Beyond the Standard Model Experimental Status

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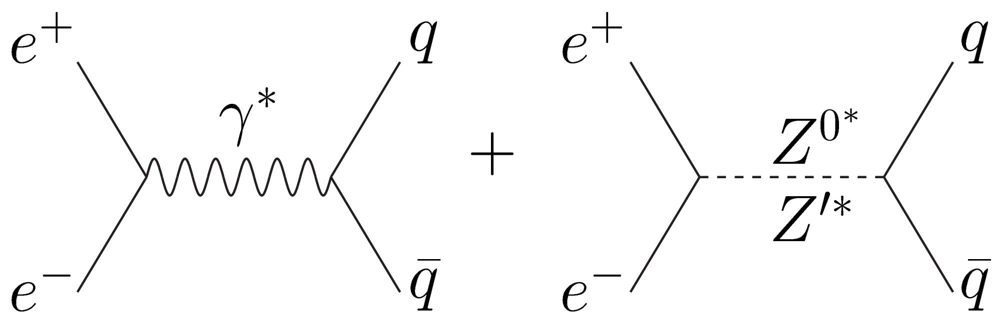
DPF, May 25th 2002

Outline:

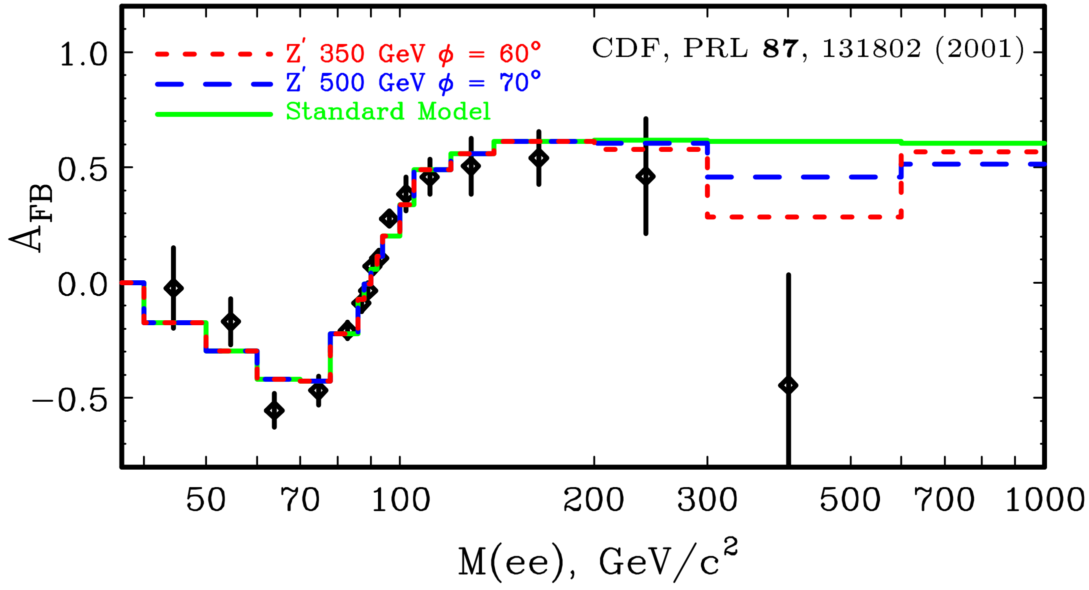
- An introductory example
- Large Extra Dimensions
- SUSY
- Tevatron Run 2

An Introductory Example

A new neutral gauge boson (Z') is a good example.

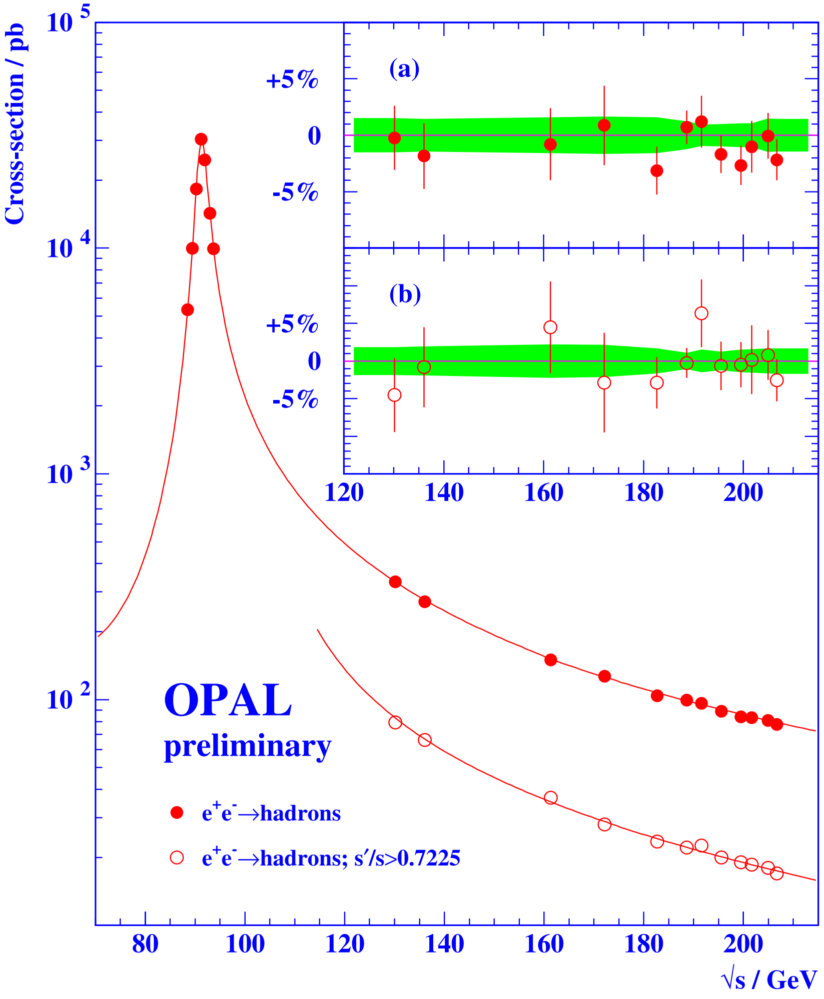


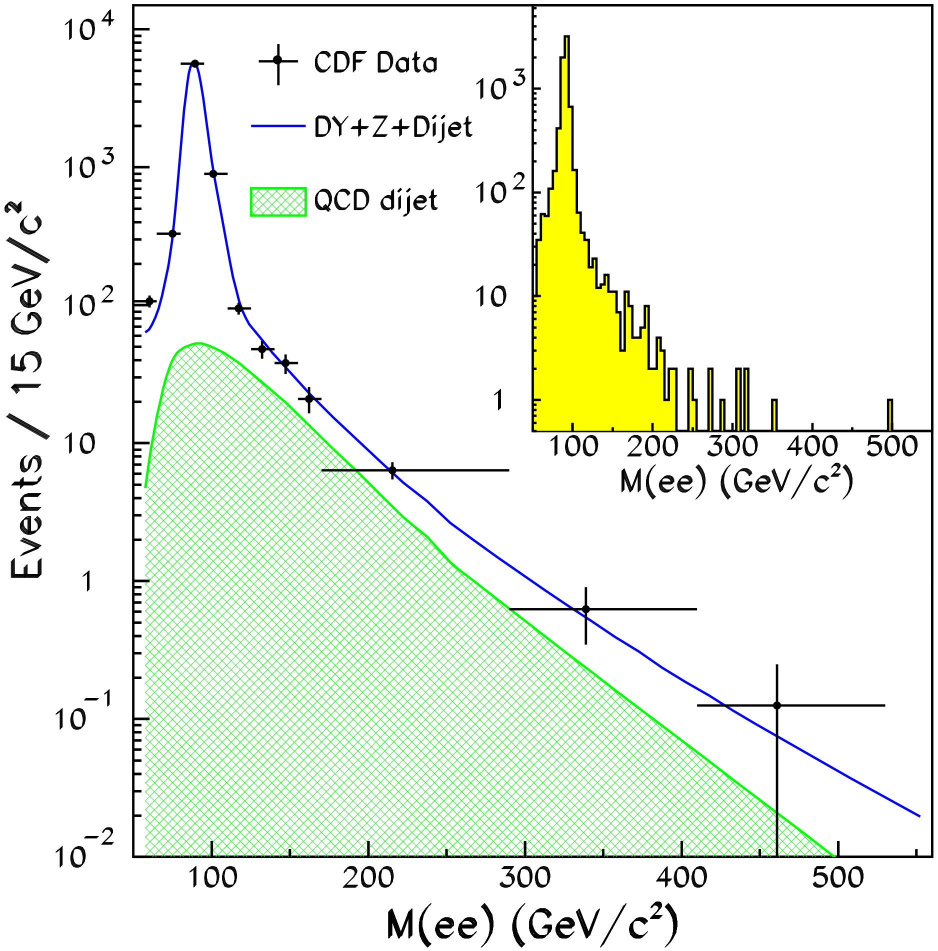
- Precision measurements
  - Z' interference effects
  - $Z^0 - Z'$ mixing



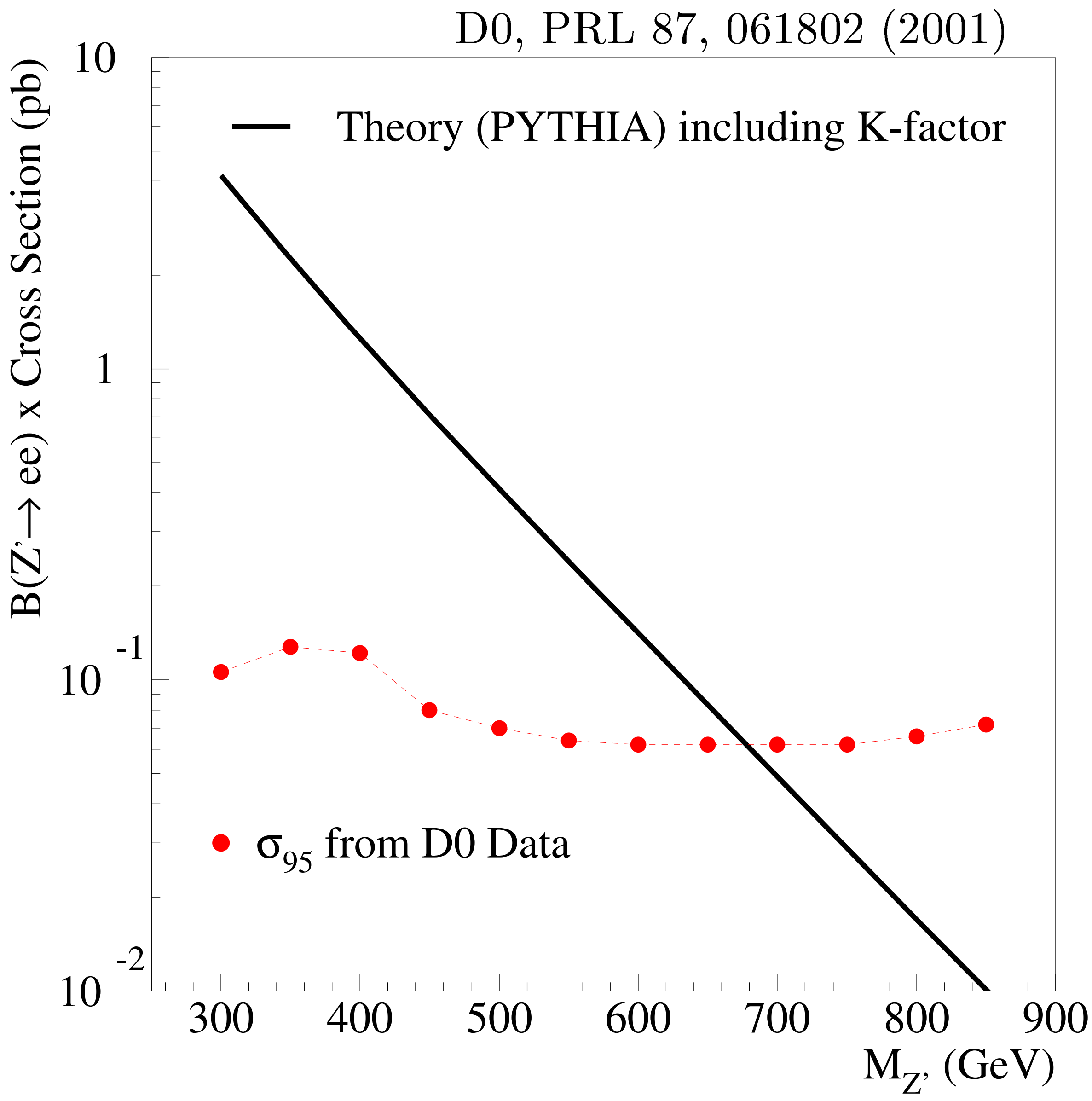
- Imprecise measurements
  - Z' interference effects
- Direct searches
  - $Z' \to f\bar{f}$ bump search

Direct $Z' \to \ell^{\pm}\ell^{\mp}$ search



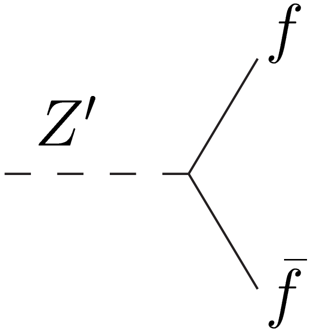


Direct $Z' \to \ell^{\pm}\ell^{\mp}$ search



Model based vs Signature based

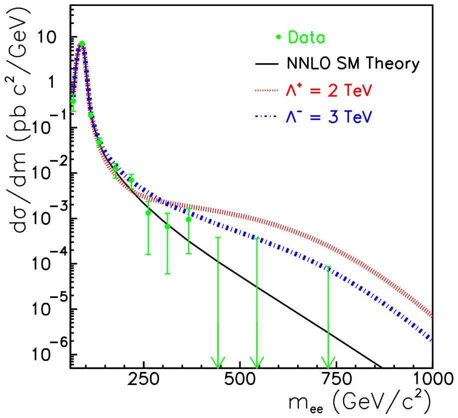
Other ways to find Z'?



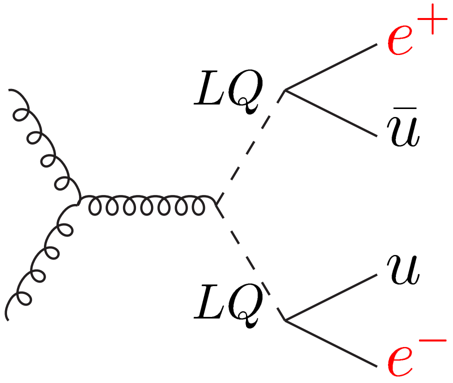
- jj bump
- $b\bar{b}$ bump
- $t\bar{t}$ bump

Other searches with $\ell^\pm\ell^\mp$?

- Compositeness



- Leptoquarks

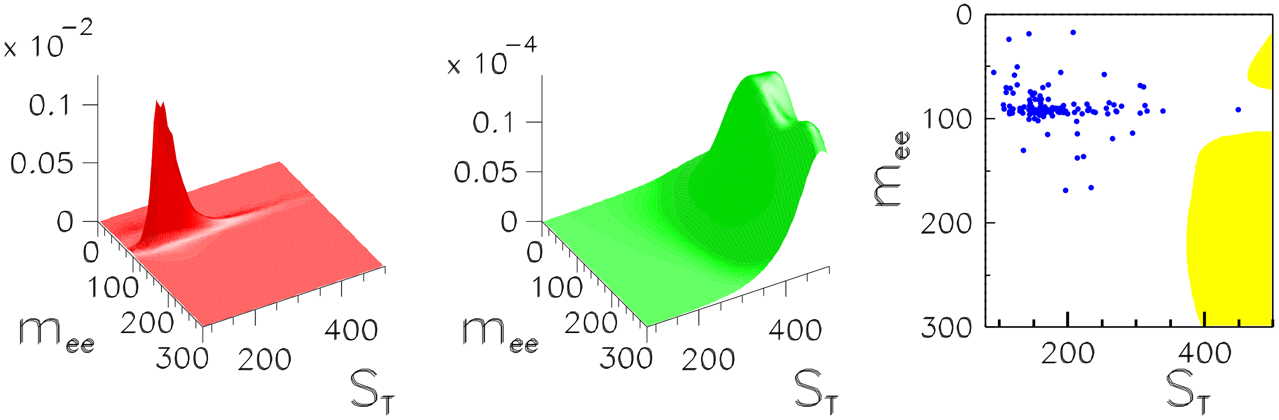


Model Independent Searches

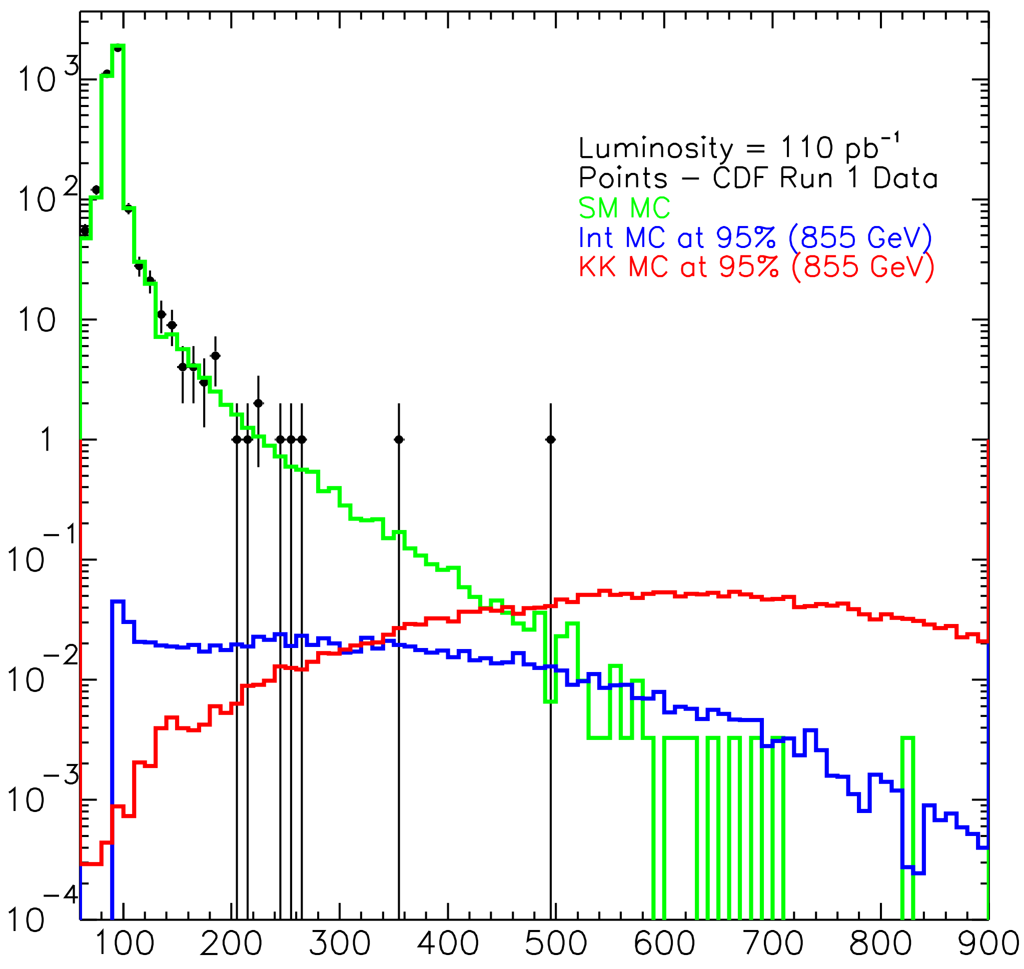
In well understood samples (e.g., dominated by EWK bkgds), can search for any new physics beyond the standard model.

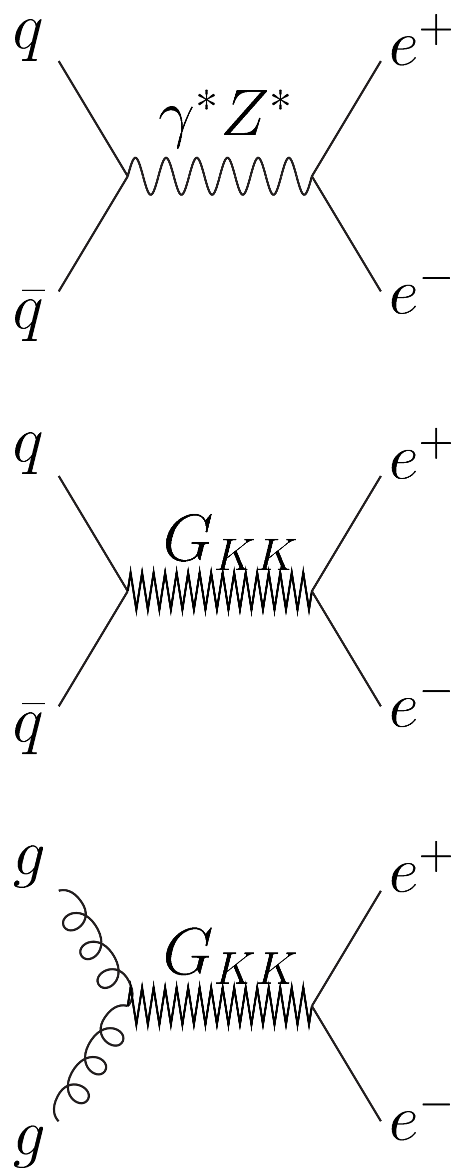
The standard model then beyond

D0 has made its $eejj$ data sample (and others) public with Quaero. Phys. Rev. Lett. **87**, 231801 (2001).

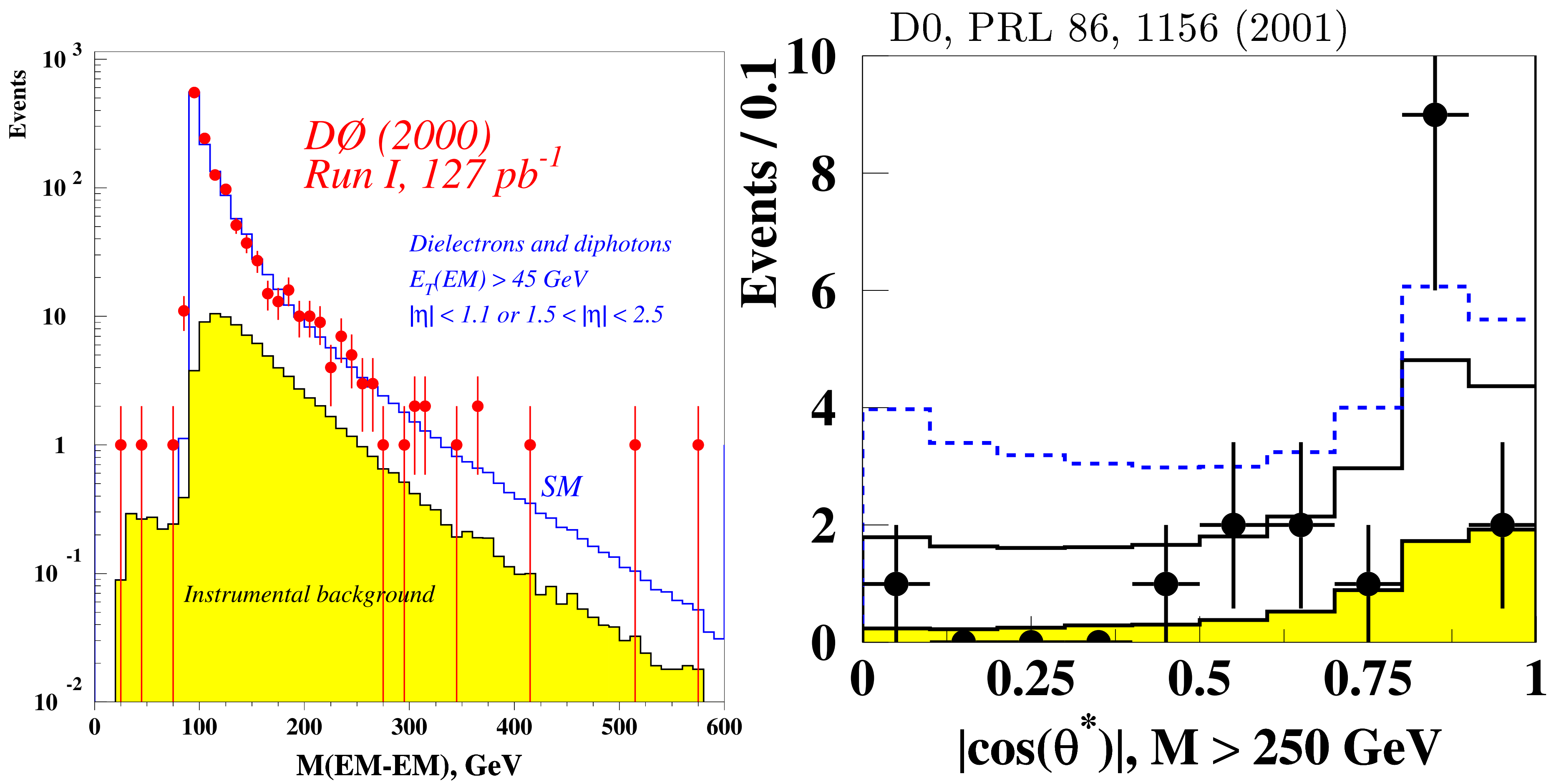


Extra dimension search in $\ell^{\pm}\ell^{\mp}$



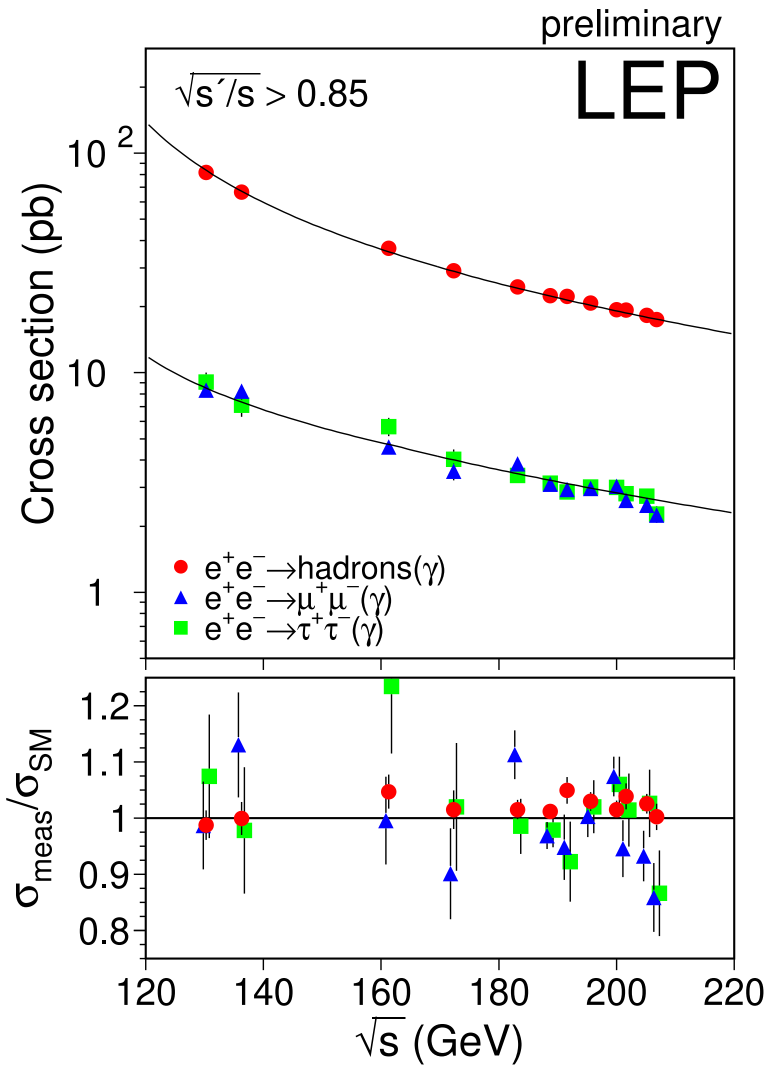


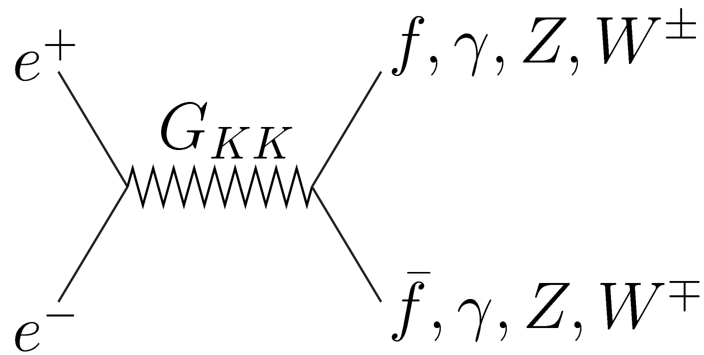
Extra dimension search in $\gamma\gamma$

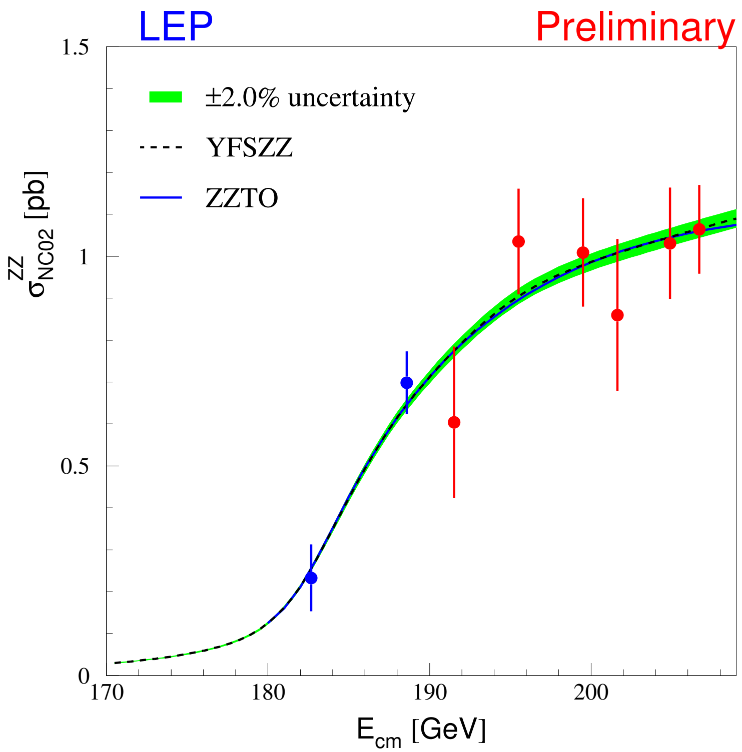


Limits: $M_s > 1.01$ TeV for $\lambda = -1$, $M_s > 1.08$ TeV for $\lambda = +1$.

LED at LEP

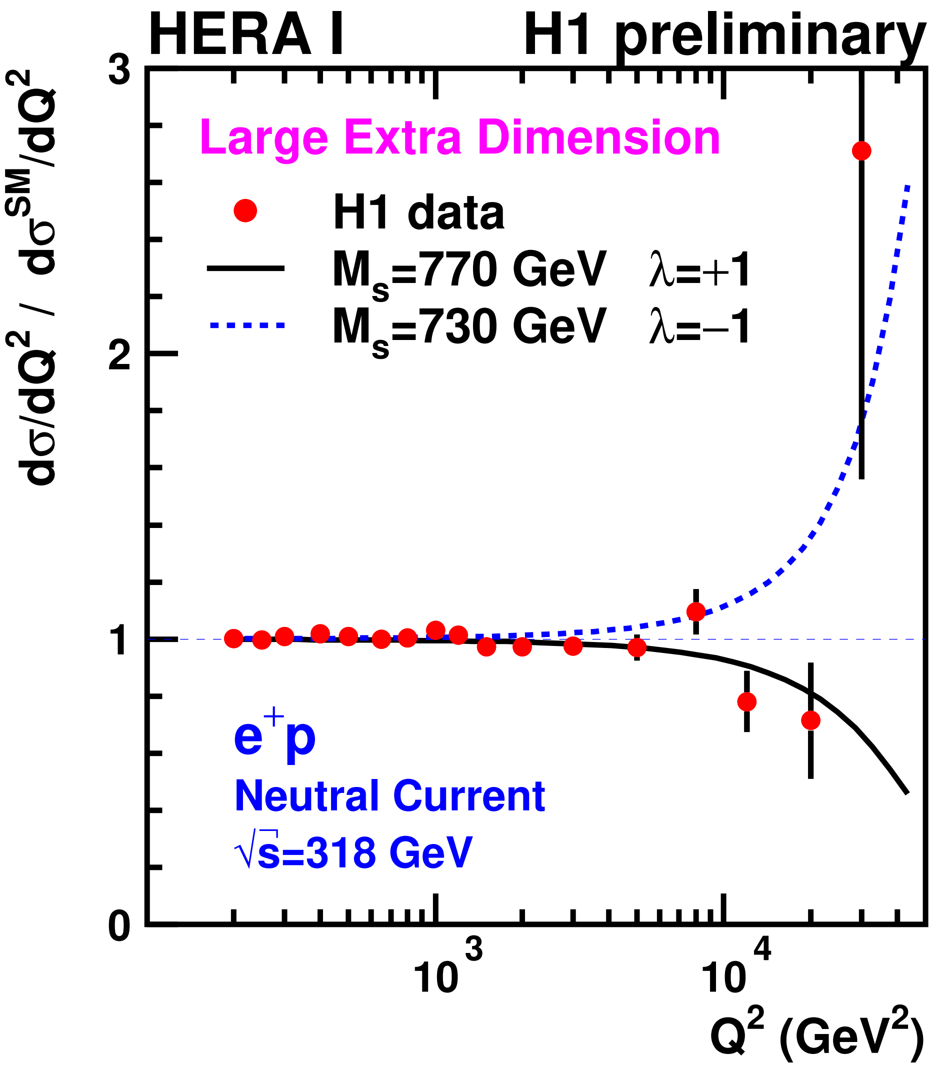


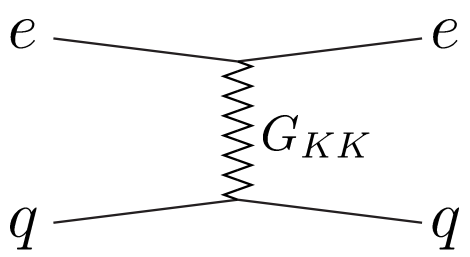


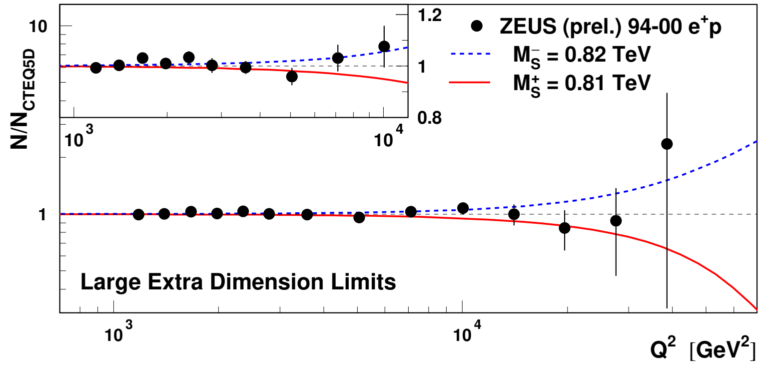


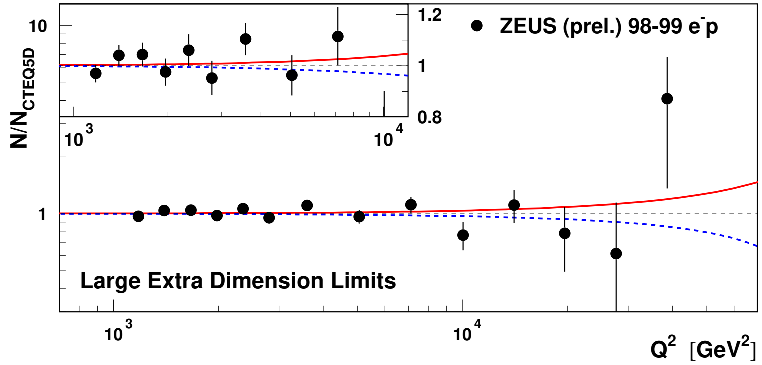
M_s Limits range from 1.0 to 1.3 TeV.

LED at HERA



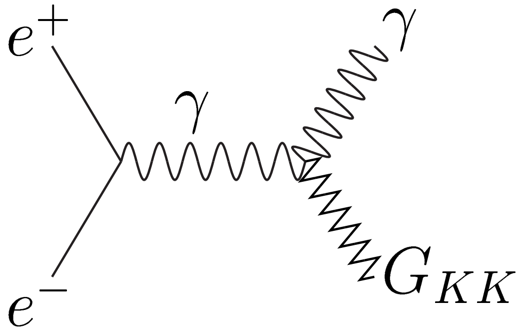




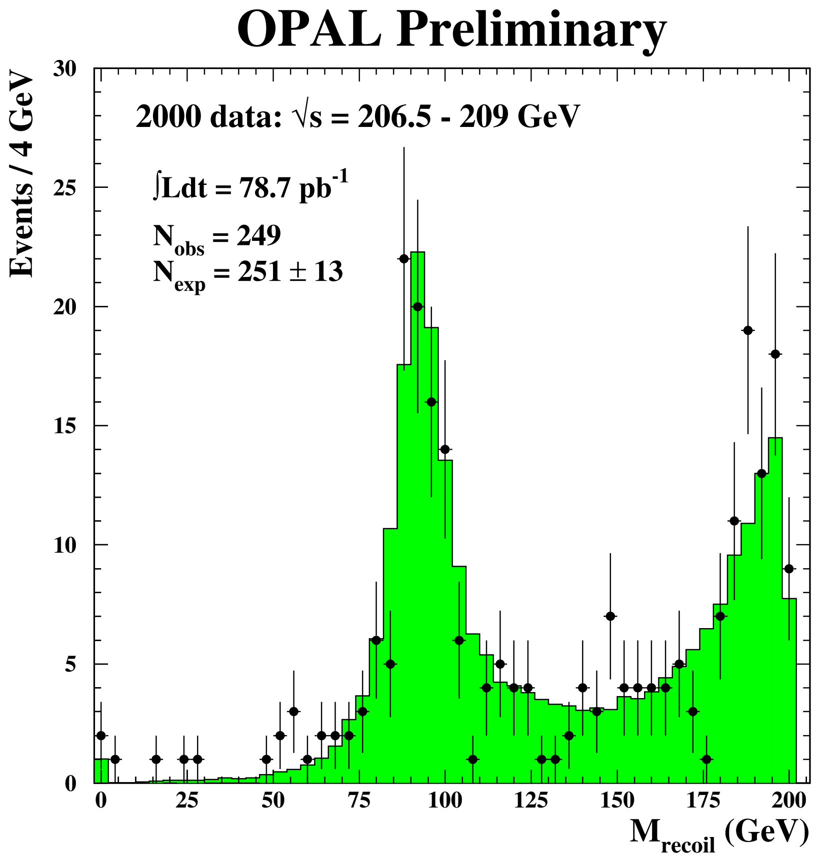


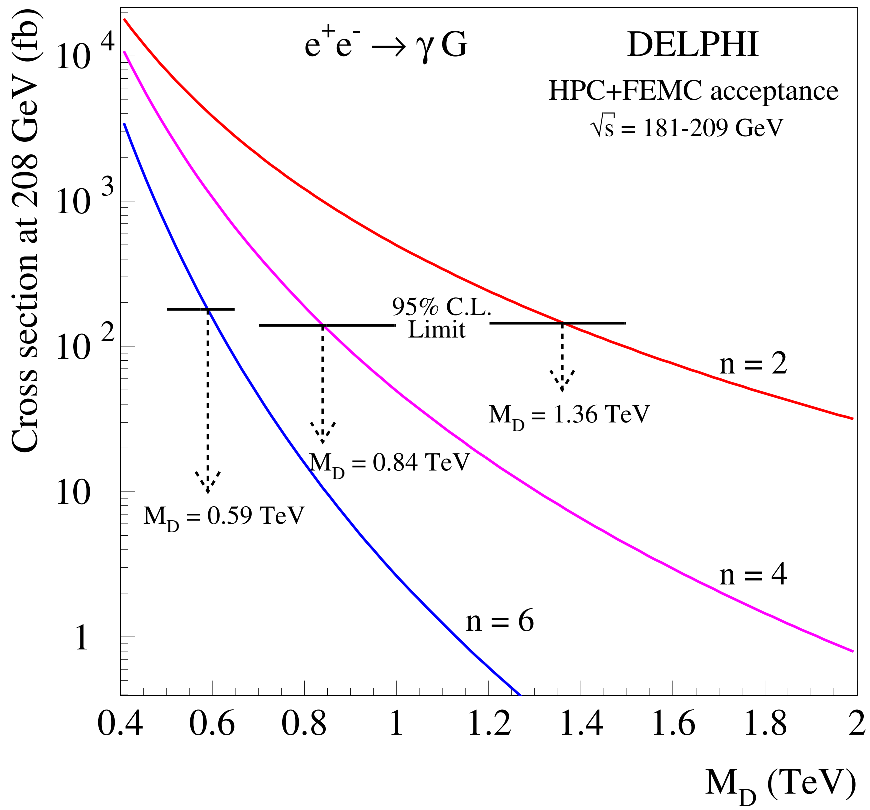
M_s Limits of ≈ 0.8 TeV.

Direct Graviton Production

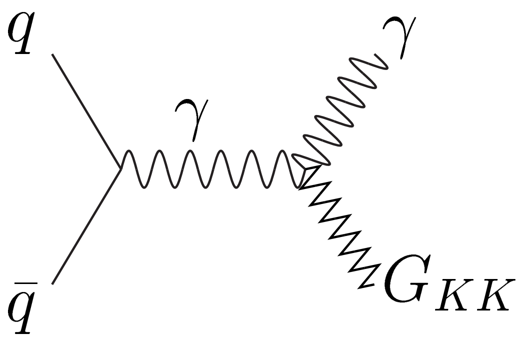


Direct graviton production suppressed by $(M_D)^{n+2}$

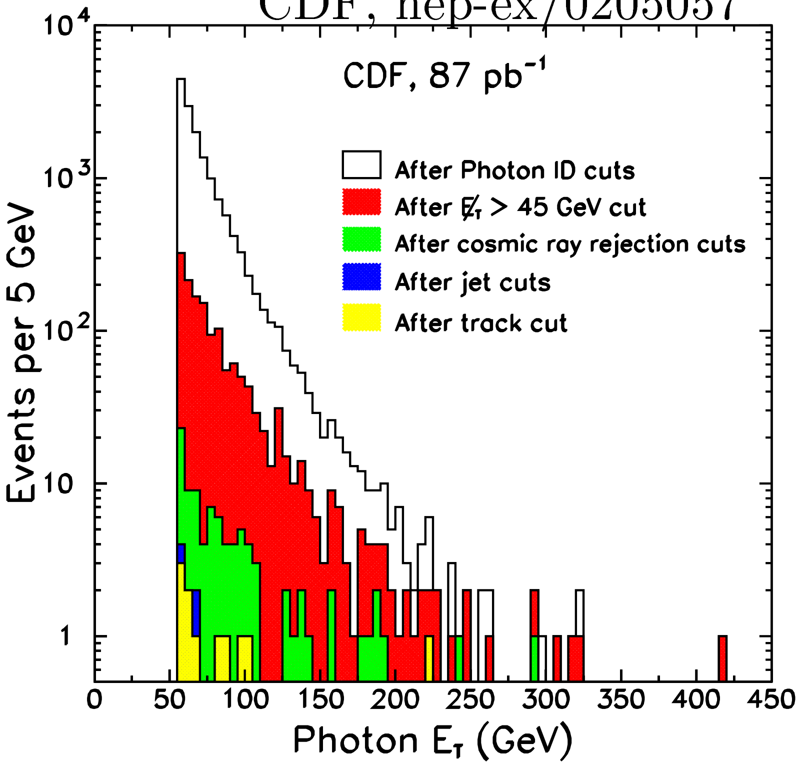




Gravitons at the Tevatron



CDF, hep-ex/0205057



Background sources (note: numbers do not add due to rounding).

Cosmic rays	6.3 ± 2.0
$Z\gamma \to \nu\bar{\nu}\gamma$	3.2 ± 1.0
$W \to e\nu$	0.9 ± 0.1
Prompt diphotons	0.4 ± 0.1
$W\gamma$	0.3 ± 0.1
Total non-QCD background	11.0 ± 2.2
QCD background	0.9*
Total observed	11

* Estimate. The uncertainty in this background is large, and this background is not considered when setting limits.

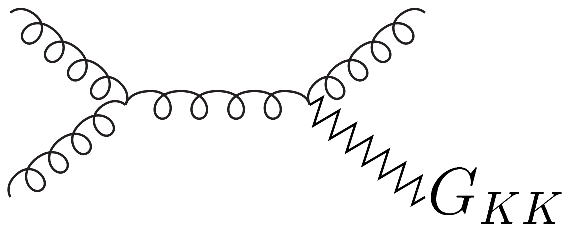
Limits

$M_D > 0.55$ TeV for n=4

$M_D > 0.58$ TeV for n=6

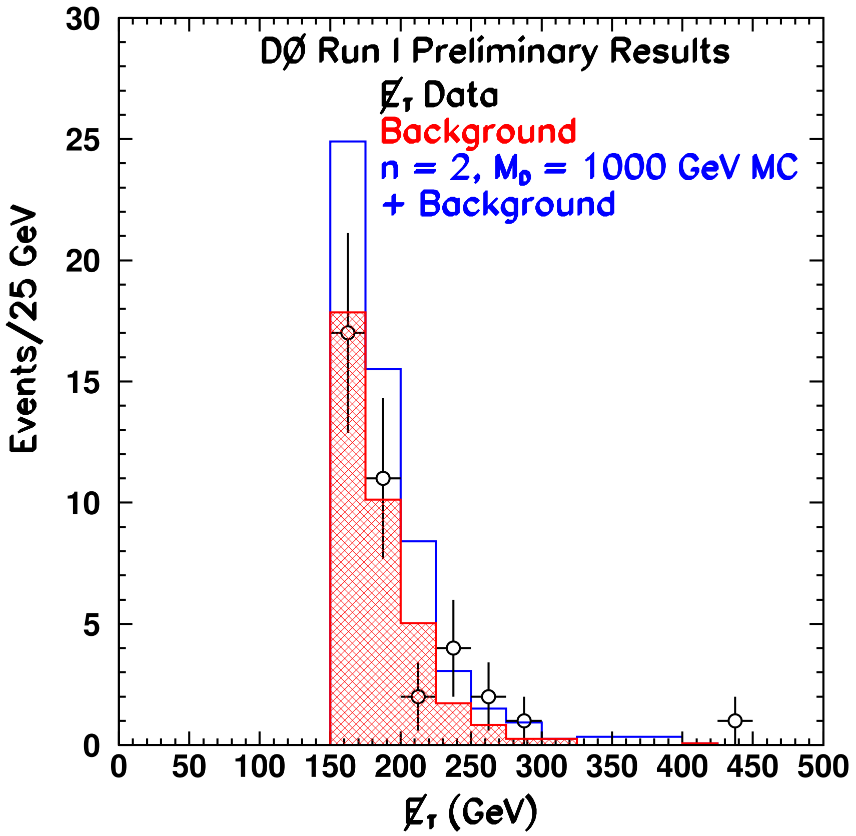
$M_D > 0.60$ TeV for n=8

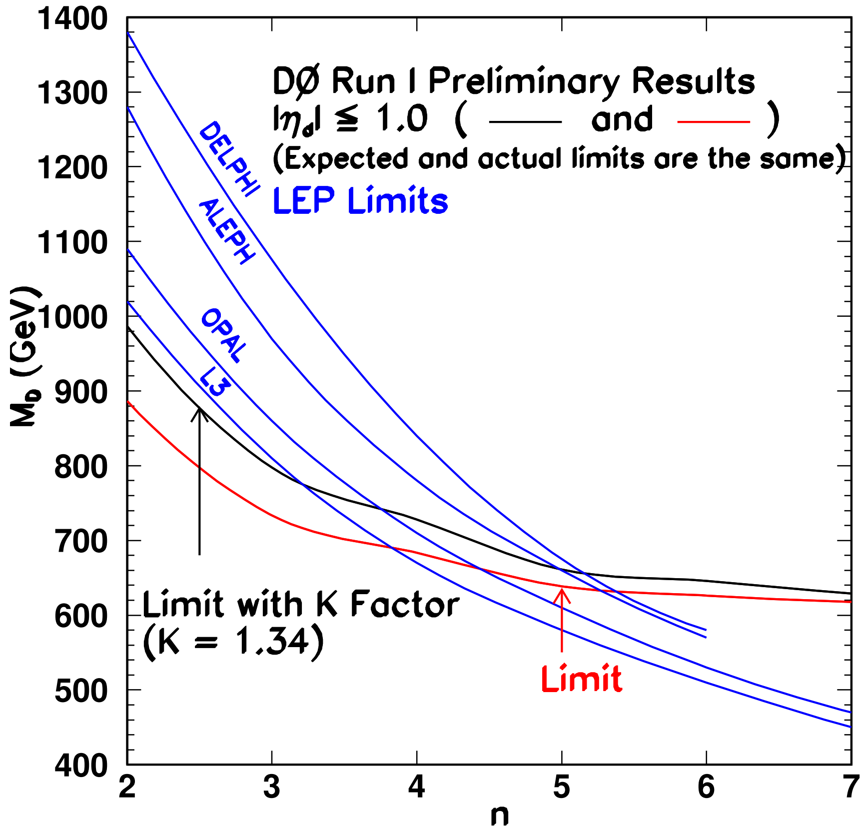
Gravitons at the Tevatron



Bkgds	
W & Z	30.2 ± 6.4
QCD & cosmics	7.8 ± 7.1
Observed	38

E_T^1 and $\not{E}_T > 150$ GeV, $E_T^2 < 50$ GeV





SUSY

SUSY can yield many signatures

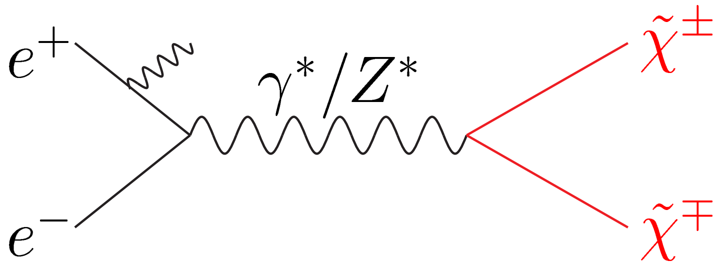
- Masses are model dependent
- Couplings are specified before mixing
- Phenomenology set by LSP, NLSP, and mass differences
- R-parity violating wildcards

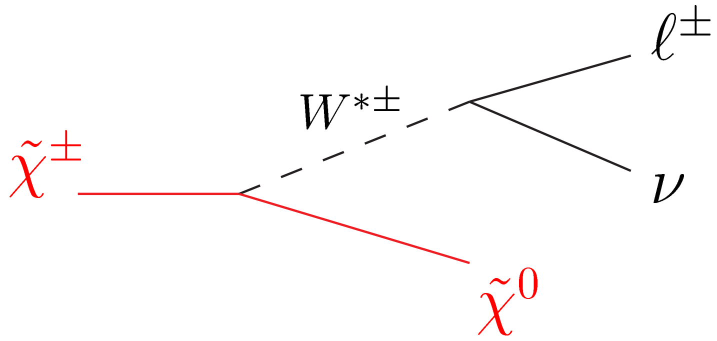
MSugra and GMSB models reduce the parameter proliferation

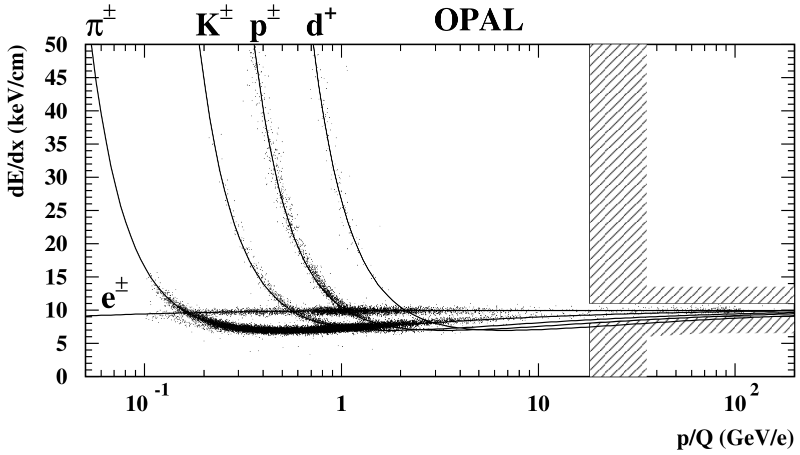
$$\tilde{W}^{\pm}\tilde{H}^{\pm} \qquad \tilde{\gamma} \;\; \tilde{Z}^0 \; \tilde{H}^0 \; \tilde{h}^0 \qquad \tilde{g} \quad \tilde{q} \qquad \tilde{\ell}^{\pm} \quad \tilde{\nu}$$

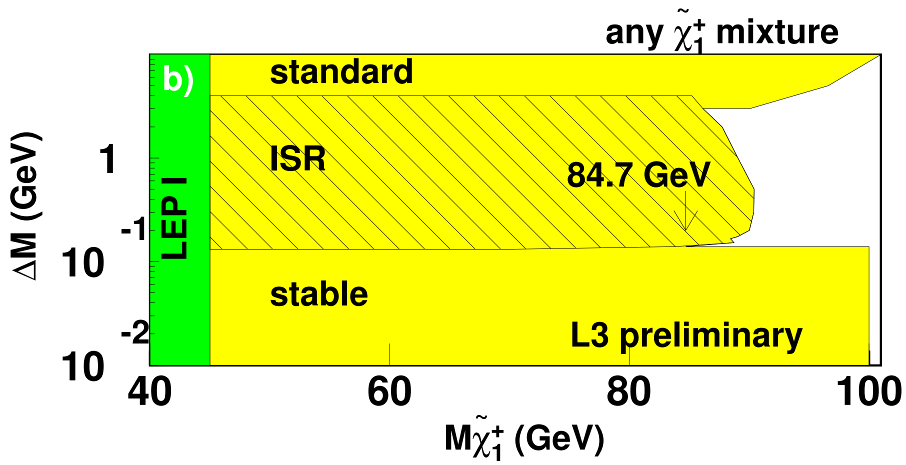
$$\tilde{\chi}_1^{\pm} \; \tilde{\chi}_2^{\pm} \qquad \tilde{\chi}_1^0 \; \tilde{\chi}_2^0 \; \tilde{\chi}_3^0 \; \tilde{\chi}_4^0 \qquad \tilde{g} \quad \tilde{q} \qquad \tilde{\ell}^{\pm} \quad \tilde{\nu}$$

$\tilde{\chi}^{\pm}$ searches at LEP

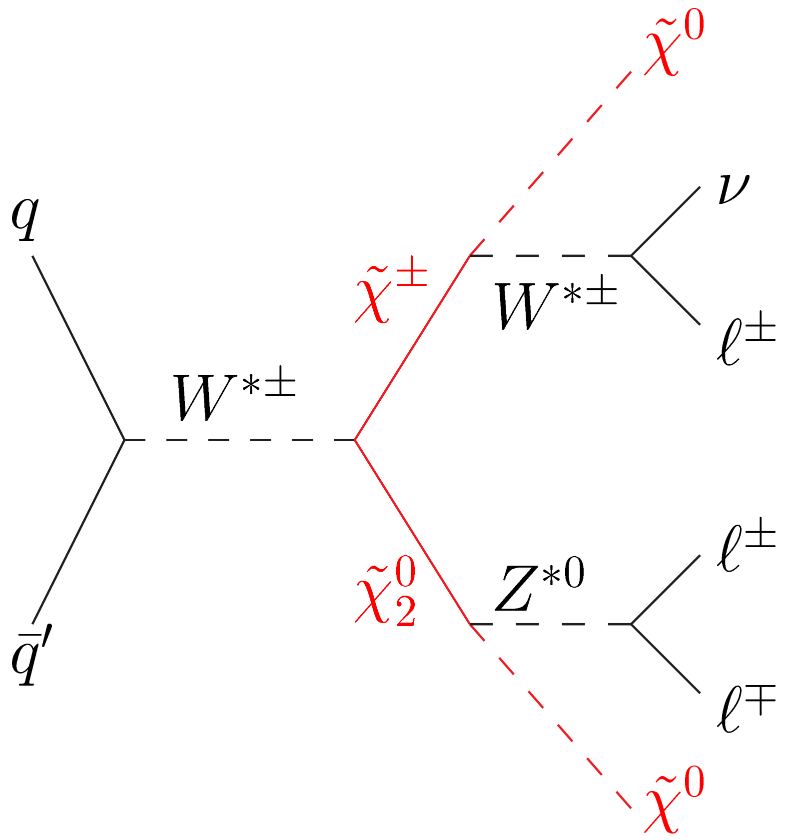


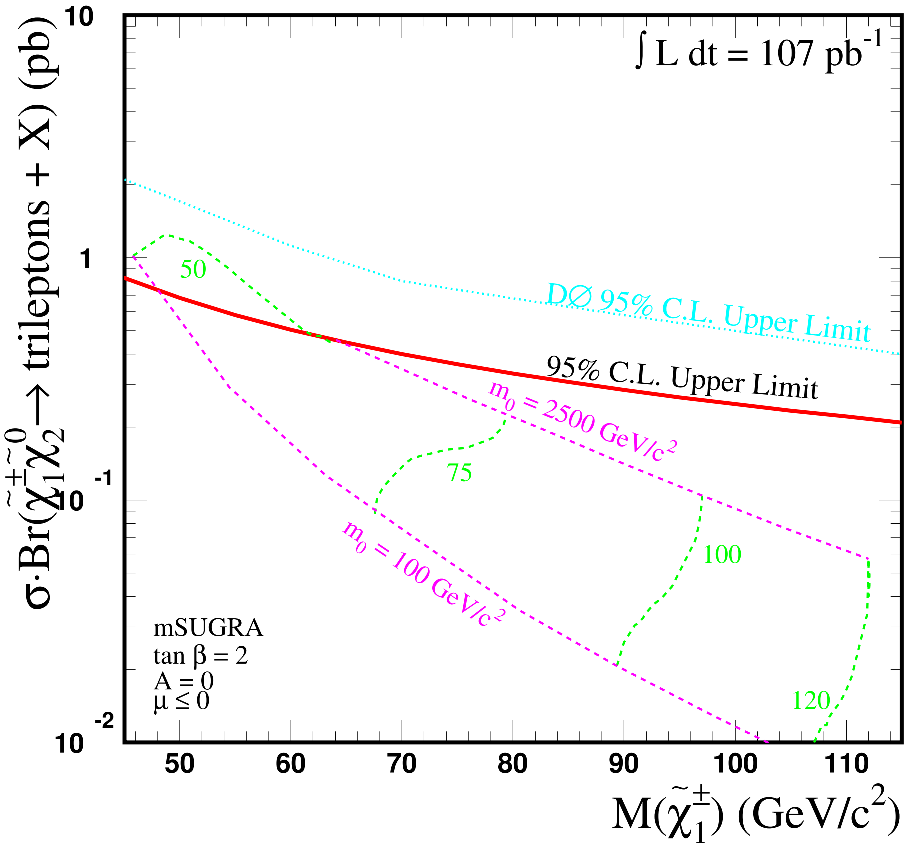






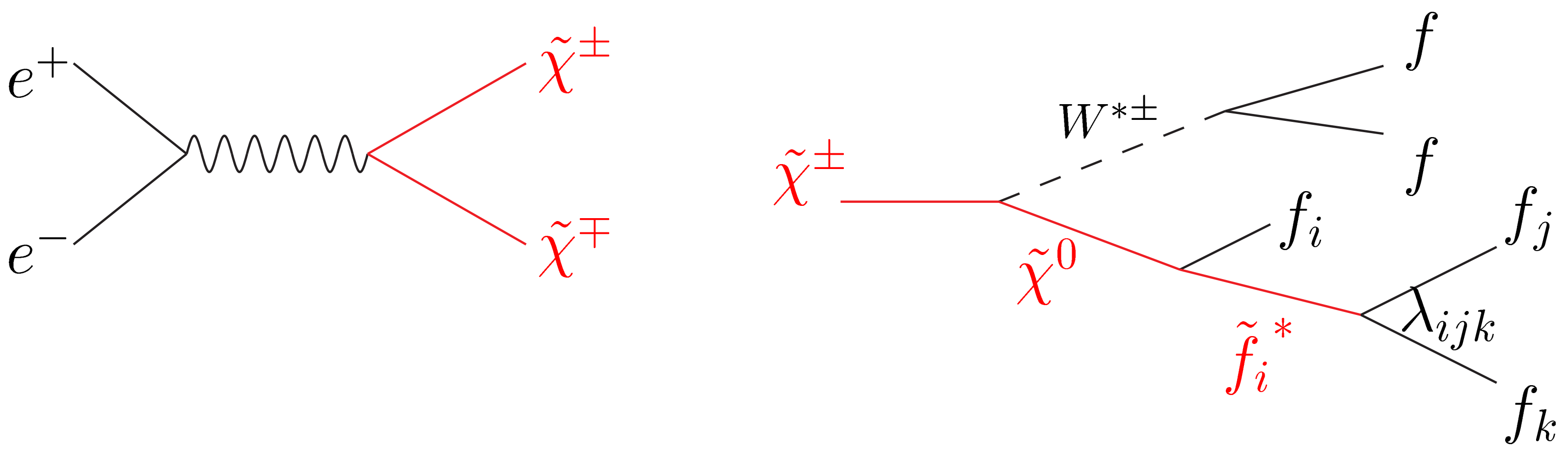
$\tilde{\chi}^{\pm}$ searches at the Tevatron





R-Parity violation searches

$$W = \lambda_{ijk} L_i L_j \bar{E}_k + \lambda'_{ijk} L_i Q_j \bar{D}_k + \lambda''_{ijk} \bar{U}_i \bar{D}_j \bar{D}_k$$



Gauge Mediated SUSY searches

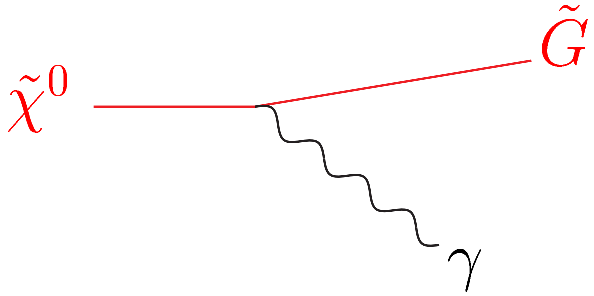
DELPHI CONF 552

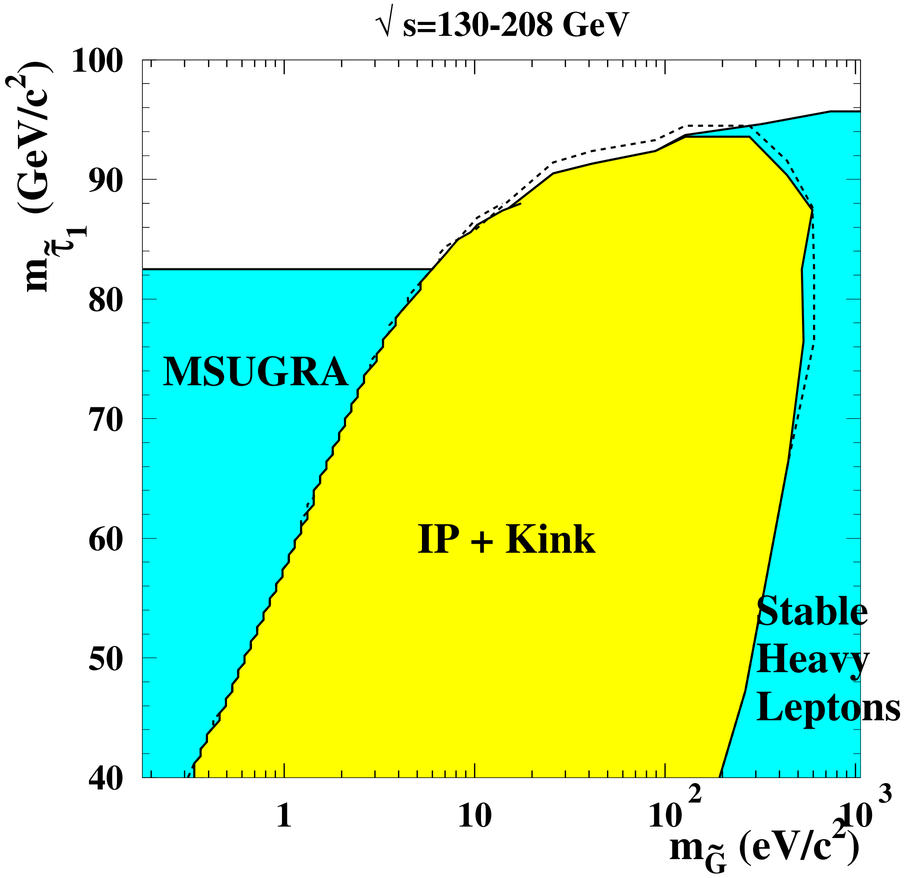
Low $\sqrt{F} \rightarrow$ low $m_{\tilde{G}}$

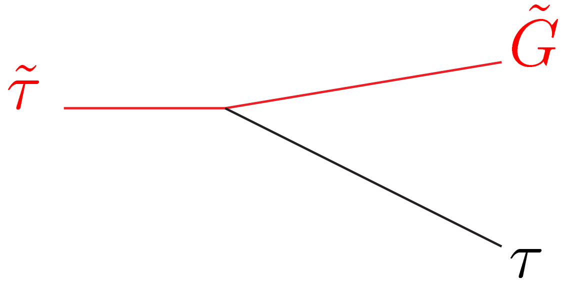
$$m_{\tilde{G}} \approx F/M_{\mathrm{Planck}}$$

$\Rightarrow \tilde{G}$ is LSP

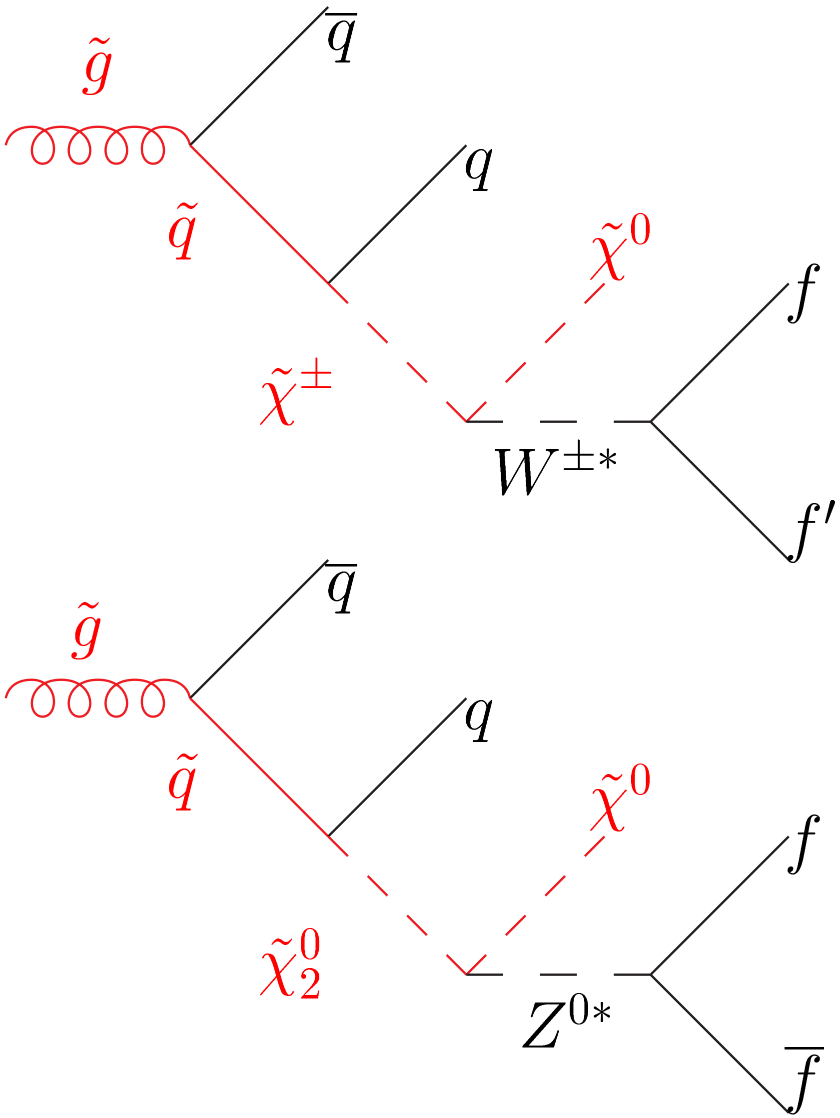
$$L \propto (m_{\tilde{G}})^2 \ (cm/eV^2)$$







$\tilde{q}$ and $\tilde{g}$ searches at the Tevatron



Several signatures:

- Dileptons + jets + $\not{E}_T$

  CDF, PRL **87**, 251803 (2001)

  D0, PRD-RC **63**, 091102 (2001)

- Multijets + $\not{E}_T$

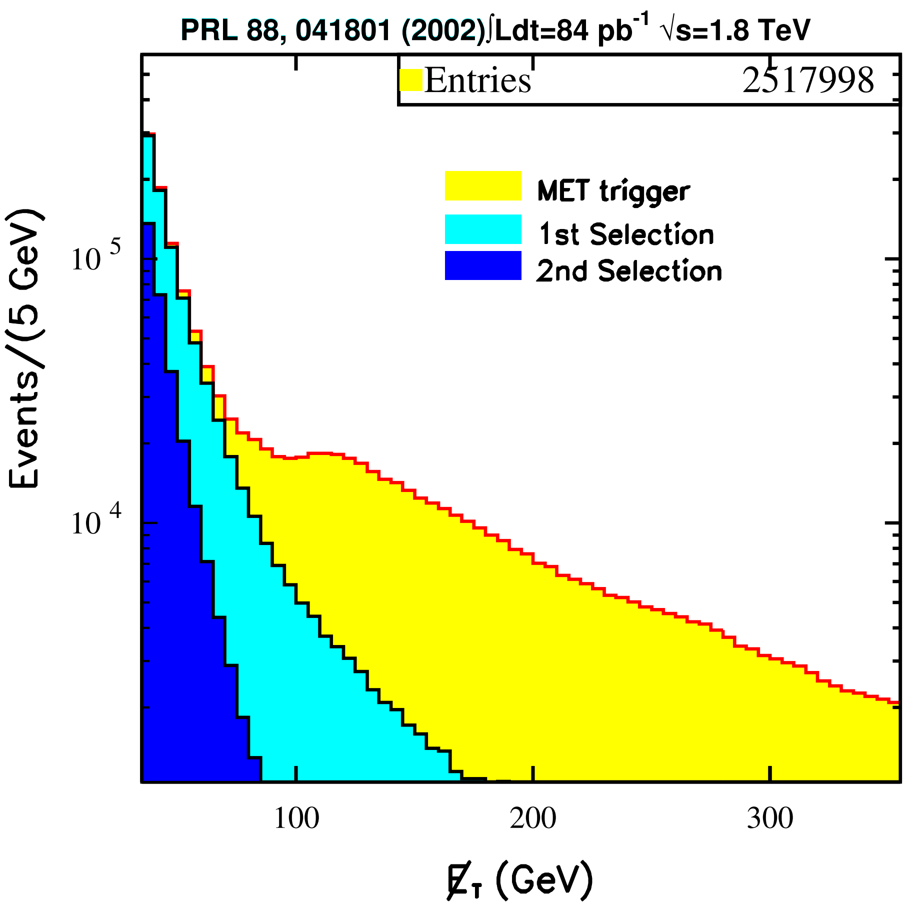
  CDF, PRL **88**, 041801 (2002)

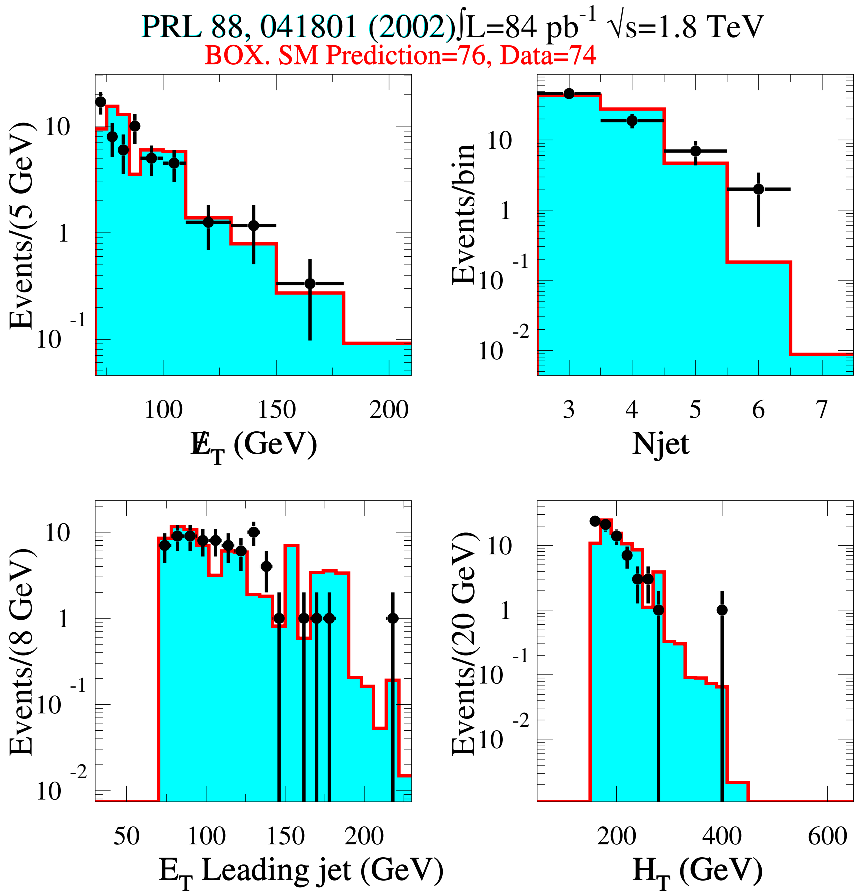
  D0, PRL **83**, 4937 (1999)

- $e^\pm$ + jets + $\not{E}_T$

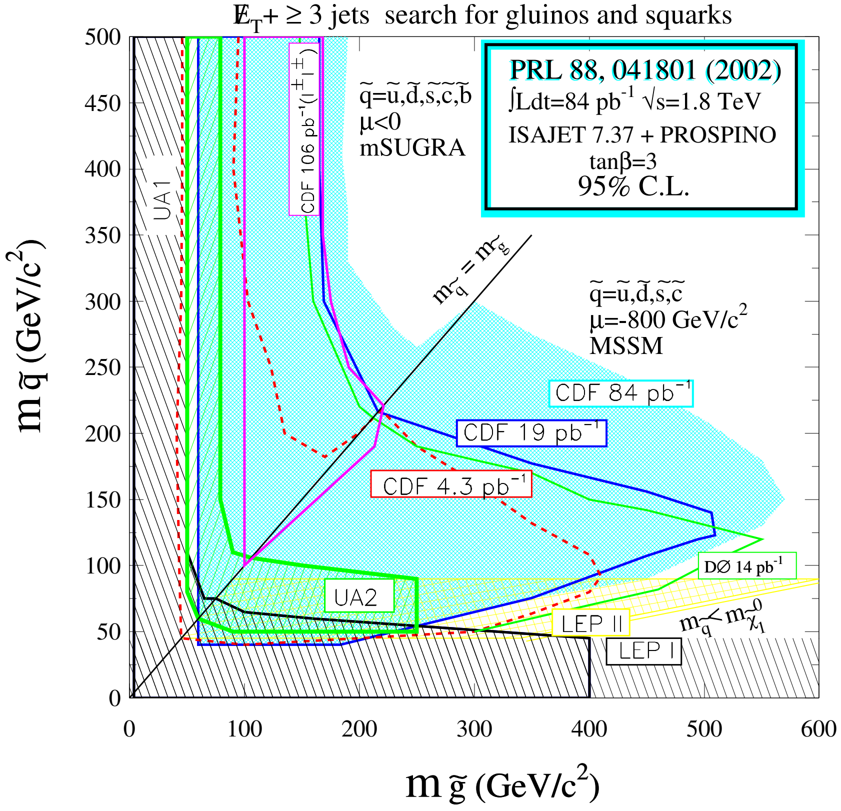
  D0, hep-ex/0205002

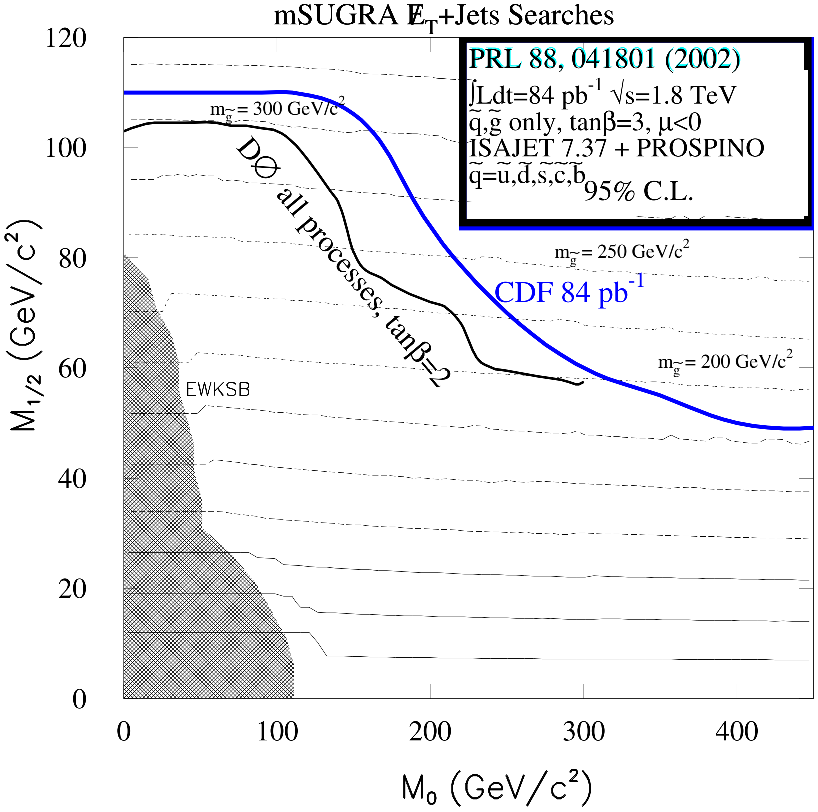
$\not\!\!E_T$ + jets search





$\not{E}_T$ + jets search





The New York Times

"Years of Research Yield Nothing, and That's Good News for Physicists"

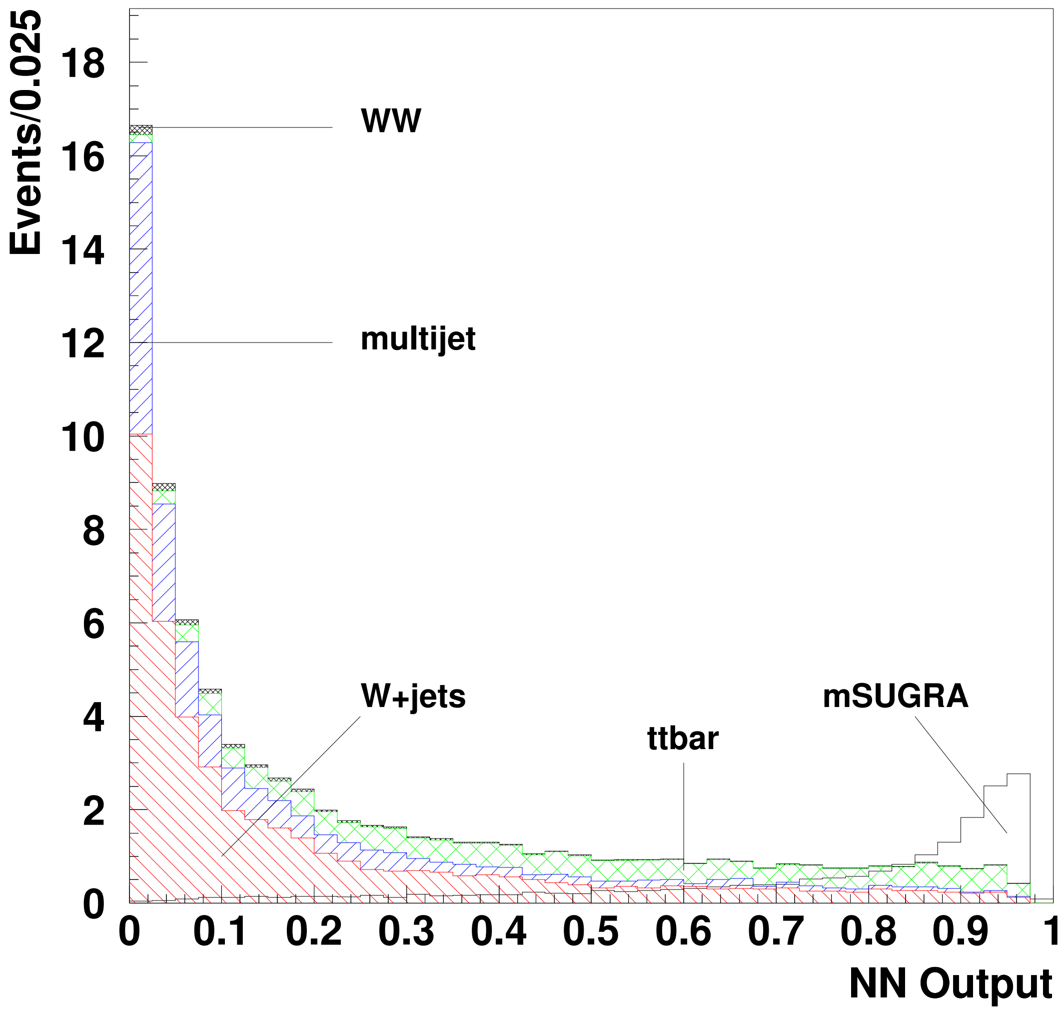
e + jets search

Neural Net based on:

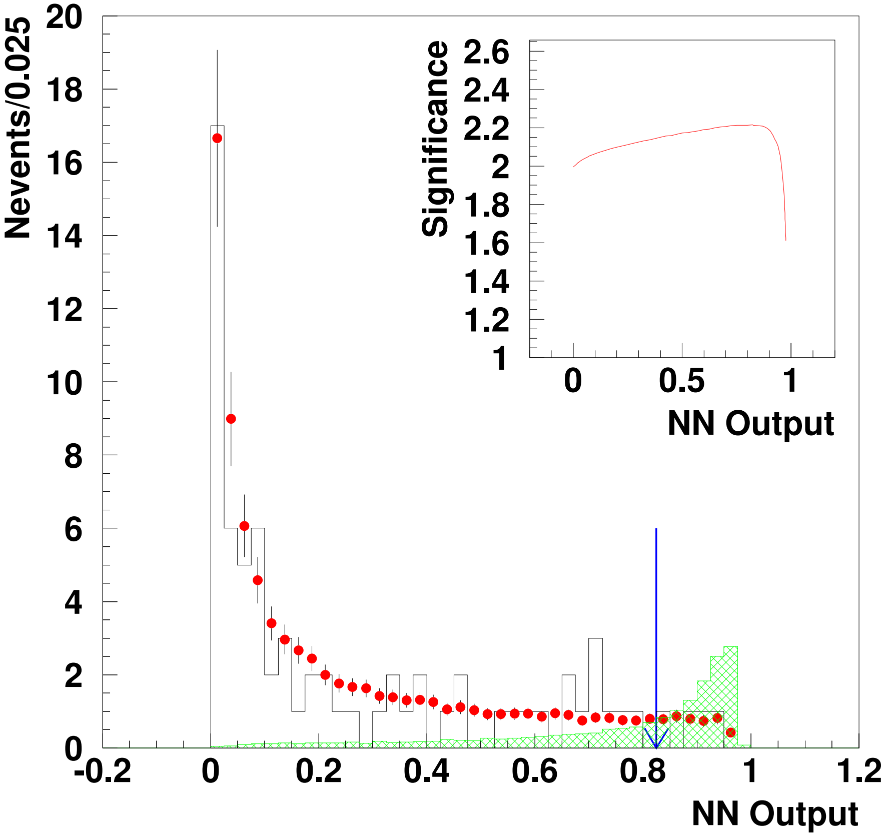
- $\not\!\!E_T$
- E_T^e, and $E_T^{j_3}$
- H_T, and M_T
- $\Delta\phi_{e,\not E_T}$
- Aplanarity
- $\cos\theta^*_{e,j}$

72 events observed,

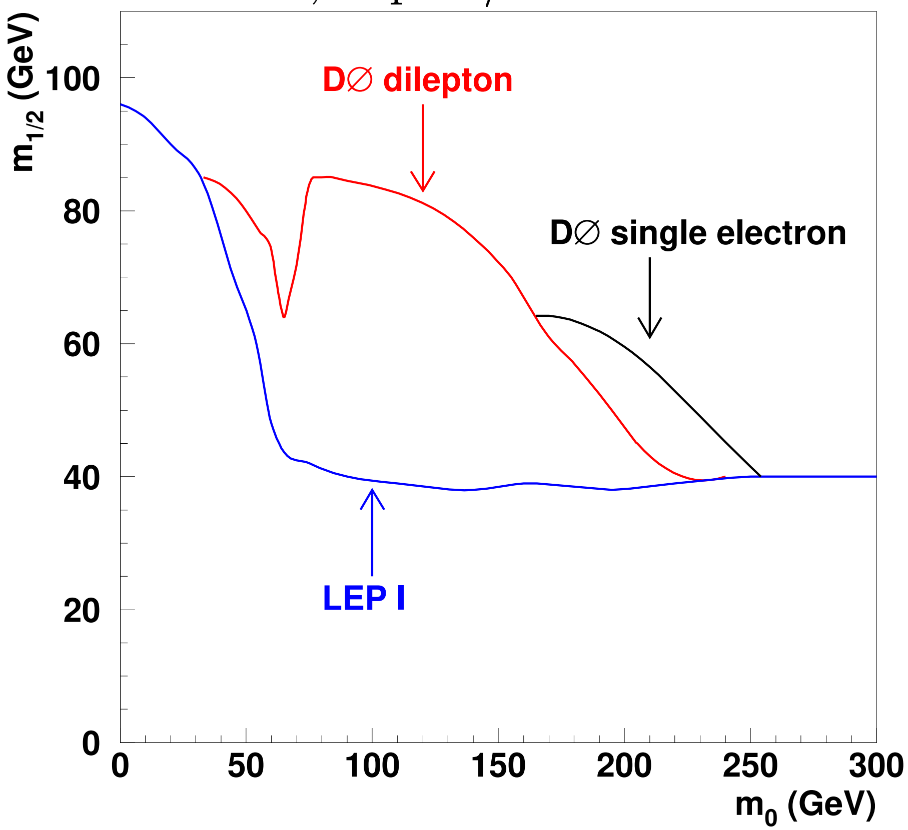
80.3 ± 10.4 expected.



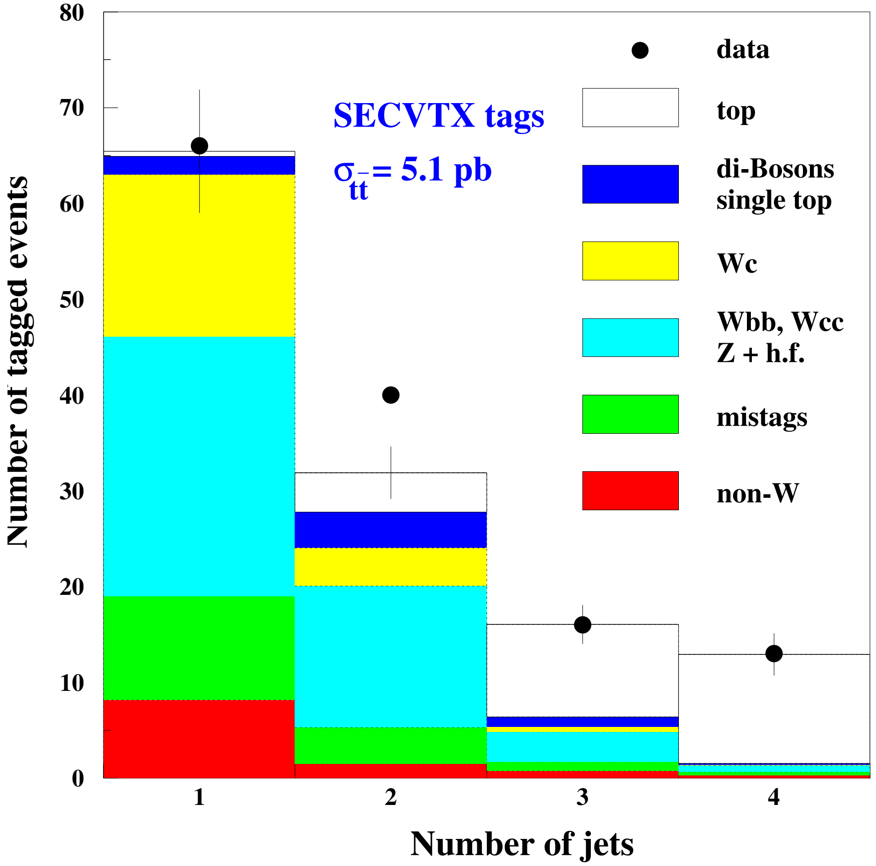
e + jets search

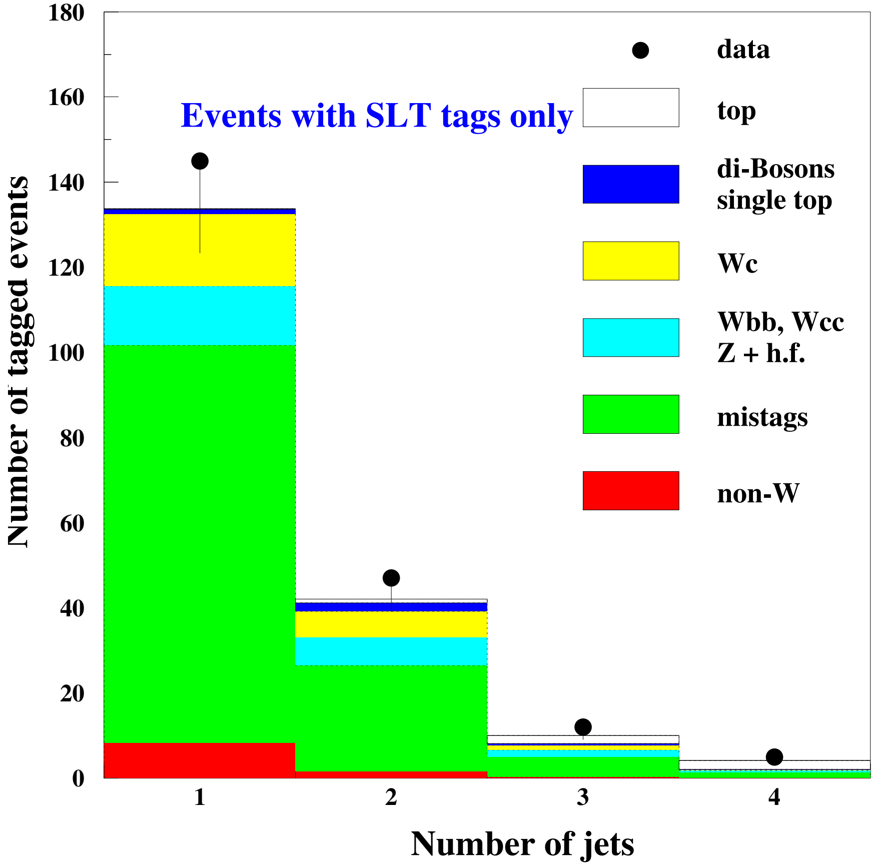


D0, hep-ex/0205002



Heavy flavor in W + jets





Heavy flavor in W + jets

Combining secondary vertex

and soft lepton tags in a jet,

Observe 13 events,

expected 4.4 ± 0.6

Compare 18 kinematic distributions

and conclude that

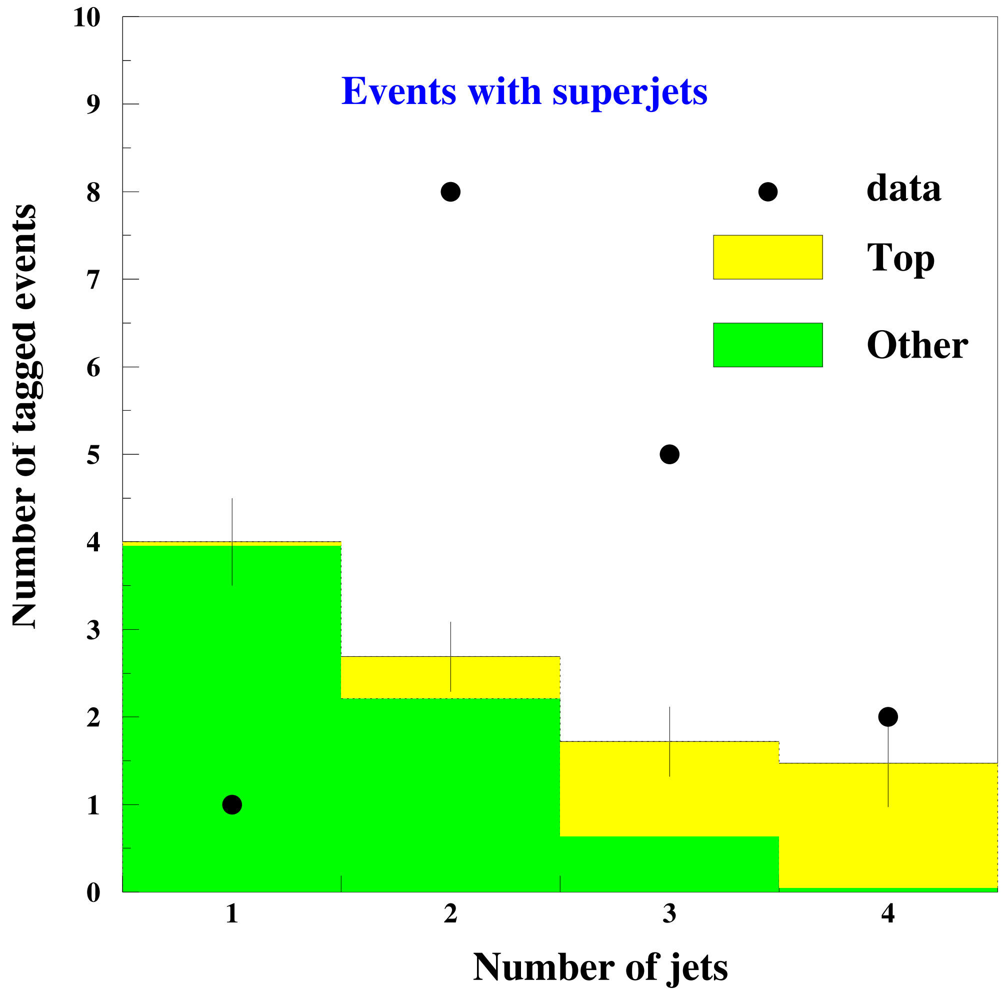
"they are statistically difficult to

reconcile with a simulation of

standard model processes"

CDF, PRD 65, 052007 (2002)

Apollinari *et al.*, hep-ex/0109019

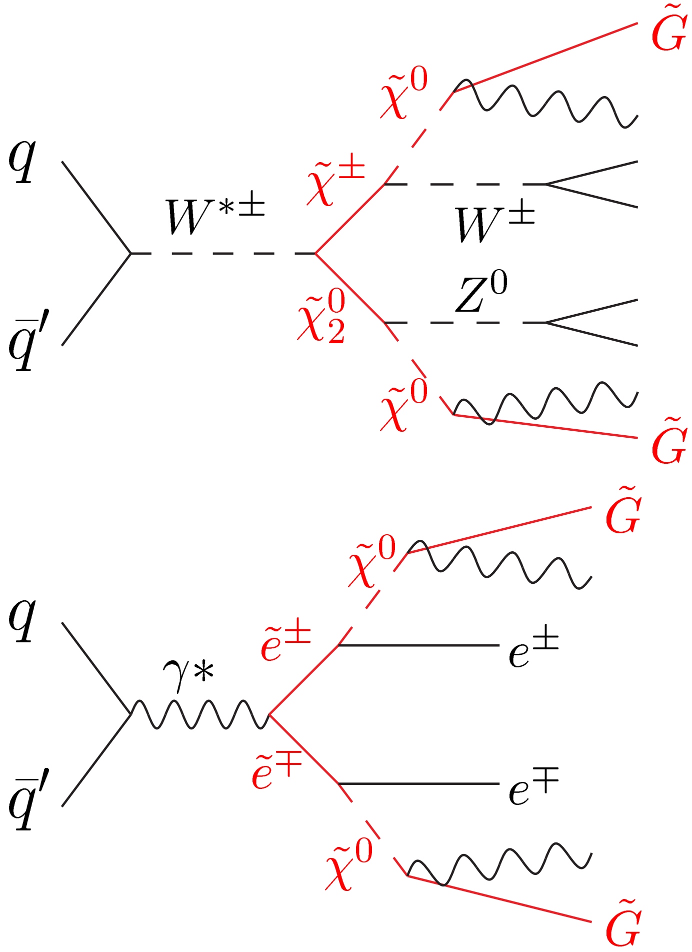


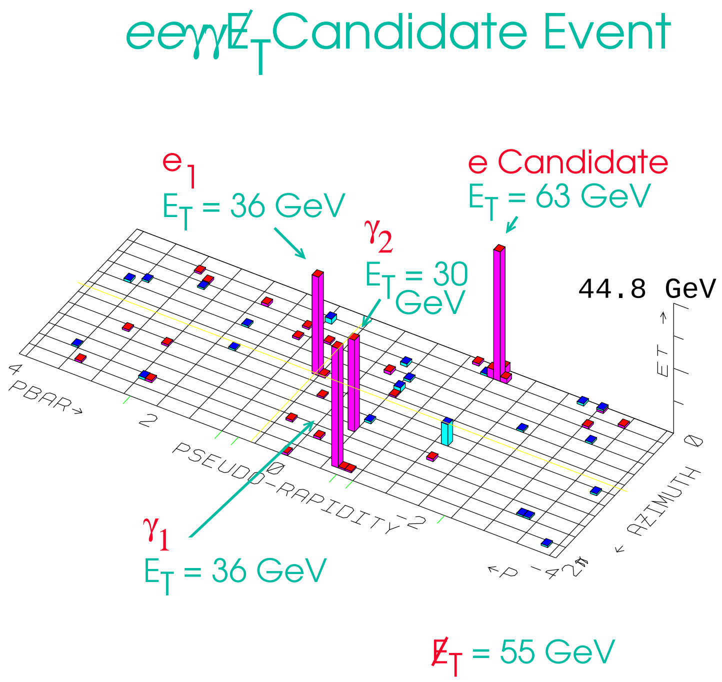
Photon searches

The expected rate for $ee\gamma\gamma\not{E}_T$ is small, CDF, PRD 59, 092002

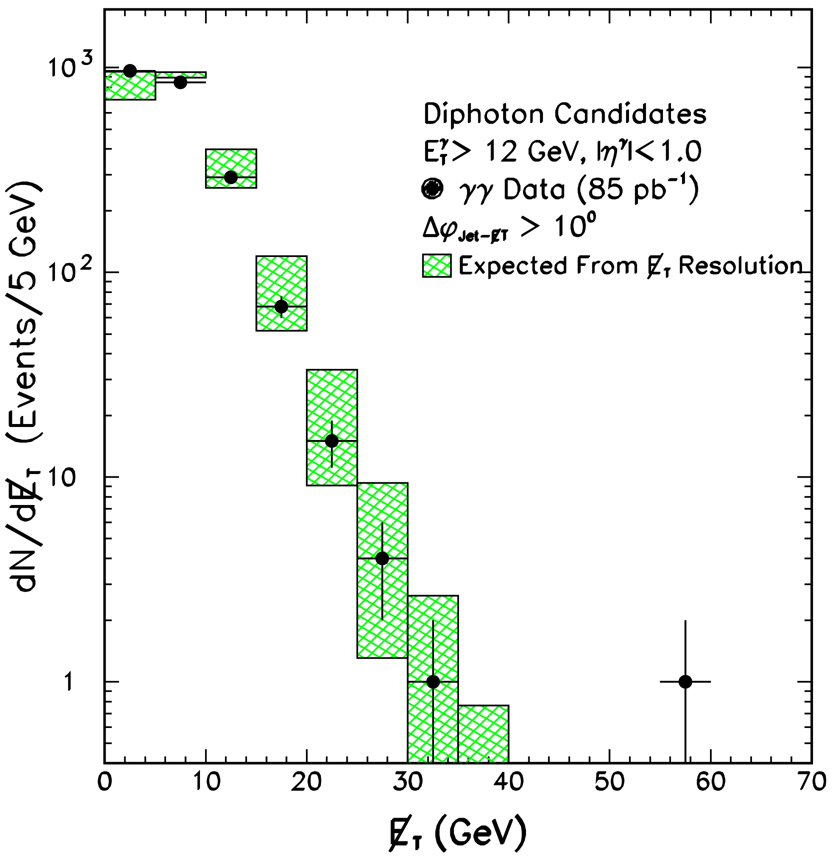
but it's a single event and is *a posteriori*.

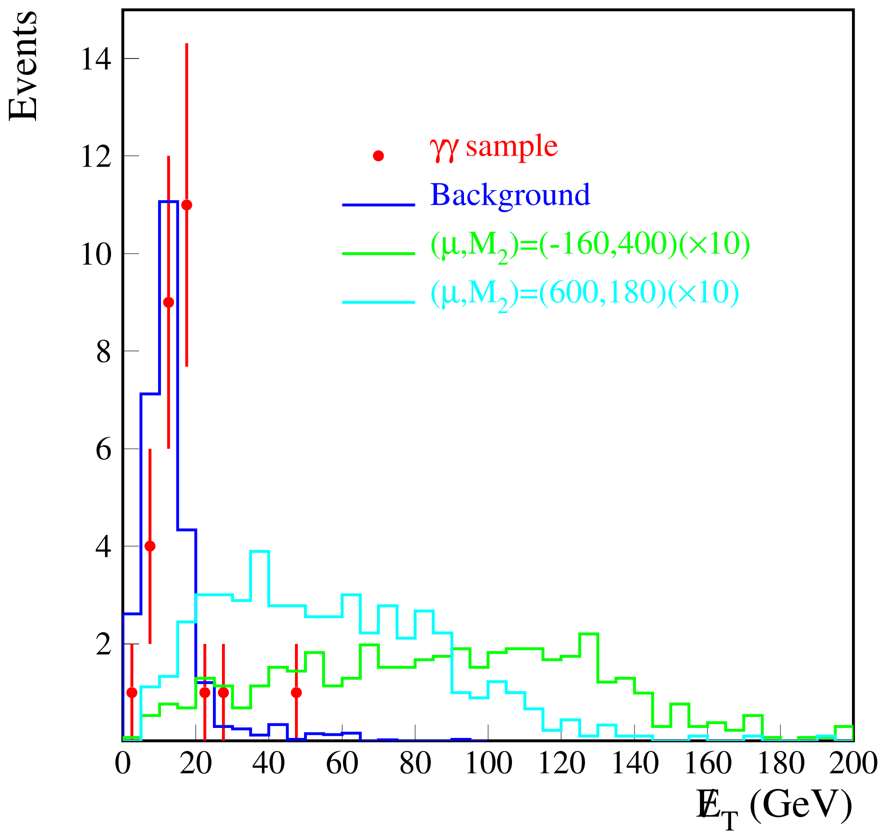
Search for other modes chosen *a priori*.



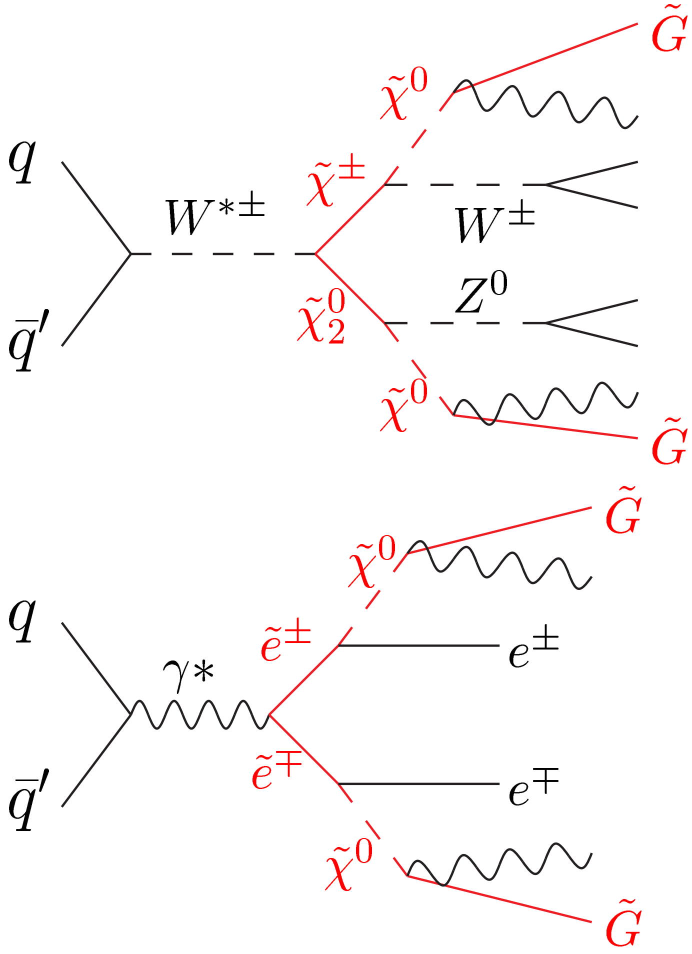


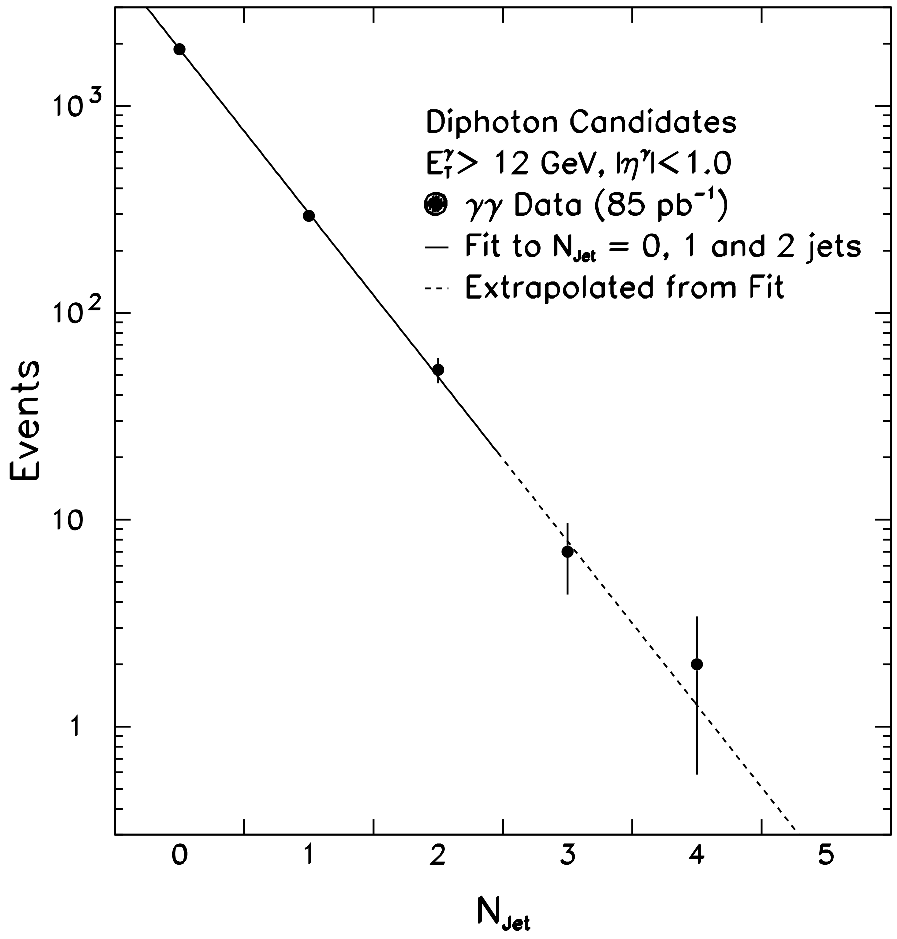
Photon searches





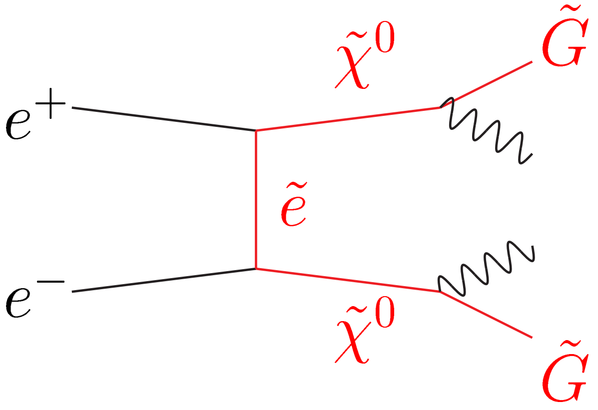
Photon searches

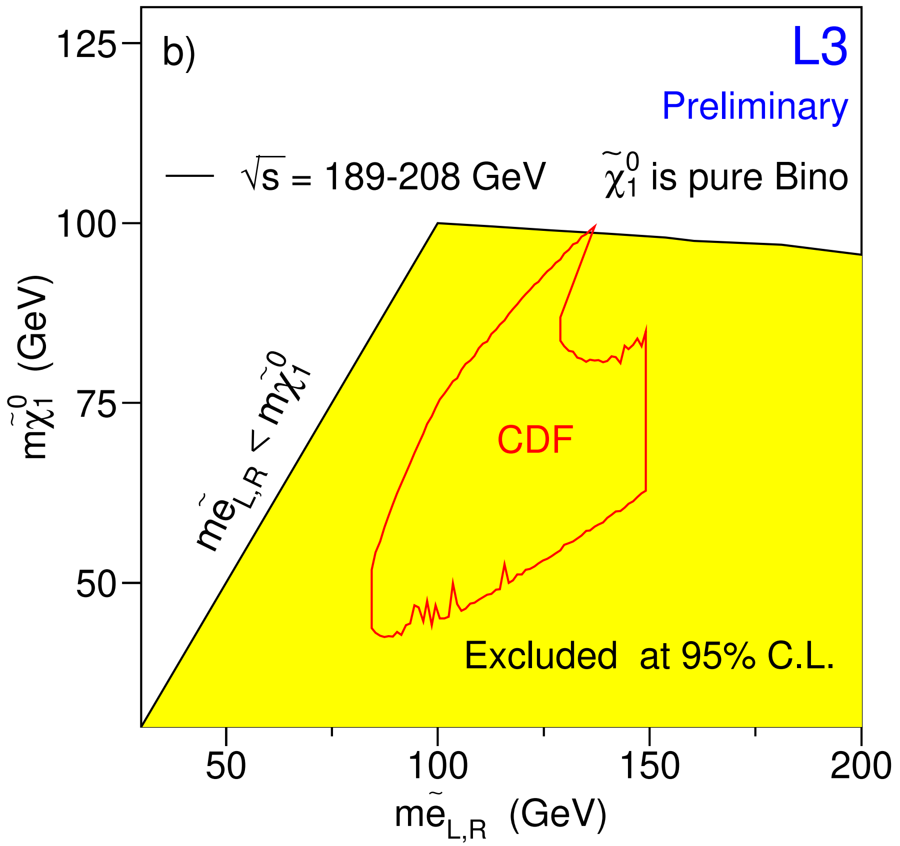




Photon searches

A selectron interpretation of CDF's $ee\gamma\gamma\not{E}_T$ is now completely excluded by LEP.





CDF $\ell\gamma\not{E}_T$

$E_T > 25$		hep-ex/0202044 & hep-ex/0110015		
Process	Two-Body	Multi-Body		
	$\ell\gamma X$	$\ell\gamma X$	$\ell\gamma\not{E}_T X$	$\ell\ell\gamma X$
W+γ	2.7 ± 0.3	5.0 ± 0.6	3.9 ± 0.5	–
Z+γ	12.5 ± 1.2	9.6 ± 0.9	1.3 ± 0.2	5.5 ± 0.6
ℓ+jet, jet $\rightarrow \gamma$	3.3 ± 0.7	3.2 ± 0.6	2.1 ± 0.4	0.3 ± 0.1
$Z \rightarrow ee, e \rightarrow \gamma$	4.1 ± 1.1	1.7 ± 0.5	0.1 ± 0.1	–
Hadron+γ	1.4 ± 0.7	0.5 ± 0.3	0.2 ± 0.1	–
π/K Decay+γ	0.8 ± 0.9	0.3 ± 0.3	0.1 ± 0.1	–
b/c Decay+γ	0.1 ± 0.1	< 0.01	< 0.01	–
Predicted μ_{SM}	24.9 ± 2.4	20.2 ± 1.7	7.6 ± 0.7	5.8 ± 0.6
Observed N_0	33	27	16	5
$P(N \geq N_0 \mid \mu_{SM})$	9.3%	10.0%	0.7%	68.0%

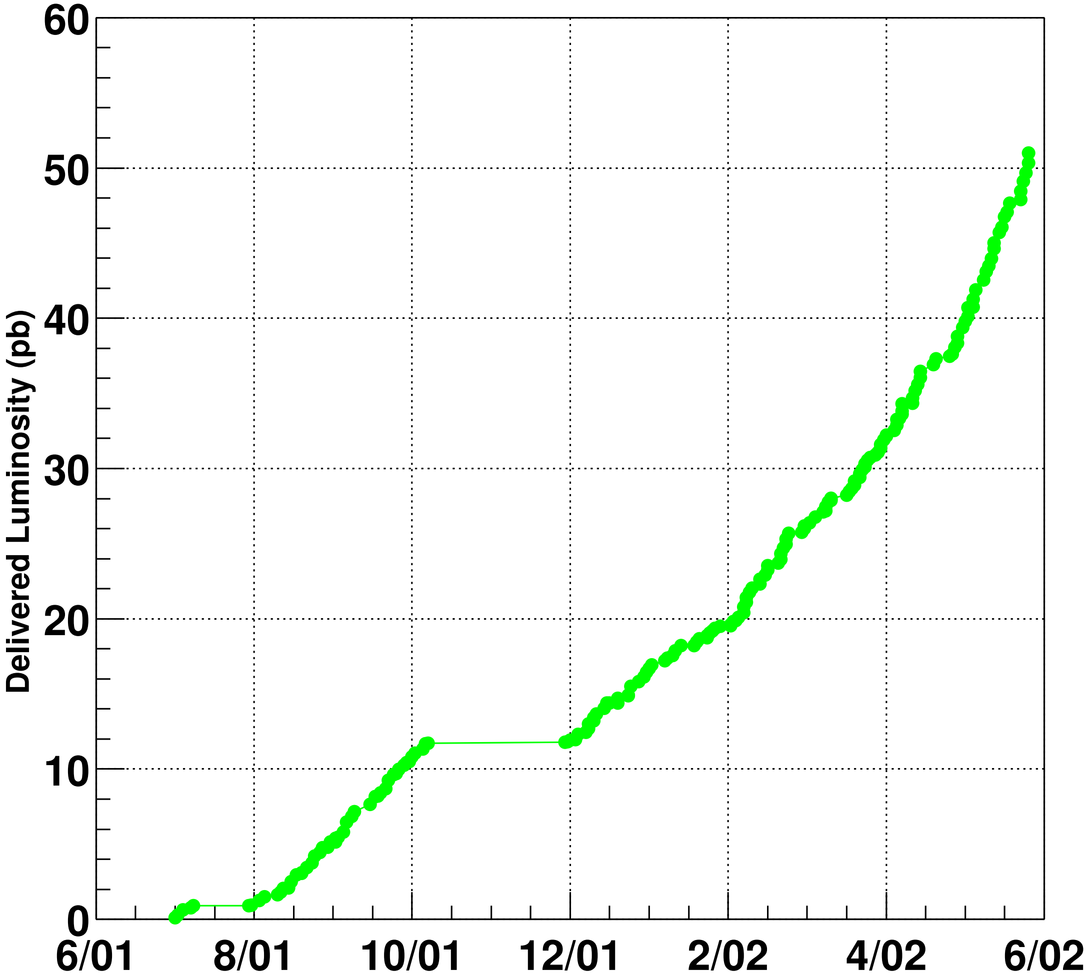
Tevatron Run 2

Run IIa

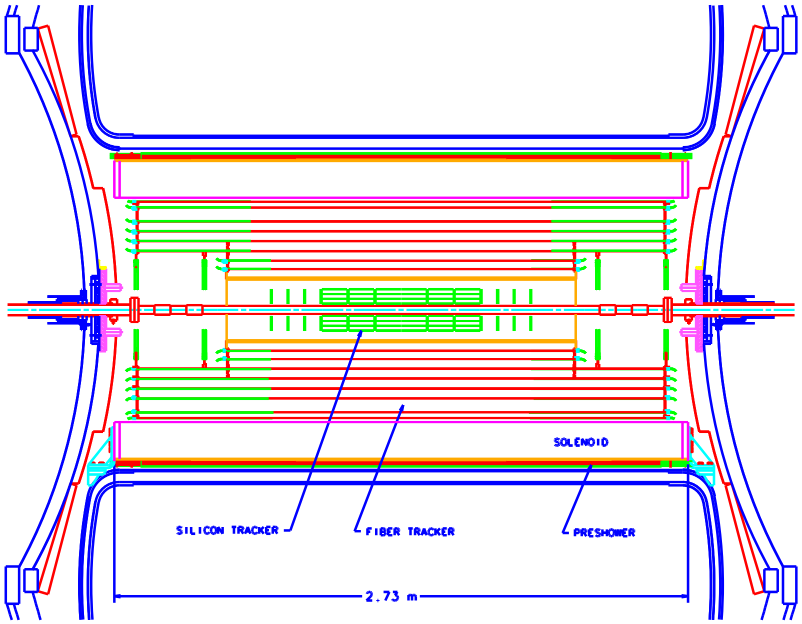
- 36×36 bunches
- $\mathcal{L} = 1 \times 10^{32}$
- $\Rightarrow 17\text{pb}^{-1}$ per week (about 119 $t\bar{t}$ per week)

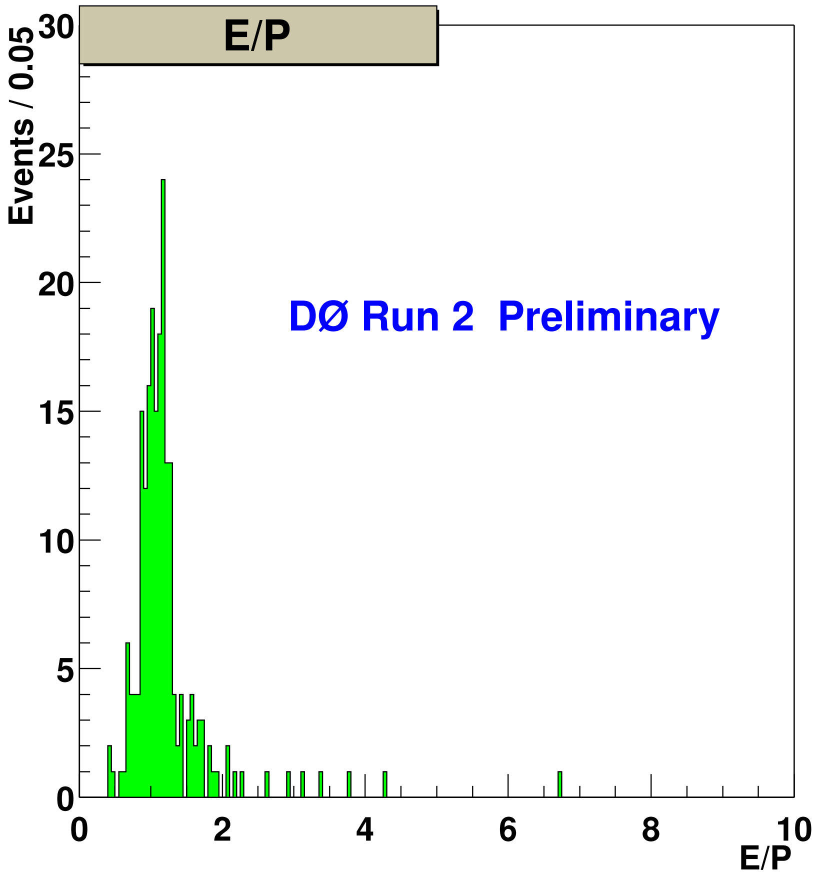
Run IIb

- 140×103 bunches
- $\mathcal{L} = 5 \times 10^{32}$
- $\Rightarrow 100\text{pb}^{-1}$ per week (about 700 $t\bar{t}$ per week)

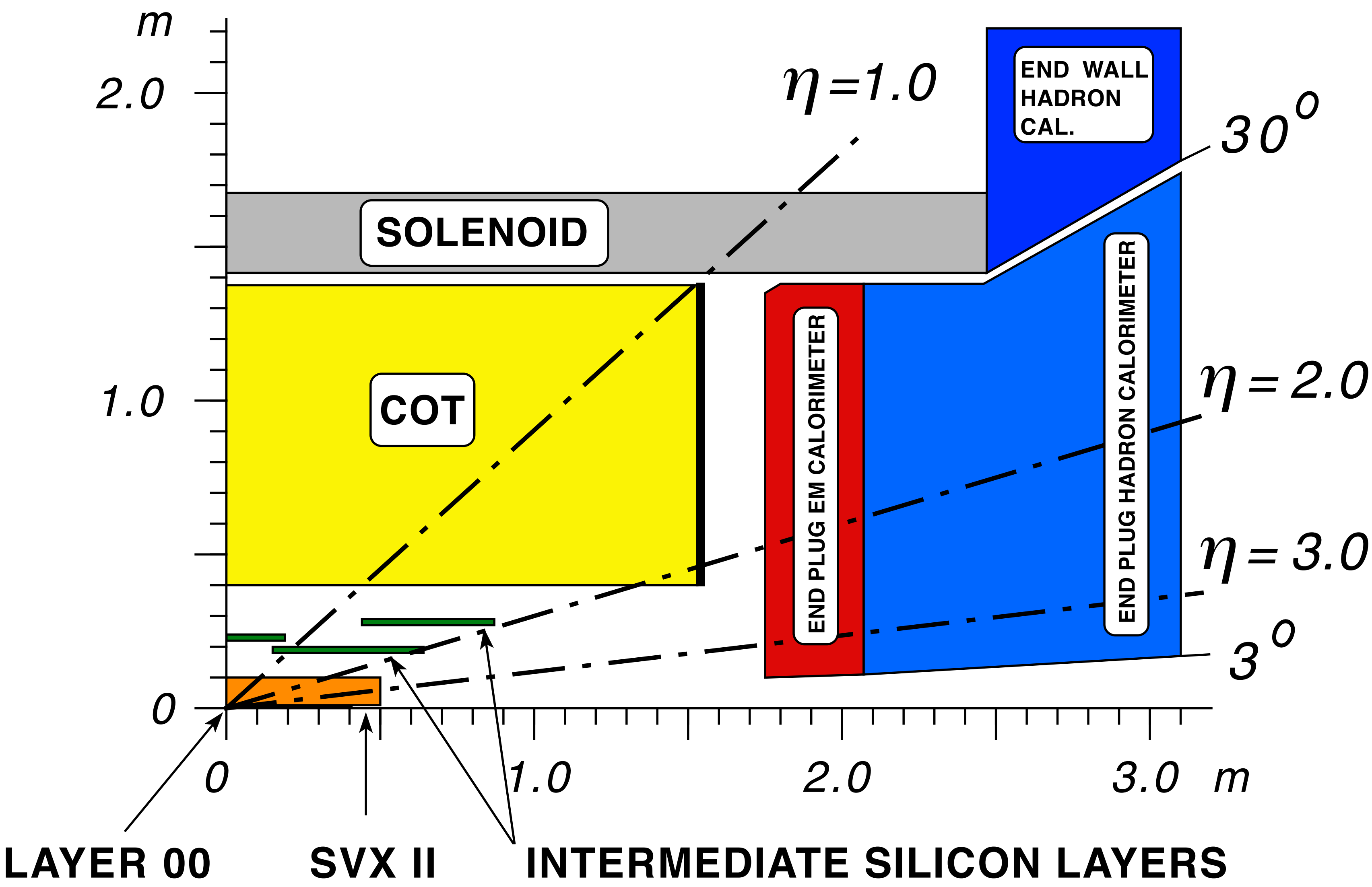


D0 in Run 2


SILICON TRACKER
FIBER TRACKER
PRESHOWER
SOLENOID
2.73 m


E/P
Events / 0.05
DØ Run 2 Preliminary
0
5
10
15
20
25
30
0
2
4
6
8
10
E/P

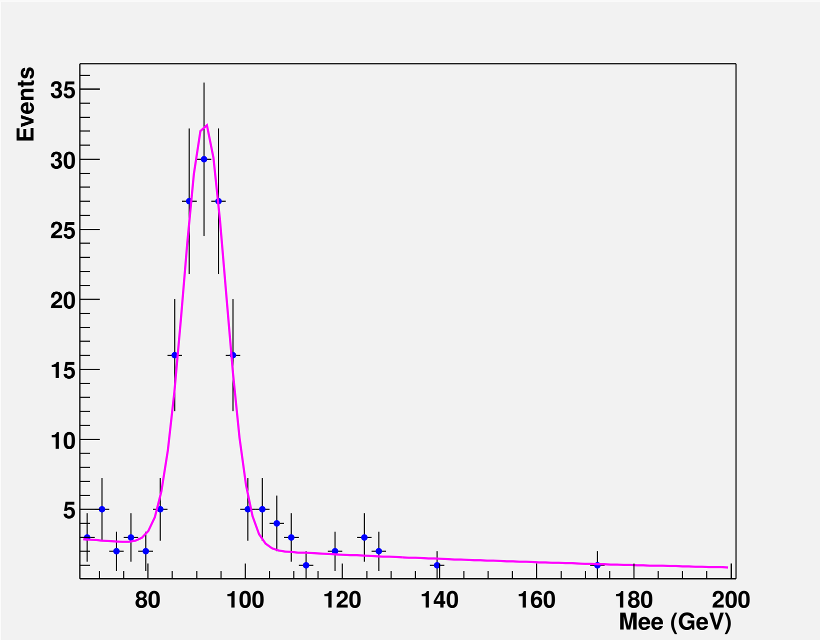
CDF in Run 2

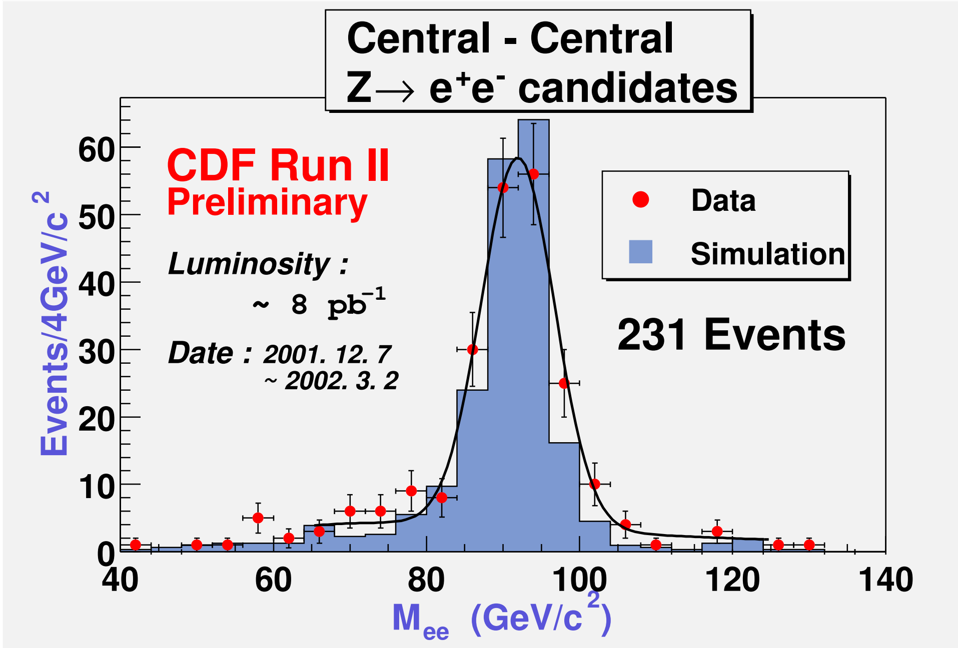


m
2.0
1.0
0
SOLENOID
COT
END WALL
HADRON
CAL.
η=1.0
30^0
$\eta = 2.0$
$\eta = 3.0$
3^0
END PLUG EM CALORIMETER
END PLUG HADRON CALORIMETER
0
1.0
2.0
3.0
m
LAYER 00
SVX II
INTERMEDIATE SILICON LAYERS

Early Run 2 data

D0 Run 2 $Z \to e^+e^-$ candidates





Conclusion

Searches talks on Monday

2:00 Search for gauge mediated supersymmetry breaking, S. Ask (Lund)

2:15 Search for Gauge Mediated SUSY in $\gamma\gamma$, Yuri Gershtein (Brown)

2:30 Search for the lightest neutralino at LEP, P. Johansson (U. Stockholm)

2:45 CDF Searches for New Physics with High-Et γ, Ray Culbertson (FNAL)

3:00 Search for New Physics in the Exclusive $\gamma \not\!\!E_T$ at CDF, P. Onyisi (U. Chicago)

3:15 Lepton Number Violating Processes at KTeV, A. Bellavance (Rice)

3:30 A new limit on νless double β decay Xi- $\rightarrow p\mu^+\mu^-$, D. Rajaram (Illinois Tech.)

3:45 Search for Heavy ν in NOMAD Forward Cal, S. Mishra (U. South Carolina)

4:30 Searches for 3rd Gen. Scalar Quarks at CDF, S. Ming Wang, (U. Florida)

4:45 Search for 1st Gen. Leptoquarks in $eejj$ for D0 Run 2, S. Fu (Columbia)

5:00 Large Extra Dimension search at D0 in Run 2, R. Hooper (Notre Dame)

5:15 Theoretical and Exp. Status of Magnetic Monopoles, K. Milton (U. Oklahoma)