Search for physics beyond the Standard Model at LEP 2

Theodora D. Papadopoulou

NTU Athens

DESY Seminar 28/10/03

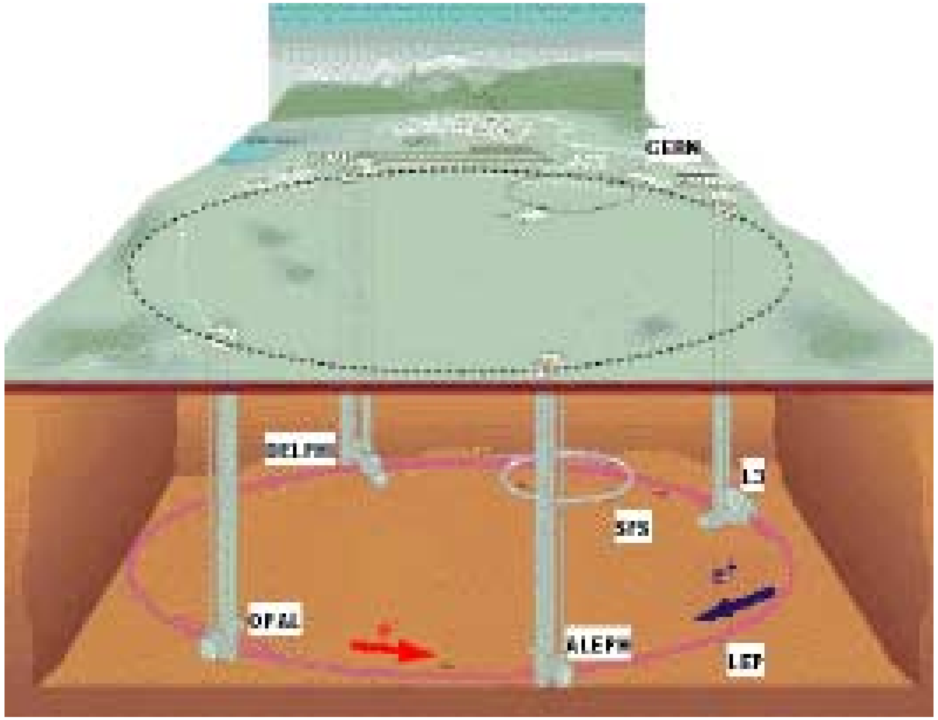
Outline

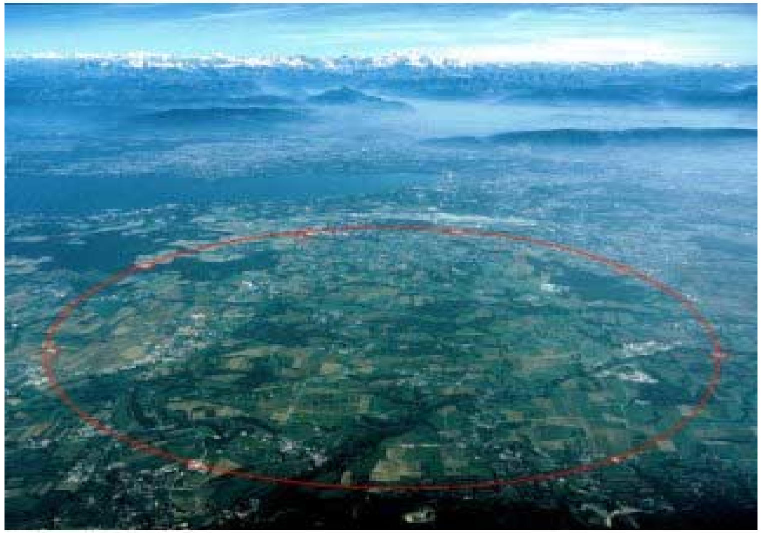
- **Introduction about LEP**
- **Alternatives to the Higgs mechanism**
- **Technicolor**
- **Contact Interactions**
- **Leptoquarks**
- **R-parity Violation**
- **Extra Dimensions**
- **Conclusion**
- **As an Epilogue**

$e^+ e^-$ Collider at CERN

12 years of data collection

with excellent performance !





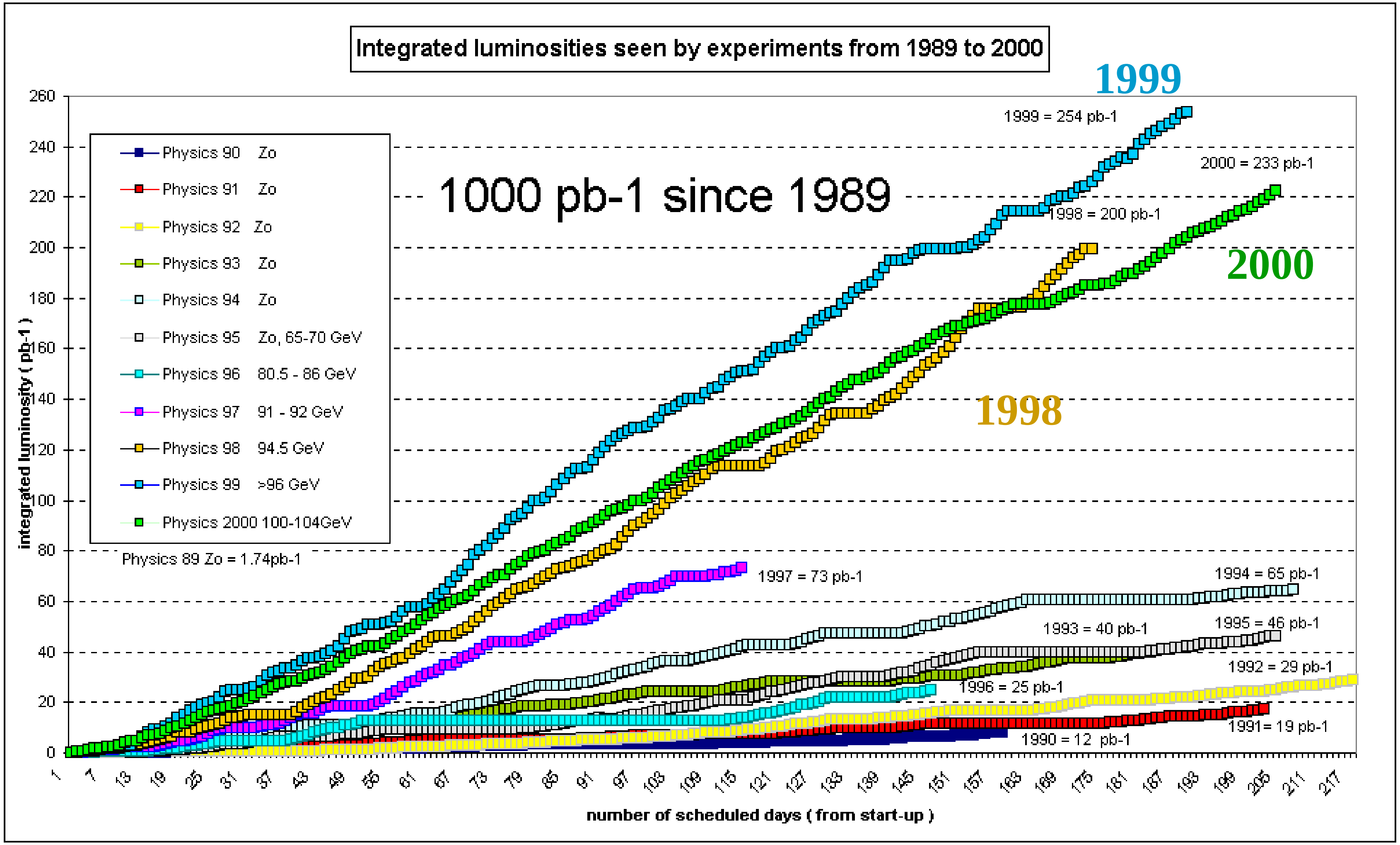
$$\sqrt{s} \approx 91\,GeV\ (1989-1995)$$

$$\sqrt{s} \approx 130-136\,GeV\ (1995)$$

$$\sqrt{s} \approx 161-209\,GeV\ (1996-2000)$$

•ALEPH, DELPHI, L3, OPAL

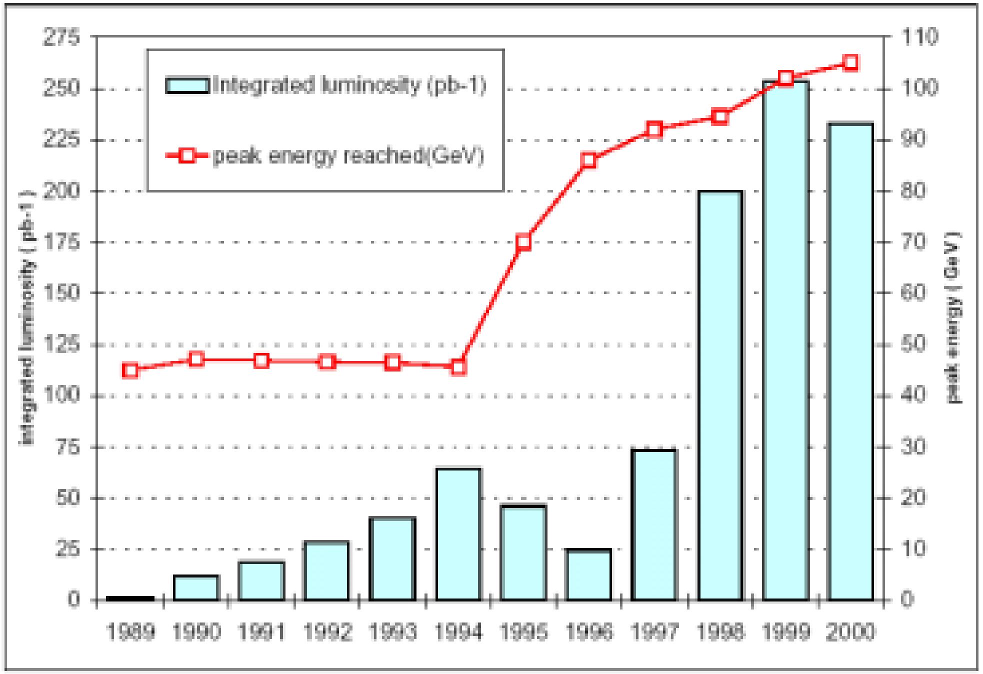
L E P Performance



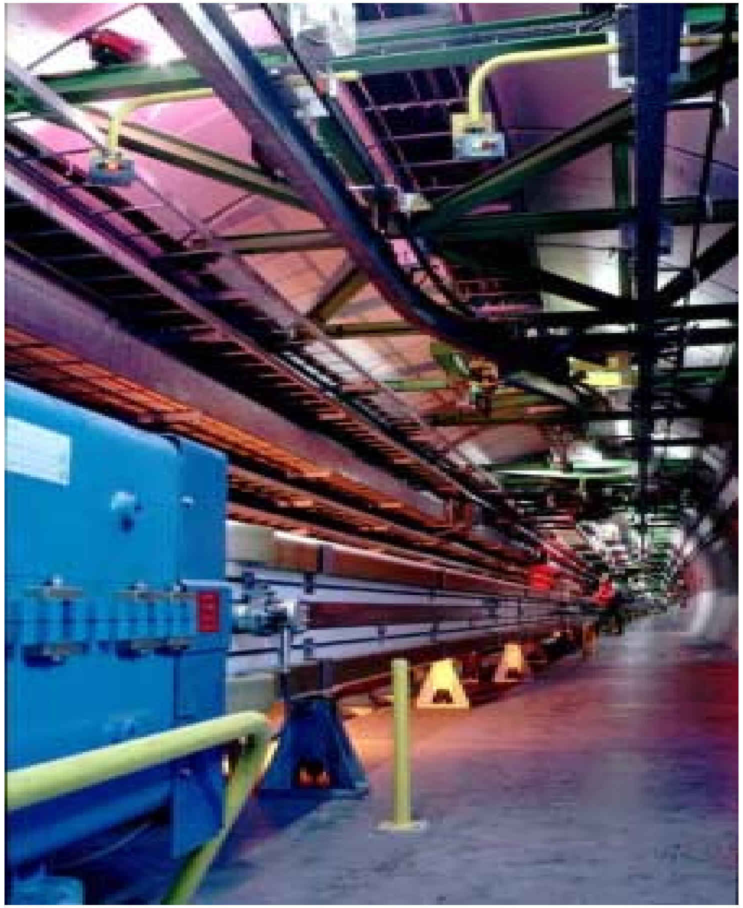
The updates and combinations of the final results are at the last stage

LEP Working Groups : for combination of measurements

L E P   Performance



Integrated luminosities in pb^{-1}					
	ALEPH	DELPHI	L3	OPAL	LEP
$\sqrt{s} \geq 189$ GeV	629	608	627	596	2461
$\sqrt{s} \geq 206$ GeV	130	138	139	129	536
$\sqrt{s} \geq 208$ GeV	7.5	8.8	8.3	7.9	32.5



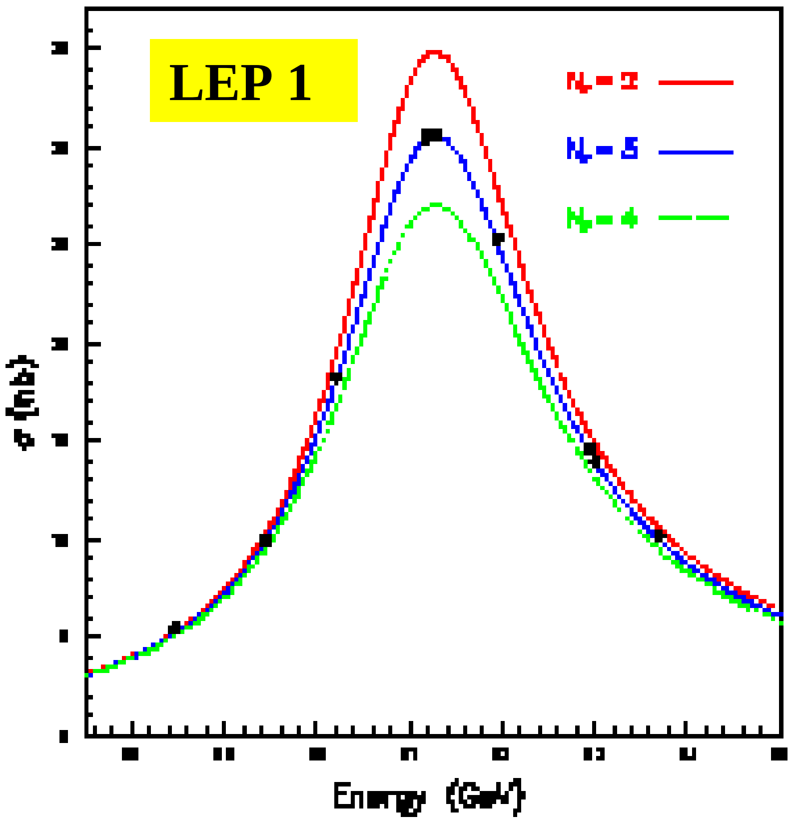
LEP 2 : E_{cm} = 161 – 209 GeV

Total int. Lum ~ 2.5 fb^{-1} (ADLO)

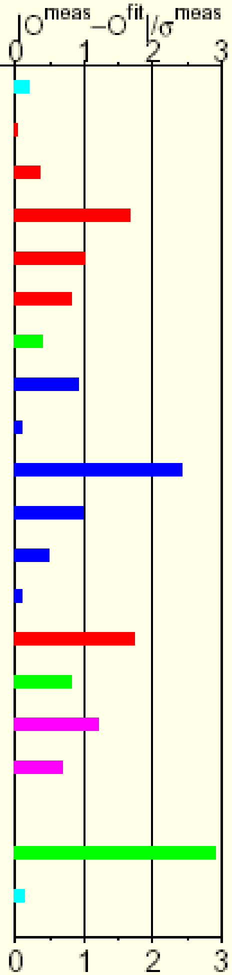
L E P   Physics

- **High precision extensive tests of the SM have been achieved to ~ 0.1 %**

$N_\nu = 2.9841 \pm 0.0088$

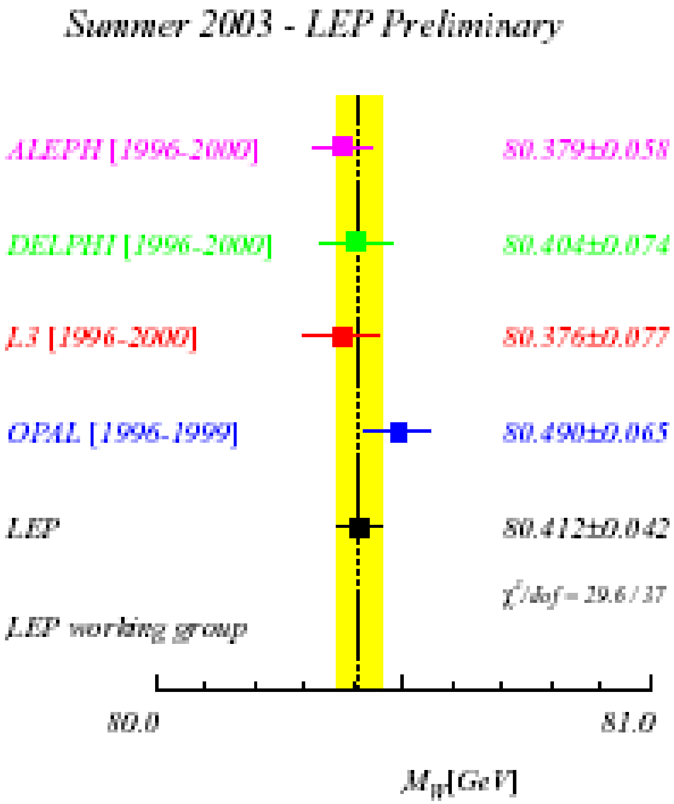


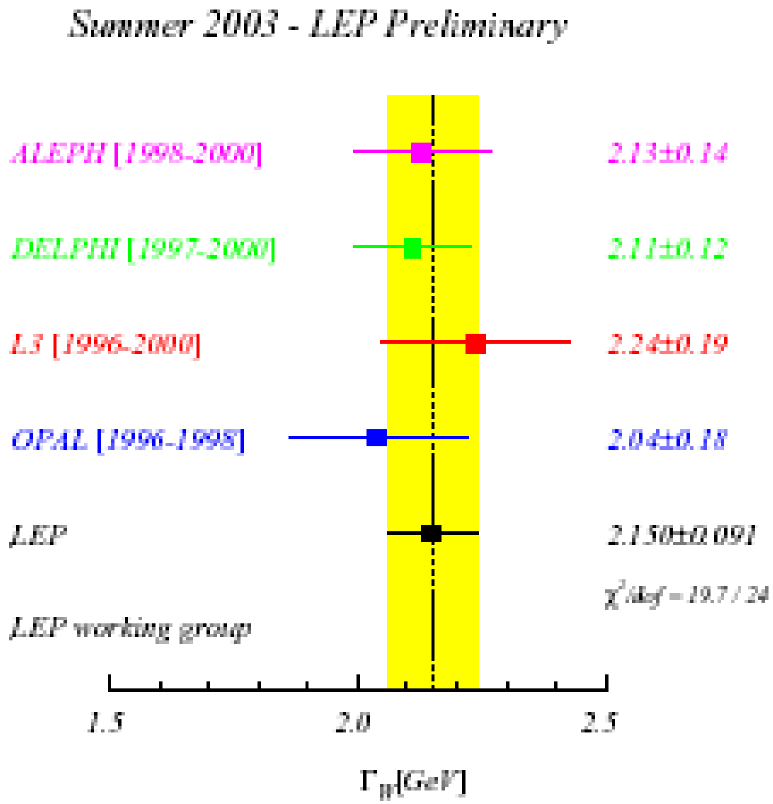
	Measurement	Fit
$\Delta\alpha^{(5)}_{had}(m_Z)$	0.02761 ± 0.00036	0.02767
m_Z [GeV]	91.1875 ± 0.0021	91.1875
Γ_Z [GeV]	2.4952 ± 0.0023	2.4960
σ^0_{had} [nb]	41.540 ± 0.037	41.478
R_l	20.767 ± 0.025	20.742
$A^{0,l}_{fb}$	0.01714 ± 0.00095	0.01636
$A_l(P_\tau)$	0.1465 ± 0.0032	0.1477
R_b	0.21638 ± 0.00066	0.21579
R_c	0.1720 ± 0.0030	0.1723
$A^{0,b}_{fb}$	0.0997 ± 0.0016	0.1036
$A^{0,c}_{fb}$	0.0706 ± 0.0035	0.0740
A_b	0.925 ± 0.020	0.935
A_c	0.670 ± 0.026	0.668
A_l(SLD)	0.1513 ± 0.0021	0.1477
$\sin^2\theta^{lept}_{eff}(Q_{fb})$	0.2324 ± 0.0012	0.2314
m_W [GeV]	80.426 ± 0.034	80.385
Γ_W [GeV]	2.139 ± 0.069	2.093
m_t [GeV]	174.3 ± 5.1	174.3
$\sin^2\theta_W(\nu N)$	0.2277 ± 0.0016	0.2229
Q_W(Cs)	-72.84 ± 0.46	-72.90



Summer 2003

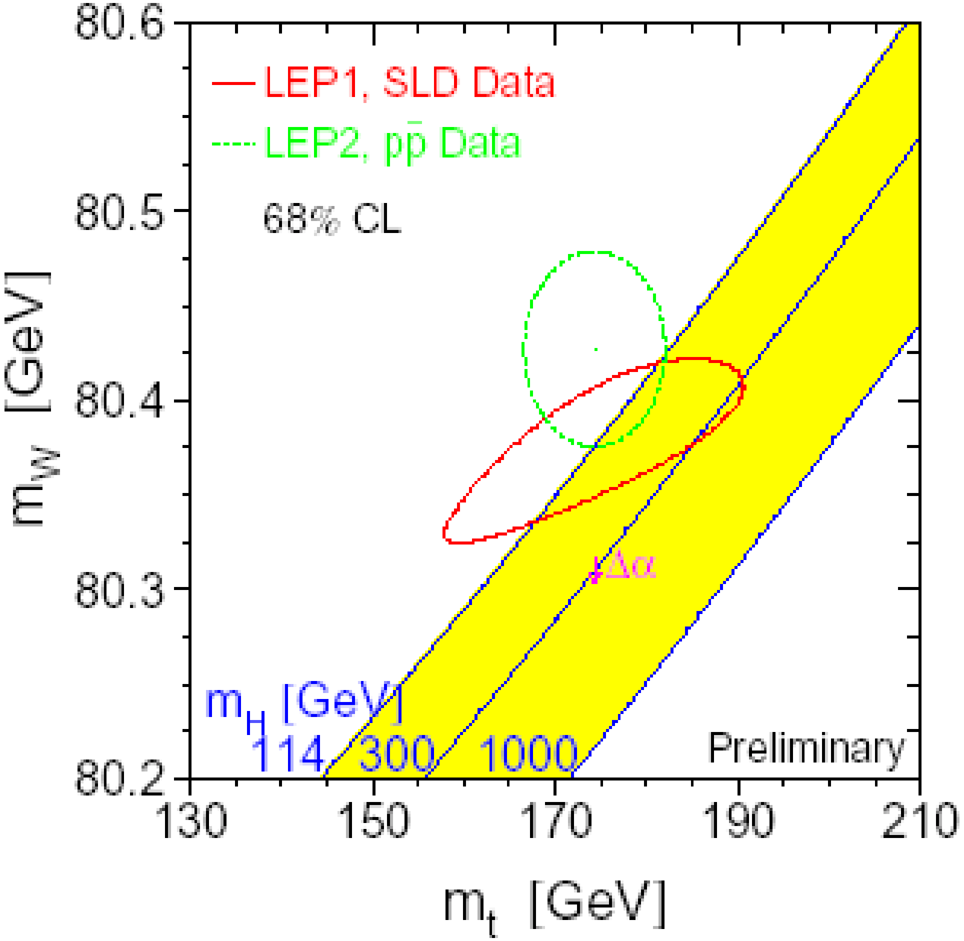
LEP Combined m_W and Γ_W results





m_W (LEP) = 80.412 $\pm$ 0.029 (stat) $\pm$ 0.031 (sys) GeV

Γ_W (LEP) = 2.150 $\pm$ 0.068 (stat) $\pm$ 0.060 (sys) GeV

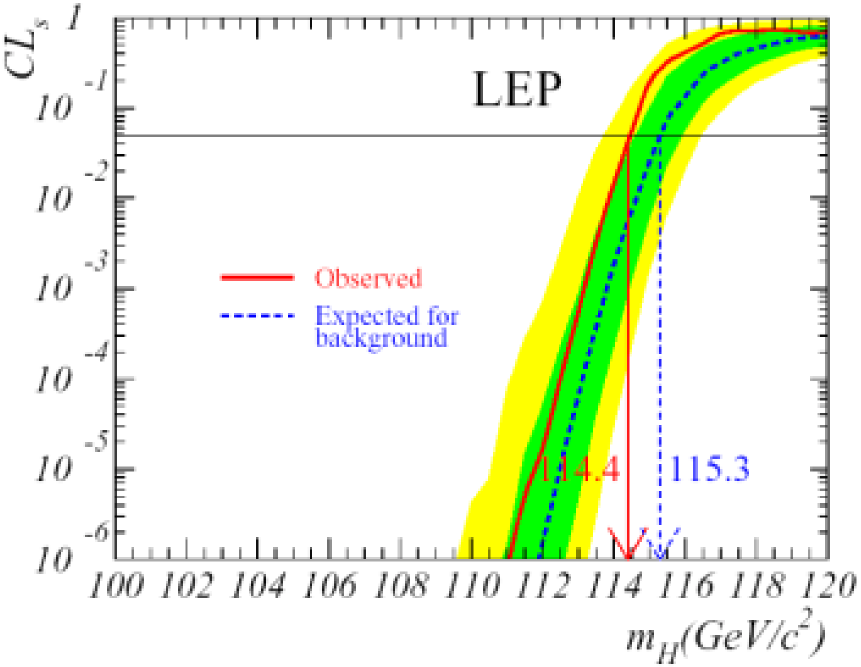


SM consistency

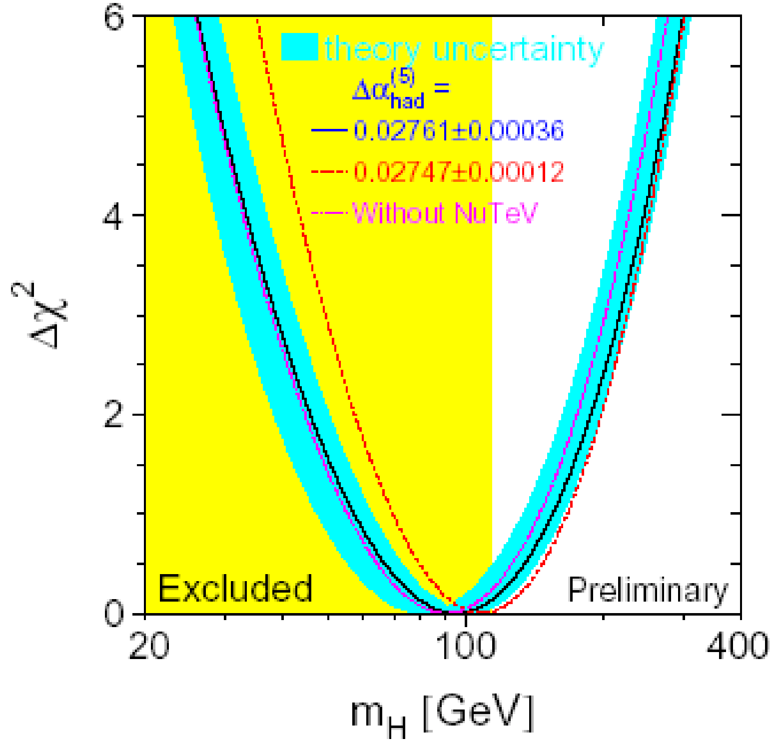
between direct measurements and predictions from radiative corrections.

Low Higgs mass preference.

Direct vs. Indirect results



Electroweak fit



LEP final results for SM Higgs :

$m_H > 114.4$ GeV at 95 % CL

Higgs limit :

$m_H < 219$ GeV at 95 % CL

Important LEP legacy !

Higgs mechanism & alternatives

- **Elementary Higgs – Spontaneous Symmetry Breaking**
  - **SM Higgs (1 Higgs doublet)**
  - **MSSM Higgs , 2HDM (2 Higgs doublets)**

    ex: Search for Fermiophobic Higgs
  - **other models**
- **Dynamical Symmetry Breaking**

  (Compositeness)
  - **Technicolor**
  - **Chiral Color Theories (High Color scenario)**

    ex: Search for Axigluons

Physics beyond SM

- **Experimental results ?**

Fermiophobic Higgs

2HDM – Model : 2 – Higgs – doublet

Type 1 – Model : One doublet couples to fermions, the other to bosons

2 CP even neutral Higgs bosons : h (light) , H (Heavy)

- **mixes with scalar field with angle α**
- **coupling to fermions is cos(α) for h & sin(α) for H**

Therefore ⇒ h is fermiophobic in the limit $\alpha \to \pi / 2$

We search for the light h :

- **h Z with h** $\to \gamma\gamma$, **Z** $\to$ **qq , l l , νν**
- **h A with h** $\to \gamma\gamma$, **A** $\to$ **bb**
- **h A with h** $\to \gamma\gamma$, **A** $\to$ **hZ, Z** $\to$ **qq**

Fermiophobic Higgs

hZ channel	#events ($\sqrt{s}$=183-209GeV)
$qq\gamma\gamma$	32 (27.2±0.4)
$\nu\nu\gamma\gamma$	19 (19.5±1.1)
$ll\gamma\gamma$	3 (5.0±0.6)

DELPHI limit :

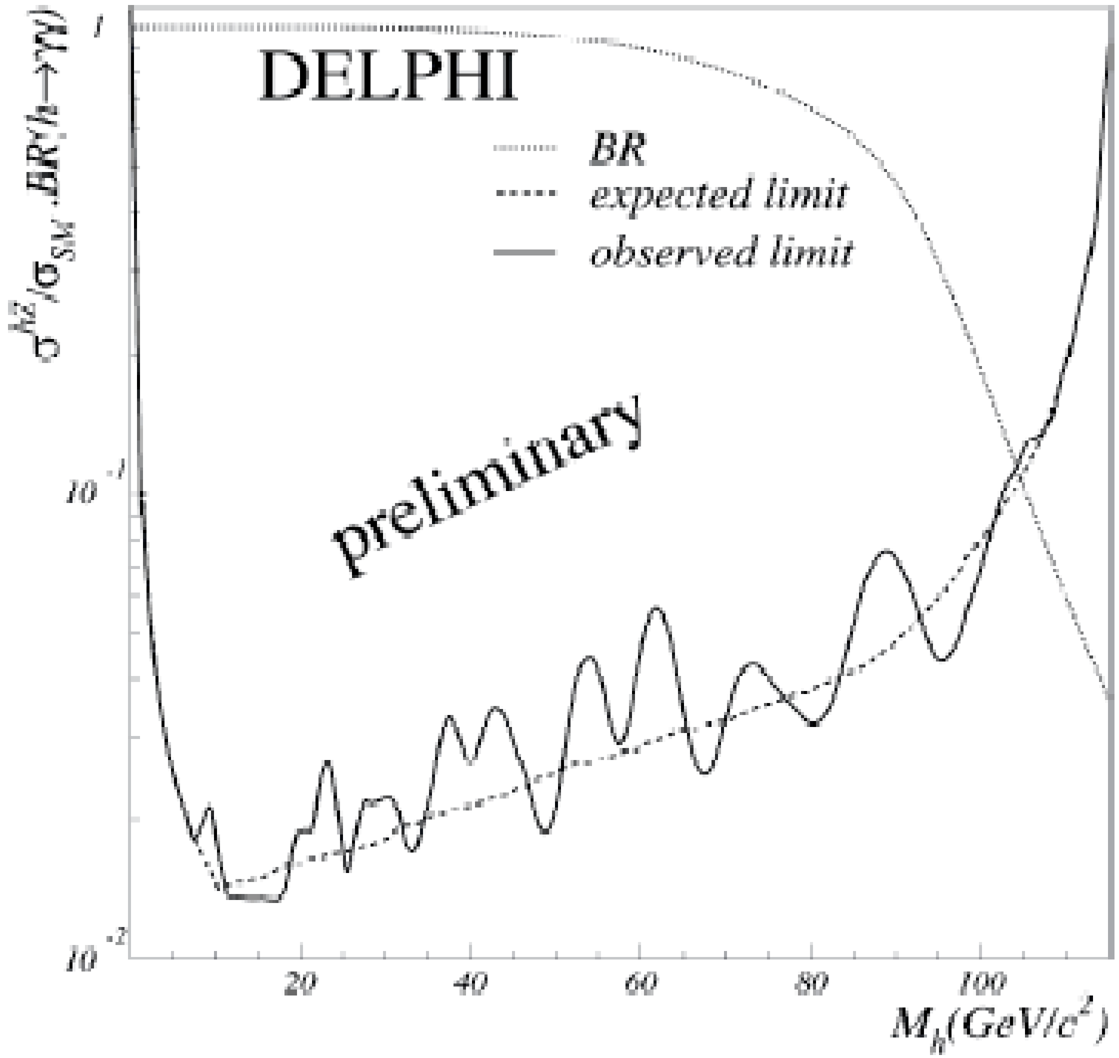
m_h > 104.1 GeV at 95% CL

Assuming SM

+ No Couplings to ff:

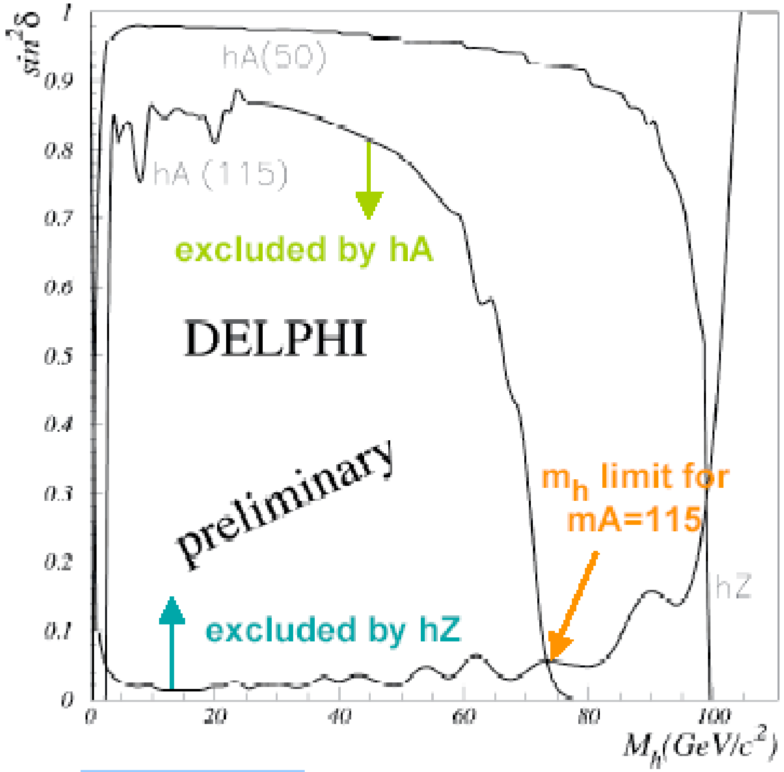
LEP Combined limit at 95 % CL

m_h > 108.2 GeV/c^2

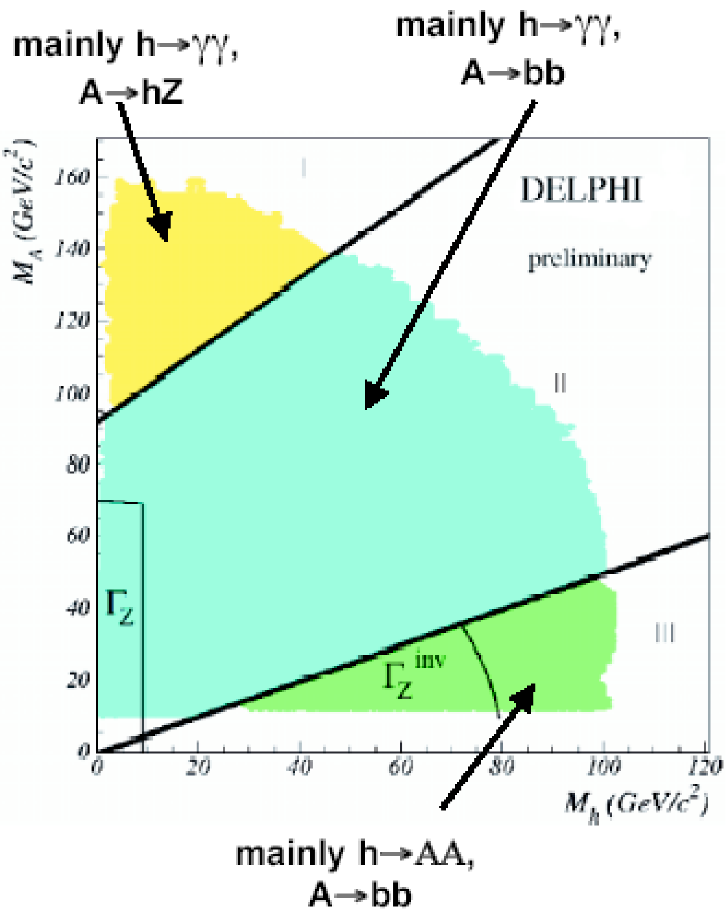


hA production: searched for

- $hA \to \gamma\gamma bb$
- $hA \to hhZ \to \gamma\gamma\gamma\gamma qq$



$\delta = \alpha\text{-}\beta$



Technicolor

- **New (strong) interactions : ($\Lambda_{TC} >> \Lambda_{QCD}$)**

  Technifermions T (coupled to W, Z)

- **Alternative to Higgs Mechanism**

  EW symmetry is broken dynamically

- **But there are problems:**

  — precision measurements of EW quantities

  — mass of top quark

  — flavour-changing neutral currents (FCNC)

- **Extensions of TC solve the problems: " topcolor- assisted technicolor " (TC2)**

Technicolor

- **New particles : Technicolor scalar π_T and vector meson ρ_T light enough to be observed at LEP**
- **N_D techidoublets**

1) Search for π_T

$$e^+ \; e^- \longrightarrow \rho_T^* \longrightarrow W_L \, \pi_T \;, \quad \pi_T \, \pi_T$$

4 jet final state

semileptonic decays : $l \, \nu \, q \, q$

$\tau \, \nu \, q \, q$

Technicolor

2) Search for ρ_T

$e^+ e^- \longrightarrow \rho_T \, (\gamma)$ with $M_\rho < \sqrt{s}$

↳ $p_?{}^0$?

↳ $b\,b$ (~ 90 %) b tagging

$e^+ e^- \longrightarrow \rho_T \, (\gamma)$ with $M_\rho > 2\, ?_{WW}$

↳ $W_L \; W_L$

additional contribution to $W^+ W^-$ cross section

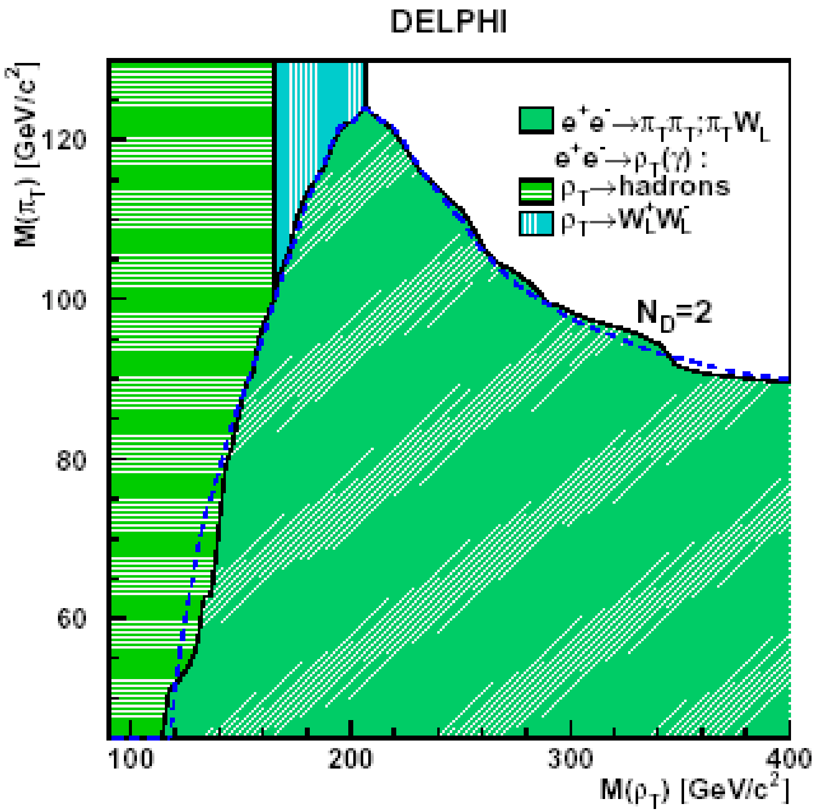
$e^+ e^- \longrightarrow \rho_T \, (\gamma)$

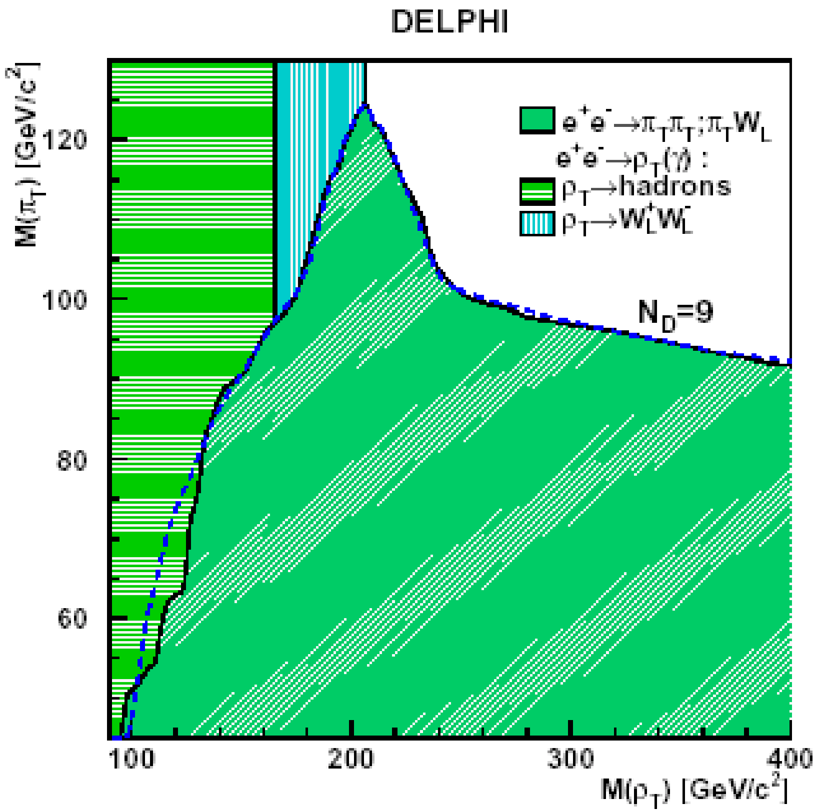
↳ hadrons ($q\,q$, $\pi_T \; \pi_T$)

Technicolor with DELPHI

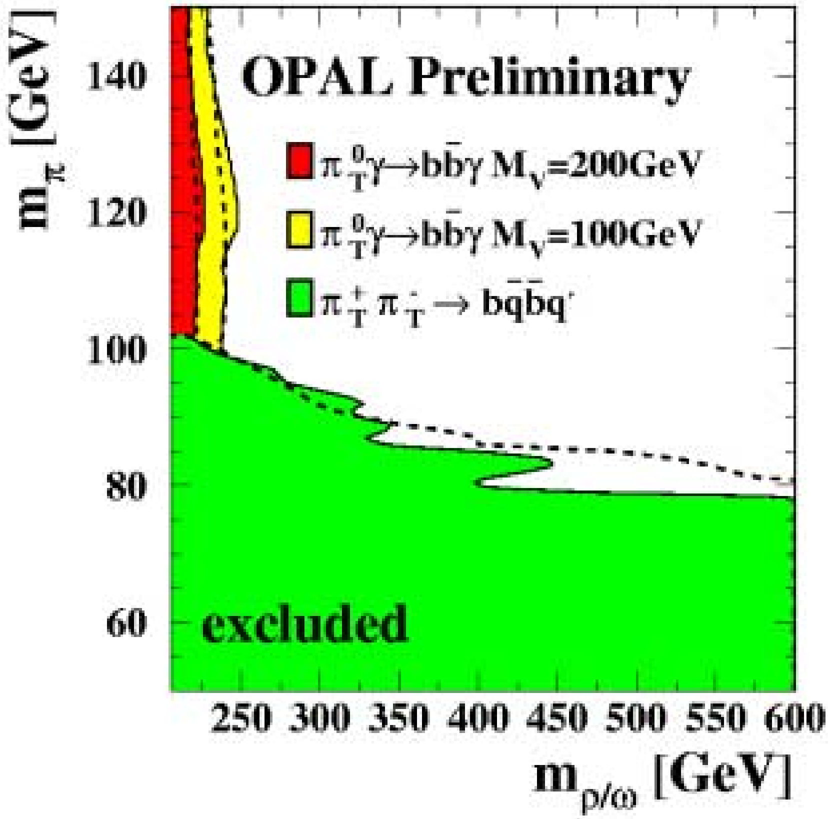
Excluded at 95% CL :

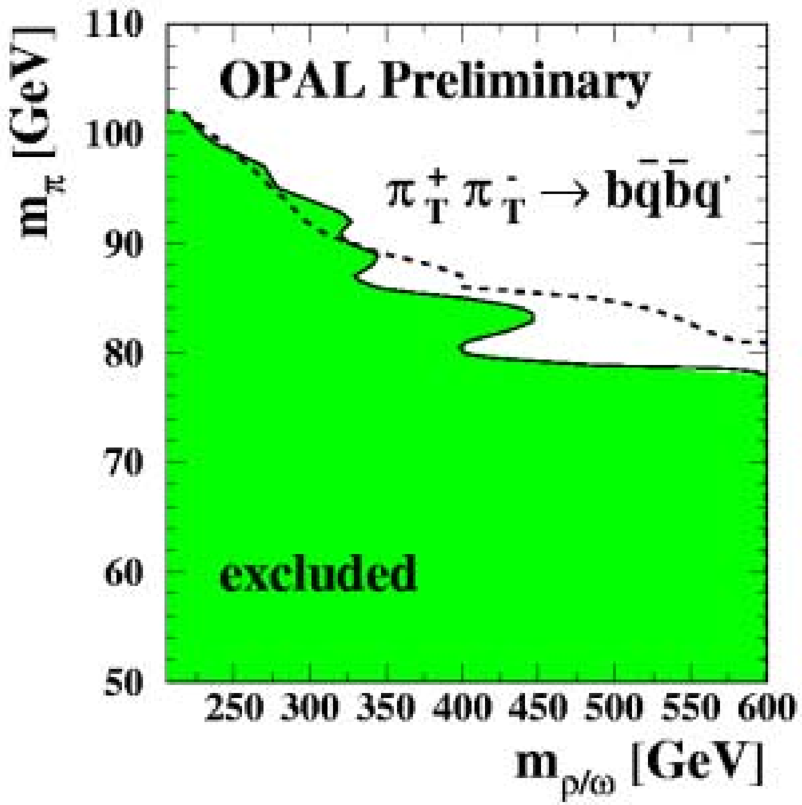
90 GeV < m_ρ < 206.7 GeV/c^2 **m_π > 79.8 GeV/c^2**





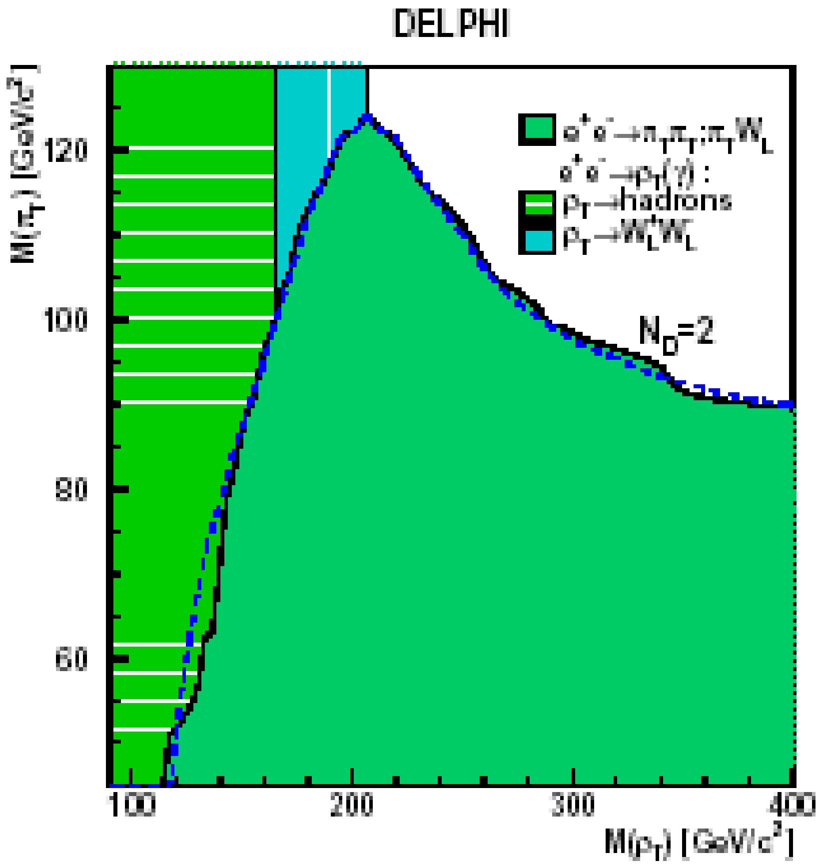
Technicolor with OPAL

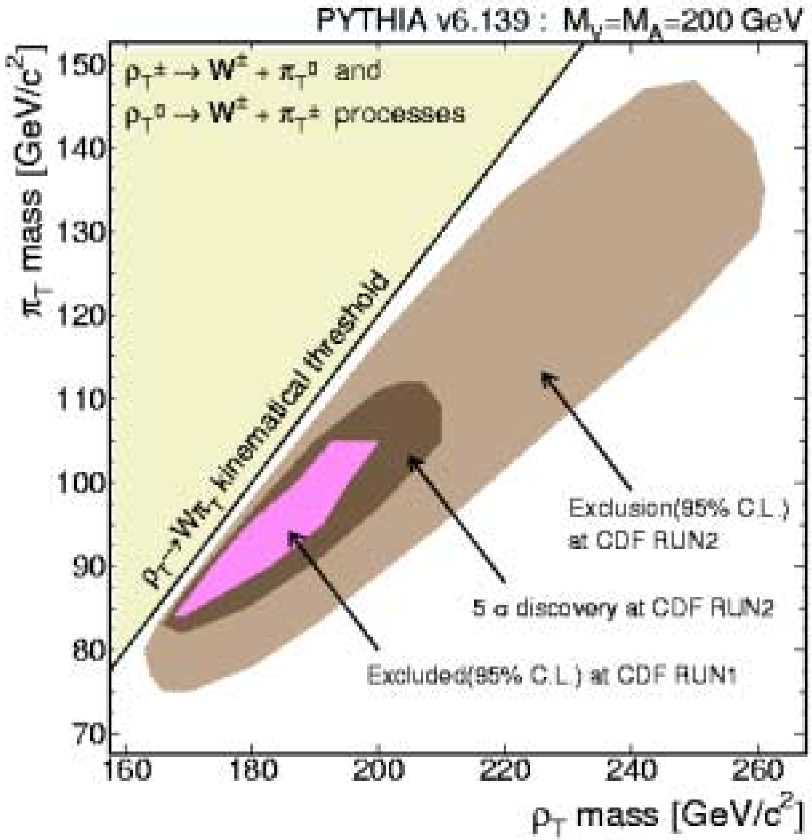




m (π_T) > 62 GeV at 95 % CL

σ (upper limits) ~ 50 - 300 fb





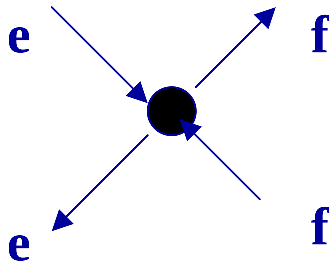
Comparison between LEP 2 and CDF Exclusion Plots

Contact Interactions

signatures of conventional compositeness at LEP 2 → Contact interactions

•**Parametrisation of new physics due to composite fermions or New heavy mediators ($m_X >> \sqrt{s}$)**

Λ is the energy scale of new physics



Model	η_{LL}	η_{RR}	η_{LR}	η_{RL}
$LL^{\pm}$	±1	0	0	0
$RR^{\pm}$	0	±1	0	0
$VV^{\pm}$	±1	±1	±1	±1
$AA^{\pm}$	±1	±1	∓1	∓1
$LR^{\pm}$	0	0	±1	0
$RL^{\pm}$	0	0	0	±1
$V0^{\pm}$	±1	±1	0	0
$A0^{\pm}$	0	0	±1	±1

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

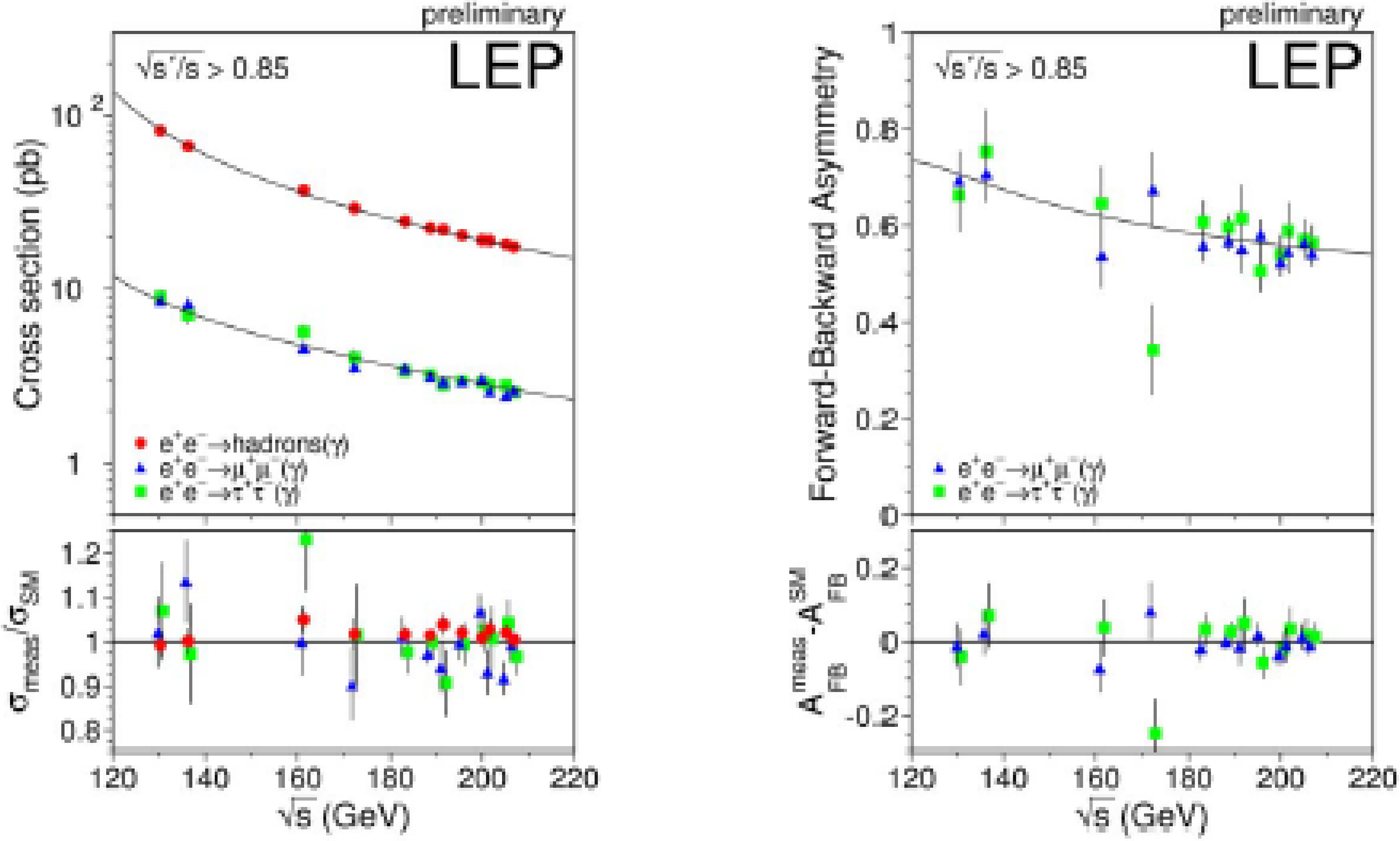
g = unknown coupling
$g^2 / 4\pi = 1$
δ = 1 for Bhabhas ,
0 otherwise

Limits set by looking for deviations from SM predictions

Observables: 2-fermions cross-sections [$\sigma(e^+e^- \to f\,\bar{f})$, $d\sigma/d\cos\theta$] , Asymmetries, R_b,R_c,…

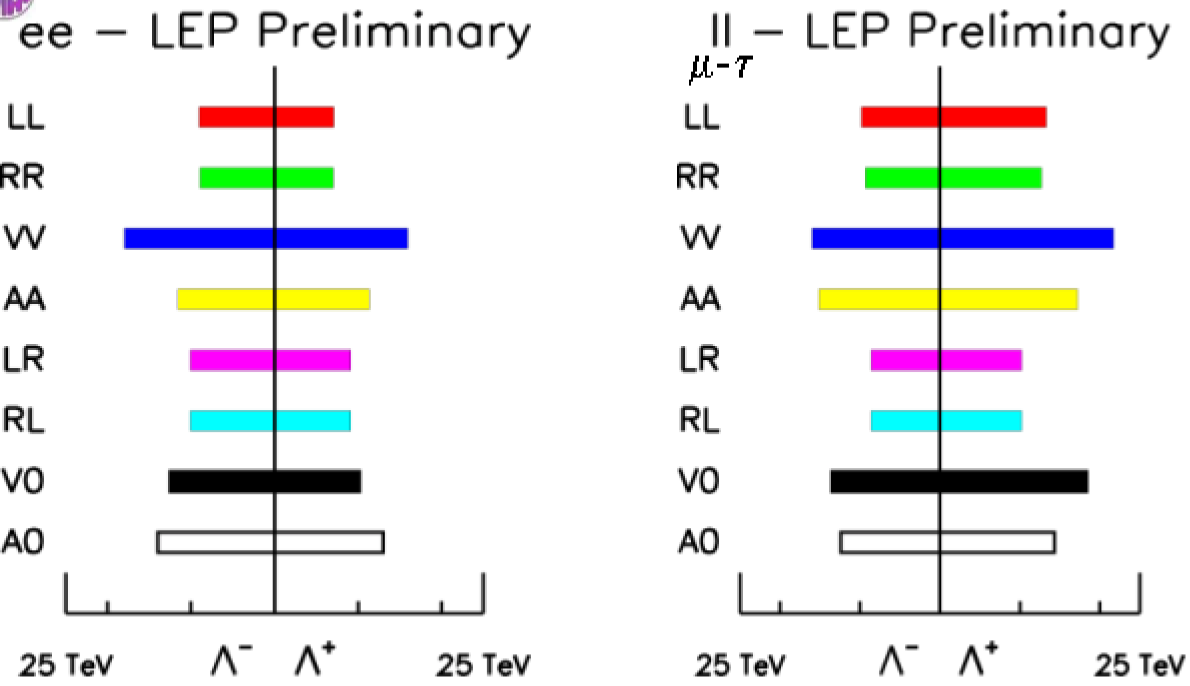
⇒ **limits Λ_+ , Λ_- , correspond to constructive, destructive interference with SM**

2-Fermions Cross-Sections and Asymmetries

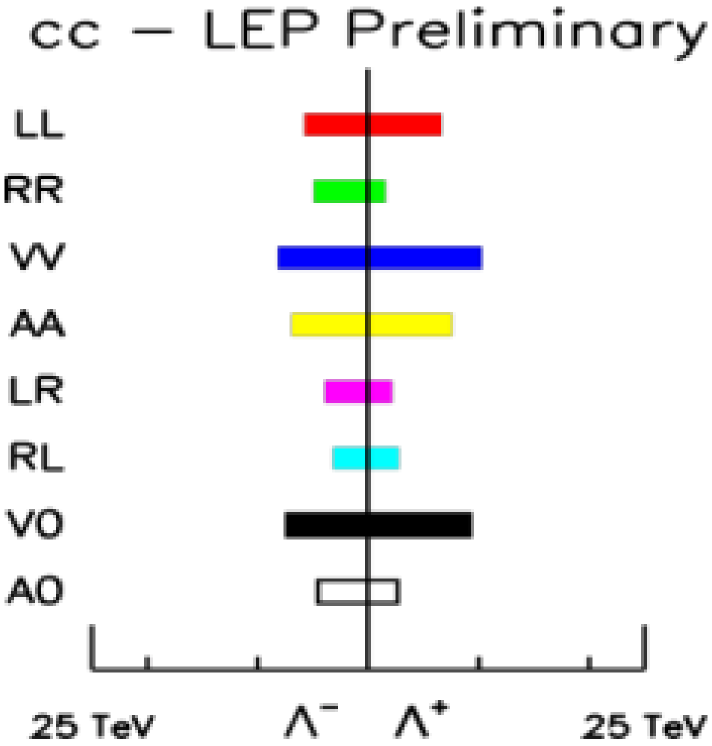


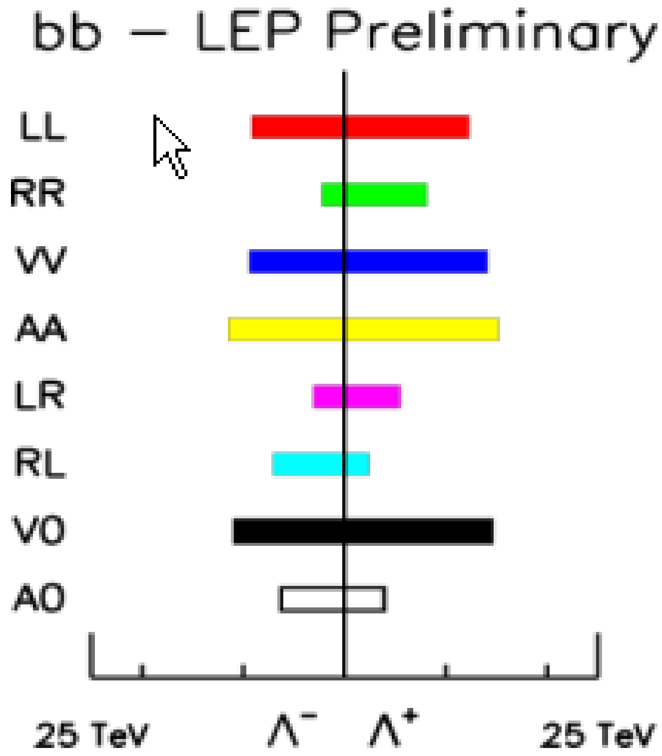
Contact Interactions

Fully Leptonic



Λ > 9 TeV


cc – LEP Preliminary
LL
RR
VV
AA
LR
RL
V0
A0
25 TeV
Λ⁻
Λ⁺
25 TeV


bb – LEP Preliminary
LL
RR
VV
AA
LR
RL
V0
A0
25 TeV
Λ⁻
Λ⁺
25 TeV

Leptoquarks

- **appear in many unification theories beyond the SM**
(GUT, Compositeness, TC, Superstring theories-E_6)

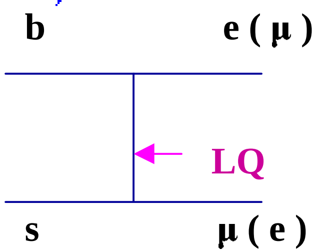
- **Color-triplet bosons with Couplings to quarks and leptons**

- **Scalars (S) and Vectors (V)** ; F=0 (e^{-1} $\bar{q}$) and F=2 (e^{-1} q)
F=3 B + L

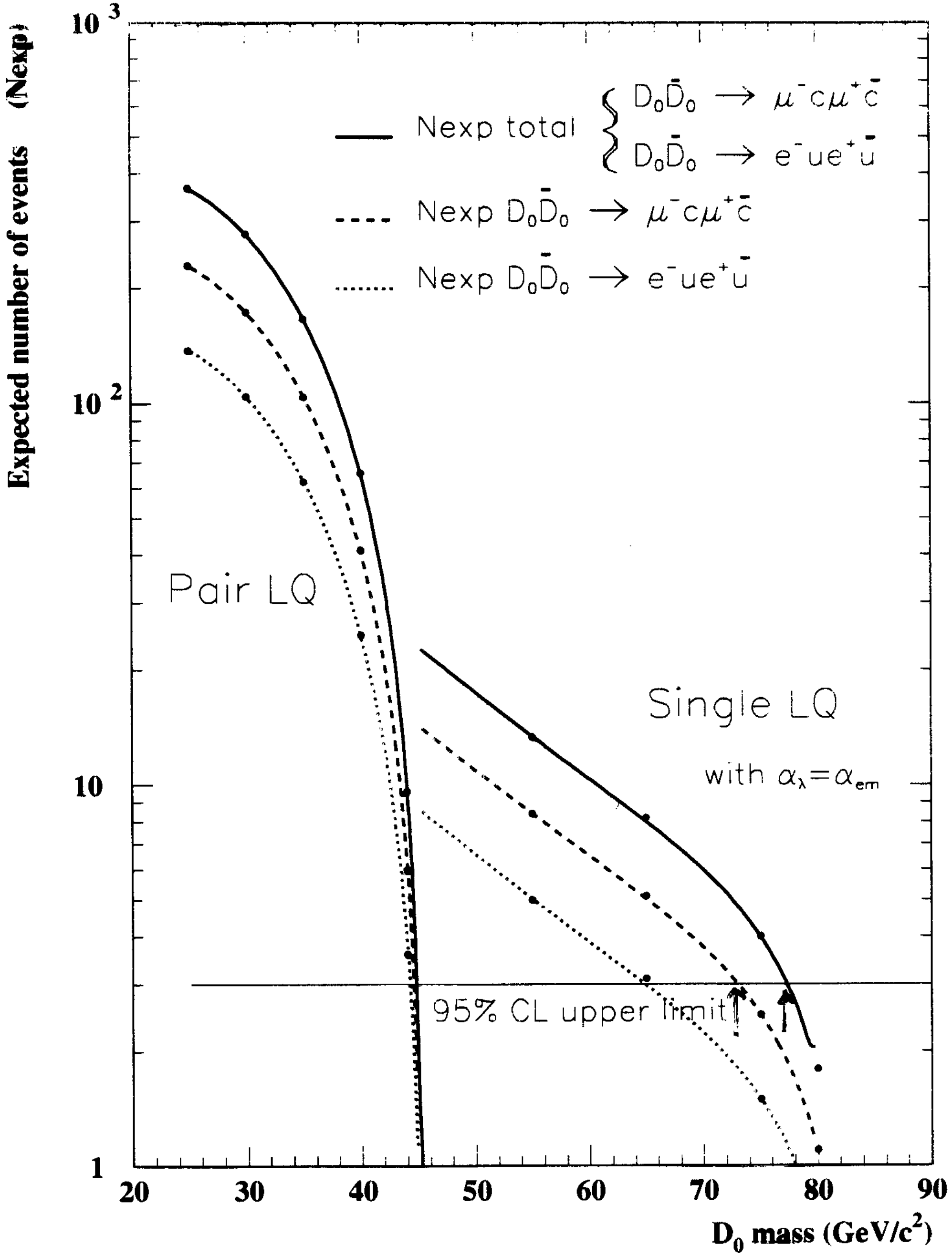
- **Only family diagonal Couplings**
(to avoid FCNC processes) — LFV also considered (HERA)

- **Chirality conserving LQ** (Very strong bounds from rare decays)
$\Longrightarrow$ 14 species (7 Scalars and 7 Vectors)
(BRW effective model : 6 isospin singlets,6 doublets and 2 triplets)

- **Pati-Salam LQ**
Search for $B_s \to e\ \mu$ decay
(CDF : $M_{LQ}(B_s) > 19.3$ TeV at 95 % CL)



Leptoquark at LEP 1



m_{LQ} > 65 GeV (1rst-gen)

m_{LQ} > 73 GeV (2nd-gen)

at 95 % CL

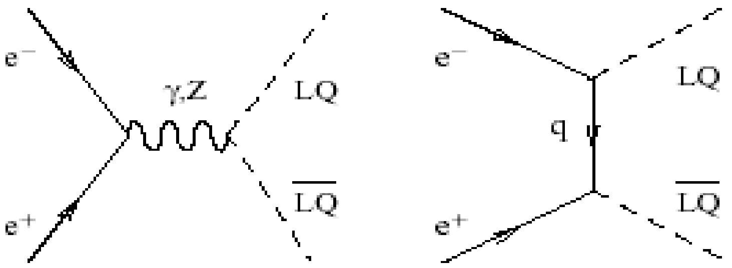
Single LQ production gives the opportunity to explore a mass region up to ~ 80 GeV/c^2

DELPHI

NTU-Athens

Th. D. Papadopoulou

Pair Leptoquark at LEP 2



OPAL results

$$\sqrt{s} = 189 - 209\,GeV$$

M(LQ) limits for β=1: 96 –102 GeV

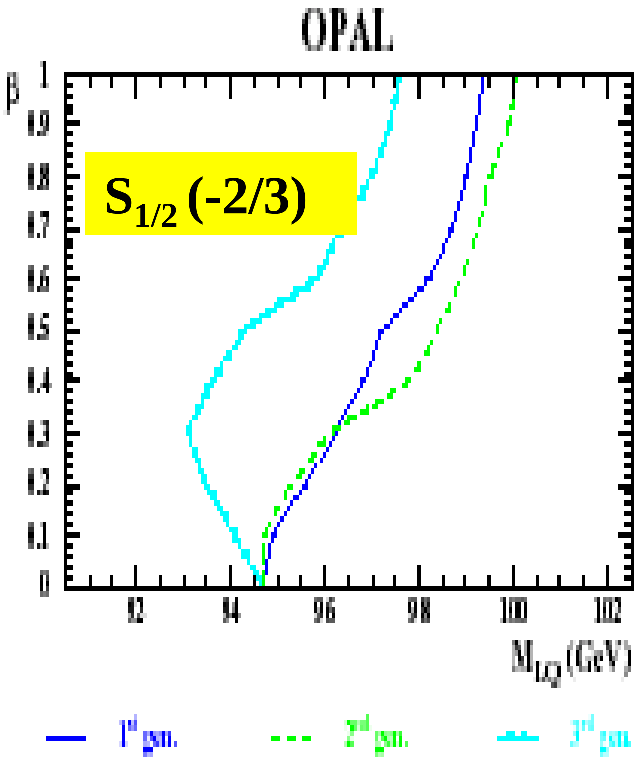
Topologies

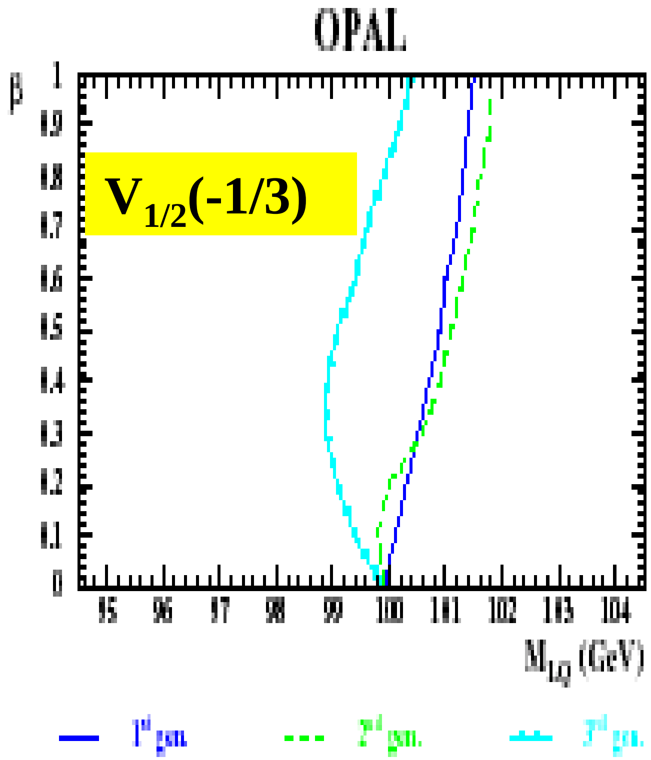
$l^+ l^-$ q q

l ν q q

ν ν q q

for l=e,μ,τ

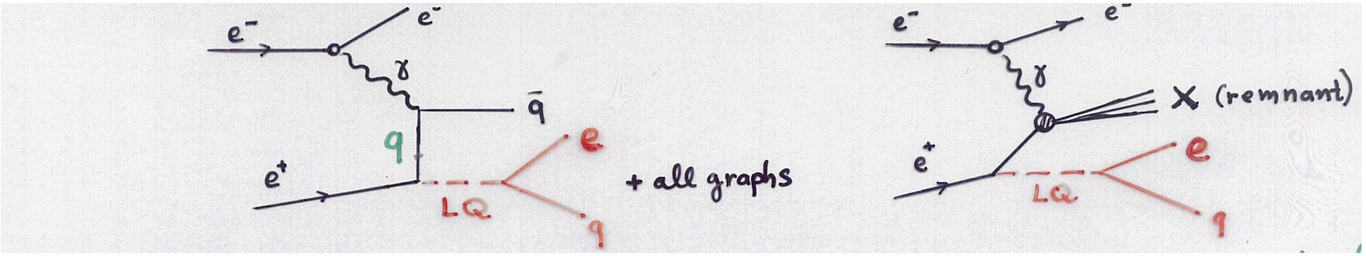




Single Leptoquark at LEP 2

$$\sigma(e^+e^- \to S_{LQ}+X) = \int_{M_{LQ}^2/s}^{1} (dx/x)\, f_{\gamma/e}(x,s)\, f_{q/\gamma}(M_{LQ}^2/(xs), M_{LQ}^2)\, \hat{\sigma}$$

Perturbative approach(PA) | Resolved photon (RP)



Perturbative approach (PA)

Advantages

- Full kinematics (subprocess)
- Scalar and Vector LQ

Disadvantages

- No H.O effects
- Non-perturbative QCD effects not included

ERATO-LQ generator C.Papadopoulos

Resolved photon (RP)

Advantages

- Includes H.O. QCD
- non-perturbative terms

Disadvantages

- Kinematics is limited to $P_T=0$
- No description of the nature of LQ (S,V)

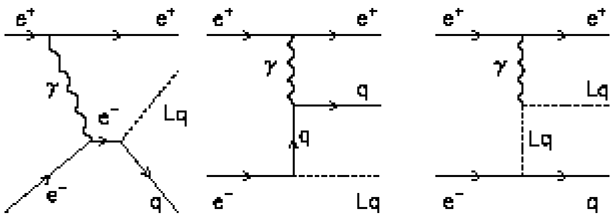
PYTHIA generator (Decay modification) M.Doncheski et al cross section

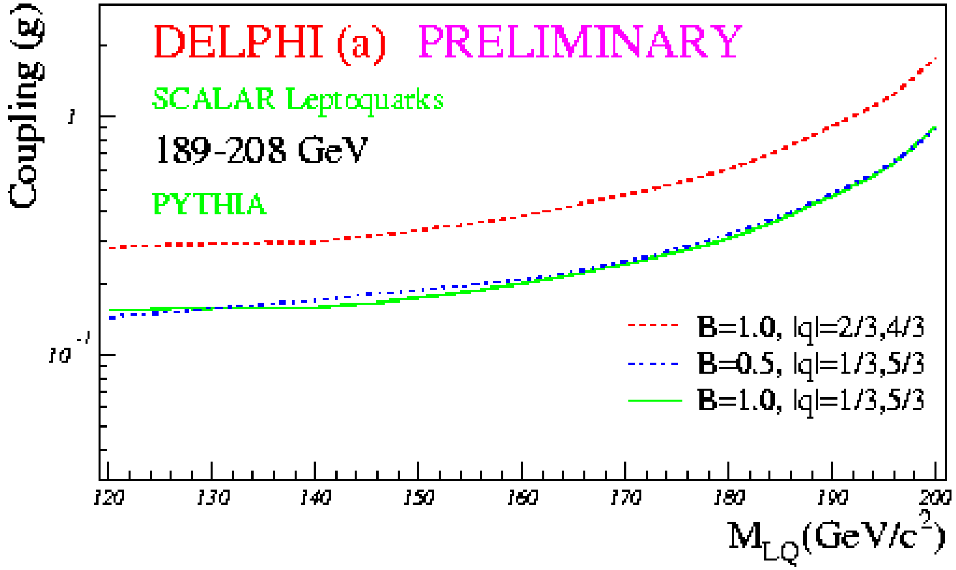
•Under the same conventions for the Couplings (Chirality) both procedures are consistent.

Single LQ at LEP 2

Pertubative Approach:

ERATO generator

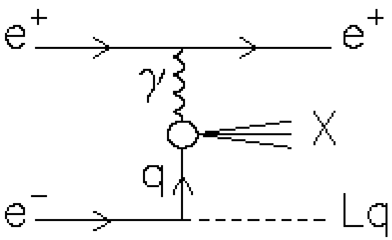


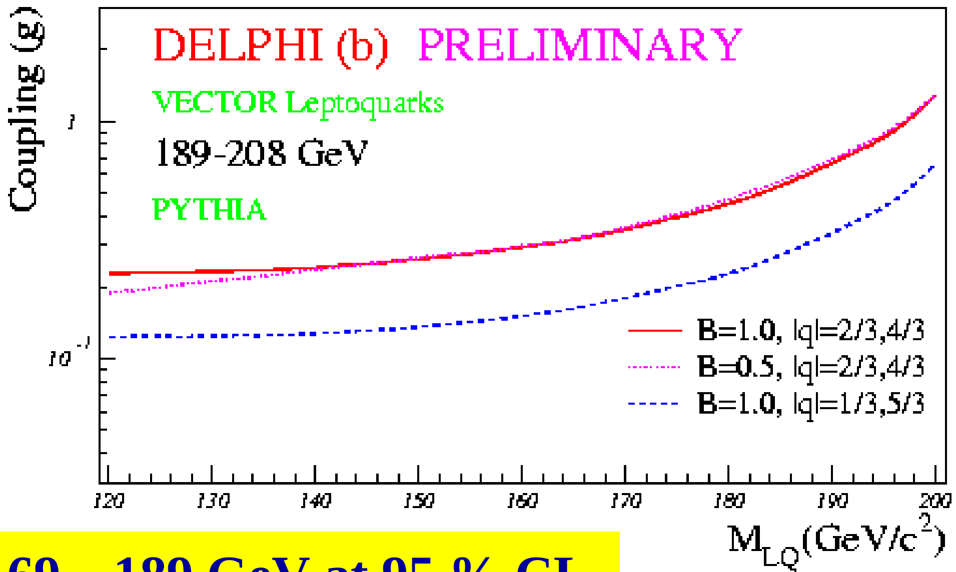


Resolved photon :

PYTHIA generator @

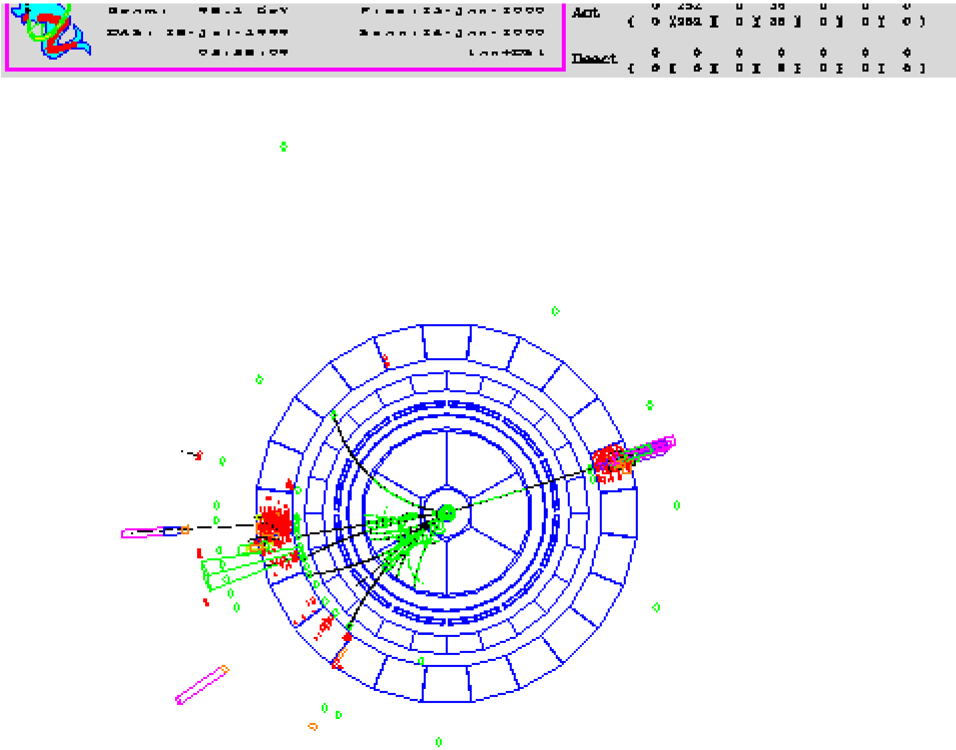
Doncheski et al. cr-section





For $\lambda = \sqrt{4\pi\alpha}$: m(LQ) > 169 – 189 GeV at 95 % CL

Event $e^+ e^- \rightarrow e^- + \text{Jet}$



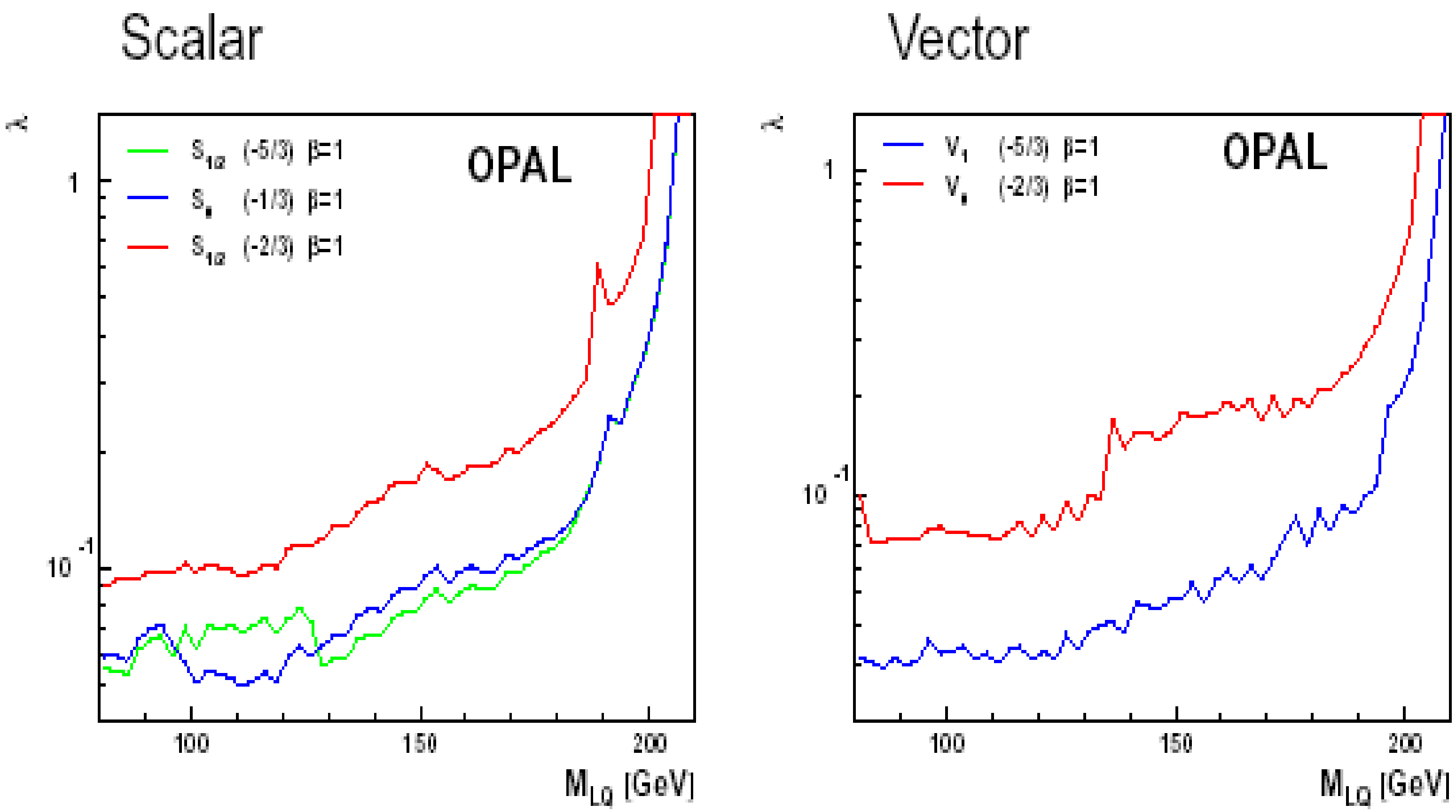
DELPHI

$$E_{CM} \cong 200\ GeV$$

Signature : e^- + jet => M (e j) ~ 180 GeV

Single LQ at LEP 2

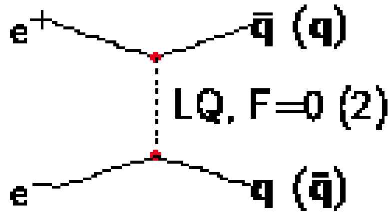
σ_{LQ} (|Q| = 1/3 ,5/3) > σ_{LQ} (|Q| = 2/3 ,4/3)

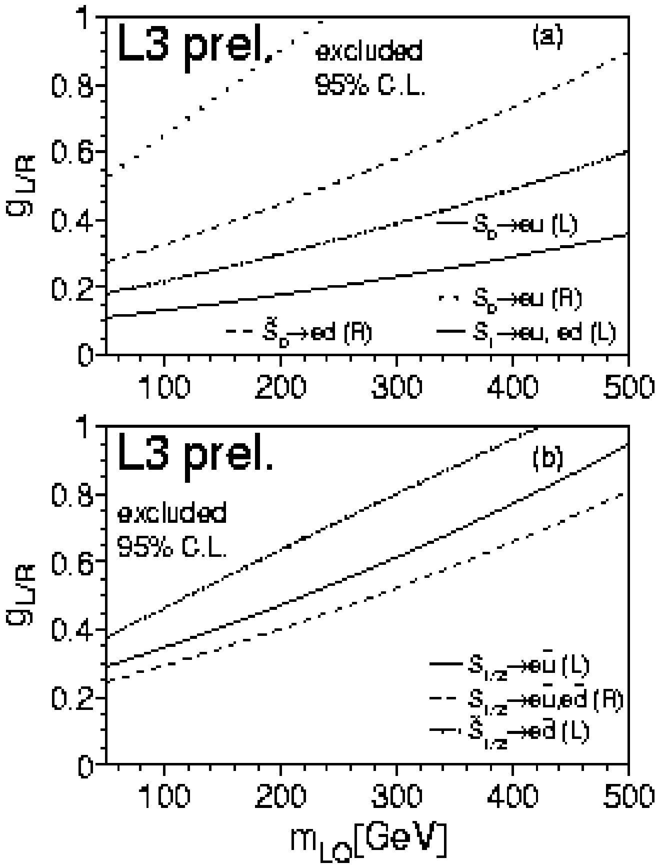


For $\lambda = \sqrt{4\pi\alpha}$ **: m(LQ) > 183 – 202 GeV at 95 % CL**

Indirect LQ search at LEP 2

$$e^+e^- \rightarrow q\,\bar{q}$$





with LQ /squark exchanges

in t/u channels

t-channel exchange F = 0

u-channel exchange F = 2

For $\lambda = \sqrt{4\pi\alpha}$ **at 95 % CL :**

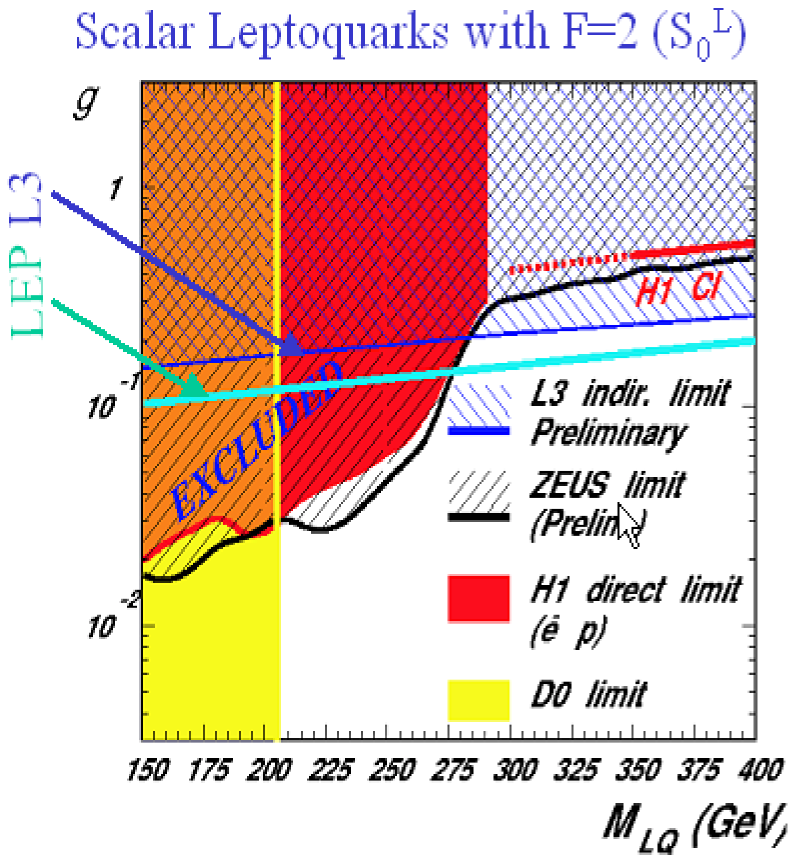
m(LQ) > 112 – 375 GeV (scalar)

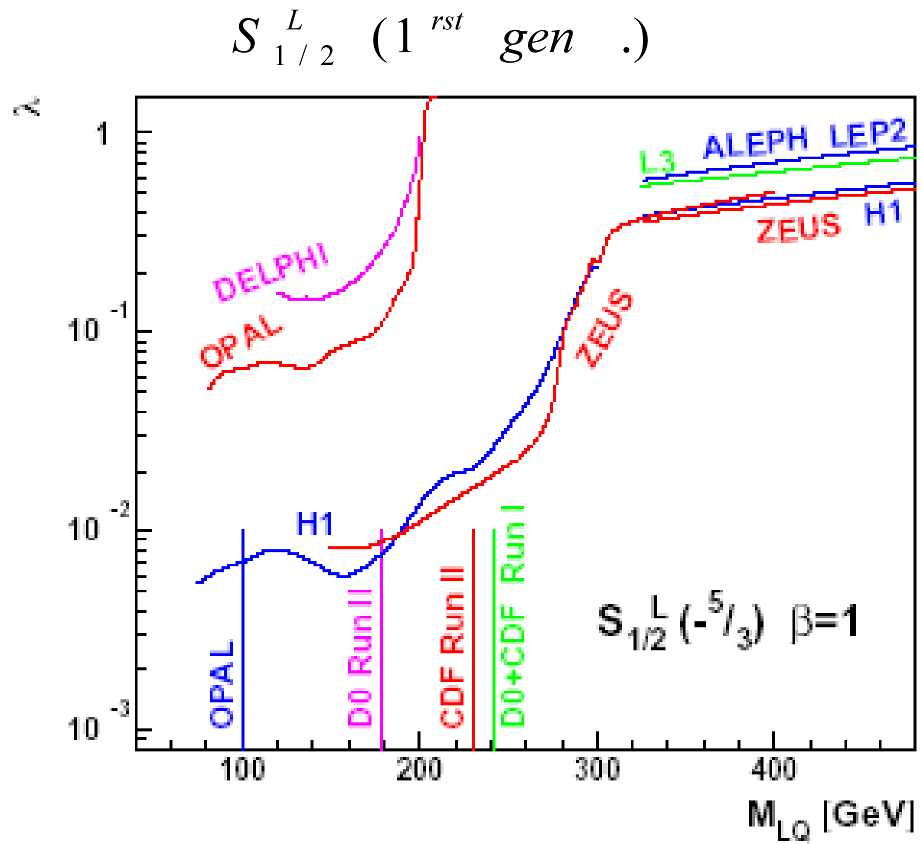
m(LQ) > 159 – 557 GeV (vector)

- **Like four fermion contact interactions at scale** $\Lambda >> \sqrt{s}$

★ Limits on LQ Couplings up to high values ; $m_{LQ} >> \sqrt{s}$

LQ limits





From EPS-2003 , A. Zarnecki

R-parity Violation

- **What is Rp and why go beyond ?**

➢ **a discrete multiplicative symmetry in SUSY models connected to matter parity**

$$R_p = (-1)^{2S+3B+L}$$

$R_p = 1$ **for SM particles**

$R_p = -1$ **for SUSY particles**

- **SUSY particles produced in pairs**
- **LSP is stable**
- **experimental signature of SUSY E_T miss**

$\longrightarrow$ **fast proton decay is suppressed**

RpV Superpotential

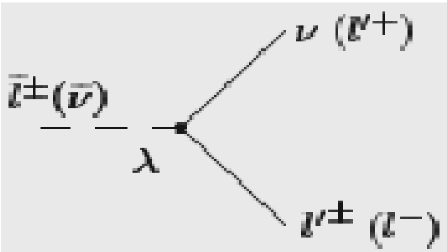
- Rp can be explicitly broken by trilinear terms in the superpotential

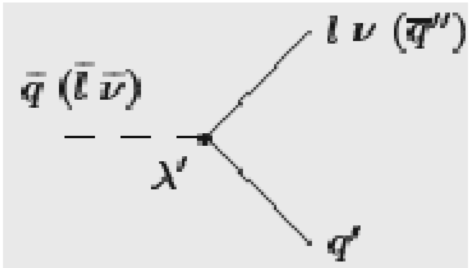
$$W = \lambda_{ijk}\, L_i L_j \overline{E}_k \quad + \lambda'_{ijk}\, L_i Q_j \overline{D}_k \quad + \lambda''_{ijk}\, \overline{U}_i \overline{D}_j \overline{D}_k$$

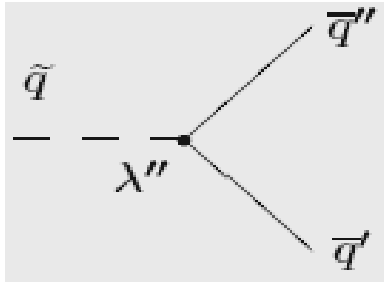
$\Delta L \neq 0$ — 9 Couplings $(i \neq j)$

$\Delta L \neq 0$ — 27 Couplings

$\Delta B \neq 0$ — 9 Couplings $(j \neq k)$







- o **single sparticle production** **via a $\Delta L \neq 0$ or a $\Delta B \neq 0$ operator**
- o **Unstable LSP !**
- o **Signature of multilepton or multijet events in excess**

$\longrightarrow$ **fast proton decay is suppressed if Lepton and Baryon number Violating Couplings not simultaneously present**

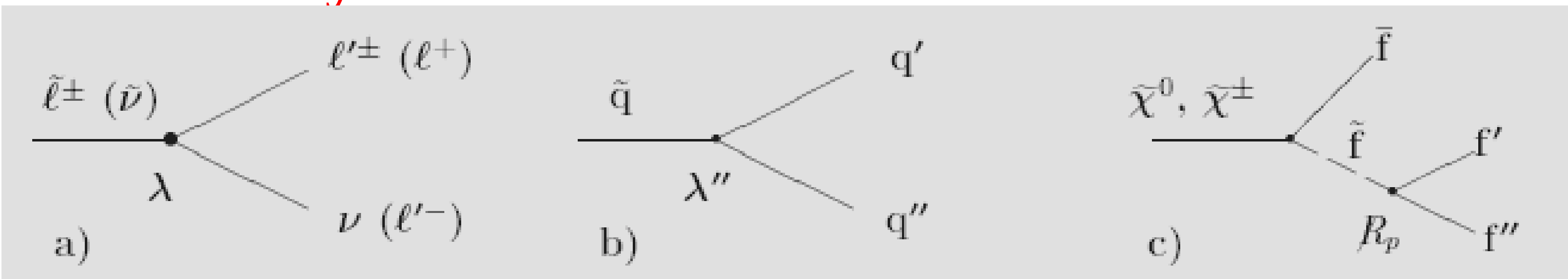
Decays via trilinear RPV Couplings

Decay topologies

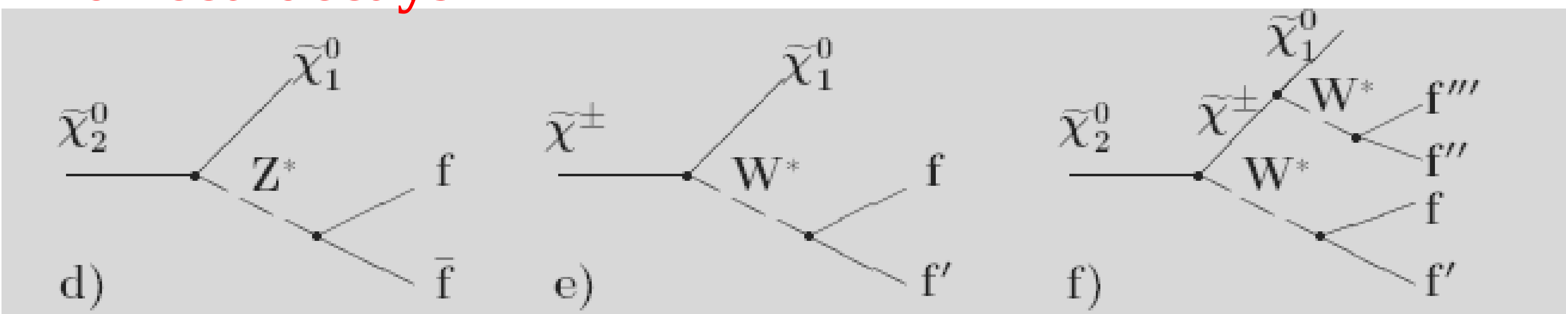
9 λ_{ijk} + 27 λ'_{ijk} + 9 λ''_{ijk} = 45 new couplings

Hierarchies in RpV Couplings expected (as for Yukawa Couplings generating fermion masses)

- **direct decays**



- **indirect decays**



⇒ **multileptons - multijets**

LSP Decay Length

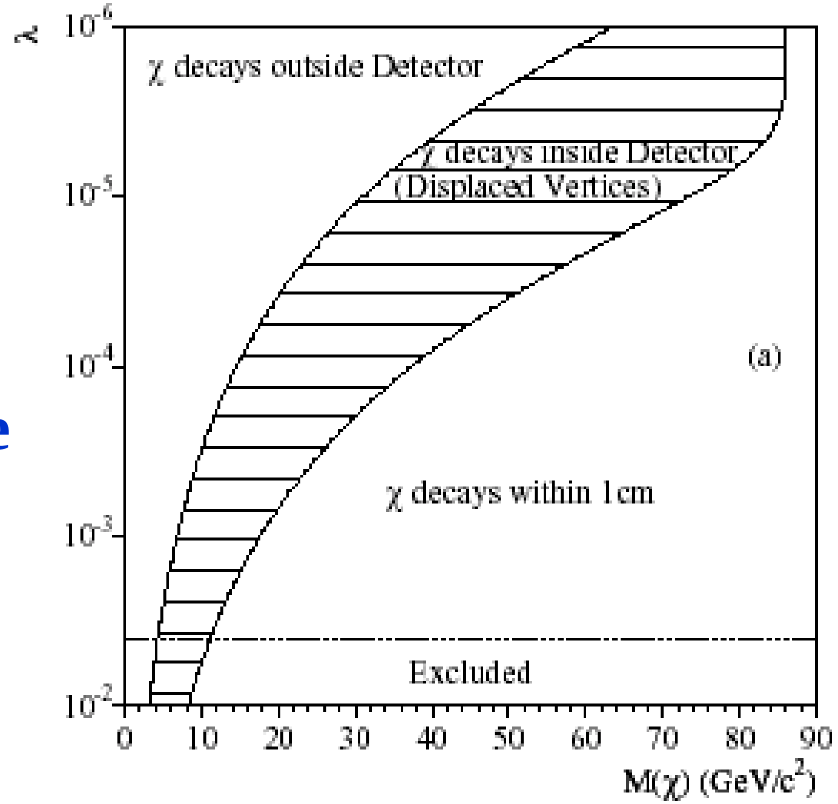
Decay Length of $\widetilde{\chi}_1^0$

$$L \approx \frac{1}{\lambda^2}\left(\frac{m_{\widetilde{f}}}{100GeV}\right)^4\left(\frac{1GeV}{m_{\widetilde{\chi}}}\right)^5$$

- **LEP analyses are sensitive only if the LSP has a negligible lifetime (L < 1 cm)**

➢ $m_{\widetilde{\chi}} > 10\ GeV$

~ $10^{-5} < \lambda < 10^{-2}$ –1



Displaced Vertices < λ < indirect SM bounds

Search strategies

- **Suppose one Coupling** $\lambda_{ijk}^{(\prime\ \prime\prime)} \neq 0$
- **Consider that many channels have to be combined**
- **Optimize Signal selection on various topologies**

  --with sequential cuts : ALEPH, OPAL, L3, DELPHI $(LL\bar{E})$

  --using lepton identification and lepton isolation criteria $(LL\bar{E}\ ,\ LQ\bar{D})$

  -- with neural network methods : DELPHI $(\bar{U}\,\bar{D}\,\bar{D})$

  -- using jet algorithm, b tagging $(LQ\bar{D}, \bar{U}\,\bar{D}\,\bar{D})$

- **Calculate signal reconstruction efficiency**

  -- optimization on different mass combinations depending on the decays and the kinematics

- **If no significant deviation from the SM, set 95 % CL limits on:**

***cross-sections * couplings and sparticle masses * exclusion plots in the MSSM regions**

Theoretical Framework of searches

Minimal SUSY scenario :

- **Topologies predicted in a Constrained MSSM =>** ***CMSSM***
- **gaugino mass unification ($M_1 \approx 0.5\ M_2$) at EW scale**
- **Mass universality at GUT scale =>** $\mu,\ \tan\beta,\ m_0$
- **Trilinear terms are set to 0 =>** $A_{b,t,\tau} = 0$
- **Mixing angles for stop and sbottom =>** $\phi_{\tilde{t}}\ ,\ \phi_{\tilde{b}}$

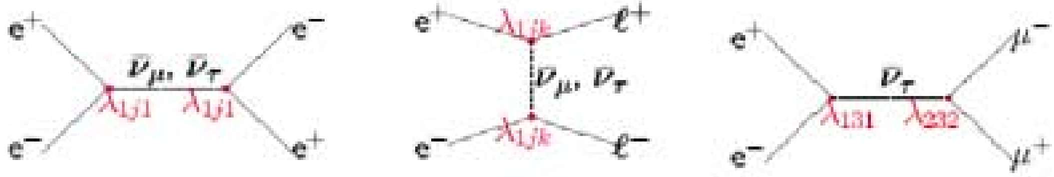
Bounds on RpV Couplings at EW scale:

λ : ~ 5. 10^{-2} λ' : ~ 2. 10^{-2} (131) up to 0.56 (232)

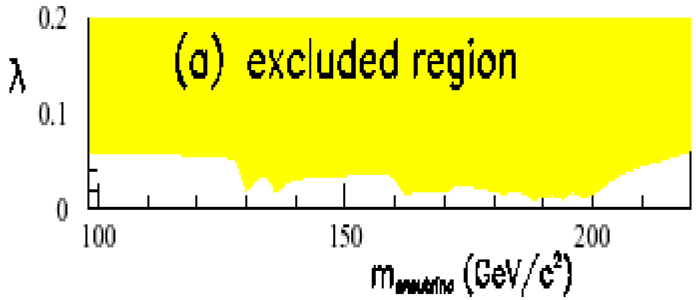
λ'': ~ 0.5 up to ~1.23 (except $\lambda''_{112} = \lambda''_{121} \sim O(10^{-9})$, $\lambda''_{131} = \lambda''_{113} = 10^{-4}$)

(for a sparticle mass of 100 GeV/c^2)

resonant sneutrino production



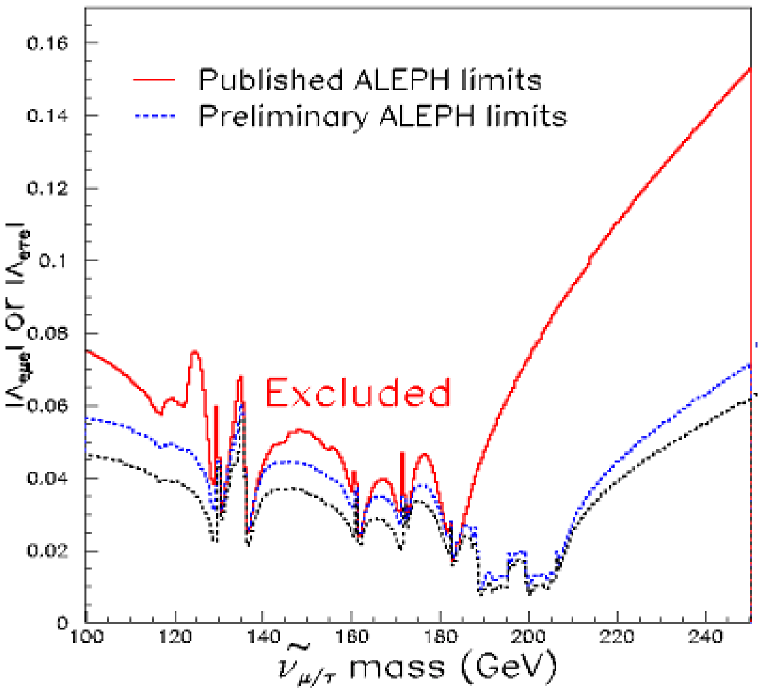
DELPHI



ALEPH

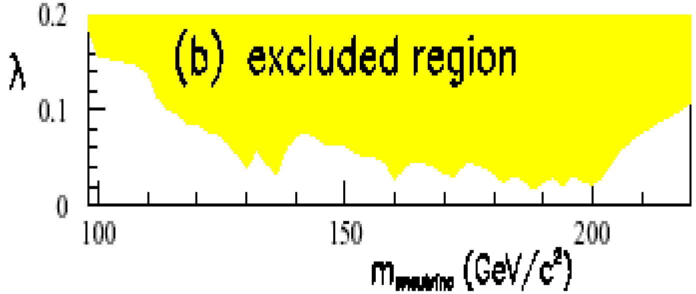
$e^+ e^-$ channel

$\lambda_{121}, \lambda_{131}$



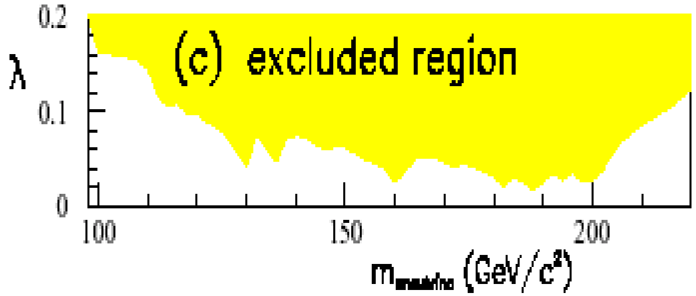
$\mu^+ \mu^-$ channel

$\lambda_{131} = \lambda_{232}$



$\tau^+ \tau^-$ channel

$\lambda_{121} = \lambda_{233}$



Single gaugino production

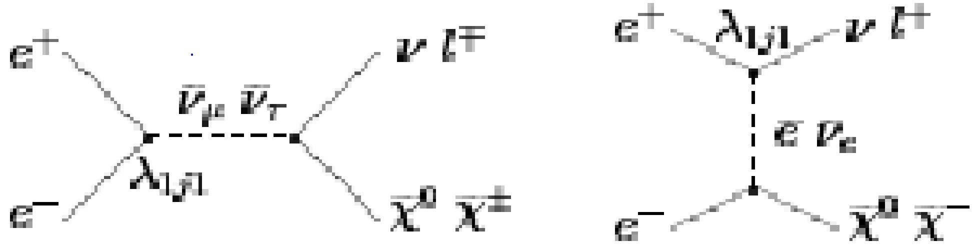
- Resonant sneutrino $\tilde{\nu}_\mu, \tilde{\nu}_\tau$ production $\sigma \propto \lambda^2_{ijk}$

→ probes masses up to E_{cm}

DELPHI

- Single gaugino production

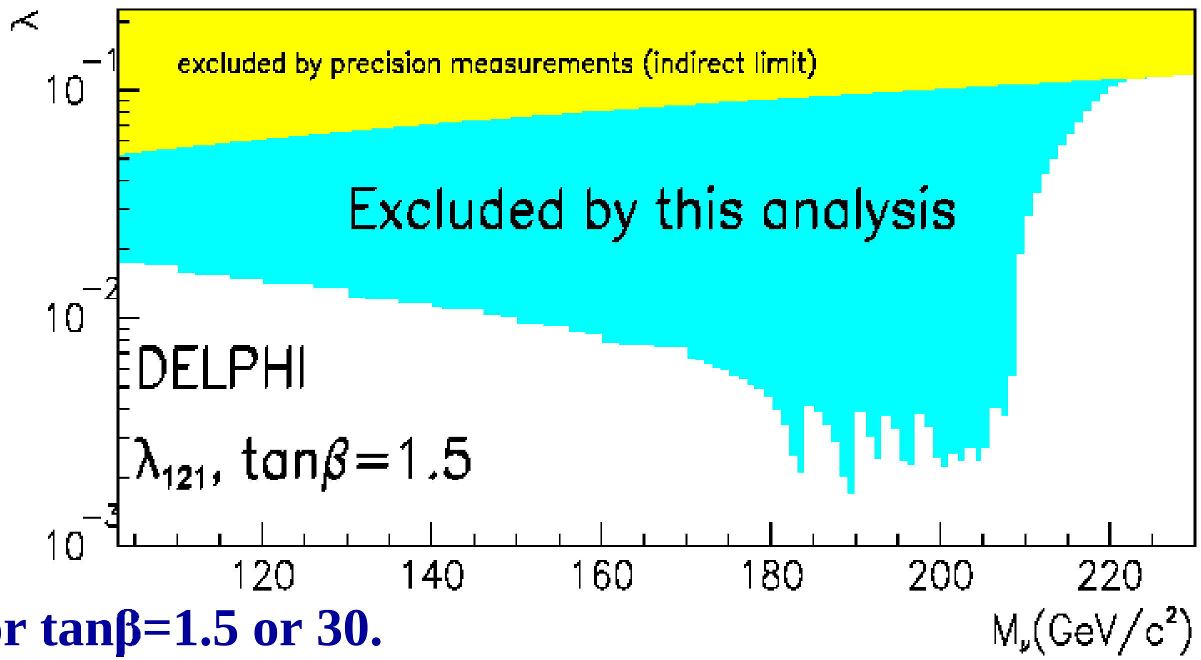
Analysis of final states : 3 topologies



- ➢ 2 leptons and E_{miss}
- ➢ 4 or 6 leptons (with or without E_{miss})
- ➢ leptons + jets

- Couplings λ_{121} , λ_{131}

limits on λ
→ 1. – 3. 10^{-3}

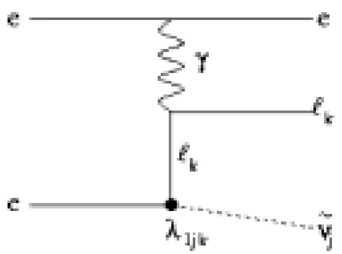


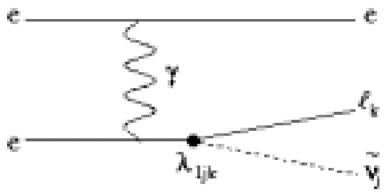
for tanβ=1.5 or 30.

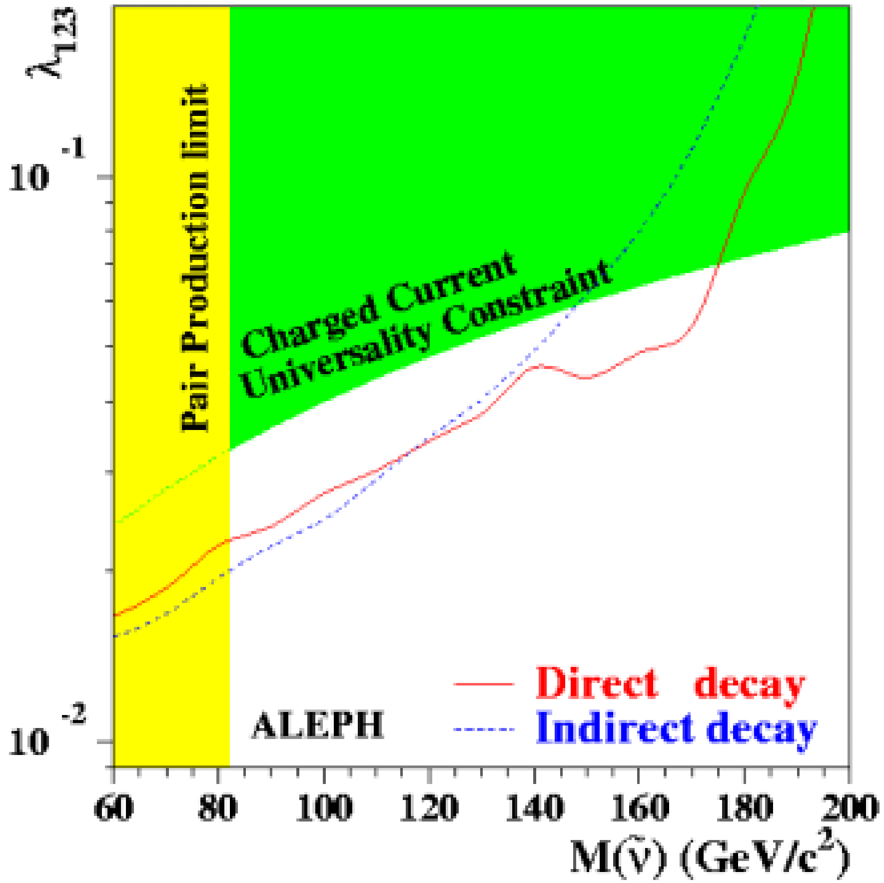
Single sneutrino production

- single sneutrino $\tilde{\nu}_e, \tilde{\nu}_\mu, \tilde{\nu}_\tau$ production : $e\,\gamma \rightarrow \tilde{\nu}_j\, l_k$

ALEPH







- Couplings λ_{1jk} and λ_{231}
- multi – lepton final states

  (direct / indirect)

  $\longrightarrow$ 6 analyses

Upper limits on λ
~ 7. 10^{-3} - 3. 10^{-2}

Gaugino pair production

λ	λ´	λ´´
2, 4 and 6 leptons (+ Emiss)	2, 4 jets +lepton(s) (+ Emiss)	multijets + leptons (+ Emiss)

- **Final states**

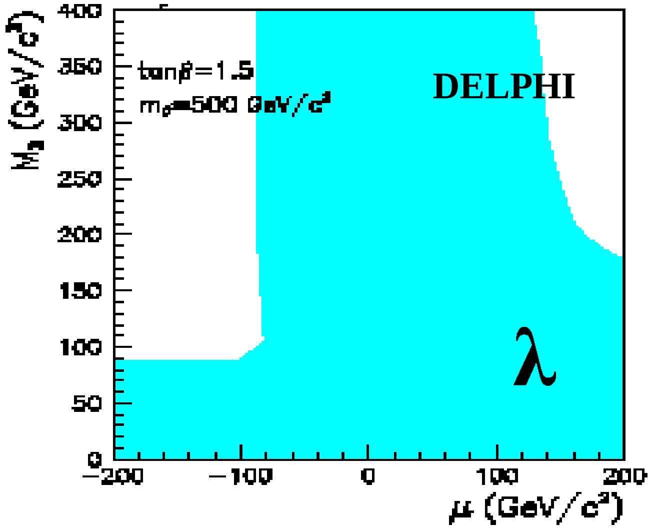
	$LL\bar{E}$	$LQ\bar{D}$	$\bar{U}\bar{D}\bar{D}$
$\tilde{\chi}^0\tilde{\chi}^0$	$4l + \not{E}$	$1,2l + 4j + \not{E}$ $2l + 4j$	$6j$
$\tilde{\chi}^{\pm}\ \tilde{\chi}^{\pm}\ (dir.)$	$2,4,6l + \not{E}$	$1,2l + 4j + \not{E}$	$6j$
$\tilde{\chi}^{\pm}\ \tilde{\chi}^{\pm}\ (ind.)$	$\tilde{\chi}^0\tilde{\chi}^0 + WW$ $\geq 4l + nj + \not{E}$	$\tilde{\chi}^0\tilde{\chi}^0 + WW$ $\geq 4j + nl + \not{E}$	$\tilde{\chi}^0\tilde{\chi}^0 + WW$ $\geq 6j + nl$

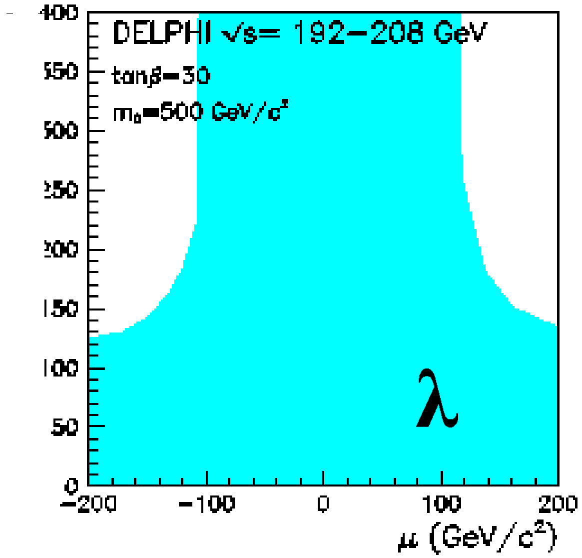
- $\tilde{\chi}^{\pm}$ **indirect decay is the dominant decay channel in almost all the MSSM parameter space**

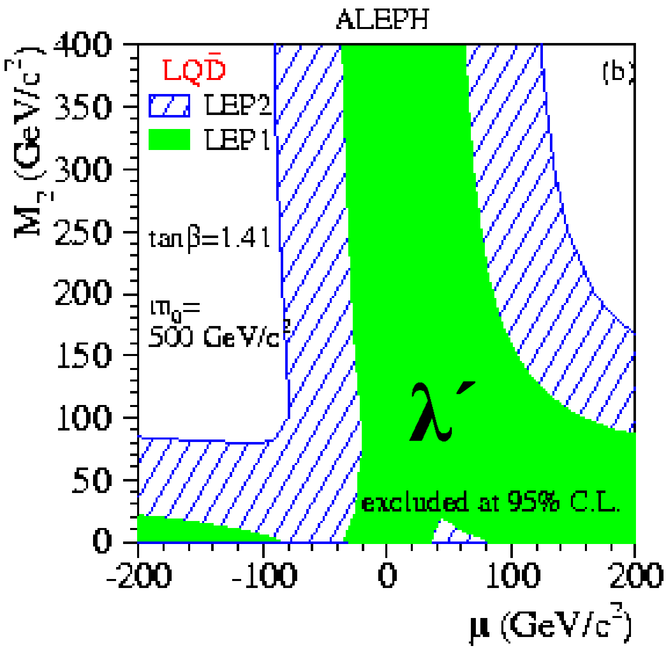
Limits from Gaugino searches

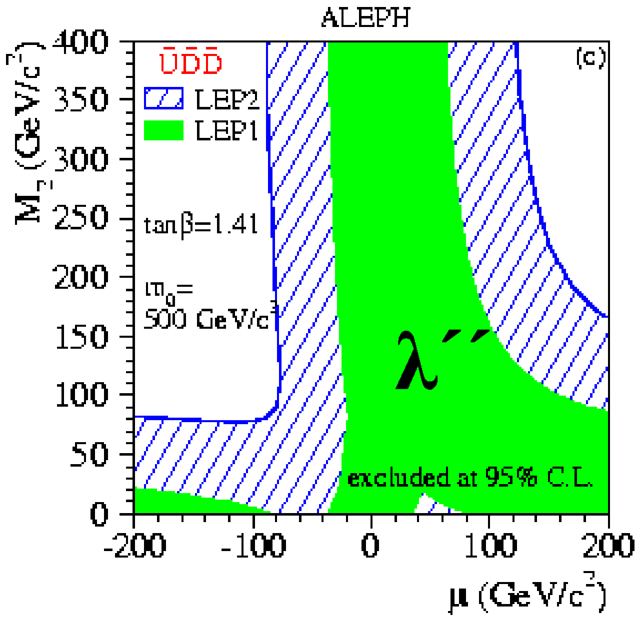
- **Limits in MSSM parameter space**

Scans in μ , M_2 for different values of m_0 and $\tan\beta$







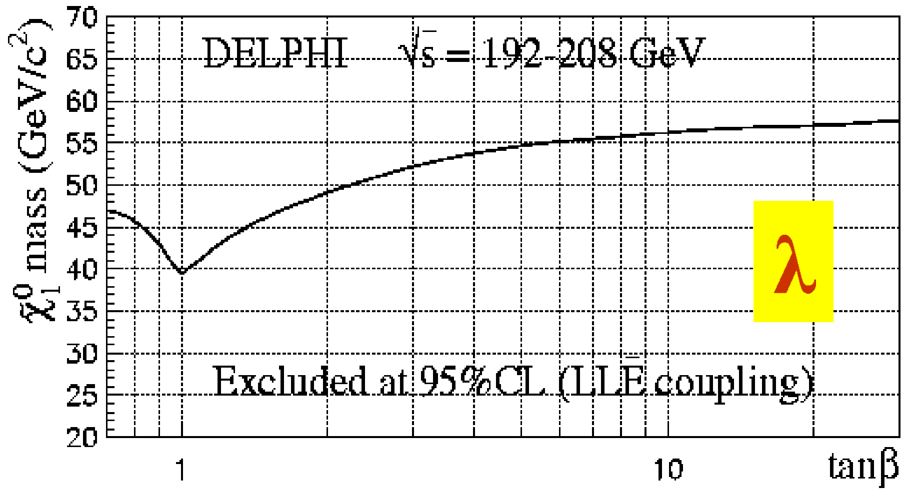


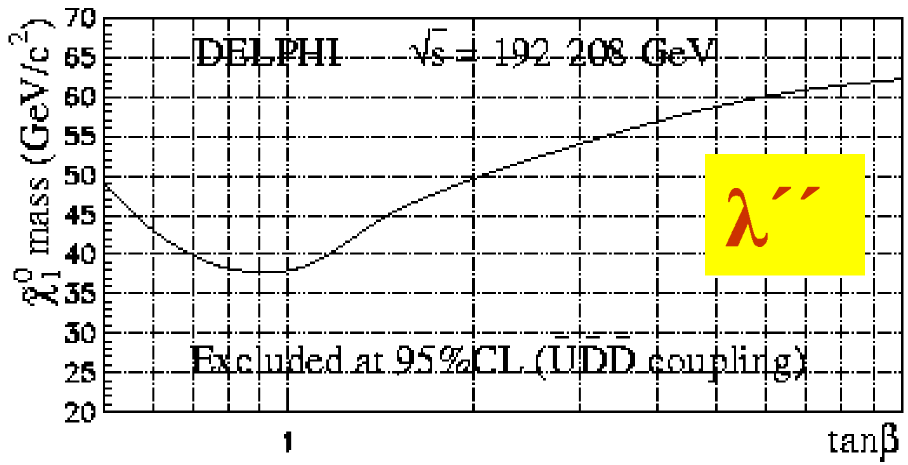
Gaugino mass limits

A D L O

- **Mass limits**
  at 95 % CL in GeV/c²

		λ	λ'	λ''
$\tilde{\chi}_1^0$	L	40.2	—	39.9
	D	39.5	—	38.0
$\tilde{\chi}_2^0$	L	84.0	—	80.0
$\tilde{\chi}_3^0$	L	107.2	—	107.2
$\tilde{\chi}_1^\pm$	A	103	103	103
	D	103		102.5
	L	103.0	—	102.7

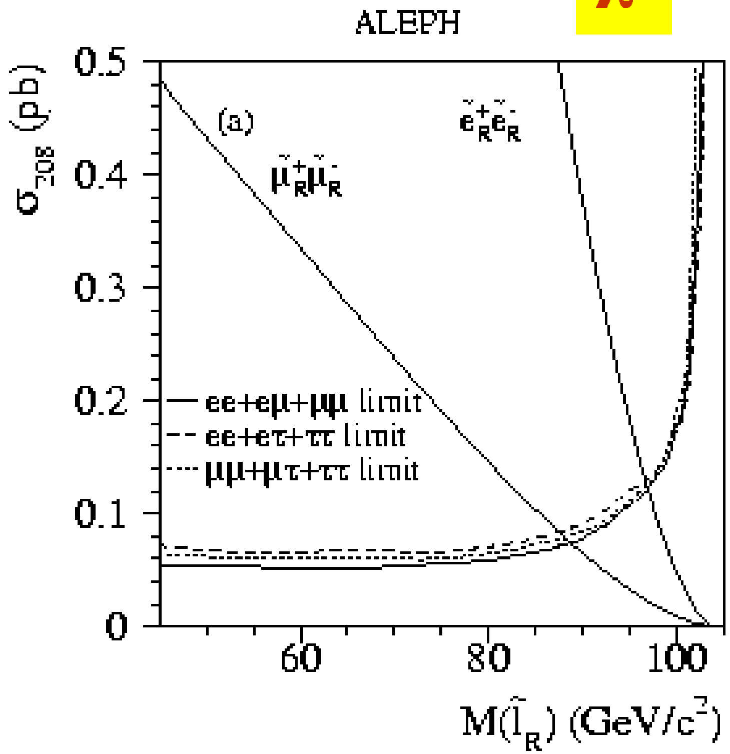




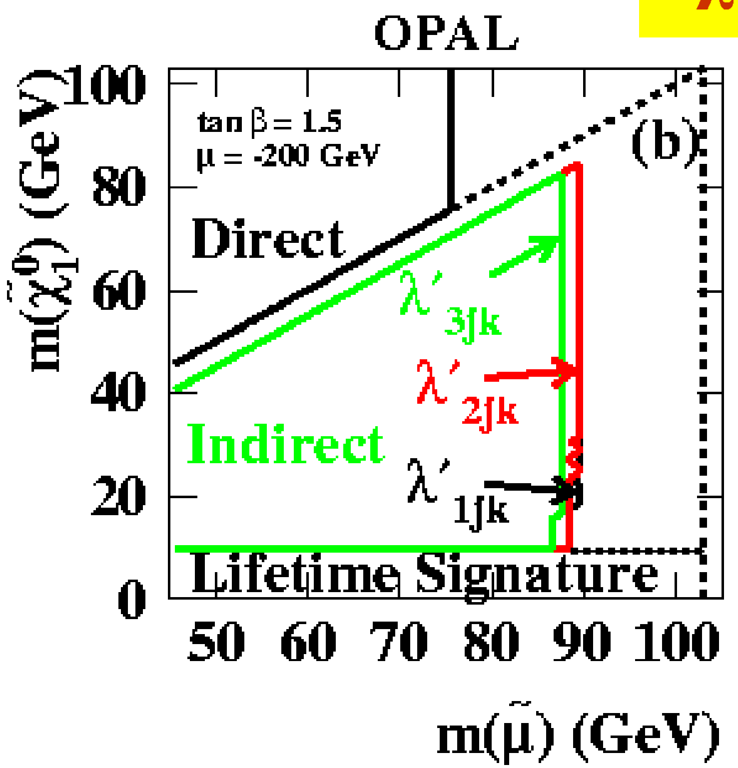
$\tilde{e}\,,\tilde{\mu}\,,\tilde{\tau}$

- **Direct decay :** $e^+e^- \rightarrow \tilde{l}\,\tilde{l} \rightarrow 4\ fermions$
- **Indirect decay :** $e^+e^- \rightarrow l\,l\,\tilde{\chi}_1^0\,\tilde{\chi}_1^0 \rightarrow 8\ fermions$

λ

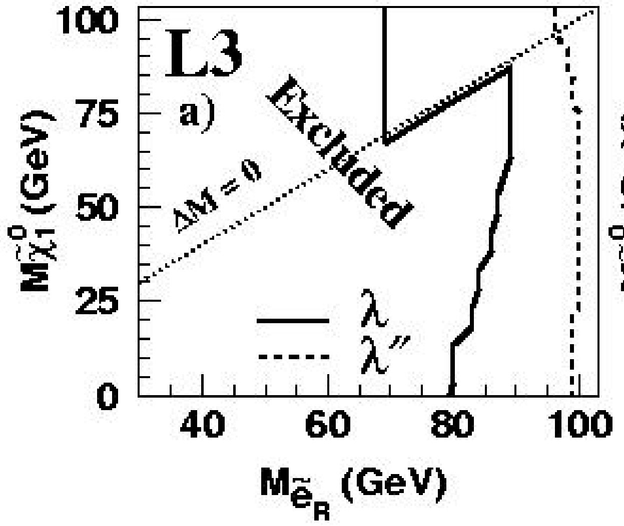


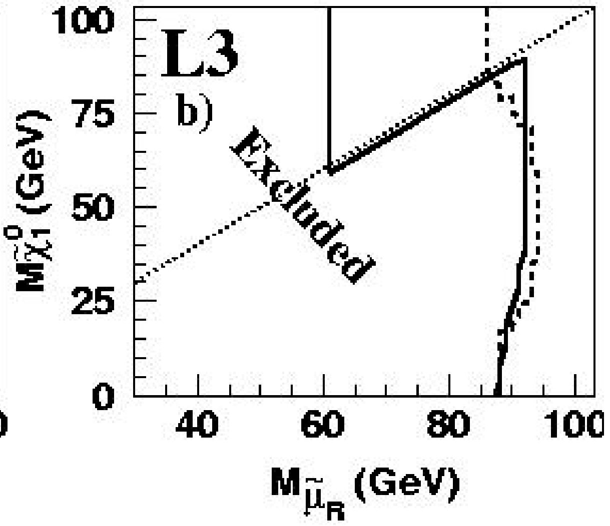
λ´



μ=200 GeV/c^2, tanβ=1.5, BR=1

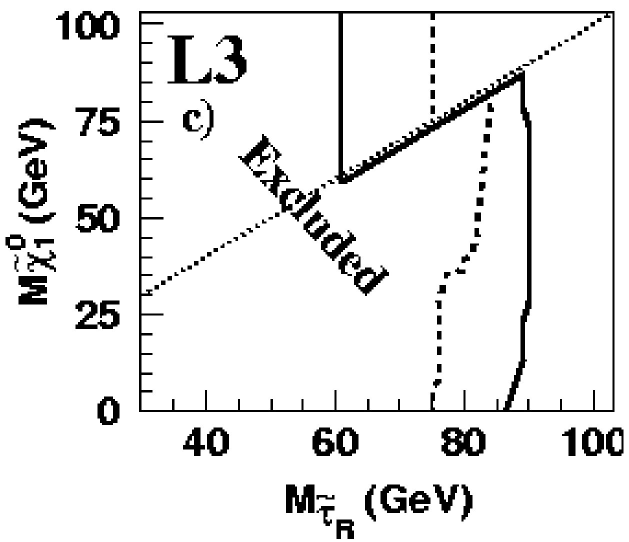
slepton pair production

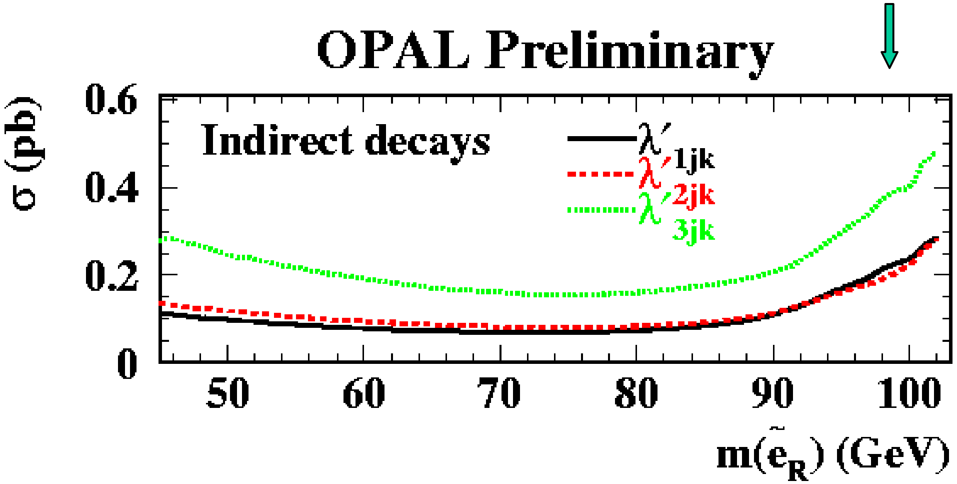




- **MSSM exclusion contours, at 95 % C.L.**

- **Cross-section upper limits, at 95 % C.L.**

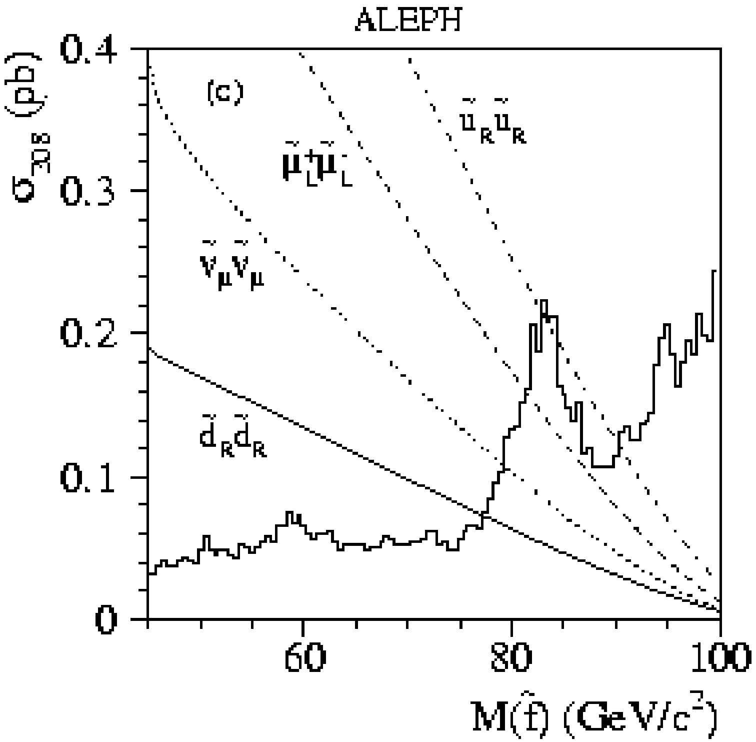




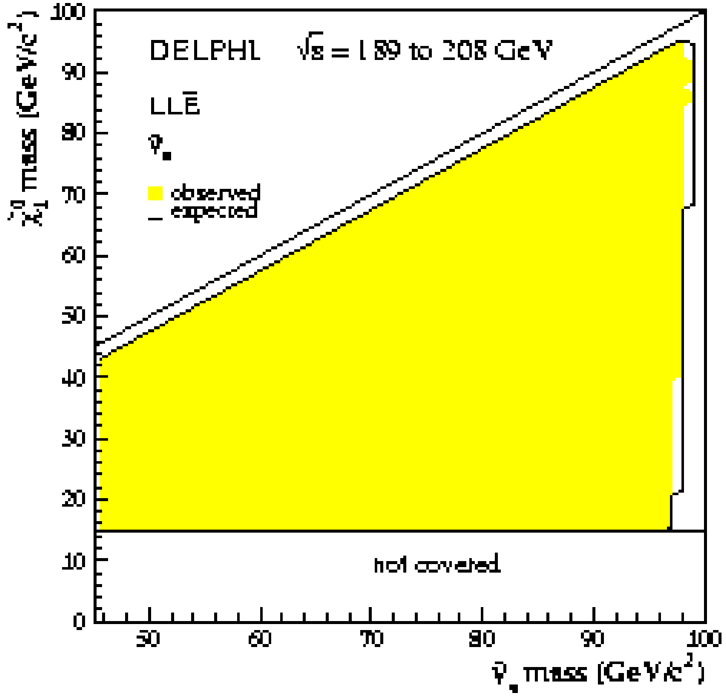
Sneutrino pair production

$\tilde{\nu}_e, \tilde{\nu}_\mu, \tilde{\nu}_\tau$

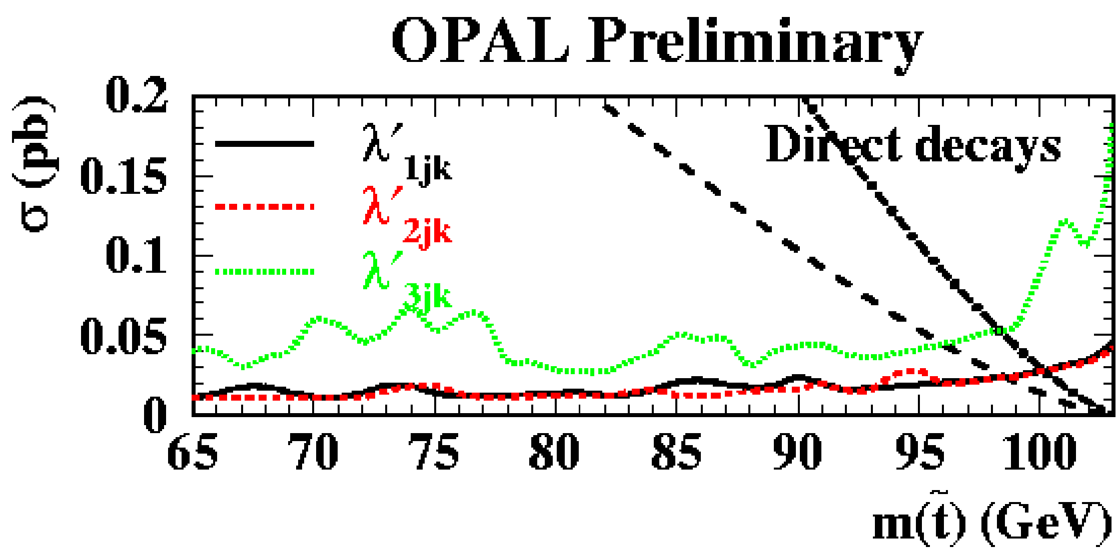
- **Direct decay :** $e^+ e^- \rightarrow \tilde{\nu}\,\tilde{\nu} \rightarrow 4\ fermions$
- **Indirect decay :** $e^+ e^- \rightarrow \nu\,\nu\,\tilde{\chi}_1^0\,\tilde{\chi}_1^0 \rightarrow 8\ fermions\,(2\nu)$



Excluded $\tilde{\nu}\,\tilde{\nu}$ cross-section (4 jets)



Excluded contour , at 95% CL for $\tilde{\nu}_e$ for indirect decays

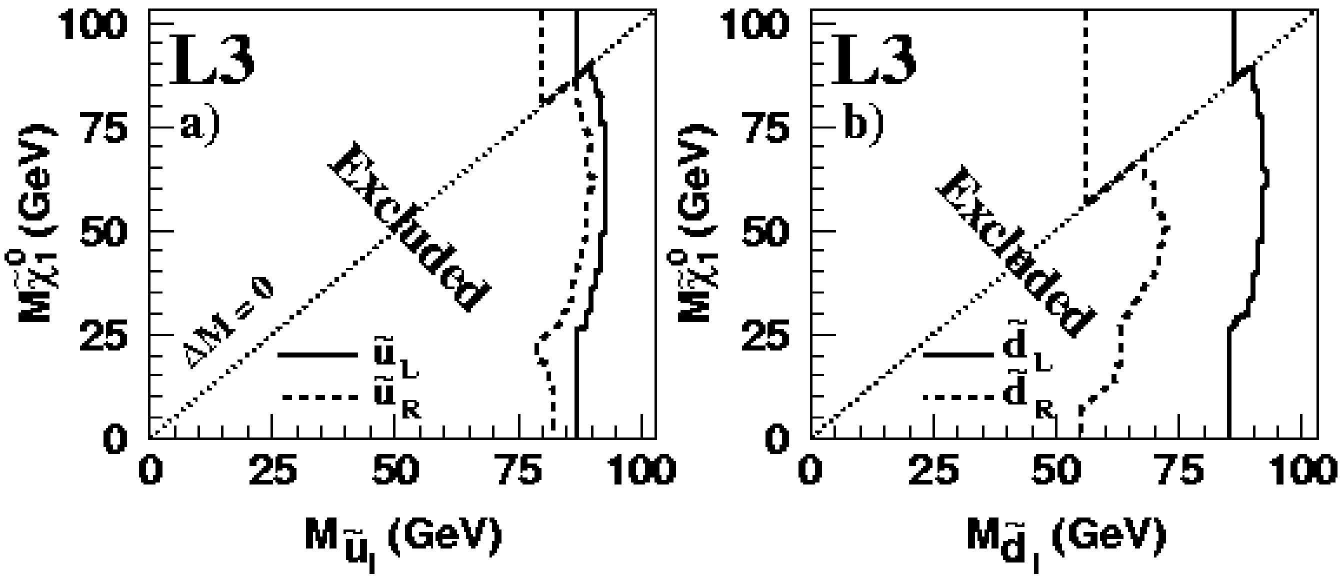


- **Direct decays :**

  => $\tilde{q}\,\tilde{q}$ => 4 fermions

- **Indirect decays :**

  => $q\,q\,\tilde{\chi}^0_1\tilde{\chi}^0_1$ => 8 fermions



λ′′

MSSM

Exclusion contours, at 95% CL

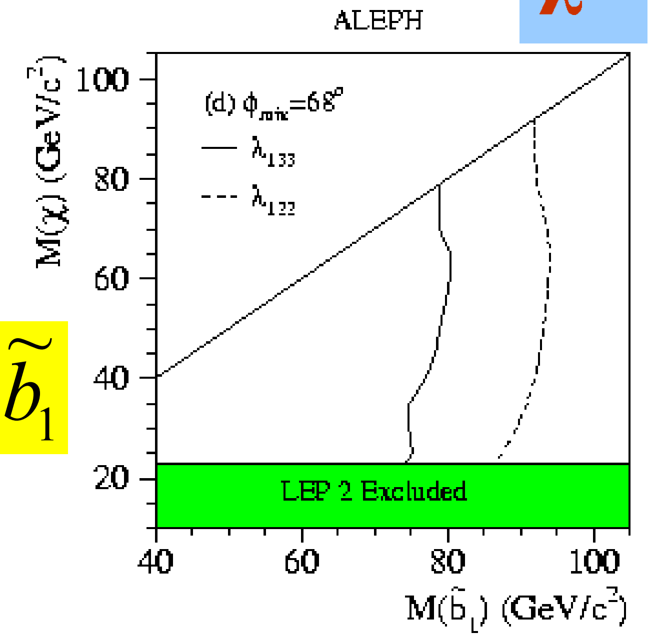
$\tilde{t}\ ,\tilde{b}$

• **Mixing :** $\tilde{t}_1 = \tilde{t}_L\ \cos\phi_{\tilde{q}} + \tilde{t}_R \sin\phi_{\tilde{q}}$

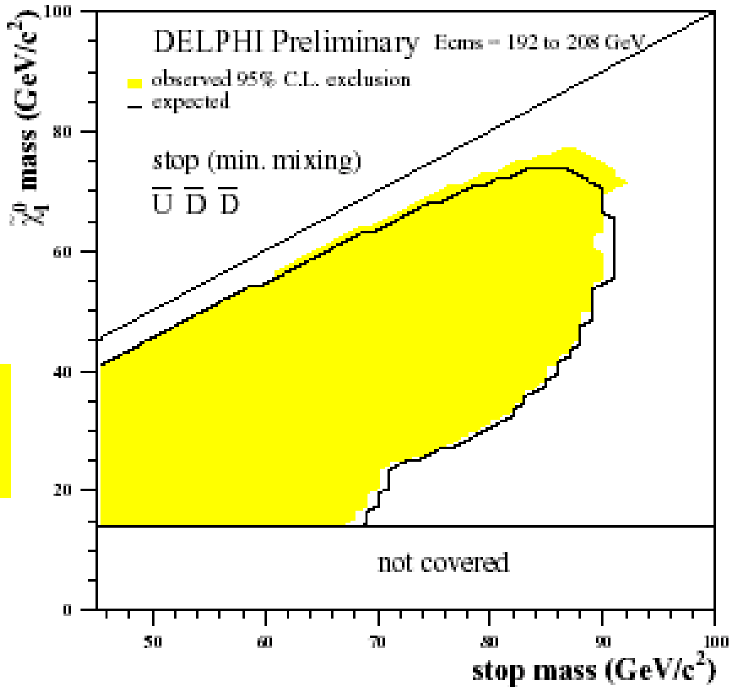
λ´´

λ

$\tilde{b}_1$



$\tilde{t}_1$



$\phi_{\tilde{b}} = 68^0$

• **Exclusion contours at 95% CL**

$\phi_{\tilde{t}} = 56^0$

Mixing angle to vanishing coupling to Z for $\tilde{t}\ ,\tilde{b}$ **=> σ min**

Conclusions for RpV searches

- RpV has inspired new interesting scenarios of SUSY searches
- RpC and RpV are two complementary ways of SUSY searches
- Searches for SUSY with RpV performed by all LEP collaborations (ADLO) in …many channels
- No evidence for SUSY with RpV so far at LEP
- Limits on SUSY particles and RpV Couplings are set at 95% CL
- Limits from RpV are in the majority of cases more conservative than the RpC ones

Extra Dimensions

- Why extra dimensions ?
- Why not ? String people believe that $d = 10$
- Extra dimensions compact on some size $R \sim 1 / M_p$
- Why is gravity so weak ? $M_P = \sqrt{1/G_N} \sim 10^{18}$ GeV

Scenario

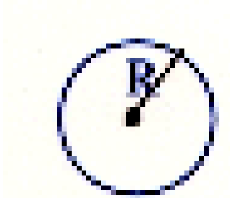
- **SM particles are confined to 3 + 1 space – time dimension**
- **Gravity propagates in $4 + \delta$ dimensions**

Extra Dimensions : Motivation

➢ **Gauss law must work in 4 and 4 + δ dimensions**

$$\frac{1}{M_P^2 r^2} \quad \textbf{vs} \quad \frac{1}{m_D^{\delta+2}\, r^{\delta+2}}$$

- **M_D is the fundamental Planck scale when r = R**
- **Hence** $M_P^2 \approx M_D^{\delta+2}\, R^{\delta}$
- **If M_D ~ 1 TeV , we have**



δ = 1 → R = 10^{13} m → excluded by macroscopic gravity

d = 2 → R = 1.0 mm → limit of small-scale gravity experiments

d = 7 → R = 1.0 Fm

=> Extra dimensions are compactified over R < 1 mm

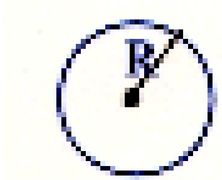
Extra - Dimensions

Arkani-Hamed, Dimopoulos, Dvali (ADD)

Our world is (4 + d) dimensional

SM fields live on a 4 – brane while gravity can propagate in the d extra compactified dimensions(“ bulk ”)

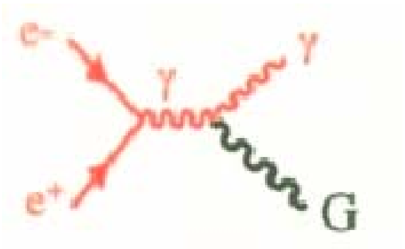
- **The gravity is strong in the “bulk” but weak at the 4-brane**
- **R can be large (~1 mm)**

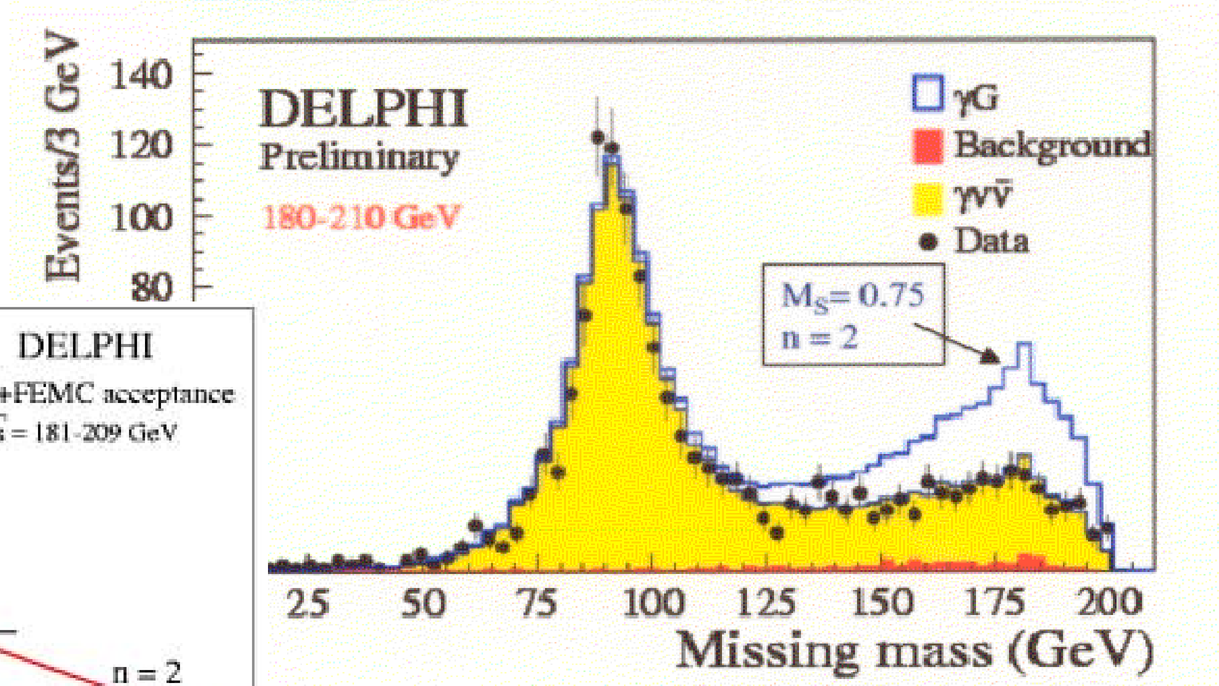


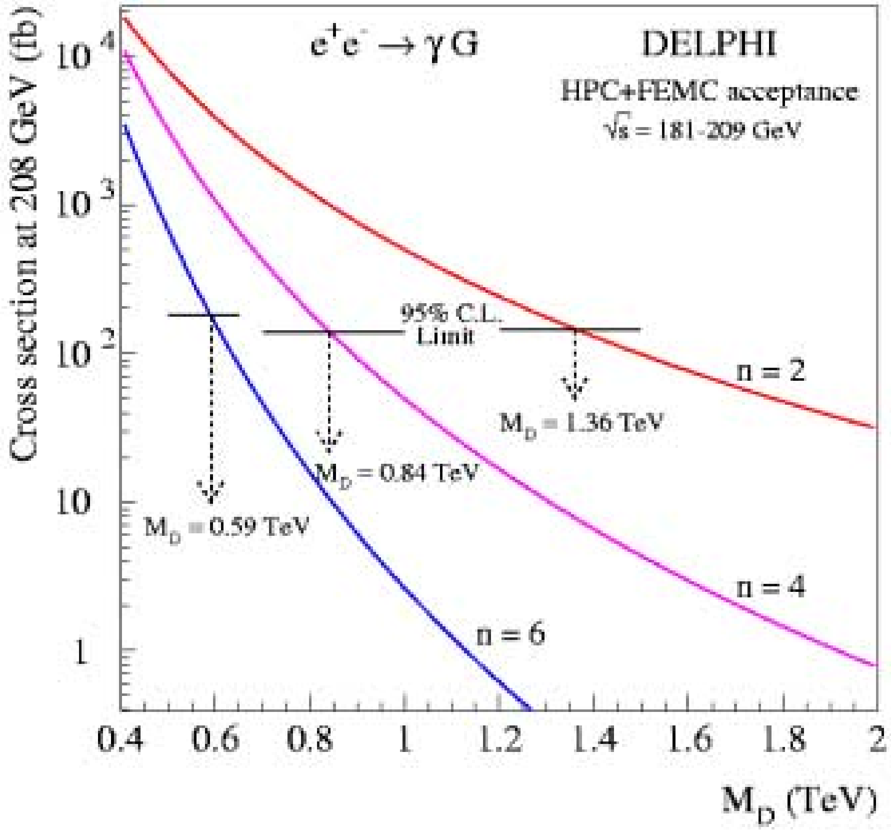
$\Rightarrow$ **Infinite tower of KK excitations of Graviton G^k**

investigation in the production cross-section of $t\,\bar{t}$ pairs at the LHC

Extra - Dimensions







signature is $\gamma + E_{miss}$

Direct search

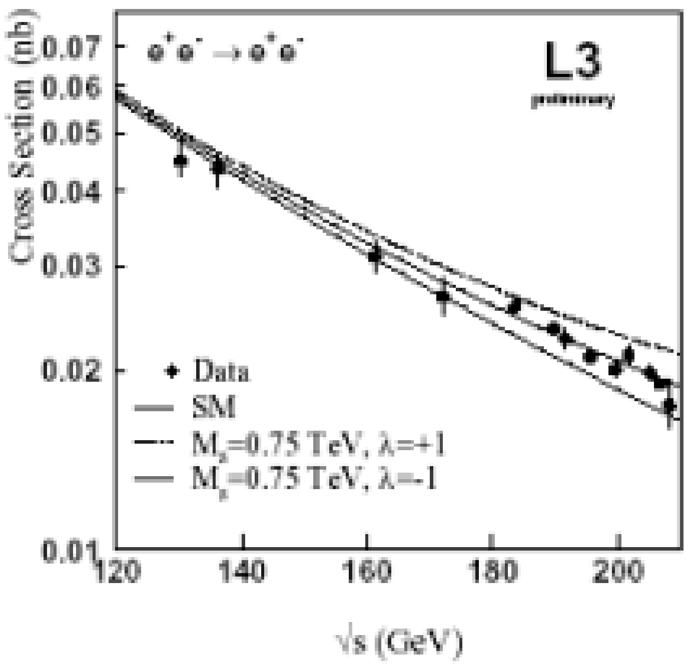
at DELPHI

Extra - Dimension

Indirect Search in LEP

Virtual G Exchange :

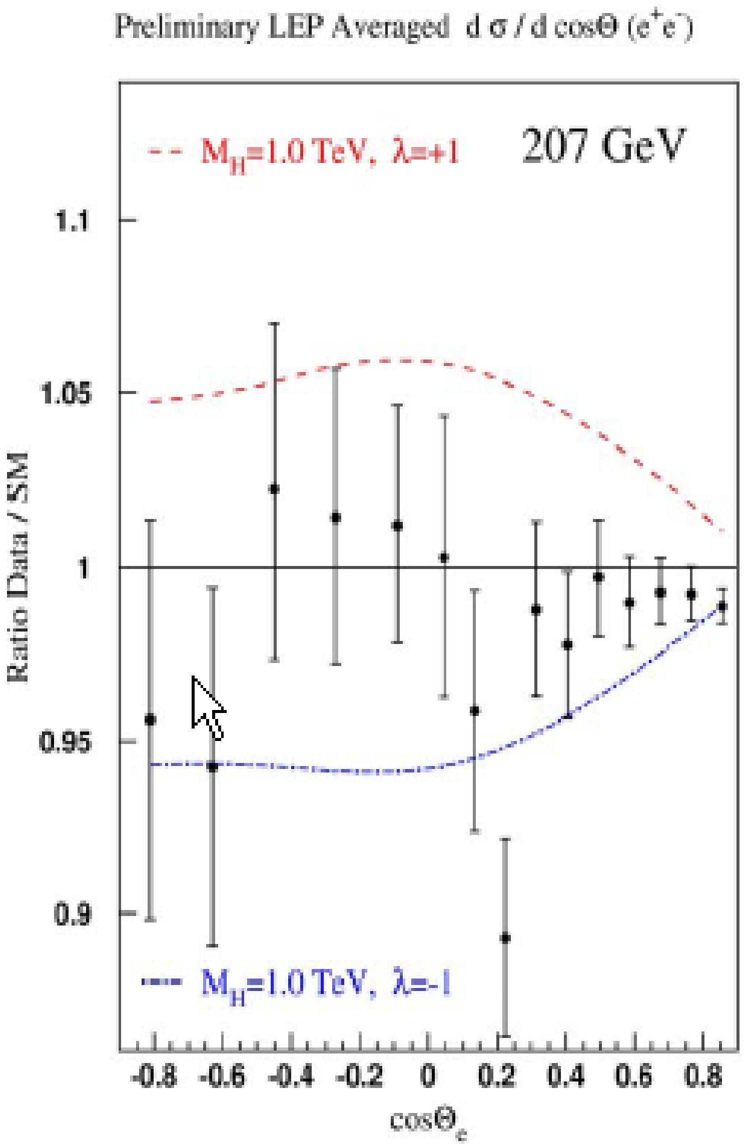
$$e^+e^- \to G^* \to f\,\bar{f}$$



λ = -1

λ =+1

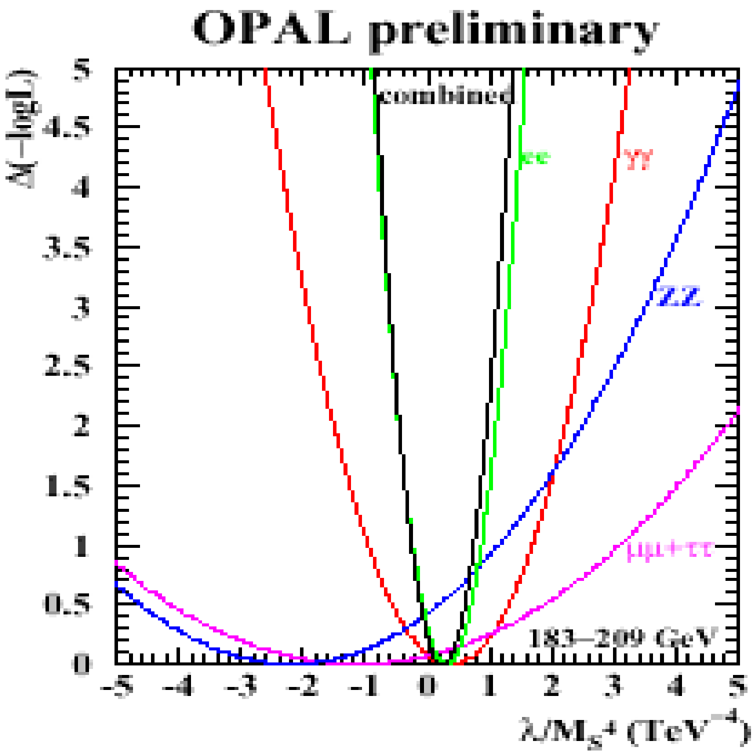
Best fit

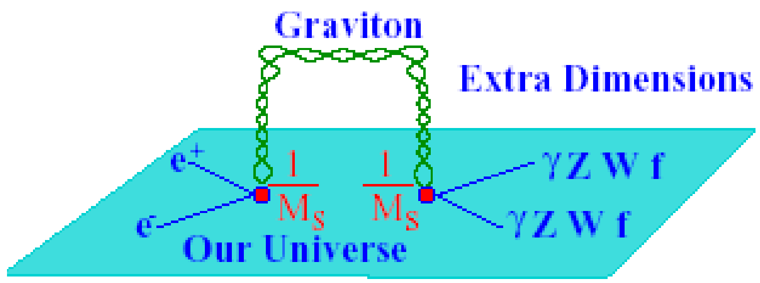


Extra Dimensions

Combined Limits at LEP

for indirect search





OPAL preliminary

M_D (λ =+1) > 1.03 TeV

M_D (λ =-1) > 1.17 TeV

Conclusions

- **Results from 4 LEP experiments are consistent and in good agreement with each other.**
- **Preliminary LEP combined results are in good agreement with SM expectations**

- **No evidence for New Physics at LEP**

- **Interesting new physics is expected to appear at the TeV range at LHC & NLC**

As an Epilogue

LEP 2 HERA Tevatron LHC & NLC

? ? ?

desert ?

New Physics ?

- **All hopes are shifted to future colliders !**

" Ithaki gave us the rewarding travel ……! "

C. Kavafys