ZZ signal definition and cross section calculations

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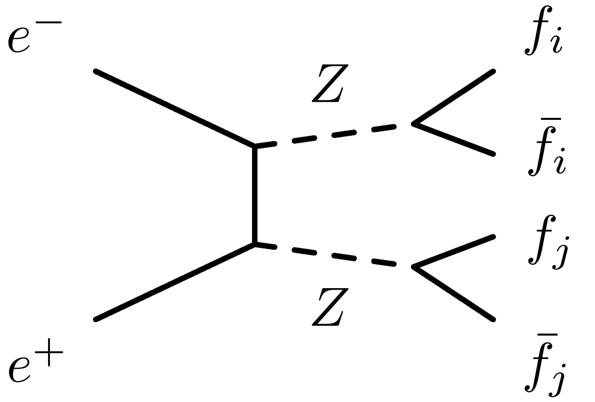
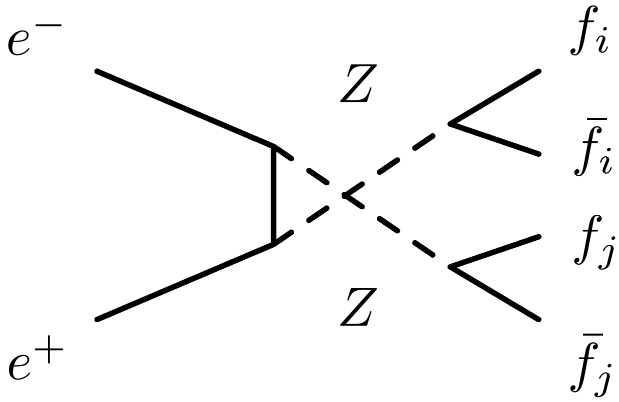
June 11, 1999

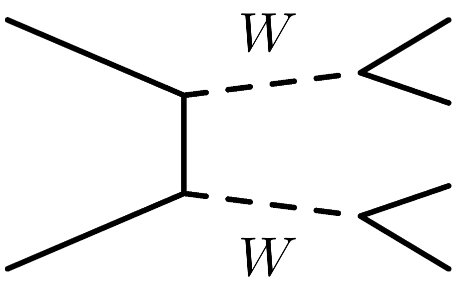
Z pair production

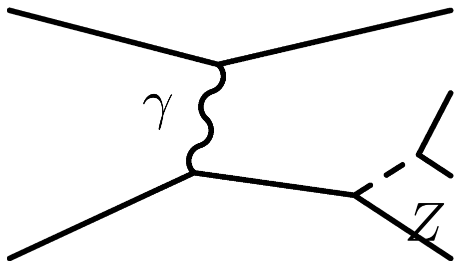
The Z pair production graphs





contribute to a 4 fermion final state and therefore interfere with other Standard Model processes leading to the same final state, e. g.





Because only the sum of all diagrams can be measured, we define our signal using phase space cuts on generator level.

ZZ signal definition

- Invariant mass M of fermion pairs $(f_i, \bar{f}_i)$ and $(f_j, \bar{f}_j)$ must be in mass range

$$70 \text{ GeV} \leq M \leq 105 \text{ GeV}$$

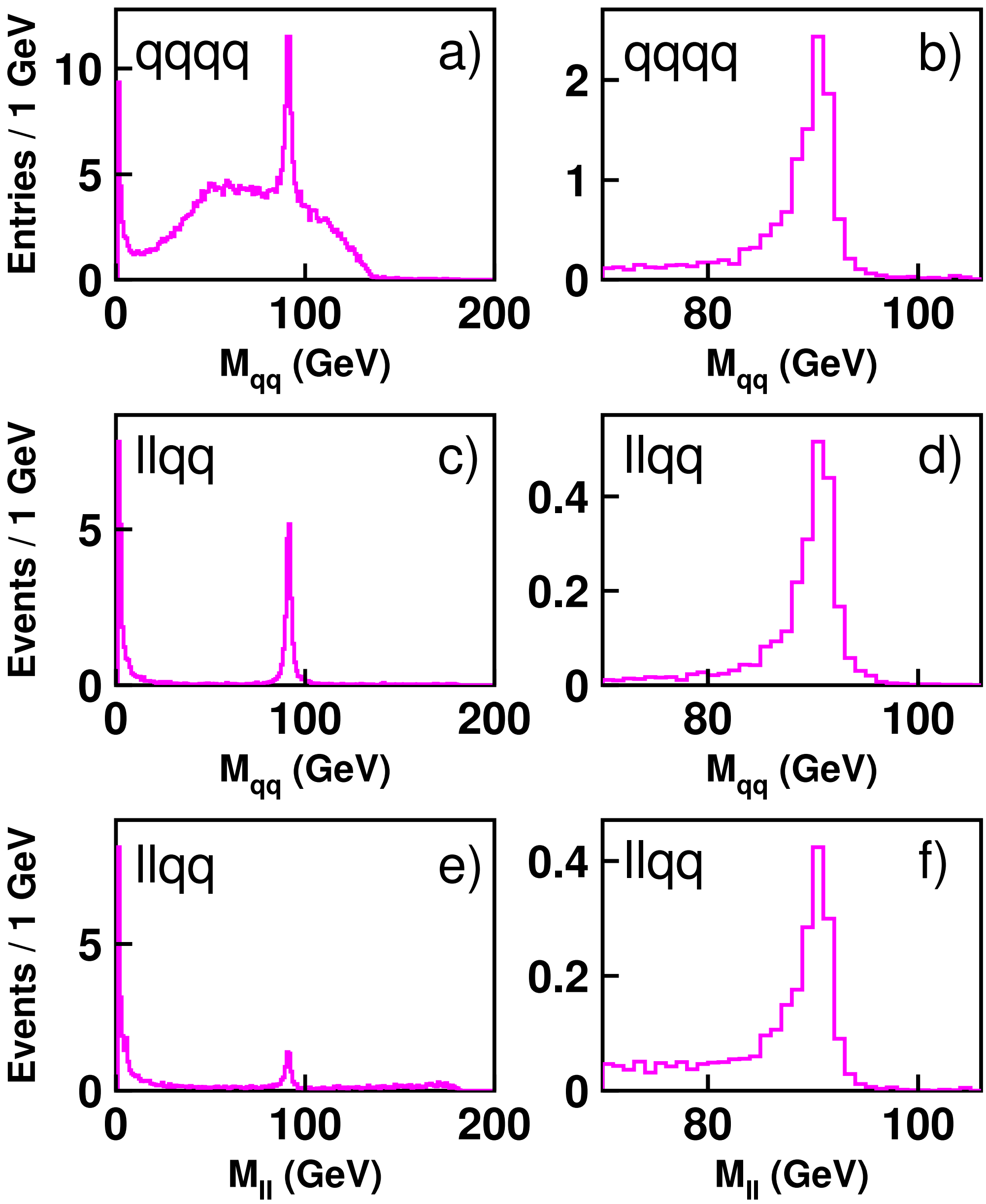
- In case of four equal fermions, $f_i = f_j$, at least one of the two possible pairings must be in the mass range mentioned above.
- In final states with contribution from W exchange (e.g. $u\bar{u}d\bar{d}$ and $\nu_l\bar{\nu}_l l^+ l^-$), the invariant masses M of the pairs susceptible to come from the W must satisfy

$$M \leq 75 \text{ GeV} \qquad \text{or} \qquad M \geq 85 \text{ GeV}$$

- Invariant mass of each combination of outgoing fermions ≥ 1 GeV
- Outgoing electrons must satisfy $|\cos(\theta_e)| \leq 0.95$

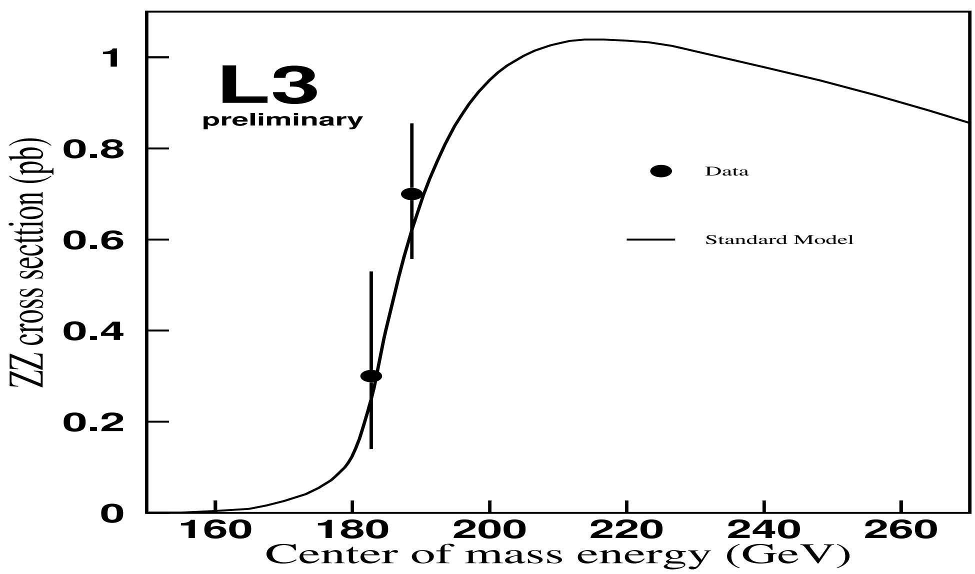
As in L3 internal note # 2333 and Phys. Lett. B 450 (1999) 281–293

Signal generation with EXCALIBUR



Cross section with EXCALIBUR

	σ_{189}/pb	Γ	Γ_{NC02}
$\sum q_i\bar{q}_i q_j\bar{q}_j$	0.317	46.7 %	48.9 %
$\sum q_i\bar{q}_i \nu_j\bar{\nu}_j$	0.179	27.4 %	28.0 %
$\sum q_i\bar{q}_i l_j^+ l_j^-$	0.102	15.7 %	14.1 %
$\sum l_i^+ l_i^- \nu_j\bar{\nu}_j$	0.027	4.4 %	4.0 %
$\sum l_i^+ l_i^- l_j^+ l_j^-$	0.011	1.8 %	1.0 %
$\sum \nu_i\bar{\nu}_i \nu_j\bar{\nu}_j$	0.025	4.0 %	4.0 %
$\sum$ all	0.662	100.0%	100.0%



Comparison EXCALIBUR ↔ GRC4F

EXCALIBUR

- All four-fermion final states included
- Cross section calculation by generating events
- Massless fermions (fast calculation)
- V_{CKM} is diagonal
- calculate only 27 out of 66 final states

GRC4F

- All four-fermion final states included
- Cross section calculation numerically
- Massive fermions (very slow)
- Need to generate events for some final states ($f\bar{f}f\bar{f}$ and contribution from WW)
- calculate all final states

Cross section EXCALIBUR ↔ Grace4f

	$\sigma(\texttt{EXCALIBUR})/\text{pb}$	$\sigma(\texttt{GRC4F})/\text{pb}$	$\Delta = \frac{\lvert a-b\rvert}{(a+b)/2}$
$\sum \mathrm{q_i \bar{q}_i q_j \bar{q}_j}$	0.2895 ± 0.0006	0.2910 ± 0.0010	0.5 %
$\sum \mathrm{q_i \bar{q}_i} \nu_\mathrm{j} \bar{\nu}_\mathrm{j}$	0.1702 ± 0.0003	0.1756 ± 0.0002	3%
$\sum \mathrm{q_i \bar{q}_i l_j^+ l_j^-}$	0.0973 ± 0.0001	0.1011 ± 0.0001	4%
$\sum \mathrm{l_i^+ l_i^-} \nu_\mathrm{j} \bar{\nu}_\mathrm{j}$	0.0271 ± 0.0001	0.0246 ± 0.0001	9%
$\sum \mathrm{l_i^+ l_i^- l_j^+ l_j^-}$	0.0111 ± 0.0002	0.0105 ± 0.0001	5%
$\sum \nu_\mathrm{i} \bar{\nu}_\mathrm{i} \nu_\mathrm{j} \bar{\nu}_\mathrm{j}$	0.0248 ± 0.0001	0.0247 ± 0.0001	0.4%
$\sum$ all	0.6200 ± 0.0007	0.6270 ± 0.0010	1.0%

Different parameters as in previous calculations

Branching ratio EXCALIBUR $\leftrightarrow$ GRC4F

	$\mathrm{q\bar{q}q\bar{q}}$	$\mathrm{q\bar{q}}\nu\bar{\nu}$	$\mathrm{q\bar{q}l^+l^-}$	$\mathrm{l^+l^-}\nu\bar{\nu}$	$\mathrm{l^+l^-l^+l^-}$	$\nu\bar{\nu}\nu\bar{\nu}$
EXCALIBUR	46.7%	27.4%	15.7%	4.4%	1.8%	4.0%
GRC4F	46.4%	28.0%	16.0%	3.9%	1.7%	4.0%