Measurements of Fermion Pair Production at LEPII energies with the L3 detector

Sandra Muijs

NIKHEF

LEP data above the Z

- Measurements of cross sections and asymmetries for:

$$
\begin{aligned}
e^+e^- &\rightarrow q\bar{q}(\gamma) \\
e^+e^- &\rightarrow e^+e^-(\gamma) \\
e^+e^- &\rightarrow \mu^+\mu^-(\gamma) \\
e^+e^- &\rightarrow \tau^+\tau^-(\gamma)
\end{aligned}
$$

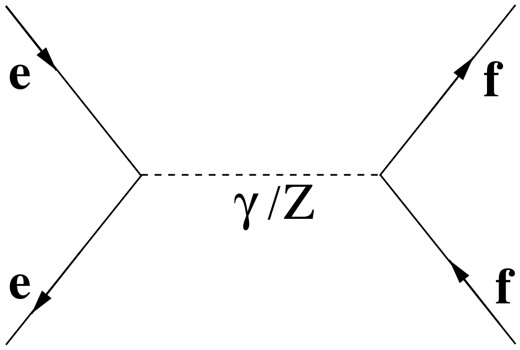
year	$\sqrt{s}$ [GeV]	$\mathcal{L}$ $[pb^{-1}]$	$q\bar{q}$ stat. err [%]
1995,1997	130	~ 6	2.3/5.2
1995,1997	136	~ 6	2.6/6.0
1996	161	~ 10	2.7/5.9
1996	172	~ 10	3.2/7.1
1997	183	~ 55	1.4/3.3
1998	189	~ 175	0.9/2.0

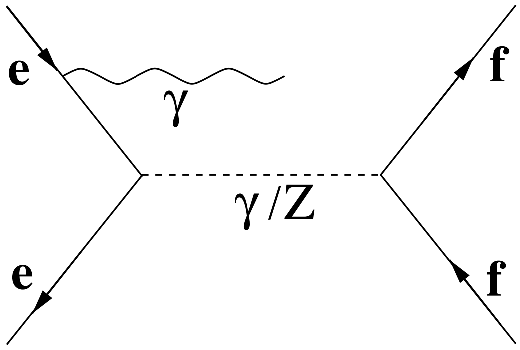
- Systematic errors gain in importance

- 189 GeV data are preliminary!

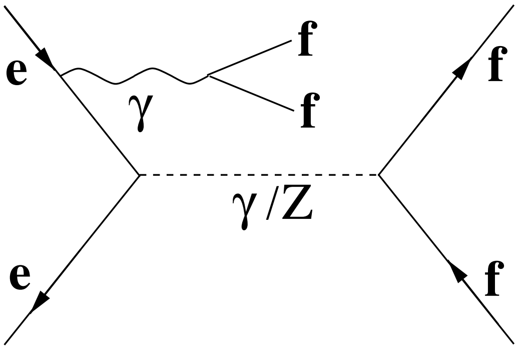
Signal Definition

- Two event classes:
  - Non-radiative events with $\sqrt{s\prime} > 0.85\sqrt{s}$
  - Inclusive events with $\sqrt{s\prime} > 0.1\sqrt{s}$

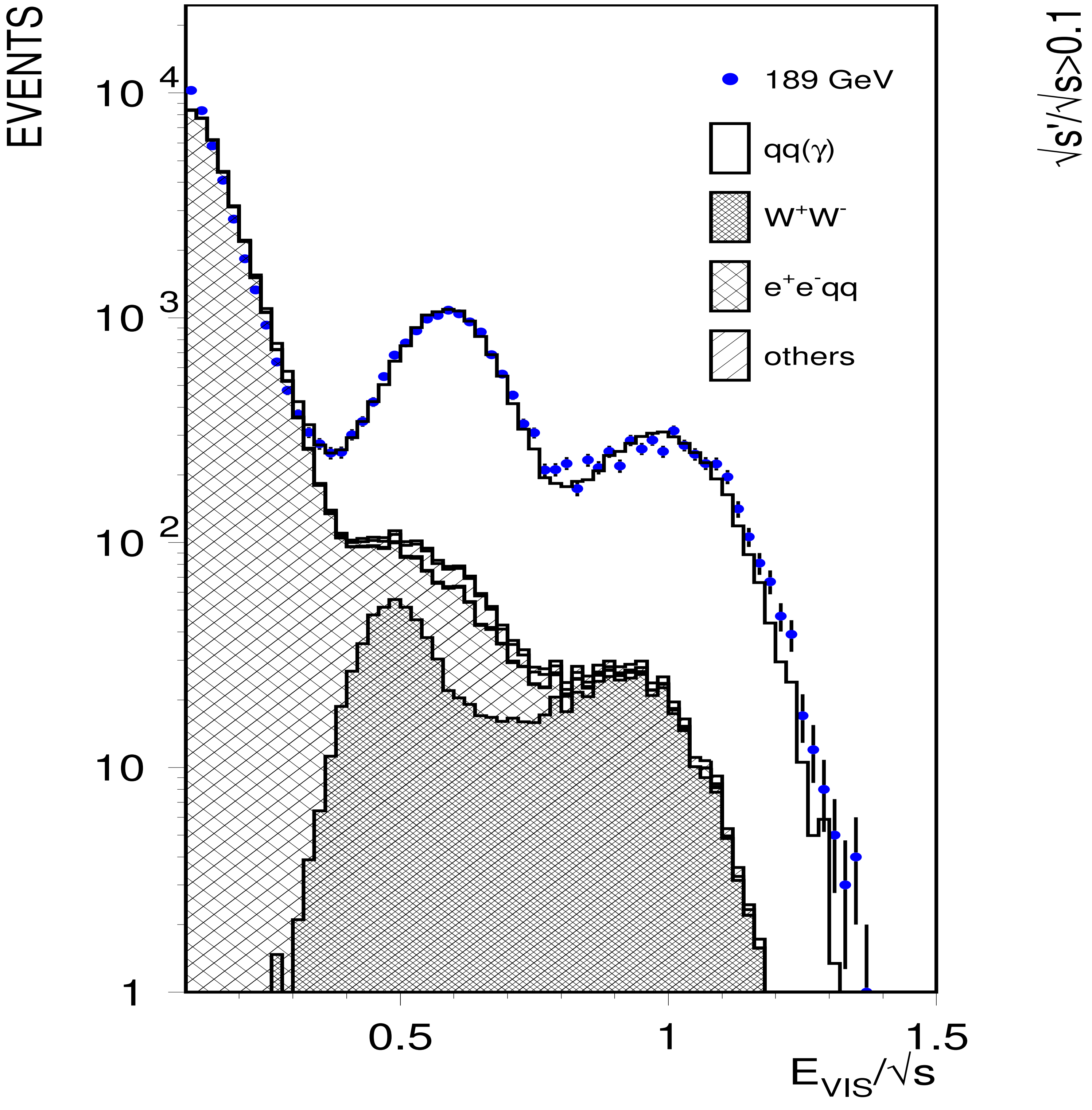




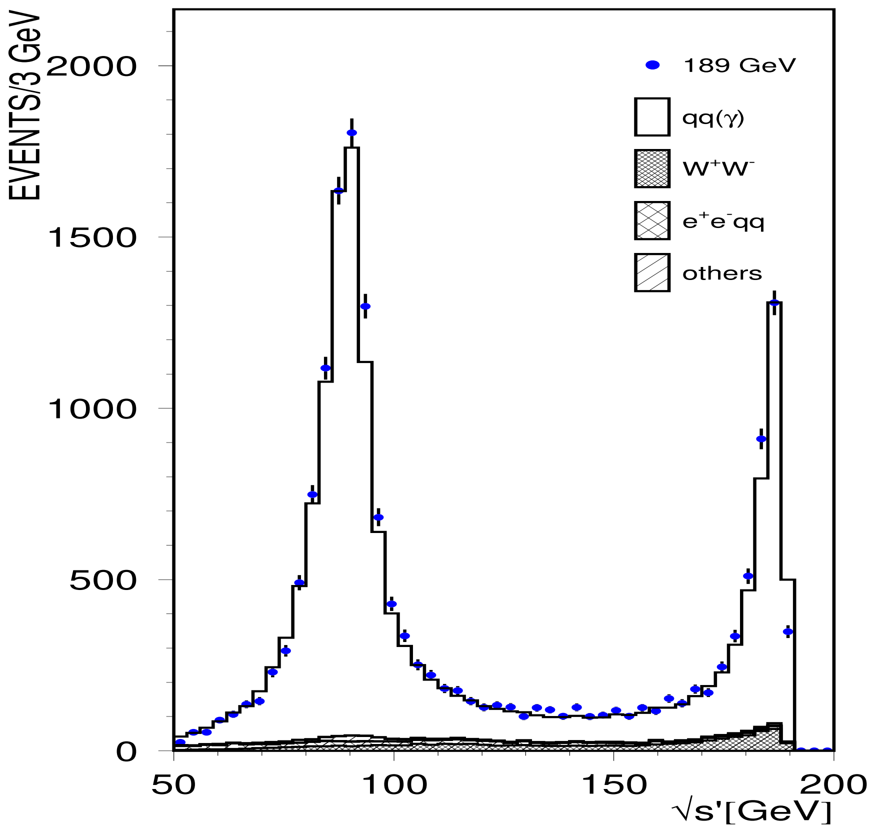
- But: $s\prime$ is not well defined due to interference between initial and final state radiation . Correction to 'no interference'. Corrections are $\sim$ 1-2 % for $\sqrt{s\prime} > 0.85\sqrt{s}$
- Four-fermion events . Events with a second fermion pair with low mass are signal.

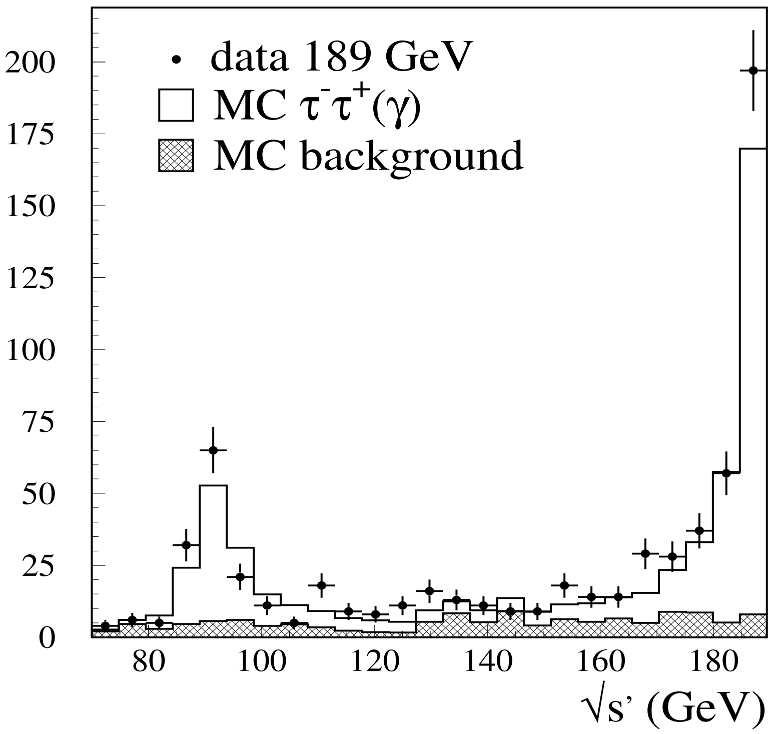


Hadrons

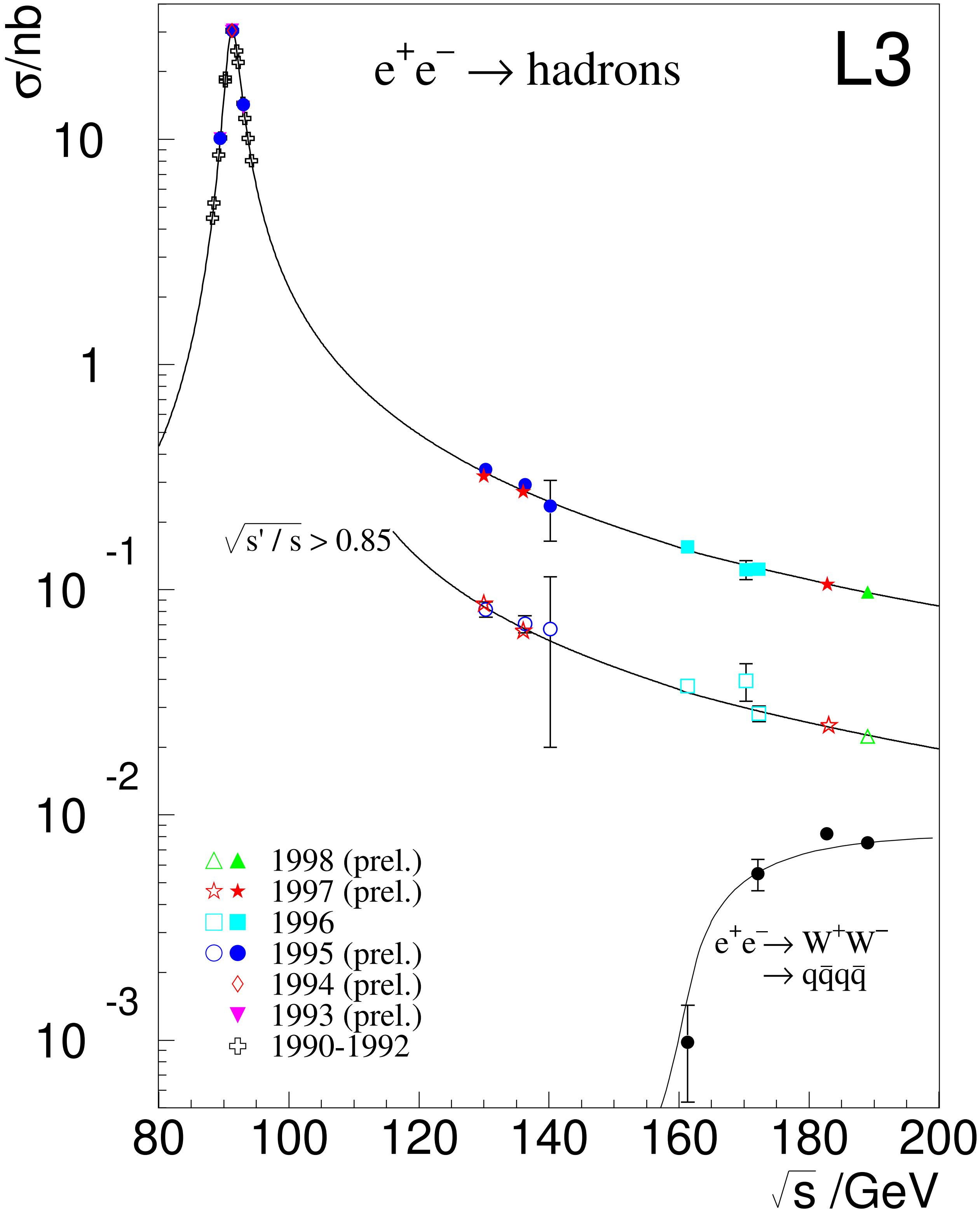


EVENTS
10^4
10^3
10^2
10
1
0.5
1
1.5
$E_{VIS}/\sqrt{s}$
189 GeV
$qq(\gamma)$
W^+W^-
e^+e^-qq
others
$\sqrt{s'}/\sqrt{s}>0.1$


EVENTS/3 GeV
2000
1500
1000
500
0
50
100
150
200
√s'[GeV]
189 GeV
qq(γ)
W⁺W⁻
e⁺e⁻qq
others

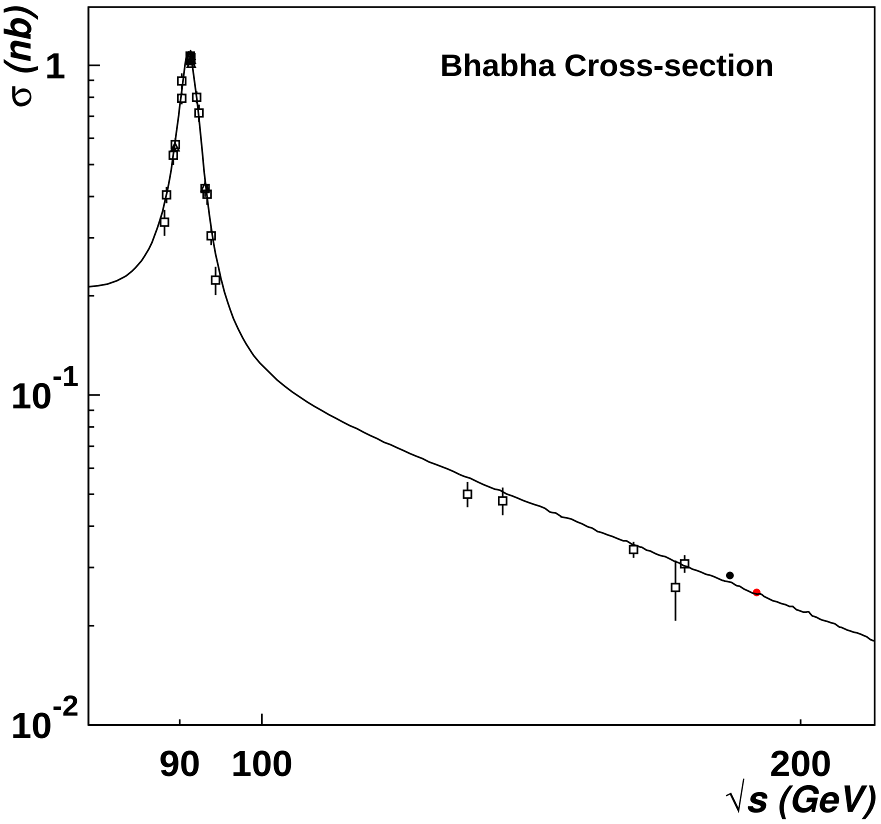

data 189 GeV
MC τ⁻τ⁺(γ)
MC background
200
175
150
125
100
75
50
25
0
80
100
120
140
160
180
√s' (GeV)

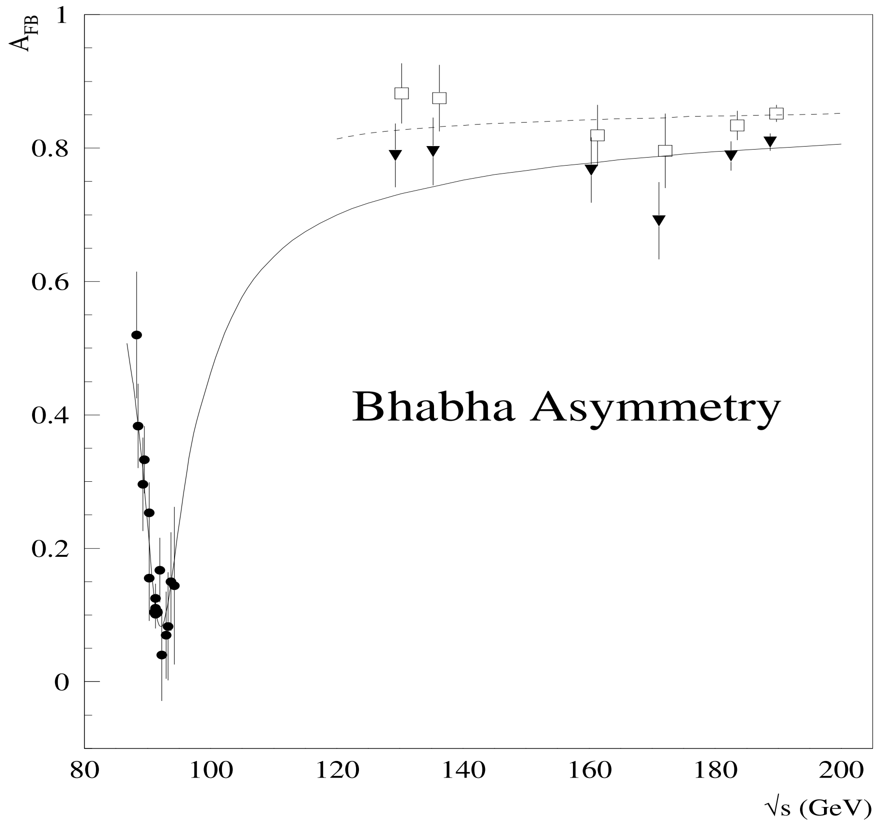
Hadrons



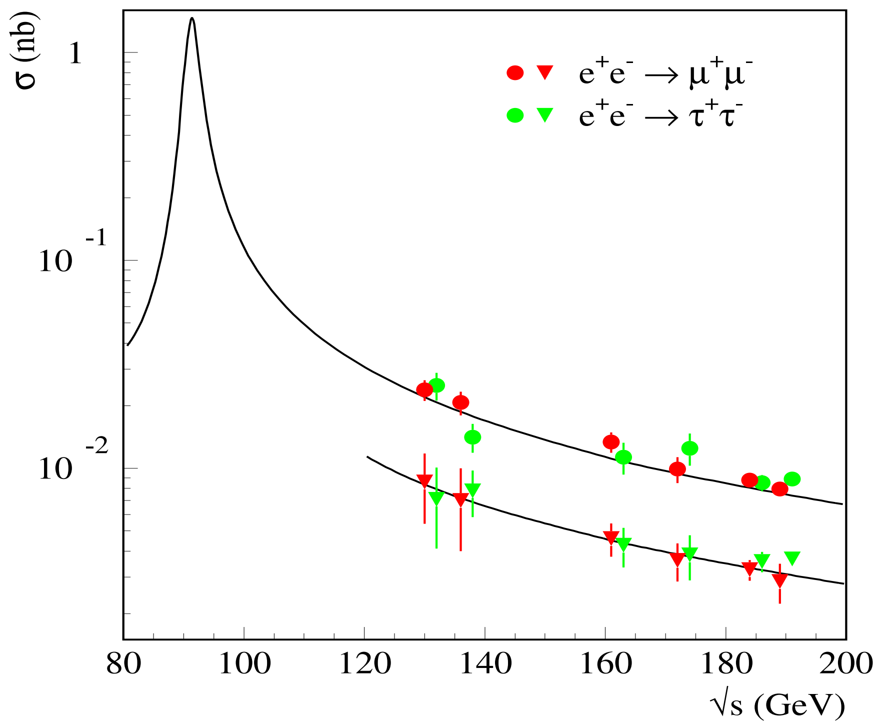
σ/nb
$e^+e^- \to$ hadrons
L3
10
1
10^{-1}
10^{-2}
10^{-3}
$\sqrt{s'/s} > 0.85$
1998 (prel.)
1997 (prel.)
1996
1995 (prel.)
1994 (prel.)
1993 (prel.)
1990-1992
$e^+e^- \to W^+W^-$
$\to q\bar{q}q\bar{q}$
80
100
120
140
160
180
200
$\sqrt{s}$ /GeV

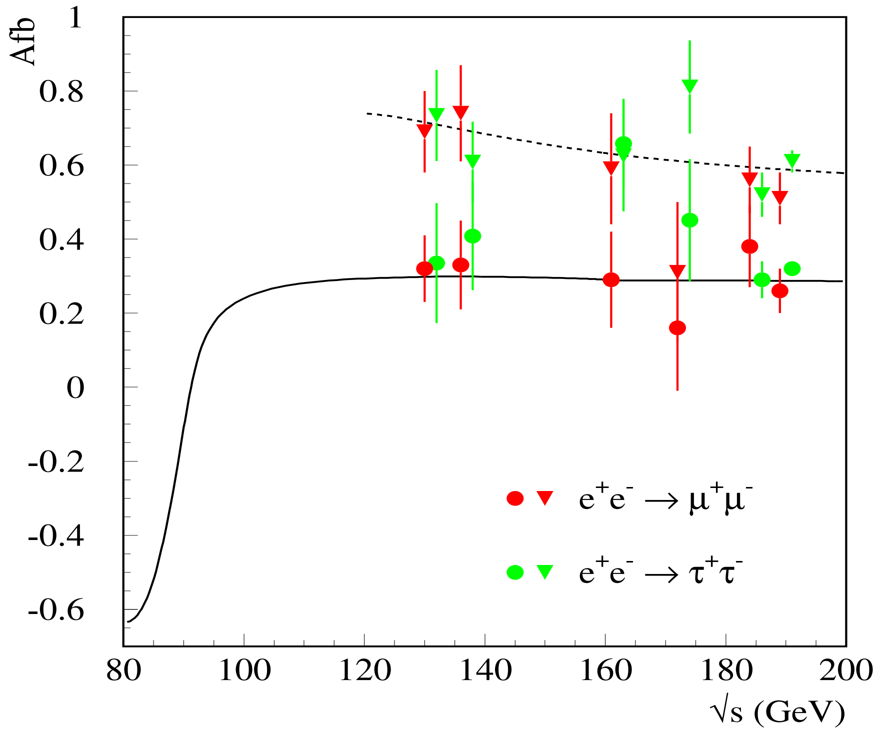
Lepton-Pairs



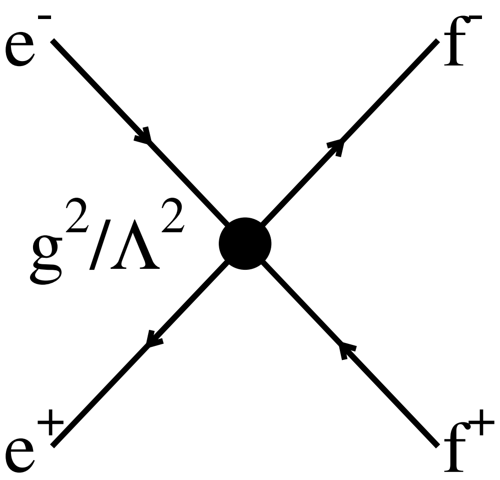


Lepton-Pairs





Contact Interactions



$$\mathcal{L} = \frac{1}{1+\delta_{ef}} \frac{g^2}{\Lambda^2} \sum_{i,j=L,R} \eta_{ij} \, (\overline{e}_i \gamma^\mu \overline{e}_i)(\overline{f}_j \gamma_\mu \overline{f}_j)$$

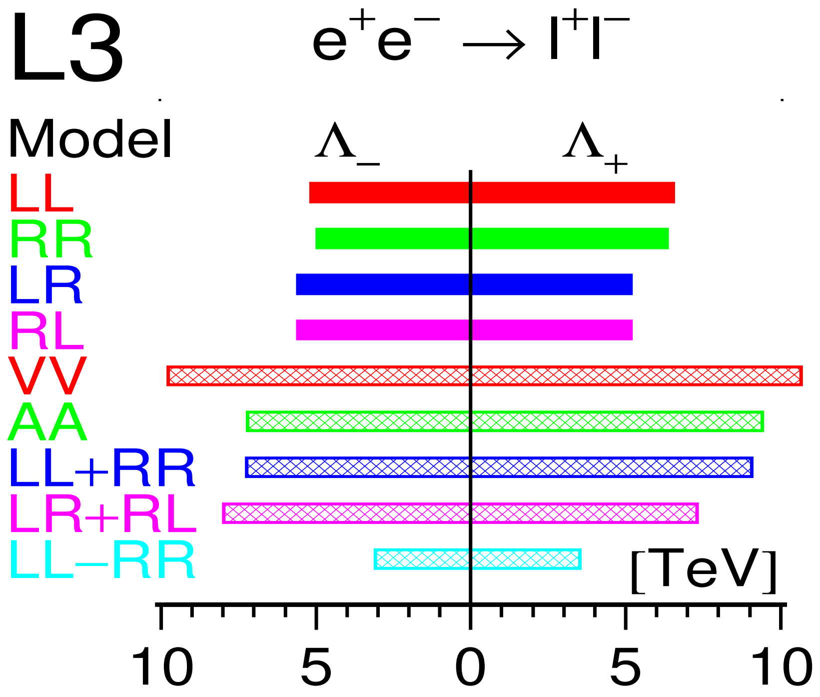
g Coupling, $g^2 = 4\pi$ by convention

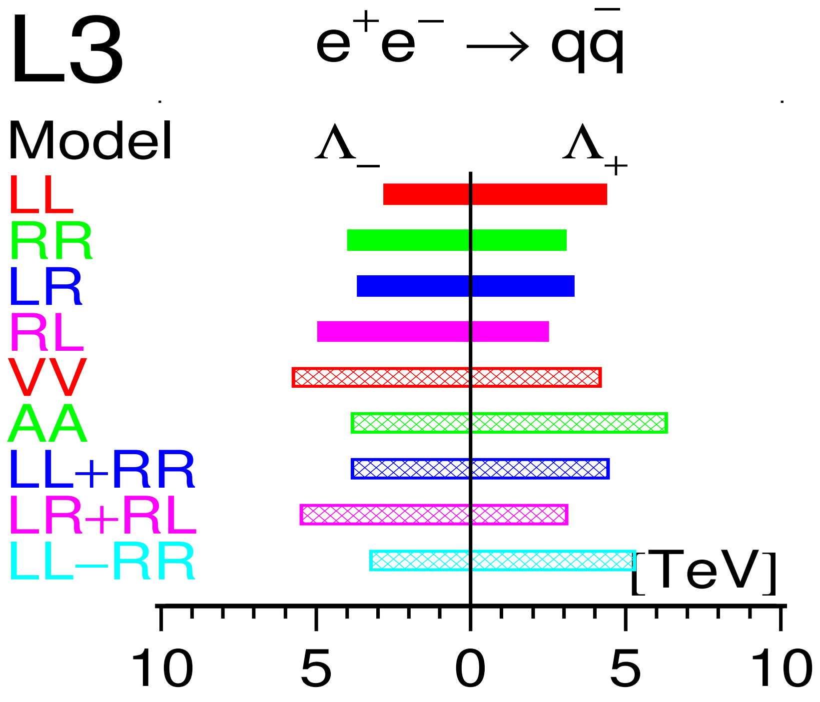
$\eta_{i,j}$ Helicity amplitudes, chosen to be $|\eta_{i,j}| = 0, 1$

Λ Energy scale

$$\frac{d\sigma}{d\Omega} = SM(s,t) + \frac{g^2}{\Lambda^2} C_{Int}(s,t) + \frac{g^4}{\Lambda^4} C_{NewPhysics}(s,t)$$

Contact Interactions





Additional Z-boson

Additional heavy vector boson :

$$\mathcal{L} \;=\; eA_\mu J^\mu_\gamma + gZ_\mu J^\mu_Z + g\prime Z'_\mu J^\mu_{Z'}$$

Z' parameters:

- Mass, $m_{Z'}$
- ZZ' mixing angle, θ_M

$$\begin{pmatrix} Z \\ Z' \end{pmatrix} = \begin{pmatrix} \cos\theta_M & \sin\theta_M \\ -\sin\theta_M & \cos\theta_M \end{pmatrix} \begin{pmatrix} Z^0 \\ Z^{0\prime} \end{pmatrix}$$

- Z' couplings to fermions, model dependent (Left-Right models, E6 models)

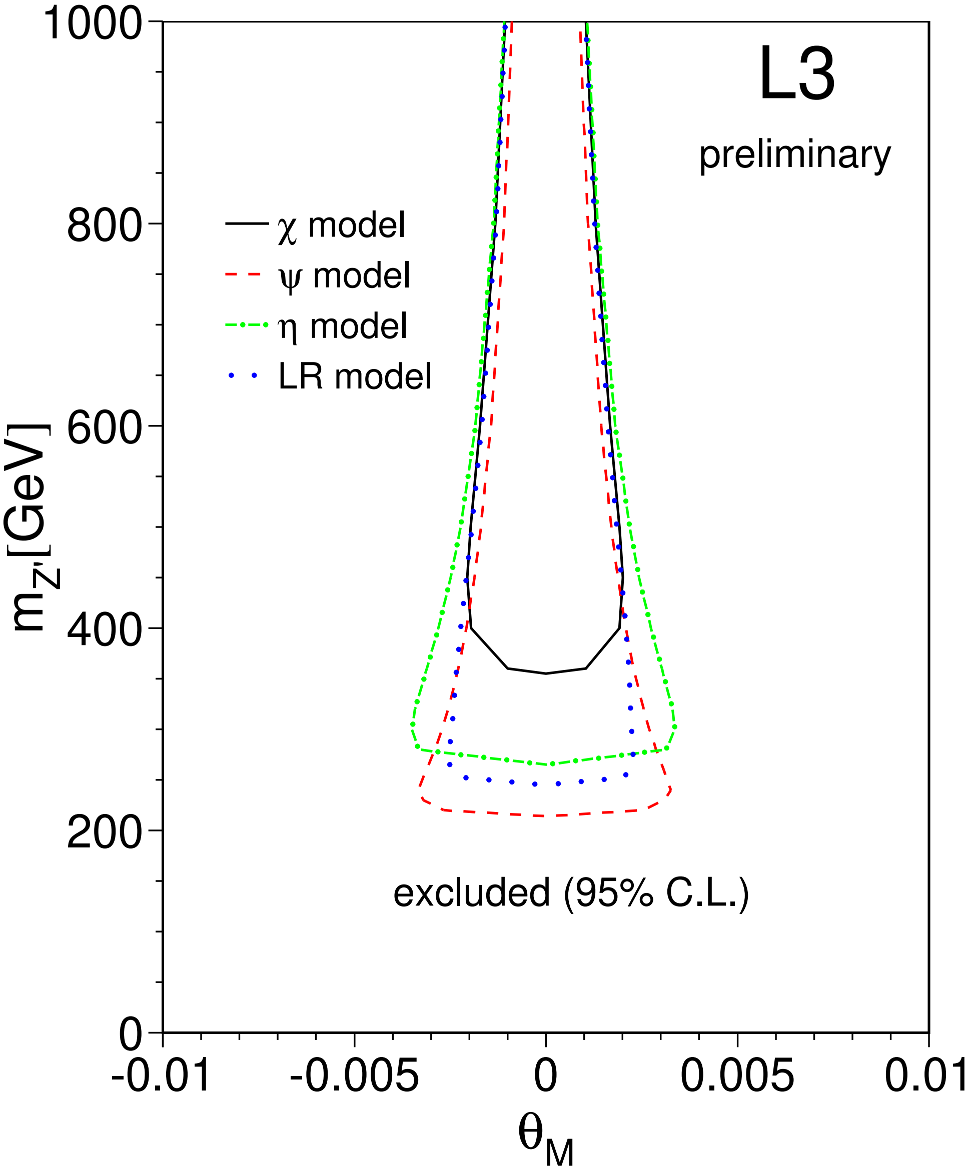
Precision measurements of Z parameters give limits on mixing angle.

Above the Z-resonance:

$$\sigma \;=\; \sigma_{\gamma\gamma} + \sigma_{\gamma Z} + \sigma_{ZZ} + \sigma_{\gamma Z'} + \sigma_{ZZ'} + \sigma_{Z'Z'}$$

Improvement of limits on $m_{Z'}$ and couplings.

Additional Z-boson



Including this year's data would improve the limits on the Z'mass and the couplings by $\sim$ 20% .

NIKHEF

R-parity violating SUSY

Even superpotential for MSSM contains L violating interactions:

$$W_{\not R} = \lambda_{ijk} L_L^i L_L^j \overline{E}_R^k + \lambda'_{ijk} L_L^i Q_L^j \overline{D}_R^k$$

L left handed doublets of leptons
E right handed singlets of charged leptons

$\lambda_{ijk}^{(\prime)} \neq 0$ only for $i < j$
9 independent Yukawa couplings λ

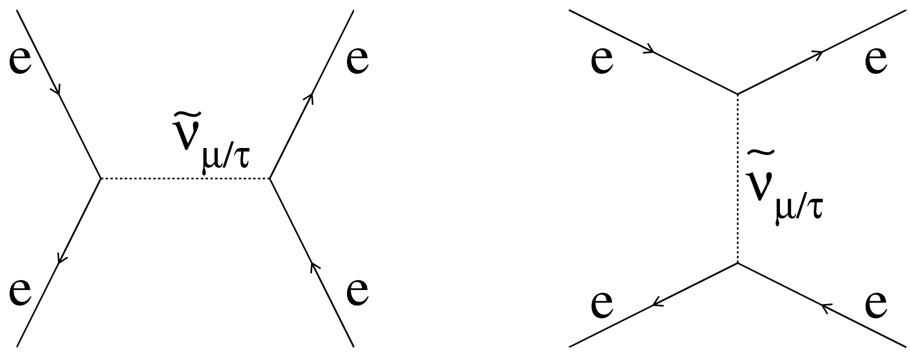
If $m_{\tilde{\nu}} \sim \sqrt{s}$ then single sneutrino resonance formation .

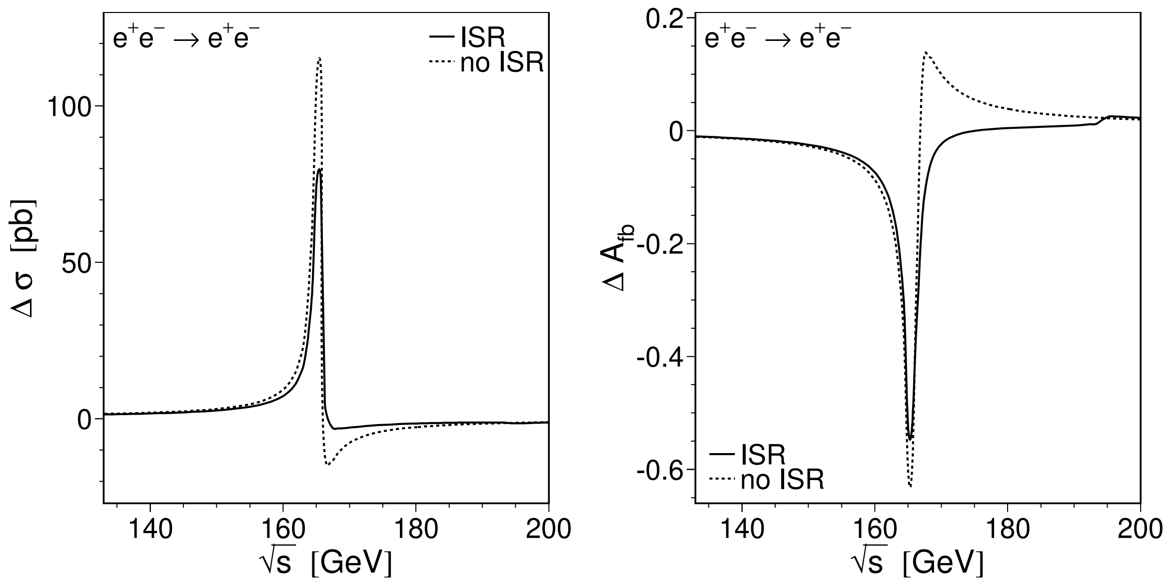
Most interesting scenarios:

- One coupling is much larger than the others.
- Two couplings are much larger than the others, where both couplings violate the same flavor, or both violate all 3 flavors.

R-parity violating SUSY

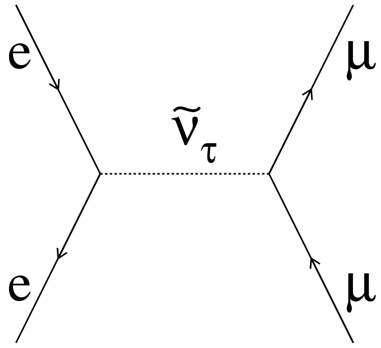
- λ_{131} (or λ_{121}) $\neq 0$

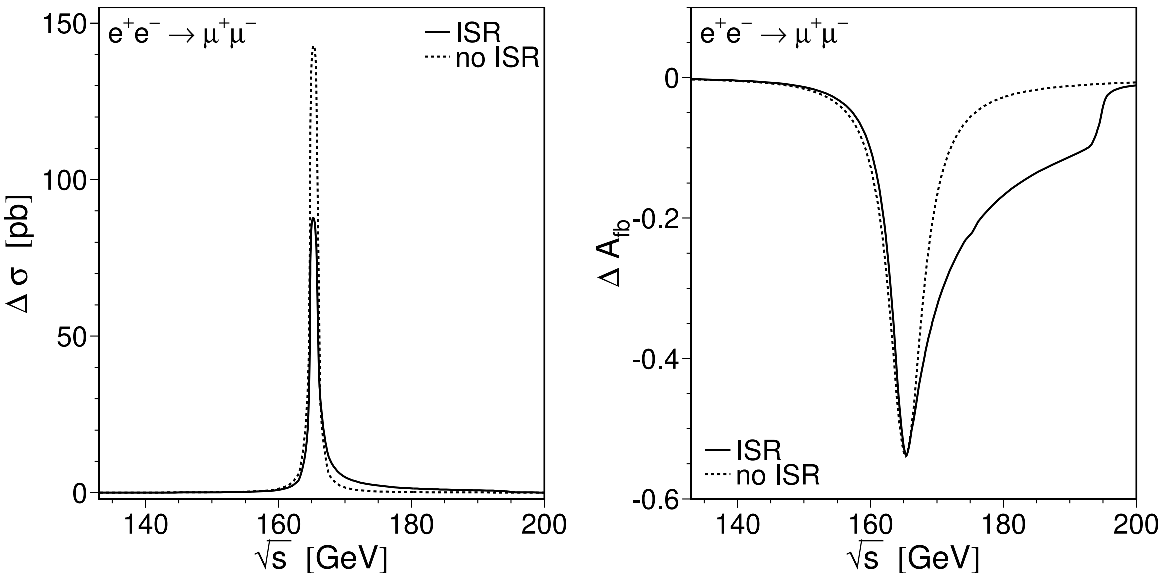




R-parity violating SUSY

- $\lambda_{131} = \lambda_{232} \neq 0$





R-parity violating SUSY