Search for Anomalous Production of Photon+Jets

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On behalf of the CDF collaboration

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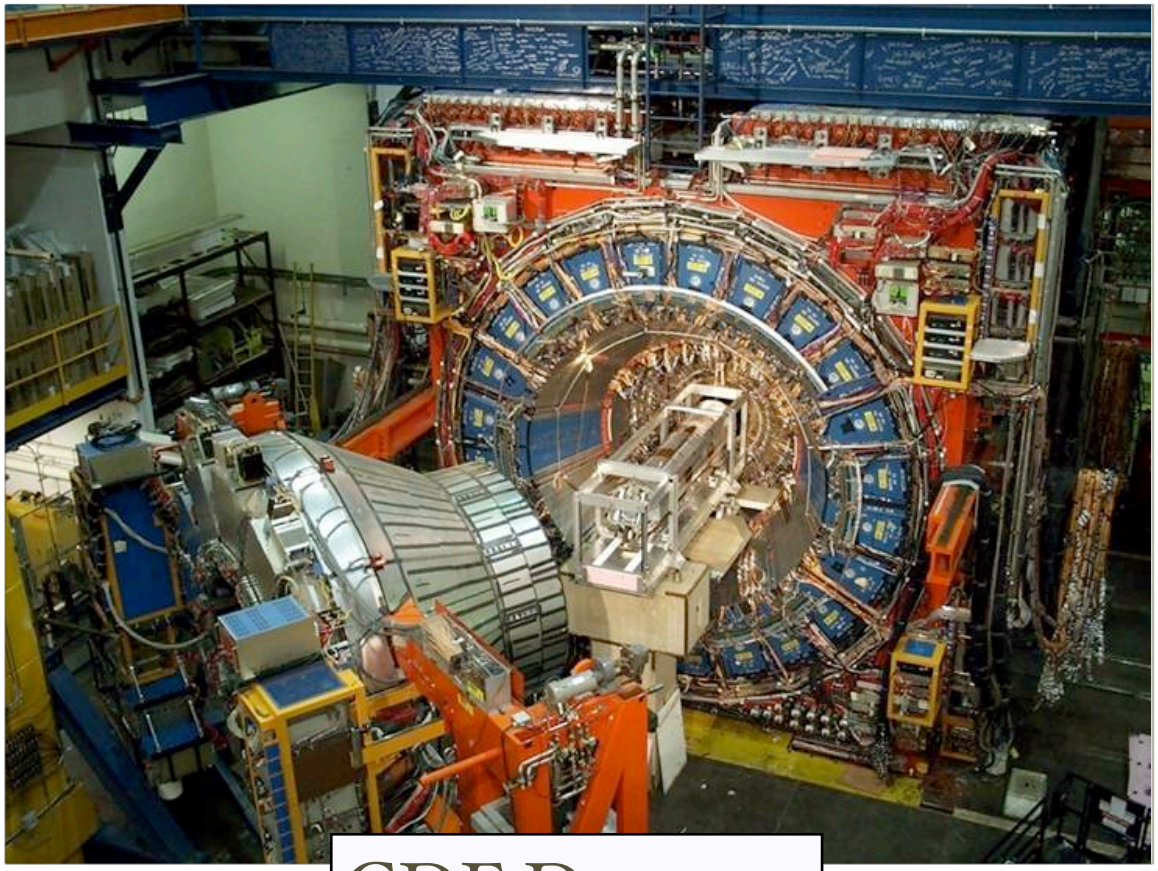
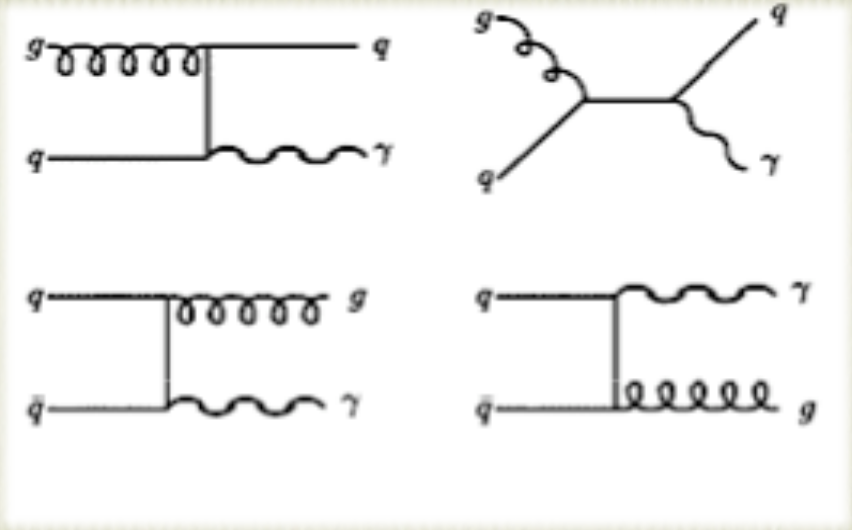
Outline

- Introduction
- Event Selection
- Backgrounds
- Results

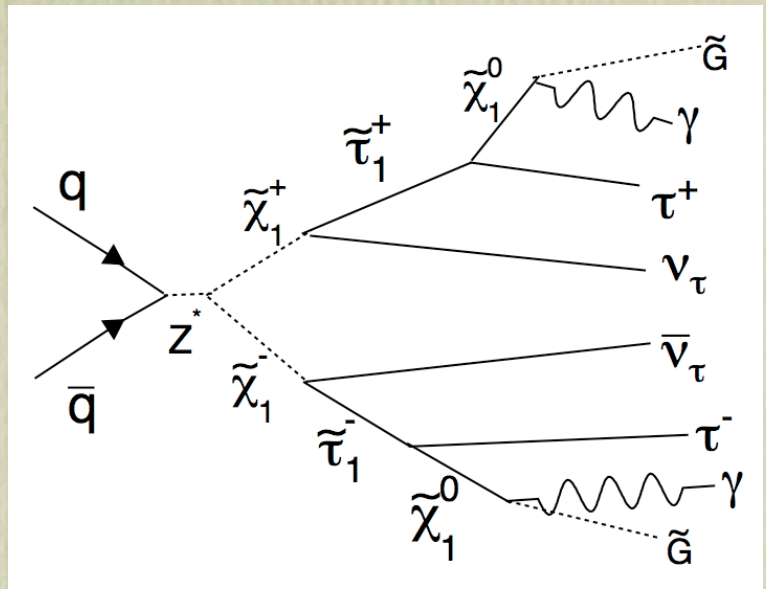


CDF Detector

Introduction



Standard Model



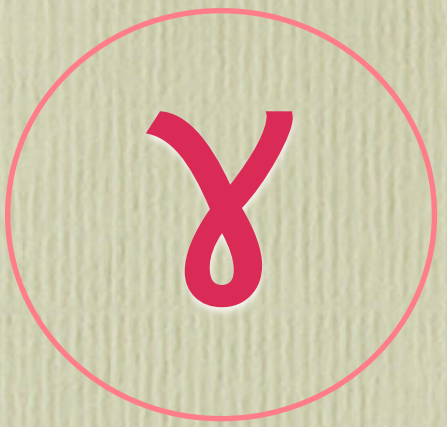
SUSY GMSB

- What are we looking for? photon+jets...
- Why this signature?
- This is a model-independent signature-based search.
- We are doing a semi-blind analysis and look at only 1/10 of the total available integrated luminosity.

Datasets

- CDF Run II data collected through 2002-2007
  - Total integrated luminosity for the entire sample = 2.0 fb^{-1}
  - We use events with event number divisible by 10.
  - Effective integrated luminosity for these results = 200 pb^{-1}
- Pythia tune A inclusive photon Monte Carlo with photon $p_T > 22$ GeV.
- Pythia tune A inclusive electroweak Monte Carlo samples.

$Z \rightarrow ee$ ($M_{ee} > 20$ GeV)	$W \rightarrow e\nu$
$Z \rightarrow \mu\mu$ ($M_{\mu\mu} > 20$ GeV)	$W \rightarrow \mu\nu$
$Z \rightarrow \tau\tau$ ($M_{\tau\tau} > 20$ GeV)	$W \rightarrow \tau\nu$



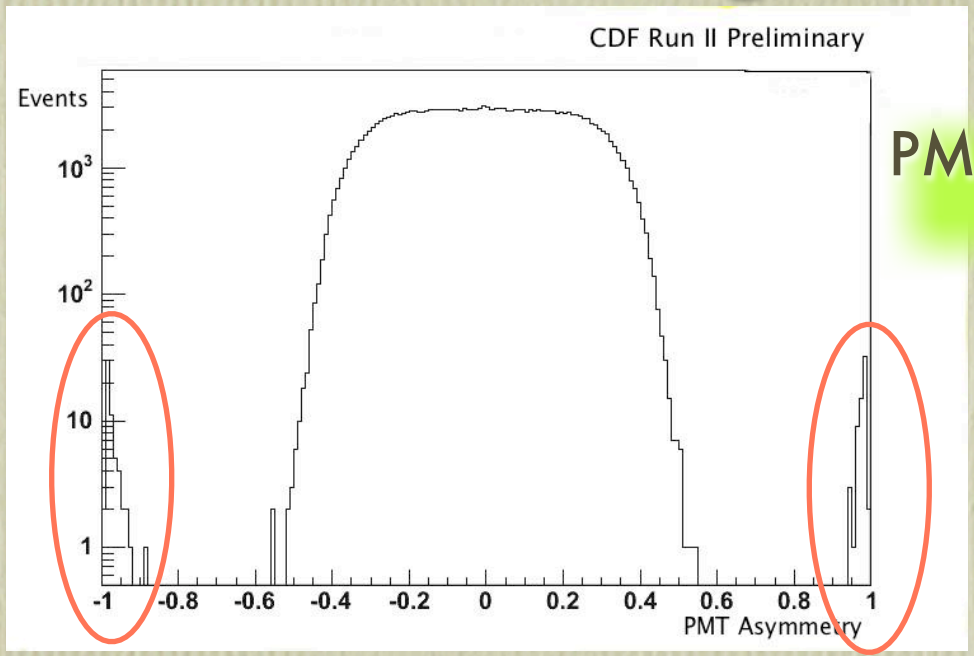
+ Event Selection

- Require a reconstructed primary vertex
- Require a trigger photon passing tight photon ID cuts (E_T > 30 GeV, central)
- Photon must be in-time → Cosmic veto
- Reject beam halo
- No track → lepton veto
- One or more jets, E_T>15GeV and $|\eta| < 3.0$

Backgrounds

- Non-collision
  - PMT (Photomultiplier tube) spikes
  - Beam halo
  - Cosmic rays
- Standard model processes where lepton fakes photon
  - W, Z
- QCD Multi-jets (where a jet fakes a photon)
- Standard model prompt photons

Background Rejection

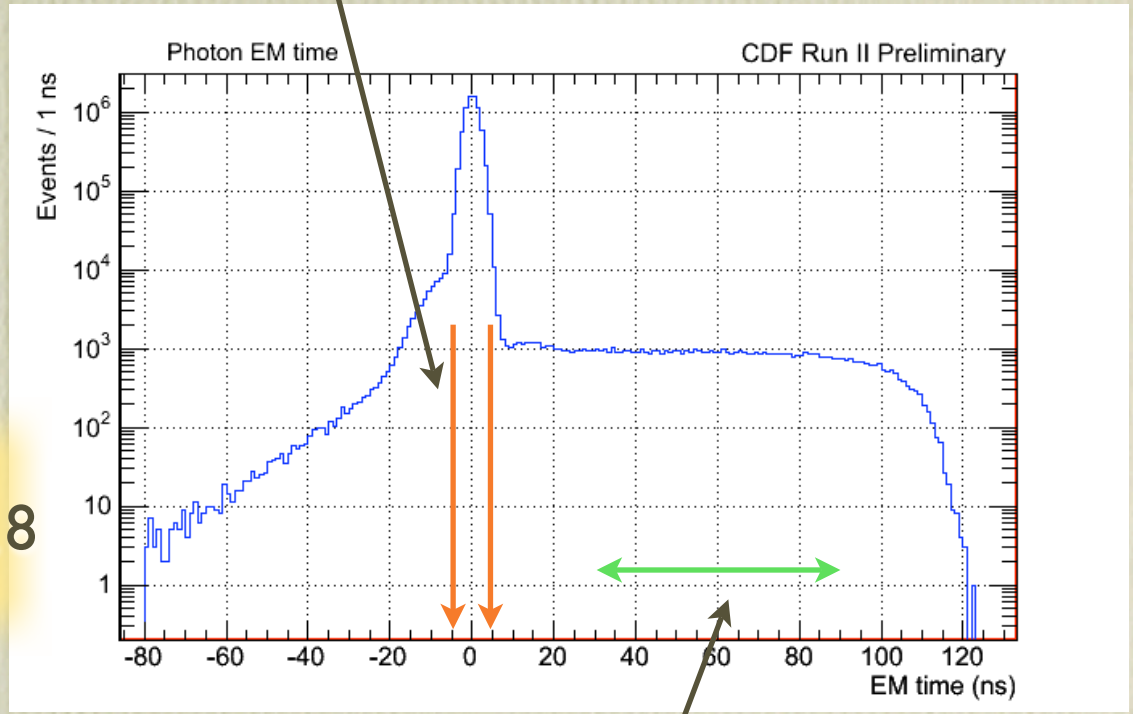


PMT Spike : Can reject 100% using PMT asymmetry.

$$\text{PMT Asymmetry} = \frac{|E^{PMT1} - E^{PMT2}|}{|E^{PMT1} + E^{PMT2}|}$$

Cosmic : Use calorimeter EM timing, require photon to be >-4.8 ns and < +4.8 ns.

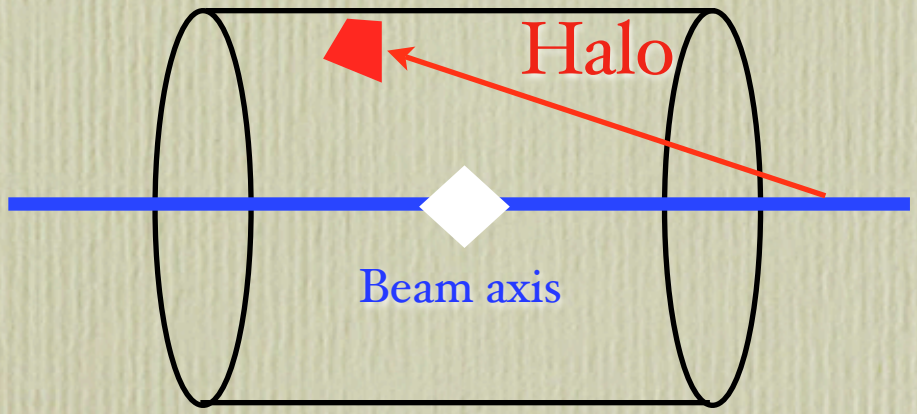
Signal Selection

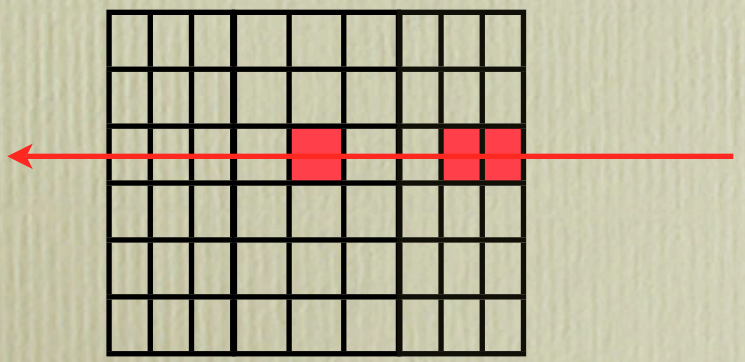


Cosmic Selection

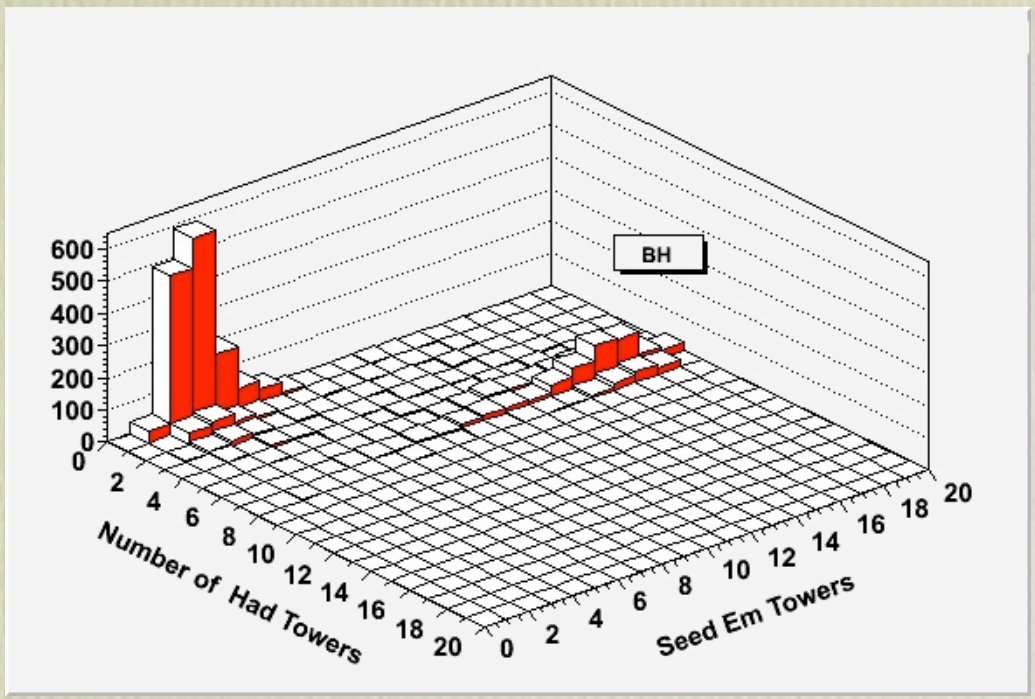
Background Rejection II

Beam halo : Use topological cuts (see backup slides). We have a rejection power of ~95%



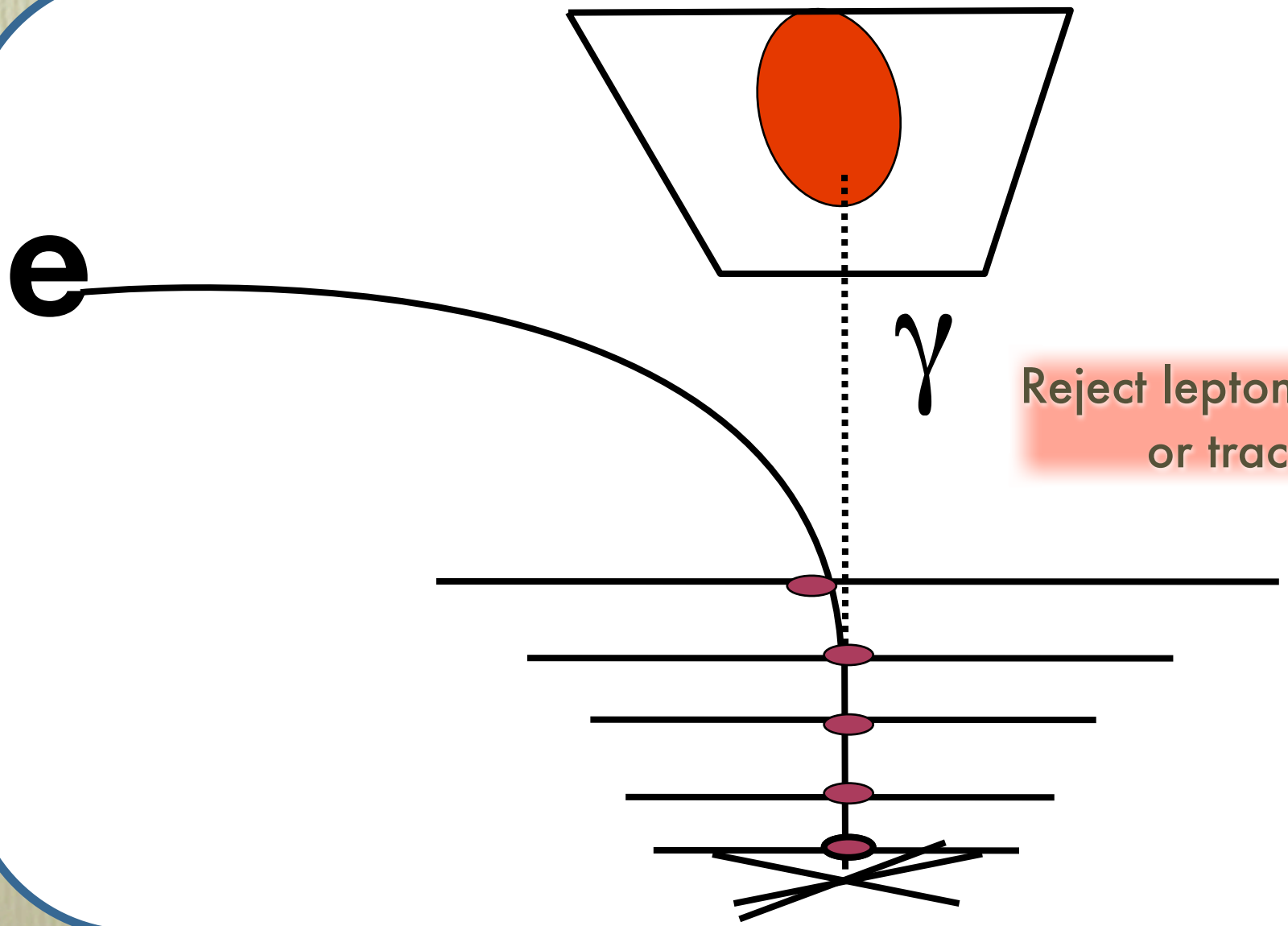


η, φ view



Background Rejection III

Electron BREM



Reject leptons by finding track or track segments.

Background Templates

- Two major backgrounds
  - SM Photon
    - Use photon MC
  - QCD Multi-jet
    - We invert one of the photon selection cuts to select a region with large fake photon fraction.
- Normalize the sum of these two background to the data minus other backgrounds.

Summary of Backgrounds

- We have ~400k signal events (1/10)
- All background predictions are for the entire dataset. We scale it down by a factor of 10 to make the plots.

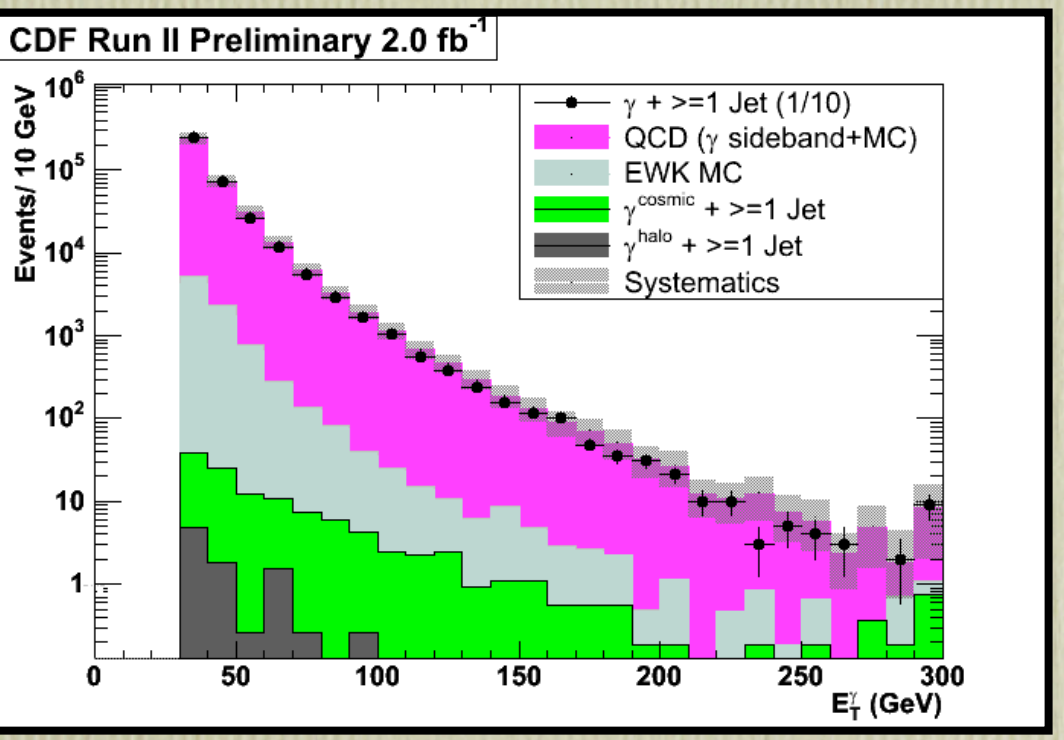
Main Backgrounds

	>= 1 Jets	>= 2 Jets
SM Photon	2.6M	650k
QCD Multi-jet	1M	280k

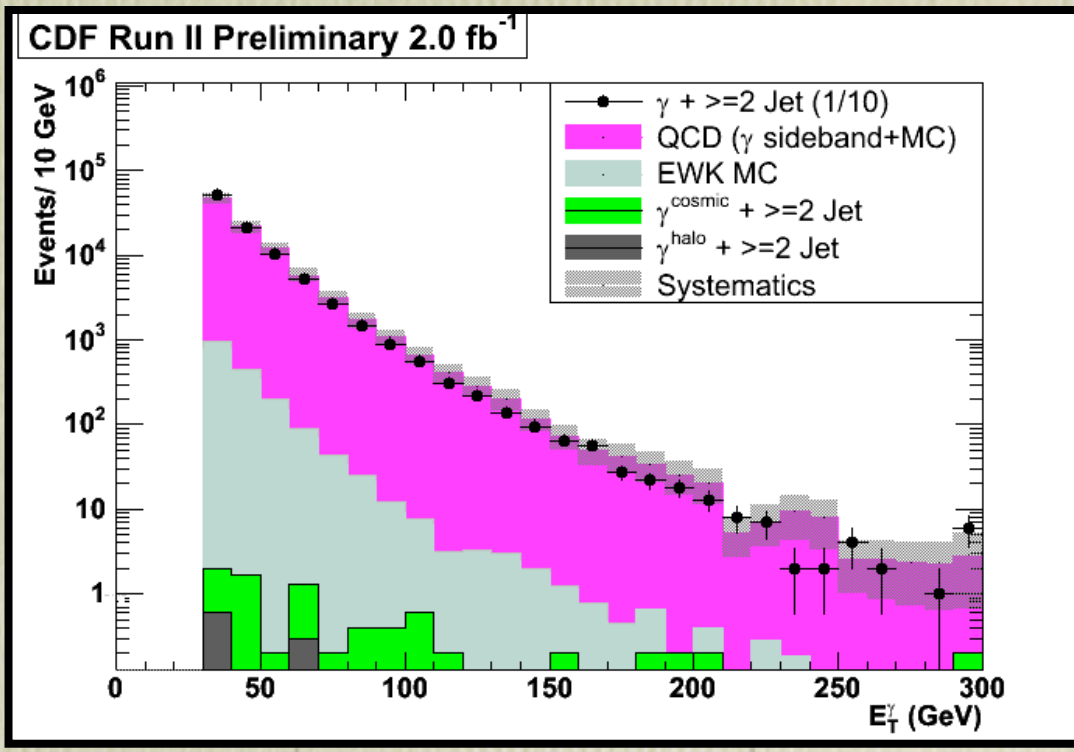
Other Backgrounds

	>= 1 Jets	>= 2 Jets
Electron	459	111
Cosmic	110±9	7±2
Beam halo	9	<1
PMT Spikes	0	0

Results

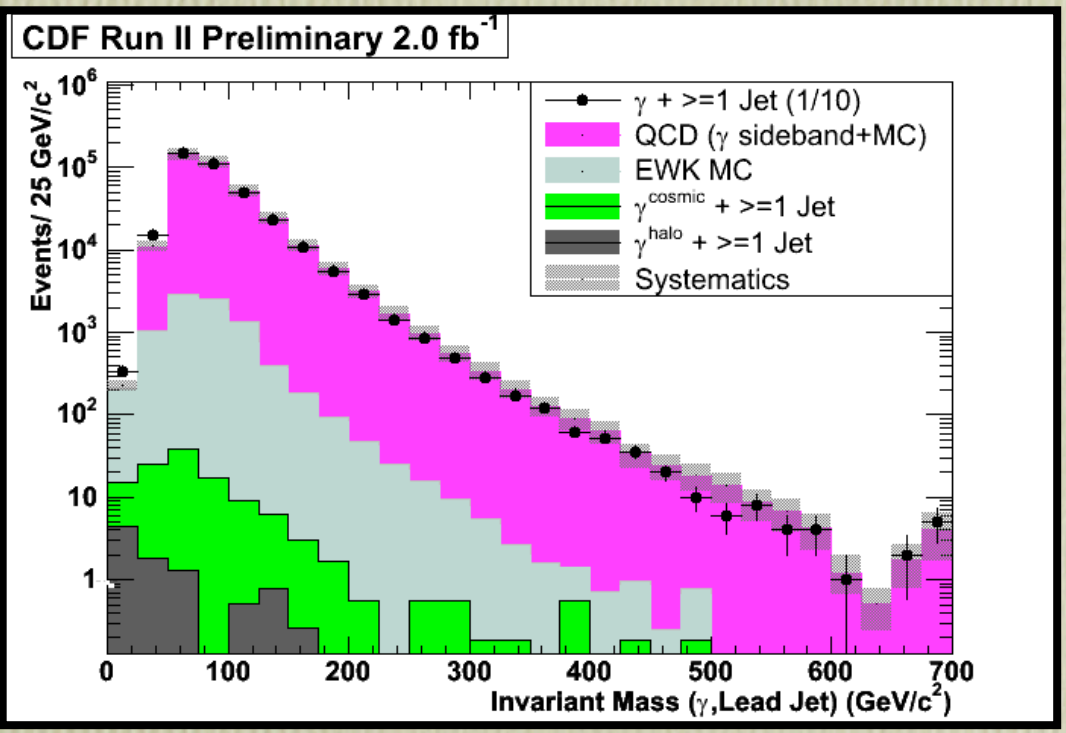


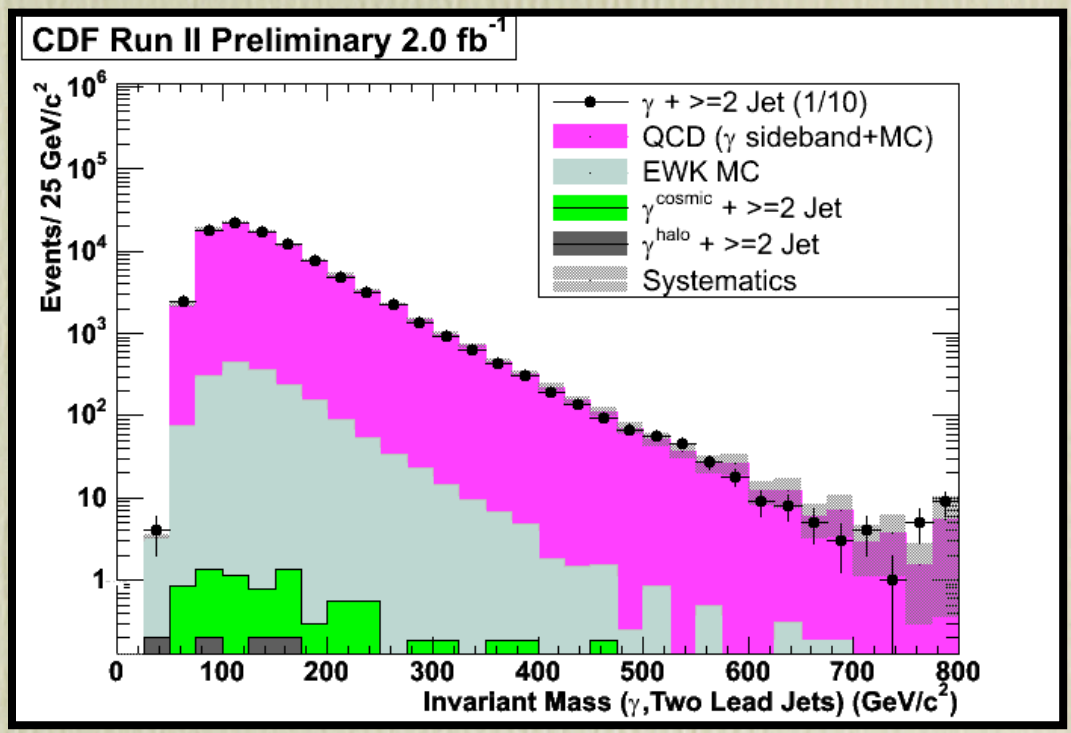
Photon E_T, ≥1 Jet



Photon E_T, ≥2 Jets

Results II

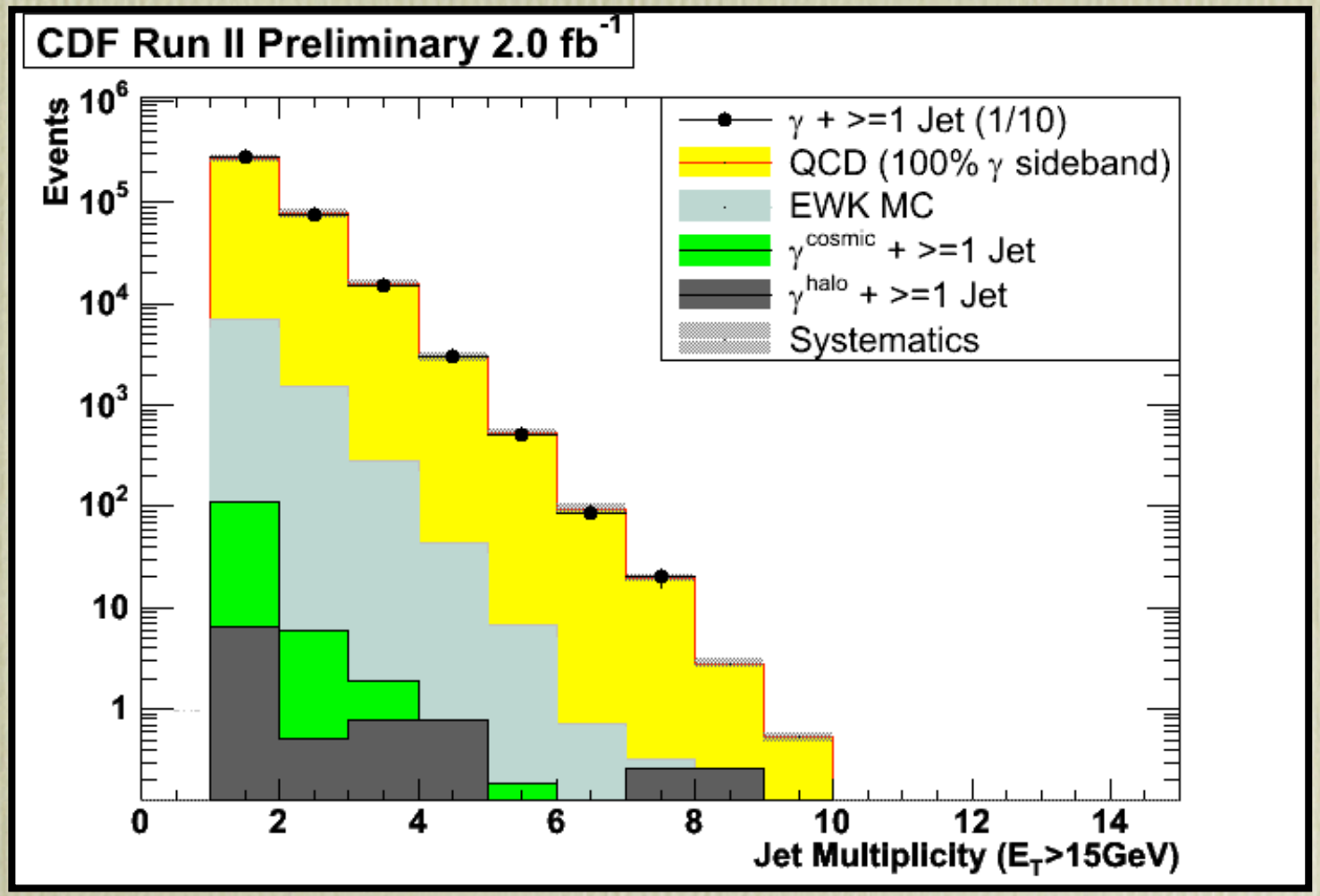




Photon + Leading Jet Invariant Mass

Photon + 2 Leading Jets Invariant Mass

Results III



Jet Multiplicity for Photon + ≥1 Jet

Summary and Outlook

- We have studied photon+jet events in CDF data.
- Looked at 1/10 of the data sample and found a very good agreement between data and the background predictions.
- Plan to improve background rejections and estimates.
- Look only at events with significant MET.
- Open the box and scan the full dataset.
- Will look for resonance (bump).

Thank you.

Backup Slides

Systematics

- We have used two different approaches.
  - 32% photon sideband and 68% photon Monte Carlo
  - 100% photon sideband

Systematics II

- When we use the 32% photon sideband and 68% photon Monte Carlo mixture, vary the mixture.
- When we use 100% photon sideband,
  - Vary cuts common(HadEm/Iso/TrkPt/TrkIso) to both loose and tight photon ID cuts
  - Tighten up one cut at a time and run the sideband sample through this modified set of cuts.
  - Normalize to sideband and divide by the sideband.
  - Repeat for all 4 and take the maximum variation out of the 4 in each bin as the systematic for that bin.

Systematics III

- Jet Energy Scale
- Photon EM energy (~1%)
- For EWK: Use the uncertainty in luminosity (~6%) to vary the normalization.
- For Cosmics: Use a smaller time window and compare the predictions.
- For Beam Halo: Assign a 50% error.

Tight Photon ID cuts

Variable	Cut value
detector	central
E_T^{corr}	> 30 GeV
CES X and Z fiducial	$\lvert X_{CES}\rvert \leq 21$ cm 9 cm $\leq \lvert Z_{CES}\rvert \leq 230$ cm
Had/Em	$\leq 0.125 \;\lvert\rvert\; \leq 0.055 + 0.00045 \times E^{corr}$
$E_T^{Iso(corr)}$ in cone 0.4	$\leq 0.1 \times E_T^{corr}$ if $E_T^{corr} < 20$ GeV $\leq 2.0 + 0.02 \times (E_T^{corr} - 20)$ if $E_T^{corr} > 20$ GeV
average CES χ^2 (Strips+Wires)/2	≤ 20
N tracks in cluster (N3D)	≤ 1
Track p_T	$< 1 + 0.005 \times E_T^{corr}$
Track Iso(0.4)	$< 2.0 + 0.005 \times E_T^{corr}$
2^{nd} CES cluster $E \times sin(theta)$ (both wire and strip E individually)	$\leq 0.14 \times E_T^{corr}$ if $E_T^{corr} < 18$ GeV $\leq 2.4 + 0.01 \times E_T^{corr}$ if $E_T^{corr} \geq 18$ GeV

Loose Photon ID cuts

Variable	Cut value
detector	central
E_T^{corr}	> 30 GeV
CES X and Z fiducial	$\lvert X_{CES}\rvert \leq 21$ cm 9 cm $\leq \lvert Z_{CES}\rvert \leq 230$ cm
Had/Em	≤ 0.125
$E_T^{Iso(corr)}$ in cone 0.4	$\leq 0.15 \times E_T^{corr}$ if E_T^{corr} <20 GeV ≤ 3.0 if E_T^{corr} >20 GeV
Track p_T	$< 0.25 \times E_T^{corr}$
Track Iso(0.4)	< 5.0

Table 1: Loose Photon ID cuts.

Beam Halo Rejection

Increase rejection power

Halo Type	Selection Cut
0	seedWedge $>$ 8 $\|\|$ Nhad $>$ 1
1	seedWedge $>$ 4 & Nhad $>$ 1
2	seedWedge $>$ 4 & Nhad $>$ 2
3	seedWedge $>$ 7 & Nhad $>$ 2
4	seedWedge $>$ 8 & Nhad $>$ 2
5	seedWedge $>$ 8 & Nhad $>$ 3

Increase efficiency

seedWedge = number of EM towers (Et>0.1 GeV) in same wedge as photon
Nhad = number of plug HAD towers (Et>0.1 GeV) in same wedge as photon

Photon-like Electron ID cuts

Variable	Cut value
detector	central
conversion	no
corrected E_T	> 30 GeV
CES fiduciality	$\lvert X_{CES}\rvert \leq 21$ cm 9 cm $\leq \lvert Z_{CES}\rvert \leq 230$ cm
average CES χ^2	≤ 20
Had/Em	$\leq 0.055 + 0.00045 \times E$
$E_T^{Iso(corr)}$ in cone 0.4	$\leq 0.1 \times E_T$ if $E_T < 20$ GeV $\leq 2.0 + 0.02 \times (E_T - 20)$ if $E_T \geq 20$ GeV
N3D tracks in cluster	$= 1, 2$
E/p of 1^{st} track	$0.8 \leq E/p \leq 1.2$ if $p_T < 50$ GeV no cut if $p_T \geq 50$ GeV
2^{nd} track p_T if N3D $= 2$	$\leq 1.0 + 0.005 \times E_T$
TrkIso(0.4) - p_T 1^{st}trk	$\leq 2.0 + 0.005 \times E_T$
E_T of 2^{nd} CES cluster (wire and strip)	$\leq 0.14 \times E_T$ if $E_T < 18$ GeV $\leq 2.4 + 0.01 \times E_T$ if $E_T \geq 18$ GeV
$\lvert\Delta z\rvert = z_{vtx} - z_{trk}$	≤ 3 cm