Les Rencontres de Physique de la Vallée d'Aoste

Non SUSY Searches at the Tevatron

Kaori Maeshima (Fermilab)

For the D0 and CDF Collaborations

Fermi National Accelerator Laboratory

Search Strategies & This Talk Organization

New Phenomena ⟺ Exp. Signatures

(Z', SUSY, Extra Dimension, LQ, etc….)

Searches are motivated by the physics beyond the Standard model.

⇒

⇐

(γγ, **e**μ, ττ, jets+$\not\!\!E_T$, etc.)

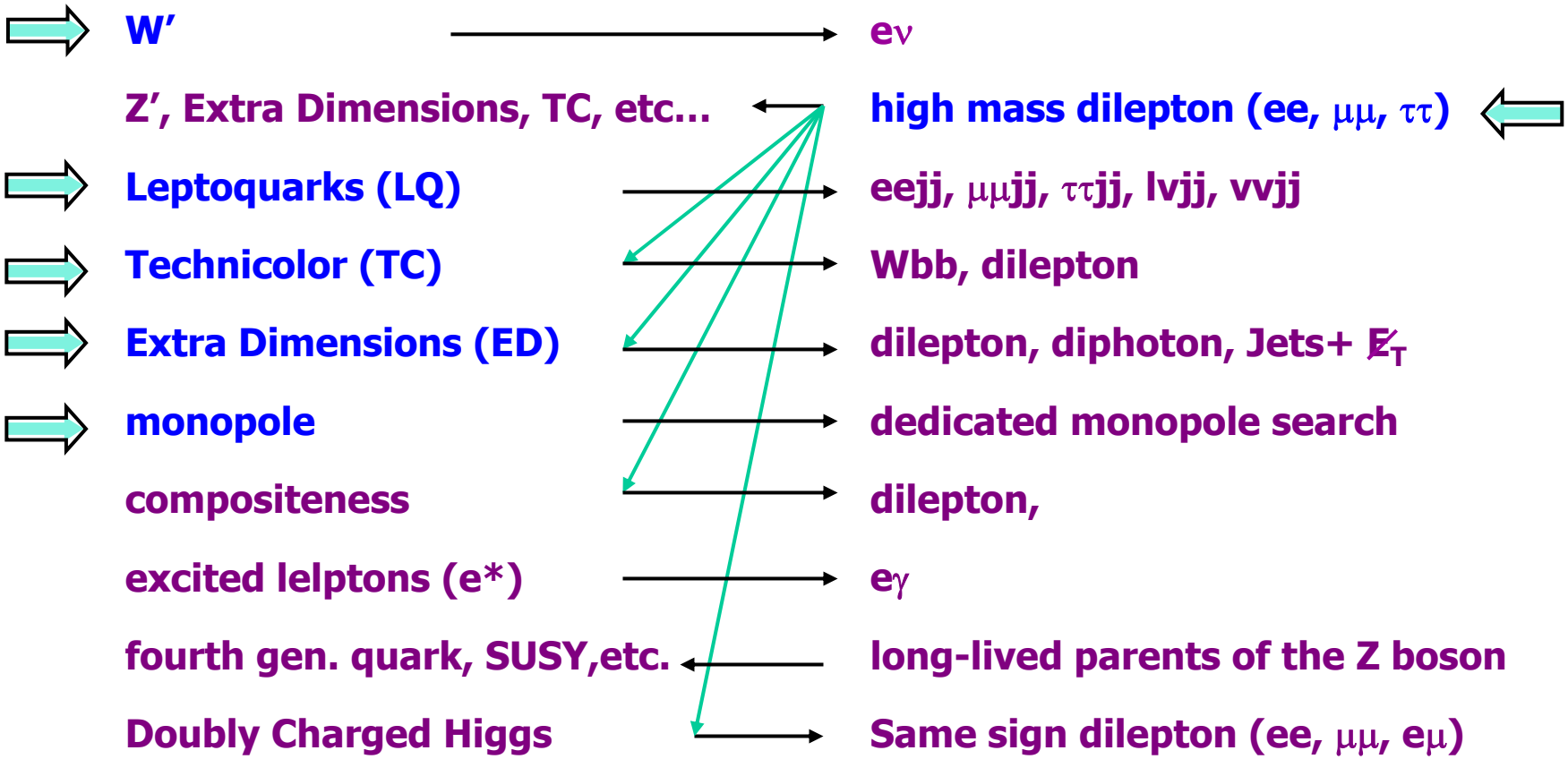
But, all the analyses start with the experimetal observables, 'final state signature'

One type of model (new particle) can predict many different signatures (decay modes).

One type of signature can explore many different models.

- In general, this talk is organized by the physics topics.
- With the exception of the high mass dilepton search (signature based approach).

New Phenomena ↔ Exp. Signatures (⇨ Topics covered)



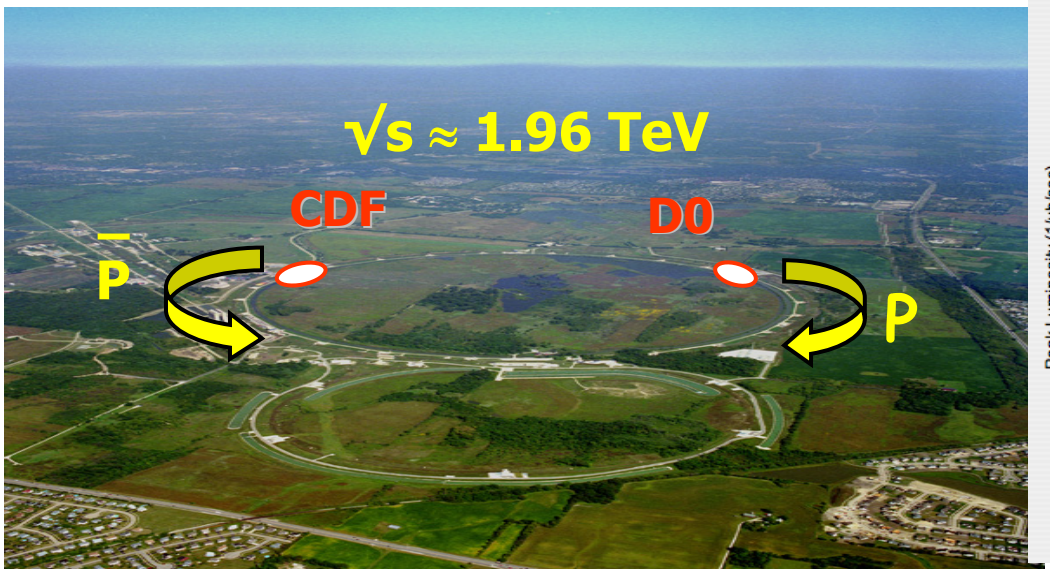
⇨ http://www-cdf.fnal.gov/physics/exotic/exotic.html
http://www-d0.fnal.gov/Run2Physics/WWW/results/np.html ⇦

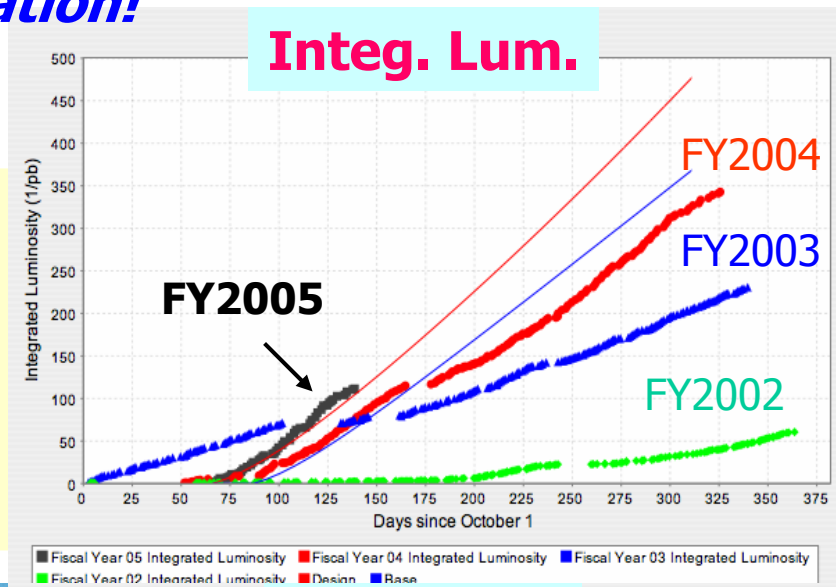
Run II Tevatron Performance

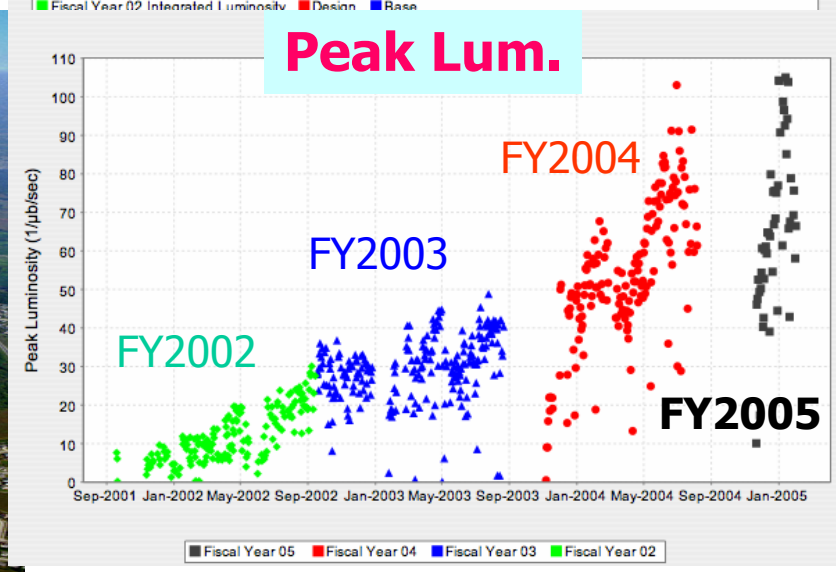
Highest Energy Collider in Operation!

→ **place to search for new physics**

- **Operating extremely well with recycler.**
- **highest Lum: 1.074 e32 $cm^{-2}sec^{-1}$,Feb.,2005**
- **single store high :5.05 pb^{-1}, Jan,2005**
- **Analyses presented here are using up to ~ 345 pb^{-1} of data**





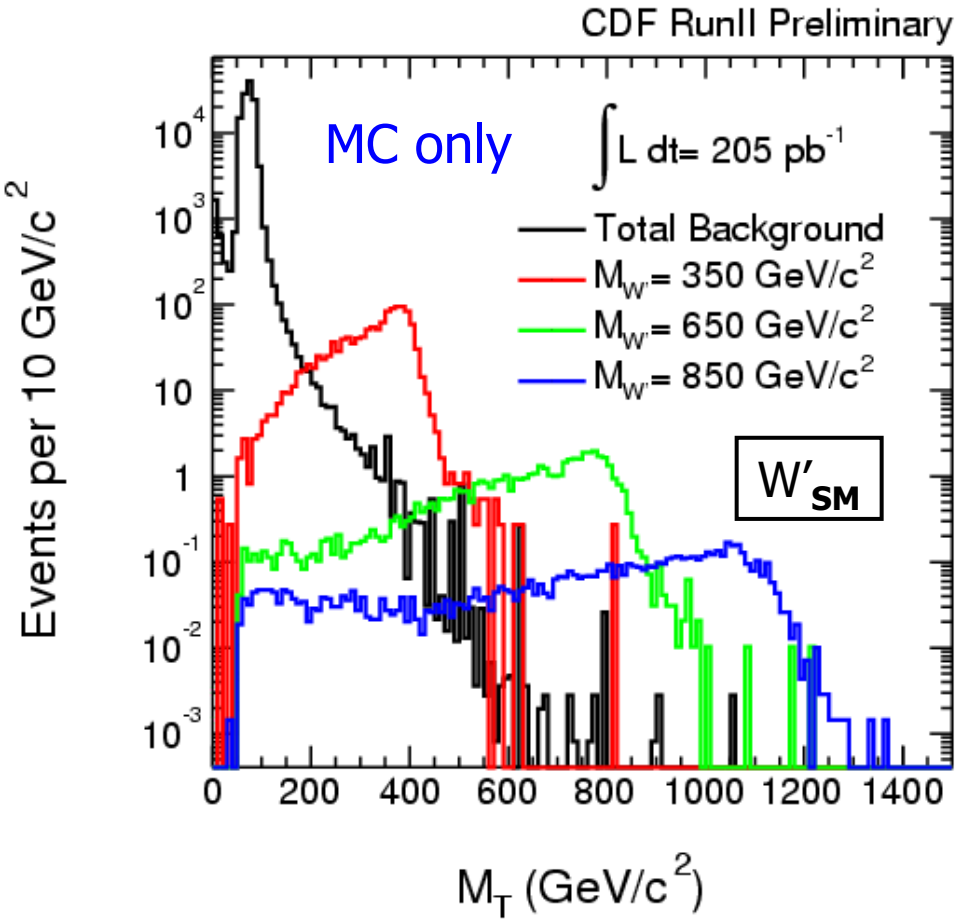


W′ search in eν channel

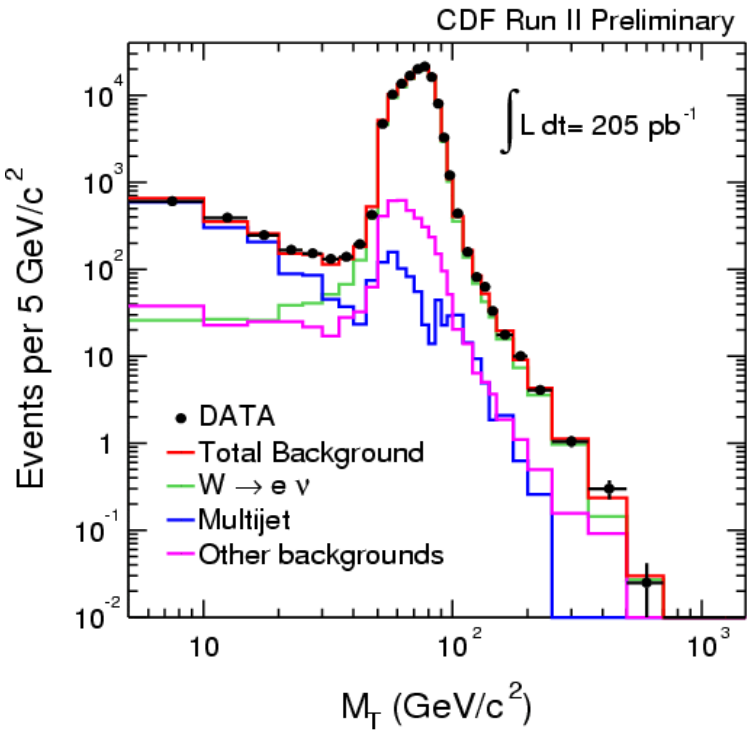
(very recent result from run II.)

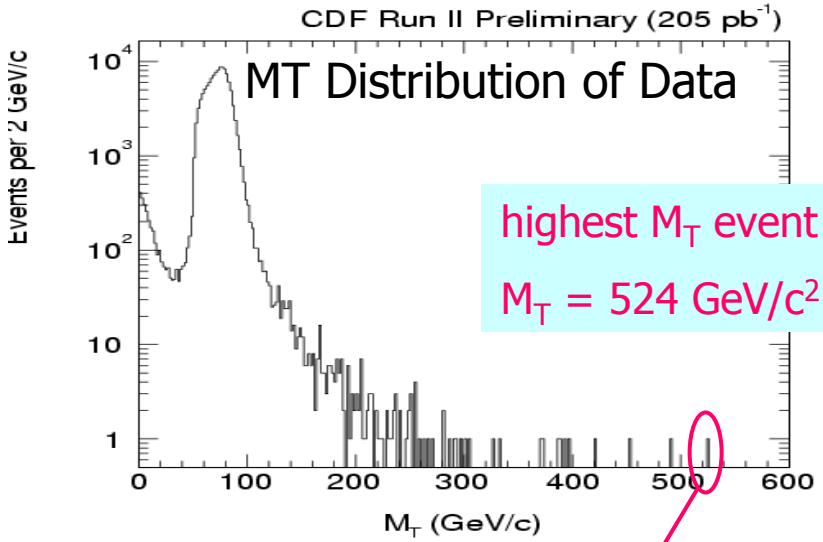
- W′: additional charged heavy vector boson
- appears in theories based on the extension of the gauge group
- e.g. Left-right symmetric models: $SU(2)_R \rightarrow W_R$
- assume: the neutrino from W′ decay is light and stable.
- signature:

high p_T electron + high $\not{E}_T$



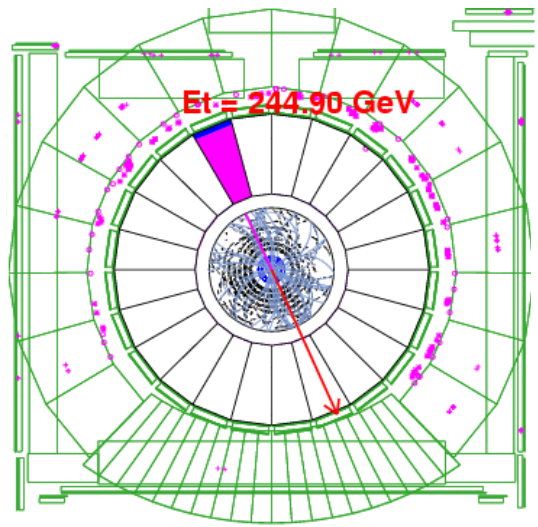
W' search (cont.)





highest M_T event

M_T = 524 GeV/c^2

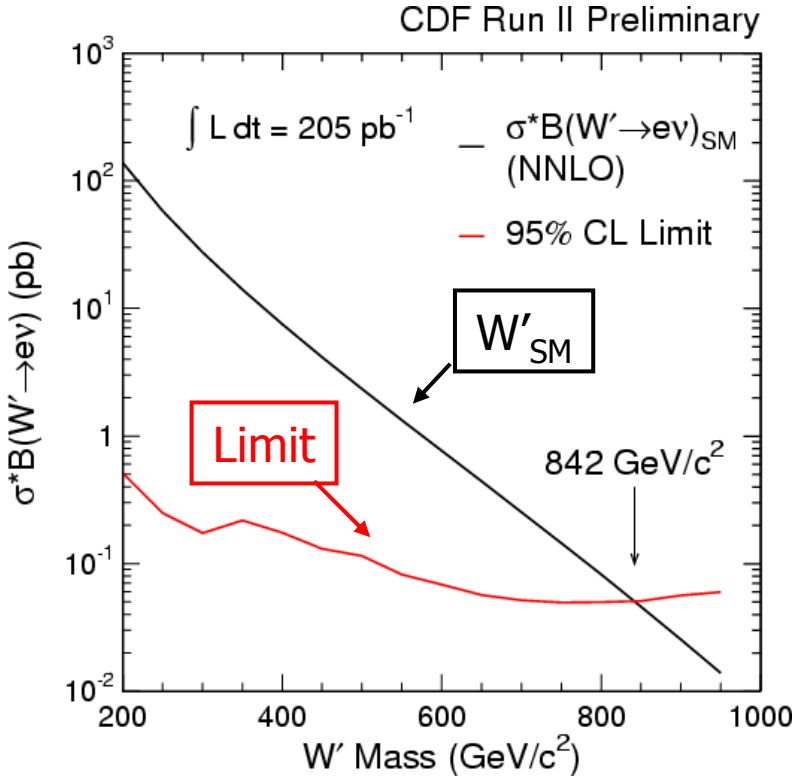


	Events in Each M_T Bins (GeV/c^2)				
	200 - 250	250 - 350	350 - 500	500 - 700	700 - 1000
$W \to e\nu$	35.8 ± 4.3	19.5 ± 2.5	4.34 ± 0.99	1.08 ± 0.73	0.0 ± 0.0
Jets	2.6 ± 6.3	0.0 ± 3.4	0.0 ± 0.31	0.0 ± 0.0	0.0 ± 0.0
Other Backgrounds	5.0 ± 0.7	3.2 ± 1.2	2.76 ± 3.26	0.12 ± 0.04	0.04 ± 0.02
Total Background	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

W' search (cont.)

- No evidence of W' existing…..
- set limits on W' production rate
- use binned likelihood fitting method
- two types of systematics are examined as a function of M_T :
  - affect event rate (dominant: PDF, ~14% at M_T= 850 GeV)
  - affect the shape (dominant: electron energy scale, ~16% at M_T= 850 GeV)
- σ*B(W'→ eν) limit: ~ 50 – 100 fb for M(W') > 500 GeV/c^2 at 95% CL.

(All the limits stated in this talk are at at 95% C.L.)



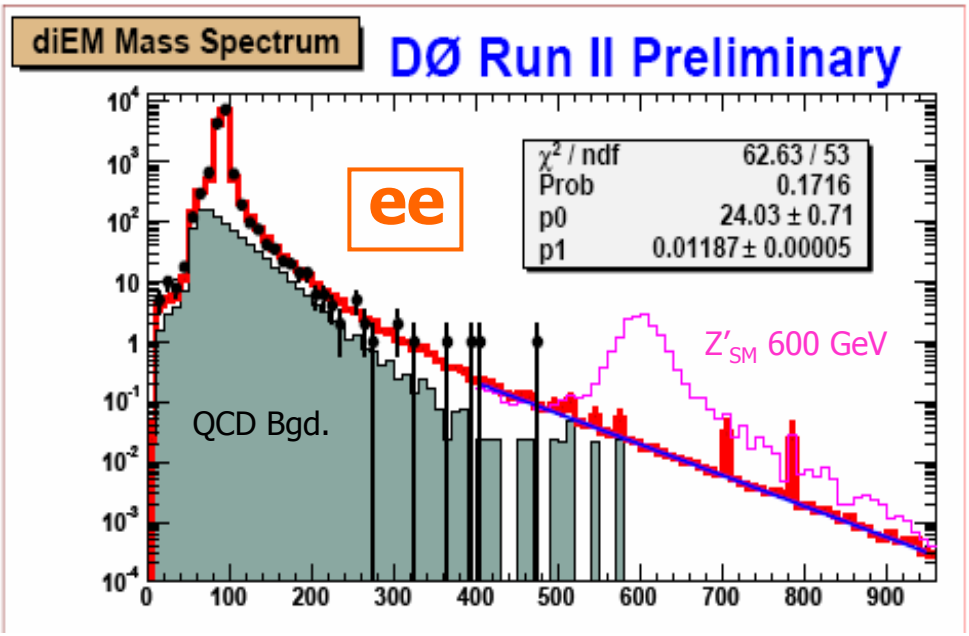
Limit: M(W'$_{SM}$)> 842 GeV/c^2

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

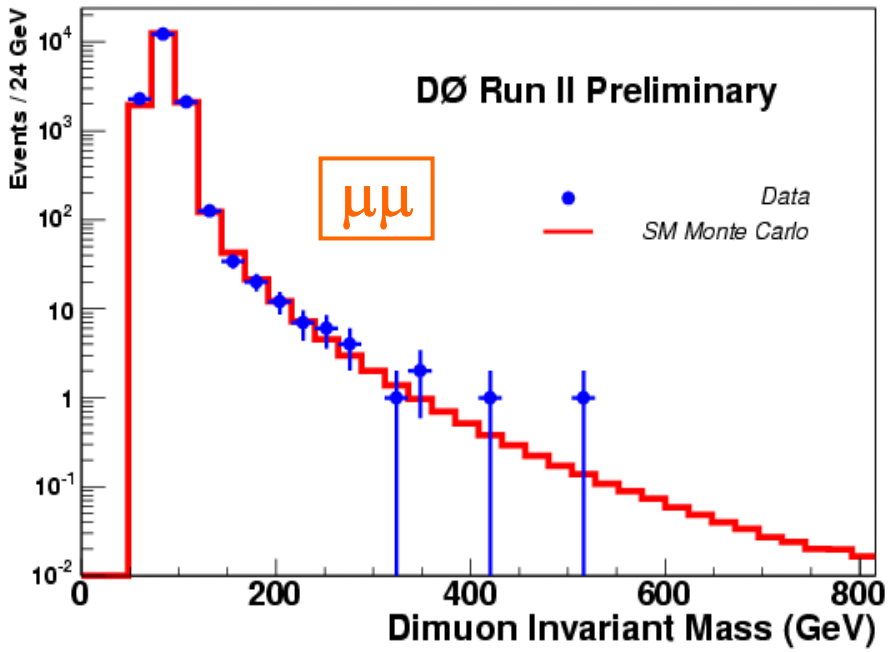
Searches in High Mass dileptons

(Signature based approach)

$\int Ldt = 200\ pb^{-1}$



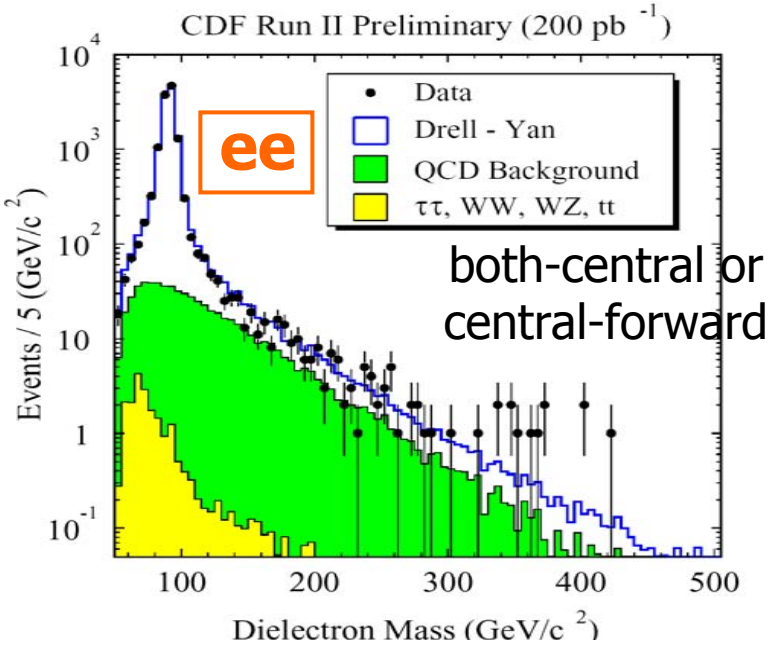
$\int Ldt = 250\ pb^{-1}$



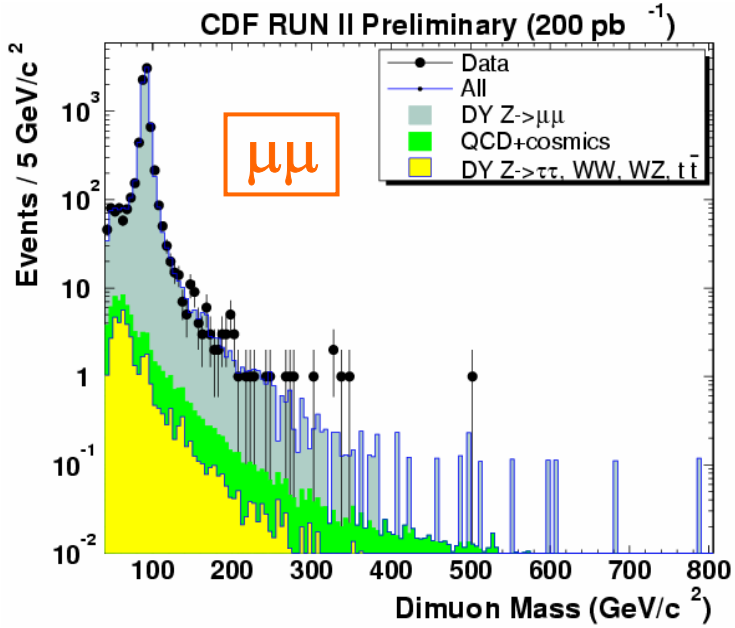
- Relatively 'clean' channel
- Z0 peak as a calibration point
- Many models to explore:

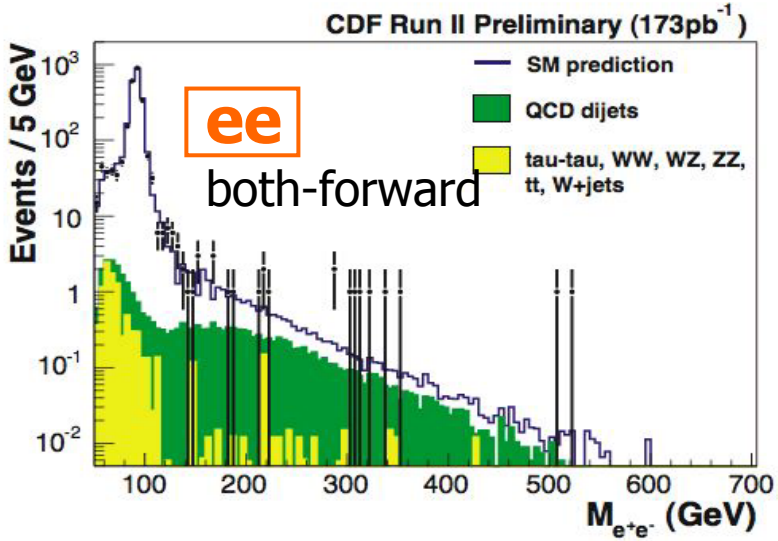
Z', TC, RS graviton, LED, compositeness, etc…

Searches in high mass dileptons (cont.)

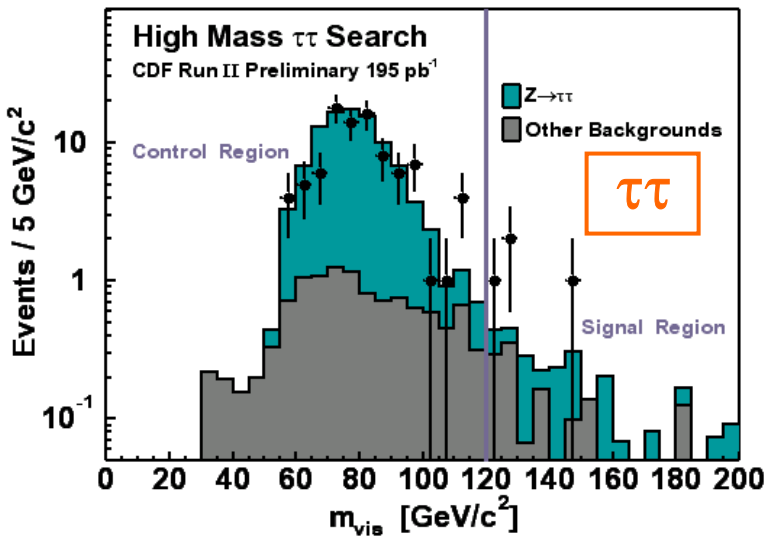


both-central or central-forward

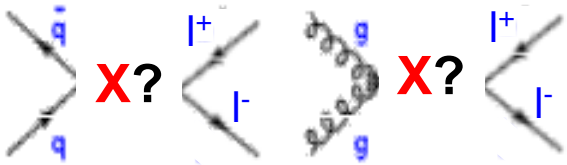




both-forward



Mass Bump Search Strategies



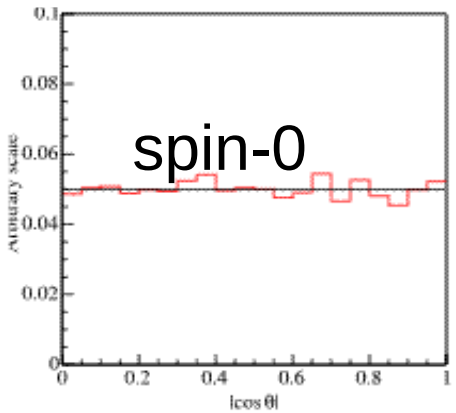
The same sensitivity for ANY X?

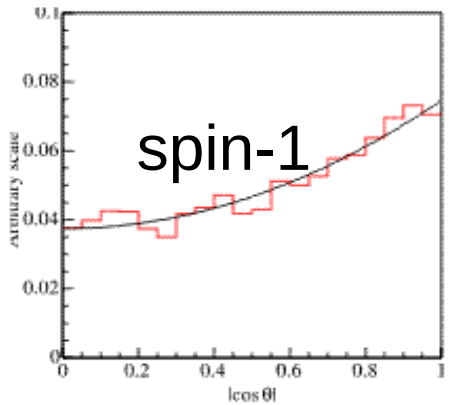
- Perform general searches comparing data to expectation
- Determine spin dependent acceptance and σ.BR*
- Interpret the results according to many new models!
  - Spin-0: RPV sneutrinos
  - Spin-1: Z'_{SM}, E6 Z', Little Higgs Z', TC (ρ_T, ω_T)
  - Spin-2: RS graviton

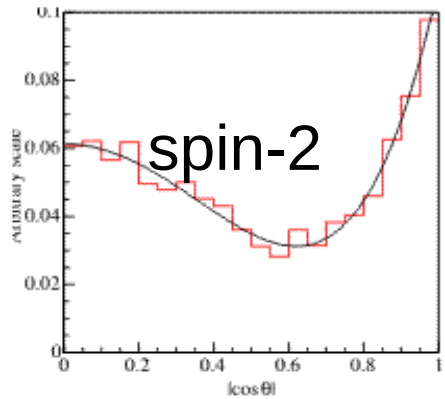
* Though D0 has not calculated the spin dependent acceptances explicitly as CDF, the approaches are similar.

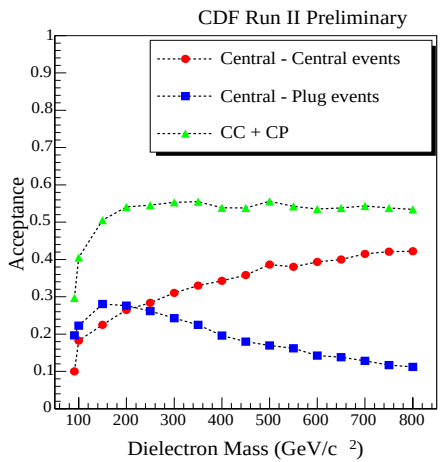
Spin-dependent Acceptance

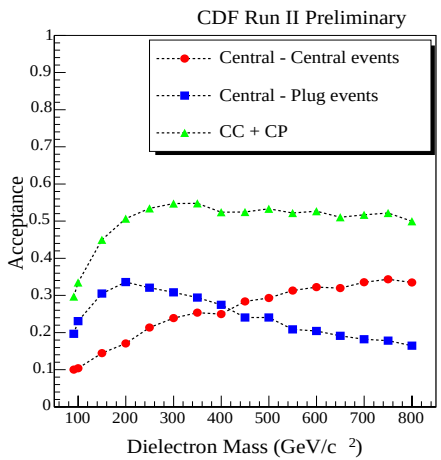
Angular distribution and therefore acceptance of decay product depends on the spin of the decaying particle.

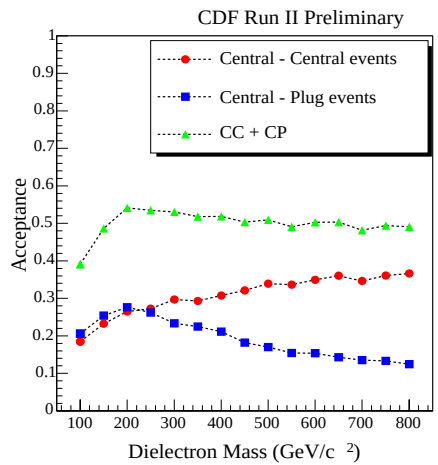










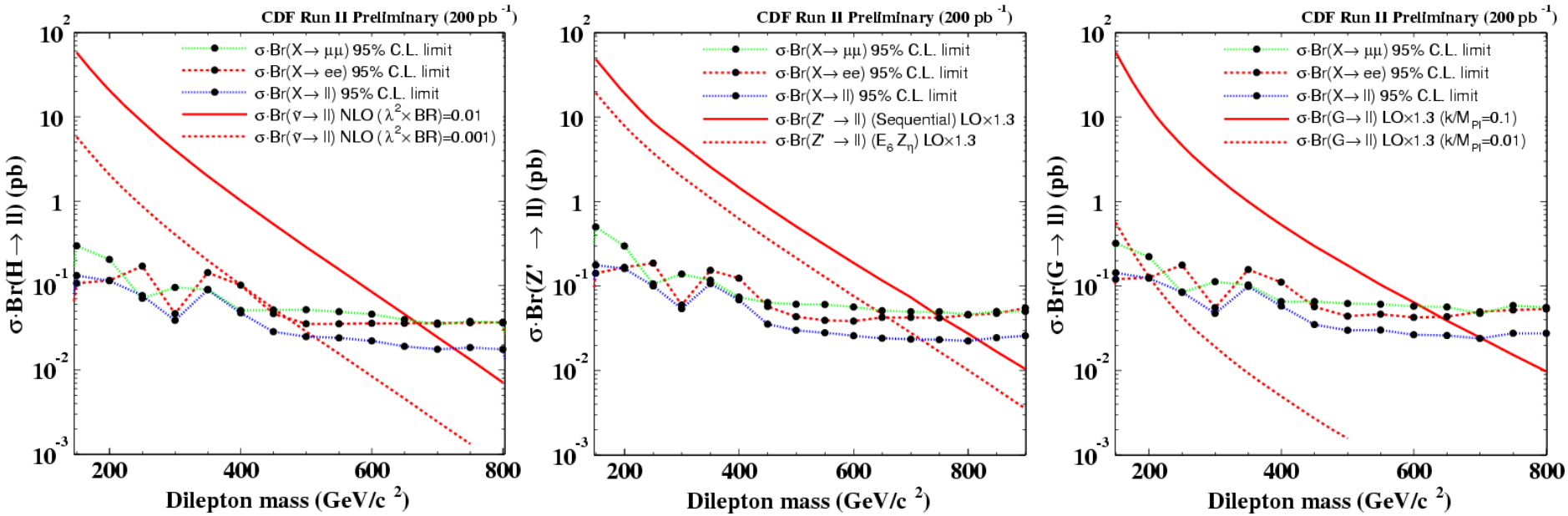


central-central electrons (CC)
central-forward electrons (CP)
above combined

central: $|\eta| < 1.0$
forward: $1.0 < |\eta| < 3.0$

σ*B Limits (ee and μμ channels combined)

spin-0 spin-1 spin-2



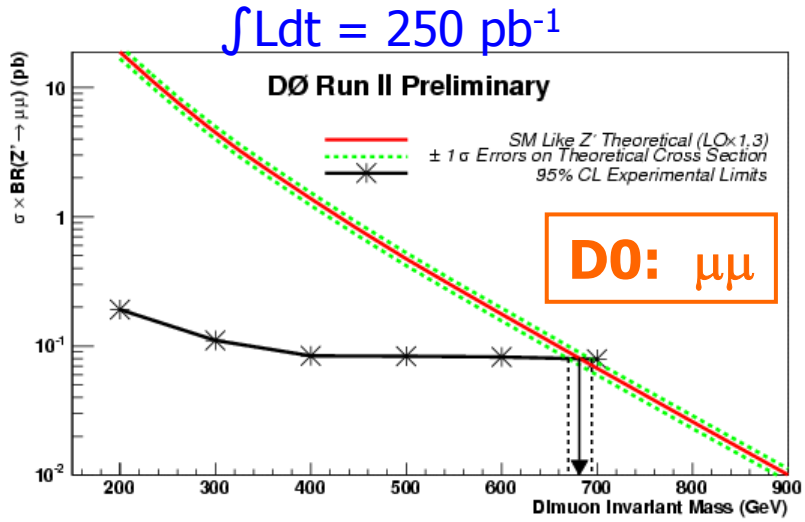
σ*Br(X → μμ) 95% CL limit

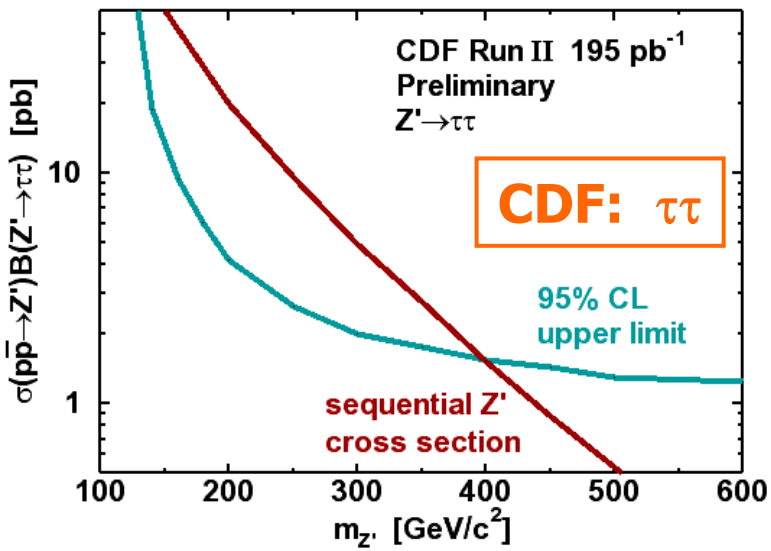
σ*Br(X → ee) 95% CL limit (CC and CP)

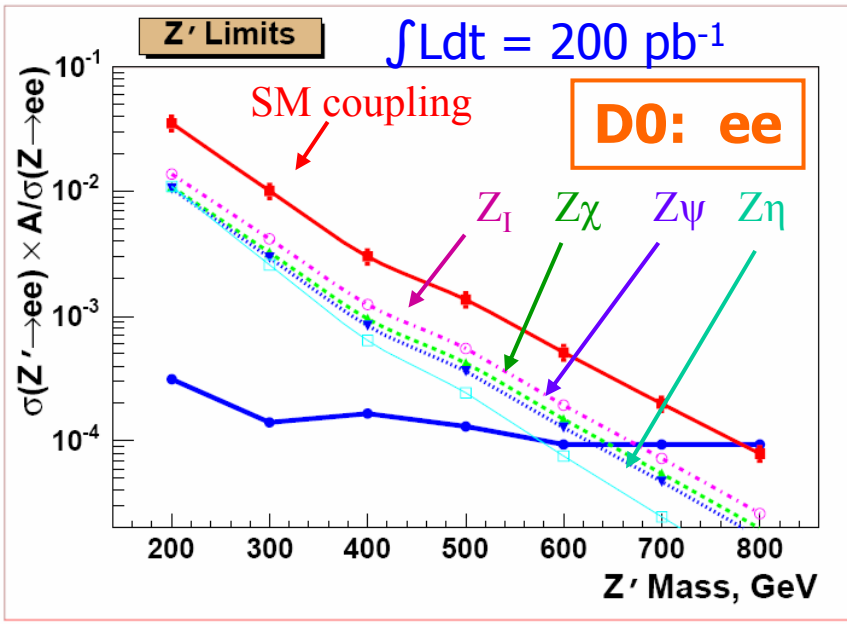
ee, μμ combined limit

- σ*Br limit: ~ 25 fb for all spins for the high mass region (M_{ll} > 600 GeV)
- These limit curves can be compared with many models
- Individual channel limits are still very important - lepton universality ?

Spin-1, Z′ limits







z′ mass limits (in GeV/c²)

SM Couplings	ee	μμ	ee+μμ	ττ
CDF :	750	735	815	394
DØ:	780	680		

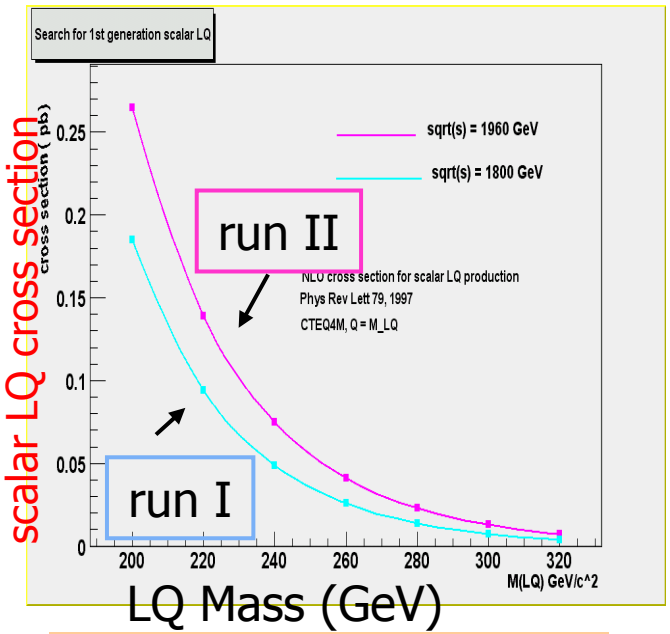
E_6	Z_I	Z_χ	Z_ψ	Z_η	
CDF:	610	670	690	715	(ee+μμ)
DØ:	575	640	650	680	(ee)

Leptoquarks (direct searches)

Several extensions 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

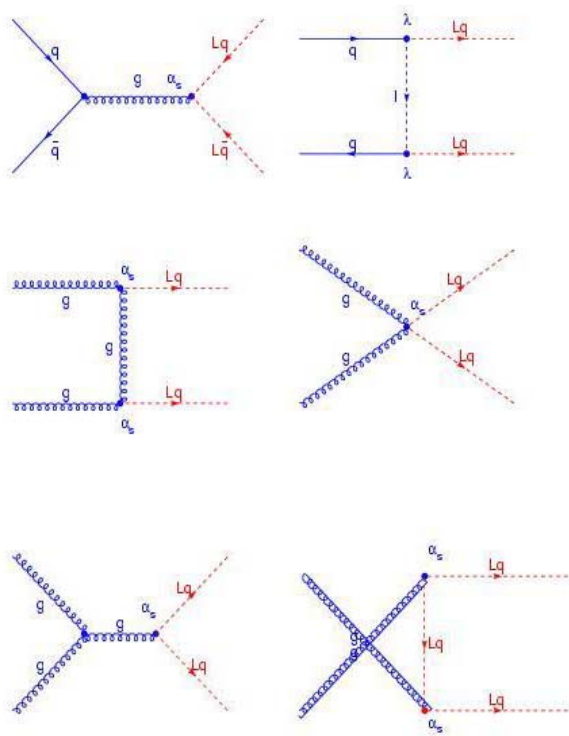


30% increase in cross section at RunII

At the TeVatron they are pair produced

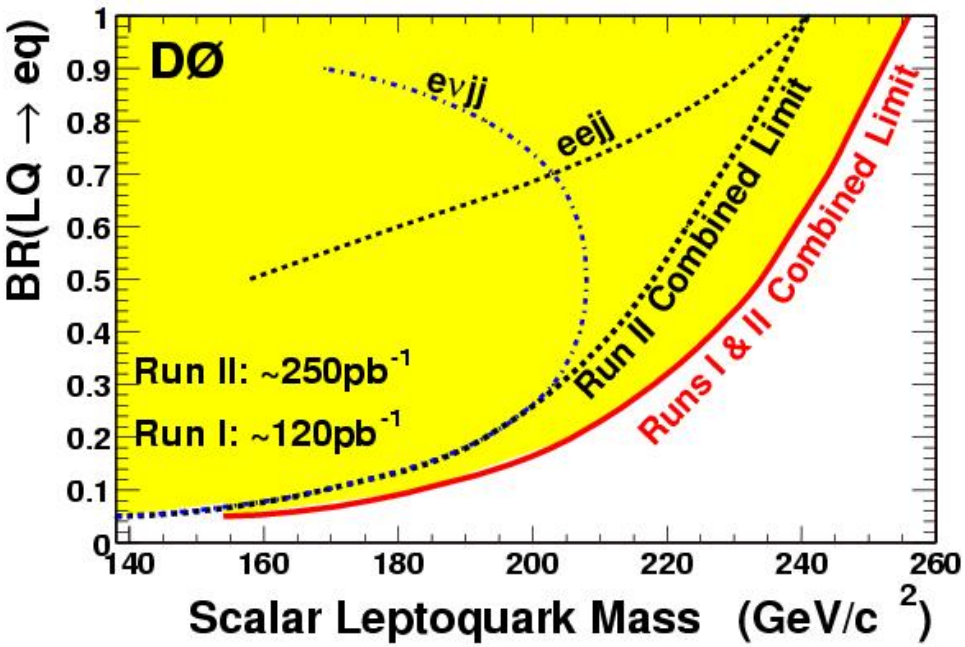
Their decay is controlled by β = BR (LQ$\rightarrow$lq)

Experimental signature:
- high P_T isolated charged lepton(s)
- and/or $\not\!\!E_T$
- & jets



1st and 2nd generation LQ

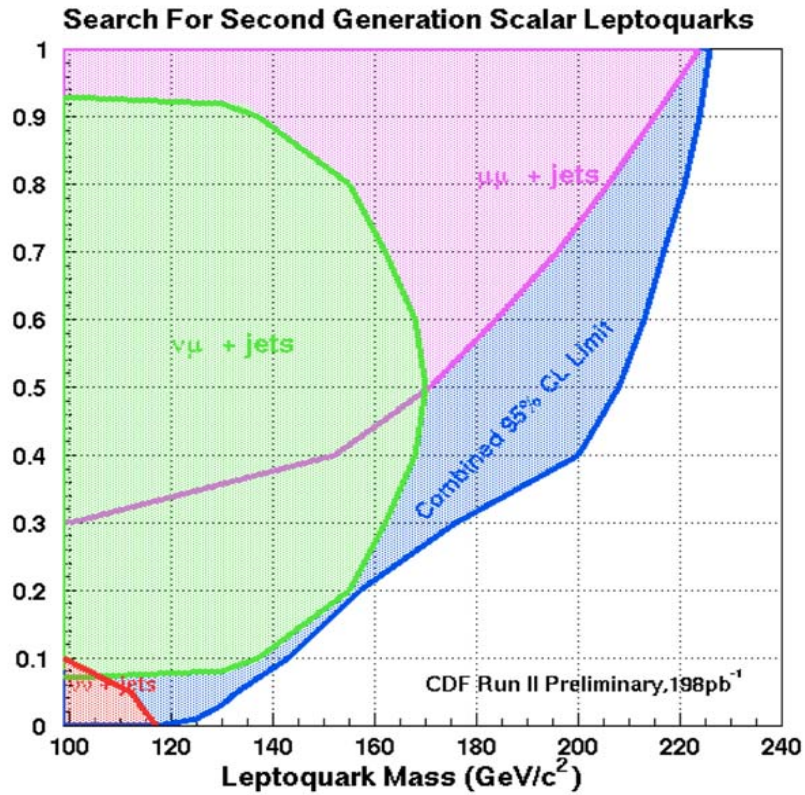
channels: eejj, evjj, (νvjj)



for β=1,
D0: Run I + II, M_{LQ} > 256 GeV/c^2
CDF: Run II, M_{LQ} > 235 GeV/c^2

HERA: 290 GeV/c^2 (1st Gen. only), $\lambda=\alpha_{em}$

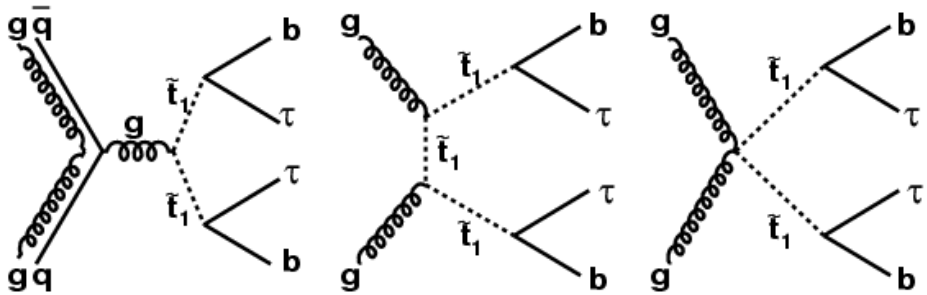
channels: μμjj, μνjj, ννjj

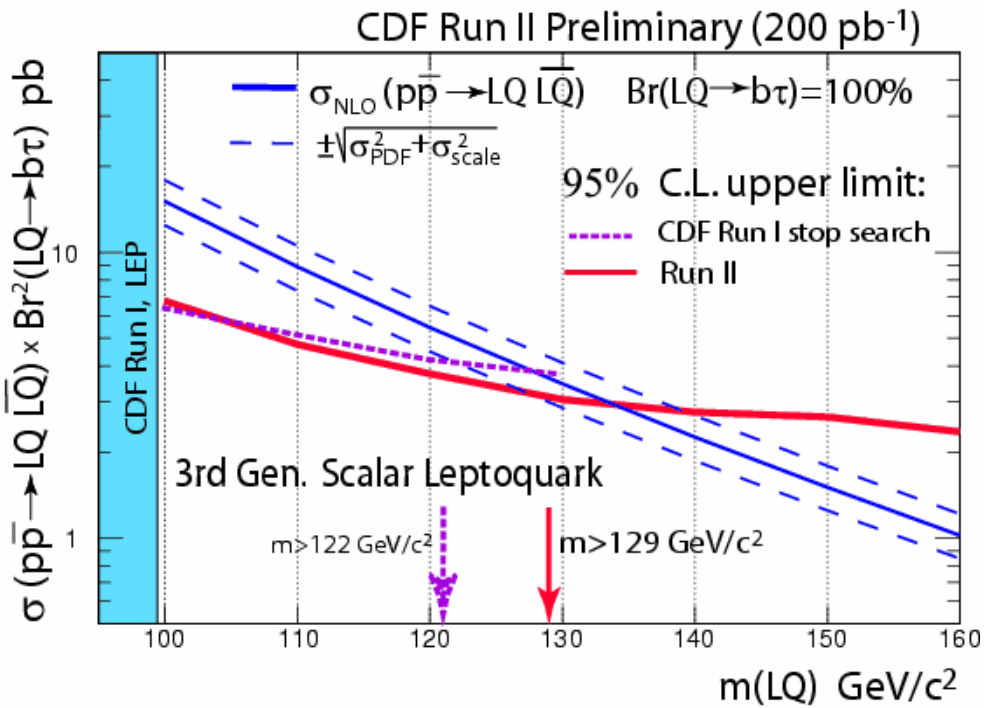


for β=1,
D0: Run I, M_{LQ} > 200 GeV/c^2
CDF: Run II, M_{LQ} > 224 GeV/c^2

3rd generation LQ

channel: $\tau_l\tau_h jj$ (one leptonic, one hadronic decayed τ's)





final state: $\tau\tau$bb, same as the RPV Stop search signature (see details → SUSY talk)

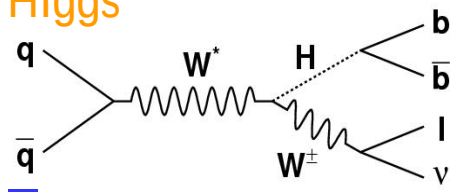
$\tau_l + \tau_h$
$n_{jet} >= 2$
$Y_T = P_T(l) + P_T(\tau_h) + \not{E}_T > 85$ GeV/c
$M_T(l, \not{E}_T) < 35$ GeV/c^2

expect 4.8 $\pm$ 0.7 events,
observed 5 events

for β=1,
CDF: Run II, $M_{LQ} > 129$ GeV/c^2

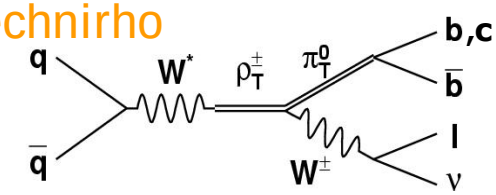
Technicolor

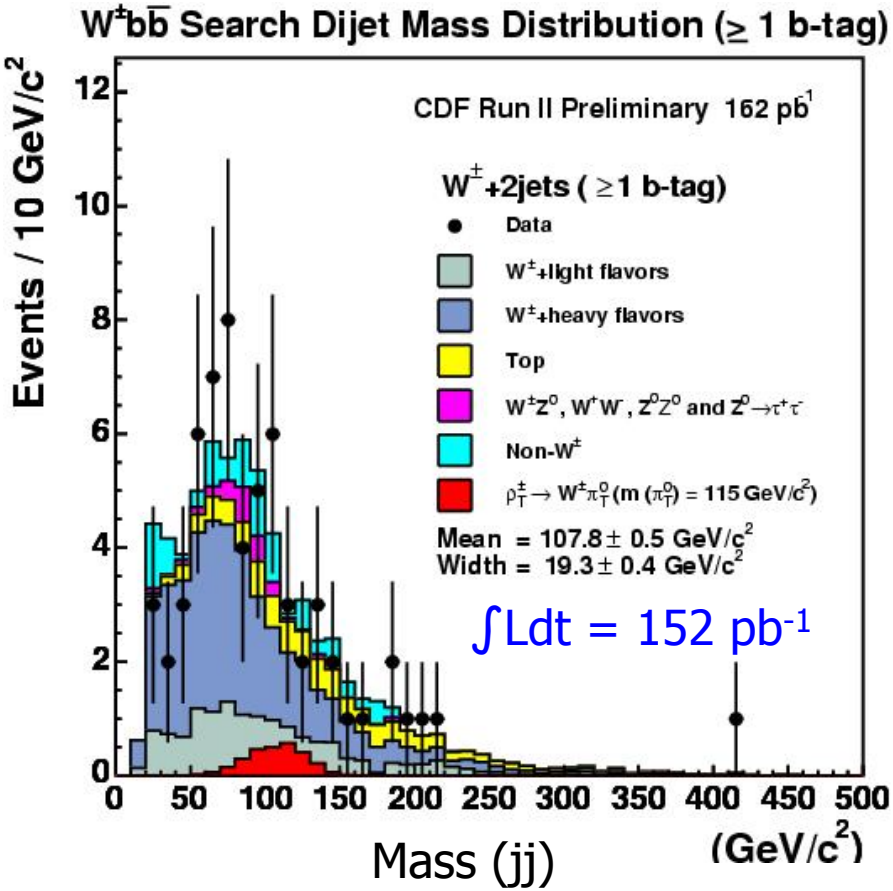
SM Higgs

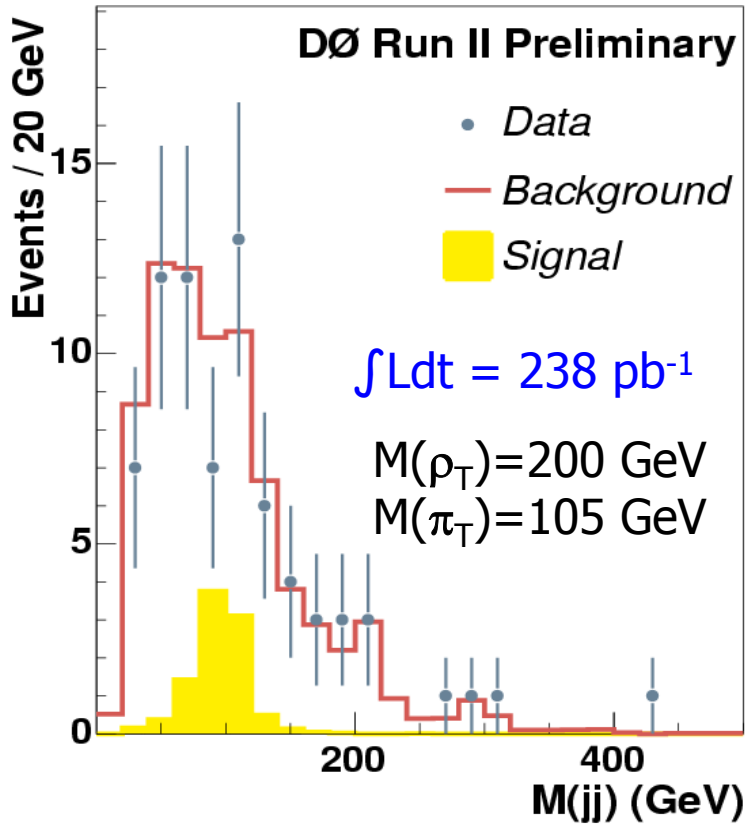


- Can search for Technicolor in many signatures
- This search explores same signature as SM Higgs (lvbq)

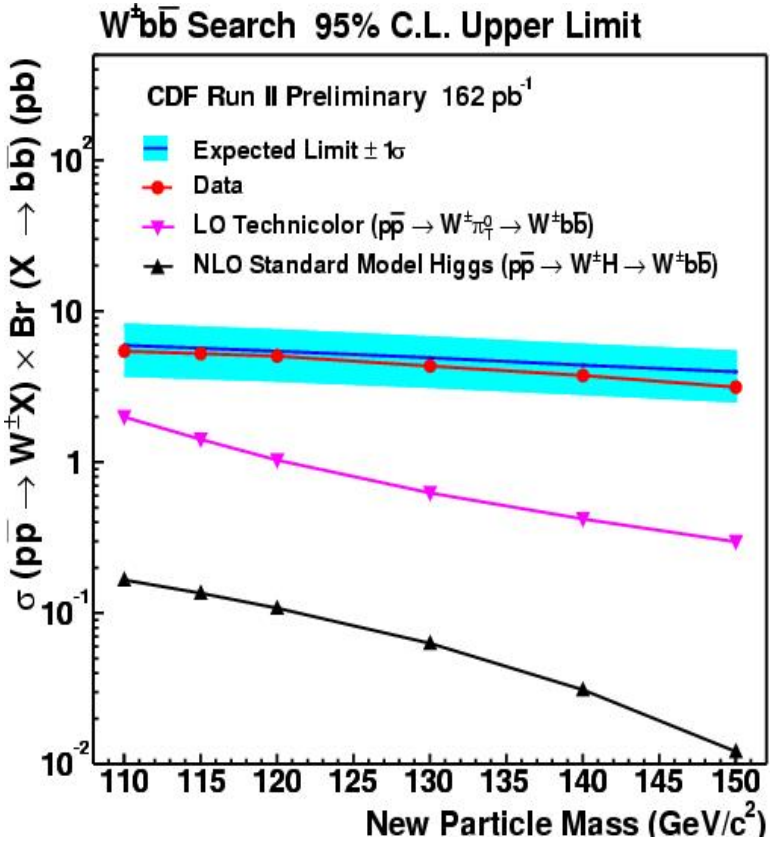
Technirho







Technicolor



From the spin-1 dilepton result, mass bounds are also obtained for ρ_T and ω_T for different M_T.

M_T is a parameter in the Straw-man TC model which affects the production cross section and the decay rates.

M_T	mass limit (GeV/c^2)
500	320
400	315
300	310
200	225

note: We had mass bounds on this channel in Run I.
Run II cross section limit is better than Run I.
The theoretical prediction was revised downwards.

Extra Dimensions (ED)

Alternatives to SUSY for solving the hierarchy problem (M_{EW} << M_{Plank} ?)

- Focus on:
- Models with n extra spatial dimensions

Large ED (ADD): Arkani-Hamed, Dimopoulos, Dvali Phys Lett B429 (98)

n>0 (n>2) compactified

$M^2_{PL} \sim R^n M_s^{n+2}$, Ms: string scale

TeV-1 ED (DDG): Dienes, Dudas, Gherghetta Nucl Phys B537 (99)

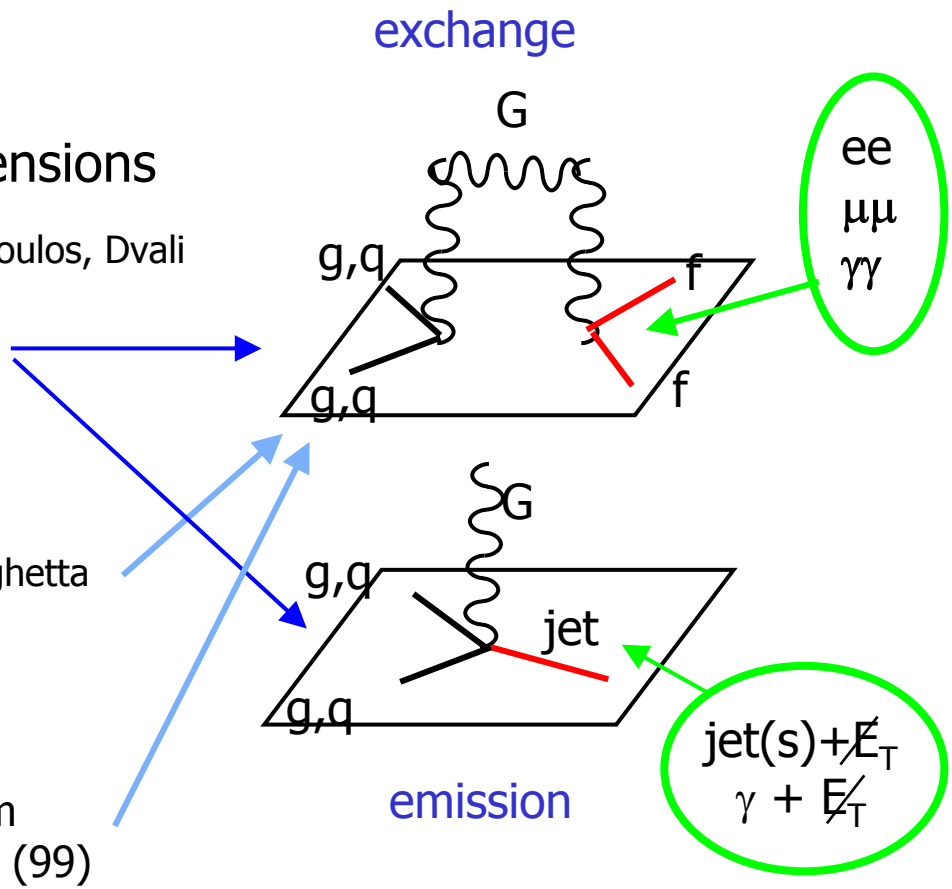
n>=1 (n=1)

M_c: compactification scale

Warped ED (RS): Randall, Sundrum Phys Rev Lett 83 (99)

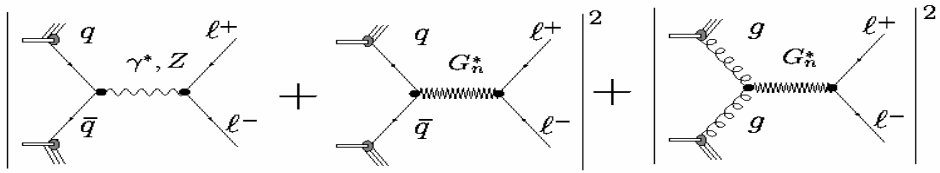
n=1, highly curved

k/M_{Pl}, k: curvature scale



LED with dilepton & $\gamma\gamma$

Search for enhanced dilepton production



Gravity effect parametrized by η_G

$$\frac{d^2\sigma}{d\mathrm{M}\, d\cos\theta^*} = f_{SM} + f_{\mathrm{int}}\eta_G + f_{KK}\eta_G^2$$

ee, $\gamma\gamma$ invariant mass

scatter. angle

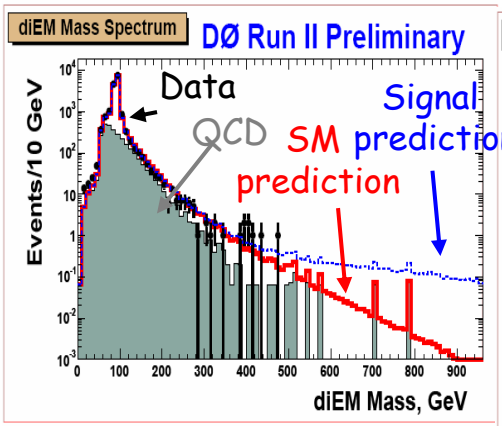
Functions of M & $\cos\theta^*$ determined by theory

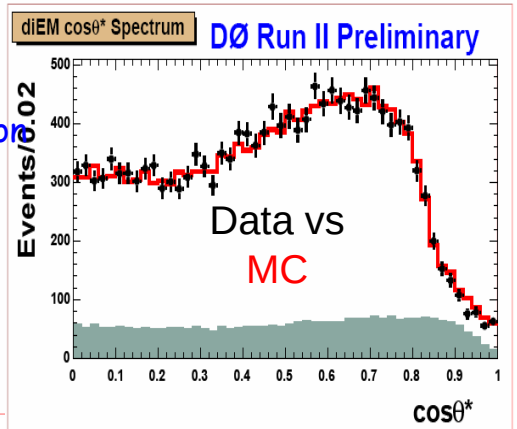
DØ Search Strategy:

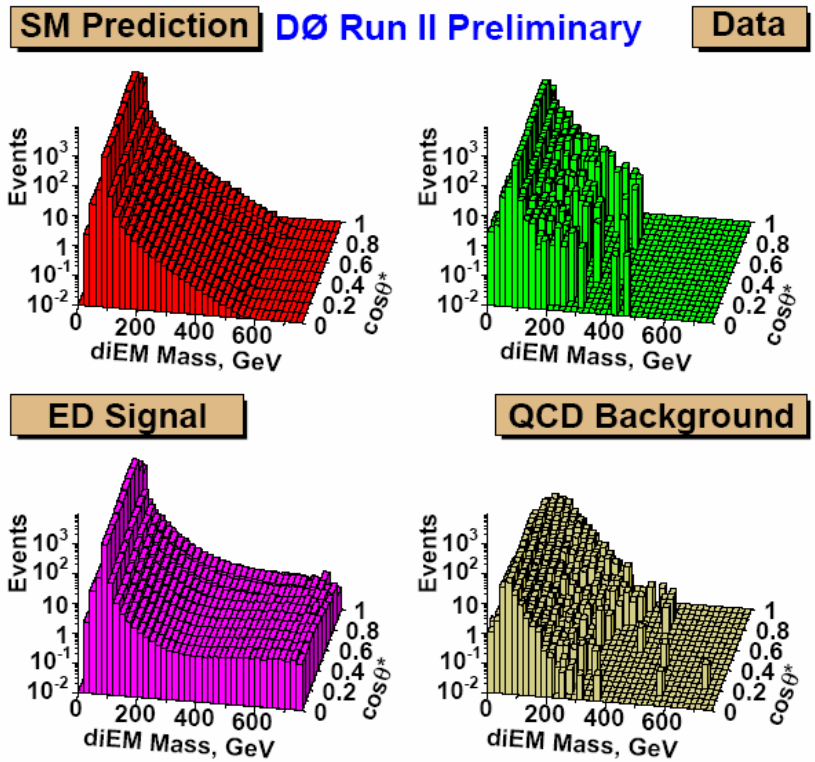
- Combine dielectron and diphoton to diEM signature
- Fit distribution of M vs $\cos\theta^*$ of Data – SM
- Extract η_G from the fit
- Translate η_G into M_s limit

- $\eta_G = F/M_S^4$
- F is a model dependent dimensionless parameter ~ 1:
  - GRW: F = 1
  - HLZ: F = $\log(M_s^2/M^2)$, n =2
    F = 2/(n-2), n > 2
  - Hewett: F = 2 λ/π, $\lambda = \pm 1$
- M_s is the UV cutoff = $M_{PL(4+n\ \mathrm{dim})}$

LED with ee & γγ







$\eta_G = 0.00 \pm^{0.12}_{0.00}\ \text{TeV}^{-4}$ $\quad \eta_G^{95\%} = 0.292\ \text{TeV}^{-4}$ for $\lambda > 0$

$\eta_G = -0.08 \pm^{0.08}_{0.18}\ \text{TeV}^{-4}$ $\quad \eta_G^{95\%} = -0.432\ \text{TeV}^{-4}$ for $\lambda < 0$

- Translate $\eta_G^{95\%}$ limits to 95% CL *lower* limits on Planck scale M_S, in TeV, using different formalisms for F

*NLO k=1.3 scale applied to signal MC

DØ RunII

DØ RunI + Run II

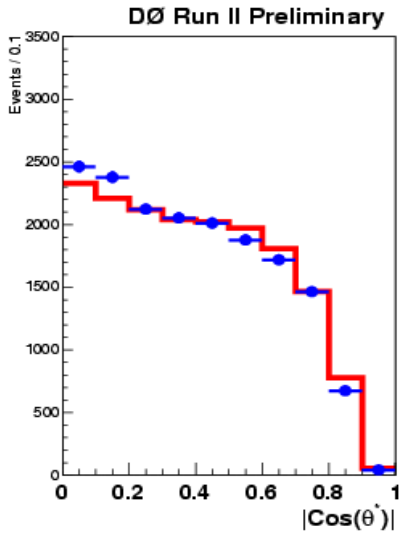
GRW	HLZ for n =						Hewett
	2	3	4	5	6	7	λ = +1/-1
1.36	1.56	1.61	1.36	1.23	1.14	1.08	1.22/1.10
1.43	1.67	1.70	1.43	1.29	1.20	1.14	1.28/NA

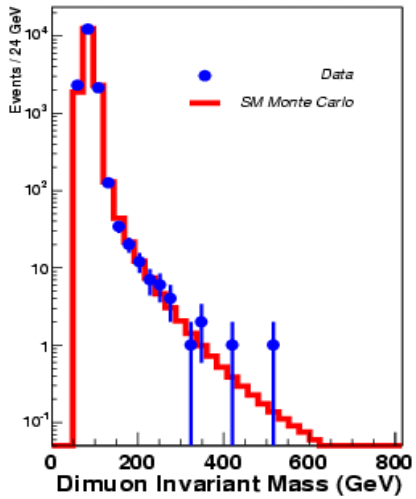
LED with μμ

- Event selection
  - pT > 15 GeV for both muon objects
  - Isolated tracks
  - M(mumu) > 50 GeV
  - Cosmics removed
  - Weighted average PT correction

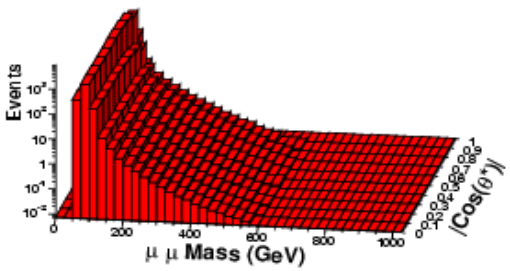
Observed events ~ 17,000 events

DØ ∫Ldt = 250 pb^{-1}

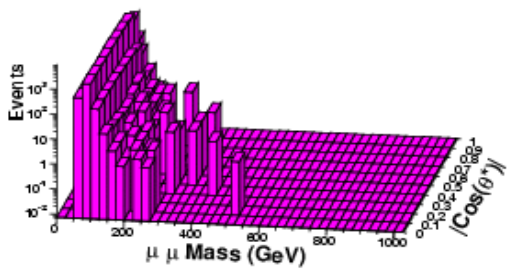




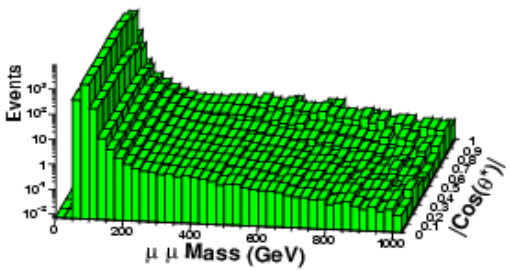
Standard Model Monte Carlo



Data



SM + ED terms (η_G=3.0 TeV^{-4})



DØ Run II Preliminary

No deviation from SM in data

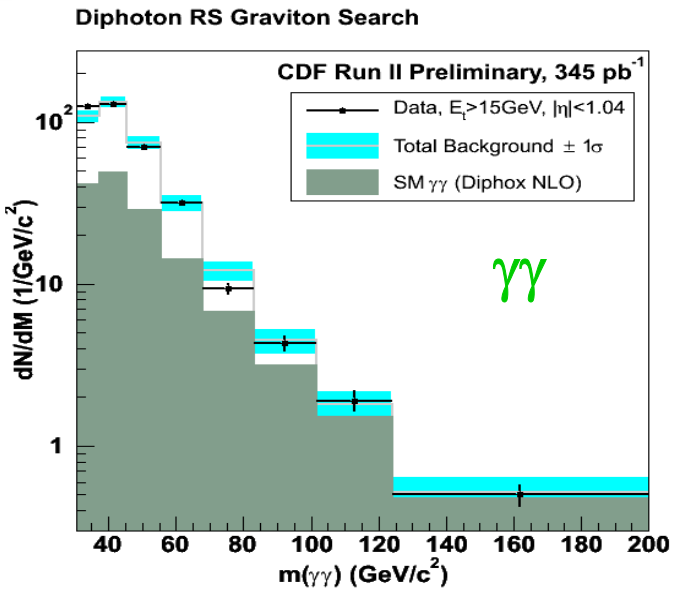
$$\eta_G = 0.00 \pm^{0.33}_{0.00} \text{ TeV}^{-4}$$

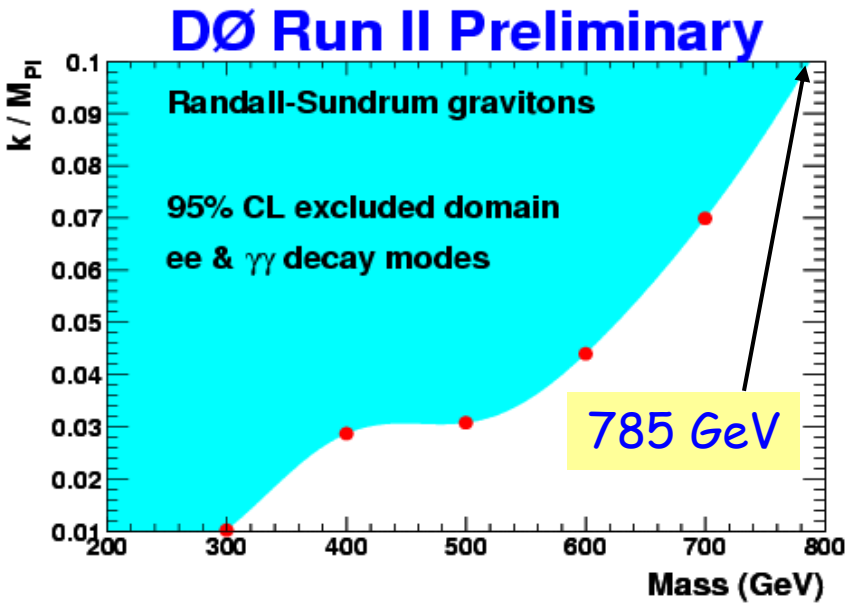
$$\eta_G^{95\%} = 0.71 \text{ TeV}^{-4}$$

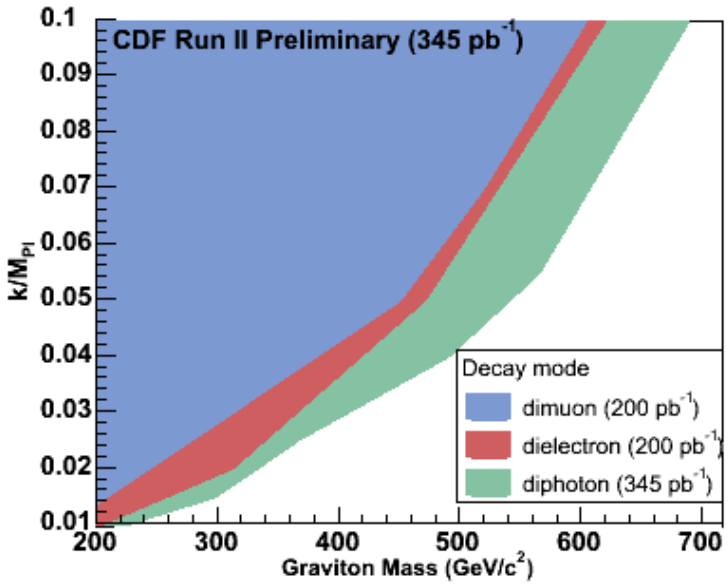
GRW	HLZ for n =						Hewett
	2	3	4	5	6	7	λ = +1/-1
1.09	1.00	1.29	1.09	0.98	0.91	0.86	0.97/0.95

Lower limits on the fundamental Plank scale, M_S in TeV

Randall-Sundrum Graviton (ee + μμ+ γγ)







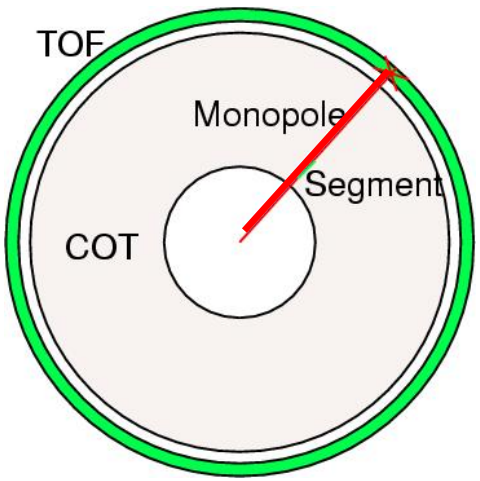
ll has largest acceptance at low mass

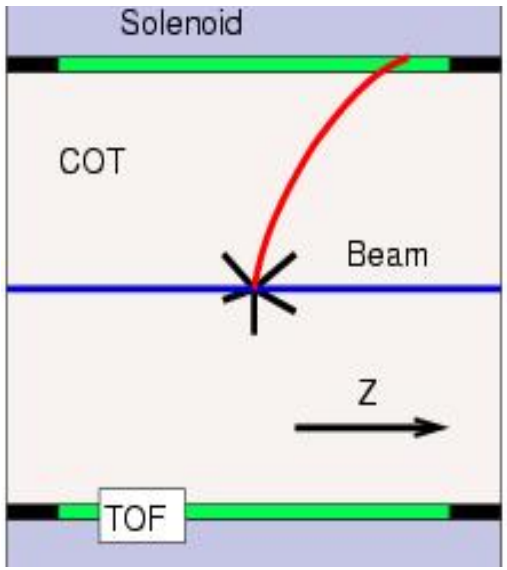
γγ has largest acceptance at high mass

BR(**G**→γγ) = 2 * BR(**G**→**ee**)

Dirac Monopoles

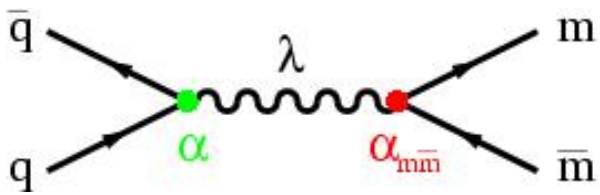
- Signature
  - Large pulses in Time of Flight (TOF)
  - Large ionization in drift chamber (COT)
  - No curvature in r-phi
  - Curvature in r-z (not used in analysis)
- Developed a dedicated trigger for Monopoles

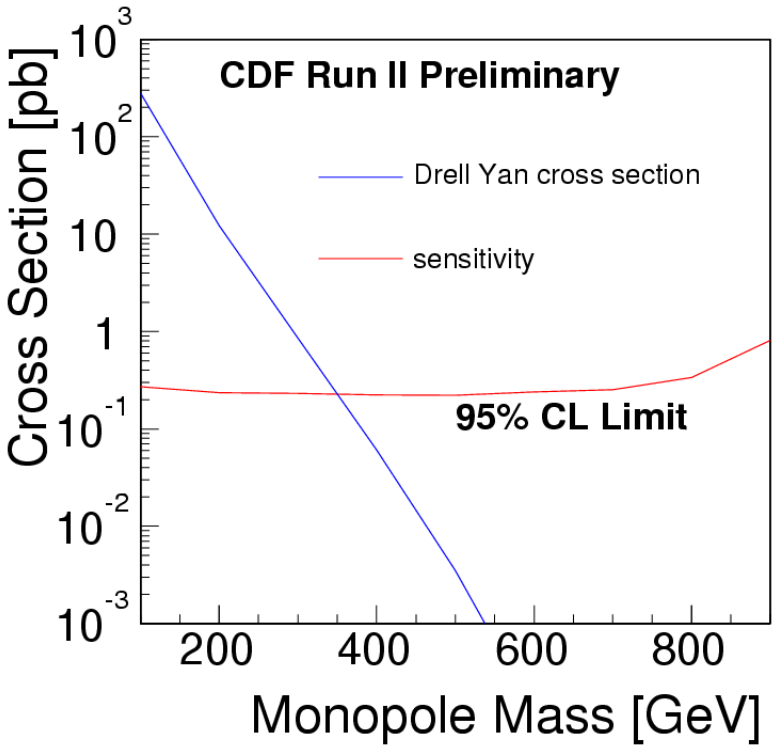




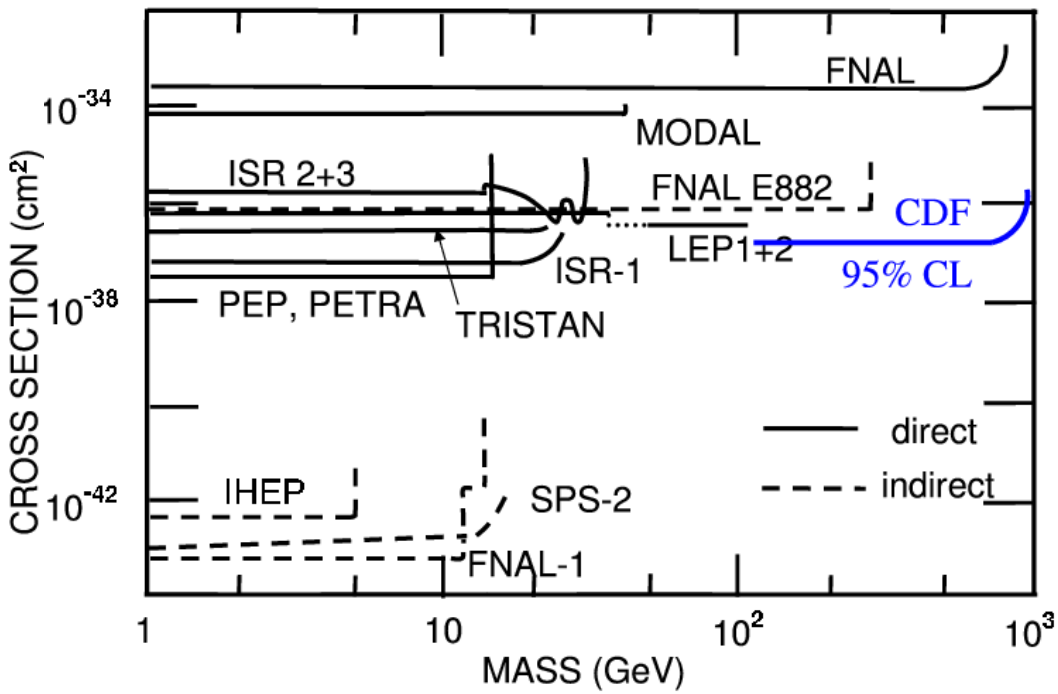
Monopole Search Results

Drell-Yan like cross section





(Giacomelli and Patrizii, hep-ex/0302011)

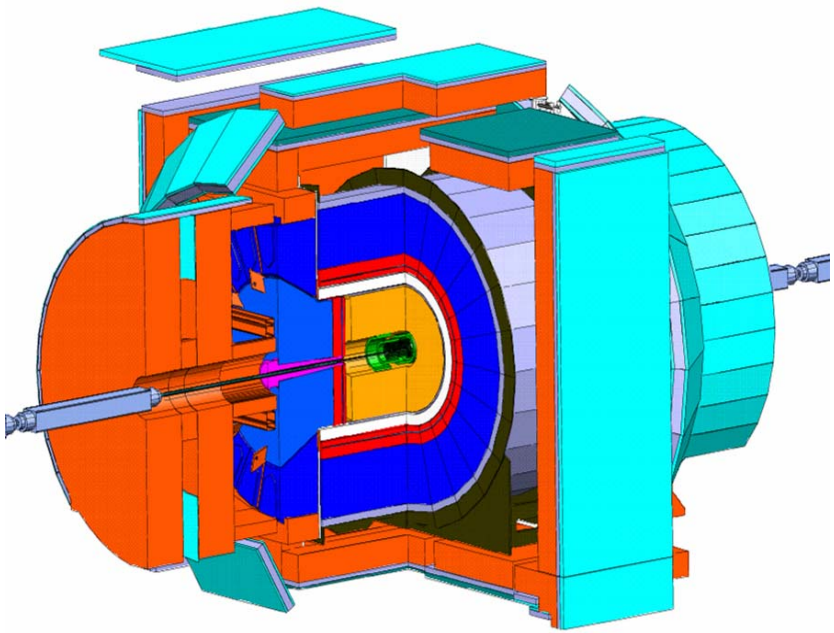


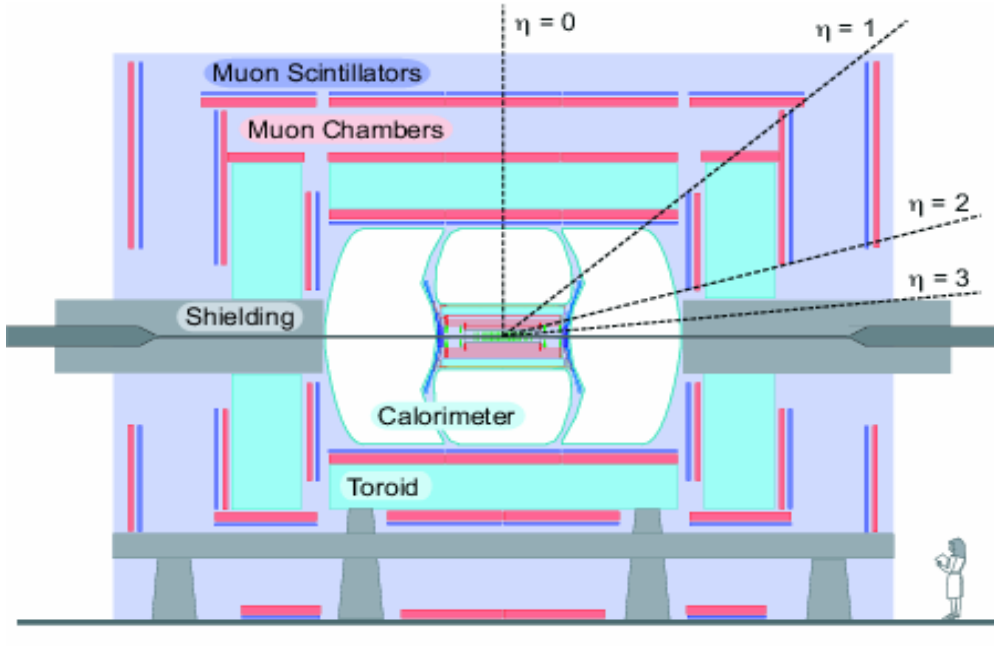
Summary and Conclusions

- Many searches for new physics are underway
- No evidence for new physics, yet.
- Presented: some of the more recent preliminary results
  - ✓ **Surpassed the sensitivity and results of Run I**
  - ✓ **Limits shown either exceed any published results of direct searches or are the first limits ever!**
- Lots more data on tape to analyse, and lots more data to collect. (4 – 8 fb^{-1})

http://www-cdf.fnal.gov/physics/exotic/exotic.html
http://www-d0.fnal.gov/Run2Physics/WWW/results/np.html

CDF & DZero Experiments





- Extended spatial e, μ coverage
- New plug calorimeter improves also MET measurement
- Improved MET triggers
- Added triggers to identify leptons at early stage

- New silicon and fiber tracker
- Solenoid (2 Tesla)
- Upgrade of muon system
- Upgrade of Trigger/DAQ