Searches for Exotic New Phenomena at

Max Goncharov for CDF Collaboration

In This Talk ...

Searches for High Mass Resonances
(RS Graviton)

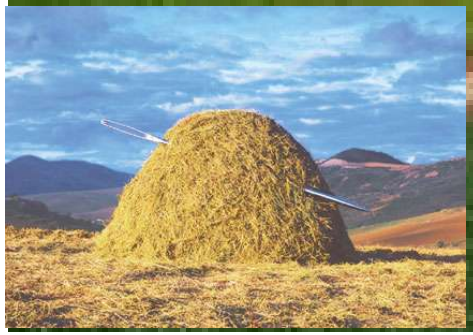
From Model Dependent to
Signature Based

Model Independent Searches

- Gamma + Lepton + X
- Global Fits

Where else to look?

Where we are going



Heavy Long Lived Particles

- Possible Signatures
- Search for Delayed Photons

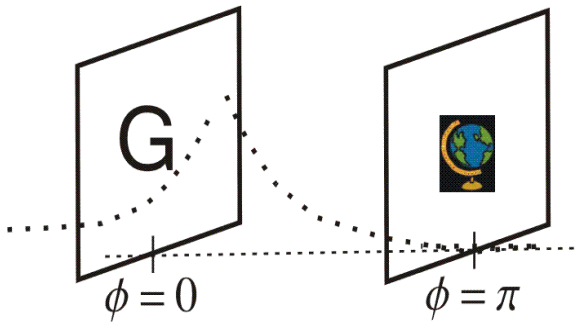
RS Model

RS Model :introduced to address the Hierarchy problem (M_{EW}<<M_{Planck}?)

- **1 highly curved extra dimension**
- **Gravity localized in the ED**

$M_{Pl}^2 \sim M^{(2+n)}_{Pl(4+n)} R^n$, set $M_{Pl(4+n)} \sim M_{EW}$

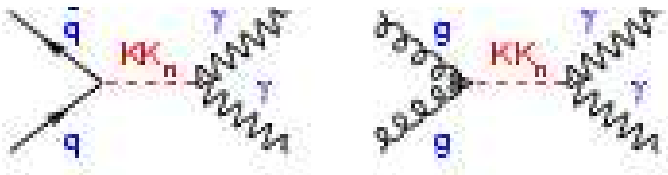
⇨ **Deviations in virtual graviton exchange**



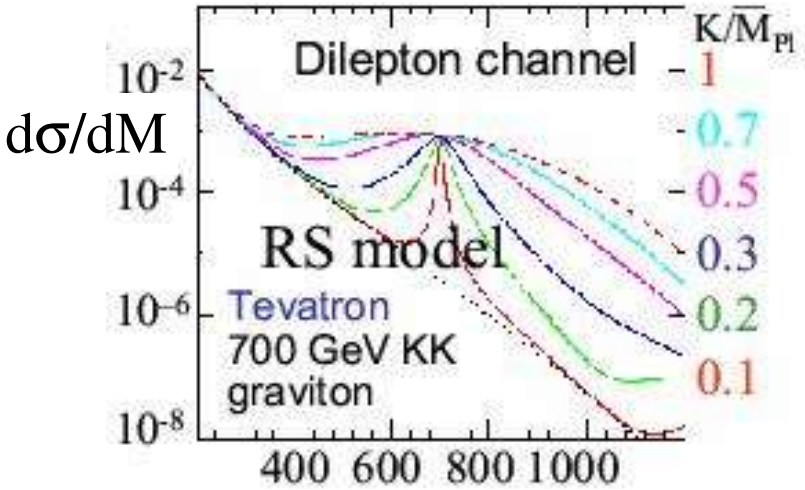
$\Lambda_\pi = M_{Pl} e^{-KR\pi}$

$\Lambda_\pi \sim$ TeV if KR ~11

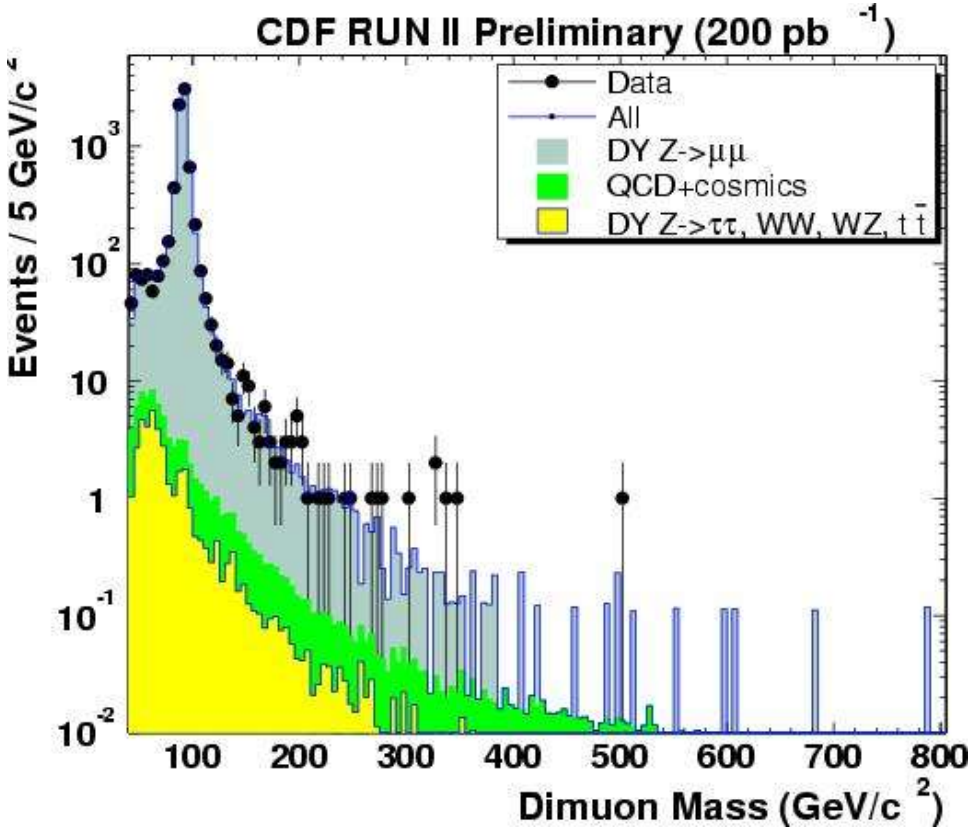
Parameters:
Graviton first excitation mass m_1
Space warp factor K/M_{Pl}

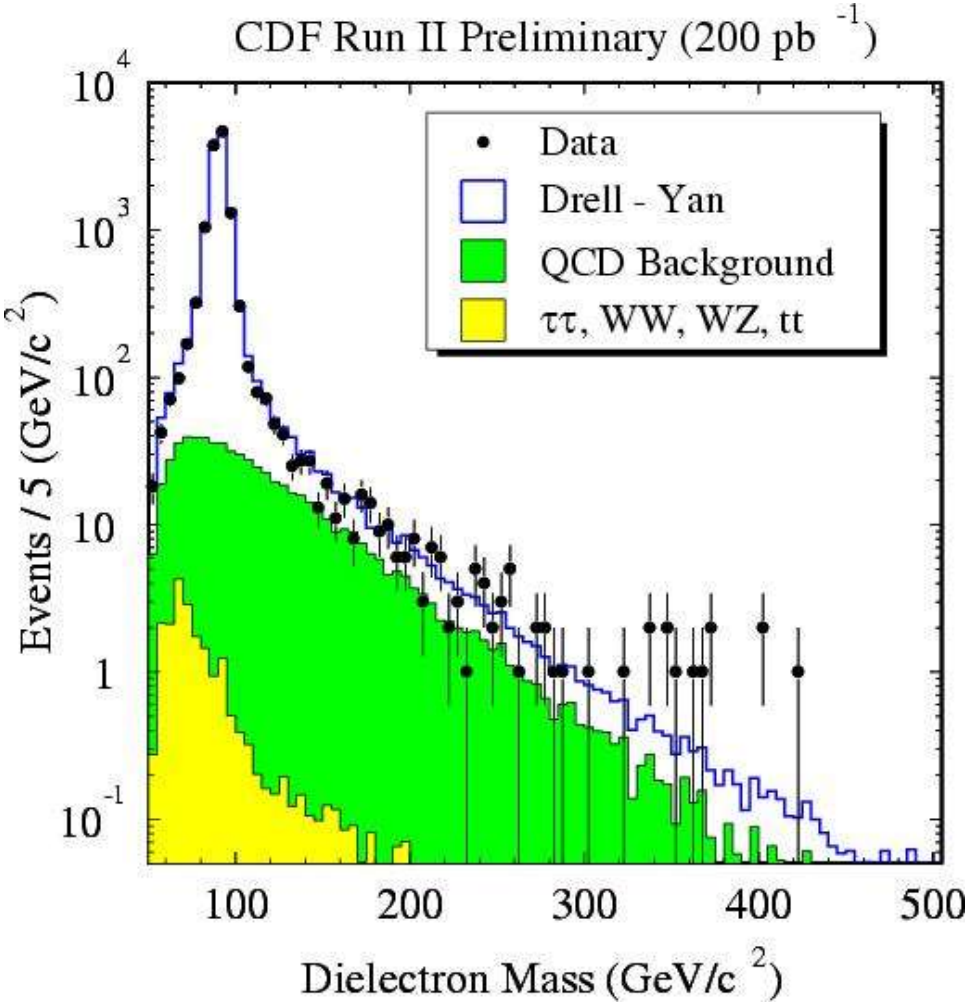


Graviton can also decay into ll, ZZ, … **BF (γγ) = 2 * BF (ll)**

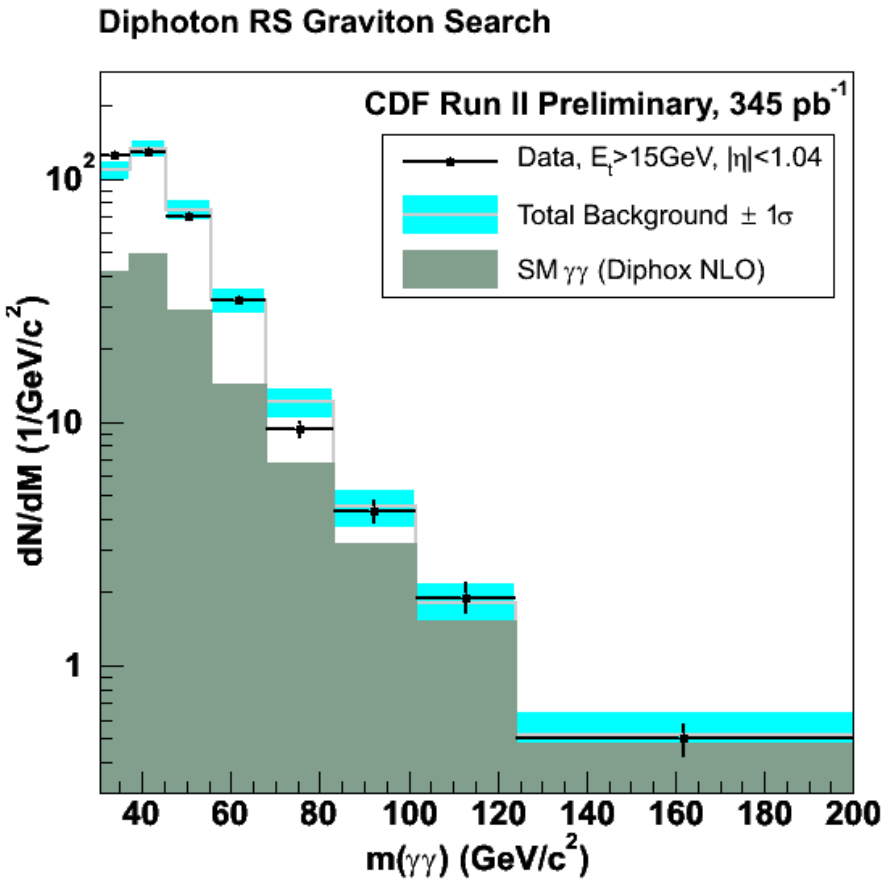


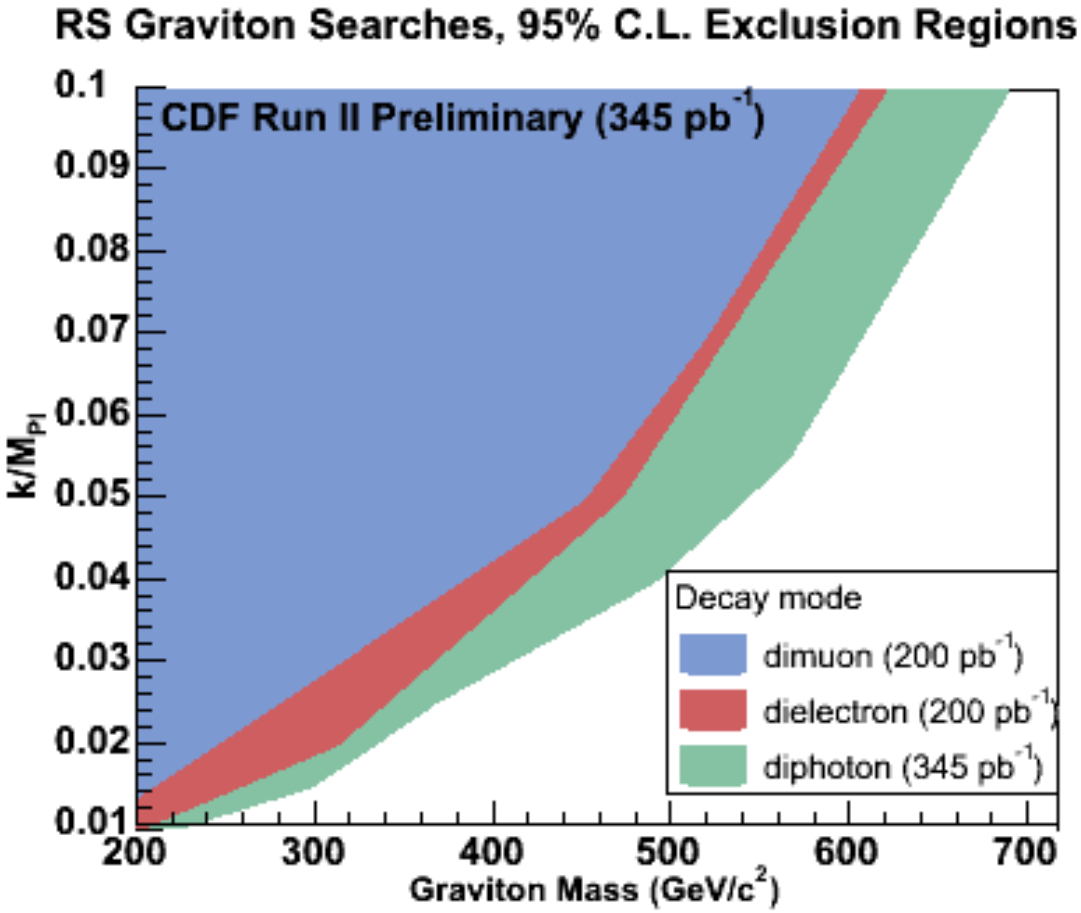
RS Graviton - ll Final State



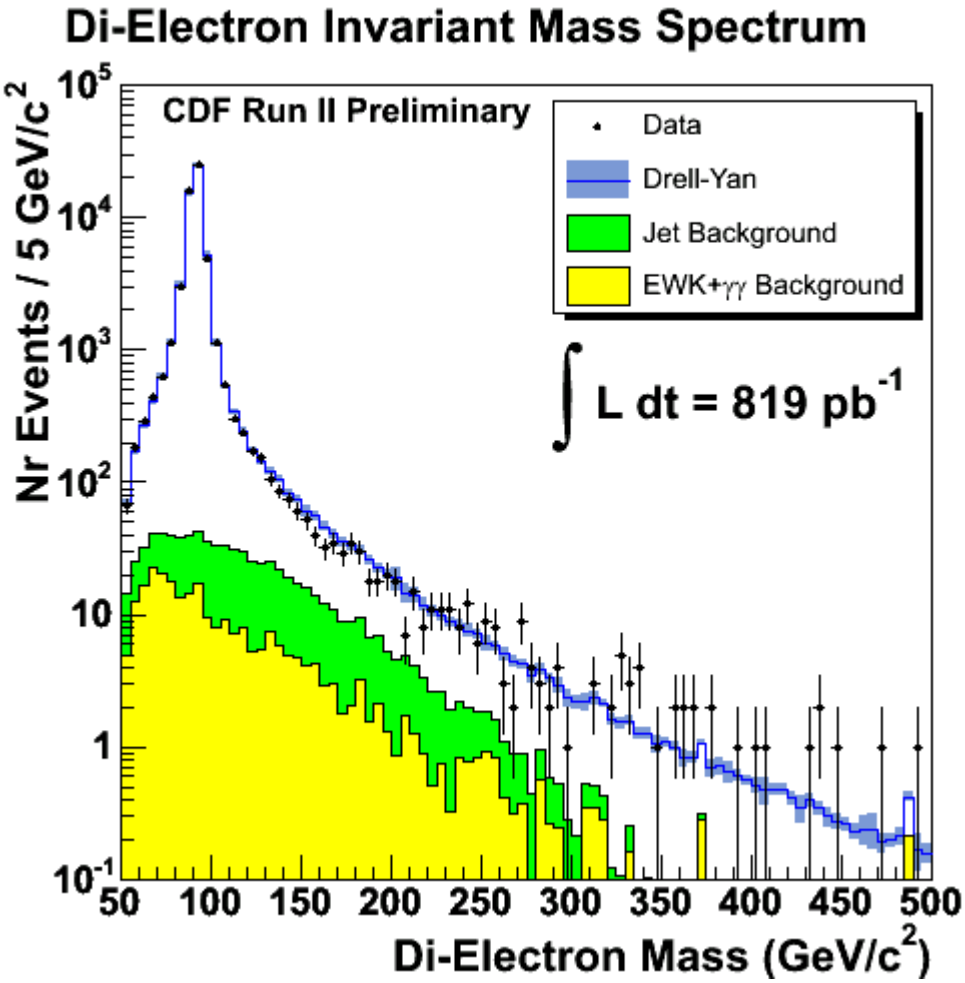


RS Graviton - γγ Final State



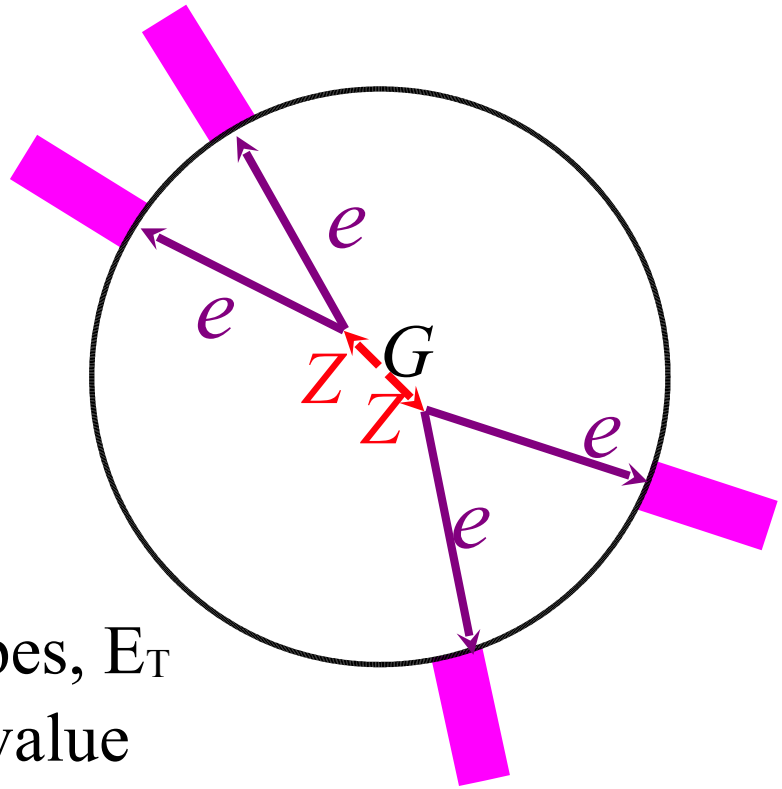


RS Graviton Update - ll and $\gamma\gamma$



- $\gamma\gamma$ channel in ~3 weeks
- will have exclusion region

Heavy Resonance in eeee Channel

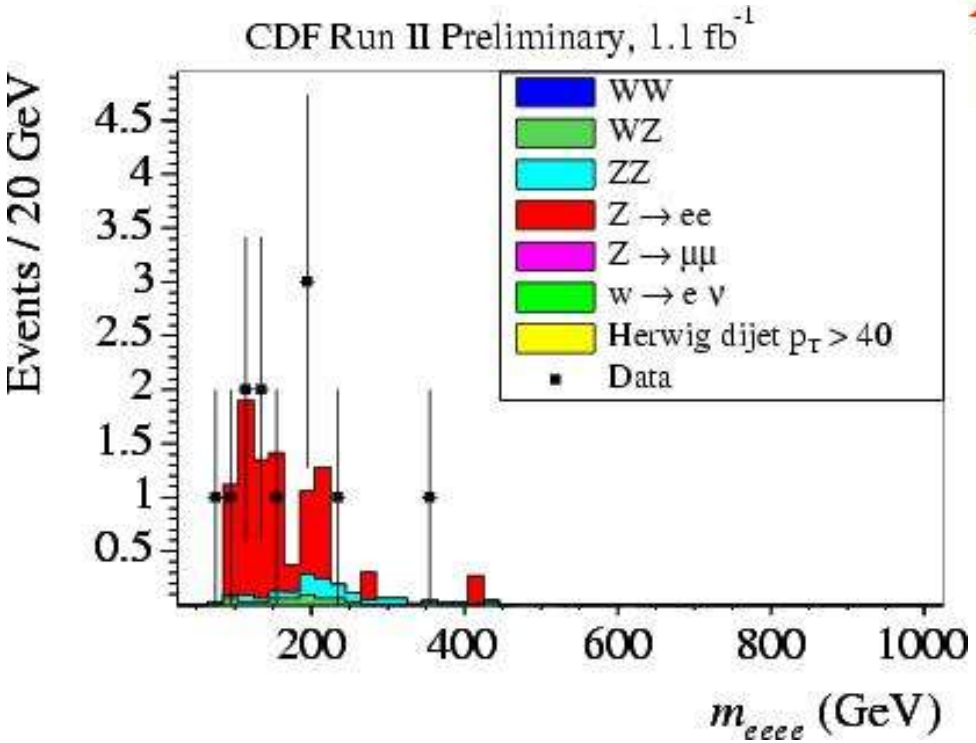


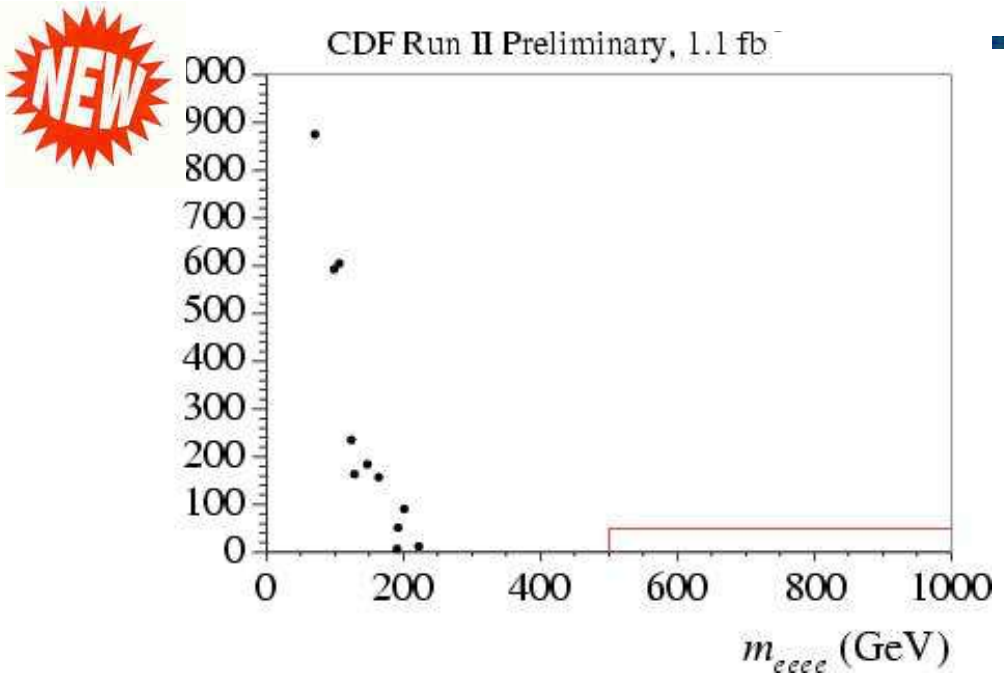
- Look for events with ≥ 4 electrons
- For each ZZ combination, compute

$$\chi^2 = \sum \left(\frac{m_{ee} - m_{Z^0}}{\sigma} \right)^2$$

- σ : 2.5-4.5 GeV, depends on electron types, E_T
- Keep one combination with smallest χ^2 value
- Require $\chi^2 < 50$.
- $m_{eeee} > 400$ GeV hidden
- Signal Region: $m_{eeee} > 500$ GeV

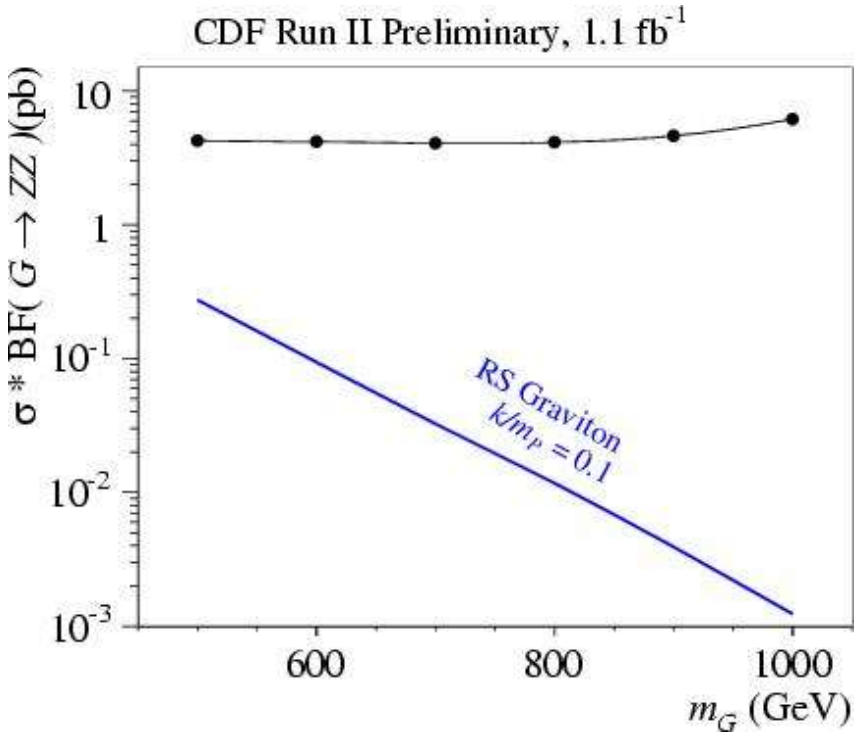
Heavy Resonance in eeee Channel





No Events above 400 GeV

Background: 0.0 +/- 0.2



Model Dependent->Signature Based

Features Common to Many Analysis:

- very specific data selection
- focus on very specific models, normally cover negligible parameter space

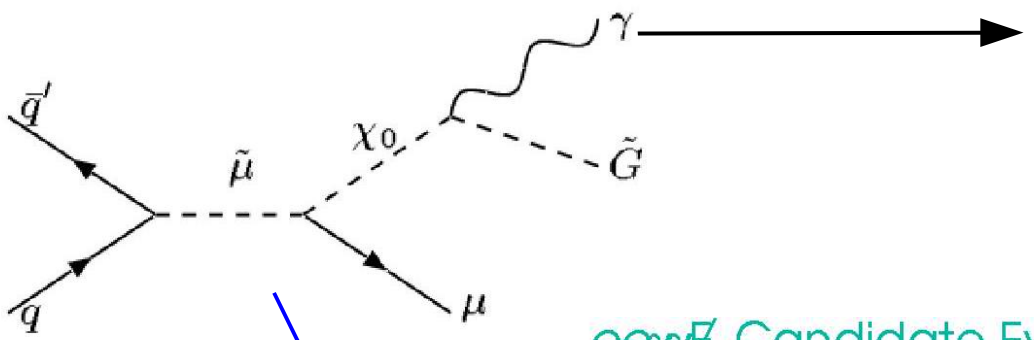
How useful to theorists to check new models?

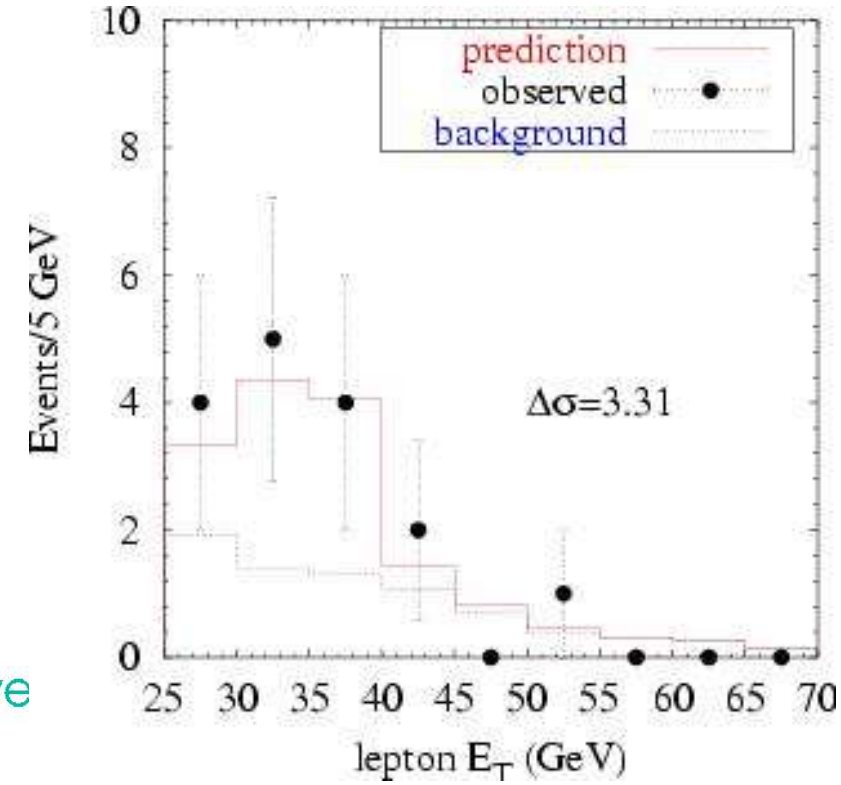
Signature Based (model independent) searches:

- apply very generic cuts
- report events with acceptances and efficiencies

Lepton + Photon + X

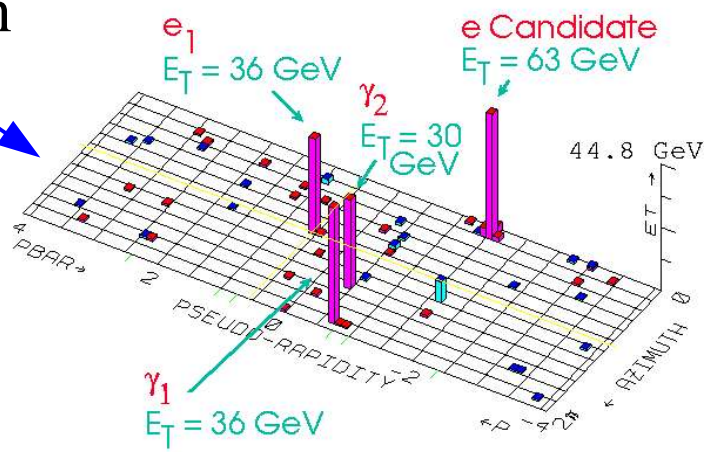
In RUN I:



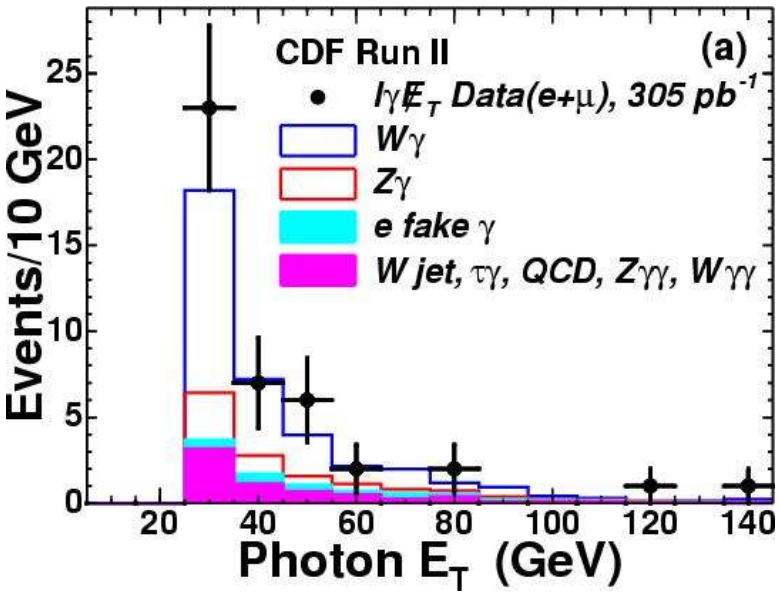


selectron

$ee\gamma\gamma\not{E}_T$ Candidate Eve



Lepton+Photon+MET



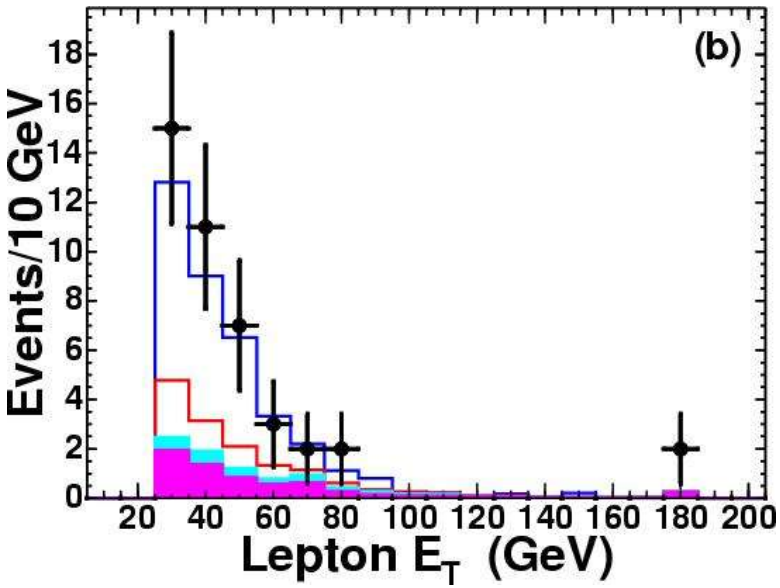
MET > 25 GeV

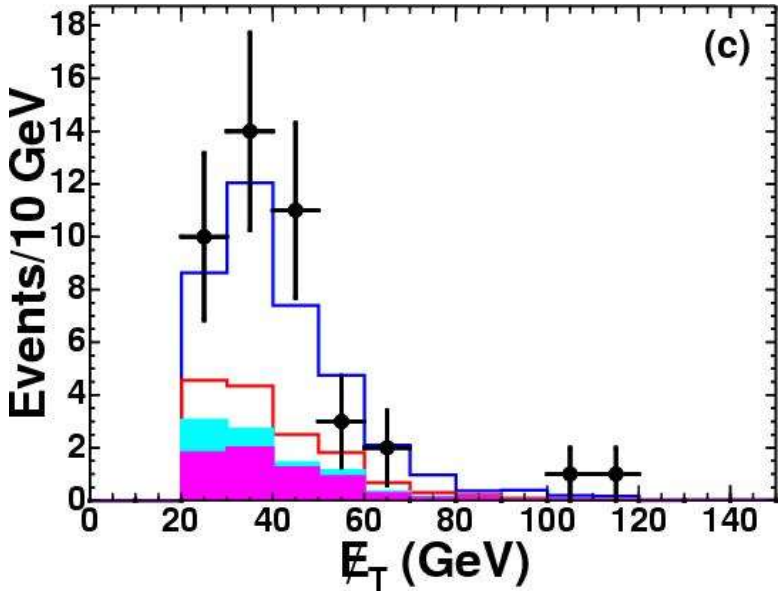
Photon E_T > 25 GeV

Lepton P_T > 20 GeV

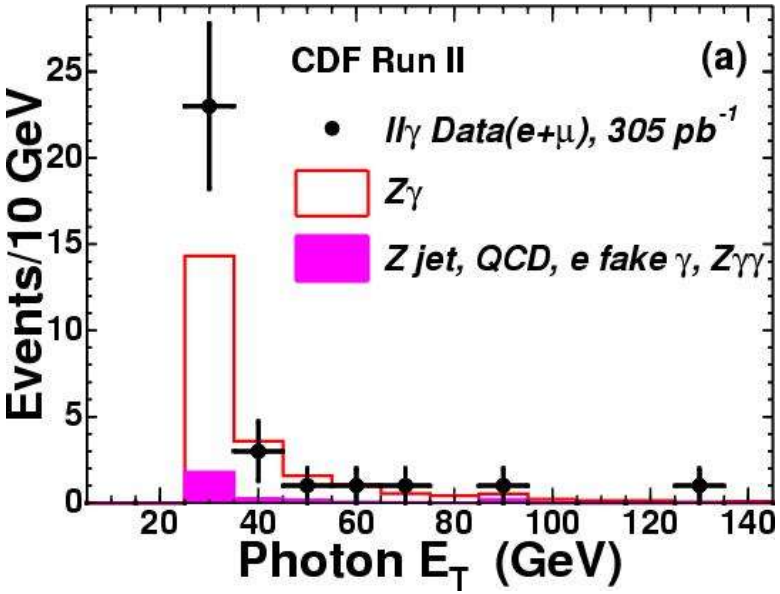
Predicted 37.3 ± 4.3

Observed 42





Leptons + Photon

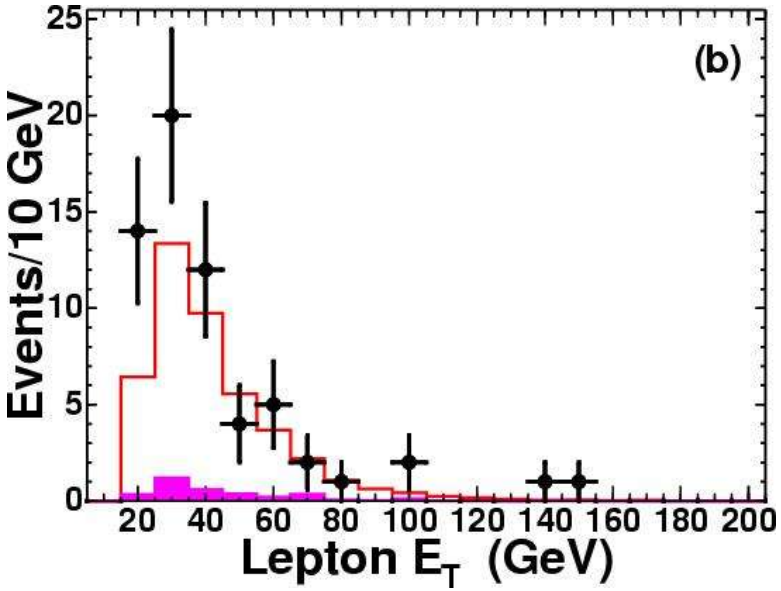


Photon $E_T > 25$ GeV

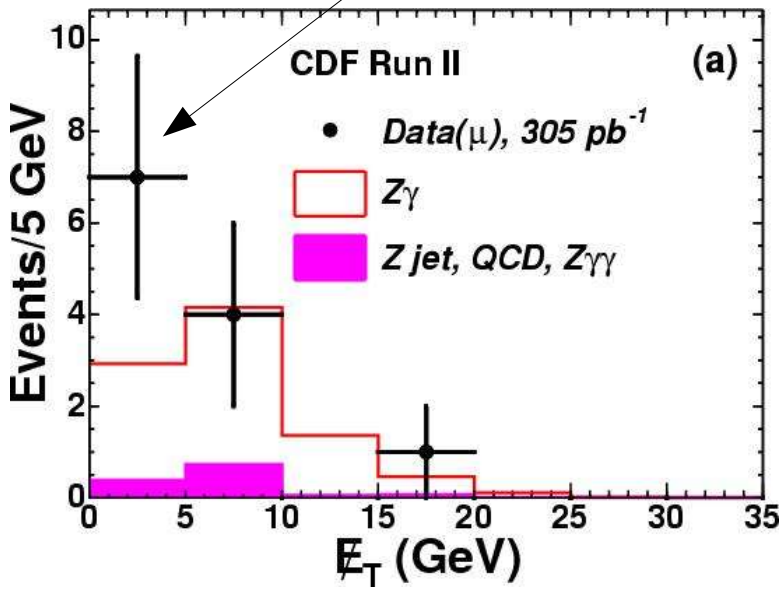
Lepton $P_T > 20$ GeV

Predicted 23.0 ± 2.7

Observed 31



Excess at low MET



Global Fits

Features Common to Many Analysis:

- **often cuts exclude regions of phase space to avoid backgrounds**
- **fake rates are common and have to be estimated**
- **in low ΣP_T regions SM backgrounds are significant**
- **what configuration would yield physics beyond SM?**

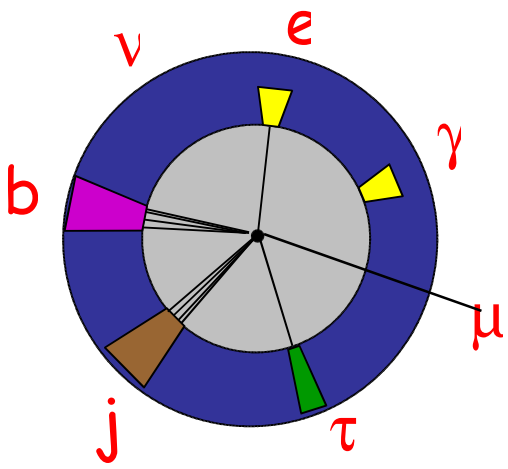
Should we look at all possible final states?

Is it possible to streamline the search procedure?

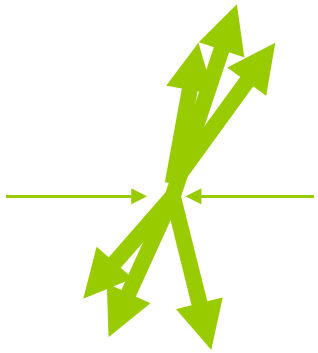
Understanding the Data

VISTA Understanding Standard Model

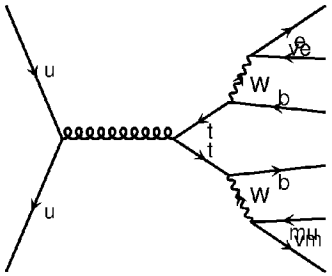
Define physics objects



Filter events of interest

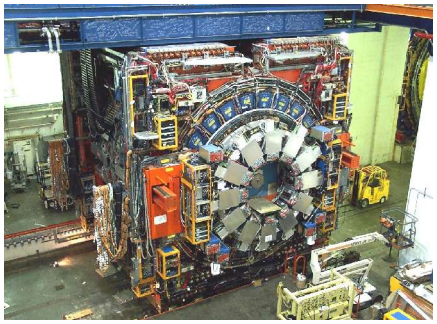


Estimate backgrounds



Fit for experimental & theoretical fudge factors

Simulate detector response



(mis)Id reconstructed

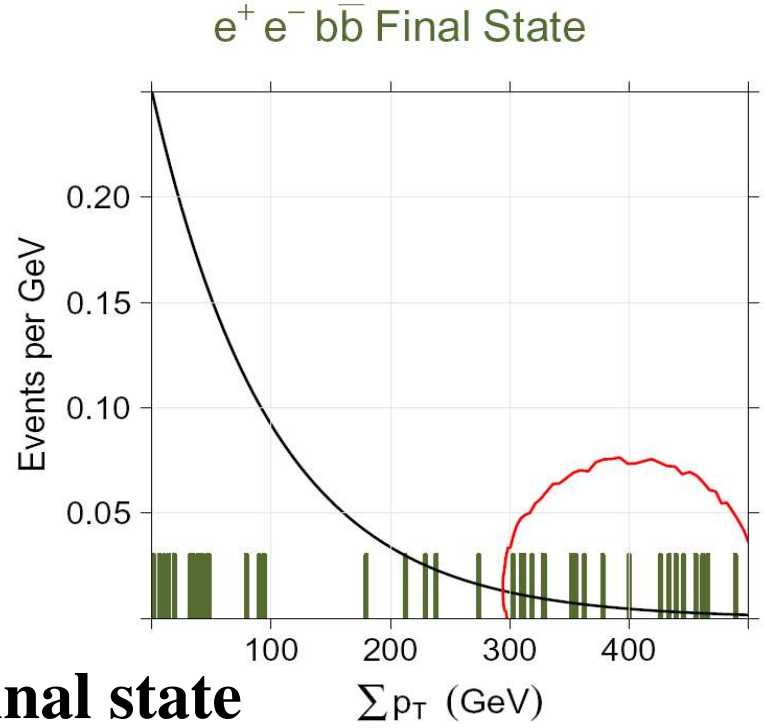
true

	e	μ	τ	γ	j	b
e	0.91		0.02	0.001	0.07	1e-3
μ		0.87				
τ			0.10		0.90	
γ				0.81	0.19	
j	1e-4	2e-6	3e-3	6e-4	1	2e-3
b	1e-3	1e-3	5e-3	8e-4	0.60	0.40

How do we find the excess?

SLEUTH **Finding Excess**

quasi model independent



New physics will appear:

1. **Predominantly in one exclusive final state**
2. **At large $\Sigma\, p_T$**
3. **As an excess**

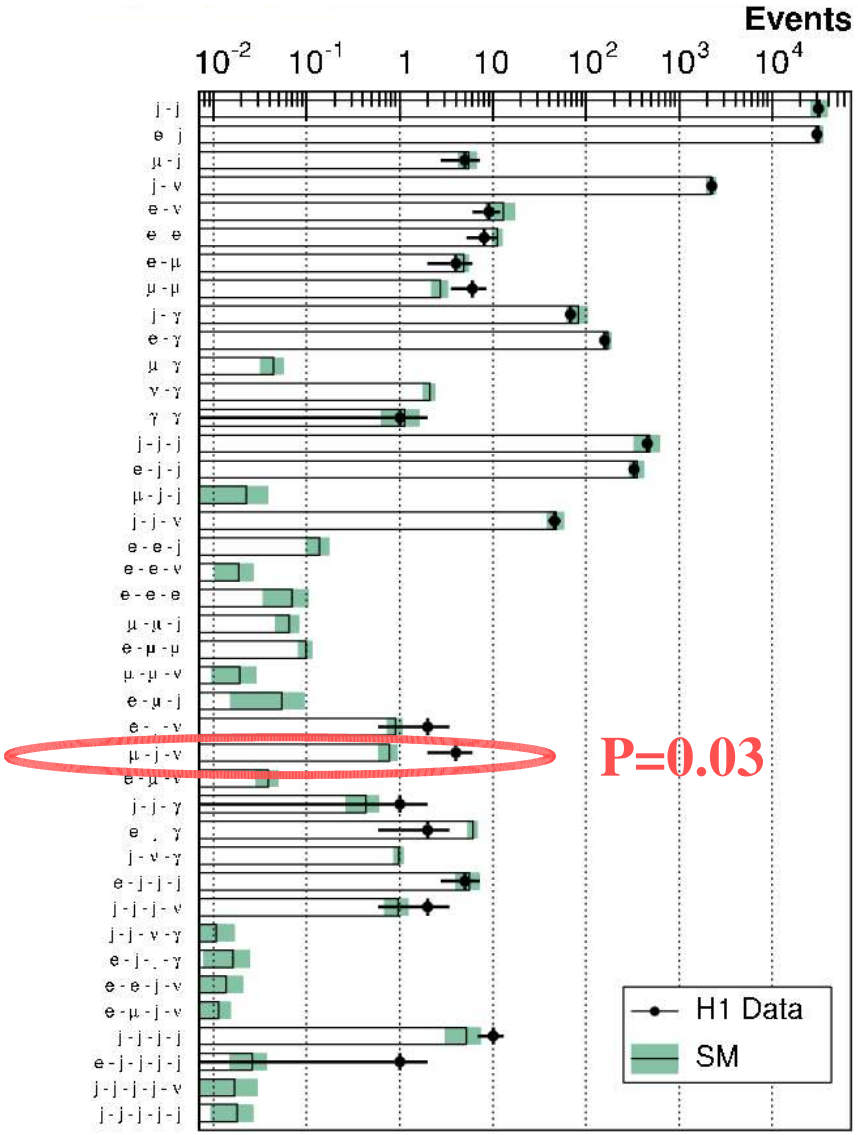
Final Data Representation?

DØ Run I

Phys.Rev.D 62:092004,2000
Phys.Rev.D 64:012004,2001
Phys.Rev.Lett.86:3712,2001

H1 Run I

Phys.Lett.B 602:14-30,2004



Where else to look?

Exotic particles can have:

GMSB: gravitino as LSP ...

long lifetime

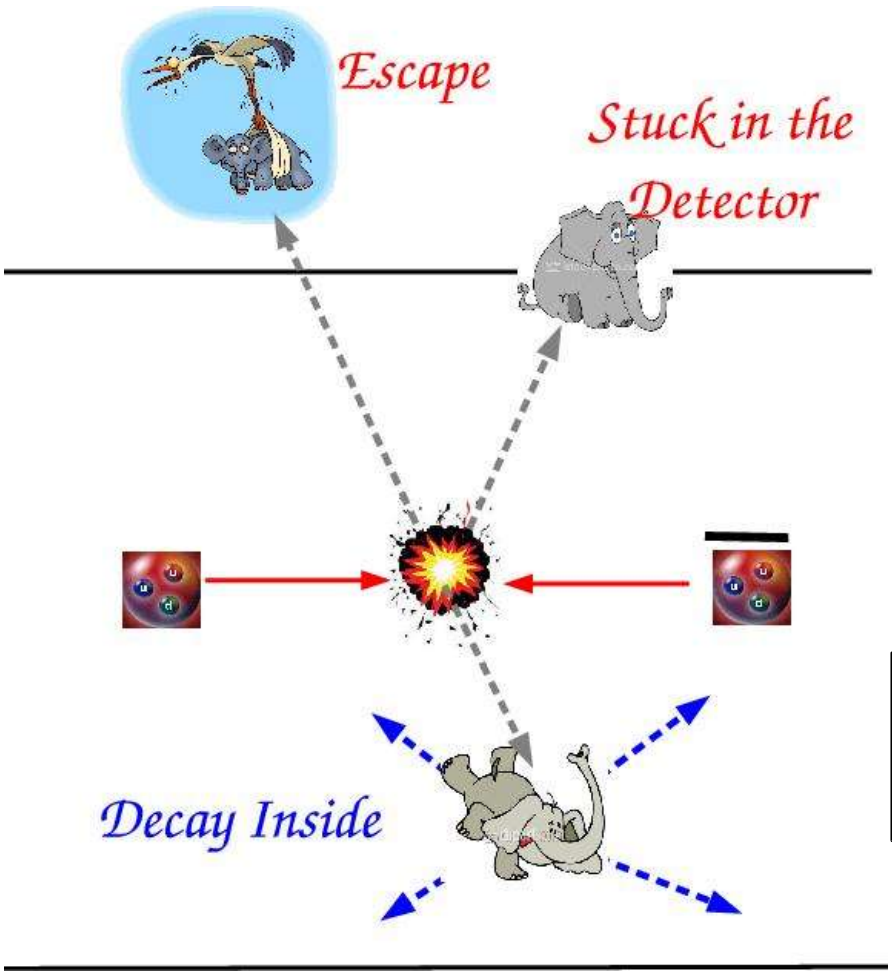
large mass

low speed

Massive Long Lived Particle can:

- **be charged or neutral**
- **decay inside or outside the detector**
- **be in events with low ΣP_T**

Long Lived Massive Particles



Charged -highly ionizing isolated track

- $\beta > 0.4$ – highly ionizing isolated track
- $\beta < 0.4$ – out of time high E_T narrow jet

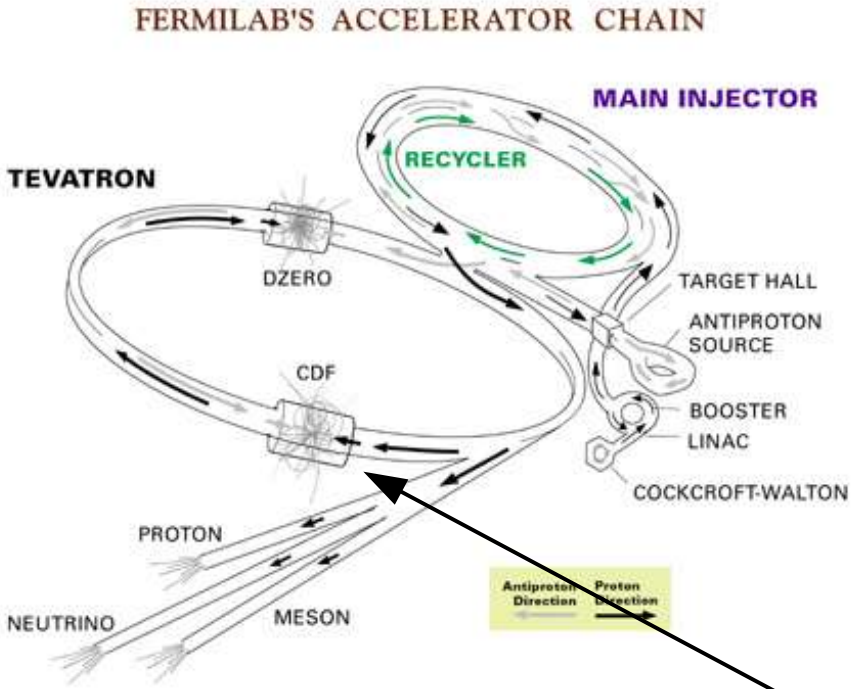
Neutral – missing energy

Decay inside – **delayed photon,** or Jet, or Highly Displaced Vertex

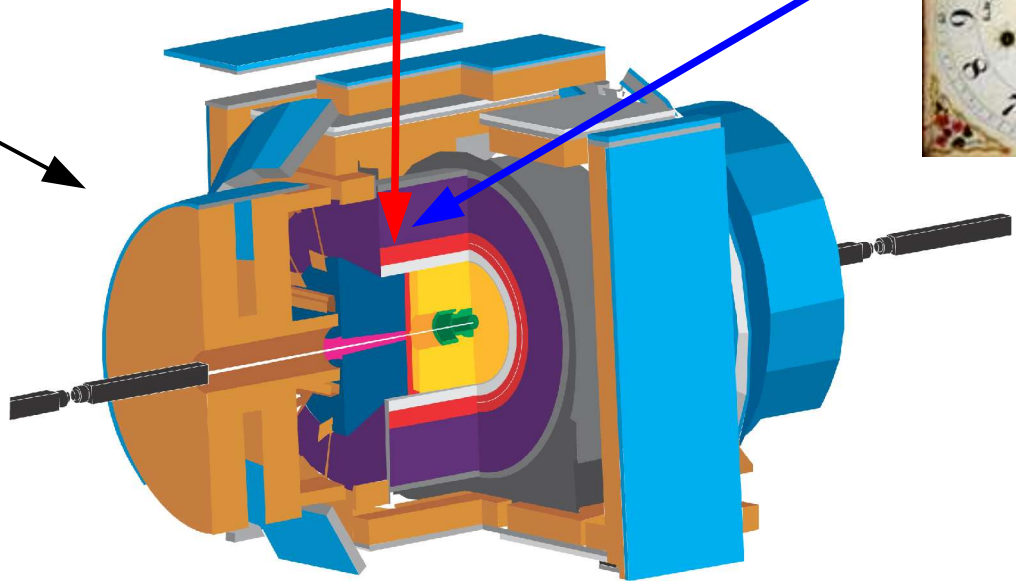
signatures should be spectacular

Search for Delayed Photons

Calorimeter Timing System

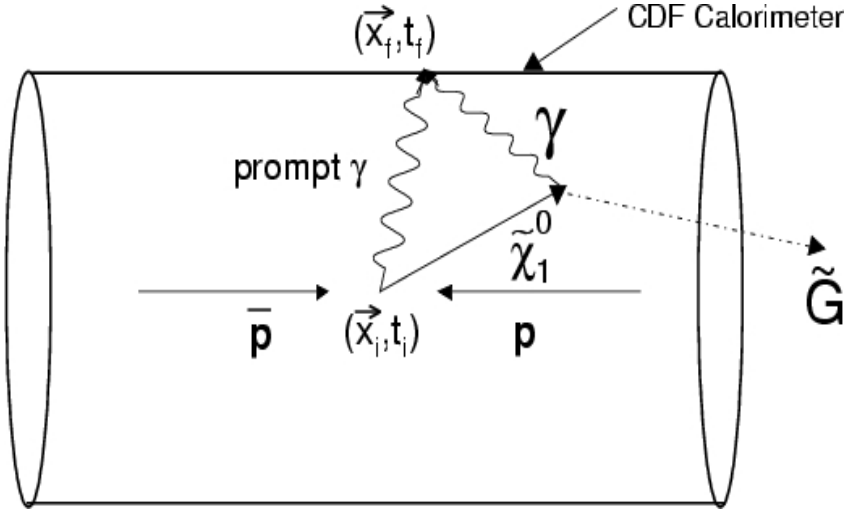


CDF Detector
Electromagnetic (EM) Calorimeter
EMTiming system

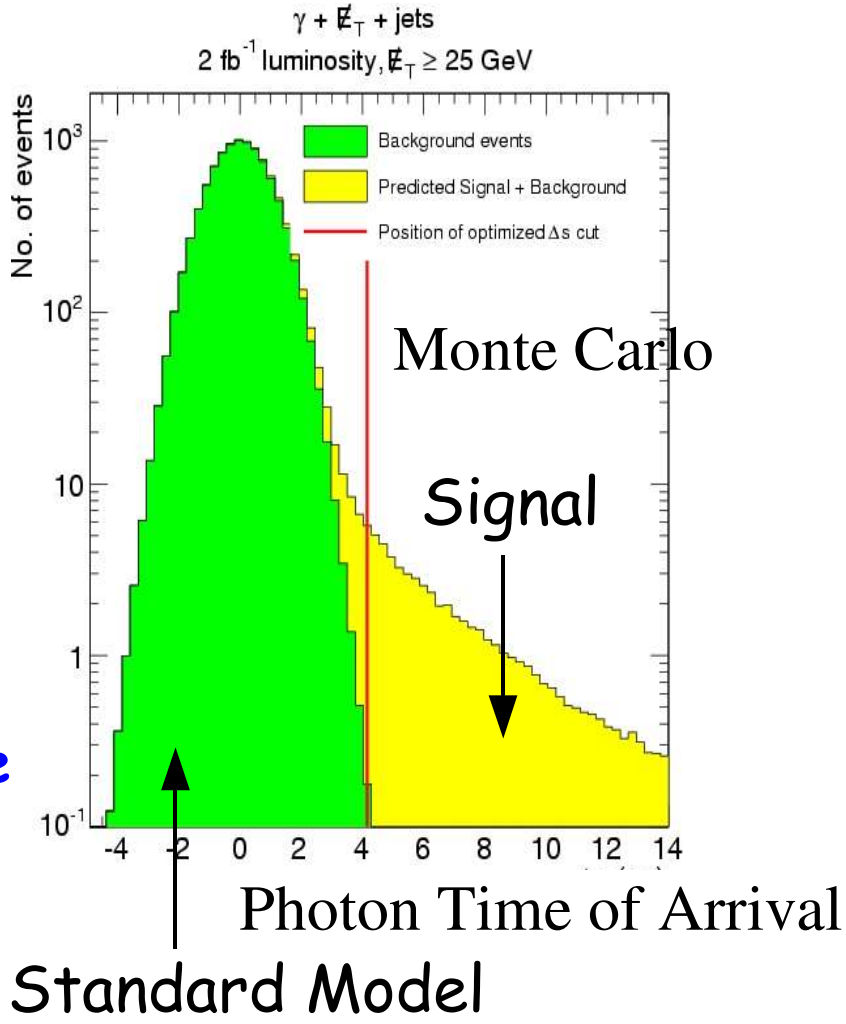


Installed in Dec. 2004
(NIM - physics/0512171)

Search for Delayed Photons

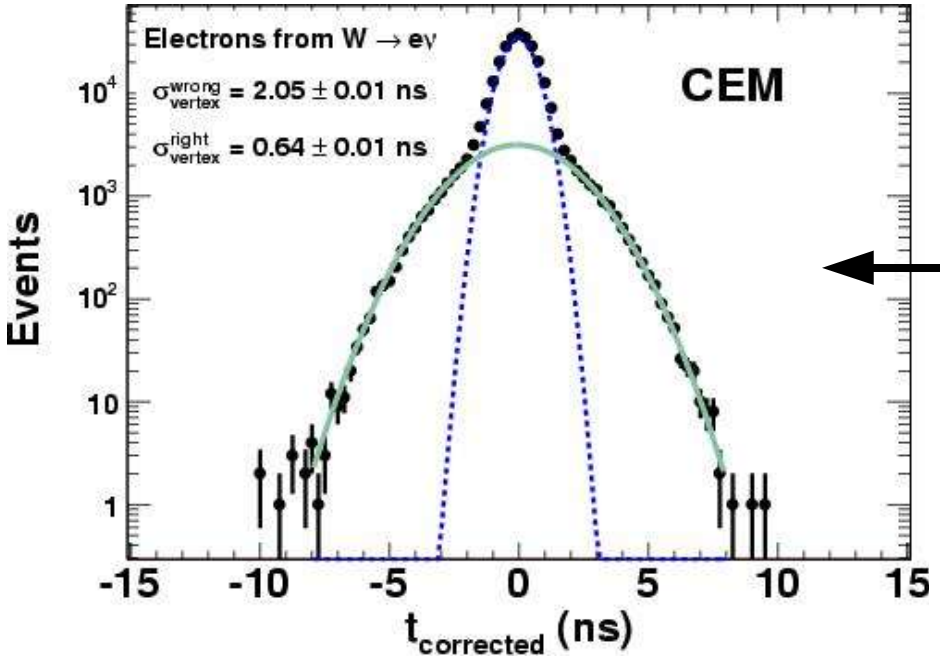


Look for non-prompt γ's that take longer to reach calorimeter.
If the χ has a significant lifetime, we can separate the signal from the backgrounds.



Search for Delayed Photons

Electrons



Backgrounds

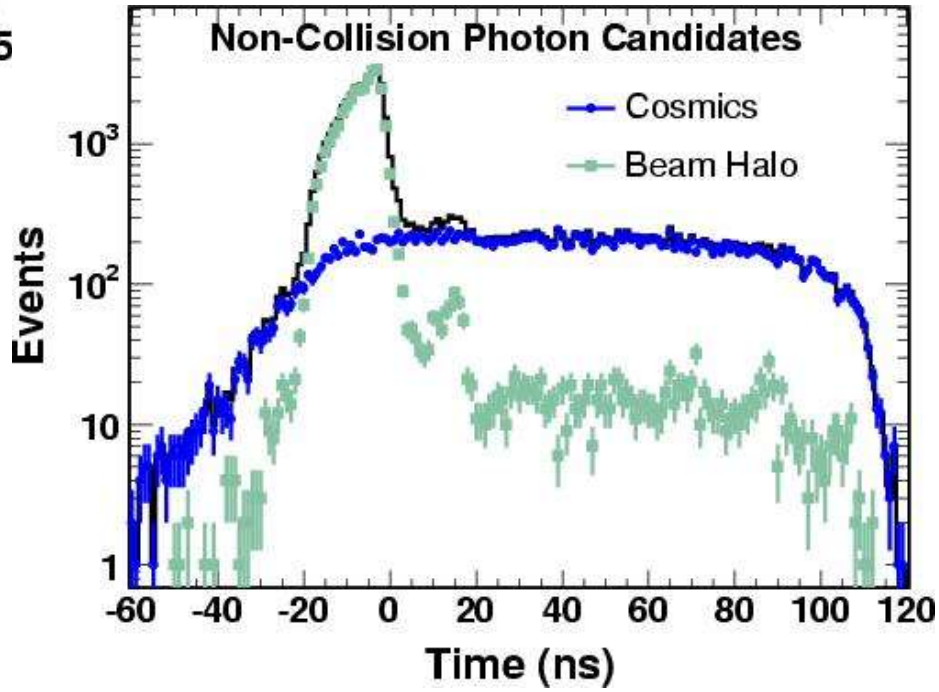
4 sources, all estimated from data

Collision Standard Model (SM) photon candidates

- **Right vertex**
- **Wrong vertex**

Non-collision photon candidates

- **Beam Halo**
- **Cosmics**



Timing system:

- **100% efficient above 5 GeV**
- **No noise**
- **Gaussian with no tails**

Search for Delayed Photons

Select: Photon E_T>30 GeV

MET > 50 GeV

Jet E_T> 30 GeV

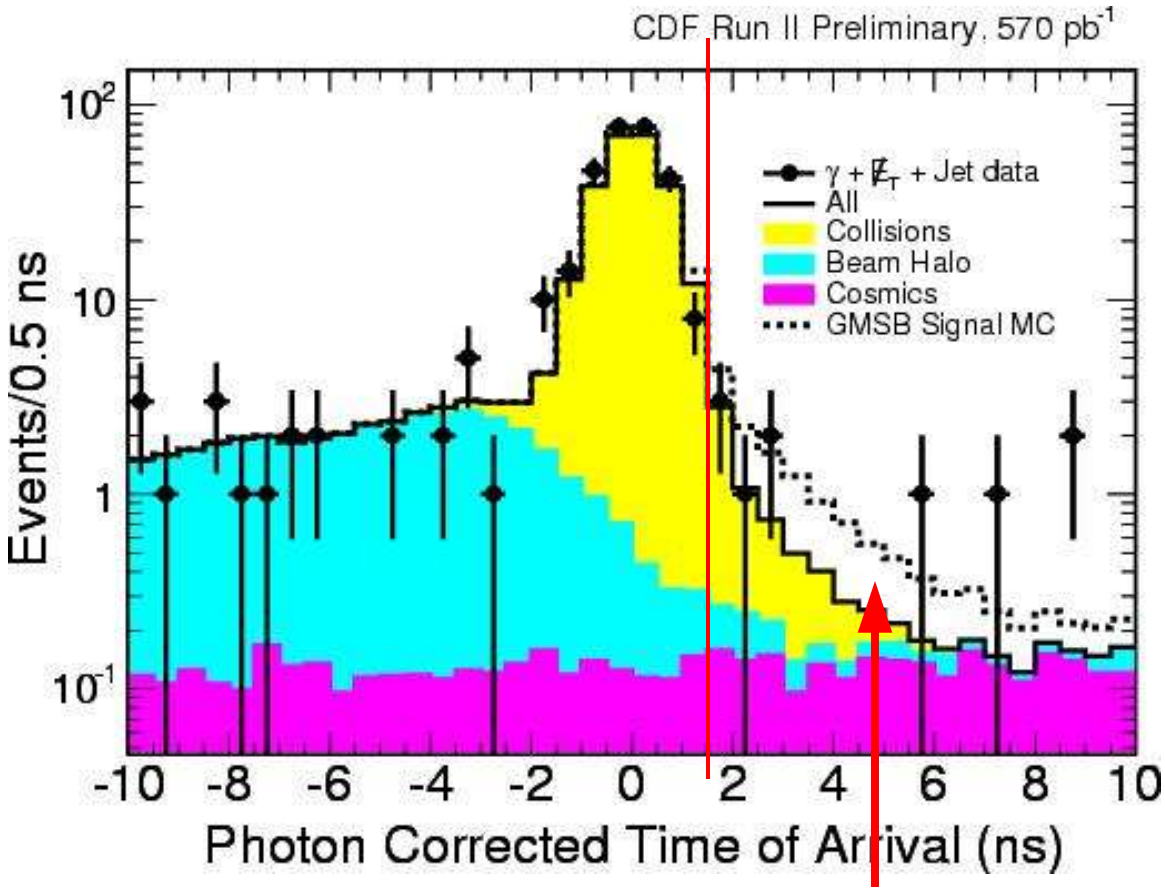
Optimized for GMSB

Predicted 7.9 ± 1.9

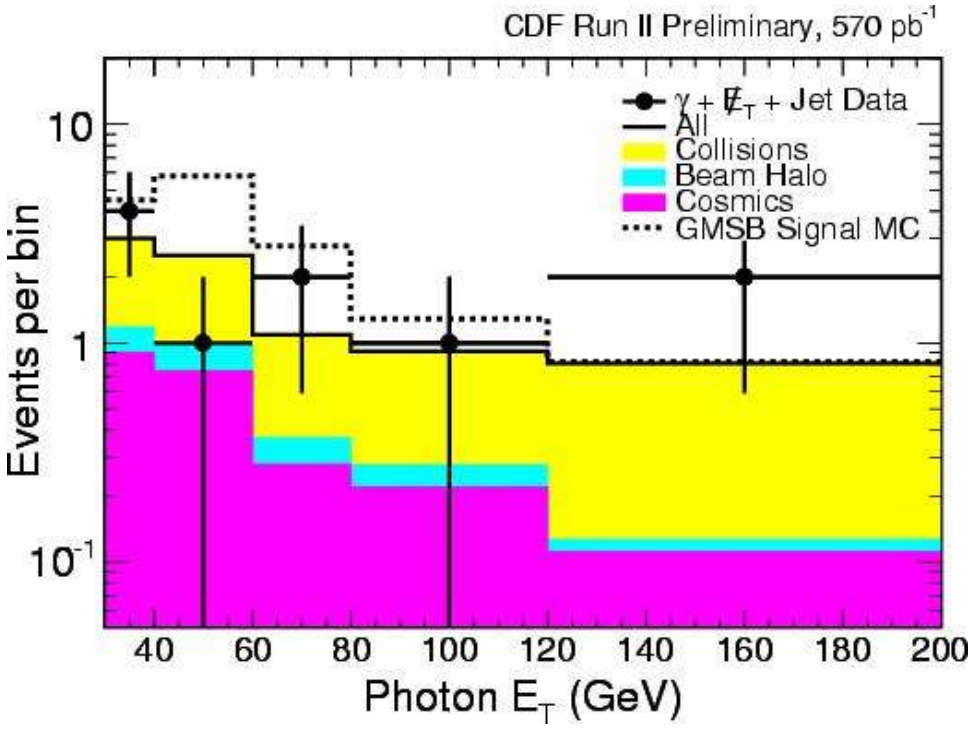
Observed 10 events

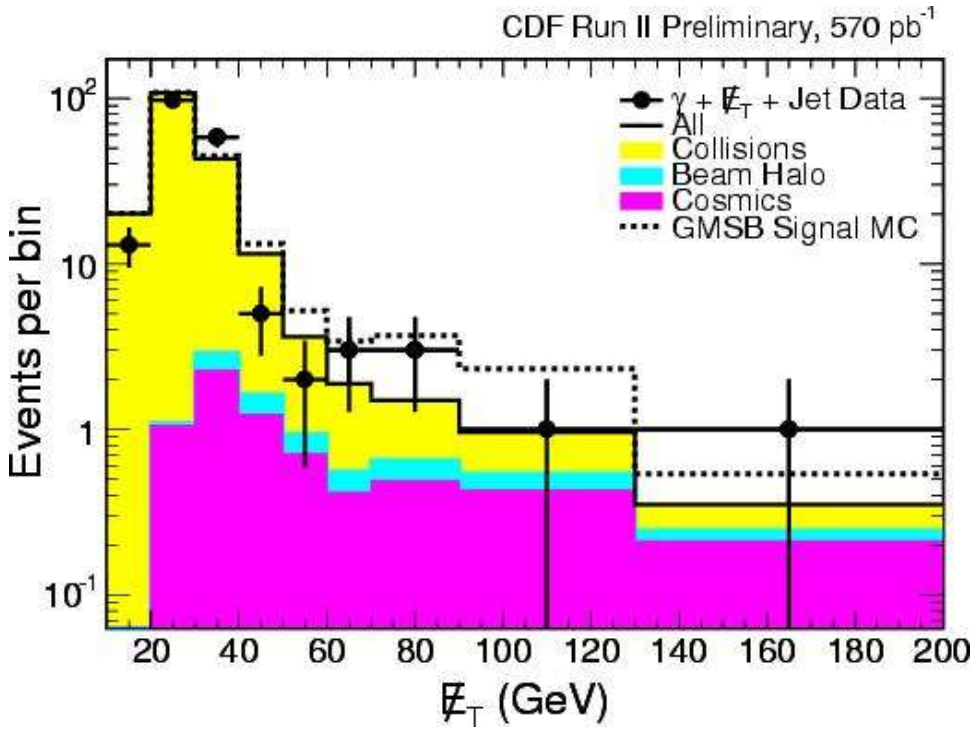
570 pb^{-1}

Will improve non-collision background rejection



Search for Delayed Photons



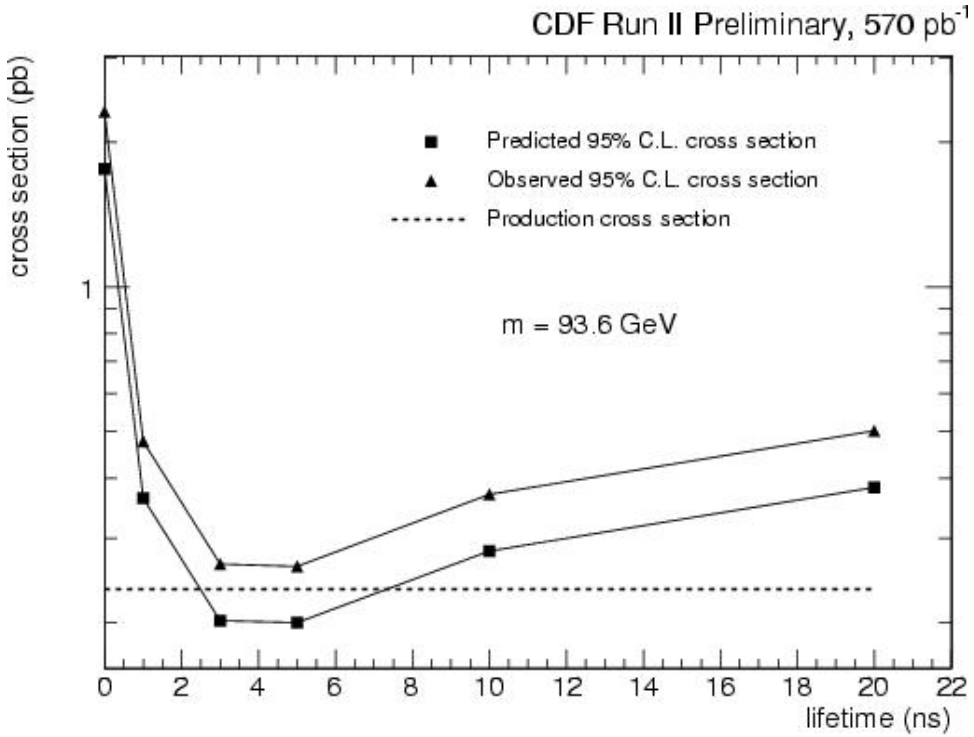


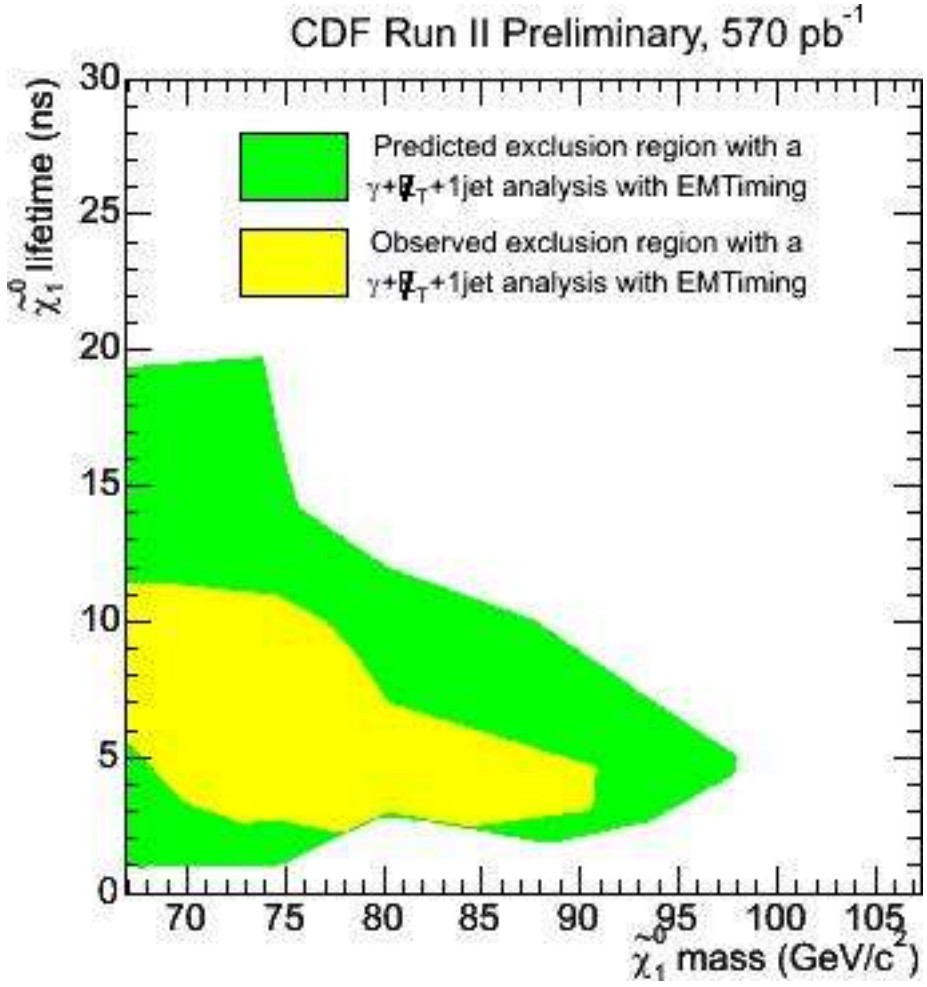
Because of a timing handle we sensitive at low ΣP_T

Search for Delayed Photons

Predicted 7.6 ±1.6 events

Observed 10





Where we are ...

Wide range of dedicated searches

A number of model independent searches

A universal model independent search technique is under construction

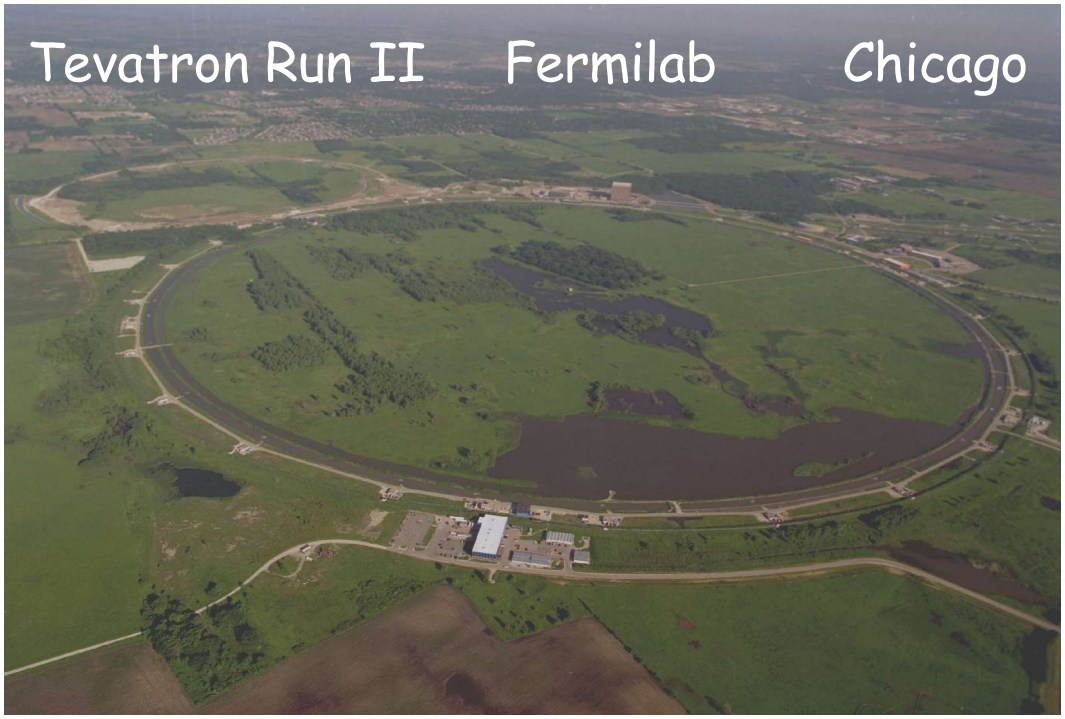
Looking for Heavy Long Lived objects

Most analysis are about to be updated w

This year promises to be very interesting

Backup Slides

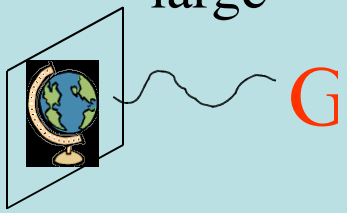
Collider Detector at Fermilab



Large extra dimensions

ADD

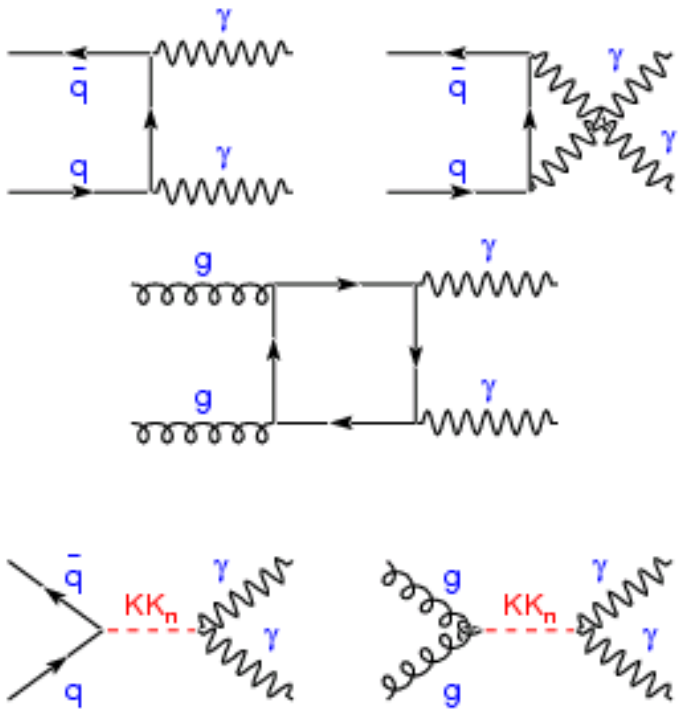
Taking compact space to be very large



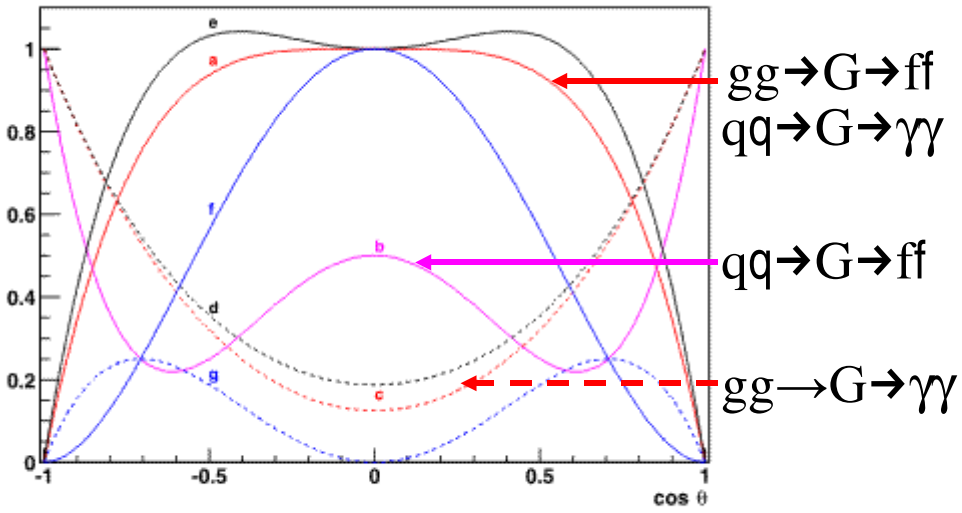
gravity freely propagates in the many large extra dimensions (n=2-7)

$$M_{Pl}^{2} = V_{n} M_{Pl(4+n)}^{(2+n)}$$

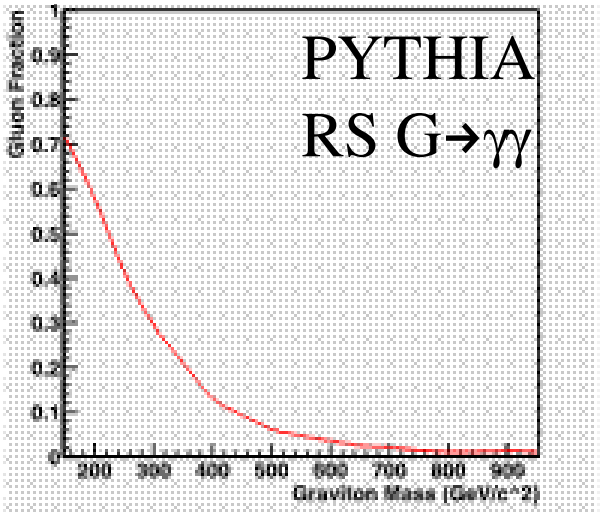
To solve hierarchy: $M_{Pl(4+n)} \sim 1$ TeV



RS Graviton



(gg→G→γγ)/(G→γγ)



Lepton + Photon + X

CDF Run II, 305 pb^{-1}

Lepton+Photon+$\not\!\!E_T$ Events

SM Source	$e\gamma\not\!\!E_T$	$\mu\gamma\not\!\!E_T$	$(e+\mu)\gamma\not\!\!E_T$
$W^{\pm}\gamma$	13.70±1.89	8.84±1.35	22.54±2.80
$Z^0/\gamma^* + \gamma$	1.16±0.40	4.49±0.64	5.65±1.03
$W^{\pm}\gamma\gamma, Z^0/\gamma^*+\gamma\gamma$	0.14±0.02	0.18±0.02	0.32±0.03
$W^{\pm}\gamma, Z^0/\gamma^*+\gamma\to\tau\gamma$	0.71±0.18	0.26±0.08	0.97±0.22
$W^{\pm}$+Jet faking γ	2.8±2.8	1.6±1.6	4.4±4.4
$Z^0/\gamma^*\to e^+e^-, e\to\gamma$	2.45±0.33	-	2.45±0.33
Jets faking $\ell + \not\!\!E_T$	0.7±0.7	0.3±0.3	1.0±0.8
Total SM Prediction	**21.7±3.4**	**15.7±2.2**	**37.3±5.4**
Observed in Data	**25**	**17**	**42**

Multi-Lepton+Photon Events

SM Source	$ee\gamma$	$\mu\mu\gamma$	$ll\gamma$
$Z^0/\gamma^* + \gamma$	12.50±1.53	7.81±0.88	20.31±2.40
$Z^0/\gamma^* + \gamma\gamma$	0.24±0.03	0.12±0.02	0.36±0.04
Z^0/γ^*+Jet faking γ	0.3±0.3	0.2±0.2	0.5±0.5
$Z^0/\gamma^*\to e^+e^-, e\to\gamma$	0.23±0.09	-	0.23±0.09
Jets faking $\ell + \not\!\!E_T$	0.6±0.6	1.0±1.0	1.6±1.2
Total SM Prediction	**13.9±1.7**	**9.1±1.4**	**23.0±2.7**
Observed in Data	**19**	**12**	**31**