Probing coherence effects with jet formation time

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SA-CERN

LUND UNIVERSITY

Introduction

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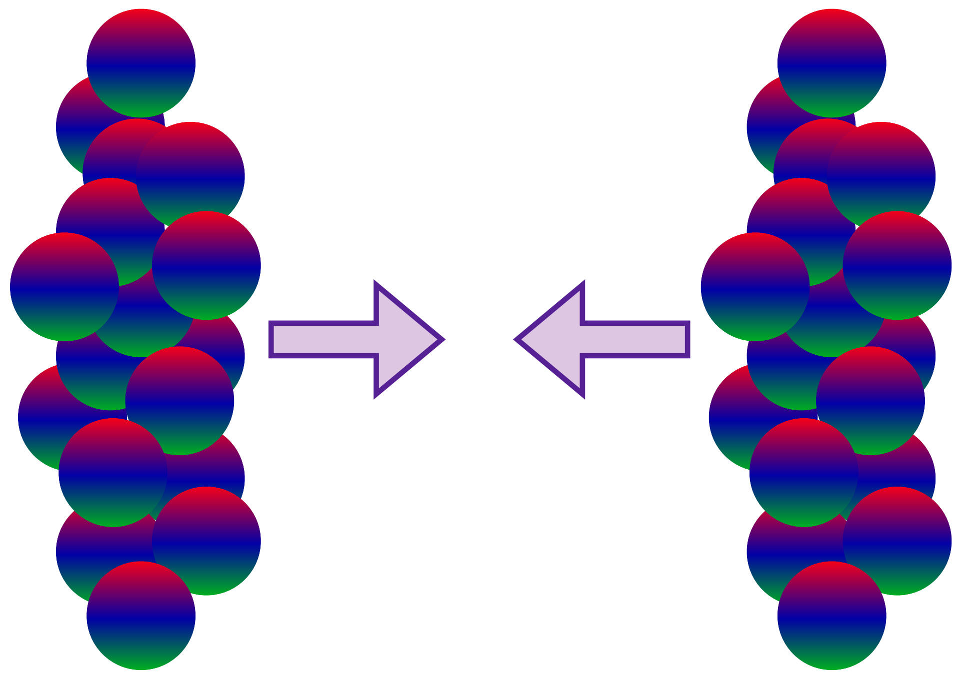
Motivation

- Well established medium formation in large systems



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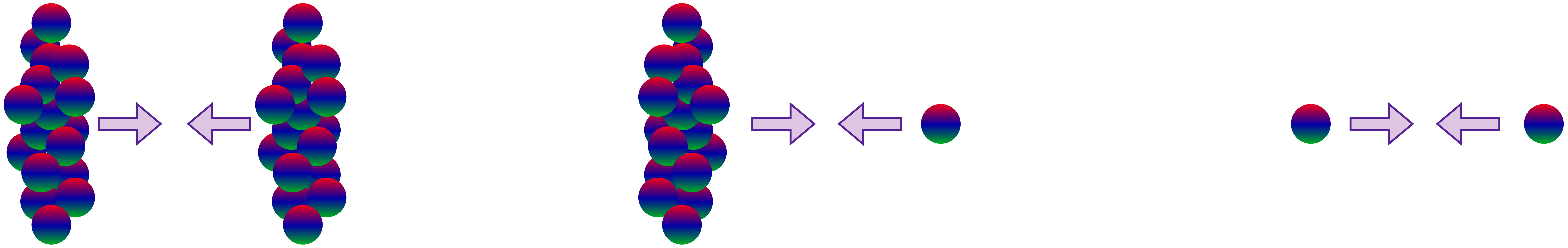

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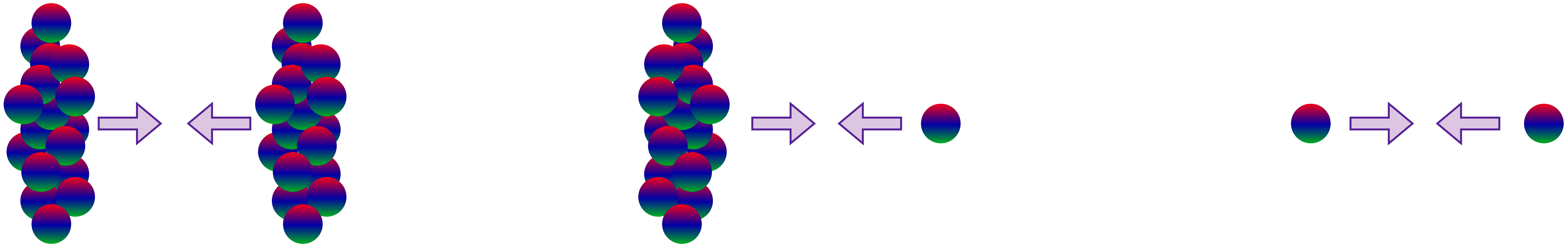
Motivation

- Well established medium formation in large systems
- Medium signatures observed in small systems, but no energy loss
- Coherence effects could help probe jet-medium interaction



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JEWEL

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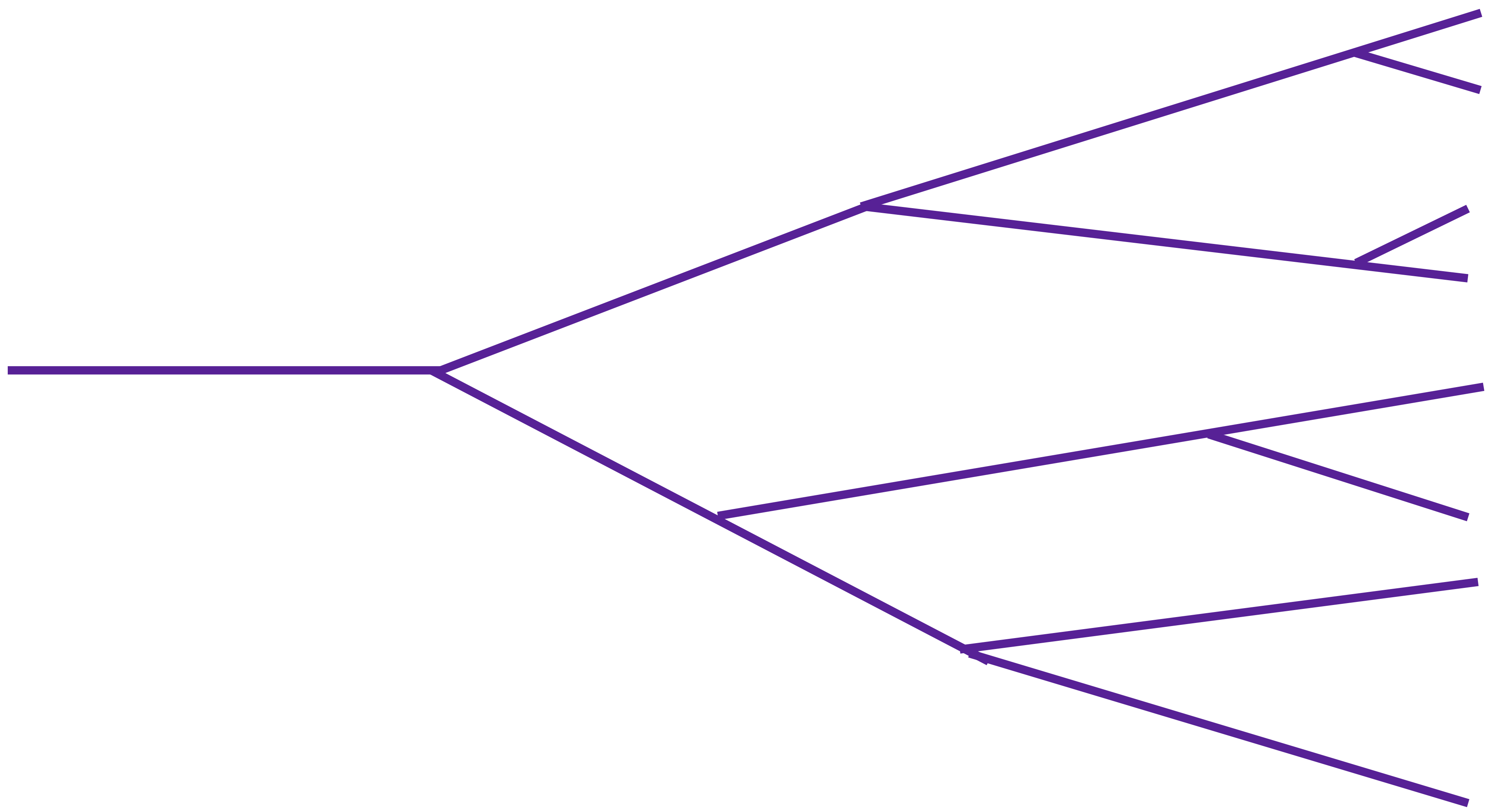

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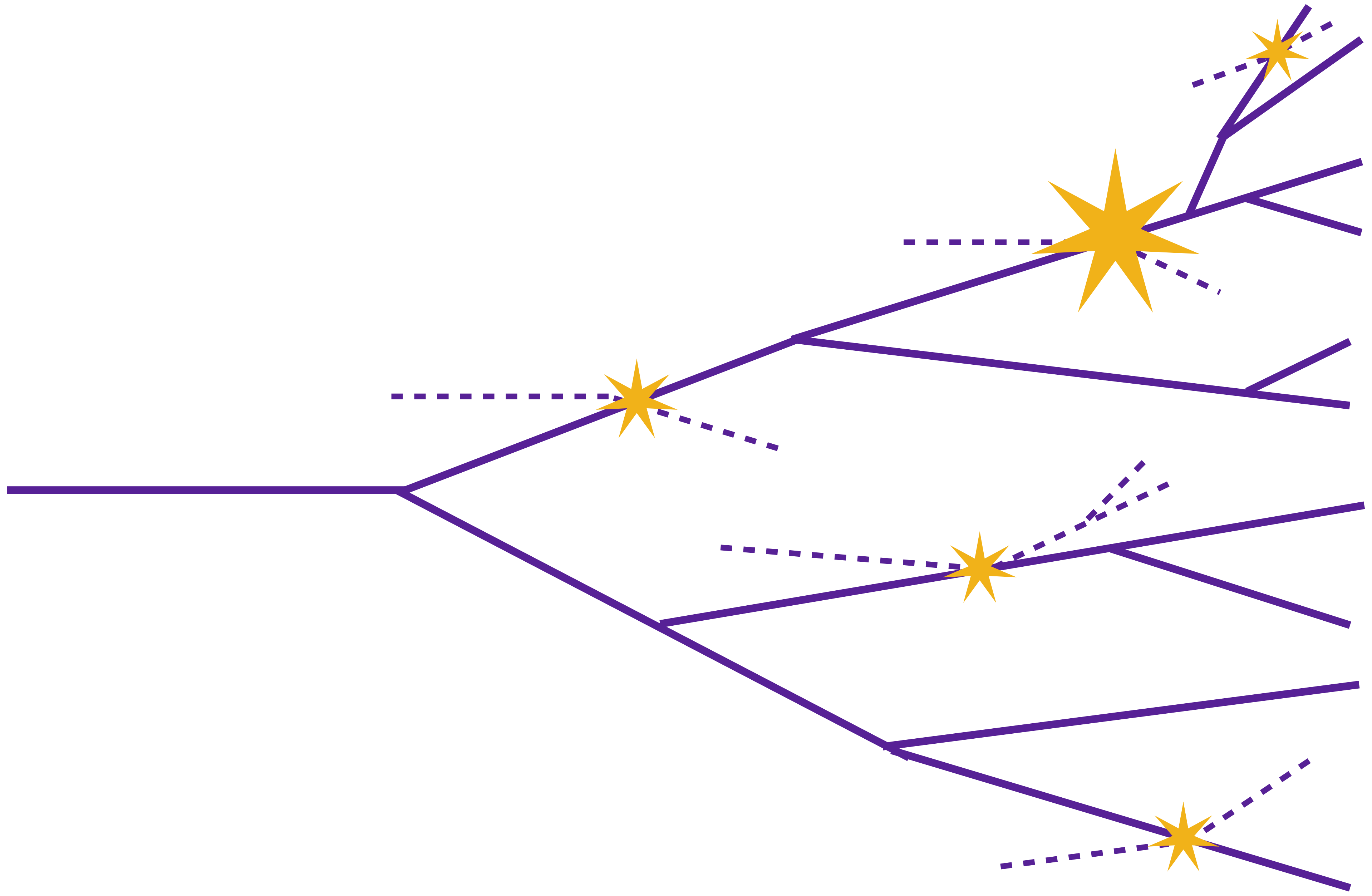

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JEWEL

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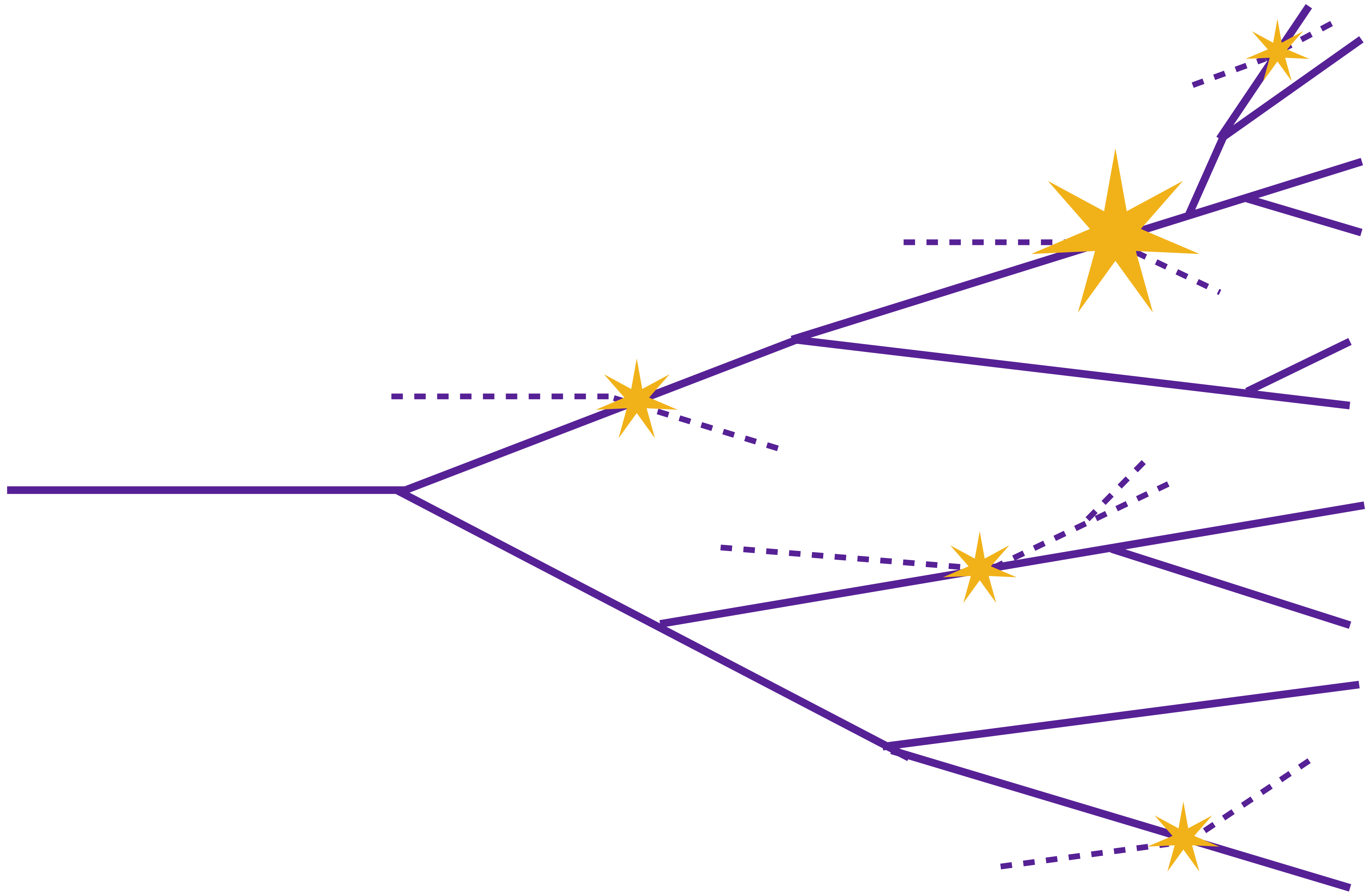
- Partons are allowed to scatter off medium particles between splittings
- Scattering cross section is calculated in pQCD and regularized by the Debye mass

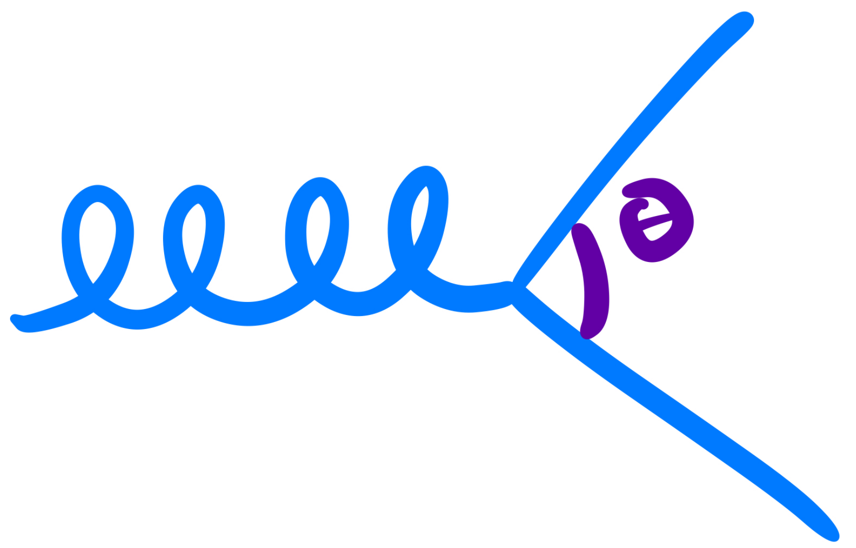


$$\frac{d\sigma}{dt} \propto \frac{\alpha_S^2}{(t+\mu_D^2)^2}$$

Introduction

Coherence: angular ordering

- Subsequent emissions in a parton shower follow angular ordering due to color coherence



1st splitting

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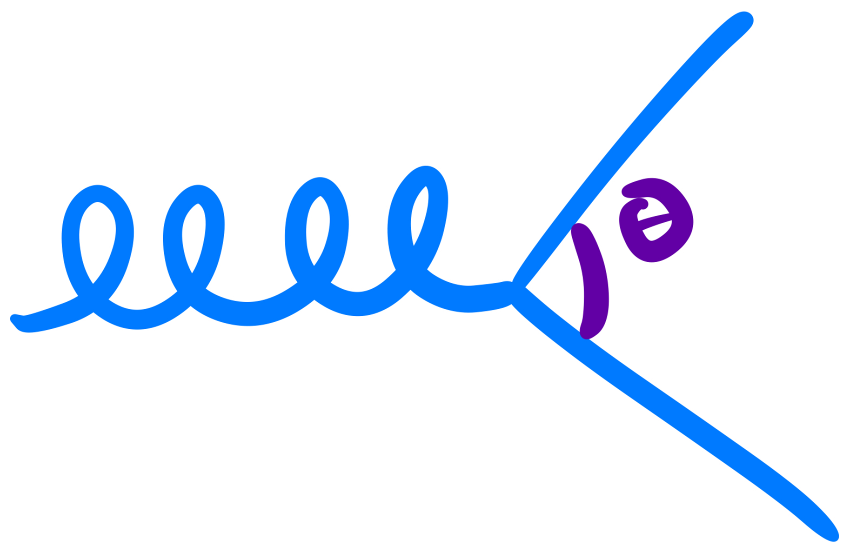

$\tilde{\theta} > \theta$

1st splitting

2nd splitting

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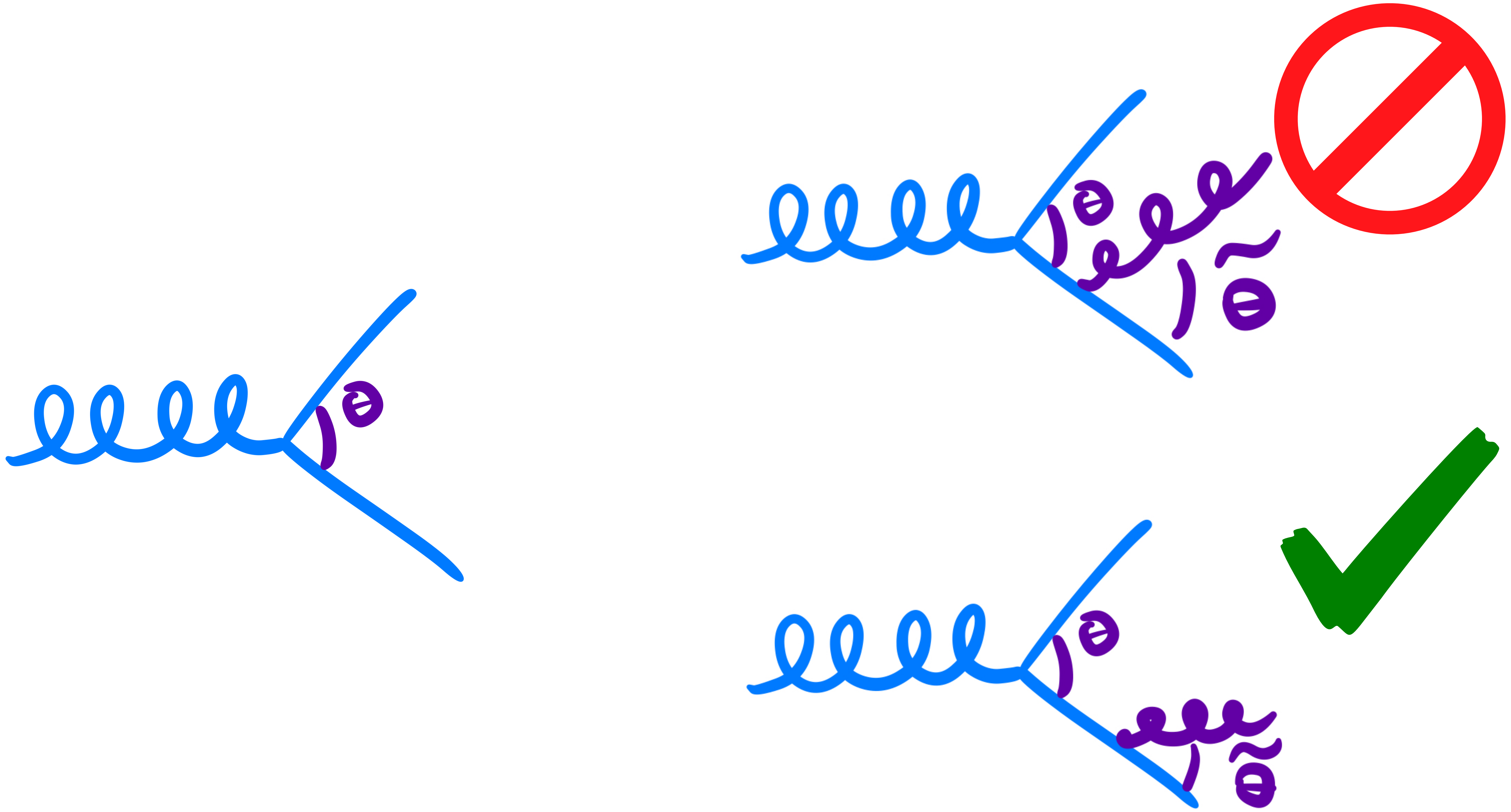

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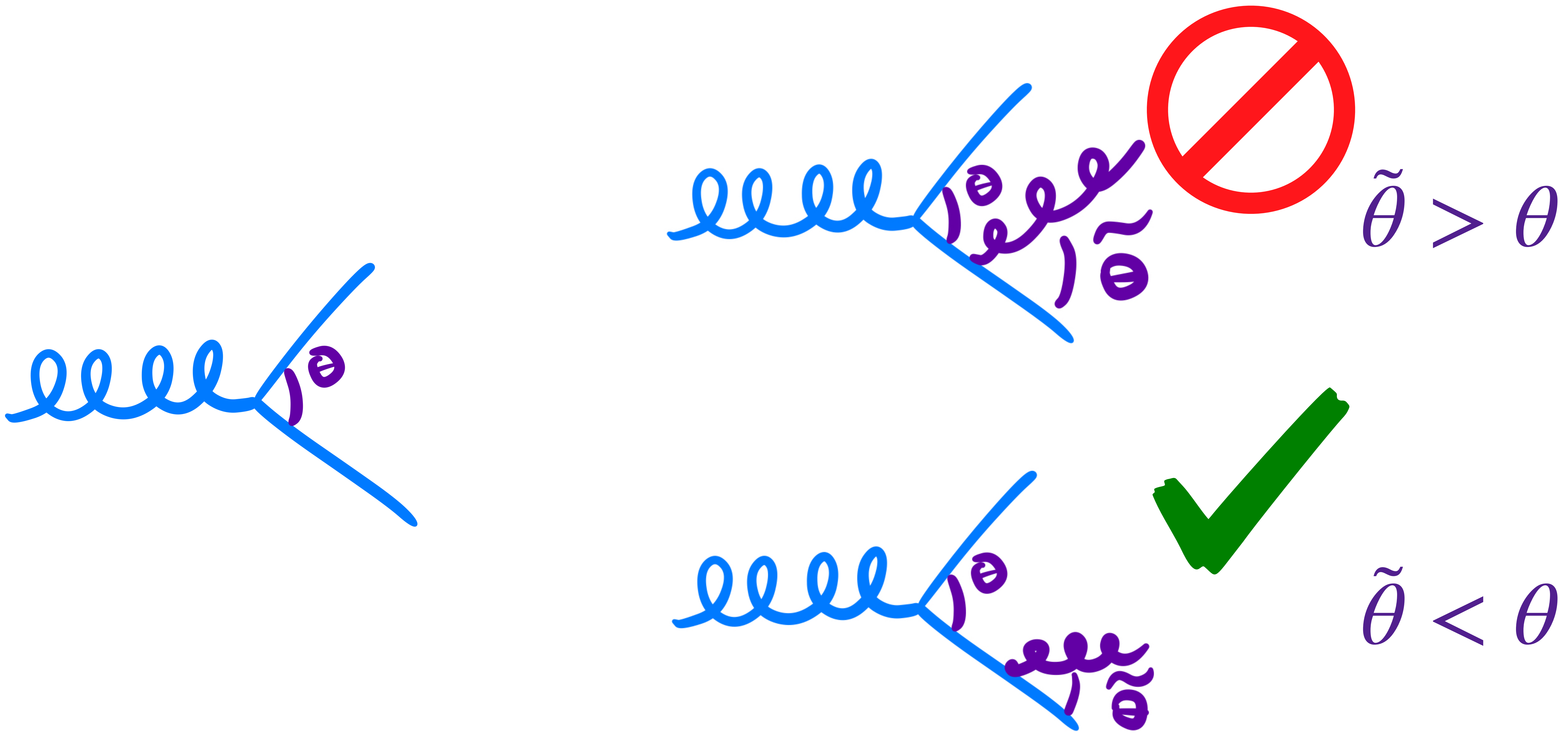


1st splitting

2nd splitting

medium interaction can break color coherence and allow $\tilde{\theta} > \theta$

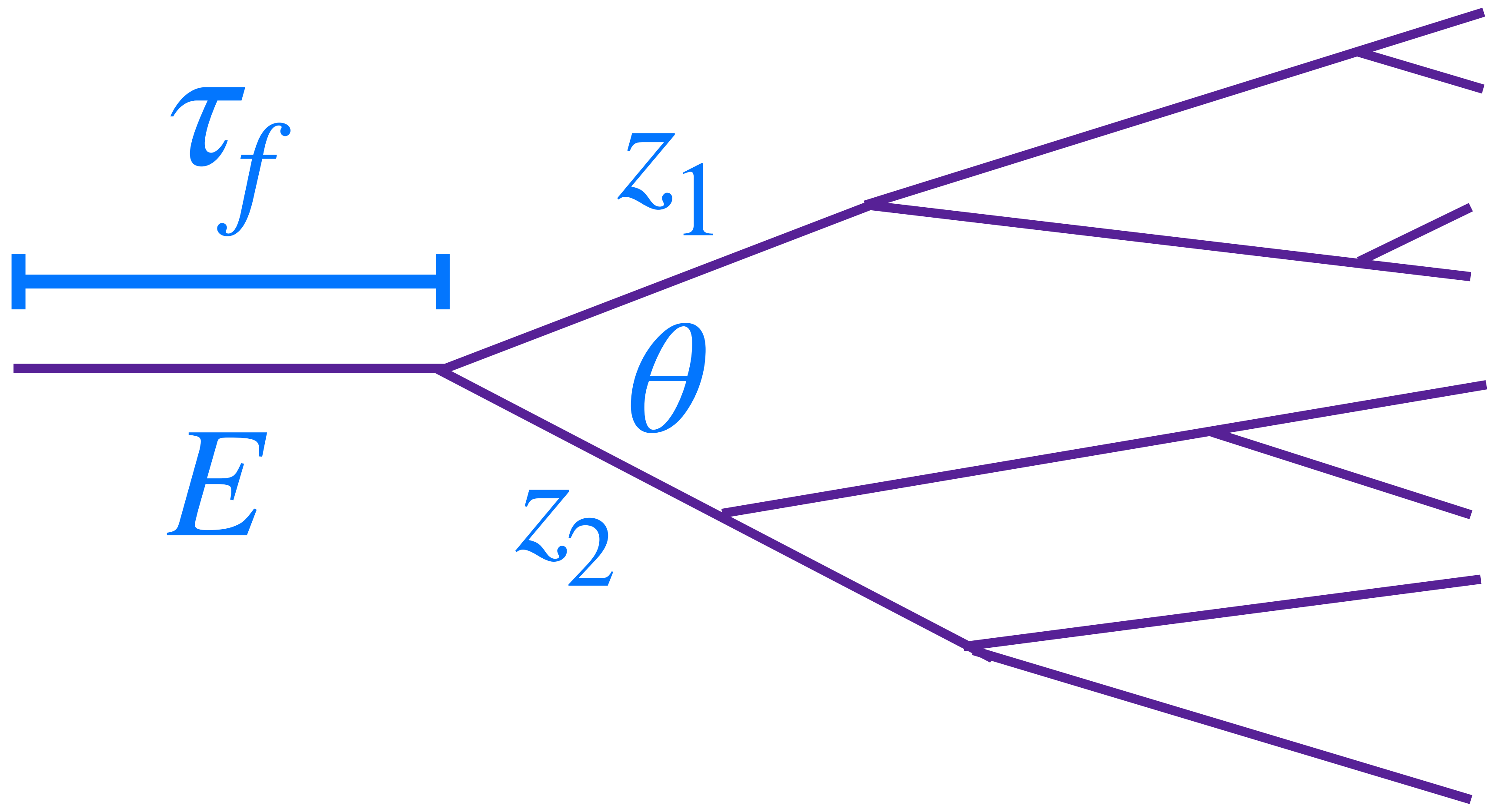
Jet Quenching without Energy Loss

arXiv:2510.11914

Jet Quenching without Energy Loss

Formation time

- Jet formation time

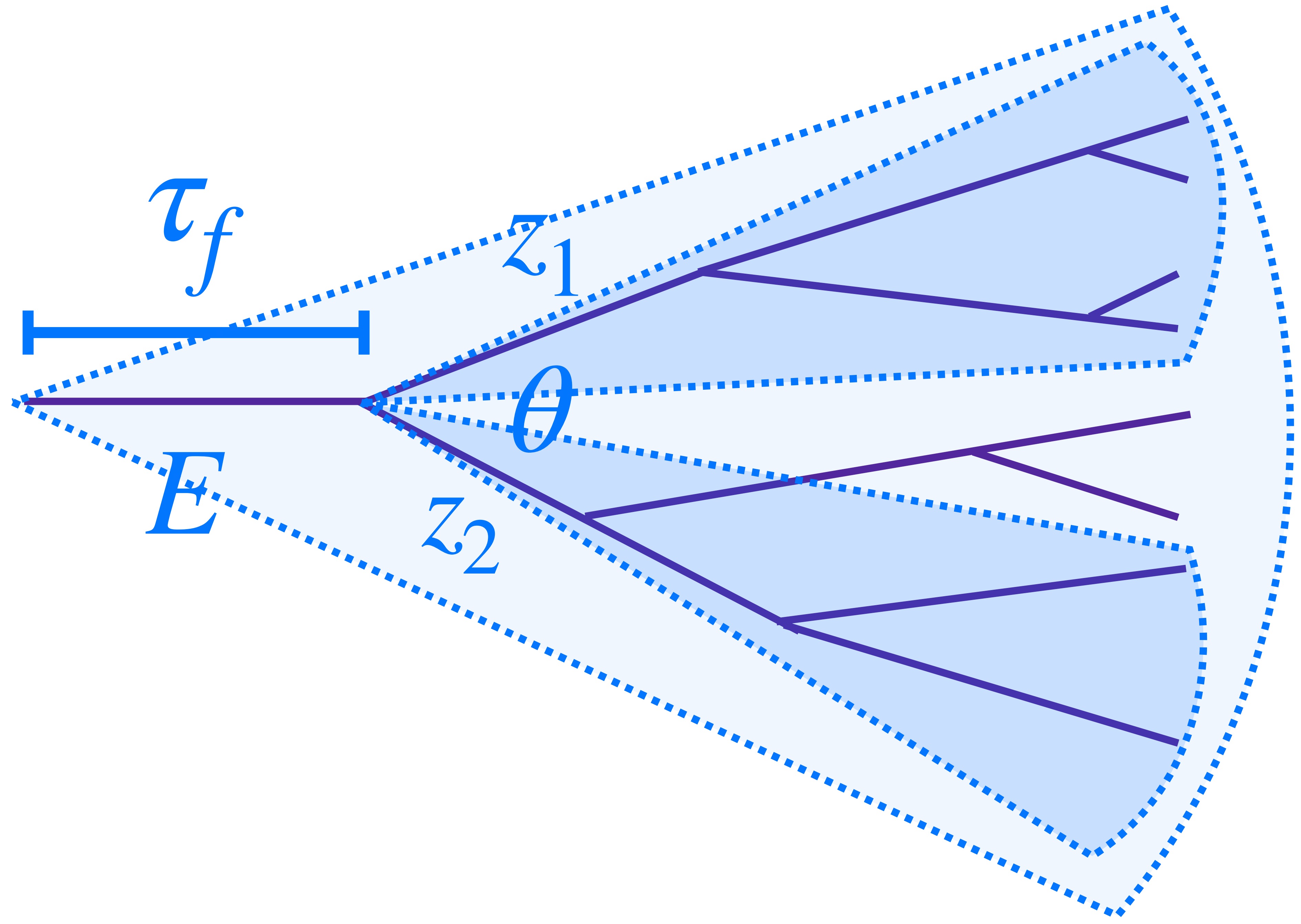


$$\tau_f \sim \frac{1}{2Ez_1z_2(1-\cos\theta)}$$

Jet Quenching without Energy Loss

Formation time

- Jet formation time
- Reconstructed with τ-reclustering algorithm



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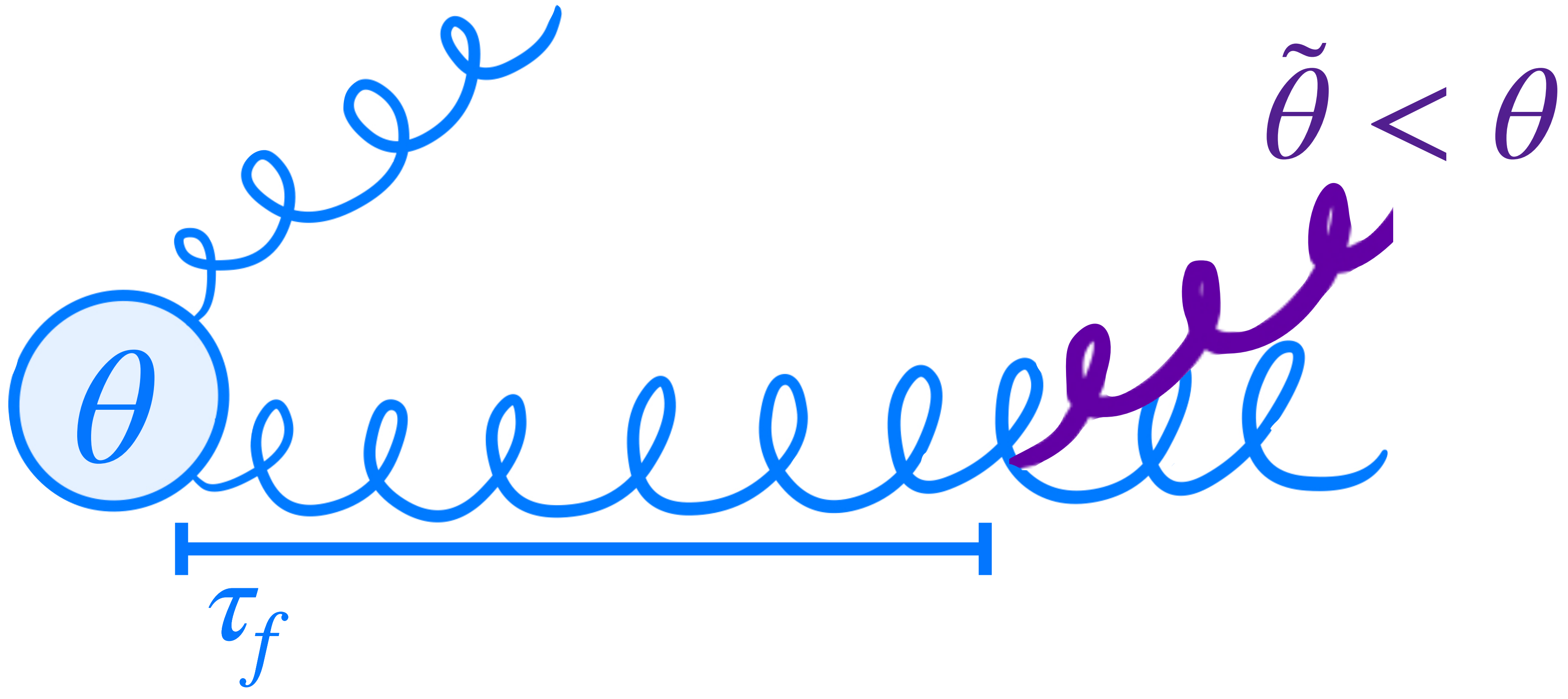

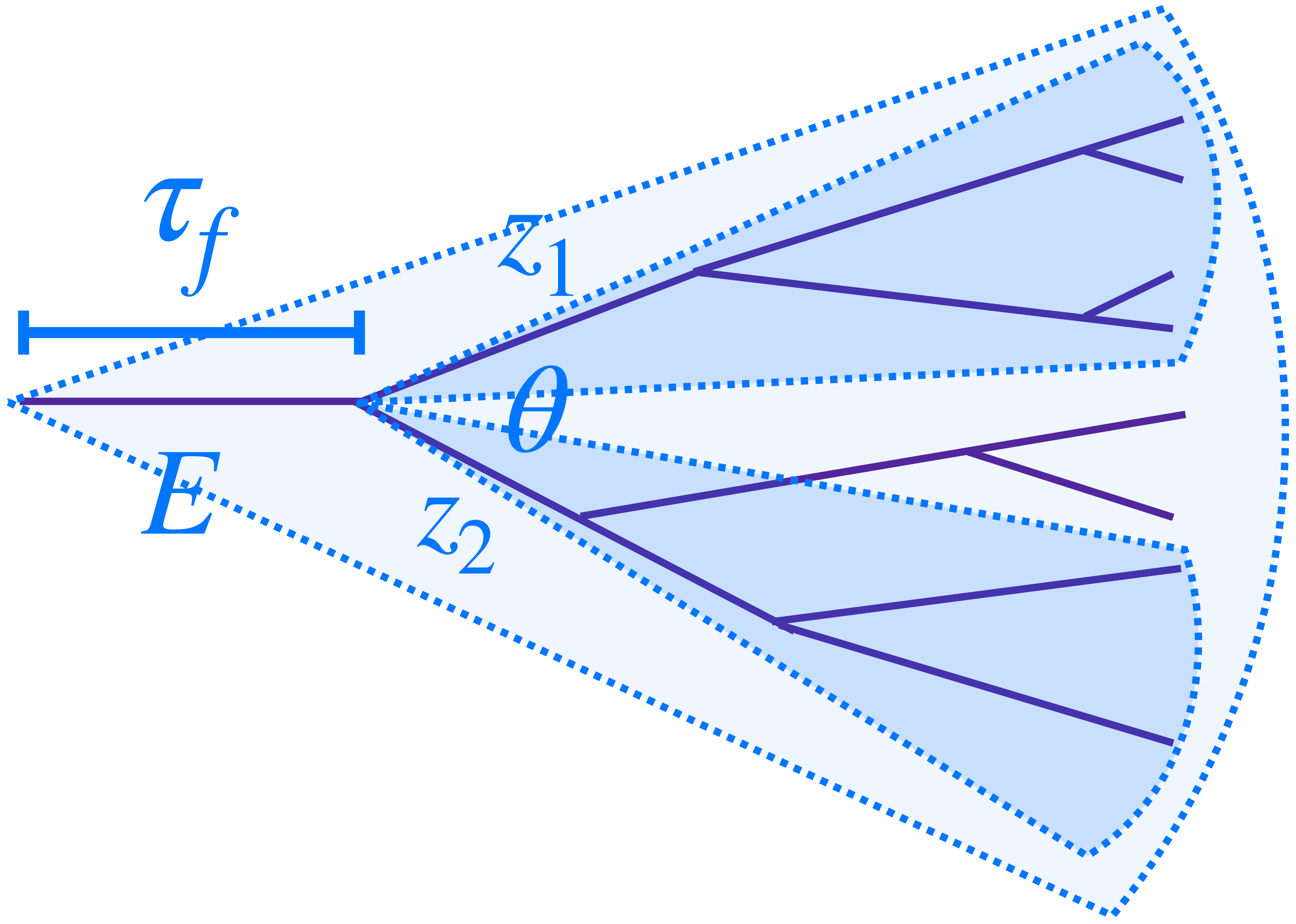

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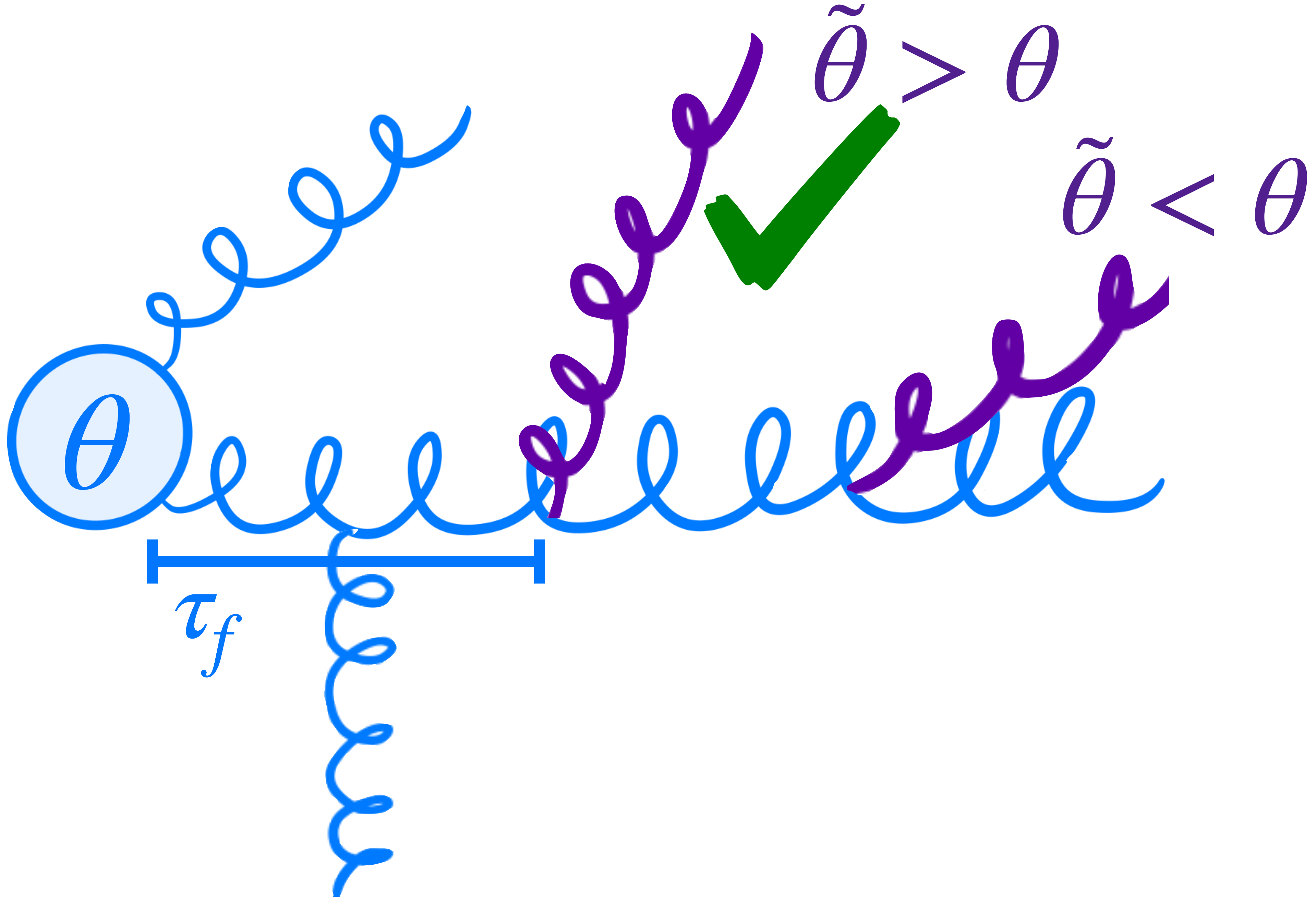

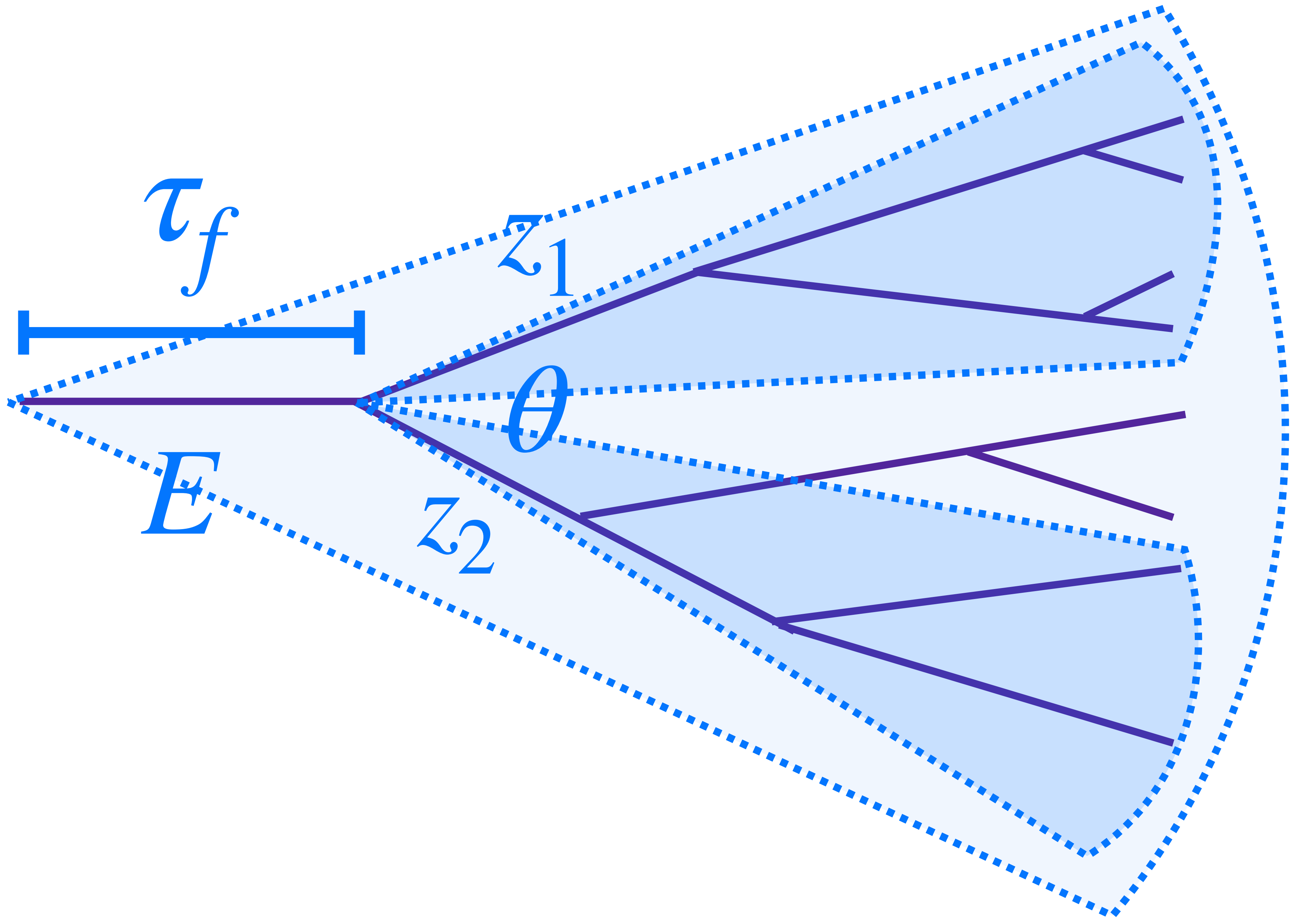

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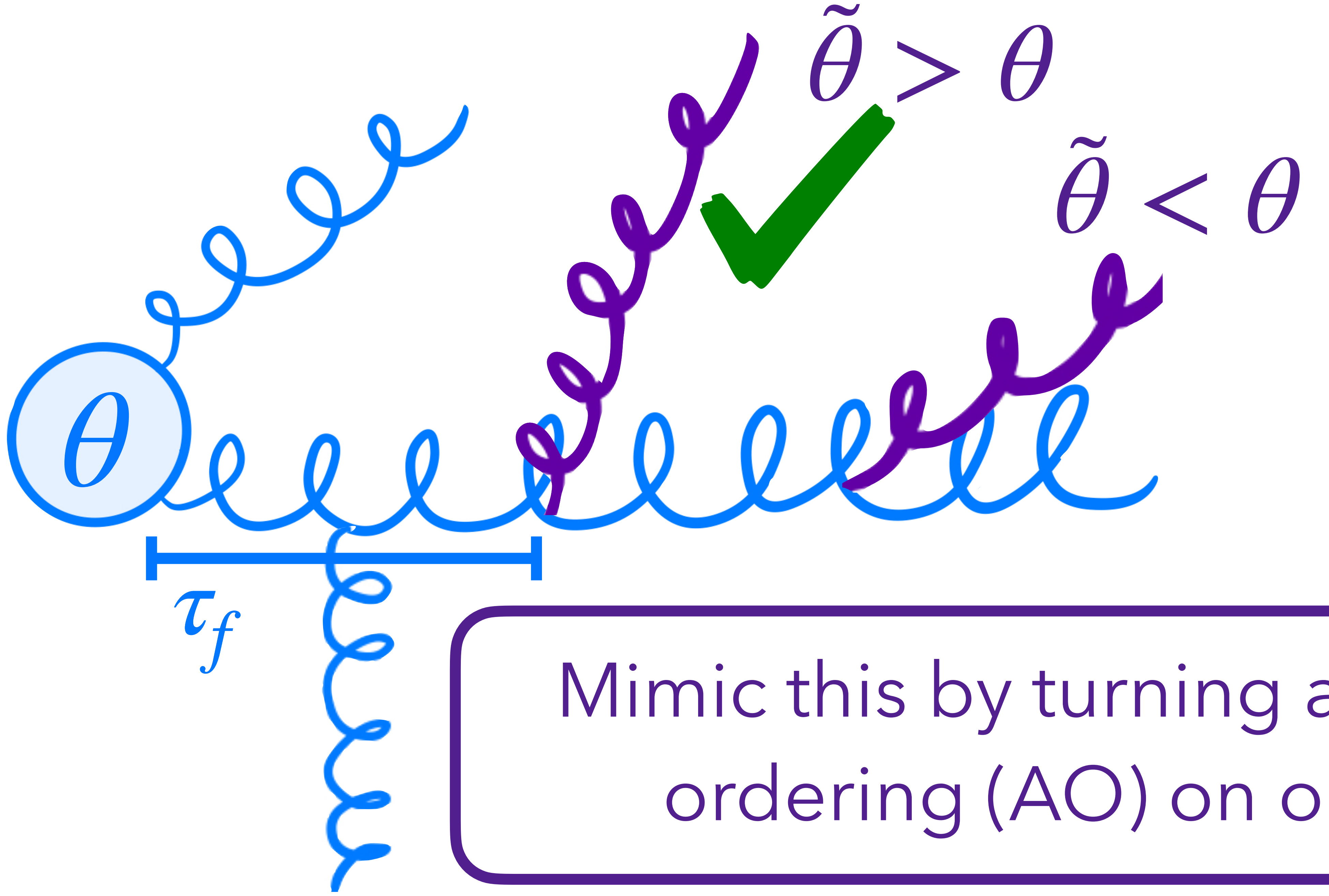
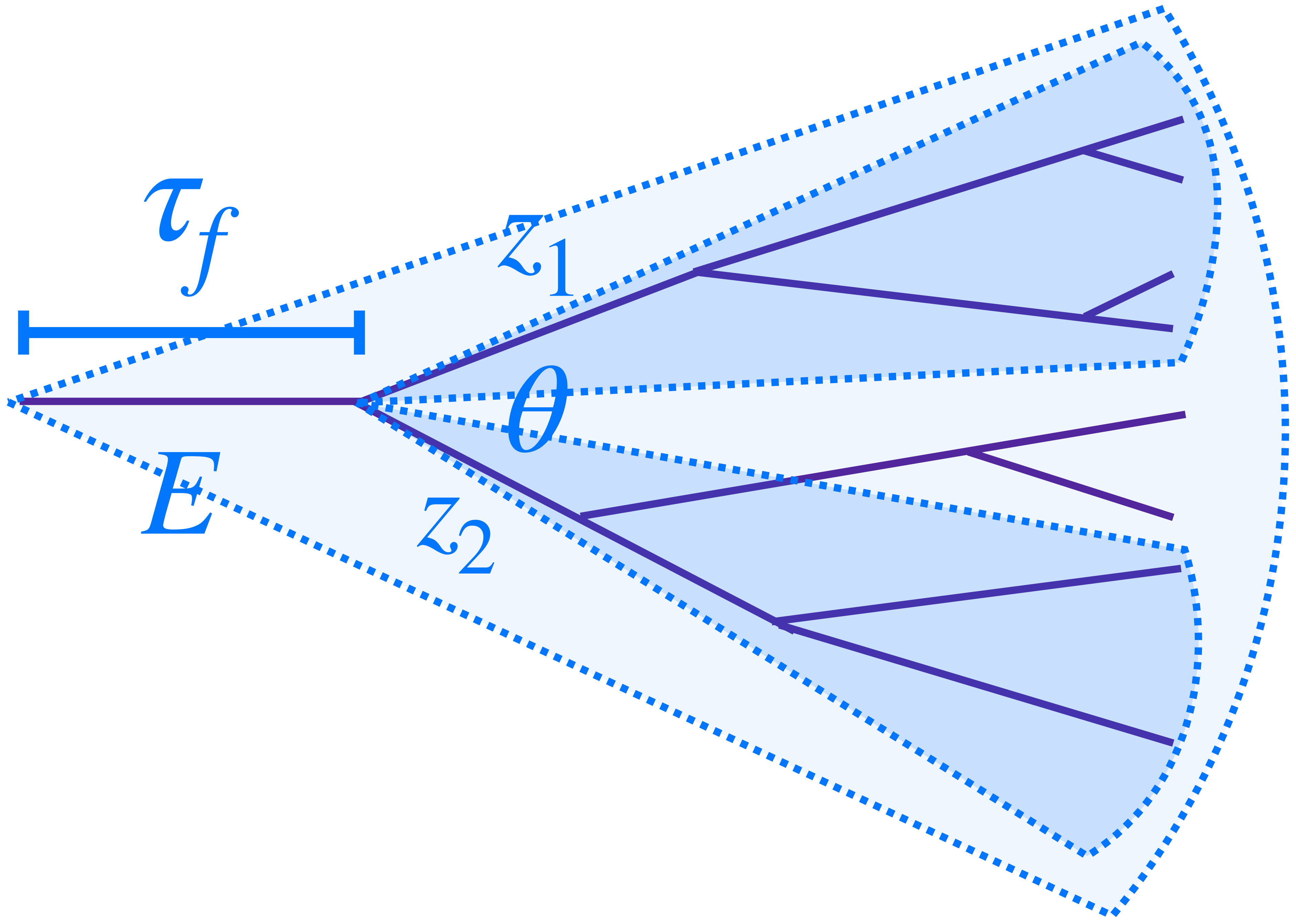


Mimic this by turning angular ordering (AO) on or off



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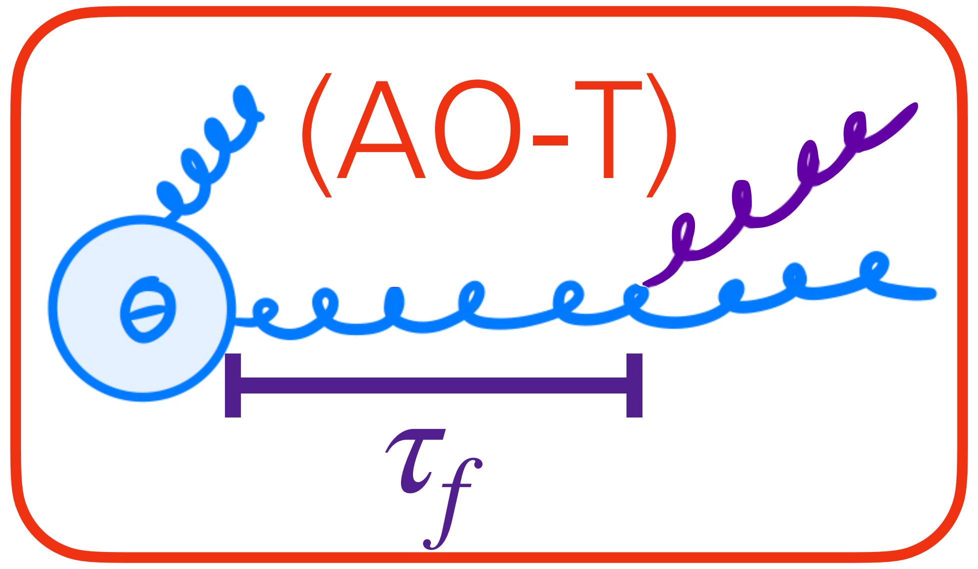
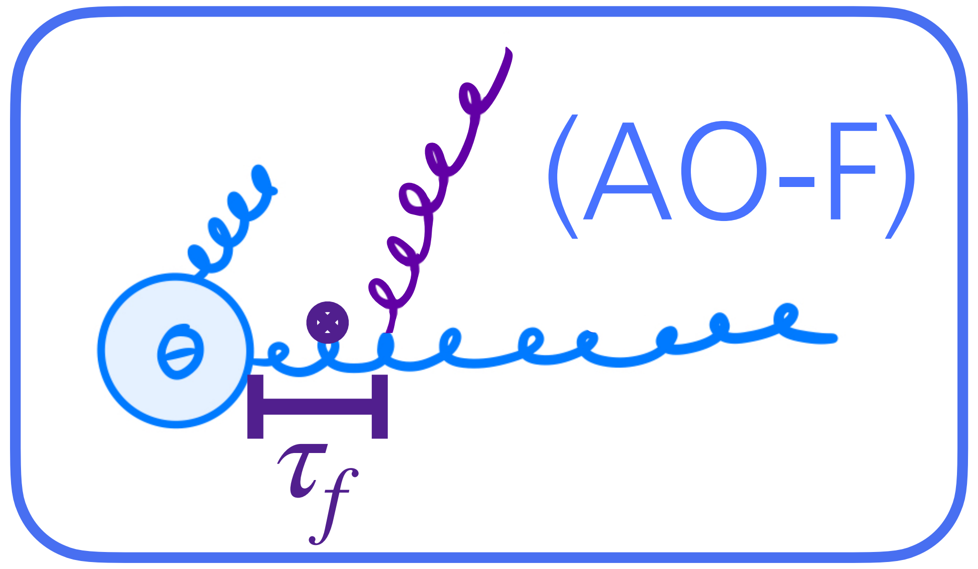
Jet Quenching without Energy Loss

Effect of coherence breaking

- Formation time distribution





Jet Quenching without Energy Loss

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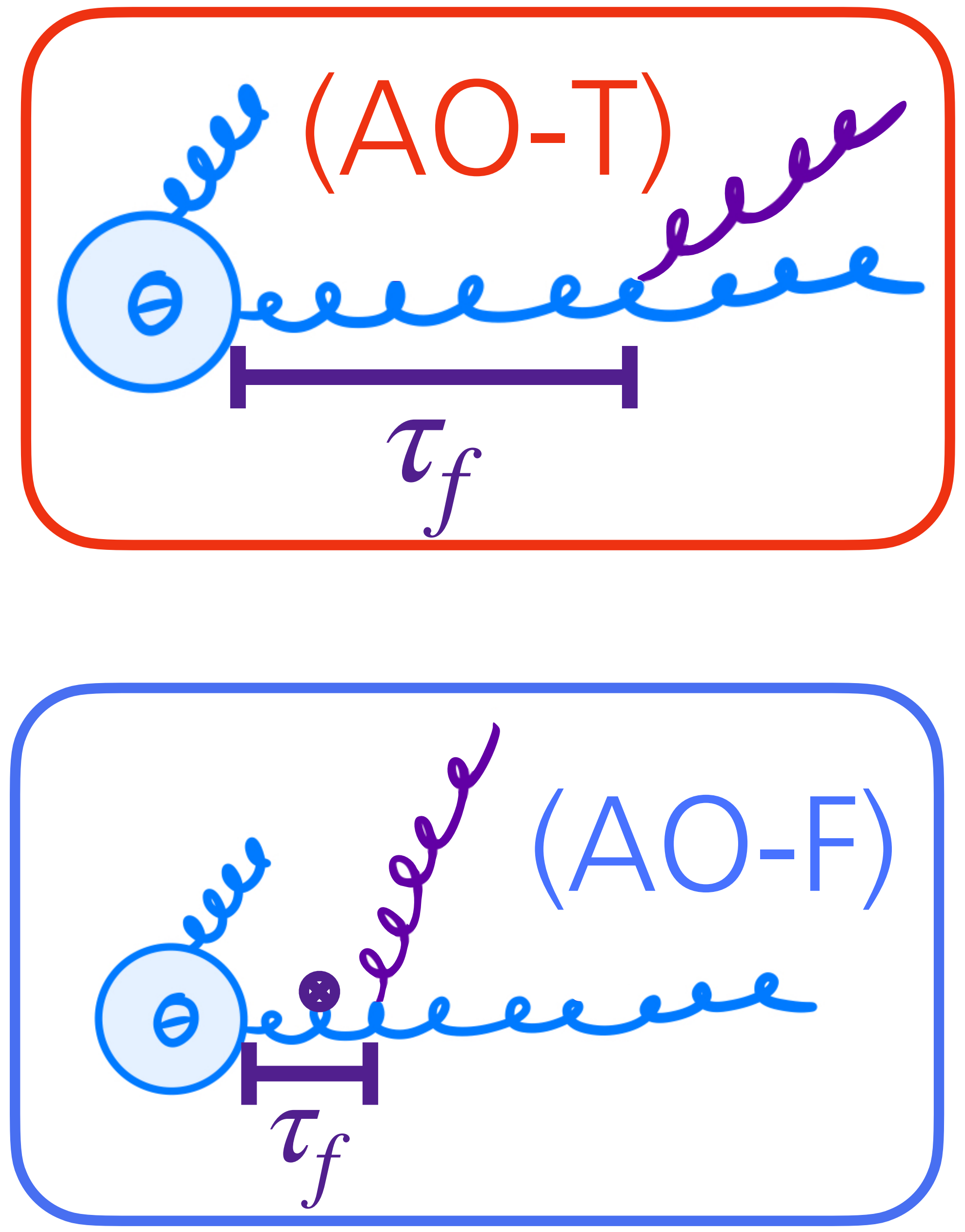

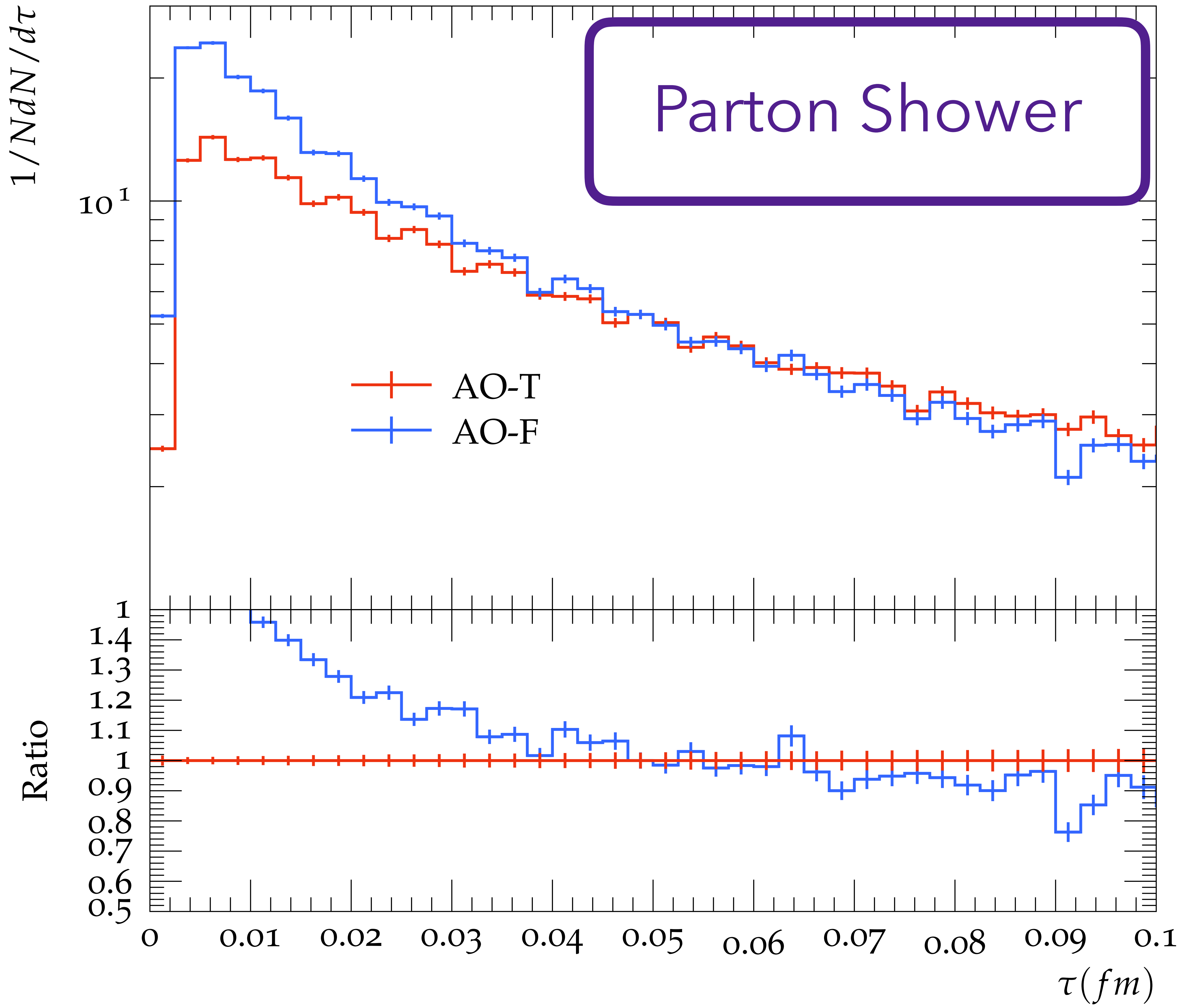

Jet Quenching without Energy Loss

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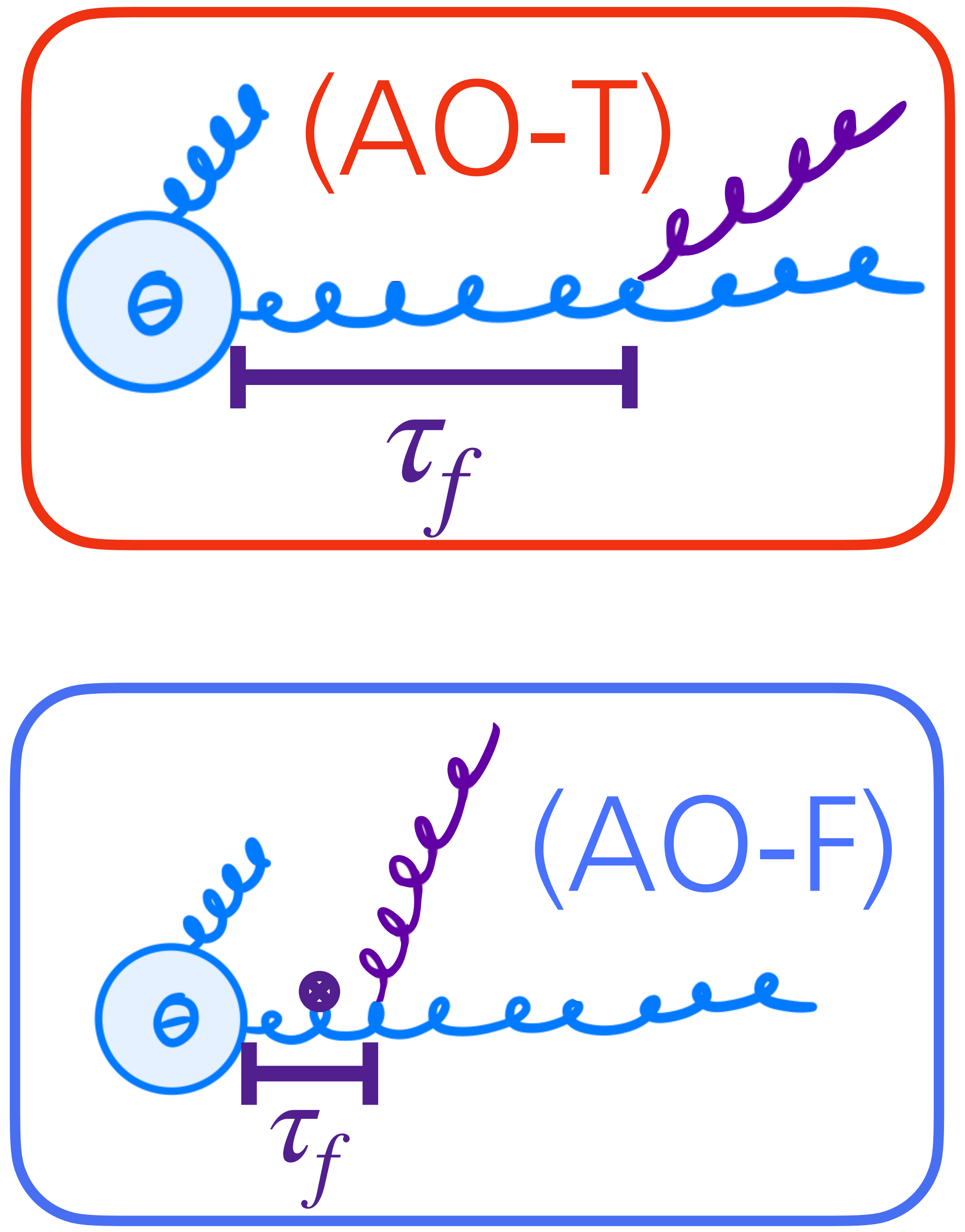

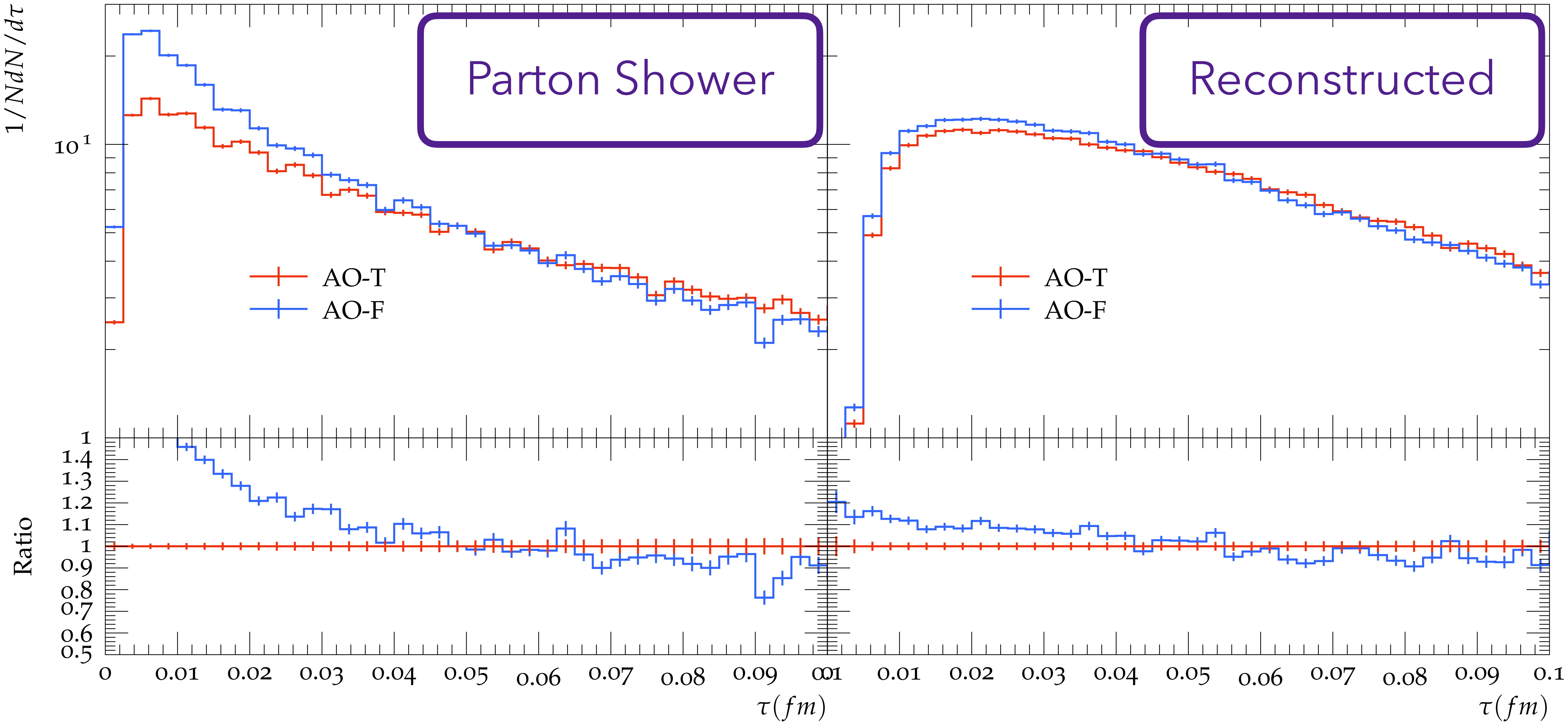

Jet Quenching without Energy Loss

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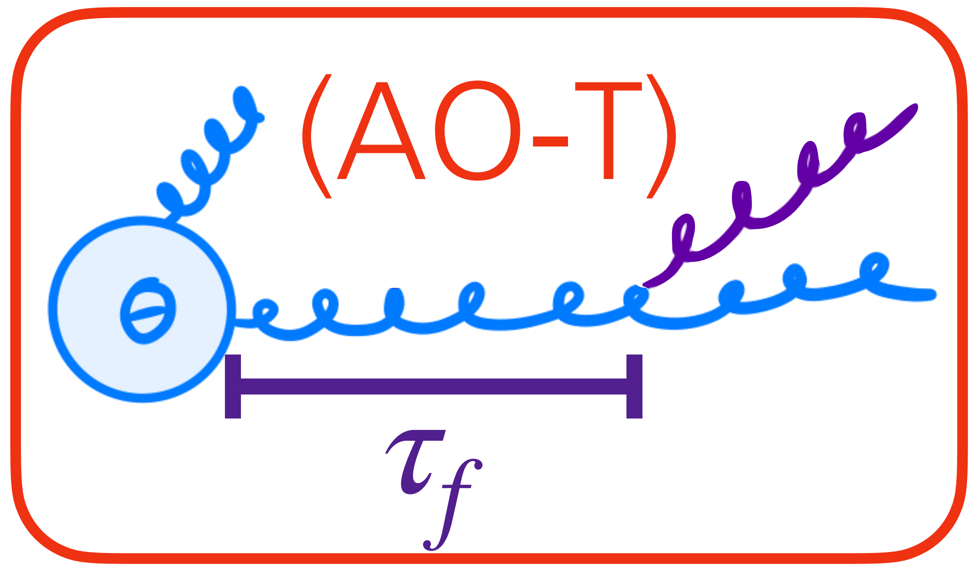

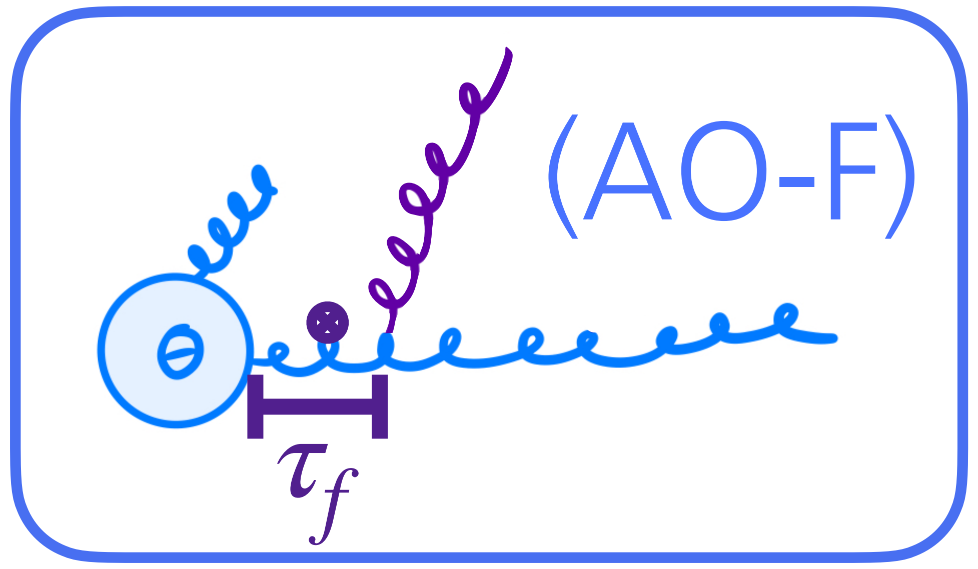

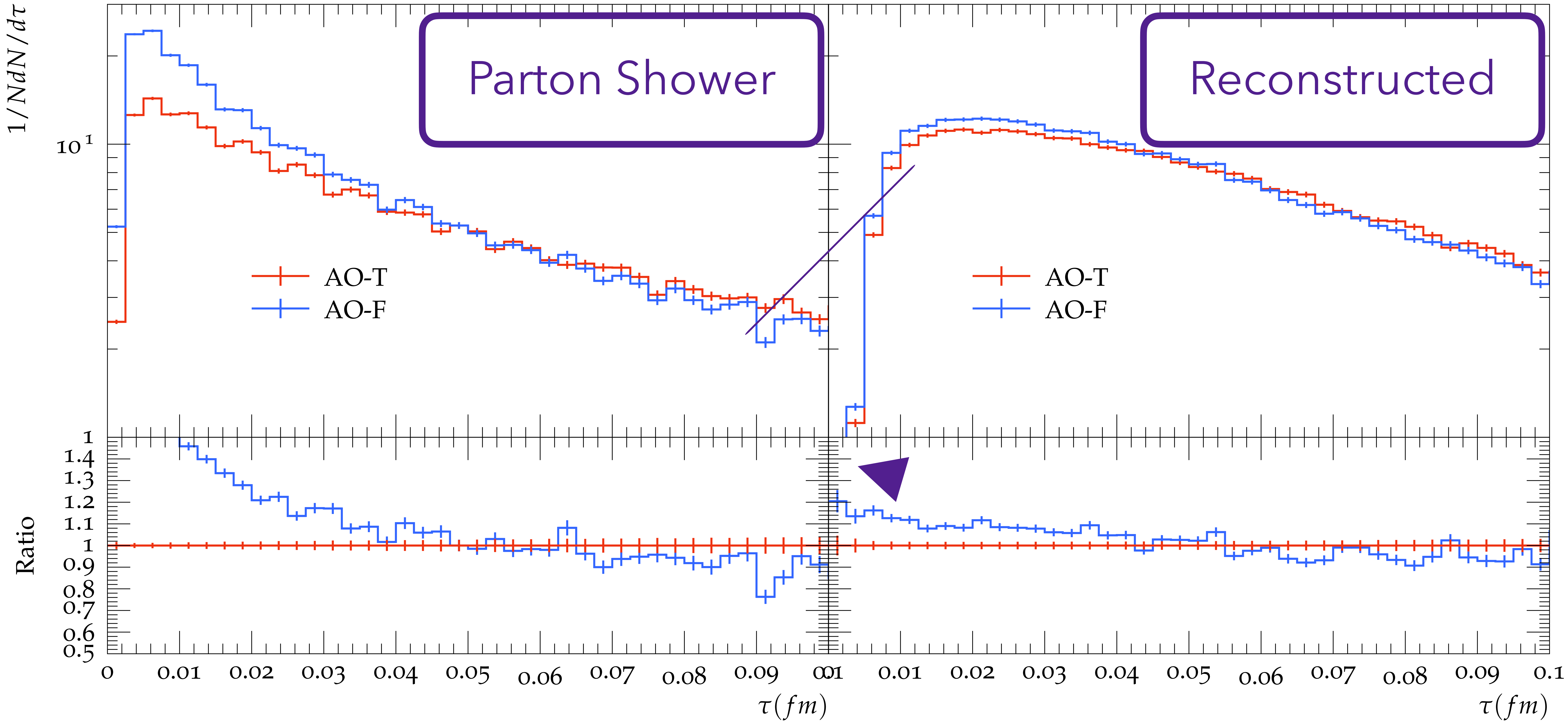

Jet Quenching without Energy Loss

Suppression

- Color decoherence also appears as a suppression in the jet spectrum

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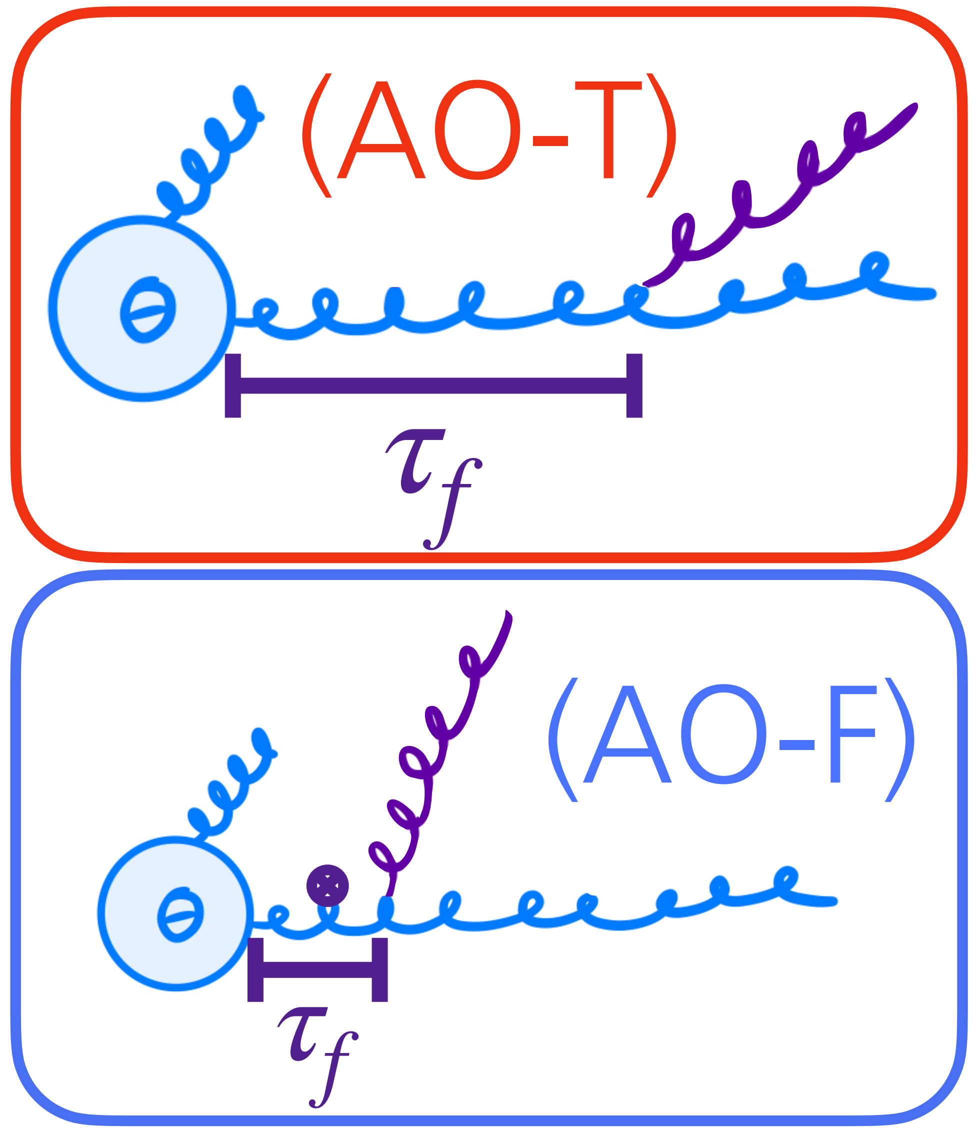

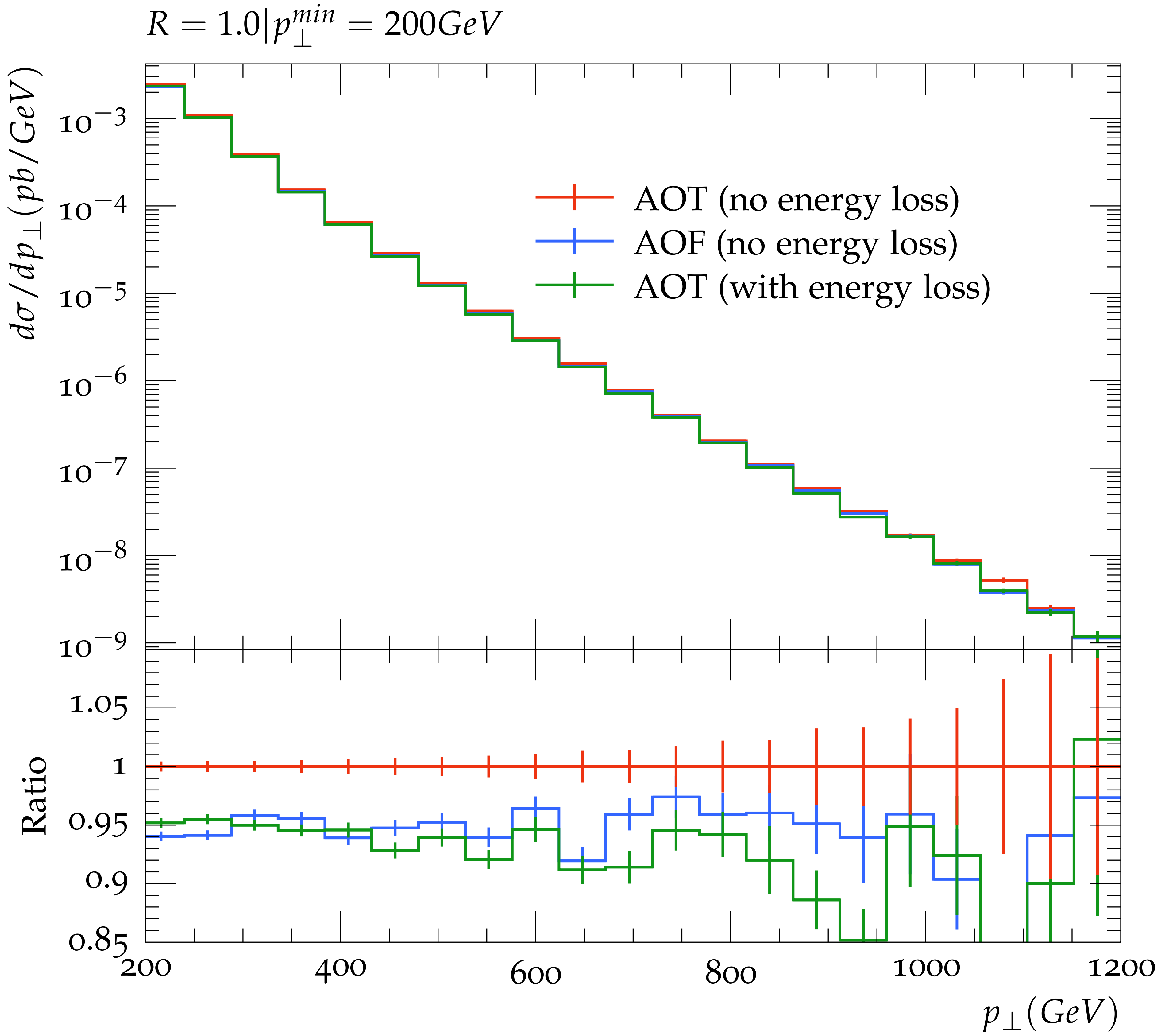

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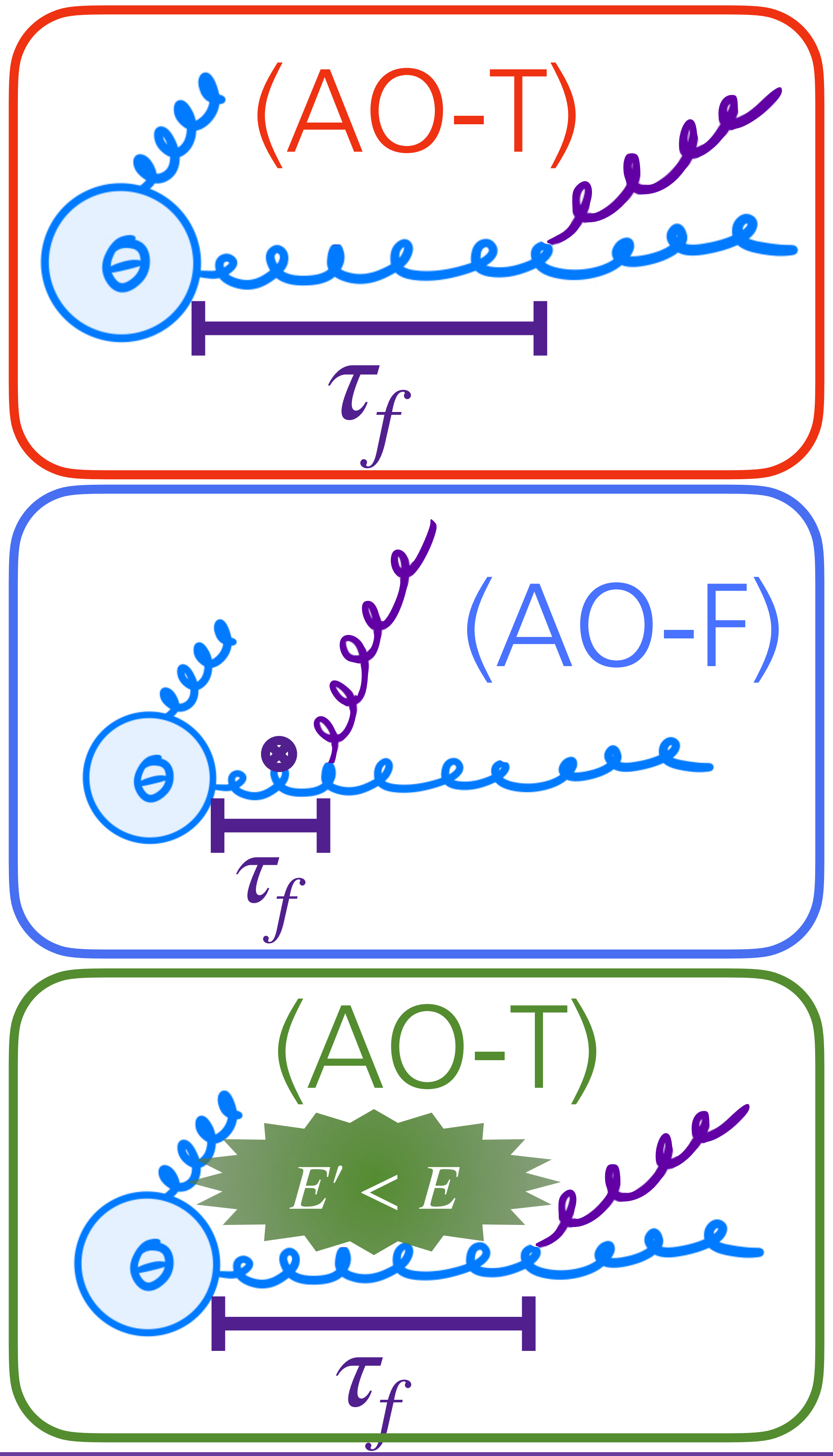
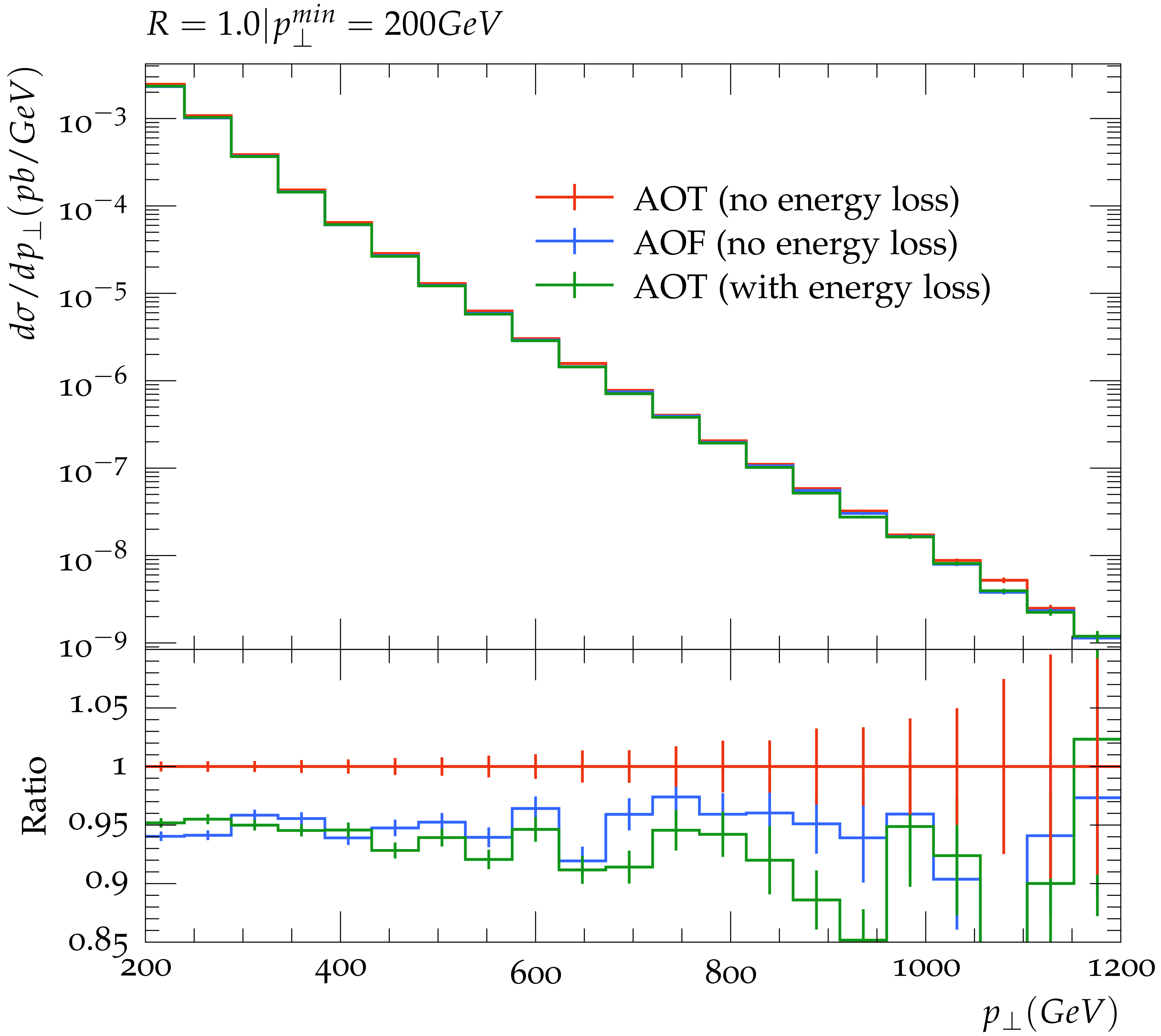
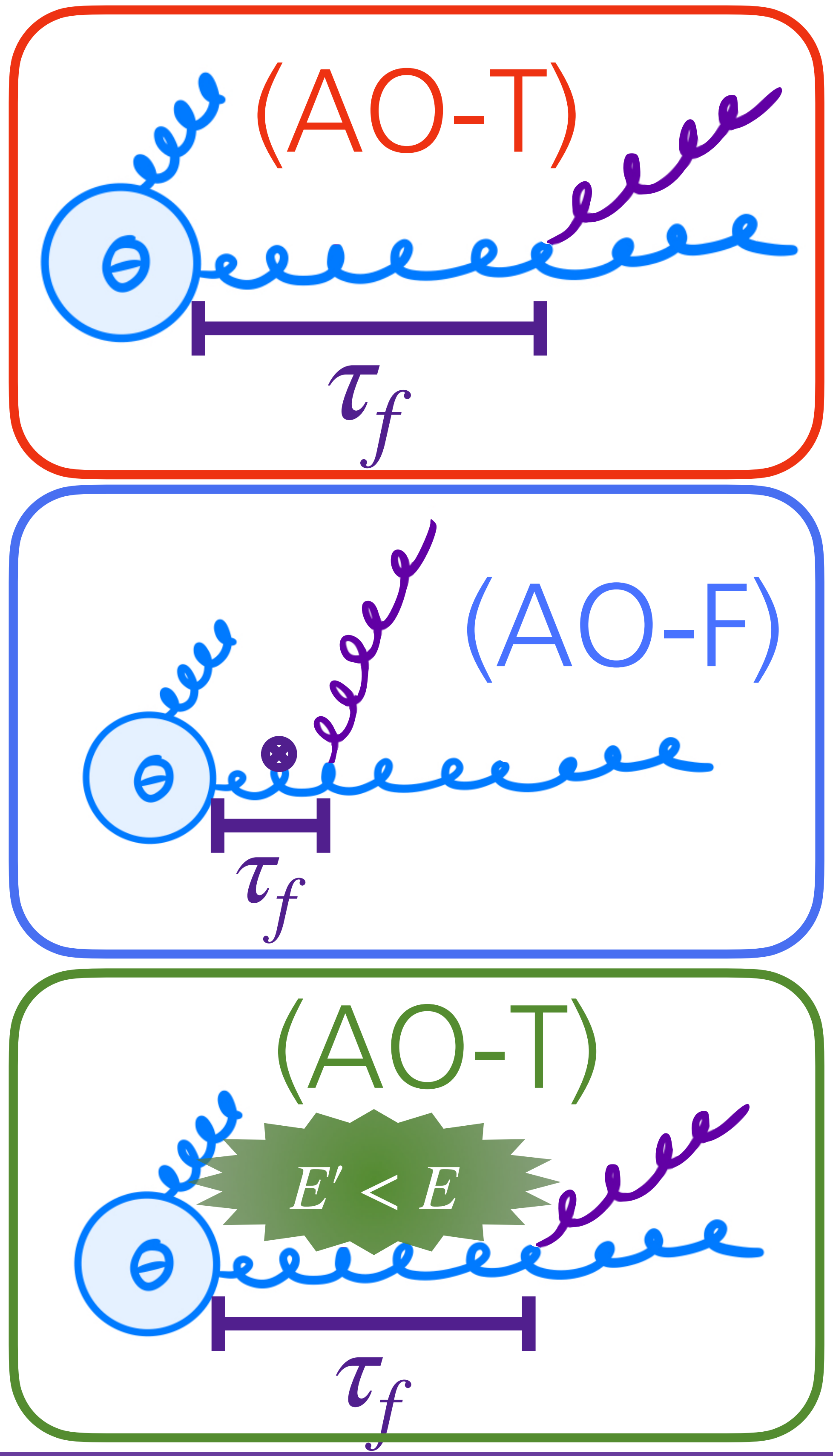


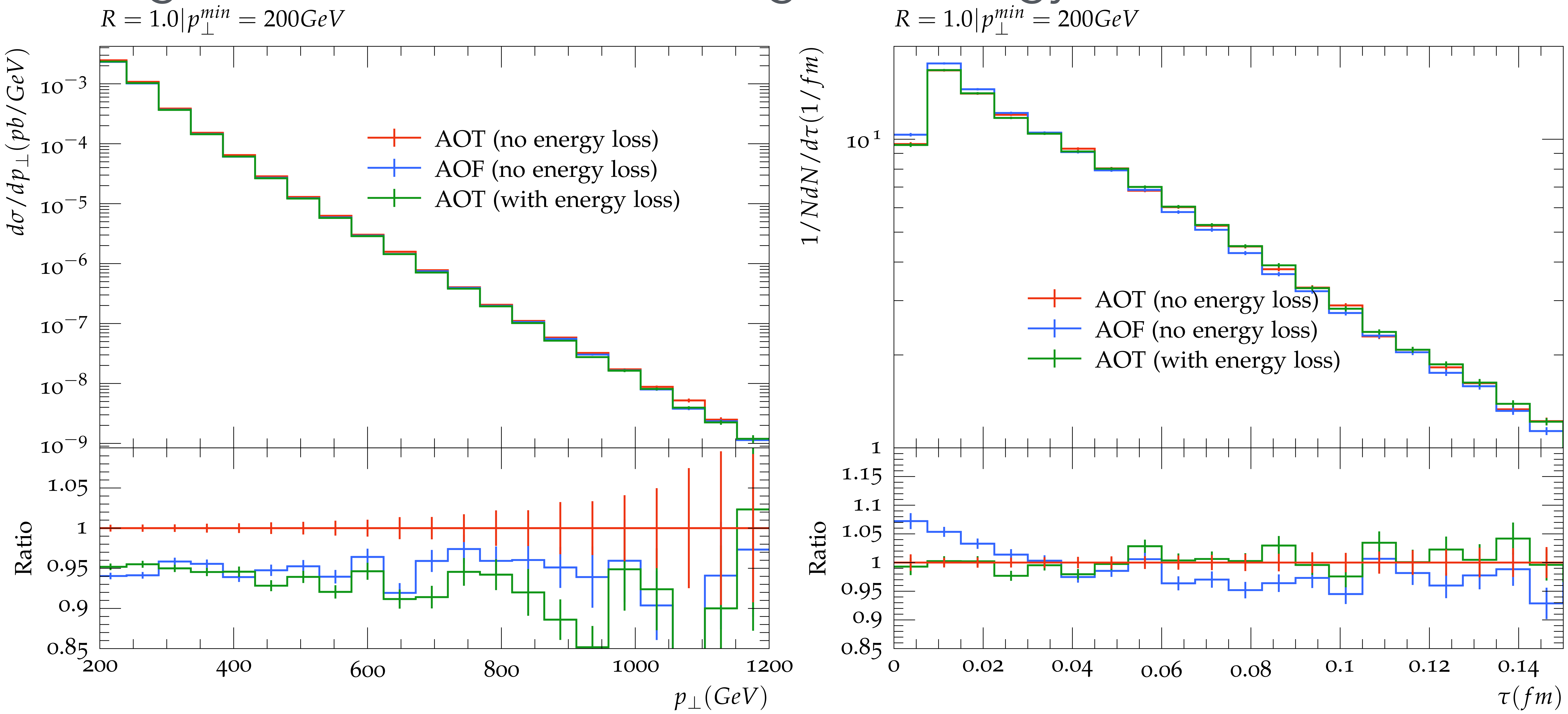


Jet Quenching without Energy Loss

Suppression

- Color decoherence also appears as a suppression in the jet spectrum
- Formation time distinguishes coherence breaking and energy loss

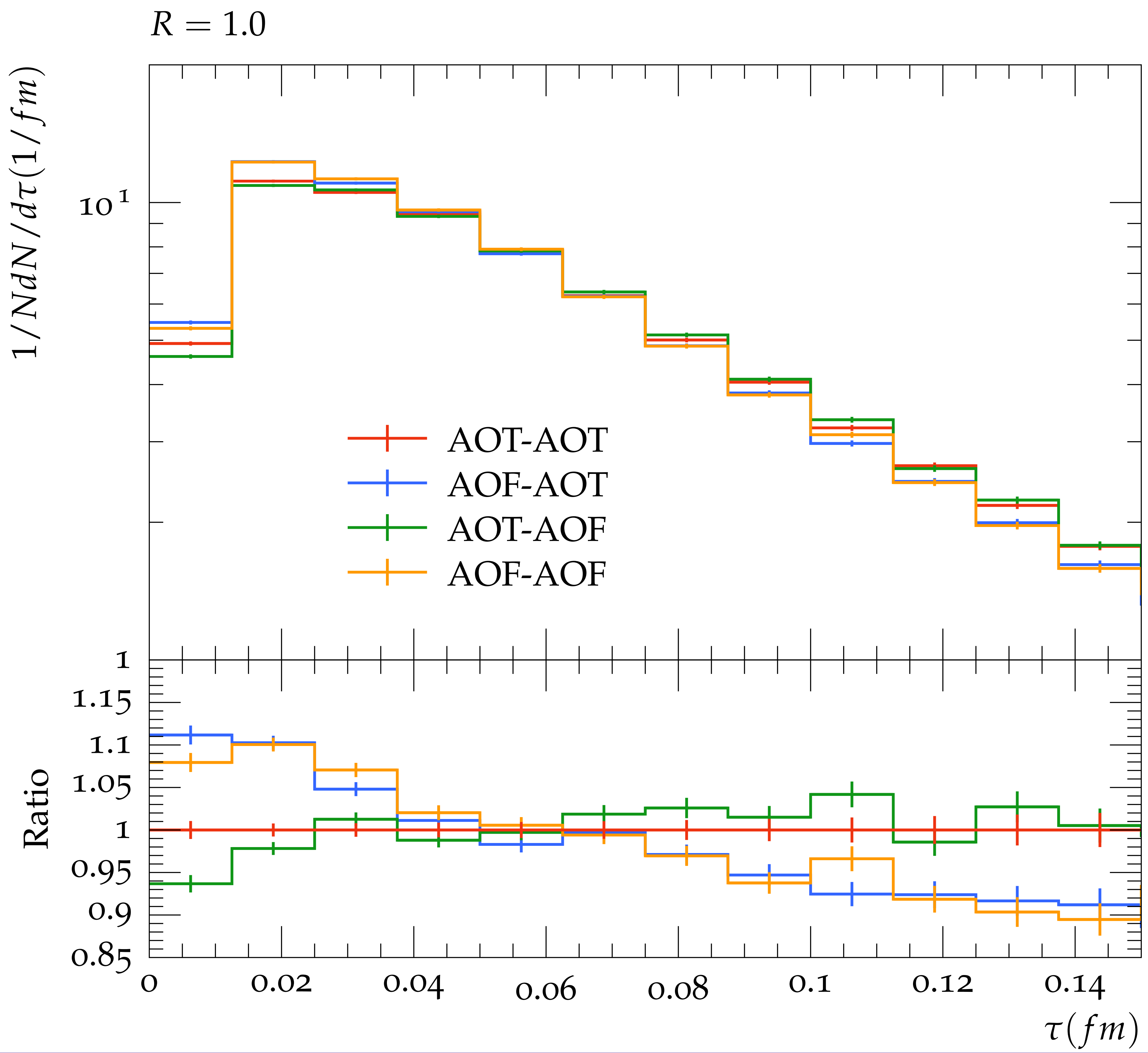




Jet Quenching without Energy Loss

Relaxing the assumptions

- τ distribution is not sensitive to coherence breaking in the second splitting



Jet Quenching without Energy Loss

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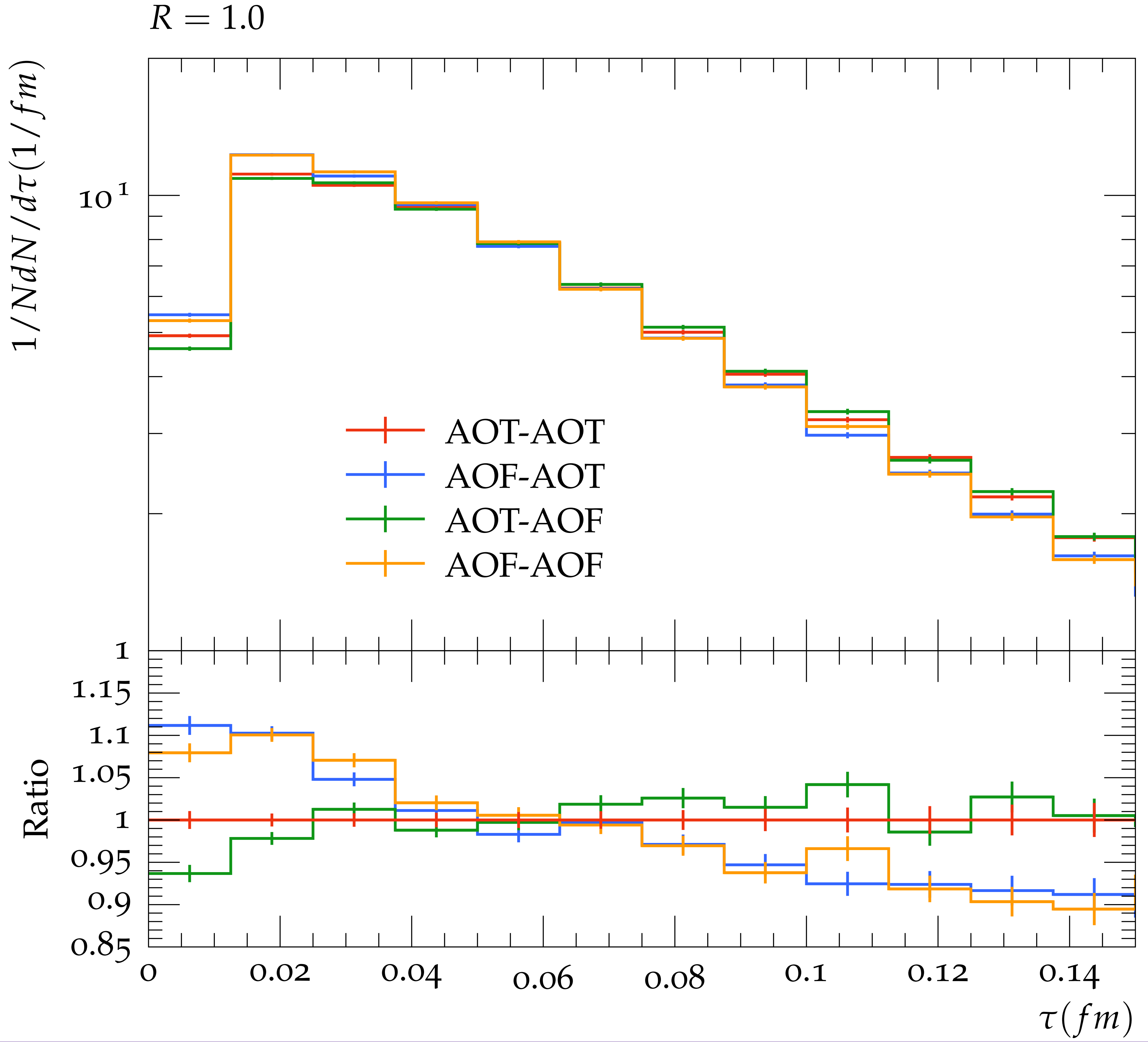
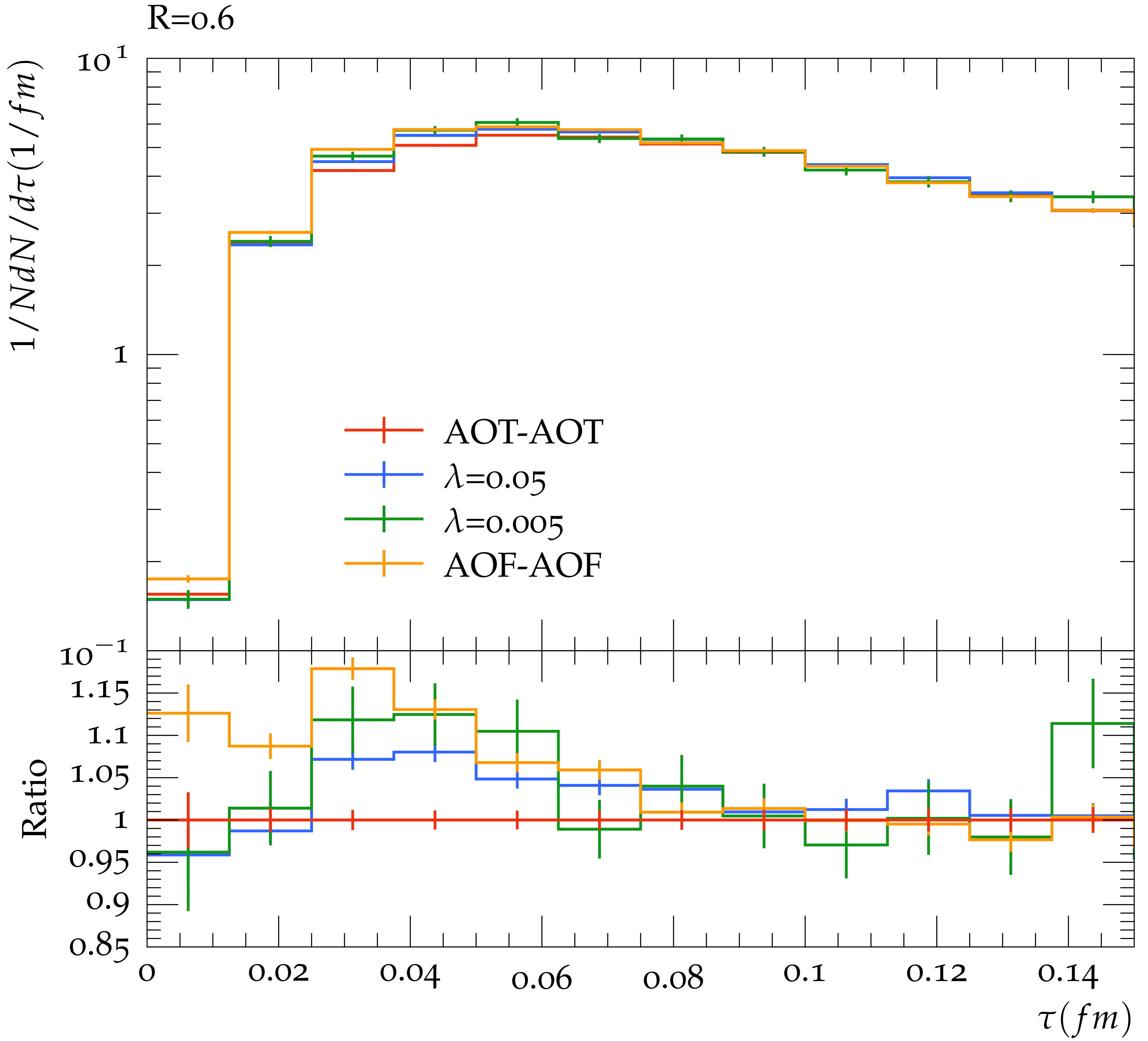
- τ distribution is not sensitive to coherence breaking in the second splitting
- With the effect also in the second splitting, we can move to smaller radii





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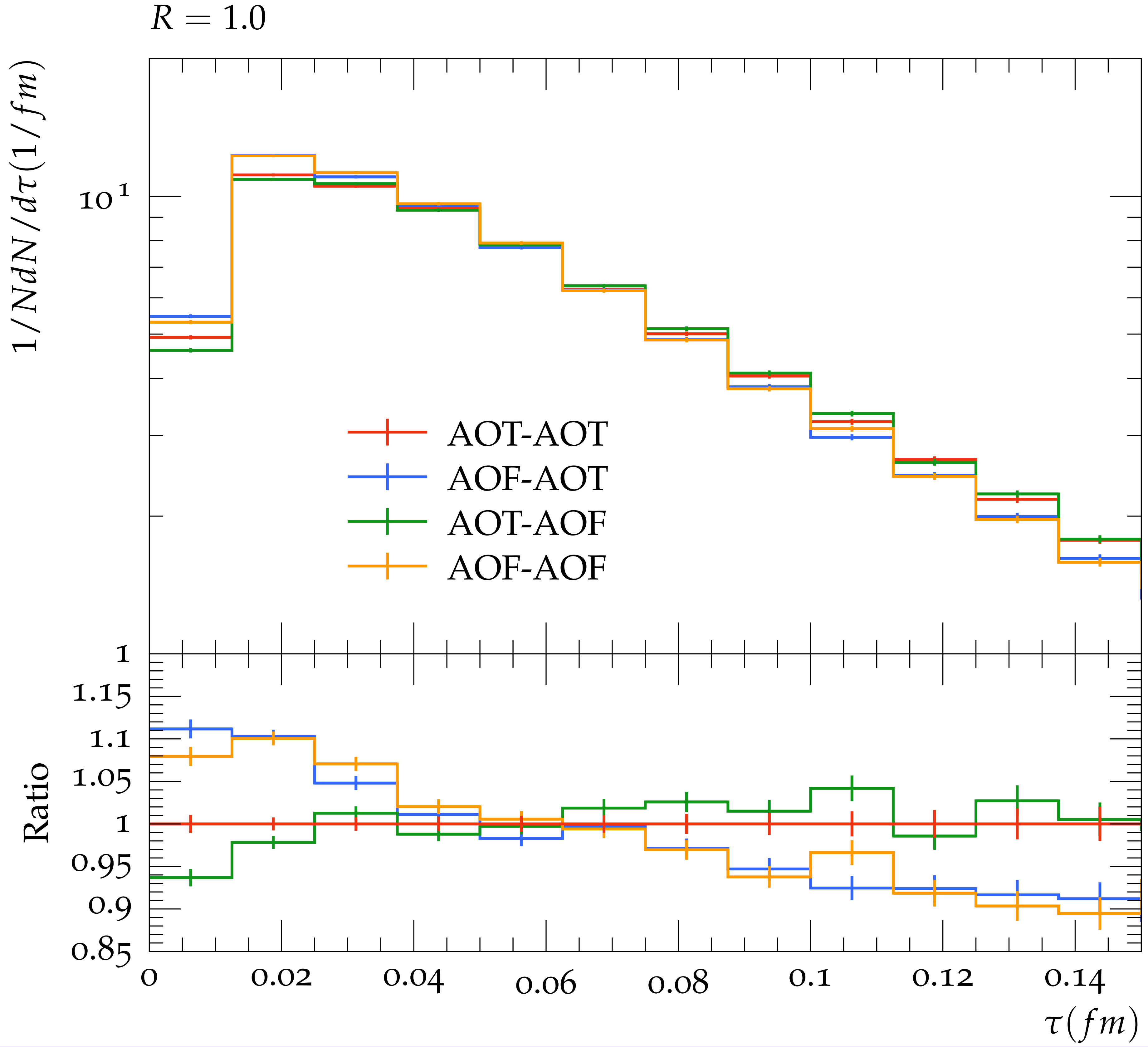
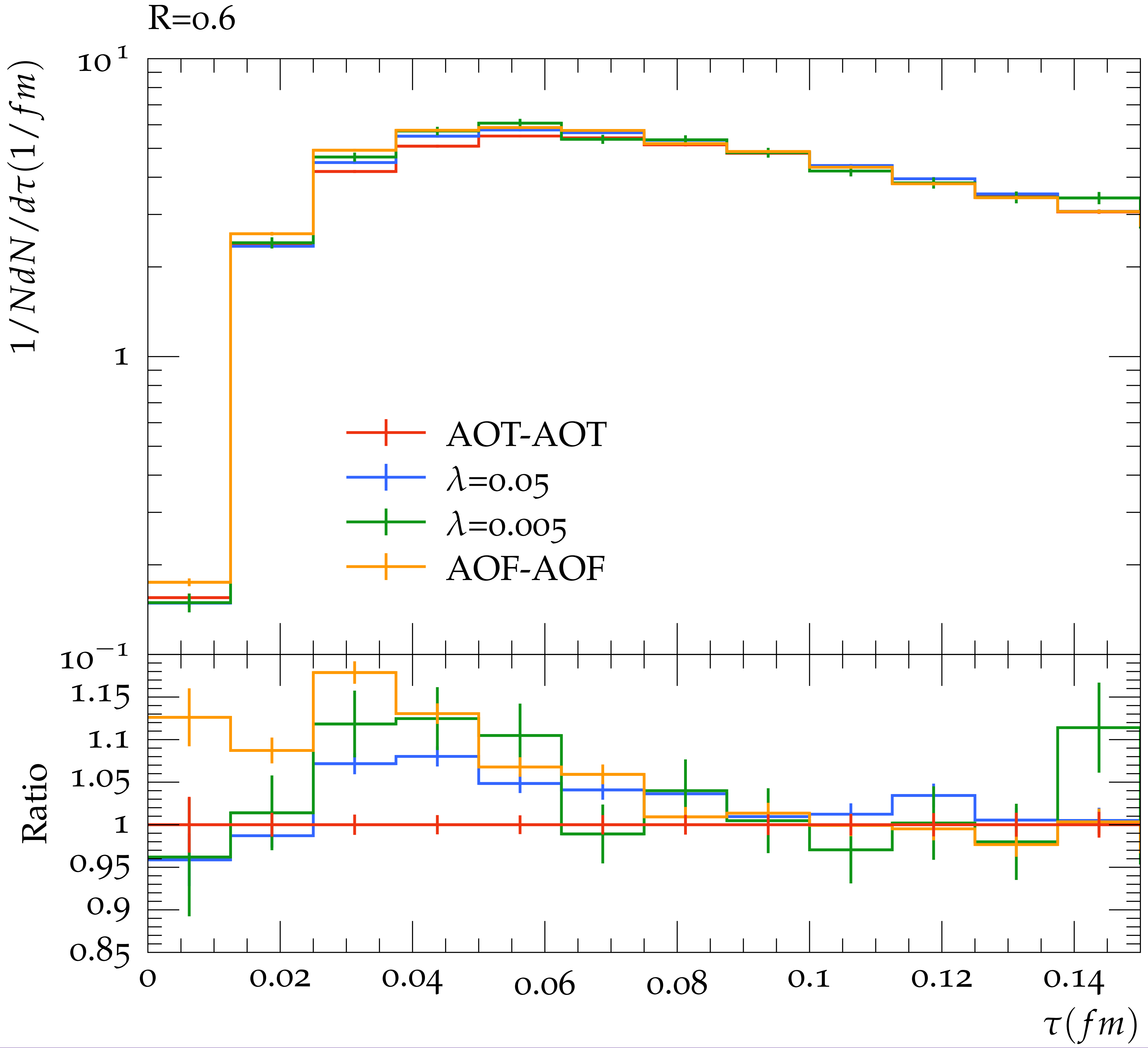




Scattering probability: $1 - e^{-\tau/\lambda}$

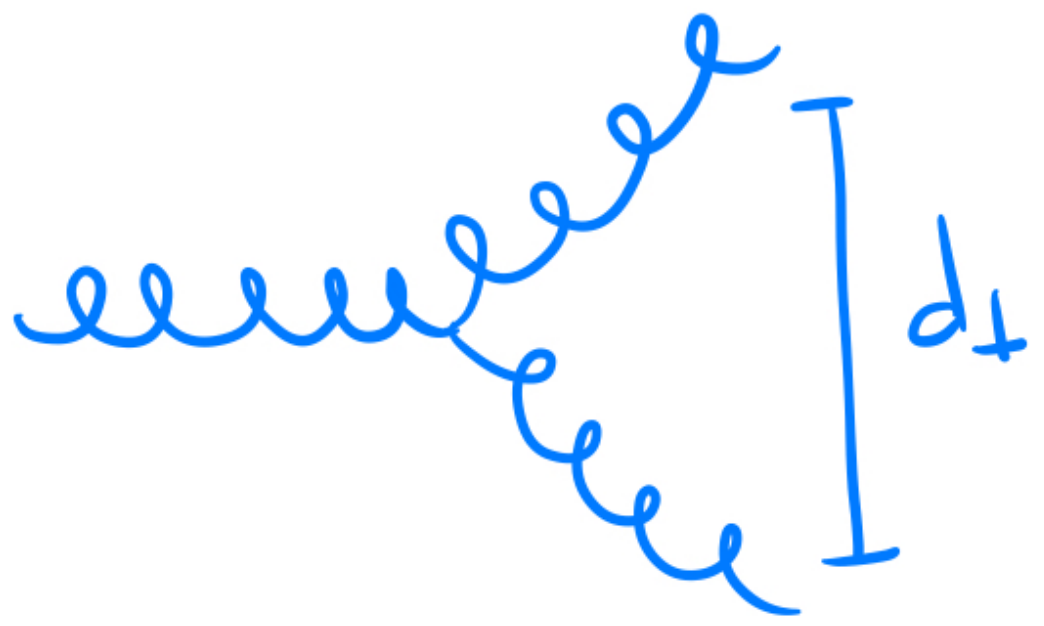
Colour coherence in small systems

arXiv:2510.17570

Introduction

Coherence in scattering

- Medium introduces an additional scale:



color dipole size in jet at the emission's formation time

$$d_\perp(\tau_f)$$

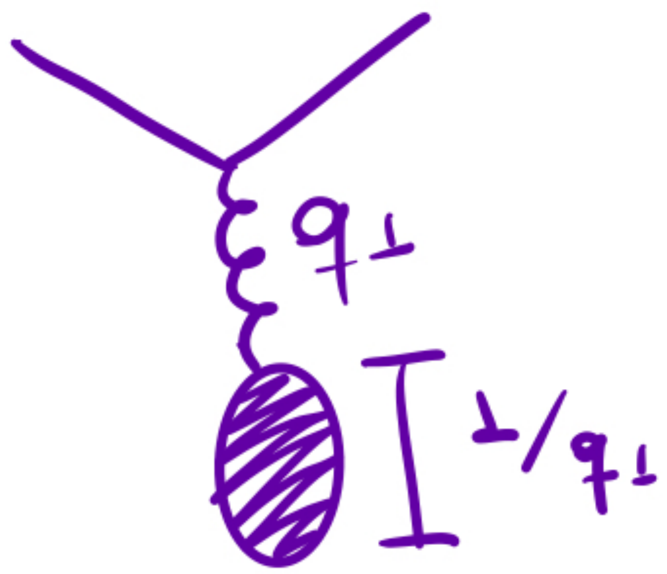
Introduction

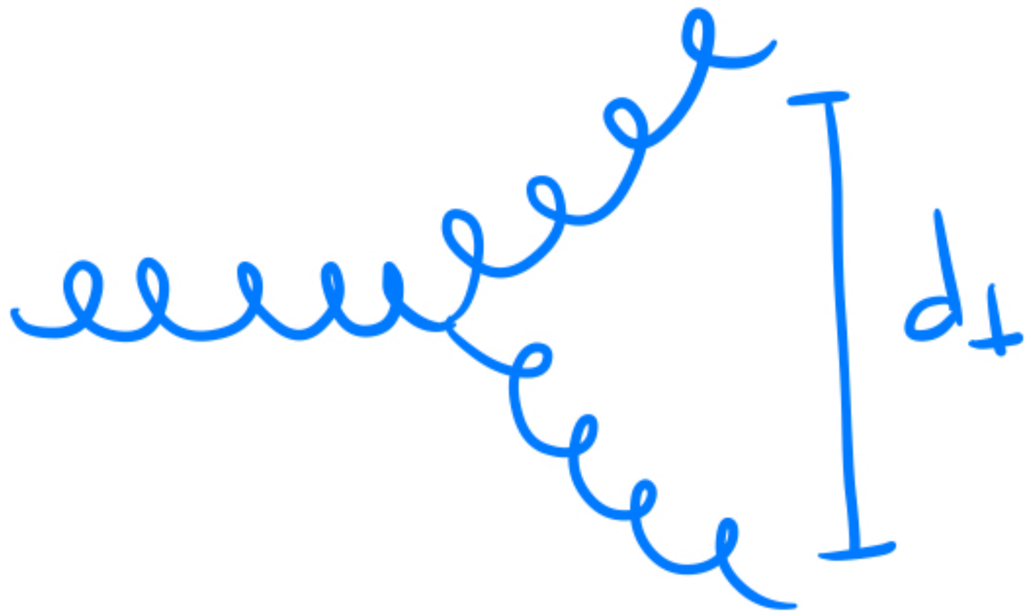
Coherence in scattering

- Medium introduces an additional scale:

medium resolution

$1/q_\perp$





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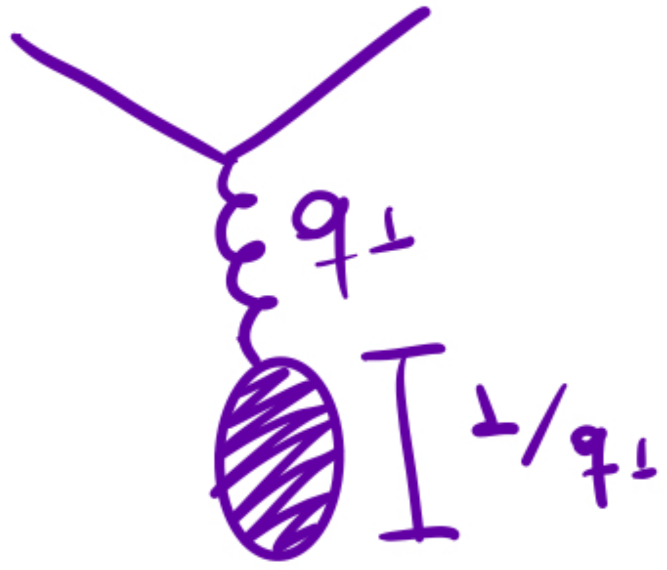
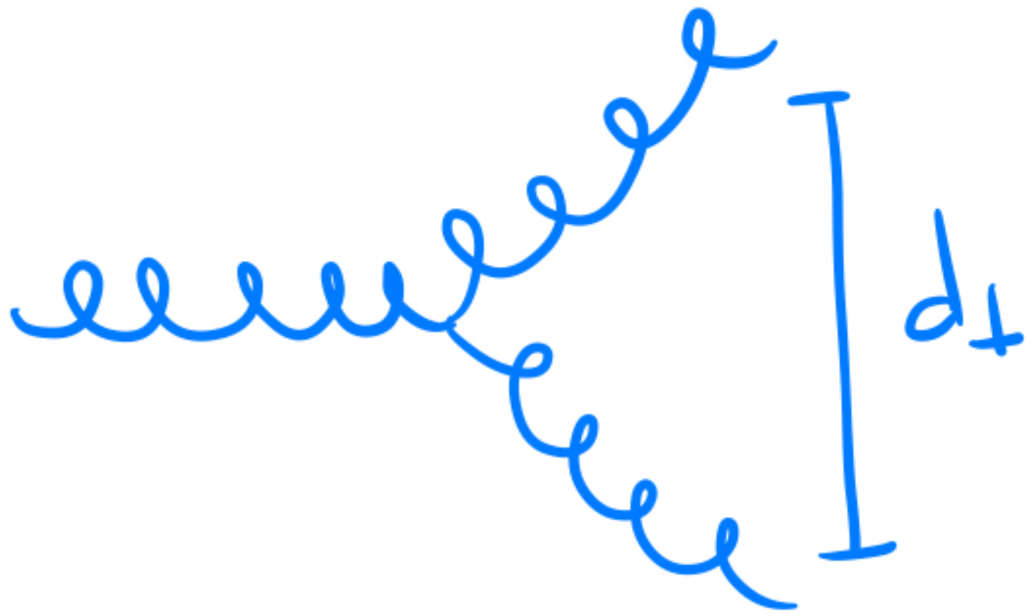


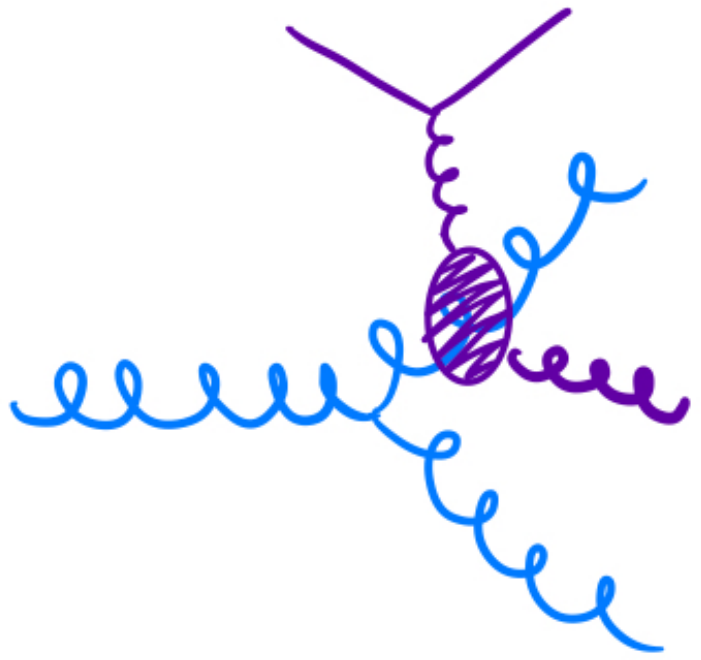


color dipole size in jet at the emission's formation time

$d_\perp(\tau_f)$

- Two possibilities:

$d_\perp > 1/q_\perp$



medium resolves individual partons

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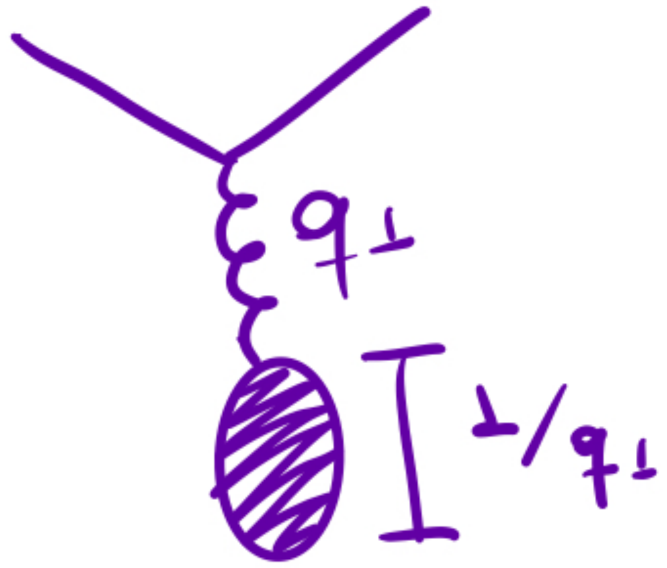

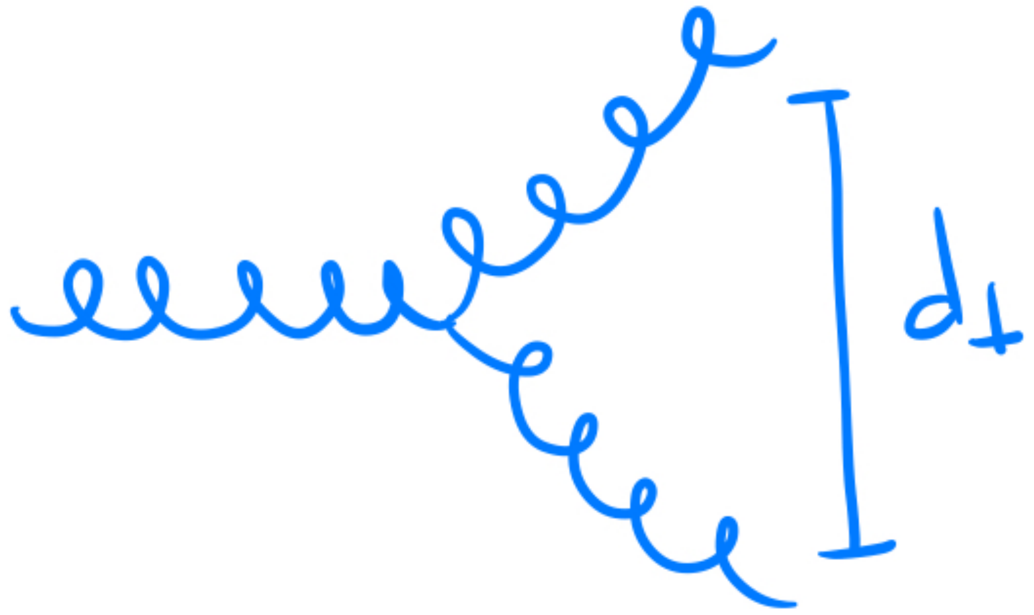

color dipole size in jet at the emission's formation time

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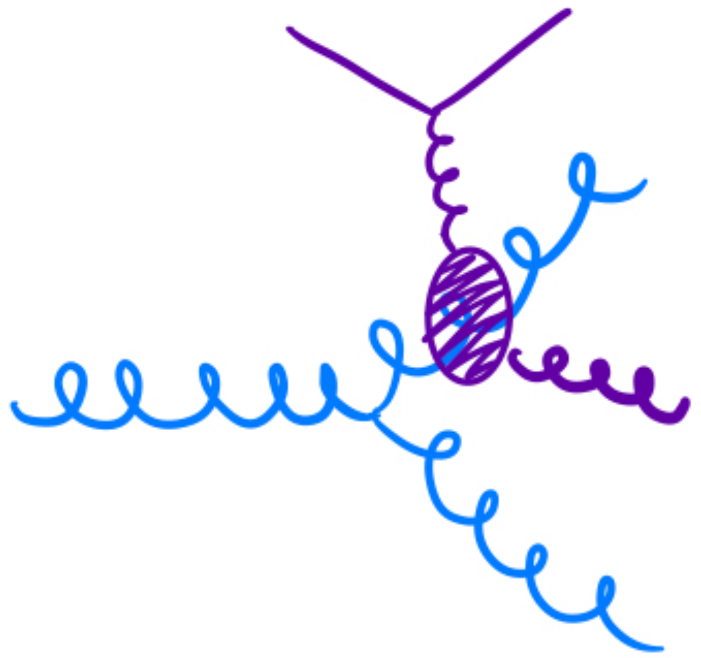

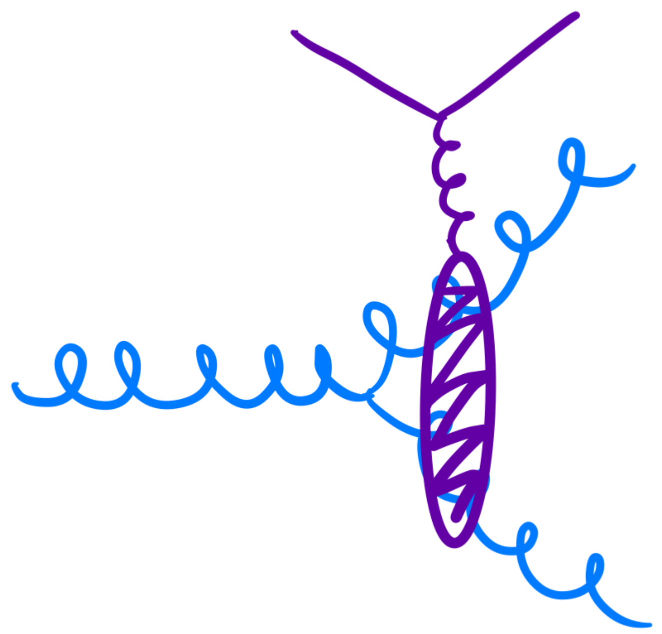

$d_\perp < 1/q_\perp$

medium resolves individual partons

medium does not resolve: scattering is rejected

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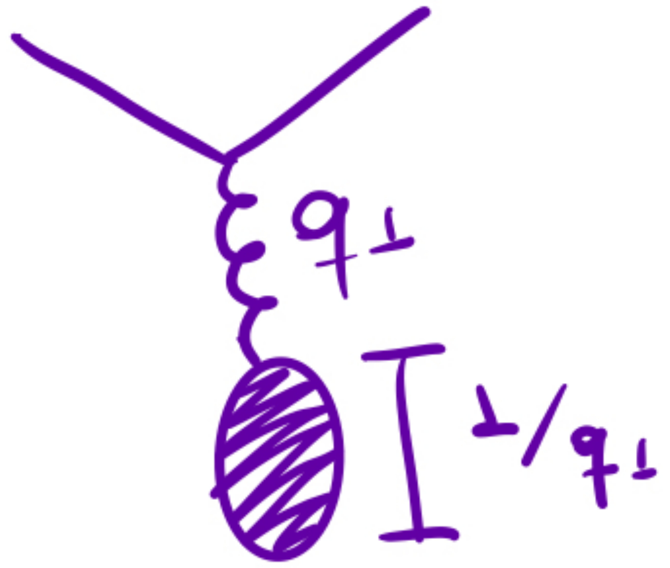

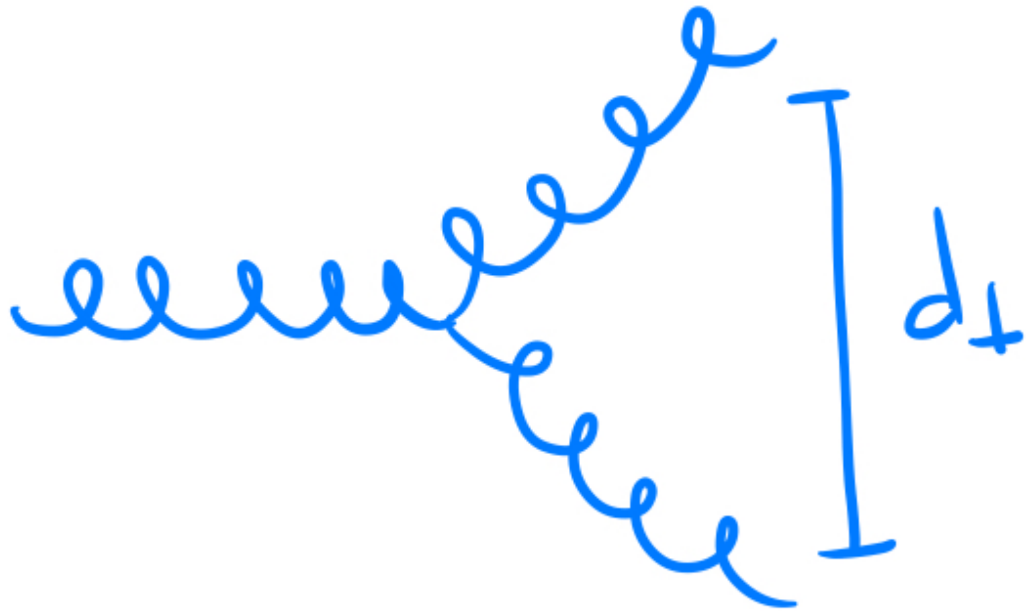

color dipole size in jet at the emission's formation time

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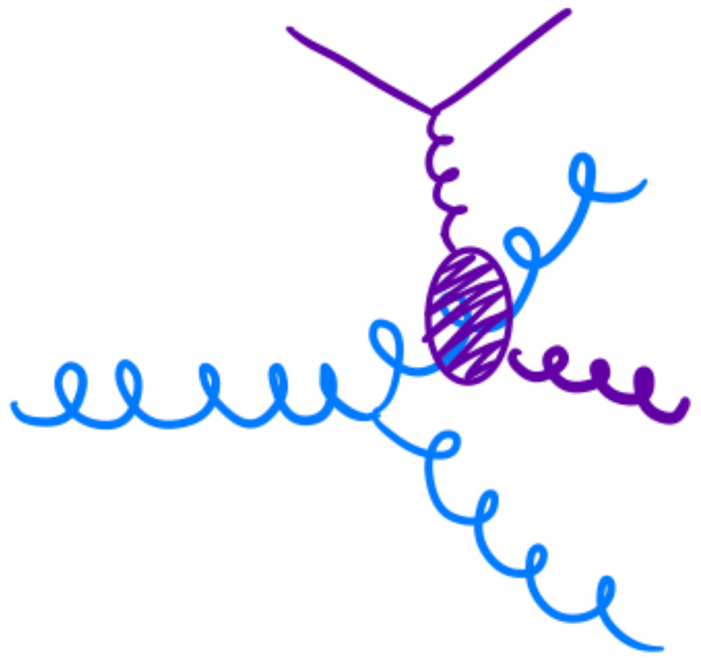
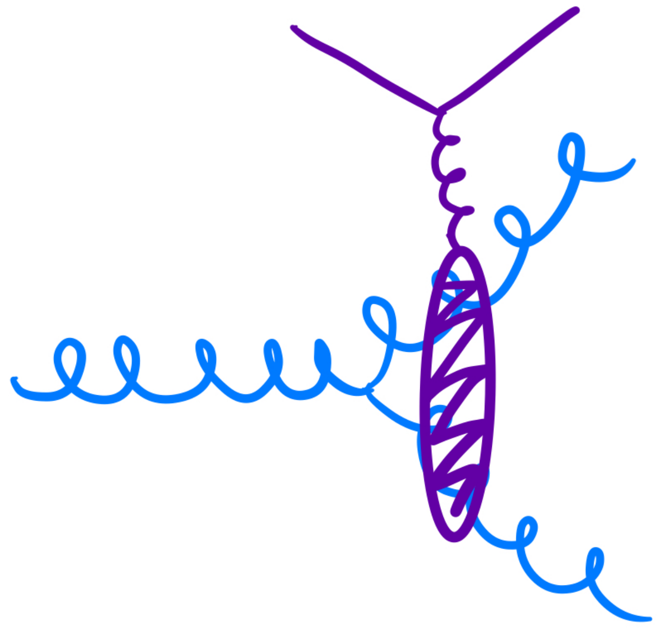




$d_\perp < 1/q_\perp$

Early times: dipoles are smaller

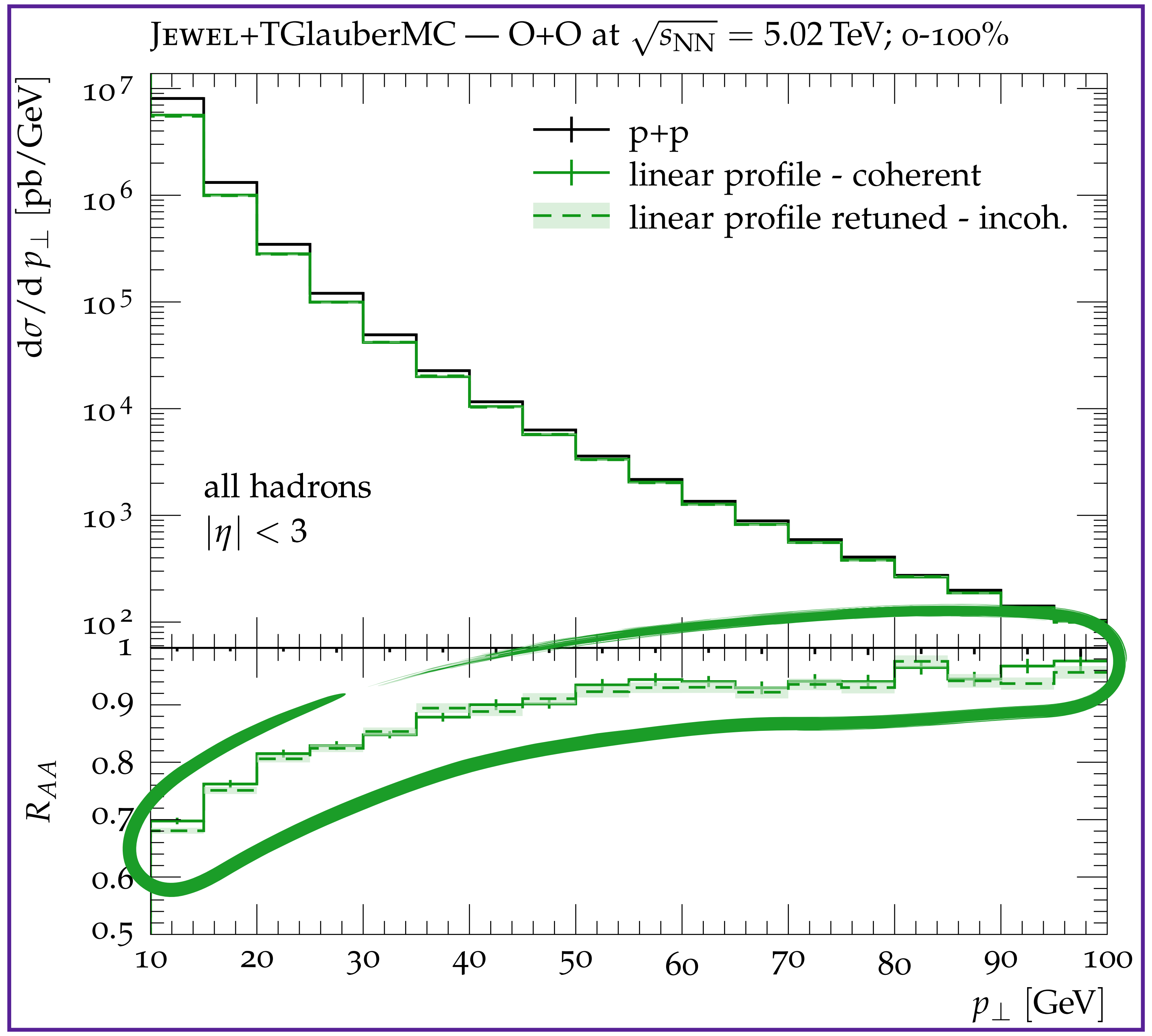
medium resolves individual partons

medium does not resolve: scattering is rejected

Color coherence in small collision systems

Coherence effect on v_2

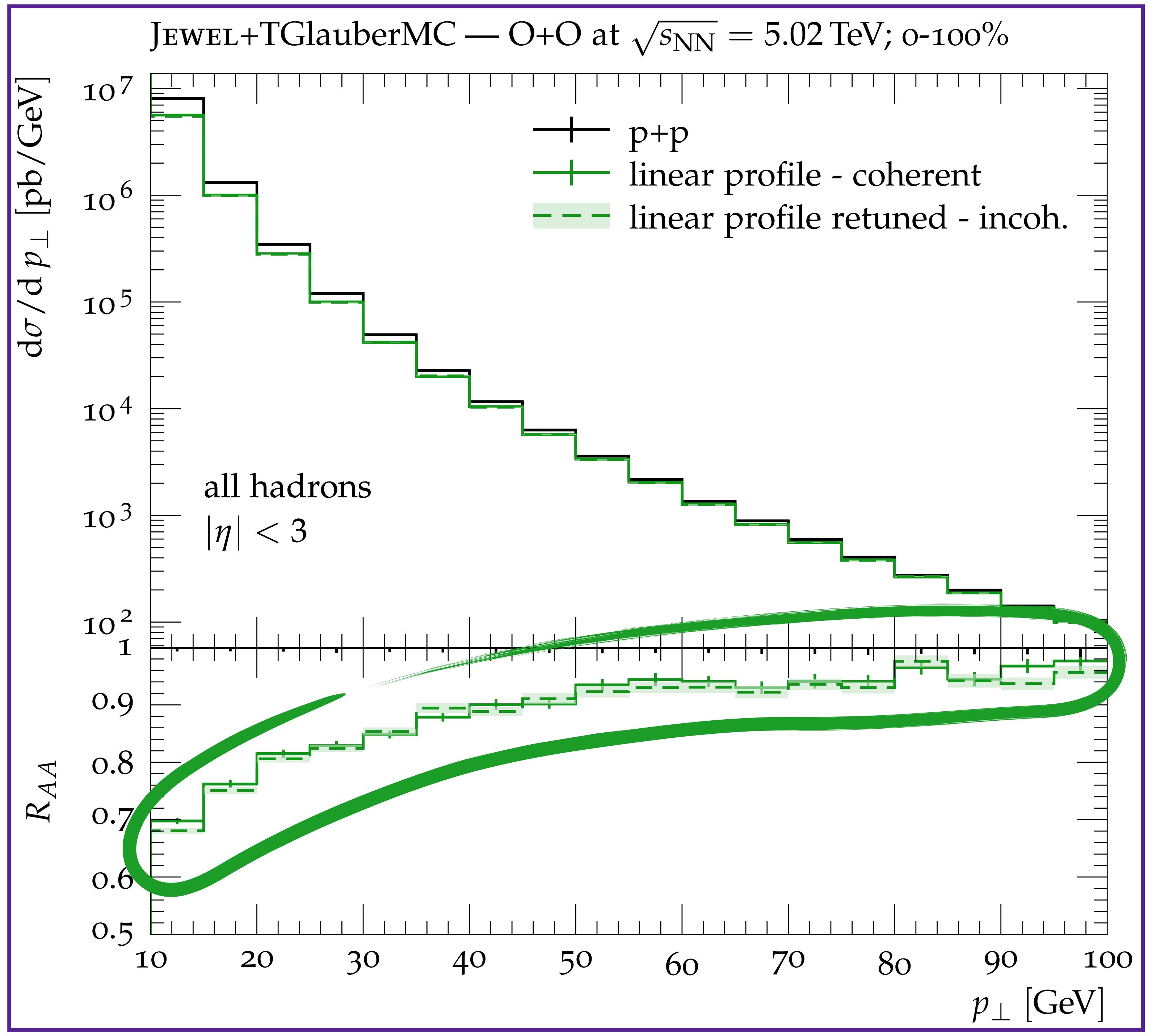
- T_i tuned such that coherent and incoherent have the same R_{AA}

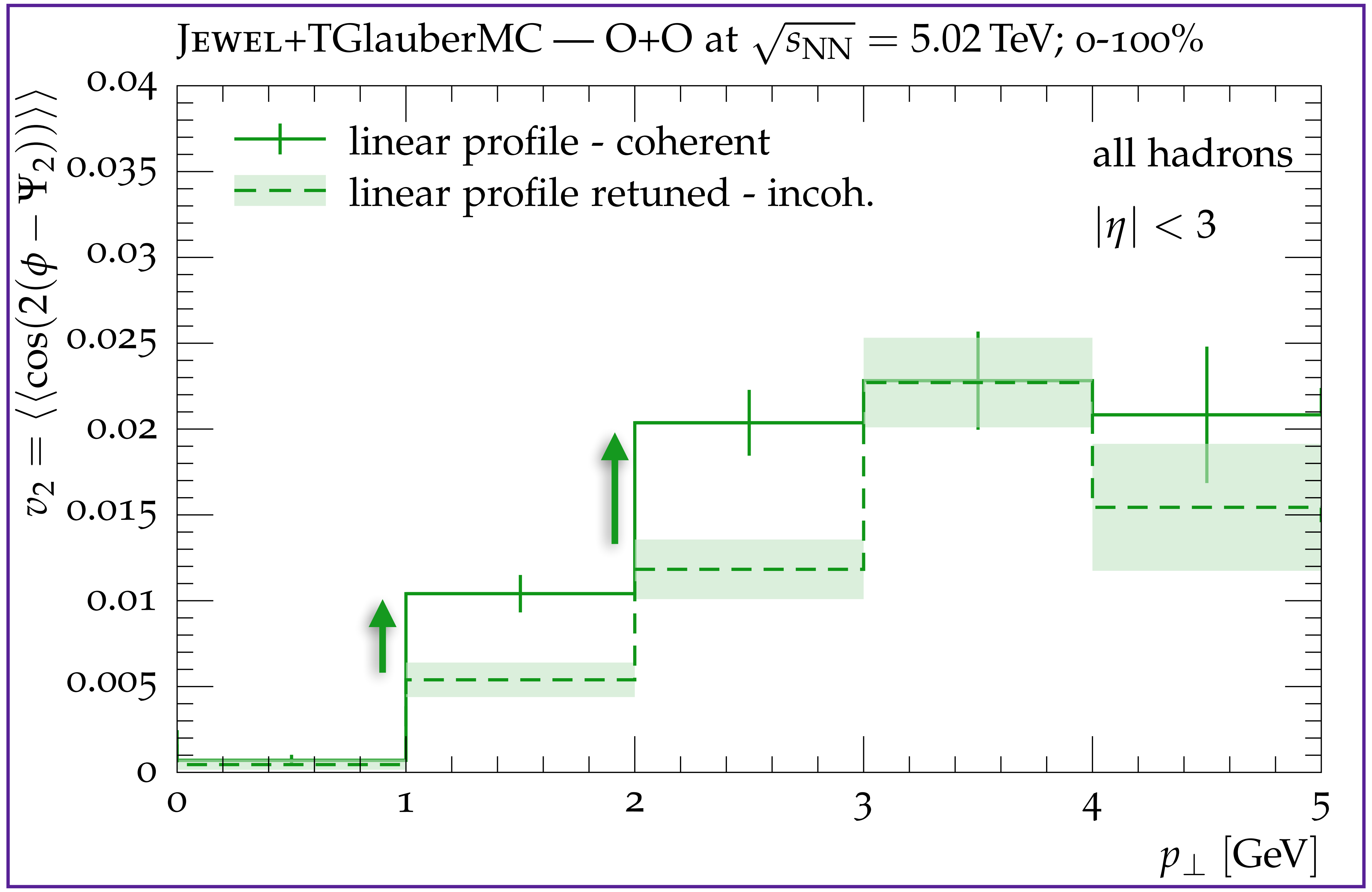


Color coherence in small collision systems

Coherence effect on v_2

- T_i tuned such that coherent and incoherent have the same R_{AA}
- Coherence increases v_2: rejected early scatterings are compensated at later times when the anisotropy is larger





Conclusions

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- In very small systems an early and soft rescattering may break angular ordering
- This affects the jet formation time distribution
- This leads to jet suppression that may be indistinguishable from energy loss in the R_{AA}
- Formation time distribution can distinguish the two scenarios and in potentially measurable
- In larger systems, coherence effects may also lead to an increase in v_2 even if the same amount of energy loss is observed

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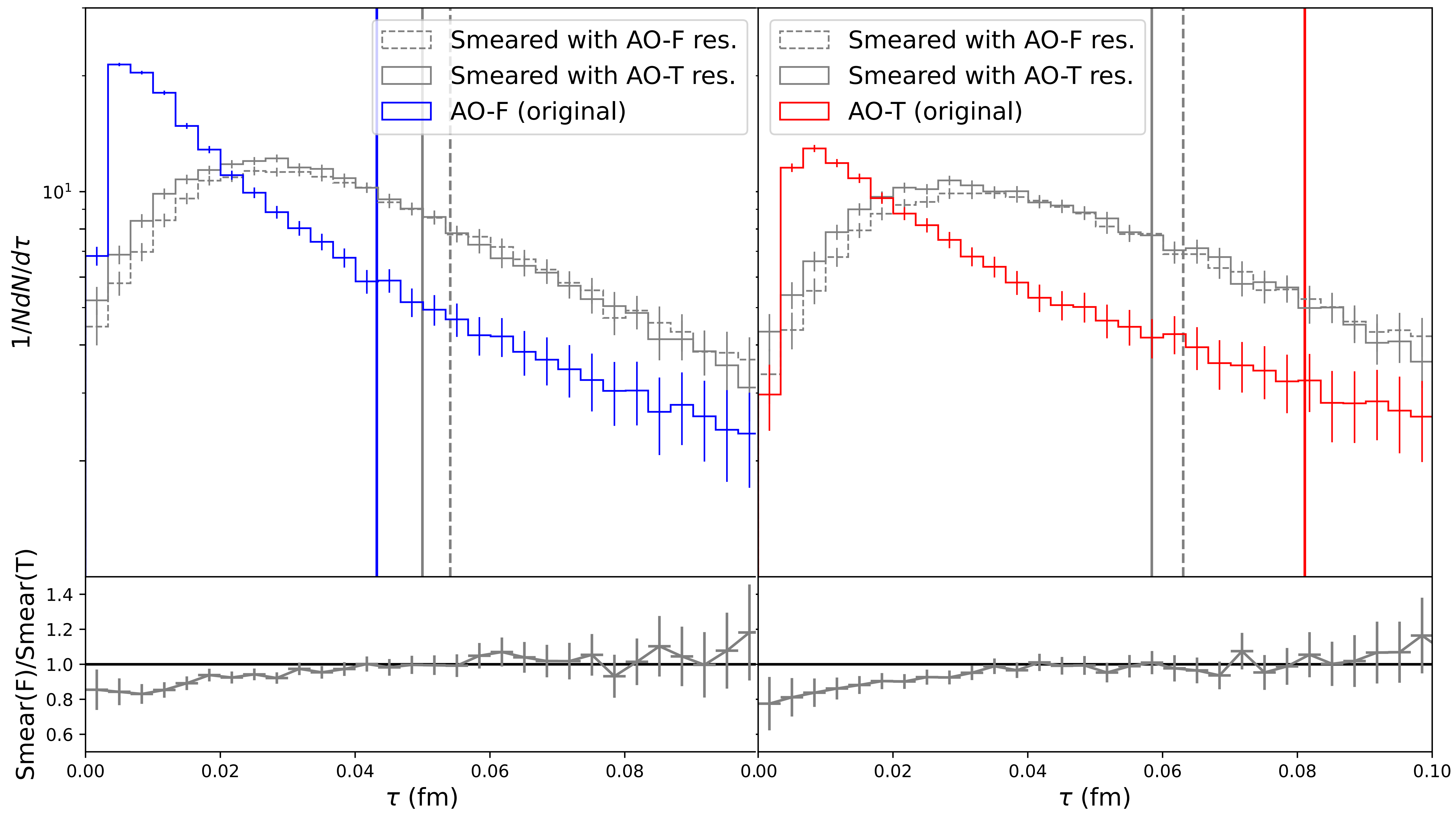
Thank you

Back up

Jet Quenching without Energy Loss

Smearing

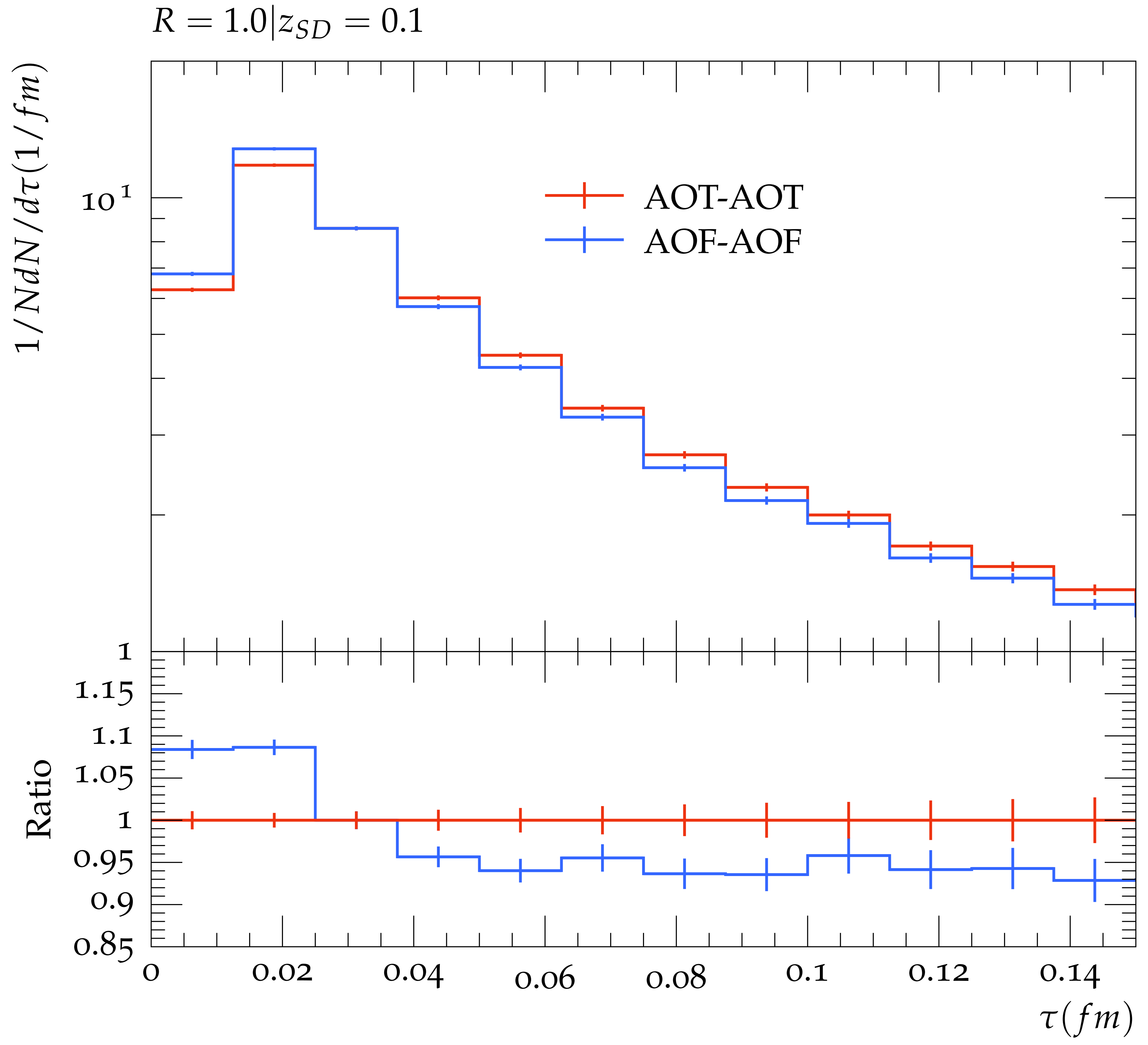
- Smearing is mainly due to misconstruction effects
- AO-F smearing skews towards larger τ compared to the AO-T smearing
- The reconstructed AO-F still has smaller τ due to the remainder of the *underlying distribution*

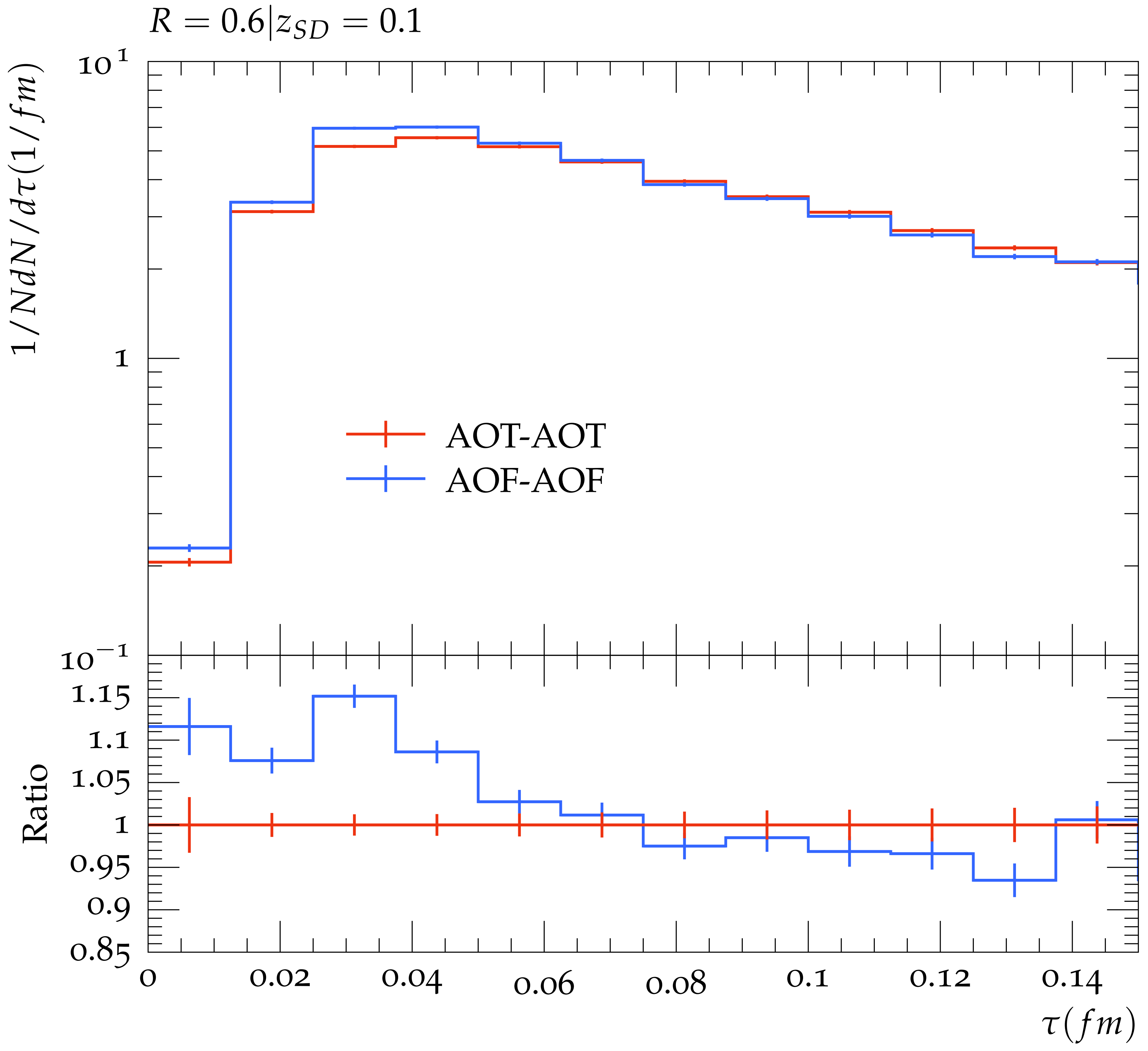


Jet Quenching without Energy Loss

Soft drop grooming

- Soft drop attenuates the signal but it remains visible

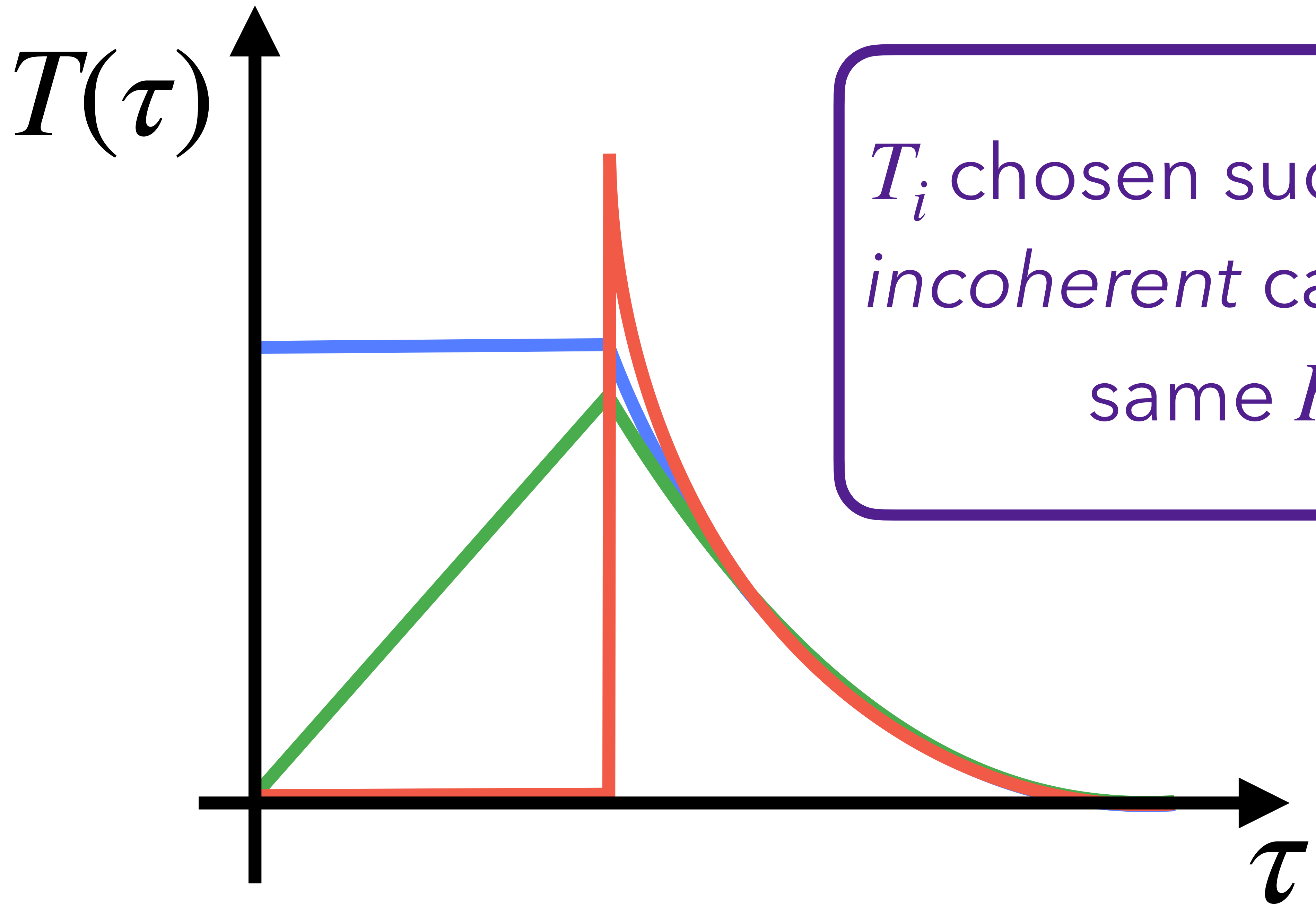




Color coherence in small collision systems

Initial temperature & R_{AA}

- JEWEL simple medium model:
- Test different models for initial temperature



T_i chosen such that all *incoherent* cases have same R_{AA}