Measurements of e-γ interactions at LEP

For the LEP collaborations

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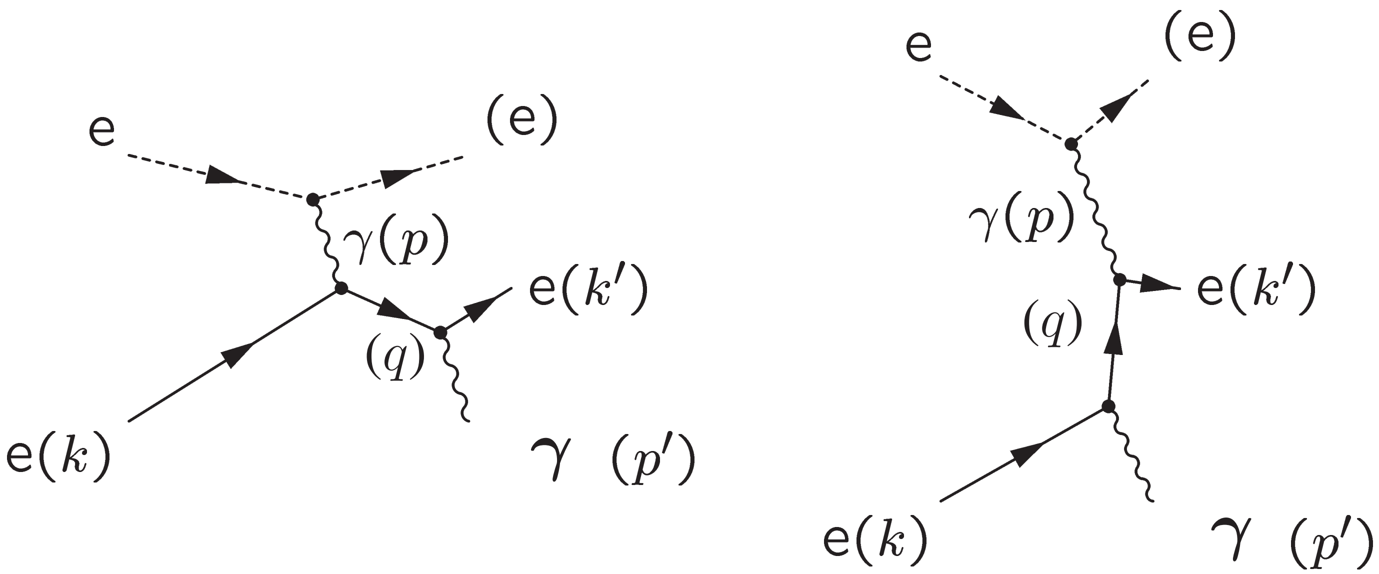
OUTLINE

- Quasi-real Compton scattering
- $e^{\pm}\gamma \rightarrow e^{\pm}\gamma$: L3 analysis
- $e^{\pm}\gamma \rightarrow e^{\pm}\gamma^{\star}/Z$: OPAL and DELPHI analyses
- Single excited electrons
- Conclusions

Quasi-real Compton scattering



$$\boxed{e^+e^- \rightarrow e^+e^-\gamma}$$

- Bremsstrahlung:

  $q^2, p^2 \rightarrow 0$, e^+, e^- and γ undetected.

- Radiative Bhabha scattering:

  $q^2 \rightarrow 0$; $|p^2| >> |q^2|$.

  e^+, e^- detected at finite angle, γ along beam direction.

- Quasi-real Compton scattering: $(e^\pm\gamma \rightarrow e^\pm\gamma)$

  $p^2 \rightarrow 0$; $|q^2| >> |p^2|$

  $e^\pm$ and γ detected ($p_T^{e\gamma} \approx 0$)

  the other $e^\pm$ scattered at zero degree.

  $E_{vis} > E_{beam}$

$e-\gamma$ interactions at LEP

Two processes have been studied:

* $e^{\pm}\gamma \to e^{\pm}\gamma$: L3

Aim: Measurement of $\sigma(e\gamma \to e\gamma)$.

* $e^{\pm}\gamma \to e^{\pm}Z/\gamma^{\star}$: OPAL, DELPHI

The real photon is replaced by a virtual one or a Z

LEP process $e^{+}e^{-} \to e^{+}e^{-}f\bar{f}$

Futher processes leading to eeff final state:

- $e^{+}e^{-} \to ZZ \to e^{+}e^{-}f\bar{f}$
- $e^{+}e^{-} \to \gamma\gamma \to e^{+}e^{-}f\bar{f}$

Two channels: $Z/\gamma^{\star} \to q\bar{q}, \mu^{+}\mu^{-}$

Aim: Measurement of $\sigma(e^{\pm}\gamma \to e^{\pm}Z/\gamma^{\star})$

Signatures:

$e^{\pm}$ escapes along the beam pipe.
The other $e^{\pm}$ is observed in the detector together with a γ or two fermions ($Z/\gamma^{\star} \to f\bar{f}$).

$e^{\pm}\gamma \to e^{\pm}\gamma$: L3 analysis

Quasi-real Compton scattering is studied at 20 GeV $< \sqrt{s'} < 185$ GeV

Data from 1991-1999, $\mathcal{L} = 634.6$ pb^{-1}, $\sqrt{s} \leq 202$ GeV

Standard Model predictions:

MC signal ($e^{\pm}\gamma \to e^{\pm}\gamma$): TEEGG $\mathcal{O}(\alpha^4)$

Background: - $e^+e^- \to \gamma\gamma(\gamma)$.

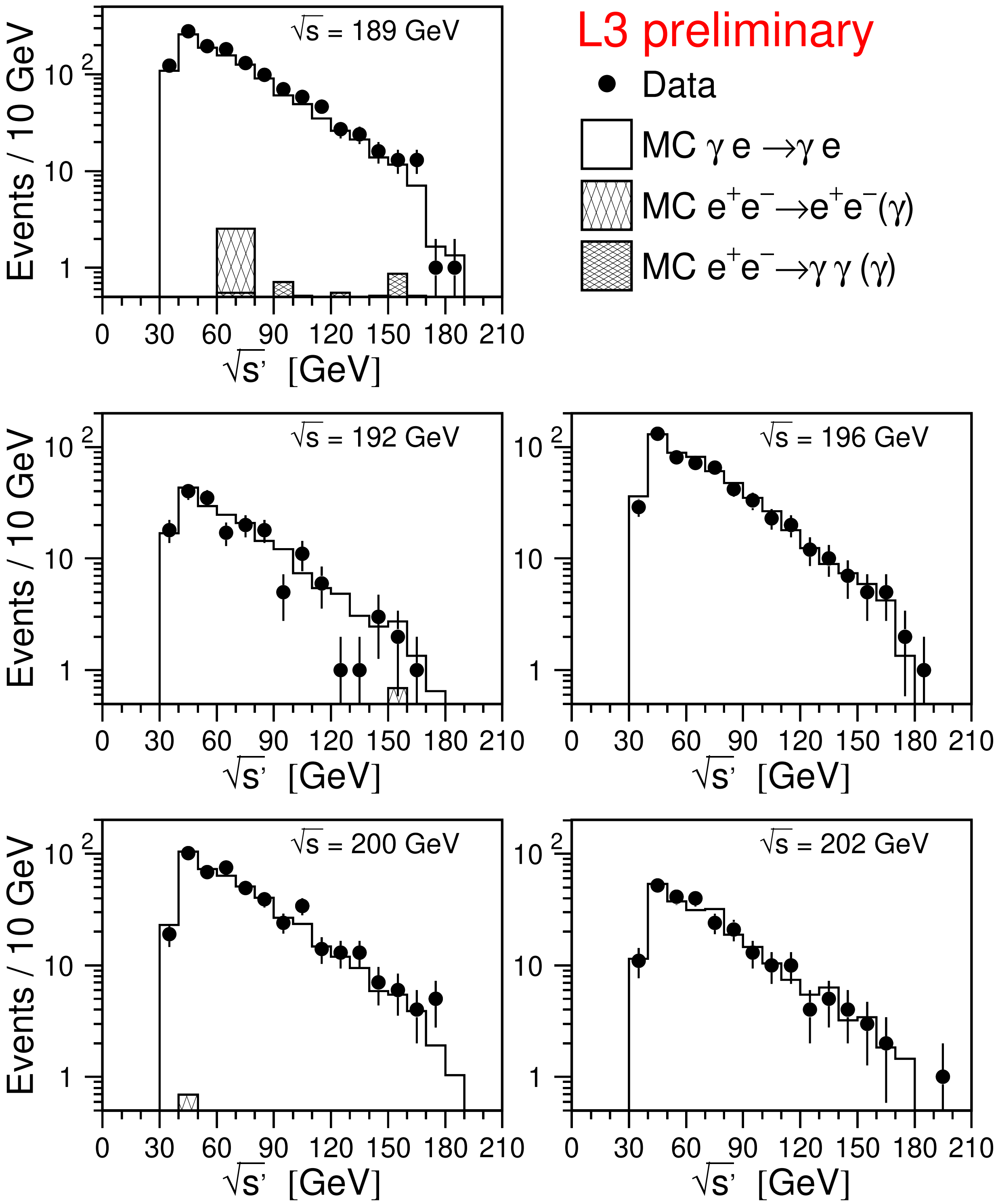
- $e^+e^- \to e^+e^-(\gamma)$.

Selection of the signal events

* γ and $e^{\pm}$ Identification: signal in electromagnetic calorimeter
* Polar acceptance for γ-e pair: $|\cos\theta| < 0.94$ and $|\cos\theta^{\star}| < 0.80$.
* To ensure the selection of quasi-real photons: $p_T^{e\gamma}/E_{beam} < 0.15$

RESULTS

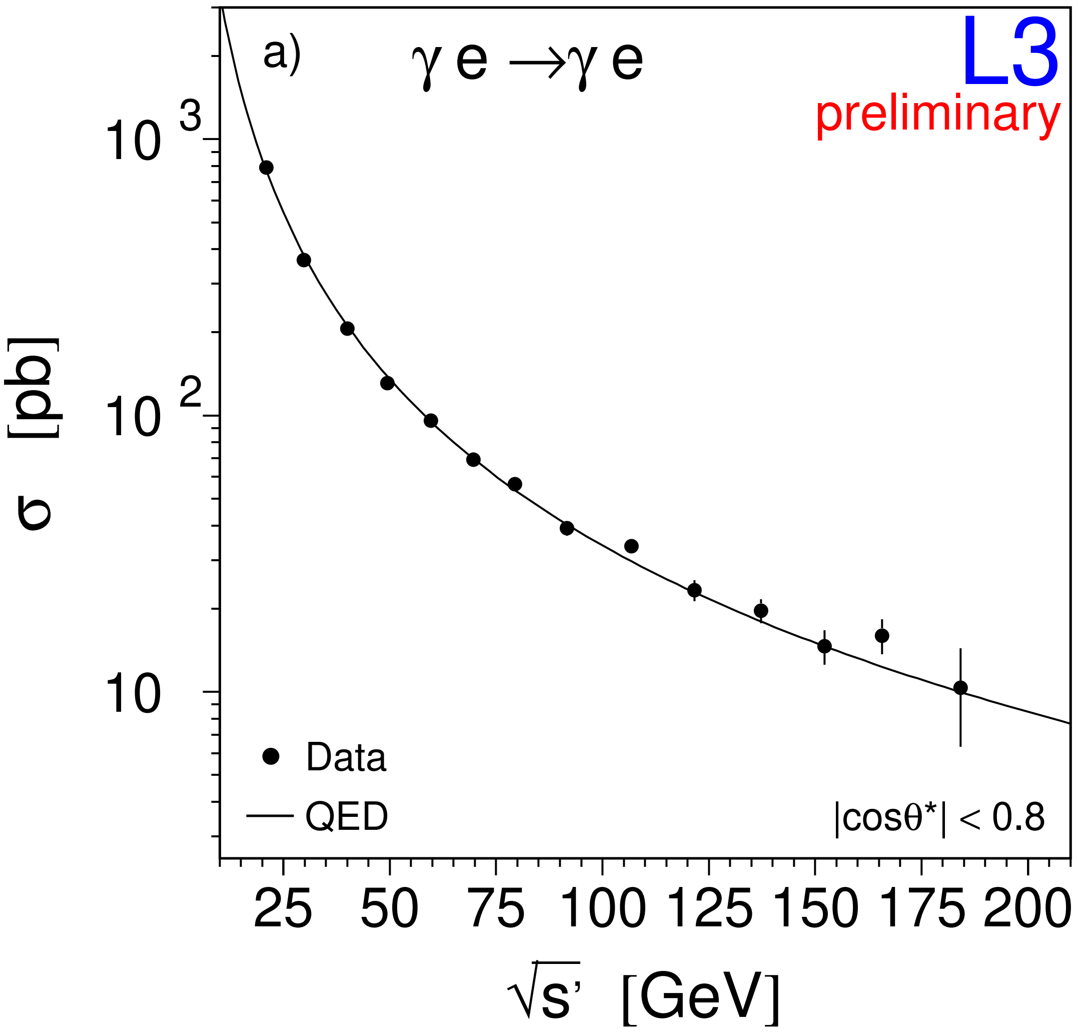
$\sqrt{s'}-$ spectra



RESULTS

- 7335 quiasi-real Compton scattering events
- Small contribution of virtual photons: $\langle P^2/s' \rangle \sim 10^{-3}$

Cross Section



$e^{\pm}\gamma \to e^{\pm}Z/\gamma^{\star}$: OPAL and DELPHI analyses

Electroweak Compton scattering $e^{\pm}\gamma \to e^{\pm}Z/\gamma^{\star}$

Subprocess of the reaction $e^+e^- \to e^+e^-Z/\gamma^{\star}$; $Z/\gamma^{\star} \to f\bar{f}$

Signal definition:

OPAL: limits in Lorentz invariant variables

$|\hat{t}| > 400$ GeV ^{2} $\quad \hat{t} = (p' - p)^2$

$|p^2| < 10$ GeV^2 $\Rightarrow \sqrt{s'} \geq 20.6$ GeV

$M_{f\bar{f}} > 5$ GeV

DELPHI: topological limits

$|\cos\theta_e| < 0.985$, $E_e > 4$ GeV, $M_{f\bar{f}} > 15$ GeV

Standard Model predictions:

MC signal ($e^+e^- \to e^+e^-Z/\gamma^{\star}$): grc4f, PYTHIA.

Background:

- 4 fermions
- $\gamma\gamma \to qqee$
- $q\bar{q}(\gamma)$
- 2 fermions

Data from 1997-1999, 183 GeV$< \sqrt{s} < 202$ GeV

$$\underline{e^{\pm}\gamma \rightarrow e^{\pm}Z/\gamma^{\star} \rightarrow e^{\pm}q\bar{q}}$$

Selection

* Preselection:

$e^{\pm}$ Identification:

Signal in Electromagnetic calorimeter.

Multiplicity

2 jets (Durham algorithm):

OPAL: $M_{jj} > 5$ GeV

DELPHI: $M_{jj} > 15$ GeV

Kinematic fit: 2 jets + 1 e detec. + 1 e beam pipe (cut in χ^2)

To ensure signal definition:

OPAL: $\sqrt{s'} = M_{\gamma e} \geq 25$ GeV

$|\hat{t}| > 500$ GeV ^{2}

$(\hat{t} \equiv 2\, E_{beam} \cdot E_e\, (1 + q_e \cdot \cos\theta_e))$

DELPHI:

$|\cos\theta_e| < 0.985$

* Selection:

  ⋆ Cuts in missing momentum

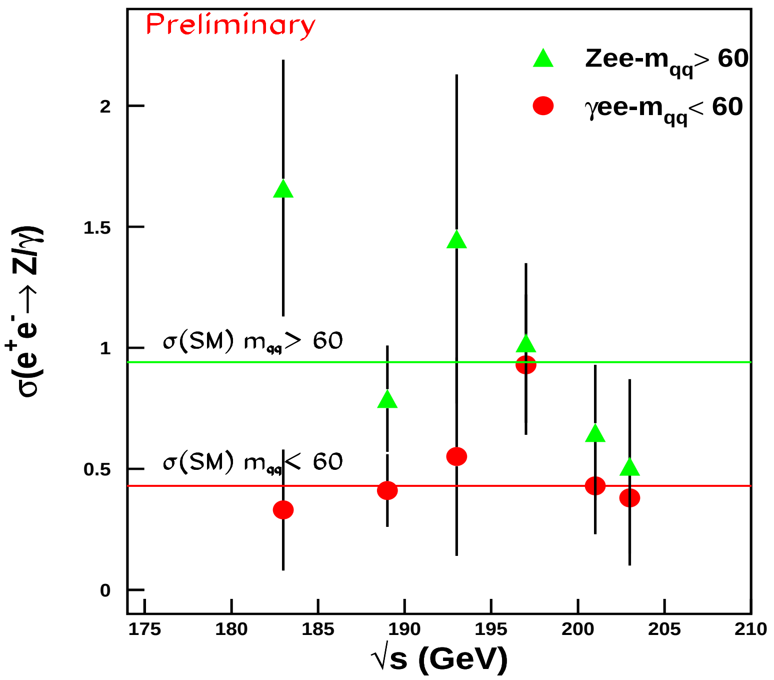
  ⋆ Angular cuts

RESULTS

Low mass region $(\gamma^{\star}ee)$ $\quad m_{q\bar{q}} < 60$ GeV

High mass region (Zee) $\quad m_{q\bar{q}} > 60$ GeV

DELPHI



OPAL

$\sqrt{s} = 183$ GeV: First observation

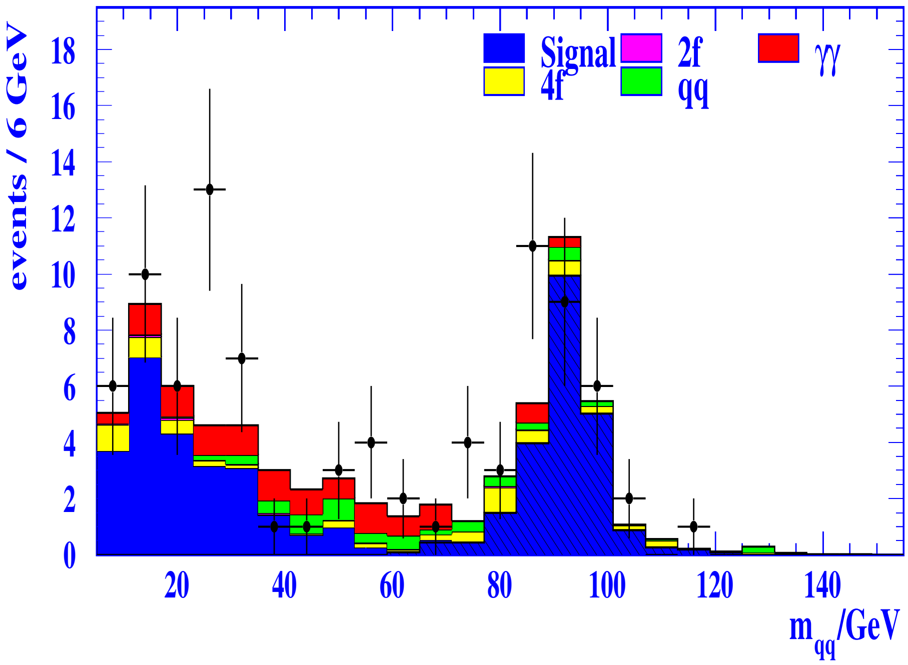
$\sqrt{s} = 189$ GeV

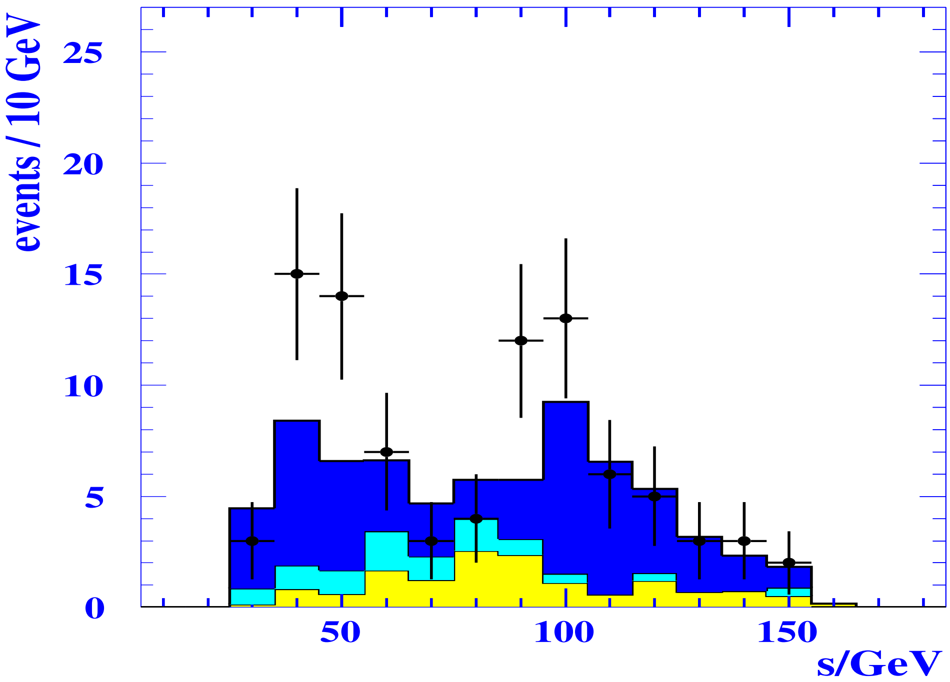
Last Results: Preliminary

Cross section (pb)	$\gamma^{\star}ee$	Zee
Measured	$4.6 \pm 0.9 \pm 0.6$	$1.5 \pm 0.3 \pm 0.3$
SM Prediction	3.06 ± 0.04	1.19 ± 0.02

OPAL

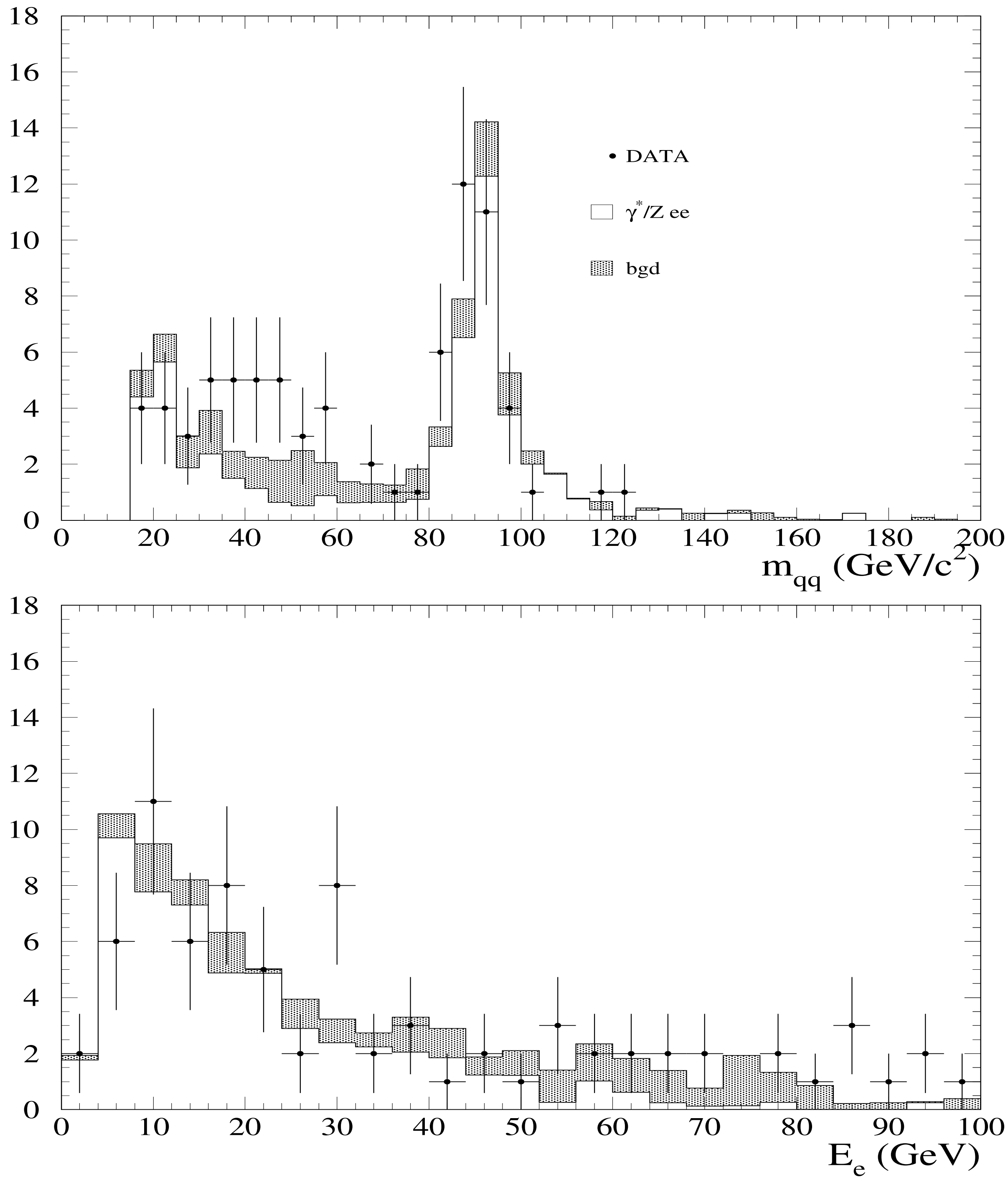
Preliminary





DELPHI Preliminary

$$\sqrt{s} = 189 \text{ GeV}$$



DELPHI: $e^{\pm}\gamma \rightarrow e^{\pm}Z/\gamma^{\star} \rightarrow e^{\pm}\mu^{+}\mu^{-}$

- ⋆ Two tracks to be identified as leptons (μ or e)
- ⋆ and at least one of them to be a muon.

RESULTS

$\sqrt{s}$(GeV)	$N_{expected}$	N_{data}	σ (fb)	σ(SM) (fb)
$15 < m_{\mu^+\mu^-} < 60$ GeV				
182.6	0.5	0	–	112
188.6	1.6	2	154^{+206}_{-129}	112
192-202	2.5	1	–	114
$m_{\mu^+\mu^-} > 60$ GeV				
182.6	0.8	1	–	33
188.6	2.4	5	80^{+48}_{-36}	33
192-202	3.8	4	34^{+30}_{-22}	34

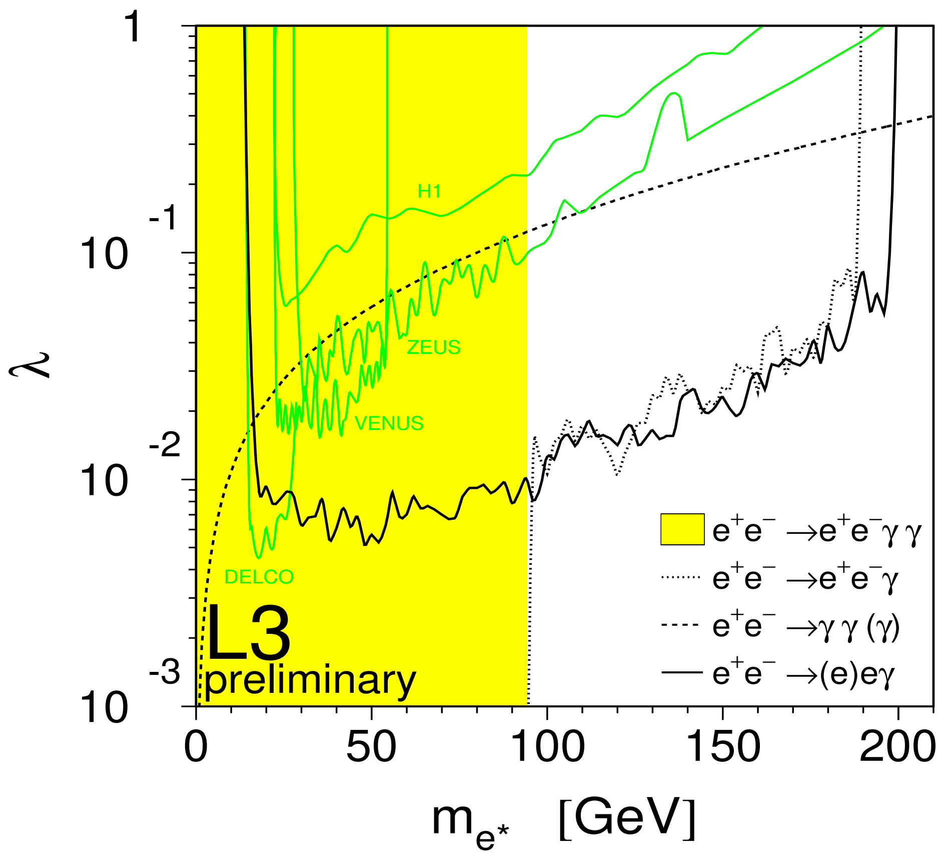
Production of single excited electron (L3)

$$e\gamma \longrightarrow e^\star \longrightarrow e\gamma$$

* The existence of $e^\star$ would enhance the number of observed γe events.
* Since $\sqrt{s'}(\equiv m_{e^\star})$ -spectra are in agreement with the SM $\Longrightarrow$ Upper limit for $N_{e^\star}$ from $N^{obs}_{\gamma e}$ and $N^{exp,SM}_{\gamma e}$.

$$\Downarrow \sigma(e\gamma \rightarrow e^\star \rightarrow e\gamma) \propto \frac{\lambda^2}{m^2_{e^\star}}$$

Upper limit coupling λ ($e^\star e\gamma$) as a function of $m_{e^\star}$



CONCLUSIONS

- γ-e events are identified as Compton scattering of quasi-real photons
  - ▷ The cross-section of this process is measured in the energy range 20 GeV $< \sqrt{s'} < 185$ GeV and it is in good agreement with the QED expectations.
- $\mathrm{Z}/\gamma^{\star}$ production in Compton scattering of quasi-real photons has been observed.
  - ▷ The cross-section of the process $\gamma\mathrm{e} \rightarrow \mathrm{eZ}/\gamma^{\star} \rightarrow \mathrm{eq\bar{q}}$ has been calculated separately for Zee-like and $\gamma^{\star}$ee-like events, with a cut at a hadronic mass of 60 GeV.
  - ▷ OPAL: The measured cross-section ($\sqrt{s}$ =189 GeV) is in agreement with the SM prediction in the Zee region, while in the $\gamma^{\star}$ee region an excess with a significance of about 1.4 standard deviations is observed in the data.

- ▷ DELPHI: The measured cross-section ($183 < \sqrt{s} < 202$ GeV) is in agreement with the prediction in both invariant mass regions.
- ▷ The cross-section of the process $\gamma \mathrm{e} \rightarrow \mathrm{eZ}/\gamma^{\star} \rightarrow \mathrm{e}\mu^{+}\mu^{-}$ has been measured as well.
- ▷ The results are not conclusive due to low statistics.

❖ An upper limit for a hypothetical coupling $\mathrm{e}^{\star}\mathrm{e}\gamma$ as a function of $\mathrm{m}_{\mathrm{e}^{\star}}$ is derived from the measurement of Compton scattering.

- ▷ λ of order of 10^{-1}-10^{-2} in the region 20 GeV$< \mathrm{m}_{\mathrm{e}^{\star}} < 200$ GeV.