Measurement of Hadron and Lepton-pair Production above the Z Resonance

D.Bourilkov

ETH - Zürich

for the L3 Collaboration

APS Centennial Meeting, Atlanta, USA, March 20-26, 1999

http://l3www.cern.ch/~bourilko/

- **Fermion-pair production**
- **Measurements of cross sections and asymmetries above the Z**

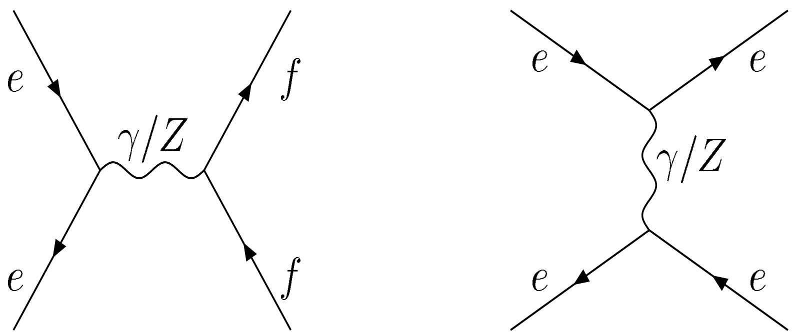
  Leptons: $e^+e^- \longrightarrow l^+l^-(\gamma)$

  Hadrons: $e^+e^- \longrightarrow q\bar{q}(\gamma)$
- **S-matrix fit**
- **Searches for new phenomena**

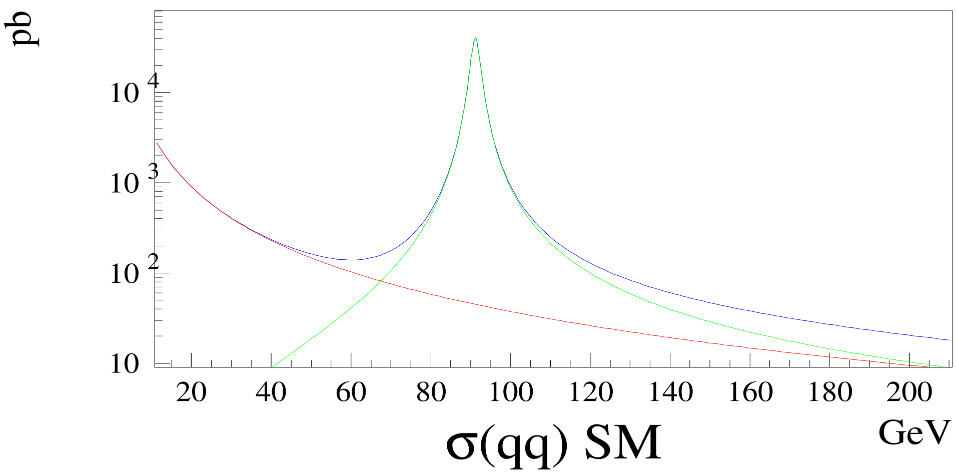
  Contact interactions & Compositeness

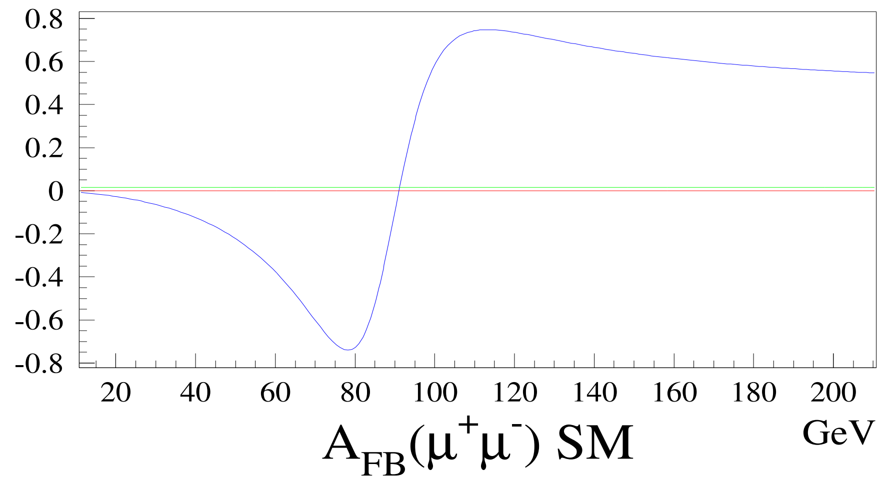
  R-parity breaking: sneutrino exchange
- **Outlook**

Fermion-pair Production



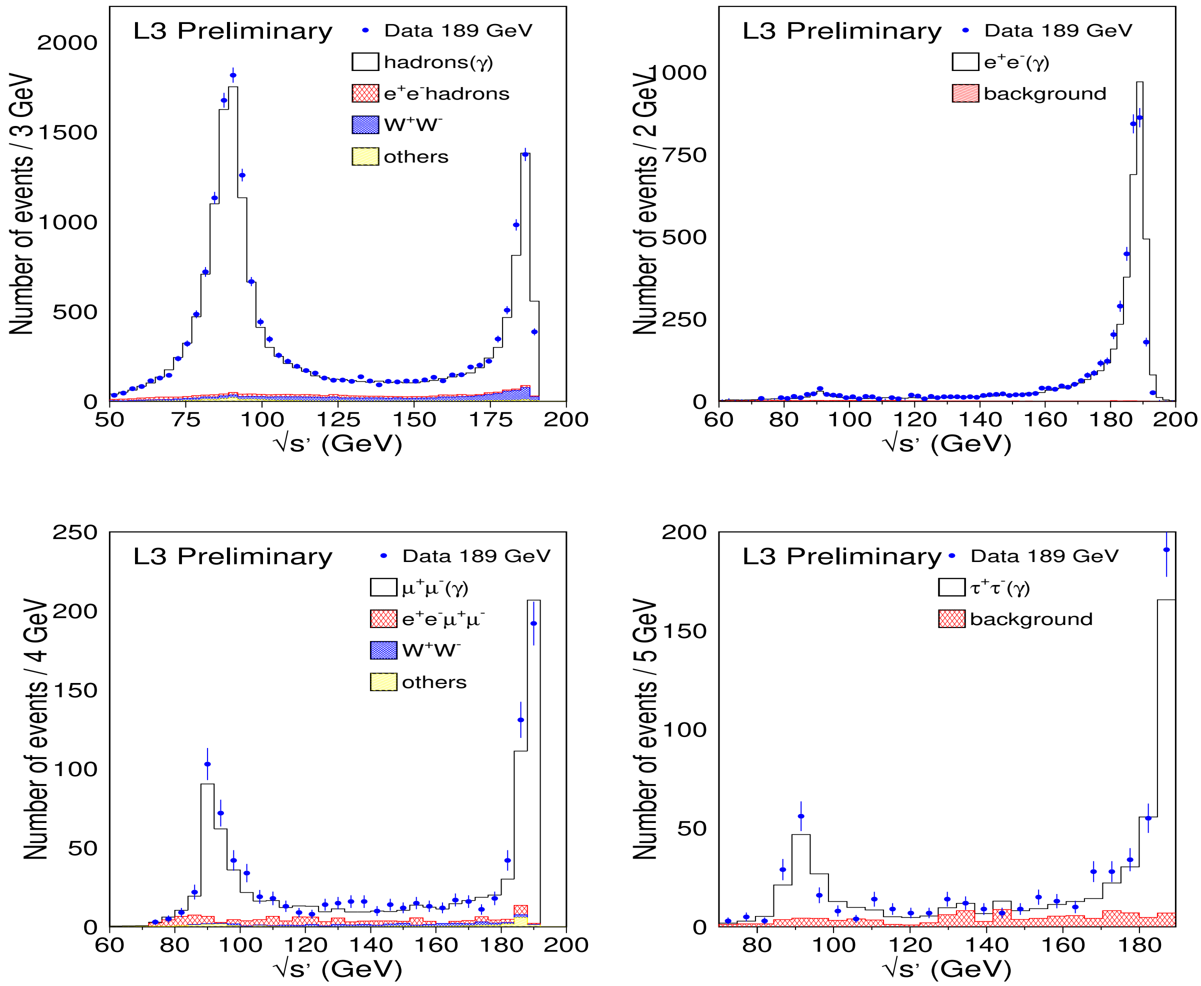
$$\frac{d\sigma}{d\Omega} = |\gamma_s + Z_s + \mathrm{elec} * (\gamma_t + Z_t) + \text{New Physics ?!}|^2$$





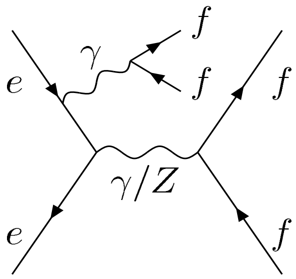
Effective CMS Energy $\sqrt{s'}$

- Cross sections and asymmetries measured for:
  inclusive events - $\sqrt{s'}/\sqrt{s} > 0.1$
  high energy events - $\sqrt{s'}/\sqrt{s} > 0.85$
- The high energy sample - main search field for new physics
- s' from ISR photon in the detector / angles of outgoing fermions / kinematic fit



Signal Definition

- Interplay between 2-f and 4-f events;
  radiative corrections, real pairs



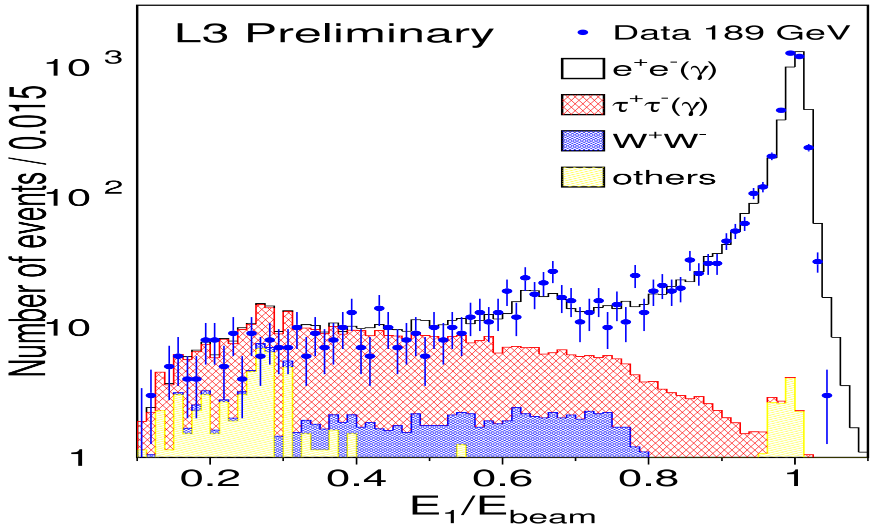
  low mass fermion pairs are signal, like photons

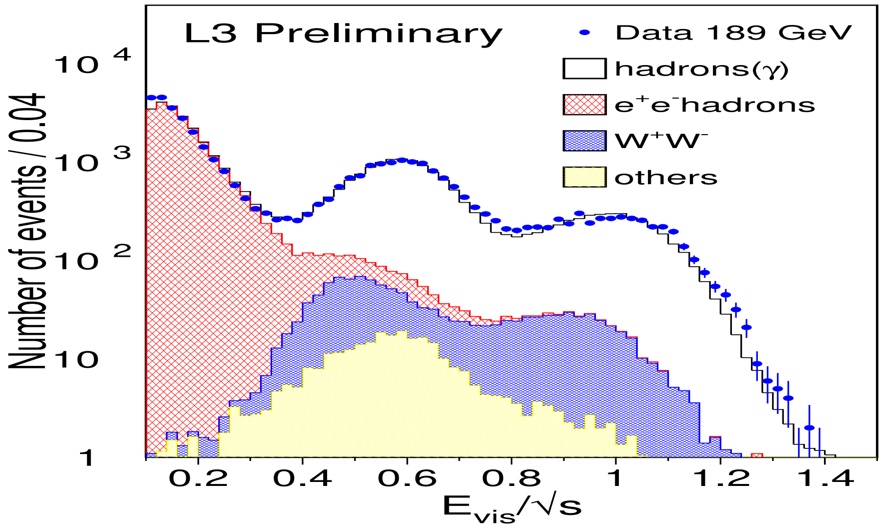
- Definition of s$'$: not unique due to interference between initial- and final-state radiation
  - interference changes the cross-sections: for $\sqrt{\mathrm{s}'}/\sqrt{\mathrm{s}} > 0.85$ by $\sim 1.5\%$ for $\mu^+\mu^-$ and $\sim 0.5\%$ for $\mathrm{q}\bar{\mathrm{q}}$ in $\mathcal{O}(\alpha)$ (efficiency changed by $\leq 50\%$ of this)
  - correct or define $\sqrt{\mathrm{s}'}$ as the effective mass of the outgoing fermion pair

- Rising 4-f background
  (W^+W^-, ZZ, Z $\mathrm{e}^+\mathrm{e}^-$, $We\nu$, ...)

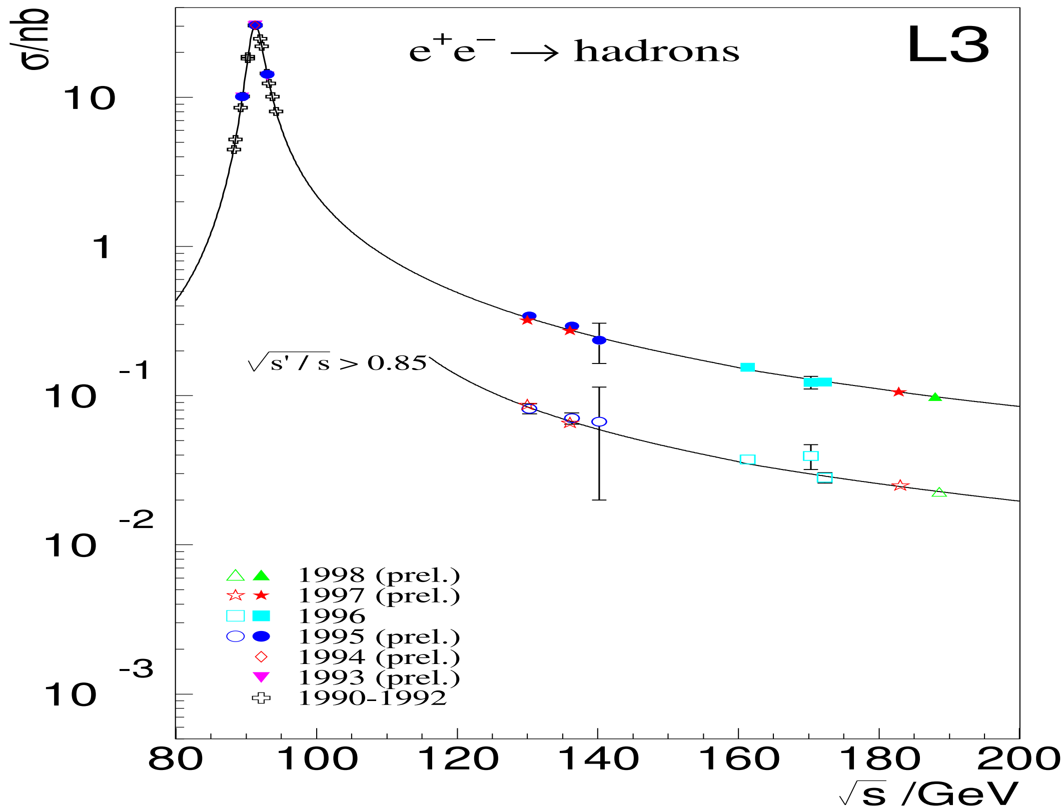
Data Analysis

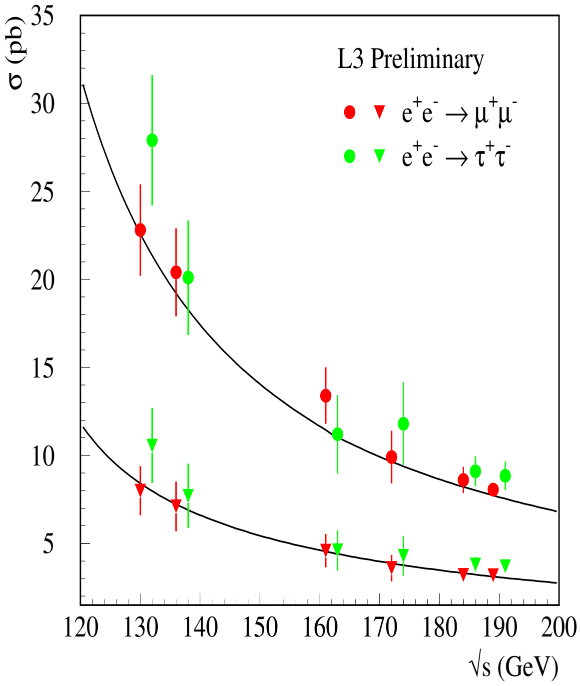
Year	$\sqrt{s}$ [GeV]	$\mathcal{L}$ [pb^{-1}]	$q\bar{q}$ stat. error [%]
1995 & 1997	130	~ 6	2.3/5.2
1995 & 1997	136	~ 6	2.6/6.0
1996	161	~ 10	2.7/5.9
1996	172	~ 10	3.2/7.3
1997	183	~ 55	1.4/3.3
1998	189	~ 175	0.8/1.8

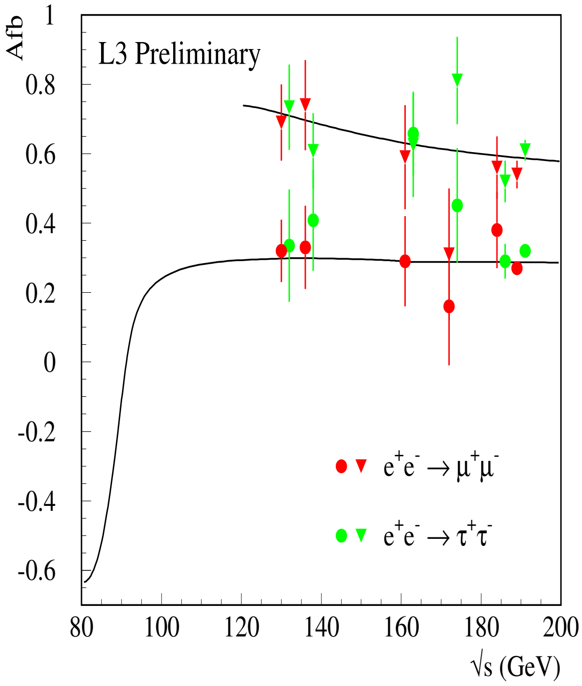




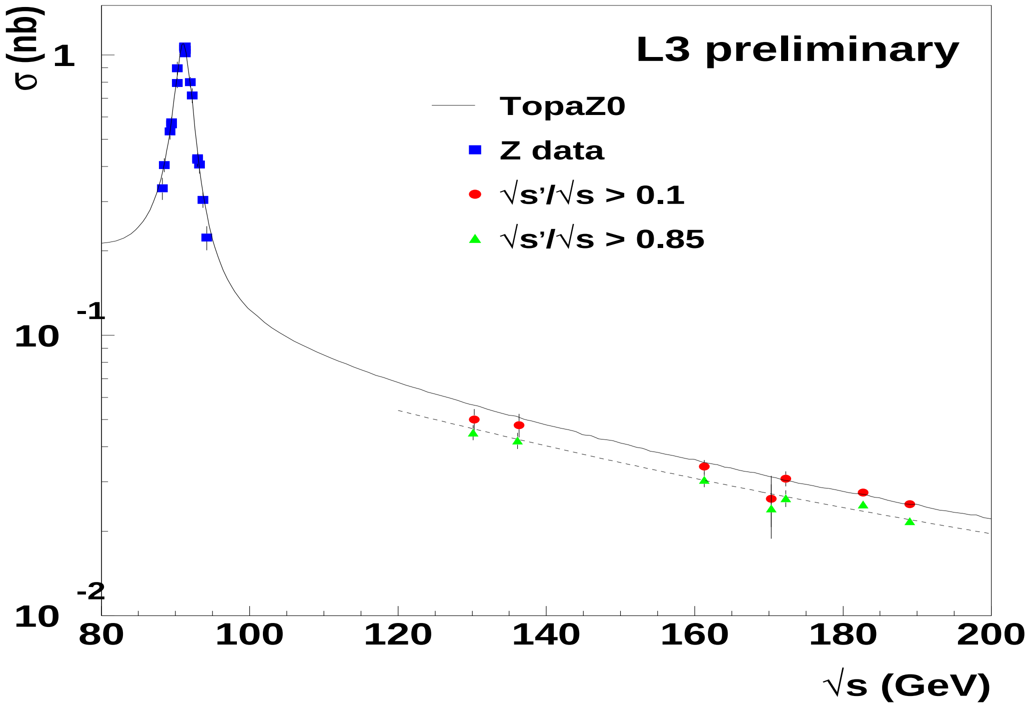
Results at 130-189 GeV

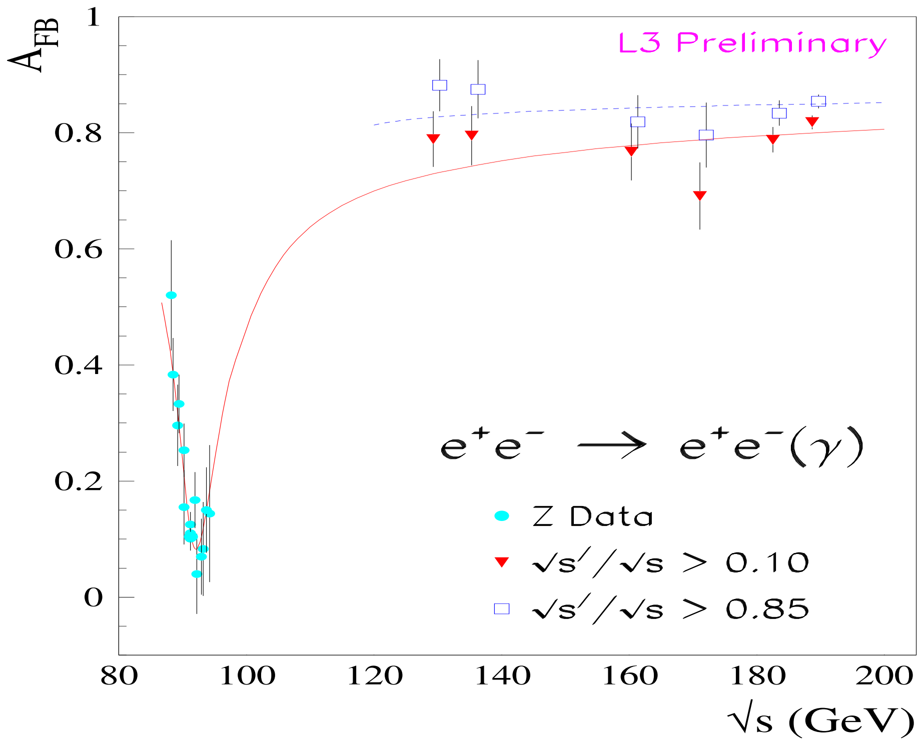






Results at 130-189 GeV



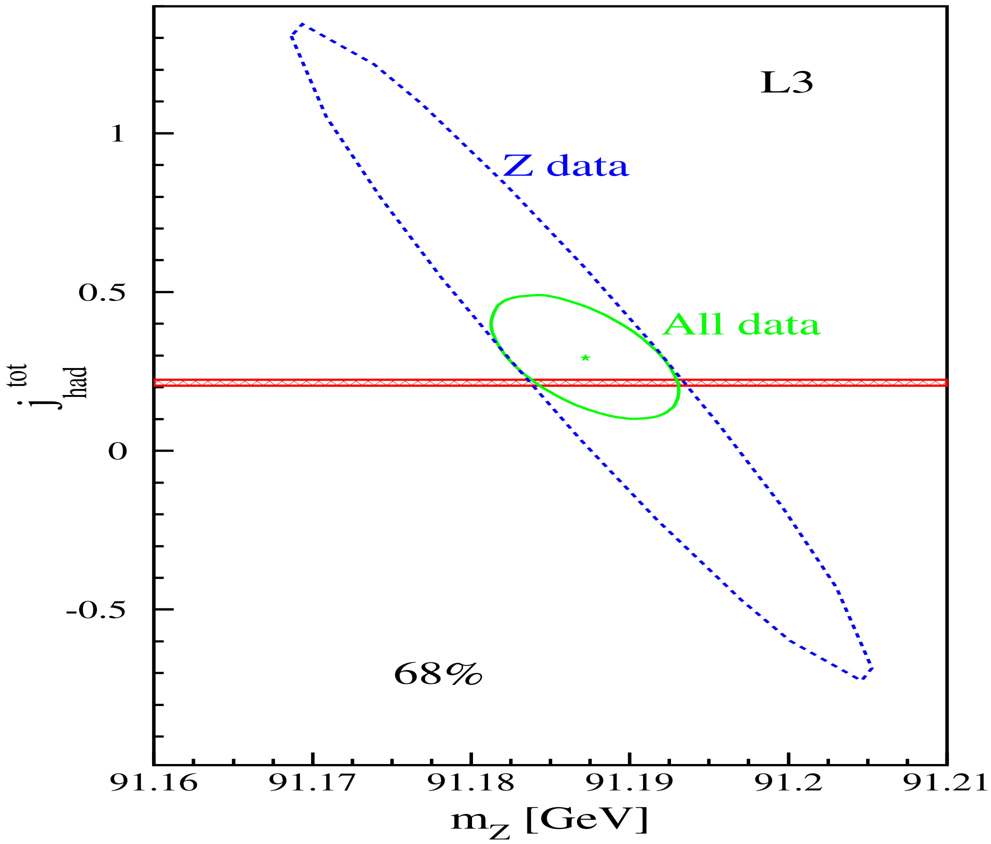


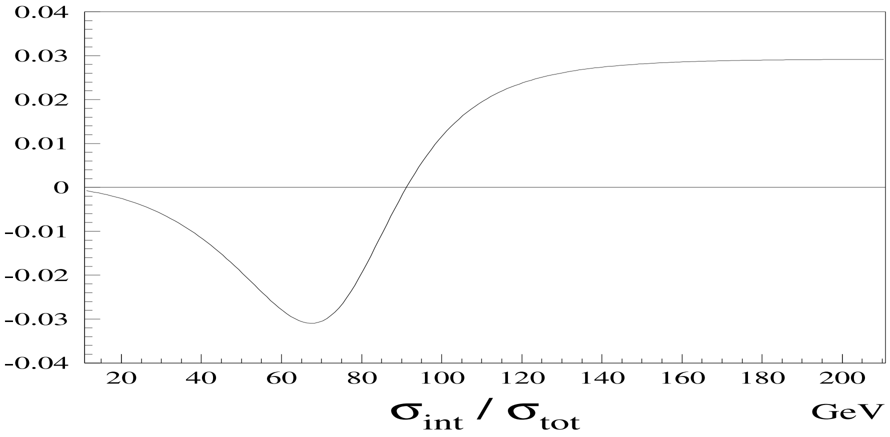
S-matrix Fit

$$\sigma_a^0(s) = \frac{4}{3}\pi\alpha^2 \left[\frac{g_f^a}{s} + \frac{j_f^a(s-\bar{m}_Z^2) + r_f^a\, s}{(s-\bar{m}_Z^2)^2 + \bar{m}_Z^2\bar{\Gamma}_Z^2}\right] \qquad \text{for a} = \text{tot}, \text{fb}$$

$$A_{\rm fb}^0(s) = \frac{3}{4}\frac{\sigma_{\rm fb}^0(s)}{\sigma_{\rm tot}^0(s)} \qquad \mathrm{j}_{\rm had}^{\rm tot} = 3\sum \mathrm{j}_{\rm f}^{\rm tot}$$

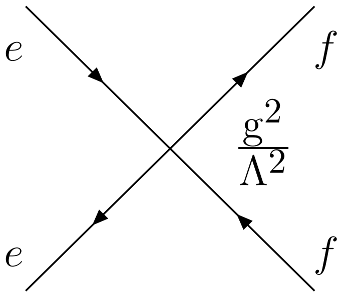
Update for 189 GeV





general framework for a new interaction with typical energy scale $\Lambda \gg \sqrt{\mathrm{s}}$

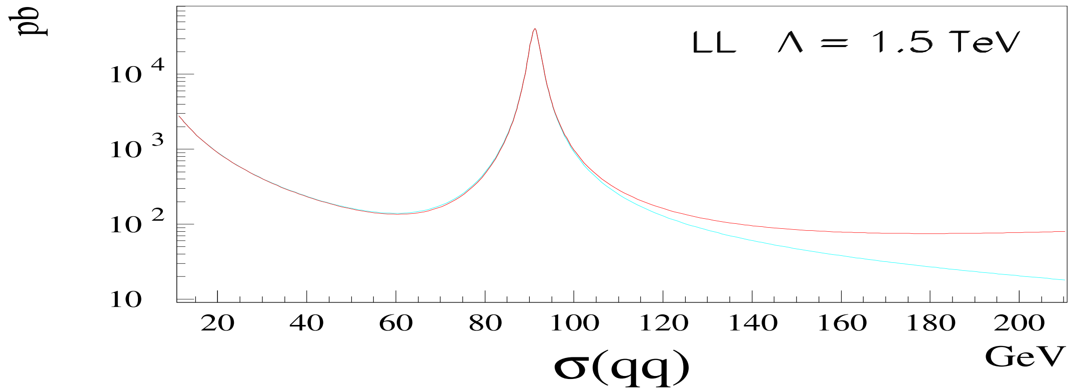
g	coupling (by convention $\frac{g^2}{4\pi} = 1$)
Λ	energy scale (or exchanged mass)
$\lvert\eta_{ij}\rvert \leq 1$	helicity amplitudes
ε	$\frac{g^2}{4\pi}\frac{sign(\eta)}{\Lambda^2}$

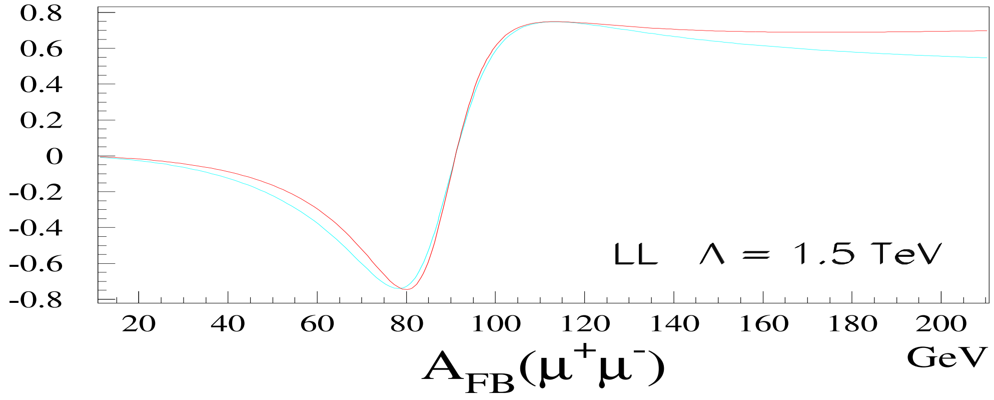


$$\frac{d\sigma}{d\Omega} = \mathrm{SM}(s,t) + \varepsilon \cdot \mathrm{C_{Int}}(s,t) + \varepsilon^2 \cdot \mathrm{C_{NewPh}}(s,t)$$

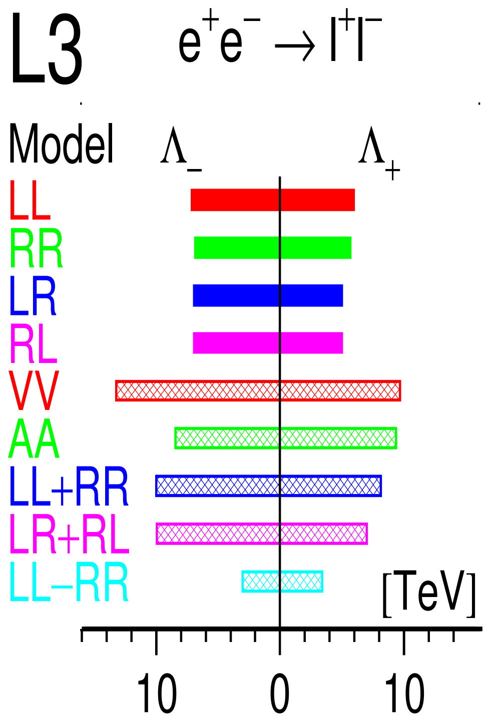
Model	LL	RR	LR	RL	VV	AA	LL+RR	LR+RL
	Non-parity conserving				Parity conserving			
η_{LL}	±1	0	0	0	±1	±1	±1	0
η_{RR}	0	±1	0	0	±1	±1	±1	0
η_{LR}	0	0	±1	0	±1	∓1	0	±1
η_{RL}	0	0	0	±1	±1	∓1	0	±1

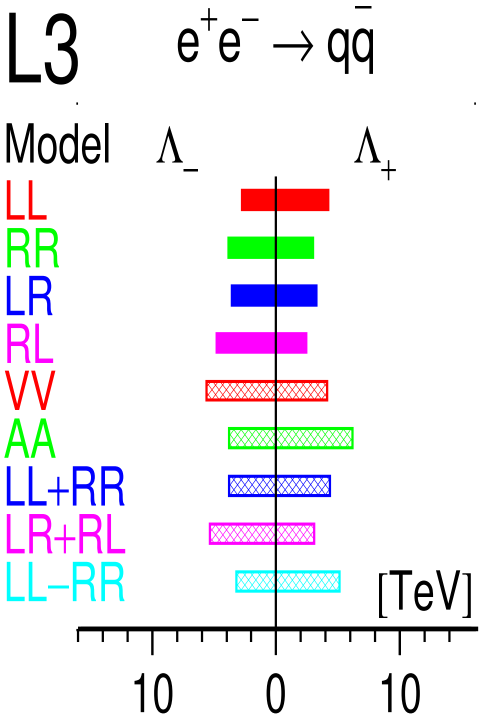
Contact Interactions



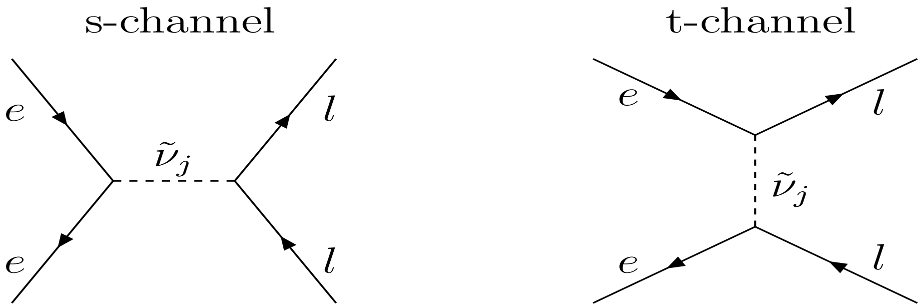


Limits for e^+e^- , $\mu^+\mu^-$, $\tau^+\tau^-$, l^+l^-, $q\bar{q}$, $u\bar{u}$, $d\bar{d}$, $f\bar{f}$ (95% CL)

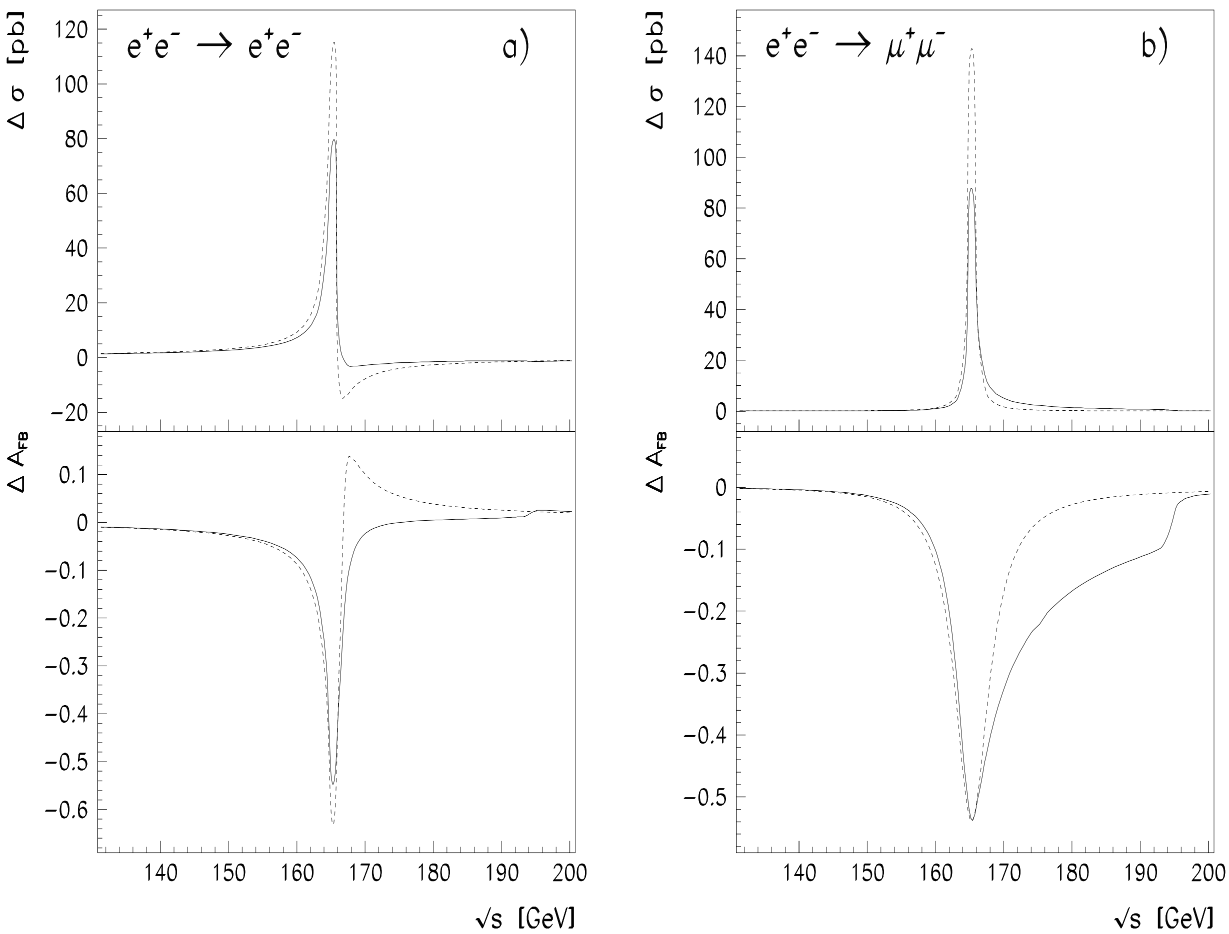




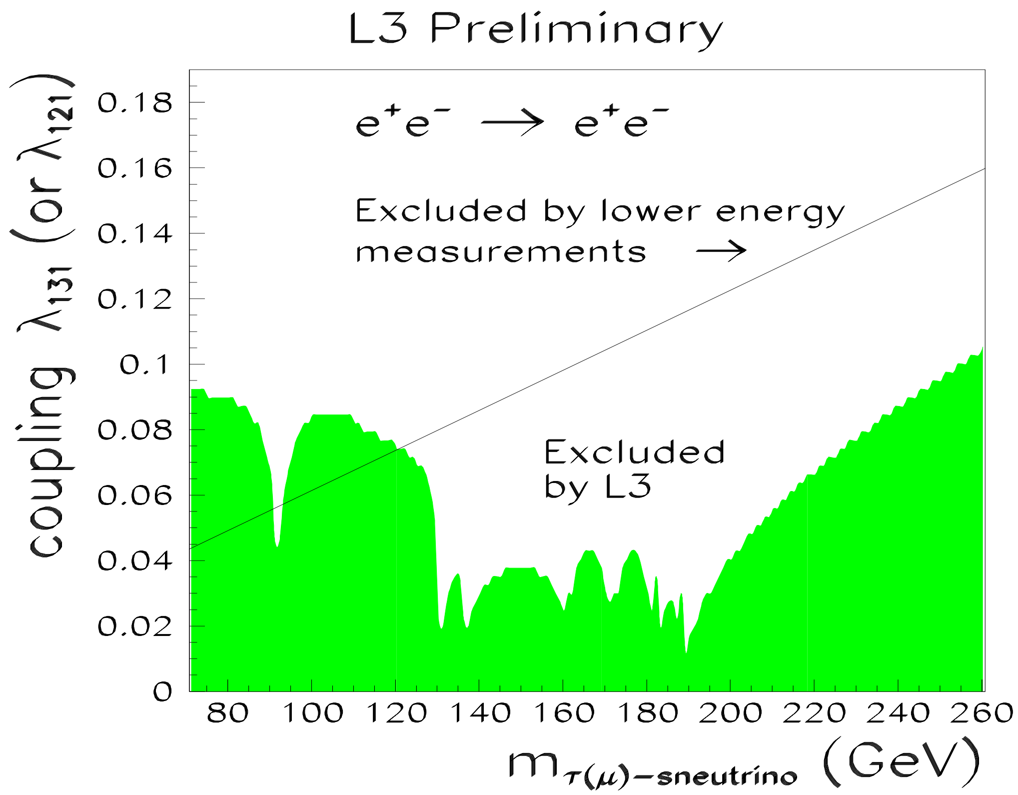
Resonance formation & t-channel exchange of single $\tilde{\nu}$ in $\not{R}_P$ theories

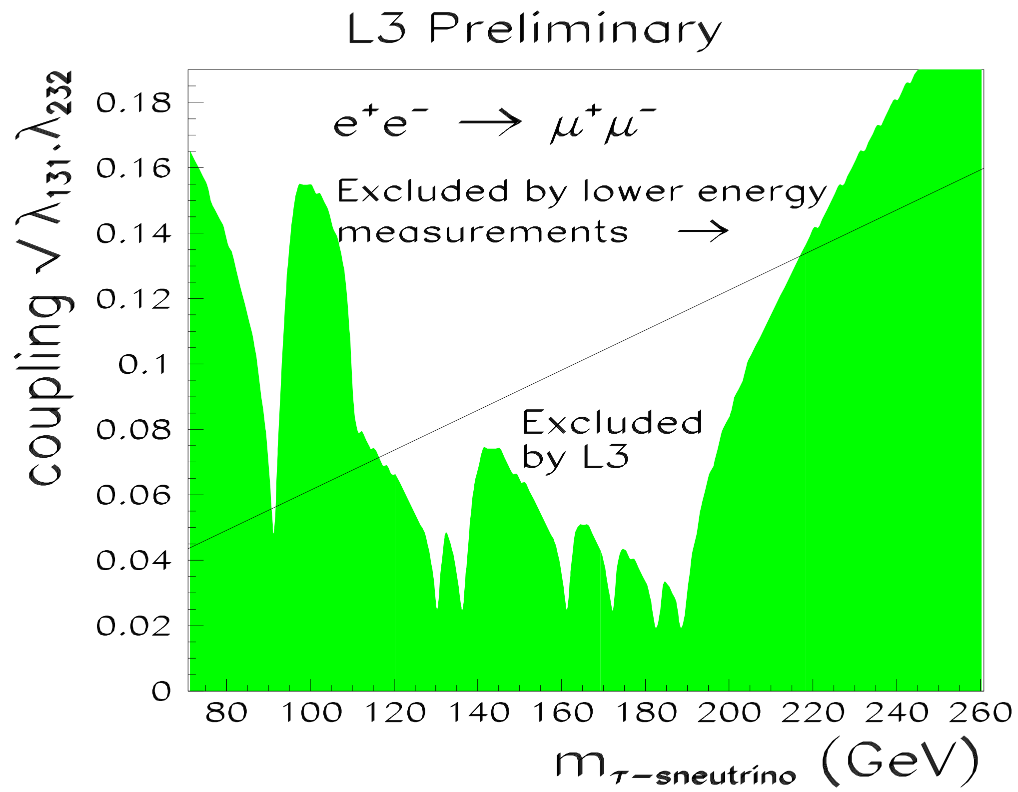


	s-channel	t/u-channel	Coupling
Amplitude	$\frac{1}{2} \cdot \frac{(\lambda_{1jk}/e)^2 \cdot s}{s - m_j^2 + i\Gamma_j m_j}$	$\frac{1}{2} \cdot \frac{(\lambda_{1jk}/e)^2 \cdot s}{t - m_j^2}$	$\frac{\lambda}{m_x} \simeq \frac{\sqrt{8\pi}}{\Lambda} \Rightarrow \lambda \simeq 5.01 \frac{m_x}{\Lambda}$



Results including 183 and 189 GeV data





Outlook

- the Standard Model describes all L3 fermion-pair production measurements from 130-189 GeV (results at 183 & 189 GeV preliminary)
- no hint for new phenomena so far
- limits on new physics :
  - contact interaction scale > 2.4 - 13 TeV $(< \ 10^{-19} \ m)$
  - improved limits on $\not{R}_{\mathrm{P}}$-couplings for $\tilde{\nu}$ masses up to 260 GeV
  - ($\tilde{\mathrm{q}}$, leptoquarks, Z')
- the LEP2 discovery potential is not exhausted; we are looking forward to more data at higher energies