Total Cross Section for Two—Photon Collisions at LEP

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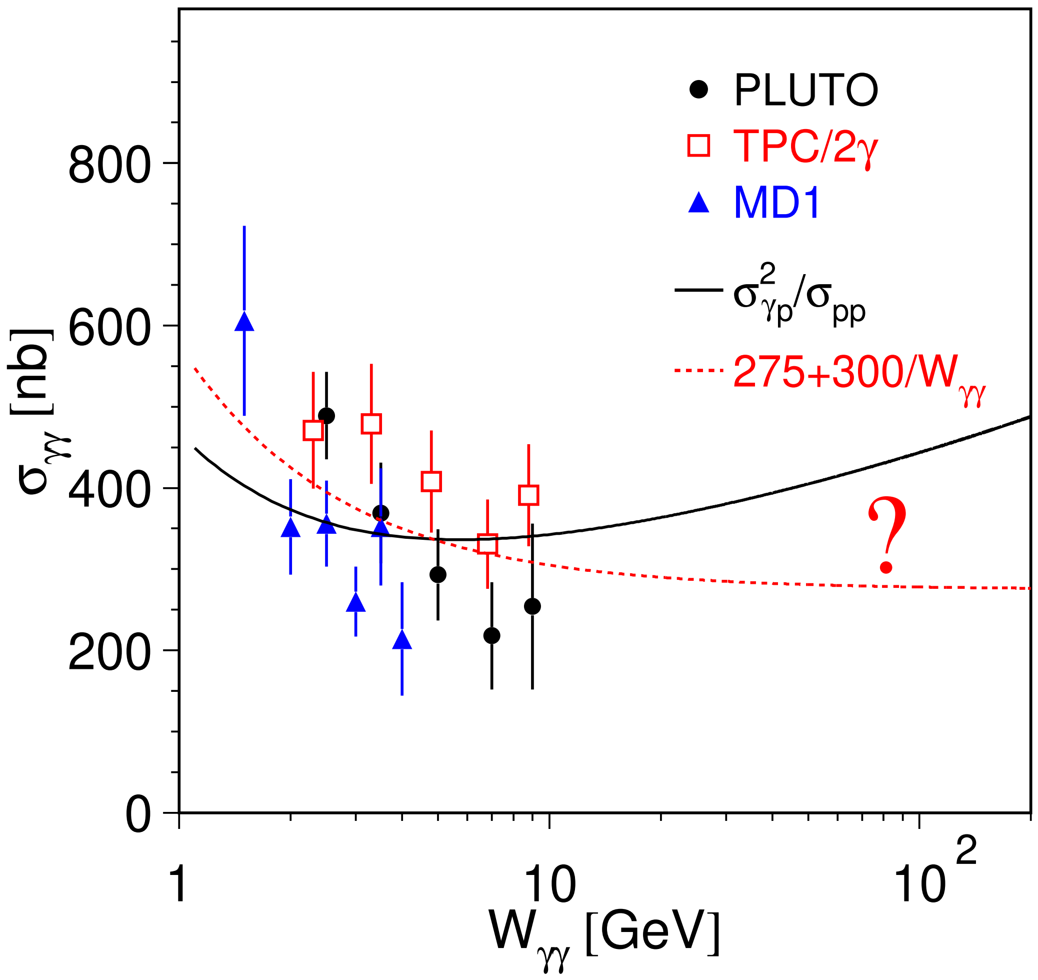
- Introduction
- Event Selection
- Data—MC comparison and unfolding
- Cross-section for real photons
- Regge fits and models
- QCD models
- Conclusions

Total $\sigma_{\gamma\gamma}$

The measurements before LEP :



- ❒ Limited by beam energy ➜ $W_{\gamma\gamma} < 10$ GeV.
- ❒ Wide spread in the measurements.
- ❒ Does $\sigma_{\gamma\gamma}$ increase at high energy ?

Total $\sigma_{\gamma\gamma}$: LEP data

- Data :
  L3 Coll. Phys. Lett. B 408 (1997) 450
  $5 < \mathrm{W}_{\gamma\gamma} < 75$ GeV.

130 - 140 GeV	4.98 pb^{-1}
161 GeV	10.4 pb^{-1}

  L3 preliminary $5 < \mathrm{W}_{\gamma\gamma} < 145$ GeV.

189 GeV	171.8 pb $^{-1}$
192-202 GeV	220.8 pb $^{-1}$

  OPAL Coll. Eur. Phys. J C 14 (2000) 199 450
  $10 < \mathrm{W}_{\gamma\gamma} < 110$ GeV.

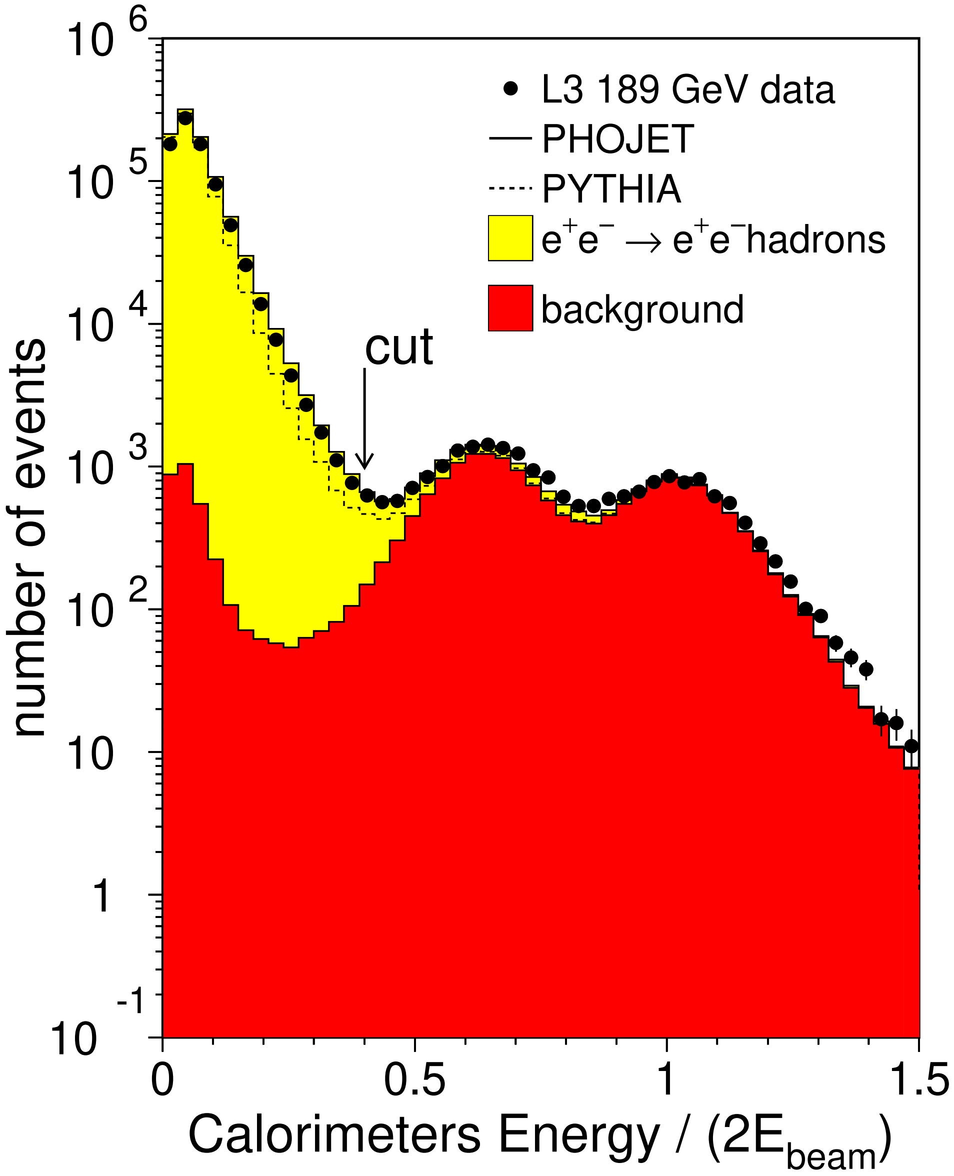
161 GeV	9.9 pb^{-1}
172 GeV	10.0 pb^{-1}
183 GeV	54.4 pb^{-1}

- Monte Carlo :
  - PHOJET v. 1.05c : R. Engel and J. Ranft. (Phys. Rev. D54, 4246, 1996)
  - PYTHIA v. 5.718: T. Sjöstrand (CPC 82, 74, 1994)

- Due to detector effect → $W_{vis} < W_{\gamma\gamma}$

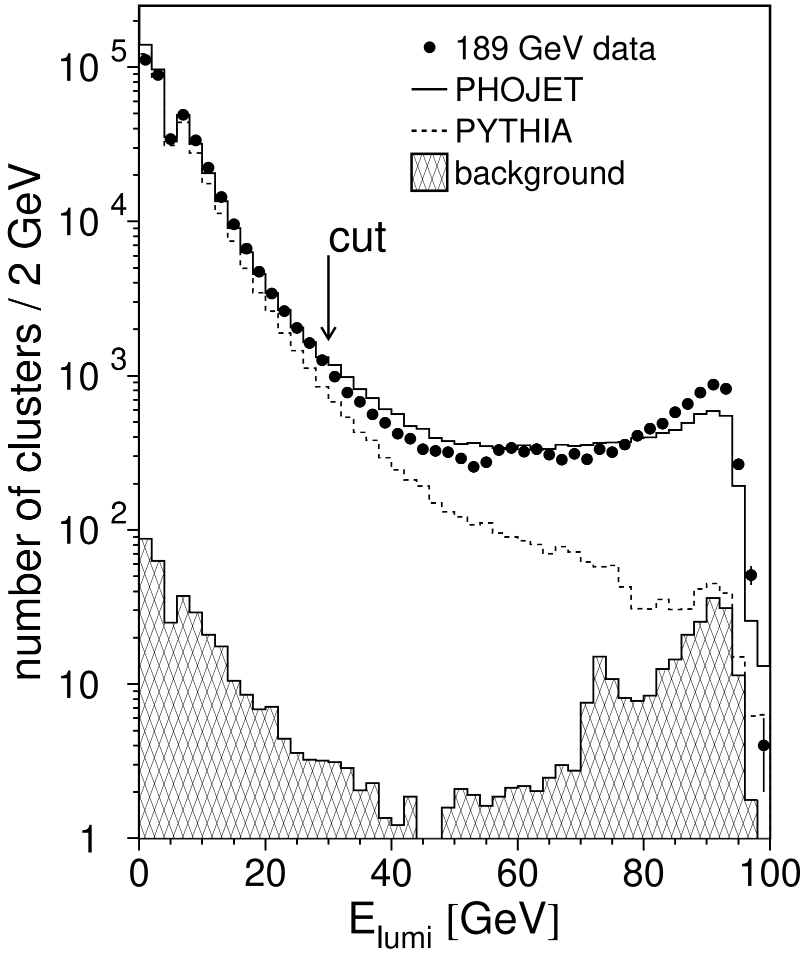
➥ Need Monte Carlo which reproduce well the data

Total $\sigma_{\gamma\gamma}$: Event Selection



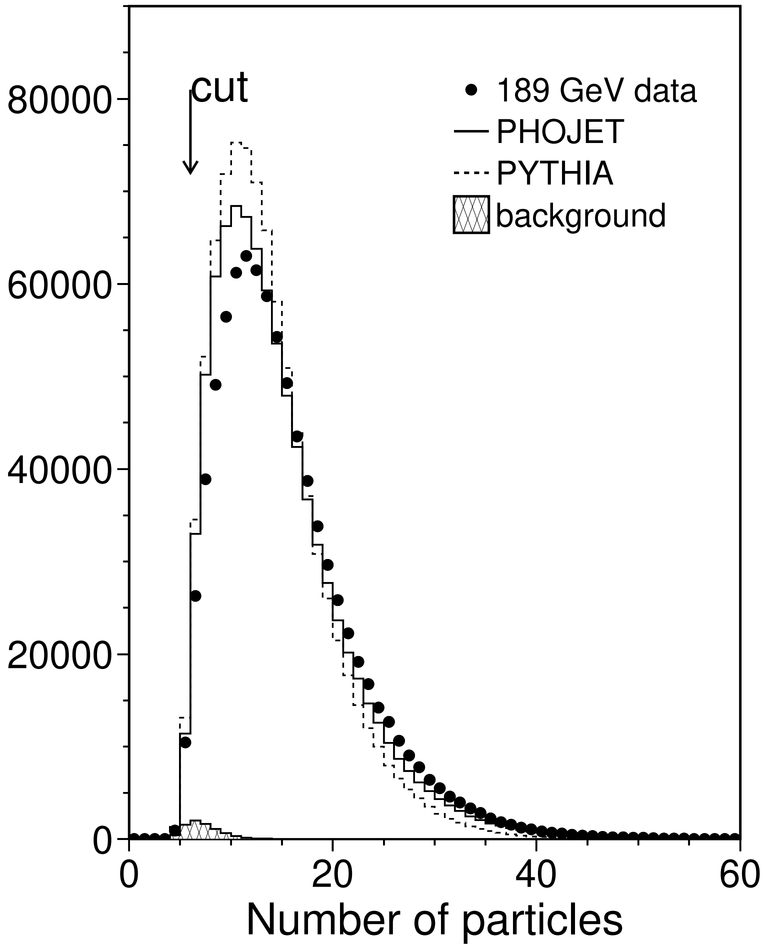
- E$_{tot} \leq 40\% \sqrt{s}$
- 0.5<E$_{em} < 50$ GeV
- The backgrounds : $e^+e^- \to e^+e^-\tau^+\tau^-$ and $e^+e^- \to hadrons$ are small $(1-15\%)$.
- systematic uncertainty $\sim 0.1 - 0.8$ %

Total $\sigma_{\gamma\gamma}$: Anti-tag



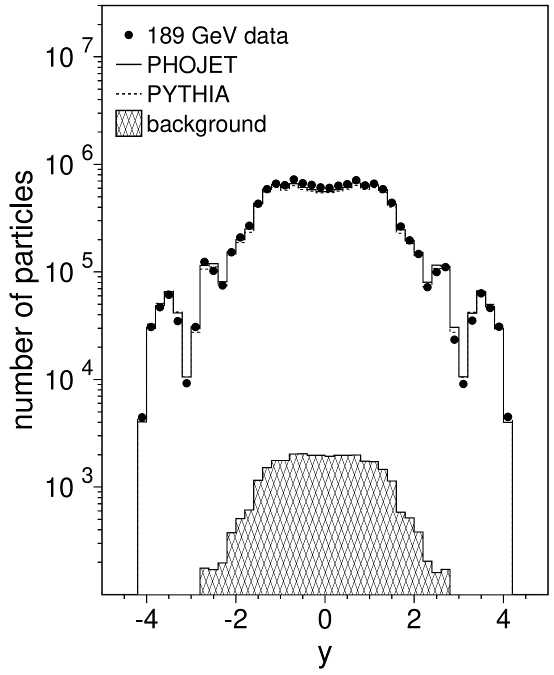
- No cluster with E > 30 GeV
  in polar angle region 33 mrad $< \theta < 64$ mrad
- Use the clusters with E < 30 GeV
  for W_{vis} calculation
- Systematic uncertainty:
  $\sim 0.1\%$ (low W_{vis}) 3%(high W_{vis})

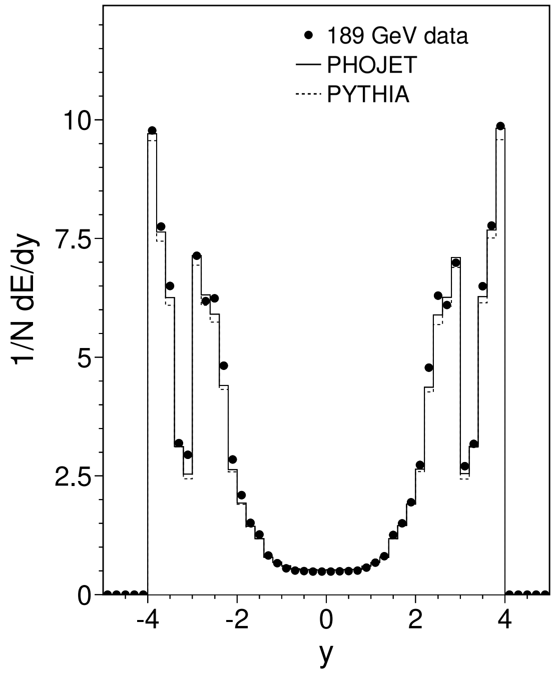
Total $\sigma_{\gamma\gamma}$: Event Selection

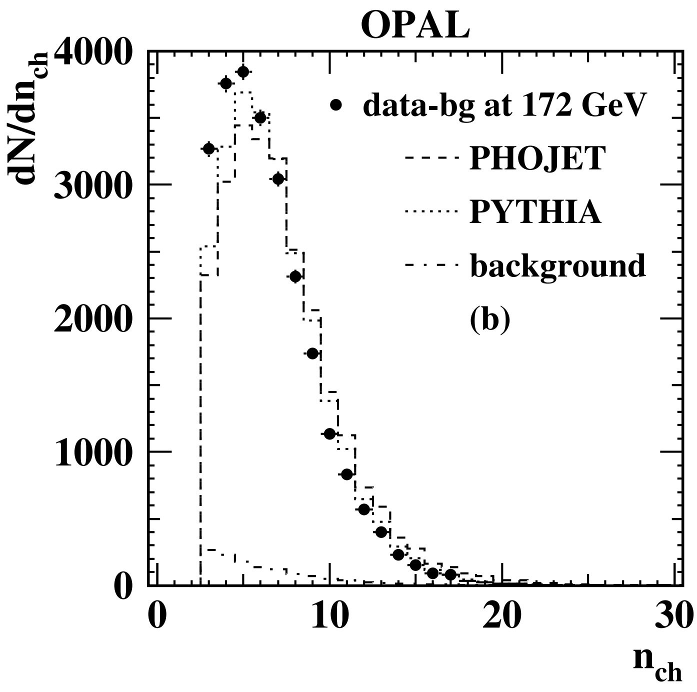


- Number of particles > 6
  (tracks and clusters in the calorimeters)
- Systematic uncertainty:
  7% (low $\mathrm{W_{vis}}$) 1 %(high $\mathrm{W_{vis}}$)

Total $\sigma_{\gamma\gamma}$: Monte Carlo comparison

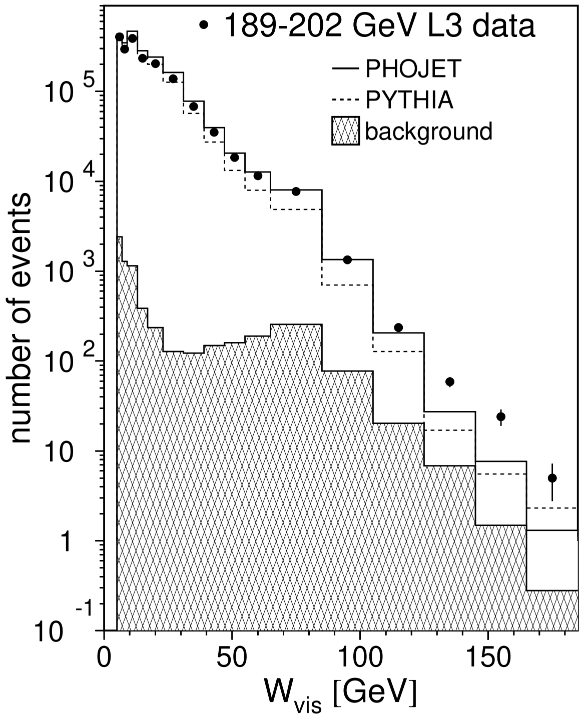




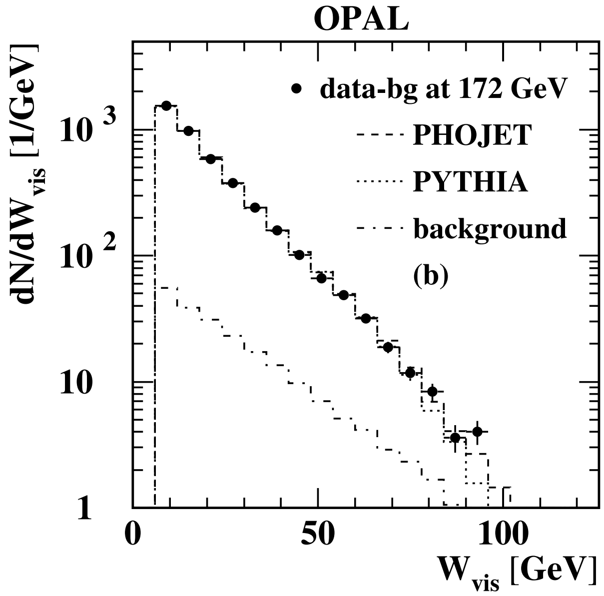


❒ Satisfactory (not perfect! $\sim 20 - 30\%$) agreement with both PYTHIA and PHOJET.

Total $\sigma_{\gamma\gamma}$: Selected Events

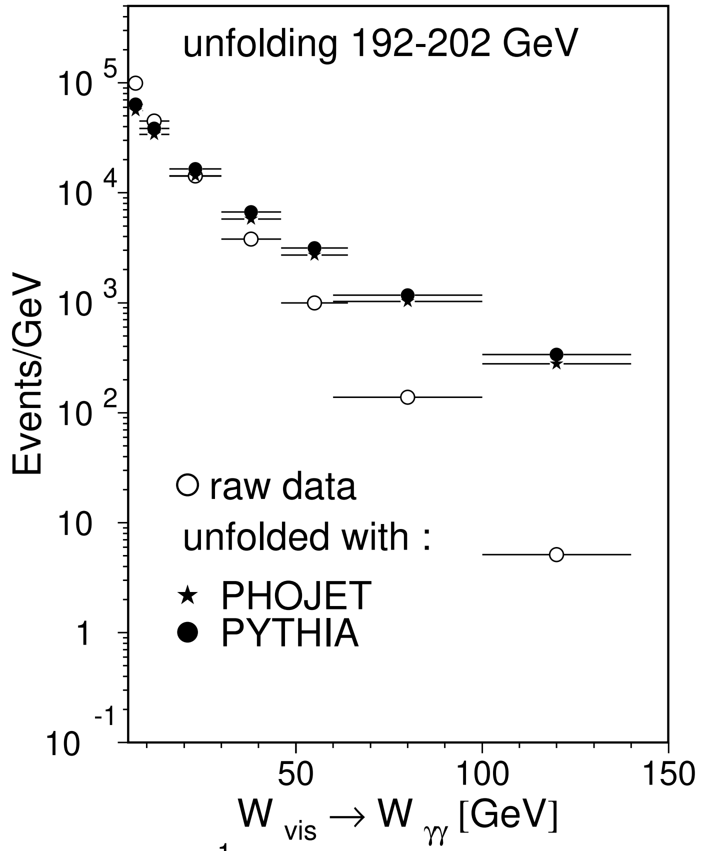


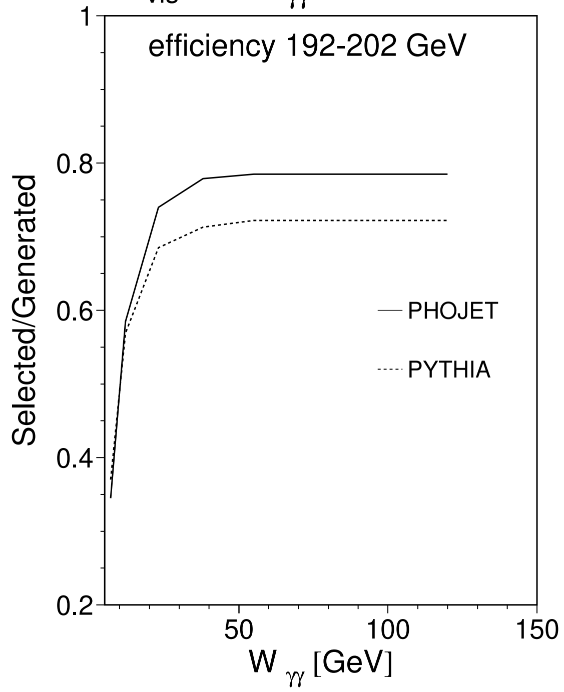
- L3 781511 events at $\sqrt{s}$= 189 GeV,
  1027939 events at $\sqrt{s}$= 192−202 GeV .



- OPAL 23250 events at $\sqrt{s}$= 161 GeV,
  25643 at $\sqrt{s}$= 172 GeV, 144147 at $\sqrt{s}$= 183 GeV .

Total $\sigma_{\gamma\gamma}$: Unfolding



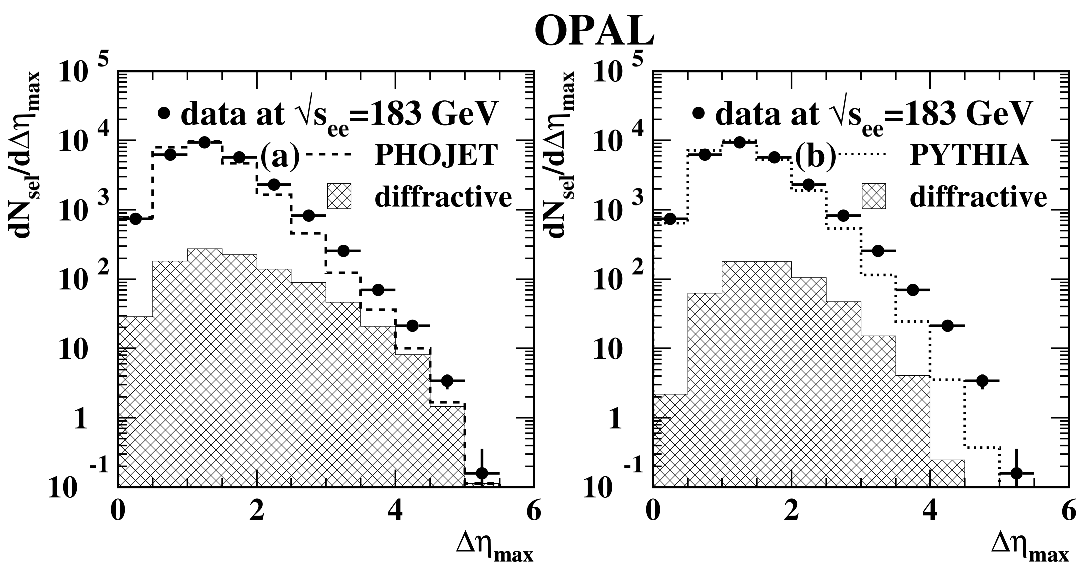


- Result depends on Monte Carlo model .

Total $\sigma_{\gamma\gamma}$: VDM

Can we choose

PYTHIA or PHOJET ?



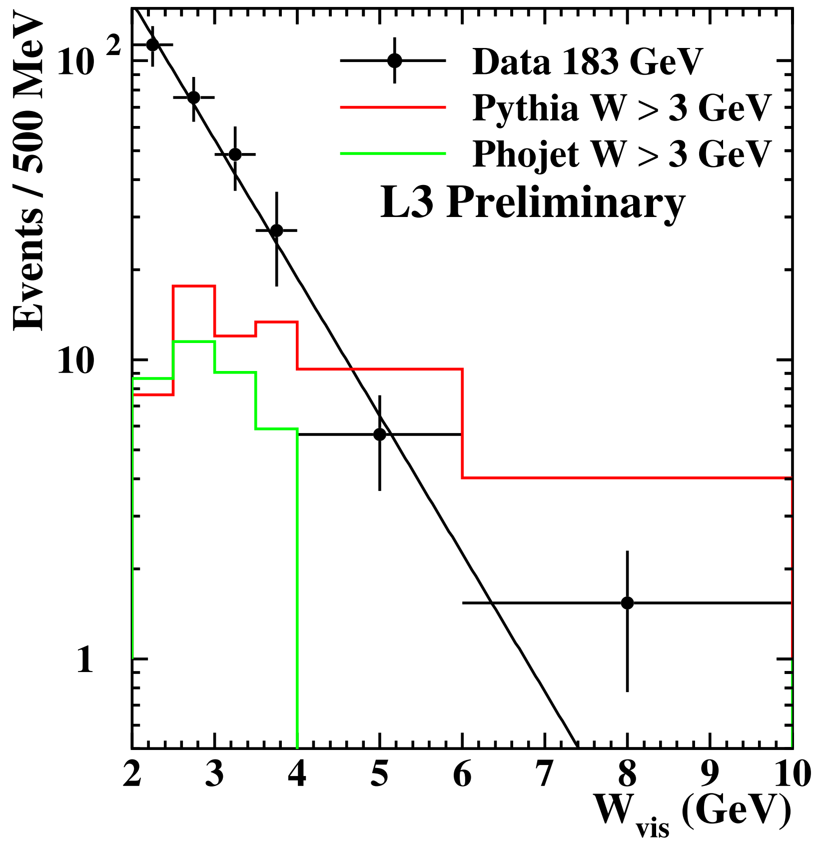
Check of the diffractive region with $\Delta\eta_{max}$, the maximum rapidity gap between any two particles.

- PHOJET in general agrees better with the data than PYTHIA .

Total $\sigma_{\gamma\gamma}$: VDM

But sometimes PHOJET fails :

- Charm production (see S. Saremi talk) .
- $e^+e^- \to e^+e^-\pi^+\pi^-\pi^+\pi^-$ (see V. Andreev talk)
- Inclusive ρ^0 production (Akos Csilling Thesis)



MC normalized to data luminosity

Bad correspondence for $e^+e^- \to e^+e^-\rho^0$ X events:

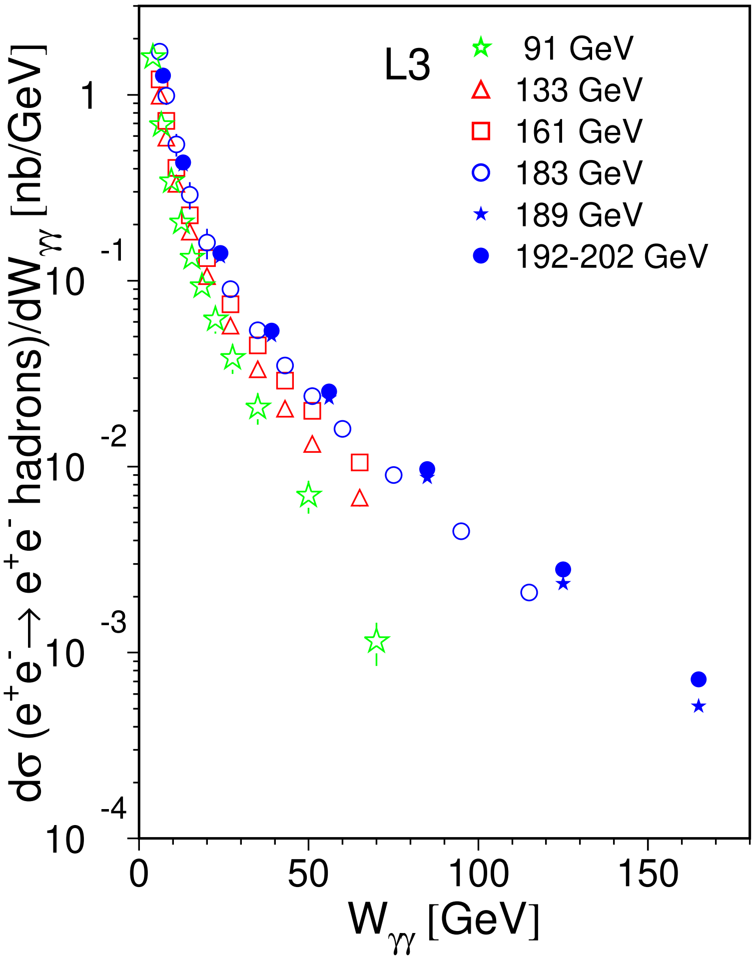
Pythia too flat

Phojet too steep

➜ Use both : PYTHIA and PHOJET

Total $\sigma_{\gamma\gamma}$: $d\sigma_{ee} \longrightarrow \sigma_{\gamma\gamma}$

❑ $d\sigma(\mathrm{e^+e^-} \to \mathrm{e^+e^-hadrons})$



✻ Effect of the $\gamma\gamma$ luminosity function

➜ $d\sigma_{ee}$ increases with increasing beam energy.

➜ $d\sigma_{ee}$ decreases with increasing $W_{\gamma\gamma}$.

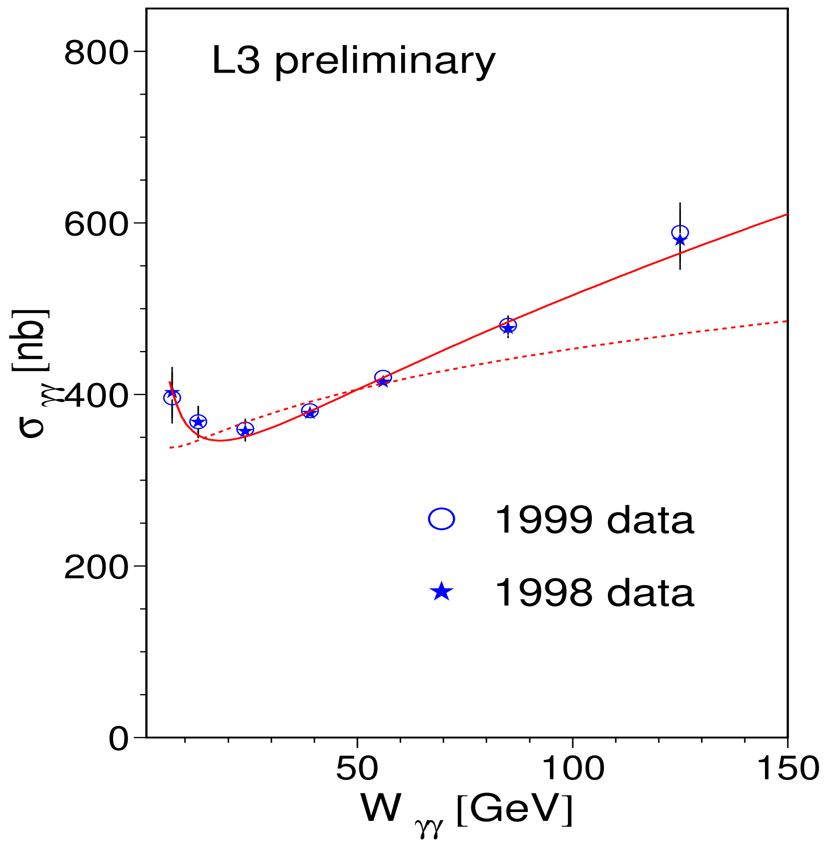
❑ Extract $\sigma_{\gamma\gamma}$ from $d\sigma_{ee}$

$$\frac{d\sigma_{ee}}{d(W^2_{\gamma\gamma}/s)} = \int \frac{dQ^2}{Q^2}\frac{dP^2}{P^2}\sum\nolimits_{a,b=T,S} \mathcal{L}_{ab}\sigma^{\gamma\gamma}_{ab}(W_{\gamma\gamma}, P^2, Q^2)$$

$$\sigma^{\gamma\gamma}_{ab}(W_{\gamma\gamma}, P^2, Q^2) = F_a(Q^2)F_b(P^2)\sigma^{\gamma\gamma}_{ab}(W_{\gamma\gamma})$$

*T and S are Transverse and Scalar photon helicity indices.

Total $\sigma_{\gamma\gamma}$: DL fit



- Statistical and experimental systematics errors
- Fit with Donnachie and Landshoff parametrisation : (Phys. Lett., B296 (1992) 227)

$$\sigma_{\gamma\gamma} = As^{\varepsilon} + Bs^{-\eta}\ ,\ s = W^2_{\gamma\gamma}$$

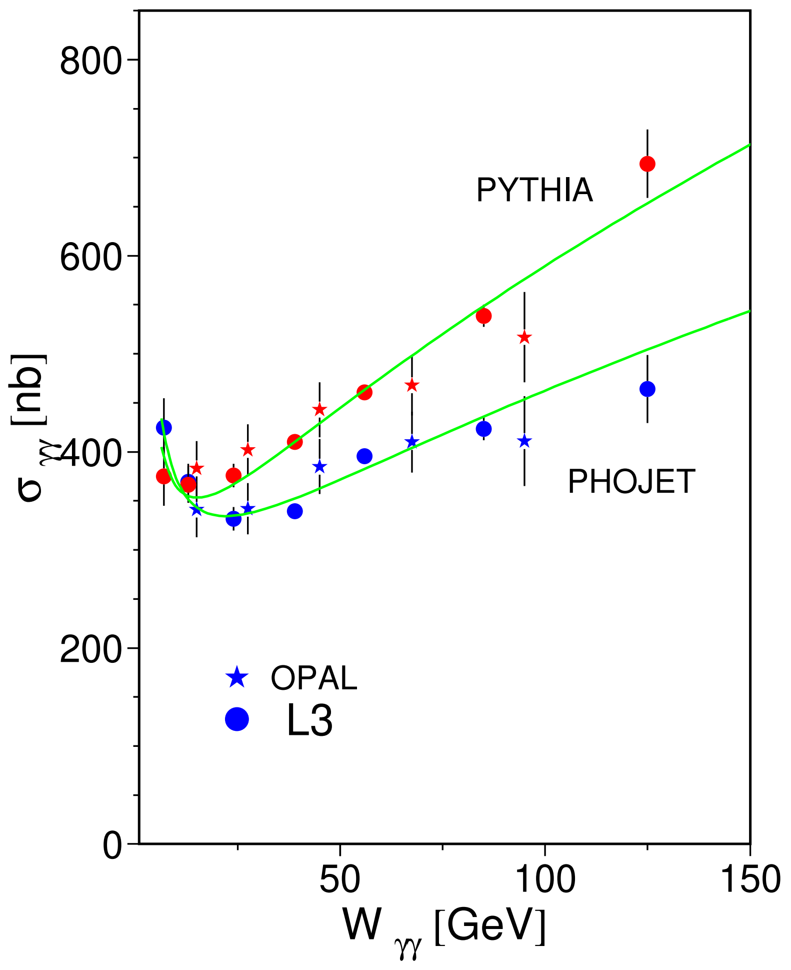
- Universal fit (PDG 1998):
  $\varepsilon = 0.095 \pm 0.002,\ \eta = 0.34 \pm 0.02,\ A, B$ free
- Fit to 189–202 GeV data (14 points)
  with correlation matrix, $\eta = 0.34$ fixed, A,B free

	ε	$\chi^2/d.o.f.$	CL
Universal ε	0.095 fixed	110 /12	6×10^{-18}
Free ε !10σ higher!	0.250 ± 0.016	13/11	30%

Total $\sigma_{\gamma\gamma}$: DL fit

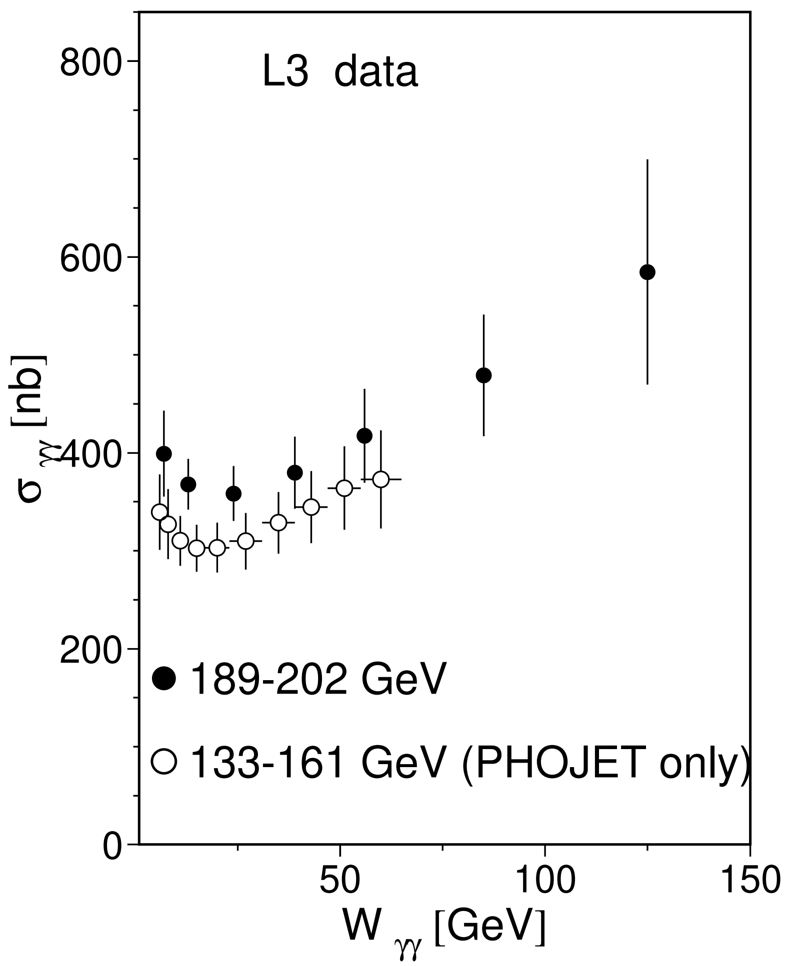
Results by unfolding with only one MC

- Statistical and experimental systematics errors
- OPAL and L3 results agree



- Slope almost independent on MC model :
  PHOJET Free $\varepsilon = 0.253 \pm 0.025$
  PYTHIA Free $\varepsilon = 0.271 \pm 0.020$
- For comparison with theoretical models we add to the experimental error the MC uncertainty and $\pm$ 5% for the luminosity function.

Total $\sigma_{\gamma\gamma}$

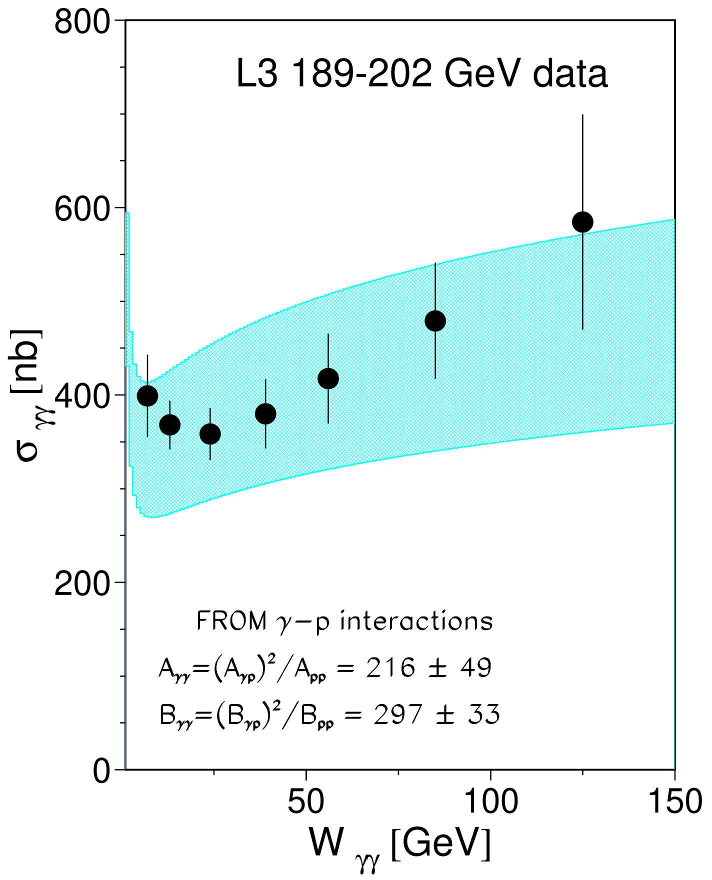


Published L3 data were unfolded with PHOJET only.
The present results supercede the old ones.

Total $\sigma_{\gamma\gamma}$

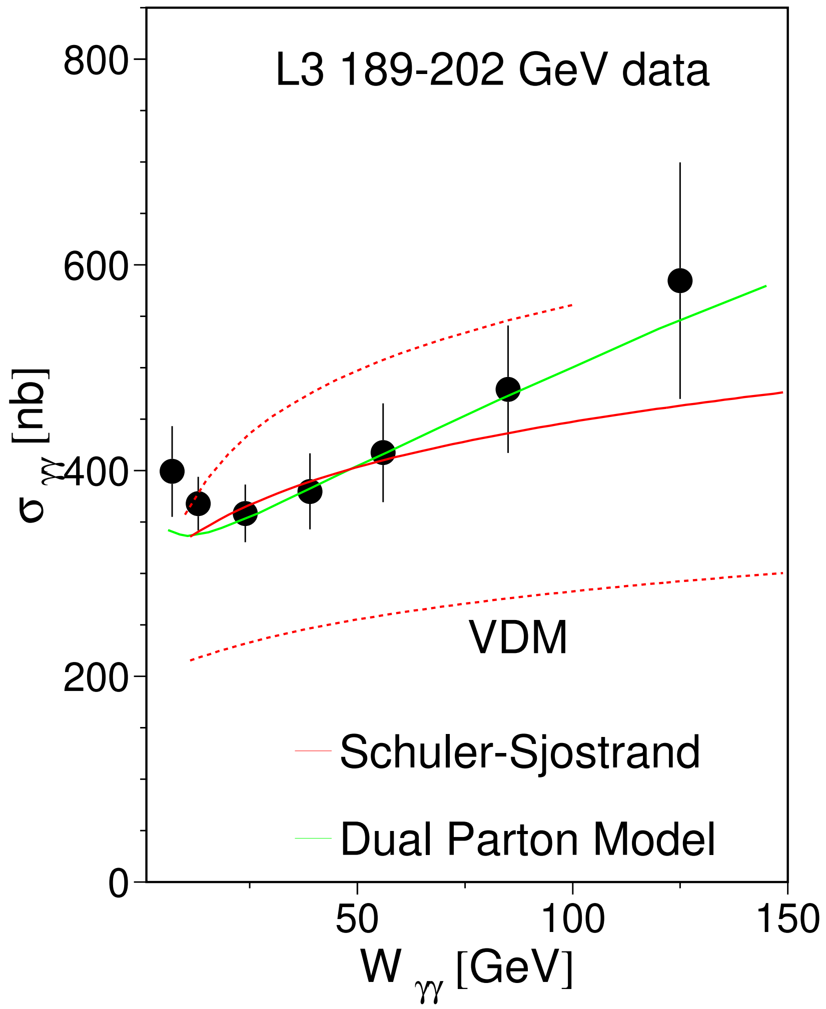
Is the steeper rise with $W_{\gamma\gamma}$ unexpected?

YES for all models with a dominant VDM contribution strongly tighted to γp data.



Expectations from the universal fit parameters and the Gribov factorisation from γp and pp data.

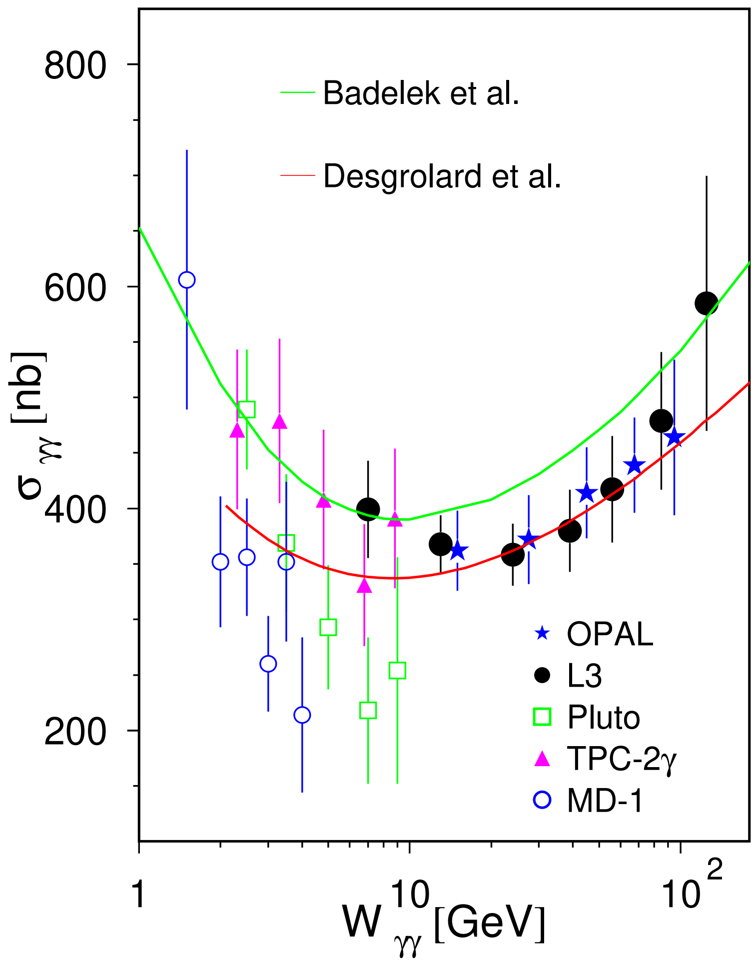
Total $\sigma_{\gamma\gamma}$: models



DPM (PHOJET): R. Engel private communication ($\pm$ 10% uncertainty)

G.A. Schuler and T. Sjöstrand , Z. Phys. C 73 (1997) 677.

Total $\sigma_{\gamma\gamma}$: models

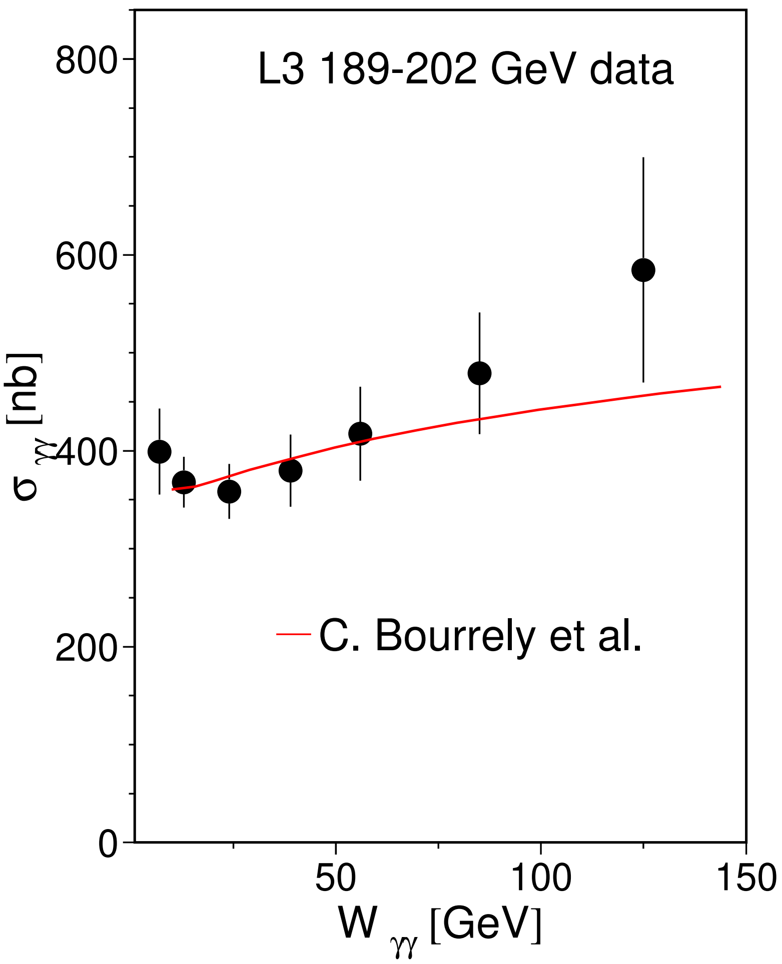


Very good agreement between L3 and OPAL data

B. Badelek, J. Kwiecinski and A.M. Stasto
Acta Phys. Polon. **30**(1999) 1807 and hep-ph/0001161 (2000)
P. Desgrolard, M. Giffon, E. Martynov and E. Predazzi
Eur. Phys. J **C 9** (1999) 623.

PLUTO Coll., Ch. Berger et al. , Phys. Lett. B 149 (1984) 421;
TPC/2γ Coll., H. Aihara et al. , Phys. Rev. D 21 (1990) 2667;
MD1 Coll., S.E. Baru et al. , Z.Phys. C 53 (1992) 219.

Total $\sigma_{\gamma\gamma}$: models

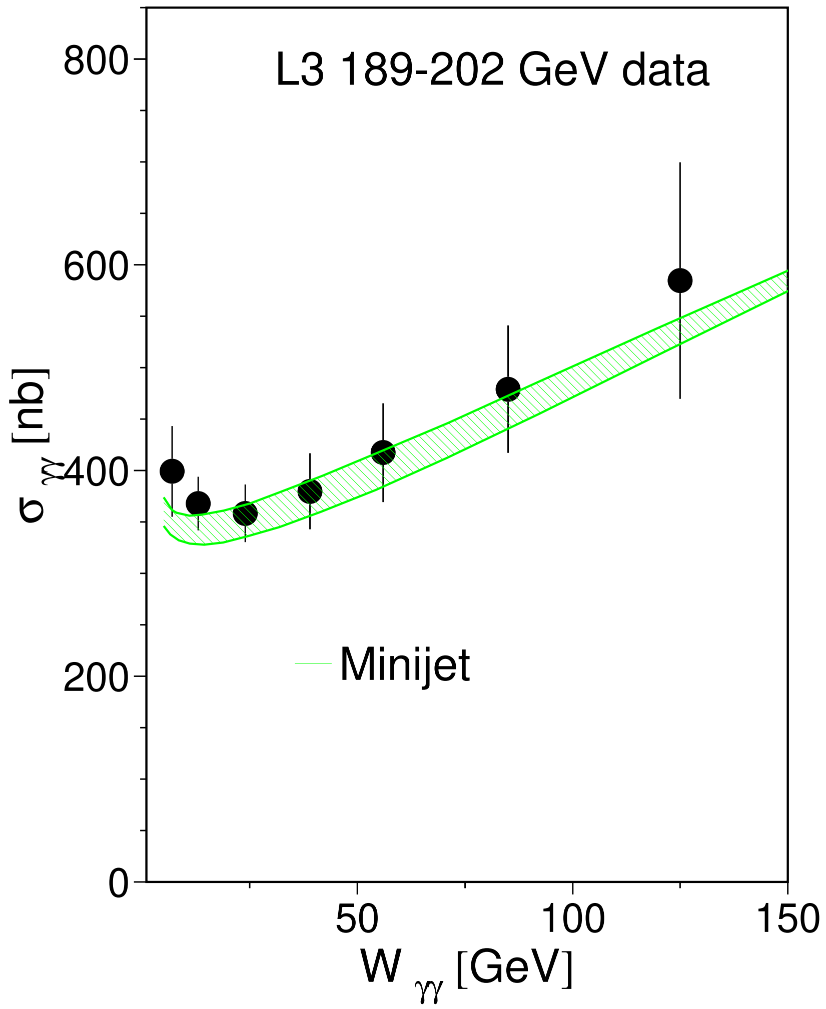


C. Bourrely, J. Soffer, T.T. Wu, hep-ph/9903438.
E. Gotsman, E. Levin, U. Maor and E. Naftali hep-ph/0001080.

Total $\sigma_{\gamma\gamma}$: QCD models

An higher slope is expected by QCD effects:

- "Hard Pomeron" : A. Donnachie, H.G. Dosch and M. Rueter Phys. Rev. **D59** (1999) 074011.
- "Minijet" : R.M. Godbole, A. Grau and G. Pancheri : Nucl. Phys. B 82 (2000) 246.



Two predictions compatible with photoproduction parameters :

lower curve : GRV, $p_{tmin} = 2$ GeV k_0=0.66

upper curve : GRS, $p_{tmin} = 1.5$ GeV k_0=0.4

Total $\sigma_{\gamma\gamma}$: Conclusions

- The total cross$-$sections for real photons are measured at LEP in the range $5\ \mathrm{GeV} < \mathrm{W}_{\gamma\gamma} < 145\ \mathrm{GeV}$
- OPAL and L3 measurements agree.
- The biggest uncertainty is due to Monte Carlo unfolding.
- $\sigma_{\gamma\gamma}$ increases faster than γp and hadron$-$hadron total cross-sections, as expected by some QCD models.
- Improvements can come only from a better understanding and modelling of the underlying processes.