A neither complete nor exhaustive review of something

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Disclaimer

Just a few slides to stimulate discussion and try to anticipate possible future steps for our benchmark

Kind of bird-eye view of different formalisms, without many technical details and with some "dictionary" included

Please forgive and point out any omission/mistake/inaccuracy: slides are meant to be continuously (even real-time!) updated

SCET

- effective field theory: high energy d.o.f. integrated out, soft and collinear d.o.f. decouple

$$A^\mu \to A^\mu_s + A^\mu_c + A^\mu_{\bar{c}} + \dots$$

$$\psi \to \psi_s + \psi_c + \psi_{\bar{c}} + \dots$$

$$\mathcal{L} = \mathcal{L}_s + \mathcal{L}_c + \mathcal{L}_{\bar{c}} + \dots$$

(DY) $$\sigma \sim Beam(\mu,\nu) \otimes Beam(\mu,\nu) \otimes Soft(\mu,\nu) \otimes Hard(\mu,Q)$$

- Beam function directly related to collinear PDF (C x f)
- two non-physical scales for renormalisation of UV (μ) and rapidity (ν) divergences
- ν arises from distinguishing soft modes from collinear modes (connected by Lorentz boost), just as μ arises from distinguishing different virtualities
- each function has its own RG evolution: $\dfrac{d \ln X}{d \ln \mu} = \Gamma_X \quad with \quad X = B, H, S$ leading to resummed predictions and customary formula (next slide)

TMD

- 2D factorisation theorem (SIDIS, DY, $e^+e^- \to$ hadrons)

(DY) $$\sigma \sim f(x, k_T^2, \mu^2) \otimes f(x, k_T^2, \mu^2) \otimes Hard$$

- same divergencies → same RG evolutions as SCET

$$f(x, k_T^2, \mu^2) \sim Beam \otimes \sqrt{Soft}$$

- For the Drell-Yan process, SCET and TMD are equivalent

$$f(x, k_T^2, \mu^2) \otimes f(x, k_T^2, \mu^2) \otimes Hard \sim Beam \otimes Beam \otimes Soft \otimes Hard$$

- Common form (CSS)

$$\sigma \sim [C \otimes f(x)]\, Hard\, [C \otimes f(x)]\ \exp(S)\ \exp(S_{NP})$$

q_T resummation

- 1D (collinear) factorisation theorem

$$\sigma \sim f(x,\mu^2) \otimes f(x,\mu^2) \otimes Hard$$

- resummation (i.e. factorisation and exponentiation) of soft-gluon emissions to all orders

- dynamical ($|M_{n-gluons}| \sim |M_{1-gluon}|^n$) and kinematical ($PS_{n\text{-gluons}} \sim \prod_n PS_{1\text{-gluon}}$) factorisation properties of QCD

- identical formula as in the previous slide

$$\sigma \sim [C \otimes f(x)]\, Hard\, [C \otimes f(x)]\ \exp(S)\ \exp(S_{NP})$$

For hadroproduction of colourless final states:

2D

SCET/TMD

RG evolution →

You Are Here

↑ q_T resummation

1D

$$\sigma \sim [C \otimes f(x)]\, Hard\, [C \otimes f(x)]\, \exp(S)\, \exp(S_{NP})$$

1st order OPE
for TMD operator/
Collinear emissions
("matching"/"Wilson"/
"collinear"/"boundary")

("Sudakov": soft emissions
contains "cusp"/"A"
and "non-cusp"/"B"
anomalous dimensions)

necessary input:
RG evol. eq. needs initial condition
(to be determined from data)

Parton Branching

- parton-shower based: evolution equation with Sudakov factor denoting probability of no-(resolvable)branching
- difference w.r.t. customary parton-shower: forward evolution (from hadron scale to hard scale) instead of backward evolution
- angular-ordered emissions from initial parton -> non-ordered emissions give subleading logs
- possible to prove formal equivalence with b-space formalism at various accuracies

Codes

- SCET: SCETlib, CuTe
- TMD: ResBos2, NangaParbat
- q_T resummation: DYRes/DYTURBO, ReSolve
- shower-like: RadISH, PartonBranching

Basic ingredients (A,B,C functions) common to all codes.

Main differences in:

- working space for resummation/evolution (b_T or q_T)
- dealing with NP-physics (prescription/cutoff and intrinsic-k_T)
- matching with fixed order at intermediate q_T

Differences

- NP-physics (1): avoiding the Landau pole
  - q_T-space: low-q_T cutoff
  - b_T-space needs either a "freezing"/"saturation" of b (MANY CHOICES for "b_*") or a "minimal prescription" (suitable integration path in complex-b plane)
- NP-physics (2): intrinsic-k_T effects
  - NP form factor to be determined from data, in principle kinematics- and flavour-dependent
- matching with fixed order at intermediate q_T
  - multiplicative $\sigma_{res} \left[\frac{\sigma_{fix}}{\sigma_{res}} \right]_{expanded}$ or additive $\sigma_{res} + \sigma_{fix} - \sigma_{asy}$
  - damping function to switch off resummation/evolution (MANY choices)
  - unitarity enforcing ($\int \frac{d\sigma}{dq_T} dq_T = \sigma$), i.e. modified logs (damping function and NP may spoil it!)
- lepton cuts