

TMDlib 1.0.8 and TMDplotter 2.1.1

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The latest versions of TMDlib and TMDplotter are presented. Parameterisations of TMDs in TMDlib are illustrated. New features of TMDplotter include plotting as a function of the momentum fraction, the transverse momentum, or the evolution scale, as well as integration of TMDs and comparison to sets from LHAPDF. Luminosity for collinear PDFs is also described. The tool is available at <http://tmdplotter.desy.de>.

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1. Introduction

The *Transverse-Momentum Dependent (TMD) Parton Density Functions* (PDF) $\mathcal{A}(x, k_t, p)$ extend collinear PDFs $f(x, p)$ by taking into account the transverse momentum k_t of the parton, where x is the momentum fraction and p the evolution scale. TMDs are necessary for a proper description of multi-scale processes [1].

TMDlib and TMDplotter are two utility tools available on internet [2, 3] to help study TMDs quantitatively [4]: the former is a C++ library that centralises many TMD parameterisations in a common framework, similarly to the LHAPDF library [5], and the latter is an online tool making use of TMDlib to plot and compare TMDs among them, or to integrate and compare them with collinear PDFs; it also allows to compute *partonic luminosities*.

In order to illustrate the tool, we will use `ccfm-JH-2013` sets [6].

2. TMDlib

TMDlib is a C++ library for working with TMDs. A precise description of the theoretical background and of the tool can be found in [4].

The list of available sets can be found on <http://tmdlib.hepforge.org>. The initialisation and the call are done on a unified way. Storage and interpolation are done automatically and do not require any action from the user.

3. TMDplotter

TMDs as a function of the momentum fraction x , the transverse momentum k_t and the evolution scale p can be plotted directly from TMDlib using TMDplotter.

Integrated TMDs are obtained from TMDs by integration over k_t (using the QAGS algorithm from the GNU Scientific Library [7]), with integration limits k_t^{\max} and k_t^{\min} to be given by the user:

$$xf(x, p) = \int_{k_t^{\min}}^{k_t^{\max}} dk_t^2 x \mathcal{A}(x, k_t, p) \quad (3.1)$$

TMDplotter can also compute and plot the *partonic luminosity*, both for collinear PDFs and for integrated TMDs. This quantity describes the contribution from the PDFs to the hadronic cross section. The partonic luminosity reads [8]:

$$\frac{d\mathcal{L}_{ij}}{d\tau} = \frac{1}{1 + \delta_{ij}} \int_0^1 dx_1 \int_0^1 dx_2 f_i(x_1, p) f_j(x_2, p) \delta(\tau - x_1 x_2) + (i \leftrightarrow j) \quad (3.2)$$

with $\tau = x_1 x_2$ the product of the momentum fractions.

Similarly, the TMD luminosity can also be defined from a TMD:

$$\begin{aligned} \frac{d^2\mathcal{L}_{ij}}{d\tau dq_t} = & \frac{1}{1 + \delta_{ij}} \int_0^1 dx_1 \int_0^1 dx_2 \int \frac{d^2\mathbf{k}_{t1}}{\pi} \int \frac{d^2\mathbf{k}_{t2}}{\pi} \mathcal{A}_i(x_1, k_{t1}, p) \mathcal{A}_j(x_2, k_{t2}, p) \times \\ & \times \delta(\tau - x_1 x_2) \delta^{(2)}(\mathbf{q}_t - (\mathbf{k}_{t1} + \mathbf{k}_{t2})) + (i \leftrightarrow j) \end{aligned} \quad (3.3)$$

where \mathbf{q}_t is the sum of the transverse momenta.

4. Application

The two sets of `ccfm-JH-2013` are extracted for gluons from the combined measurements of proton's structure functions F_2 in deeply inelastic scattering at HERA collider. The `set1` is determined from the fit to the inclusive structure function only, whilst the `set2` is determined from both the inclusive and charm structure functions. A precise description of the extraction of the sets can be found in [6].

Using those sets, we show some applications of TMDplotter: in Fig. 1, the two sets are plotted as a function of x and k_t ; and in Fig. 2 the integral of the second set is shown for different boundaries. From Fig. 2 we conclude that the lower integration limit does not play a large rôle, as soon as it is low enough, while the upper integration has a significant influence.

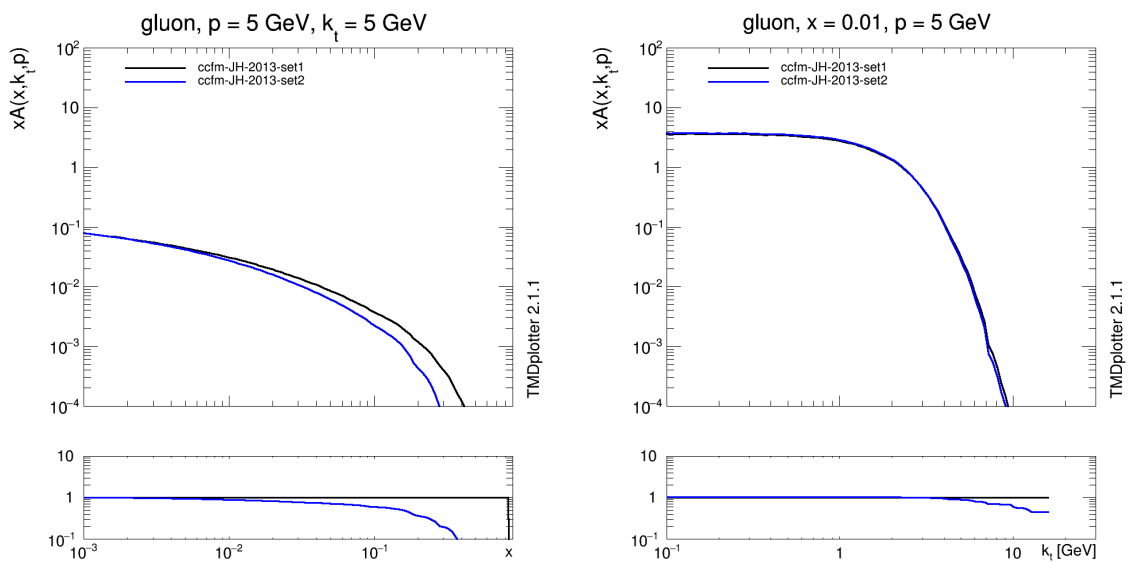


Figure 1: The `ccfm-JH-2013` sets are plotted as a function of x (left) and k_t (right). The lower panel shows the ratio with the first curve.

In Fig. 3, the partonic luminosity is plotted for two collinear PDFs for gluons and photons.

5. Summary

The two tools TMDlib and TMDplotter for working with TMDs have been presented. In particular, TMDplotter (<http://tmdplotter.desy.de>) has been augmented with many new features.

References

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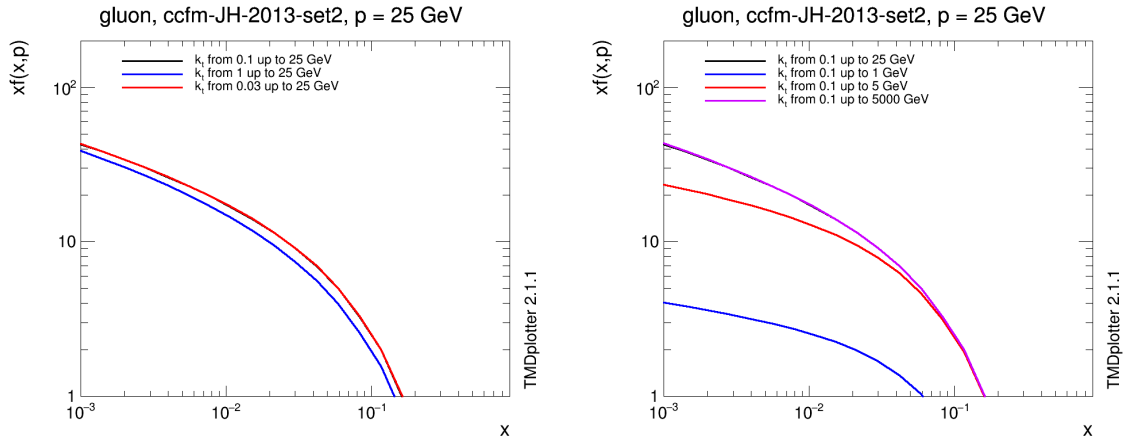


Figure 2: ccfm-JH-2013 sets are integrated. On the left (right), the lower (upper) integration boundary is varied.

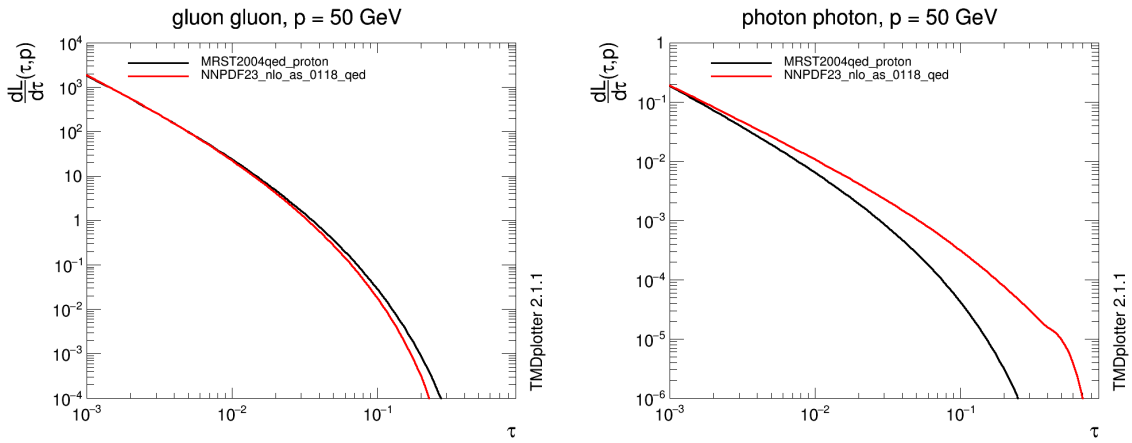


Figure 3: The partonic luminosities of two colliding gluons (left) and of two colliding photons (right) are shown for the collinear PDFs MRST2004qed_proton and NNPDF23_nlo_as_0118_qed.

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