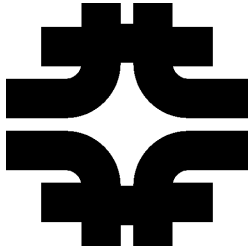


Non-SUSY Searches for New Physics at Tevatron

Sasha Pronko

Fermilab

(for CDF & DØ Collaborations)

In This Talk…

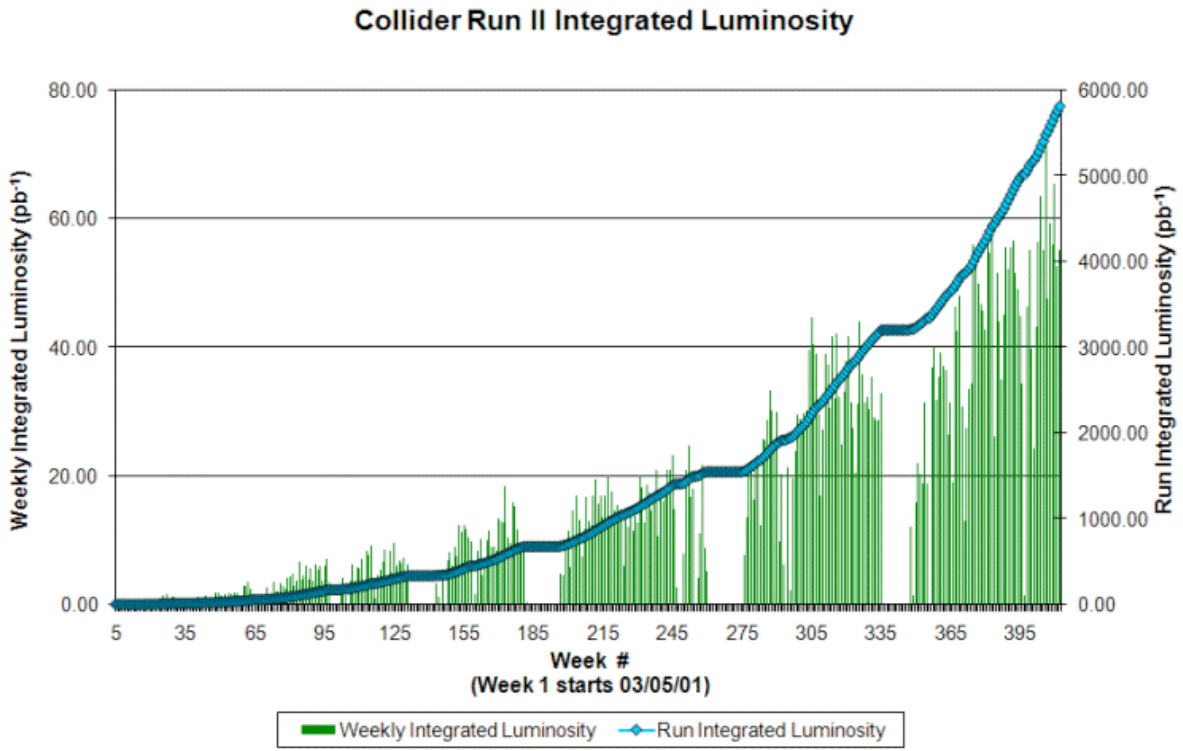
- Overview of recent CDF and DØ results on:
  - Model-independent search for $\gamma\gamma$+MET
  - Searches for New Heavy Resonances
  - Search for LED in γ+MET
  - Searches for Leptoquarks

- More CDF and DØ results at

http://www-d0.fnal.gov/Run2Physics/WWW/results/np.htm

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

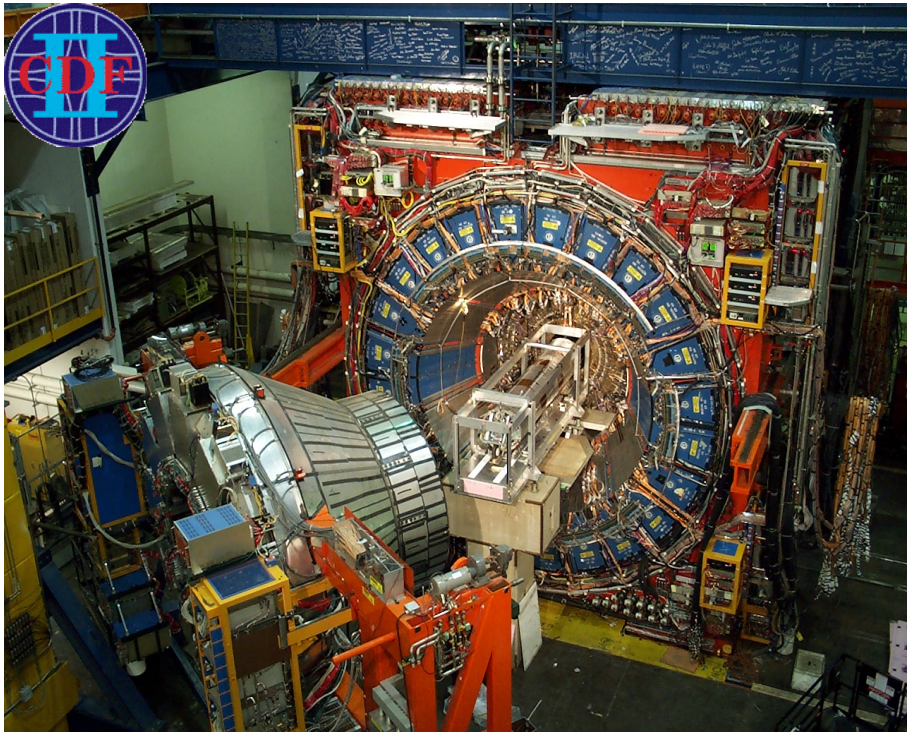
Tevatron is Running Very Well



Results in this talk are based on 1-3 fb^{-1} of data

- 6 fb^{-1} per experiment; ~1.8 fb^{-1} in FY08
- Current rate: 55-60 pb^{-1} per week
- Peak lumi is >300 $\mu b^{-1}/s$
- Goal by 2009: ~6.7 fb^{-1}
- Running till 2010? 2011?

CDF and DØ Experiments



- Multipurpose detectors — classic design
  - "silicon", central tracker, solenoid, calorimeter, muon chambers
- Operating well: 80-90% efficiency
- Broad physics program
  - QCD, EWK, top, B-physics, Higgs searches, searches for new physics

Search for Anomalous Production of γγ+MET

- Why γγ+MET? Why model-independent?

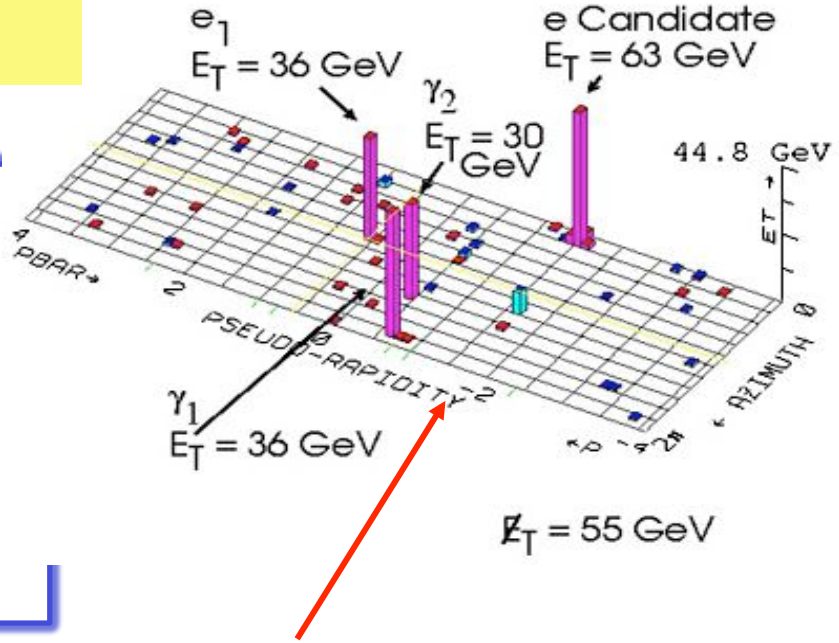
$$SUSY: \quad \gamma\gamma + \not\!\!E_T, \gamma\gamma + jets + \not\!\!E_T, \gamma\gamma + ll + \not\!\!E_T$$

$$Technicolor: \quad \gamma\gamma + ll + \not\!\!E_T$$

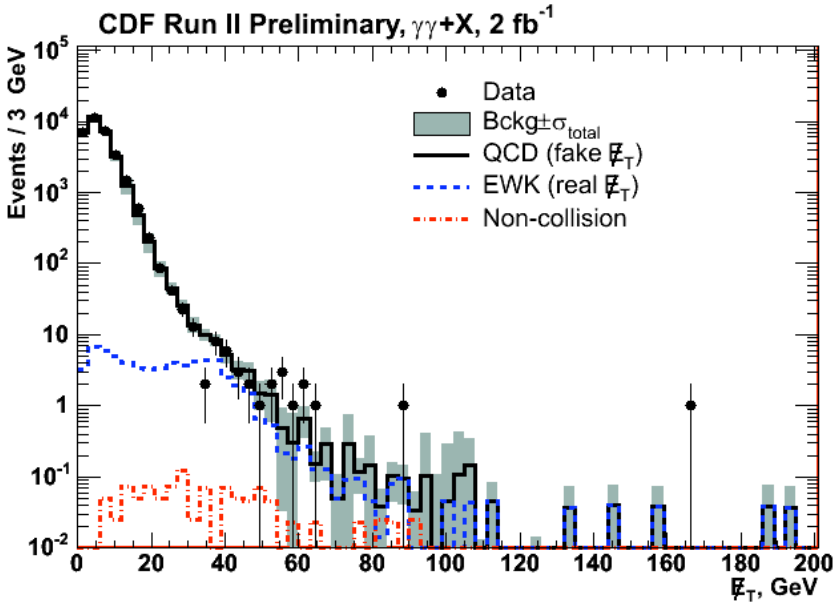
$$Higgs: \quad \gamma\gamma + \not\!\!E_T, \gamma\gamma + l + \not\!\!E_T$$

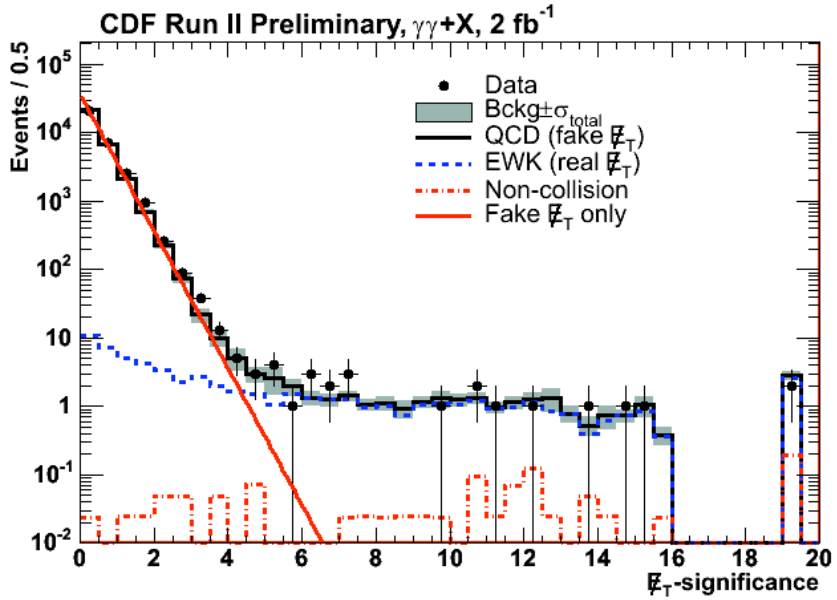
$$UED(6DSM): \gamma\gamma + m * l + \not\!\!E_T$$

- Rare γγ+X events at Tevatron
  - Infamous CDF Run I "eeγγ+MET" event
    - Dominant SM: $WW\gamma\gamma \Rightarrow 8\times10^{-7}$ events
    - Total: $\sim10^{-6}$ events
  - CDF & DO Run II "eγγ+MET" event



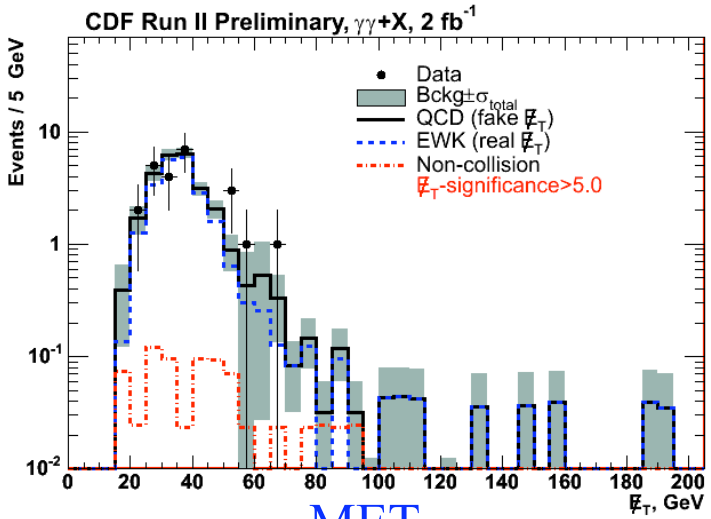
Search for Anomalous Production of γγ+MET



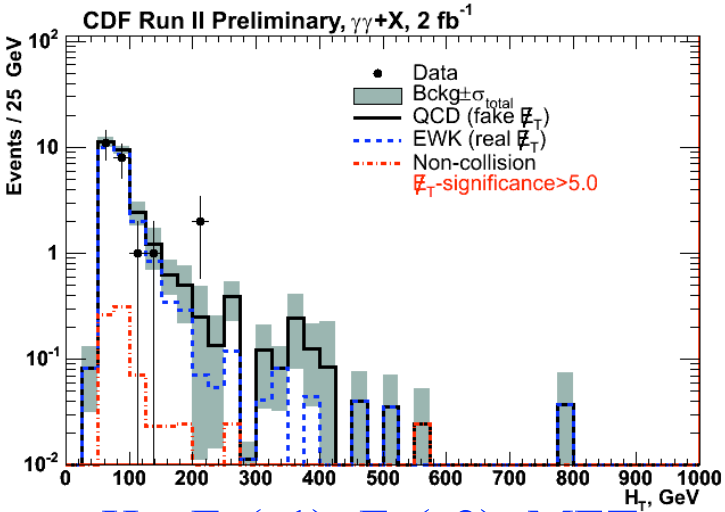


- Two central "tight" photons in time with collision
- Select events with MET-significance>3,4,5
- Backgrounds
  - QCD with fake MET (γγ, γj, jj): from data (MET Resolution Model)
  - EWK with true MET (W/Z+γ, W/Z+jet, Z→ττ)
    - shapes from MC; normalized to e+γ data
  - Non-collision (Beam Halo, Cosmics)

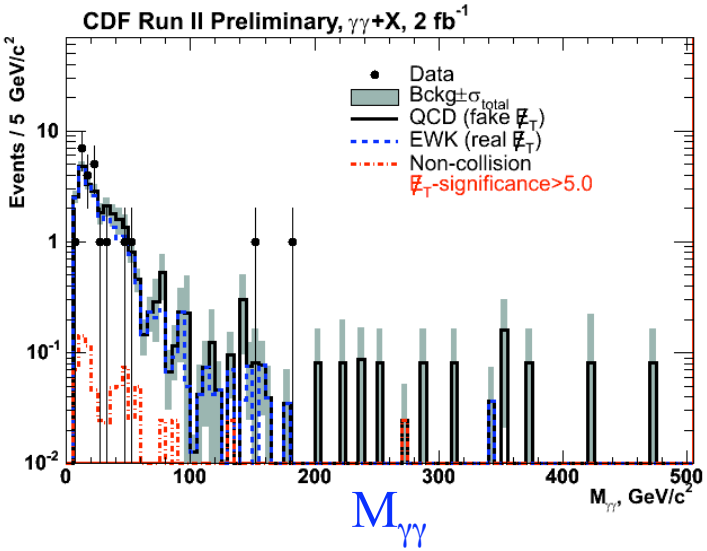
Results for γγ+MET



MET



$H_T = E_T(\gamma 1) + E_T(\gamma 2) + MET + \ldots$



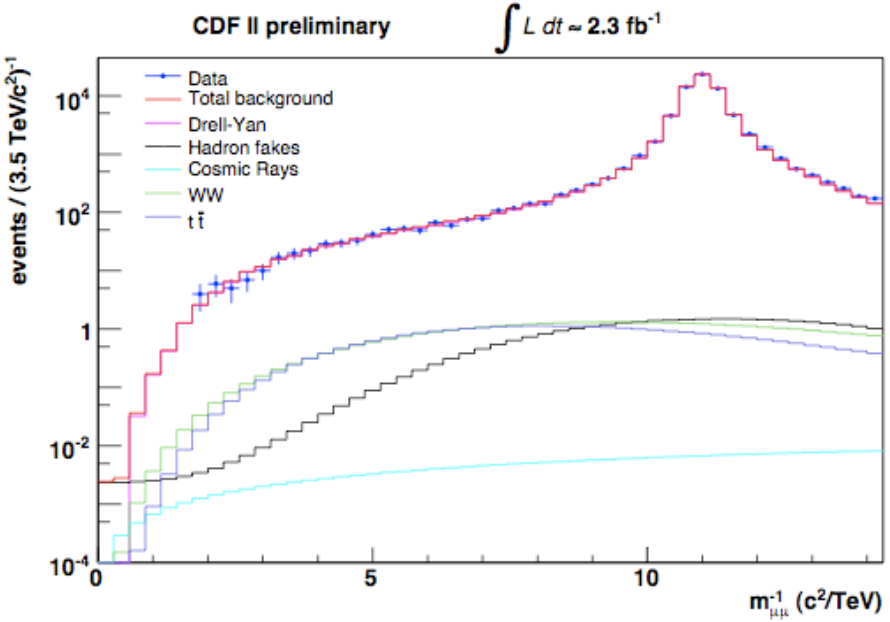
$M_{\gamma\gamma}$

	MetSig>3	MetSig>4	MetSig>5
EWK	47%	75%	84%
Background	67.9±7.5	35.8±3.0	27.3±2.3
Data	82	31	23

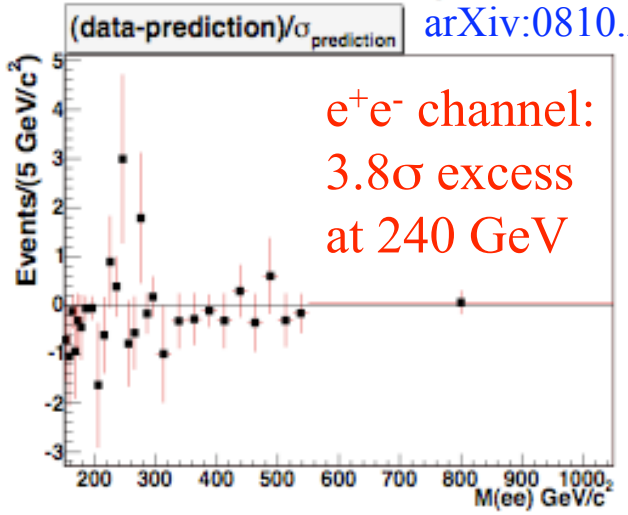
Also set limits on GMSB models (see Tevatron SUSY talk)

Search for High Mass μμ Resonances

- **Many models with di-lepton resonance**
  - Z' bosons in GUT theories (E_6)
  - RS graviton
- **Analysis with 2.3 fb^{-1} of data**
  - Two muons with P_T>30 GeV
  - Search region: $M_{\mu\mu}$>100 GeV/c^2
  - Dominant background is Drell-Yan
  - Follow up on e^+e^- search



CDF Run II Preliminary

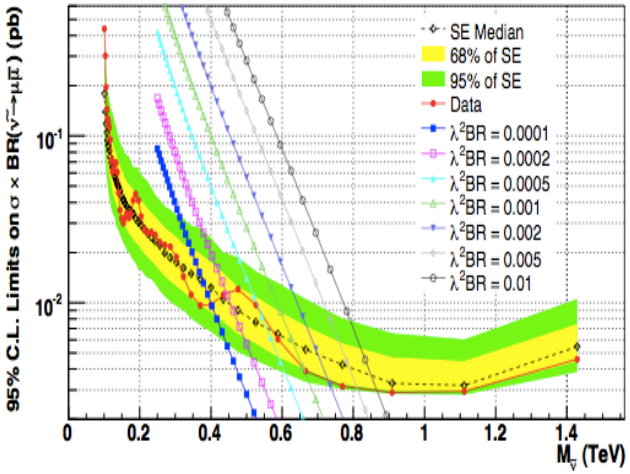


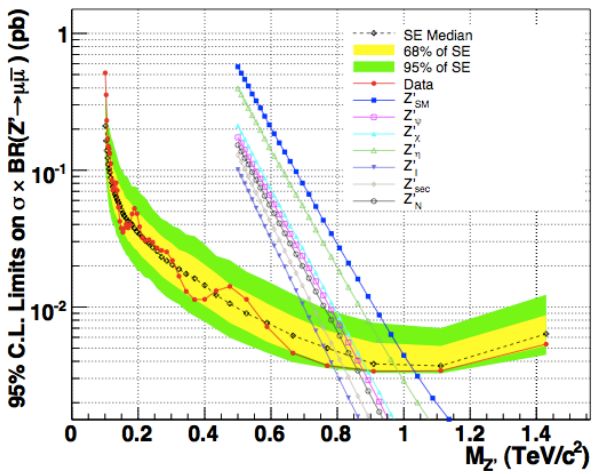
arXiv:0810.2059

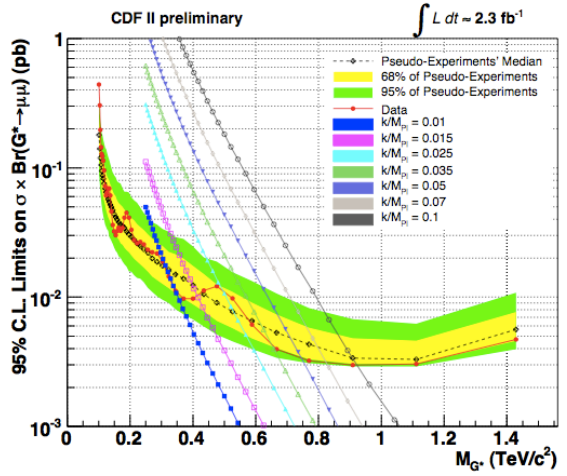
e^+e^- channel: 3.8σ excess at 240 GeV

- **Results**
  - Data agree with SM predictions
  - 95% CL Limits on
    - Spin-0 Sneutrino
    - Spin-1 Z' Models
    - Spin-2 RS graviton

Search for High Mass μμ Resonances







Spin-0
Sneutrino Mass Limits

CDF II preliminary $L = 2.3\ fb^{-1}$

$\lambda^2 \cdot BR$	Mass Limit, 95% CL (GeV/c^2)
0.01	866
0.005	810
0.002	731
0.001	662
0.0005	541
0.0002	441
0.0001	397

Spin-1
Z' Mass Limits

CDF II preliminary $L = 2.3\ fb^{-1}$

Model	Mass Limits, 95% CL (GeV/c^2)
Z' (SM)	1030
Z' (η)	904
Z' (χ)	892
Z' (ψ)	878
Z' (N)	861
Z' (sec)	821
Z' (ι)	789

Spin-2
Graviton Mass Limits

CDF II preliminary $L = 2.3\ fb^{-1}$

Graviton k/M_{Pl}	Mass Limit, 95% CL (GeV/c^2)
0.1	921
0.07	824
0.05	746
0.035	651
0.025	493
0.015	409
0.01	293

World best limits !! Submitted for publication in PRL, arXiv:0811.0053

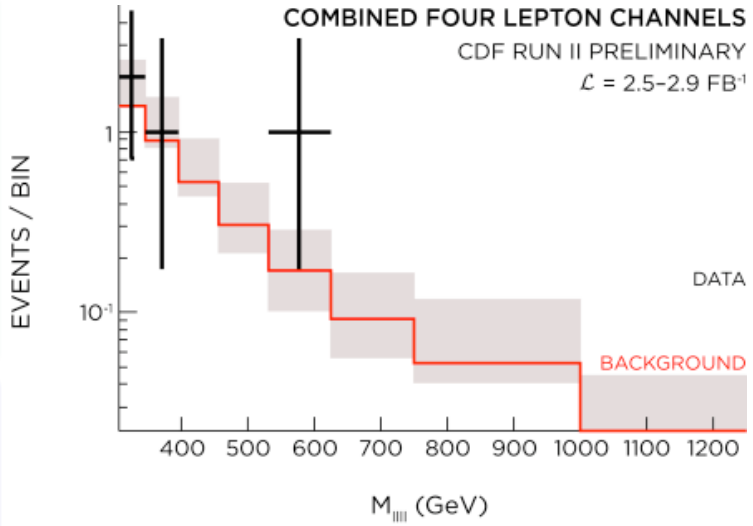
Search for X→ZZ

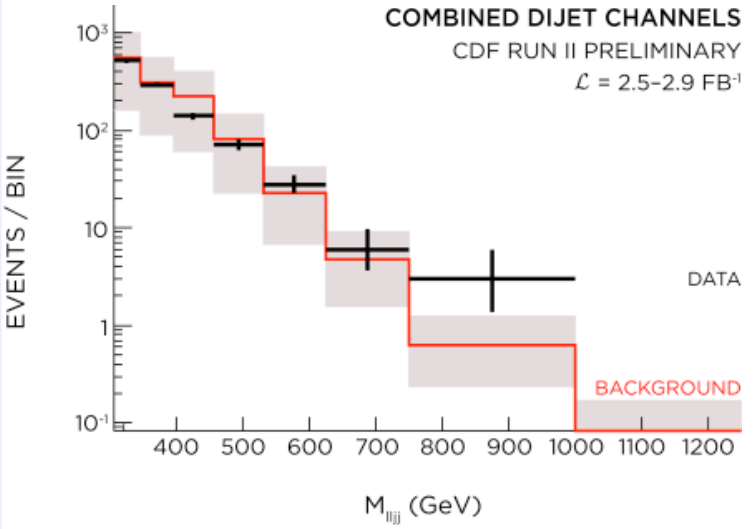
- X→ZZ signature
  - RS graviton
  - H→ZZ
    - M_H>180 GeV
  - H→ZZ→llll clean experimentally

- Analysis in 2.5-2.9 fb^{-1}
  - eeee, eeμμ, μμμμ : intermediate X masses
    - Signal: M_X>300 GeV and χ^2<50
    - Sideband: events with 2 or 3 fake leptons

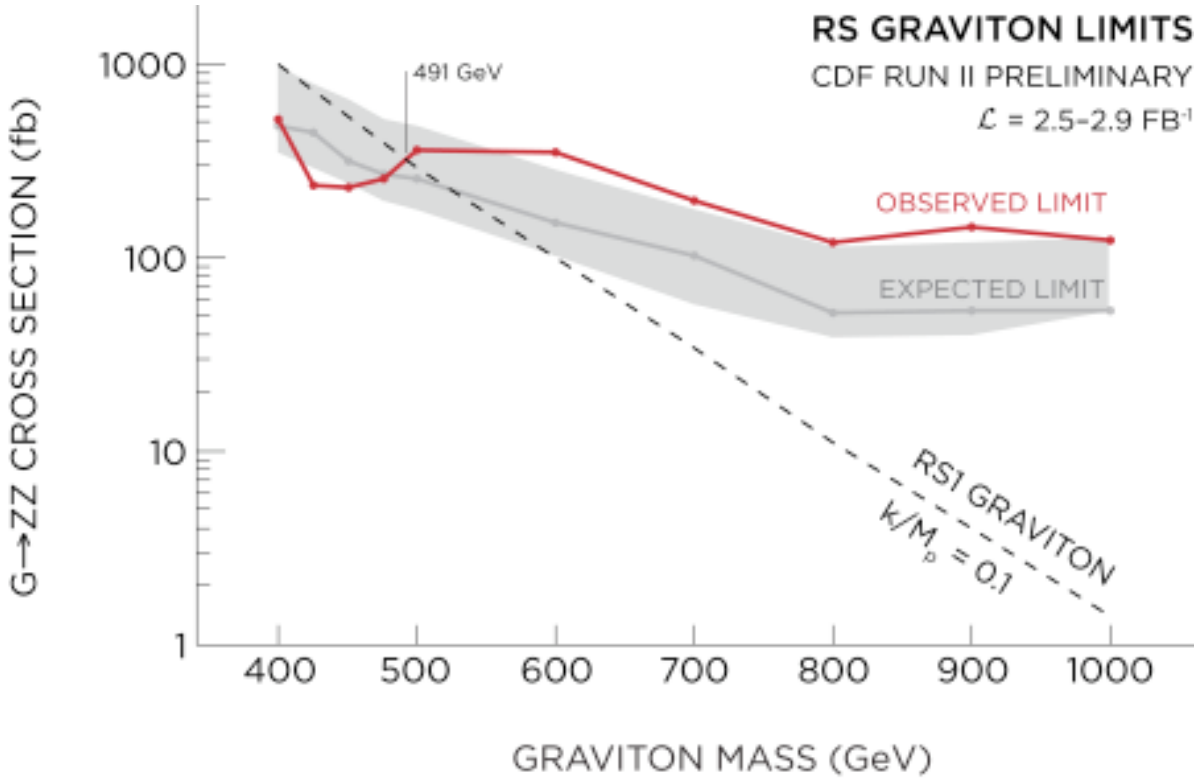
$$\chi^2_{ZZ} = \frac{\left(M_Z^{(1)} - 91.187\right)^2}{\sigma^2_{M^{(1)}} + \sigma^2_\Gamma} + \frac{\left(M_Z^{(2)} - 91.187\right)^2}{\sigma^2_{M^{(2)}} + \sigma^2_\Gamma}$$

  - eejj, μμjj: very high X masses
    - Signal: M_X>300 GeV and 65<M_{jj}<120 GeV
    - Sideband: 40<M_{jj}<65; 120<M_{jj}<200 GeV





Search for X→ZZ



- Limit on RS graviton for k/M_p=0.1: M>491 GeV

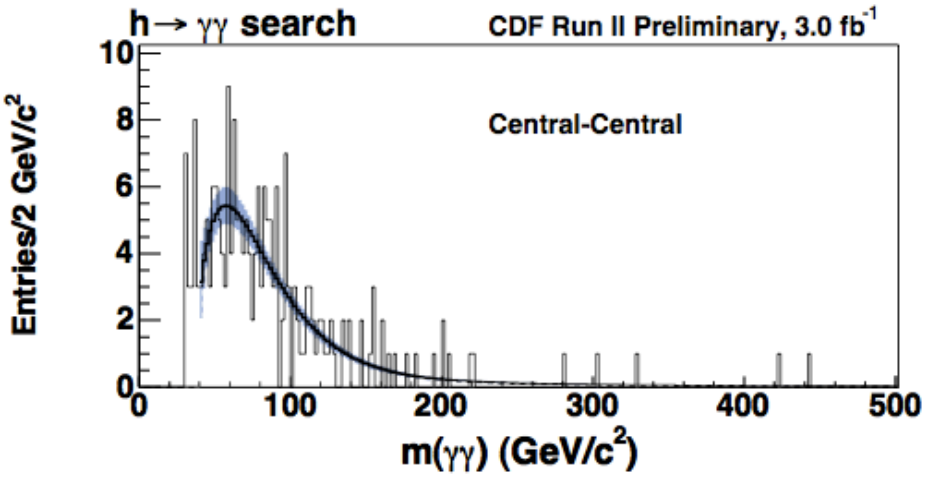
Search for Fermiophobic Higgs in H→γγ+X

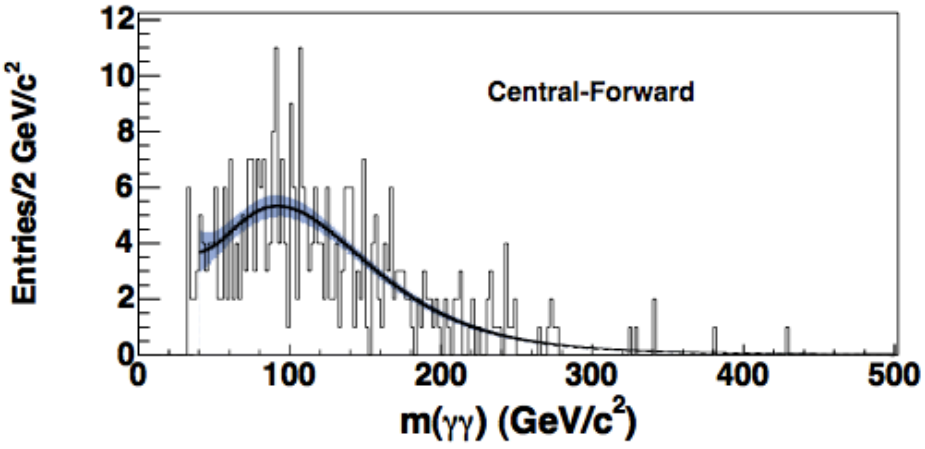
- Fermiophobic Higgs
  - Top-color models
  - LED theories

$$p\bar{p} \rightarrow VV \rightarrow h_f \rightarrow \gamma\gamma + X$$

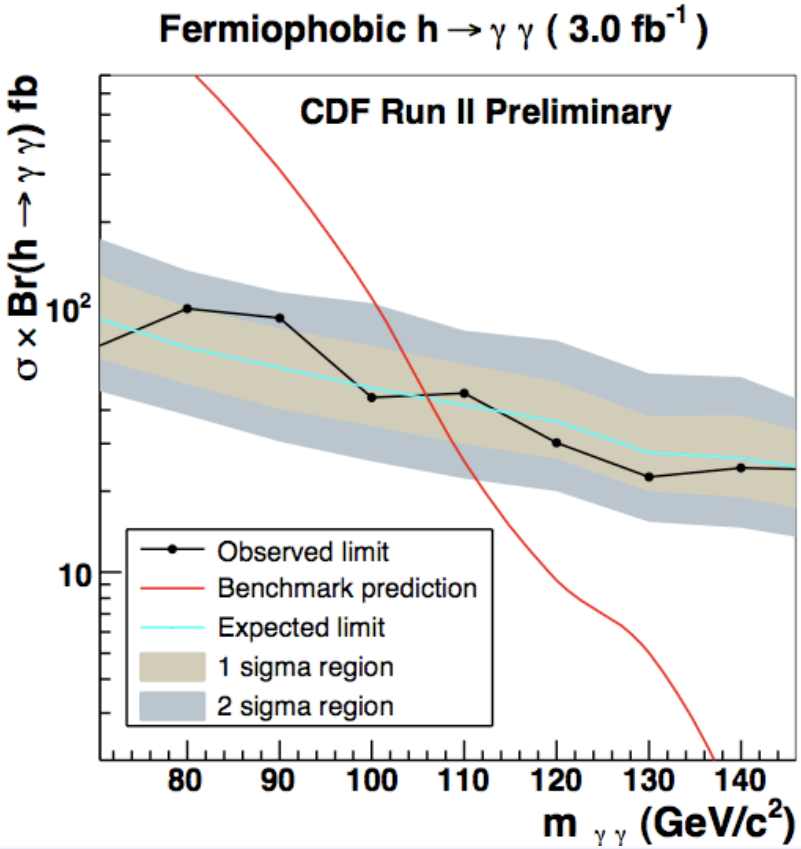
$$p\bar{p} \rightarrow h_f W^{\pm}(Z) \rightarrow \gamma\gamma + X$$

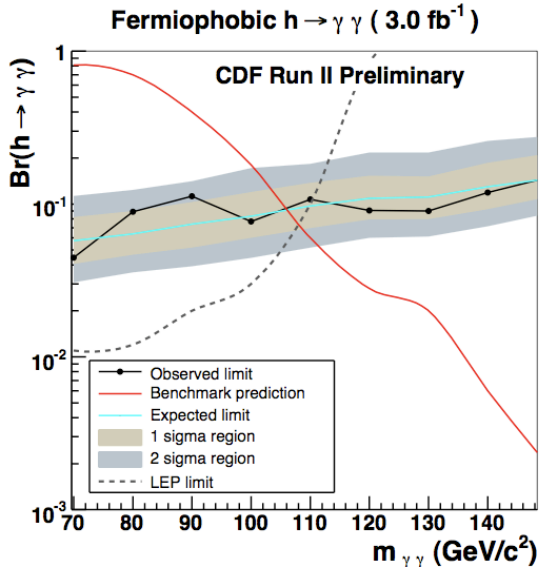
- Analysis Overview
  - Two isolated central-central or central-forward photons
  - Photon E_T>15 GeV
  - $M_{\gamma\gamma}$>30 GeV; $P_T(\gamma\gamma)$>75 GeV
  - Fit $M_{\gamma\gamma}$ with smooth function



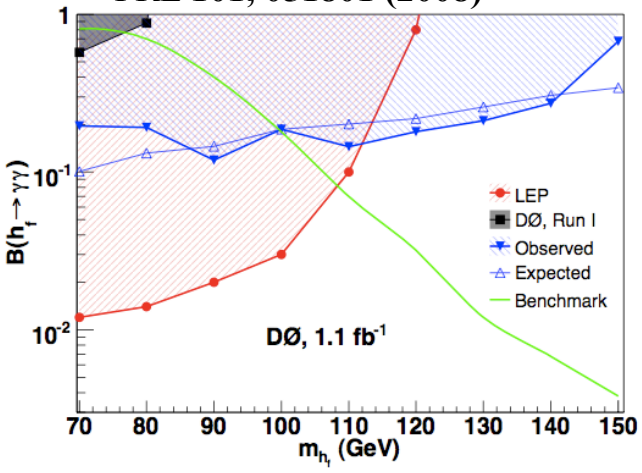


Search for Fermiophobic Higgs in H→γγ+X





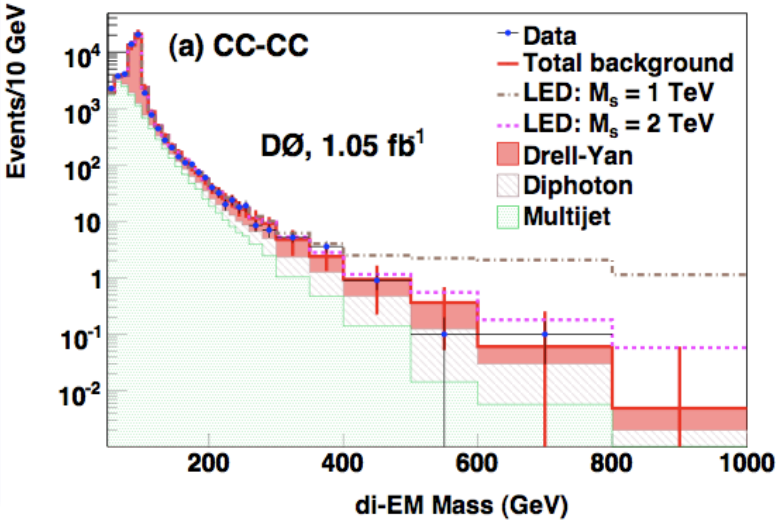
PRL **101, 051801 (2008)**

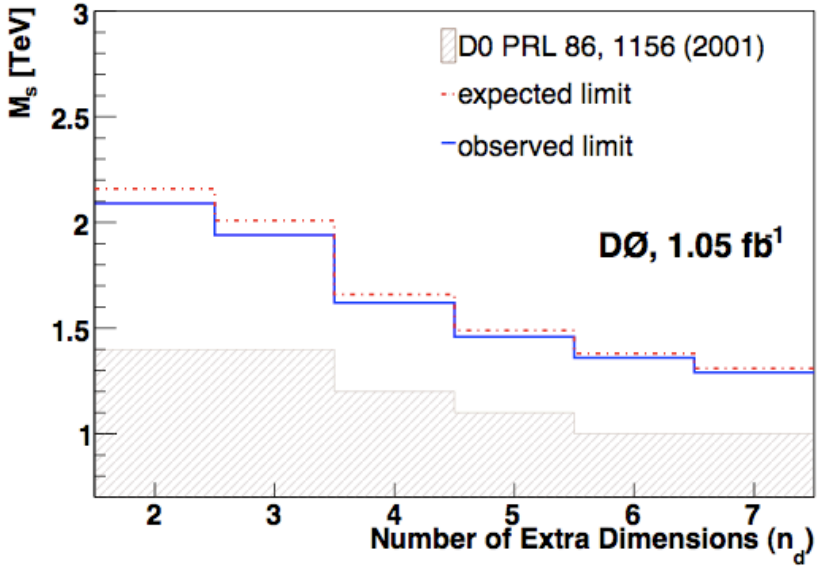


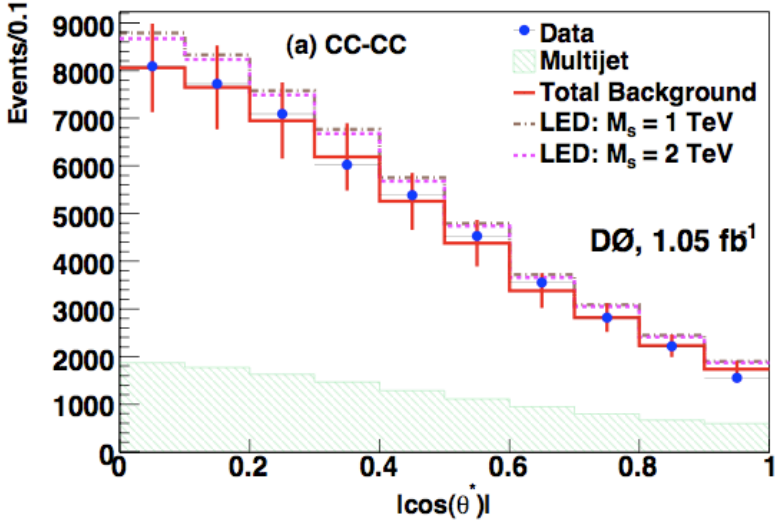
- CDF limit: M_{Hf}>106 GeV
- DØ limit: M_{Hf}>100 GeV

Search for LED in $\gamma\gamma$ & e^+e^-

- LED scenario of Arkani-Hamed, Dimopoulos, Dvali (ADD): $M_{Pl}^2 \sim R^n M_D^{n+2}$
  - Solution to hierarchy problem
  - Stable graviton
- Analysis in 1 fb^{-1} of data
  - $\gamma\gamma$ or e^+e^- events: $E_T(\gamma,e)>25$ GeV
  - Central-central & central-forward

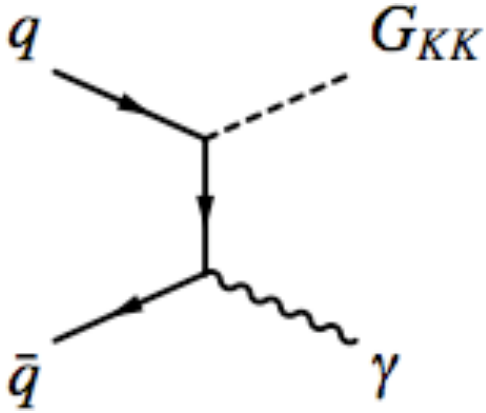




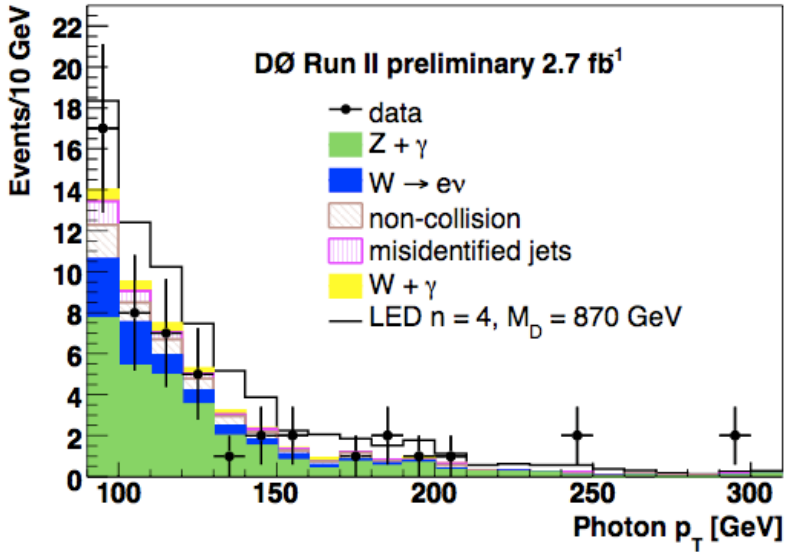


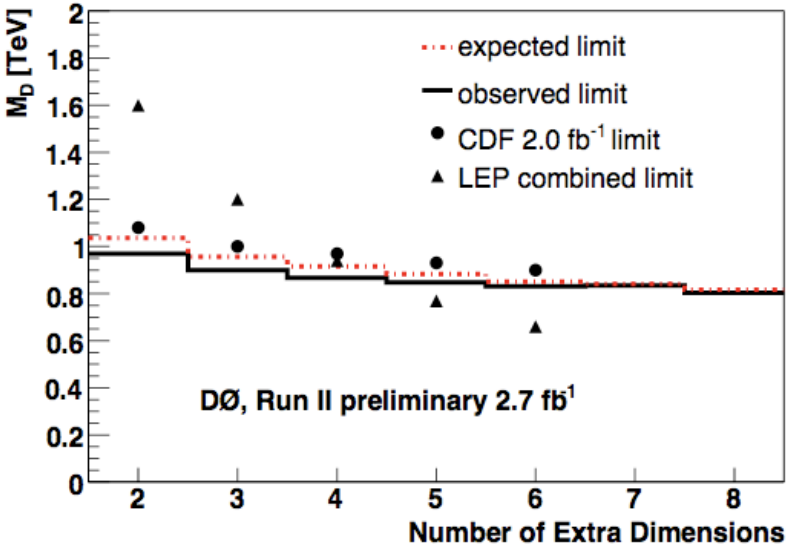
Search for LED in γ+MET

- **Analysis overview**
  - 2.7 fb^{-1}; $|\eta_\gamma|<1.1$; $E_T(\gamma)>90$ GeV; MET>70 GeV; no jet with $E_T>15$ GeV; no isolated trk with $P_T>6.5$ GeV; cosmics veto
  - EM shower pointing to reconstruct photon vertex ($\Delta z<10$ cm, $\sigma\sim2$ cm)



CDF: combination of γ+MET & jet+MET
PRL 101, 181602 (2008)

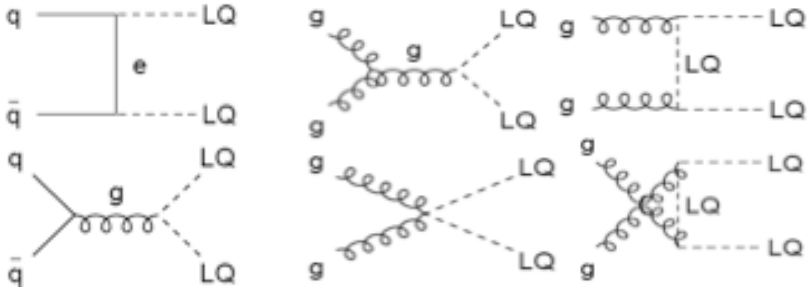




Direct searches for Leptoquarks

- Theories with LQ bosons
  - Grand unification SU(5) model
  - "Color" SU(4) Pati-Salam model
  - Technicolor
  - Compositeness

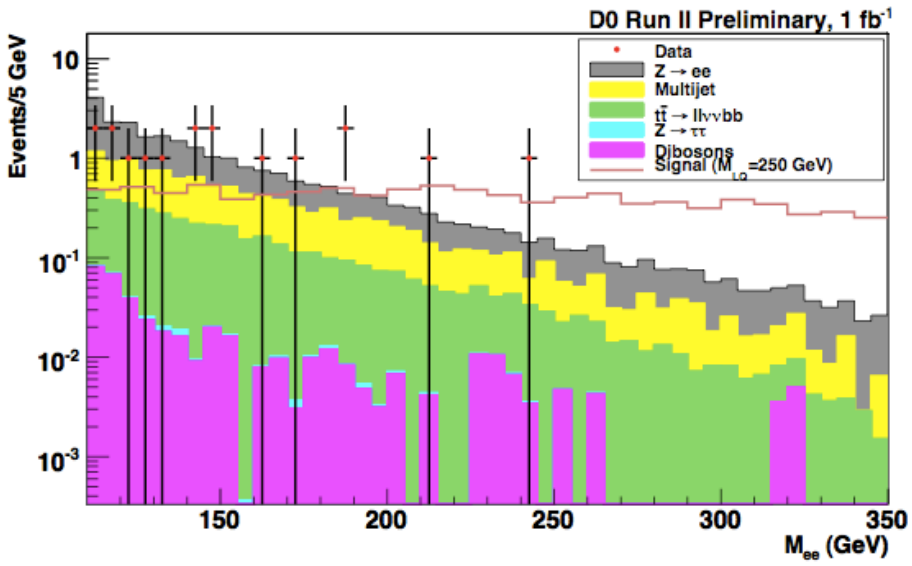
- Properties of LQ's
  - Spin-0,1
  - 3 generations
  - Q=1/3, 2/3 or 4/3
  - X-section for scalar LQ determined by M_{LQ}
  - X-section for vector LQ also depends on "anomalous" couplings k_G & λ_G

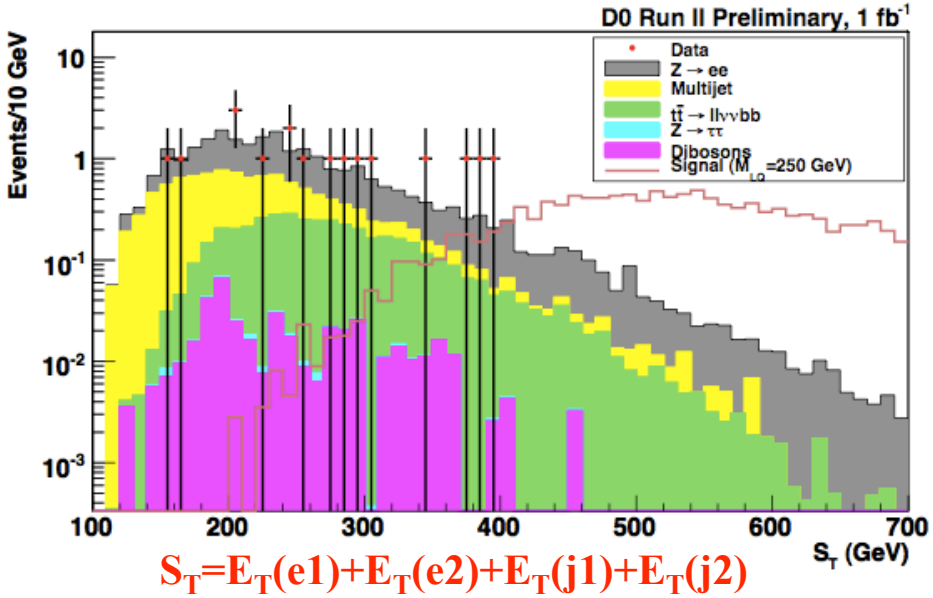


β=Br(LQ→lq)	1st Generation	2nd Generation	3rd Generation
β^2	$LQ+\overline{LQ}\to e^+e^-q\bar{q}$	$LQ+\overline{LQ}\to \mu^+\mu^-q\bar{q}$	$LQ+\overline{LQ}\to \tau^+\tau^-q\bar{q}$
$2\beta(1-\beta)$	$LQ+\overline{LQ}\to e\nu q_iq_j$	$LQ+\overline{LQ}\to \mu\nu q_iq_j$	$LQ+\overline{LQ}\to \tau\nu q_iq_j$
$(1-\beta)^2$	$LQ+\overline{LQ}\to \nu_e\bar{\nu}_eq\bar{q}$	$LQ+\overline{LQ}\to \nu_\mu\bar{\nu}_\mu q\bar{q}$	$LQ+\overline{LQ}\to \nu_\tau\bar{\nu}_\tau q\bar{q}$

Search for 1st Generation LQ

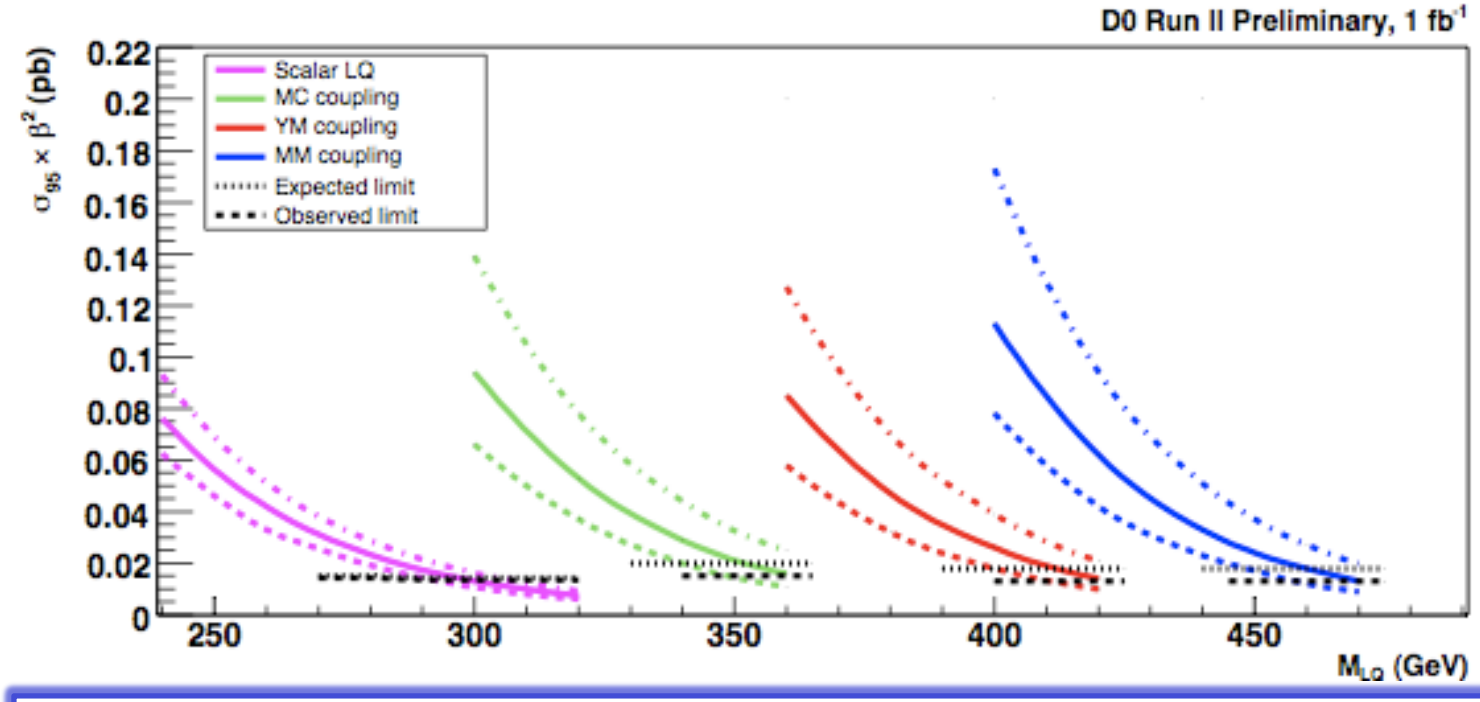
- Analysis with 1 fb^{-1} of data
  - 2 isolated electrons: E_T>25 GeV; $|\eta|$<1.1 or 1.5<$|\eta|$<2.5; M_{ee}>110 GeV
  - 2 jets: E_T>25 GeV; $|\eta|$<2.5; ΔR_{ej}>0.5
- Backgrounds
  - Z+jets; QCD multi-jet; tt; di-boson
    - Backgrounds normalized to data in two regions (matrix method)
      - ✓ 50 GeV <M_{ee}<80 GeV & 80 GeV <M_{ee}<102 GeV





$S_T=E_T(e1)+E_T(e2)+E_T(j1)+E_T(j2)$

Search for 1st Generation LQ



Vector LQ

MC coupling
$k_G=1$; $\lambda_G=0$

YM coupling
$k_G=0$; $\lambda_G=0$

MM coupling
$k_G=-1$; $\lambda_G=-1$

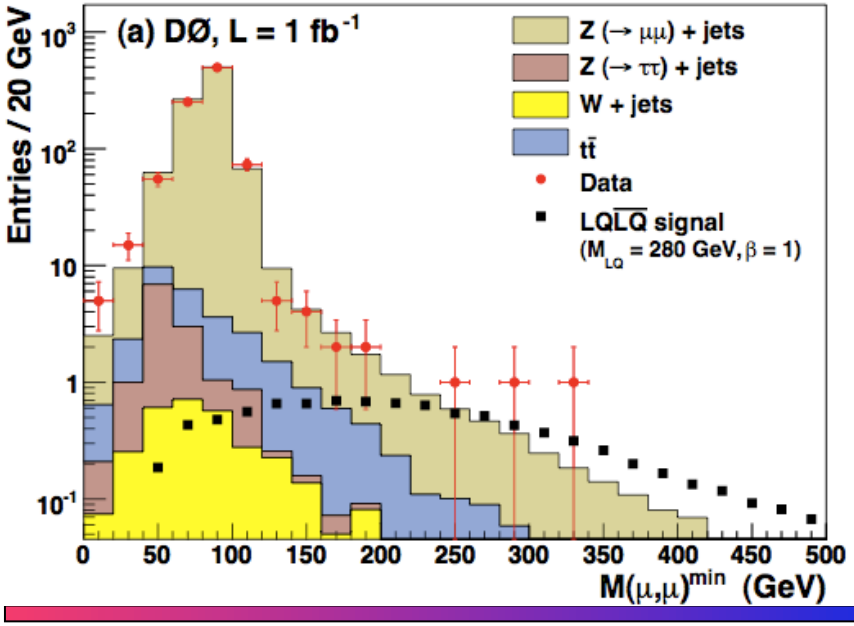
- Optimal cuts: M_{ee}>110 GeV & S_T>400 GeV
- 95% CL limit on $\sigma \times \beta^2$

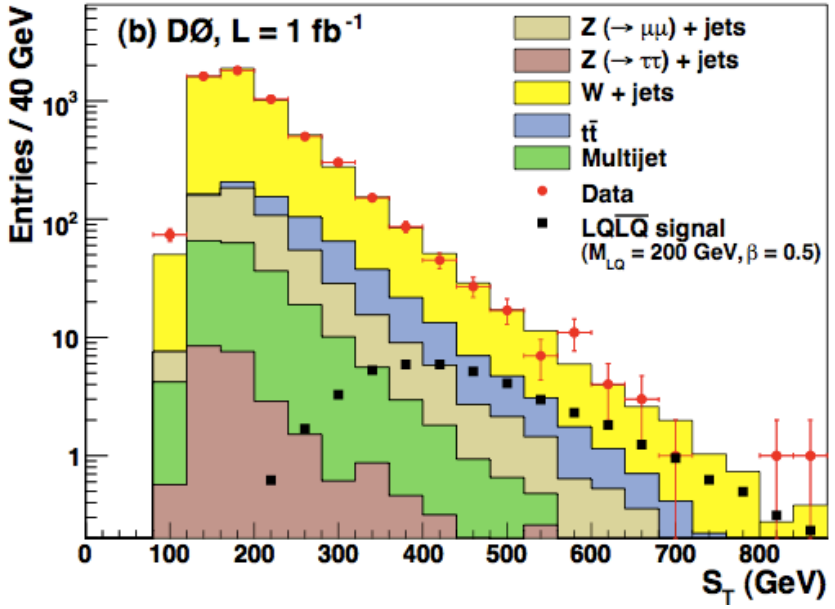
For β=1	Scalar	Vector MC	Vector YM	Vector MM
M_{LQ}	>292 GeV	>350 GeV	>410 GeV	>458 GeV

Search for 2nd Generation Scalar LQ

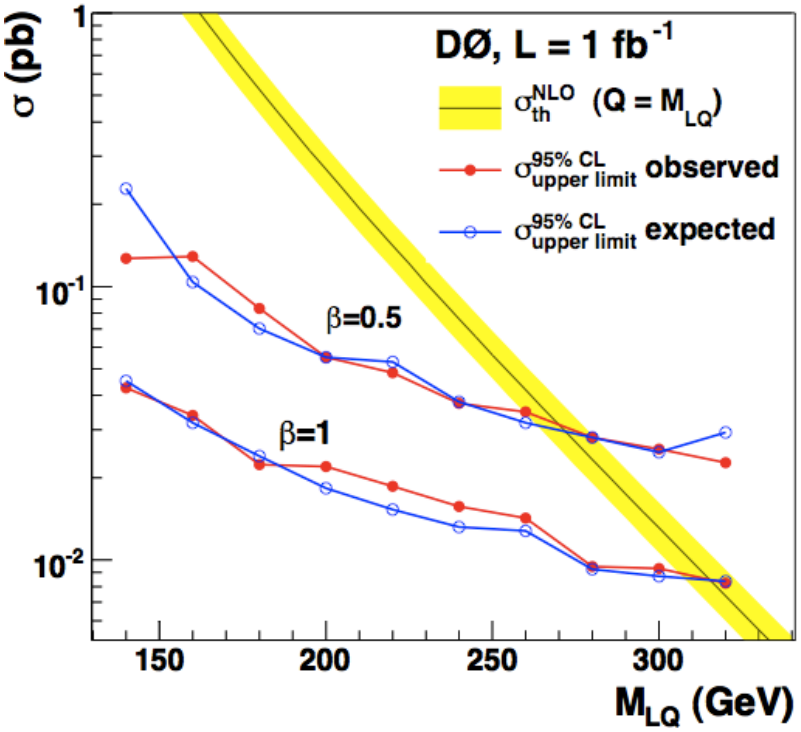
- Analysis with 1 fb^{-1} of data: μqμq (μμjj) & μqνq (μjj+MET)
  - 2 jets: E_T>25 GeV; |η|<2.5;

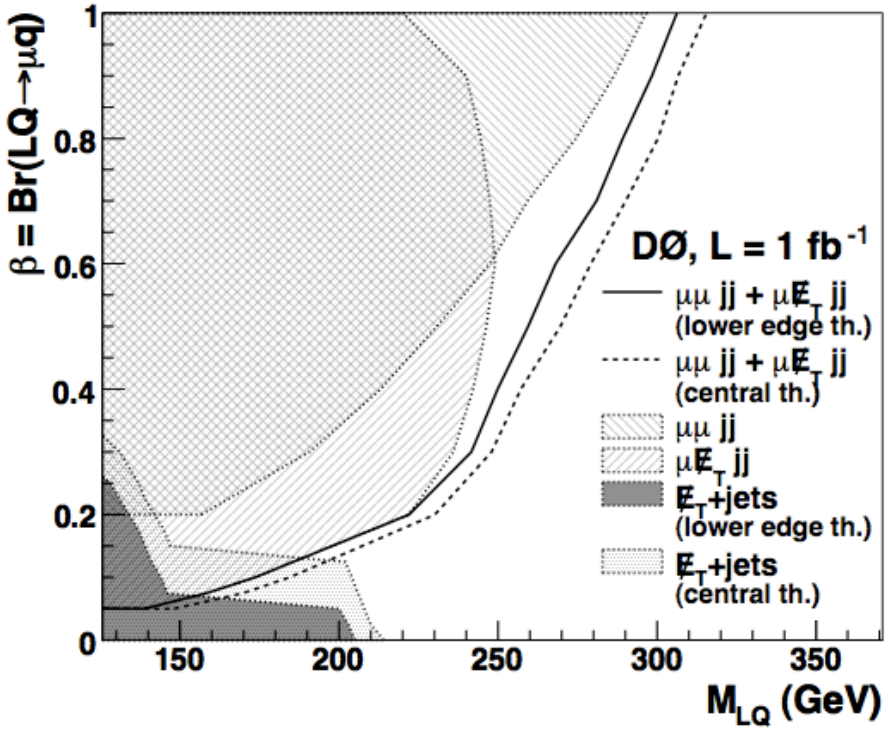
or
  - 2 muons: P_T>20 GeV; |η|<2.0; $M_{\mu\mu}$>50 GeV
  - 1 isolated muon: P_T>20 GeV; |η|<2.0; MET>30 GeV; M_T(μ,MET)>50 GeV
  - Multivariate classifier (kNN)
    - $M(\mu\mu)^{min}$, S_T, 4 M(μj)
    - M_T(μ,MET), S_T, 2 M(μj), 2 M_T(j,MET)





Search for 2nd Generation Scalar LQ



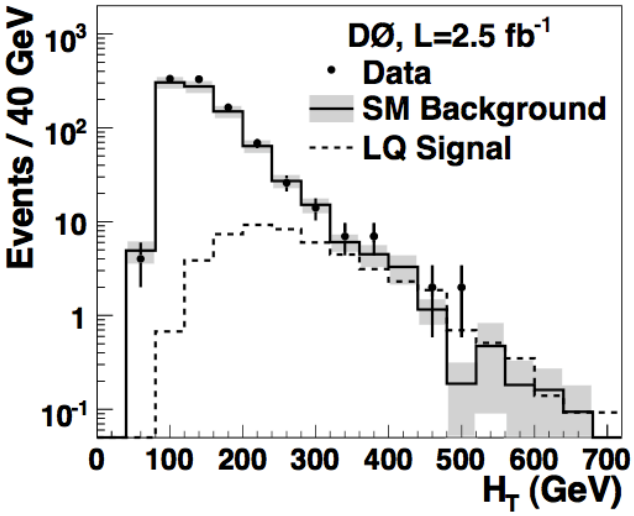


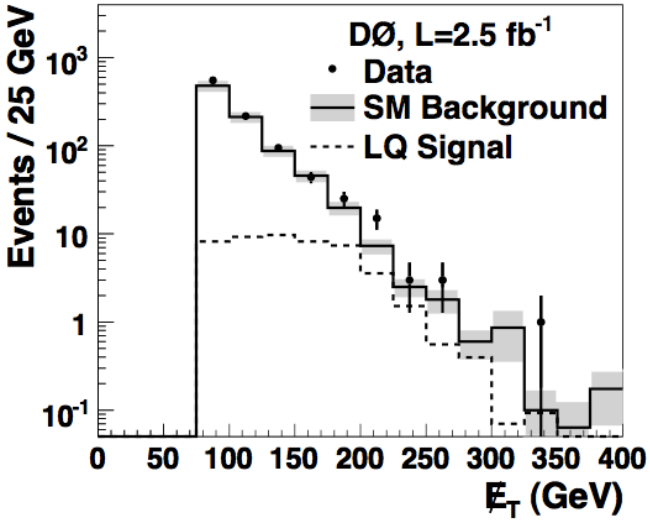
For β=Br(LQ→lq)	β=1	β=0.5	β=0.1
M_{LQ}	>316 GeV	>270 GeV	>185 GeV

- 95% CL limits on x-section and β
- Published in Phys. Lett. B 671, 224 (2009)

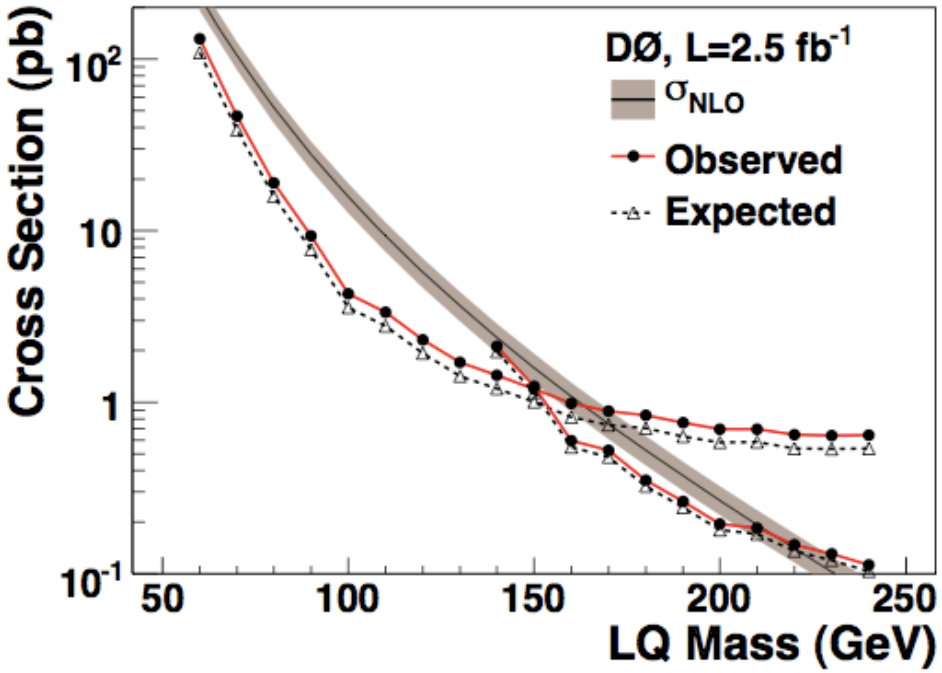
Search for Scalar LQ & T-odd Quakrs

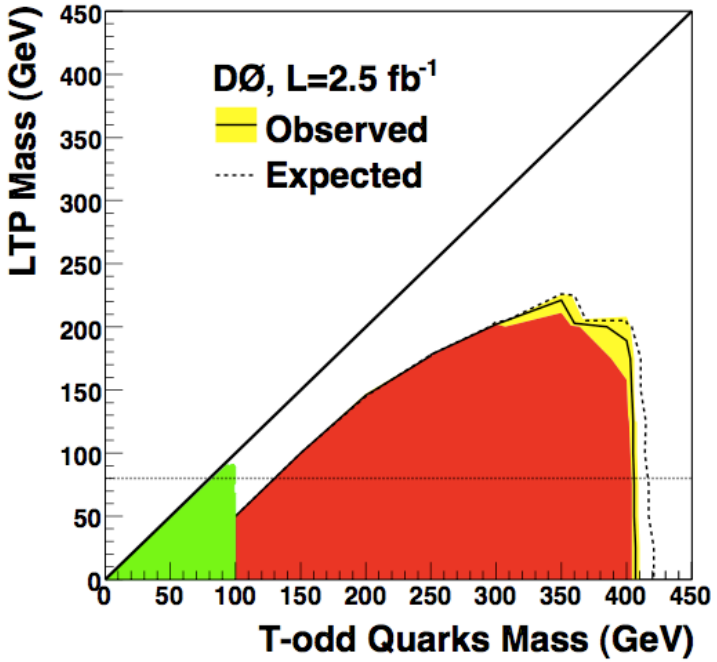
- Models
  - Scalar LQ (any generation) with β=0
  - Little Higgs (LH) model
    - T-odd LH partners of T-even SM particles
    - TQ→q$\bar{A}_H$ with Br=100%, where $\bar{A}_H$ is stable weakly interacting particle
- Analysis with 2.5 fb^{-1} of data
  - 2 acoplanar jets
    - E_T>35 GeV; $|\eta|$<0.8; $\Delta\varphi_{12}$<165°
  - MET>75 GeV; away from jets
  - Electron, muon, isolated track veto
  - Backgrounds
    - Z+jj→νν+jj
    - W+jj (lost lepton)
    - Di-Boson
    - tt





Search for Scalar LQ & T-odd Quarks



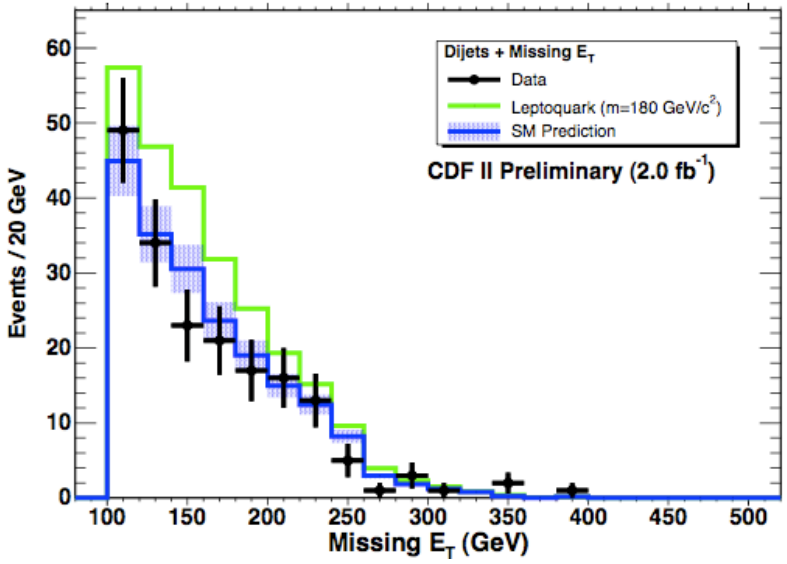


- 95% CL limit: M_{LQ}>205 GeV
  - MET>75 GeV; H_T>150 GeV (low mass M_{LQ}=140 GeV)
  - MET>125 GeV; H_T>300 GeV (large mass M_{LQ}=300 GeV)
- T-odd quark excluded up to M_{TQ}=404 GeV
  - MET,H_T optimization to scan (M_{TQ},$M_{\bar{A}}$)-plane
- Published in Phys. Lett. B 668, 357 (2008)

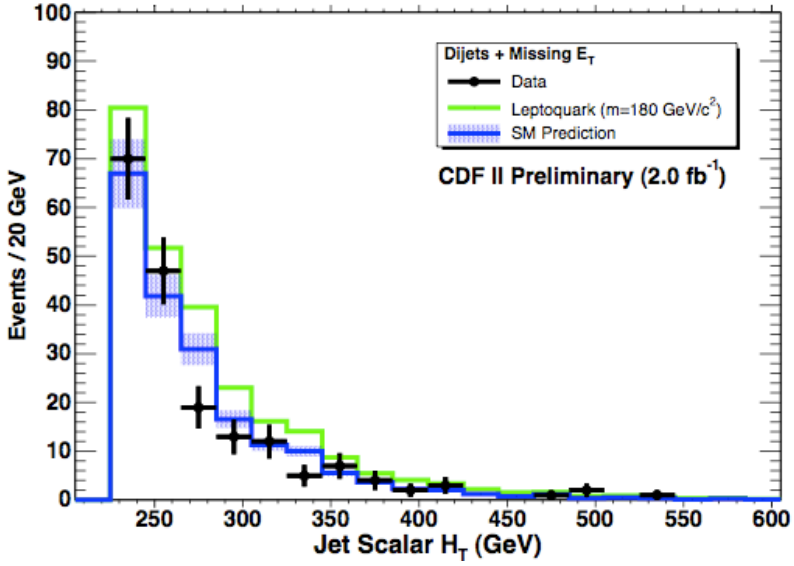
Search for Scalar LQ in jj+MET

- Performed signature based search in 2 fb^{-1};
  - set limits on LQ in the absence of excess
- Data driven background estimates

Missing E_T for High Kinematic Region



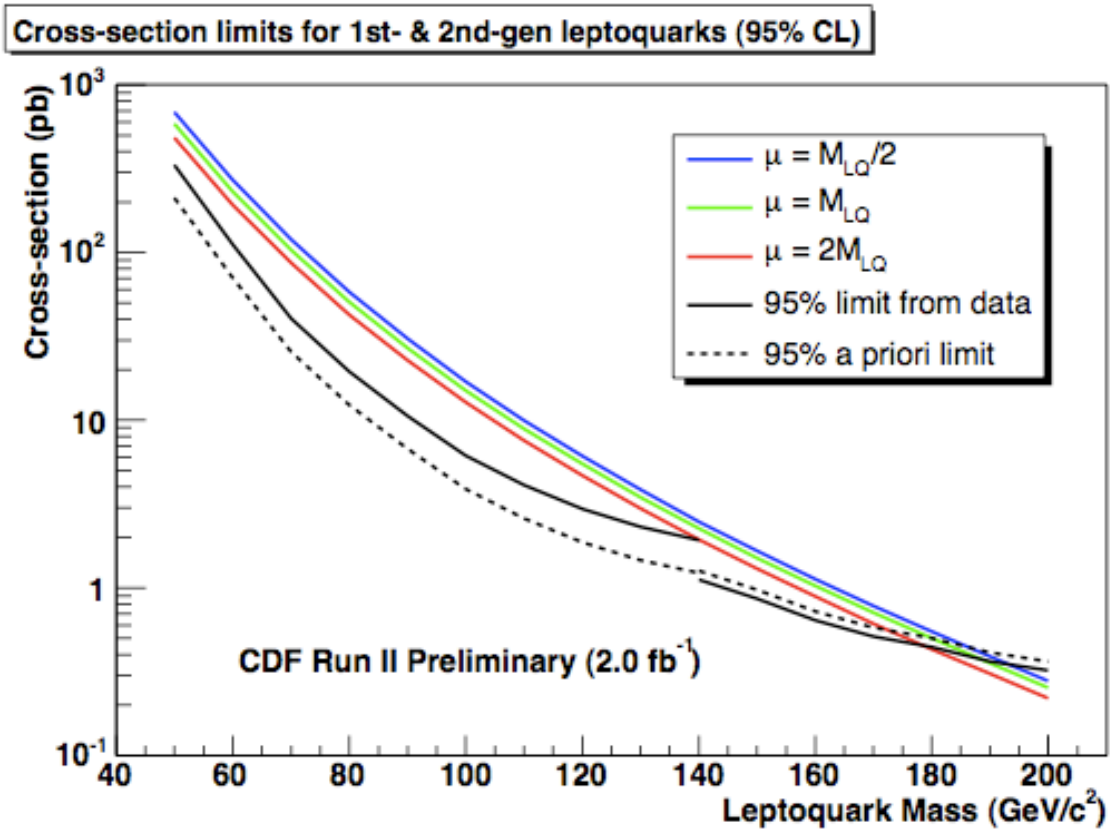
H_T for High Kinematic Region



	H_T>125 GeV; MET>80 GeV	H_T>225 GeV; MET>100 GeV
Total	2312 ± 140	196 ± 29
Observed	2506	186

Search for Scalar LQ in jj+MET

- Scalar LQ with M_{LQ}<180 GeV is excluded at 95% CL



Summary

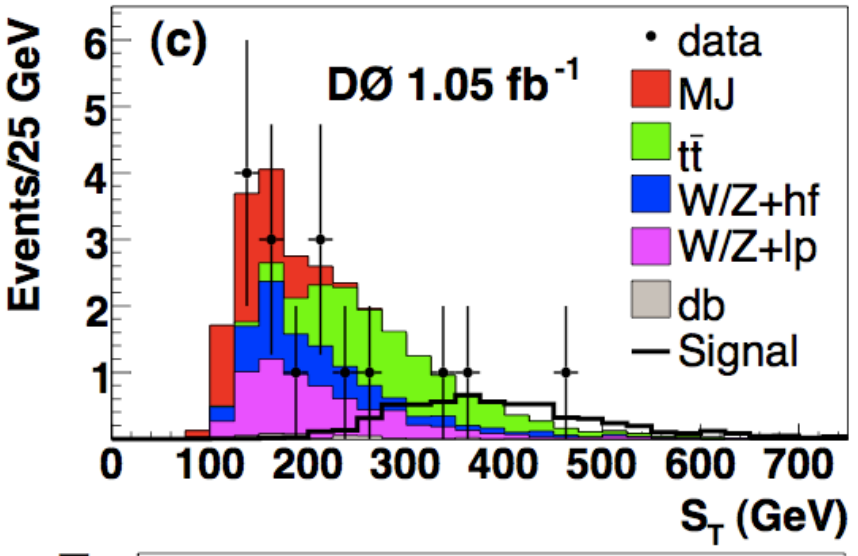
- CDF and DØ performed many searches for signatures of New Physics beyond the Standard Model
  - SM still prevails
  - Both CDF & DØ continue exploring new signatures and analysis techniques
- New Massive Resonances: approaching TeV masses
  - RS gravitons and Z'(SM) excluded up to 921 GeV and 1030 GeV
  - Earlier observed by CDF 3.8σ excess at $M(e^+e^-)\sim240$ GeV/c^2 not confirmed in $\mu\mu$-channel
- Leptoquarks
  - M_{LQ}> 292 GeV (1st gen), 316 GeV (2nd gen), 210 GeV (3rd gen)
    - Scalar LQ, β=1
- With 5 fb^{-1} on tape and 2-5 fb^{-1} still to come, expect more exciting results

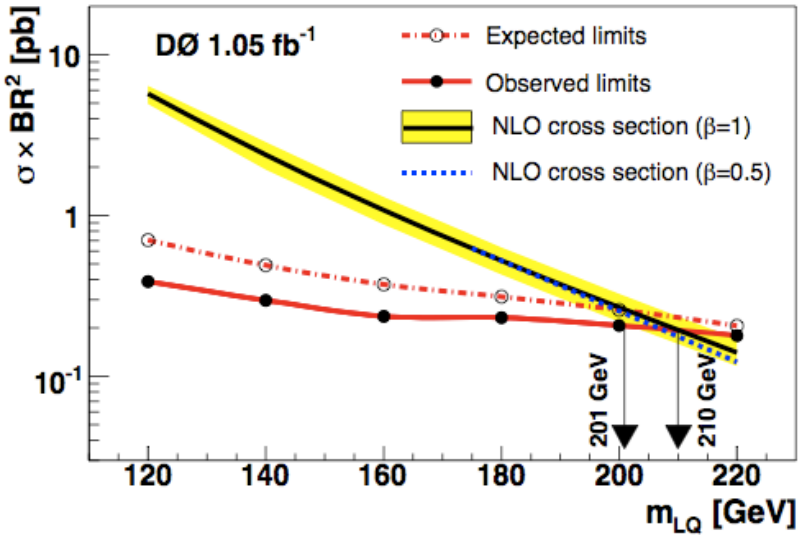
Backup Slides

Search for 3rd Generation LQ

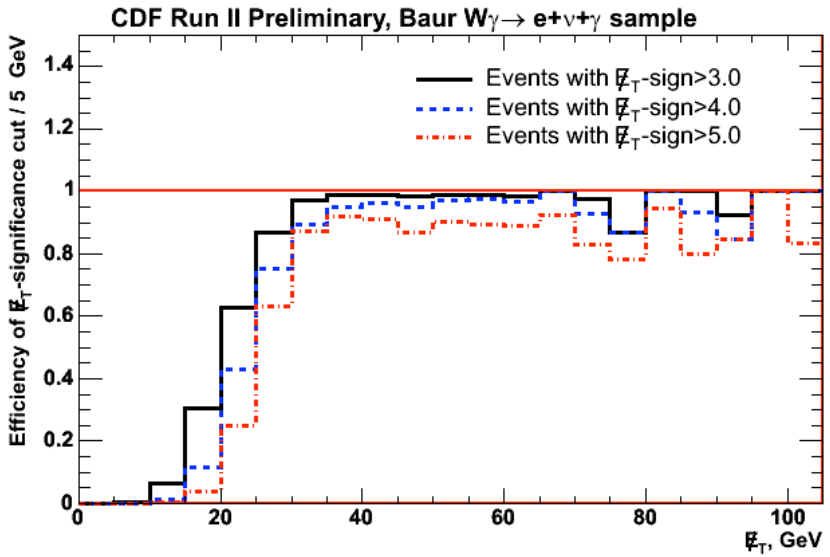
- Published in PRL 101, 241802 (2008),
- Analysis overview
  - 1.1 fb^{-1}; tau: vis. P_T>15 or 20 GeV;
  - 2 jets: E_T>25,20 GeV; $|\eta|$<2.6
  - Ele veto, M_T(MET,μ)<50 GeV
  - Two sub-samples: 1 or 2 b-tags

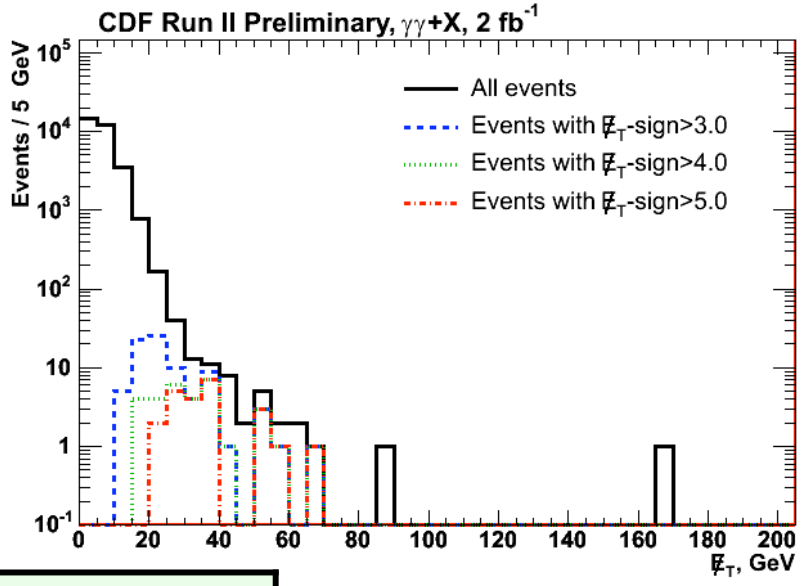
$$p\bar{p} \rightarrow \bar{L}\bar{Q}_3 L Q_3 \rightarrow b\tau b\tau$$
$$\tau \rightarrow \mu\bar{\nu}$$
$$\tau \rightarrow hadrons$$





γγ+MET: Results





Efficiency for Wγ→eνγ	MetSig>3.0	MetSig>4.0	MetSig>5.0
	84%	74%	67%

- Total number of γγ events: 31,116

	MetSig>3.0	MetSig>4.0	MetSig>5.0
EWK	47%	75%	84%
Background	67.9±7.5	35.8±3.0	27.3±2.3
Data	82	31	23