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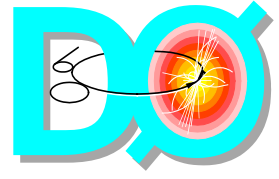
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New Phenomena Searches at TEVATRON Run I



Steve Muanza, IPN Lyon

On behalf of CDF and D0 collaborations

Outline

- Run I at the TEVATRON
- Search for SUGRA:
 - dilepton channel at CDF
 - electron channel at D0
- Search for large ED:
 - monojet channel at D0
 - diphoton channel at CDF
- Conclusions

Collider in Run I



Proton-Antiproton
Collisions

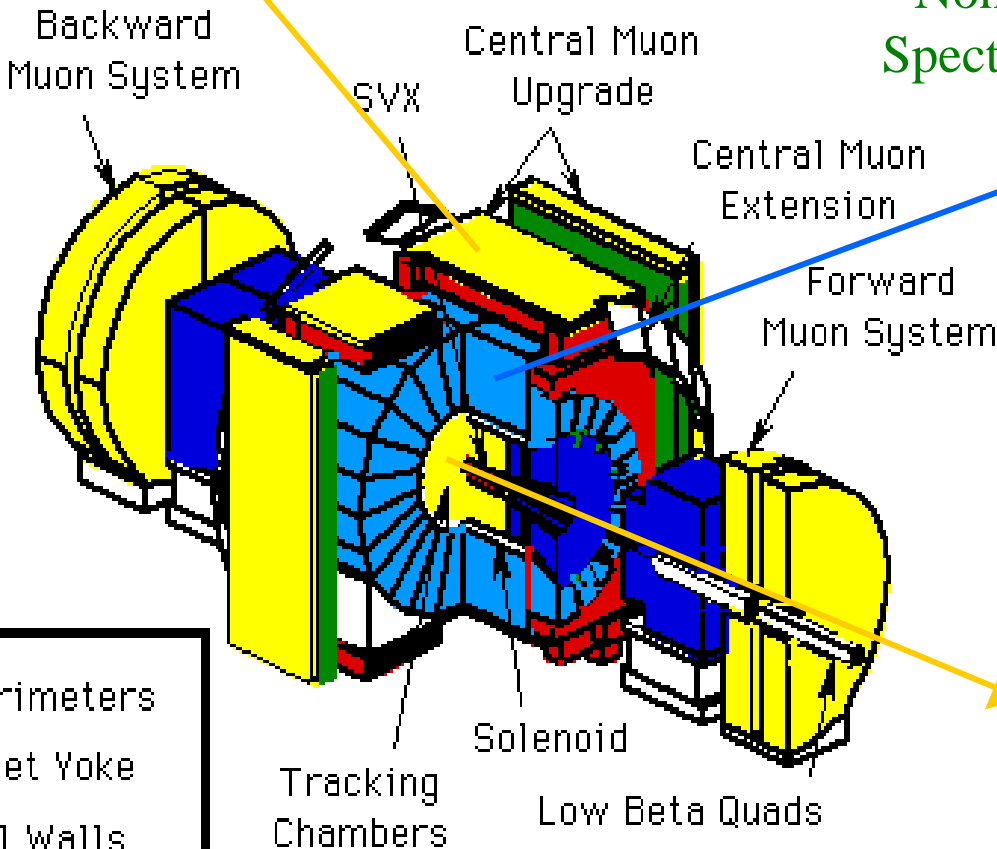
\sqrt{s}	L	Δt_x	Period
1.8TeV	$2 \times 10^{31} \text{ cm}^{-2} \text{ s}^{-1}$	$3.5 \mu\text{s}$	1992-1996

Detectors in Run I

Muon:
 $\sigma(r\phi) = 250 \mu\text{m} (\text{CMU})$

CDF Detector

- Silicon Vertex Detector
- Large Magnetic Tracking Volume
- Non-Magnetic Central Muon Spectrometer (Forward Toroid)



Calorimeter:

$$\frac{\sigma_{EM}}{E} = \sqrt{\left(\frac{13.5\%}{\sqrt{E_T}}\right)^2 + (2\%)^2}$$

$$\frac{\sigma_{HAD}}{E} = \sqrt{\left(\frac{75\%}{\sqrt{E_T}}\right)^2 + (3\%)^2}$$

Tracking:

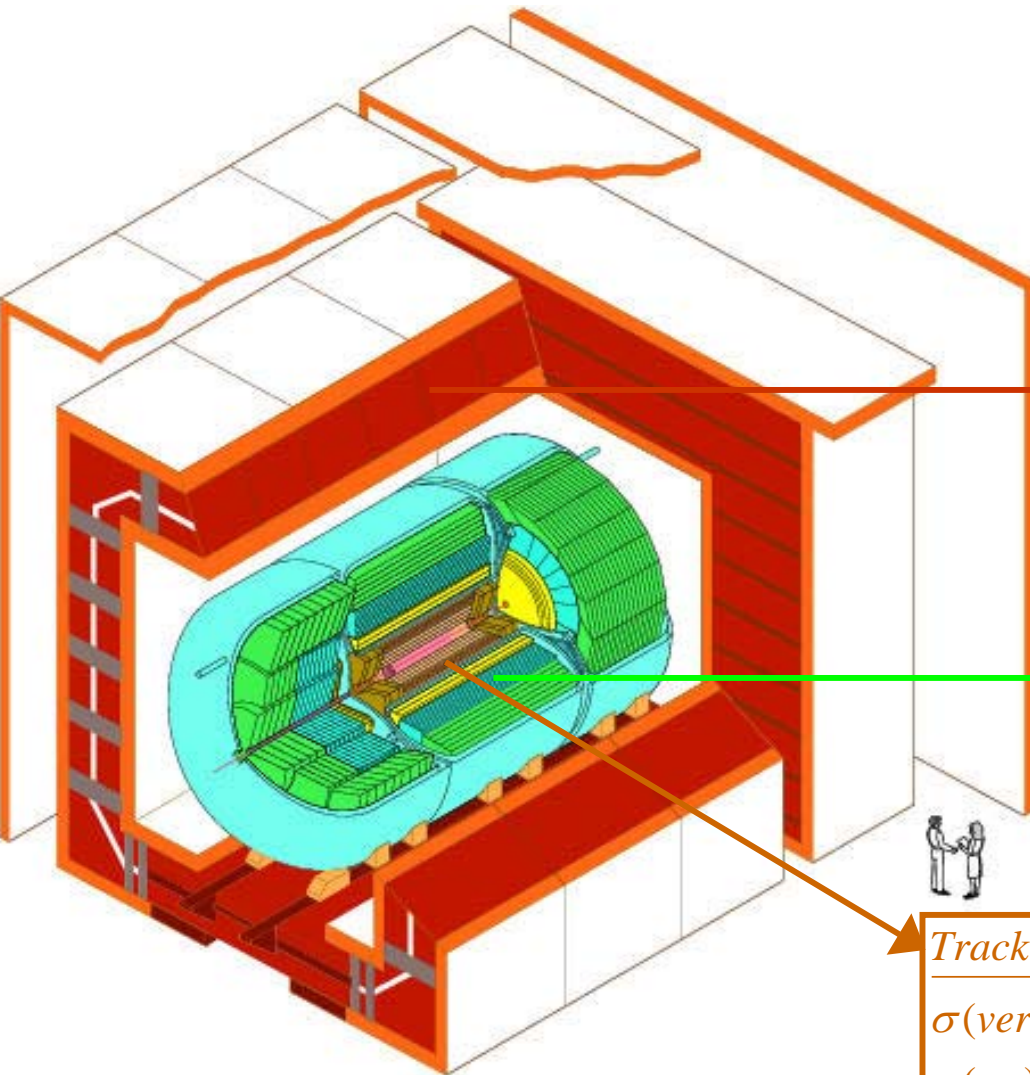
$$\sigma(r\phi) = 17 \mu\text{m} (\text{SVX})$$

$$\sigma(z) = 1 \text{mm} (\text{VTX})$$

$$\frac{\Delta p_T}{p_T} \approx (0.1\%) \times p_T (\text{SVX} + \text{CTC})$$

Detectors in Run I

- Good Calorimetry: hermeticity, resolution
- Iron Toroid Muon Spectrometer, Large Acceptance



DØ Detector

Muon :

$$|\eta| < 3.3$$

$$\frac{\Delta p}{p} = 0.2 \oplus 0.003 p$$

Calorimeter :

$$\frac{\sigma_{EM}}{E} = \frac{15\%}{\sqrt{E}} + 0.3\%$$

$$\frac{\sigma_{HAD}}{E} = \frac{45\%}{\sqrt{E}} + 4\%$$

Tracking :

$$\sigma(\text{vertex}) = 6 \text{ mm}$$

$$\sigma(r\phi) = 60 \mu\text{m (VTX)}$$

$$= 180 \mu\text{m (CDC)}$$

$$\sigma(r\phi) = 200 \mu\text{m (FDC)}$$

SUGRA Models

RPC Gravity Mediated SUSY Breaking (MSSM, mSUGRA)

MSSM Particle Content:

S=1	S=1/2	S=0
	l	\tilde{l}
	q	\tilde{q}
g	\tilde{g}	
W^\pm	$\tilde{\chi}_1^\pm$ $\tilde{\chi}_2^\pm$	ϕ_1^+ ϕ_2^-
γ	$\tilde{\chi}_3^0$ $\tilde{\chi}_4^0$	ϕ_1^0 ϕ_2^0
Z	$\tilde{\chi}_1^0$ $\tilde{\chi}_2^0$	

$$M_{\tilde{t}}^2 = \begin{pmatrix} m_{\tilde{t}_L}^2 + m_t^2 & m_t (A_t - \mu/\tan\beta) \\ m_t (A_t - \mu/\tan\beta) & m_{\tilde{t}_R}^2 + m_t^2 \end{pmatrix}$$

MSSM Phenomenology:

Parameters:

- $m_{1/2}$: universal gaugino mass
- A_0 : universal trilinear coupling
- μ : higgsino mass parameter
- $\tan\beta$: ratio of 2 Higgs doublets vev
- m_0 : universal scalar mass

R Parity: $R_P = (-1)^{L+2S+3B}$

Conservation:

- Sparticles pair production
- LSP $\tilde{\chi}_1^0$ stable $\Rightarrow E_T^{miss}$ signature

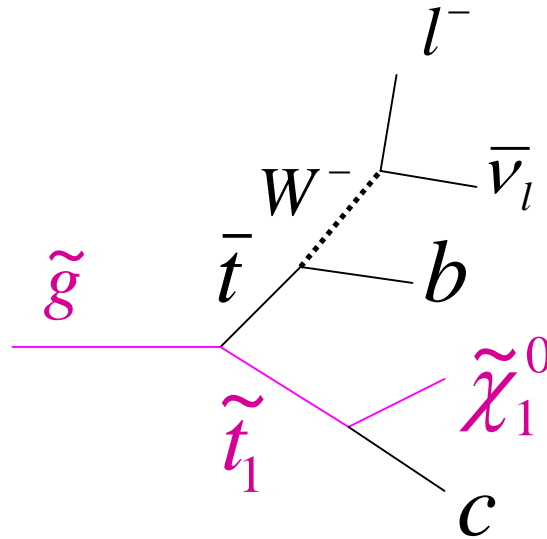
SUGRA in dileptons at CDF

Glino Pair Production

LO contributions:

$$gg \rightarrow \tilde{g}\tilde{g}$$

$$q\bar{q} \rightarrow \tilde{g}\tilde{g}$$



Glino and Stop Decays

$$\tilde{g} \rightarrow t\bar{t}_1 / \bar{t}\tilde{t}_1$$

$$\tilde{g} \rightarrow t\bar{t}_1 / \bar{t}\tilde{t}_1$$

- gluino: Majorana sparticle

$$\tilde{t}_1 \rightarrow c\tilde{\chi}_1^0 \quad (\text{stop NLSP})$$

$$t \rightarrow W^\pm b \rightarrow l^\pm \nu b$$

Final State Topology

Top dilepton events

Like-sign: $l^\pm l^\pm + jets + E_T^{miss}$

(Opp-sign: $l^\mp l^\pm + jets + E_T^{miss}$)

Main SM Backgrounds

- **Very low**
- Fake lepton ($W^\pm + \geq 3 jets$)
- SM Top pair production
- Diboson production

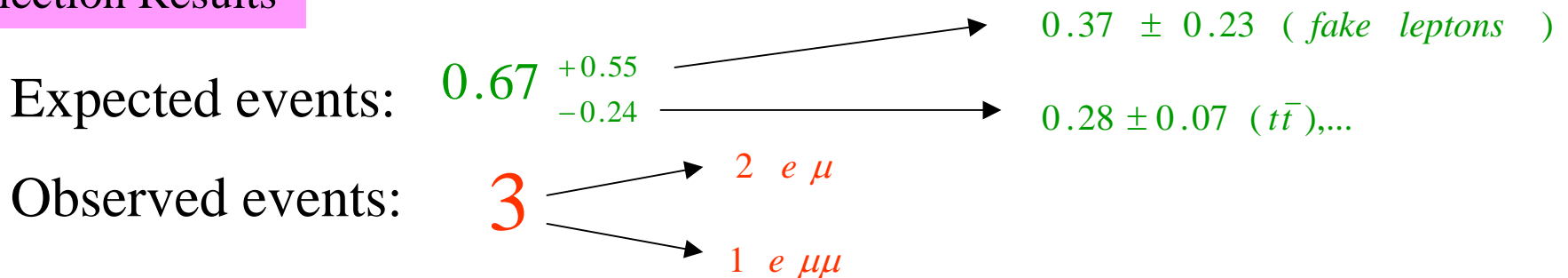
SUGRA in dileptons at CDF

Analysis

$$\int L dt = 106.1 \text{ pb}^{-1}$$

- **Trigger:** L3 inclusive electron or muon (isolation, $p_T > 13-15 \text{ GeV}, \dots$)
- **Lepton ID:** track matching (e), shower shape (e), track-calo. isol. (both),
- **Remove:** conversions (e), cosmics (mu), Z peak (both), radiative Z
- **Etmis:** $E_T^{miss} > 25 \text{ GeV}$ (isolated)
- **Jets:** at least 2 central jets with $p_T > 10 \text{ GeV}$

Selection Results



SUGRA in dileptons at CDF

Interpretation of Run I Result

- Limit on cross section:

$$\sigma_{\tilde{g}\tilde{g}} < 15.1 - 18.0 \text{ pb}$$
$$(200 \leq m_{\tilde{g}} \leq 320 \text{ GeV})$$

$$(BR(\tilde{g} \rightarrow t\tilde{t}) = 1)$$

Preliminary 95% CL Limits

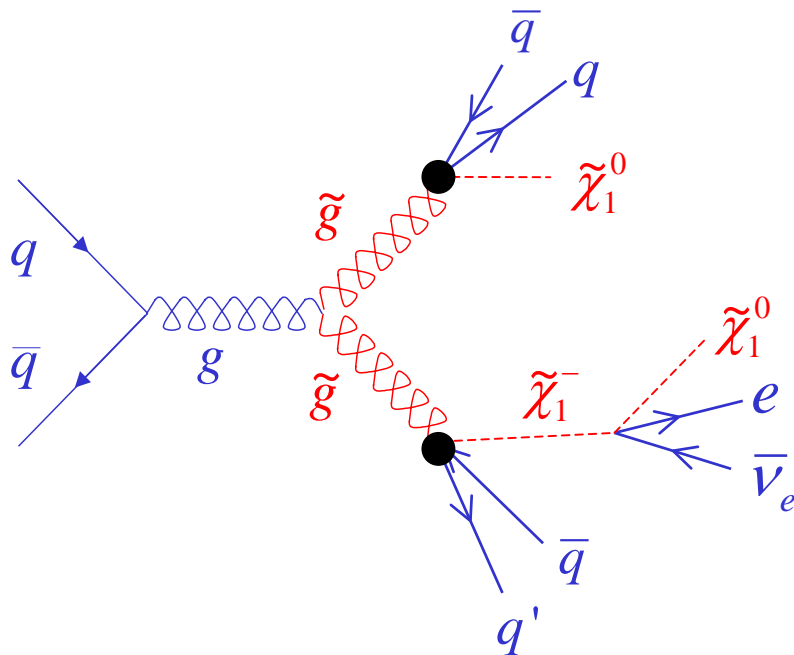
- Mass limit:

$$m_{\tilde{g}} > 180 \text{ GeV}$$

mSUGRA in electrons at D0

Glauino Pair Production/Decay

$$gg \rightarrow \tilde{g}\tilde{g}$$
$$q\bar{q} \rightarrow \tilde{g}\tilde{g}$$



Final State Topology

$$e^{\pm} + (\geq 4 \text{ jets}) + E_T^{\text{miss}}$$

Motivation

- Signal sensitive to high and moderate m_0 region: complement to (dilepton and jets)+ E_T^{miss}

Main SM Backgrounds

$$W^{\pm} + \text{jets}, t\bar{t}, QCD$$

mSUGRA in electrons at D0

Selection: NN (9-18-1)

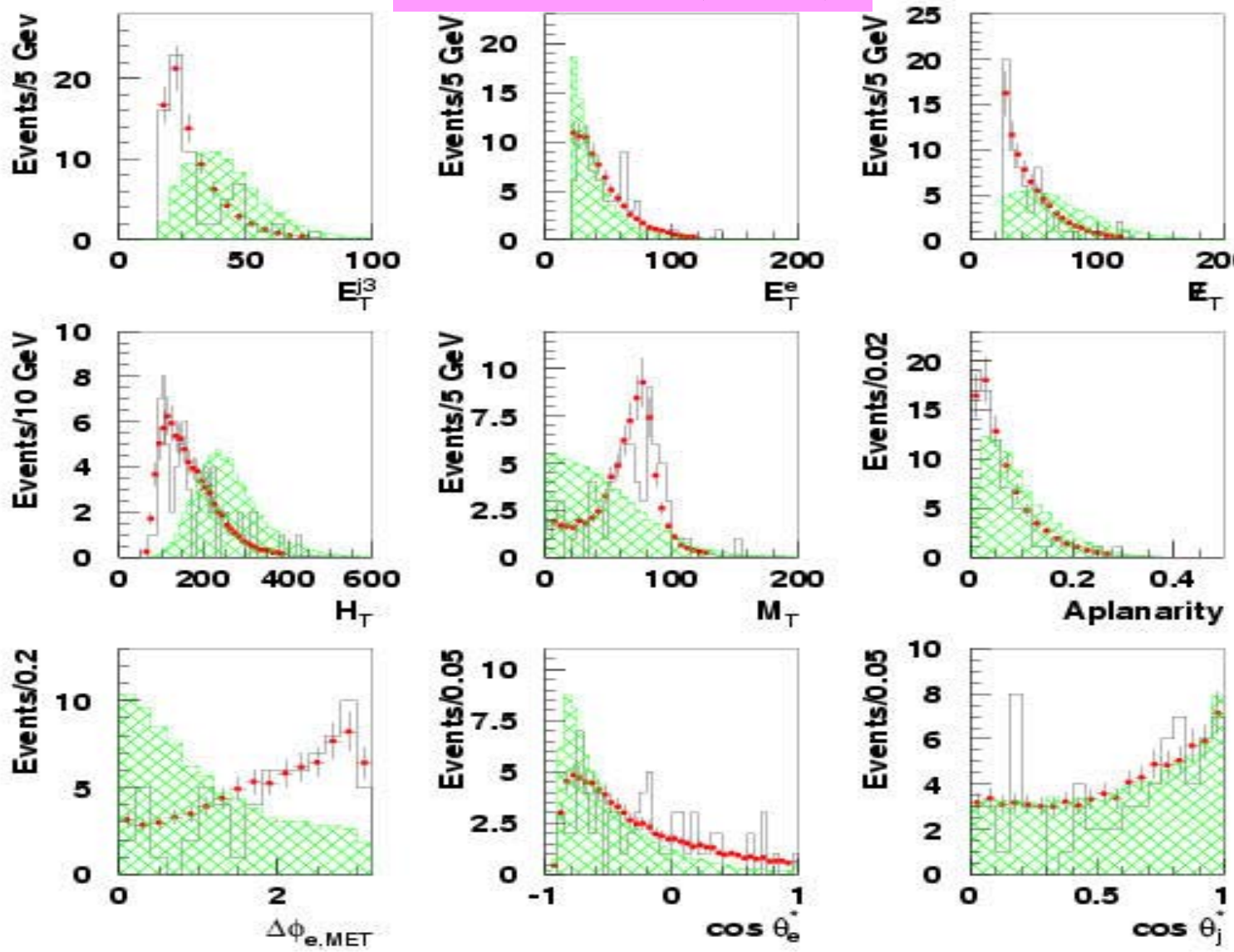
$$\int L dt = 94 \text{ pb}^{-1}$$

Preselection

$$E_T(e^\pm) > 20 \text{ GeV}$$

$$E_T(\text{jets}) > 15 \text{ GeV}$$

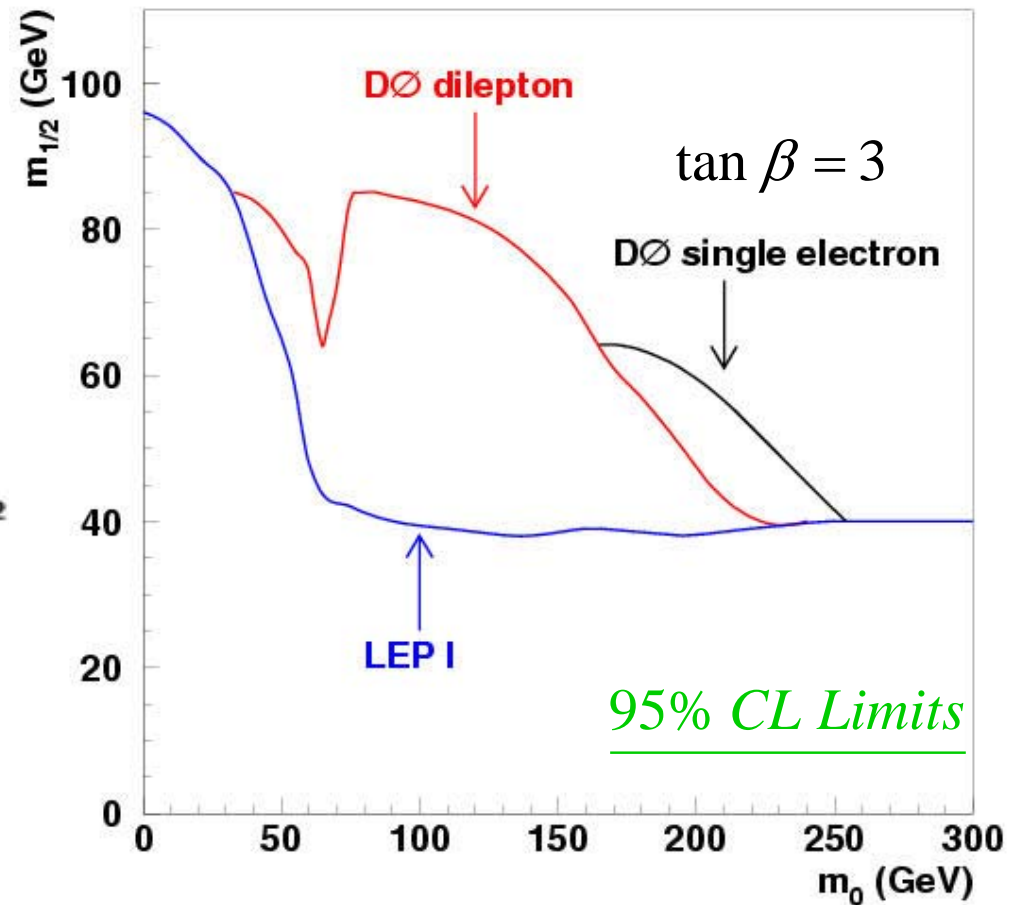
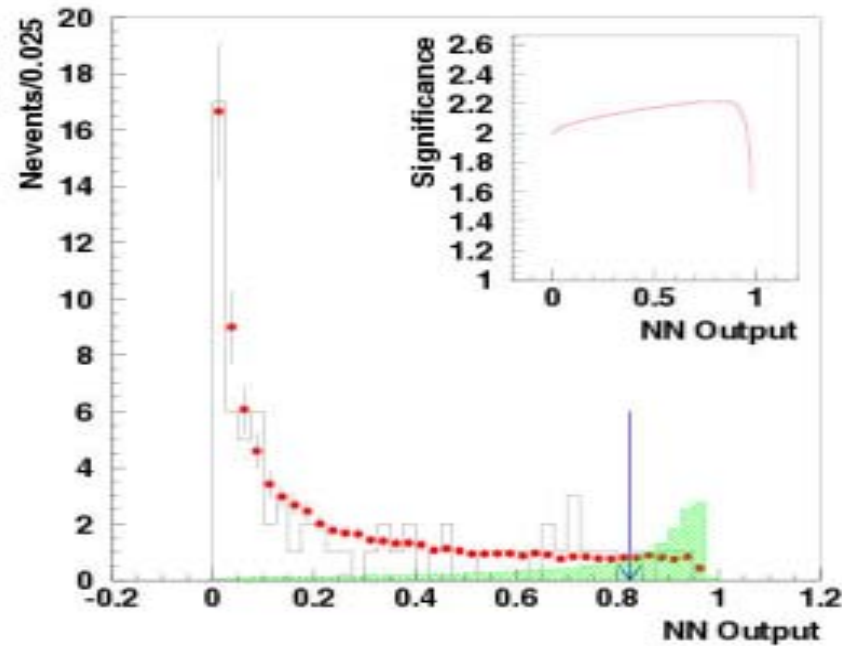
$$E_T^{\text{miss}} > 25 \text{ GeV}$$



mSUGRA in electrons at D0

Results

mSUGRA Limit



- $t \bar{t}$: 16.8 ± 5.2
- $WW + \geq 2$ jets : 1.4 ± 0.3
- QCD Multijet: 19.1 ± 4.7
- $W + \geq 4$ jets : 43.0 ± 7.6
- **Expected Events: $80.3 \pm 10.$**
- **Observed Events: 72**

Large Extra Dimensions

Theoretical Foundation:

- Quantum gravity scale M_D can be $O(1 \text{ TeV})$, solution to hierarchy problem

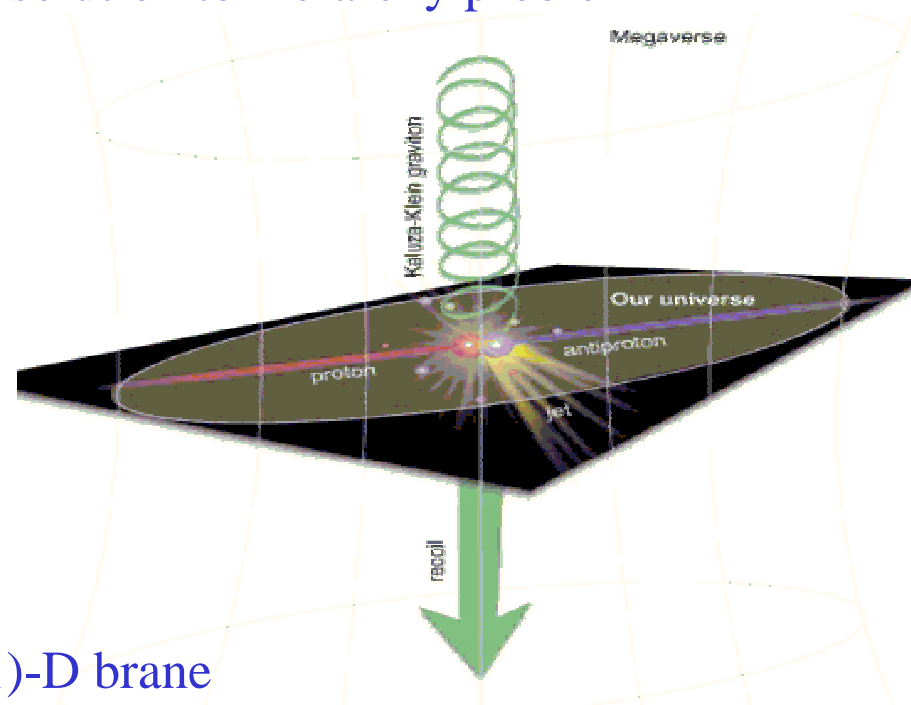
“Modified” Gravity:

$$\frac{4-D}{G_N^{-1} \sim M_{Pl}^2} \longrightarrow \frac{(4+n)-D}{G_N^{-1} \sim R^n M_D^{2+n}}$$

R: compactification (torus) radius

Phenomenology:

- SM particles (open strings): confined to (3+1)-D brane
- Graviton (closed strings): can propagate in the bulk (“weakness of gravity”)
- Equivalence: massive gravitons (KK) in 4-D and massless gravitons (4+n)-D
- Ref: Giudice, Rattazzi, Wells, NPB 544 (1999)
- Ref: Arkani-Hamed, Dimopoulos, Dvali, PLB 429 (1998)
- Ref: Antoniadis, PLB 246 (1990)



Large ED Searches at Colliders

ED Nbers and Radii

$$M_D \approx 1 \text{ TeV}$$

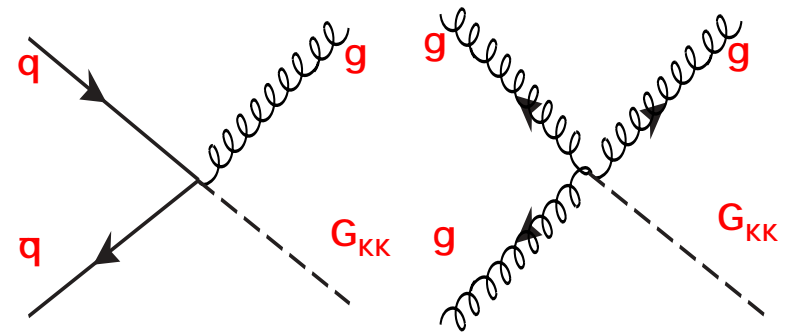
$$R = \begin{cases} 1.2 \times 10^{12} \text{ m} & n = 1 \\ 0.48 \text{ mm} & n = 2 \\ 3.6 \text{ nm} & n = 3 \\ 9.7 \times 10^{-12} \text{ m} & n = 4 \end{cases}$$

Eöt-Wash Experiment
 Test Newton's Law down to
 $O(200 \mu\text{m})$
 Ref: Adelberger et al, PRL 86 (2001)

Production Mechanisms

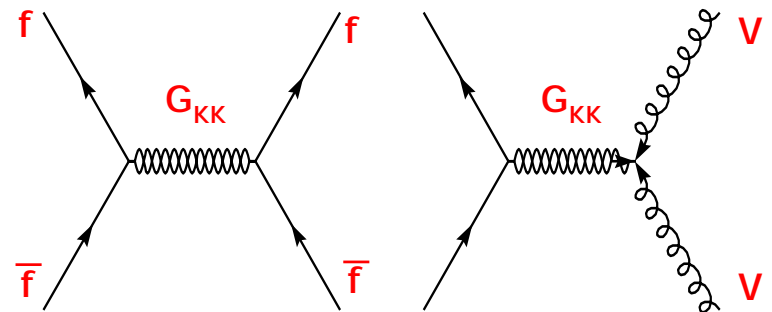
Real Gravitons

Monojets at hadron colliders



Virtual Gravitons

Fermion or VB pairs at hadron or e^+e^- colliders



LED in monojets at D0

Selection

- $N_{\text{jets}} = 1$ or 2
- $E_T(j_1) > 150$ GeV, $E_T(j_2) < 50$ GeV
- j_1 central (good quality)
- $E_T^{\text{miss}} > 150$ GeV
- Reject events with isol. muons,
- Reject cosmics

Results

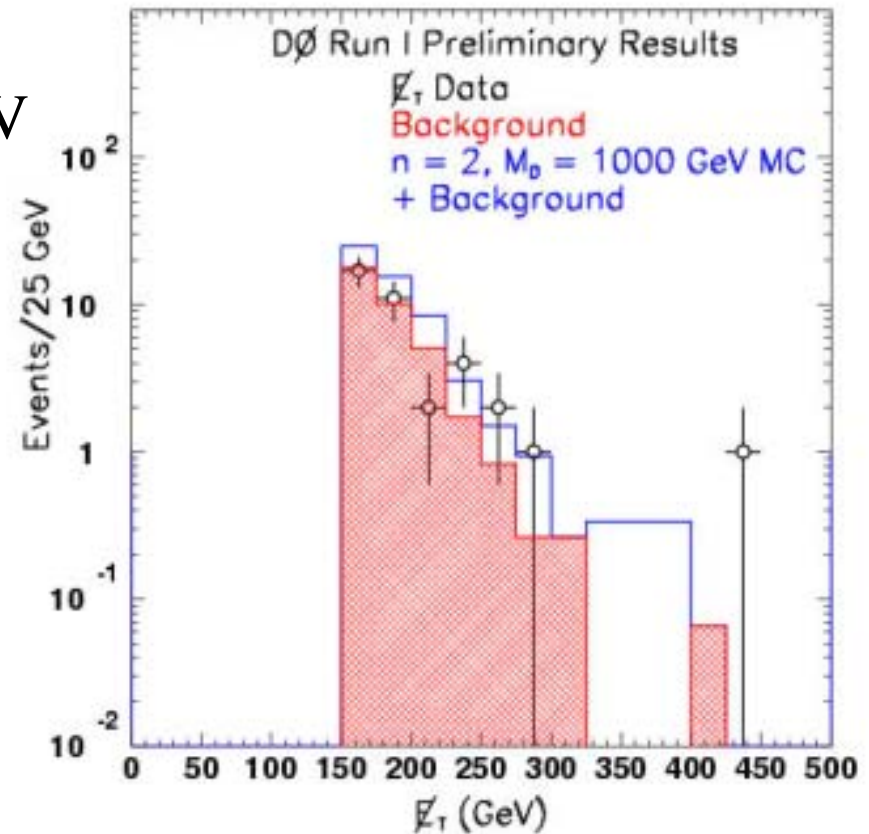
WZ background = 30.2 ± 4.0

QCD background = 7.9 ± 7.1

Expected Events = 38.0 ± 8.2

Observed Events = 38

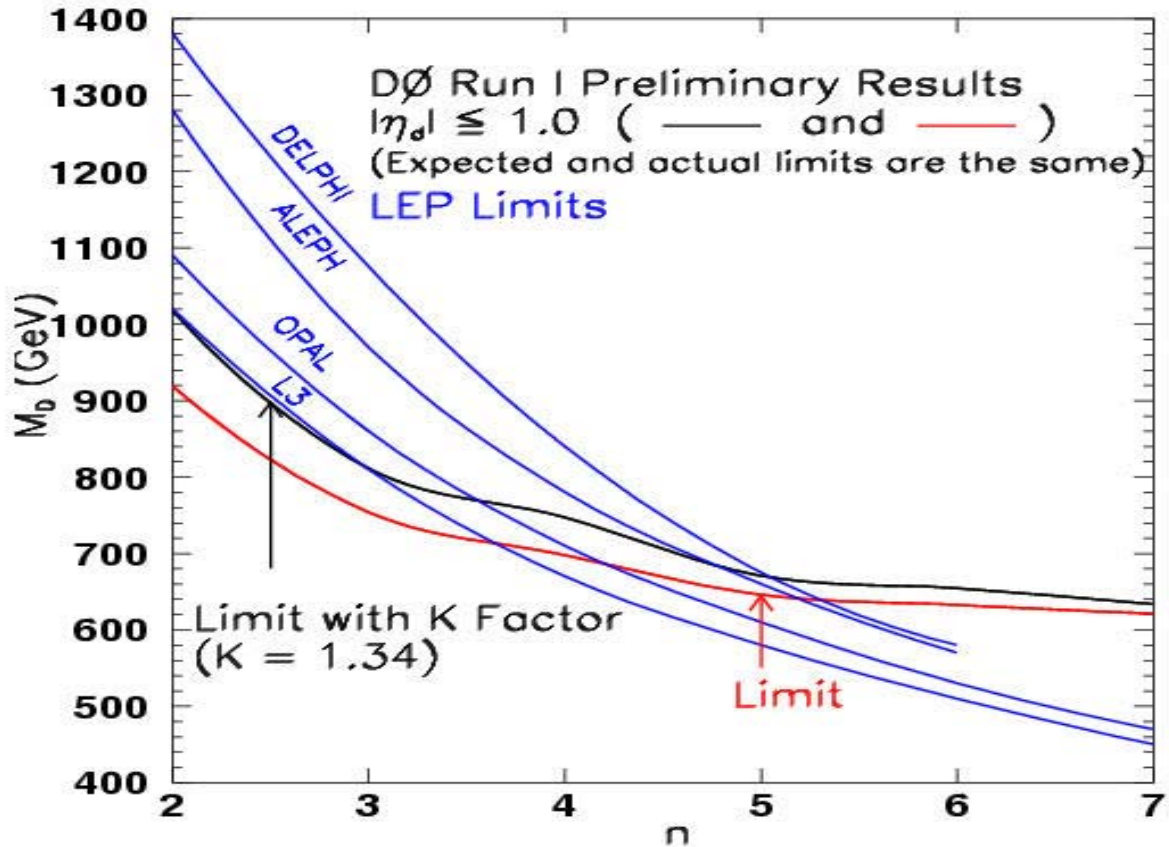
$$\int L dt = 78.8 \text{ pb}^{-1}$$



LED in monojets at D0

Limits

95% CL Limits



$n=4$
 $M_D > 698$ (840) GeV
D0 DELPHI

Conservative Limit
(no K-factor)

$n=6$
 $M_D > 632$ (580) GeV
D0 DELPHI

LED in diphotons at CDF

Signal

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

Backgrounds

γ +jets

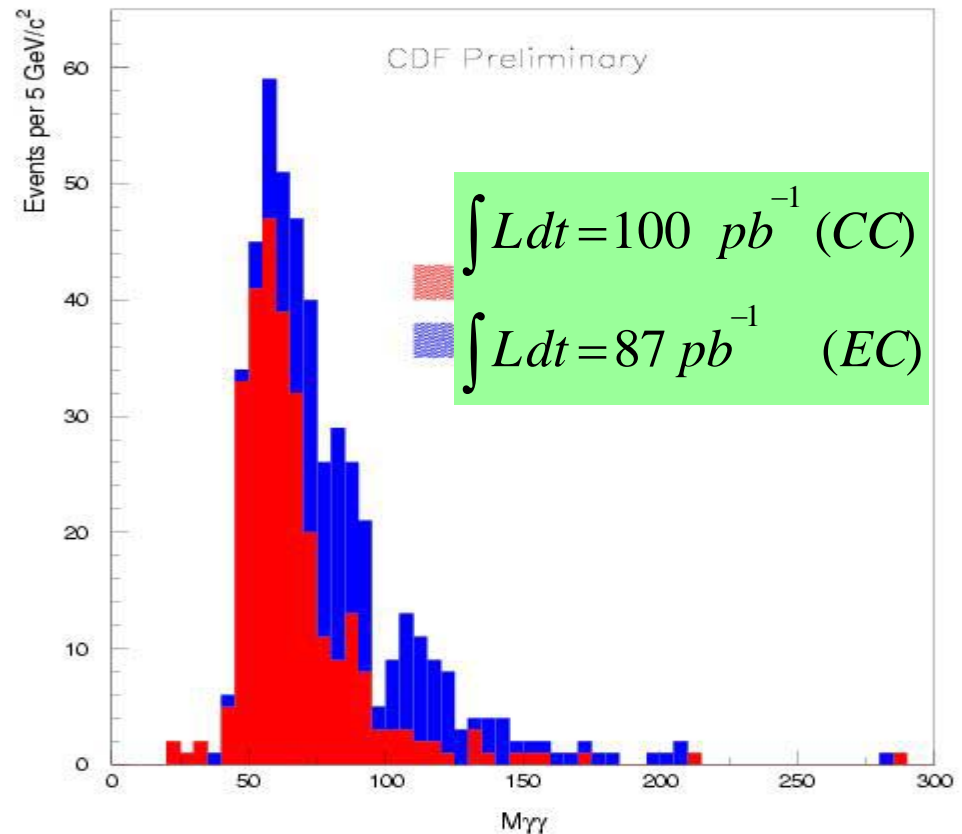
QCD dijets

Selection

- Isolated photons
- $E_T(\gamma) > 22 \text{ GeV}$, $|\eta(\gamma_1)| < 1.0$

Results

	Central	EndCap
Observed	287	192
Expected	280 ± 70	208 ± 42
SM diphotons	96 ± 31	76 ± 31
Bkgd from fakes	184 ± 63	132 ± 28



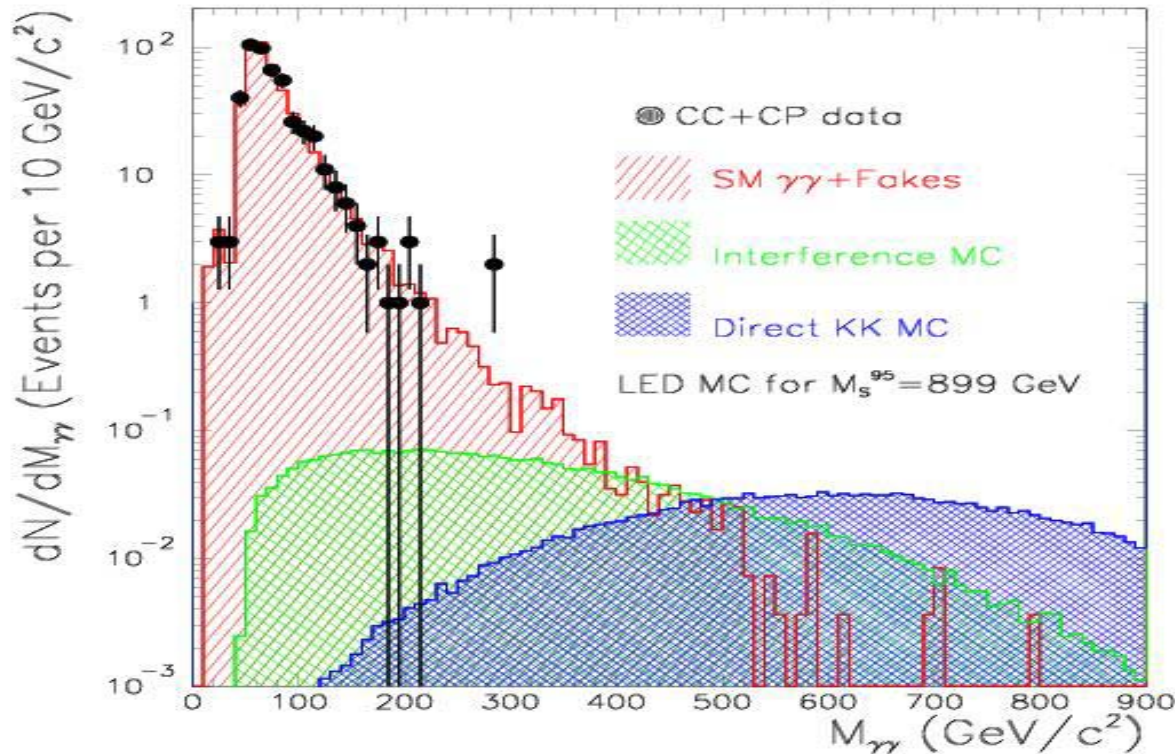
LED in diphotons at CDF

- Cross section of:

$$p\bar{p} \rightarrow q\bar{q} / gg \rightarrow \gamma\gamma + X$$

$$\frac{d\sigma}{dM_\gamma} = \left. \frac{d\sigma}{dM_\gamma} \right|_{SM} + \eta \left. \frac{d\sigma}{dM_\gamma} \right|_{INT} + \eta^2 \left. \frac{d\sigma}{dM_\gamma} \right|_{KK}$$

CDF Preliminary



- Free parameter to fit:

$$\eta = \frac{\lambda}{M_D^4}$$

Limits

CDF

$$M_D > 1.01 \text{ TeV}$$

(This analysis)

D0

$$M_D > 1.21 \text{ TeV}$$

- Add $\cos\theta^*$ to fit, 127 pb^{-1}
- Ref: PRL 86 (2001)

95% CL Limits

Conclusions

- New Analyses of Run I Data
- Better sensitivity:
 - Improved Selection Techniques
 - Use of Full Calorimeter Acceptance
- Resulting in:
 - Improved Limits
 - Complementary and Competitive wrt LEP II
- Next Moves Have Just Started in Run II:
 - Slightly Higher Energy
 - Higher Luminosity
 - Upgraded Detectors
 - Improved Trigger Designs ... News Soon

Large ED Searches

Different theoretical notations

$$\lambda_{GRW} = \frac{-2}{\pi} \lambda_{Hew.}$$

$\lambda_{Hew.} = O(\pm 1)$ Dimensionless parameter
Sign: destructive or constructive interference

Prospects for Run II

mSUGRA search in dileptons at CDF

- Estimated limit: $m_{\tilde{g}} > 181 - 182 \text{ GeV}$ \rightarrow $m_{\tilde{g}} > 280 - 295 \text{ GeV}$
(same observed and expected events than Run I analysis, with 2 fb^{-1})

LED search in monojets at D0

- $n=2$: sensitive to $M_D=920 \rightarrow 1400 \text{ GeV}$
- $n=5$: sensitive to $M_D=700 \rightarrow 900 \text{ GeV}$
(with 2 TeV and 300 pb^{-1})