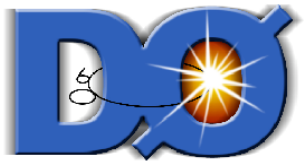
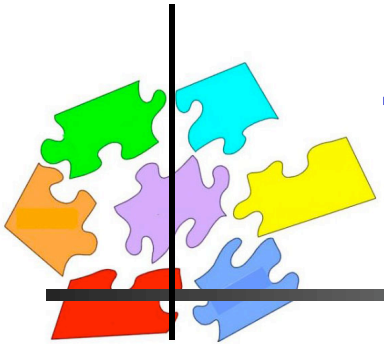


Recent results on non-SUSY searches for new physics at the TeVatron



Simona Rolli

Tufts University

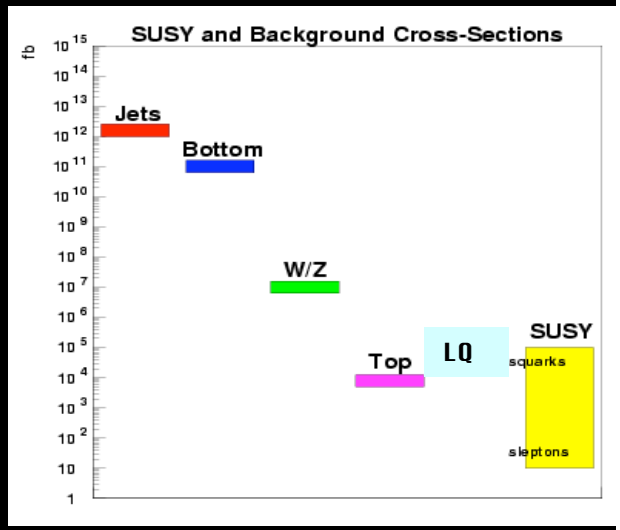
Introduction

Exciting time now at the TeVatron !

frenzy activity in physics analysis

Tests of the SM
works remarkably well
Search for new physics
hints here and there...

Cross sections for various physics processes vary over many orders of magnitude:
processes of interest are often buried under heavy background
need good rejection factors, selection and analysis strategies



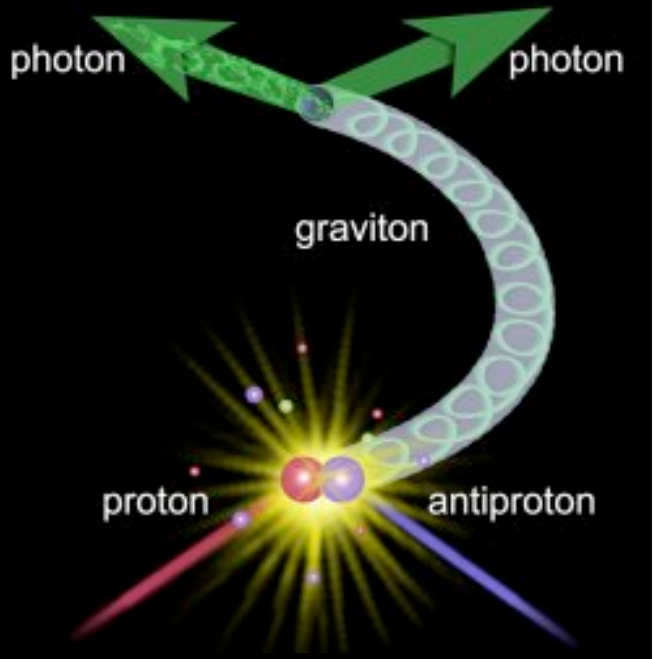
Optimize event selections for SM physics and new physics as in both cases the composition of the samples are important

Common datasets

Common identification/reconstruction cuts

Outline of the talk

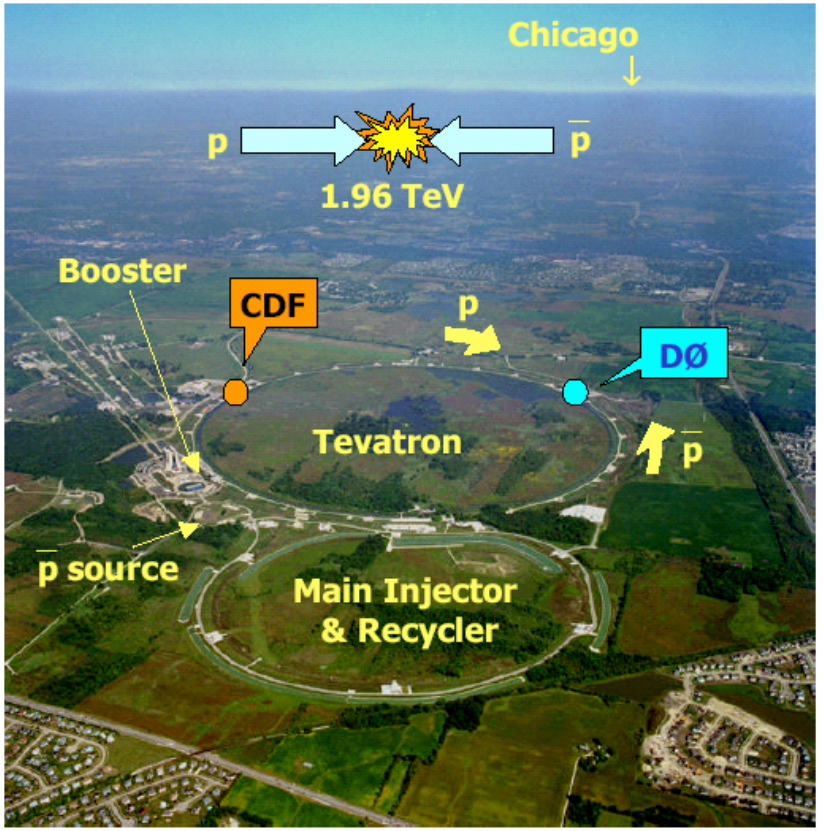
- **TeVatron Performance**
- **CDF and D0 detectors**
- **Physics Objects,**
  - **Leptons-only final states (and isolated tracks)**
    - dilepton searches
      - opposite sign leptons
      - same
  - **… + Missing Energy and Photons**
    - Events with dileptons and MET
    - Multibosons
    - excited electrons
  - **… + Jets and heavy flavors**
    - Leptoquarks
    - Higgs

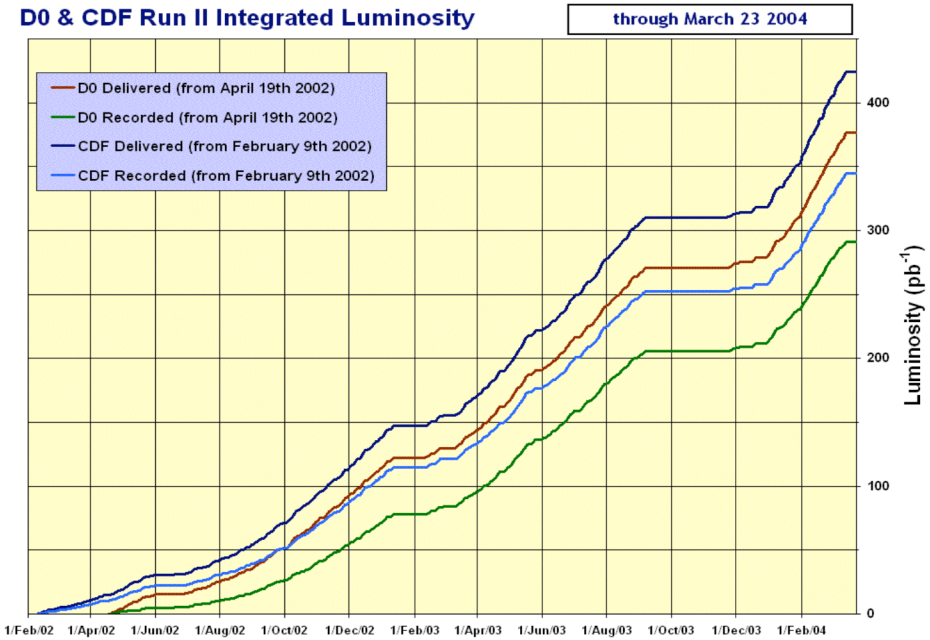


Tevatron performances

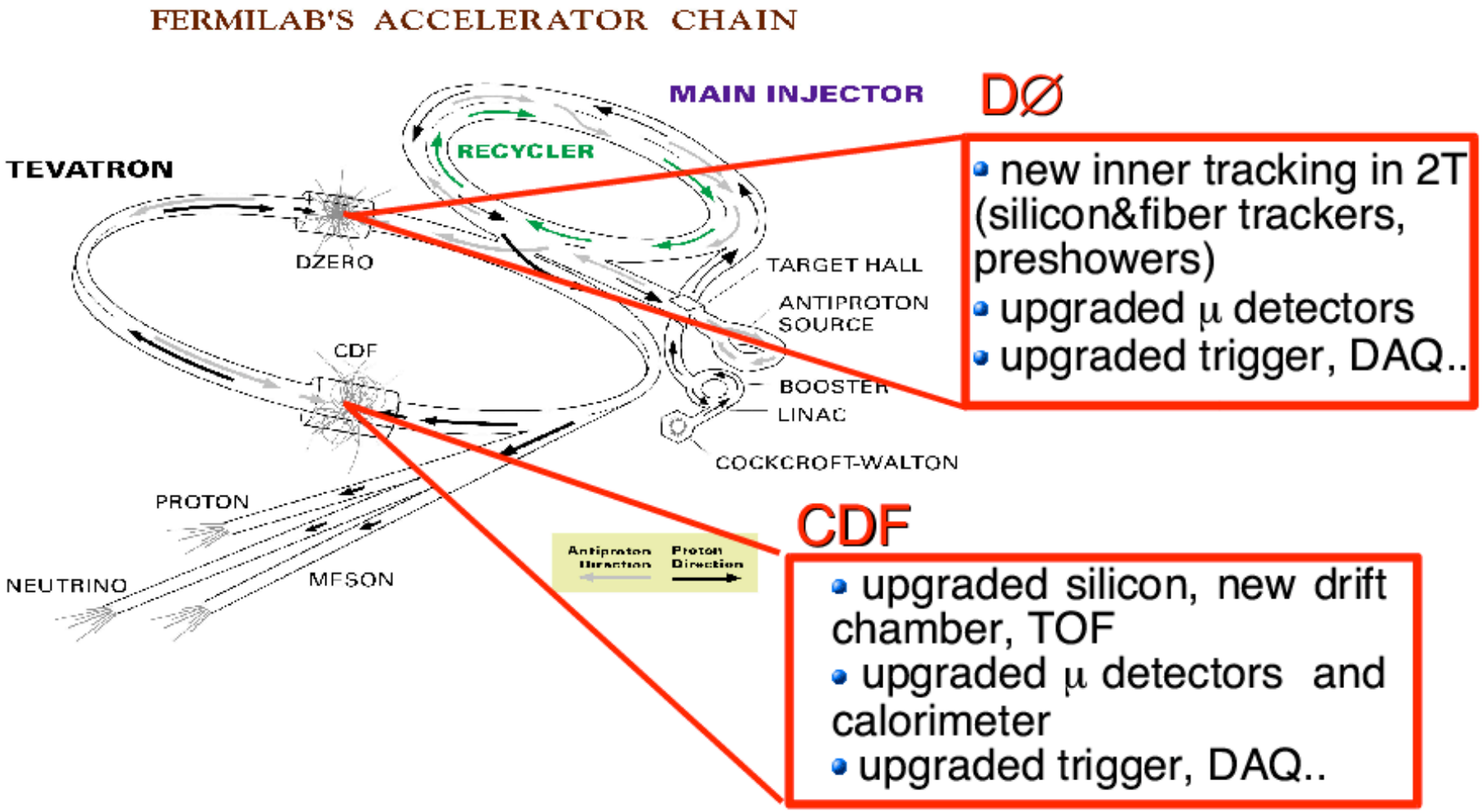
Tevatron successes in early 2004:

- Record luminosity 6.8E31
- 3.9pb^{-1} integrated in a single store
- First store w/ antiprotons from Recycler





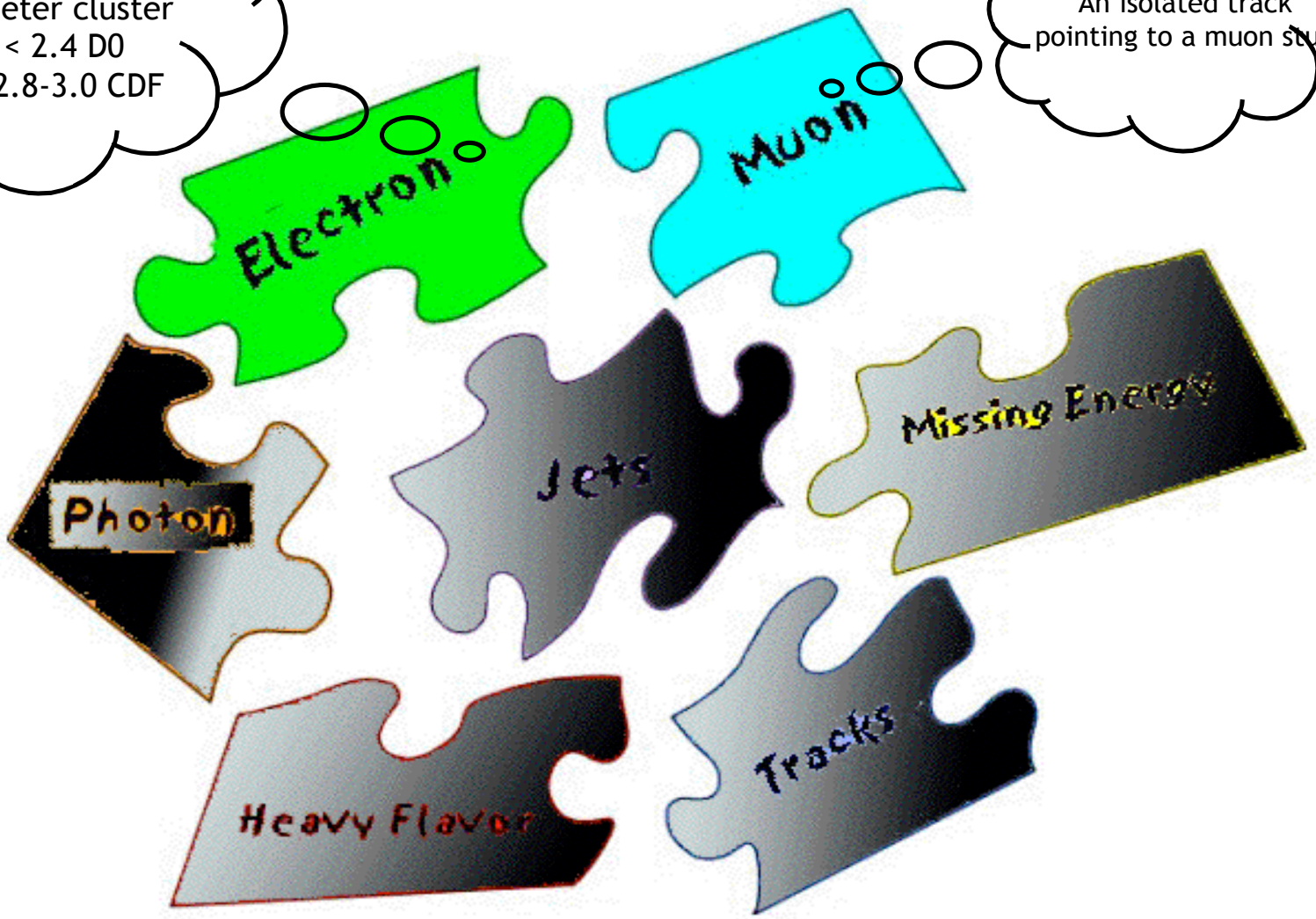
CDF and D0 Experiments



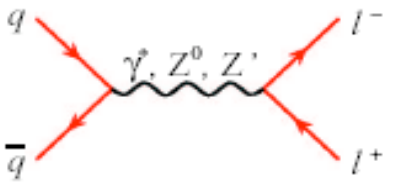
Electrons & Muons Final States

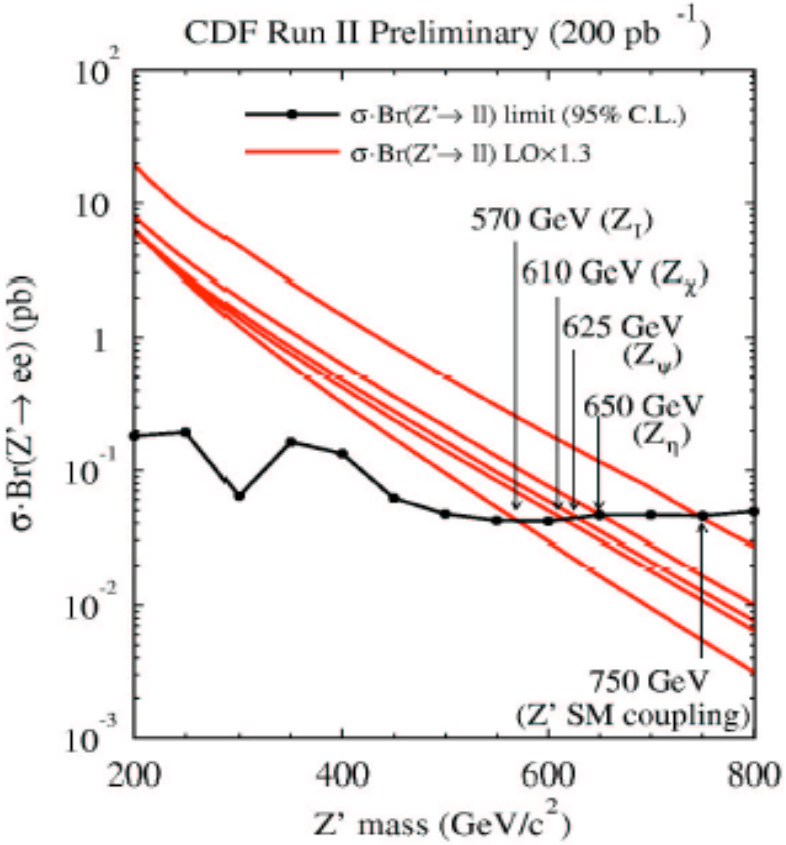
A track pointing to an EM calorimeter cluster
|□| < 2.4 D0
|□| < 2.8-3.0 CDF

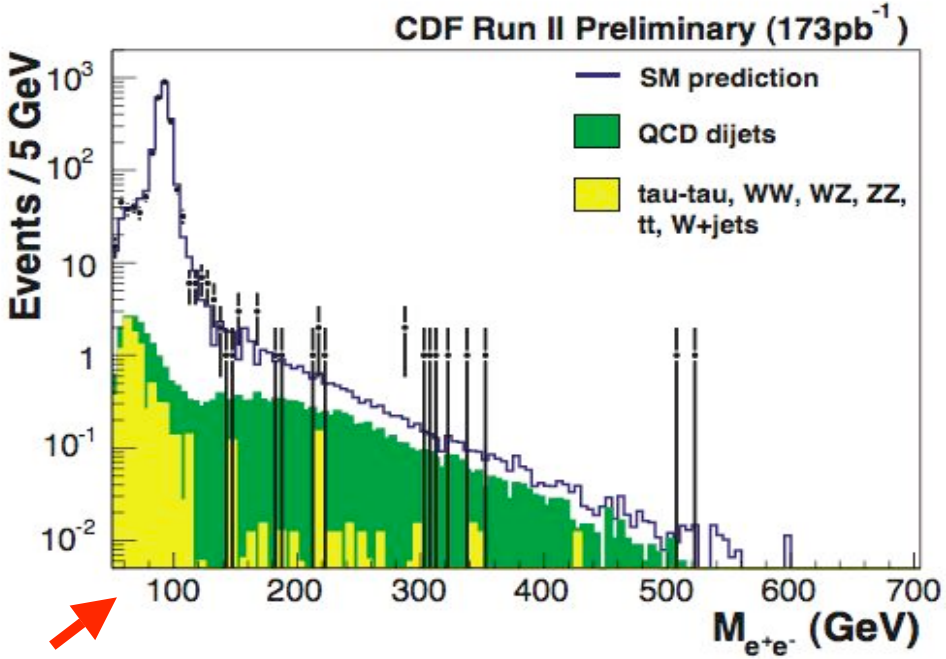
An isolated track pointing to a muon stub



Searches in dileptons at CDF

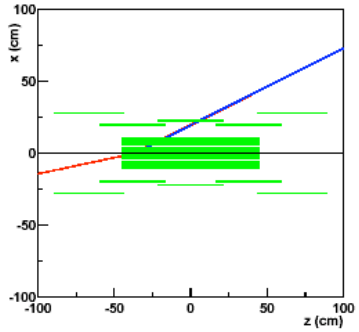


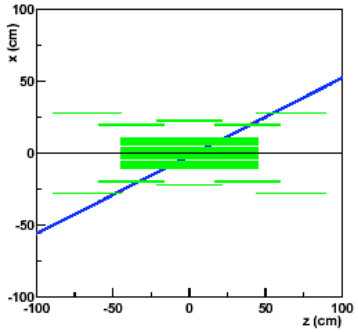




Forward electrons : $1.2 < |\eta| < 2.5$

Calorimeter seeded Si tracking

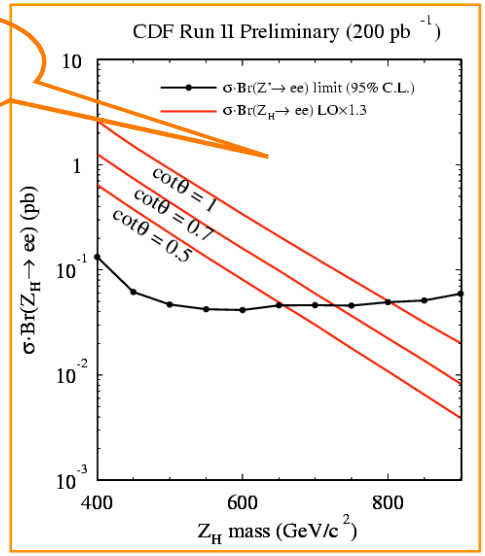




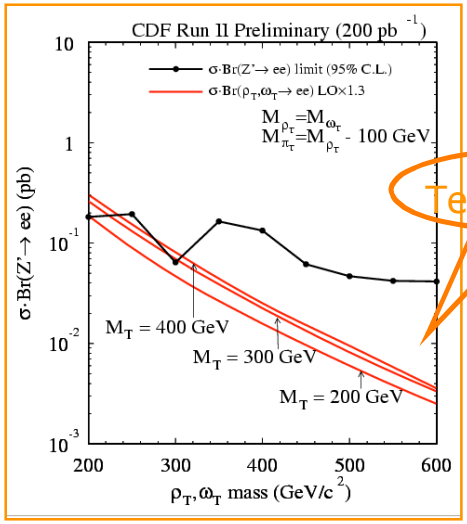
Searches in dileptons (cont'd)

Calculate the acceptances for resonant states for 3 different spin assumption (0,1,2)

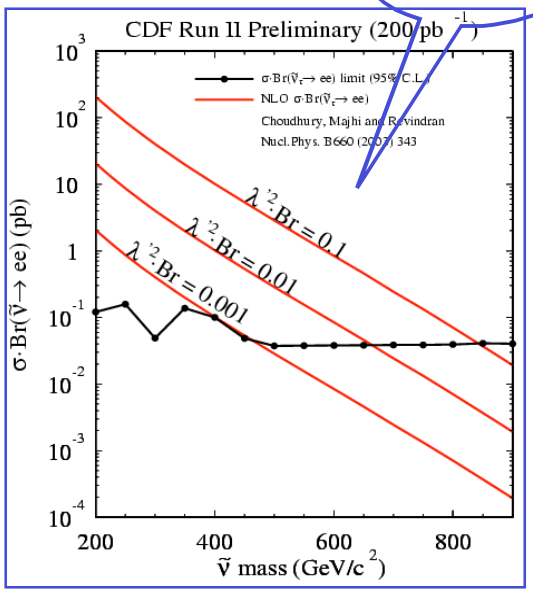
Little Higgs

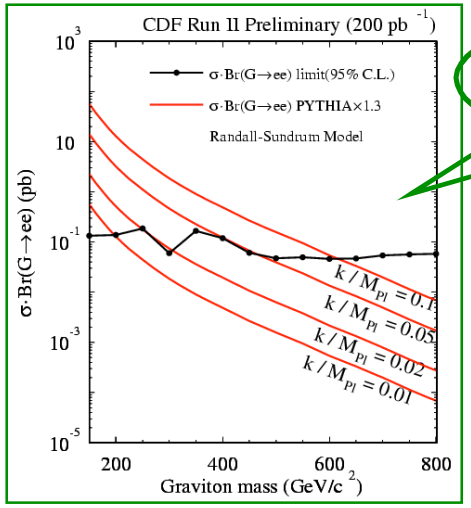


Technicolor



SUSY



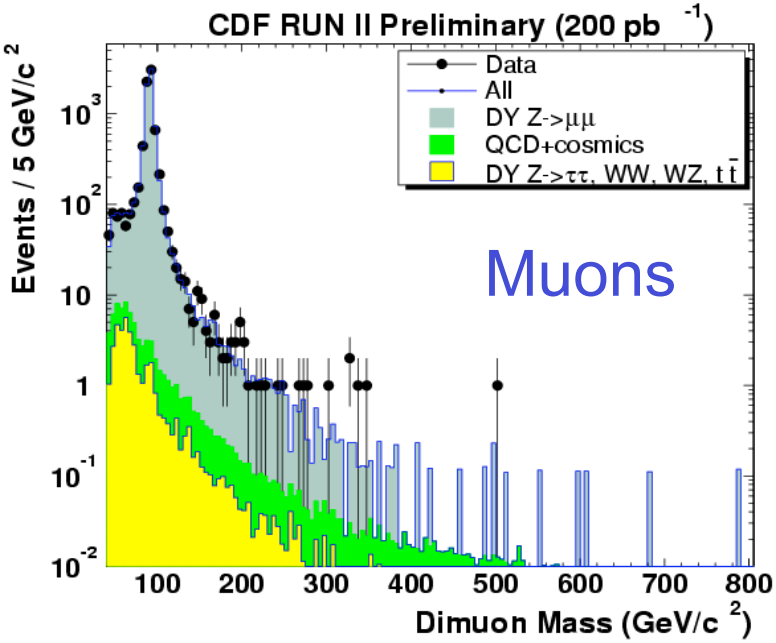


Extra-Dimensions

- Randall-Sundrum graviton model
  4-dimensional metric multiplied by *warp* factor exponentially changing with the additional dimension
  Generating a large hierarchy does not require a large r_c

The coupling of individual KK states to matter is set by the weak scale (parameters : M_G and $k/M_{P\ lanck}$)
KK states can be observed as spin 2 resonances

Searches in dileptons (cont'd)



- Z' gauge bosons: $M_{Z'} > 735 GeV/c^2$ (SM-Like)

CDF Run II Preliminary

CDF Run	Luminosity (pb^{-1})	$M_{Z',95\%C.L}$ (GeV/c^2)
IA	18.8	440
IB	88.6	575
IIA (summer '02)	16	275
IIA (winter '03)	72.0 (56.0 for CMX)	455
IIA (summer '03)	126 (110 for CMX)	585
IIA (winter '04)	200 (180 for CMX)	735

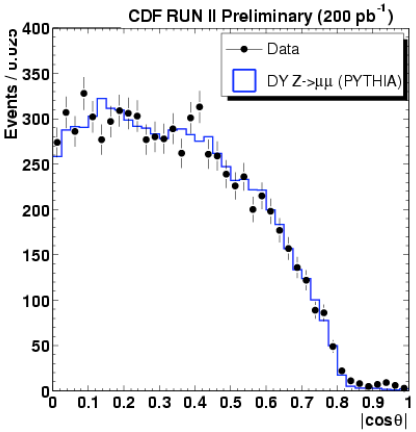
- E_6 Z' Limits:

CDF Run II Preliminary

Model	Mass Limit at 95%C.L (GeV/c^2)		
	Run I	Run II (summer '03)	Run II (winter '04)
Z'_{SM}	590	585	735
Z'_{ψ}	495	465	600
Z'_{χ}	500	455	580
Z'_{η}	520	495	635
Z'_{I}	480	425	530

- Littlest Higgs Z': $M_{Z_H} > 755 GeV/c^2$ ($\cos\theta$ =0.9)

$$\cos\theta = \frac{2}{M\sqrt{M^2 + P_T^2}}\left(\ell_1^+\ell_2^- - \ell_1^-\ell_2^+\right)$$

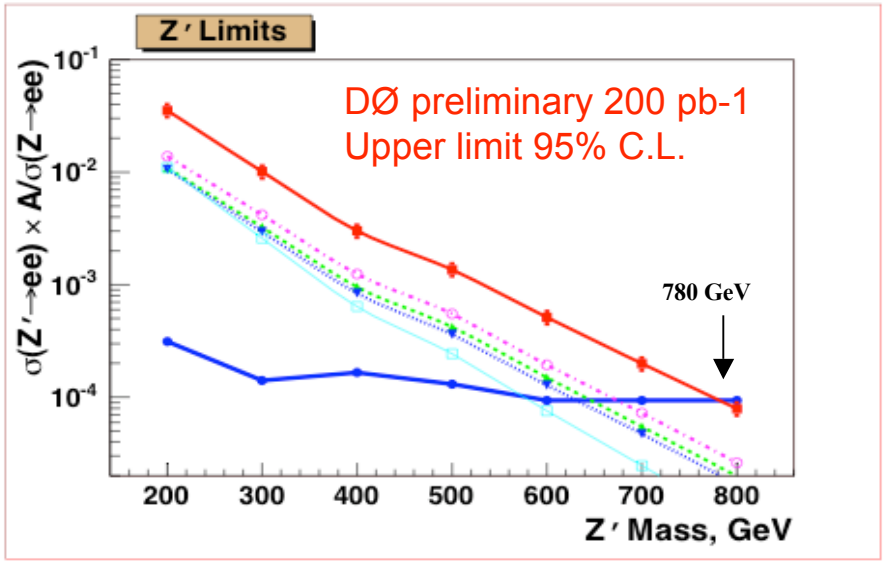


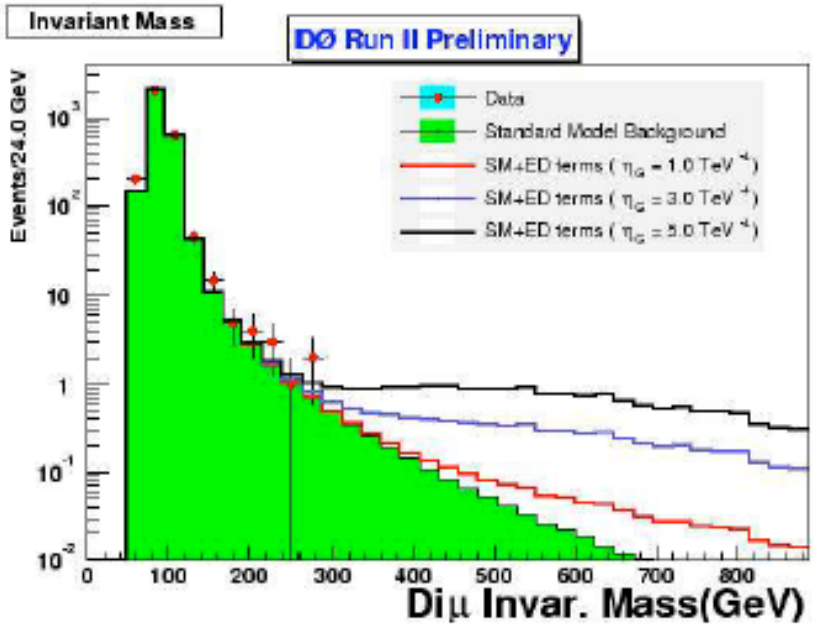
- RS Graviton of extra dimensions: $M_G > 605 GeV/c^2$ (k/M_{Pl} =0.1)

CDF Run II Preliminary

CDF Run	Luminosity (pb^{-1})	$M_{G,95\%C.L}$ (GeV/c^2) (k/Mpl = 0.1)
IA	–	–
IB	–	–
IIA (summer '02)	16	255
IIA (winter '03)	72.0 (56.0 for CMX)	370
(summer '03)	126 (110 for CMX)	475
IIA (winter '04)	200 (180 for CMX)	605

Dileptons Searches (cont'd)





Summary of CDF/DØ limits on low-energy E6 models

	channel	L (pb^{-1})	Z_I 95%C.L (GeV)	Z_χ 95%C.L (GeV)	Z_ψ 95%C.L (GeV)	Z_η 95%C.L (GeV)
CDF	ee	200	570	610	625	650
CDF	μμ	126	425	455	465	495
DØ	ee	200	575	640	650	680

LED in dimuons at D0

Compare M(μμ) and cos(θ*) to SM distributions.

$M_S > 880$ GeV

L = 100 pb^{-1}
>= 2 μ, $P_T > 25$ GeV
M(μμ) > 50 GeV

D0 searches for TeV^{-1}(longitudinal) ED

ED model where:
fermions confined to 3D world
SM gauge bosons propagate in single TeV^{-1} (longitudinal) ED
They are equivalent to KK Towers with
$M^2_n = M_o^2 + n^2M^2_c$

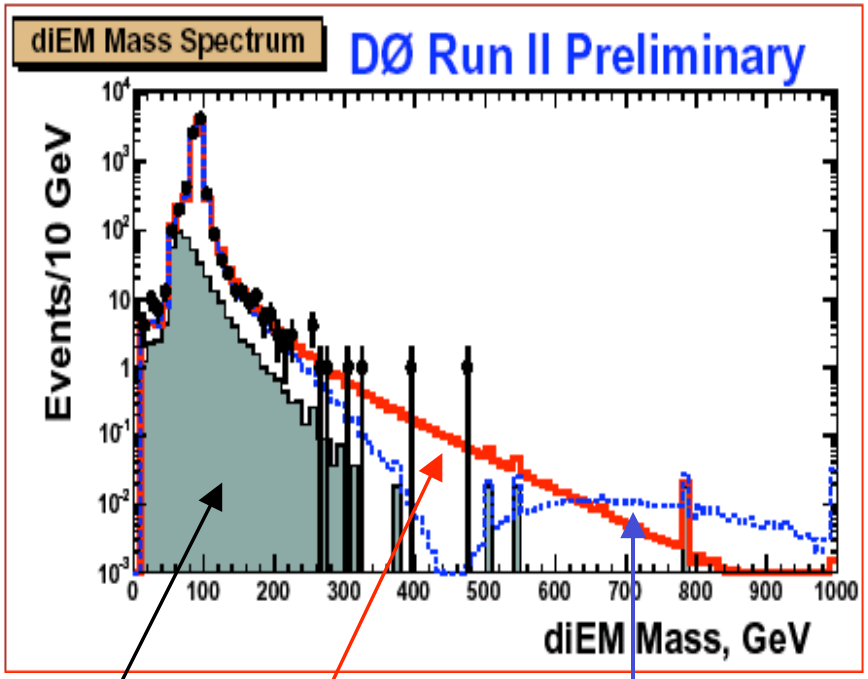
Predicts Kaluza-Klein states of gauge bosons (W,Z,g)
$R = 1/M_c$ is size of compact dimension for gause bosons

Strong negative interference effects
extra virtual effects

Di-electron dataset used

Result: $M_c >$ 1.12 TeV (95% CL)

Indirect searches:
LEP: > 6.6 TeV;
all: > **6.8 TeV**

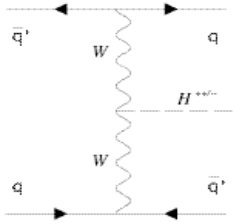


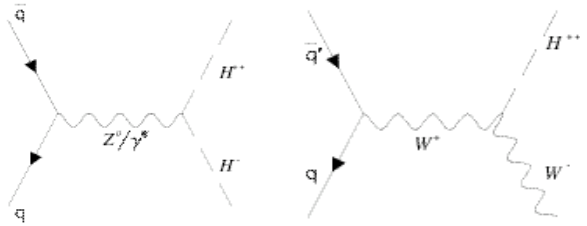
Search for doubly charged Higgs at CDF

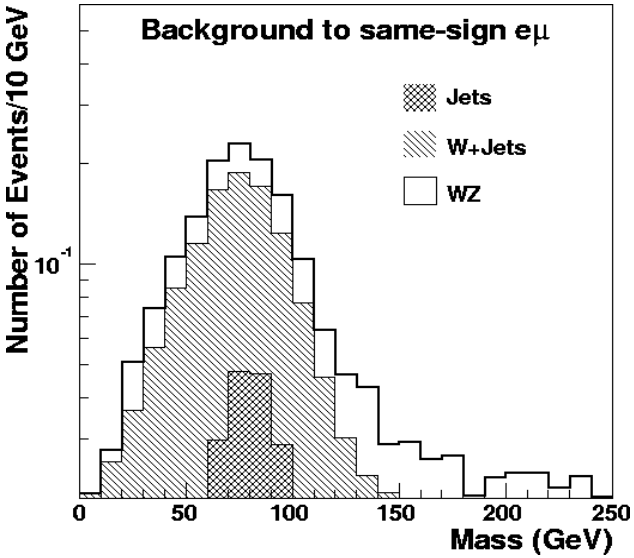
Doubly charged Higgs are members of Higgs triplets occurring in several types of models

- extensions of the Higgs sector of the SM
- left-right symmetric models
- SUSY left-right symmetric models

At the TeVatron doubly charged Higgs can be paired-produced (Z exchange) or singly produced (WW fusion)



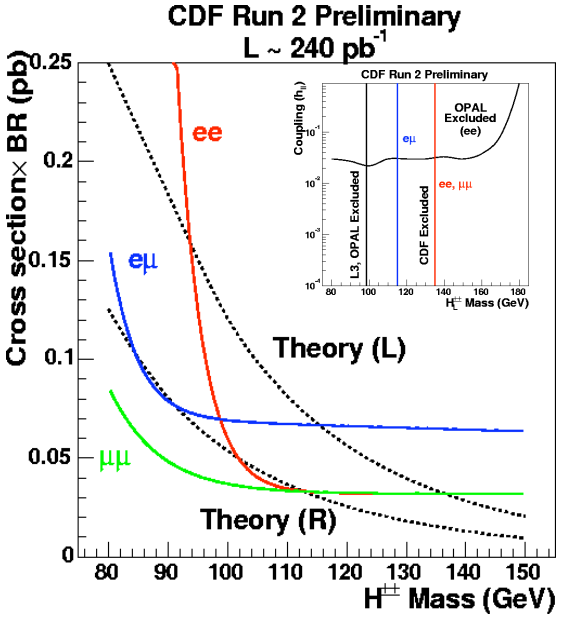




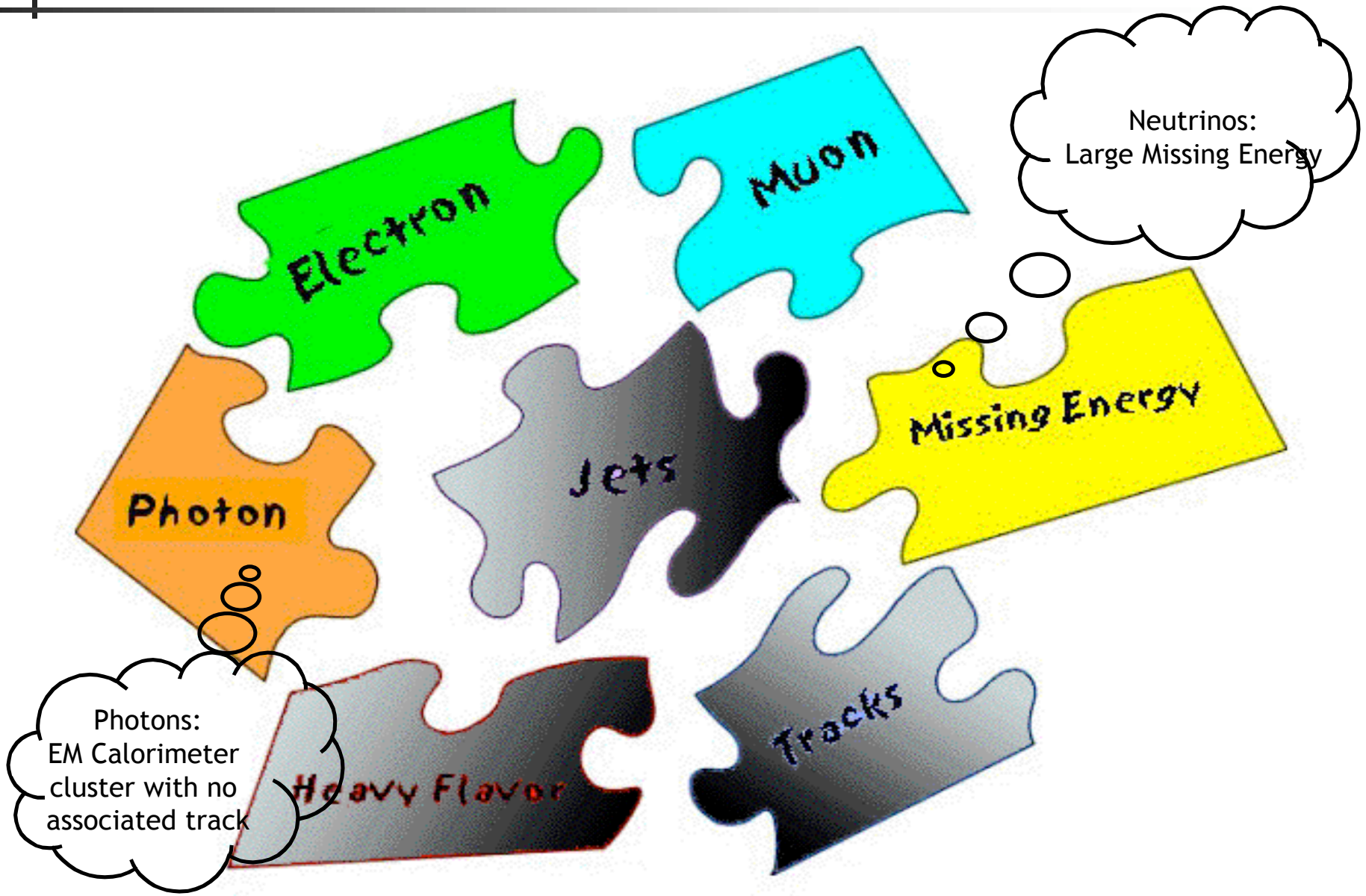
Same sign leptons signature

Very small background!

Decay Channels	# predicted Evts
ee	$1.8^{+0.8}_{-0.6}$
□□	$0.8^{+0.6}_{-0.5}$
e□	$0.9^{+0.4}_{-0.4}$

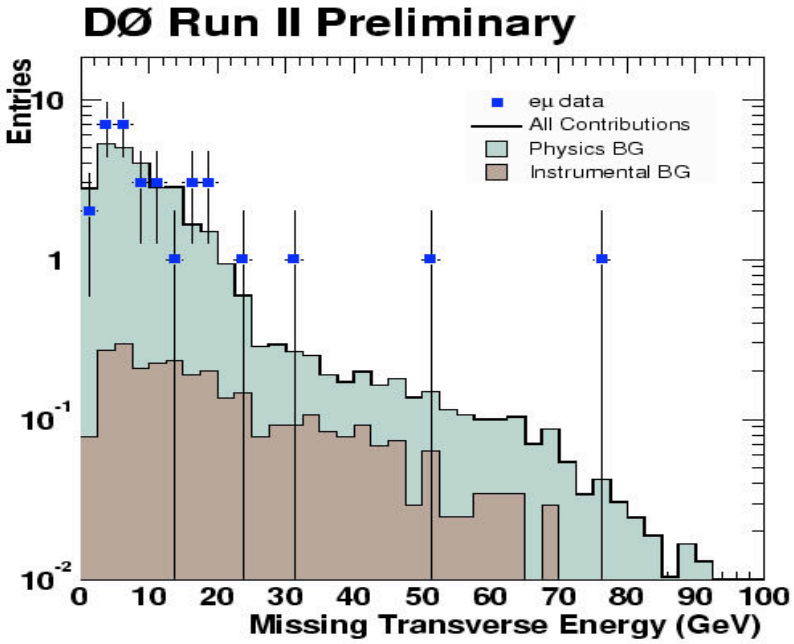


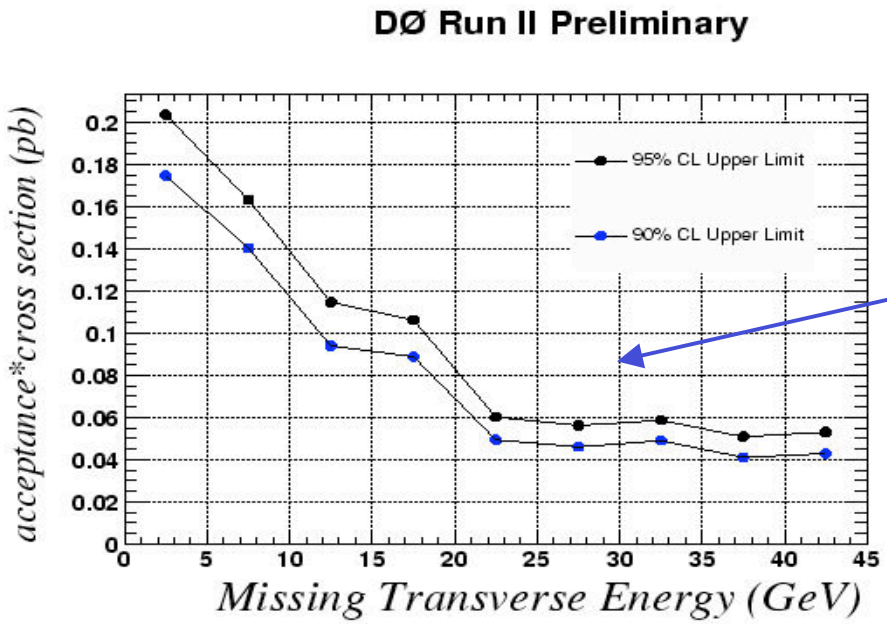
+ Photons & Neutrinos Final States



Model Independent Searches in e[

- Search for an excess over the SM prediction in the kinematic space
- Look at the Missing E_T , sensitive to new Physics
- Set upper limits at 95 % C.L. with acceptances derived from WW-like events





Limit!

L = 98 pb^{-1}
1 electron E_t>25 GeV
1 muon Pt>25 GeV
Good fiducial volume
0/1 jet

Search for ED in ee/□□ channel at D0

Strategy

Use di-EM objects

includes both ee and □□

Fit

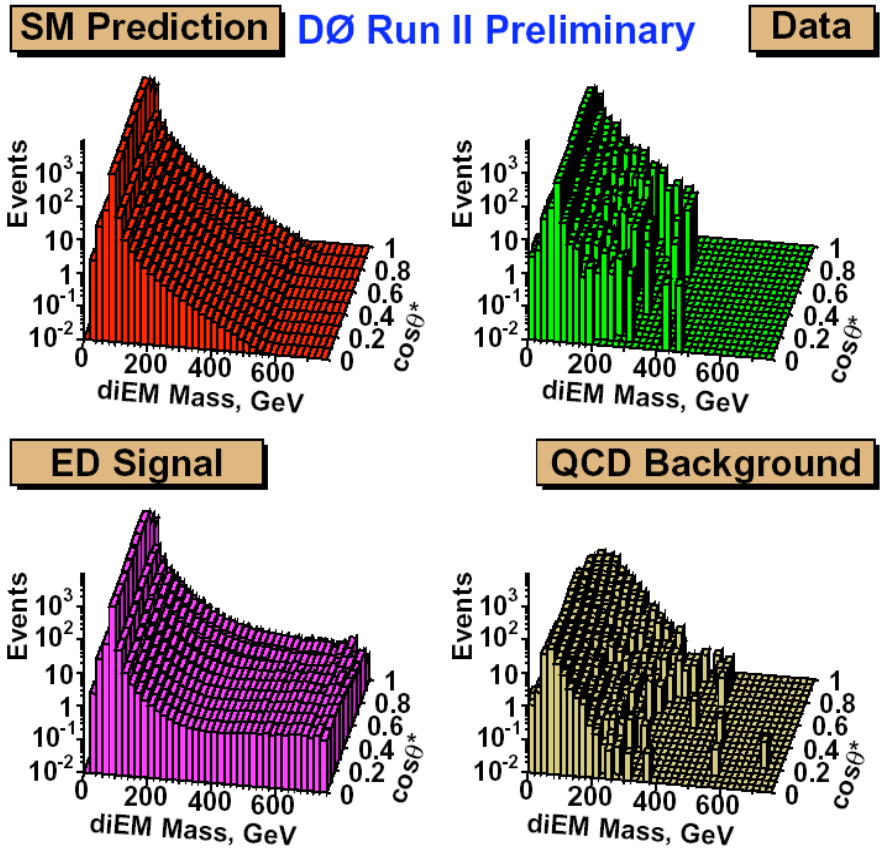
di-EM invariant mass

cos □* (scattering angle in rest frame)

Dataset 200 pb^{-1}

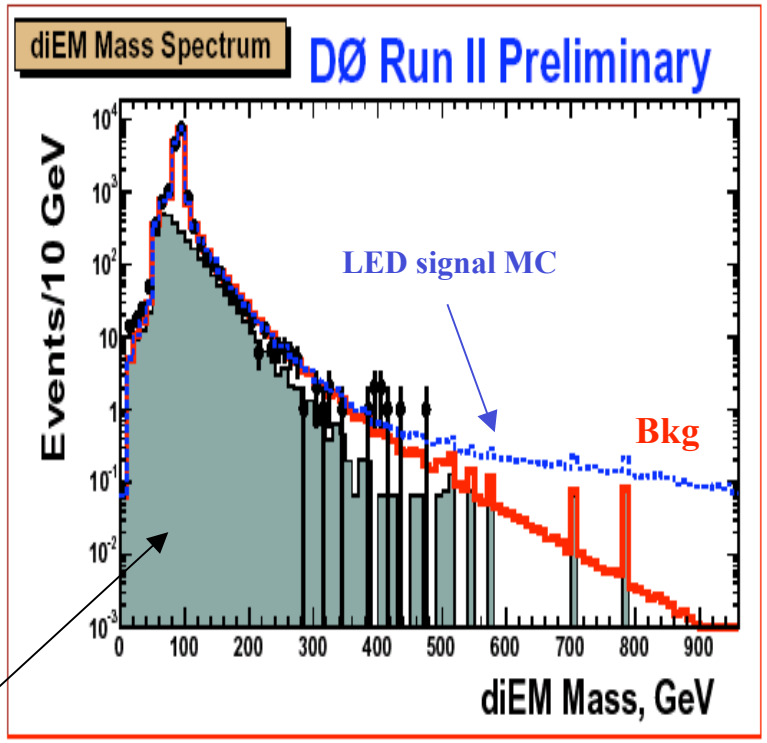
Selections

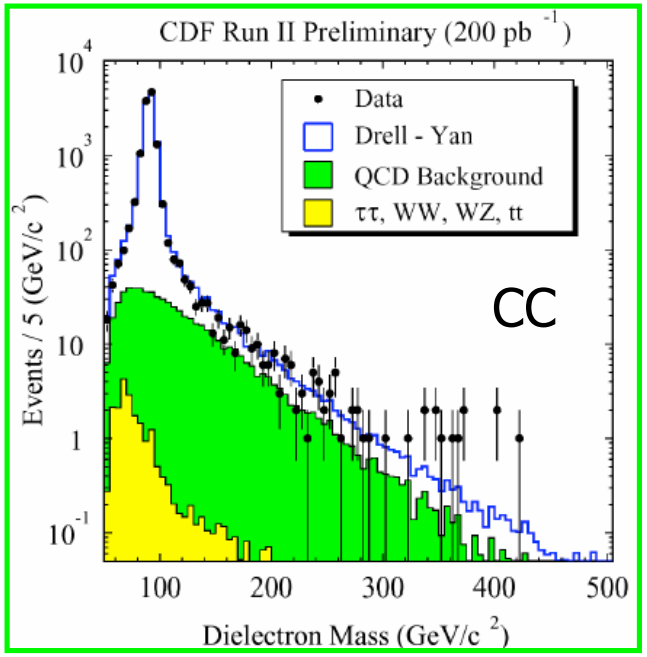
- Two EM with Et > 25 GeV with tight quality cuts
- Geometrical Acceptance
  - |eta| < 1.1 for CC
  - 1.5 < |eta| < 2.4 for EC
  - Consider CC-CC and CC-EC combinations



LED Searches in ee/□□: Results

- $\eta_G^{95} = F/M_S^4$
  - Single parameter for ED effects
- Set limits using GRW formalism:
  - F=1
- Use CC-CC & CC-EC combinations independently, combine final results





Spin 2 Acceptance

Results :

Run II : Ms > 1.36 TeV

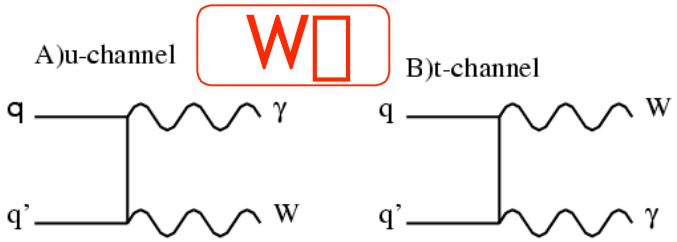
Run I + II : Ms > 1.43 TeV

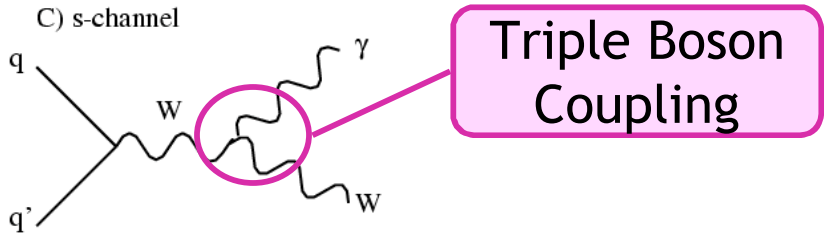
CDF Run II: M_S > 1.11 TeV

Di-boson Signals

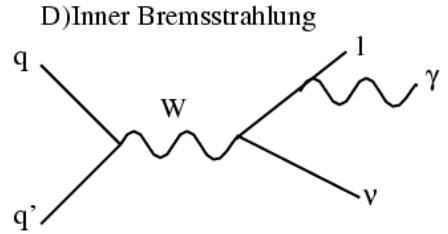
Test of gauge couplings (as predicted by the SM) and a window on new physics

W□

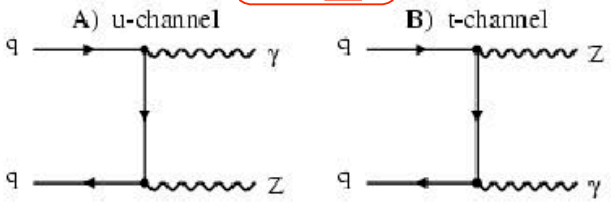


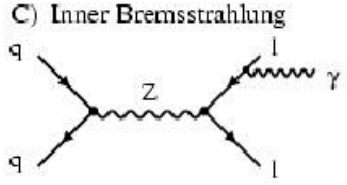


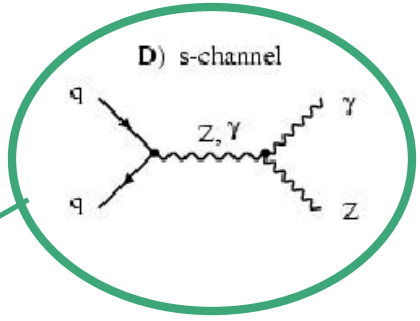
Triple Boson Coupling



Z□







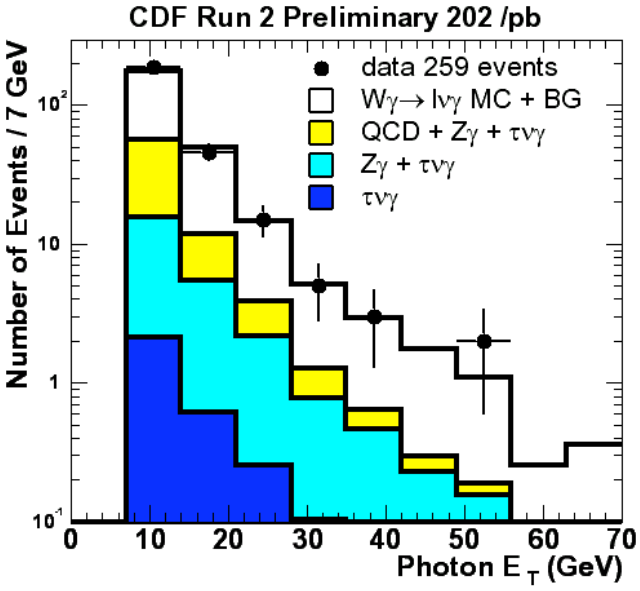
Non SM!

W□ at CDF

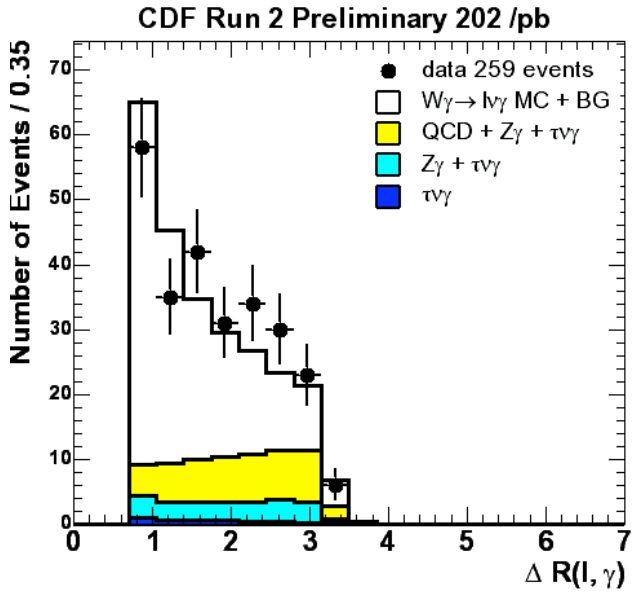
- First select W→lν events :
  - Electrons : E_T>25 GeV; missing−E_T>25 GeV
  - Muons : E_T>20 GeV; missing−E_T>20 GeV
- Then look for additional photons :
  - E_T(photon) > 7 GeV
  - $|\eta^\gamma| < 1.1$
  - $\Delta R(l,\gamma) > 0.7$

□(W□)□BR(W□ l□) = 19.7
± 1.7 (stat) ± 2.0 (sys)
± 1.1 (lumi) pb

For E_T(□) > 7 GeV and □R(l, □) > 0.7:
□(W□)□BR(W□ l□) (Theory) = 19.3 ± 1.4



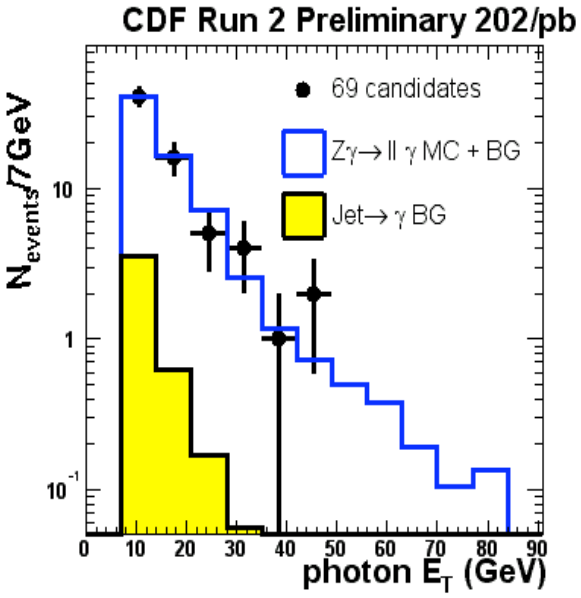
data well described over all photon E_T's and separations

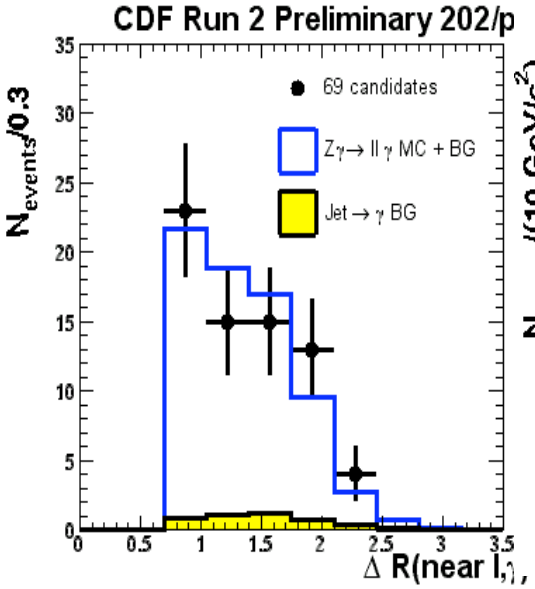


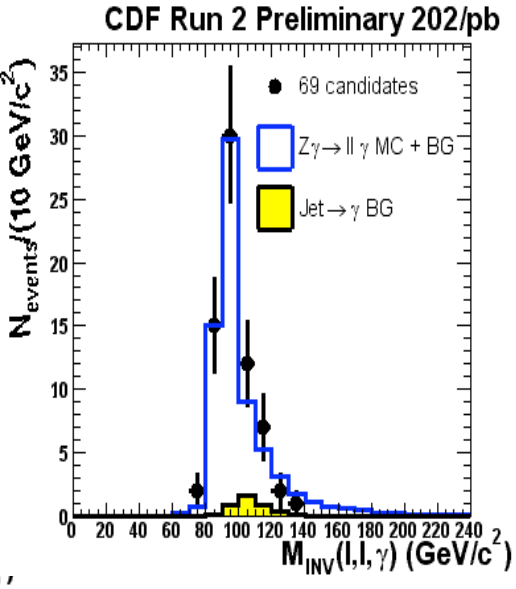
Z at CDF

(Z)BR(Z ll) =5.3
± 0.6 (stat) ± 0.4 (sys)
± 0.3 (lumi) pb

For E_T() > 7 GeV and R(l,) > 0.7:
(Z)BR(Z ll) (Theory) = 5.4 ± 0.4

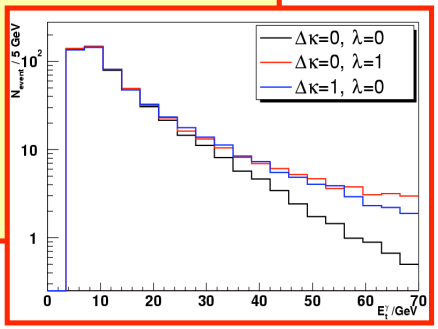






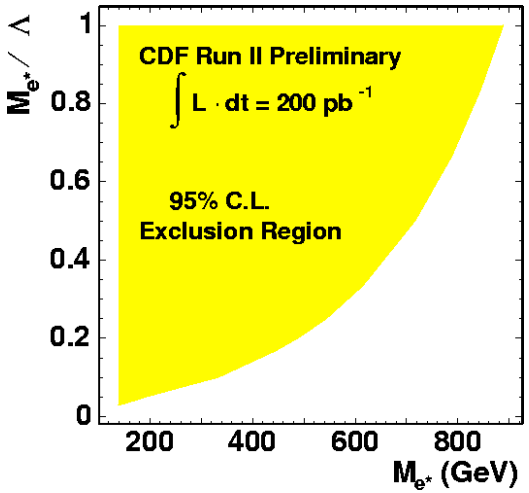
Now V+ cross-sections well established, we are:

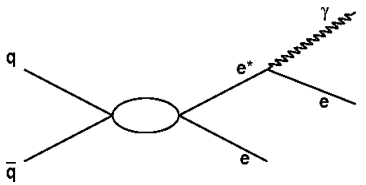
- optimizing sensitivity to anomalous coupling and new physics
- testing the Standard Model in ways unique to the TeVatron (e.g. observing RAZ in W production)



Excited electrons at CDF

Observation of excited states of quarks and leptons might confirm the hypothesis that they are not elementary particles , but composite states



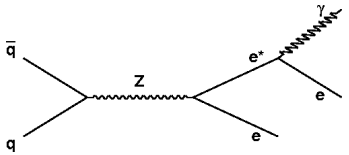


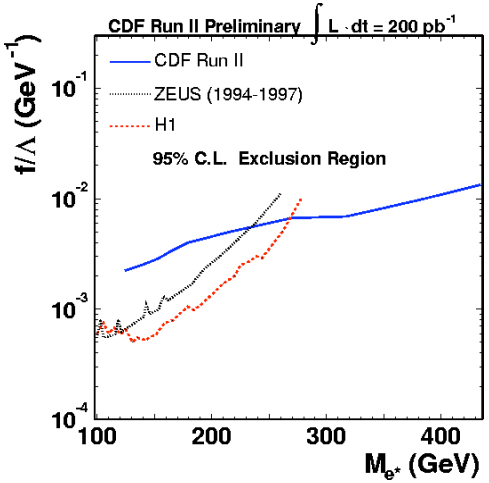
CDF searched for excited electron (e^*) using high pt electron data (L=200 pb^{-1})

At Tevatron, e^* can be produced via contact interactions or gauge mediated interactions

- Select events with ee□in the final state
- Look for resonance in M(e□)
- SM backgrounds :

  Z □+ DY , Z+jets, WZ, Multi-jets, □□+jets, …

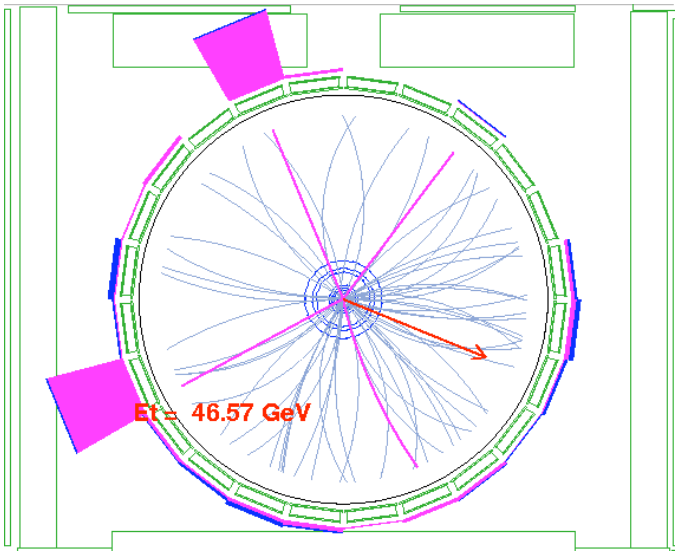


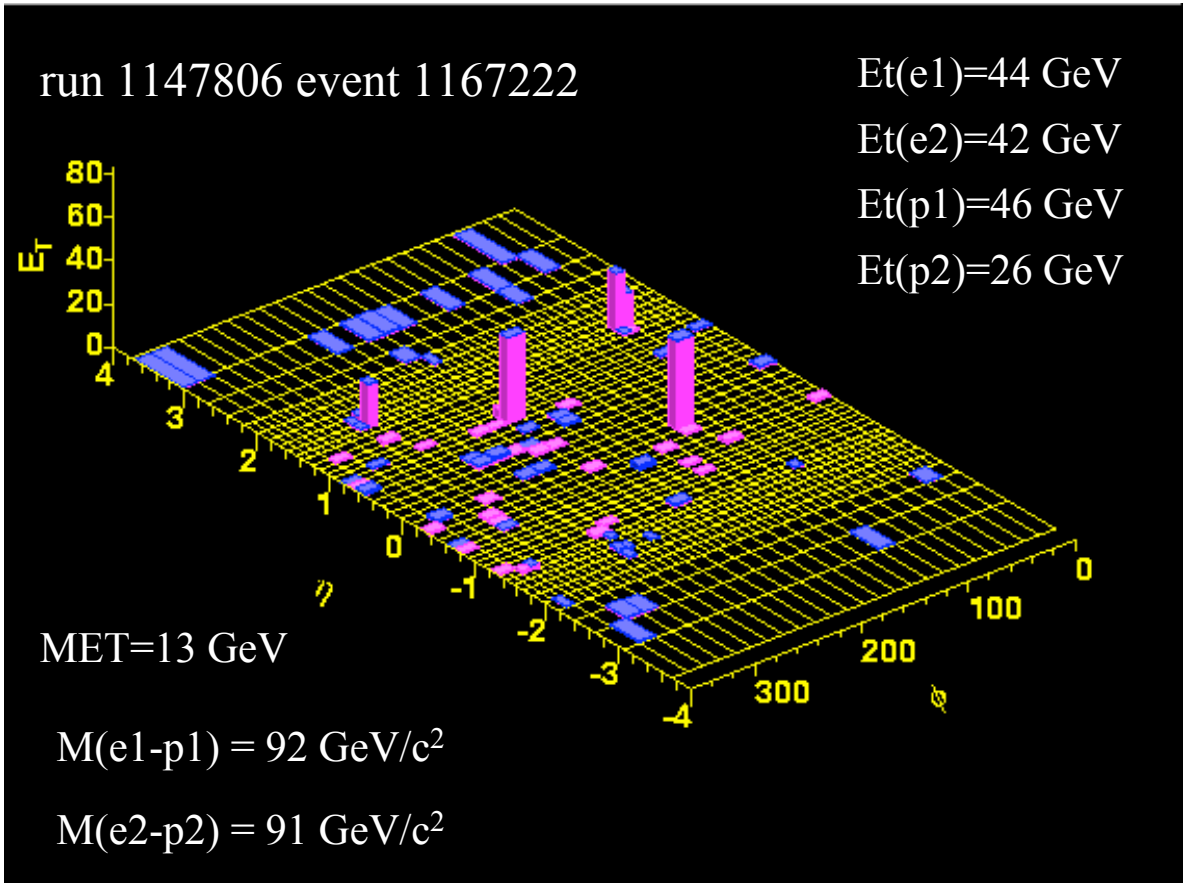


Expect 3 events, observe 3 events

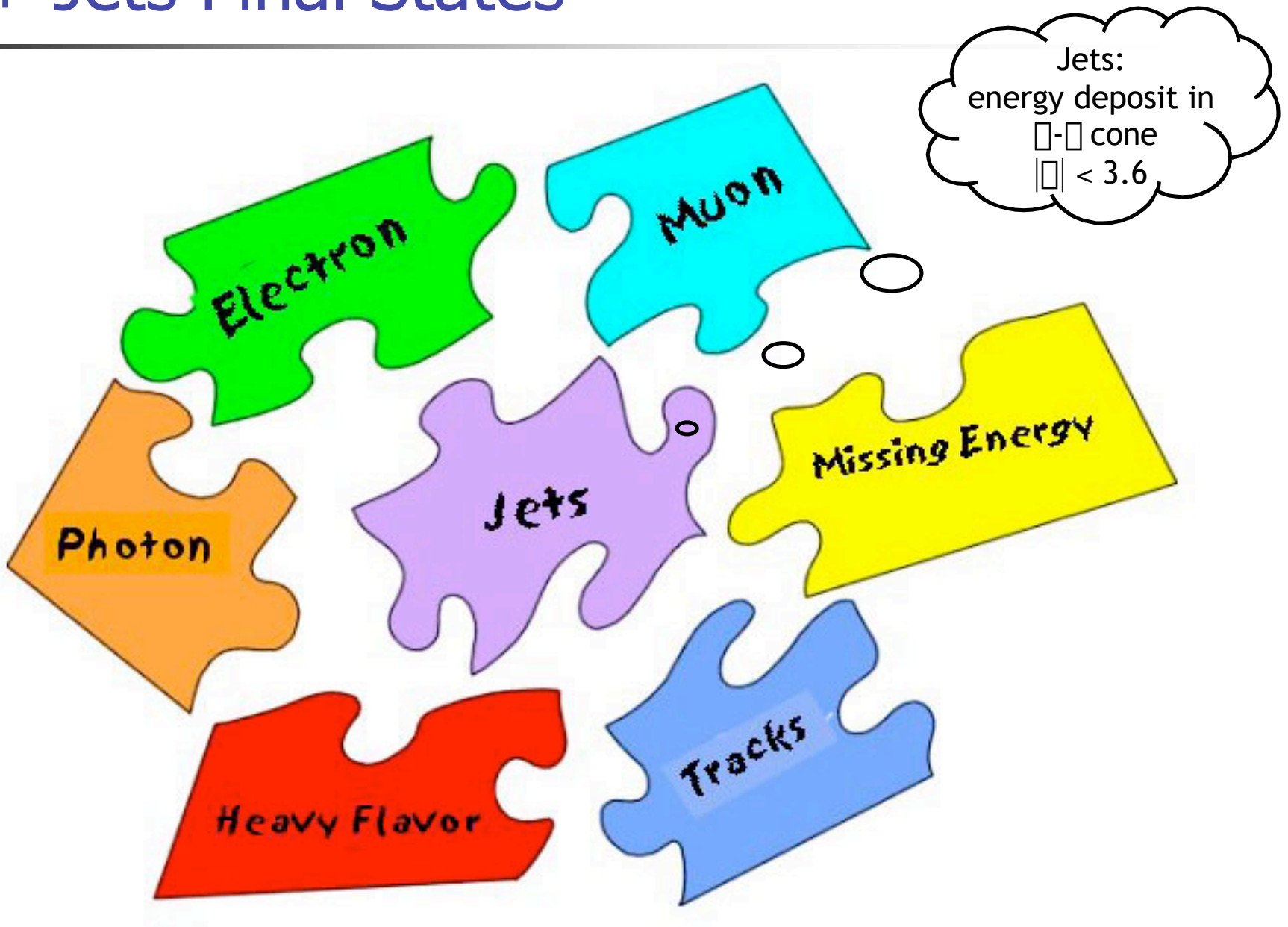
Excited electrons at CDF

- 4 EM candidates
  - Could be ZZ event!

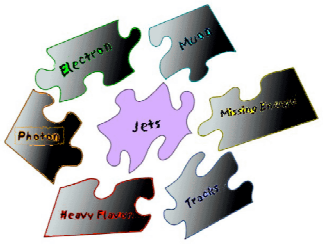




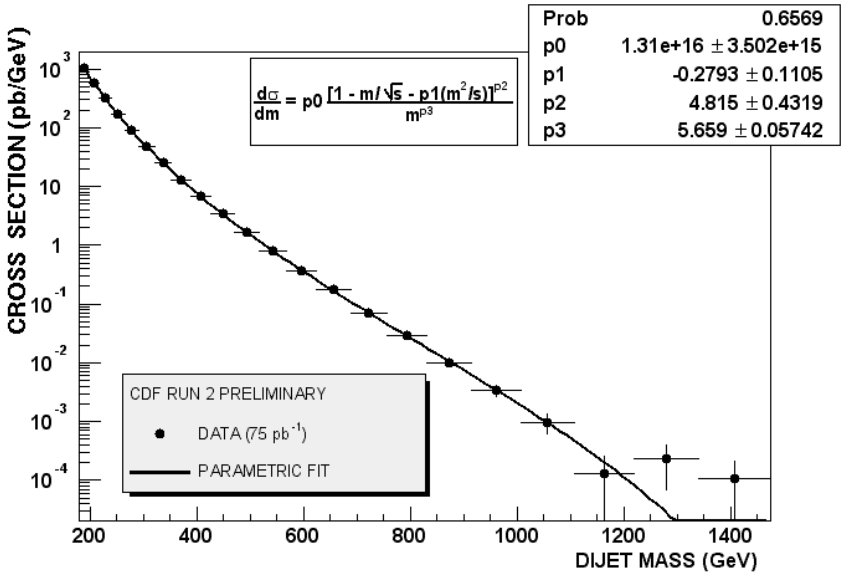
+ Jets Final States

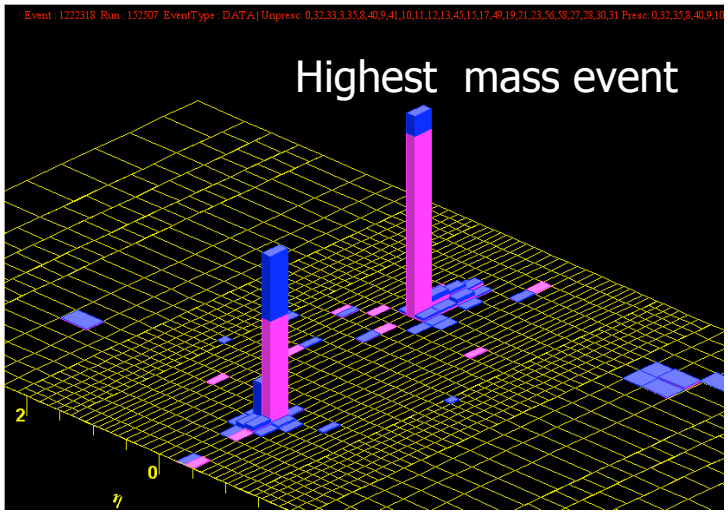


Search for Mass Bumps in Dijets at CDF



- Inclusive jet samples
- MET/ $\not{E}_T$ < 6 and $\not{E}$ < 2.2 TeV
- 2 highest E_T jets selected
- fit of the mass spectrum with a simple background parameterization and search for bumps comparable with the mass resolution.



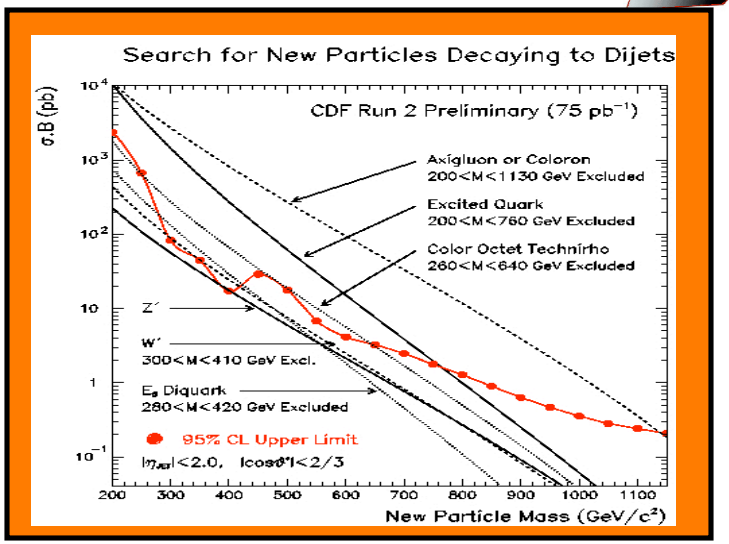


no significant evidence for a new particles…yet

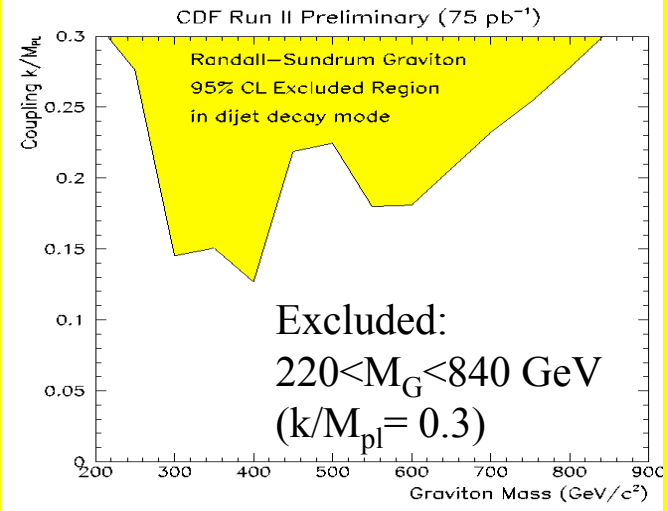
Run 152507 event 1222318
Dijet Mass = 1364 GeV/c^2
cos θ^* = 0.30
z vertex = -25 cm

Search for Mass Bumps in Dijets at CDF

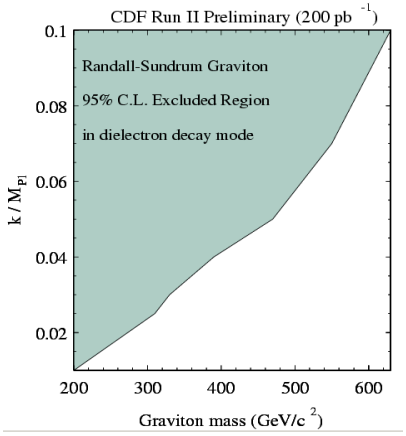
Particle	95% C.L. GeV
Axion/Coloron	200<M<1130
Excited Quark	200<M<760
E6 diquark	280<M<420
W'	300<M<410
Technirho	260<M<640

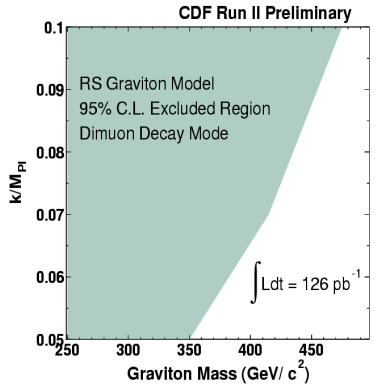


ExtraDimensions



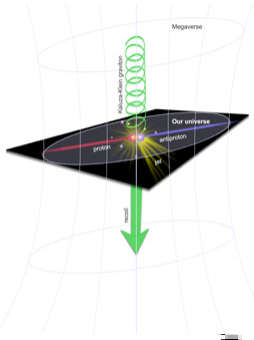
Complementary to dilepton search





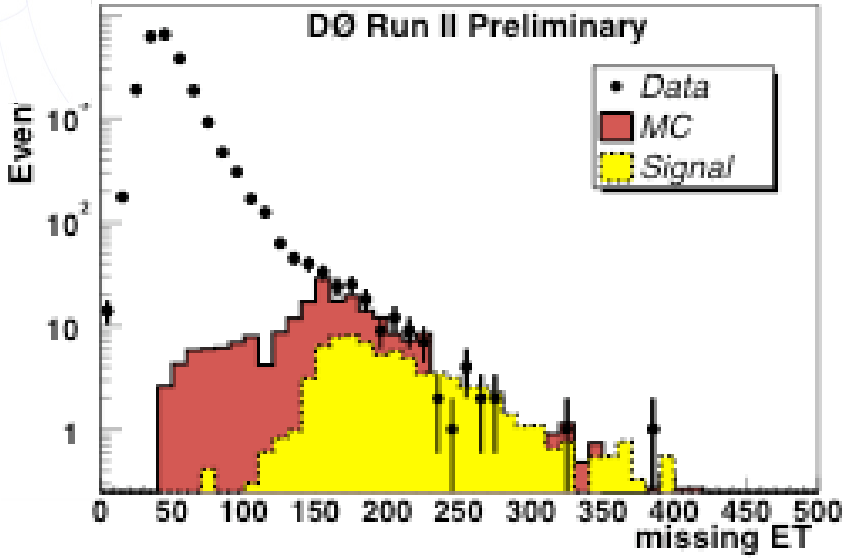
Searches for LED in Missing Energy + Jets at D0

Graviton is produced recoiling against a jet or gluon

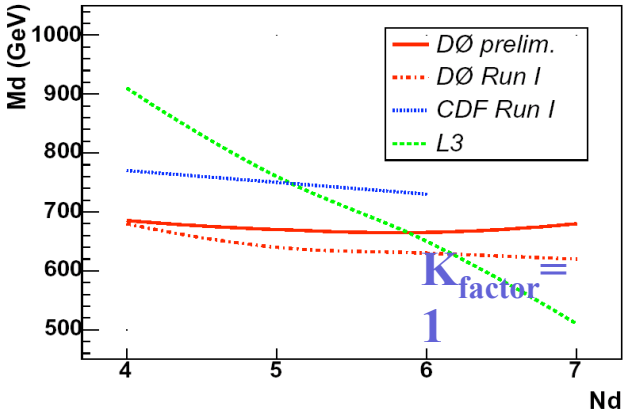


Monojet like topology

E_T (Jet1) > 150 GeV,
E_T (Jet2) < 50 GeV,
$\not\!\!E_T$ > 150GeV
D(Met,jet)> 30°



Background: Z(→□□)+jet(s)
Large energy scale uncertainty



Observe 63 events;
expect 100 ± 6 ± 7 in 85 pb^{-1}

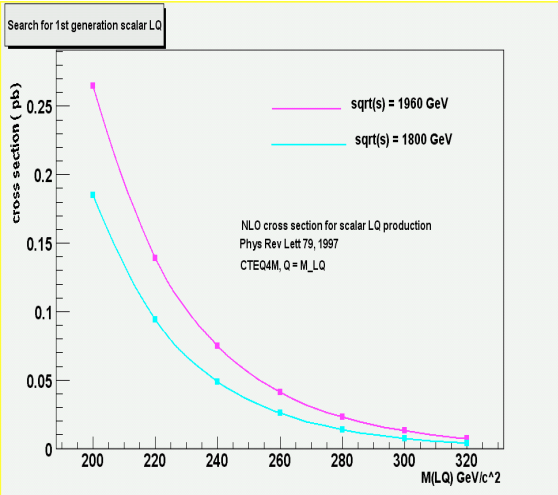
Signal Limit at 95% C.L.= 84 events
(expected limit 128 ± 28)

Leptoquarks

Several extension of the SM model (GUTS, Technicolor, Compositeness, RPV-SUSY) assume an additional symmetry between leptons and quarks

Carry both lepton (L) and baryon (B) numbers
Couple to quark and lepton of the same generation

3 generations

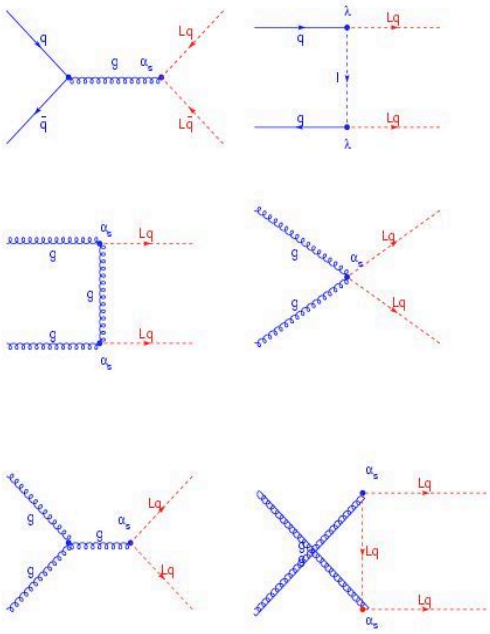


30% increase in cross section at RunII

At the TeVatron they are pair produced

Their decay is controlled by □ = BR (LQ□ lq)

Experimental signature: high P_T isolated lepton(s) and/or $\not\!\!E_T$ + 2 jets

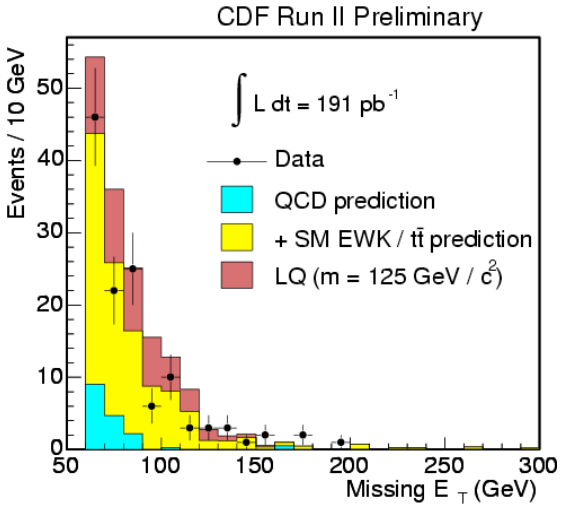


LQ search in □□jj at CDF

Signature: Large MET and 2 jets

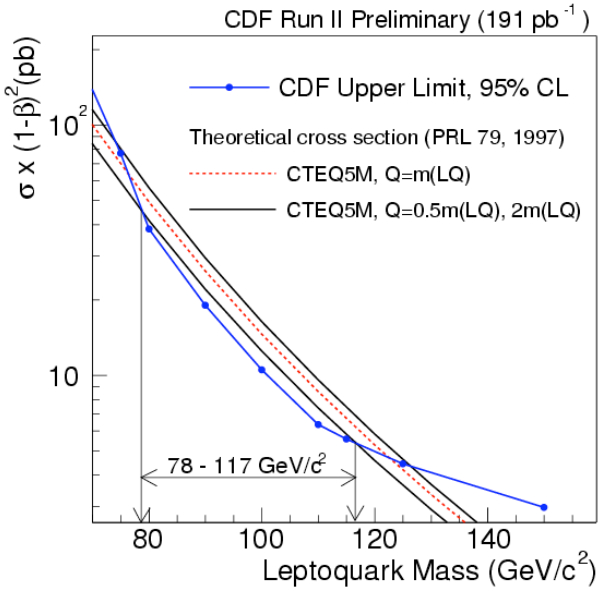
□′ =BR(LQ□ □q) = 1

Flavor independent



Sample Composition:
W/Z + jets
top
QCD fakes

Expected =118±14

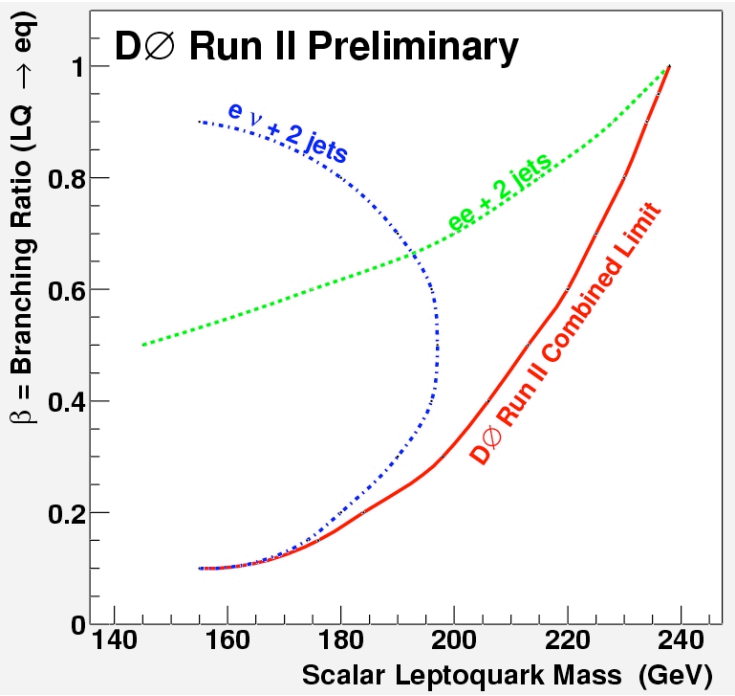


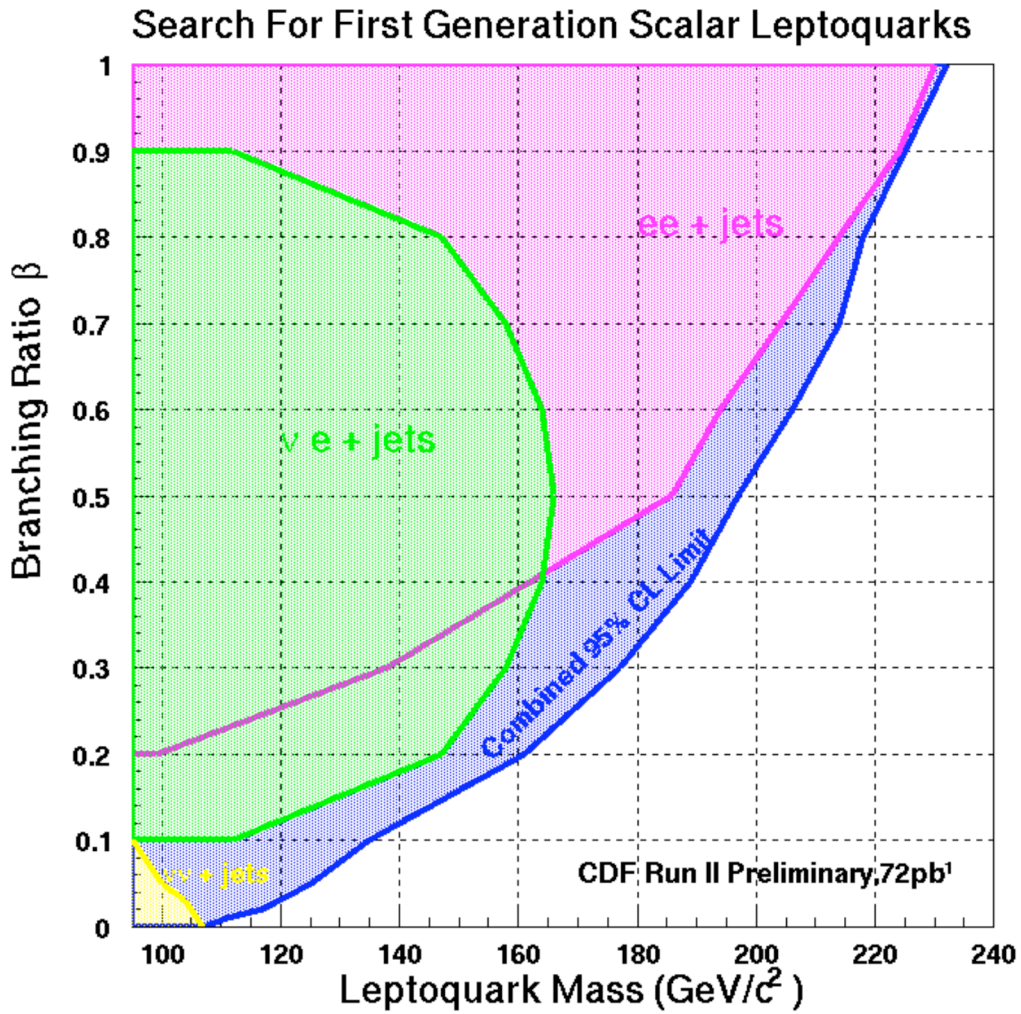
124 events seen after analysis cuts

M(LQ) > 117 GeV/c² @ 95 % C.L.

1st generation LQ at CDF

Signature:
2 electrons and 2 jets
electron, $\not\!\!E_T$ and 2 jets
$\not\!\!E_T$ and 2 jets





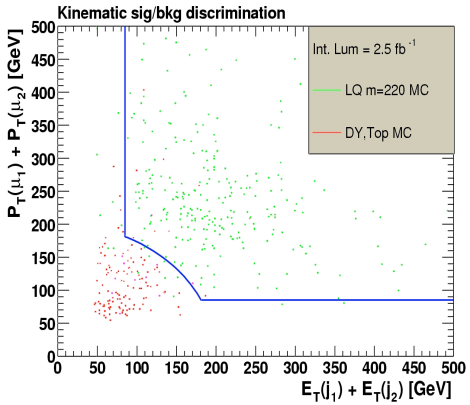
2nd generation LQ at CDF

Signature: 2 muons and 2 jets

□ =BR(LQ□ □q) = 1

Tight □'s selection complemented by □ + track selection

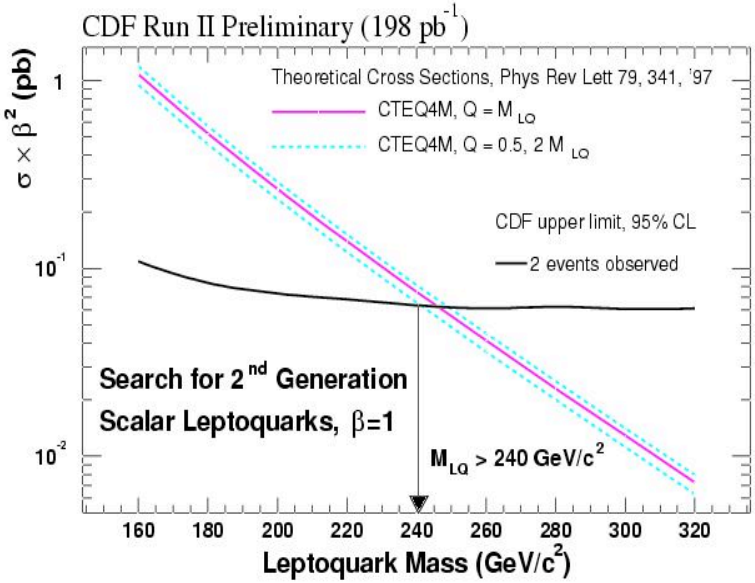
Background:
- Z + 2 jets
- top
- QCD fakes

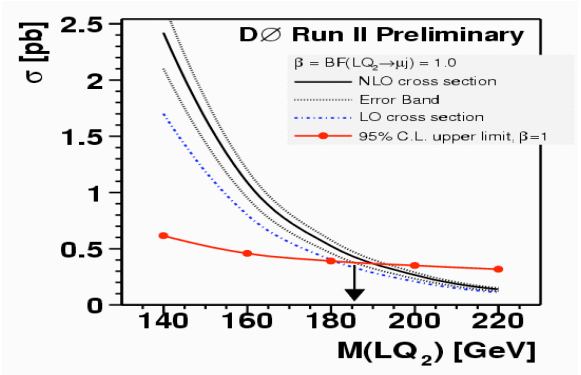


expected 3.15 ± 1.17

2 events seen after analysis cuts

M(LQ) > 240 GeV/c² @ 95% C.L.

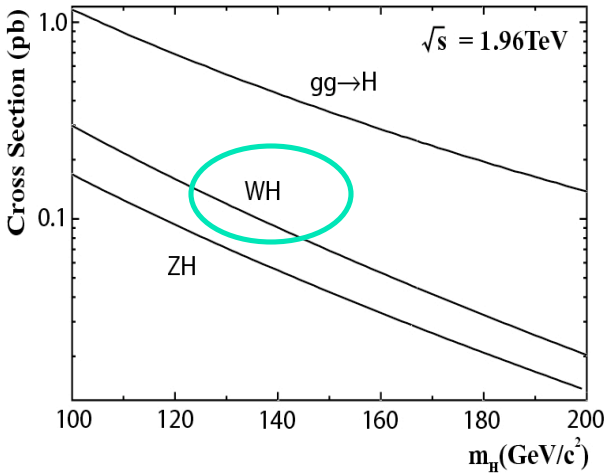


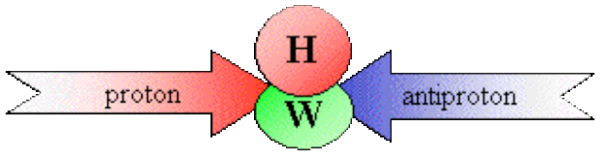


Summary of LQ searches

Scalar LQ		CDF		D∅	
Generation	□	M_{LQ} (GeV)		M_{LQ} (GeV)	
		Run 1	Run 2	Run 1	Run 2
1st	1	213	230	225	238
	0.5	182	166	204	194
	0		78-117	98	
2nd	1	202	241	200	186
	0.5	160		180	
	0		78-117	98	

S.M. Higgs Searches at CDF

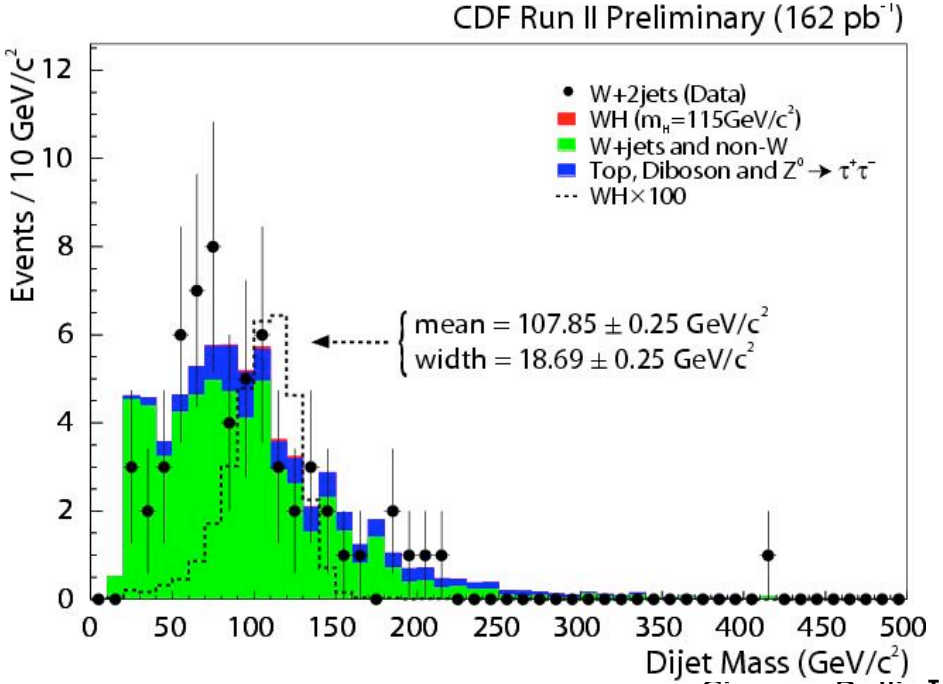




$p\bar{p} \to WH \to l\nu b\bar{b}$

Selection:

- High pt lepton data
- One high pt central *e* or μ, large MET (MET>20 GeV)
- 2 jets (at least one is tagged as b-jet)
- Veto events with >1 lepton (suppress ttbar)

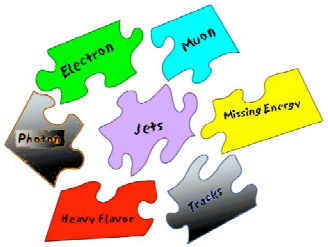


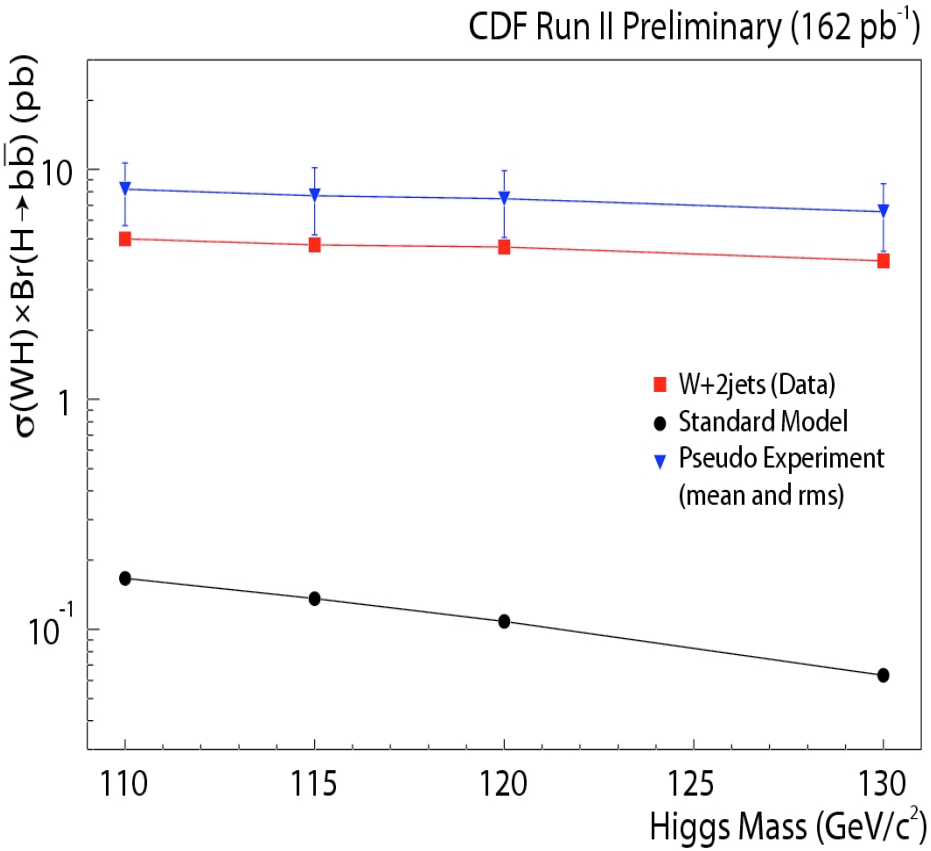
Backgrounds:

- Mistags
- Wbb, Wcc, Wc
- QCD
- tt, single t, di-boson, Z($\to$ tt)

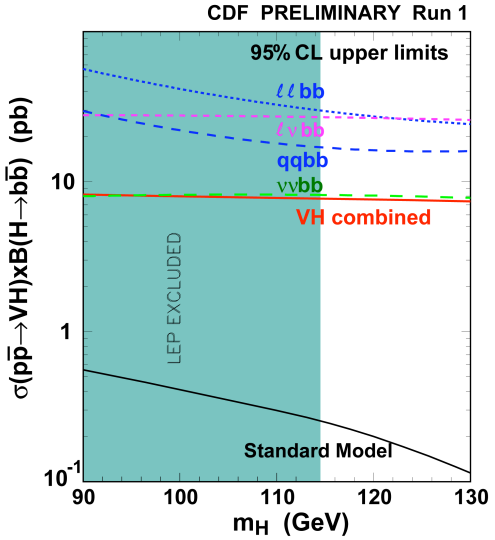
S/ B = 0.054

Higgs Search (cont'd)





Future improvements :
Include forward electron
Improvement jet energy resolution
Improve b-tagging
Combine with other channels



Improved limit over Run1, but sensitivity of current search is limited by statistics

D0 sets an upper limit of 12.4 pb at 95% C.L. for m(H) = 115 GeV/c^2

New Run I top mass combination

Old DØ top mass average: 172.1 ± 5.2(stat.) ± 4.9(sys.) GeV

New DØ top mass average: 179.0 ± 3.5(stat.) ± 3.8(sys.) GeV

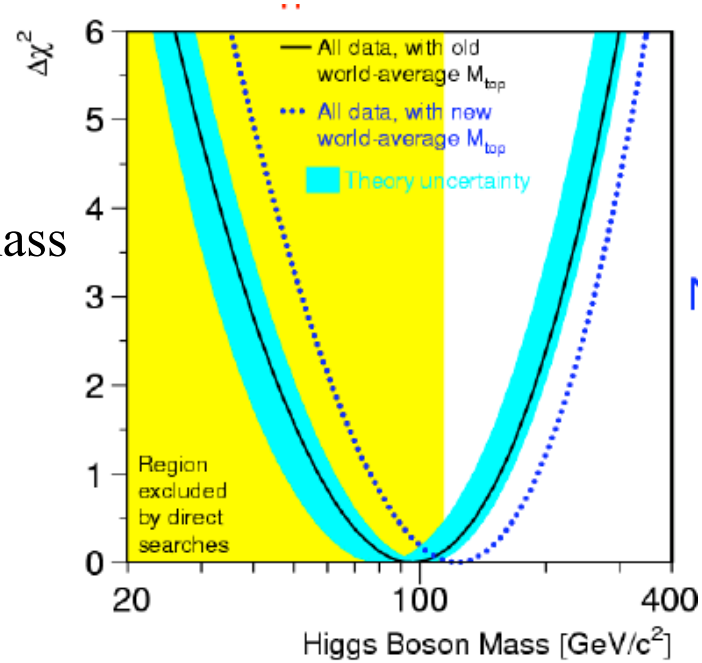
Combination Method:
weighted mean of un-correlated measurements
numerical minimization of χ^2 for correlated measurements

χ^2_{min} = 2.6 for 4 degrees of freedom: 63.2% probability.

Experiment	Measurement	Pull#	Weight [%]
CDF	leptons+jets	−0.32	22.2
	di-leptons	−1.01	7.1
	all-hadronic	+0.75	6.9
DØ	leptons+jets	+0.66	57.8
	di-leptons	−0.80	6.0

#Pull: $(x_i - \overline{x})/\sqrt{\sigma_i^2 - \sigma^2}$

New Higgs mass constraint



$M_{top} = 178.0 \pm 4.3$ GeV

$\log M_H = 2.07^{+0.20}_{-0.21}$

$M_H = 117^{+67}_{-45}$ GeV

or < 251 GeV (95% CL)

Conclusions

Many exciting results are currently produced at CDF and D0
First exotics physics papers will be submitted very soon!

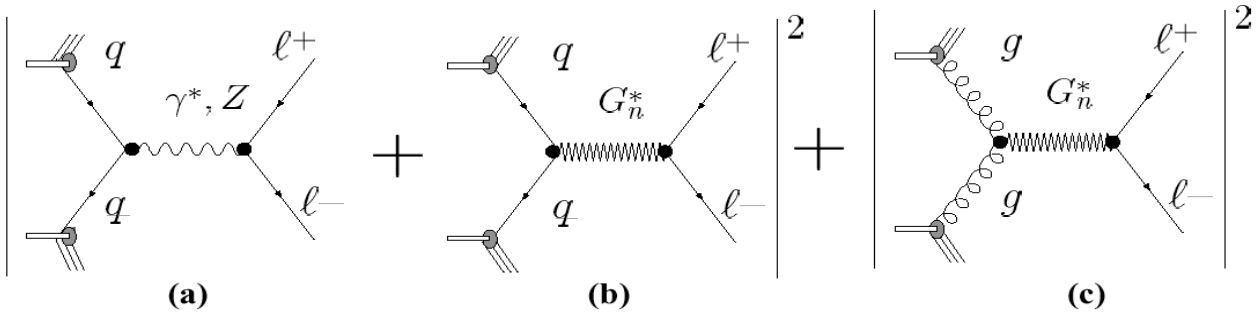
A signature-based approach is complemented by
Model-Based searches
same signature, different physics

The Puzzle is becoming more and
more interesting!

Backup Slides

Large Extra Dimensions (LED)

- Weakness of gravity is explained by Extra Dimensions
  - SM is confined to 3D-world (brane)
  - Gravity propagates in ED and is as strong as other interactions but this is apparent only to (3+n)-dimensional observer
- Can detect LED via virtual graviton effects
  - Searched for anomalies in e^+e^- and $\gamma\gamma$ events



  - Also searched for monojet signatures
    - Jet recoiling against G_n

Old Higgs mass limit from M_{Top}

Old:

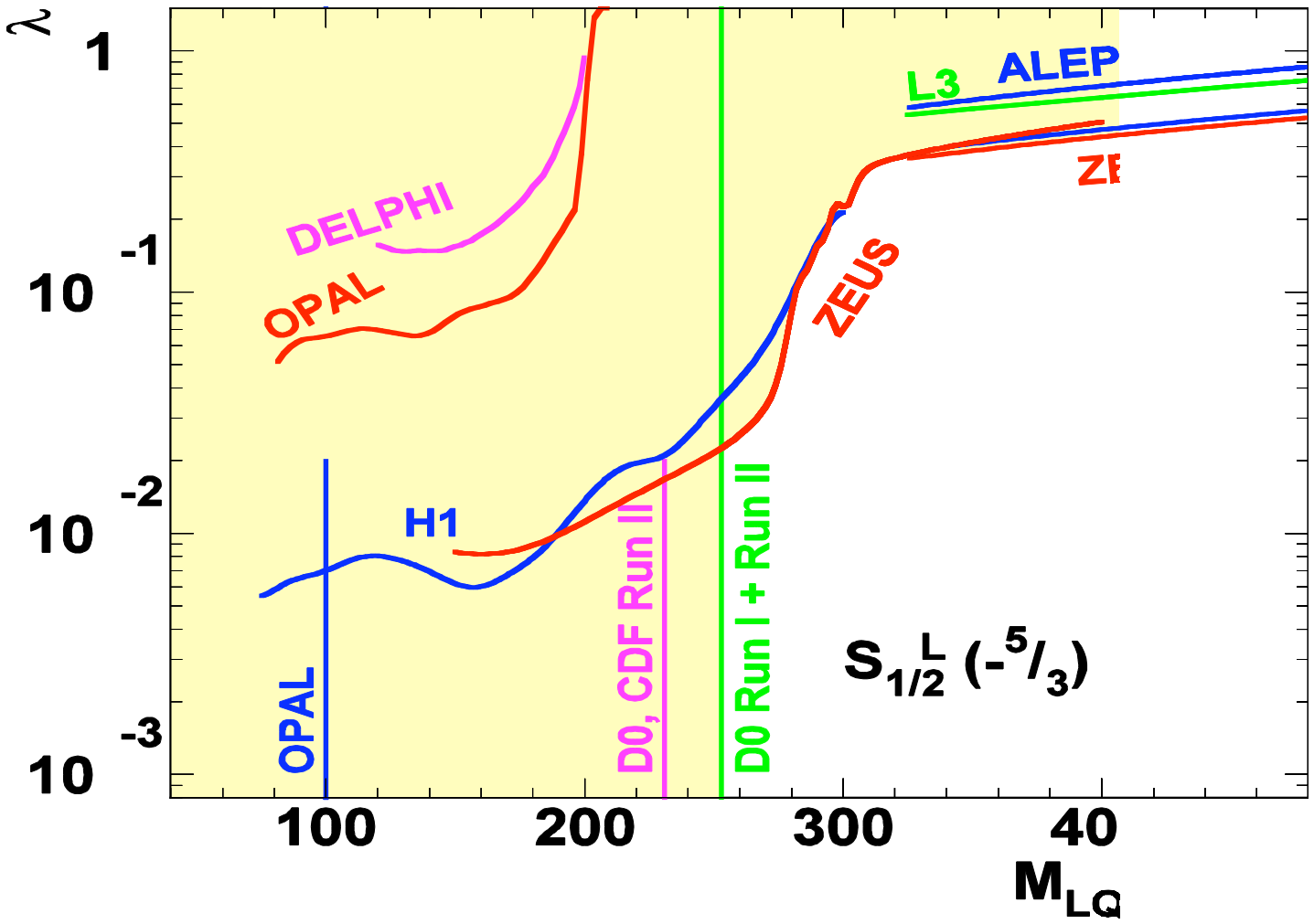
$$M_{top} = 174.3 \pm 5.1 \text{ GeV}$$

$$\log M_H = 1.98^{+0.21}_{-0.22}$$

$$M_H = 96^{+60}_{-38} \text{ GeV}$$

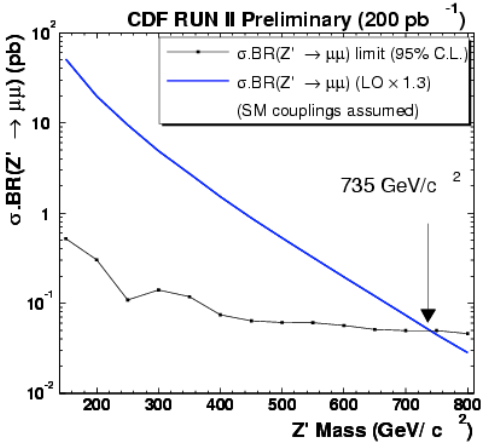
$$\text{or} < 219 \text{ GeV (95\% CL)}$$

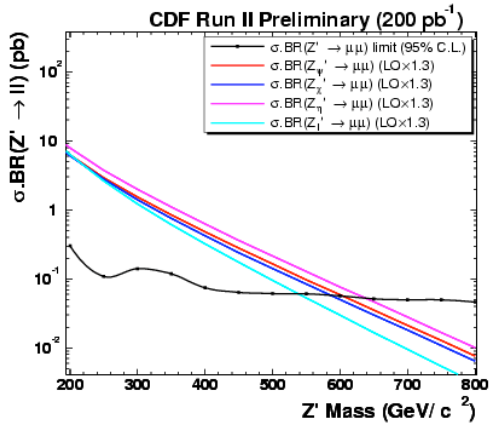
LQ limits compared to HERA



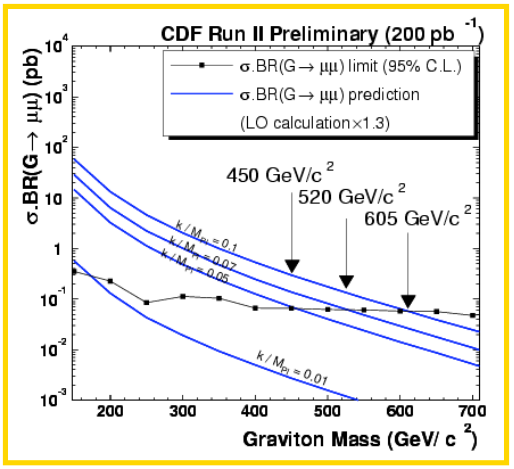
Dimuons searches at CDF

Cross section and mass limits on SM-like and E6 Z':





Cross section and mass limits on RS G:



Cross section and mass limits on Littlest Higgs Z':

We use the same cross section*BR curve as of SM-like Z' for the Littlest Higgs model limits.