



Latest L3 Results

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CIEMAT/CERN

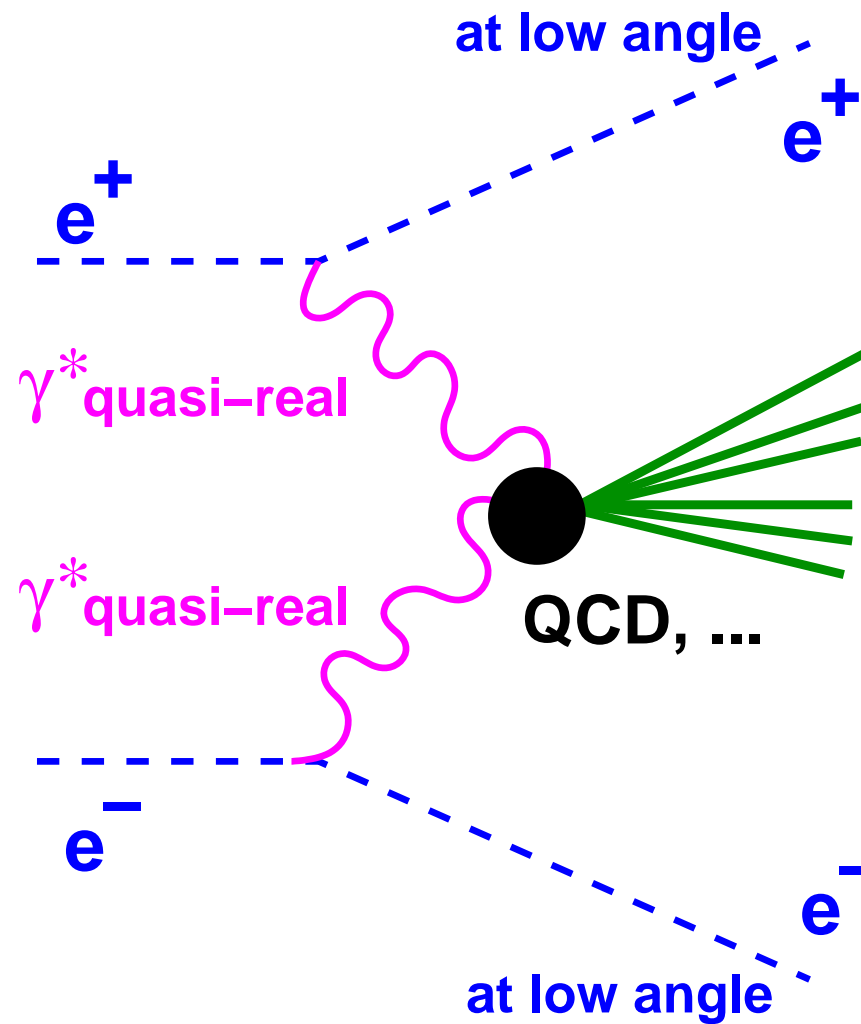
LEP Jamboree
July 22, 2002

- ❖ $\gamma\gamma$, $e\gamma$ 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

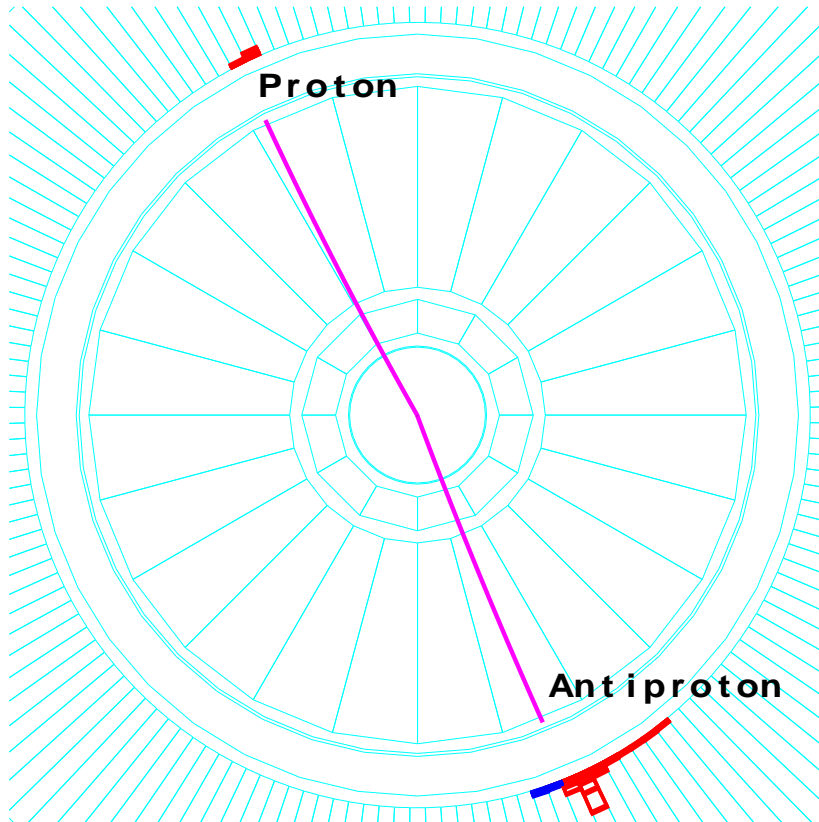


Baryon production in two-photon collisions



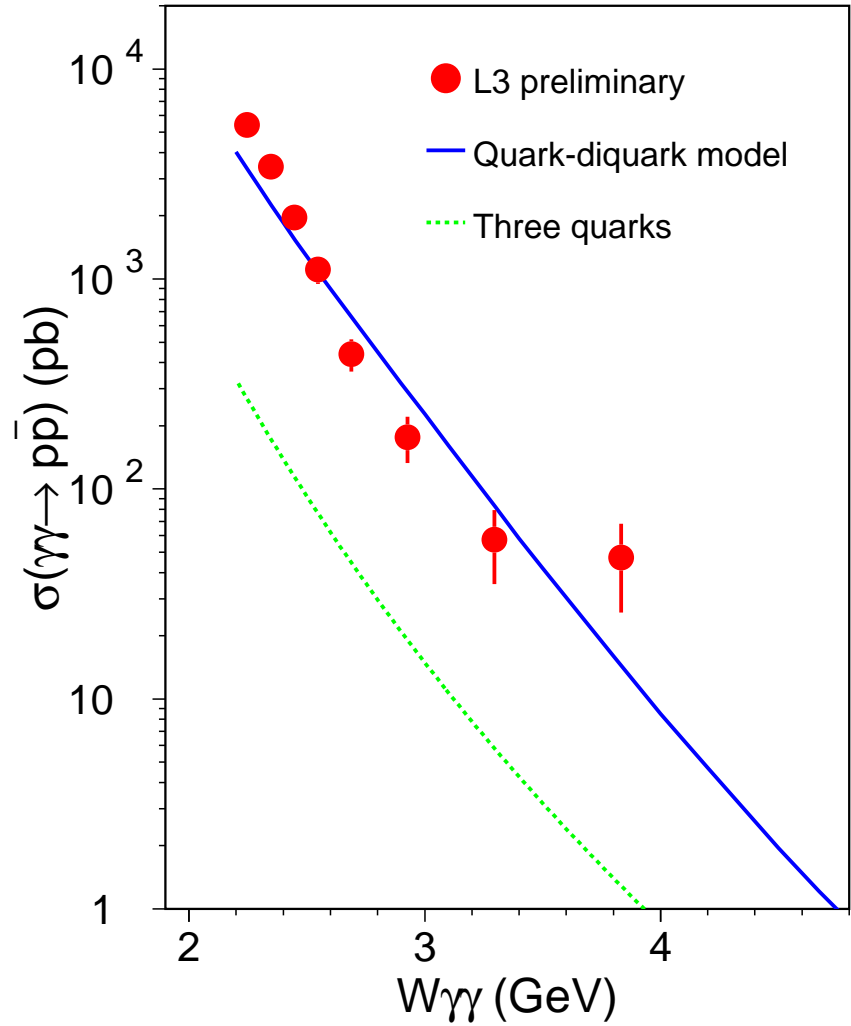
Run # 694706 Event # 1096

L3



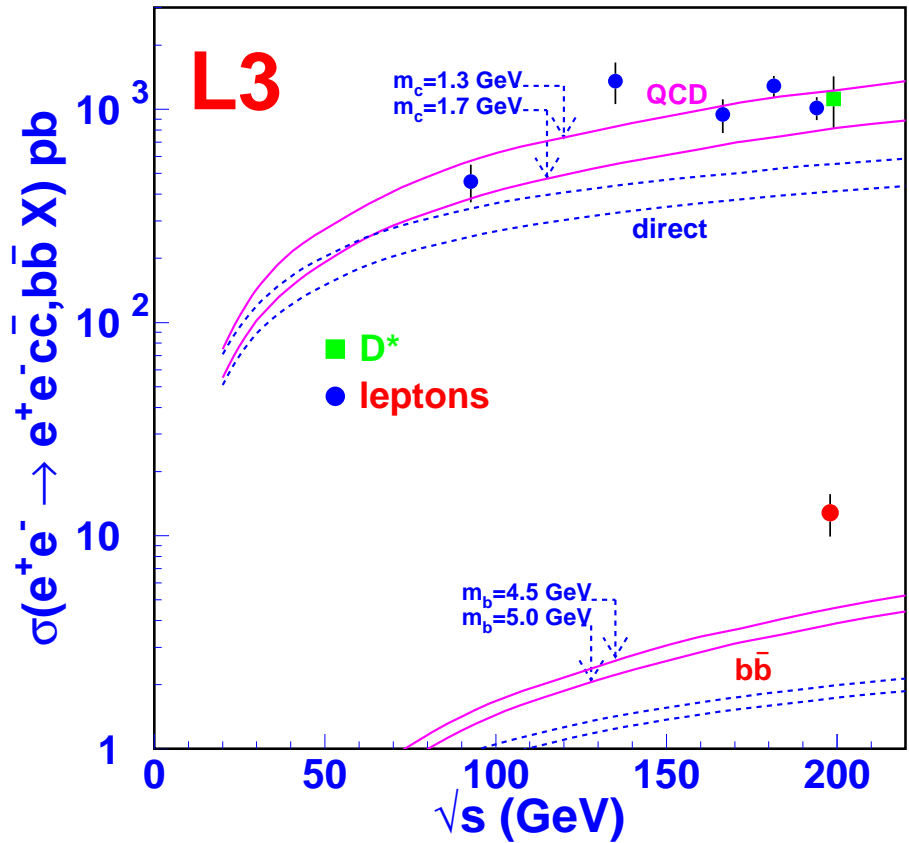
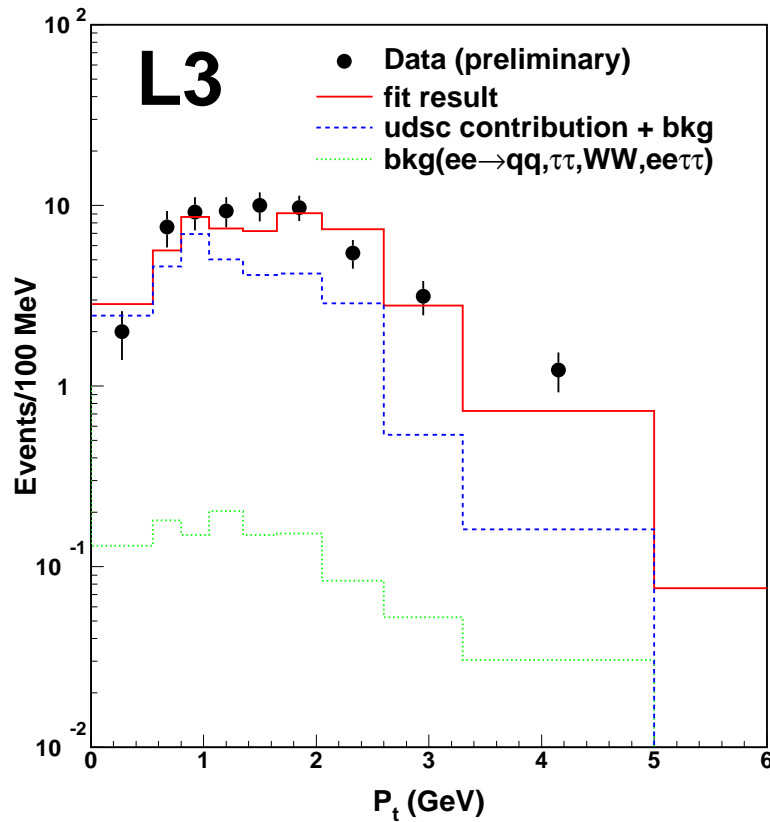
Antiproton identification criteria:

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



Baryons behave effectively as a quark-diquark system

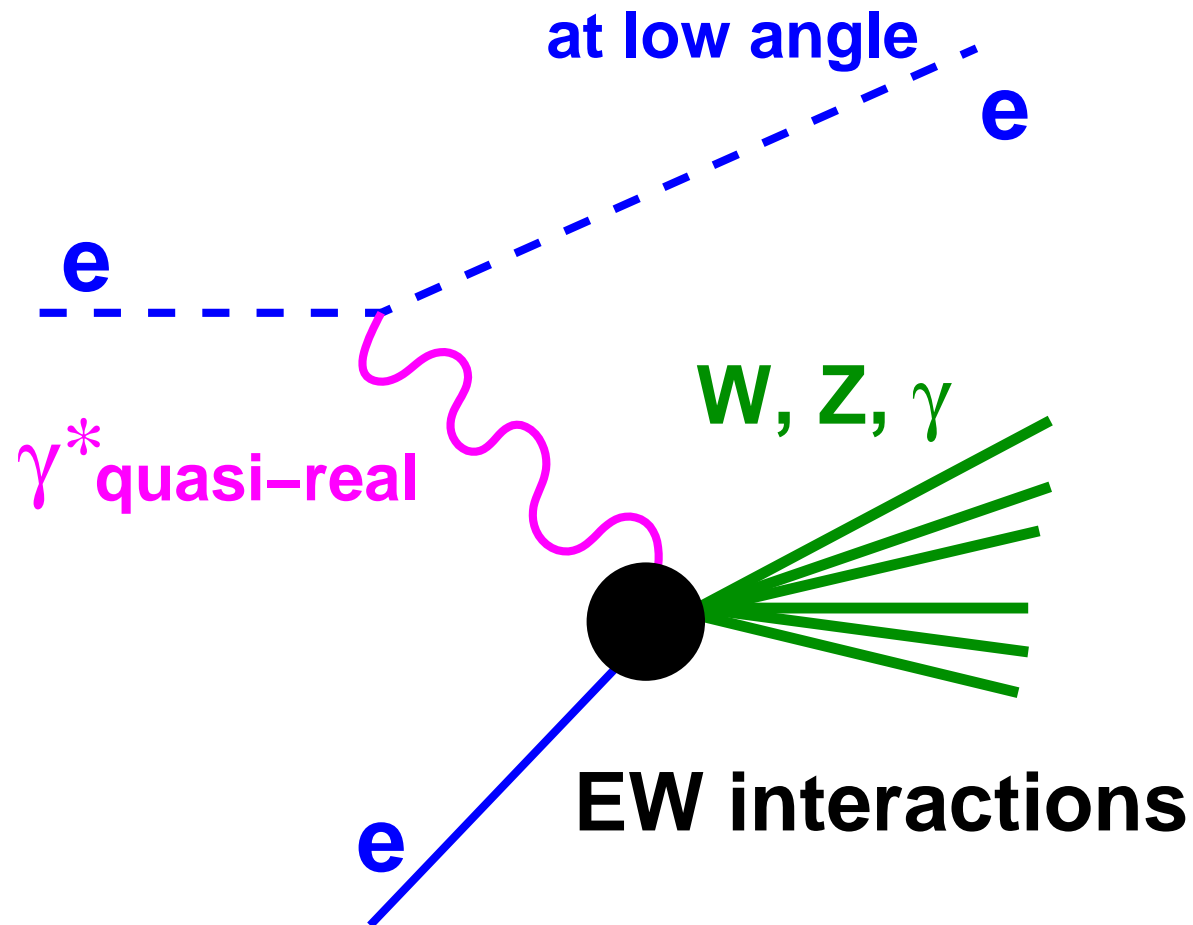
Open $b\bar{b}$, $c\bar{c}$ production



$b\bar{b}$ excess at the 5σ level

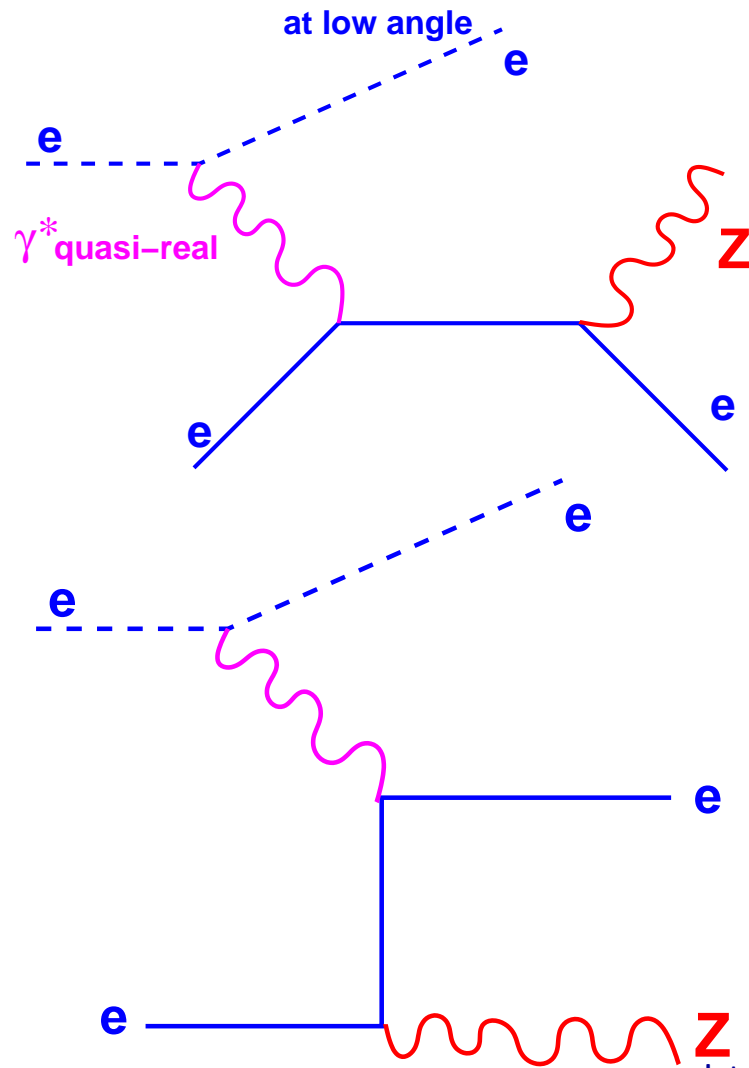
$$\sigma_{b\bar{b}}^{exp} \approx 3 \text{ times } \sigma_{b\bar{b}}^{the}$$

$e-\gamma$ Interactions

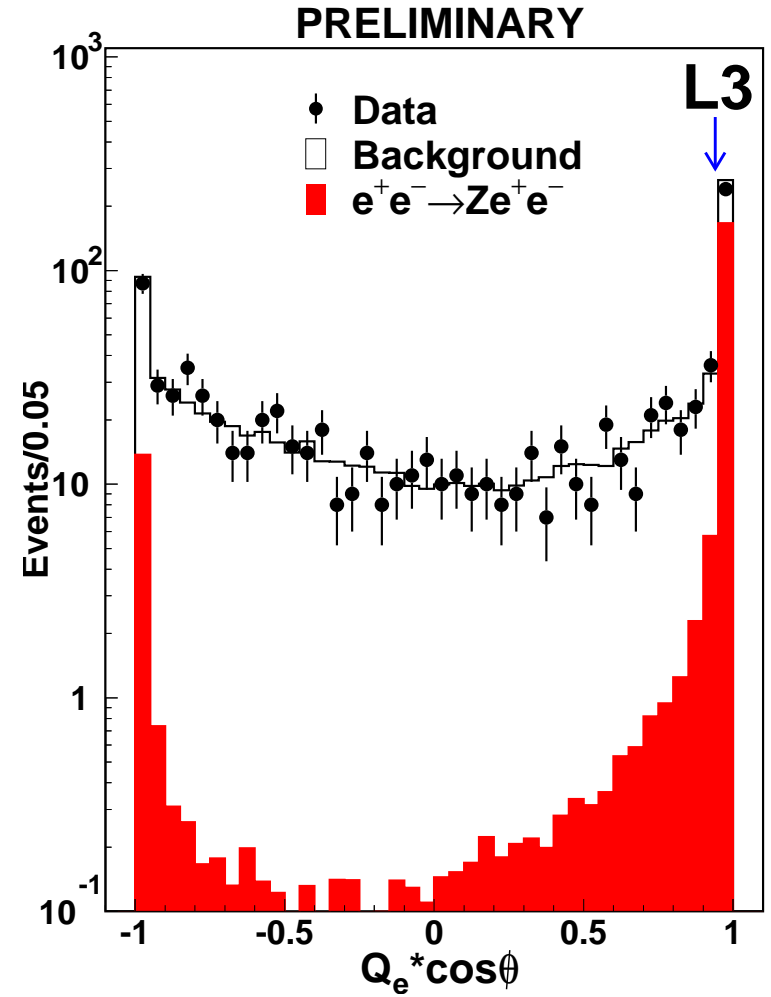


$$e\gamma \rightarrow eZ$$

In the SM

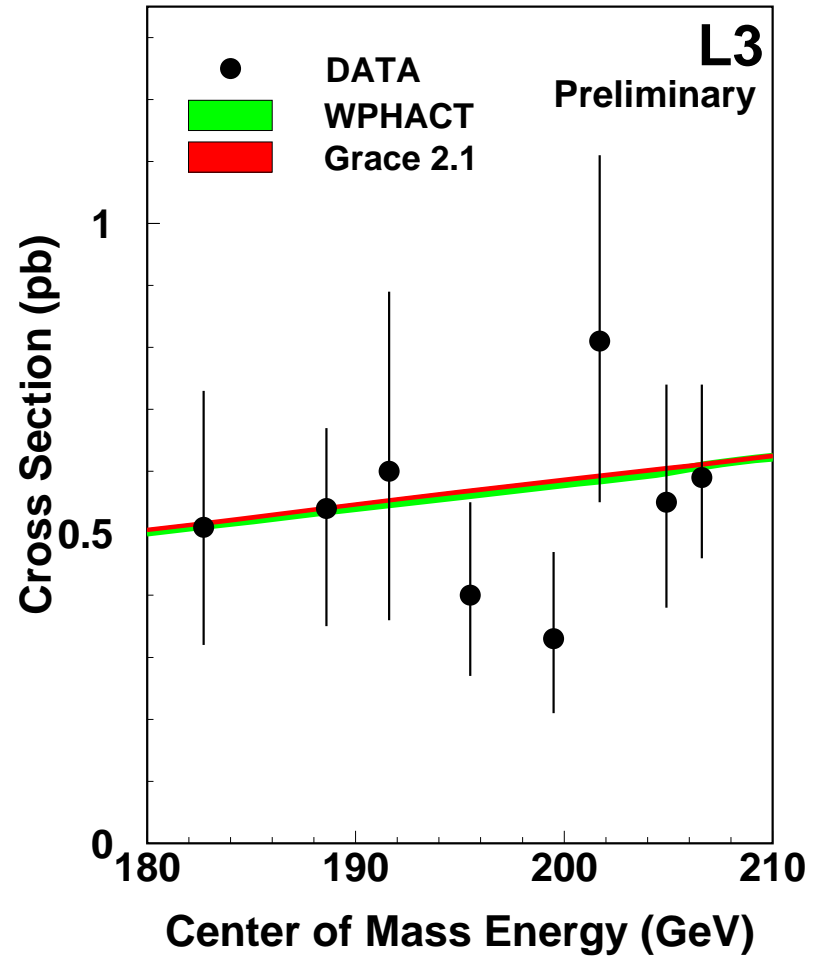
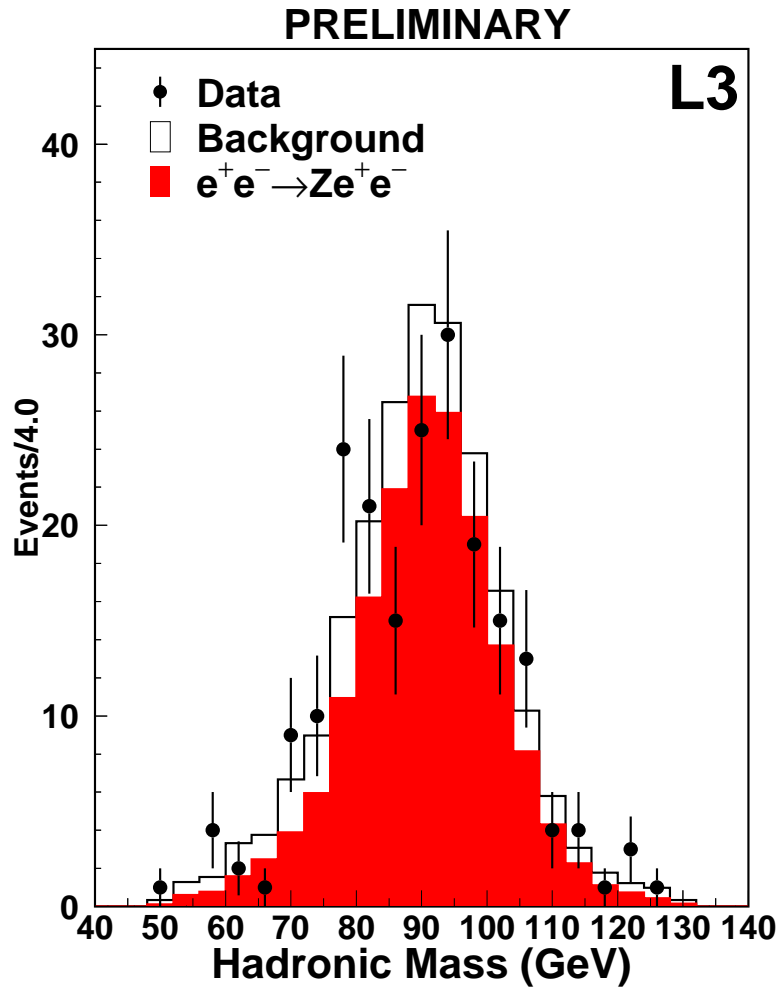


$$Z \rightarrow q\bar{q}$$



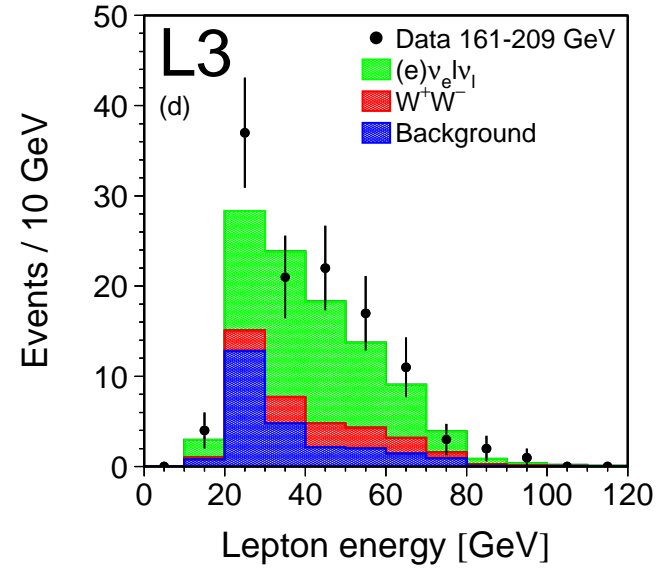
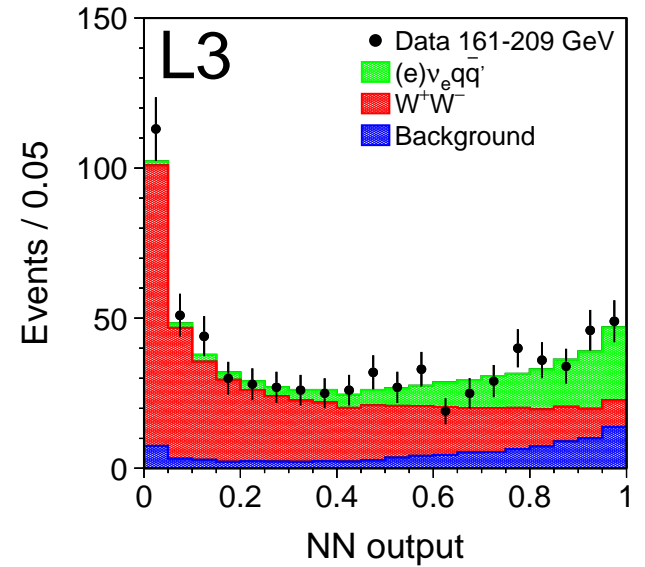
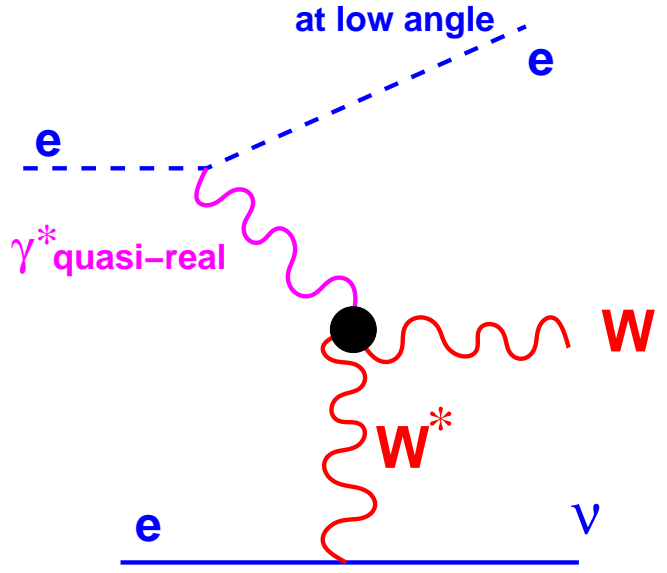
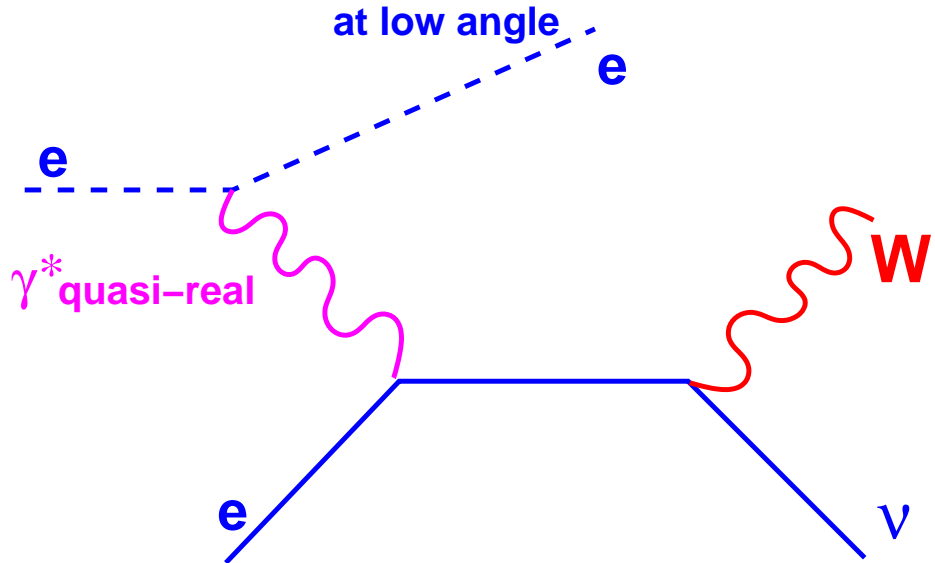
Electron at very low angle

$$e\gamma \rightarrow eZ$$

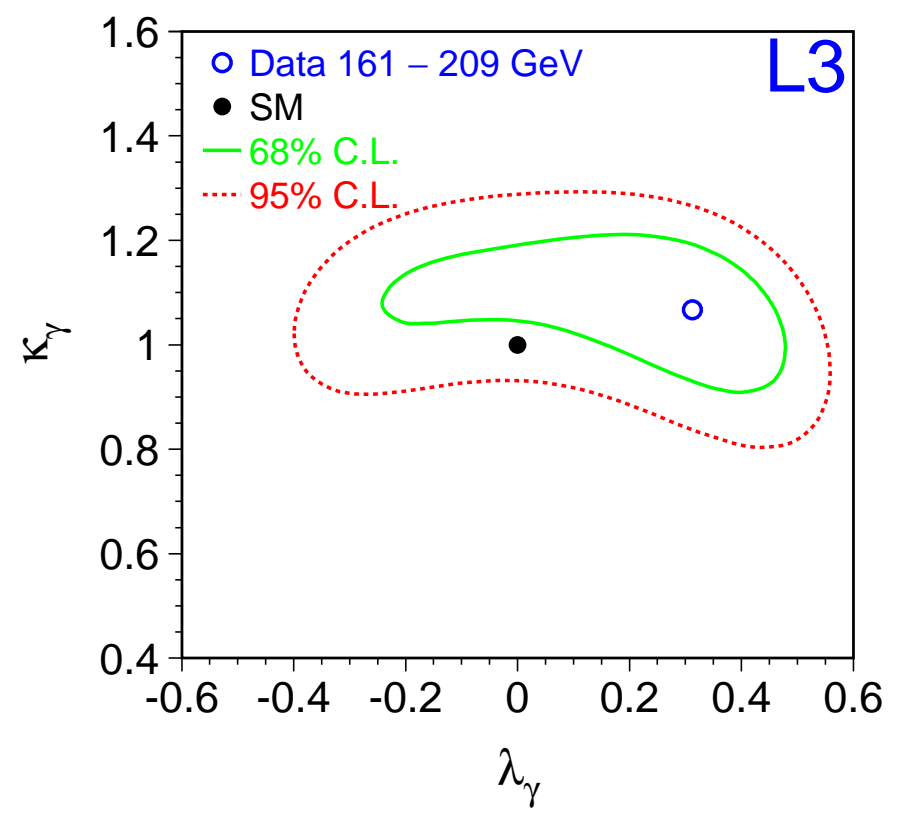
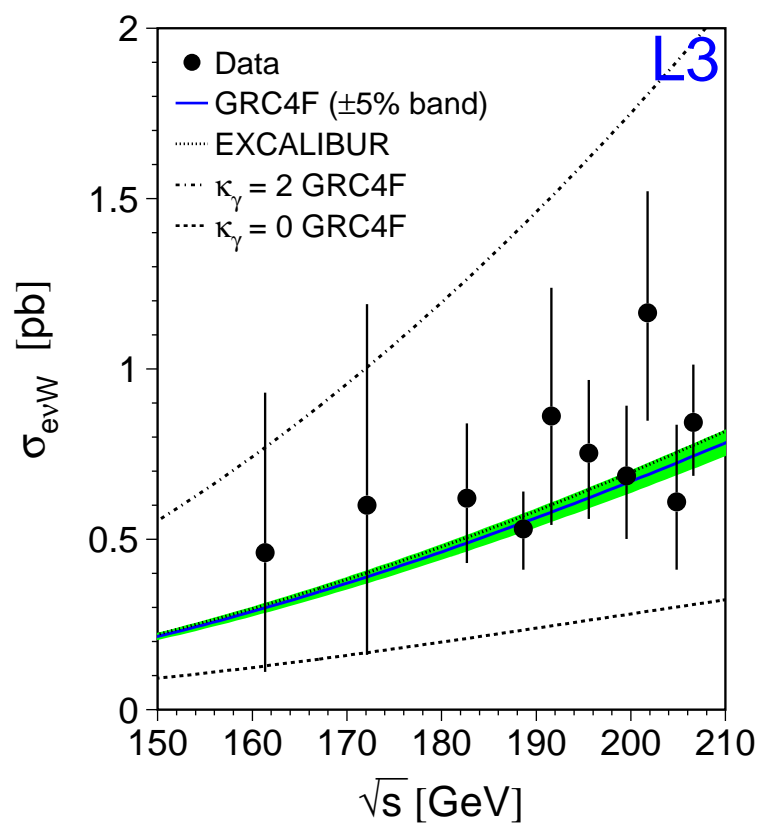


In agreement with the SM predictions

$e\gamma \rightarrow \nu W$: study of $WW\gamma$ couplings

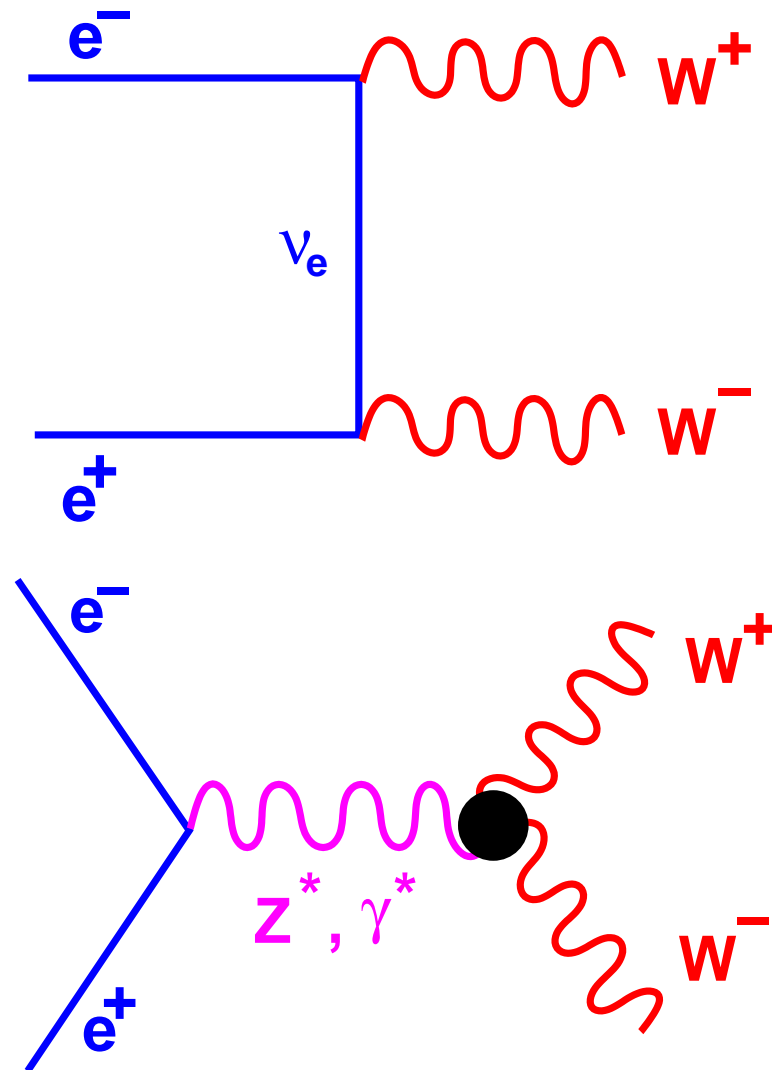


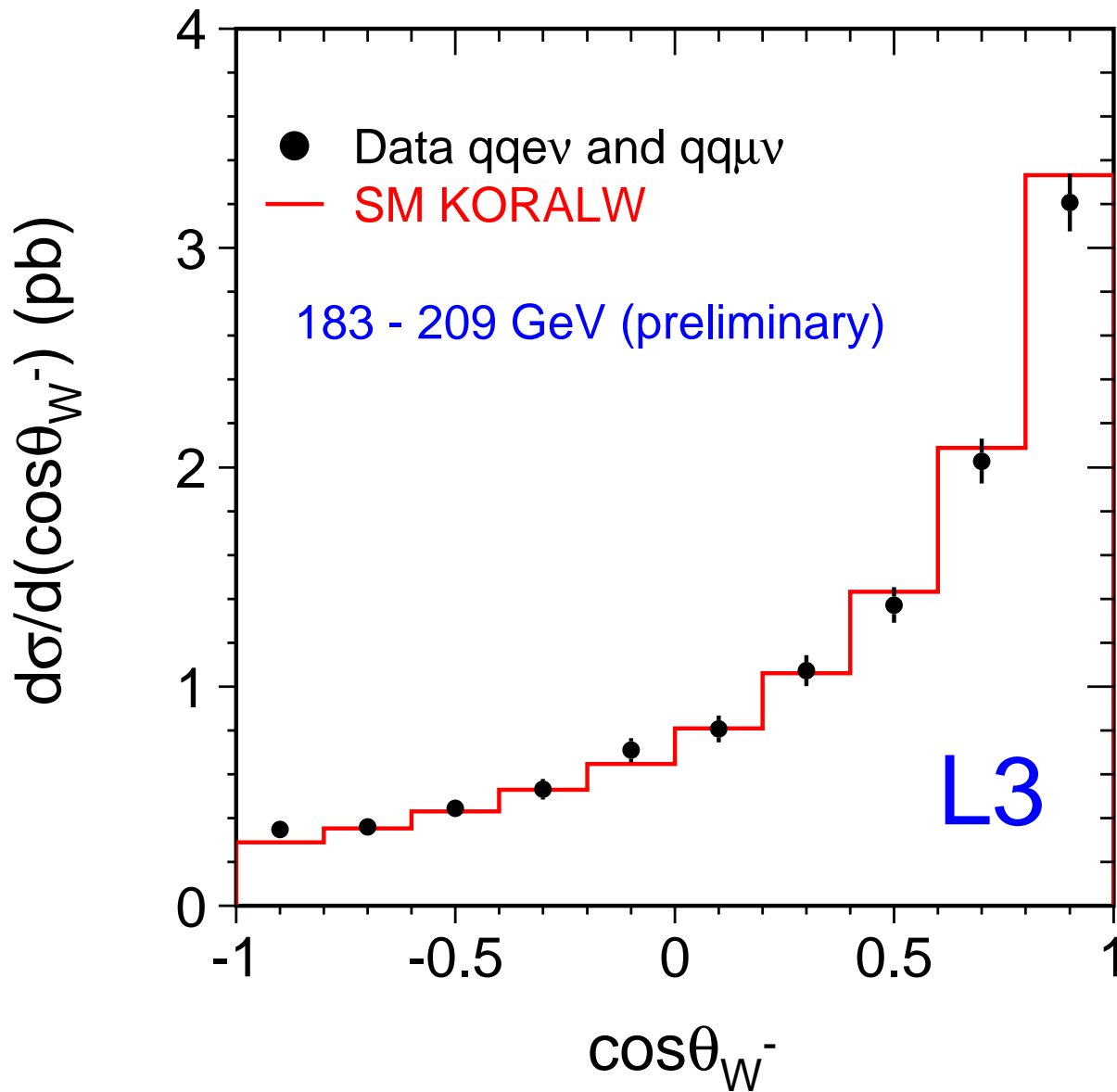
$$e\gamma \rightarrow \nu W$$



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



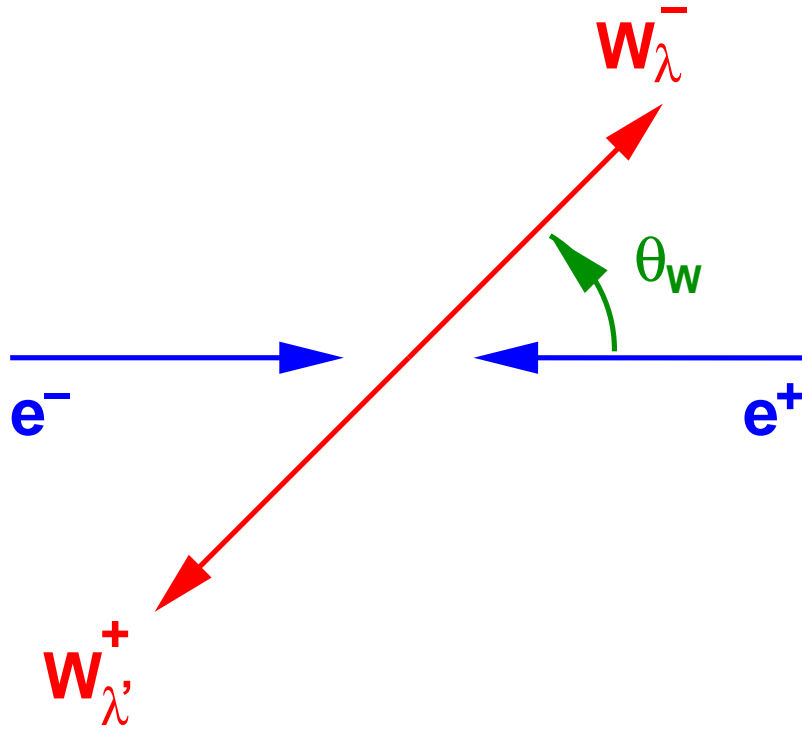


Many predictions beyond the SM manifest as deviations in the $e^+e^- \rightarrow WW$ differential cross section

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

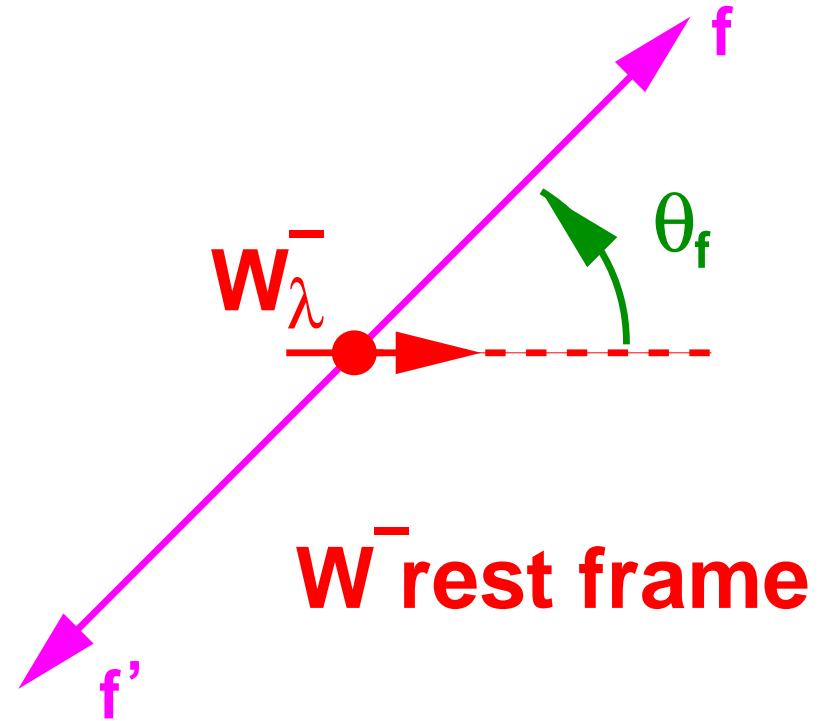
Spin analysis of the $e^+e^- \rightarrow WW$ process

Physics defined by



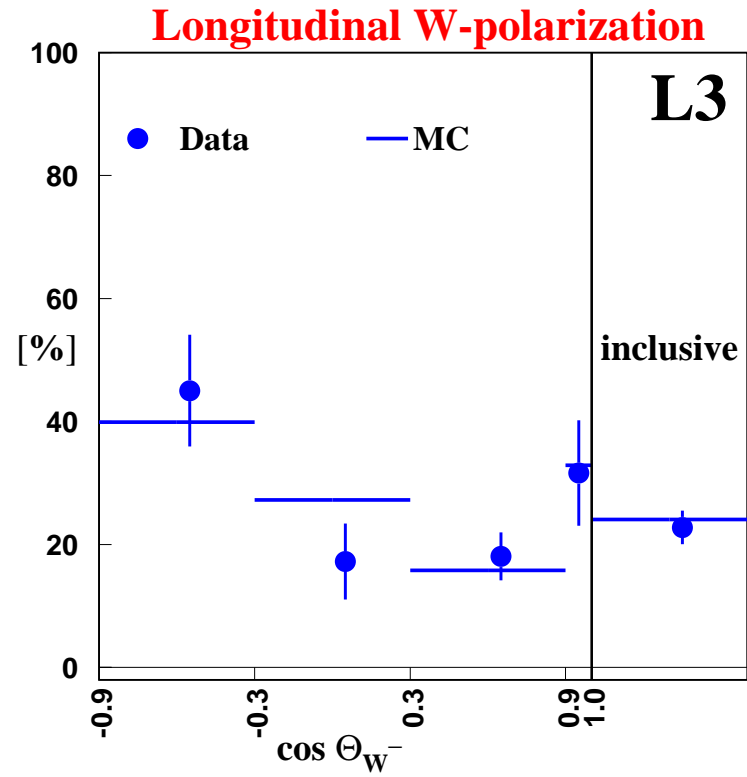
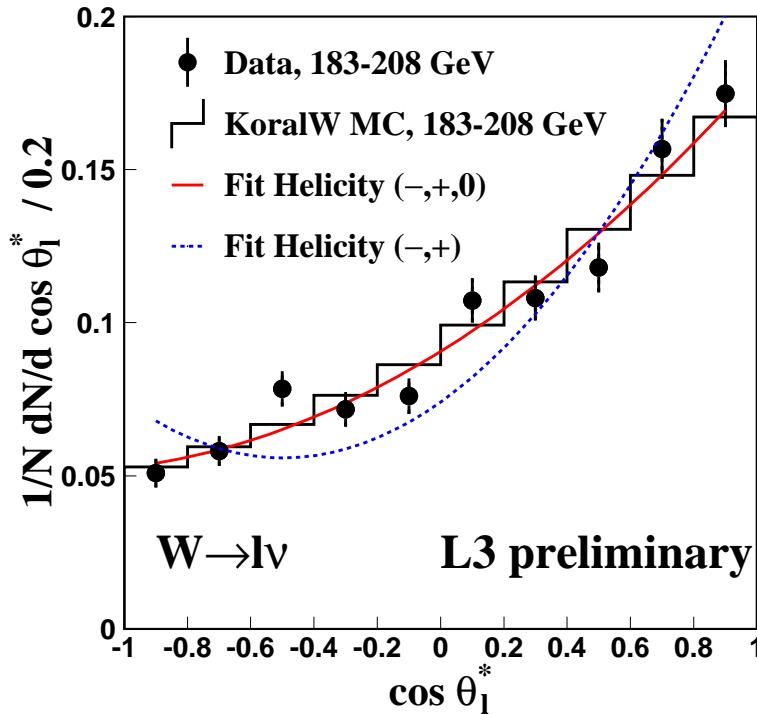
- ❖ Total cross section
- ❖ W^- polar angle distribution
- ❖ W polarizations (λ, λ')

Polarizations from W decays



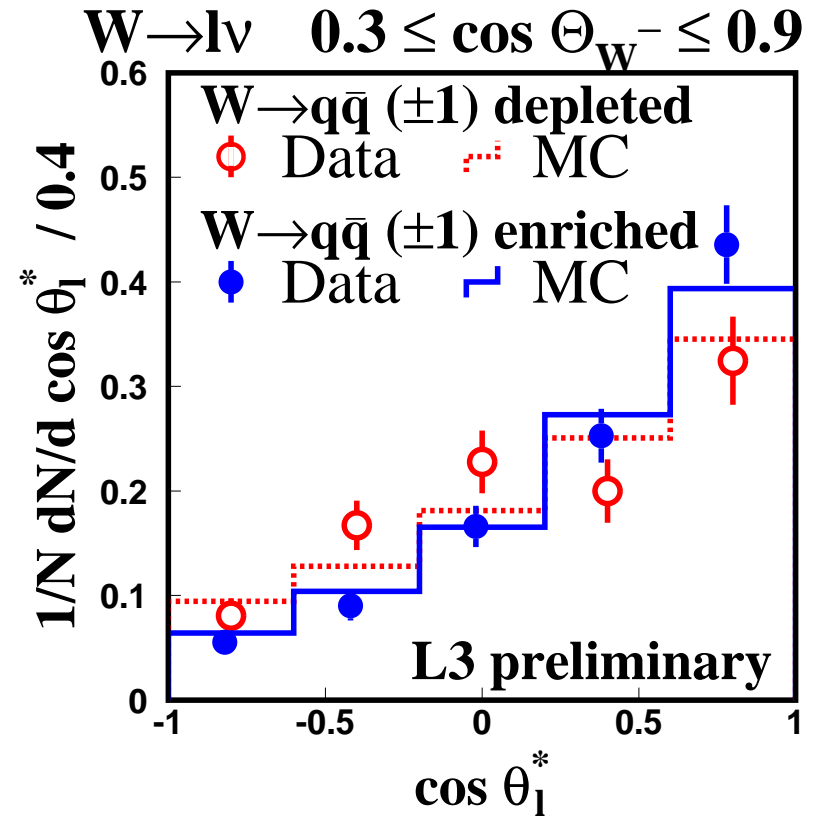
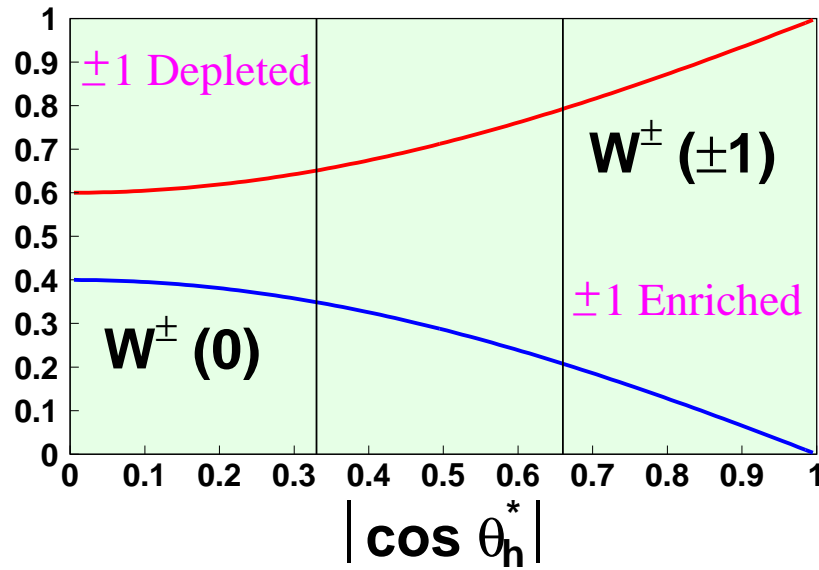
- ❖ $\lambda = \mp 1 \Rightarrow \frac{dN}{d \cos \theta_f} \propto (1 \pm \cos \theta_f)^2$
- ❖ $\lambda = 0 \Rightarrow \frac{dN}{d \cos \theta_f} \propto \sin^2 \theta_f$

First type of analysis: polarizations of the individual Ws



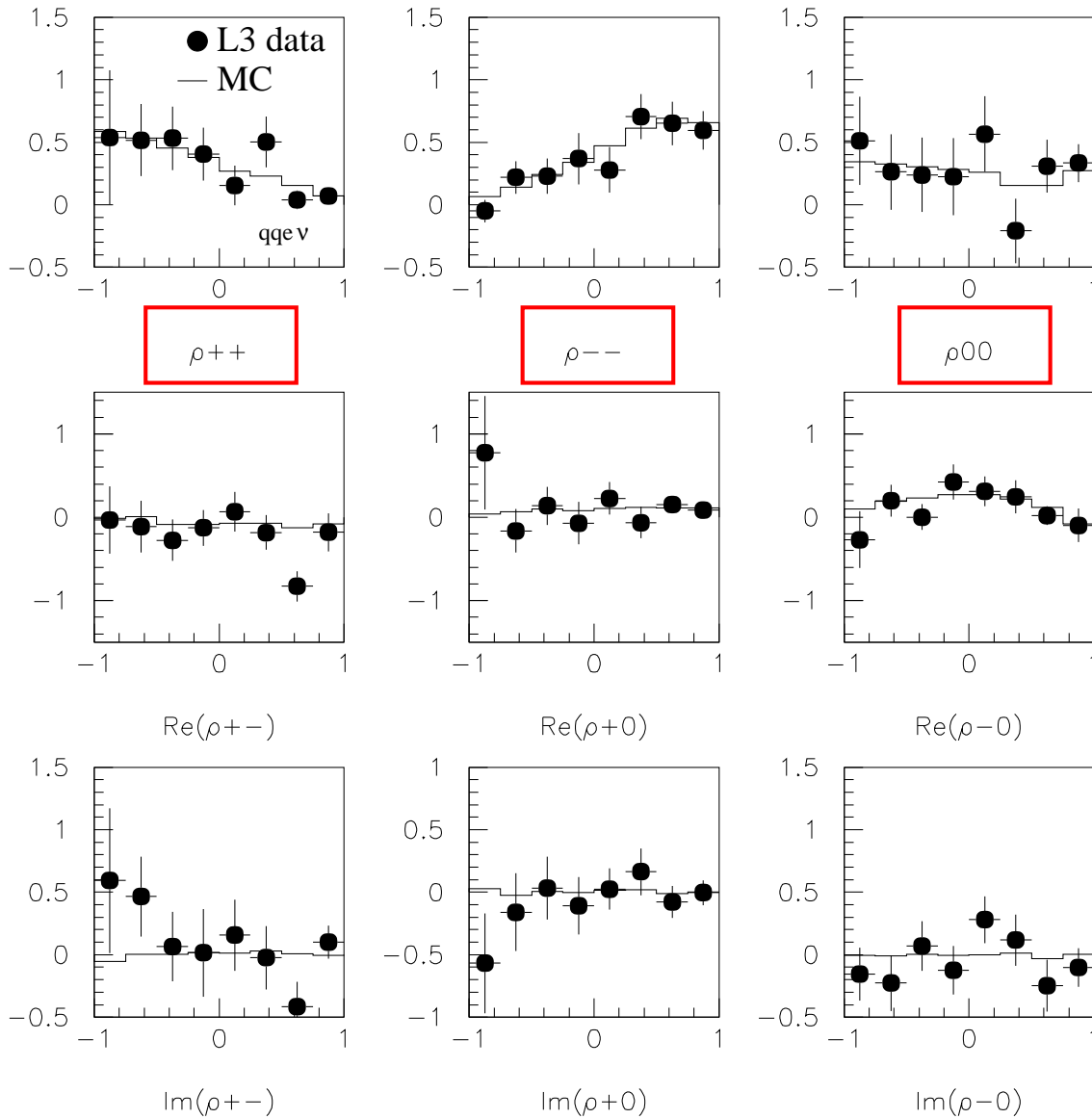
Longitudinal W polarization: $(22.8 \pm 2.7 \pm 1.2)\%$,
in agreement with SM expectations

Second type of analysis: spin correlations between W s in $q\bar{q}'l\nu$



Evidence for spin correlations between the two W 's at the 2.6σ level
 1.8σ larger than expected!

L3 preliminary



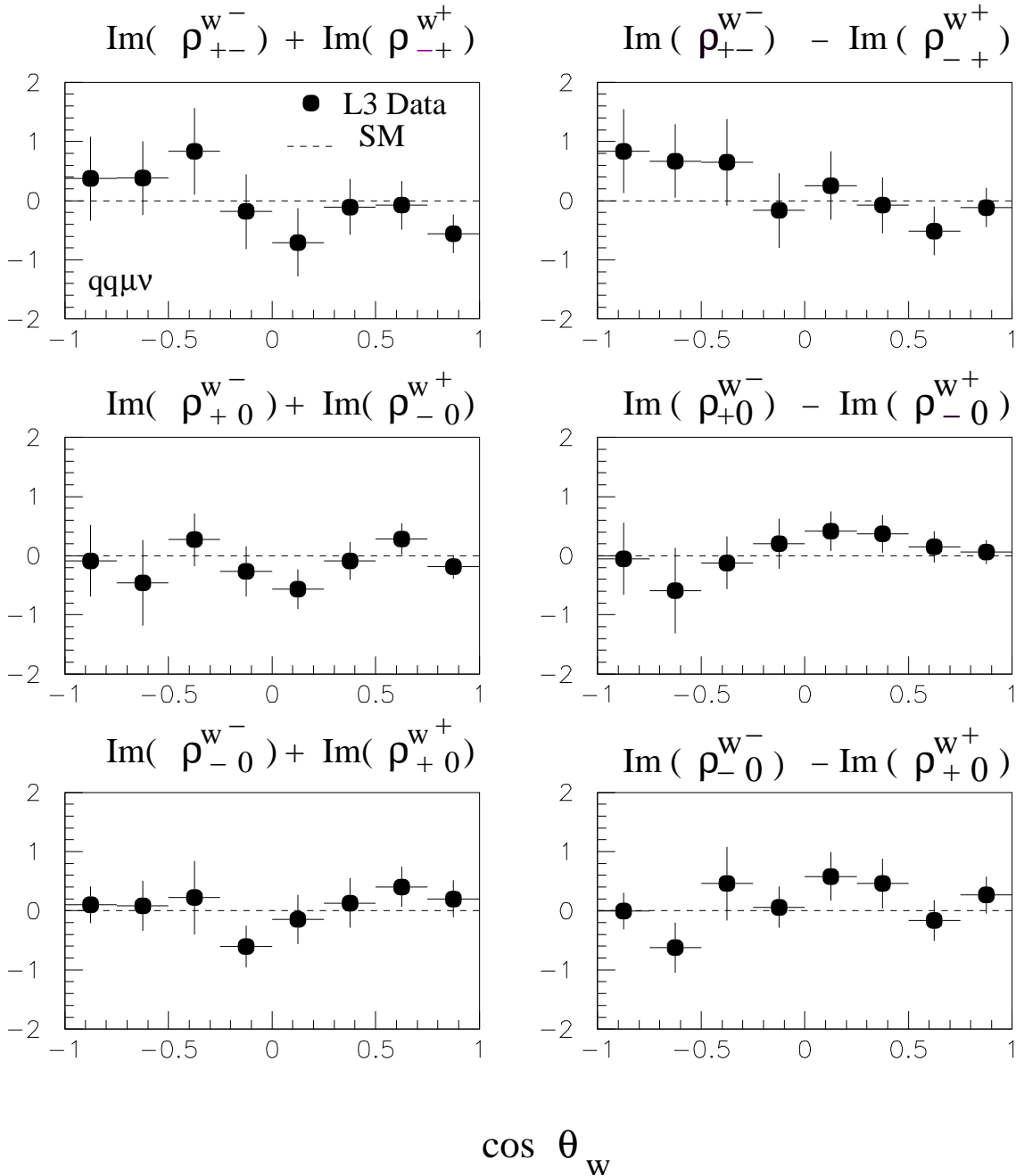
$$\cos \theta_W$$

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

CPT

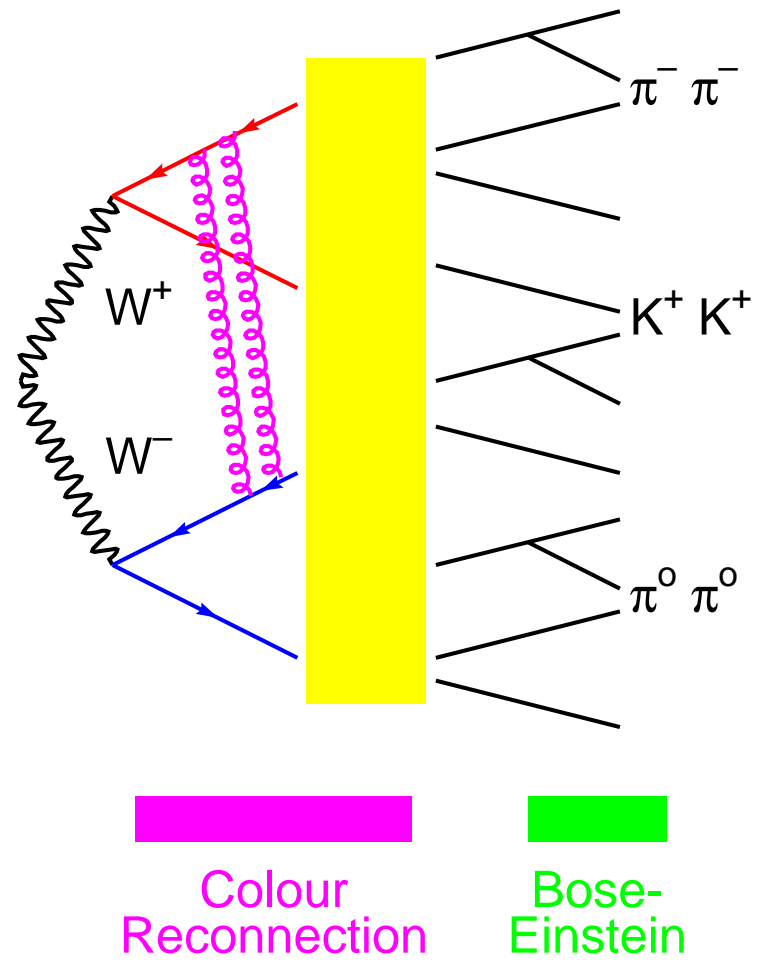
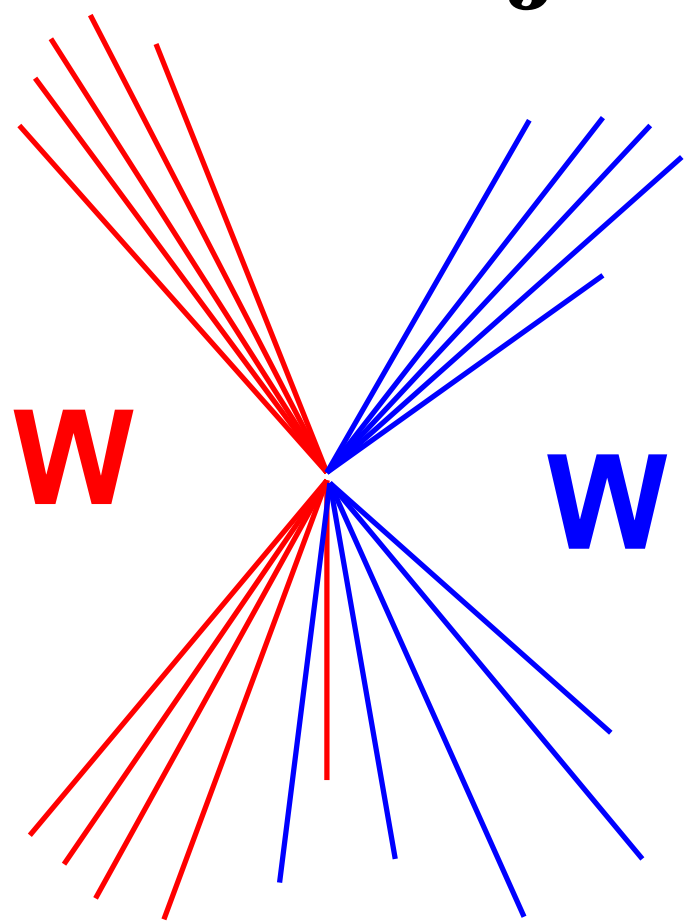
L3 Preliminary

CP



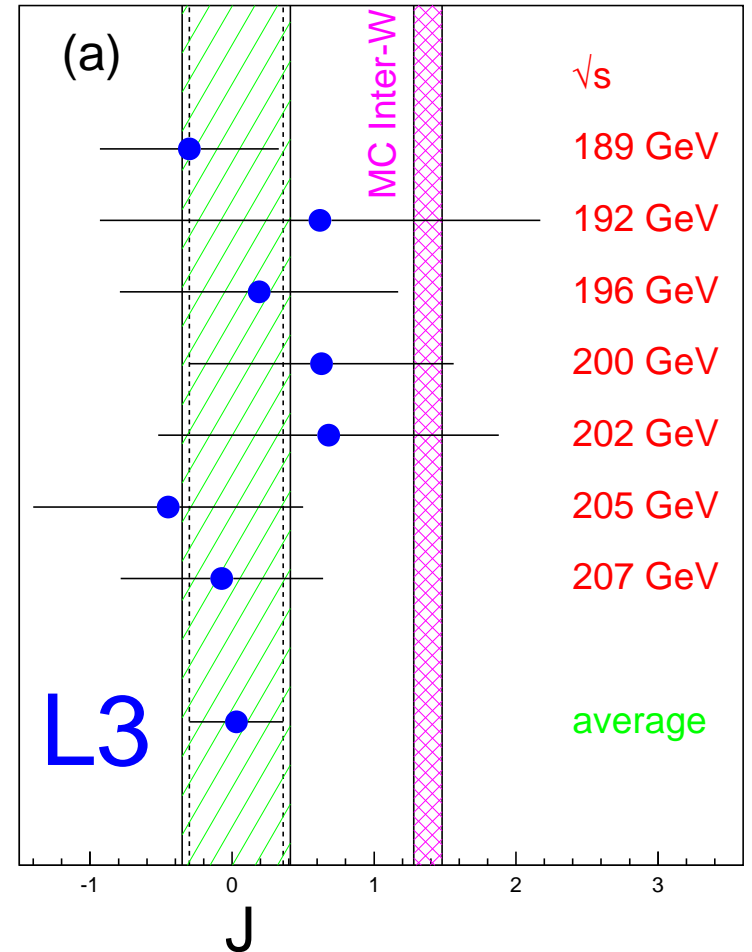
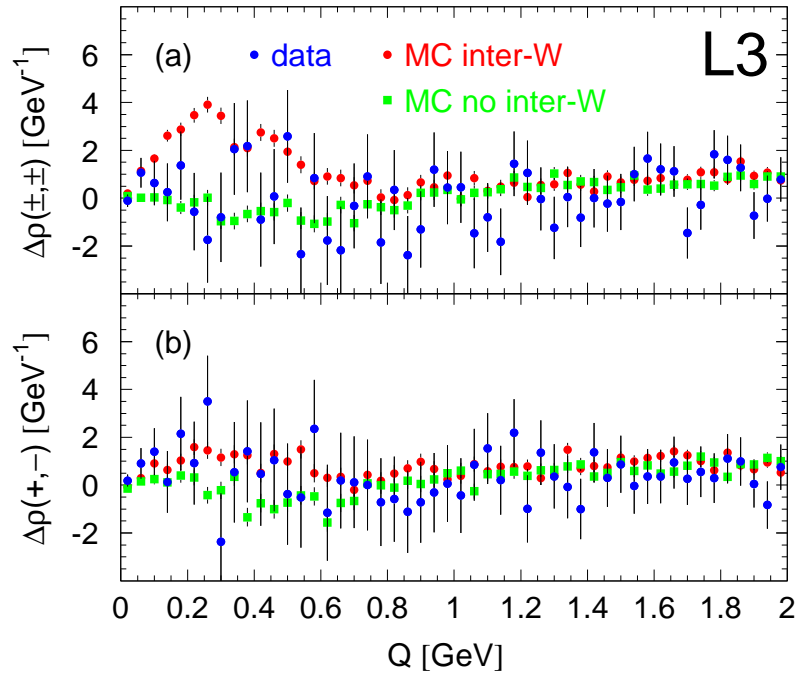
- ❖ $\text{Im}(\rho) = 0$ in the absence of CP, CPT violation
- ❖ No CP violating couplings seen
- ❖ No CPT violating effects

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



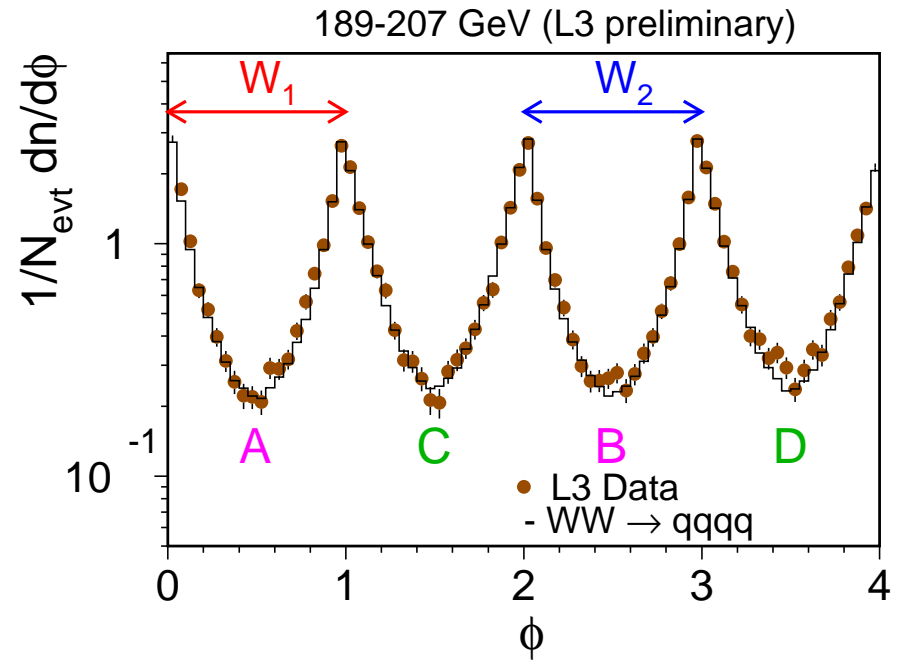
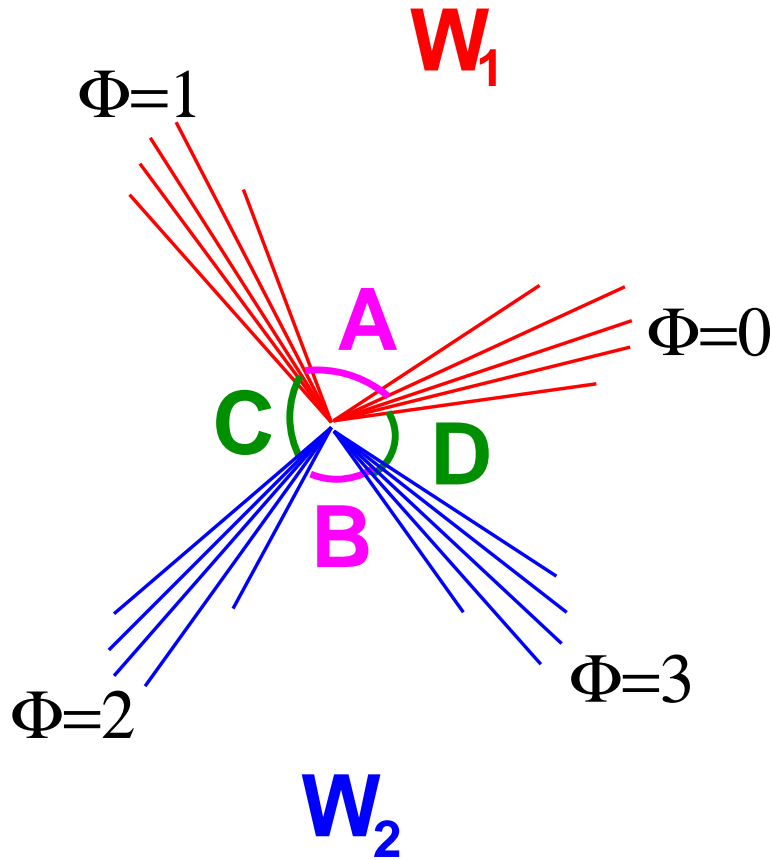
$$Q^2 = -(p_1 - p_2)^2$$

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

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

Estimated BE effect on the measured W mass: 20 MeV

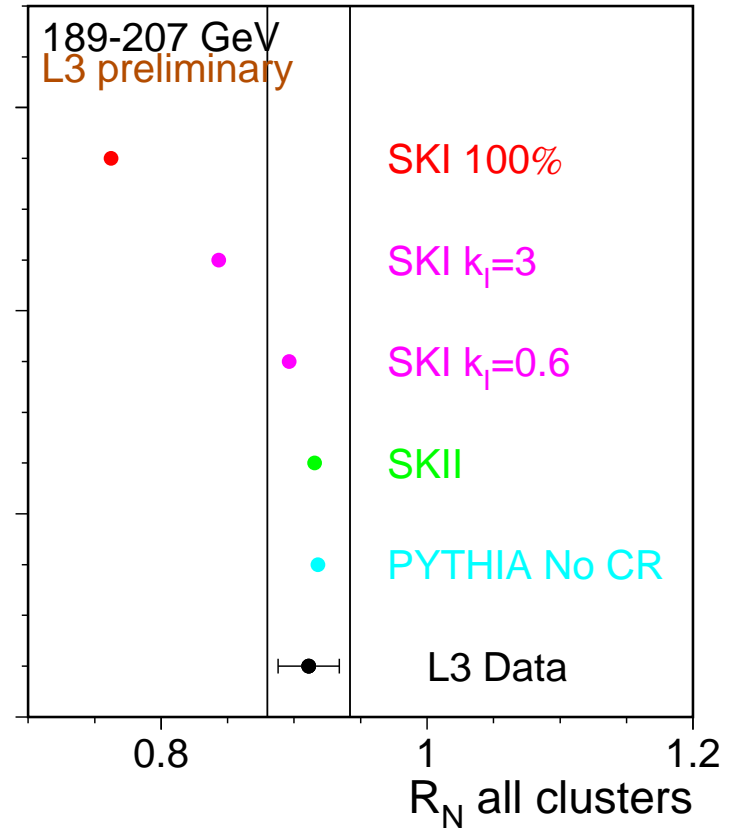
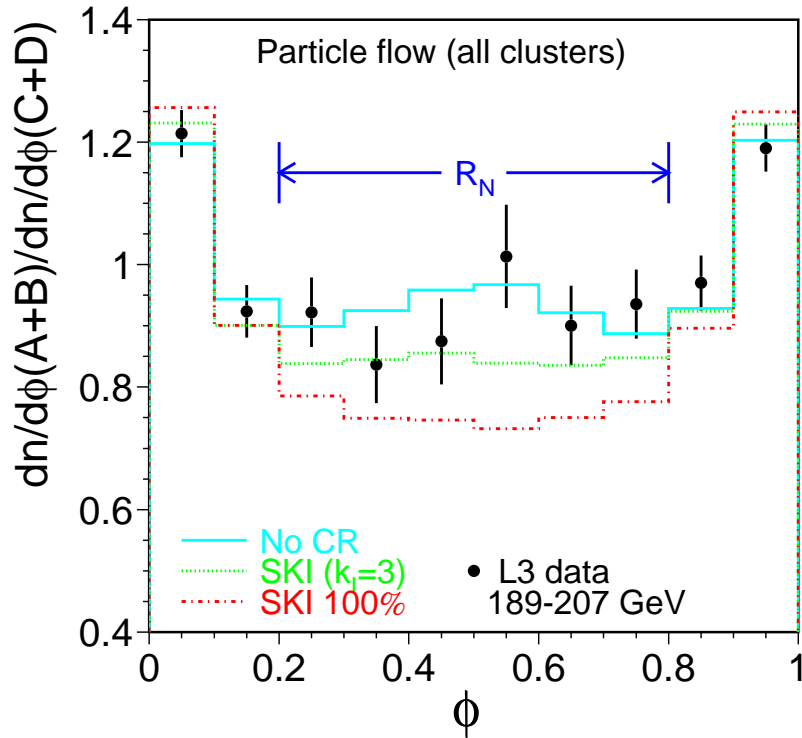
Colour-reconnection studies



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

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

Colour-reconnection studies



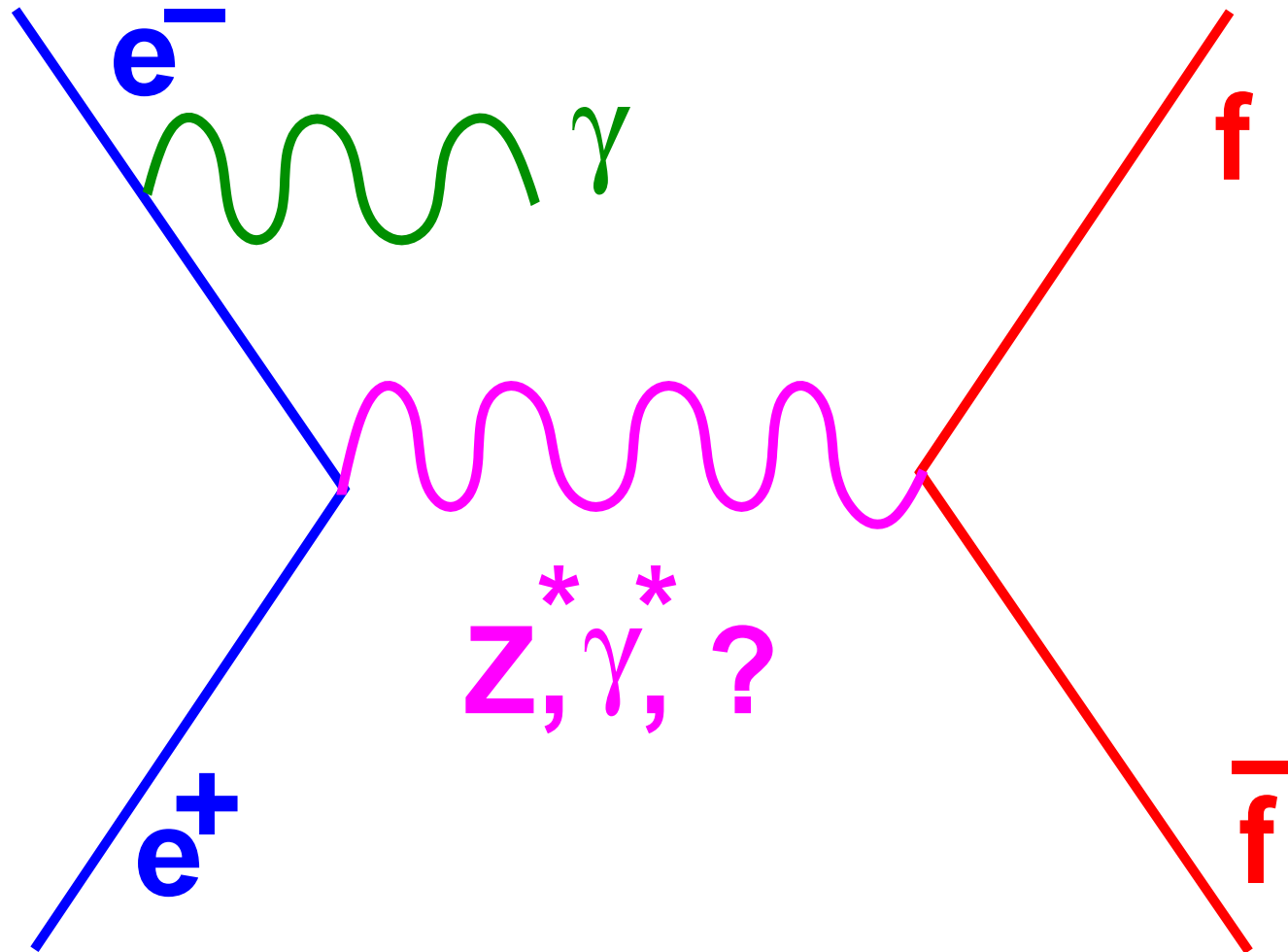
$$R_N = \frac{\frac{1}{N} \int_{0.2}^{0.8} \frac{dn}{d\phi} (A + B)}{\frac{1}{N} \int_{0.2}^{0.8} \frac{dn}{d\phi} (C + D)}$$

L3 data are consistent with a small colour reconnection probability:

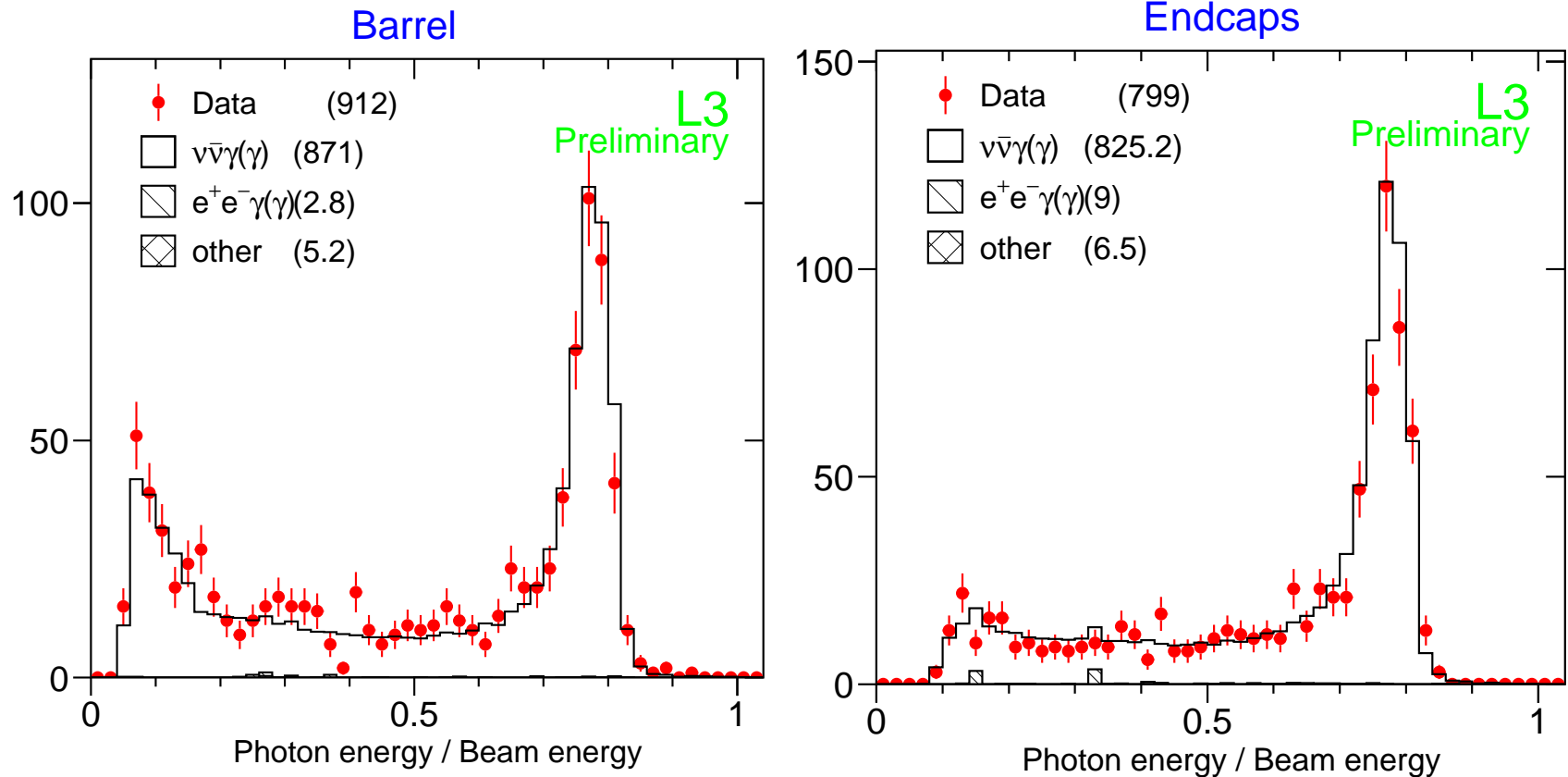
$$P_{rec} = (17^{+29}_{-17})\% \quad (\text{SKI model})$$

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

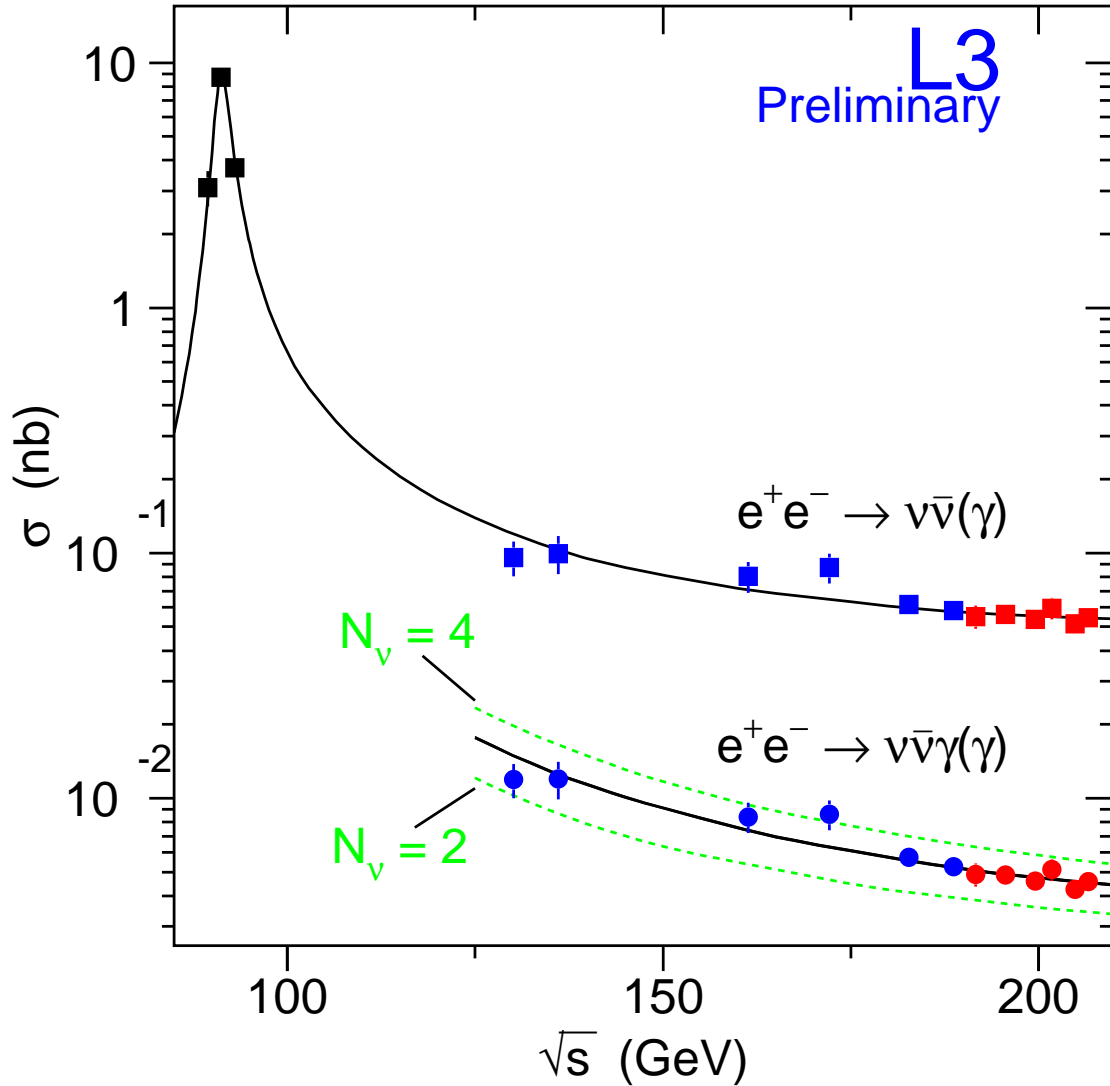
Fermion pair production



Photons with missing energy



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



Kinematic region:

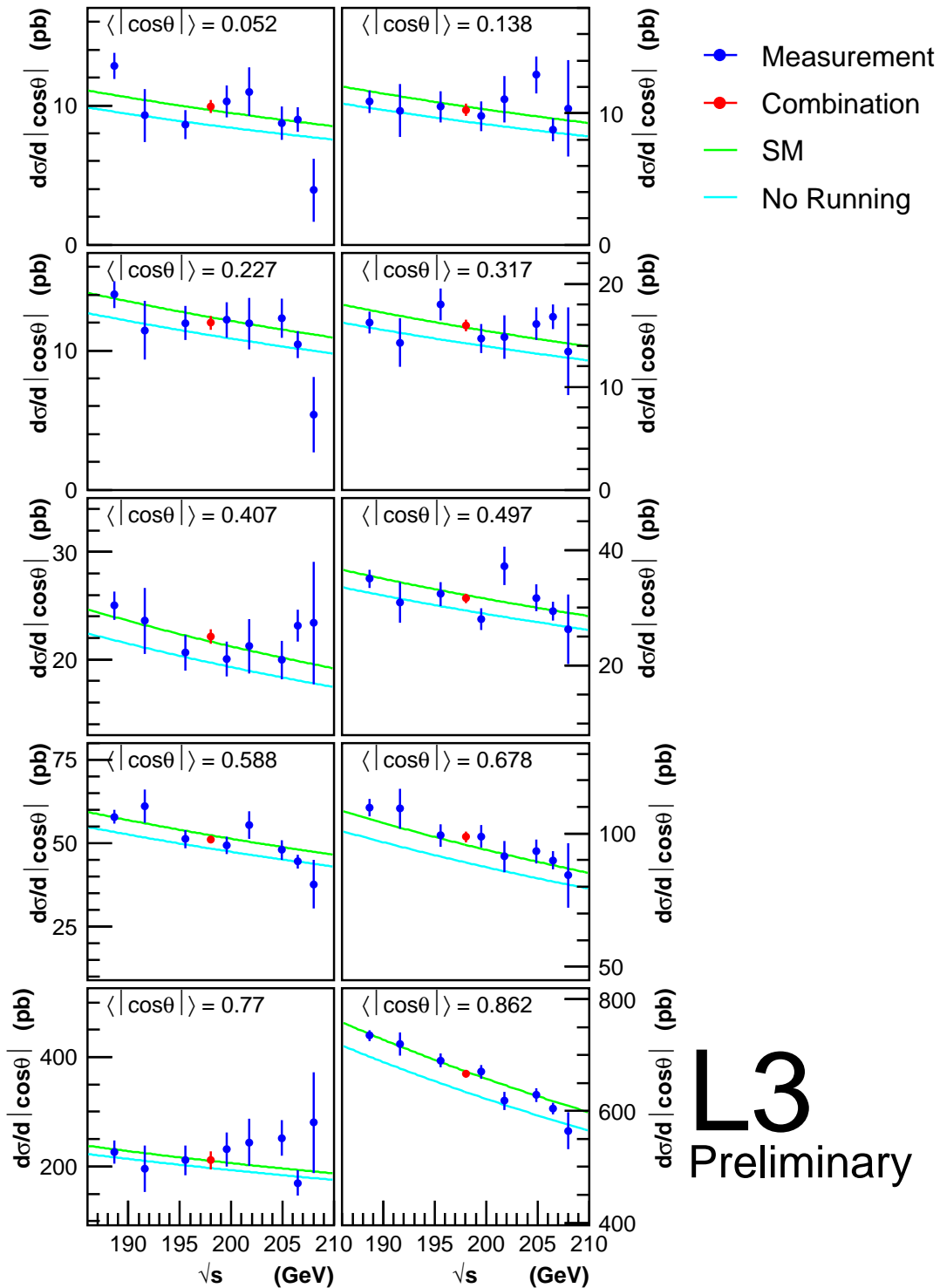
$$E_\gamma > 5 \text{ GeV}, |\cos \theta_\gamma| < 0.97$$

$$\text{LEP2: } N_\nu = 2.94 \pm 0.09$$

$$\text{LEP1: } N_\nu = 2.98 \pm 0.10$$

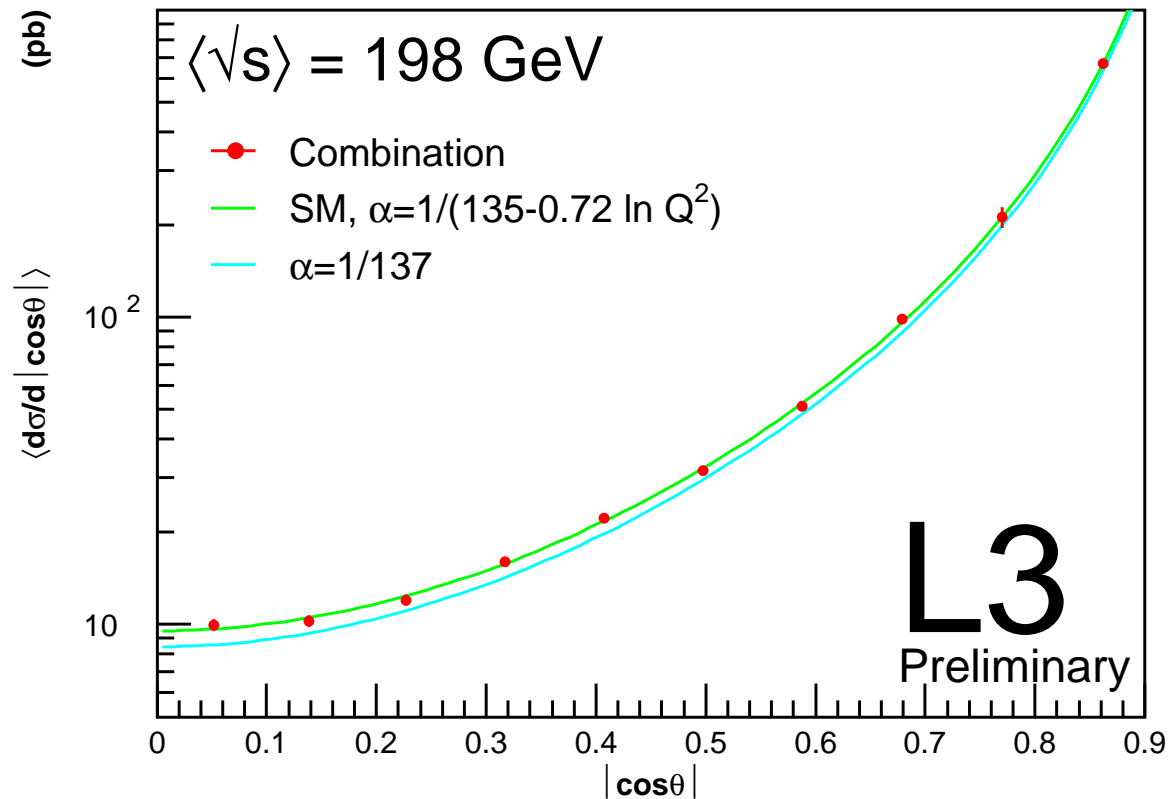


Bhabha Differential Cross-Section



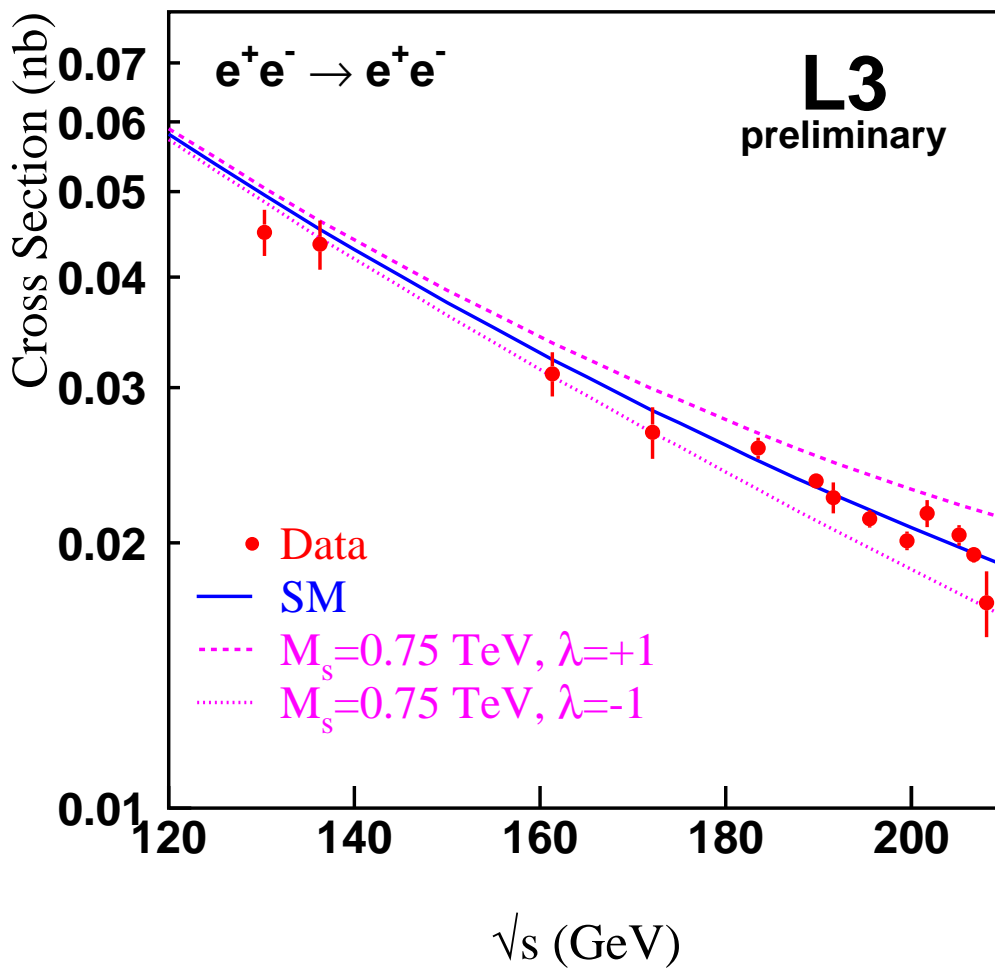
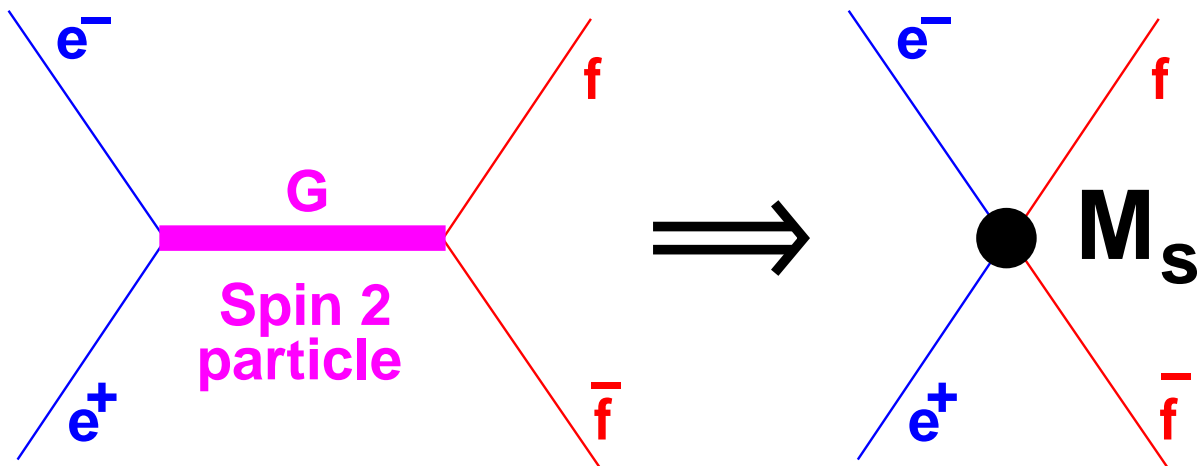
L3
Preliminary

Bhabha Differential Cross-Section



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

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

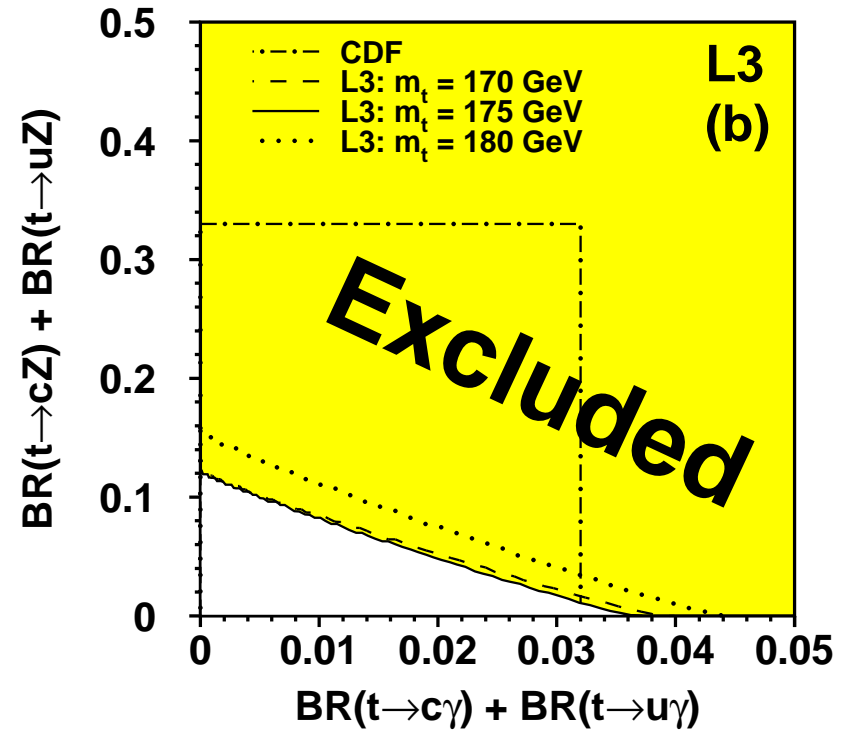
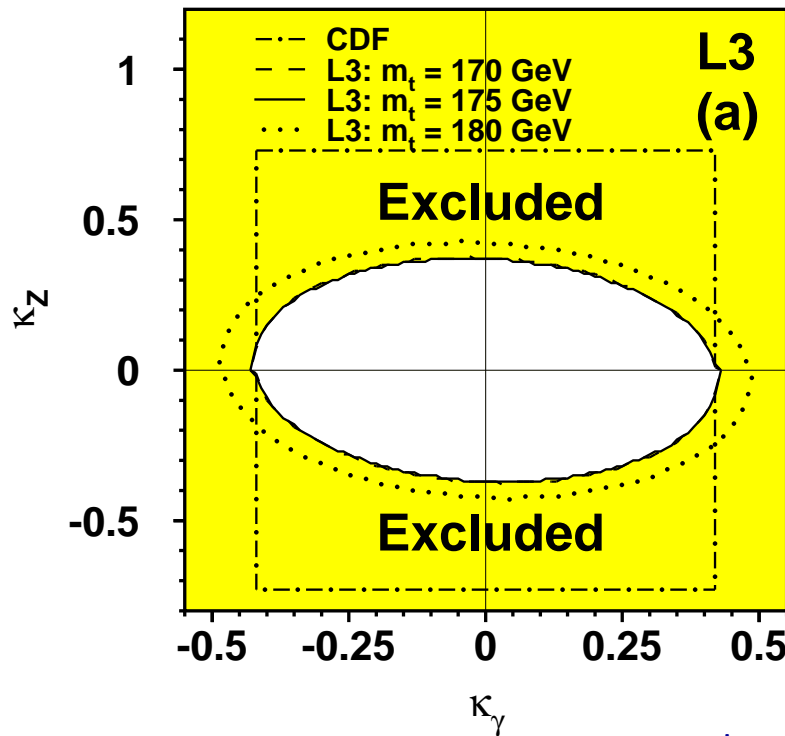
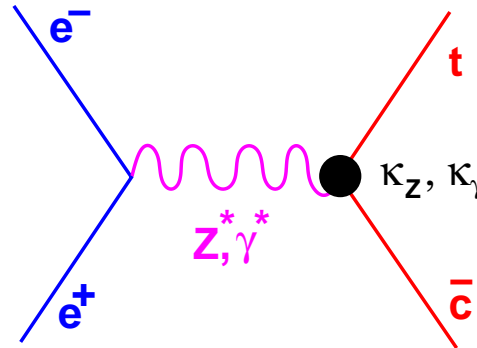


$M_s > 1.04$ TeV; $\lambda = +1$

$M_s > 1.05$ TeV; $\lambda = -1$

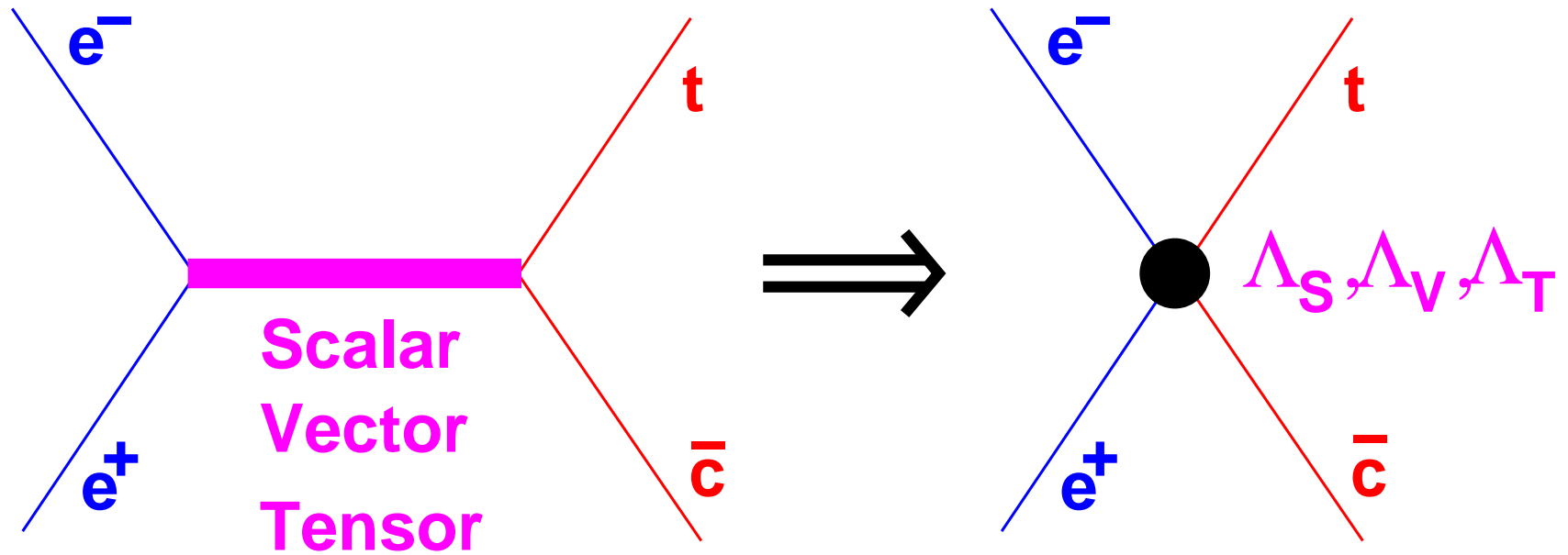
Single top searches in L3: $e^+e^- \rightarrow t\bar{c}(\bar{u})$

Interpretation in terms of anomalous couplings



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

Interpretation in terms of contact interactions



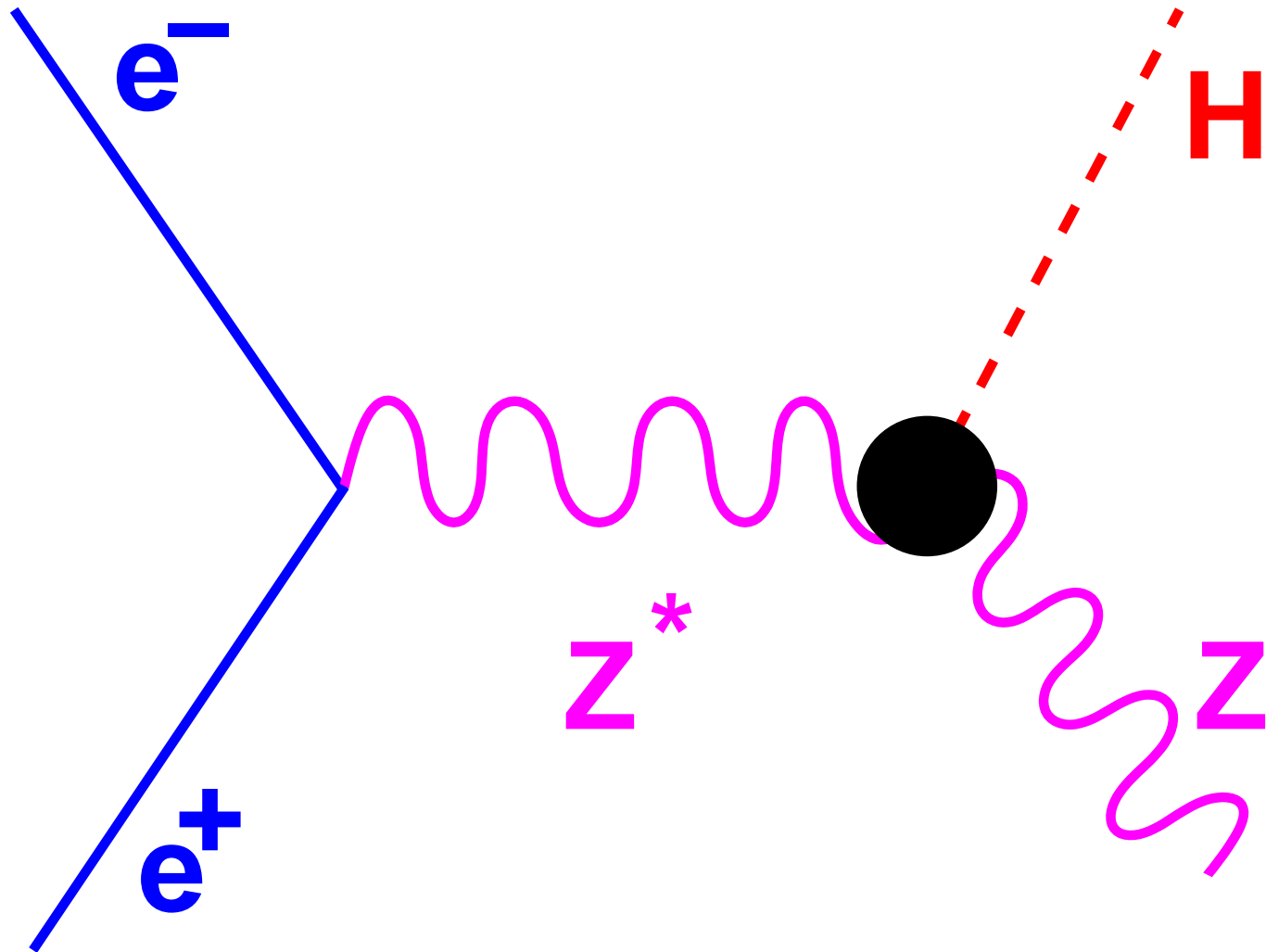
$$\Lambda_S > 0.65 \text{ TeV}$$

$$\Lambda_V > 0.75 \text{ TeV}$$

$$\Lambda_T > 1.24 \text{ TeV}$$

(for $m_t = 175 \text{ GeV}$)

Higgs searches

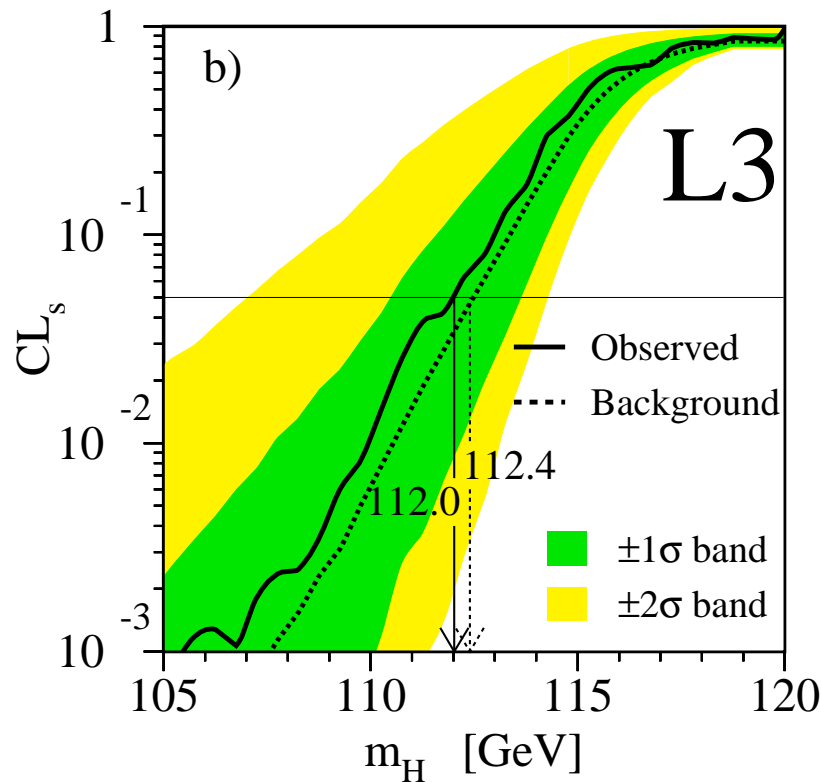


“Standard” Higgs searches

SM Searches:

$$m_H > 112.0 \text{ GeV}$$

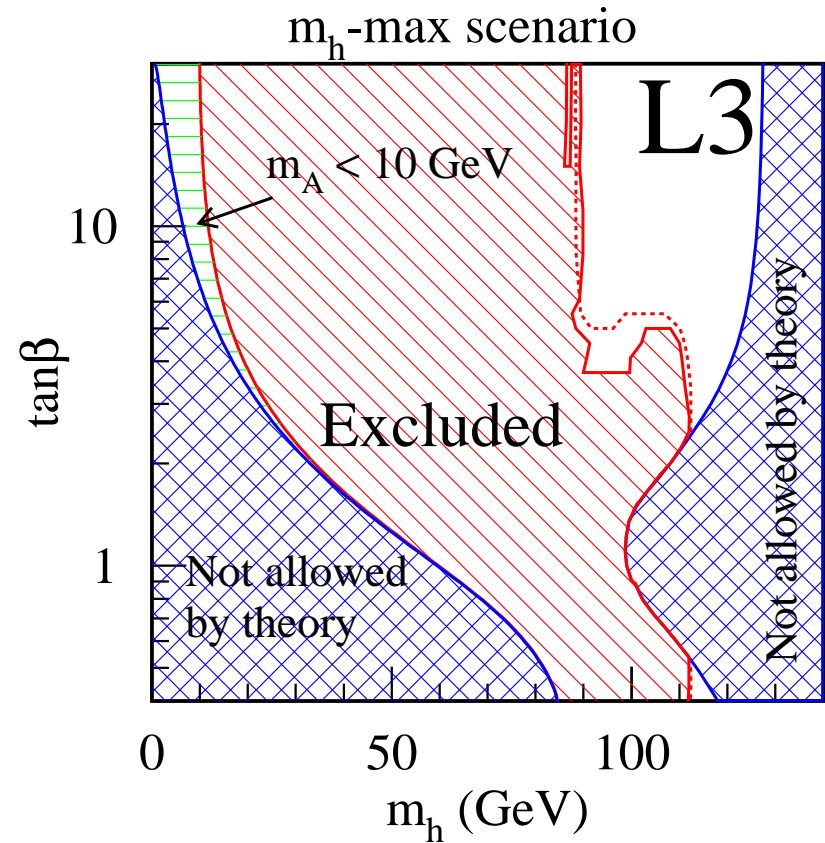
(Physics Letters B517 (2001) 319)



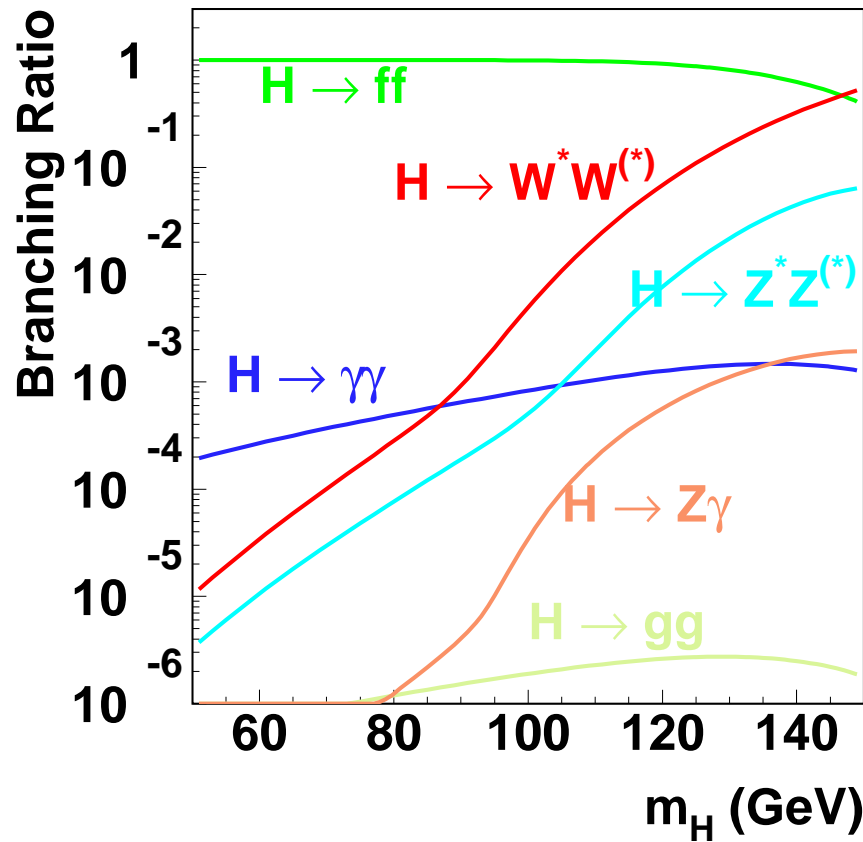
MSSM Searches:

$$m_h > 84.5 \text{ GeV}, m_A > 86.3 \text{ GeV}$$

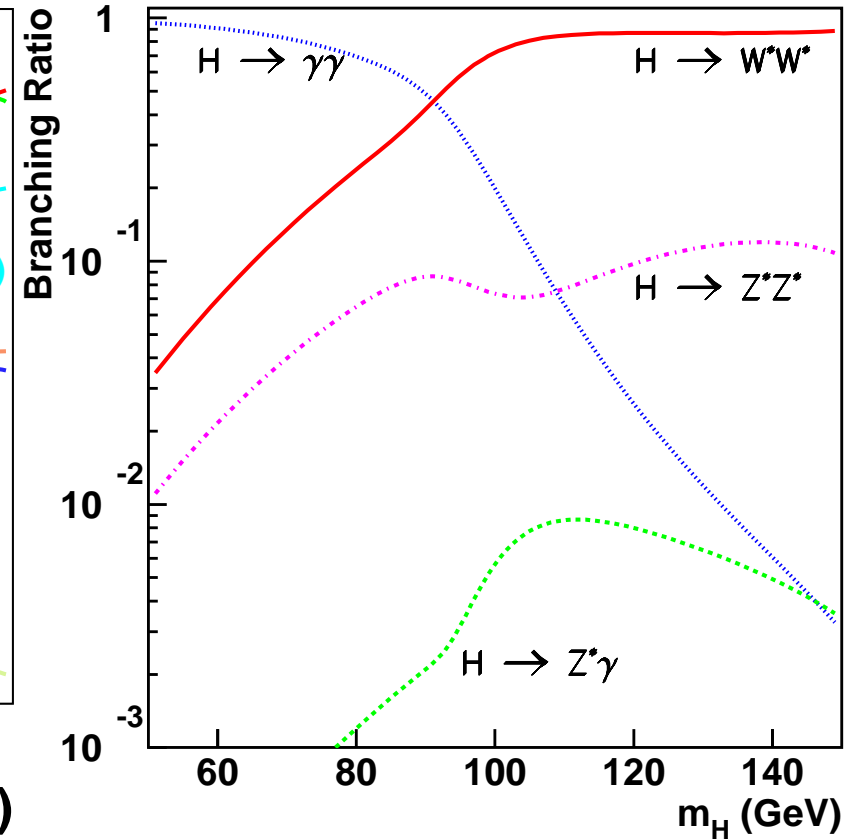
all scenarios: m_h -max, no-mixing,
large μ , FINAL



Standard Model

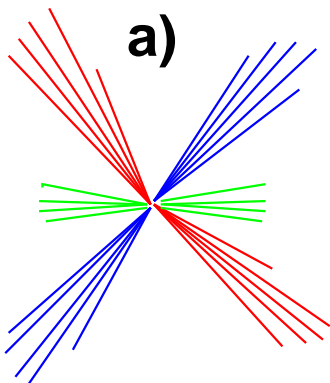


Benchmark fermiophobic scenario

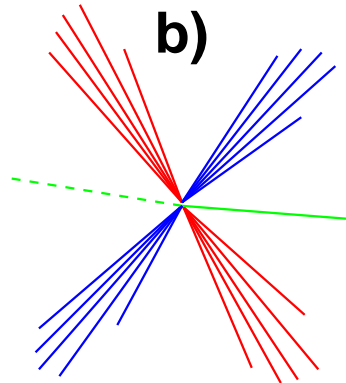


- ❖ SM: $BR(H \rightarrow WW^*) \approx 10\%$ when $m_H \approx 120$ GeV
- ❖ Fermiophobia: $H \rightarrow WW^*$ dominant for $m_H \gtrsim 90$ GeV

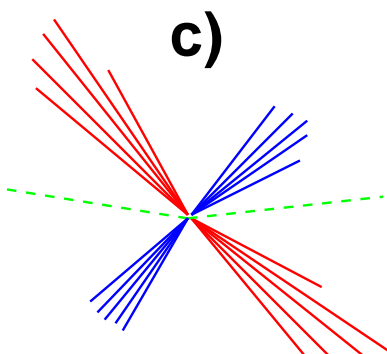
qqqqqq, 30 %



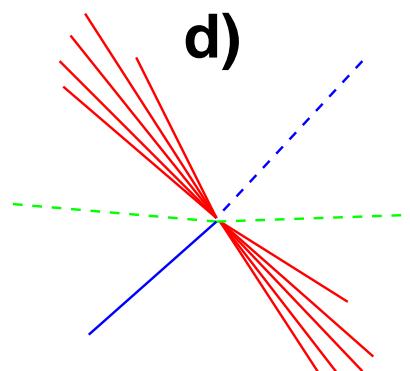
qqqqlv, 30 %



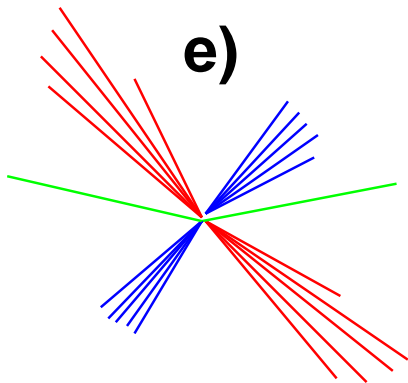
qqqqvv, 10 %



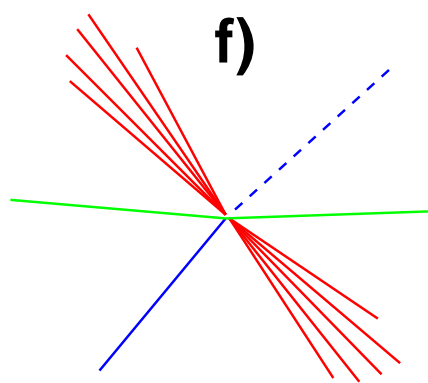
qqllvv, 10 %



qqqqll, 6 %

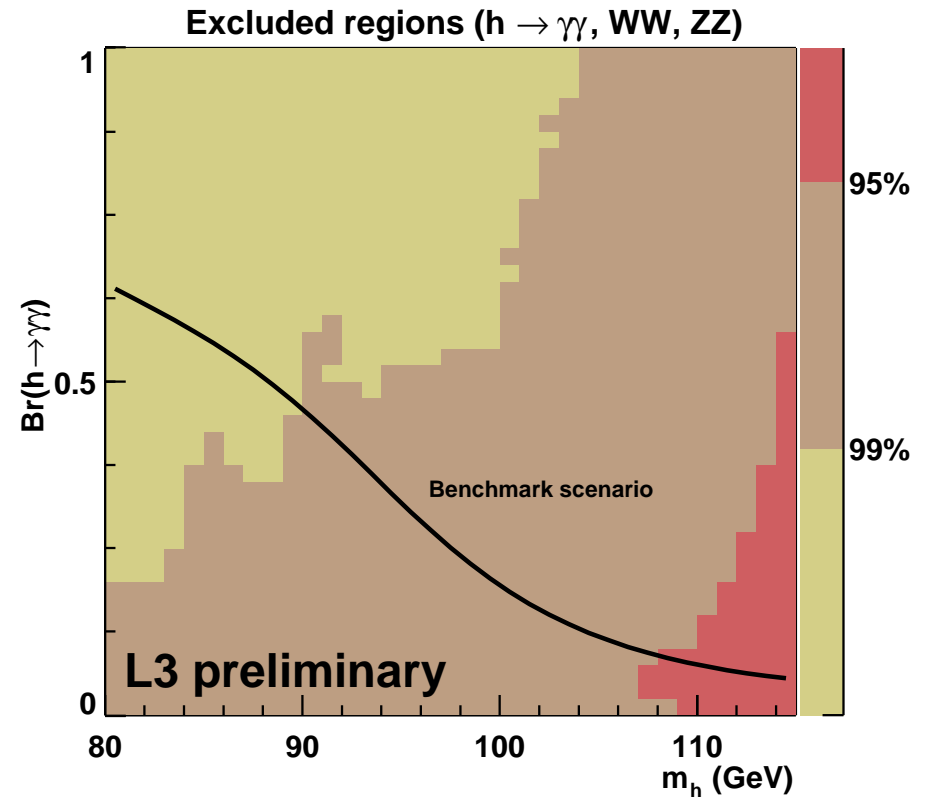
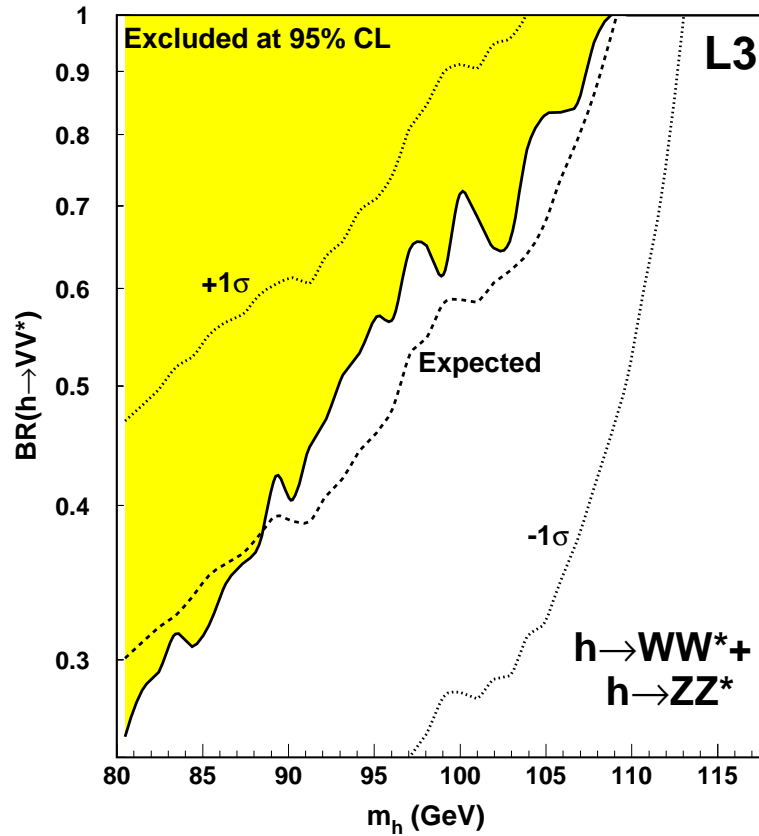


qqlllv, 6 %



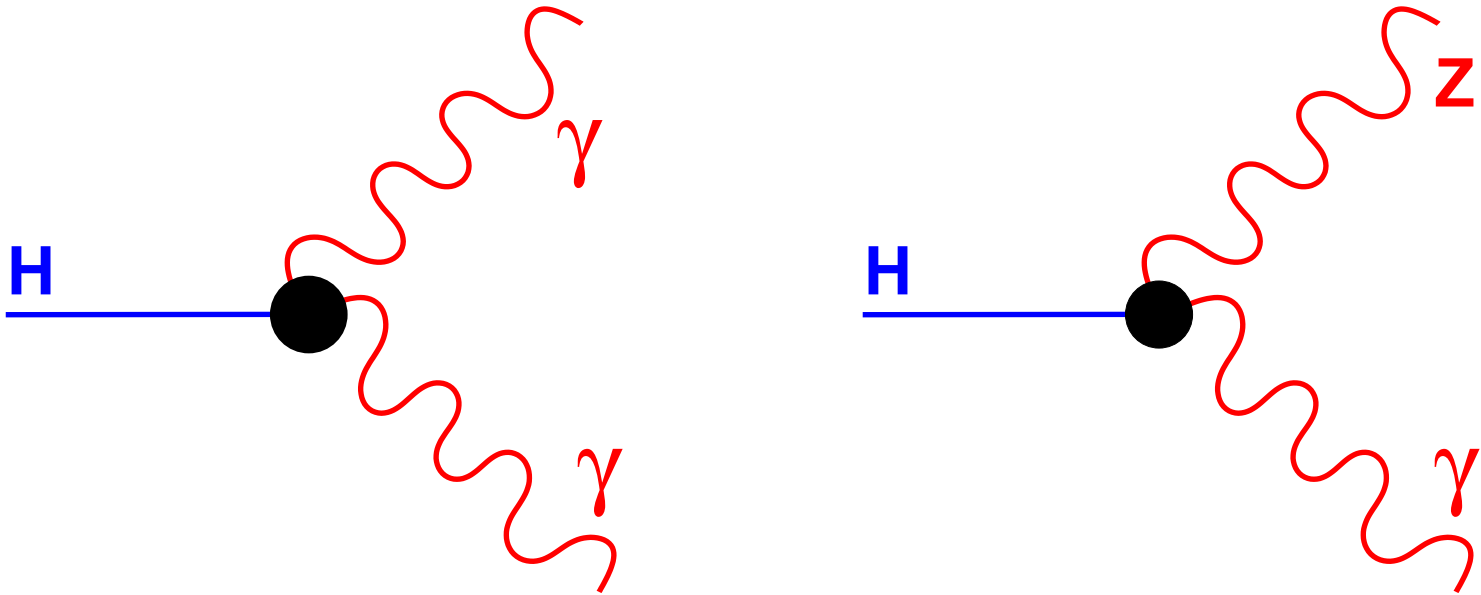
- ❖ W^* always “off-shell”, many signatures
- ❖ Large backgrounds: neural network techniques
- ❖ 93% of the decay modes searched for; $\epsilon \approx 44\%$

“Fermiophobic” searches, **NO EXCESS**



- ❖ $m_H > 109$ GeV ($BR(H \rightarrow WW^* + ZZ^*) = 100\%$, SM production)
- ❖ $m_H > 108$ GeV (benchmark scenario)
- ❖ $m_H > 107$ GeV (any BR, SM production)

Anomalous Higgs couplings in the bosonic sector

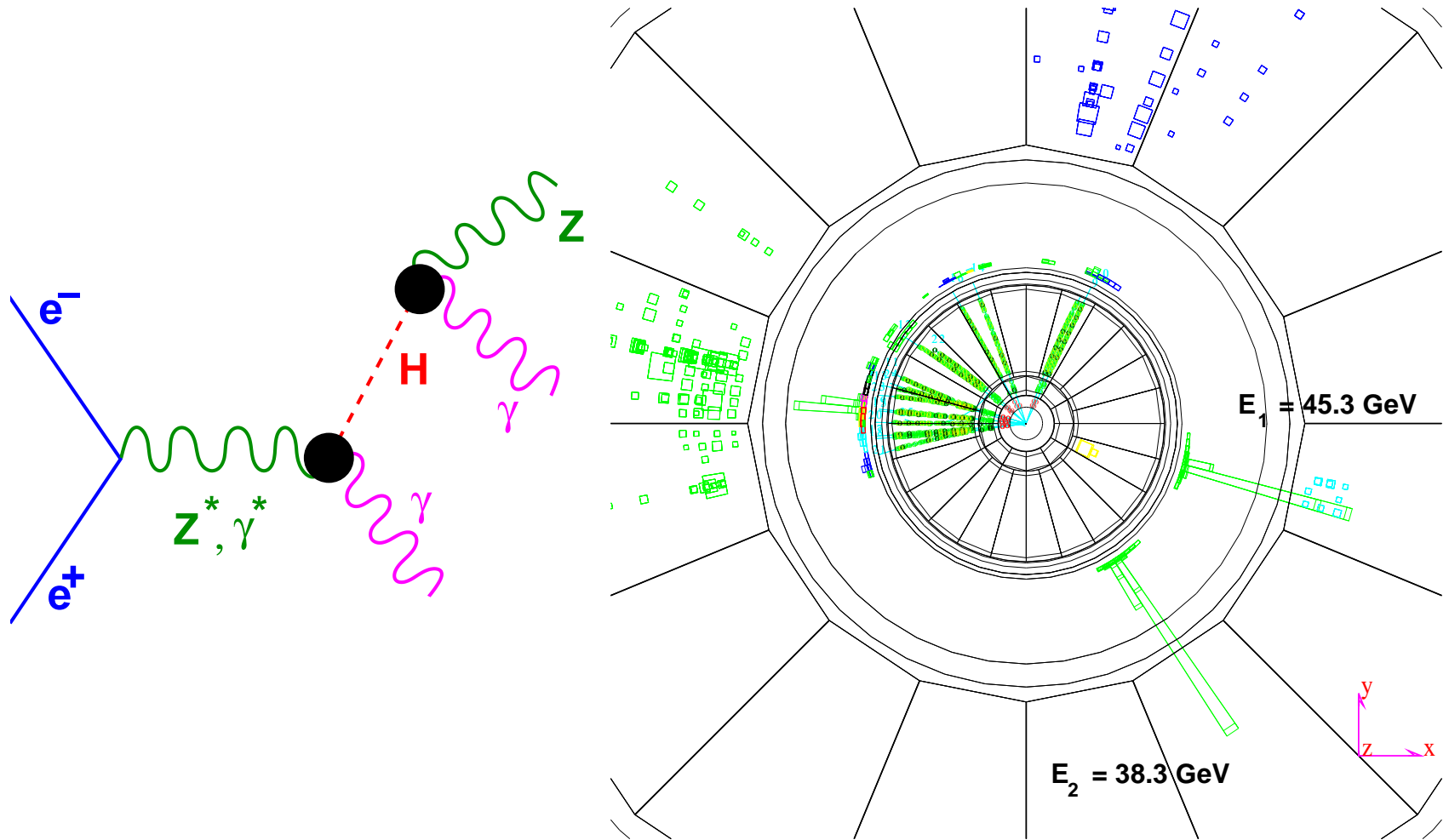


- ◆ Described in terms of the anomalous couplings d and d_B (Gounaris *et al.*, Nucl. Phys. **B459** (1996) 51)
- ◆ Clean signatures

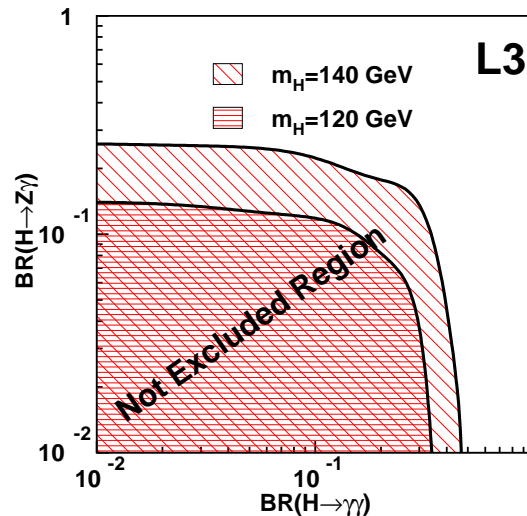
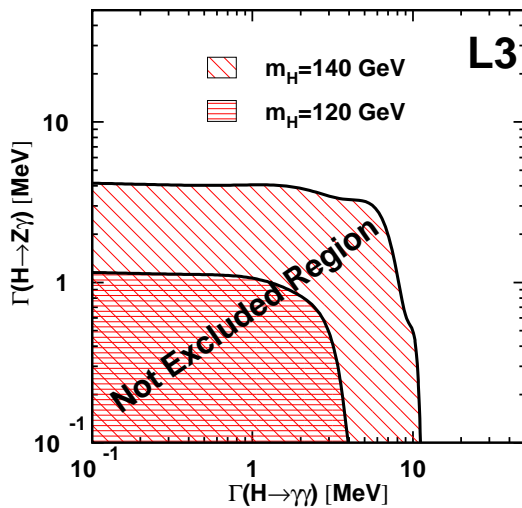
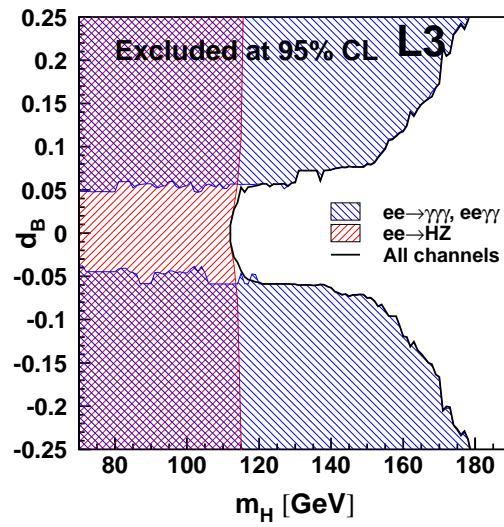
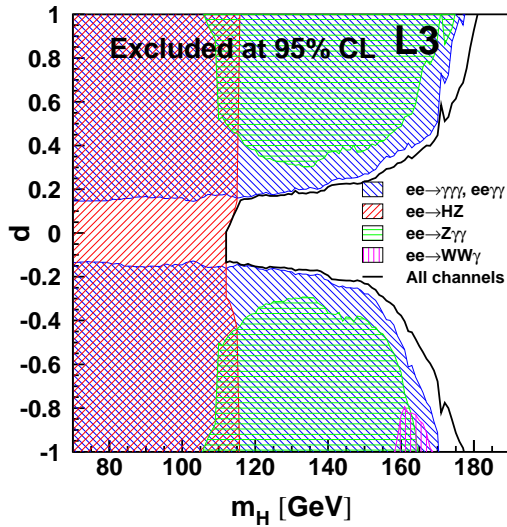
Higgs anomalous couplings: example



Run # 850706 Event # 375



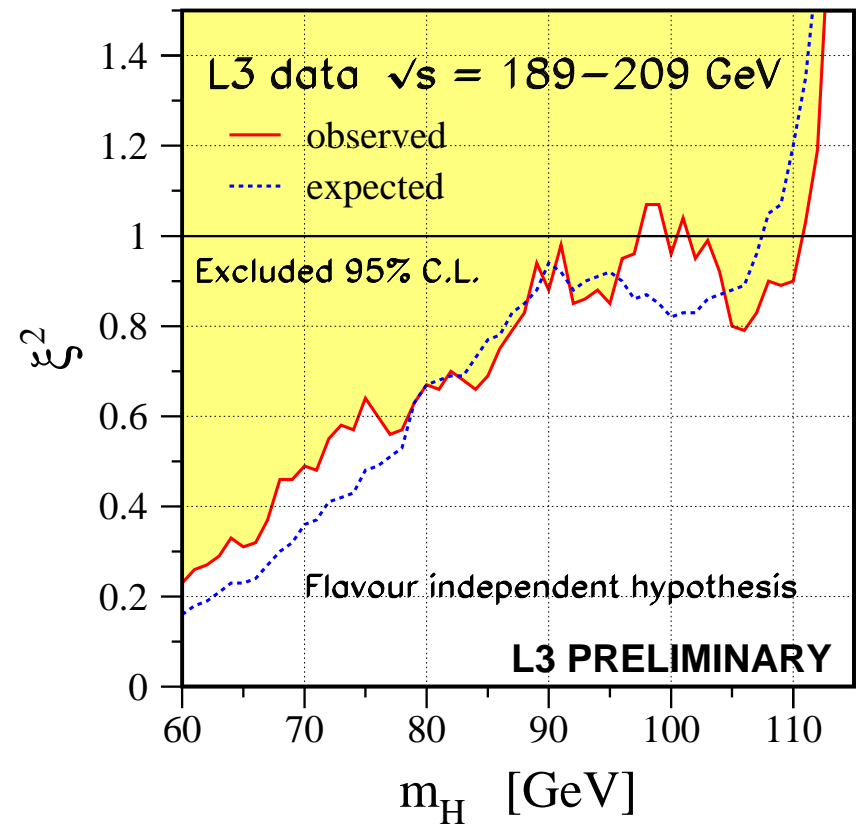
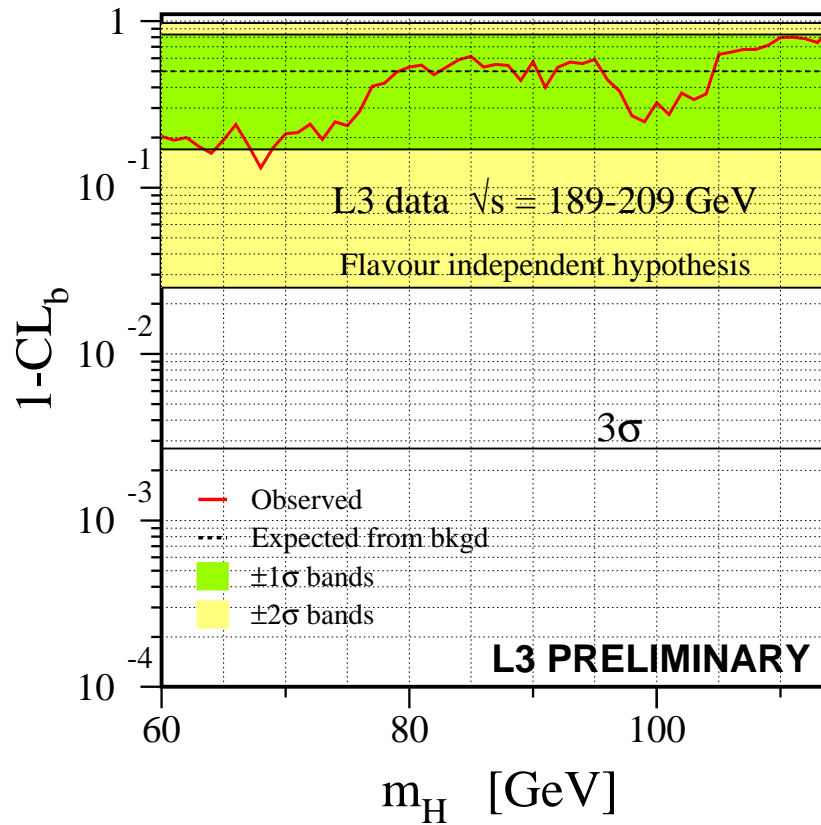
Higgs anomalous couplings: **NO EXCESS**



L3 data largely constrain these couplings in the region: $m_H \lesssim 160$ GeV

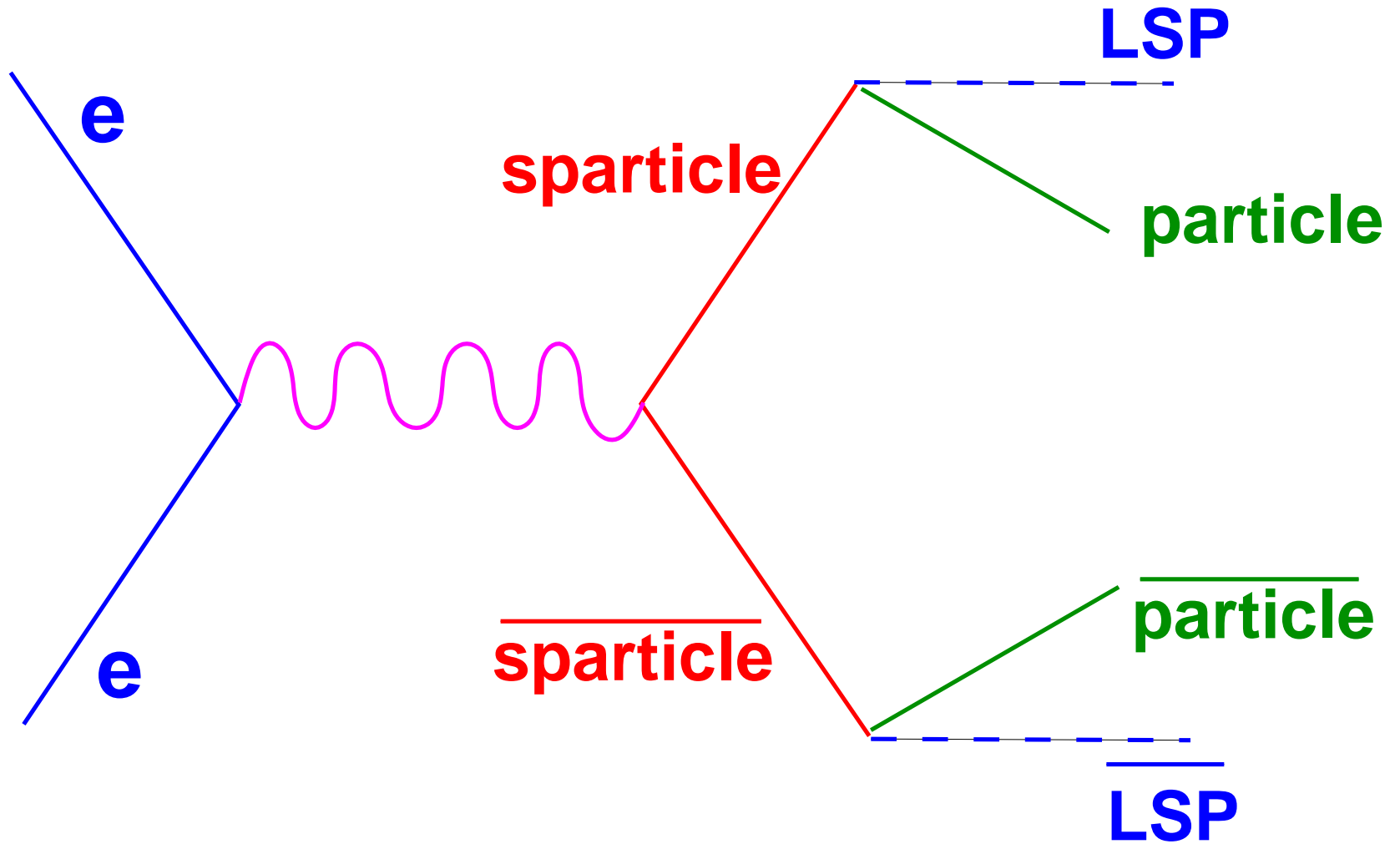
Limits to $\Gamma(H \rightarrow \gamma\gamma)$ and $\Gamma(H \rightarrow Z\gamma)$ in the region of interest for the LHC

Fermionic anomalies: flavour independent searches



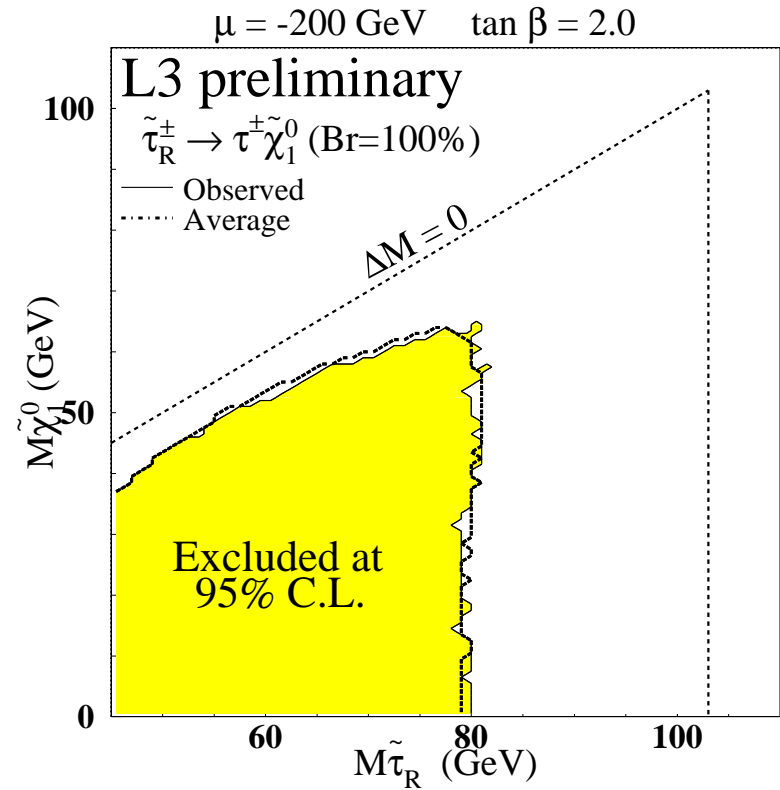
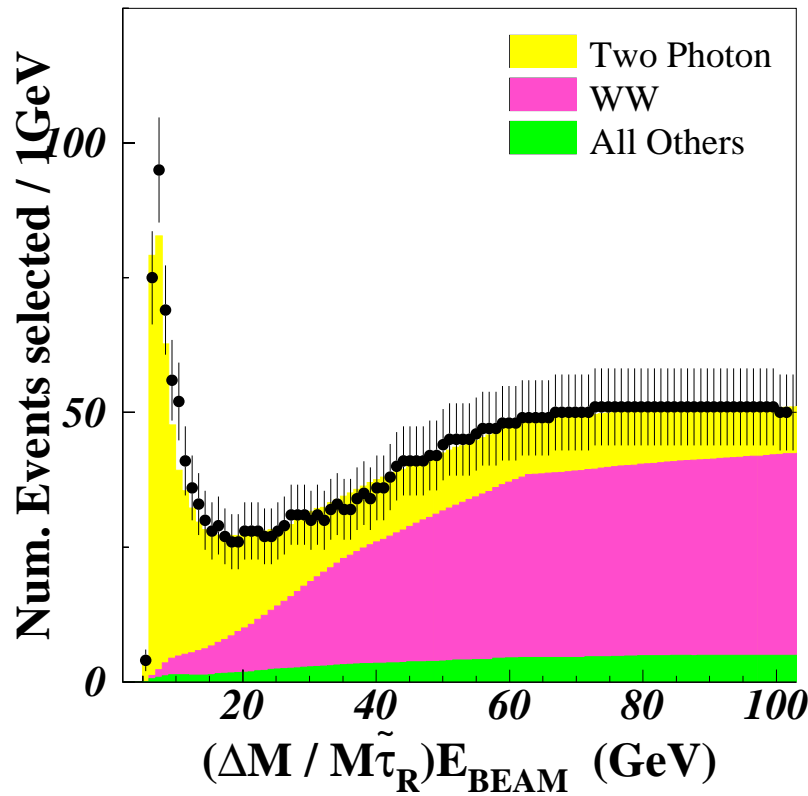
- ❖ Basic assumption: $H \rightarrow b\bar{b}$ not necessarily dominant
- ❖ Analysis strategy: eliminate b-tagging requirements
- ❖ $m_H > 97$ GeV ($BR(H \rightarrow q\bar{q}) = 100\%$, $\xi^2 = 1$)

SUSY searches



SUSY analyses: sleptons, NO EXCESS

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



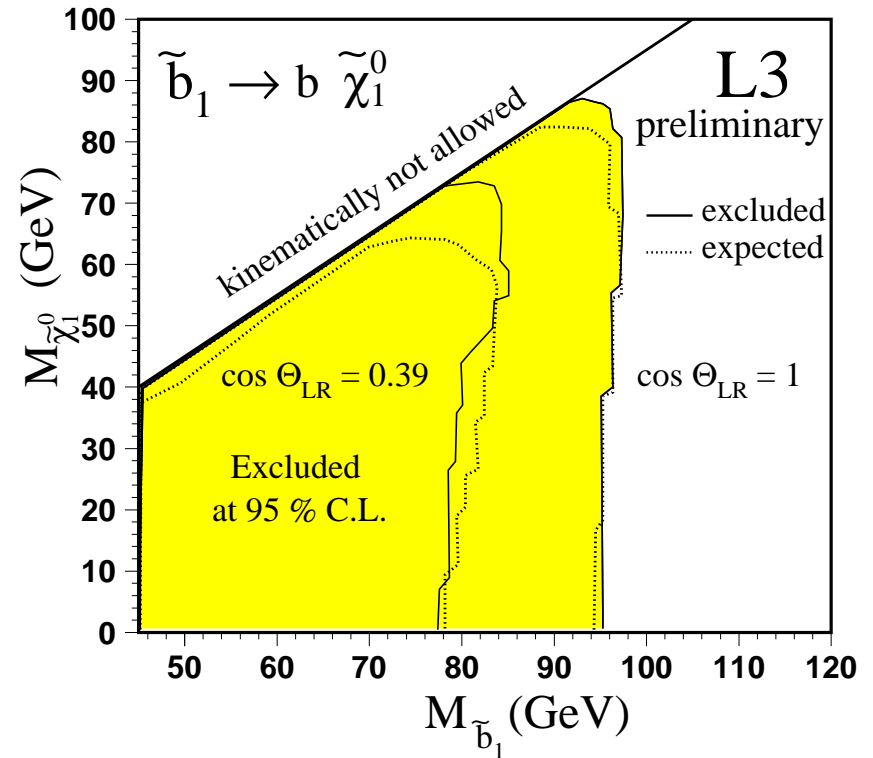
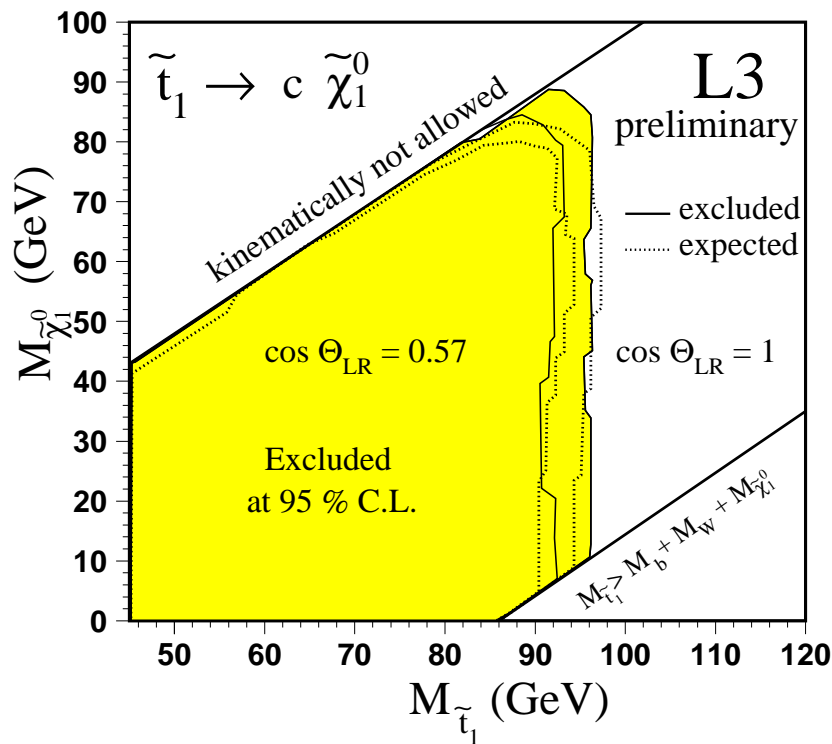
Main signature: acoplanar lepton pairs

$$m_{\tilde{e}} > 98 \text{ GeV};$$

$$m_{\tilde{\mu}} > 86 \text{ GeV};$$

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

$$e^+e^- \rightarrow \tilde{q} \tilde{q}^* \rightarrow q \tilde{\chi}_1^0 \bar{q} \tilde{\chi}_1^0$$



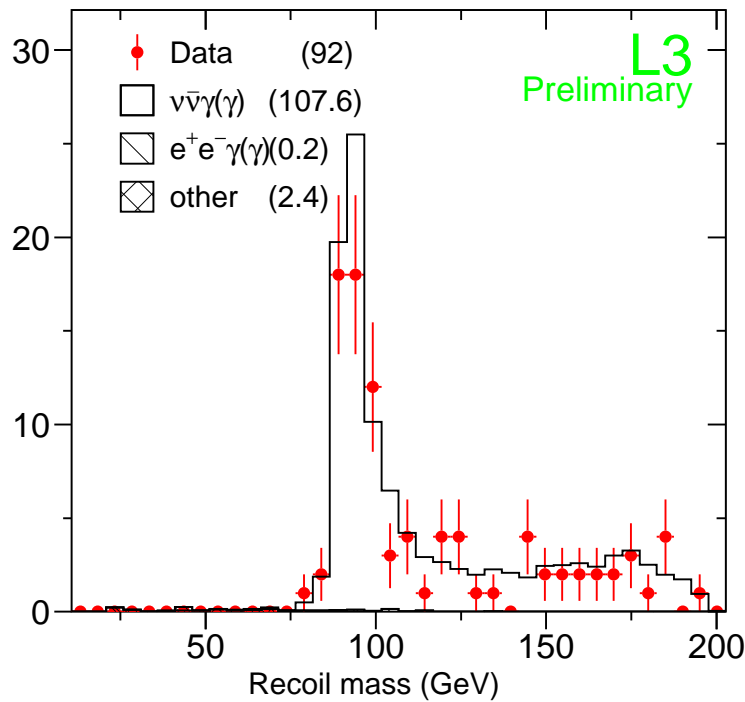
$$m_{\tilde{t}}, m_{\tilde{b}} > 95 - 97 \text{ GeV}$$

in the no mixing case

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

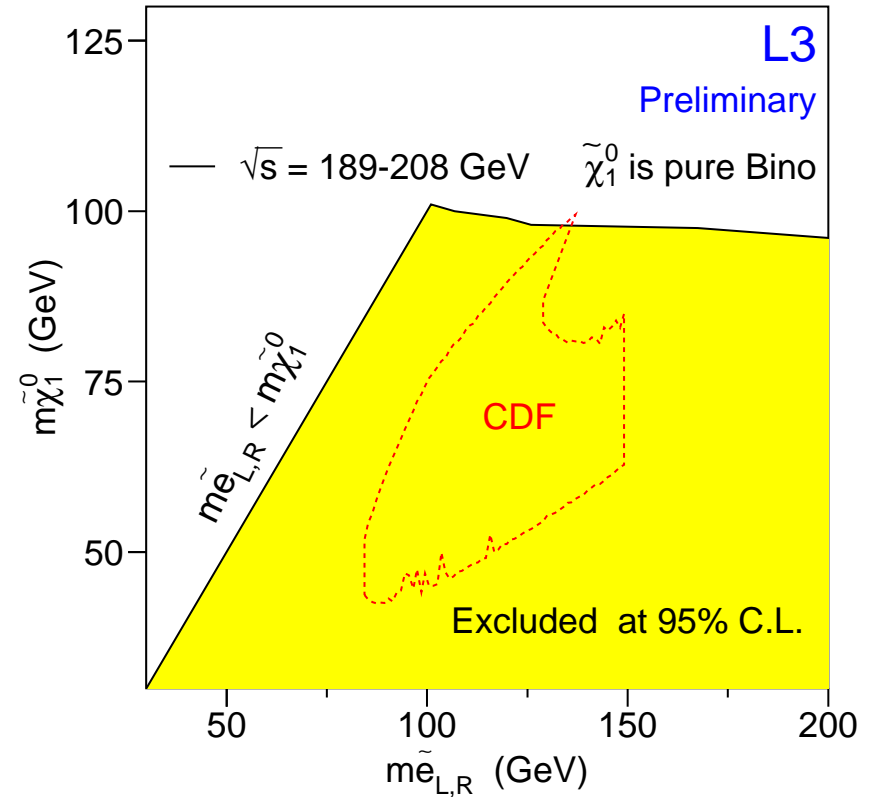
$$e^+e^- \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_1^0 \rightarrow \gamma \tilde{G} \gamma \tilde{G}$$

Two photons and missing energy



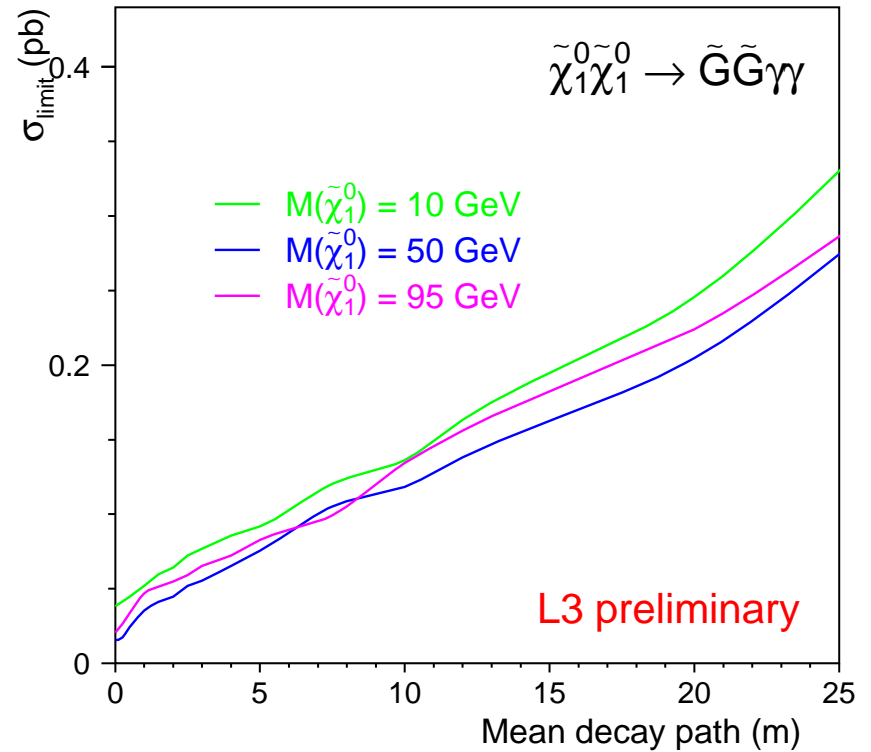
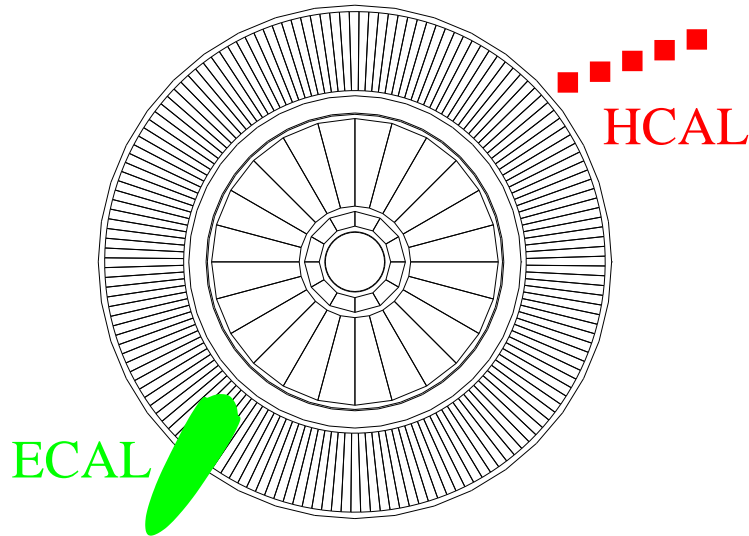
Acoplanar Photons

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

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

Decay length

Invisible (< 1 mm)

Short ($1\text{mm} < 5$ cm)

Medium (5 cm < 0.5 m)

Long (> 0.5 m)

-
-
-
-

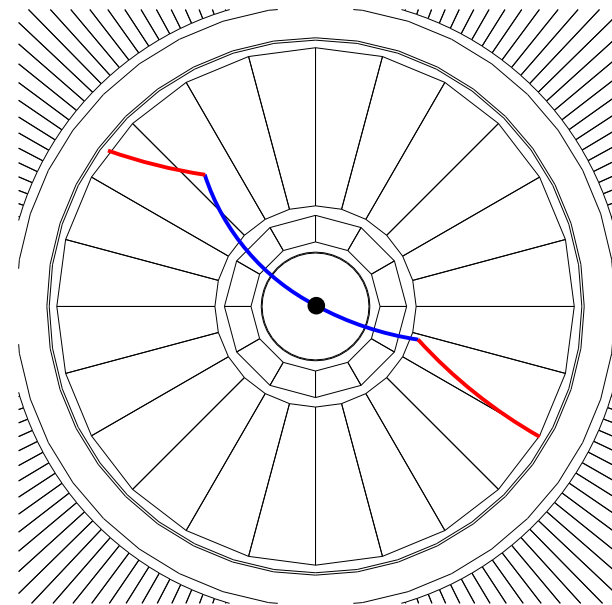
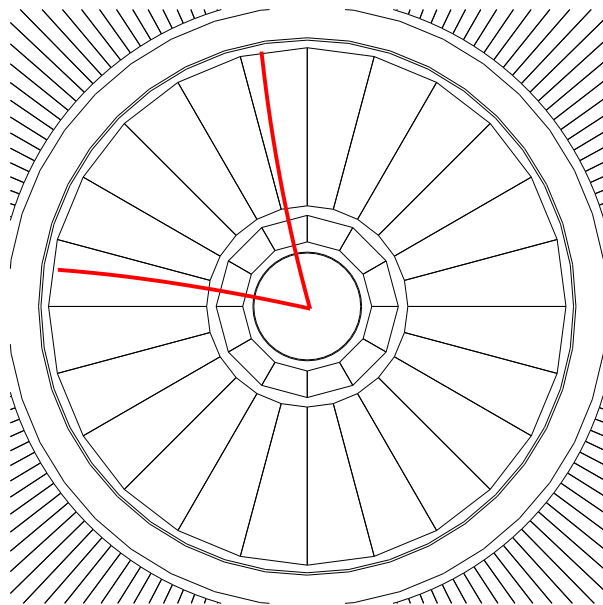
Event signature

Acoplanar leptons, missing energy

Non-zero impact parameter

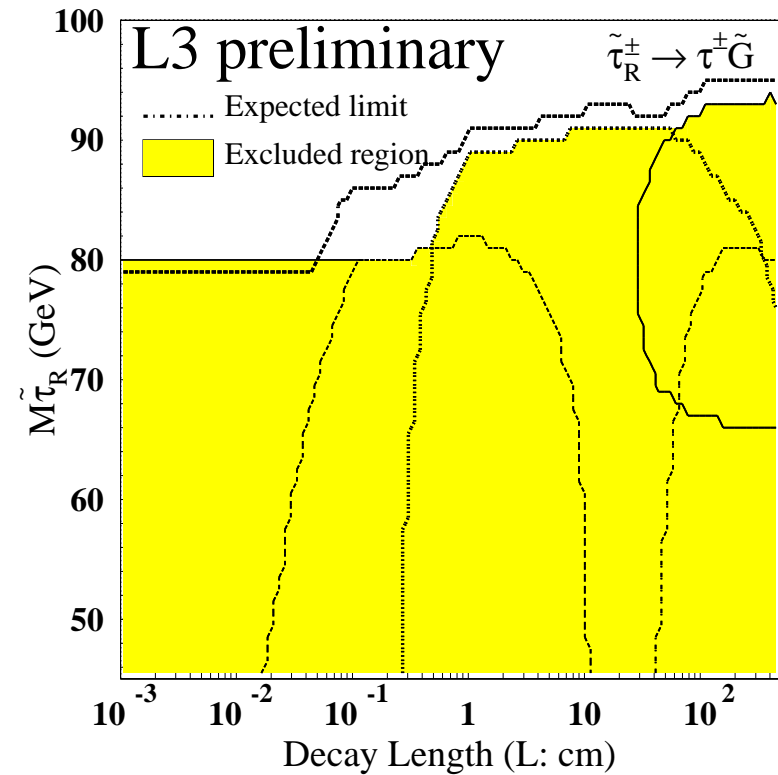
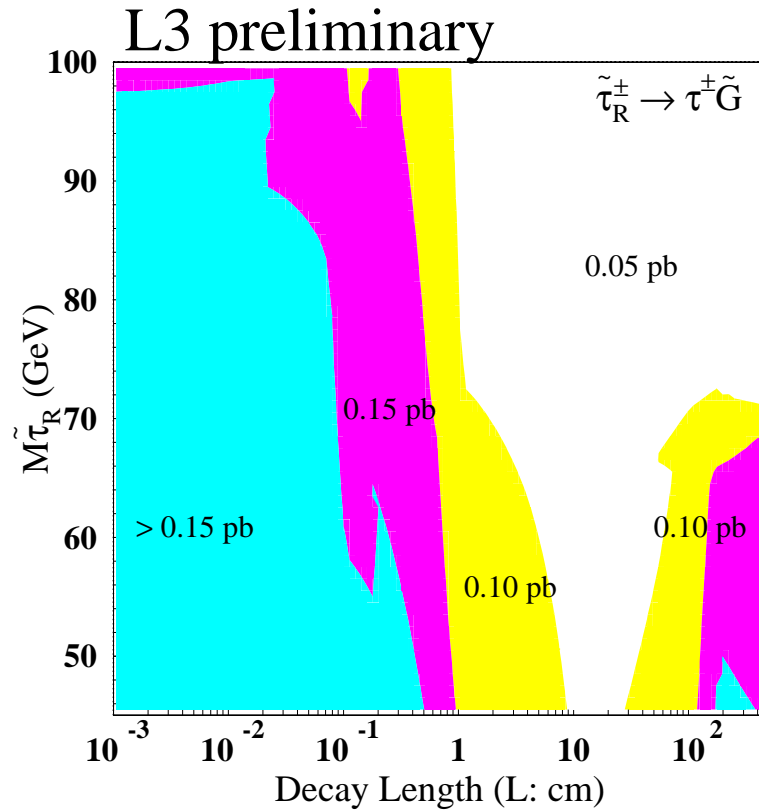
Decay vertex in tracking chamber

Heavy ionization



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

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



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

- ❖ Many (some of them new) analyses ongoing: EW studies, searches, two-photon physics, QCD.
- ❖ L3 activities will continue in 2003, as scheduled.