L3 Physics Results

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on behalf of the L3 Collaboration

- Searches For New Particles
- Z-Peak Data Analyses
- Two Photon Physics
- W and Z Bosons
- Data Archiving

LEP Jamboree

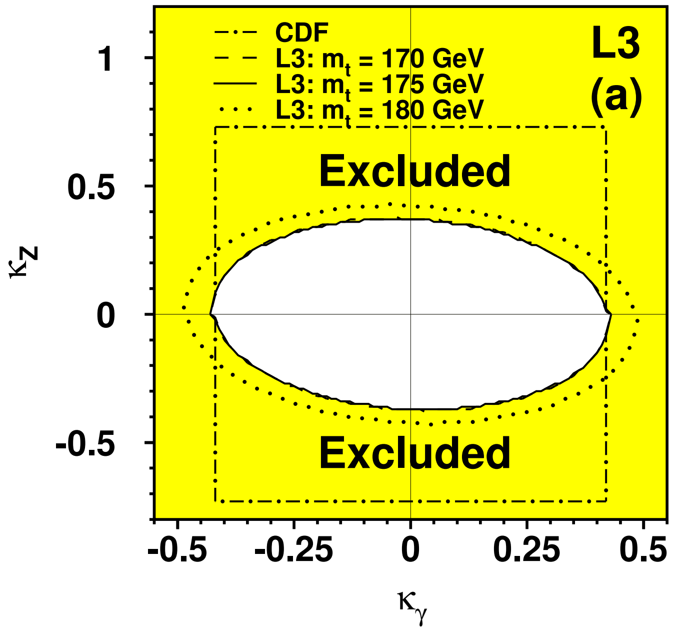
March 6, 2003

Searches For New Particles

(all limits at 95% CL)

Recently Published Results

- Single Top Production



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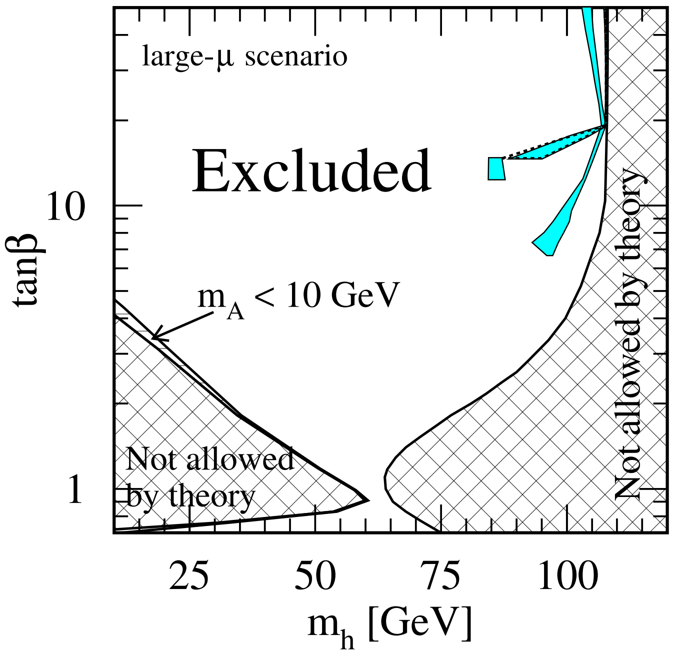
- MSSM Higgs Bosons



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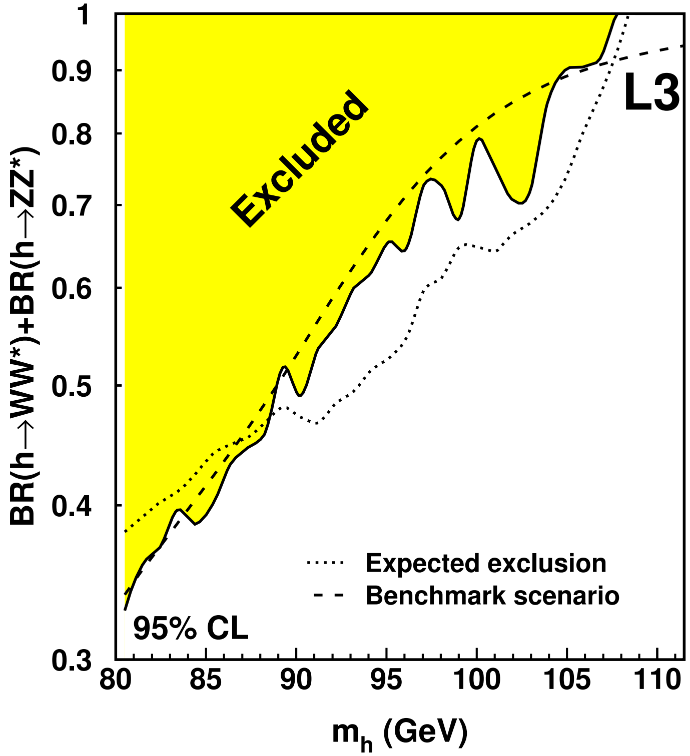
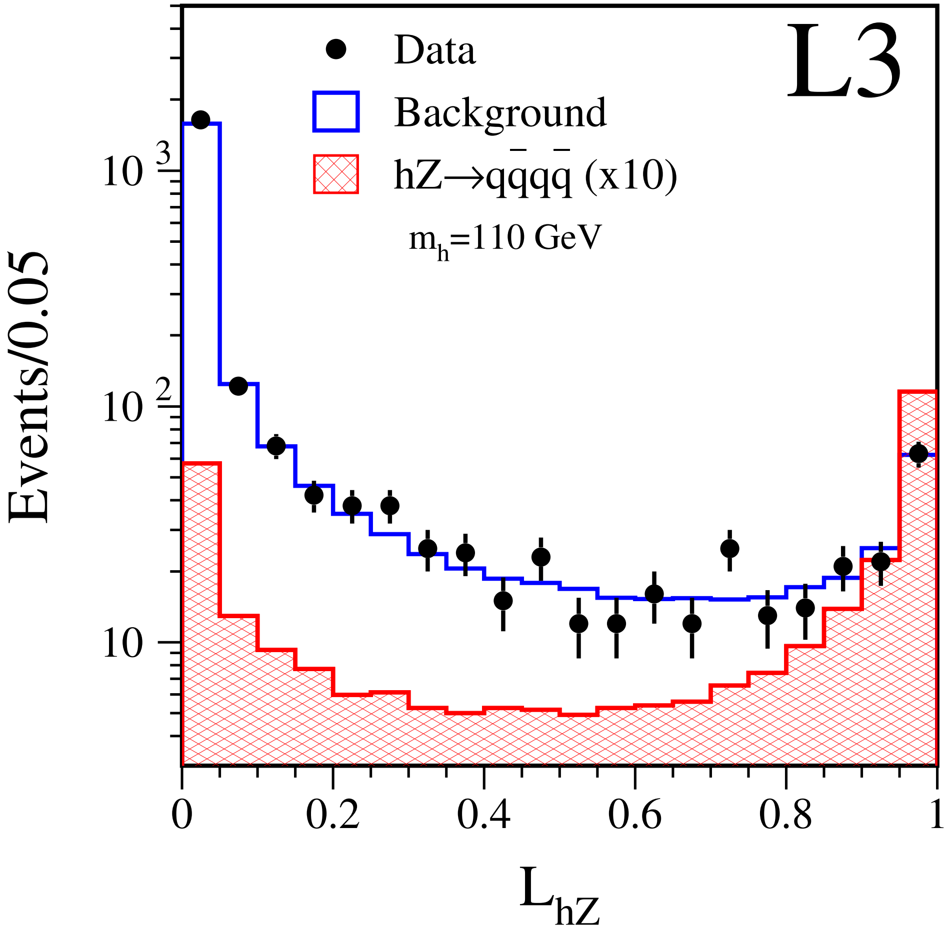
- $h \to WW^*/ZZ^*$

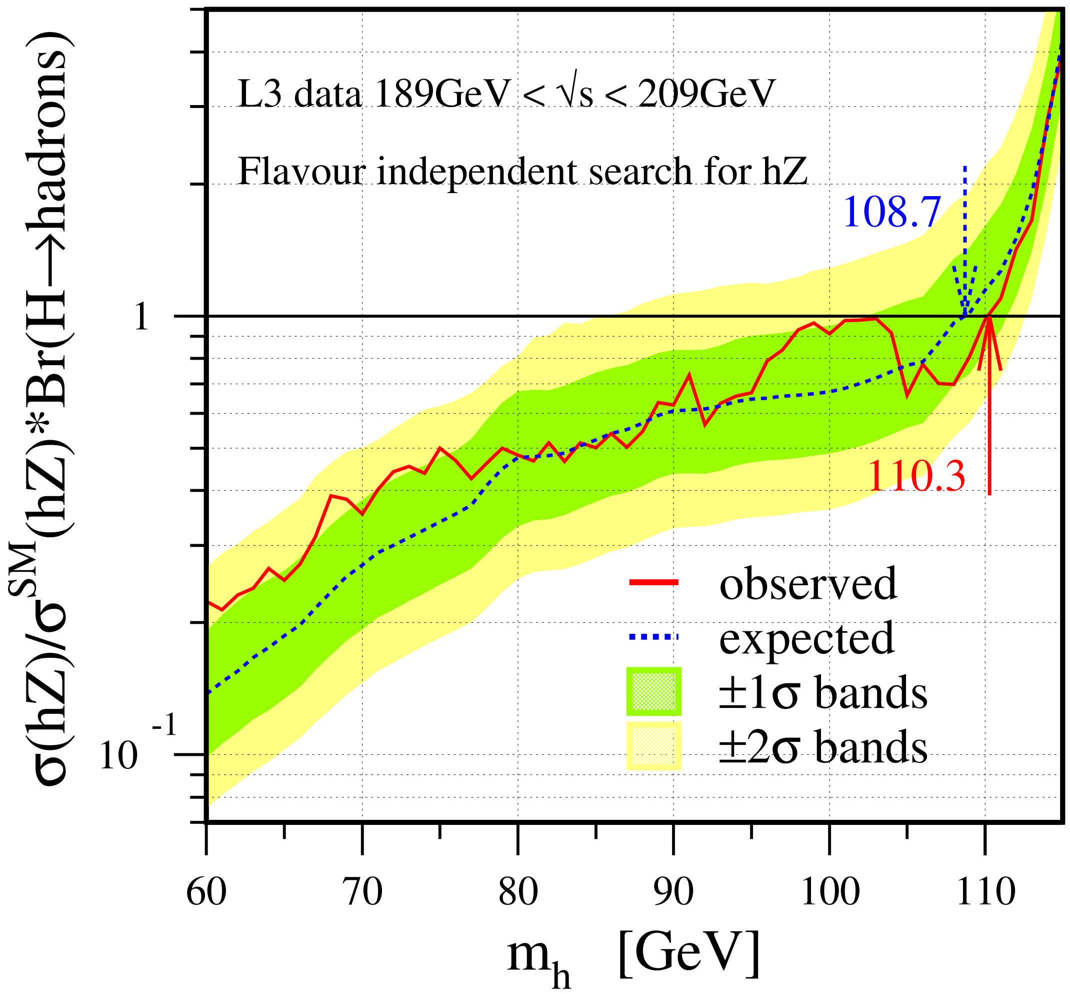


CERN-EP/2002-080

- Search for hadronic decays of the Higgs boson without assuming dominating $b\bar{b}$ decay $\longrightarrow$ no b-tag applied
- Production cross section $\sigma_{hZ} = \xi^2 \sigma_{HZ}^{SM}$



- No excess in data observed
- Derive exclusion limits:

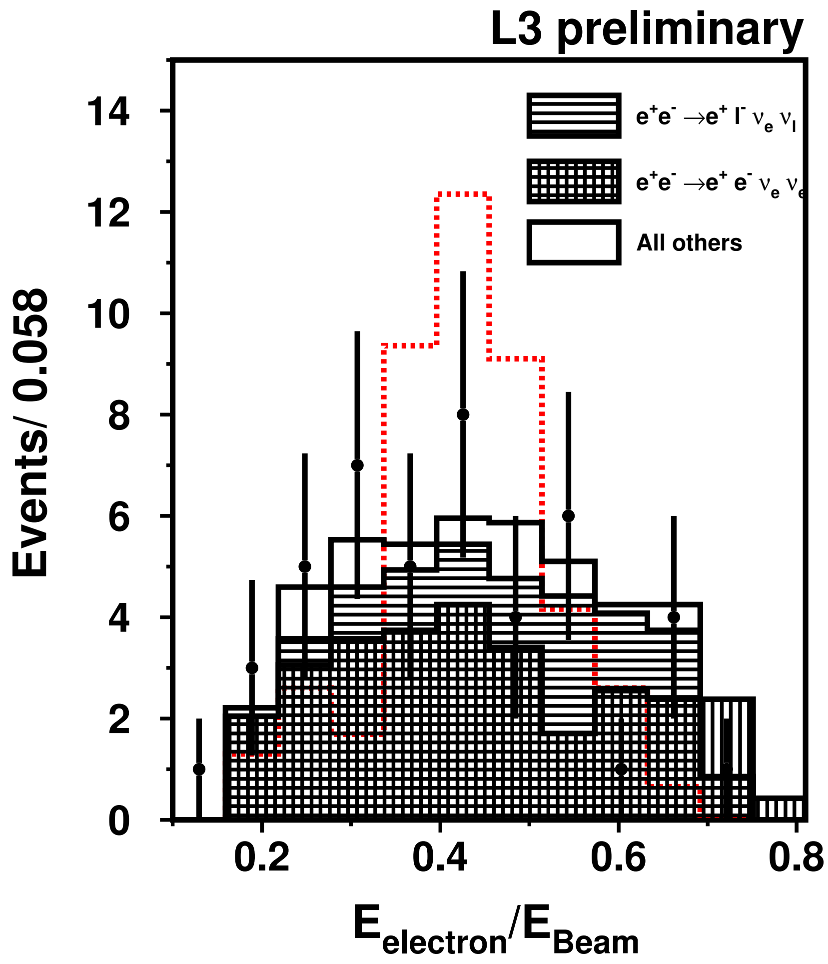


- for $\sigma_{hZ} = \sigma_{HZ}^{SM} \longrightarrow m_h > 110.3$ GeV

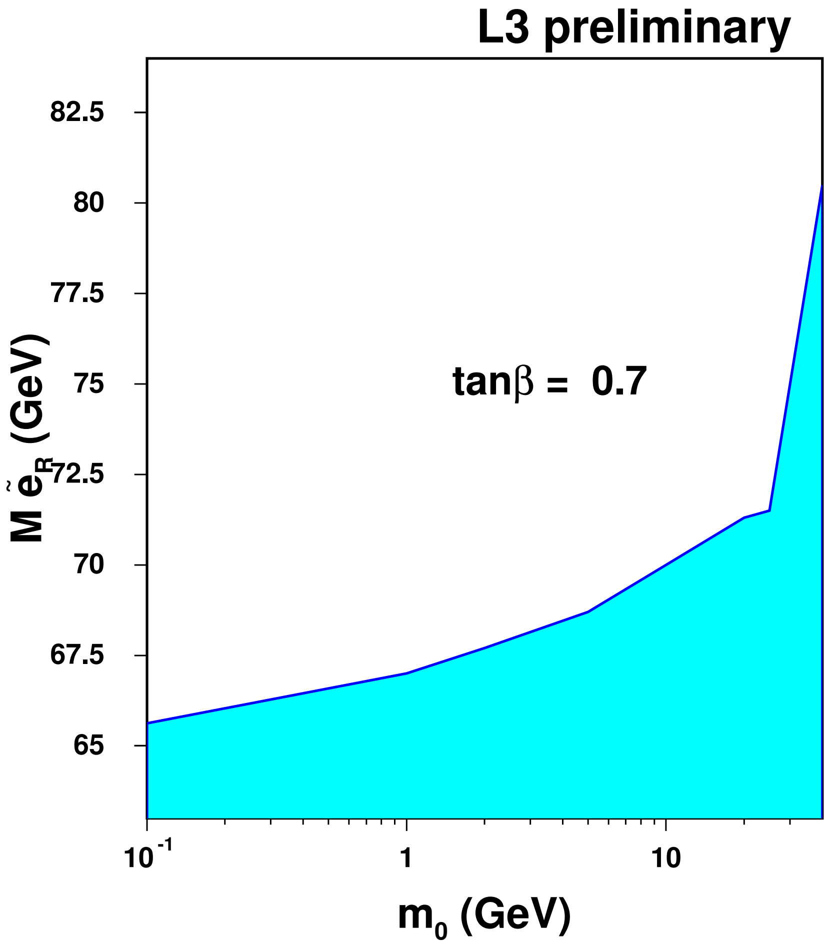
- $\tilde{e}_R$ degenerate with $\tilde{\chi}^0_1$
- Difficult point in parameter space
- Look for $e^+e^- \longrightarrow \tilde{e}_L\tilde{e}_R$
- Decay $\tilde{e}_R \longrightarrow \tilde{\chi}^0_1$ e invisible $\longrightarrow$ low E_e
- Tag events with $\tilde{e}_L \longrightarrow \tilde{\chi}^0_1$ e

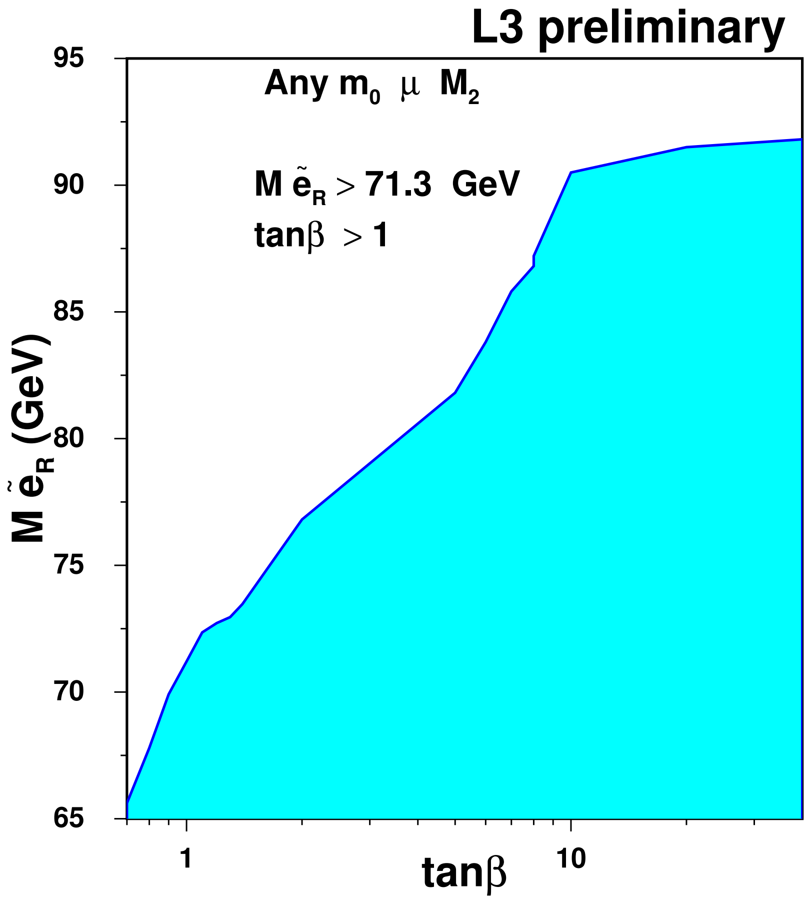
- Detector signal: single electron
- Main backgrounds: $e\nu W, ee\nu\nu$

- Data at $\sqrt{s} > 192$ GeV



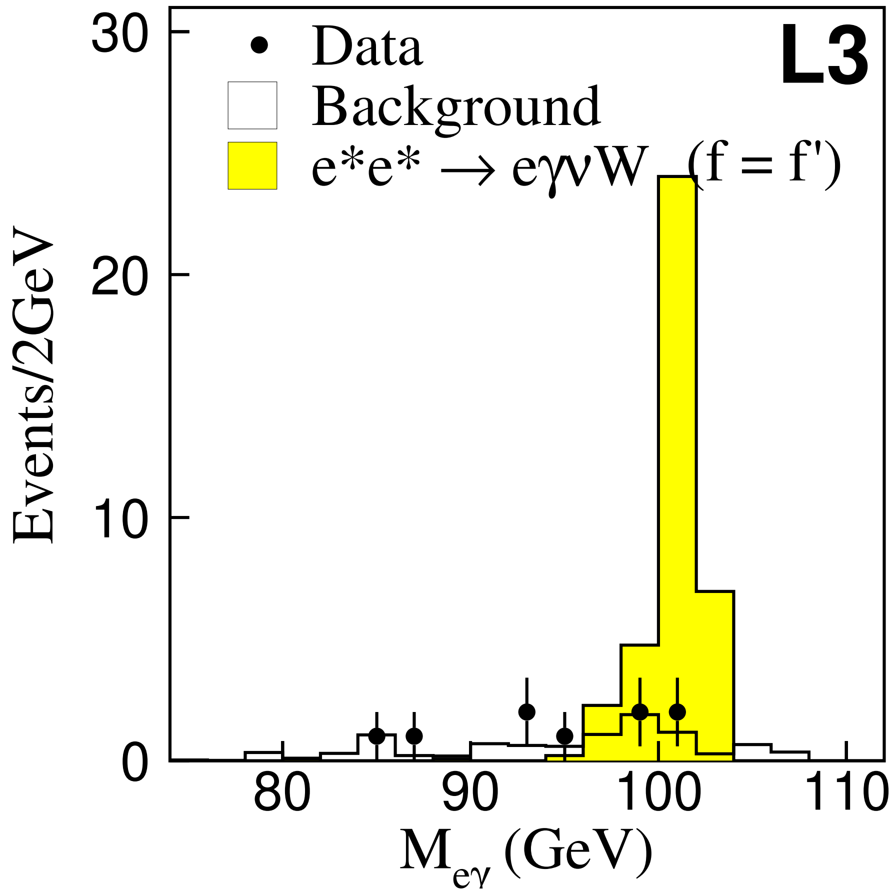
- From degenerate $\tilde{e}_R$ searches and scalar electron results:

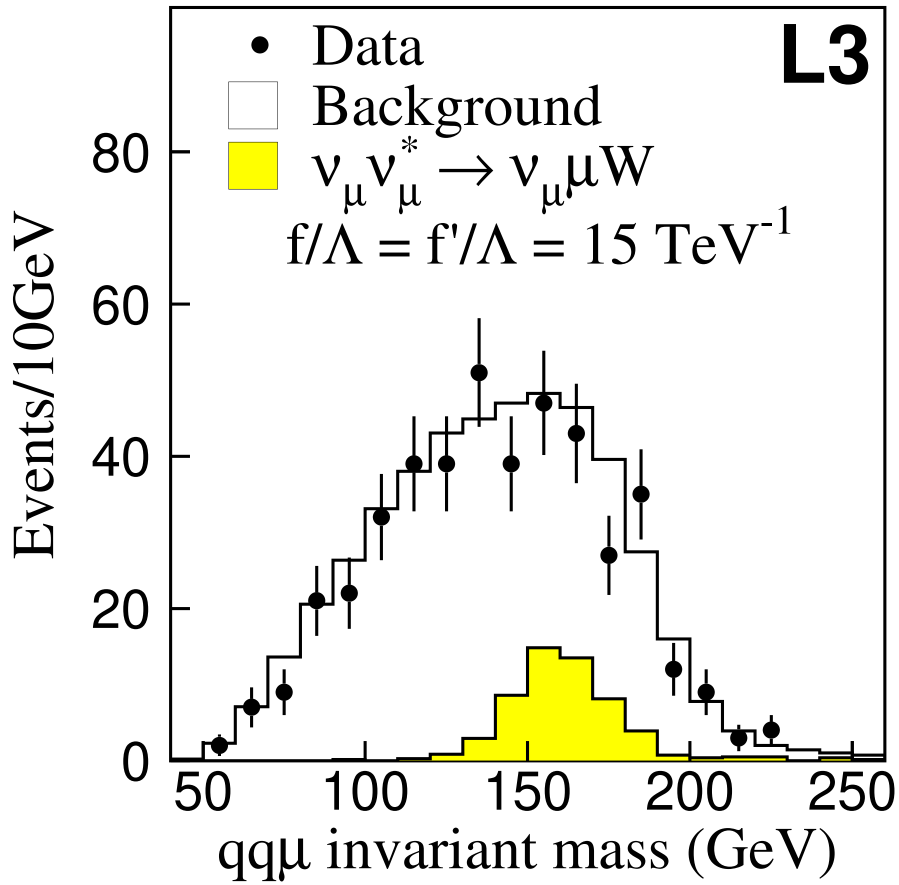




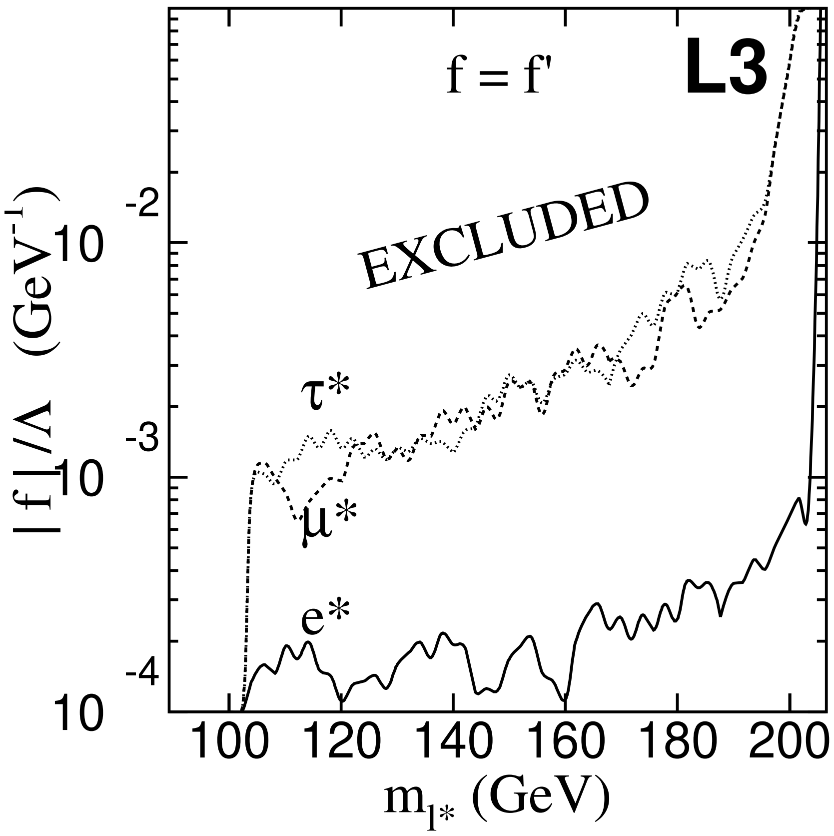
- $M_{\tilde{e}_R} > 71.3$ GeV for $\tan\beta > 1$ (95% CL)

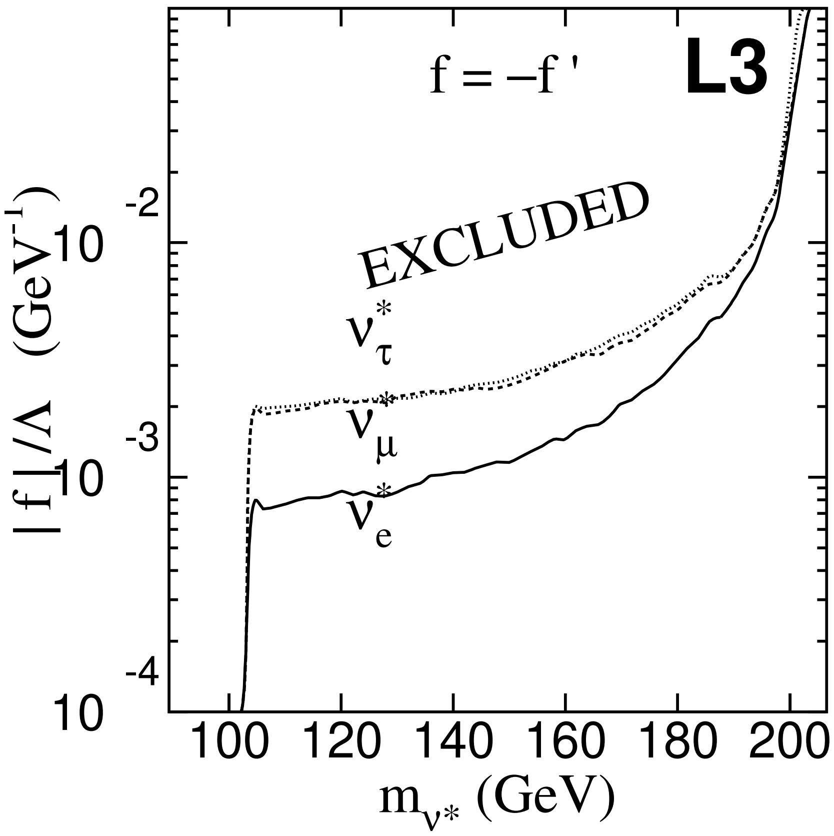
- U(1) and SU(2) coupling strength f/Λ and f'/Λ $\longrightarrow$ affect production and decay
- Possible decays: radiative $\ell^* \longrightarrow \ell\gamma$, $\nu^* \longrightarrow \nu\gamma$
  CC $\ell^* \longrightarrow \nu W$, $\nu^* \longrightarrow \ell W$
  NC $\ell^* \longrightarrow \ell Z$, $\nu^* \longrightarrow \nu Z$
- Search for all combination of decays in single and pair production





- All data analysed → no signal found → limits on masses and couplings

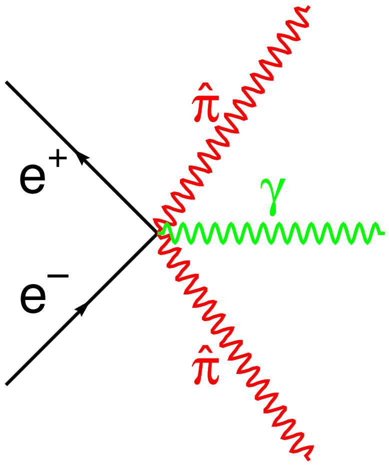




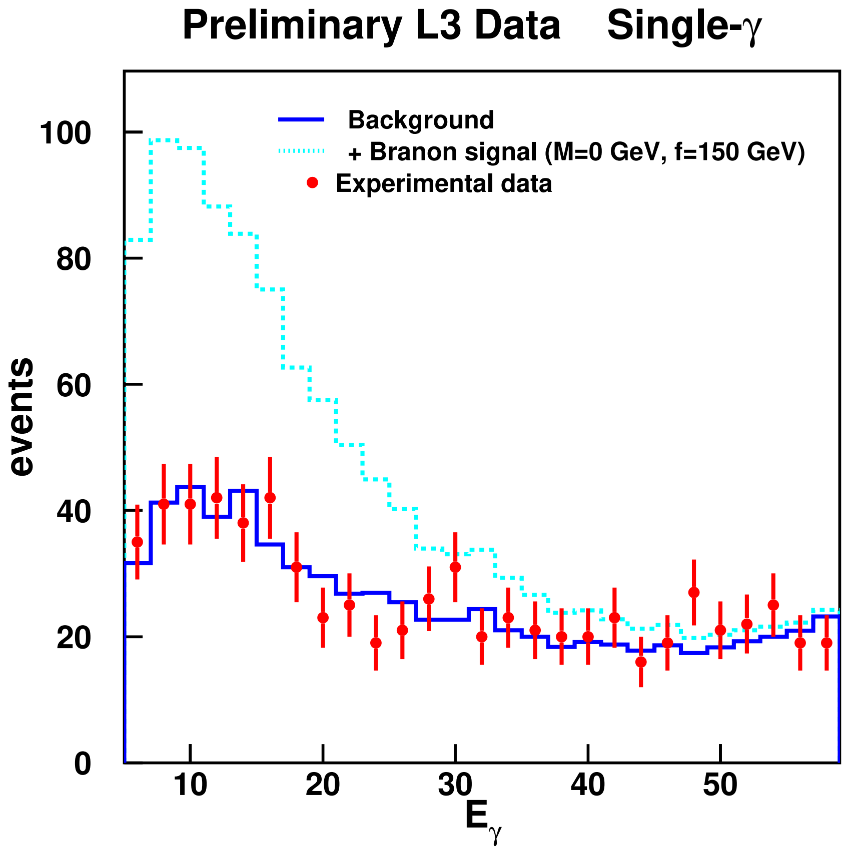
- 95% CL mass limits (in GeV):

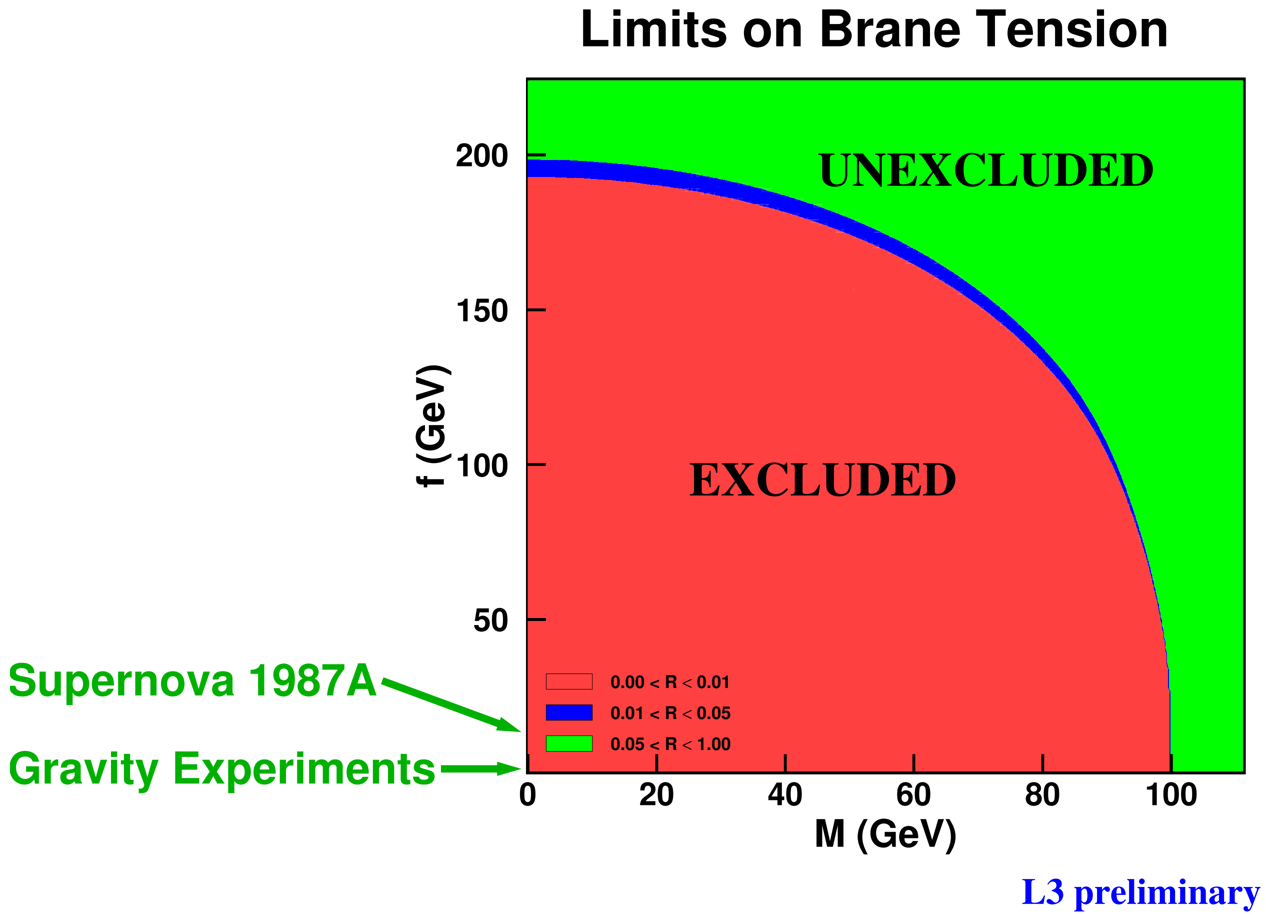
	$m^{f=f'}$	$m^{\text{any } f,f'}$		$m^{f=-f'}$	$m^{\text{any } f,f'}$
e^*	102.8	96.5	ν_e^*	102.6	101.5
μ^*	102.8	96.6	ν_μ^*	102.6	101.4
τ^*	102.8	95.6	ν_τ^*	102.6	91.3

- Extra spatial dimensions $\longrightarrow$ graviton
  ▷ extensively studied at LEP (from $e^+e^- \longrightarrow \gamma\gamma$: $M_s > 0.8 - 1.0$ TeV)
- But also branons $\hat{\pi} \longrightarrow$ brane fluctuations
- Gravitation scale M_F and brane tension scale f
- Signs of extra dimensions $\longrightarrow$ gravitons for $f \gg M_F$ and branons for $f \ll M_F$
- Effective theory with couplings to SM particles (hep-hp/0212269)
  $\longrightarrow$ single photon production $e^+e^- \longrightarrow \hat{\pi}\hat{\pi}\gamma$



- Fit single-γ double-differential cross section:

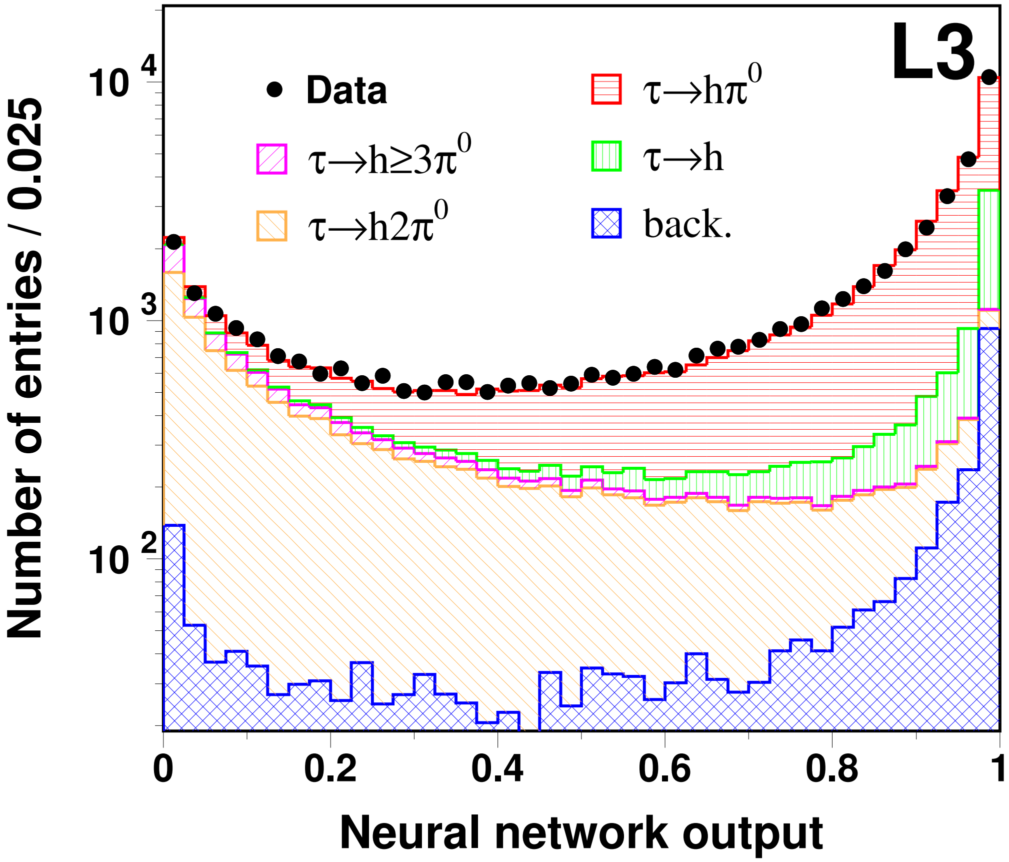




- Less stringent limits from single-Z production

Z-Peak Data Analyses

- τ decays into 1 or 3 charged hadrons and nπ^0
- NN separation for each decay channel

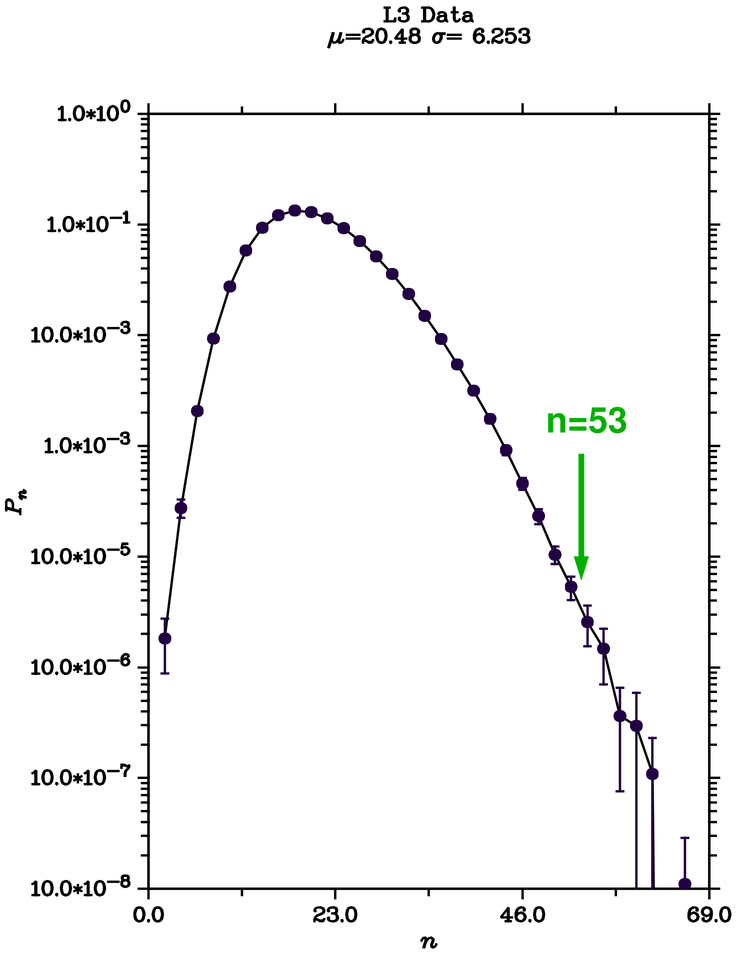


- From simultaneous fit:

τ decay channel	BR [%]
ν_τh	12.08±0.12±0.09
ν_τh π^0	25.87±0.16±0.10
ν_τh $2\pi^0$	9.07±0.15±0.17
ν_τh $\geq 3\pi^0$	1.33±0.11±0.10
ν_τ3h	9.13±0.11±0.12
ν_τ3h π^0	4.80±0.12±0.07
ν_τ3h $\geq 2\pi^0$	0.71±0.08±0.04

- Largely improves and extends our previous measurement from 1994

Moments of Particle Multiplicity Distribution



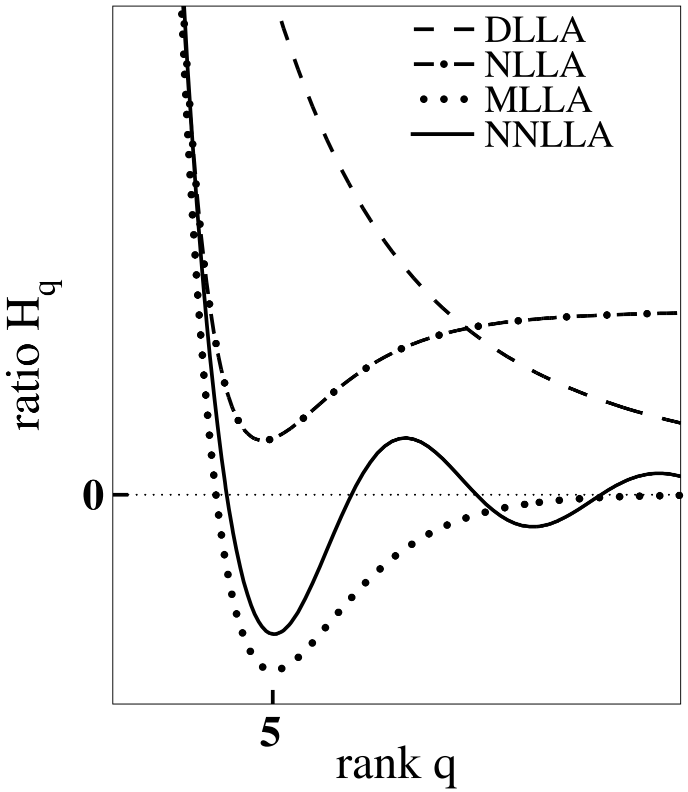
- Multiplicity distribution P(n) analysed in terms of factorial moments and cumulants

$$F_q = \frac{\Sigma_{n=0}^{\infty} n(n-1)\ldots(n-q+1)P(n)}{\left(\Sigma_{n=1}^{\infty} nP(n)\right)^q}$$

$$K_q = F_q - \Sigma_{m=1}^{q-1} \frac{(q-1)!}{m!(q-m-1)!} K_{q-m} F_m$$

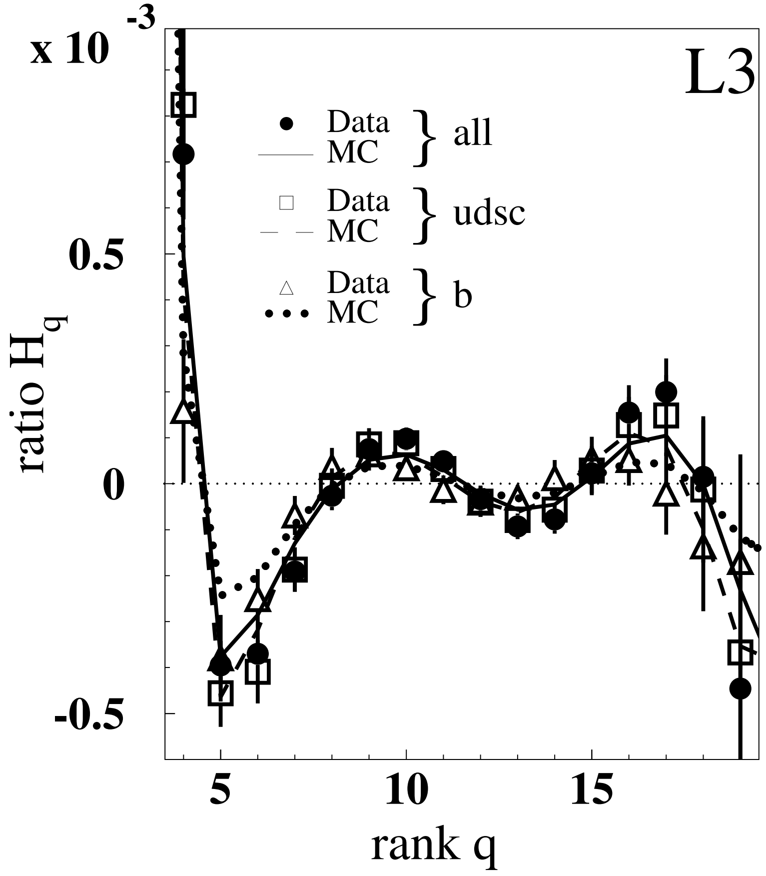
- $F_q \longrightarrow$ correlation between q or less particles
- $K_q \longrightarrow$ genuine q-particle correlations
- Both increase with q

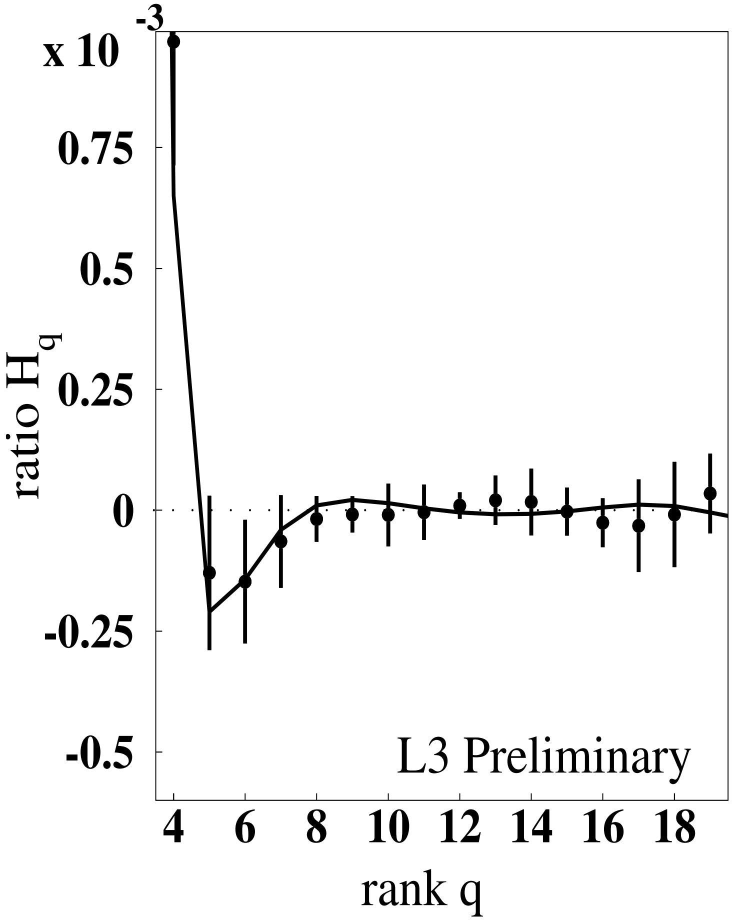
  $\longrightarrow$ take ratio $H_q = K_q/F_q$



- pQCD predicts oscillations of H_q

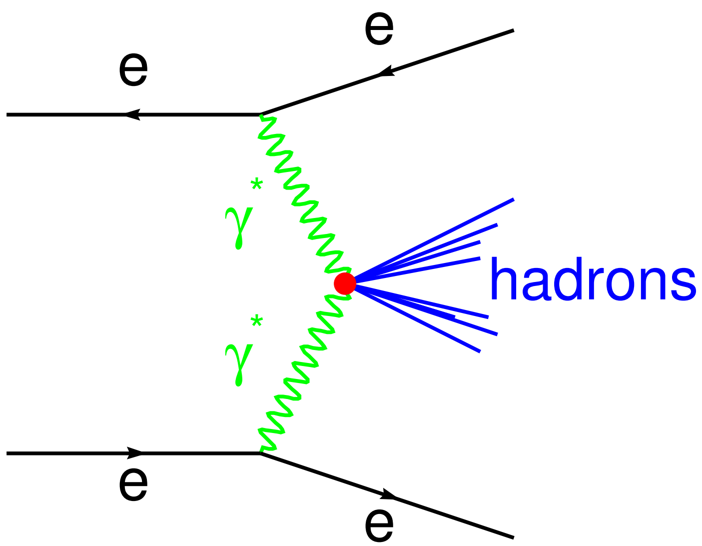
- But: oscillations may be a consequence of truncation!
  - truncation at n=53
  - no truncation



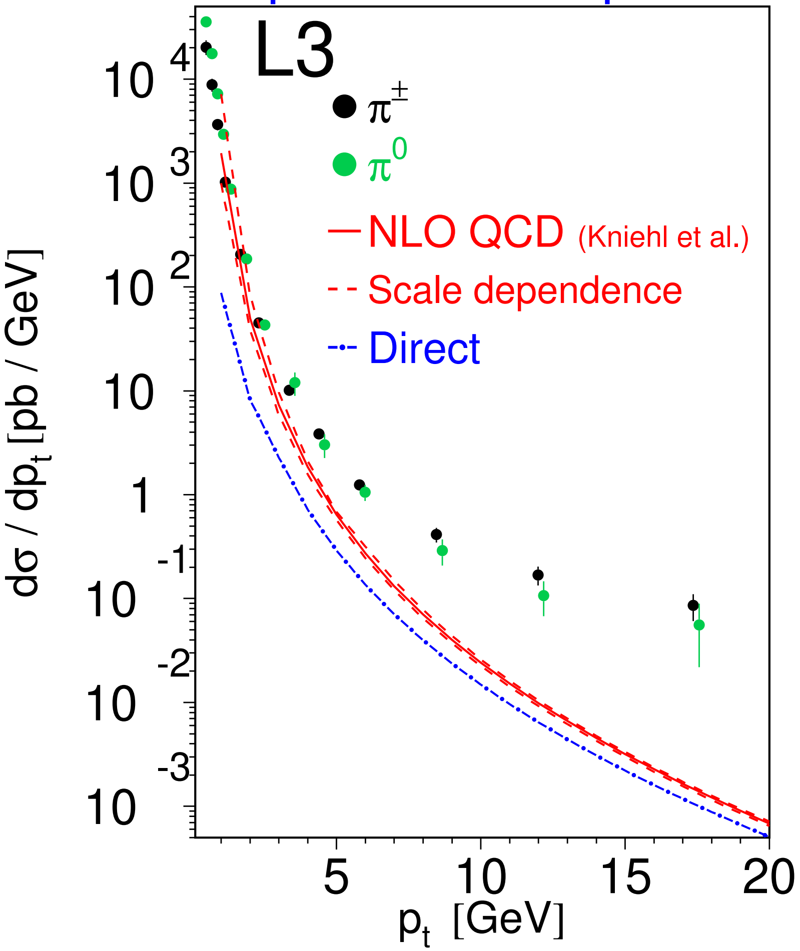


- Effect reproducible with analytical negative binomial distribution
- First minimum at $q = 5 \rightarrow$ incompatible with DLLA and NLLA
- Data can not distinguish between MLLA (non-oscillating) and NNLLA (oscillating)

Two-Photon Physics



- Hadrons with high p_t are produced by direct $\gamma^*\gamma^* \longrightarrow q\bar{q}$ or QCD processes
- Inclusive production of pions:



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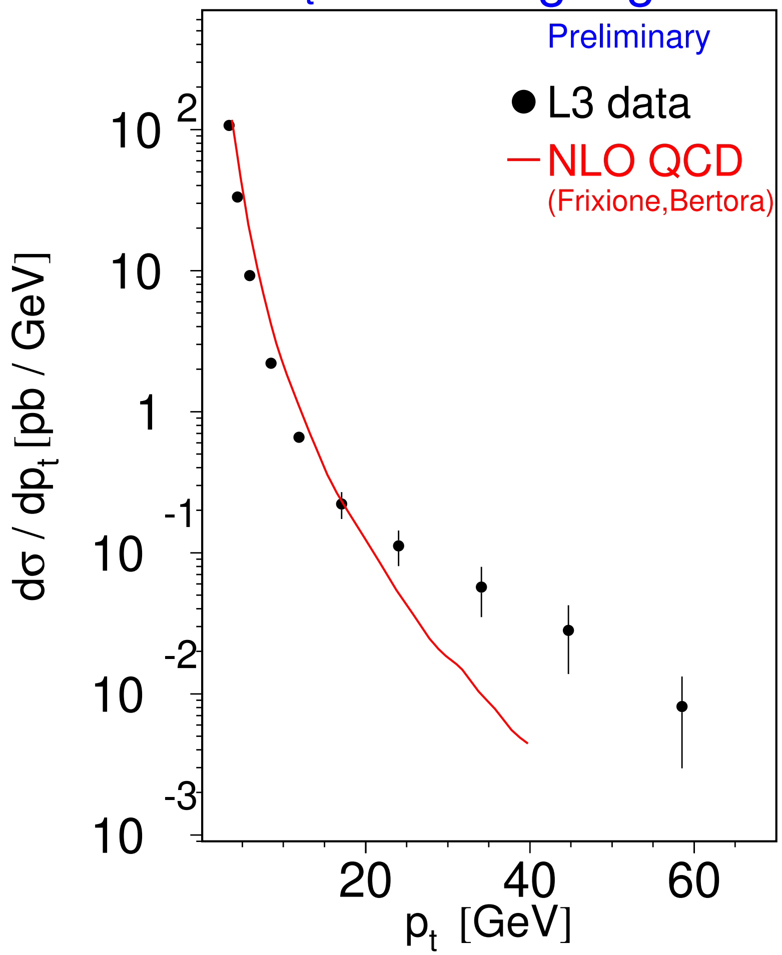
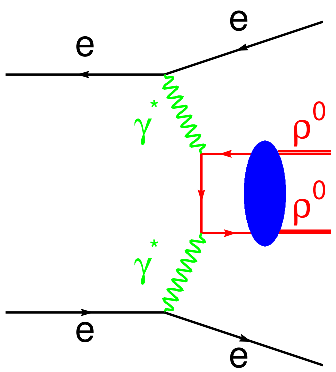
- Compare also jet production
- Jets with k_t clustering algorithm

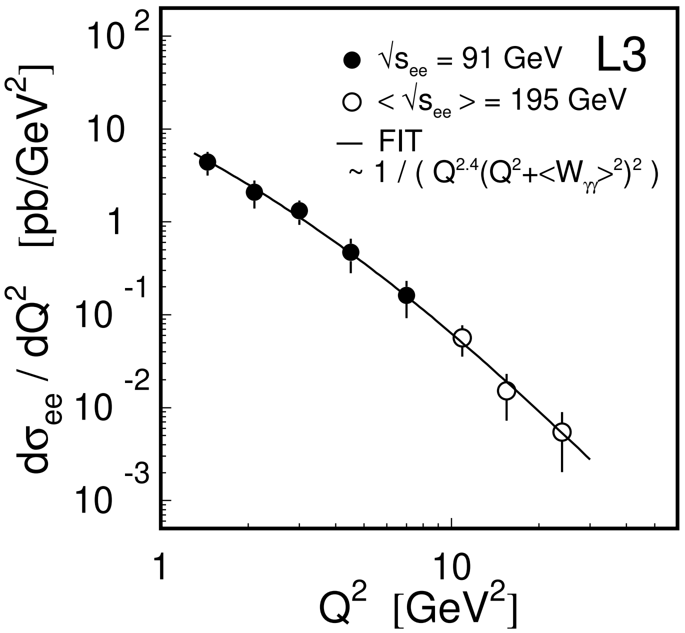


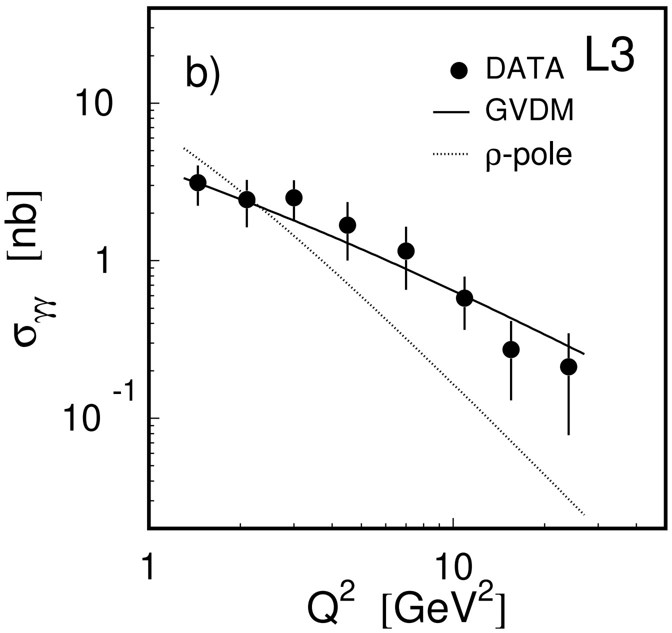
- Similar disagreement at high p_t
- Not to forget the 5σ excess in $e^+e^- \longrightarrow e^+e^-b\bar{b}X\ldots$

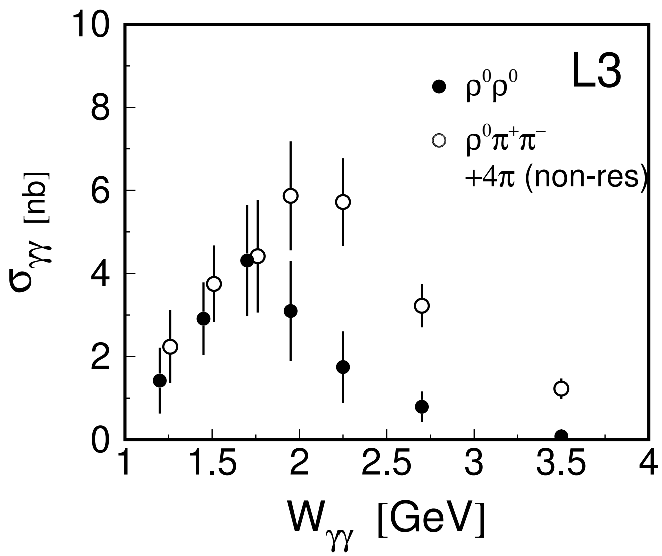
Exclusive $\rho^0\rho^0$ Production in Two-Photon Collisions



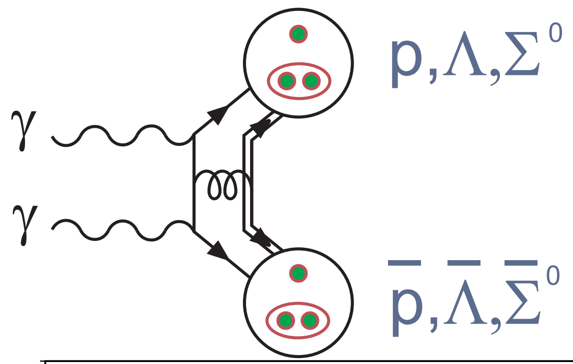
- $\gamma^*\gamma^* \to \rho^0\rho^0$ cross section at high $Q^2 > 1.2$ GeV^2



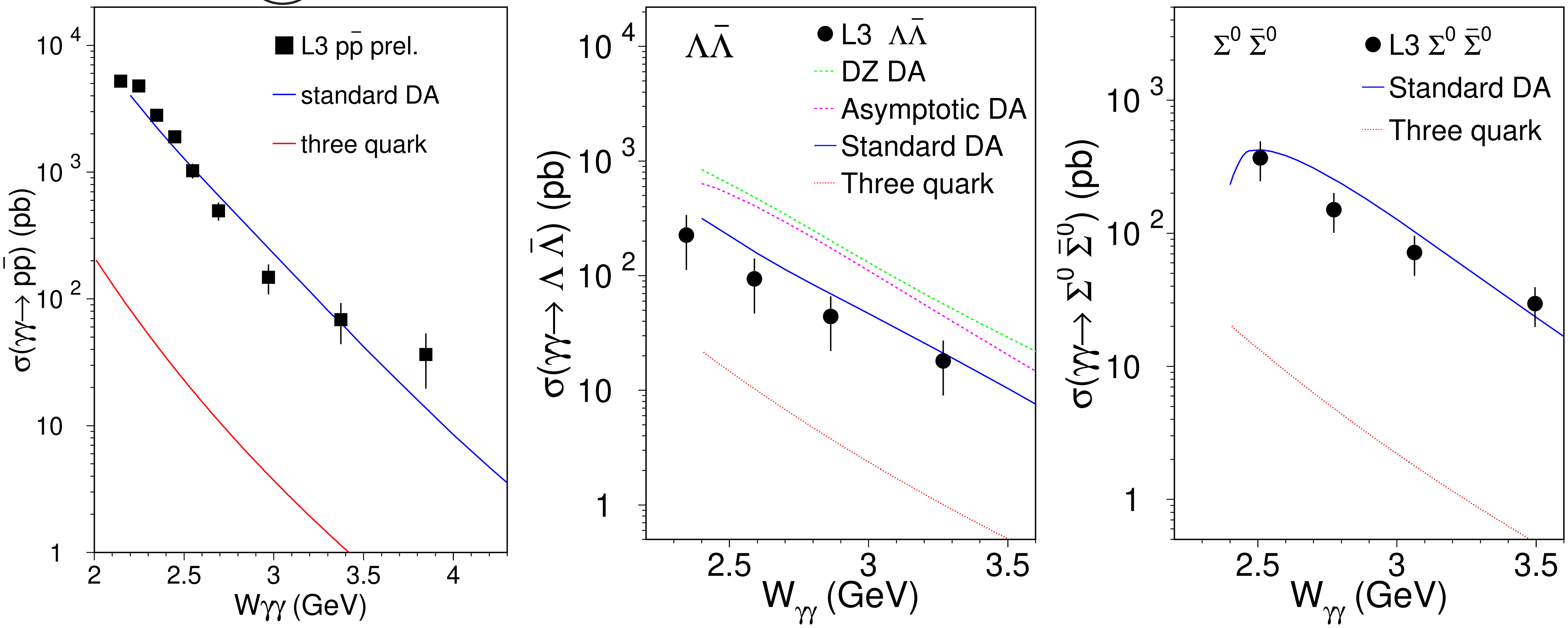




- Q^2 dependence of the fit to $d\sigma_{ee}/dQ^2$ is taken from QCD calculations (Diehl et al.)
- $\sigma_{\gamma\gamma}$ well described by generalised VDM (GVDM)
- $\rho^0\rho^0$ threshold behaviour as in measurements at $Q^2 \approx 0$



- Describe quark content of baryons with three-quark or di-quark model
- Good agreement for standard di-quark distribution amplitude (DA) for $W_{\gamma\gamma} > 2.5$ GeV



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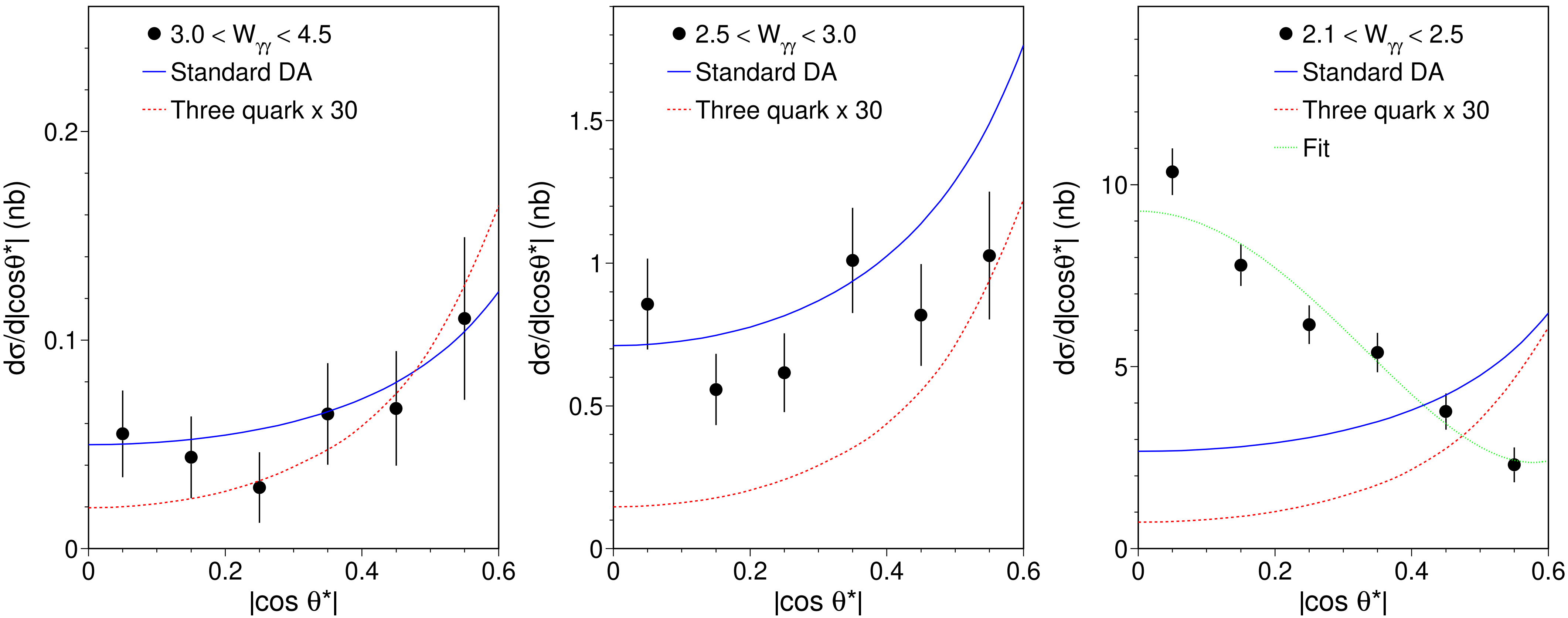
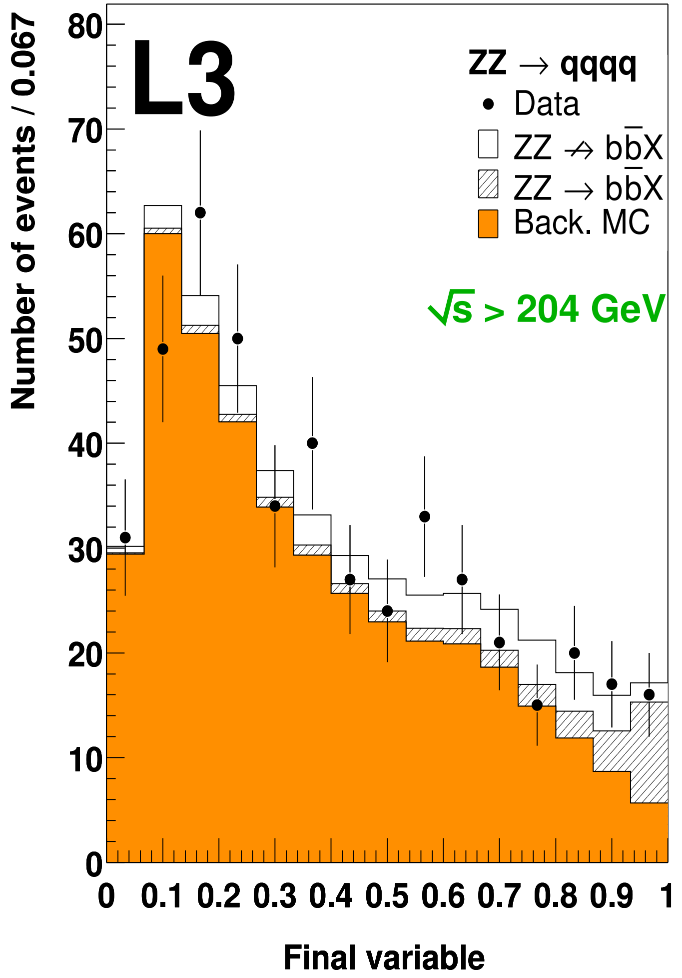
Differential Distributions for $p\bar{p}$ Production

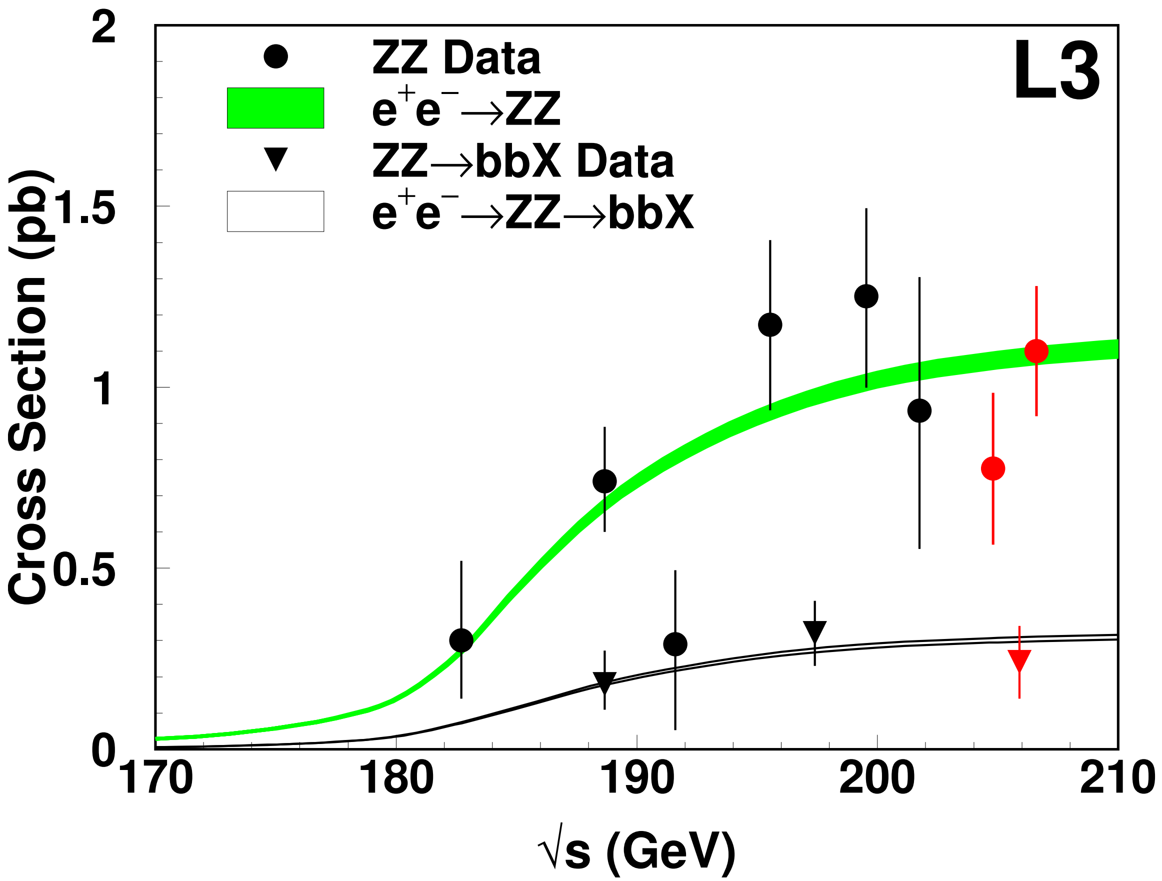


- Di-quark model describes high and medium $W_{\gamma\gamma}$ region
- Different production mechanism for $W_{\gamma\gamma} < 2.5$ GeV
- Fit to data with spherical harmonics $Y_0^0, Y_0^2, Y_1^2, Y_2^2$
- Main contributions from: Y_0^2 (92%) and Y_0^0 (8%)

W and Z Bosons

- Analysis of last data set finalised

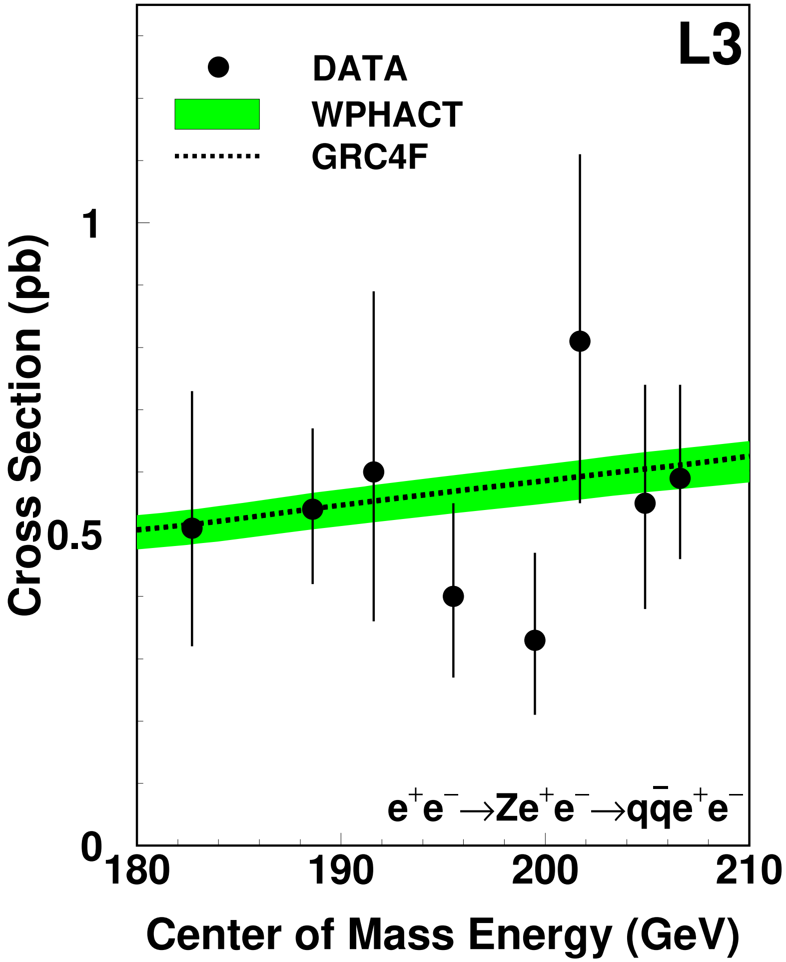




- Ratio to SM expectation: $R = 0.93 \pm 0.08 \pm 0.06$
- Theory uncertainty is 2%

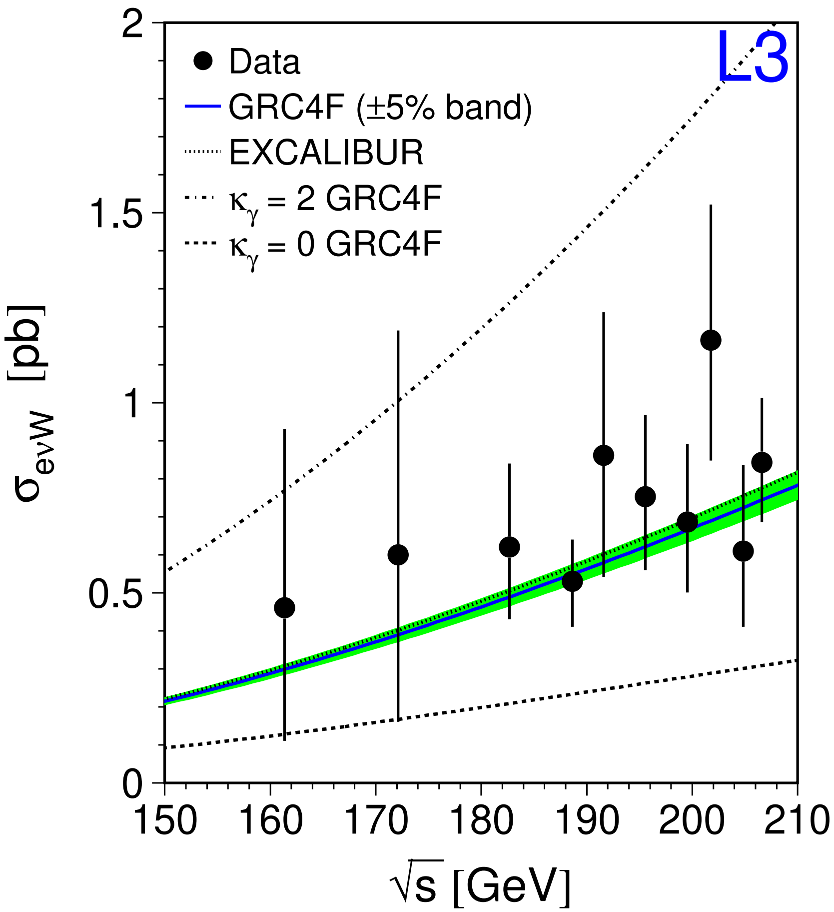
Published Results on Single Boson Production

- Zee Cross Section



CERN-EP/2002-103

- Single W Production and WWγ Gauge Couplings



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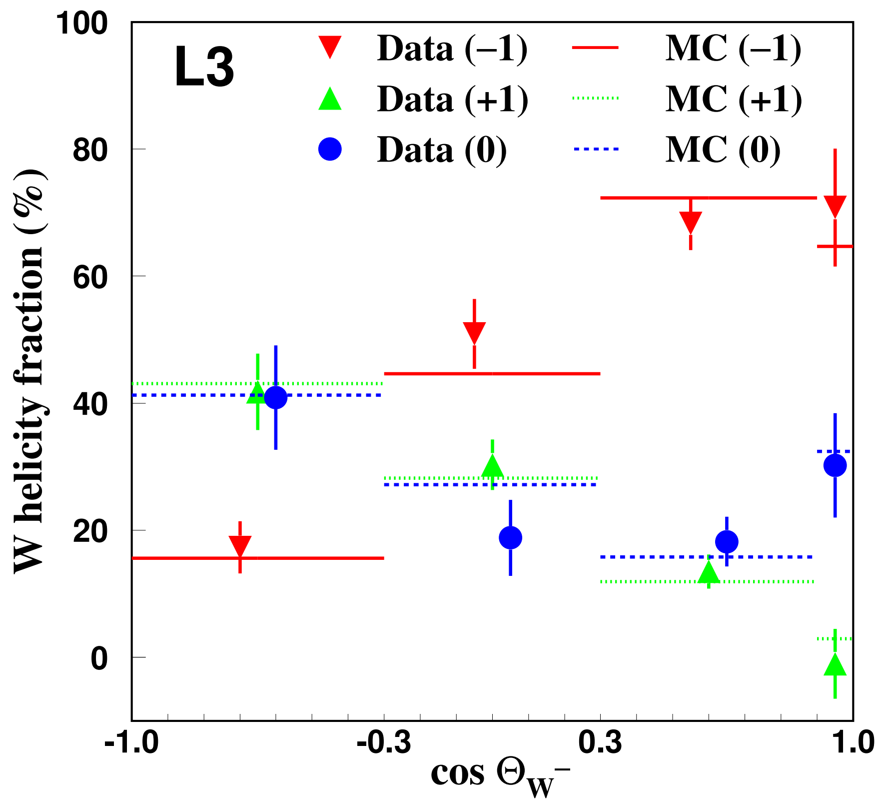
- Measurement of W Polarisation

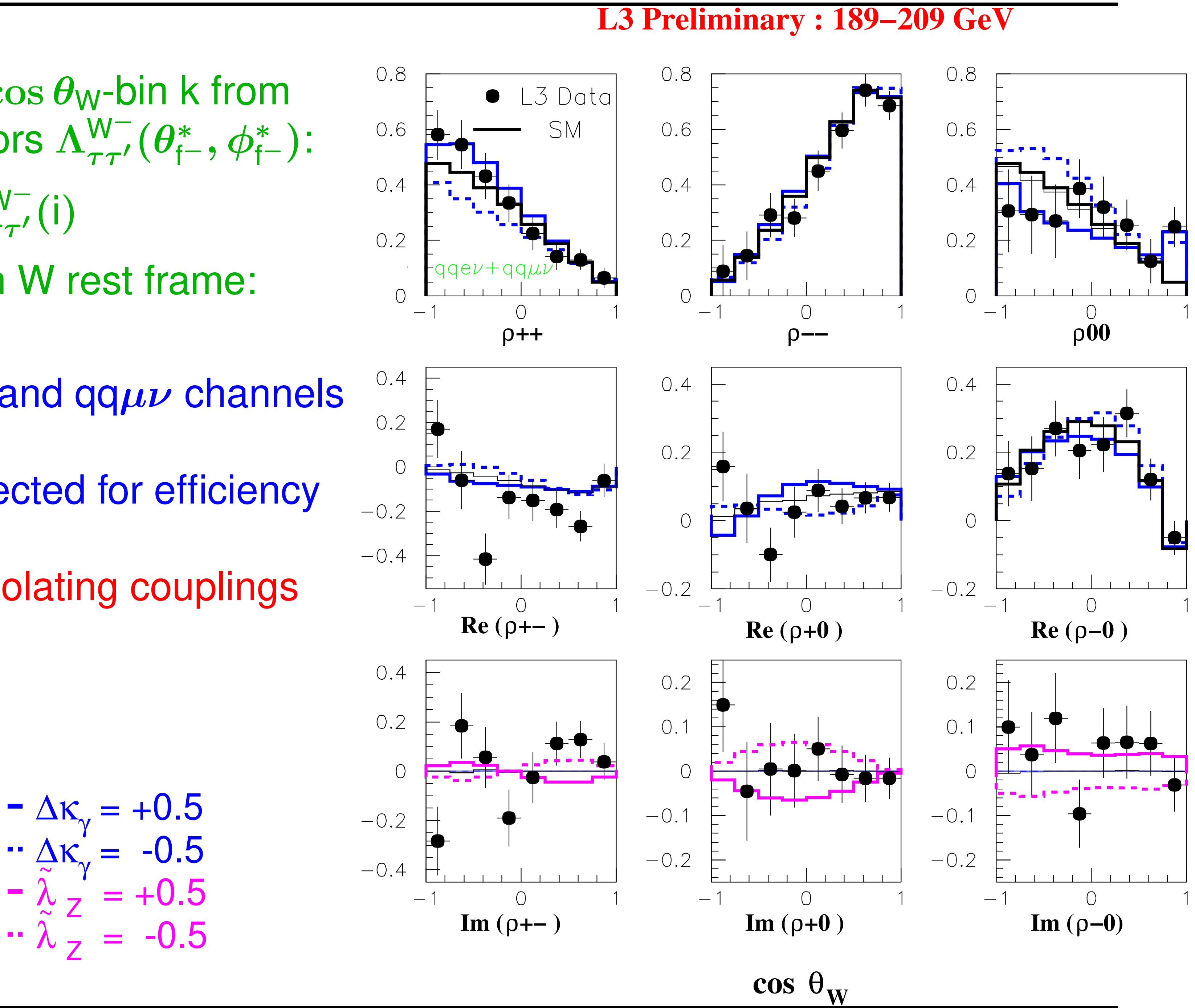


- Fraction of longitudinally polarised W bosons:
  $0.218 \pm 0.027 \pm 0.016$ (SM 0.241)

CERN-EP/2002-092

- SDM element in $\cos\theta_W$-bin k from projection operators $\Lambda^{W^-}_{\tau\tau'}(\theta^*_{f-},\phi^*_{f-})$:

  $\rho^{W^-}_{\tau\tau'} = \frac{1}{N_k}\Sigma^{N_k}_{i=1}\ \Lambda^{W^-}_{\tau\tau'}(i)$
- Fermion angles in W rest frame: $\theta^*_{f-},\phi^*_{f-}$
- Analysis of qq$e\nu$ and qq$\mu\nu$ channels with all L3 data
- Distributions corrected for efficiency and background
- Sensitive to CP violating couplings



Test of CP and CPT

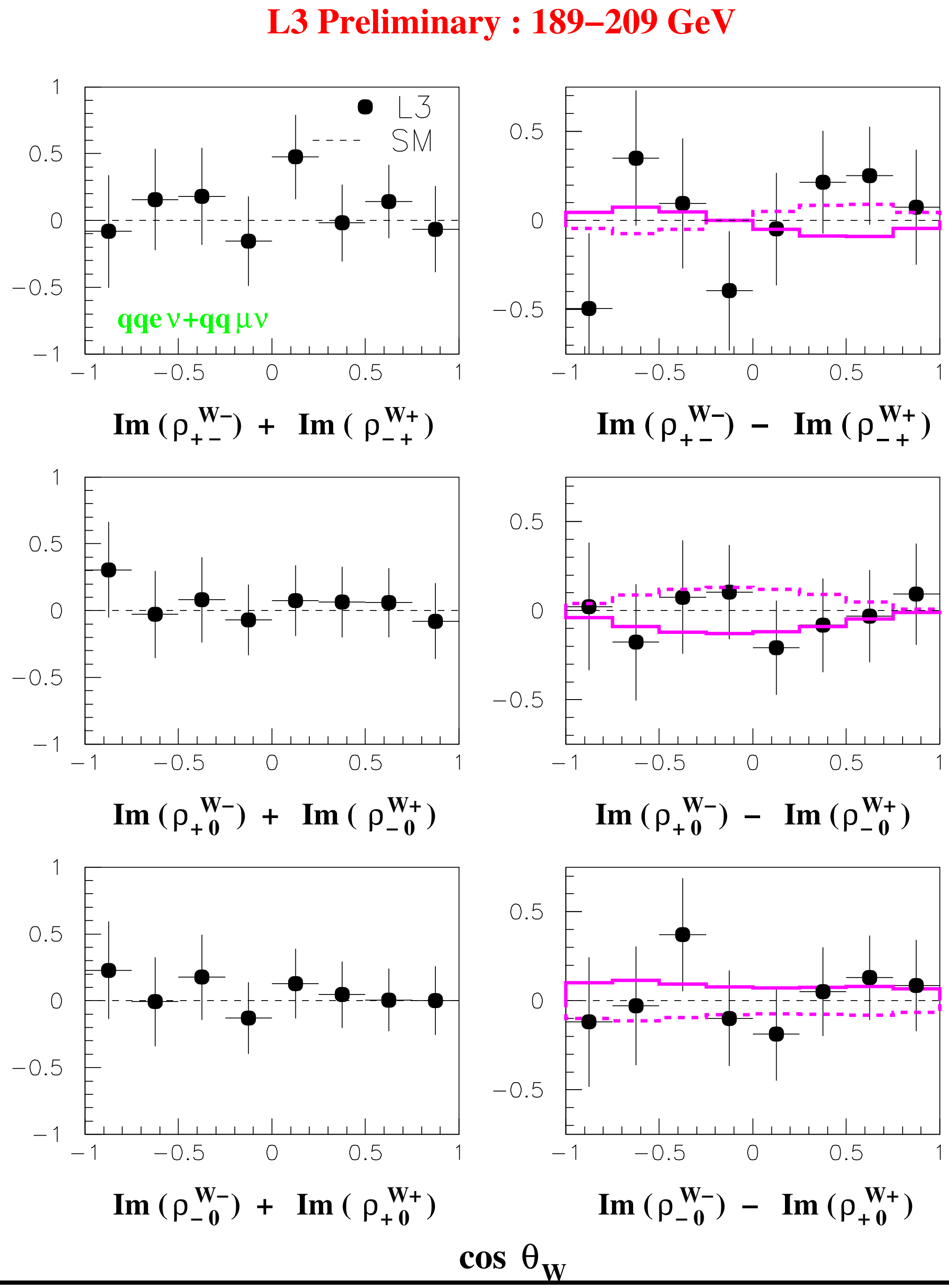
- CP invariance:

  $\mathrm{Im}(\rho^{W^-}_{\tau\tau'}) - \mathrm{Im}(\rho^{W^+}_{-\tau-\tau'}) = 0$

- CPT invariance:

  $\mathrm{Im}(\rho^{W^-}_{\tau\tau'}) + \mathrm{Im}(\rho^{W^+}_{-\tau-\tau'}) = 0$

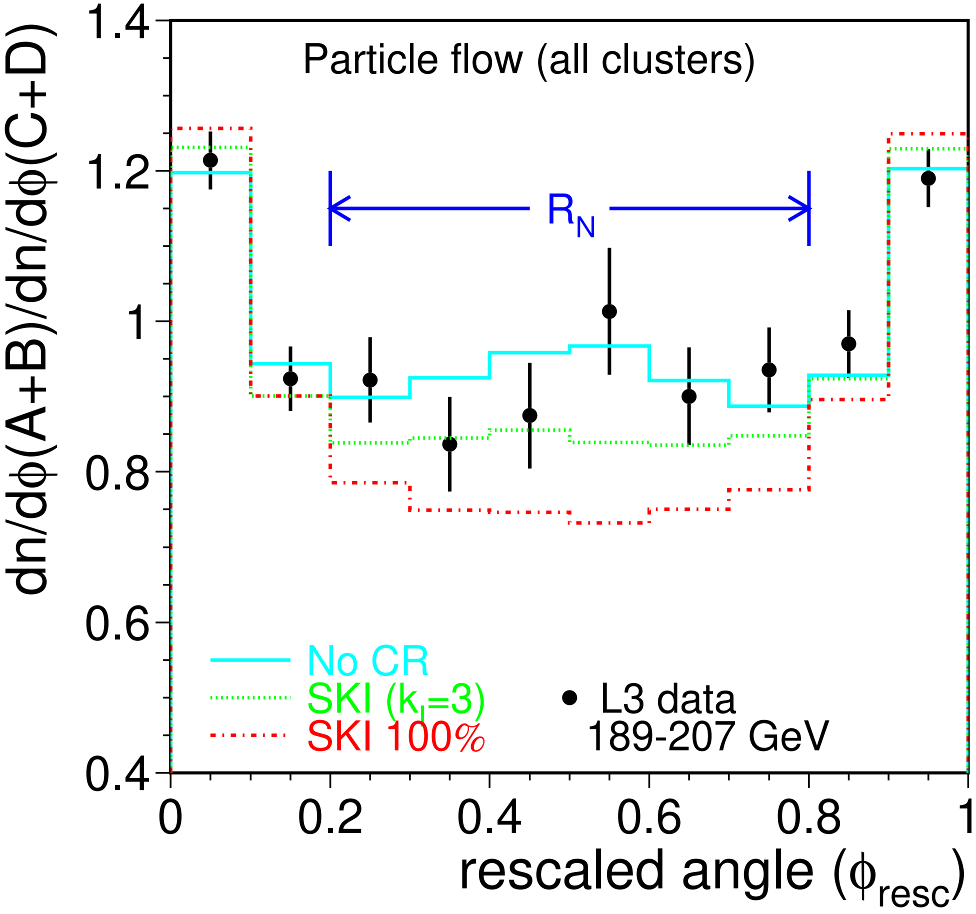
- Fit of CP violating W couplings in preparation



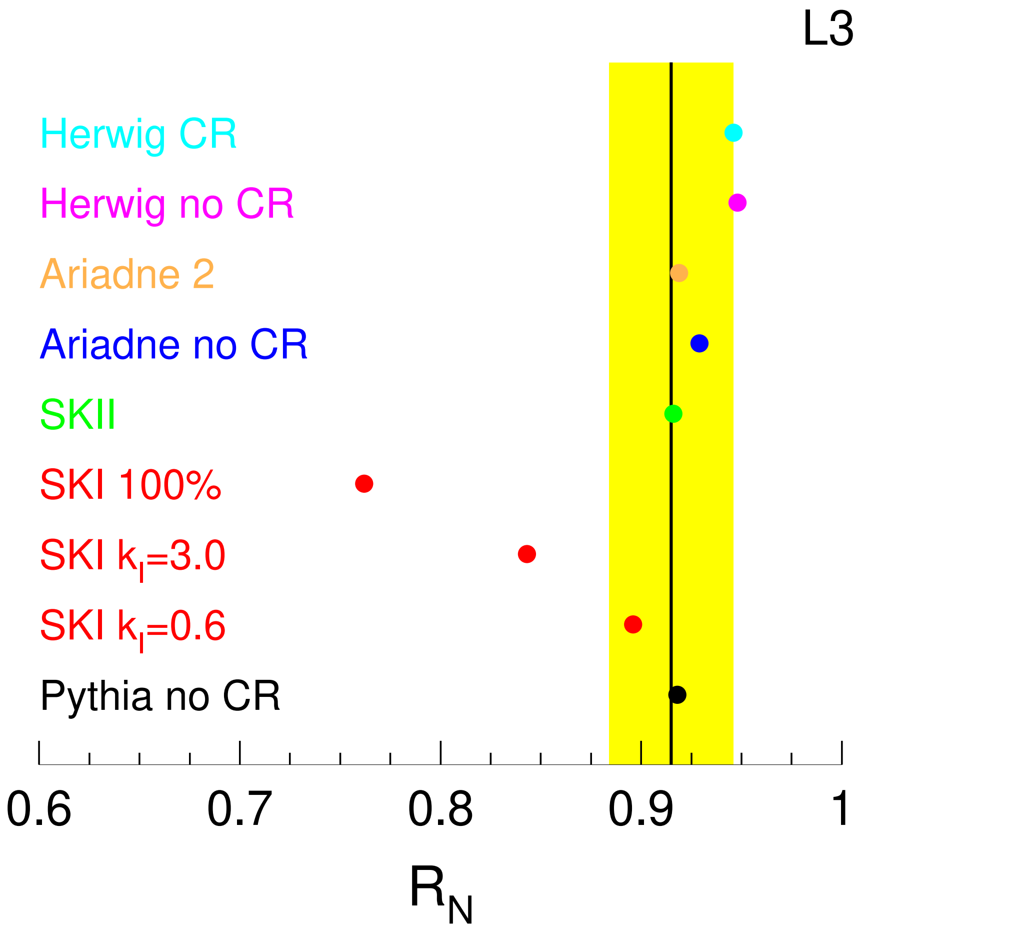
- $\tilde{\lambda}_Z$ = +0.5
·· $\tilde{\lambda}_Z$ = -0.5

- Current status:
  - ▷ Working on systematic uncertainties
  - ▷ Mainly: O(α) EW corrections
    fragmentation
    colour reconnection

- Analyse particle flow F between jets in $W^+W^- \longrightarrow$ qqqq events
- Ratio of intra-W regions and inter-W regions $\longrightarrow$ integrate $\longrightarrow R_N$



- In SK1 model: χ^2 minimum at $k_I = 0.08$ $\longrightarrow$ 6% reconnection probability
- 68% and 95% C.L. upper limits at $k_I = 1.1$ and 2.1 $\longrightarrow$ 45% and 64% reconnection prob.

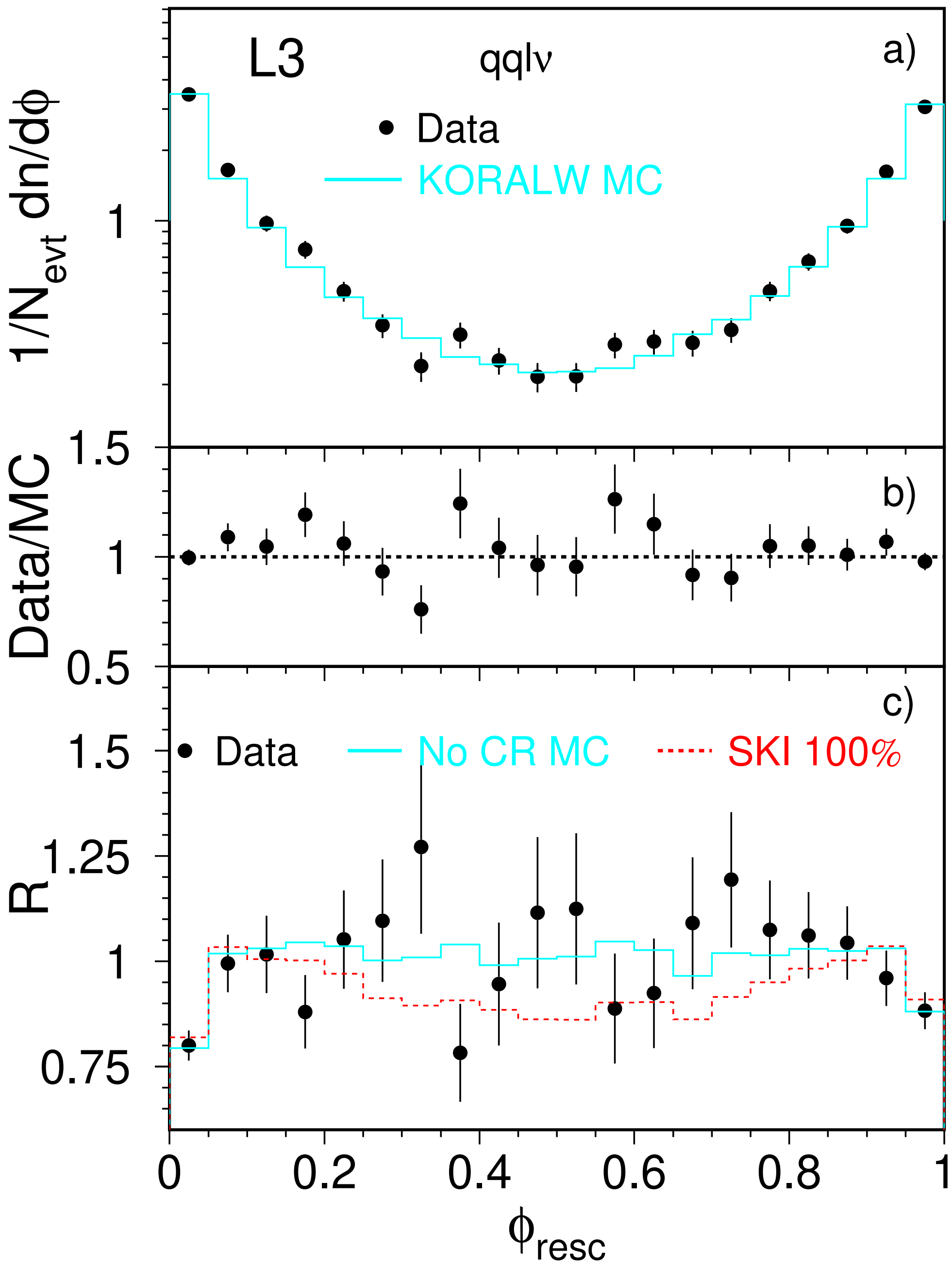


Particle Flow Analysis of qq$\ell\nu$ Events

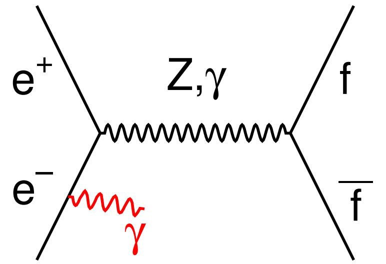
- qq$\ell\nu$ channel: treat lepton and neutrino as particles in 4-jet reconstruction

- Ratio R=F(qqqq)/2F(qq$\ell\nu$)

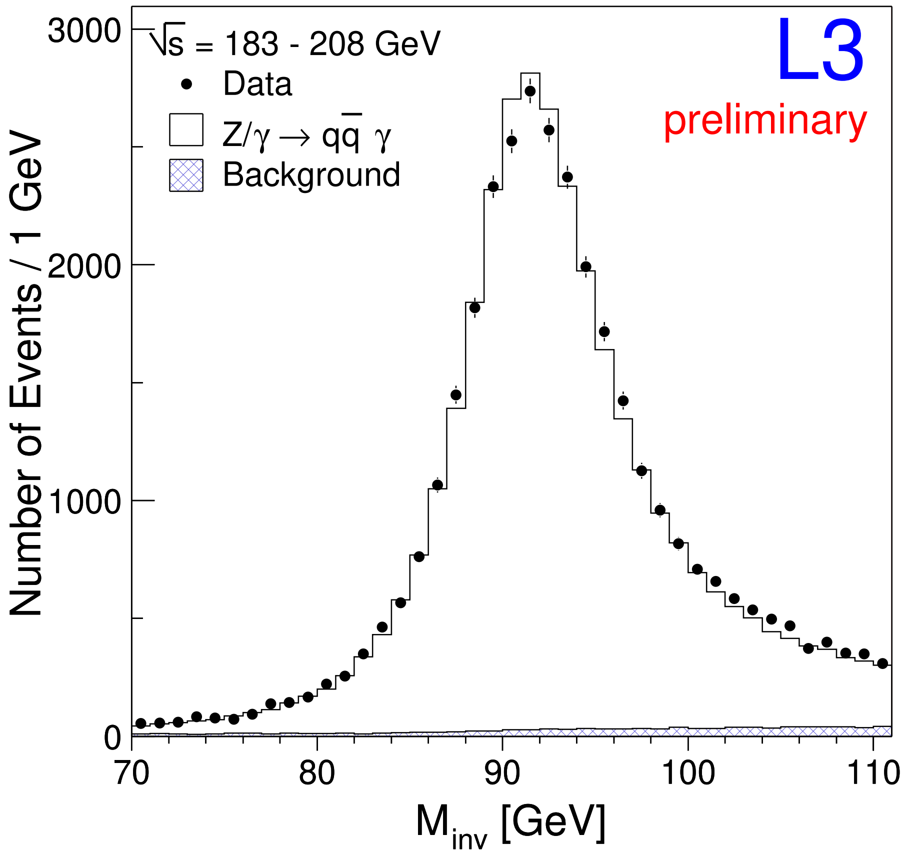
$\longrightarrow$ more model independent but less sensitive



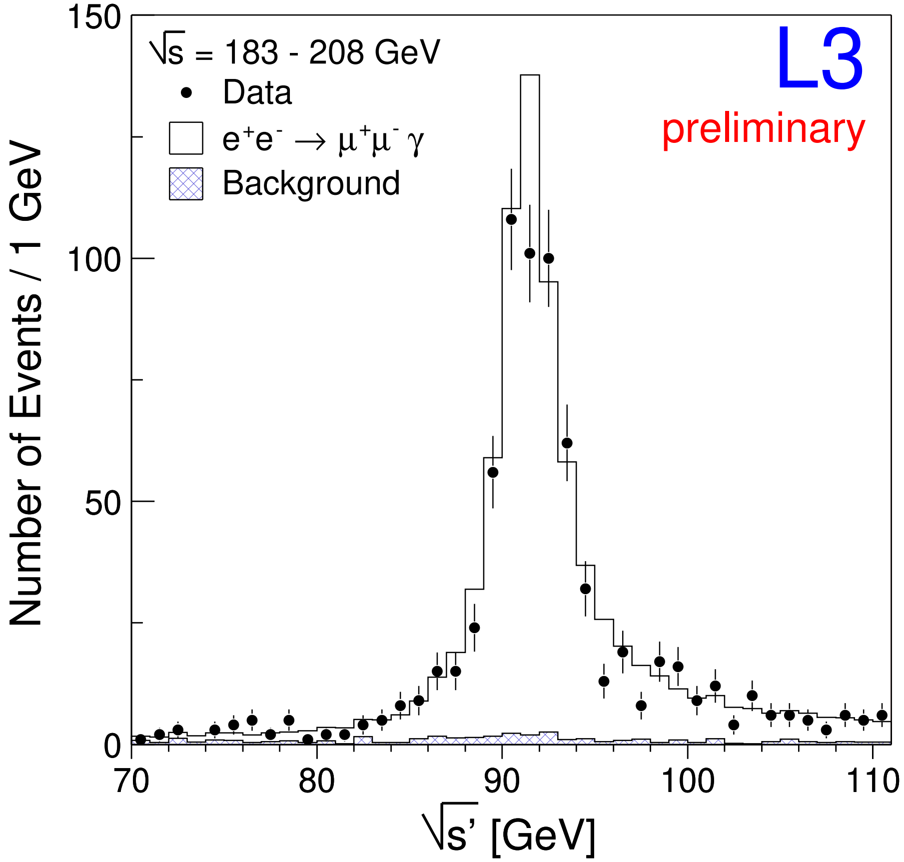
- Select radiative $e^+e^- \longrightarrow q\bar{q} + \gamma$ and $e^+e^- \longrightarrow \mu^+\mu^- + \gamma$ events



- Invariant $q\bar{q}$ mass from kinematic fit



- $\sqrt{s'}$ from muon angles



- Main systematic uncertainties in each channel:
  - ▷ Hadronisation from comparison of Pythia, Ariadne and Herwig (36 MeV)
  - ▷ Determination of muon angles from comparison of muon chamber track and MIP signal in calorimeter (11 MeV)
- From all data at $\sqrt{s} = 183 - 209$ GeV:

$$\begin{aligned} m_Z(\mu\mu\gamma) &= 91.181 \pm 0.107 \pm 0.028 \text{ GeV} \\ m_Z(q\bar{q}\gamma) &= 91.233 \pm 0.031 \pm 0.051 \text{ GeV} \end{aligned}$$

- Channels combined:

$$m_Z(f\bar{f}\gamma) = 91.222 \pm 0.033 \pm 0.042 \text{ GeV}$$

- Converted into LEP beam energy:

$$\begin{aligned} \Delta E_{beam} &= -E_{beam} \frac{m_Z(f\bar{f}\gamma) - m_Z}{m_Z} \\ \Delta E_{beam} &= -0.034 \pm 0.036 \pm 0.041 \text{ GeV} \end{aligned}$$

- No deviation from result of LEP energy working group

Data Archiving

Data Archiving

- Best way to archive data: publish physics results in an adequate form $\longrightarrow$ analysis and interpretation within future theories and models
  - ▷ Tables with efficiencies, data and Monte Carlo counts, differential cross sections, . . .

- All data and MC samples are stored in Castor
- Additional data streams in HBOOK ntuple format for searches and W physics with condensed information $\longrightarrow$ Castor
- Considering translation into ROOT trees
- Reconstruction, simulation and analysis software runs on Linux/RedHat 7
- Cernlib and Castor access needed
- We need PC cluster with above specifications ("museum system") as discussed and agreed with IT

- Since LEP shutdown: in total 32 publications
- Currently: 12 circulating paper drafts
- Near future: another 30 topics to be published

- Number of PhD students: $\approx$12
  Number of post-docs/senior physicists: 10-15 (FTE)

- More analyses will be completed in 2003:

  Fermion Pair Production
  W Physics
  Searches for New Particles
  Two-Photon Physics
  . . .