# $k_t$-Factorisation in the Drell-Yan Process

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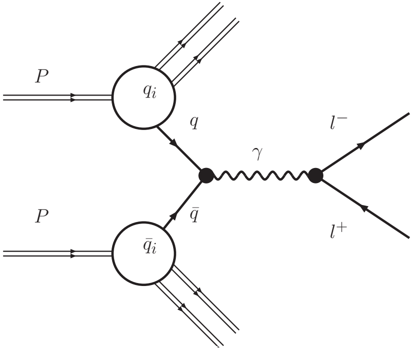
# Motivation

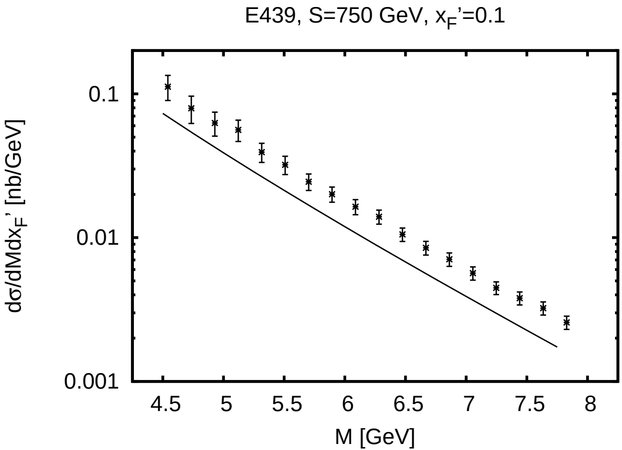
- Exclusive Drell-Yan observables give important insights into nucleon structure
- Problems:
    - Standard pQCD parton model description needs "K-factor" to reproduce data
    - PANDA @ FAIR will allow measurements of the Drell-Yan Process down to small energies
    $\Rightarrow$ non-perturbative effects become important
- Account for these shortcomings by improving standard parton model description

# The Drell-Yan Process ($pp \longrightarrow l^+l^-X$)

- Parton model:
  "Infinite momentum frame"
  $\Rightarrow$ partons collinear
  carrying momentum fraction $x$
- Factorisation:
  - $d\sigma = \int \sum_i e_{q_i}^2 f_i(x) d\hat{\sigma}(x)$
  - hard subprocess ($d\hat{\sigma}$)
  - parton distribution functions ($f_i$)
- Accessible: $d^2\sigma/(dMdx_F)$
- Not accessible:
  $p_T$-spectrum of DY-pair



# Invariant mass distribution

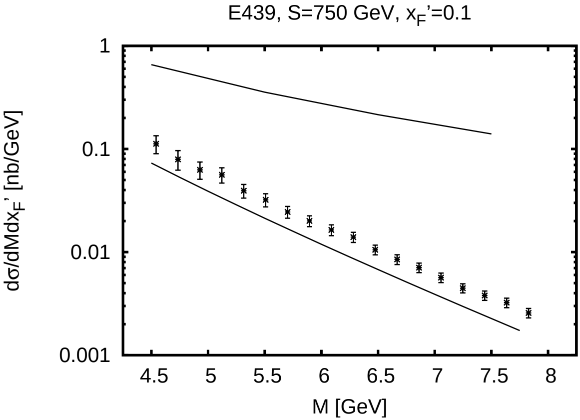



K-factor necessary to reproduce absolute values

# Quark transverse momentum

- Parton model: Neglect initial $k_T$ of quarks
  $\Rightarrow p_T$-spectrum of DY-pairs inaccessible
  in LO calculation!
- Initial $k_T$-approach:
  $d\sigma = \int \sum_i e_{q_i}^2 f_i(x) \cdot g(\vec{k}_t) \cdot d\hat{\sigma}(x)$
- Shape of $p_T$-spectrum reproduced,
  still K-factor needed to yield absolute values
- First improvement: Include initial
  transverse momentum with full kinematics
  $\Rightarrow d\hat{\sigma}(x) \rightarrow d\hat{\sigma}(x, \vec{k}_t)$
- Problem: Result is totally off data

# Full kinematics



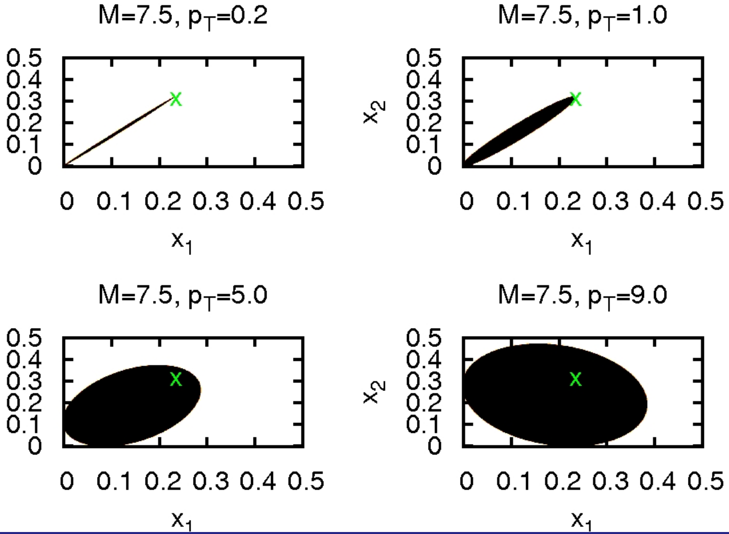

Simple $x$-independent Gaussian for initial $k_t$-distribution:

Slope and height not reproduced

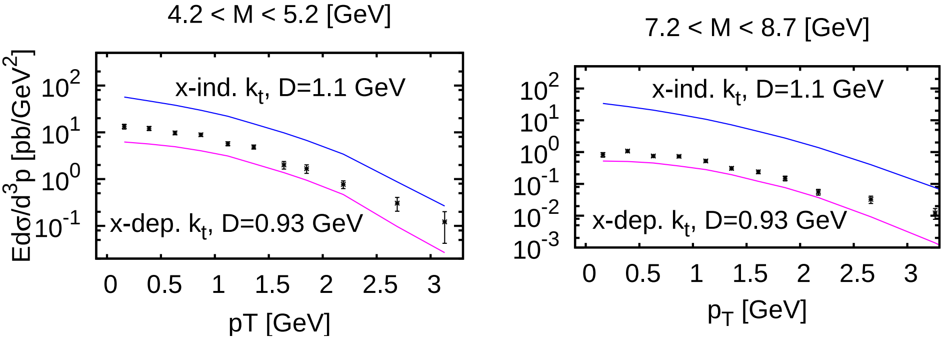
# Interdependency of $x$ and $k_t$

- Gaussian description $g(\vec{k}_t) \sim \exp(-k_t^2/D^2)$ fails in full kinematics $\Rightarrow$ no $k_t$-factorisation!
- Reason: For $x \rightarrow 0$ is $k_t^2 \sim x$
- Then Gaussian does not suppress for small $x$, but sea quark distributions diverge!
- Unphysical behavior demands $x$-dependent $k_t$-distribution
- Better choice: $\exp(-k_t^2/(x/x_{\mathrm{LO}} \cdot D^2))$
- $x_{\mathrm{LO}}$ is the $x$ obtained from the collinear parton model

# Probed range of $x_1$ and $x_2$



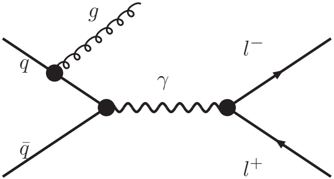
# E866: $k_t$-spectrum for $S = 1500$ GeV$^2$

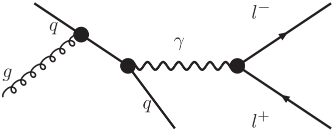



- Overshoot for $x$-independent $k_t$-distribution (blue) is worse for larger invariant Mass $M$
- $x$-dependent approach (purple) agrees with collinear parton model + simple initial Gaussian $k_t$

# Next to Leading Order

- NLO calculation reduces the necessary K-factor in invariant mass distribution
- However: Dynamically generated $p_T$-spectrum is divergent for $p_T \longrightarrow 0$ in NLO
- Higher twist effects are important to describe data



# Summary and Outlook

- pQCD parton model has deficiencies in describing exclusive DY observables
- Simple improvement by using full kinematics for initial parton transverse momentum with standard Gaussian smearing fails
- $x$-dependent initial $k_t$-distribution necessary to reproduce parton model results
- Next steps:
  - Include NLO processes with full kinematics and study effects of off-shell quarks in that approach
  - Make predictions for PANDA @ FAIR, where non-pertubative effects become more important