Exclusive photoproduction of lepton pairs at high energy

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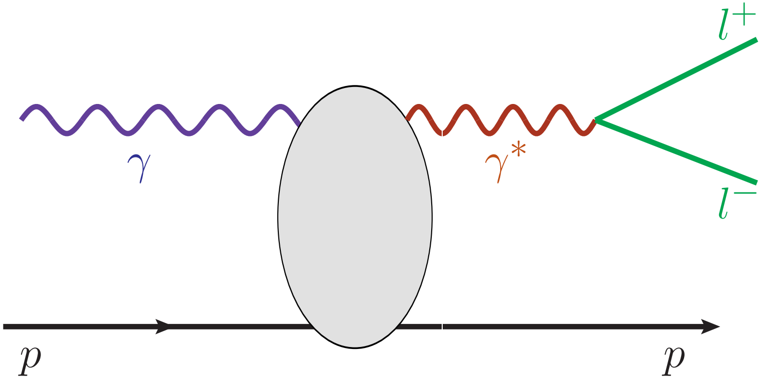


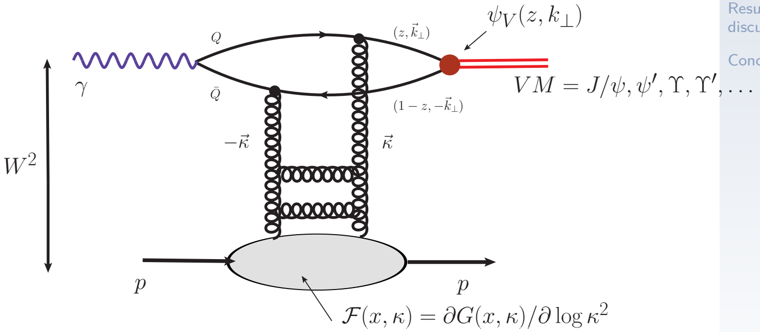
γ
γ^*
l^+
l^-
p
p

Outline

in collaboration with W.Schäfer & A.Szczurek

Introduction

- *VM(vector meson)* $\to e^+ e^-$ decays is not the only source of leptons



Introduction

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- formalism of VM photoproduction can be found

- I.P. Ivanov, N.N. Nikolaev, A.A. Savin Phys. Part. Nucl. **37**:1-85,(2006)
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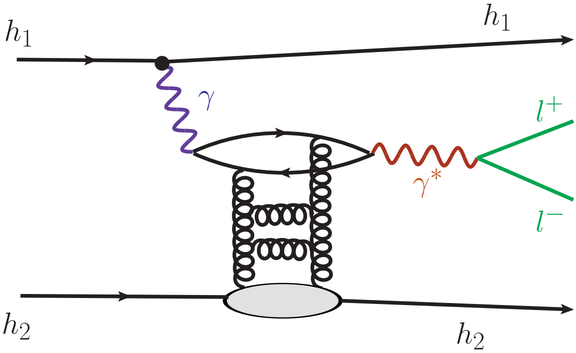
- very much the same formalism applies to $\gamma p \to l^+ l^- p$ via timelike Compton scattering
- The QED process $pp \to pl^+l^-p$ is important for measuring the luminosity at LHC. It is therefore important to estimate non-QED contributions to exclusive l^+l^- production.

Hadroproduction



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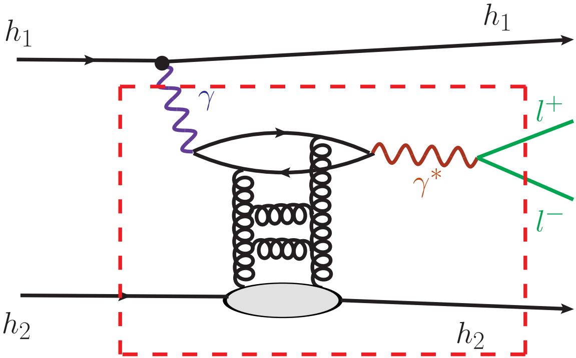
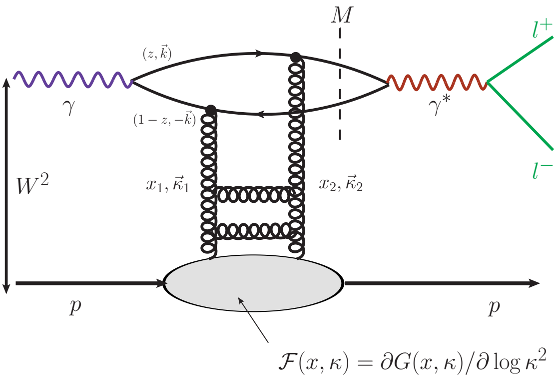


Photoproduction



A. Cisek, W. Schafer, and A. Szczurek Phys. Rev. **D80** (2009) 074013.

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

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

$$\mathcal{M}_f = W^2 c_f \, 2 \, g_{em}^2 \int_0^1 \frac{dz}{z(1-z)} \int_0^\infty \pi dk^2 \frac{\mathcal{A}_f(z,k^2)}{\left[\frac{k^2+m_f^2}{z(1-z)} - q^2 - i\varepsilon\right]}$$

where

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

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- $\mathcal{A}_f(z, k^2)$- glue convolution $\to$ 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

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

$$\begin{aligned}
A_{0f}(z,k^2) &= m_f^2 \\
A_{1f}(z,k^2) &= [z^2 + (1-z)^2] \frac{k^2}{k^2 + m_f^2} \\
W_{01}(k^2,\kappa^2) &= \frac{1}{k^2 + m_f^2} - \frac{1}{\sqrt{(k^2 - m_f^2 - \kappa^2)^2 + 4 m_f^2 k^2}} \\
W_{1f}(k^2,\kappa^2) &= 1 - \frac{k^2 + m_f^2}{2k^2} \left(1 + \frac{k^2 - m_f^2 - \kappa^2}{\sqrt{(k^2 - m_f^2 - \kappa^2)^2 + 4 m_f^2 k^2}} \right)
\end{aligned}$$

Spectral density

$$M^2 = \frac{k^2 + m_f^2}{z(1-z)}$$

$$\mathcal{M}_f = W^2 c_f 2 \cdot 2\pi \int_{4m_f^2}^{\infty} \frac{a_f(W^2, M^2)}{M^2 - q^2 - i\varepsilon} dM^2$$

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spectral density

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

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

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

cross section

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

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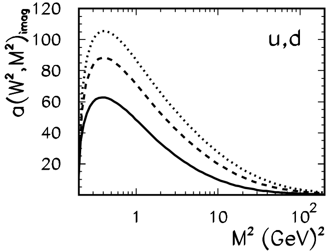
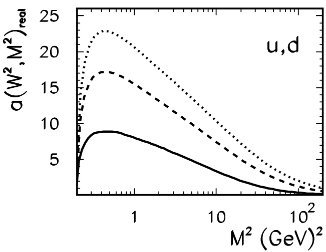
- $\mathcal{M} = \sum_f \mathcal{M}_f$
- $\mathcal{B} = 4GeV^{-2}$ - slope parameter
- q^2 - invariant mass of $l^+ l^-$

Spectral density for quark u,d

imag part:



real part:

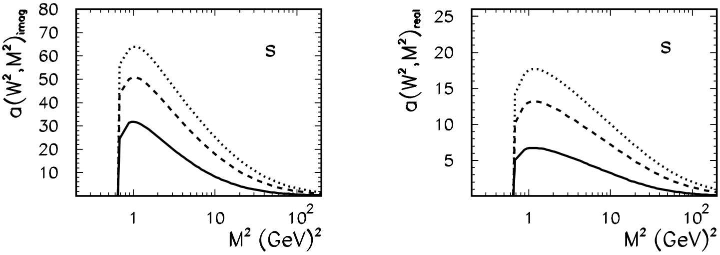


—— $100 GeV$ - - - - $500 GeV$ ········ $1000 GeV$

$m_u, m_d = 0.22\,GeV$

Spectral density for quark s

imag part: real part:

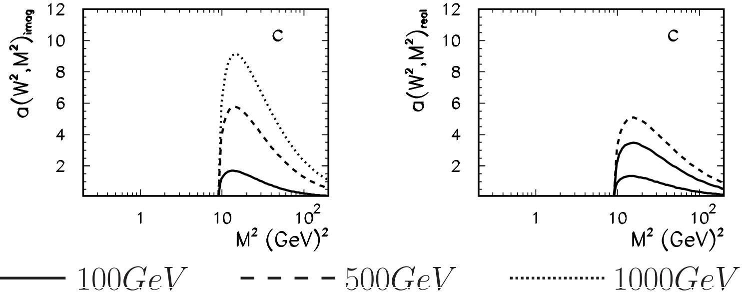


—— $100 GeV$ - - - - $500 GeV$ ········ $1000 GeV$

$m_s = 0.37 GeV$

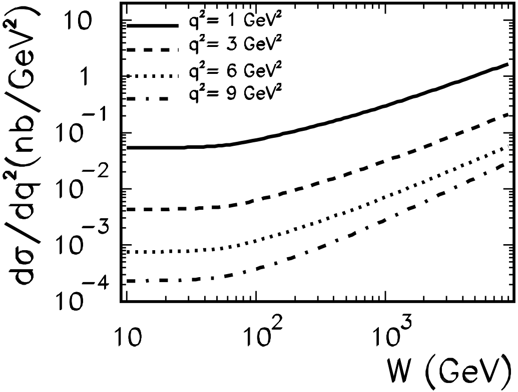
Spectral density for quark c

imag part: real part:



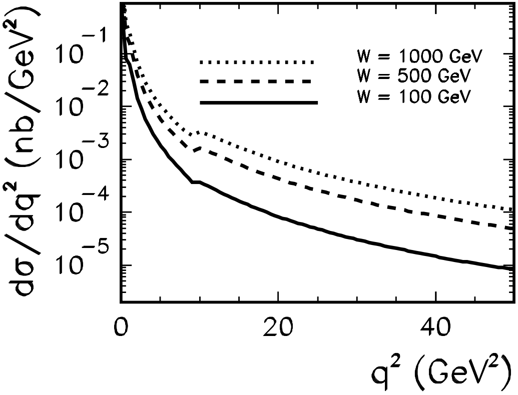
$m_c = 1.5\,GeV$

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



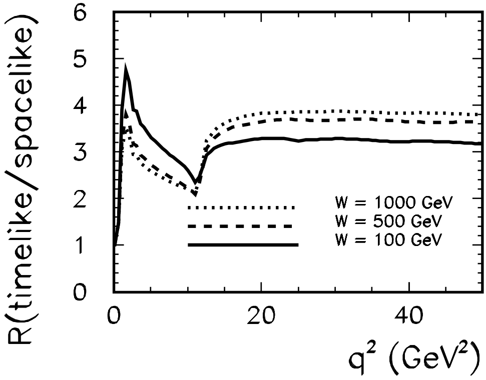
$\gamma p \to l^+ l^- p$

Dependence on dilepton invariant mass

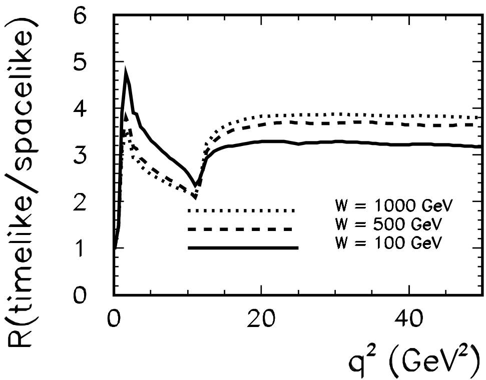


- q^2 - invariant mass of $l^+ l^-$

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

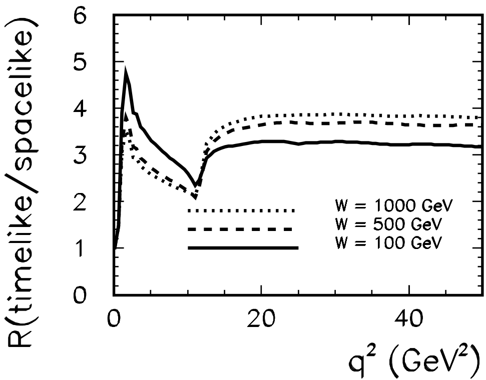
Ratio



timelike

$$a(M^2) = \int_{4m_f^2}^{\infty} \frac{a(M^2)}{M^2 - q^2 - i\varepsilon} dM^2$$

Ratio



timelike

$$a(M^2) = \int_{4m_f^2}^{\infty} \frac{a(M^2)}{M^2 - q^2 - i\varepsilon} dM^2$$

spacelike

$$a(M^2) = \int_{4m_f^2}^{\infty} \frac{a(M^2)}{M^2 + q^2} dM^2$$

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 $q\,(= M_{l^+l^-})$ 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 compared to earlier estimates.
- Future: go to hadroproduction and see what is background to the QED process (luminosity monitor).

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