Search for Heavy particles Decaying into Electron-Positron Pairs in $p\bar{p}$ Collisions

- Motivations
- Data Selection and Backgrounds
- Limits on Technicolor Particles
- Limit on a Heavy Neutral Gauge Boson
- Conclusion

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Motivations

The decay to lepton-antilepton pairs

\[ X \rightarrow e^+e^- \text{ or } \mu^+\mu^- + ... \]

Discovery channels for \( J/\psi \) (1974), \( \Upsilon \) (1977), and \( Z^0 \) (1983)

- Relatively low backgrounds compared to hadronic decay channels
- Electrons and muons are relatively easy to trigger on and their momenta can be measured precisely
- Particles that decay to \( e^+e^- \) or \( \mu^+\mu^- \) can be identified as resonances in the dilepton mass spectrum

Many extensions of SM predict the existence of particles that decay to \( l^+l^- \)

\[ \rho_T, \omega_T \rightarrow e^+e^- \]

\[ Z' \rightarrow e^+e^- \]

⇒ Search for resonance in the \( e^+e^- \) mass spectrum @ Tevatron
Motivations

Technicolor
the collective name for a class of models attempting to explain EWSB by condensates of fermion-antifermion pairs

Extended Technicolor (ETC)

Topcolor-assisted Technicolor (TC2)
genrating the fermion masses
including $m_{\text{top}} \sim 175$ GeV

Extra Neutral Gauge Boson
a feature of many models of physics beyond SM (GUTs, superstring theories...)

Indirect Manifestations
@ LEP, LC

Direct Searches
@ Tevatron, LHC

Lightest color-singlet technivector meson
$\rho_T, \omega_T \rightarrow V\pi_T, \bar{ff} \ldots$
where $V$ is a transversely polarized electroweak gauge boson, $\gamma, Z$ or $W^\pm$, and $f$ is fermion

$p\bar{p} \rightarrow \rho_T, \omega_T \rightarrow e^+e^-$

$M_{Z'} > 300-750$ GeV
@ LEP (ICHEP2000)

$p\bar{p} \rightarrow Z' \rightarrow e^+e^-$

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DPF 2000

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DØ Run I Detector (1992-1996)

DØ Detector

Pseudorapidity:
\( \eta = -\ln \tan (\theta/2) \)

CALORIMETRY
- \(|\eta| < 4\)
- \(\Delta \eta \times \Delta \phi = 0.1 \times 0.1\)
- GEM = 15\% / \(\sqrt{E}\)
- CHAD = 50\% / \(\sqrt{E}\)

TRACKING
- \(\sigma(\text{vertex}) = 6 \text{ mm}\)
- \(\sigma(r_0) = 60 \mu\text{m} \) (VTX)
  = 180 \(\mu\text{m} \) (CDC)
  = 200 \(\mu\text{m} \) (FDC)

MUON
- \(|\eta| < 3.3\)
- \(\frac{\delta p}{p} = 0.2 \oplus .003p\)

DØ is perfectly suited for identification of:
- Electrons/Photons
- Jets
- Muons
- Neutrinos (Missing Transverse Energy)
Data Selection

• Entire Run I Statistics (120.9 pb$^{-1}$)
  ✷ EM trigger fully efficient for high mass dielectrons

• Electrons:
  ✷ $|\eta_e| < 1.1$ (Central Calorimeter) or $1.5 < |\eta_e| < 2.5$ (End Calorimeters)
  ✷ “Loose”:
    ▶ At least 95% of its energy in the electromagnetic calorimeter
    ▶ Good energy isolation
    ▶ Cluster shape typical for the EM object
  ✷ “Tight”:
    ▶ Additionally required to have matching track in the drift chambers

• Events:
  ✷ Two highest $E_T$ electrons with $E_T > 25$ GeV ($> 20$ GeV at trigger level)
  ✷ Any forward electron is required to be “tight”
  ✷ At least one “tight” electron in each electron pair

⇒ CC/CC events and CC/EC events are separately examined
Dielectron Invariant Mass for CC/CC, CC/EC Events

CC/CC Events

CC/EC Events

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Backgrounds for Heavy Particles $\rightarrow e^+e^-$

- **Drell-Yan process** (via intermediate $\gamma$ and $Z^0$)
- **Jets misidentified as electrons**
  - *QCD multijet events* with two jets misidentified as electrons
  - *Direct-photon events* where both the jet and $\gamma$ misidentified as electrons
  - *$W + jets$ events* in which one of the jets misidentified as an electron
- **Backgrounds from** $W\gamma$, $Z\gamma$, $t\bar{t}$, $WW$, $\gamma^*/Z \rightarrow \tau\tau$ negligible
Dielectron Invariant Mass

Data are consistent with the background hypothesis; no evidences for excess are found.
Limits on Technicolor Particles

Proceed to set an upper limit on \((\sigma \cdot Br)\) as a function of dielectron invariant mass.

- Determine the 95% confidence level upper limit on the signal cross section \((\sigma_{95})\) from the definition

\[
\int_0^{\sigma_{95}} \frac{P_{CC}(\sigma) \cdot P_{EC}(\sigma)}{\int_0^{\infty} P_{CC}(\sigma) \cdot P_{EC}(\sigma) \ d\sigma} \ d\sigma
\]

where \(\ln P = \langle \Sigma \ln p_i \rangle\),
\(p_i\) is the probability to observer the number of events seen \(n_i\), given the expected number \(\mu_i\).
Mass Limits in $\rho_T, \omega_T \rightarrow e^+e^-$

Latest theoretical calculations of the cross section from K. Lane

Theoretical predictions for $M_T = 100$ GeV
and if $M_{\rho}, M_{\omega} - M_{\pi} < M_W$ ($\rho_T \rightarrow W + \pi_T$ forbidden, the branching ratio to dielectrons enhanced)

⇒ Excluding $\rho_T$ and $\omega_T$ with masses below 207 GeV/c²

Theoretical predictions for $M_T = 100$ GeV
and if $M_{\rho}, M_{\omega} - M_{\pi} > M_W$

Experimental upper limits at 95% confidence level for $\rho_T, \omega_T \rightarrow e^+e^-$ production compared with predictions
Mass Limits in $\rho_T, \omega_T \to e^+e^-$

The mass limit depends on the technicolor-scale mass parameter, $M_T$

Excluding $\rho_T$ and $\omega_T$ with masses below 203 GeV/c$^2$ for $M_T > 200$ GeV

Experimental upper limits at 95% confidence level for $\rho_T, \omega_T \to e^+e^-$ production compared with predictions
Limits on $Z'$

Proceed to set an upper limit on $(\sigma \cdot Br)$ as a function of dielectron invariant mass

- Use a reference model assuming the couplings of $Z'$ to fermions as $Z$.

- Theoretical values: the cross section times branching ratio with the next-to-leading order calculations (by Van Neerven et al.).
Mass Limits in $Z' \rightarrow e^+e^-$

Excluding $Z'$ with mass below 670 GeV/c$^2$ assuming same couplings to fermions as $Z$

Experimental upper limits at 95% confidence level for $Z' \rightarrow e^+e^-$ production compared with predictions
Conclusion

• No excess is found in the searches for $\rho_T$, $\omega_T$, and $Z'$ particles, using the decay channels $\rho_T$, $\omega_T$, $Z' \rightarrow e^+ e^-$ in 120.9 pb$^{-1}$ D0 Run I (1992-1996) data.

• Existence of degenerate $\rho_T$ and $\omega_T$ states with masses below 207 GeV/$c^2$ is excluded.

• Existence of $Z'$ with masses below 670 GeV/$c^2$ is also excluded.