Fermion Pair Production at LEPII And Limits on New Physics Processes

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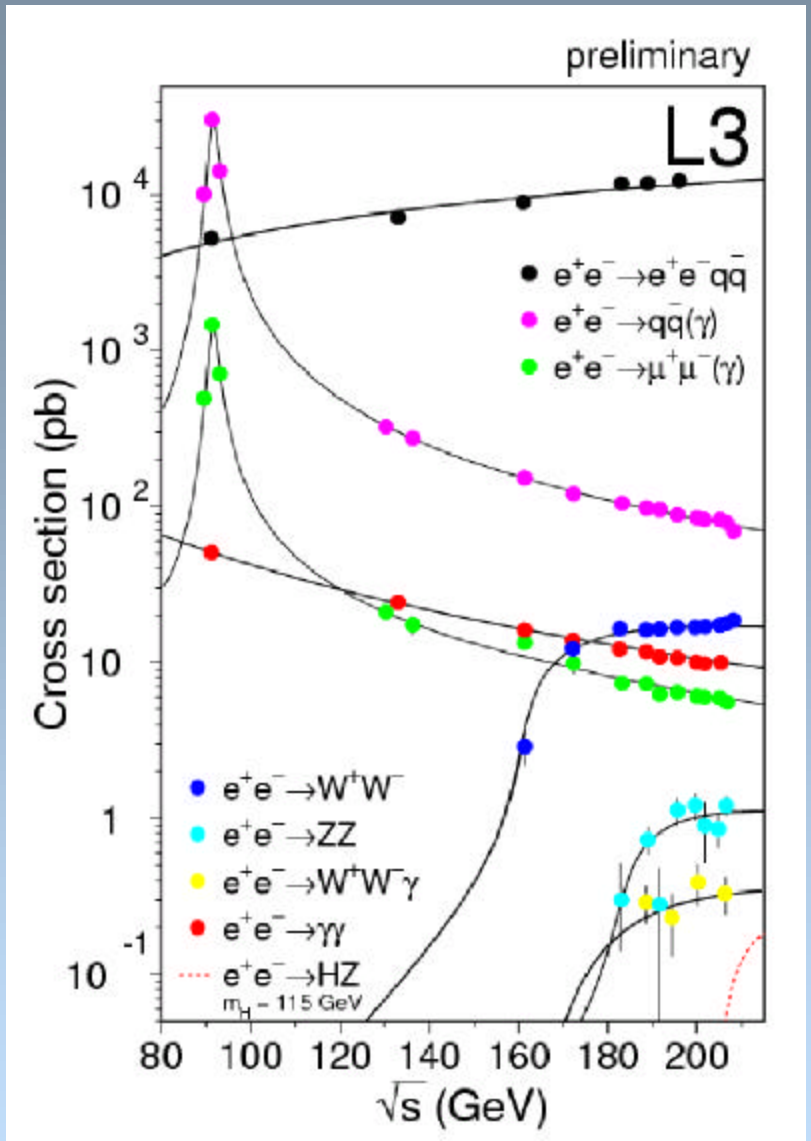
On behalf of the L3 collaboration

Outline

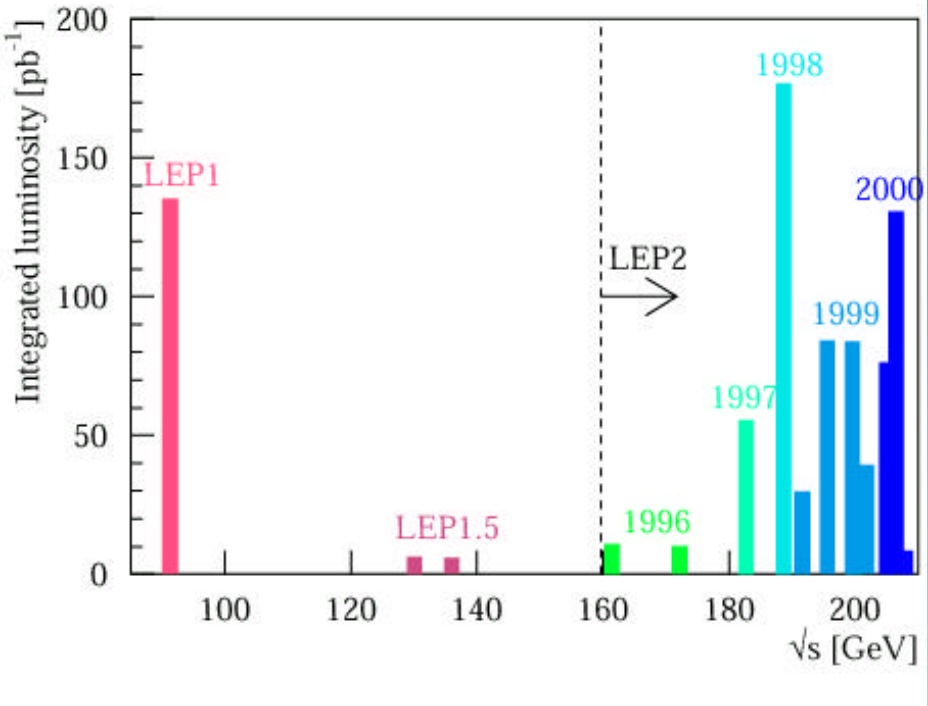
- Introduction on the LEPII program
- Measurements of fermion pair cross sections and leptonic forward-backward asymmetries
  - $e^+e^- \Rightarrow$ hadrons
  - $e^+e^- \Rightarrow e^+e^-$
  - $e^+e^- \Rightarrow \mu^+\mu^-$
  - $e^+e^- \Rightarrow \tau^+\tau^-$
- Interpretation of the results in terms of limits on New Physics processes

LEP2: $\sqrt{s} > M_Z$

- Standard Model cross sections for $e^+e^- \Rightarrow ff$ drop significantly above Z peak
- Sensitivity to New Physics processes increases
- WW and ZZ thresholds are passed: new backgrounds
- Radiative corrections are important



Achieved Integrated Luminosities



LEP2:
Ös > M_Z

- LEP performed very well in its final years: over 700 pb^{-1} were collected per experiment (design goal for LEPII: 500 pb^{-1} / experiment)
- Center-of-mass energies between 161 GeV and 208.8 GeV

$\sqrt{s} > M_Z$: Hard Initial State Radiation

- Initial state photons are mostly colinear to the beam particles
- Photons escape undetected in the beam pipe
- Effective centre-of-mass energy important variable for both signal definition and selection procedures.

Reconstruction of $\sqrt{s'}$ using the polar angles or with a kinematic fit.

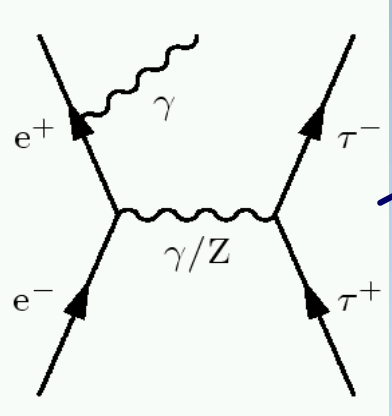
$\sqrt{s} > M_Z$:Radiative returns to the Z

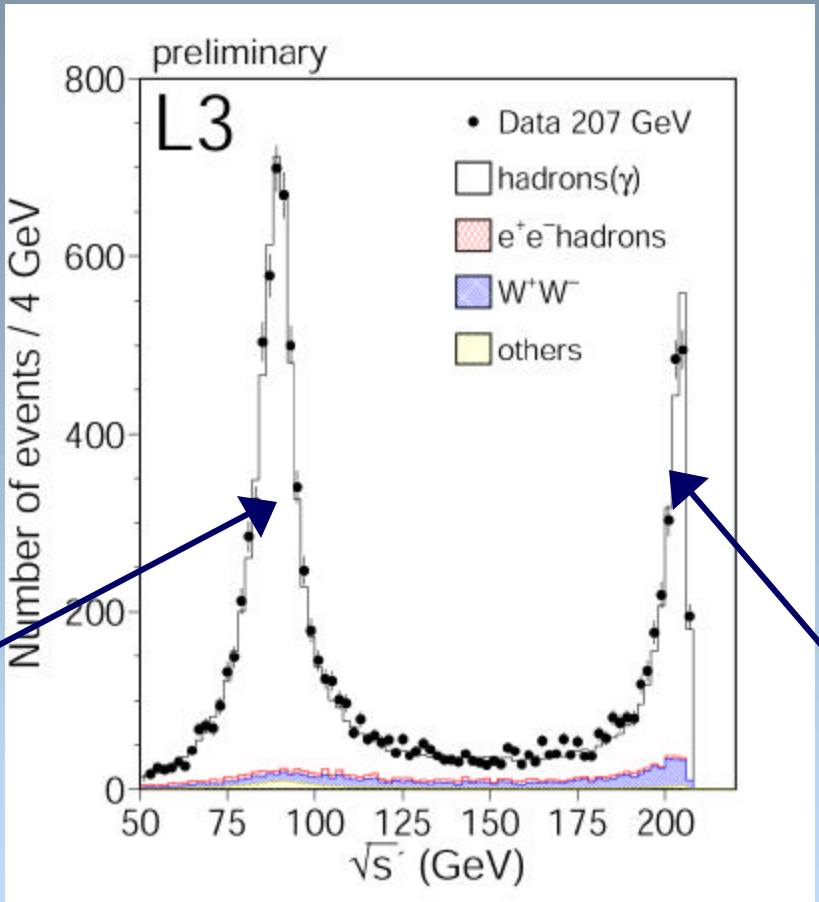
$e^+e^- \Rightarrow$ hadrons:
$\sqrt{s'} >$ 80 GeV

$e^+e^- \Rightarrow \mu^+\mu^-, \tau^+\tau^-$:
$\sqrt{s'} >$ 75 GeV

$e^+e^- \Rightarrow e^+e^-$:

$\zeta < 25^o$

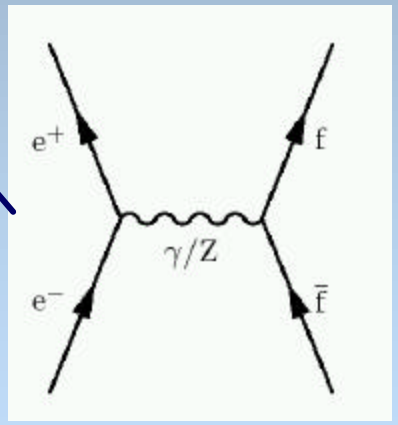




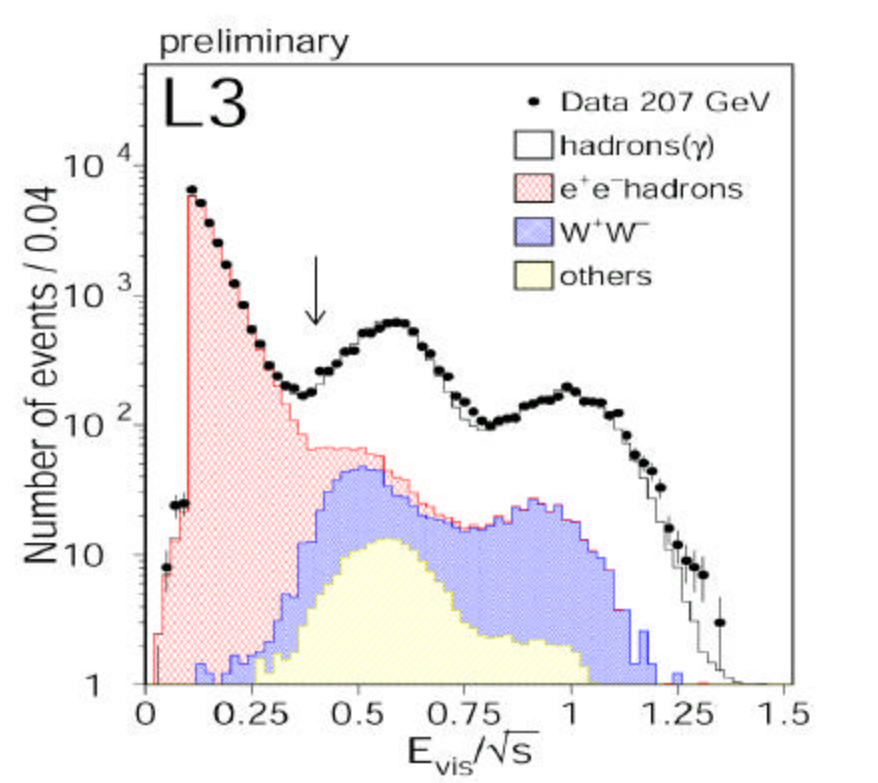
$e^+e^- \Rightarrow$ hadrons,
$e^+e^- \Rightarrow \mu^+\mu^-$,
$\tau^+\tau^-$:
$\sqrt{s'} >$ 0.85 $\sqrt{s}$

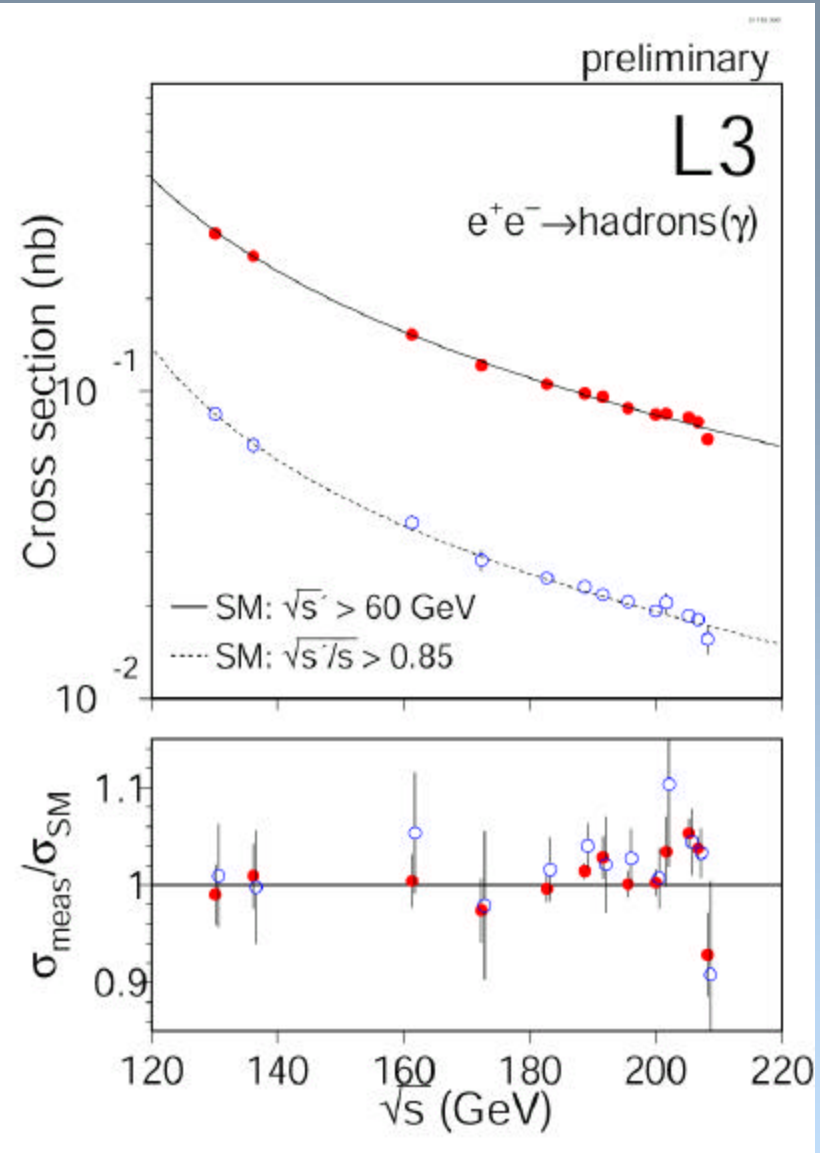
$e^+e^- \Rightarrow e^+e^-$:

$\zeta < 120^o$

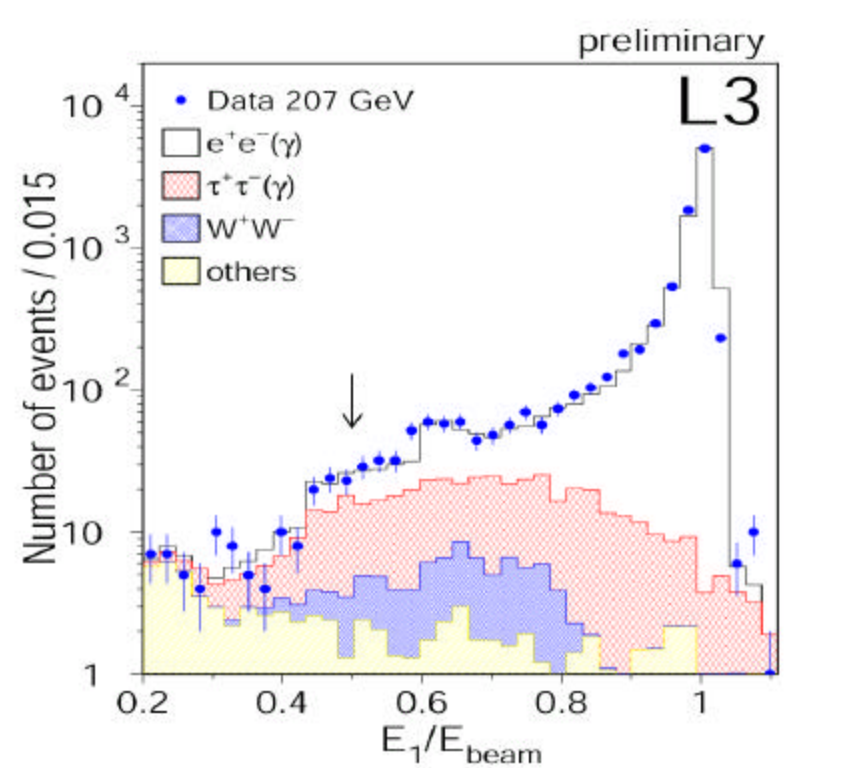


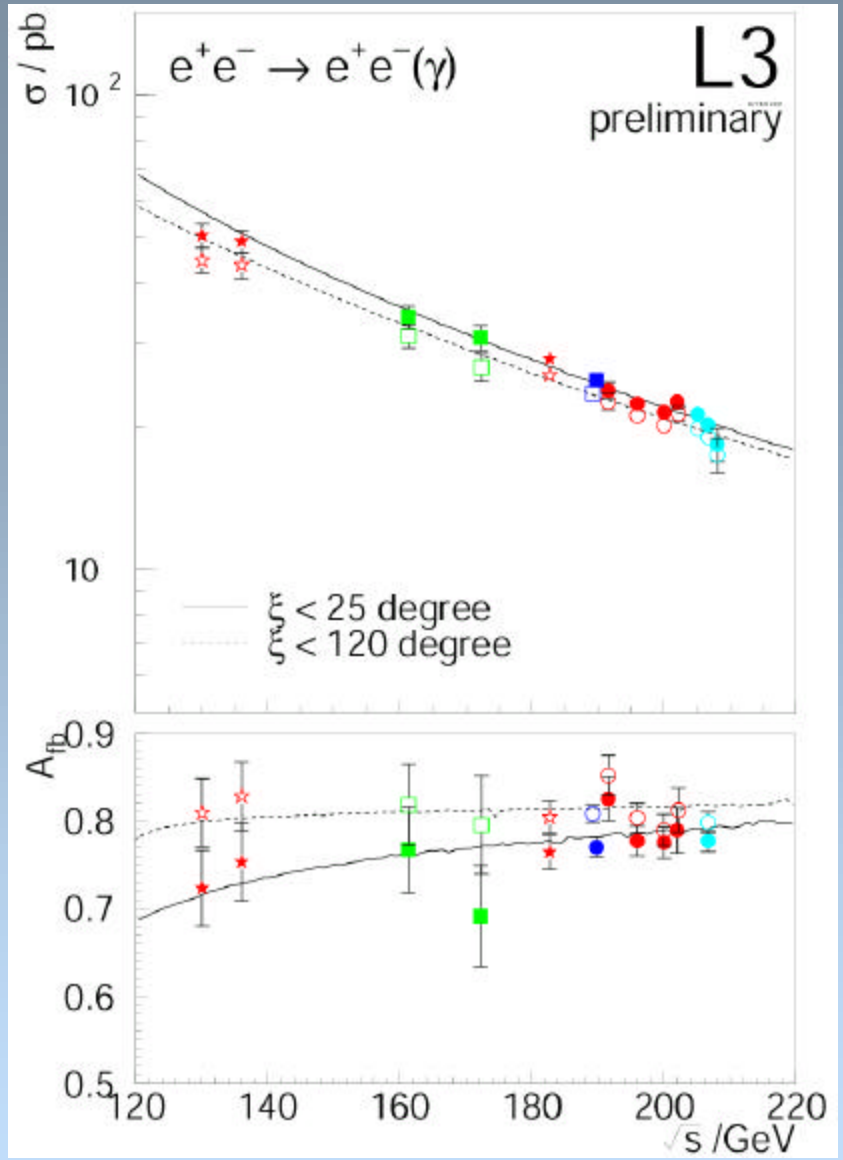
Cross section results for $e^+e^- \Rightarrow$ hadrons





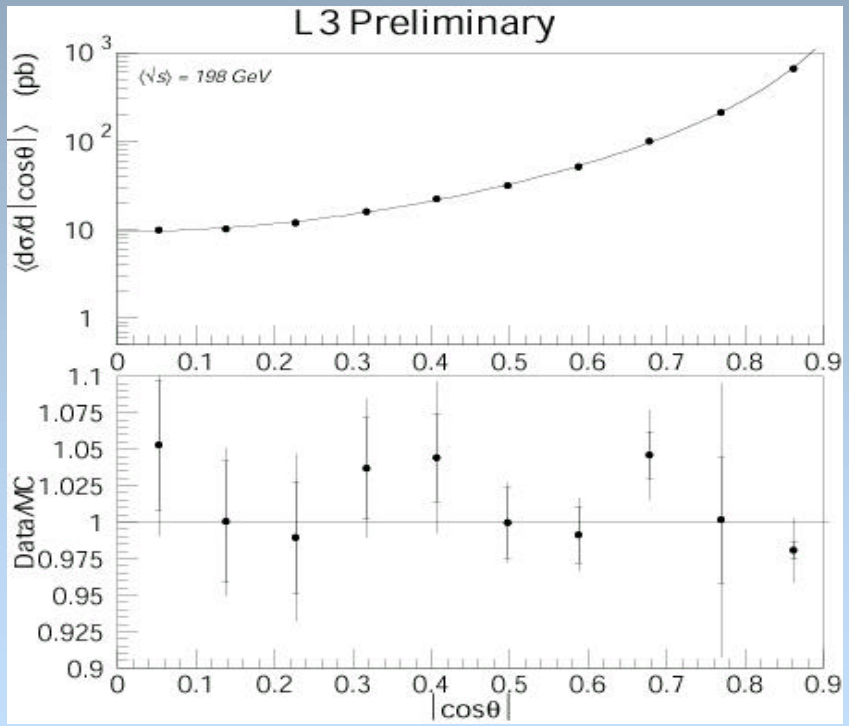
Cross section and asymmetry results for Bhabha scattering

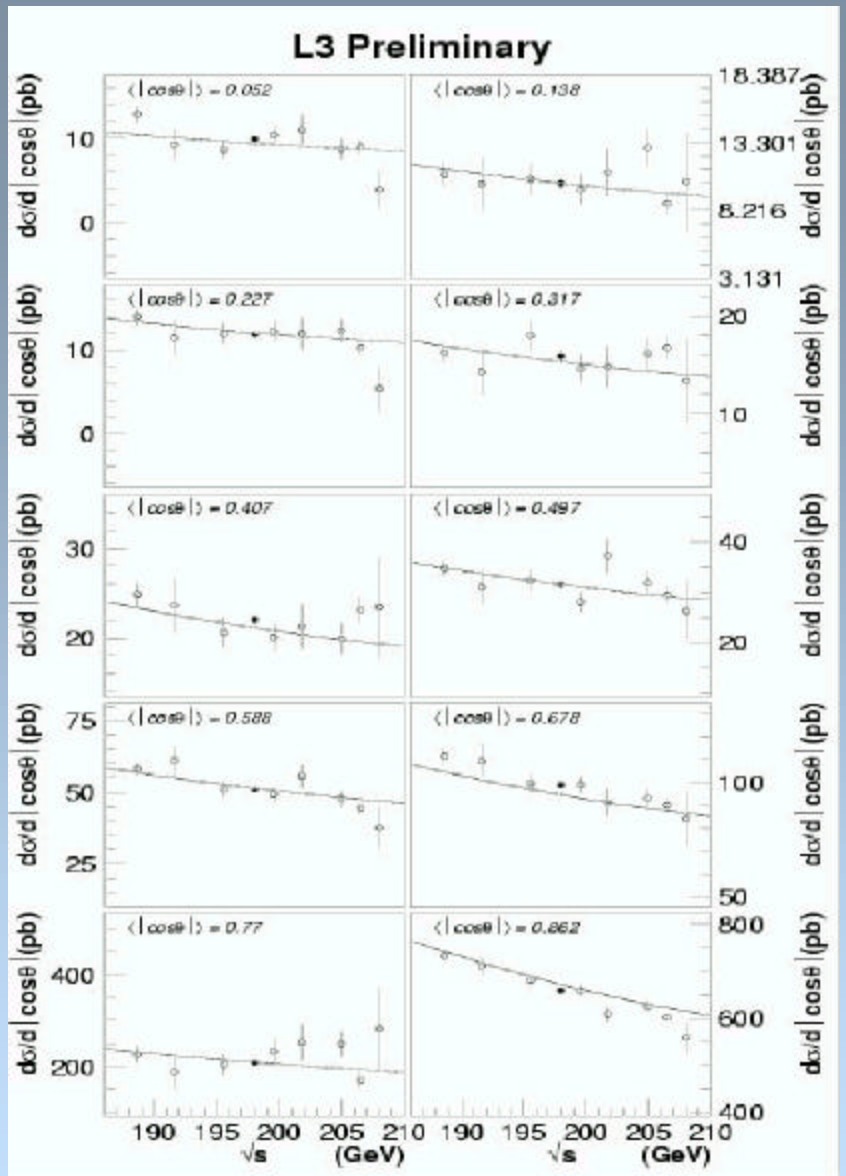




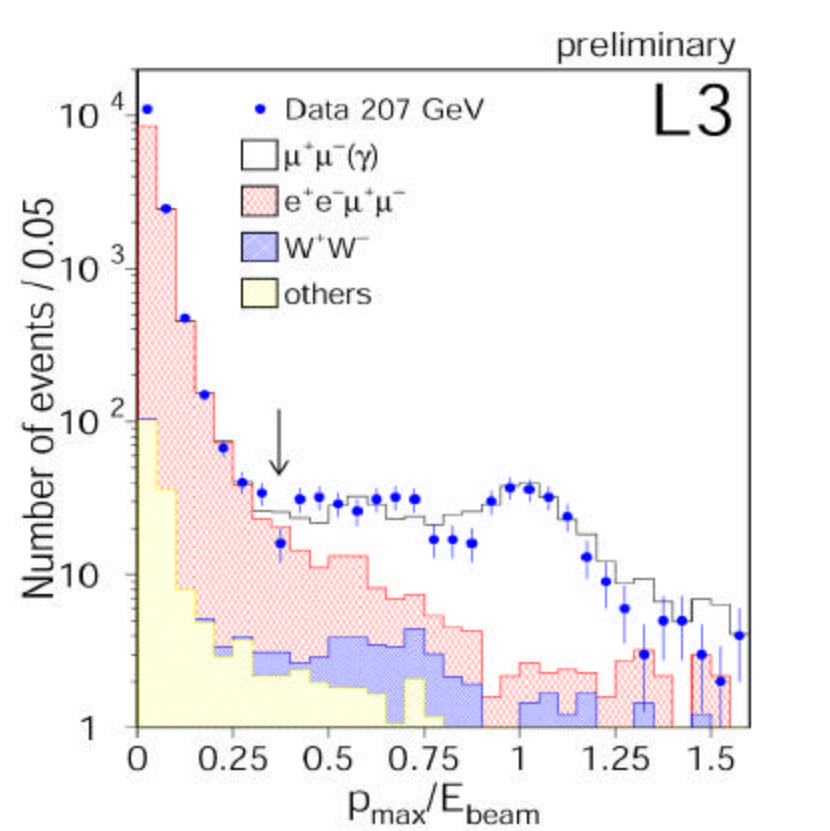
Differential cross sections for Bhabha scattering

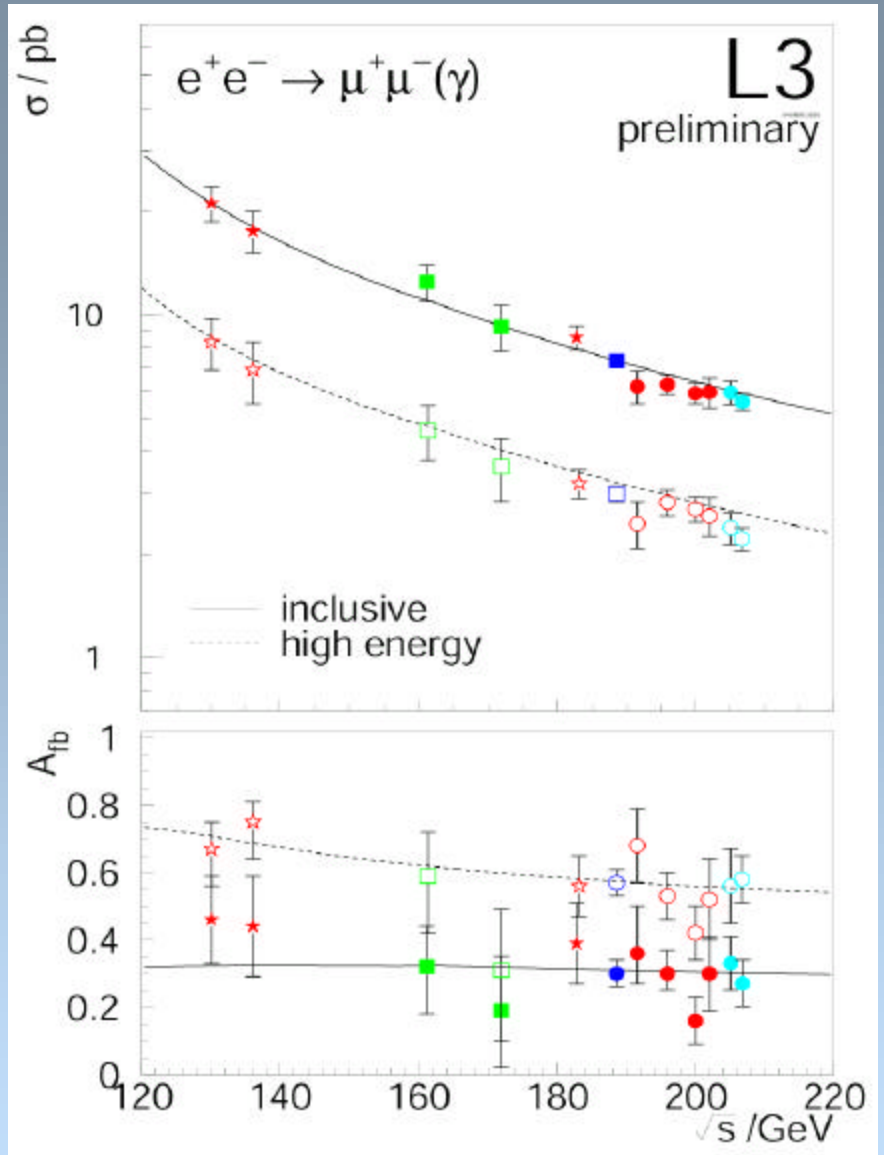
For each bin average cross section is computed, taking into account the energy dependence



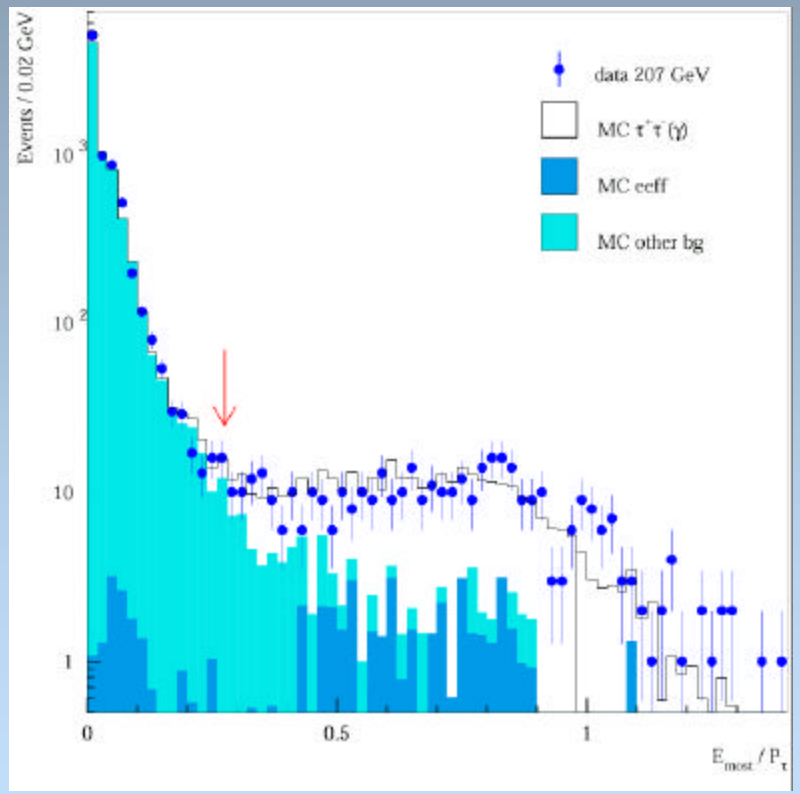


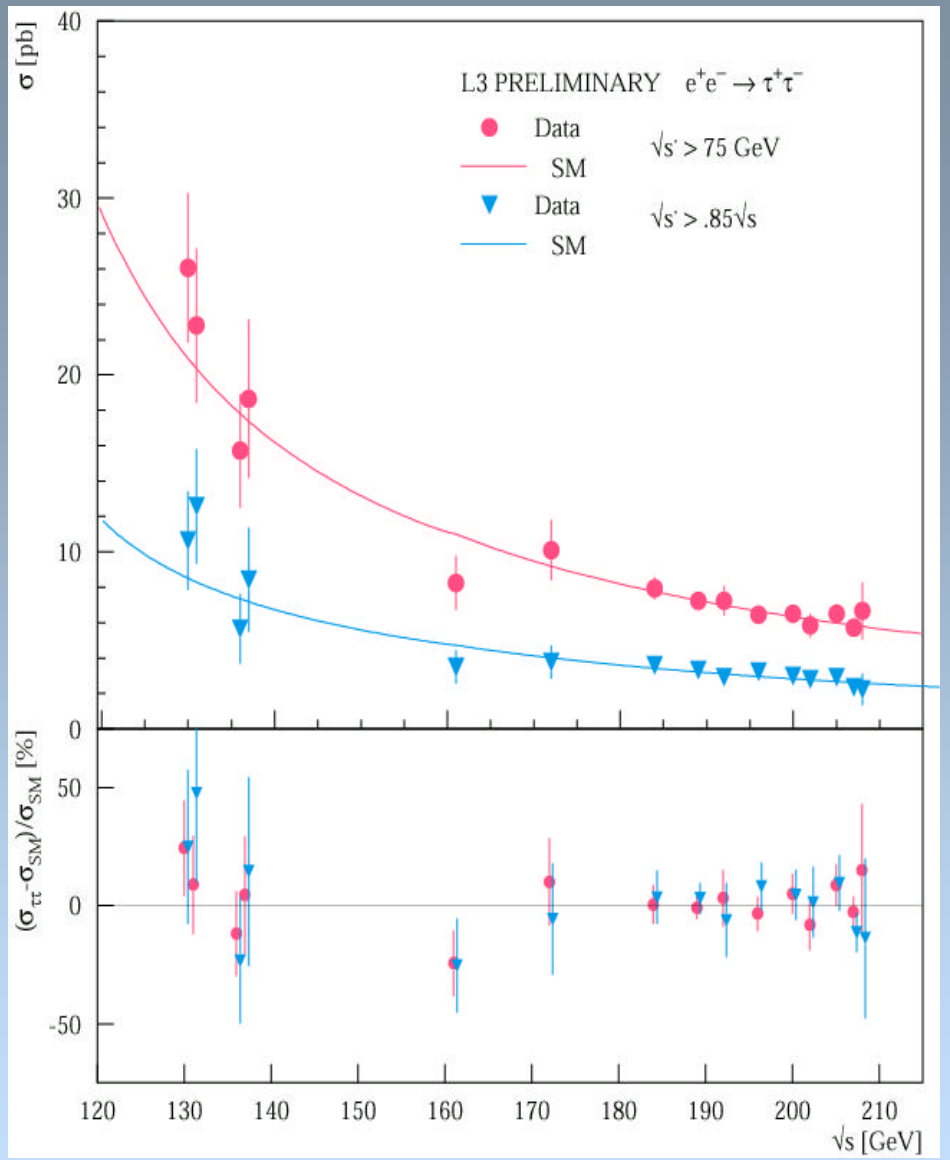
Differential cross sections for Bhabha scattering





Cross section results for $e^+e^- \Rightarrow \tau^+\tau^-$

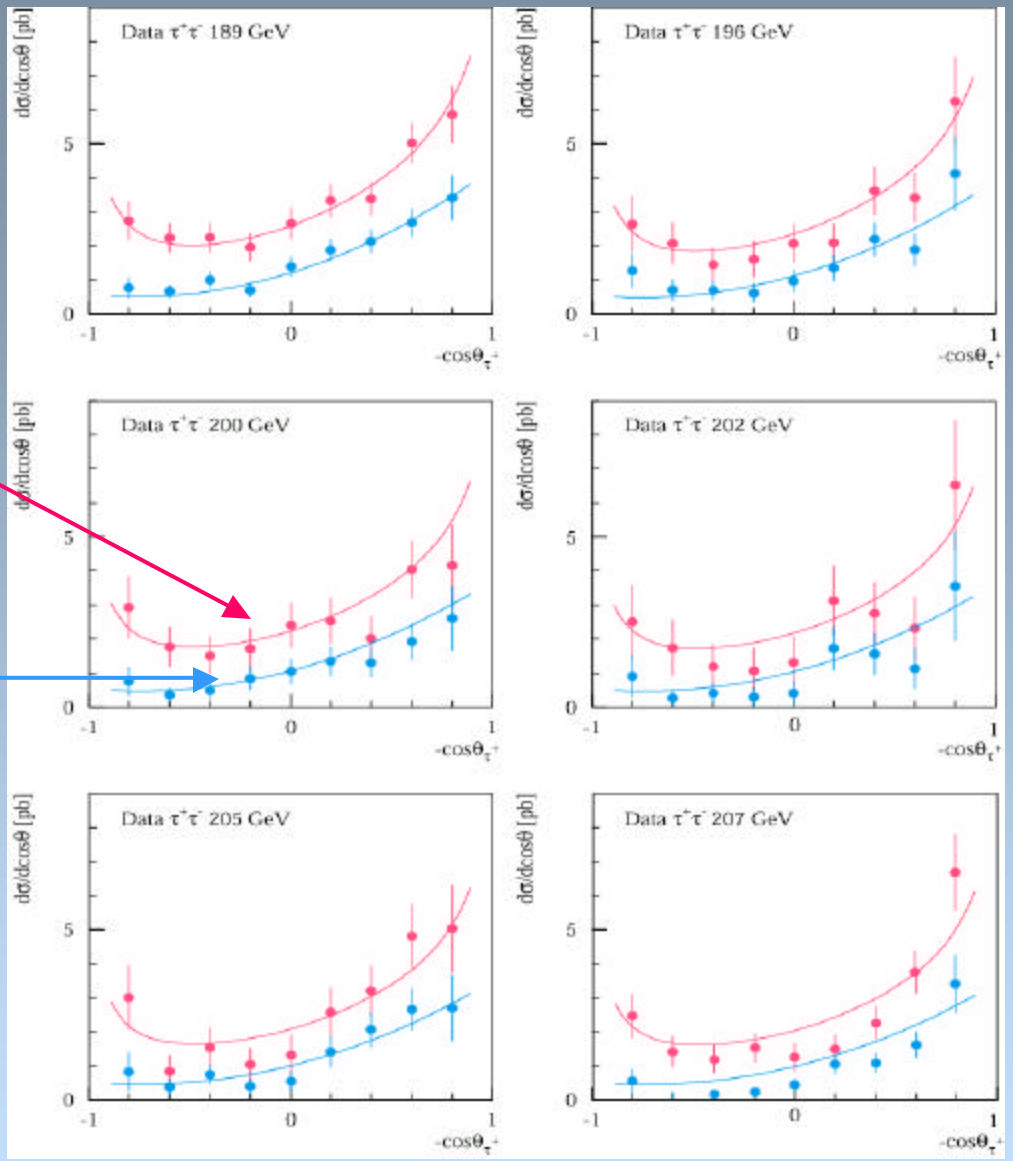




Differential cross sections for $e^+e^- \Rightarrow \tau^+\tau^-$

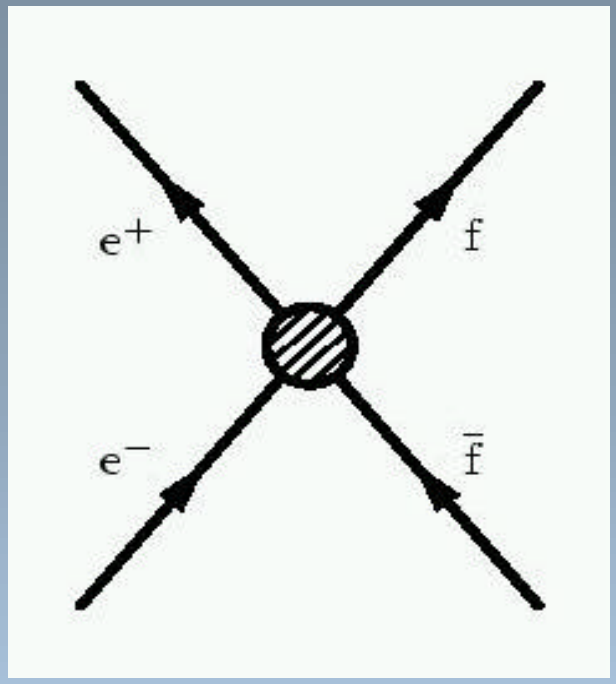
Non-radiative sample

Inclusive sample



Contact interactions

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



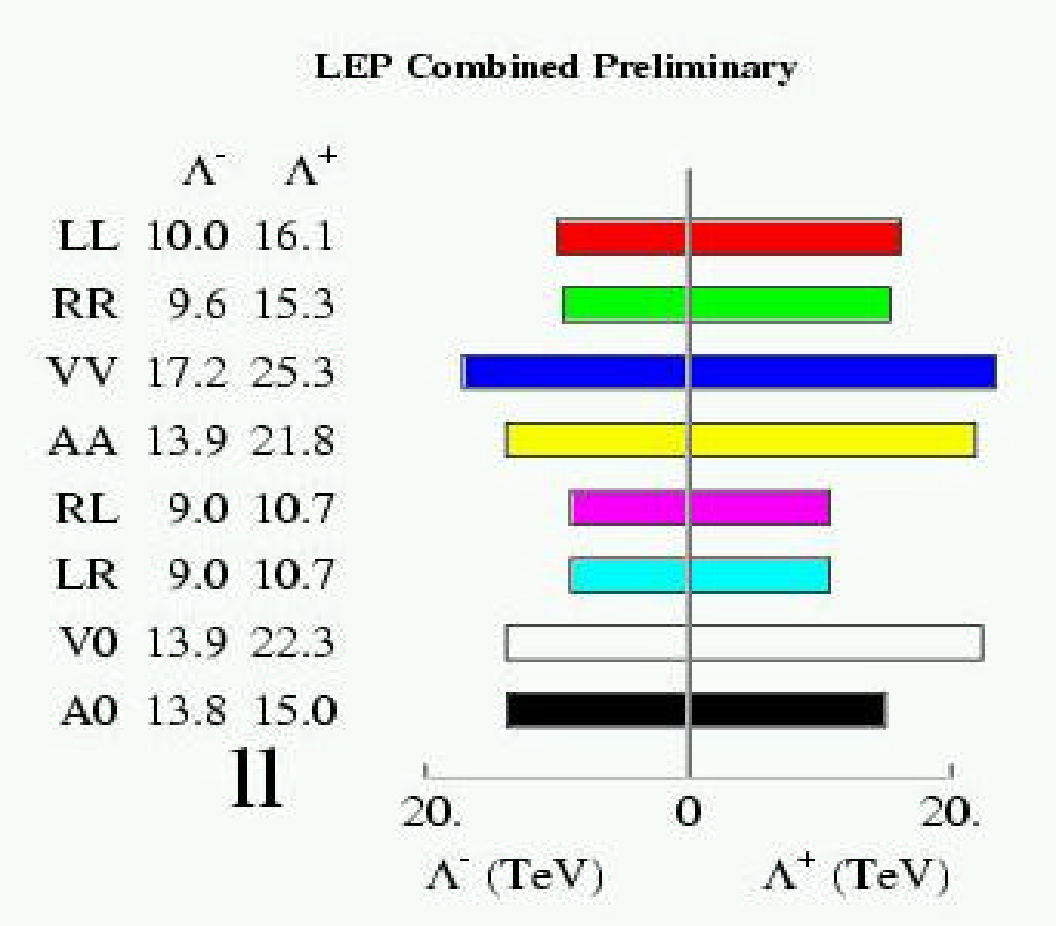
- G = Coupling, fixed to g = 4π
- η_{ij} = helicity amplitudes, $|\eta_{ij}| = 0,1$
- Λ = energy scale

Standard Model **New Physics**

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

Interference

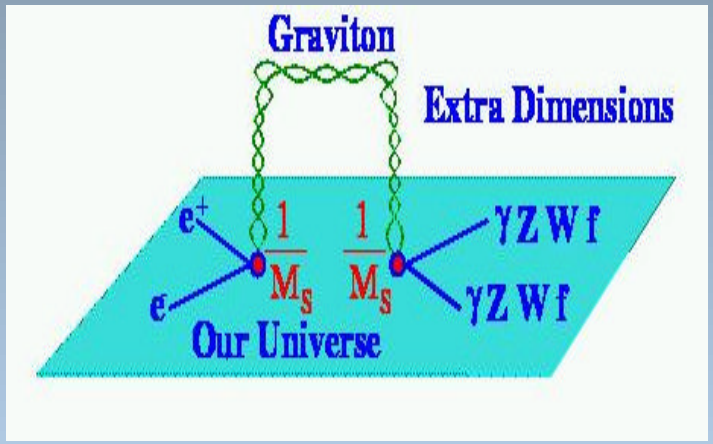
Limits on Contact Interactions for $e^+e^- \Rightarrow l^+l^-$ (assuming universality between μ and τ)



Indirect Searches for extra dimensions

- Model proposed to overcome the hierarchy problem:
  Relative weakness of the gravitational force, or the large scale M_{PL}

Gravity travels in a (compactified) higher dimensional world



Standard Model particles are confined to the normal 3+1 dimensional world

The quantum gravity scale M_S in N dimensions is related to the large Planck mass in the 4-dimensional world:

- $M_{PL}^2 \approx R^\delta M_S^{2+\delta}$
- δ = N-4 number of extra dimensions
- δR = size of the extra dimensions

Limits on extra dimensions from Bhabha measurements

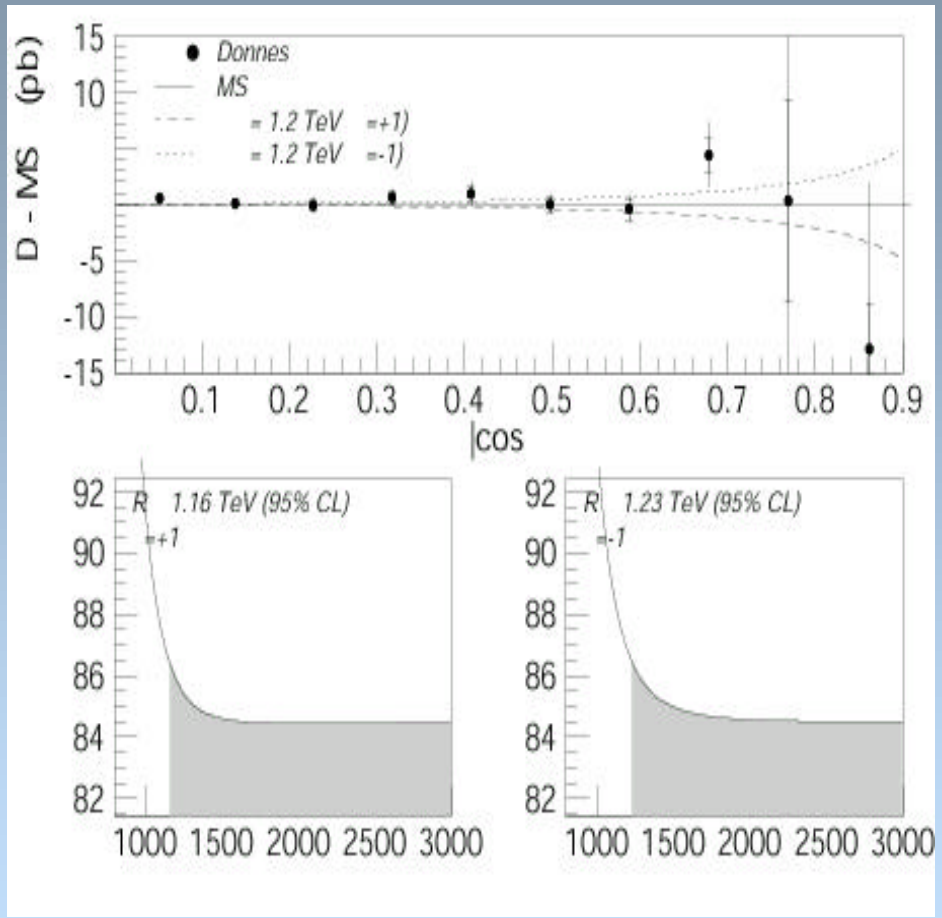
Bhabha channel is most sensitive for quantum gravity effects due to t-channel contributions

- Direct gravity effects are of order λ^2/M_S^8
- Interference contributions are of order λ/M_S^4
- λ is fixed to +/- 1

Limits:

M_S > 1.16 TeV for λ = + 1

M_S > 1.23 TeV for λ = - 1



Fermion sizes

Finite size of fermions introduces a correction to the differential cross sections, which can be described by form factors:

$$\frac{d\sigma}{dq^2} = \left(\frac{d\sigma}{dq^2}\right)_{SM} F_e^2(q^2) F_f^2(q^2)$$

Assuming a Dirac form factor:

$$F(q^2) = 1 + \frac{1}{6} q^2 R^2$$

Gives limits on the radius of the fermions:

$e^+e^- \Rightarrow$ hadrons	$3.0 \cdot 10^{-19}$ m
$e^+e^- \Rightarrow e^+e^-$	$3.1 \cdot 10^{-19}$ m
$e^+e^- \Rightarrow \mu^+\mu^-$	$2.4 \cdot 10^{-19}$ m
$e^+e^- \Rightarrow \mu^+\mu^-$	$4.0 \cdot 10^{-19}$ m
$e^+e^- \Rightarrow l^+l^-$	$2.2 \cdot 10^{-19}$ m

Conclusions

- Precise measurements of cross sections and asymmetries of leptons pairs at 13 energy points above the Z-peak
- Measurements are in good agreement with the Standard Model predictions
- Measurements have been used to set limits on:
  - Contact Interactions: Λ >10-20 TeV
  - Fermion sizes: leptons < $2.2 \cdot 10^{-19}$m , quarks < $3.0 \cdot 10^{-19}$ m
  - Quantum Gravity: $M_S > 1.2$ TeV