Two-photon physics in L3

(total cross section, open charm production)

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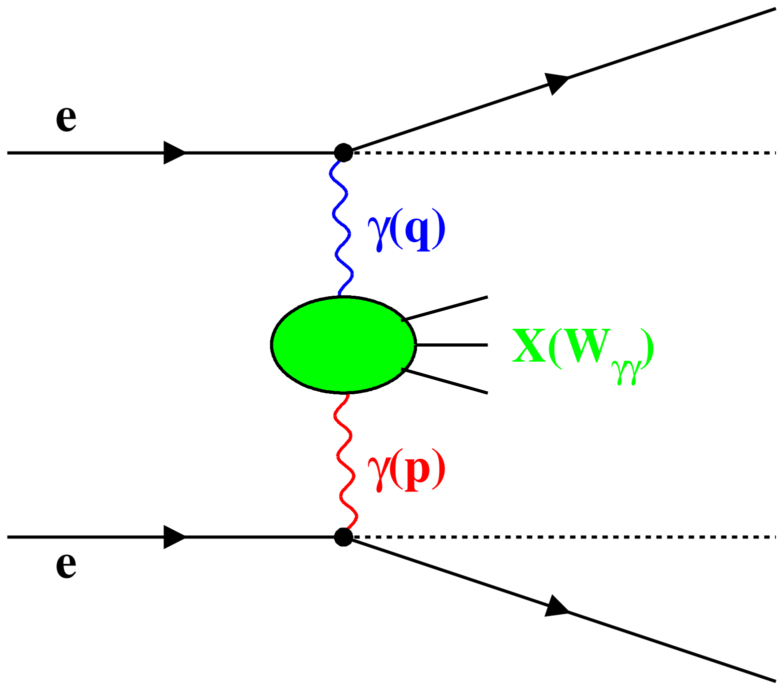
Outline

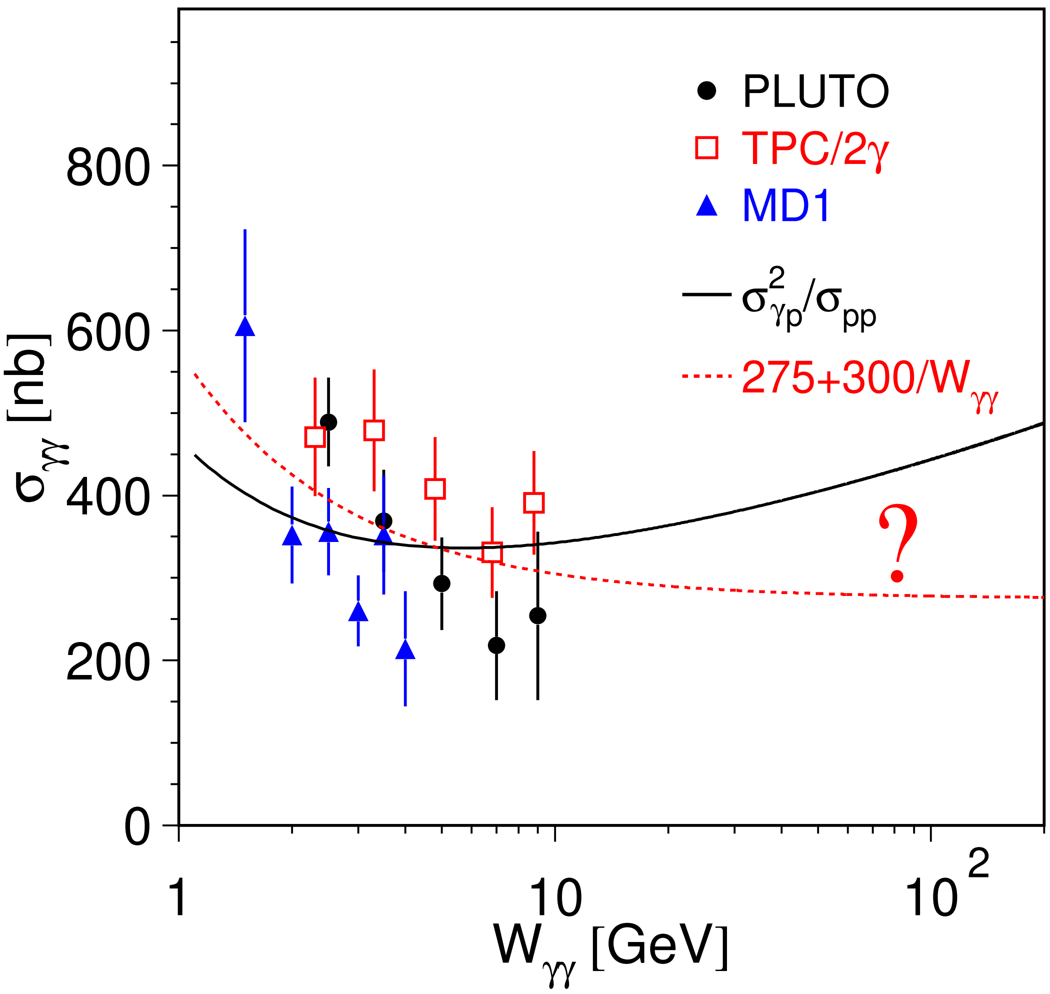
- Introduction
- Total cross section measurement
- Charm production measurement
- Conclusion and Outlook

Motivation



- High energy behaviour of two-photon collisions (non-perturbative domain)
- Perturbative QCD domain - heavy (charm) quark production

$\sigma_{\gamma\gamma}$, the measurements before LEP



- limited by beam energy ➜ $W_{\gamma\gamma} < 10 GeV$.
- very wide spread in the measurements.
- Does $\sigma_{\gamma\gamma}$ increase at high energy ?
- At LEP, $5 < W_{\gamma\gamma} < 145 GeV$ is measured.

$\sigma_{\gamma\gamma}$ measurement

- **Data :**

L3 :	91 GeV,	140 pb^{-1}
	130 - 140 GeV,	5 pb^{-1}
	161 GeV,	10 pb^{-1}
	183 *GeV*,	52 *pb*$^{-1}$
	189 *GeV*,	22 *pb*$^{-1}$

- **Monte Carlo :**

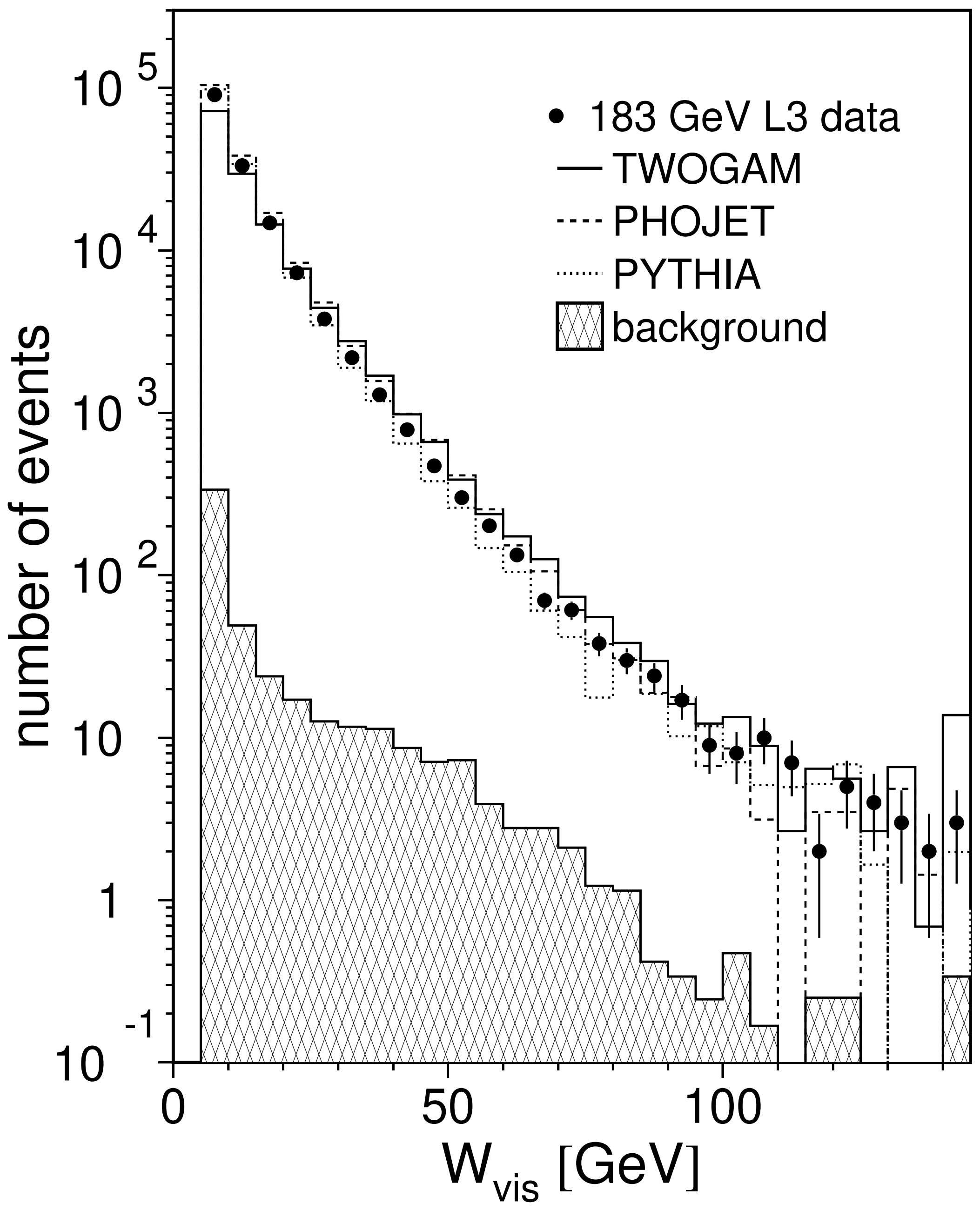
PHOJET: Engel and Ranft

PYTHIA: Sjöstrand and Schuler

- **Due to detector effects** ➜ $W_{vis} < W_{\gamma\gamma}$
  - ⇨ Use unfolding for $W_{vis} \rightarrow W_{\gamma\gamma}$
  - ⇨ Need good Monte Carlo

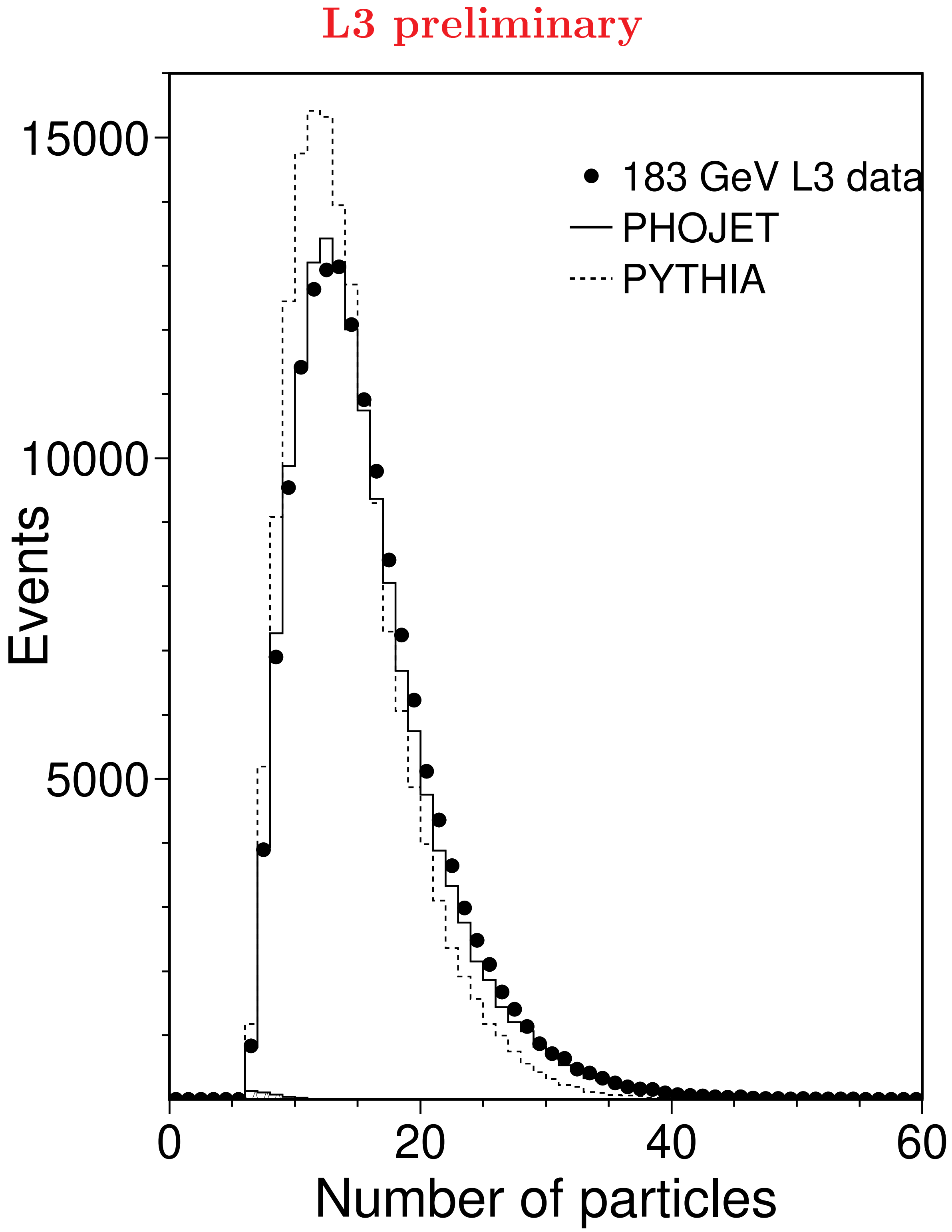
MC Comparison

L3 preliminary



- background is negligible
- W_{vis} is rather well described by MC

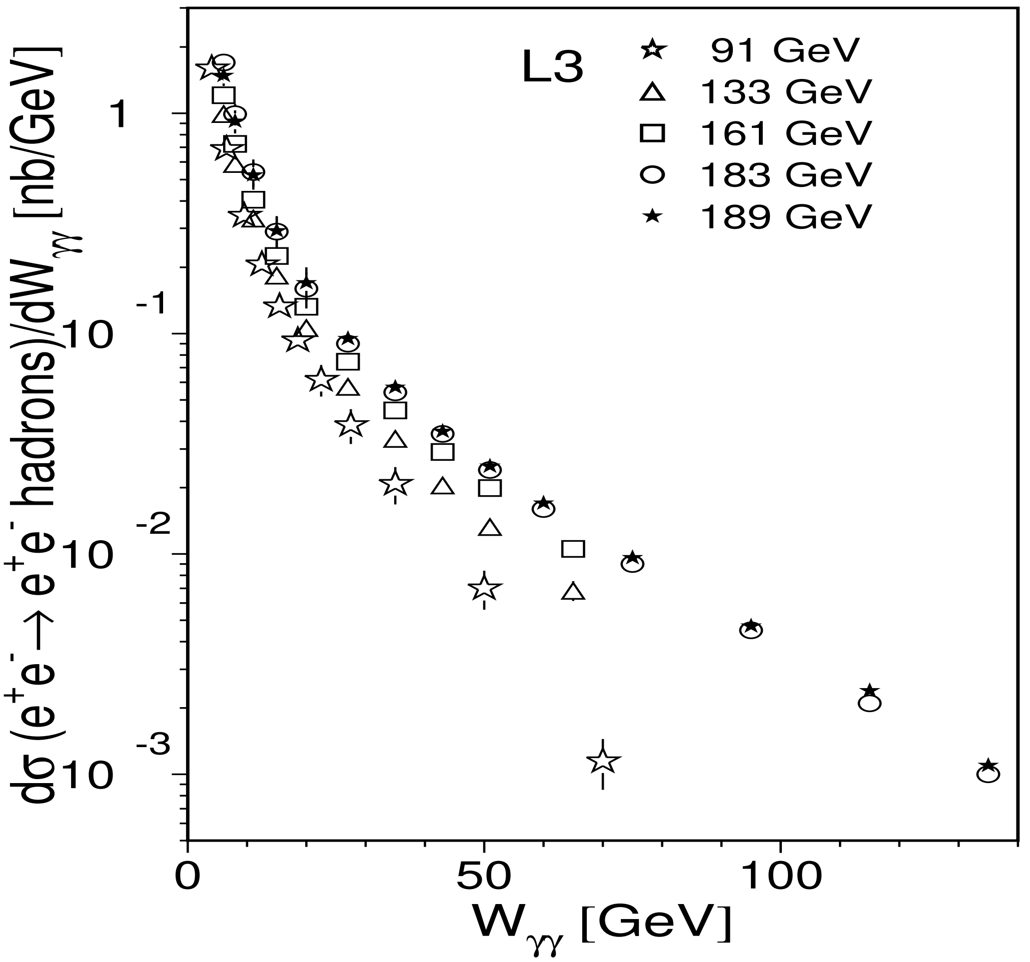
MC Comparison



*particles = charged particles + photons

- better data-MC agreement than for # of charged particles

$d\sigma(e^+e^- \to e^+e^-$ 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 $d\sigma_{ee}$

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

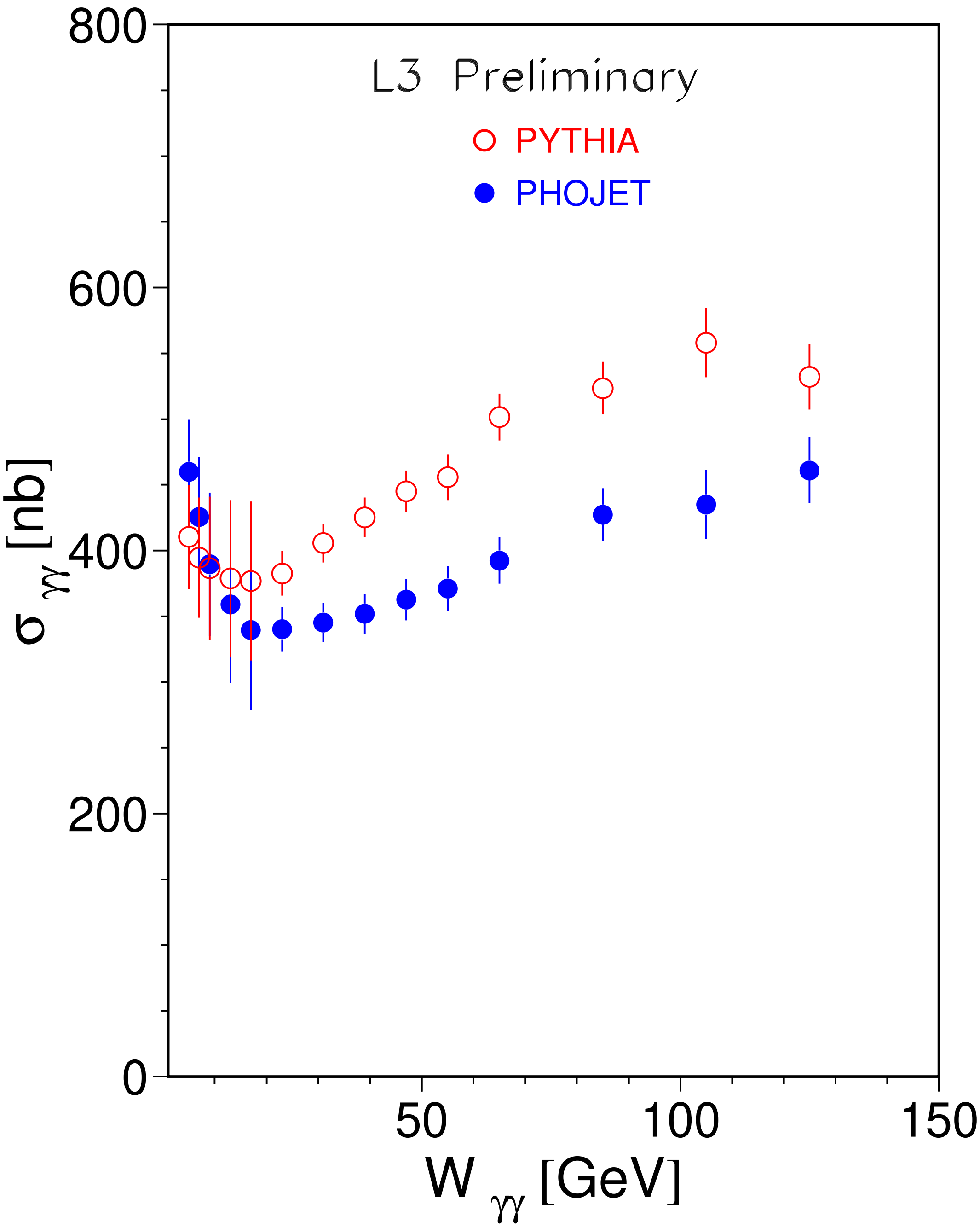
$$\sigma^{\gamma\gamma}_{ab}(W_{\gamma\gamma}, P^2, Q^2) = F_a(Q^2)F_b(P^2)\sigma^{\gamma\gamma}_{ab}(W_{\gamma\gamma})$$

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

➩ $\sigma^{\gamma\gamma}_{TT}$ is dominant.

➩ Remove the effect of $\mathcal{L}$ and $F(Q^2, P^2)$ ➜ $\sigma_{\gamma\gamma}(W_{\gamma\gamma})$

MC systematics
PYTHIA vs PHOJET



L3 uses PHOJET because it fits the data better

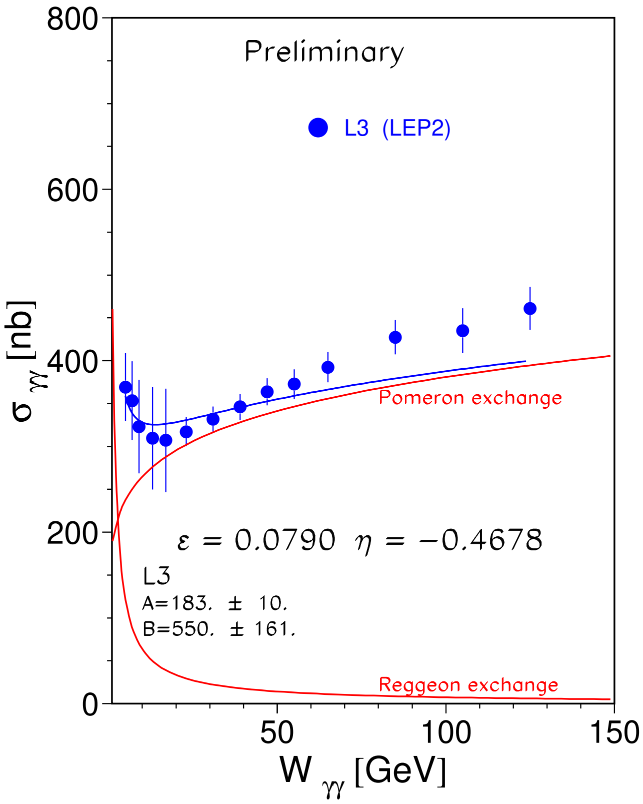
- The data show clear rising behaviour with increasing energy. ⇨ Independent of MC

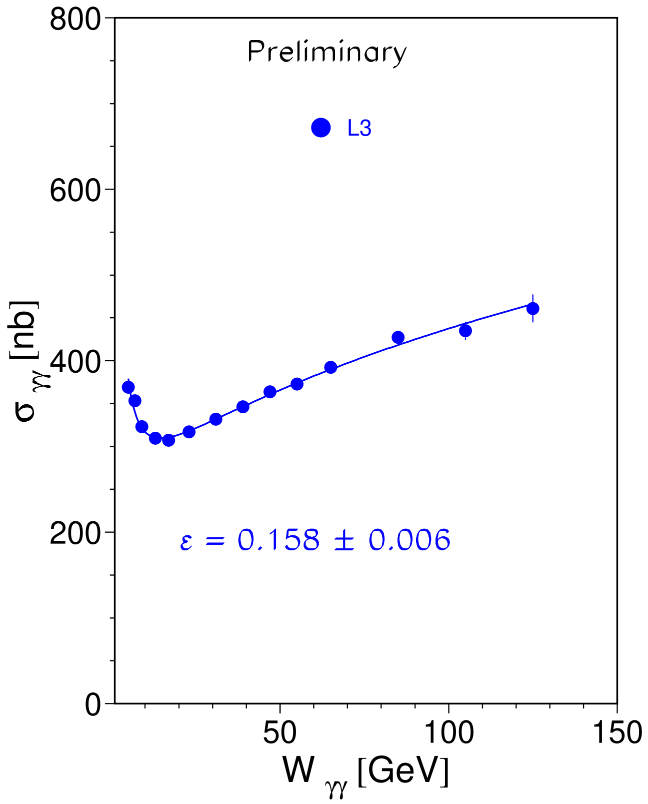
DL fit

Fit with Donnachie and Landshoff parametrisation : (Phys. Lett., B296, 227, 1992)

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

Using the universal value of $\eta = -0.47$ (PDG96)



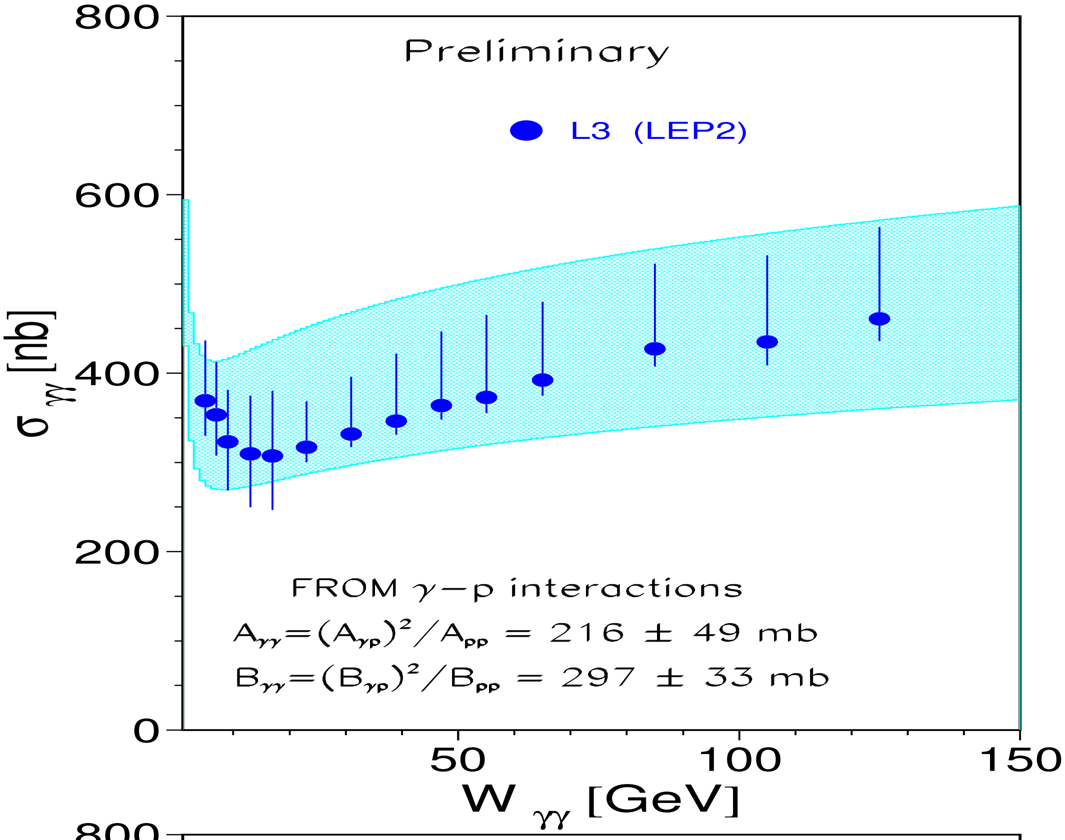


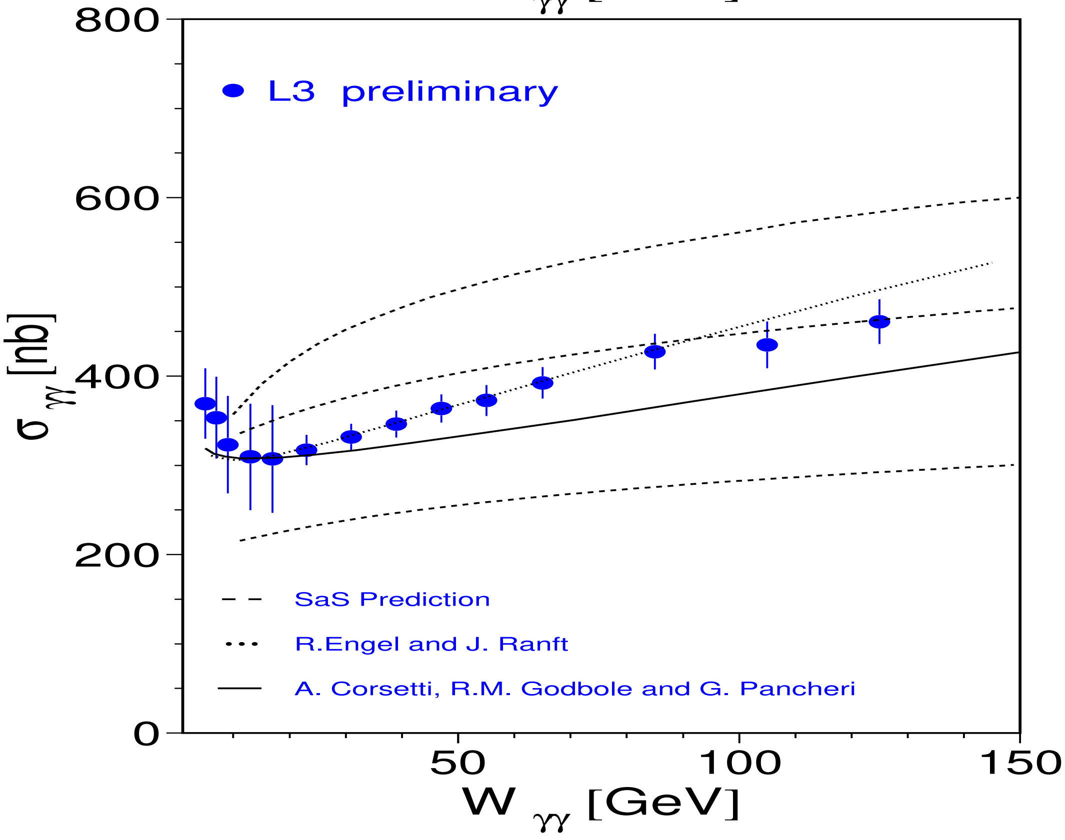
L3 : $\epsilon = 0.158 \pm 0.006(\mathrm{stat}) \pm 0.028(\mathrm{sys})$

PDG96 : $\epsilon = 0.079 \pm 0.001$

- **ϵ is a factor of two bigger !**

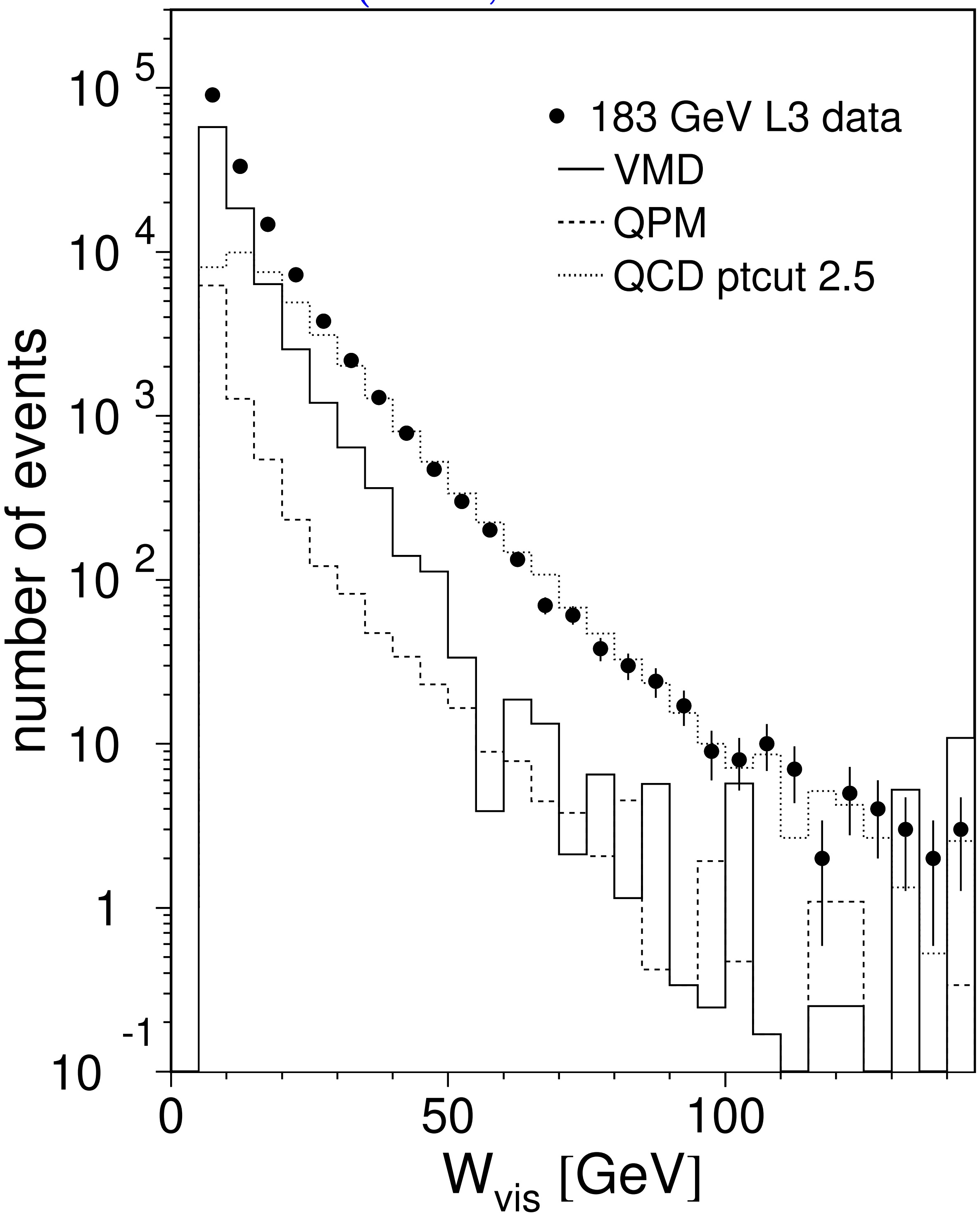
Results


Preliminary
L3 (LEP2)
FROM $\gamma-p$ interactions
$A_{\gamma\gamma}=(A_{\gamma p})^2/A_{pp}$ = 216 ± 49 mb
$B_{\gamma\gamma}=(B_{\gamma p})^2/B_{pp}$ = 297 ± 33 mb
$\sigma_{\gamma\gamma}$ [nb]
$W_{\gamma\gamma}$ [GeV]
0
200
400
600
800
50
100
150


L3 preliminary
SaS Prediction
R.Engel and J. Ranft
A. Corsetti, R.M. Godbole and G. Pancheri
$\sigma_{\gamma\gamma}$ [nb]
$W_{\gamma\gamma}$ [GeV]
0
200
400
600
800
50
100
150

$W_{\gamma\gamma}$ dependence

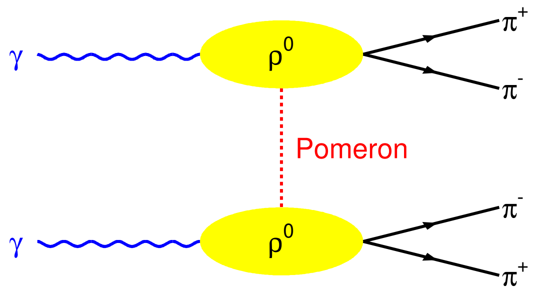
MC=TWOGAM (Nova,Olshevski and Todorov)



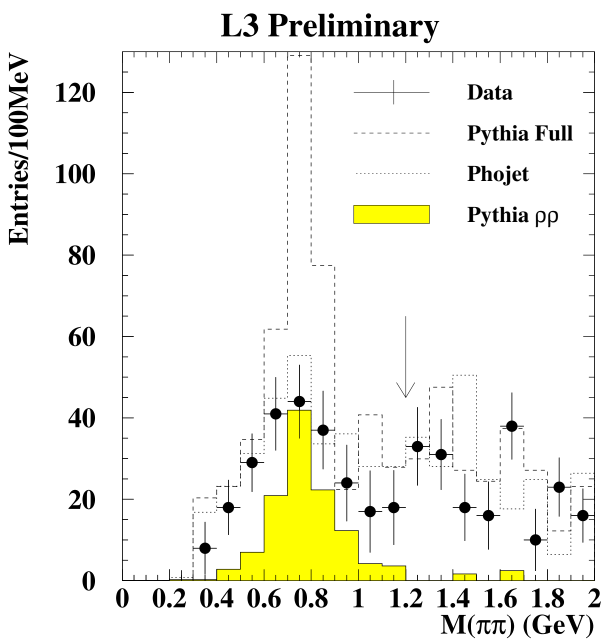
- **QCD contribution for a high energy part of spectrum is vital (the name = 'Pomeron', 'hard Pomeron', 'pQCD', 'mini-jets', ...)**

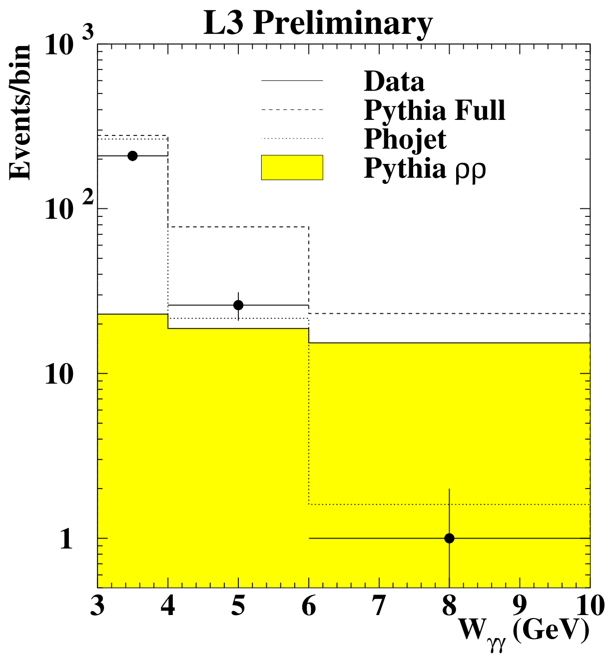
$\rho^0 - \rho^0$ elastic scattering

$\gamma\gamma \to \rho^0\rho^0 \to \pi^+\pi^-\pi^+\pi^-$ at 183 GeV



➜ The cross-section is expected to remain large at high $W_{\gamma\gamma}$ because of the Pomeron exchange.



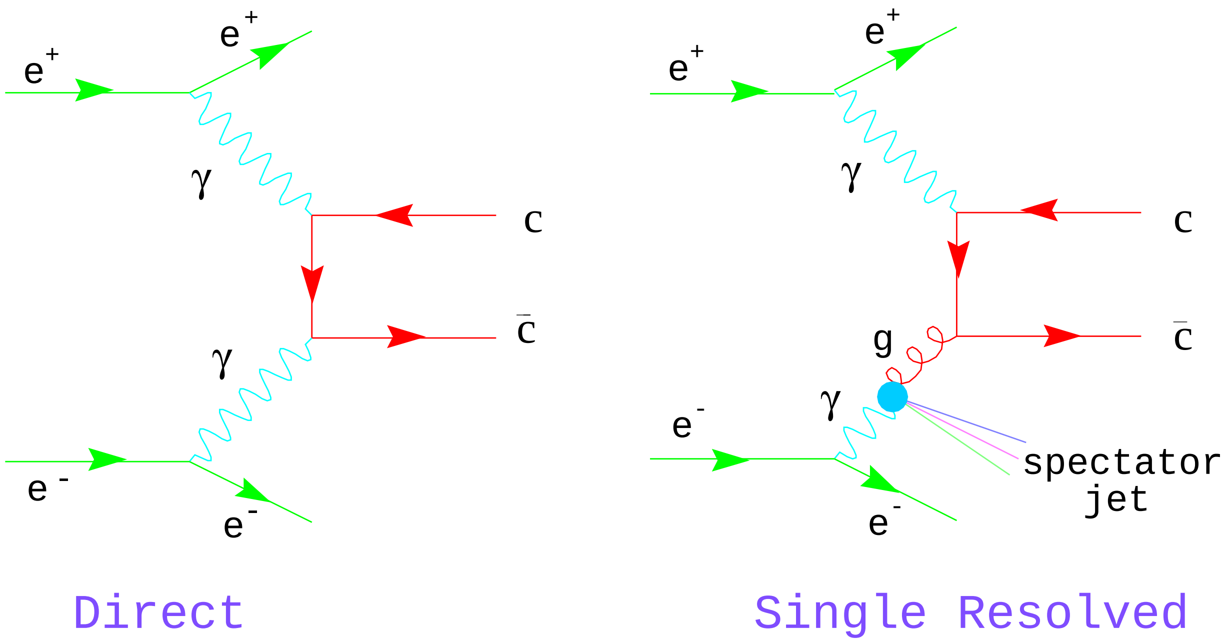


⇨ For $W_{\gamma\gamma} < 10$ GeV, the cross-section estimated by PYTHIA is too large.

⇨ The measurement for $W_{\gamma\gamma} > 10$ GeV is difficult, but important.

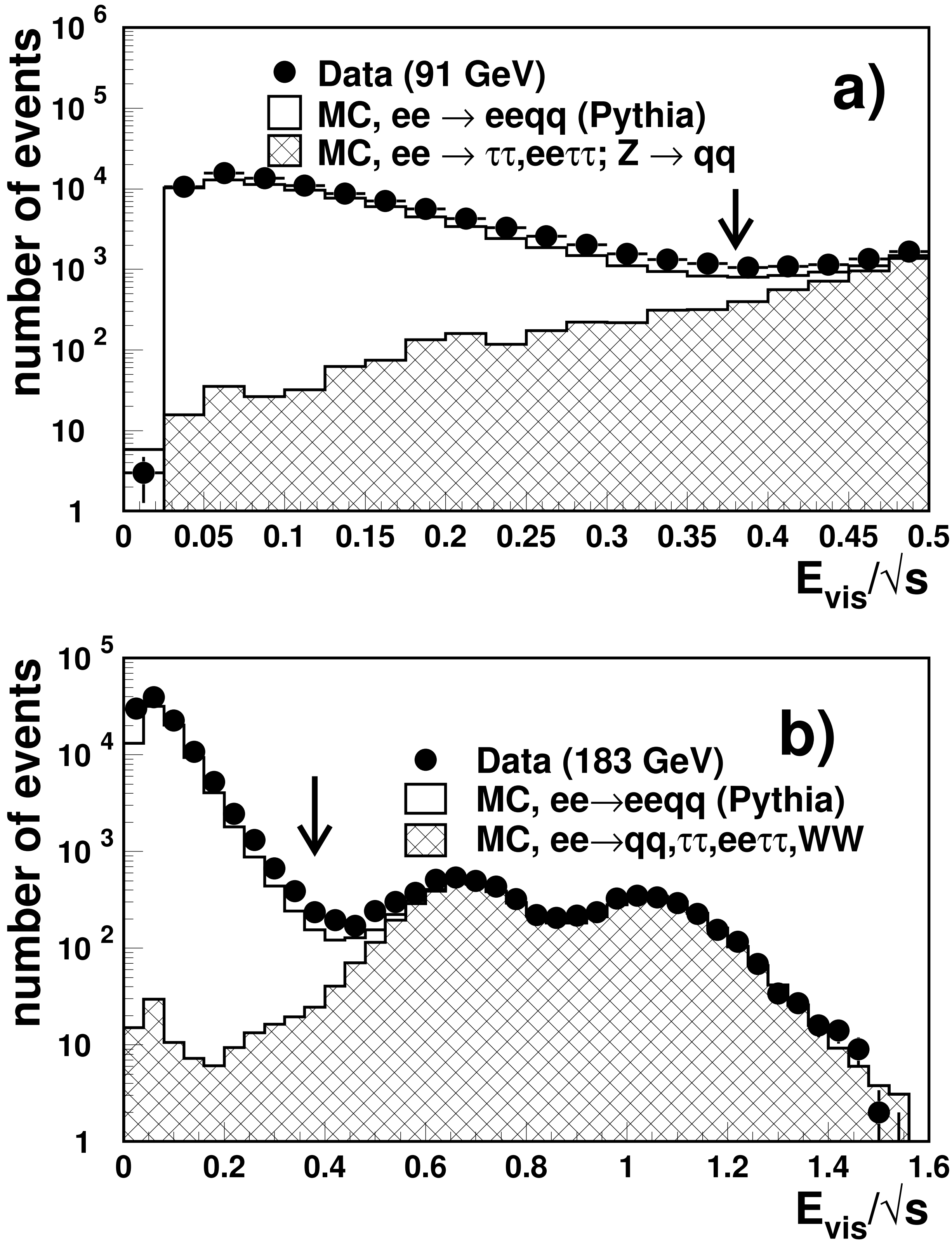
Motivation

$$ee \to eec\bar{c}$$



- **Direct process:**
  dependent upon m_c and α_s
- **Resolved process:**
  $\gamma g \to c\bar{c}$ dominant $\Longrightarrow$ measurement of the *gluon content* in the *photon*
  - **at high energies the resolved processes are of the same order as the direct ones**

$\gamma\gamma \to q\bar{q}$ selection



Lepton Selection

$$c \to l$$

$\mu^{\pm}$ Selection

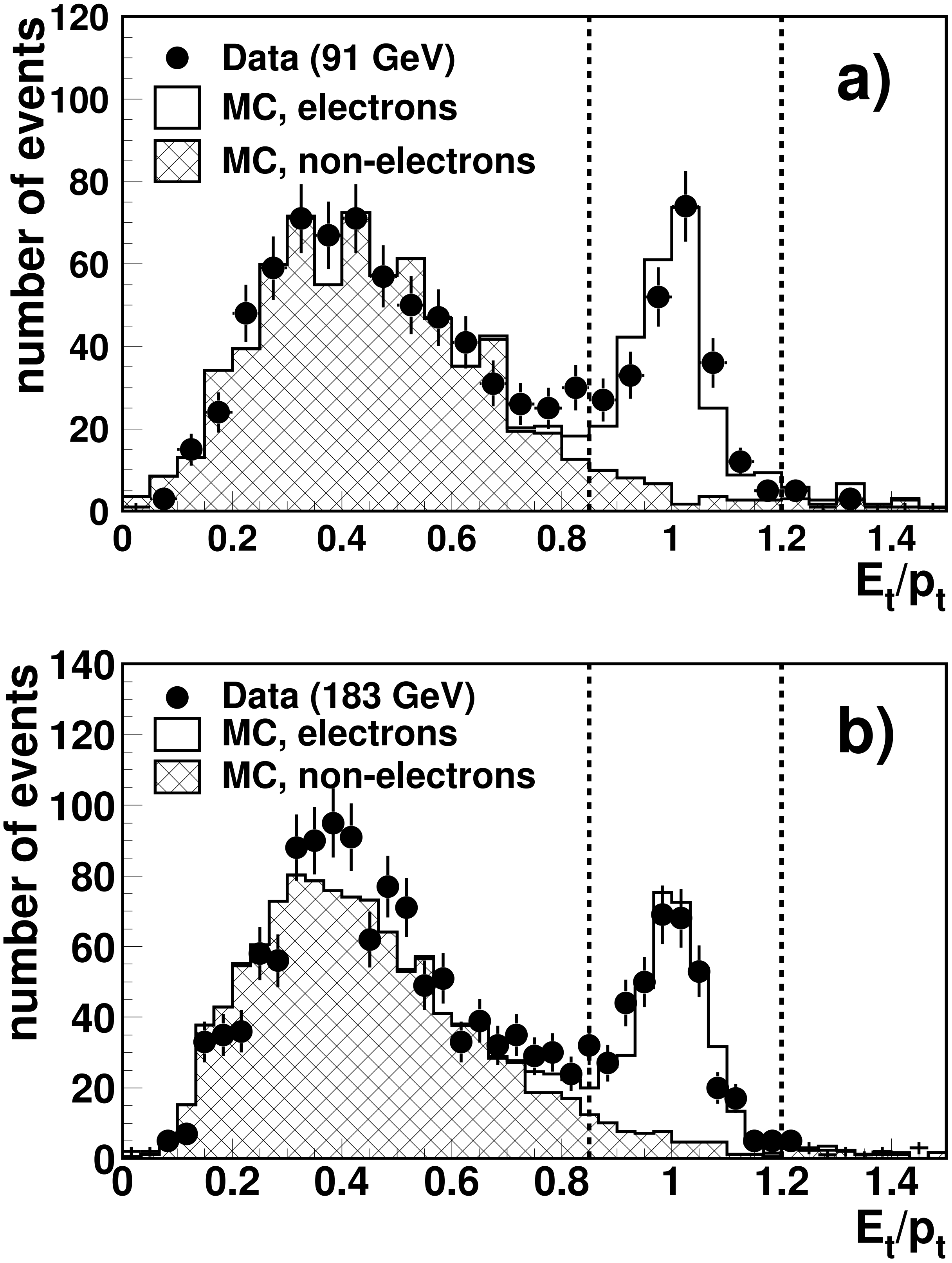
track in muon ch.
$|\cos\theta| < 0.90$
$P_{\mu} > 2$ GeV/c
$P_{\mu} < 0.2E_{beam}$

$e^{\pm}$ Selection

e.m. shower shape
$|\cos\theta| < 0.90$
$P_{e} > 0.6$ GeV
$\Delta\phi < 20$mrad
$0.85 < E_T/p_T < 1.2$

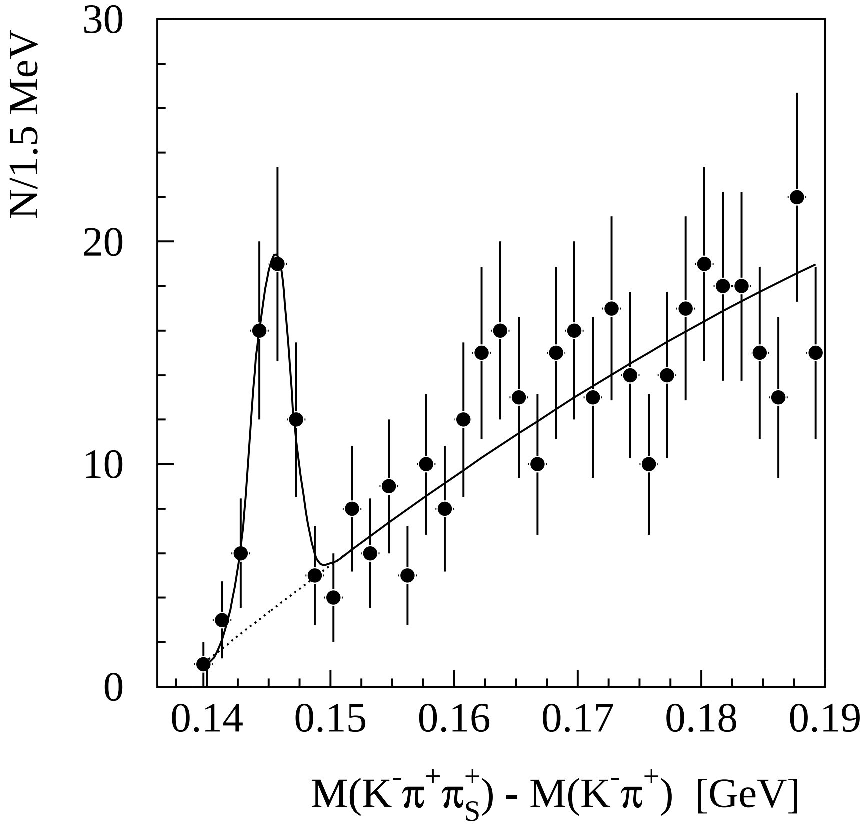
$\sqrt{s}$ GeV	$\mathcal{L}$ pb^{-1}	Hadrons # ev.	Electrons # ev.	Muons # ev.
91	80	93204	282	62
130 – 140	12	21045	82	-
161 – 172	21	44444	156	17
183	52	116760	433	52

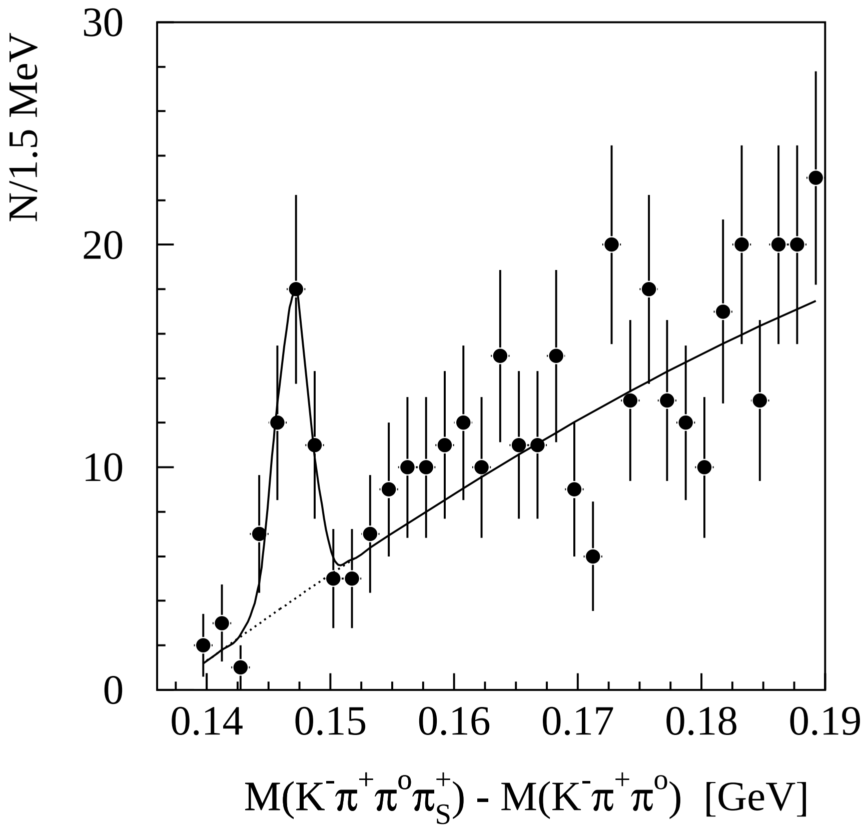
Electron Identification



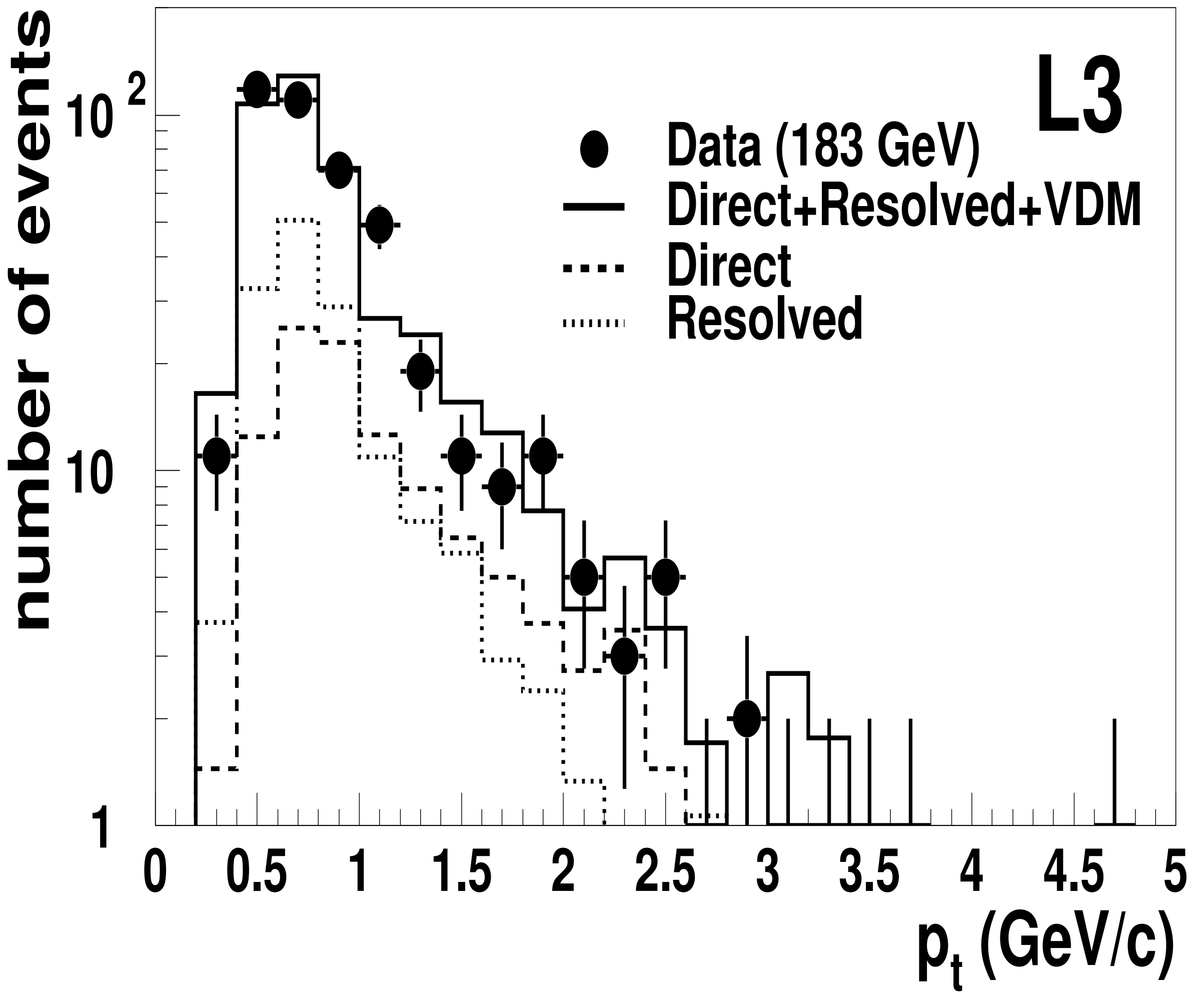
* MC is PYTHIA

D^* Identification



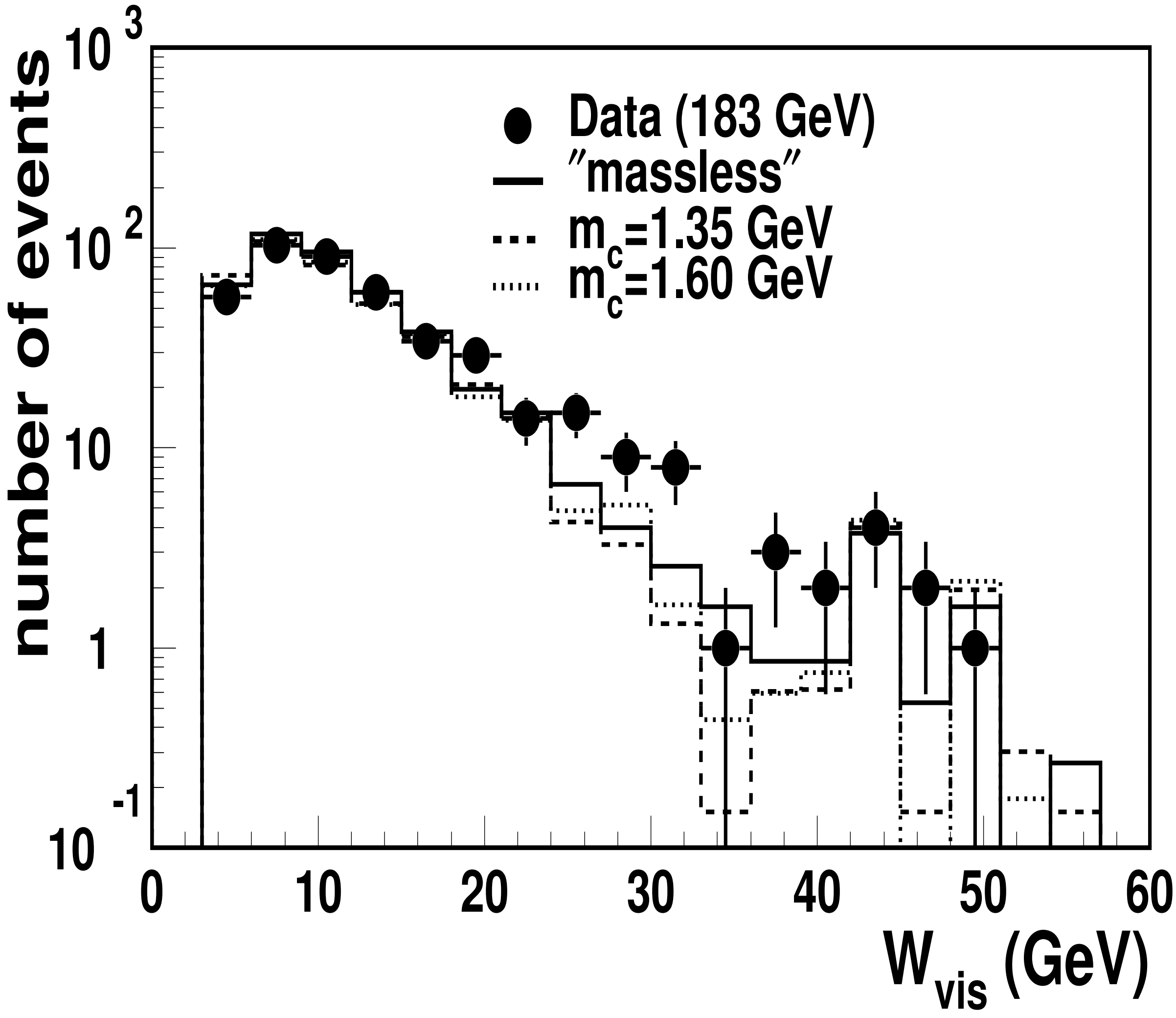


Inclusive lepton production



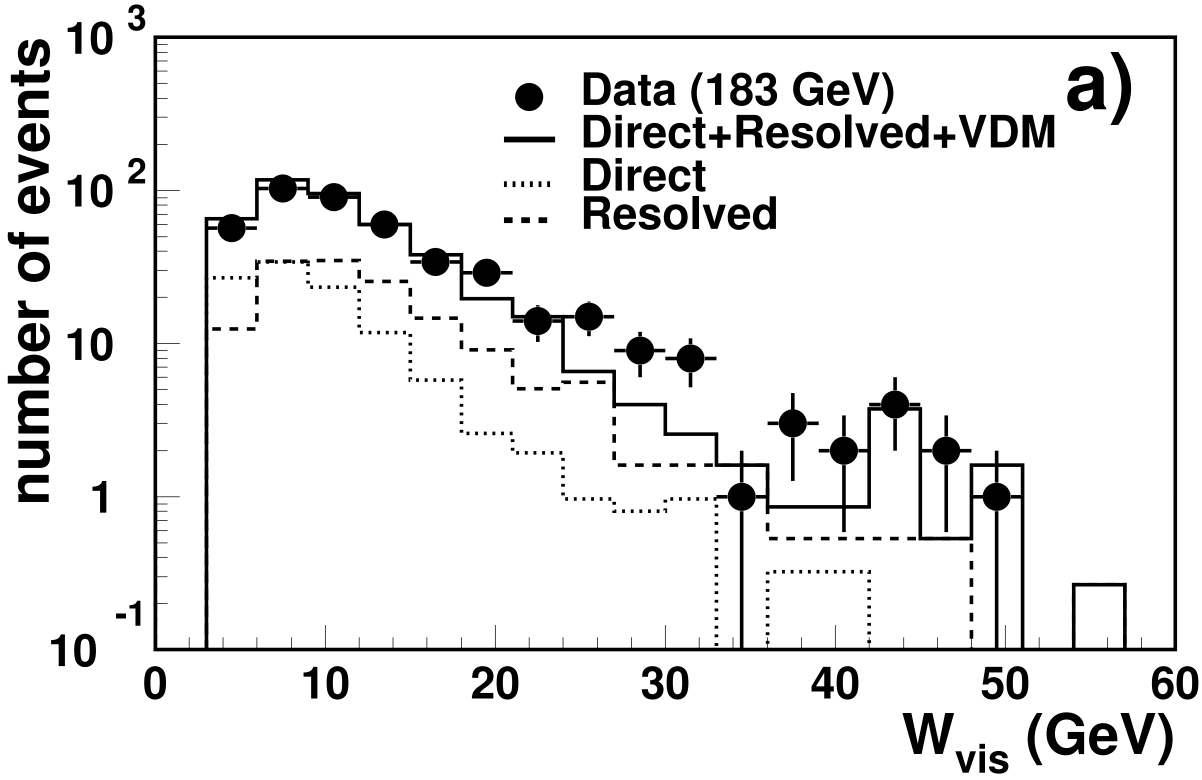
- p_t spectrum is well described by PYTHIA
- direct process produces ,in average, more energetic leptons than resolved one
- fraction of charm events is increasing with p_t of lepton

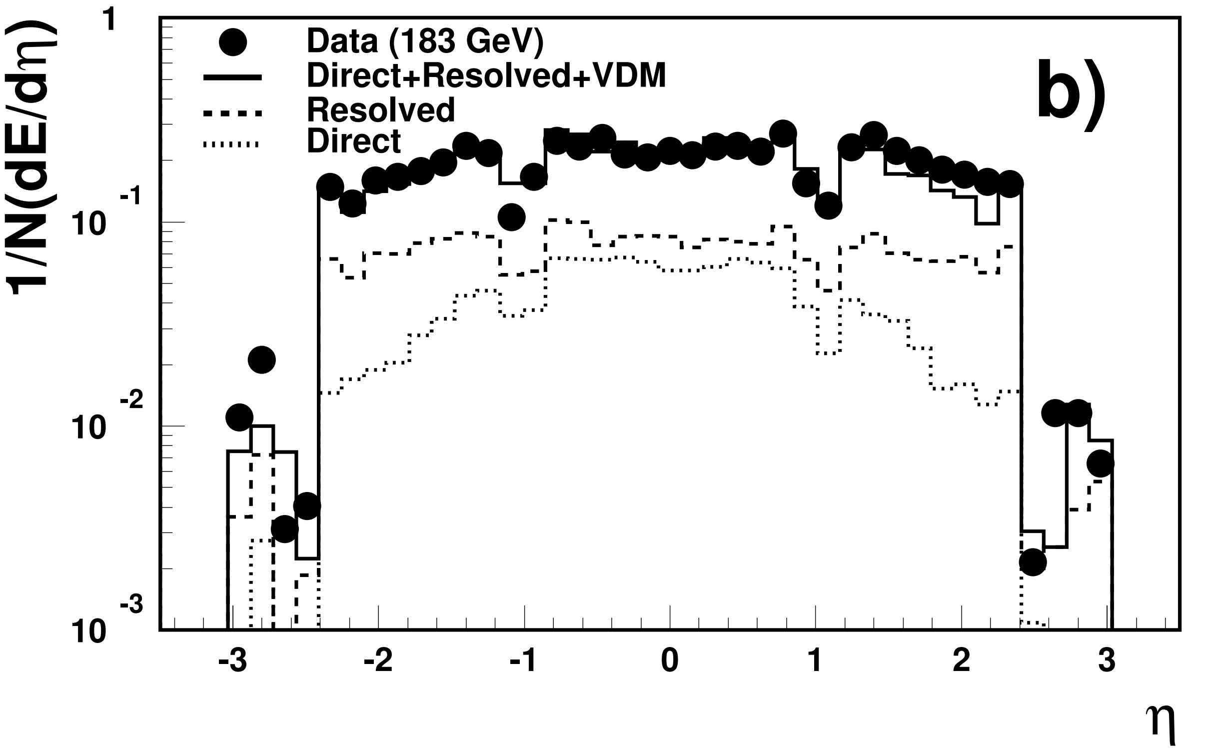
Massive vs Massless



- the W_{vis} spectrum shape is not very sensitive to the mass of charm quark

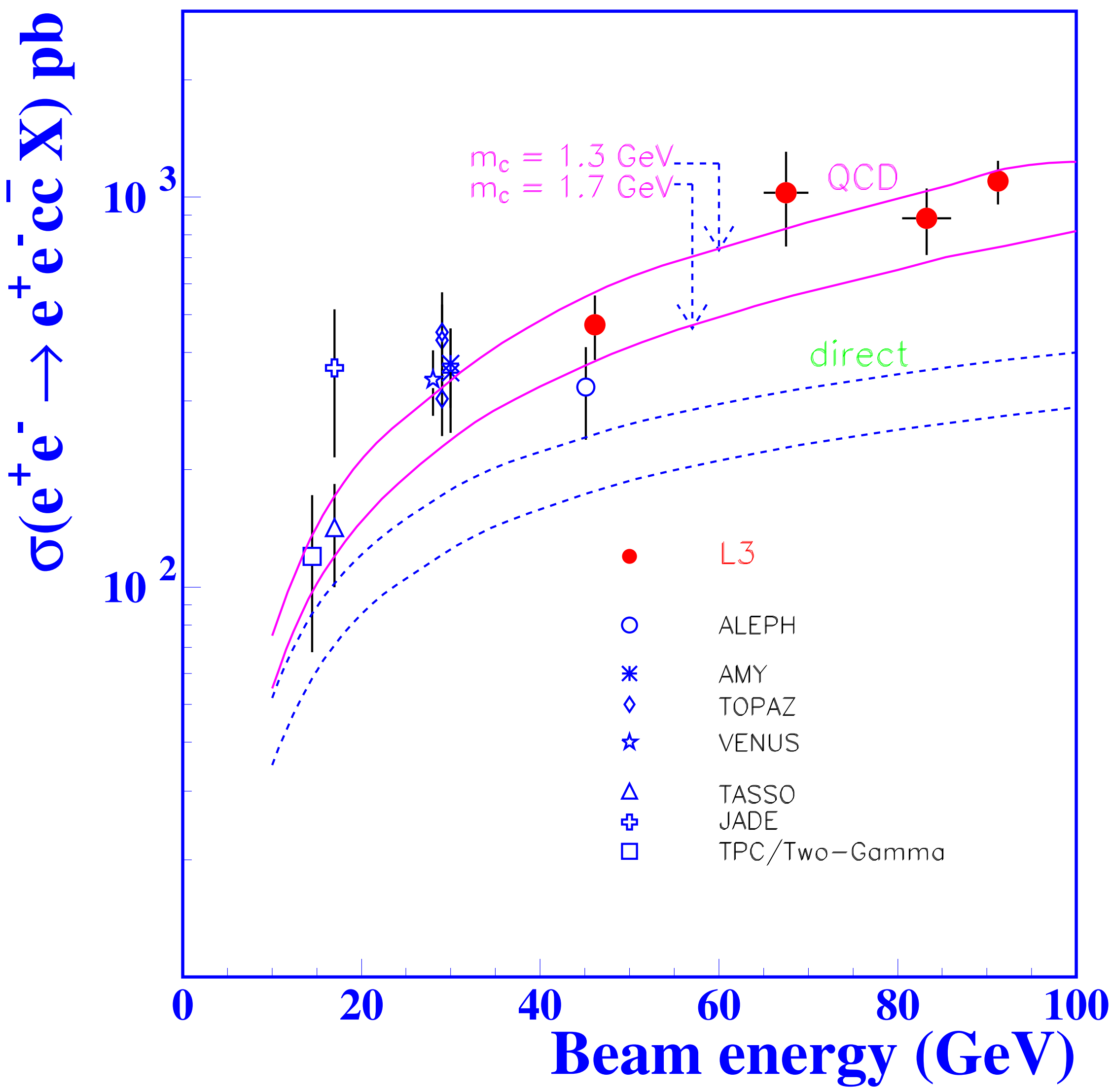
Direct vs Resolved





- direct and resolved processes can be separated to some extent

Charm production in $\gamma\gamma$ collisions



* theory prediction from
M.Drees,M.Krämer,J.Zunft and P.M.Zerwas,Phys. Lett. B306 (193) 371

Conclusion

- Total cross section
  - $\sigma_{\gamma\gamma}$ increases at high energies (5 GeV $\leq W_{\gamma\gamma} \leq$ 145 GeV) ➜ independent of MC !
    Fitted Pomeron value of ε, 0.16 ± 0.03, larger than PDG value, 0.079. ➜ contribution from hard Pomeron !?
  - The dominant uncertainty is the modelling dependence.

- Charm production
  - Lepton tag ($>$ 50 % purity) and clean D^* signal at LEP1 and LEP2
  - Event distributions and cross sections require resolved processes,
    sensitive to the gluon content in the photon

Outlook

– more data coming till year 2001

– need improved general purpose MC :
PYTHIA($\rho\rho$, NLO), PHOJET($c\bar{c}$), ...

– hope to understand transition between non-perturbative and perturbative domains

– Theoreticians are kindly invited to help us on the effort to build a consistent picture of the two-photon collisions