Latest L3 Results

J. Alcaraz
CIEMAT/CERN

LEP Jamboree
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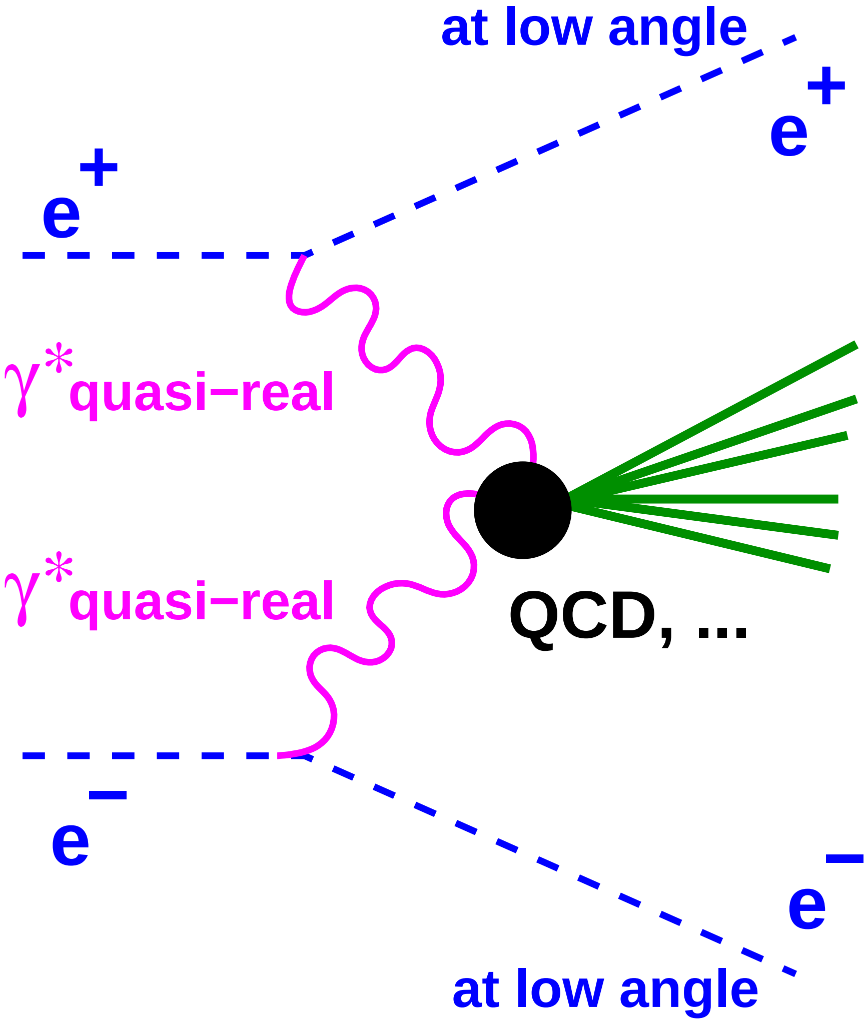
- $\gamma\gamma$, $e\gamma$ interactions
- WW physics. Final state interactions
- Fermion pair production
- Searches: Higgs, SUSY
- Outlook

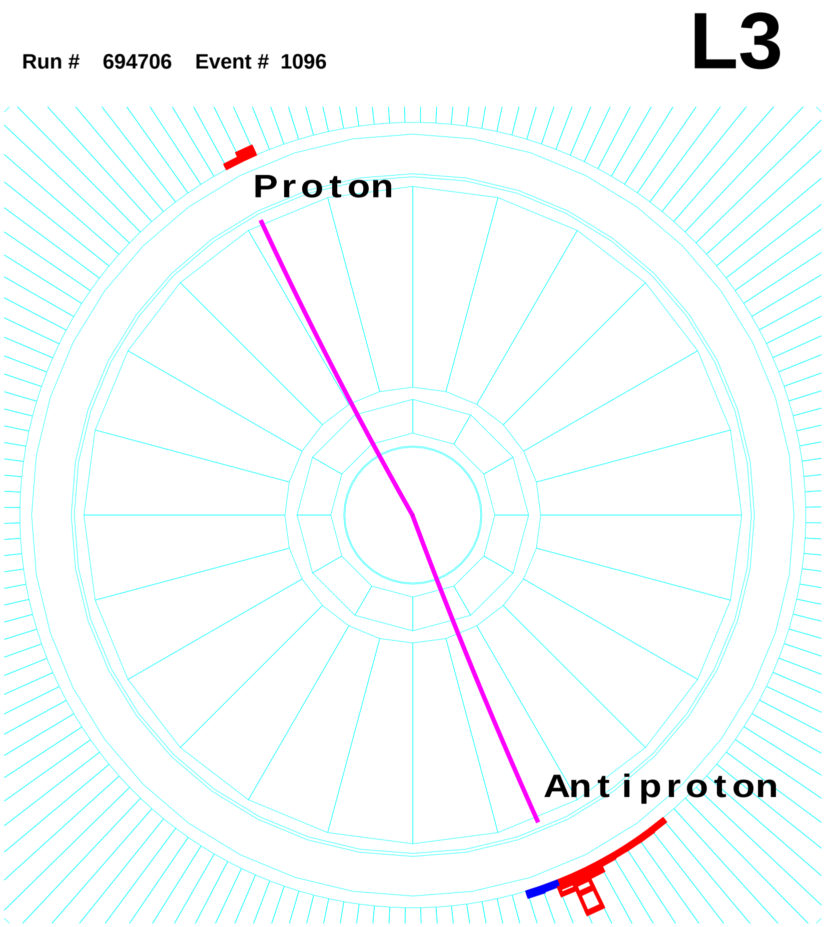
Selected new/final results are presented

All limits are given at the 95% CL

Two–photon Physics

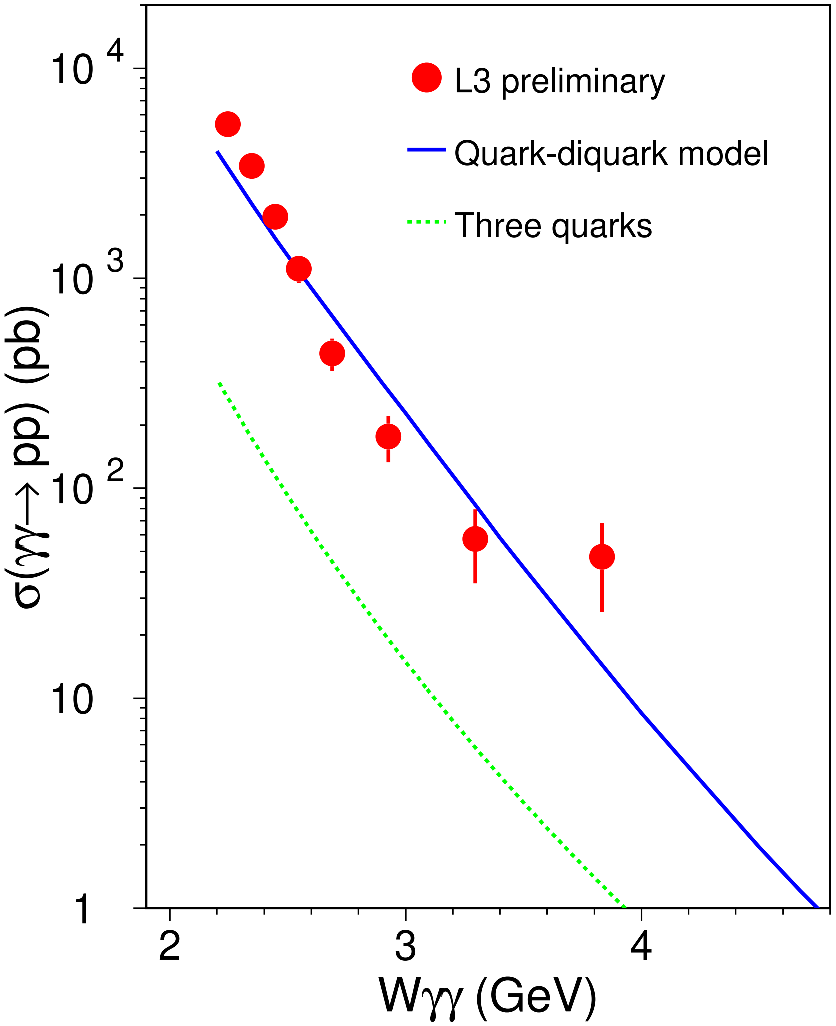


Baryon production in two-photon collisions



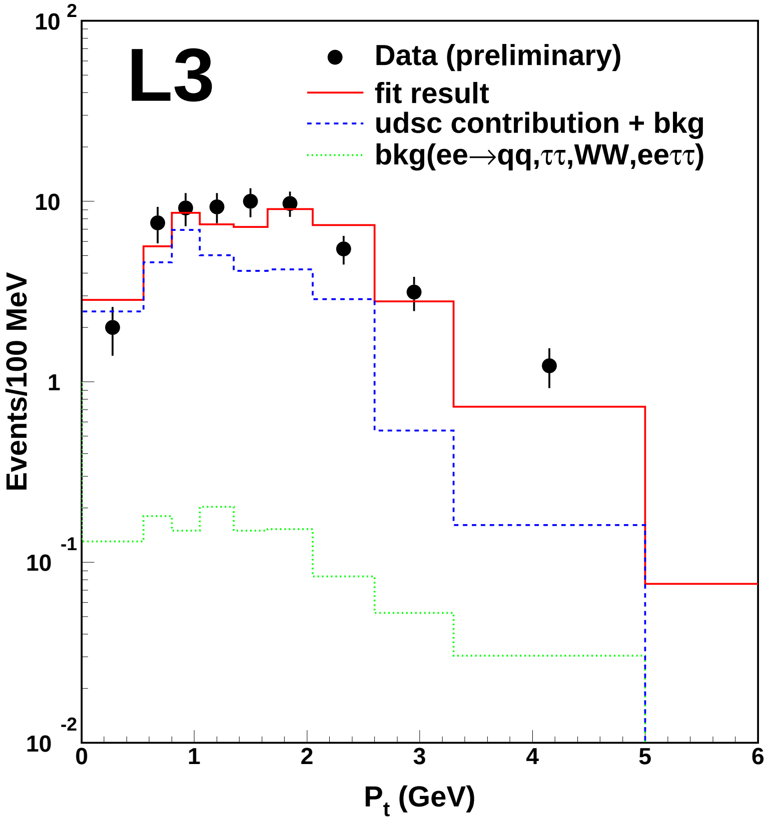
Antiproton identification criteria:

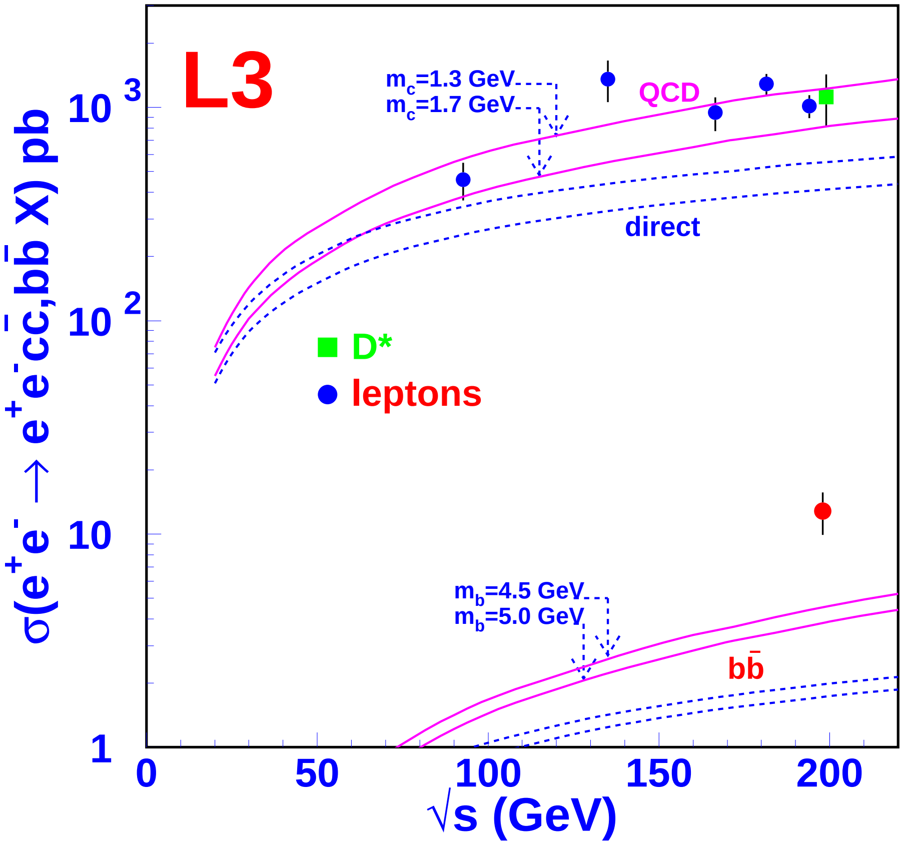
- **dE/dx**
- **Calorimeter energy vs momentum**
- **Cluster shape**



Baryons behave effectively as a quark-diquark system

Open $\mathrm{b\bar{b}}$, $\mathrm{c\bar{c}}$ production

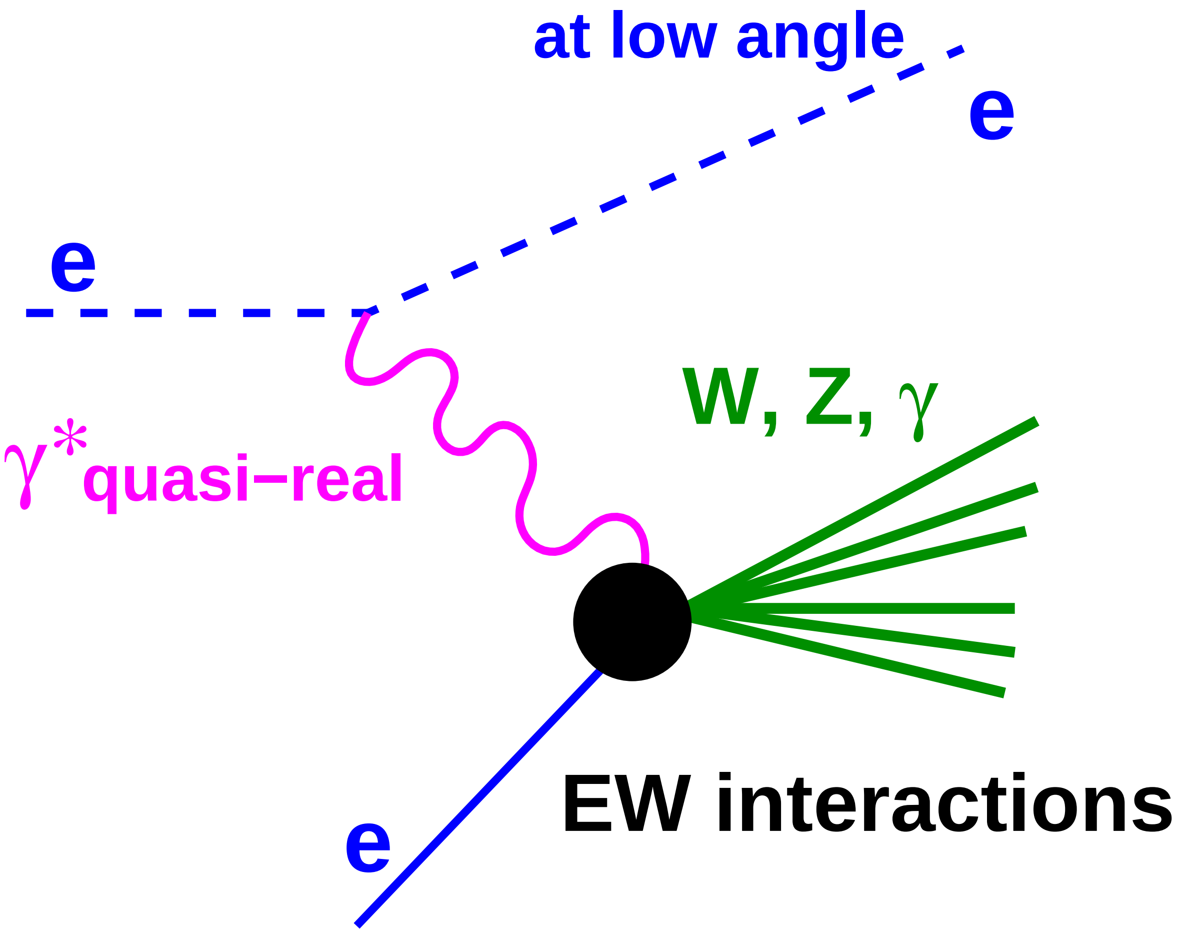




$\mathrm{b\bar{b}}$ excess at the 5σ level

$$\sigma^{exp}_{\mathrm{b\bar{b}}} \approx 3 \text{ times } \sigma^{the}_{\mathrm{b\bar{b}}}$$

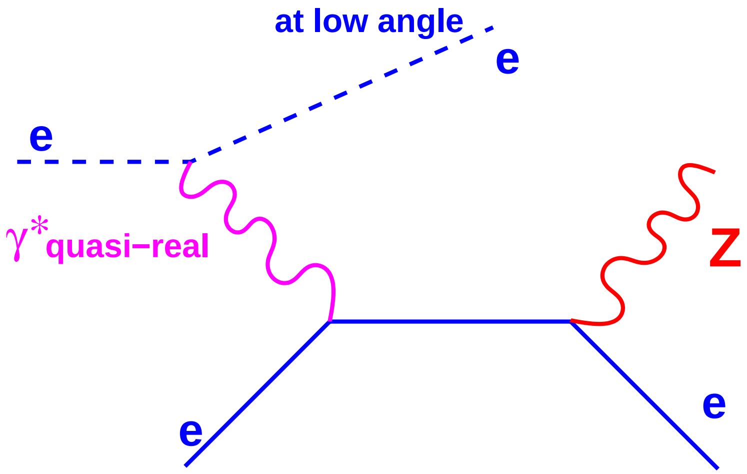
e–γ Interactions

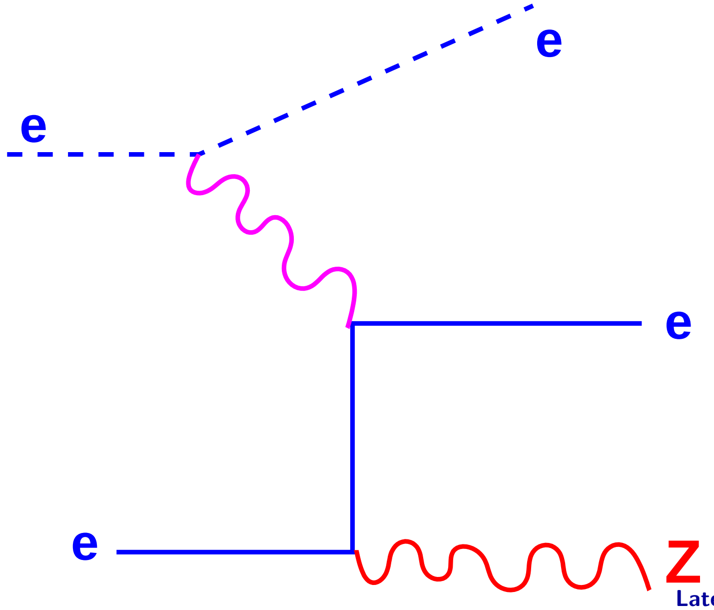


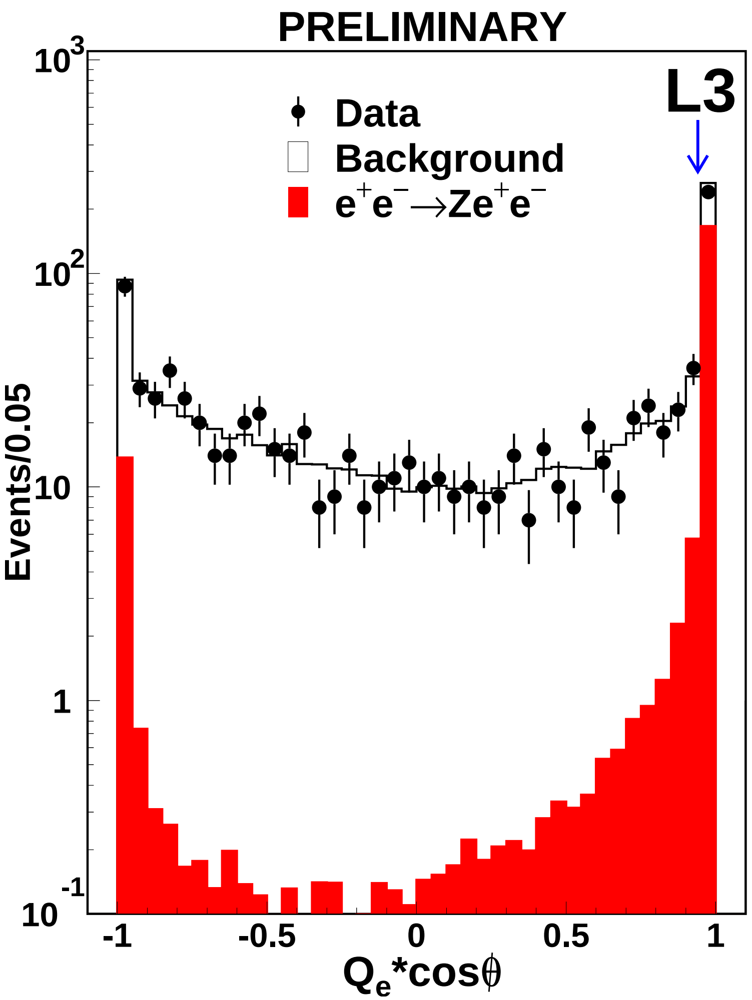
$e\gamma \longrightarrow eZ$

In the SM

$Z \longrightarrow q\bar{q}$

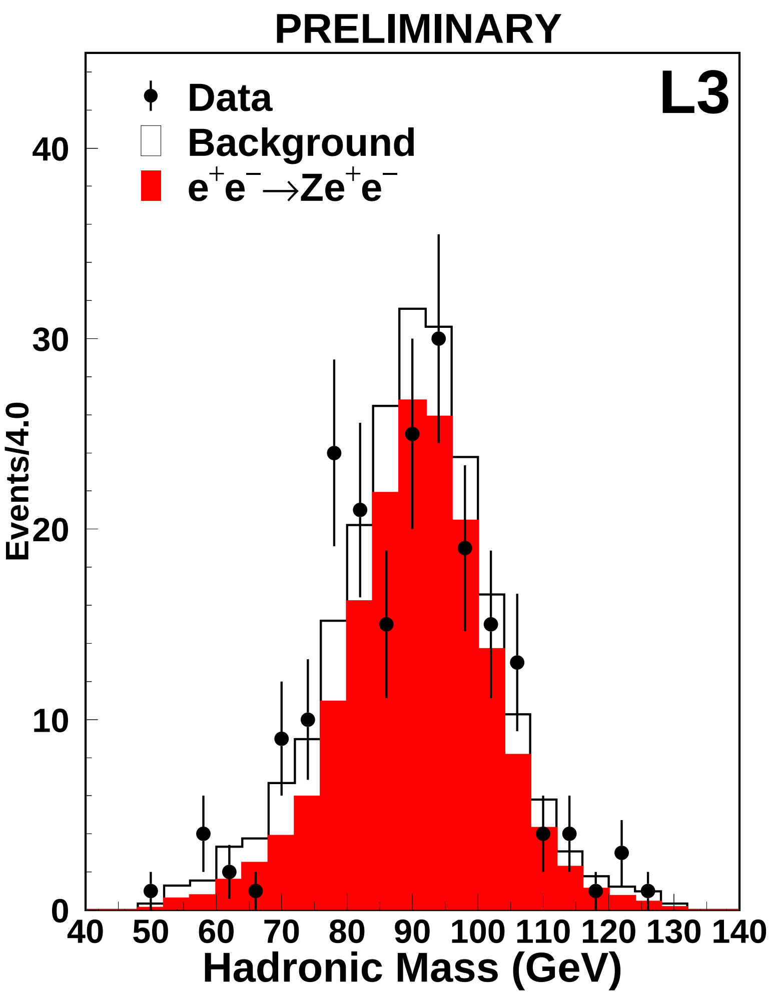


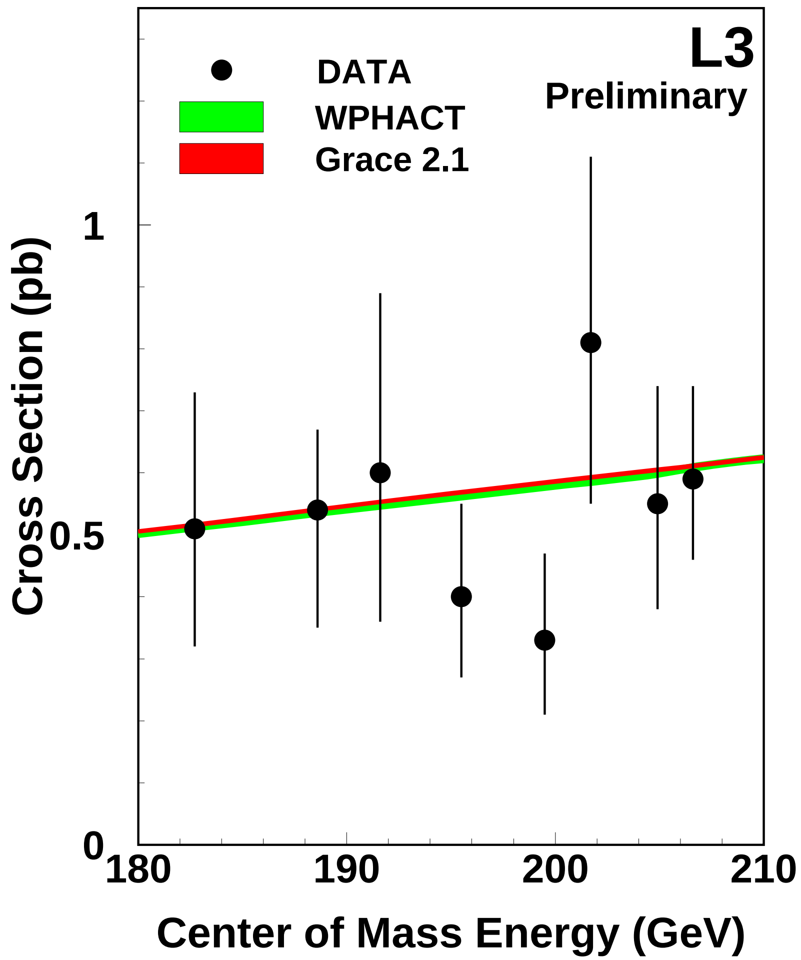




Electron at very low angle

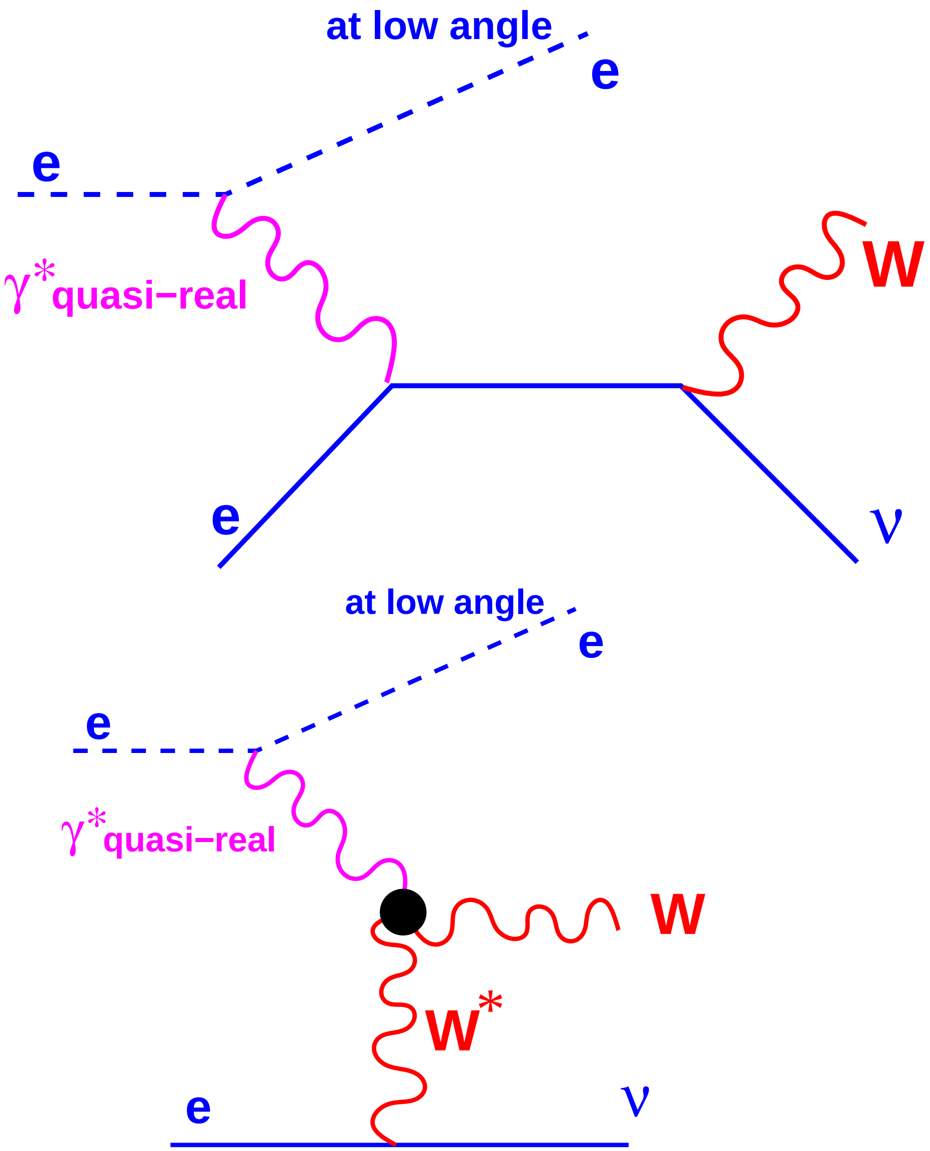
$e\gamma \longrightarrow eZ$

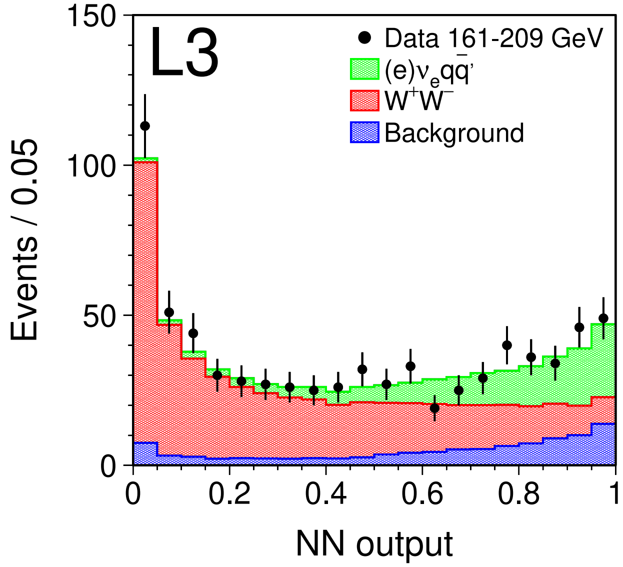


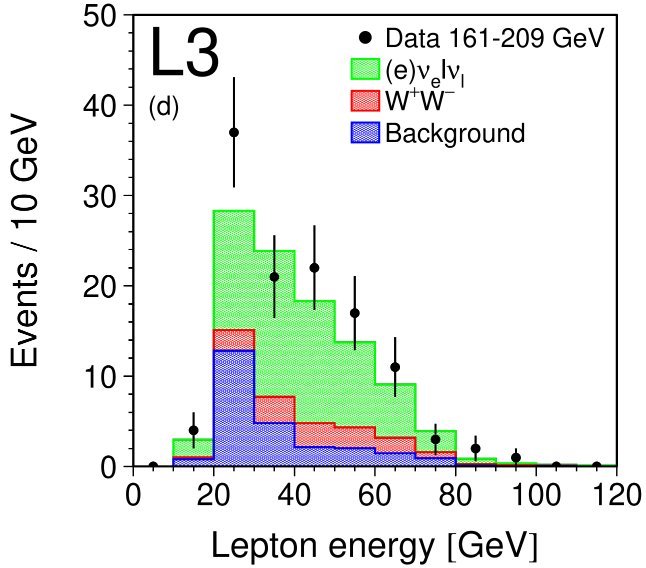


In agreement with the SM predictions

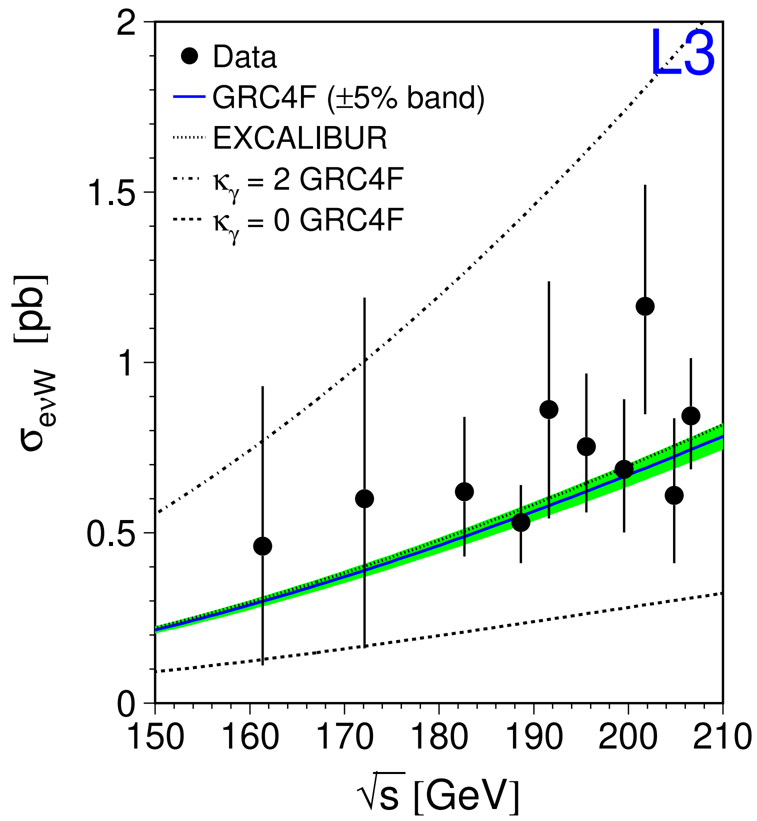
$e\gamma \to \nu W$: *study of* $WW\gamma$ *couplings*

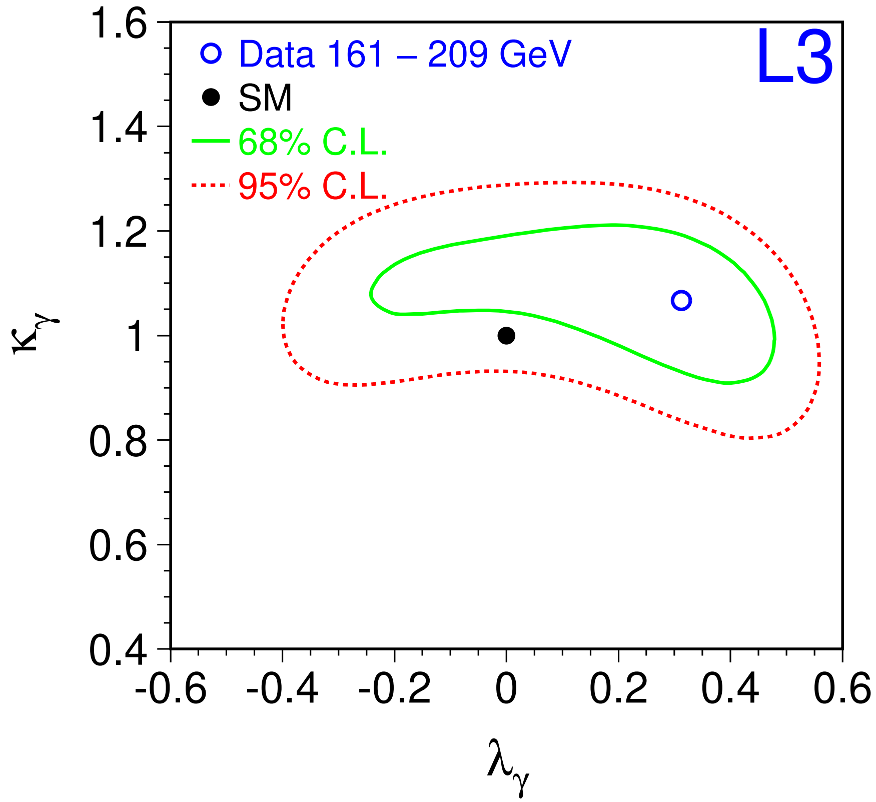






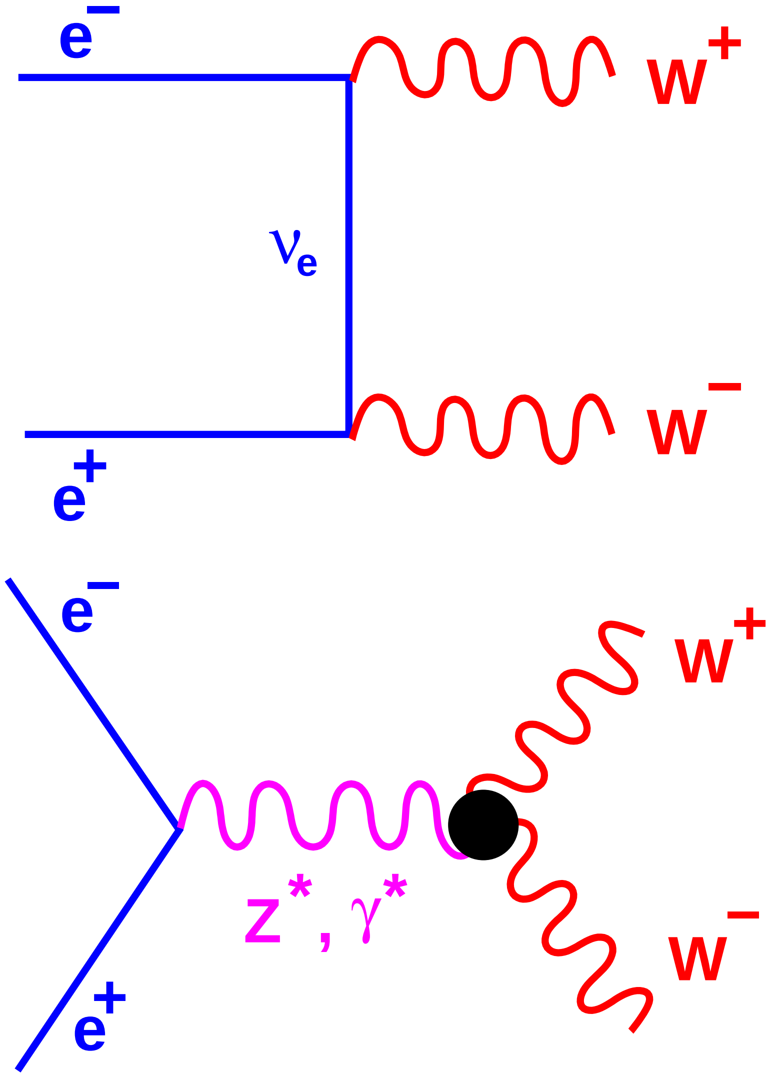
$e\gamma \to \nu W$



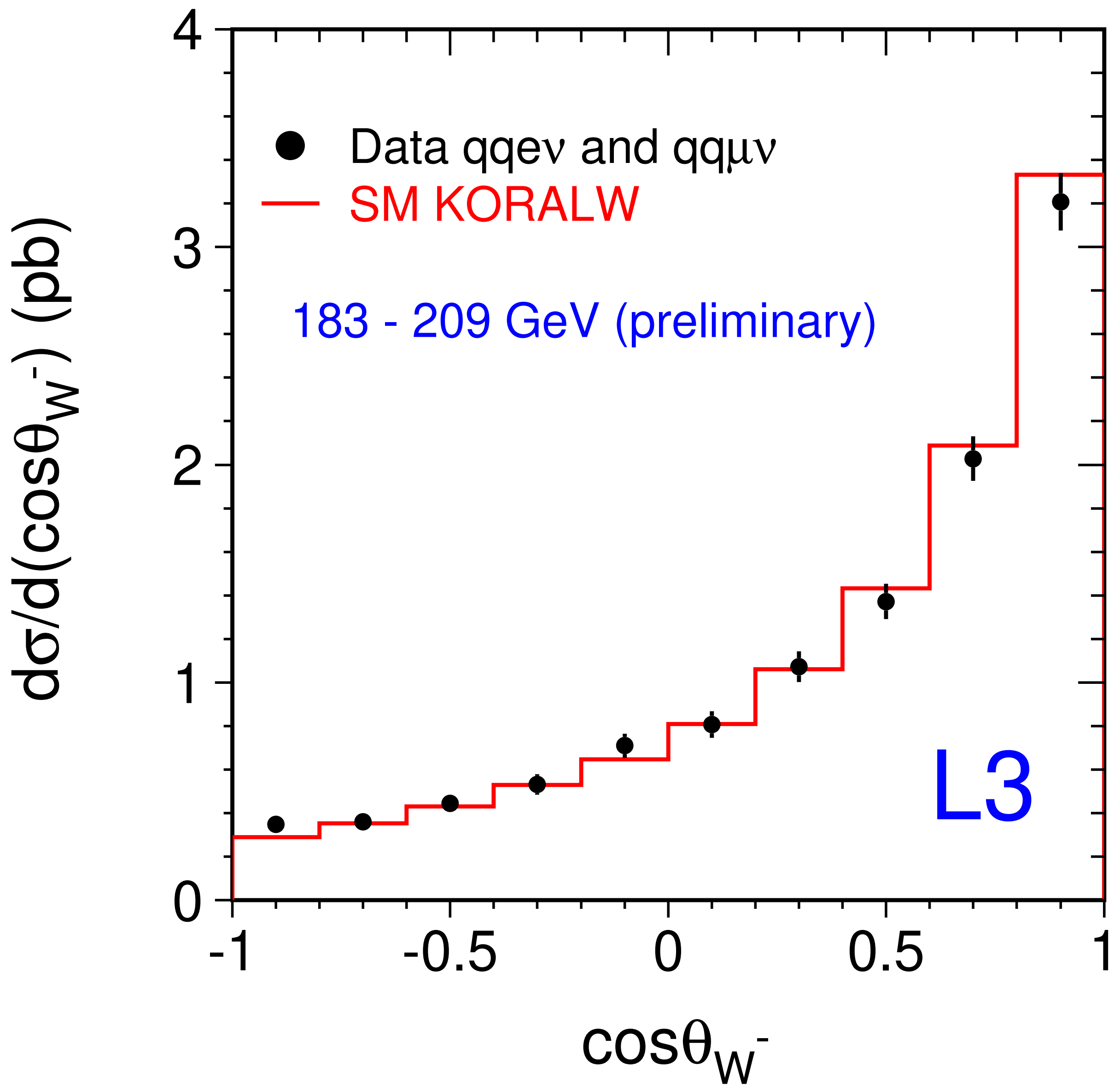


Evidence at the 8σ level for the non-abelian $WW\gamma$ couplings predicted in the SM: $\kappa_\gamma = 1.12 \pm 0.08 \pm 0.07$

WW Physics



Unfolding the $e^+e^- \to WW$ differential cross sections

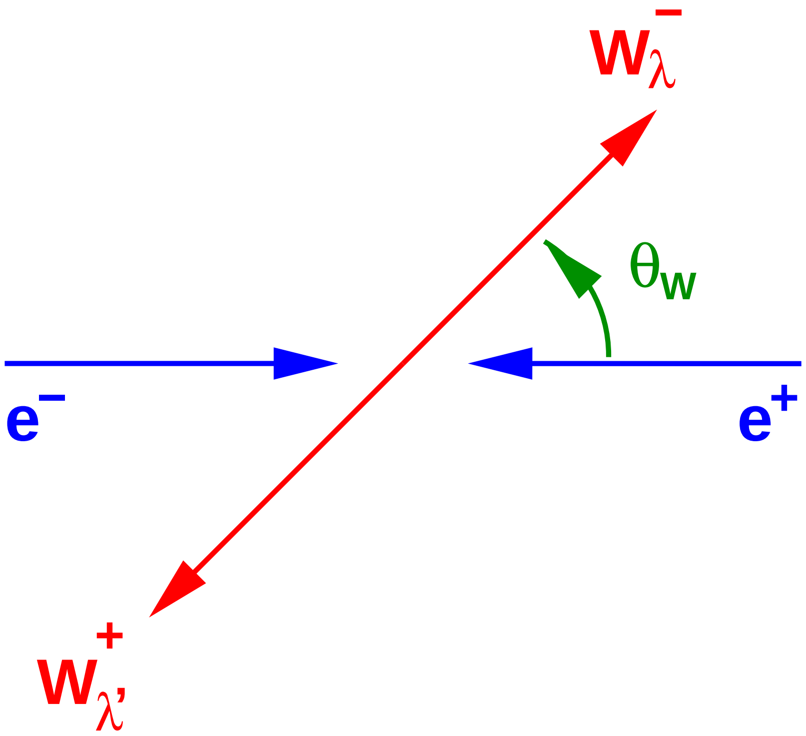


Many predictions beyond the SM manifest as deviations in the $e^+e^- \to WW$ differential cross section

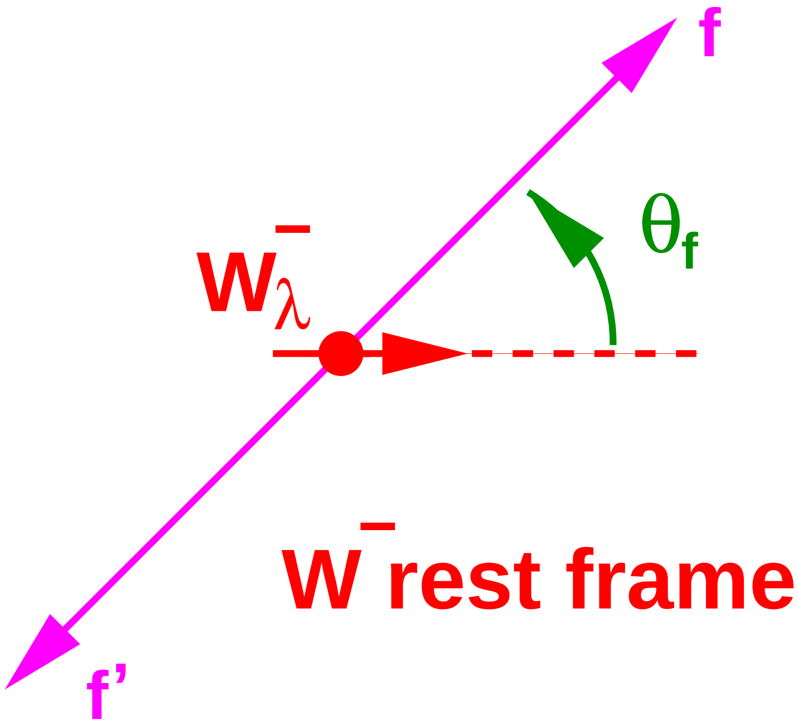
Total cross section is not enough: provide $d\sigma/d\cos\theta$

Spin analysis of the $e^+e^- \rightarrow WW$ *process*

Physics defined by



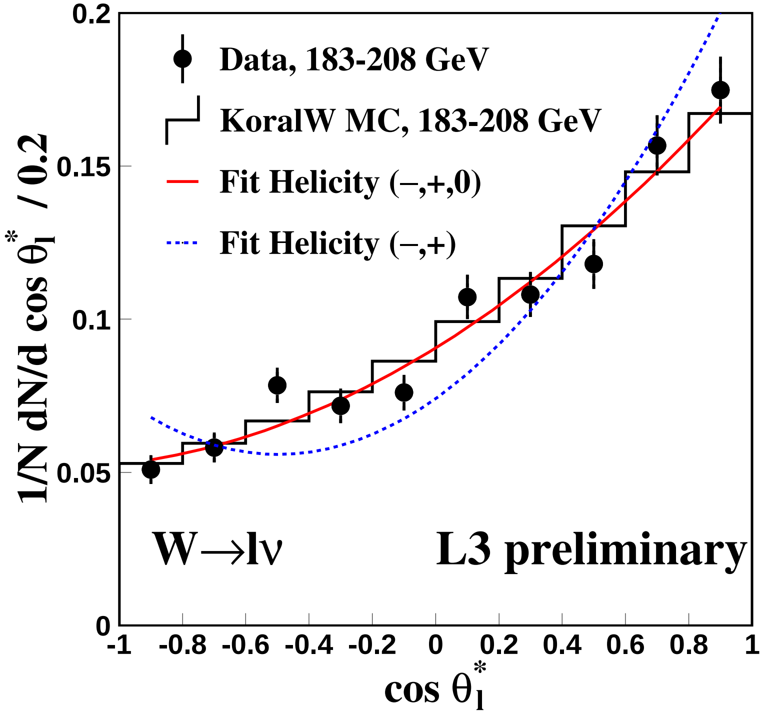
Polarizations from W decays

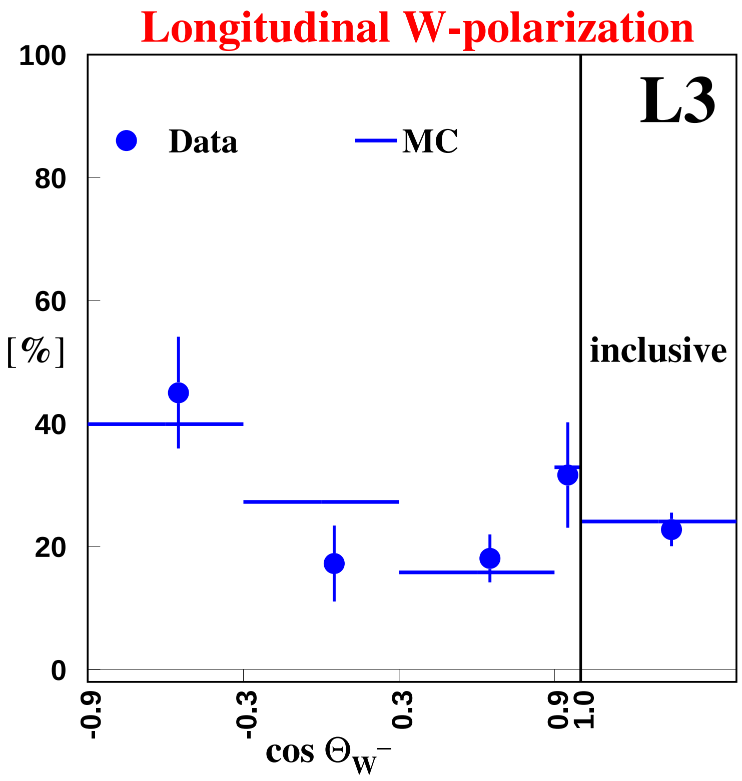


- Total cross section
- W^- polar angle distribution
- W polarizations (λ, λ')

- $\lambda = \mp 1 \Rightarrow \dfrac{dN}{d\cos\theta_f} \propto (1 \pm \cos\theta_f)^2$
- $\lambda = 0 \Rightarrow \dfrac{dN}{d\cos\theta_f} \propto \sin^2\theta_f$

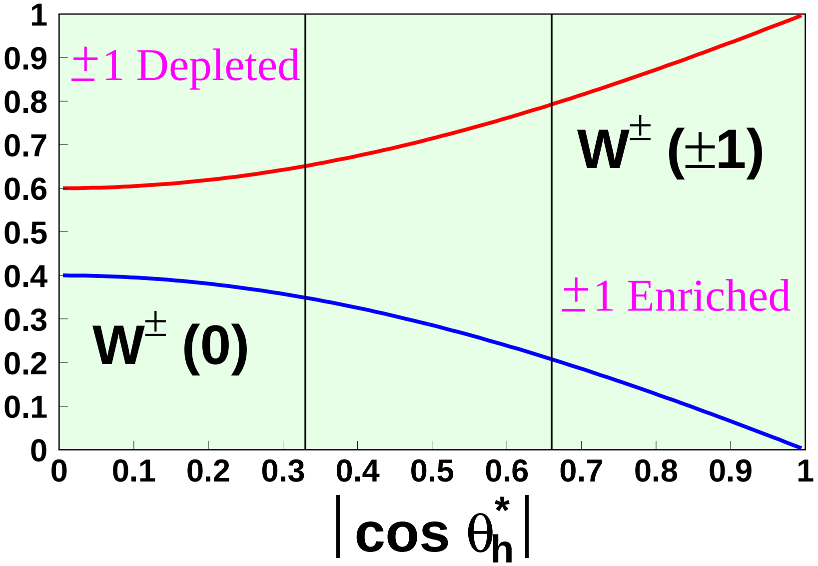
First type of analysis: polarizations of the individual Ws

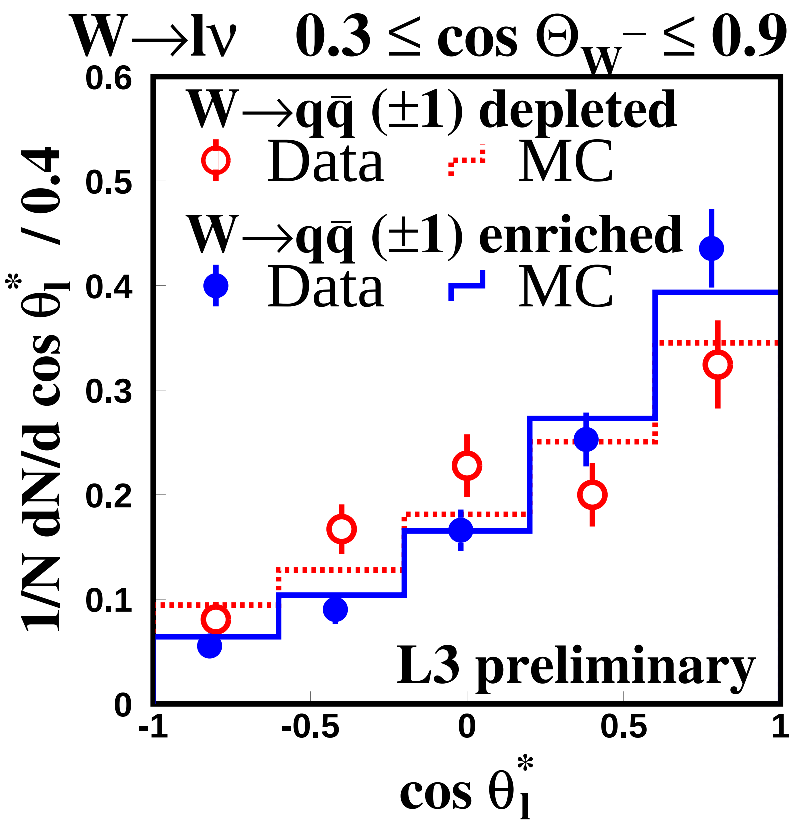




Longitudinal W polarization: $(22.8 \pm 2.7 \pm 1.2)\%$,
in agreement with SM expectations

Second type of analysis: spin correlations between Ws in $q\bar{q}'\ell\nu$

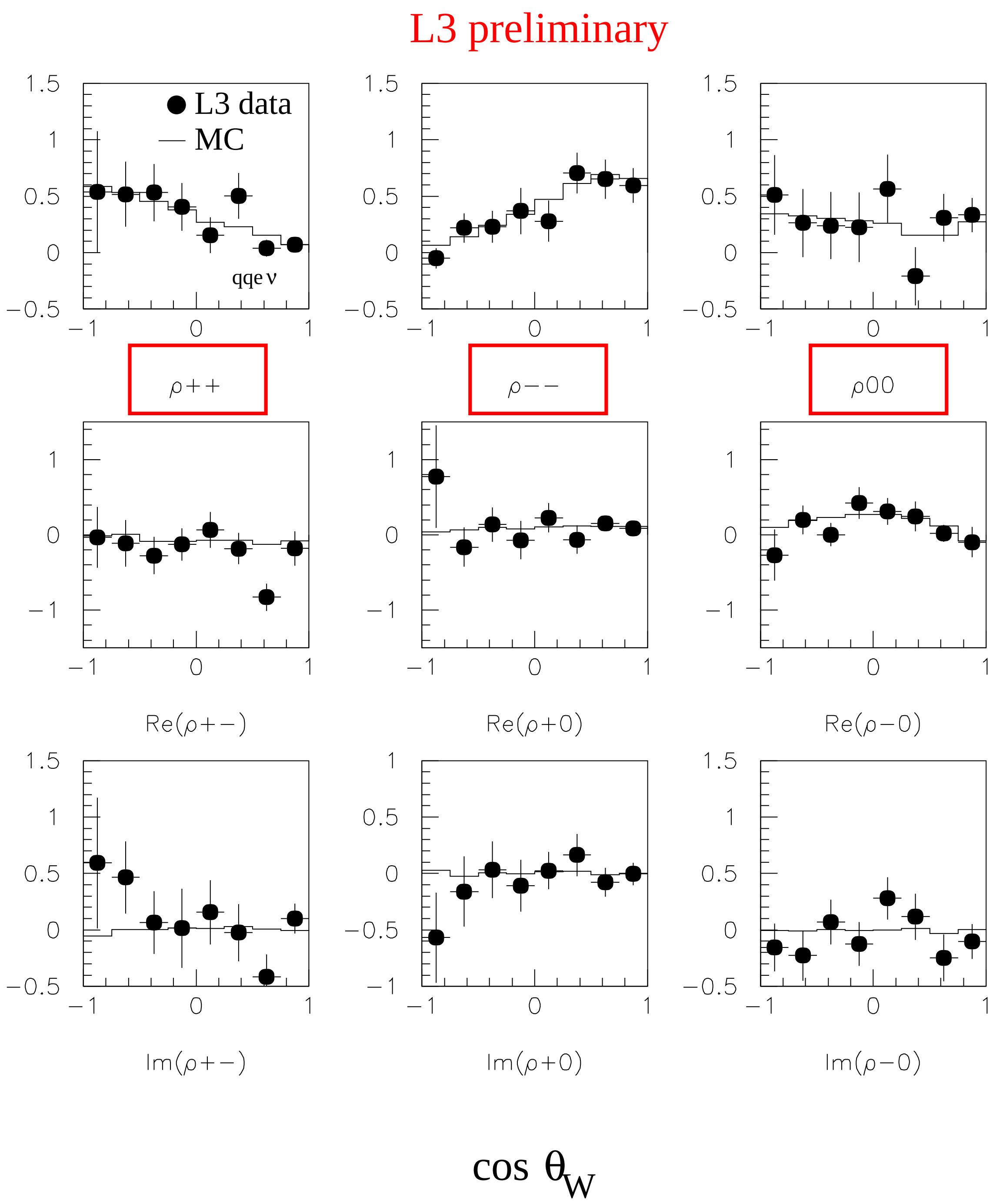




Evidence for spin correlations between the two W's at the 2.6σ level

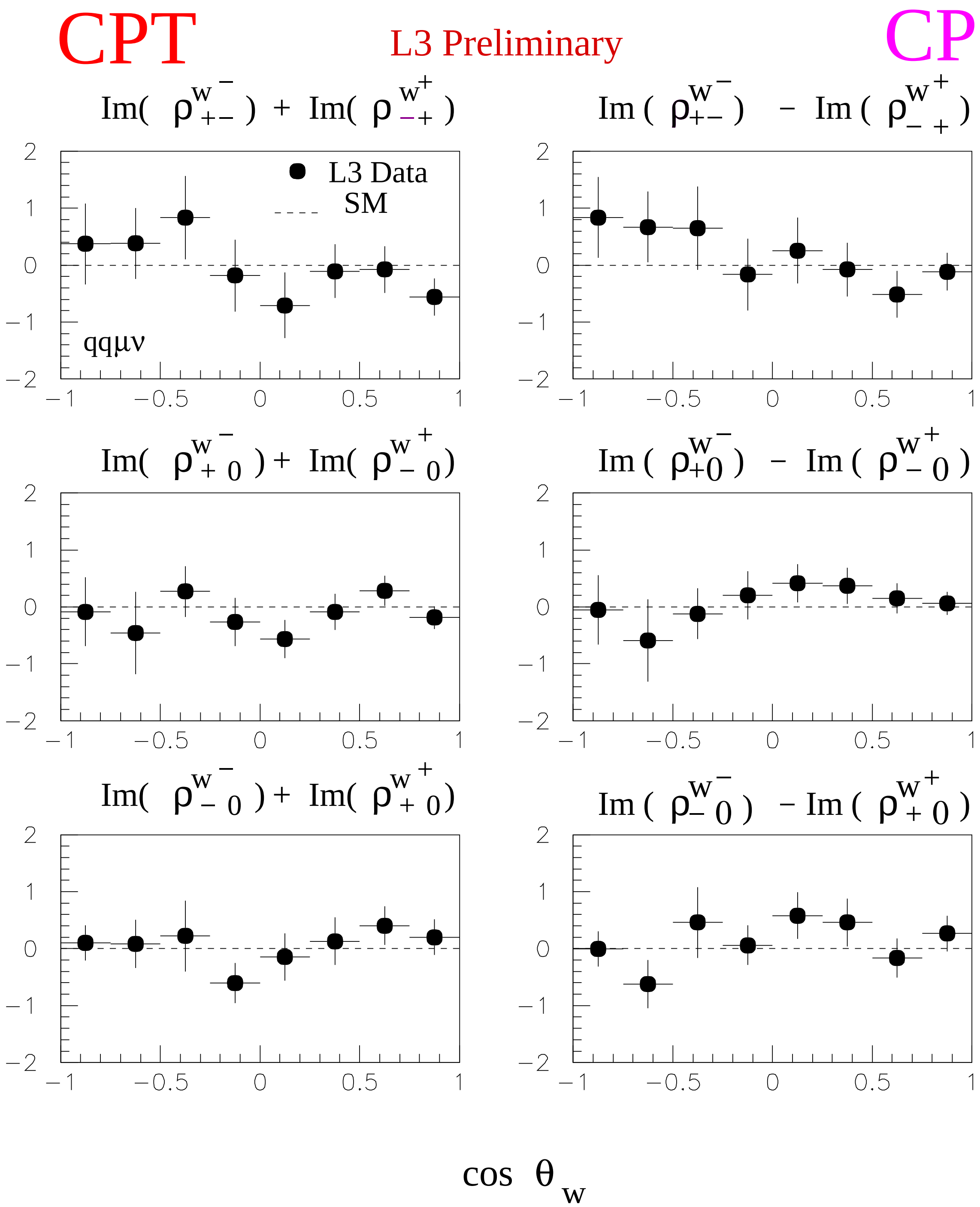
1.8σ larger than expected!

Third type of analysis: spin density matrix



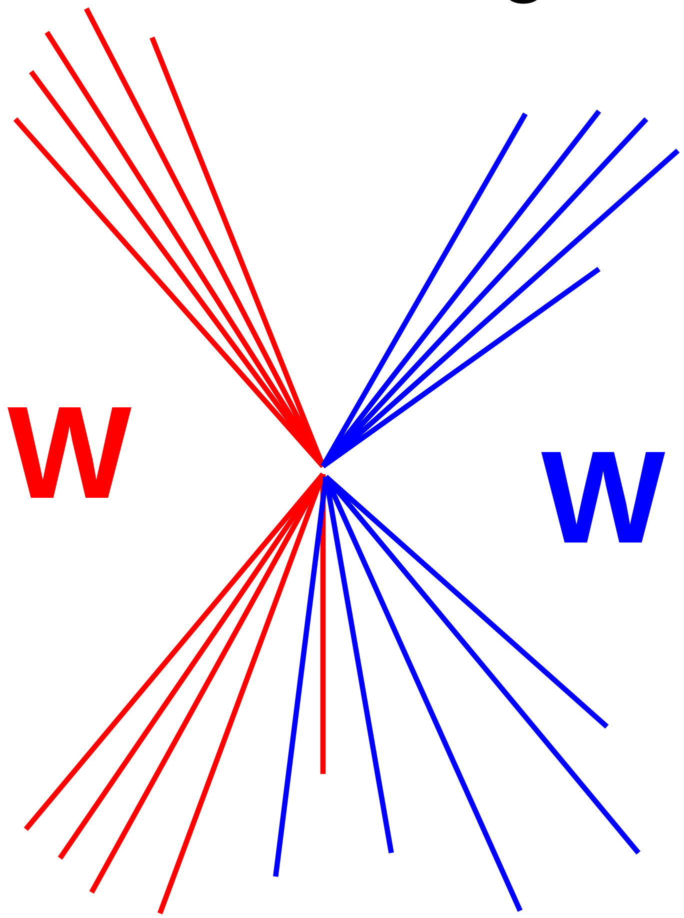
- Information equivalent to the W polarization analysis in the diagonal elements: $\rho_{00}, \rho_{++}, \rho_{--}$
- Extra pieces of information in the non-diagonal terms

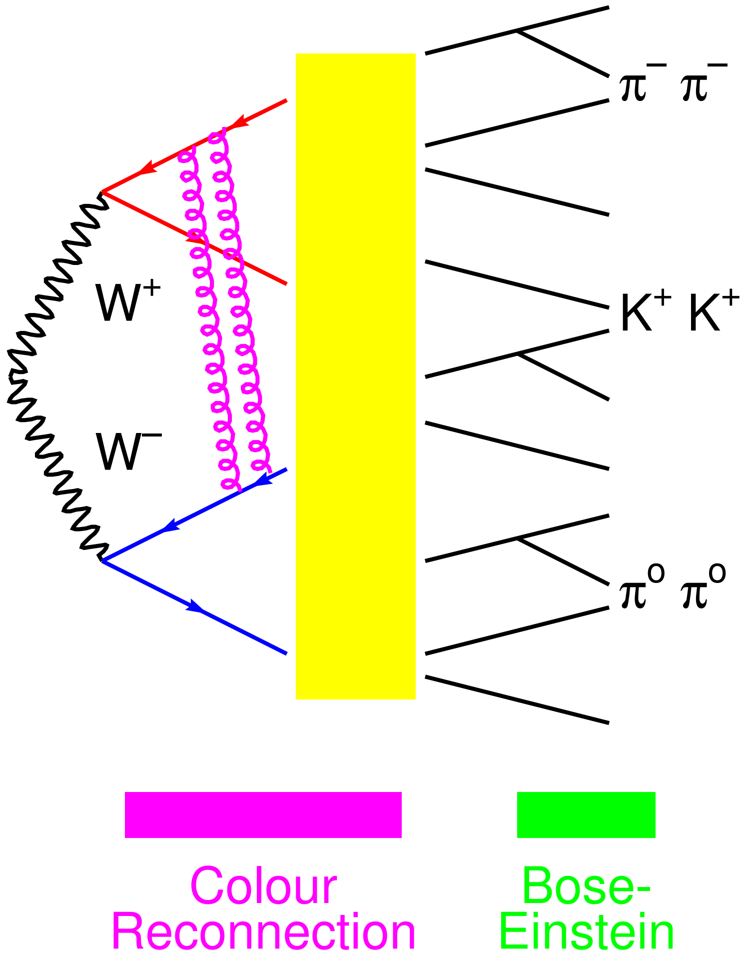
Third type of analysis: spin density matrix



- $Im(\rho) = 0$ in the absence of CP, CPT violation
- No CP violating couplings seen
- No CPT violating effects

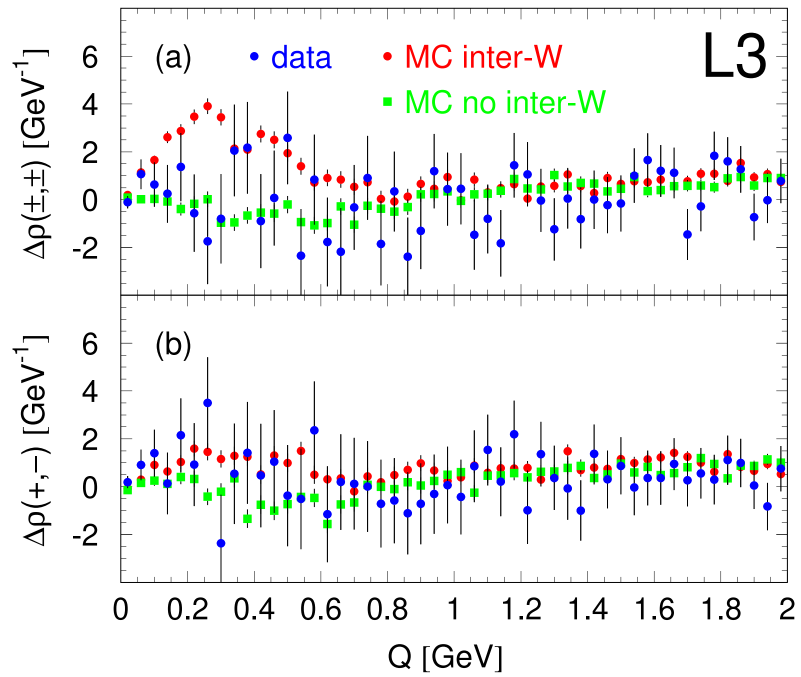
WW–> 4 jets

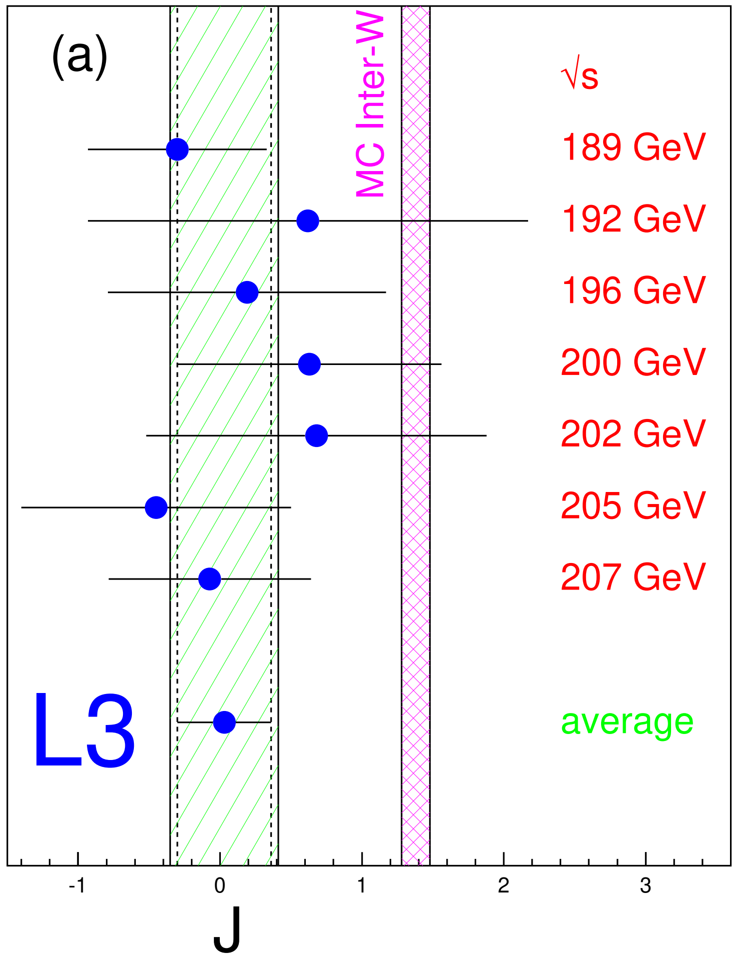




- Colour reconnection: affects the inter-W jet region
- Bose-Einstein correlations: identical bosons connected in phase space

Intra-W Bose-Einstein correlations





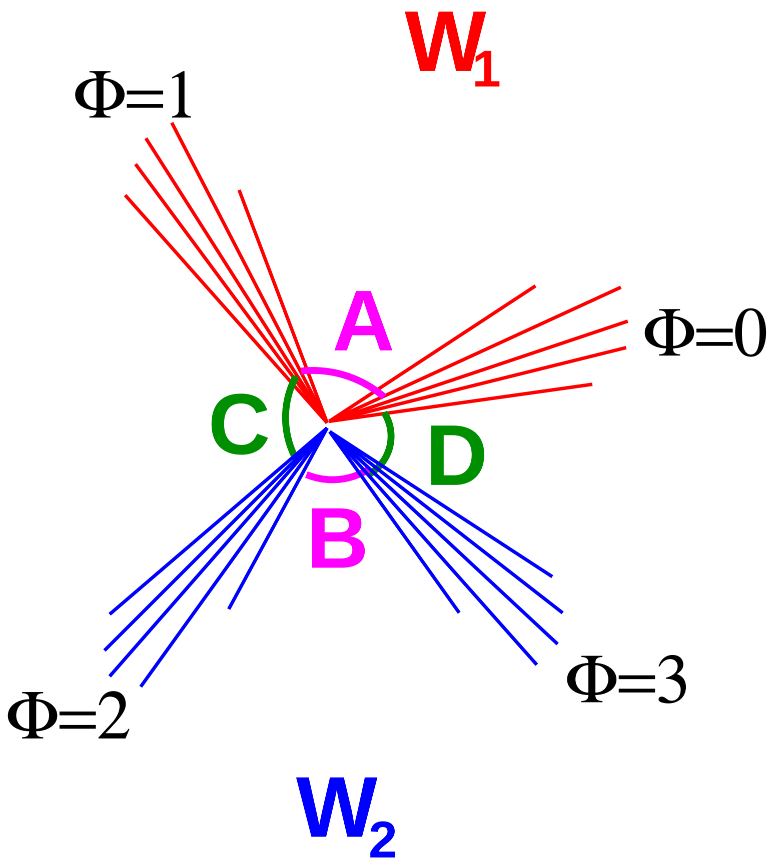
$$Q^2 = -(p_1 - p_2)^2$$

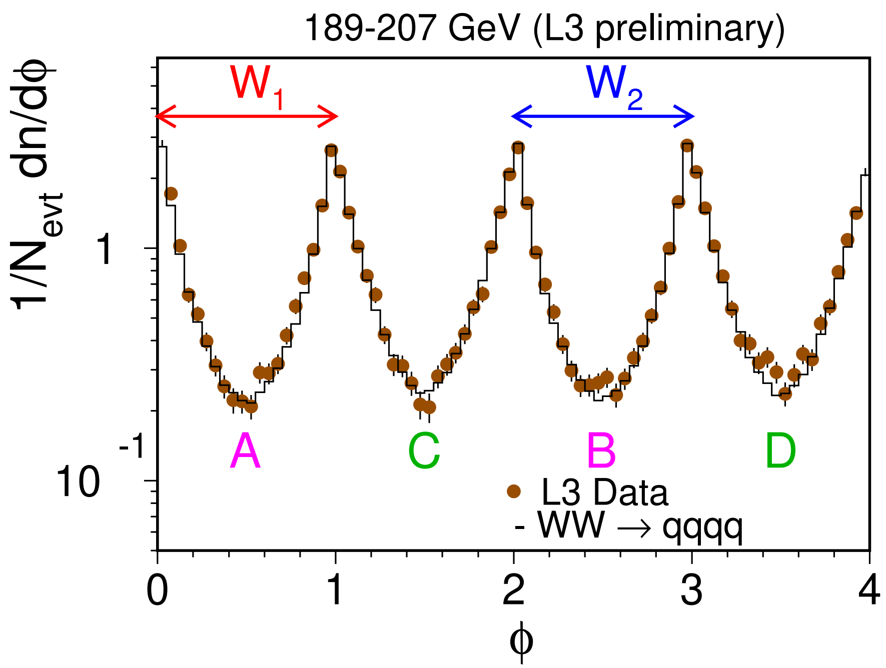
$$\Delta\rho(Q) = \frac{dN}{dQ} - \frac{dN}{dQ}\Big|_{\rm no\ inter-W}$$

$$J = \int_0^{0.68} \Delta\rho(\pm,\pm)(Q)dQ$$

Estimated BE effect on the measured W mass: $20\ \mathrm{MeV}$

Colour-reconnection studies



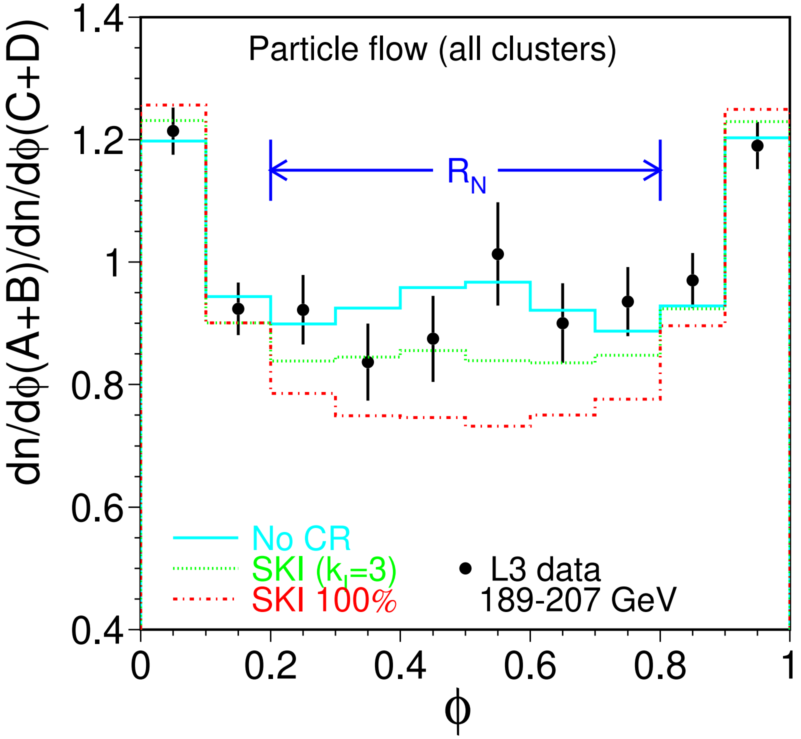


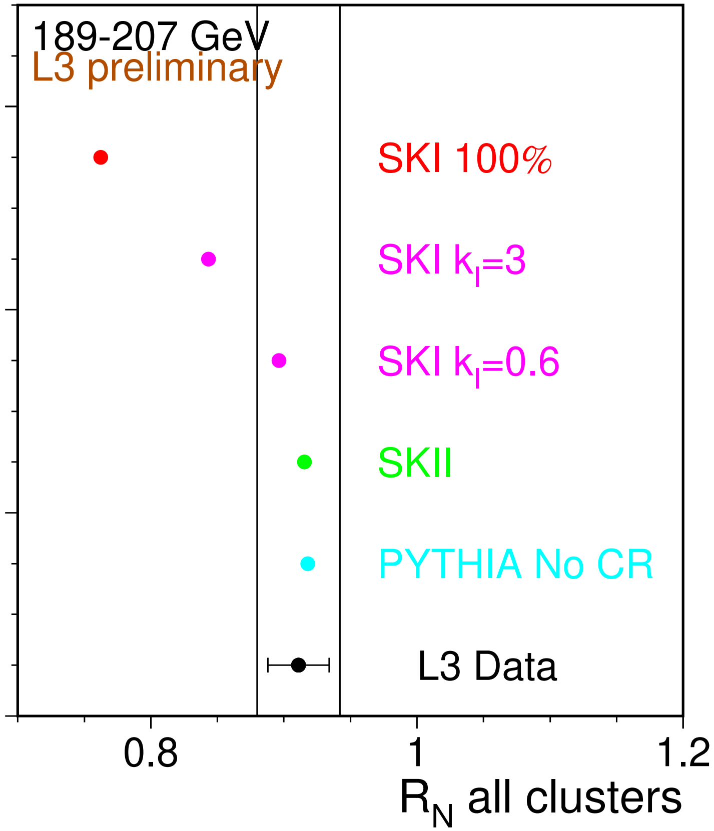
Planar configurations selected

Φ angles rescaled to the $[0, 1]$ interval

Quantify the differences between A+B and C+D regions...

Colour-reconnection studies





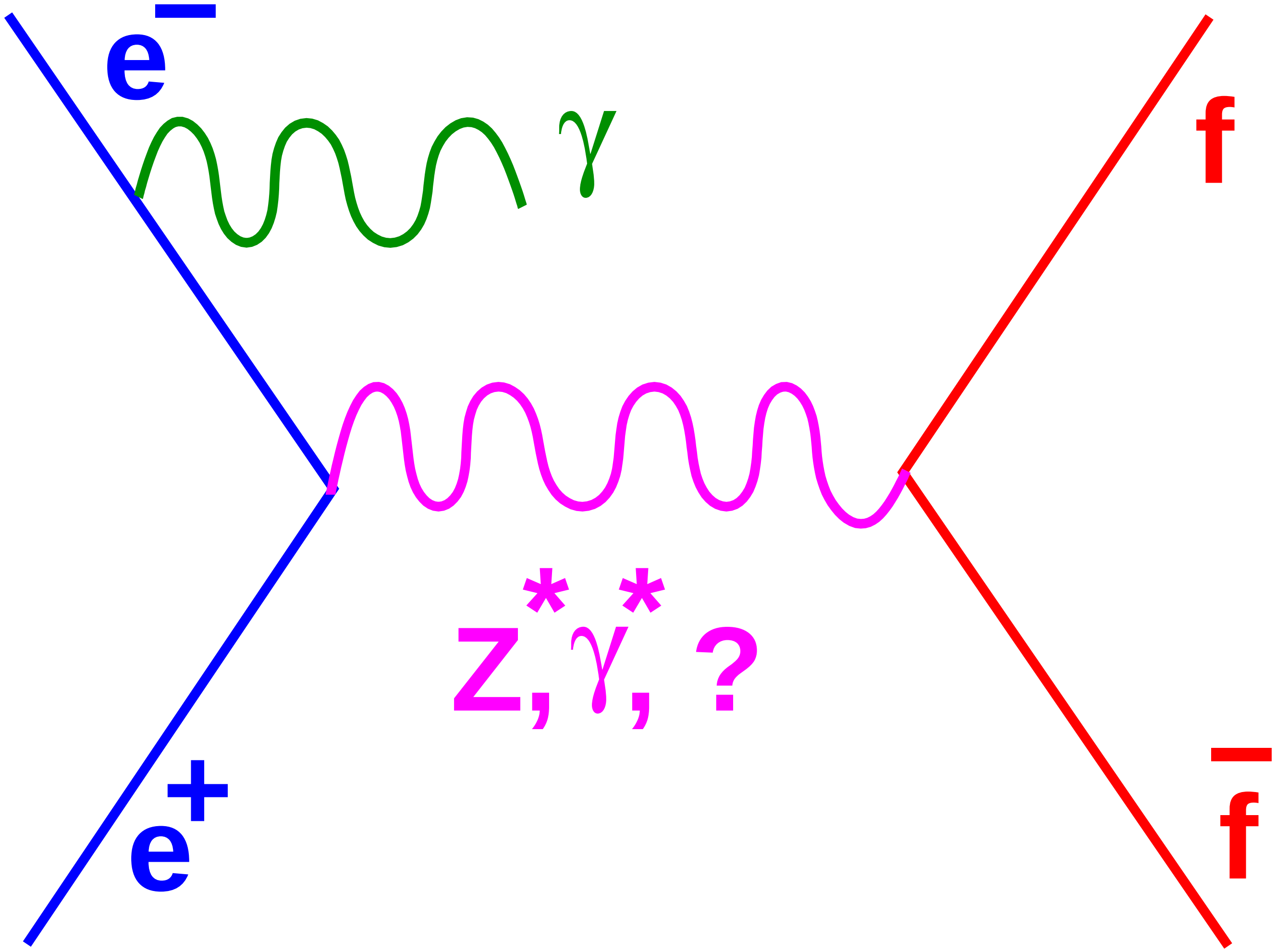
$$R_N = \frac{\frac{1}{N} \int_{0.2}^{0.8} \frac{dn}{d\phi}(A+B)}{\frac{1}{N} \int_{0.2}^{0.8} \frac{dn}{d\phi}(C+D)}$$

L3 data are consistent with a small colour reconnection probability:

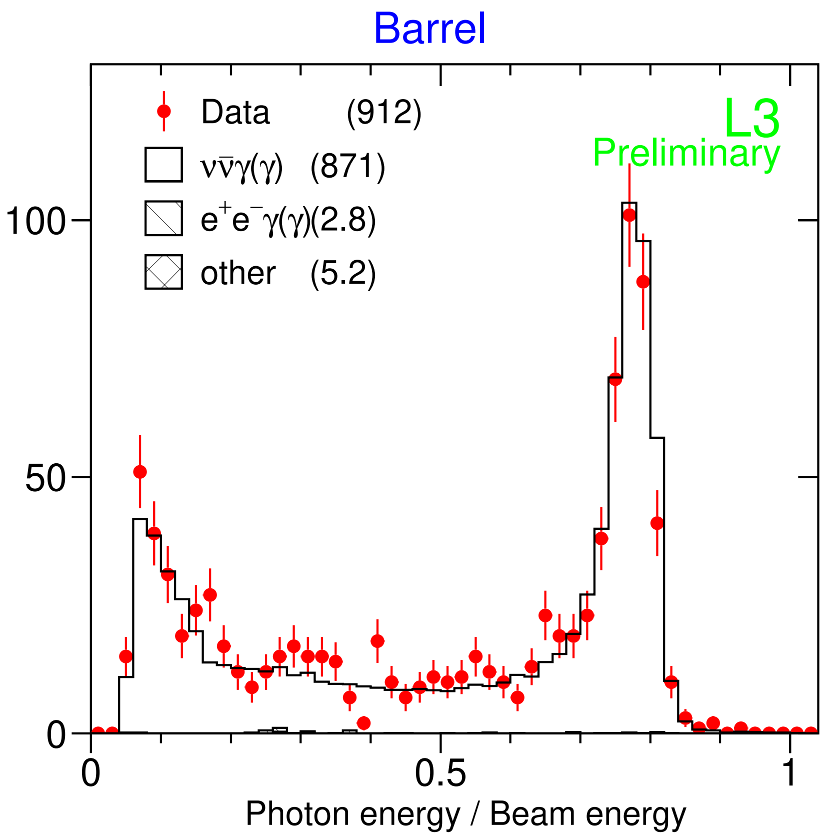
$P_{rec} = (17^{+29}_{-17})\%$ (SKI model)

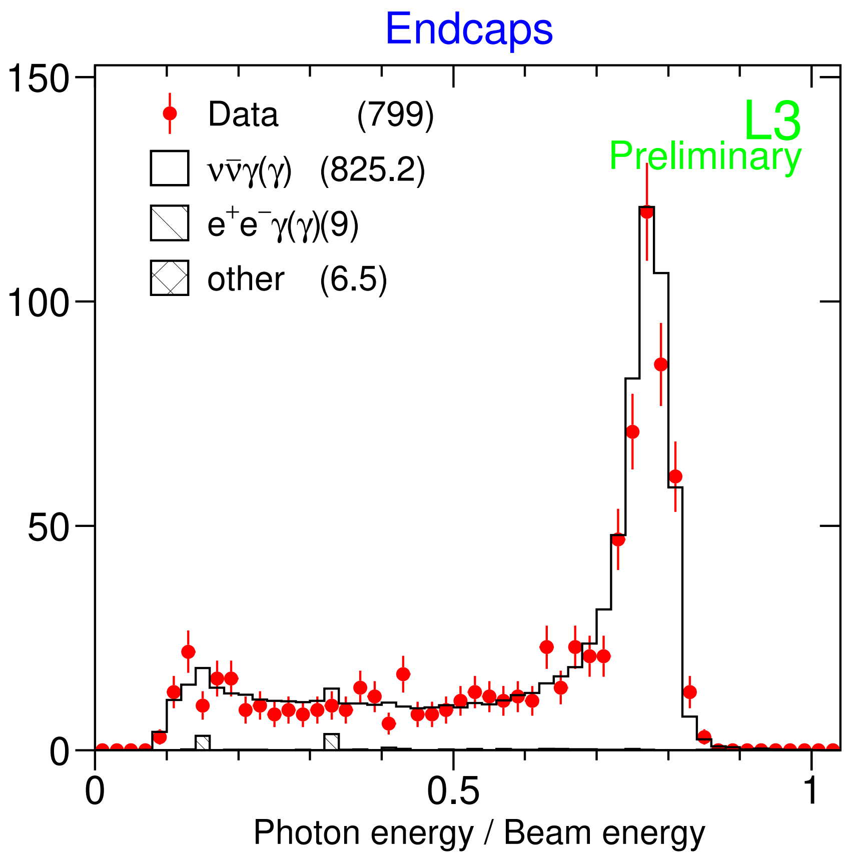
Shift in the measured W mass at $\sqrt{s} = 189\ \mathrm{GeV}$: $\lesssim 40\ \mathrm{MeV}$

Fermion pair production



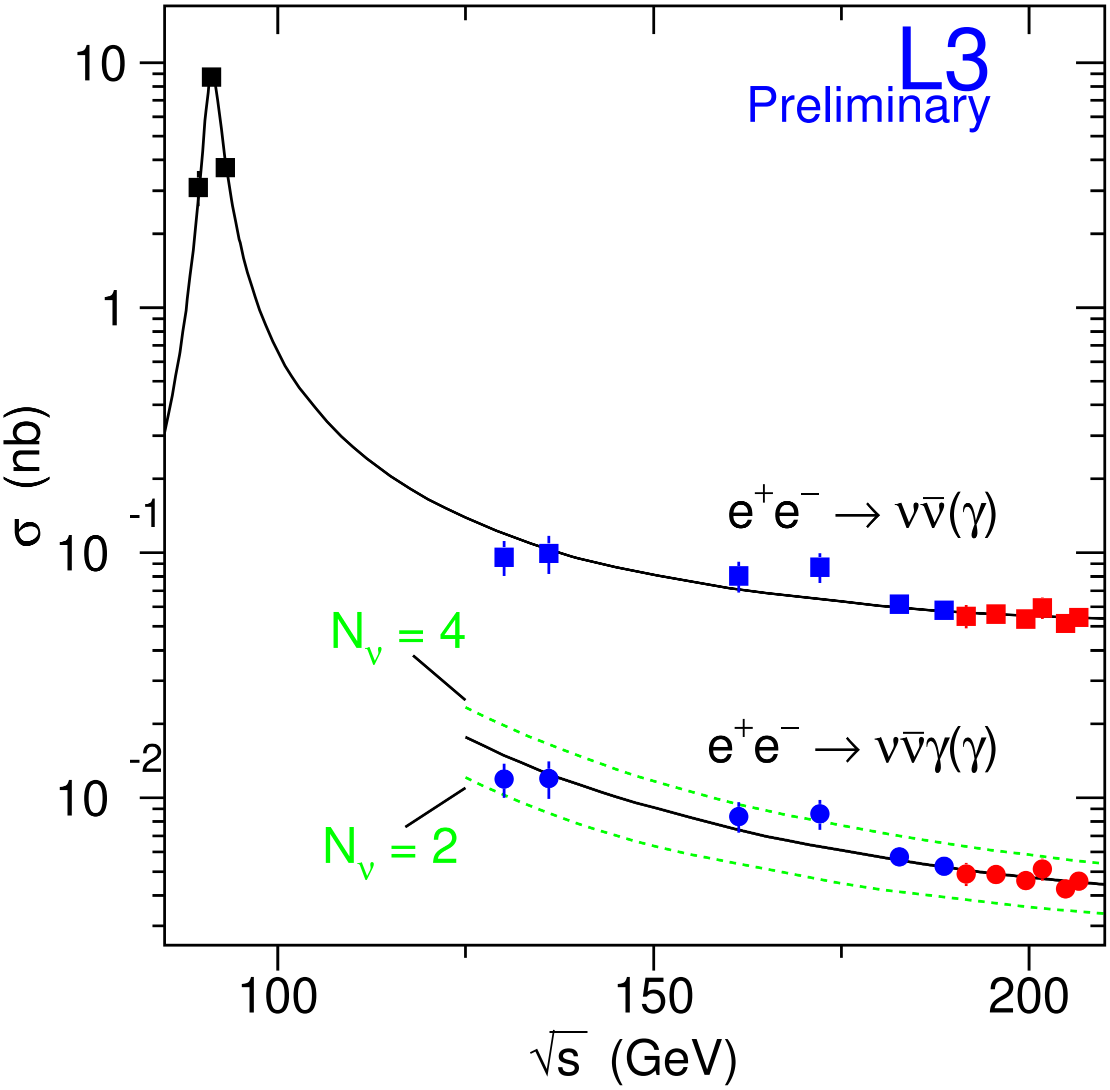
Photons with missing energy





- New $\mathrm{e^+e^-} \rightarrow \nu\bar{\nu}\gamma(\gamma)$ generator (KKMC)
- Estimated precision: $\lesssim 1\%$
- Good agreement DATA-MC

Fermion-pair cross sections



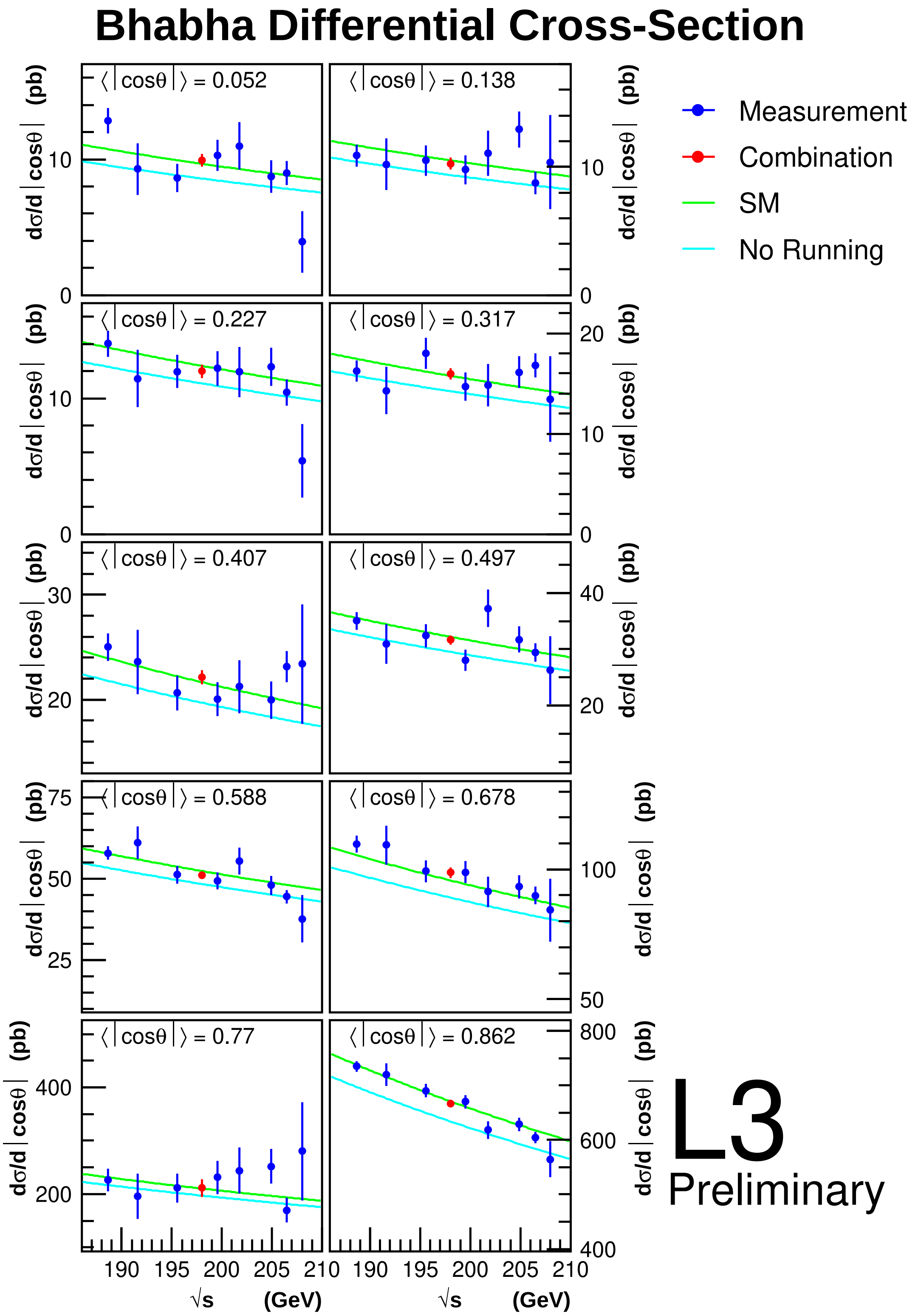
Kinematic region:

$E_\gamma > 5$ GeV, $|\cos\theta_\gamma| < 0.97$

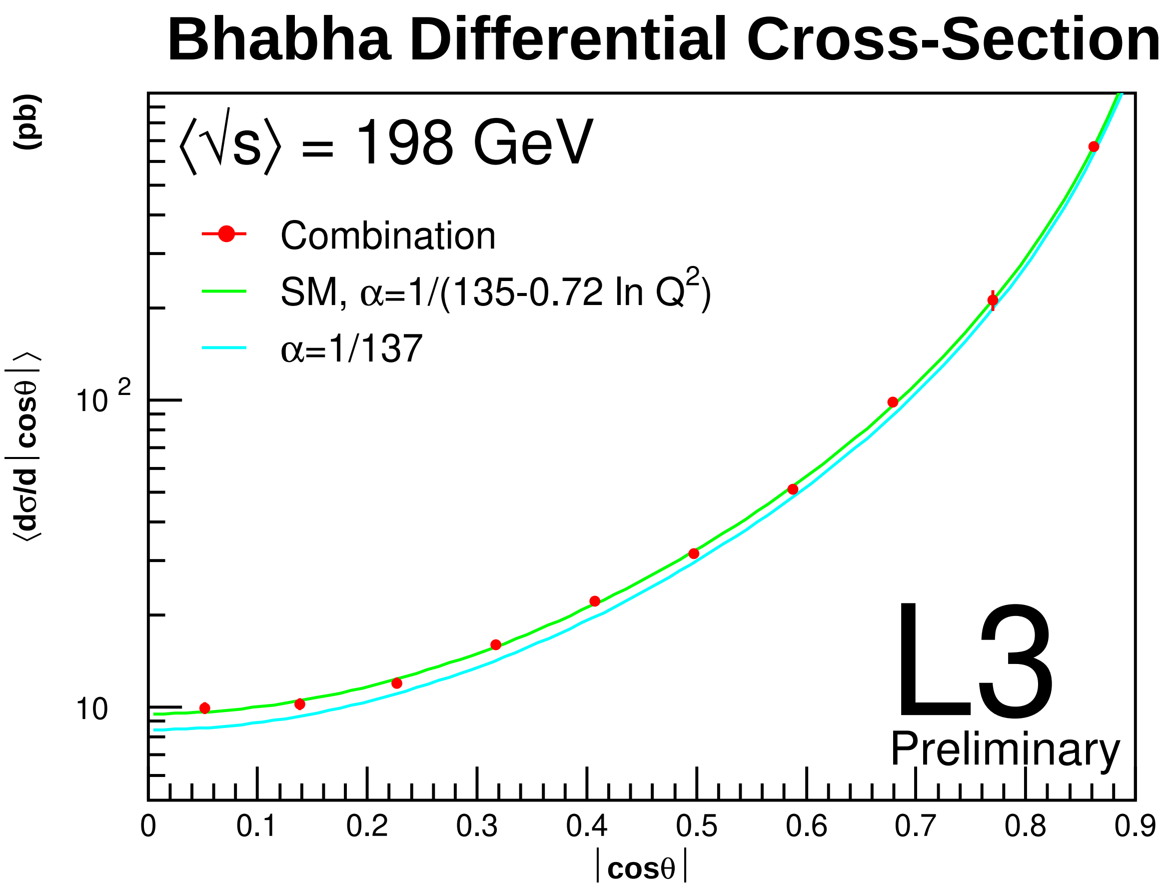
LEP2: $N_\nu = 2.94 \pm 0.09$

LEP1: $N_\nu = 2.98 \pm 0.10$

$e^+e^- \to f\bar{f}$. *Differential distributions*

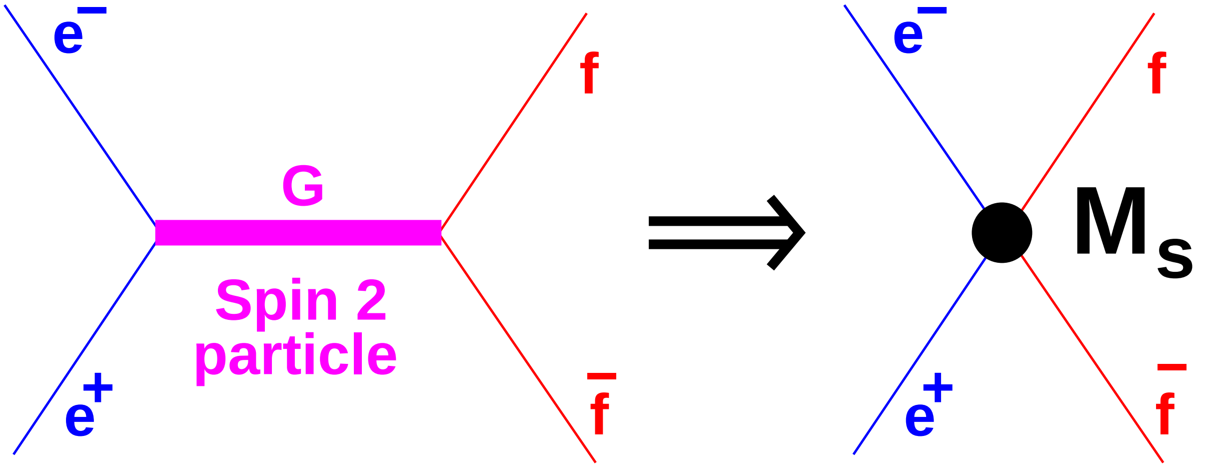


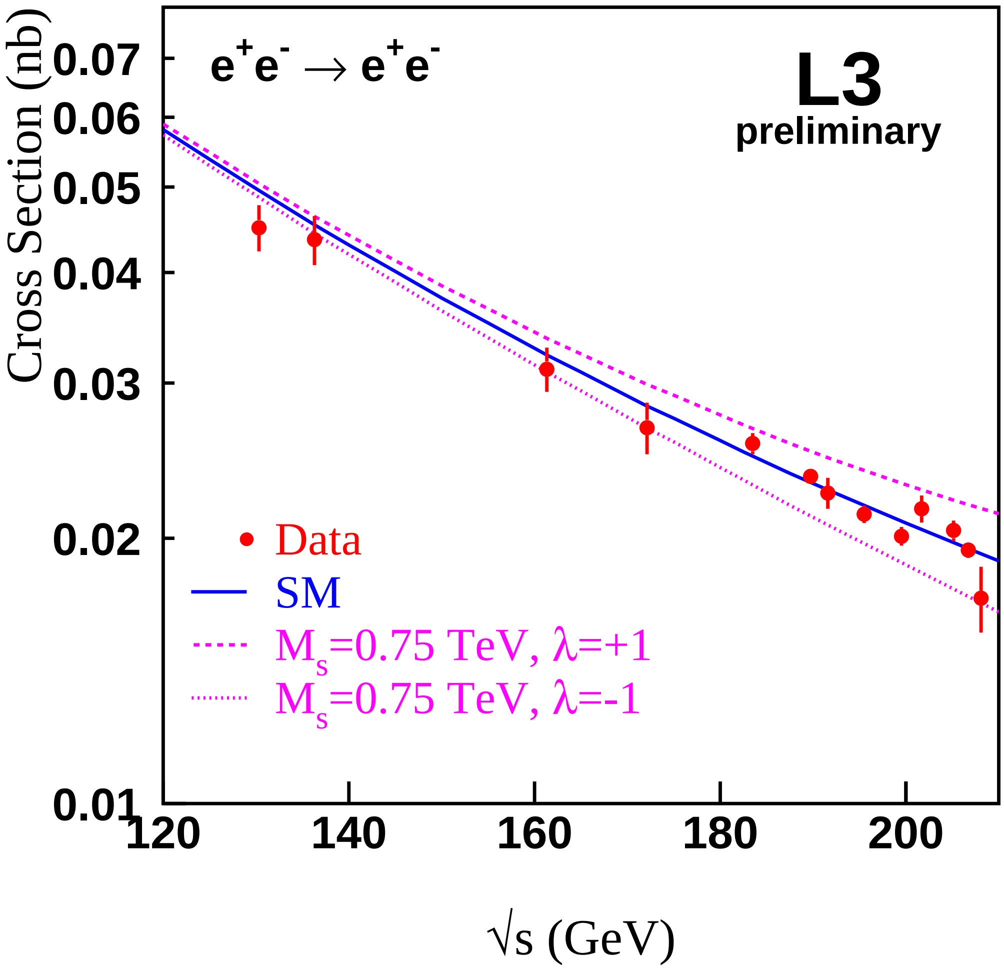
$e^+e^- \to f\bar{f}$. *Differential distributions*



- No running ($\alpha = 1/137$): $\chi^2/\mathrm{ndof} = 173/80$ (CL=10^{-8})
- Consistency with the running of α: $\chi^2/\mathrm{ndof} = 81/80$

$e^+e^- \to f\bar{f}$: *sensitivity to spin-2 particles*



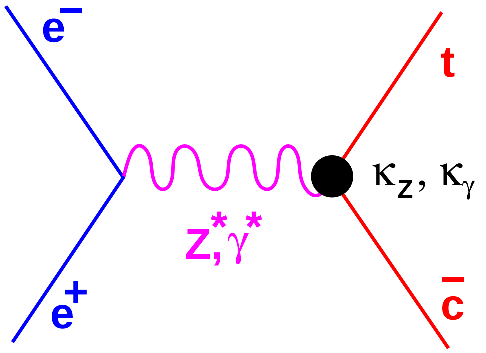


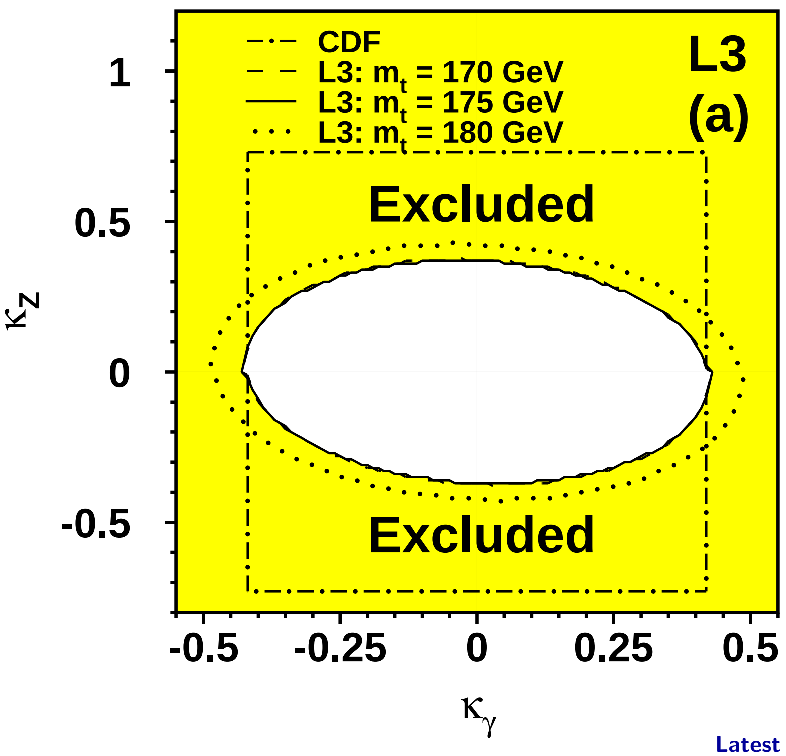
$$M_s > 1.04 \text{ TeV}; \quad \lambda = +1$$

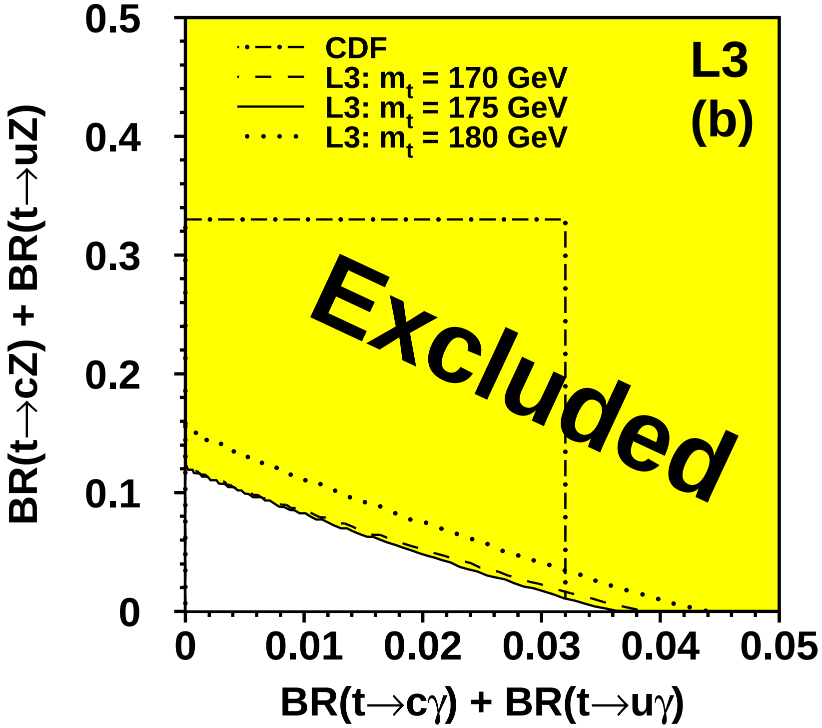
$$M_s > 1.05 \text{ TeV}; \quad \lambda = -1$$

Single top searches in L3: $e^+e^- \longrightarrow t\bar{c}(\bar{u})$

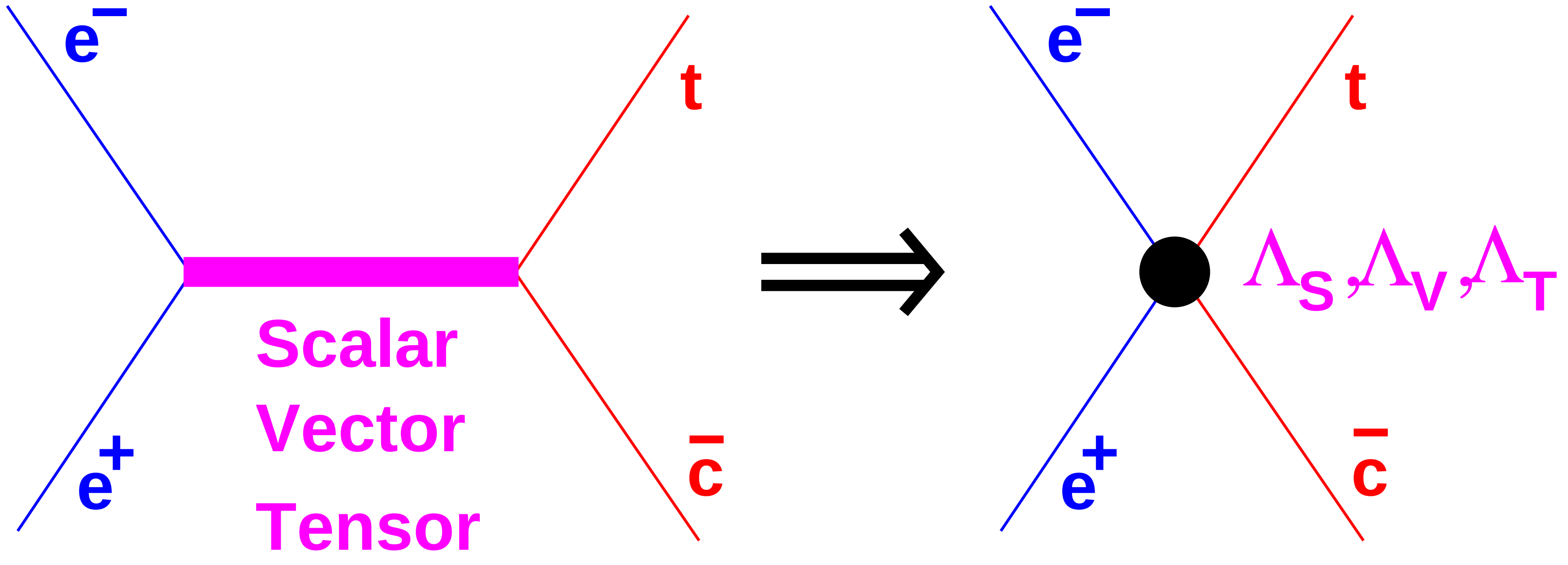
Interpretation in terms of anomalous couplings







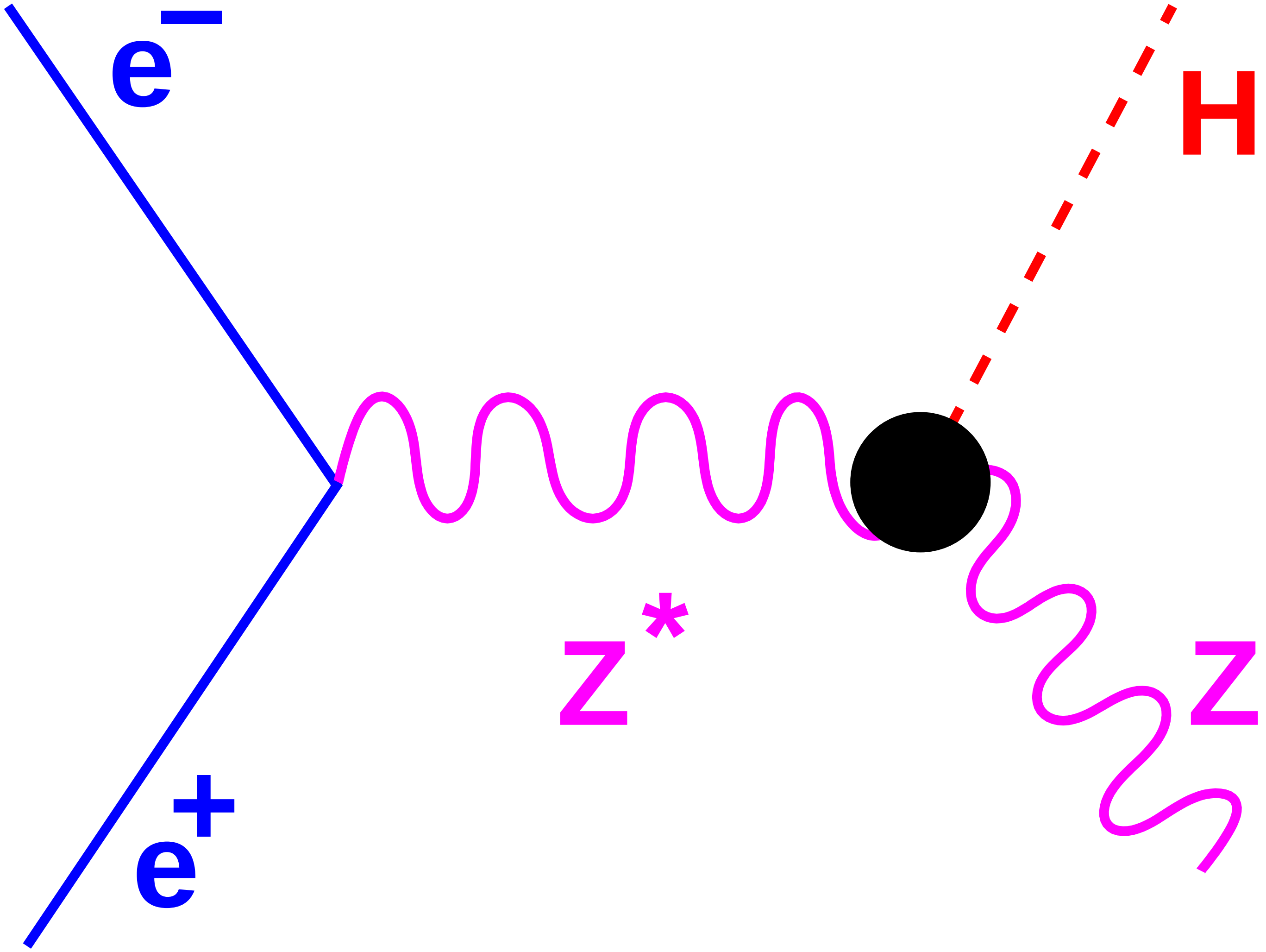
Interpretation in terms of contact interactions



$$\Lambda_S > 0.65 \text{ TeV}$$
$$\Lambda_V > 0.75 \text{ TeV}$$
$$\Lambda_T > 1.24 \text{ TeV}$$

(for m_t = 175 GeV)

Higgs searches



"Standard" Higgs searches

SM Searches:

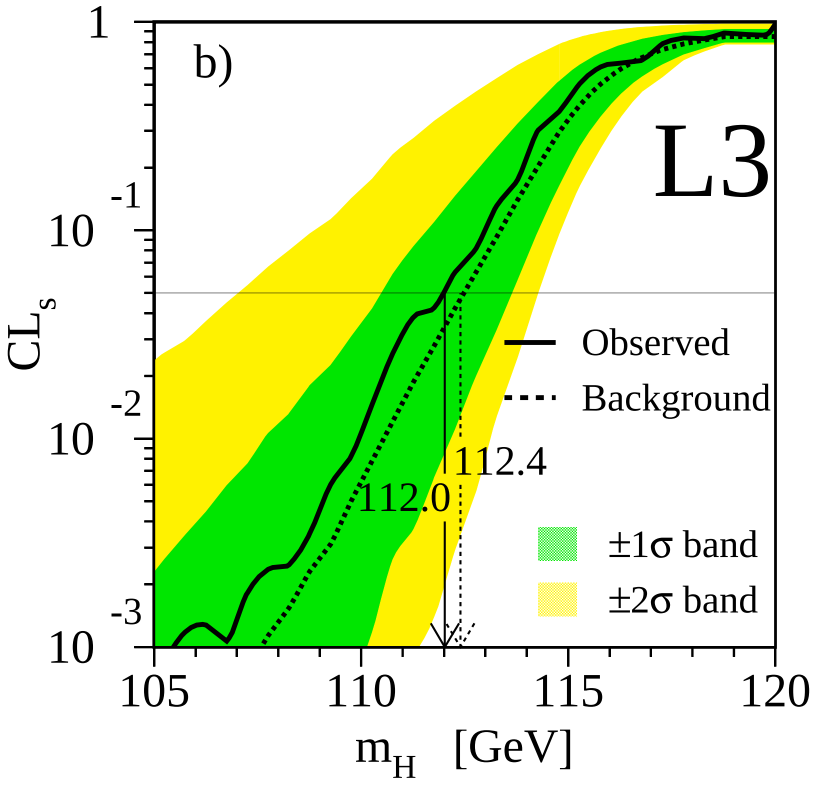
$m_{\rm H} > 112.0$ GeV

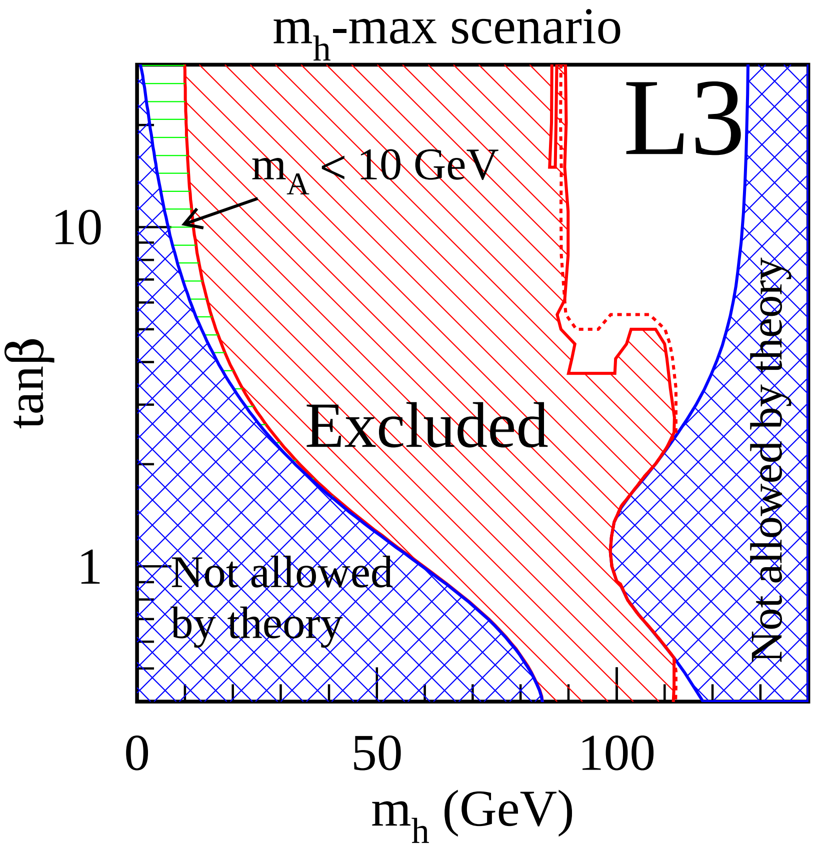
(Physics Letters B517 (2001) 319)

MSSM Searches:

$m_{\rm h} > 84.5$ GeV, $m_A > 86.3$ GeV

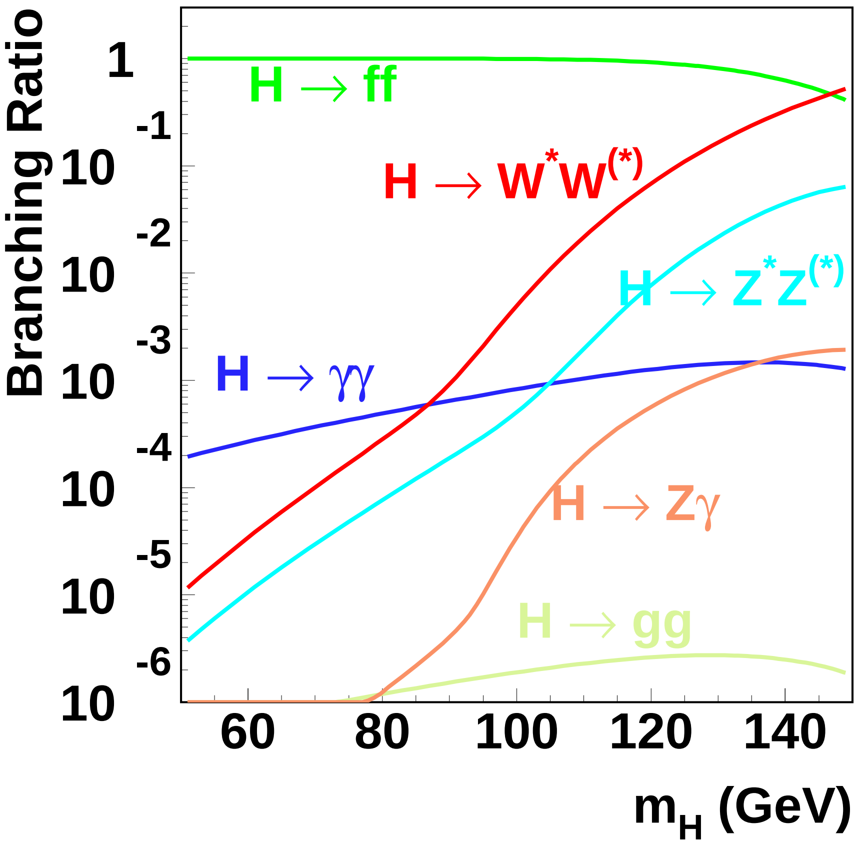
all scenarios: $m_{\rm h}$-max, no-mixing, large μ, FINAL



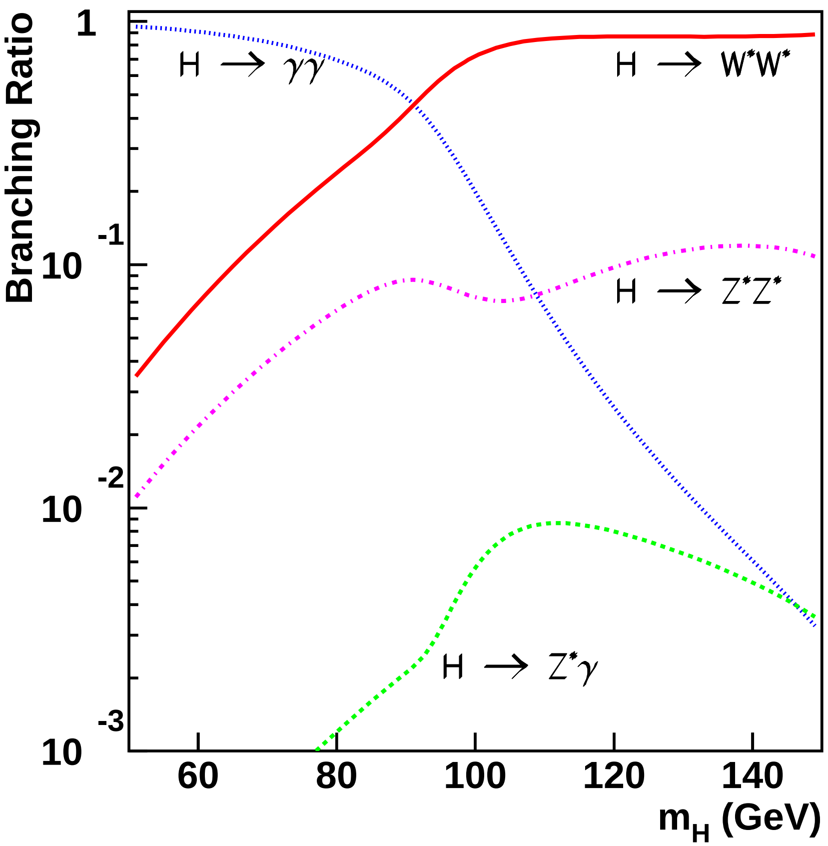


$\mathrm{H} \to \mathrm{WW}^*$ *searches*

Standard Model

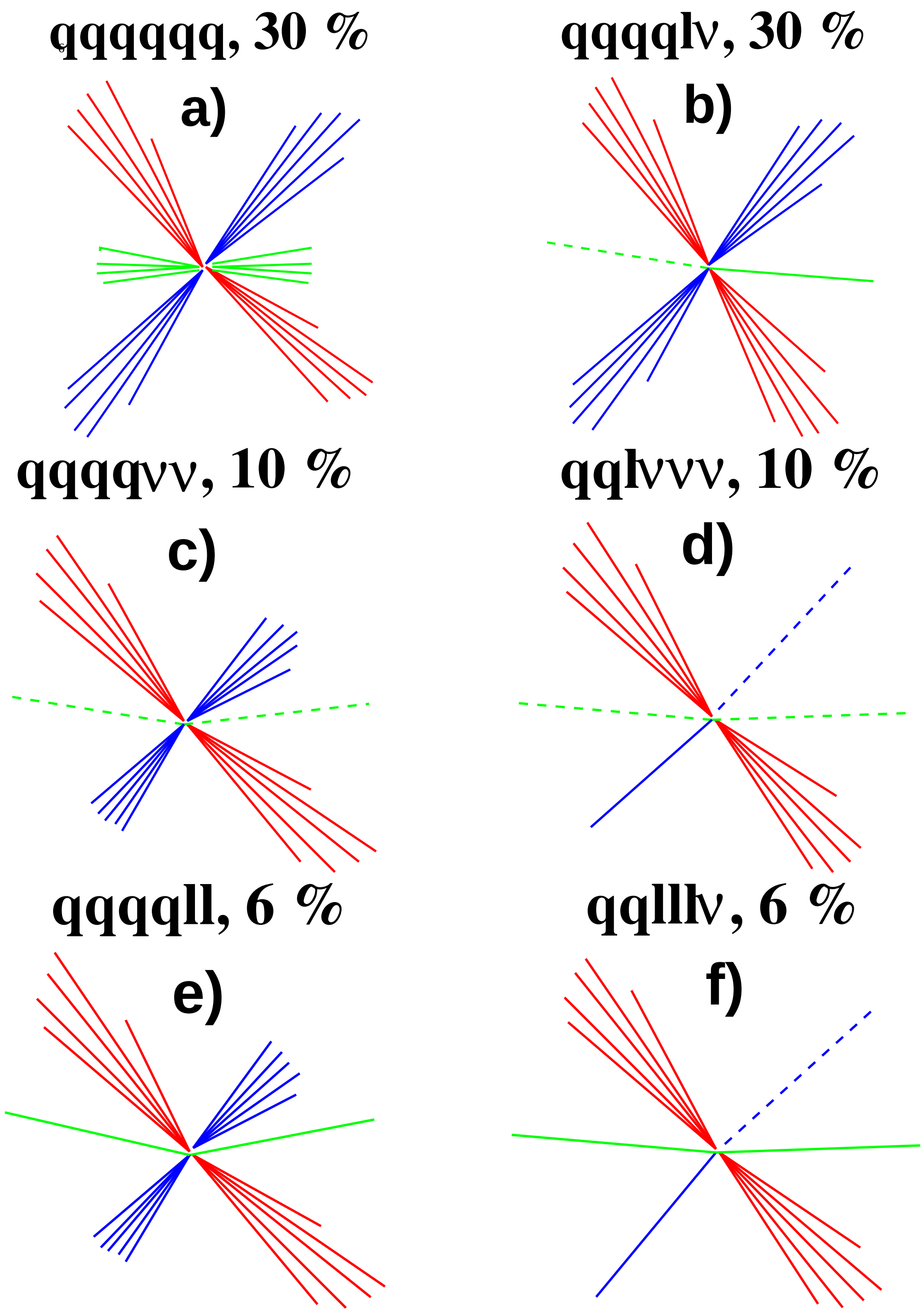


Benchmark fermiophobic scenario



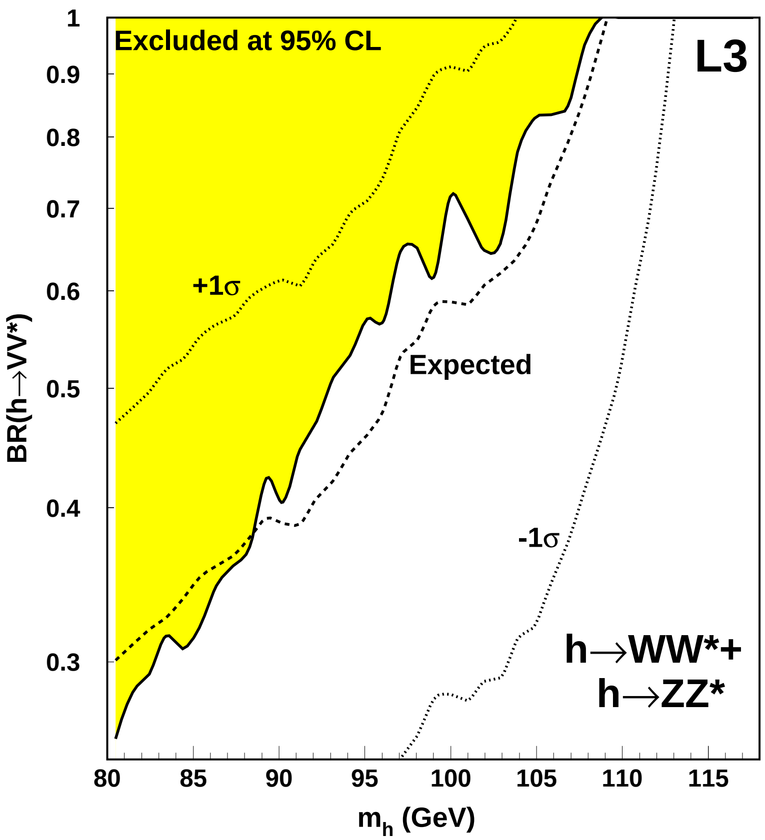
- SM: $BR(\mathrm{H} \to \mathrm{WW}^*) \approx 10\%$ when $m_\mathrm{H} \approx 120\ \mathrm{GeV}$
- Fermiophobia: $\mathrm{H} \to \mathrm{WW}^*$ dominant for $m_\mathrm{H} \gtrsim 90\ \mathrm{GeV}$

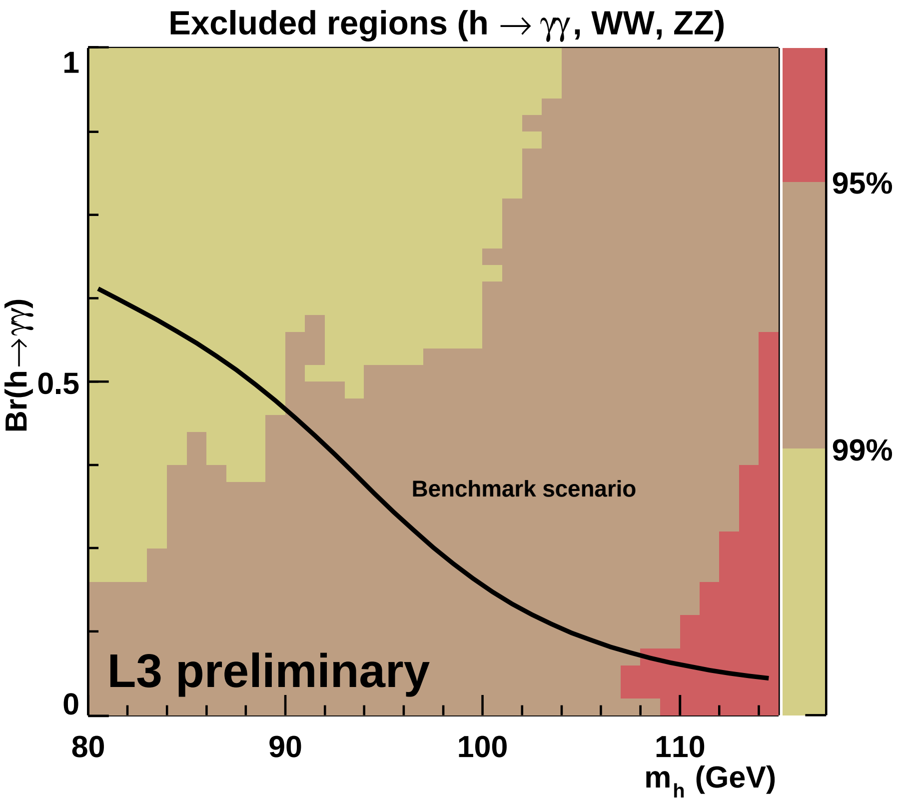
$e^+e^- \rightarrow ZH \rightarrow ZWW^*$ *search*



- W^* always "off-shell", many signatures
- Large backgrounds: neural network techniques
- 93% of the decay modes searched for; $\epsilon \approx 44\%$

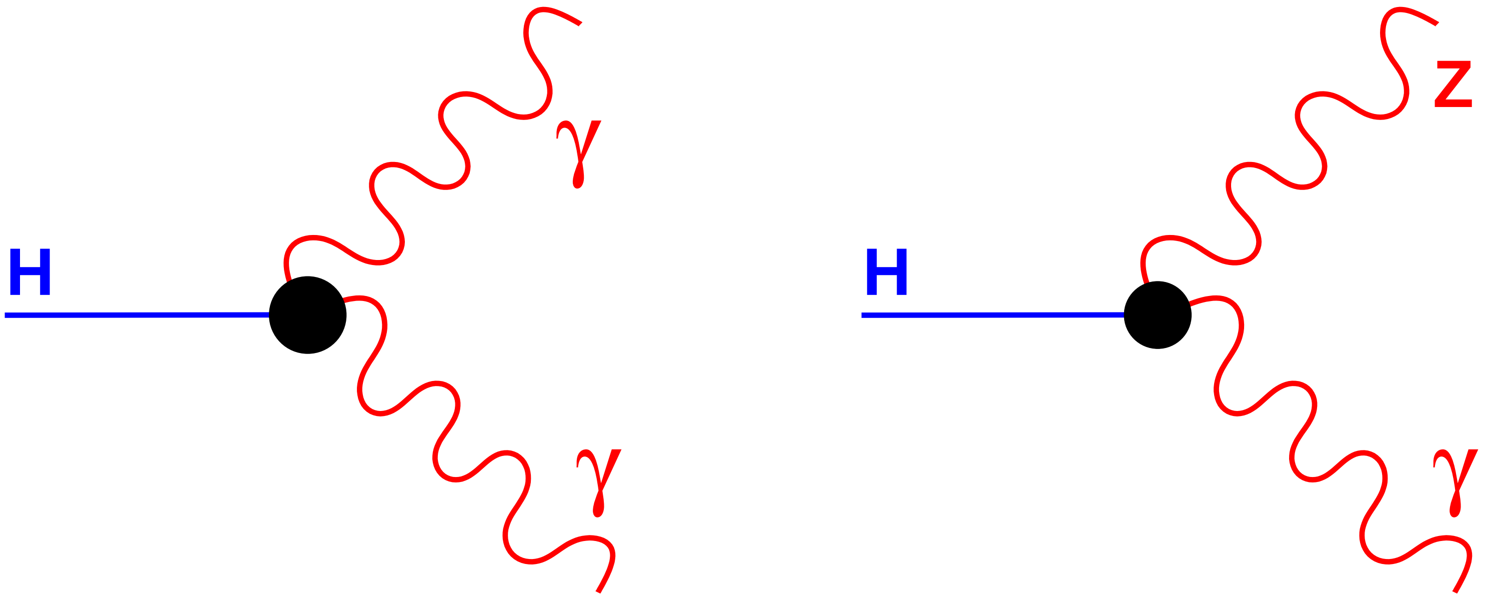
"Fermiophobic" searches, NO EXCESS





- $m_{\rm H} > 109$ GeV $(BR({\rm H} \to {\rm WW}^* + {\rm ZZ}^*) = 100\%$, SM production)
- $m_{\rm H} > 108$ GeV (benchmark scenario)
- $m_{\rm H} > 107$ GeV (any BR, SM production)

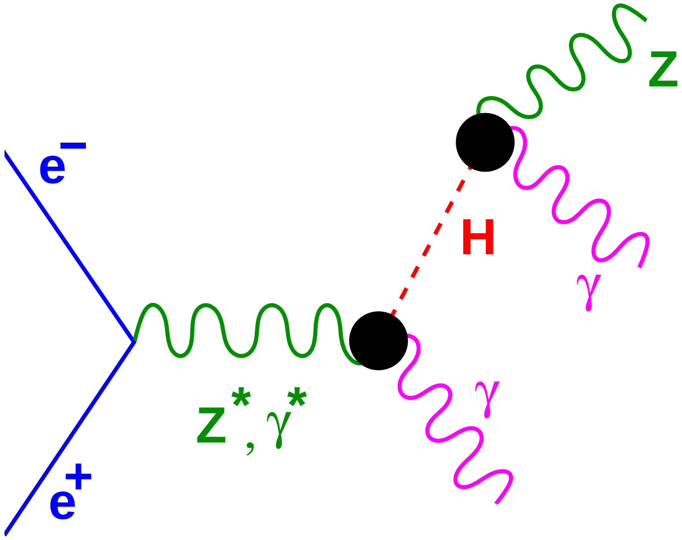
Anomalous Higgs couplings in the bosonic sector

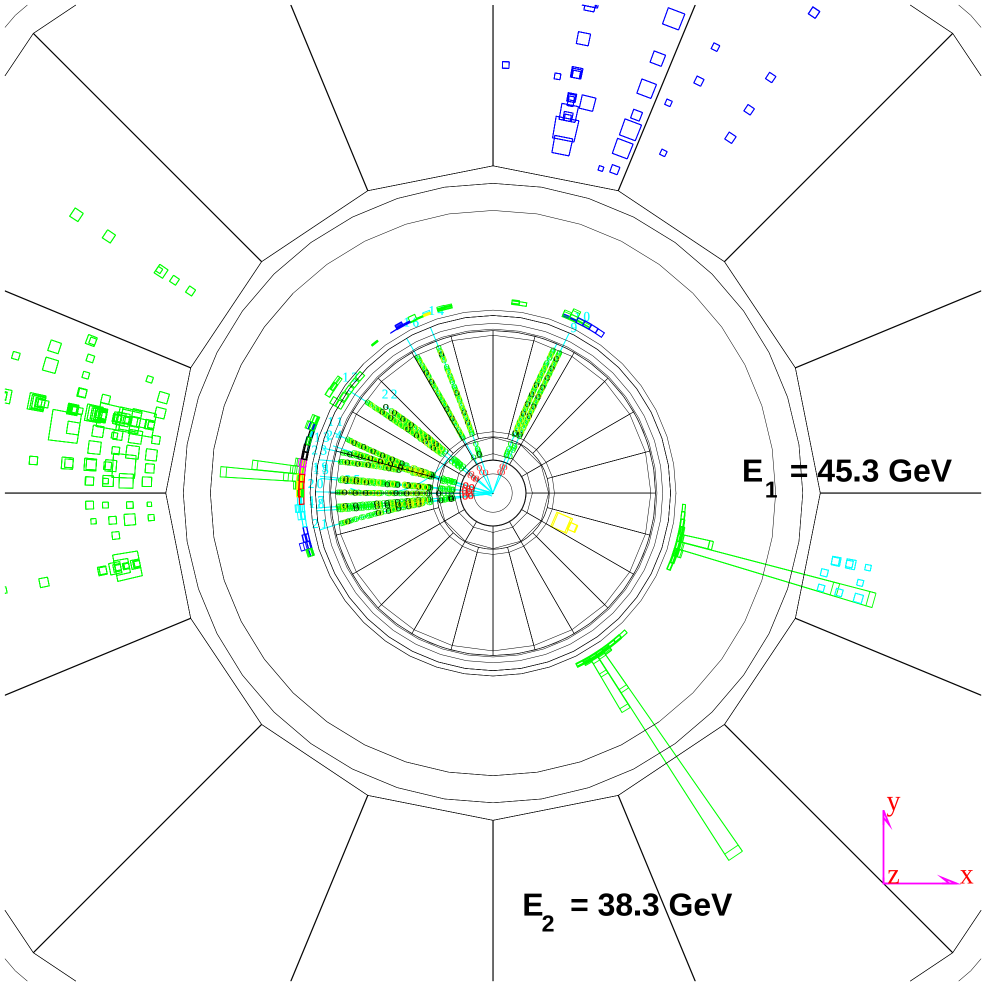


$\Downarrow$

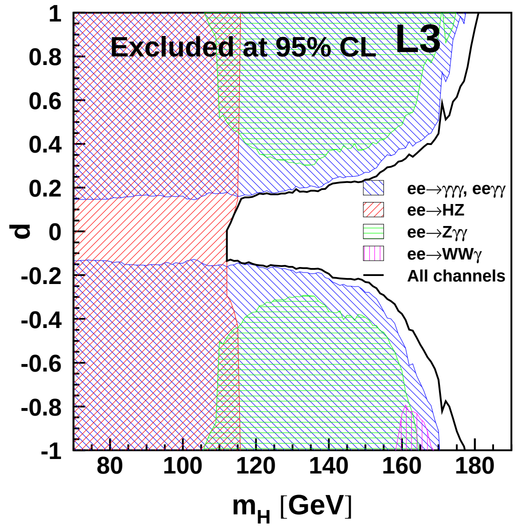
- Described in terms of the anomalous couplings d and d_B (Gounaris *et al.*, Nucl. Phys. **B459** (1996) 51)
- Clean signatures

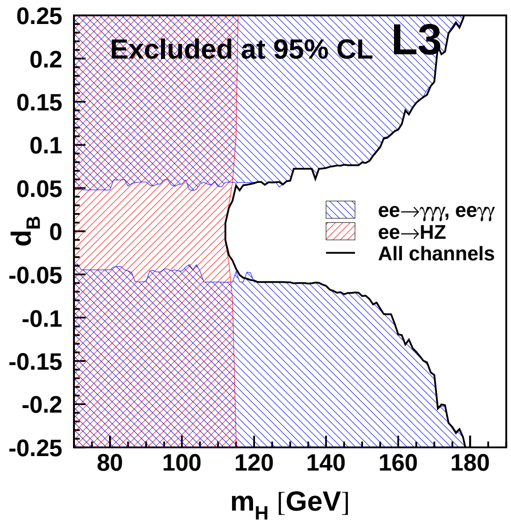
Higgs anomalous couplings: example

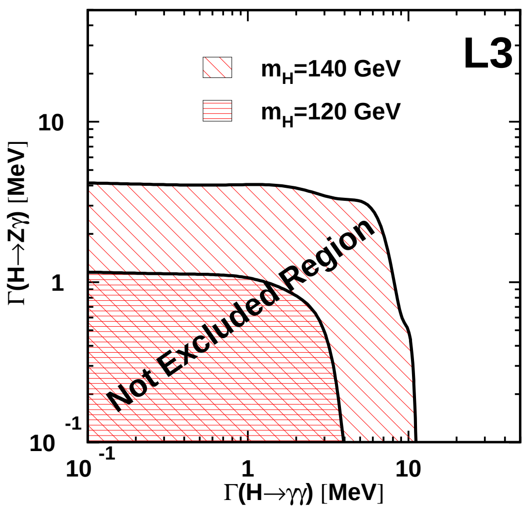


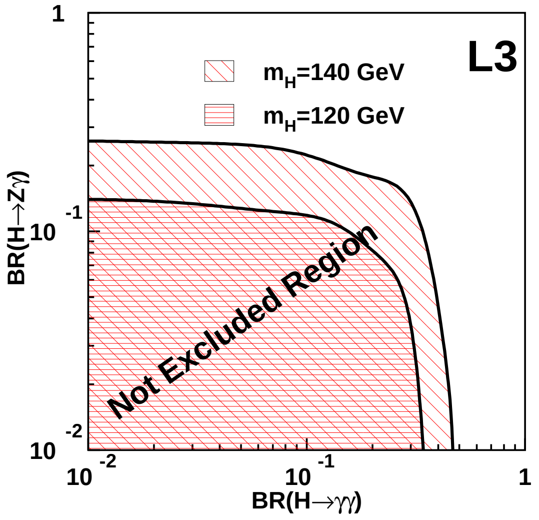


Higgs anomalous couplings: NO EXCESS





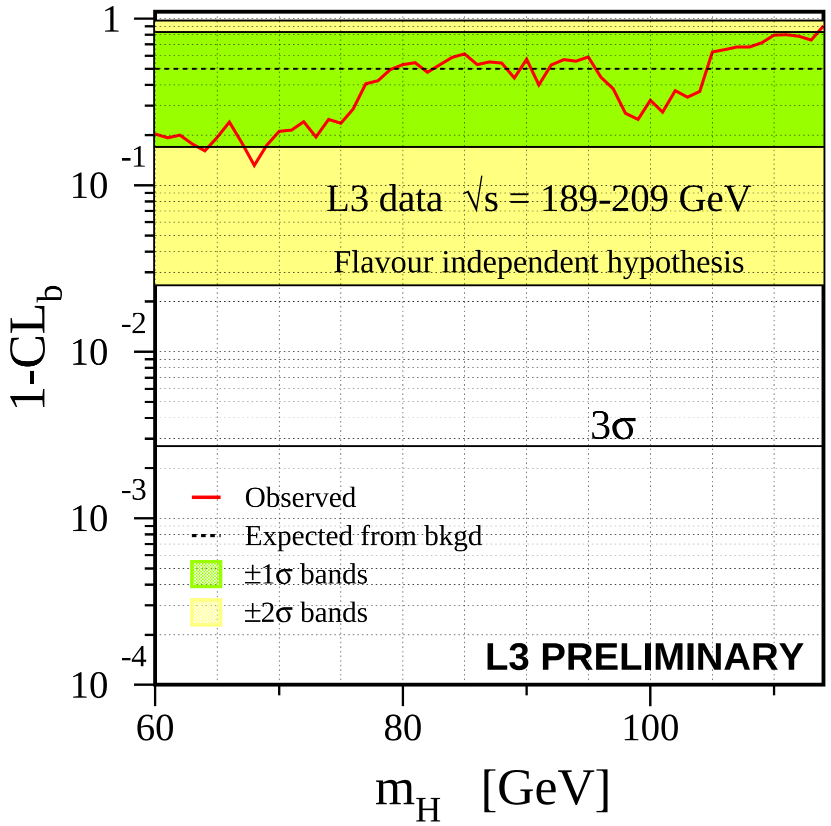


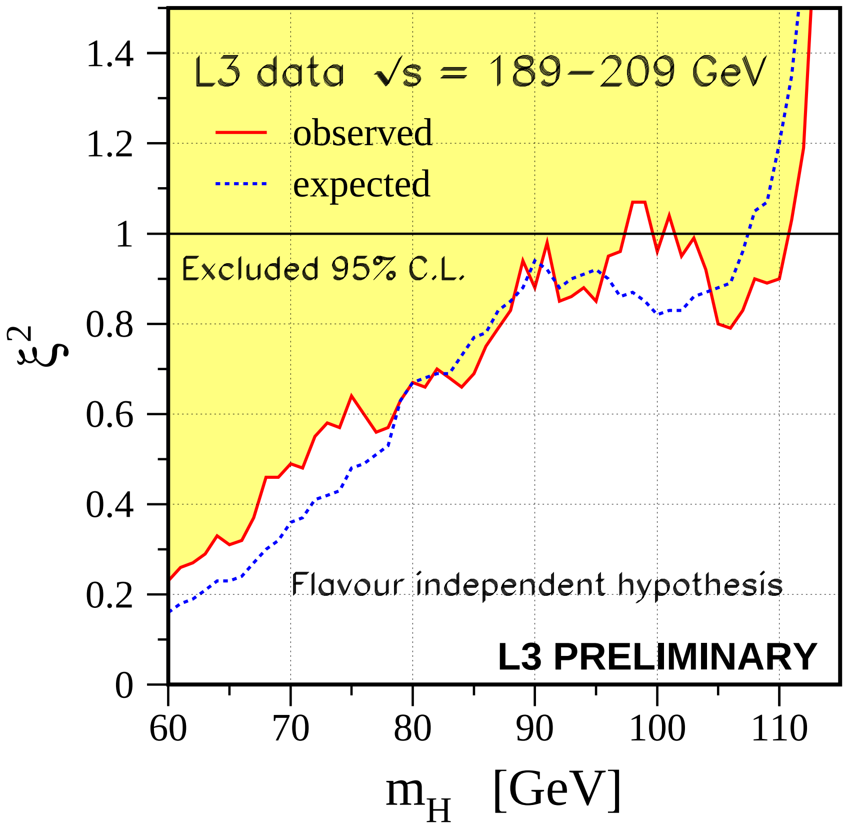


L3 data largely constrain these couplings in the region: $m_{\rm H} \lesssim 160\ \mathrm{GeV}$

Limits to $\Gamma(\mathrm{H}\to\gamma\gamma)$ and $\Gamma(\mathrm{H}\to \mathrm{Z}\gamma)$ in the region of interest for the LHC

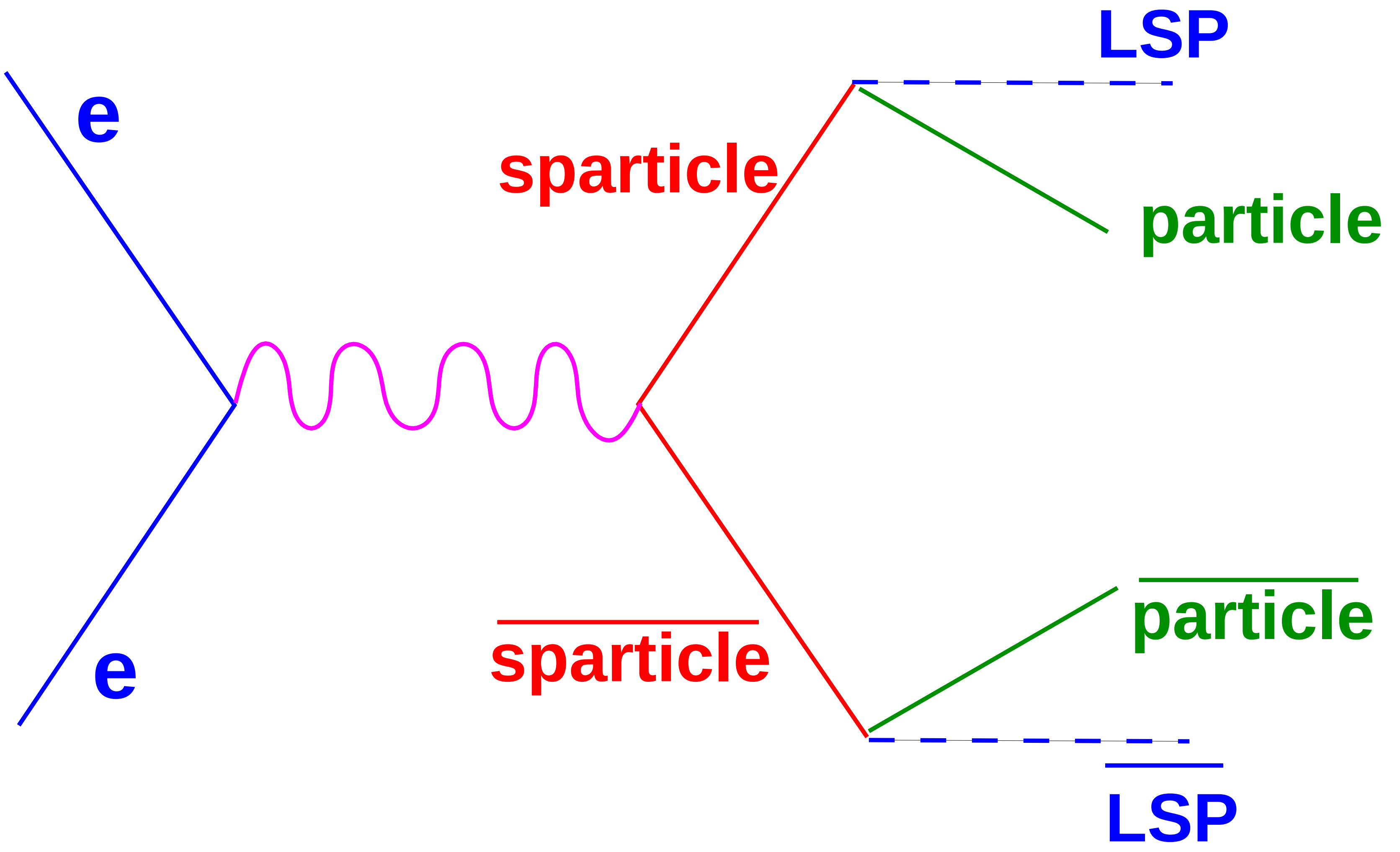
Fermionic anomalies: flavour independent searches





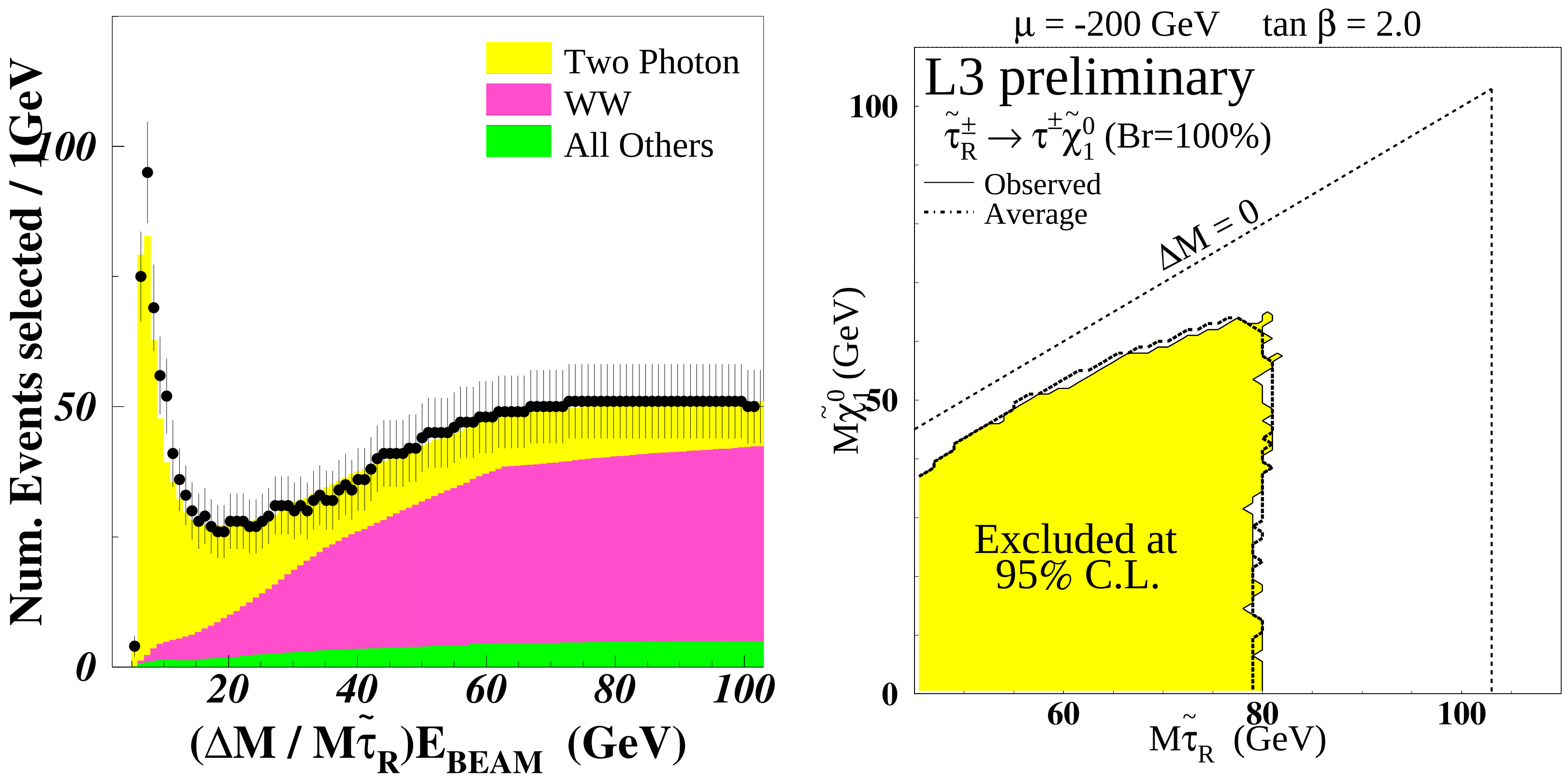
- Basic assumption: $\mathrm{H} \rightarrow \mathrm{b\bar{b}}$ not necessarily dominant
- Analysis strategy: eliminate b-tagging requirements
- $m_{\mathrm{H}} > 97$ GeV $(BR(\mathrm{H} \rightarrow \mathrm{q\bar{q}}) = 100\%,\ \xi^2 = 1)$

SUSY searches



SUSY analyses: sleptons, NO EXCESS

$$e^+e^- \rightarrow \tilde{\ell}^+ \; \tilde{\ell}^+ \rightarrow \ell^+ \tilde{\chi}_1^0 \; \ell^- \tilde{\chi}_1^0$$

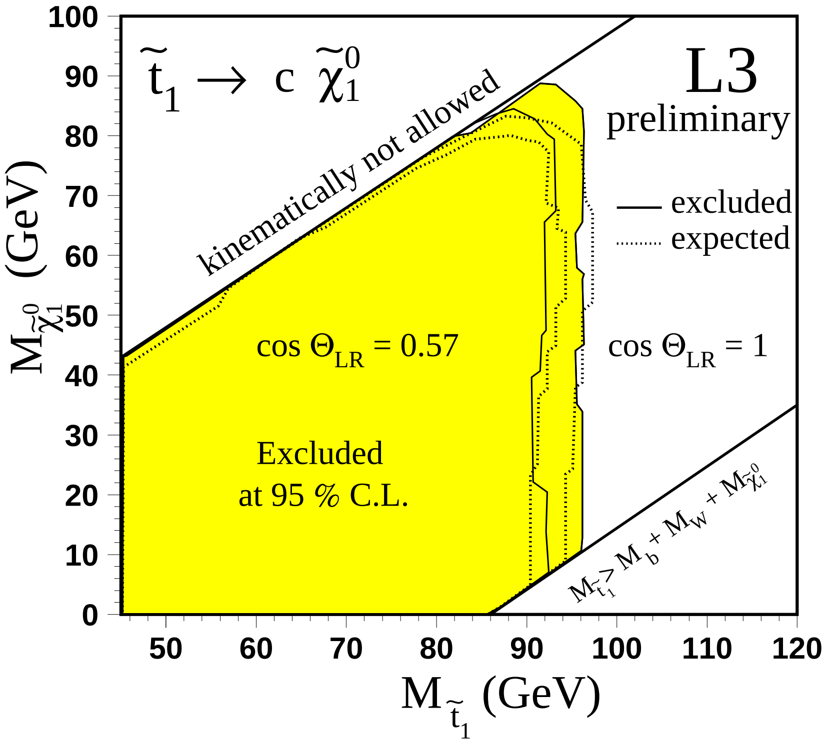


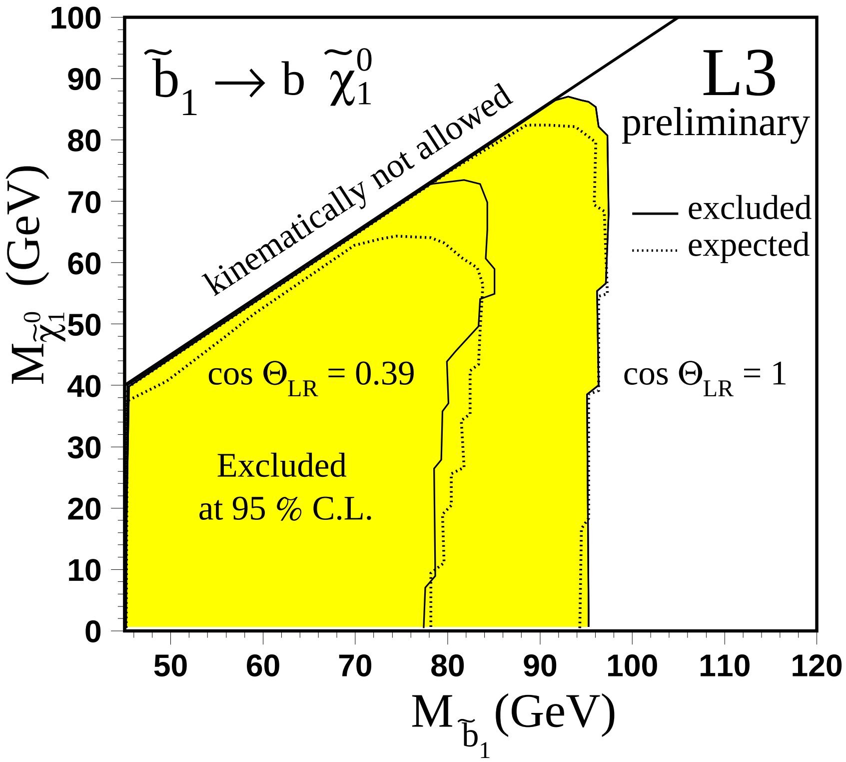
Main signature: acoplanar lepton pairs

$m_{\tilde{e}} > 98$ GeV; $m_{\tilde{\mu}} > 86$ GeV; $m_{\tilde{\tau}} > 80$ GeV

SUSY analyses: stop, sbottom, NO EXCESS

$$e^+e^- \to \tilde{q}\,\bar{\tilde{q}} \to q\tilde{\chi}_1^0\,\bar{q}\tilde{\chi}_1^0$$





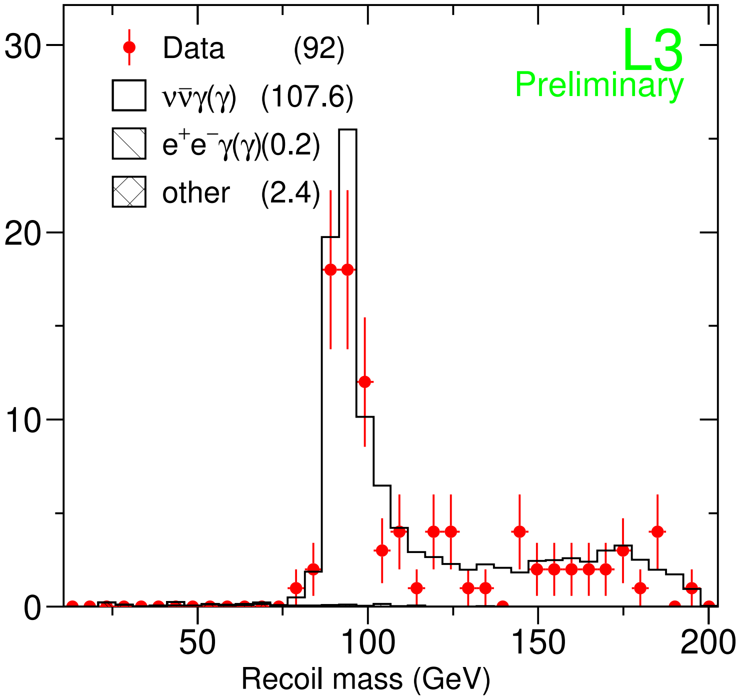
$$m_{\tilde{t}}, m_{\tilde{b}} > 95 - 97 \text{ GeV}$$

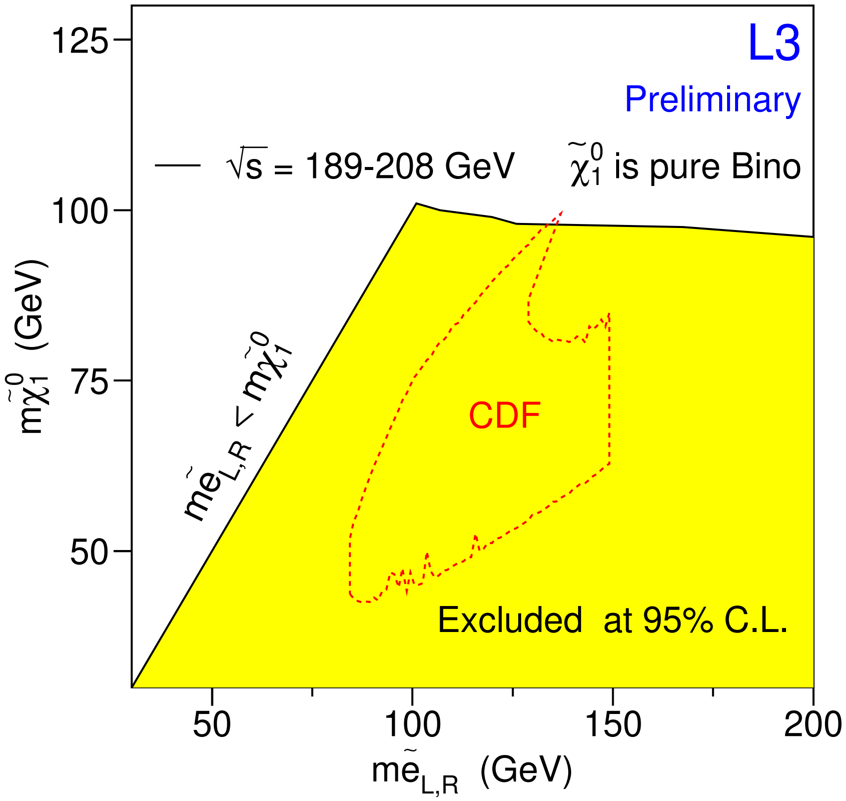
in the no mixing case

$$(\cos\Theta_{LR} = 1 \Rightarrow m_{\tilde{t}_L} = m_{\tilde{t}_R}, m_{\tilde{b}_L} = m_{\tilde{b}_R})$$

$$e^+e^- \rightarrow \tilde{\chi}_1^0\ \tilde{\chi}_1^0 \rightarrow \gamma\tilde{G}\ \gamma\tilde{G}$$

Two photons and missing energy



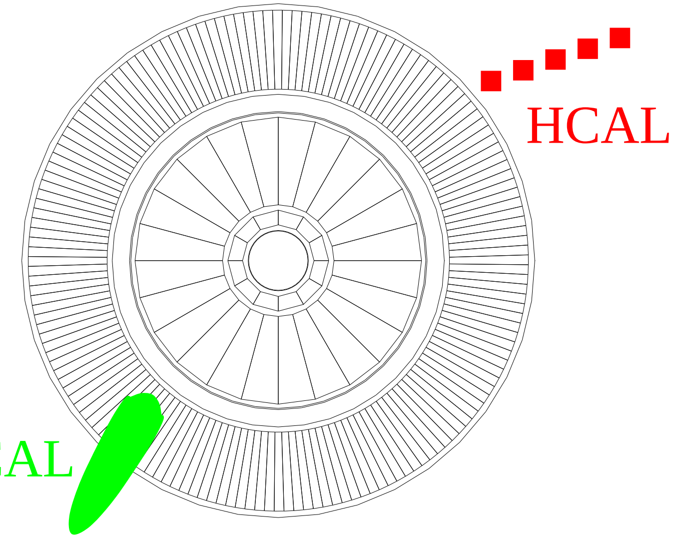


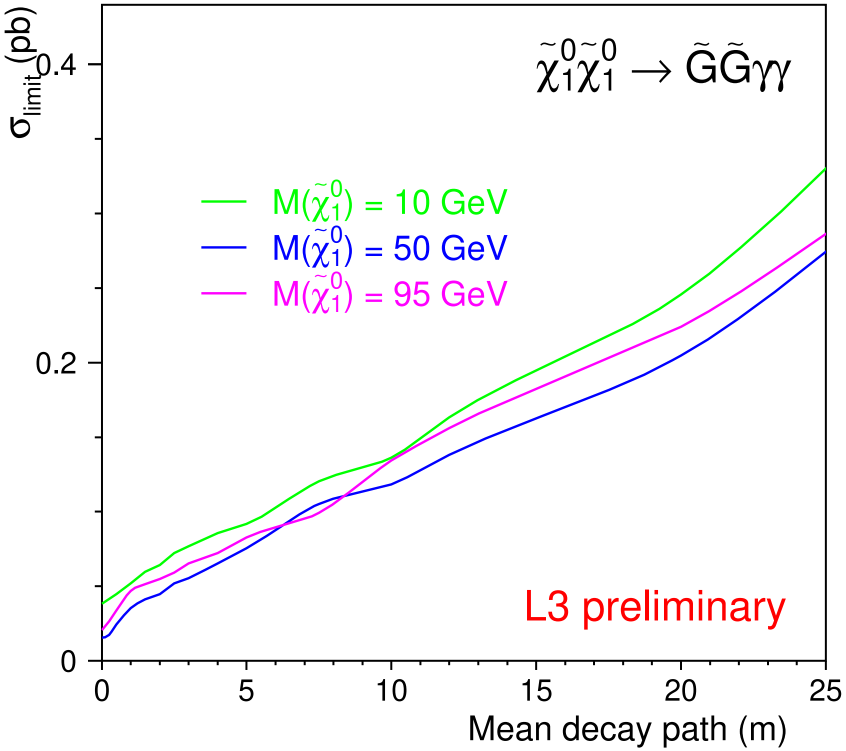
Acoplanar Photons

Observation consistent with the expectations from the SM $e^+e^- \rightarrow \nu\bar{\nu}\gamma\gamma(\gamma)$ process

Limits in the $m_{\tilde{e}} - m_{\tilde{\chi}_1^0}$ plane

$$e^+e^- \rightarrow \tilde{\chi}_1^0\ \tilde{\chi}_1^0 \rightarrow \gamma\tilde{G}\ \gamma\tilde{G}$$





$\tilde{\chi}_1^0$ with long lifetime $\Rightarrow$ decays in the calorimeters

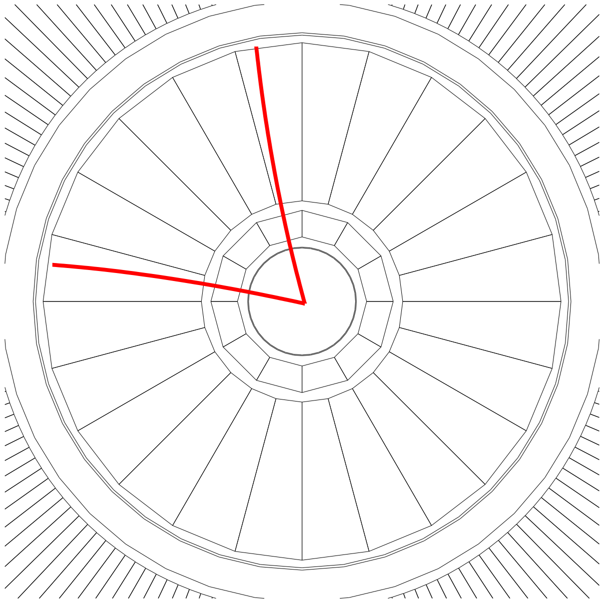
L3 advantage: segmented HCAL closer to the IP

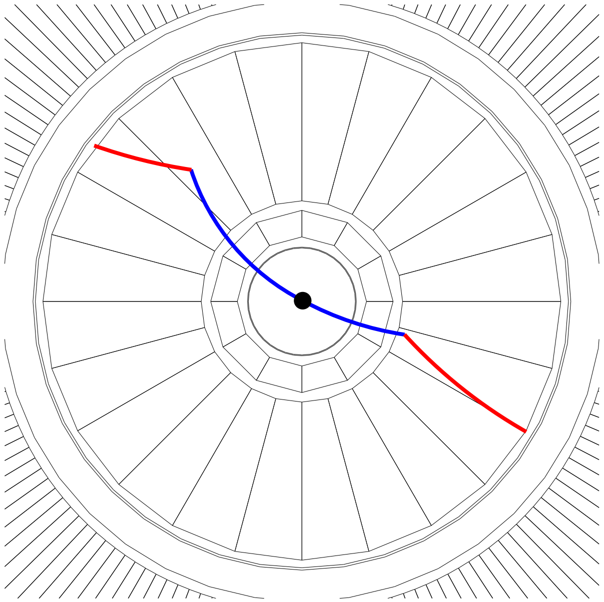
1.2 ± 0.6 events expected, none found

SUSY analyses: GMSB $\tilde{\tau}$

$$e^+e^- \longrightarrow \tilde{\tau}^+\tilde{\tau}^- \longrightarrow \tau^+\tilde{G}\ \tau^-\tilde{G}$$

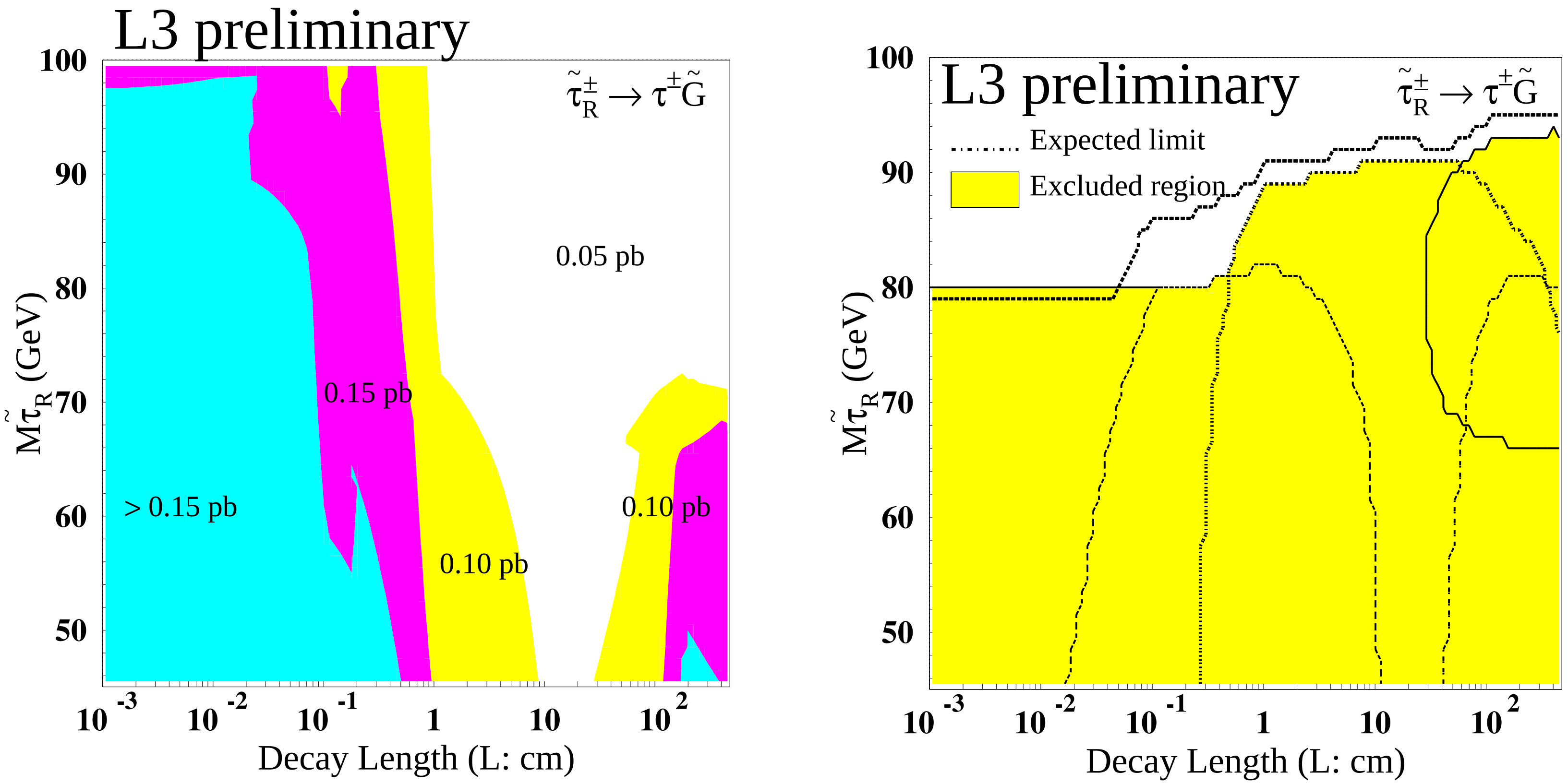
Decay length		Event signature
Invisible ($<$ 1 mm)	$\longrightarrow$	Acoplanar leptons, missing energy
Short (1mm $<$ 5 cm)	$\longrightarrow$	Non-zero impact parameter
Medium (5 cm $<$ 0.5 m)	$\longrightarrow$	Decay vertex in tracking chamber
Long ($>$ 0.5 m)	$\longrightarrow$	Heavy ionization





SUSY analyses: GMSB $\tilde{\tau}$, NO EXCESS

$$e^+e^- \longrightarrow \tilde{\tau}^+\tilde{\tau}^- \longrightarrow \tau^+\tilde{G}\ \tau^-\tilde{G}$$



$$m_{\tilde{\tau}} > 80\ \mathrm{GeV}$$

- Many (some of them new) analyses ongoing: EW studies, searches, two-photon physics, QCD.

- L3 activities will continue in 2003, as scheduled.