# Search for GMSB and new physics using photons at the Tevatron

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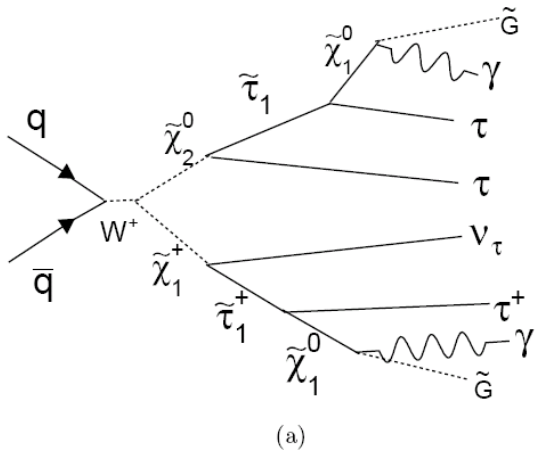
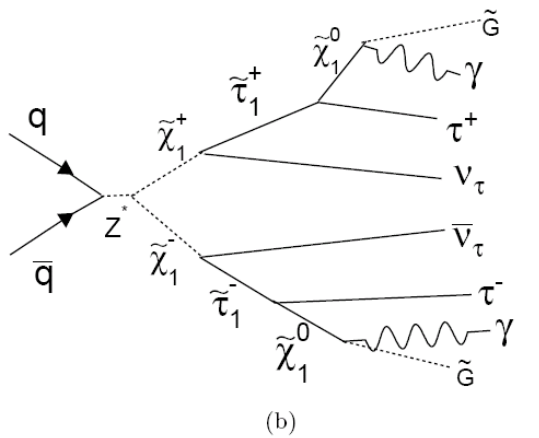
- GMSB
- Large Extra Dimensions
- Diphoton resonances
- Signature based searches

# Gauge mediated SUSY backing (GMSB)



(a)



(b)

Events with isolated Photons if:

- LSP Gravitino
- NLSP Neutralino
- Neutralino lifetime depends on model parameters

  Neutralinos with short live time:

  ⇒"normal" Isolated Photons and MET

  Neutralinos decaying in flight

  ⇒ Special analysis
- Often tau in final state but not exploited in current analysis to keep results less model dependent

# GMSB: 2γ + missing transverse energy (MET)

Selection:

- 2 isolated Photons from primary vertex
- Large MET (D0) or MET-Sig.>3 (CDF)
- CDF: $H_T$ > 200 GeV

Main Background

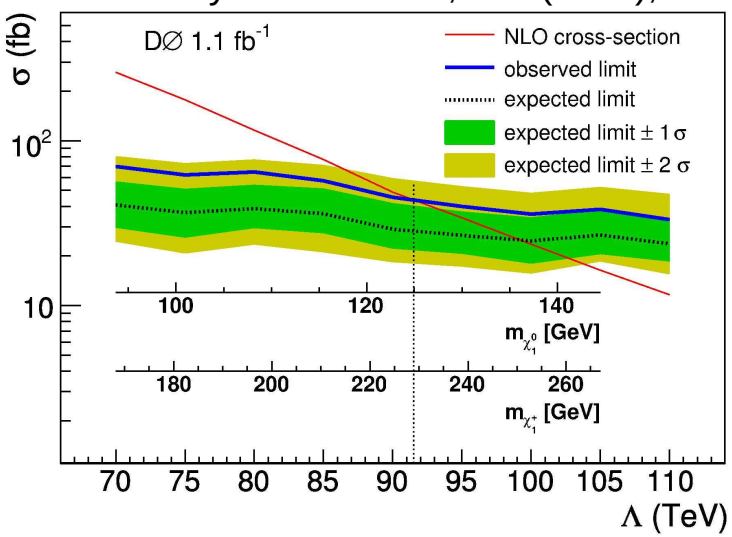
- Misid. electron and real MET
  - estimated from eγ events
- QCD with fake photons and fake MET
  - estimate fake MET probability (CDF)
  - estimate Photon fake prob. (D0)
- non Collision backgrounds
  - beam halo
  - cosmics
  - suppress and estimate with timing and pointing information.

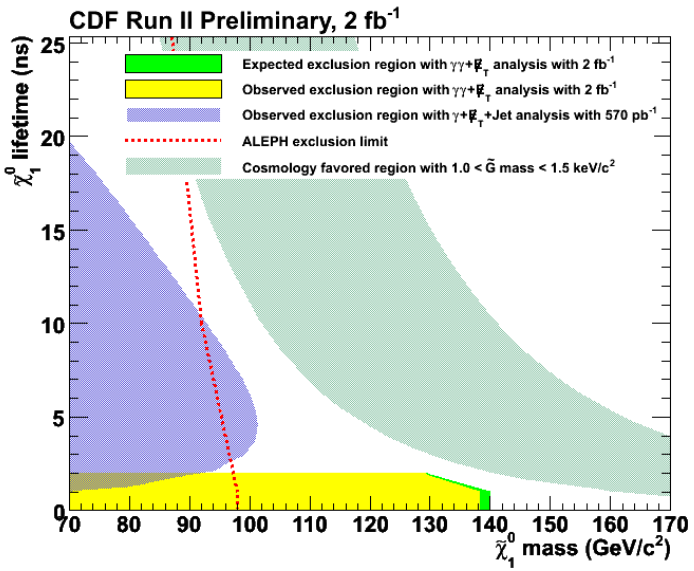
95% CL exclusion for:

CDF: $m(\tilde{\chi}_1^0) < 138\,GeV$ for $\tau(\tilde{\chi}_1^0) < 1ns$

D0: $m(\tilde{\chi}_1^0) < 125\,GeV$

Phys. Lett. B 659, 856 (2008),



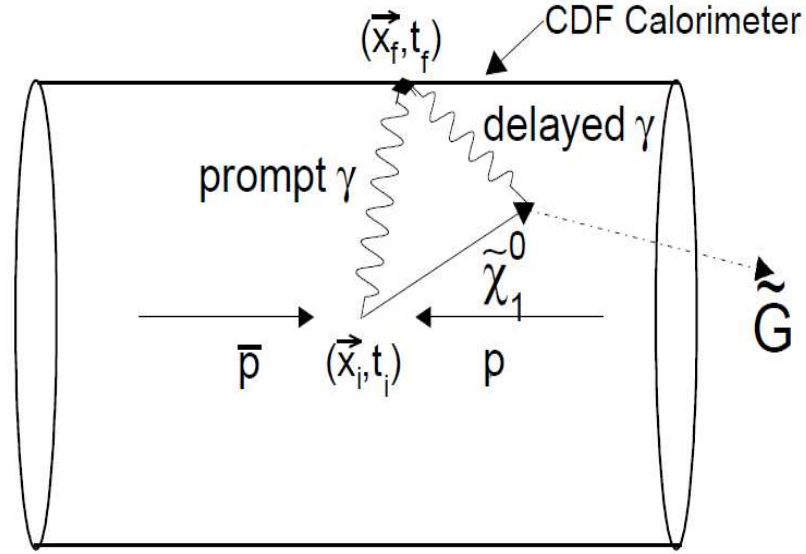
# GMSB: Photons with displaced vertex $\tau(\tilde{\chi}^0) \approx 5$ns

Replaced vertex results in:

- Photon not pointing to primary vertex
- Delayed arrival in Calorimeter

$\Rightarrow$ will reduce efficiency of standard photon id.

$\Rightarrow$ can be used to select events.



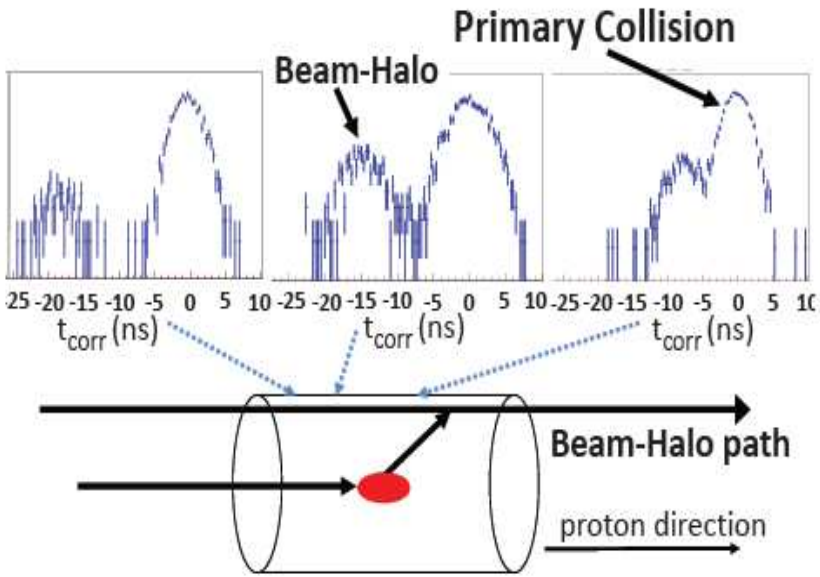

Selection:

| Preselection Requirements | Cumulative (individual) Efficiency (%) |
|---|---|
| $E_T^\gamma > 30$ GeV, $\not{E}_T > 30$ GeV | 54 (54) |
| Photon ID and fiducial, $\lvert\eta\rvert < 1.0$ | 39 (74)* |
| Good vertex, $\sum_{\text{tracks}} p_T > 15$ GeV/$c$ | 31 (79) |
| $\lvert\eta^{\text{jet}}\rvert < 2.0$, $E_T^{\text{jet}} > 30$ GeV | 24 (77) |
| Cosmic ray rejection | 23 (98)* |
| **Requirements after Optimization** | |
| $\not{E}_T > 40$ GeV, $E_T^{\text{jet}} > 35$ GeV | 21 (92) |
| $\Delta\phi(\not{E}_T, \text{jet}) > 1$ rad | 18 (86) |
| 2 ns $< t_c^\gamma <$ 10 ns | 6 (33) |

Photon id efficiency drops only by 15% at large angle (60 deg) w.r.t. primary vertex direction with only slightly mod. standard id ( remove $\chi^2_{CES} < 20$ cut)

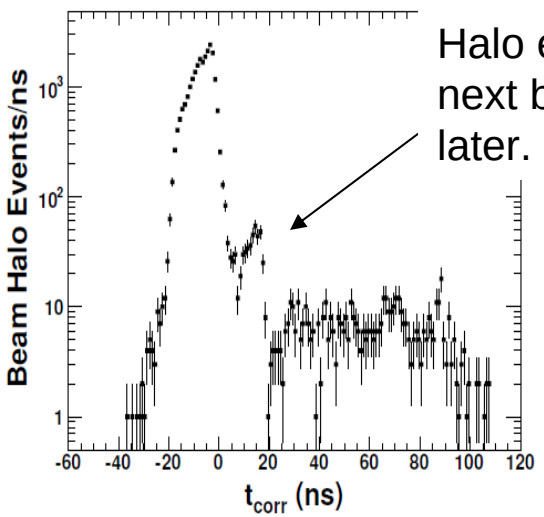
Overall effect small since only few events have these large angles.

# Photons with displaced vertex background

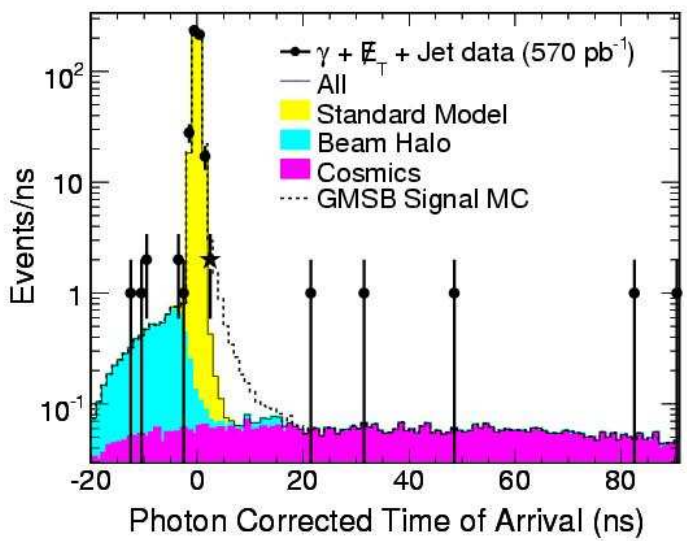



Estimate background by fit to time distribution in control region.

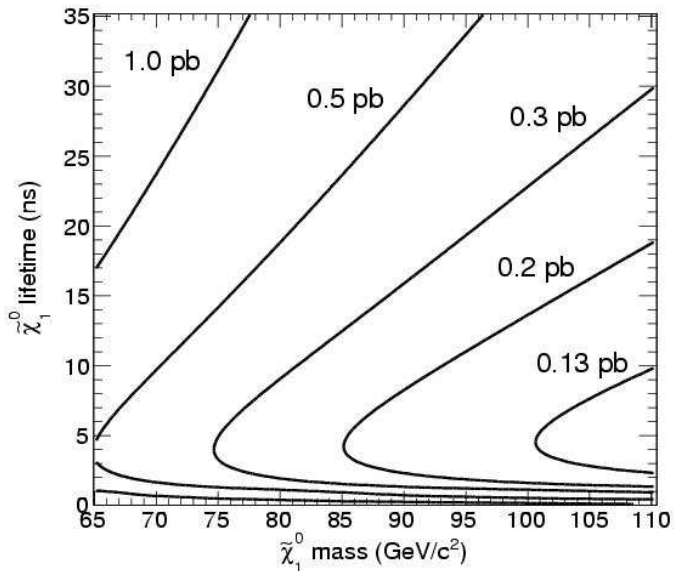
- No interaction backgrounds: from events without vertex.
  - Cosmics
  - beam Halo
  - separate both by number of EM and HAD Tower
- Prompt photons: from W→ eν

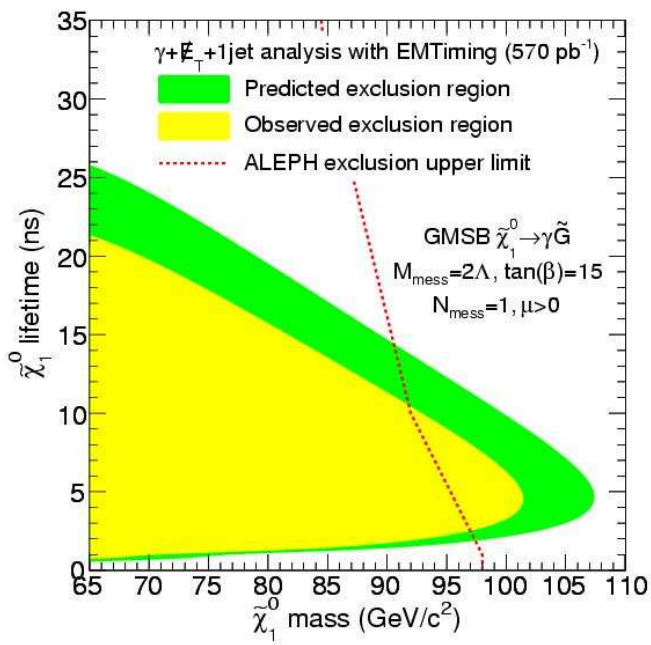



Halo events from next bucket 18ns later.

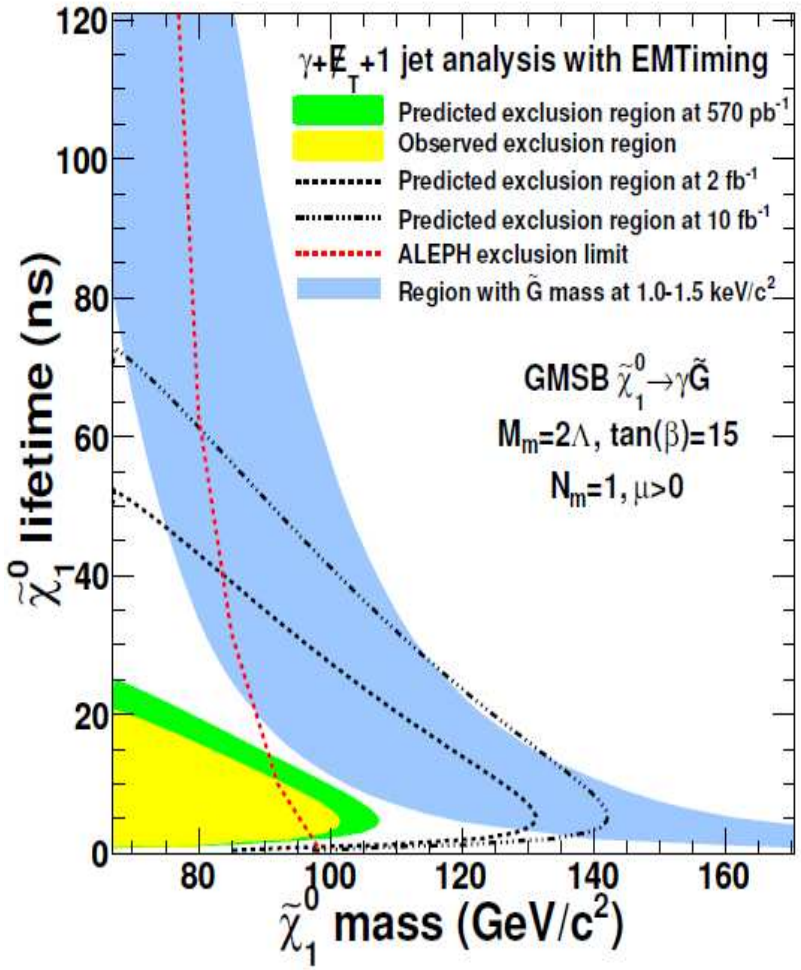


# GMSB: Photons with displaced vertex  Results



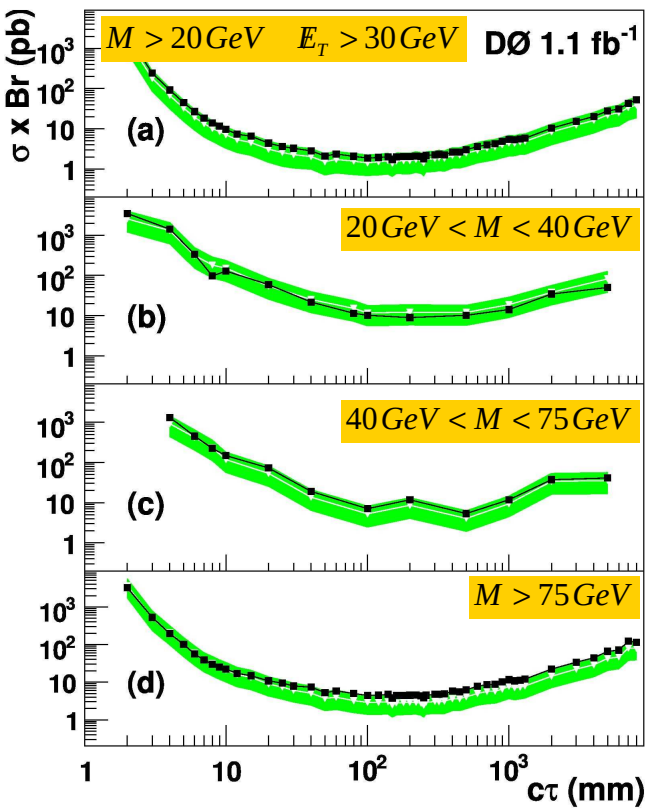

CDF: Phys.Rev.D78, 032015 (2008)




$$m(\tilde{\chi}_1^0) < 101\,GeV \text{ for } \tau(\tilde{\chi}_1^0) = 5\,ns$$

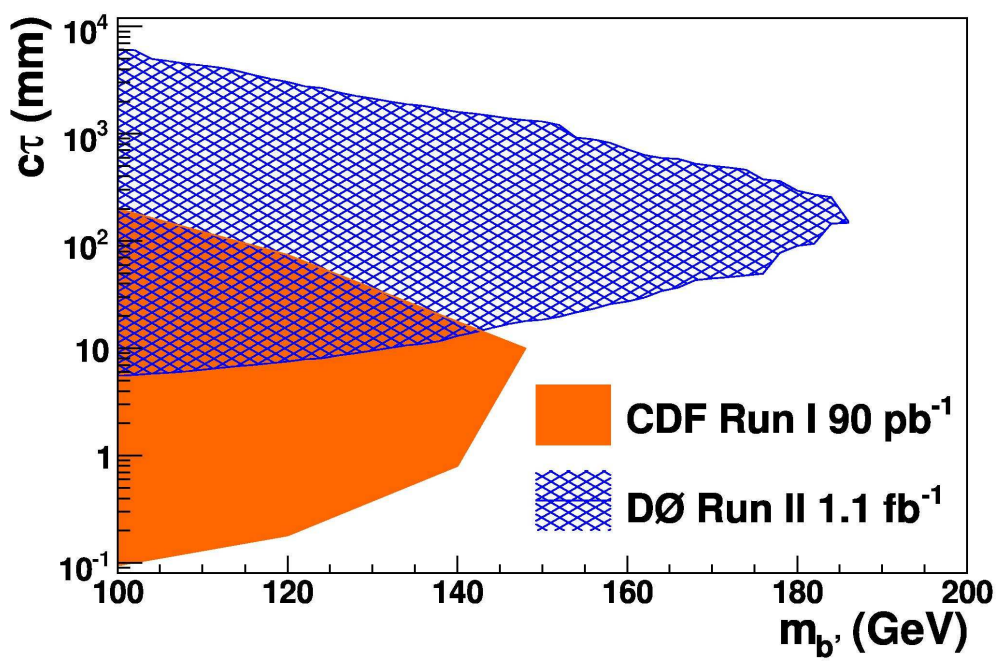
# Long lived particle decaying into γγ or ee

- Use position of cluster in the preshower and 4 EM-layer to extrapolate photon direction (DCA accuracy about 2 cm)
- Estimate significance of distance of intersection from primary vertex
- Estimate background from events with negative distance

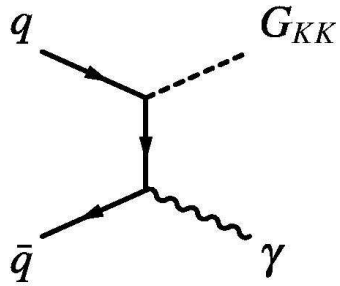



Limit interpretation in: $\bar{b}'b' \rightarrow ZbZb \rightarrow e^+e^- + X$

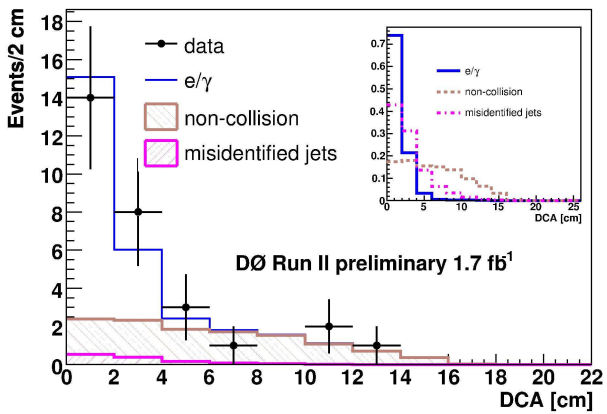
Phys. Rev. Lett. 101, 111802 (2008),

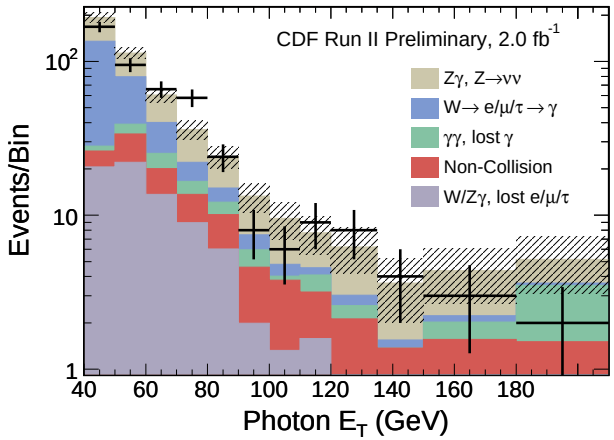


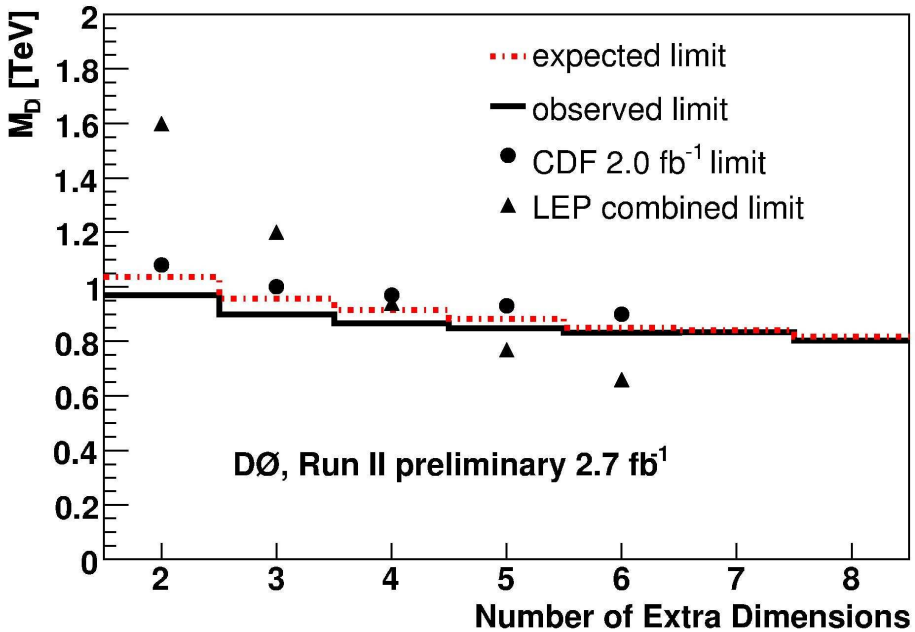
# Large Extra Dimensions: Photon+ Missing Et




- Main backgrounds
  - misidentified jets (estimated from events failing track isolation)
  - $Z\gamma \rightarrow \nu\nu\gamma$ (est. from MC)
  - $W \rightarrow e\nu$ (est. from identified electrons)
  - non collision (est. from fit to DCA)

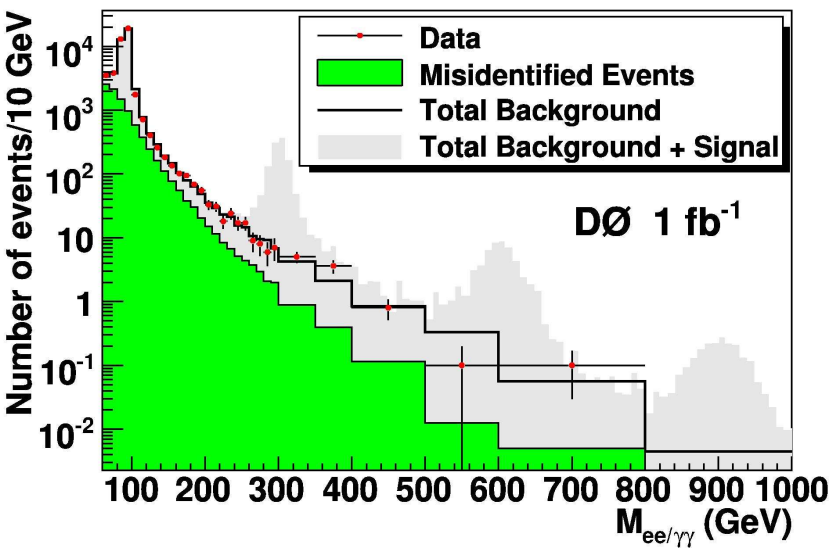


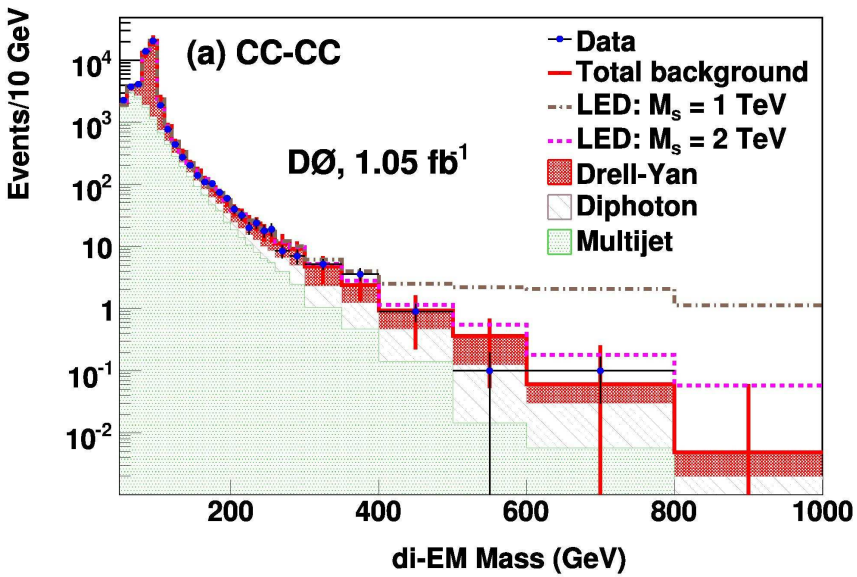



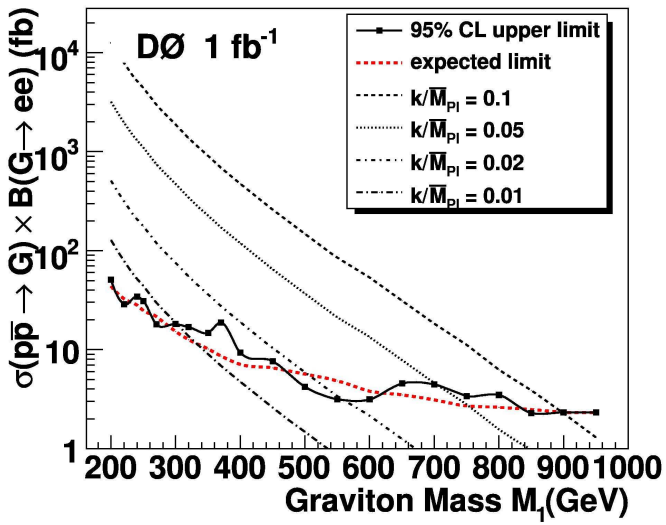
# Diphoton: RS-Graviton, KK-Graviton, Fermiophobic Higgs

Compare invariant $\gamma\gamma$/ee Spectrum with expectation from standard model and extra contribution from tested model.

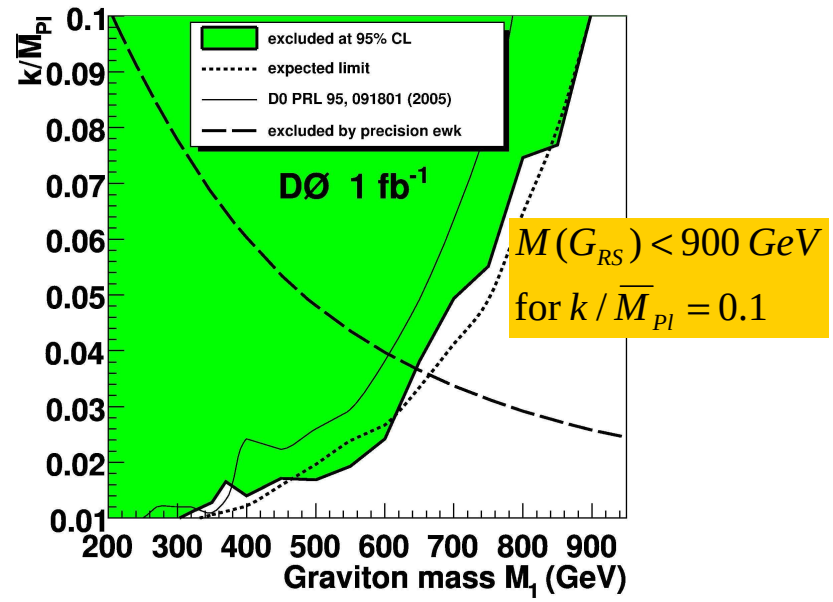


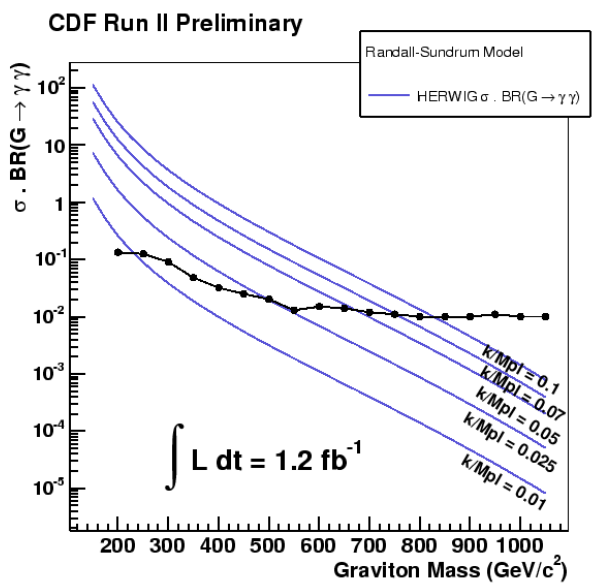



# Limits for RS-Gravitons

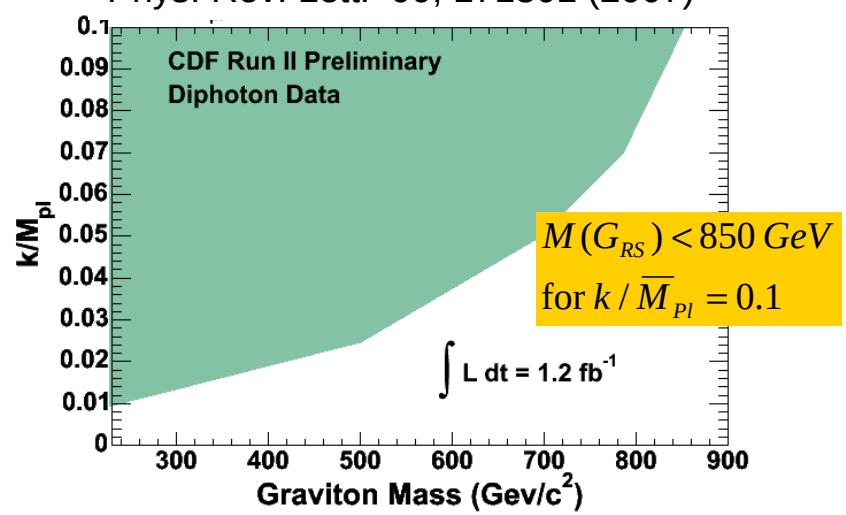



Phys. Rev. Lett. 100, 091802 (2008)



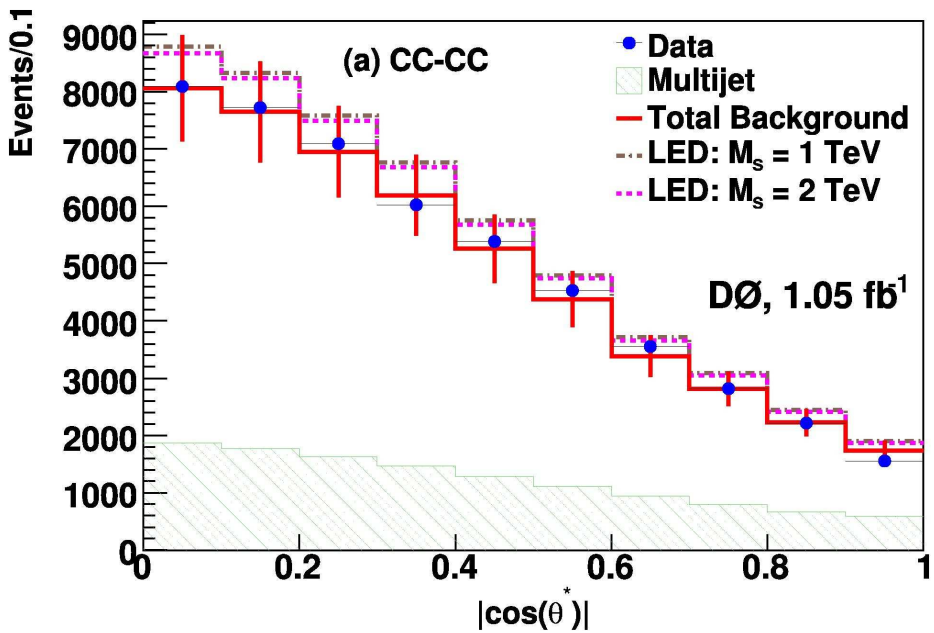




Phys. Rev. Lett. 99, 171801 (2007)

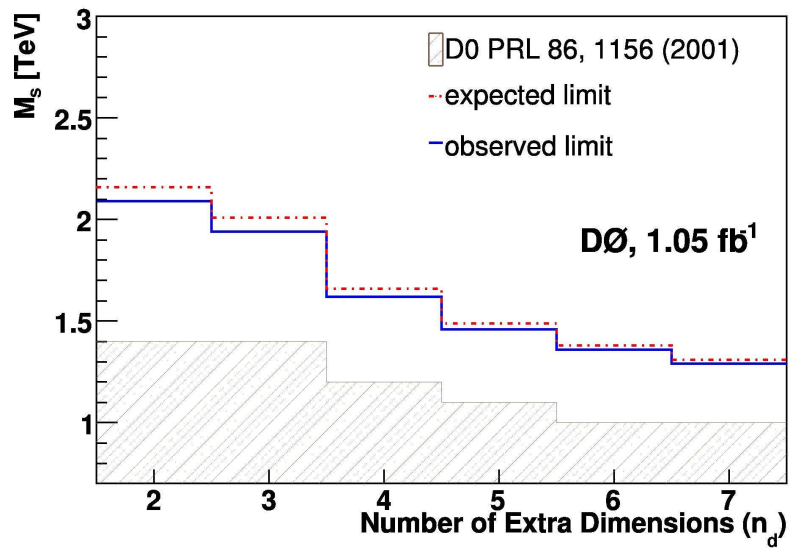


# Limits for Large Extra Dimensions (ADD)

- For ADD models use extra information from cos θ* distribution




Phys. Rev. Lett. 102, 051601 (2009),

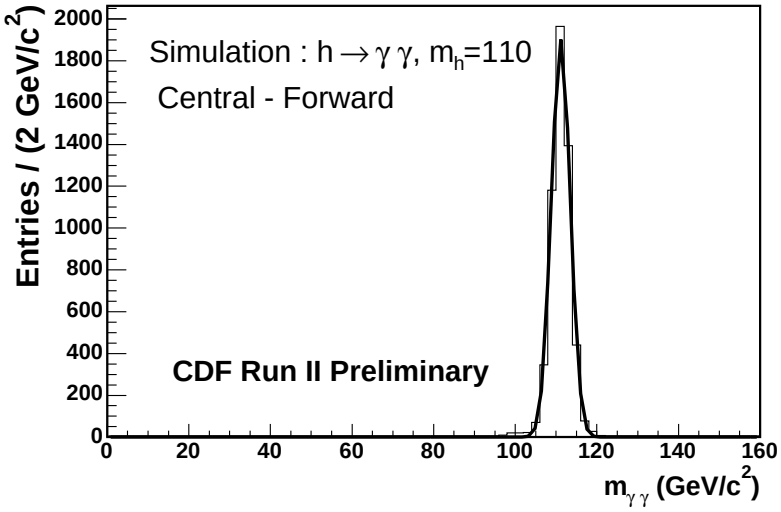


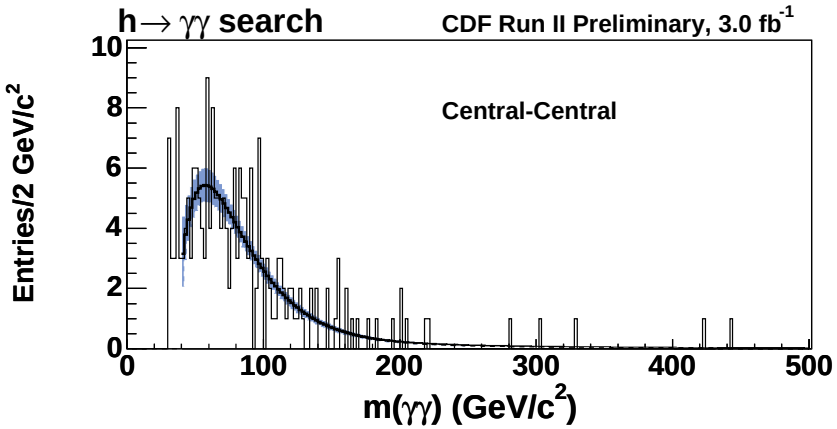

$M_s$ effective Planck scale in HLZ

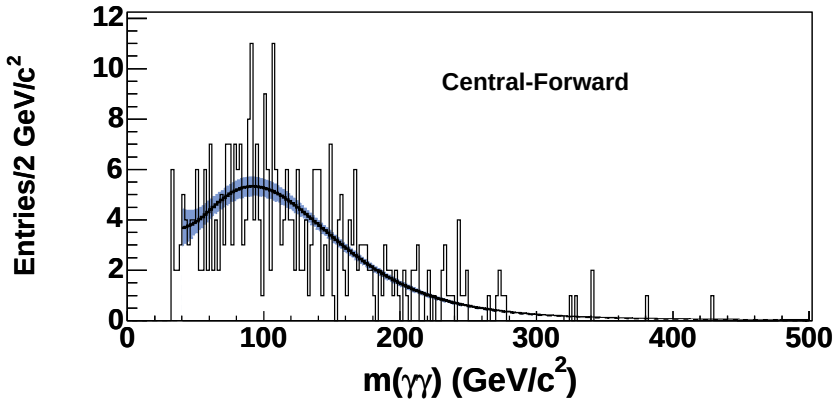
# Fermiophobic Higgs

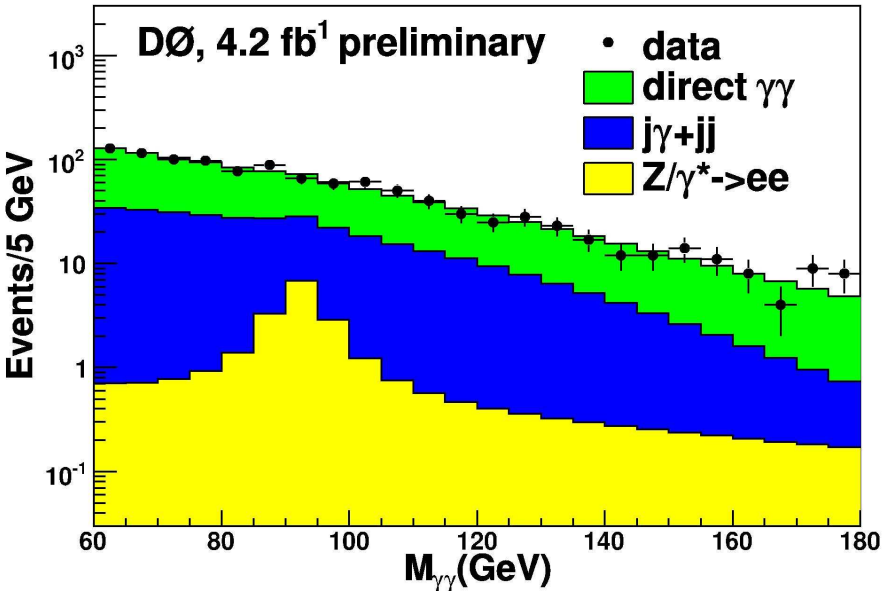
## Veto on electrons

- sharp peak expected for signal
- broad distribution for background



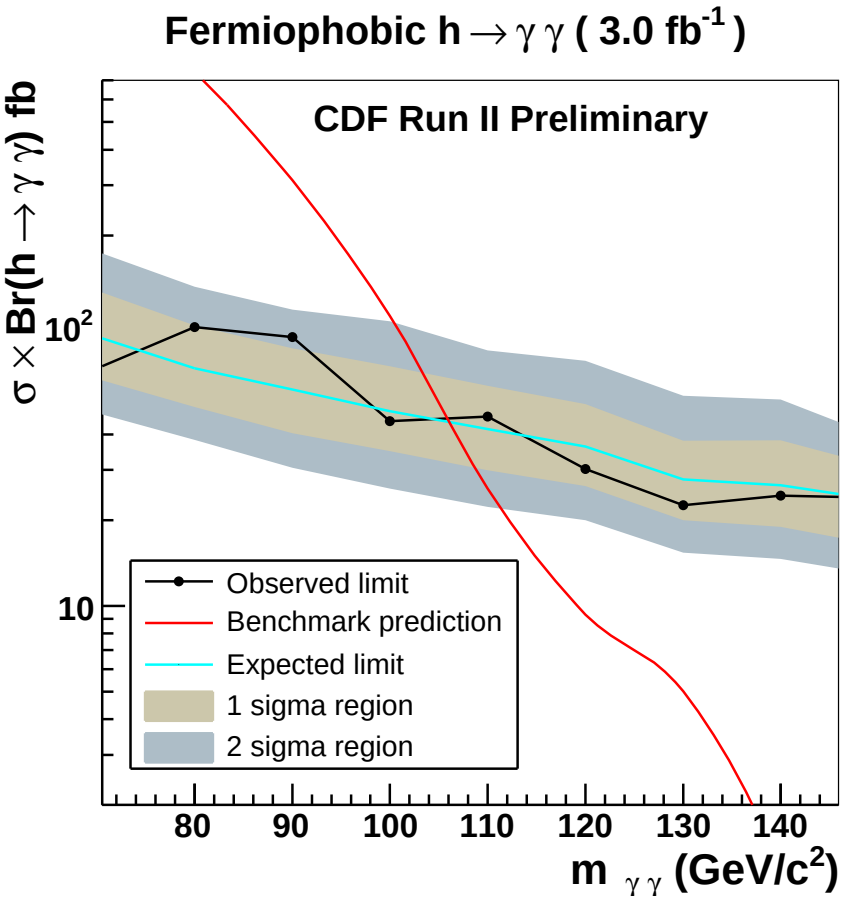



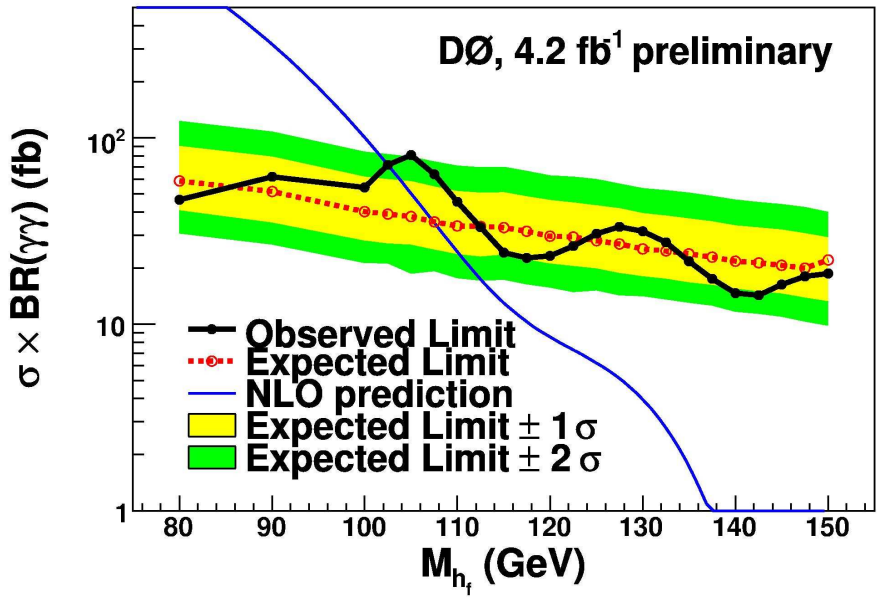



# Fermiophobic Higgs

Extract limit with a sliding mass window




CDF: $M_{h_f} < 106\,GeV$

D0: $M_{h_f} < 102.5\,GeV$

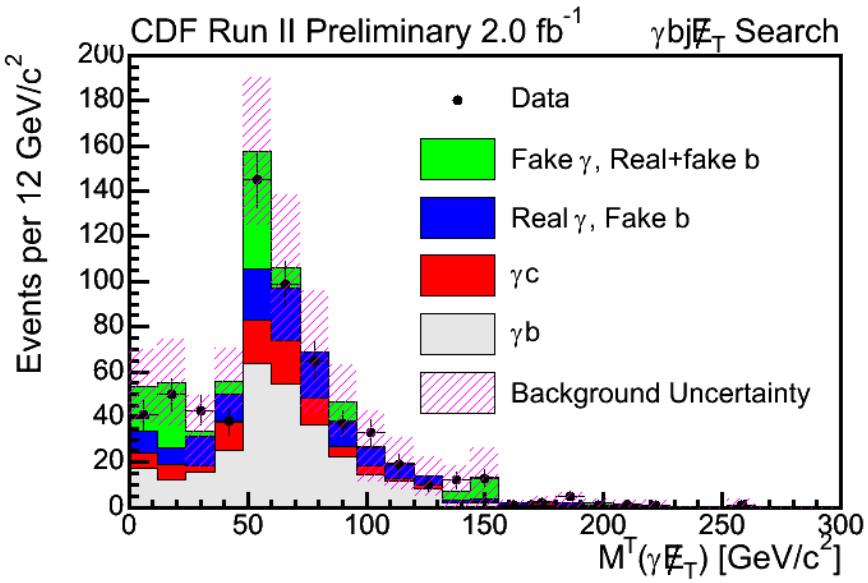
# Topological Searches

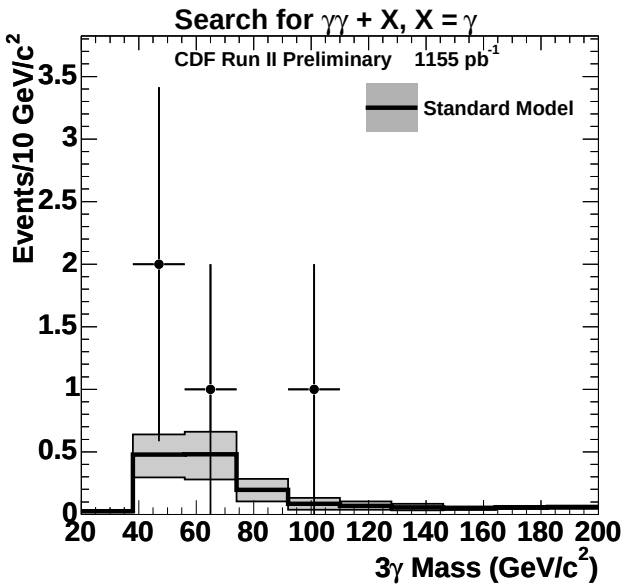
Search for final states containing photons.

⇒ Compare observed number of events with expectation from SM

- Lepton + Photon + X
- Lepton + Photon + b-Jet + Missing ET
- Photon+ b + jet + Missing ET
- Photon + Jet ( + Missing ET)
- Diphoton + X (X = e, μ, γ, τ, MET)

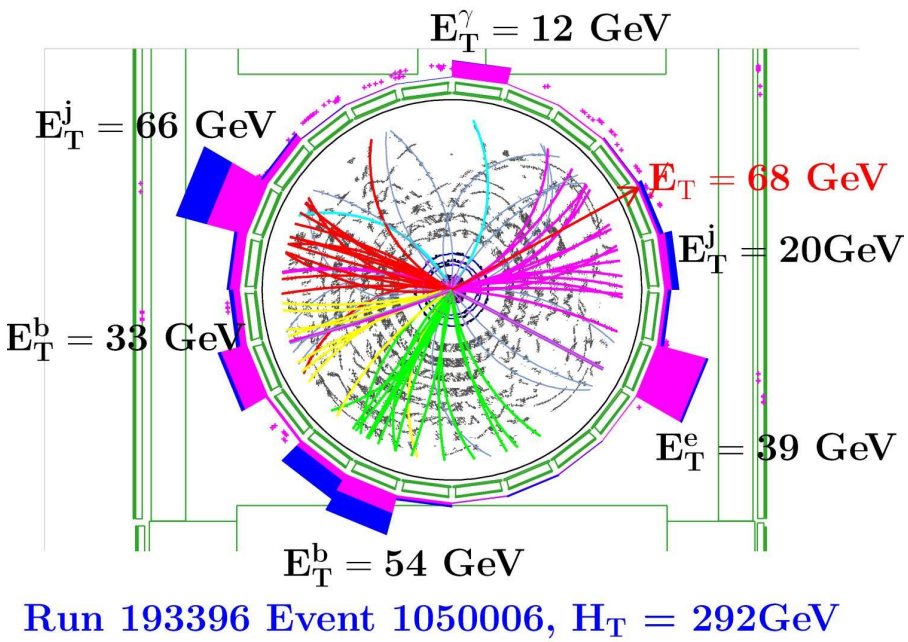
All results are consistent with standard model expectations.



# Lepton+Photon+MET+b, ttγ

- Select events with a lepton, a photon missing Et and a tagged b-jet
- Additional cuts on $H_T$ > 200 GeV and more than 2 jets to increase ttγ fraction




| CDF Run II Preliminary, $1.9\text{fb}^{-1}$ | | | |
|---|---|---|---|
| $t\bar{t}\gamma$ | | | |
| SM Source | $e\gamma b\not{E}_T$ | $\mu\gamma b\not{E}_T$ | $(e+\mu)\gamma b\not{E}_T$ |
| $t\bar{t}\gamma(semileptonic)$ | $1.97 \pm 0.36$ | $1.47 \pm 0.27$ | $3.44 \pm 0.62$ |
| $t\bar{t}\gamma(dileptonic)$ | $0.52 \pm 0.10$ | $0.43 \pm 0.08$ | $0.95 \pm 0.17$ |
| $W^\pm c\gamma$ | $0.0^{+0.02}_{-0}$ | $0.0^{+0.02}_{-0}$ | $0^{+0.03}_{-0}$ |
| $W^\pm cc\gamma$ | $0.0^{+0.02}_{-0}$ | $0.01 \pm 0.01$ | $0.01^{+0.02}_{-0.01}$ |
| $W^\pm bb\gamma$ | $0.06 \pm 0.03$ | $0.01 \pm 0.01$ | $0.07 \pm 0.03$ |
| $WZ$ | $0.02 \pm 0.02$ | $0.0^{+0.02}_{-0}$ | $0.02 \pm 0.02$ |
| $\tau \to \gamma$ fake | $0.08 \pm 0.01$ | $0.02 \pm 0.01$ | $0.10 \pm 0.01$ |
| Jet faking $\gamma$ | $2.37 \pm 1.22$ | $1.42 \pm 0.70$ | $3.79 \pm 1.92$ |
| B-jet mistags | $0.78 \pm 0.20$ | $0.83 \pm 0.22$ | $1.61 \pm 0.31$ |
| QCD | $0.53 \pm 0.46$ | $0^{+1}_{-0}$ | $0.53^{+1.10}_{-0.46}$ |
| $ee\not{E}_T b,\ e \to \gamma$ | $0.34 \pm 0.11$ | – | $0.34 \pm 0.11$ |
| $\mu e\not{E}_T b,\ e \to \gamma$ | – | $0.20 \pm 0.06$ | $0.20 \pm 0.06$ |
| Predicted | $6.7 \pm 1.4(tot)$ | $4.4^{+1.3}_{-0.8}(tot)$ | $11.1^{+2.3}_{-2.1}(tot)$ |
| Observed | 8 | 8 | 16 |

Probability to see 16 events if there where no contrib. from ttγ < 1%

$$\sigma^{obs}_{sem_lep}(t\bar{t}\gamma) = 0.15 \pm 0.08\,pb$$

$$\sigma^{SM}_{sem_lep}(t\bar{t}\gamma) = 0.080 \pm 0.011\,pb$$

# Conclusion

## Analyses shown today based on 1-2 $fb^{-1}$ (Ferbiphobic Higgs 4 $fb^{-1}$)

- 5.5 $fb^{-1}$ on tape and 2-5 $fb^{-1}$ still to come $\Rightarrow$ expect more exciting results

## Photons can be produced

- at the primary vertex
- with significant decay length

## Background

- Electrons
- Jets faking Photons
- Comics
- Beam Halo Events

## Background estimation from data is essential