Exotic Searches* at the Tevatron

* Not SUSY,
* Not Higgs,
* Not Extra Dimension

Kaori Maeshima

Fermilab

for the CDF and D0 Collaborations

ICHEP2000 at Osaka
July 29th, 2000
Session: PA-11d

Exotic Searches* at the Tevatron

* Not SUSY, * Not Higgs, * Not Extra Dimension

Are there anything left?

Yes, indeed!
We have over 35 publications from CDF and D0 from Run I, in this 'NOT' category.

- Heavy gauge bosons $\Longleftarrow$
- Compositeness $\Longleftarrow$
- Leptoquarks $\Longleftarrow$
- Technicolor $\Longleftarrow$
- ? $\rightarrow$ High Mass Diphoton
- Monopoles
- Fourth generation Quark
- Excited quarks and leptons
- ? $\rightarrow t\bar{t}$
- ? $\rightarrow b\bar{b}$
- Long-Lived Parents of Z^0 Bosons
- New Heavy Stable Particles
- .....

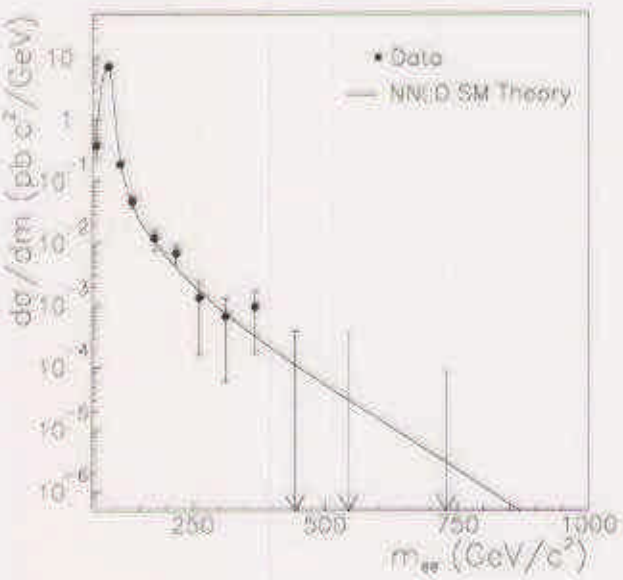
Heavy gauge bosons (Z', W')

Many models with extension of the gauge group predict existence of Z' and W'(less often).

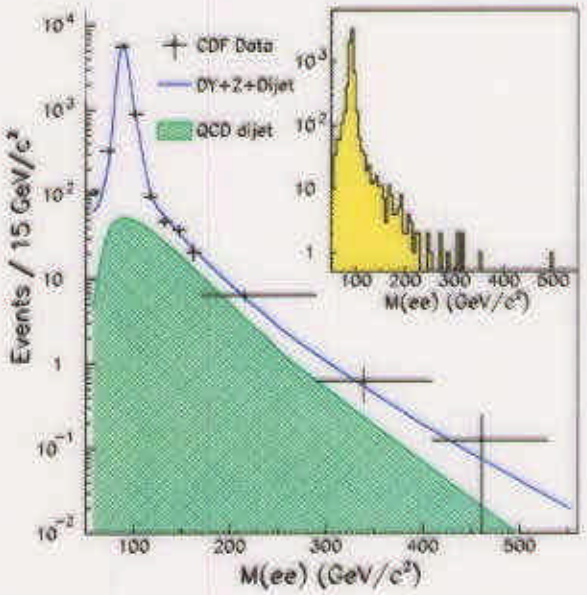
Signatures Searched

$Z' \to ee, \mu\mu, jetjet$
$W' \to e\nu, \mu\nu, jetjet$
$W_R \to eN_R$ (*eeqq final state*)

ee Invariant Mass Distributions



D0



CDF

Data are consistent with the b.g. expectations
⇒ The upper σ limit is 40 fb at 95% C.L. for $M_{Z'} > 600$ GeV (CDF, 110 pb^{-1})

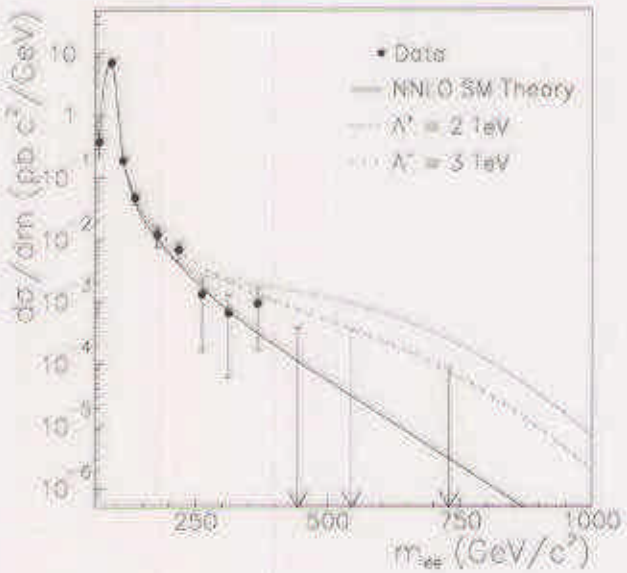
Compositeness

How pointlike are quarks and leptons?

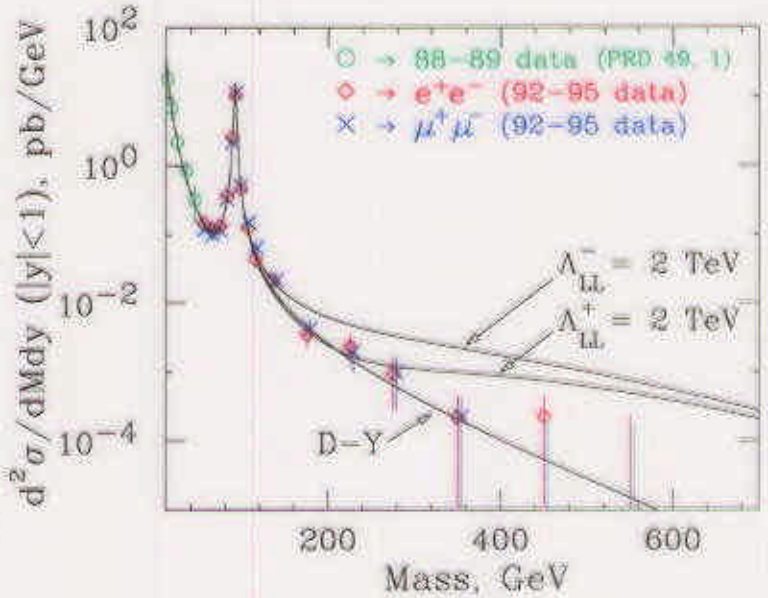
Signatures Searched

- *high mass DY spectrum (ee, $\mu\mu$)*
  → Quark-Lepton Compositeness Scale
- *$jetjet$ mass, angular distributions*
  → Quark Compositeness Scale
- *high energy jets (H_T)*
  → Quark Compositeness Scale

M(ee, $\mu\mu$) and Q-L Compositeness



D0



CDF

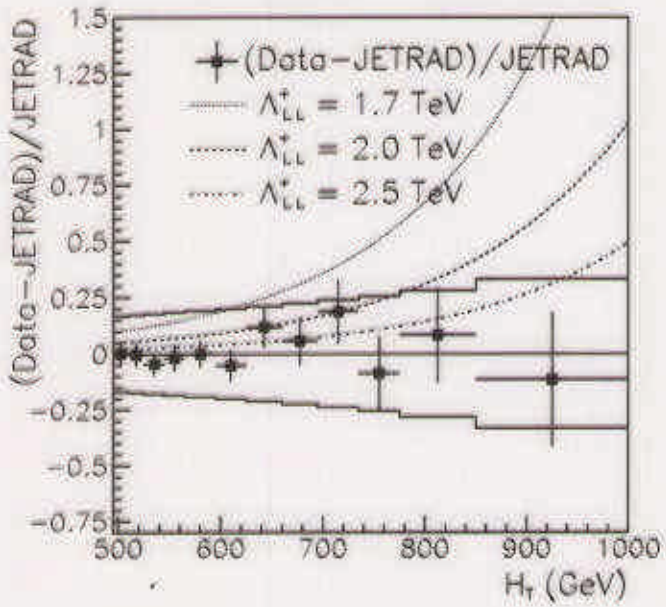
Data are consistent with SM expectation

⇒ The lower limit on Q-L compositeness scale is set in 3-6 TeV range at 95% C.L.

Compositeness (cont.)

Quark Compositeness Search using H_T (D0)

- H_T ($\equiv \sum_{i=1}^{N} E_T^i$) *is a pretty robust quantity.*
- *Formalism of Eichten et. al. (PRL 50, 811 (1983))*
- *Require* ≥ 1 *jet with* $E_T > 115$ *GeV,* $H_T > 500$ *GeV.*



* *JETRAD (NLO) for SM*
* *PYTHIA to simulate signal*
* *PDF: CTEQ4M, MRST*
* *Syst. Uncertainty: 17 - 34 %*

Data are consistent with SM expectation

$\Rightarrow \Lambda_{LL} > 1.9 - 2.2$ *TeV at 95% C.L.*
Resolving power: $\Delta x \sim \hbar c / \Lambda_{LL} \sim 1 \times 10^{-4}$ *fm*

Leptoquarks

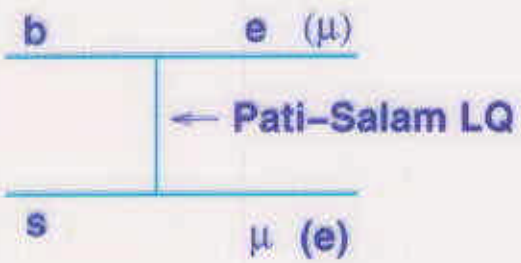
↪ *Result of attempts to unify quark and lepton sectors (GUT, Compositeness, TC).*

↪ *Leptoquarks are color-triplet bosons with couplings to quarks and leptons.*

↪ *No theoretical reason to prefer the same generations, but there are more strict experimental constraints in the mixed states.*

Signatures Searched

- *First generation* (ej-ej, ej-νj, νj-νj)
- *Second generation* (μj-μj, μj-νj, νj-νj, νc-νc)
- *Third generation* (τj-$\tau j \rightarrow \ell\nu j$-$j_\tau j$, νb-νb)
- *Pati-Salam LQ (generation mixed)*



Search for: $B_s \rightarrow e\mu$ *decay*

$Br(B_s \rightarrow e\mu) < 8.2 \times 10^{-6}$ *at 95% C.L.*

$\Rightarrow M_{LQ}(B_s) > 19.3$ *TeV at 95% C.L.*

(CDF, 102 pb^{-1}*)*

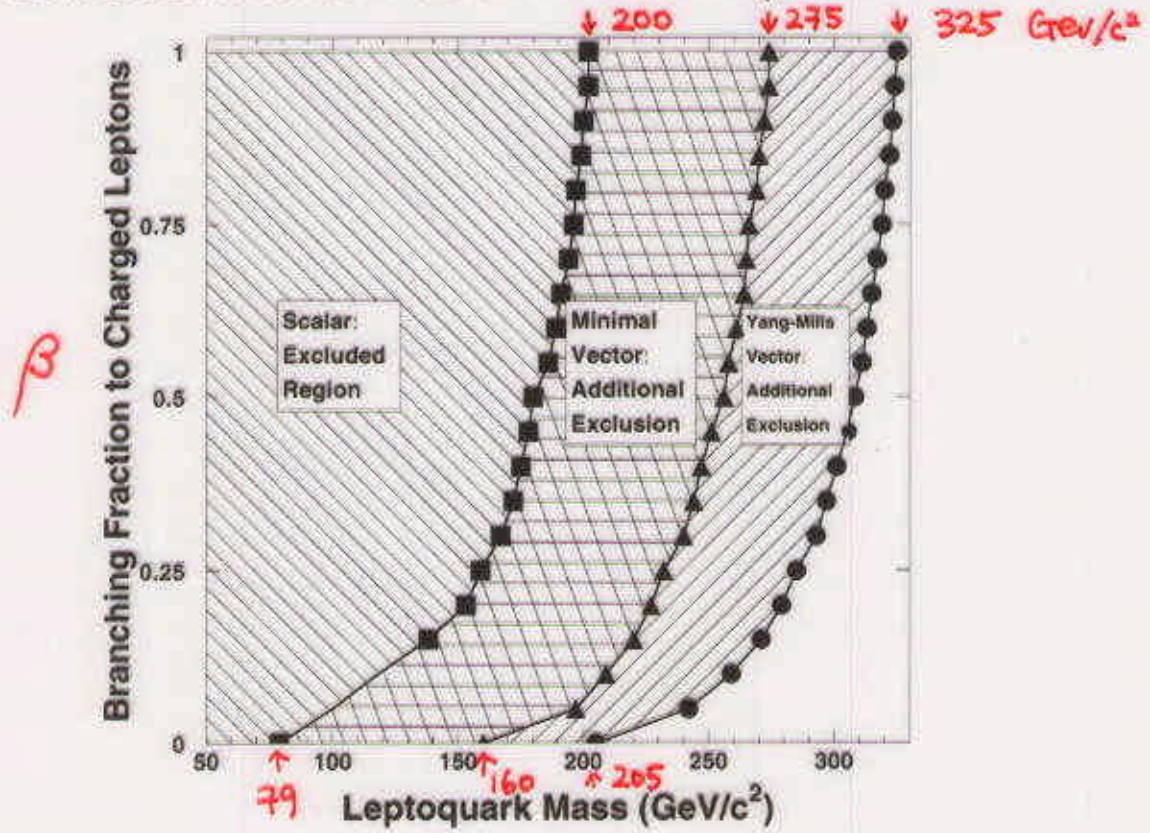
Leptoquarks (cont.)

μj-μj, μj-νj, νj-νj channels combined (D0)

↪ *LQ can be Scalar or Vector*

↪ *Decay of LQ is parametrized by the branching ratio into charged leptons, β.*

Use neural network discriminant to optimize the sensitivity.



Efficiencies for $M_{LQ2} = 100 - 400$ GeV:
10 - 26 % for μj-μj channel,
4 - 17 % for μj-νj channel.

Leptoquarks (cont.)

Search for Second and Third generation LQ

with $\beta = 0$ (CDF)

$\hookrightarrow$ *Two heavy flavor (c for LQ2, b for LQ3) jets, large $\not\!\!E_T$ and no high p_T charged leptons.*

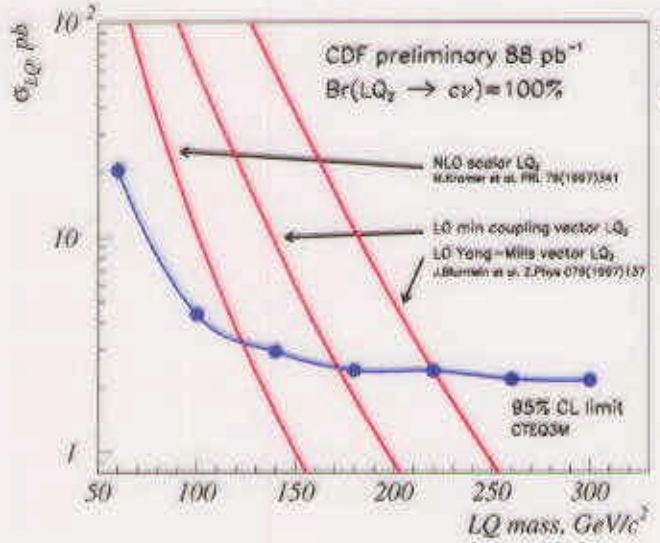
$\begin{cases} LQ_2 \to jc \\ LQ_3 \to jb \end{cases}$

$jjcc$, $jjbb$

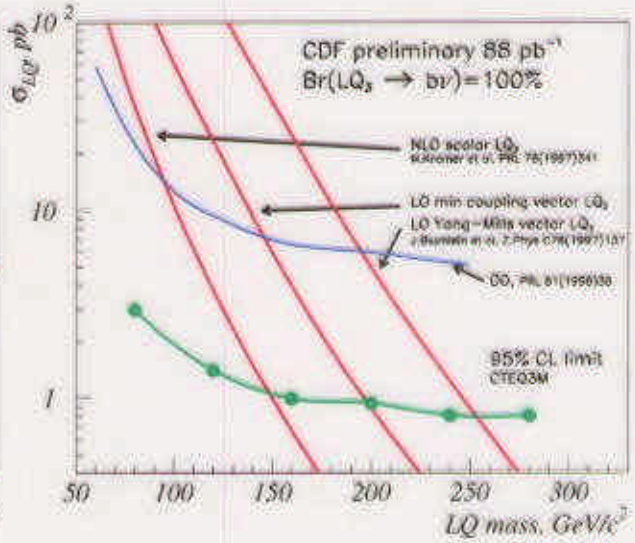
$\hookrightarrow$ *Use the silicon vertex detector (displaced vertex) to tag heavy flavors (Jet Probability method)*

Before tagging, 396 events selected.
c tagging (effi. = 25%) $\Rightarrow$ 11 evts observed (14.5 expected)
b tagging (effi. = 45%) $\Rightarrow$ 5 evts observed (5.8 expected)

Main background are from $W \to \tau \to$ hadrons and generic QCD jet events.



LQ2



LQ3

Technicolor

↪ *Alternative to Higgs Mechanism for EWSB*

↪ *Analog to QCD: Symmetry broken dynamically by new interaction.*

↪ *Went through several iterations in the past years:*
TC (M(f)=0) → ETC (big FCNC) → WTC (light M(t)) → Topcolor → Topcolor assisted EWTC

↪ *Predicts rich spectrum of TC particles with clear mass peaks. The cross section is relatively large at Tevatron energy.*

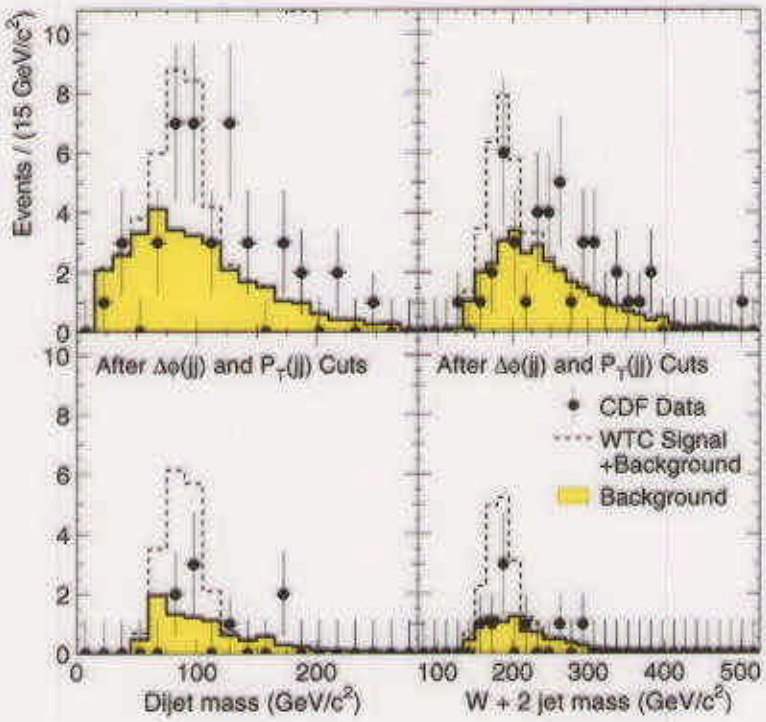
⇒ *potential of discovery at Tevatron.*

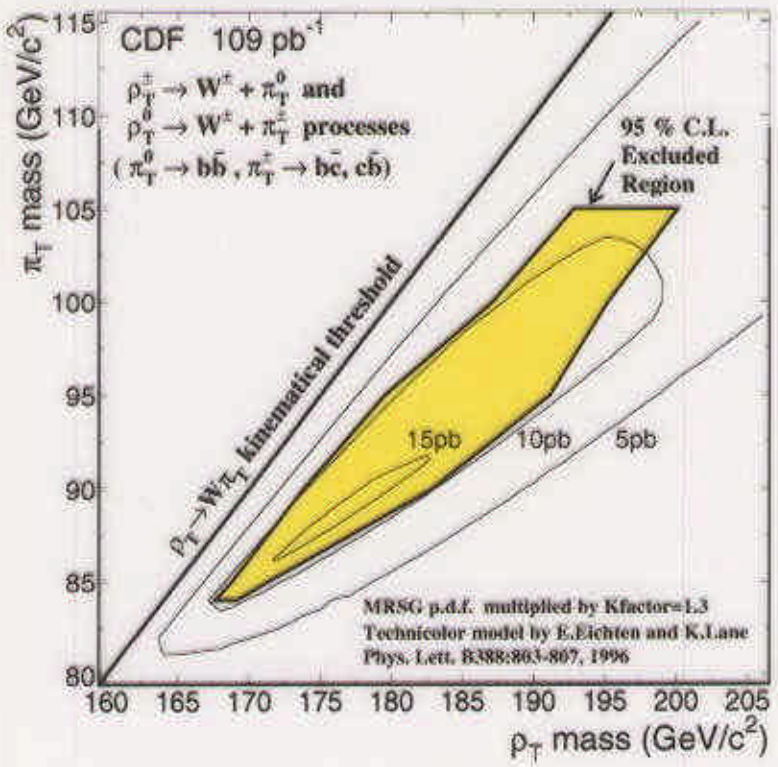
Signatures Searched

- $\rho_T \to W\pi_T \to \ell\nu + 2$ *jets, with at least one b-tag.*
- $\rho_T \to$ *all hadronic mode with at least two b-tags.*
- $\omega_T \to \gamma$ *+ 2 jet with at least one b-tag.*
- ρ_{T8} *(color octet)* $\to \pi_{LQ} + \pi_{LQ}$ *(color triplet)* $\to qq\nu\nu$ *where qq are cc and bb.*
  This is a study with third and mixed second generation leptoquarks with a signature of 2 heavy flavored jets and $\not\!\!E_T$.

Technicolor (cont.)

$\rho_T \to W\pi_T \to \ell\nu + bj$

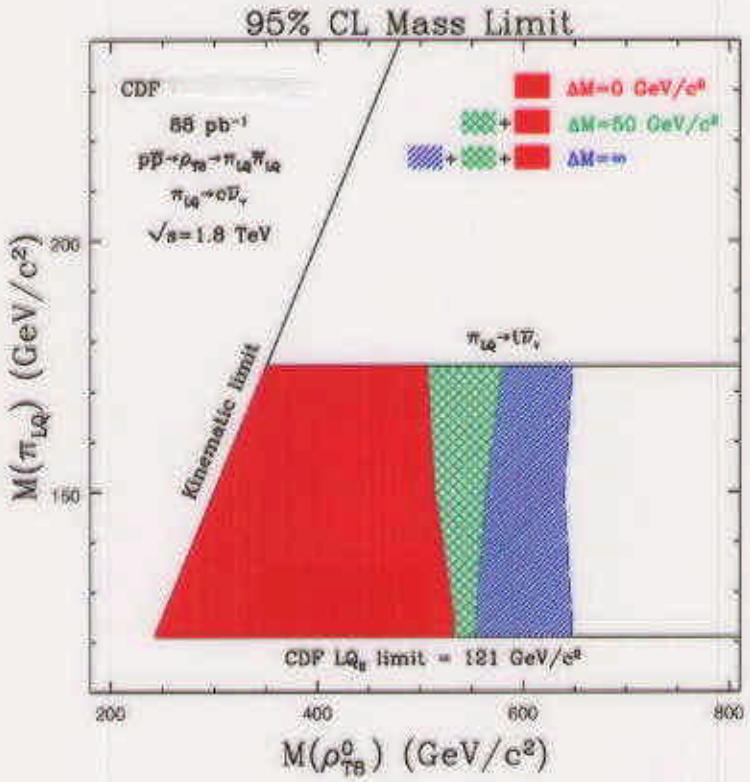




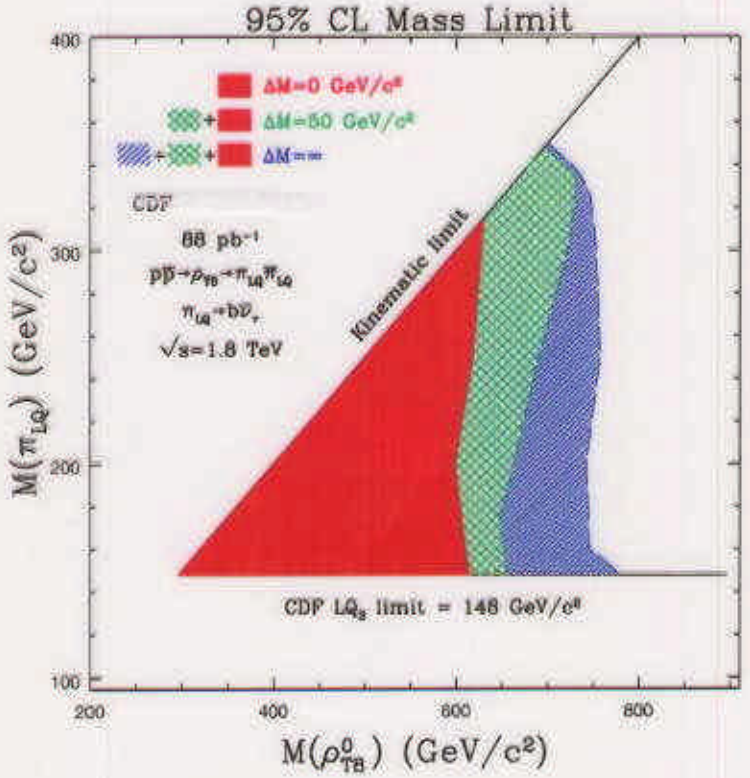
In $M_{\rho_T} < M_{W+\pi_T}$ region, $\rho_T(\omega_T) \to e^+e^-$ channel is studied.

Technicolor (cont.)

TC limits from LQ2 and LQ3



$\Delta M = M(\pi_{TC}) - M(\pi_{LQ})$



My Last Transparency for This Talk

It is about the time to make a breakthough in SM, isn't it?

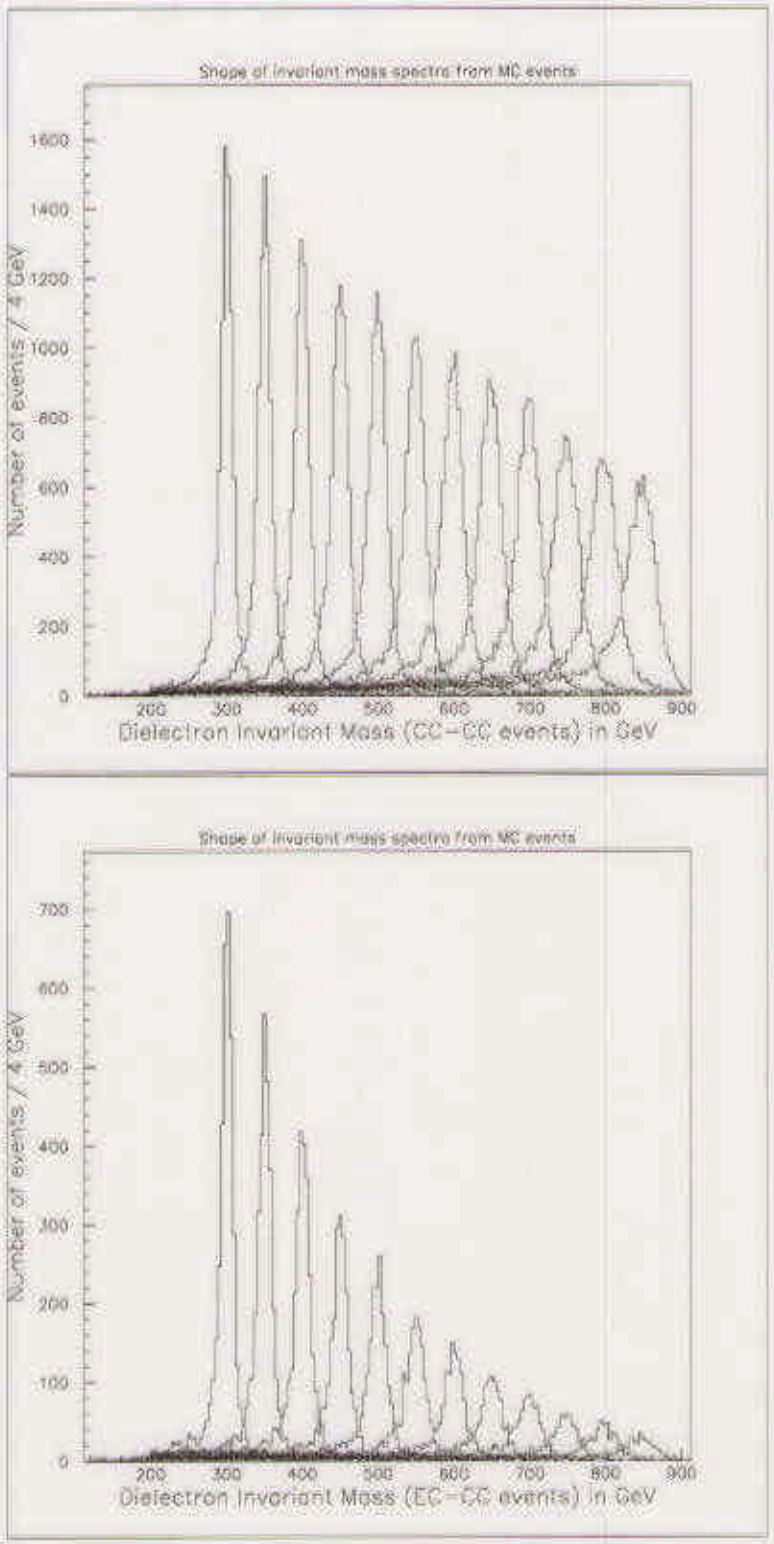


FIG. 10. Shapes of the dielectron invariant mass spectra for the $Z' \to e^+e^-$ signal.