The Relation between Electron-Photon and Electron-Proton Scattering

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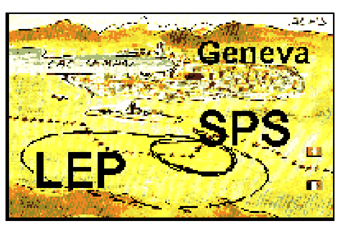
Hamburg, April, 28 1998

- Similarities of ep and eγ Scattering
- $\gamma\gamma \longrightarrow$ hadrons
- Deep inelastic eγ Scattering

For the

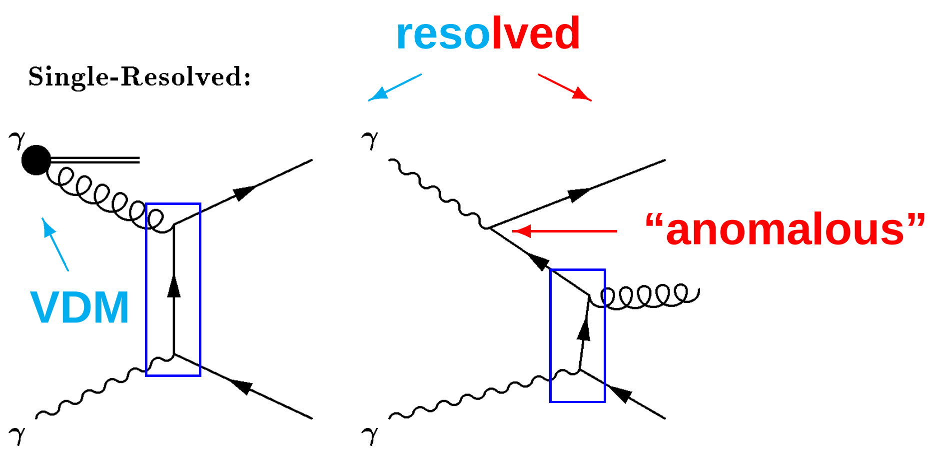


Two-Photon WG

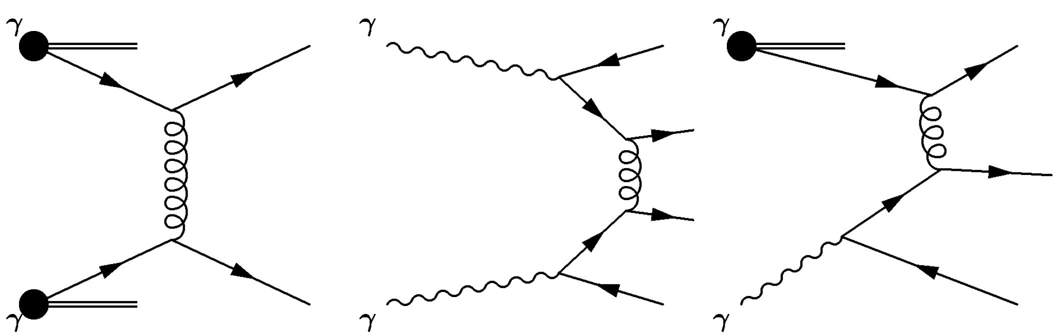
Leading order diagrams

Direct:

Single-Resolved:

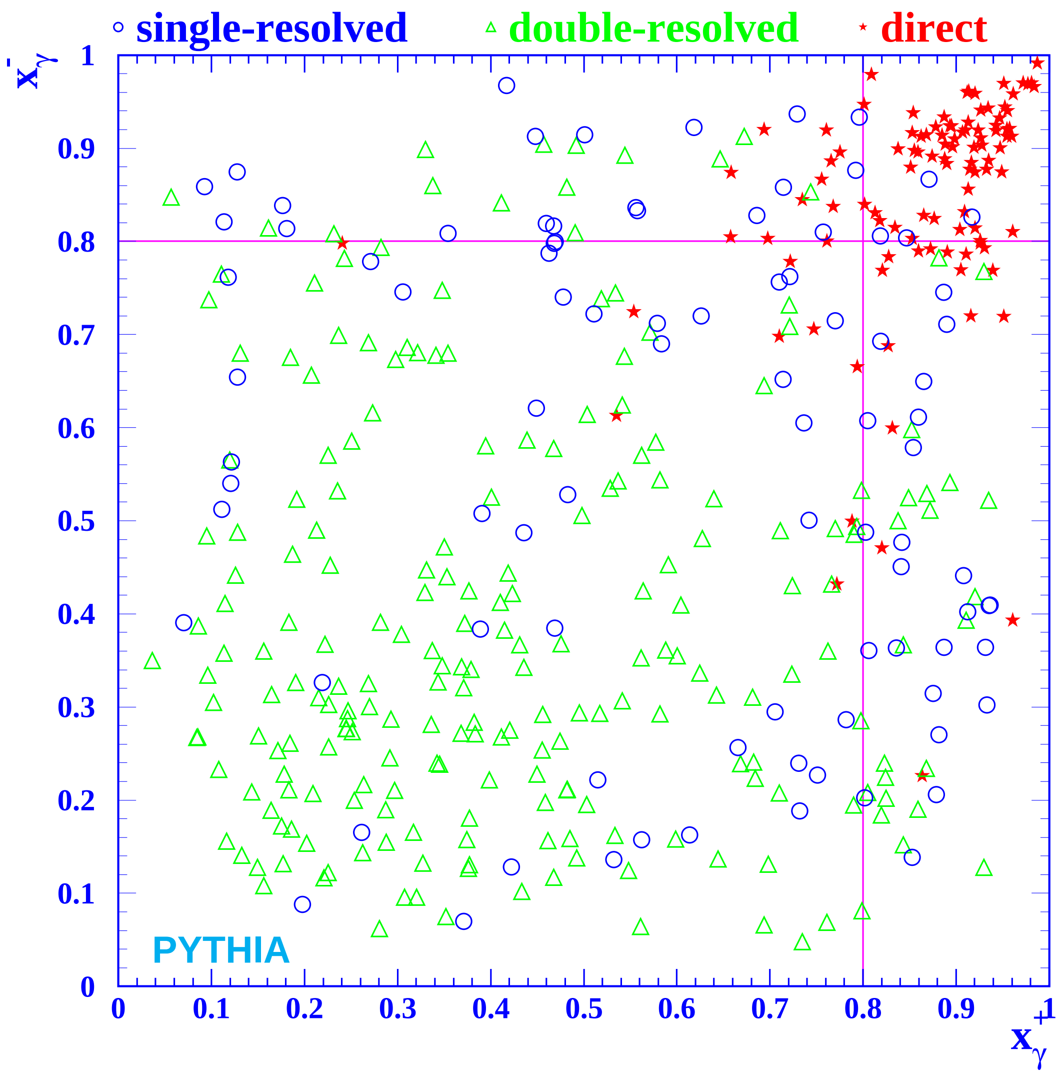


Double-Resolved:



The separation of event classes

at $\sqrt{s_{ee}}$ = 133 GeV

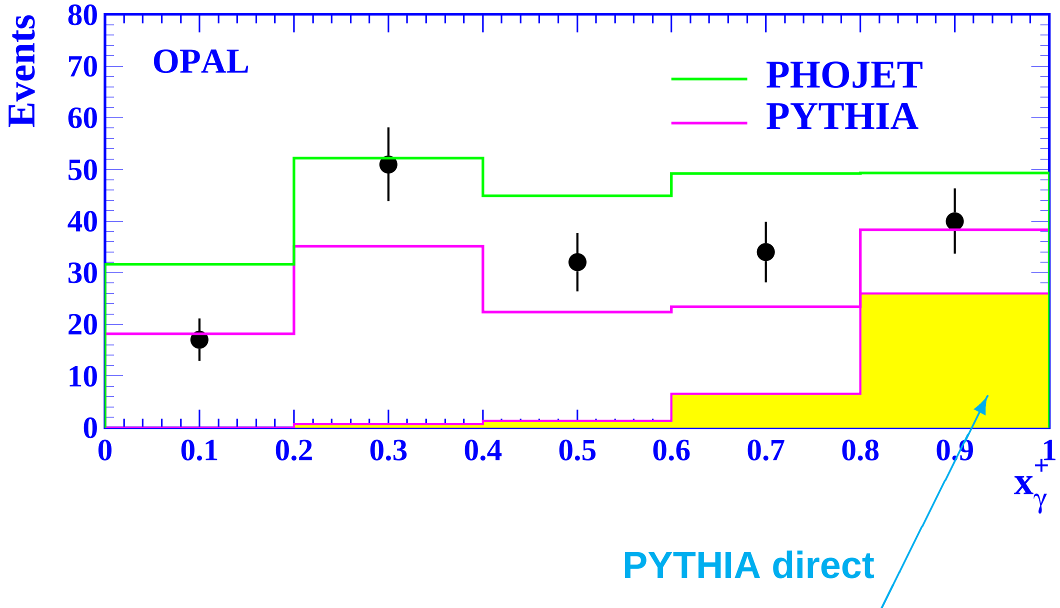


$$x_\gamma^\pm = \frac{\sum_{\text{jets}}(E \pm p_z)}{\sum_{\text{hadrons}}(E \pm p_z)}$$

The x_γ distribution for 2–jet events at $\sqrt{s_{\rm ee}}$ = 133 GeV

x_γ is the fraction of the photon momentum participating in the hard interaction

$$x_\gamma^\pm = \frac{\sum_{\rm jets}(E \pm p_z)}{\sum_{\rm hadrons}(E \pm p_z)}$$

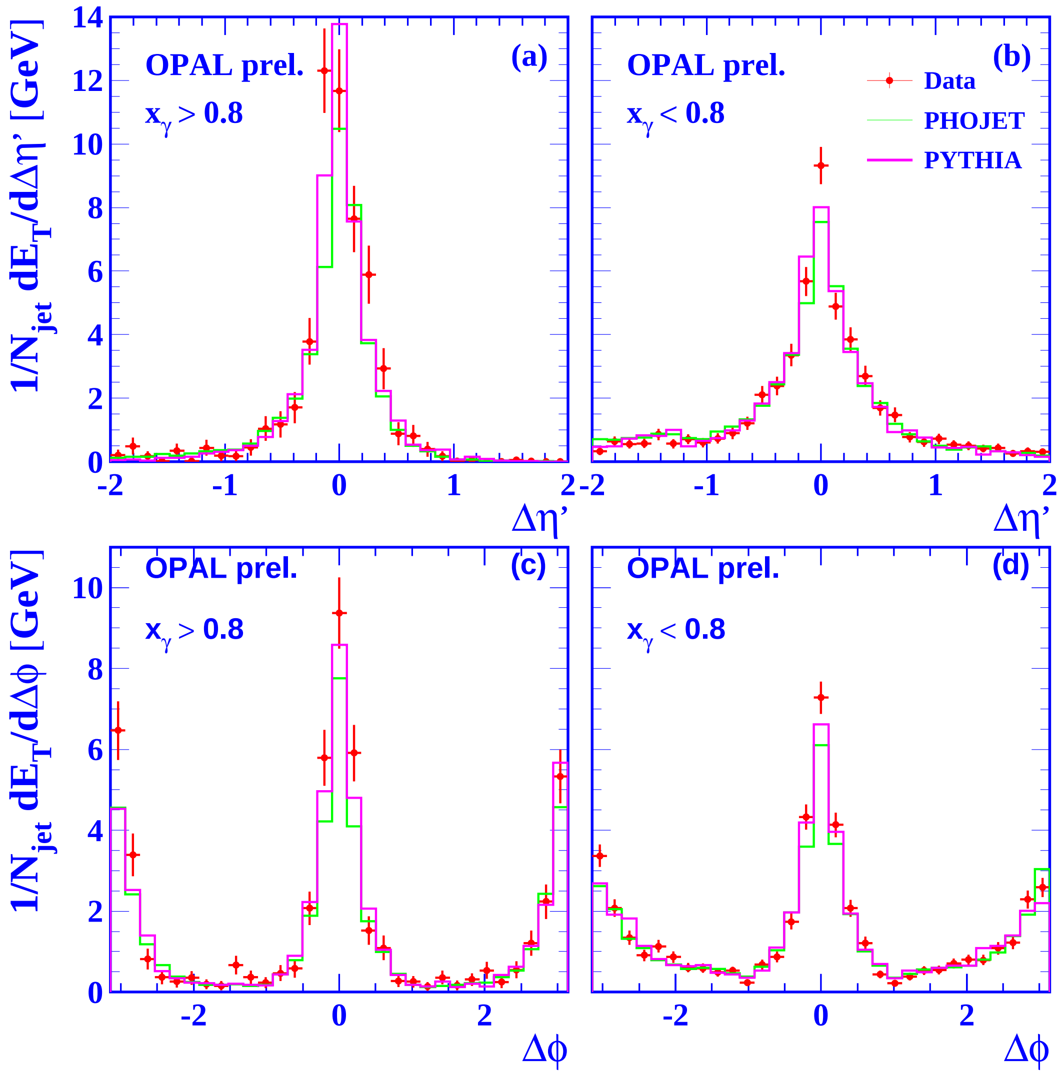


Direct events : $x_\gamma \equiv 1$ no remnant jet

Resolved events : $x_\gamma < 1$ remnant jets possible

The energy flow for 2–jet events

$$\Delta\eta' = \pm(\eta - \eta_{\rm jet})$$

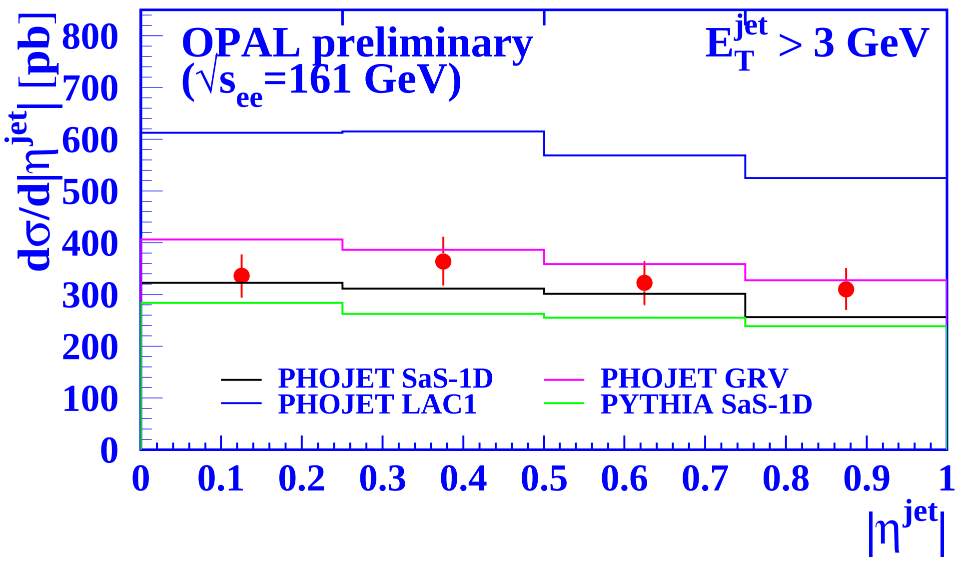


"direct" $x_\gamma > 0.8$ "resolved" $x_\gamma < 0.8$

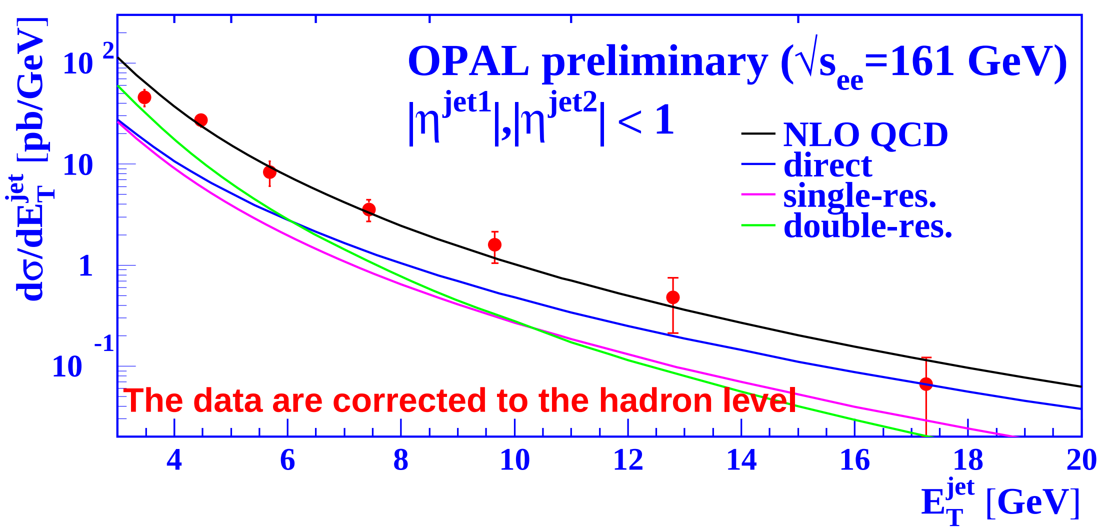
The inclusive jet cross-sections

at $\sqrt{s_{ee}} = 161\,\mathrm{GeV}$

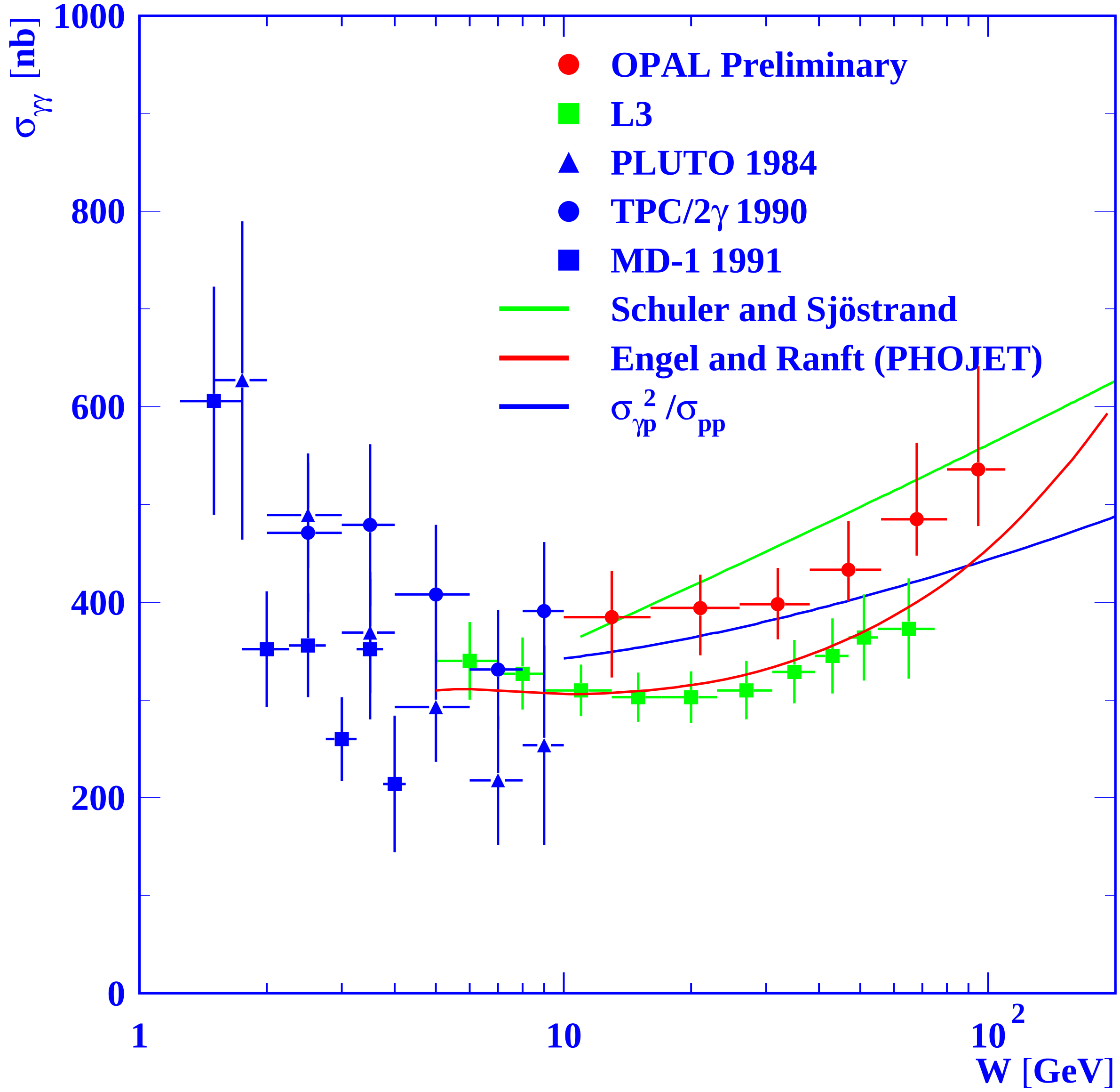
$\frac{d\sigma}{d\eta^{jet}}$ compared to *Monte Carlo models*



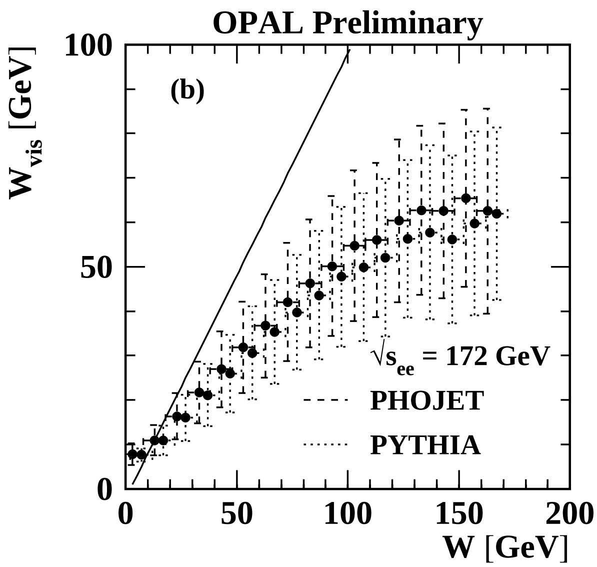
$\frac{d\sigma}{dE_T^{jet}}$ compared to *NLO Calculations*

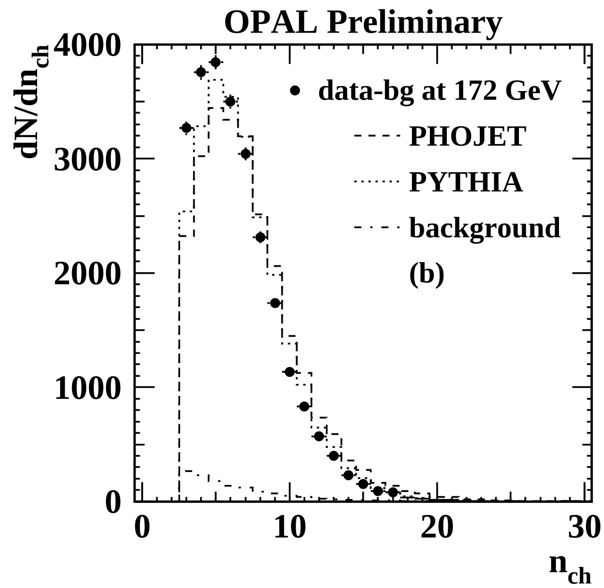


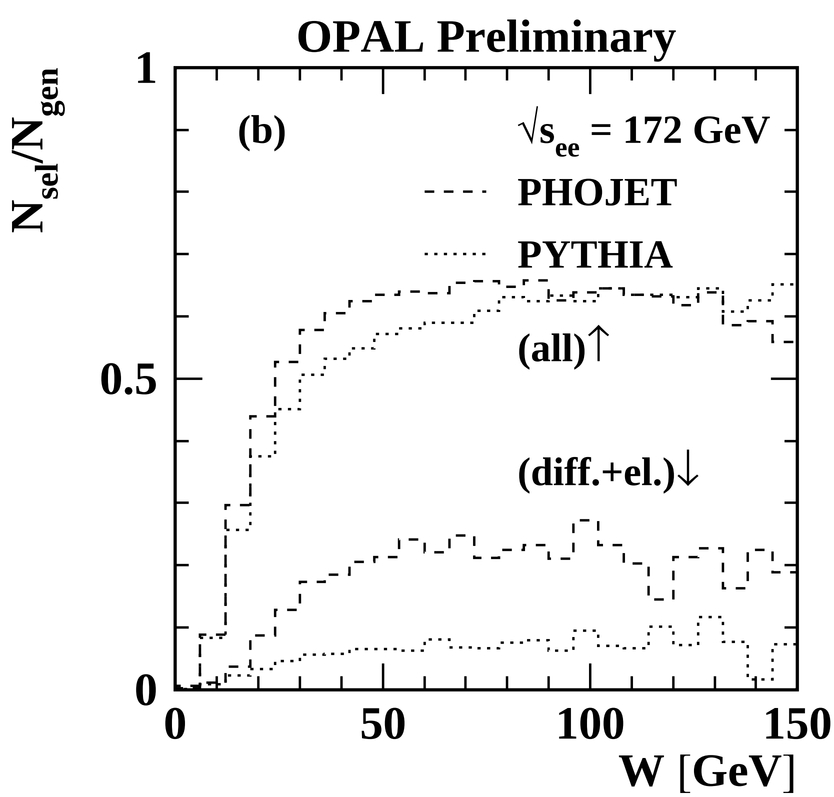
The total γ-γ cross section



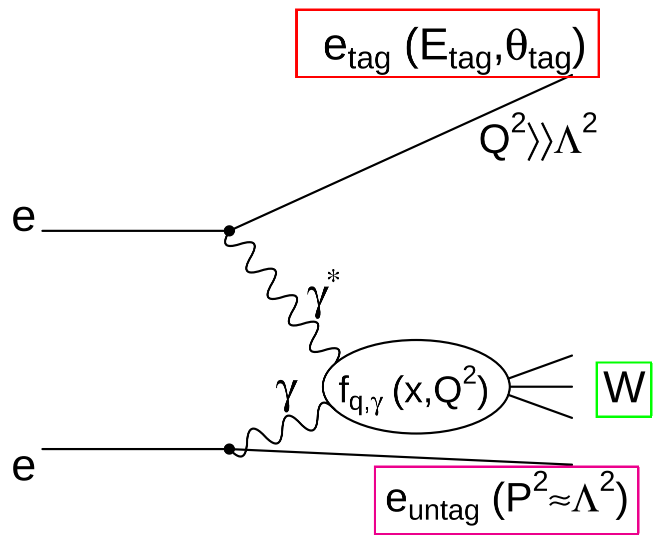
Some hadronic properties







Electron-Photon Scattering



$$\frac{d^2\sigma_{e\gamma\to eX}}{dx dQ^2} = \frac{2\pi\alpha^2}{x\,Q^4}\cdot$$

$$\left[(1+(1-y)^2)\,F_2^\gamma(x,Q^2) - \underbrace{y^2 F_L^\gamma(x,Q^2)}_{\to 0}\right]$$

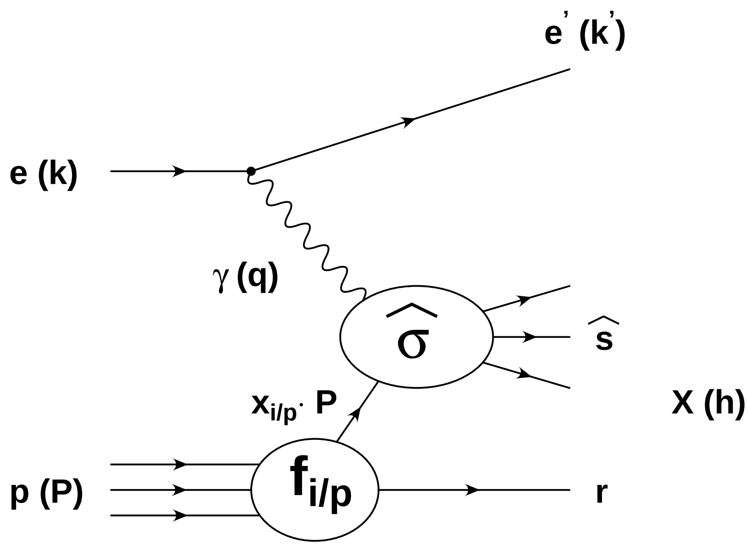
$$Q^2 = 2\,E_b\,E_{tag}\,(1-\cos\theta_{tag}) \gg P^2$$

$$x = \frac{Q^2}{Q^2+W^2+P^2}$$

$$y = 1 - \frac{E_{tag}}{E_b}\cos^2\left(\frac{\theta_{tag}}{2}\right) \ll 1$$

Deep Inelastic ep Scattering

$$\mathbf{e}(\mathbf{k})\,\mathbf{p}(\mathbf{P}) \rightarrow \mathbf{e}^{'}(\mathbf{k}^{'})\mathbf{X}(\mathbf{h})$$



$$Q^2 \equiv -q^2 = -(k-k^{'})^2$$

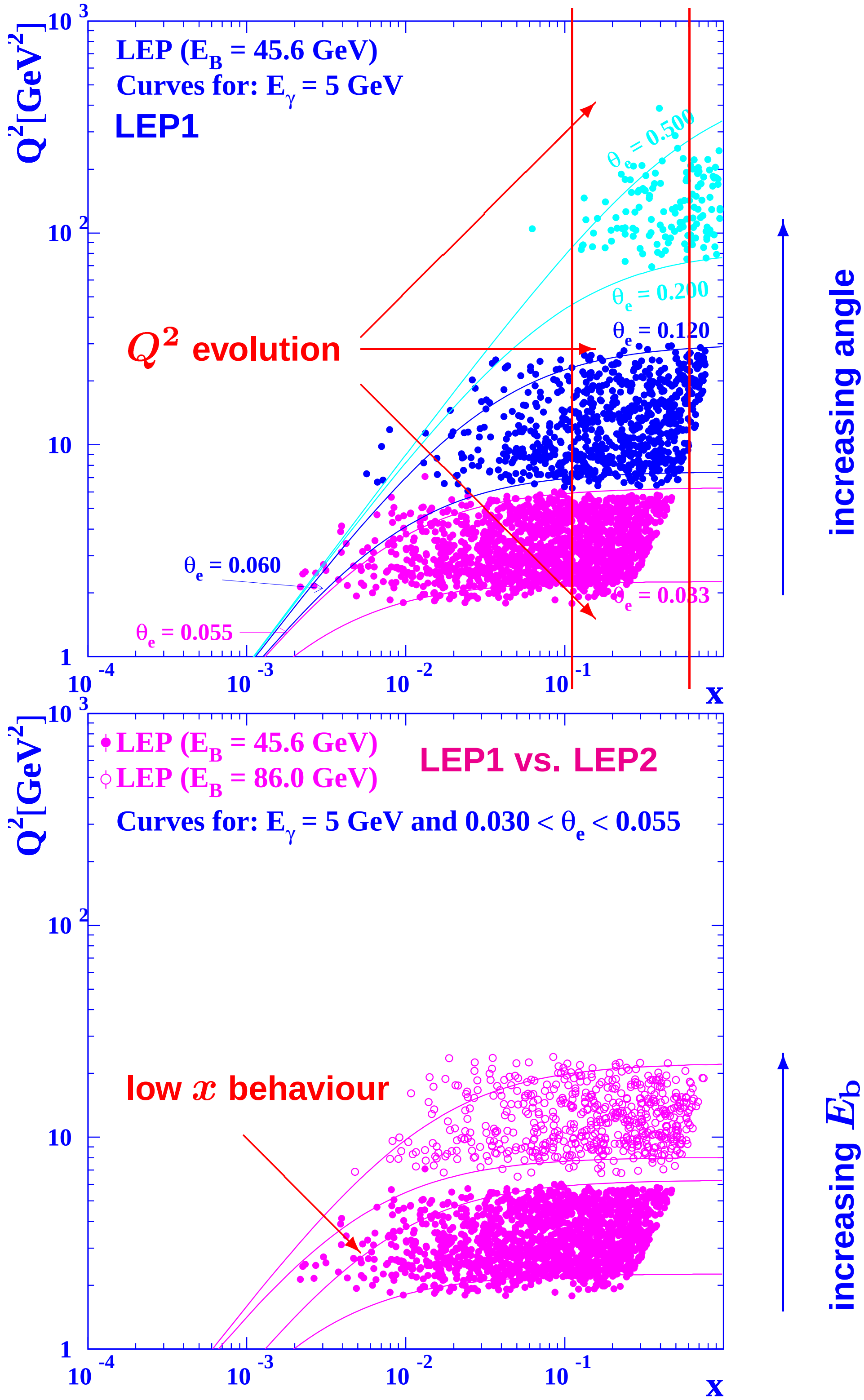
$$x \equiv \frac{Q^2}{2Pq}, \quad y \equiv \frac{Pq}{Pk} \quad W^2 = Q^2 \cdot \frac{1-x}{x}$$

$$\sqrt{s_{\rm ep}} = (P+k)^2 = 2Pk$$

$$\frac{\mathrm{d}^2\sigma_{ep\rightarrow e' X}}{\mathrm{d}x\mathrm{d}Q^2} = \frac{4\pi\alpha^2}{xQ^4}\left(1-y+\frac{y^2}{2[1+R]}\right) F_2\,(x,Q^2)$$

$$R\,(x,Q^2) = \frac{F_2\,(x,Q^2)}{2xF_1\,(x,Q^2)} - 1$$

The $x - Q^2$ plane



The general procedure to measure F_2^γ

1. Events are triggered with high efficiency by the luminosity detectors nearly independent of the hadronic final state.

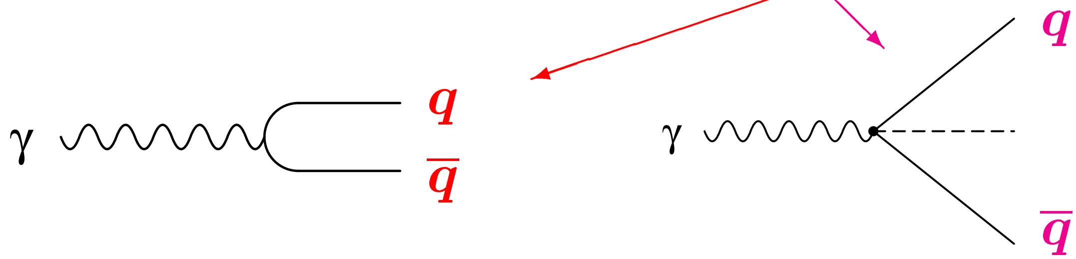
2. Q^2 is accurately measured from the electron.

3. E_γ is unknown and varies from event to event
   $\Rightarrow W_{\rm vis}$ has to be measured from the hadrons.
   (No electron alone method as e.g. at HERA)

4. x is obtained from $x_{\rm vis}$ via unfolding (Blobel, ...)
   $\Rightarrow$ Dependence on the formation of the hadronic final state as assumed by the Monte Carlo models!

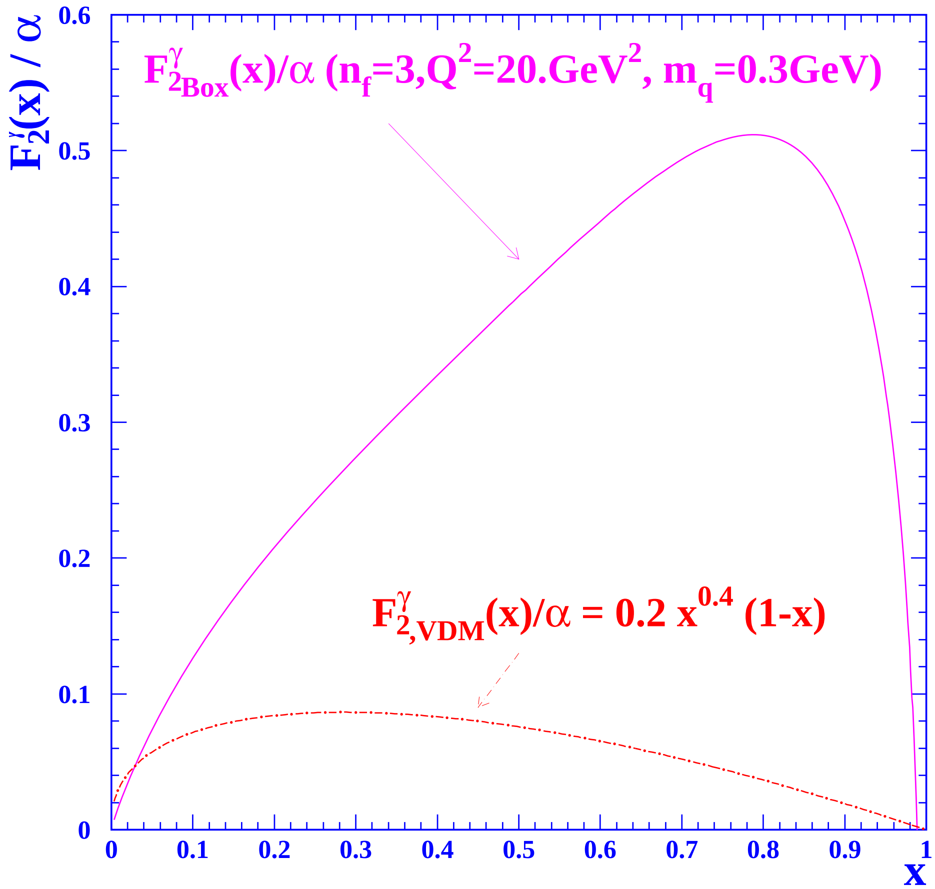
The contributions to $F_2^\gamma(x,Q^2)$

$$F_2^\gamma(x,Q^2) = x \sum_{c,f} e_q^2 \, f_{q,\gamma}(x,Q^2)$$

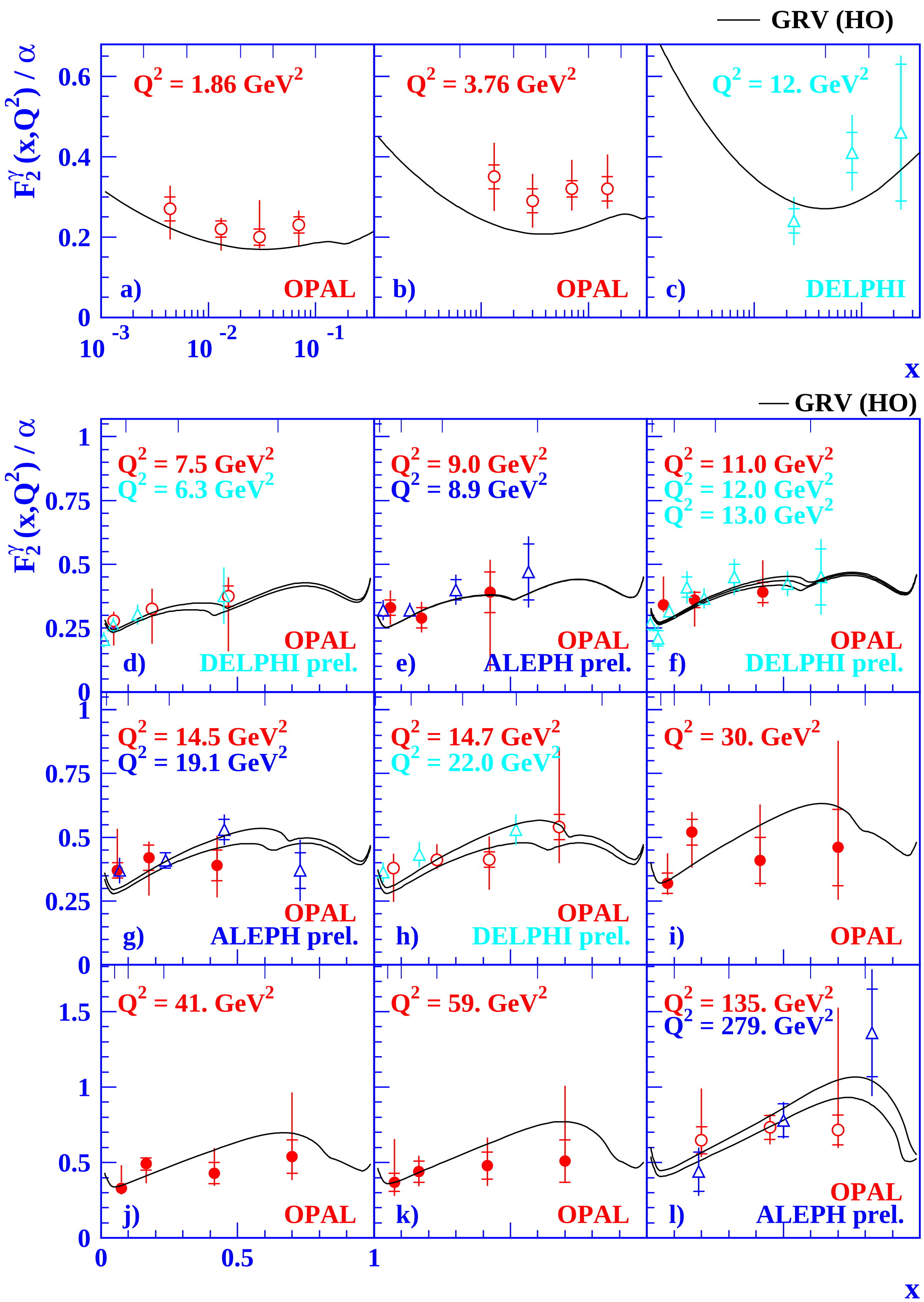


'hadronic', p_T = "small"
non–perturbative
VDM (ρ, ω, ϕ)

'pointlike', p_T = "large"
perturbative

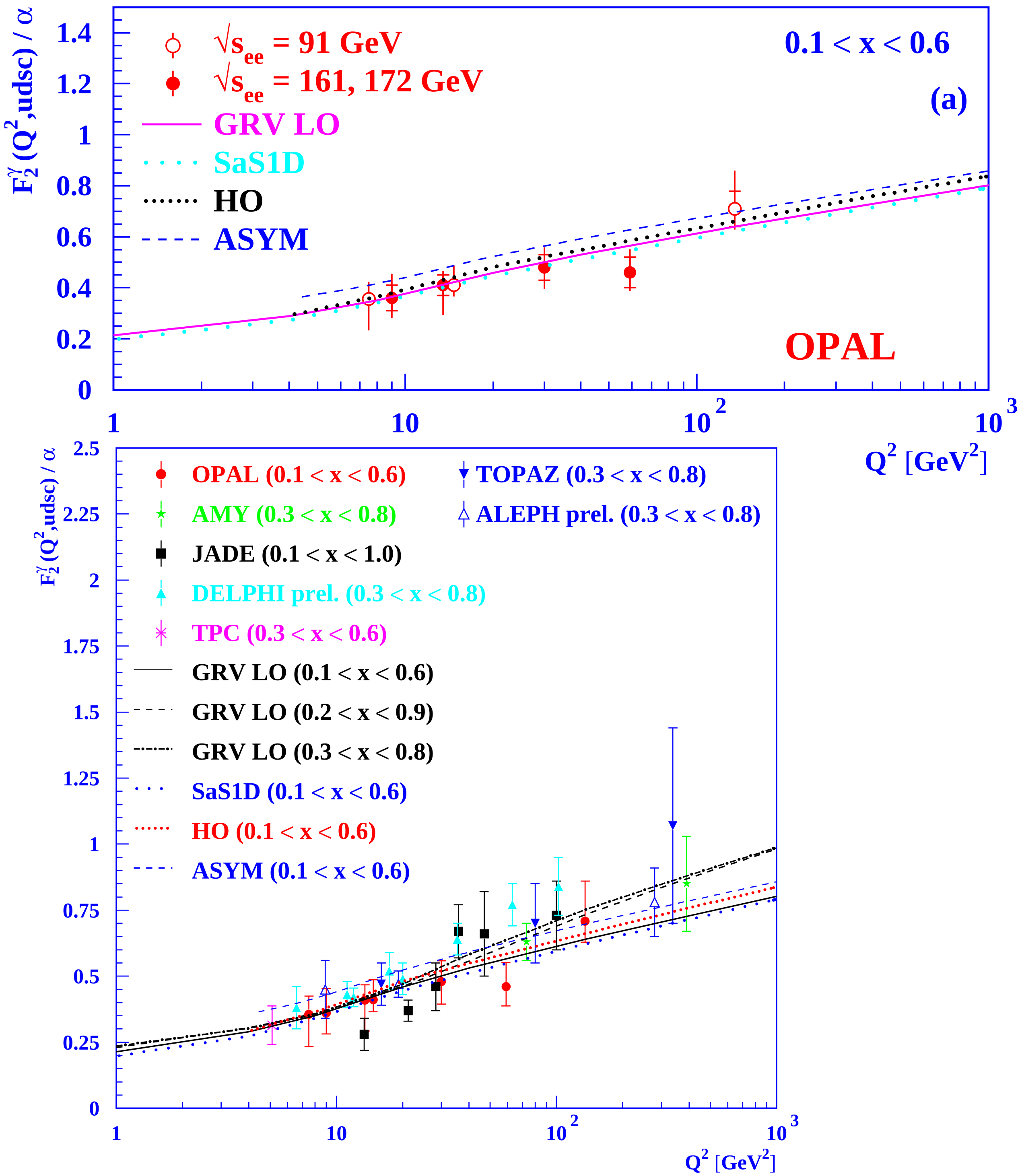


The LEP data on F_2^γ



The Q^2 evolution of F_2^γ

$$F_2^\gamma = (0.16 \pm 0.05^{+0.17}_{-0.16}) + (0.10 \pm 0.02^{+0.05}_{-0.02}) \ln(Q^2/\mathrm{GeV}^2)$$



The Status of MC generators for DIS

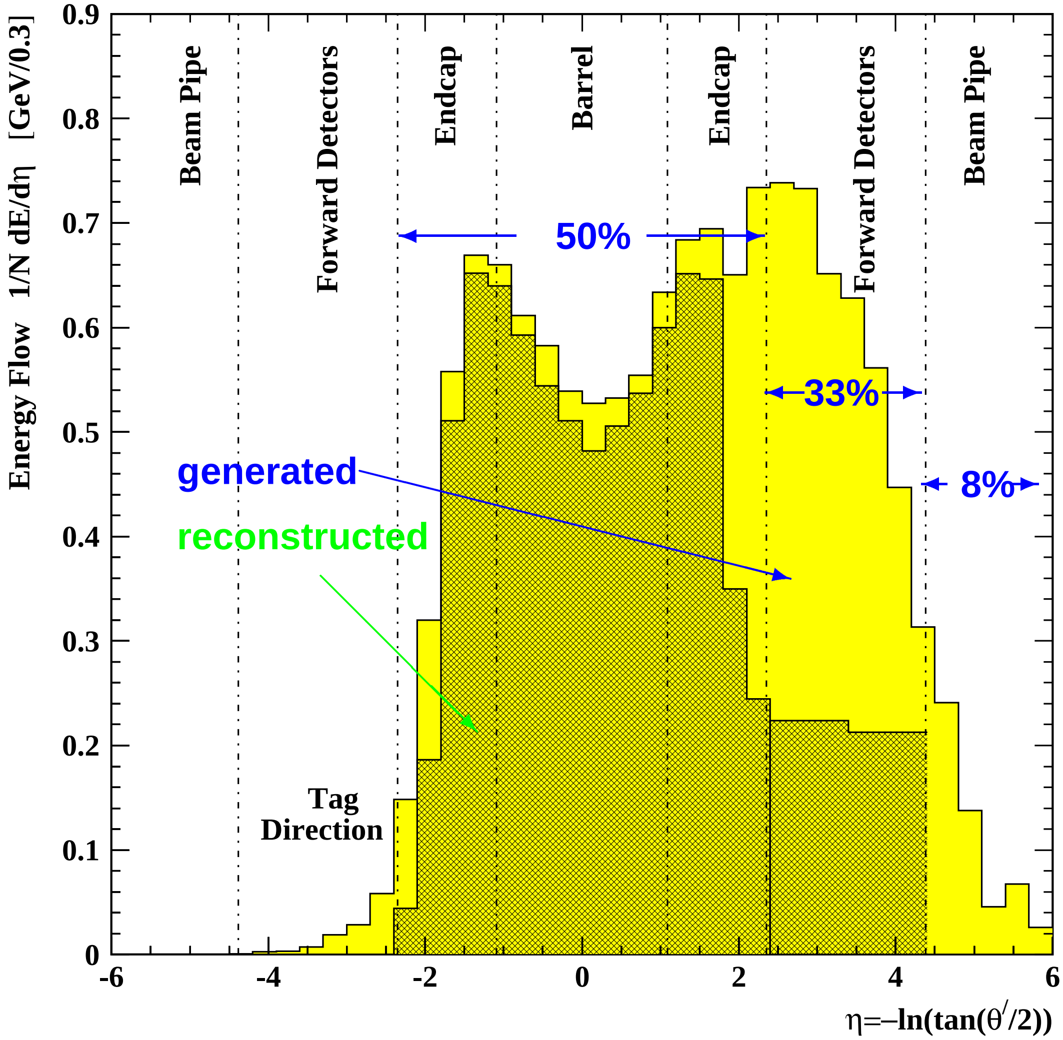
Home made generators

1. There exist several special purpose MCs (F2GEN,TWOGAM,...) for Two-Photon physics at LEP.
2. They usually have simple hadronisation models (NO parton shower, backward evolution, Multiple Interactions,...).
3. The turnaround time for changes required is short.
4. They cannot be cross-checked with other reactions.

General purpose MCs

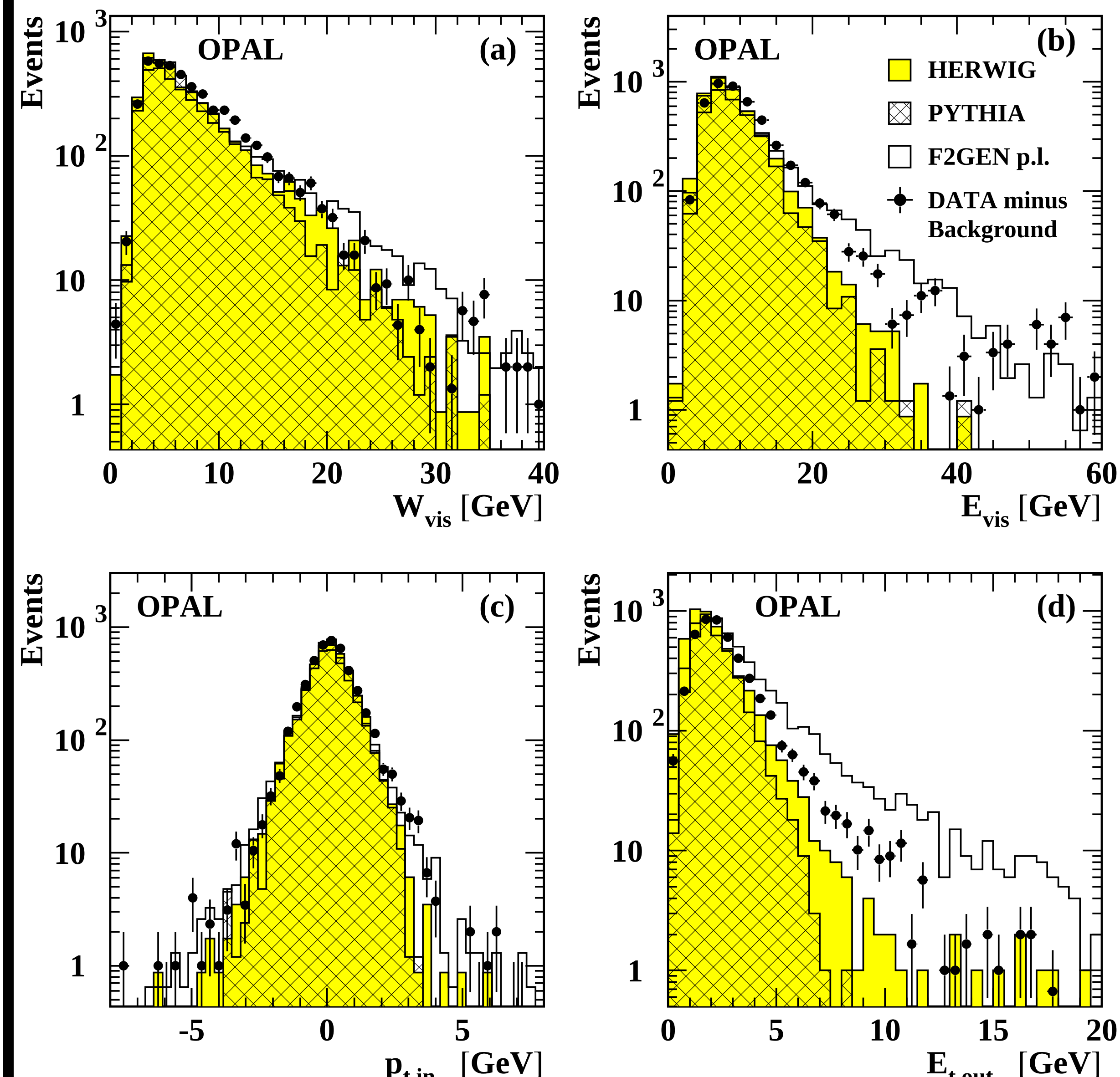
1. There exist several general purpose MCs (HERWIG, PYTHIA, PHOJET).
2. They have better hadronisation models tuned to other reactions, e.g. they can only be modified within the limits set by the HERA data.
3. The turnaround time for changes required is too long.

The hadronic Energy Flow from HERWIG

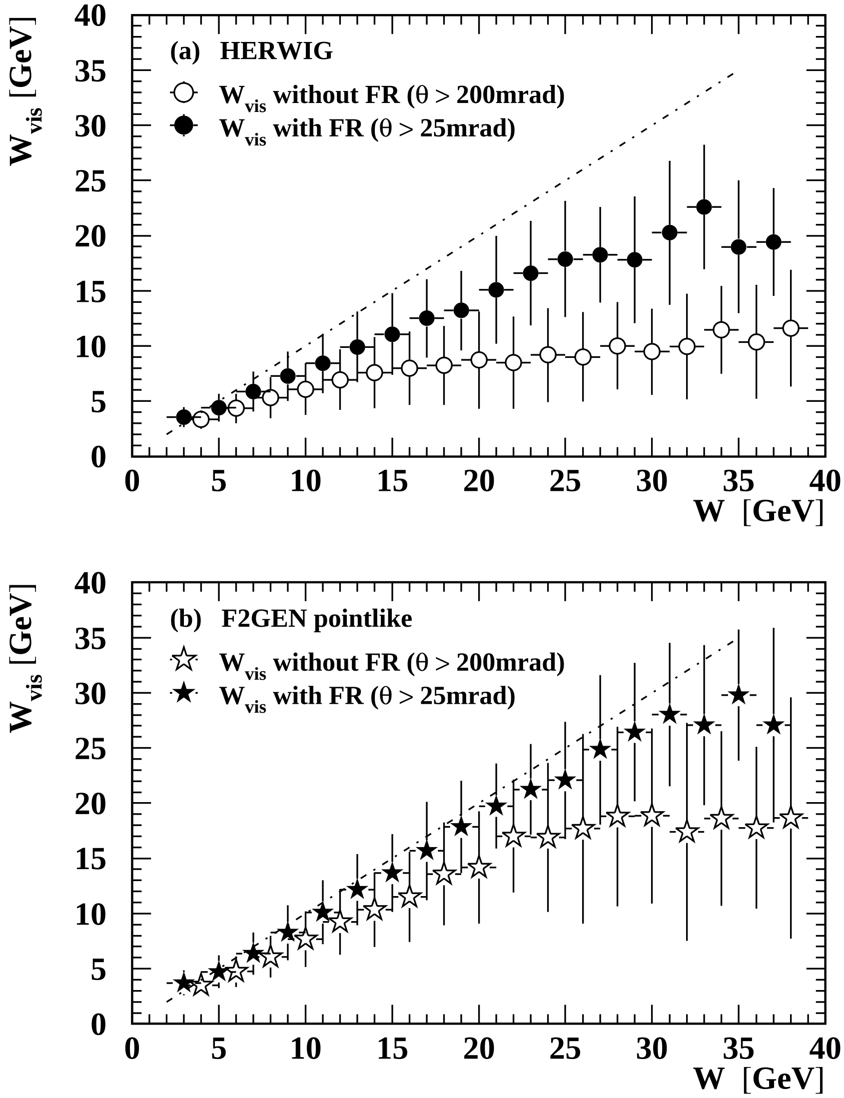


Only about 10% of the energy is deposited outside of the detector acceptance

Some global quantities



The W – $W_{\rm vis}$ correlation

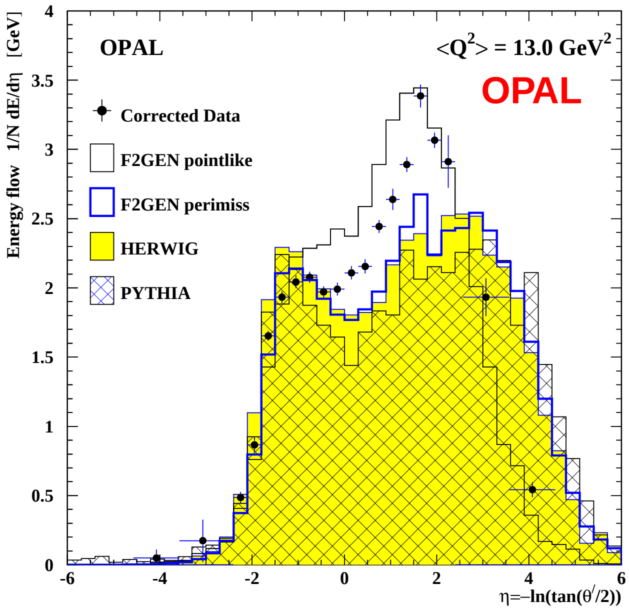


The correlation based on F2GEN is much stronger

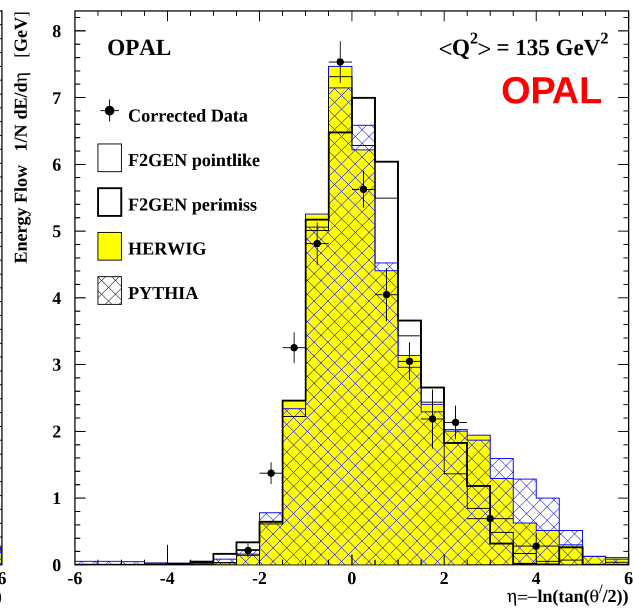
The inclusion of the Forward Region significantly improves the correlation

The energy flow Part I

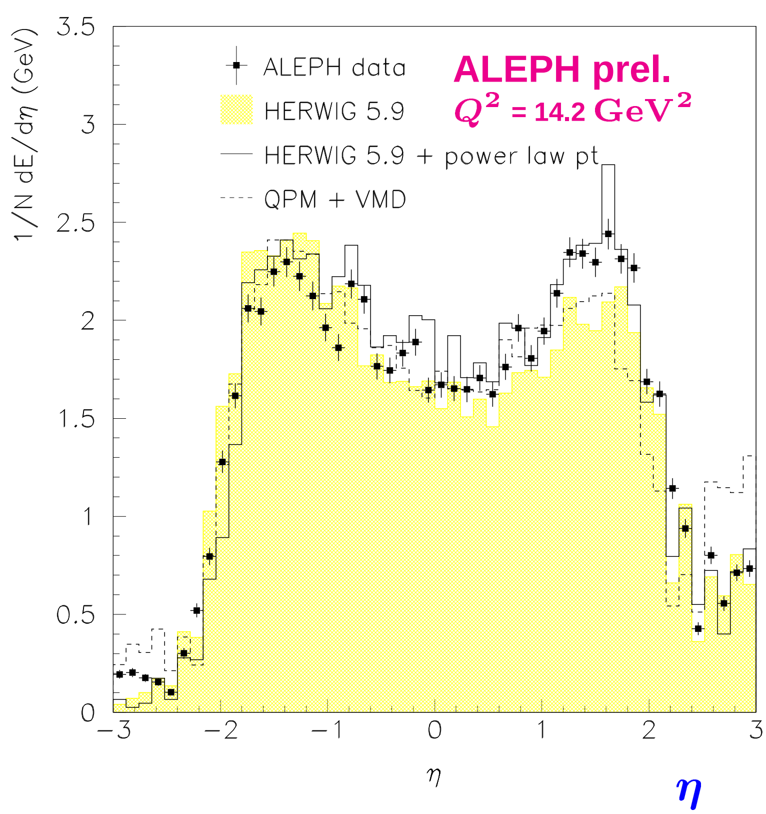
$1/N\ \mathrm{d}E/\mathrm{d}\eta$



$1/N\ \mathrm{d}E/\mathrm{d}\eta$

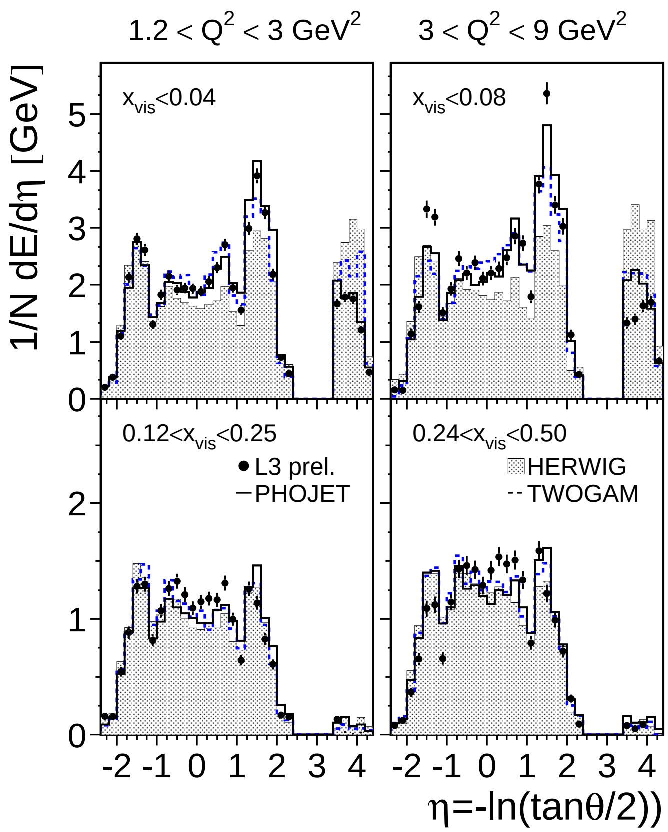


η η

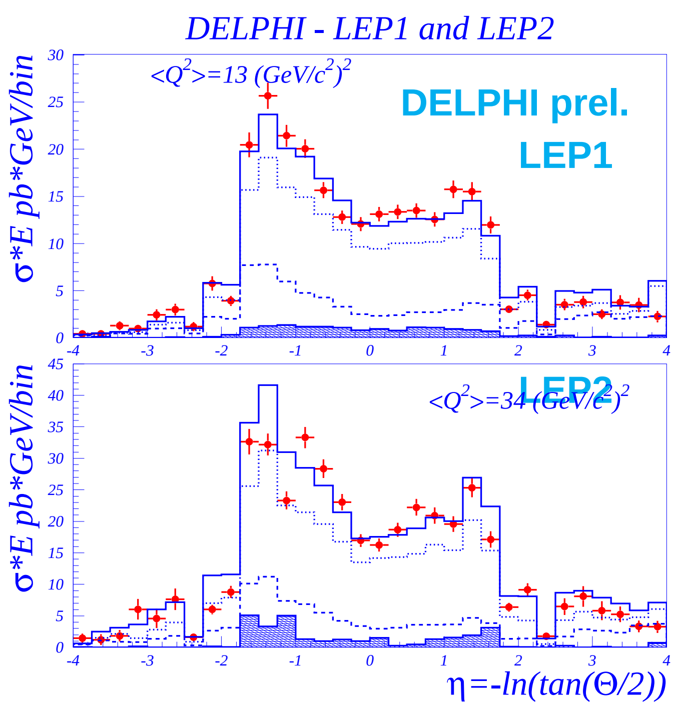


η

The energy flow Part II



L3 (LEP1) prel.



Improvements on the Monte Carlo programs are needed

Some wishes for the Workshop

$\gamma\gamma \rightarrow$ hadrons

1. Simulate correctly the electron kinematics.
2. Resolve the differences in the elastic and diffractive part in Phojet and Pythia.

Deep inelastic eγ Scattering

1. Improve on the energy flow in order to reproduce the data.
2. Get the same formulas for the Bremsstrahlungs spectra of the quasi-real photons in all MCs. (e.g. a marriage of Pythia and Galuga).
3. Include the contribution to F_2^{γ} from massive charm quarks.
4. Include the structure functions for virtual photons, and simulate correctly the correseponding electron kinematics.

Get a smooth transition between the two regions

Conclusions

1. The measurement of the total cross section suffers from the not very well know unseen cross section.
2. The measurement of $F_2^{\gamma}(x, Q^2)$ is systematics limited and most of it comes from dependence on the simulation of the hadronic final state.
3. Multi purpose generators are in principle the better choice, but in practice very much depends on the progress made by the authors.

The Physics results from LEP could considerably profit from improvements of the Monte Carlo models.

slides:

http://wwwcn1.cern.ch/~nisius