LEP Search for Single Top production and new fermions

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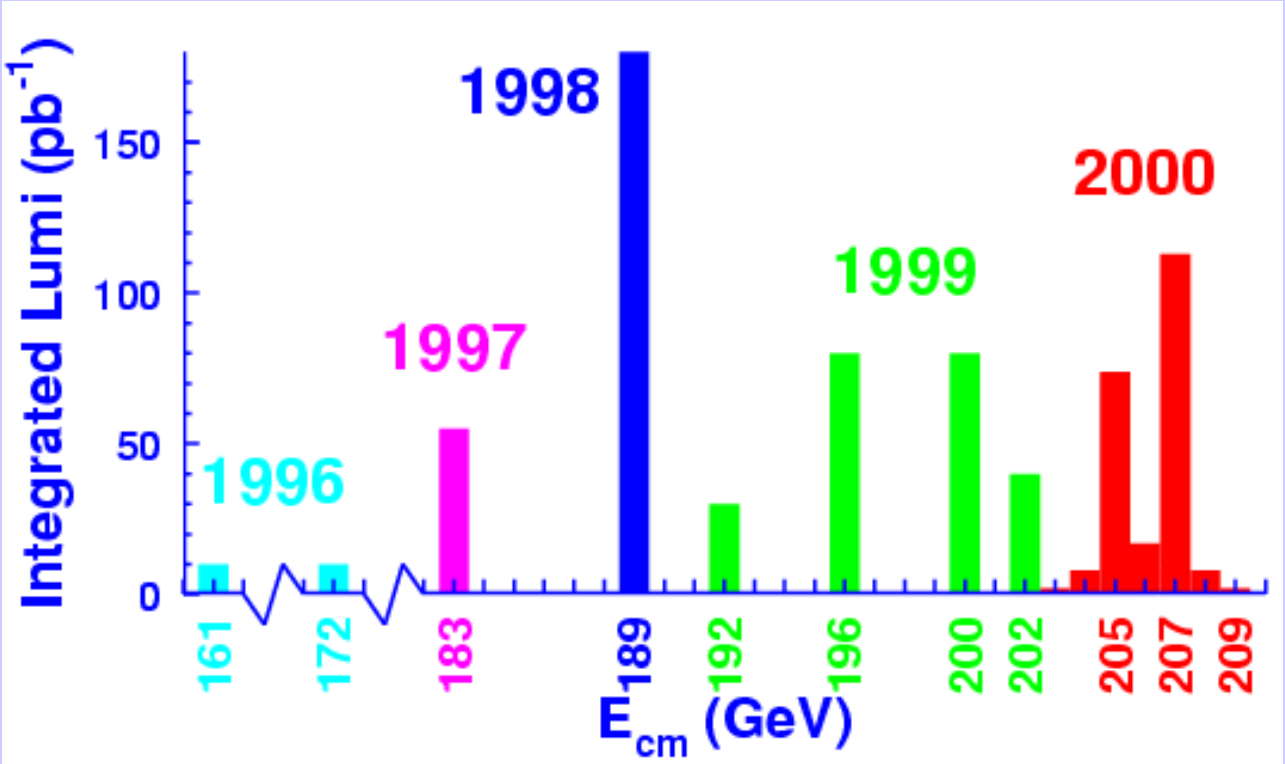
Amsterdam

on behalf of the 4-  experiments

The LEP e^+e^- collider



High centre of mass energy + Luminosity
+ clean experimental environment

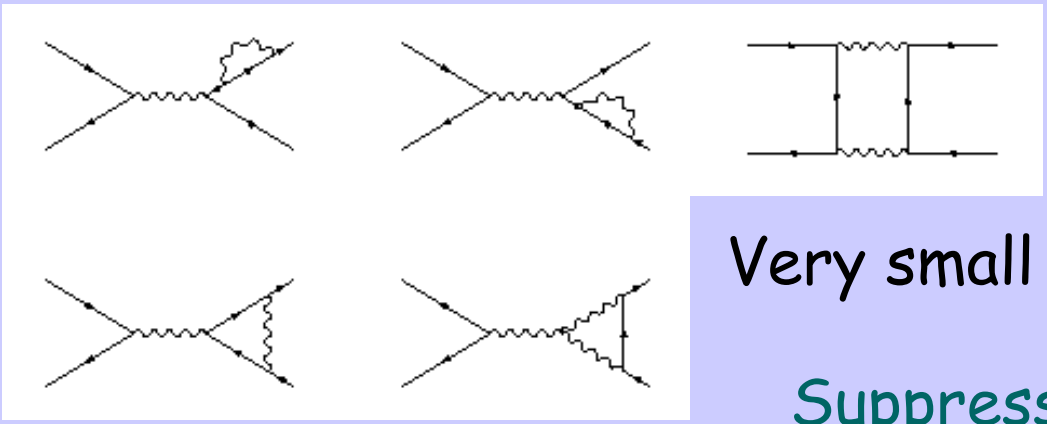
All limits are at 95 % CL and preliminary

Search for single top production via FCNC

$$e^+e^- \rightarrow t\bar{q} \quad (\bar{q} = \bar{c}, \bar{u})$$

At tree level SM, there are no vertices for these FCNC processes (GIM mechanism $V_{CKM}=V_{CKM}^{-1}$).

FCNC appear at loop level



Very small cross section (10^{-9} fb)

Suppressed by loop + GIM

Extensions of SM could lead to enhancement of such transitions

The FCNC vertices tqV (V = γ,Z) probed in

- rare decays of top quark
- top-q associated production

Existing limits

TEVATRON: $p\bar{p} \to t\bar{t}X$

CDF:

$BR(t \to c\gamma) + BR(t \to u\gamma) < 3.2\%$

$BR(t \to cZ) + BR(t \to uZ) < 33\%$

↳ very weak constraint: $N_{tt} \sim 10^2$

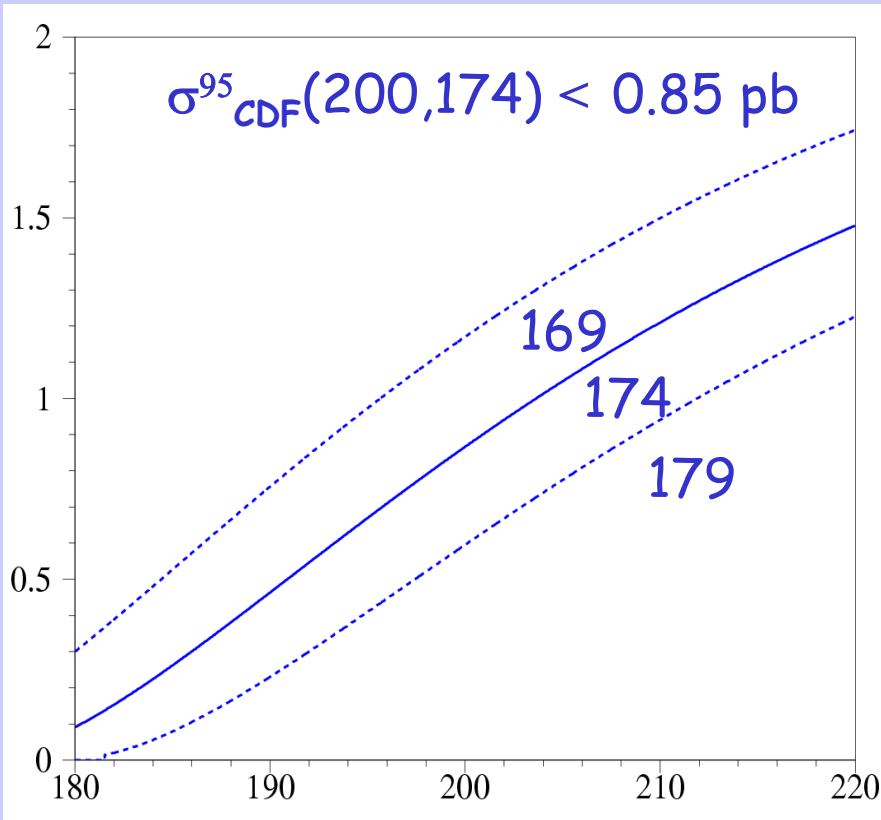
HERA: $ep \to eu\bar{t}X$

Sensitivity to tuγ coupling $K_{ut\gamma}$

ZEUS:

$BR(t \to u\gamma) < 0.7\%$ ($K_{tu\gamma} < 0.19$)

σ corresponding to CDF limits



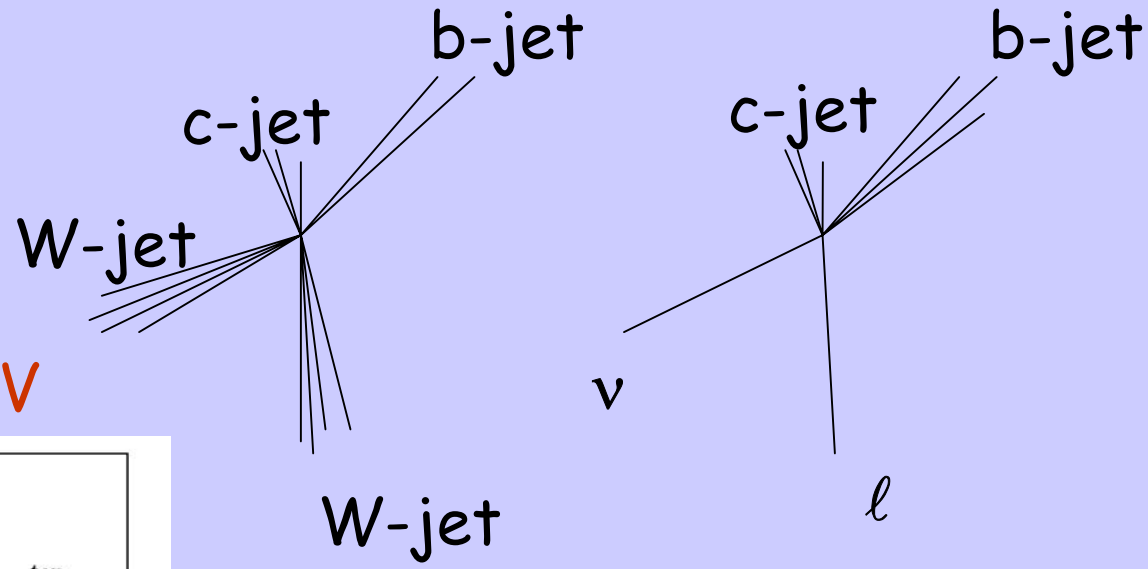
Topologies

Top decays rapidly via
(10^{-24} sec) ⟹ no top hadrons formed

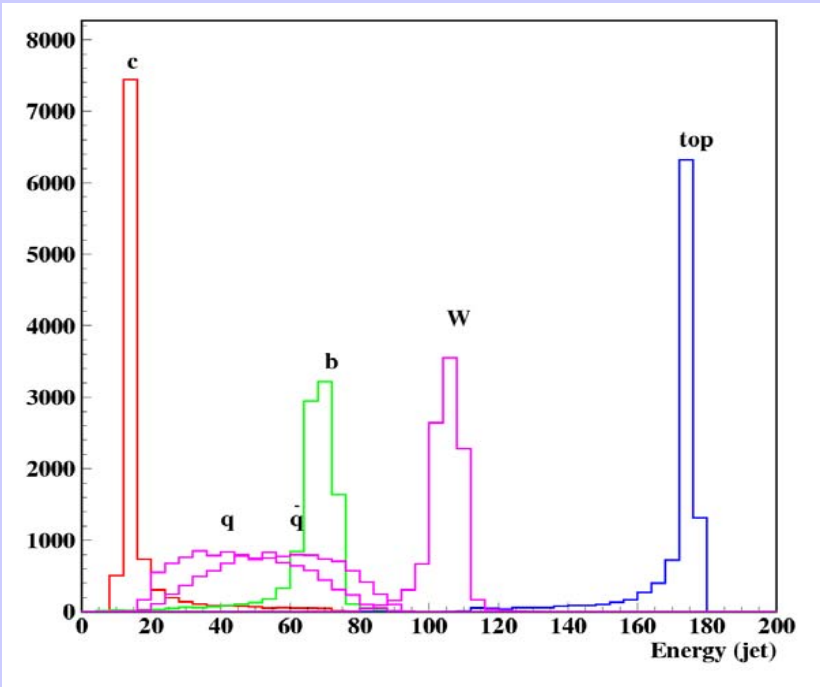
$e^+e^- \to \bar{c}\,t$

$t \to bW$

$W \to f\bar{f}'$



Kinematics at 189 GeV



$E_t \sim m_t$

$E_W \sim (m_t^2+m_W^2-m_b^2)/2m_t$

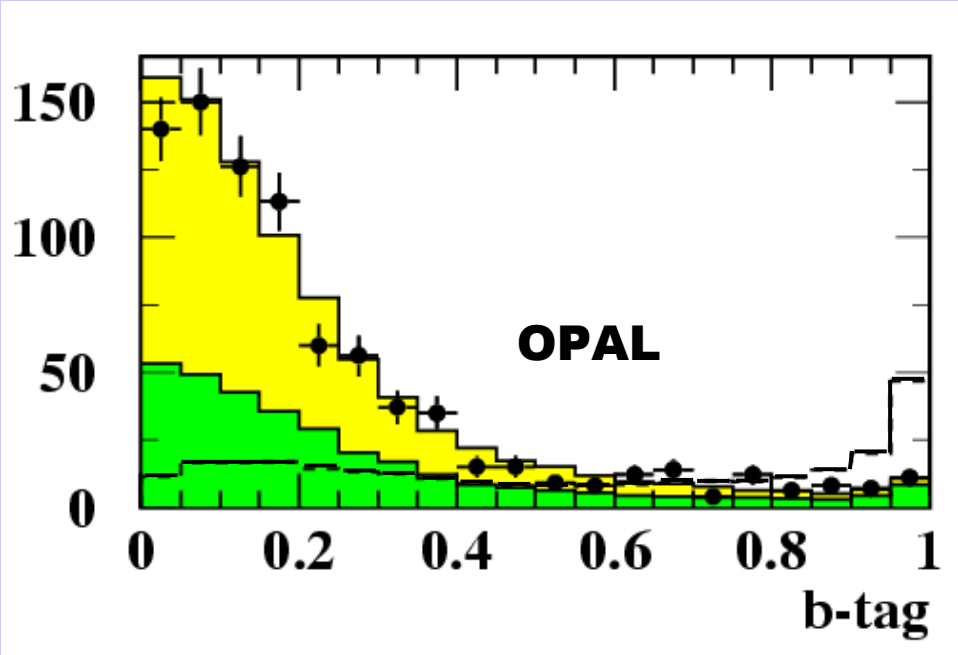
$E_b \sim (m_t^2-m_W^2+m_b^2)/2m_t$

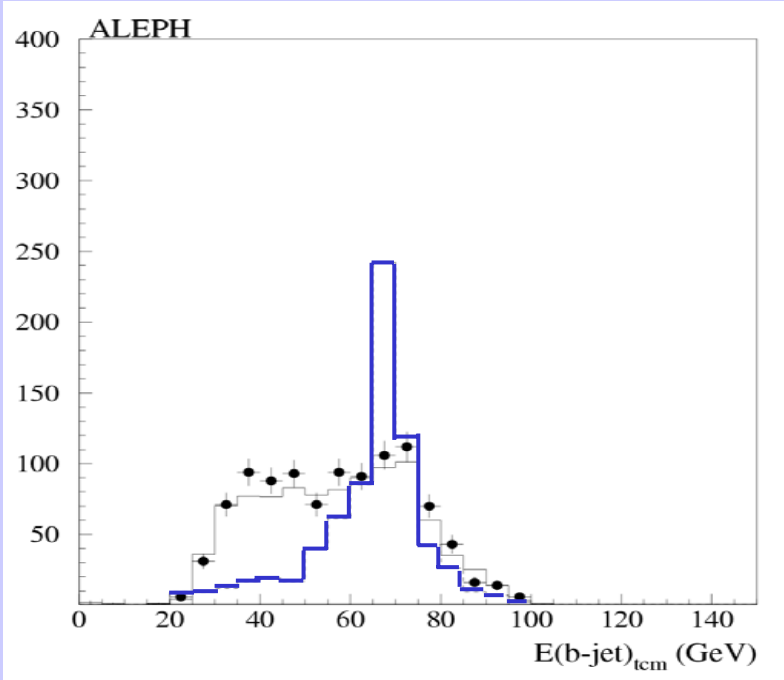
$E_q \sim \sqrt{s} - m_t$

Selections and performances

2 selections: hadronic and Leptonic W decay

kinematics + b-tag + lepton id + Emiss





ε ~ 10%-15% 4%-7%

Bkg ~ 50-200 fb (WW,qq) 10-30 fb (WW)

No excess seen in data

Combined* LEP results LEPEXOTICA WG

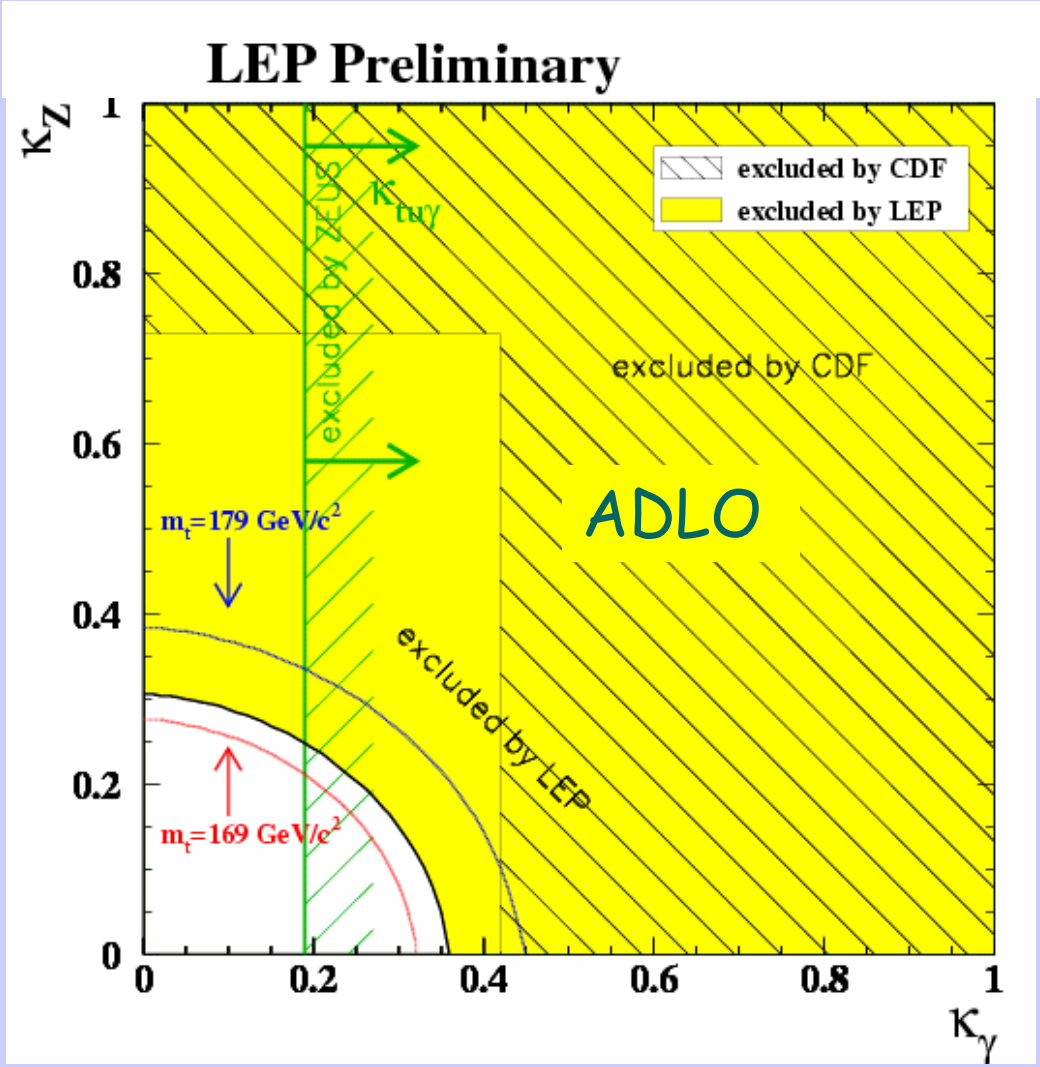
Cross section upper limits for m_t =174 GeV

<√s> GeV	σ95(obs) pb	σ95(exp) pb
189	0.11	0.11
192	0.38	0.33
196	0.36	0.20
200	0.21	0.21
202	0.30	0.35
205	0.20	0.25
207	0.17	0.18

About 0.55 fb^{-1} per experiment

*LR method for combination

Limits on FCNC couplings



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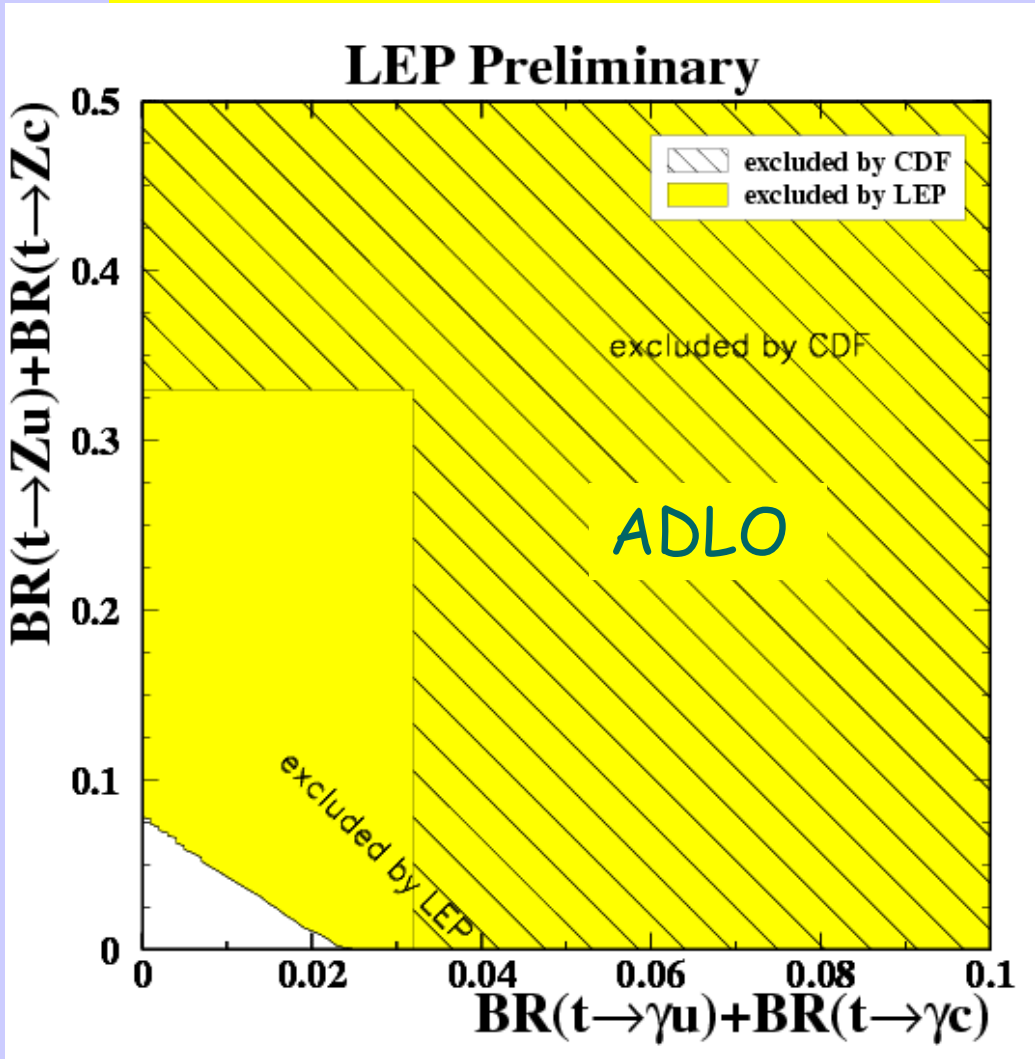
Limits on branching ratios



Search for excited and heavy fermions

Fermions in SM

$$\begin{pmatrix} \nu_e \\ e^- \end{pmatrix}_L \quad \begin{pmatrix} \nu_\mu \\ \mu^- \end{pmatrix}_L \quad \begin{pmatrix} \nu_\tau \\ \tau^- \end{pmatrix}_L$$

$$e_R^- \qquad \mu_R^- \qquad \tau_R^-$$

$$\begin{pmatrix} u \\ d \end{pmatrix}_L \quad \begin{pmatrix} c \\ s \end{pmatrix}_L \quad \begin{pmatrix} t \\ b \end{pmatrix}_L$$

$$u_R\, d_R \qquad c_R s_R \qquad t_R\, b_R$$

and beyond

New fundamental particles ?

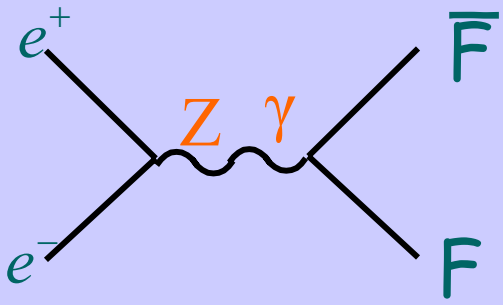
- Sequential, vector, mirror $L^{\pm} L^0$
- Isosinglet neutrino N_l
- Heavy quarks b'

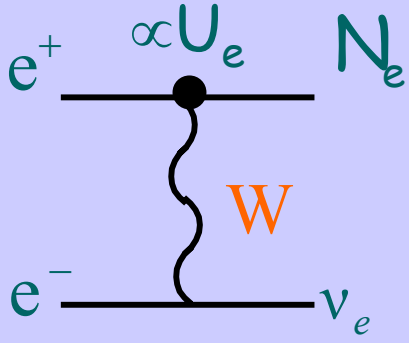
Substructures?

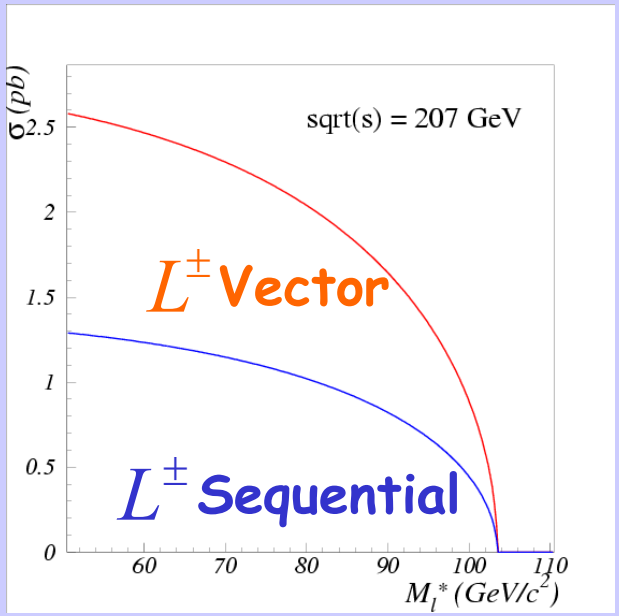
- Excited Leptons $l^* \nu^*_l$

Search for heavy fermions

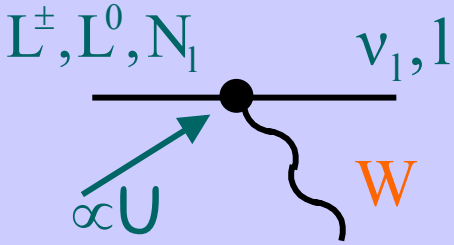
Production:

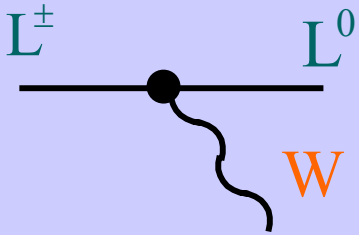




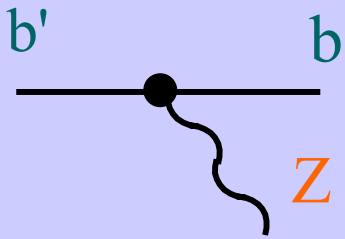


Decay*:





NEW



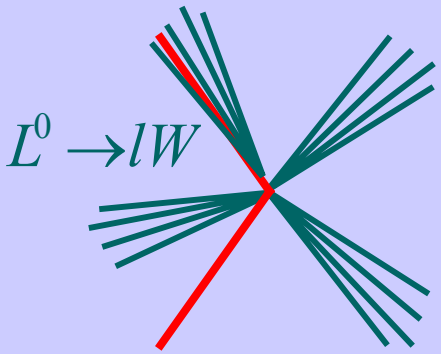
Could be sizeable if :

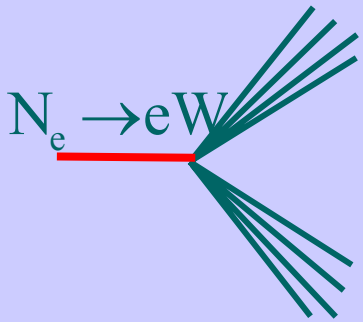
$$M_{b'} < M_t(M_{t'}) + M_W$$

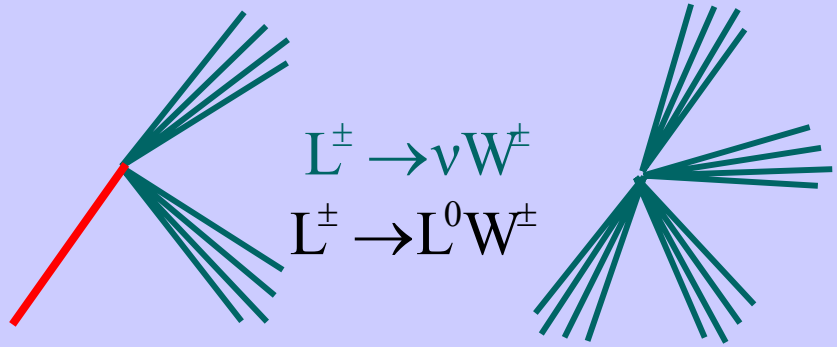
*decay to W favored these energies

Heavy leptons

Jets and leptons

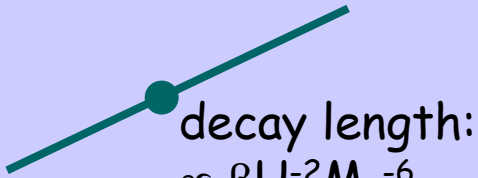






E_{miss} + P_{tmiss} depending on $M_{L^{\pm}} - M_{L^0}$

Heavy stable charged particles



Small U and $M_{L^{\pm}} < M_{L^0}$

	J-L	HSCP
ε	~ 35-15%(5%)	65%
Bkg*	~ 0.3-1 pb	0.01 pb

Candidates in agreement with SM expectation

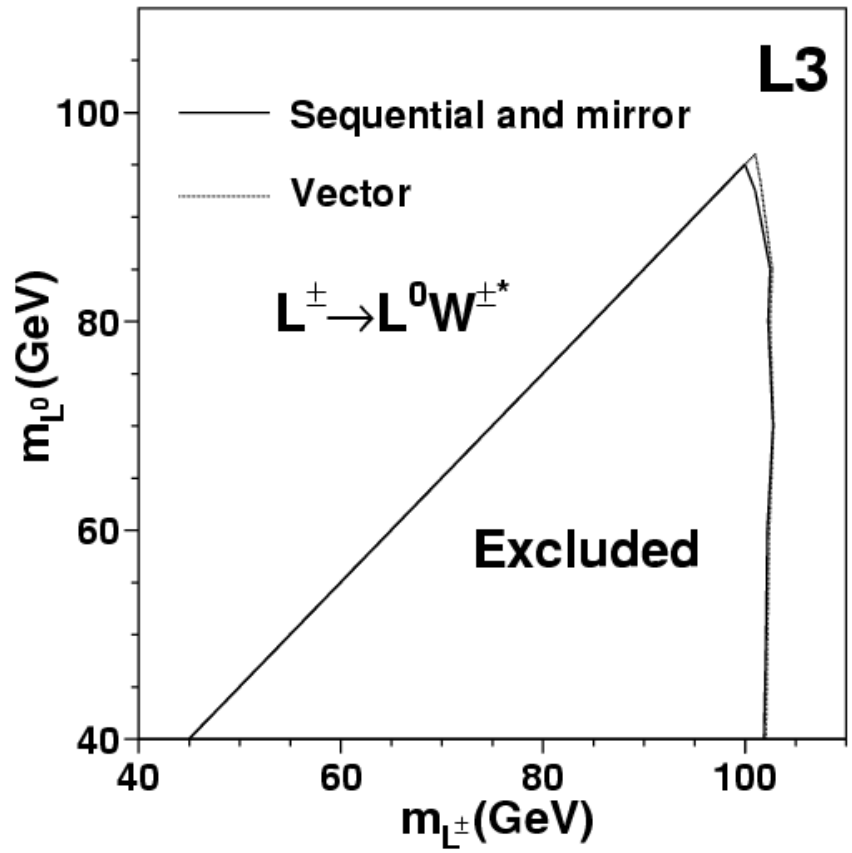
*$WW,\ f\bar{f}(\gamma),\ ZZ,\ \gamma\gamma, \ldots$

Lower mass limits

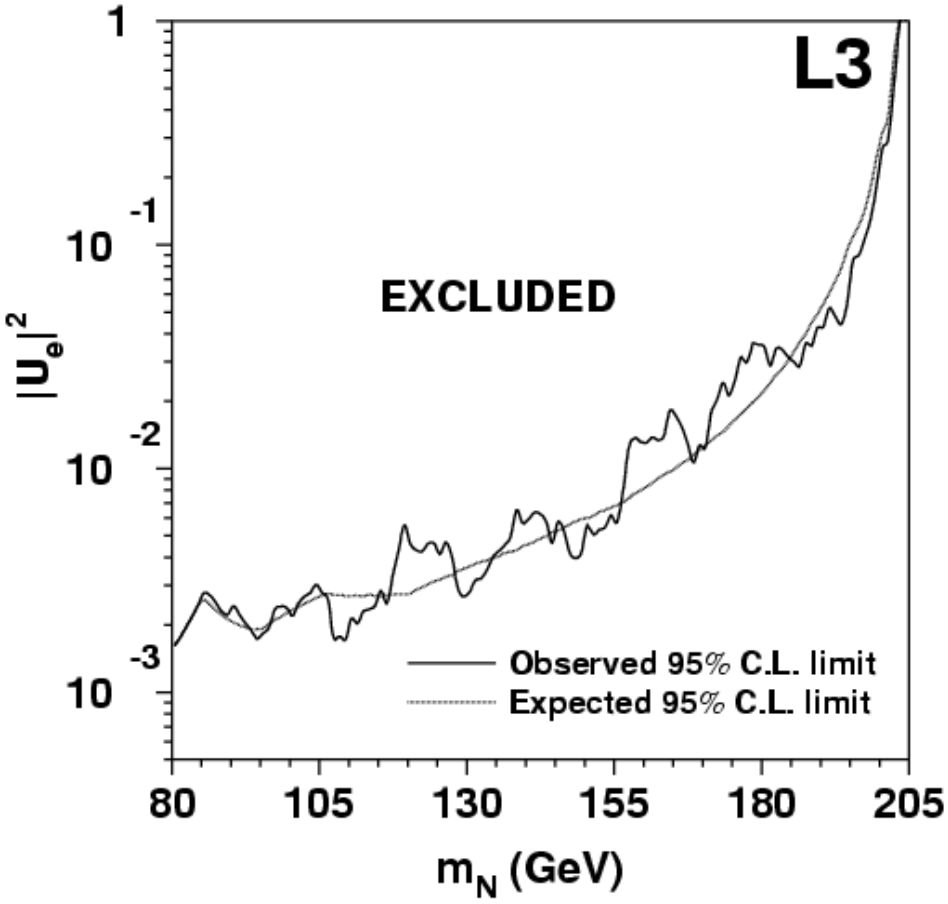
Decay Mode	Model	Dirac	Majorana	Decay Mode	
$L^0 \to e\ W$	Sequential	101.3	89.5	$L^{\pm} \to \nu\ W$	100.8
	Vector	102.6	-----		101.2
	Mirror	100.8	89.5		100.5
$L^0 \to \mu\ W$	Sequential	101.5	90.7	$L^{\pm} \to L^0\ W$	101.9
	Vector	102.7	-----		102.1
	Mirror	101.0	90.7		101.9
$L^0 \to \tau\ W$	Sequential	90.3	80.5	Stable	102.6
	Vector	99.3	-----		102.6
	Mirror	90.3	80.5		102.6

limits

$L^{\pm} \rightarrow L^{0}\ W$



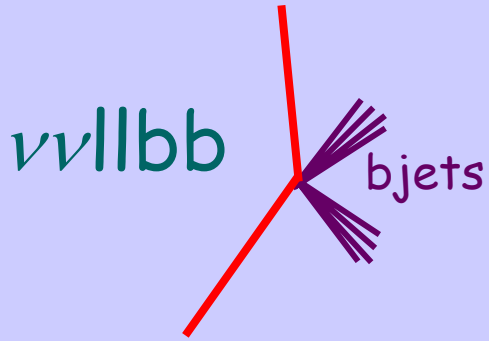
$N_e \rightarrow eW$

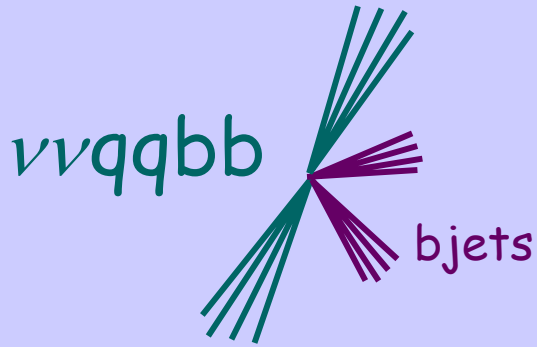


$|U_l|^2 < 10^{-7}$ $M_N < 3$ GeV

$|U_l|^2 < 10^{-5} - 10^{-3}$ $3 < M_N < 80$ GeV

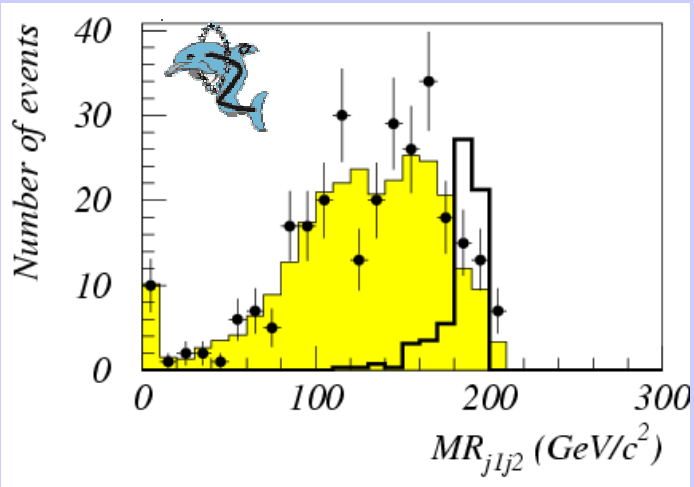
Search for $e^+e^- \rightarrow b'\bar{b}' \rightarrow b\bar{b}ZZ$ NEW

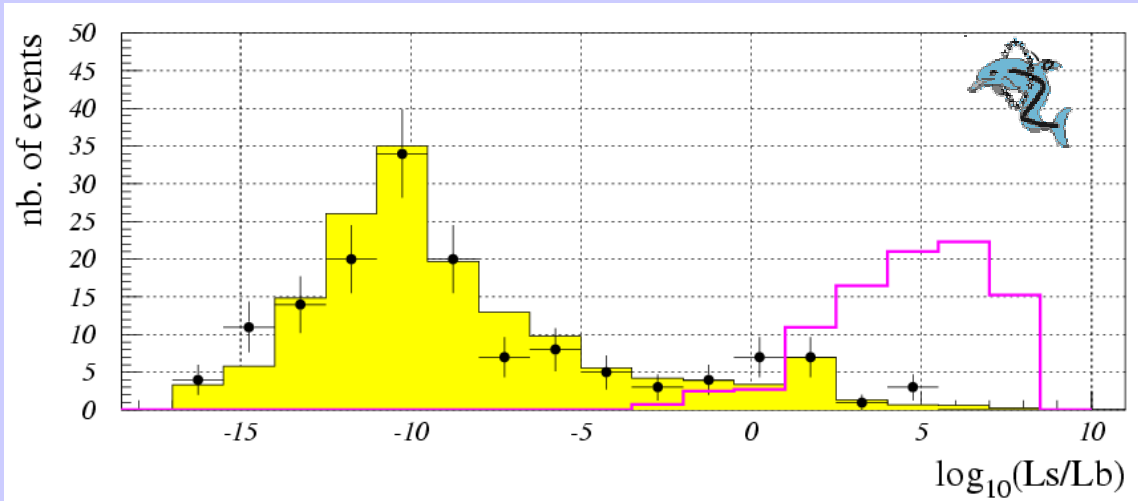




+ clean signature
- BR (ZZ->llvv) ~4%

- large background
+ BR (ZZ->qqvv) ~28%





simple cut analysis

shape analysis

Search for $e^+e^- \to b'\bar{b}' \to b\bar{b}ZZ$ NEW

Preliminary results

about 344 pb^{-1} at energies above 200 GeV

	$\nu\nu llbb$	$\nu\nu qqbb$
efficiency	~50% (x 4%)	~40% (x 28%) for $M_{b'}$=100 GeV
background	~ 8	~665
data	8	599
σ95(exp)	0.8 pb	0.29 pb
σ95	0.65 pb	0.26 pb

σ95= 95% CL upper limit on $\sigma(e^+e^- \to b'\bar{b}')BR(b' \to bZ)^2$

Combined: $\sigma(e^+e^- \to b'\bar{b}')BR(b' \to bZ)^2 < 0.21$ pb for $M_{b'}$=100 GeV

$\sigma(e^+e^- \to b'\bar{b}')SM \approx 0.6$pb at $\sqrt{s}$=206.6 GeV

CDF limits (PRL 84 (2000) 835) $M_{b'}$=100 GeV :

$\sigma(p\bar{p} \to b'\bar{b}')BR(b' \to bZ)^2 < 37$pb

$\sigma(p\bar{p} \to b'\bar{b}')SM \approx 102$pb

DELPHI

$BR(b' \to bZ)^2 < 0.35$

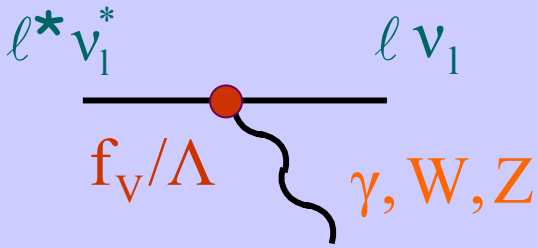
CDF

$BR(b' \to bZ)^2 < 0.36$

Search for excited leptons

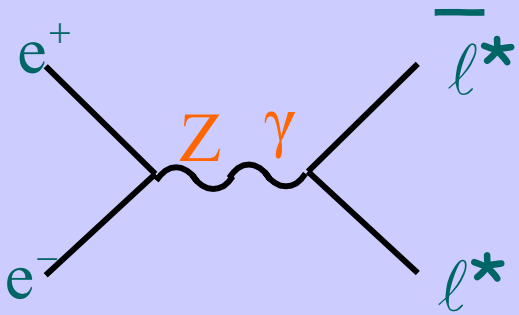
Substructure at a scale Λ ⟹ excited leptons

Prompt decay:

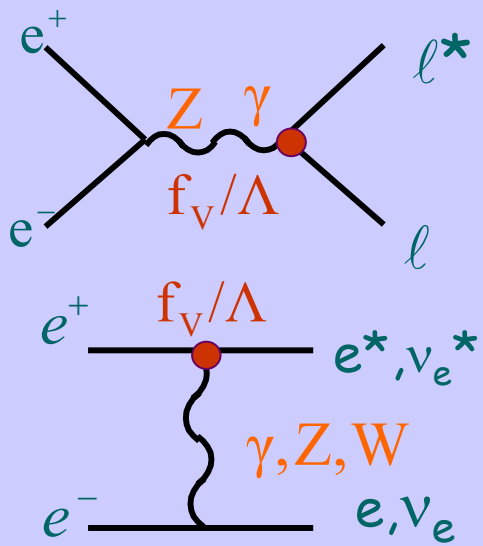


f, f' control strength of SU(2), U(1) couplings
(eg: f=f' no $\nu_e^* \to \nu_e \gamma$ f=-f' no $e^* \to e\gamma$)

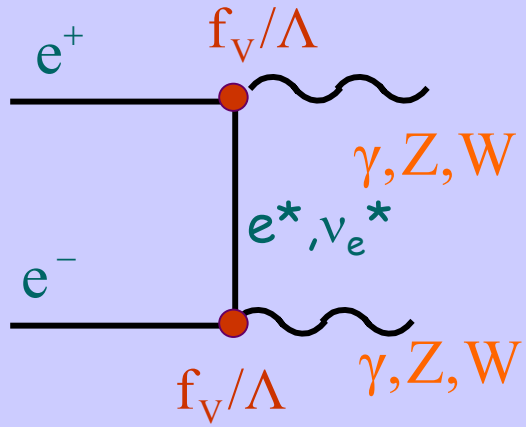
Pair production



single production



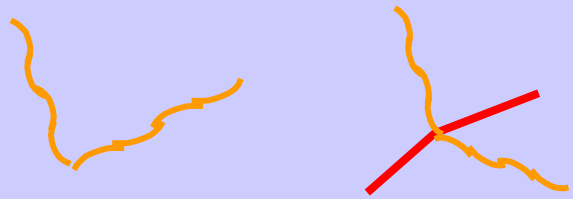
Virtual contribution



Search for pair produced excited leptons

Mass reach up to $\sqrt{s}/2$

Topologies: as heavy leptons +



Photons, Leptons and photons

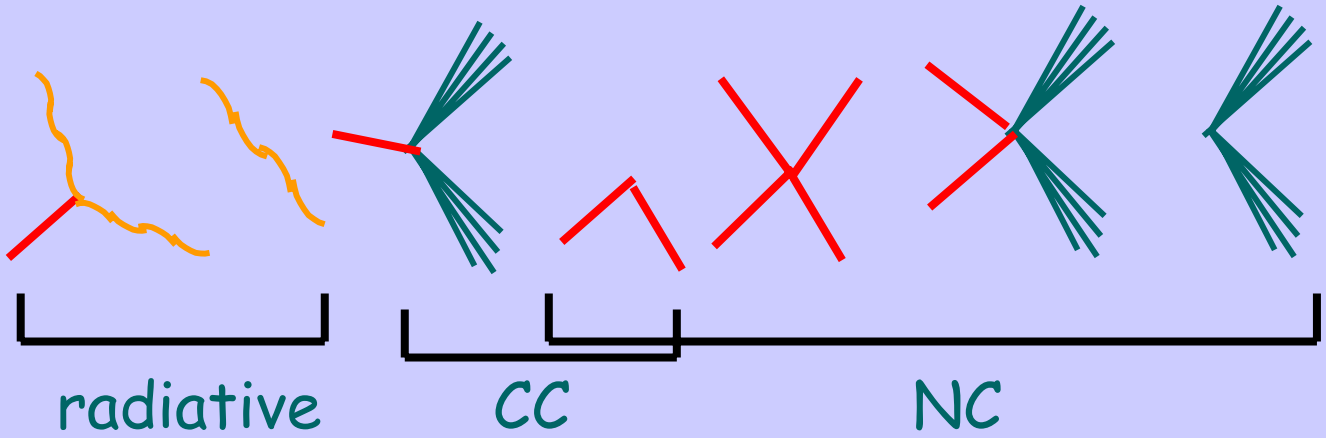
	e^*	μ^*	τ^*	ν_e^*	ν_μ^*	ν_τ^*
f = f ′	103.0	103.1	102.2	102.0	102.4	95.3
f = -f‘	98.0	98.0	98.0	102.7	102.8	102.8

f = f ′	102.9	102.9	102.8

Single production

Mass reach extended up to ~$\sqrt{s}$

Many topologies:

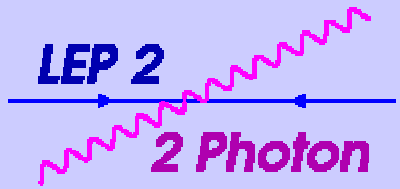


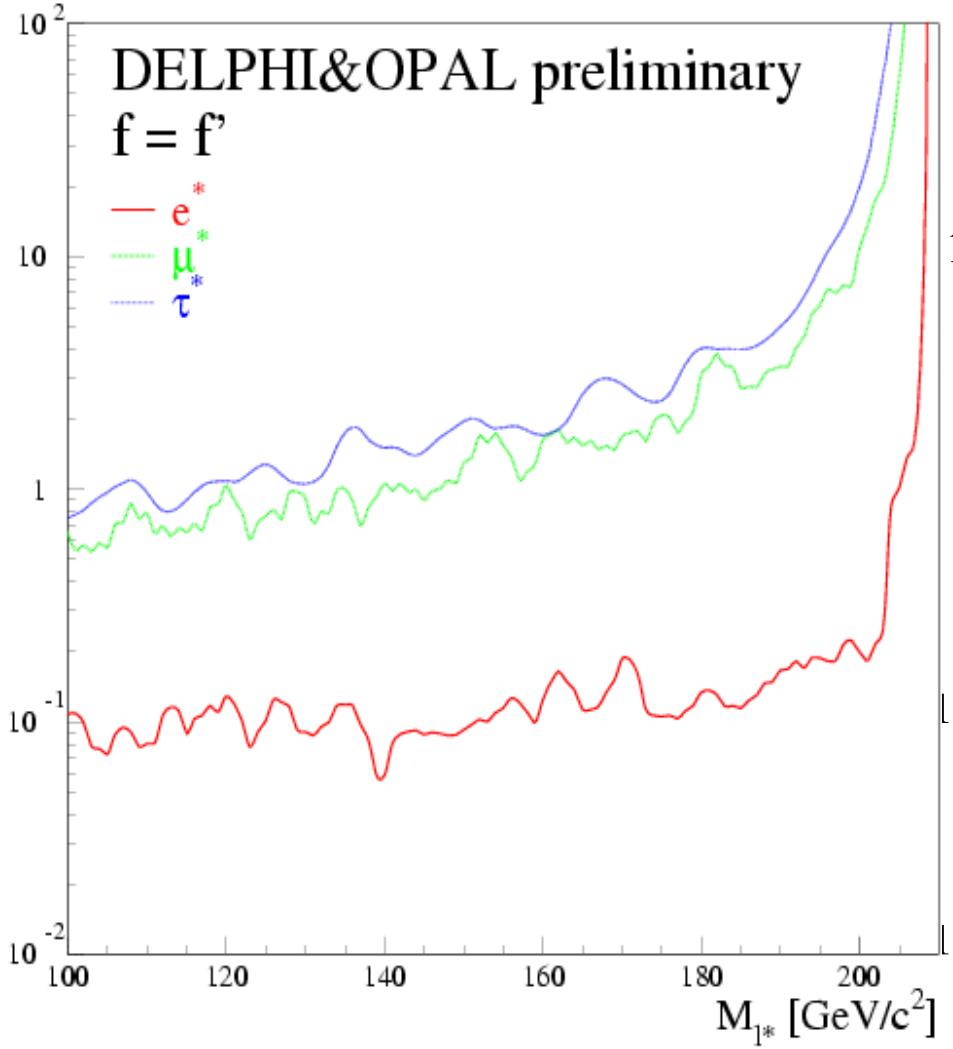
Typical efficiency: 15% (τW) - 60% ($\mu\gamma$)

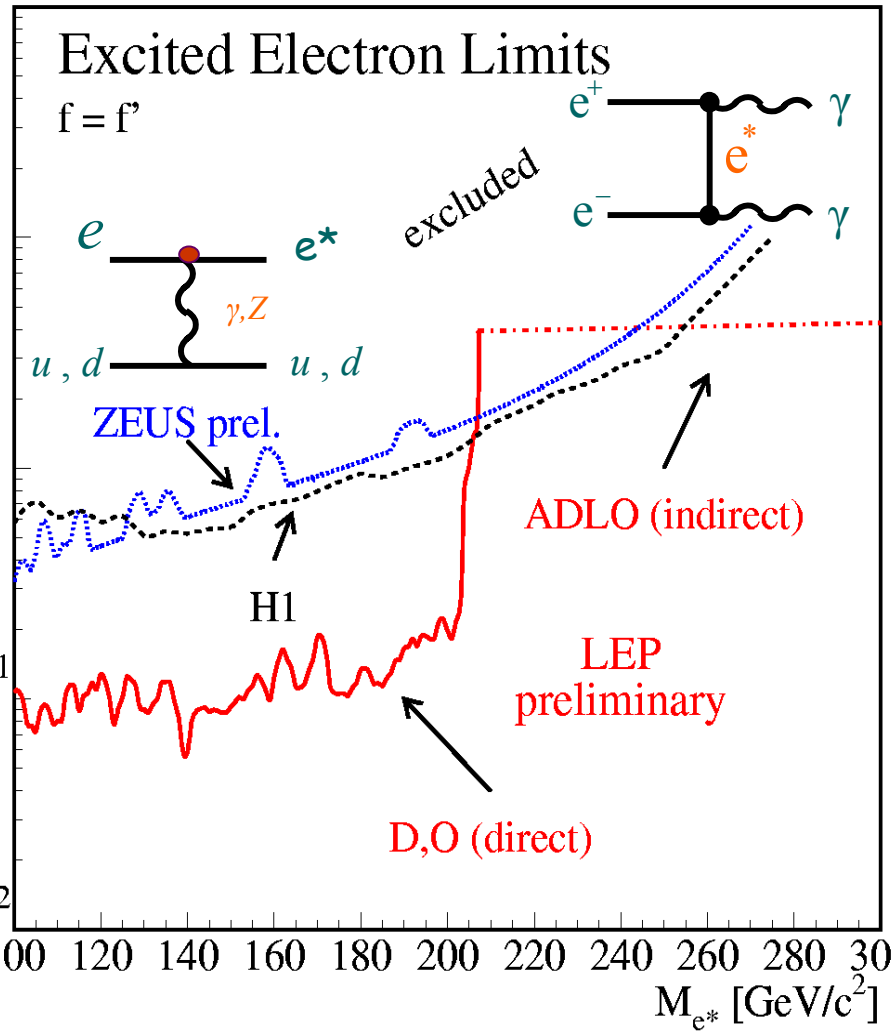
Combined LEP results

LEPEXOTICA WG

f/Λ (1/TeV)







Conclusion

LEP is (was) beautifull:
centre-of-mass energies and luminosities above the specifications.

New physics thoroughly searched for with the 2.5 fb^{-1} luminosity collected at LEP at E_{cm} up to 209 GeV

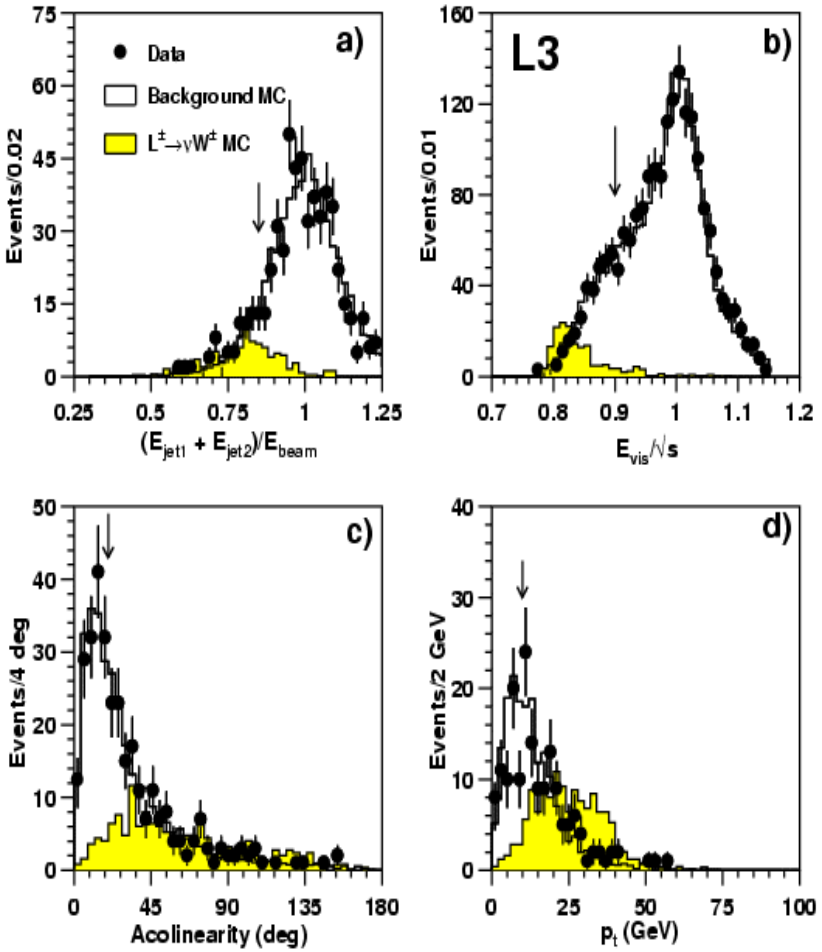
Numbers and properties of the events selected generally in agreement with SM expectation

Experimental constrains are dramatically improved.

We look forward to the near(?) future

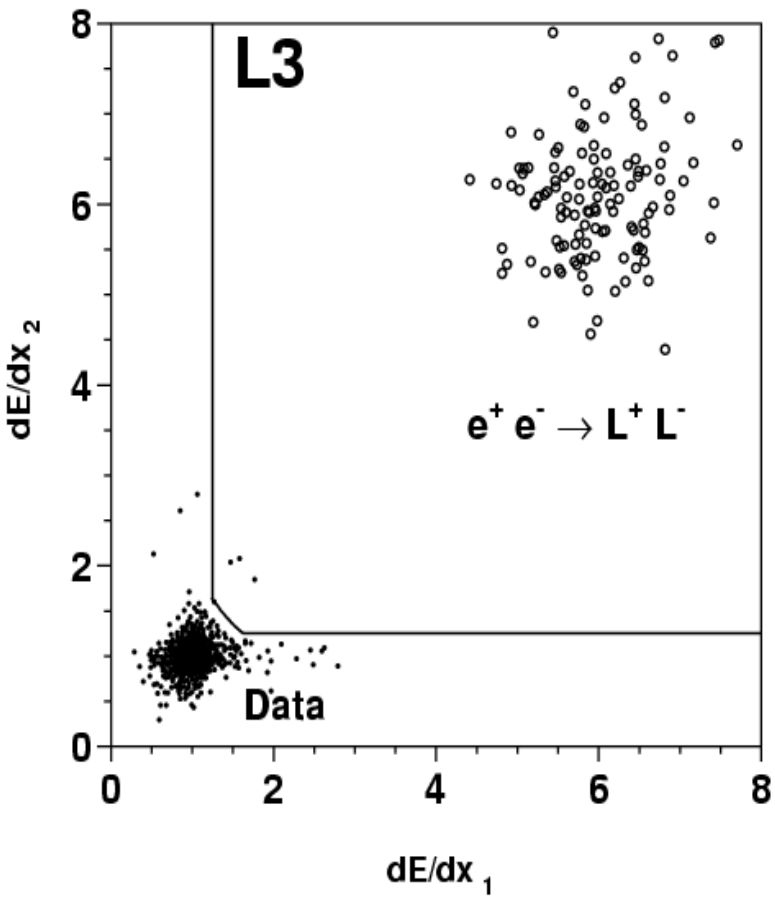
$L^{\pm} \rightarrow \nu\ W^{\pm}$

4 jets and missing energy



$L^{\pm}$ stable

Anomalous ionization loss



Combined LEP results

LEP 2

2 Photon