DELPHI Results at 183 GeV
(and below)

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- QCD studies
- fermion pair production
- W production
- searches for new particles
- conclusions

Total DELPHI integrated luminosity at 183 GeV:

$$\mathcal{L} = 53.5\mathrm{pb}^{-1}$$

Small intermittent readout problem in 1/2 of HPC discovered for $\sim 3.5\mathrm{pb}^{-1}$

$\Rightarrow$ For the moment excluded from critical analyses

$\Rightarrow$ Should be recoverable mostly for final publications

All results shown are preliminary!

If not stated otherwise all limits are 95% $c.l.$

LEP 1 highlights

Michel parameters in τ decays:

$$
\begin{aligned}
\eta_l &= -0.01 \pm 0.10 \pm 0.04 \\
\rho_l &= 0.794 \pm 0.036 \pm 0.029 \\
\xi_l &= 0.988 \pm 0.070 \pm 0.063 \pm 0.054 \\
\xi_l \delta_l &= 0.682 \pm 0.063 \pm 0.054 \\
h_{\nu_\tau} &= -1.006 \pm 0.034 \pm 0.008
\end{aligned}
$$

Currently best at LEP

R_b:

Jerusalem (94-95 data):

$$R_b = 0.21660 \pm 0.00082 \pm 0.00088$$

92-93 analysis finished soon

Charged decay multiplicity of B-hadrons:

$$n_B = 4.97 \pm 0.03 \pm 0.06$$

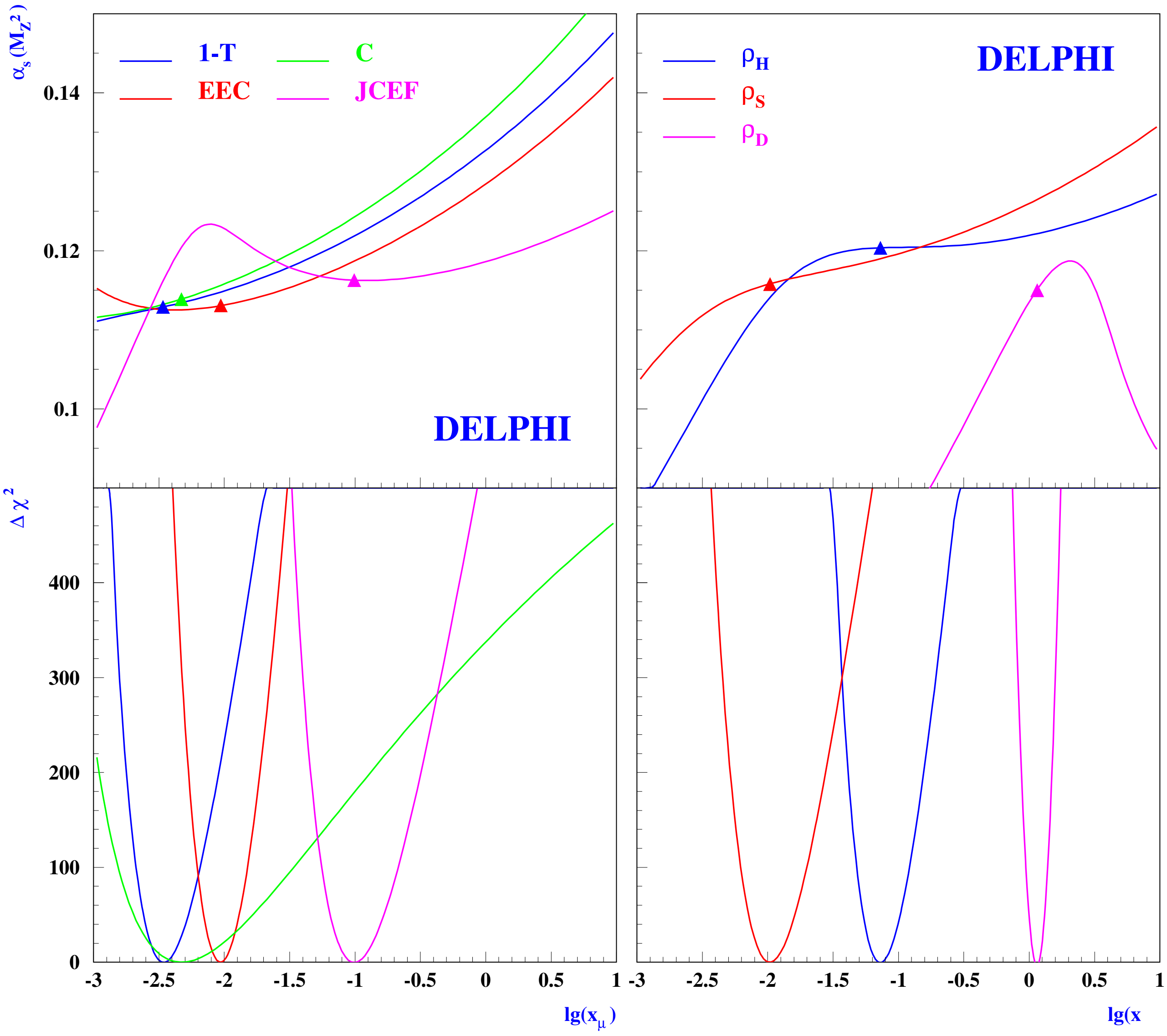
Important number to understand systematics

α_s from angular dependence of event shapes:

Analyse 14 event shape variables including angular dependence

$\rightarrow$ Most variables have very pronounced "optimal scale"

$\rightarrow$ α_s at "optimal scale" agree very well

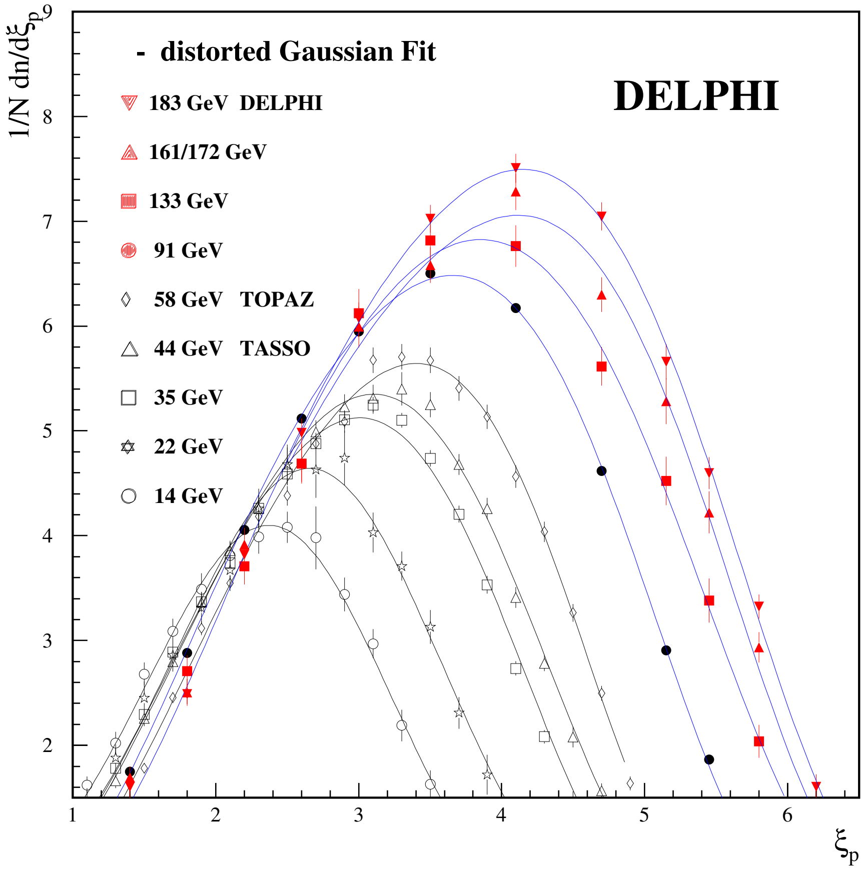


$$\alpha_s(m_Z^2) = 0.1164 \pm 0.0021(exp) \pm ??(theo)$$

QCD studies

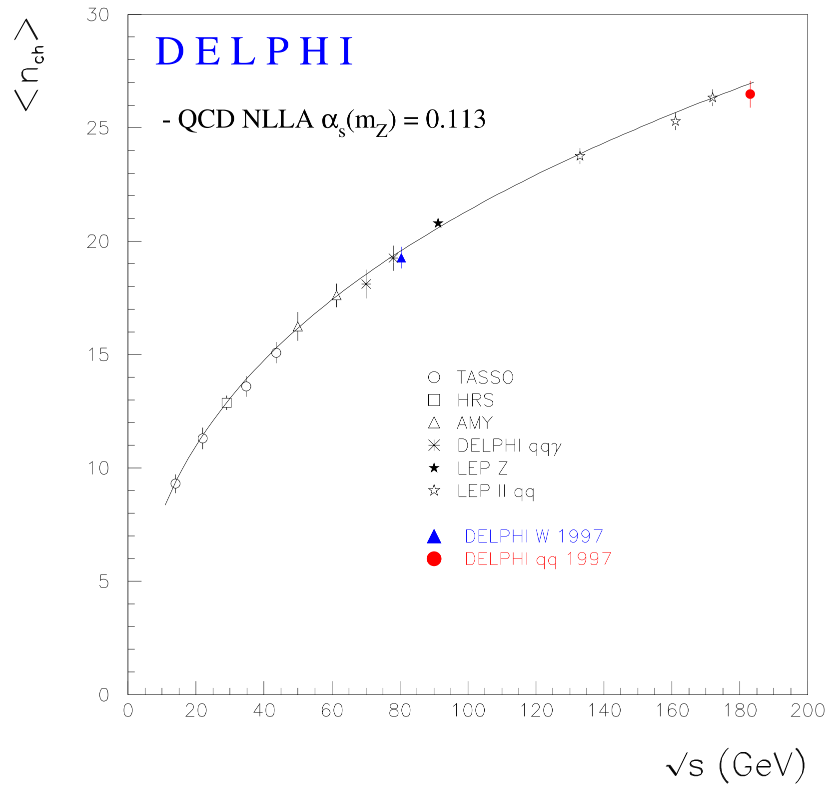
Momentum distributions and multiplicities:

QCD predicts energy dependence of charged multiplicity and maximum of $\xi_p = \ln(1/x_p)$ distributions

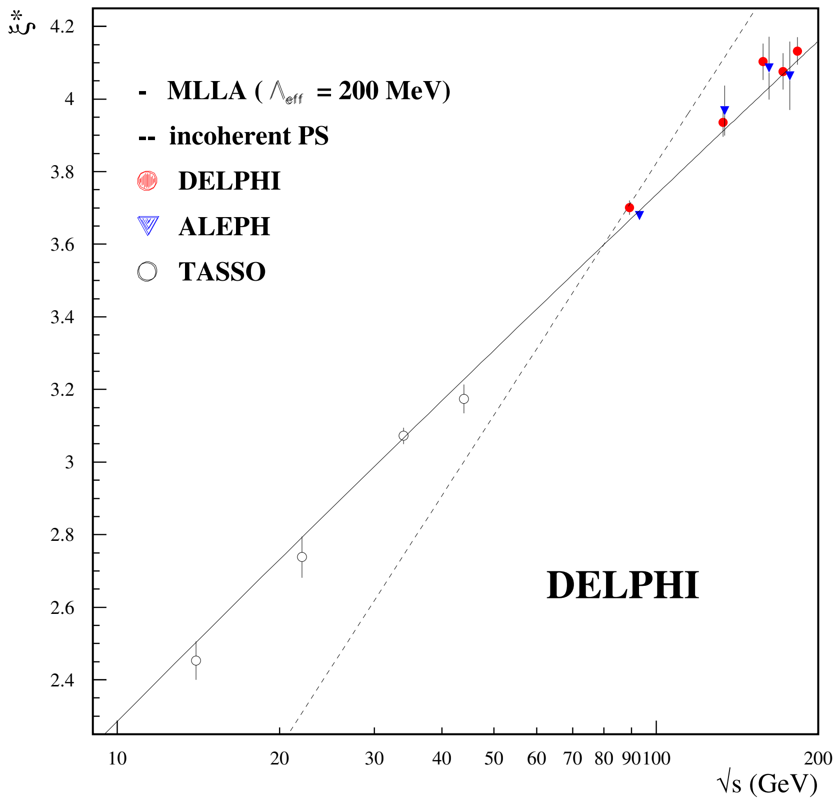


Data and prediction agree well → plot

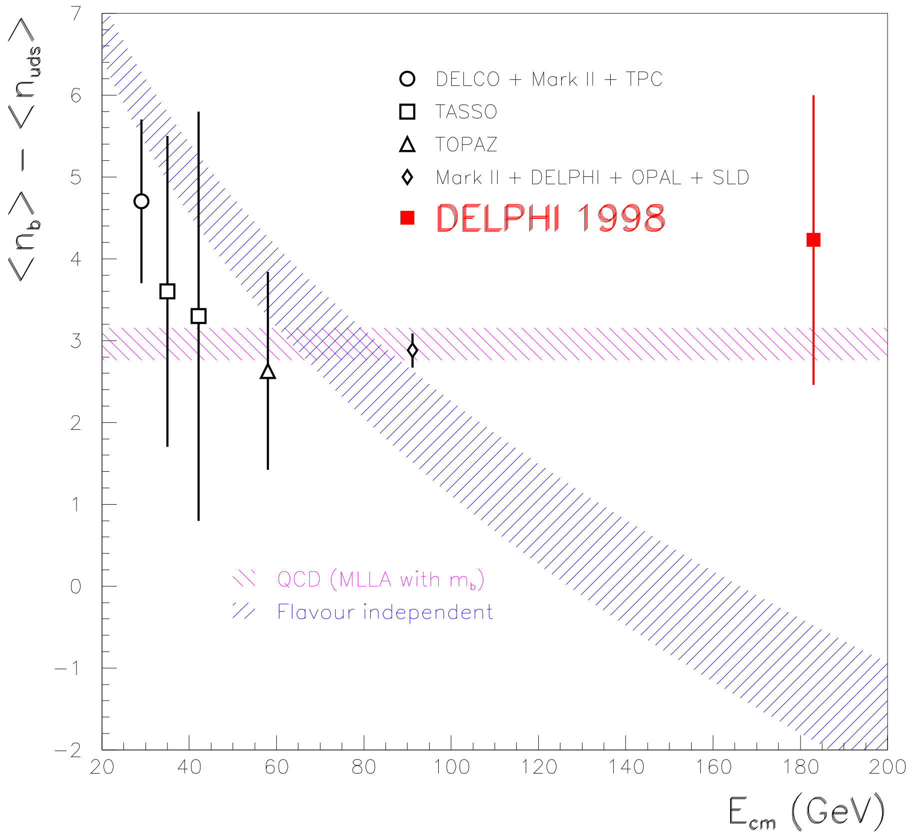
Energy evolution of $\langle n_{ch} \rangle$ (corrected for $b\bar{b}$-content)



Maximum of ξ_p distributions:

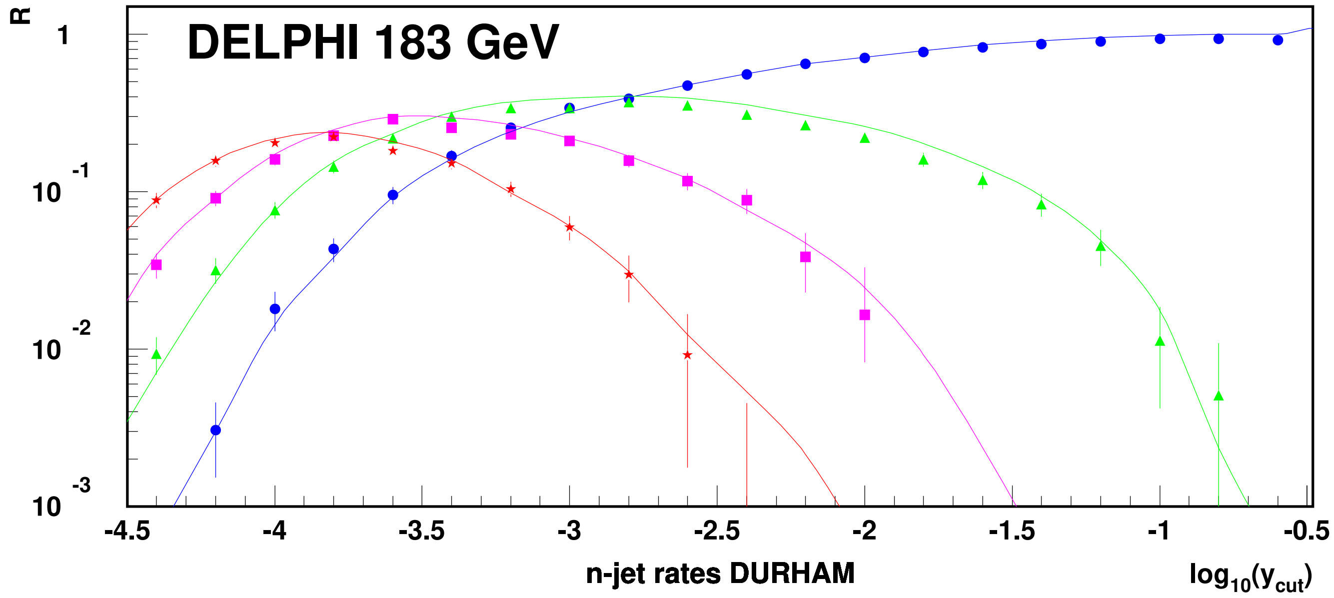


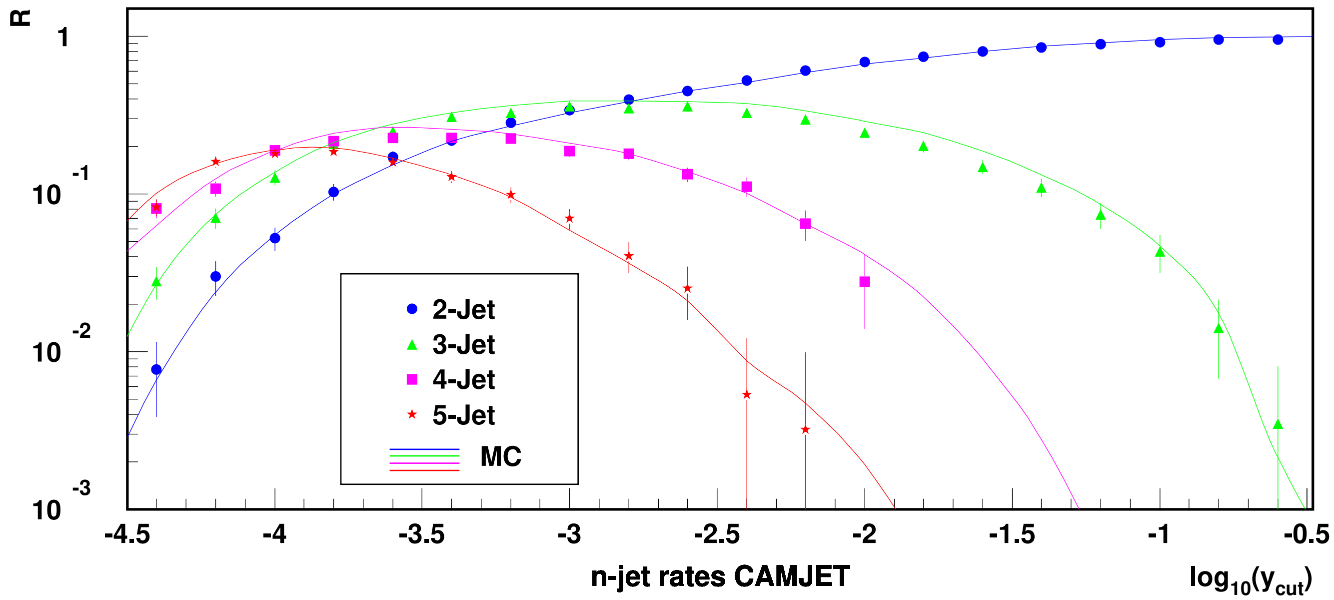
Multiplicity difference in light quark and $b\bar{b}$ events:



Data clearly prefer QCD towards independent fragmentation

Event shapes





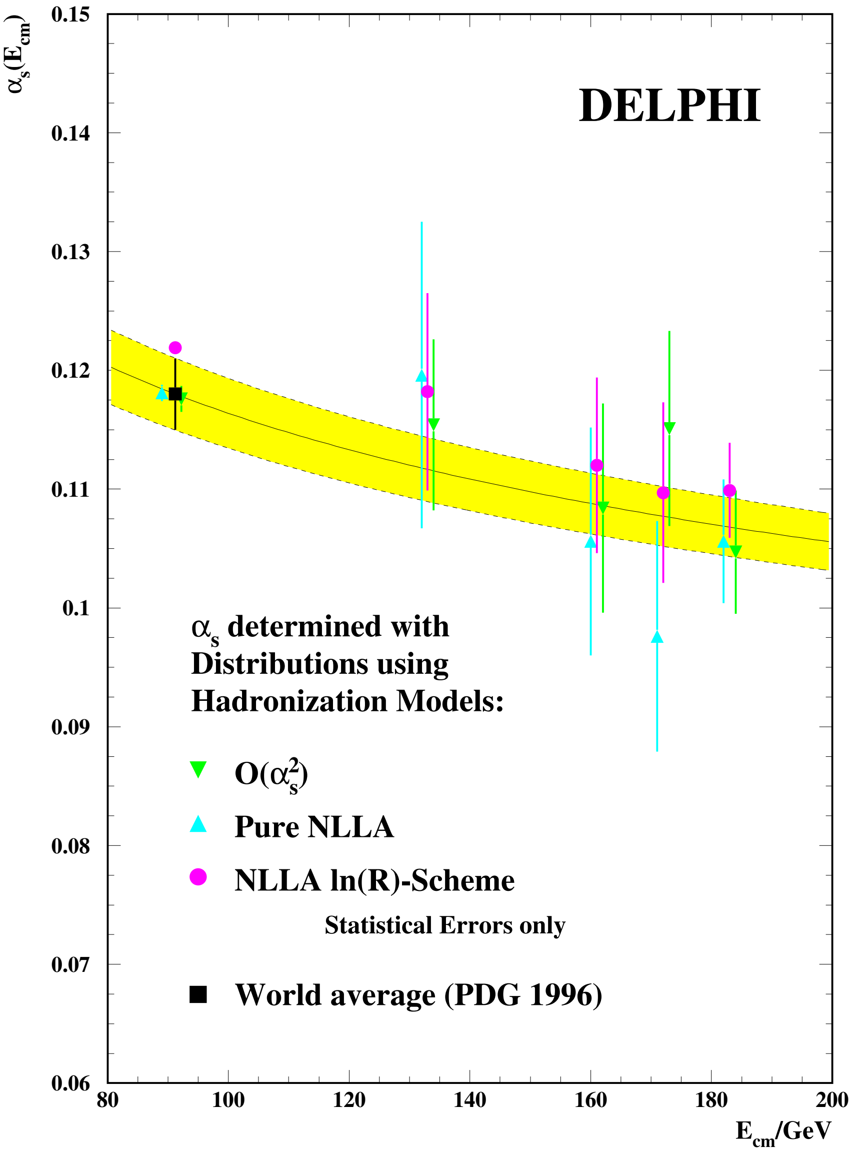
Jetset describes energy extrapolation from $\sqrt{s} = m_Z$ to 183GeV well, apart from small problem in hard 3-jet region

Running of α_s

Analyse 1 – T and M_h^2/E_{vis}^2 distributions

3 analyses:

pure NLLA, pure $\mathcal{O}(\alpha_s^2)$, combined NLLA $+\mathcal{O}(\alpha_s^2)$

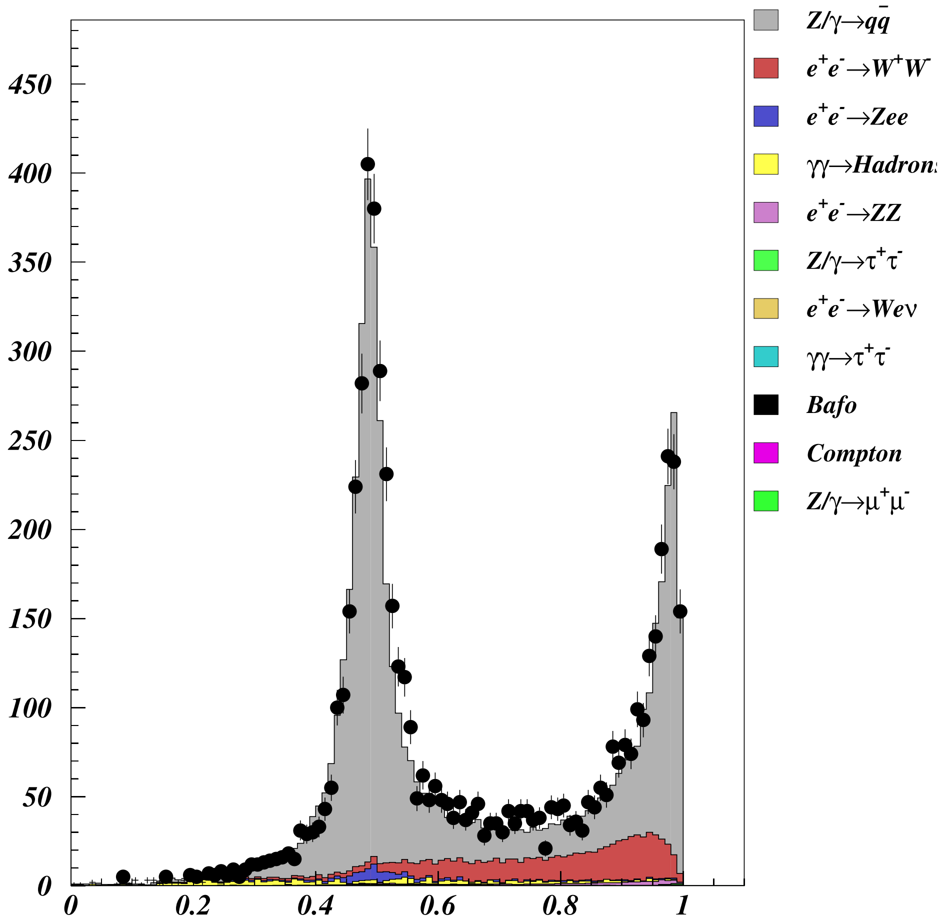


Consistent results:	$\partial\alpha_s/\partial E_{cm}$	$=$	-0.13 ± 0.04
QCD:	$\partial\alpha_s/\partial E_{cm}$	$=$	-0.122
QCD + light gluino:	$\partial\alpha_s/\partial E_{cm}$	$=$	-0.089

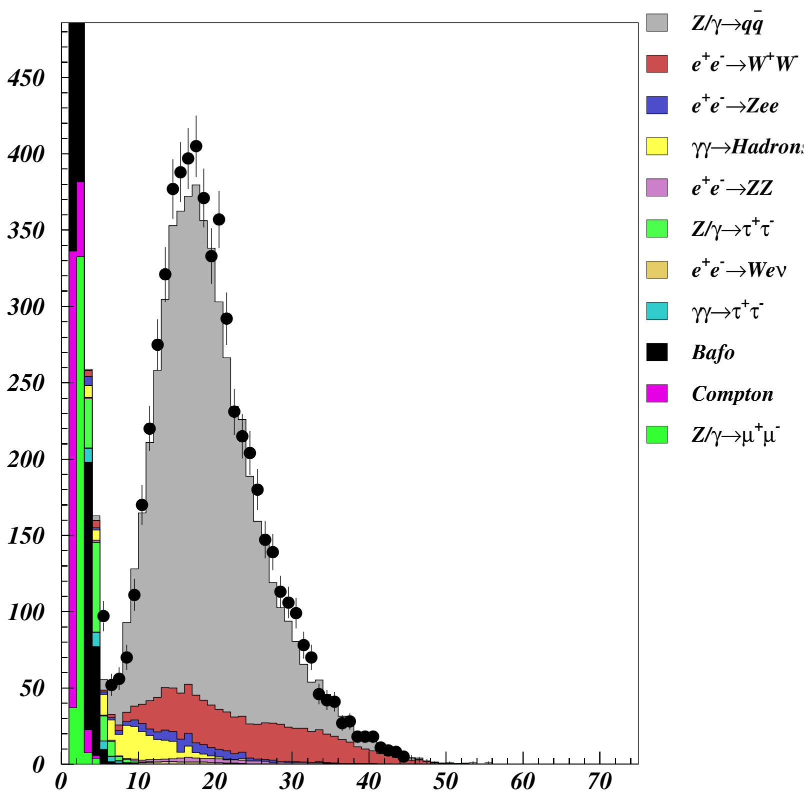
Hadronic cross section

Hadronic event selection:

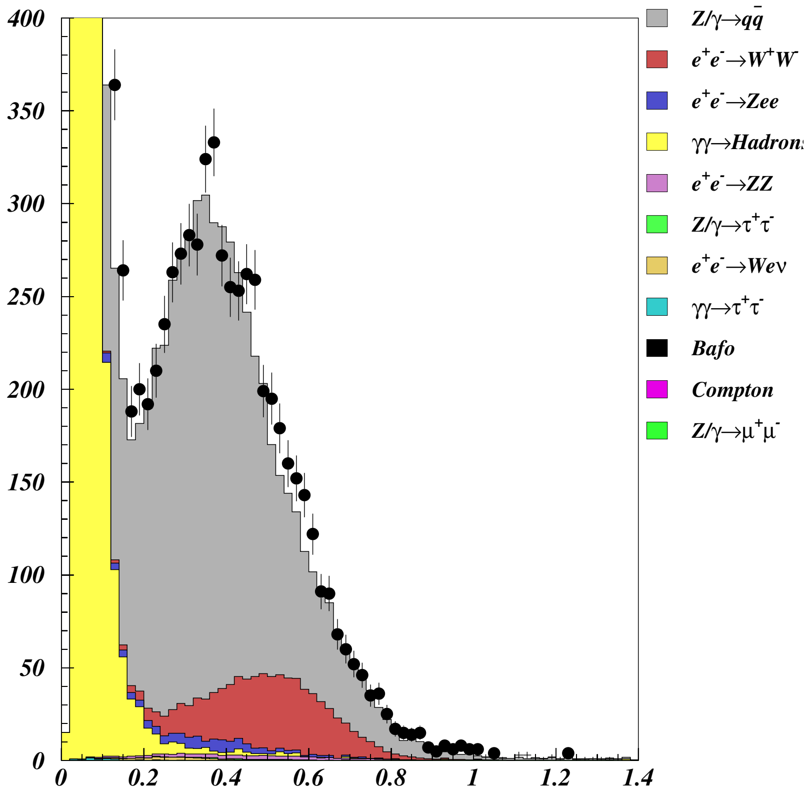
- $n_{ch} \geq 7, \;\; E_{ch} \geq 0.15\sqrt{s}$
- total cross section:
  $\varepsilon = (83.7 \pm 1.3)\%, bg = (21.0 \pm 1.2)pb$
- high energy cross section (($\sqrt{s'/s} > 0.85$):
  calculate s' from jet directions and reconstructed photons:



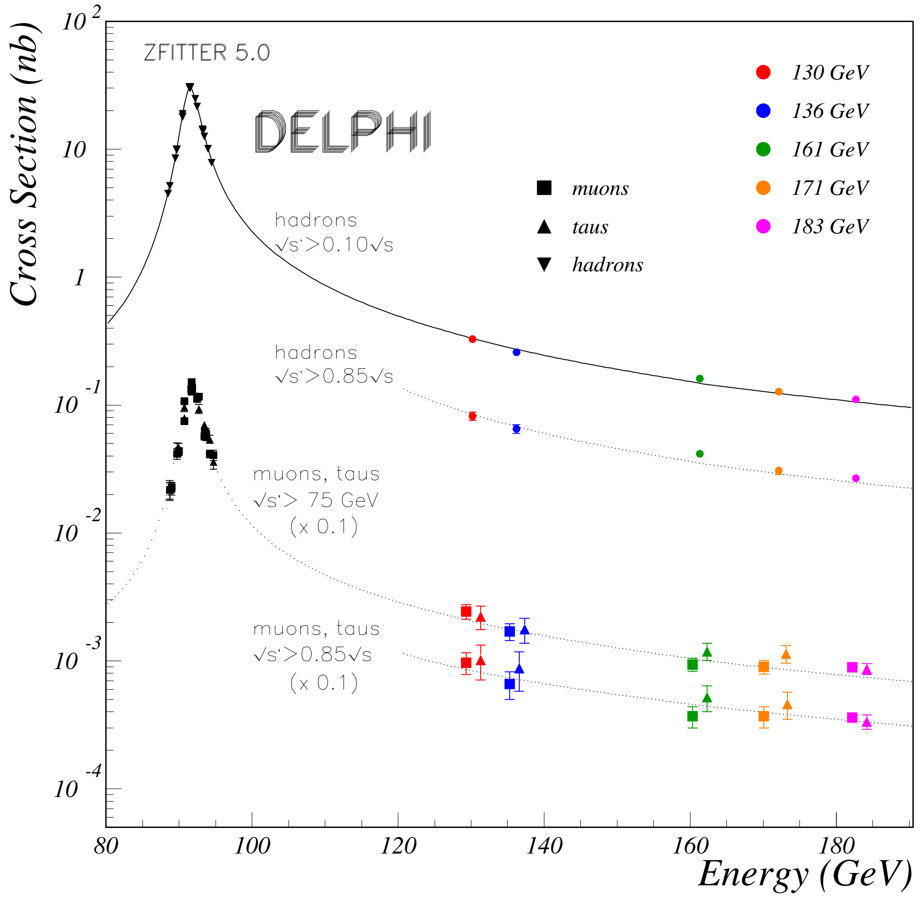
Charged multiplicity:

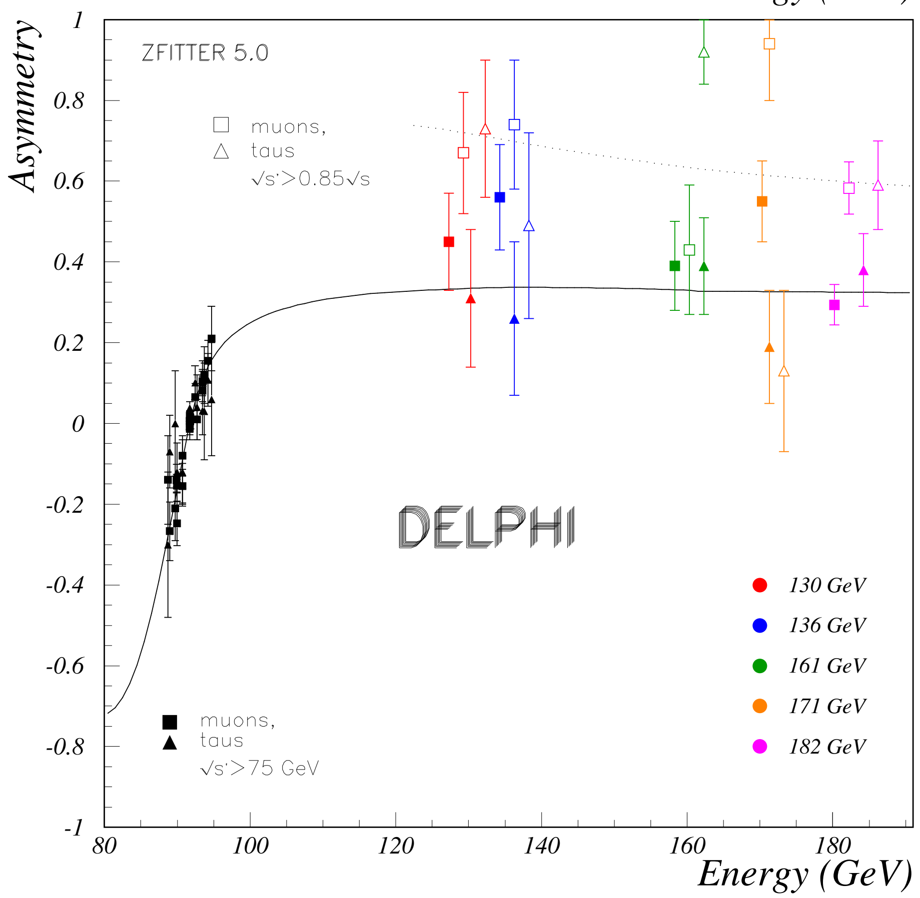


Charged energy:



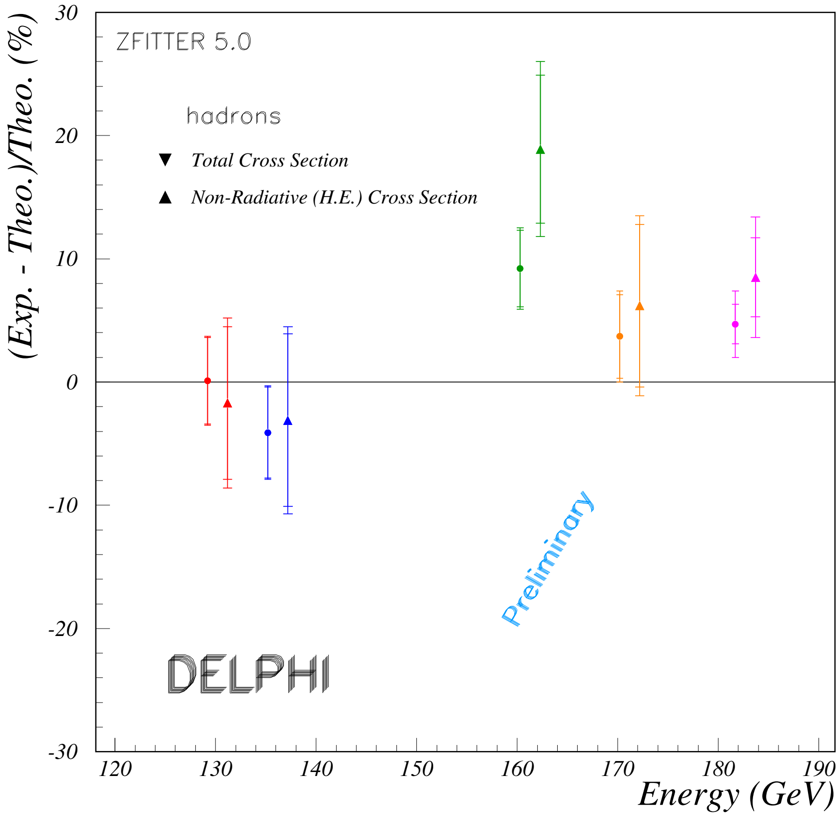
Fermion cross sections and asymmetries





Good agreement for leptons

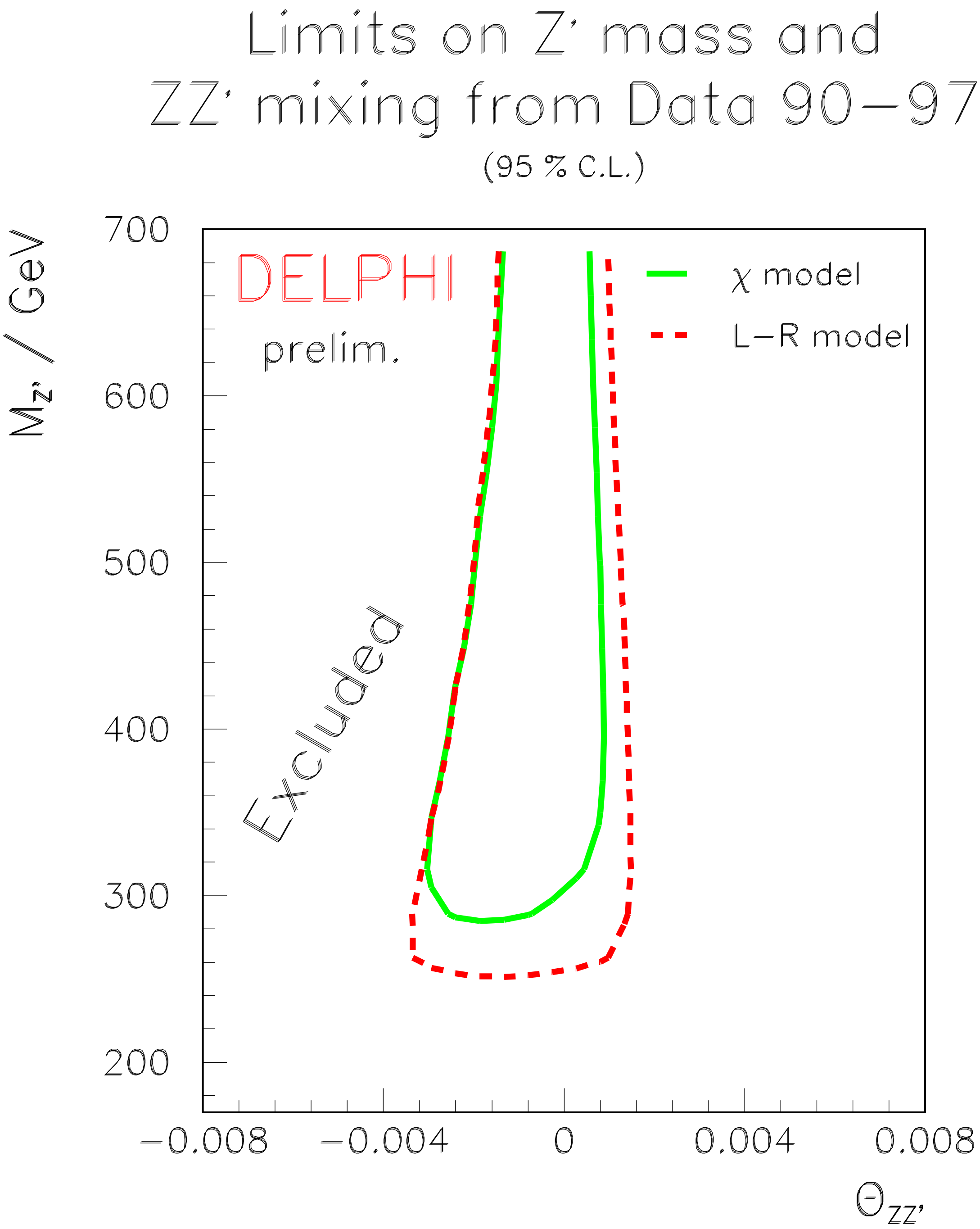
Ratio hadronic cross section/ZFITTER:



Including common systematics for hadrons total ($\geq$ 161GeV) difference DELPHI-SM $< 2.5\sigma$

Z' fits

Fits of Z' models to DELPHI LEP1 and high energy cross sections and asymmetries:



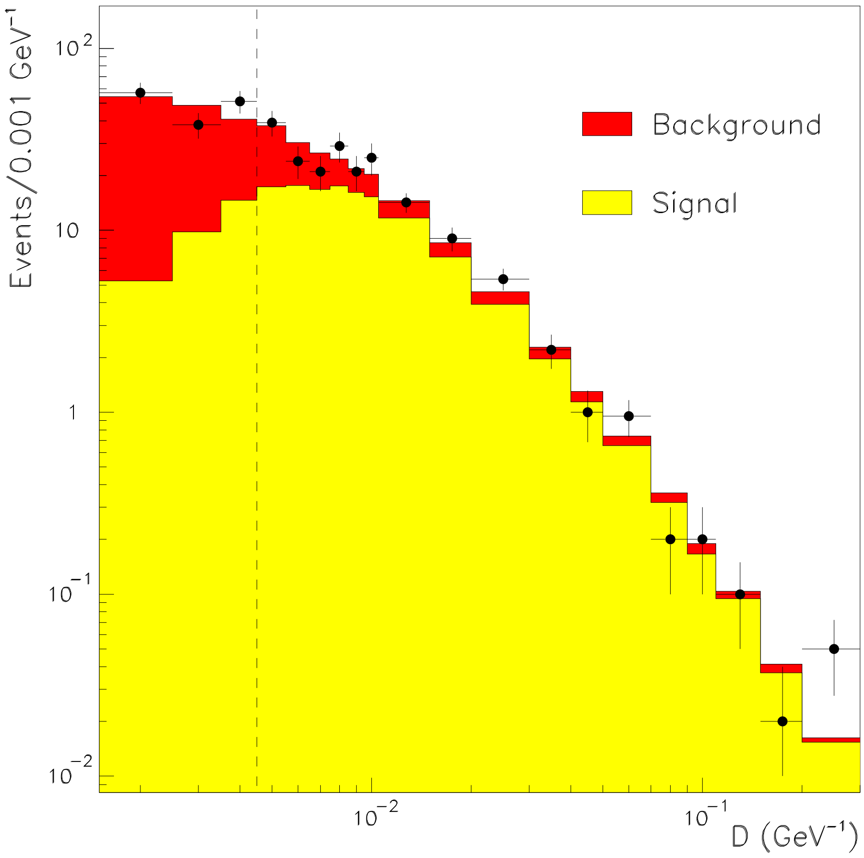
$\Theta_{ZZ'} \sim 0$ excluded from LEP 1

$m_{Z'} > 250 - 300\,\mathrm{GeV}$ depending on model

W cross section and branching ratios

- Similar analysis as 172GeV
- Leptonic channels splitted into different lepton species
- Conservative estimate of systematic errors
  $\rightarrow$ will decrease for final publication
- results:

Channel	eff.	bg. [pb]	events	$\sigma \times BR$ [pb]
$qqqq$	$81.3 \pm 0.3\%$	1.89 ± 0.03	391	$7.33 \pm 0.48(stat) \pm 0.29(syst)$
$qq\ell\nu$	$72.6 \pm 0.3\%$	0.66 ± 0.04	288	$7.04 \pm 0.47(stat) \pm 0.28(syst)$
$\ell\nu\ell\nu$	$60.1 \pm 0.7\%$	0.20 ± 0.02	59	$1.64 \pm 0.26(stat) \pm 0.09(syst)$



Branching ratio results (including $161, 172$GeV):

- No lepton universality:

$$
\begin{aligned}
BR(W \to e\nu) &= 0.099 \pm 0.011 \pm 0.005 \\
BR(W \to \mu\nu) &= 0.114 \pm 0.011 \pm 0.005 \\
BR(W \to \tau\nu) &= 0.112 \pm 0.017 \pm 0.007
\end{aligned}
$$

- With lepton universality:

$$
\begin{aligned}
BR(W \to \ell\nu) &= 0.108 \pm 0.005 \pm 0.003 \\
BR(W \to q\bar{q}') &= 0.675 \pm 0.015 \pm 0.009
\end{aligned}
$$

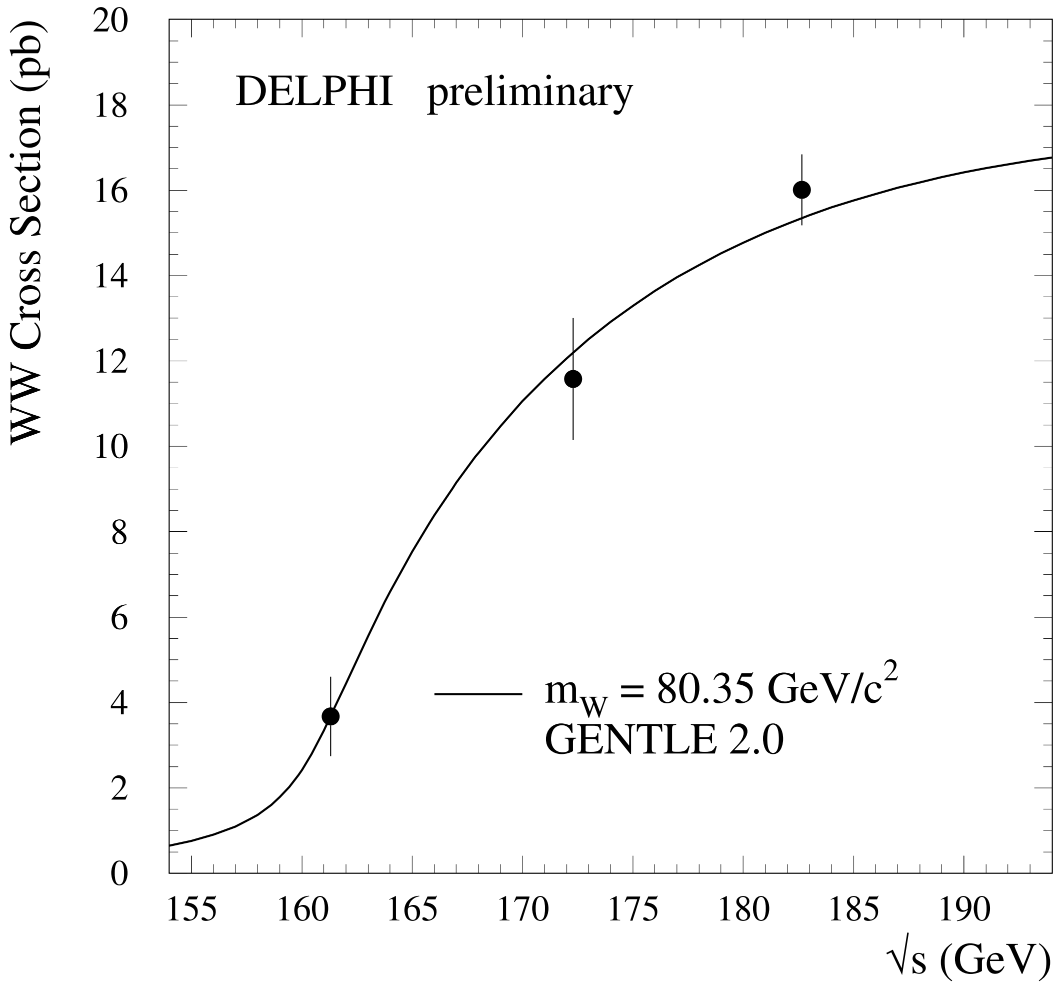
- V_{cs} interpretation:

$$V_{cs} = 0.98 \pm 0.07 \pm 0.04$$

$(V_{cs} = 0.9743 \pm 0.0007$ from CKM-unitarity$)$

Cross section result (assuming SM BRs):

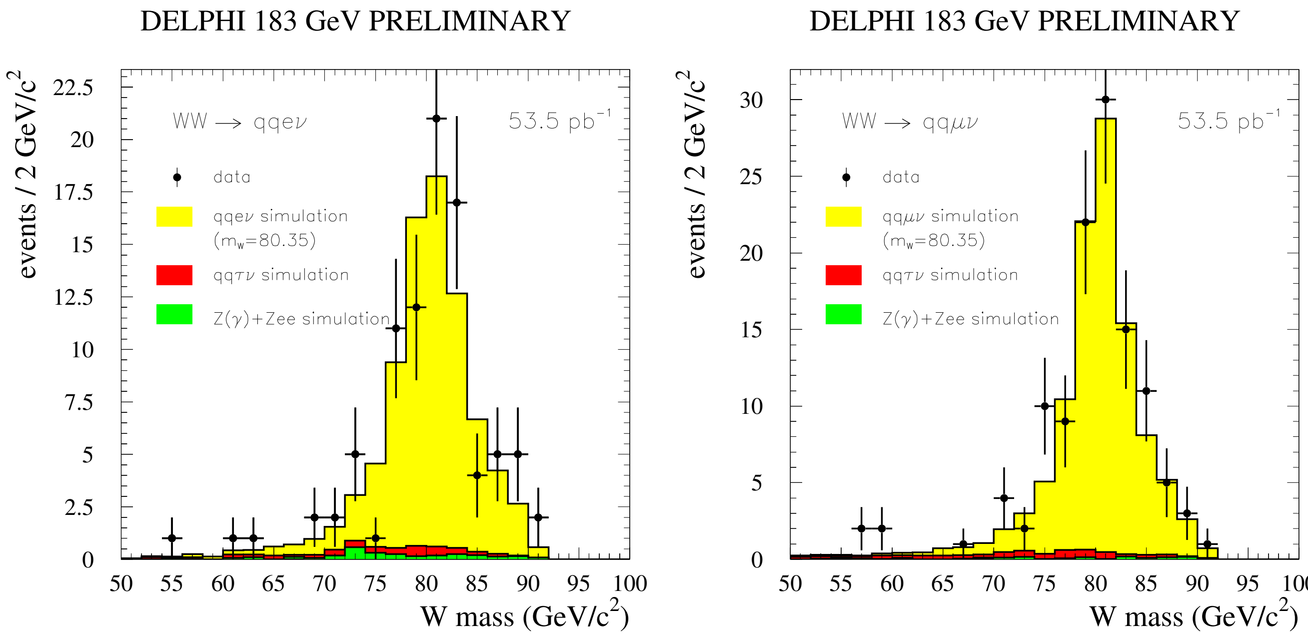
$$\sigma_{e^+e^-\to W^+W^-}(182.7\mathrm{GeV}) = (16.01 \pm 0.71(stat) \pm 0.43(syst))\,\mathrm{pb}$$



Measurement of m_W

$WW \to \ell\nu qq$: (very similar to 172GeV)

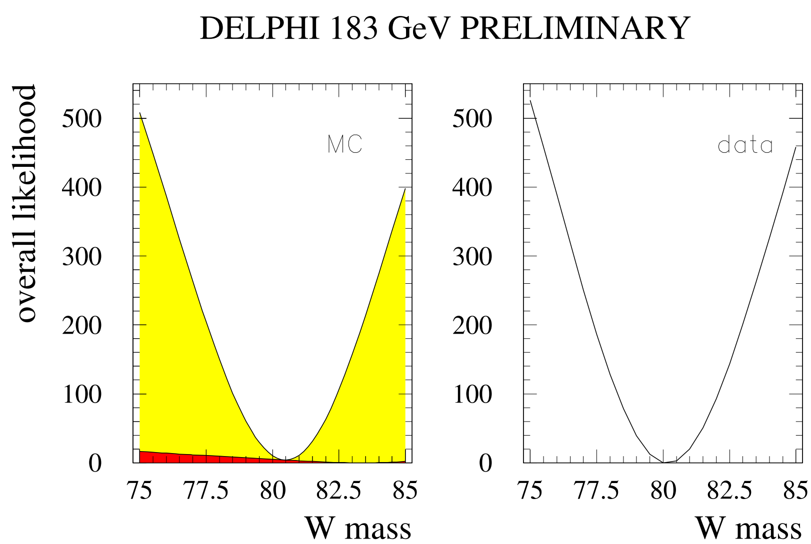
- Selection similar to cross section analysis (e, μ only)
  $e: \ \varepsilon = 69\% \ p = 93\% \ \mu: \ \varepsilon = 83\% \ p = 95\%$
- Event fit: Constrained fit imposing equal masses



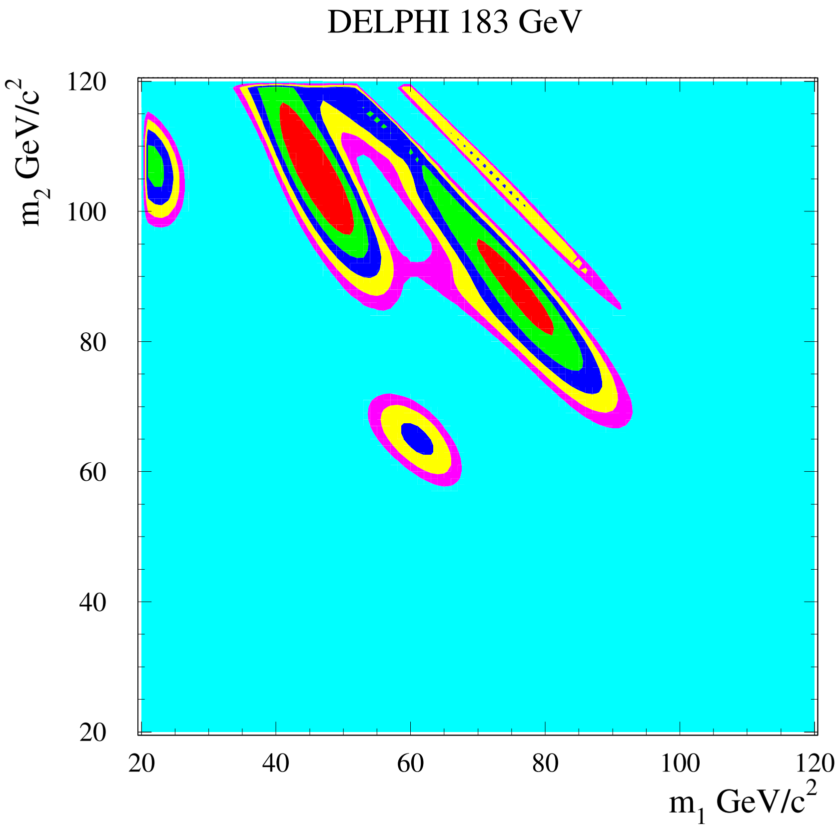
- Mass fit: Maximum Likelihood fit using
  Breit Wigner $\otimes$ Resolution $\otimes$ Phase space
  taking event by event errors
- Calibration (correction for ISR, fit method etc.) with MC

$WW \to qqqq$:

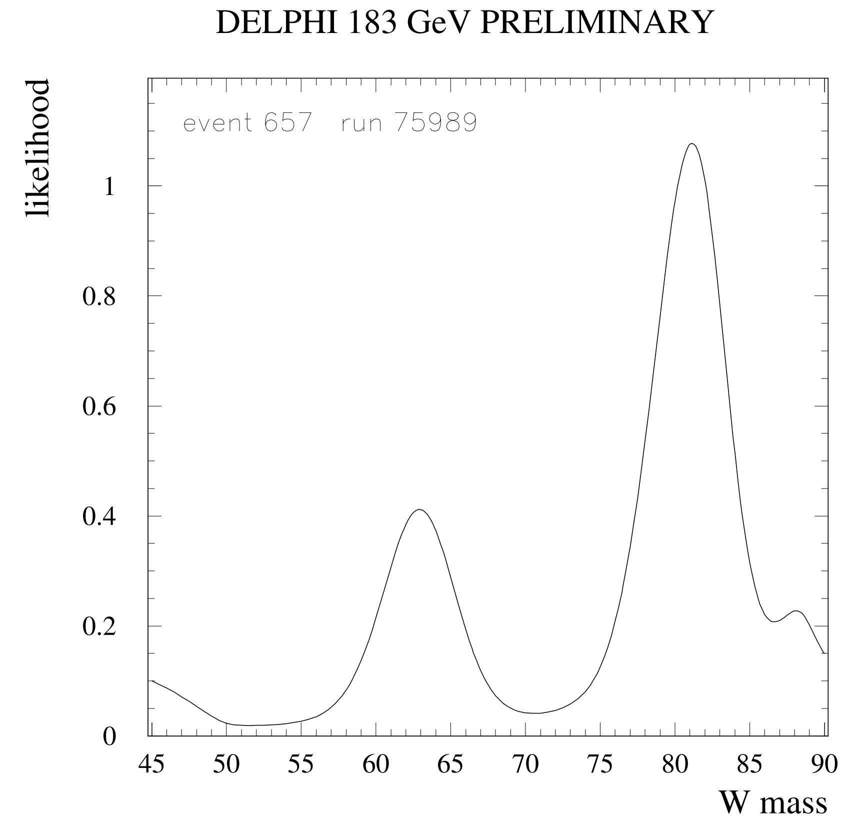
- Event selection:
  Balanced hadronic event with ≥ 4 jets
  $\varepsilon = 85\% \; p = 65\%$
- m_W extraction:
  - Keep four and five jet events
  - Calculate probability for all (m_1, m_2) combinations taking into account 3 or 10 different pairings (2D-ideogram) $\to$ plot
  - Weight different pairings with jet charge weight and, for 5-jets, $1/k_t$.
  - Calculate likelihood by folding ideogram with product of two Breit-Wigner and weight with signal probability according to discriminating variable $D = E_{min} \cdot \theta_{min}$ $\to$ plot
  - correct for biases with MC



Ideogram for a 5-jet event:



Corresponding likelihood curve:



Results:

	$e\nu qq$	$\mu\nu qq$	$qqqq$
m_{W}[GeV]	80.757	80.336	80.024
stat	0.391	0.366	0.200
expected stat	0.400	0.350	0.220
exp syst	0.090	0.060	0.030
phys syst	0.015	0.015	0.030
LEP	0.030	0.030	0.030
BE/CR	–	–	0.100

DELPHI 183GeV:

$$\begin{aligned} m_{\mathrm{W}} = (80.23 &\pm 0.16(stat) \\ &\pm 0.04(syst) \\ &\pm 0.06(BE/CR) \\ &\pm 0.03(LEP) \quad)\mathrm{GeV} \end{aligned}$$

All DELPHI:

$$\begin{aligned} m_{\mathrm{W}} = (80.24 &\pm 0.15(stat) \\ &\pm 0.04(syst) \\ &\pm 0.05(BE/CR) \\ &\pm 0.03(LEP) \quad)\mathrm{GeV} \end{aligned}$$

W-decays

Some models of colour reconnection predict change in charged W-decay multiplicity

bulk of models: $$\frac{\langle n_{ch}^{(4q)}\rangle}{2\langle n_{ch}^{(2q)}\rangle} \sim 0.95 - 1.05$$

extreme models: $$\frac{\langle n_{ch}^{(4q)}\rangle}{2\langle n_{ch}^{(2q)}\rangle} \sim 0.8$$

Measure charged multiplicity in hadronic and mixed WW-events $\rightarrow$ plot

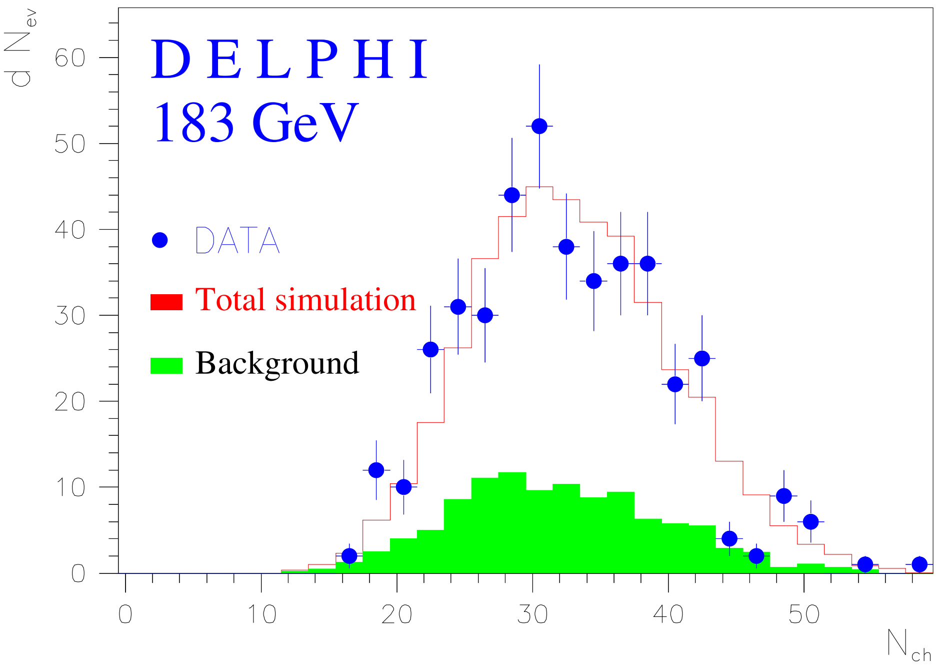
$$\langle n_{ch}^{(4q)}\rangle = 37.35 \pm 0.54 \pm 0.93$$
$$\langle n_{ch}^{(2q)}\rangle = 19.48 \pm 0.37 \pm 0.63$$
$$\frac{\langle n_{ch}^{(4q)}\rangle}{2\langle n_{ch}^{(2q)}\rangle} = 0.96 \pm 0.02 \pm 0.03$$

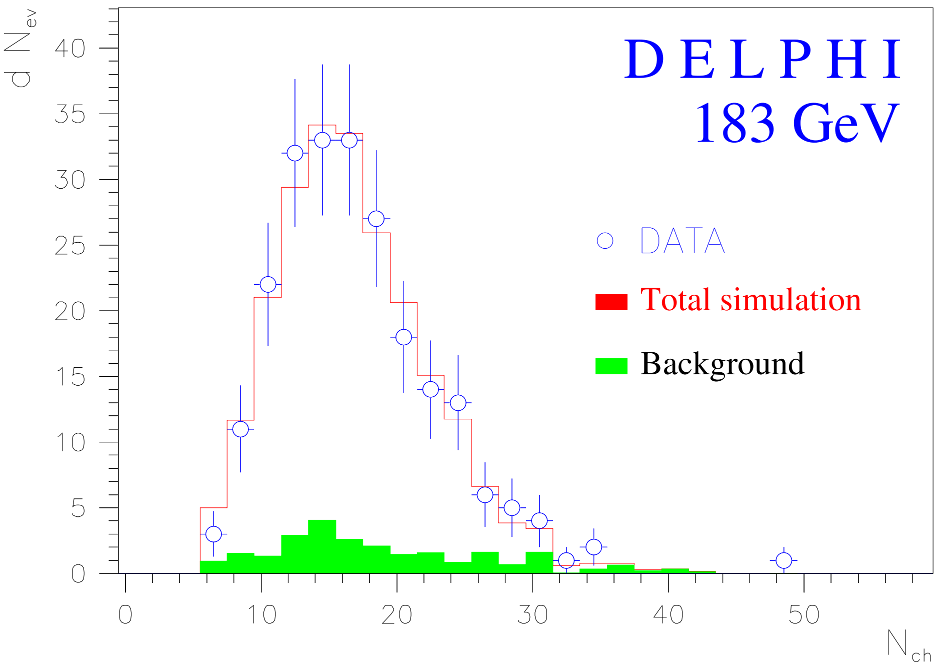
$\Rightarrow$ Only extreme models can be excluded

Models predict larger effect for heavy particles (K,p)
Measure multiplicity ratio for 0.3GeV $< p_{p,K} <$ 1GeV with dE/dx from TPC and VD:

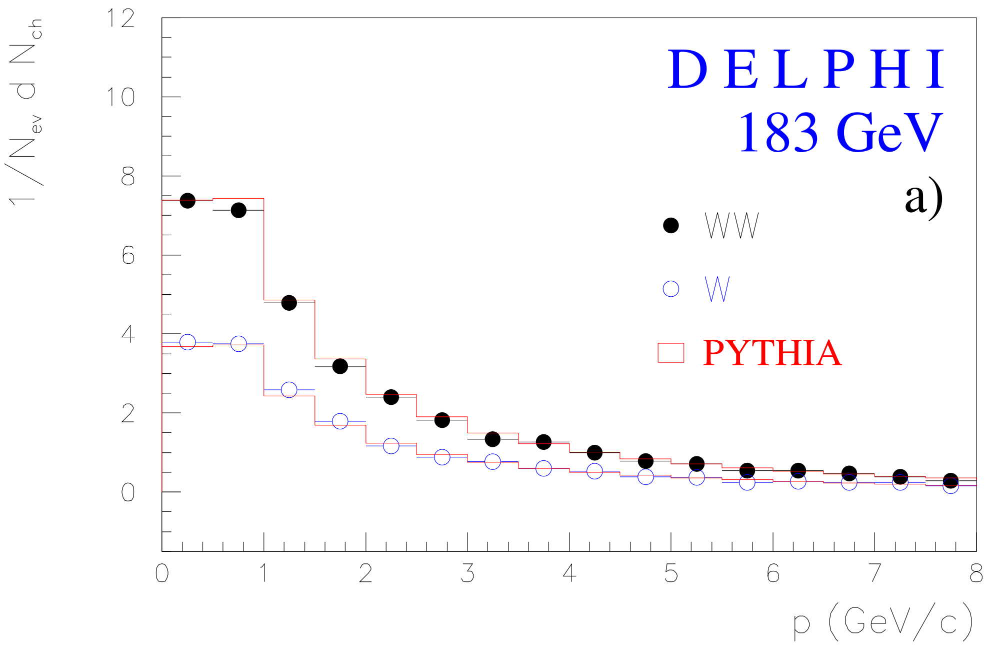
$$\frac{\langle n_{p,K}^{(4q)}\rangle}{2\langle n_{p,K}^{(2q)}\rangle} = 1.03 \pm 0.15$$

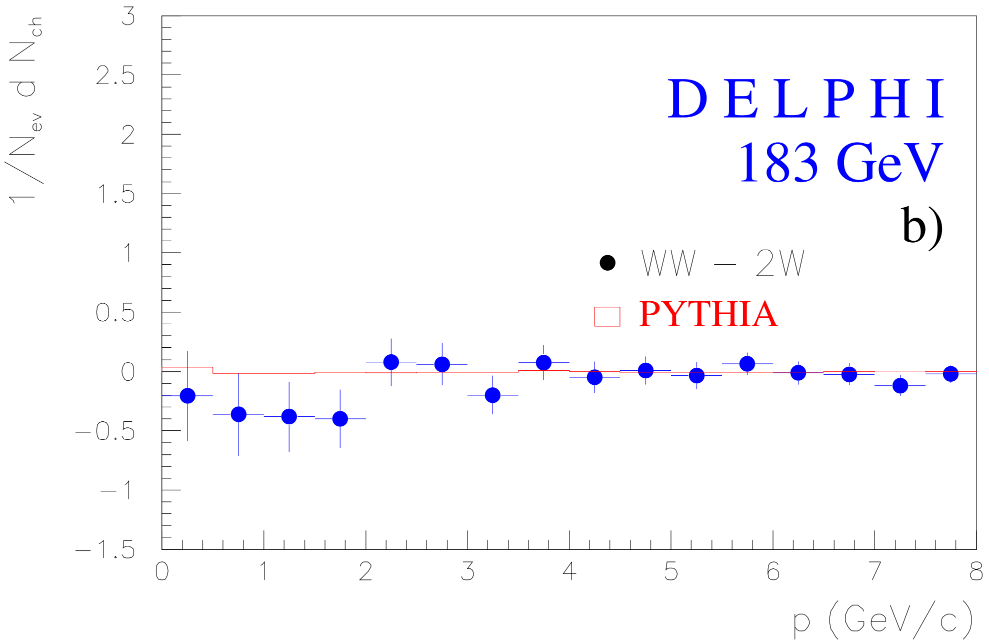
Multiplicity distribution in $WW \rightarrow qqqq$ and $WW \rightarrow \ell\nu qq$ events:





Agreement between hadronic and mixed decays also good in momentum distributions:



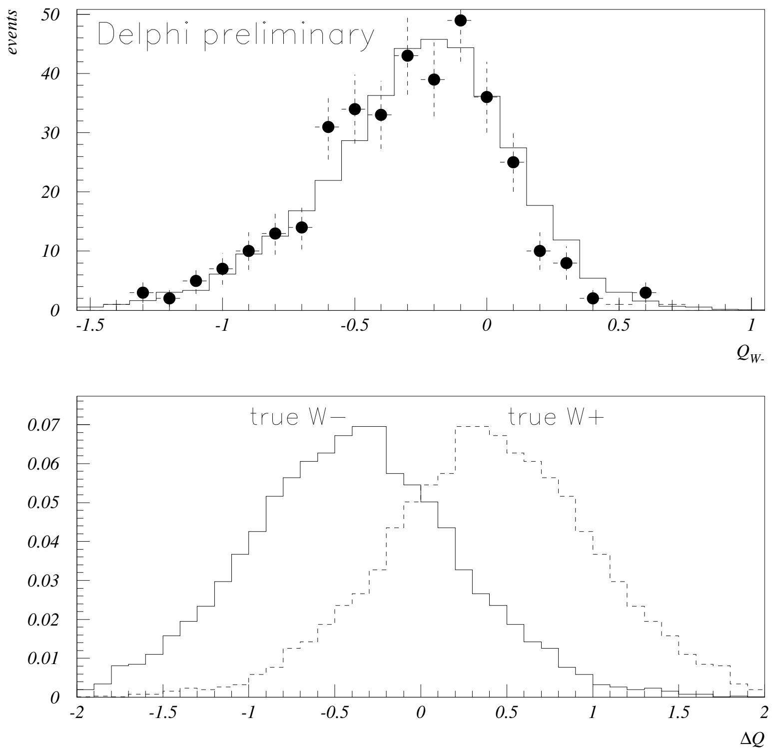


Triple gauge couplings

$WW \to \ell\nu qq$: Fit to "well measured observables" ($\cos\theta_W$, $\cos\theta_\ell$)
(optimal observables give consistent results)

$WW \to qqqq$:

- W-pair selection similar to cross section analysis
- kinematic fit with equal mass constraint
- best combination in mass window around m_{W}
- resolve $W^+ - W^-$ ambiguity partially with jet charge



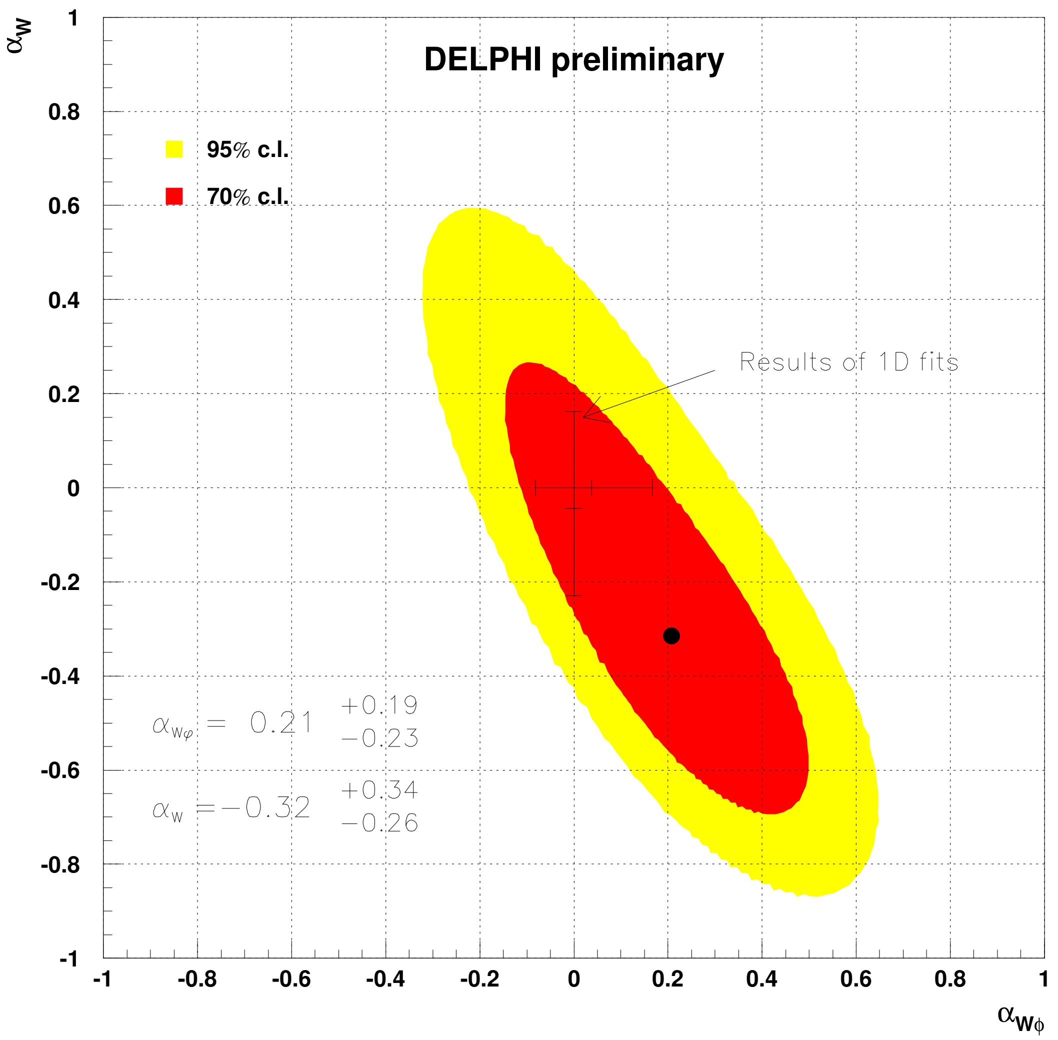
- fit with optimal observable

Results:

Single parameter fits:

$$\alpha_{W\Phi} = 0.01^{+0.11}_{-0.08} \pm 0.03$$
$$\alpha_{W} = -0.10^{+0.16}_{-0.16} \pm 0.07$$
$$\alpha_{B\Phi} = 0.31^{+0.76}_{-0.51} \pm 0.21$$

Two parameter fits ($WW \to \ell\nu qq$ only)

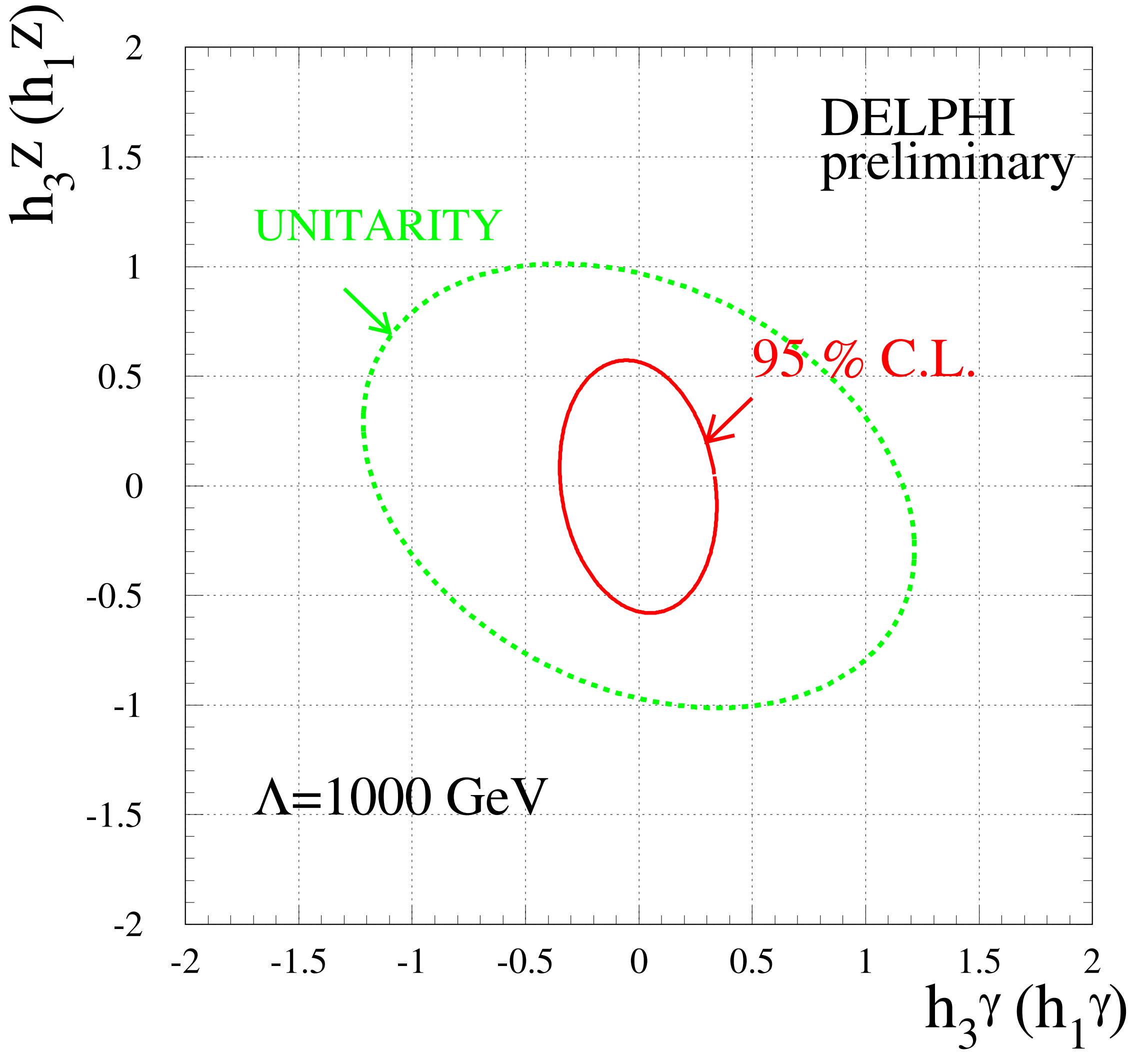


Neutral gauge couplings

Search for $e^+e^- \to Z\gamma$ with $Z \to \nu\bar{\nu},\ q\bar{q}$

Ask for high energy ($E_\gamma > 50(\nu\bar{\nu}),\ 60(q\bar{q})$ GeV) in barrel

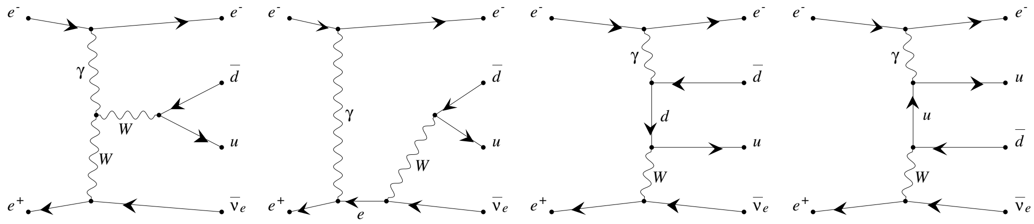
Sensitive to anomalous $ZZ\gamma$ and $Z\gamma\gamma$ coupling



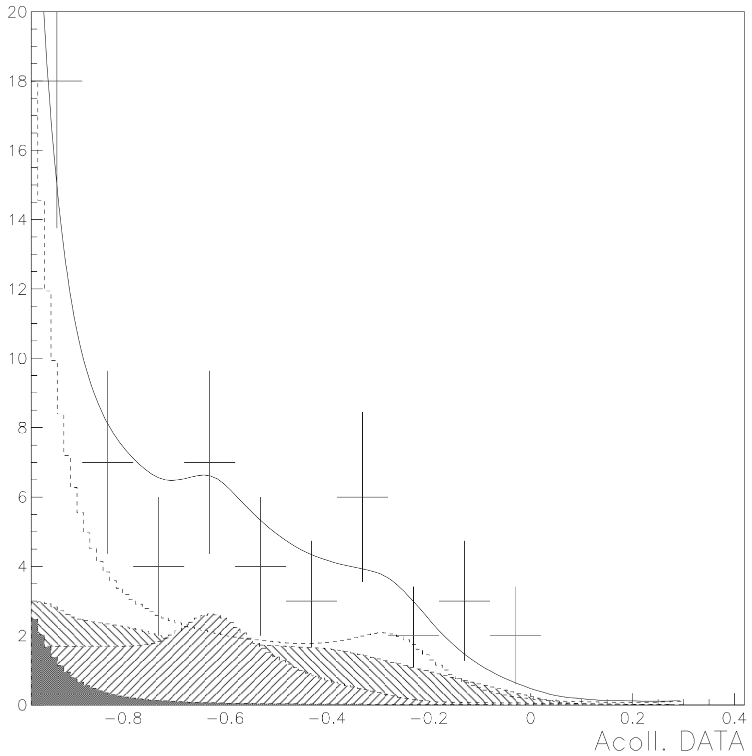
$$\left|h_3^\gamma\right| < 0.34 \qquad \left|h_3^Z\right| < 0.55 \qquad 95\%\ c.l.$$

Single W production

Measure $e^+e^- \to We\nu$ with $W \to q\bar{q}'$ in singular region ($|\cos\theta_e| > 0.98$)



Fit to acolinearity distribution of jets:

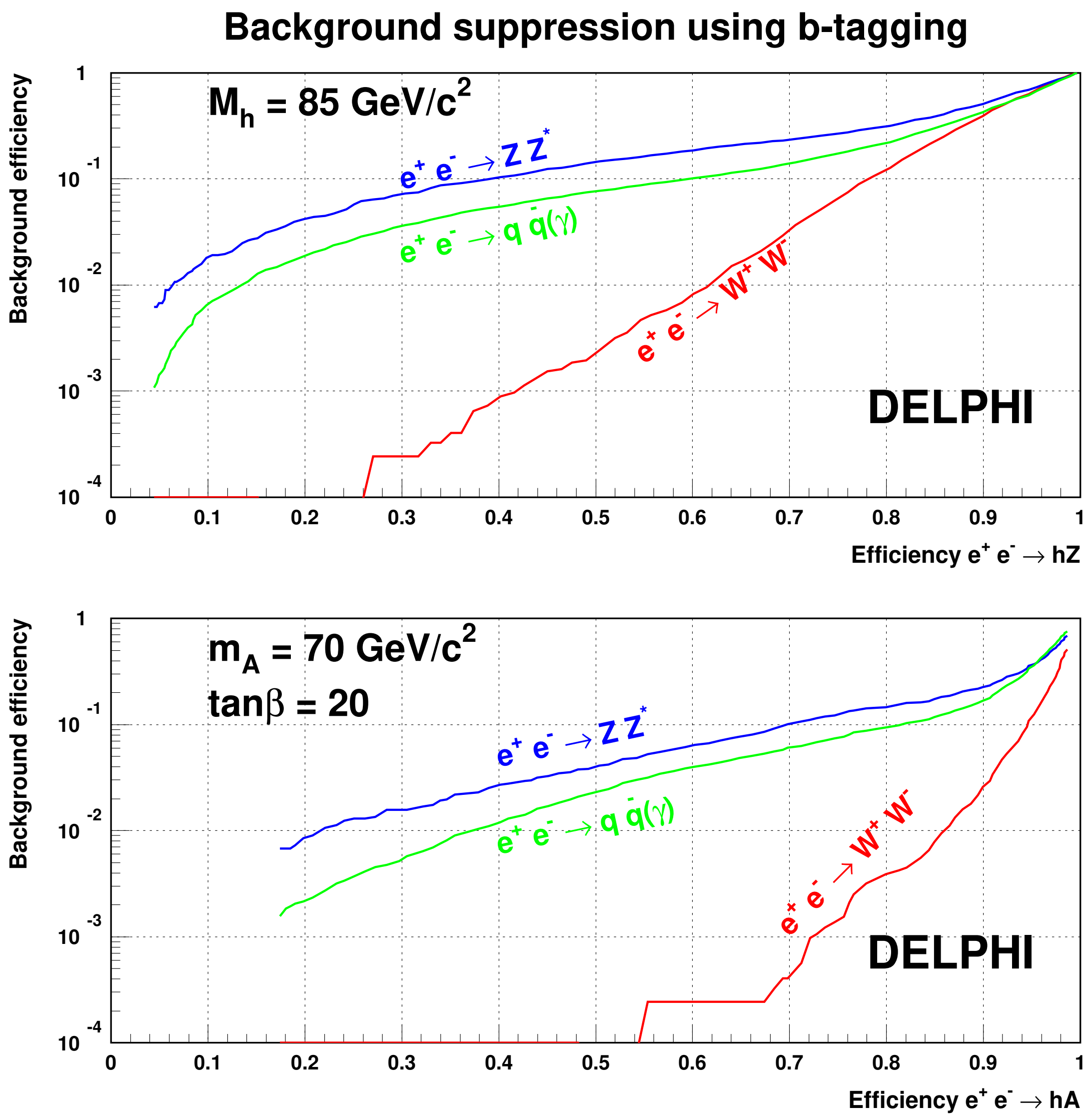


$$\sigma(e\nu qq) = 0.61 \pm 0.28\,\mathrm{pb}$$

$$\mathrm{SM:}\quad \sigma(\mathrm{e}\nu\mathrm{qq}) = 0.51\,\mathrm{pb}$$

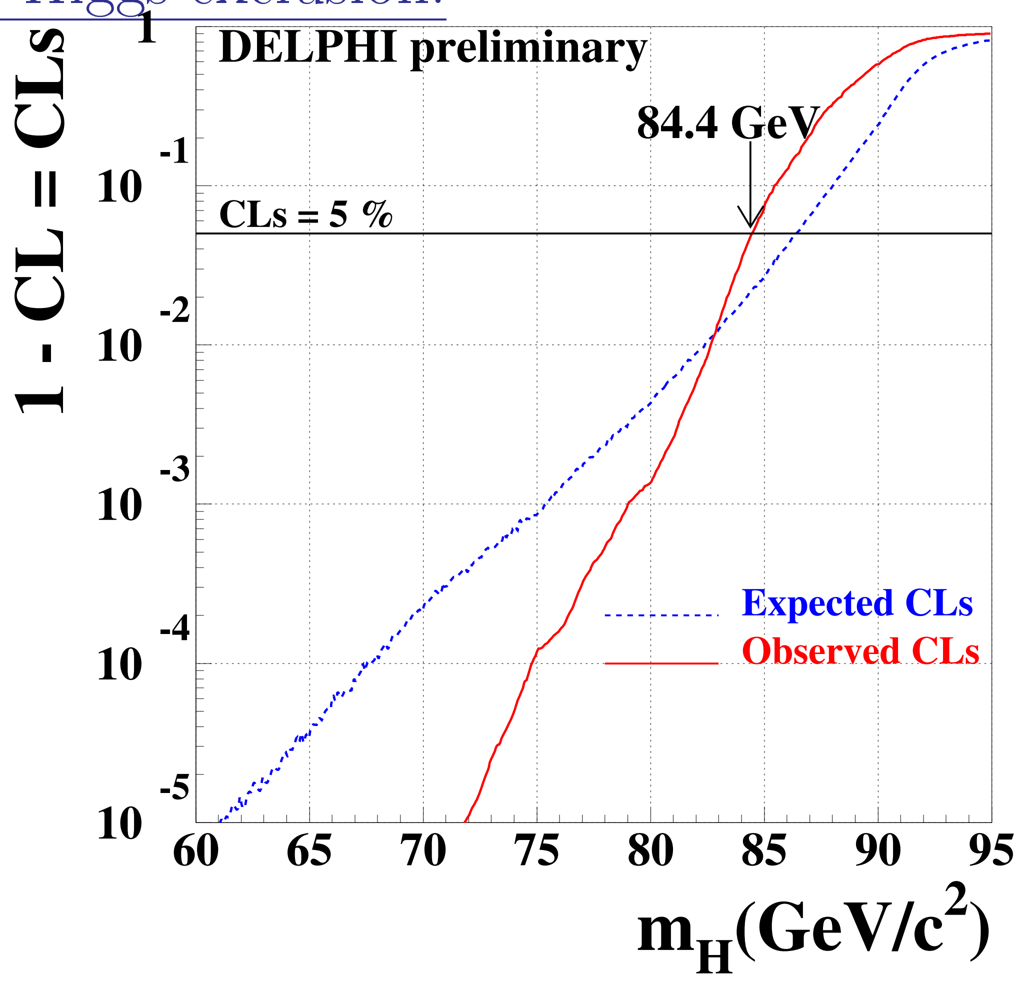
Search for Higgses (hZ, hA)

- channels searched:
  hZ: hee, $h\mu\mu$, $h\nu\nu$, $hq\bar{q}$, $h\tau\tau$, $\tau\tau Z$
  hA: $4b$, $\tau\tau bb$
- in all channels mass information is used
- global optimisation of cuts using likelihood ratio method
- key tool: b-tag



hZ	ε(85GeV)	bkg.	obs.
hee	39.9%	0.66	1
$h\mu\mu$	62.4%	0.44	2
$h\nu\nu$	30.1%	0.58	1
$hq\bar{q}$	40.1%	5.34	4
$h\tau\tau$	20.0%	0.41	0
$\tau\tau Z$	20.0%	0.74	1
hA	ε(70GeV)		
$4b$	55.0%	1.45	0
$\tau\tau bb$	22.6%	0.47	0
total		10.1	9

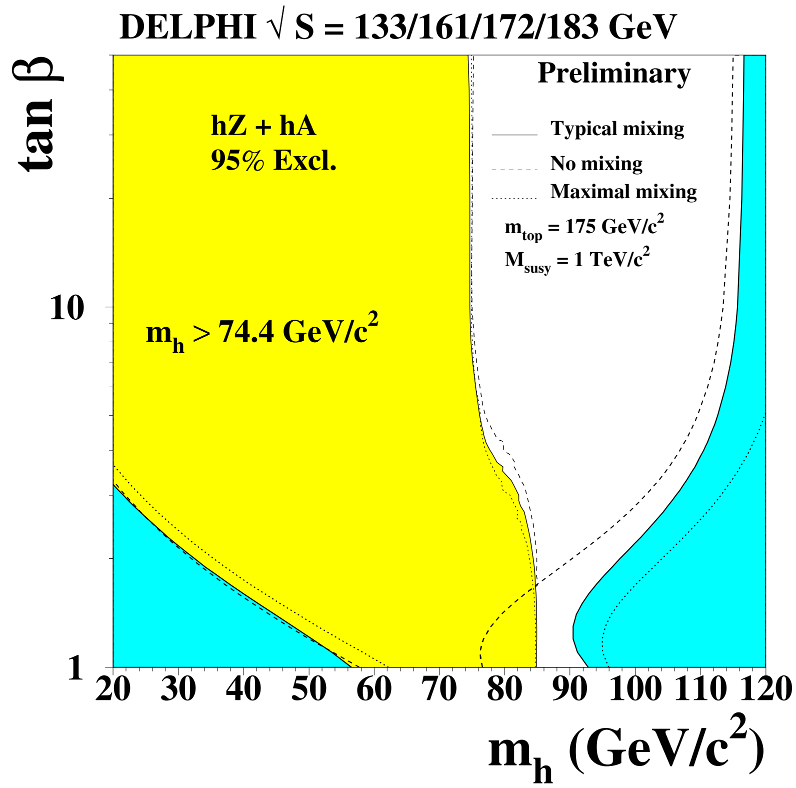
SM-Higgs exclusion:

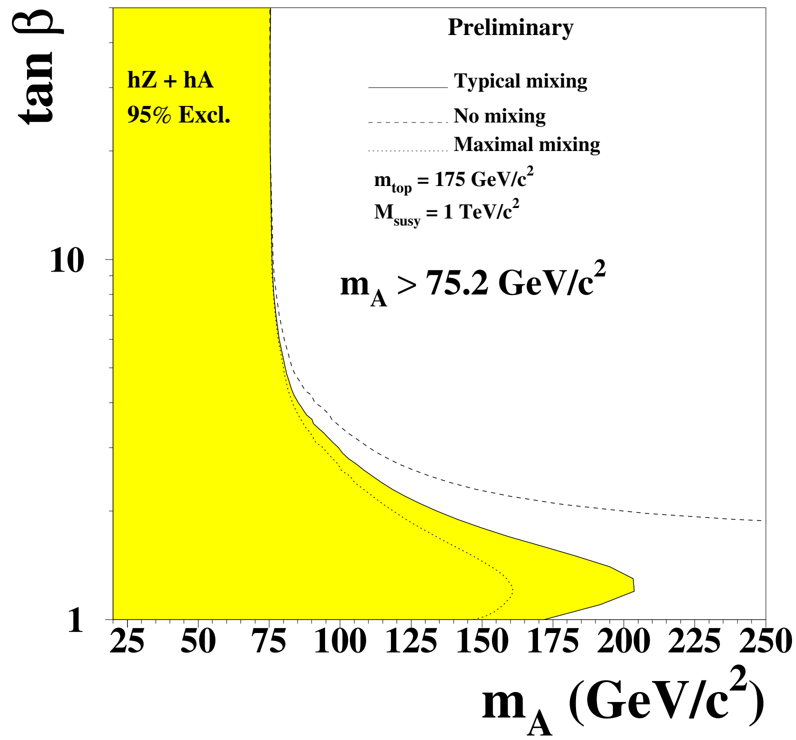


hA exclusion:

observed: $m_A > 75.2\text{GeV}$ $m_h > 74.4\text{GeV}$ $95\% c.l.$

expected: $m_A > 70.9\text{GeV}$ $m_h > 70.2\text{GeV}$

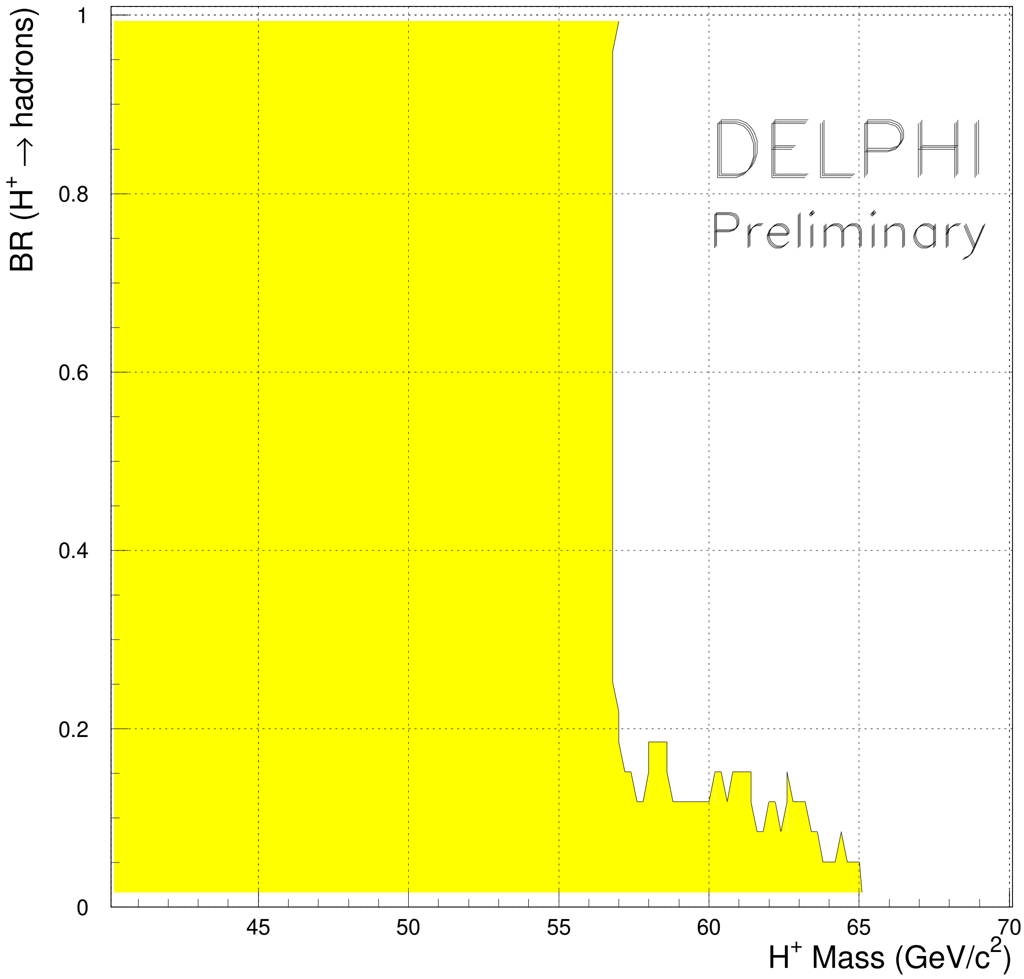




Charged Higgses

H^+H^-	ε(60GeV)	bkg.	obs.
$\tau\nu\tau\nu$	27%	10.1	9
$\tau\nu qq$	31%	3.3	4
$qqqq$	20%	14.9	12

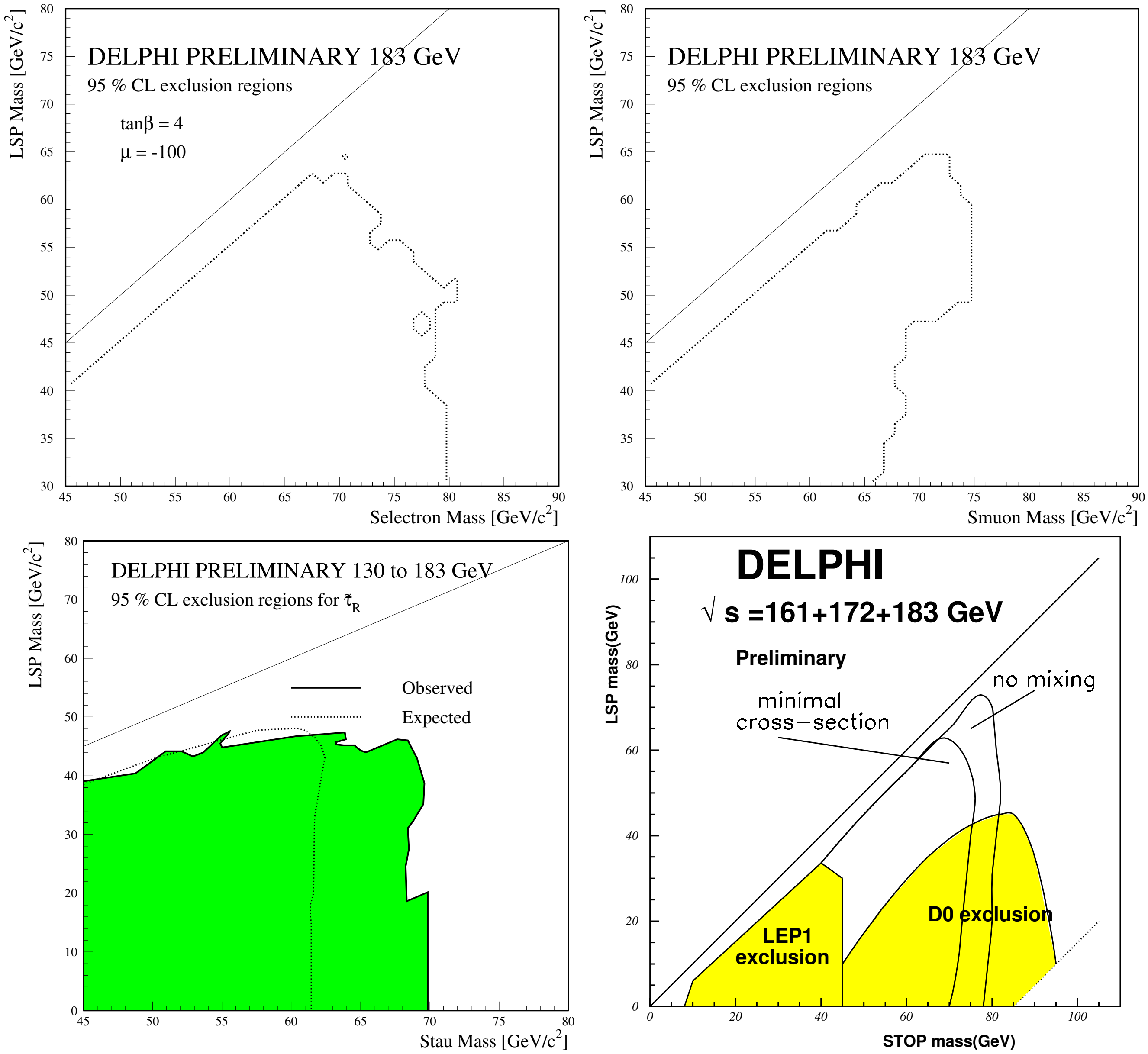
95% exclusion limit:



Not yet interesting for SUSY

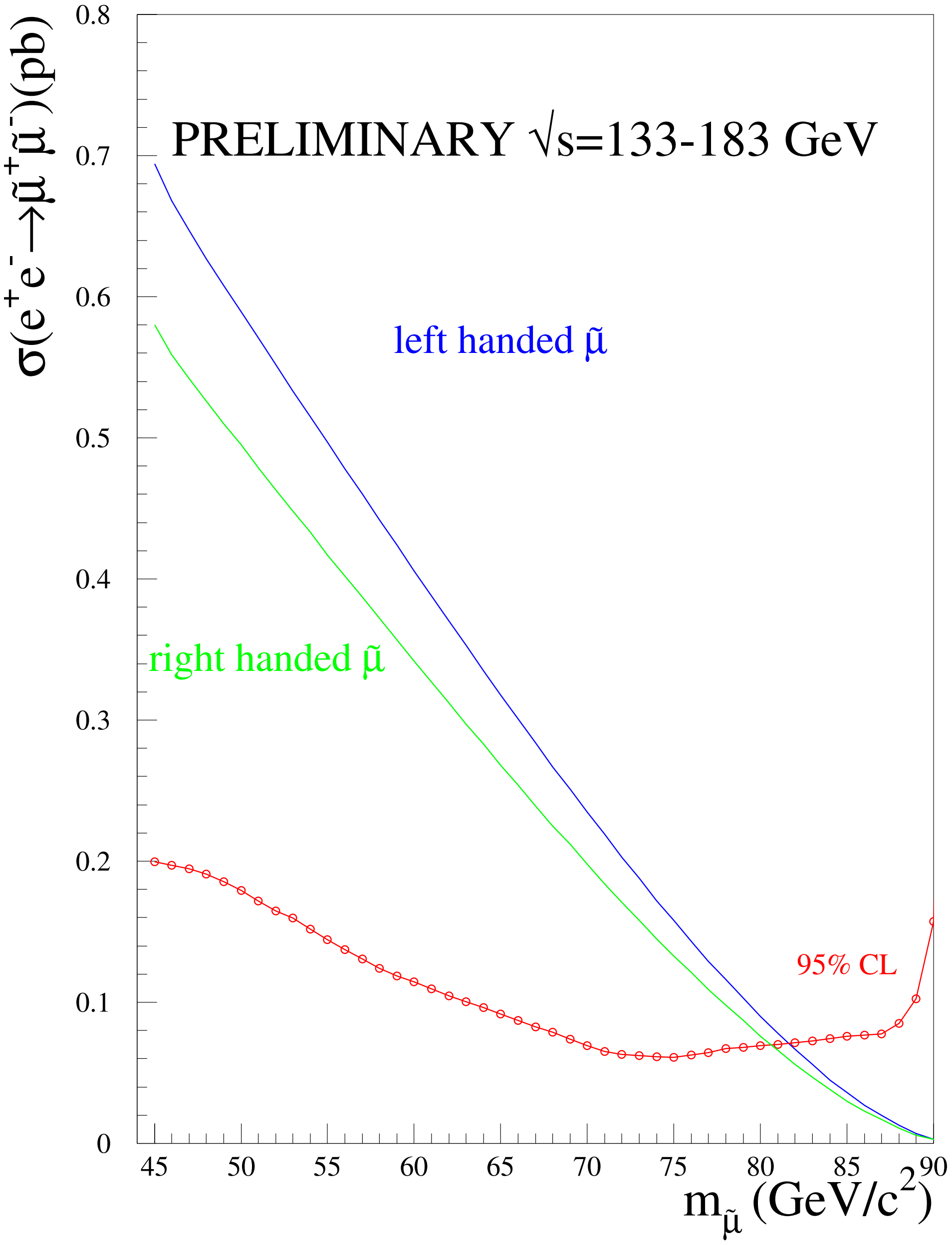
Sfermion searches:

Search for short-lived selectrons, smuons, staus and stops:

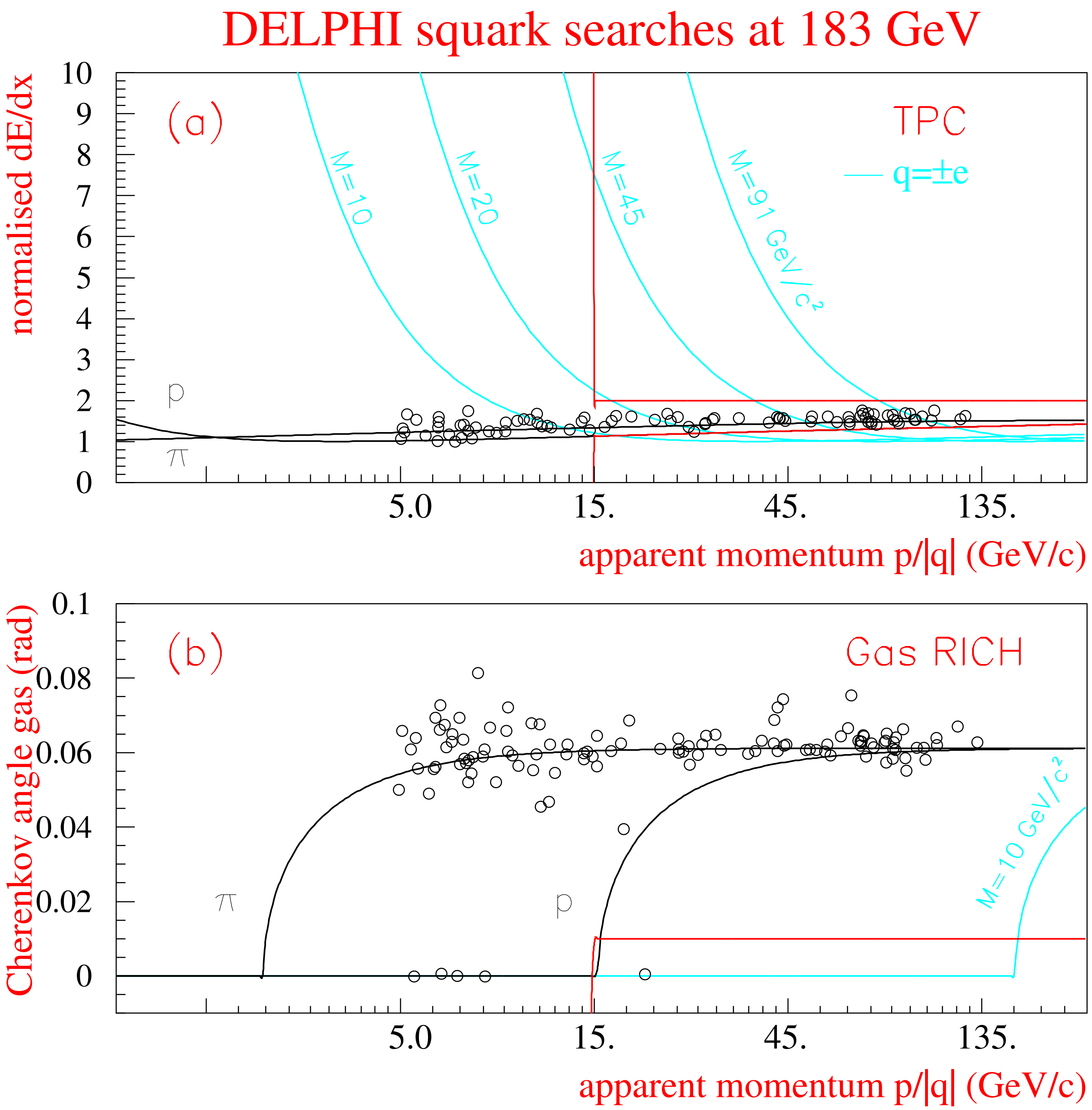


Search for stable heavy particles

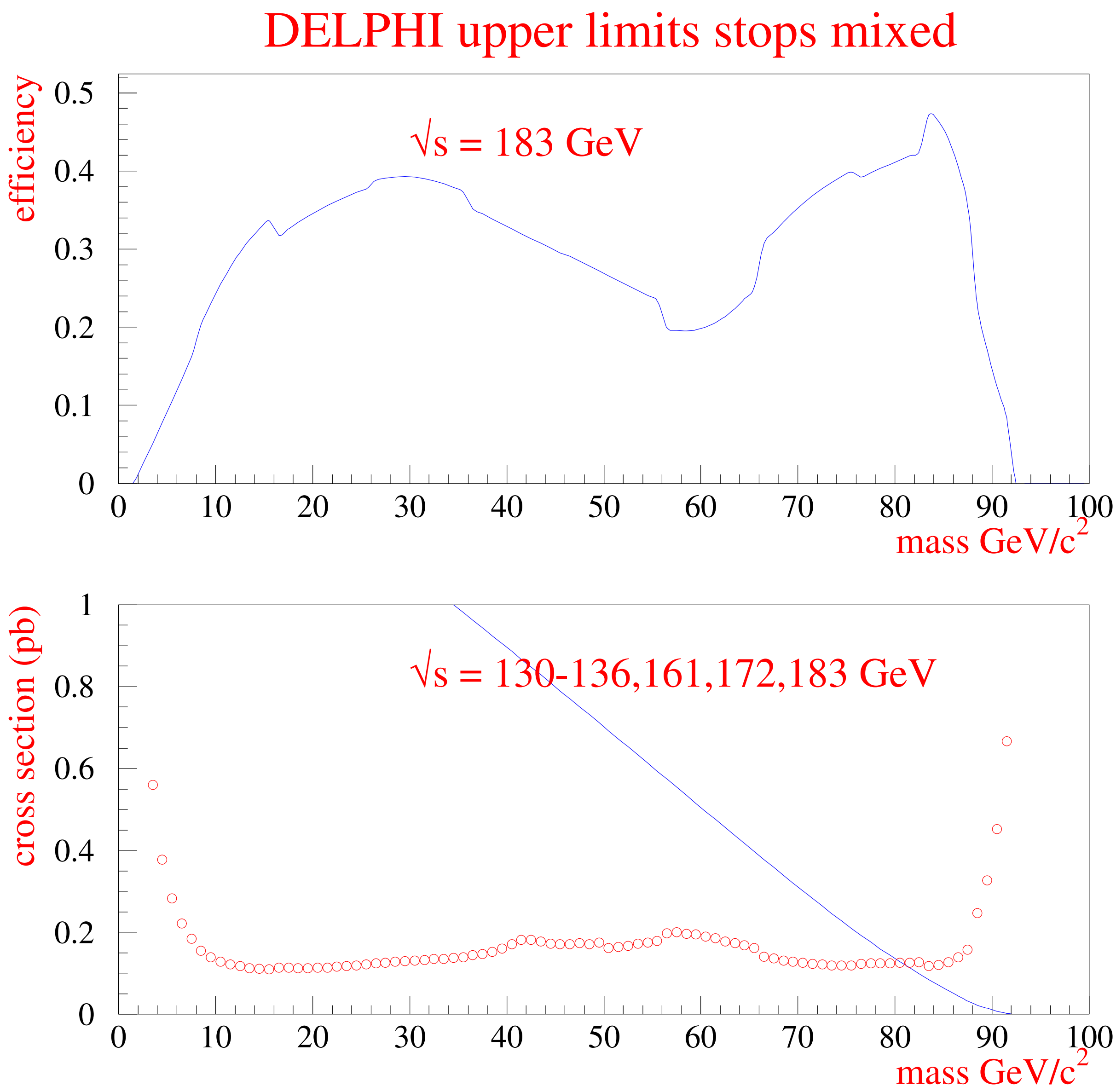
DELPHI limits stable sleptons



RICH-dE/dx combination works also in hadronic events for $m > 2$GeV without holes:



Fragmenting stable stop



$$m_{\tilde{t}} > 80\mathrm{GeV} \quad 95\%\ c.l.$$

Free stop slightly better

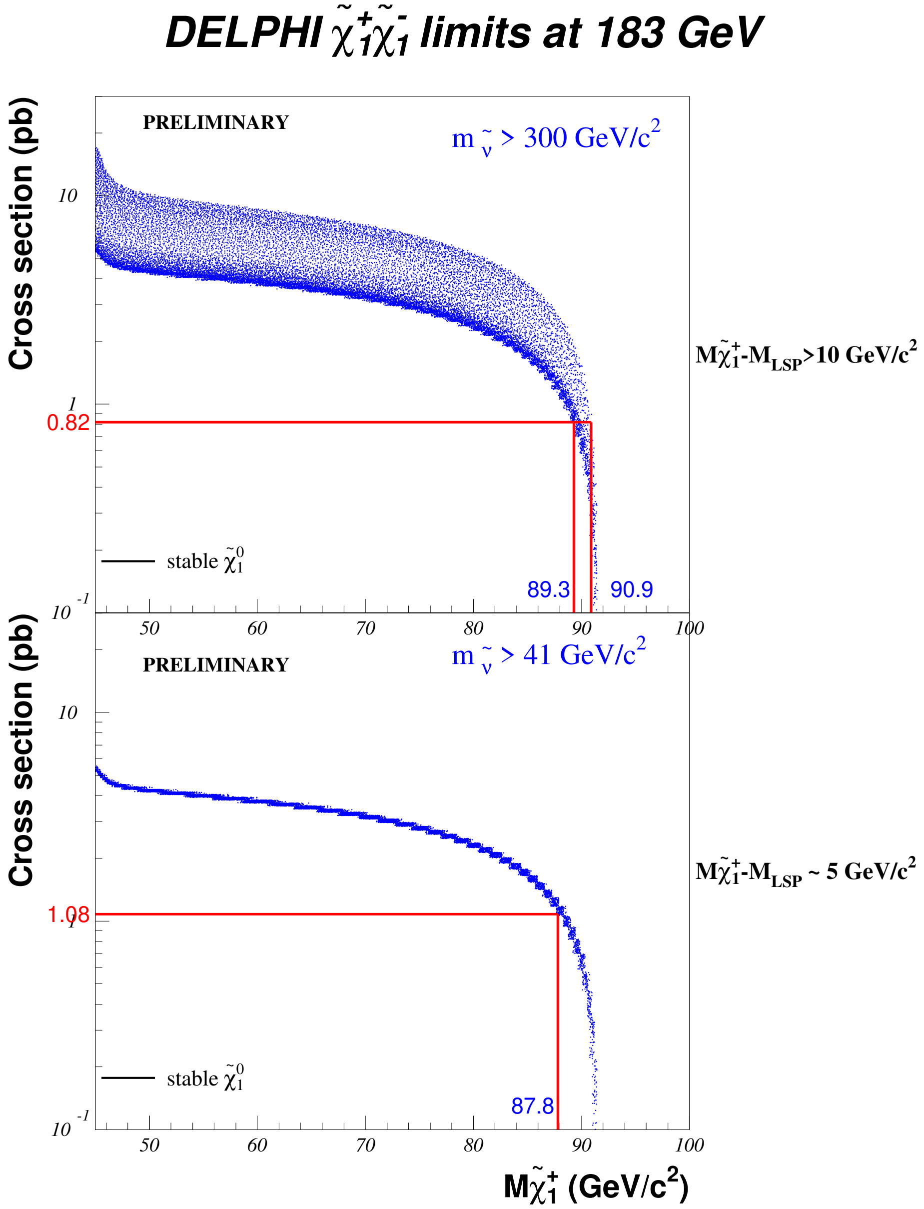
fragmenting sbottom:

maximal mixing: $m_{\tilde{b}} > 38\mathrm{GeV}$ $\tilde{b}$-left: $m_{\tilde{b}} > 83\mathrm{GeV}$

No limit for free sbottom!

SUGRA charginos (χ_1^0 is LSP)

large Δm:



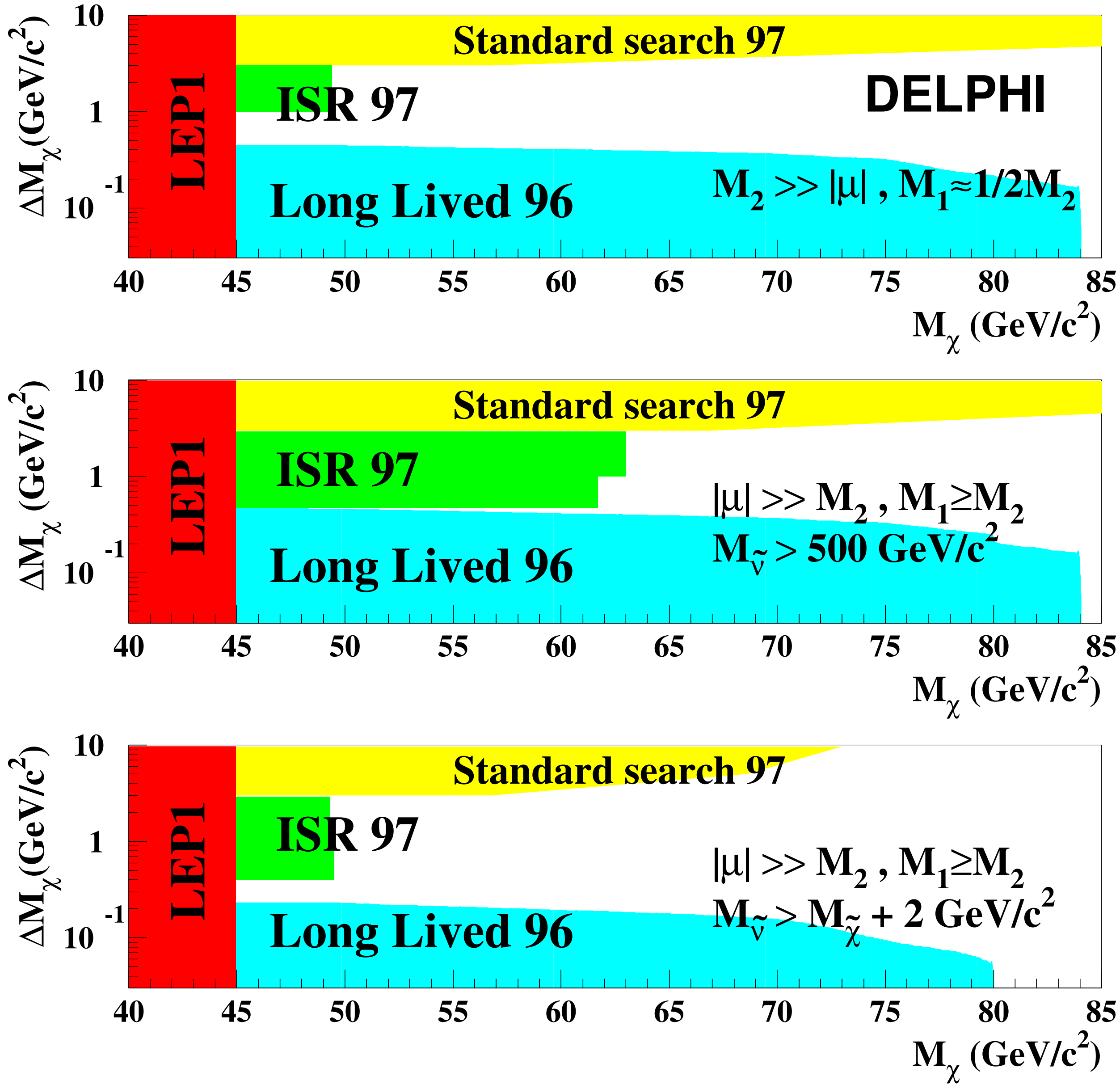
very small Δm:

Search for stable charginos or decays inside the detector

183GeV analysis not ready yet

small Δm:

Search for ISR-photons with little energy in the detector

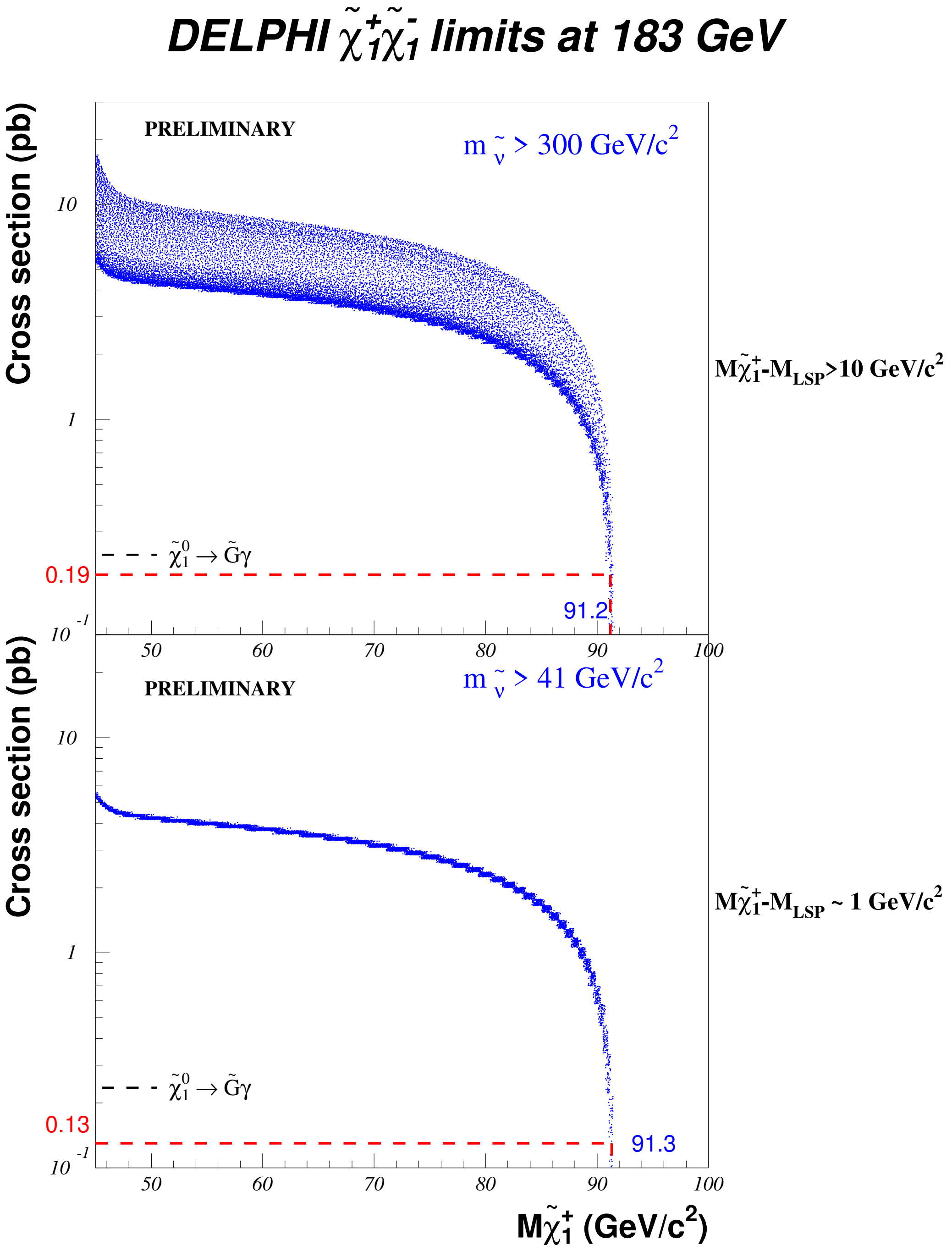


Gaugino with heavy $\tilde{\nu}$: $m(\chi_1^\pm) > 61\mathrm{GeV}$ for all Δm

Higgsino or light $\tilde{\nu}$ needs more luminosity

GMSB charginos and neutralinos ($\tilde{G}$ is LSP)

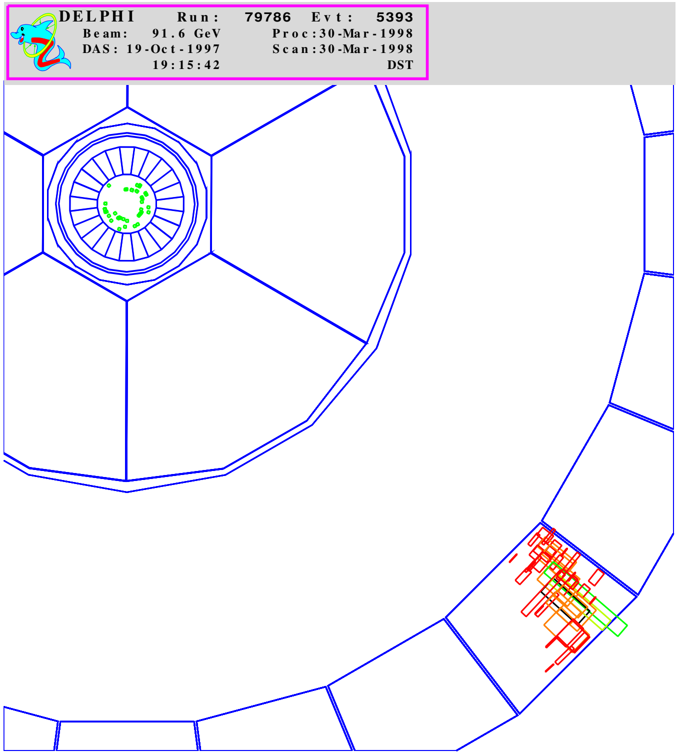
χ_1^0 is NLSP: ($\chi_1^0 \to \tilde{G}\gamma$)
Chargino limit from standard search plus photons:



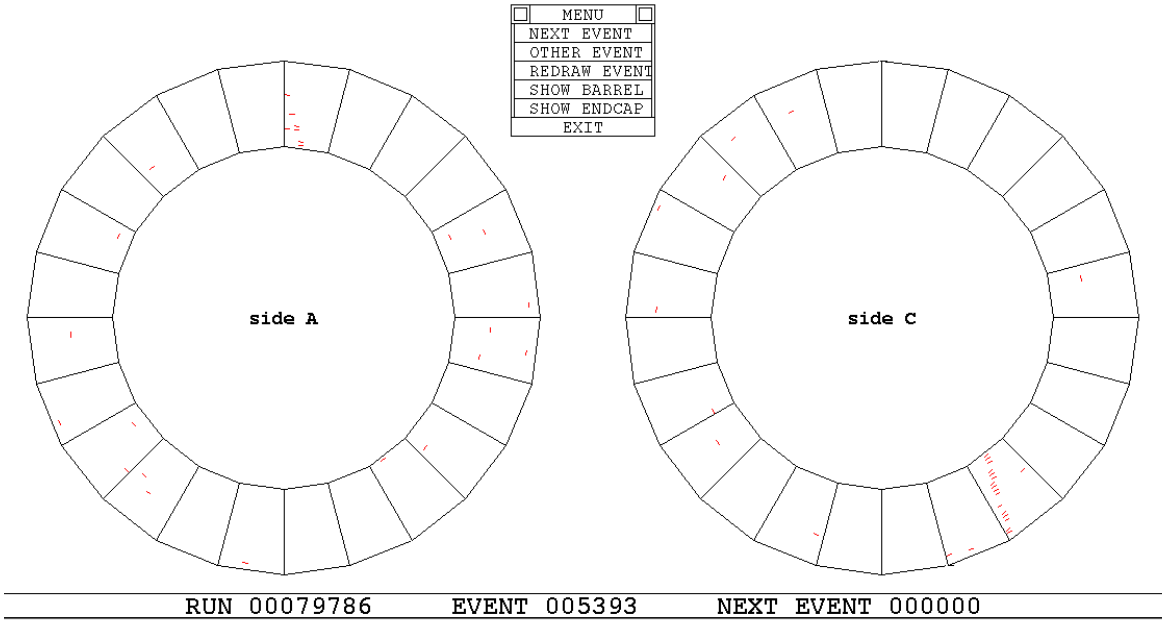
Neutralino search with photons

Long lived Neutralino: Search for "non pointing" photons (0 cand., 0.4 exp.)

Possible candidate: HPC:



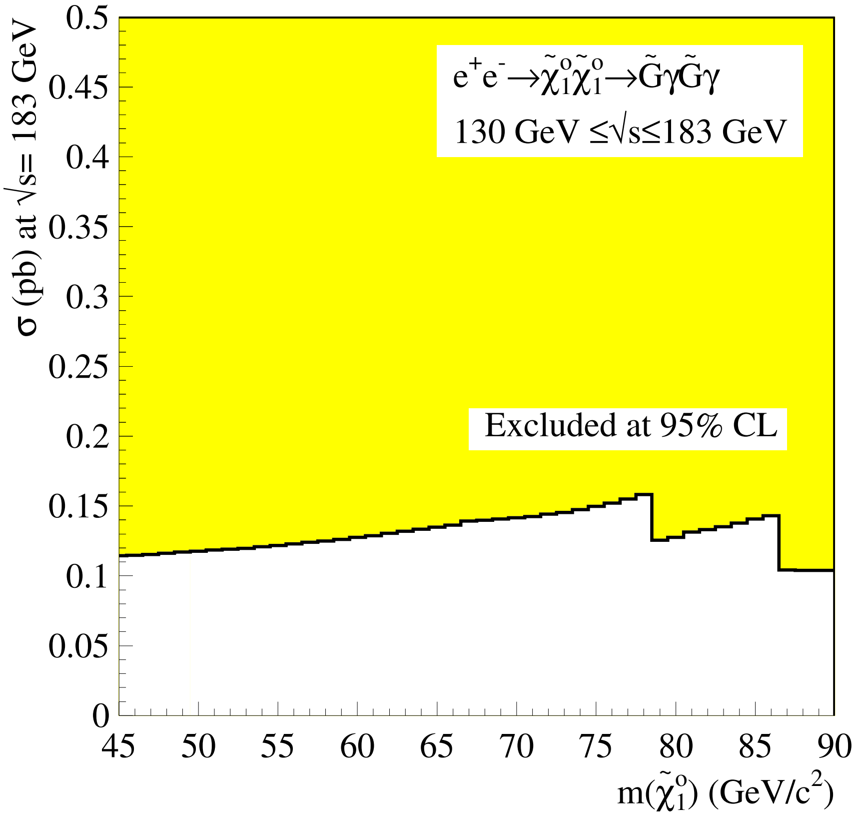
HCAL cathode readout:

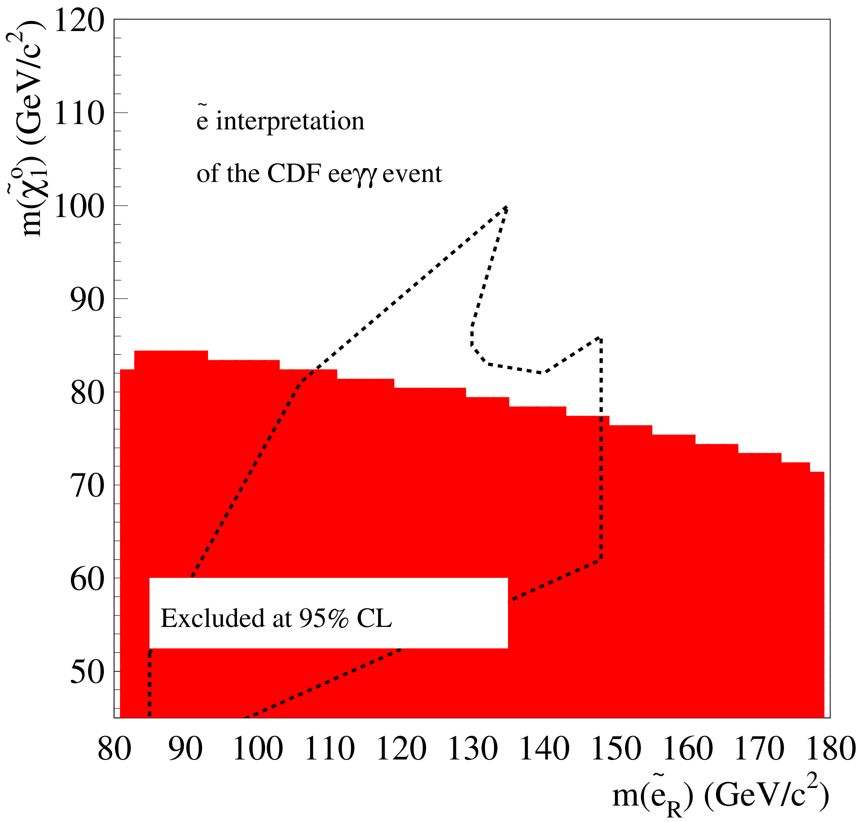


Short lived Neutralino:

Search for acoplanar photons plus missing energy

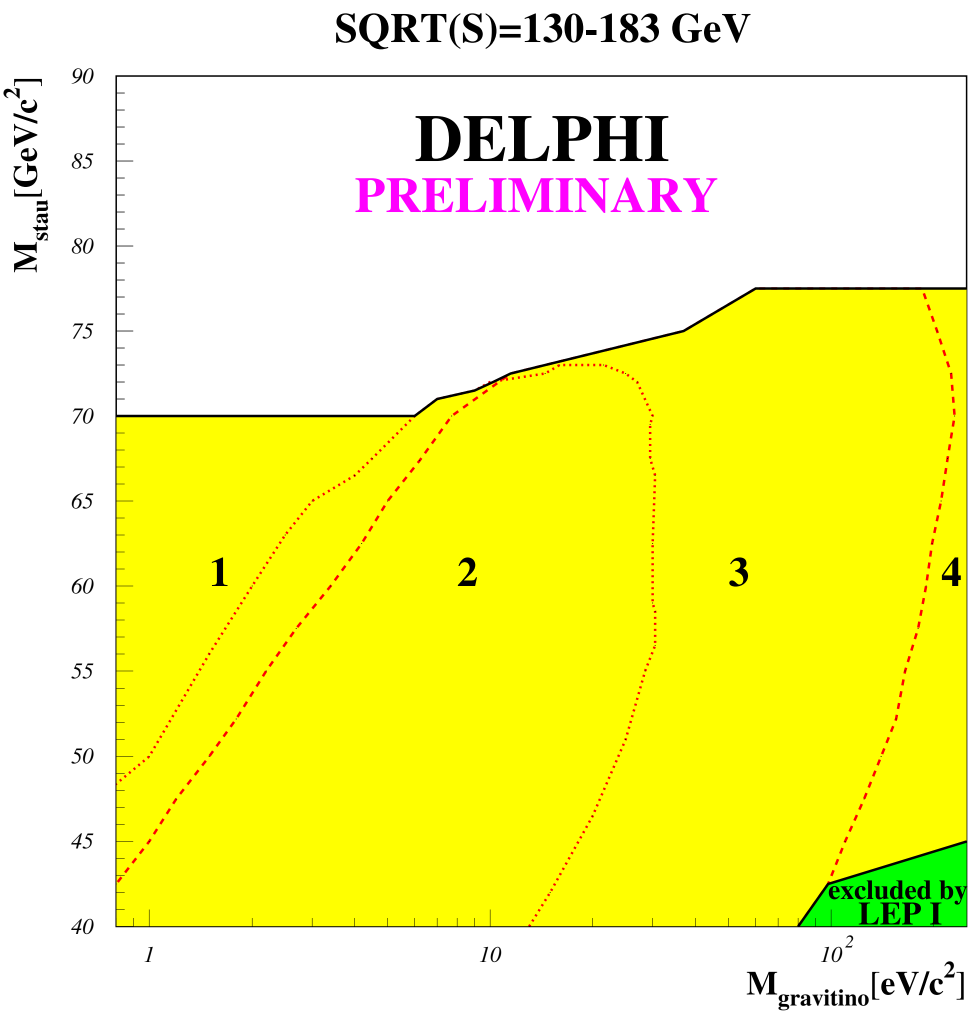
(2 candidates, 2.8 expected at all energies)





$\tilde{\tau}$ is NLSP: $(\tilde{\tau} \to \tilde{G}\tau,\ \chi_1^0 \to \tilde{\tau}\tau)$

$\tilde{\tau}$ can be short-lived, decaying in the detector or "stable" depending on the $\tilde{G}$-mass



1) $\tilde{\tau}$ short lived $(m_{LSP} \sim 0)$

2,3) $\tilde{\tau}$ decays inside DELPHI

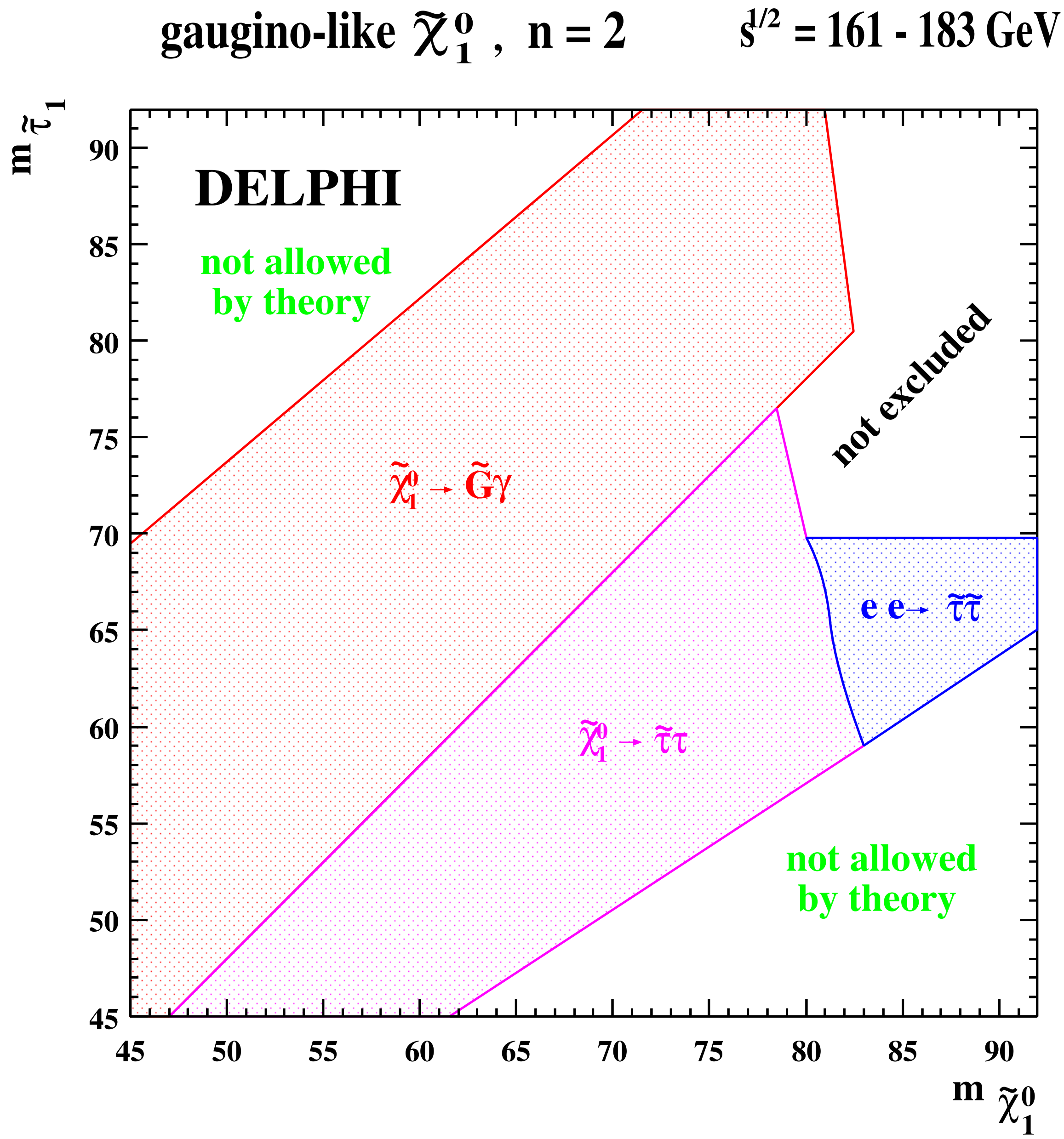
4) $\tilde{\tau}$ "stable"

Search for $\chi_1^0\chi_1^0 \rightarrow \tilde{\tau}\tilde{\tau}\tau\tau$:

Search for 4τ plus missing energy

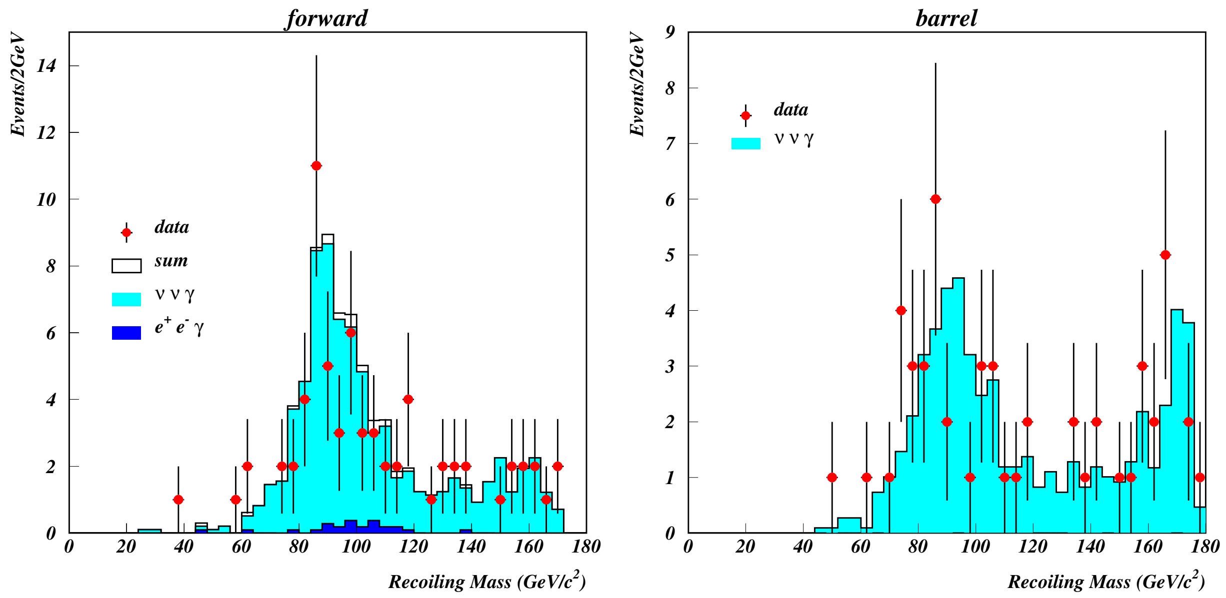
(2 candidates 0.5 expected at 183GeV)

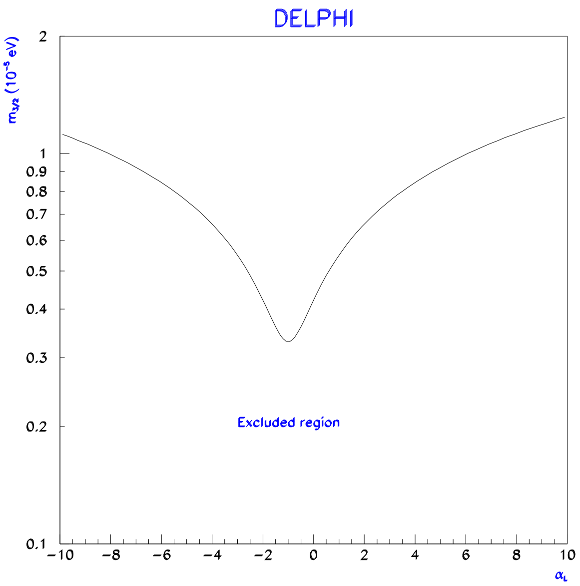
Model dependent limit



Limit on $\tilde{G}$ mass from “neutrino counting”

Look for $e^+e^- \to \gamma\tilde{G}\tilde{G}$ in region $m_{rec.} > m_Z$

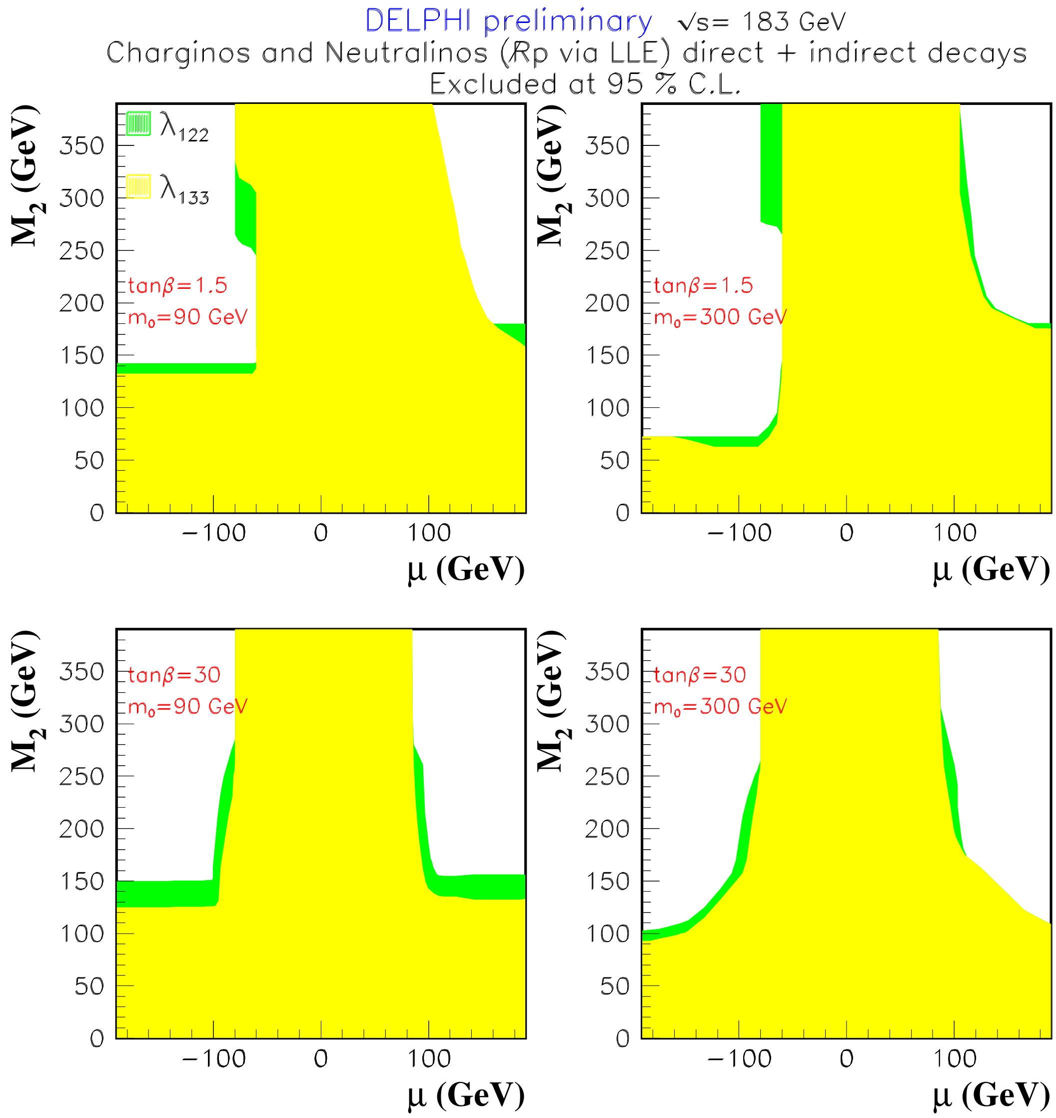




$$m_{\tilde{G}} > 0.33 \cdot 10^{-5} eV \quad \Rightarrow \quad \Lambda_s > 117\mathrm{GeV}$$

R_p violating Susy

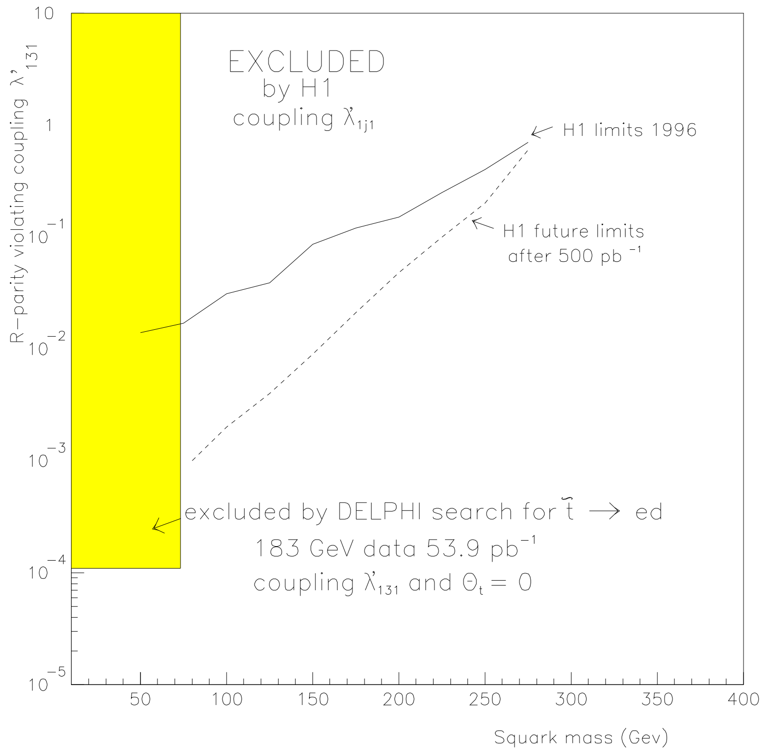
Search for charginos and neutralinos:



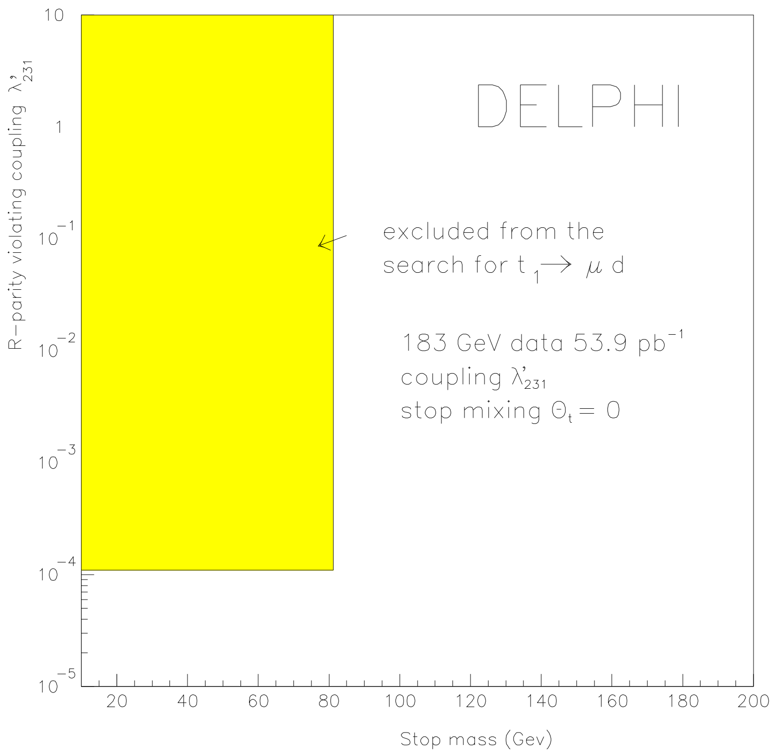
$\Rightarrow$ $m(\chi_1^0) > 24\mathrm{GeV}$ independent of m_0

Search for stop pair production

$\tilde{t} \to ed$



$\tilde{t} \to \mu d$



Search for excited leptons

Pair production:

Search for $e^+e^- \to \ell^{*+}\ell^{*-}$, $e^+e^- \to \nu^*\nu^*$ with $\ell^*, \nu^* \to (\gamma, W)(\ell, \nu)$

$f = \quad f'$: $\ell^* \to \gamma\ell, \nu^* \to W\ell$ dominates

$f = -f'$: $\ell^* \to W\nu, \nu^* \to \gamma\nu$ dominates

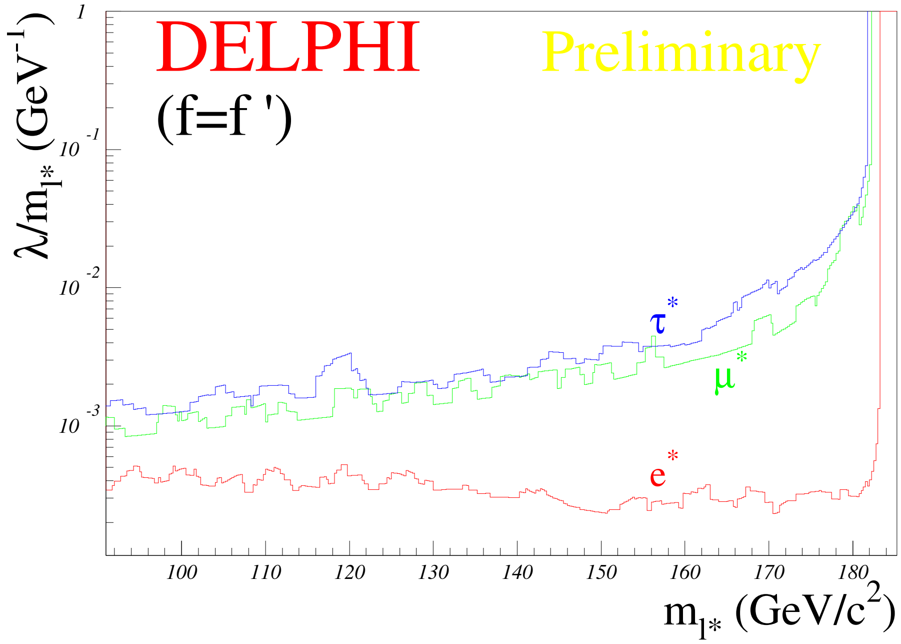
Results:

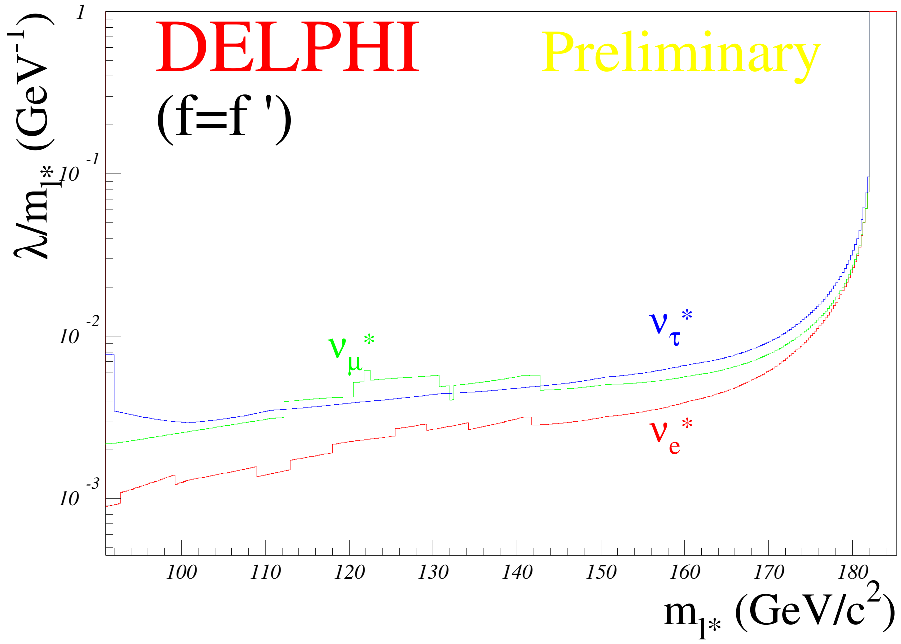
	e^*	μ^*	τ^*	ν_e^*	ν_μ^*	ν_τ^*
$f = \quad f'$	90.5	90.5	89.7	87.3	87.7	83.0
$f = -f'$	81.7	81.7	81.7	90.3	90.3	90.3

Single production:

- sensitive to much higher masses
  $\Rightarrow BR((\ell^*, \nu^*) \to W(\nu, \ell)) \sim 50\%$ independent of f'/f
  $\Rightarrow BR((\ell^*, \nu^*) \to Z(\ell, \nu))$ becomes relevant
- limits get dependent on coupling λ/m

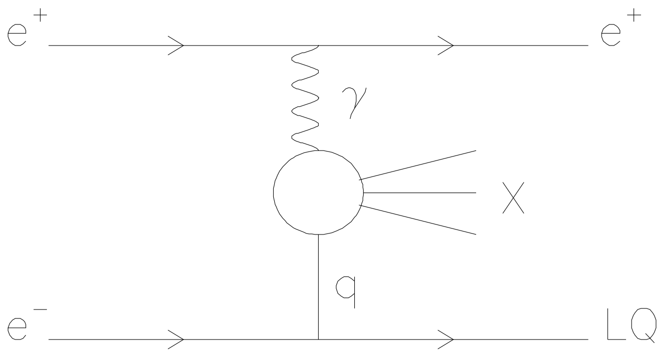
Single Production of Excited Leptons



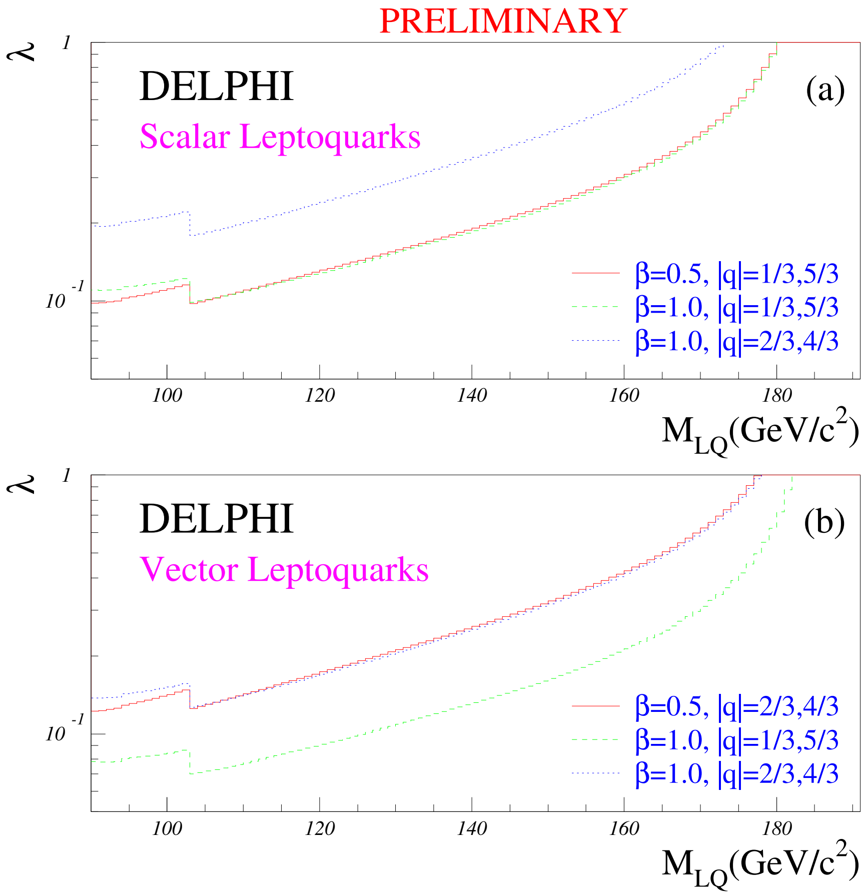


Similar limits for $f = -f'$

Leptoquark search



Search for "lepton + 1-jet" events



Similar search for $e^+e^- \to ct \to cb\ell\nu$: $\sigma < 0.55$pb

Conclusions

- QCD behaves normal between m_Z and 183GeV
- W-physics enters the regime of precision physics
- The Higgs searches start to probe the interesting region
- Many other searches, although unfortunately nothing found
- The Standard Model still rules