Measurement and Interpretation of Lepton–Pair Production at LEP2 energies

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12.08.2000

DPF2000, Electroweak Session V

- Introduction, Features of LEP2
- Measurement of Cross–Sections and A_{fb}
- Interpretations of the Results

Lepton-Pair Production at LEP2

- Motivation: **Test of the Standard Model**
 $\Rightarrow$ deviations may be a **hint for new physics, indirect search**
- observed channels: $f = e, \mu, \tau$
- at LEP2 many events undergo **Initial State Radiation**
 $\Rightarrow$ reduction of the effective centre-of-mass energy $\sqrt{s'}$
 Z returns: $\sqrt{s'} \approx M_Z$ (acollinear events)

$$\sqrt{s'} = m_{l\bar{l}}, \text{ invariant Mass of the final Lepton-Pair}$$

after **ISR** and **FSR** (initial and final state radiation)

- calculation of cross-section and A_{fb} for 2 event samples
 - **inclusive** sample (including radiative events)
 - **non-radiative** sample
- non-radiative sample most sensitive to new physics effects

Determination of $\sqrt{s'}$

Computation of $\sqrt{s'}$ using the following information:

- E_{Beam}
- directions and momentum of the final state leptons
- deposited energy of isolated photons in the calorimeters

1. Angular Method

$$\boxed{s' = s - 2 E_{\gamma} \sqrt{s}} \text{ with energy of the ISR-Photon:}$$

$$E_{\gamma (ISR)} = \frac{|\sin(\theta_1 + \theta_2)| \sqrt{s}}{\sin\theta_1 + \sin\theta_2 + |\sin(\theta_1 + \theta_2)|}$$

2. Kinematic Fit

- (a) different topology assumptions ($\mu\mu, \mu\mu + \gamma, \dots$)
- (b) fitted parameters: $(|\vec{p}|, \theta, \phi)$
- (c) constraints: energy and momentum conservation
- (d) cut on $P(\chi^2)$
- (e) $\sqrt{s'}$ set accordingly to fitted parameters

$\Rightarrow$ improves the $\sqrt{s'}$ resolution ($\Delta\sqrt{s'}/\sqrt{s'} \sim 5\%$)

Distributions of $\sqrt{s'}$

Event Selection

Different cuts for each channel on:

- charged multiplicity
- impact to interaction point
- polarangle ($|\cos \theta| \leq 0.97/0.94$ for μ/τ)
 $44^\circ \leq \theta \leq 136^\circ$ for electrons
- acollinearity
- **inclusive class:** $\sqrt{s'} > 75 \text{ GeV}$ (μ, τ)
- **non-radiative class** $\sqrt{s'}/\sqrt{s} > 0.85$ (μ, τ)
($e^+e^- \rightarrow$ acollinearity $< 20^\circ$)

Remaining Backgrounds:

- 4-fermion-events ($WW, ZZ, Ze^+e^-, We\nu\dots$)
- 2-photon-events ($e^+e^- \rightarrow e^+e^- f\bar{f}$)
- Cosmics
- Feed through from radiative events

Results for Lepton–Pair Selection

Year	95	96	97	98	99
Energy (GeV)	130/136	161/172	183	189	192-202
$\int \mathcal{L} dt \text{ (pb)}^{-1}$	~ 6	~ 20	~ 54	~ 155	~ 225
number of events $e^+e^- \rightarrow e^+e^-(\gamma)$	129/152	276/312	1109	2804	4446
$e^+e^- \rightarrow \mu^+\mu^-(\gamma)$	56/40	72/70	354	880	1256
$e^+e^- \rightarrow \tau^+\tau^-(\gamma)$	33/29	58/54	232	682	640

Errors on σ and A_{fb} dominated by statistics

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running in Y2K:

204 - 208 GeV

→ preliminary results

for 2 energy bins:

$\sqrt{s} < 205.5 \text{ GeV}$

$\sqrt{s} \geq 205.5 \text{ GeV}$

Lepton Cross-Sections at LEP2

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Typical Systematic Errors: $\mu \sim 3\%$, $\tau \sim 5\%$, $e \sim 1\%$

Lepton Asymmetries at LEP2

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Typical Systematic Errors: $\mu \sim 10^{-3}$, $\tau \sim 10^{-2}$, $e \sim 10^{-3}$
All results in a reasonable agreement with the SM Prediction!

Differential Cross Sections

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Z' -Models

Several theories predict an **additional heavy gauge boson Z'**
parameters: mass $m_{Z'}$, $Z Z'$ mixing θ_M , couplings to fermions

$\Rightarrow$ Sensitivity above Z resonanz: mass $m_{Z'}$

Fits to measured $\sigma_{ll,qq}$, $A_{FB_{ll}}$ (LEP1+2) with 2 different approaches:

- Model independent: a'_f , v'_f free

Z' -Models

- Model dependent (E6-models, L-R model, sequential SM):
 $m_{Z'}$, $\theta_{ZZ'}$ free

Model	χ	ψ	η	L-R	SSM
$m_{Z'}^{limit} \text{ (GeV}/c^2\text{)}$	468	345	330	397	676

$\Rightarrow m_Z$ compatible with SM, $\theta_{ZZ'}$ with 0

Contact Interactions

New physics with a high characteristic energy scale ($m \gg \sqrt{s}$) parameterized by the effective Lagrangian:

$$\mathcal{L}_{eff} = \frac{g^2}{(1+\delta)\Lambda^2} \sum_{i,j=L,R} \eta_{ij} \bar{e}_i \gamma_\mu e_i \bar{f}_j \gamma^\mu f_j, \text{ assume } g^2 = 4\pi$$

- Λ is the scale of C.I, $\epsilon = 1/\Lambda^2$ the fitted parameter,
- input: σ_{ll} , A_{fb} , assuming lepton universality

lower limits of the scale Λ (at 95% C.L)

Gravity in extra Dimensions

- Process $e^+e^- \rightarrow G \rightarrow f\bar{f}$
 $\frac{d\sigma}{dz} = A(z) + B(z)\left[\frac{\lambda}{M_S^4}\right] + C(z)\left[\frac{\lambda}{M_S^4}\right]^2$, $z = \cos(\theta)$
- parameter is $\epsilon = \frac{\lambda}{M_S^4}$
- fit the measured differential cross-sections ($\mu^+\mu^-$, $\tau^+\tau^-$)
- biggest effect at large $|\cos\theta|$

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Final State	$\sqrt{s}$ (GeV)	ϵ_{Best} (TeV^{-4})	λ	$M_S(\text{TeV})$
l^+l^-	192 – 202	$-2.77^{+2.39}_{-2.37}$	-1	0.623
			+1	0.711
	183 – 202	$-4.39^{+2.10}_{-1.65}$	-1	0.598
			+1	0.755

Conclusions

- Lepton–pair production above the Z resonanz still a good process to test the SM
- Results for the cross-sections and asymmetries at 130-202 GeV in a good agreement with the SM expectations
- Preliminary results at 205-206 GeV also consistent with the SM
- Interpretations in terms of possible new interactions gave no evidence for the existence of new physics, but limits on the energy scales (95% C.L.) were derived
(Z' boson > 350 GeV, Contact Interaction energy scale above 10-20 TeV, Gravity in extra Dimensions $M_S > 600$ GeV)
- Last chance to find something new at LEP **THIS YEAR!**