Searches for New Physics *at Colliders*

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Why ?

Why should we search for *New Physics?*

- There are several *theory-oriented* answers
  - ⇨Problems in the Standard Model
    - →From the hyerarchy problems to FCNC to CP violation
    - →The Higgs sector becomes unstable at high energy
    - →Why three generations? And masses..?
    - →...
- Also some hints of open questions:
  - ⇨Cold Dark Matter
  - ⇨Neutrino masses
  - ⇨Unification of coupling constants at Mp scale?
  - ⇨How to marry gravity with QT?
- Overall in the following I will restrict to the view that at "very large energy" something must happen
  - ⇨It is lot of fun to check whether this has an impact on today phenomenology

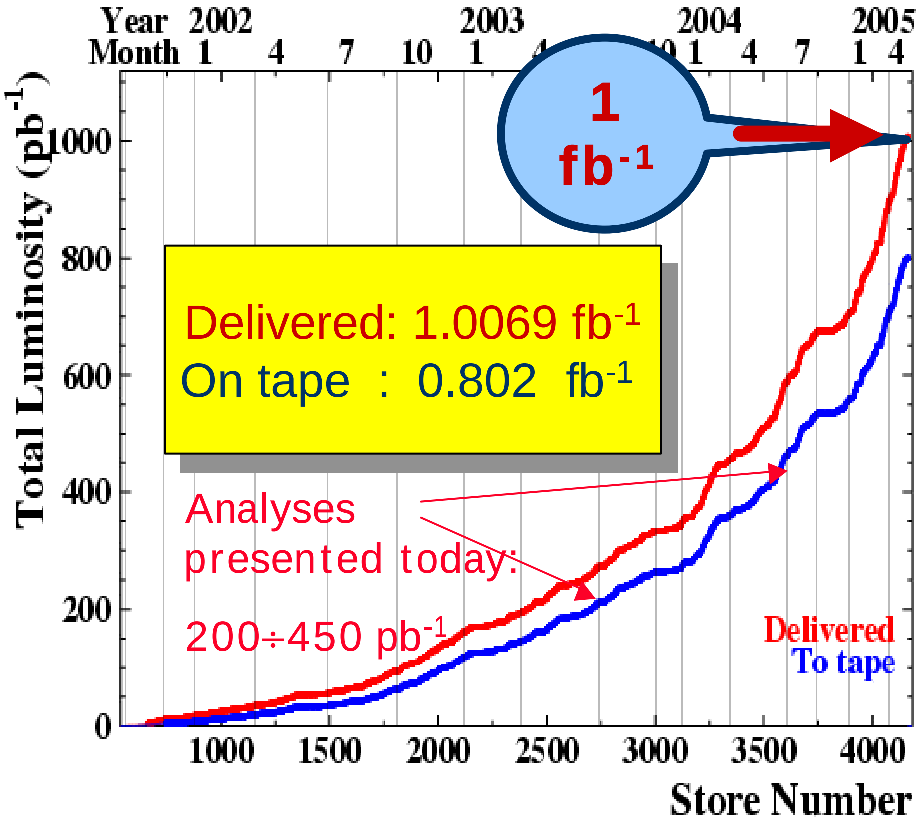
Where?

The energy frontier is an optimal place to look for new physics

- Present:
  - HERA (DESY, Hamburg)
    - A collider where electron and proton collide with beam energies of 27.6 and 920 GeV, i.e. sqrt(s)=320 GeV
    - Hera2: since 1/2005 e-p with polarized leptons
  - Tevatron (Chicago)
    - Pbar-p collider at cms energy of 1.8 TeV from 1985 through 1996 now running at 1.96 TeV
- Future
  - LHC
    - p-p collider starting operations in 2007 at CERN
  - ILC?
- I will concentrate on results from present machines
  - Results since Summer 04

For description of experiments and machines see talks by Robin, Pierre, Zhiquing, Don, Juan..

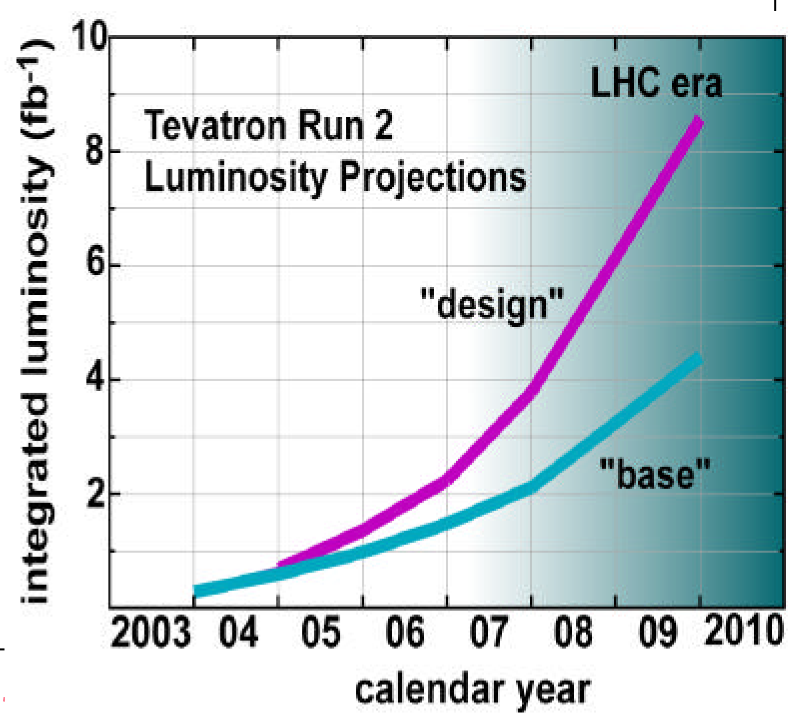
Tevatron Run II integrated luminosity



As of May 23, '05, 1 fb^{-1} data delivered !!

So far, ~ 800 pb-1 to tape for both CDF and D0

Total Luminosity till 2009 : Base ~ 4.5 fb^{-1}, Design ~ 8 fb^{-1}

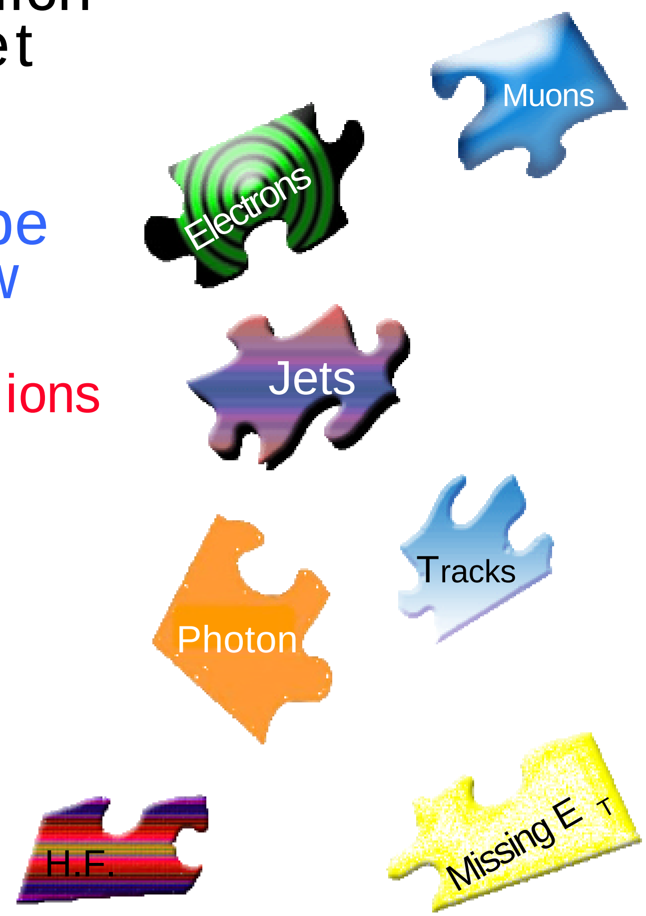


D0 & CDF would like to congratulate and thanks the Accelerator Division for this great accomplishment!!

What is *New Physics* ?

By dubbing *New Physics* anything which is not Standard Model we already set the way to look for it from an experimental point of view

- Select observables which might be affected by the existence of new physics
  - ⇨Compare Standard Model expectations with data
    - →It takes a lot of ingenuity

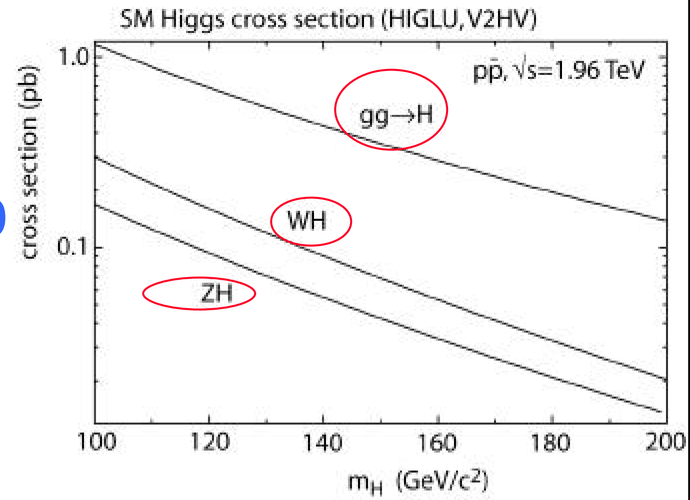


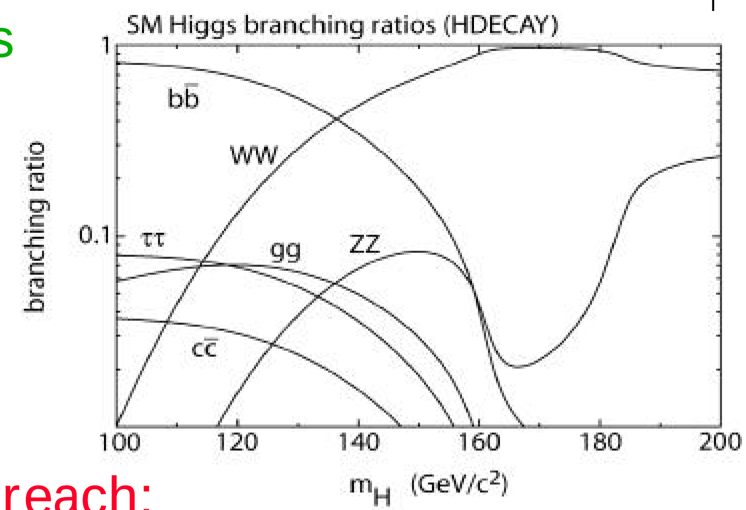
- Therefore we will be talking of familiar physics objects:
  - ⇨charged leptons
  - ⇨missing energy due to n escaping detection
  - ⇨jets
- Different scenarios sometimes share the same final state topology

Possibilities for new physics

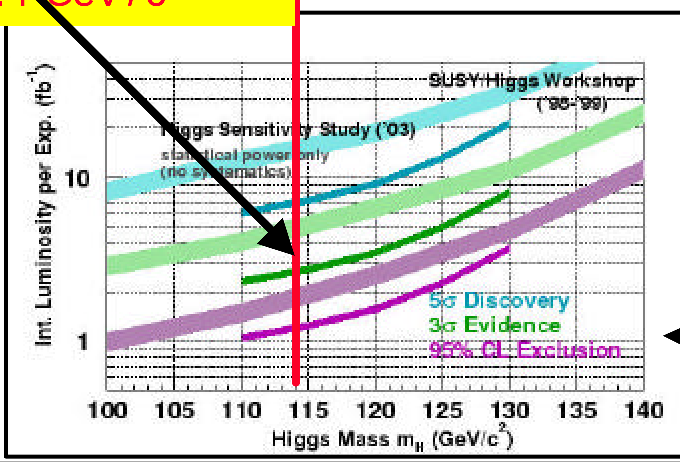
Several possibilities..and lots of constraints

- ➢ The SM has been tested to unprecedented accuracy
  - ⇨ but the Higgs sector, a key ingredient has not been discovered
    - → That leaves room for options
    - → But first let's look at what's going on





LEP Legacy: >114.4 GeV/c^2



Tevatron reach: M_H ~130 GeV/c^2

SM Higgs at the Tevatron

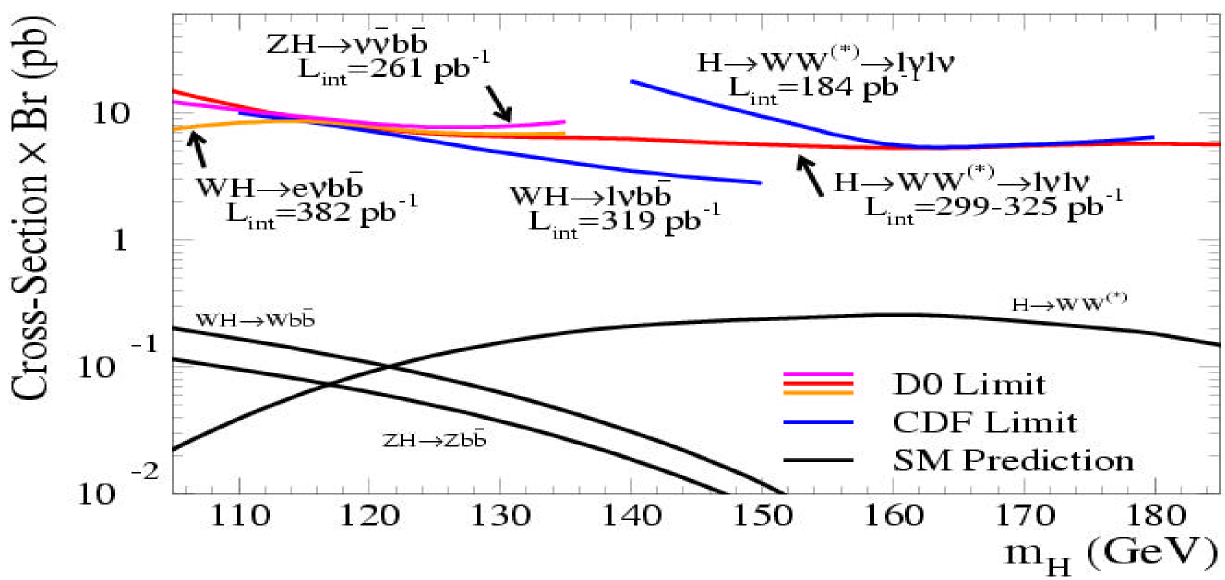
CDF has searched for the Higgs in

- WH (H→bb)→lνbb
  - ⇨ Low M_H, b-jet tagging
- WH(H→WW*) → l±l± +X
  - ⇨ Relevant for
    - → M_H> 160 GeV/c²
    - → Bosophilic/fermiophobic H
- H→WW*→l±l±+νν l ll
  - ⇨ Relevant for M_H>150

D0 searched for SM Higgs in

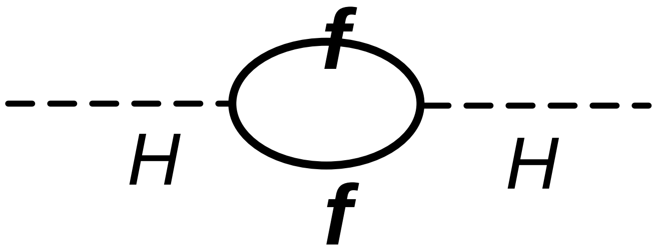
- ZH (H→bb, Z→νν)
  - ⇨ Good calorimetric coverage
- WH(H→bb, W→lν)
  - ⇨ b tagging
- WW*→ll+X

Tevatron Run II Preliminary



Problems...

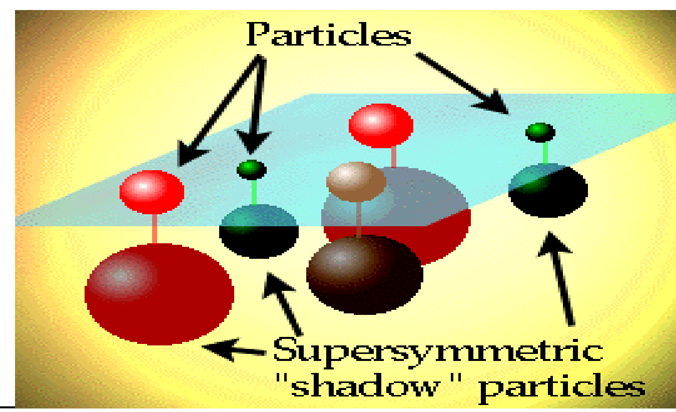
The Higgs sector (being a scalar) brings (technical) problems in the theory. Its mass gets large corrections



$$\delta m_H^2 = \frac{|\lambda_f|^2}{16\pi^2}\left[-2\Lambda_{UV}^2 + \ldots\right]$$

→ Which must cancel out to give the Higgs mass

- It is possible to solve this problem in several ways…the most popular one is SUperSYmmetry
  - ⇨ Introduce for each particle its superpartner which differs by spin assignment: a scalar for each fermion and a spin ½ particle for each spin 0,1



Some implications

Different phenomenology for different SUSY breaking scenarios but in all cases

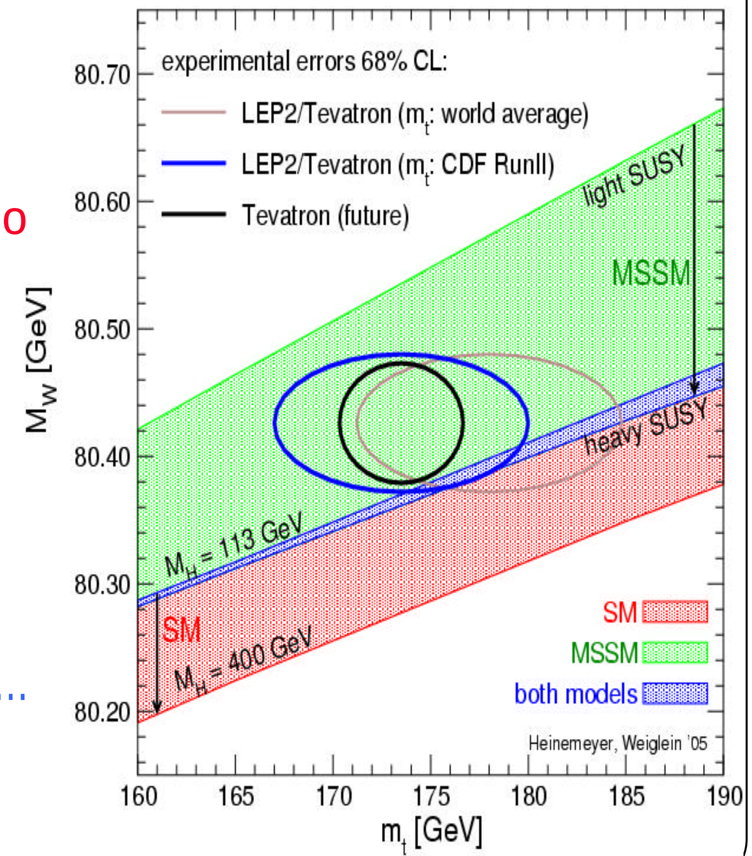
- enlarged Higgs sector
  - ⇨ One Higgs doublet replaced by two, phenomenology predicts neutral and charged Higgs bosons.

In most models assumed that $R=(-1)^{3(B-L)+2s}$ is conserved

  - ⇨ Missing energy in the final state due to Lightest Super Particle escaping detection
- There are models (*R violating*) in which *R* is not conserved
  - ⇨ Different final states

SUSY strongly constrained by LEP results

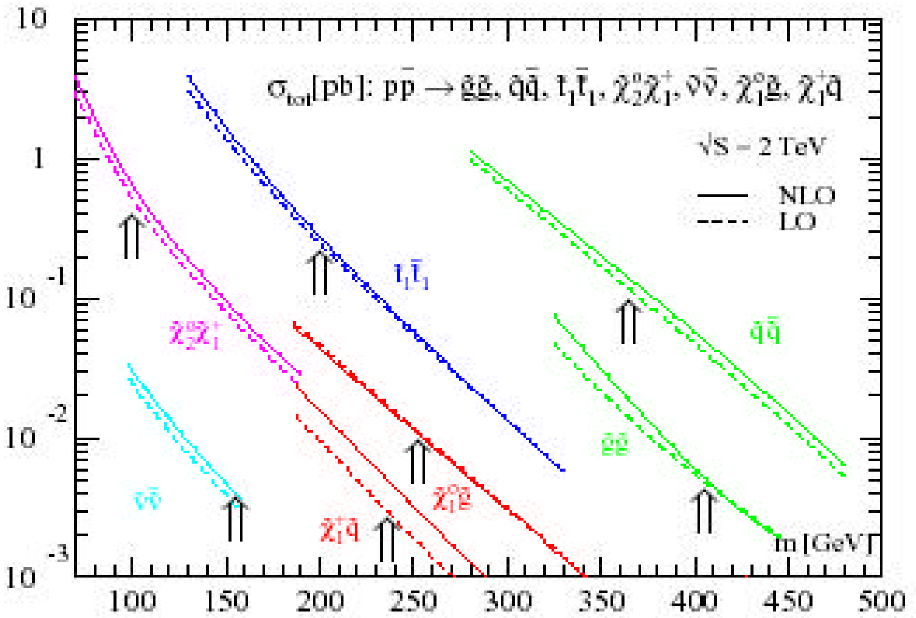
- models/benchmarks set accordingly…



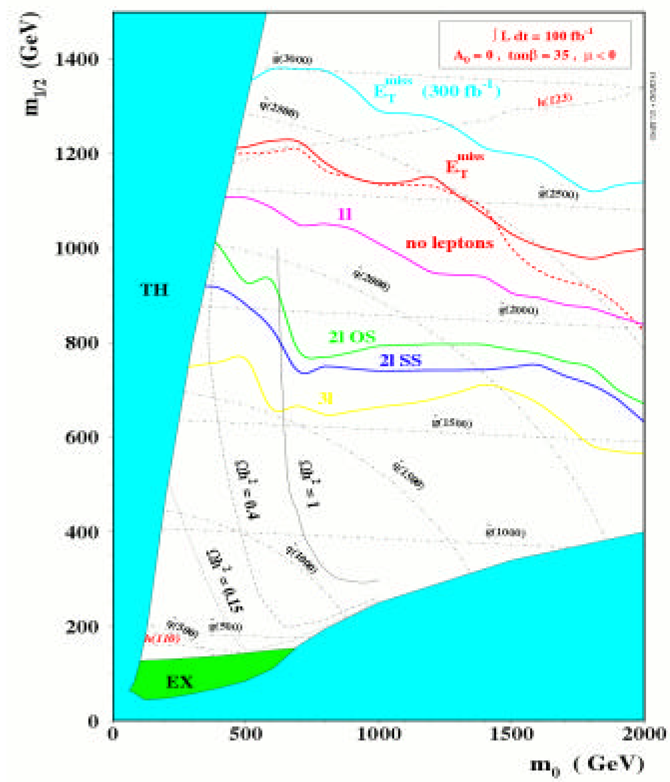
SUSY at the Tevatron

masses of sparticles are unknown

- The energy frontier is the best place to look for SUSY particles



CMS ? L = 100 (300) fb^{-1}
A_0 = 0, tan(ß) = 35, μ < 0



- Implication:
  - LHC will be favoured after startup period

MSSM Higgs

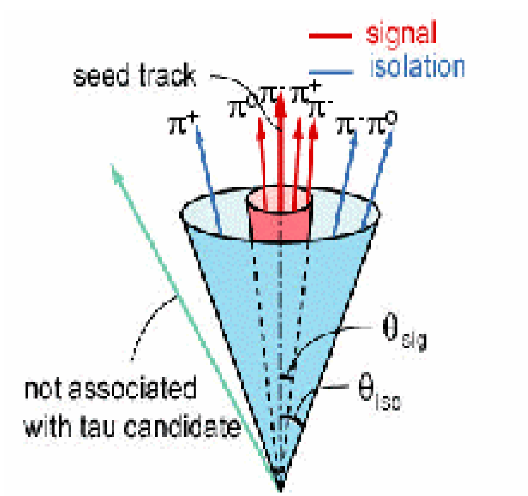
In MSSM Higgs production can be enhanced for large tan*b* (=v_2/v_1). decays mostly to b,t

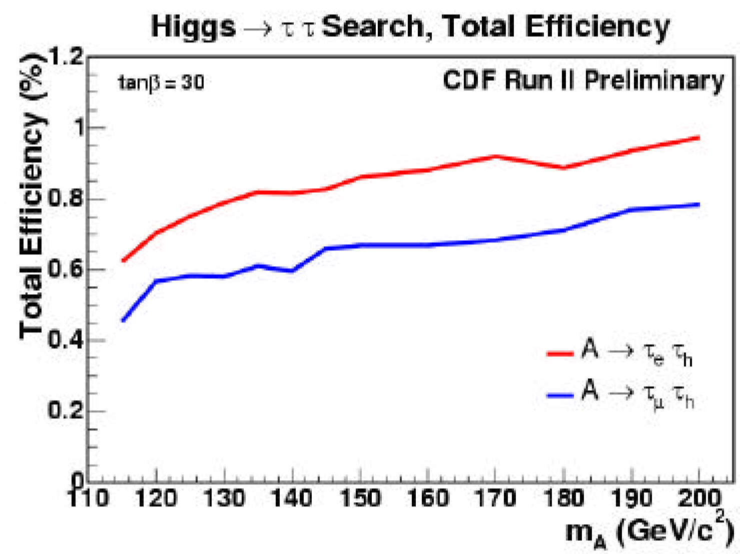
- tt decay up to ~8%

Several production mechanisms:

⇨ f (from gg or qq) or bbf, with f ® tt

- Good τ id is the key

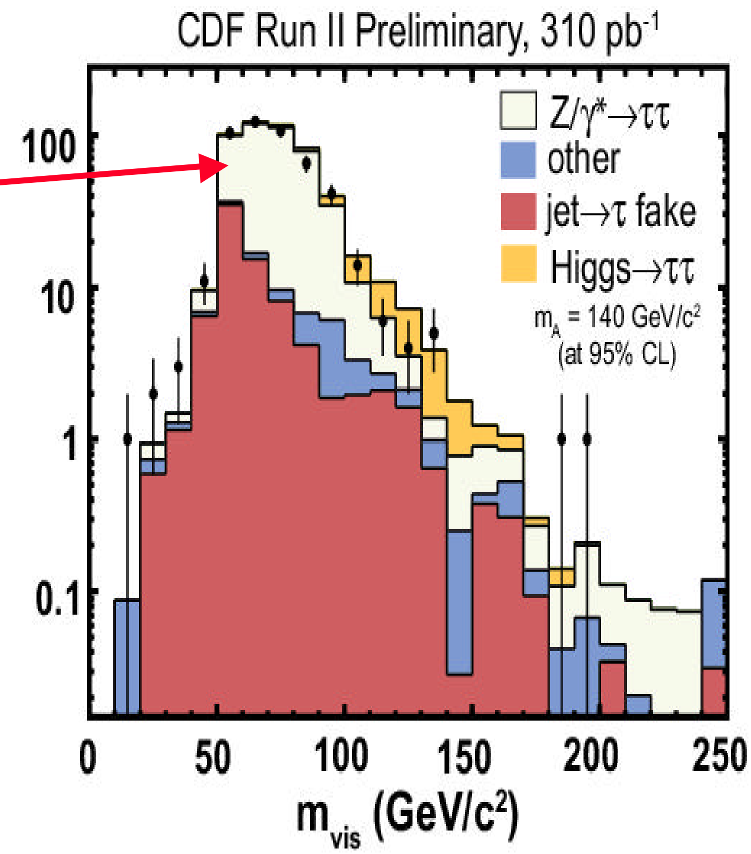




MSSM Higgs

CDF searched for f (from gg or qq), f ® tt

- background mostly due to Z decays
  - Smaller backgrounds: ttbar, (di)bosons, QCD



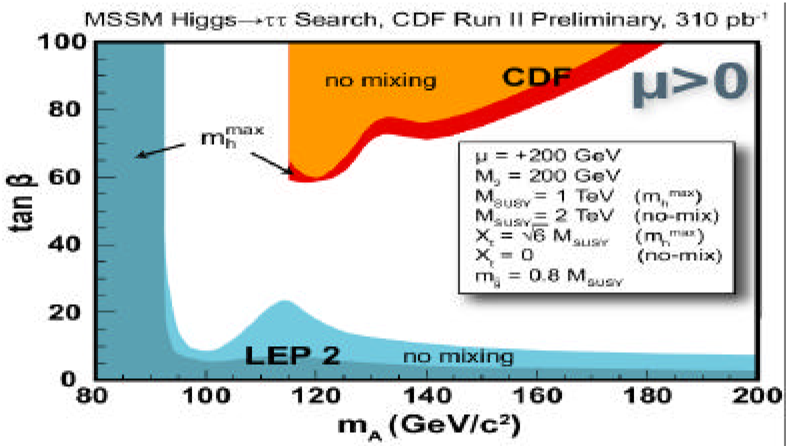
MSSM Higgs $\to \tau\tau$ Search, final events

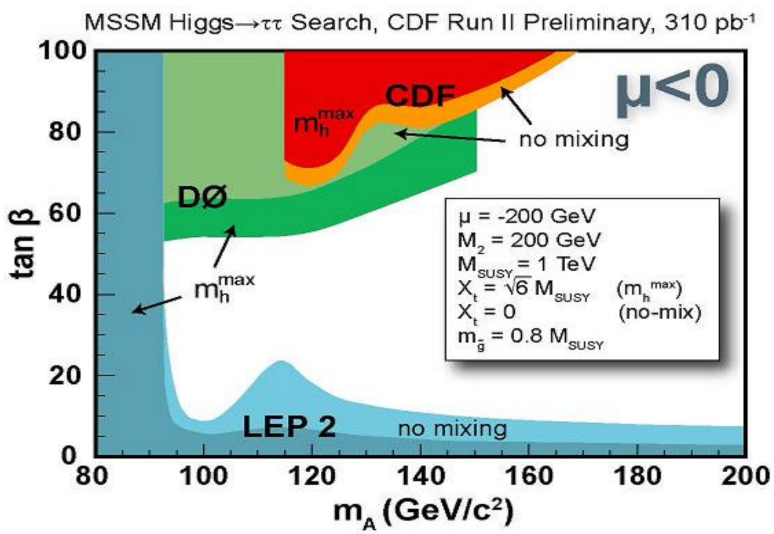
	$\tau_h\tau_e$	$\tau_h\tau_\mu$	Combined
$Z \to \tau\tau$	132.3 ± 17.1	104.1 ± 13.3	236.4 ± 29.5
$Z \to ll$	1.8 ± 0.2	4.9 ± 0.4	6.7 ± 0.6
$t\bar{t}, VV$	0.7 ± 0.1	0.8 ± 0.1	1.5 ± 0.1
$jet \to \tau$	12.0 ± 3.6	7.0 ± 2.1	19.0 ± 5.7
Total predicted	146.8 ± 17.5	116.8 ± 13.5	263.6 ± 30.1
Data	133	103	236

CDF Run II Preliminary

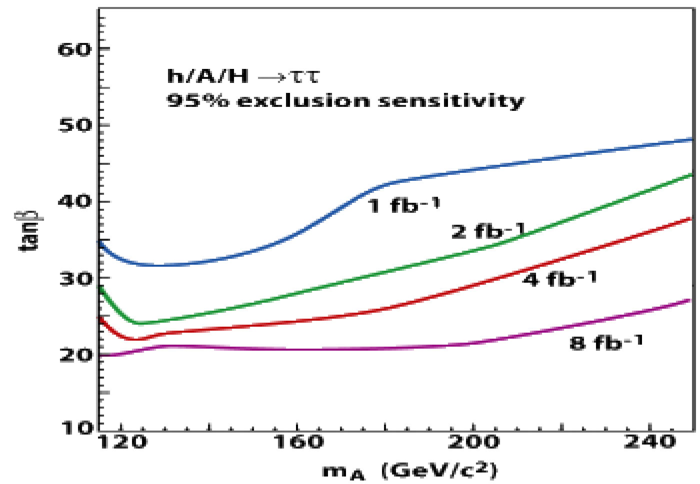
Limits and perspectives

Limits are set within the framework of MSSM

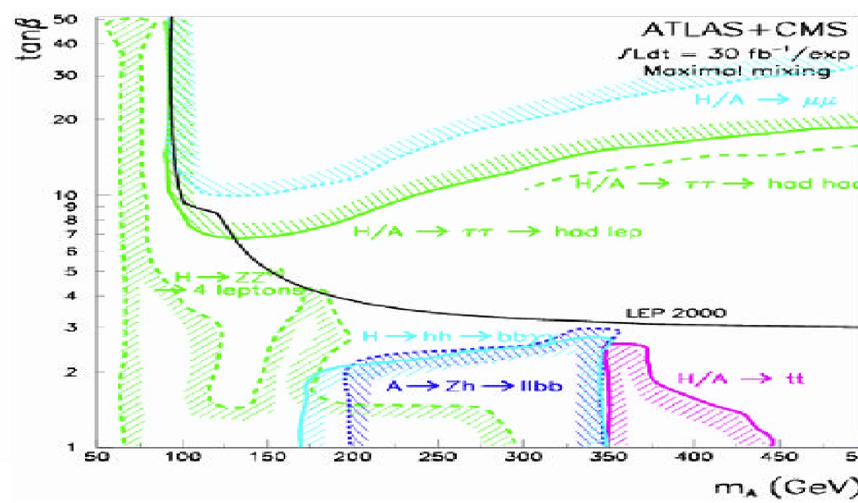




Perspectives are good

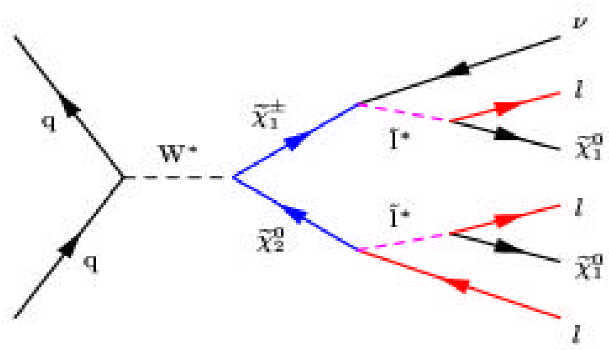


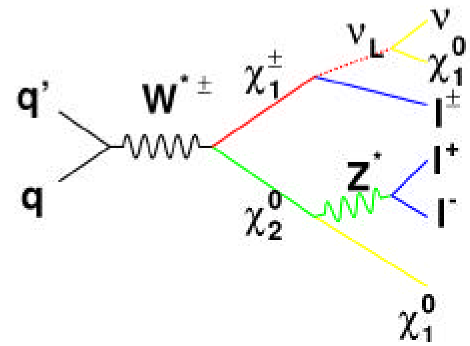
But competition is coming…



Chargino/neutralino searches

Charginos and neutralinos decay through different channels depending upon the available phase space





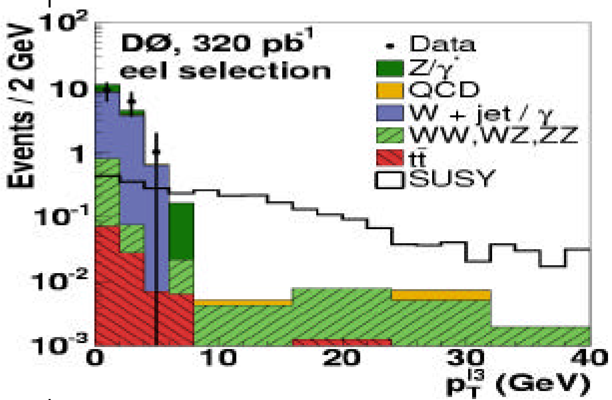
- Final state with three leptons
  - ⇨ Golden channel
    - → Low background
    - → Easy triggering
  - ⇨ However
    - → Low efficiency
      - Large charged lepton coverage helps (D0)
      - Adding taus to *e* and *m* helps

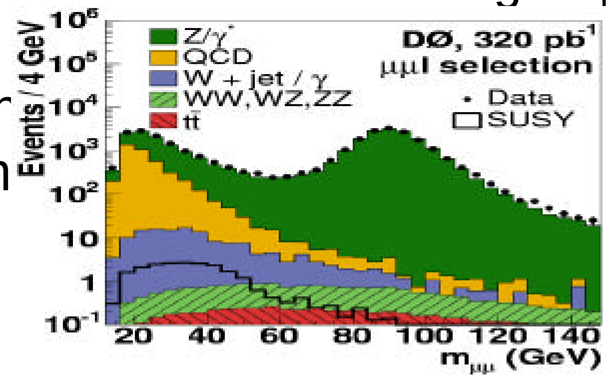
$$\tilde{c}_2^0 \tilde{c}_1^\pm \to l^\pm l^\mp l^\pm \tilde{c}_1^0 \tilde{c}_1^0 X$$

D0 Searches –3l

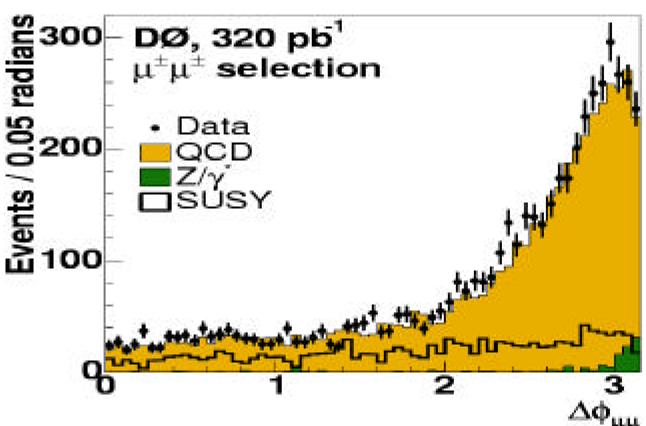
D0 searched for events with

- ⇨ Large MET and high P_T charged leptons:
  - → eel, mml, m±m ± (LS muons),eml
    - here l indicates an isolated track of large P_T
  - → Main bckg
    - misidentified leptons
    - di-boson production

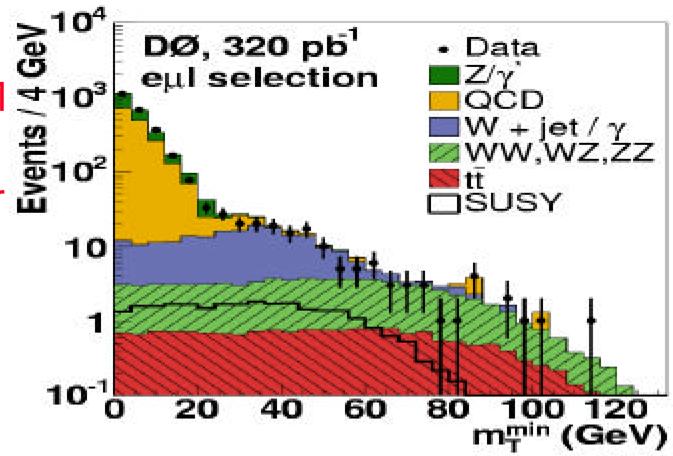




hep-ex 0504032 ubmitted to PRL



Data consistent with SM background (different quantities for each channel are shown)



Limits

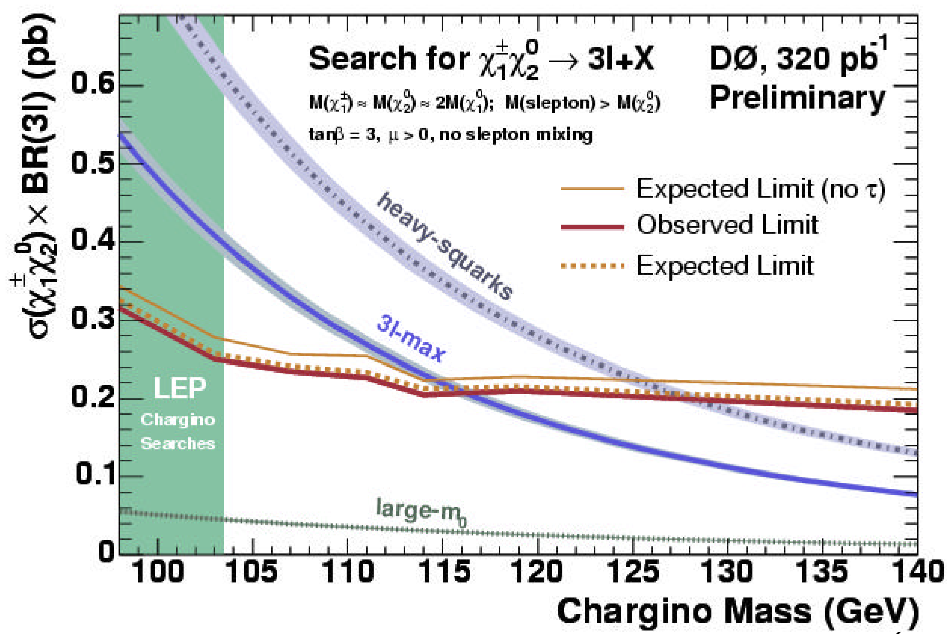
D0 adds taus and observes

	eel	μμl	μμ	eμl	μτl	eτl	total
Bckg. Expect.	0.21±0.12	1.75±0.57	0.66±0.37	0.31±0.13	0.36 ±0.13	0.58 ±0.14	3.85 ±0.75
Obs.	0	2	1	0	1	0	4

- As data agrees with SM expectations, limits are set within the mSUGRA model:

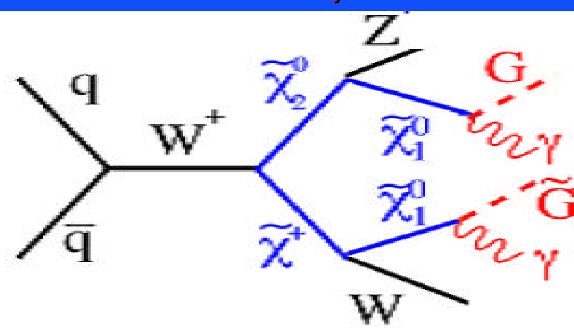
$M_{\chi^{\pm}}$>117 GeV/c^2 at 95%CL

Under the assumption of slepton degenerate masses and Mslepton>Mχ^0_2



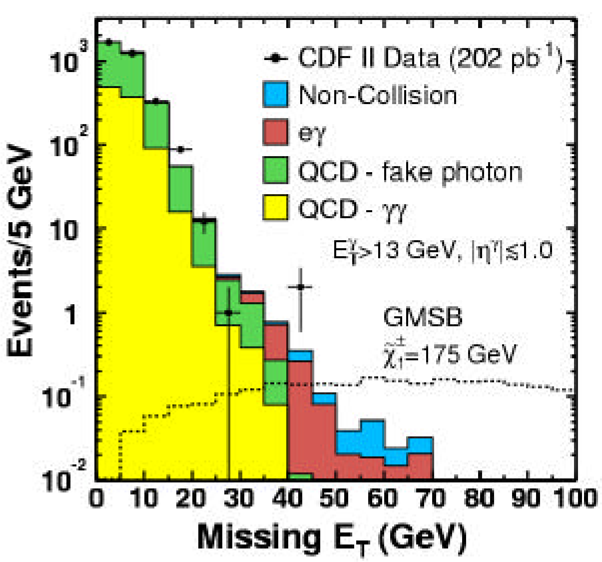
Diphoton+$\not\!E_T$ (GMSB $\chi^\circ_1, \chi^\pm_1$)

In GMSB scenario:
NLSP can be $\chi^\circ_1 \rightarrow \gamma\tilde{G}$

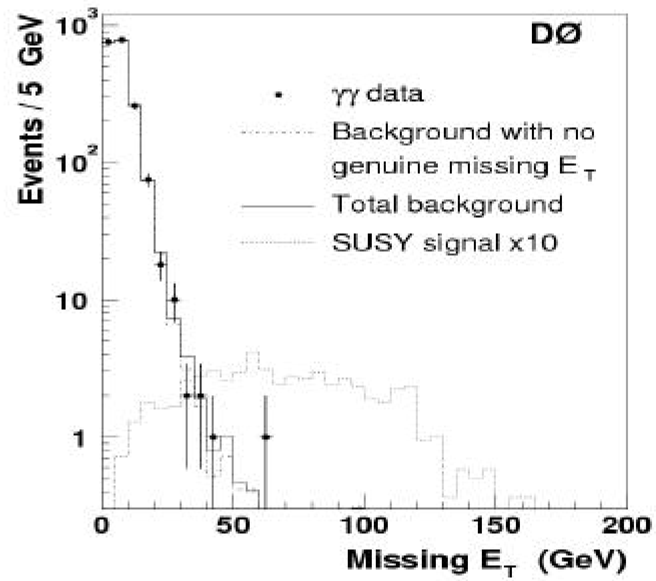


$2\gamma + \not\!E_T$

- For short χ°_1 lifetimes: final state: $2\gamma+\not\!E_T$+X
- Search for anomalous production
  - ⇨ 2γ>20, $\not\!E_T$>40 GeV (D0, 263pb^{-1})
  - ⇨ 2γ>13, $\not\!E_T$>45 GeV (CDF, 202pb^{-1})



No excess



Chargino-Neutralino

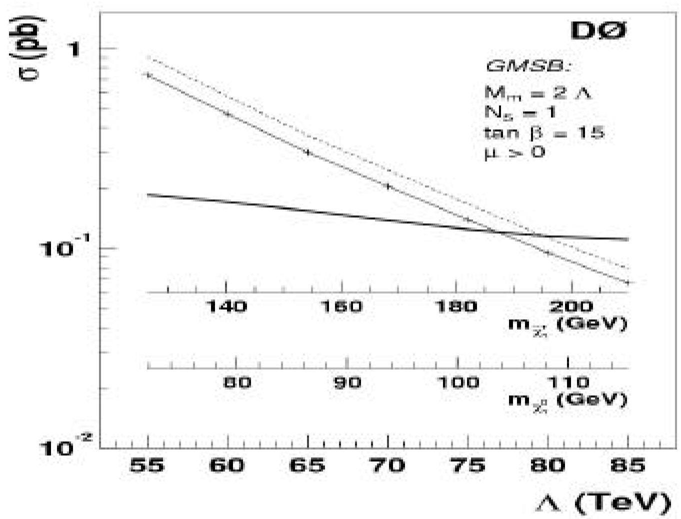
As events are consistent with background

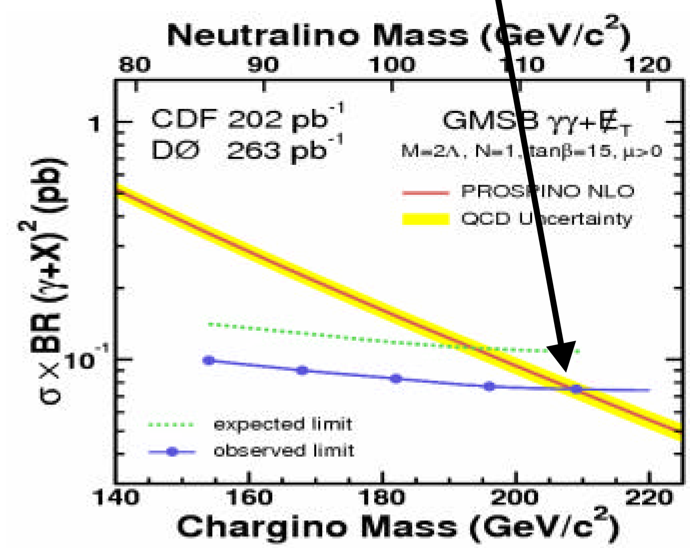
⇨ Both experiments set limits within the GMSB

	Bkgnd Expect	Obs	Limit m_{χ^+} (GeV/c^2)	Limit m_{χ° (GeV /c^2)
D0	3.7±0.6	2	195	108
CDF	0.27±0.07±0. 1	0	167	93

Combined limit

$M_{\chi^\pm}$>209 GeV/c^2





Gluinos and Squarks

Decays of $\tilde{q}$,$\tilde{g}$ at the Tevatron, produce

- Multijet events with missing energy
- For the case of third generation $\tilde{q}$ ($\tilde{b}$,$\tilde{t}$), specific final states can be favoured

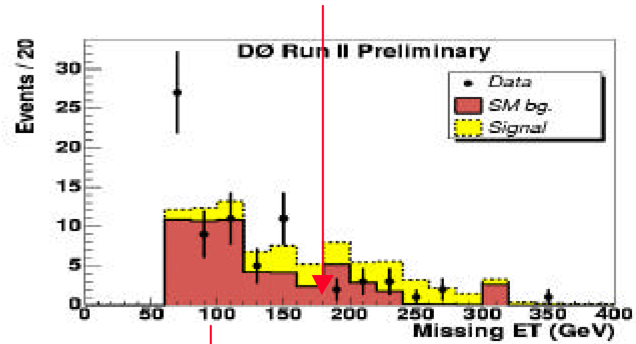
Therefore CDF and D0 search for

- Large Missing E_T
- Multijet events
  - Identification of one or more jet as containing debris from the fragmentation of b-quarks can be useful

Jets+MET (gluino/squarks)

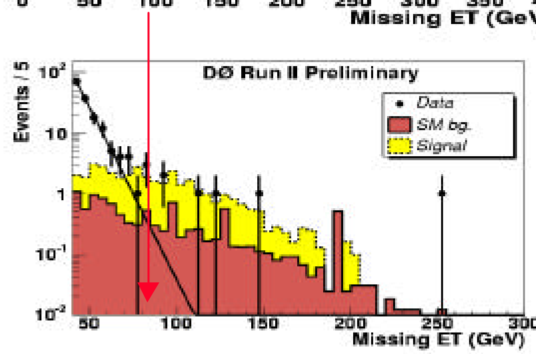
3 different samples are designed to investigate different regions of the $m_{\tilde{g}}$-$m_{\tilde{q}}$ plane

- ≥2 jets (E_T >50 GeV), $\not{E}_T$>175 GeV
  - ⇨ low m_0, $m_{\tilde{g}}$>$m_{\tilde{q}}$, production dominated by qq
- ≥4 jets ($E^{1\text{-}3}_T$>30, E^4_T>20 GeV), $\not{E}_T$>75 GeV
  - ⇨ high m_0, $m_{\tilde{q}}$>>$m_{\tilde{g}}$, gg production dominates
- ≥3 jets (E^1_T>25 GeV), $\not{E}_T$>100 GeV
  - ⇨ Intermediate case, optimized to cover region $m_{\tilde{q}}$~m_g,
- Additional requirements to reduce QCD bckg



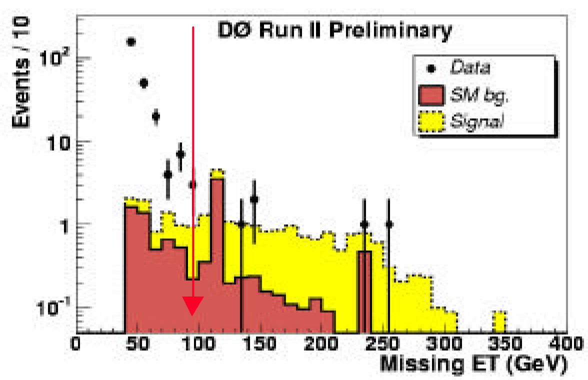
Data: 12

Bckg:12.8±5.4



Data: 10

Bckg:7.1 ±0.9



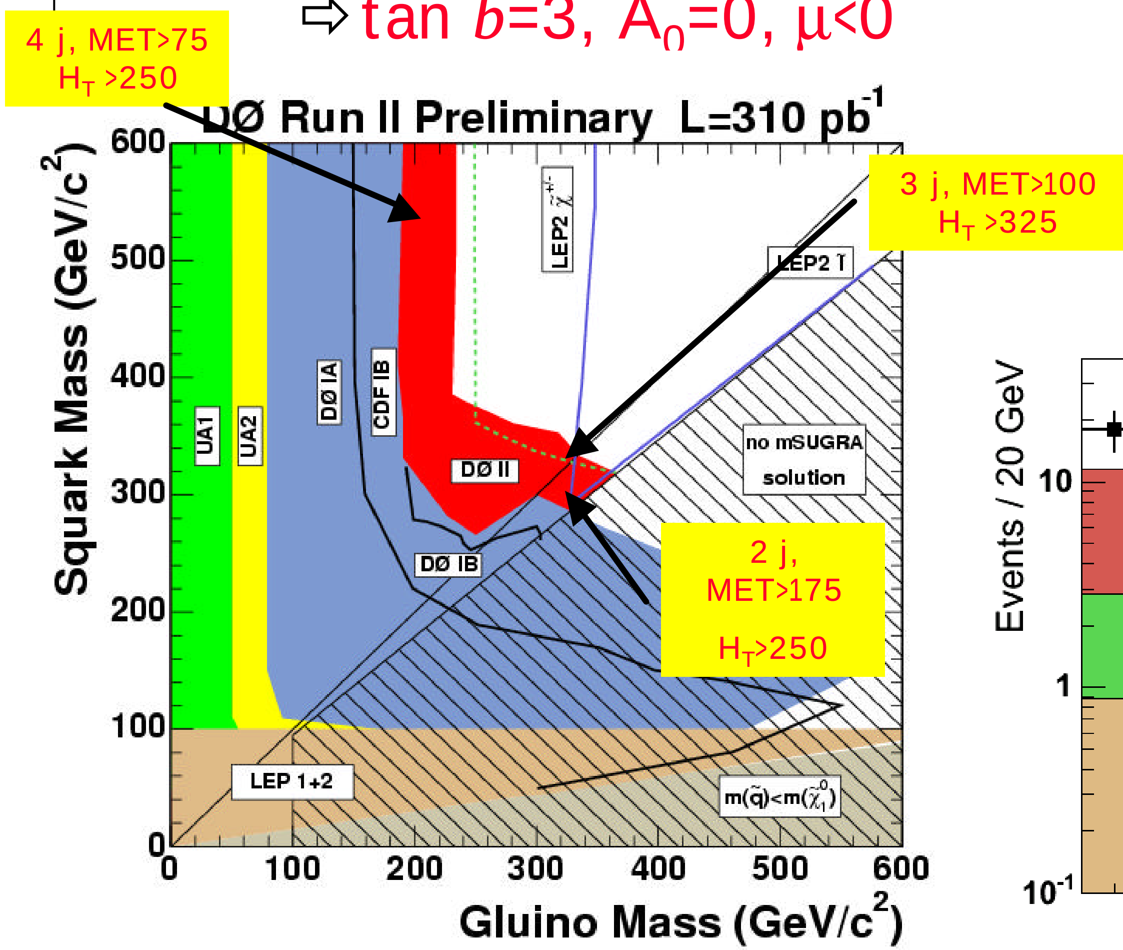
Data: 5

Bckg:6.1 ±3.1

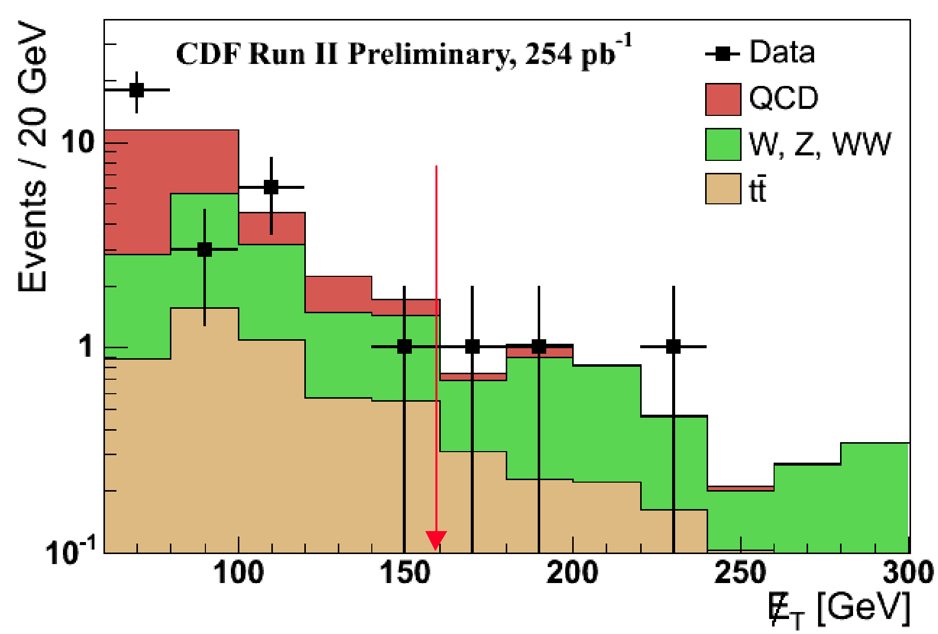
Limits

Use mSUGRA as a framework. Combine results from the 3 analyses, limits are set for the case:

⇨ tan b=3, A_0=0, μ<0



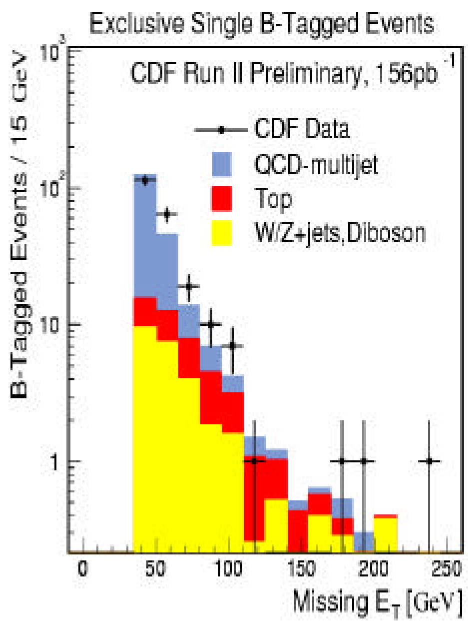
Expect improvement with larger statistics, CDF ongoing analysis…

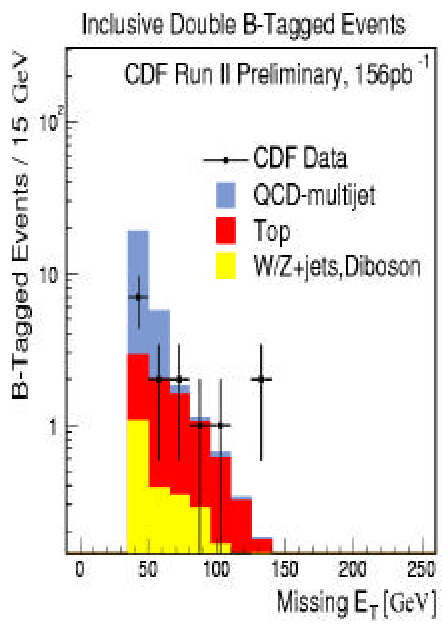


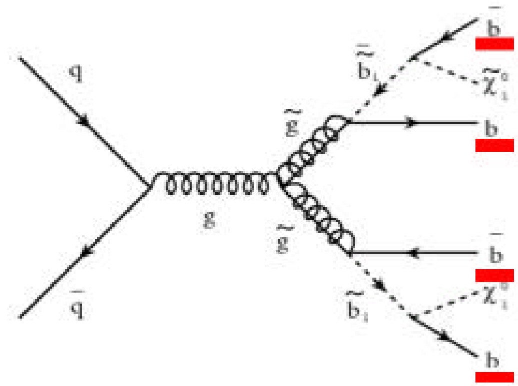
Gluino → sbottom decays

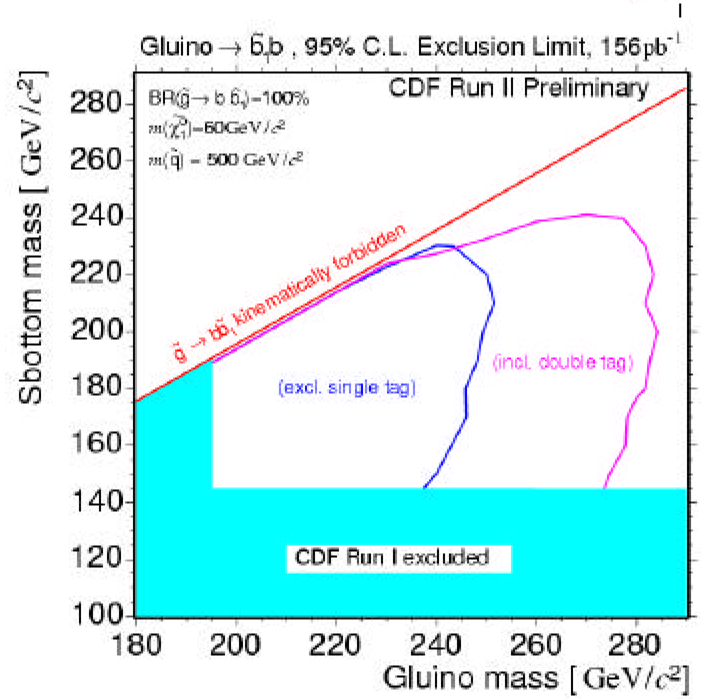
CDF searched for gluino→sbottom

- 4 b-jets and missing ET









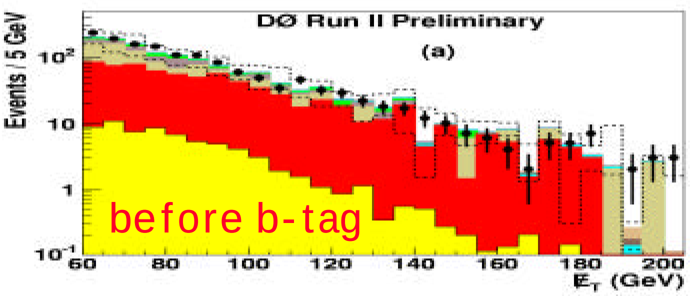
Process	Exclusive Single B-Tag	Inclusive Double B-Tag
EWK	$5.66 \pm 0.76(stat) \pm 1.72(sys)$	$0.61 \pm 0.21(stat) \pm 0.19(sys)$
TOP	$6.18 \pm 0.12(stat) \pm 1.42(sys)$	$1.84 \pm 0.06(stat) \pm 0.46(sys)$
QCD	$4.57 \pm 1.64(stat) \pm 0.57(sys)$	$0.18 \pm 0.08(stat) \pm 0.05(sys)$
Total Predicted	$16.41 \pm 1.81(stat) \pm 3.15(sys)$	$2.63 \pm 0.23(stat) \pm 0.66(sys)$
Observed	21	4

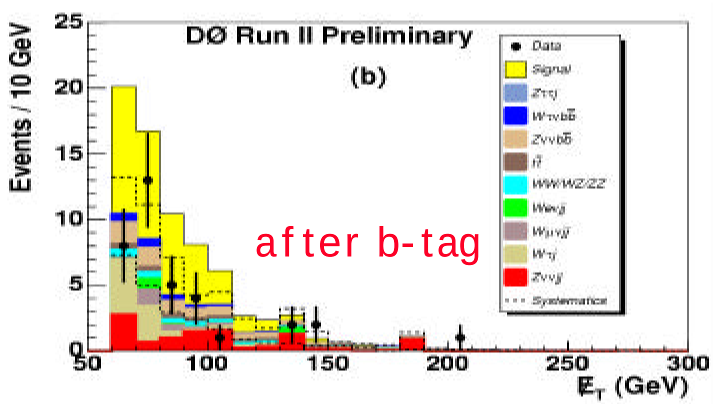
Table 24: Number of expected and observed events in signal region.

Direct sbottom production

D0 searched for sbottom→b+χ^1_0 (LSP)

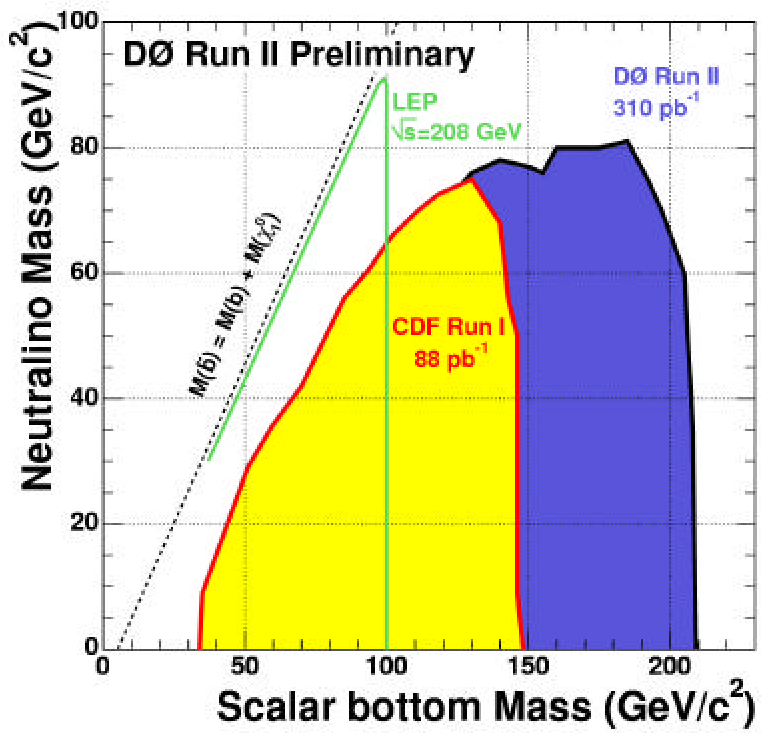
- 2 b-jets and missing E_T
  - ⇨Optimize MET, E_T^j for different masses
  - ⇨lepton id used to remove e,μ
    - →b-tagging to improve S/B





No excess

Set limits



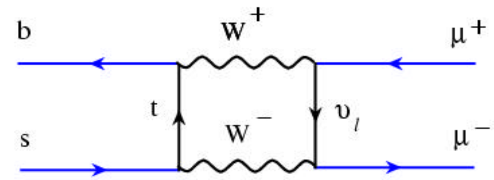
Indirectly seeking Susy

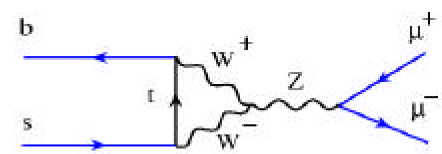
Supersymmetric corrections to SM processes can be relevant

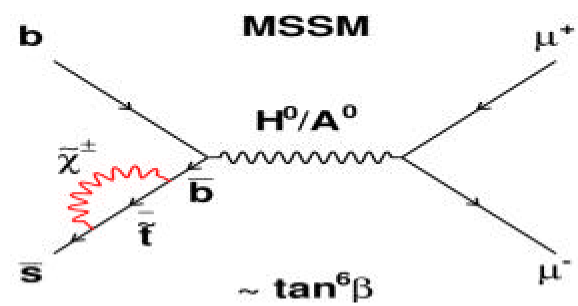
- By precision measurement one can check prediction and/or find if SUSY exists...

important check is

- B rare decays ($B_s \to \mu\mu$, $B_d \to \mu\mu$)
  - ⇨ $B_{s,d}$ decays to $\mu\mu$ via loop
    - → Nano-BF: $B_s \to \mu\mu$
  - ⇨ SUSY enhances the BF
    - → Good
  - ⇨ Decays are rare but B_s are copiously produced at the Tevatron (and B_d at both Tevatron and factories)





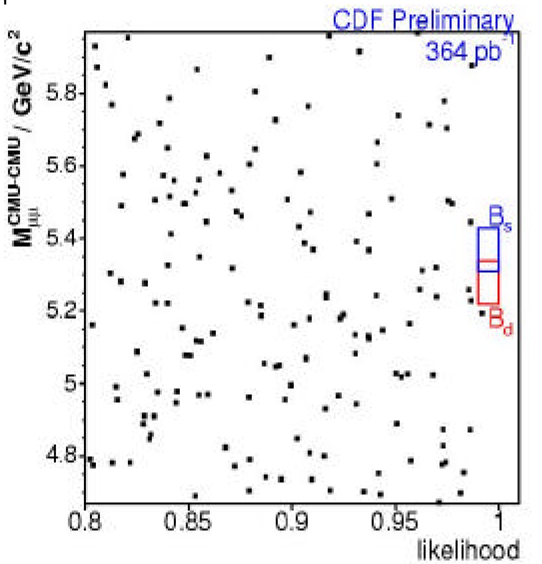


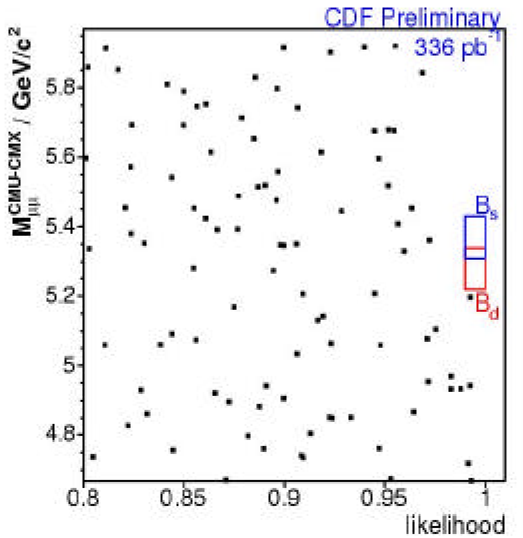
$$BR(SUSY) \propto BR(SM) \cdot \frac{m_b^4 \cdot (\tan b)^6}{m_{H^0}^4}$$

$B_s \rightarrow \mu\mu$ results

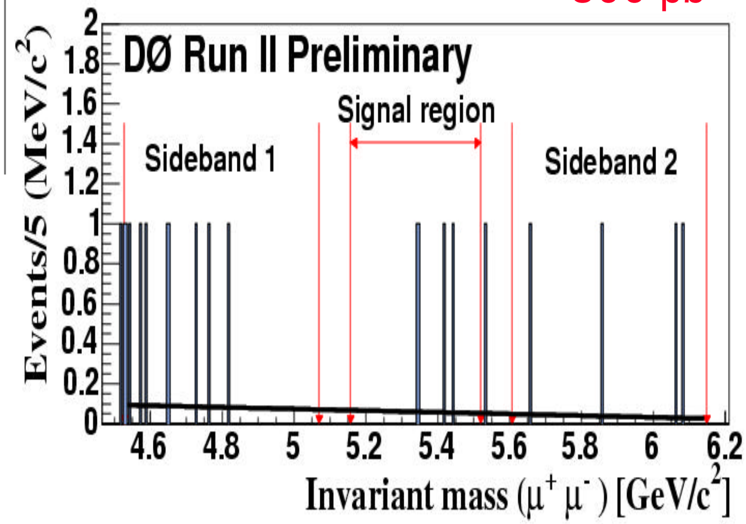
CDF and D0 searched for B_s decays in $\mu\mu$

- D0 finds 4 events (4.3±1.2 expected)
- CDF finds 0 (1.47±0.18 exp.)





300 pb^{-1}



Limits

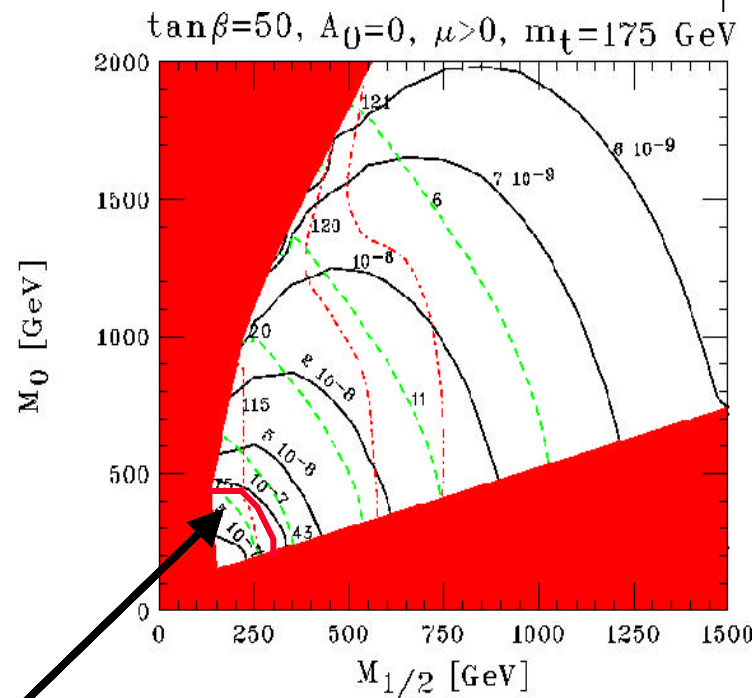
- No signal found, limits set
  - Still no sensitivity for SM rate ($3.5\pm0.9 \times 10^{-9}$)
  - Can set strong limit to *specific* SUSY models

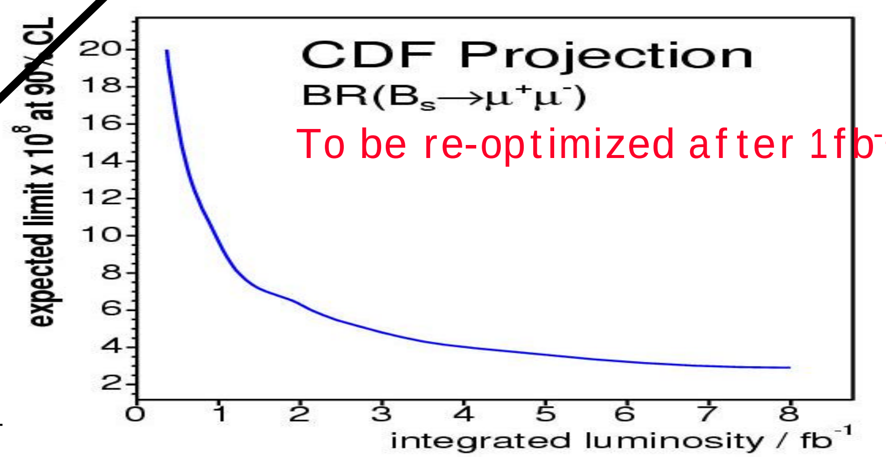
$B_s \to \mu\mu$	$<1.6\times10^{-7}$ @90%CL.	CDF
$B_s \to \mu\mu$	$<4.1\times10^{-7}$ @90%CL	D0
$B_d \to \mu\mu$	$<3.x10^{-7}$ @90%CL	D0
$B_d \to \mu\mu$	$<8.0\times10^{-8}$ @90%CL	BaBar
$B_d \to \mu\mu$	$<3.9\times10^{-8}$ @90%CL	CDF

CDF @95%CL:

$B_s \to \mu\mu < 2.1\times10^{-7}$

$B_d \to \mu\mu < 5.1\times10^{-8}$





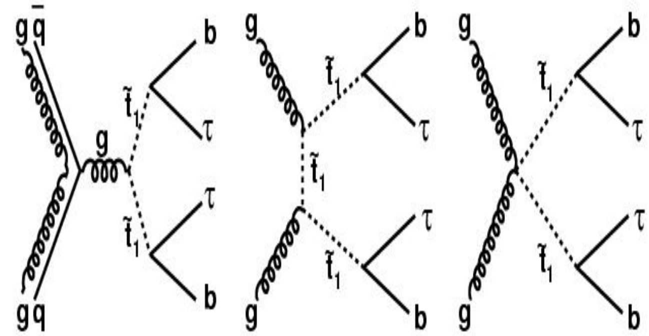
RPV SUSY

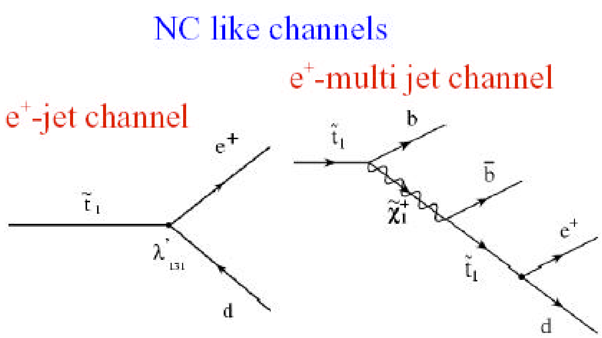
Some SUSY models give up *R* conservation

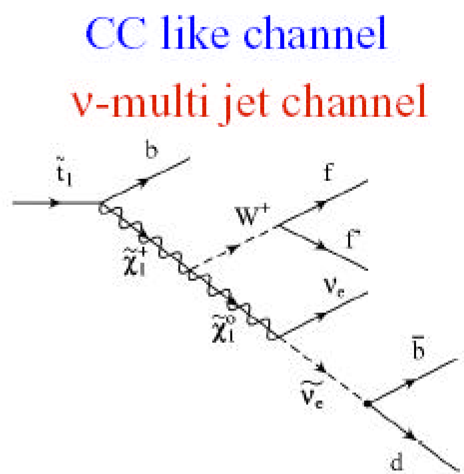
- ⇨MET is not a must anymore
- ⇨Important parameter is the coupling strength λ_{ijk}

➢Searches at theTevatron and HERA

- ⇨H1,ZEUS looked for resonant production through RPV ed→stop



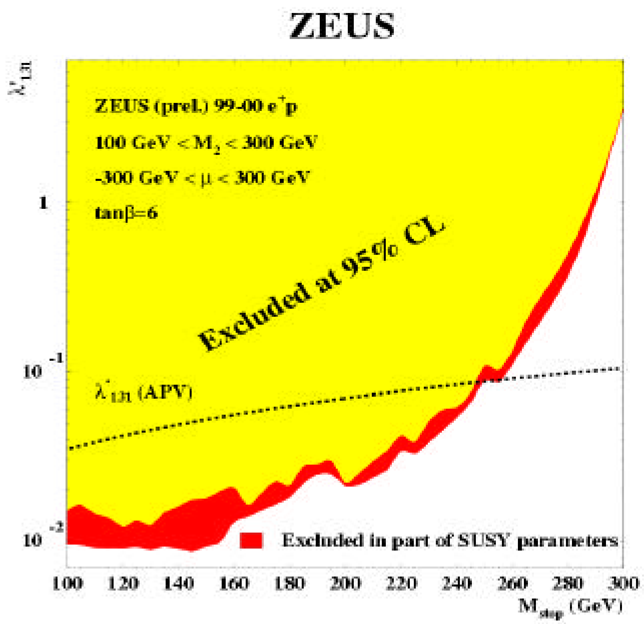


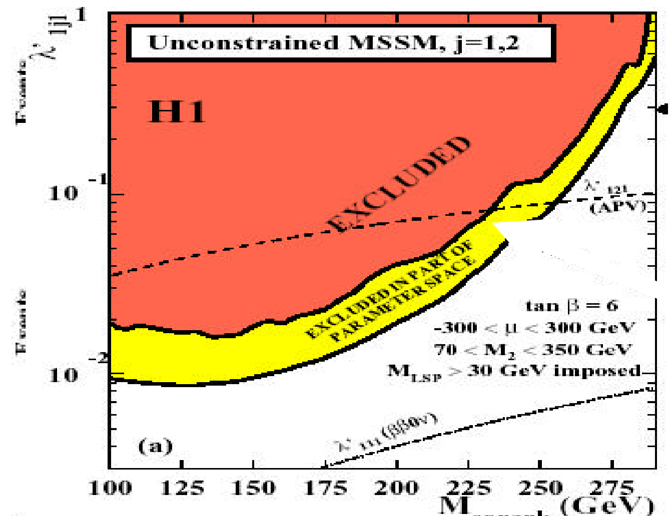


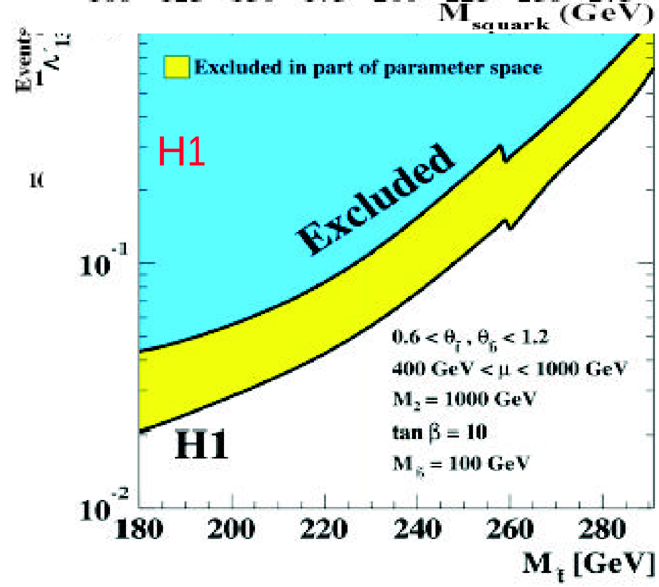
Squarks in RPV SUSY

ZEUS looks for

- e+jet(s), ν+jets
  - ⇨Good agreement with SM expectations
  - ⇨limit as a function of couplings.



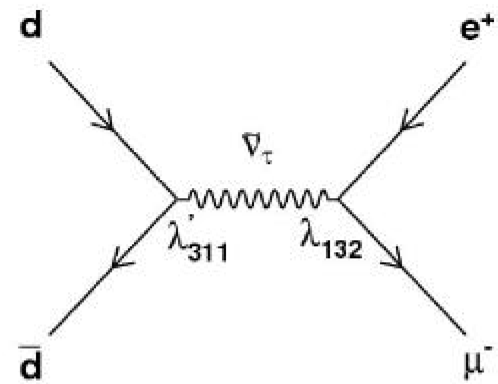




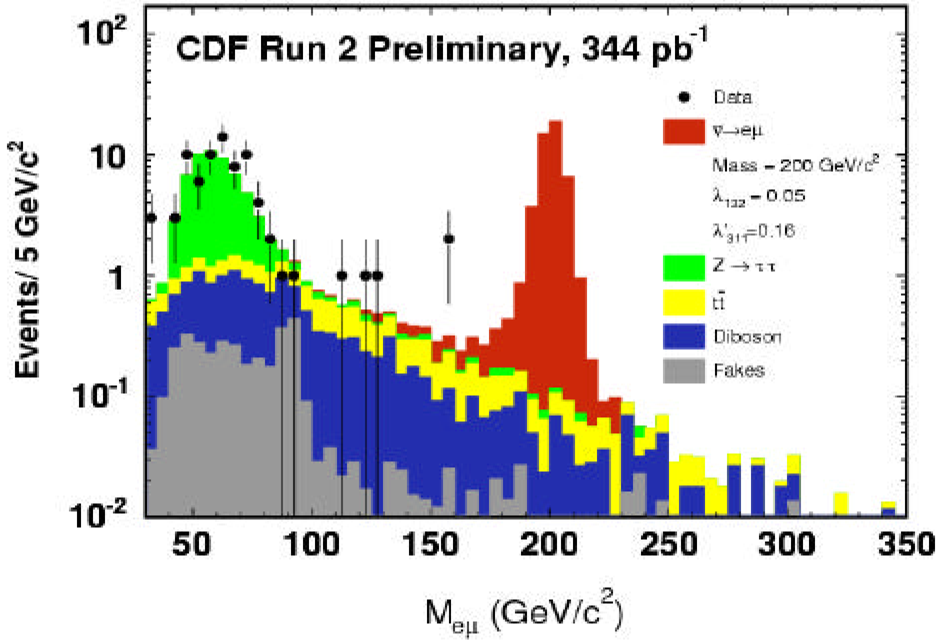
Sneutrinos in RPV Susy

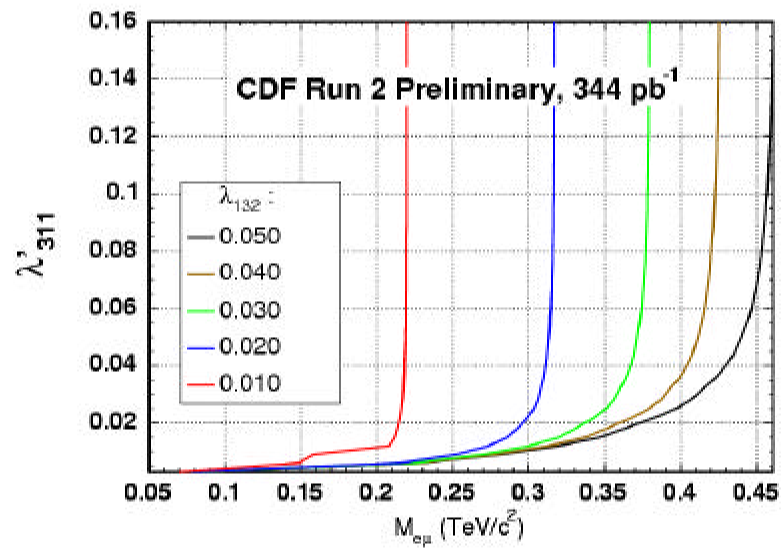
CDF searched for sneutrino production in e-μ events

- P_T lepton>20 GeV/c
- After selection main background from Z



No excess set limits





Living on a brane..

In recent years a new paradigm for the Physics BSM:

- Extra Dimensions are not small!
  - We are ants on a surface
  - Particles replaced by strings
- A whole new phenomenology
  - → Good!
  - A lot of new particles
    - → Very good!
  - No satisfactory description of current situation yet

Replacement of particles with strings seems promising to quantize gravity

- Has an important consequence:
  - Gravitation in our world is a remnant of a stronger interaction which propagates in extra (compactified) dimensions
- Current limits from gravitational experiments leave room for a rich spectrum of searches

Different options

Arkani-Hamed, Dimopolous,Dvali (ADD):

- Several extra dimensions
  - Gravity freely propagates in the (n>2) ED, compactified
  - $M^2_{Pl} \sim R^n M_s^{n+2}$, Ms: string scale

Dienes, Dudas, Gherghetta (DDG)

- TeV^{-1} ED
  - $n \geq 1$, Mc is the compatification scale

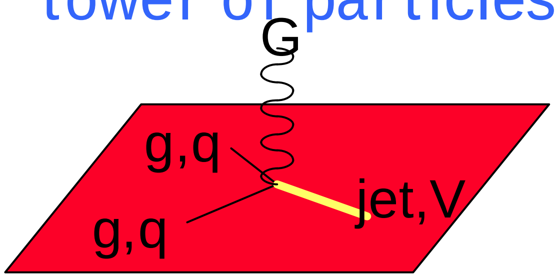
Randall-Sundrum (RS)

- One highly curved ED
  - Gravity is localized in the ED
  - Scale of physical phenomena on the TeV-brane is specified by an exponential warp factor:
  - $\Lambda_\pi = M_{Pl} e^{-kRc\pi}$
  - $\Lambda_\pi \sim$ TeV if $kR_c \sim 11\text{-}12$. Where Rc is the compactification radius and *k* is the curvature scale

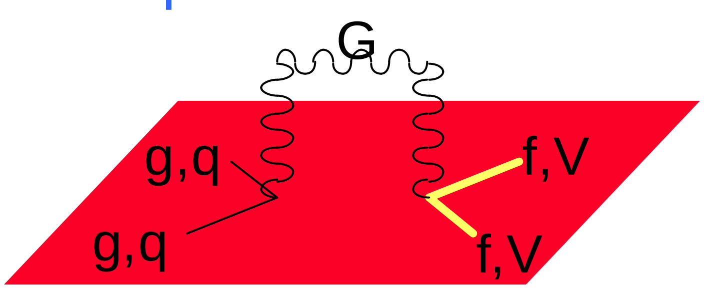
Extra Dimensions

Phenomenology at Tevatron collider:

- Direct production of graviton/Kaluza Klein excitations (a whole tower of particles…)



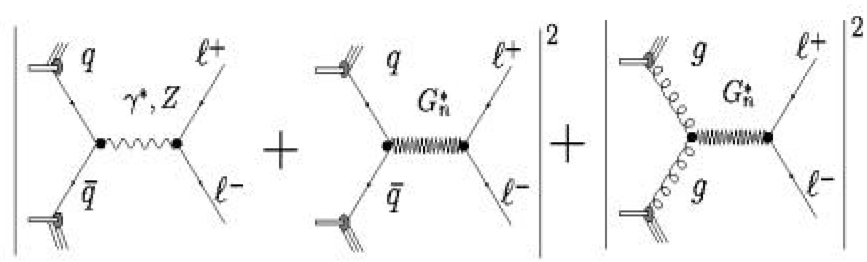
- Indirect effect (i.e. modification of spectra/cross section)



- CDF and D0 searched for modification of ee,$\mu\mu$,$\gamma\gamma$ production
  - Interpreted in both LED and RS models
- D0 also searched for effects of TeV^{-1} ED in its ee data
- Searches for excess of missing energy in jet events could be interpreted within the ED framework
  - CDF performed a search in 70 pb-1 which has not been updated to the current dataset

LED with dileptons and γγ

Search for enhanced dilepton production:



Gravity effects parametrized by η_G:

$$\frac{d^2 s}{d\mathrm{M}\; d\cos q^*} = f_{SM} + f_{\mathrm{int}} h_G + f_{KK} h_G^2$$

ee, ?? invariant mass

scatter. angle

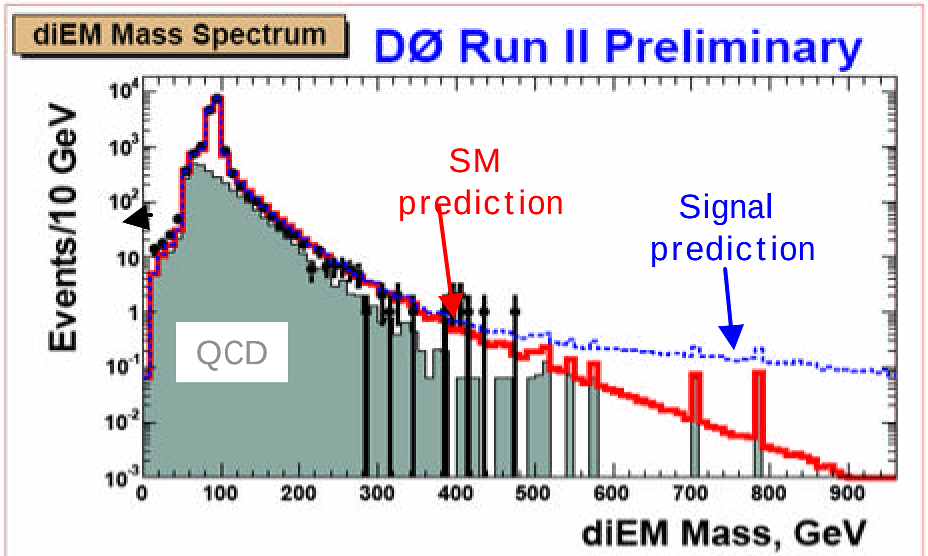
Functions of M & cosθ* determined by theory

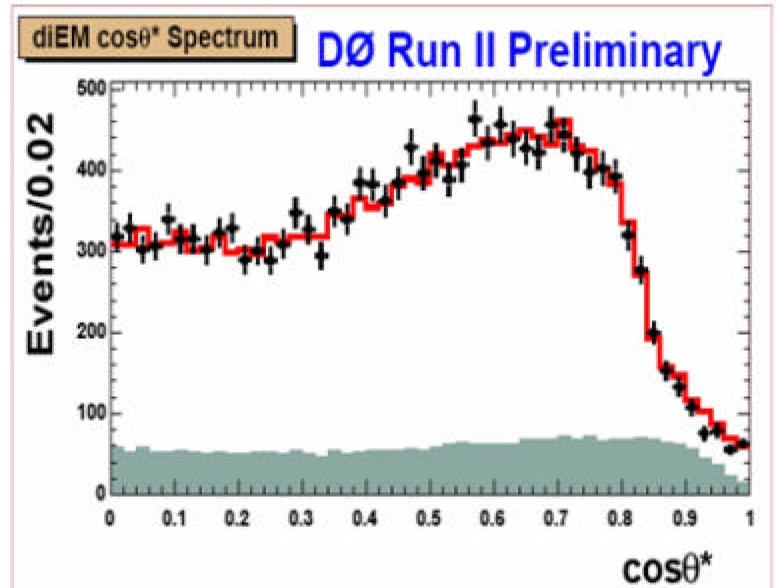
DØ Search Strategy:

- Fit distribution of M vs cosθ* of Data – SM
- Extract $?_G$ from the fit
- Translate $?_G$ into M_s limit
  - $\eta_G = F/M_s^4$
  - F model dependent parameter ~1:
    - ⇨ GRW: 1
    - ⇨ HLZ: $F = \log(M_s^2/M^2)$, n=2; $F = 2/(n-2)$, n > 2
    - ⇨ Hewett F= 2 ?/p, ? = ±1
    - ⇨ M_s is the UV cutoff $= M_{PL(4+n\ \mathrm{dim})}$

LED (ee + γγ): graviton exchange

Results since 04:





Cosθ* spectrum

M_{ee}, $M_{\gamma\gamma}$ and cosθ* → Data consistent with background expectation

Bayesian likelihood fitting → set 95% CL on η_G

95% CL mass limits on Fundamental Planck Scale(Ms) (in TeV)

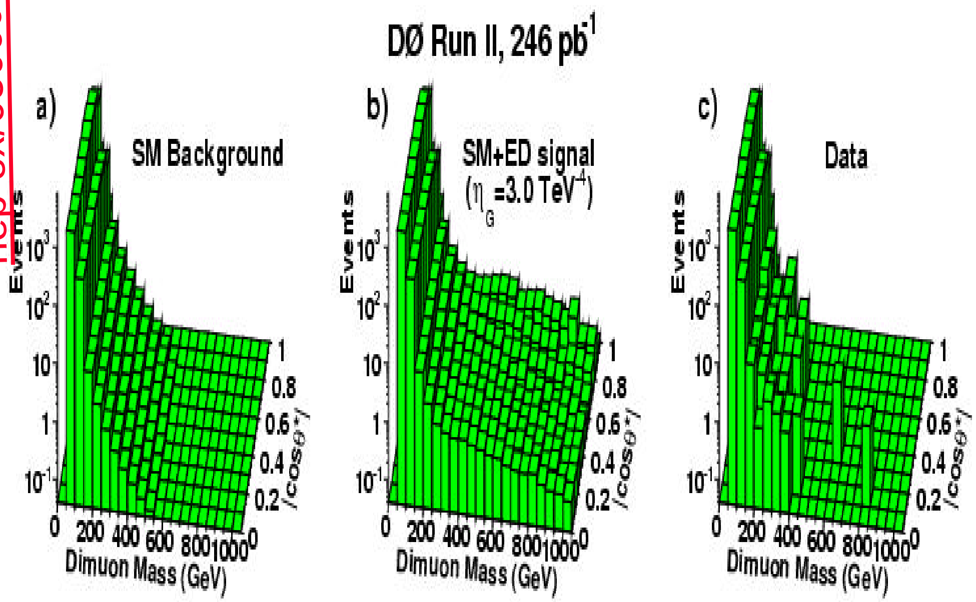
	GRW	HLZ for n = 2	3	4	5	6	7	Hewett λ = +1
DØ RunII	1.36	1.56	1.61	1.36	1.23	1.14	1.08	1.22
DØ RunI + Run II	1.43	1.67	1.70	1.43	1.29	1.20	1.14	1.28

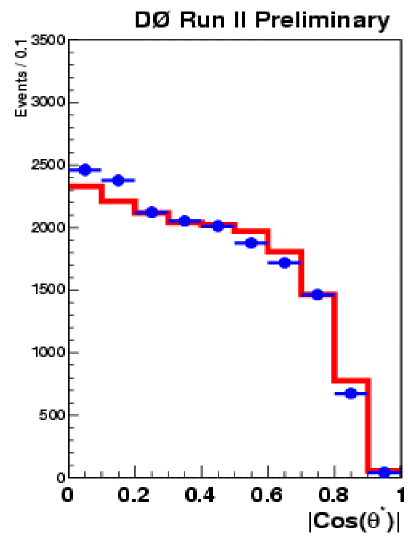
hep-ex/0506063, Submitted to PRL

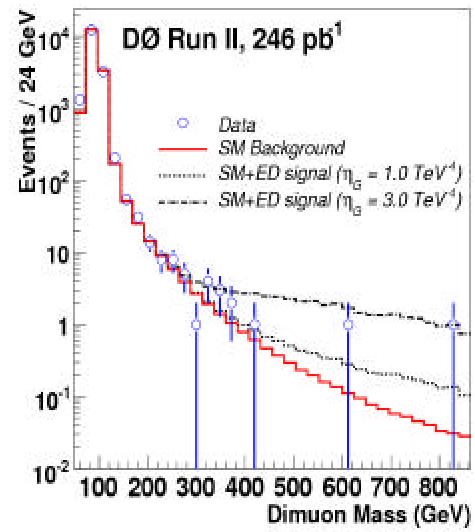
LED with μμ

Search for

- ⇨ 2 μ-like obj with P_T>15 GeV/c
- ⇨ Mμμ>50 GeV/c2







No deviation from SM in data

$$\eta_G = 0.00 \pm^{0.33}_{0.00} \text{ TeV}^{-4}$$

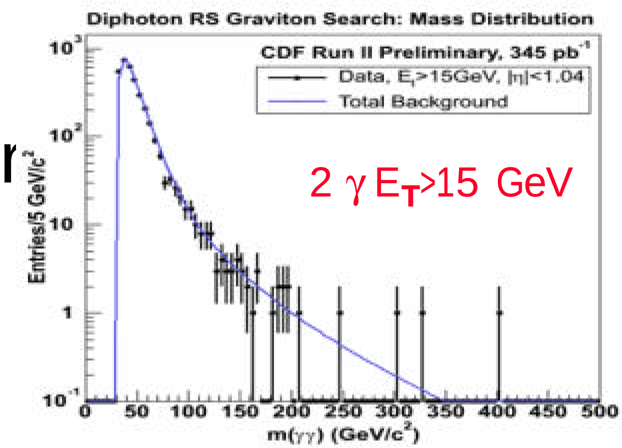
$$\eta_G^{95\%} = 0.71 \text{ TeV}^{-4}$$

Lower limits on the fundamental Plank scale, M_S in TeV

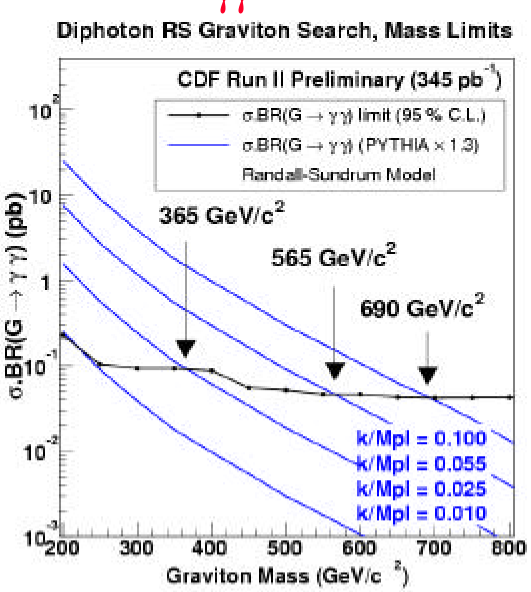
GRW	HLZ for n =						Hewett
	2	3	4	5	6	7	**l = +1/-1**
1.09	1.00	1.29	1.09	0.98	0.91	0.86	0.97/0.95

Randall-Sundrum Graviton

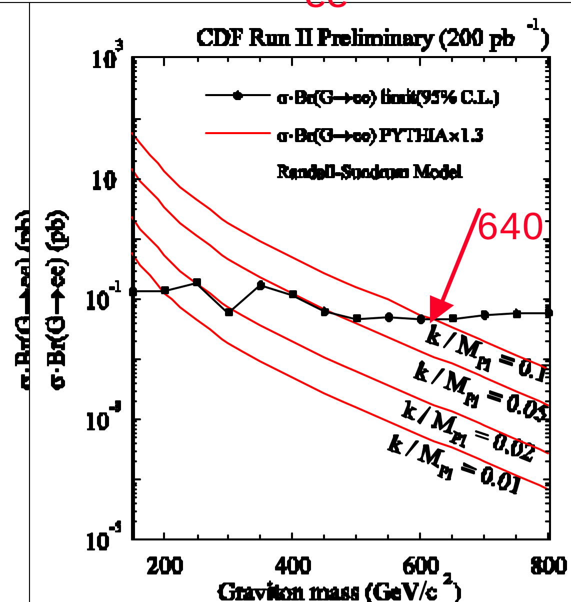
RS graviton is a spin 2 particle. KK searched as a peak in dilepton (see later) or $\gamma\gamma$ invariant mass (BF(G→gg)=2xBF(G→ee))



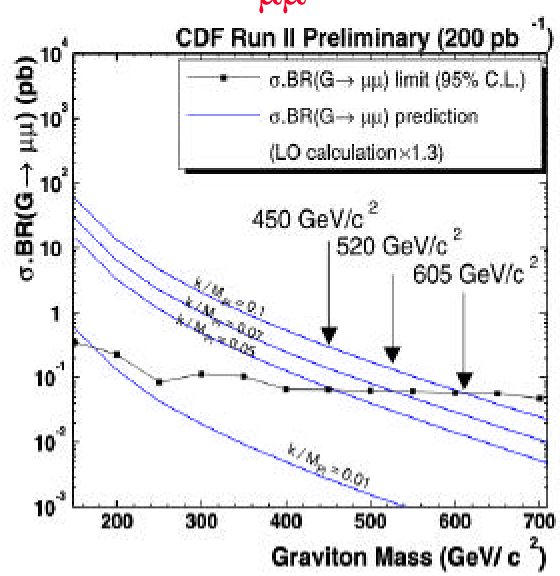
γγ



ee



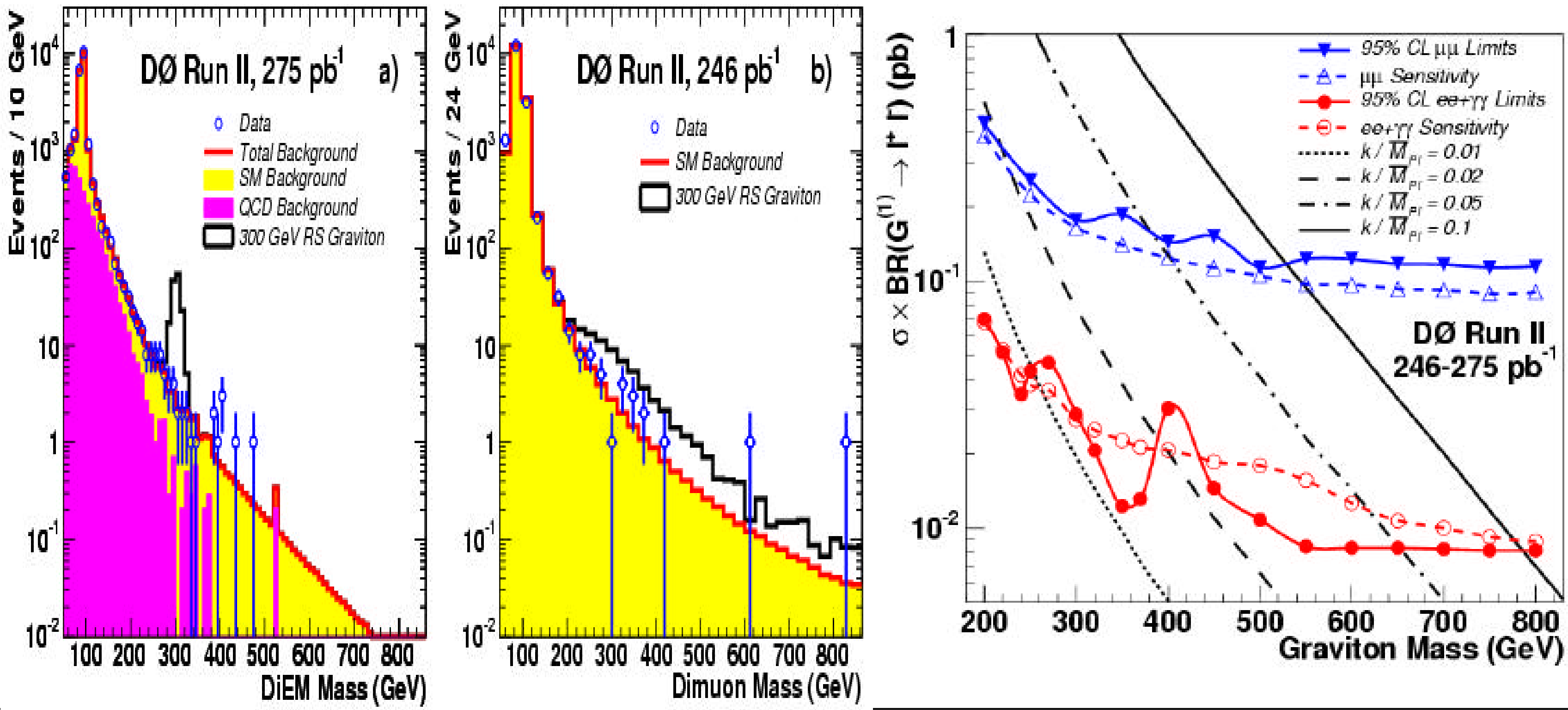
μμ



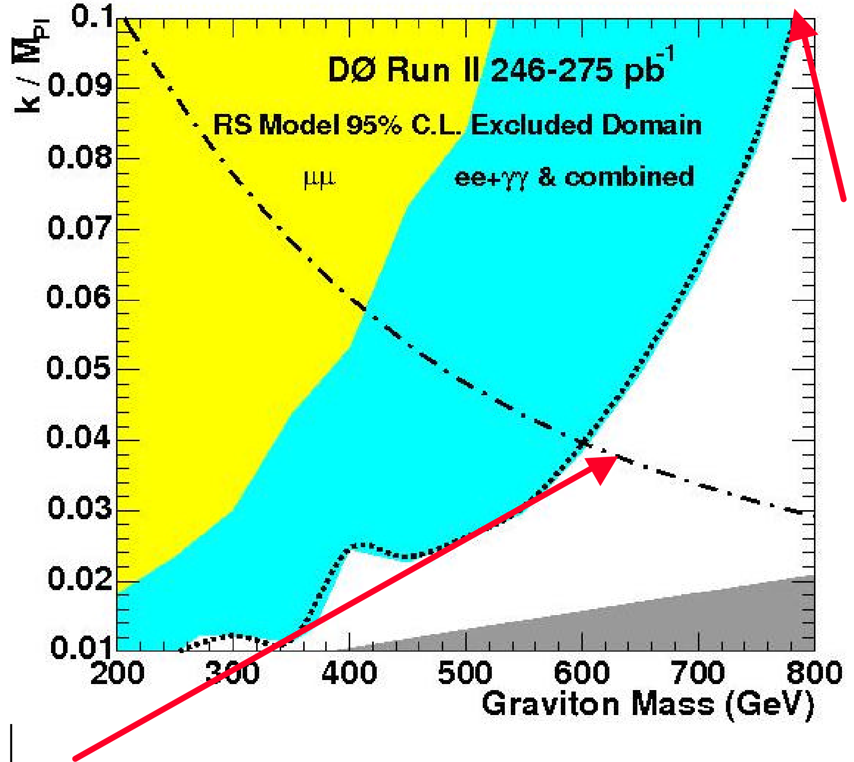
Randall-Sundrum Graviton

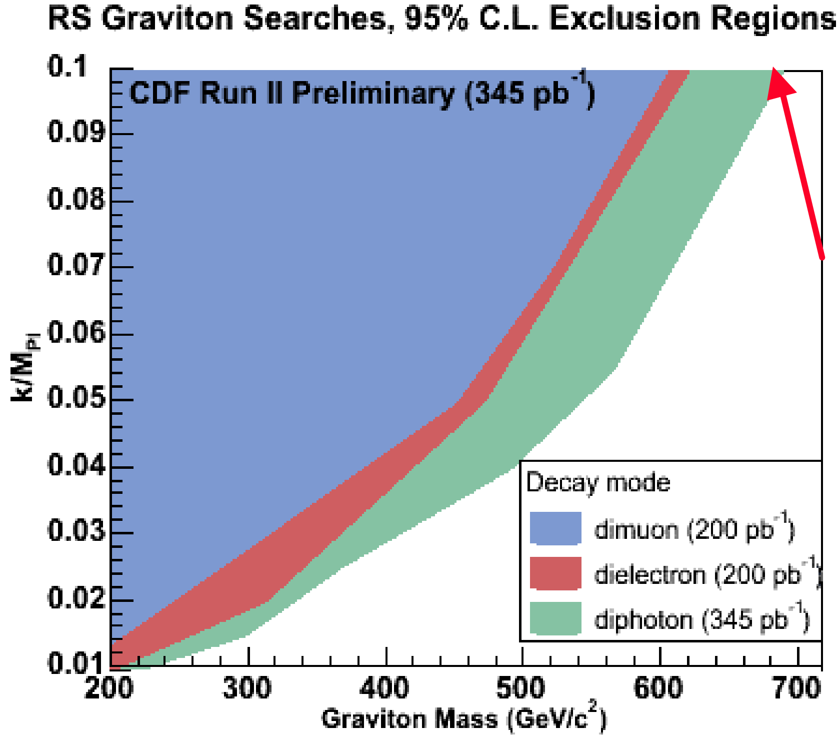
D0 searches in dimuon and dielectron+diphoton

- ⇨ e and g identified as EM clusters
  - → No attempt to separate
- ⇨ No excess over background



Randall-Sundrum Graviton (ee + mm+ gg)





Area below dashed-dotted line is excluded by EWK (LEP) data

ll has largest acceptance at low mass

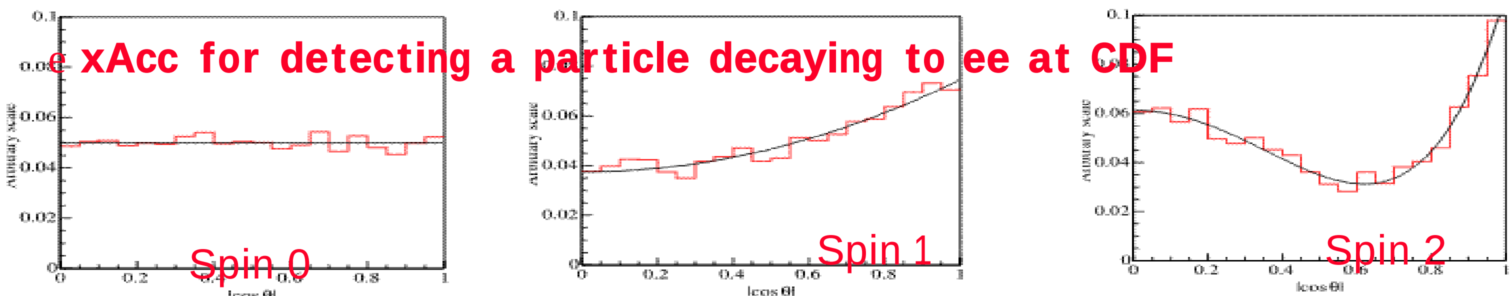
γγ has largest acceptance at high mass

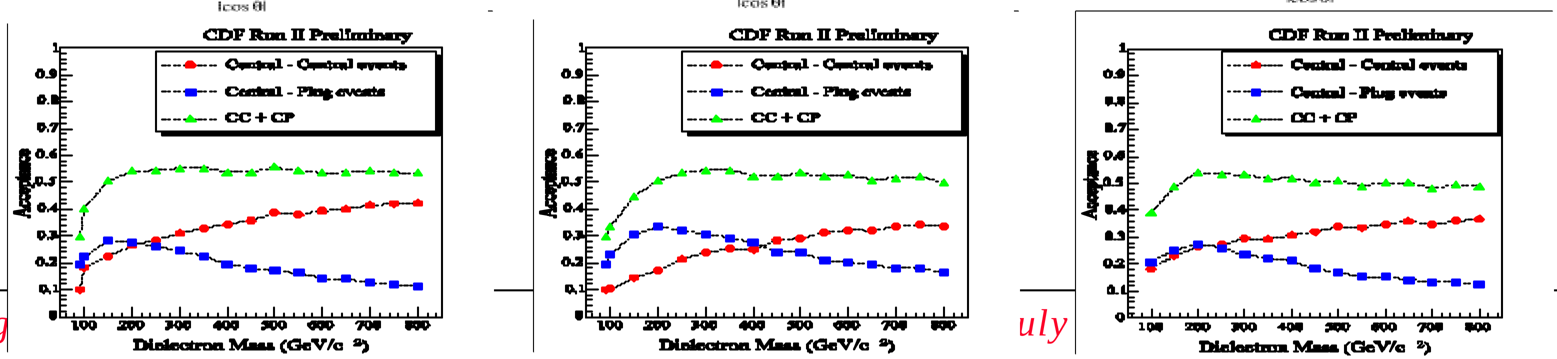
Searches in dilepton channels

There is more than search for ED in *ll* channels

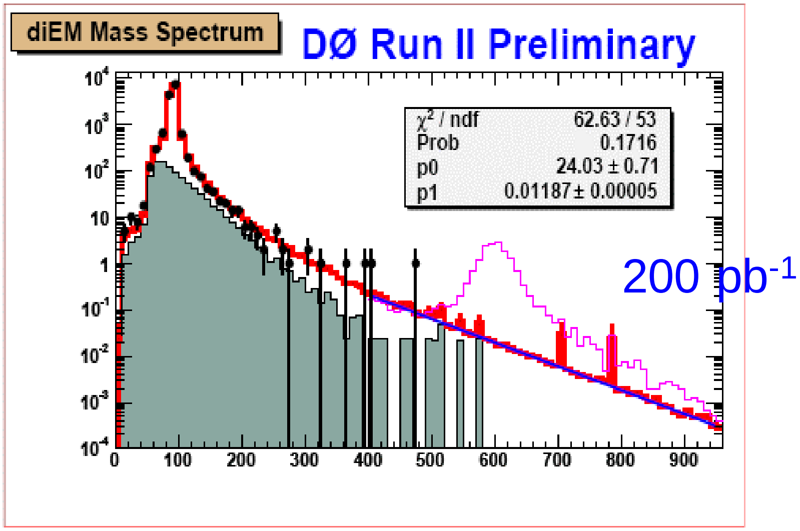
- Check measured spectrum against SM expectations for different backgrounds
  - ⇨ If you see a mass bump: signal found!
  - ⇨ Otherwise
    - → look at different possibilities for mother particle. The actual measurement, once corrected for the acceptance is of σxBR(p-pbar→X→ll)
    - → Interpretations (i.e. limits for physical states) dependent upon assumptions on couplings etc

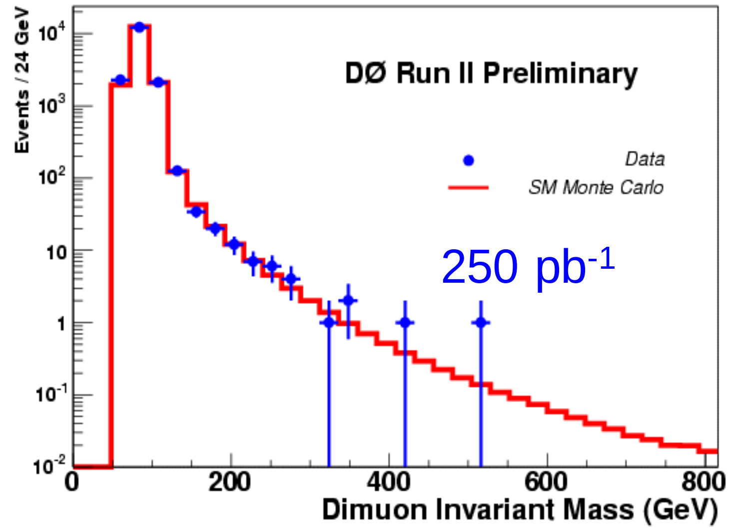
σ xAcc for detecting a particle decaying to ee at CDF

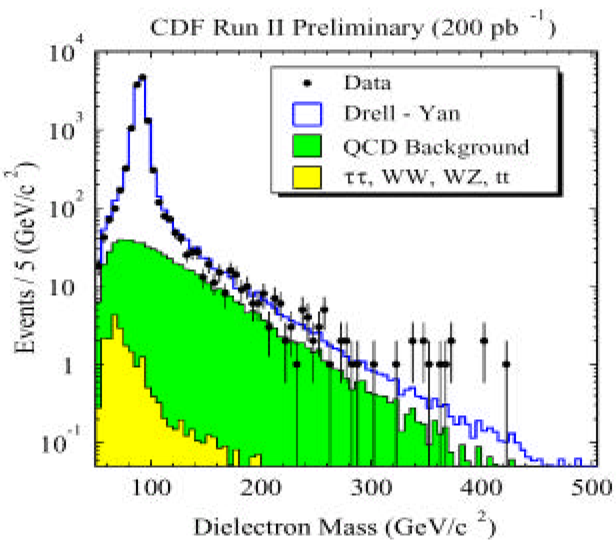


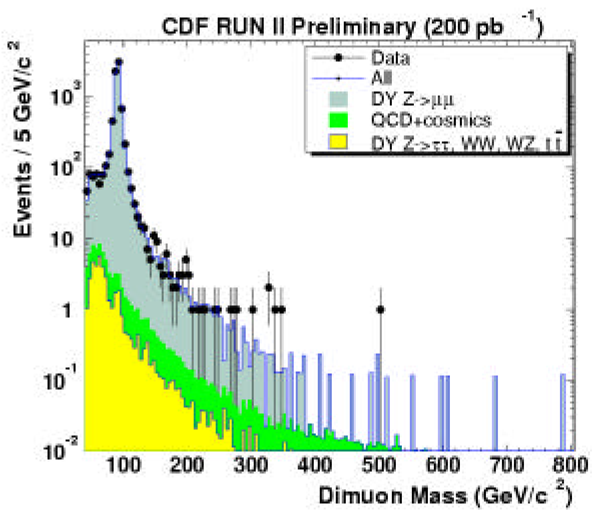


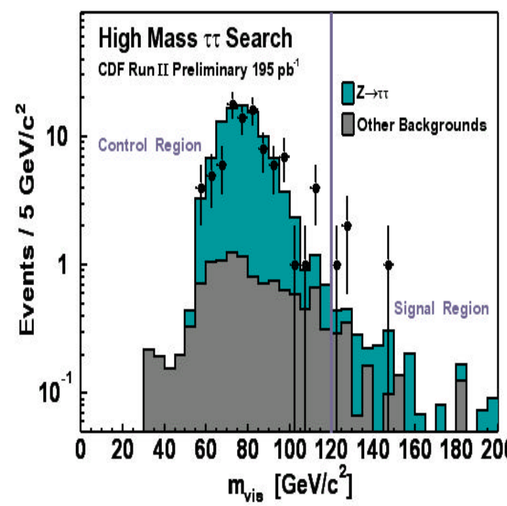
Search in high mass *ll*- cont.d









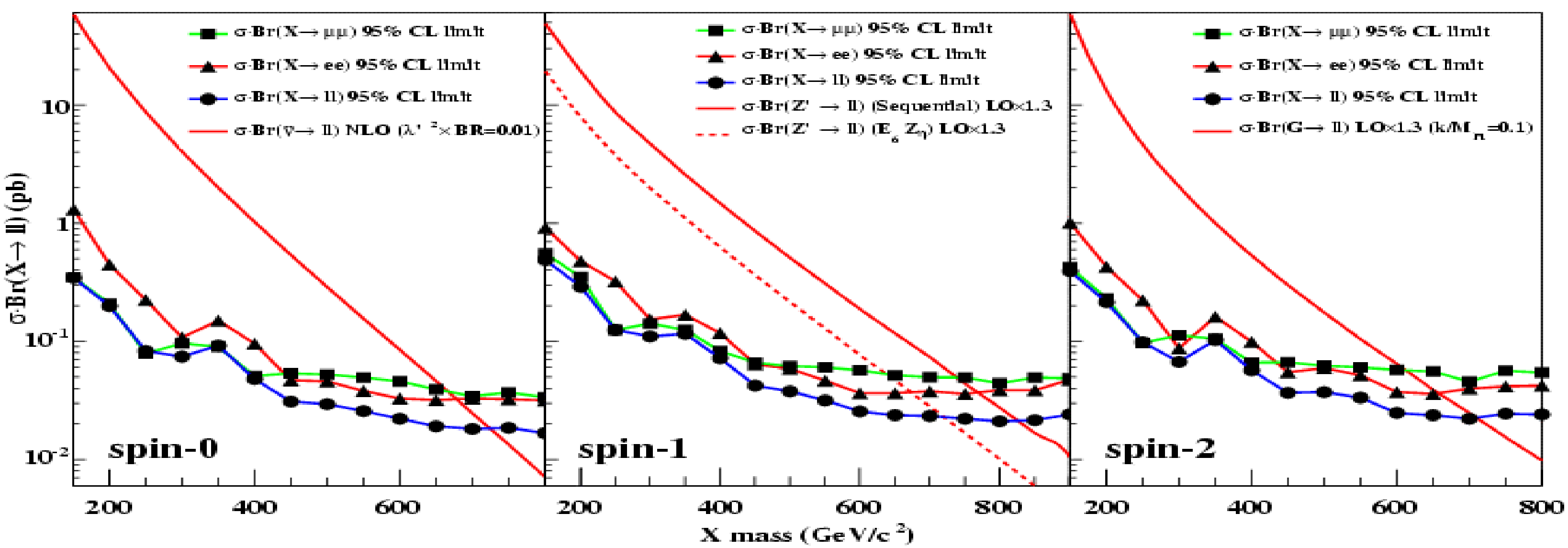


In absence of a signal

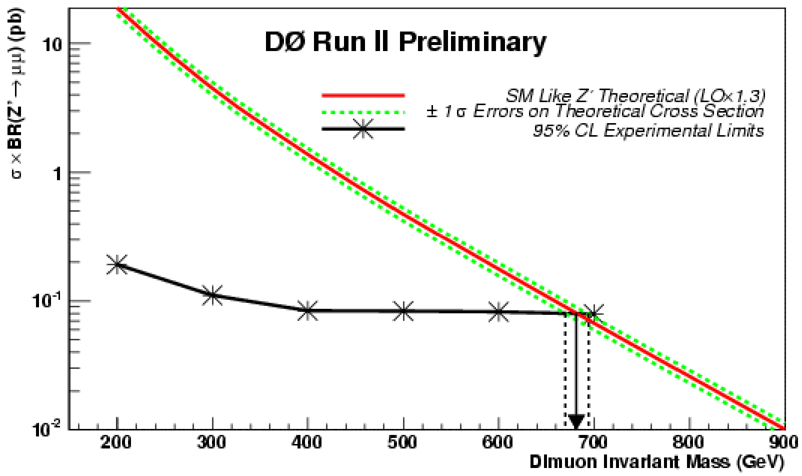
You can interpret the absence of a signal as an upper limit on new physics in different scenarios

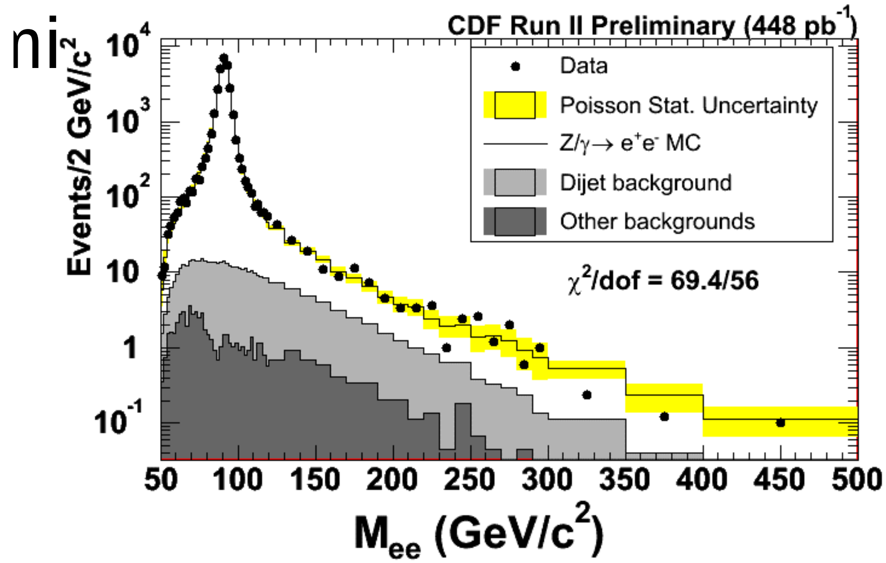
- Sequential neutral gauge boson (Spin 1)
- RS graviton (spin 2)
- Light Higgs scenario
- Technicolor

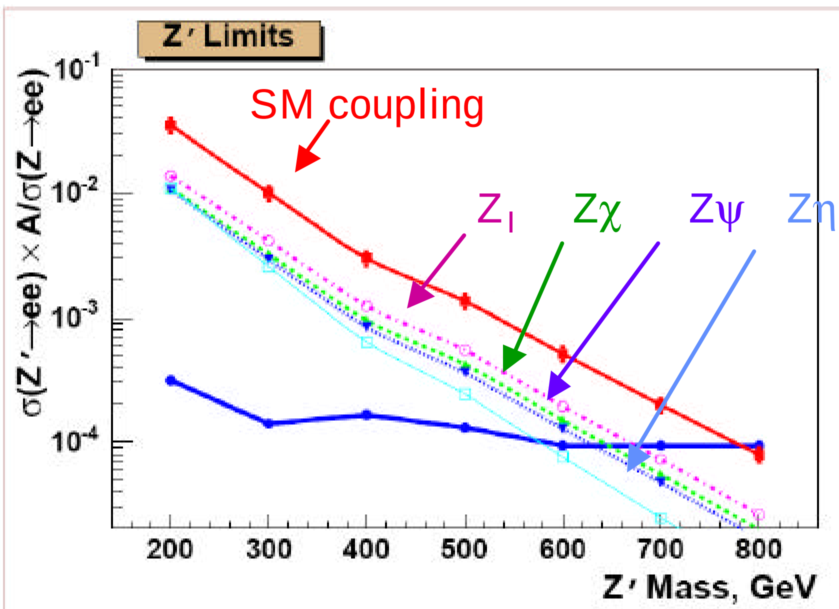
σxBR (X→ee,μμ)



Z' limits







SM Couplings	ee	mm	ee+mm	tt
CDF :	750	735	815	394
DØ:	780	680		

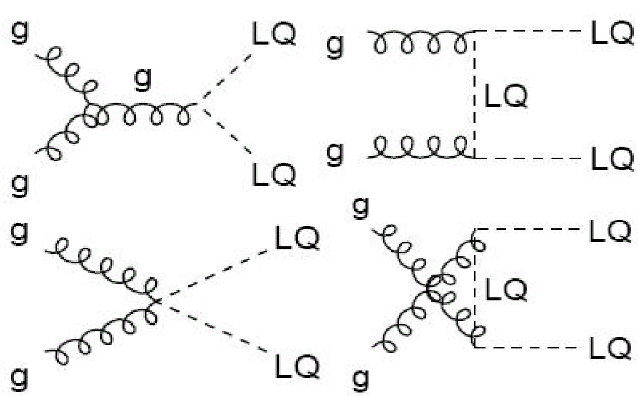
E_6	Z_I	Zc	Zψ	Zη	~200 pb^{-1}
CDF:	610	670	690	715	(ee+mm)
DØ:	575	640	650	680	(ee)

Very new limit CDF
ee Z'_{SM}>845 GeV with 448 pb^{-1}

Leptoquarks

The fermionic sector of the SM can be symmetrized by the introduction of LQ

- ⇨ Predicted in many models
- ⇨ Couple to both quarks and leptons, carry SU(3)c, B and L numbers, fractional electric charge, F=3B+L conserved



- ⇨ Relevant parameters:
- ⇨ Couplings λ_{ij} and
- ⇨ Decays, ordered according to BF(LQ→lq)

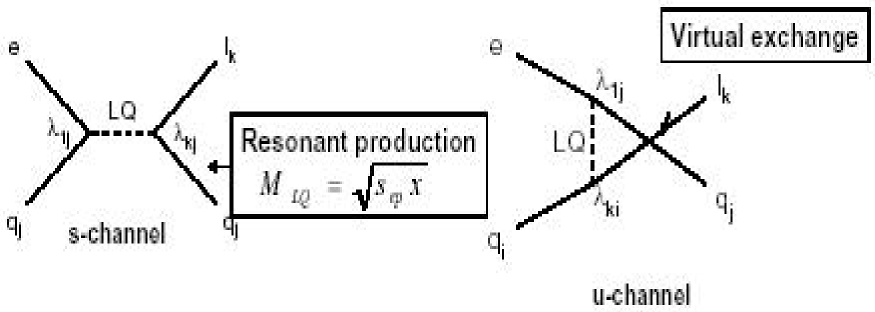
LQ have been searched at colliders (LEP, Tevatron, HERA) for both indirect effect and direct production

- ep colliders are a natural place for direct production of 1st generation LQ
- Pair-produced at the Tevatron where all generations are available:

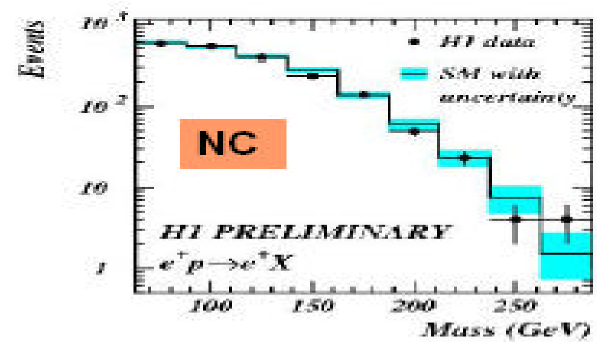
	1st Generation	2nd Generation	3rd Generation
$\beta=1$	$LQ\,\overline{LQ} \to e^- e^+ q\bar{q}$	$LQ\,\overline{LQ} \to \mu^+\mu^- q\bar{q}$	$LQ\,\overline{LQ} \to \tau^+\tau^- q\bar{q}$
$\beta=0.5$	$LQ\,\overline{LQ} \to e^\pm \nu_e q_i q_j$	$LQ\,\overline{LQ} \to \mu^\pm \nu_\mu q_i q_j$	$LQ\,\overline{LQ} \to \tau^\pm \nu\, q_i q_j$
$\beta=0$	$LQ\,\overline{LQ} \to \nu_e \nu_e q\bar{q}$	$LQ\,\overline{LQ} \to \nu_\mu \nu_\mu q\bar{q}$	$LQ\,\overline{LQ} \to \nu_\tau \nu_\tau q\bar{q}$

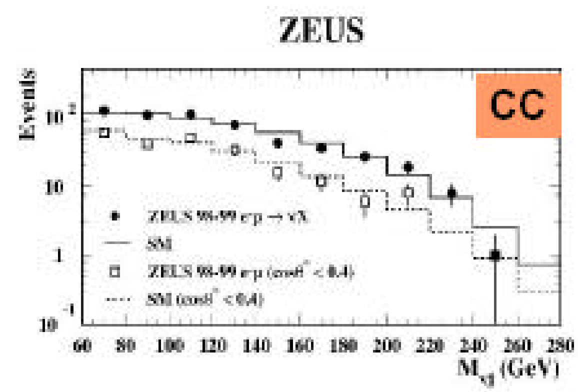
First generation

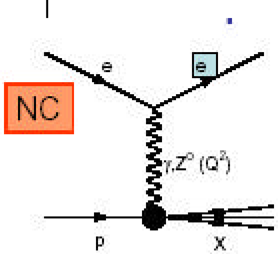
HERA unique facility for resonant production:



H1 search in NC events:



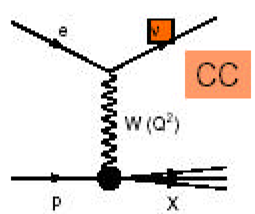




Q^2 – momentum transfer squared (“resolution”)

x – fraction of proton momentum carried by struck quark

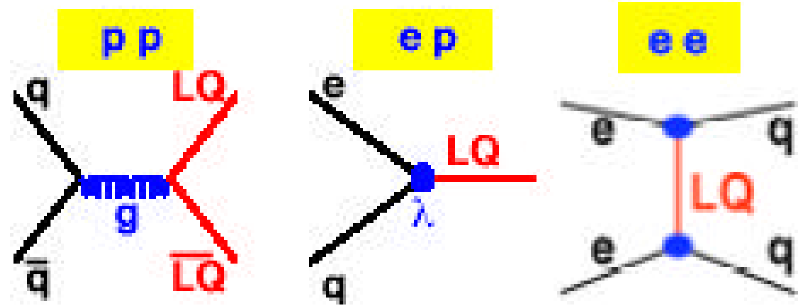
y – inelasticity (fractional electron loss)

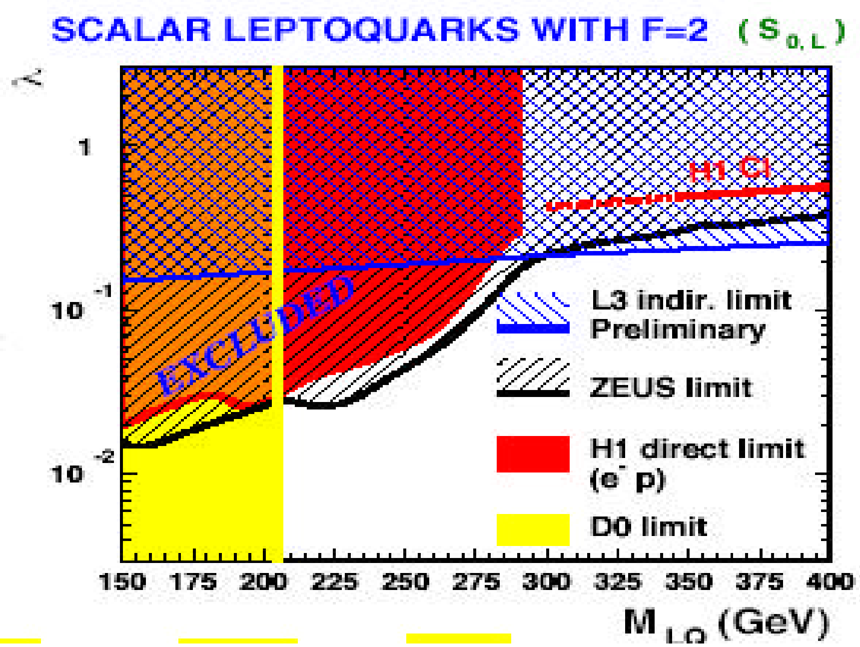


Limits at HERA

HERA:

- Resonant production of LQ:
  - ⇨ Dependence upon coupling
- No evidence,
  - ⇨ set limits





For λ about 0.3
M_{LQ}>290 GeV/c^2

Tevatron searches

D0 and CDF searched for LQ of 1st, 2nd, 3rd

- 1st generation → e+jet or ν+jet (β=0)
- 2nd generation → μ+jet or ν+jet
- 3rd generation → τ+jet or ν+jet
- For 1st and 2nd generation also e+jet+ν+jet case (intermediate case, β between 0 and 1)
  - ⇨ Search generation specific and generation blind
  - ⇨ The actual measurement can be one of the following:
    - → $\sigma \times \beta^2$ (two charged leptons and two jets)
      $\sigma \times 2\beta \times (1-\beta)$ (one charged l, 2 jets, neutrino)
      $\sigma \times (1-\beta)^2$ (two neutrinos, two jets in final state)
  - ⇨ Independent from couplings

LQ search in ννjj

$\beta' = BR(LQ \rightarrow \nu q) = 1$

Signature: Large MET and 2 jets

Sample Composition:
- W/Z + jets
- top
- QCD fakes

Expected =118±14

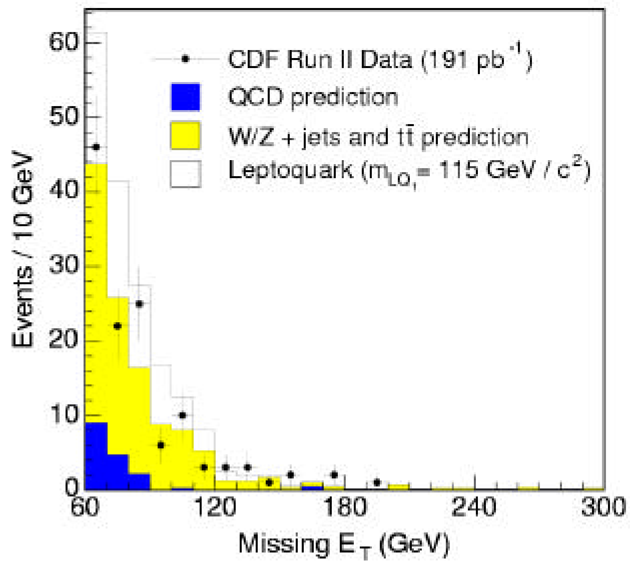
124 events seen after analysis cuts

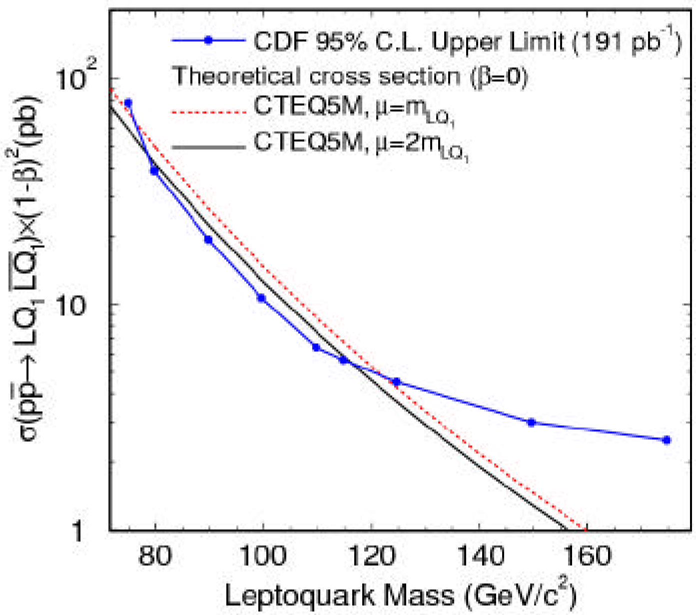
M(LQ) > 117 GeV/c^2 @ 95 % C.L. (1st generation)

Flavor independent
Phys.Rev.D71:112001,2005

D0 result with 85 pb^{-1} not yet updated

M(LQ)>109 GeV/c^2

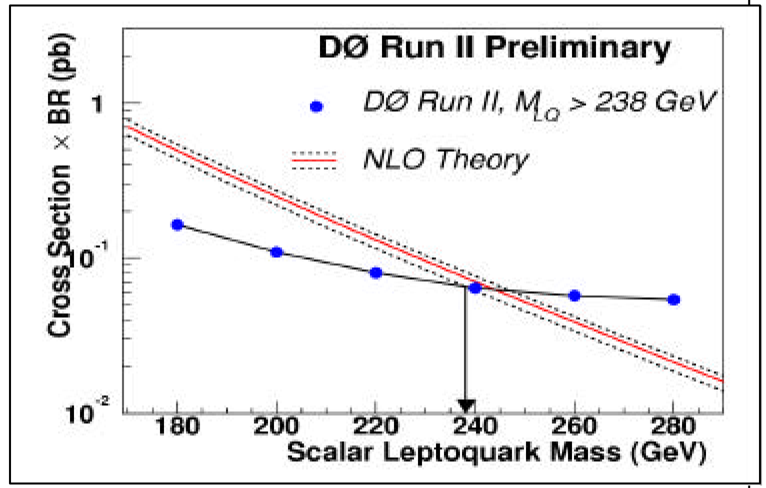




1^{st} generation

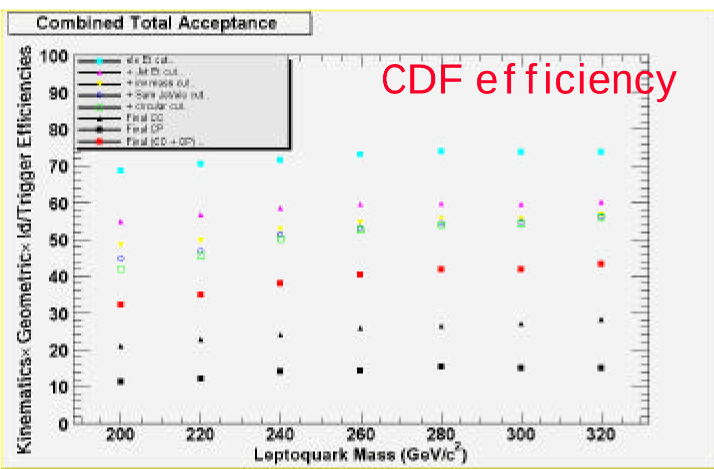
D0 searched in ee+jets

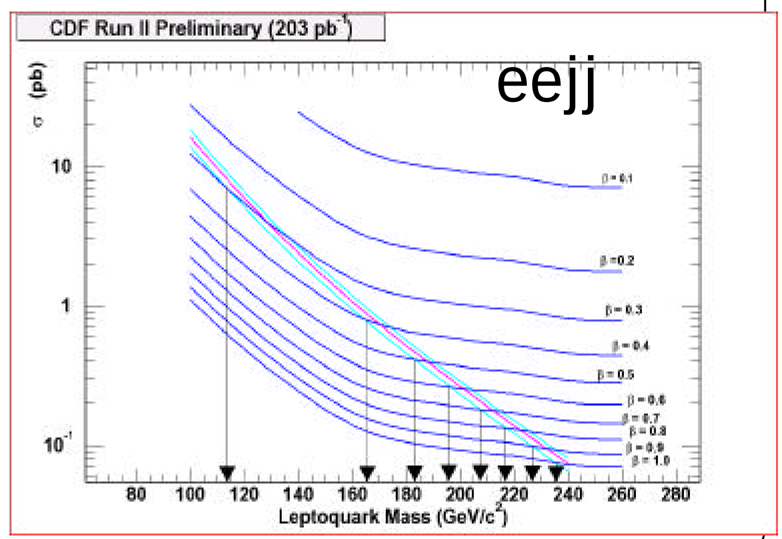
- 2 EM cluster E_T>25 GeV
- 2 jet E_T>20 GeV, |η |<2.4
- Z Veto
  - Bckg:Z/DY, QCD,ttbar
  - Signal ε~12-20%



CDF searched with similar selection criteria

- 2 e, 2 jets, no Z

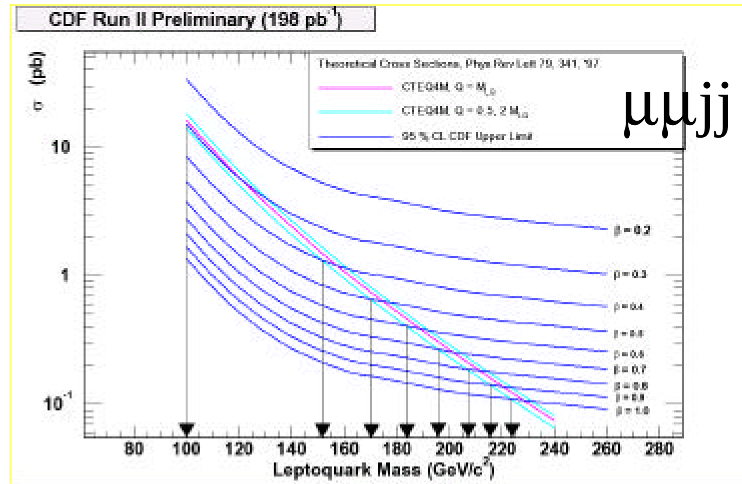




2^{nd} generation

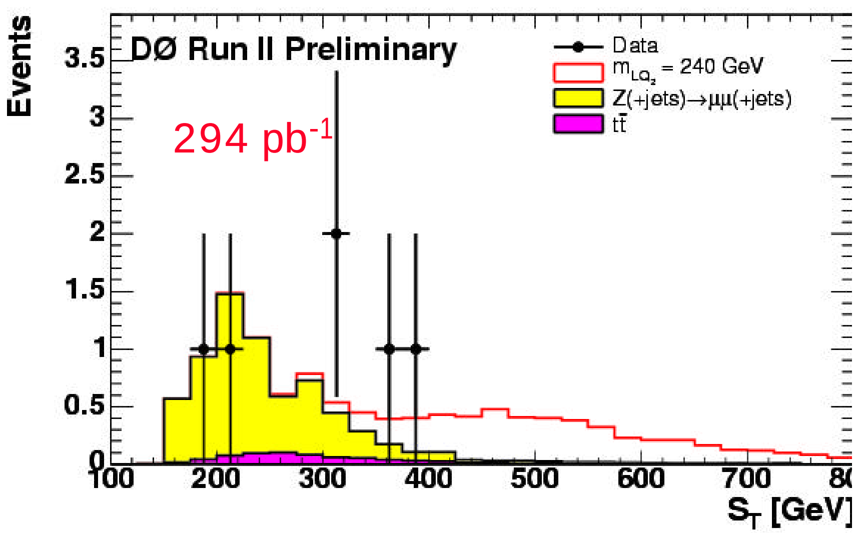
CDF searches μμjj events:

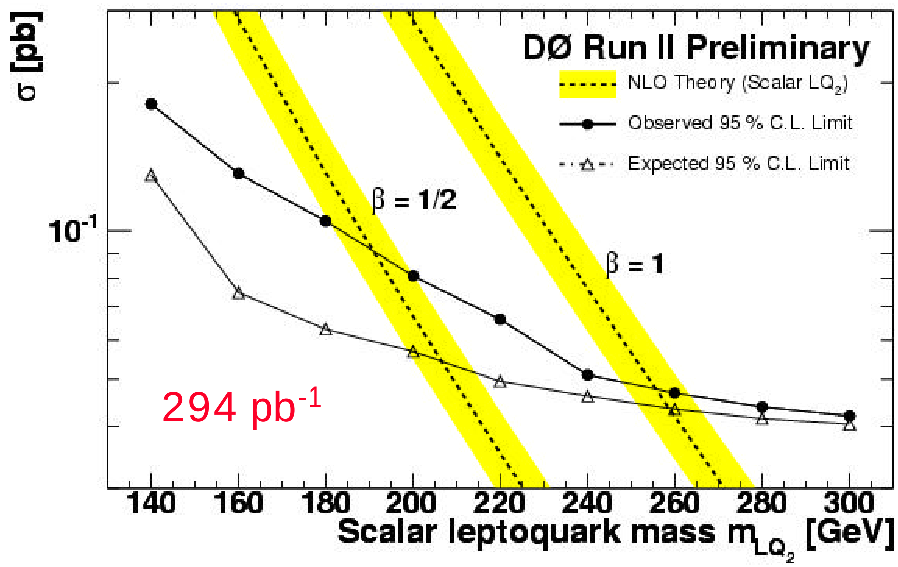
- 2 μ P_T> 25 GeV/c
- 2 j E_T(j1,j2)>(30,15) GeV
- Z removal
  - ⇨Bckg: DY, top, fakes



D0 searches in μμjj

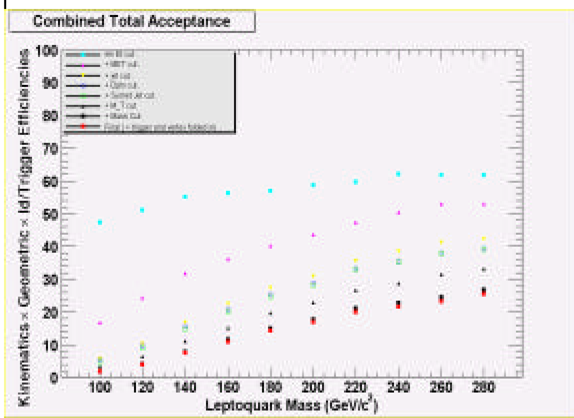
- 2 μ P_T> 15 GeV/c, 2j E_T>25 GeV

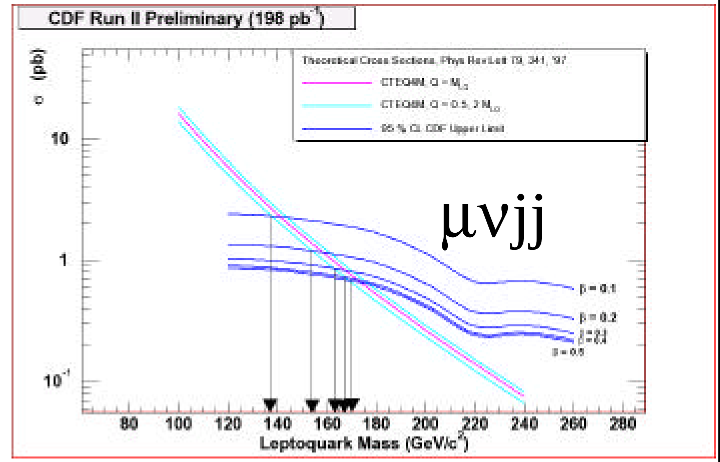


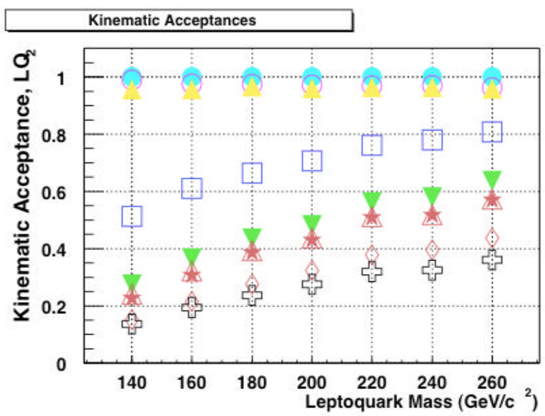


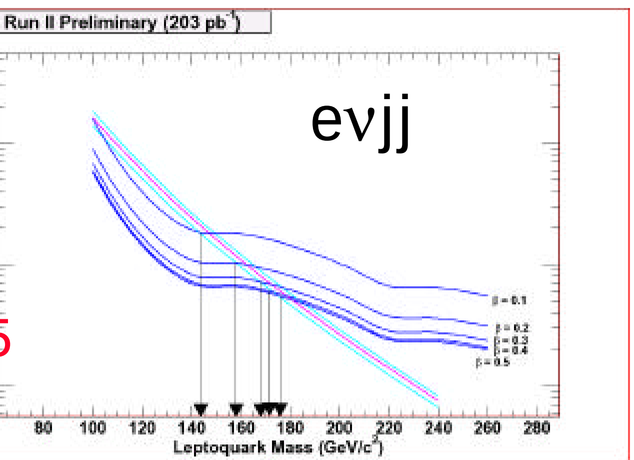
Scalar LQ in lepton + MET+jets

Exclude at 95% CL M_{LQ}<170 GeV/c^2 for β = 0.5





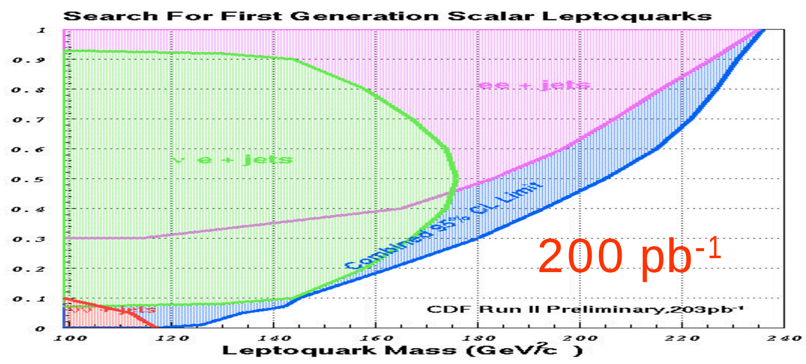


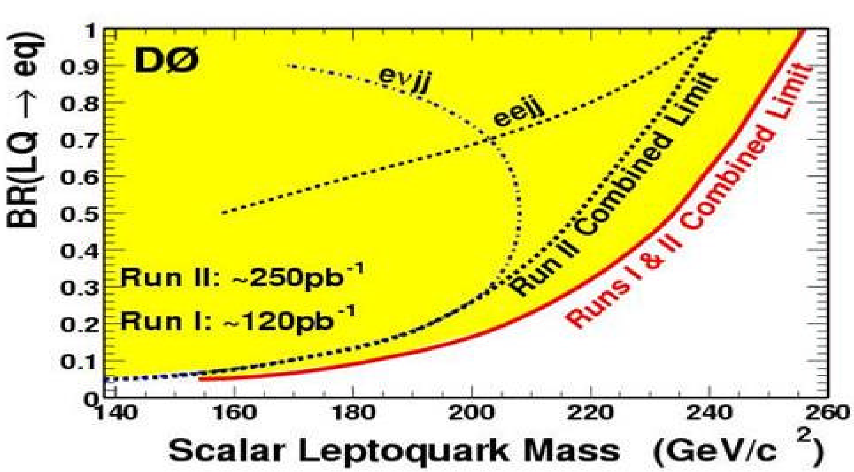


Exclude at 95% CL M_{LQ}<176 GeV/c^2 for β = 0.5

1^{st} and 2^{nd} combined

Channels: eejj,,eνjj, ννjj



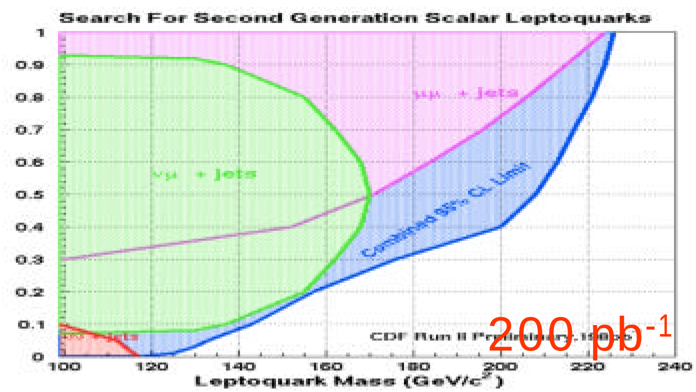


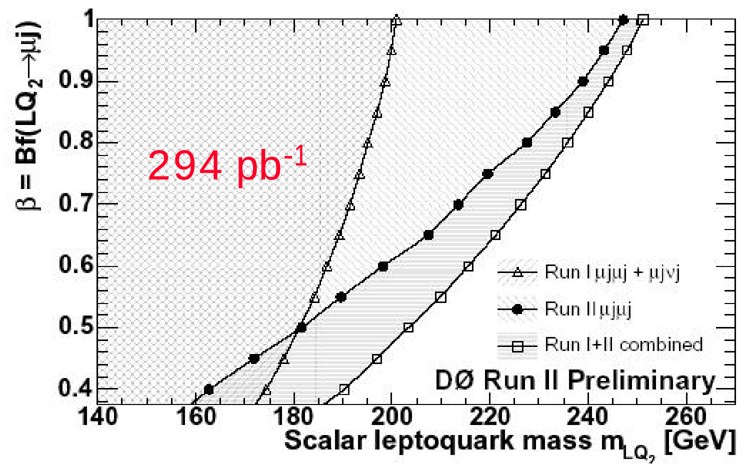
For β =1, I generation

CDF: Run II, M_{LQ} > 235 GeV/c^2

D0: Run I + II, M_{LQ} > 256 GeV/c^2

Channels: μμjj,ννjj,μνjj





for β =1, II generation

CDF: Run II, M_{LQ} > 224 GeV/c^2

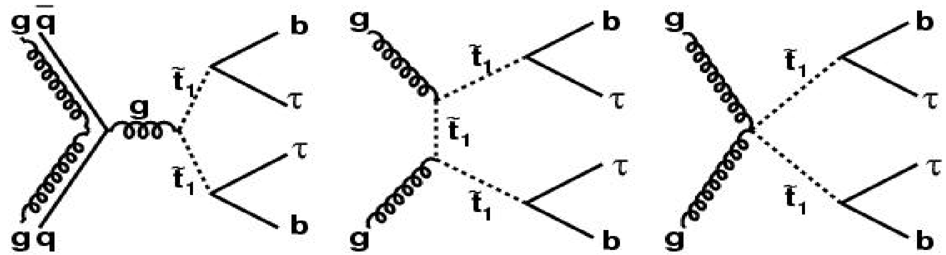
D0: Run I+II, M_{LQ} > 251 GeV/c^2

3rd generation LQ

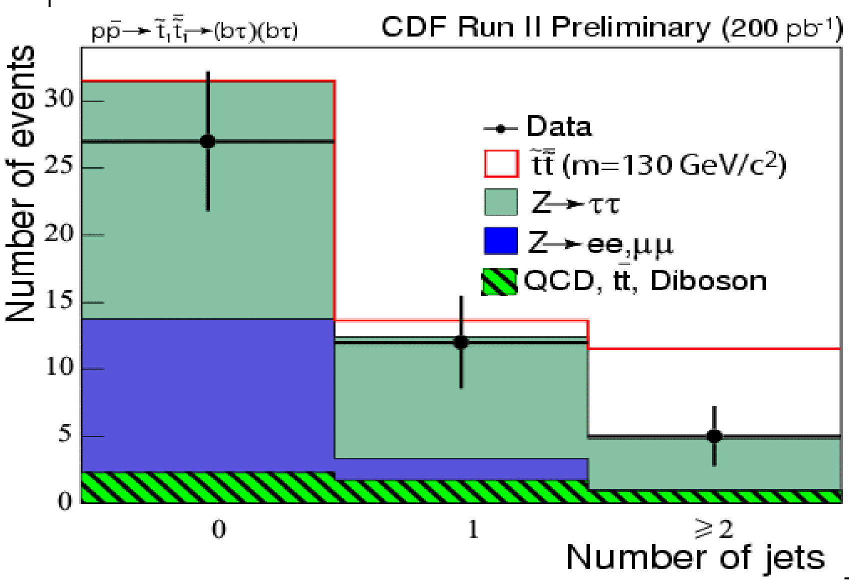
Limits obtained from stop searches in RPV SUSY

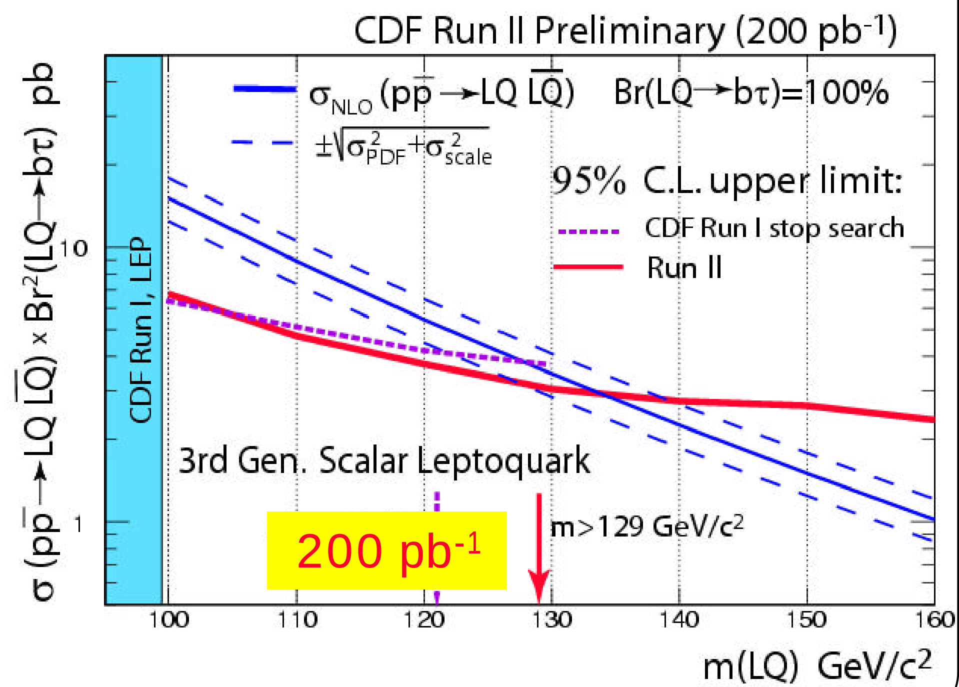
⇨ 1 l(e,μ)+1τ+≥2 j

→ 1 τ leptonic decay



	e+τ	μ+τ	SUM
Expected	2.6±0.6	2.2±0.5	4.8±0.7
Observed	2	3	5





Other possibilities

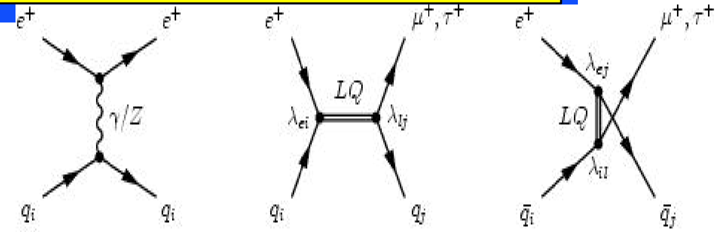
There are scenarios which include the existence of

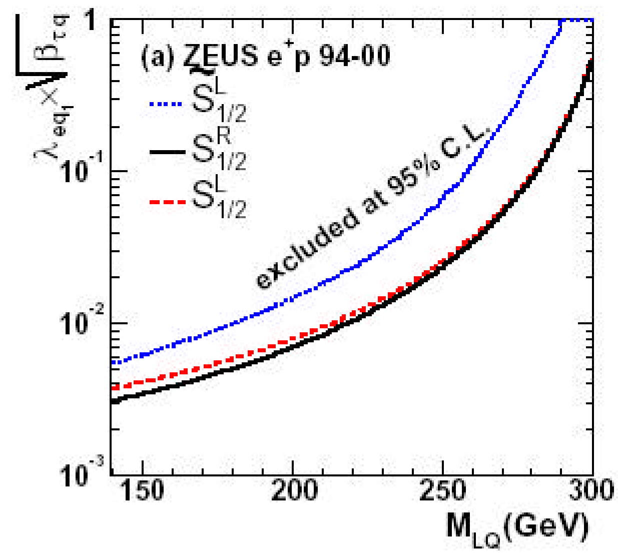
- ⇨ LFV
- ⇨ Additional charged bosons (W')
- ⇨ compositness
- ⇨ excited leptons
- ⇨ ...

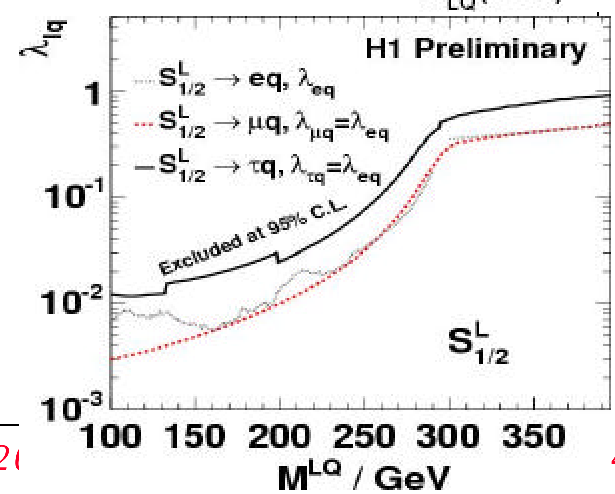
Lepton Flavour Violation

At HERA studied LFV processes ep→μ(τ)+j

- Extension of LQ searches
- Searches performed by ZEUS and H1
  - ⇨ ZEUS final results based on the whole HERA-I dataset (~180pb^{-1})
    - → No event pass selection, set limits in the framework of LQ theory
  - ⇨ H1, preliminary results based on 66pb^{-1} dataset
    - → No candidate in m channel, 0.74±0.25 exp.
    - → 1 cand in t chann 0.56 ± 0.16 exp.
    - → Set limits







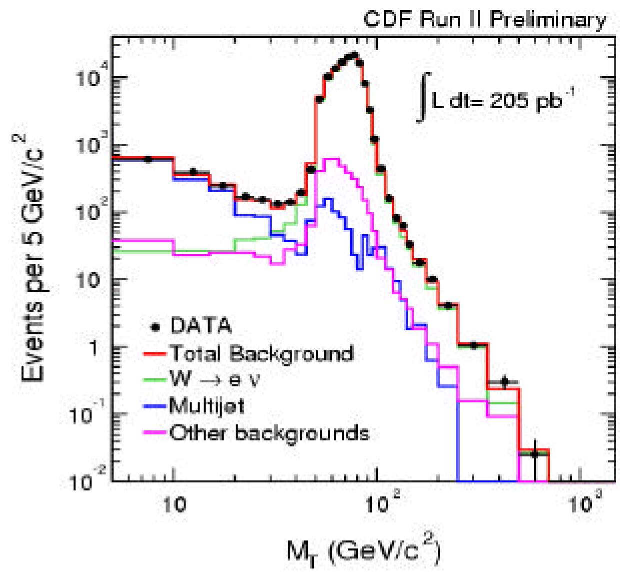
W'

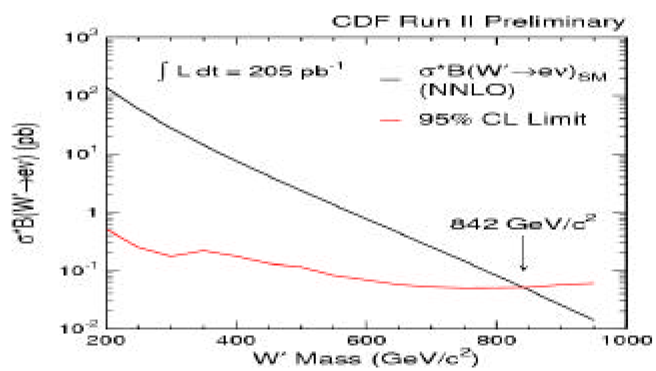
A possibility in (for example)

- Left-Right Symmetric Model: $SU(2)_L x SU(2)_R x U(1)_Y$
- High P_T e+MET
  - Compare M_T distribution

Highest M_T events at 524 GeV/c^2

- No excess over background





	Events in Each M_T Bins (GeV/c^2)				
	200 - 250	250 - 350	350 - 500	500 - 700	700 - 1000
$W \to e\nu$	35.8 ± 4.3	19.5 ± 2.5	4.34 ± 0.99	1.08 ± 0.73	0.0 ± 0.0
Jets	2.6 ± 6.3	0.0 ± 3.4	0.0 ± 0.31	0.0 ± 0.0	0.0 ± 0.0
Other Backgrounds	5.0 ± 0.7	3.2 ± 1.2	2.76 ± 3.26	0.12 ± 0.04	0.04 ± 0.02
Total Background	43.3 ± 7.6	22.7 ± 4.5	7.10 ± 3.66	1.20 ± 0.77	0.04 ± 0.02
Data	41	21	9	1	0

Limit: $M(W'_{SM}) > 842$ GeV/c^2

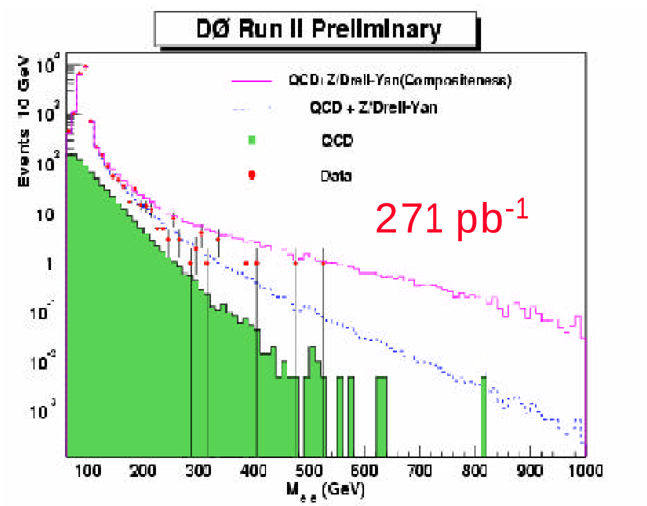
Run I results : $M(W'_{SM}) > 754$ GeV/c^2 CDF

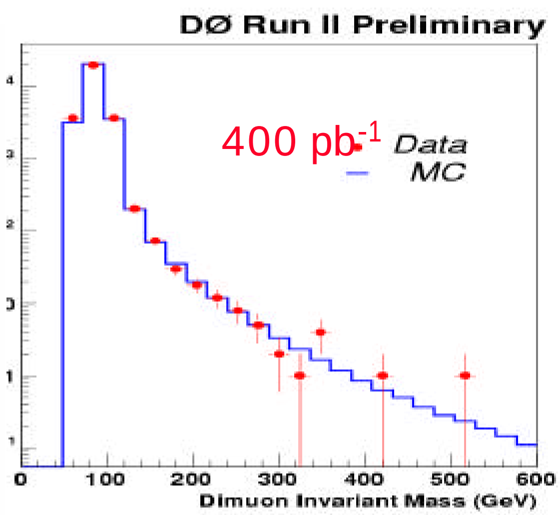
Compositness

preons, elementary constituents of leptons and quarks, are searched at low energy where they appear as bound states. Effects parametrized by

- scale, Λ and sign(destr. or constr.interference)
  - ⇨ In Run I CDF and D0 searched for by studying the dilepton spectra
  - ⇨ In Run II D0 studied

$$\frac{d^2 s}{dM\, d\cos q^*} = f_{SM} + \frac{I}{\Lambda^2} + \frac{C}{\Lambda^4}$$





Λ>3.6(+)-9.1(-) TeV (ee)

Run I:3.3-6.1

Λ>4.2(+)-9.8(-) TeV (μμ)

Conclusion

The Standard Model has been very successful

- still missing piece (Higgs particle)
  - ⇨ and possibilities of inconsistencies ahead of us
- Hints of open questions

Models for new physics still looking for experimental evidence

- challenging task…no unique path yet

We are working at the energy frontier and a very exciting period ahead of us in experimental physics

- Tevatron/HERA will lead the path to the LHC
  - ⇨ Almost an order of magnitude in energy available
    - → New regime?