L3 Report

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L3 collaboration

LEPC
November 9th, 1999
CERN

Summary of running

Luminosity collected in 1999:

- **91 GeV : $2.52 + 0.5 + 0.88$ pb^{-1}.**
- **192 GeV : 29.4 pb^{-1}.**
- **196 GeV : 81.6 pb^{-1}.**
- **200 GeV : 79.9 pb^{-1}.**
- **202 GeV : 26.9 pb^{-1}.**

Luminosity on tape = 232 pb^{-1}

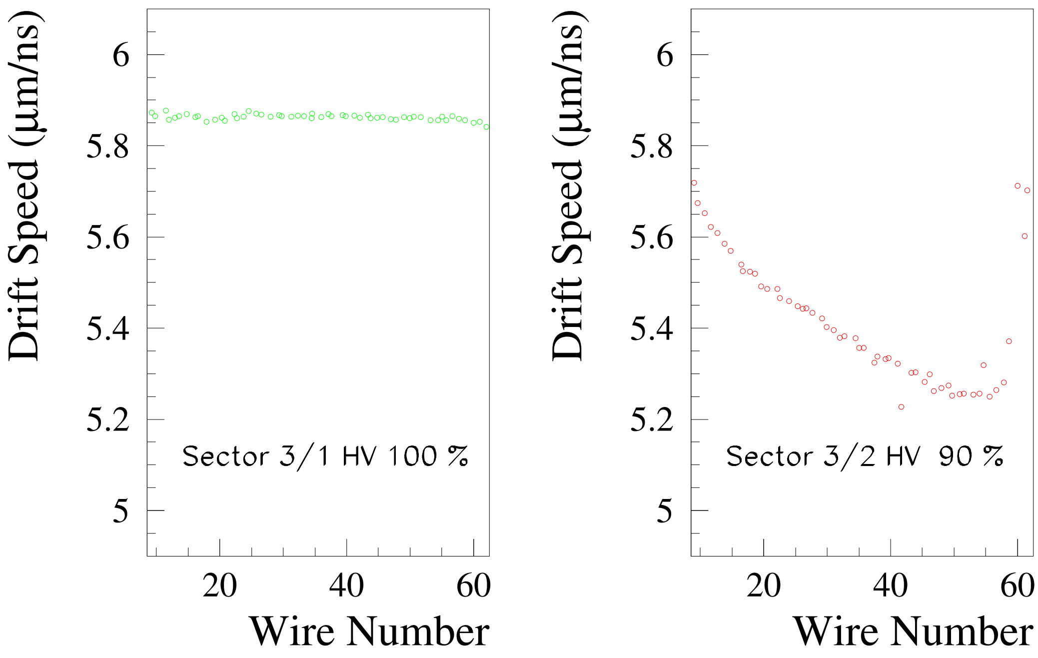
Delivered luminosity > 250 pb^{-1}

DAQ efficiency : 91.5%

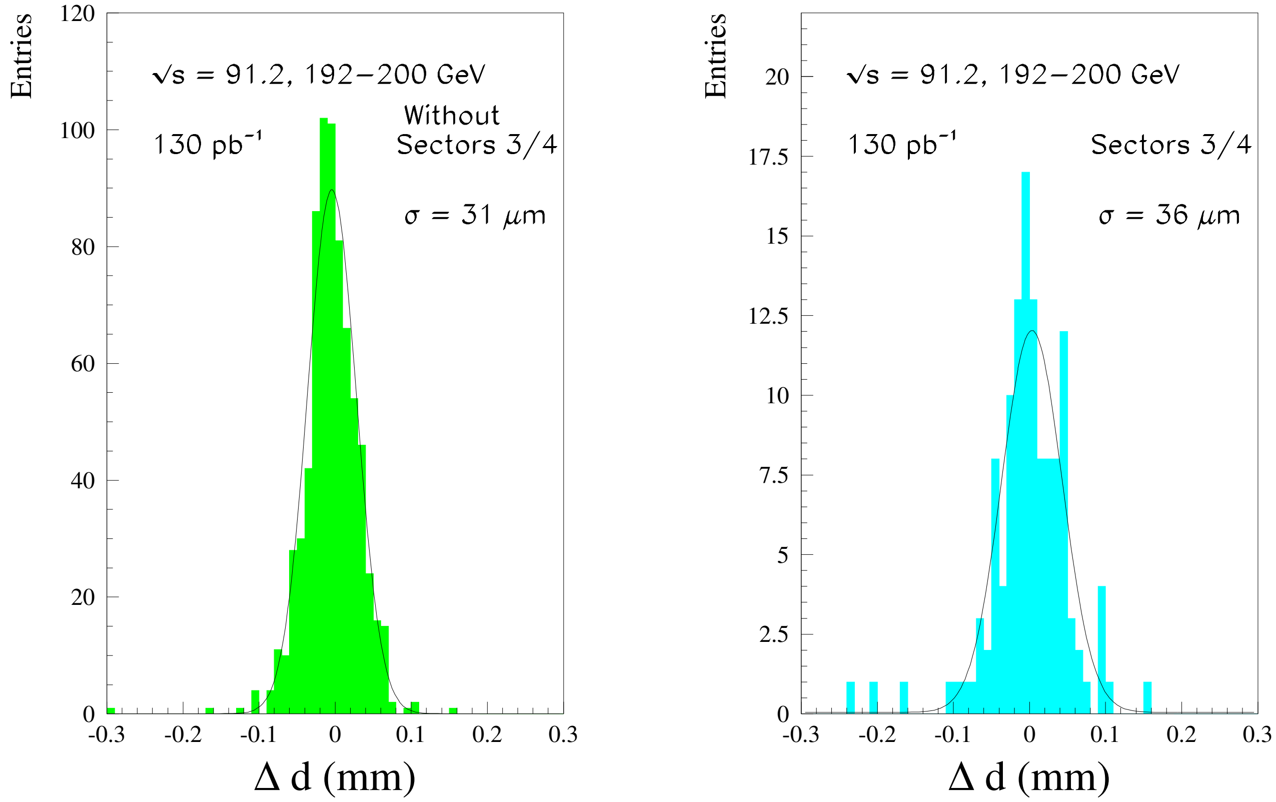
Summary of running

Central Tracker (TEC)

- 19th of May: Damage to the cathode between sectors 3 and 4 during the ramping of the beam.
- HV could be raised to 90% of nominal value.
- Recalibration only possible at the end of August (129 pb^{-1} at high energy + 0.4 pb^{-1} at the Z peak):



Summary of running



We have come a long way!

- 3rd of September: SIMILAR damage between sectors 20 and 21: HV could only be raised at 80% of nominal value
- requested and received 0.9 pb^{-1} instead of 0.5 pb^{-1} at Z peak during the September run.

Other Detectors: functioned OK

Shutdown activities:

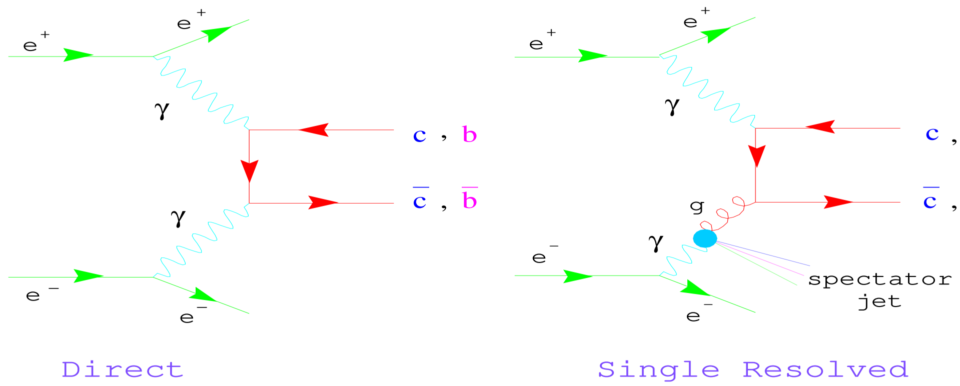
- **Normal maintenance of the muon chambers**
- **Y2K compliance.**

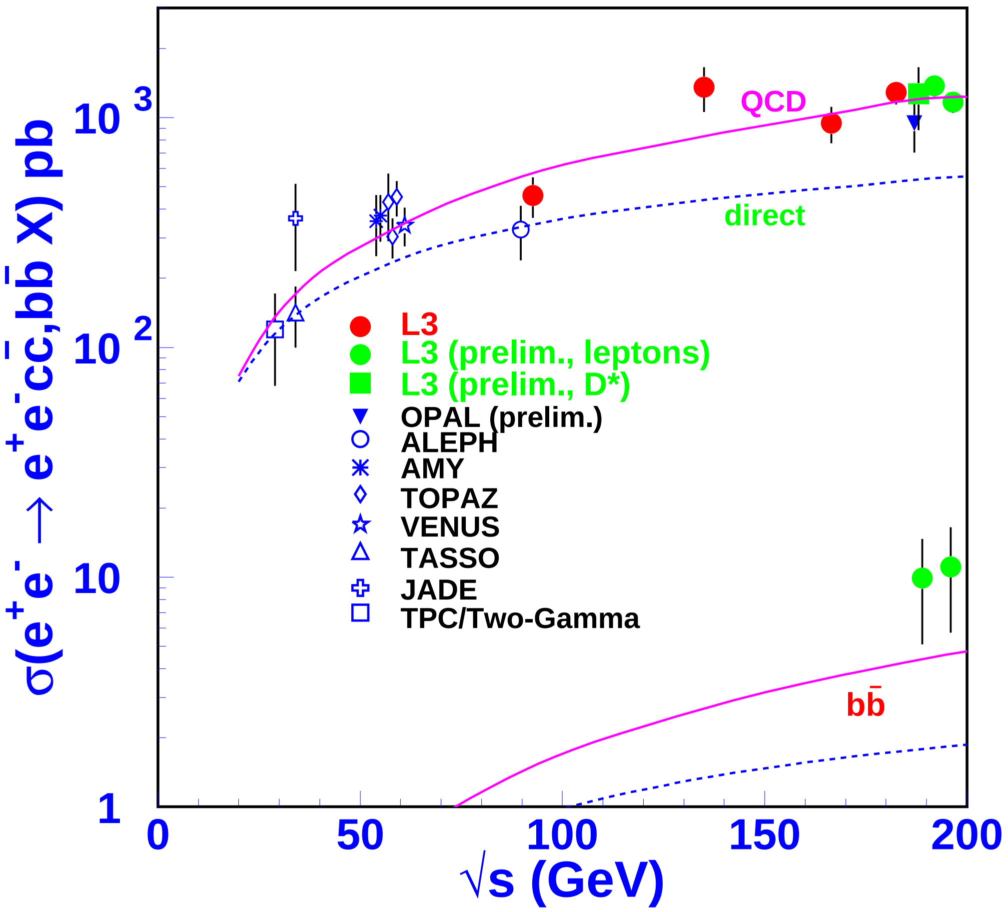
Some Physics Results:

- **Final calibrations and rerun of the data before the end of the year.**
- **For most of the results, the bad sectors 3/4 and 20/21 have been suppressed from the analysis.**
- **Results on this year data are PRELIMINARY.**

Two Photon Physics

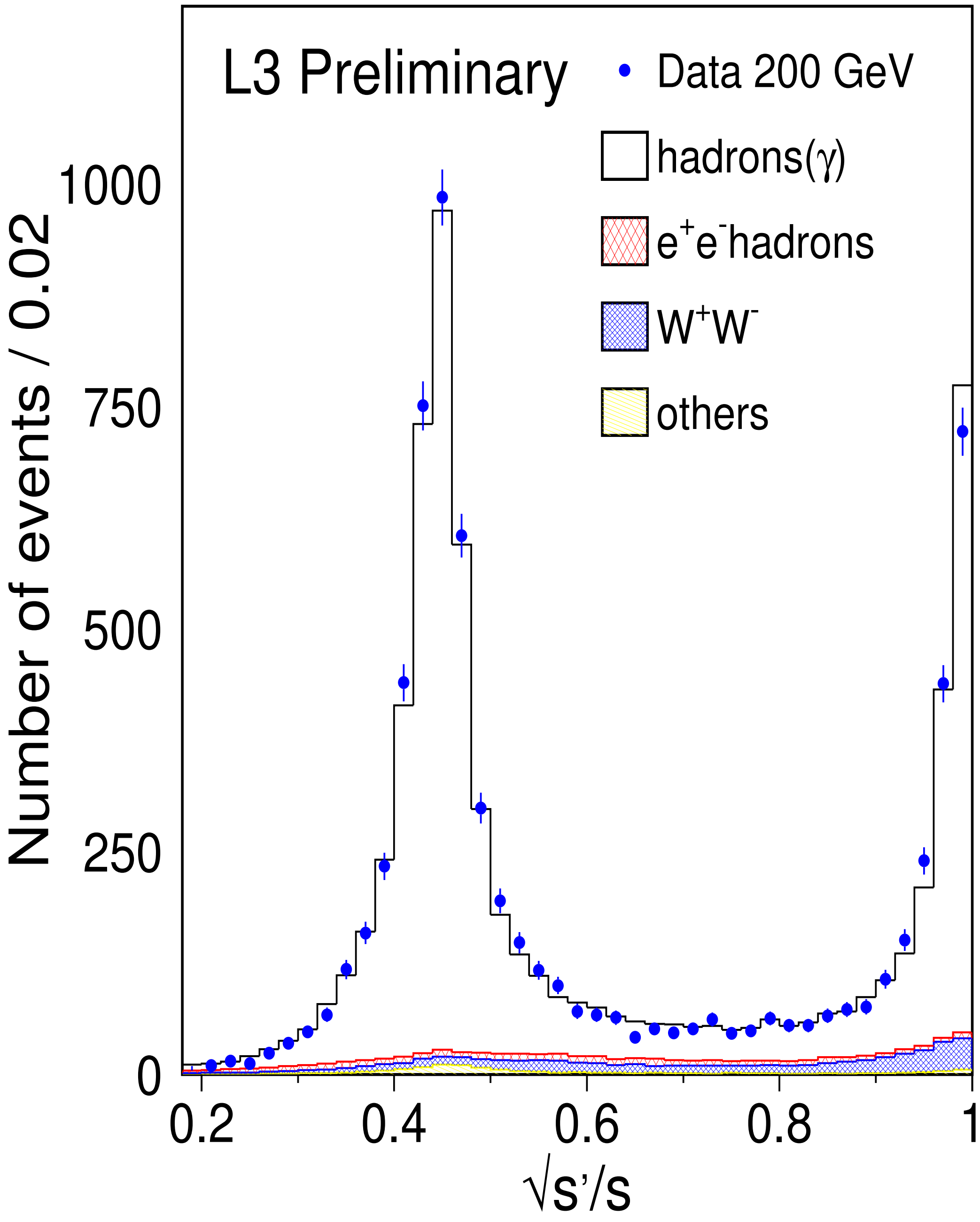
- Highest cross section at LEP!
- Production of b and c quark: good test of perturbative QCD.

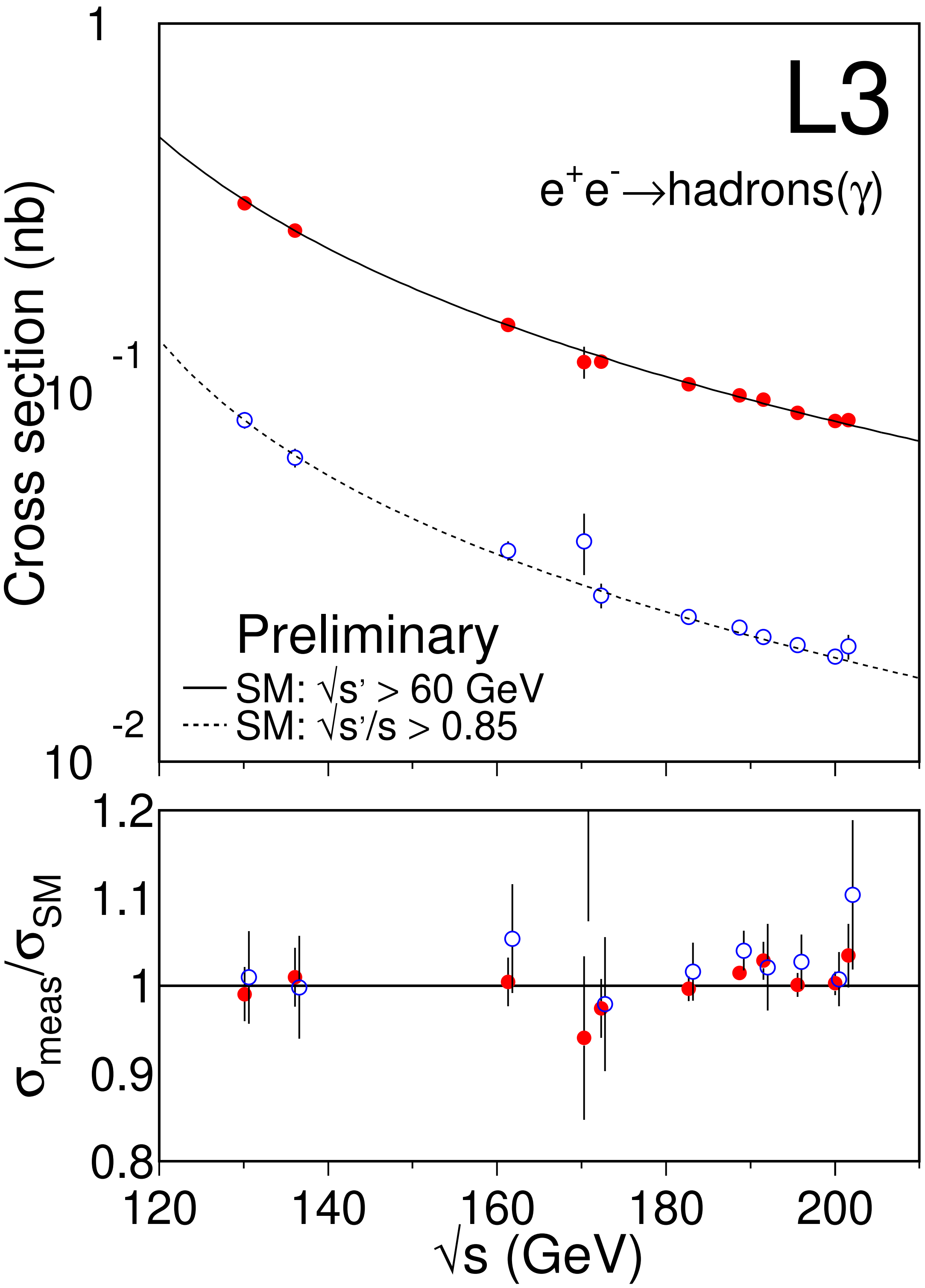




First Measurement of $b\bar{b}$ in $\gamma\gamma$ collisions!

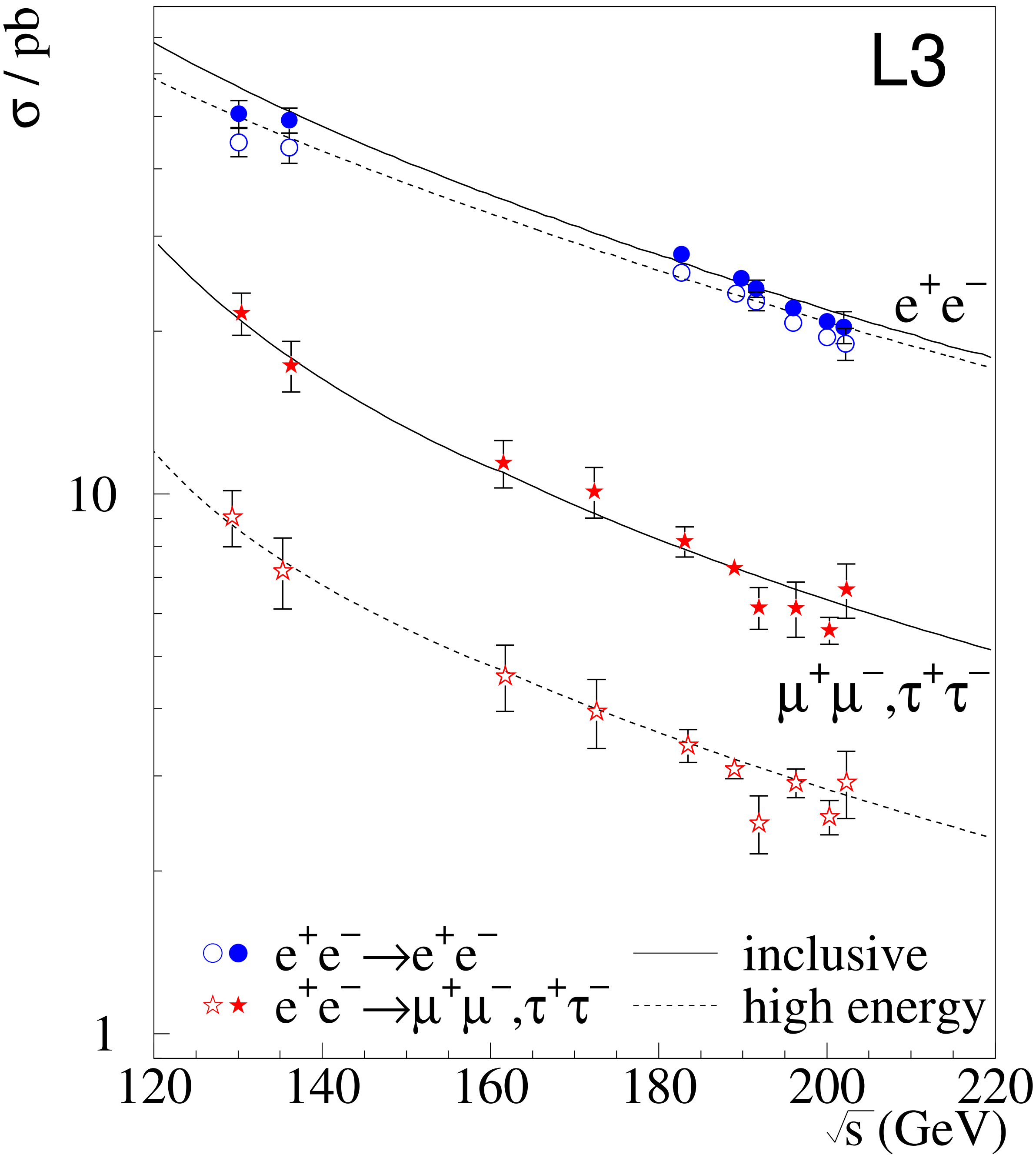
$e^+e^- \longrightarrow$ hadrons



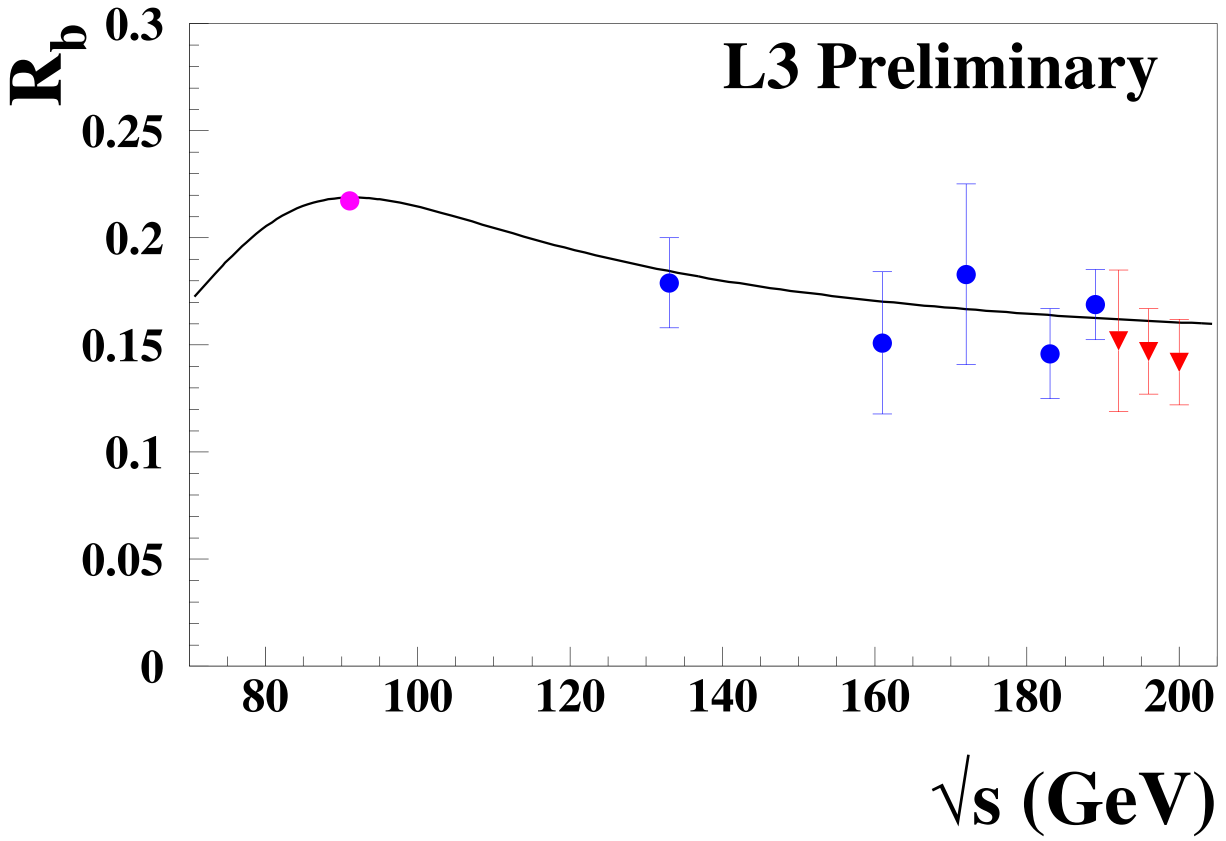


L3
e+e-→hadrons(γ)
Preliminary
SM: √s' > 60 GeV
SM: √s'/s > 0.85
Cross section (nb)
1
10-1
10-2
σmeas/σSM
1.2
1.1
1
0.9
0.8
120
140
160
180
200
√s (GeV)

$e^+e^- \longrightarrow \ell^+\ell^-$

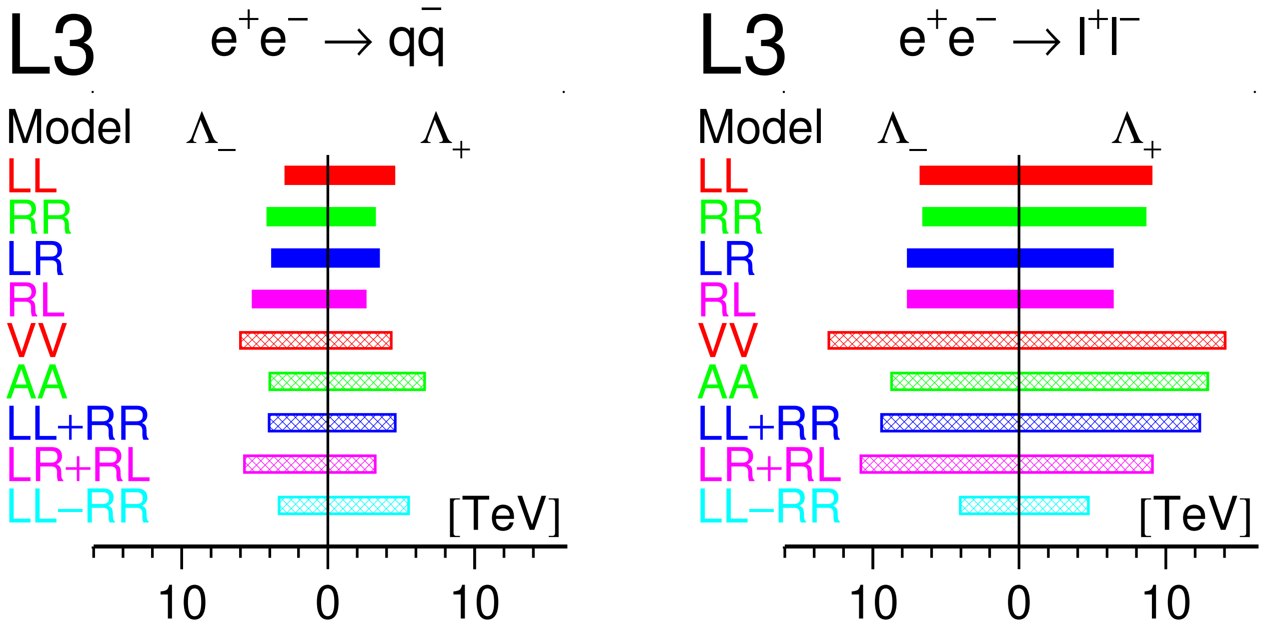


$$R_b = \frac{\sigma(e^+e^- \rightarrow b\bar{b})}{\sigma(e^+e^- \rightarrow q\bar{q})}$$



New Physics?

- from $e^+e^- \rightarrow f\bar{f}$
- New interaction at an energy scale Λ ($\Lambda \gg \sqrt{s}$) can be described by four-fermion contact interaction.
- using measured cross sections and asymmetries:



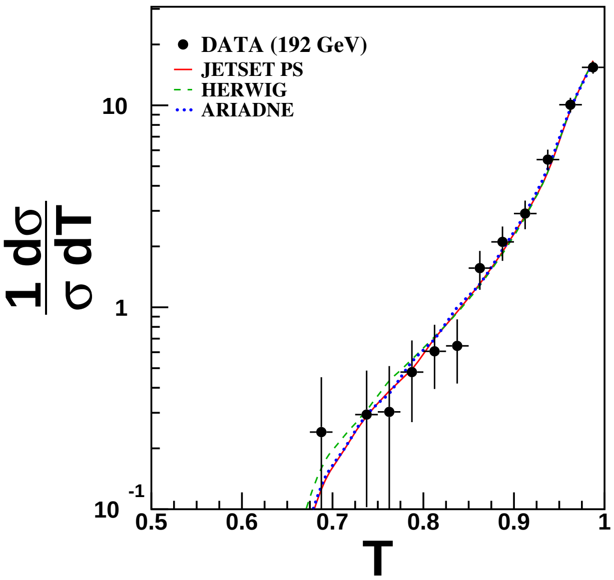
- Sensitivity increased by 20 to 30 % in leptonic channels compared to 189 GeV.

QCD

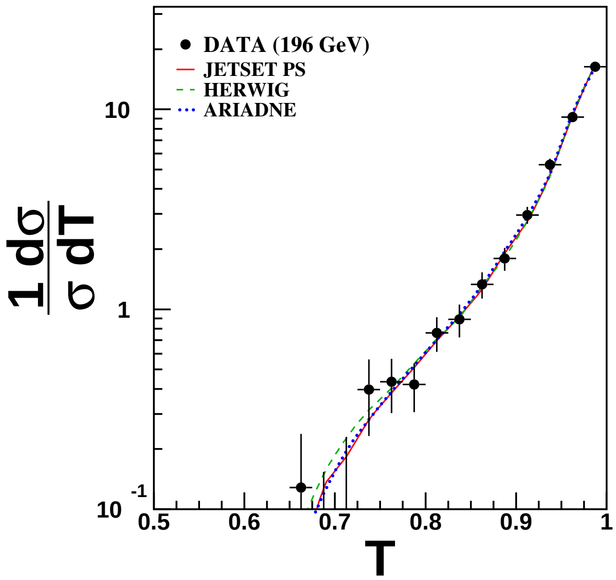
$e^+e^- \longrightarrow$ hadrons

Event shape variable: Thrust

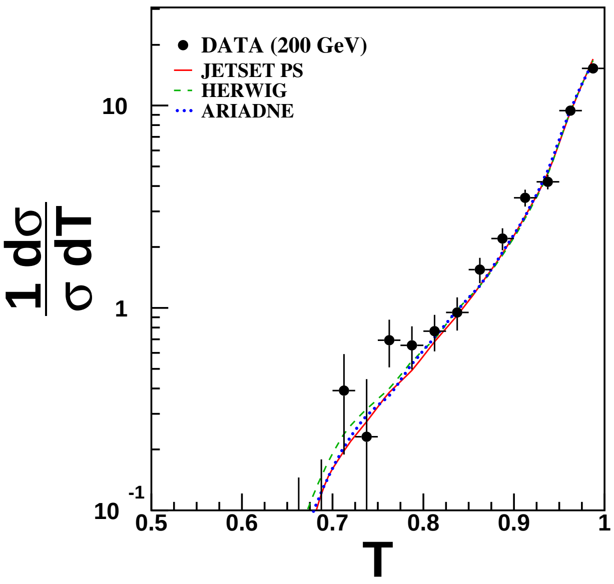
192 GeV



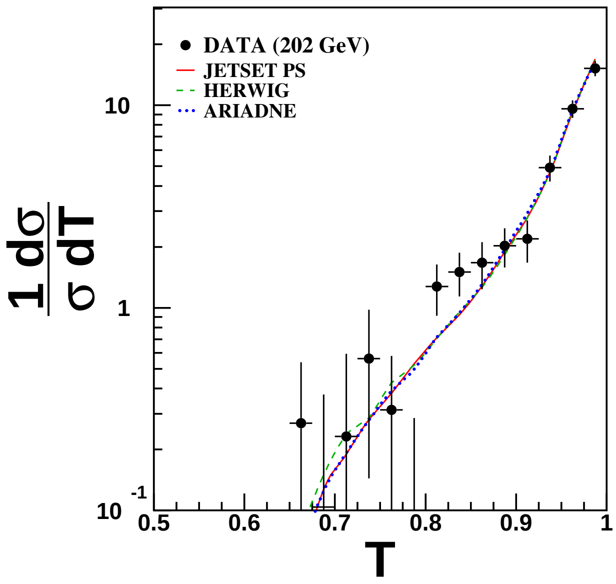
196 GeV



200 GeV



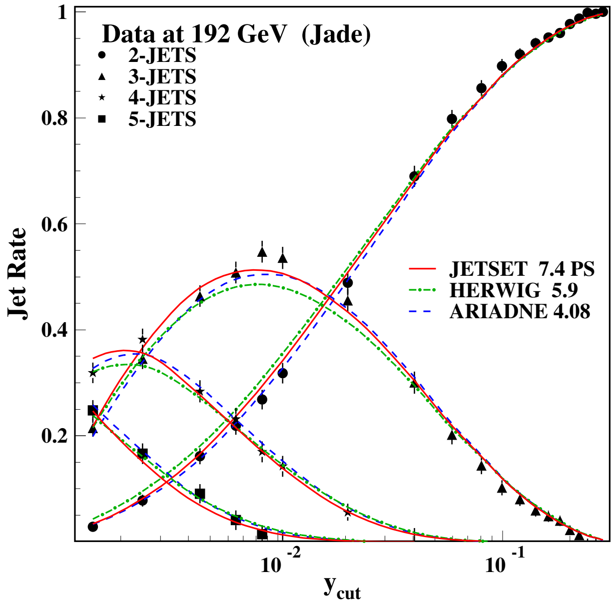
202 GeV



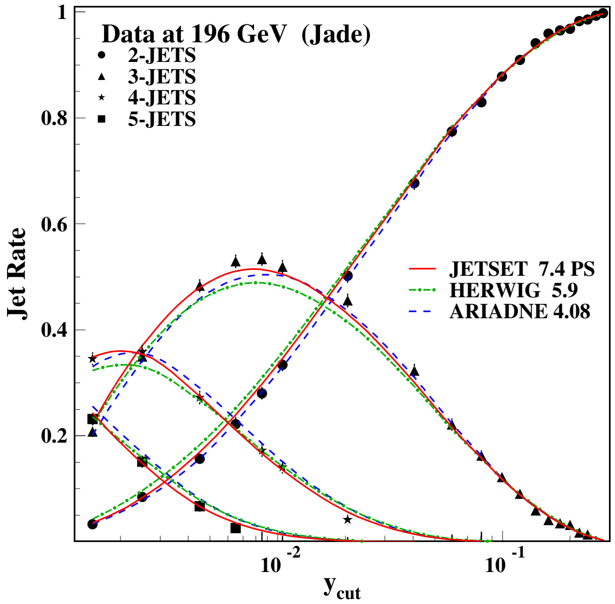
$e^+e^- \longrightarrow$ hadrons

Jet rate:

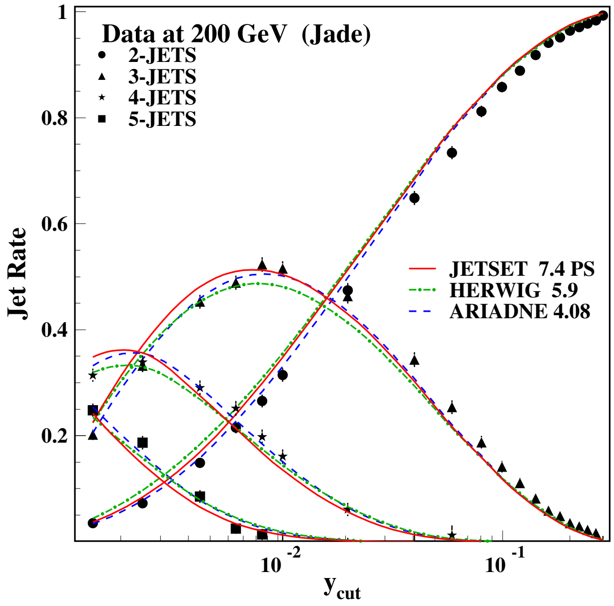
192 GeV



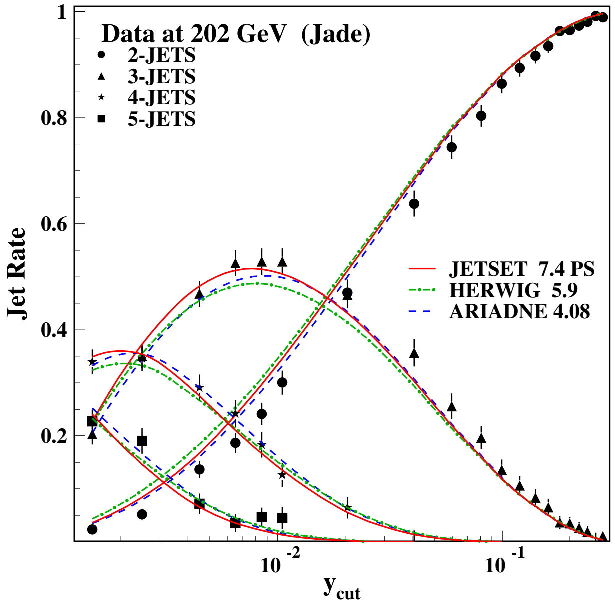
196 GeV



200 GeV



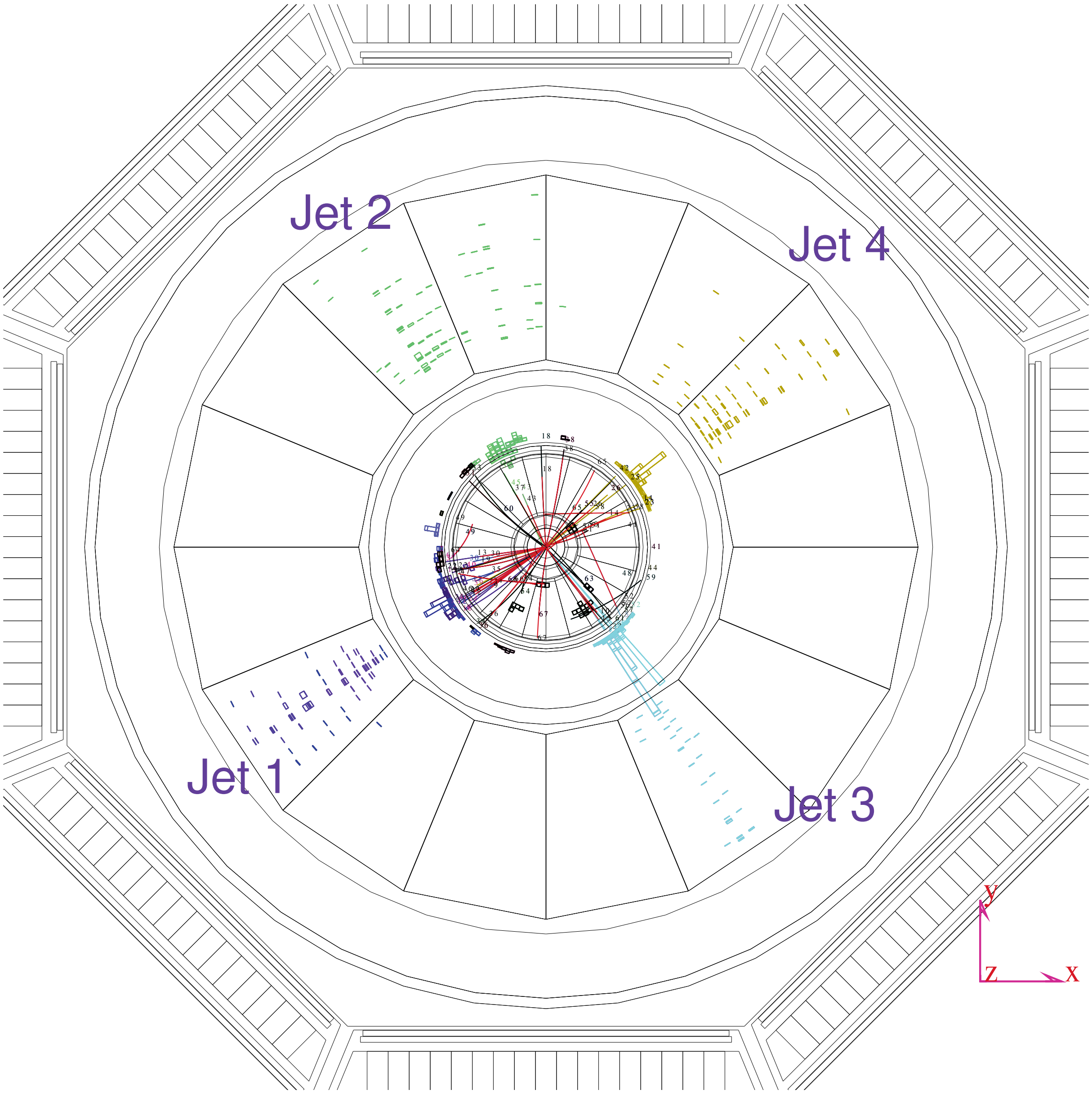
202 GeV



W Boson Production

$e^+ e^- \to W^+ W^- \to$ 4 Jets $\sqrt{s} = 200$ GeV

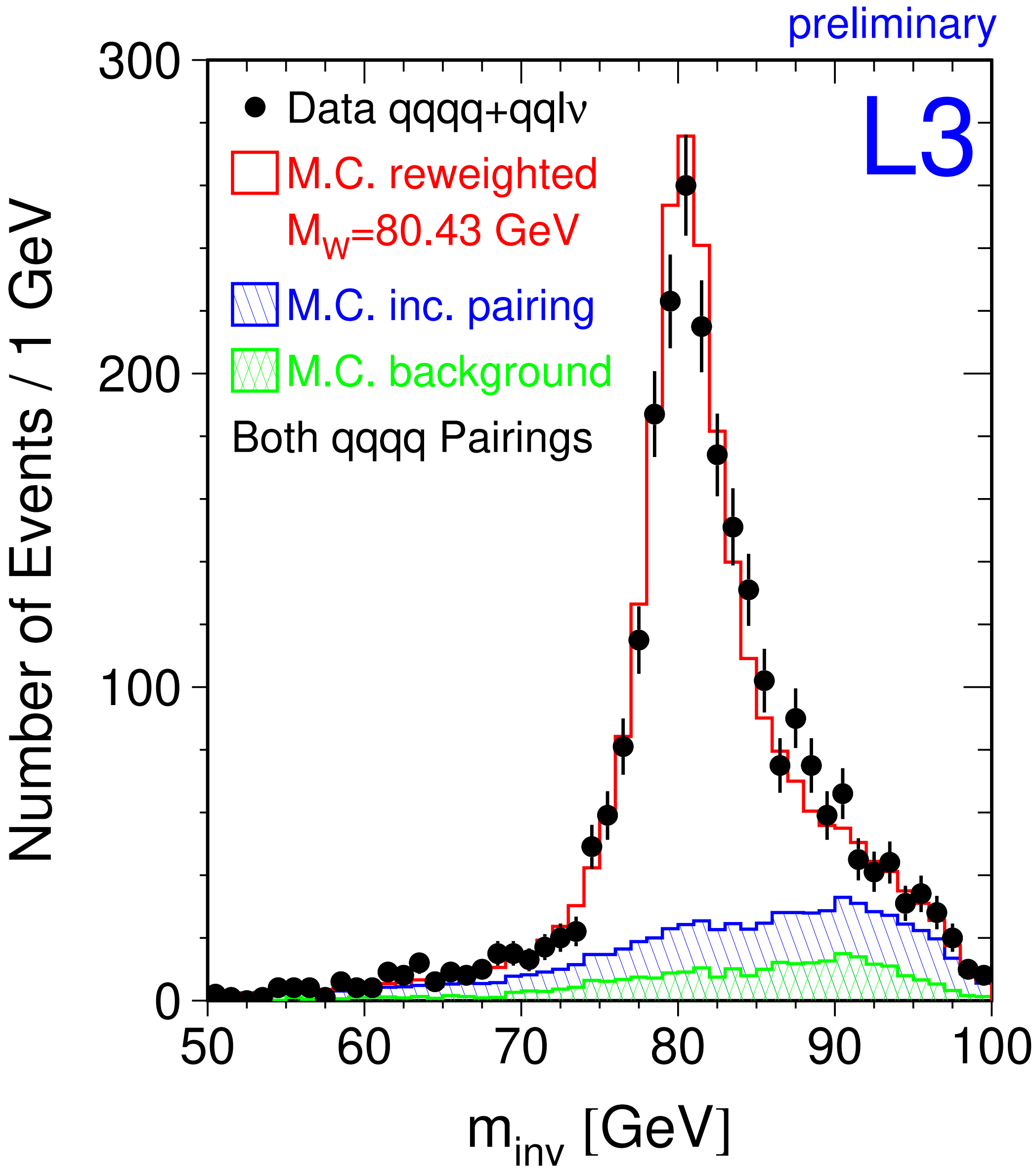
$m_{1\text{-}3} = 80.4$ GeV $m_{2\text{-}4} = 82.3$ GeV



W Pair Production

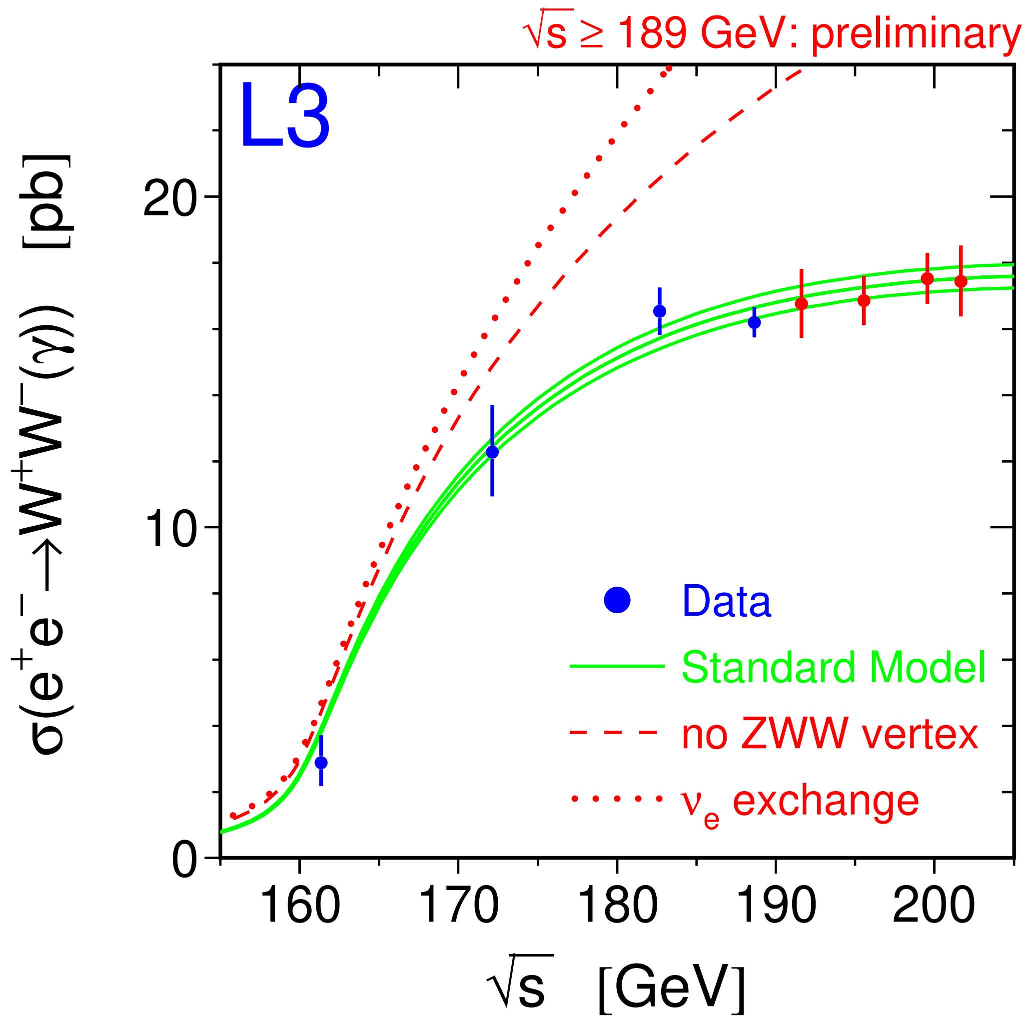
$$W^+W^- \longrightarrow qq\ell\nu \ , \ qqqq$$

$\sqrt{s} \geq 192$ GeV (30pb^{-1} @ 202 GeV)



This year: 3414 WW events

W Pair Production



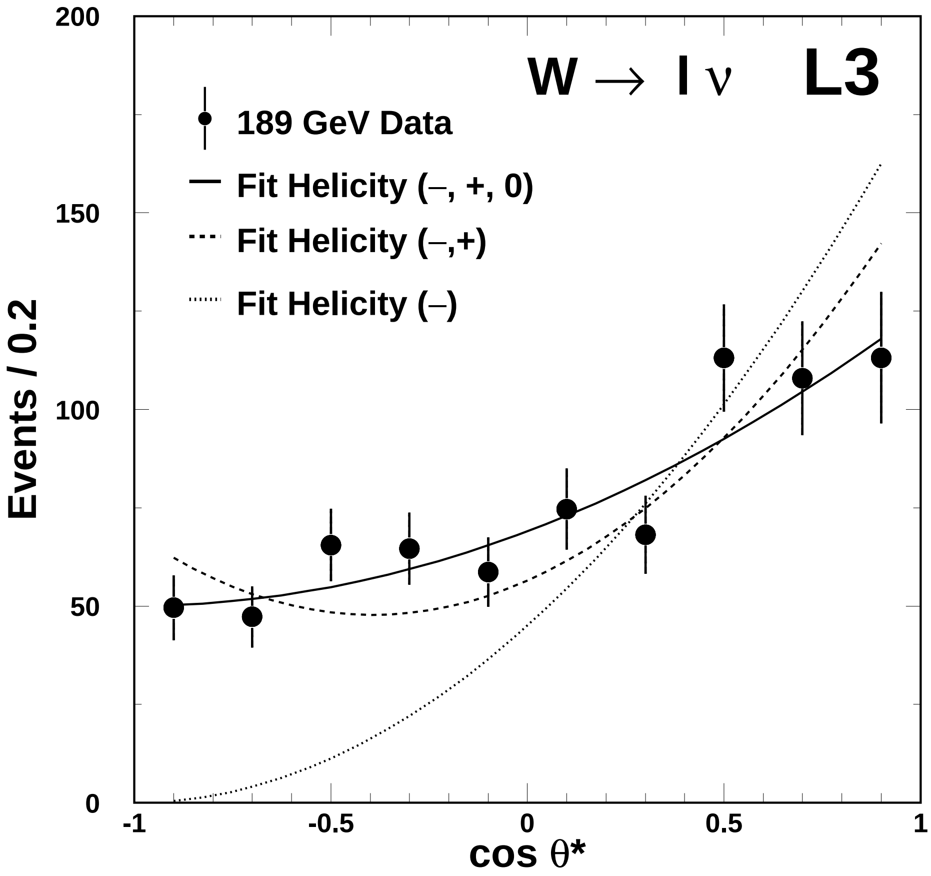
$\sqrt{s}$ **from 161 to 202 GeV:**

Channel	Branching Fraction (%)		S.M.
$W \rightarrow e\nu$	10.31±0.33	10.62±0.16	10.83
$W \rightarrow \mu\nu$	10.18±0.35		
$W \rightarrow \tau\nu$	11.52±0.47		
$W \rightarrow qq'$	67.99±0.50	68.15±0.49	67.51

$\sqrt{2}$ **improvement in statistical error**

Longitudinal Polarisation of W accessible in $e^+e^- \to$WW@ LEPII

$\sqrt{s} = 189$ GeV

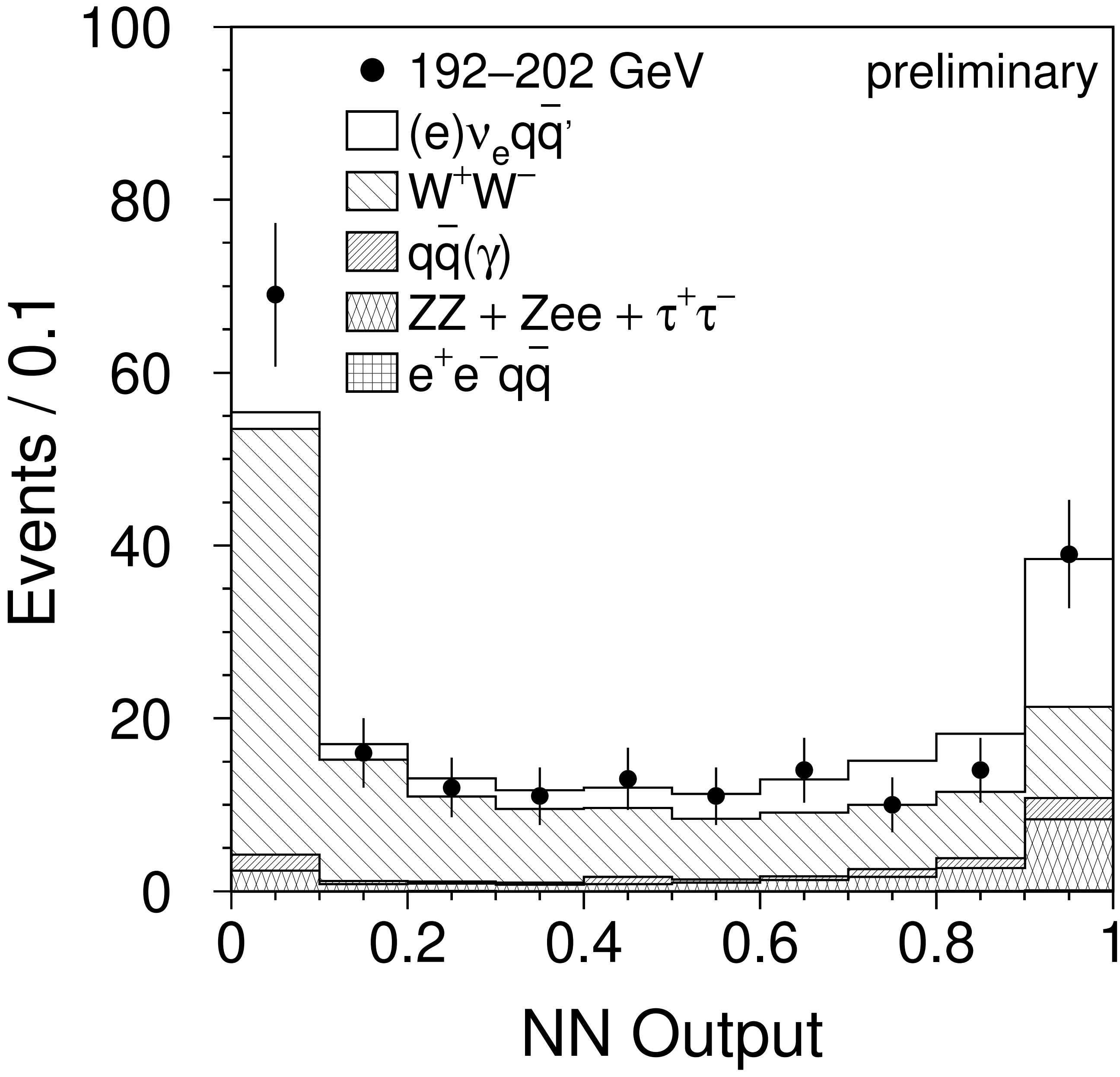


Fraction of Longitudinal W:

$$26.1 \pm 5.1(stat) \pm 1.6(sys) \quad \%$$

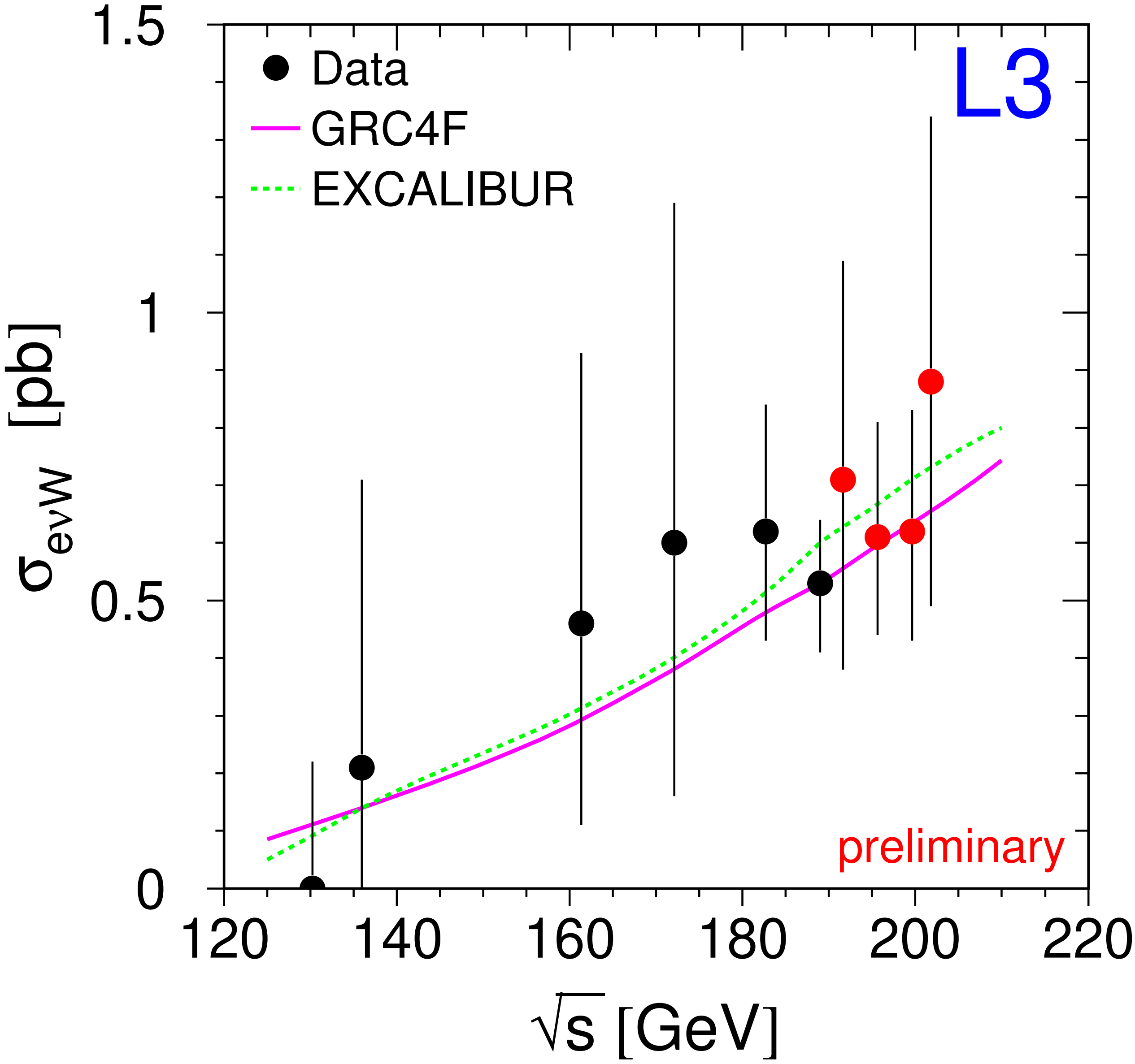
In agreement with 26% expected in SM

$e^+e^- \rightarrow \mathbf{We}\boldsymbol{\nu}$



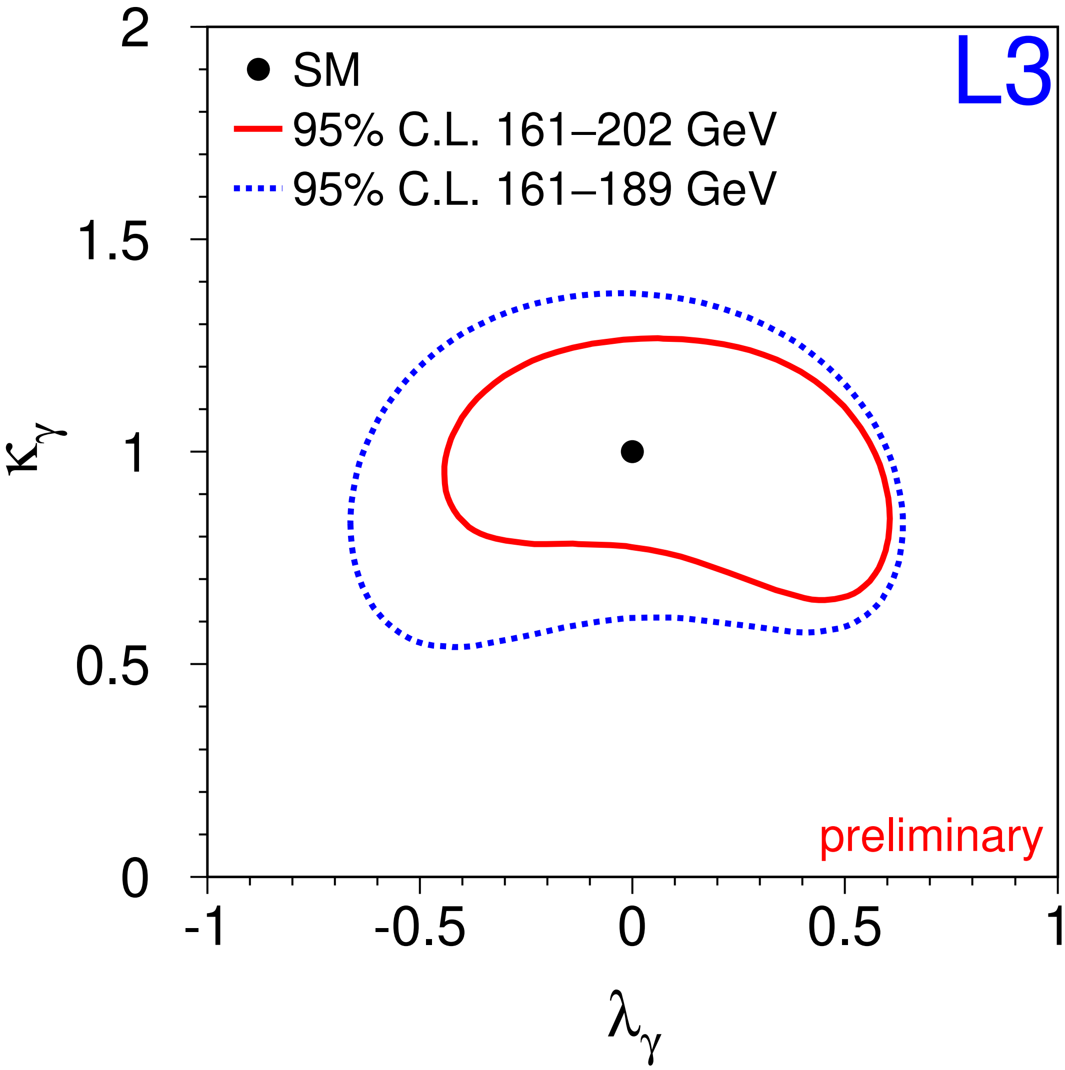
Single W boson production

$e^+e^- \to We\nu$



22.6 pb^{-1} used at $\sqrt{s} = 202$ GeV

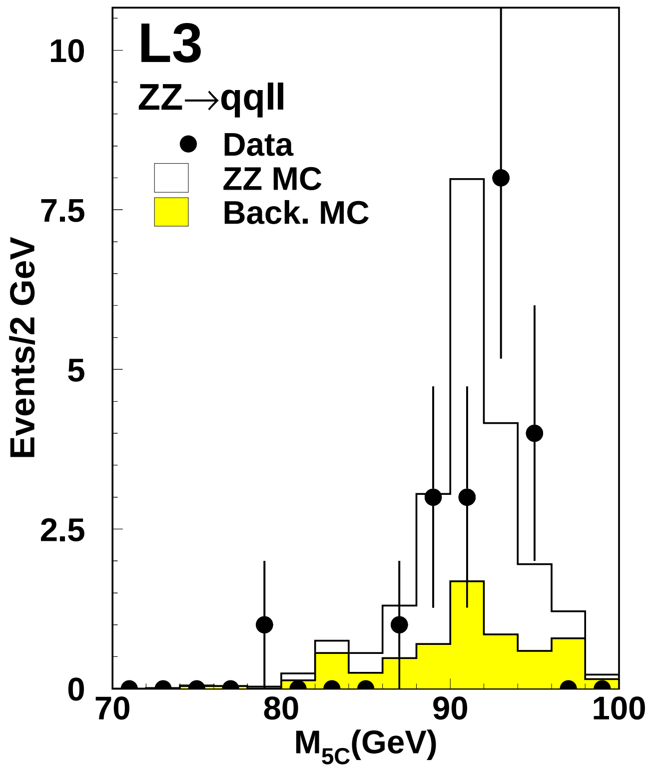
Triple Gauge Boson Couplings

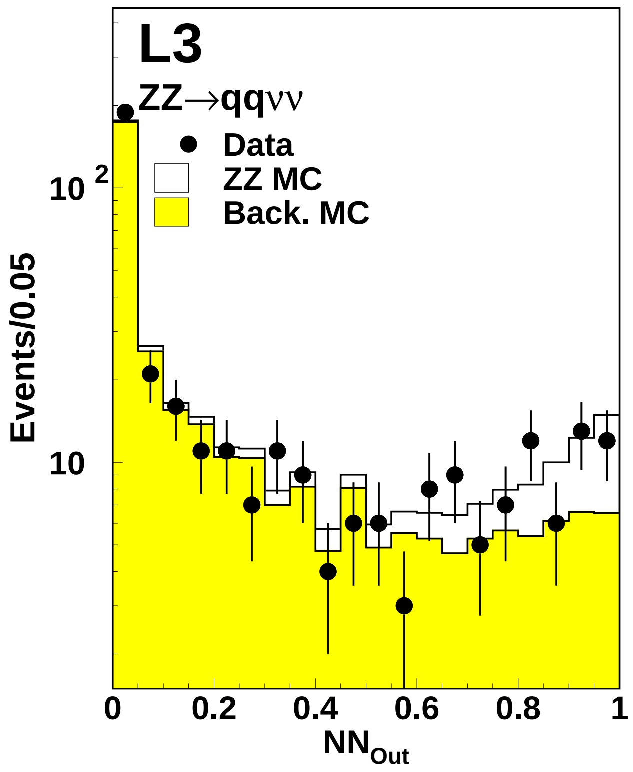


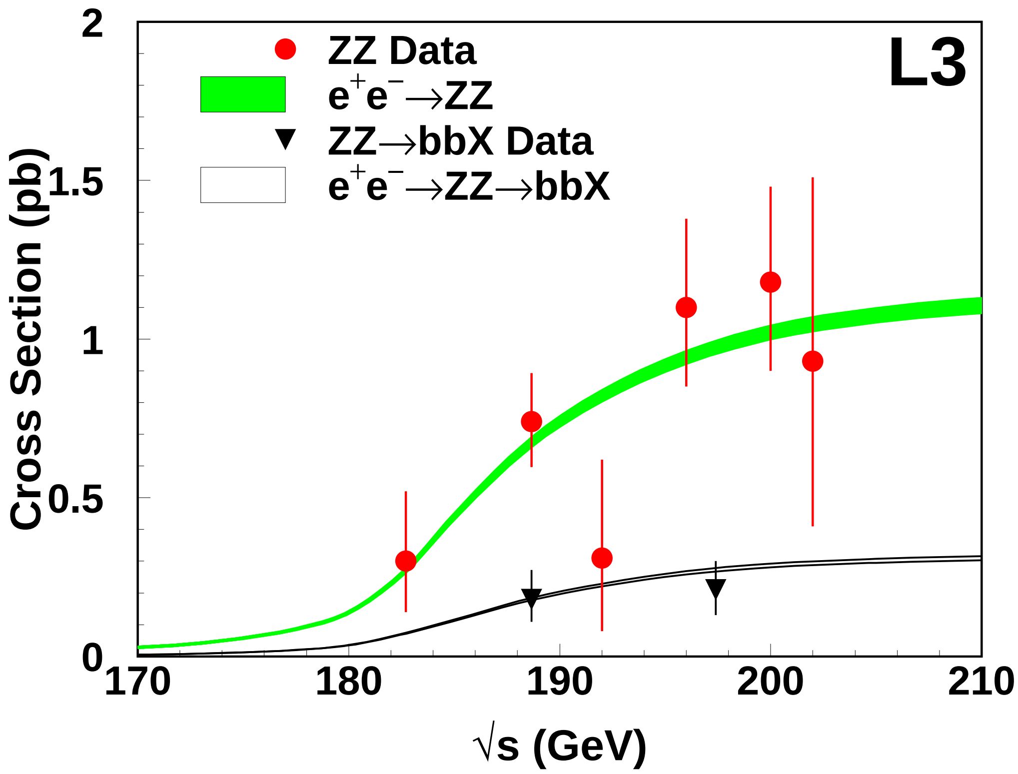
$$\kappa_\gamma = +1.00^{+0.13}_{-0.12}$$

$$\lambda_\gamma = +0.26^{+0.34}_{-0.17}$$

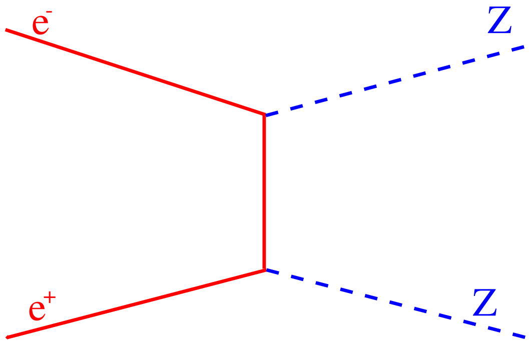
Z Boson Pair Production



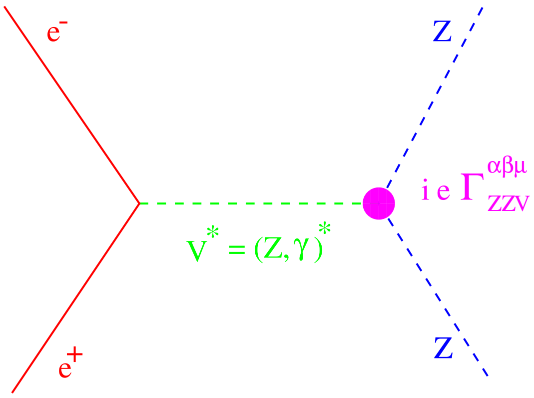




ZZ final states with non-SM couplings



SM tree level



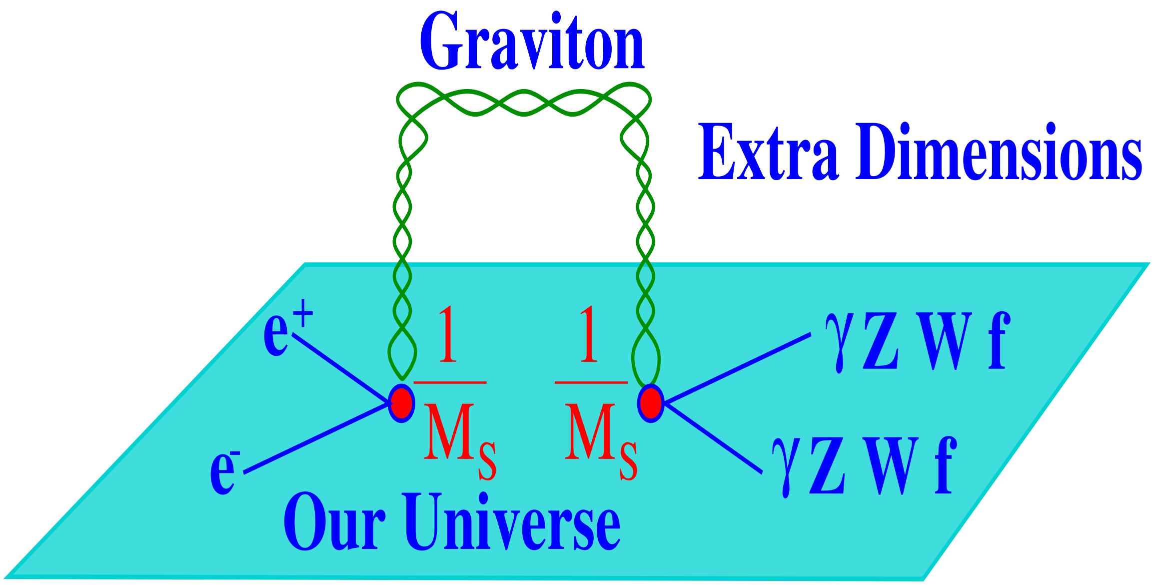
$\Gamma^{\alpha\beta\mu}_{ZZV}$:
Triple Gauge Boson anomalous coupling

- $f_4^{Z,\gamma} \neq 0 \Rightarrow$ $\not{C}$ $\not{C}P$ contribution
- $f_5^{Z,\gamma} \neq 0 \Rightarrow$ $\not{P}$ CP contribution

Limits at 95% CL combining 1997 to 1999:

$$-0.87 < f_4^Z < 0.87$$
$$-1.93 < f_5^Z < 2.02$$
$$-0.53 < f_4^\gamma < 0.50$$
$$-1.20 < f_5^\gamma < 1.23$$

More than a factor 2 improvement compared to $\sqrt{s} \leq 189$ GeV



ZZ channel updated from 192 to 200 GeV

95 % C.L. lower limits on M_S:

Final State	$\sqrt{s}$ GeV	M_S (TeV) $\lambda = +1$	M_S (TeV) $\lambda = -1$
ZZ	192-202	1.1	1.1
Fermions+Bosons	$\leq$189	1.1	0.9

Large improvement with the ZZ channel as the energy and luminosity increase

Heavy Lepton Searches

Decay	Dirac	Majorana
$L^0 \longrightarrow eW$	96.3	85.2
$L^0 \longrightarrow \mu W$	95.7	87.0
$L^0 \longrightarrow \tau W$	86.3	75.5

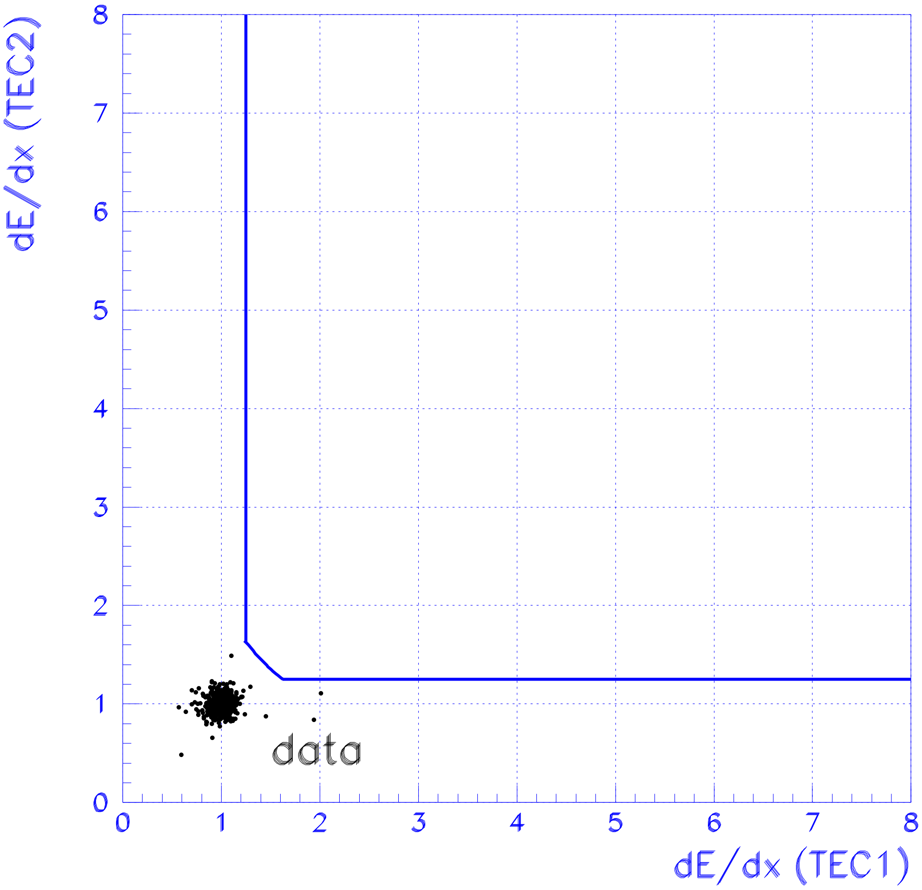
(Mass limits in GeV)

Unstable Neutral Heavy Lepton

Decay	Mass Limit
$L^\pm \longrightarrow \nu W^\pm$	97.0

Unstable Charged Heavy Lepton

202 GeV Data L=17.7pb-1



Stable charged Heavy Lepton

$m_{L^\pm} \geq 100$ GeV

Excited Leptons

Search for Pair Production of Charged Excited Leptons

	Radiative Decays			Weak Decays		
Signal	Signature	Data	Bkg	Signature	Data	BKG
e^*e^*	$\rightarrow ee\gamma\gamma$	1	0.7	$\rightarrow WW\nu\nu$	3138	3124
$\mu^*\mu^*$	$\rightarrow \mu\mu\gamma\gamma$	1	0.4			
$\tau^*\tau^*$	$\rightarrow \tau\tau\gamma\gamma$	0	0.2			

For $f = -f'$, Radiative Decay forbidden; limits from weak decay.

Excited Lepton Coupling	95% CL Mass Limit (GeV)	
	$f = f'$	$f = -f'$
e^*	99.5	94.4
μ^*	99.6	94.4
τ^*	99.6	94.4

Similar Analysis for Excited Neutrinos

Excited Neutrino Coupling	95% CL Mass Limit (GeV)	
	$f = f'$	$f = -f'$
ν_e^*	99.2	99.3
ν_μ^*	99.2	99.3
ν_τ^*	93.6	99.3

SUSY particle searches

MSSM with:

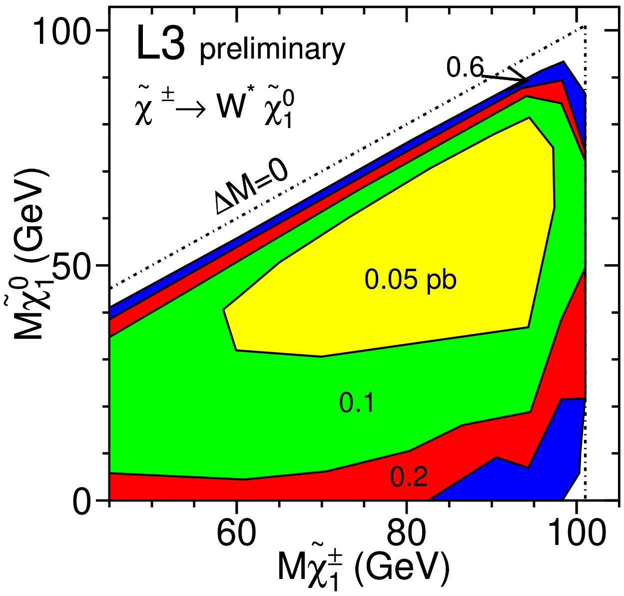
- R parity conservation
  $\Rightarrow$ pair production
- LSP is $\tilde{\chi}_1^0$ and is stable
  $\Rightarrow$ missing energy
- $\tilde{\chi}^+\tilde{\chi}^- \hookrightarrow \mathrm{W}^+\mathrm{W}^-$, $\ell^+\ell^-$
- $\tilde{\ell}^+ \ \tilde{\ell}^- \hookrightarrow \ell^+\ell^-$
- Various selections depending on

$$\Delta M = M_{NLSP} - M_{LSP}$$

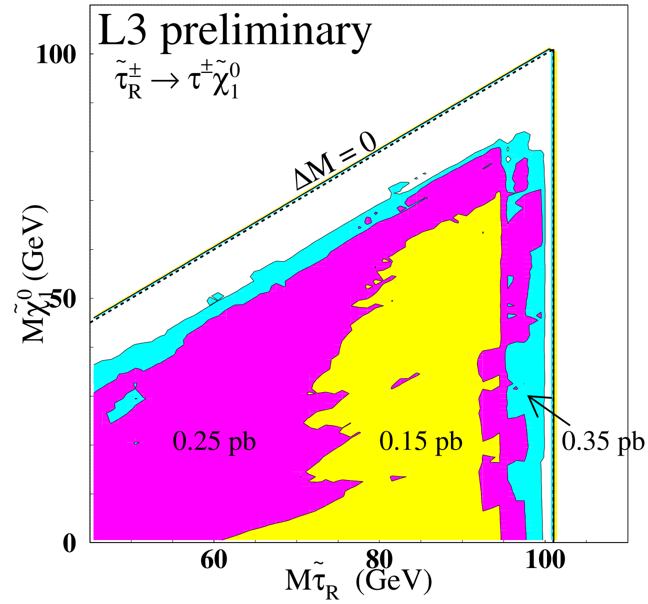
	Low ΔM		Medium ΔM		High ΔM		.OR.	
	N_{data}	N_{exp}	N_{data}	N_{exp}	N_{data}	N_{exp}	N_{data}	N_{exp}
$\tilde{\chi}^{\pm}$	70	82.0	15	13.0	88	94.8	164	182.8
$\tilde{\chi}_2^0$	43	48.0	7	9.0	5	3.0	55	59.4
$\tilde{\mathrm{e}}$	8	7.0	6	5.0	15	15.3	29	28.4
$\tilde{\mu}$	9	14.0	4	1.0	8	11.2	19	25.9
$\tilde{\tau}$	6	3.0	11	10.0	20	14.7	28	19.1
.OR.	101	119.0	34	31.0	119	124.8	230	255.7

No excess observed in the data

Chargino and Stau

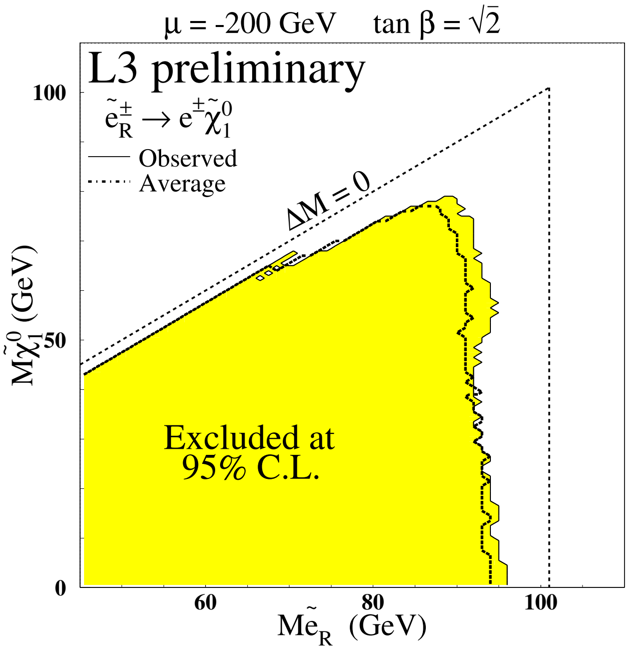


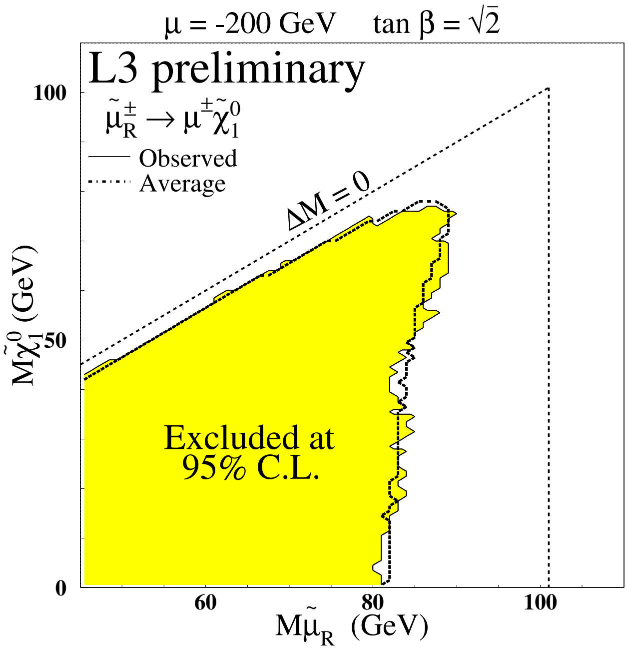
$\tilde{\chi}^{\pm}$ cross section upper limit: factor 2 improvment compared to $\leq$ 189 GeV

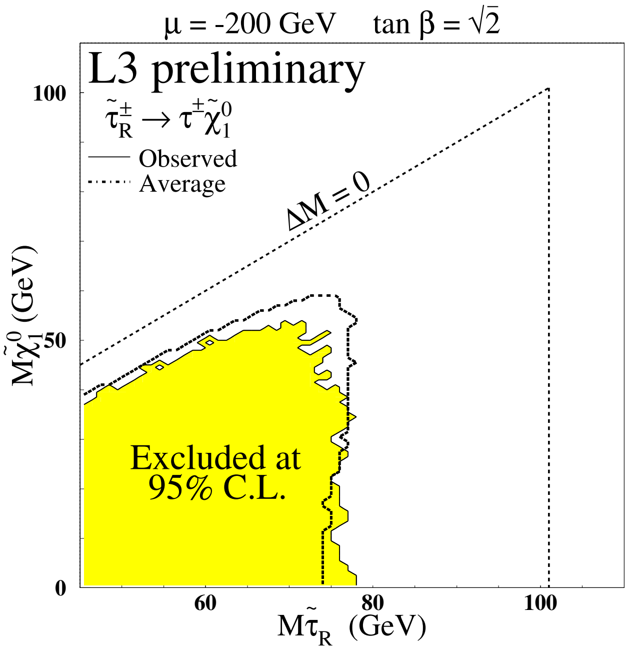


$\tilde{\tau}$ cross section upper limit: same improvment

Sleptons







Slepton mass limits

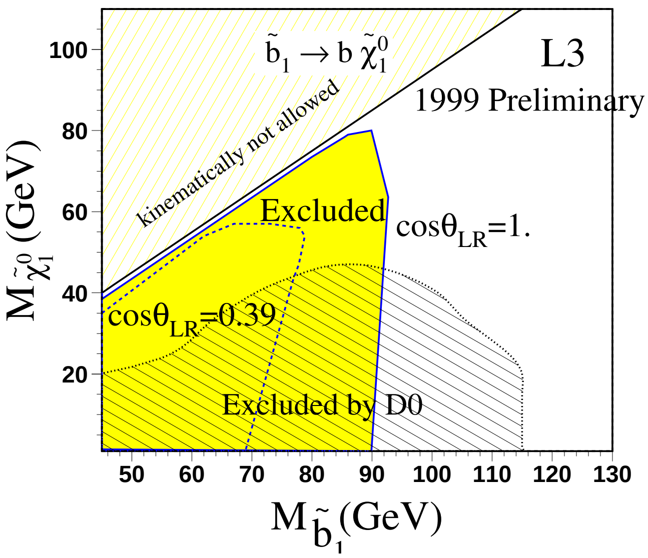
$m_{\tilde{e}} >$ 92 GeV $\Delta M > 17$ GeV

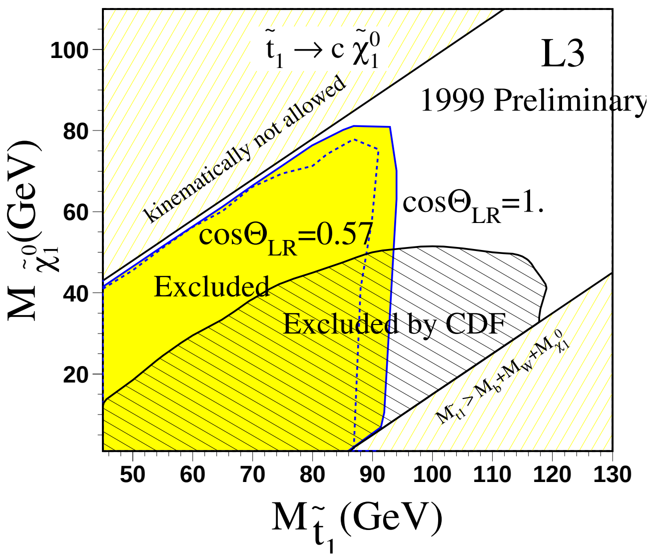
$m_{\tilde{\mu}} >$ 81 GeV $\Delta M > 7$ GeV

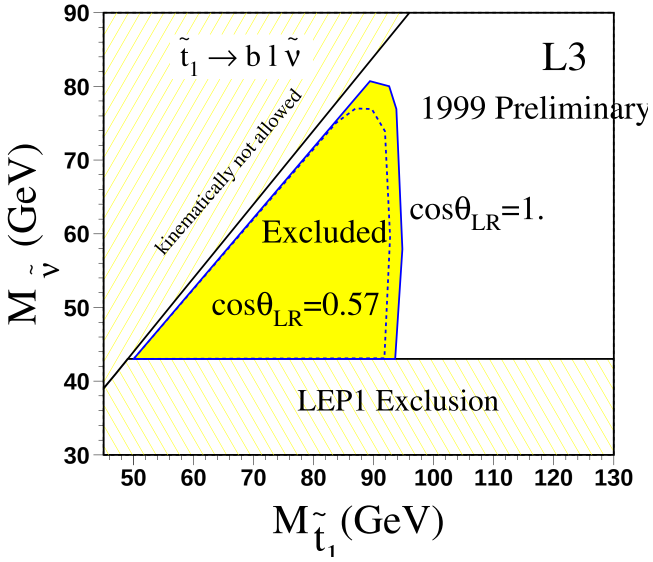
$m_{\tilde{\tau}} >$ 74 GeV $\Delta M > 20$ GeV

SUSY Particle Searches

Squark mass limits







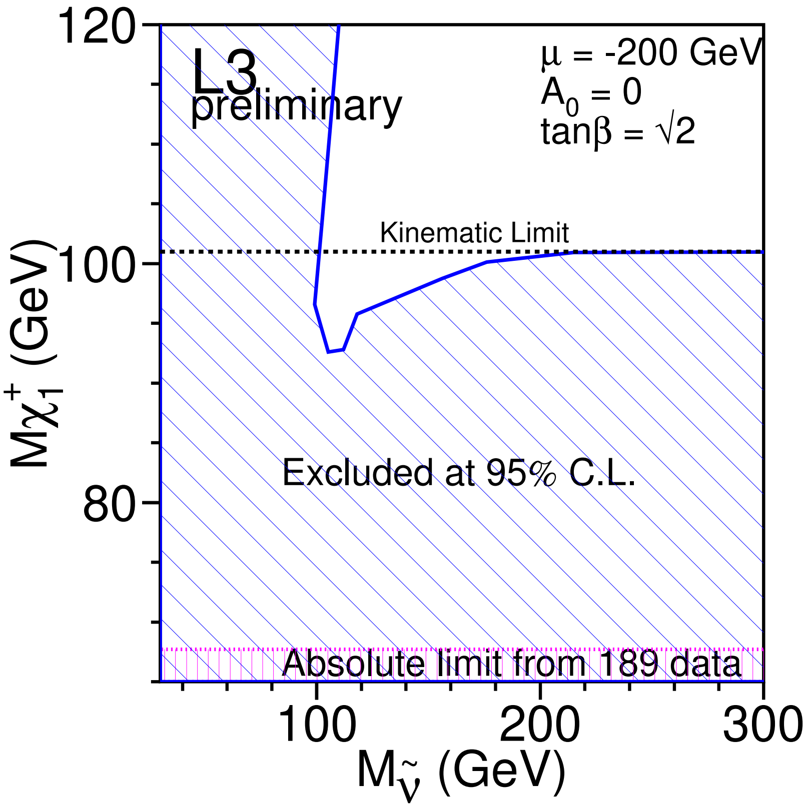
for $\Delta M > 10$ GeV
and $cos\theta_{LR} = 1$

$m_{\tilde{b}_1 \to b\tilde{\chi}^0_1} > 90$ GeV

$m_{\tilde{t}_1 \to c\tilde{\chi}^0_1} > 92$ GeV

$m_{\tilde{t}_1 \to bl\tilde{\nu}} > 92$ GeV

Mass limits 4 GeV higher than at $\sqrt{s} \leq 189$ GeV

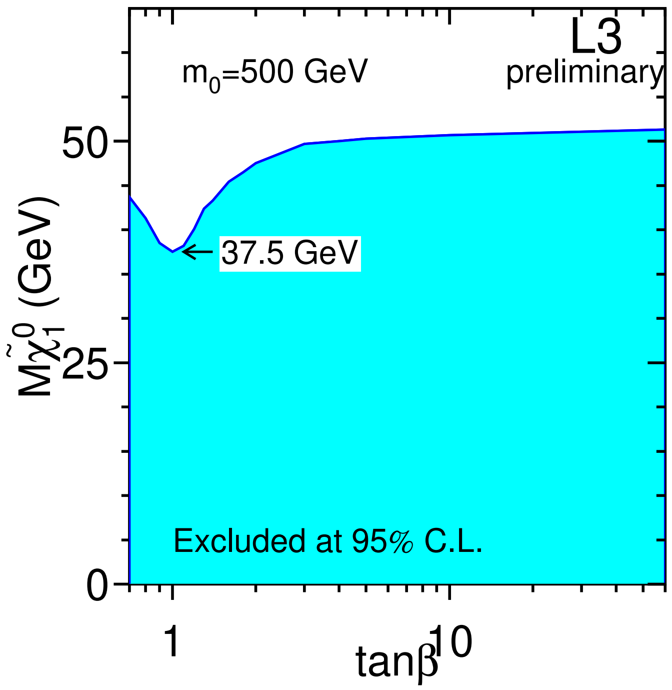


$\tilde{\chi}^{\pm}$ **mass limit**

combining $\tilde{\chi}^0$,$\tilde{\chi}^{\pm}$,slepton searches:

$$M_{\tilde{\chi}^{\pm}} > \mathbf{93\ GeV}$$

(was 88 GeV)



$\tilde{\chi}_1^0$ **mass limit**

Combining $\tilde{\chi}^0$, $\tilde{\chi}^{\pm}$, searches, scanning on μ, M_2

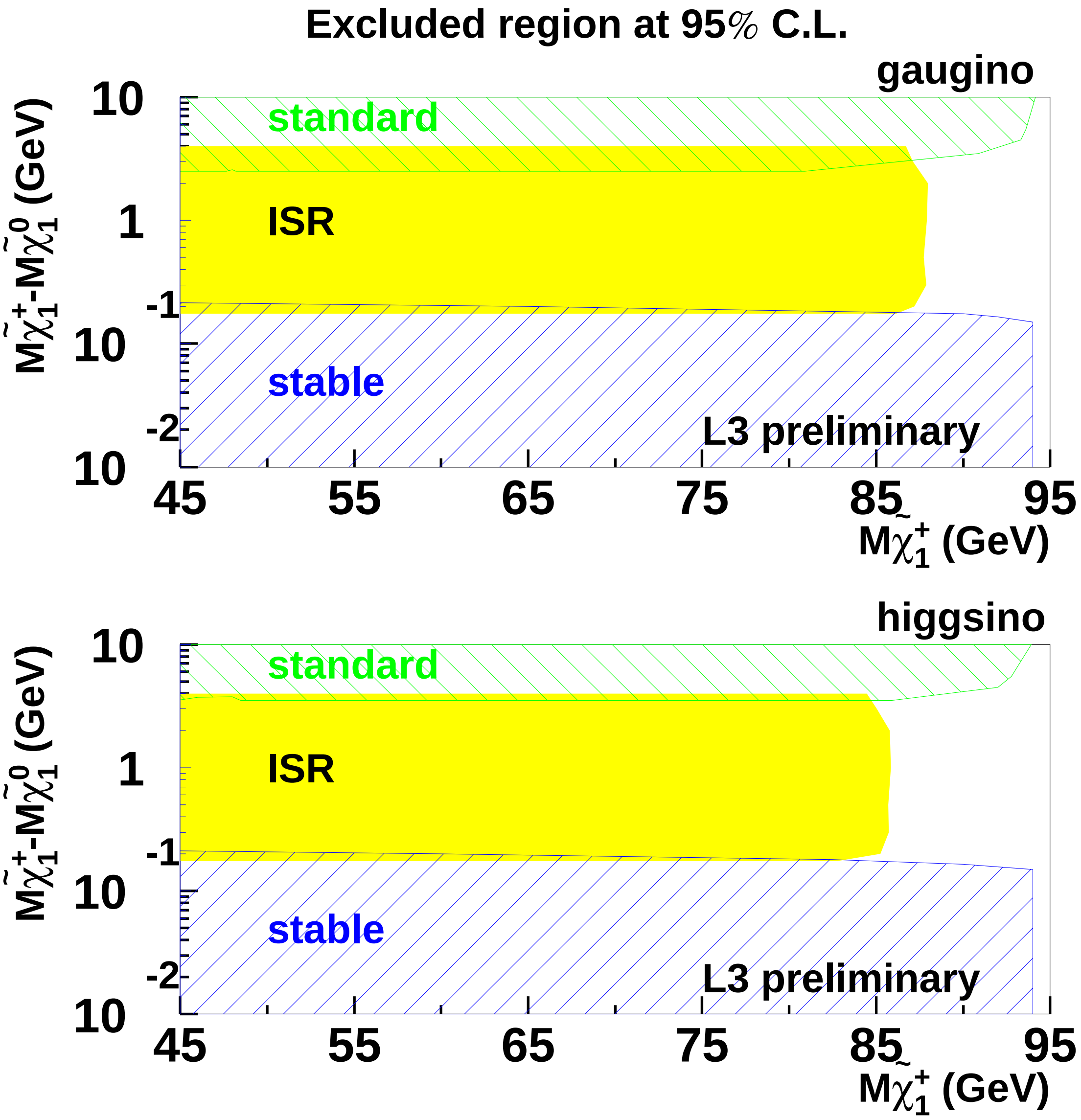
$$M_{\tilde{\chi}_1^0} > \mathbf{37.5\ GeV}$$

(was 32.5 GeV)

Chargino mass limit

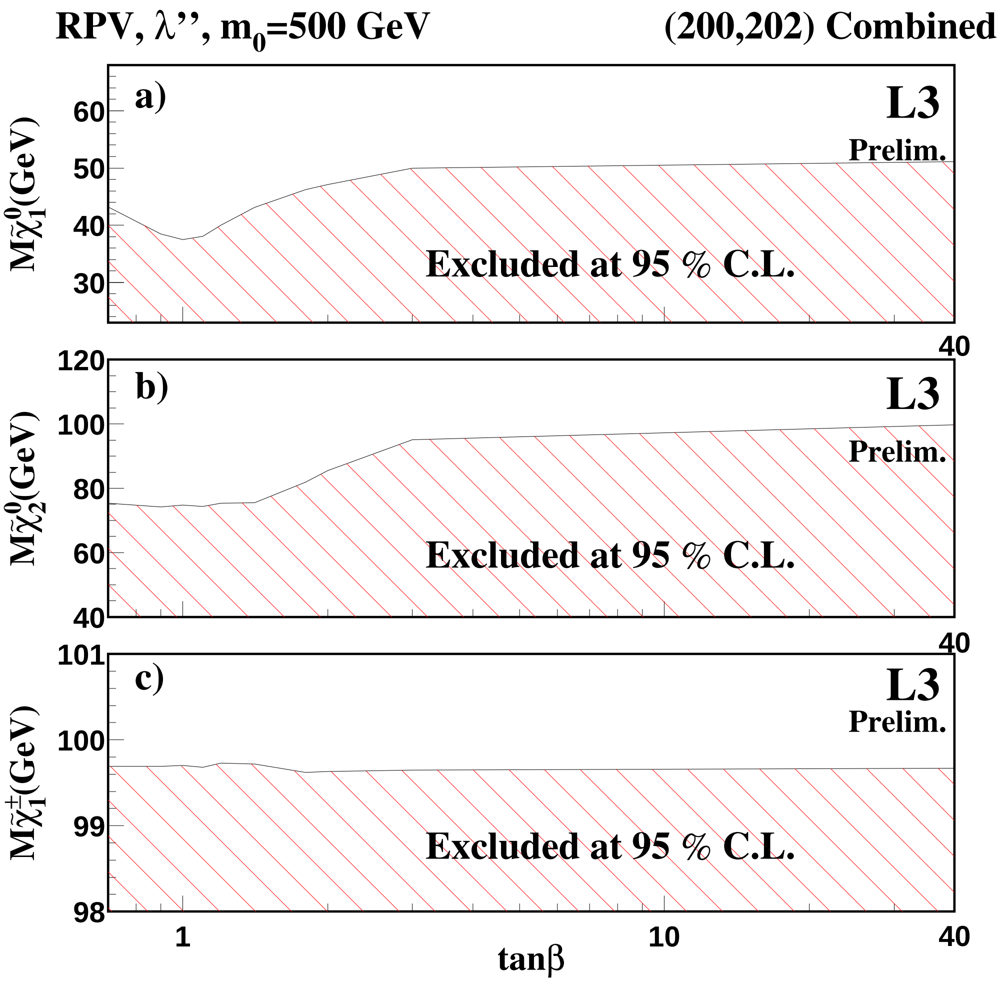
- Standard search on chargino: $\Delta M \gtrsim 2.5$ GeV
- Search for stable heavy particle: $\Delta M \lesssim 170$ MeV.
- Probe the intermediate ΔM region with:

$$e^+e^- \to \gamma\tilde{\chi}^+\tilde{\chi}^- \to \gamma\tilde{\chi}_1^0\tilde{\chi}_1^0 X$$



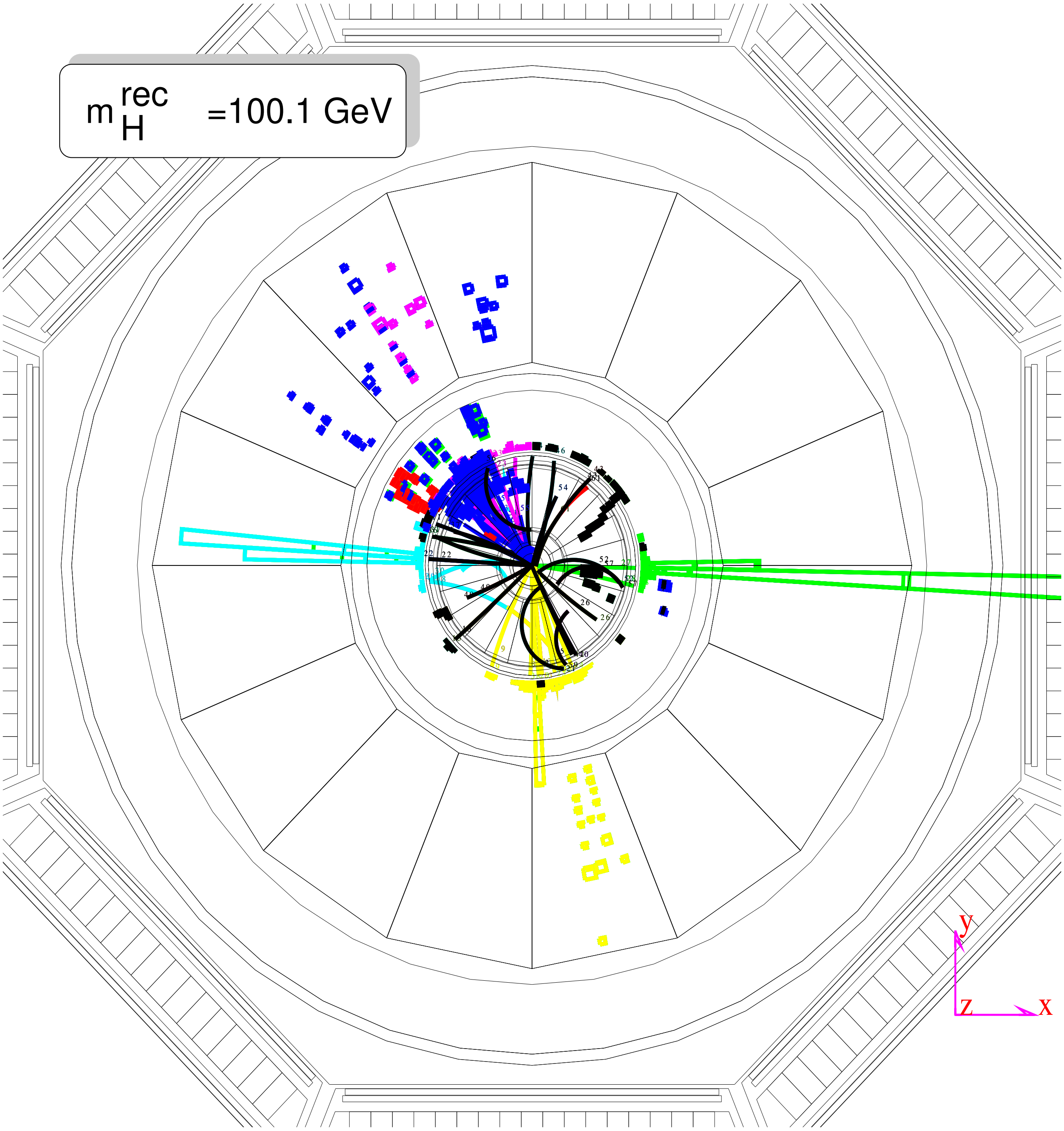
MSSM with R Parity Violation.

coupling		N_{data}	N_{exp}
λ	$\tilde{\chi}^0_1,\tilde{\chi}^+_1$	2	3.8
λ''	$\tilde{\chi}^0_1$	169	174.6
	$\tilde{\chi}^+_1$	101	97.5
	$\tilde{\mu},\tilde{e}$	5	6.61
	$\tilde{\tau}$	93	91.5



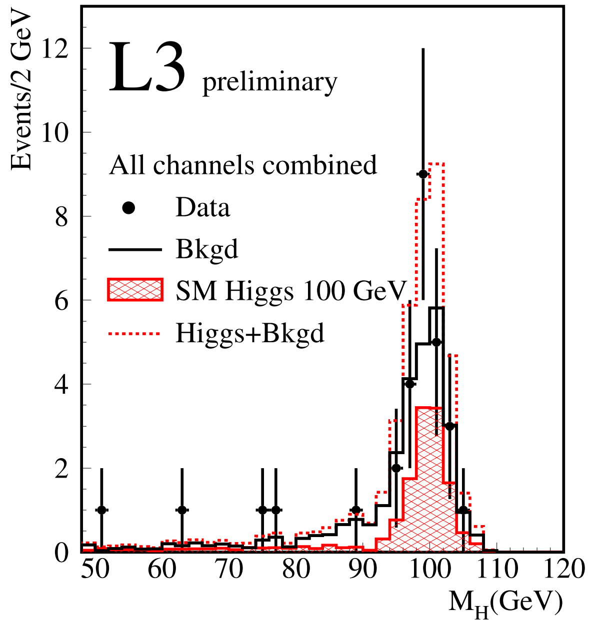
Limits Comparable with R Parity conservation

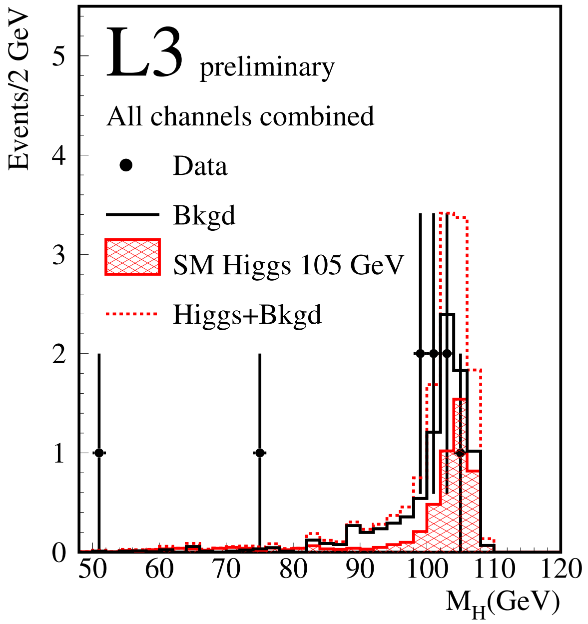
Higgs Boson Search



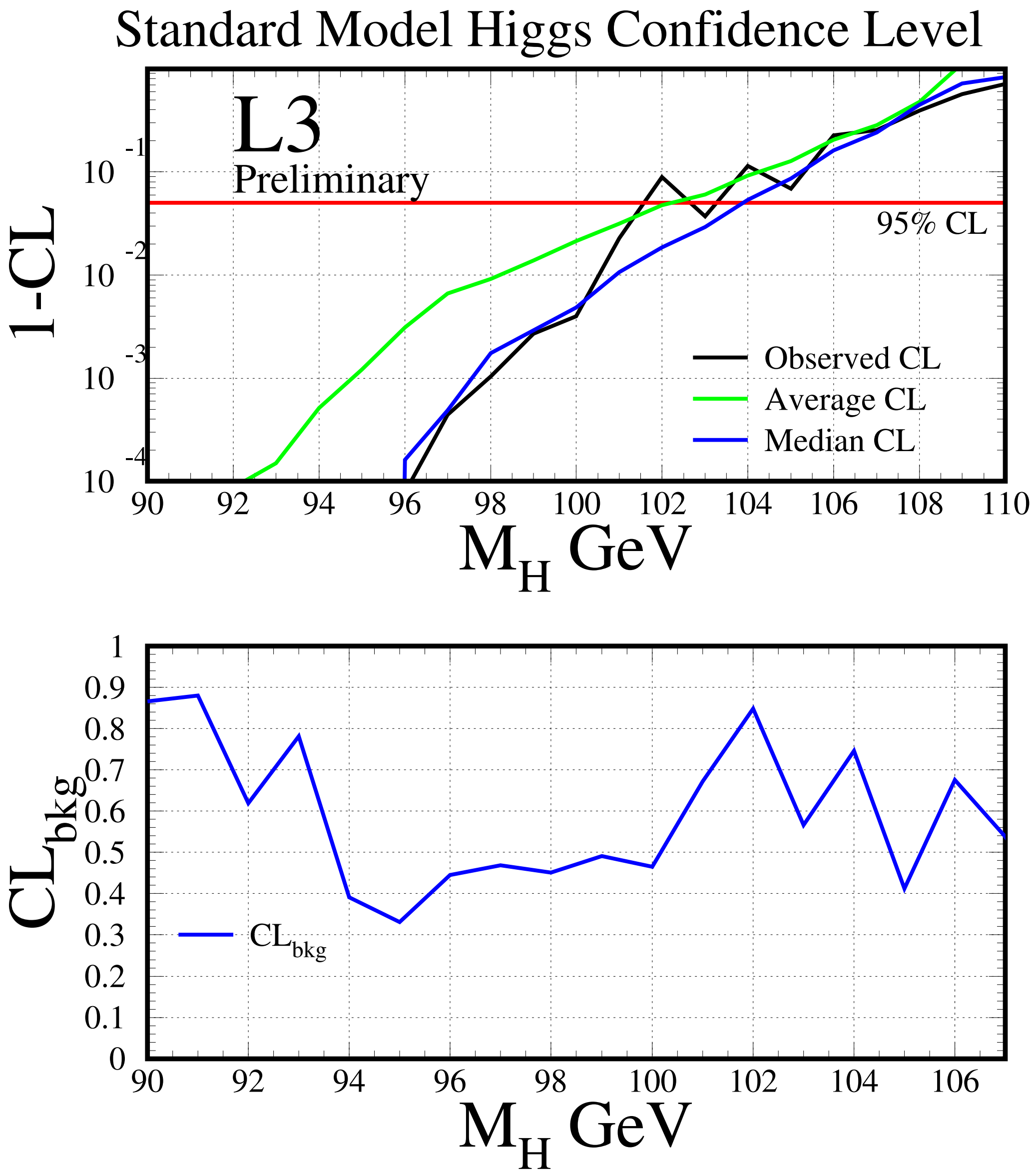
$e^+e^- \rightarrow ZH \rightarrow e^+e^-q\bar{q}$

mass dependent distribution





channel	data	bkgd	Higgs 105 GeV
$q\bar{q}q\bar{q}$	7	5.5	3.6
$q\bar{q}\nu\nu$	1	2.4	1.5
$q\bar{q}\ell^+\ell^-$	1	1.1	0.9
total	9	9.0	5.9
			100 GeV
$q\bar{q}q\bar{q}$	19	19.1	10.6
$q\bar{q}\nu\nu$	3	6.5	3.5
$q\bar{q}\ell^+\ell^-$	7	3.6	2.2
total	29	29.1	16.3

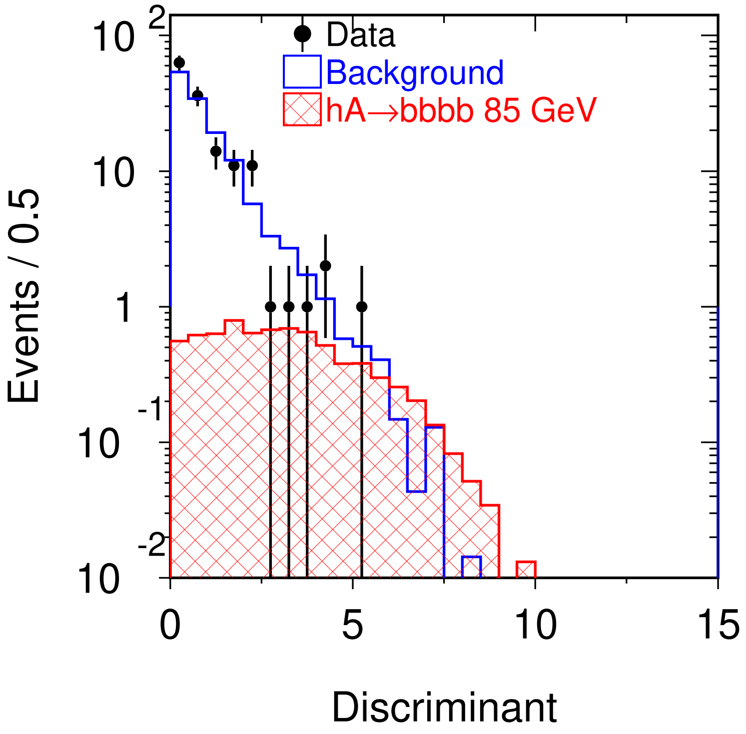


$m_{\rm H} > 101$ GeV @ $95\% CL$

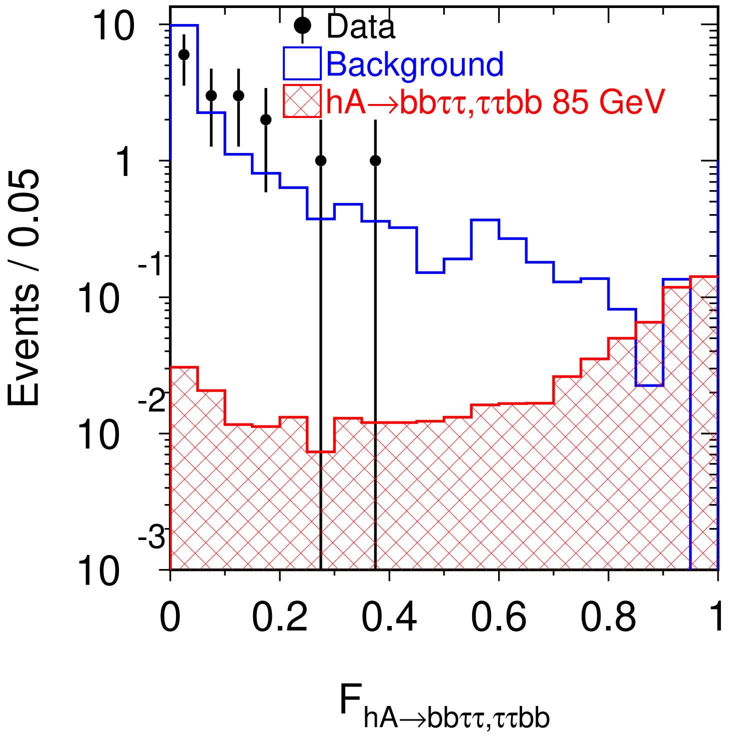
expected: 104 GeV

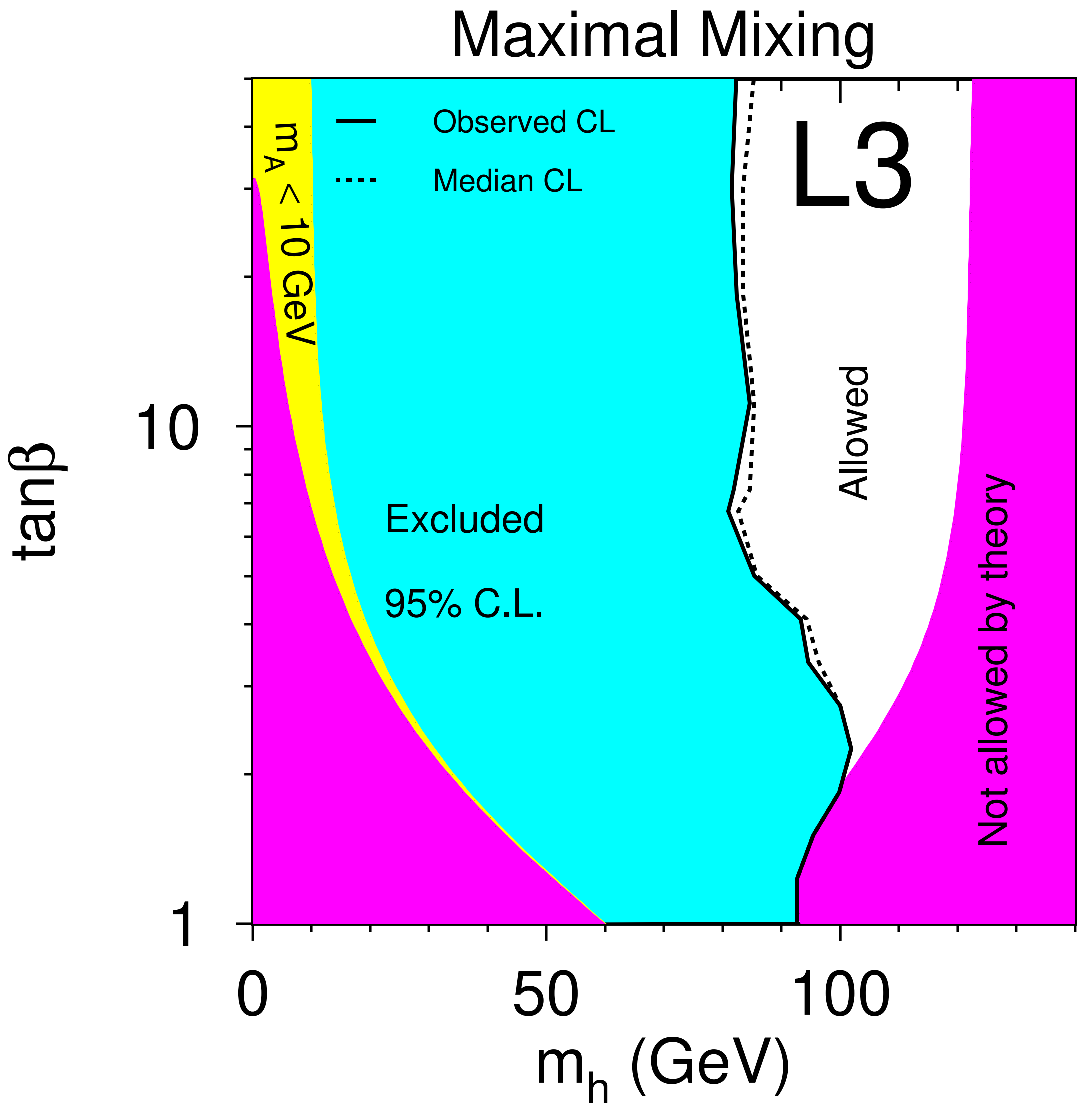
Neutral Higgs Search in MSSM

$e^+e^- \rightarrow hA \rightarrow b\bar{b}b\bar{b}$



$e^+e^- \rightarrow hA \rightarrow b\bar{b}\tau\bar{\tau}$



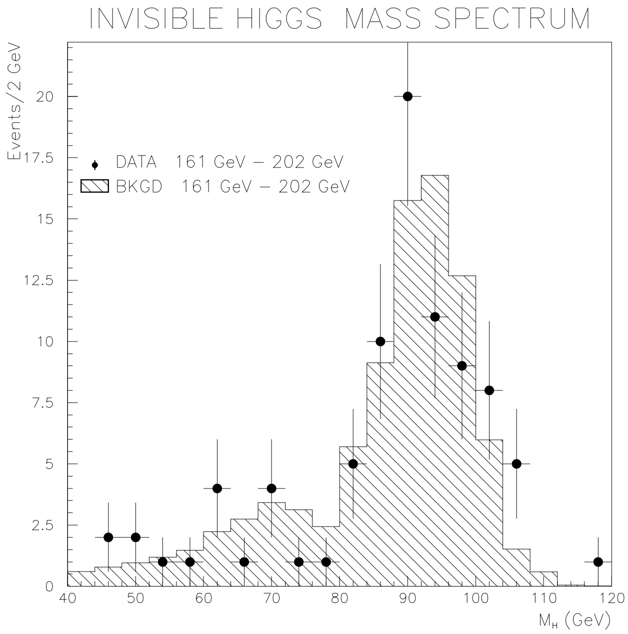


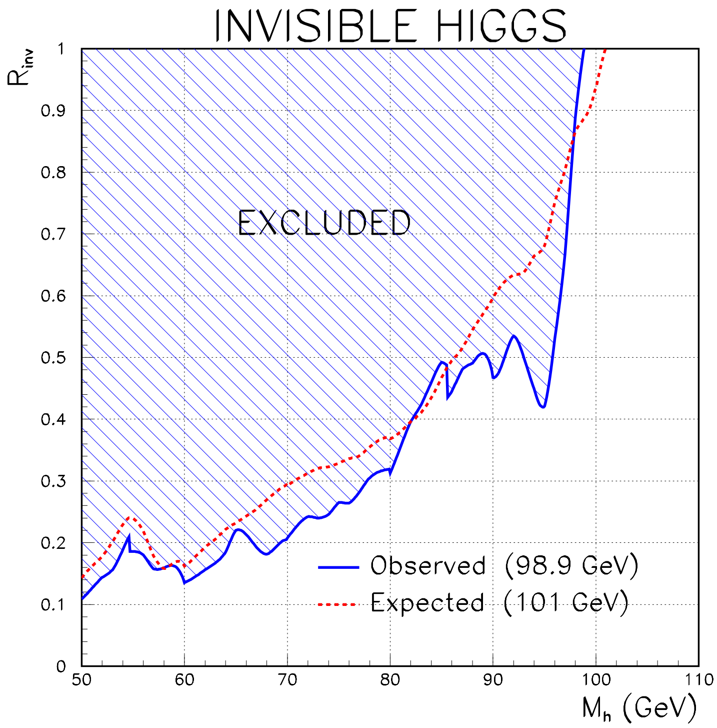
$$m_{\mathrm{h}} > 81 \text{ GeV} \quad @\ 95\% CL$$
$$m_{\mathrm{A}} > 82 \text{ GeV} \quad @\ 95\% CL$$

was: 77.1 GeV

Invisible Higgs Search

$$e^+e^- \longrightarrow Z^* \longrightarrow hZ$$





$$m_h > 98.9 \text{ GeV} \quad @95\% \quad CL$$

Summary and Request

- No evidence of a Higgs Boson but improvements on the limits:

$$
\begin{array}{llll}
m_{\mathrm{H}} > 101\ \mathrm{GeV} & @\ 95\%\mathrm{CL} & \mathrm{in} & \mathrm{SM} \\
m_{\mathrm{h}} > 81\ \mathrm{GeV} & @\ 95\%\mathrm{CL} & \mathrm{in} & \mathrm{MSSM} \\
m_{\mathrm{A}} > 82\ \mathrm{GeV} & @\ 95\%\mathrm{CL} & &
\end{array}
$$

- New particle searches:

$$
\begin{array}{lll}
M_{\tilde{\chi}^0_1} > 37.5\ \mathrm{GeV} & \mathrm{for} & m_0 = 500\ \mathrm{GeV} \\
M_{\tilde{\chi}^\pm}\ \ \text{at the kinematic limit} & &
\end{array}
$$

- W pairs: twice the statistics will improve mass and coupling measurements.

- Running in 2000: besides the 2.5 pb^{-1} for calibration,

L3 is hoping for the Highest Energy !