Cross-section of Hadron Production in $\gamma\gamma$ Collisions at LEP

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DIS 98

4 - 8 April 1998 . Brussels

Cross-section of Hadron Production in $\gamma\gamma$ Collisions at LEP

- Introduction.
- Event selection and analysis.
- Results.
- Conclusion.

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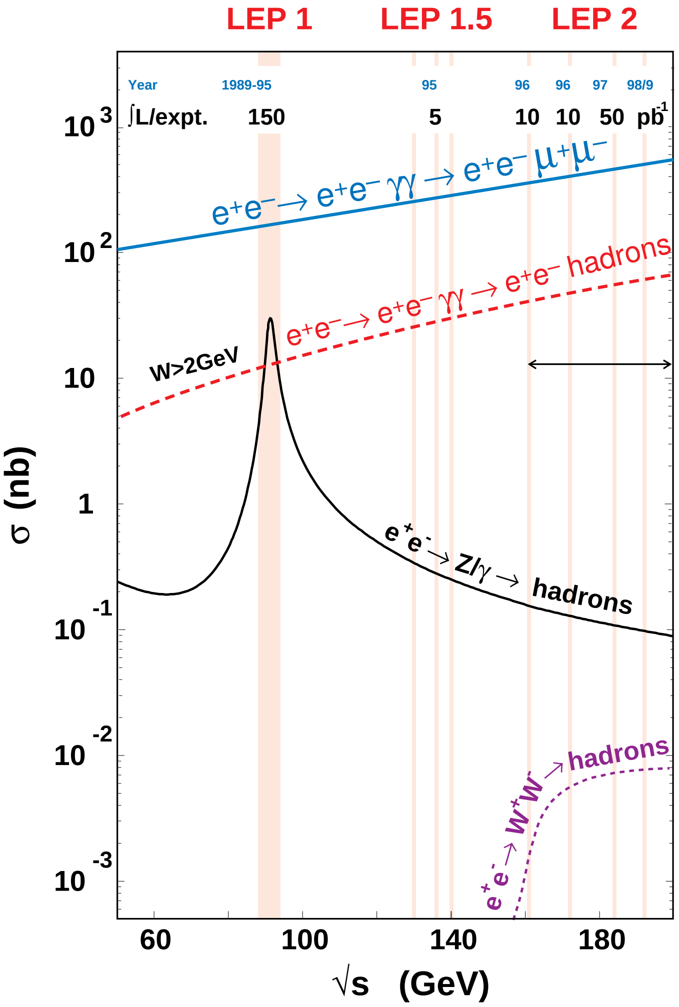
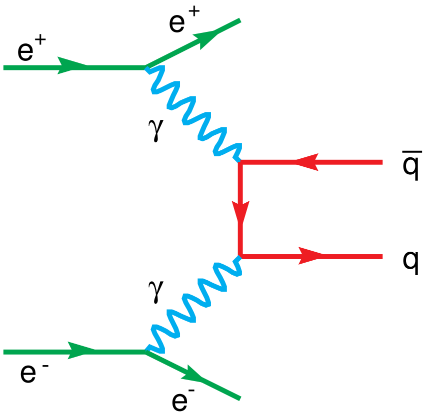
Introduction



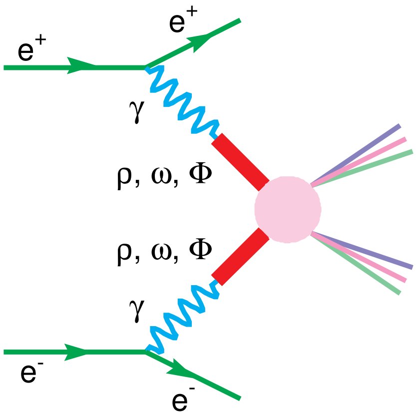
- $e^+e^- \rightarrow e^+e^-\gamma\gamma \rightarrow e^+e^-$**hadrons**, is the main contribution to hadron production.
- Background to other processes.
- Investigate the complex structure of the γ.

Physics Motivation

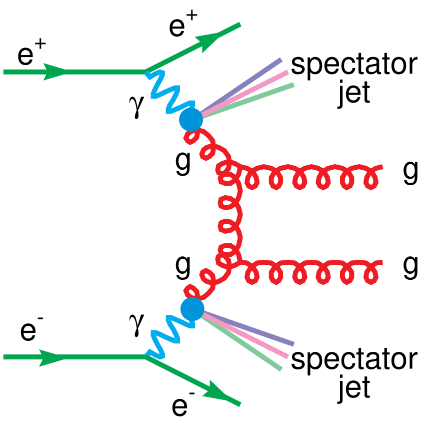
Some diagrams contributing to
$$\mathbf{e^+e^- \to e^+e^-\gamma\gamma \to e^+e^- hadrons.}$$



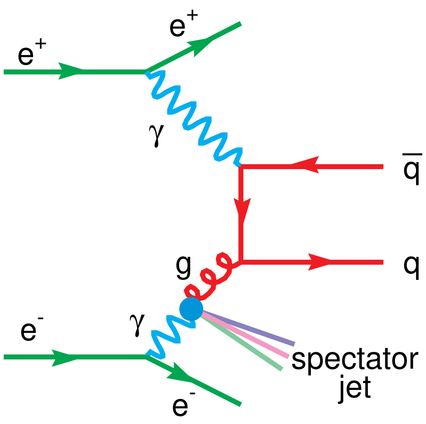
Direct



VDM



Double Resolved



Single Resolved

Event selection

- Only hadronic events:
  Number of particles ≥ 6

  Particles:
  $\pi^{\pm}$: tracks, clusters in Hcal and LUMI.
  γ : clusters only in ECAL.
- Exclude annihilation events :
  $E_{Ecal+Hcal} < 50GeV$.
- Low Q^2 $\rightarrow$ only anti tagged events :

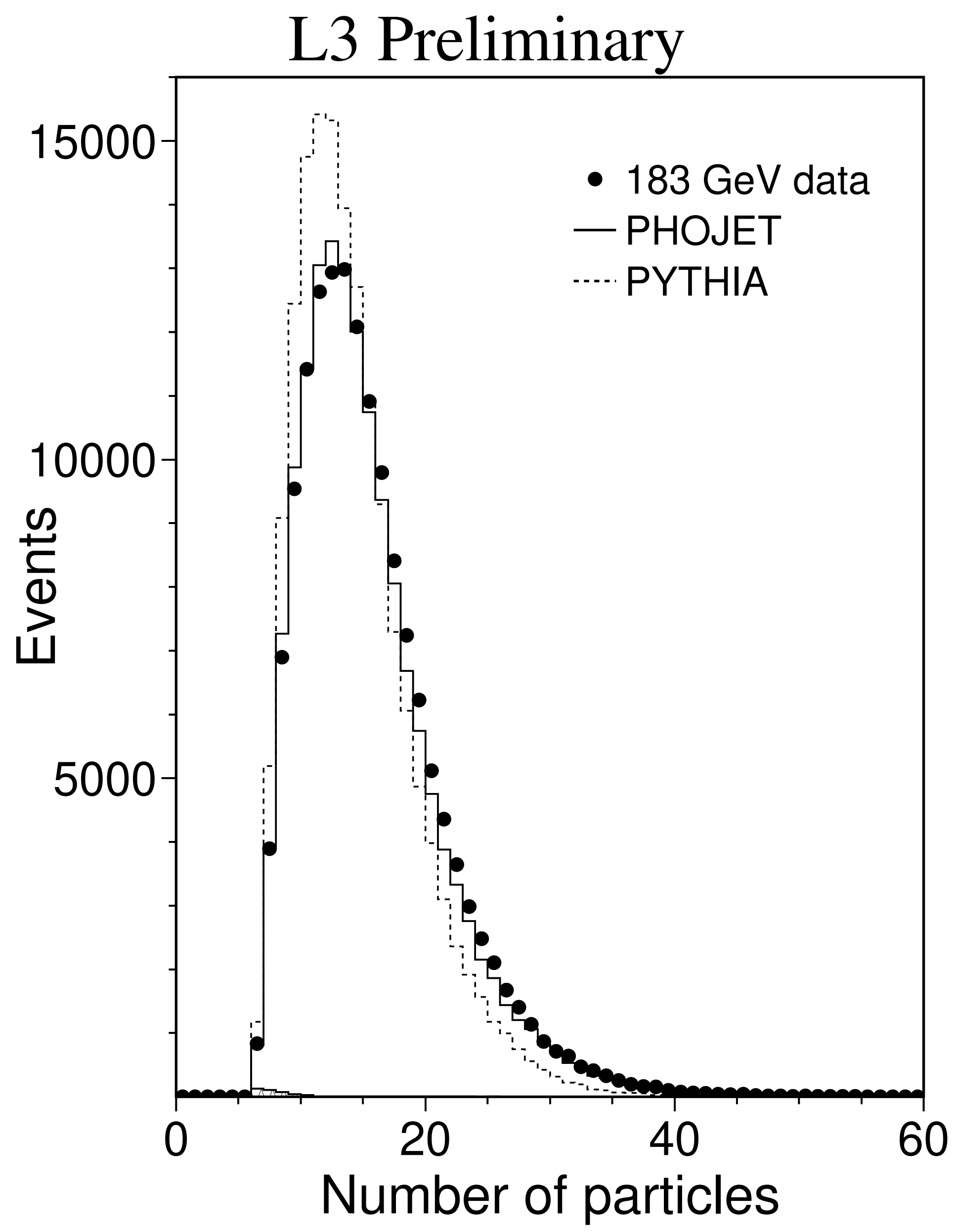
  both photons are almost real

  $E_{LUMI} < 50GeV$
  $\mathbf{33} < \theta < \mathbf{64}$ mrad
- $W_{vis} > 5GeV$

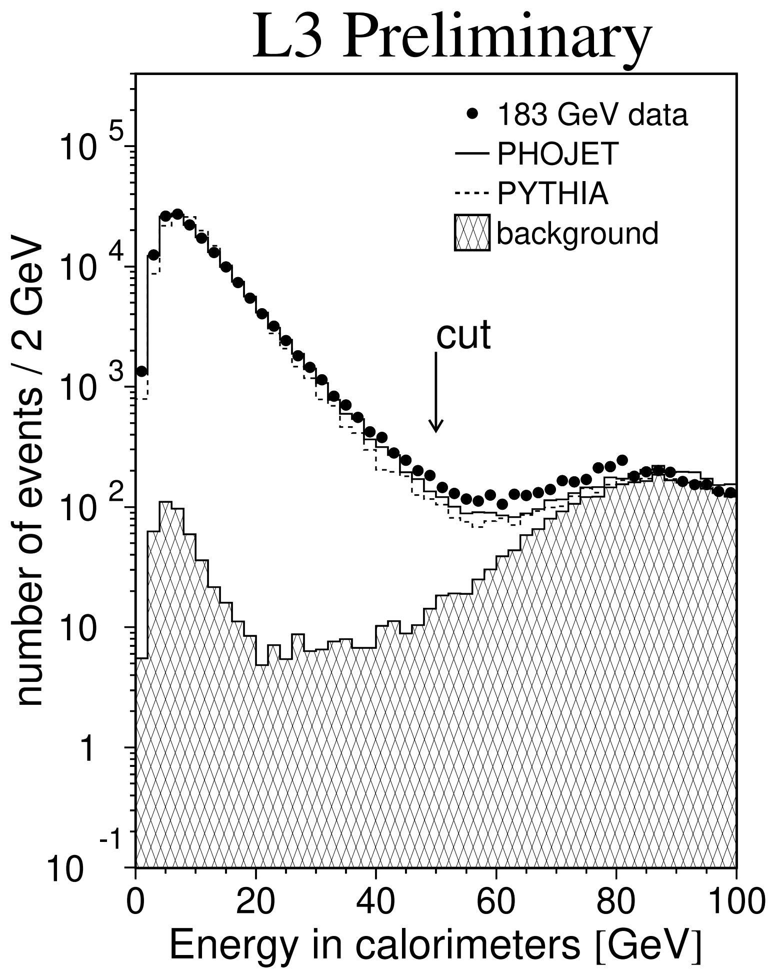
$$W_{vis}^2 = (\sum E_i)^2 - (\sum \vec{P}_i)^2$$

i = particles.

Event selection



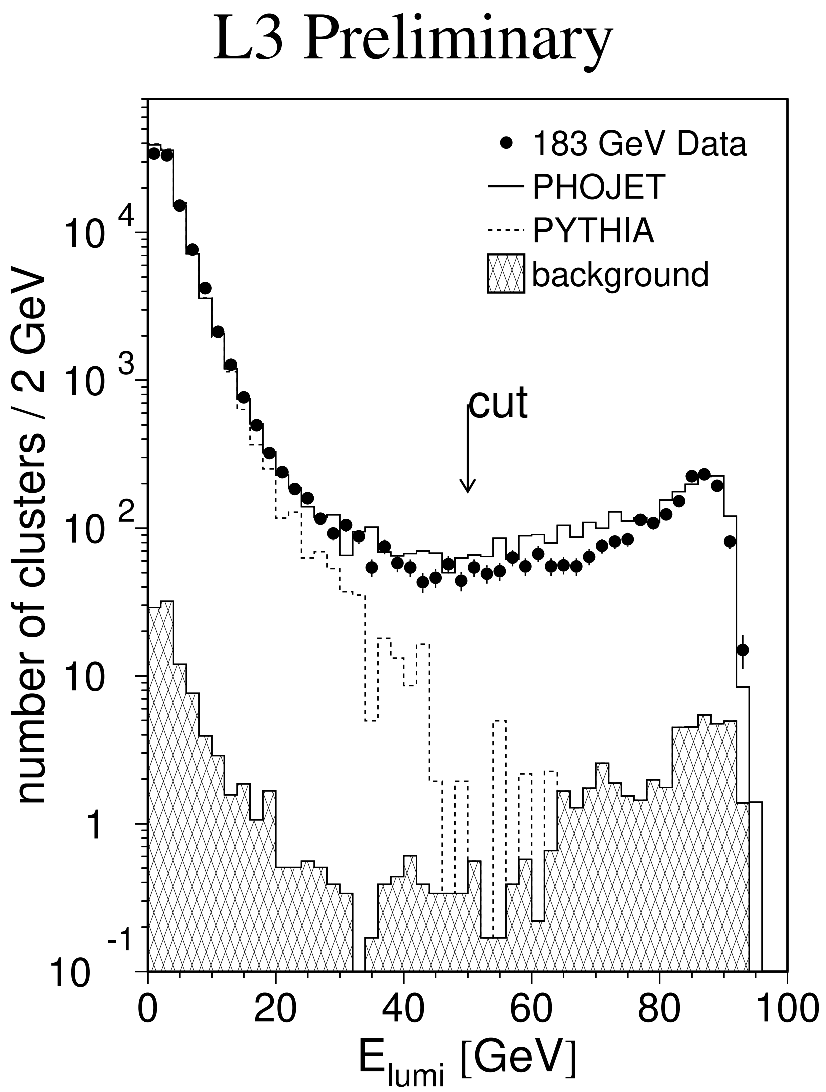
Events with more than 6 particles are selected



Backgrounds contributions

- PYTHIA
  $e^+e^- \longrightarrow hadrons(\gamma), ZZ(\gamma), Zee(\gamma), We\nu(\gamma)$
- KORALW
  $e^+e^- \longrightarrow W^+W^-$
- KORALZ
  $e^+e^- \longrightarrow (\gamma/Z^o)^* \longrightarrow \tau^+\tau^-(\gamma)$
  $e^+e^- \longrightarrow (\gamma/Z^o)^* \longrightarrow \mu^+\mu^-(\gamma)$
- DIAG36
  $e^+e^- \longrightarrow e^+e^-\tau^+\tau^-$

Event selection



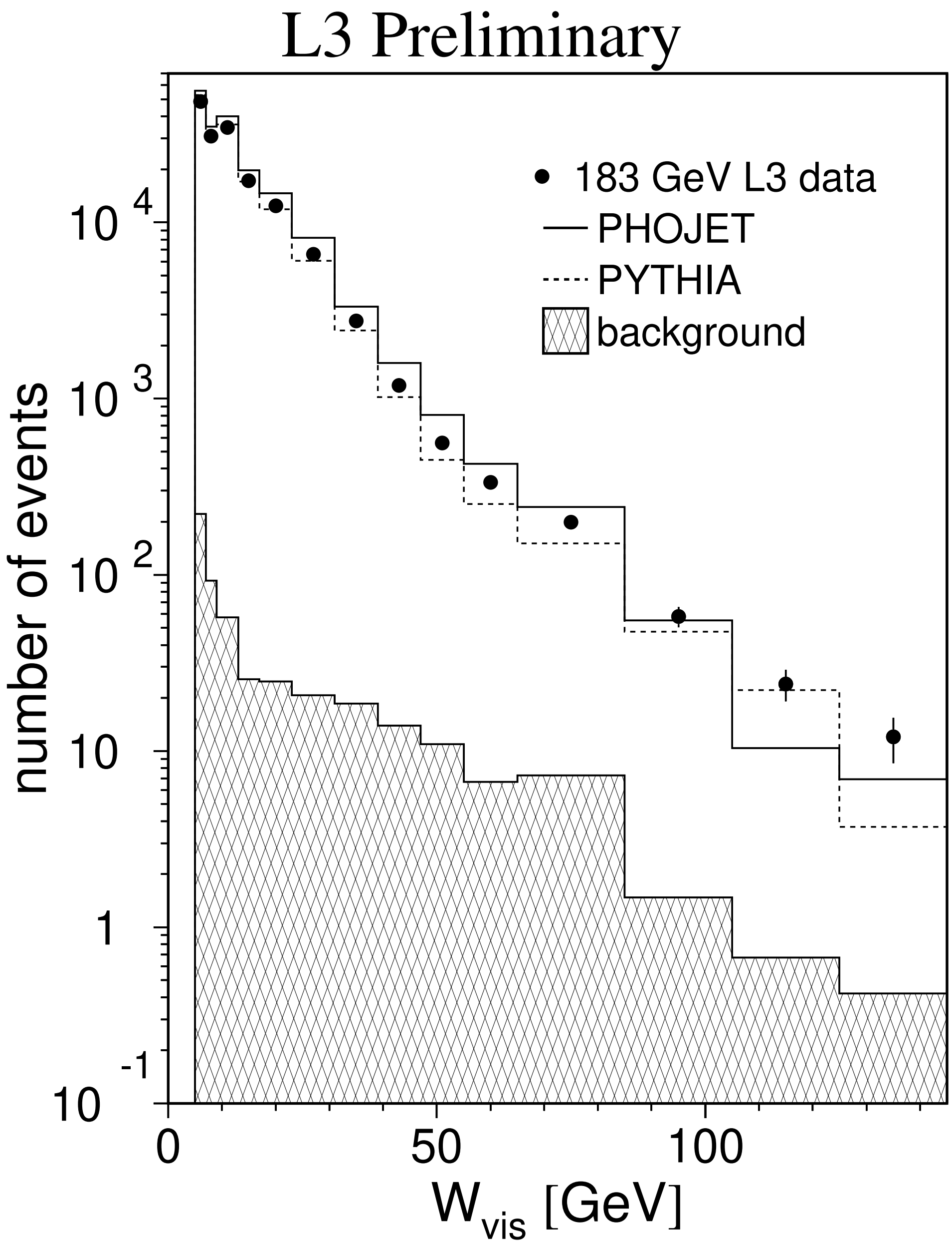
- **PHOJET (R. Engel and J. Ranft)**

  Uses $\gamma\gamma$ luminosity function $\mathbf{L}_{\gamma\gamma}$ for transverse photons, taking into account the hadronic couplings of the photon by using a generalised VDM.

- **PYTHIA (T. Sjöstrand and G.A. Schuler)**

  Both photons are on the mass shell. We complemented the code by generating the photon fluxes in the EPA with a cutoff $Q^2 \leq m_\rho^2$. Valid only for events with $Q^2 \simeq 0$.

Event selection



Total background contribution is lower than 0.6 %.

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

$$= d^5 L_{\gamma\gamma} \times \sigma_{\gamma\gamma}(W_{\gamma\gamma}, Q_1^2, Q_2^2).$$

$$\sigma_{\gamma\gamma}(\mathbf{W}_{\gamma\gamma}, \mathbf{Q_1^2}, \mathbf{Q_2^2}) = \sum_{\mathbf{a,b=T,S}} \sigma_{\mathbf{ab}}(\mathbf{W}_{\gamma\gamma}, \mathbf{Q_1^2}, \mathbf{Q_2^2})$$

** a,b are the two γ's,*

** T and S are for the Transverse and Scalar helicity components of the photon respectively.*

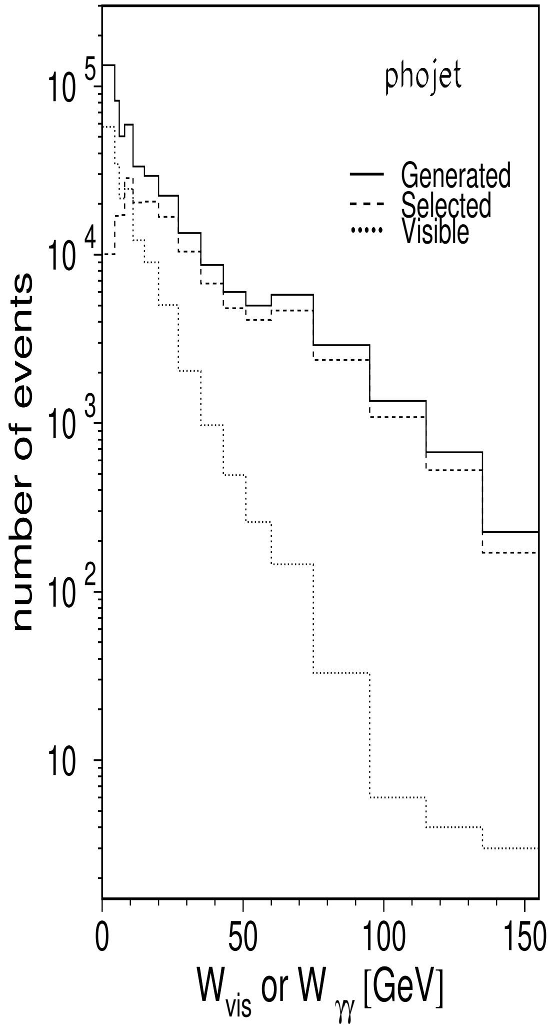
$$\sigma_{\mathbf{ab}}(\mathbf{W}_{\gamma\gamma}, \mathbf{Q_1^2}, \mathbf{Q_2^2}) = \mathbf{F_a^2}(\mathbf{Q_1^2})\mathbf{F_b^2}(\mathbf{Q_2^2})\sigma_{\gamma\gamma}(\mathbf{W}_{\gamma\gamma}, \mathbf{0}, \mathbf{0})$$

$$\mathbf{F}(\mathbf{Q^2}) = \sum_{\mathbf{v}=\rho,\omega,\phi} \mathbf{m_v^2}/(\mathbf{Q^2} + \mathbf{m_v^2})$$

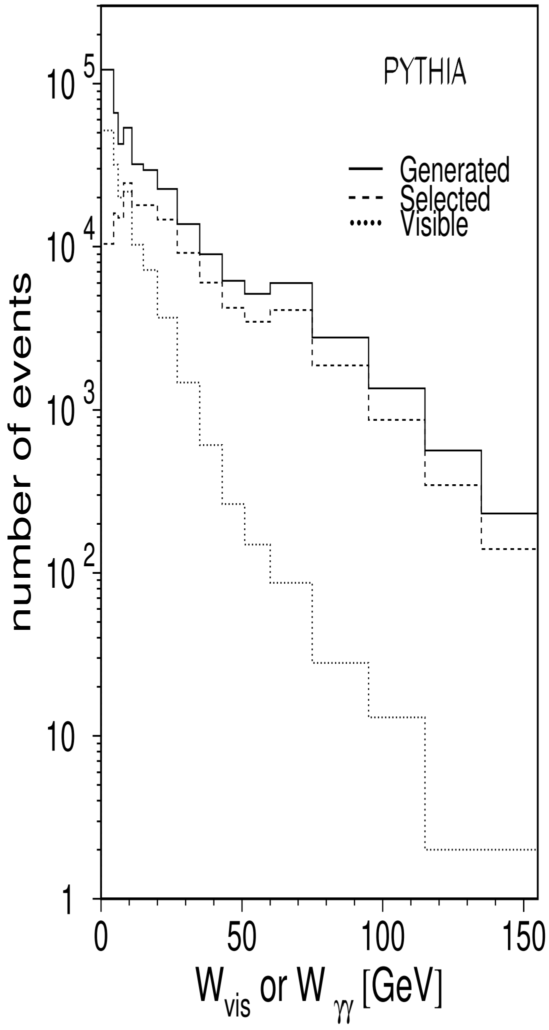
- **$\mathrm{d^5L}_{\gamma\gamma}(\alpha_\mathrm{i})$ $\mathrm{F^2(Q^2)} \Leftarrow$ Schuler numerical integration.**

Unfolding i.e. $W_{vis} \Longrightarrow W_{\gamma\gamma}$

PHOJET



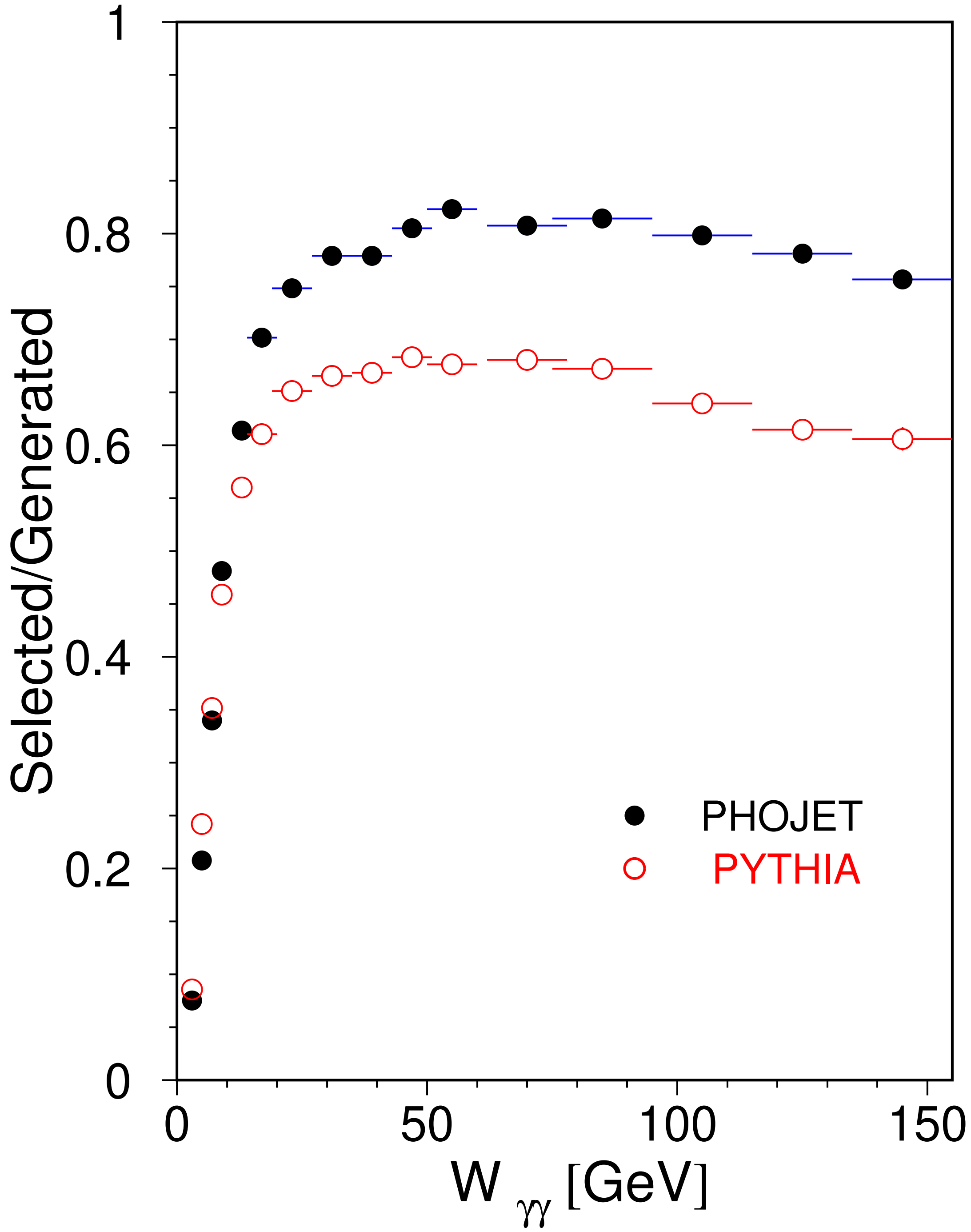
PYTHIA



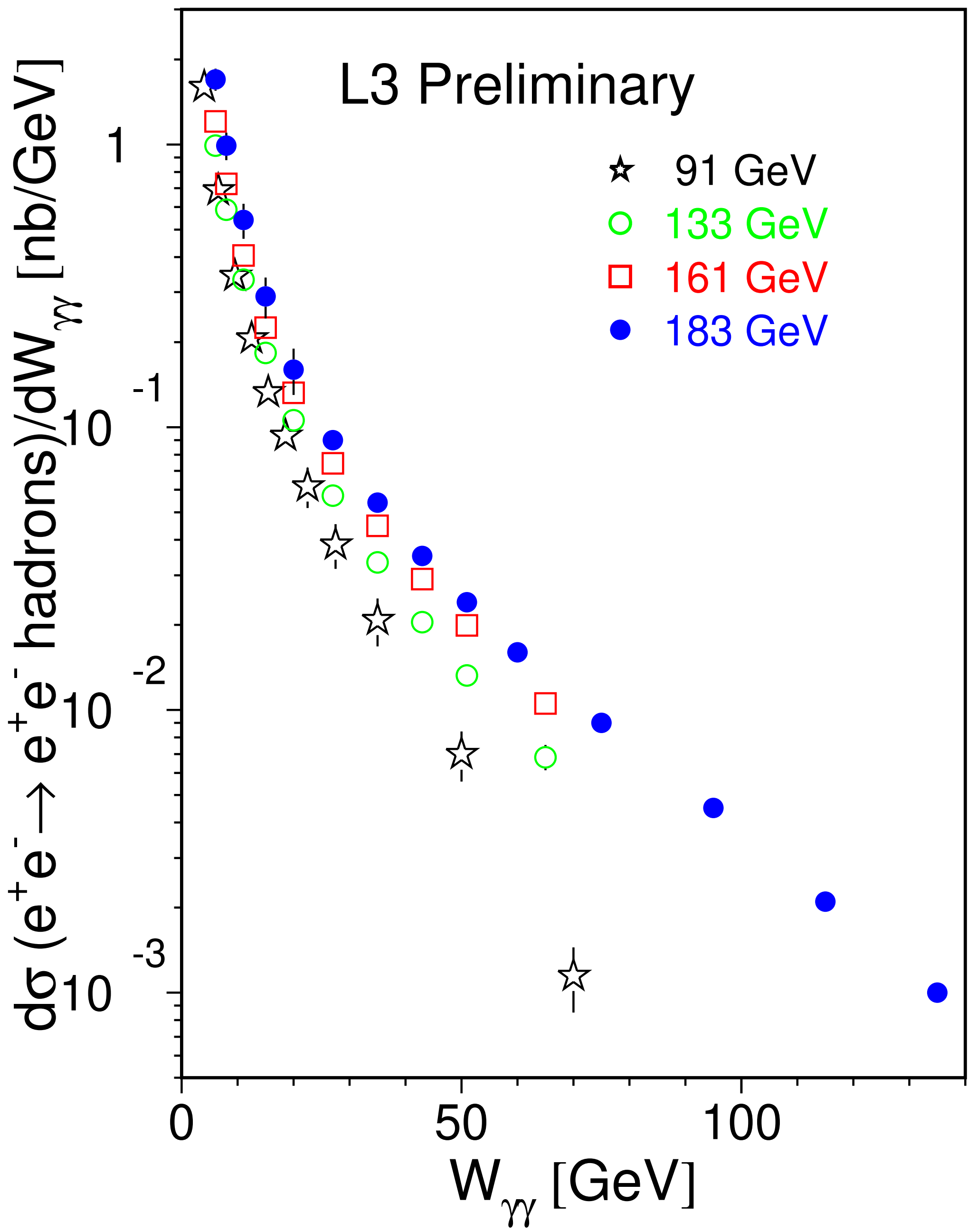
- **Unfolding: Visible $\Longrightarrow$ Selection $\Longrightarrow$ Generated.**
- *real life :Generated $\Longrightarrow$ Selection $\Longrightarrow$ Visible.*

Unfolding according to G. D'Agostini, Nucl. Inst. Meth. **A362** (1995) 487

Compare Selected/Generated PHOJET and PYTHIA

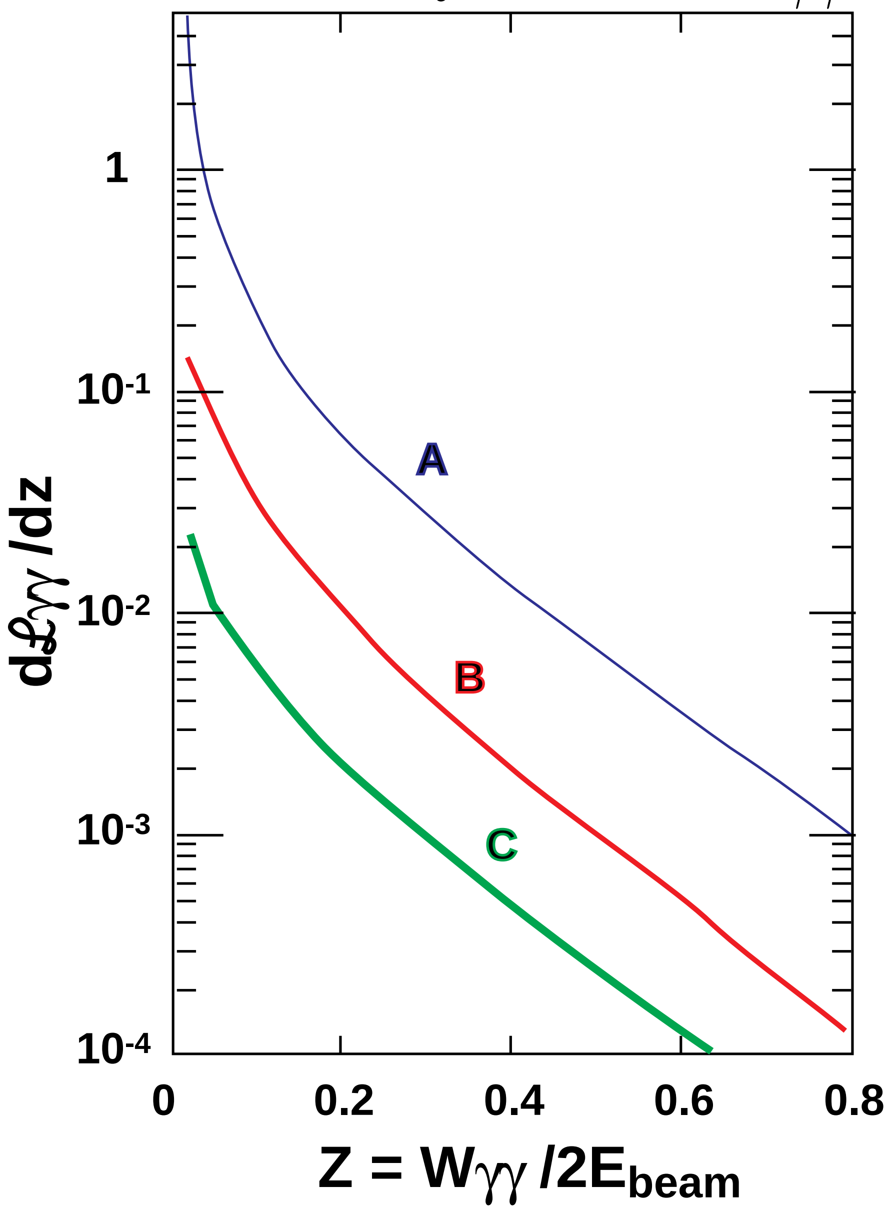


$d\sigma(e^+e^- \longrightarrow e^+e^-$hadrons$)$ **After Unfolding**



The shape is dominated by the Luminosity function $L_{\gamma\gamma}$

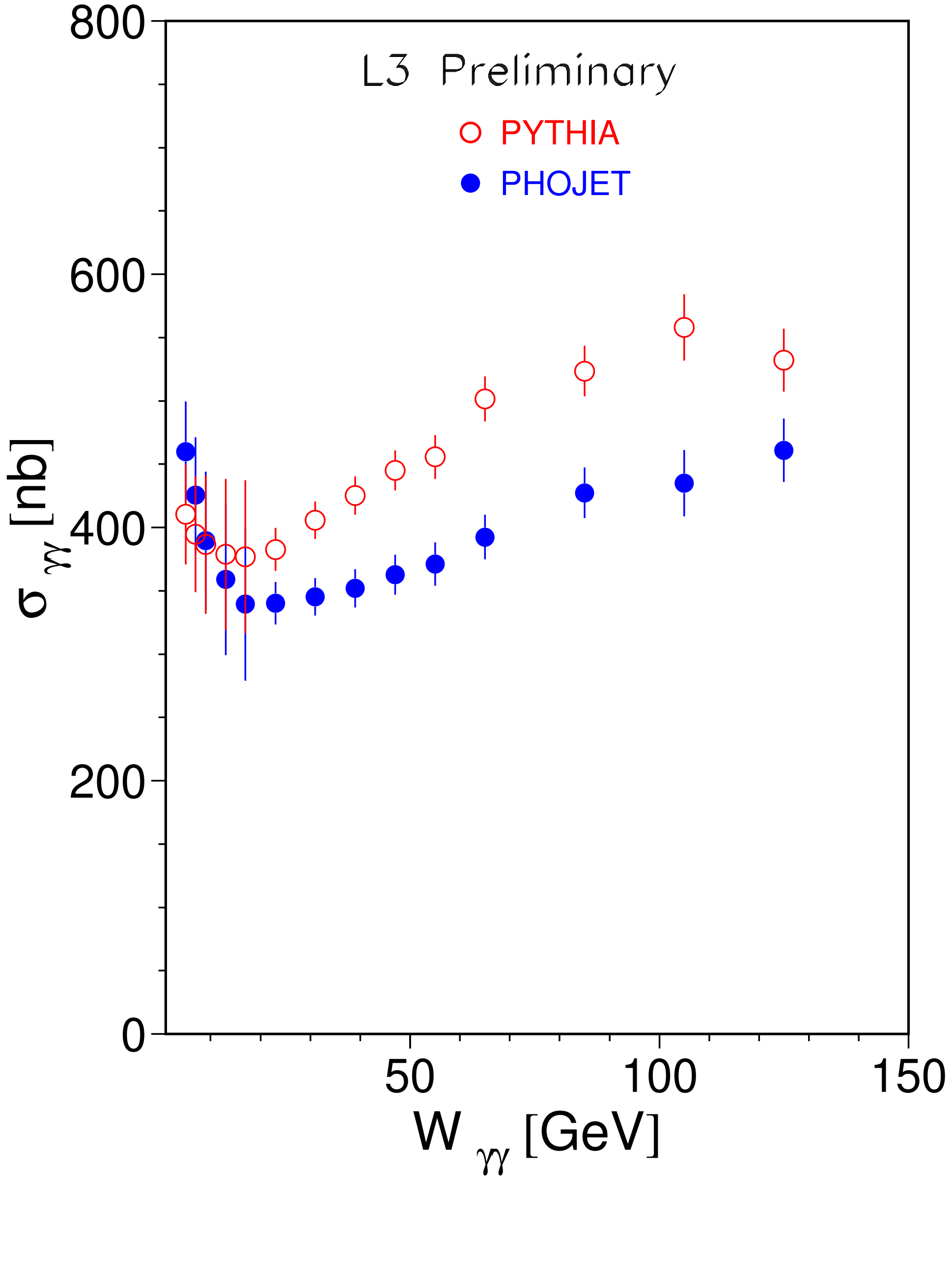
The Luminosity Function $L_{\gamma\gamma}$



- A - no tag
- B - single tag $20 < \theta < 200$ mrad
- C - Double tag

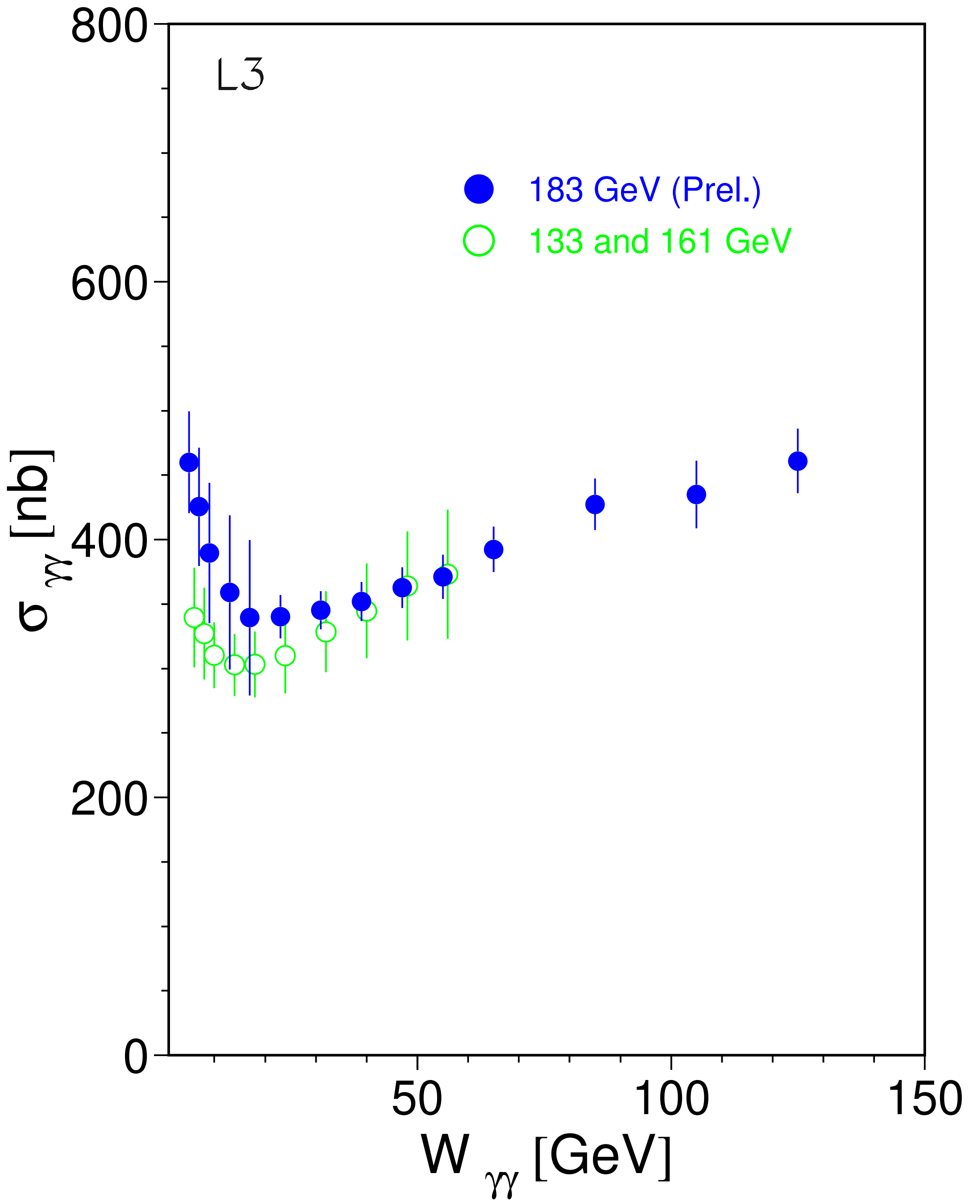
MC Systematics

PYTHIA vs PHOJET



L3 uses PHOJET because it fits better the data.

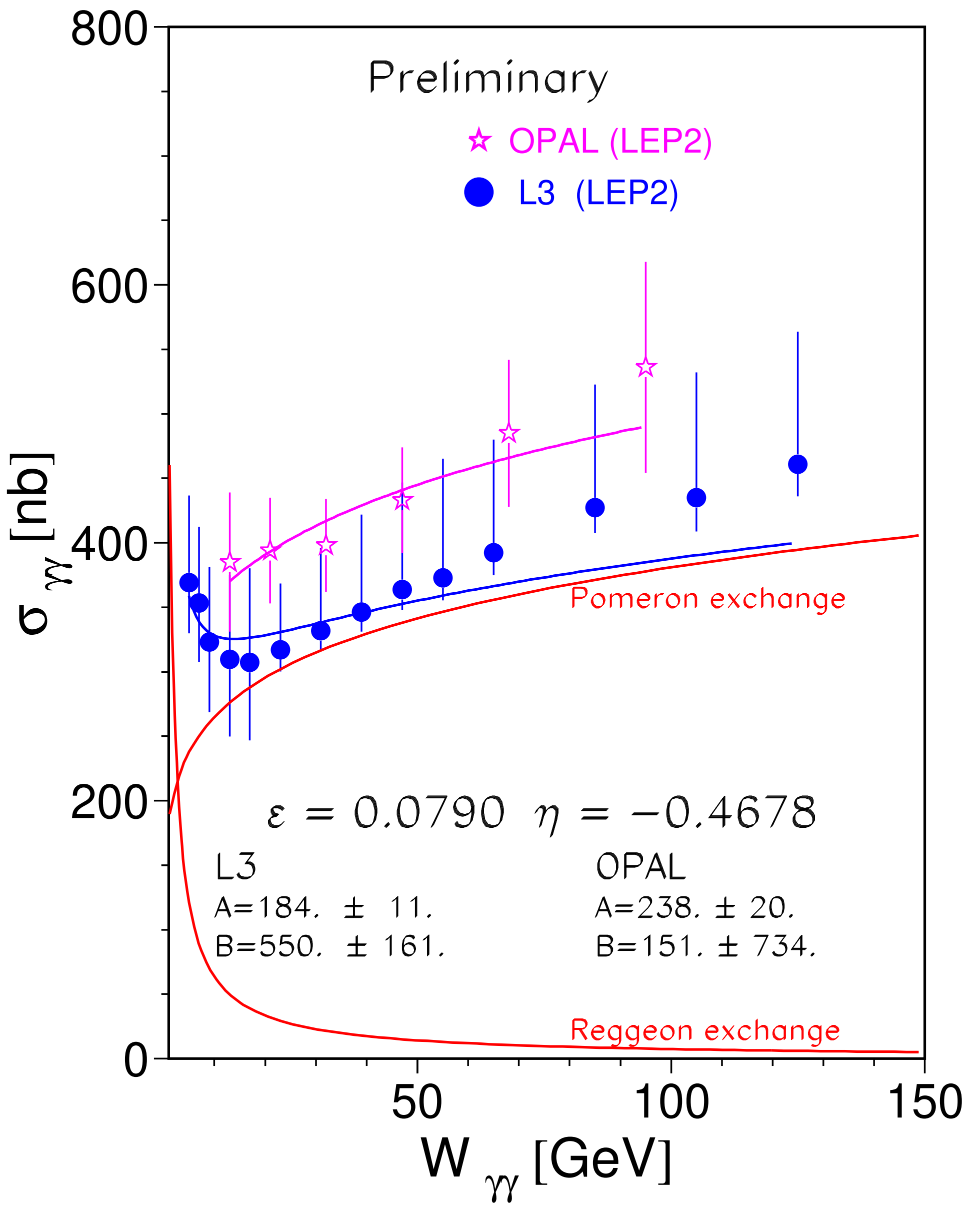
Results



The 183 GeV data are with experimental (systematics and statistics) errors.

Systematics errors: trigger (low masses), Energy ($\simeq 2\%$), tracks ($\simeq 2\%$)

- The $\sqrt{s}$ = 133, 161 and 183 GeV results are compatible.



Universal total cross section fit: $\sigma_{\gamma\gamma} = As^{\epsilon} + Bs^{\eta}$

(Donnachie and Landshoff, Phys. Lett. **B296**, 227 (1992))

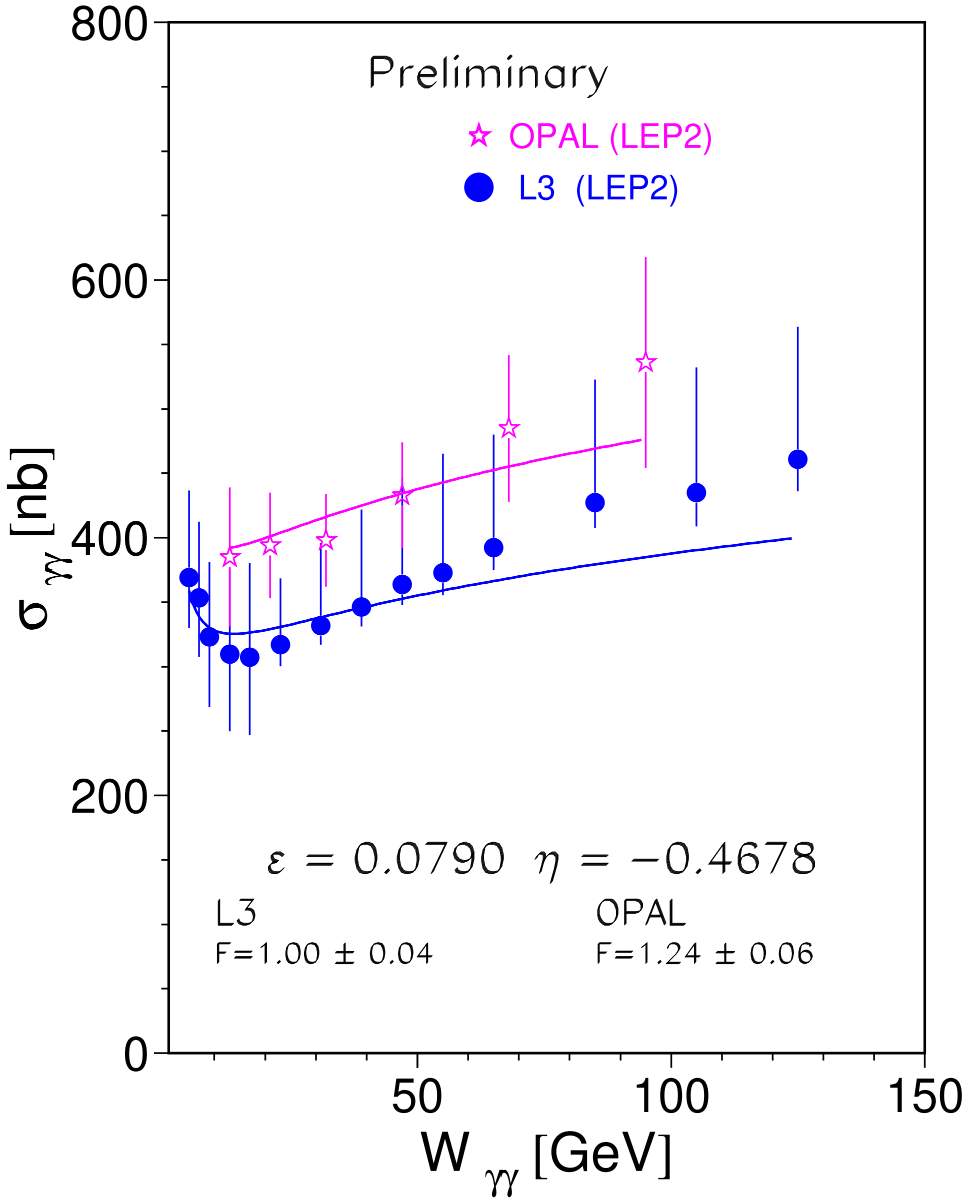
$$s = W_{\gamma\gamma}^2$$

ϵ and η from PDG '96

Here we include the total errors for L3 (experimental + MC)

Results

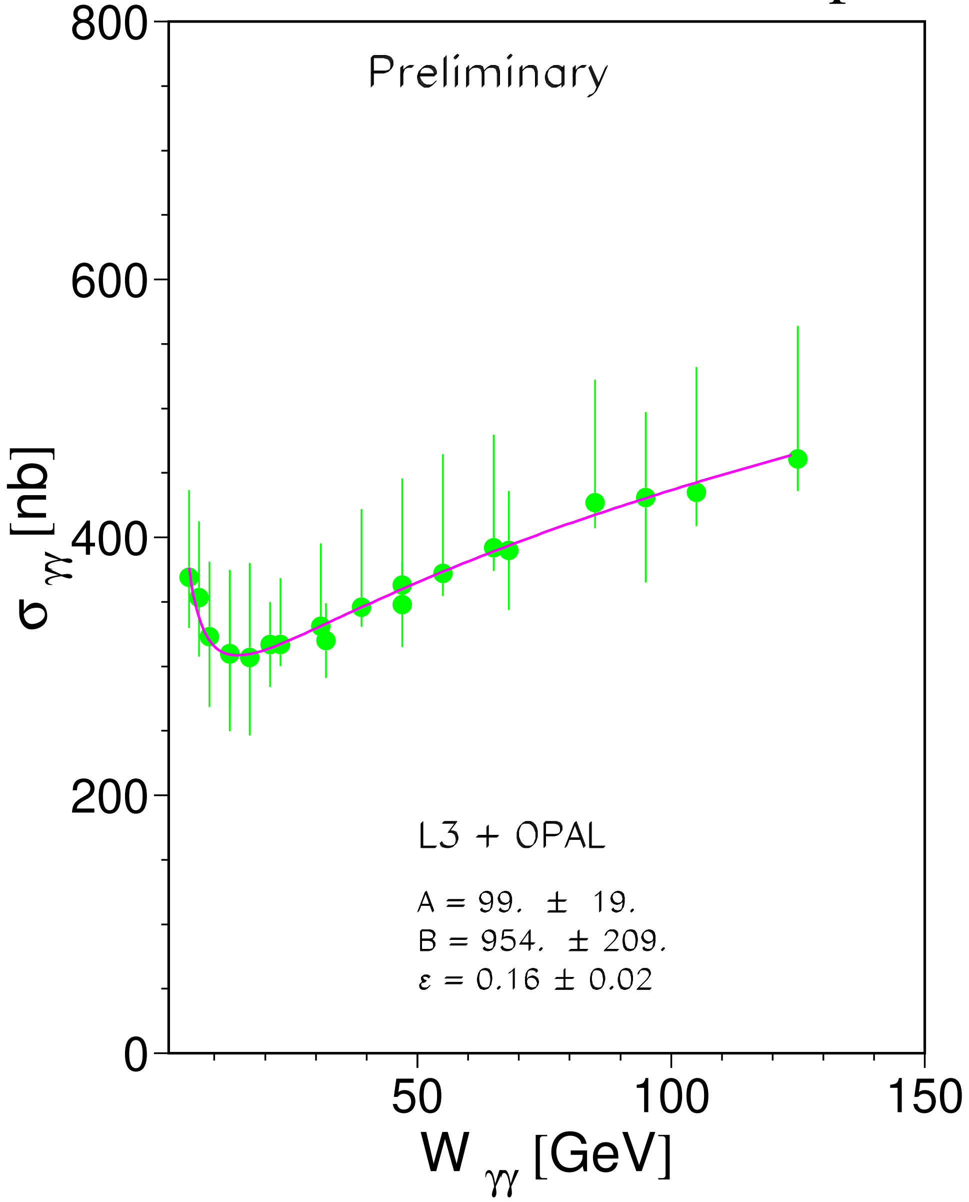
Weight OPAL data with L3



Fit with $\sigma_{\gamma\gamma} = \mathbf{F} \times (As^{2\epsilon} + Bs^{2\eta})$
With A and B extracted from L3.
OPAL fit is 24% higher than that of L3.

Results

Rescale OPAL and fit with ϵ as free parameter

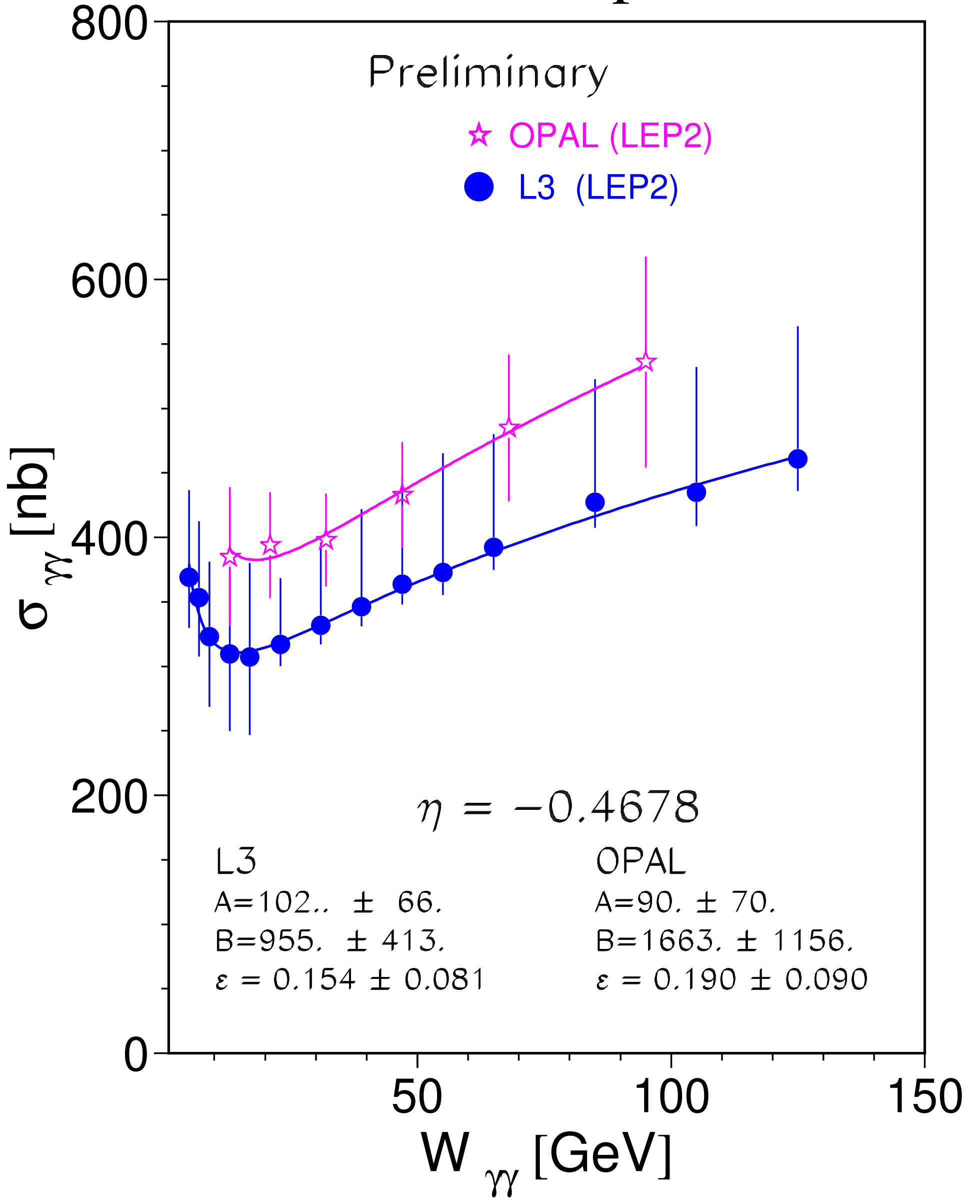


$$< \epsilon >= \mathbf{0.16 \pm 0.02}$$

$$(\epsilon_{PDG} = 0.0790 \pm 0.0011)$$

Results

If we leave ϵ as free parameter:

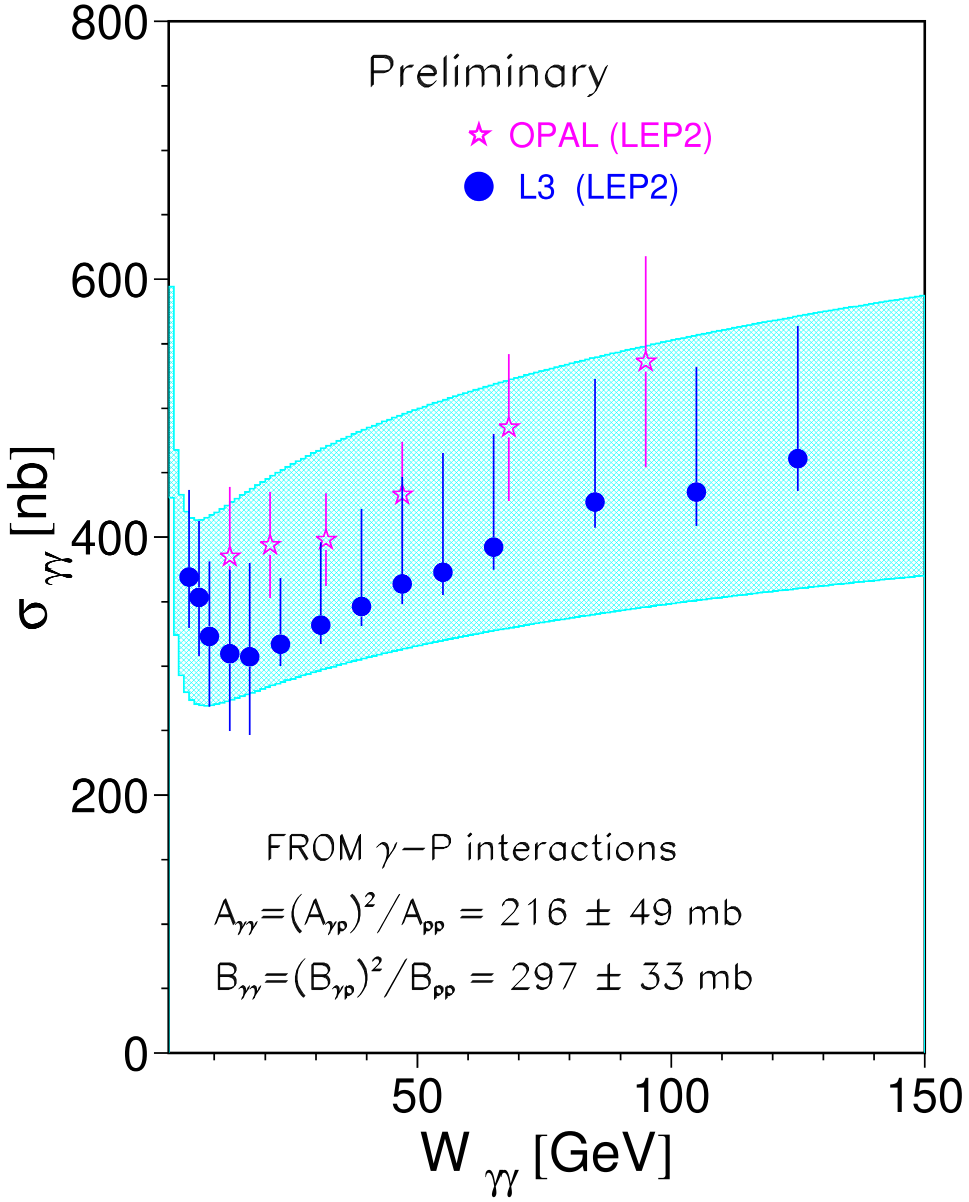


$$< \epsilon >= \mathbf{0.17 \pm 0.06}$$

$$(\epsilon_{PDG} = 0.0790 \pm 0.0011)$$

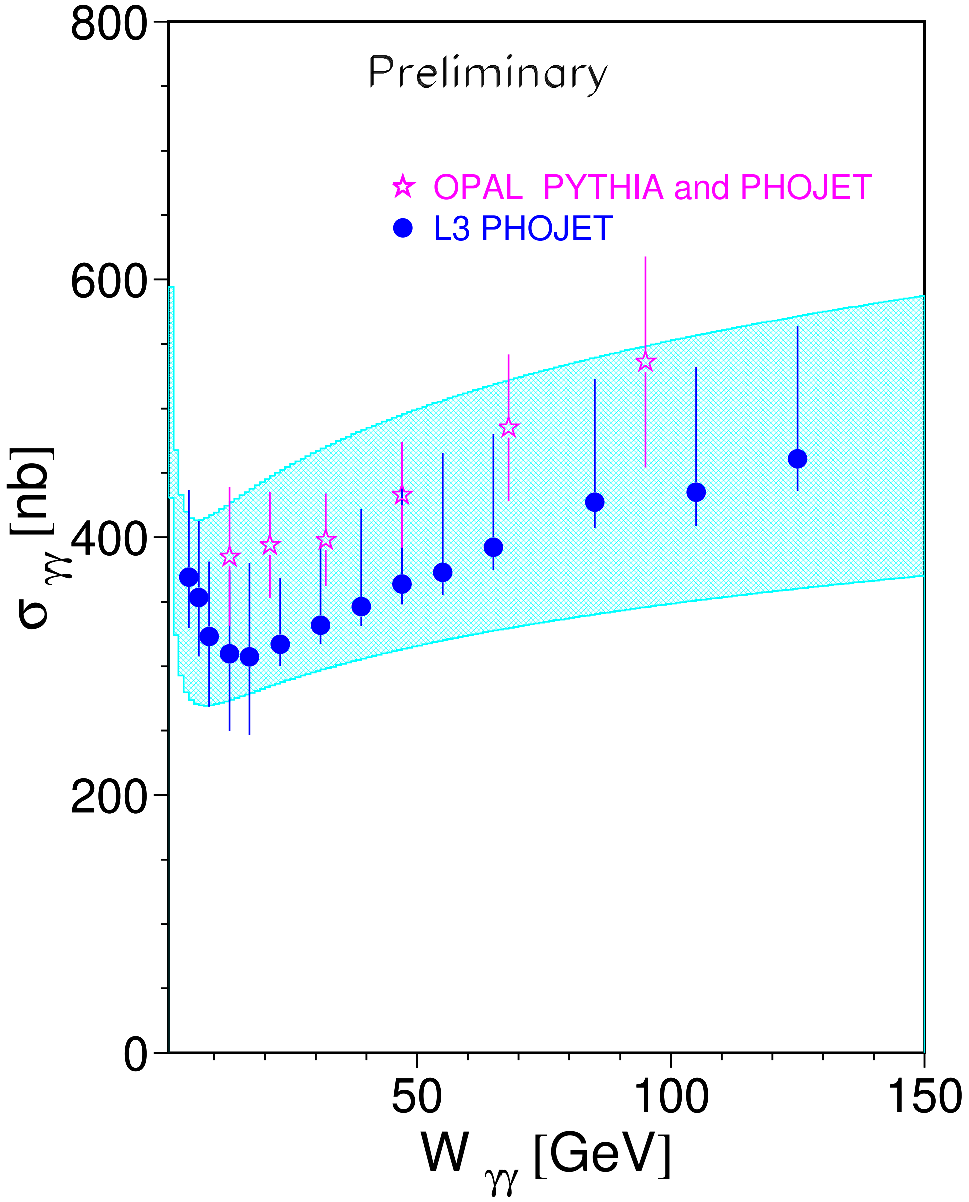
Results

Both are compatible with factorisation.



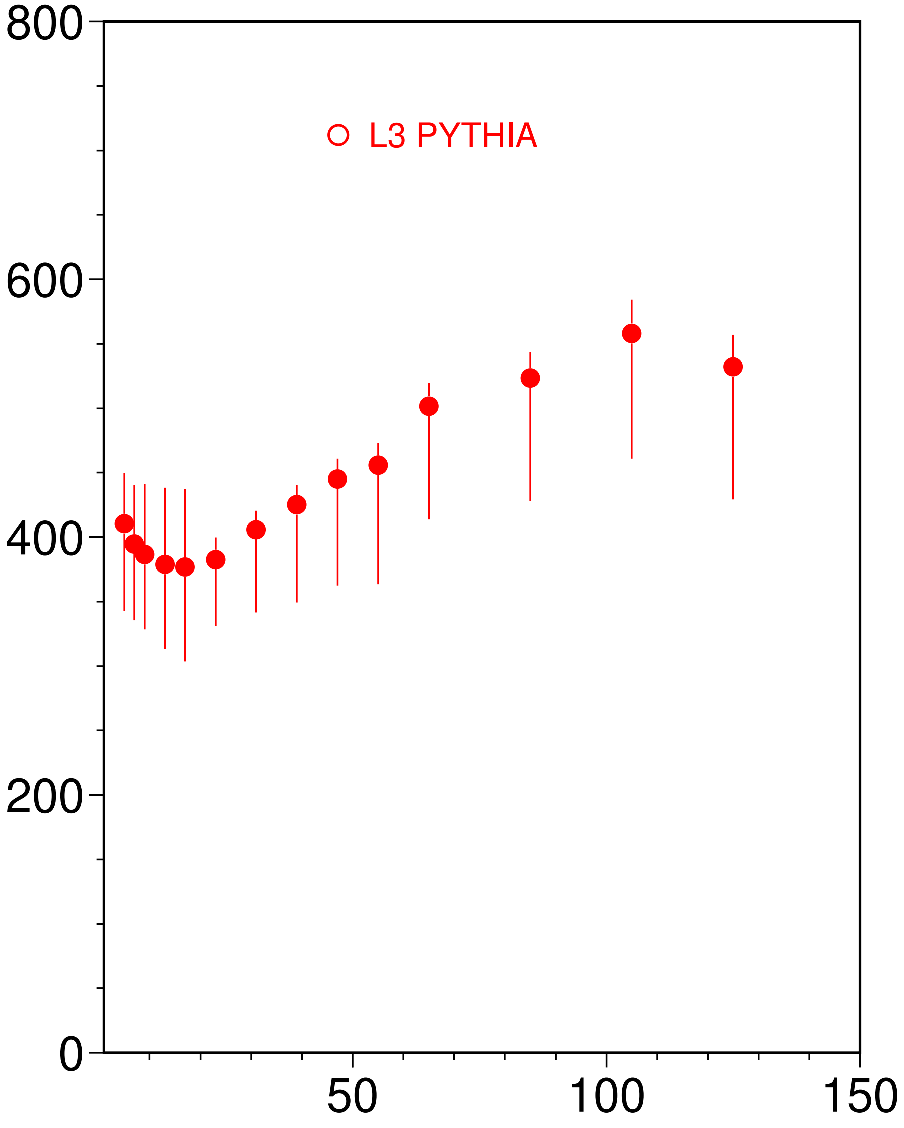
Naive factorisation
from refitted γ-p and p-p inetractions.

Results



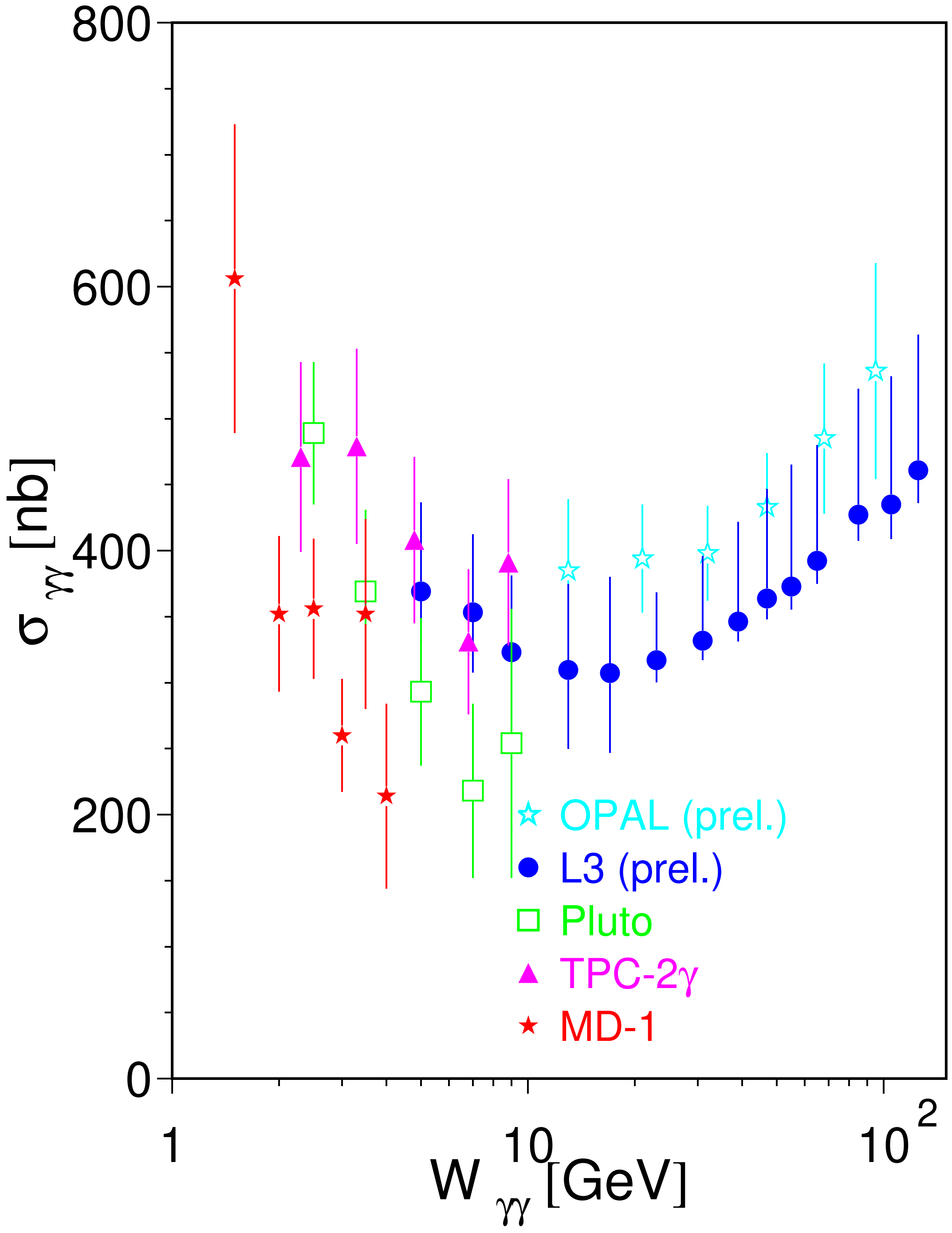
Preliminary
☆ OPAL PYTHIA and PHOJET
● L3 PHOJET
$\sigma_{\gamma\gamma}$ [nb]
800
600
400
200
0
50
100
150
$W_{\gamma\gamma}$ [GeV]

L3 with PYTHIA is in excellent agreement with OPAL



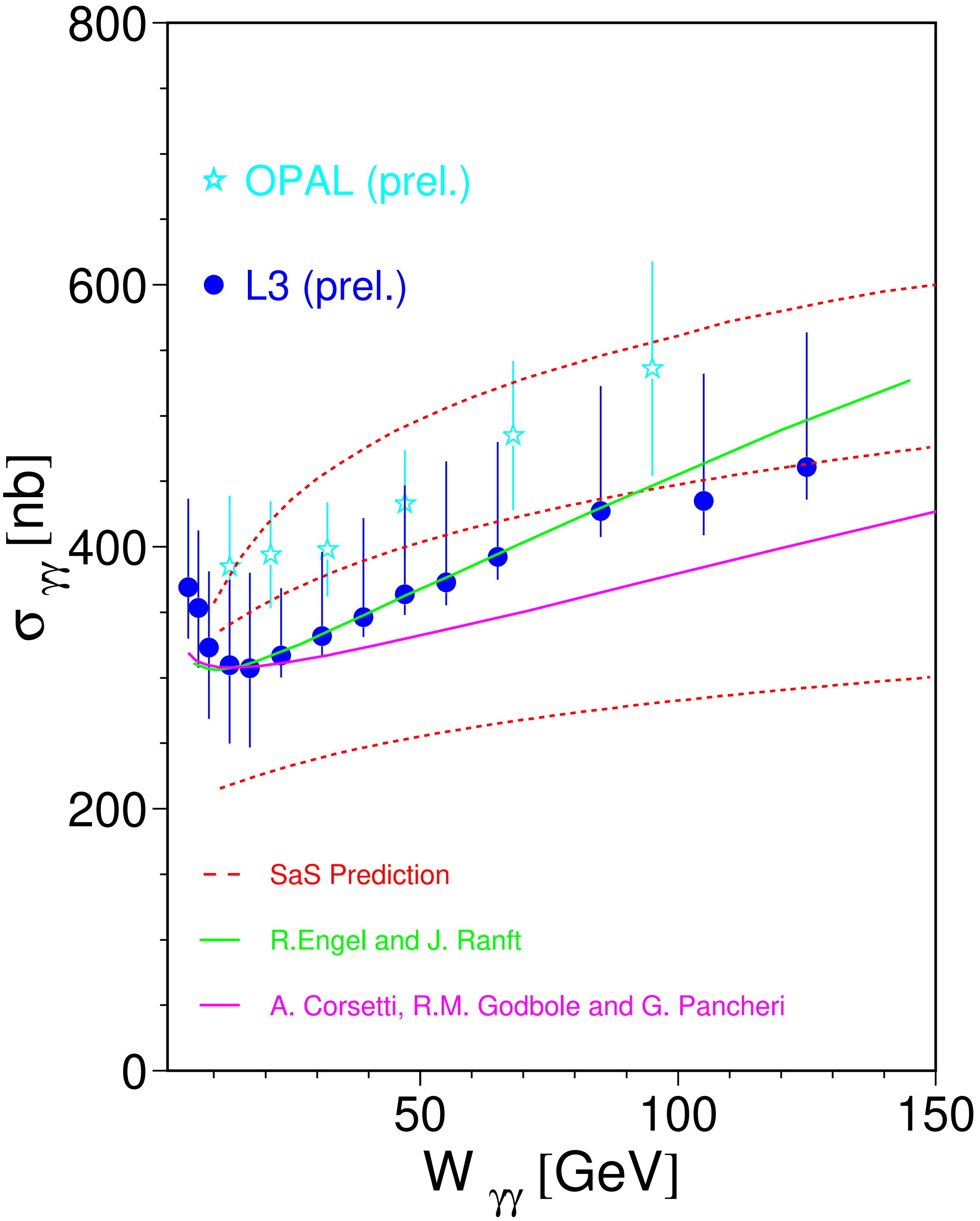
Results

Comparison with previous measurements.



Results

Comparison with predictions.



Conclusion

- Good **experimental** conditions at LEP2 for $\gamma\gamma$ physics.
- $\sigma(\gamma\gamma \Rightarrow hadrons)$ has been measured at LEP by L3 and OPAL at Low Q^2 $5 < W_{\gamma\gamma} < 145\,GeV$ $\sqrt{s} = 133\,GeV - 183\,GeV$.
- Photons interact predominantly as hadrons: The universal Regge fit

$$\sigma = As^{0.079} + Bs^{-0.47} \quad (s = W_{\gamma\gamma}^2)$$

is consistent with the data.

- OPAL and L3 agree with **a different** ϵ

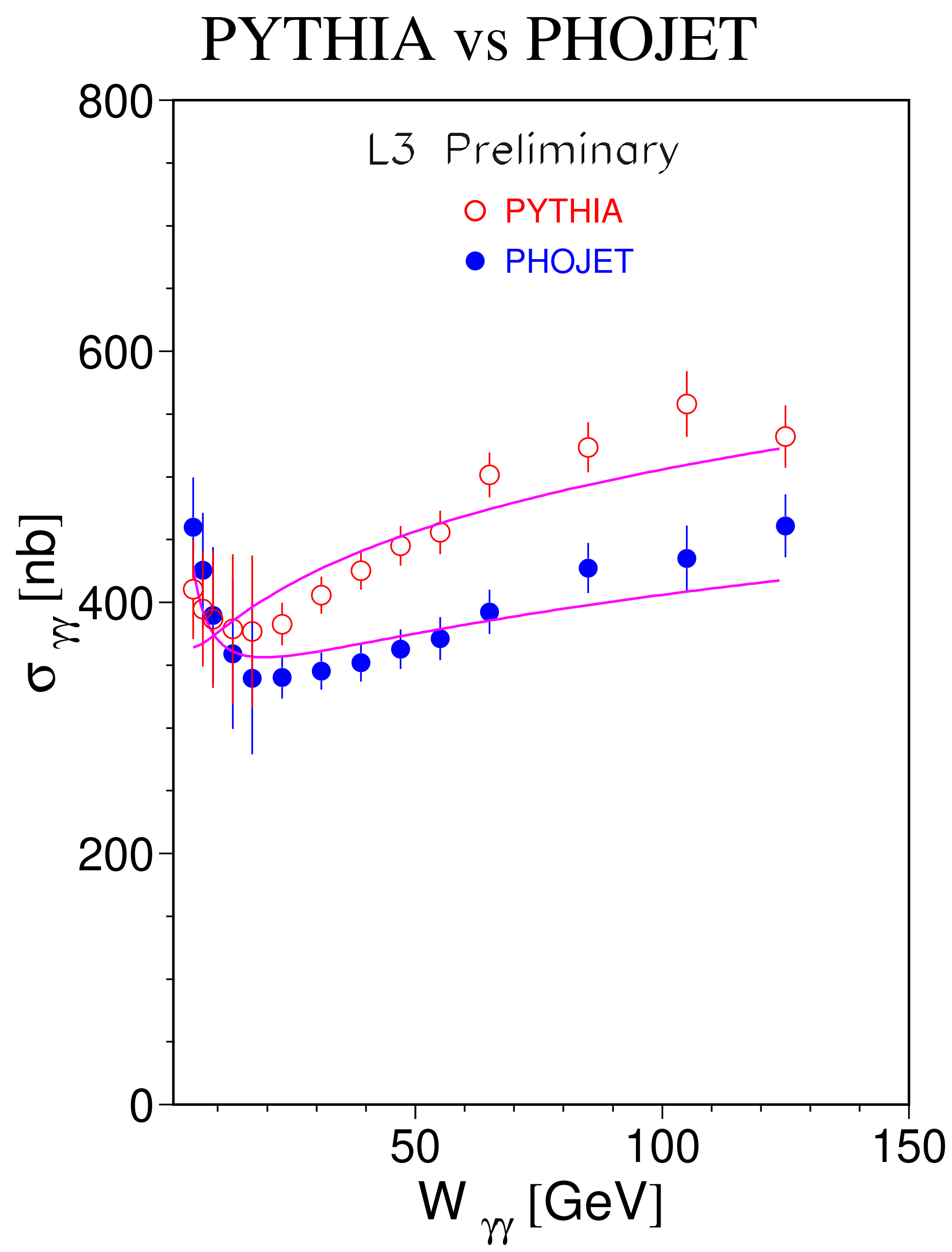
$$< \epsilon >= \mathbf{0.16 \pm 0.02}$$

$$(\epsilon_{PDG} = 0.0790 \pm 0.0011)$$

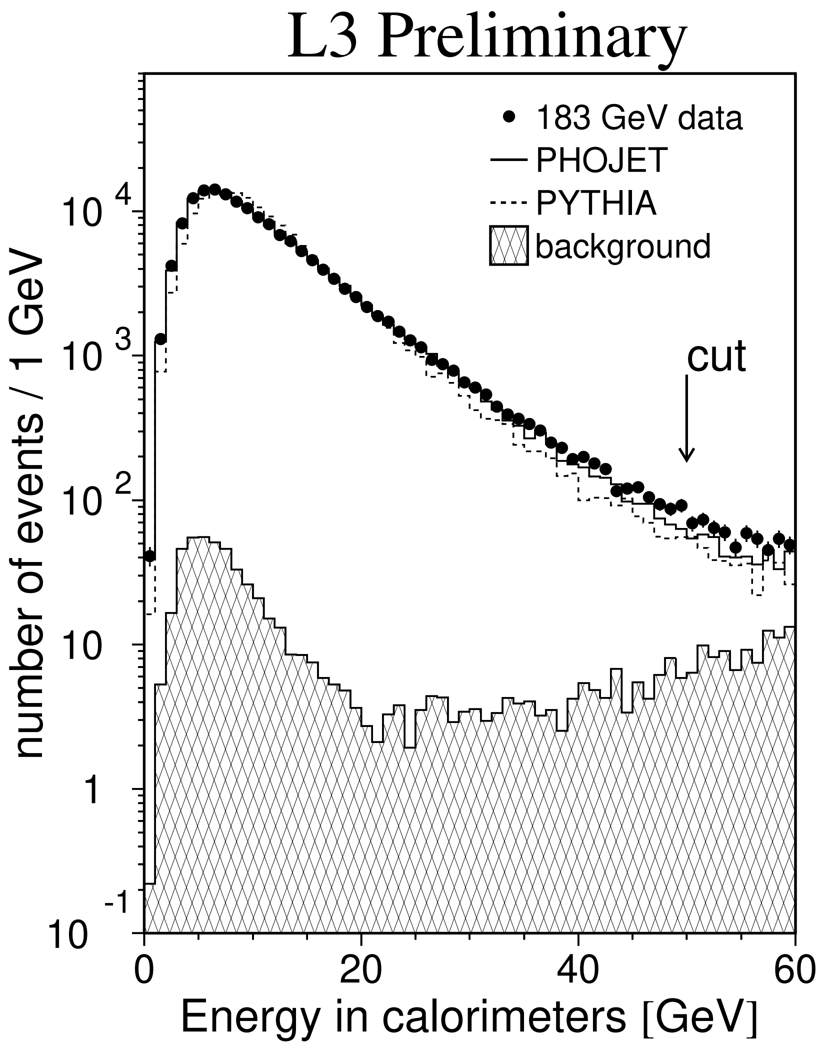
Possible minijets contribution?

- We urgently need more theoretical input.

Results

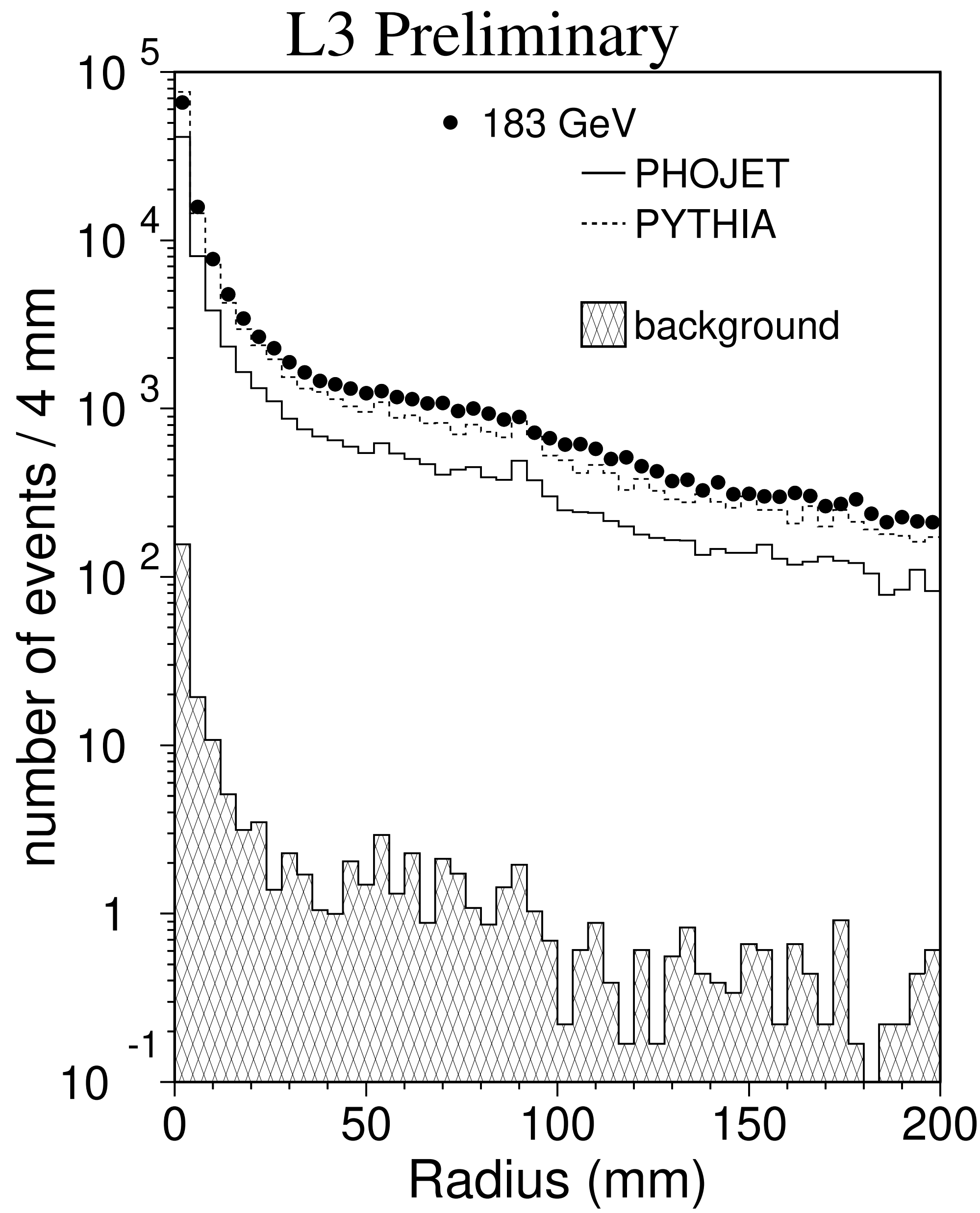

PYTHIA vs PHOJET
L3 Preliminary
PYTHIA
PHOJET
800
600
400
200
0
50
100
150
$\sigma_{\gamma\gamma}$ [nb]
$W_{\gamma\gamma}$ [GeV]

Event selection



Calorimeters = Ecal and Hcal

Event selection



No Beam gas nor beam wall events

Comparison with previous measurements.