

# Roundtable Discussion on Factorization, Endpoints, etc.

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# Basics of EFT

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- Factorization of SD (calculable) from LD effects (same as in full theory)
- Extract Wilson coefficients and anomalous dimensions (IR insensitive)  
→ SD physics (RG improved)
- EFT constructed to reproduce low-energy behavior of full theory

# Basics of EFT

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- Never worry that pQCD is formulated in terms of quarks & gluons, while nature (“true QCD”) uses hadrons
- Working with quarks & gluons fine as long as we extract SD quantities
- Importance of factorization theorems:

$$\text{Observable} = C_{\text{PT}} \otimes M_{\text{hadr}}$$

Extracted from quark-gluon theory

Hadronic matrix elements

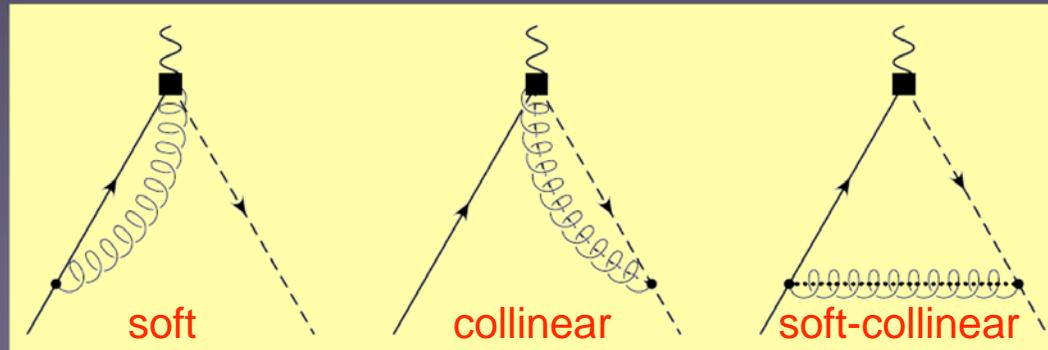
# An unexpected fact

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- Processes with soft-collinear dynamics sensitive (at least in pQCD) to scales below  $\Lambda_{\text{QCD}}$  (not external scales)
- **Crucially important** that EFT has same IR sensitivity to these scales (else wrong matching, anom. dimensions, ...)

# Soft-collinear current

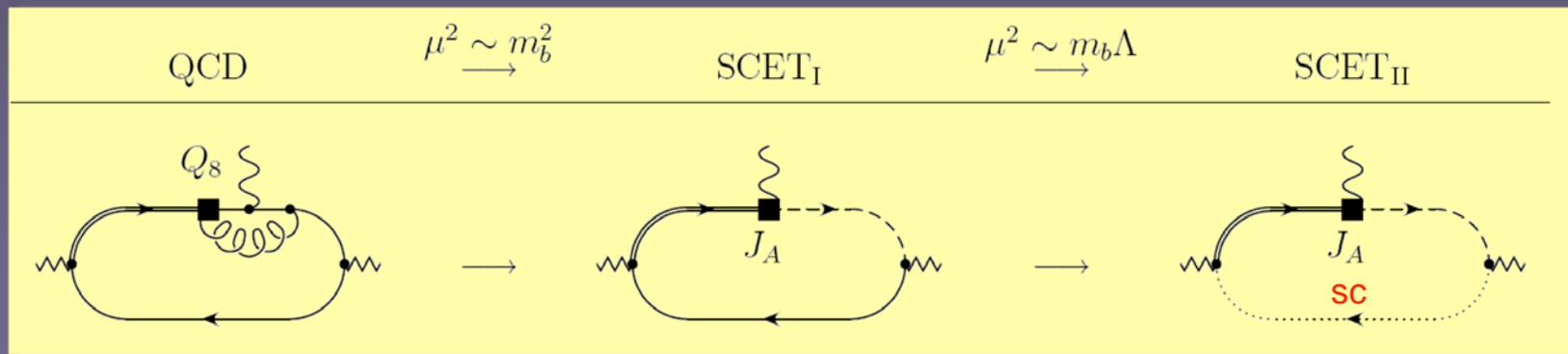
- Anomalous dimension calculated with off-shell IR regulator:



$$\begin{aligned}
 & \left( \frac{2}{\epsilon^2} - \frac{2}{\epsilon} \ln \frac{-p_s^2}{\mu^2} + \frac{3}{2\epsilon} \right)_{\text{soft}} + \left( \frac{2}{\epsilon^2} - \frac{2}{\epsilon} \ln \frac{-p_c^2}{\mu^2} + \frac{3}{2\epsilon} \right)_{\text{collinear}} + \left( -\frac{2}{\epsilon^2} + \frac{2}{\epsilon} \ln \frac{(-p_s^2)(-p_c^2)}{2p_{s+} \cdot p_{c-} \mu^2} \right)_{\text{soft-collinear}} \\
 & = \frac{2}{\epsilon^2} + \frac{2}{\epsilon} \ln \frac{\mu^2}{2p_{s+} \cdot p_{c-}} + \frac{3}{\epsilon}.
 \end{aligned}$$

# EFT should describe arbitrary correlation functions

- Soft-collinear region present in on-shell Green functions (LSZ reduction of external hadron states):



# IR regulators?

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- Messenger modes appear in all schemes preserving gauge and Lorentz invariance (still no counter examples)
- Can cook up (inconvenient) schemes where sc modes are not present
- Nothing wrong with this, but, as Iain said:  
*“SCET should be defined independent of UV and IR regulators”*

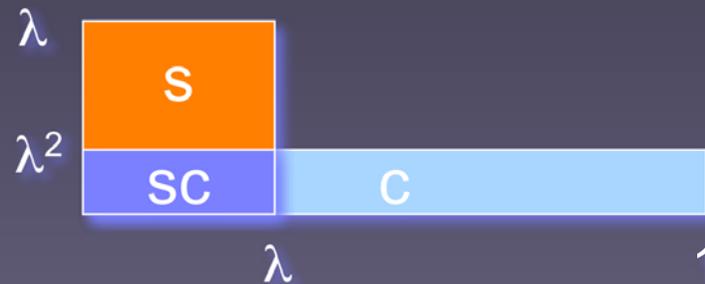
# IR regulators?

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- Eliminating messengers with mass terms has several problems:
  - Breaks gauge invariance
  - Requires analytic regulators (theory no longer defined in dim. reg.)
  - Troubles with method of regions: need more and more modes in higher orders?
  - Too strong distortion of low-energy QCD?  
Useful to discuss factorization?

# Double counting?

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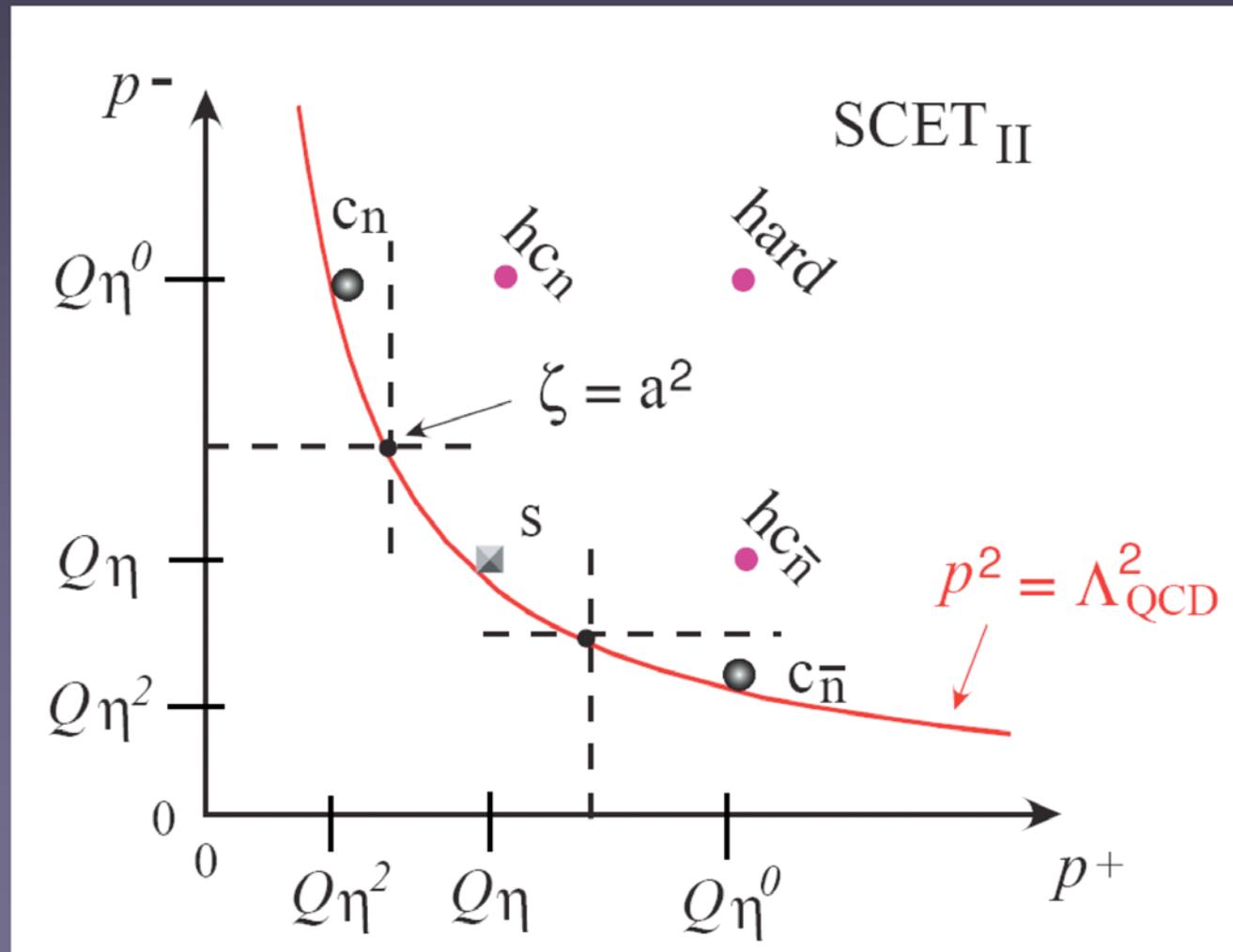
- In cutoff regularization, subtractions required to avoid 3x counting (no need for this in dim. reg.)
- **Zero-bin subtraction does not eliminate the sc region!**

# Should “everything factorize”?

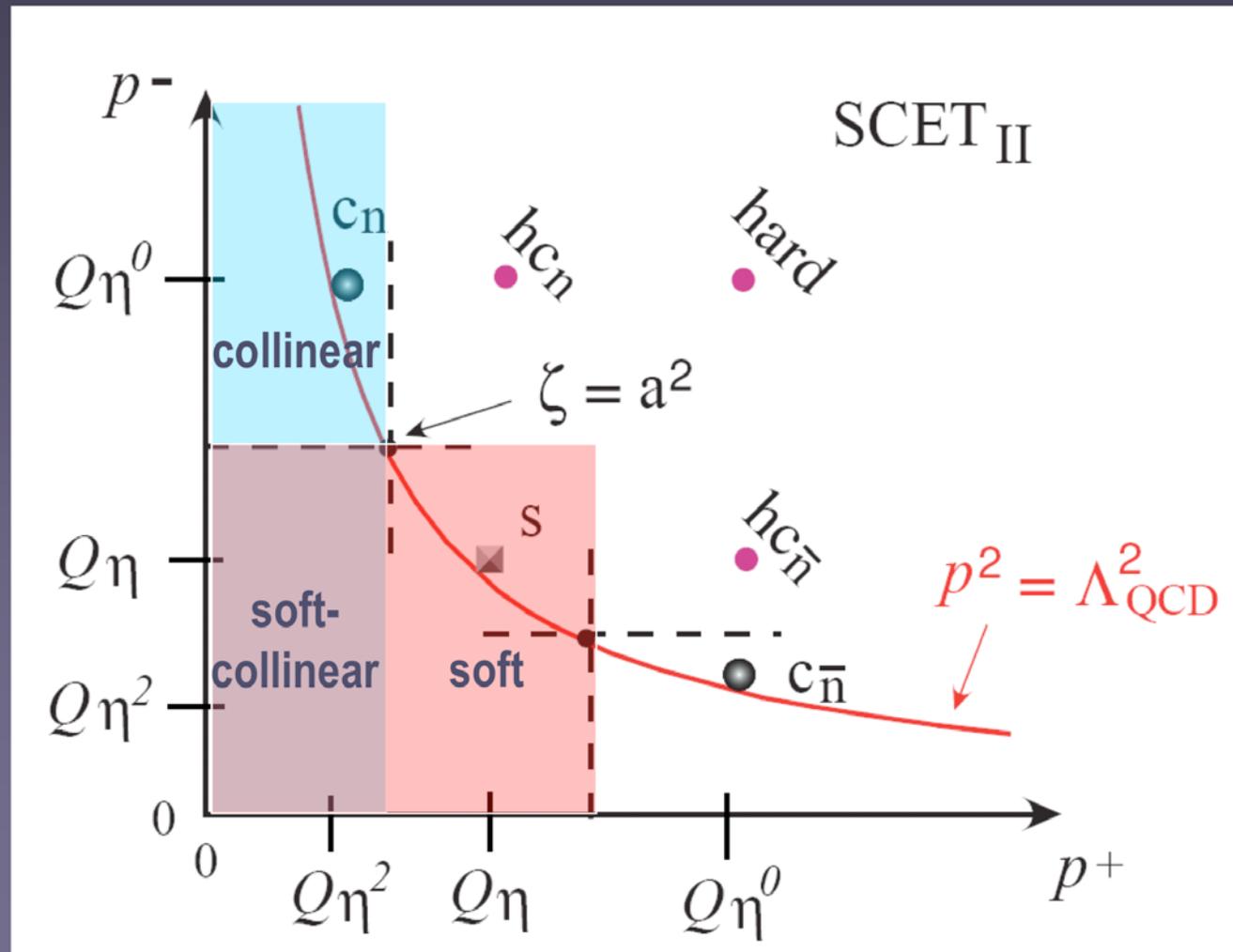
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- Would be nice if this were true, but ...
- Messenger sector of SCET<sub>II</sub> is source of nonfactorizable effects
- Given that soft and collinear modes have some scale  $p^2$ , why should we expect them to always factorize?

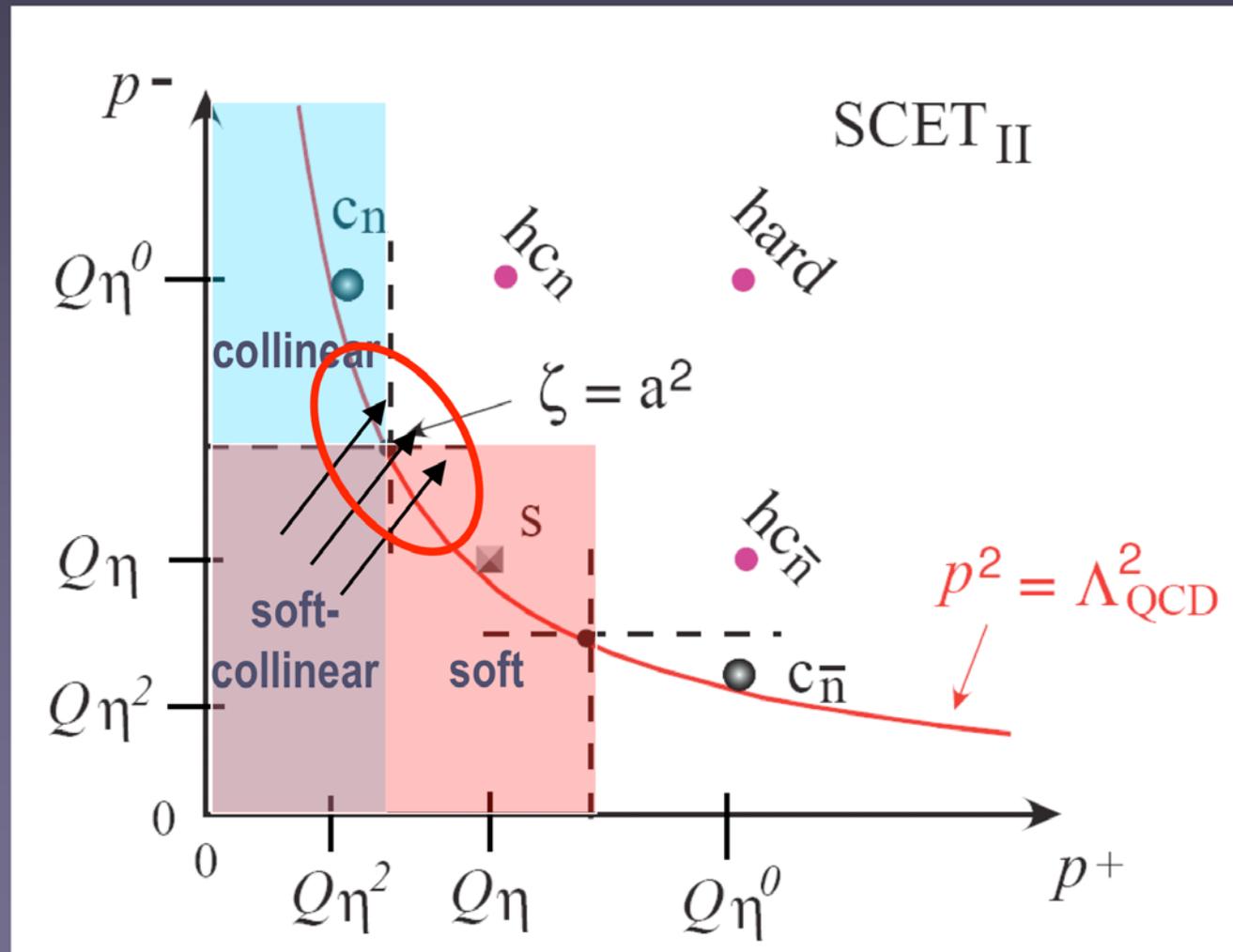
# Soft-collinear interactions?



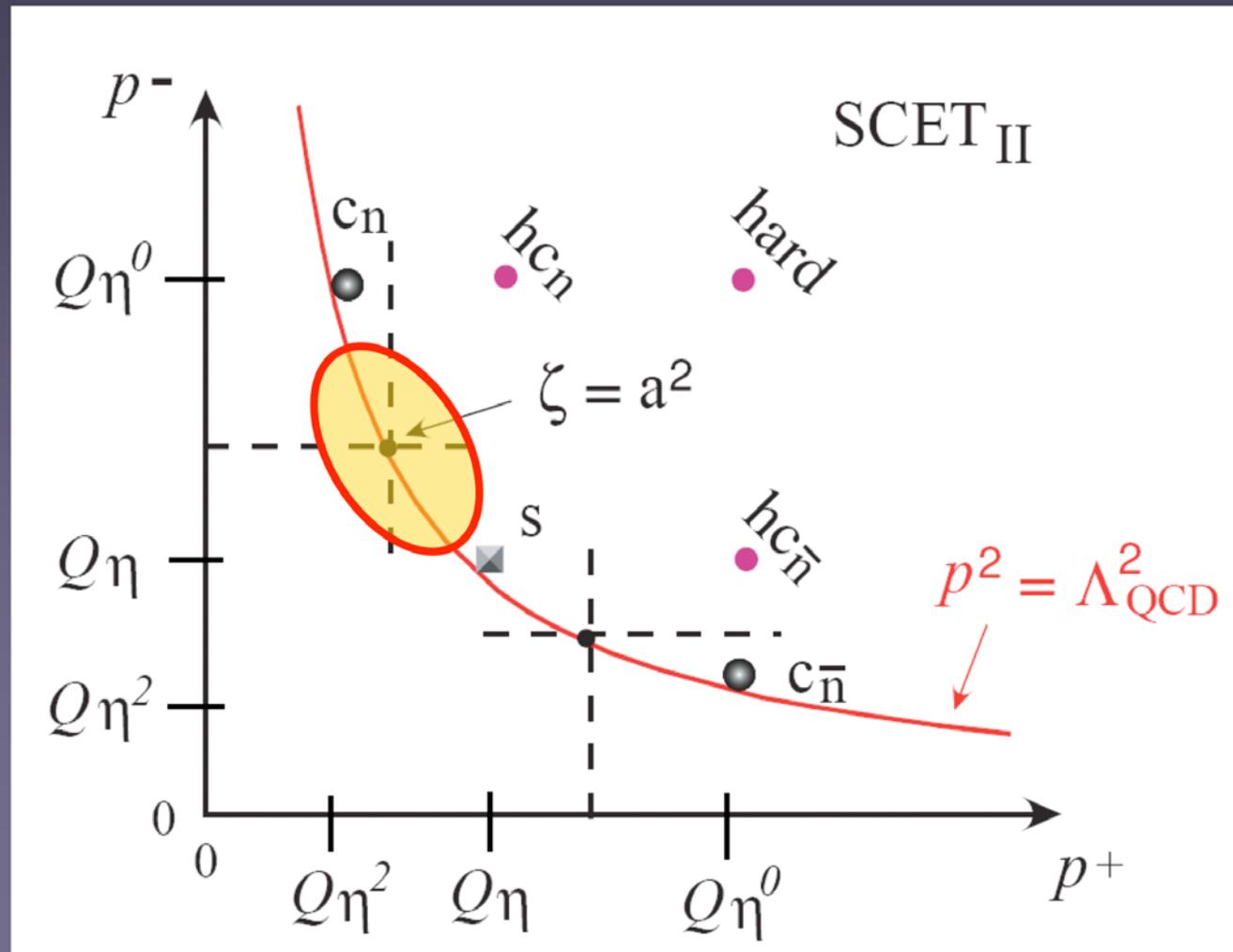
# Soft-collinear interactions?



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# Soft-collinear interactions?

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- Argument that there are no interactions between soft and collinear modes is probably too naïve
- Presence of  $\Lambda_{\text{QCD}}$  as IR regulator not sufficient to discard soft-collinear modes