Glauber Gluons

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Some SCET ingredients

- **Identify the relevant degrees of freedom.**

Relevant scaling for QCD:

$\lambda \ll 1$

- Hard Scaling $k^\mu \sim (1,1,1)Q$
- Collinear 1 region $k^\mu \sim (1,\lambda^2,\lambda)Q$
- Collinear 2 region $k^\mu \sim (\lambda^2,1,\lambda)Q$

} **Interact via soft modes**

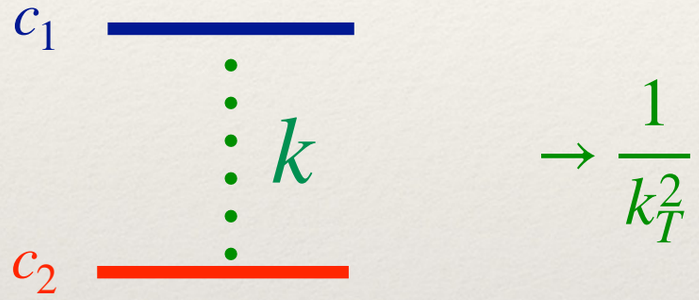
- Soft/ultra-soft region $k^\mu \sim (\lambda,\lambda,\lambda)/k^\mu \sim (\lambda^2,\lambda^2,\lambda^2)$

→ Subtlety: Glauber regions (soft scaling)

$$\begin{cases} G_1 \sim (\lambda^2,\lambda,\lambda)Q \\ G_2 \sim (\lambda,\lambda^2,\lambda)Q \\ G \sim (\lambda^2,\lambda^2,\lambda)Q \end{cases} \quad p_T \gg p^+, p^-$$

Glauber gluons

They appear in forward and hard scattering scattering but mostly relevant for forward scattering.



$$\to \frac{1}{k_T^2} \qquad k_T \gg k^+, k^-$$

- **Off-shell Glauber gluon ⇒never appear in final states**
- **Instant interaction of the collinear regions**
- **Intuitively think of these gluons as an external potential and it might spoil the factorization theorems.**

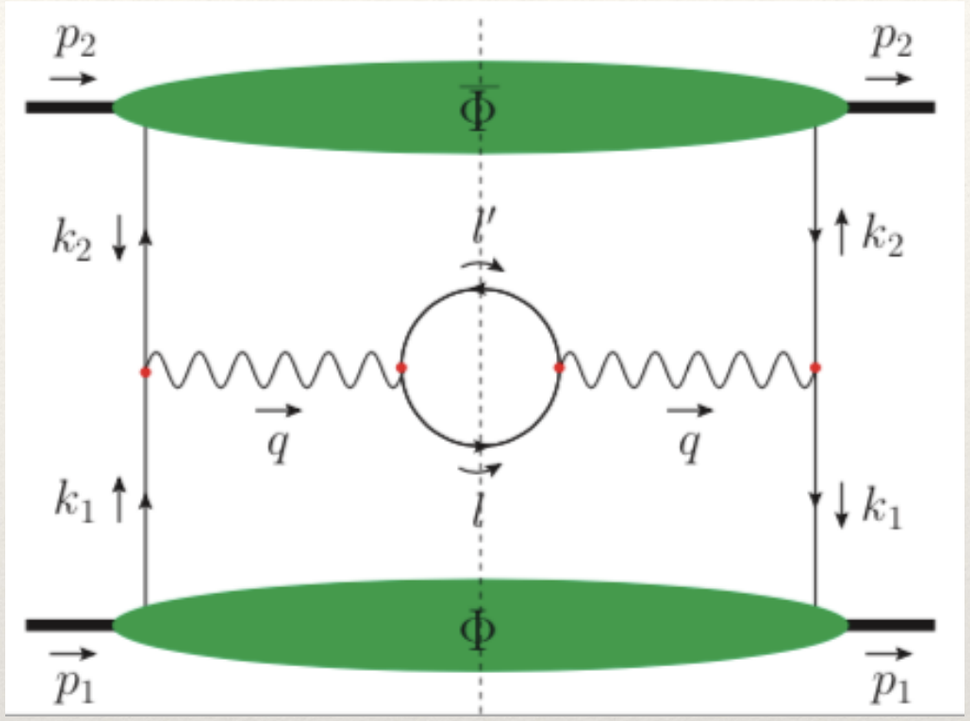
Factorization in QCD

$$\sigma = short \quad distance \otimes long \quad distance$$

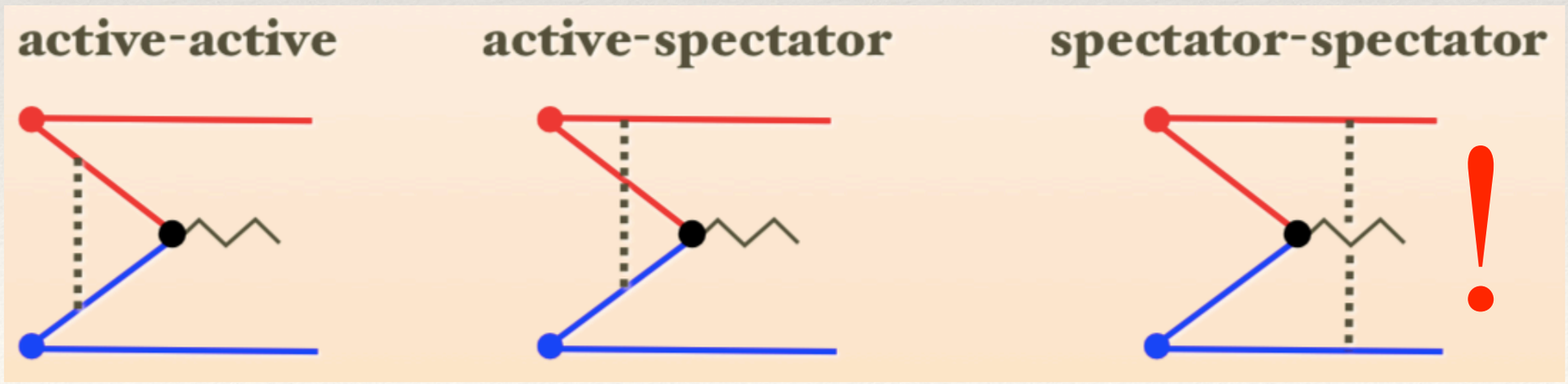
$$\sigma = \Phi(c_1) \otimes \Phi(c_2) \otimes Hard$$

Partons might (they do!) interact

between each other via gluon exchange.



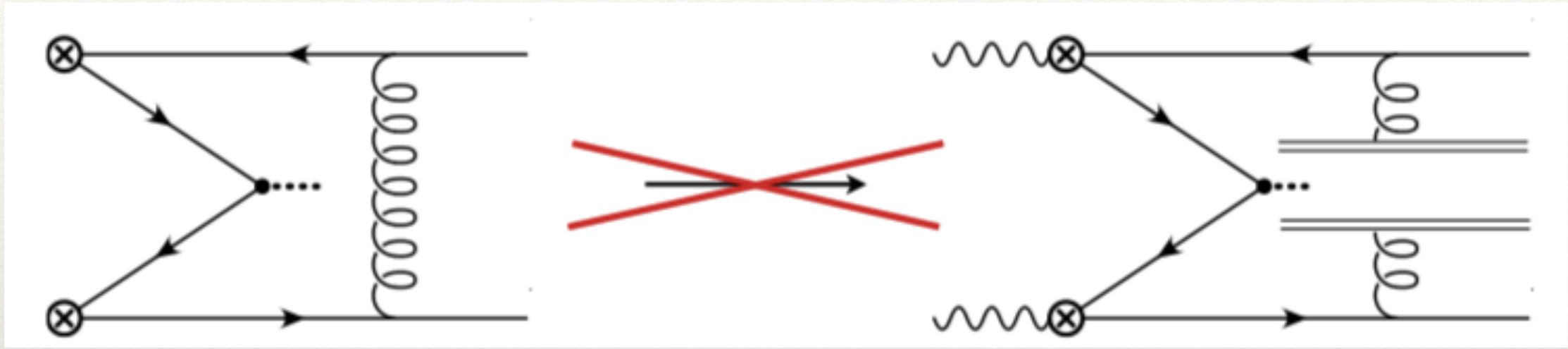
Parton interactions



Picture courtesy I.Stewart

Interactions among constituents might spoil the factorization. When? How?

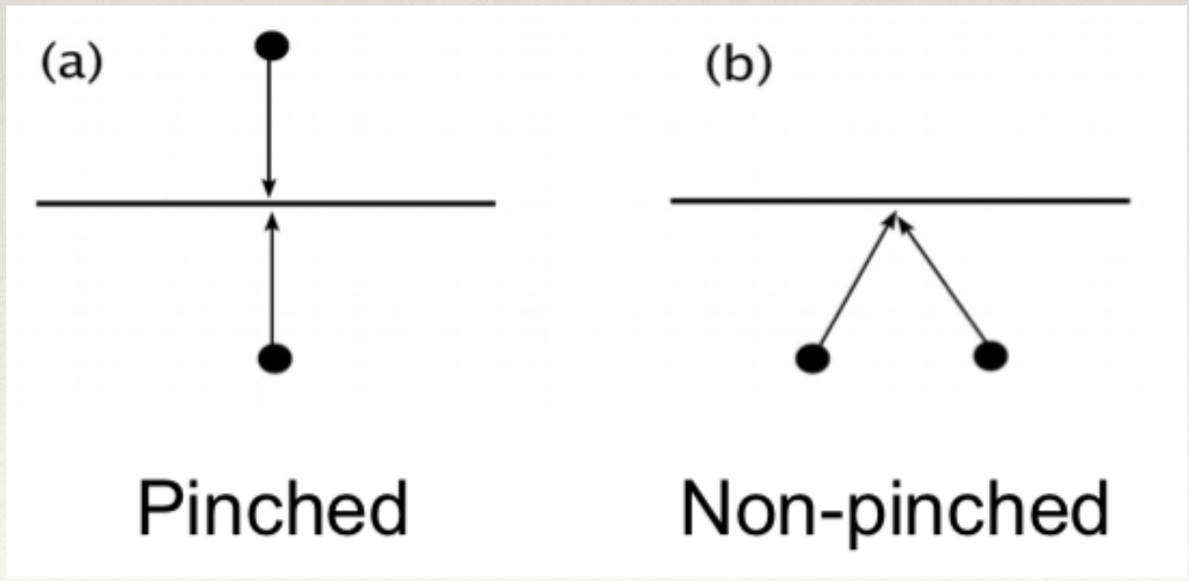
Factorization in QCD



Spectator-Spectator Glauber exchange violates factorization.

If the Glauber scaling can be "absorbed" into one of the collinear directions, the factorization is not spoiled.

Pinch singularities in Feynman graphs correspond to physically allowed processes. Coleman-Norton theorem.



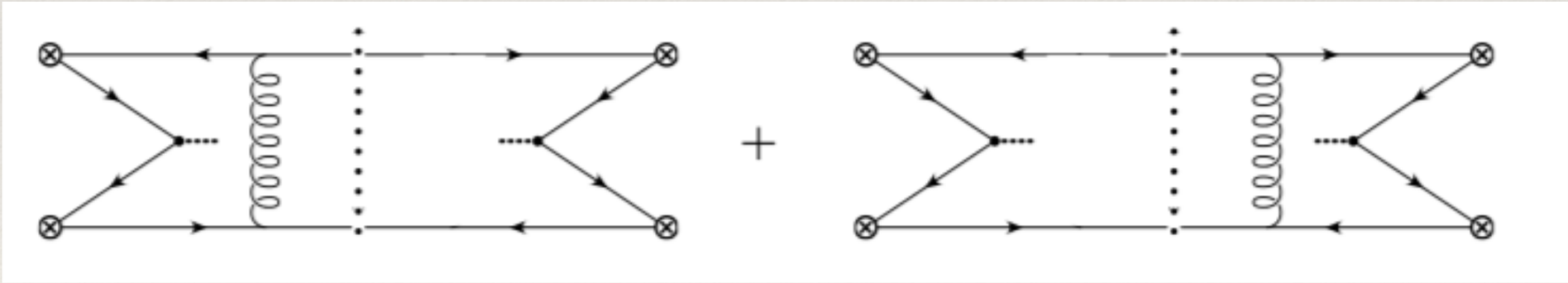
The momentum integration is performed in the complex plane.

Inclusive processes

In reality the factorization theorem might or might not hold for different observables. It tends to be violated for less inclusive observables.

For example the Glauber effect vanishes for the inclusive $\frac{d\sigma}{dq^2 dy}$

$$P_1 P_2 \to l^+ l^- X$$

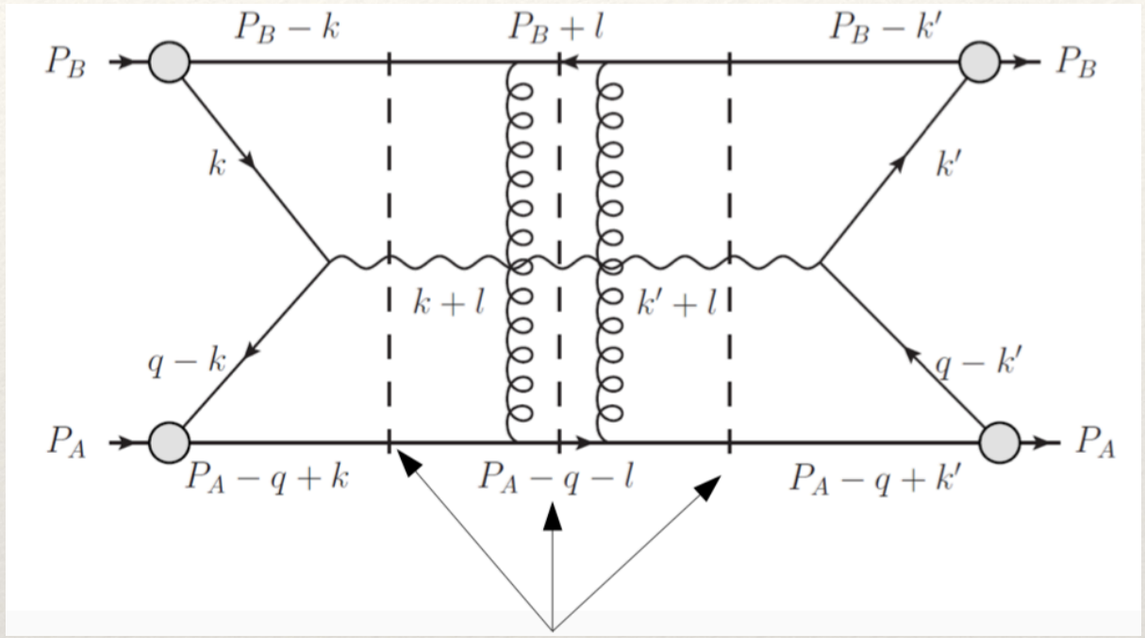


Sum over all final state cuts will vanish

Examples of violation

Event shape variables, transverse energy distributions.

Production of coloured states in the final state.



2 Glauber exchange

Factorization usually fails for observables that are sensitive to Multi-Parton-Interactions (MPI).

Eg:Beam thrust, transverse thrust.

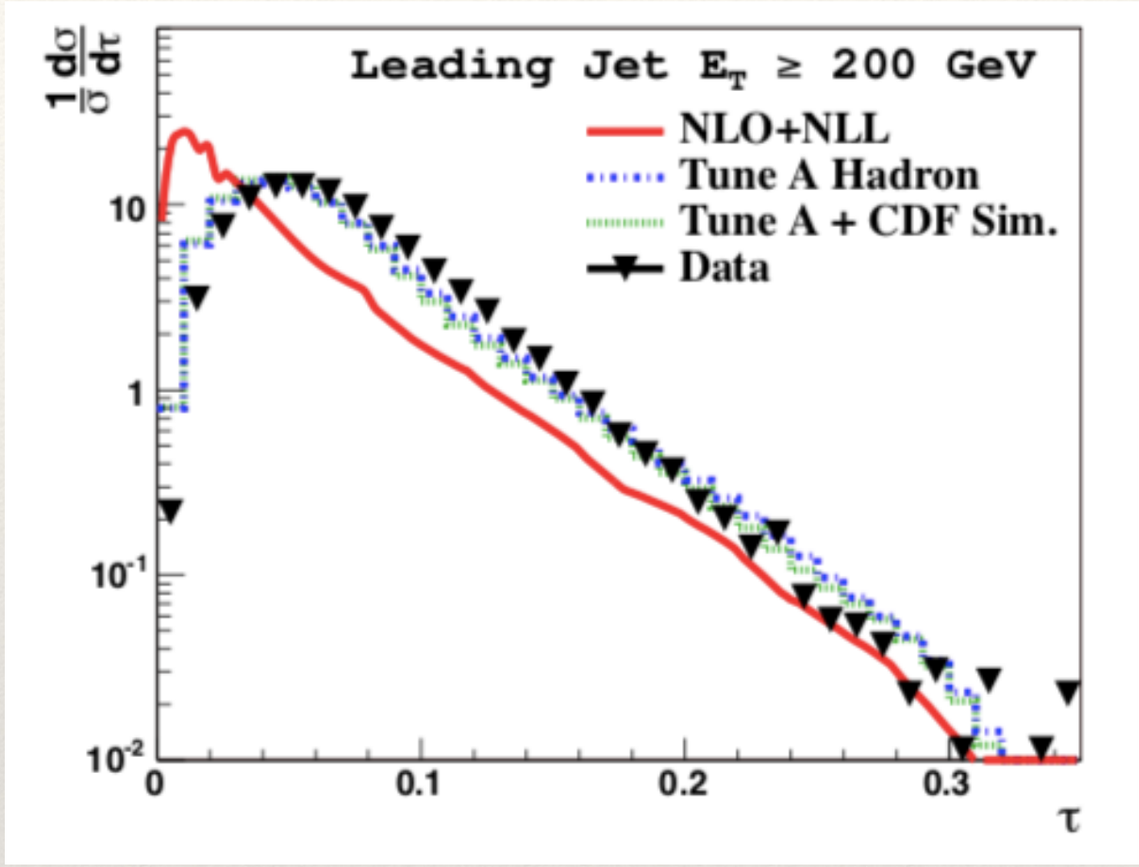
State of art

Use Monte Carlo simulations

to include Glauber gluons

effects. They are still not

understood using first principles.



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Thank you!