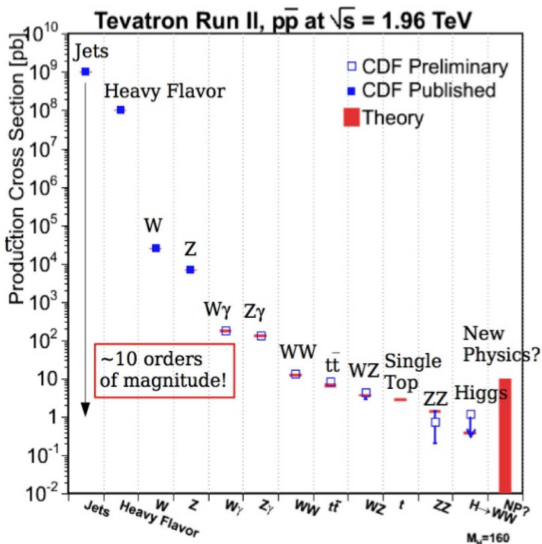
- Central silicon and drift tracking
- Uranium/Steel + liquid-argon calorimeter
- Outer muon chambers
- Magnetic field of 1.8 Tesla



What Do We Know Today



Cross-section Measurements at Tevatron



Search for New Physics Beyond SM

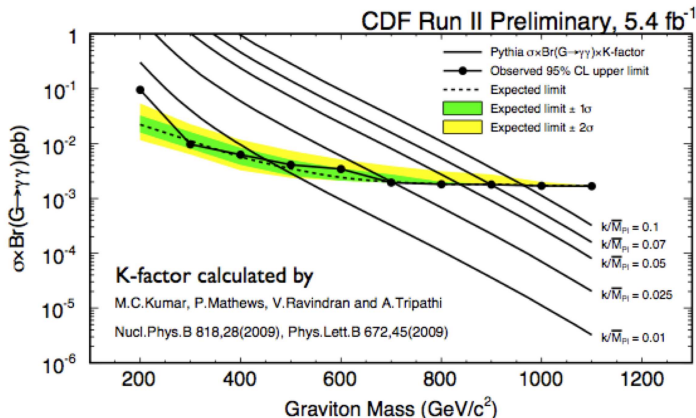
- Model driven search
- Data driven search (signature based search)

- recent results with $\sim 5 \text{ fb}^{-1}$ of data
 - RS Graviton to diphotons
 - Graviton $\rightarrow ZZ$
 - Lepton+Photon+MET+Bjet
 - 3-jet resonances
 - Z' search
 - W' search
 - b' search
 - t' search
 - ...

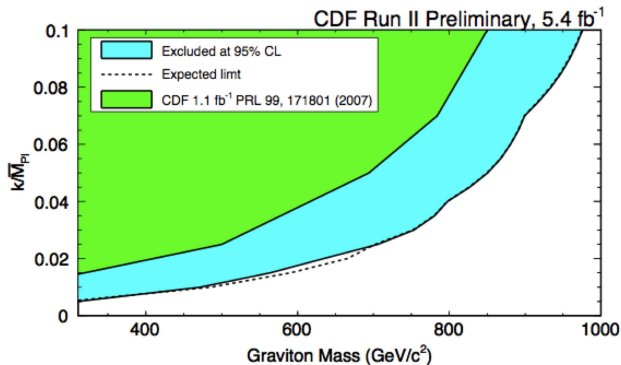
- recent results with $\sim 5 \text{ fb}^{-1}$ of data
 - Diphoton + Dielectron resonance
 - WZ resonance
 - Scalar bottom quarks + 3rd generation leptoquarks
 - Sneutrino (e mu)
 - Leptonic jets + mET
 - New fermions "quirks"
 - Diphotons + mET
 - Zprime(e e)
 - Scalar top (e mu)
 - Vector-like quarks
 - ...

- Randall-Sundrum Extra Dimension Model
 - introducing an extra dimension
 - SM particles confined in the "TeV" brane
 - Gravity localized on the Planck brane
 - Parameters
 - k : curvature of extra dimension
 - r_c : compactification radius of extra dimension
 - Kaluza-Klein tower of graviton states
 - Mass of first excitation: m_1
 - Width parameter: k/M_{pl}
 - Decay products of RS graviton
 - $G \rightarrow \gamma\gamma, G \rightarrow ll \dots$
- Event Selection
 - 5.4 fb^{-1}
 - Two Photons: $E_T > 15 \text{ GeV}, |\eta| < 1.1$

Cross Section Limits

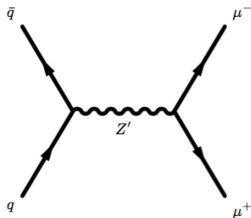


Limit on RS Model



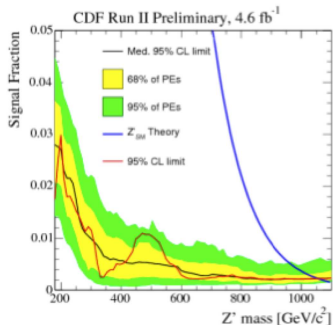
- $M_G > 472$ GeV for $k/M_{pl} = 0.01$, and $M_G > 976$ GeV for $k/M_{pl} = 0.1$

New Physics Search in Dimuon Channel

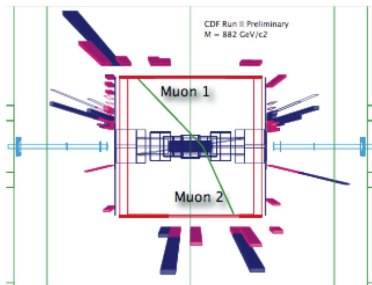


- Goals:
 - Sensitive to any dimuon mass bump
 - Z' Search
 - R-S Graviton Search
- Event Selection:
 - 4.6 fb^{-1}
 - two isolated muons
 - $P_T > 30 \text{ GeV}$, $|\eta| < 1.0$
 - $M(\mu\mu) > 130 \text{ GeV}$
 - cosmic rejection

New Physics Search in Dimuon Channel



Mass $Z'_{\text{SM}} > 1071 \text{ GeV}$

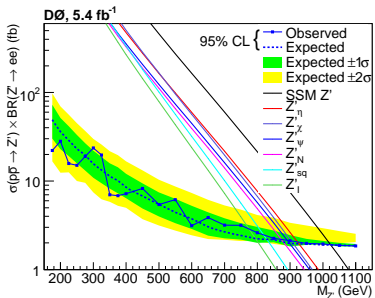
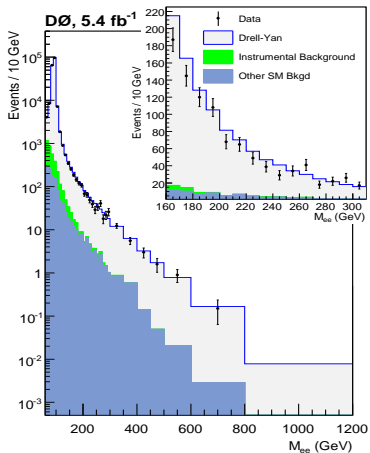


Highest dimuon mass = 882 GeV

New Physics Search in Dielectron Channel

- Goal:
 - Search for Z'
- Event Selection
 - 5.4 fb^{-1}
 - 2 central, isolated electrons
 - $E_T > 25 \text{ GeV}$
- Main background: $DY \rightarrow ee$
- Background estimation is fitted to $60 < M_{ee} < 150$
- Mass limit: $Z'_{SM} > 1023 \text{ GeV}$

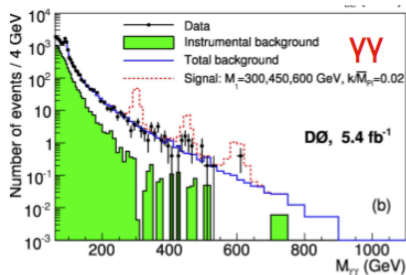
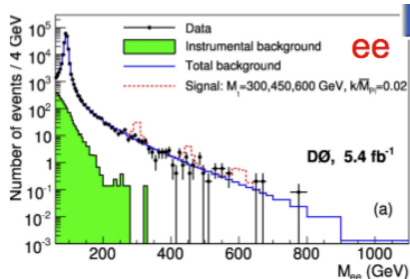
New Physics Search in Dielectron Channel



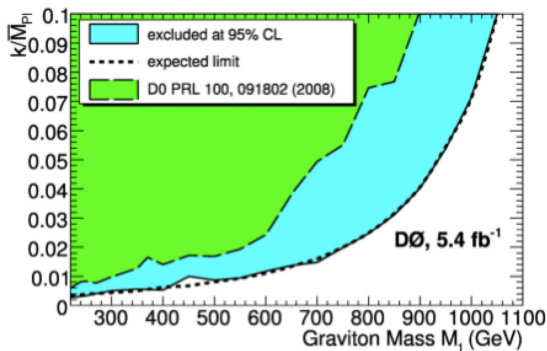
Graviton Search in diphoton and dielectron combined

- Goal:
 - Search the lightest KK graviton
- Event Selection
 - 5.4 fb^{-1}
 - in ee and $\gamma\gamma$ decay channels
 - $\text{BR}(\gamma\gamma) \sim 2 \text{ BR}(ee)$
 - 2 central, isolated electrons or photons
 - $E_T > 25 \text{ GeV}$
- Main background: $DY \rightarrow ee / \text{SM } \gamma\gamma$
- Background estimation is fitted to $60 < M_{ee}(M_{\gamma\gamma}) < 200$
- Phys. Rev. Lett. 104, 241802 (2010)

Graviton Search in diphoton and dielectron combined



Graviton Search in diphoton and dielectron combined



- $M_G > 560 \text{ GeV}$ for $k/M_{pl} = 0.01$
- $M_G > 1050 \text{ GeV}$ for $k/M_{pl} = 0.1$

● Goals

● Gauge Mediated Supersymmetry Breaking (GMSB)

- Gravitino (\tilde{G}) the lightest SUSY particle (LSP)
- the lightest neutralino decays to photon and Gravitino ($\chi_1^0 \rightarrow \gamma + \tilde{G}$)
- Parameter: the breaking scale Λ

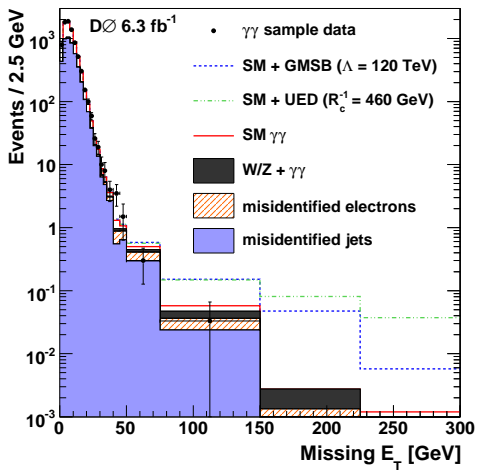
● Universal Extra Dimensions (UED)

- Extra spatial dimensions are accessible to all SM particles
- Consider a single UED compactified with radius R_c
- pair production of KK particles
- KK photon (γ^*) the lightest KK particle
- Exist large additional extra dimensions only accessible to gravity
- KK photon decays to photon and graviton

● Event Selection

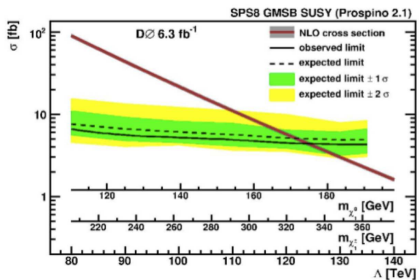
- 6.3 fb^{-1}
- 2 photons $> 25 \text{ GeV}$, MET $> 50 \text{ GeV}$

Diphoton + MET channel



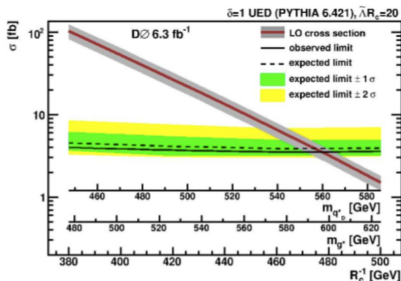
Diphoton + MET channel

GMSB limit



$M_{\tilde{\chi}_0} > 170 \text{ GeV}/c^2$ at 95% CL

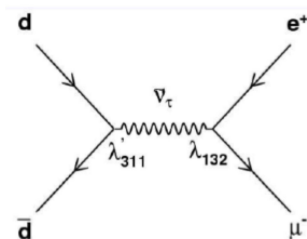
Universal extra dimensions limit



$R_c^{-1} > 477 \text{ GeV}/c^2$ at 95% CL

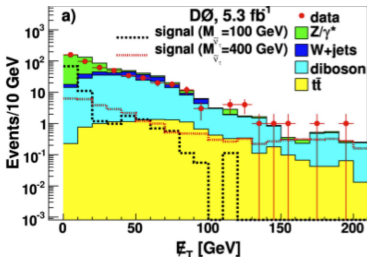
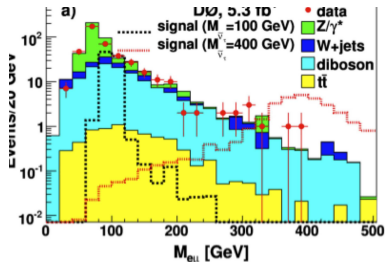
R-parity Violating (RPV) Signals

- If R-parity conserved, SUSY particles produced in pair
- If R-parity violated
 - Singly-produced SUSY particles decays to SM particles
 - lepton-number or /and baryon number violation
- present two searches:
 - multijet searches on RPV gluino production
 - sneutrino production with lepton-number violated decay

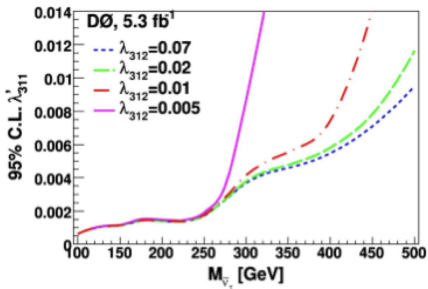
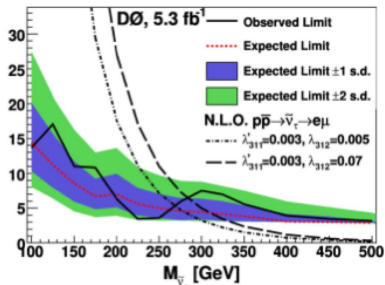


- Look for electron + muon production (lepton-number violation)
- Event Selection
 - 5.3 fb^{-1}
 - 1 electron $E_T > 35 \text{ GeV}$
 - 1 muon $P_T > 25 \text{ GeV}$
 - jet veto
- Main background: $Z \rightarrow \tau\tau$, diboson
- Expected 410 ± 38 , observed 414

R-parity Violating (RPV) Sneutrino Search

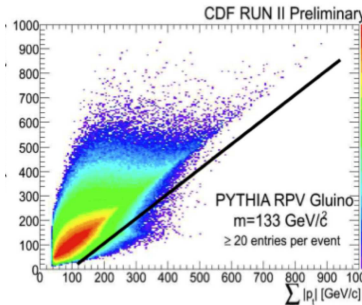
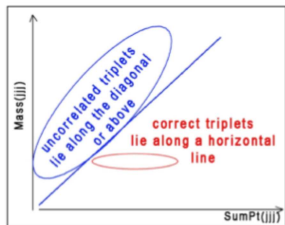


R-parity Violating (RPV) Sneutrino Search



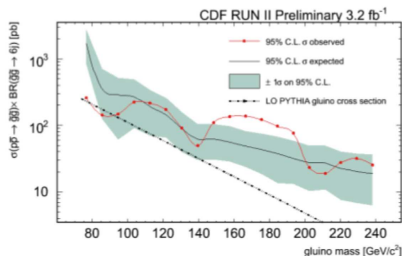
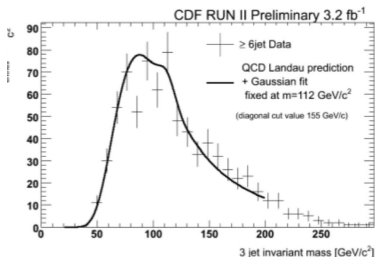
R-parity Violating (RPV) Gluino Search

- R-Parity violating gluinos pair
- decay to 6 outgoing partons
- 3.2 fb^{-1}
- 6 jets $> 15 \text{ GeV}$
- $\sum E_T > 250 \text{ GeV}$
- $\text{MET} < 50 \text{ GeV}$
- Diagonal cut optimized for different gluino masses



R-parity Violating (RPV) Gluino Search

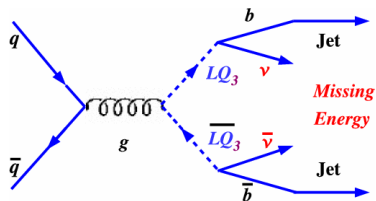
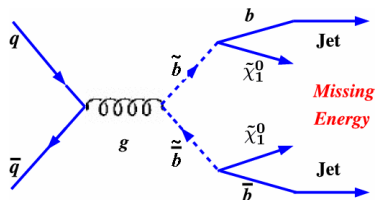
- Background
 - EWK negligible
 - QCD shape from 5j data
 - scale Sum PT to match 6j data
 - plot 3j mass
- Data consistent with SM expectation



Sbottom pairs or Leptoquarks

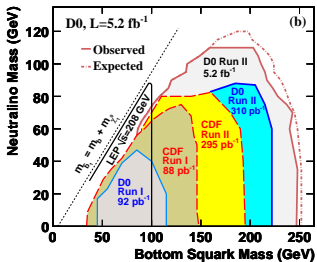
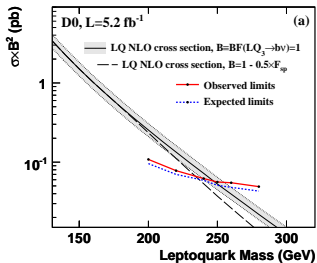
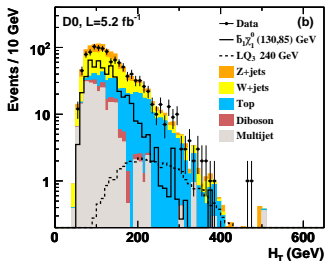
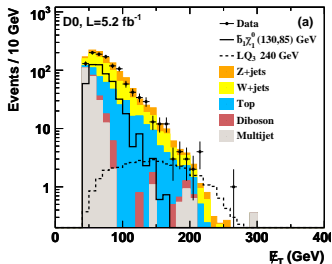
- Goals:
 - SUSY: sbottom pair production
 - Leptoquarks: $LQ_3 \rightarrow \nu_T + b$
- Signatures: MET + b quarks
- Event Selection: 5.2 fb^{-1}
 - 2 or 3 jets, $E_T > 20 \text{ GeV}$
 - at least 2 b-tagged jets, leptons vetoed
 - MET > 40 GeV, MET away from jets
 - Optimize for each signal
- Main Backgrounds: W/Z + jets, multi-jet with fake MET
- PLB 693, 95

Sbottom pairs or Leptoquarks



- Leptoquarks:
 - Composite models, SUSY RPV
 - fundamental particles
 - have color, electric charge
 - have both lepton and baryon quantum numbers
 - $M_{LQ3} > 247$ GeV at 95% CL
- Sbottom:
 - sbottom mass limit is ~ 250 GeV (for neutralino mass < 70 GeV)

Sbottom pairs or Leptoquarks



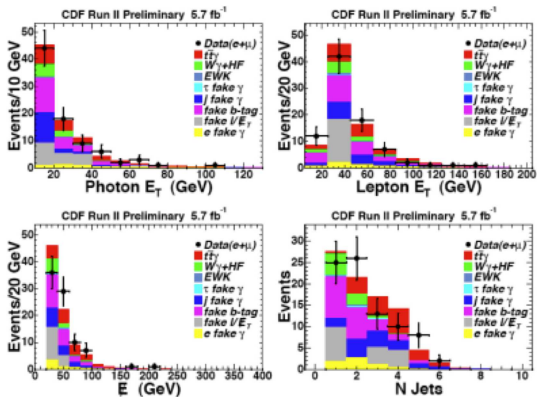
- Goal:
 - Signature based new physics search
- Event Selection
 - 5.7 fb^{-1}
 - one electron or muon, $E_T > 20 \text{ GeV}$
 - $\text{MET} > 20 \text{ GeV}$
 - one photon with $E_T > 12 \text{ GeV}$
 - b-tagged jet with $E_T > 20 \text{ GeV}$
- Background:
 - $t\bar{t} + \text{photon}$ production with semileptonic decay
 - $W\gamma + \text{jets}$
- Expected 86.4 ± 9.0 events, observed 84 events
- CDF public note 10270

lepton + gamma + MET + b quark

CDF Run II Preliminary, 5.74fb⁻¹

Lepton + Photon + \cancel{E}_T + b Events, Isolated Leptons

Total SM Prediction	56.5 ± 7.9	29.8 ± 2.1	86.4 ± 8.5
Observed in Data	51	33	84

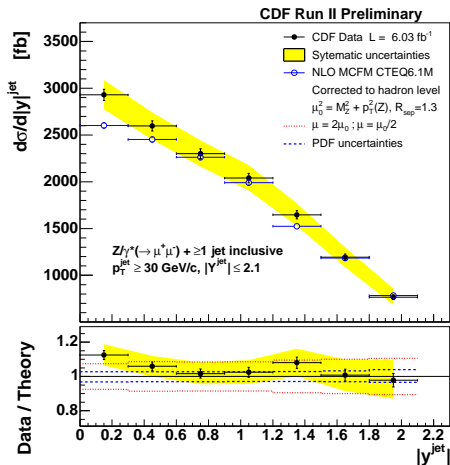


- Prompt diphoton production, 5.4 fb⁻¹, CDF note 10160
- Substructure of High p_T Jets, 5.95 fb⁻¹, CDF note 10199
- Z(mumu) + Jets, 6.03 fb⁻¹, CDF note 10216
- W + charm, 4.3 fb⁻¹, CDF note 10089

- direct photon pair production cross sections,
 - 4.2 fb⁻¹, Phys. Lett. B 690, 108 (2010)
- Ratio of Inclusive σ (ppbar - \rightarrow Z+b jet) / σ (ppbar \rightarrow Z+jet),
 - 4.2 fb⁻¹, Submitted to Phys. Rev. Letters

- goal:
 - measure cross-section as a function of jet transverse momentum and rapidity
- Event Selection
 - 6.0 fb^{-1}
 - $Z/\gamma^* + \text{jets}$ production
 - two muons: $P_T^\mu > 25 \text{ GeV}/c$, $|\eta^\mu| < 1.0$,
 - Z mass windows: $66 < M_{\mu\mu} < 116 \text{ GeV}/c^2$
 - $P_T^{\text{jet}} > 30 \text{ GeV}/c$, $|\eta^{\text{jet}}| < 2.1$, cone size 0.7
- Good agreement with the NLO MCFM calculations

QCD Measurement: $Z/\gamma^* + \text{jets}$



- Tevatron continue to search for new physics beyond SM
 - Prime time for Tevatron
 - RunII game is the luminosity and well-understood detectors
 - Rich program of beyond Standard Model search
- New results coming in with more data
 - Published results with data up to 6.2 fb^{-1}
 - More data coming: 10 fb^{-1} delivered
 - 12 fb^{-1} expected by the end of 2011 run
- No evidence of new physics yet
- Stay tuned:
 - <http://www-cdf.fnal.gov/physics/exotic/exotic.html>
 - http://www-d0.fnal.gov/d0_publications/d0_pubs_list_bydate.html
- Other Measurements at Tevatron:
 - See Frank's talk "Challenging the Standard Model at Tevatron"