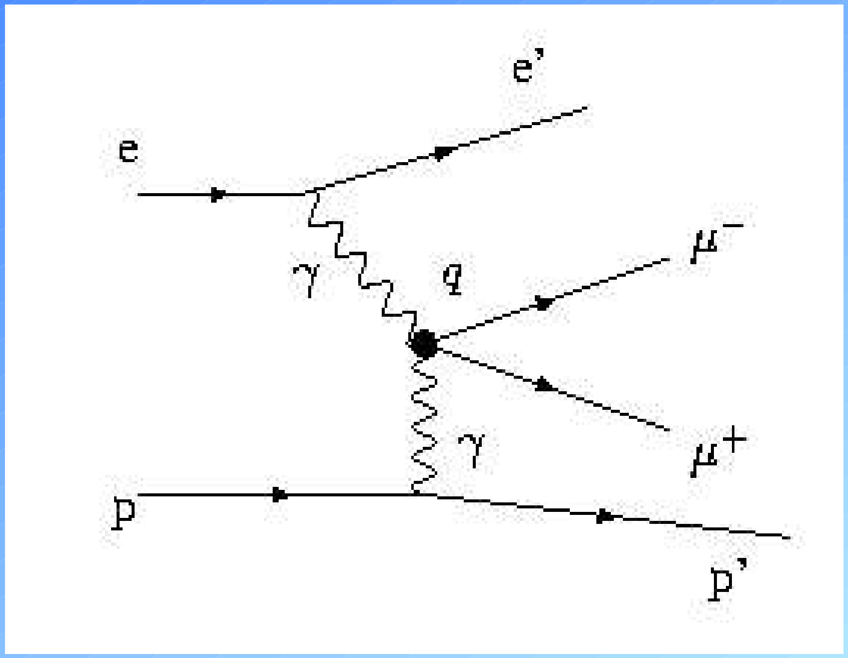
Light-cone wave function of the photon

Justyna Ukleja, Warsaw University
for ZEUS Collaboration



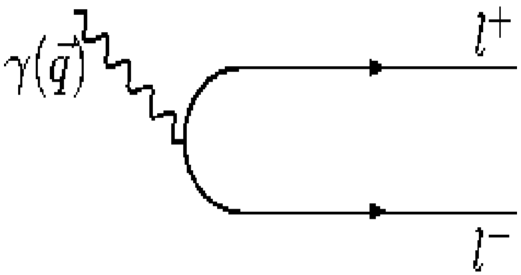
DIS04, 15.04.2004

Motivation

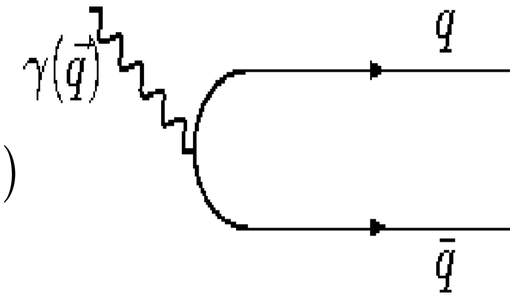
- The LCWF is an important aspect of structure functions and distribution amplitudes of many different processes,
- it is frame independent,
- it is useful for understanding exclusive processes,
- the electromagnetic part is calculable in QED,
- the hadronic part of the photon LCWF is model depended.

Measurements of the photon light-cone wave function

Light-Cone Wave Function (LCWF)



$$\to \psi_\gamma = a|\gamma_p\rangle + b|l\,l\rangle + (\text{other e.m}) + c|q\,\bar{q}\rangle + (\text{other hadronic})$$

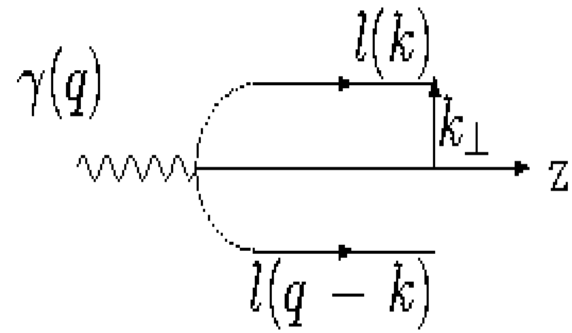


- is the probability amplitude to find a component with a given momentum in the momentum space
- is the solution of the Hamiltonian $H_{LC}^{QCD}|\psi_\gamma\rangle = M_h^2|\psi_\gamma\rangle$
- is usually tested through measurements of form factors

Measurements of the photon light-cone wave function

The LCWF for the lowest Fock states:

$$\psi^{\lambda}_{\lambda_1\lambda_2}(k_{\perp},u) = -e\,e_l \frac{\bar{l}_{\lambda_1}(k)\,\lambda\cdot\epsilon^{\lambda}\,l_{\lambda_2}(q-k)}{\sqrt{u(1-u)}\left(Q^2+\frac{k_{\perp}^2+m^2}{u(1-u)}\right)}$$



- Longitudinal light-cone momentum fraction: $u_i = \frac{k_i^+}{p^+} = \frac{k_i^0 + k_i^z}{p^0 + p^z}$ $\qquad \sum_{i=1}^{n} u_i = 1$

- Transverse momentum: $\vec{k}_{\perp_i}$ $\qquad \sum_{i=1}^{n} \vec{k}_{\perp_i} = \vec{0}$

Electromagnetic and hadronic LCWF

For $k_\perp^2 \gg \Lambda_{QCD}^2$ the **hadronic** $|q\,\bar{q}\rangle$ LCWF is expected by pQCD to be the same as for the **electromagnetic** $|l\,l\rangle$:

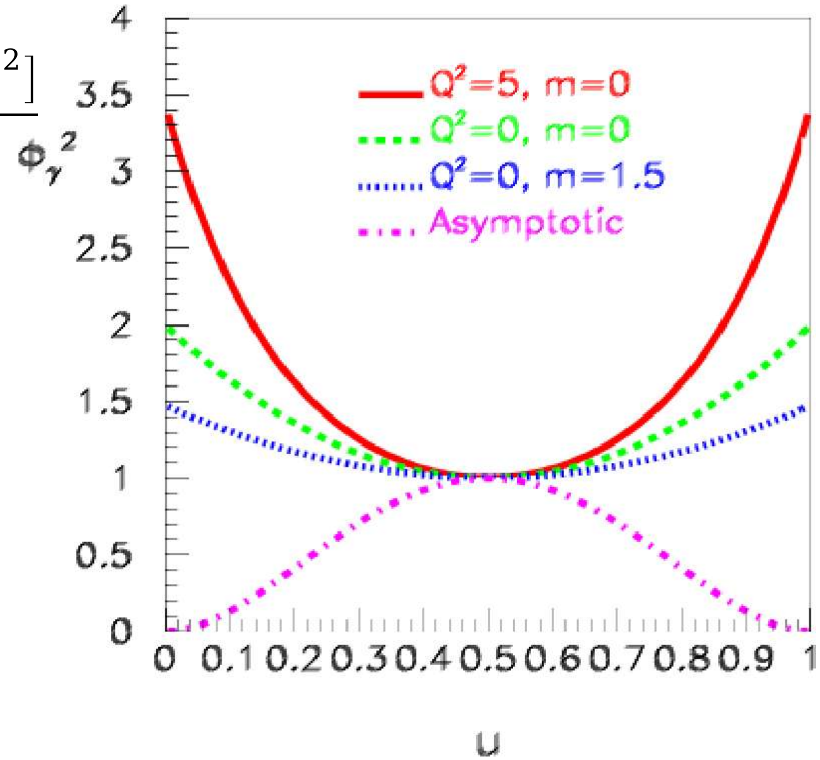
- For the transversely polarized photons:

$$\phi^2_{l\bar{l}/\gamma_T^*}(u, k_\perp) \sim \sum_{\mu=1}^{2} \frac{1}{4} \mathrm{Tr}\, \psi^2_{\gamma^*} = \frac{m_l^2 + k_\perp^2 [u^2 + (1-u)^2]}{[k_\perp^2 + a_l^2]^2}$$

$$a_l^2 = m_l^2 + Q^2 u (1-u)$$

- For the longitudinally polarized photons:

$$\Phi^2_{f\bar{f}/\gamma_L^*} \sim \frac{Q^2 [u^2 (1-u)^2]}{[k_\perp^2 + a^2]^2}$$



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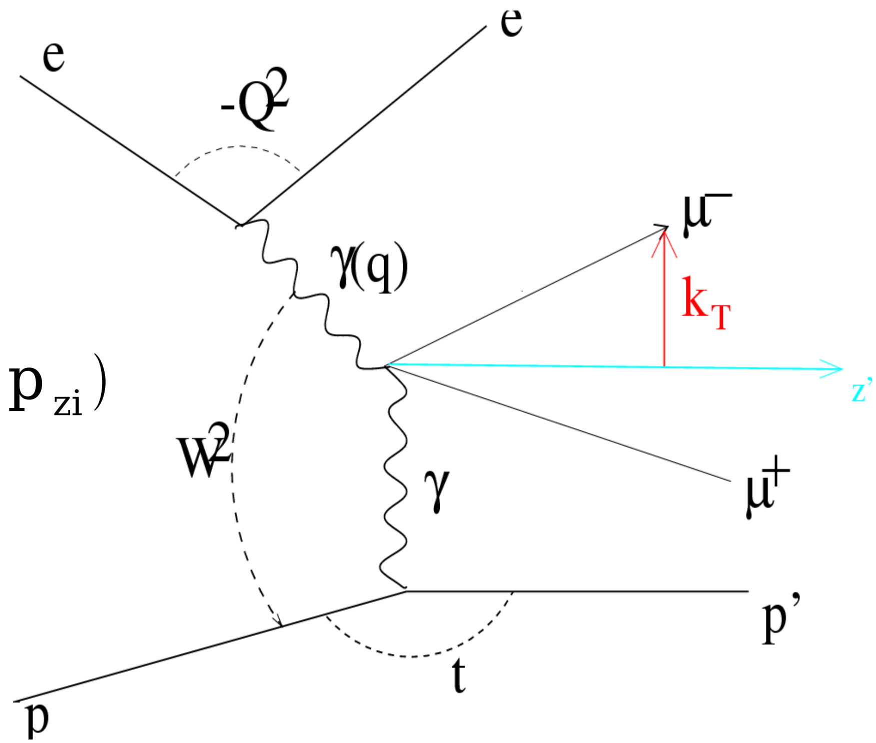
LCWF - variables

- $u = \frac{E_1 + p_{z'_1}}{E_1 + p_{z'_1} + E_2 + p_{z'_2}}$
- $\vec{k}_{T_1} + \vec{k}_{T_2} = \vec{0}$
- $W^2 = (q+P)^2 \approx 2E_p \sum_i (E_i - p_{zi})$
- $t = (P - P')^2 \approx -p^2_{T\mu\mu}$
- $M^2_{\mu\mu} = (p_1 + p_2)^2$



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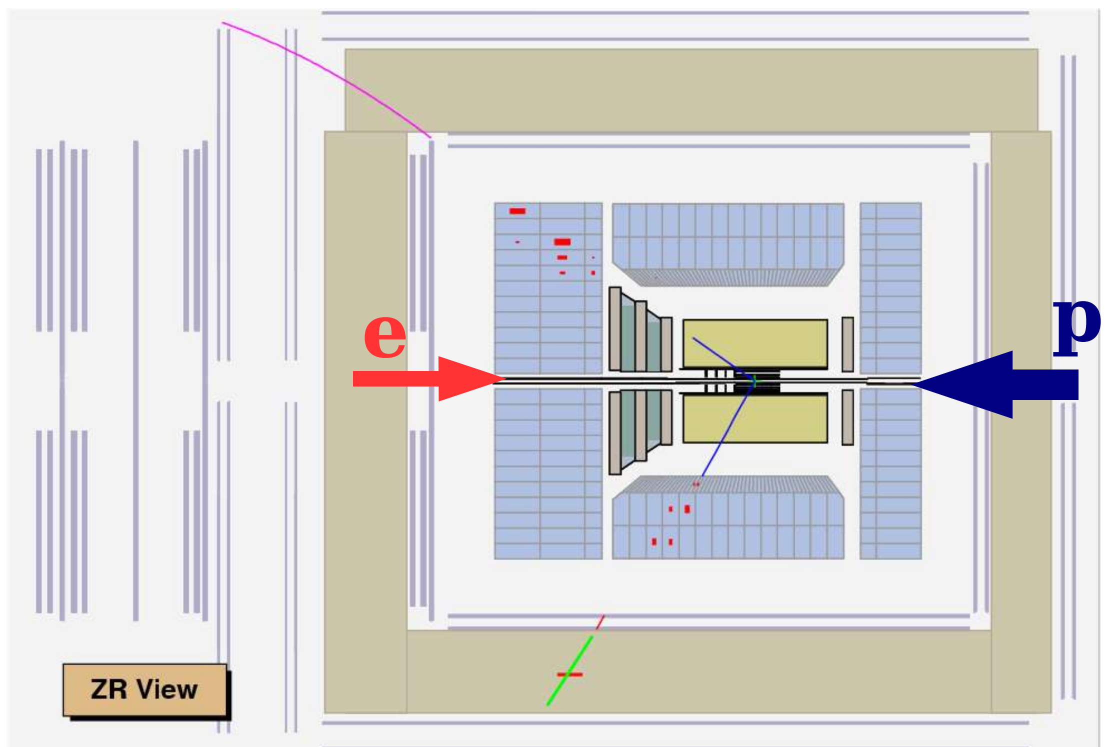
LCWF – QED component

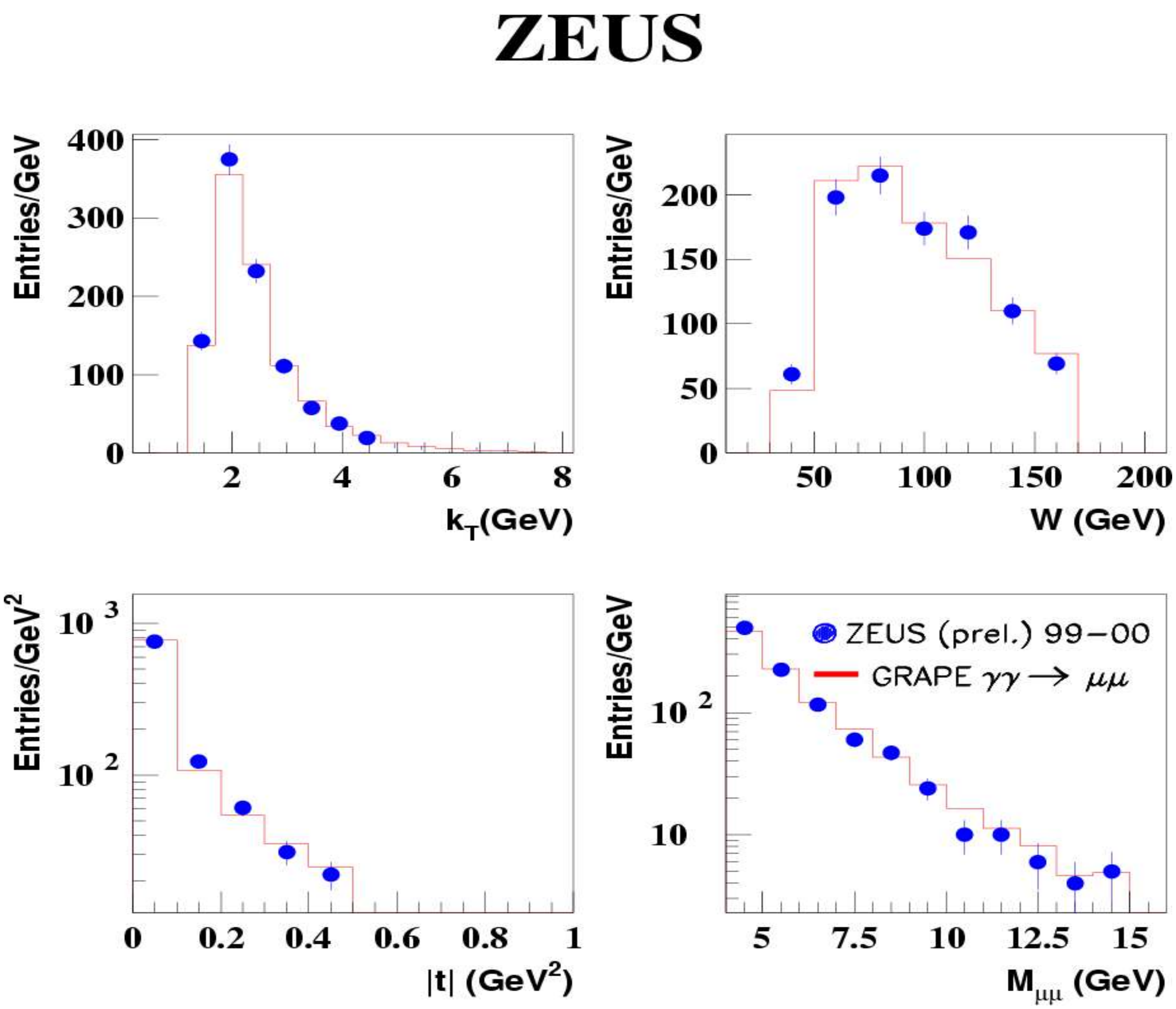
$\gamma\gamma \rightarrow \mu\mu$

- Photoproduction (electron undetected)
- Proton undetected
- Only 2 μ in detector
- Diffractive (small t)
- $4 < M_{\mu\mu} < 15$ GeV



$\sqrt{s} = 318$ GeV

Kinematical variable distributions for the LCWF



DATA and MC are in good agreement

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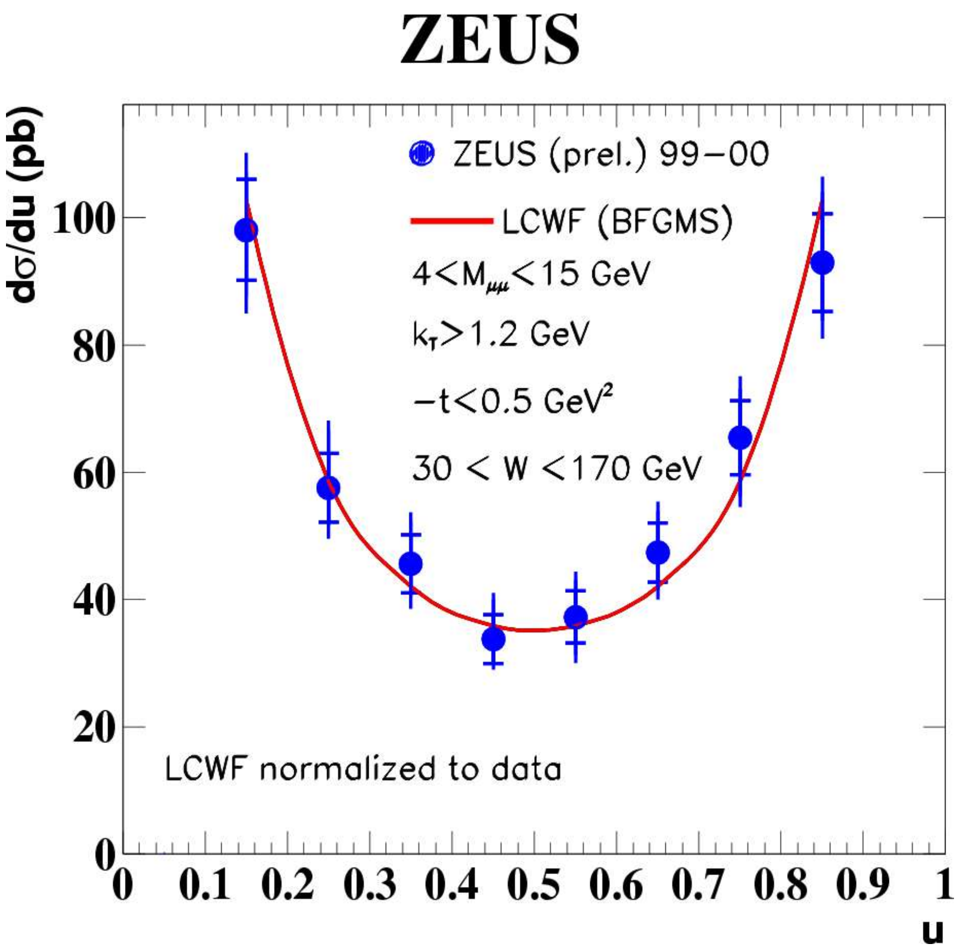
The electromagnetic component of the LCWF of the photon



Brodsky, Frankfurt, Gunion, Muller, Strikman (BFGMS)

- **Measured are in agreement with QED**
- **Results provide the first proof that diffractive production of particles can be reliably used to measure the photon LCWF**

Summary

- The electromagnetic component of the photon LCWF has been measured and is in agreement with QED.
- This provides the first proof that diffractive production of particles can be reliably used to measure the photon LCWF.