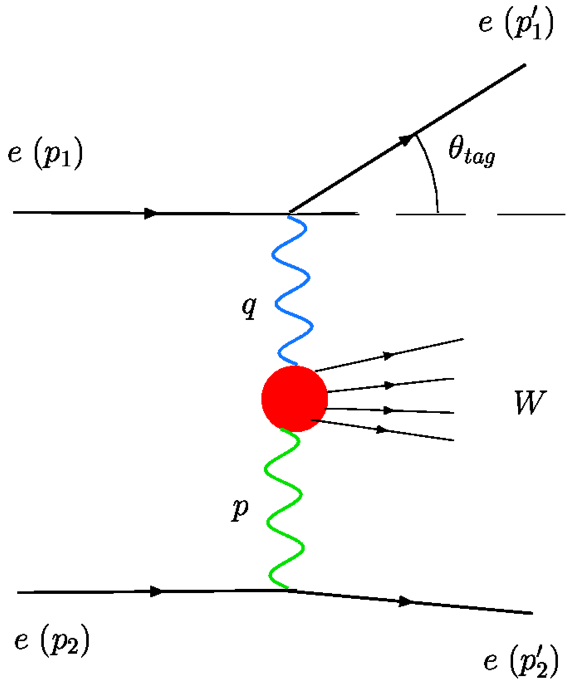
The Photon Structure Function and The Parton Content of the Photon

Fernando Cornet
Universidad de Granada

Kinematics



$$W^2 = (p+q)^2$$

$$Q^2 = -q^2 = 2E_1E_1'(1-\cos\theta_{tag})$$

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

$$y = 1 - \frac{E_1'}{2E_1}(1+\cos\theta_{tag})$$

$$\frac{d\sigma(e\gamma)}{dE_1 d\cos\theta_{tag}} = \frac{4\pi\alpha^2 E_1}{Q^4 y}\{[1+(1-y)^2]F_2^\gamma(x,Q^2) - y^2 F_L^\gamma(x,Q^2)\}$$

Heavy Quark Contributions

- Fixed Flavor Number Scheme (FFNS)
  - Number of quark flavors in the photon fixed: $N_f = 3$
  - Heavy Quarks appear only in the final state.
  - The mass m_h is included in the calculation.
  - Poor approximation for large energy scales
- Zero Mass Variable Flavor Number Scheme (ZVFNS)
  - Non-zero heavy quark densities
  - Number of flavors increases when crossing thresholds
  - Heavy quark masses kept to zero
  - Poor approximation near threshold
- Variable Flavor Number Scheme
  - Includes heavy quarks as partons
  - Includes direct production of heavy quarks
  - One should avoid double-counting

The FFNS$_{\mathrm{CJK}}$ Parametrization

[F.C., P. Jankowski and M. Krawczyk]

We work in the DIS$_\gamma$ factorization scheme [Glück, Reya and Vogt]

$$\frac{1}{x}F_2^\gamma(x,Q^2)|_{FFNS} =$$

$$\sum_{i=1}^{3} e_i^2 \left\{ (q_i^\gamma + \bar{q}_i^\gamma)(x,Q^2) + \frac{\alpha_s(Q^2)}{2\pi}\int_x^1 \frac{dy}{y}\left[(q_i^\gamma + \bar{q}_i^\gamma)(y,Q^2) C_{2,q}^{(1)}(\frac{x}{y}) + G^\gamma(y,Q^2) C_{2,G}^{(1)}(\frac{x}{y}) \right] \right\}$$

$$+ \sum_{h(=c,b)}^{2} e_h^2 \left\{ \frac{\alpha_s(Q^2)}{2\pi}\int_{\chi_h}^1 \frac{dy}{y} G^\gamma(y,Q^2) C_{2,G}^{h,(1)}(\frac{x}{y},\frac{Q^2}{m_h^2}) + e_h^2 \frac{\alpha}{2\pi} C_{2,\gamma}^{h,(0)}(x,\frac{Q^2}{m_h^2}) \right\}.$$

hard (parton) process	coefficient function
$\gamma^* + q^\gamma(\bar{q}^\gamma) \longrightarrow q(\bar{q}) + G$	$C_{2,q}^{(1)}(x)$
$\gamma^* + G^\gamma \longrightarrow q + \bar{q}$	$C_{2,G}^{(1)}(x)$
$\gamma^*\gamma \longrightarrow h + \bar{h}$	$C_{2,\gamma}^{h,(0)}$
$\gamma^* + G^\gamma \longrightarrow h + \bar{h}$	$C_{2,G}^{h,(1)}(x)$

The Input

The input parton densities for the hadron-like part are obtained assuming VMD at the scale $Q_0^2 = 0.765\ GeV^2$

$$f^{\gamma}_{had}(x, Q_0^2) = \sum_V \frac{4\pi\alpha}{\hat{f}_V^2} f^V(x, Q_0^2)$$

$\hat{f}_V^2$ is obtained from the decay $\rho^0 \to e^+e^-$

Substitute $\sum_V$ by κ and leave κ as a free parameter

The form of the valence and gluon densities are taken in analogy with the ones from the pion:

$$\begin{aligned} xv^{\rho}(x, Q_0^2) &= N_v x^{\alpha}(1-x)^{\beta}, \\ xG^{\rho}(x, Q_0^2) &= \tilde{N}_g xv^{\rho}(x, Q_0^2) = N_g x^{\alpha}(1-x)^{\beta}, \\ x\zeta^{\rho}(x, Q_0^2) &= 0, \end{aligned}$$

where $v^{\rho}(x, Q_0^2) = \frac{1}{4}(u^{\rho^+} + \bar{u}^{\rho^-} + d^{\rho^-} + \bar{d}^{\rho^+})(x, Q_0^2)$

Results from the Fits

We used all the existing data in 2004 except the DELPHI LEP2 data (they present three sets of mutually inconsistent data). (192 data points covering $0.001 \leq x \leq 0.65$ and $1.3\ GeV^2 \leq Q^2 \leq 780\ GeV^2$

NLO model	χ^2 (192 pts)	χ^2/DOF	κ	α	β
FFNS$_{CJK}$ 1	243.3	1.29	$2.288^{+0.108}_{-0.096}$	$0.502^{+0.071}_{-0.066}$	$0.690^{+0.282}_{-0.252}$
CJK	256.8	1.37	$2.662^{+0.108}_{-0.099}$	$0.496^{+0.063}_{-0.057}$	$1.013^{+0.284}_{-0.255}$

Including DELPHI LEP2 data

CJK	TWOGAM	PHOJET	PYTHIA
χ^2/DOF	1.50	1.54	1.66

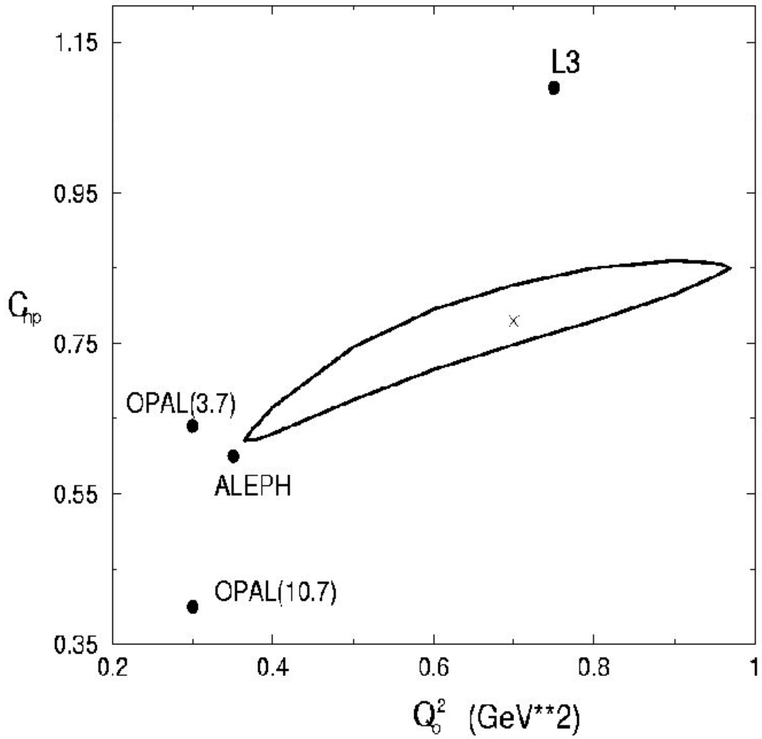
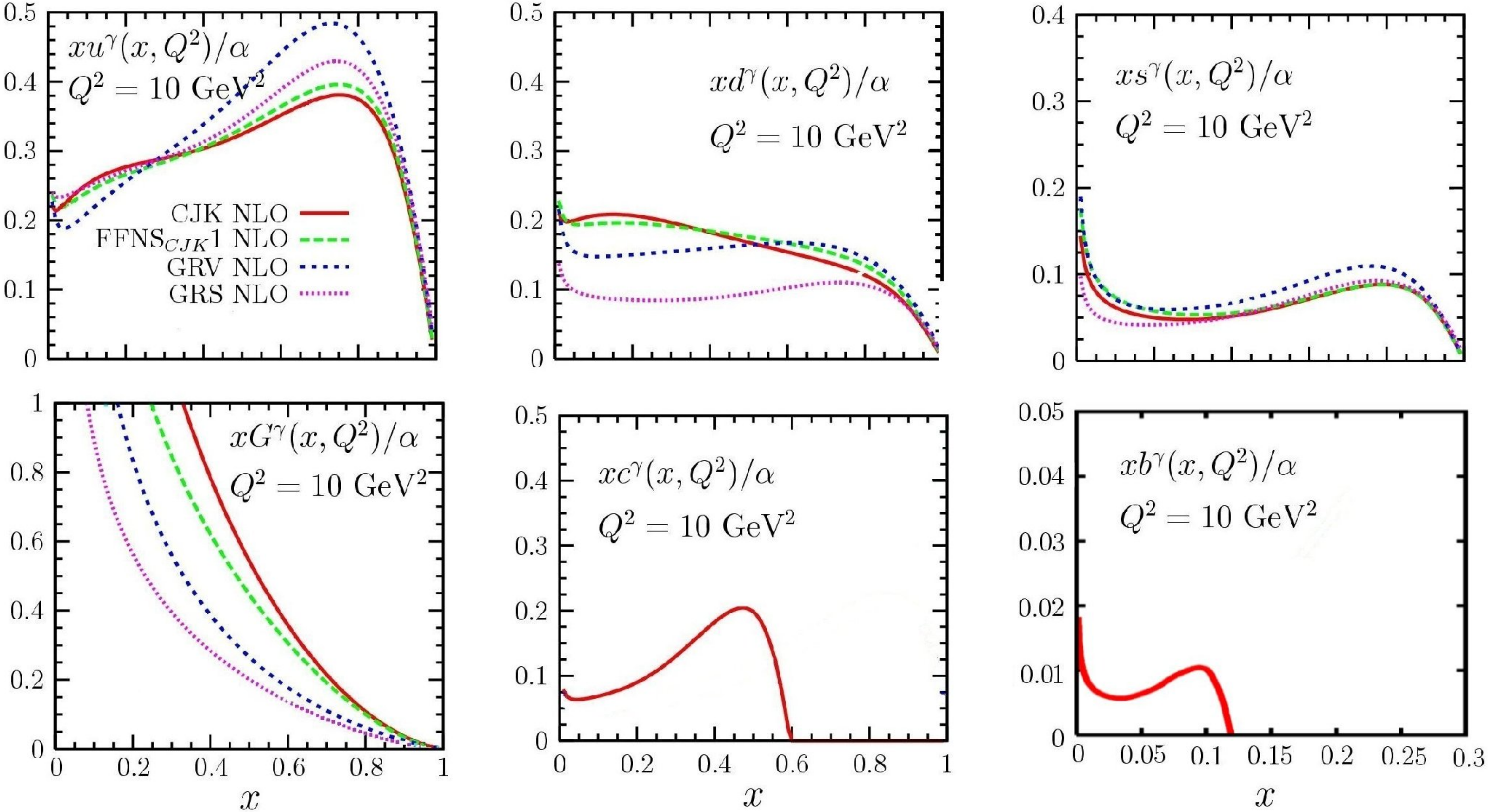


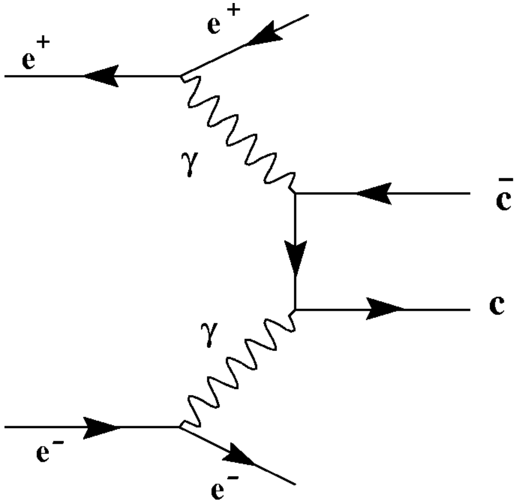
Figure 6: The $\Delta\chi^2 = 1$ contour in the $Q_0^2 - C_{np}$ plane with the individual best fits of the LEP data. The DELPHI (12.7) point ($Q_0^2 = 1.5$ GeV^2, $C_{np} = 1.05$) is outside the figure and DELPHI (3.7) has no minimum for $Q_0^2 < 1.9$ GeV^2.

[Aurenche, Fontannaz, Guillet]

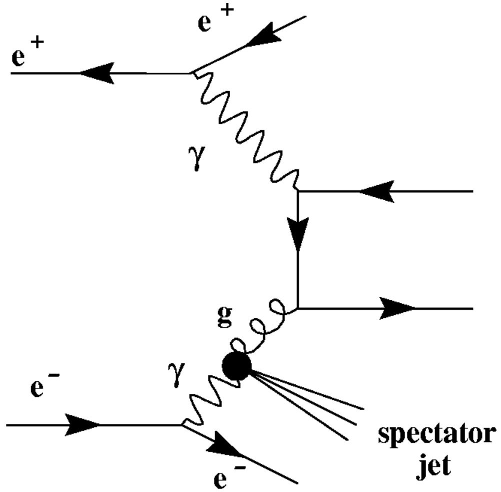


$xu^\gamma(x,Q^2)/\alpha$
$Q^2 = 10$ GeV^2
CJK NLO
FFNS$_{CJK}$1 NLO
GRV NLO
GRS NLO
$xd^\gamma(x,Q^2)/\alpha$
$Q^2 = 10$ GeV^2
$xs^\gamma(x,Q^2)/\alpha$
$Q^2 = 10$ GeV^2
$xG^\gamma(x,Q^2)/\alpha$
$Q^2 = 10$ GeV^2
$xc^\gamma(x,Q^2)/\alpha$
$Q^2 = 10$ GeV^2
$xb^\gamma(x,Q^2)/\alpha$
$Q^2 = 10$ GeV^2
x

Heavy Quark Pair Production in Two Photon Processes



Direct



Single Resolved

$\sigma(c\bar{c})$ (pb)	Direct	Resolved
$200\ GeV$	314	266
$500\ GeV$	496	846
$1000\ GeV$	659	921

$\sigma(b\bar{b})$ (pb)	Direct	Resolved
$200\ GeV$	1.39	1.44
$500\ GeV$	2.56	7.16
$1000\ GeV$	3.67	19.1

The Photon Collider

The resolved photon contribution has to be taken into account in many processes at the photon collider

- QCD studies:
  - $\gamma\gamma \to c\bar{c},\ b\bar{b},\ t\bar{t}$
  - $\gamma\gamma \to$ jets
  - Exclusive processes
- SUSY studies
  - Gluino pair production
  - Stoponium
- Electroweak processes
  - $\gamma\gamma \to W^+W^-,\ ZZ$