Tests of QED at LEP

$e^+e^- \to$ photons

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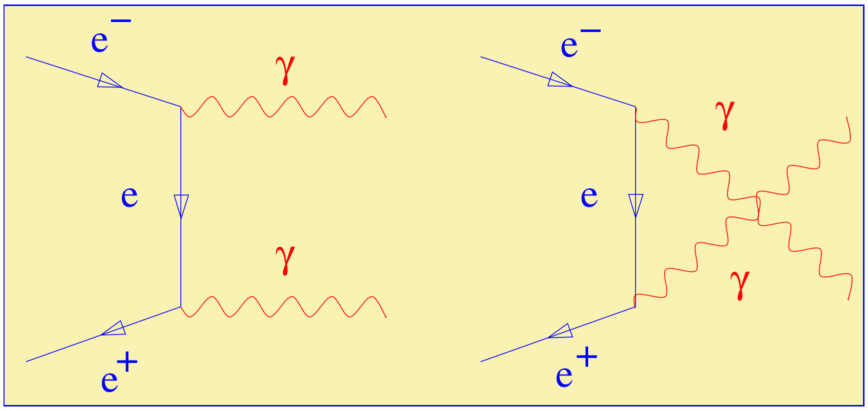
OUTLINE

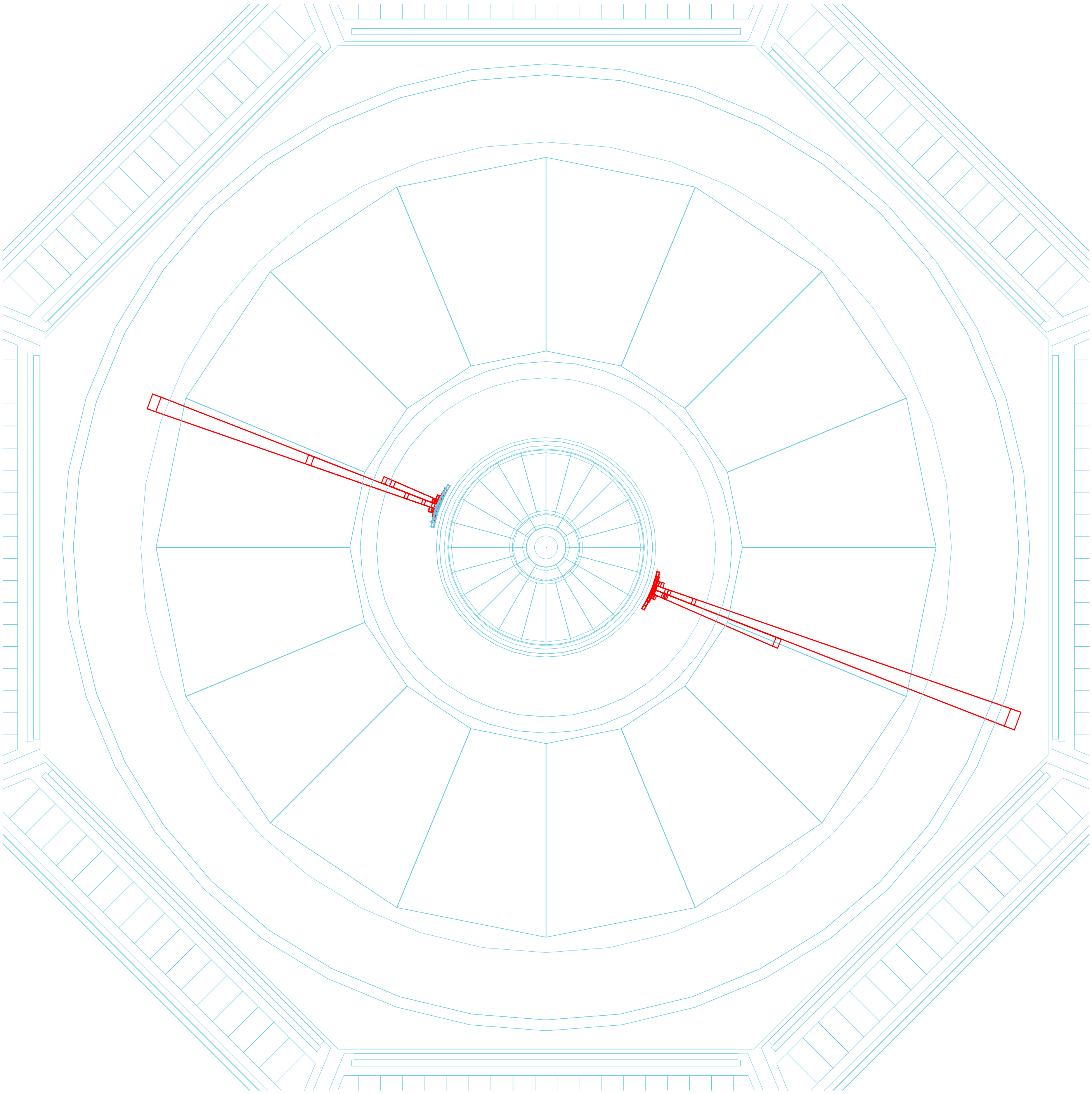
- Introduction
- Event selection
- Cross-sections and QED predictions
- Limits on deviations from QED
- First look at 189 GeV '98 data
- Conclusions



- $e^+e^- \rightarrow$ photons provides a clean test of QED
- At LEP it is a process with very small background
- At LEP energies it is one of the few processes having negligible contributions from weak interactions
- It is very precisely described by theory
- It may be influenced by new phenomena
- Sensitivity increases with center of mass energy
- Update results with data taken in '97 with LEP at 183 GeV
  Luminosity $\approx 55\ pb^{-1}$ per detector

Event selection

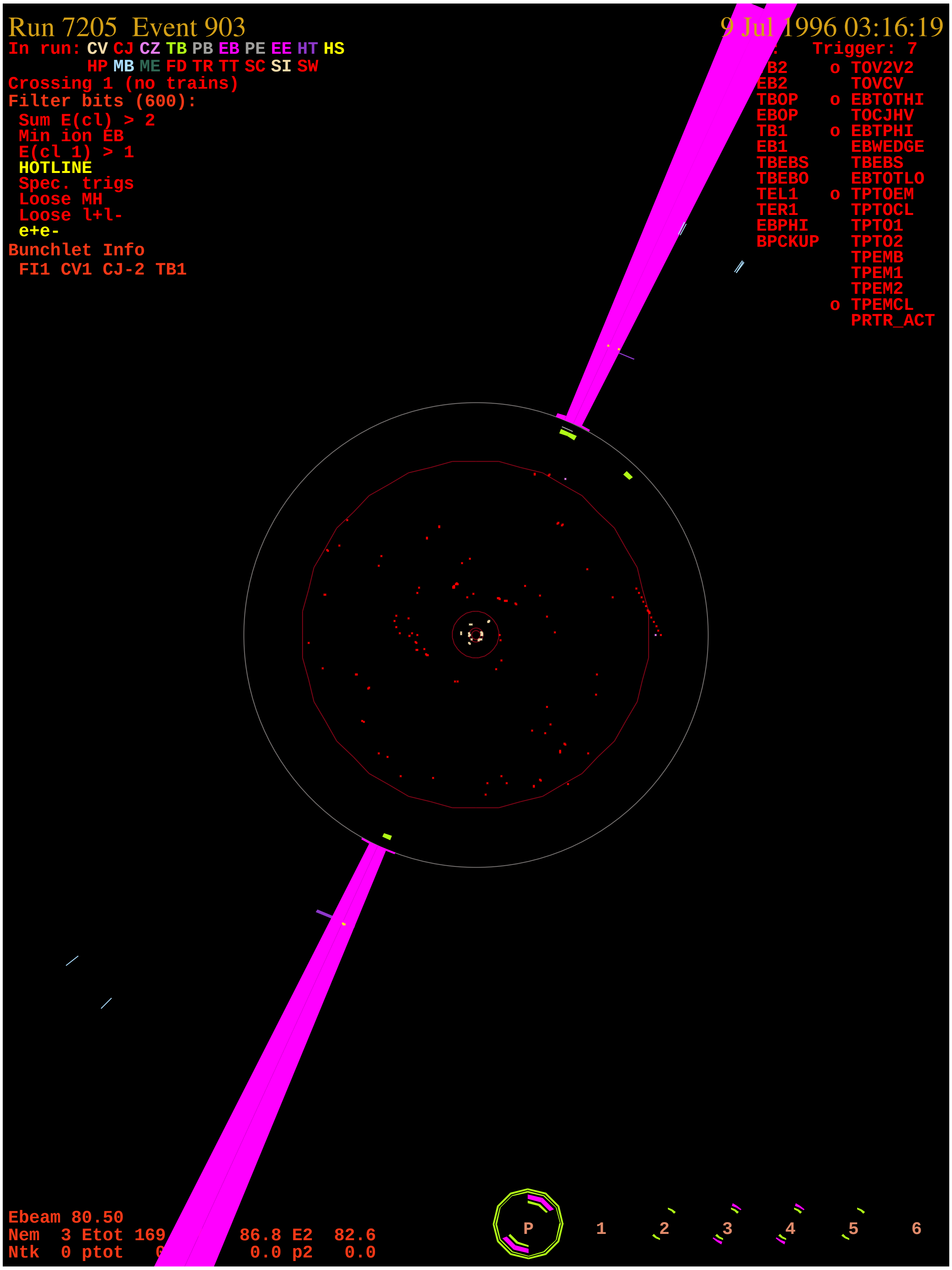
$e^+e^- \to \gamma\gamma$



Event selection

$$e^+e^- \to \gamma\gamma$$

OPAL



Event selection

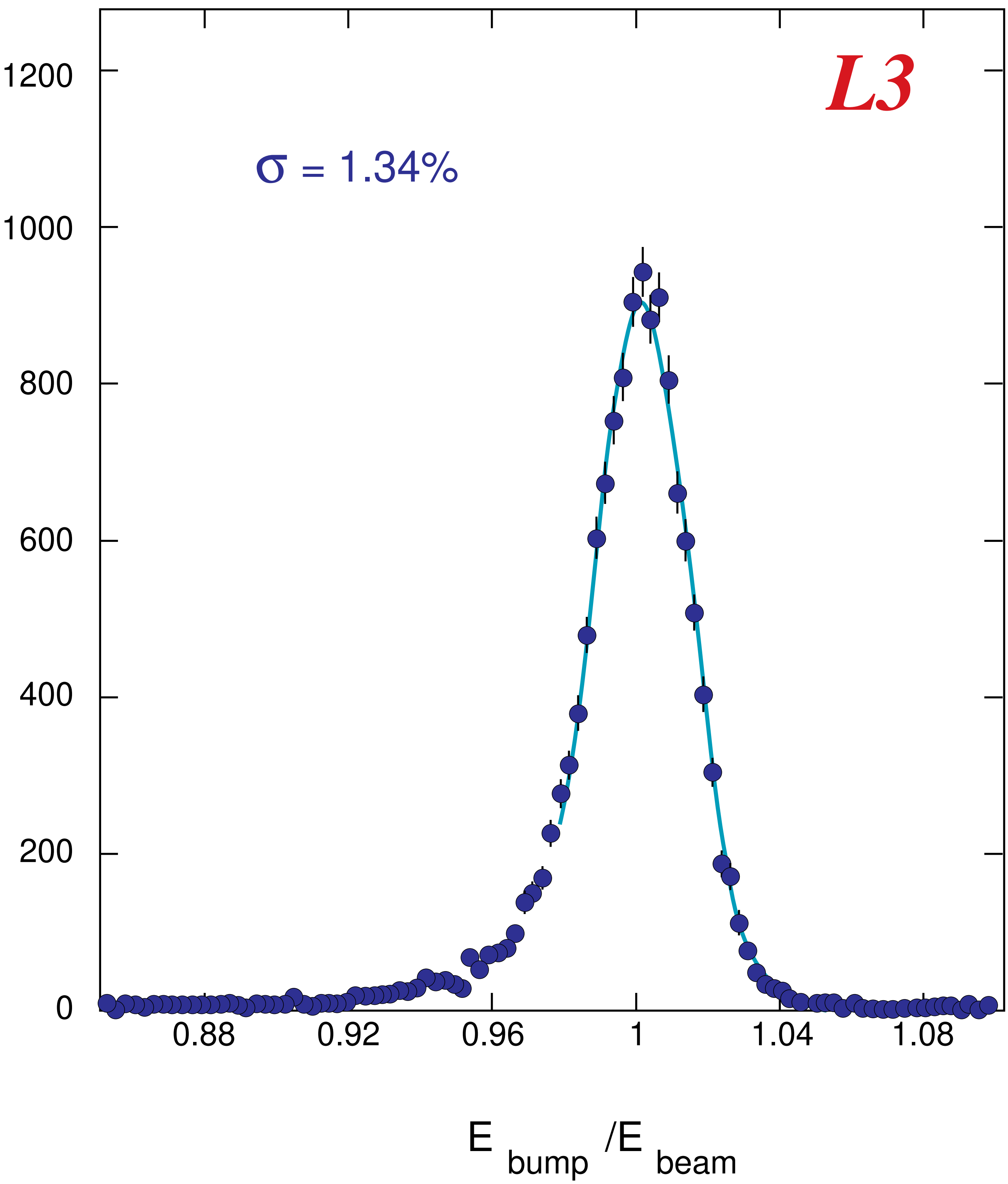
- Only photons in the detectors
- The key elements are the electromagnetic calorimeters and tracking detectors:
  - Two or more electromagnetic clusters
    Cuts in energy and shower profile
  - No tracks
- Fiducial Volume:

Detector	ALEPH	DELPHI	L3	OPAL
$\mid cos(\theta) \mid <$	0.95	0.90	0.96	0.97

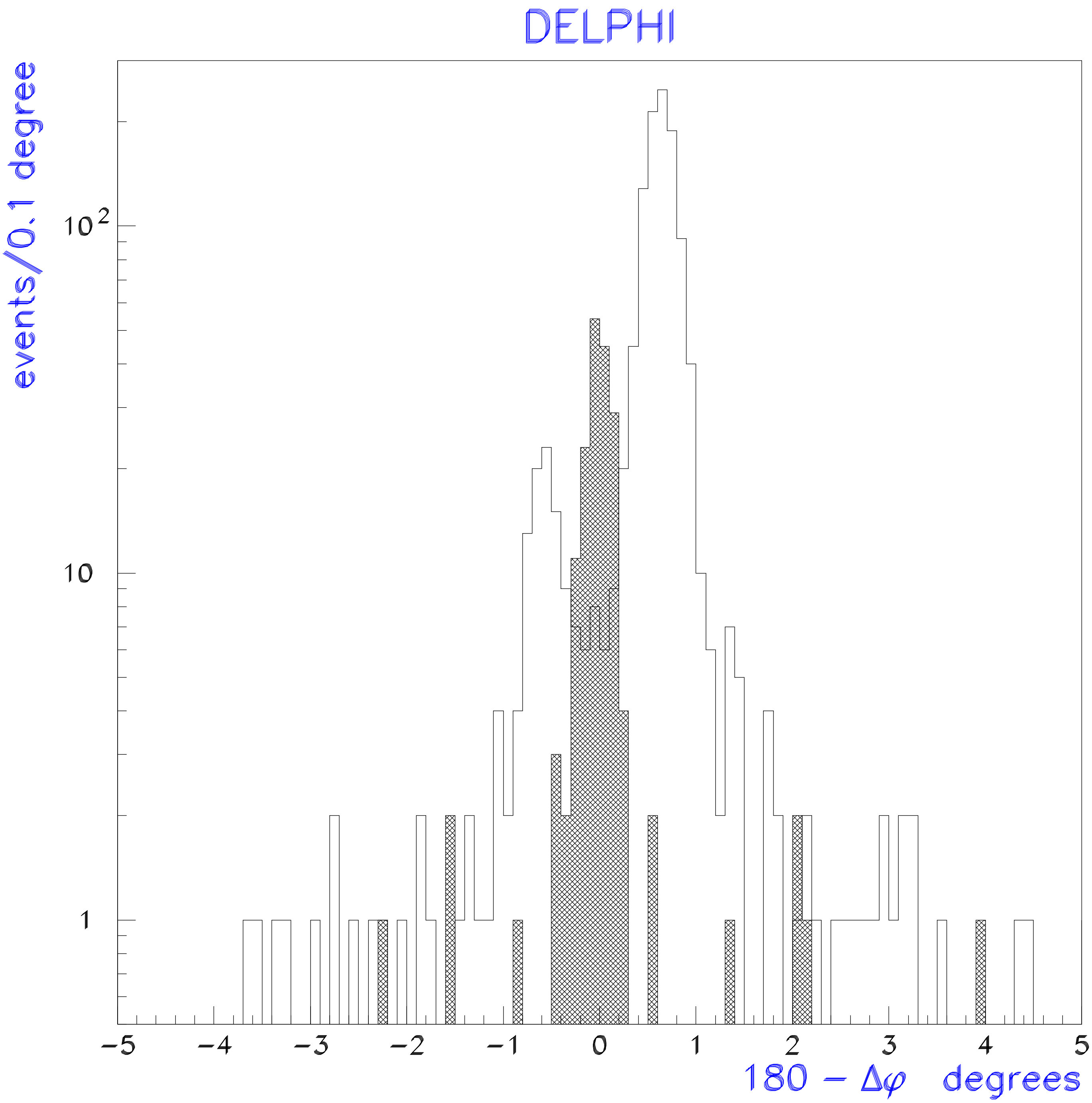
- OPAL selection based in kinematics requirements
- Background rejection:
  - Bhabha scattering: No tracks in the event
  - $e^+e^- \to \nu\nu\gamma\gamma$: Total energy and acollinearity
  - Cosmic ray events: Complete detector and timing
- Efficiency in the fiducial volume computed by MC:

Detector	ALEPH	DELPHI	L3	OPAL
$\varepsilon(\%)$	84	79	80	85

Photon energy resolution

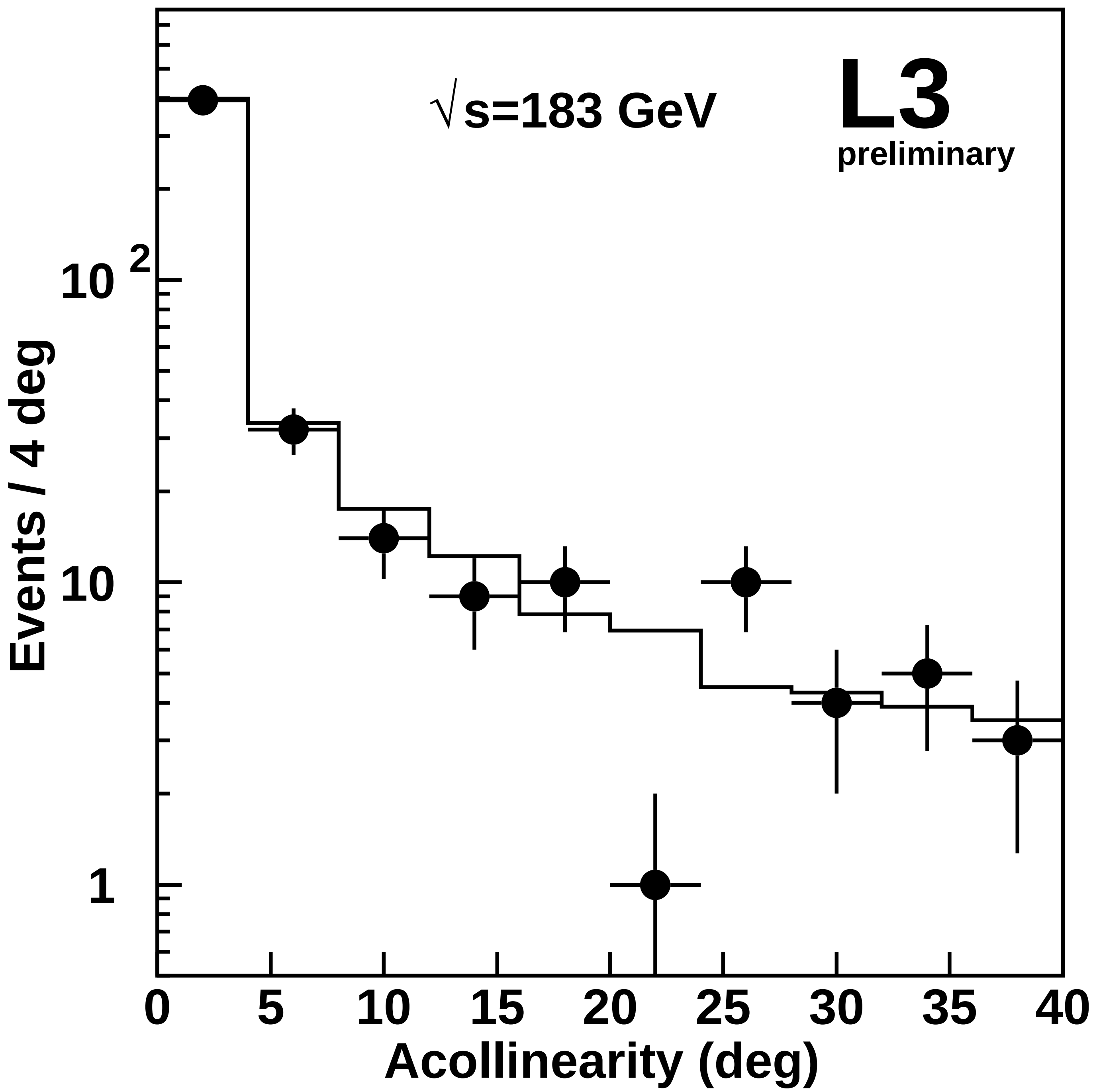


Neutral clusters vs electrons



Magnetic field bending effect

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



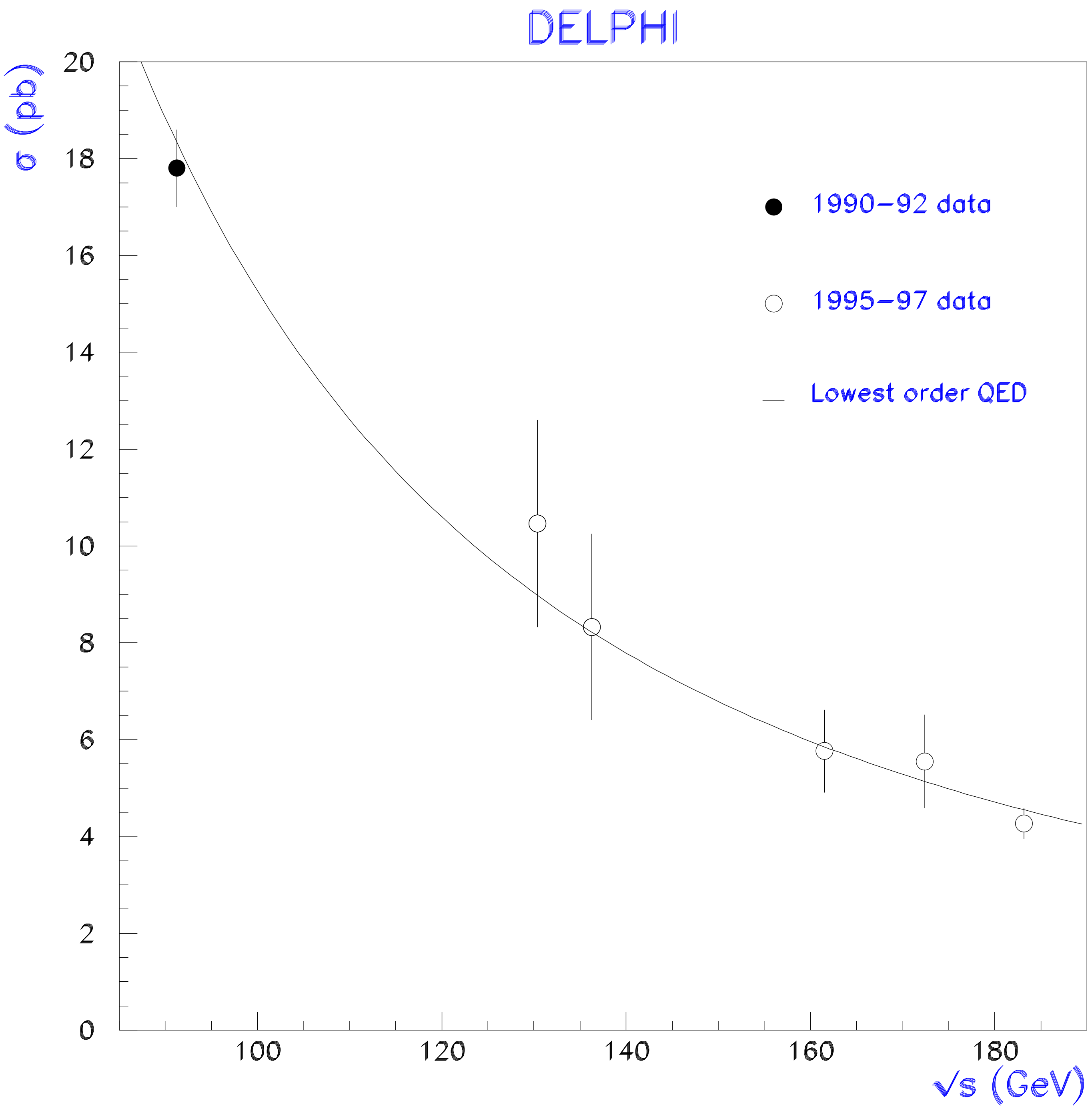
Comparison with QED prediction

- Observed and expected number of events:

$\sqrt{s}$ (GeV)	ALEPH		DELPHI		L3		OPAL	
	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.
183	500	496	236	243	504	521	620	602
172	99	103	46	43	114	115	92	87
161	114	124	63	57	137	139	102	97
133	81	102	41	41	107	105	66	73

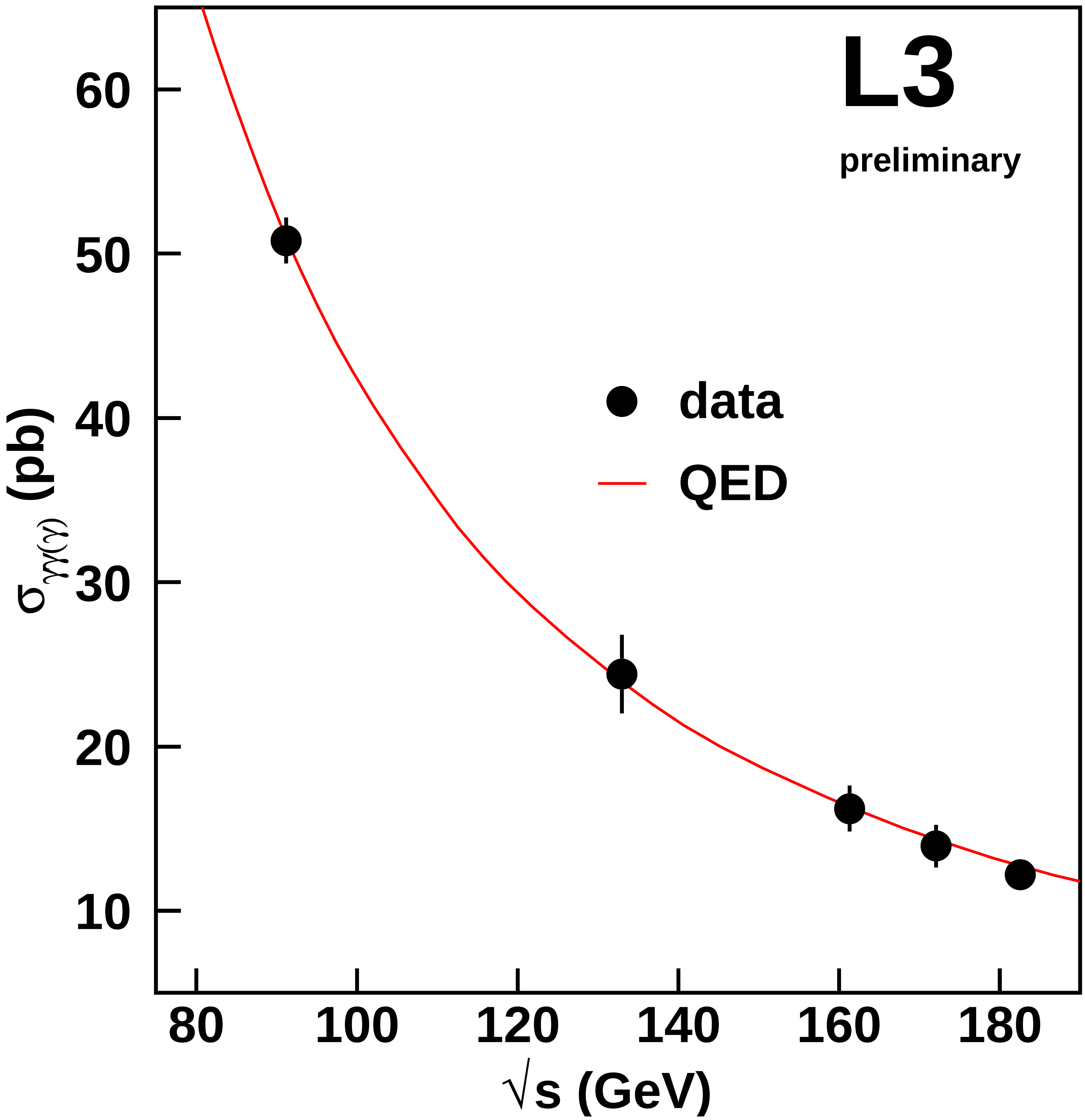
- Background negligible (ALEPH $< 1\%$)
- Systematic uncertainties $\approx 2\%$ (DELPHI 3.3%)
- $\frac{d\sigma}{d\Omega}$ and σ vs $\sqrt{s}$ agree well with QED expectations

$\sigma_{\gamma\gamma(\gamma)}$ versus $\sqrt{s}$



$\sigma_{\gamma\gamma(\gamma)}$ compared with QED prediction

$\sigma_{\gamma\gamma(\gamma)}$ versus $\sqrt{s}$



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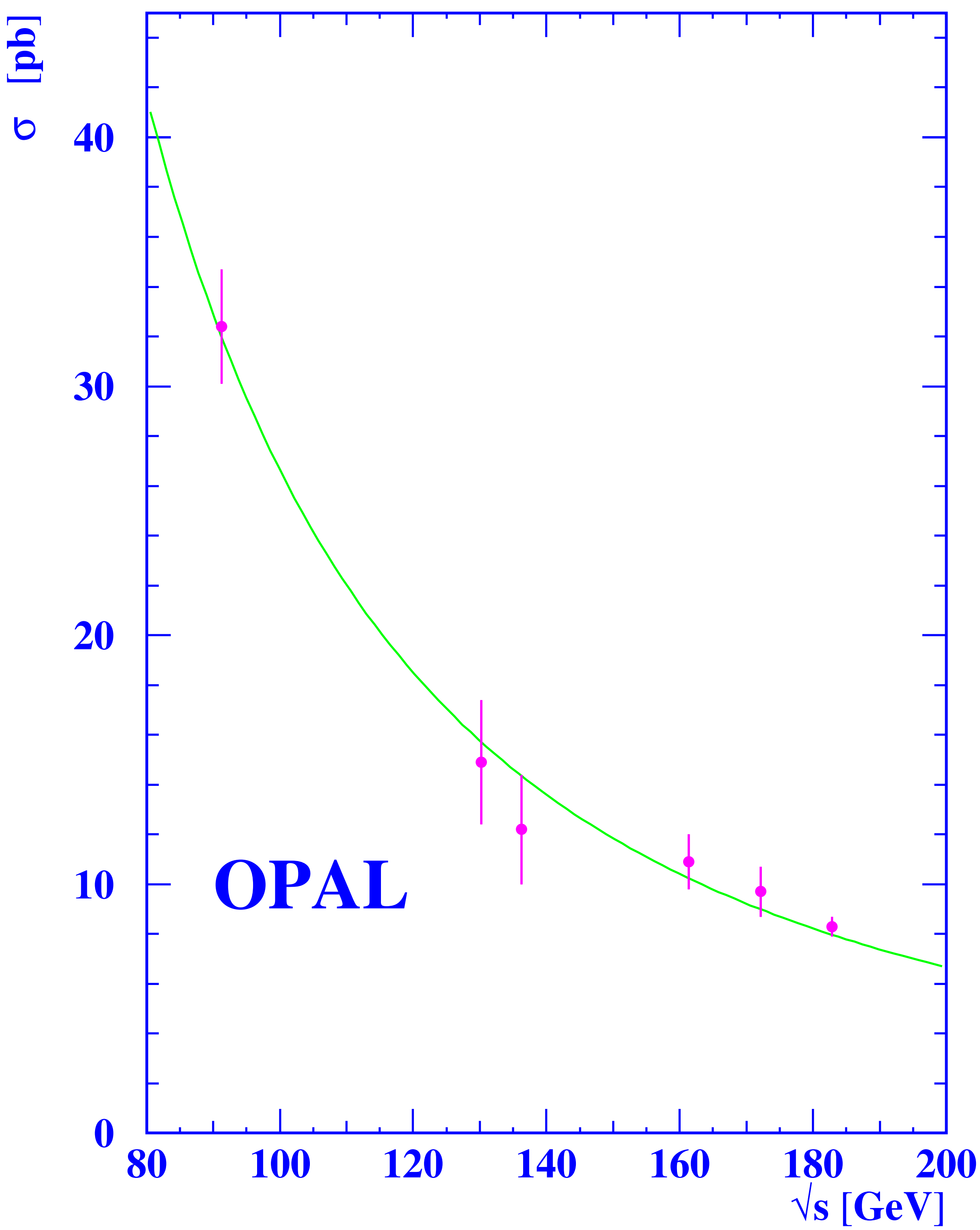
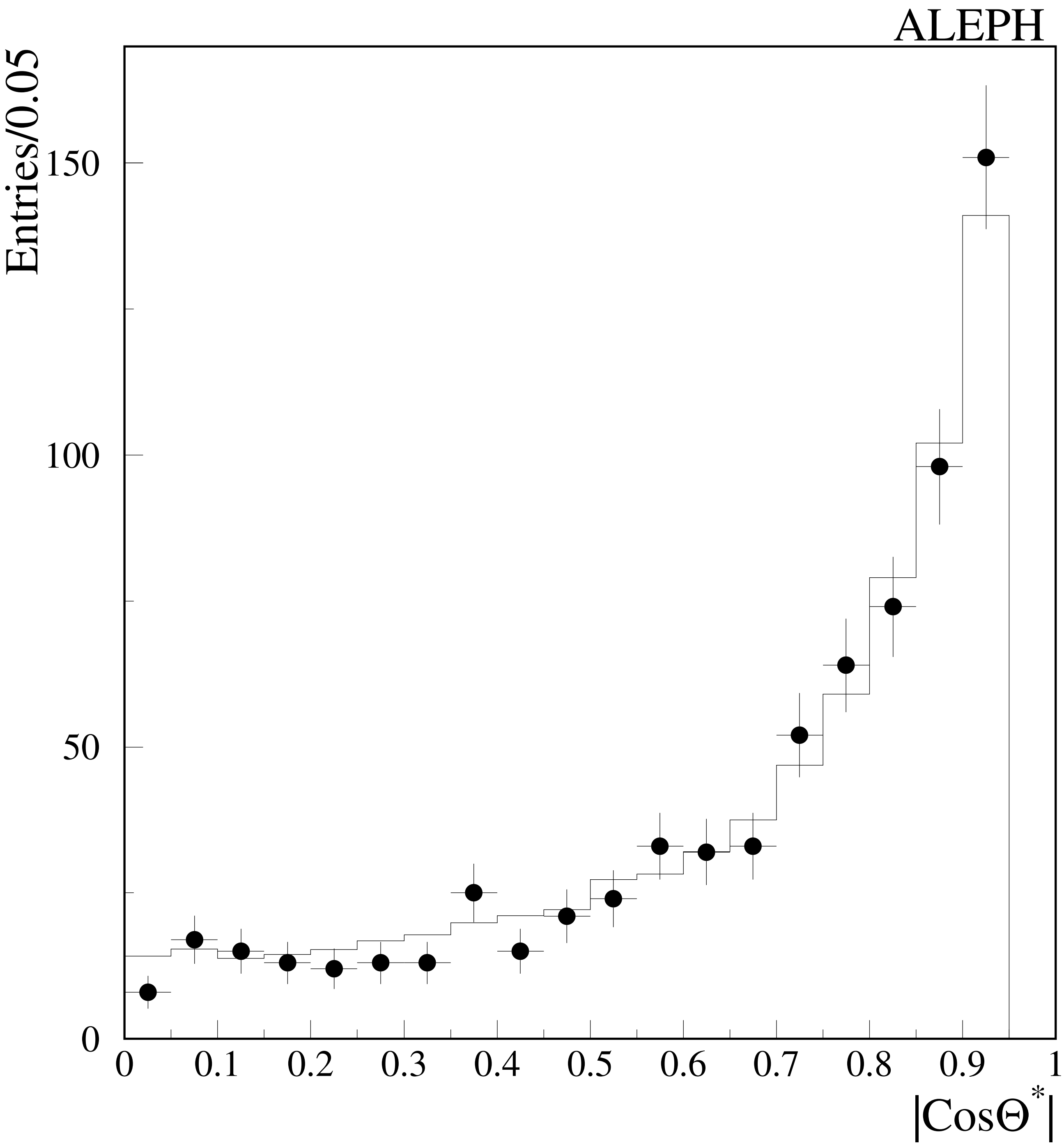


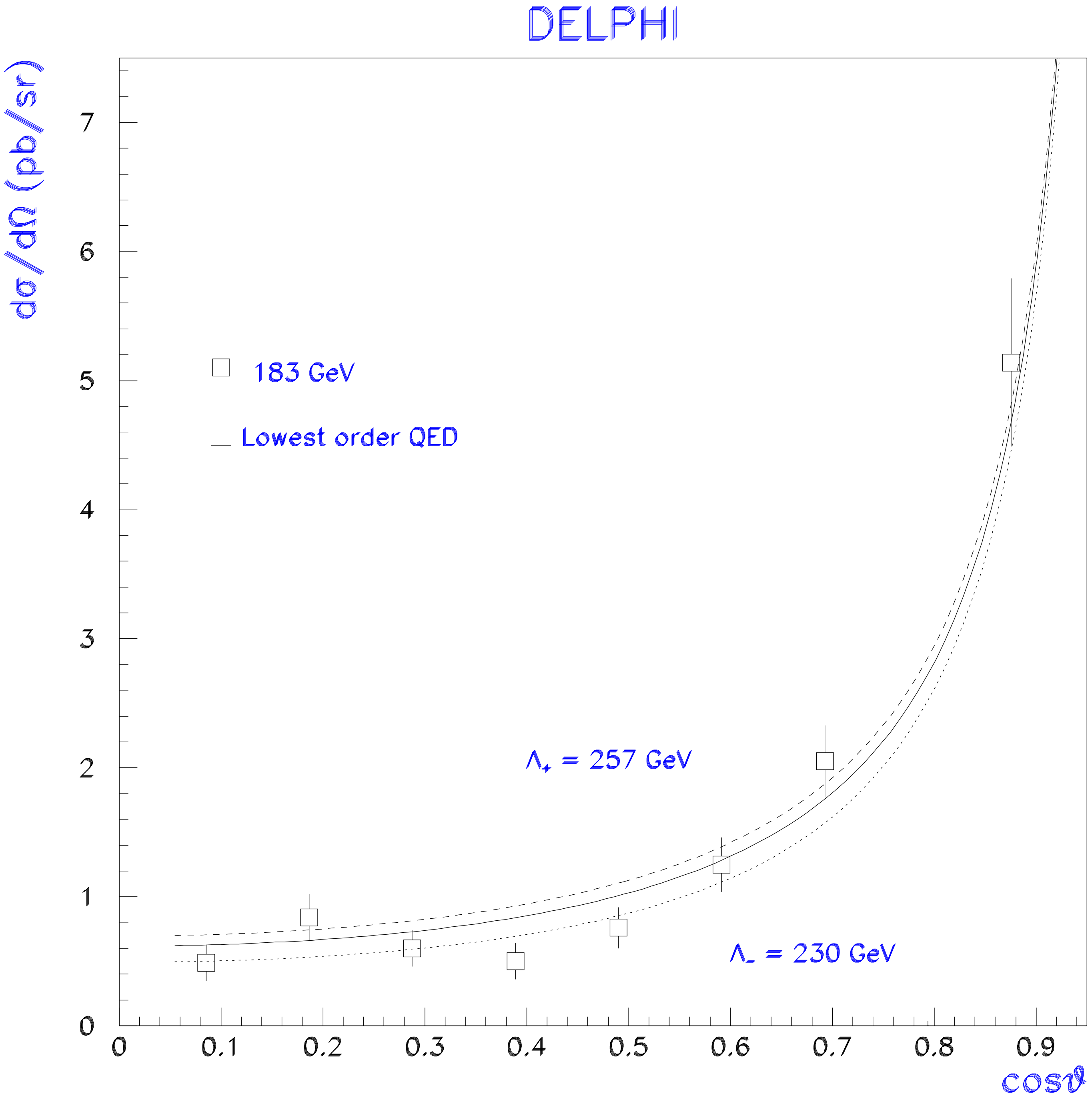
$\sigma_{\gamma\gamma(\gamma)}$ compared with QED prediction

$\frac{d\sigma}{d\Omega}$ versus $|\cos(\theta^*)|$



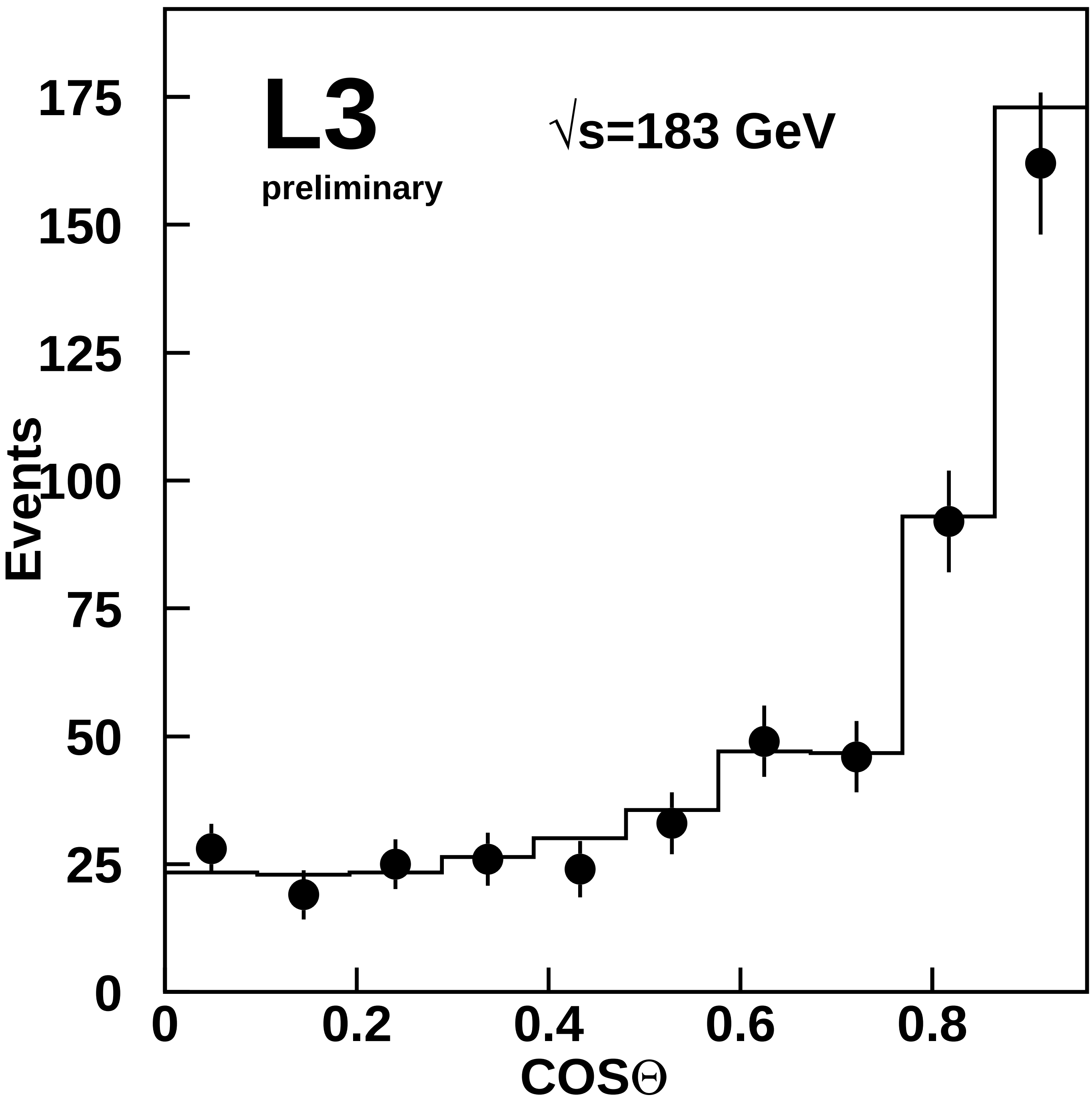
$\frac{d\sigma}{d\Omega}$ compared with QED prediction

$\frac{d\sigma}{d\Omega}$ versus $|\cos(\theta^*)|$



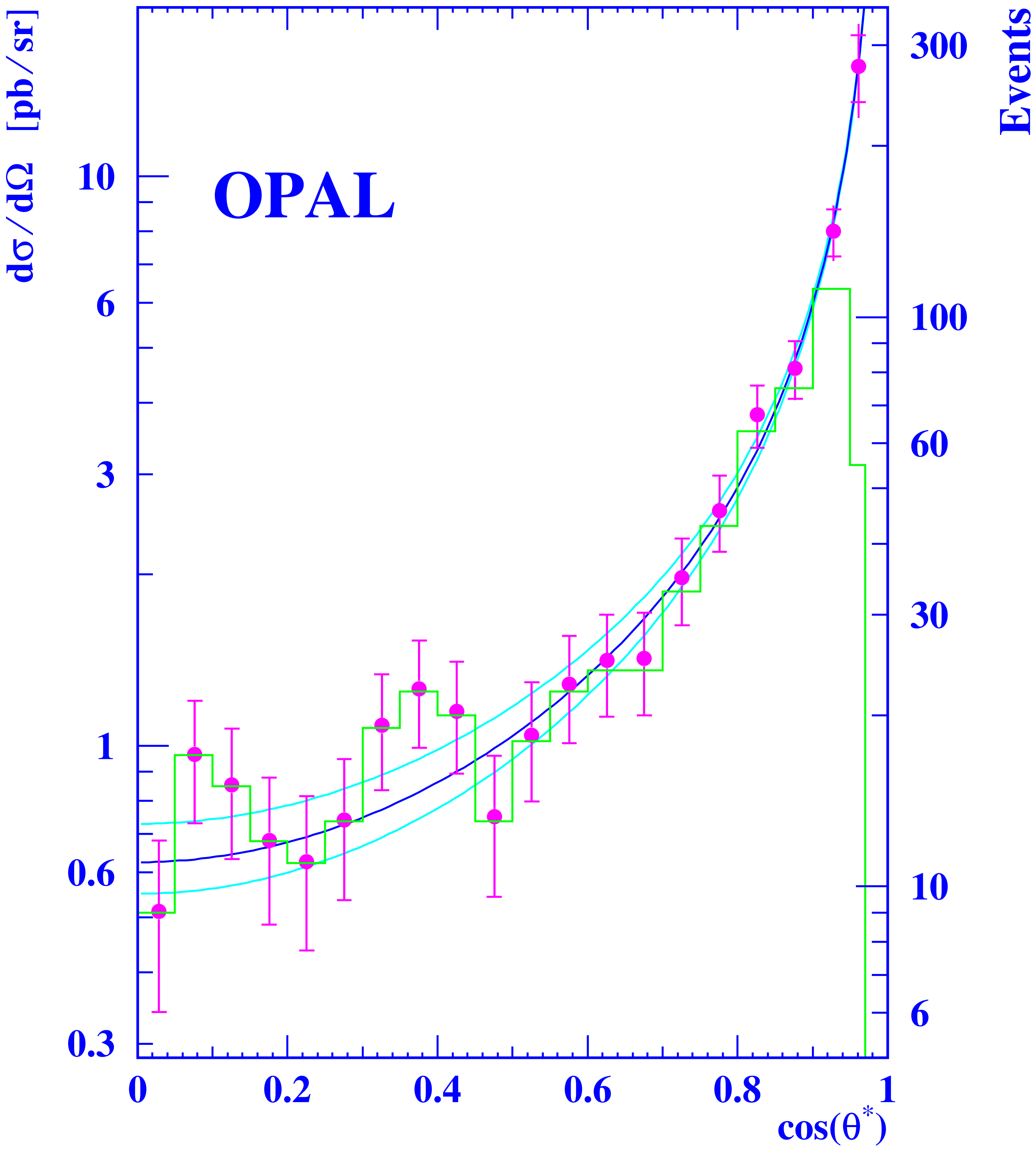
$\frac{d\sigma}{d\Omega}$ compared with QED prediction

$\frac{d\sigma}{d\Omega}$ versus $|\cos(\theta^*)|$



$\frac{d\sigma}{d\Omega}$ compared with QED prediction

$\frac{d\sigma}{d\Omega}$ versus $|\cos(\theta^*)|$



$\frac{d\sigma}{d\Omega}$ compared with QED prediction

Limits on deviations from QED

- σ and $\frac{d\sigma}{d\Omega}$ are sensitive to possible deviations from QED:
  - QED cut-off parameters:

$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_{QED} \left[1 \pm \frac{s^2}{2{\Lambda_\pm}^4}(1 - cos^2\theta^*)\right]$$

  - Contact interactions (Effective lagrangians dim. 6, 7):

$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_{QED} \left[1 + \frac{s^2}{\alpha{\Lambda_6}^4}(1 - cos^2\theta^*)\right]$$

$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_{QED} \left[1 + \frac{s^3}{32\alpha^2\pi{\Lambda_7}^6}\frac{(1-cos^2\theta^*)}{(1+cos^2\theta^*)}\right]$$

  - Excited electron exchange (approx. if $m_{e^*} \gg \sqrt{s}$):

$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_{QED} \left[1 + \frac{s^2\lambda_\gamma^2}{2{m_{e^*}}^4}(1 - cos^2\theta^*)\right]$$

- Fitting the measured $\frac{d\sigma}{d\Omega}$ to previous expresions:

Parameter	ALEPH	DELPHI	L3	OPAL	Combined
Λ_6 (GeV)	1100	1035[1]	1065	947[1]	1302
Λ_+ (GeV)	270	253	262	233	320
Λ_- (GeV)	230	225	245	265	277
Λ_7 (GeV)	624	–	603	557	667
m_{e^*} (GeV)	250	231	263	227	284[2]

(1) Limits estimated from the fitted values

(2) Only DELPHI, L3 and OPAL combined

First look at 189 GeV

- ✔ $\mathcal{L} = 32.3 pb^{-1}$ recorded by L3
- ✔ 290 $e^+e^- \rightarrow \gamma\gamma(\gamma)$ events found
- ✔ 17 events with 3 γ. No events with $n_\gamma > 3$

PRELIMINARY

- ✔ Cross-section:

$$\boxed{\sigma_{\gamma\gamma(\gamma)}(\sqrt{s} = 188.7\ GeV) = (11.0 \pm 0.6 \pm 0.4)\ pb}$$

- ✔ Limits on deviations from QED:

Λ_6	1186 GeV
Λ_+	292 GeV
Λ_-	248 GeV
Λ_7	614 GeV
m_{e^*}	293 GeV
$m_{e^*(\mathrm{L/R})}$	200 GeV

CONCLUSIONS

- The measured $\sigma(e^+e^- \to \gamma\gamma(\gamma))$ cross-sections show good agreement with QED predictions
- Lower limits are established for QED cut-off parameters, contact interaction and e^* mass
- With $\mathcal{L} \sim 100pb^{-1}$ at 189 GeV limits will improve $\sim 12\%$