Kinematic effects and ordering variables in TMD parton distributions obtained from HERA data

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Outline

1. TMD evolution in XFitter: current status

2. Open Issues in DIS at Low Q^2

3. The coupled DGLAP-TMD approach

4. Problem I: The large-k_t tail issue

5. Problem II: The ordering variable issue

6. Conclusion

Previous talk ...

✓ The description of the evolution package with all its different pieces was presented. In this method, DGLAP evolution equation is solved with a MC method.

✓ This method was applied to extract both collinear and transverse momentum dependent (TMD) quark and gluon parton densities using the precision HERA DIS data.

Outline

TMD evolution in XFitter: current status

Several new features implemented for usage of the TMD evolution in XFitter completely different compared to the old version.

- ✓ We can use the TMDs integrated over k_t and have that together with the coefficient function of the ME which comes from QCDNUM, to calculate F_2, F_L, etc.

- ✓ It can work over the whole kinematic range of x and Q^2.

- ✓ We have transverse momentum dependent gluons, sea quarks and valence quarks.

- ✓ The parametrization is changed now such that TMD uses just the standard XFitter parametrization.

- ✓ We can use the whole plotting package while comes from XFitter and plot the integrated parton distribution and F_2.

- ✓ We have TMD evolution but also directly get integrated PDF's out.

Outline

GBW with the full TMD evolution ...

✓ What we had originally in our mind was a better description of small-x, small-Q^2 F_2 data. We tried the CCFM evolution and GBW (the saturation ansatz). We realized that we cannot get good description of higher Q^2 data for F_2.

✓ In parallel we had activities for coupled DGLAP-TMD evolution. The idea was that we can have a better description at small-x, because in the standard approach GBW with DGLAP seems to work well (this is what many authors did), so we had problem with CCFM evolution.

The idea was to use a similar approach but with DGLAP-TMD evolution with GBW as an input to get proper description.

Outline

- GBW with DGLAP evolution seems to work, but GBW has k_t dependence. Therefore one would need an evolution which also treats the k_t dependence (not integrated over k_t). So we started with the coupled DGLAP-TMD evolution.

- Before one can apply that to the full cross section calculation, we have to check that if it works at medium and large Q^2. We started with the standard fit using integrated TMD.

- The next step is F_2 calculation with TMD. Stuck at the moment with technical difficulties!
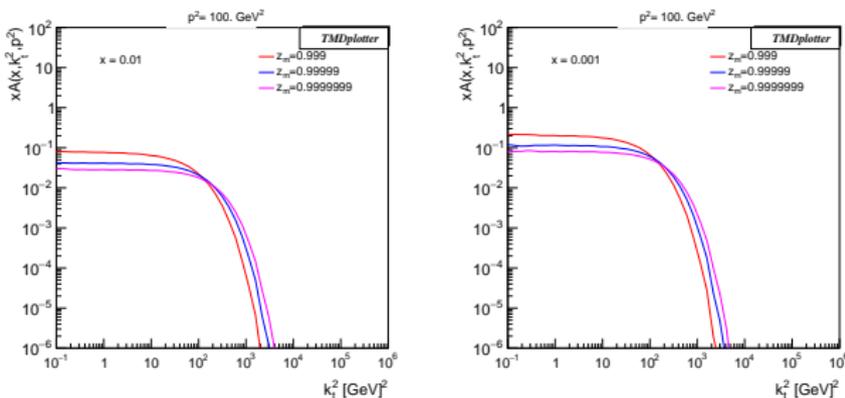
Now we discuss where the problems appear!

Outline

The large-k_t tail issue

At first we realize that there is an effect on z_{max} which is in the evolution, so the k_t dependence changes. We see there is a small dependence on z_{max}. The k_t distribution is different if we have smaller z_{max} or if we go to really close to one.
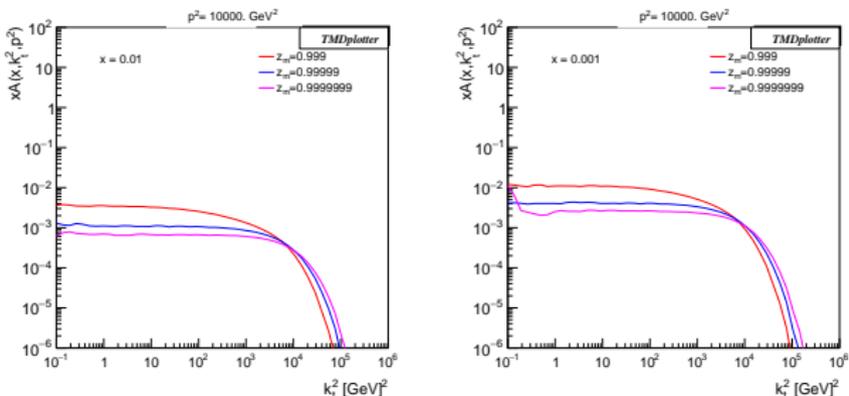

Figure 1: The plots show the k_t dependence as a function of the z_{max} cut applied in the splitting fct and in the sudakov factor. The important point in all the plots is that there is a tail of k_t to large values and the k_t can be larger than p (which one would naively not expect). This has quite some importance when calculating the cross section, as there are kinematic limitations and if k_t is included, then $x' = x(1 + k_t^2/Q^2)$.

What is even more interesting and which causes the problem is that we would normally integrate over TMD from zero-k_t up to the scale. While we have to integrate over the whole k_t range which has kinematic effects. If we just include the k_t, then x changes ($x' = x(1 + k_t^2/Q^2)$).
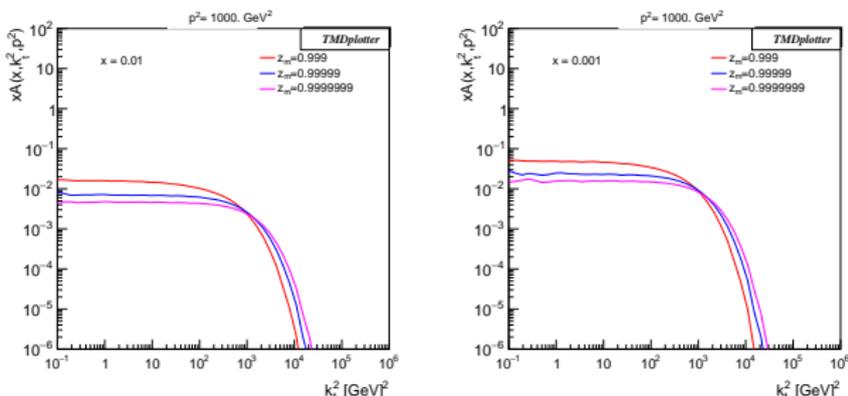
Figure 2: The important point in all the plots is, that there is a tail of k_t to large values and the k_t can be larger than p (which one would naively not expect). This has quite some importance when calculating the cross section, as there are kinematic limitations and if k_t is included, then $x' = x(1 + k_t^2/Q^2)$.

We can conclude from these plots that there is a tail to large k_t which is larger than the scale. The different sets of plots belong to the different scales. It's not a problem of one specific scale, this exists at every scale. k_t is just shifted to larger values.

Figure 3:   The important point in all the plots is, that there is a tail of k_t to large values and the k_t can be larger than p (which one would naively not expect). This has quite some importance when calculating the cross section, as there are kinematic limitations and if k_t is included, then $x' = x(1 + k_t^2/Q^2)$.
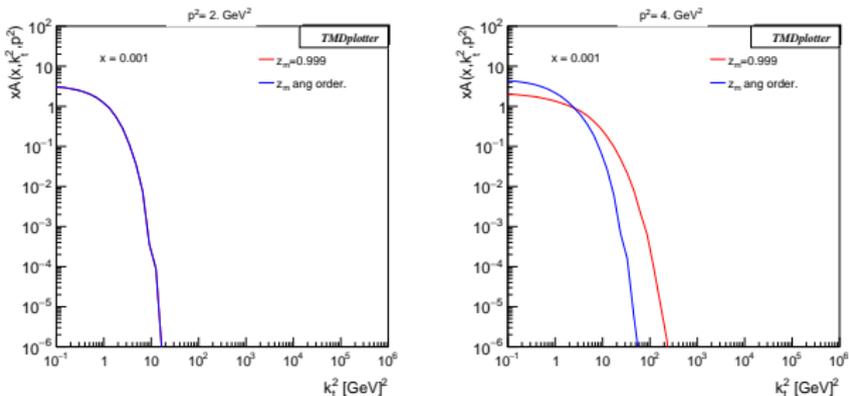
Outline

The ordering variable issue

In the evolution one can either have

- Q^2 ordering with fixed z_{max} (standard DGLAP)
- angular ordering

The integrated distributions are not changed very much but the way how k_t is calculated changes. Because different evolutions have different k_t treatment, there is a significant effect of the changed ordering!

Figure 4: At the scale of 2 GeV^2, curves both agree, since it is at the starting scale. At 4 GeV^2, where there is some evolution, the angular ordering curve at the scale is half of the size of Q^2 ordering.

The curve of angular ordering at the scale is already suppressed by the factor of two and it is half of the size of Q^2 ordering curve. This also makes an effect when calculating F_2 using the full TMD.
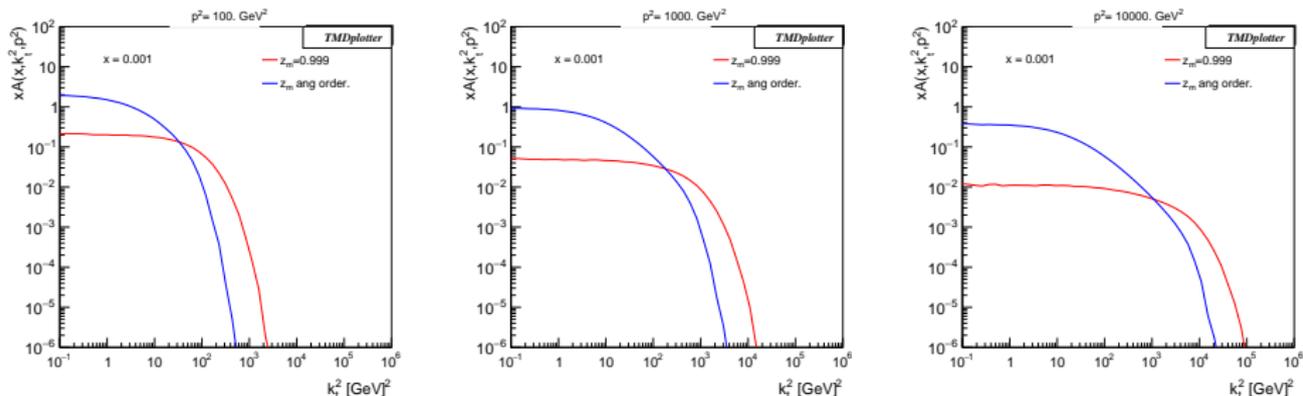
Figure 5: the k_t dependence for different ordering in the evolution: the standard ordering with a fixed z_{max}, the angular ordering with $z_{max} = 1 - p^2/q_0^2$ where p^2 is the evolution scale and q_0^2 is a soft cutoff ($q_0^2 = 1.9 \text{GeV}^2$). In the angular ordering k_t is calculated as $k_t = q(1 - z)/z$, so it is smaller than in the other cases.

Outline

Conclusion

- GBW with CCFM does not lead to a good fit.
- Test performed with full coupled TMD-DGLAP evolution.
- k_t dependence of TMD is significant.
- Future apply to small x.
- work in progress... stay tuned.

We are open to constructive comments and discussion.

Thanks for your paying attention.