Diffractive photoproduction of lepton pairs at high energy

Gabriela Ślipek

Institute of Nuclear Physics PAN, Cracow

DIS 2010,19-23 April, Florence

Introduction

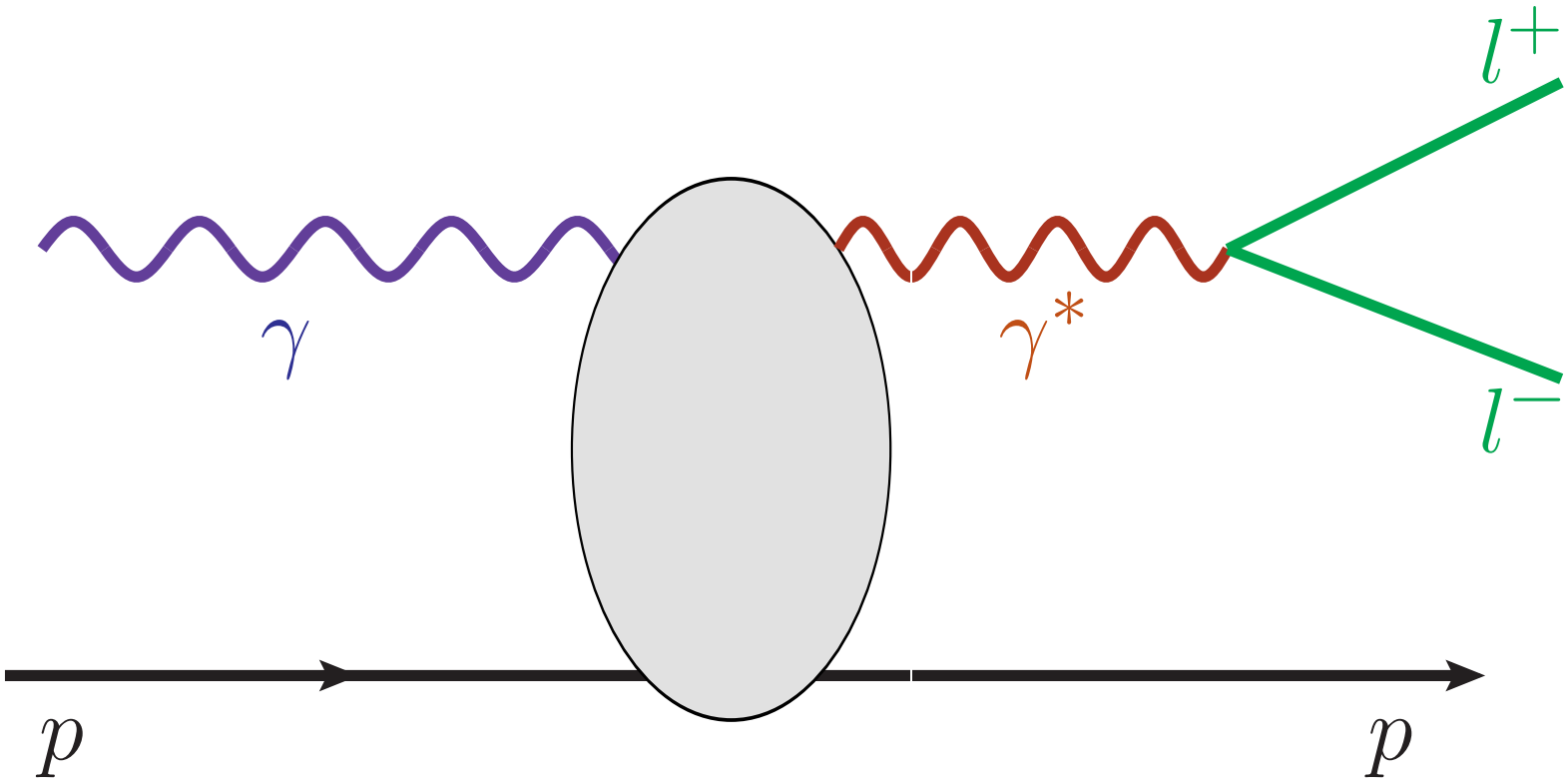
Formalism

Amplitude for production $\gamma p \to \gamma^* p$

Cross section for $\gamma p \to l^+ l^- p$

Results and discussion

Conclusions


l^+
γ
γ^*
l^-
p
p

Outline

Introduction

Formalism

Amplitude for production $\gamma p \longrightarrow \gamma^* p$

Cross section for $\gamma p \longrightarrow l^+ l^- p$

Results and discussion

Conclusions

Introduction

Formalism

Amplitude for production $\gamma p \longrightarrow \gamma^* p$

Cross section for $\gamma p \longrightarrow l^+ l^- p$

Results and discussion

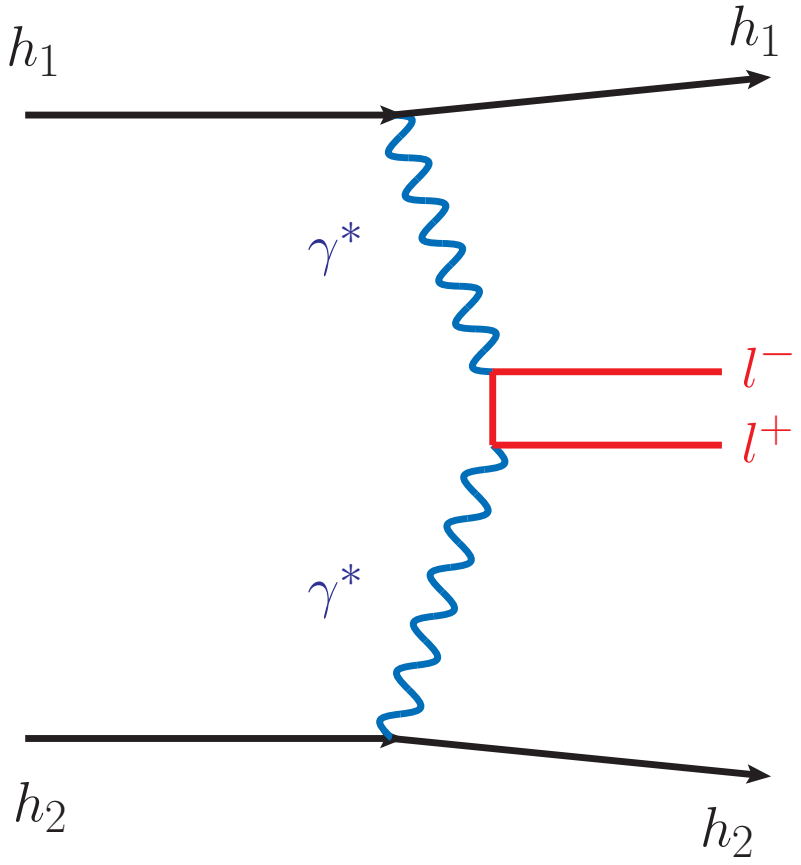
Conclusions

in collaboration with W.Schäfer & A.Szczurek

W. Schäfer, G. Ślipek and A. Szczurek, arXiv:1003.0610 [hep-ph],in print in Phys. Lett. B.

Introduction

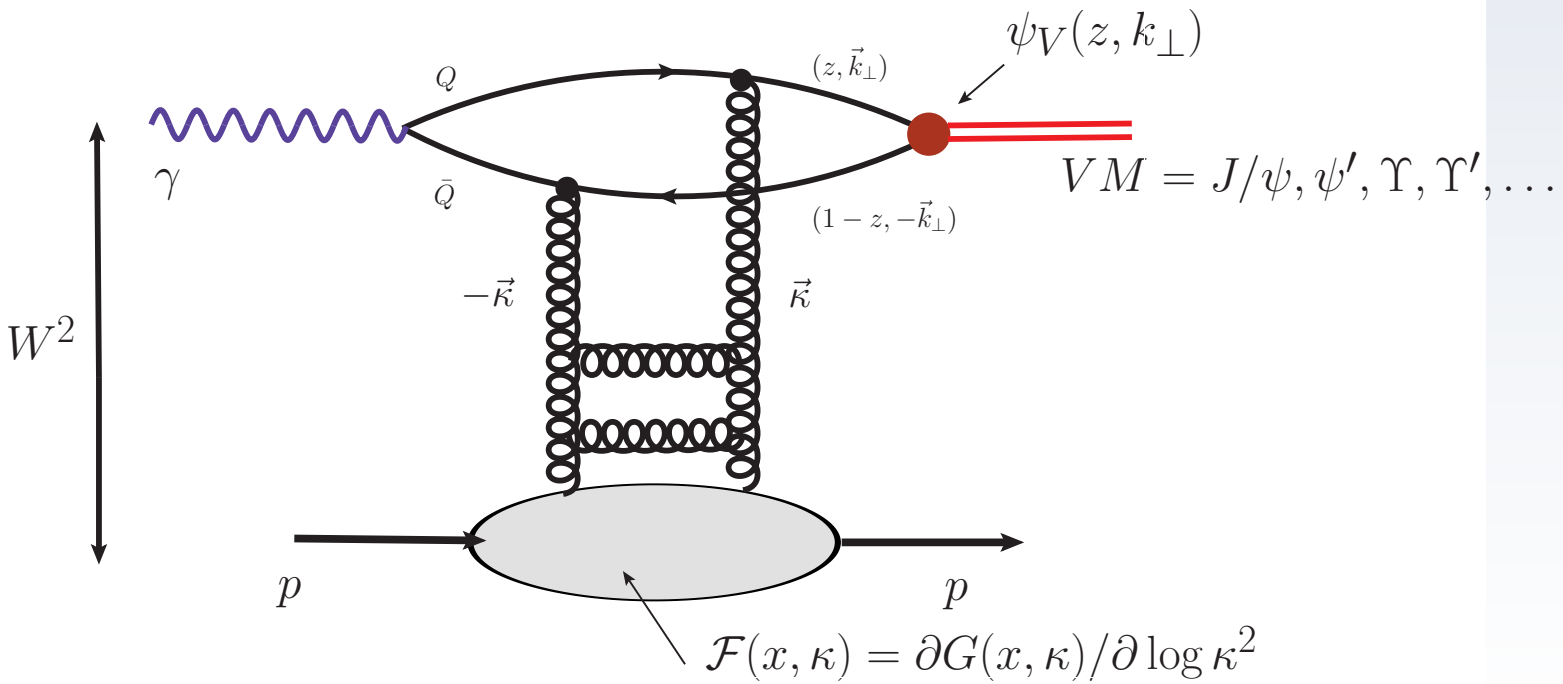
- The QED process $pp \to pl^+l^-p$ is important for measuring the luminosity at LHC.



It is therefore important to estimate non-QED contributions to exclusive l^+l^- production.

Introduction

- The QED process $pp \to pl^+l^-p$ is important for measuring the luminosity at LHC.
  It is therefore important to estimate non-QED contributions to exclusive l^+l^- production.
- $VM(\textit{vector meson}) \to e^+e^-$ decays is not the only source of leptons



Introduction

Introduction

Formalism

Amplitude for production $\gamma p \to \gamma^* p$

Cross section for $\gamma p \to l^+ l^- p$

Results and discussion

Conclusions

- The QED process $pp \to pl^+l^-p$ is important for measuring the luminosity at LHC.
  It is therefore important to estimate non-QED contributions to exclusive l^+l^- production.
- $VM(\textit{vector meson}) \to e^+e^-$ decays is not the only source of leptons

- formalism of VM photoproduction has been worked out recently

 W.Schäfer and A. Szczurek Phys. Rev. D **76**, 094014 (2007).

 A. Rybarska, W. Schäfer and A. Szczurek, Phys. Lett. B **668** (2008) 126.

Introduction

Introduction

Formalism

Amplitude for production $\gamma p \to \gamma^* p$

Cross section for $\gamma p \to l^+ l^- p$

Results and discussion

Conclusions

- The QED process $pp \to pl^+l^-p$ is important for measuring the luminosity at LHC.
  It is therefore important to estimate non-QED contributions to exclusive l^+l^- production.
- $VM(\textit{vector meson}) \to e^+e^-$ decays is not the only source of leptons

- formalism of VM photoproduction has been worked out recently

 W.Schäfer and A. Szczurek Phys. Rev. D **76**, 094014 (2007).

 A. Rybarska, W. Schäfer and A. Szczurek, Phys. Lett. B **668** (2008) 126.

Introduction

- The QED process $pp \to pl^+l^-p$ is important for measuring the luminosity at LHC.
  It is therefore important to estimate non-QED contributions to exclusive l^+l^- production.
- $VM(vector\ meson) \to e^+e^-$ decays is not the only source of leptons

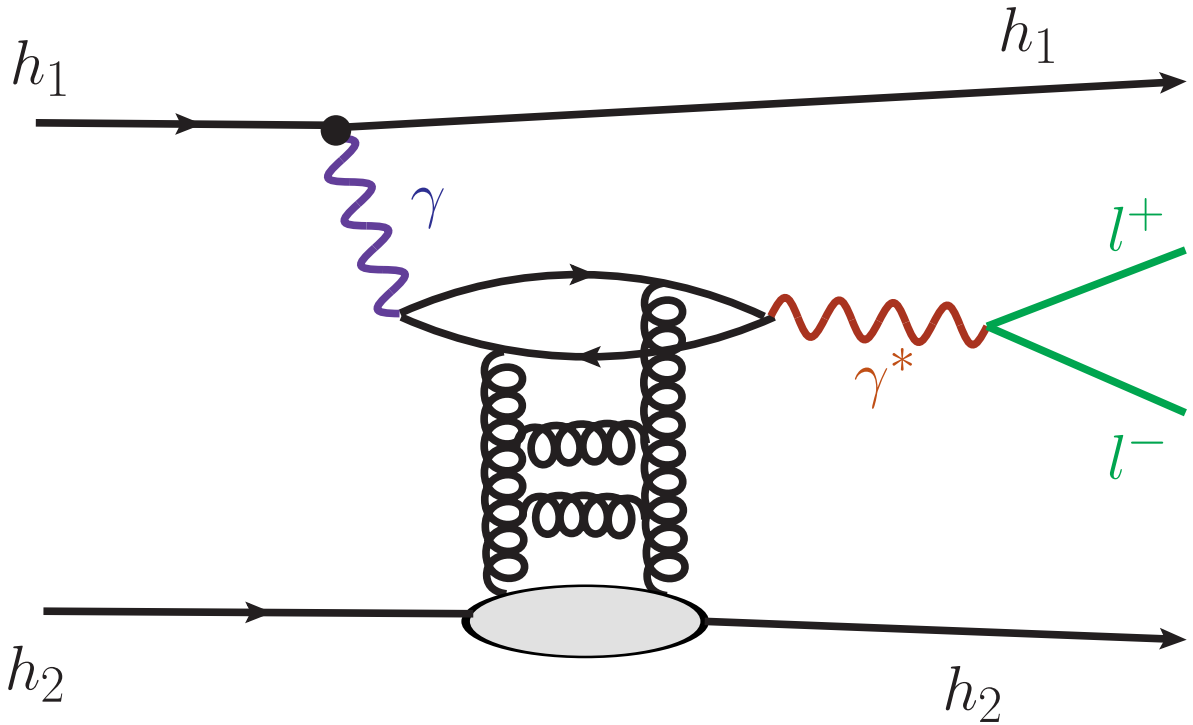
- formalism of VM photoproduction has been worked out recently

W.Schäfer and A. Szczurek Phys. Rev. D **76**, 094014 (2007).

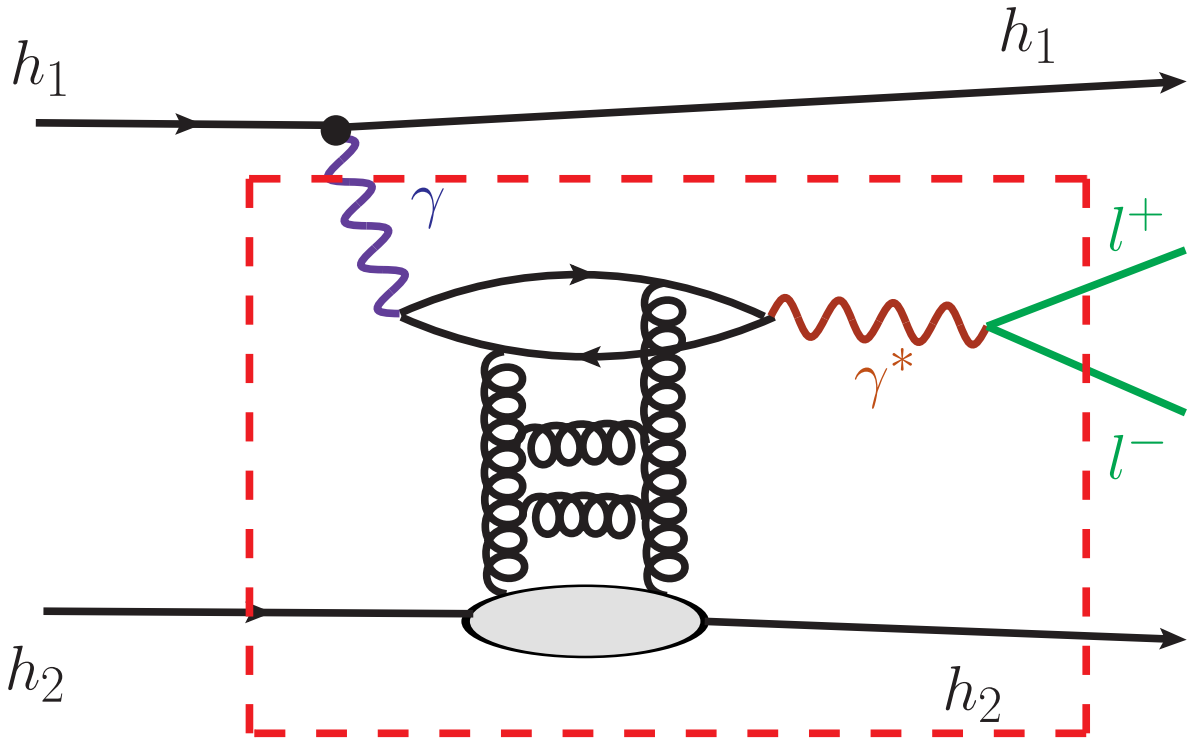
A. Rybarska, W. Schäfer and A. Szczurek, Phys. Lett. B **668** (2008) 126.

- very much the same formalism applies to $\gamma p \to l^+l^-p$ via timelike Compton scattering

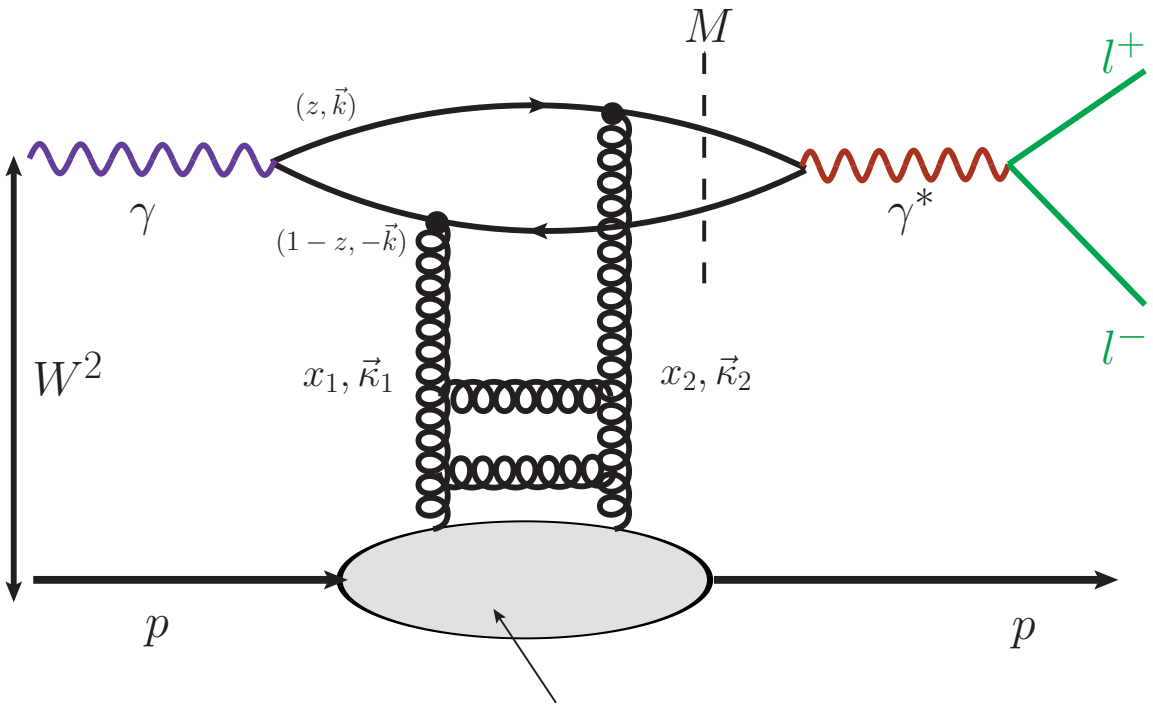
Hadroproduction



Hadroproduction



Photoproduction



$$\mathcal{F}(x, \kappa) = \partial G(x, \kappa)/\partial \log \kappa^2$$

Forward amplitude for production $\gamma p \longrightarrow \gamma^* p$

$$\mathcal{M} = \sum_f \mathcal{M}_f$$

$$\mathcal{M}_f(\gamma p \to \gamma^*(q^2)p) = W^2\, 4\pi\alpha_{\rm em}\, e_f^2\, 2 \cdot 2 \int_0^{1/2} \frac{dz}{z(1-z)} \int_0^{\infty} \pi dk^2 \frac{\mathcal{A}_f(z, k^2, W^2)}{\left[\frac{k^2+m_f^2}{z(1-z)} - q^2 - i\varepsilon\right]},$$

where

- $\mathcal{A}_f(z, k^2)$- glue convolution $\longrightarrow$ see next page

Forward amplitude for production $\gamma p \longrightarrow \gamma^* p$

$$\mathcal{M}_f(\gamma p \to \gamma^*(q^2)p) = W^2\, 4\pi\alpha_{\rm em}\, e_f^2\, 2 \cdot 2 \int_0^{1/2} \frac{dz}{z(1-z)} \int_0^{\infty} \pi dk^2 \frac{\mathcal{A}_f(z,k^2,W^2)}{\left[\frac{k^2+m_f^2}{z(1-z)} - q^2 - i\varepsilon\right]},$$

where

- $\mathcal{A}_f(z,k^2)$- glue convolution $\longrightarrow$ see next page
- z-longitudinal momentum fraction of quark in the photon

Forward amplitude for production $\gamma p \longrightarrow \gamma^* p$

$$\mathcal{M}_f(\gamma p \to \gamma^*(q^2)p) = W^2\, 4\pi\alpha_{\rm em}\, e_f^2\, 2 \cdot 2 \int_0^{1/2} \frac{dz}{z(1-z)} \int_0^{\infty} \pi dk^2 \frac{\mathcal{A}_f(z,k^2,W^2)}{\left[\frac{k^2+m_f^2}{z(1-z)} - q^2 - i\varepsilon\right]},$$

where

- $\mathcal{A}_f(z,k^2)$- glue convolution $\longrightarrow$ see next page
- z-longitudinal momentum fraction of quark in the photon
- k-transverse momentum of the quark

Forward amplitude for production $\gamma p \longrightarrow \gamma^* p$

$$\mathcal{M}_f(\gamma p \to \gamma^*(q^2)p) = W^2\, 4\pi\alpha_{\rm em}\, e_f^2\, 2 \cdot 2 \int_0^{1/2} \frac{dz}{z(1-z)} \int_0^{\infty} \pi dk^2 \frac{\mathcal{A}_f(z,k^2,W^2)}{\left[\frac{k^2+m_f^2}{z(1-z)} - q^2 - i\varepsilon\right]},$$

where

- $\mathcal{A}_f(z,k^2)$- glue convolution $\longrightarrow$ see next page
- z-longitudinal momentum fraction of quark in the photon
- k-transverse momentum of the quark
- $M^2 = \frac{k^2+m_f^2}{z(1-z)}$-invariant mass of $q\bar{q}$ pair

$\mathcal{A}_f$ - function

$$\mathcal{A}_f(z, k^2) = \pi \int_0^\infty \frac{\pi d\kappa^2}{\kappa^4} \alpha_s(q^2) \mathcal{F}(x, \kappa^2)$$

$$\left[A_{0f}(z, k^2)\, W_{0f}(k^2, \kappa^2) + A_{1f}(z, k^2)\, W_{1f}(k^2, \kappa^2) \right]$$

$\mathcal{A}_f$ - function

$$\mathcal{A}_f(z,k^2) = \pi \int_0^\infty \frac{\pi d\kappa^2}{\kappa^4} \alpha_s(q^2) \mathcal{F}(x,\kappa^2)$$
$$\left[A_{0f}(z,k^2)\, W_{0f}(k^2,\kappa^2) + A_{1f}(z,k^2)\, W_{1f}(k^2,\kappa^2) \right]$$

$$A_{0f}(z,k^2) = m_f^2$$

$$A_{1f}(z,k^2) = [z^2 + (1-z)^2] \frac{k^2}{k^2 + m_f^2}$$

$$W_{01}(k^2,\kappa^2) = \frac{1}{k^2+m_f^2} - \frac{1}{\sqrt{(k^2 - m_f^2 - \kappa^2)^2 + 4m_f^2 k^2}}$$

$$W_{1f}(k^2,\kappa^2) = 1 - \frac{k^2+m_f^2}{2k^2} \left(1 + \frac{k^2 - m_f^2 - \kappa^2}{\sqrt{(k^2 - m_f^2 - \kappa^2)^2 + 4m_f^2 k^2}} \right)$$

$\mathcal{A}_f$ - function

$$\mathcal{A}_f(z,k^2) = \pi \int_0^\infty \frac{\pi d\kappa^2}{\kappa^4} \alpha_s(q^2) \mathcal{F}(x,\kappa^2)$$
$$\left[A_{0f}(z,k^2)\, W_{0f}(k^2,\kappa^2) + A_{1f}(z,k^2)\, W_{1f}(k^2,\kappa^2) \right]$$

- $\mathcal{F}(x,\kappa^2) = \frac{\partial G(x,\kappa^2)}{\partial \log \kappa^2}$- unintegrated gluon distribution
- $x = \frac{M^2}{W^2}$-longitudinal momentum fraction of the gluon
- κ^2-transverse momentum of the gluon

$\mathcal{A}_f$ - function

Spectral density

$$(z, k^2) \to (M^2, k^2)$$

$$\mathcal{M}_f(\gamma p \to \gamma^*(q^2) p) = W^2\, 16\pi^2 \alpha_{\rm em}\, e_f^2 \cdot \int_{4m_f^2}^{\infty} \frac{a_f(W^2, M^2)}{M^2 - q^2 - i\varepsilon}\, dM^2.$$

Spectral density

$$(z, k^2) \to (M^2, k^2)$$

$$\mathcal{M}_f(\gamma p \to \gamma^*(q^2)p) = W^2\, 16\pi^2 \alpha_{\rm em}\, e_f^2 \cdot \int_{4m_f^2}^{\infty} \frac{a_f(W^2, M^2)}{M^2 - q^2 - i\varepsilon}\, dM^2.$$

spectral density

$$a_f(W^2, M^2) = \int_0^{\frac{1}{4}M^2 - m_f^2} \frac{dk^2}{J_f}\, \mathcal{A}_f(M^2, k^2, W^2)$$

Spectral density

$(z, k^2) \to (M^2, k^2)$

$$\mathcal{M}_f(\gamma p \to \gamma^*(q^2)p) = W^2\, 16\pi^2 \alpha_{\rm em}\, e_f^2 \cdot \int_{4m_f^2}^{\infty} \frac{a_f(W^2, M^2)}{M^2 - q^2 - i\varepsilon}\, dM^2.$$

spectral density

$$a_f(W^2, M^2) = \int_0^{\frac{1}{4}M^2 - m_f^2} \frac{dk^2}{J_f}\, \mathcal{A}_f(M^2, k^2, W^2)$$

$$J_f = \sqrt{1 - 4\left(\frac{k^2 + m_f^2}{M^2}\right)}$$

Cross section for $\gamma p \longrightarrow l^+ l^- p$

non-forward amplitude

$$\mathcal{M}_f(\gamma p \to \gamma^*(q^2)p; t) = \mathcal{M}_f(\gamma p \to \gamma^*(q^2)p)\ \exp[Bt]$$

Cross section for $\gamma p \to l^+ l^- p$

non-forward amplitude

$$\mathcal{M}_f(\gamma p \to \gamma^*(q^2) p; t) = \mathcal{M}_f(\gamma p \to \gamma^*(q^2) p)\ \exp[Bt]$$

$$\sigma(\gamma p \to \gamma^* p) = \frac{(\Re e \frac{\mathcal{M}}{W^2})^2 + (\Im m \frac{\mathcal{M}}{W^2})^2}{16\pi \mathcal{B}}$$

Cross section for $\gamma p \to l^+ l^- p$

non-forward amplitude

$$\mathcal{M}_f(\gamma p \to \gamma^*(q^2)p; t) = \mathcal{M}_f(\gamma p \to \gamma^*(q^2)p)\ \exp[Bt]$$

$$\sigma(\gamma p \to \gamma^* p) = \frac{(\Re e \frac{\mathcal{M}}{W^2})^2 + (\Im m \frac{\mathcal{M}}{W^2})^2}{16\pi \mathcal{B}}$$

$$\frac{d\sigma}{dq^2}(\gamma p \to l^+ l^- p) = \frac{\alpha_{em}}{3\pi q^2}\sigma(\gamma p \to \gamma^* p)$$

Cross section for $\gamma p \to l^+ l^- p$

non-forward amplitude

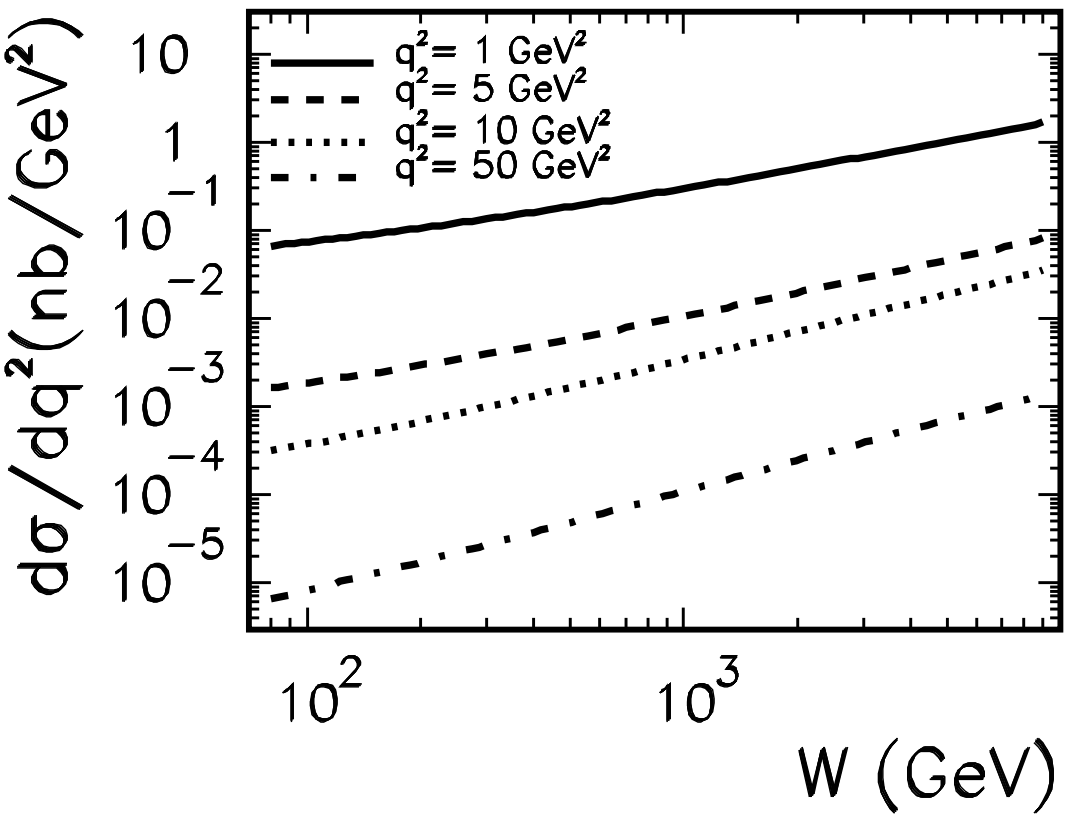
$$\mathcal{M}_f(\gamma p \to \gamma^*(q^2) p; t) = \mathcal{M}_f(\gamma p \to \gamma^*(q^2) p) \exp[Bt]$$

$$\sigma(\gamma p \to \gamma^* p) = \frac{(\Re e \frac{\mathcal{M}}{W^2})^2 + (\Im m \frac{\mathcal{M}}{W^2})^2}{16\pi \mathcal{B}}$$

$$\frac{d\sigma}{dq^2}(\gamma p \to l^+ l^- p) = \frac{\alpha_{em}}{3\pi q^2} \sigma(\gamma p \to \gamma^* p)$$

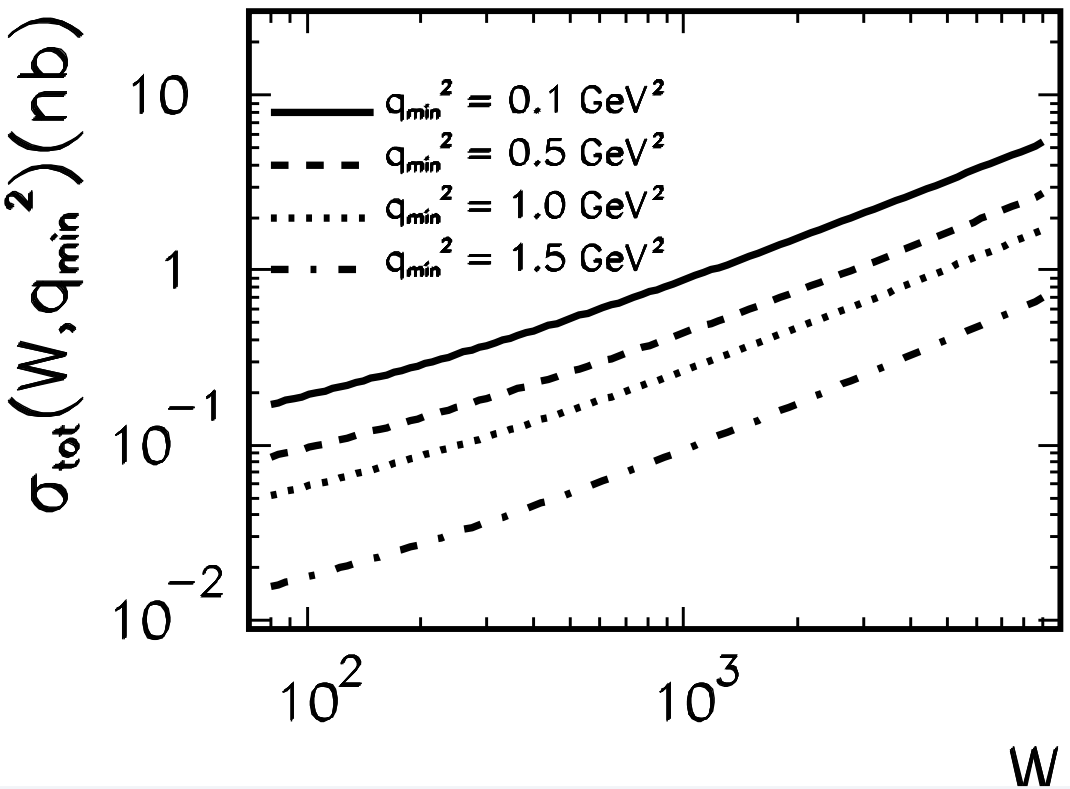
- $\mathcal{M} = \sum_f \mathcal{M}_f$
- $\mathcal{B}$ - slope parameter
- q^2 - invariant mass of $l^+ l^-$

$d\sigma/dq^2$ as a function of γp cm energy



$$\gamma p \to l^+ l^- p$$

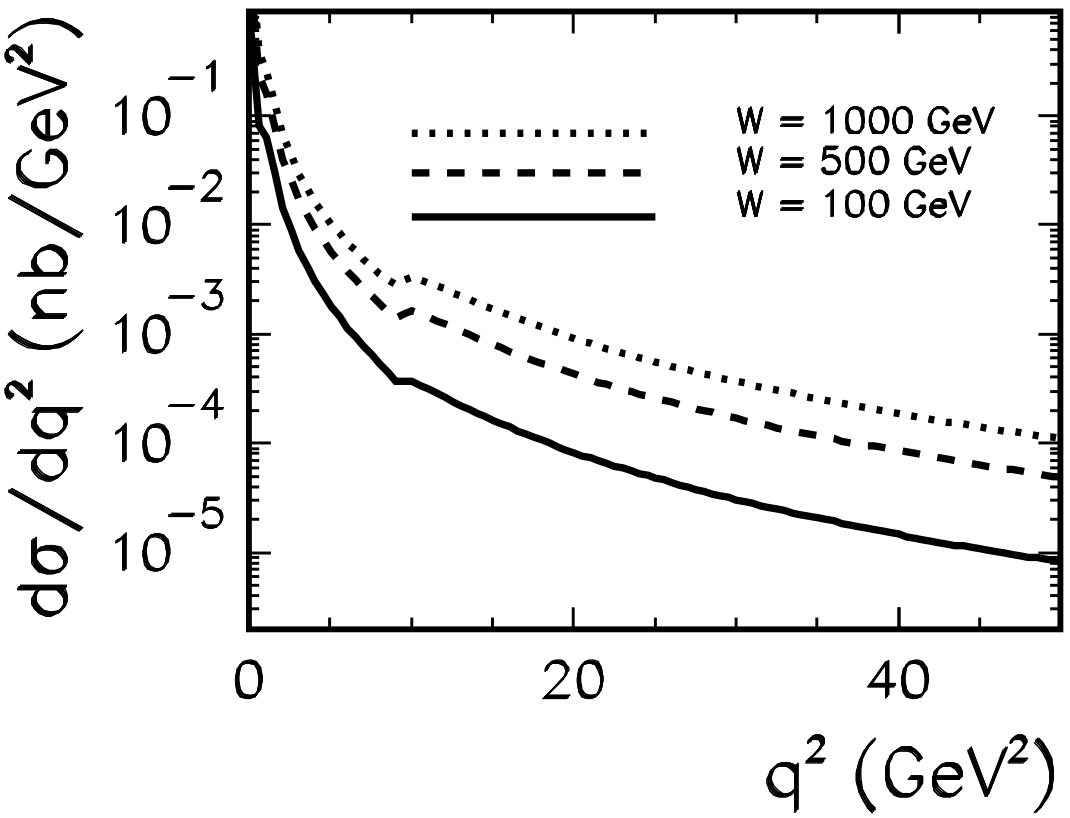
Energy dependence



$$\sigma_{tot}(\gamma p \to l^+ l^- p; q^2_{min}) = \int_{q^2_{min}}^{\infty} \frac{d\sigma}{dq^2} dq^2$$

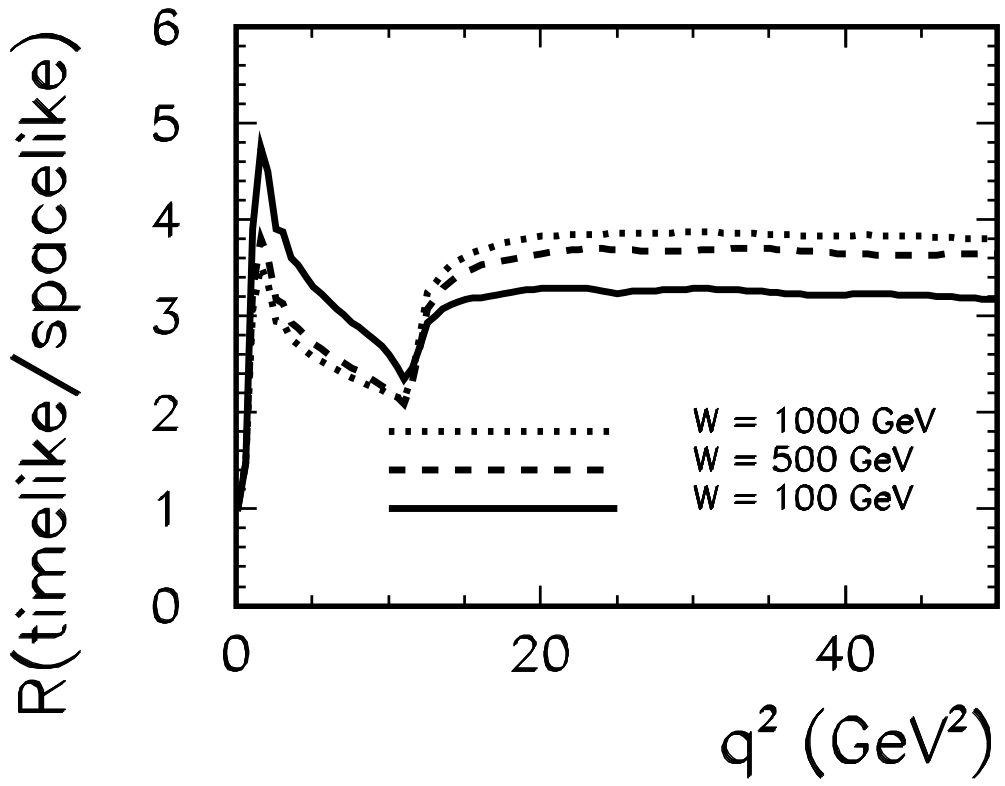
M.V.T. Machado, Phys. Rev. **D78** (2008) 034016.

Dependence on dilepton invariant mass



- q^2 - invariant mass of $l^+ l^-$

Ratio


R(timelike/spacelike)
6
5
4
3
2
1
0
0
20
40
q² (GeV²)
W = 1000 GeV
W = 500 GeV
W = 100 GeV

Ratio

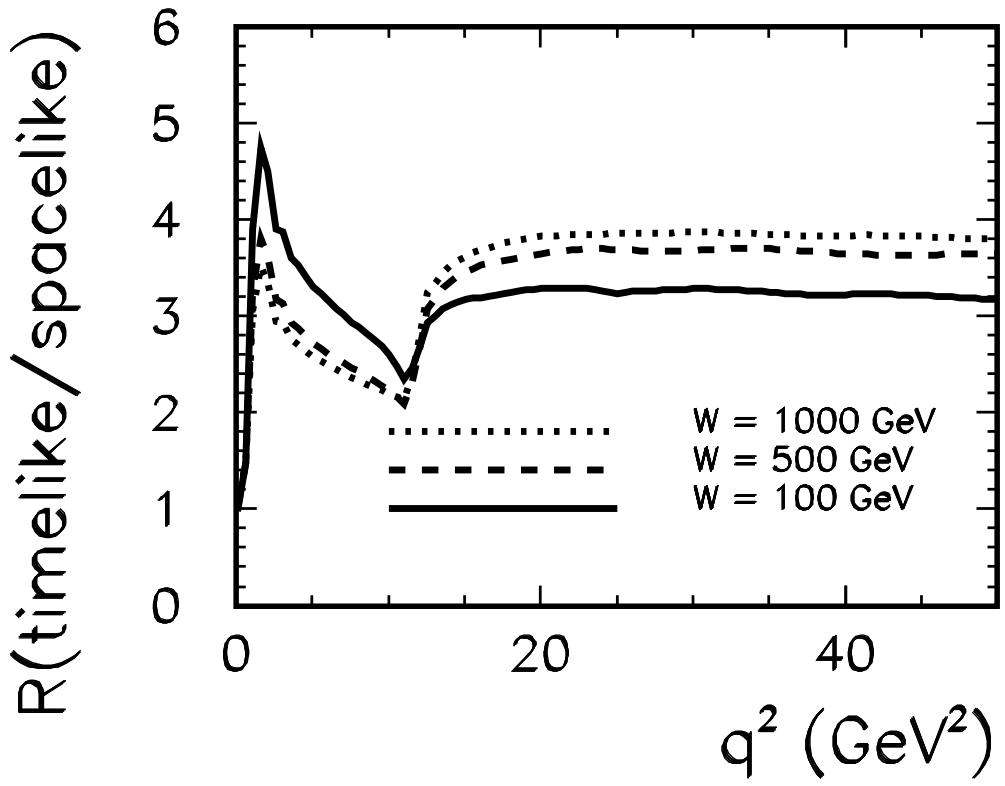
timelike

$$\mathcal{M}_f = W^2\, 16\pi^2 \alpha_{\mathrm{em}} e_f^2 \cdot \int_{4m_f^2}^{\infty} \frac{a_f(W^2, M^2)}{M^2 - q^2 - i\varepsilon}\, dM^2.$$

spacelike

$$\mathcal{M}_f = W^2\, 16\pi^2 \alpha_{\mathrm{em}} e_f^2 \cdot \int_{4m_f^2}^{\infty} \frac{a_f(W^2, M^2)}{M^2 + q^2}\, dM^2.$$

Ratio


R(timelike/spacelike)
6
5
4
3
2
1
0
0
20
40
q² (GeV²)
W = 1000 GeV
W = 500 GeV
W = 100 GeV

Conclusions

Introduction

Formalism

Amplitude for production $\gamma p \to \gamma^* p$

Cross section for $\gamma p \to l^+ l^- p$

Results and discussion

Conclusions

- Amplitude for the $\gamma p \to \gamma^* p$ has been derived in the k_t - factorization approach.
- I have presented results for exclusive photoproduction of lepton pairs (energy and q dependences).
- I have done calculations assuming time-like photons instead of space-like photons as wrongly done in the literature. This leads to an enhancement of the cross section compared to earlier estimates.
- Future: go to hadroproduction and see what is background to the QED process (luminosity monitor).

Conclusions

Introduction

Formalism

Amplitude for production $\gamma p \to \gamma^* p$

Cross section for $\gamma p \to l^+ l^- p$

Results and discussion

Conclusions

- Amplitude for the $\gamma p \to \gamma^* p$ has been derived in the k_t - factorization approach.
- I have presented results for exclusive photoproduction of lepton pairs (energy and q dependences).
- I have done calculations assuming time-like photons instead of space-like photons as wrongly done in the literature. This leads to an enhancement of the cross section compared to earlier estimates.
- Future: go to hadroproduction and see what is background to the QED process (luminosity monitor).

Conclusions

Introduction

Formalism

Amplitude for production $\gamma p \to \gamma^* p$

Cross section for $\gamma p \to l^+ l^- p$

Results and discussion

Conclusions

- Amplitude for the $\gamma p \to \gamma^* p$ has been derived in the k_t - factorization approach.
- I have presented results for exclusive photoproduction of lepton pairs (energy and q dependences).
- I have done calculations assuming time-like photons instead of space-like photons as wrongly done in the literature. This leads to an enhancement of the cross section compared to earlier estimates.
- Future: go to hadroproduction and see what is background to the QED process (luminosity monitor).

Conclusions

Introduction

Formalism

Amplitude for production $\gamma p \to \gamma^* p$

Cross section for $\gamma p \to l^+ l^- p$

Results and discussion

Conclusions

- Amplitude for the $\gamma p \to \gamma^* p$ has been derived in the k_t - factorization approach.
- I have presented results for exclusive photoproduction of lepton pairs (energy and q dependences).
- I have done calculations assuming time-like photons instead of space-like photons as wrongly done in the literature. This leads to an enhancement of the cross section compared to earlier estimates.
- Future: go to hadroproduction and see what is background to the QED process (luminosity monitor).