Search for $\ell\gamma + X$ events

Andrey Loginov
for the CDF Collaboration

Search for $\ell\gamma + X$ events

Andrey Loginov
for the CDF Collaboration

- Introduction
- Samples
- Background Estimates
- Searches
  - $\ell\gamma \not{E}_{\mathrm{T}}$
  - $\ell\ell\gamma$
  - $\ell\gamma\gamma$, $e\mu\gamma$
- Conclusions

Motivation

$\surd$ **Well Motivated Theories**

→ **Most importantly Supersymmetry**
$\tilde{\ell} \to \ell\widetilde{\chi}_2^0$, $\widetilde{\chi}_2^0 \to \widetilde{\chi}_1^0\gamma$

$\surd$ **History**

→ **Follow up on some of the anomalies from CDF in Run I**

$\surd$ **The Photon is**

→ **coupled to electric charge**
→ **massless**
→ **stable**
→ **a boson**

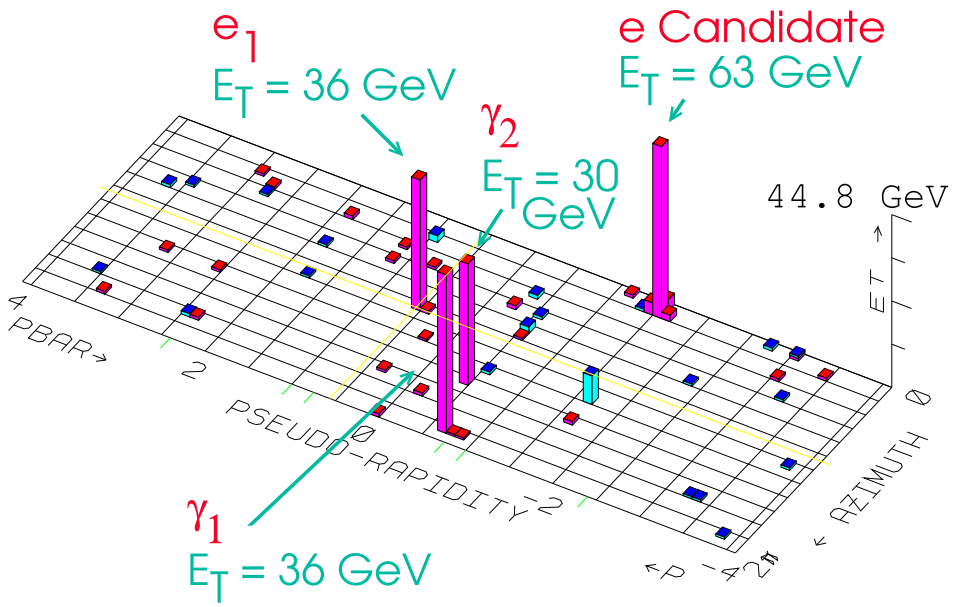
$\surd$ $\ell\gamma + X$

→ **Fundamental particles:** γ, Z^0, $W^{\pm}$
→ **SM Backgrounds are low for searches**

Motivation

Run I Results: $ee\gamma\gamma \not\!\!E_T$ Event

$ee\gamma\gamma \not\!\!E_T$ Candidate Event



$\not\!\!E_T$ = 55 GeV

Rare in the Standard Model

√Run I Searches for $\gamma\gamma$+X

Results consistent with the SM

(CDF PRL 81, 1791 (1998), PRD 59, 092002 (1999))

⇒ Search for $\ell\gamma$+X instead of $\gamma\gamma$+X

Run I Photon-Lepton Results (86 pb^{-1})

Category	μ_{SM}	N_0	$\mathbf{P}(N \geq N_0 \mid \mu_{SM})$, %
All $\ell\gamma X$	–	77	–
Z-like $e\gamma$	–	17	–
Two-Body $\ell\gamma X$	24.9±2.4	33	9.3
Multi-Body $\ell\gamma X$	20.2±1.7	27	10.0
Multi-Body $\ell\ell\gamma X$	5.8 ± 0.6	5	68.0
Multi-Body $\ell\gamma\gamma X$	0.02±0.02	1	1.5
Multi-Body $\ell\gamma \not\!\!E_T X$	7.6 ± 0.7	16	0.7

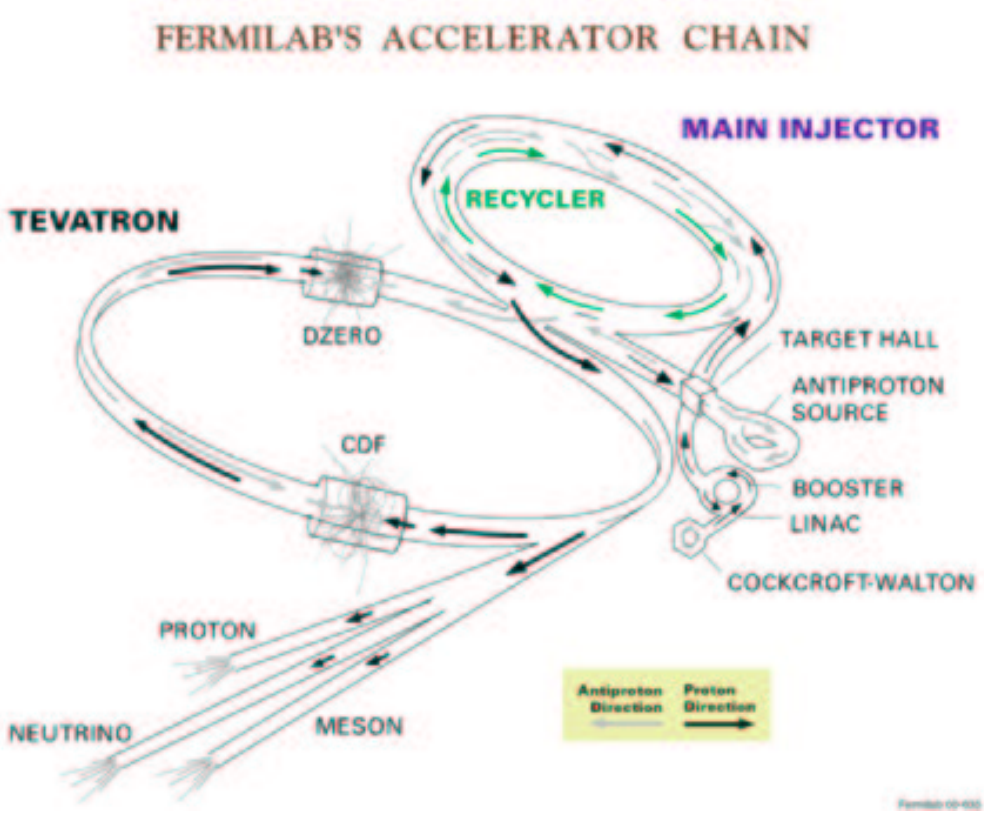
CDF PRL 89, 041802 (2002), PRD 66, 012004 (2002)

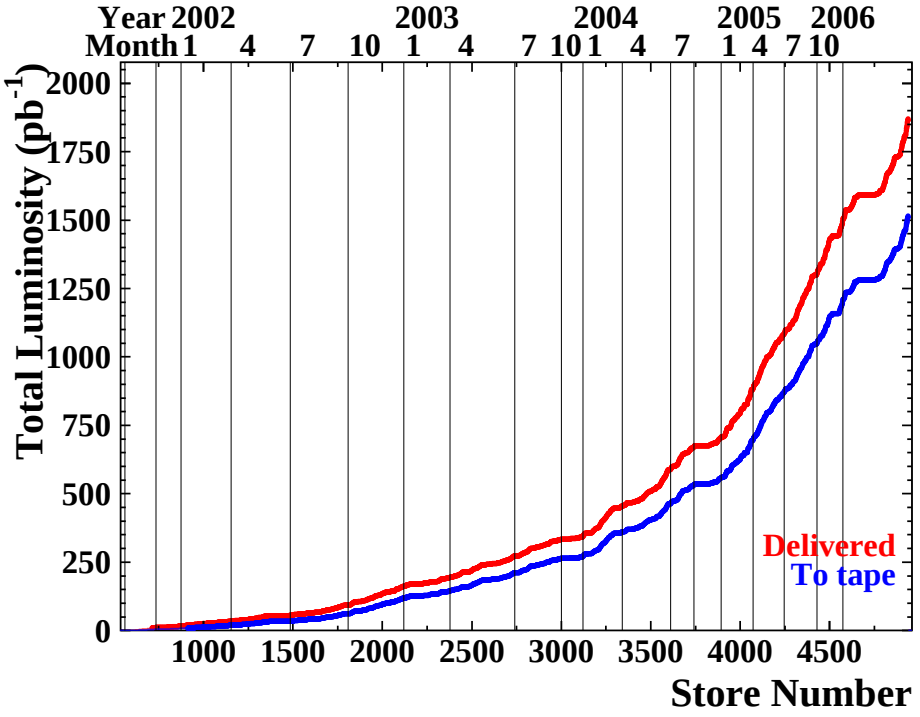
√Run II: Need more data.

Run I $\Rightarrow$ Run II

Tevatron

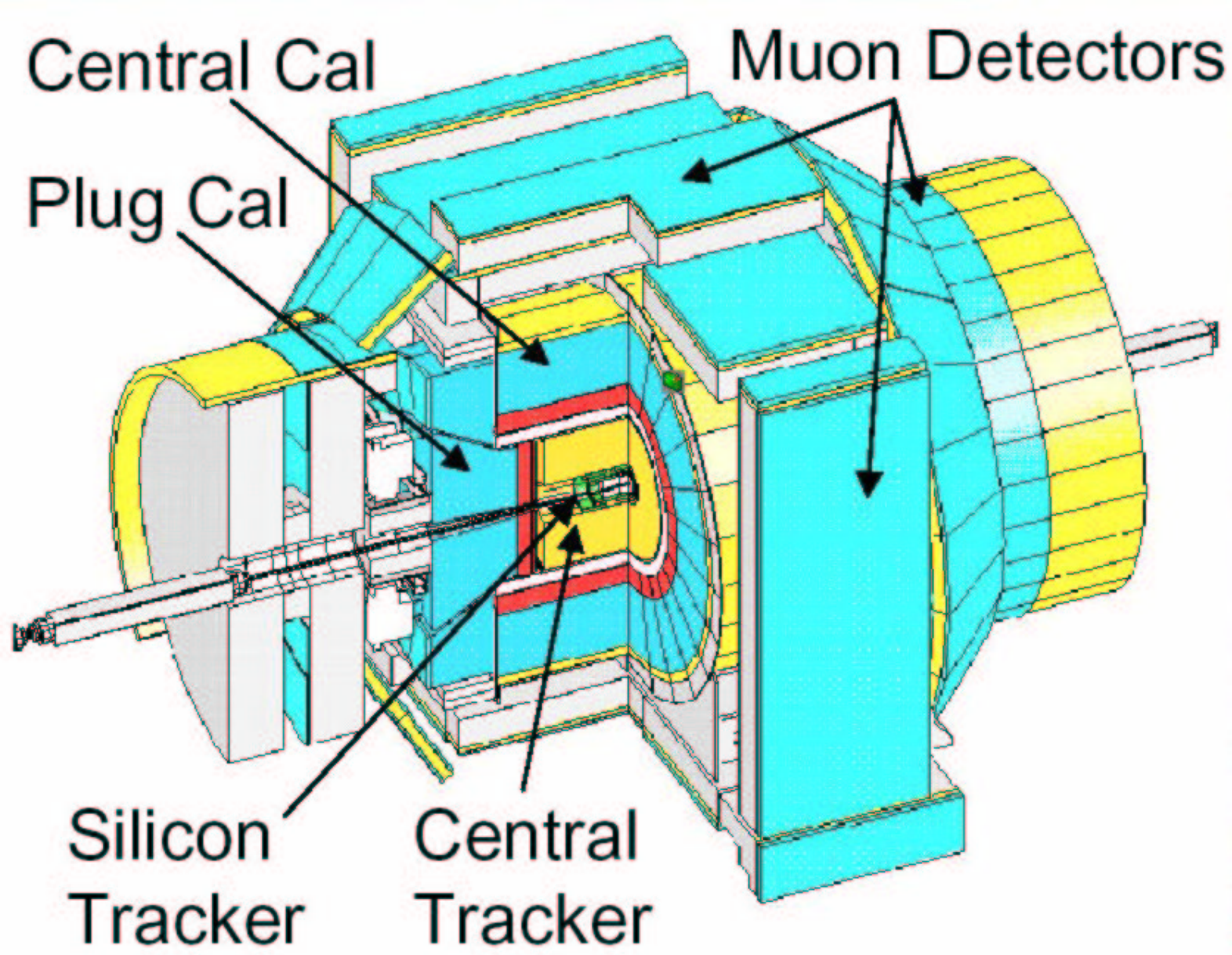
- $p\bar{p}$ **Collisions**
- $\sqrt{s}$**=1.96** TeV
- $\mathcal{L}_{peak} = \mathbf{2.2}\times 10^{32}$ **sm**$^{-2}$**s**$^{-1}$
  August, 31 2006!





- $\mathcal{L}$ for a week: 26.119 pb^{-1}
  July, 22-29 2006!
- $\mathcal{L}$ for a month (CDF): 94.4 pb^{-1}
  July 2006!

CDF


Central Cal
Muon Detectors
Plug Cal
Silicon Tracker
Central Tracker

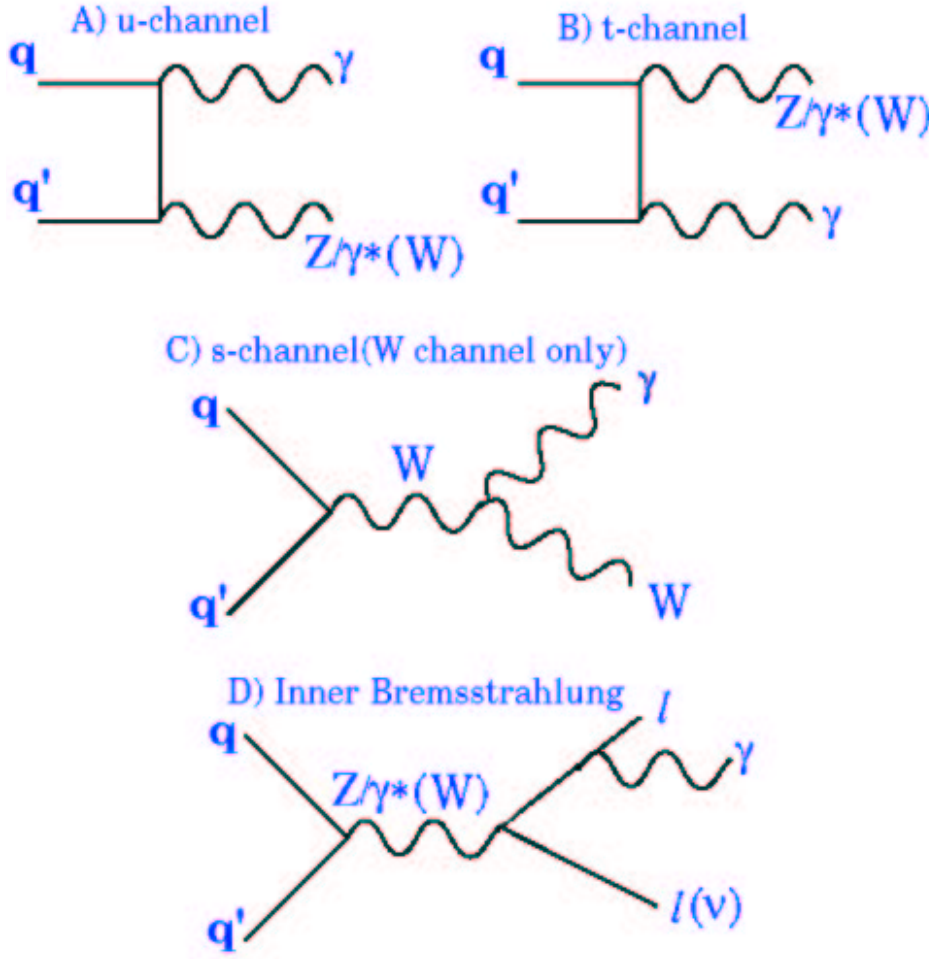
DATA

- $\mathcal{L} = 1\ fb^{-1}$ (2002 - 2006)
- *a priori* Selection Criteria:
  - 25 GeV for "tight" central ($|\eta| \lesssim 1$) objects: e, μ, γ
  - 25 GeV for $\not\!\!E_{\rm T}$
  - 20 GeV for "loose" central ($|\eta| \lesssim 1$) objects: e, μ
  - 15 GeV for electrons in end-plug calorimeter ($1 \lesssim |\eta| \lesssim 2$)
- DATA Samples (High-$P_{\rm T}$ Lepton OR High-$E_{\rm T}$ Photon Trigger)
  - Inclusive muon samples
  - Inclusive electron samples
  - Inclusive photon samples

MC

√ Standard Model Contribution

- MadGraph, CompHep and Baur SM LO MC
- $W\gamma$, $Z\gamma$, $W\gamma\gamma$, $Z\gamma\gamma$ Samples

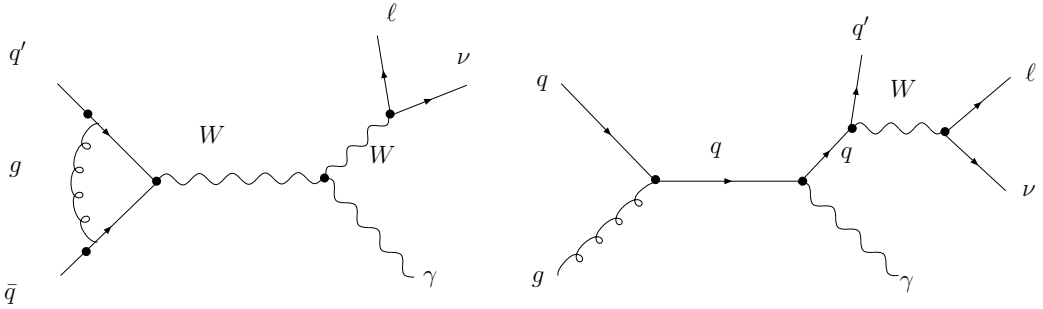


√ From LO to NLO:

A correction for higher-order processes that depends on both the dilepton mass and photon E_T has been applied:

$$K_{factor} = \frac{\sigma_{NLO}}{\sigma_{LO}}$$

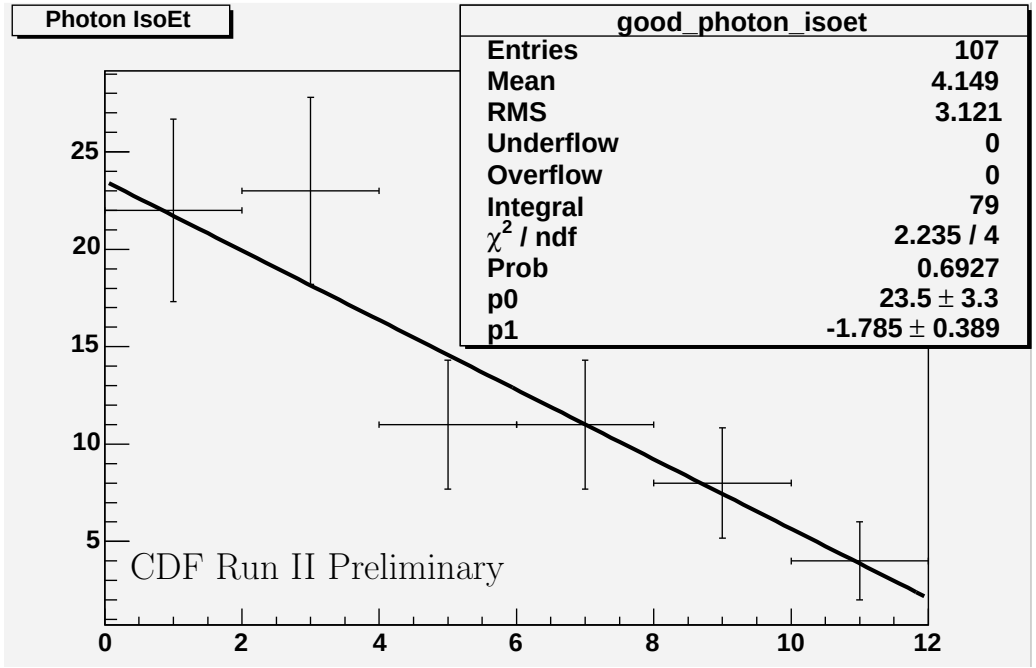
U.Baur, T.Han, J.Ohnemus PRD 48:5140,1993
U.Baur, T.Han, J.Ohnemus PRD 57:2823-2836,1998



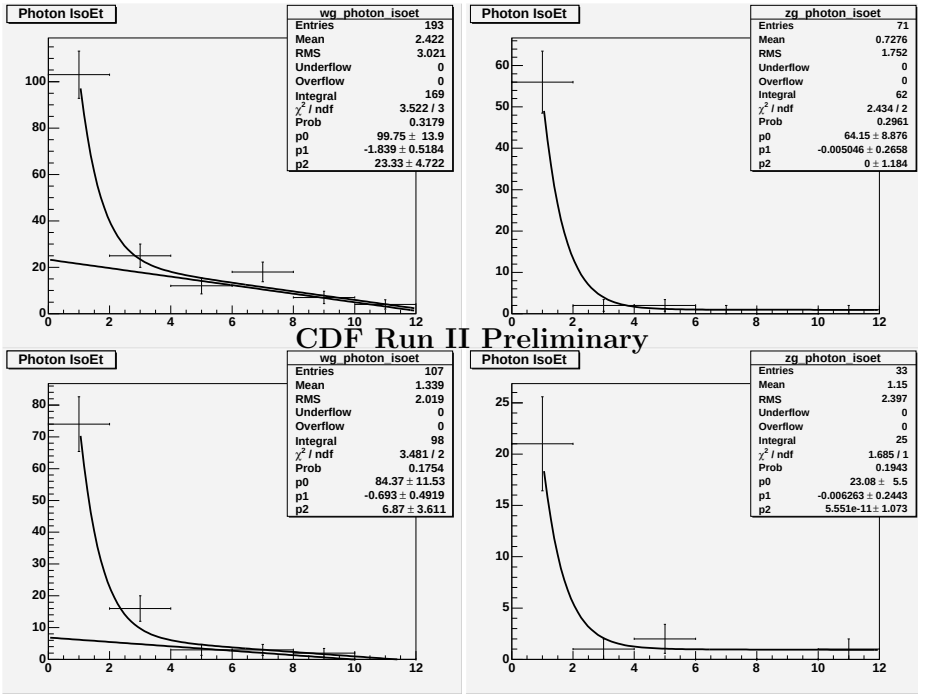
Backgrounds

- √ **Diboson and Triboson production**
  - Baur and MadGraph $Z\gamma$, $W\gamma$, $Z\gamma\gamma$, $W\gamma\gamma$ samples for e's, μ's, τ's
- √ **Jet faking photon:** $\ell j + X$**,** $j \to \gamma$
  - use the calorimeter isolation for photons for $\ell\gamma \not{E}_{\rm T}$ and $\ell\ell\gamma$
  - jet faking photon rate for $\ell\gamma\gamma$ and $e\mu\gamma$
- √ **Electron faking photon:** $\ell e + X$**,** $e \to \gamma$
  - use events with back-to-back $e\gamma$ with $M_{e\gamma}$ within 10 GeV of M_{Z^0}
- √ **Jets faking** ℓ **and** $\not{E}_{\rm T}$
  - study the total $\rm P_T$ of tracks in a cone in $\eta - \varphi$ space of radius $R = 0.4$ around the lepton track
- √ **Kaons decays-in-flight**
  - use the number of transitions

$jet \to \gamma$ Background Estimates



(a) **Calorimeter isolation for a π^0 sample**



(b) **Background estimate for $\ell\gamma \not\!\!E_{\mathrm{T}}$ and $\ell\ell\gamma$ samples**

Figure 1: Linear behaviour of the background - from fake photon sample ("π^0"): we reject real photons (based on shower max detector); we also omit calorimeter and track isolation requirements. Signal behaviour - from $\mathrm{Z}^0 \to e^+e^-$.

QCD (Jets faking lepton and $\not\!\!E_T$)

"Track Iso": total P_T of tracks in a cone in $\eta - \varphi$ space of radius $R = 0.4$ around the lepton track

Samples:

- **Non-W/Z sample**: 1 ℓ + jet(s), no W or Z candidates
- **Golden-Lepton**: Tight ℓ's, $Z^0 \to \ell^+\ell^-$ close to Z^0 mass
- **Signal Sample**: $\ell\gamma\not\!\!E_T$ or $ll\gamma$
- **Jet Faking Photon**: $\ell j\not\!\!E_T$ or $\ell\ell j$

Track Iso Regions:

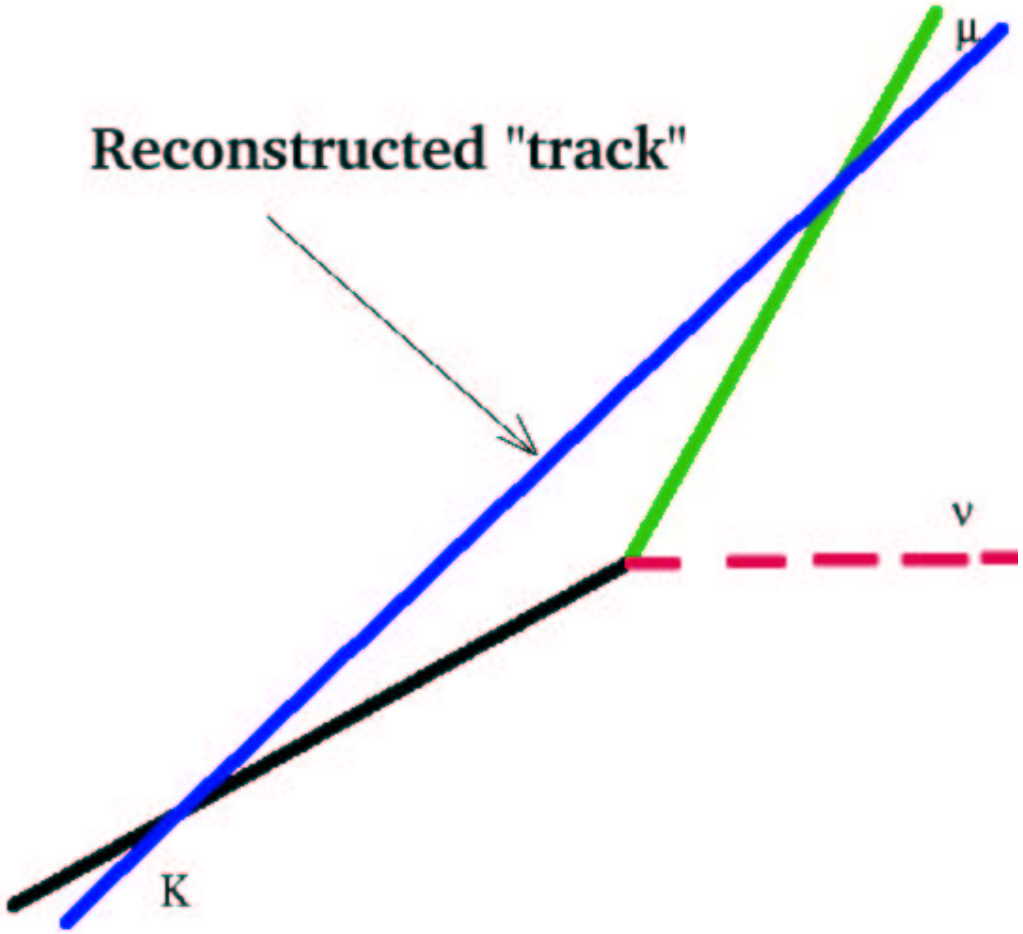
- **Isolated, Non-Isolated, Intermediate**

Procedure:

- Estimate fraction of Non-Isolated *golden* leptons
- Estimate fraction of Isolated *non-W/Z* leptons
- Estimate **QCD(Jets faking lepton and $\not\!\!E_T$)** background
- Vary Track Iso Regions to get systematics

Decays-In-Flight

Number of transitions, N_{tr} defined as the number of times a hit in Central Tracker (COT) is on the opposite side of a track from the previous hit as one goes along the track, for muon tracks.



Decays-In-Flight

Number of transitions, N_{tr} defined as the number of times a hit in Central Tracker (COT) is on the opposite side of a track from the previous hit as one goes along the track, for muon tracks.

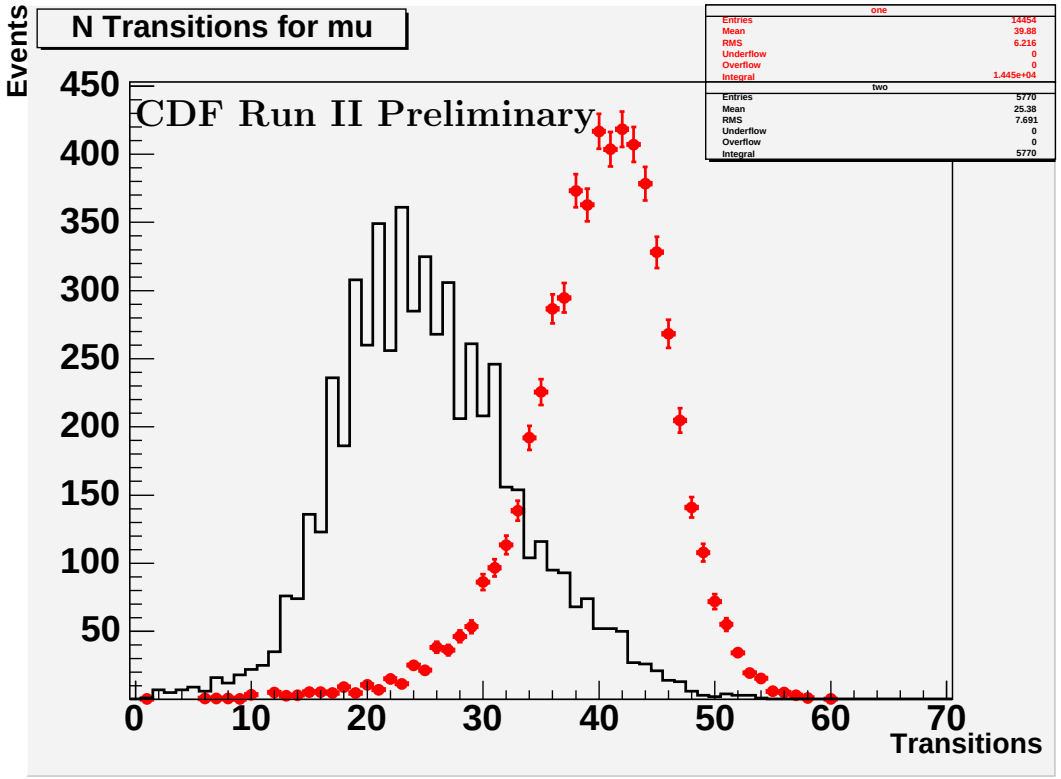


Figure 2: **μ's from DIF sample(black histogram) vs. μ's from Z's (red dots).**

Decays-In-Flight (DIF) sample: μ with large d_0, jet(s), $\not\!\!E_{\rm T}$ >25 GeV

Photon-Lepton Observed Events

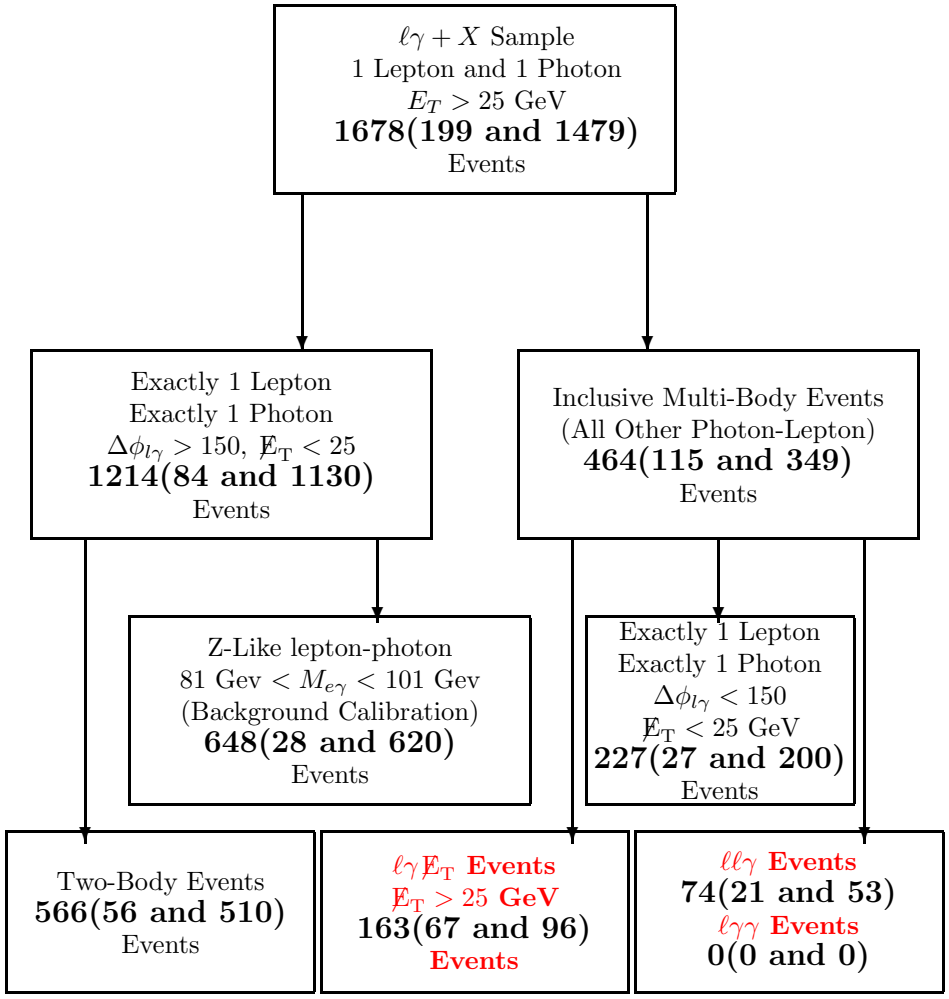


Figure 3: $\ell\gamma + X$ Sample. The number of events in each subcategory is given as a sum of muons and electrons (number of muons, number of electrons)

$\ell\gamma \not\!\!E_{\rm T}$

CDF Run II Preliminary, $929pb^{-1}$			
Lepton+ Gamma $+\not\!\!E_{\rm T}$ Events			
Standard Model Source	$e\gamma \not\!\!E_{\rm T}$	$\mu\gamma \not\!\!E_{\rm T}$	$(e+\mu)\gamma \not\!\!E_{\rm T}$
$W^{\pm}\gamma$	41.65 ± 4.84	29.85 ± 5.62	71.50 ± 10.01
$Z^0/\gamma + \gamma$	3.65 ± 1.31	14.10 ± 2.36	17.75 ± 3.65
$W^{\pm}\gamma\gamma$	0.32 ± 0.042	0.18 ± 0.025	0.50 ± 0.064
$Z^0/\gamma + \gamma\gamma$	0.087 ± 0.012	0.38 ± 0.048	0.47 ± 0.058
$t\bar{t}\gamma$	0.22 ± 0.029	0.13 ± 0.019	0.35 ± 0.045
$Z^0 \to e^+e^-, e \to \gamma$	9.59 ± 0.76	–	9.59 ± 0.76
Jet faking γ	21.5 ± 4.80	6.2 ± 3.60	27.7 ± 6.00
$\tau\gamma$ contribution	2.15 ± 0.56	0.76 ± 0.24	2.91 ± 0.65
QCD(Jets faking ℓ and $\not\!\!E_{\rm T}$)	15.0 ± 4.12	0.0 ± 0.100	15.0 ± 4.12
DIF (Decays-In-Flight)	–	2.3 ± 0.72	2.3 ± 0.72
Total	$94.17 \pm 8.14(tot)$	$53.90 \pm 7.11(tot)$	$148.07 \pm 12.97(tot)$
Observed in Data	96	67	163

Figure 4: $\ell\gamma \not\!\!E_{\rm T}$

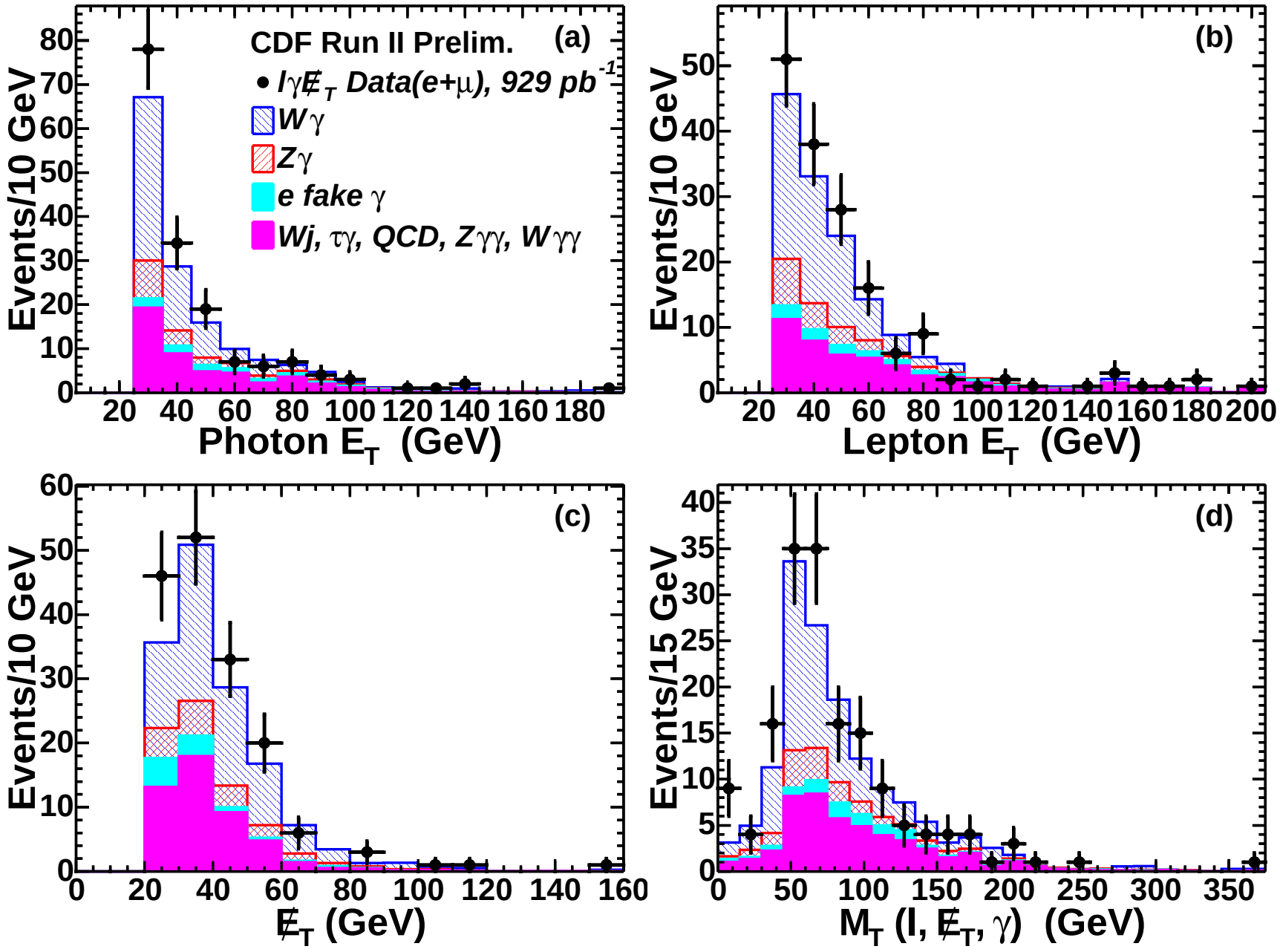
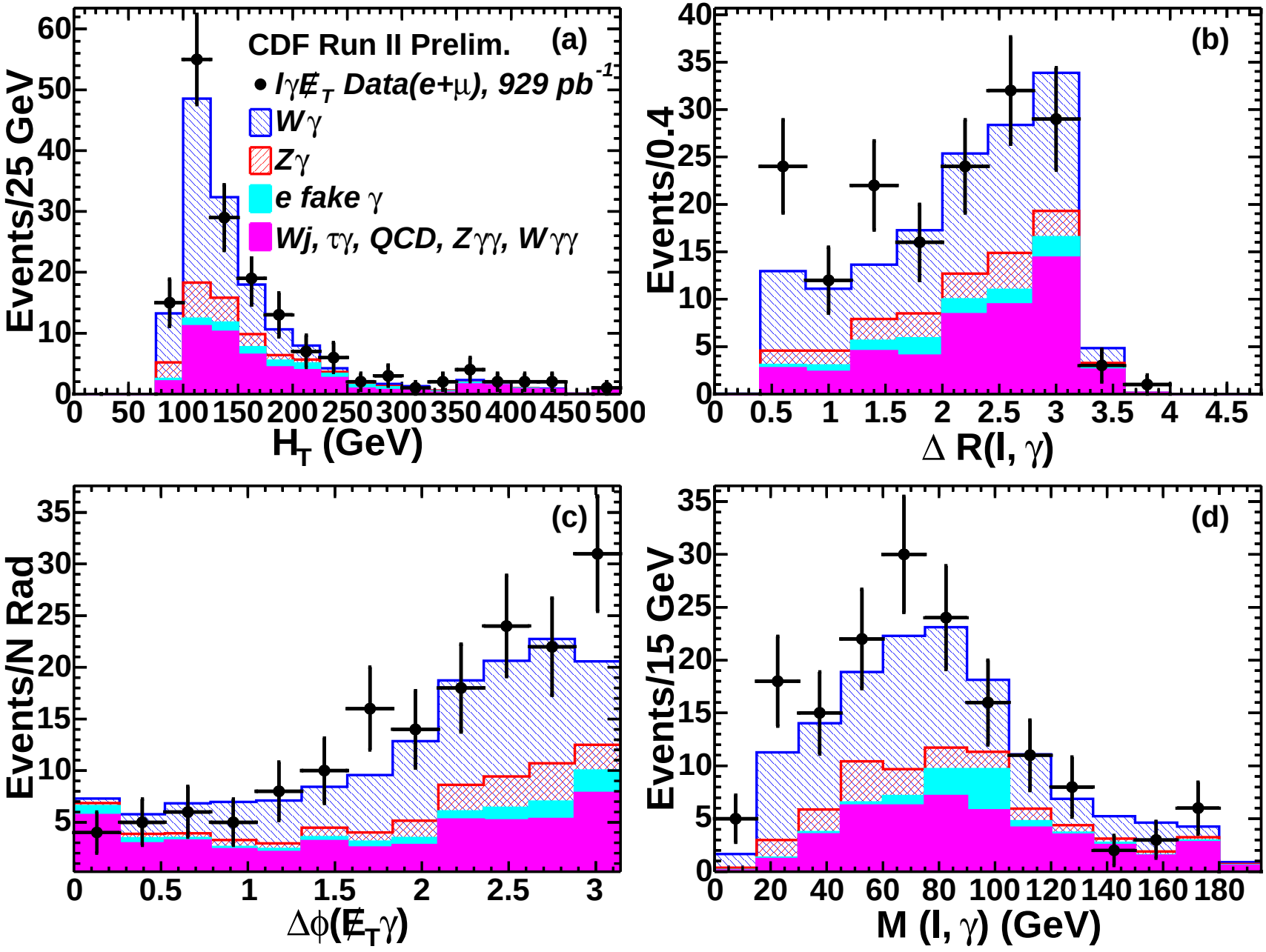


Figure 5: $\ell\gamma \not\!\!E_{\rm T}$



$\ell\ell\gamma$

CDF Run II Preliminary, $929pb^{-1}$			
Multi-Lepton + Photon Predicted Events			
SM Source	$ee\gamma$	$\mu\mu\gamma$	$\ell\ell\gamma$
$Z^0\gamma$	37.85 ± 4.65	25.55 ± 2.88	63.40 ± 7.48
$Z^0\gamma\gamma$	0.72 ± 0.088	0.40 ± 0.050	1.12 ± 0.13
Z^0+Jet, jet faking γ	0.0 ± 1.20	0.0 ± 1.10	0.0 ± 1.60
$Z^0 \to e^+e^-, e \to \gamma$	0.38 ± 0.11	–	0.38 ± 0.11
QCD (Non-WZ) fakes	0.0 ± 0.20	0.0 ± 0.100	0.0 ± 0.20
DIF (Decays-In-Flight)	–	0.0 ± 0.20	0.0 ± 0.20
Total	$38.95 \pm 4.80(tot)$	$25.95 \pm 3.09(tot)$	$64.93 \pm 7.65(tot)$
Observed	53	21	74

Figure 6: $\ell\ell\gamma$

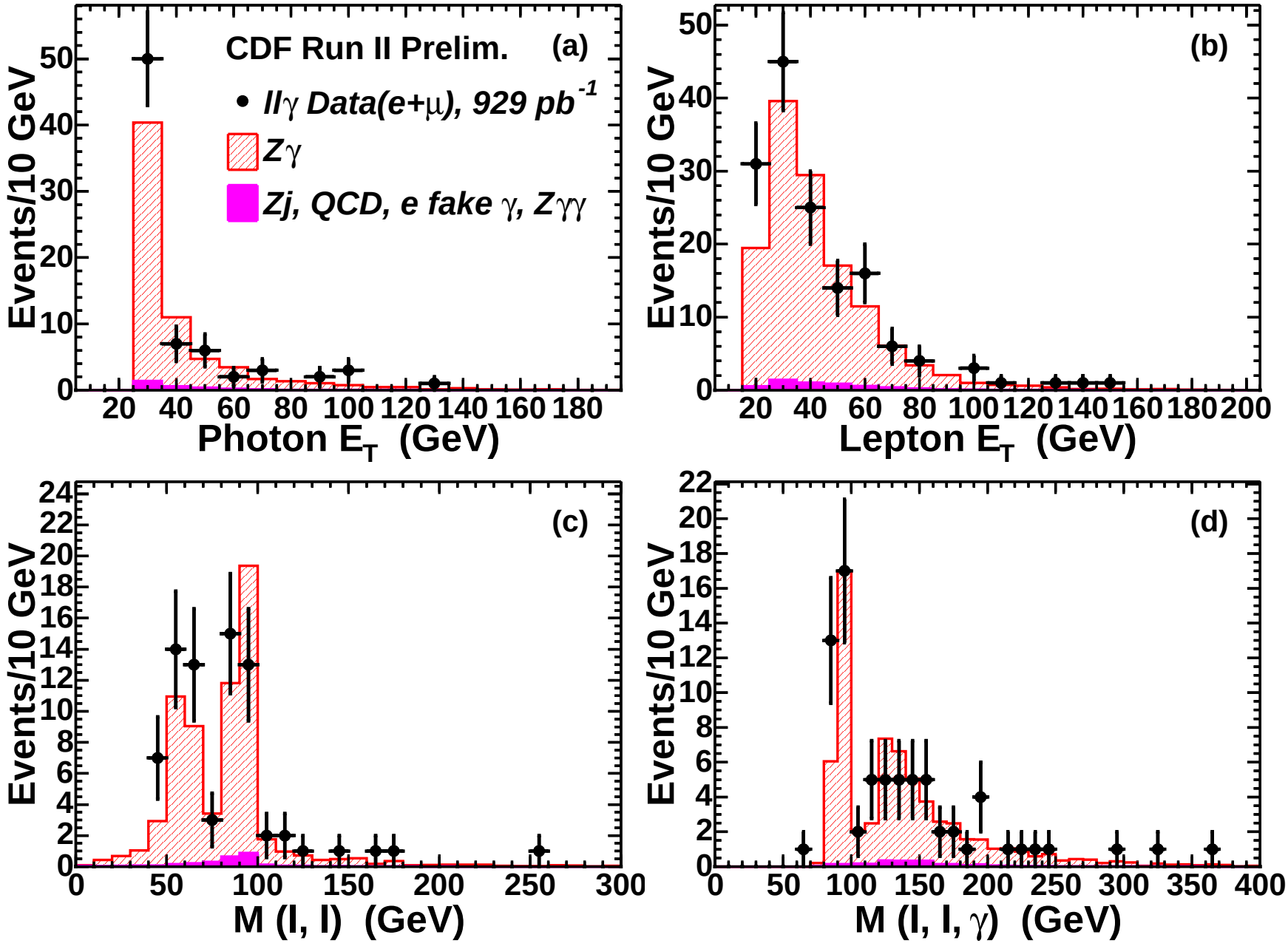


Figure 7: $\ell\ell\gamma$

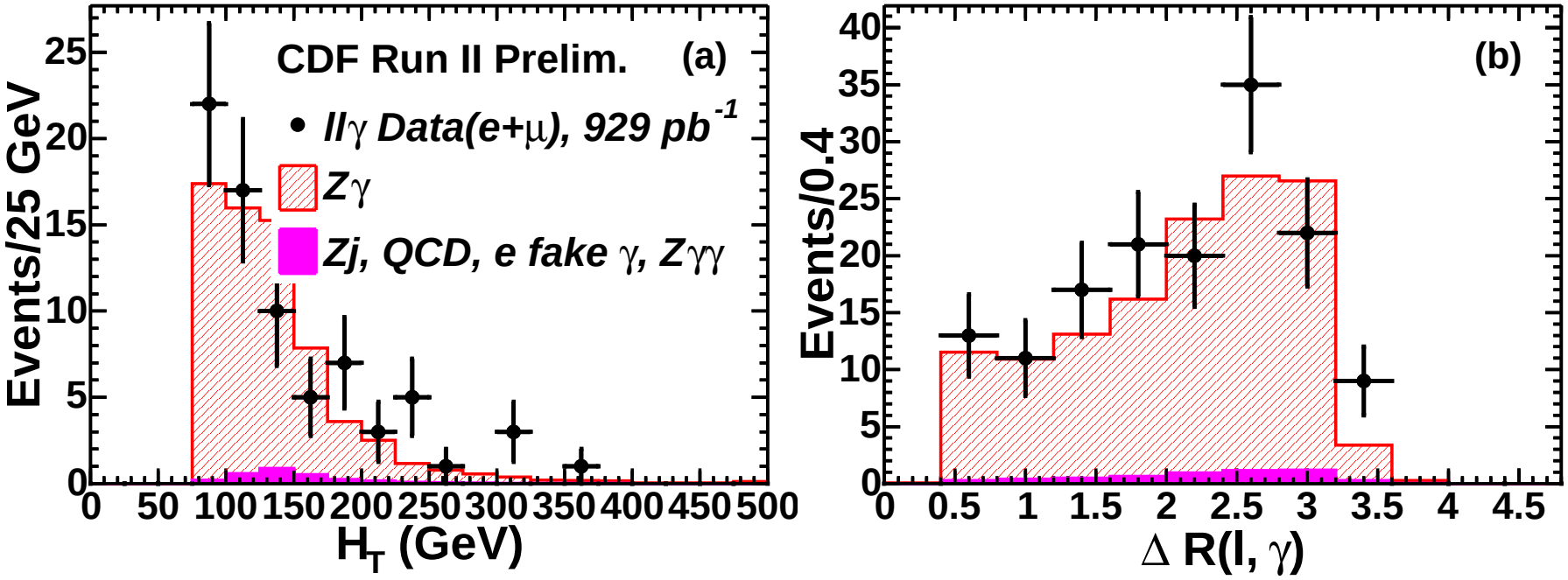
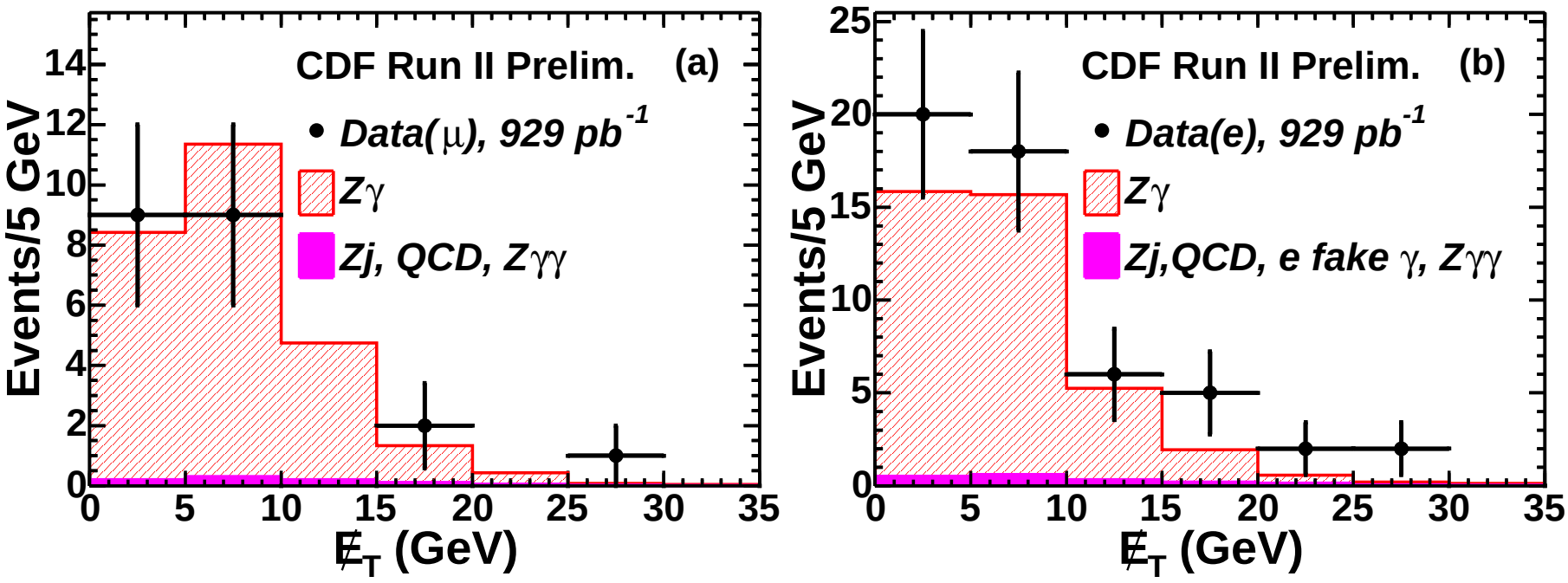


Figure 8: $\ell\ell\gamma$



$e\mu\gamma$

CDF Run II Preliminary, $929pb^{-1}$	
$e\mu$ + Photon + X Predicted Events	
Standard Model Source	$e\mu\gamma + X$
$Z^0\gamma$	0.66 ± 0.088
$W\gamma$	0.095 ± 0.18
$Z^0\gamma\gamma$	0.057 ± 0.0054
$W\gamma\gamma$	0.011 ± 0.0028
$e\mu j$, $j \rightarrow \gamma$	0.05 ± 0.00700
$ee\mu$, $e \rightarrow \gamma$	0.063 ± 0.045
$\tau\gamma$ contribution	0.089 ± 0.18
Total	1.01 ± 0.33
Observed	0

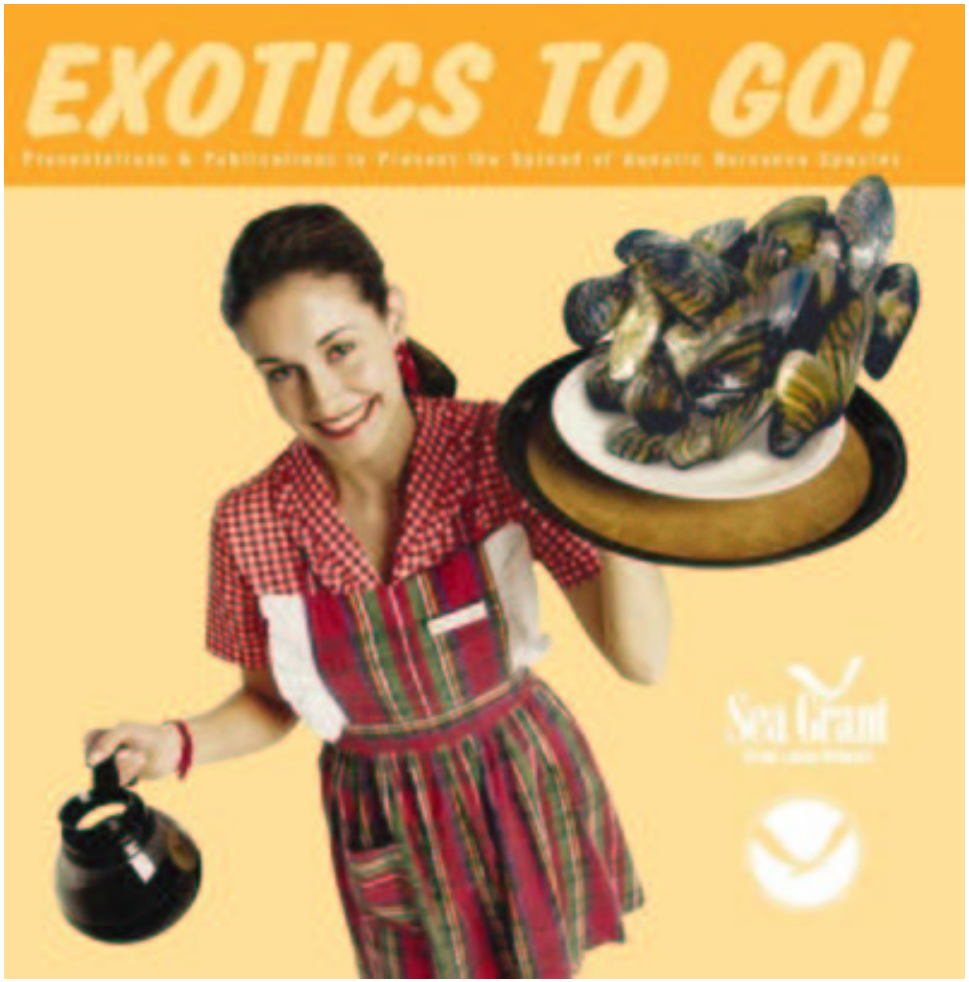
$\ell\gamma\gamma$

CDF Run II Preliminary, $929pb^{-1}$			
Multi-Photon + Lepton Predicted Events			
SM Source	$e\gamma\gamma$	$\mu\gamma\gamma$	$\ell\gamma\gamma$
$W^{\pm}\gamma\gamma$	0.021 ± 0.0043	0.015 ± 0.0034	0.036 ± 0.0055
$Z^0\gamma\gamma$	0.045 ± 0.0051	0.038 ± 0.0045	0.083 ± 0.0068
$Z^0\gamma$, $e \to \gamma$	0.413 ± 0.116	-	0.413 ± 0.116
ℓjj, $\ell\gamma j$, $j \to \gamma$	0.04917 ± 0.049	0.05060 ± 0.051	0.09 ± 0.090
Total	0.53 ± 0.13	0.10 ± 0.051	0.62 ± 0.15
Observed	0	0	0

Summary

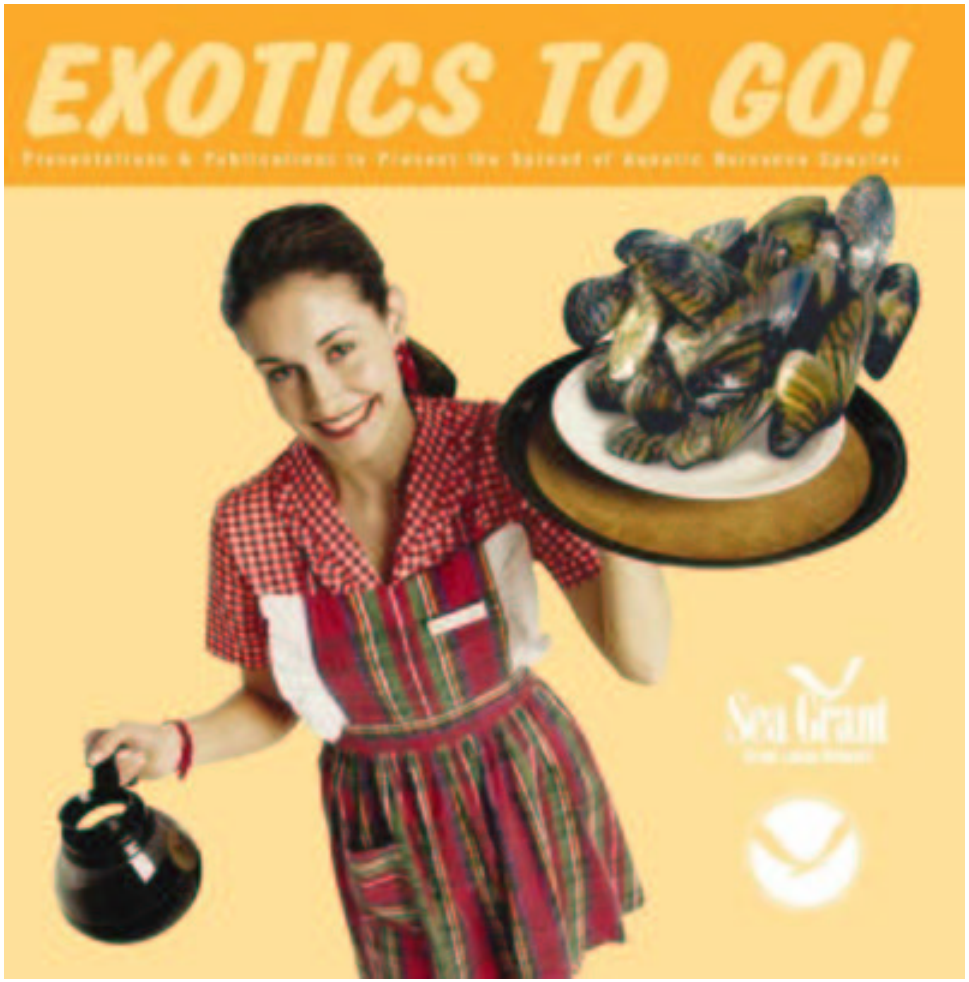
- **Run I 2.7σ in $\ell\gamma \not\!\!E_{\rm T}$ is not confirmed with much more data**
- **We find that the numbers of events in the $\ell\gamma \not\!\!E_{\rm T}$, $\ell\ell\gamma$, $\ell\gamma\gamma$, $e\mu\gamma$ subsamples of the $\ell\gamma + X$ sample agree with SM predictions.**
- **Explore other channels (the first look at $t\bar{t}\gamma$ - will be in I.Shreyber's talk)**
- **Tevatron is in great shape: taking new data really fast.**
- **We do understand the SM: this will help to search for physics beyond it.**

Tevatron?..



Or...

Tevatron?..



LHC!