

TEVATRON: THE LAST ROUND

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Looking to New Physics Signals
from Tevatron to LHC

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*BSM at the LHC era Workshop at KIAS,
Seoul, Korea, March 10, 2011*

Beyond Standard Model Physics at Tevatron

Lot of new and interesting analyses were achieved in 2010 by CDF & D0, testing new ideas, new models and looking for all sorts of signatures.

- W'
- Extra Dim: RS Graviton in $\gamma\gamma$ +MET or Gravitons in $\gamma\gamma$ inclusive
- Vector like quarks
- Quirks (*bizareries*)
- Search for Dark Matter
- 4th generation
- Hidden Valleys
- Long-Lived Particles

Champs and others...

And many more but no time for reviewing them all!

Including some updates from the presentation by Simona Rolli

at La Thuile Conference Feb 28-March 5

W'

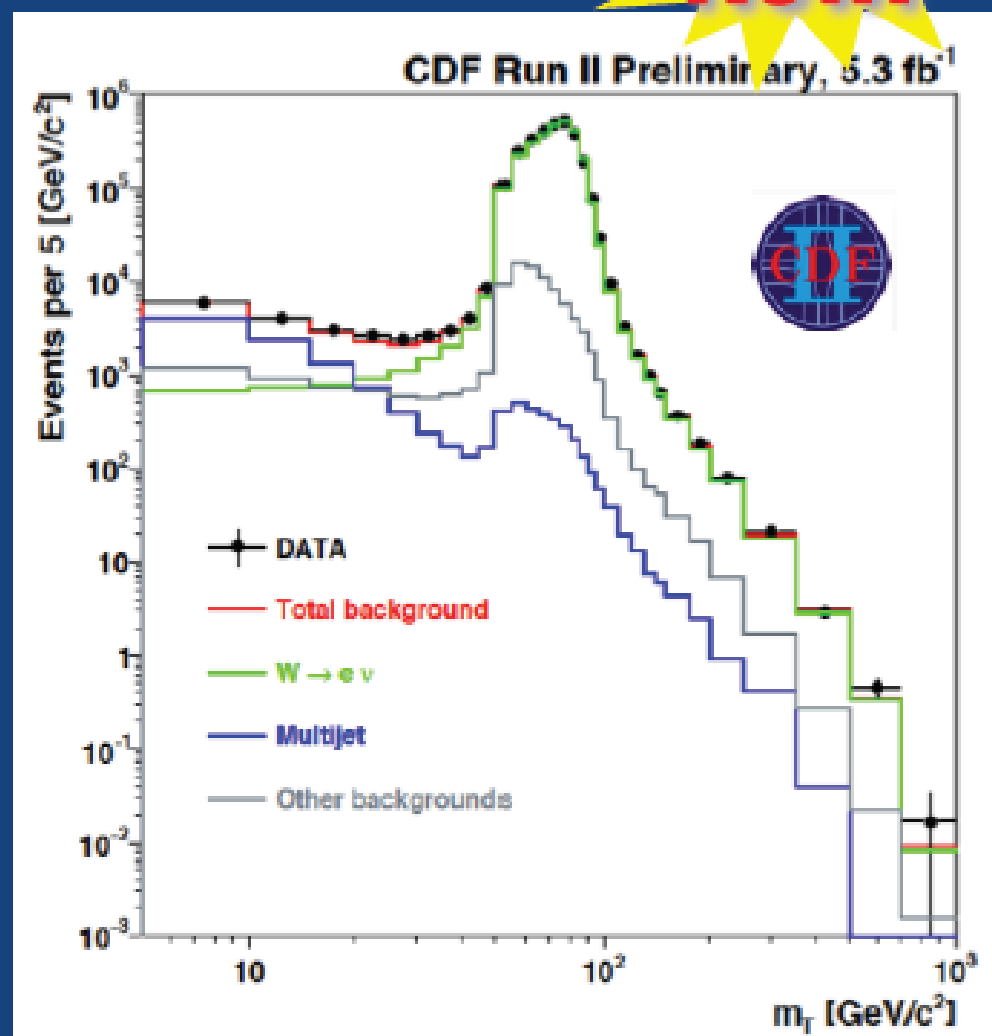
New!

Search for heavier versions of the EW gauge boson: simple final state with lepton and neutrino

Pushing the envelope by going up to energies far from benchmarks!

Understanding of the SM tails very important.

No excess observed -
95% CL limit $m_{W'} > 1.1\text{TeV}$



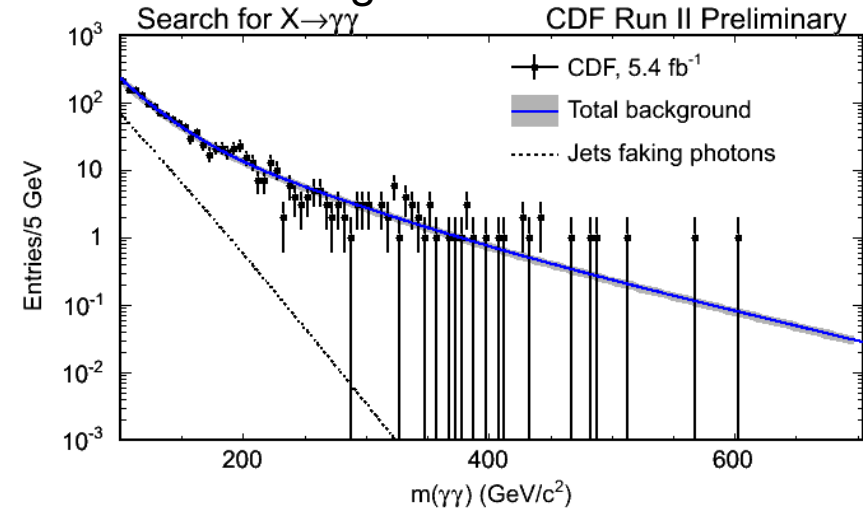
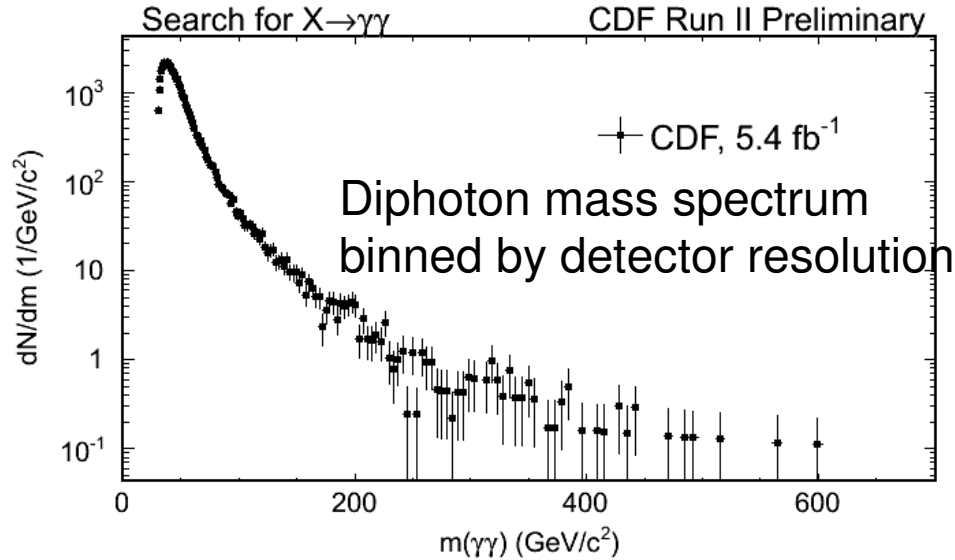
Phys.Rev.D83:031102,2011



RS Graviton in diphoton inclusive

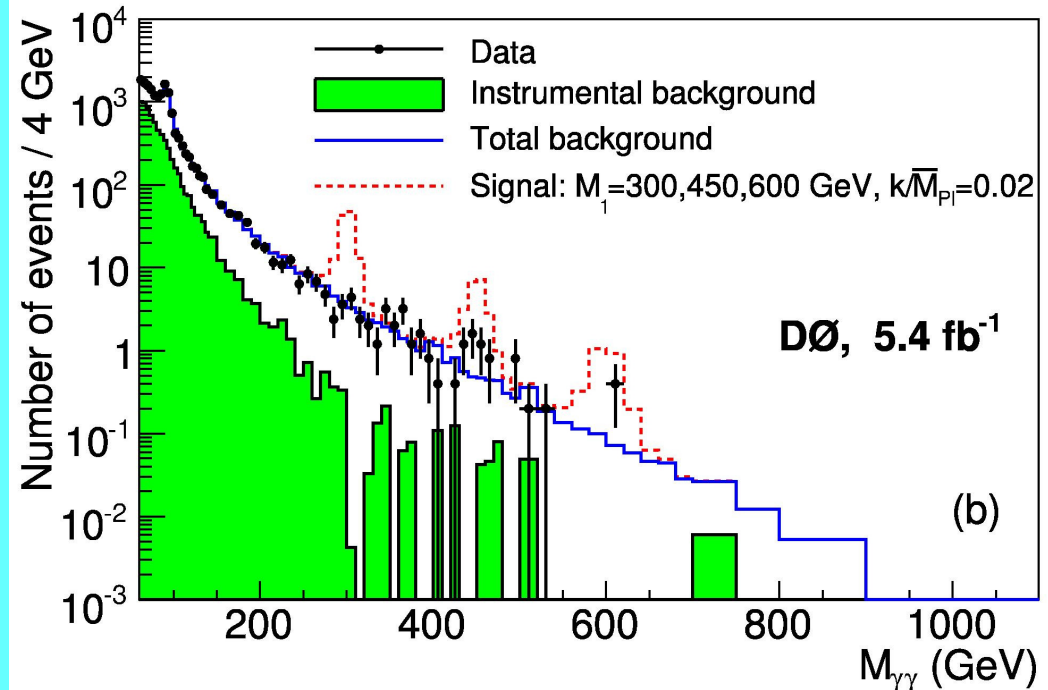


$\gamma\gamma$ mass spectrum with background fit overlaid



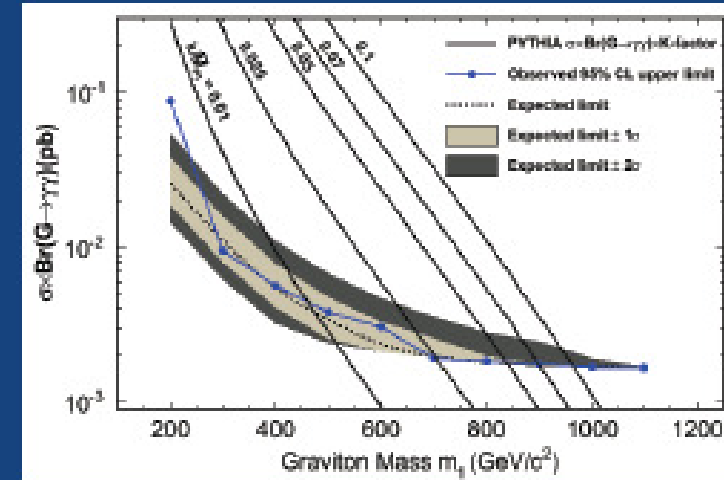
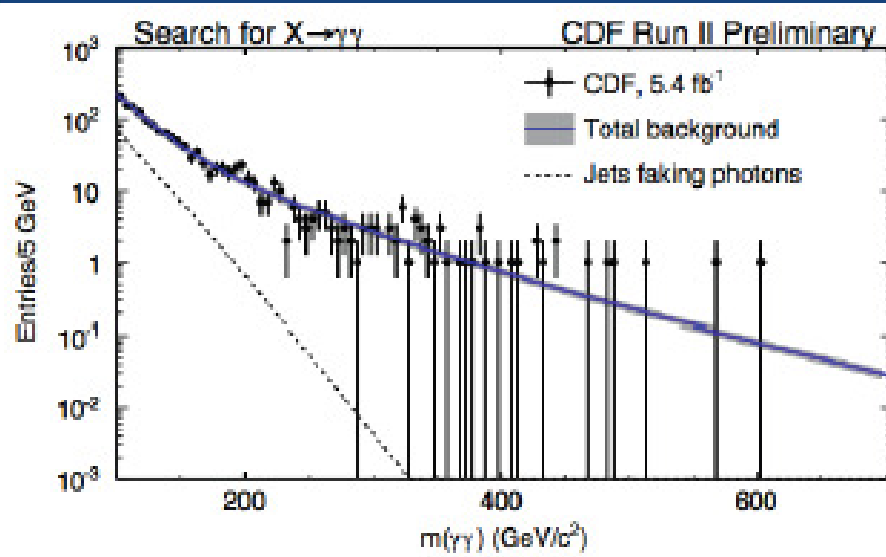
CDF: Look for 2 central well identified photon events with: $E_t^{\text{em}}(\gamma) > 15 \text{ GeV}$ and $\text{Inv Mass } (\gamma\gamma) > 30 \text{ GeV}/c^2$

Use the sample of $Z^0 \rightarrow e^+ e^-$ as calibration sample because no pure $\gamma\gamma$ sample



Diphotons

CDF: 5.4 fb^{-1}



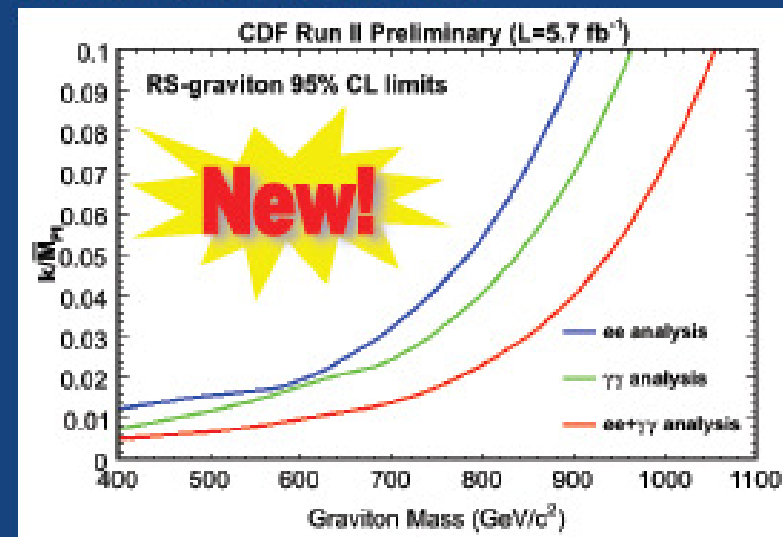
$M(\text{RSG}) > 963 \text{ GeV}/c^2$ $k/M_{\text{PL}} = 0.1$
 Best limit in this channel!

Phys.Rev.D83:011102,2011

Combined with dielectron channel gives the most stringent limits to date

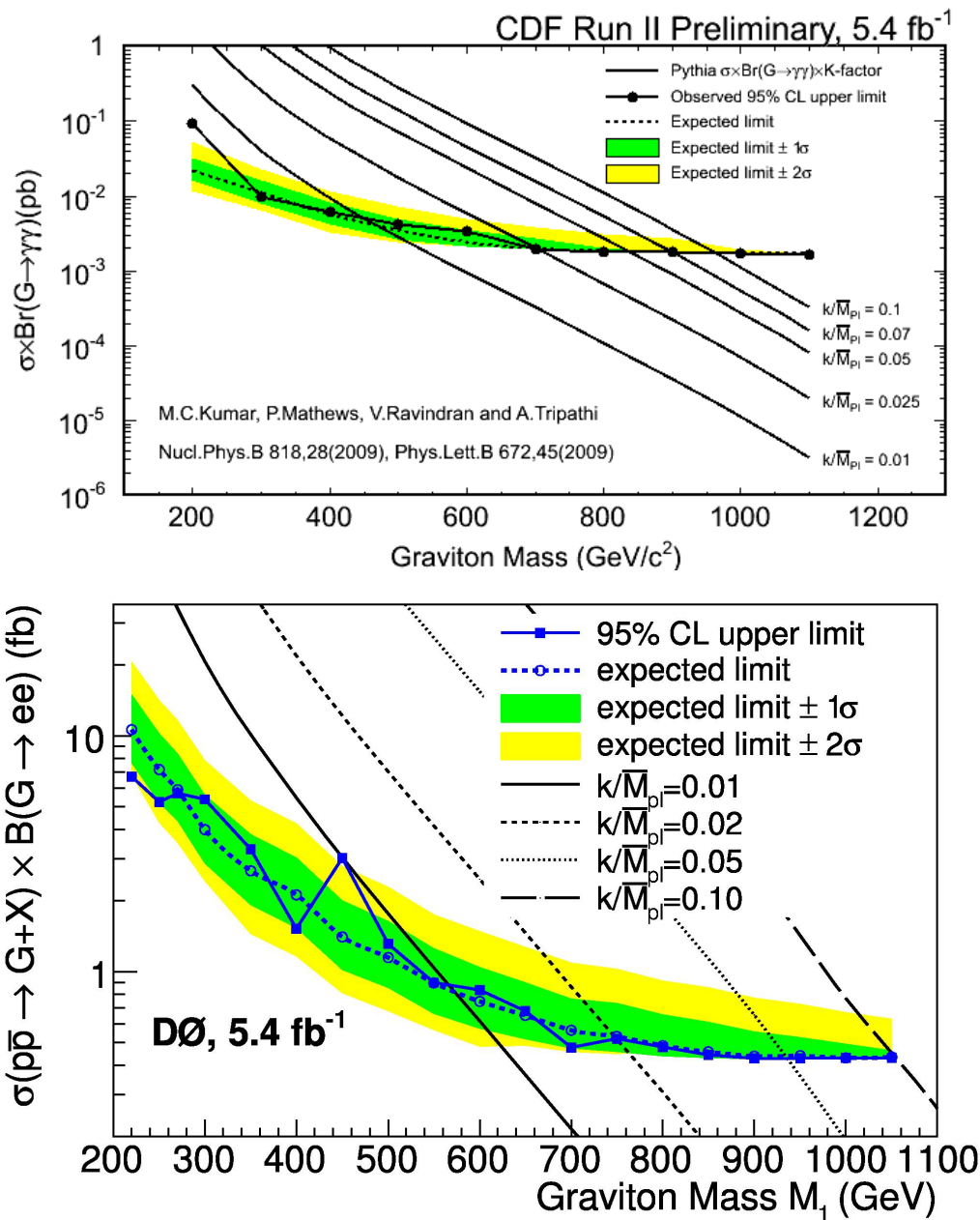
$604\text{-}1055 \text{ GeV}/c^2$ for $0.01 \leq k/M_{\text{PL}} \leq 0.1$
 (variable k-factor)
 1089 for k/M_{PL} for fixed k-factor

CDF Public Note 10405





Randall-Sundrum Graviton in diphoton



Upper limits on $\sigma \times \text{Br}$ (RS graviton) as function of diphoton mass
 => Lower limits on Graviton mass:
 Depending coupling parameter k/\bar{M}_{pl} values:

➤ if $k/\bar{M}_{\text{pl}} = 0.01$:

=> 472 GeV/c² (CDF) at 95% CN

=> 560 GeV/c² (DØ) at 95%CL

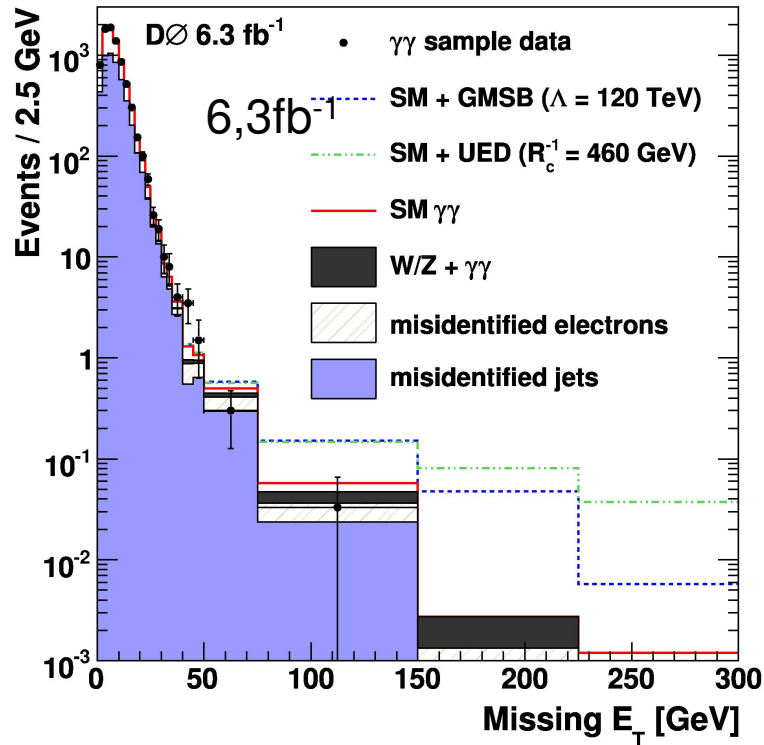
➤ if $k/\bar{M}_{\text{pl}} = 0.1$:

=> 976 GeV/c² (CDF) at 95% CL

=> 1050 GeV/c² (DØ) at 95% CL



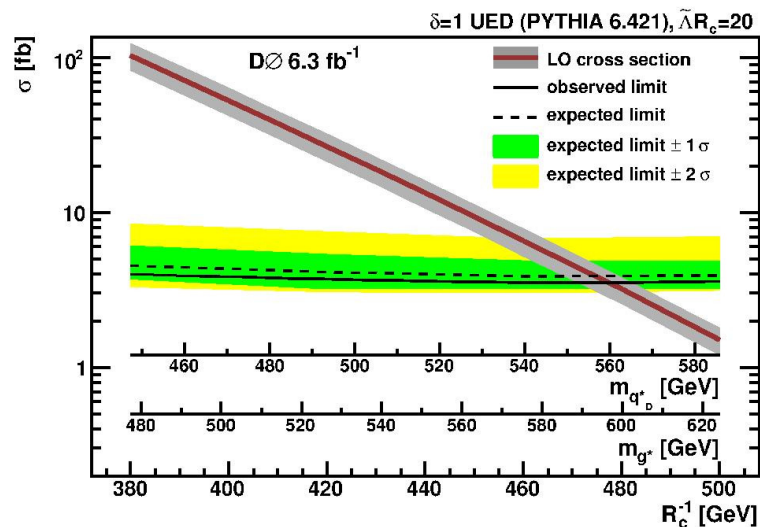
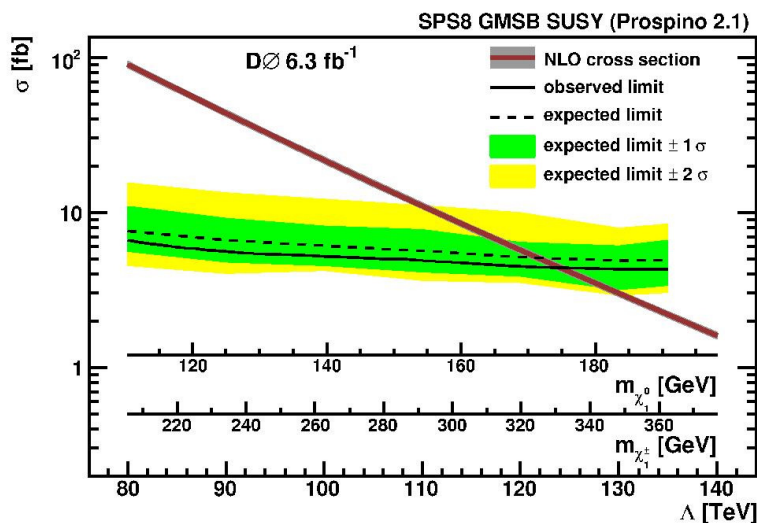
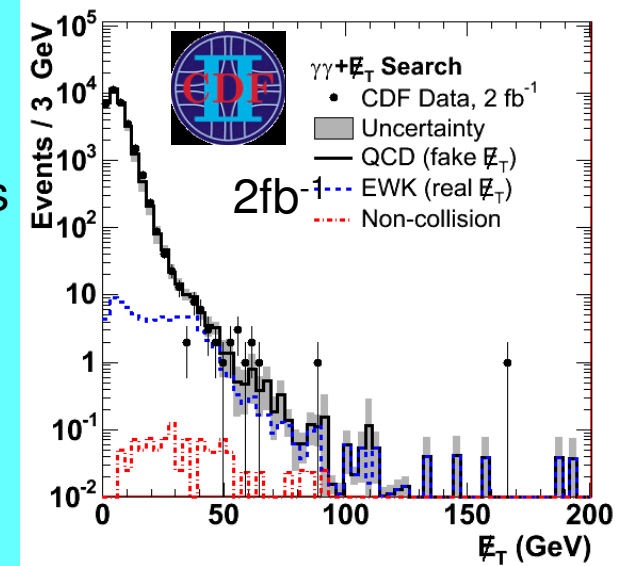
RS Graviton/universal EDM in diphoton+MET



Look for diphoton events with large MET:

- GMSB scenario: Breaking Scale $\Lambda < 124$ TeV
- Universal EDM including gravitational decays:

Compactification radius R_c is excluded for:
 $R_c^{-1} < 477$ GeV

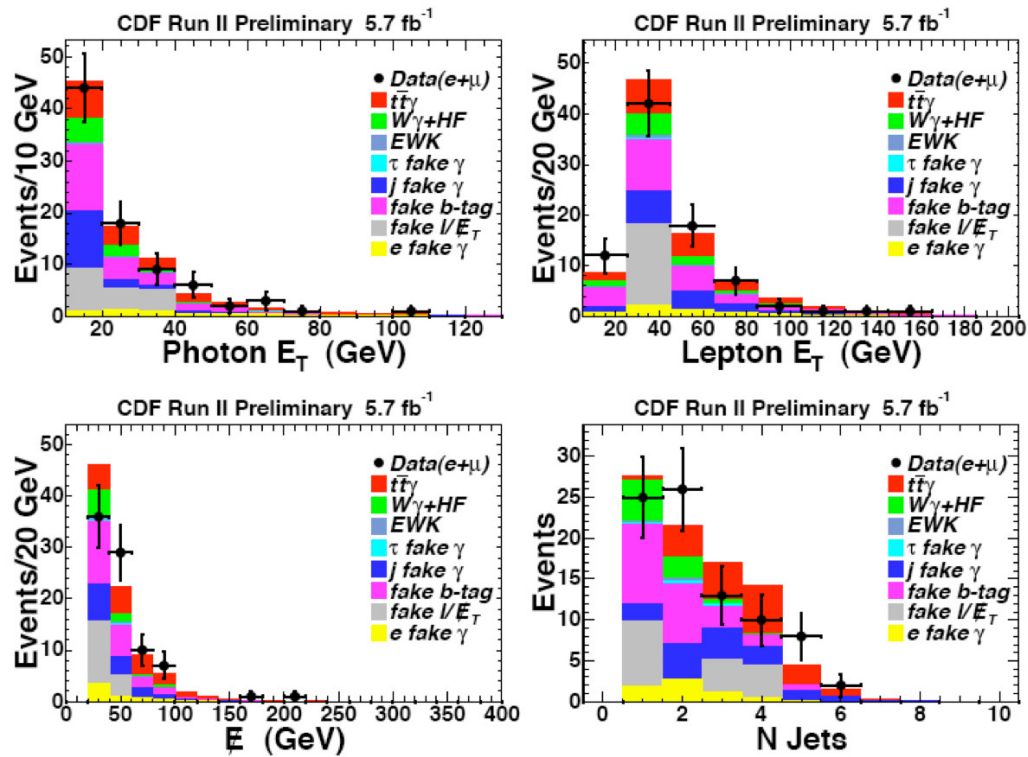




Search for anomalous γ +lepton+MET+b-quark

Could be due to radiative production; t-tbar +photon with semi-leptonic decay or to N.P.

CDF Run II Preliminary, 5.74fb^{-1}			
Lepton + Photon + 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



Select:

- one electron or one muon
- $E_T > 20$ GeV & MET > 20 GeV
- Photon with $E_T > 12$ GeV
- tagged b-jet with $E_T > 20$ GeV

Results compatible with t-tbar+ γ and $W\gamma$ +jets

\Rightarrow An extension of this analysis is the search for ttbar radiative production

Look for events with large H_t

$$\sigma(\text{ttbar}+\gamma) = 0.08 \pm 0.04 \text{ pb}$$

$$\sigma(\text{ttbar}+\gamma) / \sigma(\text{ttbar}) = 0.013 \pm 0.005$$

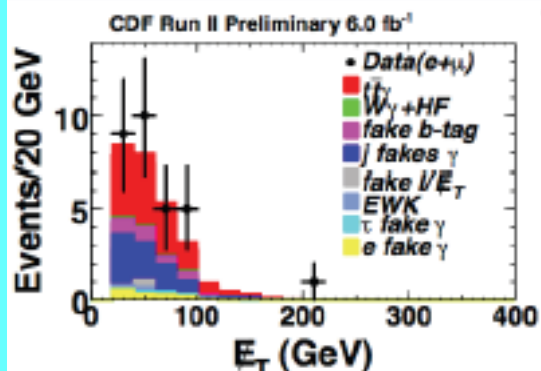
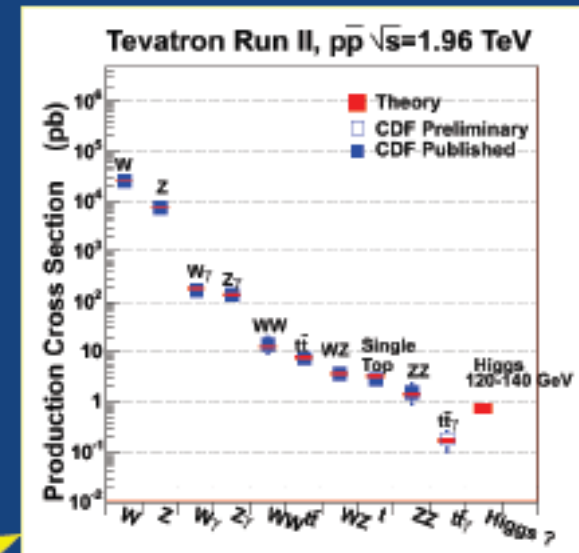
More Complex Topologies



γ + MET + b-jet + lepton

6.0 fb⁻¹

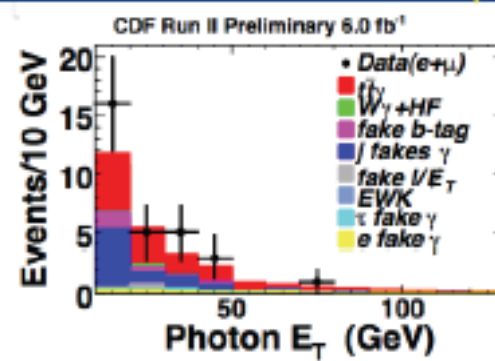
- Sensitive to the same kind of new physics as the more general final state.
- Leading background is Standard Model $t\bar{t} + \gamma$.
- Pleasant synergy, search for deviation from the Standard Model, and measurement of the ratio of the cross section: $\gamma\text{-}t\bar{t}/t\bar{t}$.



Possibly the smallest cross-section measured!



CDF Public Note 10270



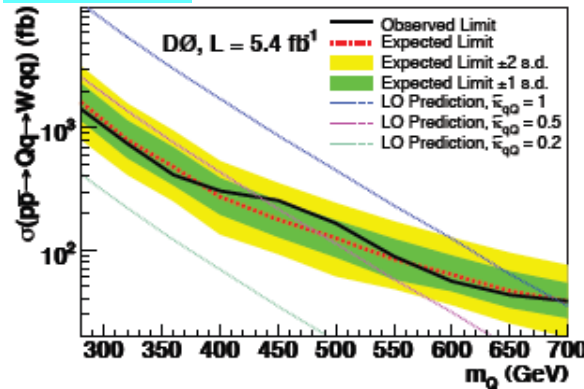
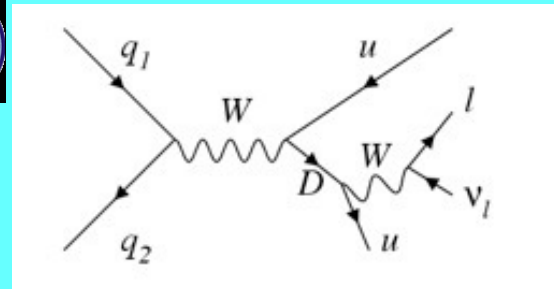
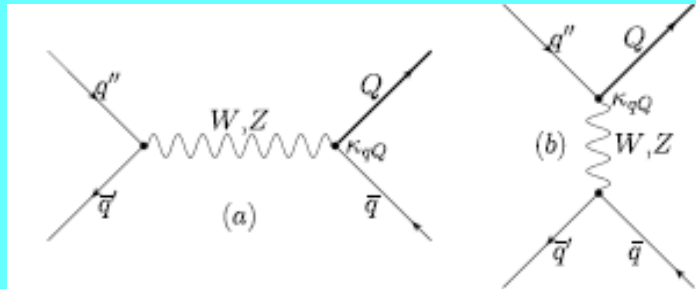
No excess observed,
 $\sigma(\text{ditop} + \gamma) = 0.18 \pm 0.07 \text{ pb}$

$R(\text{tt}\gamma/\text{tt}) = 0.024 \pm 0.009$

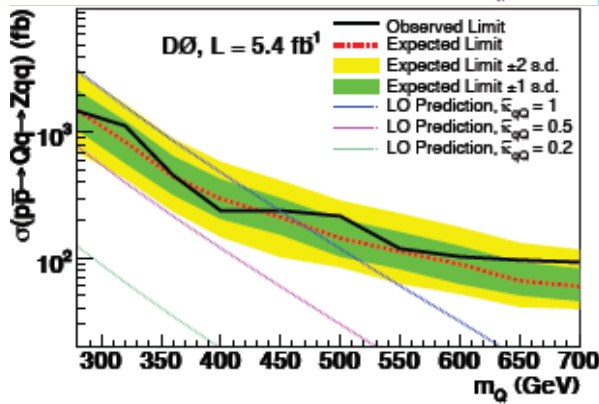
VECTOR-LIKE QUARKS: W/Z+jets

Vector-like quarks are predicted by different BSM: Little Higgs, warped & Universal EDM

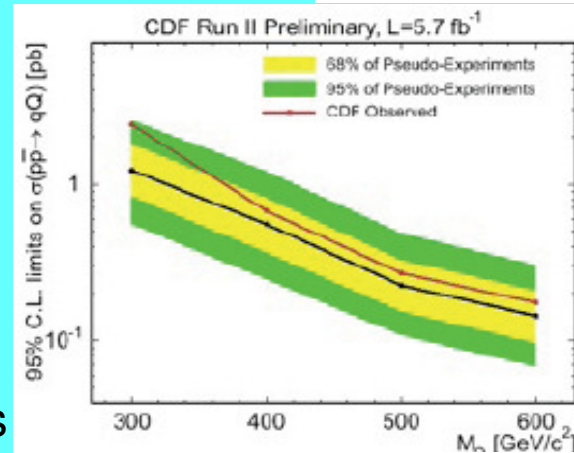
- ❖ Look for single production via EWK interaction
- ❖ Decay W/Z+jets+(MET)



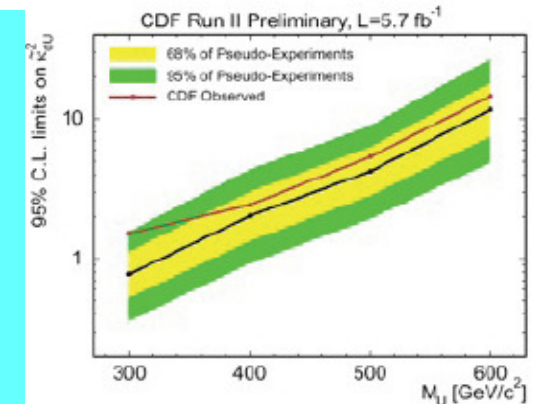
DØ:
Assume mixing parameter = 1
100% Br into respective decays



$M_Q < 693 \text{ GeV}$, 95%CL
If $Q \rightarrow W + \text{jets}$
 $M_Q < 449 \text{ GeV}$, 95%CL
If $Q \rightarrow Z + \text{jets}$



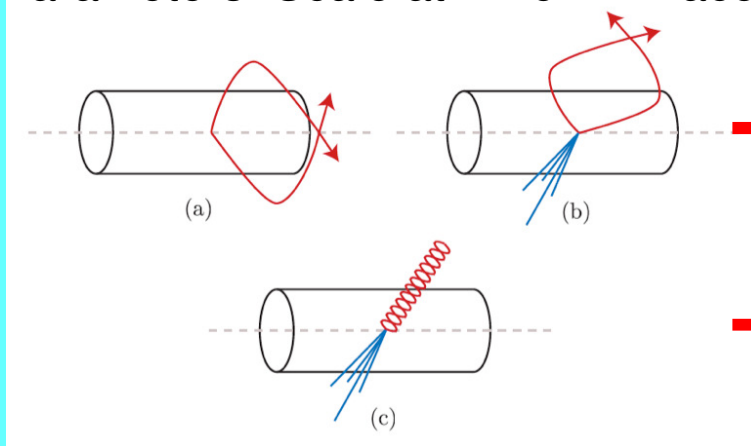
CDF:
Focus on U&D-type heavy quark
 $\text{Br}(Q \rightarrow Wq) = 100\%$



QUIRKS & HIDDEN VALLEYS => new signatures

Nature is not only $SU(2) \times SU(3) \times U(1)$

- Scenarios with extra QCD-like $SU(N)$ sectors ($N=2, 3$ or 5): old idea recently revisited..
Parameters: Scale at which “Infracolor” becomes strong: Λ , and Mass of Quirks: M_Q

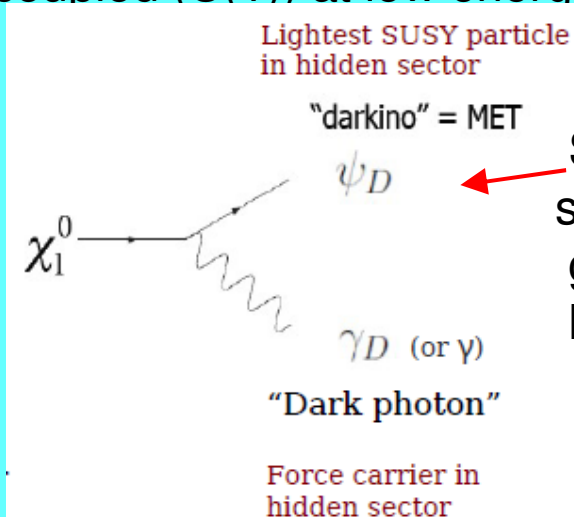


Signatures:
strange tracks

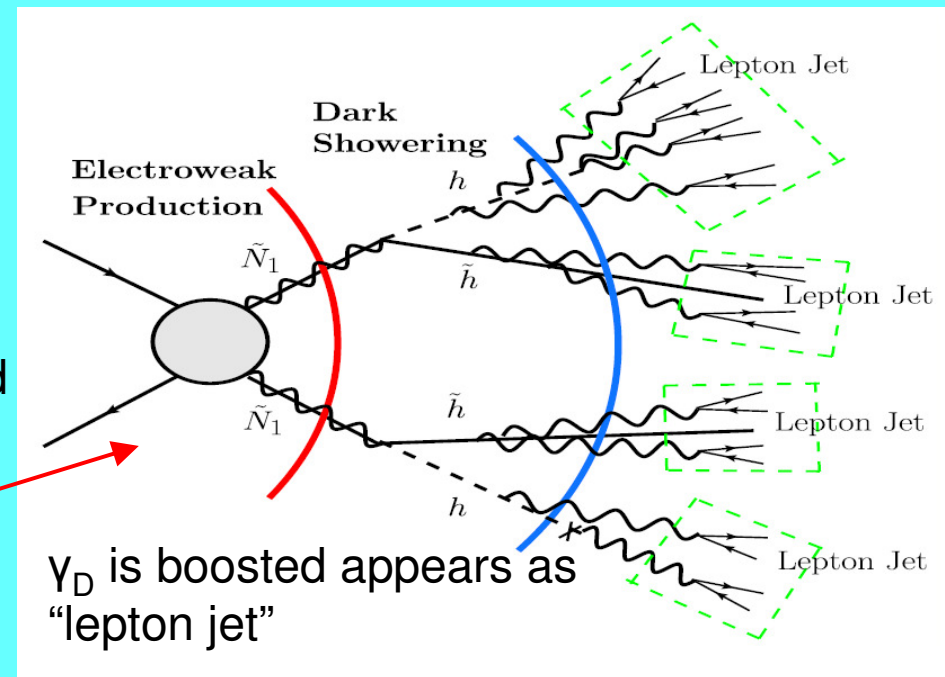
OR

highly-ionizing slow heavy particle

- New Additional Gauge groups weakly coupled ($U(1)$) at low energy.

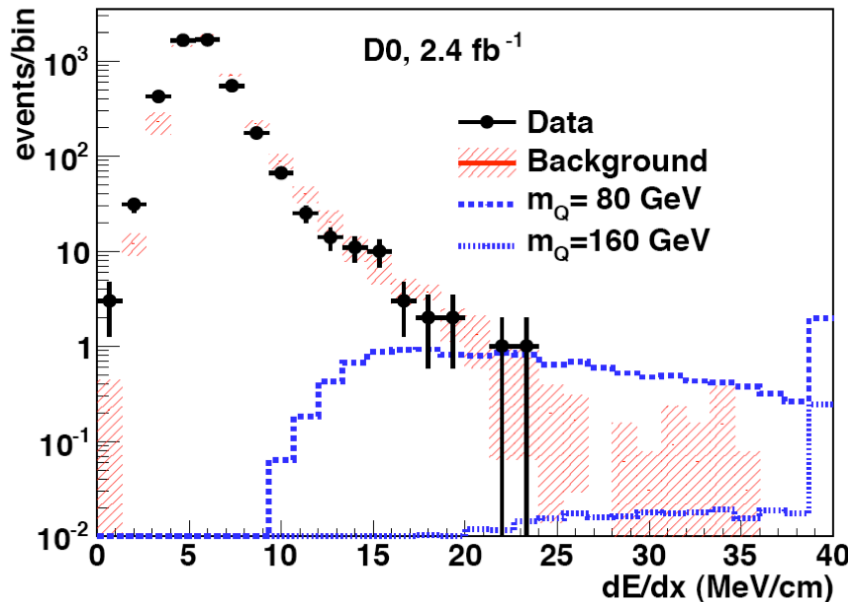


SUSY hidden sector γ_D could give rise to lepton jets





Search for Quirks ...vous avez dit bizarre...?



First experimental search (2.4fb⁻¹)

If quirks carry SM charges, they can be pair produced at colliders

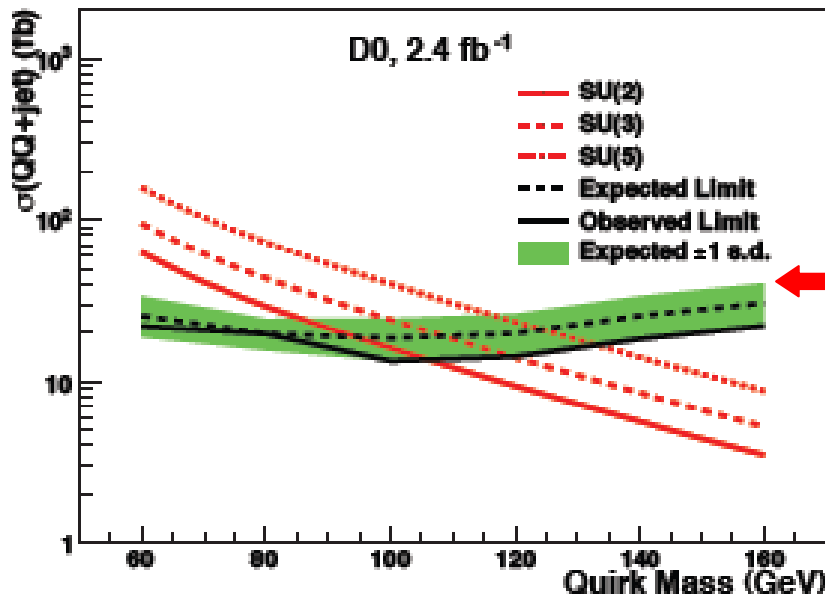
Quirk-Antiquirk pair stay connected => “metastable” bound states ($L \sim M_Q/\Lambda^2$)

- ✓ Search for particles with anomalously high ionization in events: *expected $dE/dx \sim 15$ MeV/cm (measured in Silicon)*
- ✓ with large E_{miss} . aligned with the track
- ✓ High E_t jet opposite direction

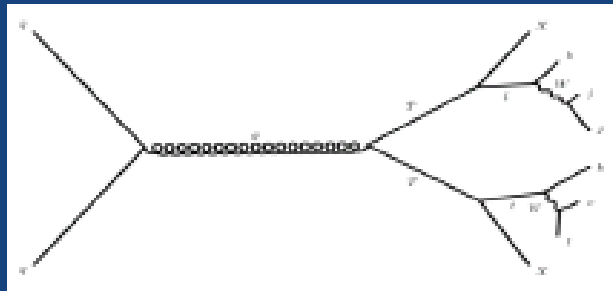
Main background: W+jets and Multijets

For $10\text{KeV} < \Lambda < 1\text{MeV}$: $M_Q > 107, 119, 133$ GeV for SU(2), SU(3) and SU(5) respectively

NOW CDF, CMS are looking for also...



Search for Dark Matter Particles



Exotic 4-th generation quarks $t' \rightarrow tX$, where X is a dark matter candidate

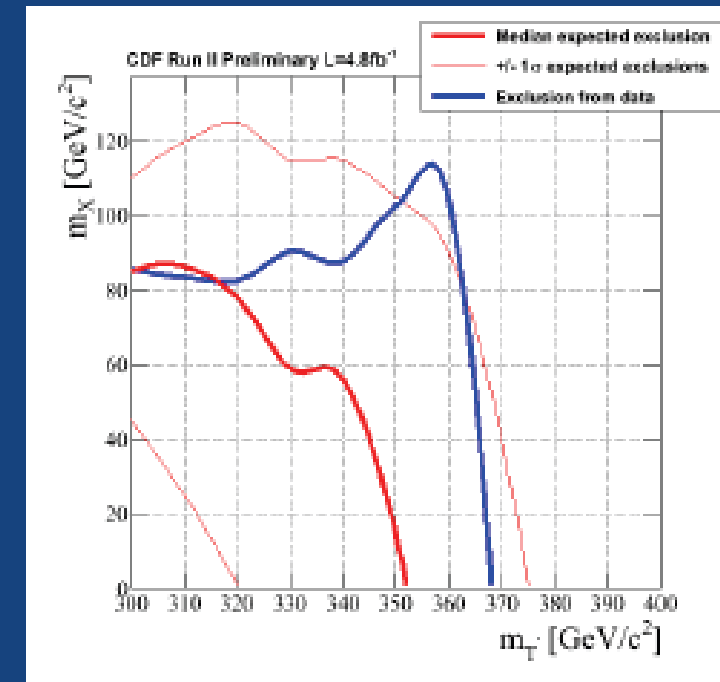
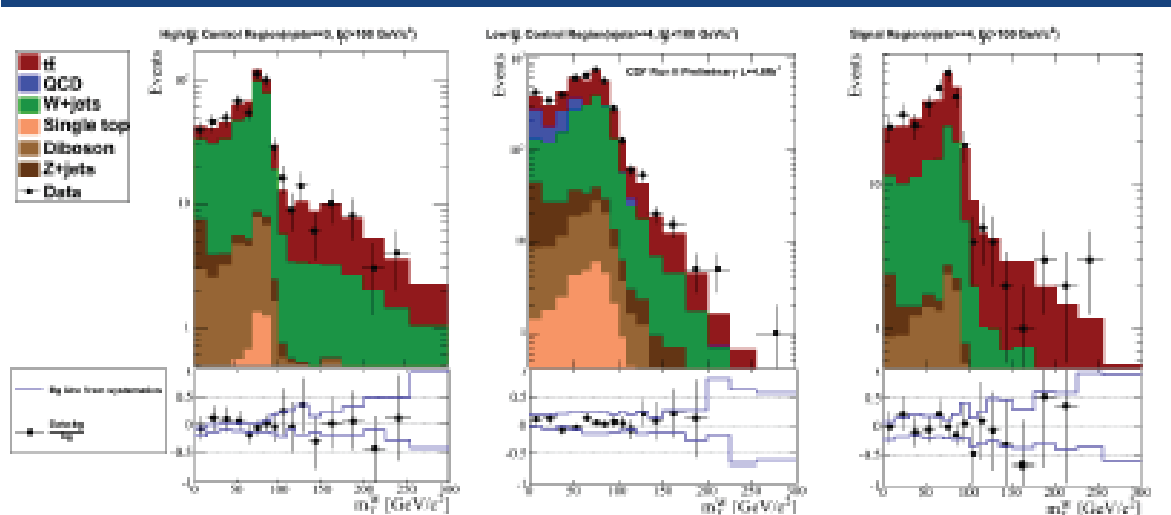
- J.Feng et al, arXiv:1002.3366
- Other scenario: stop \rightarrow top + neutralino
- **Signature: $t\bar{t}$ + large MET**
- **Dominant background, $t\bar{t}$ and W +jets**

4.8 fb⁻¹
New!

Strategy: fit background + signal transverse mass distribution

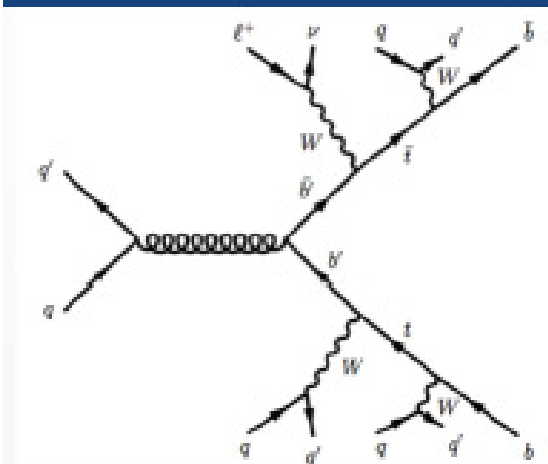
Optimize the MET cut for different points

Modeling of background is tested in control regions



CDF Public Note 10374

Search for 4th generation quarks



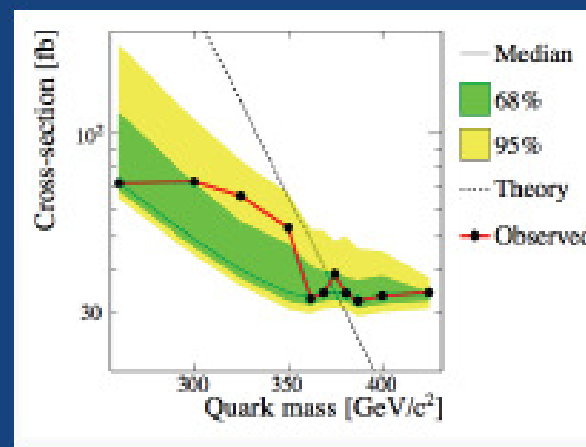
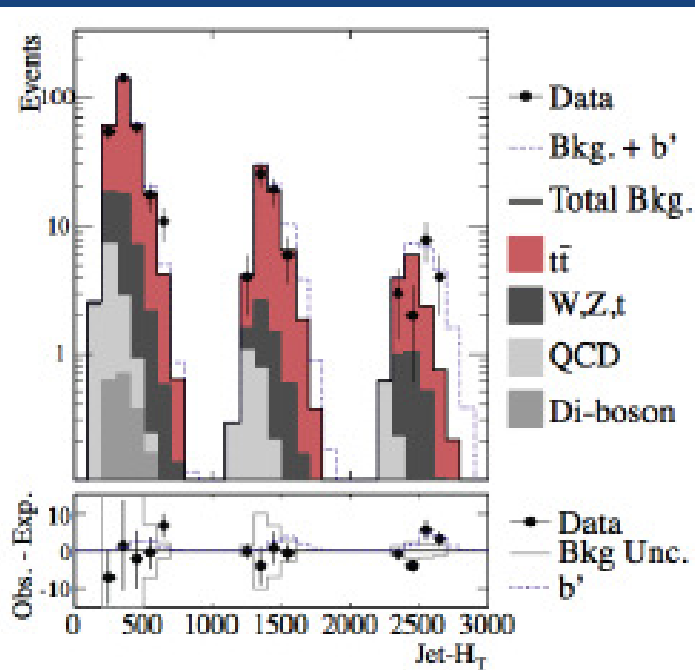
Current limits push 4th generation down-type quark to be above $m(\text{top})+m(W)$

Final state comprising top and extra W'

Lepton+jets signature - high acceptance due to hadronic decaying W 's



Fit to $H_T = \Sigma(\text{Jet } E_T + \text{lepton } E_T + \text{MET})$
Across different jet multiplicity bins



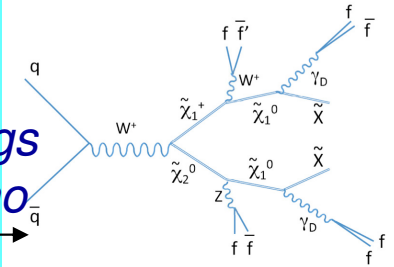
Exclude b'
below 385 GeV/c^2
@95% CL
Best Limit to date!

arXiv:1101.5728



Search for hidden valleys

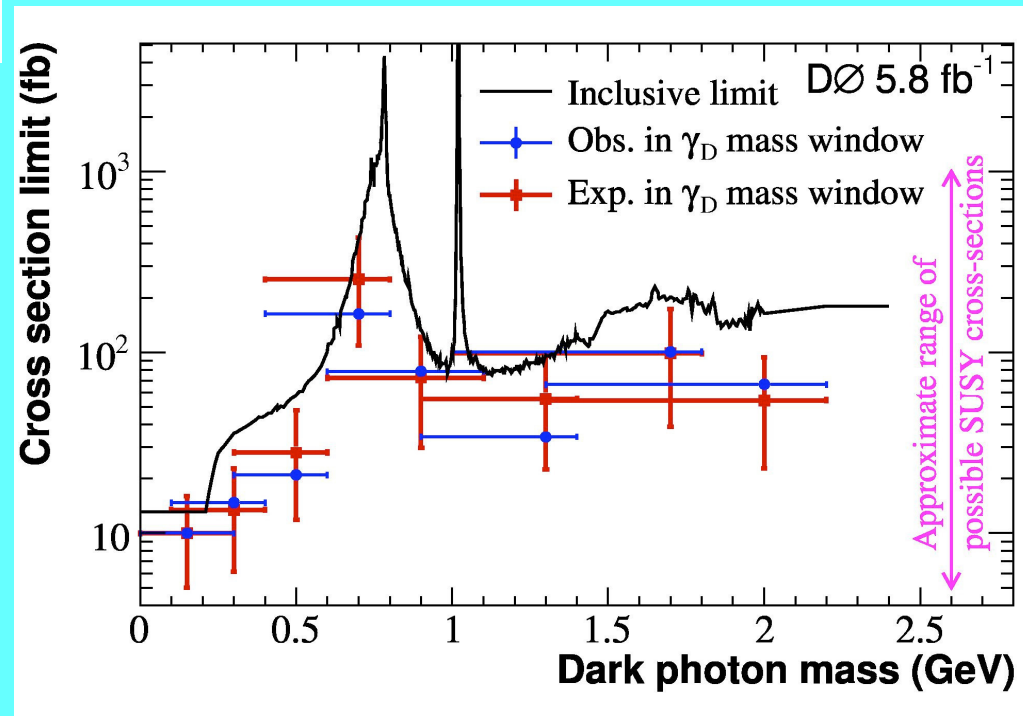
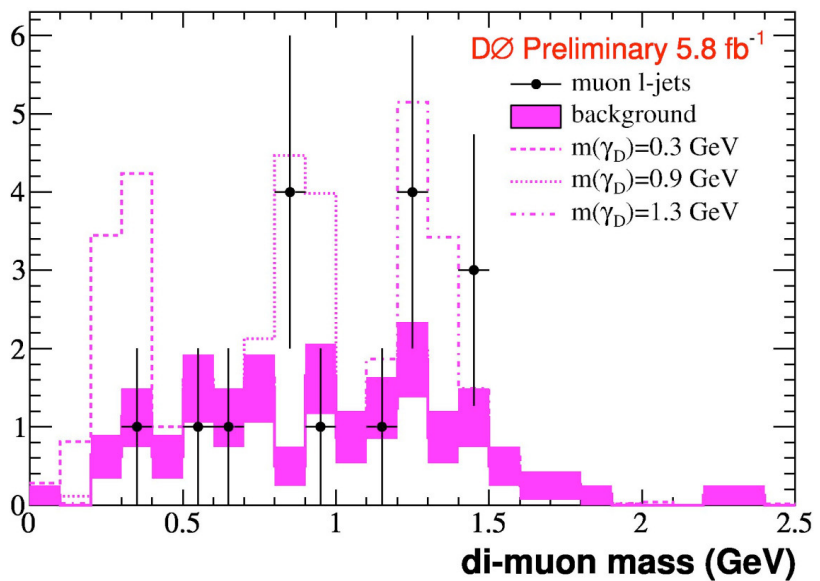
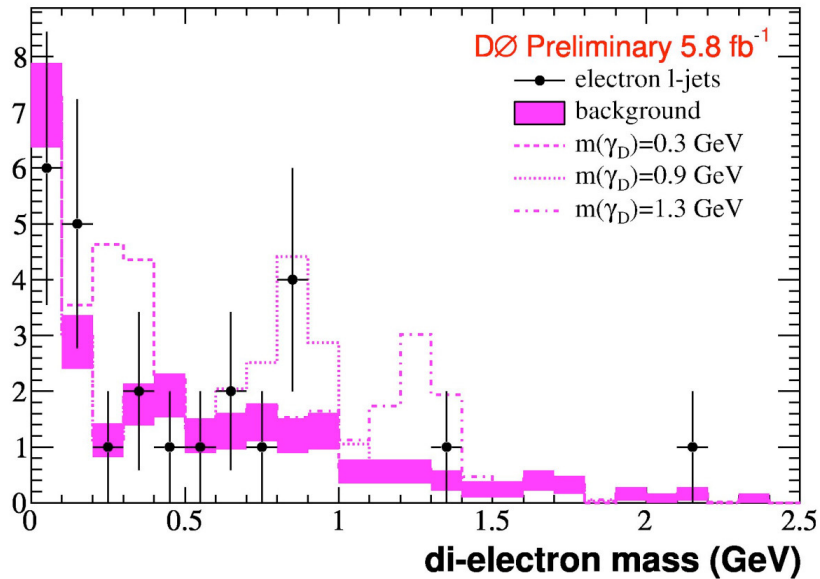
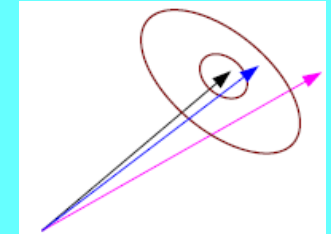
Change dramatically SUSY, Higgs signatures; ex chargino/neutralino



The dark photon (hidden sector force carrier will decay to leptons

Signature: ≥ 2 "lepton-jets"
= a seed electron or muon track with companion track of opposite

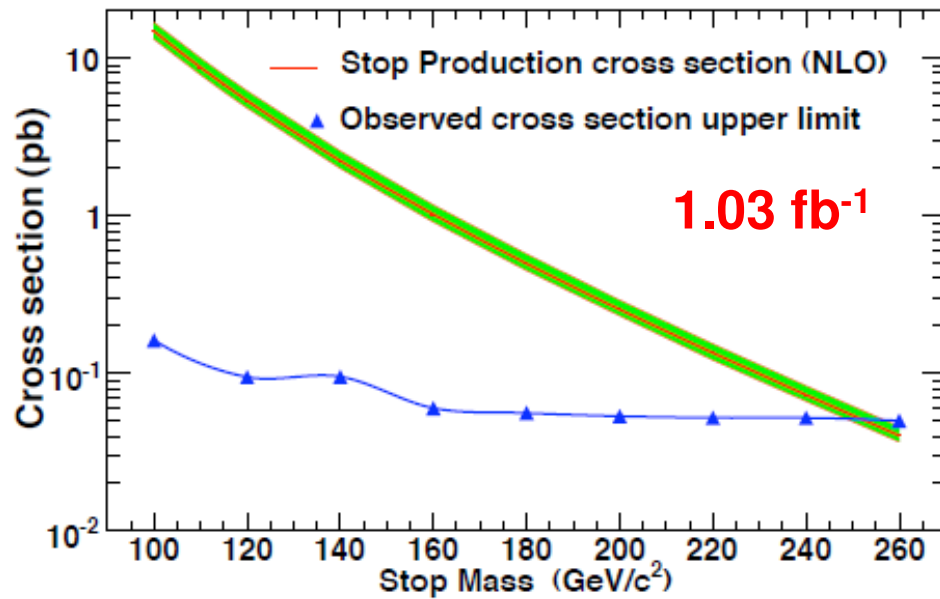
Charge (isolation but loose: possible radiation)
+ Large E_{miss}





Search for charged, massive stable particle: CHAMPS

⇒ Slowly moving, highly ionizing and highly penetrating particle with large E_t . Can be typically reconstructed as a muon
⇒ Rely on TOF measurement (β) of high P_t tracks (High P_t muon trigger)



Result: Limit on M_{CHAMPS}

- Model independent:
120 GeV
- Stable stop scenario
250 GeV

