Preliminary Measurements of the Quark-AntiQuark Production Cross-Section in e^+e^- Annihilations up to LEP2 Highest Energies

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Outline

- Features of fermion-pair production above the Z pole
- Experimental aspects and measurements of cross - sections for the process:

Initial State Radiation

Final State Radiation

IF State Radiation interference

initial state Pair Production

(gluon radiation)

$f\bar{f} = e^+e^-, \mu^+\mu^-, \tau^+\tau^-, q\bar{q}$
(e^+e^- : also t-channel)

- Interpretations of the results
- Conclusions

Effective Center of Mass Energy

DELPHI

fermion pair production at LEP2:

- 1) radiative return events - ($\sqrt{s'} \approx M_Z$)
- 2) full energy events - ($\sqrt{s'} \approx \sqrt{s}$)

$\sqrt{s'}$ measured from detected γ
 jet/lepton angles
 visible energy
 kinematic fit

SM Processes above the Z Peak

Two classes of events:

①+② (inclusive sample): $\begin{cases} \sqrt{s'}/\sqrt{s} > 0.10 \text{ (} q\bar{q} \text{)} \\ \sqrt{s'} > 75 \text{ GeV (} \mu, \tau \text{)} \end{cases}$

② (non-radiative sample): $\sqrt{s'}/\sqrt{s} > 0.85$

②/(①+②) $\cong$ 22 % for hadrons
(42 % for μ, τ)

①+② same physics as measured at LEP1
(with higher accuracy)

② sensitive to new physics

theoretical error on σ_{had} : ~ 0.5 %

Definition of the Signal

1) $\sqrt{s'}$ - mass of the s - channel propagator
IFSR interference subtracted (L3, OPAL)

2) $\sqrt{s'}$ - $q\bar{q}$: mass of the s - channel propagator
 l^+l^- : bare invariant mass of lepton pair
IFSR interference included (ALEPH, DELPHI)

$\left(\begin{array}{l} \text{IFSR interference for } \sqrt{s'}/\sqrt{s} > 0.85 \text{ is about 1 - 2 \%} \\ \text{predominantly for large } |\cos\theta| \end{array} \right)$

DataSamples

in 1999: $\sim 228 \text{ pb}^{-1}/\text{exp.}$
at $E \div 192\text{-}202 \text{ GeV}$

in 2000: $\sim 58 \text{ pb}^{-1}/\text{exp.}$
at $\langle E \rangle \sim 205 \text{ GeV}$
 $\sim 29 \text{ pb}^{-1}/\text{exp.}$
at $\langle E \rangle \sim 207 \text{ GeV}$

$(\mathcal{L}_{\text{LEP2}} \cong 580 \text{ pb}^{-1}/\text{exp. !!!})$

A Typical Hadronic Event

@20 GeV

(two collinear jets, no ISR)

TrackSelection

The event selection relies only on charged tracks with:

- transverse impact parameter below 4 cm
- longitudinal impact parameter below 10 cm
- polar angle larger than 20°
- momentum greater than 10 MeV
- error on momentum below 10%
- track length above 30 cm

HadronicEventSelection - I

ChargedEnergyCut:

$$E_{ch} = \sum E_{ch,i} > 0.10\sqrt{s}$$

HadronicEventSelection - II

ChargedMultiplicityCut:

$$N_{ch} \geq 7$$

HadronicEventSelection - III

TransverseEnergyCut:

$$E_T = \sum E_i |\sin \theta_i| > 0.20\sqrt{s}$$

RadialEnergyCut:

$$E_{rad} = \sqrt{E_{em,F}^2 + E_{em,B}^2} > 0.45\sqrt{s}$$

HadronicEventSelection - IV

$\sqrt{s'}/\sqrt{s}$	eff. (%)	bkg (%)	rad-bkg (%)
> 0.10	~ 80	~ 25	-
> 0.85	~ 95	~ 40	~ 10

Main Backgrounds

to inclusive (non-radiative) cross-sections:

W-pair production: ~ 16 (~ 9) pb

Z-pair and Ze^+e^- production: ~ 4 (~ 1) pb

two-photon collisions: ~ 2 (~ 0) pb

Cross-Sections

①+② (inclusive sample):

selection efficiency: 1.0 %
background: 0.5 %
luminosity (exp.): 0.5 %
(theo.): 0.25 %

TOT: 1.25 %

Typical
Systematic
Errors:

② (non-radiative sample):

selection efficiency: 1.0 %
background: 1.5 %
 s' cut: 1.0 %
luminosity (exp.): 0.5 %
(theo.): 0.25 %

TOT: 2.1 %

theoretical error on σ_{had} : ~ 0.5 %

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Interpretation of the Results

- comparisons with Standard Model predictions:
 - S-Matrix framework
- constraints on new physics:
 - upper limit on potential deviation of the real cross-sections from SM predictions

FermionCross -Sections

LEP averages of published and preliminary results:

- fair agreement with Standard Model predictions (hadronic cross-section is high)
- correlated errors are taken into account in the combinations

S-MatrixFramework - I

Z lineshape fit, LEP1 data only,
to $M_Z, \Gamma_Z, \sigma_h^0, \Gamma_h/\Gamma_Z, A_{FB}^{0,l}$
(γZ interference fixed to SM value):

$$M_Z = 91186.3 \pm 2.8 \text{ MeV}$$

$$\Gamma_Z = 2487.6 \pm 4.1 \text{ MeV}$$

$$\sigma_a^0(s) = \frac{4}{3} \pi \alpha^2 \left[\frac{g_f^a}{s} + \frac{j_f^a (s - \bar{M}_Z^2) + r_f^a s}{(s - \bar{M}_Z^2)^2 + \bar{M}_Z^2 \bar{\Gamma}_Z^2} \right]$$

$$A_{FB}^0(s) = \frac{3}{4} \frac{\sigma_{fb}^0(s)}{\sigma_{tot}^0(s)} \quad a = tot, fb$$

g_f^a - γ exchange

r_f^a - Z exchange

j_f^a - γZ interference

At LEP2, for μ, τ and for $\sqrt{s'} \approx \sqrt{s}$
 γ - exchange is 2-4 $\times$ Z - exchange

S-MatrixFramework - II

S-matrix fit, LEP1 + LEP2 data [LEP1 data only]
(assuming lepton universality):

(*VERY* preliminary results !)

$$M_Z = 91190 \pm 5[9] \text{ MeV}$$

$$\Gamma_Z = 2488 \pm 4[5] \text{ MeV}$$

$$r_{\text{had}}^{\text{tot}} = 2.9527 \pm 0.010[0.011]$$

$$r_{\text{lept}}^{\text{tot}} = 0.1423 \pm 0.0006[0.0006]$$

$$j_{\text{had}}^{\text{tot}} = 0.09 \pm 0.21[0.54]$$

$$j_{\text{lept}}^{\text{tot}} = 0.011 \pm 0.020[0.038]$$

$$r_{\text{lept}}^{\text{FB}} = 0.0033 \pm 0.0004[0.0004]$$

$$j_{\text{lept}}^{\text{FB}} = 0.784 \pm 0.021[0.027]$$

(LEP2 : 130 to 206 GeV data)

Constraint on New Physics

Compatibility of the results for non -radiative cross -sections with SM predictions allow to constrain extensions of the SM

Upper limit on potential deviations from SM expectations:

$$\langle E \rangle = 205.5 \text{ GeV} \Rightarrow \begin{cases} \sigma_{new}^{+} < 1.0 \text{ pb} & @ 95 \% \text{ CL} \\ \sigma_{new}^{-} < 1.3 \text{ pb} & @ 95 \% \text{ CL} \end{cases}$$

Summary and Outlook

- cross-section measurements at 130 - 202 GeV are in good agreement with SM predictions
- preliminary results at 205 - 206 GeV are also consistent with SM
- further improvements on $\sigma_{Z, j \text{ had}}$ within S-matrix framework
- upper limit on potential new physics