Towards a self-consistent determination of Fragmentation Functions

J. Osvaldo Gonzalez Hernandez
Old Dominion University

In collaboration with:
Mariaelena Boglione (Torino)
Leonard Gamberg (Penn State Berks)
Ted Rogers (ODU/JLab)
Nobuo Sato (JLab)

outline

Motivation

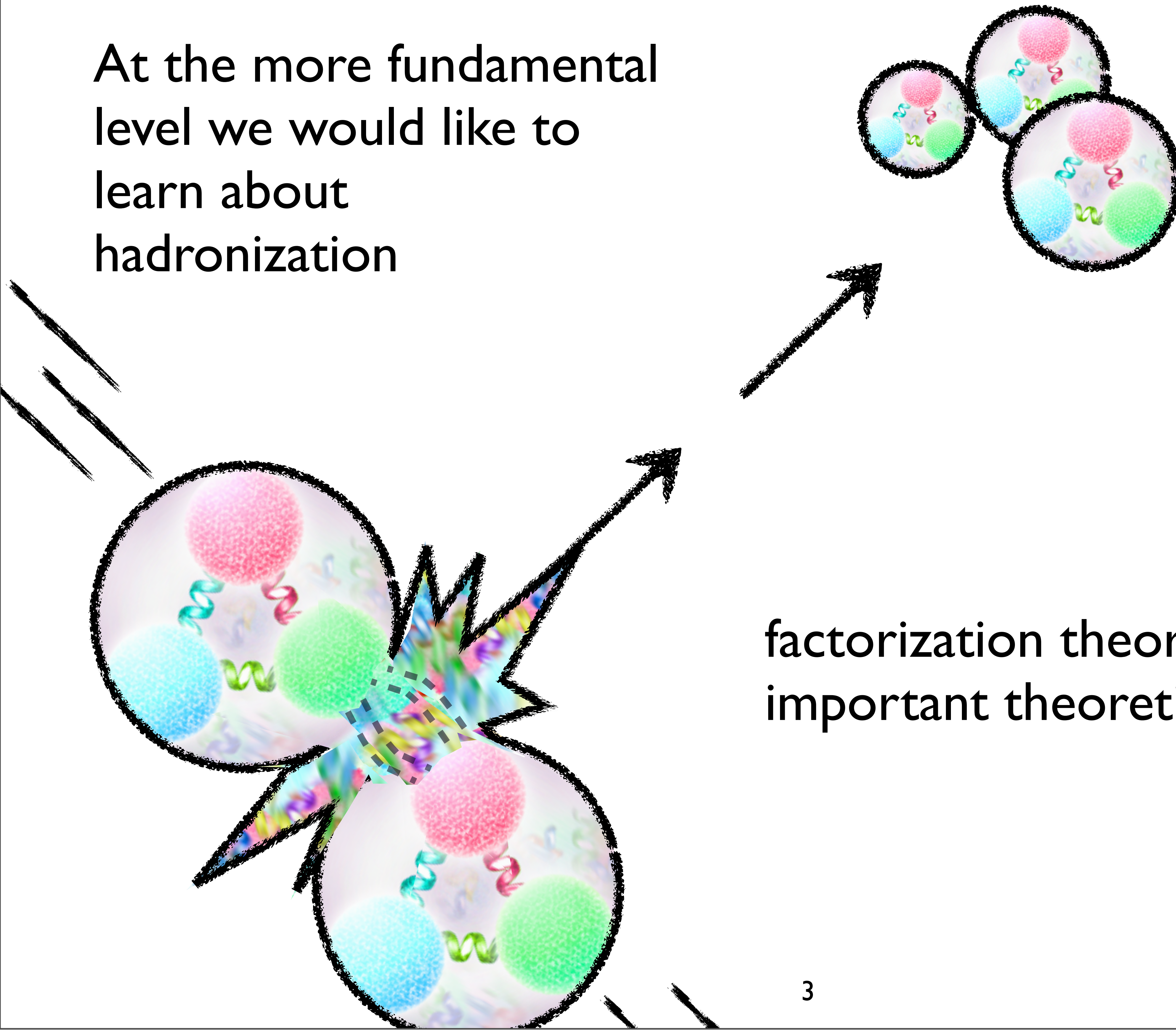
SIDIS and the current
fragmentation region: physical picture

Power counting and kinematics
of the current region

Final remarks

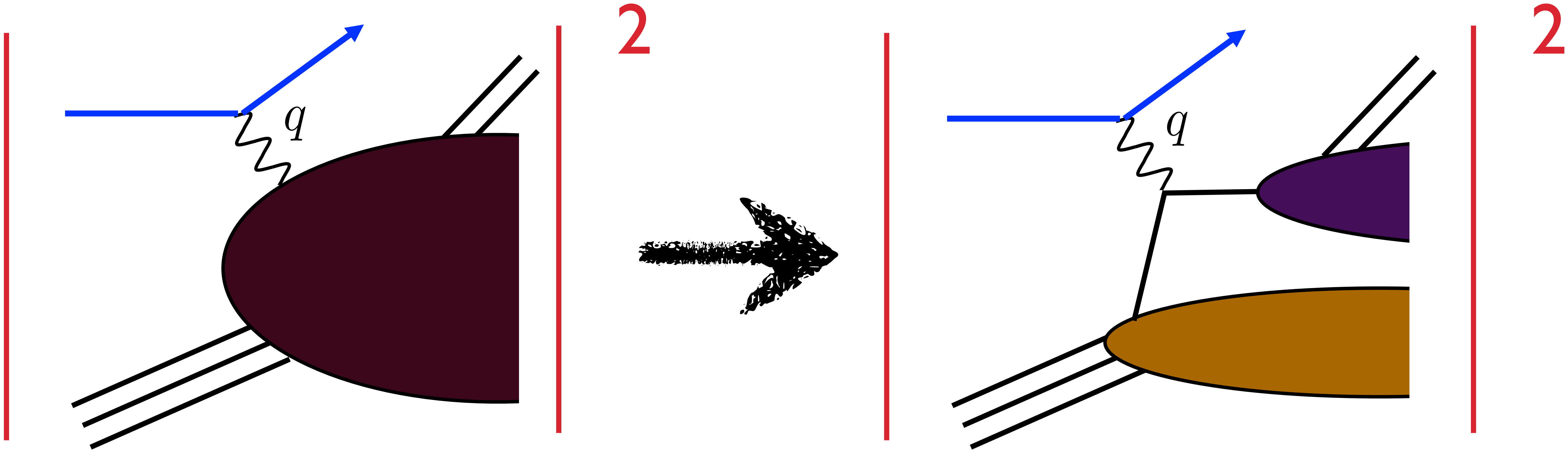
Motivation

At the more fundamental level we would like to learn about hadronization



factorization theorems, important theoretical tool

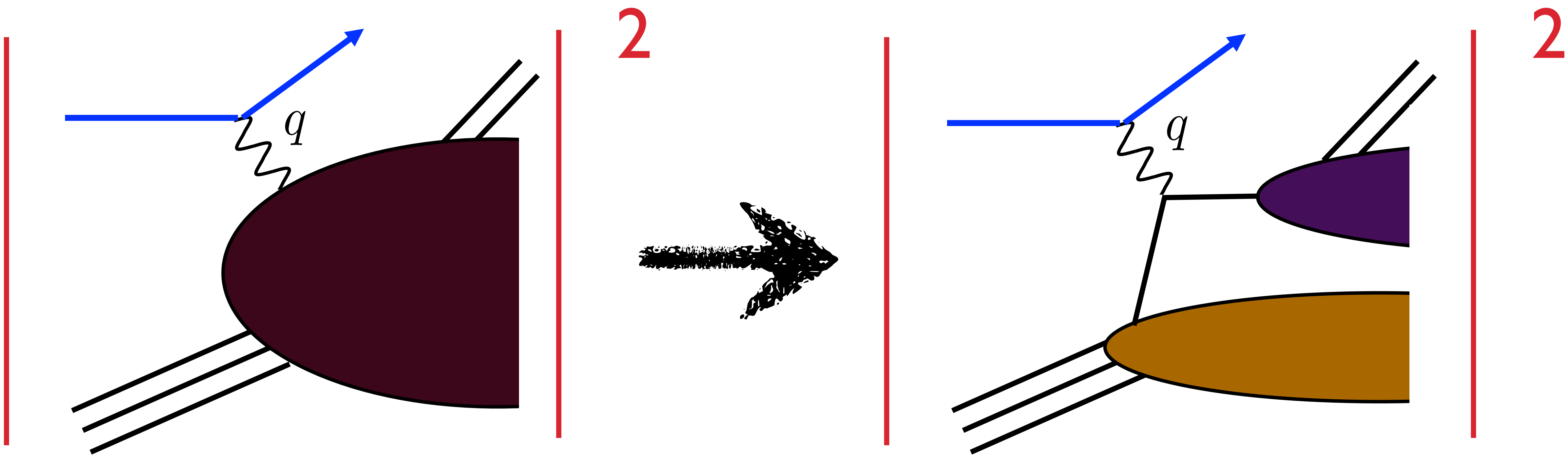
Motivation



Fragmentation functions

Not the most general picture. Certain conditions must be met to compare to experiment. Need always to be self-consistent

Motivation



In this talk I will focus on the kinematics of SIDIS:

i) simple necessary conditions

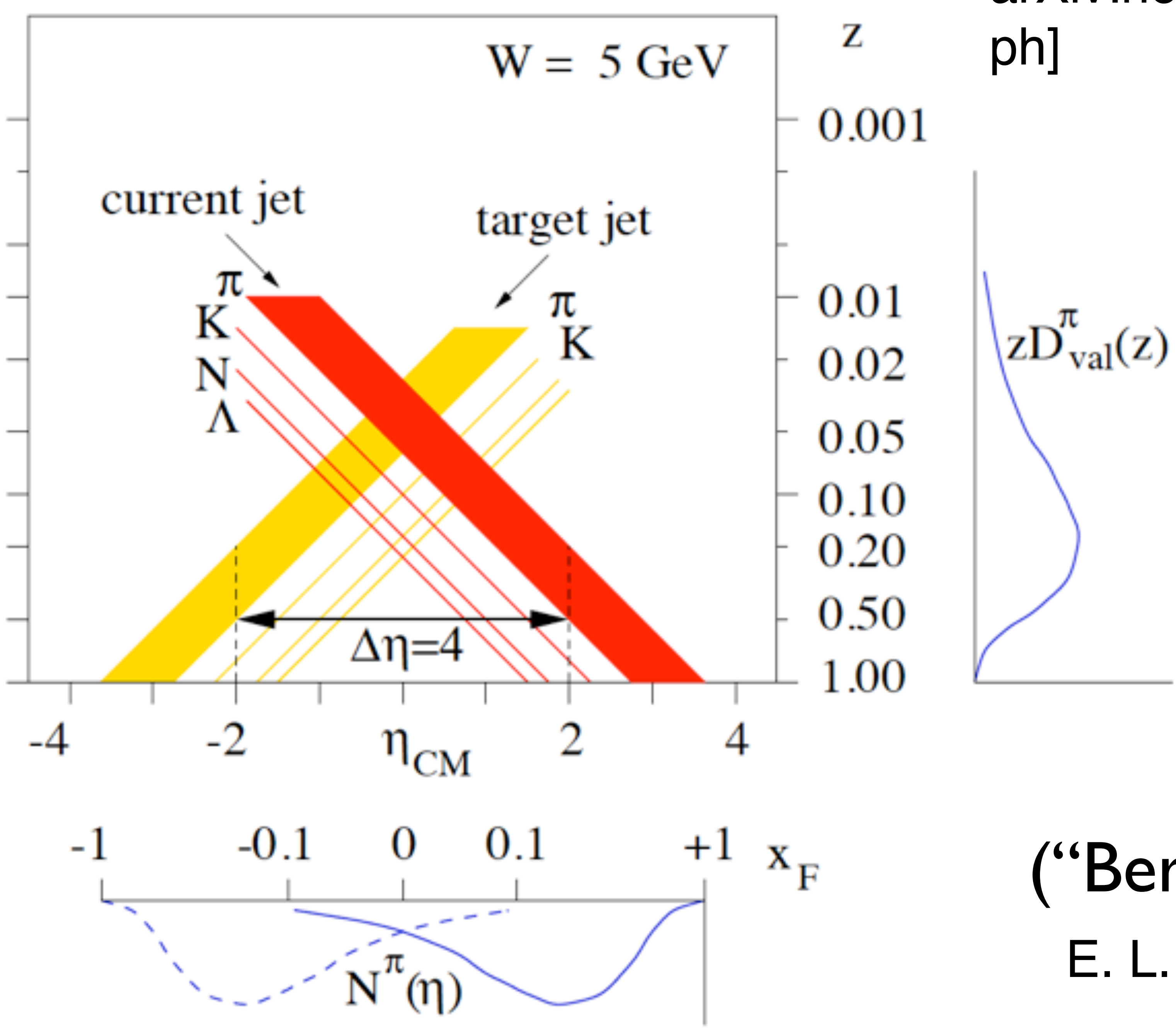
ii) often overlooked

Guiding principle: power counting of the factorization theorem

Motivation

It should be noted ...

P. J. Mulders, AIP Conf. Proc. 588, 75 (2001), [,75(2000)], arXiv:hep-ph/0010199 [hep-ph]



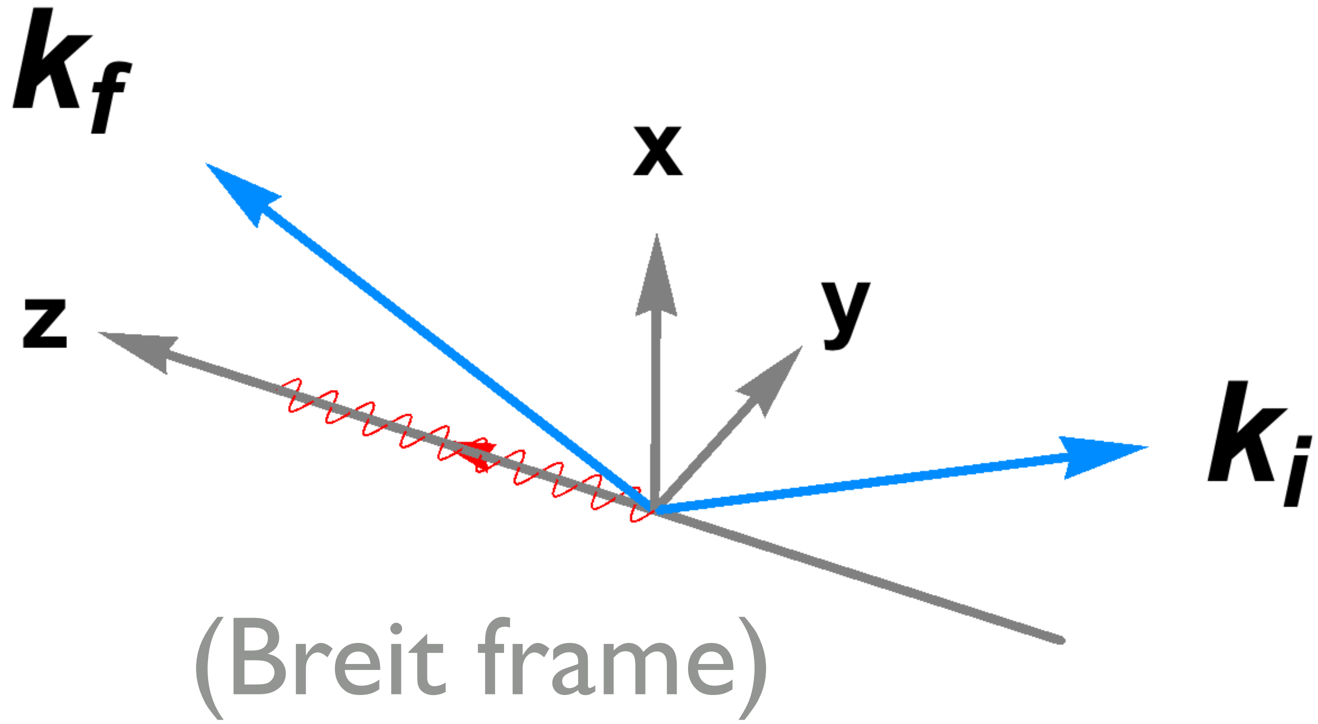
Phase space should be large enough to distinguish current/target regions

("Berger criterion")

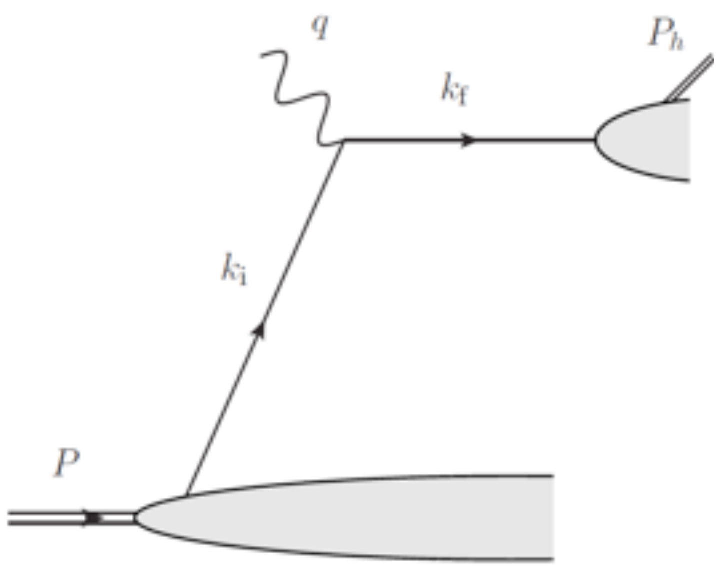
E. L. Berger, (1987).

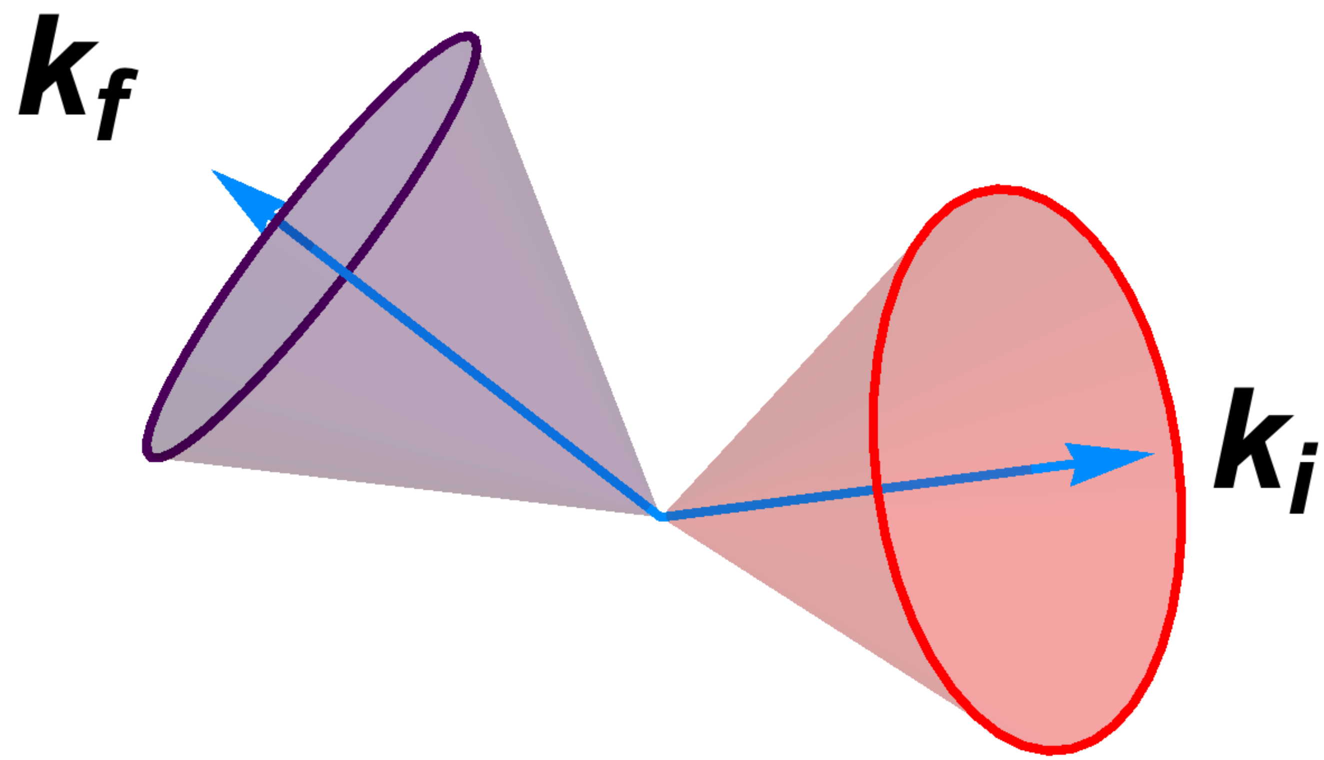
Motivation

We need a quantitative way to identify the current region.

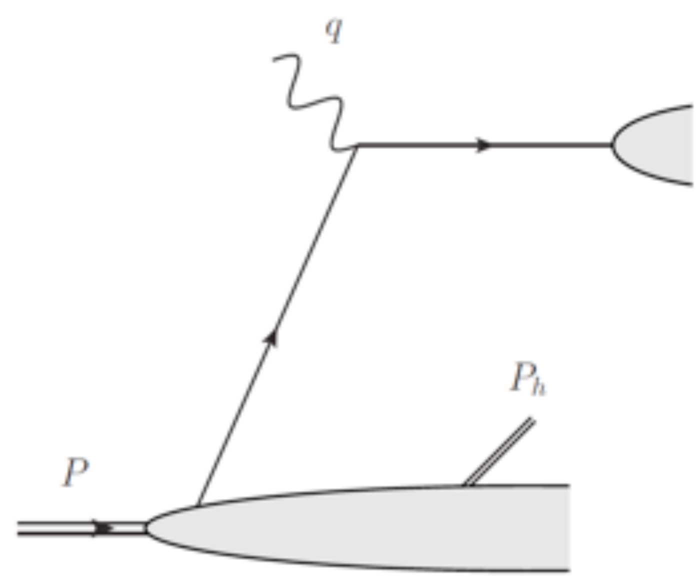


SIDIS and the current fragmentation region: physical picture

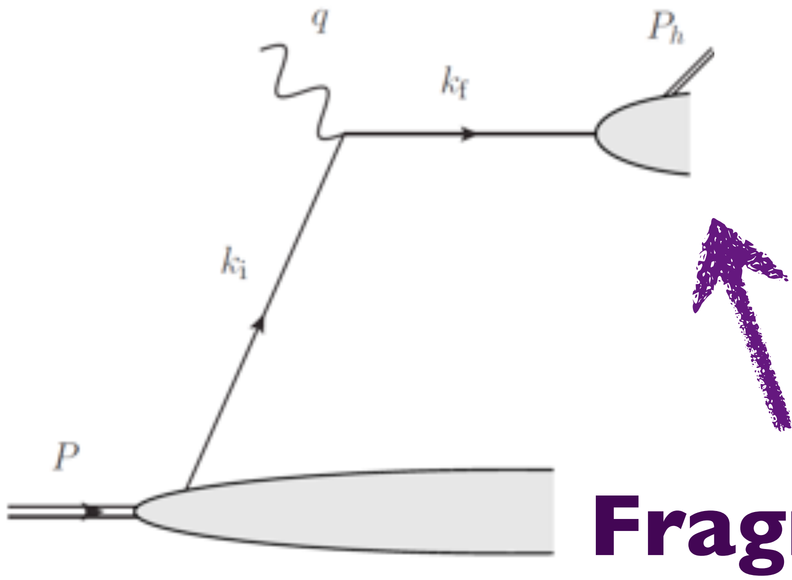


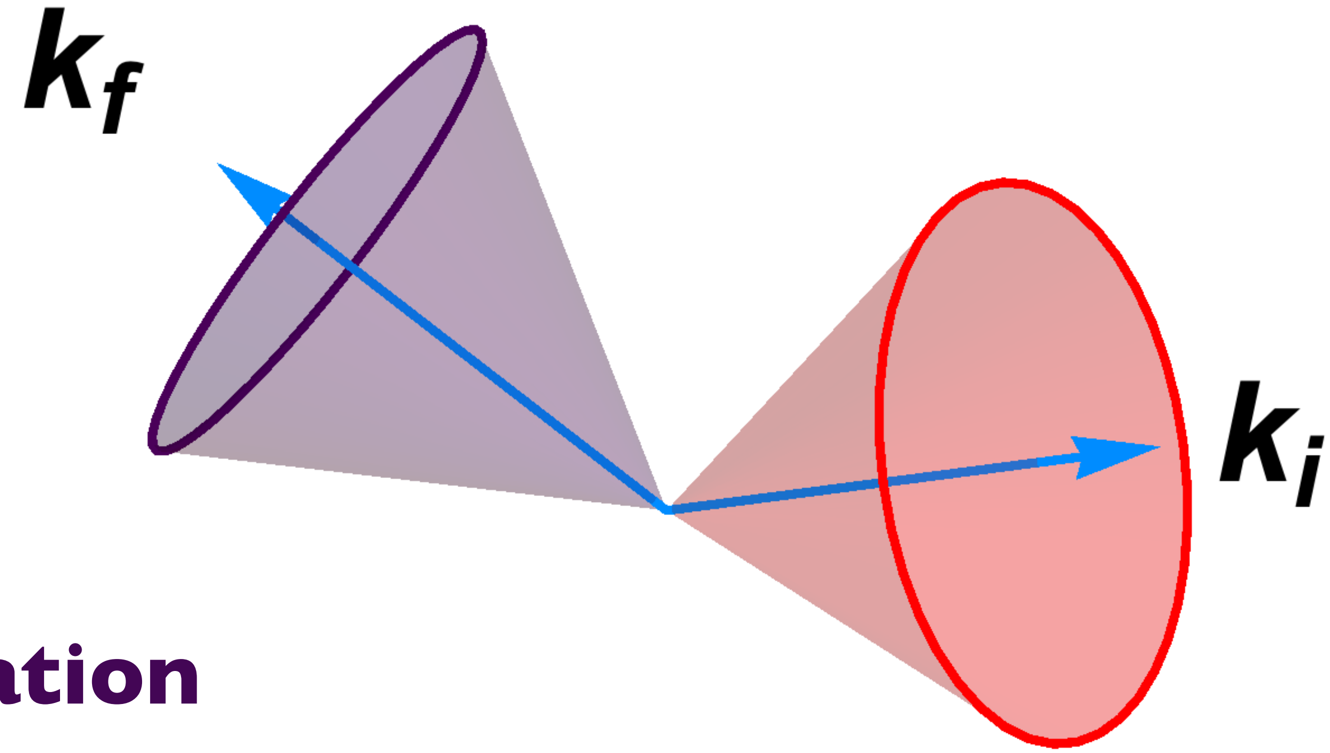


current



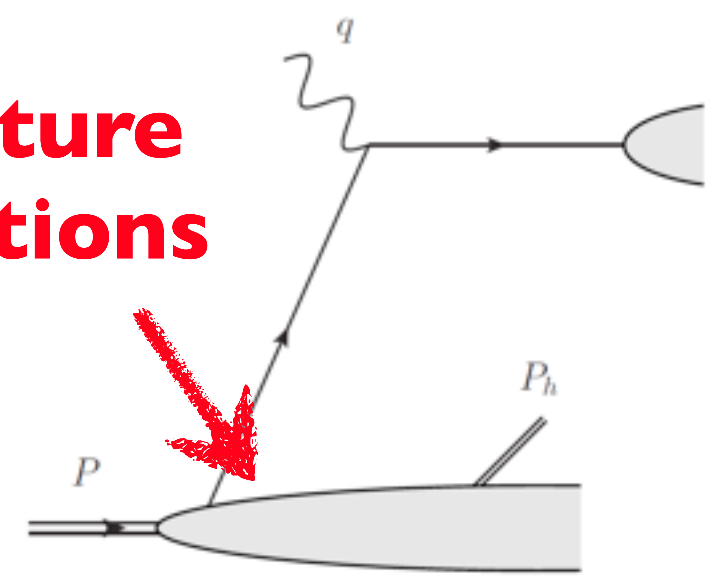
target





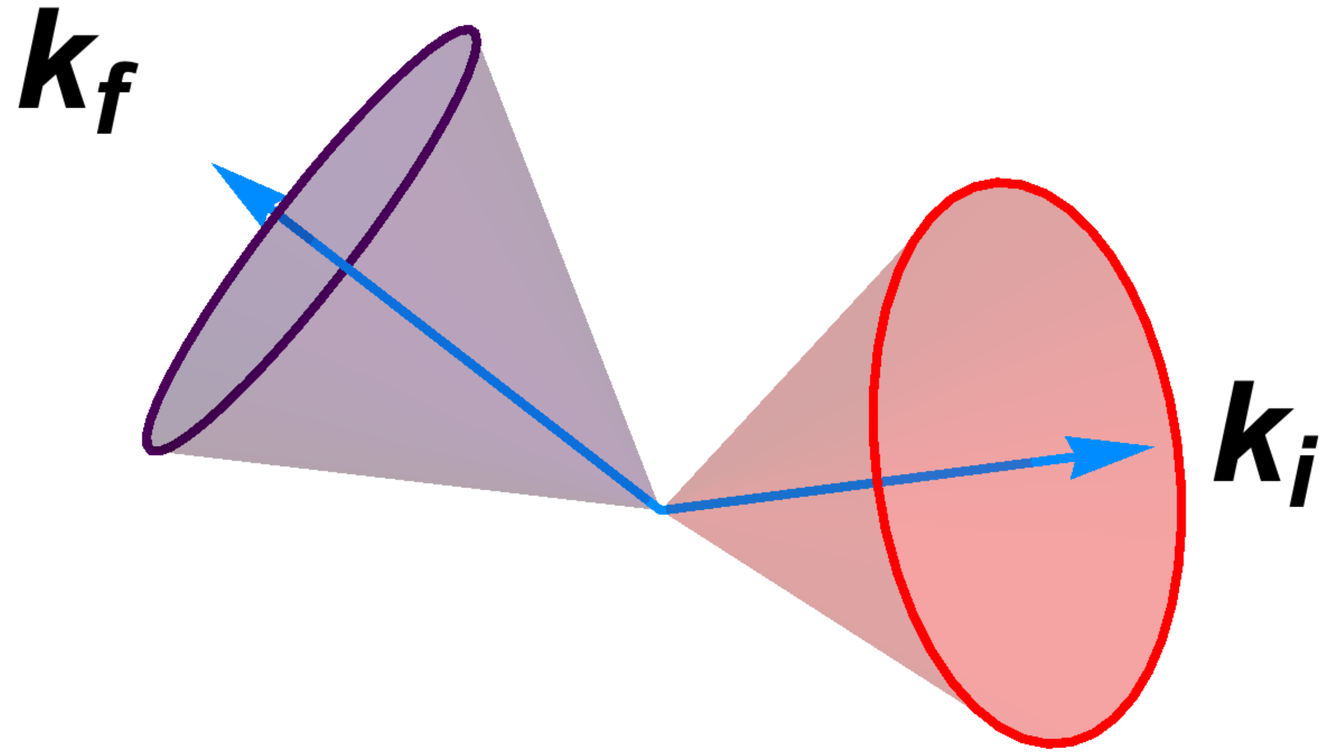
Fragmentation Functions

Fracture Functions

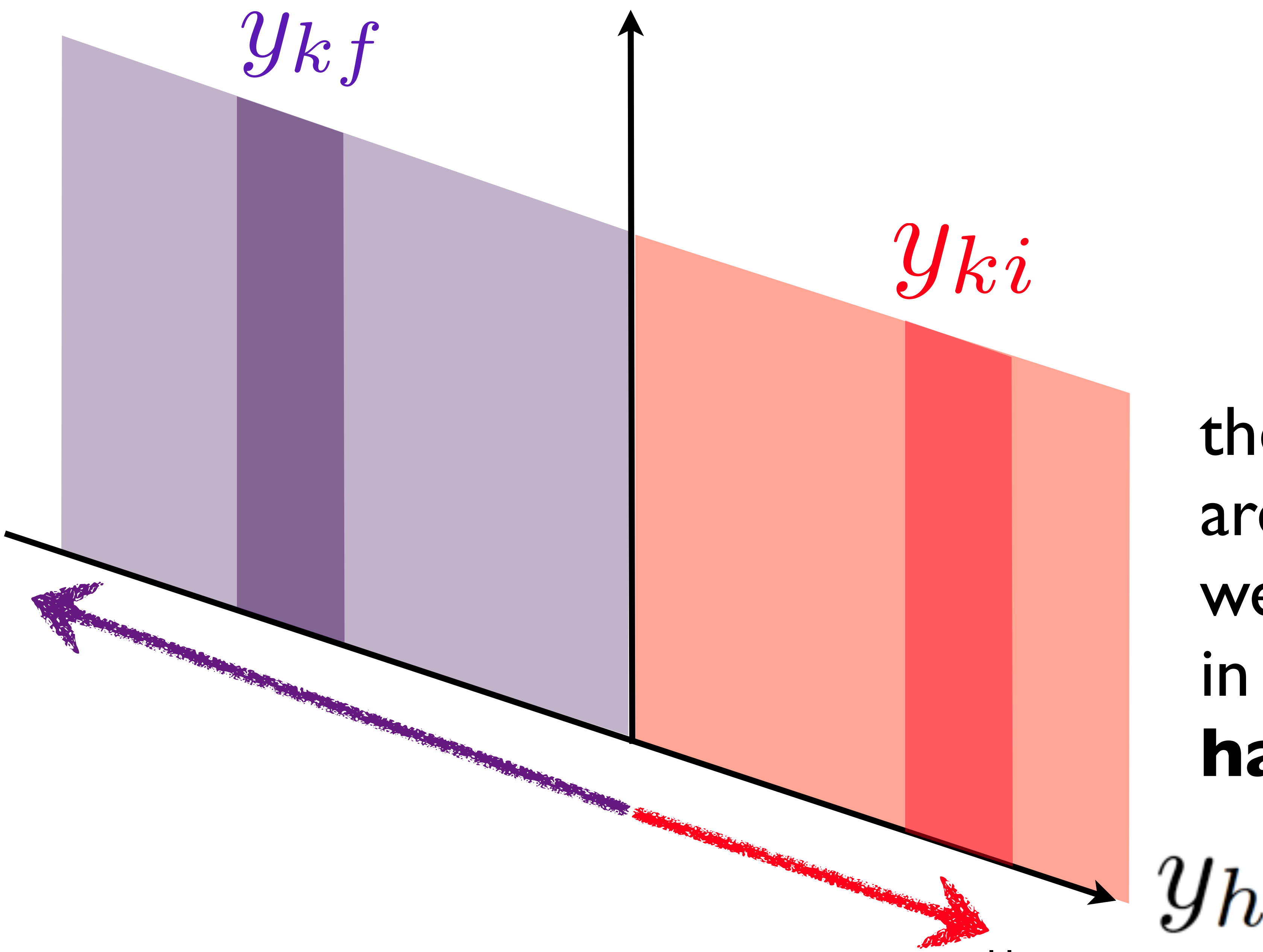


factorization theorems

$$y_h \equiv \frac{1}{2}\log\frac{P_h^+}{P_h^-}$$

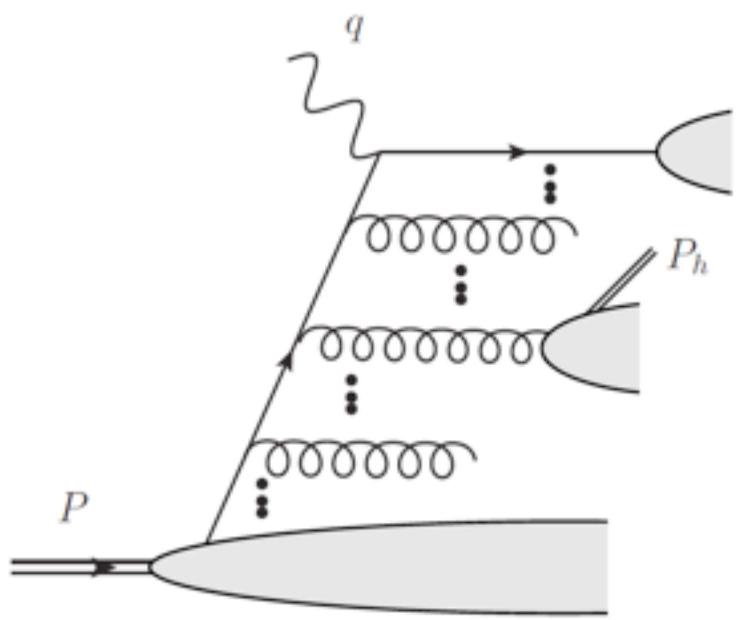


Observable

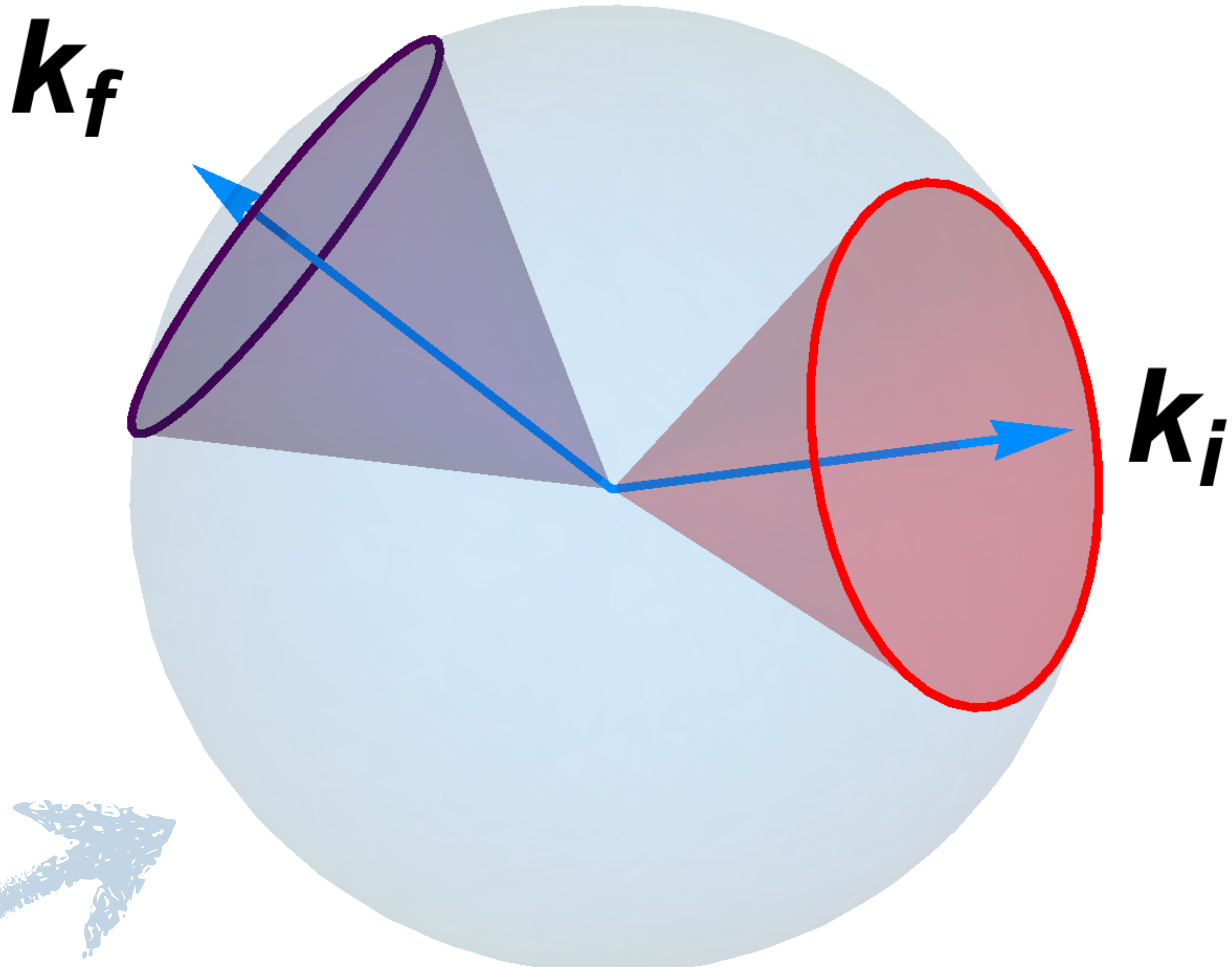


these regions are assumed to be well separated in the **observed hadron rapidity**

$$y_h \equiv \frac{1}{2} \log \frac{P_h^+}{P_h^-}$$



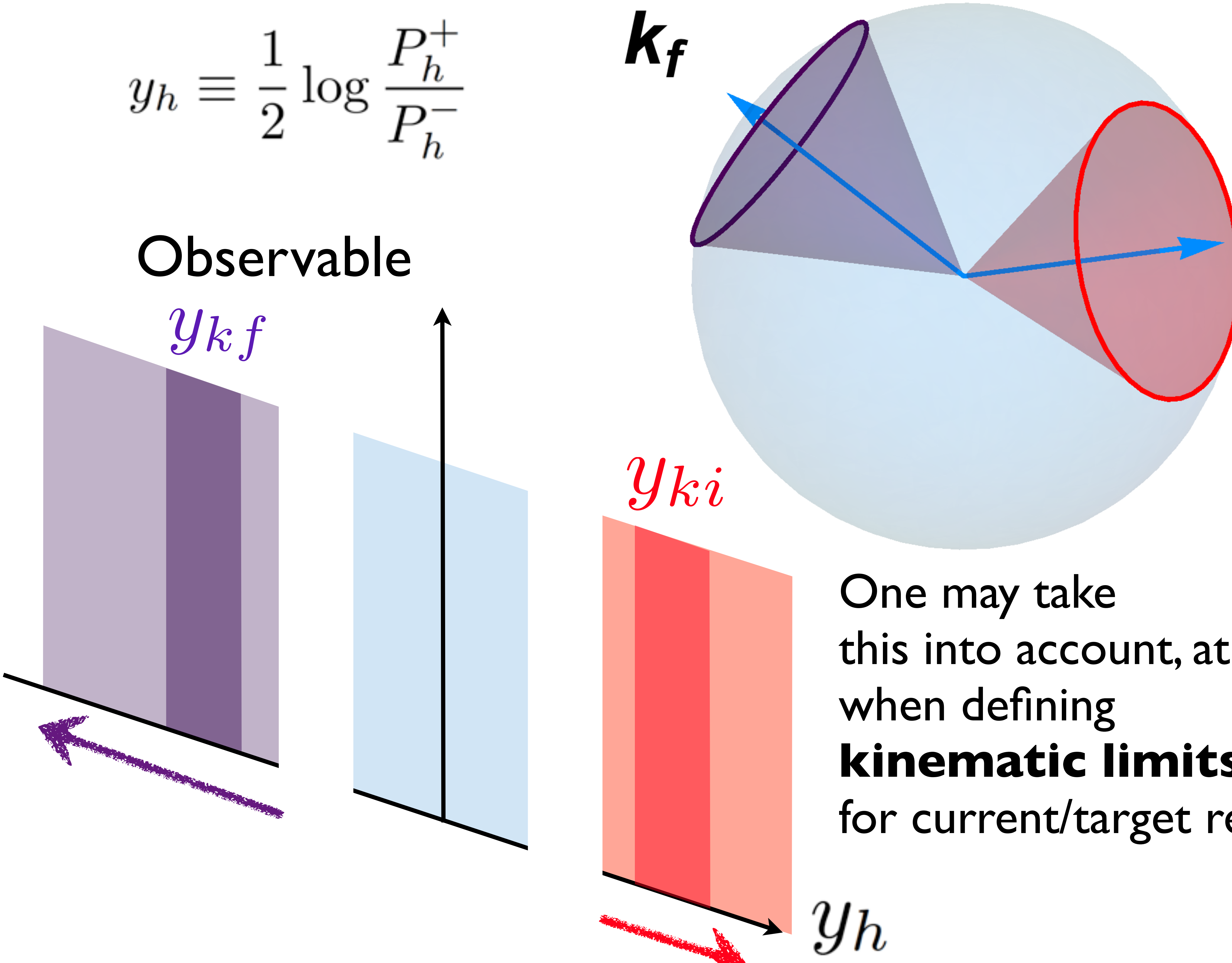
soft



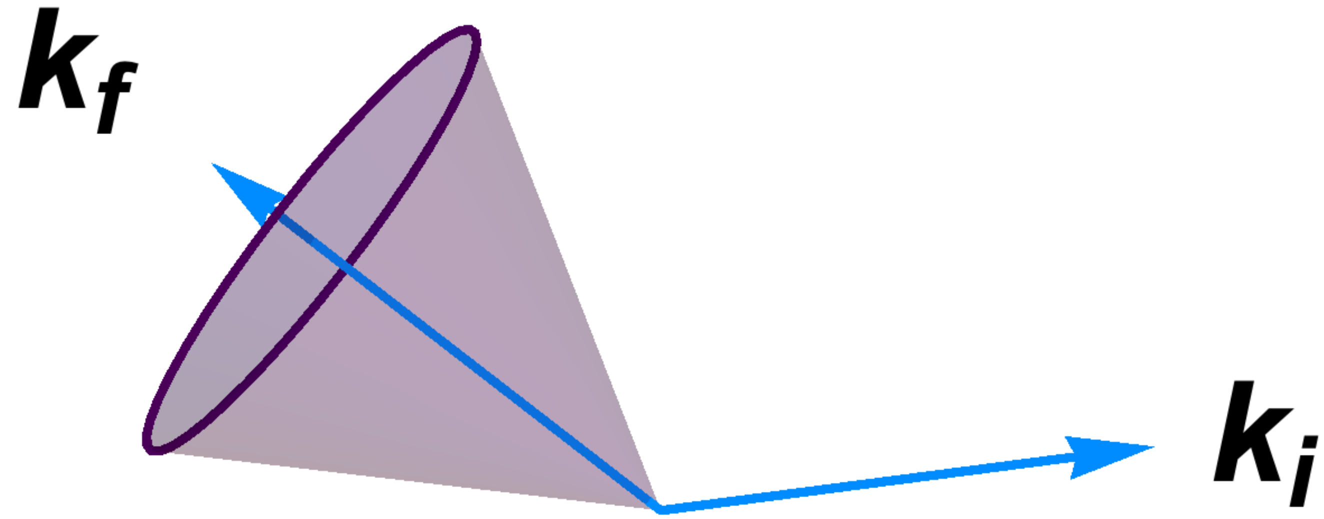
However, this neglects the soft fragmentation region

(No factorization theorem for this region)

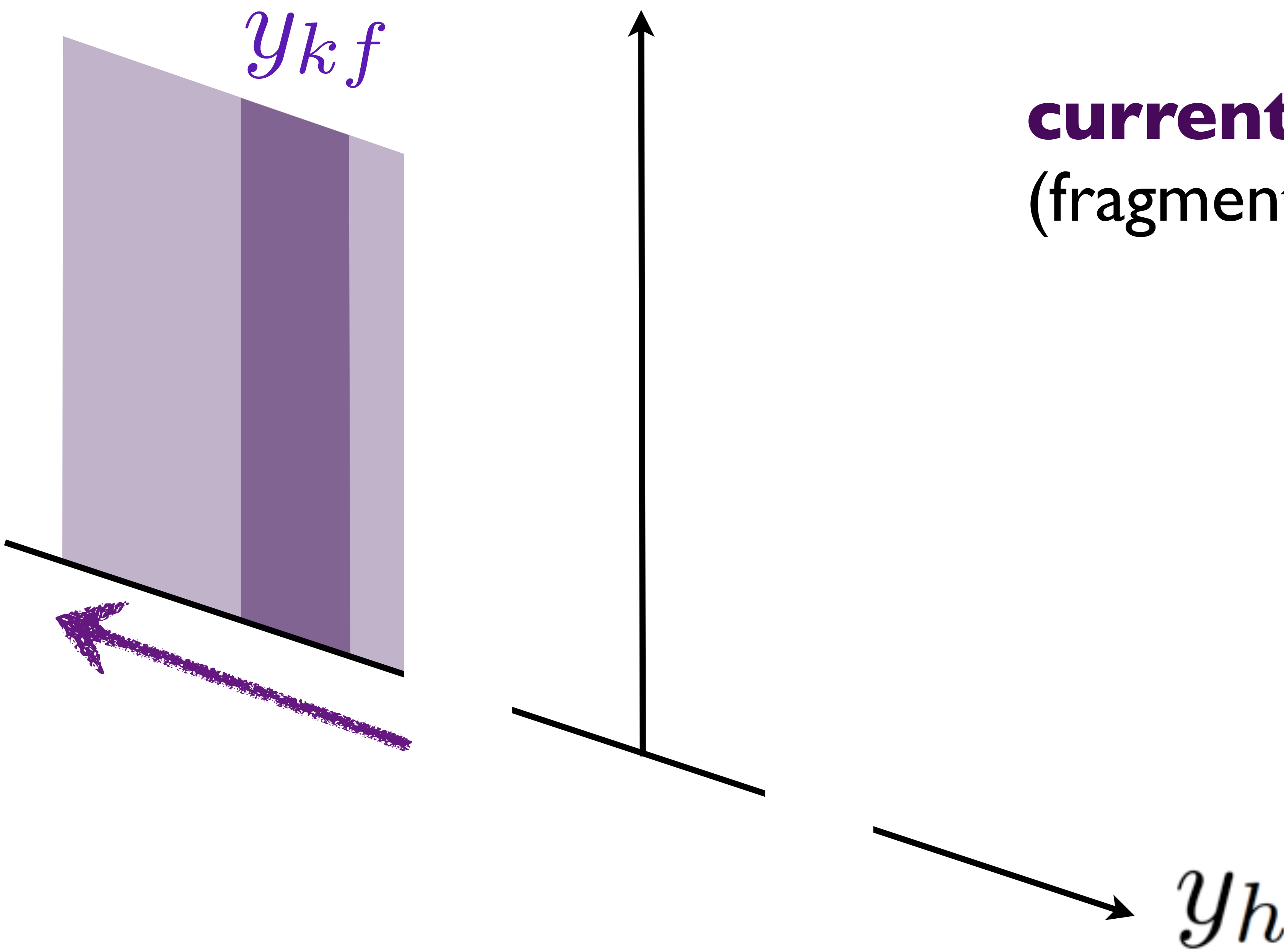
$$y_h \equiv \frac{1}{2} \log \frac{P_h^+}{P_h^-}$$



One may take
this into account, at least
when defining
kinematic limits
for current/target region



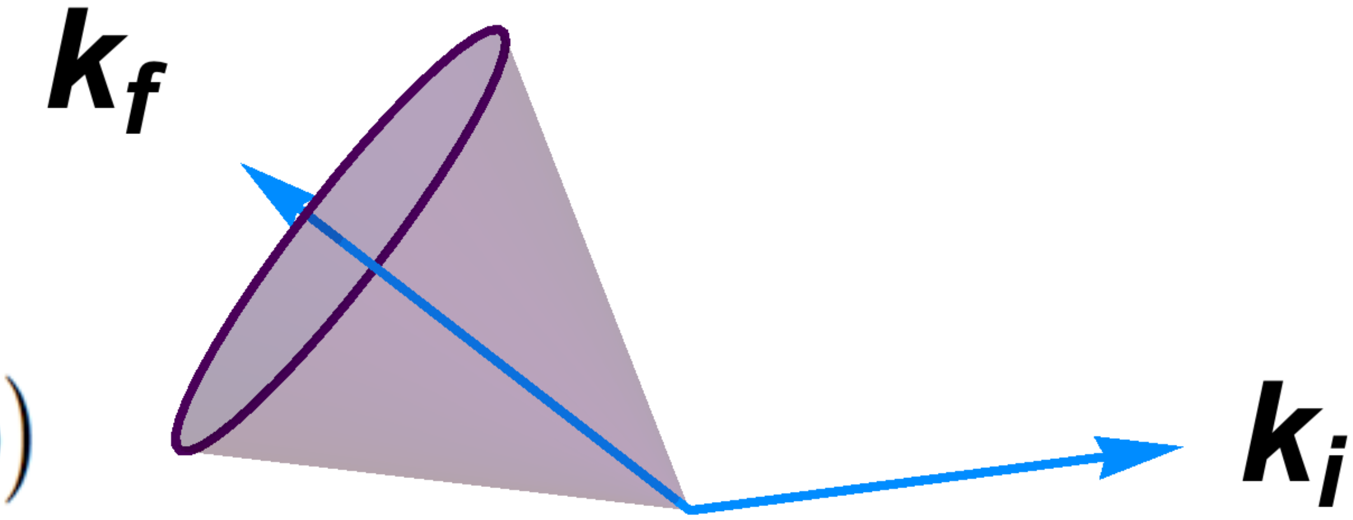
Observable



current region
(fragmentation functions)

Power counting and kinematics of the current region

Factorization implies a power counting for the quark momenta



$$k_{\mathrm{i}} = \left(O(Q), O(m^2/Q), O(\mathbf{m})\right)$$

$$k_{\mathrm{f}} = \left(O(m^2/Q), O(Q), O(\mathbf{m})\right)$$

current region

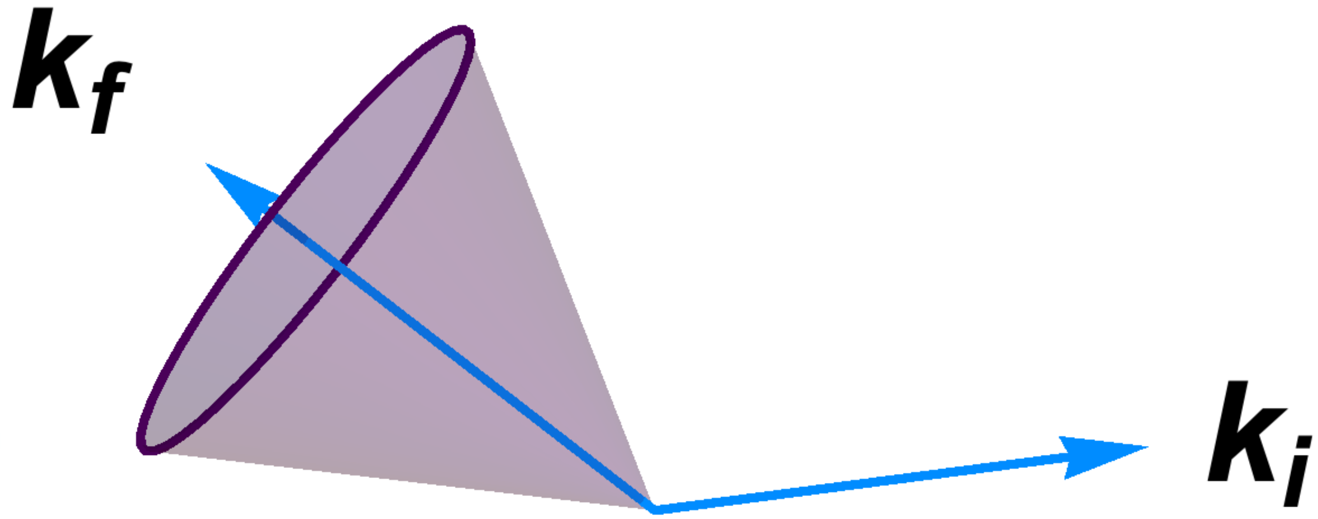
$$P_h \cdot k_{\mathrm{f}} = O\left(m^2\right)$$

$$|k_{\mathrm{i}}^2| = O(m^2)$$

$$P_h \cdot k_{\mathrm{i}} = O\left(Q^2\right)$$

$$k_{\mathrm{f}}^2 = M_J^2 = O(m^2)$$

Factorization implies a power counting for the quark momenta



$$k_{\mathrm{i}} = \left(O(Q), O(m^2/Q), O(\mathbf{m})\right)$$

$$k_{\mathrm{f}} = \left(O(m^2/Q), O(Q), O(\mathbf{m})\right)$$

current region

$$P_h \cdot k_{\mathrm{f}} = O\left(m^2\right)$$

$$P_h \cdot k_{\mathrm{i}} = O\left(Q^2\right)$$

$$|k_{\mathrm{i}}^2| = O(m^2)$$

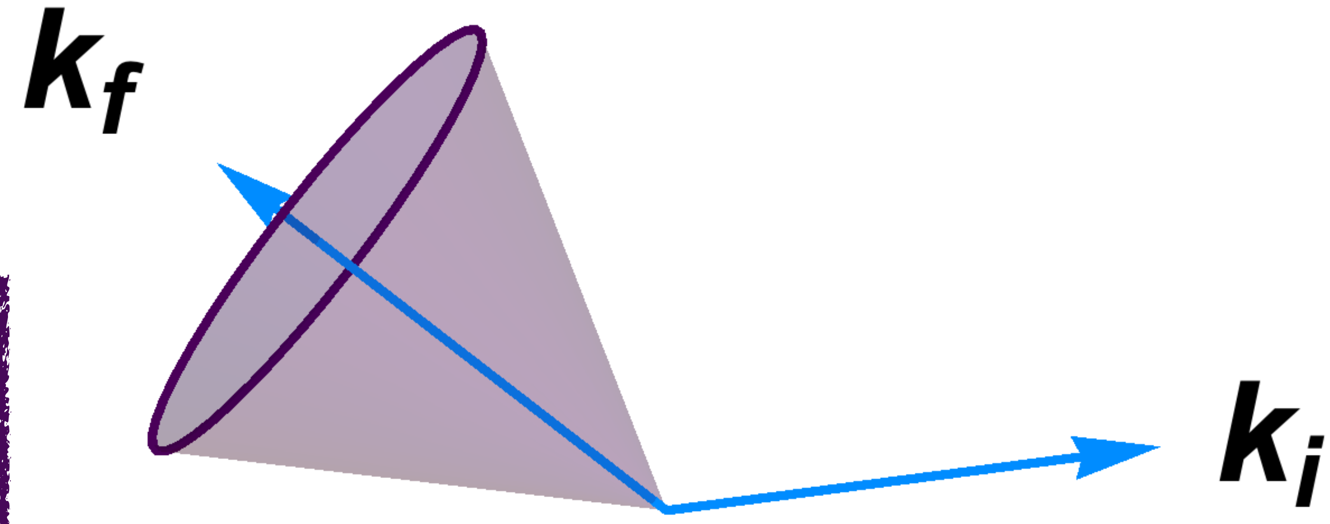
$$k_{\mathrm{f}}^2 = M_J^2 = O(m^2)$$

hard scale

small masses

This quantity must remain small.

$$R(y_h, z_h, x_{bj}, Q) \equiv \frac{P_h \cdot k_f}{P_h \cdot k_i}$$



current region

$$P_h \cdot k_f = O(m^2)$$

$$P_h \cdot k_i = O(Q^2)$$

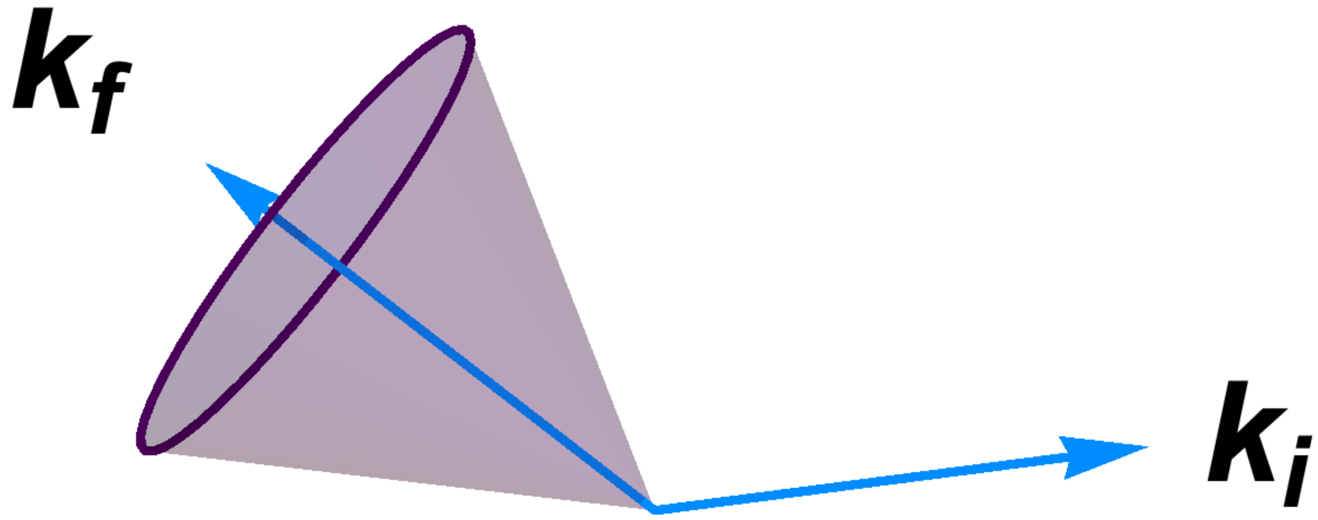
$$|k_i^2| = O(m^2)$$

$$k_f^2 = M_J^2 = O(m^2)$$

hard scale

small masses

This quantity must remain small.



$$R(y_h, z_h, x_{bj}, Q) \equiv \frac{P_h \cdot k_f}{P_h \cdot k_i}$$

$$P_h \cdot k_f = O\left(m^2\right)$$

$$|k_i^2| = O(m^2)$$

$$P_h \cdot k_i = O\left(Q^2\right)$$

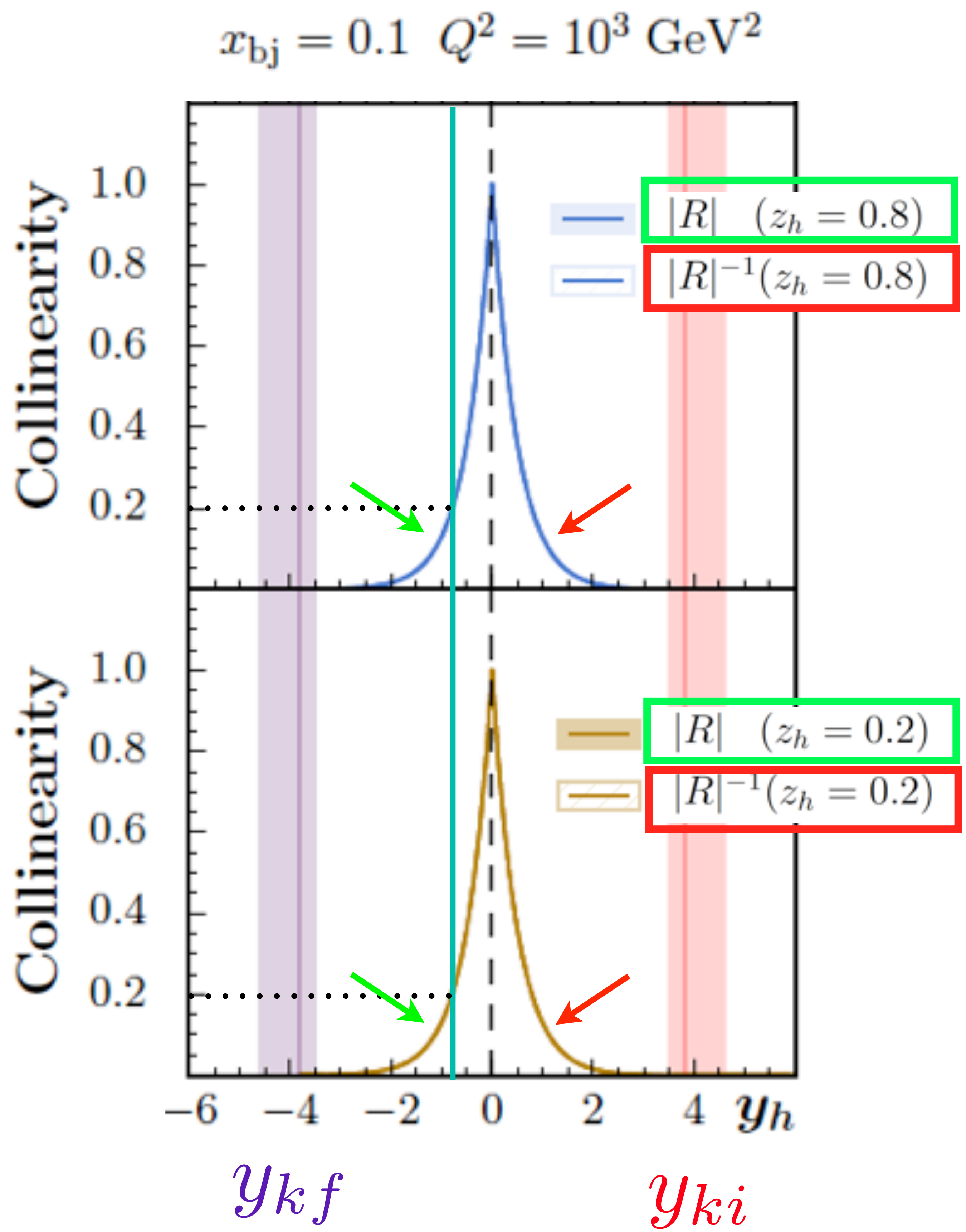
$$k_f^2 = M_J^2 = O(m^2)$$

hard scale (large)

$$R \equiv \frac{P_h \cdot k_f}{P_h \cdot k_i}$$

It seems simple enough to set a criterion by imposing a cut in rapidity.

At these kinematics, even for $z_h = 0.2$ R remains small in a sizeable range of rapidity



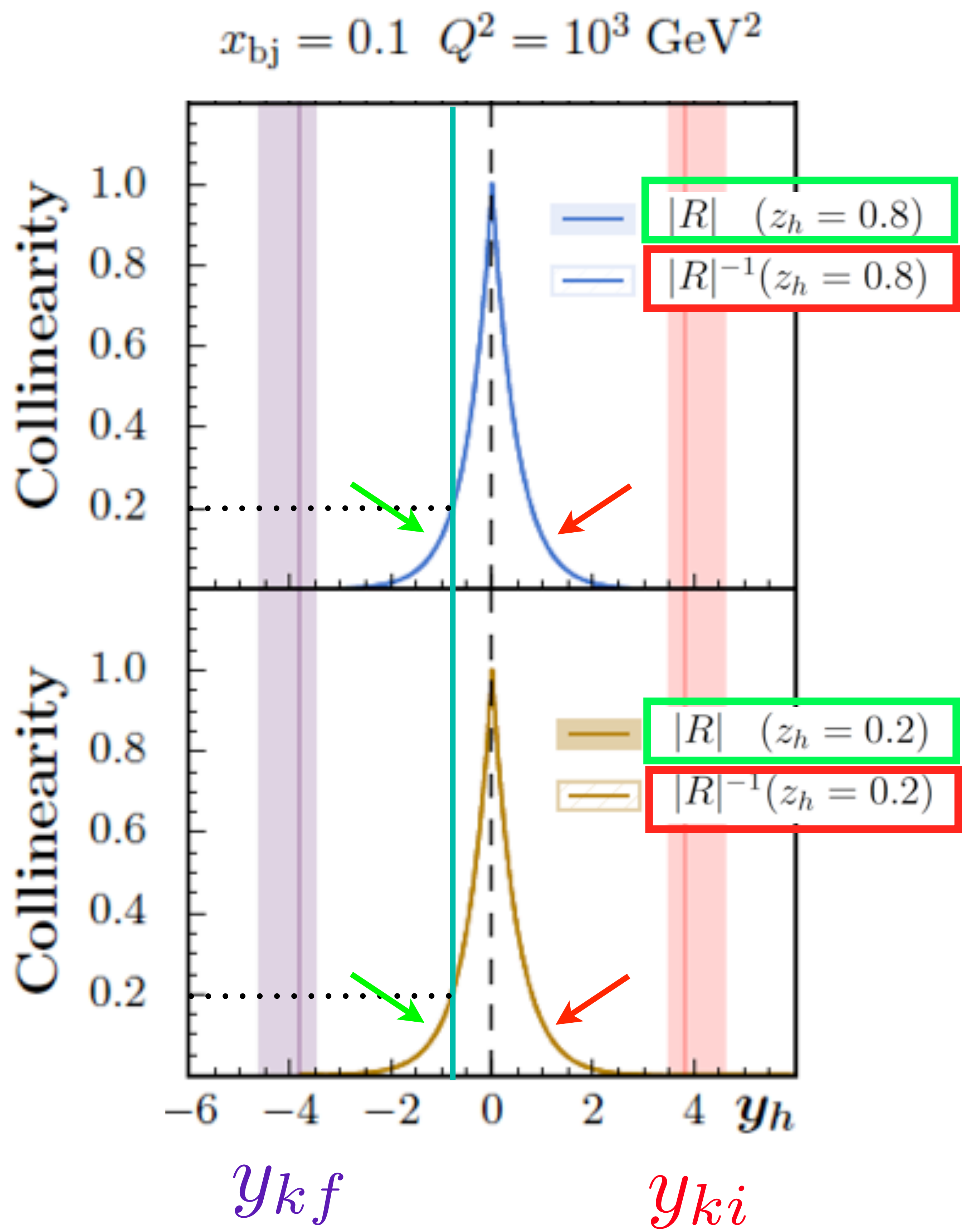
$$R \equiv \frac{P_h \cdot k_f}{P_h \cdot k_i}$$

quark momenta should be estimated

$$k_i = \left(O(Q), O(m^2/Q), O(\mathbf{m})\right)$$

$$k_f = \left(O(m^2/Q), O(Q), O(\mathbf{m})\right)$$

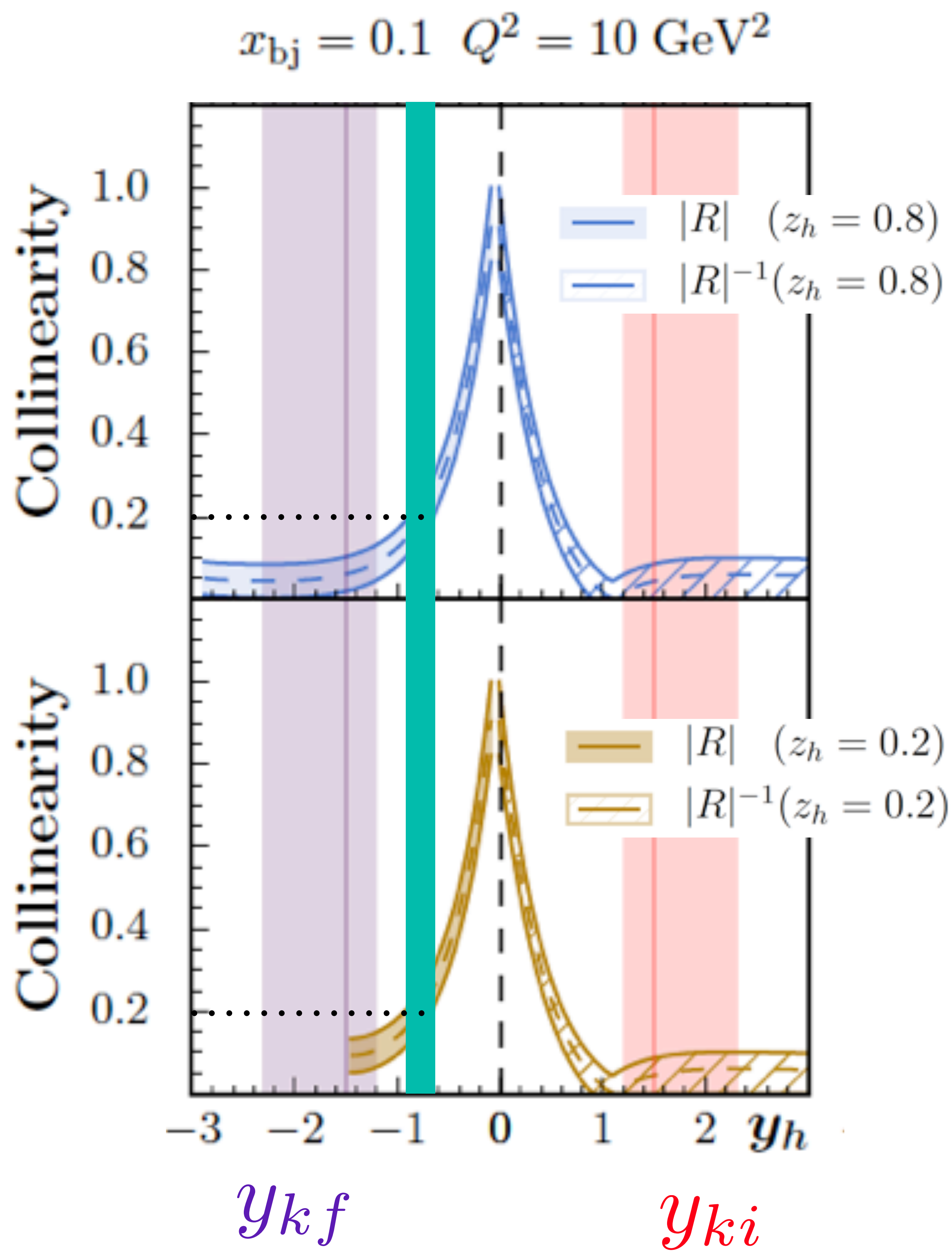
Note the uncertainty in the quark rapidities are unimportant



$$R \equiv \frac{P_h \cdot k_f}{P_h \cdot k_i}$$

The picture starts to change when looking at lower values of Q^2

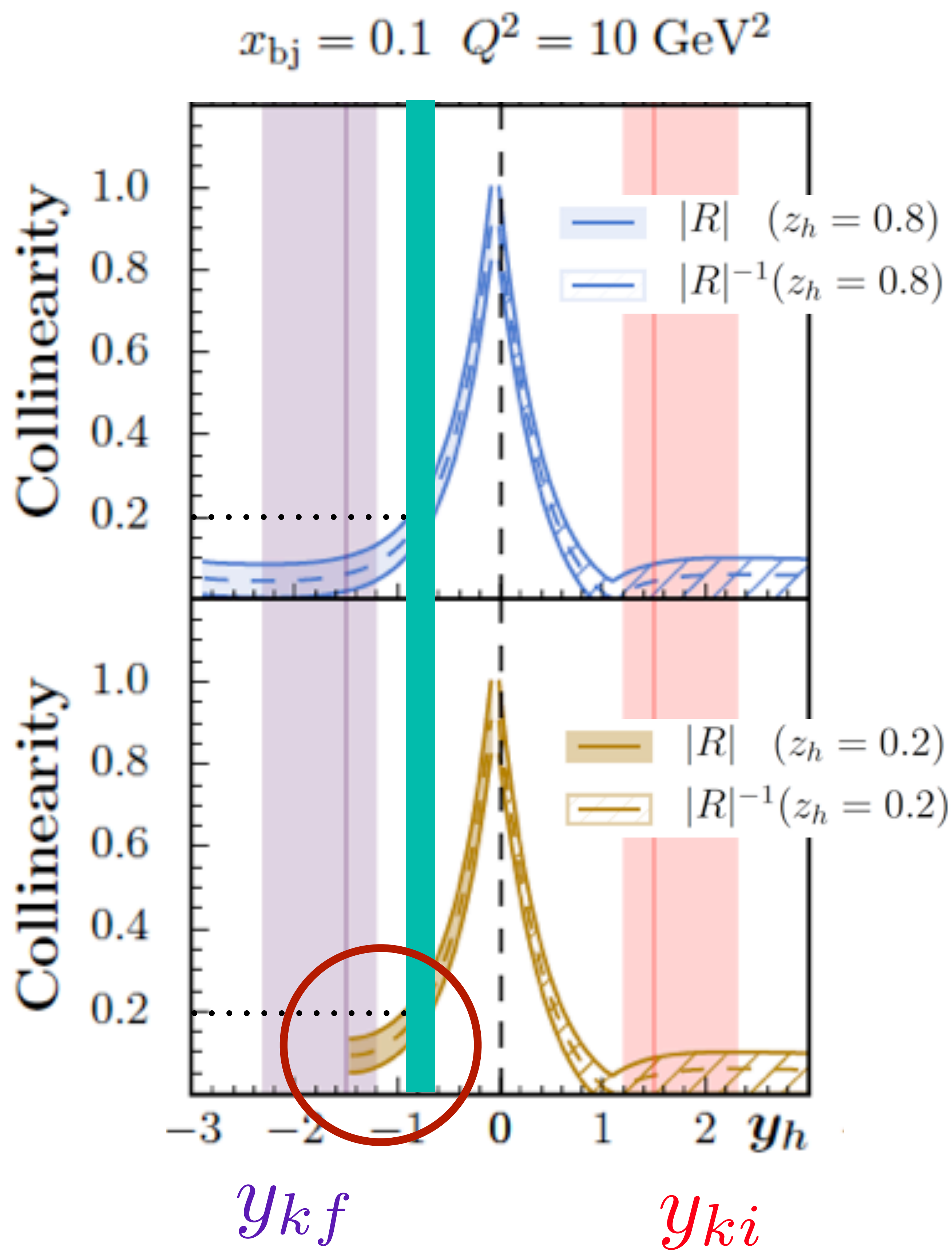
Assumptions about quark momenta become more relevant



$$R \equiv \frac{P_h \cdot k_\mathrm{f}}{P_h \cdot k_\mathrm{i}}$$

The picture starts to change when looking at lower values of Q^2

Current region shrinks, low values of z_h lie almost entirely outside

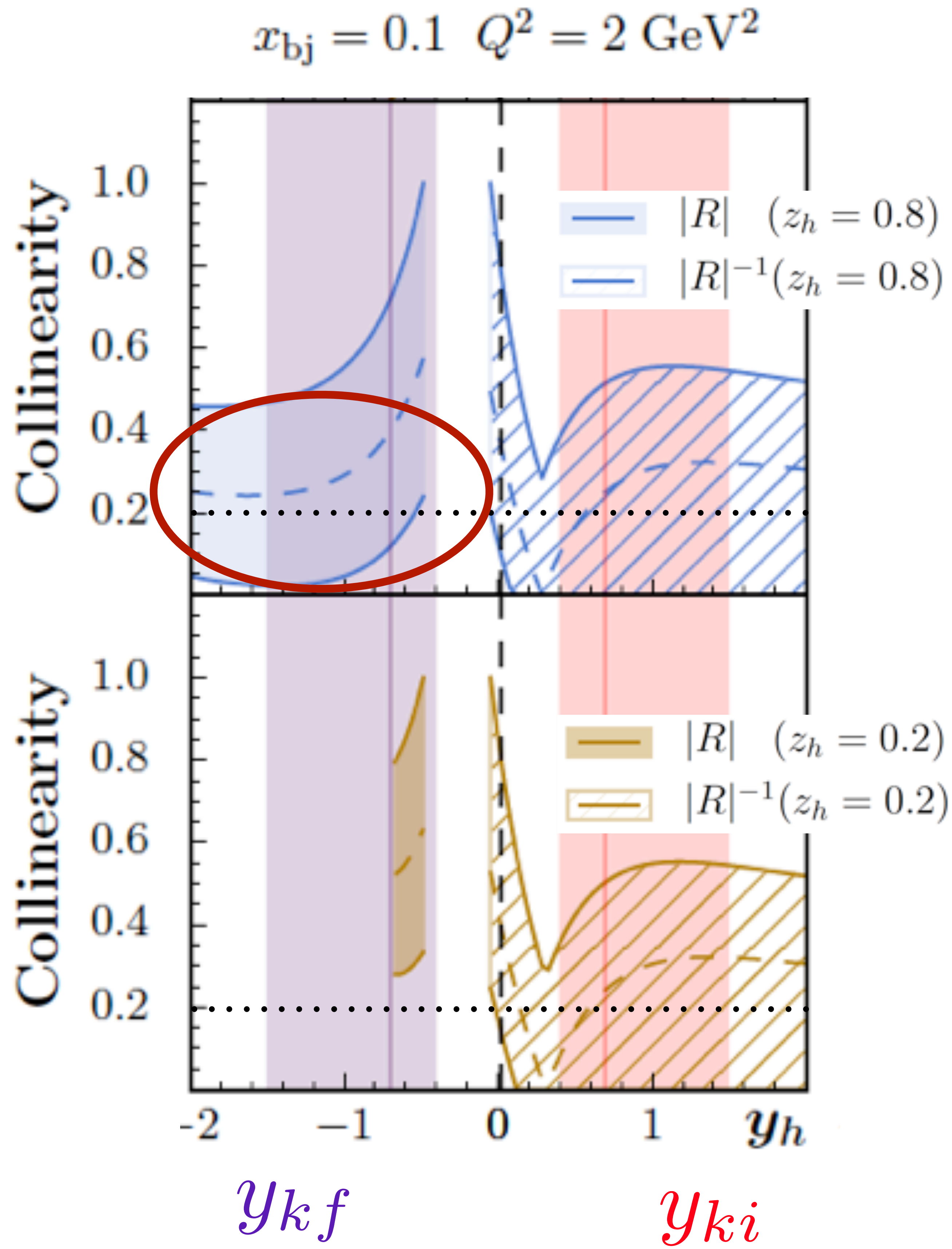


Monday, September 26, 16

$$R \equiv \frac{P_h \cdot k_\mathrm{f}}{P_h \cdot k_\mathrm{i}}$$

For very low values of Q^2 things get fuzzy

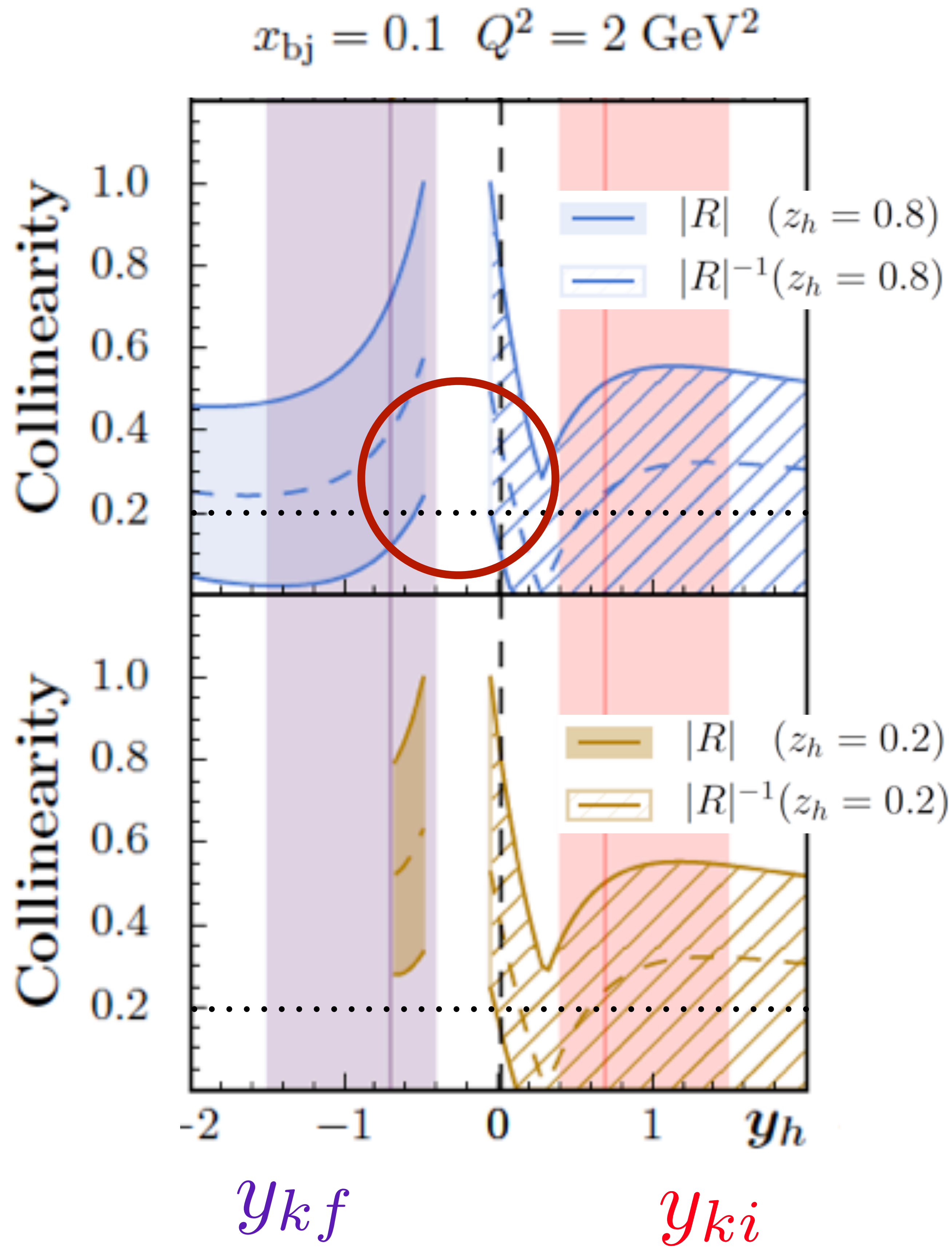
It’s hard to establish a criterion (thick bands)



$$R \equiv \frac{P_h \cdot k_f}{P_h \cdot k_i}$$

Estimated quark rapidities are dangerously close.

Within this picture,
the current and non-current regions strongly overlap



$$R \equiv \frac{P_h \cdot k_f}{P_h \cdot k_i}$$

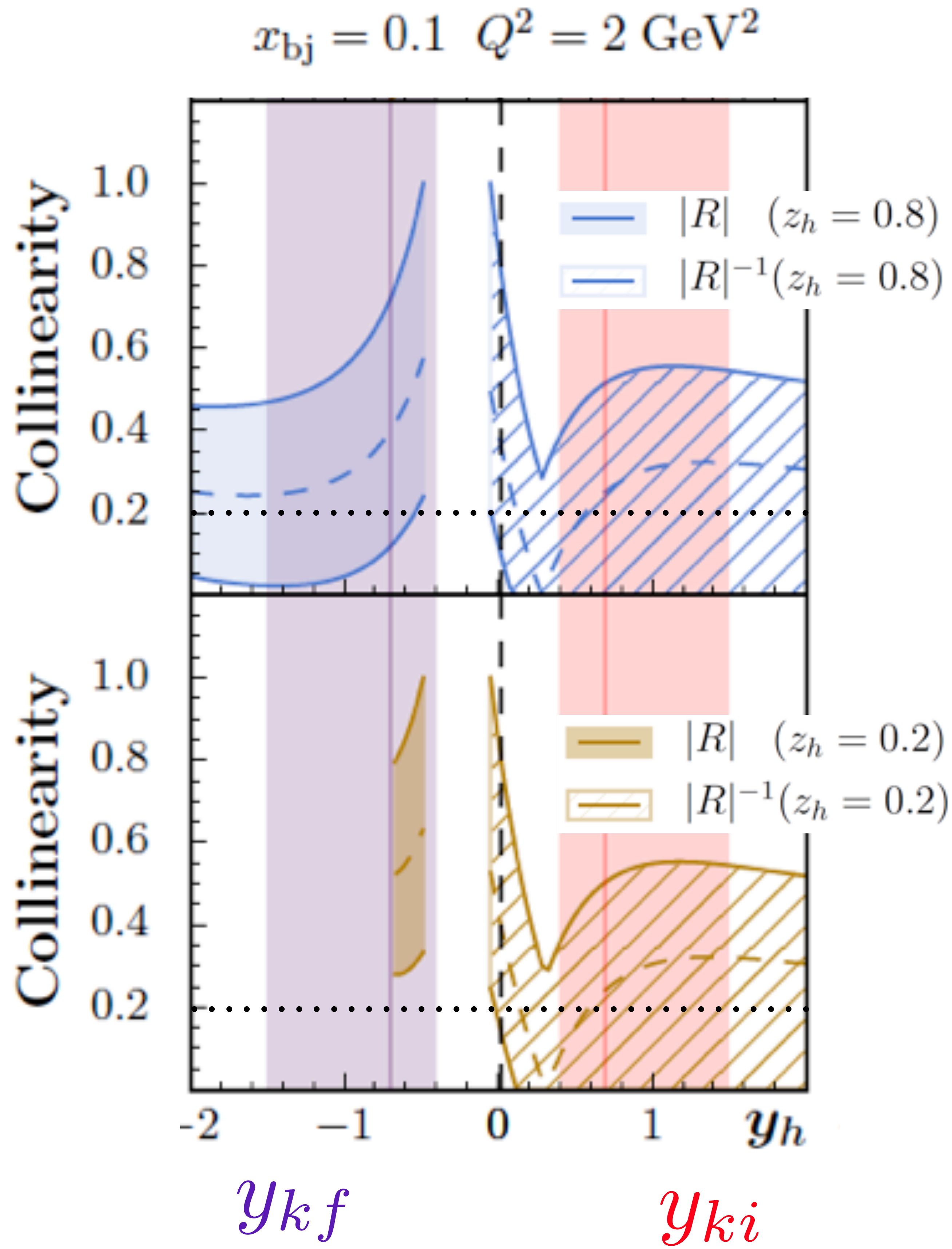
These likely are signals of the breaking of the formalism

$$P_h \cdot k_f = O\left(m^2\right)$$

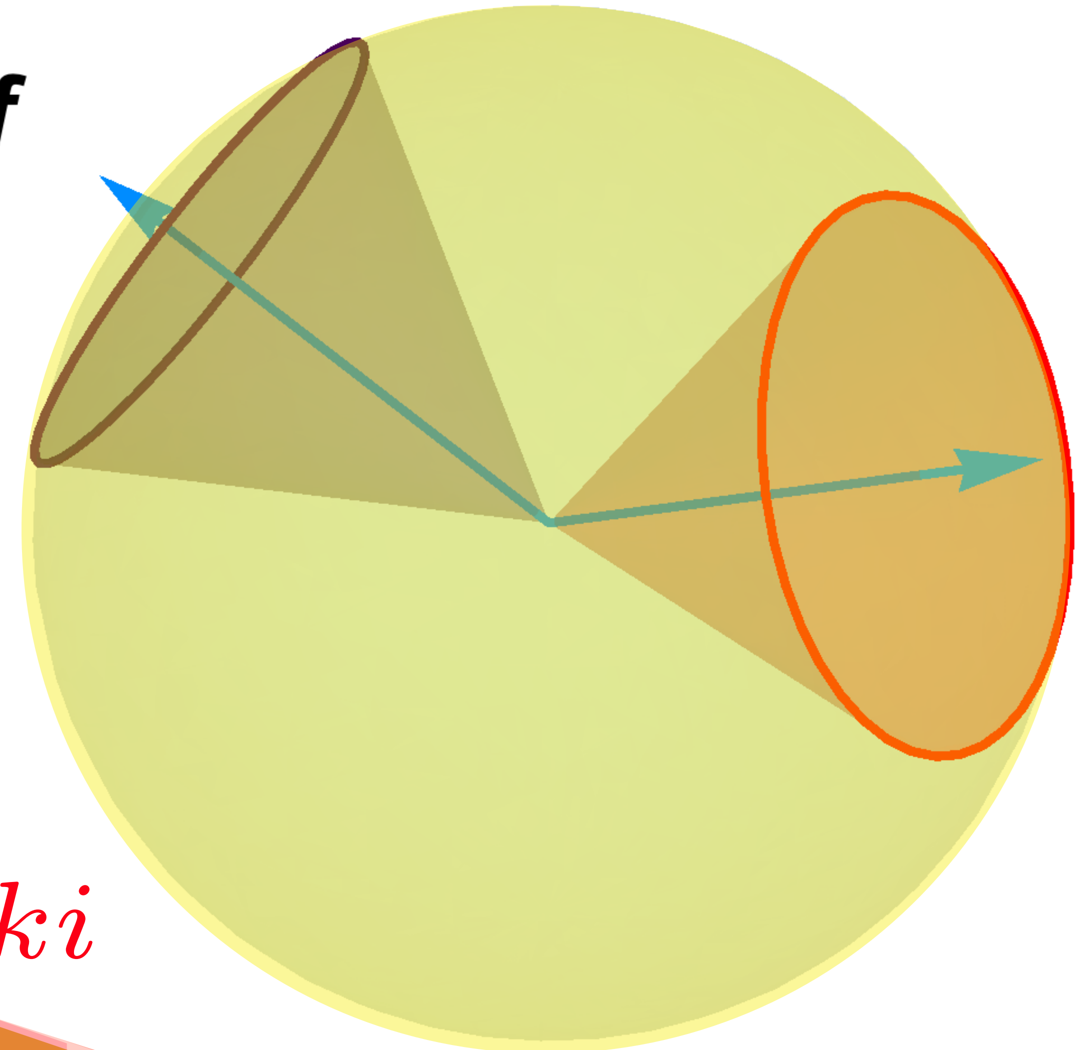
$$P_h \cdot k_i = O\left(Q^2\right)$$

hard scale

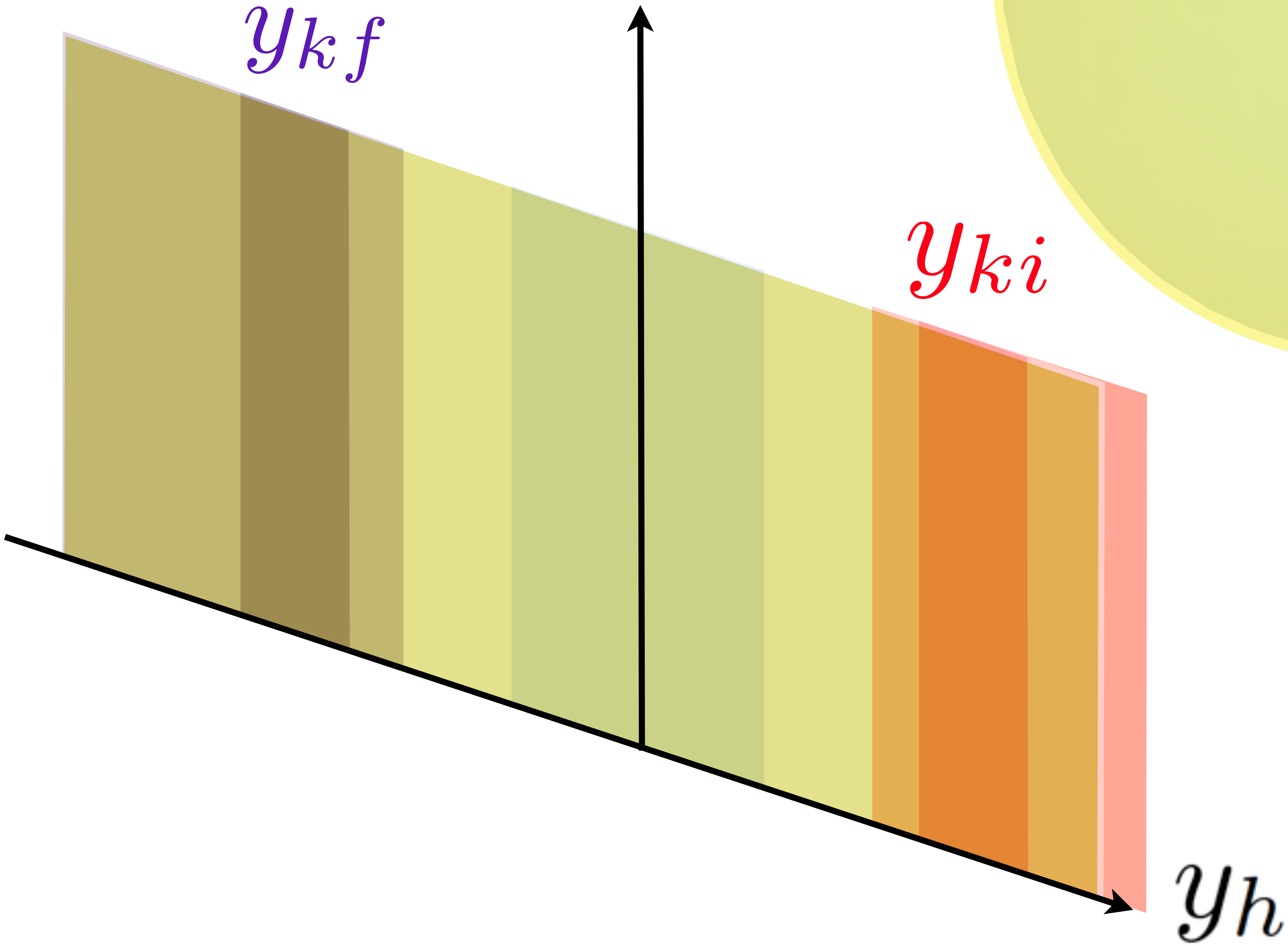
Can't tell precisely how large it should be



$$y_h \equiv \frac{1}{2} \log \frac{P_h^+}{P_h^-}$$



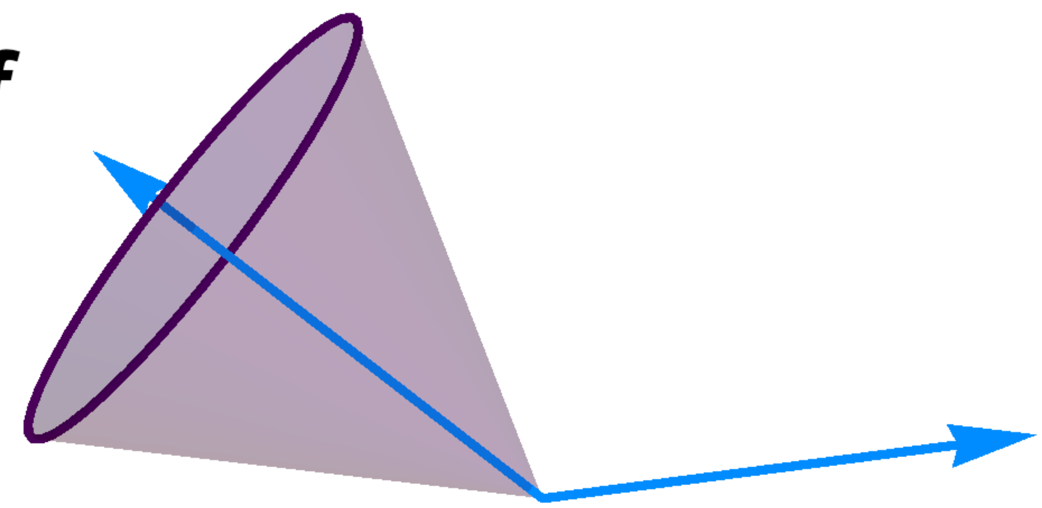
Observable



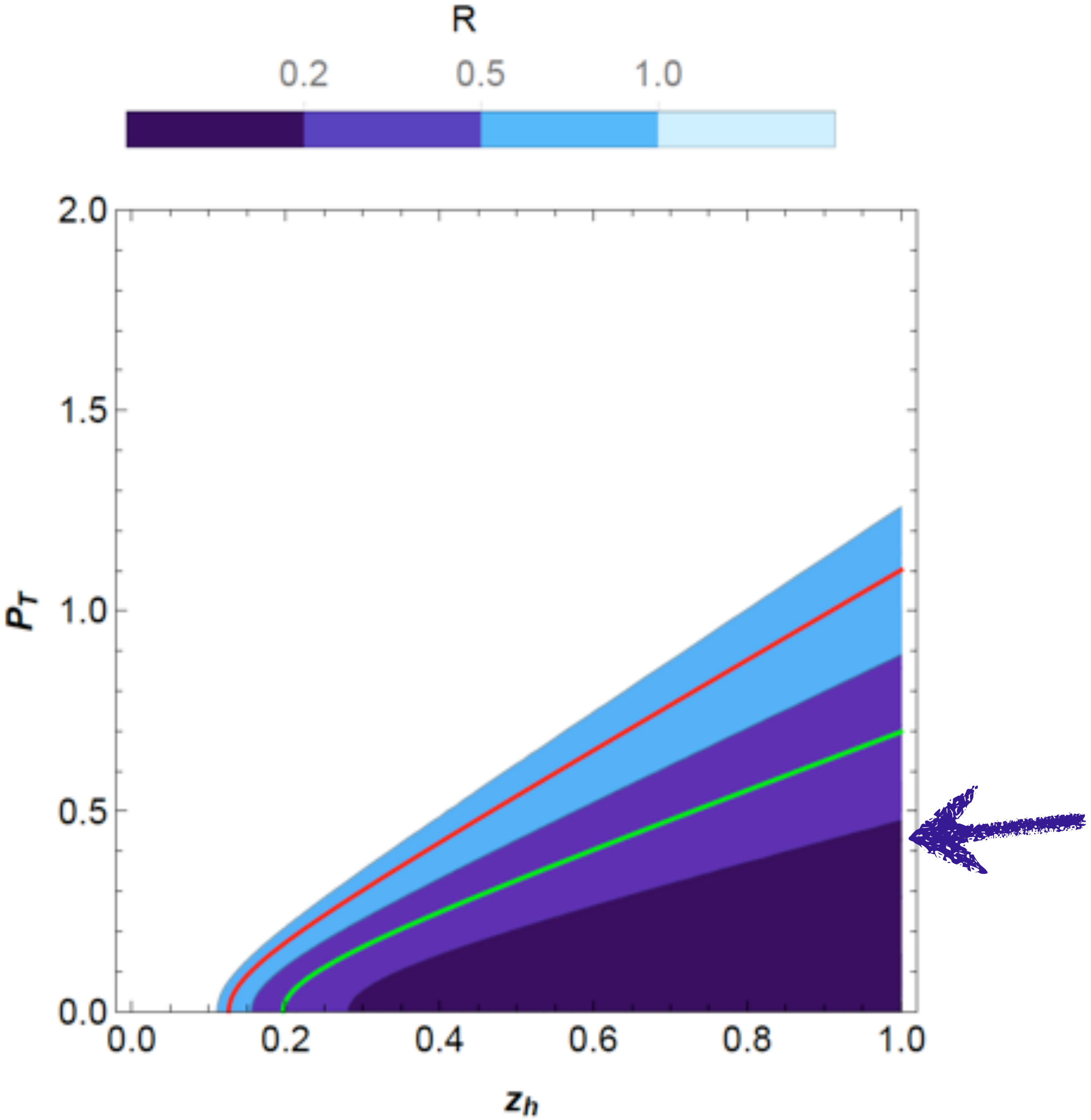
New formalism for low Q2 ??

In the mean time

$$R \equiv \frac{P_h \cdot k_\mathrm{f}}{P_h \cdot k_\mathrm{i}}$$



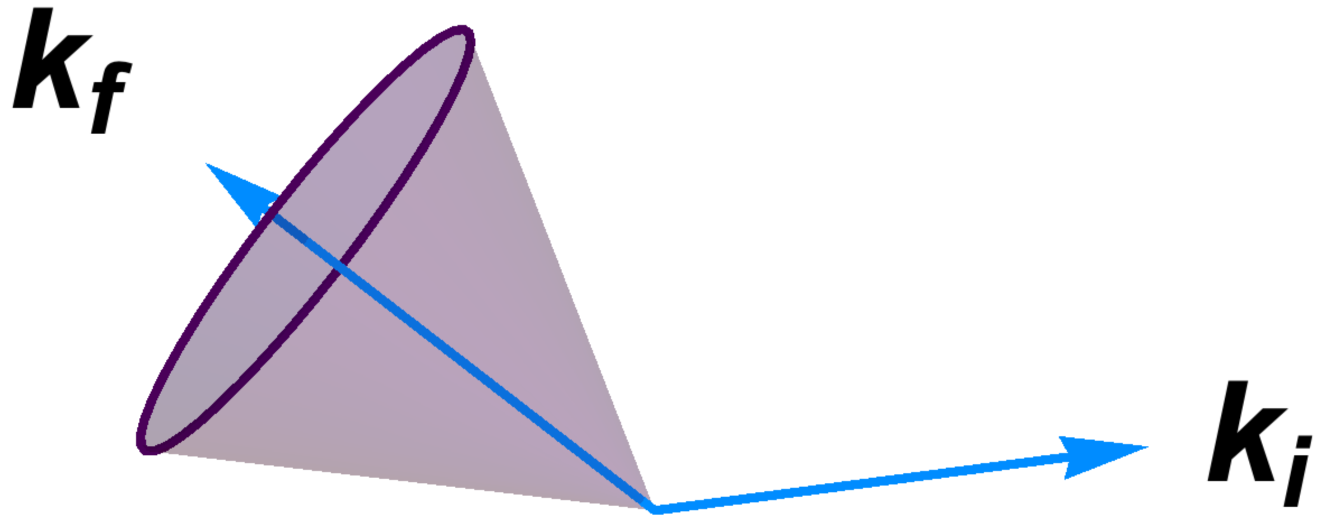
current region



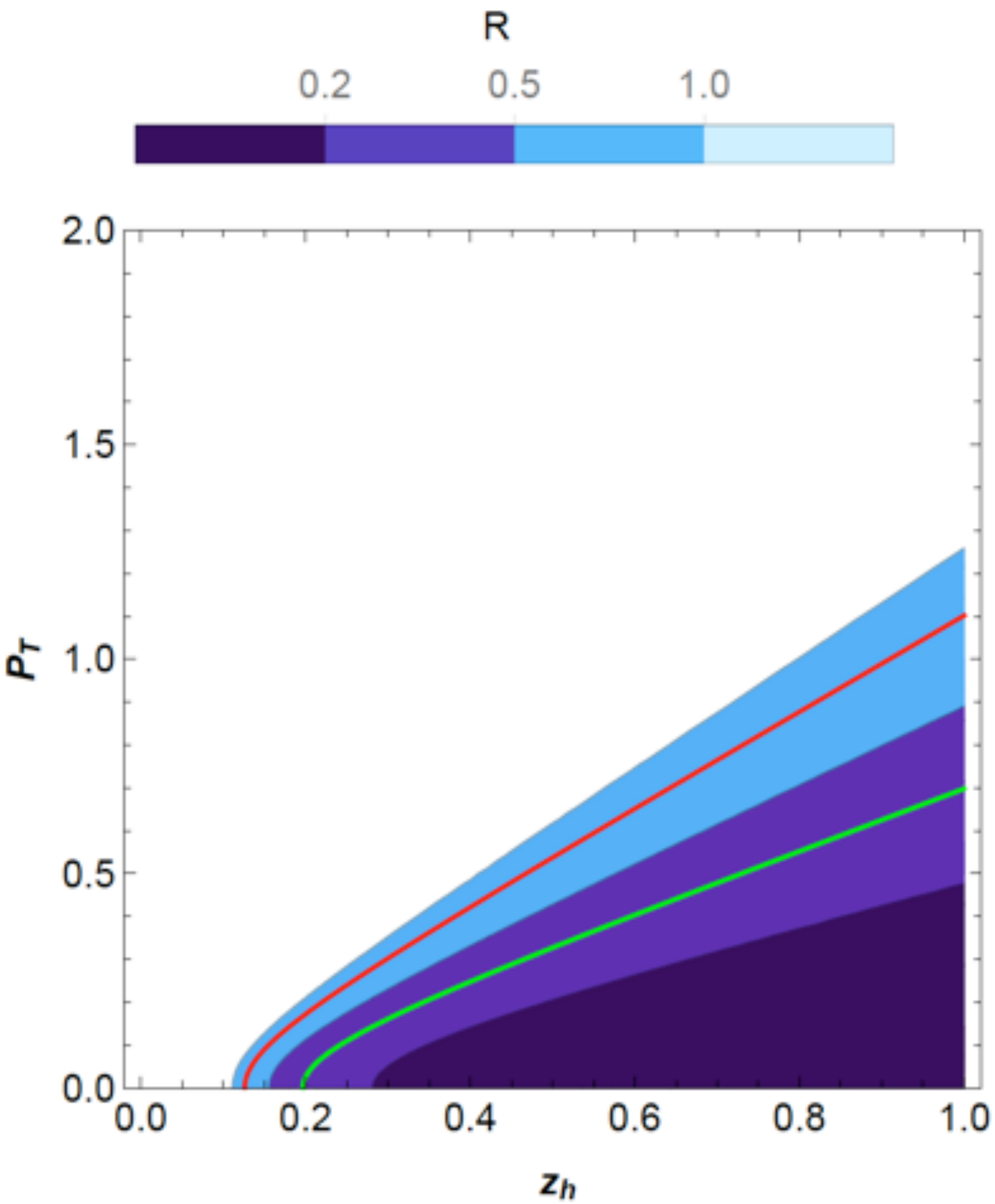
One may incorporate these considerations into phenomenological analyses by looking at **regions of small** R

In the mean time

$$R \equiv \frac{P_h \cdot k_\mathrm{f}}{P_h \cdot k_\mathrm{i}}$$



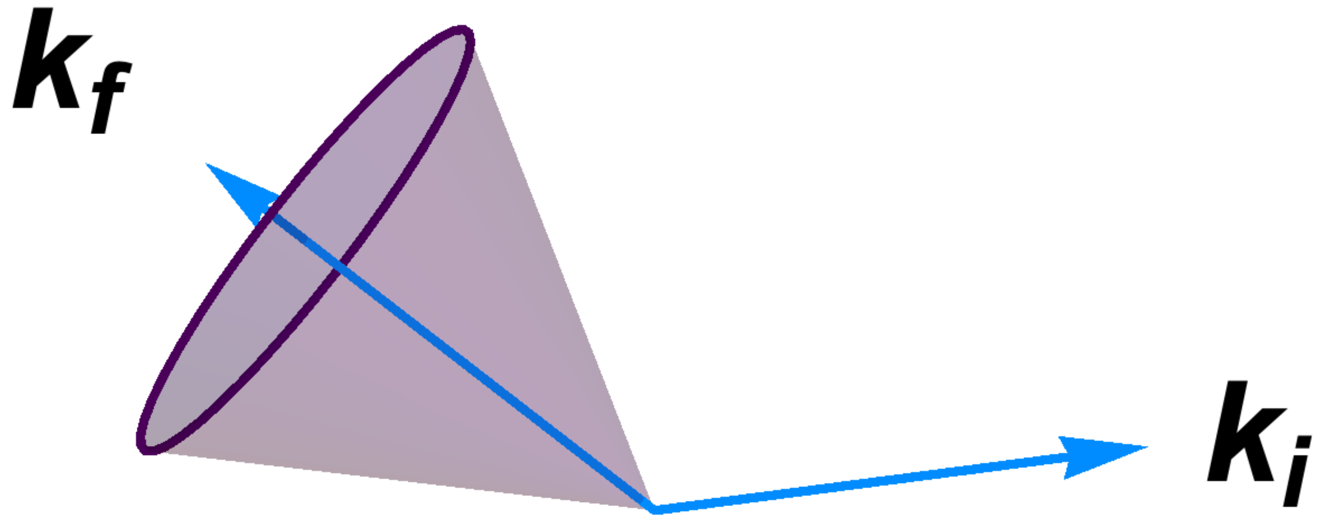
current region



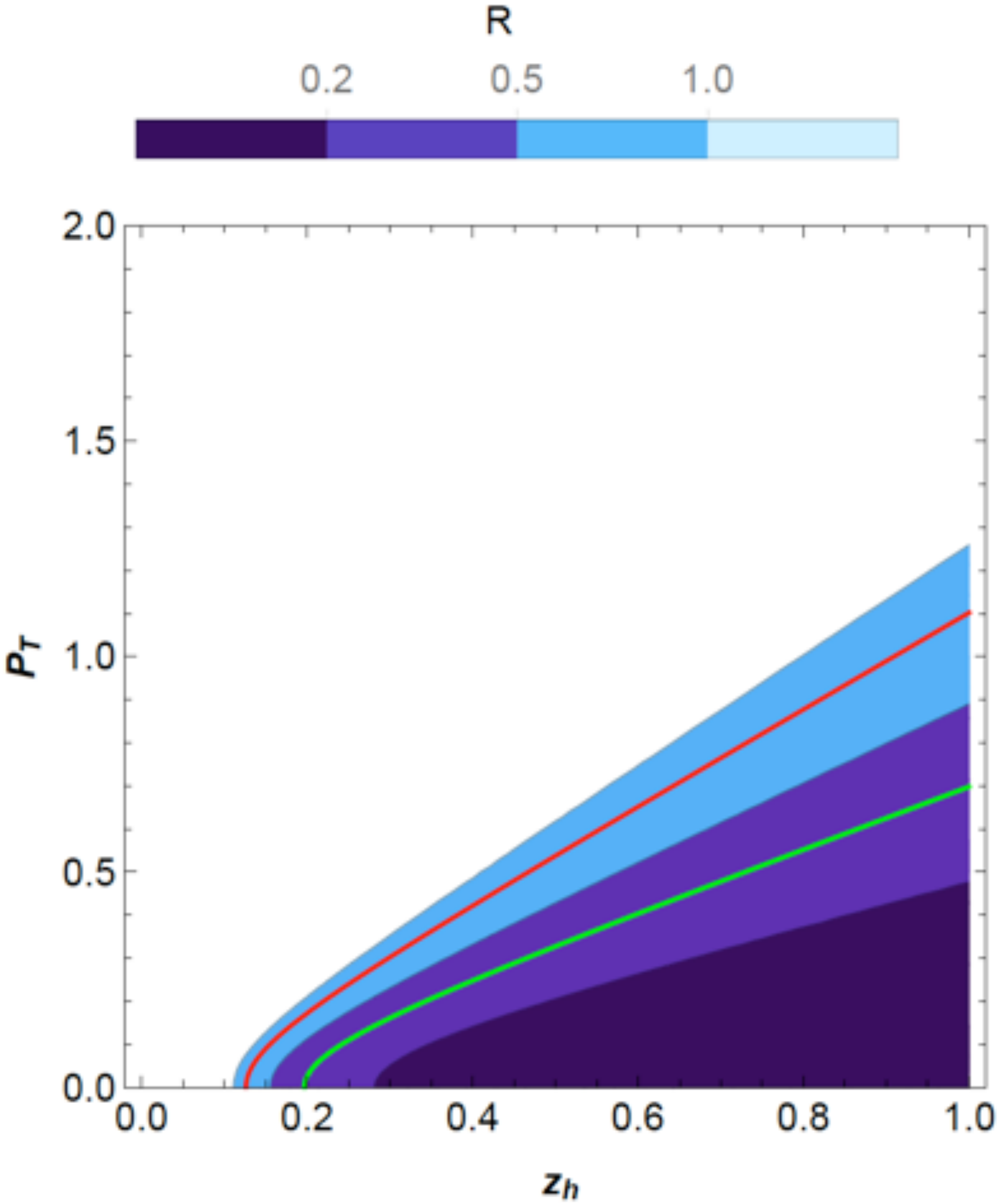
Note this implies also a dependence on P_{hT}, the transverse momentum of the observed hadron

In the mean time

$$R \equiv \frac{P_h \cdot k_{\rm f}}{P_h \cdot k_{\rm i}}$$



current region



Alternatively, imposing rapidity cuts

Final remarks

Important to always keep track of the range of applicability of the formalism of fragmentation functions (self-consistency)

Requiring $R \equiv \dfrac{P_h \cdot k_\mathrm{f}}{P_h \cdot k_\mathrm{i}}$ to be small, simple test for current region

Kinematical constraints involve both P_{hT} and z_h

Within the available formalisms, fragmentation and fracture functions may overlap at low Q^2 (how low?)

At low values of Q^2 the notion of current region starts to fade. New formalism needed.