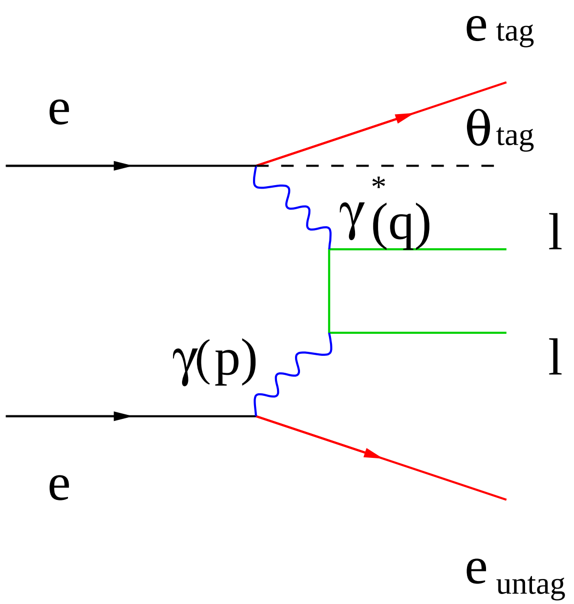
QED Structure Functions of the Photon in $\gamma\gamma$ collisions at LEP

Claudia Cecchi
University of Geneva

15-21 June 1999
EPS Tampere

- **Introduction**
- **The Leptonic Structure Function $F^{\gamma}_{2,QED}$**
- **Azimuthal correlations; F^{γ}_{A}, F^{γ}_{B}**
- **Conclusions**

Introduction $e^+e^- \to e^+e^-l^+l^-$



Single tag

$$\begin{cases} probe\ \gamma^*: & Q^2 = -q^2 > 0 \\ target\ \gamma^*: & P^2 = -p^2 \approx 0 \end{cases}$$

$$M_{ll}^2 = W_{\gamma\gamma}^2 = (p+q)^2$$

$$\frac{d^2\sigma}{dx dQ^2} = \frac{2\pi\alpha^2}{xQ^4}[(1+(1-y^2))F_2^\gamma(x,Q^2) - y^2 F_L^\gamma(x,Q^2)]$$

$$x = \frac{Q^2}{Q^2+P^2+W_{\gamma\gamma}^2} \qquad y = 1 - \frac{E_{tag}}{E_{beam}} cos^2\frac{\theta_{tag}}{2} \ll 1$$

F_2^γ and F_L^γ "structure functions" of the photon

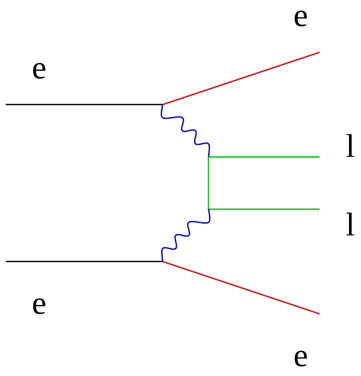
$$F_2^\gamma = 2xF_T^\gamma + F_L^\gamma,\ F_T^\gamma \propto \sigma_{TT},\ F_L^\gamma \propto \sigma_{TL}$$

L = longitudinal photon = helicity 0 (only for highly virtual (probe) photon)

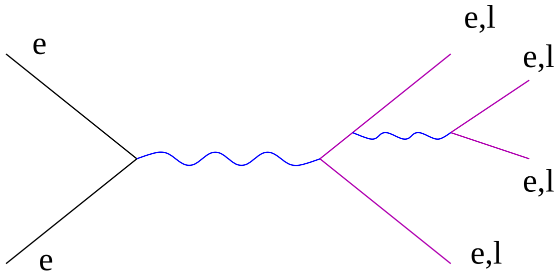
T = transverse photon = helicity ± 1

$y \ll 1 \to$ cross section measures only F_2^γ

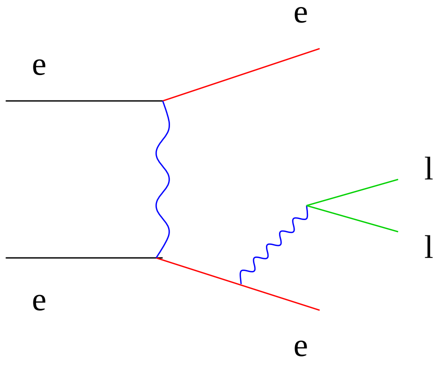
Introduction $e^+e^- \rightarrow e^+e^-l^+l^-$



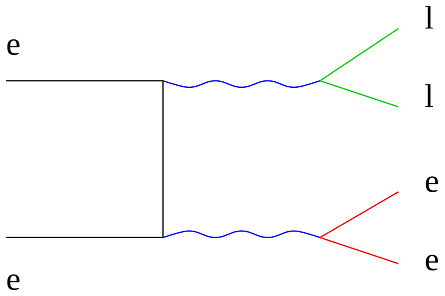
Multiperipheral



Annihilation



Bremsstrahlung



Conversion

Data collected at $\sqrt{s} = 91$ GeV

Exp.	$\mathcal{L}(pb^{-1})$	θ (degree)	$Q^2(GeV^2)$
ALEPH	42.0	1.48-18.2	0.6-60.0
DELPHI	138.5	2.46-7.73	2.4-752.8
L3	93.7	1.55-3.67	1.4-7.6
OPAL	64.7 (SW)	1.43-1.66	1.5-7.0
	81.3 (FD)	3.44-8.02	6.0-30.0
	129.1 (EE)	11.5-36.1	70-400

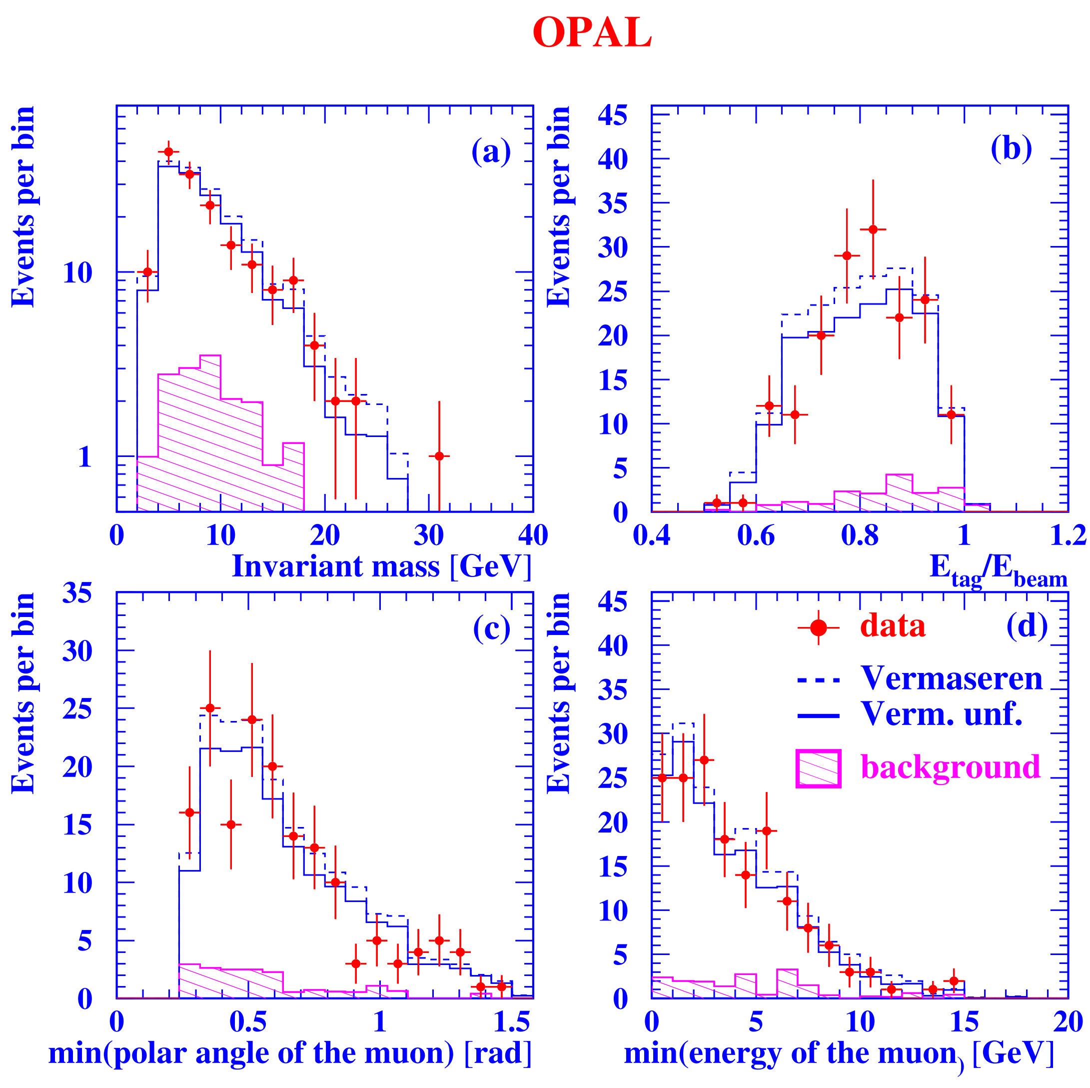
Full x interval

SW = small angle calorimeter
FD = forward detectors
EE = e.m. endcaps

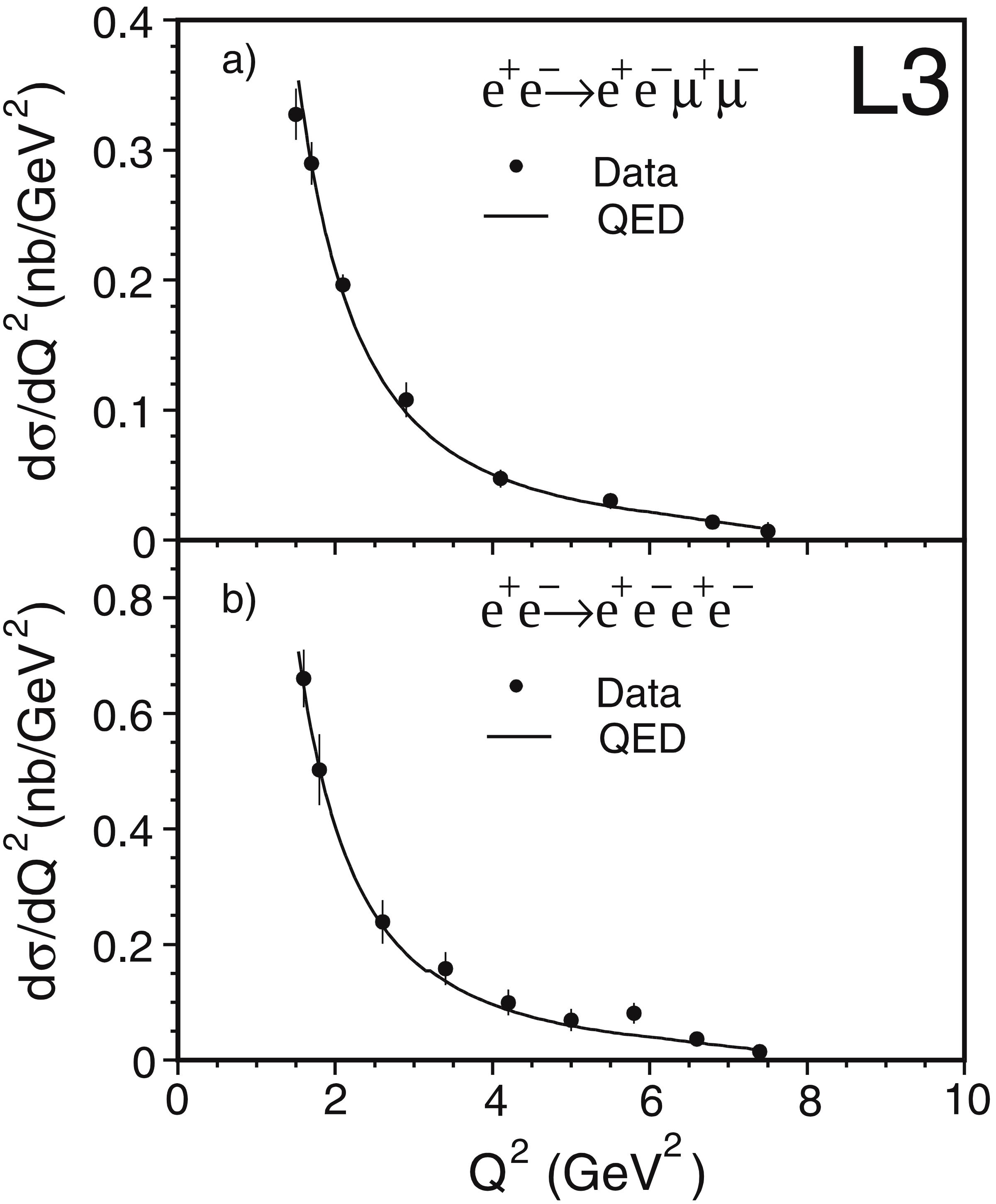
Event selection

- **Tagged electron:** forward calorimeter
  $E > E_{cut}$ ($\simeq 0.5 E_{beam}$)
- **Lepton pair:** two tracks with opposite charges and with $p_T > p_T^{cut}$ ($\geq 2\ GeV$)
  - **electrons:** e.m. calorimeter
  - **muons:** e.m. and hadronic calorimeters plus track

Comparison data-MC $e^+e^- \rightarrow e^+e^-\mu^+\mu^-$

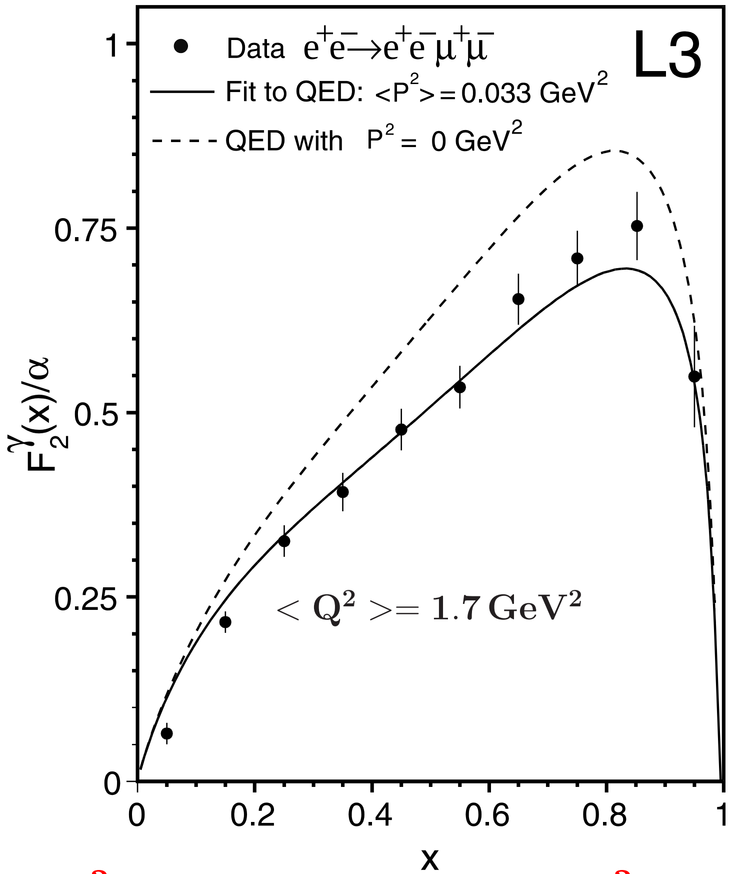


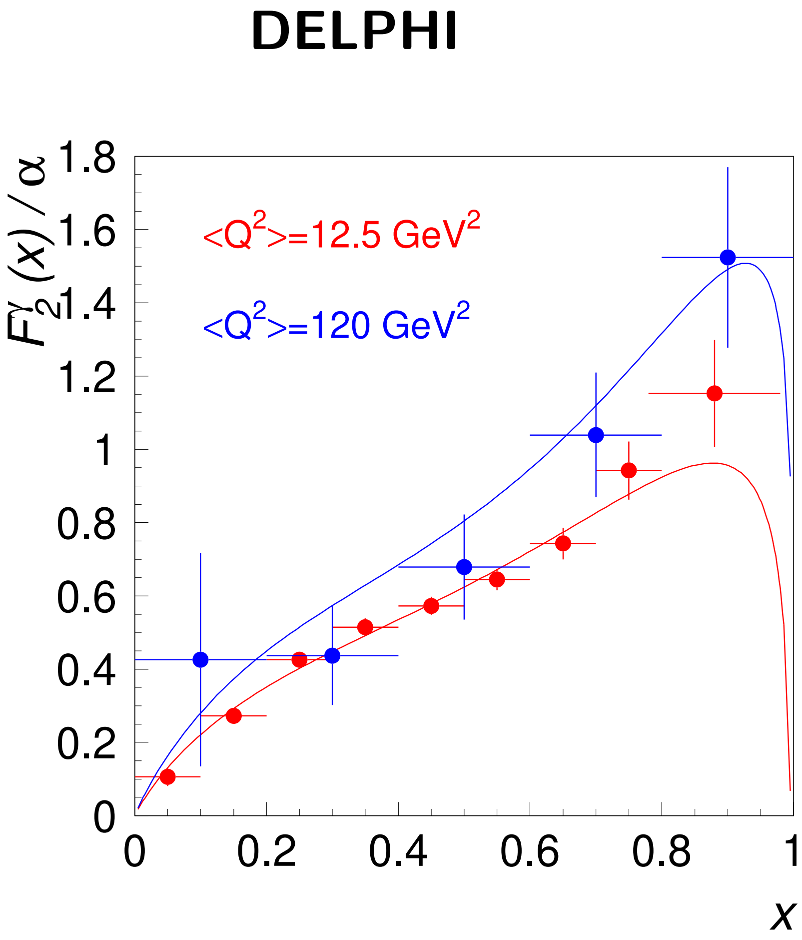
Cross section



$d\sigma/dQ^2$ after corrections
(background,acceptance)

F_2^γ $(e^+e^- \rightarrow e^+e^-\mu^+\mu^-)$





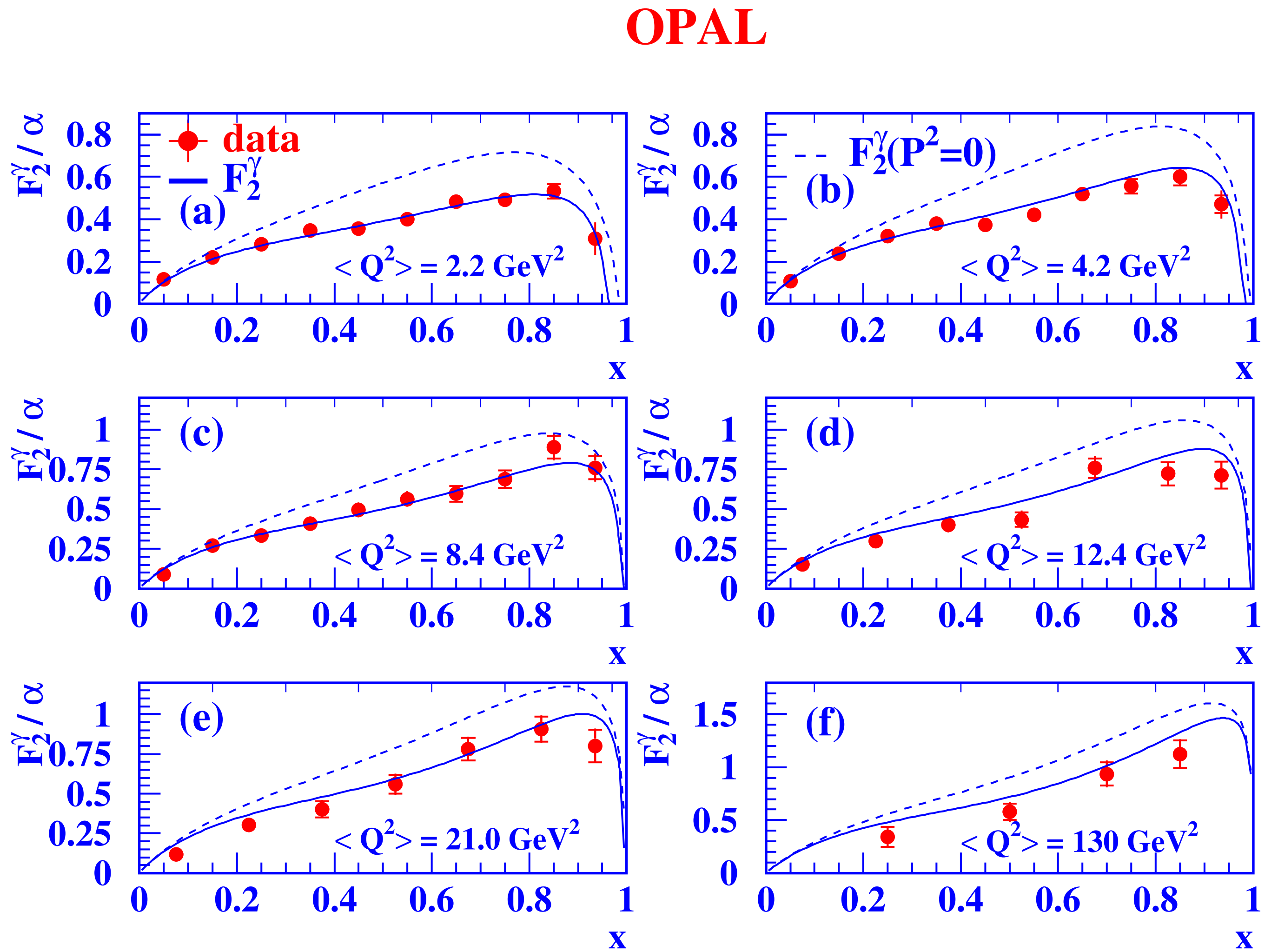
$< P^2 >= 0.033 \pm 0.005\ GeV^2$

$< P^2 >_{MC}= 0.034 \pm 0.002\ GeV^2$

with radiative corrections

without $< P^2 >_{MC}= 0.024 \pm 0.003\ GeV^2$

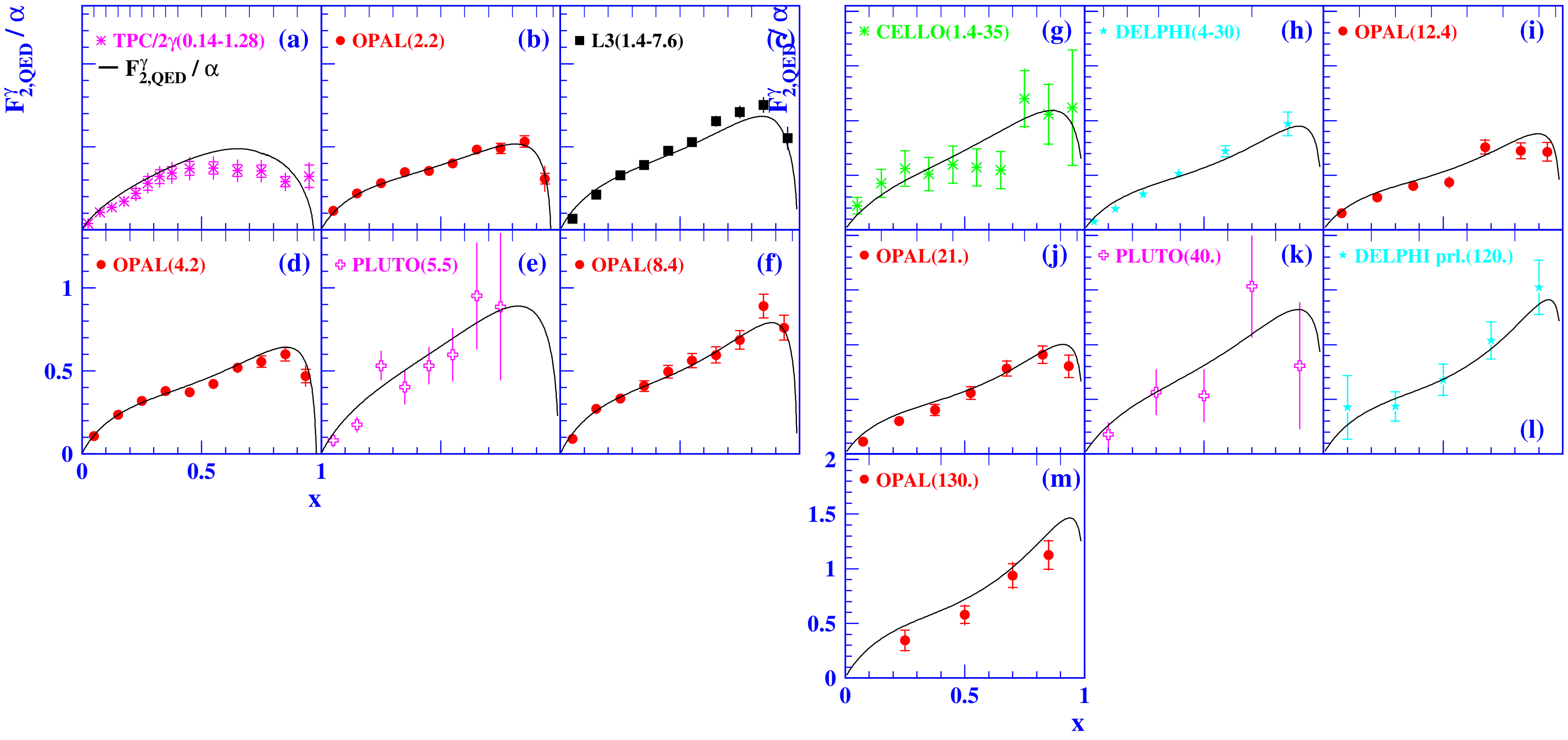
F_2^γ $(e^+e^- \rightarrow e^+e^-\mu^+\mu^-)$



Solid line $< P^2 >= 0.05\ GeV^2$

Dashed line $P^2 = 0$

$F_2^\gamma \; (e^+e^- \rightarrow e^+e^-\mu^+\mu^-)$

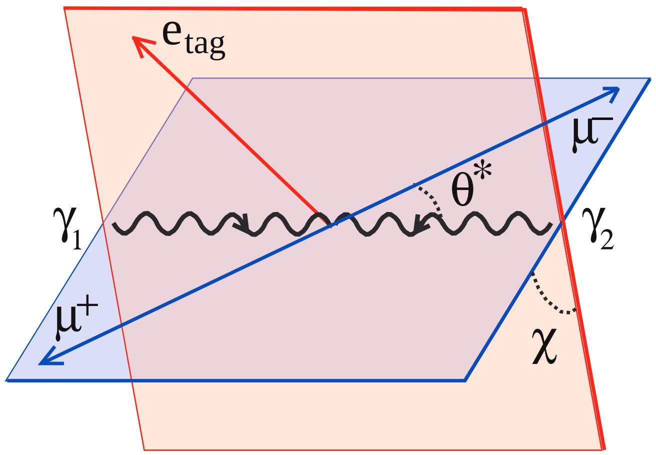


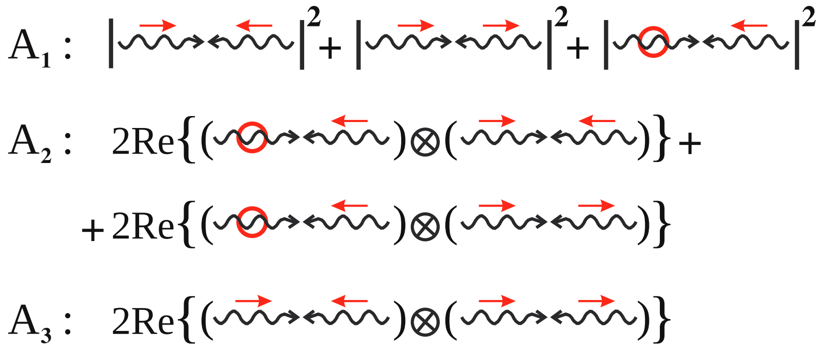
QED Structure Functions of the Photon in $\gamma\gamma$ collisions at LEP

Claudia Cecchi
University of Geneva

Azimuthal correlations

The azimuthal angle $\chi \Longrightarrow$
information on the **longitudinal** component of the probe photon $\gamma^*(q)$





probe photon (left) target photon (right)

$$d\sigma \propto 1 - \rho(y) F_A^{\gamma}/F_2^{\gamma} cos\chi + \frac{1}{2}\epsilon(y) F_B^{\gamma}/F_2^{\gamma} cos2\chi$$

$$\epsilon(y) = \frac{2(1-y)}{1+(1-y)^2} \approx 1 \quad \rho(y) = \frac{(2-y)\sqrt{1-y}}{1+(1-y)^2} \approx 1$$

$A_1 \propto F_2^{\gamma} \Longrightarrow$ sum of the amplitudes squared of the helicity states

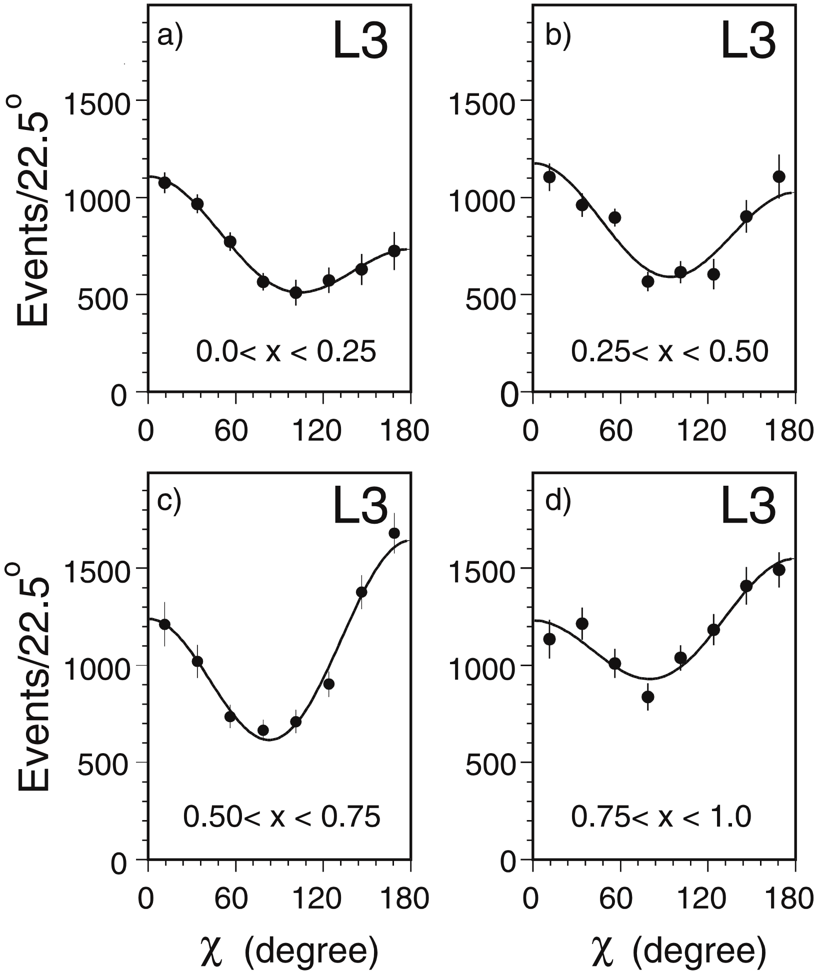
$A_2 \propto F_A^{\gamma} \Longrightarrow$ interference term between longitudinal and transverse photon

$A_3 \propto F_B^{\gamma} \Longrightarrow$ interference term between two transverse photons

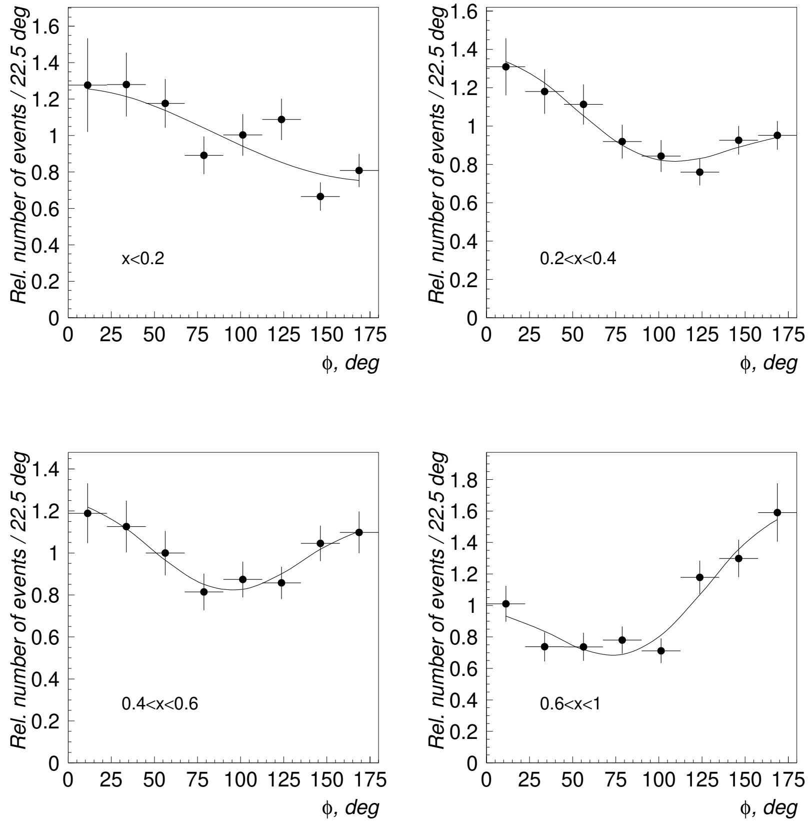
The χ dependence give access to other structure functions

Azimuthal distributions

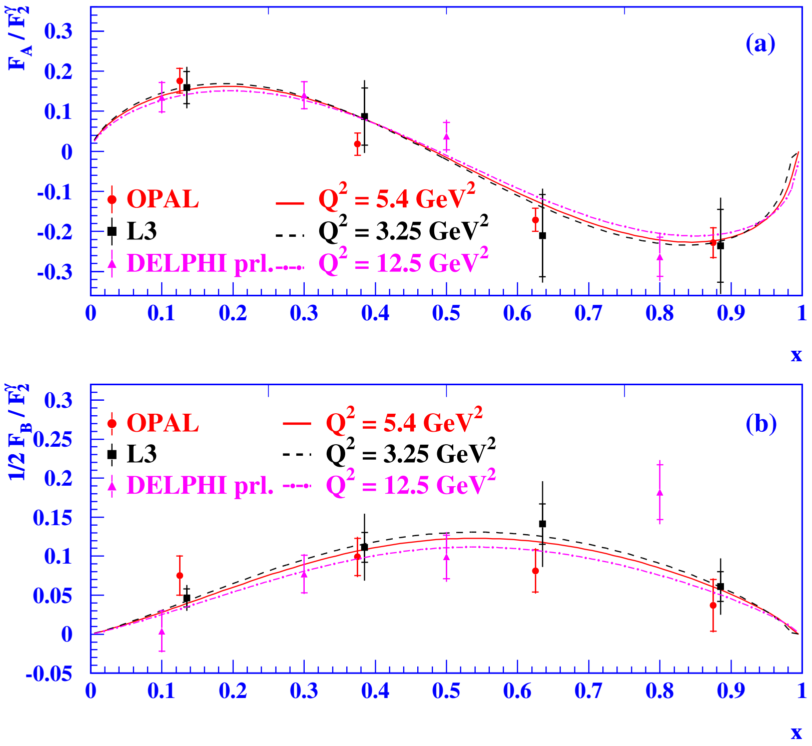
$e^+e^- \to e^+e^-\mu^+\mu^-$

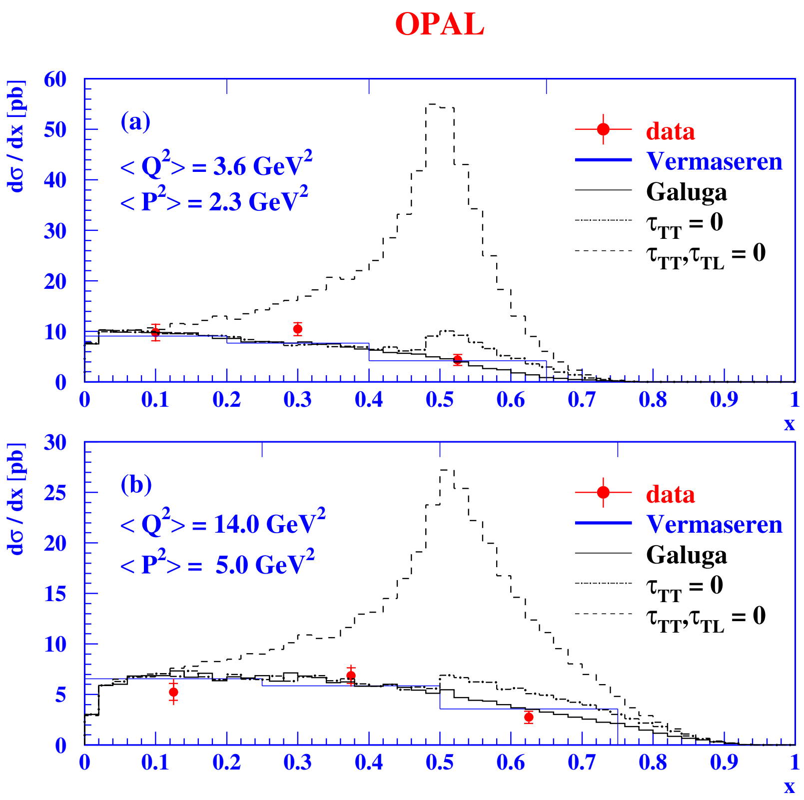


DELPHI ($\phi = \chi$)



F_A^γ and F_B^γ





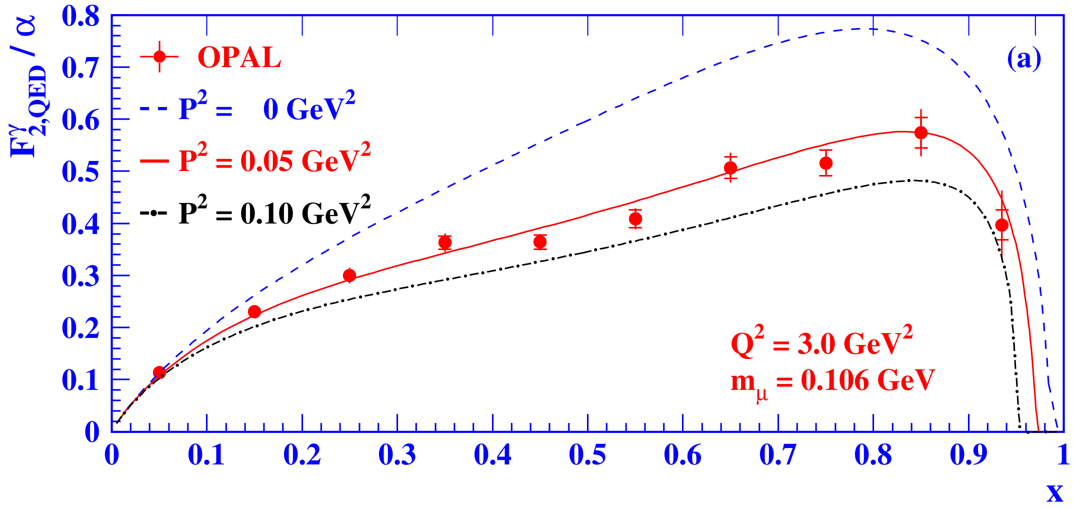
good agreement with QED predictions

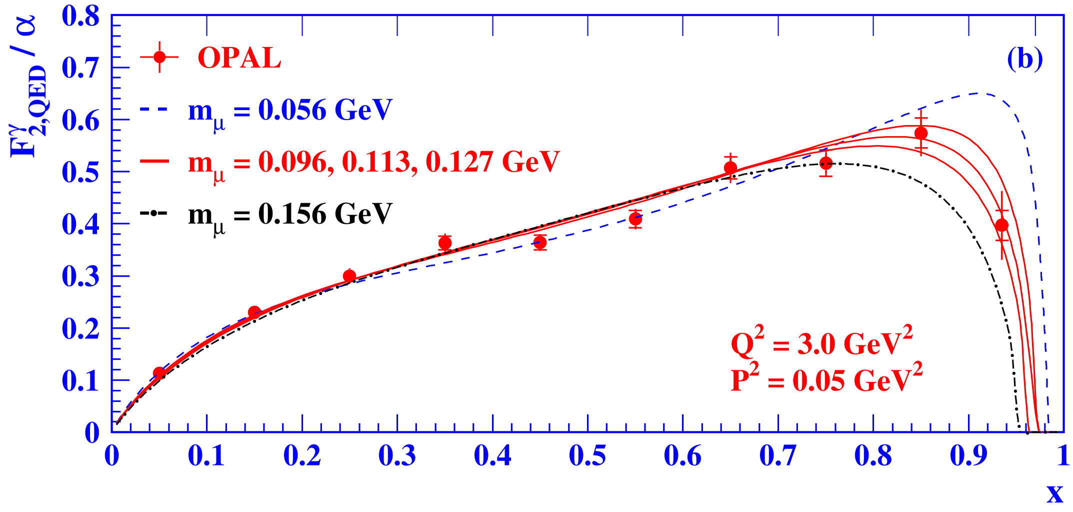
$F_A^\gamma \neq 0 \Longrightarrow F_L^\gamma \neq 0$

Interference term between transverse and longitudianl photons very important

Dependence of F_2^γ on P^2 and m_μ

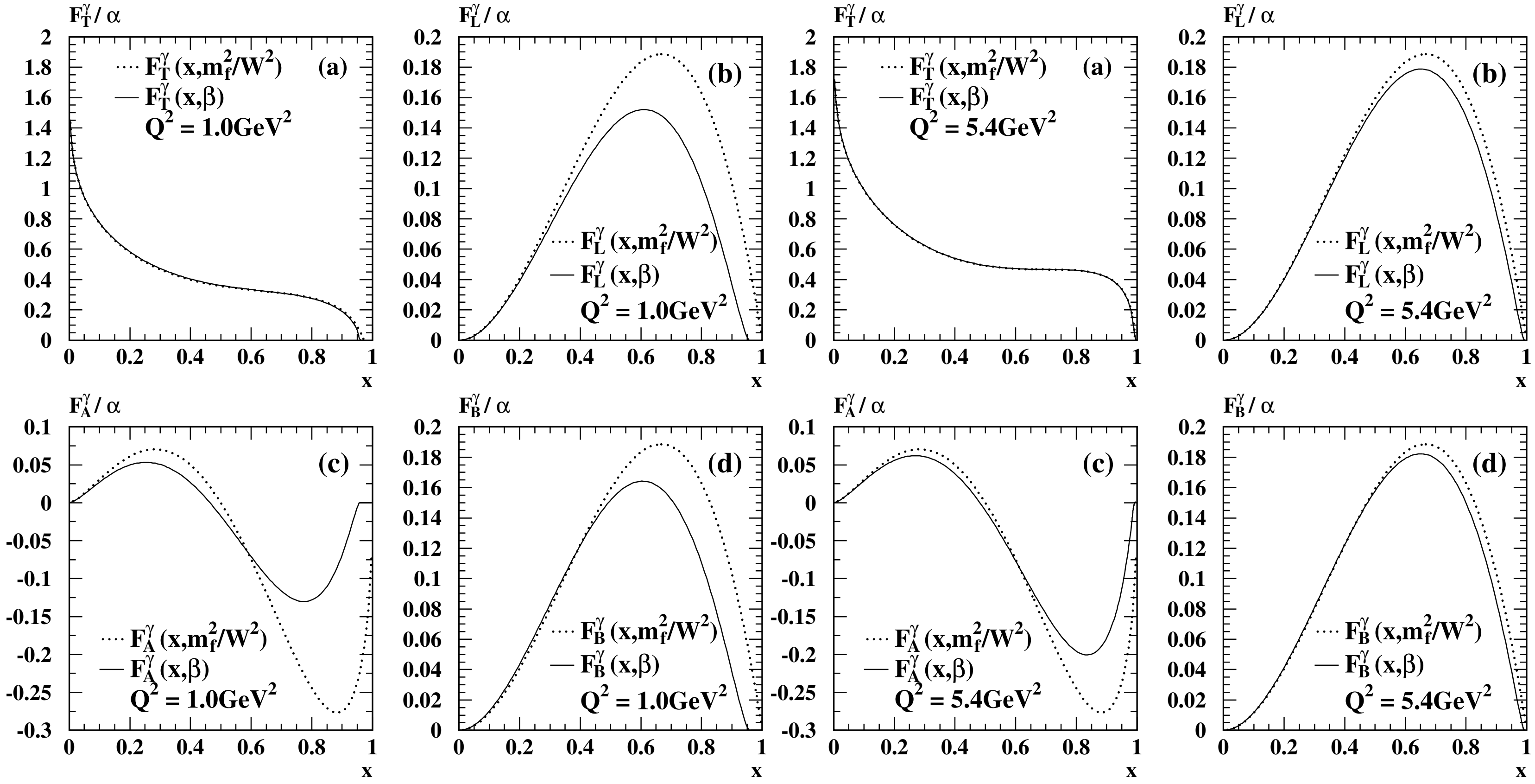
Sensitivity to the photon virtuality





Some sensitivity to the muon mass (15%)

Ref. R.Nisius M.H. Seymour Phys.Lett.B452:409-413,1999



Dotted line full mass dependence
Continous line small mass limit

Conclusions

- Differential cross sections of single tag two photon reaction

$$e^+e^- \rightarrow e^+e^-e^+e^-$$
$$e^+e^- \rightarrow e^+e^-\mu^+\mu^-$$

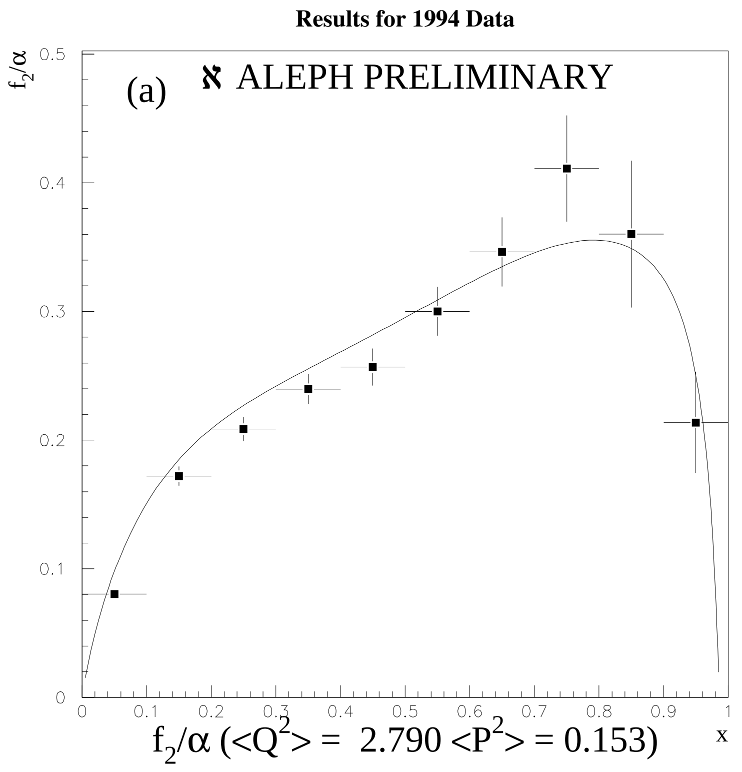
  have been measured and found in good agreement with QED predictions.

- The leptonic structure function F_2^γ has been extracted from the differential cross section $d^2\sigma/dxdQ^2$.

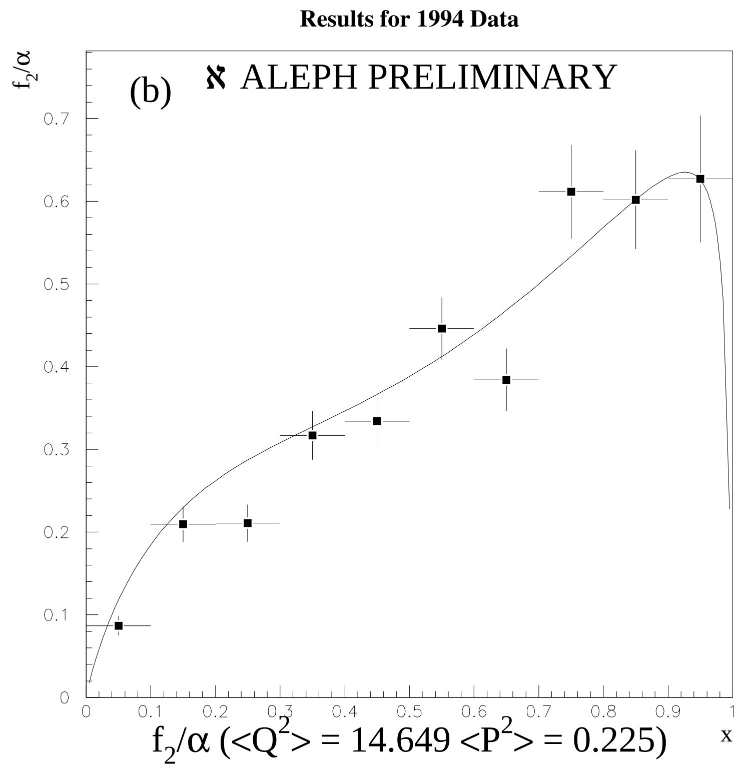
- The mean photon virtuality is found to be different from zero, in good agreement with the QED predictions if initial state radiation is included.

- The leptonic structure functions F_A^γ and F_B^γ have been measured from azimuthal angle χ distributions.
  The longitudinal photon helicity amplitude has been measured from the interference term.

F_2^γ $(e^+e^- \to e^+e^-\mu^+\mu^-)$



tag in SiCAL



tag in LCAL

$F_A F_B$ $(e^+e^- \longrightarrow e^+e^-\mu^+\mu^-)$