

Physics Beyond the Standard Model with Photonic Final States at CDF

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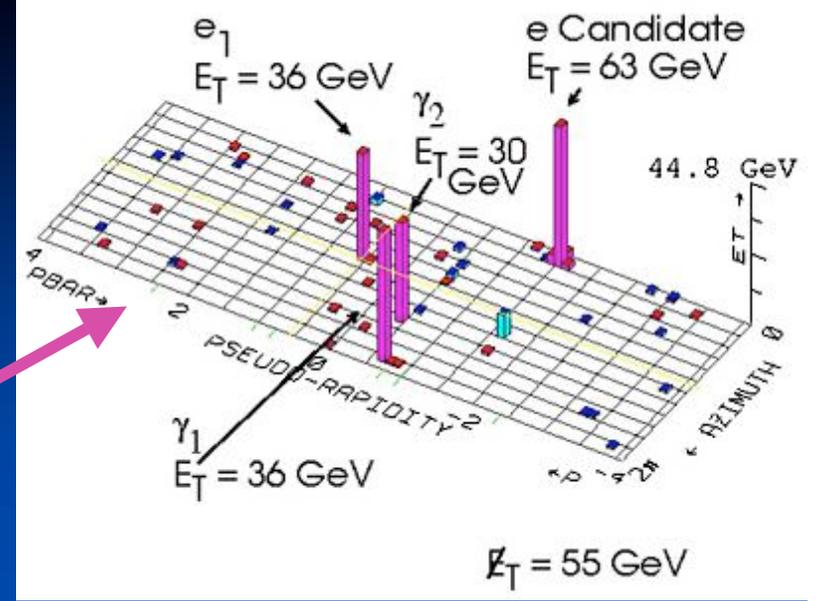


For the CDF collaboration

EPS 2003, Aachen, 17.-23.7.2003

Exotics Searches with Photons in CDF Run II

The CDF event: $ee\gamma\gamma + \cancel{E}_T$
 10^{-6} events expected!



The CDF event: $ee\gamma\gamma$

- CDF at Run 2
- Search for **LED** in **Di-Photon** Production
- Search for **Anomalous Photon**+Lepton Production
- Search for **GMSB** with **Di-Photon**+ \cancel{E}_T
- Search for **Photon**+ **Heavy Flavour** Production
- Search for **LED** with **Photon**+ \cancel{E}_T
- **Anomalous Couplings: W/Z+Photon**

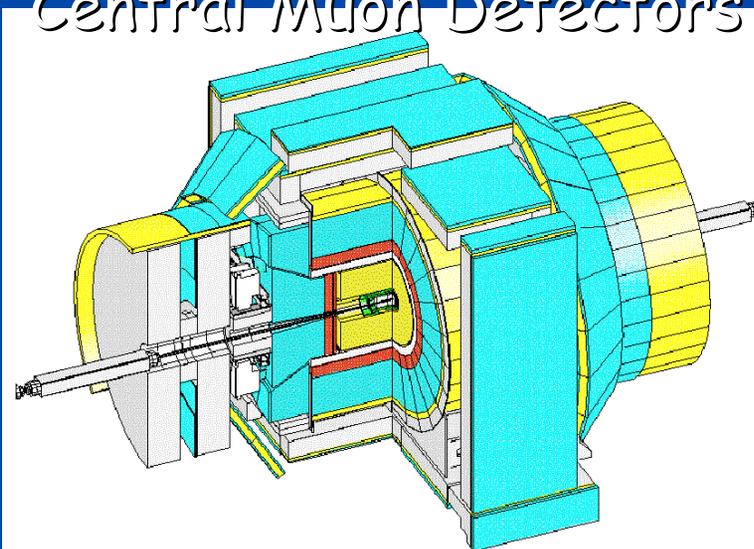
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The CDF 2 Detector

Retained from Run 1

- Solenoidal magnet (1.4 Tesla)
- Central Calorimeters
- Central Muon Detectors



New for Run 2

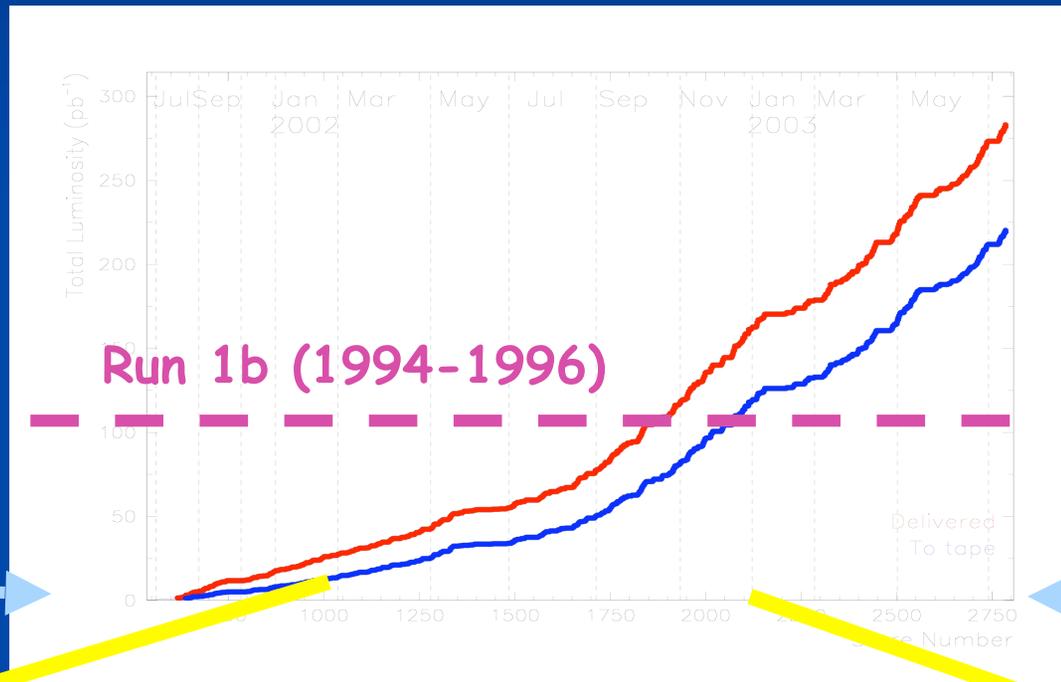
- Tracking System
 - ✓ Silicon Vertex detector (SVX II)
 - ✓ Intermediate silicon layers (ISL)
 - ✓ Central Outer tracker (COT)
- Scintillating tile forward calorimeter
- Intermediate muon detectors
- Time-Of-Flight system
- Front-end electronics (132 ns)
- Trigger System (pipelined)
- DAQ system

CDF Run 2 Luminosity

~ commissioning

physics

Integrated
Luminosity
 pb^{-1}



~280 pb^{-1} delivered

~220 pb^{-1} recorded

08/2001

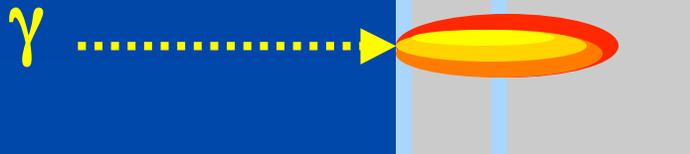
07/2003

- Physics Analyses use about 80 pb^{-1} recorded up to Jan 2003 (about twice as much good quality data on tape since)
- Data taking efficiency about 90% now

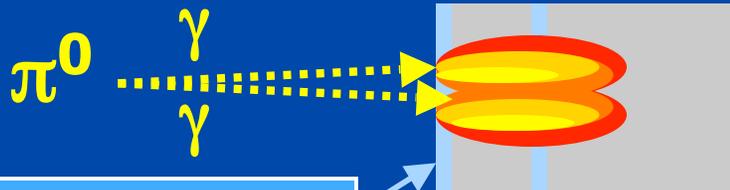
Identification of Photon Signals in CDF

Photon candidates: Isolated electromagnetic showers in the calorimeter, with no charged tracks pointing at the calorimeter cluster

• Signals



• Backgrounds



Pre-shower Detector

Shower Maximum Detector

e.g. for diphoton candidates,
S/B result using CPR method is..

- Two techniques for determination of photon signals;
 1. EM Shower width (shape):
using Shower Max. Detector
 2. Probability of Conversion:
using pre-radiator hits
- Statistical background subtraction

	γ - γ	γ -Jet	Jet-jet
CP	29±23	40±28	30±23%

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Di-Photon Mass Spectrum

- Search Selection:
2 photons with $E_T > 13$ GeV, cosmic and beam-halo rejection cuts
- Main backgrounds:
fakes from photon-jet and jet-jet: determined from data!
- Results: 1365(95) events for $E_T > 13(25)$ GeV

For $M > 150$ GeV

Expected background: 3.3
Observed: 2.0

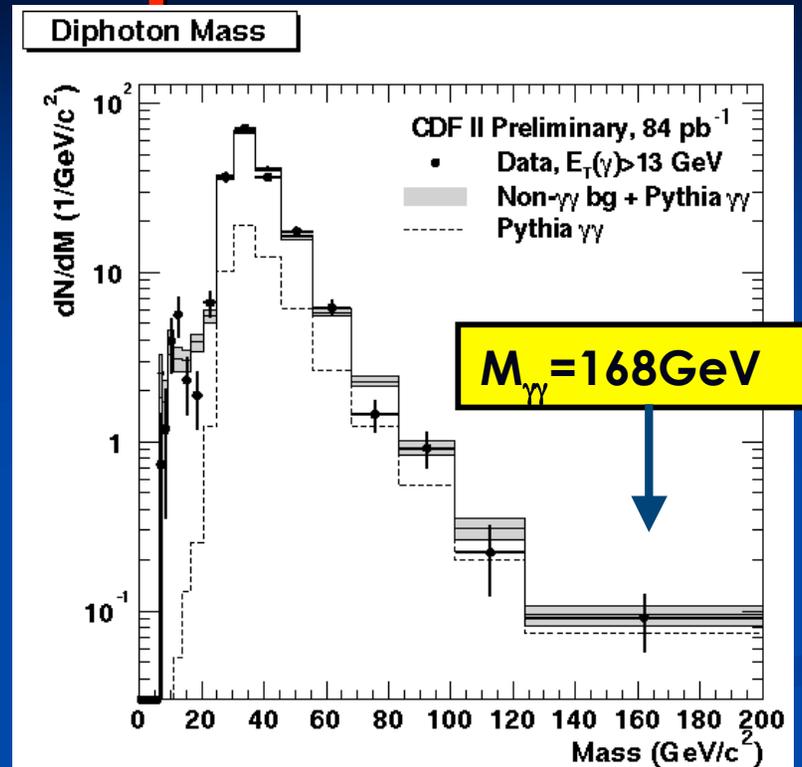
Run I Results (LED Search)

observed: 287(192) CC(CP) events

For $M_{\gamma\gamma} > 150$ GeV

Expected background: 4.5 ± 0.6
Observed: 5

95% C.L. Limits on eff. string scale:
using a maximum likelihood fit method



NO excess observed @ High invariant mass, good agreement b/w Run II Data and expectation

95 % C.L. $M_s > 899 / 815$ GeV
 $K_{LED} = 1.0$ ($\lambda = -1/+1$, Hewett)

γ of

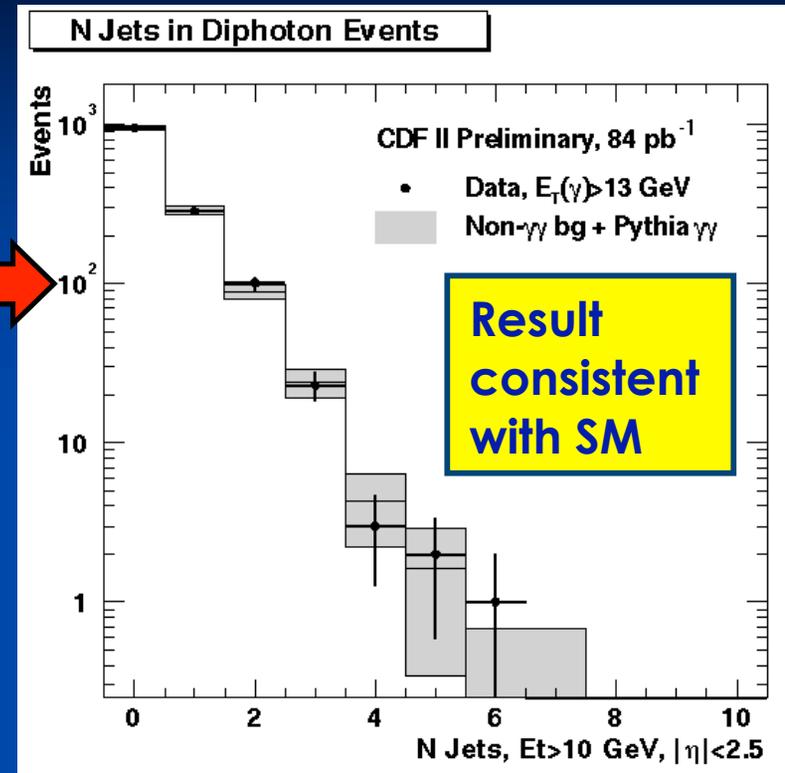
$\gamma\gamma$ +Jets and $\gamma\gamma$ +Leptons Search

- Search for $\gamma\gamma + X$; $X=\text{jet}(s)$

To search for anomalous production of quarks and gluons, look in anomalous N_{jet} production in $\gamma\gamma$ data

- Search for $\gamma\gamma + X$; $X=\text{lepton}(s)$

- Search Selection:
Diphoton+extra lepton(s)
- Main backgrounds:
 $W/Z+\gamma\gamma$, fake γ , $Z\gamma, e(\mu)\gamma+\text{jet}$



No event found

CDF II Preliminary $\gamma\gamma\ell$ Search, 84 pb⁻¹

Selection	Observed	Predicted
$\gamma\gamma (E_t > 13 \text{ GeV}), e^\pm (E_t > 20 \text{ GeV})$	0	$0.27 \pm 0.10 \pm 0.14$
$\gamma\gamma (E_t > 25 \text{ GeV}), e^\pm (E_t > 20 \text{ GeV})$	0	$0.04 \pm 0.03 \pm 0.02$
$\gamma\gamma (E_t > 13 \text{ GeV}), \mu^\pm (P_t > 20 \text{ GeV})$	0	$0.04 \pm 0.007 \pm 0.02$
$\gamma\gamma (E_t > 25 \text{ GeV}), \mu^\pm (P_t > 20 \text{ GeV})$	0	$0.007 \pm 0.005 \pm 0.004$

Good agreement of Run II data with expectation..

Search GMSB for $\gamma\gamma + \cancel{E}_T$

- Gravitino is the LSP
- NLSP: Neutralino $\chi_1 \rightarrow \gamma G$

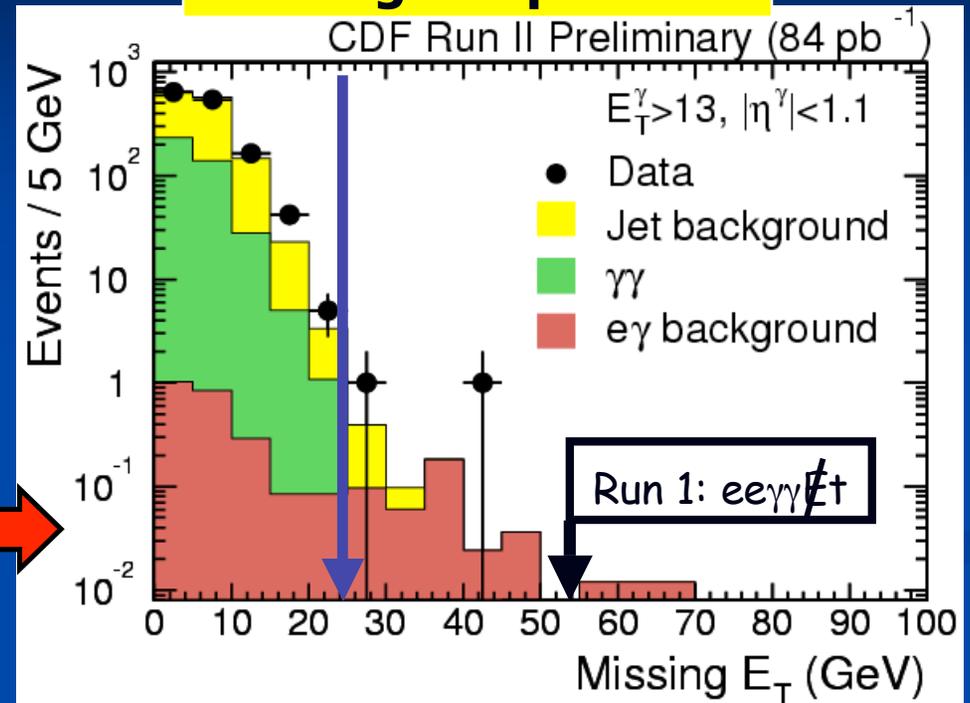
$$p\bar{p} \rightarrow \chi_1\chi_1 + X \rightarrow \gamma\gamma GG + X$$

- **Experimental Signature: $\gamma\gamma + \cancel{E}_T$**

SUSY would show up as an excess of events with large Missing Energy

- Search Selection:
2 central photons w/ $E_T > 13(25)$
Cosmic/beam halo clean-up
- Main backgrounds: (see plot)
QCD diphoton,
jet mis-ID, W+photon (lost track)
- Results:
1392(97) events for $E_T > 13(25)$

Missing Et Spectrum

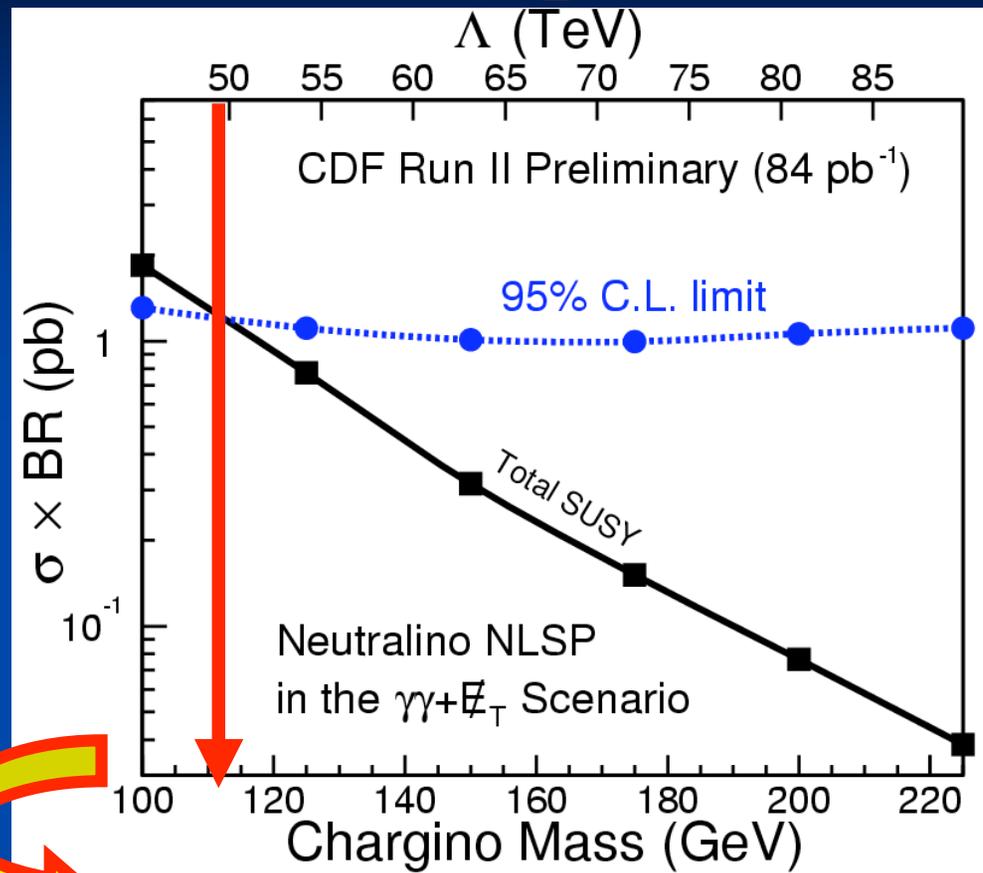
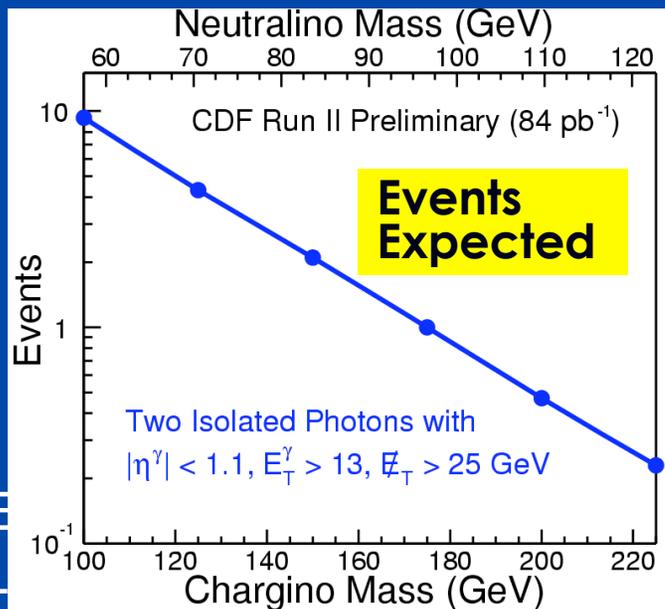
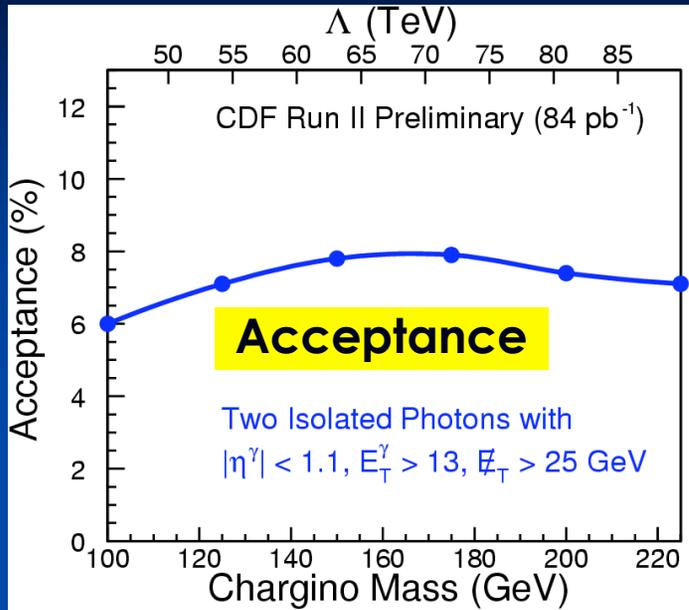


For Missing $E_T > 25 \text{ GeV}$

Expected background: 2 ± 2
Observed: 2

→ Set cross section limit

Search GMSB for $\gamma\gamma + \cancel{E}_T$ (II)



Set the lower mass limit on the lightest chargino in GMSB:

$$M_c > 113 \text{ GeV @ 95\% C.L.}$$

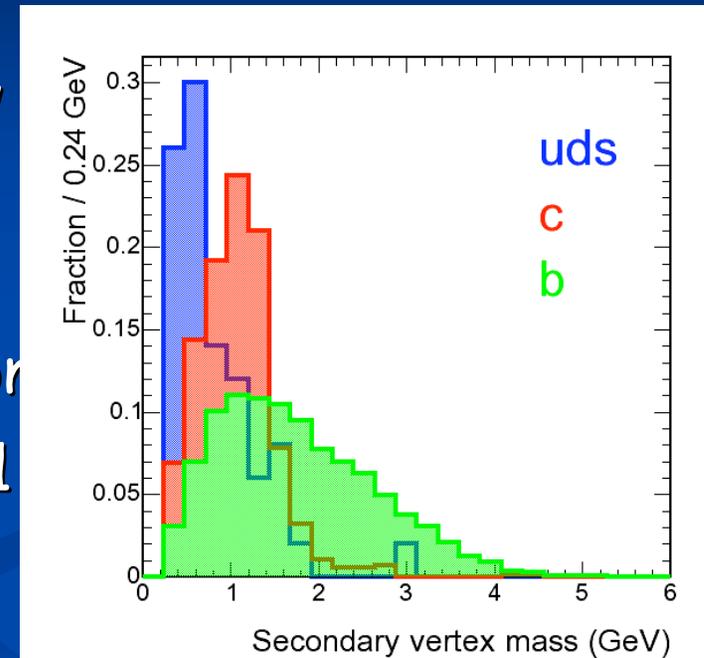
B+γ: Motivation

- Topological search sensitive to “new physics”
 - Require photon and b-jet
 - Can look for μ , e , τ , jets in addition
- Search originally motivated by Run 1 $ee\gamma\gamma$ MEt event
- E.g in **MSSM**: chargino + neutralino

$$\chi_i^+ \chi_2^0$$

$$\rightarrow \chi_2^0 \rightarrow \gamma \chi_1^0, \chi_1^+ \rightarrow \chi_1^0 t b$$

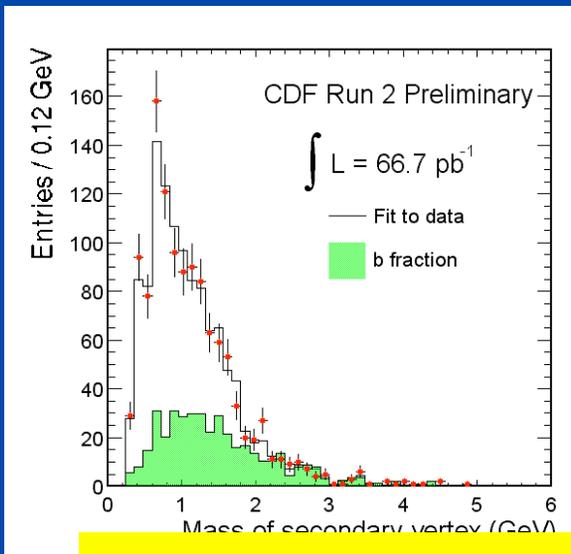
2b-jets, photon, lepton, missing Et



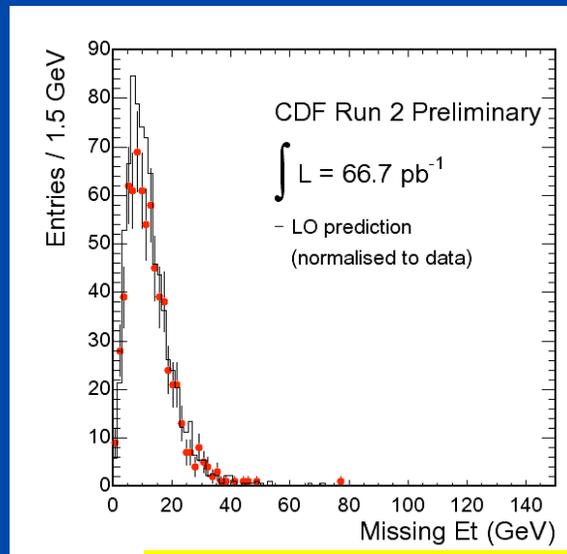
Mass at sec. Vertex:
separate b-, c- and
light quarks

Photon + b-jet: A first look

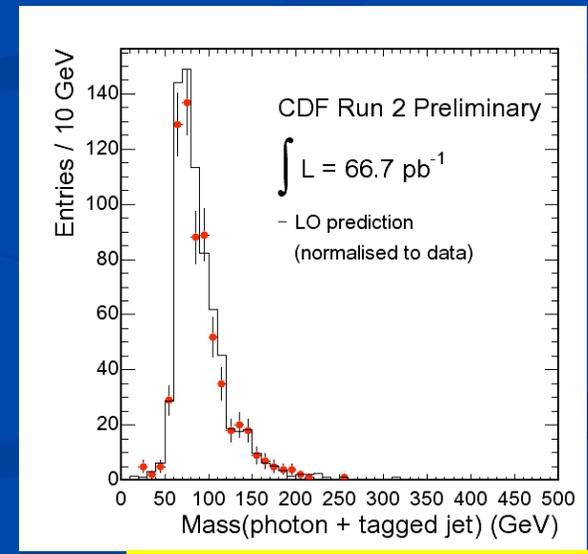
- Cross Sections:
 - $b\text{-}\gamma$: $40.6 \pm 19.4(\text{stat.}) \pm 7.6(\text{syst.}) \text{ pb}$, LO: 68.6 pb
 - $c\text{-}\gamma$: $486 \pm 153(\text{stat.}) \pm 88(\text{syst.}) \text{ pb}$, LO: 368.4 pb
- Data agree with LO QCD predictions
- More excl. Searches and Limits on New Physics soon



Mass @ sec. vertex



Missing Et /GeV



B-jet- γ -Mass/GeV

Search for New Physics in $\gamma + \cancel{E}_T$

Search Selection: (84 pb^{-1})

- one γ with $E_T > 47 \text{ GeV}$ and $|\eta| < 1$
- Missing $E_T > 42 \text{ GeV}$
- No jets with $E_T > 10 \text{ GeV}$
- No tracks with $p_T > 5 \text{ GeV}$

Main backgrounds:

Cosmic ray	3.9 ± 1.0
muons $Z\gamma \rightarrow \nu\nu + \gamma$	4.8 ± 0.5
$W \rightarrow e\nu$	7.3 ± 1.7
QCD diphotons	1.1 ± 0.4
$W\gamma (\nu\gamma)$	0.9 ± 0.3

Results: No excess was found

Expected background: 18.0 ± 2.1

Observed: 17

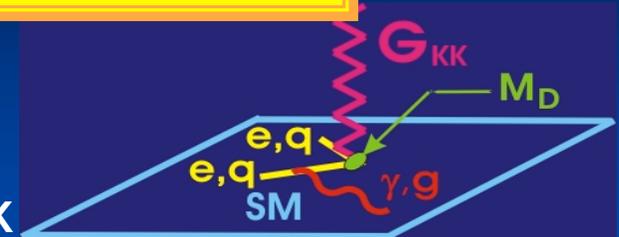
**95% C.L. upper limit on
(accep. x eff. x cross-section) of
121 fb was set**

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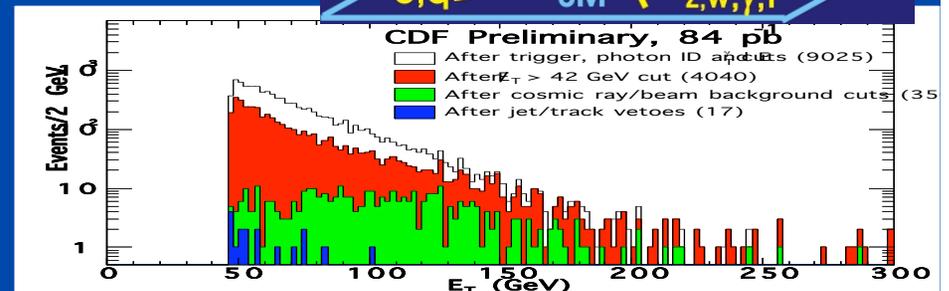
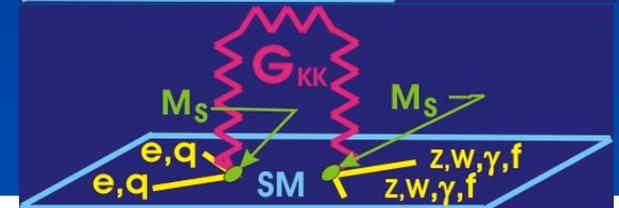
Extra Dimensions

ADD

$q\bar{q} \rightarrow \gamma G_{KK}$



Randall-Sundrum

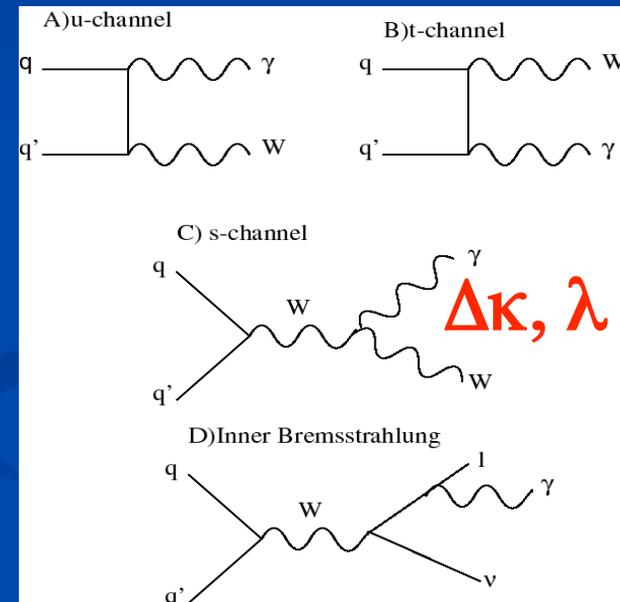


Run I limit: $M_S > 0.58 \text{ TeV}$

New Physics in $W\gamma$ Production?

- Sensitive to TGC ($\Delta\kappa, \lambda$):
e.g. compositeness of W/Z
- ✓ Run I: excess at high E_t :
lepton $E_t > 25$ GeV, $M_{et} > 25$ GeV,
photon $E_t > 25$ GeV

lepton	Data	SM exp
muon	11	4.2
electron	5	3.4
both	16	7.6

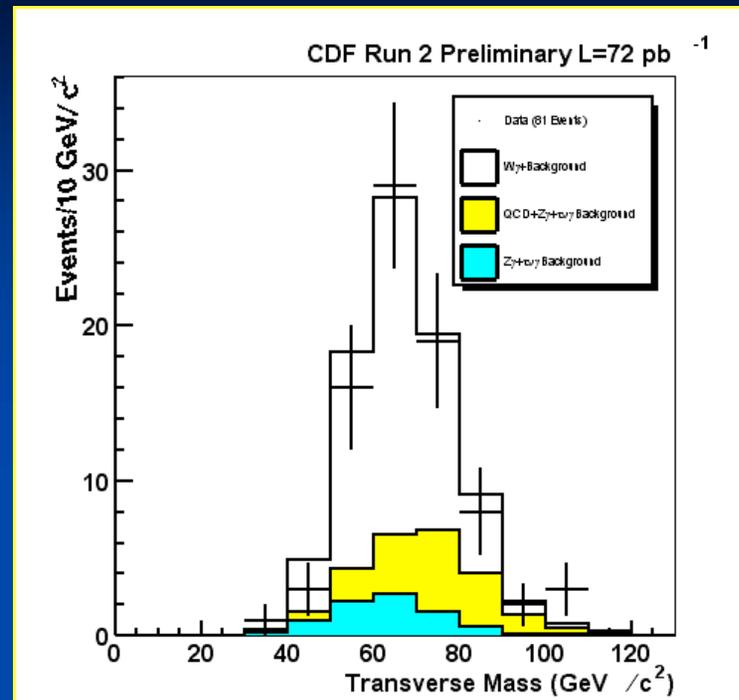


$W\gamma$ Production

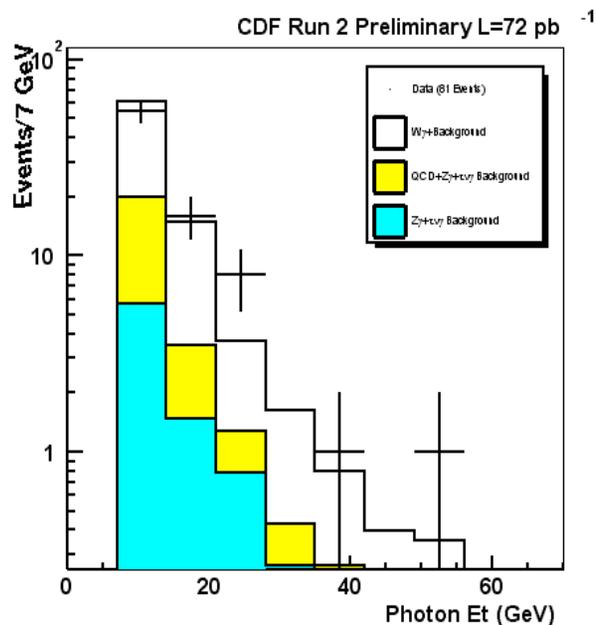
- s-channel diagram not present in SM
- Signature: high p_T lepton (e/μ) + γ , $MET > 25$, photon $E_T > 7$ GeV, $\Delta R(\gamma-l) > 0.7$

- Results: **No excess was found**

Data: 43(38)
 Signal MC+Background : $46.6 \pm 1.3 \pm 4.5$
 ($36.5 \pm 0.7 \pm 3.0$)



... derived the cross section for $E_T(\gamma) > 7, \Delta R > 0.7$



	Data	BG	$\sigma \cdot BR(W\gamma \rightarrow l\nu\gamma)$ (pb)
e	43	33%	$17.2 \pm 3.8_{\text{stat}} \pm 2.8_{\text{sys}} \pm 1.0_{\text{lum}}$
μ	38	29%	$19.8 \pm 4.5_{\text{stat}} \pm 2.4_{\text{sys}} \pm 1.2_{\text{lum}}$

Results consistent with SM

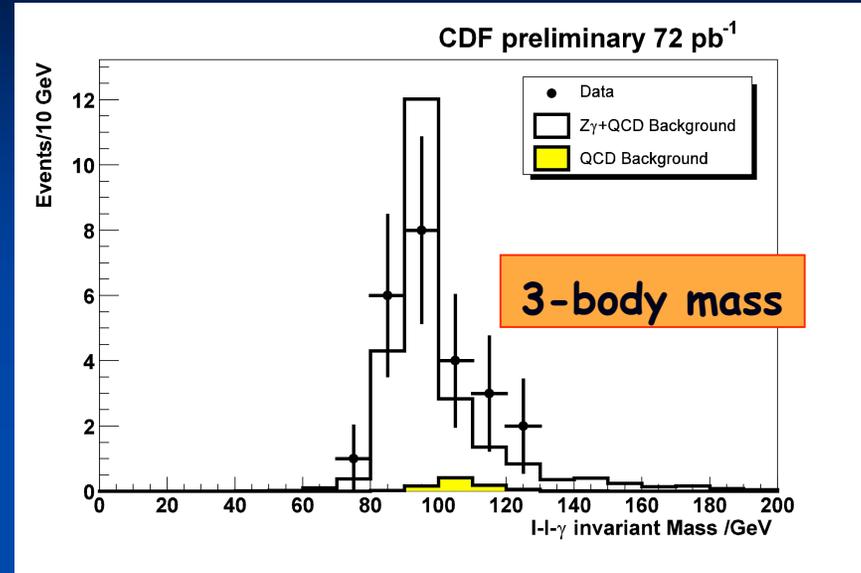
SM: $\sigma \cdot B(W\gamma \rightarrow l\nu\gamma) = 18.7 \pm 1.3$ pb

Z γ Production

• Signature: two high p_T lepton(e/ μ) + γ
 ($\Delta R(\gamma-l) > 0.7$)

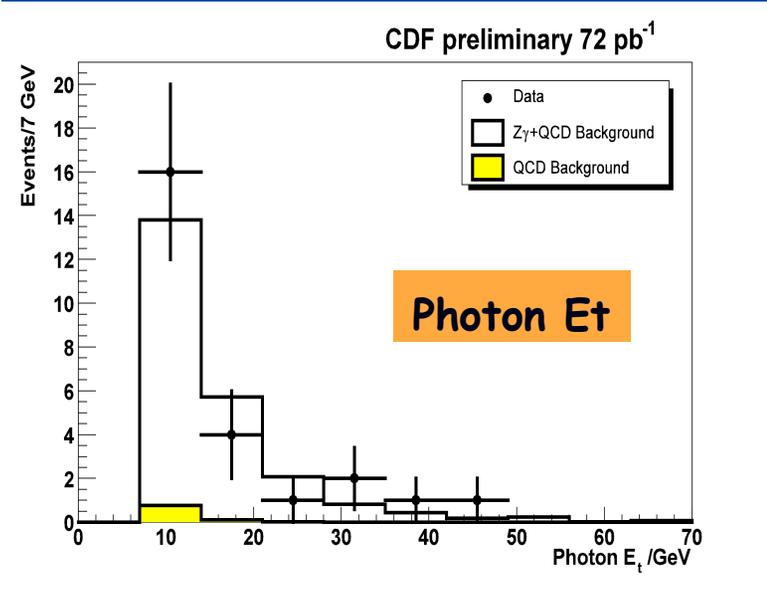
• Results: No excess was found

Data: 11(14)
 Signal MC+BGD : $10.8 \pm 0.9 \pm 0.6$
 ($12.4 \pm 1.2 \pm 0.7$)



cross-section for
 $E_T(\gamma) > 7, \Delta R > 0.7$

	Dat	BG	$\sigma \cdot B(Z\gamma \rightarrow ll\gamma)$ (pb)
e	11	4.6	$5.5 \pm 1.7_{\text{stat}} \pm 0.6_{\text{sys}} \pm 0.3_{\text{th}}$
μ	14	4.0	$6.0 \pm 1.6_{\text{stat}} \pm 0.7_{\text{sys}} \pm 0.4_{\text{th}}$



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Results consistent with SM
 SM: $\sigma \cdot B(Z\gamma \rightarrow ll\gamma) = 5.4 \pm 0.4$ pb

Conclusions

- CDF is taking high quality data in Run 2
- Run 2 statistics about twice of Run 1
- Covering broad range for photon searches:
 - Model independent, LED, SUSY,...
- No evidence of new physics found
- Nothing like run 1 event found yet

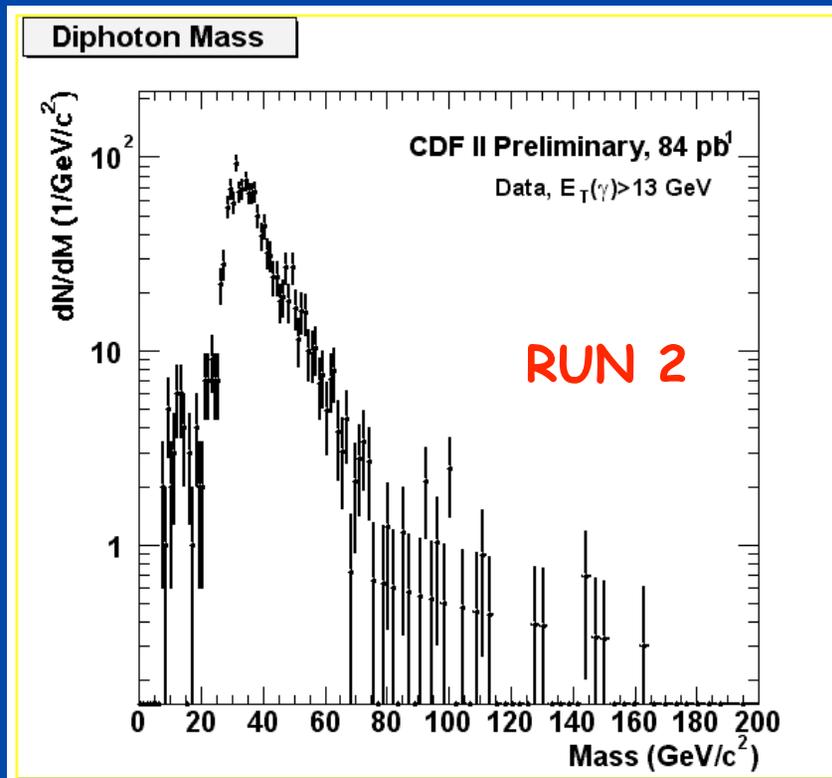
... but if mother nature gives it to us we
will for sure find it!

Backup Slides

Di-Photon Mass Spectrum

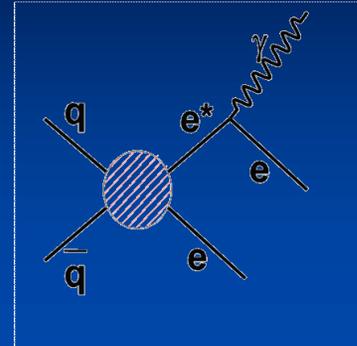
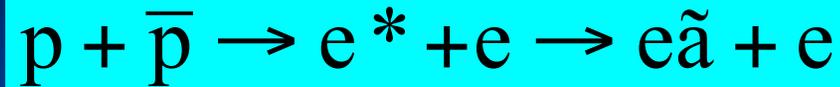
- Search Selection:
2 central photons with $E_T > 13(25)$
Cosmic and beam halo clean-up
- Results: 1365 events for $E_T > 13$ GeV

- Classic LHC higgs search channel
- SM higgs cross section factor 100 too low for TeVatron, but e.g. bosophilic higgs
- Model independent search for “bump” in di-photon mass spectrum
- No Signal, limits soon



Search for Excited Electrons

- Search for the production of excited or exotic electrons (e^*) in :

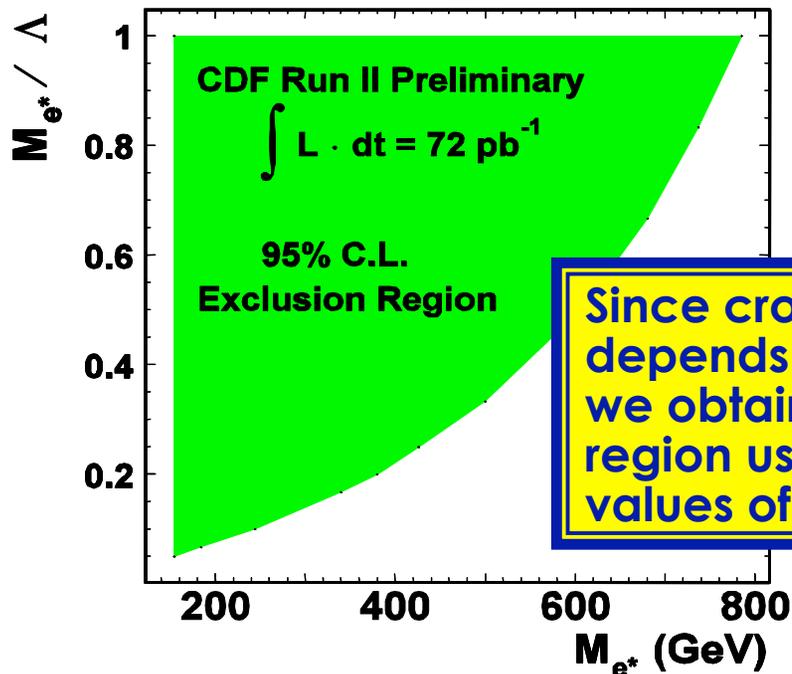


- resonance in $e\gamma$ invariant mass in $e\tilde{e}\gamma$ events:

select two high p_T electrons + one photon ($E_T > 25$ GeV)

- 0 event observed:** set **mass limit on e^*** for contact interaction model: For $M_{e^*} = \Lambda$, the mass limit is **785 GeV**

Λ = Compositeness Scale



Since cross-section depends on M_{e^*} & Λ , we obtain exclusion region using various values of M_{e^*} and Λ

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$M(e^*) < 785$ GeV

