Search for New Phenomena at Colliders

E. Nagy (CPPM)

for the

CDF, D0 (Tevatron)

and

H1, ZEUS (HERA)

Collaborations

In spite of the great success of the SM we still miss an ultimate theory (TOE) which would provide unification of all the 4 known forces (gravity!) into a finite (renormalizable) theory.

Therefore, new, BSM physics is expected at some energy scale M_X.

The questions are: what is the TOE and what is M_X?

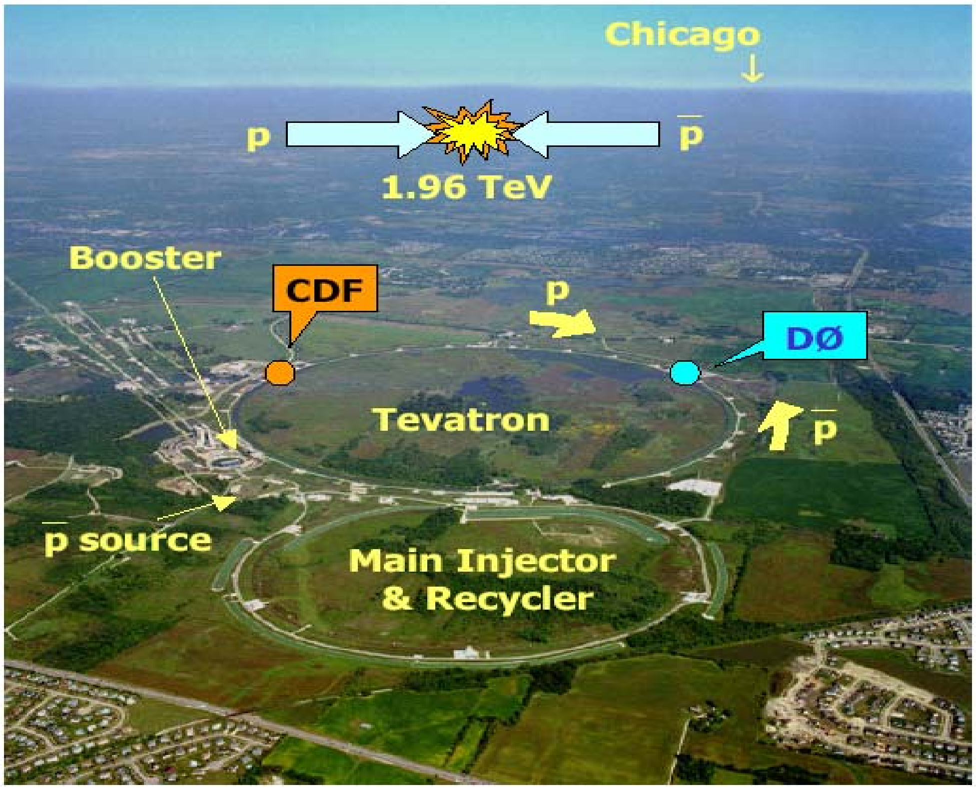
Today only elements of such a theory are proposed for experimental tests. In the present talk: some arbitrary choice of topics addressed by two active colliders: Tevatron and HERA.

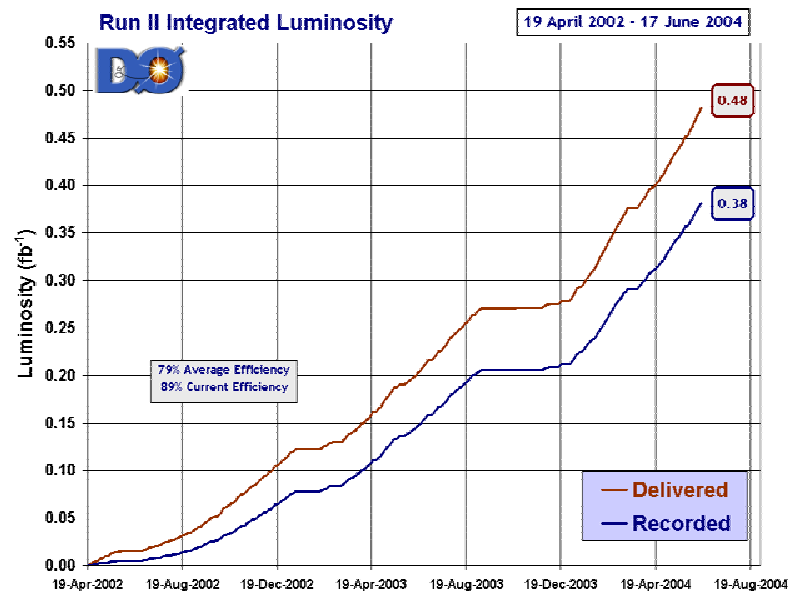
- **Extra Dimensions**
- **Super Symmetry**
- **Z’, Lepto-Quarks, Beyond SM Higgses**
- **Substructure** **(Contact Interactions, Excited Leptons)**
- **Anomalies**

Frequently, the same event topology (e.g. high mass di-leptons) allows to test several theoretical models

For M_X the natural value is M_{Pl} to unify gravity.
However this leads to « unnatural » fine tuning of scalar masses (problem of hierarchy).
Some of the above topics present solution to this problem.

Tevatron

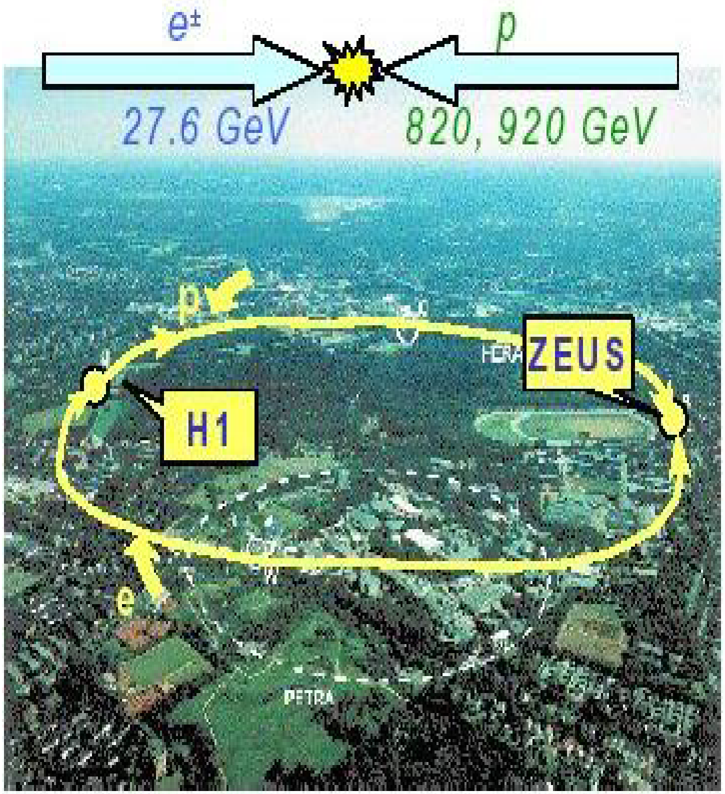




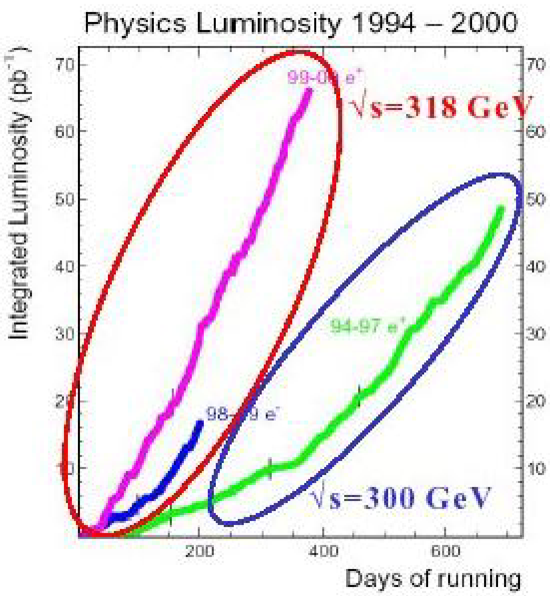
>3 times more luminosity than in Run I; soon $\mathcal{L}$ is $10^{32}cm^{-2}s^{-1}$ and counted in fb^{-1}

~ 200 pb^{-1} and only most recent results from Run II reported here

HERA



HERA I Luminosity



HERA II will deliver ~10 times more luminosity (at present ~70 pb^{-1})
+ longitudinal polarisation of e-beam

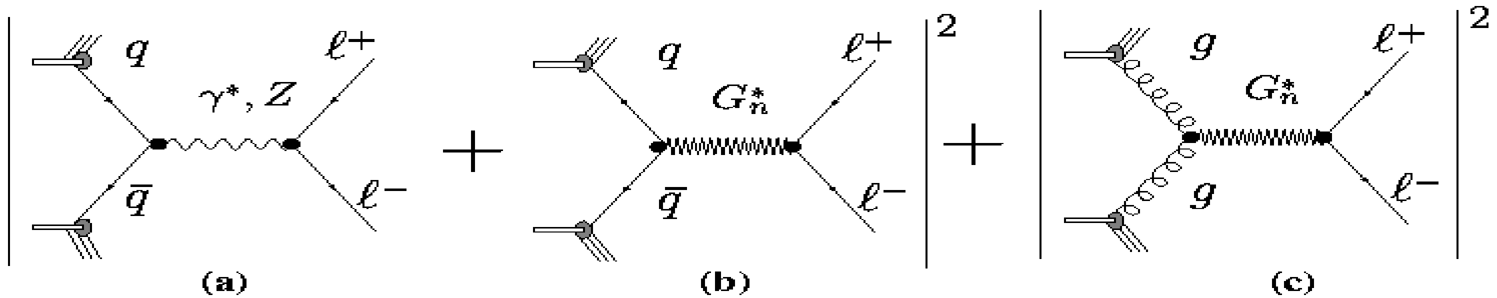
Results mainly from HERA I

Extra Dimensions (ED)

- ED's provide framework for unification with gravity (Th. Klauza, 1919)
- ED's are compact since not seen (O. Klein, 1926)
- Compact ED's generate replica of particles (KK-tower) propagating in them
- In string theories, ED's restore QM probabilities in the range [0,1].
- ED's can be large (LED: $R \gg TeV^{-1}$) – if only gravity can propagate in them
- LED can explain why gravity is weak: $1/G \sim M^2_{Pl} \sim M_s^{n+2} R^n$ and can solve the hierarchy problem: $M_s \sim M_W$
- LED can be tested by gravity experiments (n<3) but also at colliders through virtual effects or direct emission of KK gravitons (n>2).
- Smaller ED's ($R \sim TeV^{-1}$) can also be tested at colliders (interference of KK states)
- Randall-Sundrum model (1 small ED of size $R \sim 1/M_{GUT}$ with a metric damped by $e^{-kR\varphi}$) predicts graviton resonances (S=2) of k~1.

Determination of M_s of LED

Look for effects of virtual gravitons in high mass lepton (photon) pairs

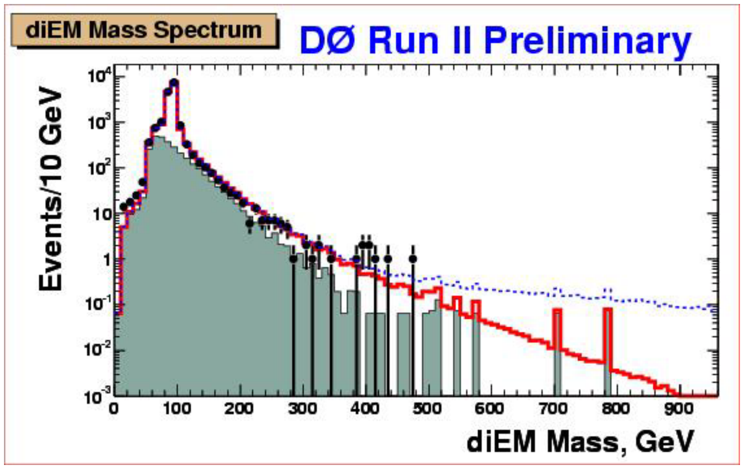


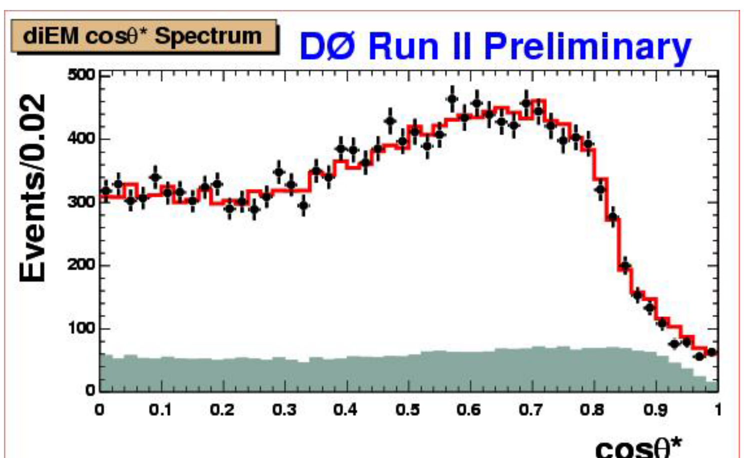
$$\frac{d^2\sigma}{dMd\cos\theta^*} = f_{SM} + f_{\text{int}}\eta_G + f_{KK}\eta_G^2$$

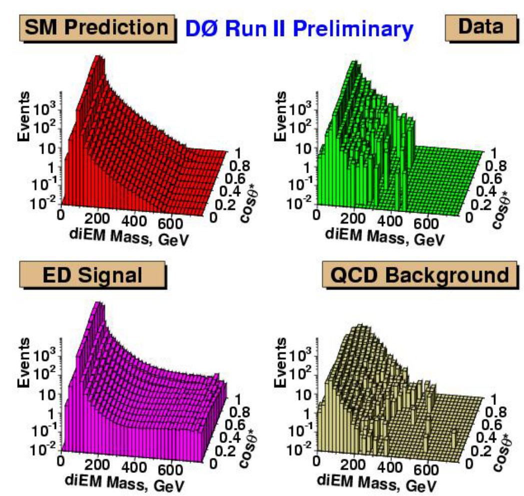
$$\eta_G = \frac{2\lambda}{\pi}\frac{1}{M_S^4}; \quad \lambda = \pm 1 \;\; (Hewett)$$

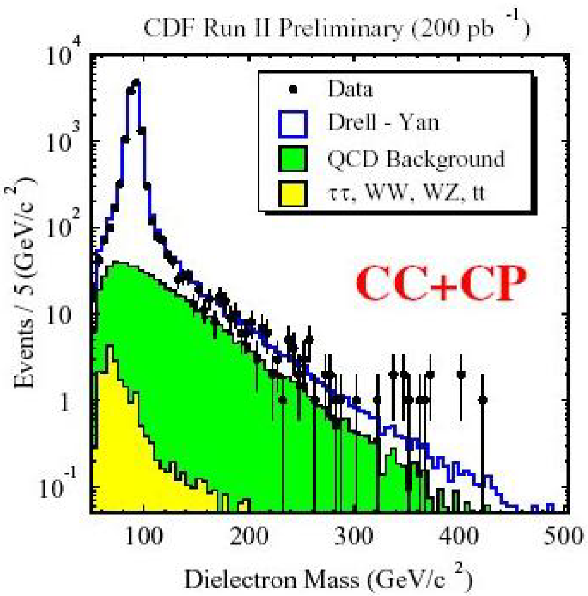
- **Select:**
- **2 (and only 2) high pT em objects: pT>25 GeV**
- **Precisely determined vertex**
- **Compare:**
- **SM and instrumental (mis-ID) background**
- **Extract limit:**

	$\eta(\mathrm{TeV}^{-4})$	$M_S(\mathrm{TeV})$
$\lambda = +1$	0.292	1.22
$\lambda = -1$	-0.432	1.10









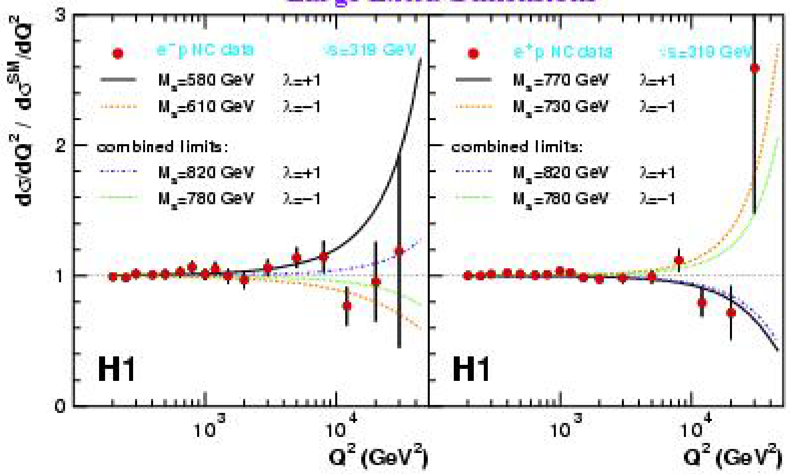
Mass >(GeV/c^2)	N_{exp}	N_{obs}
200	66.9	70
250	25.1	29
300	10.4	14
350	4.7	8
400	2.4	3
450	1.4	0

Limit on M_S from HERA
$\eta=\lambda/M_S^4$

	H1	ZEUS
λ= +1	0.82	0.78
λ = -1	0.78	0.79

Total of ~12500 CC+CP candidates in 200 pb^{-1} data

Large Extra Dimensions

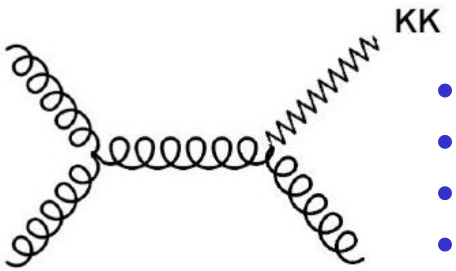


CDF ee limit

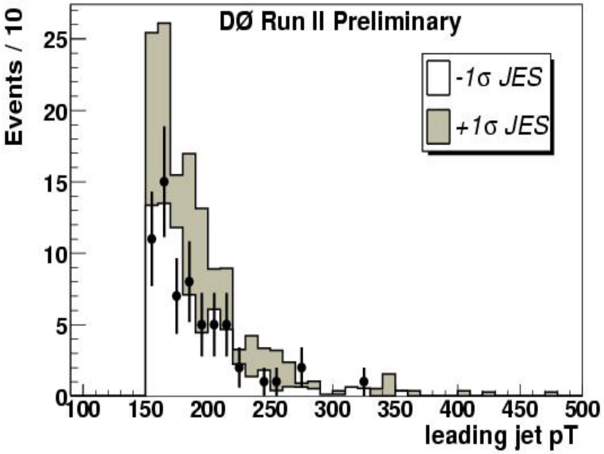
	η(TeV^{-4})	M_S(TeV)
λ= +1	1.17	0.961
λ = -1	1.05	0.987

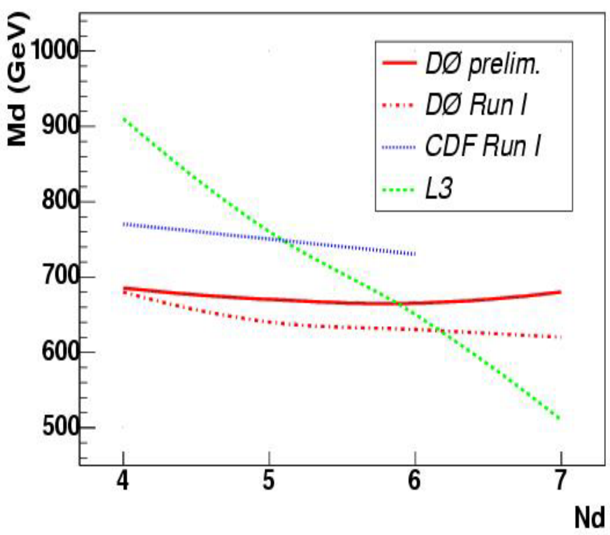
Determination of M_d from KK graviton emisson

Signature is Monojet + MET



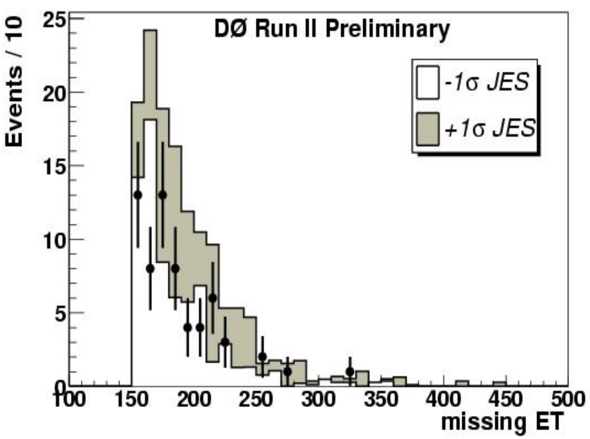
- Selection:
- Leading jet pT>150 GeV
- 2nd jet pT < 50 GeV
- MET>150 GeV
- Lepton (e,μ) veto





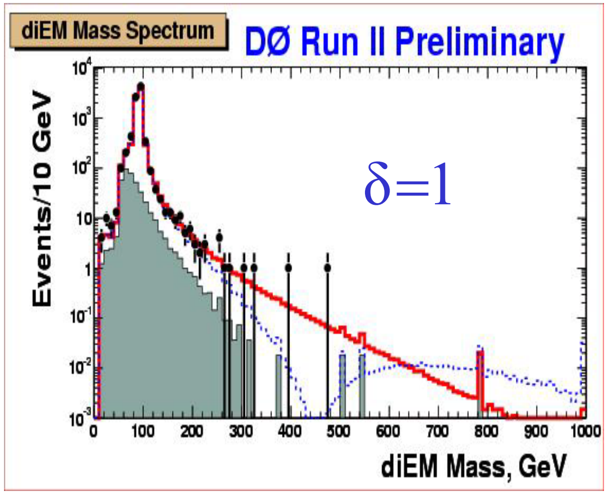
Main Background:
Z(->νν)+nj
W(->lν)+nj

Main uncertainty:
Jet energy scale

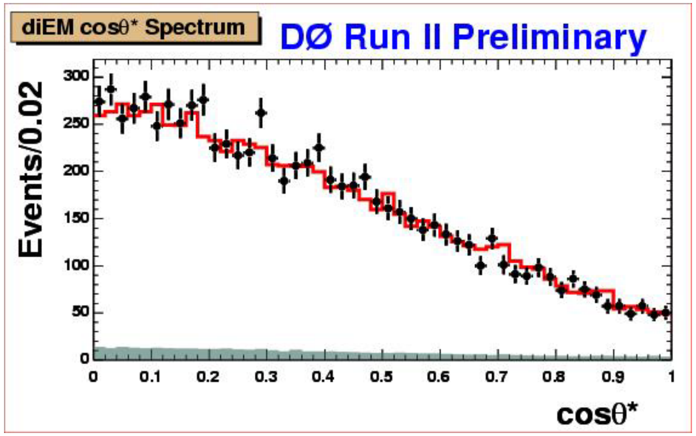


Determination of M_c of TeV^{-1}-size (Longitudinal) ED

- Fermions are confined in the ordinary 3d world.
- Gauge bosons can propagate in 3+δ brane of δ compact ED.
- Look for effects of KK replica of gauge bosons in high mass lepton pairs and determine the scale M_c of ED.

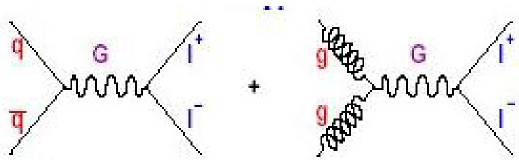


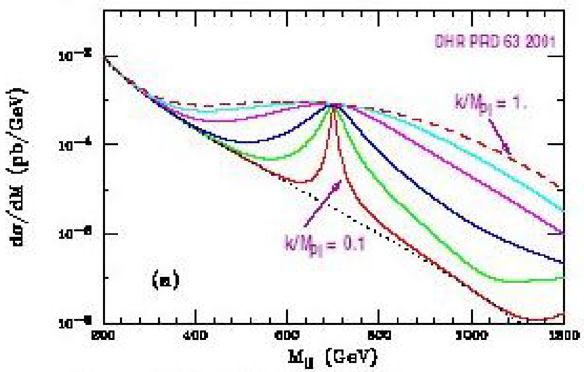
Interference of KK states



- Same selection as above + trackmatch of at least 1 em object
- Data is compatible with SM
- M_c > 1.12 TeV @ 95%

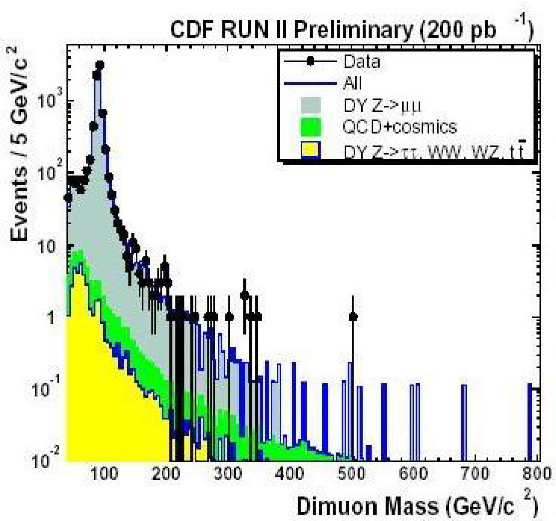
Search for Randall-Sundrum resonances in high mass di-lepton states

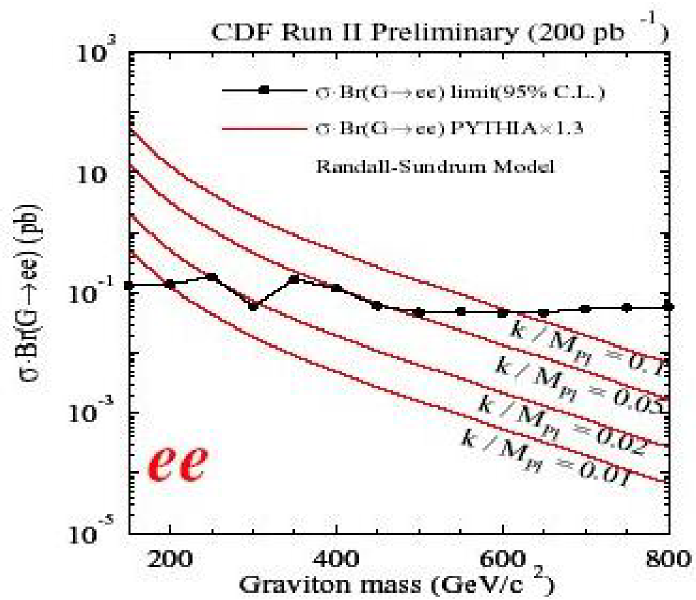




CDF Run II Preliminary

CDF Run	L(pb^{-1})	M_G @95%CL (k/M_{Pl}=0.1)	
		ee	$\mu\mu$
IIA (winter '04)	200	**620**	**605**





SUper SYmmetry

Symmetry of Nature for Boson<->Fermion interchange

- Basic ingredient for unification with gravity (SuperString/M-theory)
- The only nontrivial extension of the Lorentz-Poincaré group
- Provides elegant solution for the hierarchy problem

Minimal extension of the SM: MSSM

- every SM particle has ΔS = ±1/2 partner
- R = $(-1)^{3B+2L+S}$ = +1 (SM); = -1 (SUSY)
- 2nd Higgs doublet is needed

$$q, l \Leftrightarrow \tilde{q}, \tilde{l}$$

$$g \Leftrightarrow \tilde{g}$$

$$\gamma, Z, h, H, A \Leftrightarrow \chi^0_{1,\ldots,4}$$

$$W^\pm, H^\pm \Leftrightarrow \chi^\pm_{1,2}$$

If SUSY were exact: only 1 additional parameter (μ) needed

SUSY is a broken symmetry since nobody has seen the partners

- many more parameters describe breaking
- with additional hypotheses they are reduced in the 2 models treated here
  - gravitation mediated (mSUGRA) model to 5 (m_0, $m_{1/2}$, $\tan\beta$, $\mathrm{sgn}\mu$, A_0)
  - gauge mediated (GMSB) model to 6 (Λ, M_m, N_5, $\tan\beta$, $\mathrm{sgn}\mu$, C_{grav}) parameters.

R-parity is approximately conserved:

- severe limits on B- and L-violating processes
- SUSY partners are pair produced
- LSP is stable (neutral and weakly interacting)

Basic signature is MET (LSP), + multiple jets and leptons

- from cascade decays

Main bg is t tb and gauge boson pair production

Small violation of R-parity is not excluded:

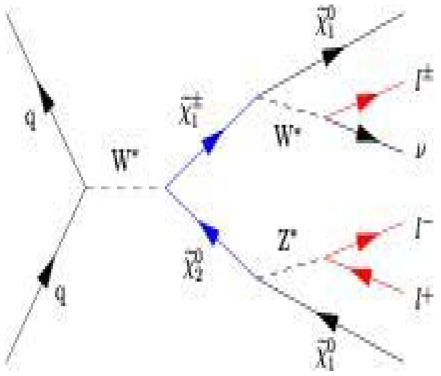
- allows single resonant formation of SUSY particles
- many more jets/leptons in final state
- additional couplings (48)

At Tevatron both RPC and RPV can be studied
HERA is competitive only for RPV processes

The “golden” signature:

chargino ($\chi_1^{\pm}$) and neutralino (χ_2^0) pair production

The signatures exploited by D0:
MET from χ_1^0 and ν +
3 leptons (e,μ,l/e,e,l) or
2 leptons (μ, μ) of same sign



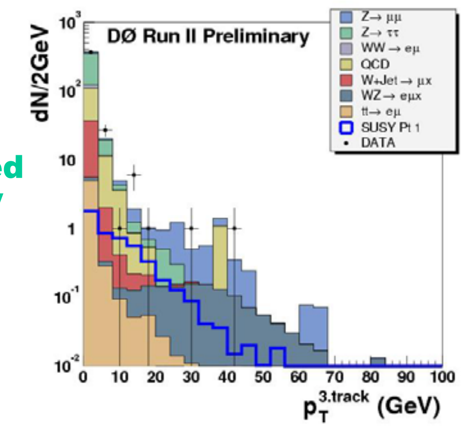
D0 has searched beyond the stringent mSUGRA LEP limit and has chosen the following parameter region:

$$72 \le m_0 \le 88\,\mathrm{GeV}; 165 \le m_{1/2} \le 185\,\mathrm{GeV}; \tan\beta = 3; \mu > 0; A_0 = 0$$

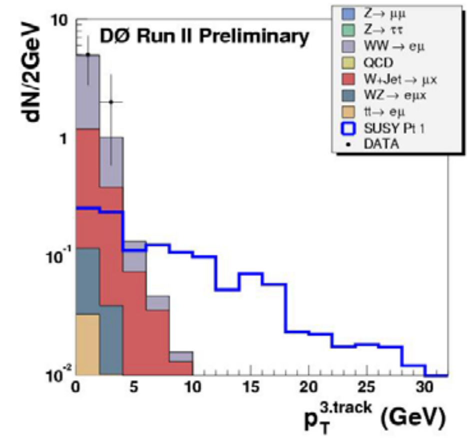
$$m_{\chi_1^{\pm}} \approx m_{\chi_2^0} \approx 2\, m_{\chi_1^0} \approx m_{\tilde{l}}$$

e+ μ +l

High quality, isolated electron: p_T>12 GeV
muon: p_T>8 GeV
charged track

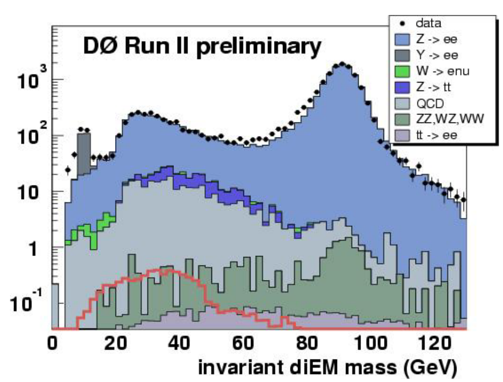


Jet veto
m_T^{min} >15 GeV
15<$m_{e\mu}$<100 GeV
METsignif>25 GeV½
p_T^3> 3 GeV
0 data – 0.54±0.25 bg

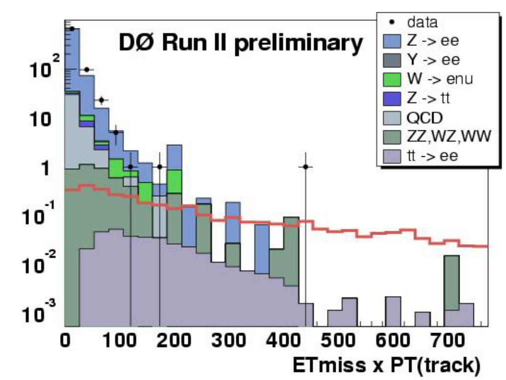


e+e+l

High quality, isolated electrons:
p_T>8,12 GeV



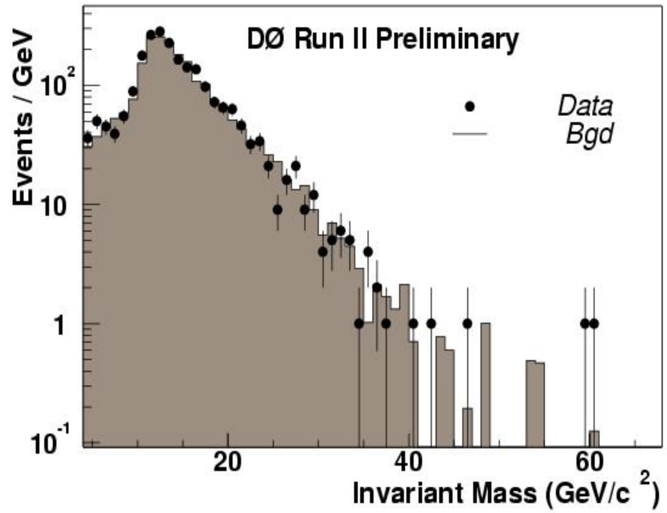
Jet veto
m_T^e >15 GeV
m_{ee}<60 GeV
$\Delta\varphi_{ee}$<2.8
MET>20 GeV
p_T^3xMET> 250 GeV²
1 data – 0.27±0.42 bg

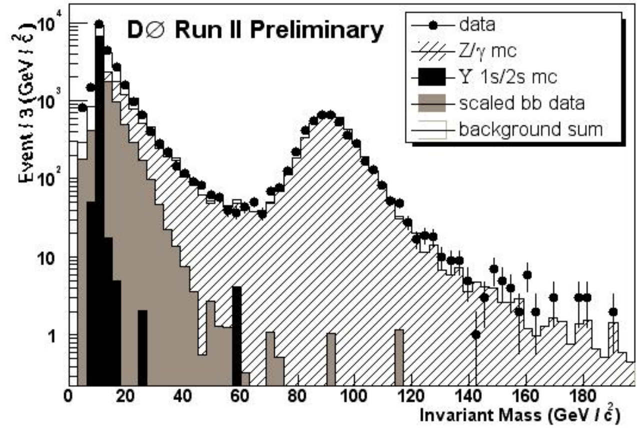


μ± μ±

High quality, isolated like-sign muons:
p_T^1>11 GeV, p_T^2>5 GeV
MET>15 GeV
$m_{\mu\mu}$<80 GeV
$\Delta\varphi_{\mu\mu}$<2.7 (if p_T^2<11 GeV)
$\Delta\varphi_{MET\mu}^{min}$>0.5 (if p_T^2<11 GeV)
$\Delta\varphi_{MET\mu}^{max}$<2.4 (if p_T^2<11 GeV
$\Delta\varphi_{MET,j}$<2.4

1 data – 0.13±0.06 bg

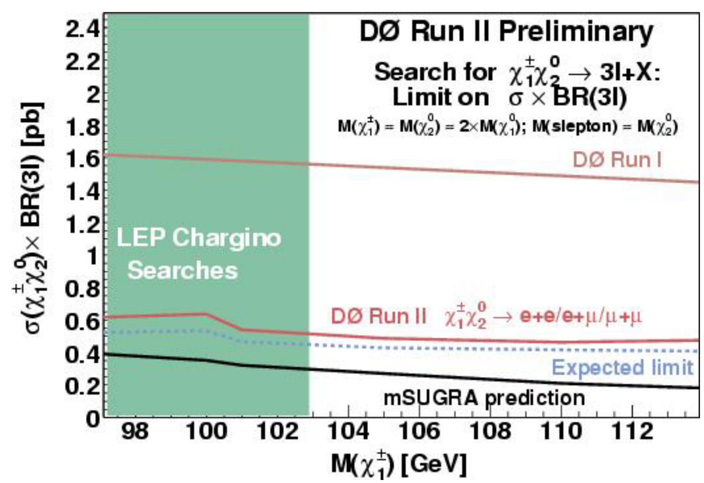




Bg is mainly heavy flavour
Estimated from OS pairs

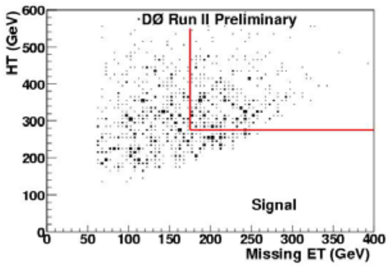
Combined 3l+MET

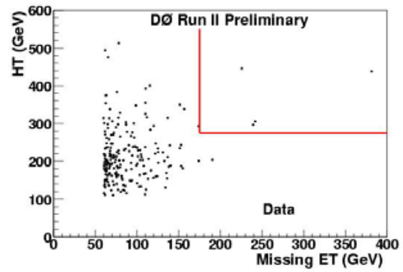
Great improvement wrt Run I
Sensitivity very near to mSUGRA prediction

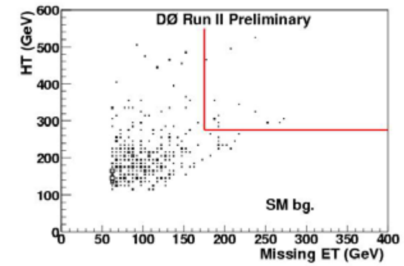


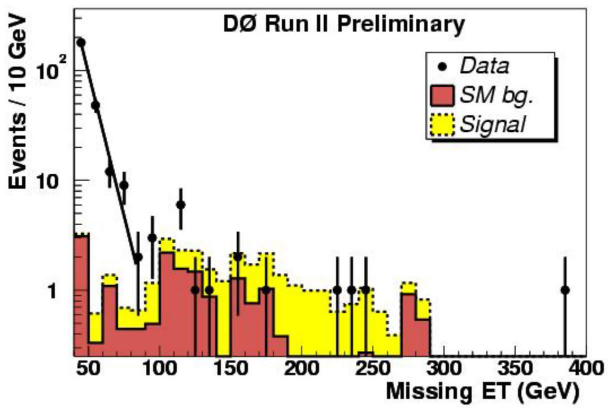
Search for $\tilde{q} \to q + \chi_1^0, \tilde{g} \to \bar{q} q \chi_1^0$ in jet + MET

At least 2 jets:
$p_T^1 > 60$ GeV
lepton veto
$\Delta\varphi_{METj}^{min} > 30^o$
$\Delta\varphi_{METj}^{max} < 165^o$
MET>175 GeV
$H_T = \Sigma p_T^j > 275$ GeV
4 data – 2.67±0.95 bg
Bg mainly Z->vv+nj



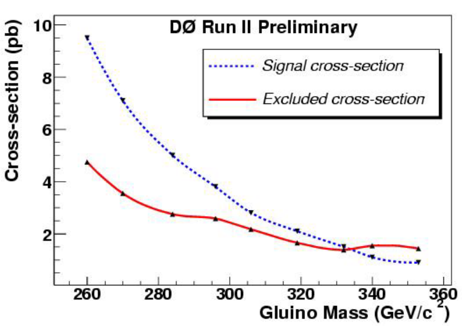


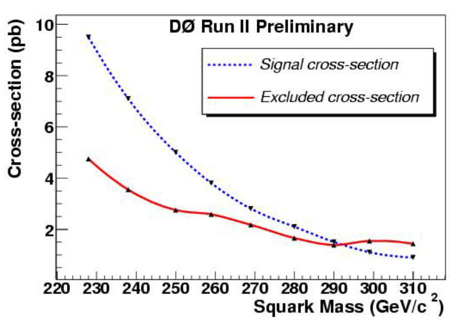




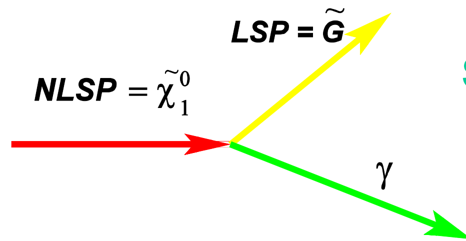
mSUGRA

$$m_0 = 25\,\text{GeV}; 100 \le m_{1/2} \le 140\,\text{GeV}; \tan\beta = 3; \mu < 0; A_0 = 0$$

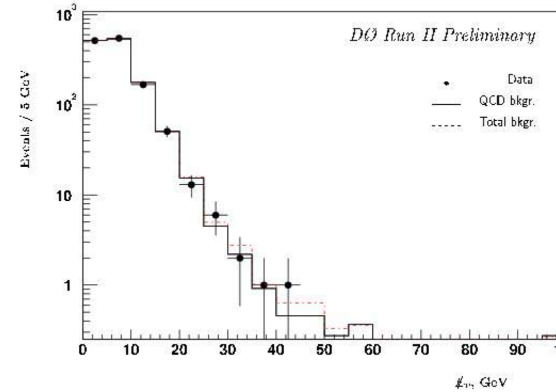




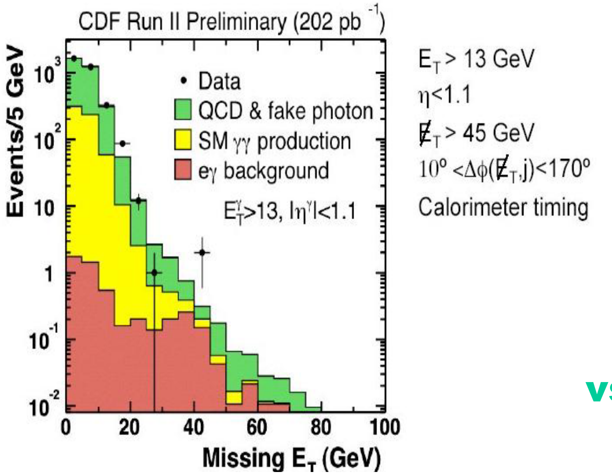
GMSB



Select 2 photons p_T > 20 GeV

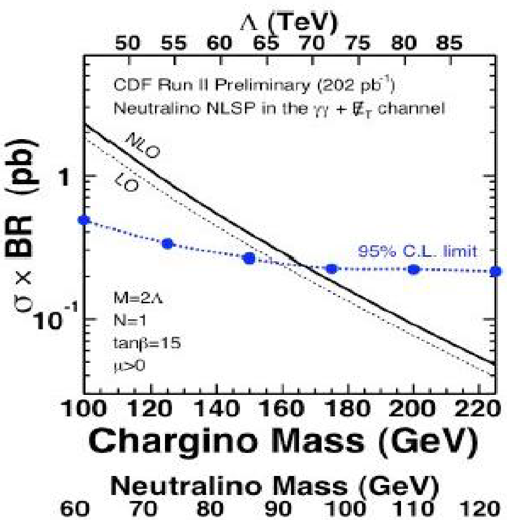


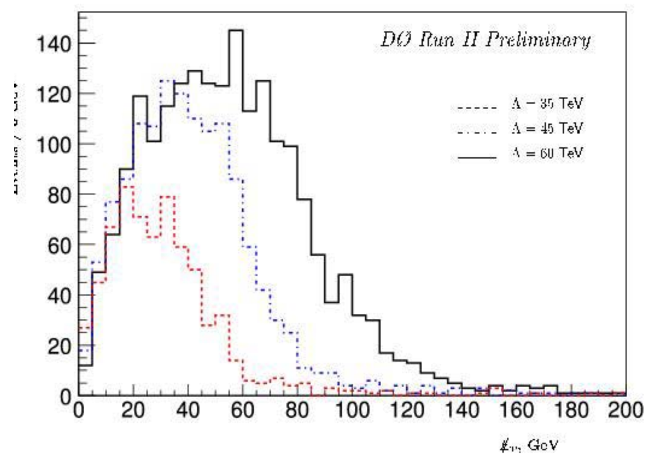
Di-Photons+MET

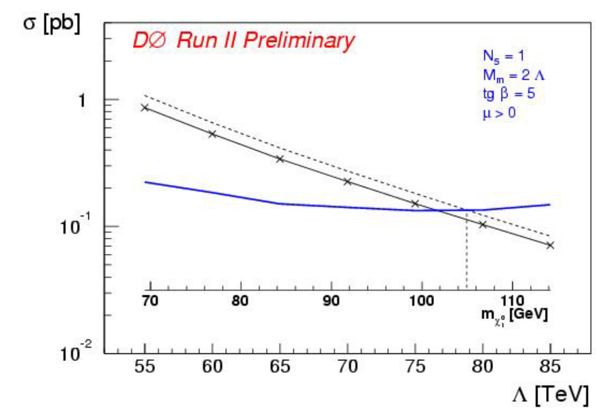


Expected signal vs M=2Λ messenger mass scale

Signal is at high MET:
MET > 40 GeV
Data: 1 Bg: 2.5±0.5







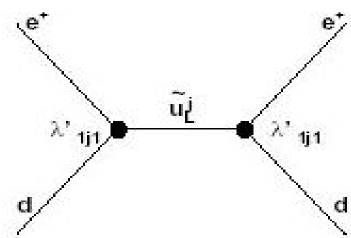
Best limit on: Λ > 78.8 TeV
$m_{\chi 0}$ > 105 GeV, $m_{\chi\pm}$ > 192 GeV

R-parity violation

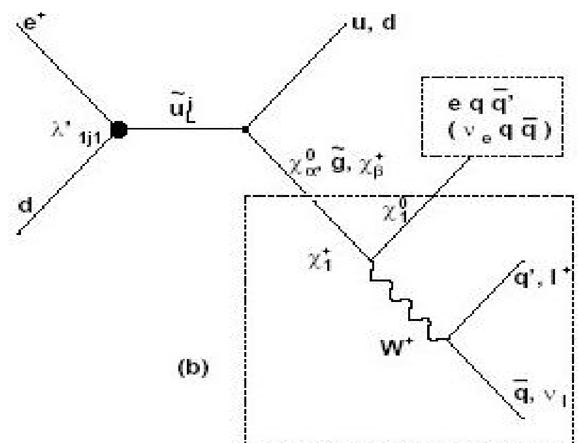
Introduces 48 new L and B violating Yukawa couplings:

$$L = \lambda_{ijk} L_i L_j \tilde{E}_k + \lambda'_{ijk} L_i Q_j \tilde{D}_k + \lambda''_{ijk} U_i D_j \tilde{D}_k$$

with more leptons, jets in the final state



(a)



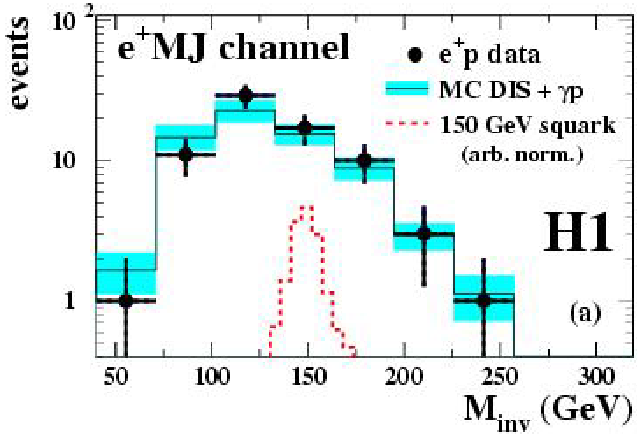
(b)

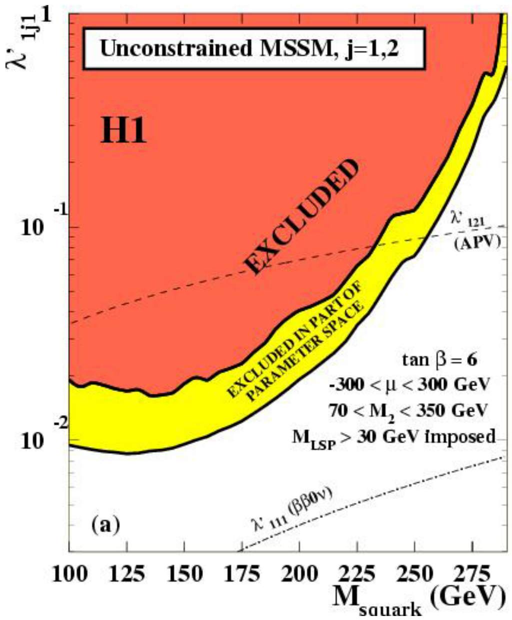
Single sparticle production and decay depends on coupling λ

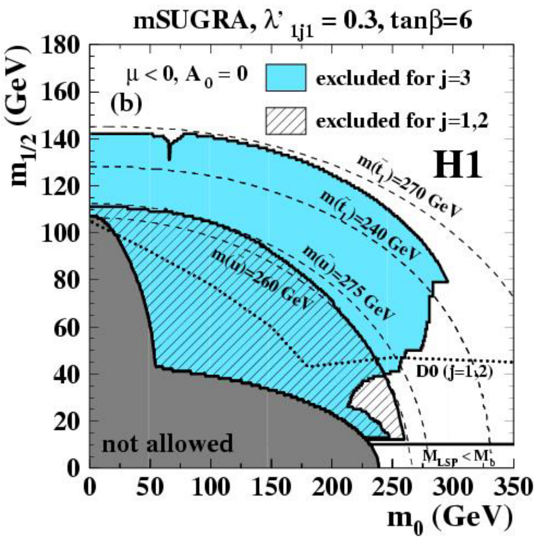
Decay of the LSP (χ_1^0) – if fast, does not depend on coupling λ

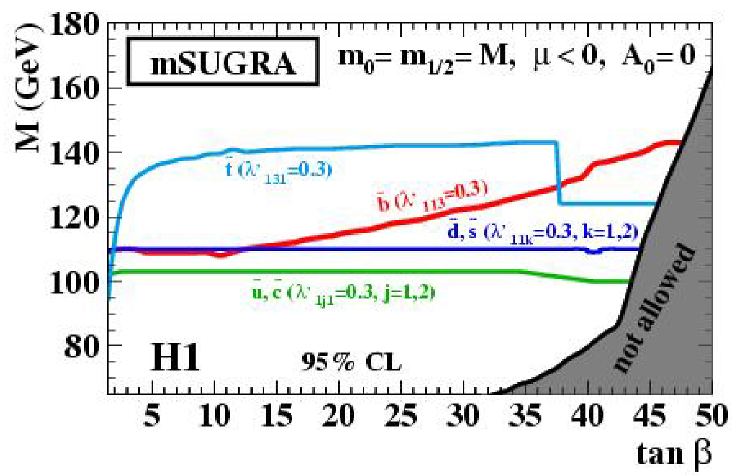
Look for signal in multiple event topology (H1). Below an exemple of the lepton-jet(s) inv mass spectrum

No deviation from the SM -> Limits on λ_{1j1} and m_0, m_{sq}, $\tan\beta$

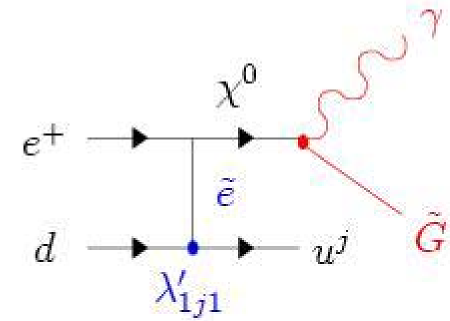








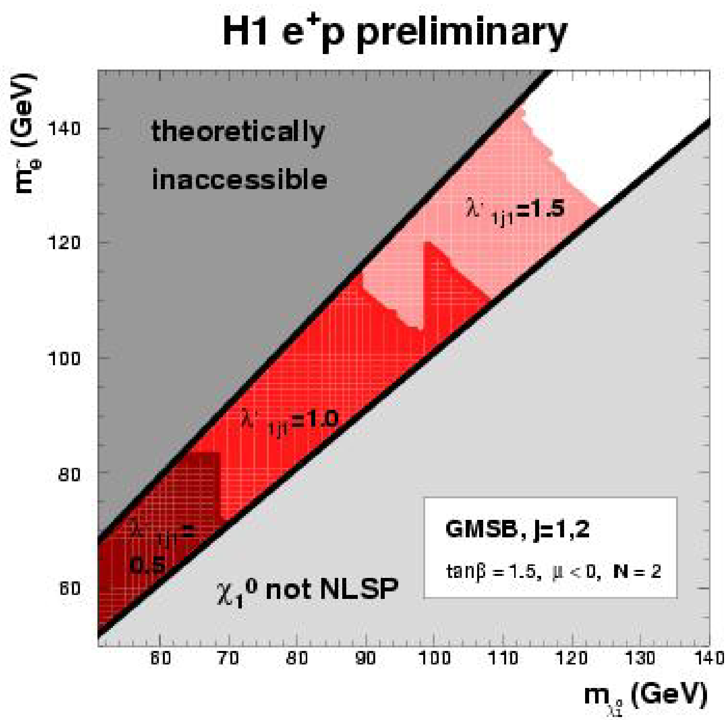
R-parity violation in GMSB (H1)

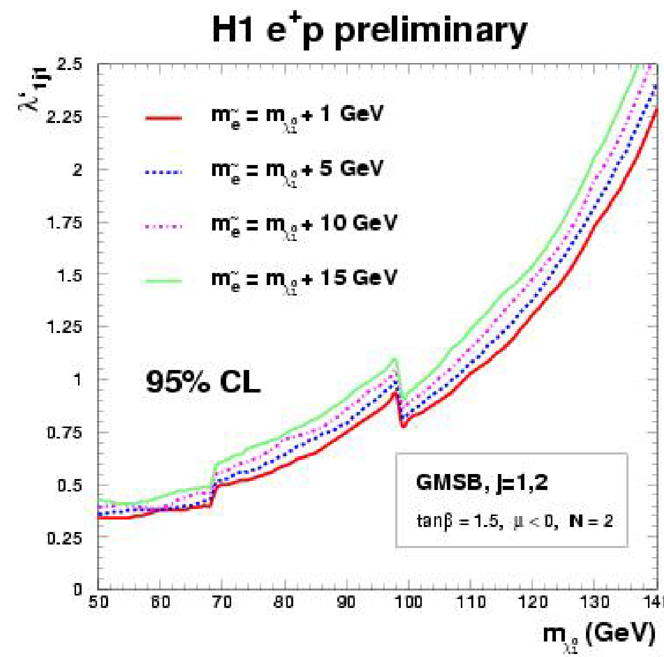


Signature: MET>25 GeV, and an isolated γ (p_T>25 GeV)

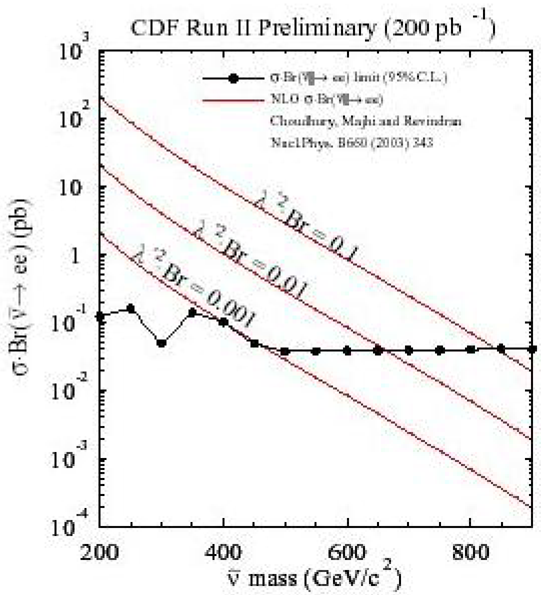
1 event found, 2.55±1.30 expected

Limits on λ'_{1j1}, m_{NLSP}, m_{sel}

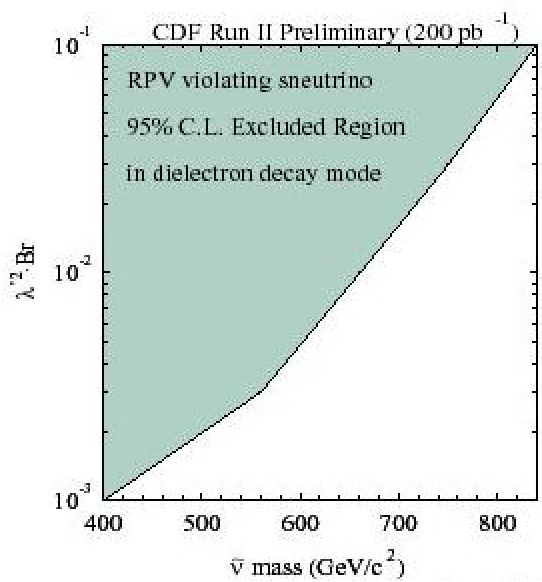




CDF: agreement of the high mass di-lepton spectra with the SM is transformed into limits on λ’ and m_{snu}



	CC (GeV)	CP (GeV)	CC+CP (GeV)
$\lambda'^2 \cdot Br = 0.1$	830	710	840
$\lambda'^2 \cdot Br = 0.01$	650	550	660
$\lambda'^2 \cdot Br = 0.001$	400	340	400



Z'

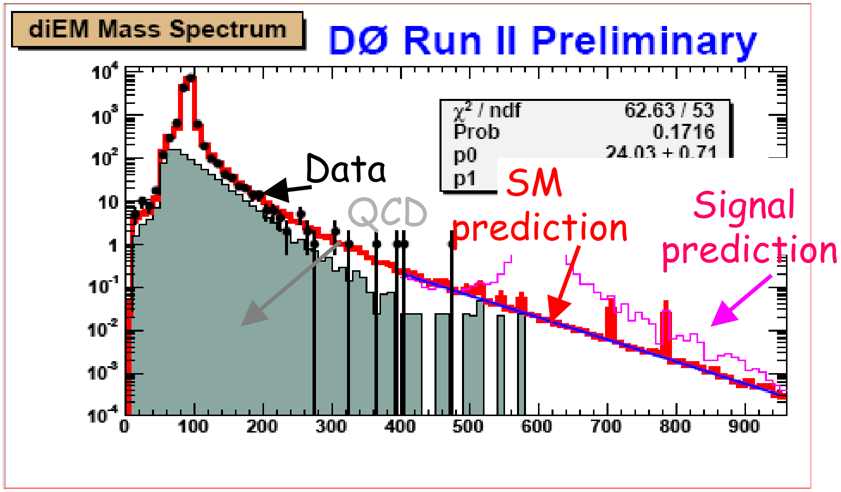
Z' is predicted in several extensions of the SM
E_6 and little Higgs models are considered here

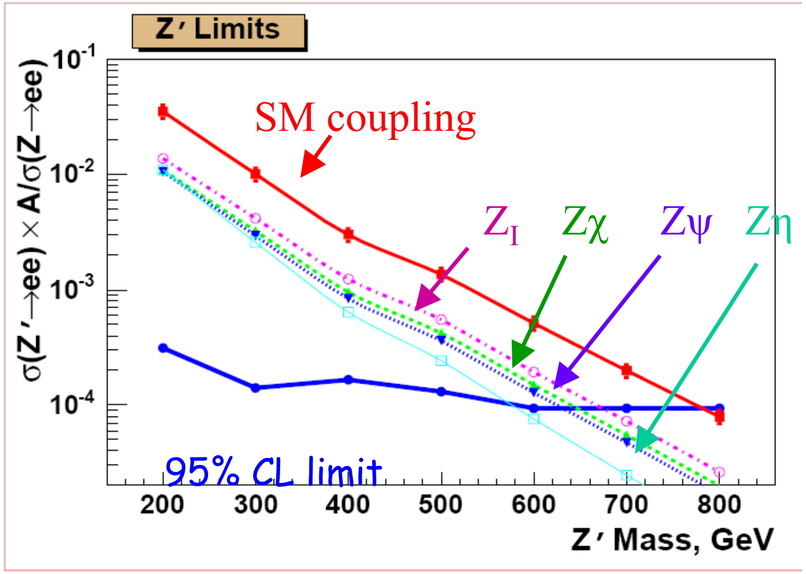
$$E_6 \rightarrow SO(10) \times U(1)_\psi \rightarrow SU(5) \times U(1)_\chi \times U(1)_\psi \rightarrow SU(3) \times SU(2) \times U(1)_Y\, U(1)_\chi\, U(1)_\psi$$

$$Z'(\theta) = Z_\psi \cos\theta + Z_\chi \sin\theta$$

θ	0^o	90^o	37.76^o	-37.76^o
Z'	Z_ψ	Z_χ	Z_η	Z_I

DØ ∫Ldt = 200 pb⁻¹





Limits for e^+e^- (in GeV)

SM Couplings

CDF :	750
DØ:	780

E_6	Z_I	$Z\chi$	$Z\psi$	$Z\eta$
CDF:	570	610	625	650
DØ:	575	640	650	680

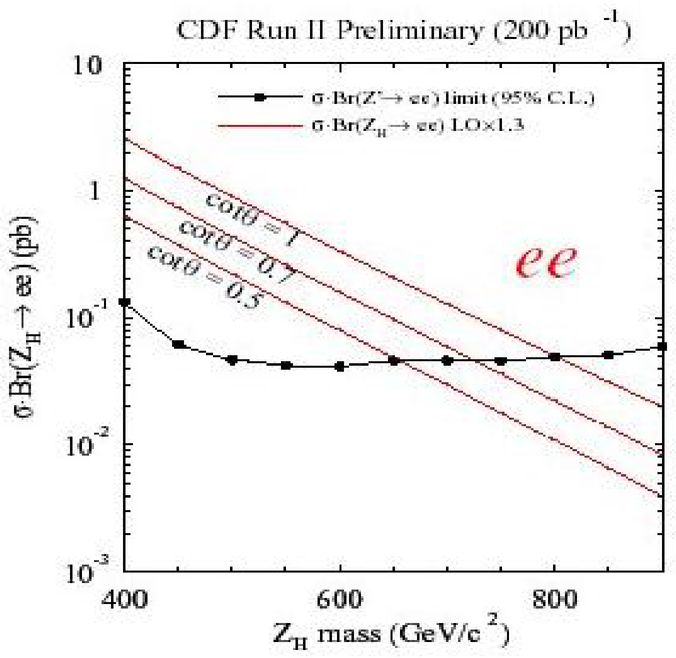
Similar, somewhat smaller limits for $\mu^+\mu^-$

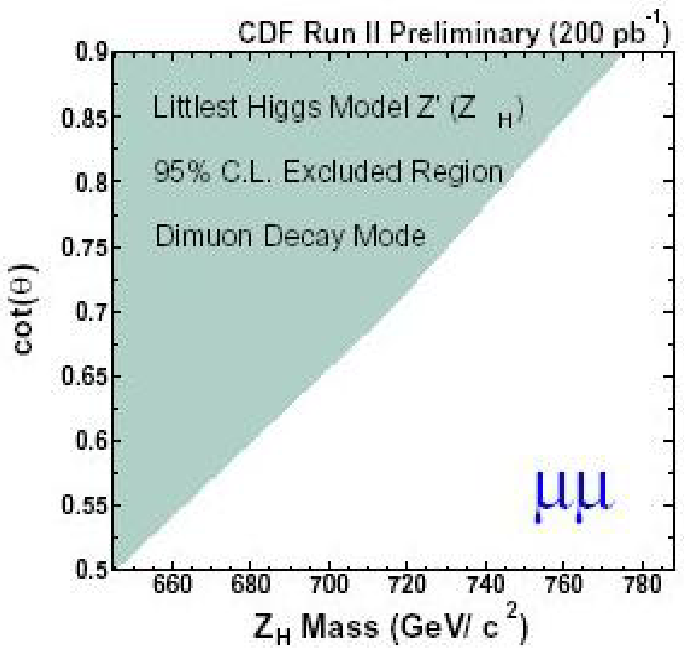
Little Higgs

Proposes new fermions and bosons to solve the hierarchy problem.
Contrary to SUSY, here the quadratically divergent diagrams are cancelled by the same type of particle (fermion-loops by fermion-loops, etc.)
Z_H is one of the new bosons to cancel divergent boson loop.
Its coupling is parametrized by Θ.
CDF establishes limits on the mass of Z_H and Θ in both of ee and μμ final states.

ee: $M(Z_H) > 800\ \mathrm{GeV}/c^2$ for $\cot\theta = 1.0$

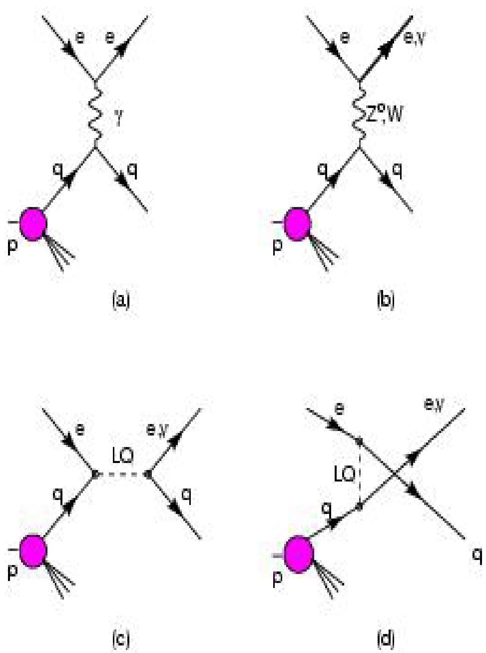
μμ: $M(Z_H) > 755\ \mathrm{GeV}/c^2$ for $\cot\theta = 0.9$

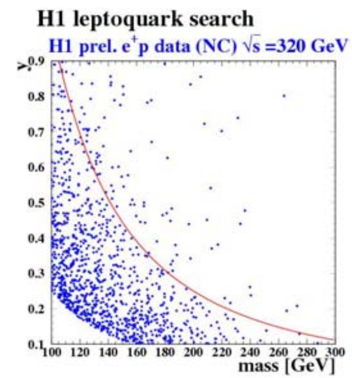


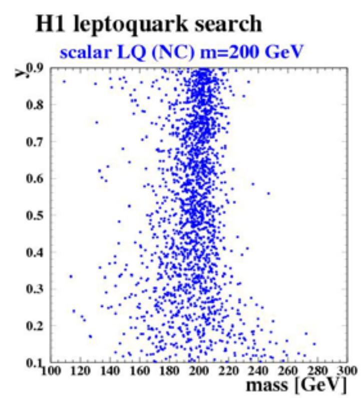


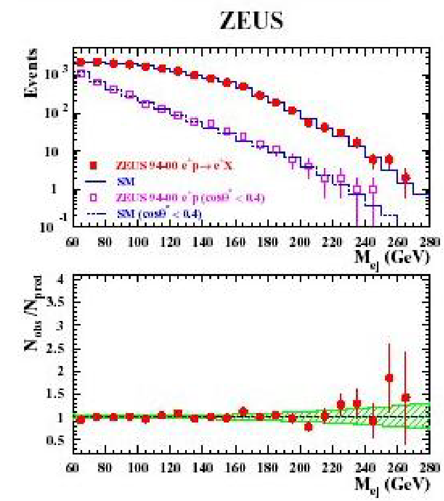
Lepto-Quarks

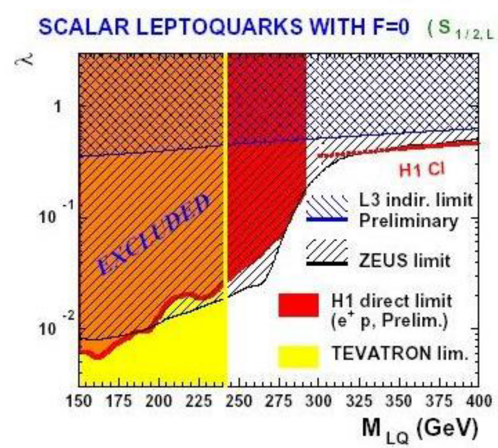
Hypothetical bosons (scalars or vectors) carrying both L and B.
Proposed in several extension of SM based on Q-L symmetry.
HERA is an ideal machine to produce 1st generation LQ's.
No deviation is found wrt SM -> Limits on M_{LQ} and coupling λ



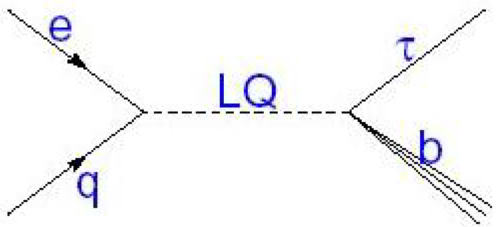


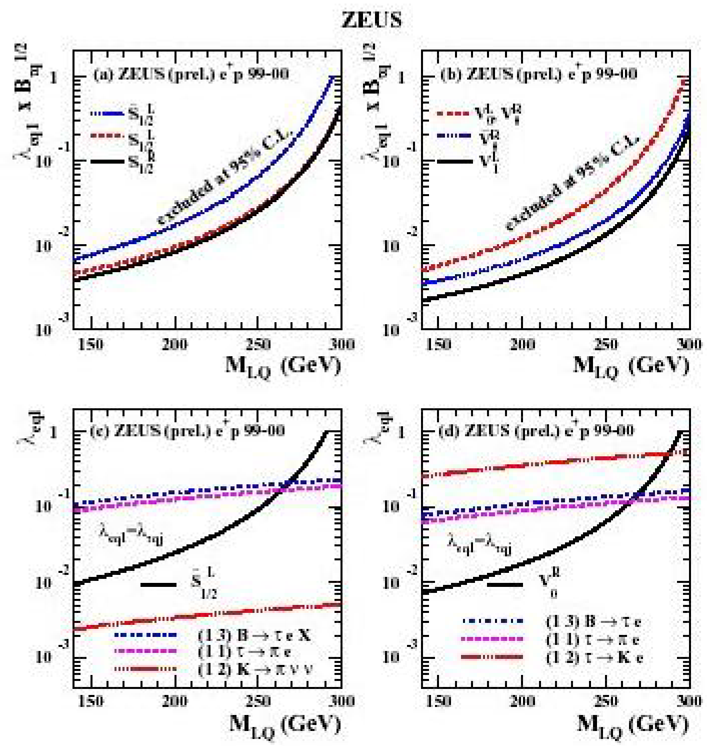






ZEUS has also searched for tau's in the final state:
Lepton Flavour Violation



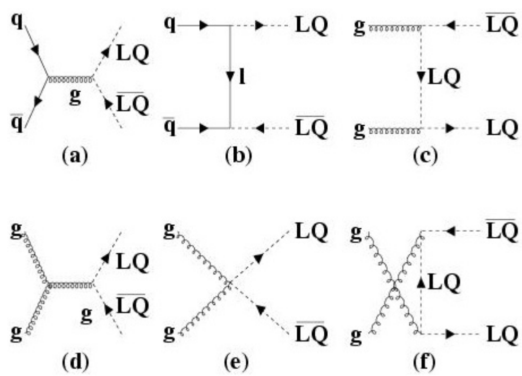


No events have been found:

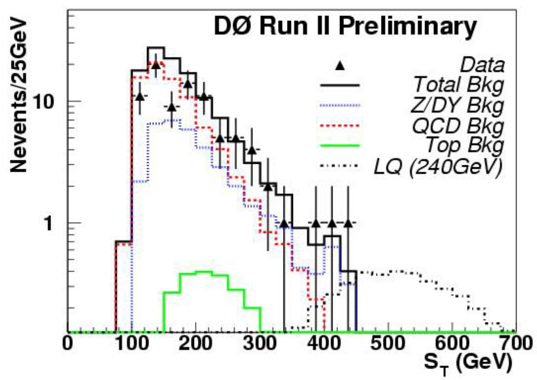
limits on $\lambda_{eq1} = \lambda_{\tau qj}$ vs M_{LQ}

1st generation Lepto-Quarks at Tevatron

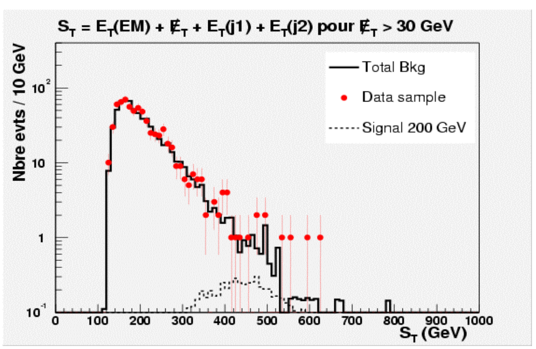
Dominantly produced in pairs of the same generation (avoid topology of FCNC or LFV)
Production is ~independent of λ
Final state is characterized by 2j+2l
lepton can be charged or neutral with BR β
-> possible final states: 2j+2l, 2j+l+MET, 2j+MET

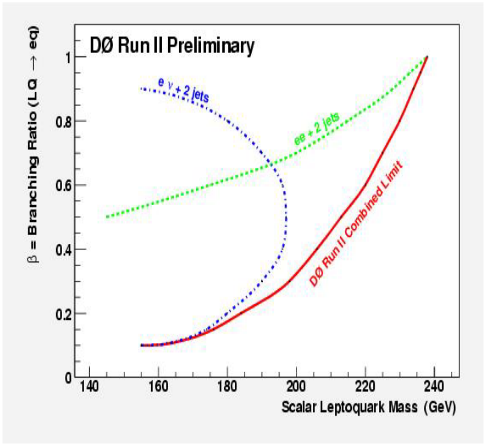


2j+2e channel:
2j E_T>20 GeV
2e E_T>25 GeV
Z-veto
$S_T=\Sigma E_T^j+\Sigma E_t^e$>450GeV
0 data, 0.4±0.1 bg



2j+eν channel:
2j E_T>25 GeV
1e E_T>25 GeV
MET>30 GeV
W-veto: m_T>130 GeV
S_T>330GeV
2 data, 4.7±0.9 bg



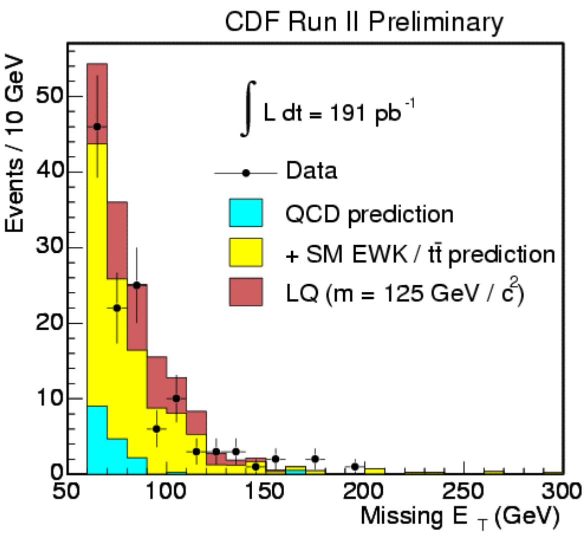


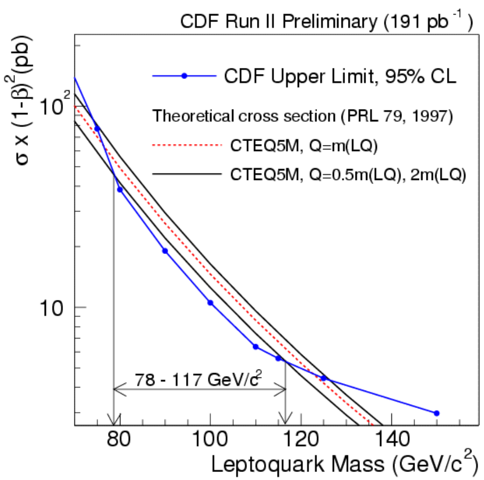
D0 M_{LQ1} limits in GeV

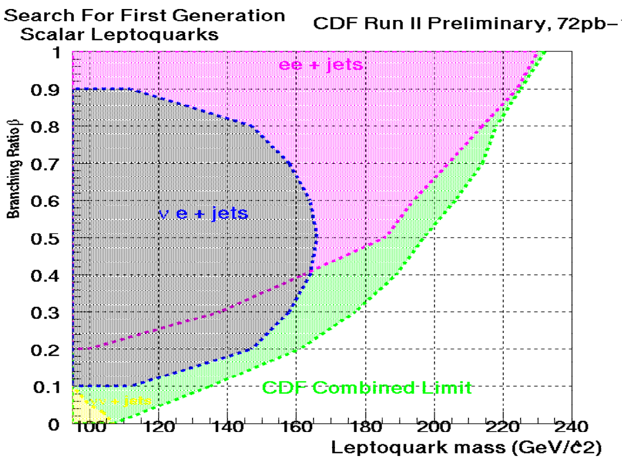
β	0.1	0.5	1.0
Run I	110	204	225
Run II	155	213	238

Similar analyses of CDF - also in the jjMET channel

MET+Jets channel:
>2j ($j^{1,2}$ central w/4 tracks)
Jets and MET shouldn't be aligned
e/μ-veto
MET>60 GeV
80<ΔΦ($j^{1,}j^2$)<165°
124 data, 118±13 bg
78<M_{LQ}<117 GeV excluded





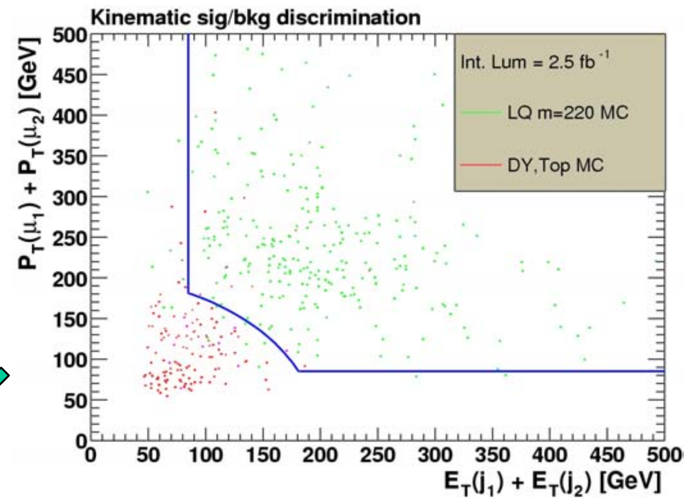


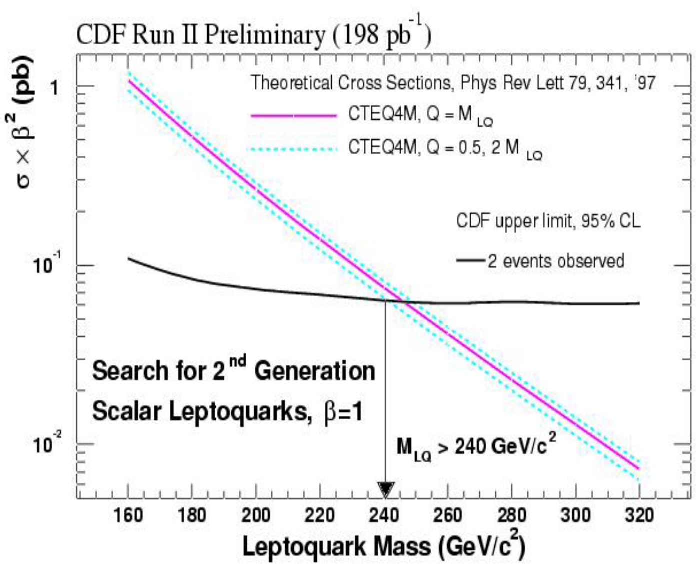
CDF M_{LQ1} limits in GeV

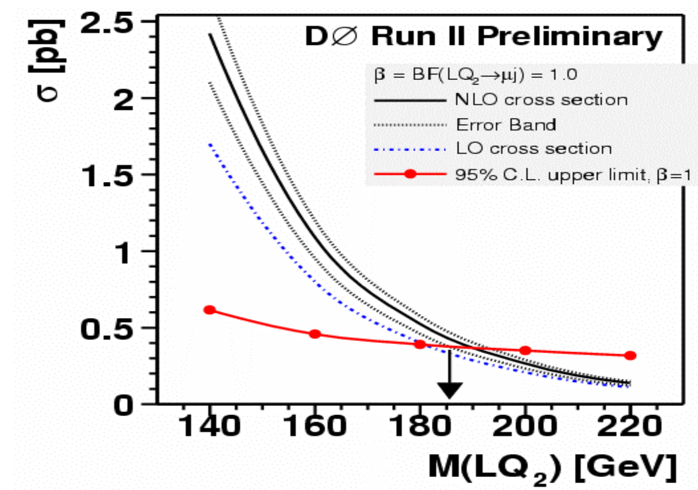
β	0.1	0.5	1.0
Run I		182	220
Run II	135	197	230

2nd generation Lepto-Quarks at Tevatron

jj+μμ channel:
2μ p_T>25 GeV
2j $E_T^{1,2}$>30, 15 GeV
Z-veto
Topological cuts (see Fig.)
2 data, 3.2±1.2 bg
M_{LQ}<240 GeV excluded







M_{LQ}<186 GeV excluded (L=104 pb^{-1})

Beyond SM Higgses

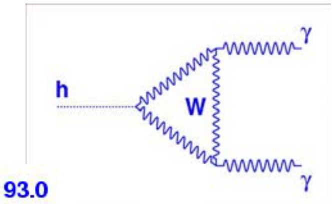
On the way to discover H_{SM} ...

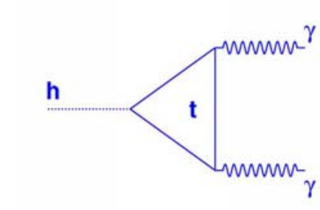
... one may find BSM Higgses

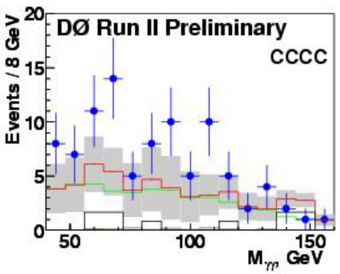
- **H->γγ**
- **H->WW**
- **Neutral SUSY/2-Doublets: h,H,A**
- **H++/--**

In some extensions of the SM BR(H->γγ) can be ~ 1

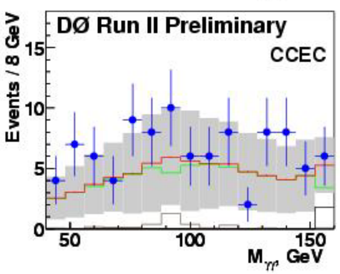
(e.g. Fermiophobic or Topcolor Higgs)



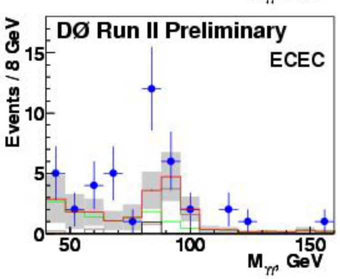




data = 93.0
bkgd = 52.4 +- 28.0
QCD = 42.7 +- 28.0
DY = 1.4 +- 1.3
γγ = 8.3 +- 0.6

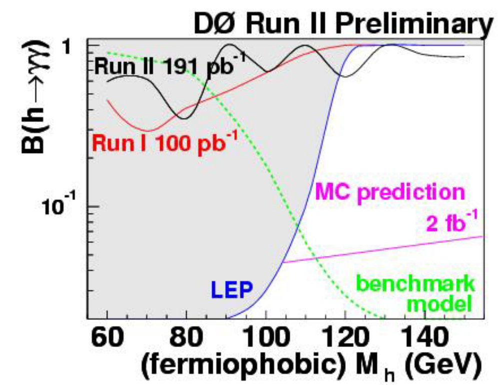


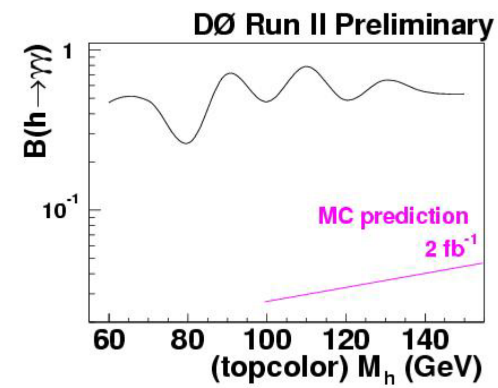
data = 97.0
bkgd = 68.8 +- 45.8
QCD = 64.0 +- 45.7
DY = 3.0 +- 3.0
γγ = 1.8 +- 0.1



data = 41.0
bkgd = 20.8 +- 10.4
QCD = 13.1 +- 10.0
DY = 6.7 +- 3.0
γγ = 1.0 +- 0.1

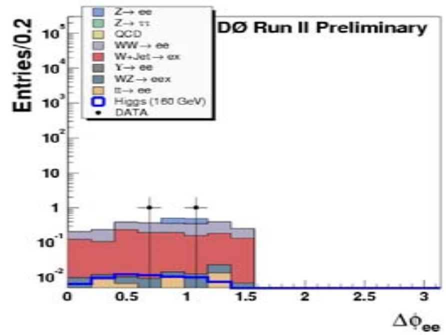
Select 2 isolated photons:
$p_T^{1,2}$>25 GeV
$p_T^{\gamma\gamma}$>35 GeV
Estimate background:
Instrumental, DY, γγ
Determine limit on BR:
sliding window technique



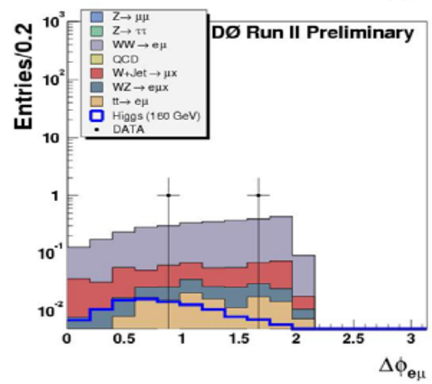


H->WW->2l+MET

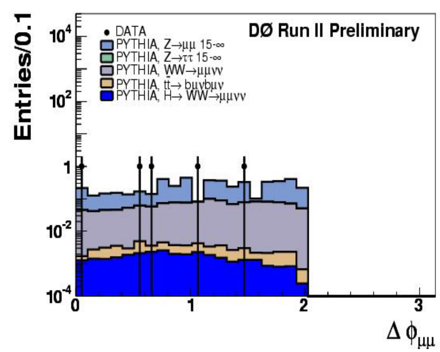
ee (OS) channel:
$p_T^{1,2}$>12,8 GeV
MET>20 GeV
METsig>15 GeV$^{1/2}$
Σp_T+MET>100 GeV
12< M_{ee} < 80 GeV
Jet-veto
$\Delta\varphi_{ee}$<1.5
2 data, 2.7±0.4 bg

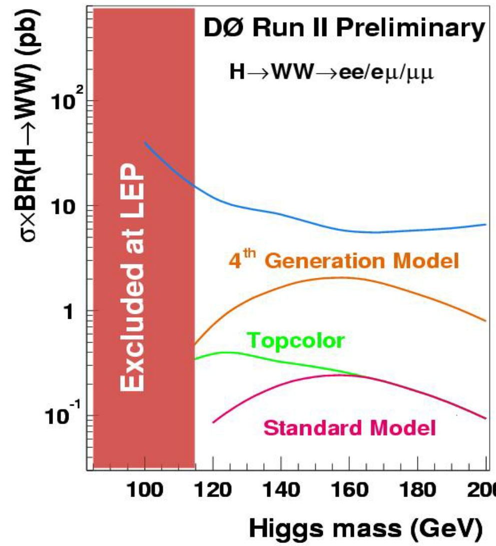


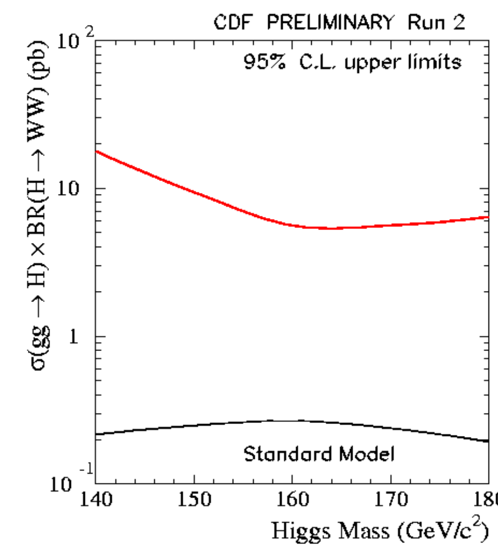
eμ (OS) channel:
$p_T^{e,\mu}$>12,8 GeV
MET>20 GeV
METsig>15 GeV$^{1/2}$
Σp_T+MET>90 GeV
M_T^{min} < 20 GeV
Jet-veto
$\Delta\varphi_{e\mu}$<2.0
2 data, 3.1±0.3 bg



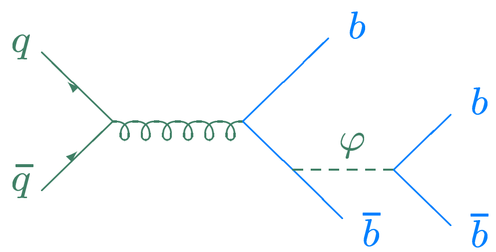
μμ (OS) channel:
$p_T^{1,2}$>20,10 GeV
MET>30 GeV
MET>10+0.75×p_T^1 GeV
Jet-veto
Z-veto
$\Delta\varphi_{\mu\mu}$<2.0
2 data, 3.1±0.3 bg



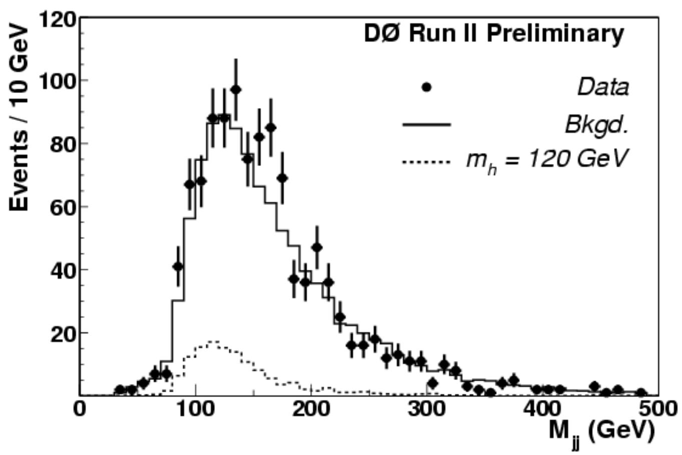




H,h,A (φ) $gg,qq \to \varphi + b\bar{b} \to b\bar{b}b\bar{b}$ or $gb \to b\varphi \to bb\bar{b}$

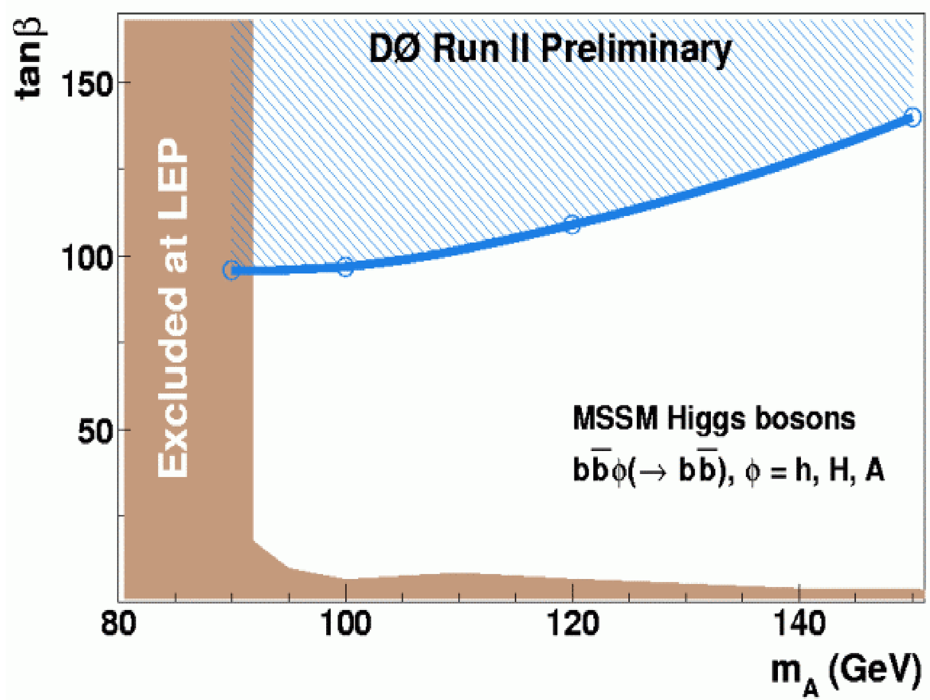


Background:
Multijet fakes (estimated from data)
HF + fakes (estimated from data and MC)
Bg is normalized to data outside the signal
Limits for $m_A=m_h$(<135) or $m_A=m_H$(>135GeV) and for tanβ are calculated



$\sigma_\varphi \sim \tan^2\beta$

Select:
>2j E_T^1>20 GeV, $E_T^{2,3}$> 15 GeV
with well defined vertex (>3 tracks)
Apply b-tag with SVT algorithm
ε_{tag}=0.75, ε_{btag}=0.51, ε_{ctag}= 1/4ε_{btag}, fake=0.02

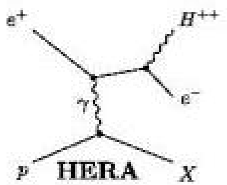


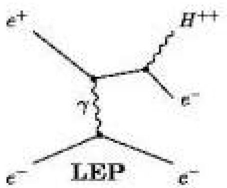
H++/--

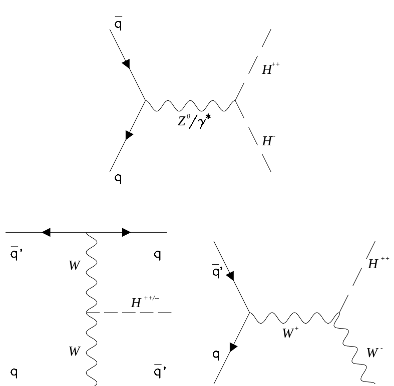
Predicted in L-R symmetric, Triple Higgs, Little Higgs, etc. models

Signature is multilepton (SS) events

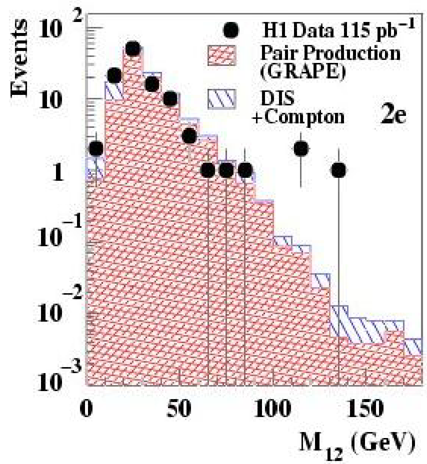
At HERA one searched for multi-e events (in general):
H1 finds 6 multi-e events with M_{12}>100 GeV (0.54±0.6 expected)
No excess for ZEUS: 2 found (1.2±0.1 expected)

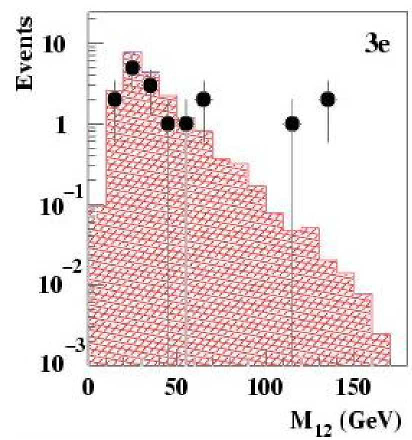


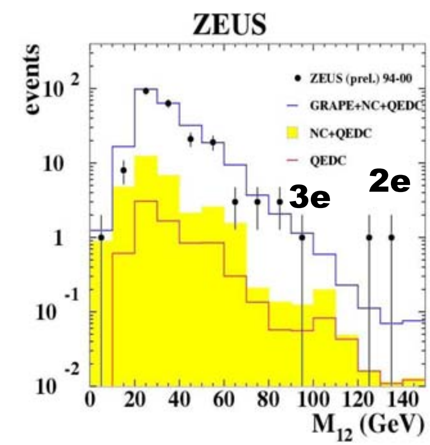




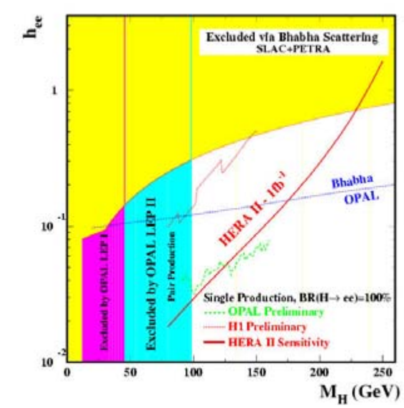
TEVATRON



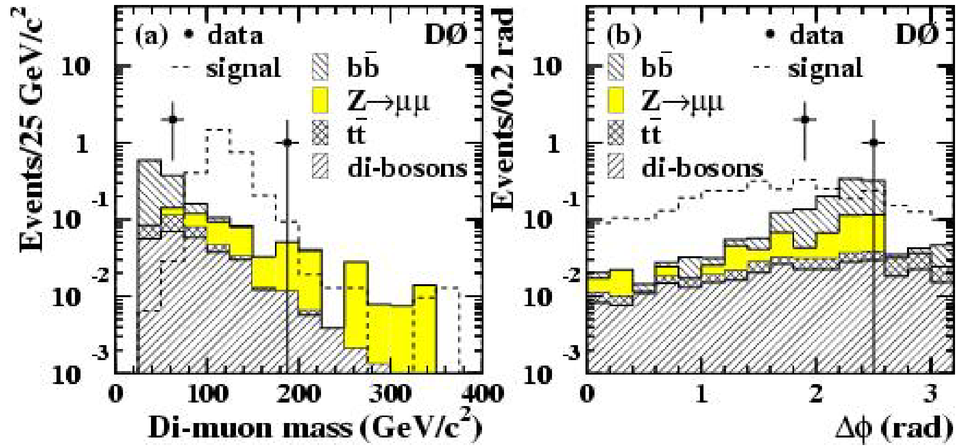




However only 1 event of H1 agrees with H++/-- topolgy
Limit on coupling h_{ee} vs M_H



D0 selected events in the 2μ channel:
At least 2 isolated muons, pT>15 GeV of same charge with ΔΦ<0.8 (anti-Z)
Bg mainly HF and Z (wrong charge id)
3 events observed, 1.5±0.4 expected

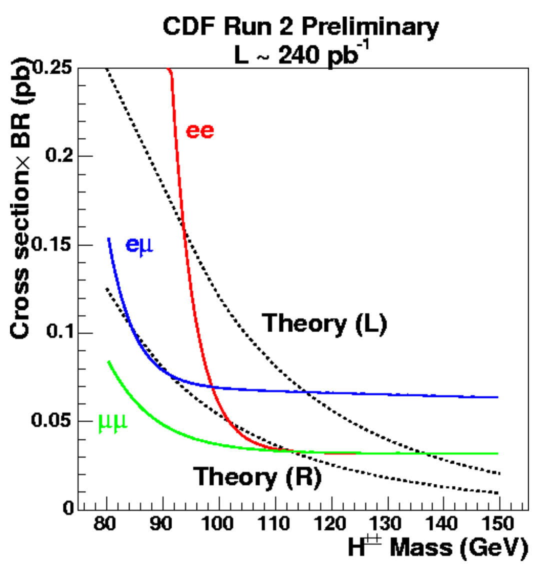


CDF selected events in the ee, eμ and μμ channels

Predicted background

Channel	Events
ee	$1.8^{+0.8}_{-0.6}$
μμ	$0.8^{+0.6}_{-0.5}$
eμ	$0.9^{+0.4}_{-0.4}$

0 events observed



Mass Limit	CDF 240 pb^{-1}		D0 113 pb^{-1}	
	H_L^{++}	H_R^{++}	H_L^{++}	H_R^{++}
ee	135	~102-113		
μμ	135	113	118.4	98.2
*e*μ	115			

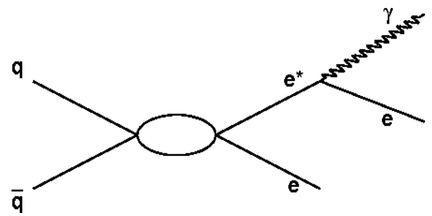
Substructure of quarks and leptons

A possible substructure manifests itself by:

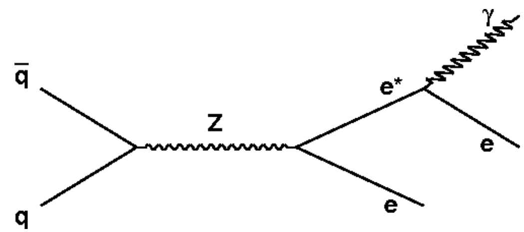
- Excited states of quarks and leptons
- Finite size of quarks and leptons
- Contact interaction of q's / l's of scale Λ>>sqrt(s)

Excited Leptons at the Tevatron (CDF)

Contact interaction



Gauge mediated interaction



Select $ee\gamma$ events:

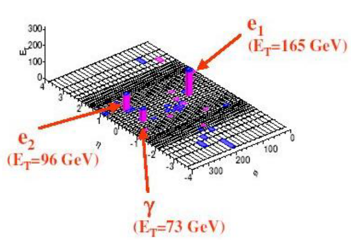
$E_T^{e1}, E_T^{e2}, E_T^{\gamma} > 25$ GeV

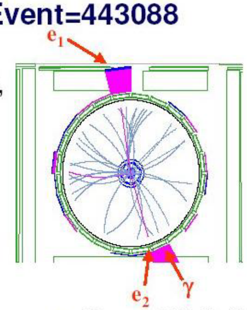
Z-veto

3 events observed

Run=167866 Event=443088

- 2 Central Electrons (e_1 and e_2), 1 Central Photon (γ)

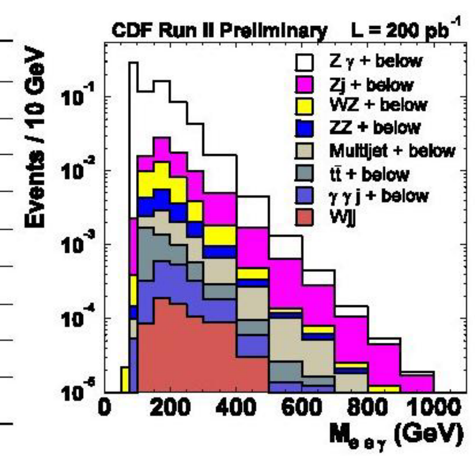




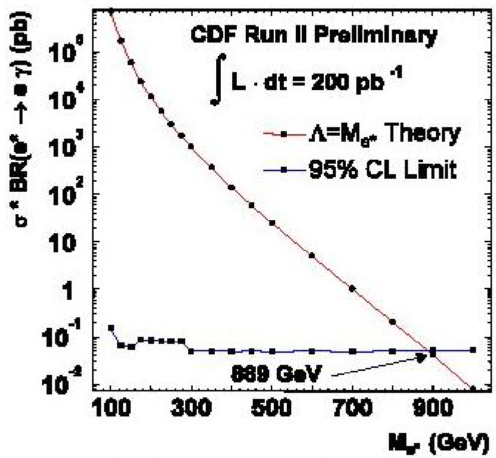
- $M_{e_1e_2}$ = 256 GeV
- $M_{e_1\gamma}$ = 220 GeV
- $M_{e_2\gamma}$ = 64 GeV
- $M_{e_1e_2\gamma}$ = 344 GeV

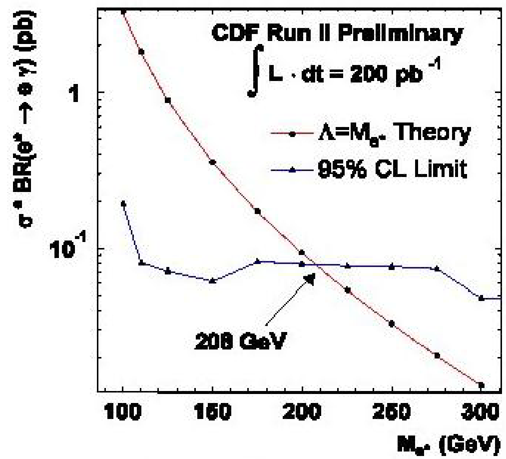
Expected background events:

Source	Events
$Z(\to ee)\gamma$	2.56 ± 0.24
$Z(\to ee)$+jet	$0.24^{+0.24}_{-0.07}$
$W(\to e\nu)Z(\to ee)$	0.11 ± 0.01
$Z(\to ee)Z(\to ee)$	0.038 ± 0.004
Multi-jet	$0.03^{+0.03}_{-0.01}$
$t\bar{t}$	0.015 ± 0.005
$\gamma\gamma$+jet	$0.008^{+0.005}_{-0.003}$
$W(\to e\nu)$+jet	$0.004^{+0.005}_{-0.002}$
Total	$3.01^{+0.39}_{-0.28}$

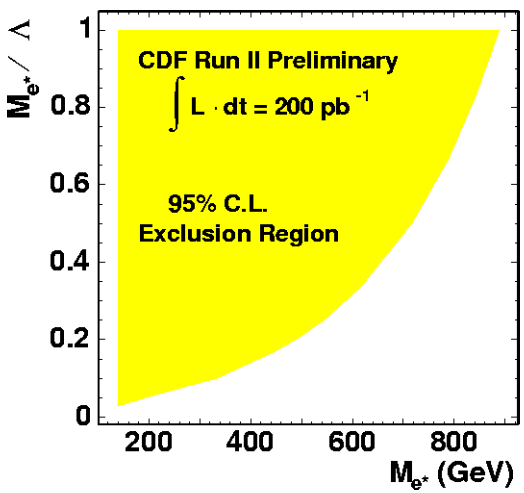


Excited Leptons at the Tevatron (CDF)

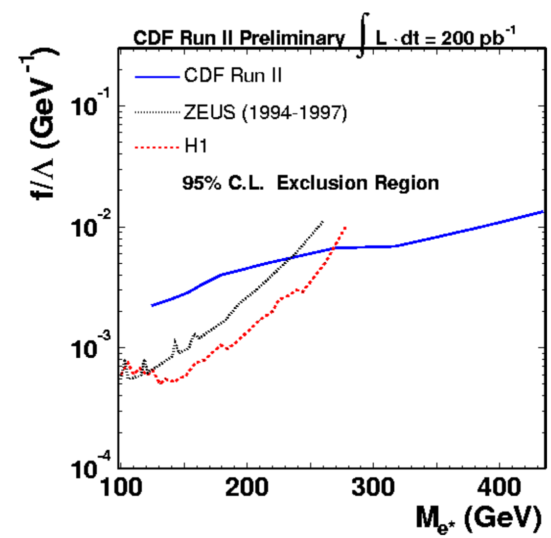




- Contact Interaction Model
- Gauge Mediated Model



Λ - **compositness scale**
f – **relative coupling strength to SU_{2L} gauge boson**

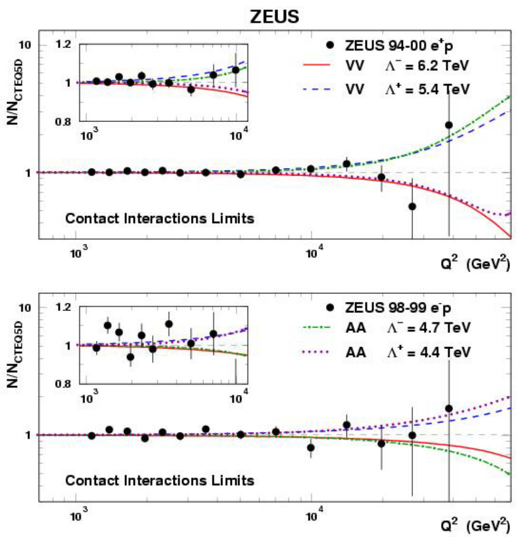


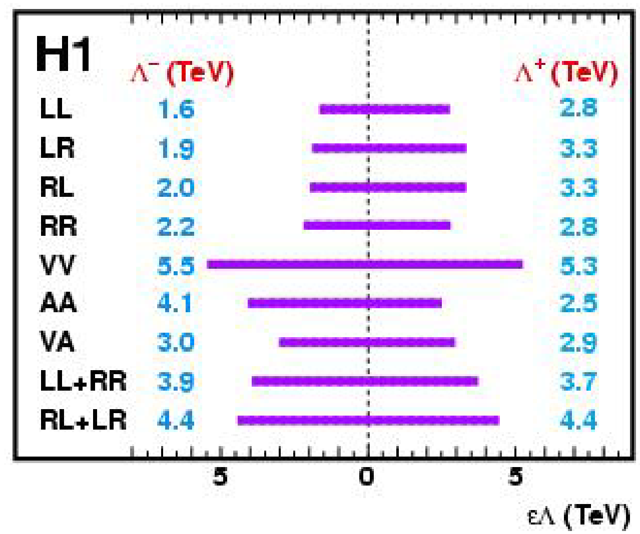
Contact Interactions

Deviation from the SM of inclusive ep->eX is parametrized as:

$$L = \frac{4\pi}{\Lambda^2} \sum_{q=u,d} \sum_{\alpha,\beta=L,R} \eta_{\alpha,\beta}^{e,q} (\bar{e}_\alpha \gamma^\mu e_\alpha)(\bar{q}_\beta \gamma_\mu q_\beta); \quad \eta_{\alpha,\beta}^{e,q} = 0, \pm 1$$

No deviation (ZEUS, H1) is transformed to limits on Λ:





and also to limits on q-radius:

R_q<1.0 10^{-18} m (H1)

R_q<0.85 10^{-18} m (ZEUS)

$$\frac{d\sigma}{dQ^2} = \frac{d\sigma^{SM}}{dQ^2}\left(1 - \frac{R_q^2}{6}\right)^2; \quad \text{(for pointlike electron)}$$

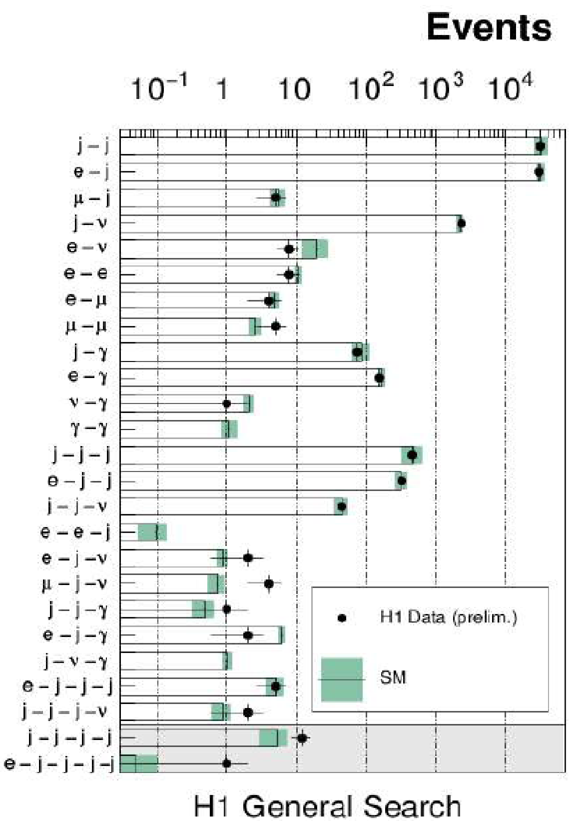
General search for deviations from the SM

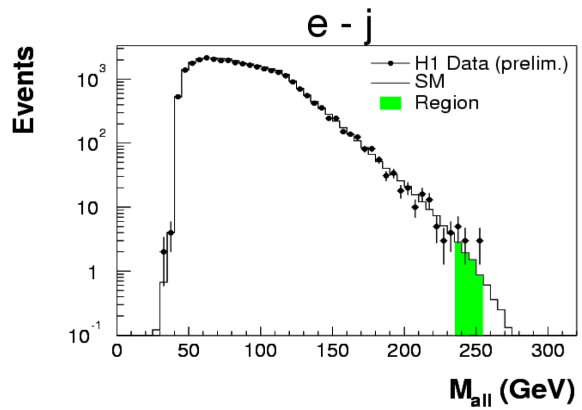
pioneered by D0, here carried out by H1

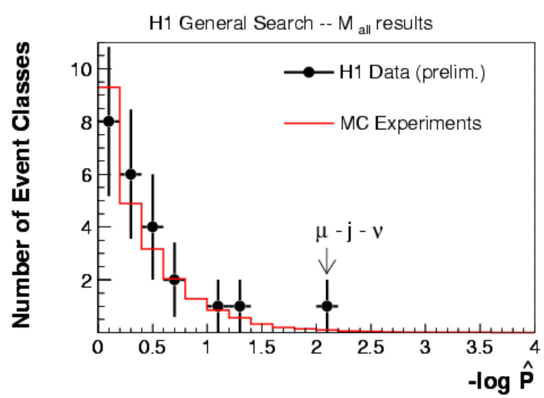
Select events with at least 2 isolated objects: e, μ, j , γ, ν with P_T > 20 GeV

to look for large deviation from SM in M_{all} and $\sum p_T$

HERA I

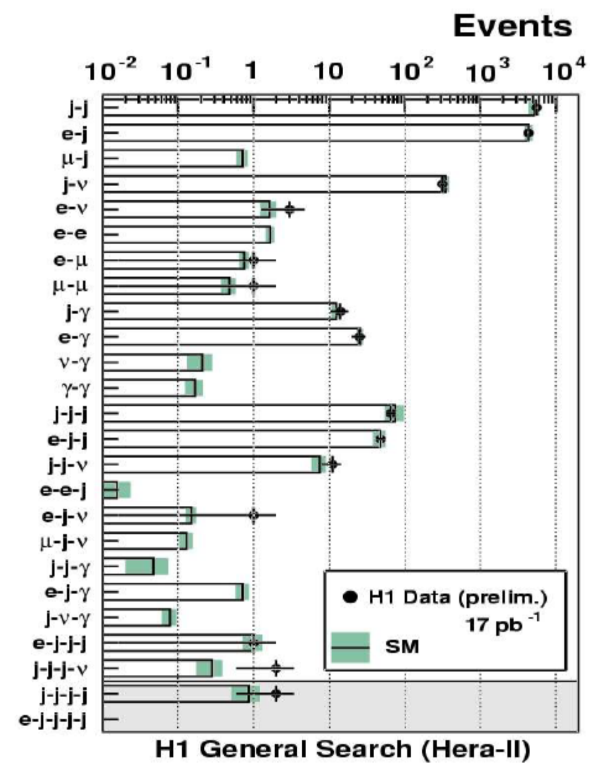




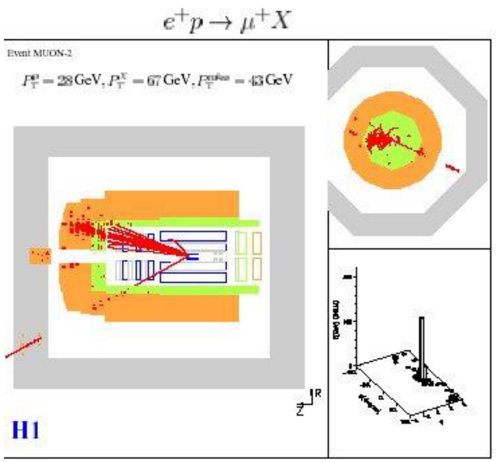


Largest deviation in μ-j-ν

HERA II

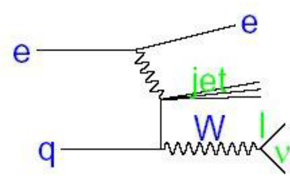


Excess of isolated leptons at HERA



1 isolated lepton (μ, e), with high p_T, p_T^{miss}, jet (p_T^X)

Main SM process:

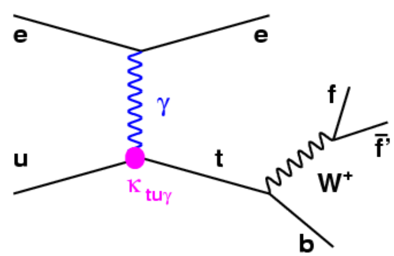


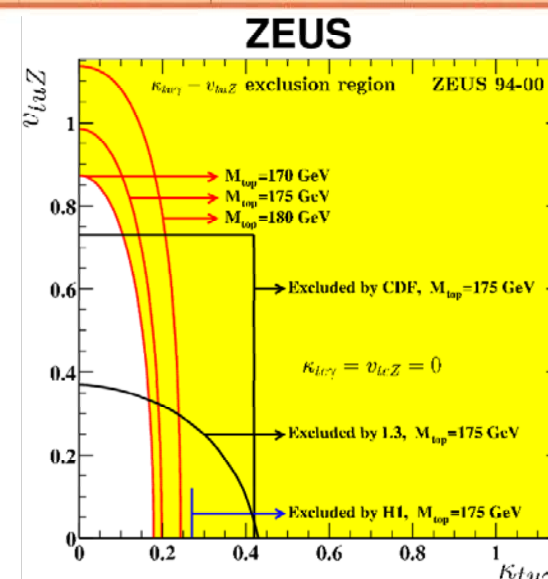
Summary Tables of all Isolated Lepton Searches at HERA-I

1994-2000 *ep* 118 pb⁻¹	Electron observed / expected	Muon observed / expected	**Tau** (108 pb⁻¹) **observed / expected**
Full Sample	**11 / 11.54**	**8 / 2.94**	**5 / 5.81**
P_TX > 25 GeV	**5 / 1.76**	**6 / 1.68**	**0 / 0.53**
P_TX > 40 GeV	**3 / 0.66**	**3 / 0.64**	**0 / 0.22**

1994-2000 *ep* 130 pb⁻¹	Electron observed / expected	Muon observed / expected	Tau observed / expected
Full Sample	**24 / 20.6**	**12 / 11.9**	**3 / 0.40**
P_TX > 25 GeV	**2 / 2.9**	**5 / 2.75**	**2 / 0.20**
P_TX > 40 GeV	**0 / 0.94**	**0 / 0.95**	**1 / 0.07**

5 H1 events are compatible with FCNC single top production:
σ(ep->etX) = 0.29±0.15 pb
Alternatively, upper limit on:
$k_{tu\gamma}$ <0.27 @ 95%CL
ZEUS is compatible with SM:
limit on v_{tuZ} vs $k_{tu\gamma}$





Is the tau excess of ZEUS a sign of stop decay at large tanβ?

Conclusions

The performances of both Tevatron and HERA improve steadily allowing to test experimentally many new ideas in the search for an ultimate theory

Although some anomalies observed already, no conclusive sign of new, BSM physics yet

More results are expected soon…

Apologies for subjects I haven't had time to present here

Acknowledgments for help in preparing this material

to colleagues of the D0, CDF, H1 and ZEUS collaborations

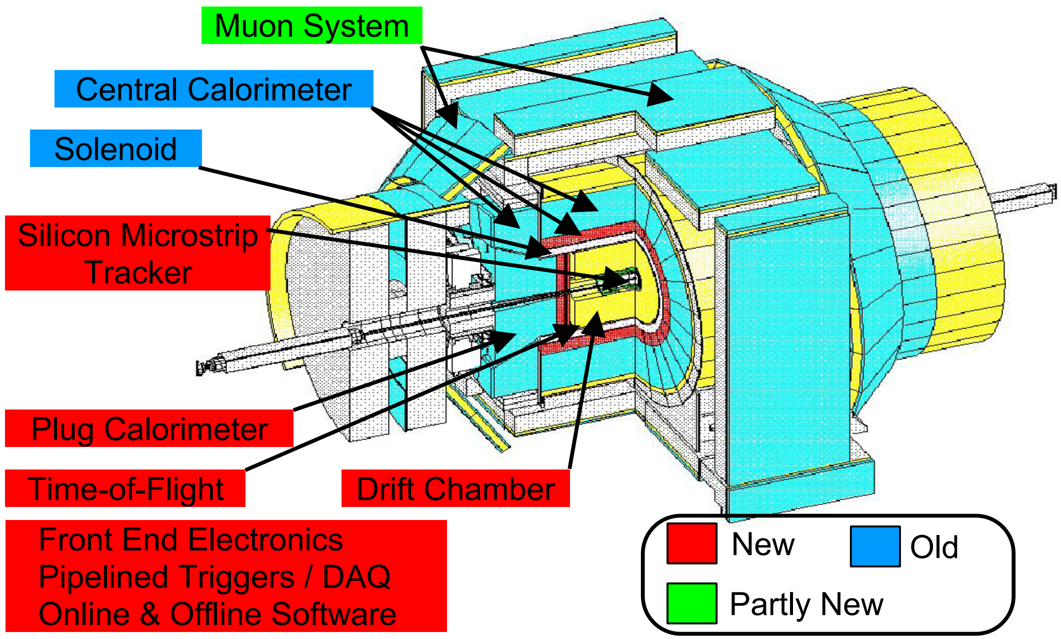
and especially to

Elisabetta Gallo (ZEUS) and

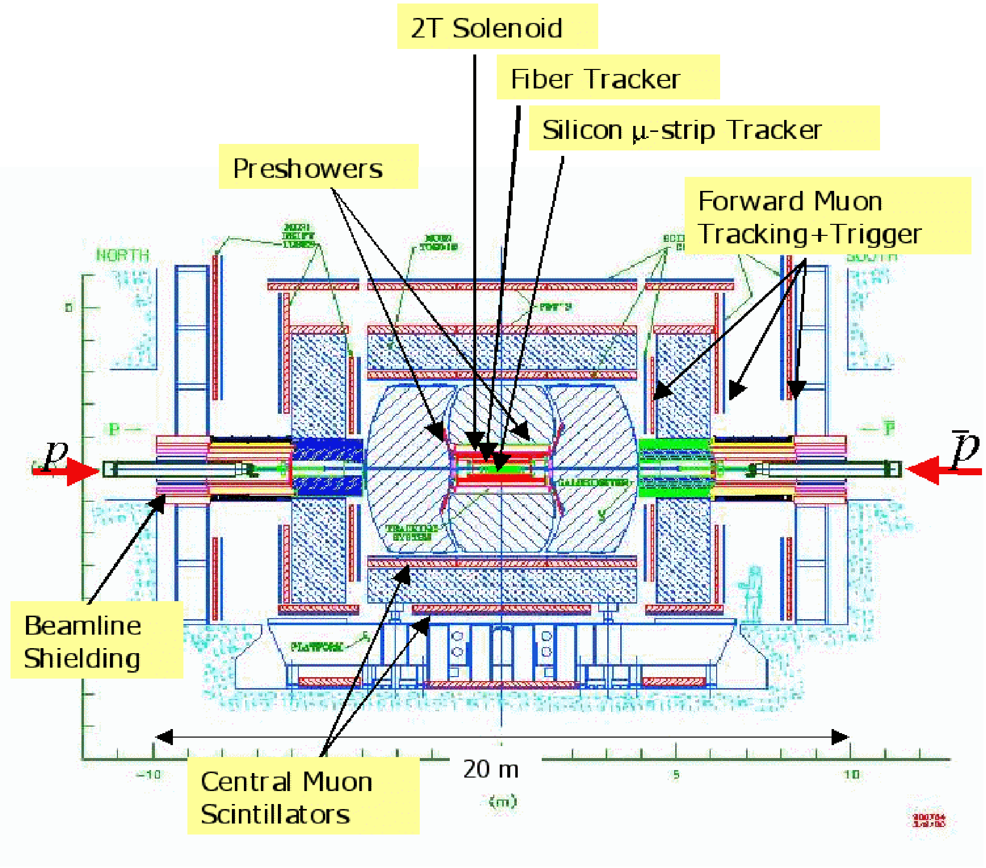
Jianming Qian (D0)

Backup slides

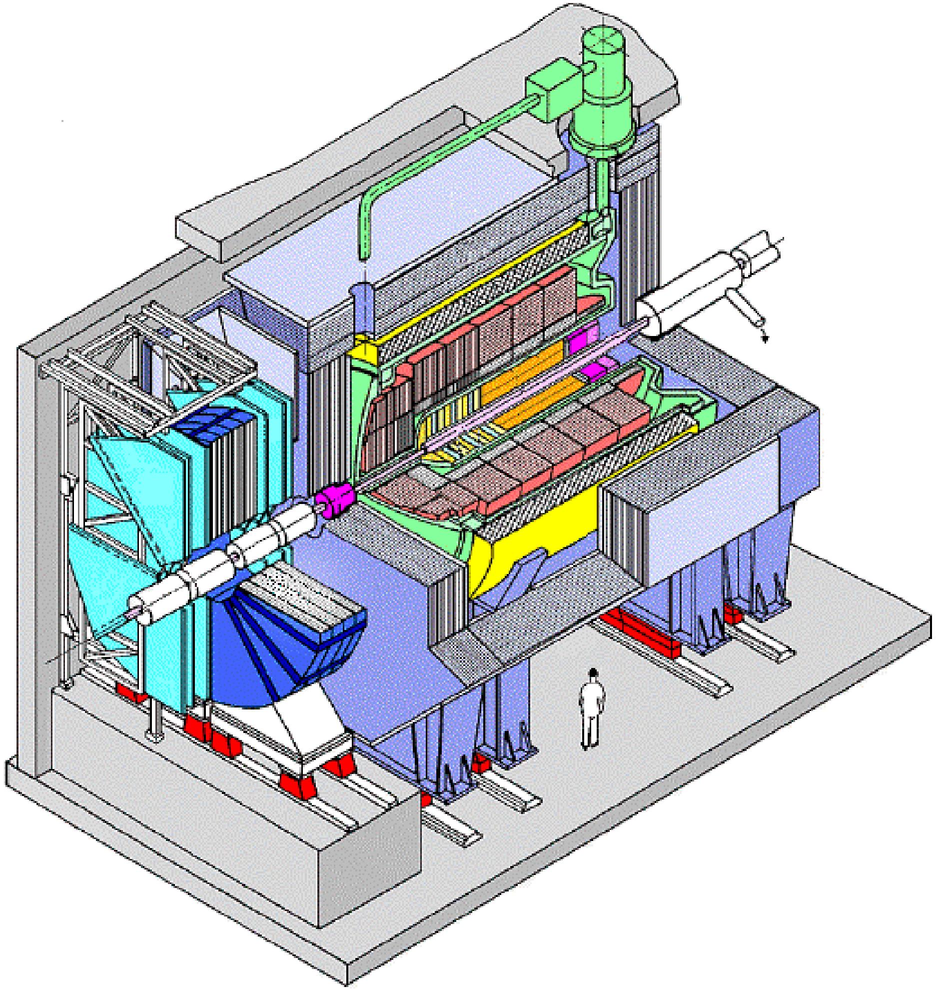
The CDF upgraded detector



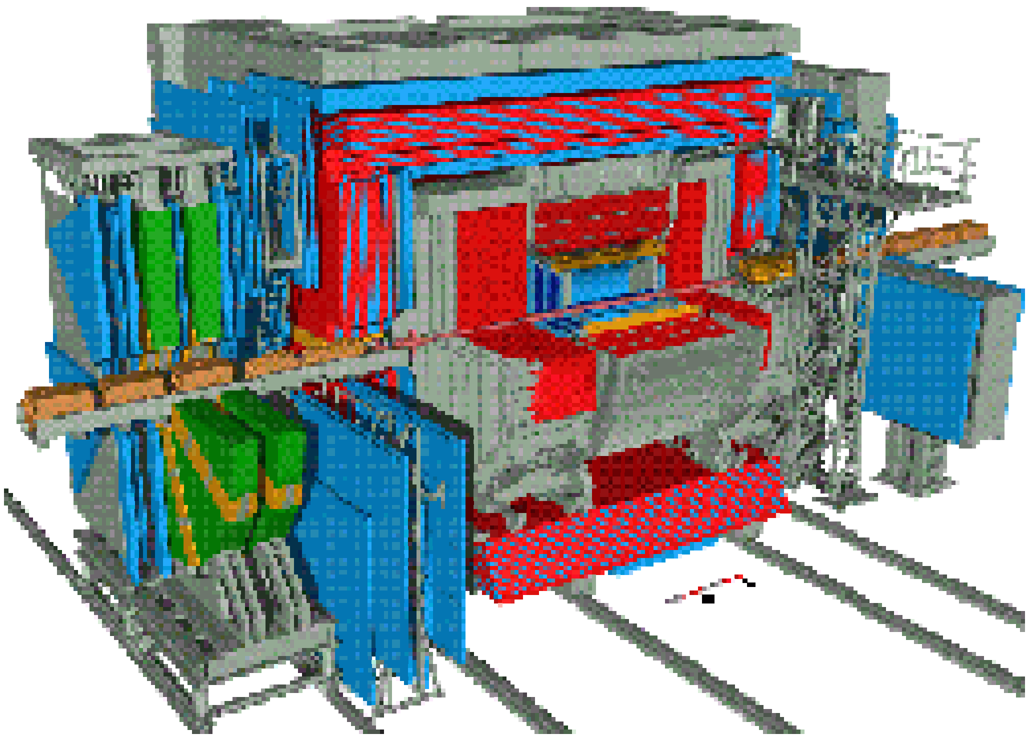
The D0 upgraded detector



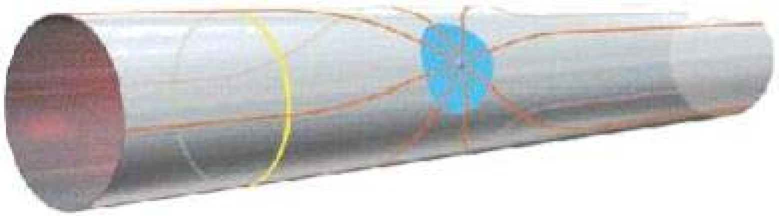
The H1 detector



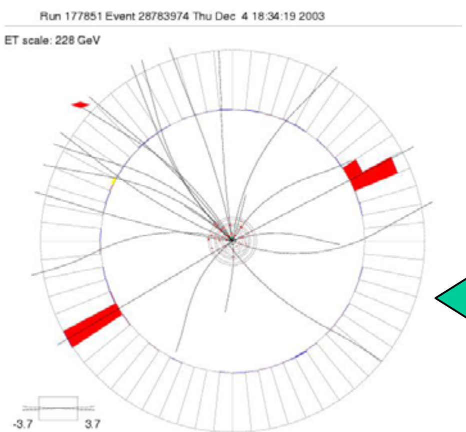
The ZEUS detector

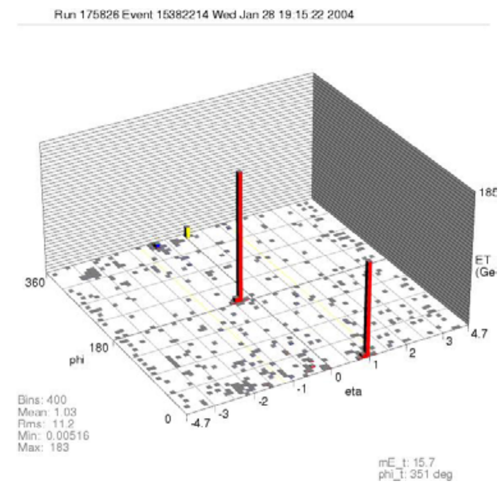


Extra Dimensions

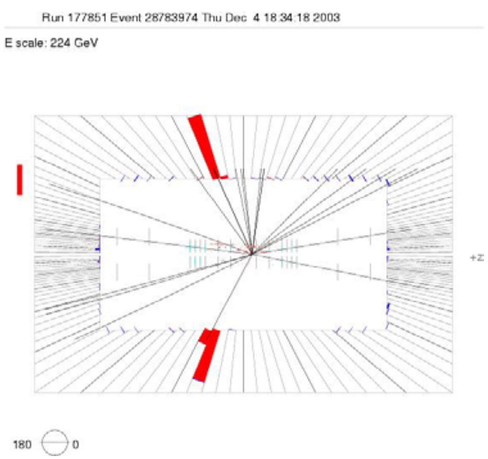


Highest DiEm Masses

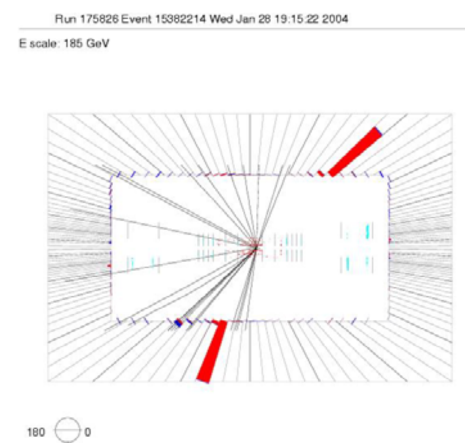




M_{ee} = 475 GeV
cosΘ*=0.01

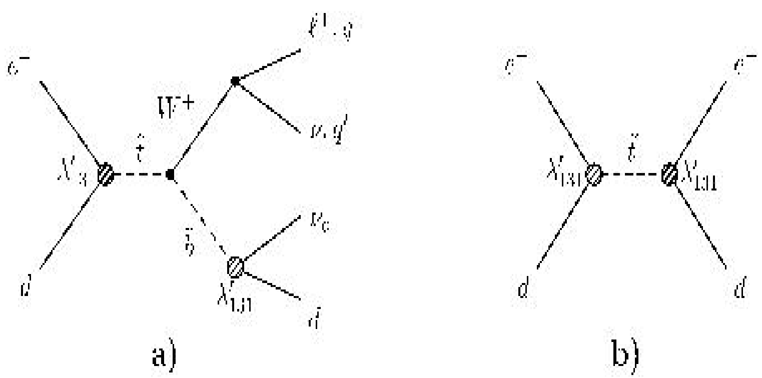


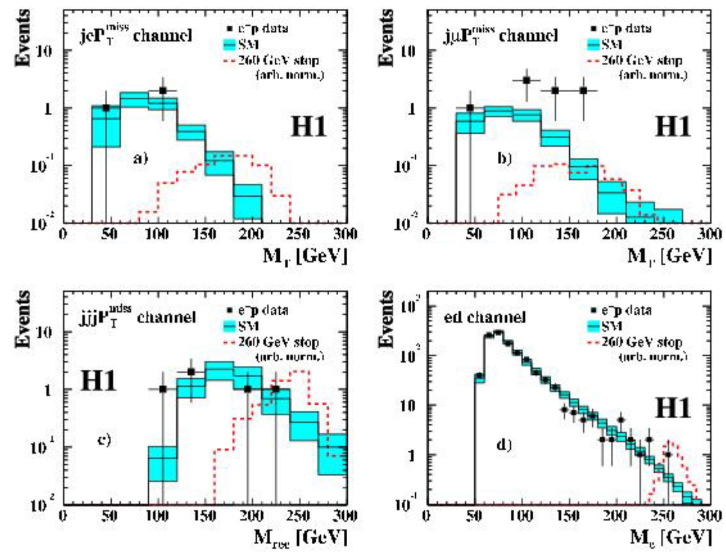
$M_{\gamma\gamma}$ = 435 GeV
cosΘ*=0.02

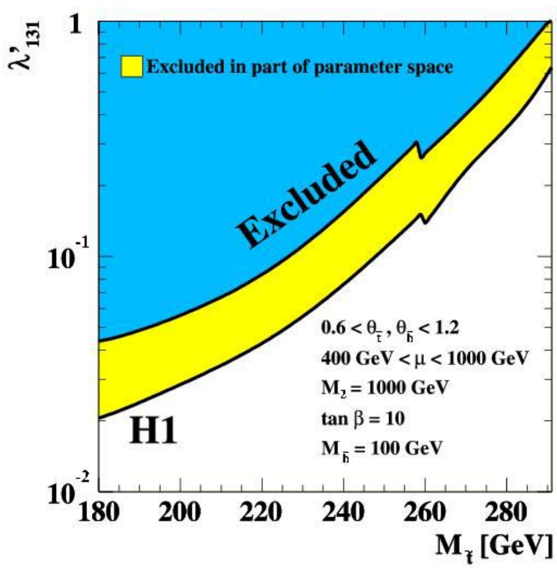


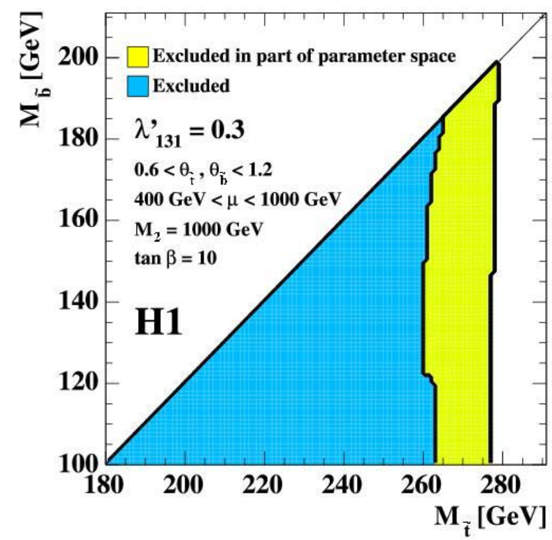
Analogous study for stop (H1) assuming $m_{st}>m_{sb}$

Doesn't explain isolated lepton events -> Limits on λ_{131} and m_{st}

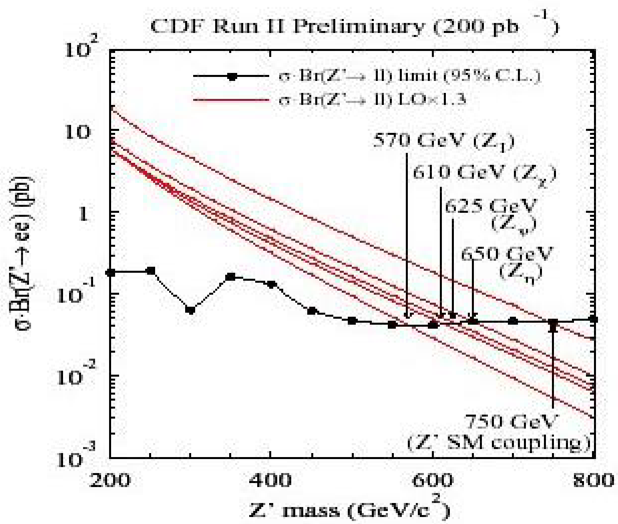








Z'->μμ



ee Z'$_{SM}$ CDF Run II Preliminary

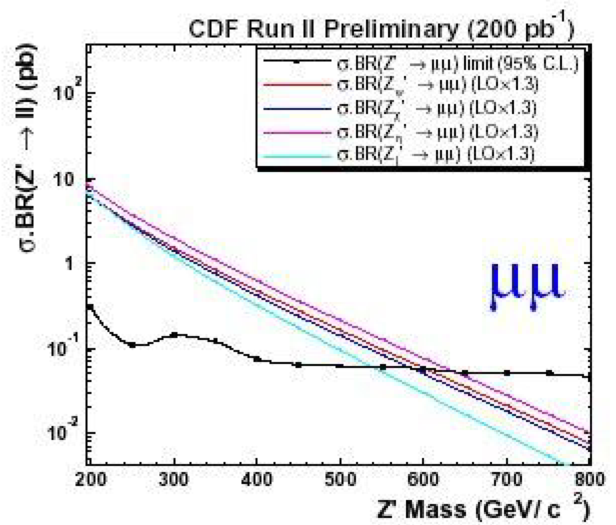
CDF Run	L(pb^{-1})	Mass limit @95%CL
IA ('92-'93)	20	**505**
IB (('94-'95)	90	**640**
IIA (winter '04)	200	**750**

(D0 Run II limit: 780 GeV/c^2)

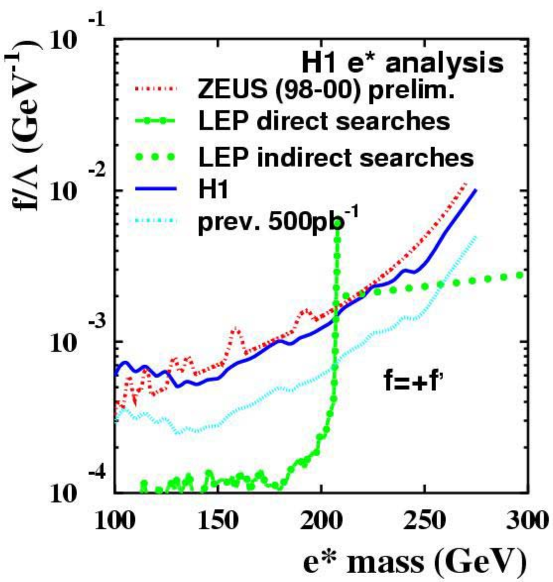
CDF Run II Preliminary

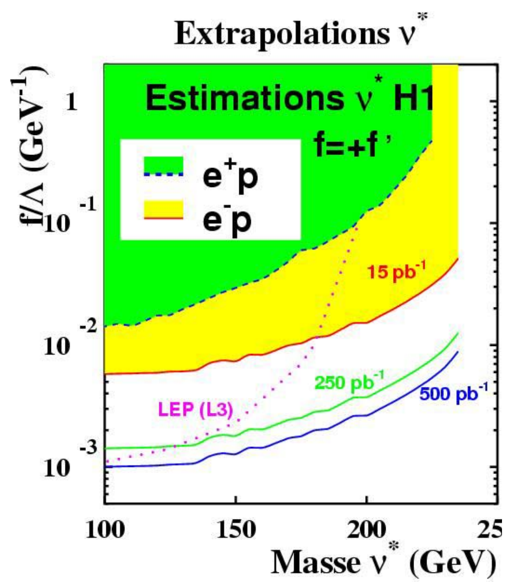
μμ Z' Mass limit @95%CL (GeV/c^2)

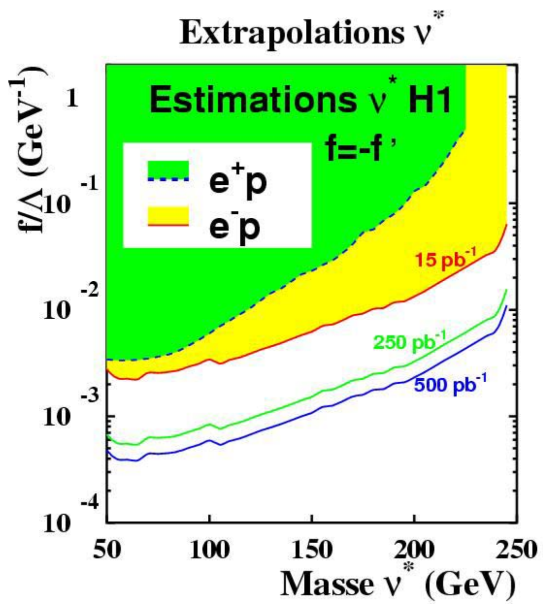
Model	Run I	Run II (winter '04)
Z'$_{SM}$	590	735
Z$_\psi$	495	600
Z$_\chi$	500	580
Z$_\eta$	520	635
Z$_I$	480	530



Excited Leptons

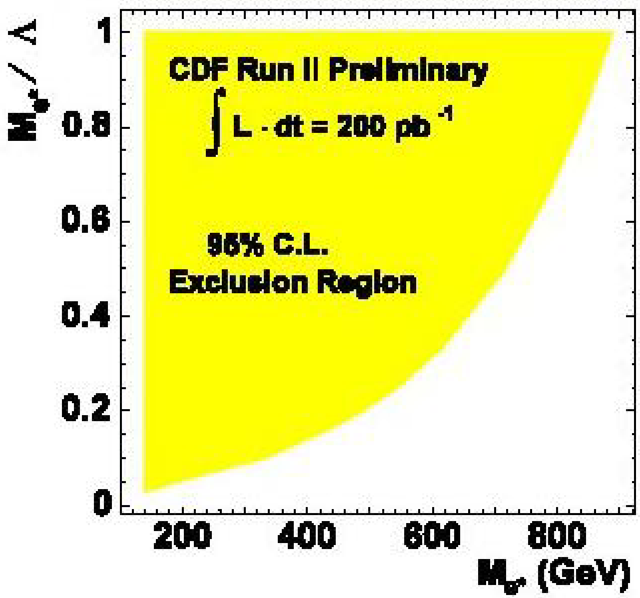






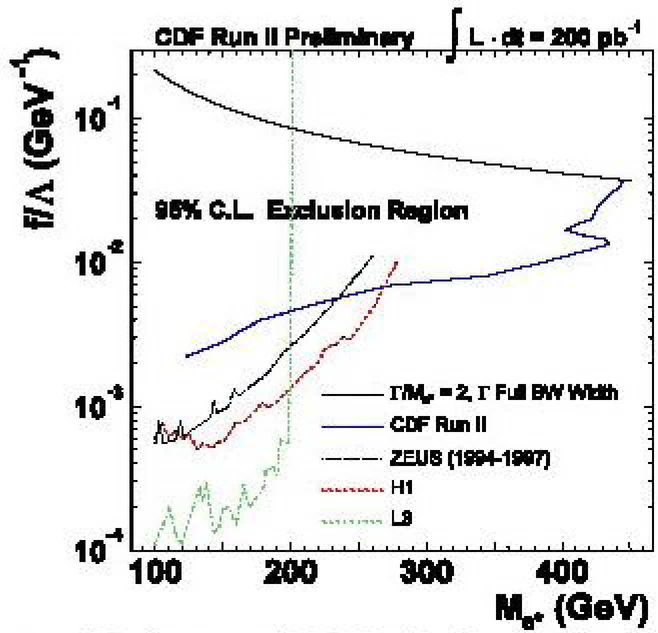
Excited Leptons at the Tevatron (CDF)

- Contact Interaction Model depends on M_{e^*} and Λ
- $M_{e^*} < \Lambda$



- No published limits

- Gauge mediated model depends on M_{e^*} and f/Λ



- L3: hep-ex/0306016, Zeus: hep-ex/0109018, H1: hep-ex/0207038

Multi-e events at HERA II