TMDlib 1.0.6 and TMDplotter 2.1.0

Deep Ineslatic Scattering 2016 Hamburg

Patrick L.S. Connor Johannes Scheller

under the supervision of
Francesco Hautmann Hannes Jung

Deutsches Elektronen-Synchrotron

14 April 2016

Introduction I

TMDs

The *Transverse-Momentum Dependent* PDFs extend collinear PDFs by taking into account the transverse momentum of the parton:

$$f(x,p) \equiv \int \frac{\mathrm{d}^2\mathbf{k_t}}{2\pi} \mathcal{A}(x,k_t,p) \tag{1}$$

$\longrightarrow$ properer description of two-scale processes

Introduction II

Tools

TMDlib[1] similar to the LHAPDF library[2] for TMDs

TMDplotter[3] similar to the Durham PDF Plotter[4] for TMDs *and* collinear PDFs

---

[1] https://tmdlib.hepforge.org
[2] https://lhapdf.hepforge.org/
[3] http://tmdplotter.desy.de
[4] http://hepdata.cedar.ac.uk/pdf/pdf3.html

TMDlib

Purpose

Provide a central framework to all TMD fits à la LHAPDF as a function of x, k_t and p in $50 \times 50 \times 50$ grids.

Sets

	uPDF/TMD name	#sets	Λ^4_{QCD}	$\frac{k_t^{\text{cut}}}{\text{GeV}}$	$\frac{Q_0}{\text{GeV}}$	Ref.
gluon	ccfm-JS-2001	1	0.25	0.25	1.4	jung-dis04
	ccfm-setA0	4	0.25	1.3	1.3	jung-dis04
	ccfm-setB0	4	0.25	0.25	1.3	jung-dis04
	ccfm-JH-set 1	1	0.25	1.33	1.33	jung-dis03
	ccfm-JH-set 2	1	0.25	1.18	1.18	jung-dis03
	ccfm-JH-set 3	1	0.25	1.35	1.35	jung-dis03
	ccfm-JH-2013-set1	13	0.2	2.2	2.2	Hautmann:2013tba
	ccfm-JH-2013-set2	13	0.2	2.2	2.2	Hautmann:2013tba
	GBWlight	1	–	–	–	wuesthoff-golec-biernat
	GBWcharm	1	–	–	–	wuesthoff-golec-biernat
	KS-2013-linear	1	0.3	–	–	Kutak:2012rf
	KS-2013-non-linear	1	0.35	–	–	Kutak:2012rf
	Kutak-linear-scale	1	0.35	–	–	Kutak:2014wga
	Kutak-nonlinear-scale	1	0.35	–	–	Kutak:2014wga
	EKMP	1	0.35	–	–	Echevarria:2015uaa
quark	ccfm-setA0	1	0.25	1.3	1.3	jung-dis04
	ccfm-JH-2013-set1	1	0.2	2.2	2.2	Hautmann:2013tba
	ccfm-JH-2013-set2	1	0.2	2.2	2.2	Hautmann:2013tba
	SBRS-2013-TMDPDFs	1	–	–	1.55	Signori:2013mda
	SBRS-2013-TMDPDFs-par	1	–	–	1.55	Signori:2013mda
	EKMP	1	0.35	–	–	Echevarria:2015uaa

ccfm-JH-2013-set2

Density $\mathcal{A}(x, k_t, \mu)$ is fitted using

$$F_2 \sim \sigma_2 = \hat{\sigma}_2 \otimes \mathcal{A} \tag{2}$$

from measurements of the DIS structure fonctions:

- F_2 at $x < 0.005$ and $Q^2 > 5\,\mathrm{GeV}^2$
- F_2^{charm} at $Q^2 > 2.5\,\mathrm{GeV}^2$

(Jung et Hautmann, 2014)

TMDplotter

Basic purpose

Provide on line a powerful tool to graphically compare TMDs with one another and with collinear PDFs.

Functionalities

1. Plot $x\mathcal{A}(x, k_t^2, p)$;
2. integrate $x\mathcal{A}(x, k_t^2, p)$ and compare it with collinear PDFs from LHAPDF;
3. plot the ratios of the same curves.

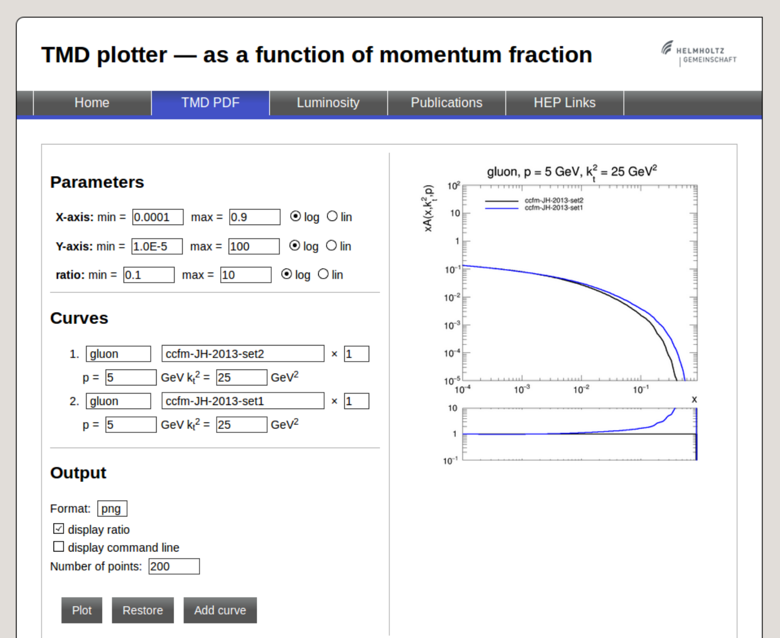
Novelties:

4. Differentiate collinear PDFs and compare with TMDs;
5. plot partonic luminosities, collinear *as well as unintegrated*.

Hands-on I

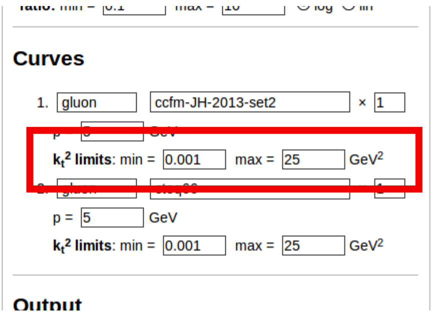
1. Go to `http://tmdplotter.desy.de`
2. TMD PDFs $\longrightarrow$ Function of x
3. Select *gluon* and *ccfm-JH-2013-set2*
4. Select *ratio*
5. Click on *Plot*
6. Enjoy!

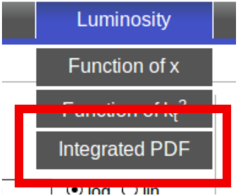
Hands-on II


TMD plotter — as a function of momentum fraction
HELMHOLTZ GEMEINSCHAFT
Home
TMD PDF
Luminosity
Publications
HEP Links
Parameters
X-axis: min = 0.0001 max = 0.9 log lin
Y-axis: min = 1.0E-5 max = 100 log lin
ratio: min = 0.1 max = 10 log lin
Curves
1. gluon ccfm-JH-2013-set2 × 1
p = 5 GeV k_t^2 = 25 GeV^2
2. gluon ccfm-JH-2013-set1 × 1
p = 5 GeV k_t^2 = 25 GeV^2
Output
Format: png
display ratio
display command line
Number of points: 200
Plot
Restore
Add curve
gluon, p = 5 GeV, k_t^2 = 25 GeV^2
xA(x,k_t^2,p)
ccfm-JH-2013-set2
ccfm-JH-2013-set1
x

Applications

1. What is the dependence of the limits on the k_t-integration of a TMD?

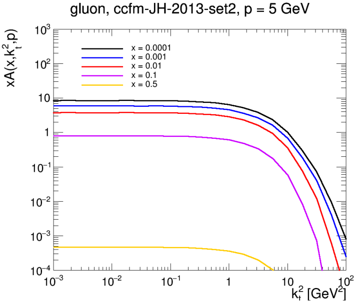


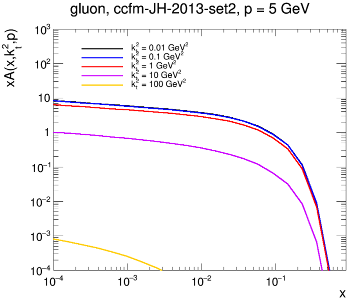


2. What is the luminosity of densities? Are they similar for TMDs and collinear PDFs?

Sensitivity to integration limits I

$x\mathcal{A}(x, k_t^2, p)$



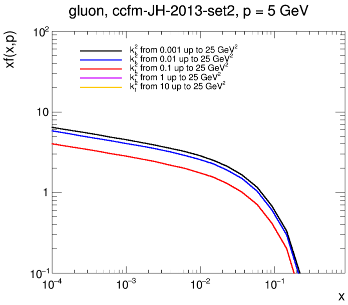


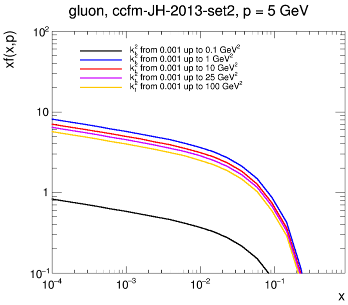
left function of k_t^2 for different x values

right function of x for different k_t^2 values

Sensitivity to integration limits II

$$xf(x,p) = \int \mathrm{d}k_t x\mathcal{A}(x,k_t^2,p)$$





left integrated TMD compared on *lower* boundary

right integrated TMD compared on *upper* boundary

$\longrightarrow$ **the upper boundary plays a non-negligeable rôle on the result!**

Partonic luminosity

Idea

- The *collider luminosity* describes the amount of hadrons that a collider can provide.
- Analogously, the *partonic luminosity* describes the amount of partons that colliding hadrons can provide.

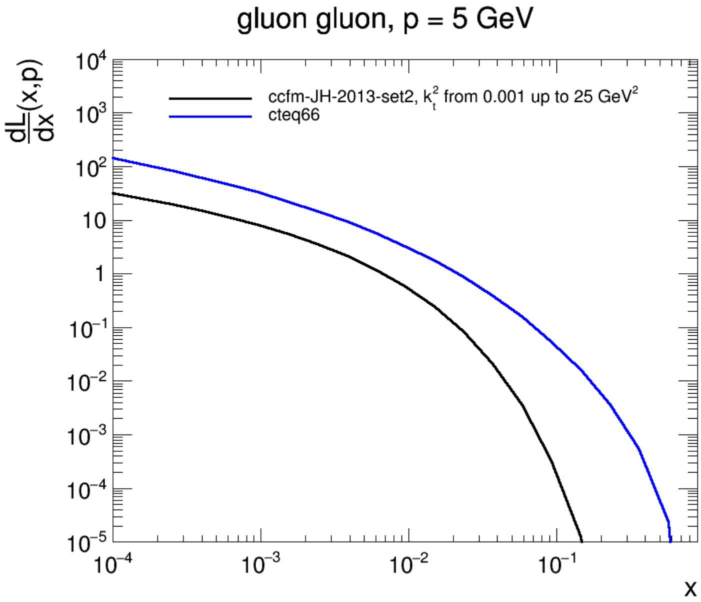
Given a PDF f, with partons i and j:

$$\sigma \sim \sum_{ij} f_i \otimes f_j \otimes \hat{\sigma} \tag{3}$$

$$\mathcal{L}_{ij} \sim f_i \otimes f_j \otimes \delta \tag{4}$$

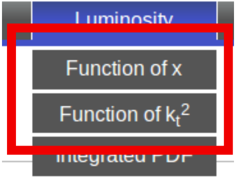
$\longrightarrow$ can be differentiated w.r.t. x

In LHC conditions



Novelties

1. Definition of a *TMD luminosity*.

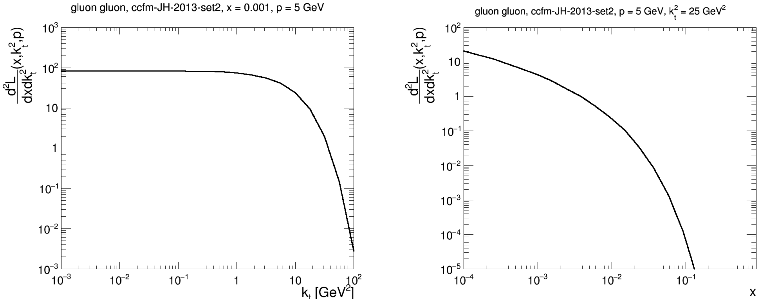


2. Derivation of collinear PDFs w.r.t. the scale.

TMD luminosity

Natural extension of the definition of the luminosities with TMDs:

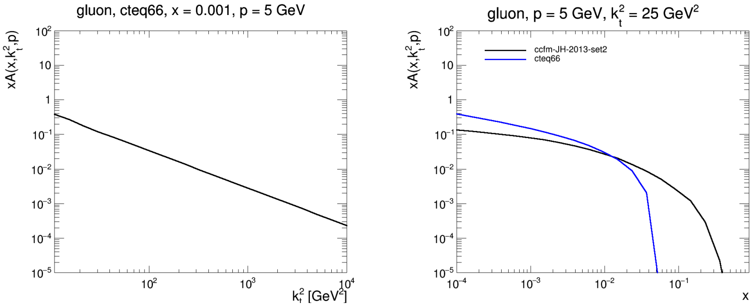
$$\mathcal{L}_{ij} \sim \mathcal{A}_i \otimes \mathcal{A}_j \otimes \delta_x \otimes \delta_{\mathbf{k_t}} \tag{5}$$



left function of k_t^2 at fixed x

right function of x at fixed k_t^2

Derivative of collinear PDFs



left function of k_t^2 at fixed x

right function of x at fixed k_t^2

Summary

- TMDplotter is now available on `http://tmdplotter.desy.de`.
- It can plot momentum-weighted TMDs from TMDlib and collinear PDFs from LHAPDF.
- In addition, TMDplotter is also able to plot *partonic luminosities*, collinear as well as differential.
- Finally, it can produce derivative of collinear PDFs.

Wish

Please contact us to include your sets in TMDlib and TMDplotter!

Thank you for your attention!

ccfm-JH-2013-set2

Cross section

$$\sigma_{2,L} = \int_x^1 \mathrm{d}x' \int \mathrm{d}^2\mathbf{k_t}\hat{\sigma})_{2,L}(x,p,x',k_t)\mathcal{A}(x',k_t,p) \quad (6)$$

Structure functions

$$\sigma_{2,L} = \frac{4\pi^2\alpha}{p^2}F_{2,L} \quad (7)$$

Parametrisations

$$x\mathcal{A}_0(x,k_t) = Nx^{-B}(1-x)^C(1-Dx+e\sqrt{x})\exp[-k_t^2/\sigma^2] \quad (8)$$

Luminosity I

Relation with cross section from Ellis et al.

$$\sigma(s) = \sum_{ij} \int_{\tau_0}^{1} \frac{\mathrm{d}\tau}{\tau} \left[\frac{1}{s} \frac{\mathrm{d}\mathcal{L}_{ij}}{\mathrm{d}\tau} \right] [\hat{s}\hat{\sigma}_{ij}] \tag{10}$$

where $\tau = x_1 x_2$ and $s = \tau \hat{s}$

Simple differential luminosity

$$\frac{\mathrm{d}\mathcal{L}_{ij}}{\mathrm{d}x} = \frac{1}{1+\delta_{ij}} \int_0^1 \mathrm{d}x_1 \int_0^1 \mathrm{d}x_2 f_i(x_1, p) f_j(x_2, p) \delta(x - x_1 x_2) + (i \leftrightarrow j) \tag{11}$$

$$= \frac{1}{1+\delta_{ij}} \int_x^1 \frac{\mathrm{d}x'}{x'} f_i(x', p) f_j(x/x', p) + (i \leftrightarrow j) \tag{12}$$

Luminosity II

Double differential luminosity

$$\frac{\mathrm{d}^2\mathcal{L}_{ij}}{\mathrm{d}x\,\mathrm{d}q_t} = \frac{1}{1+\delta_{ij}}\int_0^1 \mathrm{d}x_1 \int_0^1 \mathrm{d}x_2 \int \frac{\mathrm{d}^2\mathbf{k_{t1}}}{2\pi} \int \frac{\mathrm{d}^2\mathbf{k_{t2}}}{2\pi} \mathcal{A}_i(x_1, k_{t1}, p)\mathcal{A}_j(x_2, k_{t2}, p) \times$$

$$\times\, \delta(x - x_1 x_2)\delta^{(2)}(\mathbf{q_t} - (\mathbf{k_{t1}} + \mathbf{k_{t2}})) + (i \leftrightarrow j) \tag{13}$$

$$= \frac{1}{1+\delta_{ij}}\int_x^1 \frac{\mathrm{d}x'}{x'} \int \frac{\mathrm{d}^2\mathbf{k_t}}{2\pi} \mathcal{A}_i(x', k_t, p)\mathcal{A}_j(x/x', |\mathbf{q_t} - \mathbf{k_t}|, p) + (i \leftrightarrow j) \tag{14}$$

Code

References