NITheCS
National Institute for
Theoretical and Computational Sciences

MITP
Mandelstam Institute for Theoretical Physics

Coherence Effects as Probes for a Medium

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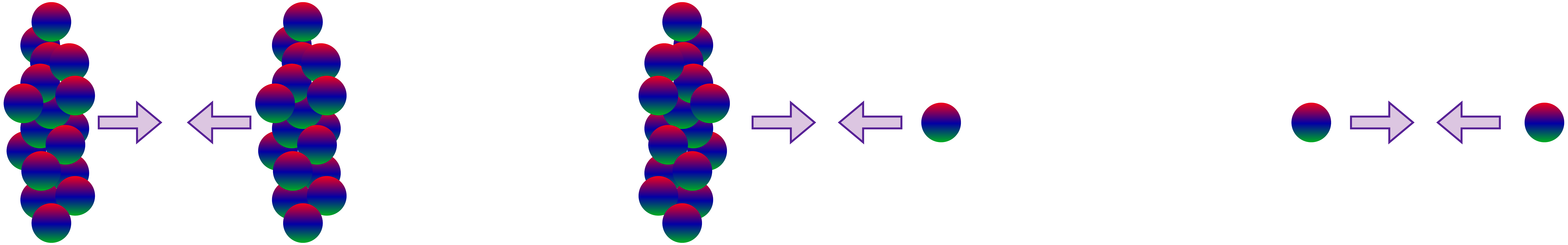
Introduction

Introduction

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



Introduction

JEWEL

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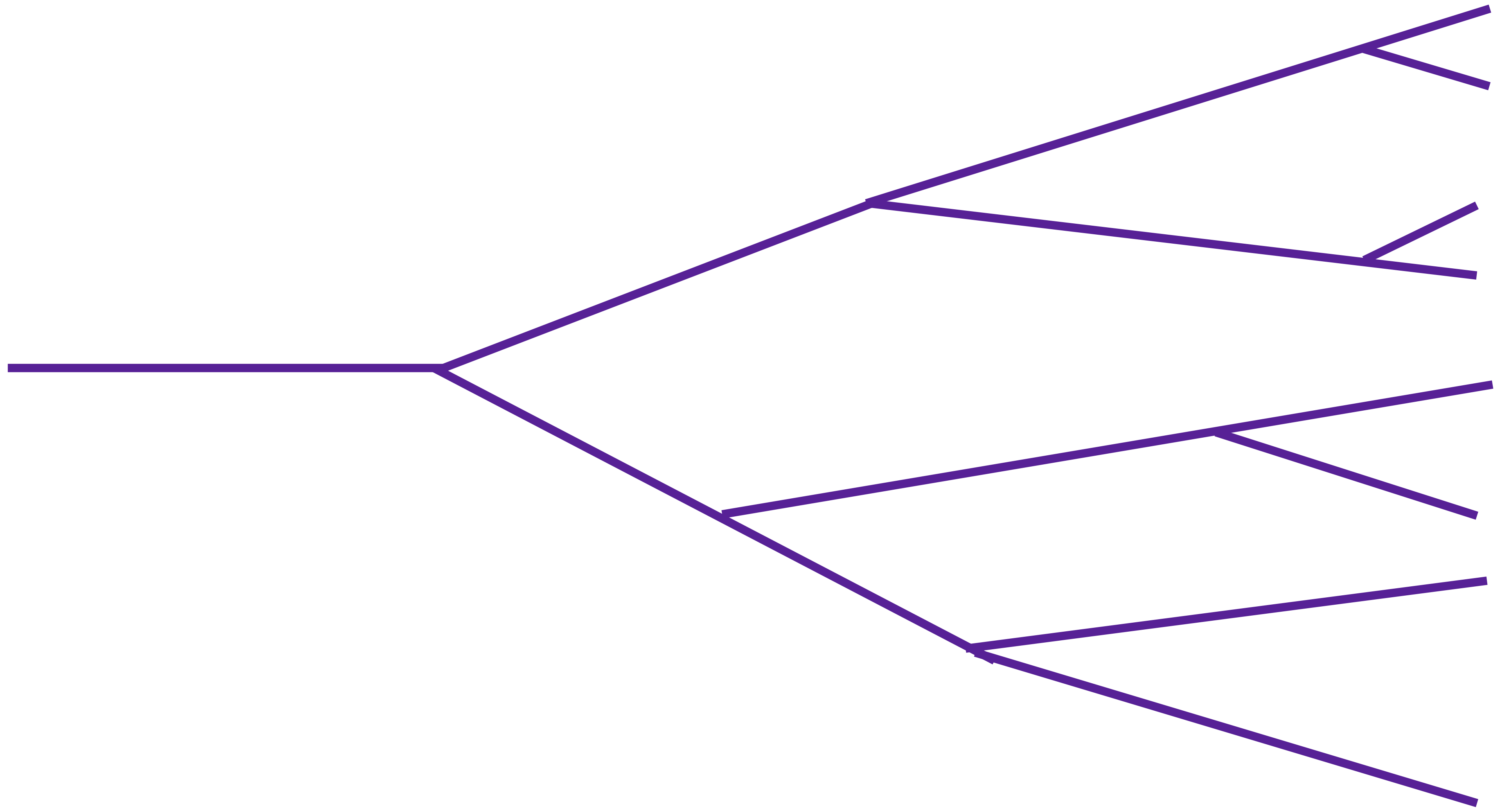
- JEWEL uses Pythia-6.4 structure but with its own virtuality ordered final state parton shower



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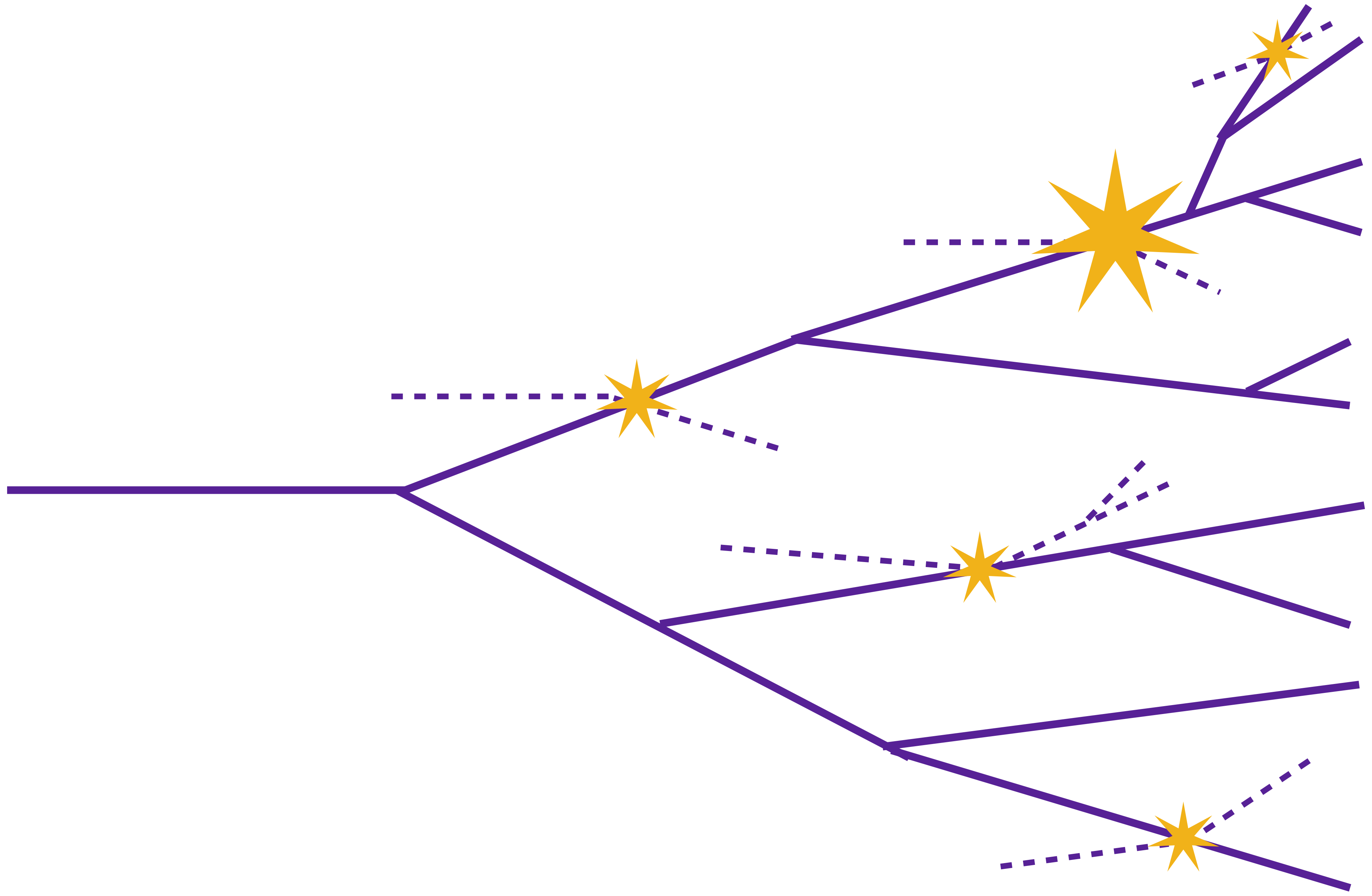
- Partons are allowed to scatter off medium particles between splittings



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JEWEL

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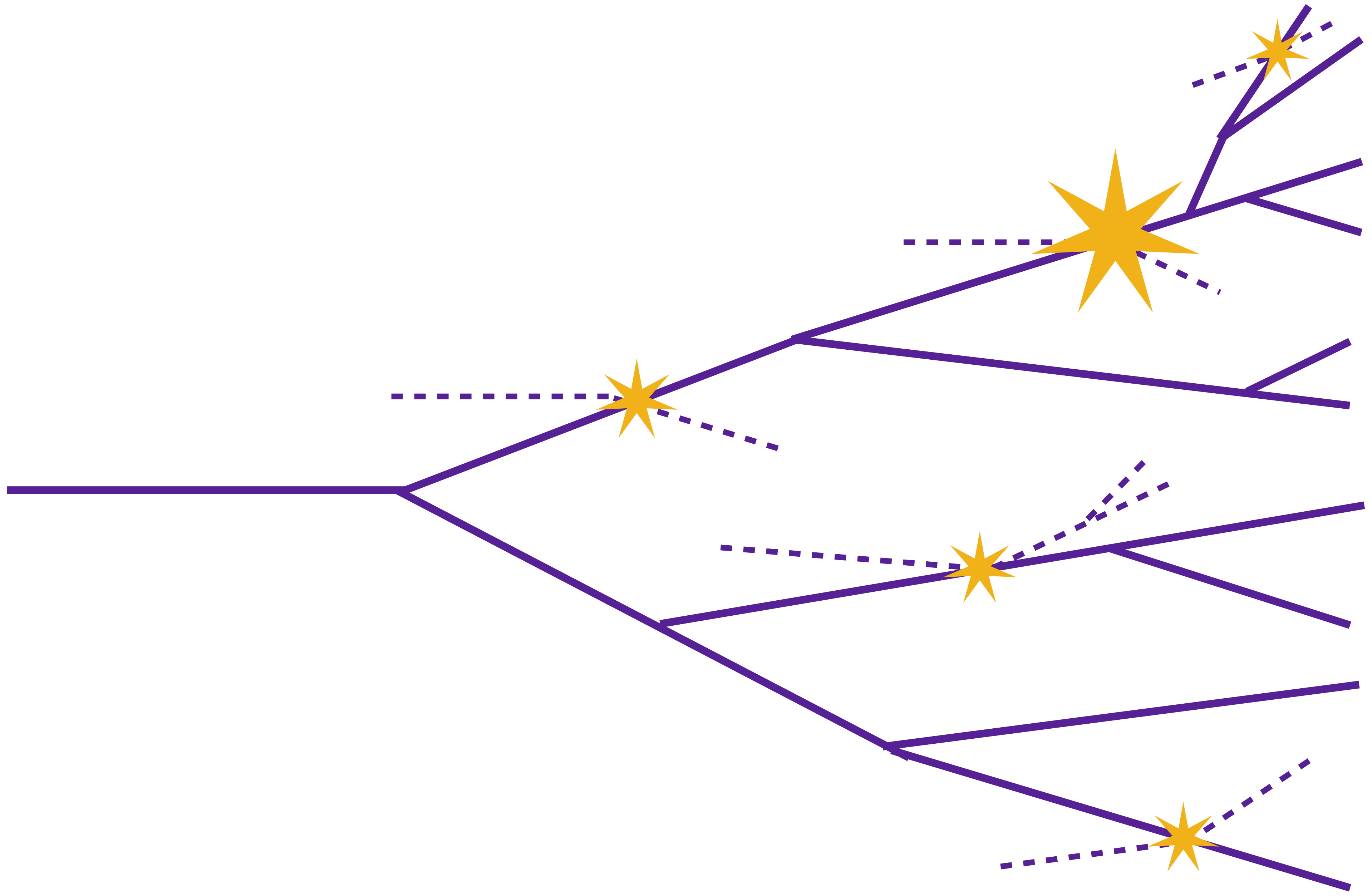
- Partons are allowed to scatter off medium particles between splittings
- Scattering cross section is calculated in pQCD and regularized by the Debye mass



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

Introduction

Angular ordering

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

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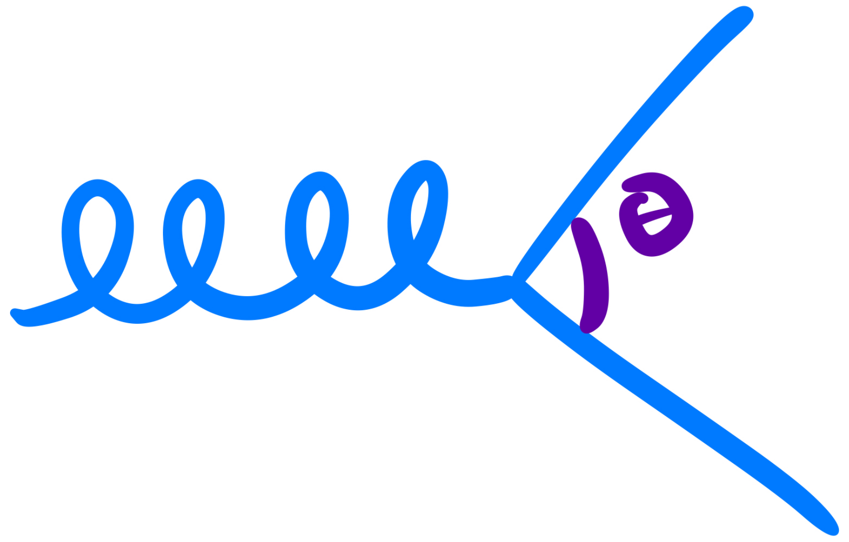

1st splitting

Introduction

Angular ordering

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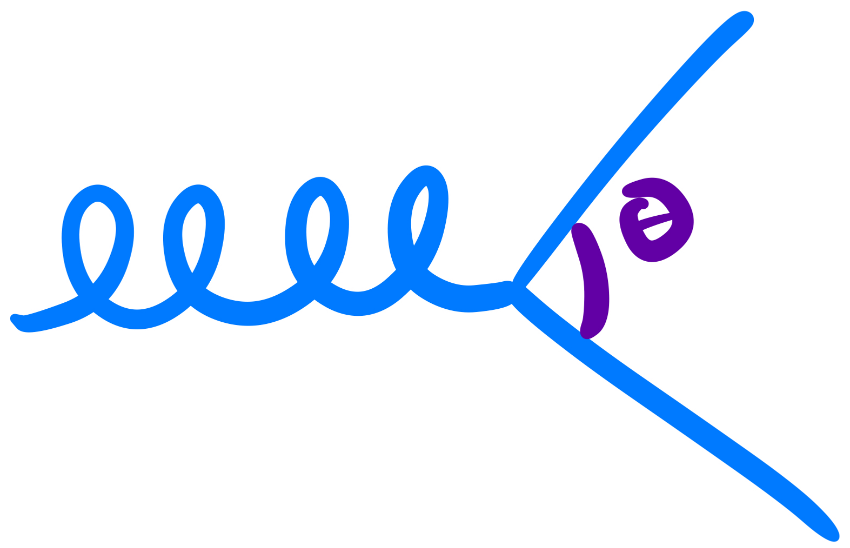

1st splitting

$\tilde{\theta} > \theta$

2nd splitting

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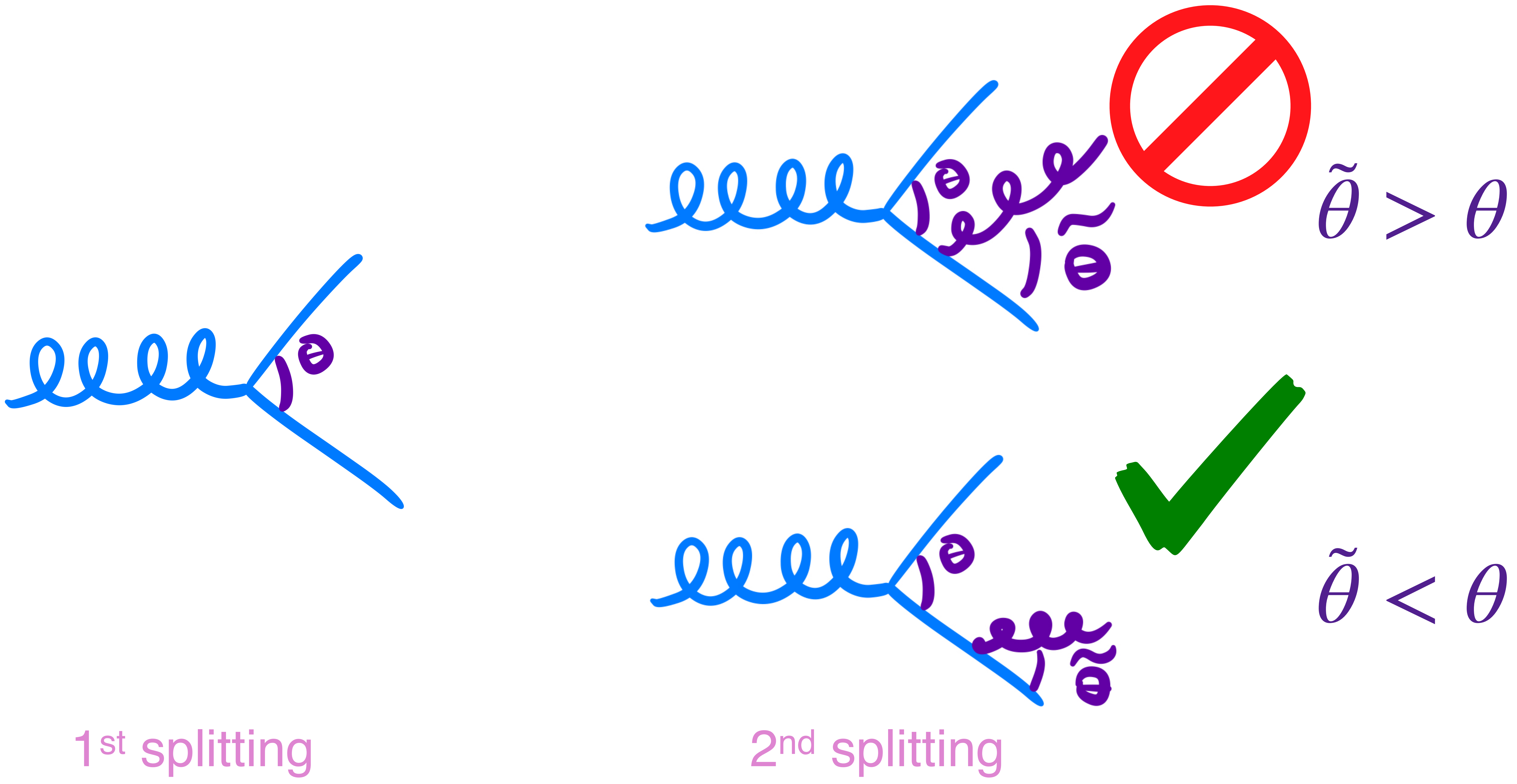

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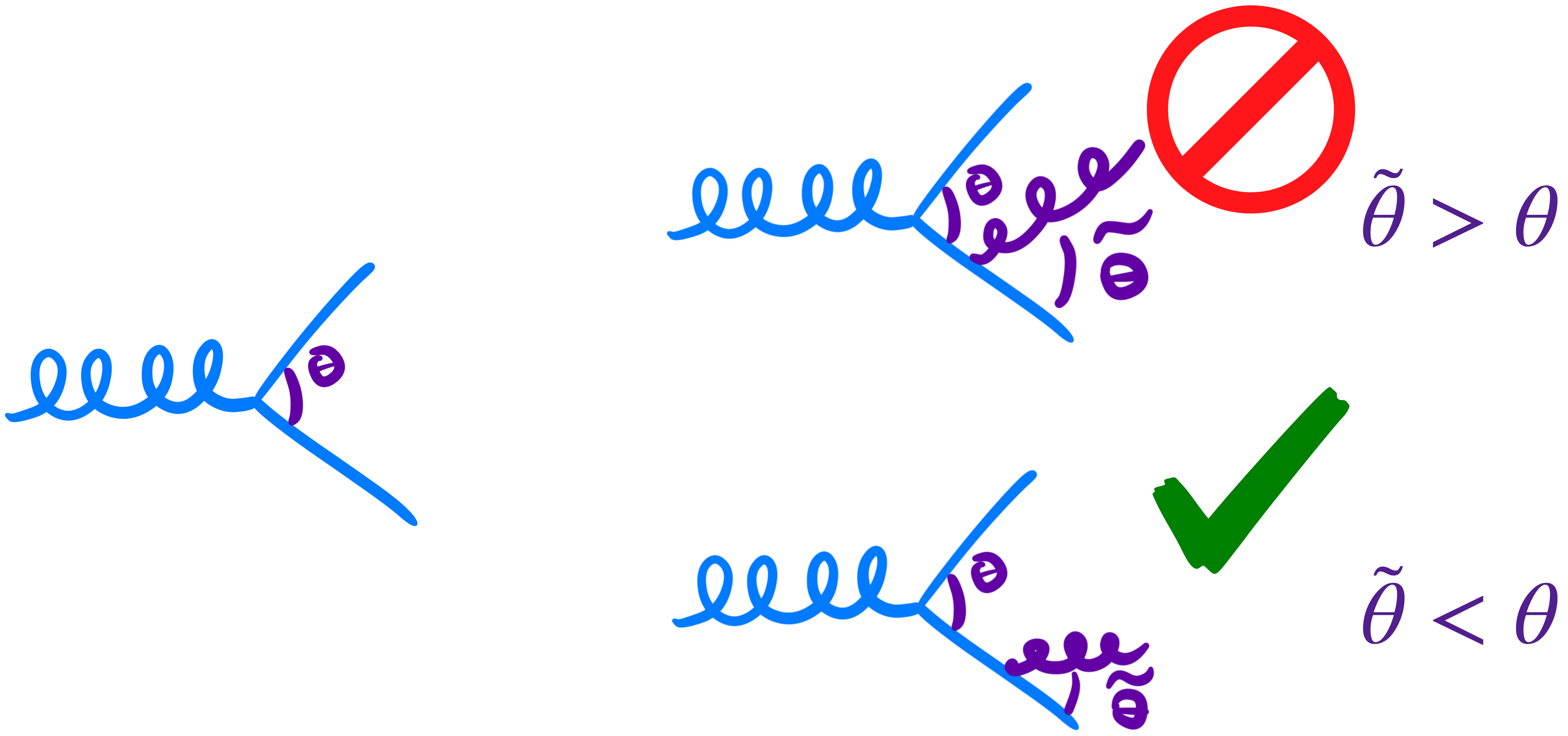


$\tilde{\theta} > \theta$

$\tilde{\theta} < \theta$

1st splitting

2nd splitting

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

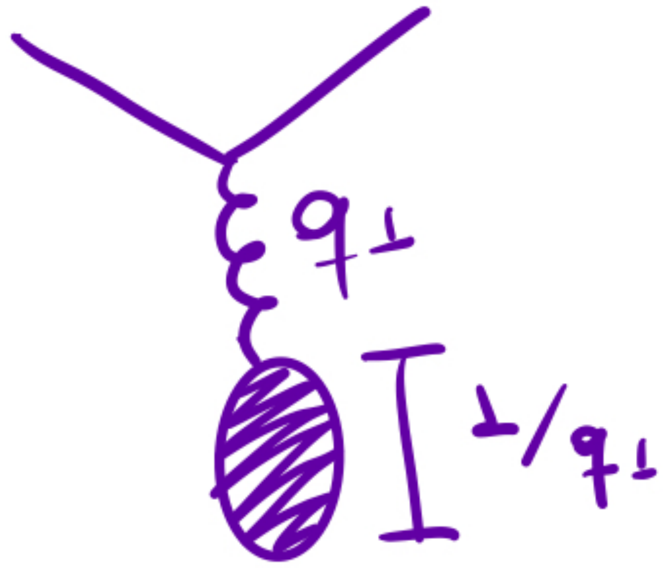
Introduction

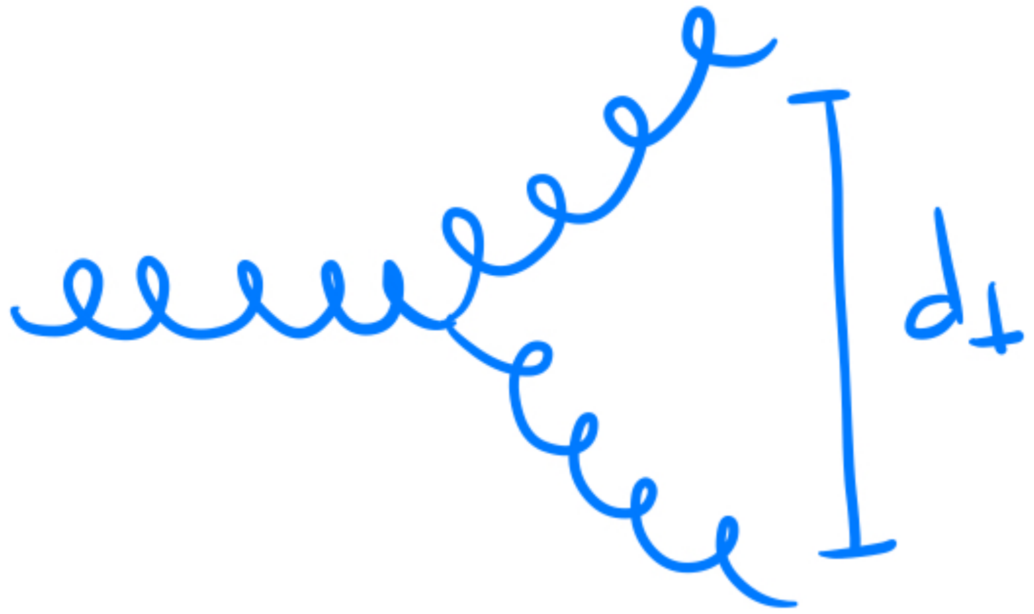
Coherence in scattering

- Medium introduces an additional scale:

medium resolution

$1/q_\perp$





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

$d_\perp(\tau_f)$

- Two possibilities:

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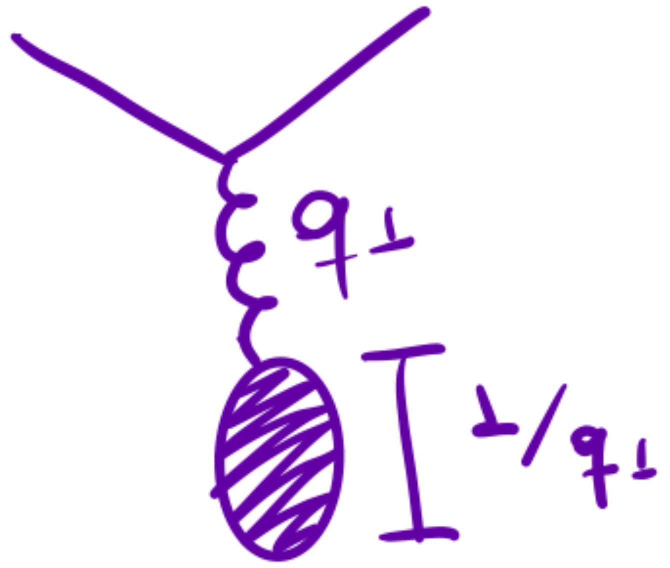

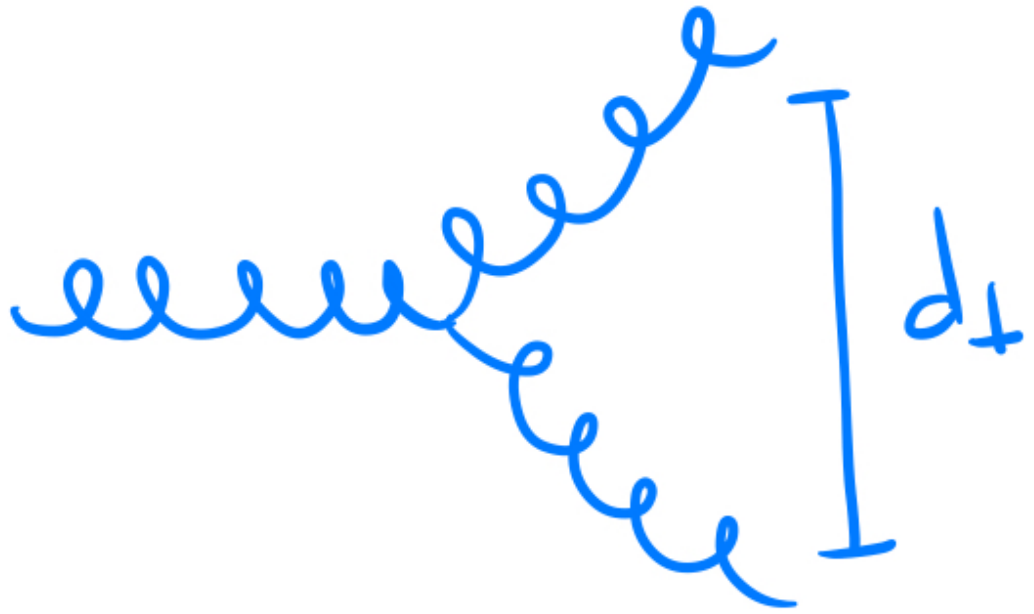

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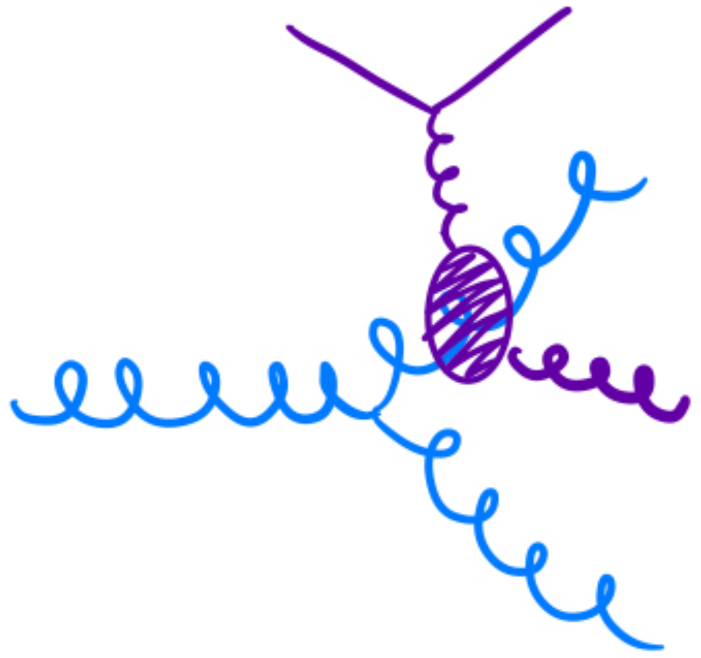

medium resolves individual partons

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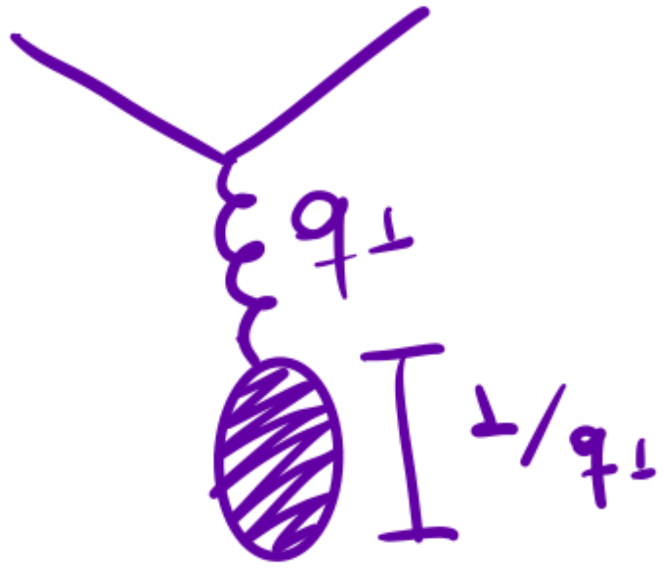

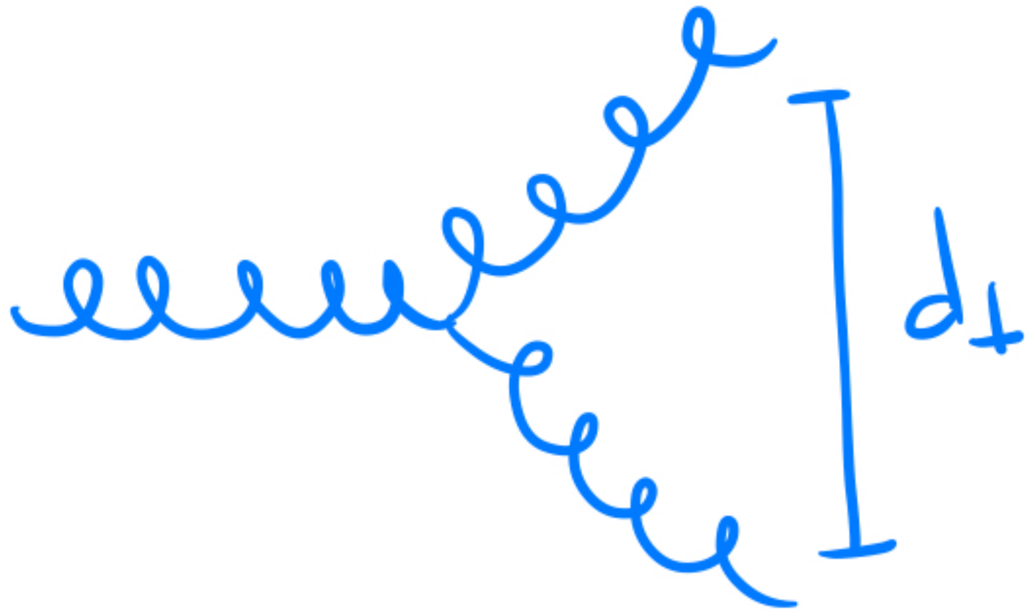

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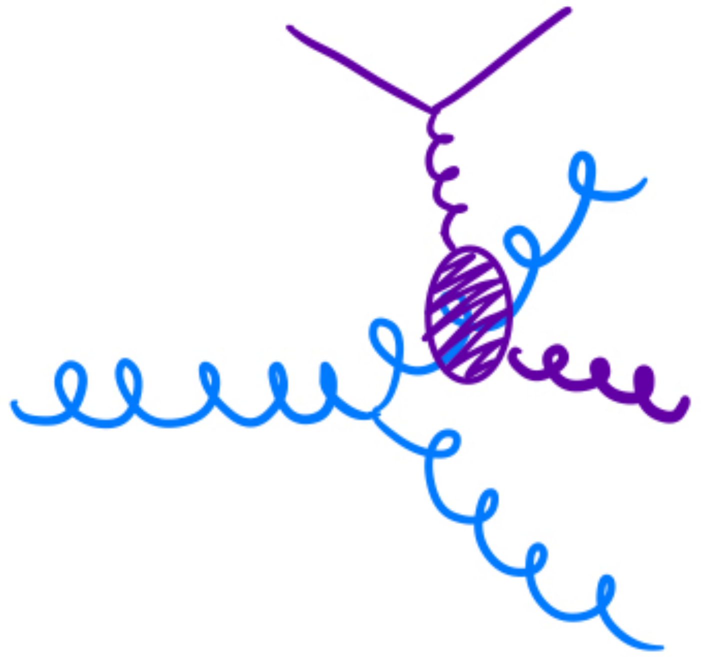
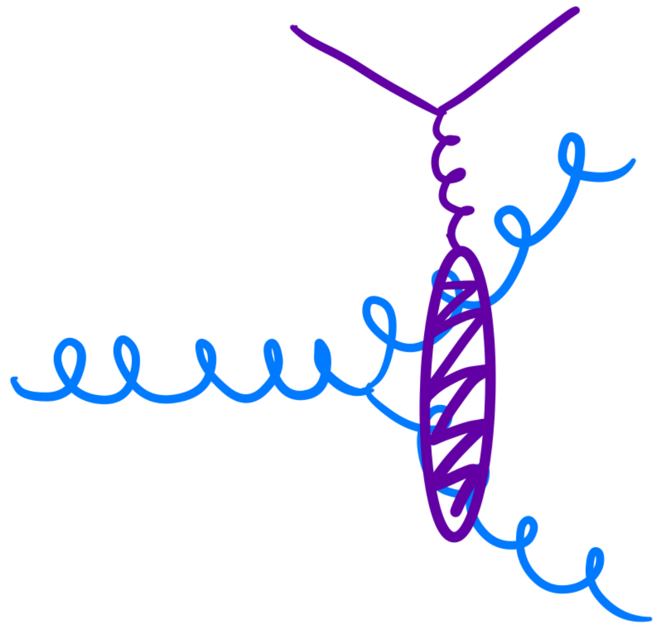




$d_\perp < 1/q_\perp$

medium resolves individual partons

medium does not resolve: scattering is rejected

Jet Quenching without Energy Loss

arXiv:2510.11914

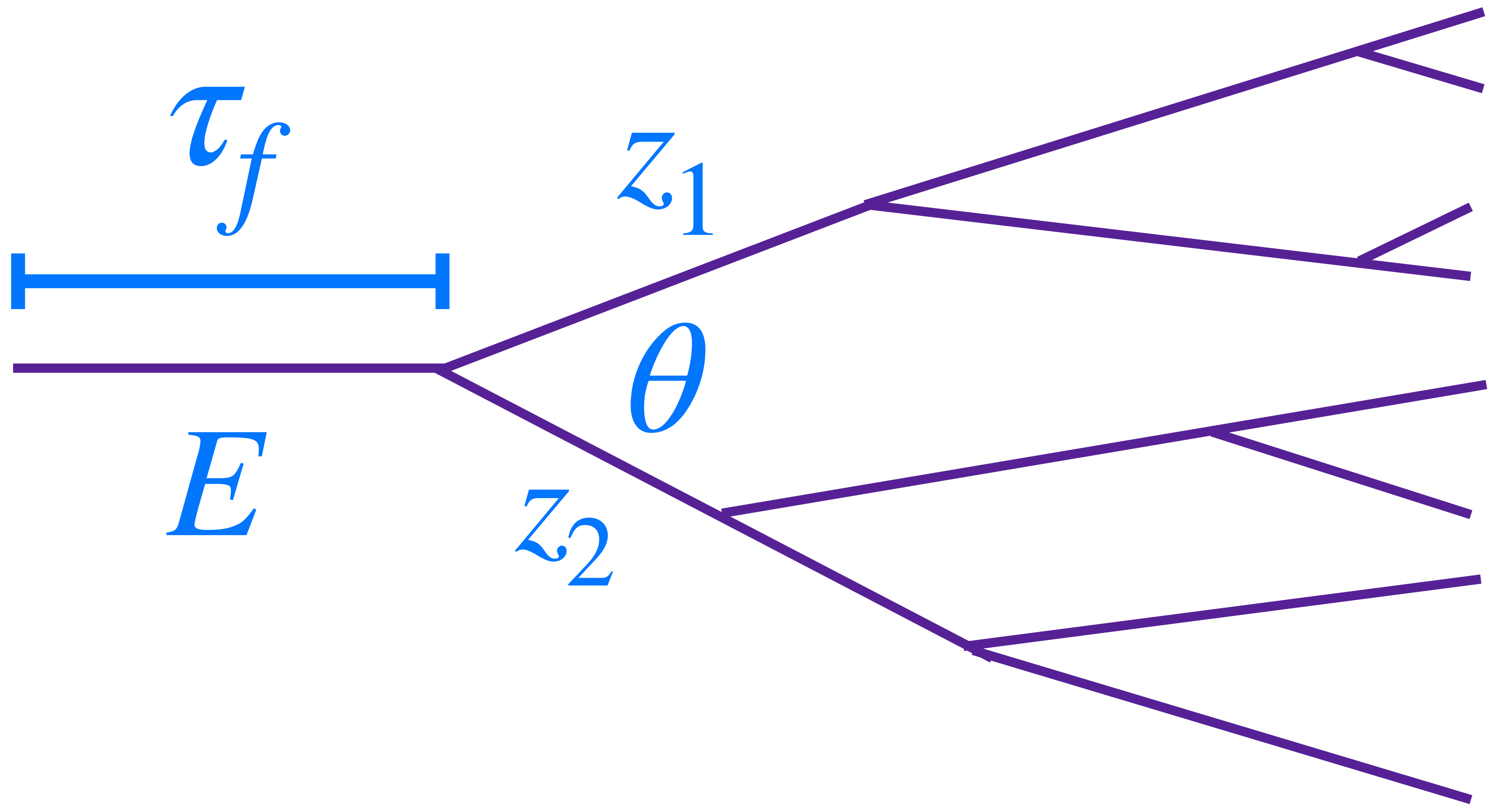
Jet Quenching without Energy Loss

Formation time

Jet Quenching without Energy Loss

Formation time

- Jet formation time

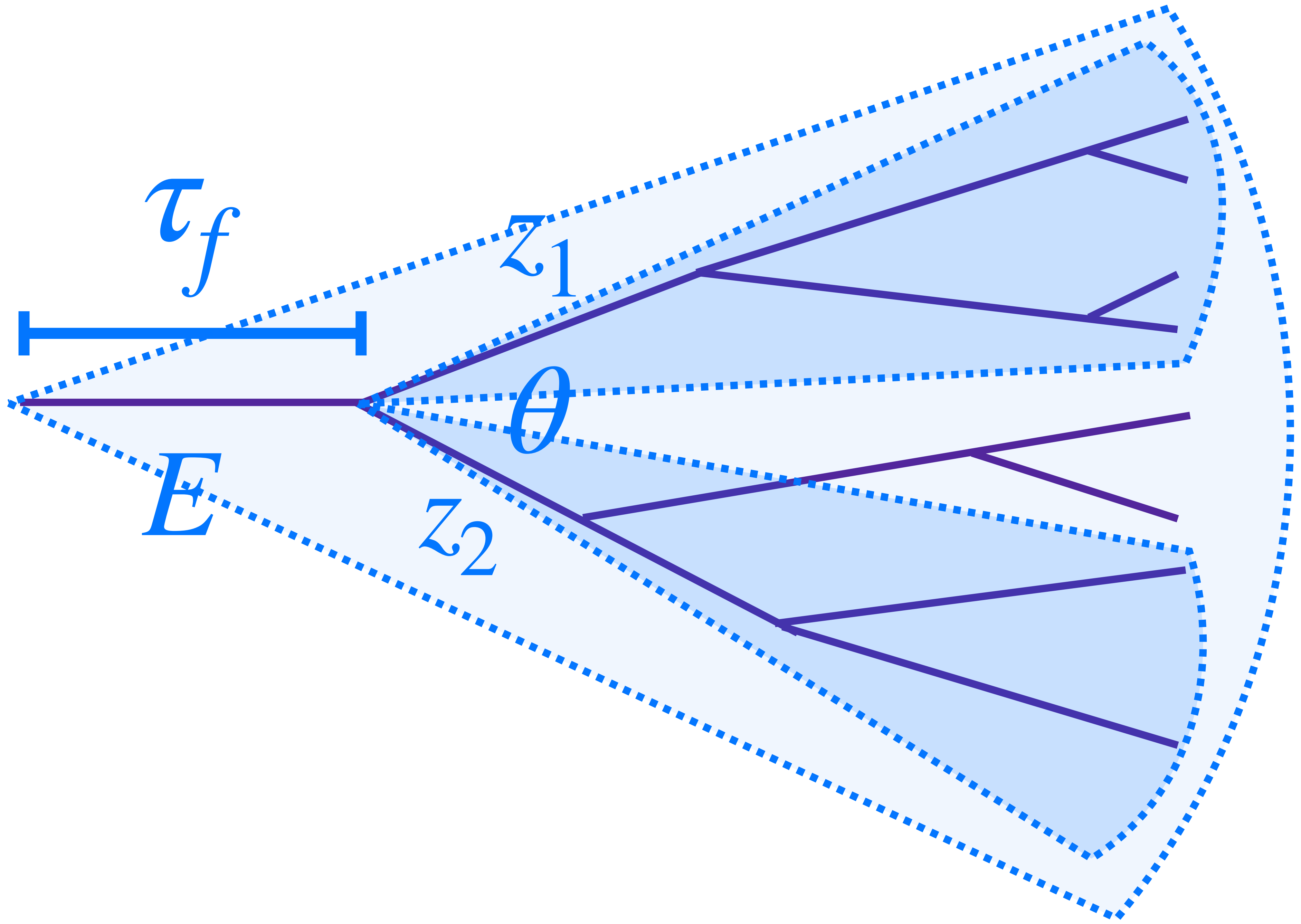


$$\tau_f \sim \frac{1}{2Ez_1z_2(1-\cos\theta)}$$

Jet Quenching without Energy Loss

Formation time

- Jet formation time
- Reconstructed with τ-reclustering algorithm



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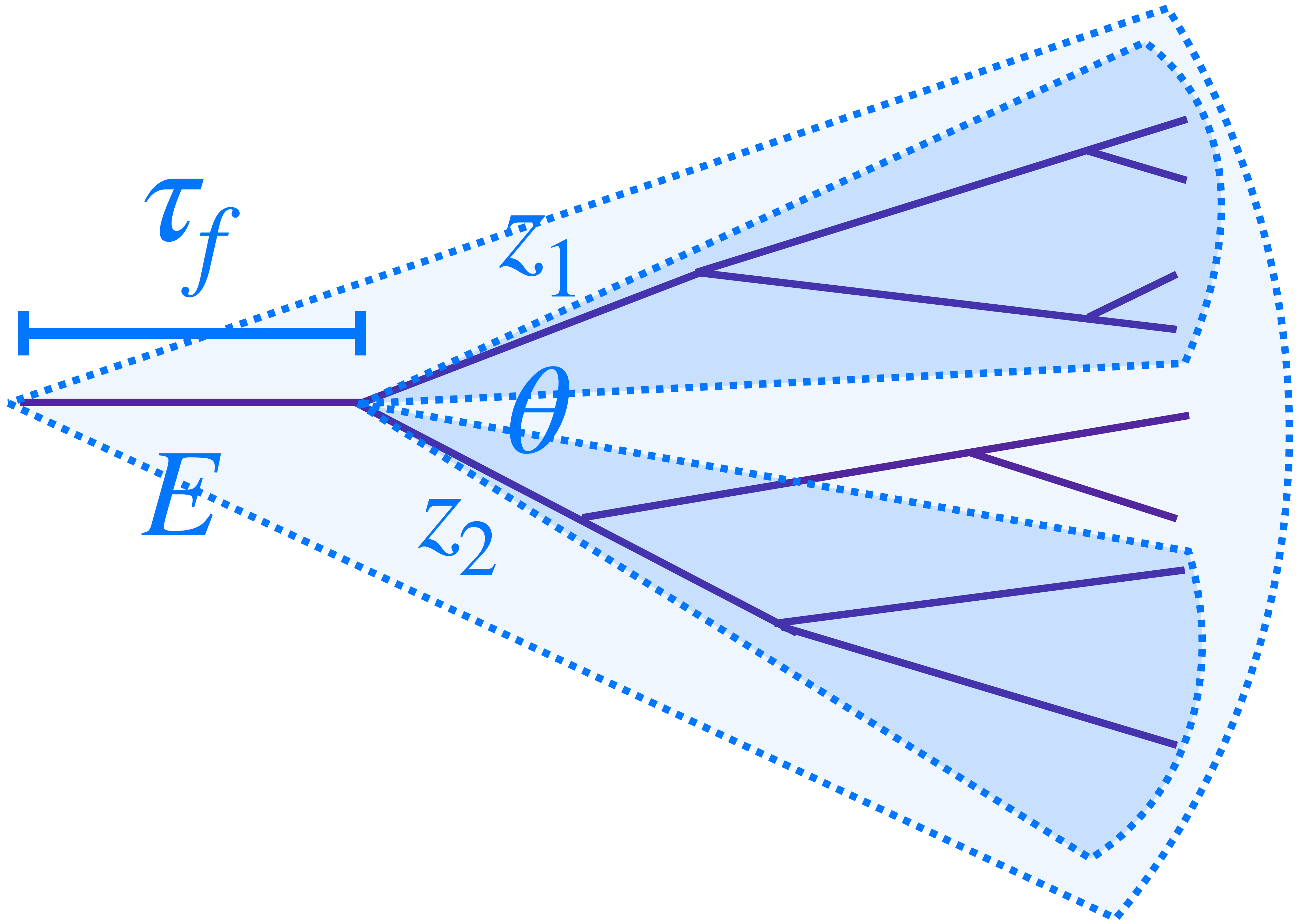

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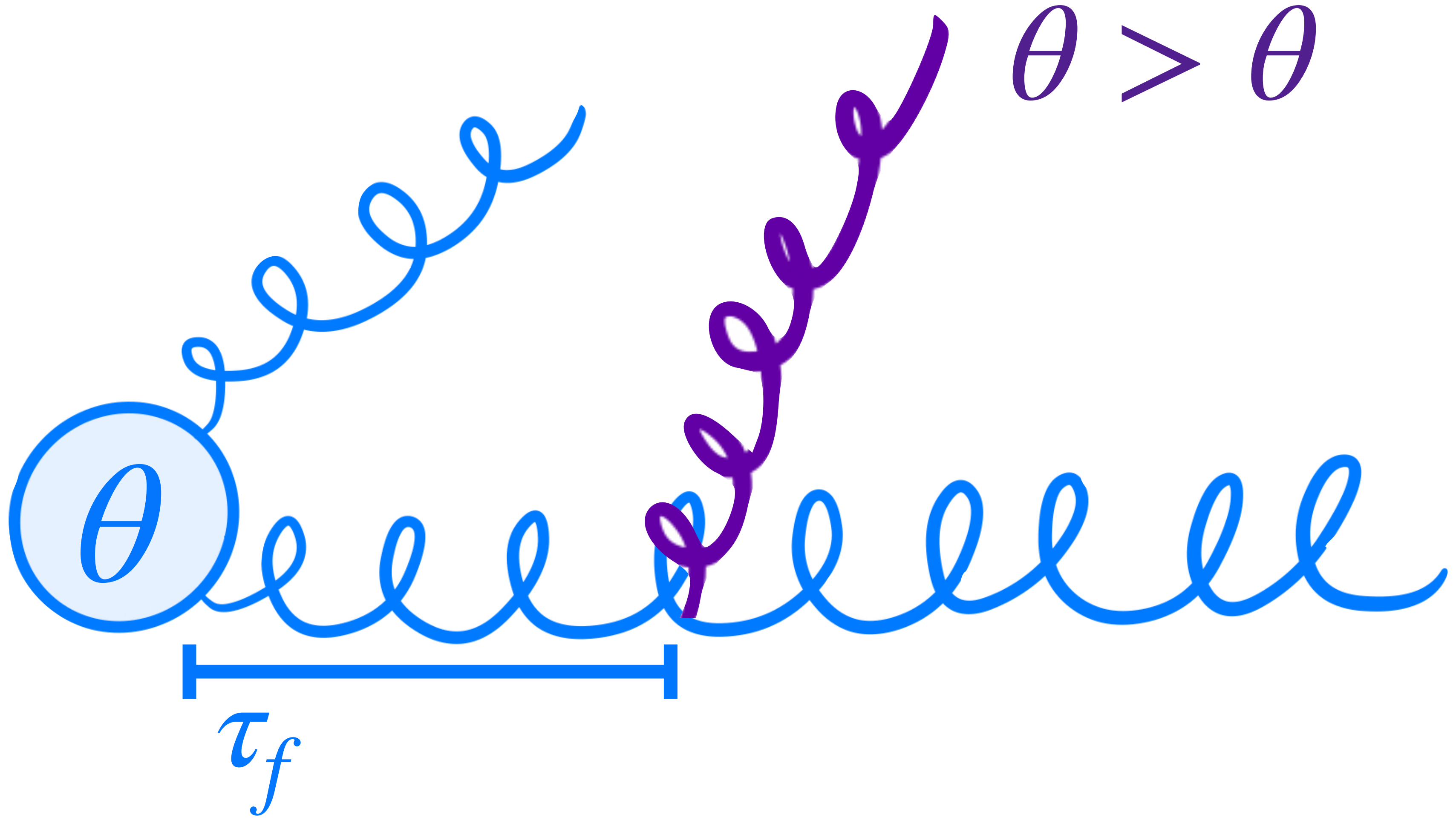

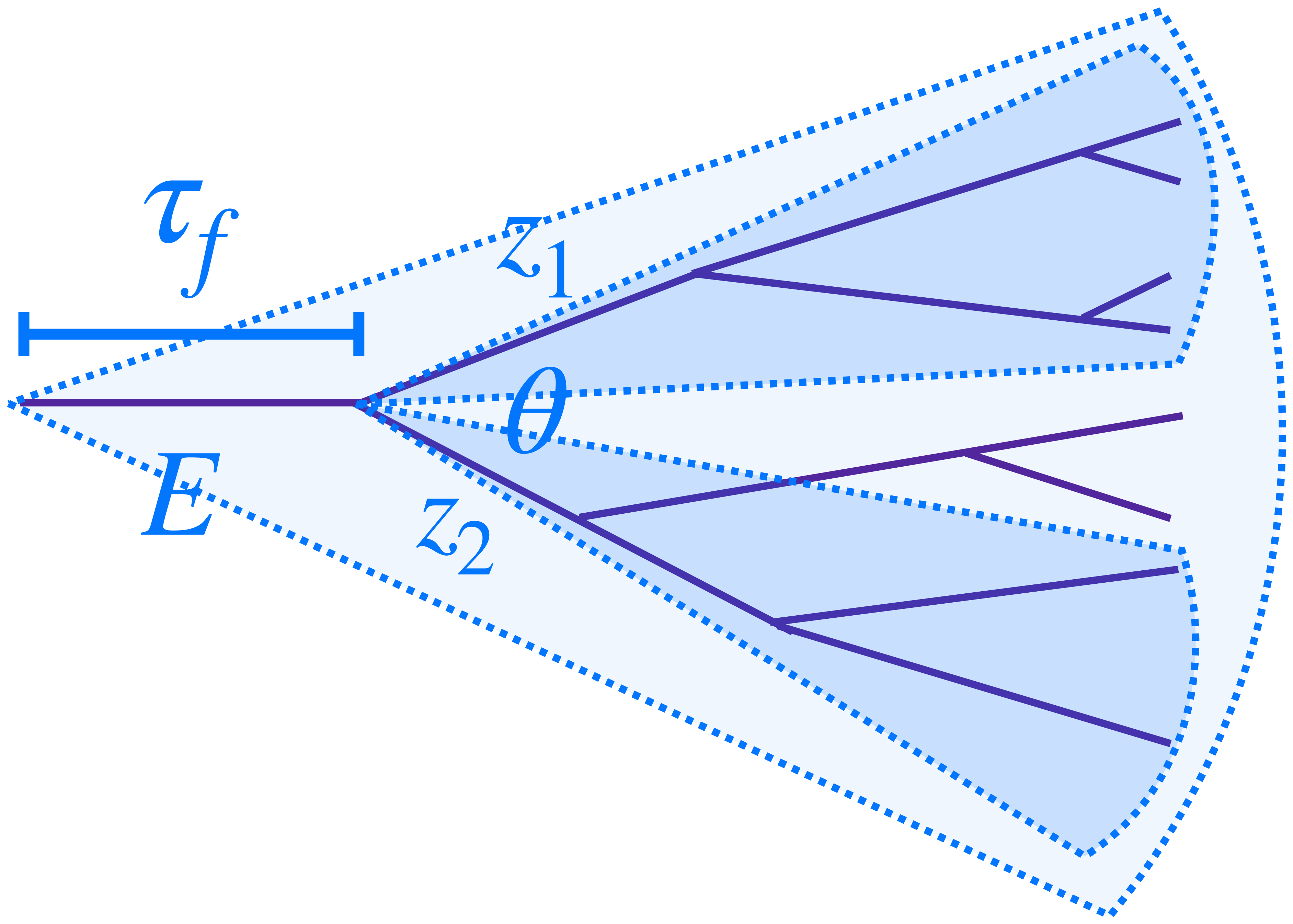

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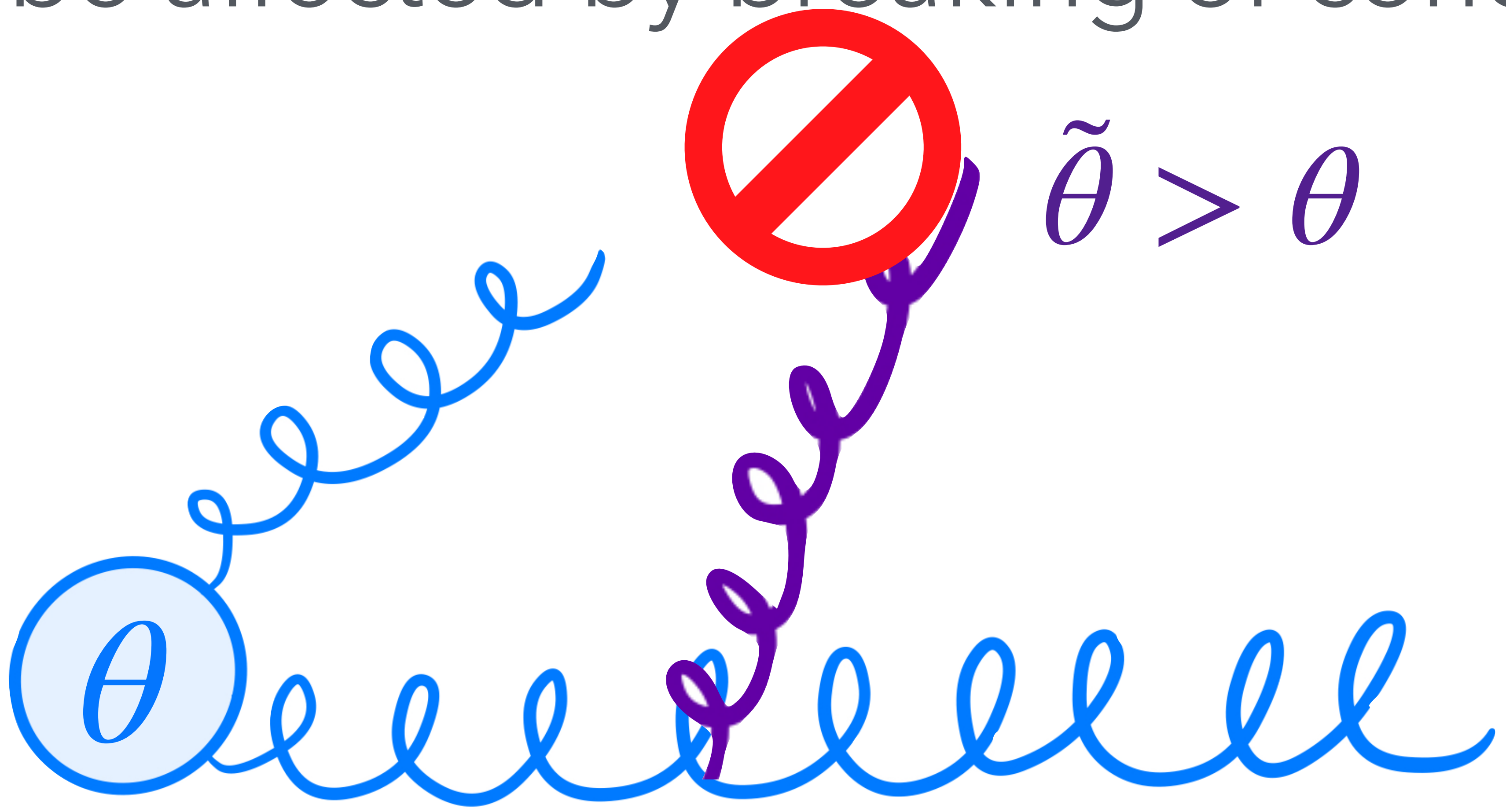

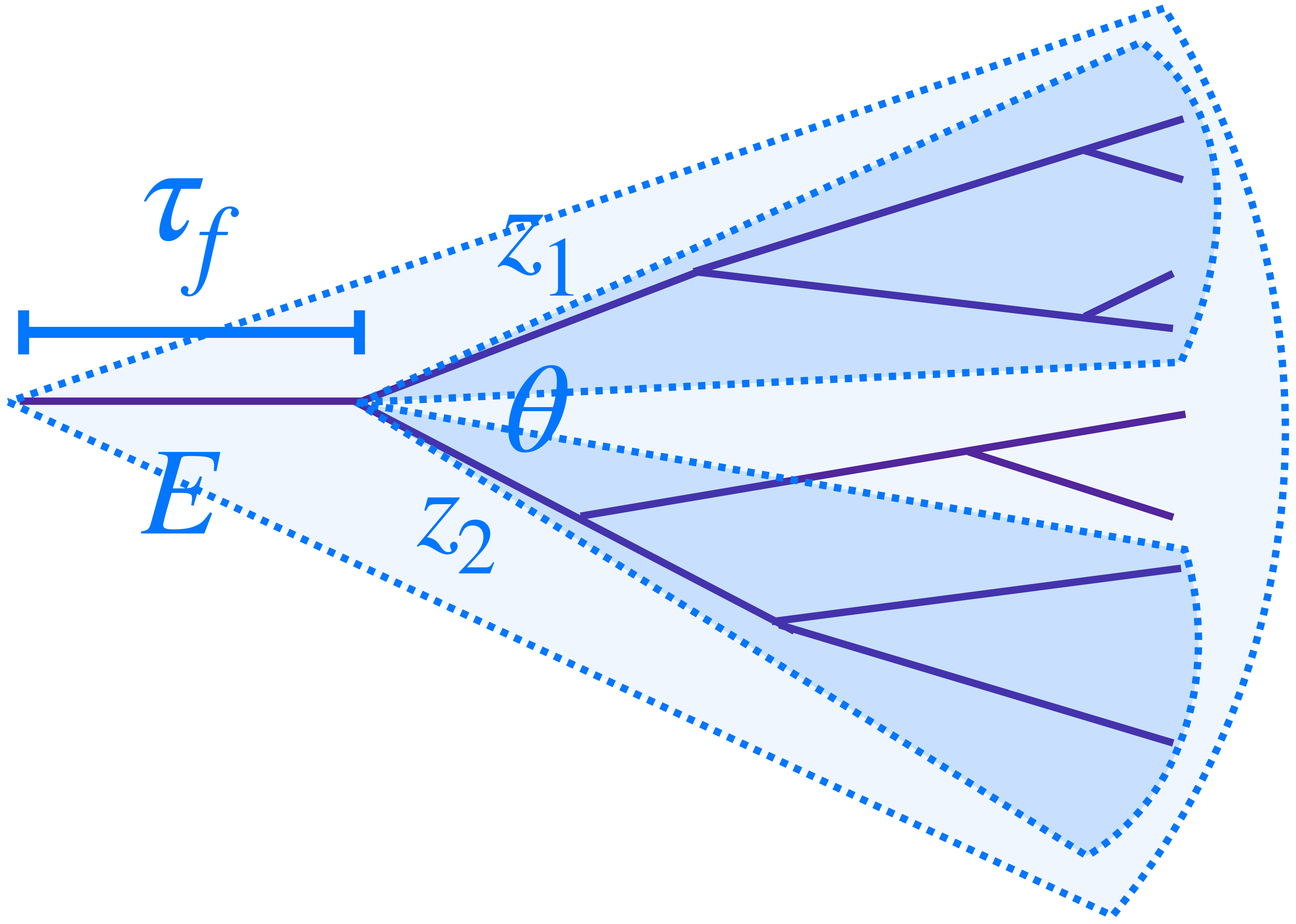

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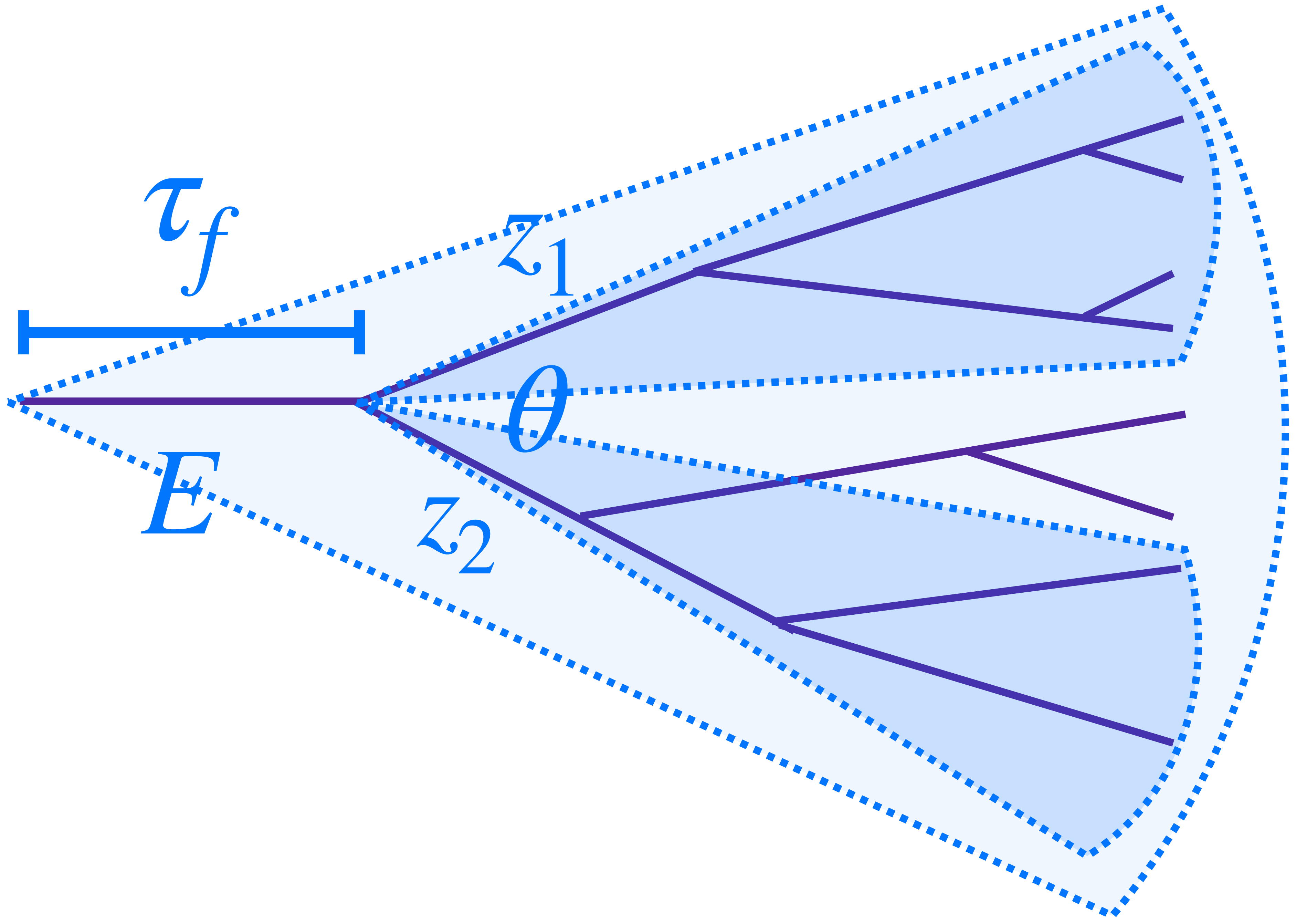

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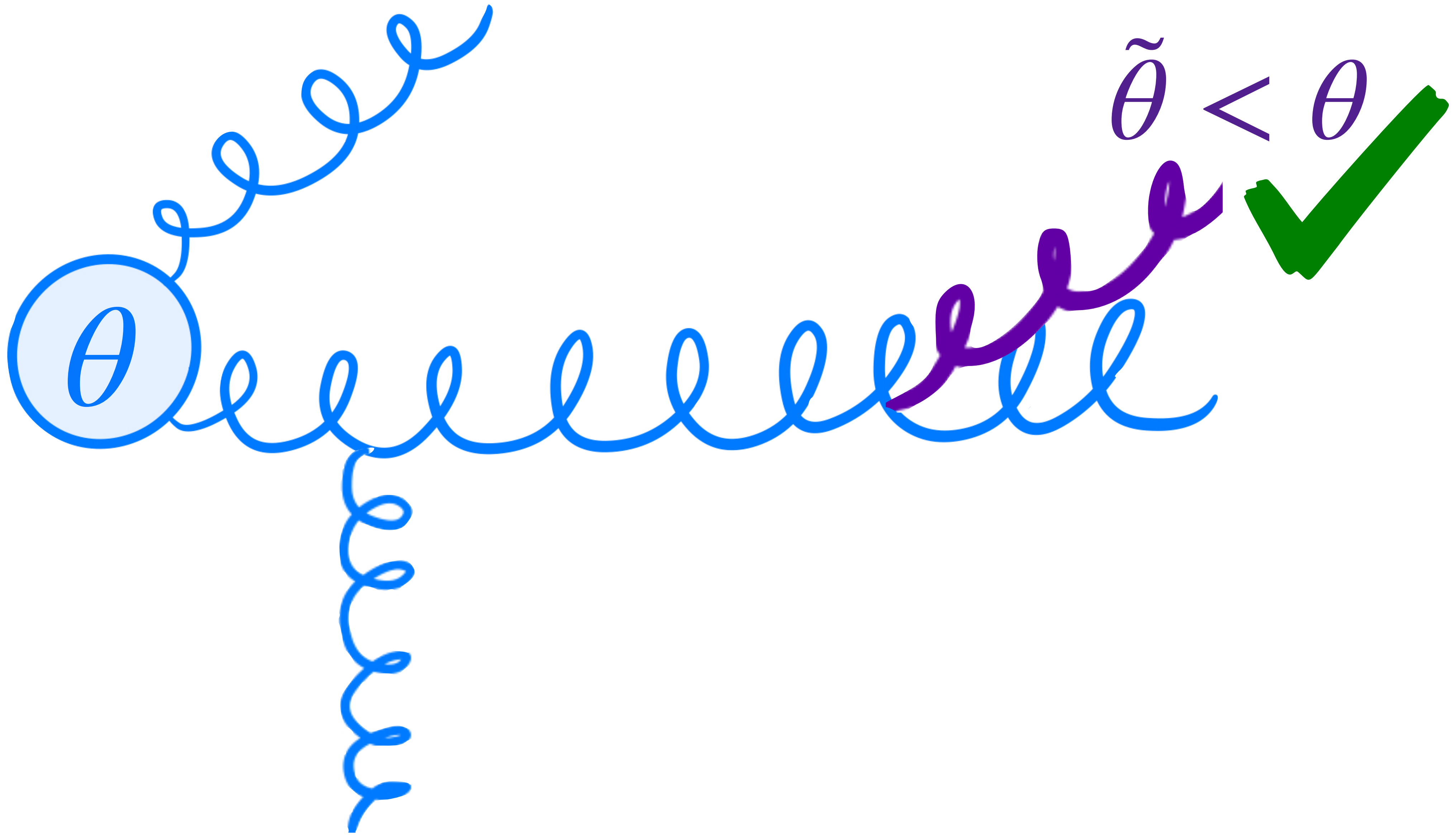

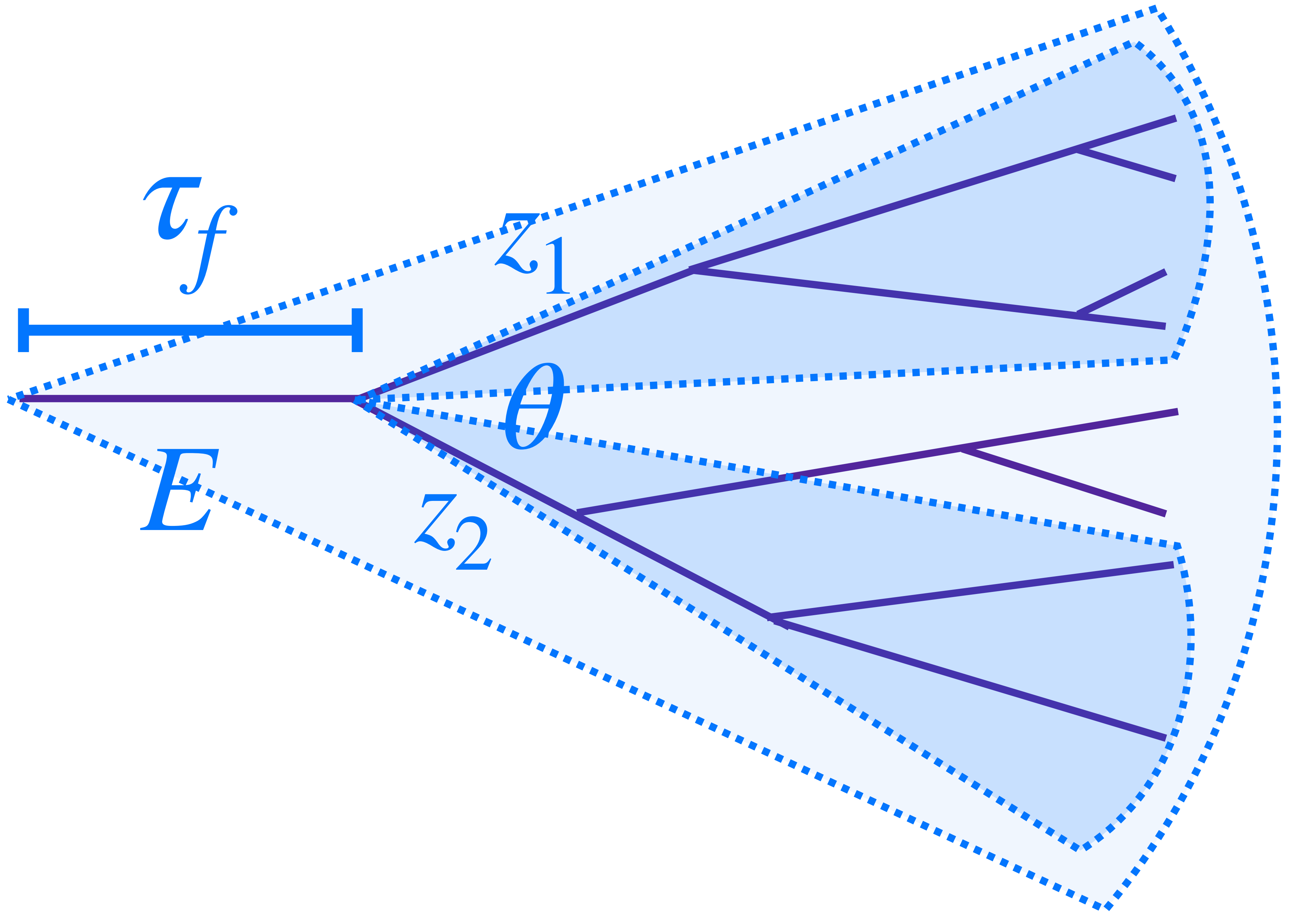

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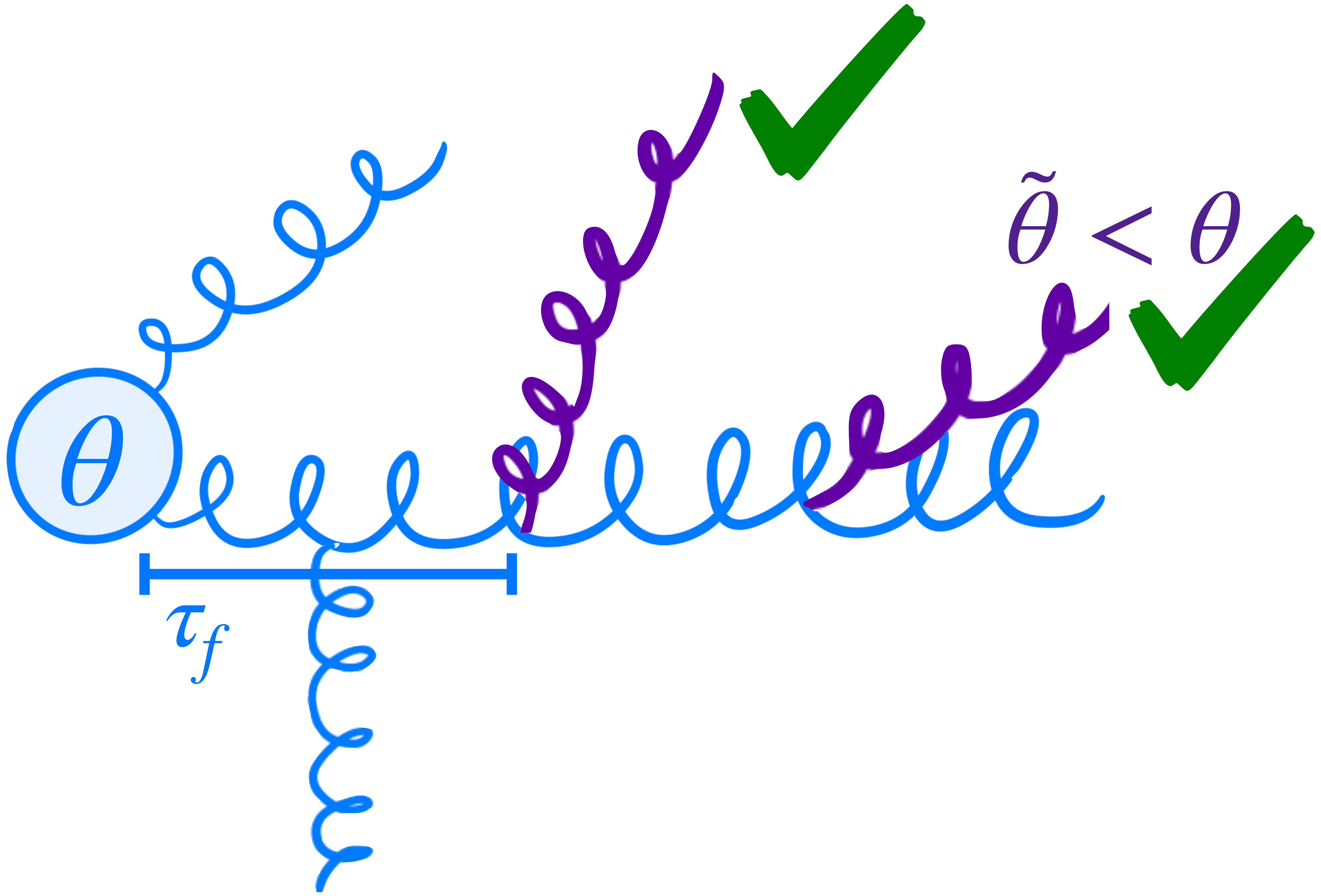

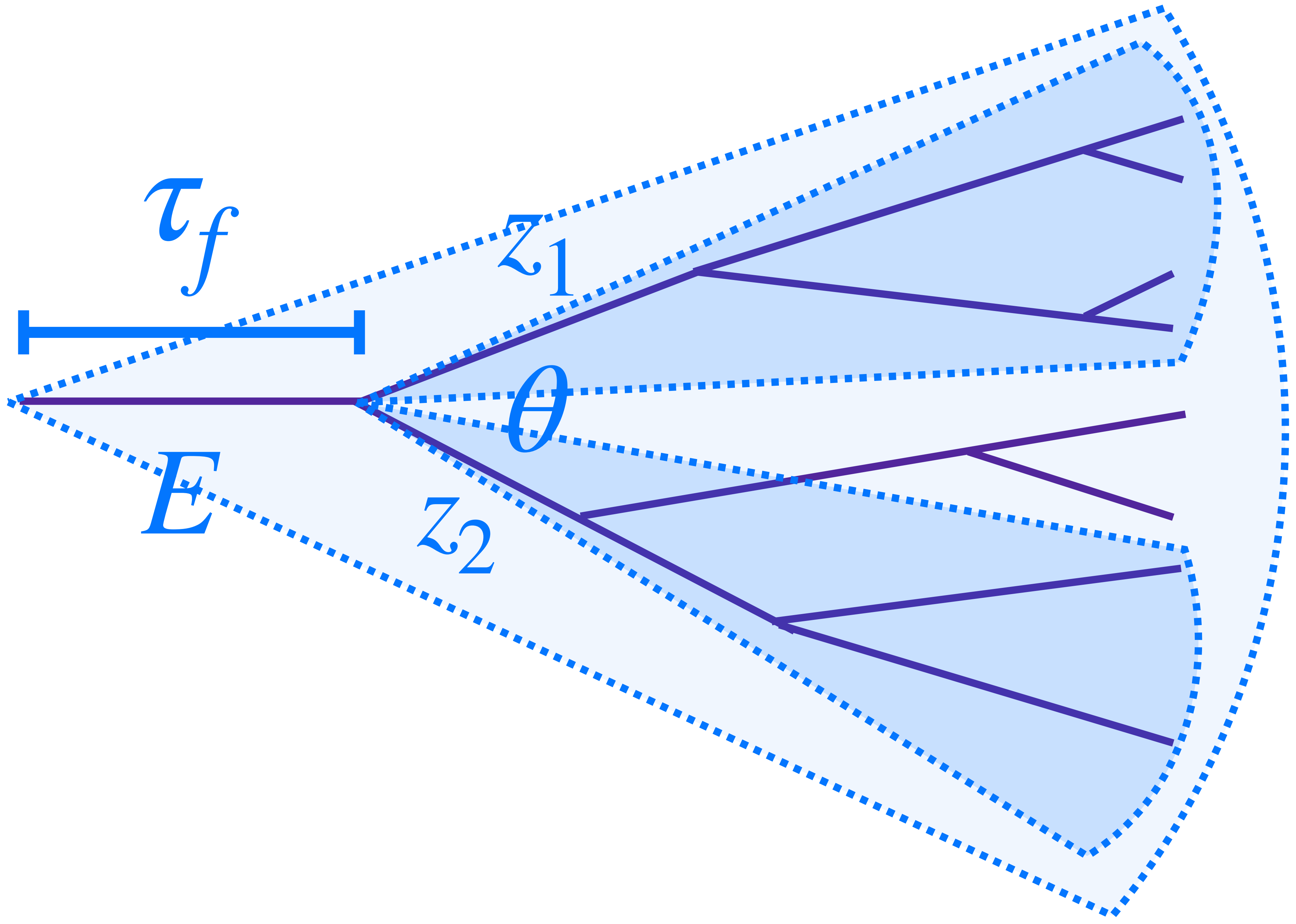

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Jet Quenching without Energy Loss

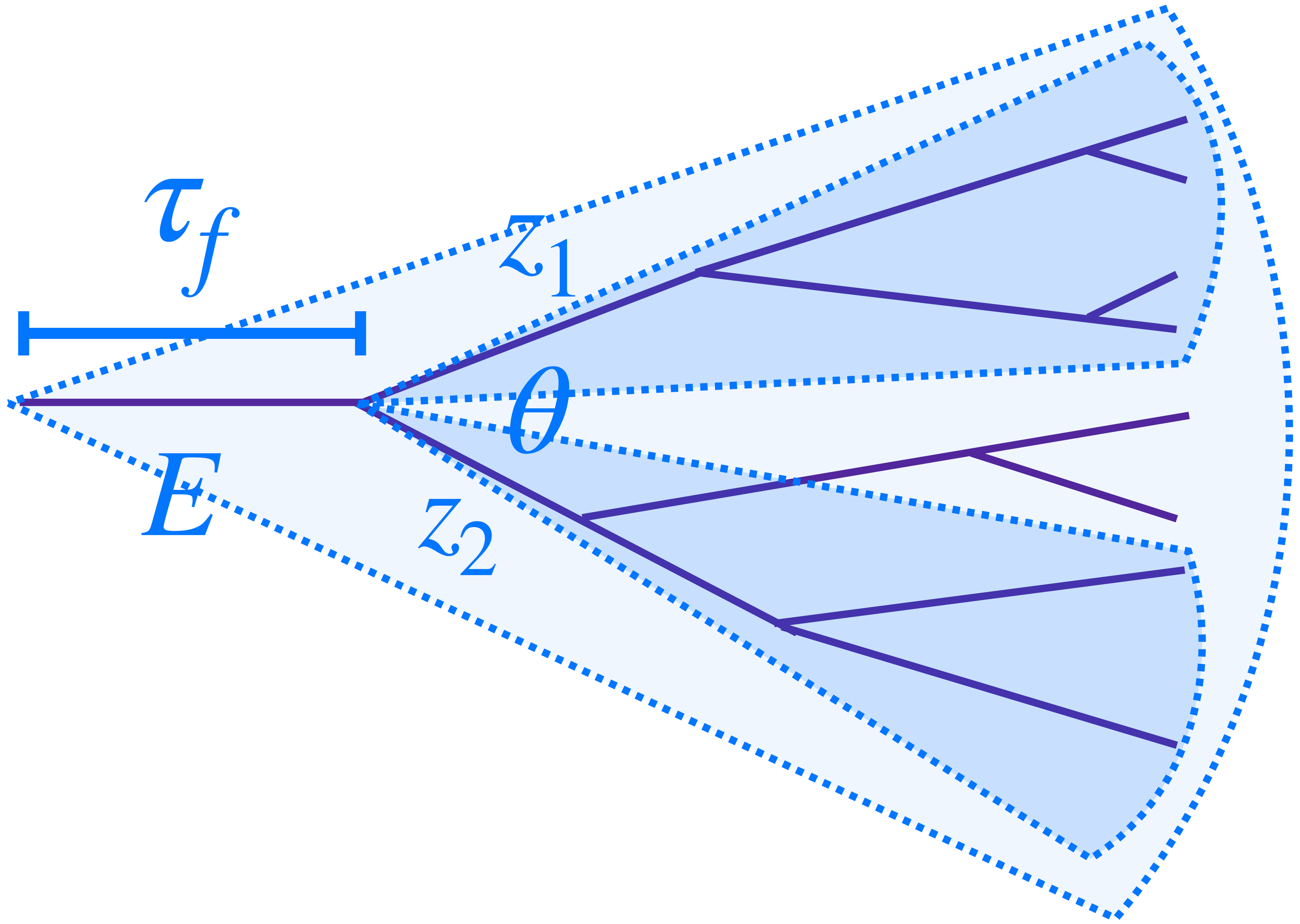
Jet Reconstruction

- Anti-kT R=1.0 jets & no Soft-Drop
  - Retain wide-angle radiation to capture decoherence signal

$$z = \frac{E_{\text{soft}}}{E_{\text{hard}}}$$

$$\theta_{12} = \frac{M}{E\sqrt{z(1-z)}}$$

$$\tau = \frac{1}{2Ez(1-z)(1-\cos\theta_{12})}$$



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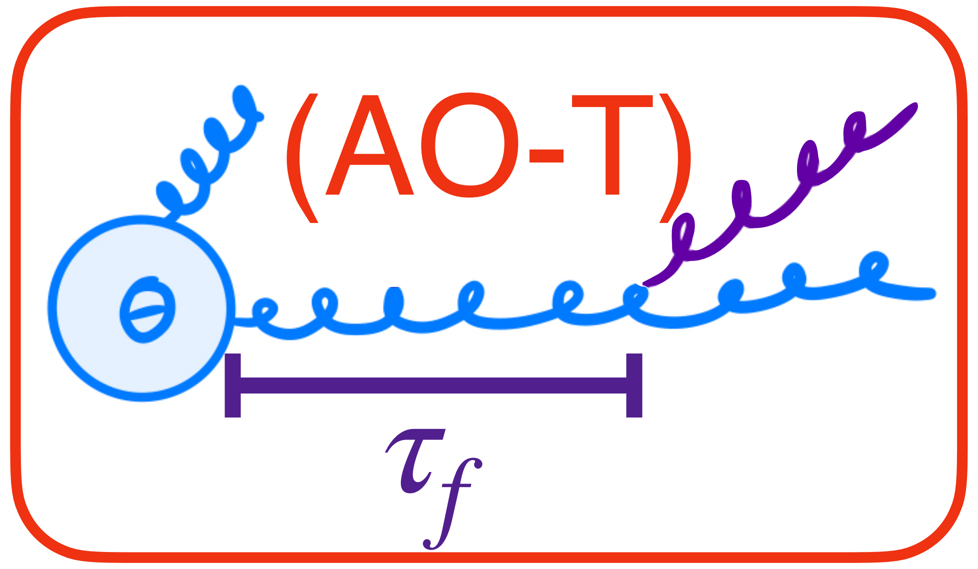
Jet Quenching without Energy Loss

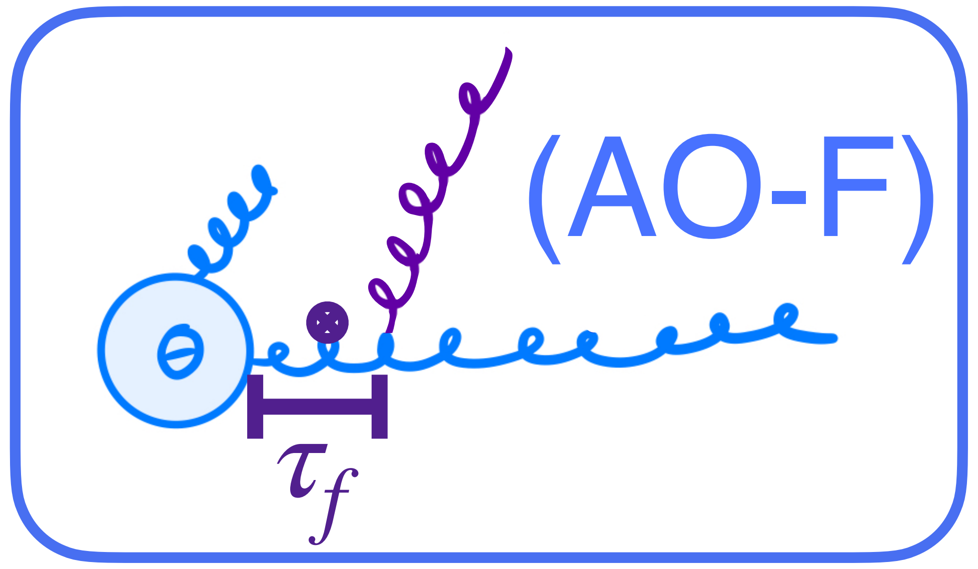
Effect of coherence breaking

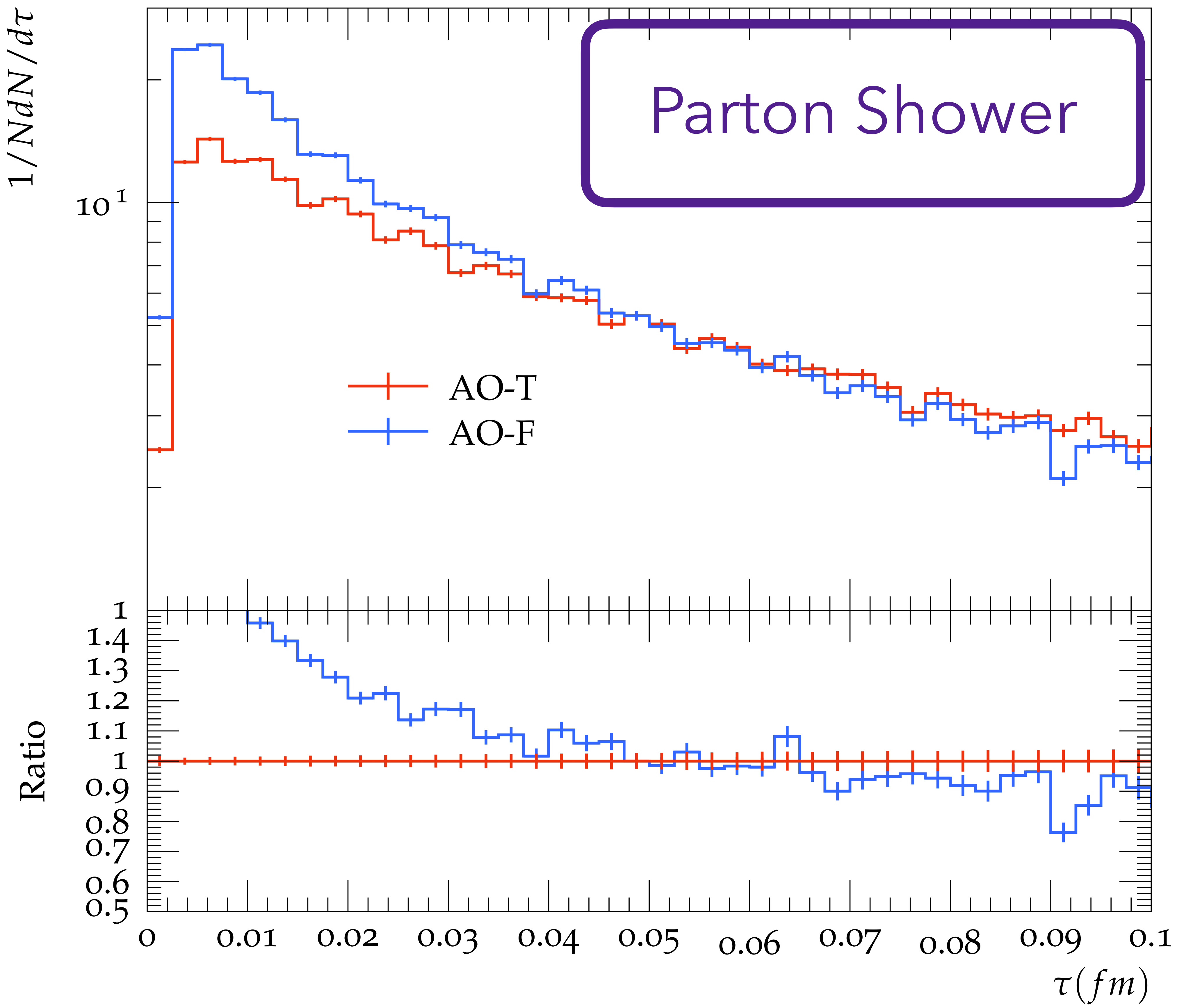
Jet Quenching without Energy Loss

Effect of coherence breaking

- Formation time distribution for 2 different cases







Jet Quenching without Energy Loss

Effect of coherence breaking

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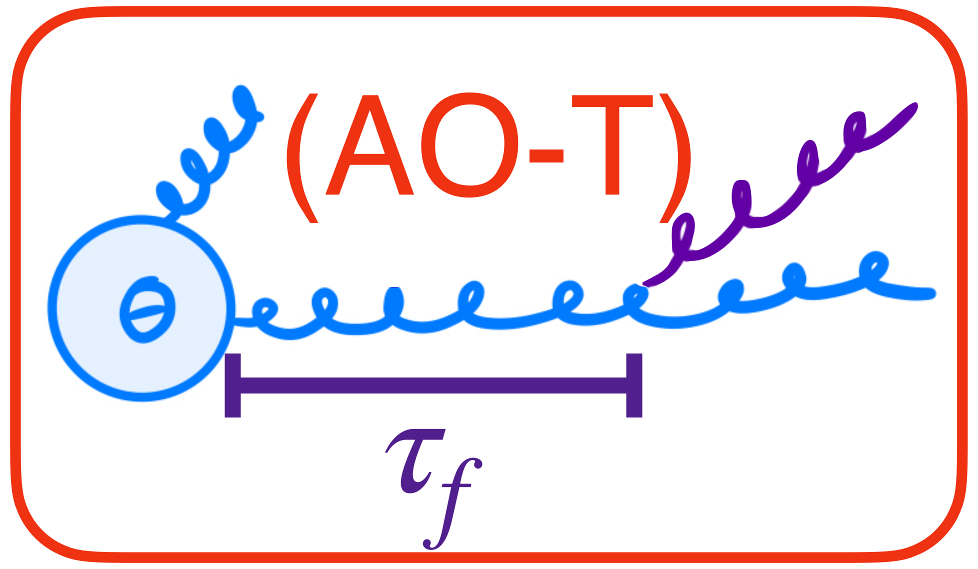
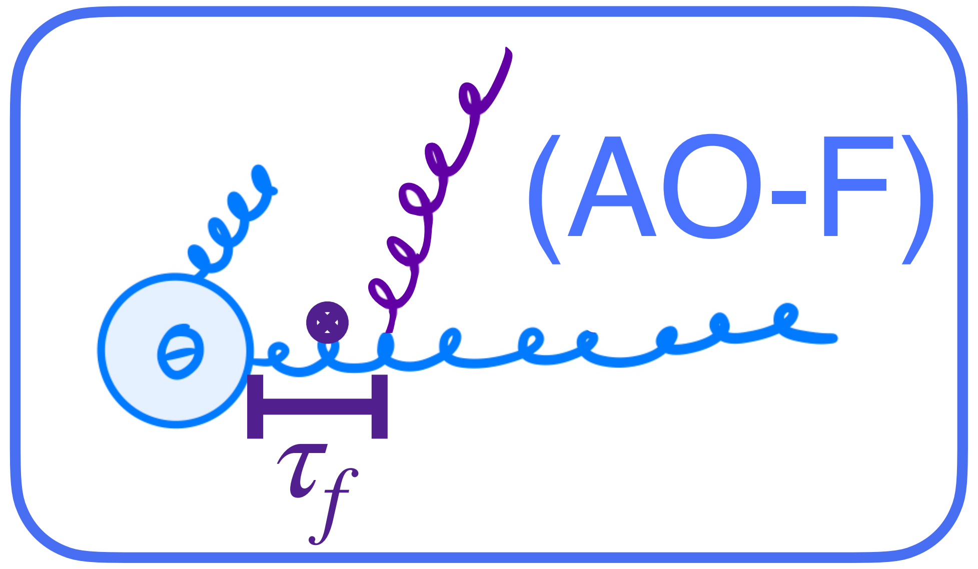
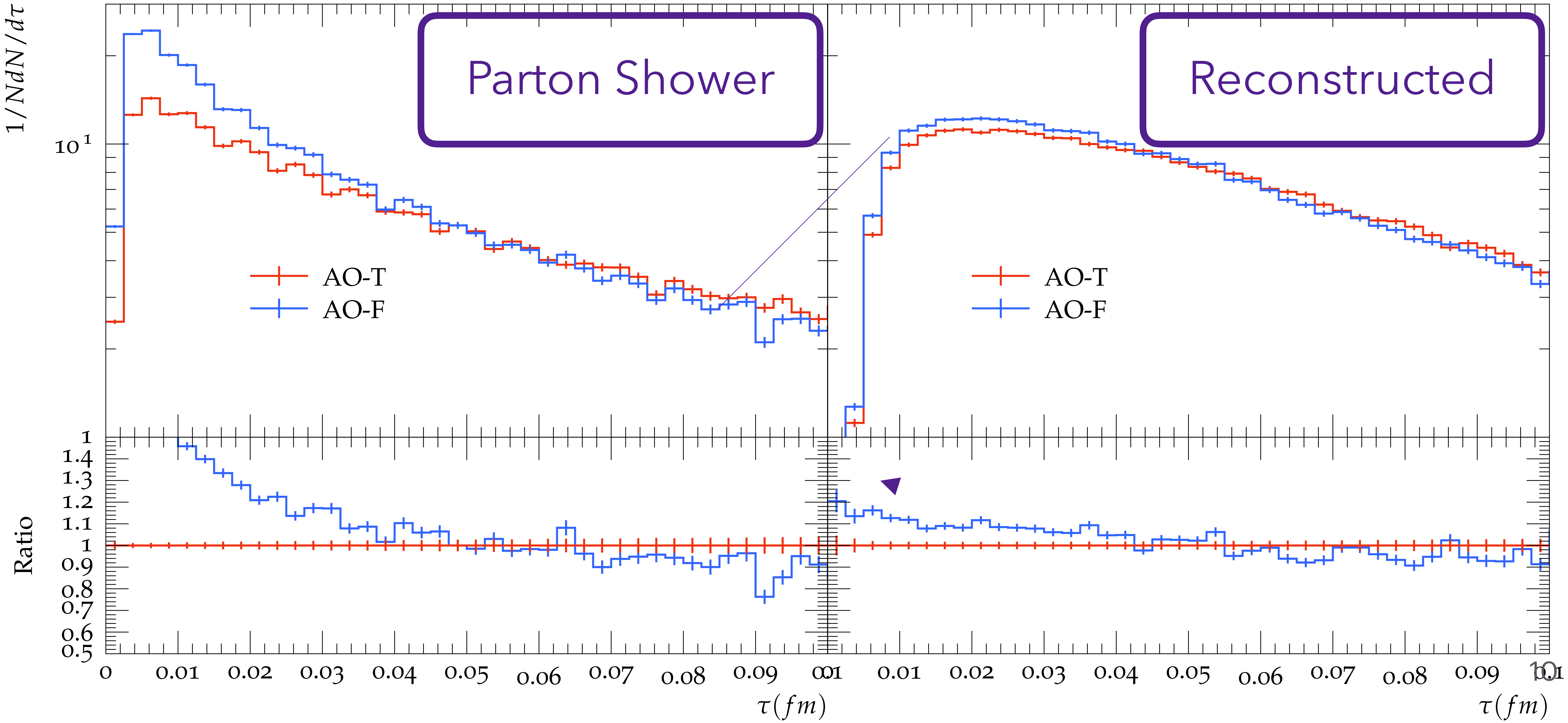






Jet Quenching without Energy Loss

Smearing

Jet Quenching without Energy Loss

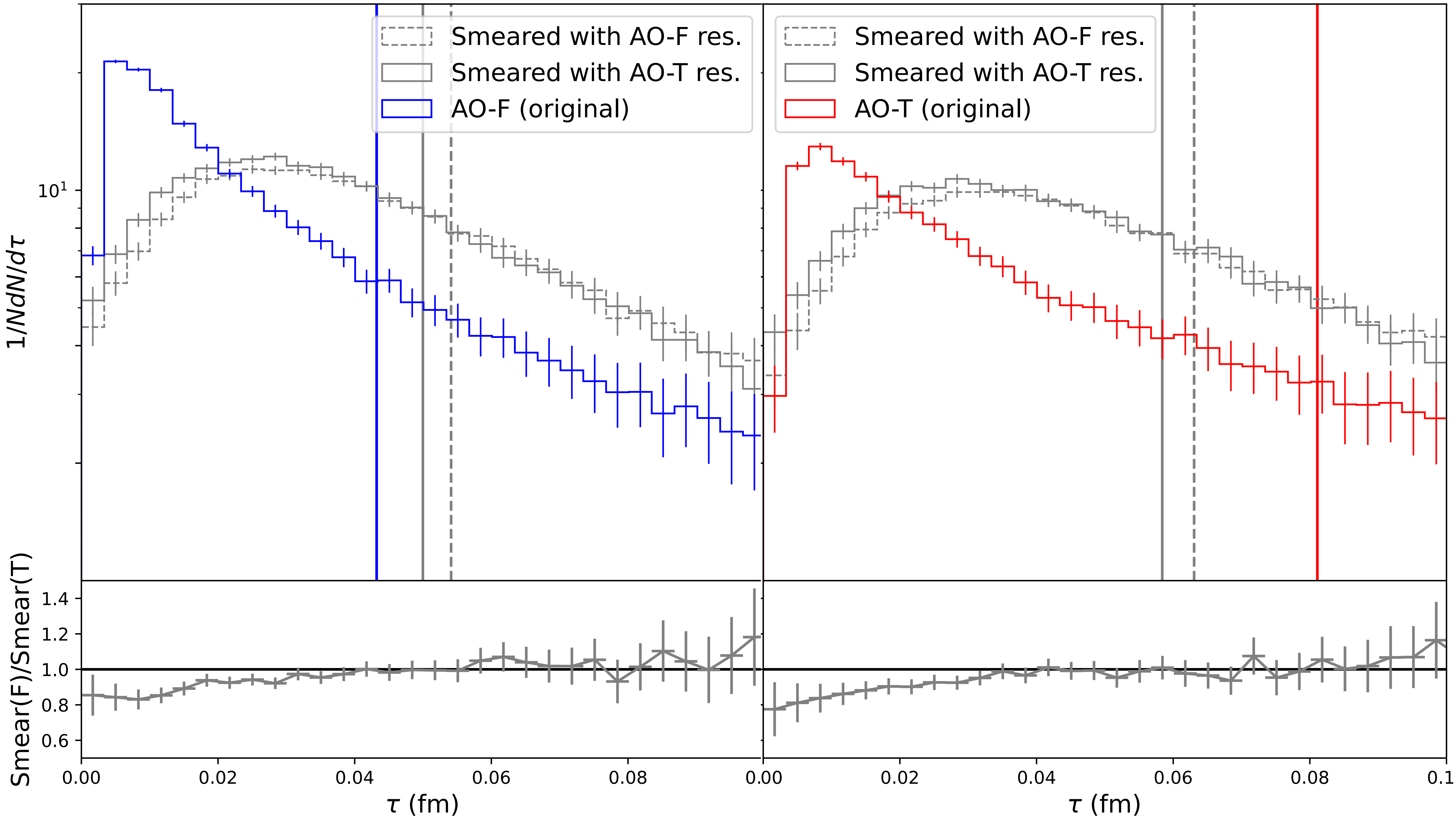
Smearing

- Smearing is mainly due to misconstruction effects

Jet Quenching without Energy Loss

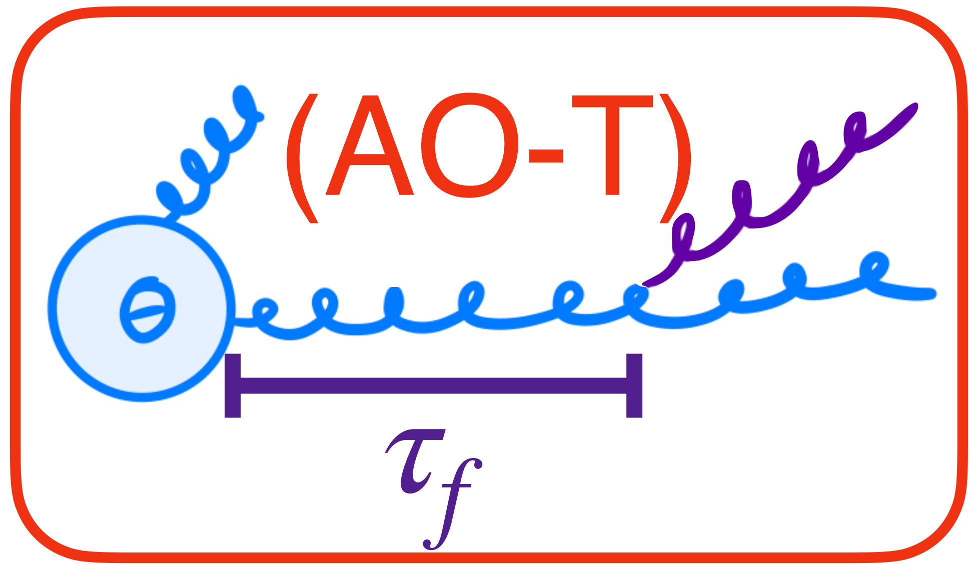
Smearing

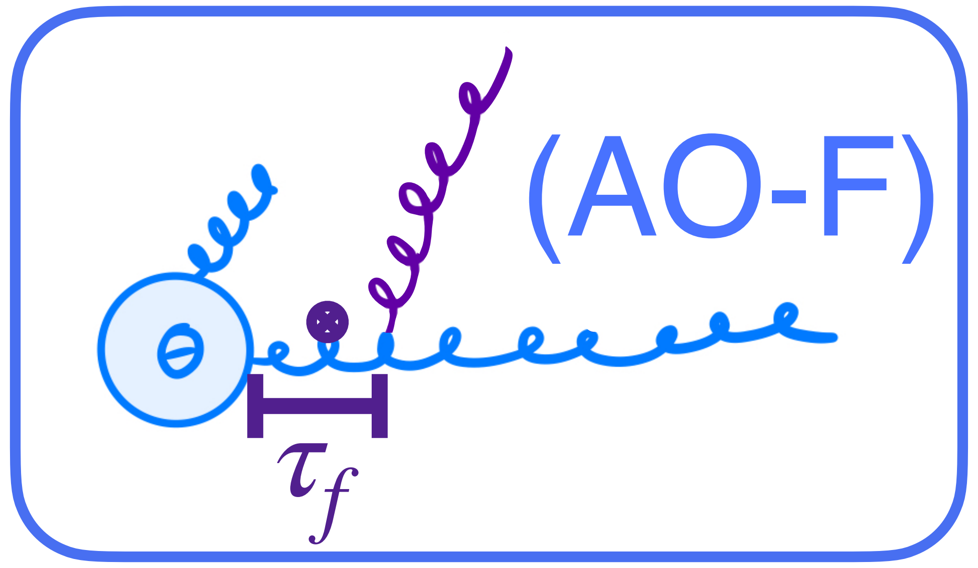
- Smearing is mainly due to misconstruction effects
- AO-F smearing skews towards larger τ compared to the AO-T smearing
- The reconstructed AO-F still has smaller τ due to the remainder of the *underlying distribution*

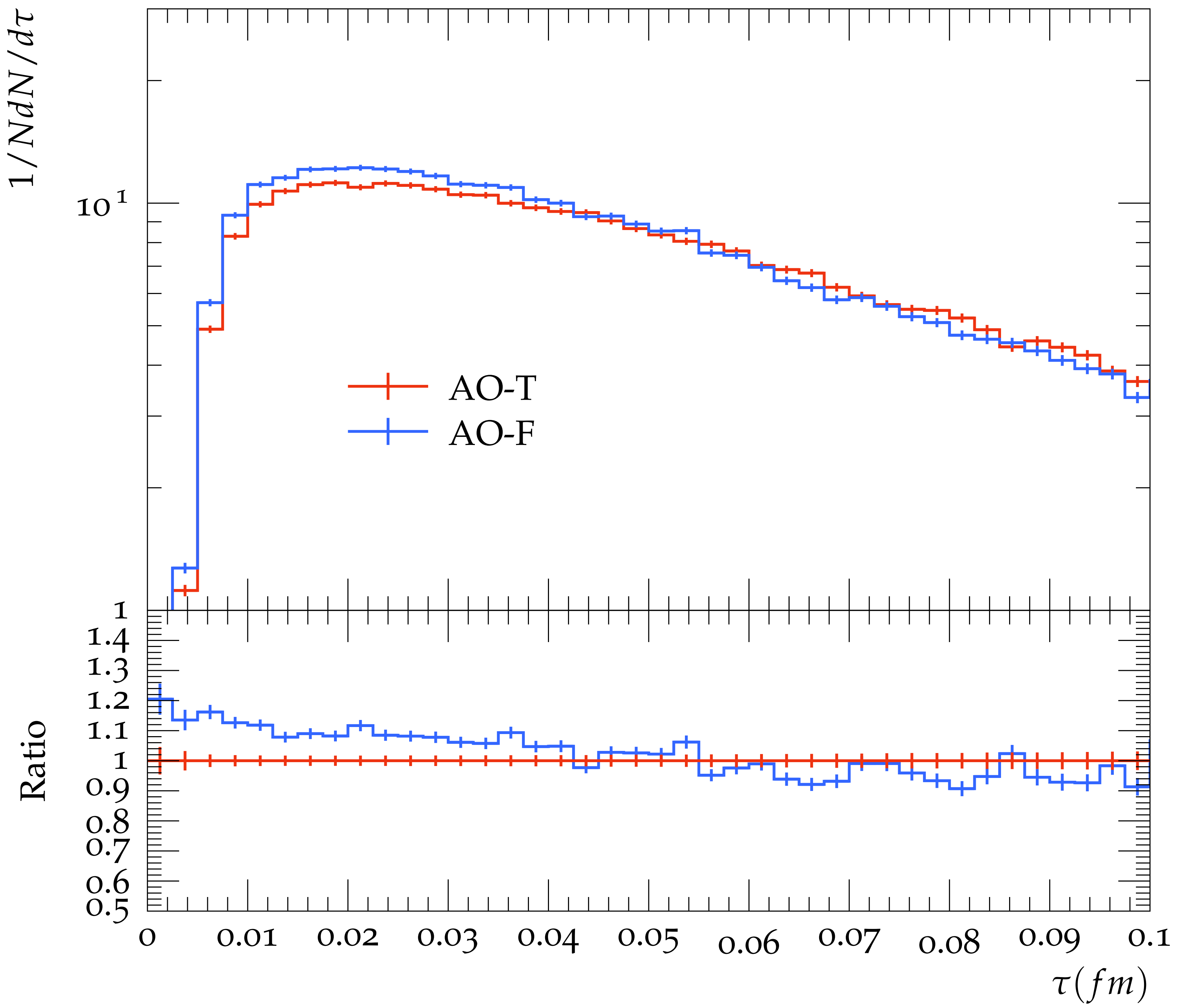


Jet Quenching without Energy Loss

Suppression



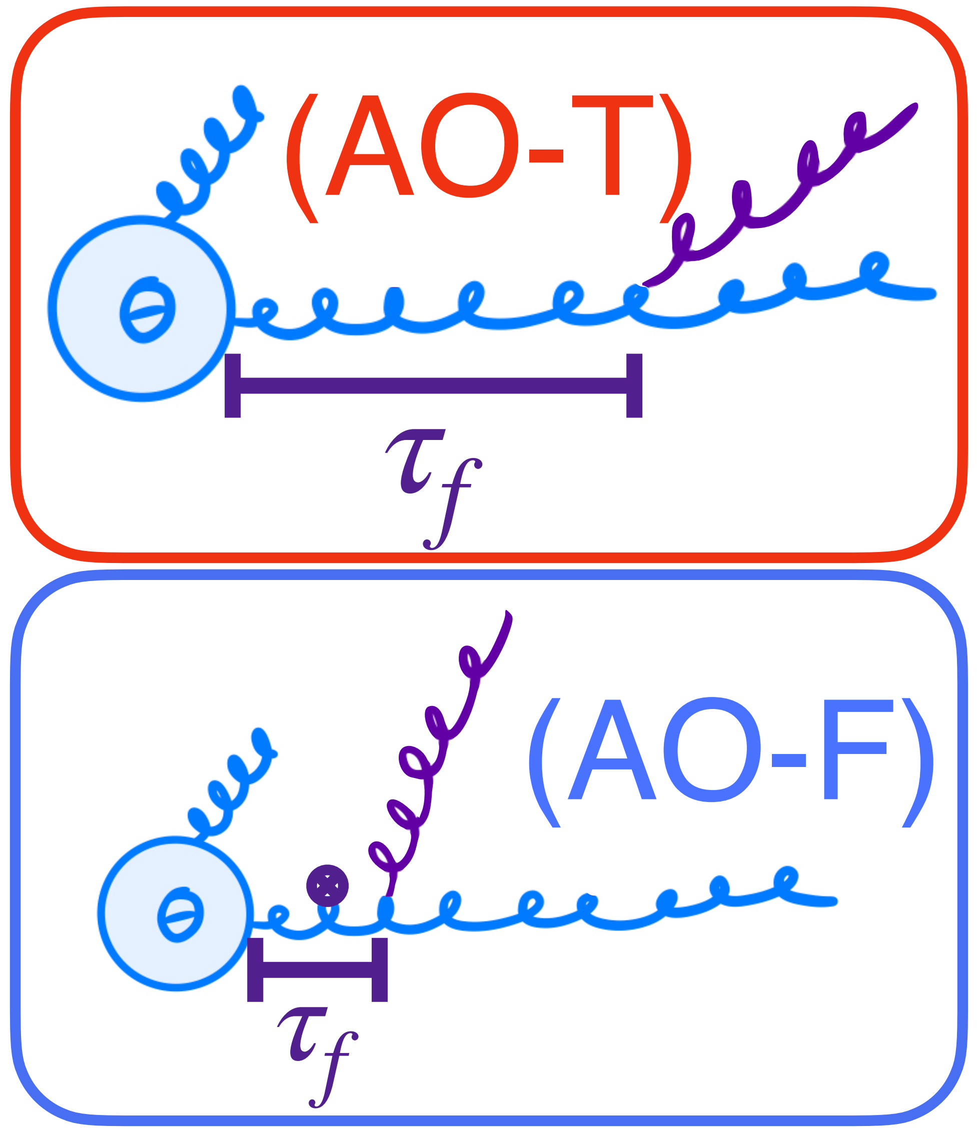


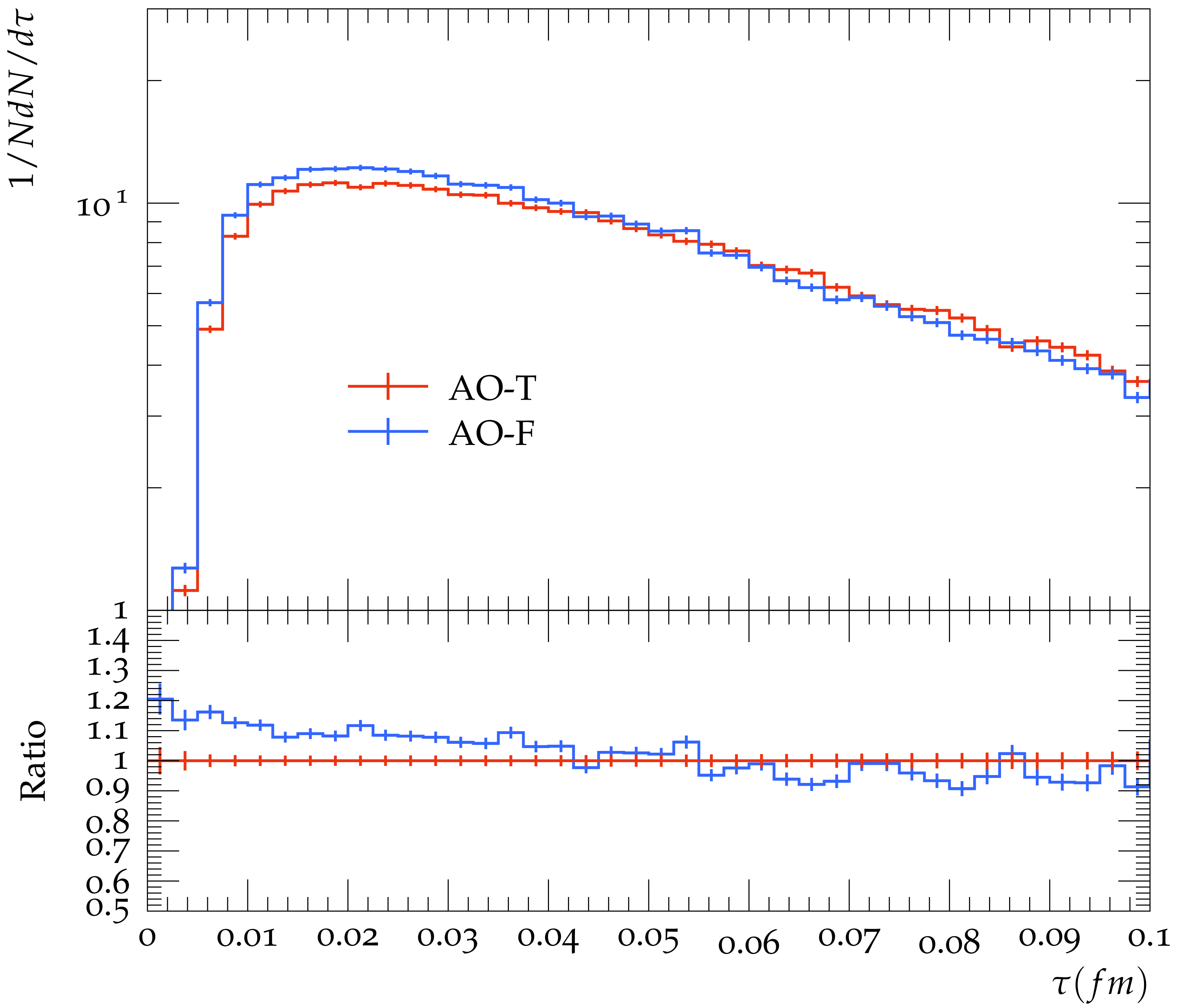


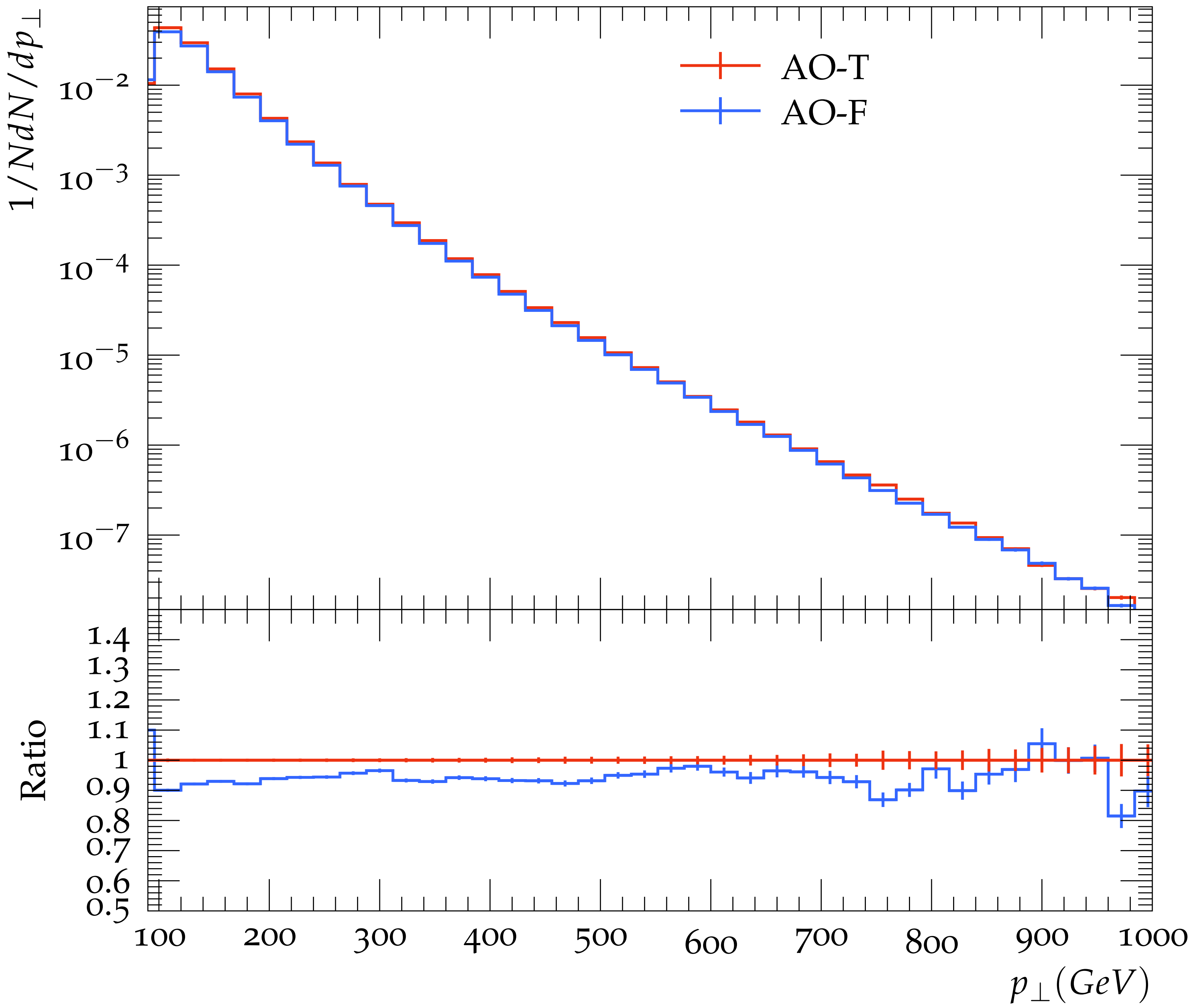
Jet Quenching without Energy Loss

Suppression

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







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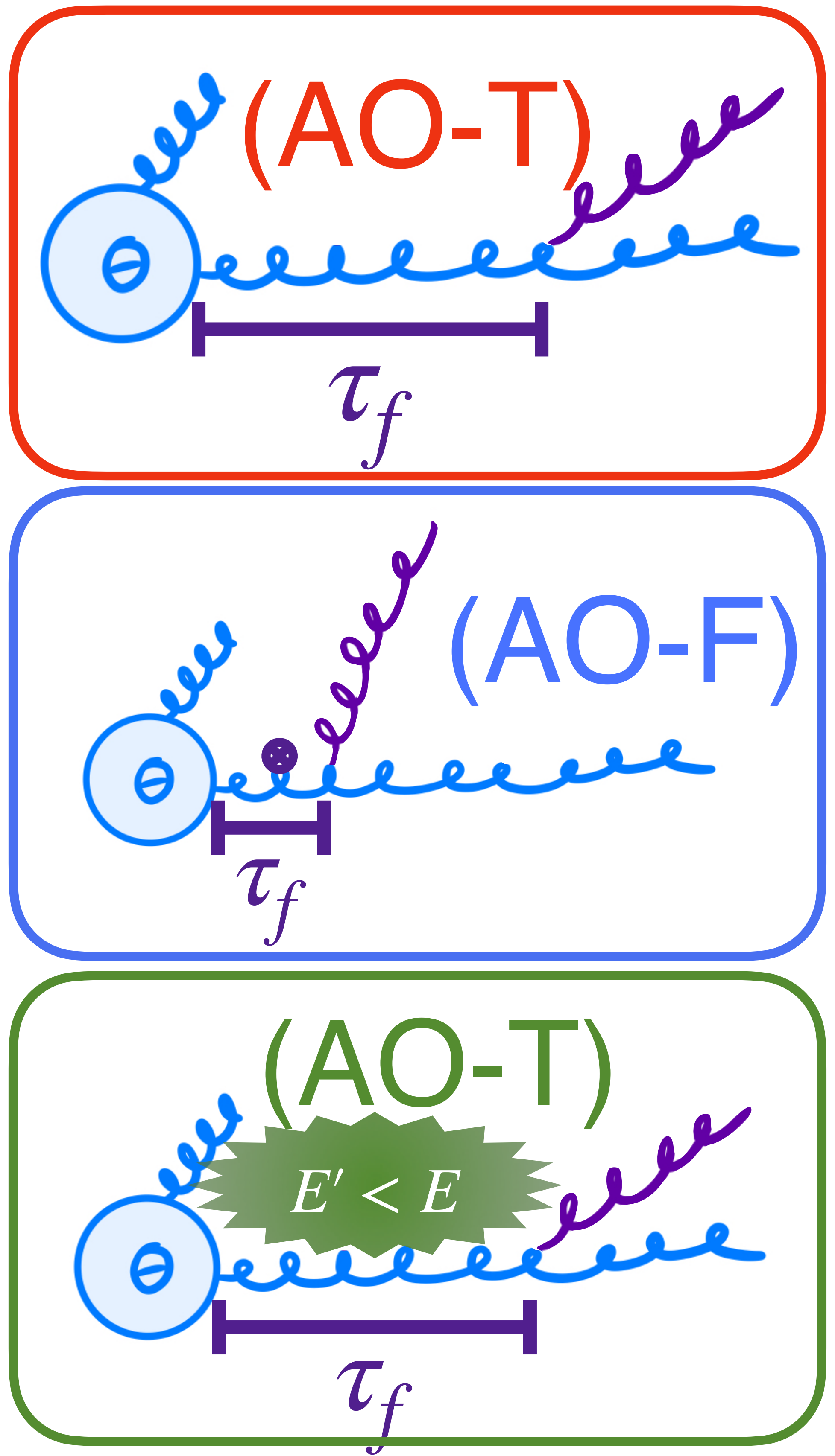
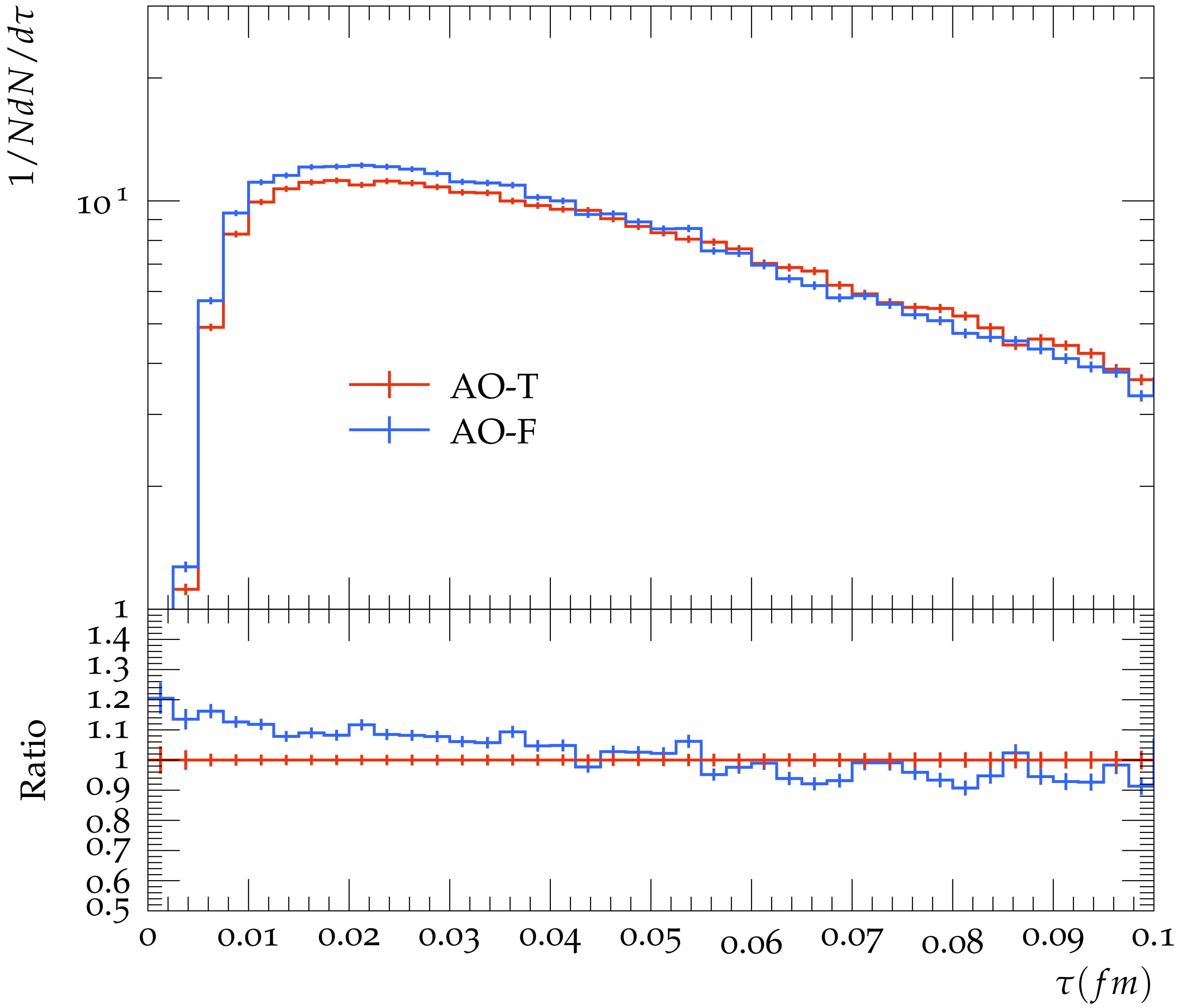
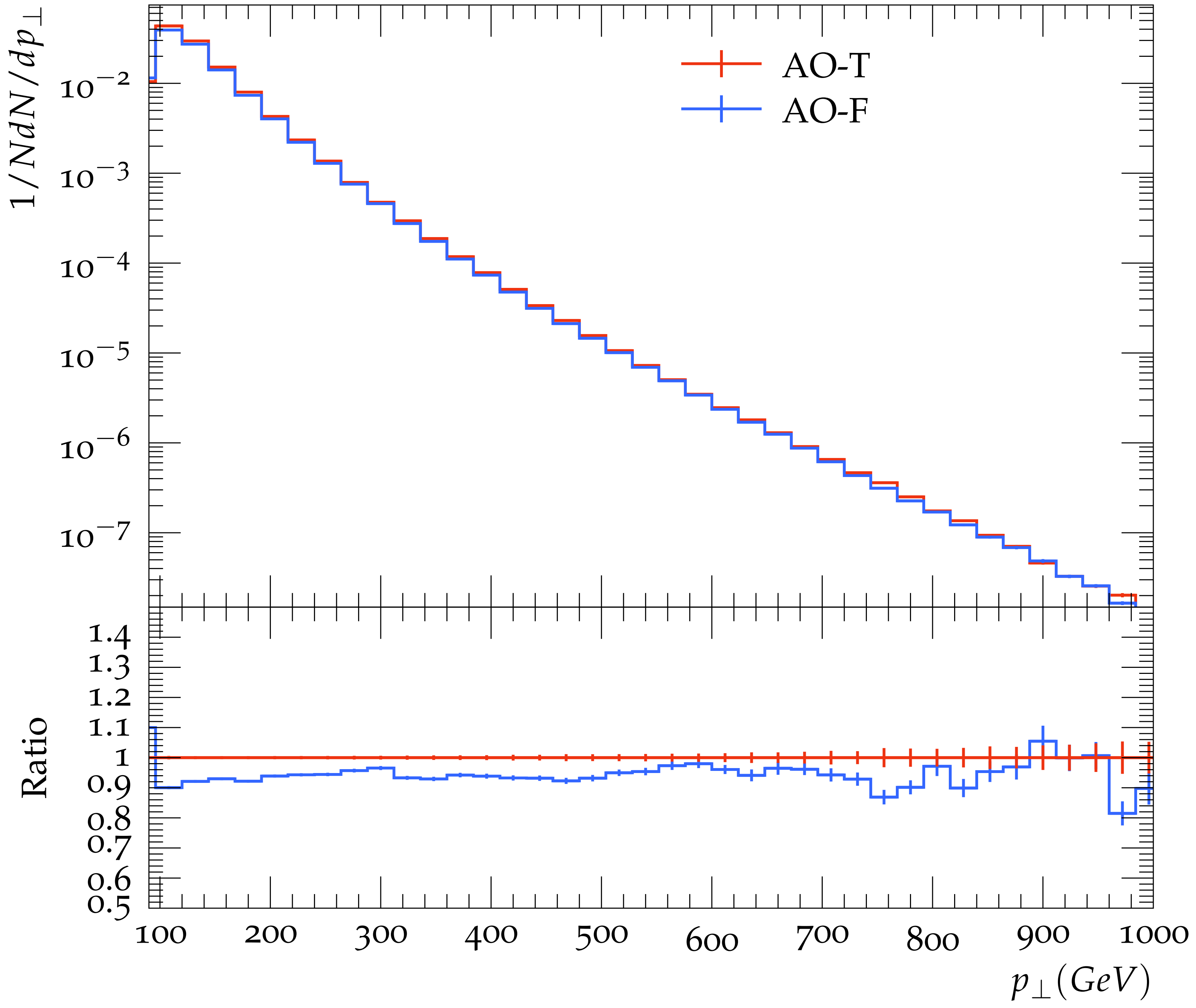


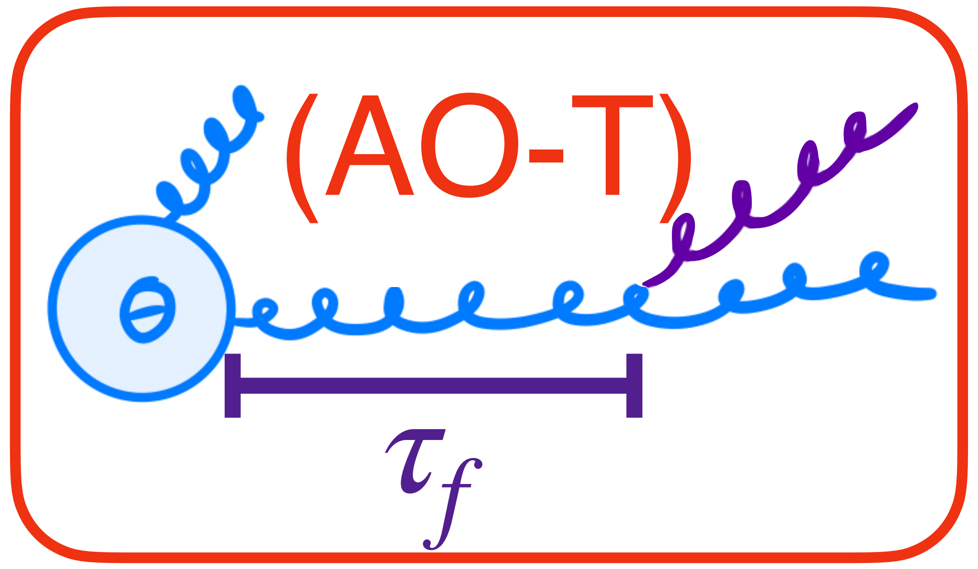


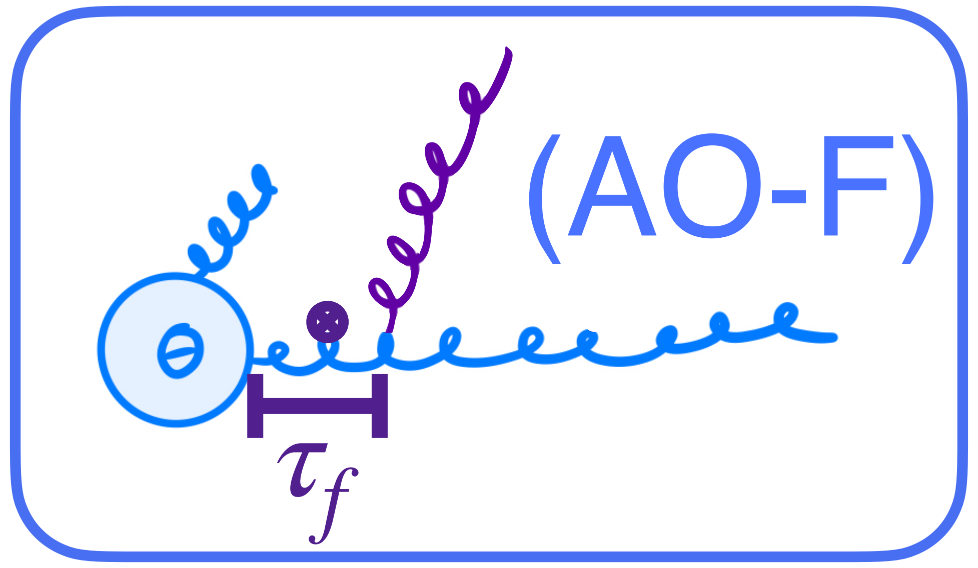


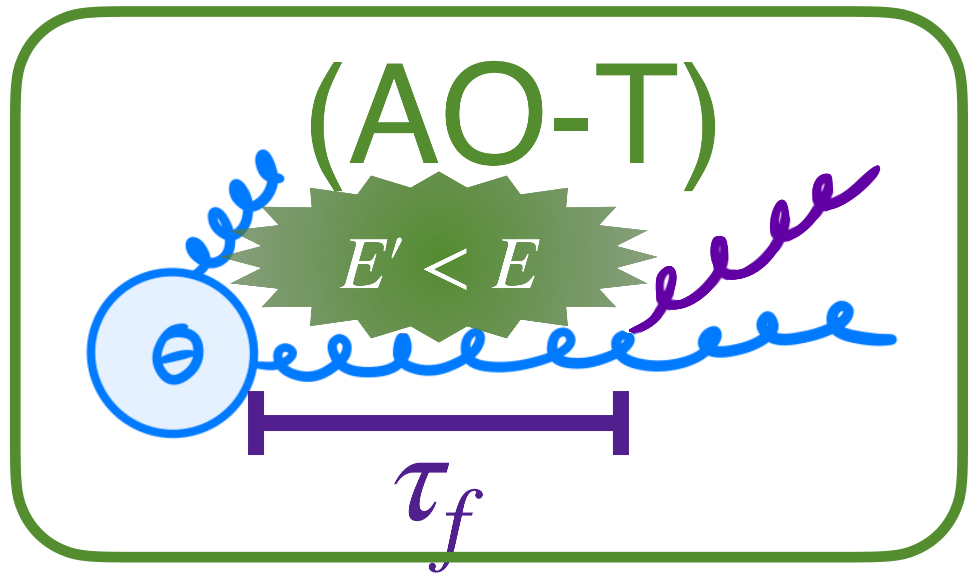
Jet Quenching without Energy Loss

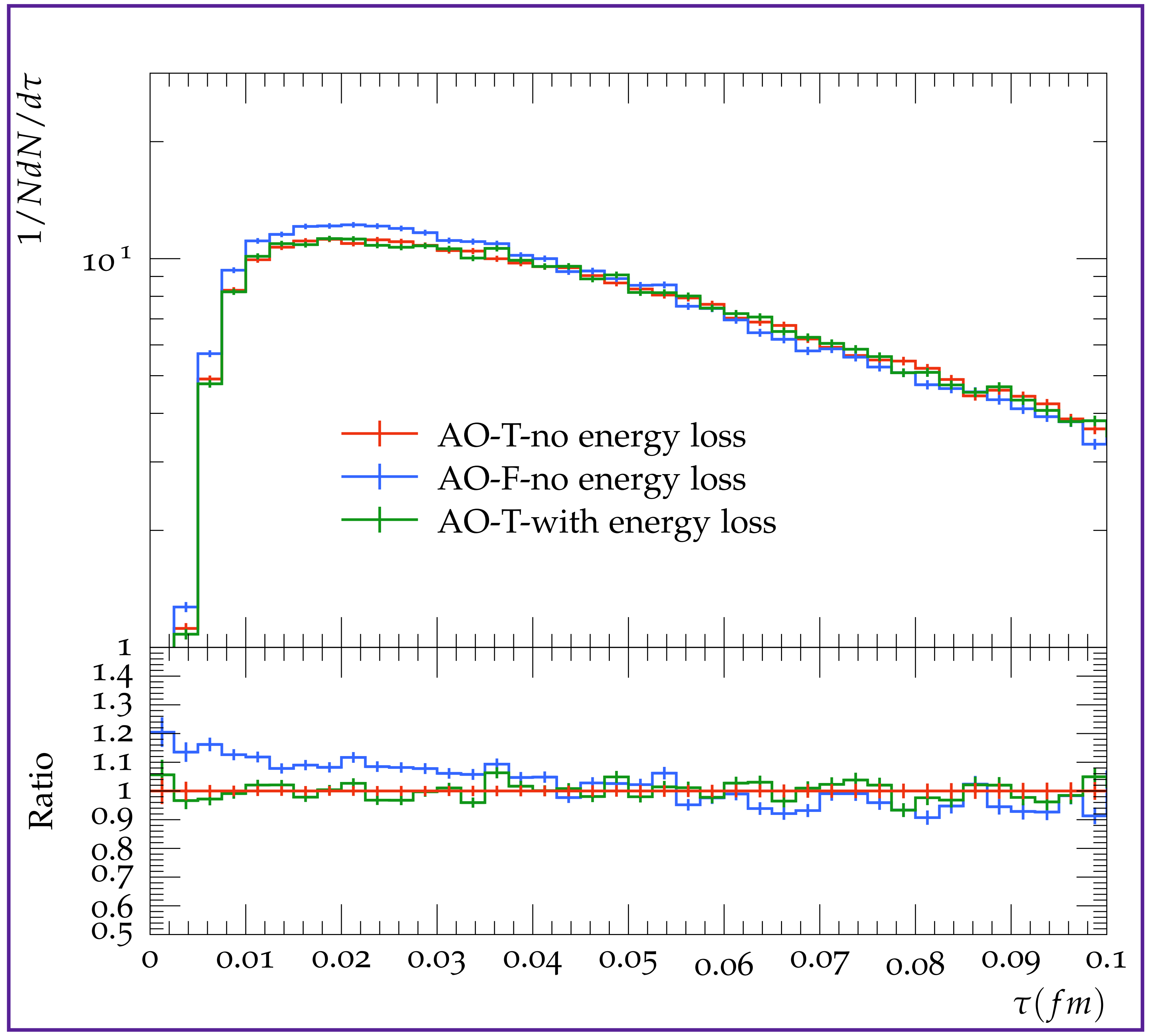
Suppression

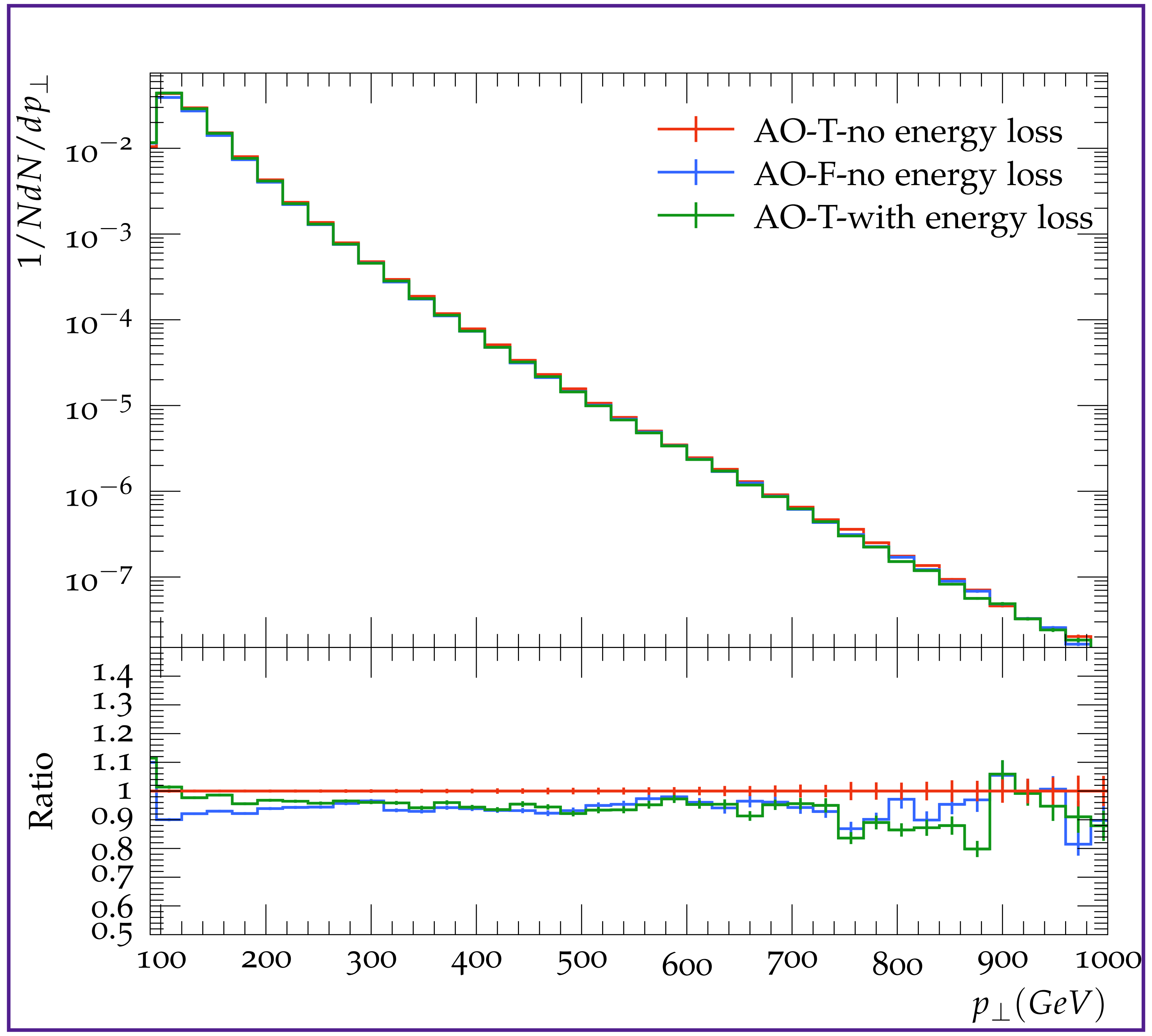
- Color decoherence also appears as a suppression in the jet spectrum
- Formation time distinguishes coherence breaking and energy loss











Colour coherence in small systems

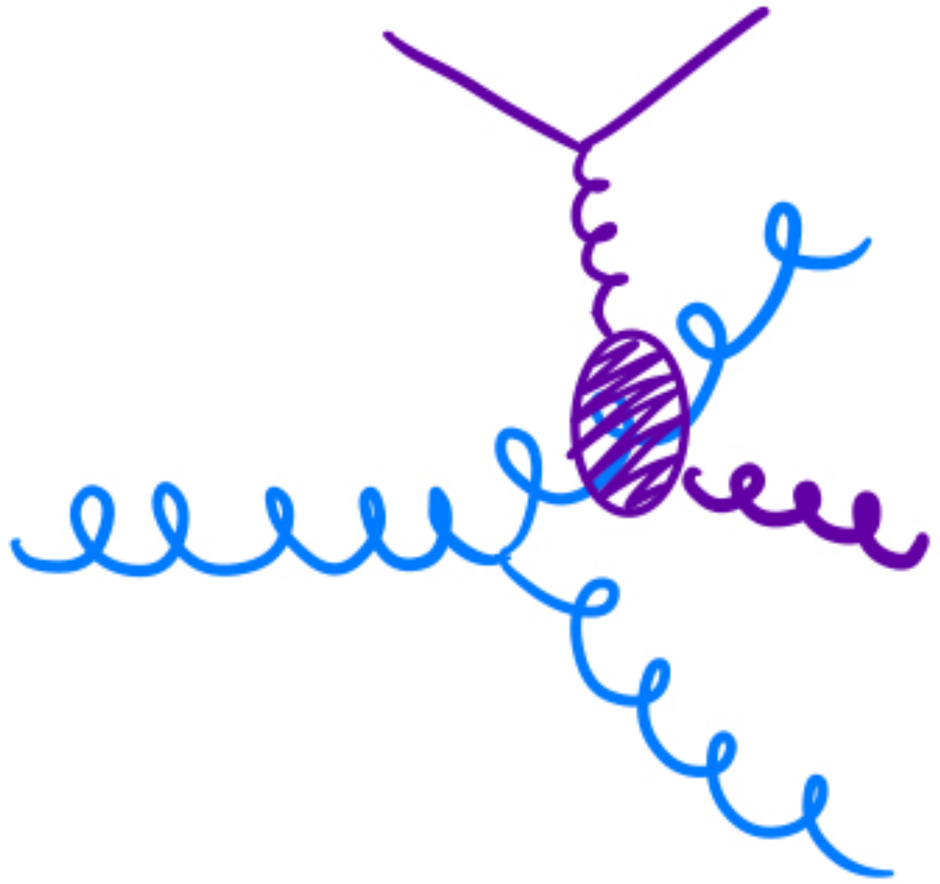
** PRELIMINARY **

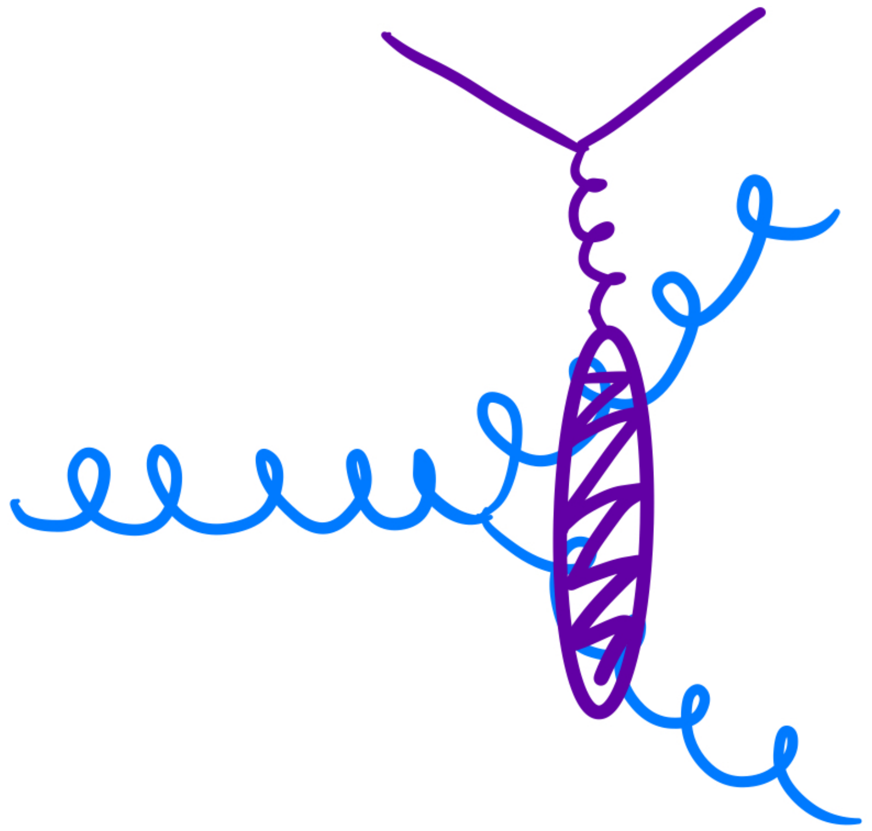
Color coherence in small collision systems

Coherence in scattering

- Medium adds another transverse size scale
- Early times: dipoles are smaller
- Small systems…?

$d_\perp > 1/q_\perp$



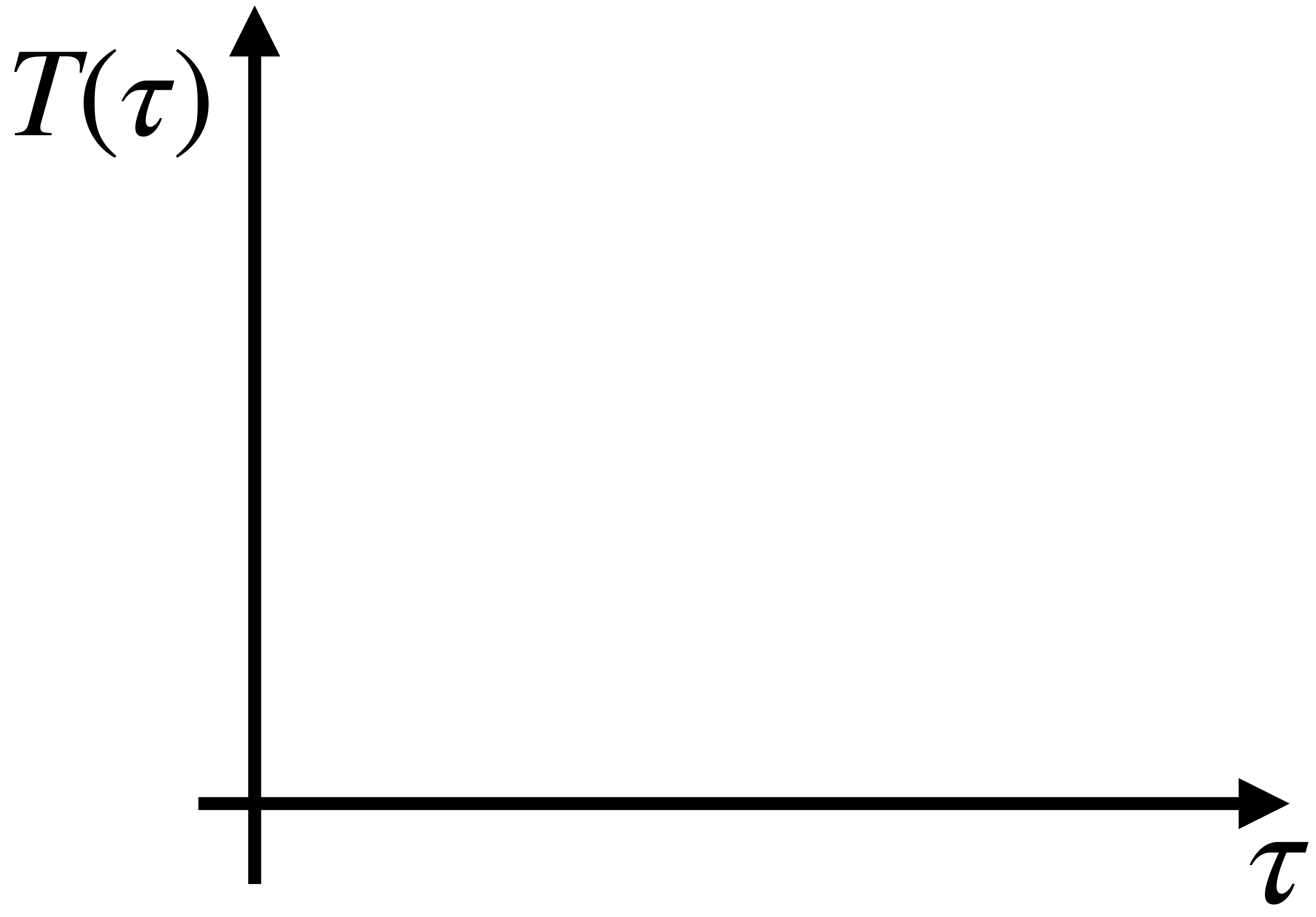


$d_\perp < 1/q_\perp$

Color coherence in small collision systems

Initial temperature & R_{AA}

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



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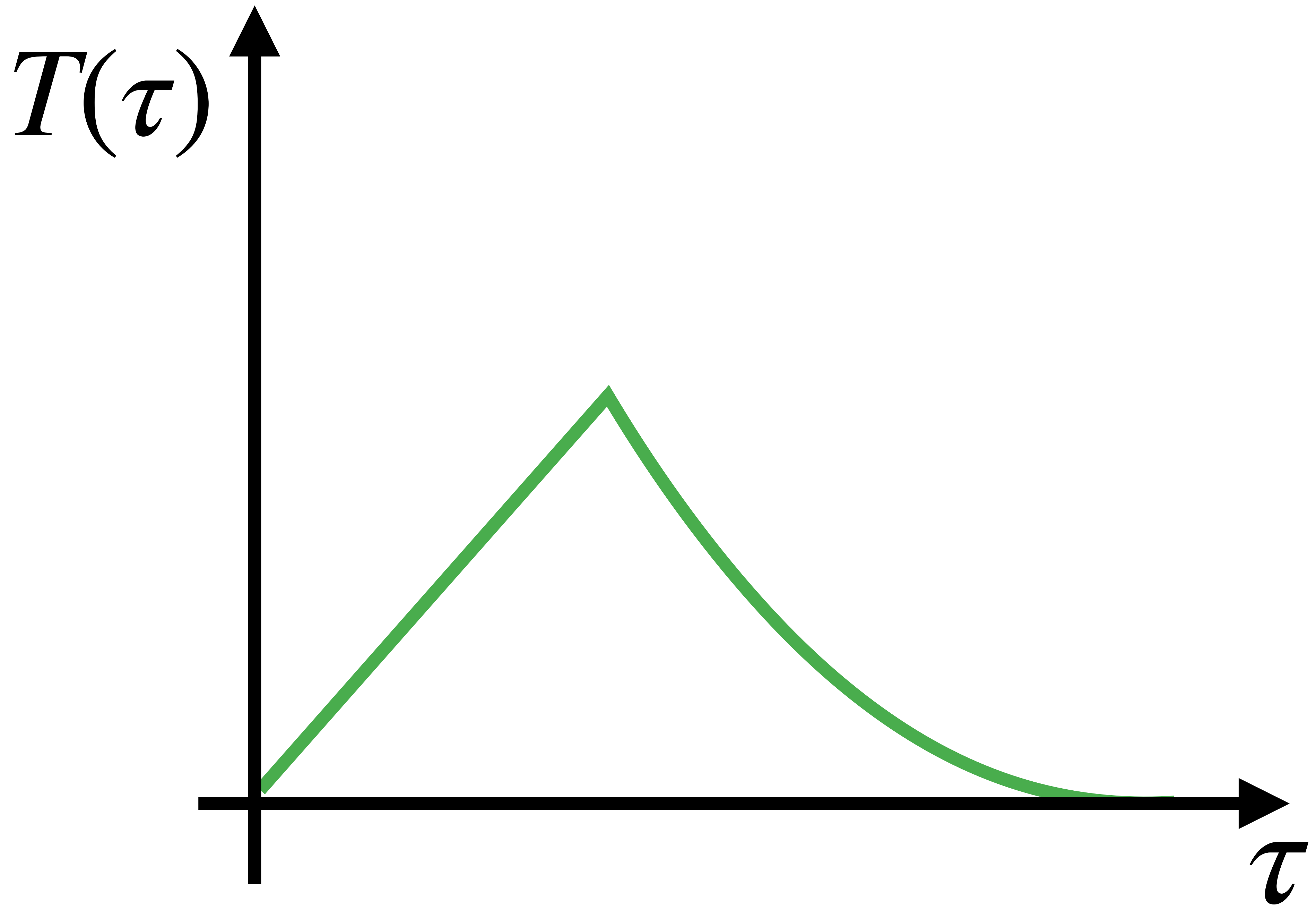

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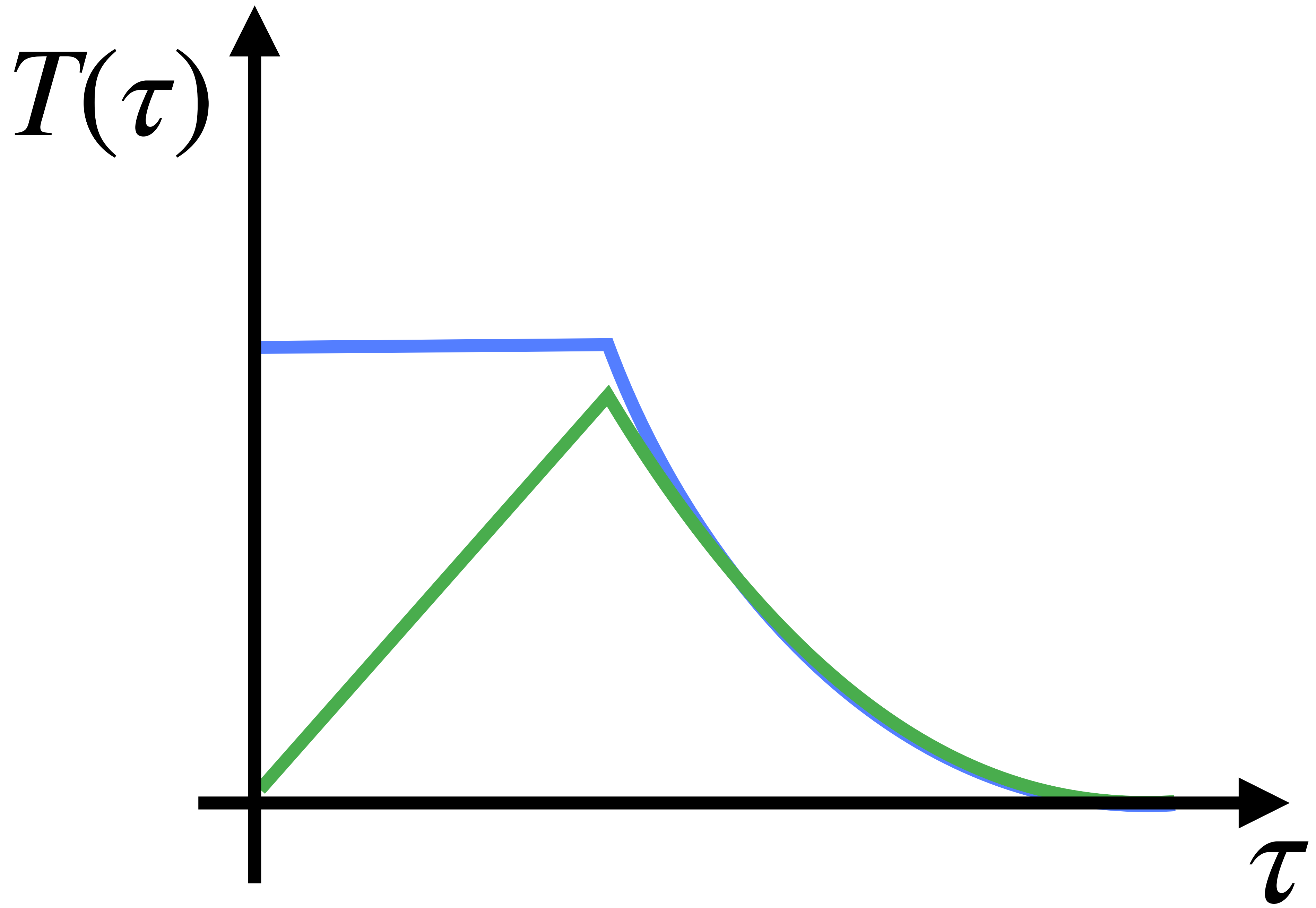

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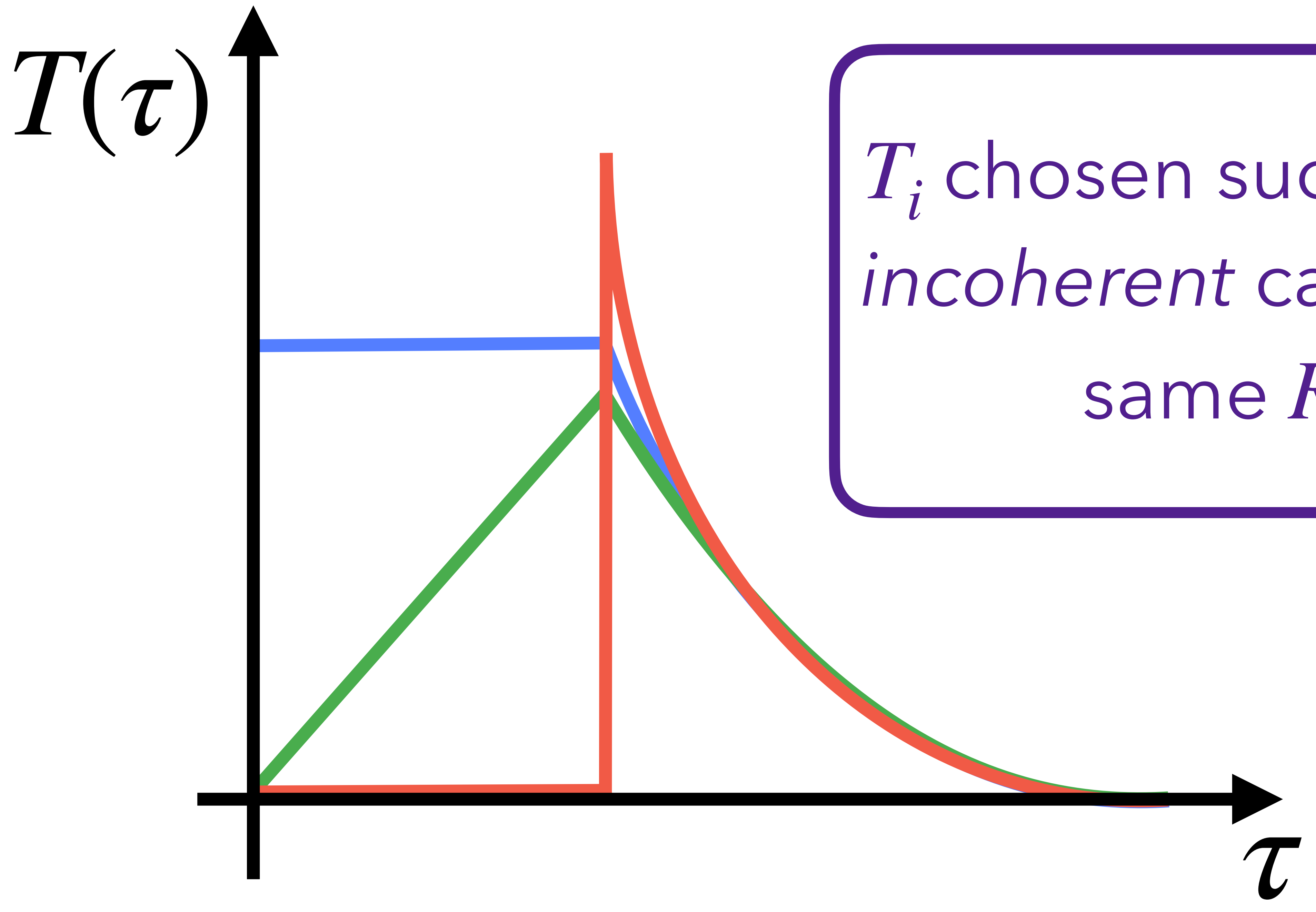

T_i chosen such that all *incoherent* cases have same R_{AA}

Color coherence in small collision systems

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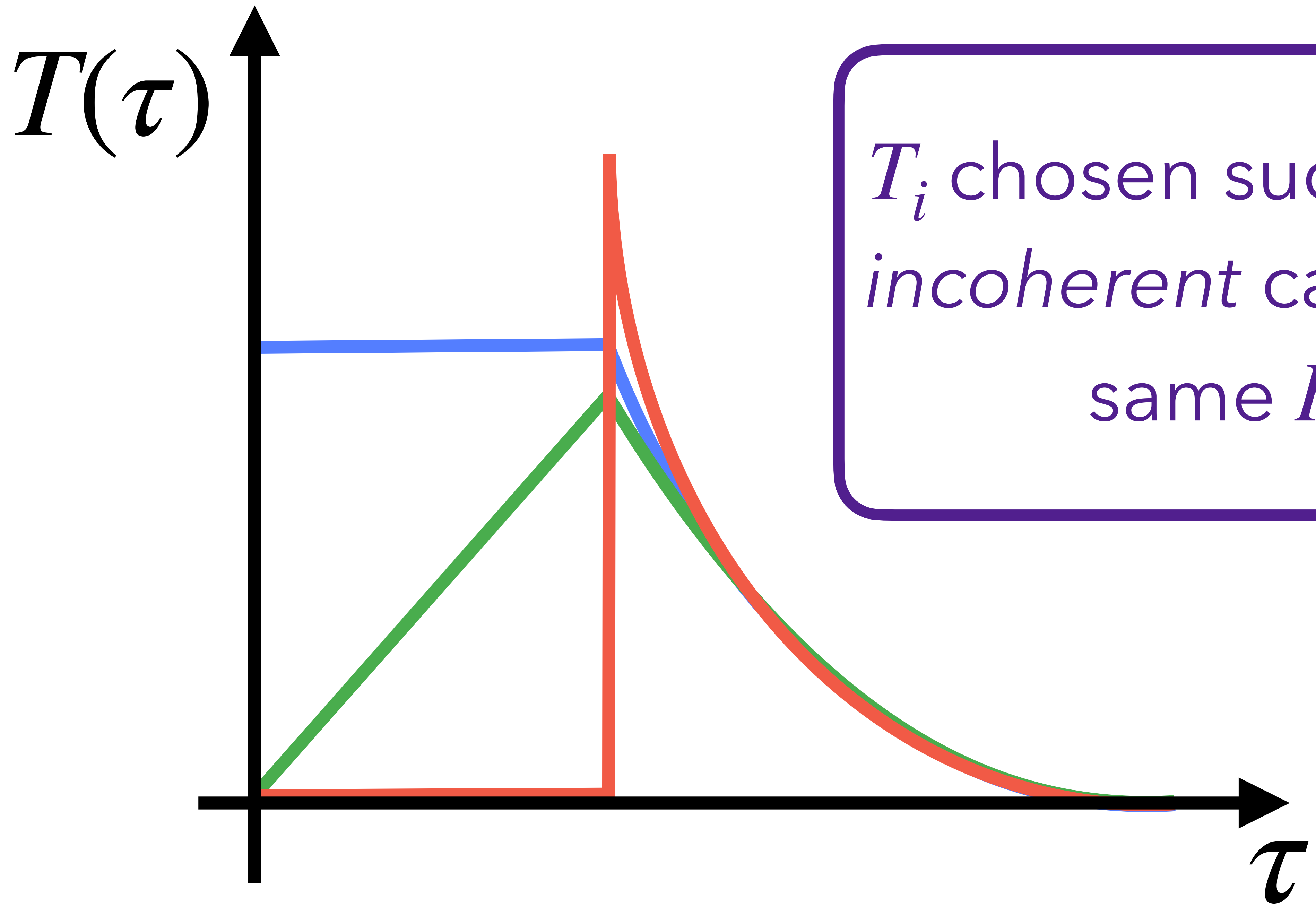
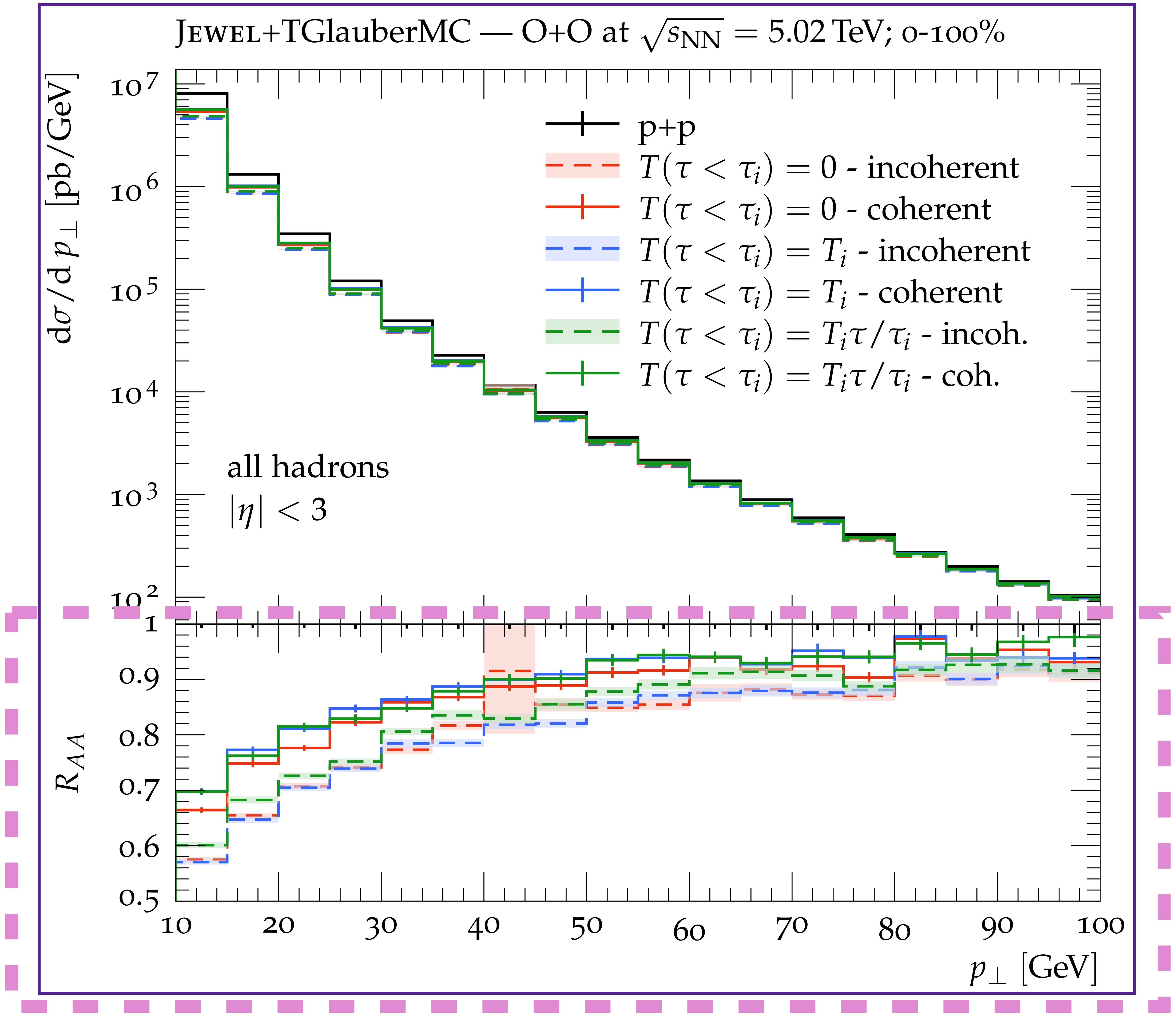
- JEWEL simple medium model:
- Test different models for initial temperature



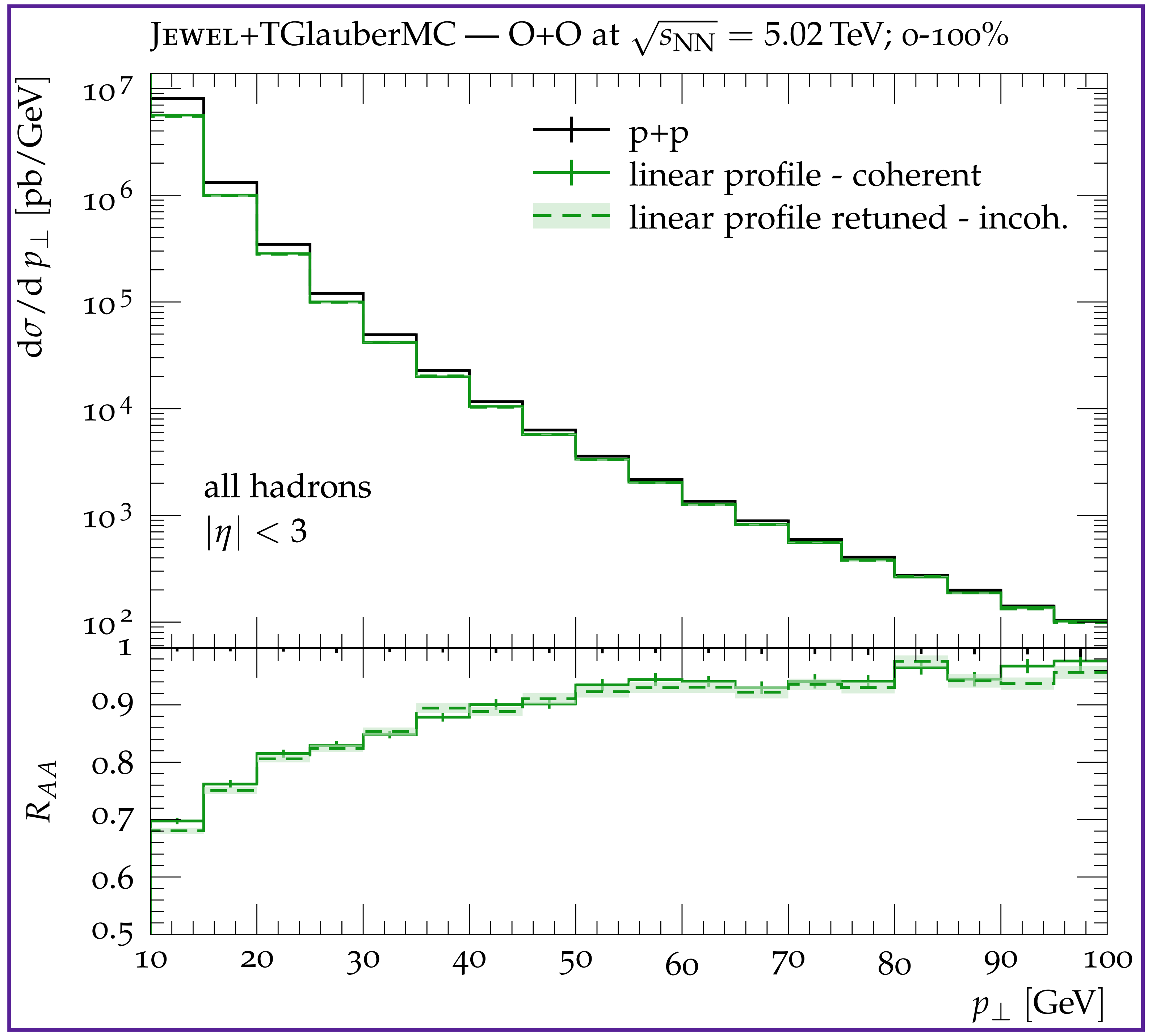
T_i chosen such that all *incoherent* cases have same R_{AA}



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



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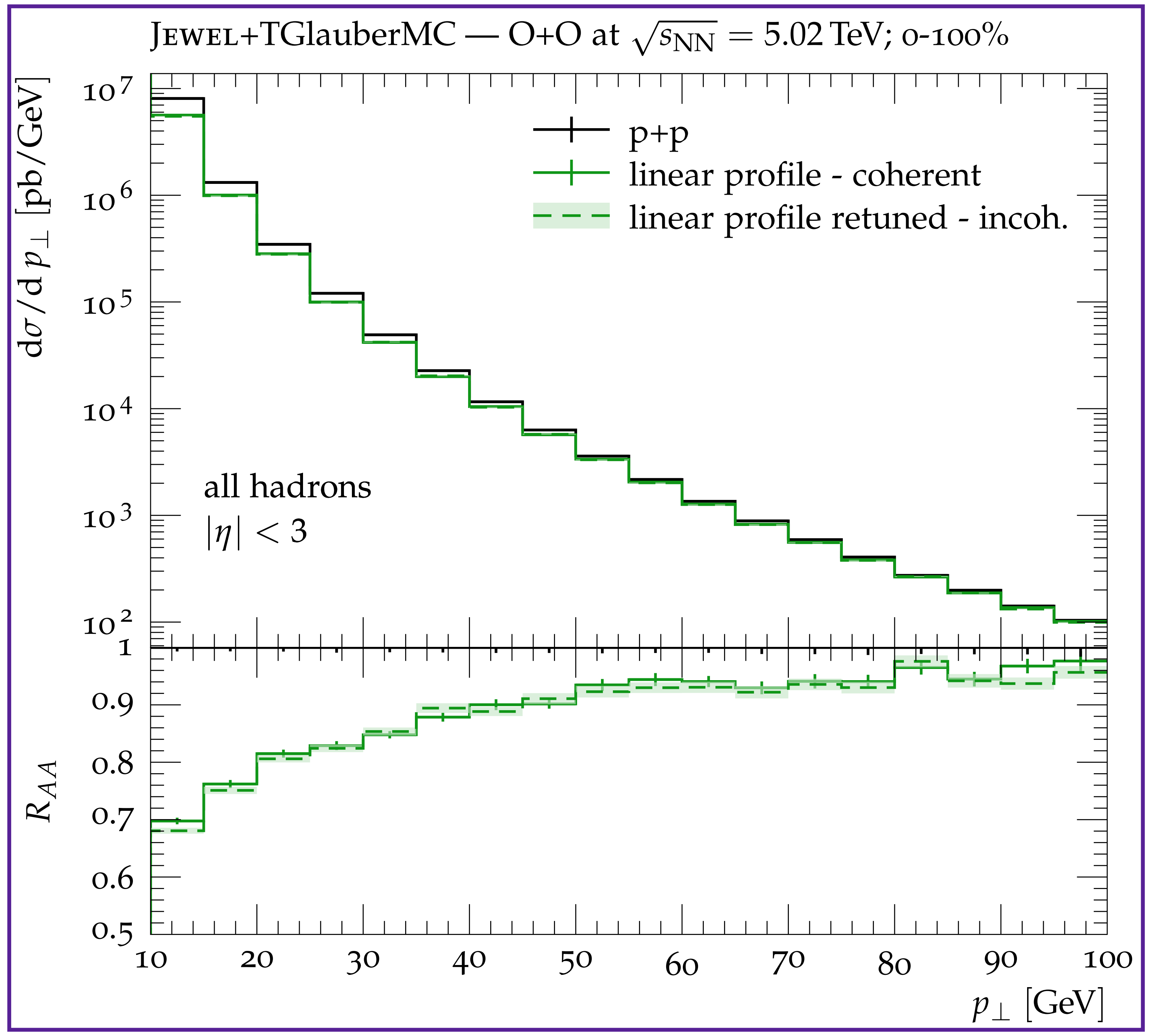

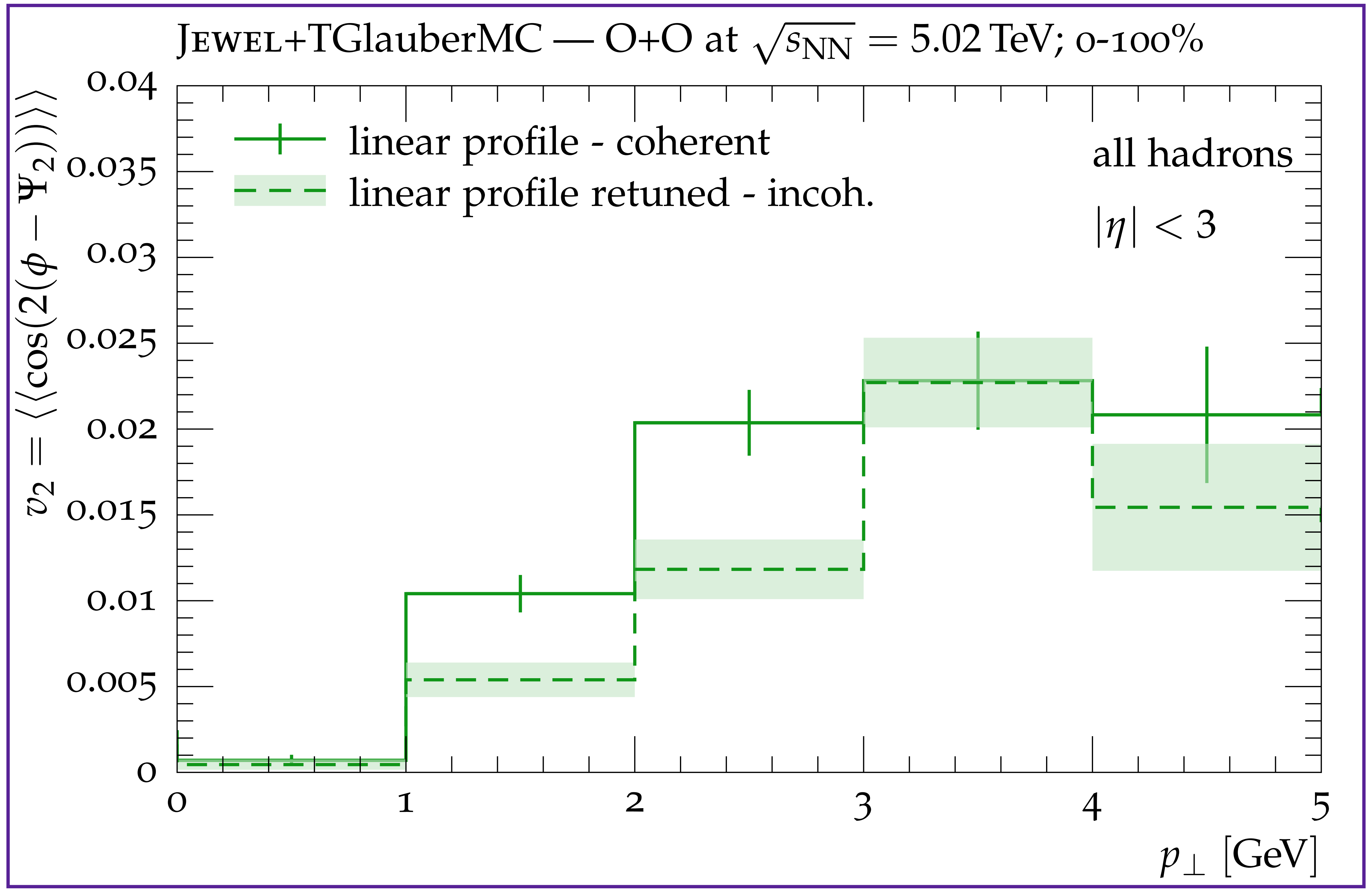

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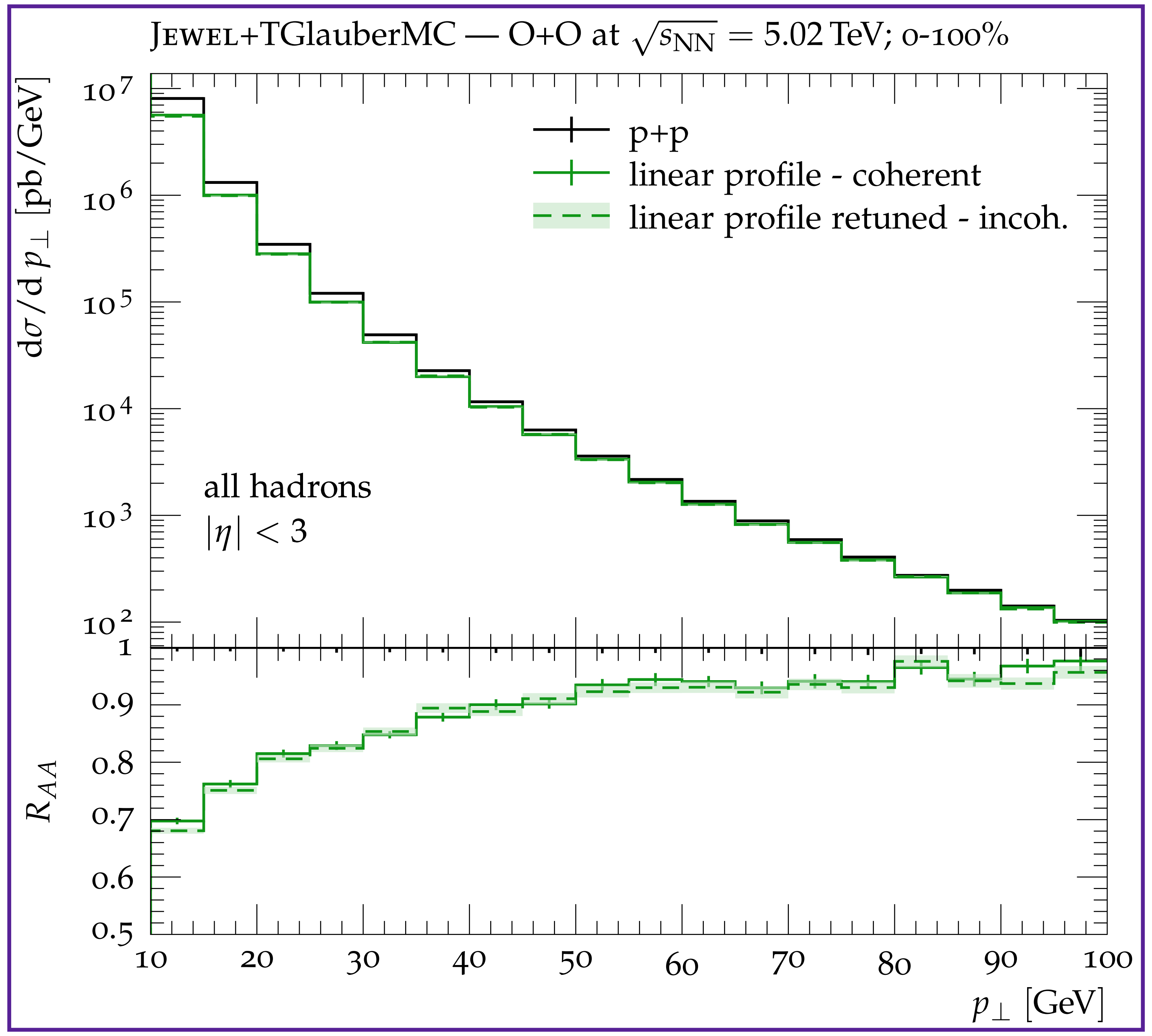

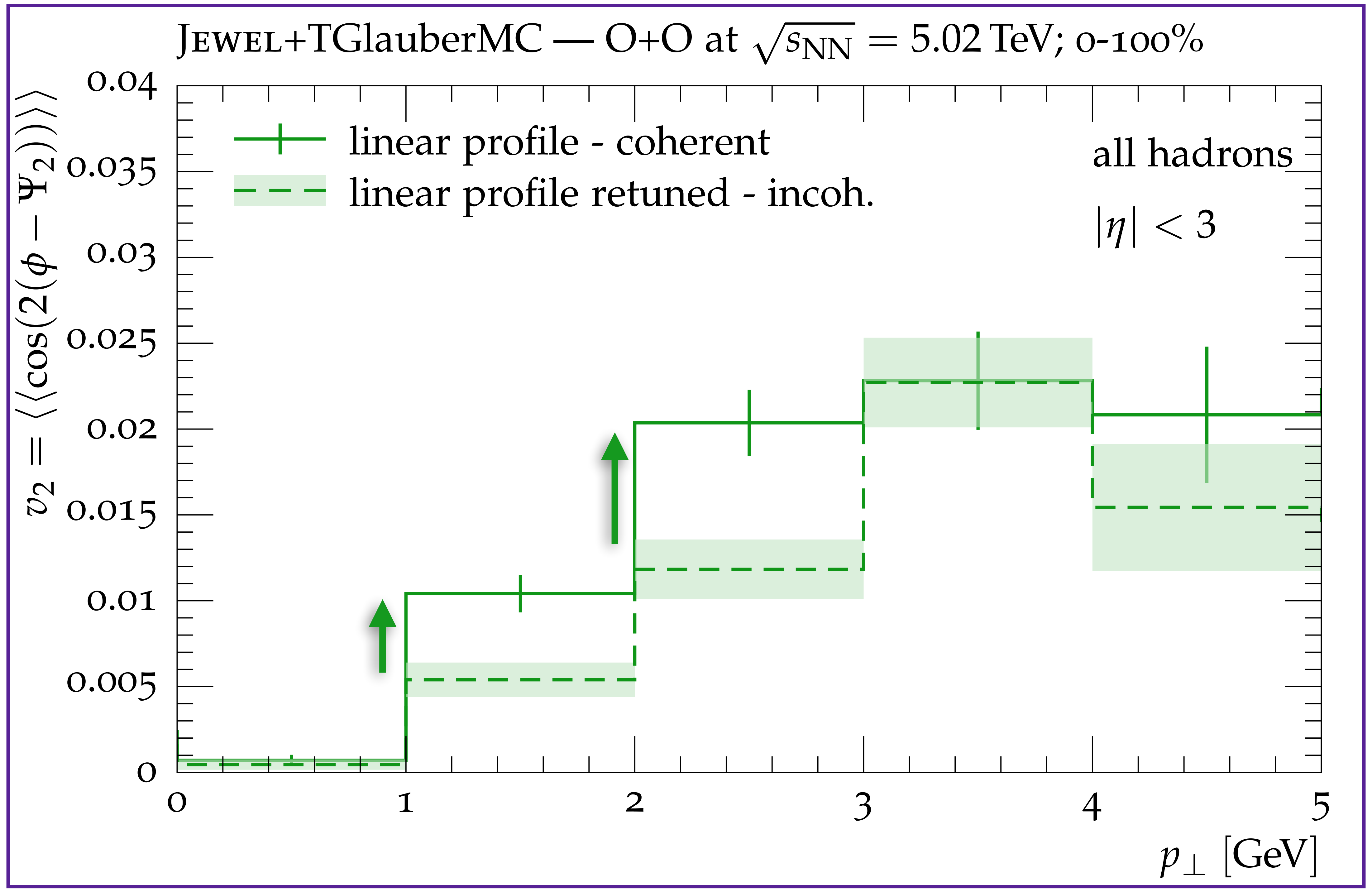

Conclusions

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- Colour **coherence vs decoherence** effects are relevant also in **small systems**.
  - Jet modification can appear even with small energy loss.

- **Formation time** helps **distinguish small** coherent **energy loss** from decoherence effects.

- Preserving **coherence** in the presence of energy loss **might lead to a jet v_2 enhancement** (preliminary)