

Signature-Based Searches for New Physics Involving Photons at the Tevatron

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Motivation

- As rare phenomenon are observed theorists get ever more creative in devising new possibilities for why
 - why limit ourselves to the current crop of TOE
 - review the exotic signatures and see if anything sticks out
- Photons are a good candidate since they don't add a big mass burden to the event and are reasonably rare
- Cautionary note
 - looking for rare phenomenon sometimes succeeds in finding fluctuations
 - one such fluctuation is the $e\bar{e}\gamma\gamma$ missing E_T event described in the 1995 $\bar{P}P$ workshop at FNAL
 - we've been looking for another for 15 years
- Perhaps because of the above event this has been a popular CDF sport
- D0 has a dark photon & GMSB search but nothing that fits this description so all the results here are from CDF

Where might you look?

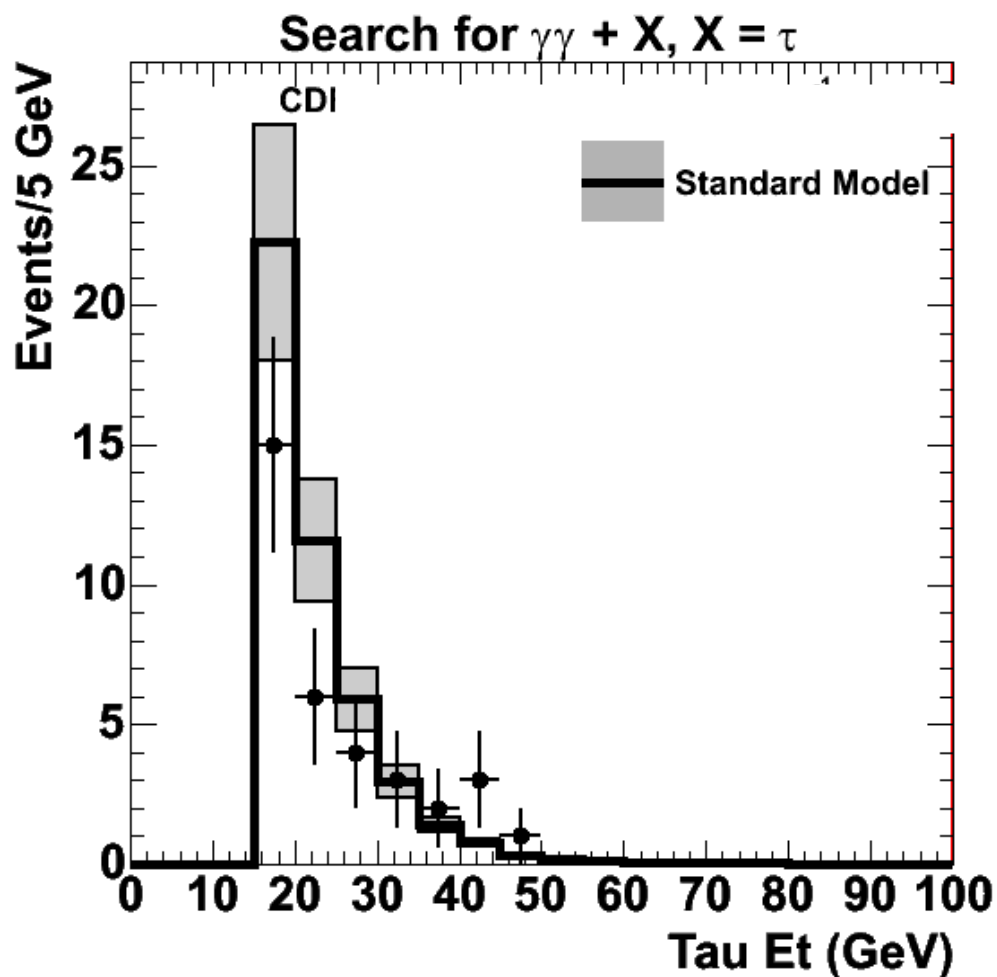
- Searches described here include
 - $\gamma\gamma$ plus
 - τ
 - e
 - μ
 - Missing E_T
 - γ +jet+b+missing E_T
 - γ +b+missing E_T +lepton (e or μ)
 - this one is of particular interest because it includes $t\bar{t}\gamma$ events
- Numerous as yet unconfirmed theories lead to such signatures
 - SUSY, Technicolor, associated Higgs production...

Diphoton + X searches

arXiv:0910.5170v2 submitted to PRD

- Two triggered photons
 - 2 photon candidates
 - both isolated with $E_T > 12$ GeV
 - no isolation requirement but both with $E_T > 18$ GeV
- Candidate events have:
 - 2 candidates with $E_T > 13$ GeV & $0.05 < |\eta| < 1.05$
 - shower maximum lateral profile consistent with single shower
 - no high P_T tracks pointing at the candidate
 - isolation (track and calorimeter) in a cone of $\Delta\eta, \Delta\phi$ with $R < 0.4$
 - calorimeter $0.1 \times E_T$ for $E_T < 20$ GeV or 2.0 GeV + $0.02 \times (E_T - 20)$ GeV above 20 GeV
 - track:: 2.0 GeV + $0.005 \times E_T$
- Sample of $\gamma\gamma$ from 2.0 ± 0.1 fb⁻¹
 - 31,116 candidates (~30% true diphotons)
 - 42,708 control events with at least one failed γ

$\gamma\gamma$ plus τ results

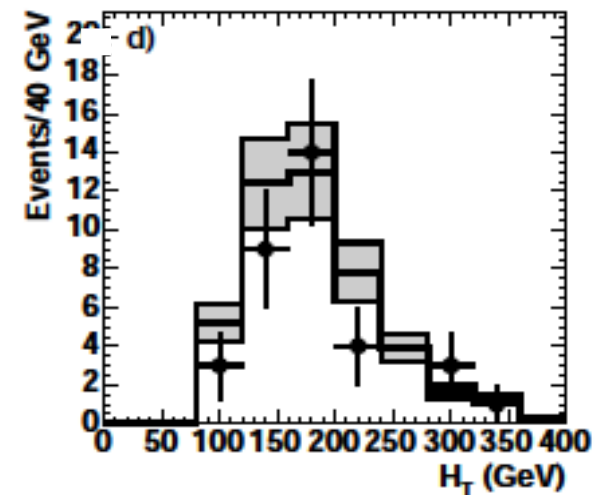
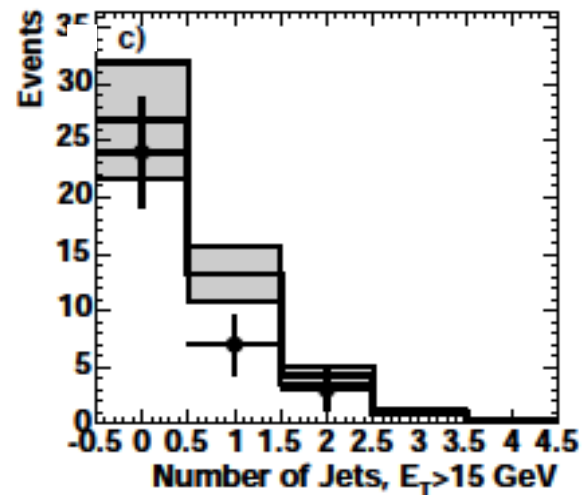
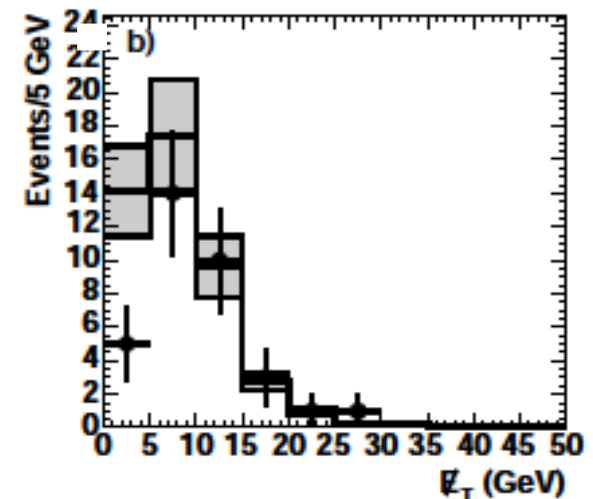
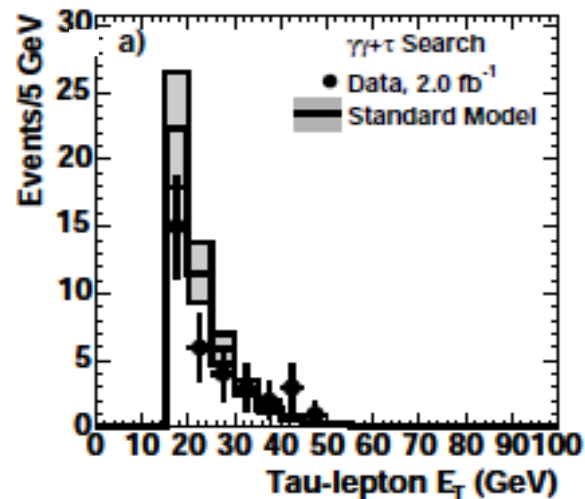


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- τ reconstruction using calorimeter and shower max. for π^0 plus tracking
 - Mass $< 1.8 \text{ GeV}/c^2$
 - Reconstruction in cone with size dependent on E_T
 - $\theta < 0.17$ for 30 GeV
 - $\theta < 0.05$ for 100 GeV
 - Isolation annulus with outer radius of 0.52
 - Track $P_T < 1.0 \text{ GeV}$
 - $\pi^0 E_T < 0.6 \text{ GeV}$
- 34 events observed in $2.0 \pm 0.1 \text{ fb}^{-1}$
 - Expect 46 ± 10

$\gamma\gamma$ plus τ results

- Fake τ dominates the background (44 out of 46 events)

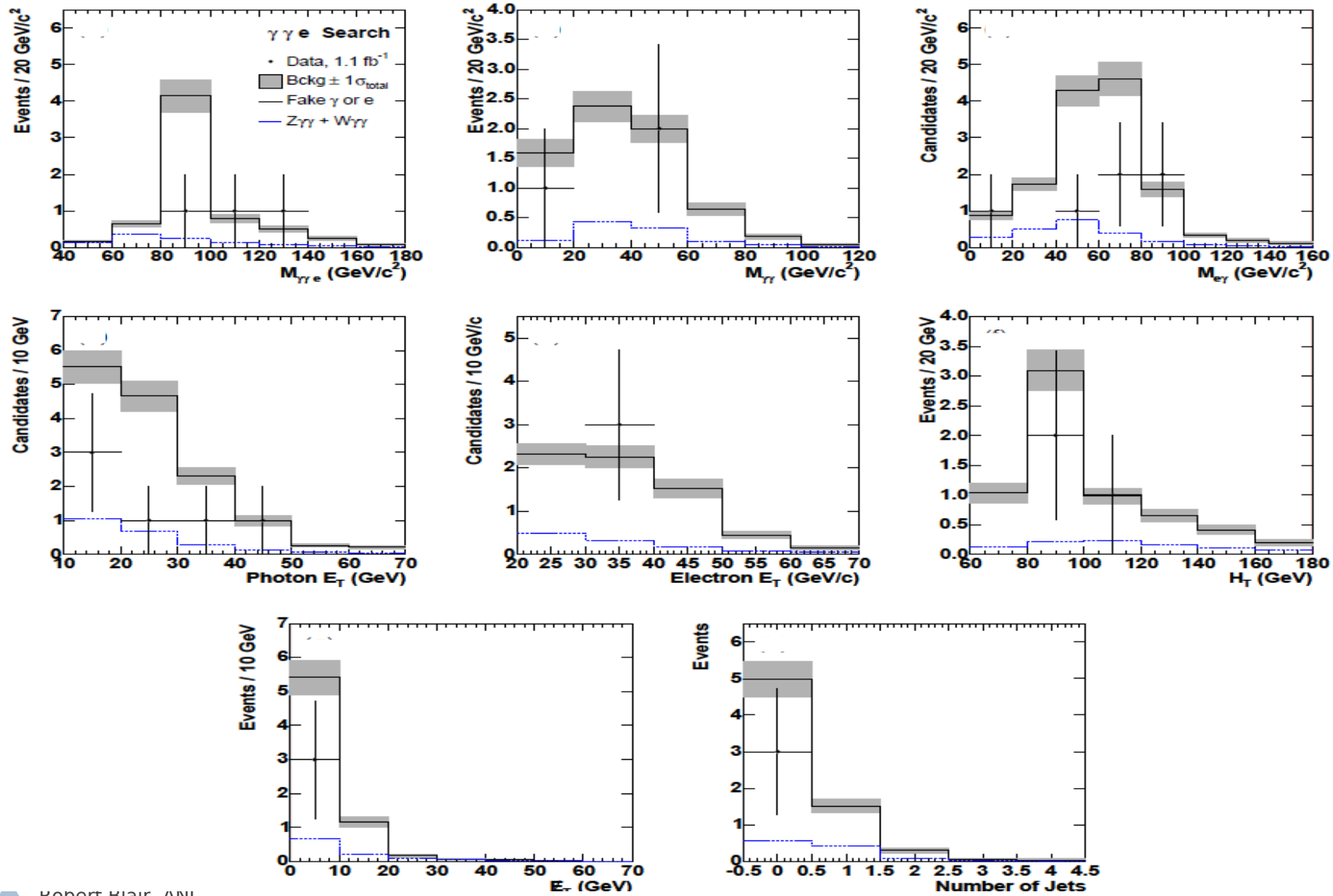


$\gamma\gamma$ plus lepton results

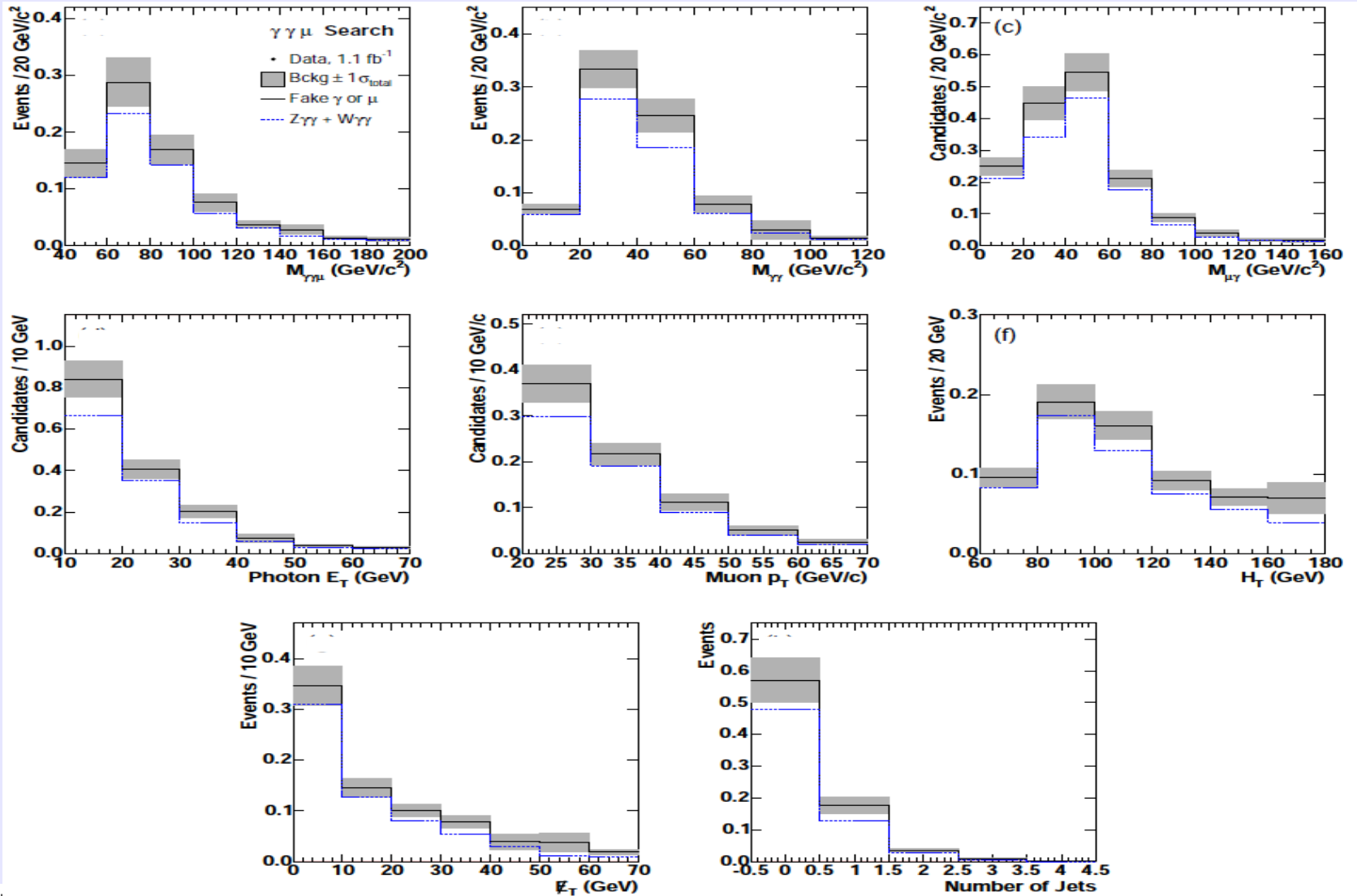
- $1.1 \pm 0.1 \text{ fb}^{-1}$
- $E_T^{\gamma} > 20 \text{ GeV}$
- SM sources estimated using Madgraph+Pythia for Z/W $\gamma\gamma$ K factor of 1.4 for LO \rightarrow NLO
- Background estimates come from event sample plus rates of jet or e to fake gamma
- Table includes a cut on silicon hits pointing at γ (events plotted don't have this cut which adds 2 such events)

Source	electron	muon
Z $\gamma\gamma$	0.82 ± 0.08	0.50 ± 0.05
W $\gamma\gamma$	0.15 ± 0.02	0.08 ± 0.01
l γ +e $\rightarrow\gamma$	2.26 ± 0.46	0.004 ± 0.004
l γ +jet $\rightarrow\gamma$	0.44 ± 0.26	0.12 ± 0.08
Fake l+ $\gamma\gamma$	0.12 ± 0.05	0.004 ± 0.004
Total	3.79 ± 0.54	0.71 ± 0.10
Observed	1	0

$\gamma\gamma$ plus electron results



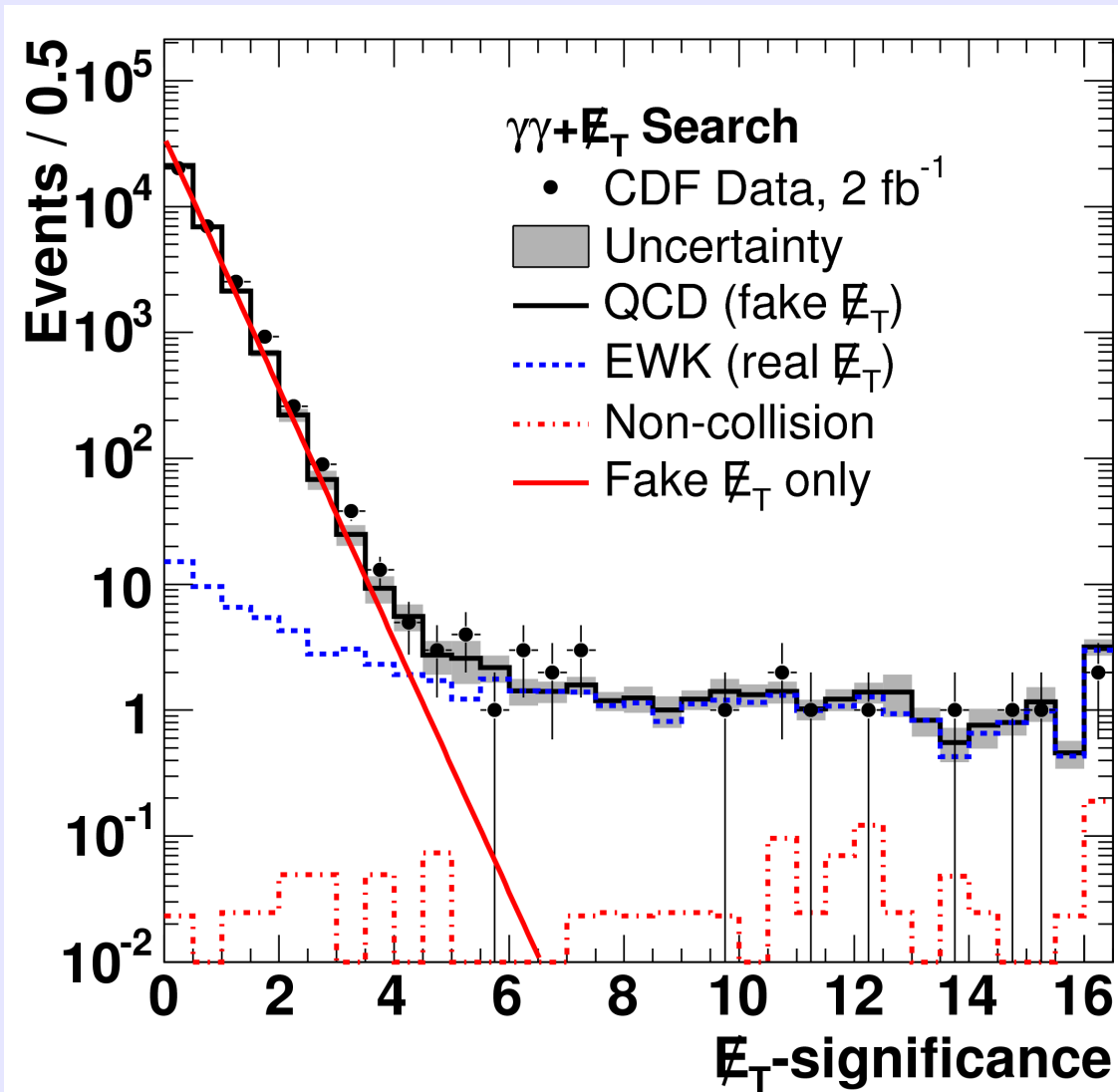
Expected muon distributions



$\gamma\gamma$ plus ~~E_T~~

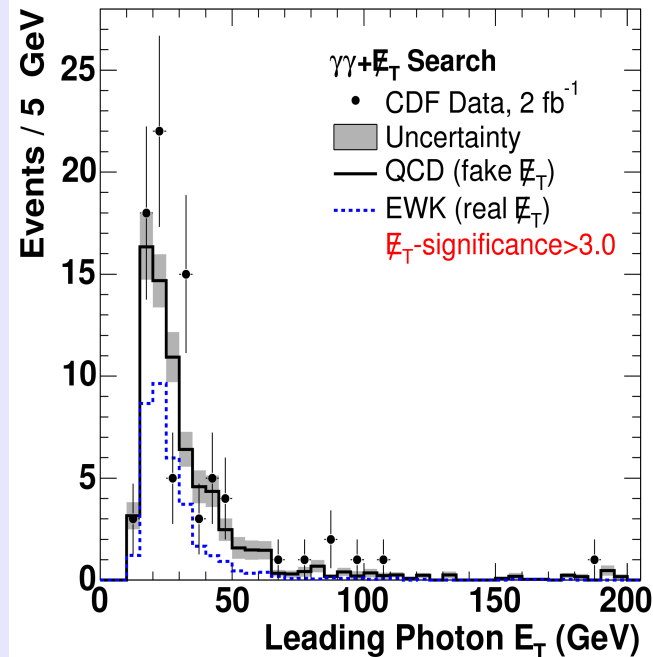
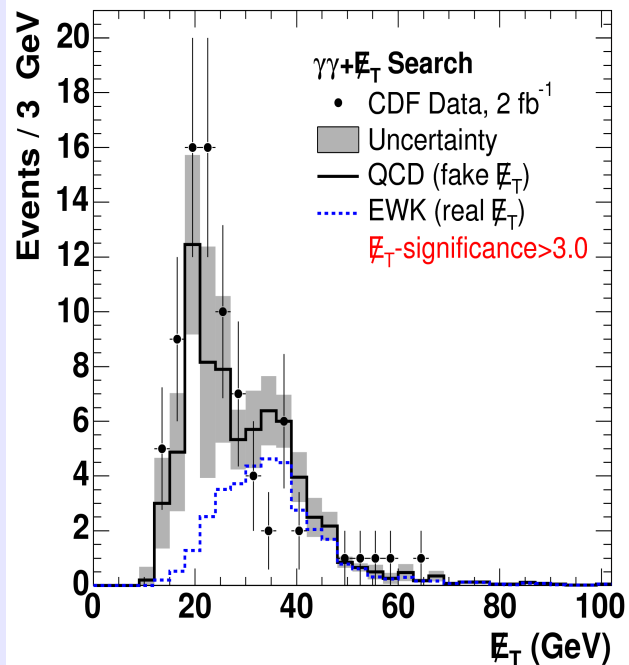
- Missing E_T modeled using detailed understanding of jet resolution and underlying event contribution
 - Significance constructed to estimate log likelihood of a given event missing E_T
- Several other sources estimated
 - Incorrect vertex
 - Other vertices considered and if one produces less missing E_T it is used instead
 - Leaves cases where other vertex is not reconstructed (this contribution is estimated)
 - Three gamma events with a missing gamma (this is estimated from the data)
 - Non collision events (cosmic rays) TDC's used to estimate this

$\gamma\gamma$ plus missing E_T



$\gamma\gamma$ plus missing E_T

	signif.>3	signif.>4	signif.>5
EWK	35.4 ± 2.2	29.9 ± 2.0	25.9 ± 1.9
Total exp.	71.7 ± 7.5	39.0 ± 3.1	30.4 ± 2.4
Observed	82	31	23

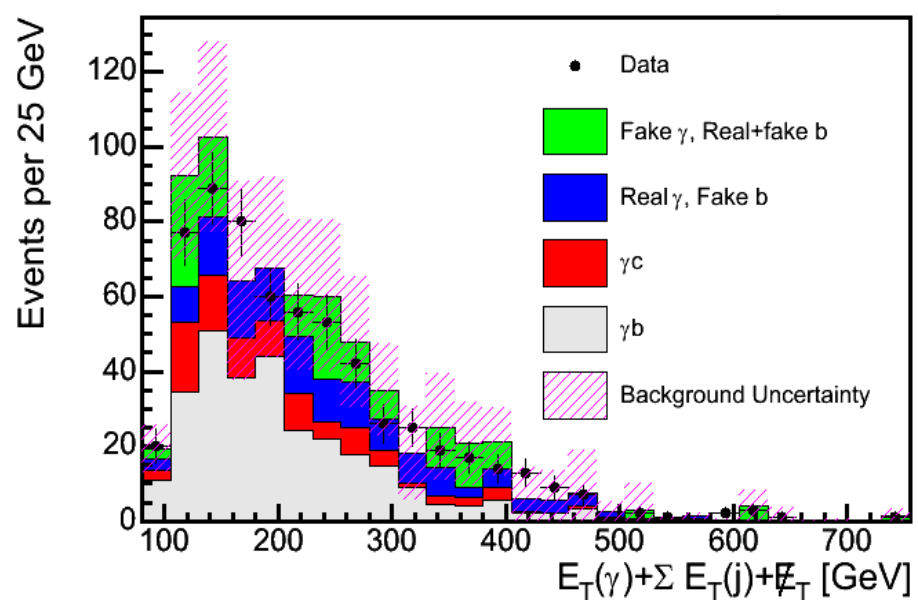
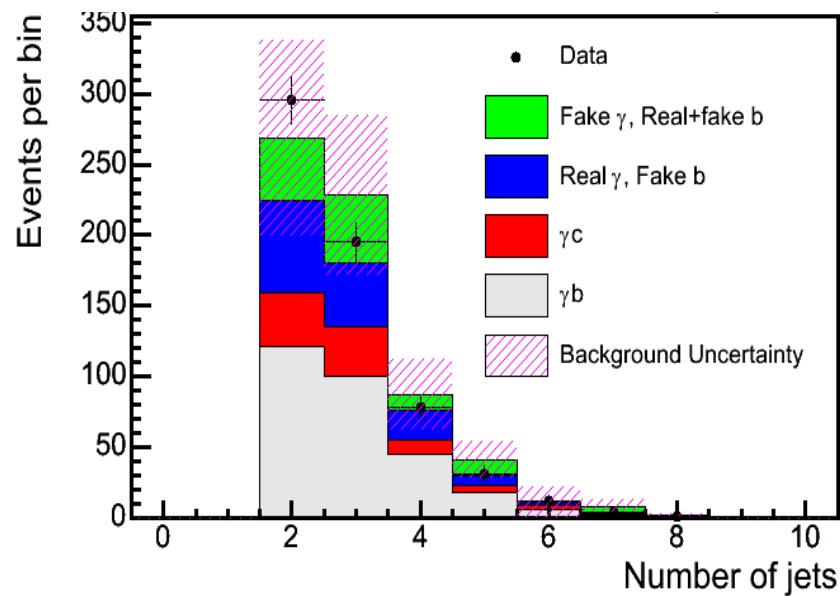
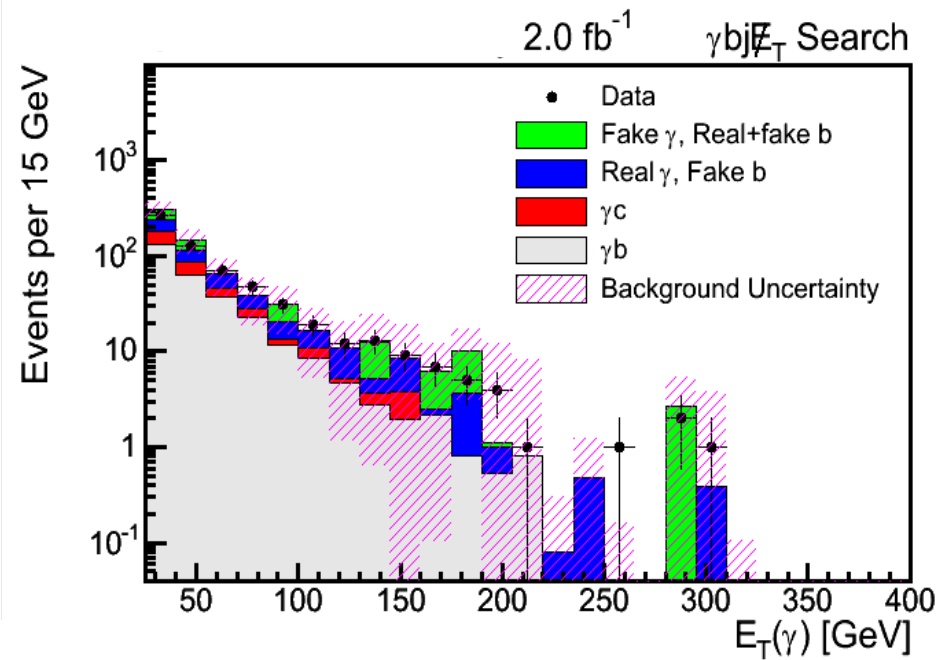
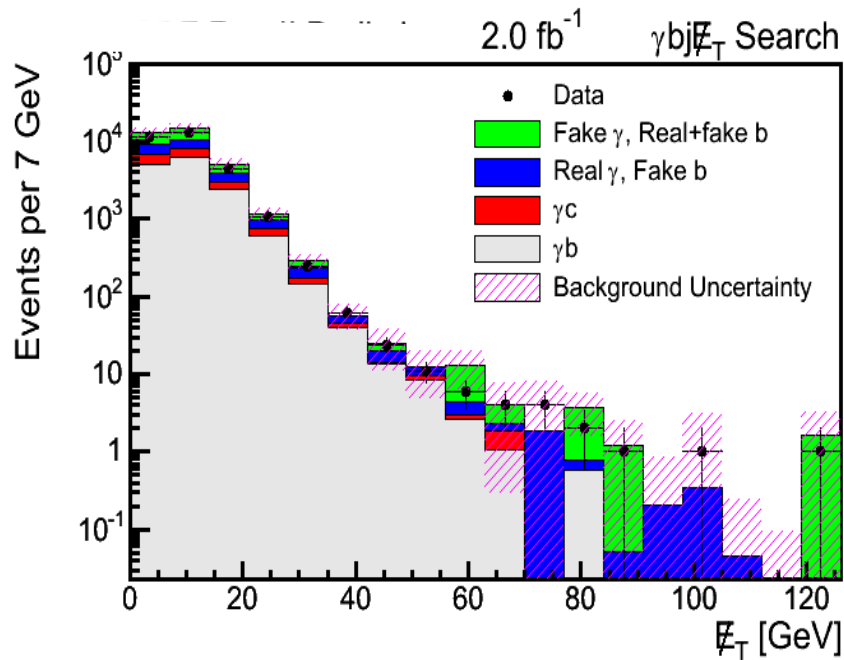


γ + jet + b + missing E_T

PRD 80, 052003 (2009)

- Photon candidate with $E_T > 25$ GeV and $|\eta| < 1.1$
- Two jets with $E_T > 15$ GeV and $|\eta| < 2.0$
- $\Delta R > 0.4$ for all of the above (γ and jets)
- Missing $E_T > 25$ GeV
- $\Delta\phi(\text{jet and met}) > 0.3$
- 1 SECondary VerTeX (SECVTX) b tag
 - 617 events satisfy above
 - Expect $607 \pm 74(\text{stat.}) \pm 86(\text{syst.})$
 - This includes $115 \pm 49 \pm 54$ fake γ and $141 \pm 6 \pm 30$ true γ fake b
 - γ b ($341 \pm 18 \pm 91$) dominates
- Veto events with track ($P_T > 20$ GeV) carrying $> 90\%$ track ΣP_T in $\Delta R < 0.4$
 - 17 events eliminated by this cut
- 600 events satisfy all cuts in 2.0 fb^{-1} sample

γ + jet + b + missing E_T



γ +b+missing E_T +lepton (e or μ)

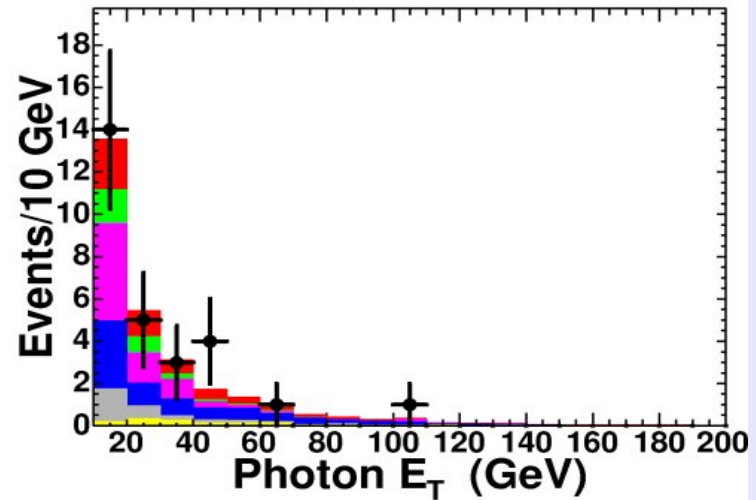
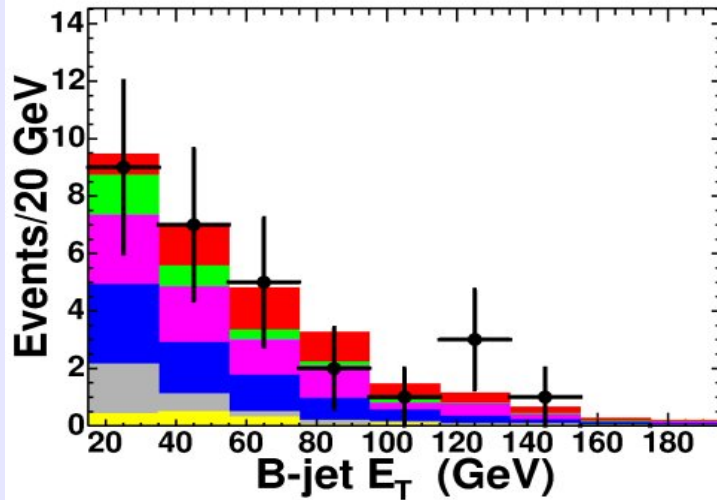
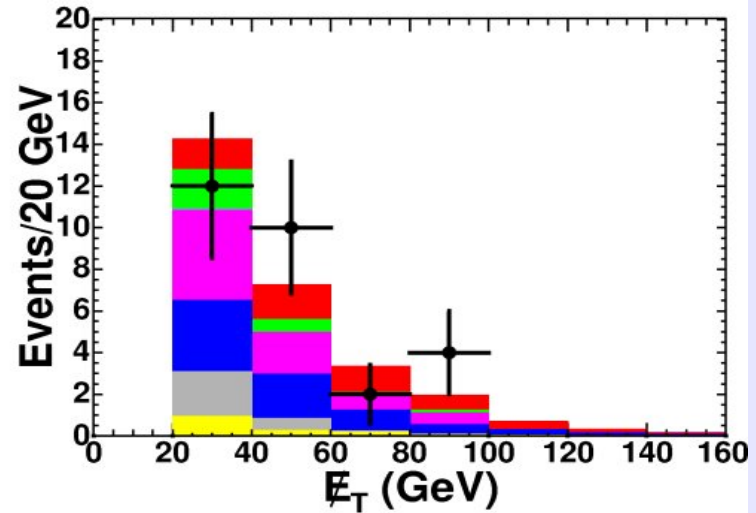
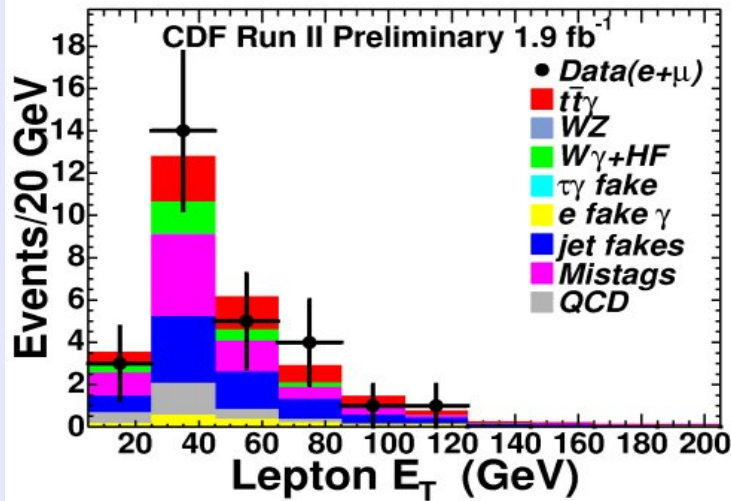
PRD 80, 011102(R) (2009)

- γ +b+missing E_T +lepton (e or μ) 1.9 fb^{-1} (trigger on high P_T lepton)
 - Central photon with $E_T > 10 \text{ GeV}$
 - B tagged jet with $E_T > 15 \text{ GeV}$
 - Missing $E_T > 20 \text{ GeV}$
 - e or μ with $E_T > 20 \text{ GeV}$
- 28 events observed
 - Expect $31.0(+4.1-3.9)$
 - Dominated by jets faking γ and mistagged b jets (7.58 ± 3.11 & 7.65 ± 0.70 respectively)
 - Top plus gamma come in next (semileptonic: 3.58 ± 0.65 & dilepton: 2.32 ± 0.41)
- subsample rich in $t\bar{t}\gamma$
 - require $H_T > 200 \text{ GeV}$
 - require $N_{\text{jets}} \geq 3$

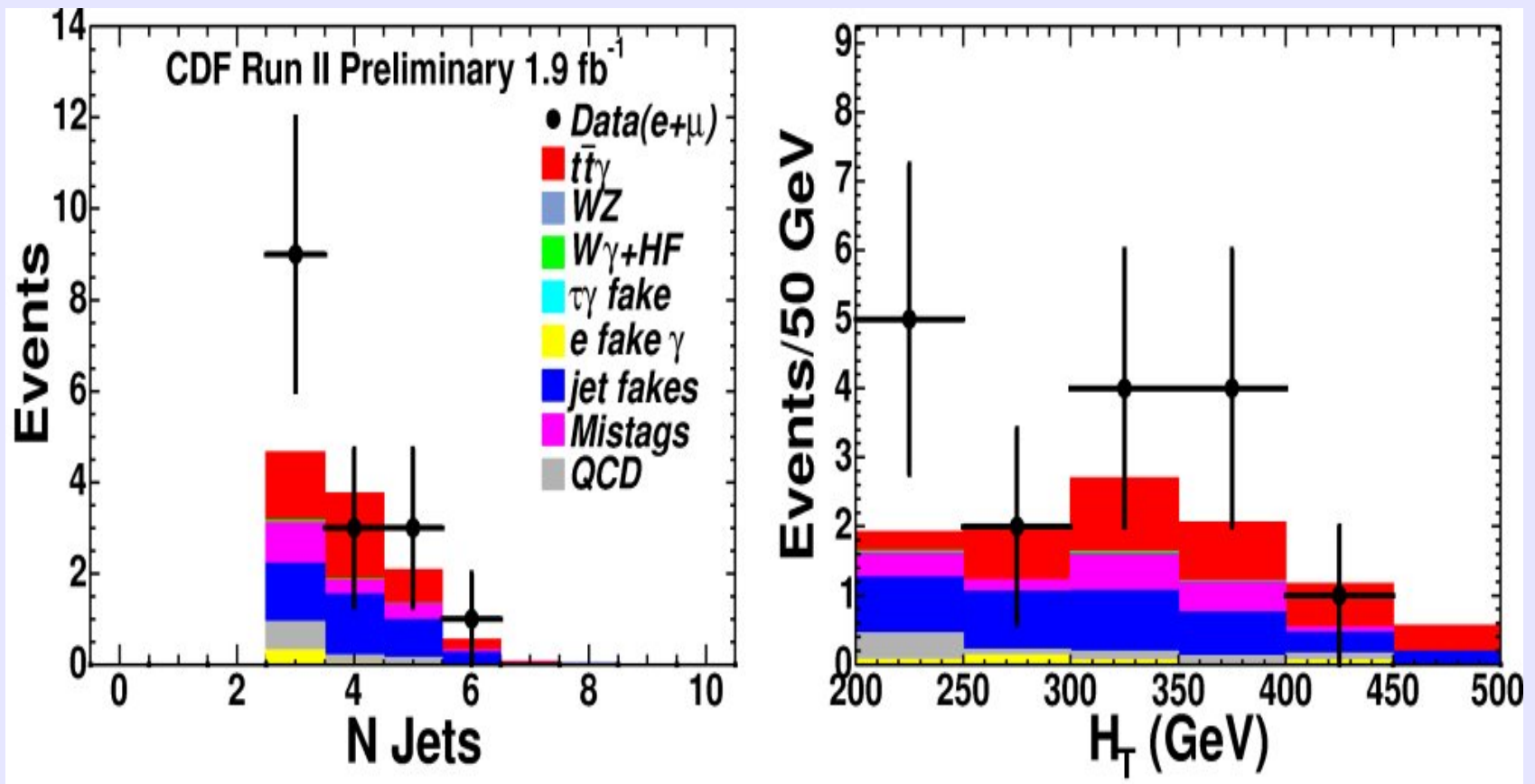
$\gamma + b + \text{missing } E_T + \text{lepton (e or } \mu)$

CDF Run II Preliminary, 1.9fb^{-1}			
Lepton + Photon + \cancel{E}_T + b Events			
SM Source	$e\gamma b\cancel{E}_T$	$\mu\gamma b\cancel{E}_T$	$(e + \mu)\gamma b\cancel{E}_T$
$t\bar{t}\gamma$ semileptonic	2.06 ± 0.38	1.52 ± 0.28	3.58 ± 0.65
$t\bar{t}\gamma$ dileptonic	1.30 ± 0.23	1.02 ± 0.18	2.32 ± 0.41
$W^\pm c\gamma$	0.75 ± 0.16	0.72 ± 0.15	1.47 ± 0.26
$W^\pm cc\gamma$	0.08 ± 0.04	0.22 ± 0.06	0.30 ± 0.08
$W^\pm bb\gamma$	0.62 ± 0.11	0.42 ± 0.08	1.04 ± 0.17
$Z(\tau\tau)\gamma$	0.13 ± 0.09	0.11 ± 0.08	0.24 ± 0.12
WZ	0.08 ± 0.04	0.01 ± 0.01	0.09 ± 0.04
$\tau \rightarrow \gamma$ fake	0.12 ± 0.01	0.10 ± 0.01	0.22 ± 0.01
Jet faking γ	4.56 ± 1.92	3.02 ± 1.19	7.58 ± 3.11
Mistags	4.11 ± 0.41	3.54 ± 0.37	7.65 ± 0.70
QCD	1.49 ± 0.77	0_{-0}^{+1}	$1.49_{-0.77}^{+1.30}$
$ee\cancel{E}_T b, e \rightarrow \gamma$	1.50 ± 0.28	–	1.50 ± 0.28
$\mu e\cancel{E}_T b, e \rightarrow \gamma$	–	0.45 ± 0.10	0.45 ± 0.10
Predicted	16.8 ± 2.2 (tot)	$11.1_{-1.4}^{+1.7}$ (tot)	$27.9_{-3.5}^{+3.6}$ (tot)
Observed	16	12	28

$\gamma + b + \text{missing } E_T + \text{lepton (e or } \mu)$

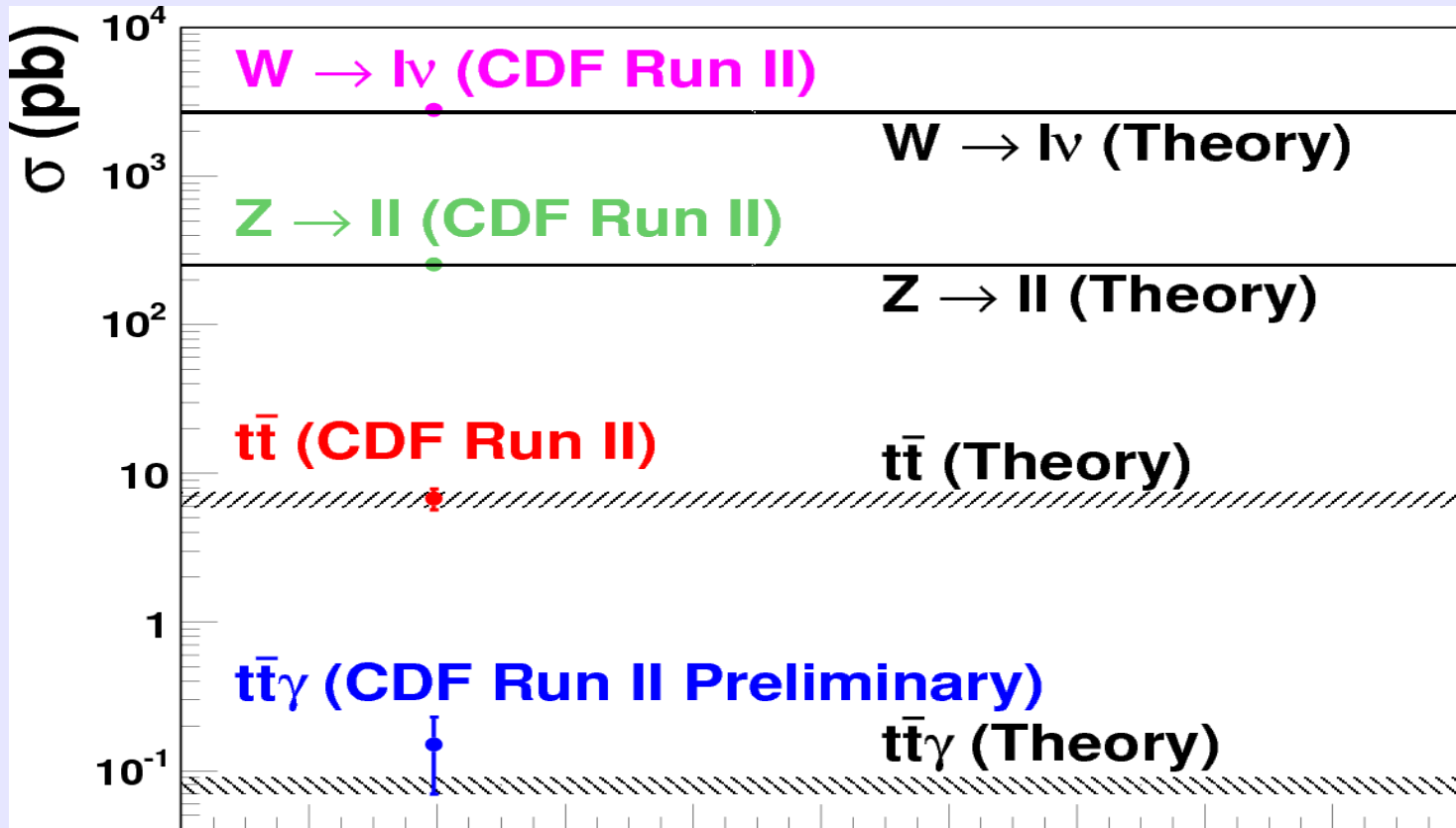


Require $H_T > 200$ GeV and $N_{\text{jets}} > 2$



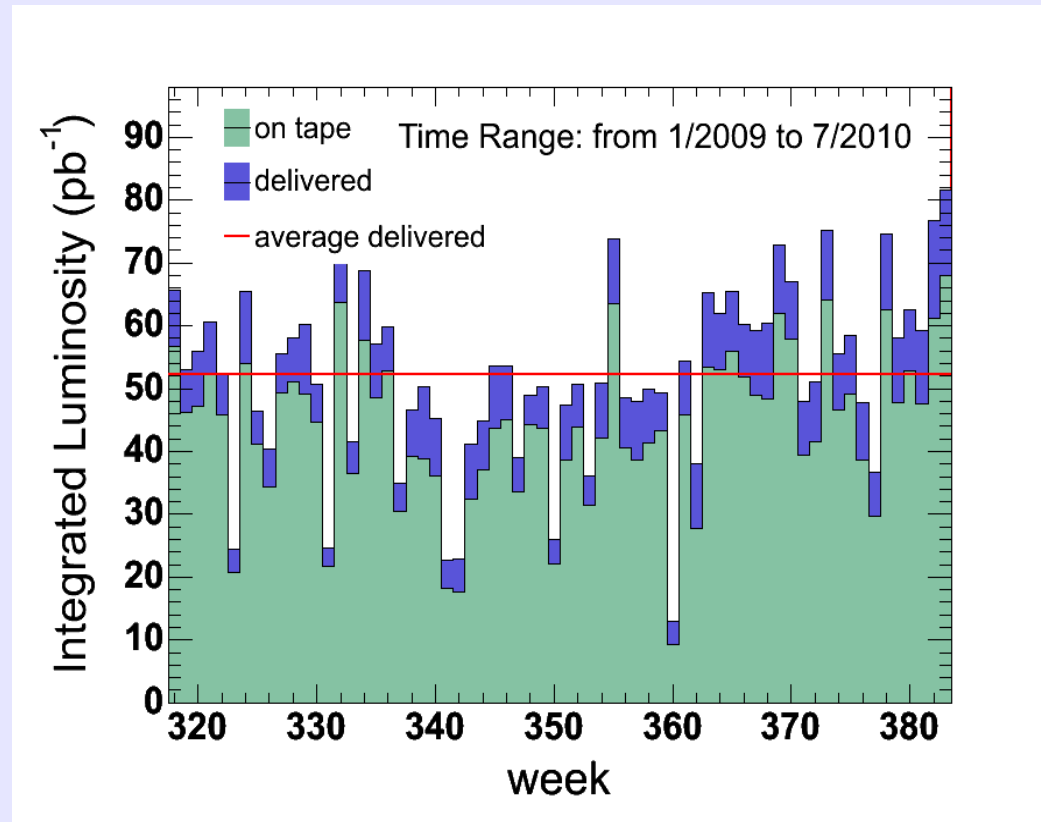
16 events with ~ 4 expected top plus gamma ($11.2+2.3-2.1$ expected total)

$\gamma + b + \text{missing } E_T + \text{lepton (e or } \mu)$



- Subtracting non-top sources yields $0.15 \pm 0.08 \text{ pb}$ for $t\bar{t}\gamma$

Conclusion



- No surprises so far.
- Tevatron physics is going strong!
 - Sensitive to processes that are two orders of magnitude rarer than top production
 - lots more data to come