TMDlib 1.0.7 and TMDplotter 2.1.0

Deep Inelastic Scattering 2016 Hamburg

Patrick L.S. Connor

Francesco Hautmann   Hannes Jung   Johannes Scheller

Deutsches Elektronen-Synchrotron

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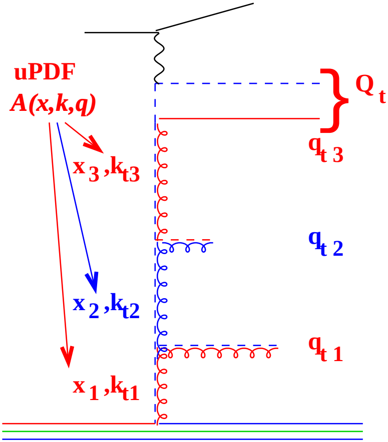
Introduction I

TMDs

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

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

$\longrightarrow$ proper 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

See Hautmann et al. [6]

[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 1.0.7

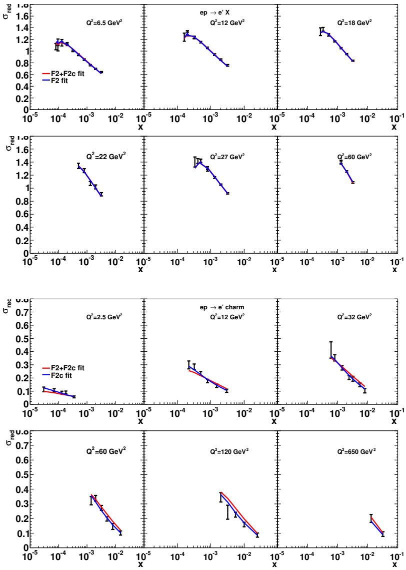
Purpose of the library

Provide a central, standard framework to all TMD fits à la LHAPDF as a function of x, k_t and p. (See Hautmann et al. [6])

Available sets as of today

	uPDF/TMD name	#sets	Λ^4_{QCD}	$\frac{k_t^{\mathrm{cut}}}{\mathrm{GeV}}$	$\frac{Q_0}{\mathrm{GeV}}$	Ref.
gluon	ccfm-JS-2001	1	0.25	0.25	1.4	[7]
	ccfm-setA0	4	0.25	1.3	1.3	[7]
	ccfm-setB0	4	0.25	0.25	1.3	[7]
	ccfm-JH-set 1	1	0.25	1.33	1.33	[4]
	ccfm-JH-set 2	1	0.25	1.18	1.18	[4]
	ccfm-JH-set 3	1	0.25	1.35	1.35	[4]
	ccfm-JH-2013-set1	13	0.2	2.2	2.2	[5]
	ccfm-JH-2013-set2	13	0.2	2.2	2.2	[5]
	GBWlight	1	–	–	–	[3]
	GBWcharm	1	–	–	–	[3]
	KS-2013-linear	1	0.3	–	–	[9]
	KS-2013-non-linear	1	0.35	–	–	[9]
	Kutak-linear-scale	1	0.35	–	–	[8]
	Kutak-nonlinear-scale	1	0.35	–	–	[8]
	EKMP	1	0.35	–	–	[1]
quark	ccfm-setA0	1	0.25	1.3	1.3	[7]
	ccfm-JH-2013-set1	1	0.2	2.2	2.2	[5]
	ccfm-JH-2013-set2	1	0.2	2.2	2.2	[5]
	SBRS-2013-TMDPDFs	1	–	–	1.55	[10]
	SBRS-2013-TMDPDFs-par	1	–	–	1.55	[10]
	EKMP	1	0.35	–	–	[1]

The two sets ccfm-JH-2013



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

$$F_2 \sim \sigma_2 = \hat{\sigma}_2 \otimes \mathcal{A} \qquad (1)$$

from measurements of the DIS structure fonctions in

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

See Jung et Hautmann [5]

TMDplotter 2.1.0

Basic purpose

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

Functionalities

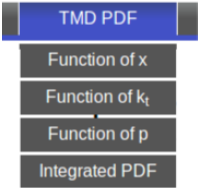
1. Plot $x\mathcal{A}(x, k_t, p)$;
2. integrate $x\mathcal{A}(x, k_t, p)$ and compare it with collinear PDFs from LHAPDF;
3. plot the ratios of the same curves;
4. and plot **partonic luminosities**, collinear *as well as transverse-momentum dependent*!

Remark

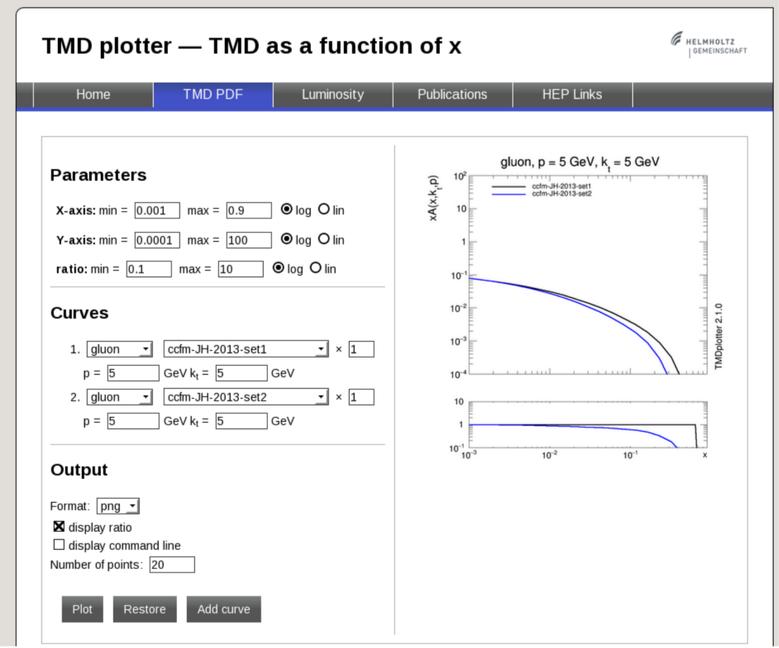
- Not limited to TMDs
- and not limited to densities!

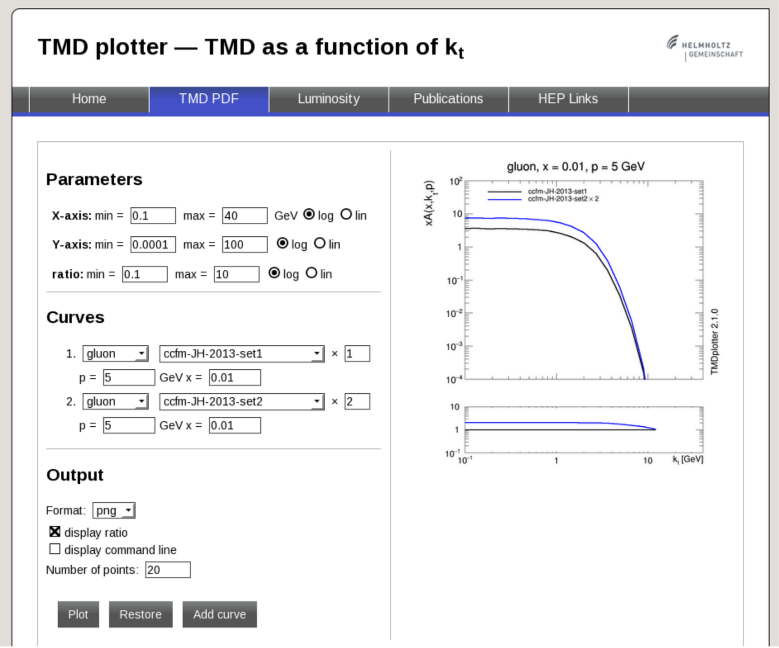
Hands-on

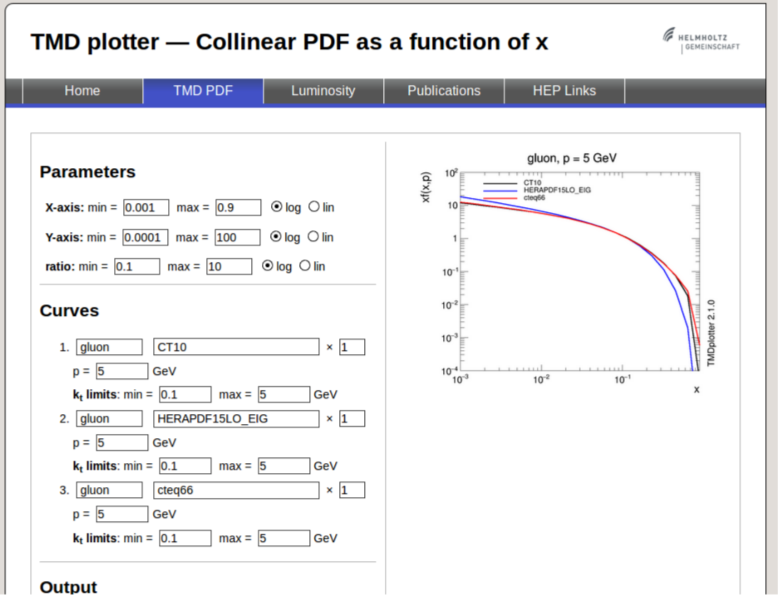
1. Go to `http://tmdplotter.desy.de`
2. TMD PDFs $\longrightarrow$ Function of x



3. Select:
   1. *gluon* and *ccfm-JH-2013-set1*
   2. *gluon* and *ccfm-JH-2013-set2*
4. Select *ratio*
5. Click on *Plot*

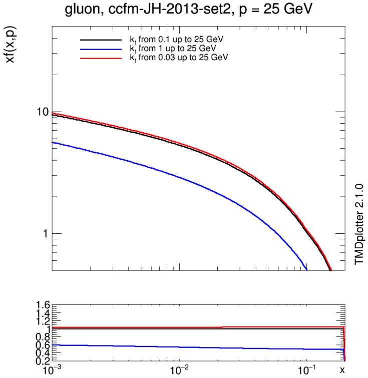

TMD plotter — TMD as a function of x
HELMHOLTZ GEMEINSCHAFT
Home
TMD PDF
Luminosity
Publications
HEP Links
Parameters
X-axis: min = 0.001 max = 0.9 log lin
Y-axis: min = 0.0001 max = 100 log lin
ratio: min = 0.1 max = 10 log lin
Curves
1. gluon ccfm-JH-2013-set1 × 1
p = 5 GeV k_t = 5 GeV
2. gluon ccfm-JH-2013-set2 × 1
p = 5 GeV k_t = 5 GeV
Output
Format: png
display ratio
display command line
Number of points: 20
Plot
Restore
Add curve
gluon, p = 5 GeV, k_t = 5 GeV
xA(x,k_t,p)
ccfm-JH-2013-set1
ccfm-JH-2013-set2
TMDplotter 2.1.0
x


TMD plotter — TMD as a function of k_t
HELMHOLTZ GEMEINSCHAFT
Home
TMD PDF
Luminosity
Publications
HEP Links
Parameters
X-axis: min = 0.1 max = 40 GeV log lin
Y-axis: min = 0.0001 max = 100 log lin
ratio: min = 0.1 max = 10 log lin
Curves
1. gluon ccfm-JH-2013-set1 × 1
p = 5 GeV x = 0.01
2. gluon ccfm-JH-2013-set2 × 2
p = 5 GeV x = 0.01
Output
Format: png
display ratio
display command line
Number of points: 20
Plot
Restore
Add curve
gluon, x = 0.01, p = 5 GeV
xA(x,k_t,p)
ccfm-JH-2013-set1
ccfm-JH-2013-set2 × 2
TMDplotter 2.1.0
k_t [GeV]

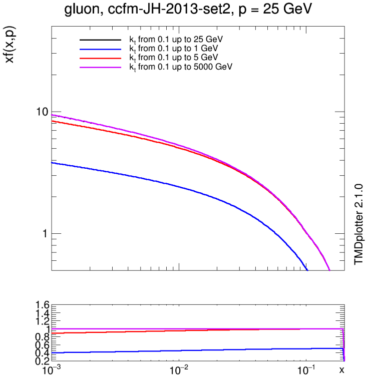

TMD plotter — Collinear PDF as a function of x
HELMHOLTZ GEMEINSCHAFT
Home
TMD PDF
Luminosity
Publications
HEP Links
Parameters
X-axis: min = 0.001 max = 0.9 log lin
Y-axis: min = 0.0001 max = 100 log lin
ratio: min = 0.1 max = 10 log lin
Curves
1. gluon CT10 × 1
p = 5 GeV
k_t limits: min = 0.1 max = 5 GeV
2. gluon HERAPDF15LO_EIG × 1
p = 5 GeV
k_t limits: min = 0.1 max = 5 GeV
3. gluon cteq66 × 1
p = 5 GeV
k_t limits: min = 0.1 max = 5 GeV
Output
gluon, p = 5 GeV
xf(x,p)
CT10
HERAPDF15LO_EIG
cteq66
TMDplotter 2.1.0
x

TMD integration

Varying the lower boundary



Varying the upper boundary



$$xf(x,p) = \int_{k_{t,\text{min}}}^{k_{t,\text{max}}} \mathrm{d}k_t \, x\mathcal{A}(x,k_t,p) \quad (2)$$

Luminosity

Idea

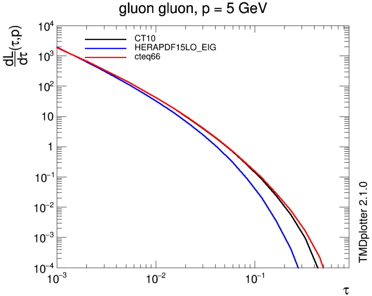
- The *collider luminosity* describes the amount of hadrons that a collider can provide.
- Analogously, the *partonic luminosity* describes the amount of partons that colliding hadrons can provide.

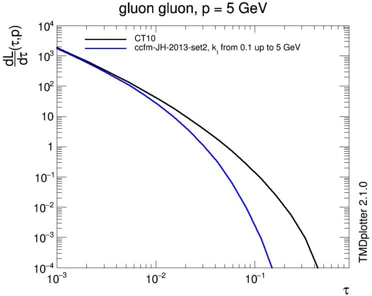
Following convention from Ellis et al. [2]:

$$\sigma(s) = \sum_{ij} \int_{\tau_0}^{1} \frac{\mathrm{d}\tau}{\tau} \left[\frac{1}{s} \frac{\mathrm{d}\mathcal{L}_{ij}}{\mathrm{d}\tau} \right] [\hat{s}\hat{\sigma}_{ij}] \tag{3}$$

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

Collinear luminosity

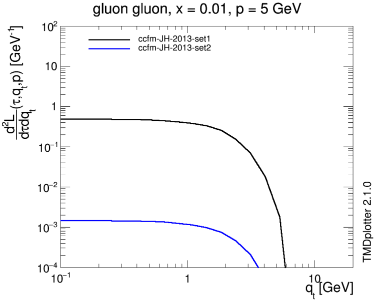


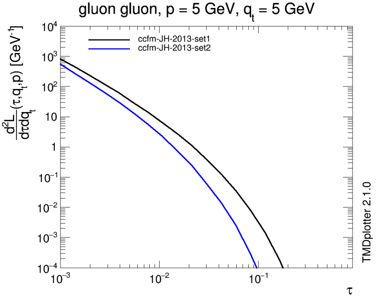


$$\frac{\mathrm{d}\mathcal{L}_{ij}}{\mathrm{d}\tau} = \frac{1}{1+\delta_{ij}} \int_0^1 \mathrm{d}x_1 \int_0^1 \mathrm{d}x_2 \, f_i(x_1, p)\, f_j(x_2, p)\, \delta(\tau - x_1 x_2) + (i \leftrightarrow j) \quad (4)$$

$$= \frac{1}{1+\delta_{ij}} \frac{1}{\tau} \int_\tau^1 \frac{\mathrm{d}x}{x} f_i(x, p)\, f_j(\tau/x, p) + (i \leftrightarrow j) \quad (5)$$

TMD luminosity





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

$$\times\,\delta(\tau - x_1x_2)\,\delta^{(2)}(\mathbf{q_t} - (\mathbf{k_{t1}}+\mathbf{k_{t2}})) + (i \leftrightarrow j) \tag{6}$$

$$= \frac{1}{1+\delta_{ij}}\,\frac{1}{\tau}\int_\tau^1 \frac{\mathrm{d}x}{x} \int \frac{\mathrm{d}^2\mathbf{k_t}}{2\pi}\, \mathcal{A}_i(x,k_t,p)\,\mathcal{A}_j(\tau/x, |\mathbf{q_t}-\mathbf{k_t}|, p) + (i \leftrightarrow j) \tag{7}$$

Summary

- TMDplotter will be soon 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*, simple as well as double differential.

Please take contact with us to include your sets in TMDlib and TMDplotter at `tmdlib@projects.hepforge.org`!

Thank you for your attention!

DIS16 DESY, HAMBURG 11-15 APRIL 2016

24th International Workshop on Deep-Inelastic Scattering and Related Subjects

11-15 April 2016, DESY, Hamburg

ccfm-JH-2013-set2

Cross section

$$\sigma_{2,L} = \int_x^1 \mathrm{d}z \int \mathrm{d}^2\mathbf{k_t}\, \hat{\sigma}_{2,L}(x,p,z,k_t)\, \mathcal{A}(z,k_t,p) \tag{8}$$

Structure functions

$$\sigma_{2,L} = \frac{4\pi^2\alpha}{p^2} F_{2,L} \tag{9}$$

Parametrisations

$$x\mathcal{A}_0(x,k_t) = Nx^{-B}(1-x)^C(1-Dx+e\sqrt{x})\left[-\frac{k_t^2}{\sigma^2}\right] \tag{10}$$

$$x\mathcal{A}_0(x,k_t) = Nx^{-B}(1-x)^C \exp\left[-\frac{k_t^2}{\sigma^2}\right] \tag{11}$$

TMD Plotter Code

- trying to use full power of C++
  - polymorphism
  - error handling
- library dependencies:
  - Root
  - GSL
  - LHAPDF 6.X
  - TMDlib
- will be soon released for download
  - smart, intuitive command line
  - extensible to other applications
  - documentation + doxygen

References I

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