Subleading Power Discussion

Moderator: Iain Stewart

Topics

- Lattice Limits: when does Euclidean (LaMET) work (A.V's talk)
- Choice of Basis for subleading power operators (L.G.'s talk)

- <u>Factorization ok?: </u> Glauber interactions @ Subleading Power
- Endpoint Divergences@ Subl.Power, impede factorization?
- Resummation: form of RGE at subleading power

“Factorization Violation”

My Definition: The expected form for a factorization formula is invalid.

Reasons Factorization can fail:

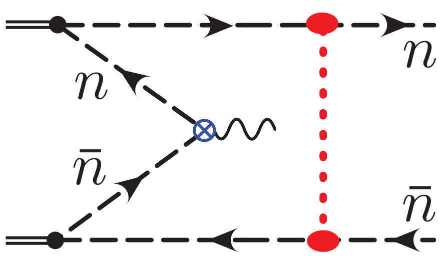
- Measurement doesn’t factor: no simple factorization with universal functions. (eg. Jade jet algorithm)

- Divergent convolutions, not controlled by ones regulation procedures. (Requires more careful construction.)

$$\int_0^1 \frac{dx}{x^2}\, \phi_\pi(x,\mu)$$

- Interactions that couple other modes and spoil factorization.

  Glauber exchange



  spectator-spectator CSS
  cancel in proof for Drell-Yan

- Collinear Wilson Line universality fails.

  examples studied by Collins, Qiu, Aybat, Rogers, …

  $H_3, H_4 \simeq$ back-to-back
  $H_1 + H_2 \to H_3 + H_4 + X$
  pT dependent

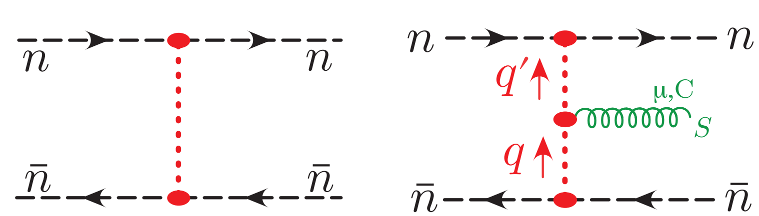
Factorization ok?: Glauber interactions @ Subleading Power

easy to state precisely what is required in SCET

$$\mathcal{L}_{\mathrm{SCET_{II}}} = \mathcal{L}_s^{(0)}(\psi_s, A_s) + \sum_n \mathcal{L}_n^{(0)}(\xi_n, A_n) + \mathcal{L}_{\mathrm{hard}}(\text{field products})$$
$$+ \mathcal{L}_G^{(0)}(\psi_s, A_s, \xi_{n_i}, A_{n_i})$$
$$+ \sum_j \mathcal{L}^{(j)}_{\mathrm{subl.power}}(\text{field products})$$

only $\mathcal{L}_G^{(0)}$ can break factorization, even at subleading power
question is simply how it interferes with subleading power operators

$$\mathcal{L}_G^{\mathrm{II}(0)} = \sum_{n,\bar n} \sum_{i,j=q,g} \mathcal{O}_n^{iB} \frac{1}{\mathcal{P}_\perp^2} \mathcal{O}_s^{BC} \frac{1}{\mathcal{P}_\perp^2} \mathcal{O}_{\bar n}^{jC} + \sum_n \sum_{i,j=q,g} \mathcal{O}_n^{iB} \frac{1}{\mathcal{P}_\perp^2} \mathcal{O}_s^{j_n B}$$



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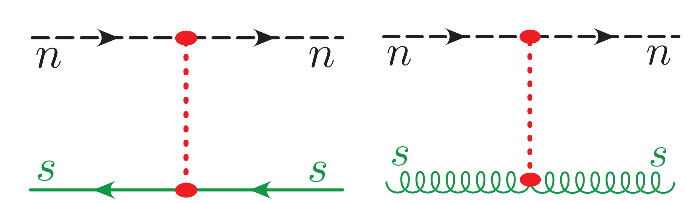

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- Endpoint Divergences @ Subl.Power, do they impede factorization?

SCET literature:

$$\int_0^1 \frac{dx}{x}\frac{\phi(x)}{x} \sim \int_0 \frac{dx}{x} = ?$$

- $B \to \pi\ell\nu$, $B \to \pi\pi$ are subleading power (we must turn convert a spectator quark from soft to collinear) & have endpoint singularities. These processes involve sums of contributions, including terms with both soft & collinear components.
  [Bauer, Pirjol, Stewart; Beneke, Feldmann; Neubert et.al. (~2001) …]

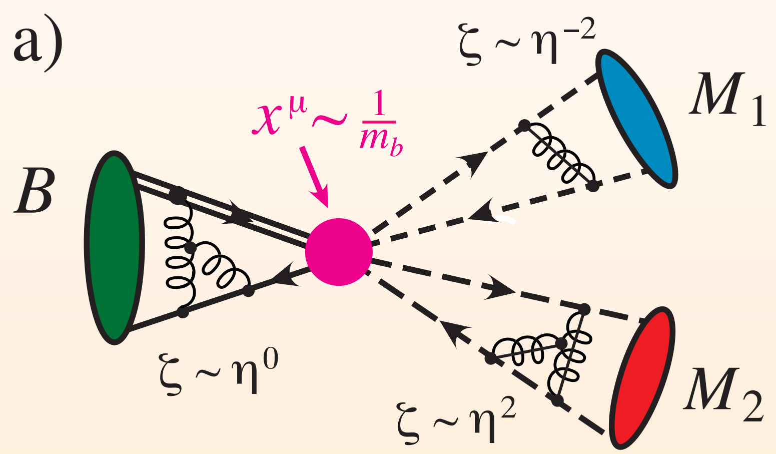
- Zero-bin subtractions avoid double counting between collinear and soft regions at subleading power
  [Manohar & Stewart hep-ph/0605001]

- Rapidity regulators; and how they work at subleading power
  [Chiu, Jain, Neill, Rothstein (2012); …,]

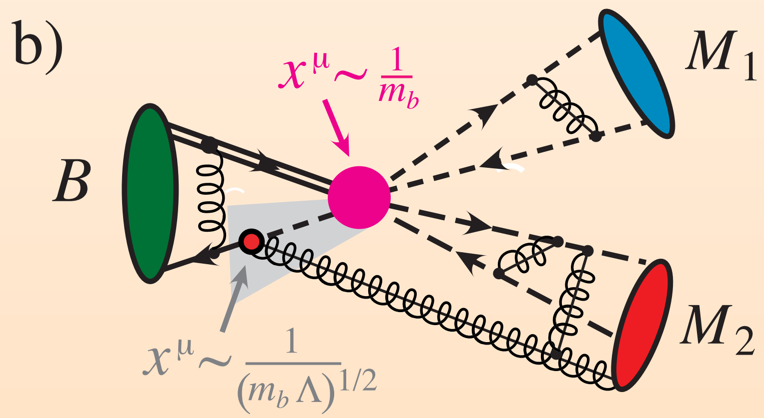
- eg. Annihilation channel for $B \to \pi\pi$ and soft-collinear overlaps
  [Arnesen, Ligeti, Rothstein, & I.S. (2006)]

Slide from my talk at CKM 2006 in San Diego

Annihilation is real at lowest order in α_s expansion



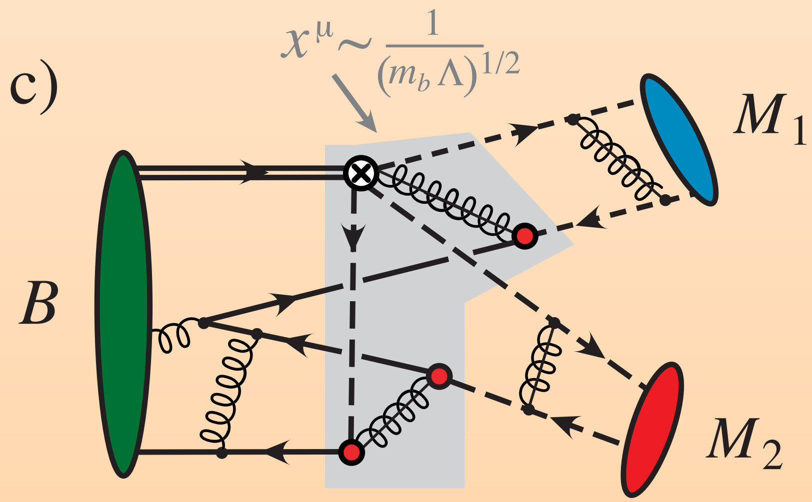
Suffers from endpoint divergences.
But they do not introduce a phase.



Leading order, its same size as a).
No endpoint divergences here.
No imaginary part here either.

$\propto \phi_B^+(k)\, \phi_{M_1}(y)\, \phi_{3M_2}(x_1, x_2)$

Arnesen et al.
hep-ph/0611356



A soft rescattering annihilation contribution DOES have a strong phase, but is one higher order in α_s

However:
Might be large if intermediate scale α_s expansion did not converge here

Solution to endpoint divergence problem has been worked out explicitly in SCET for several (simpler) examples

see talk by Julian Strohm at SCET 2022 for a review

Factorization Theorems for processes with endpoint divergences

$B \to \chi_{cJ} K$ and $h \to \gamma\gamma$

[Beneke, Vernazza; 0810.3575]

[Liu, Mecaj, Neubert, Wang; 1912.08818, 2009.04456, 2009.06779]

NLP Endpoint Factorization and Resummation of Off-Diagonal "Gluon" Thrust

Simplest example to look at: Julian Strohm SCET 2022

Joint Work with **Martin Beneke**, **Mathias Garny**, **Sebastian Jaskiewicz**, **Robert Szafron**, **Leonardo Vernazza**, and **Jian Wang**.

arXiv:2207.14199

For off-diagonal channels, the leading logarithms already exhibit non-trivial structure in contrast to diagonal channels.

[Moult, Stewart, Vita, Zhu; 1804.04665][Beneke et al.; 1809.10631]

we referred to this as the "Soft Quark Sudakov"

- Resummation: form of RGE at subleading power

Known for many operators in SCET
[Beneke et.al. (2004); Neubert et.al. (2004), …,
Beneke et.al. (2017, 2018); Vladimirov, Moos, Scimemi (2021)]

Factorization theorems are sums of factorized terms, and RGEs in general are not multiplicative, but can mix into new operators
eg. thrust, threshold resummation $\delta(k - \ldots) \to \theta(k - \ldots)$
[Moult, I.S., Vita, Zhu (arXiv:1804.04665), Beneke et.al. (arXiv:2205.04479), …]

In general at subleasing power we get a combination of
cusp anomalous dimension terms (dble. logs),
convolutions from the hard region (DGLAP), and
convolutions from the soft region

Harder to solve in general