Out of Medium Fragmentation from Long-Lived Jet Showers.

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(ArXiv: 1111.0310)

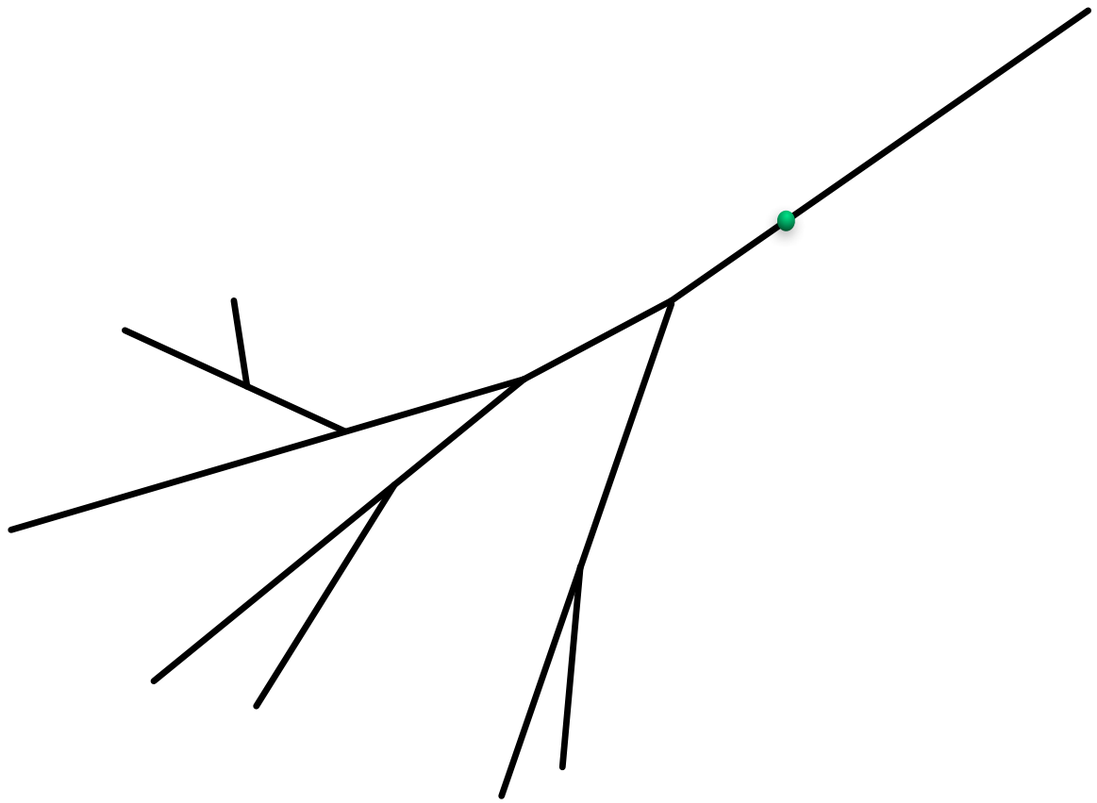
Motivation

- Preliminary data in QM11: unmodified in-medium jet FF
- Simple interpretation: jets fragment outside

Is this possible?

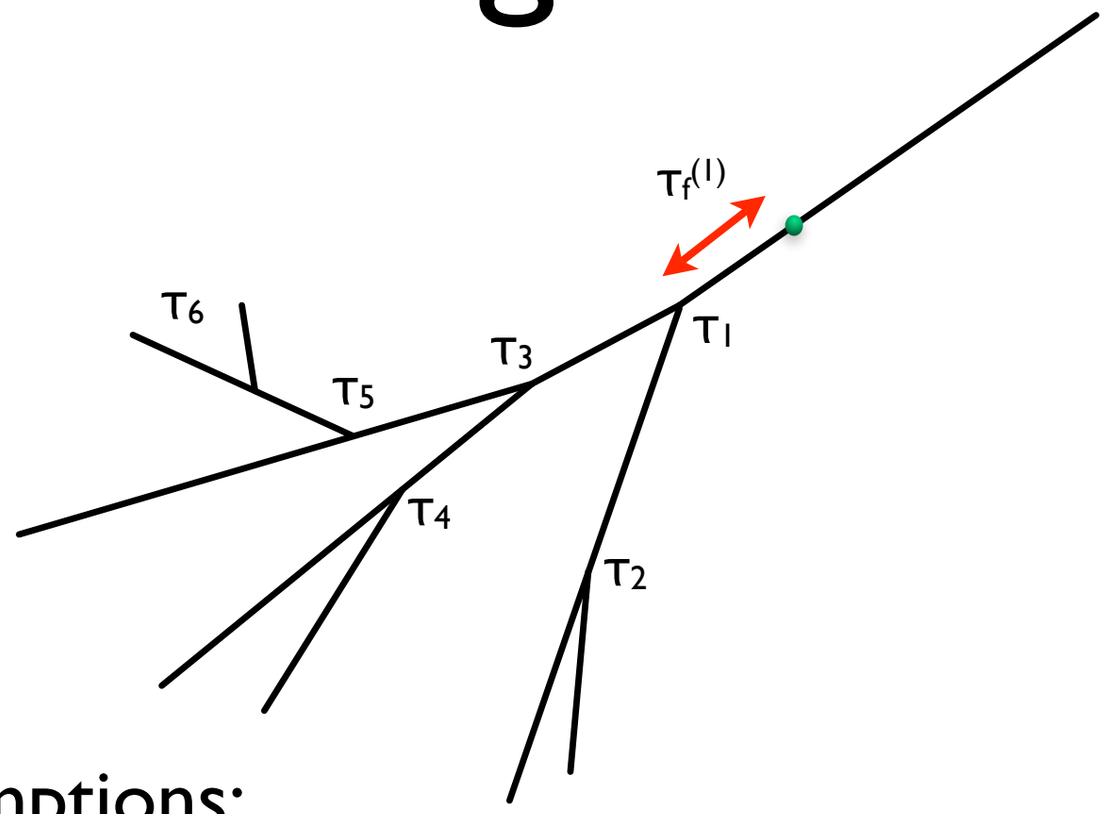
- Goal:
  - How long does a vacuum shower take to develop?
  - How does this time compare to in-medium path lengths?

Vacuum Shower



- In vacuum:
  - Jet evolution is described by pQCD (up to a scale Q_0).
  - Well controlled momentum space description.
  - Limited space-time knowledge: only time scale estimates
  - Below Q_0, non-perturbative modeling is needed

Estimating Time Scales



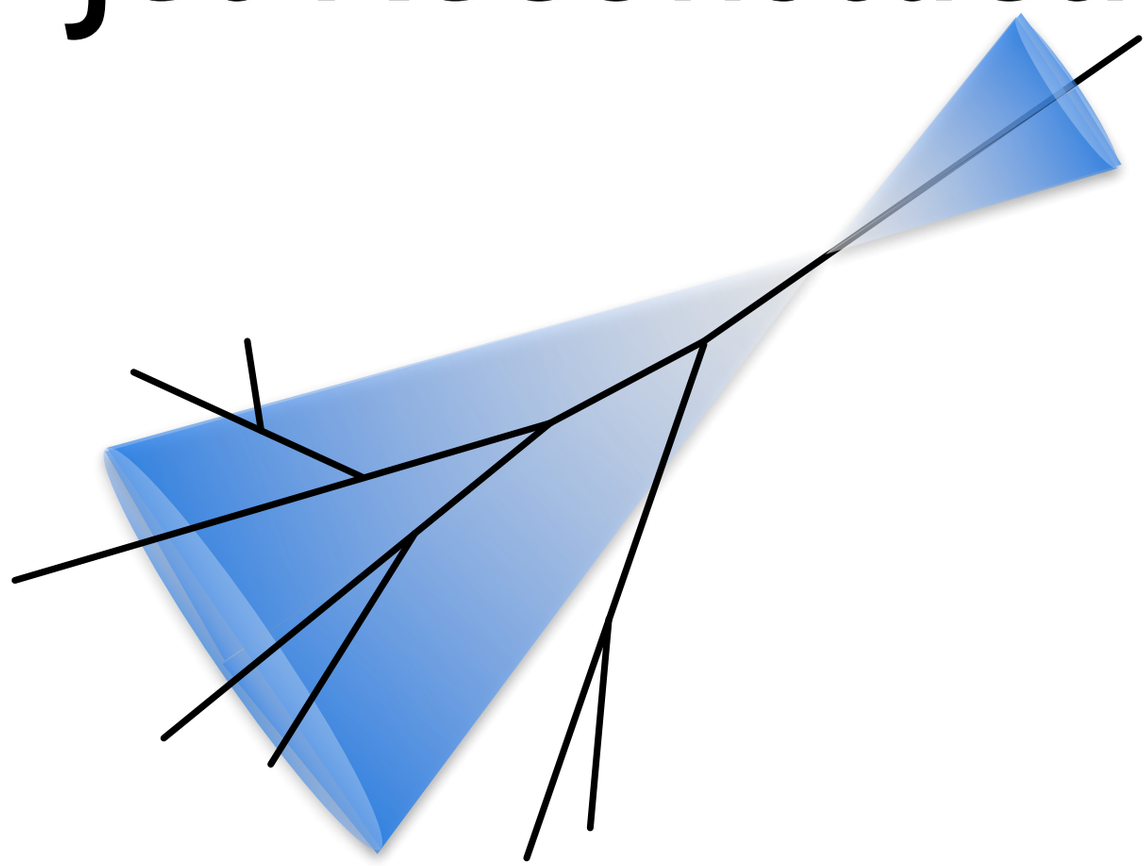
- Assumptions:
  - Q-ordered shower ⇒ time-ordered shower
  - The emission time accumulates
  - The typical time between splittings is the formation time:

$$\tau_f = 2\frac{E}{Q^2} \qquad \underset{\omega \to 0}{\Longrightarrow} \qquad \tau_f = \frac{2\omega}{k_\perp^2}$$

  - We also allow for a decay-like dispersion (“error gauge”)

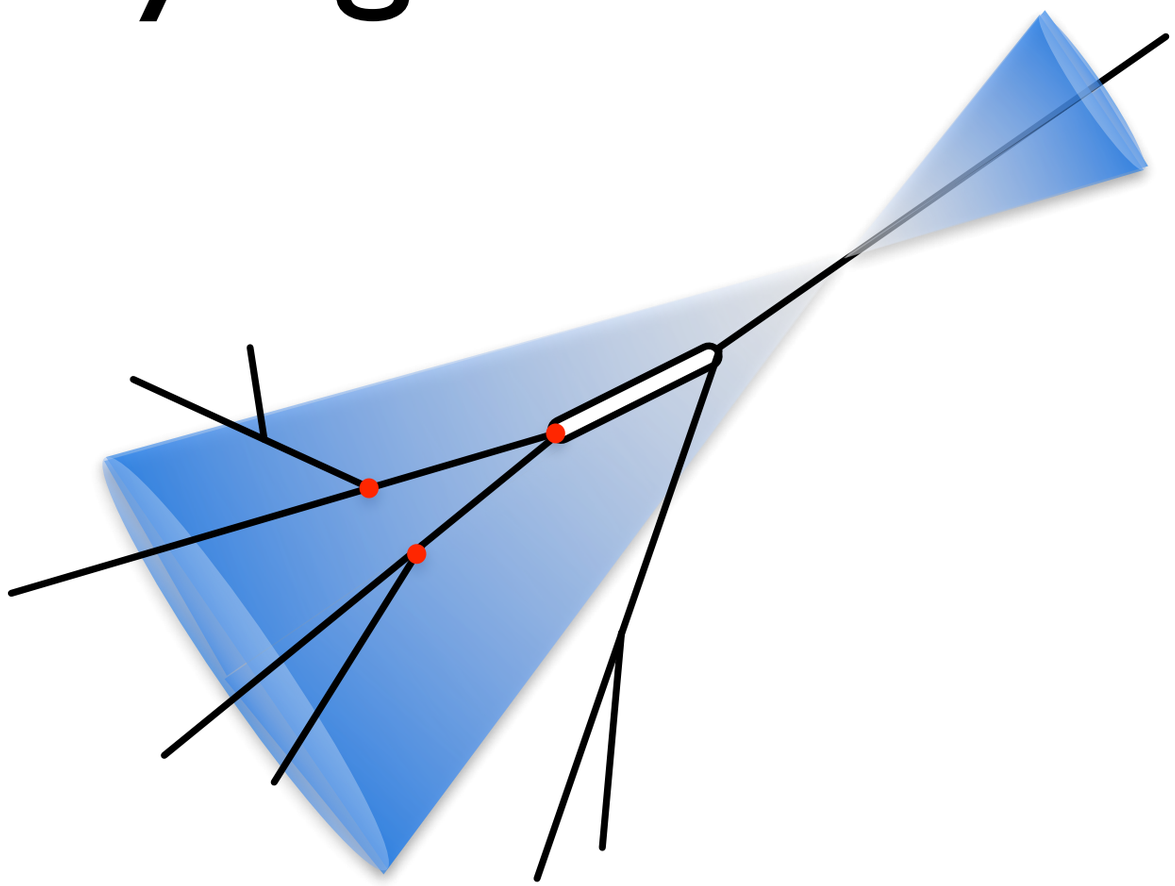
$$D(\tau) = \frac{1}{\tau_f} e^{-\tau/\tau_f}$$

Jet Reconstuction



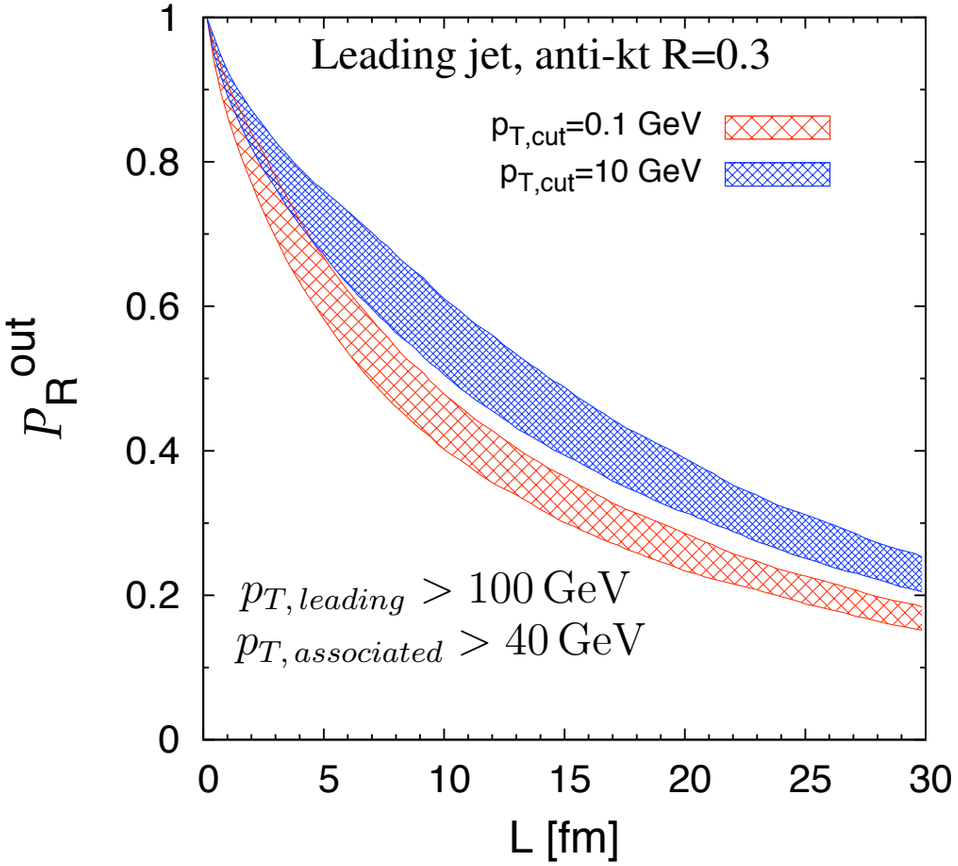
- Reconstruction only captures fragments within a “cone”
- Not all vertexes affect the reconstructed particles
- All identified fragments originate from a common vertex
  - This is not necessarily the hard vertex

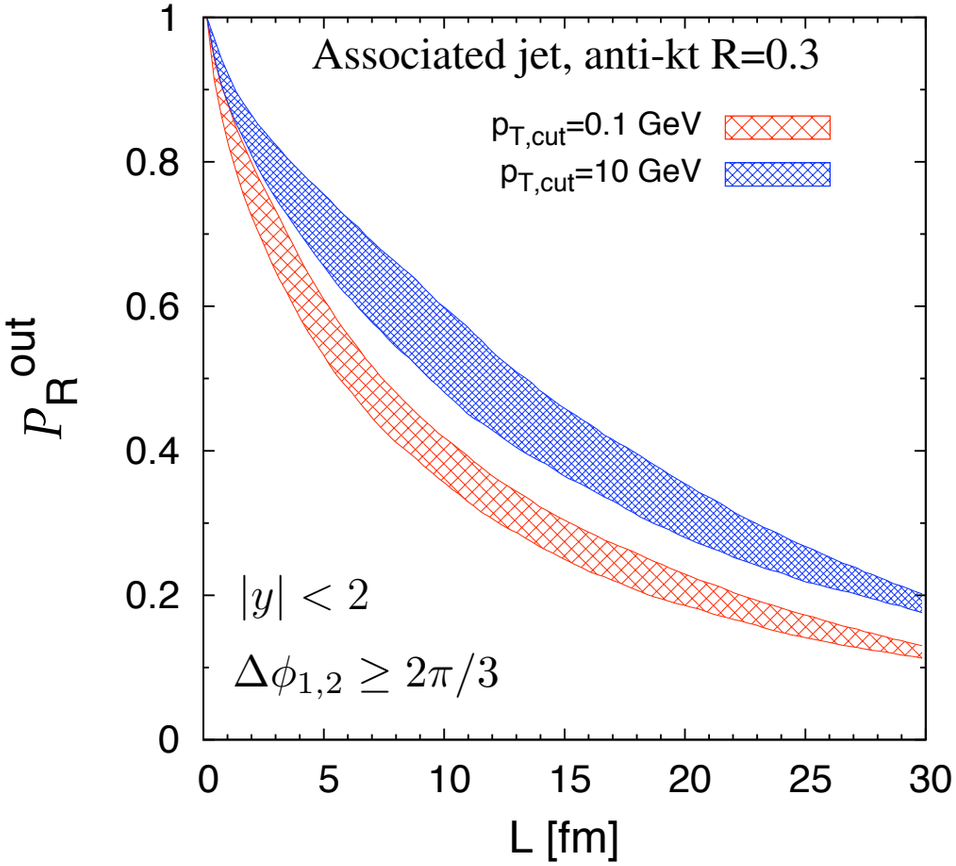
Identifying Relevant Vertexes



- We only consider vertexes after the common vertex.
- Vertexes prior to the “common ancestor” only change its kinematics (E and Q available for the decay)
- We disregard late vertexes of partons outside of the cone.
- We neglect non perturbative effects (color flows) in the final distribution.

Identifying Relevant Vertexes





- Boosting to the frame where each parton is transverse: the probability of splitting after a transverse length L

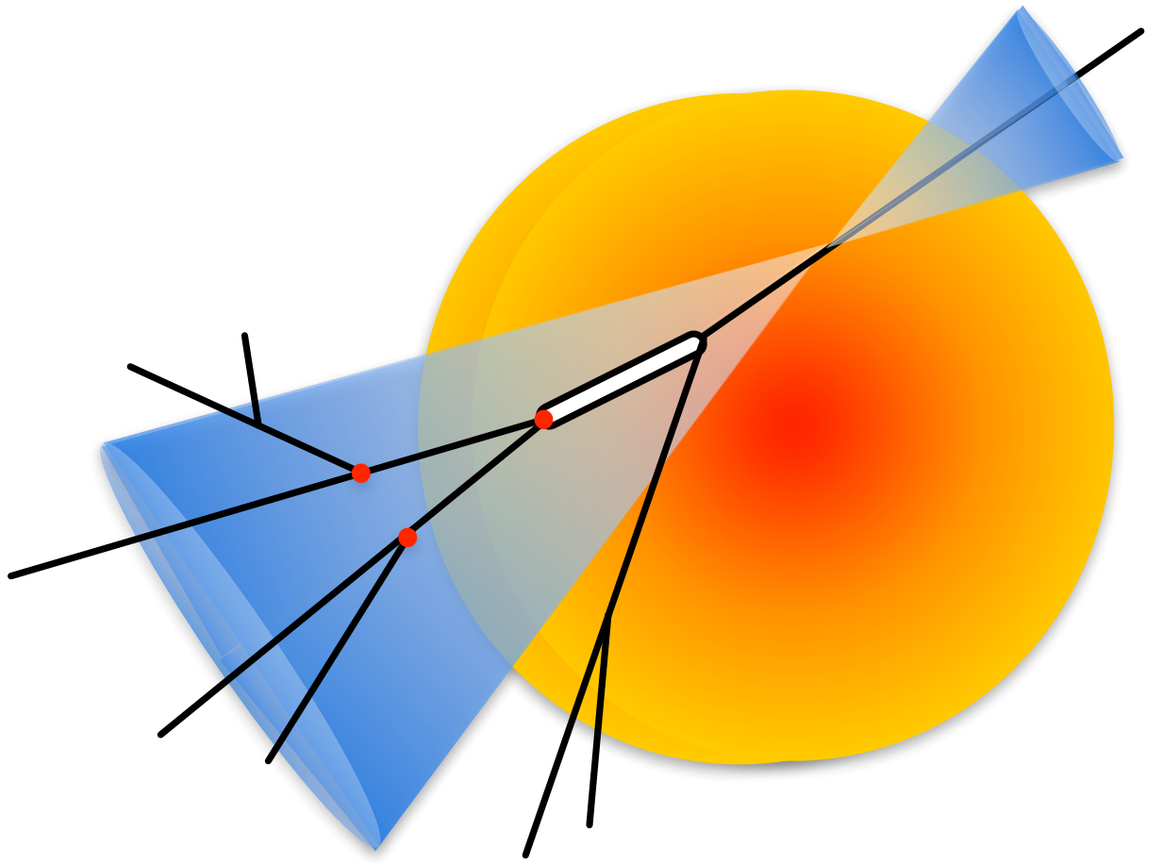
$$\mathcal{P}_R^{out}(L) = \left\langle \frac{n_R^{out}(L)}{n_R} \right\rangle$$

- We evaluate this observable in PYTHIA for di-jet events

(parton level, no underlying event)

- Vacuum fragmentation develops over a very long time!

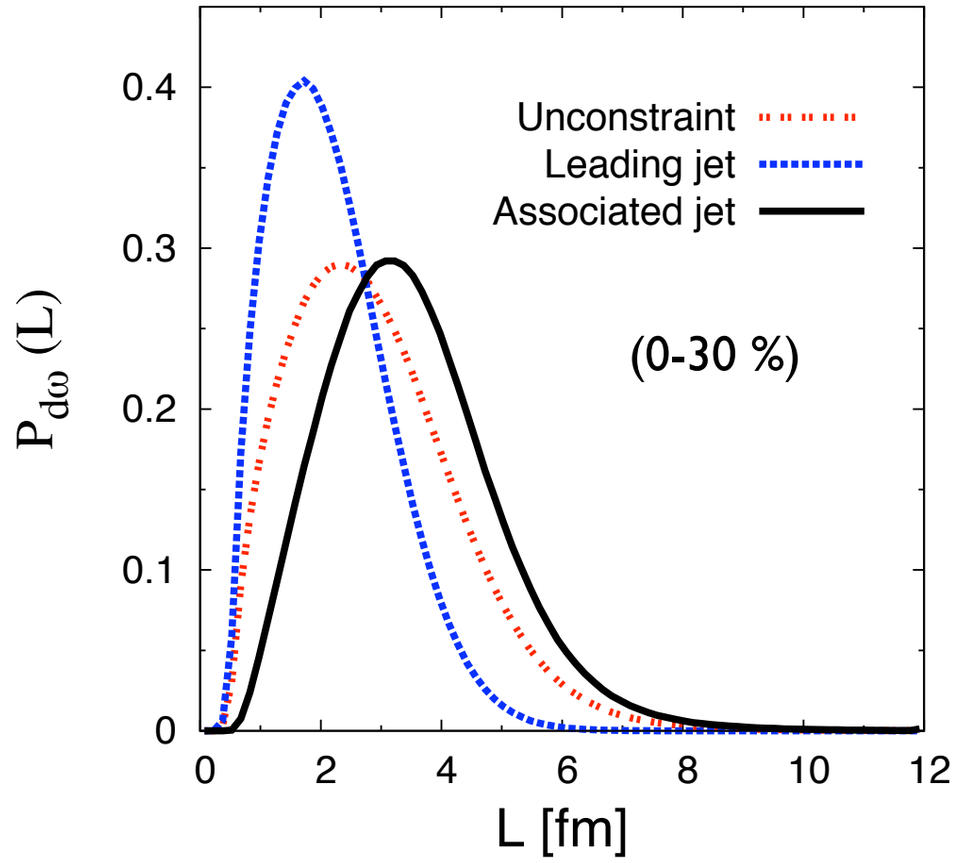
Comparing to Nuclear scale



- How does the vacuum pattern compare to the in-medium length evolution?

- If there would be no large modifications of the evolution time: what would be the probability of splitting outside?

In-Medium Path Length



- Woods-Saxon profile with 1/τ longitudinal expansion
- From each point, the density weight length:

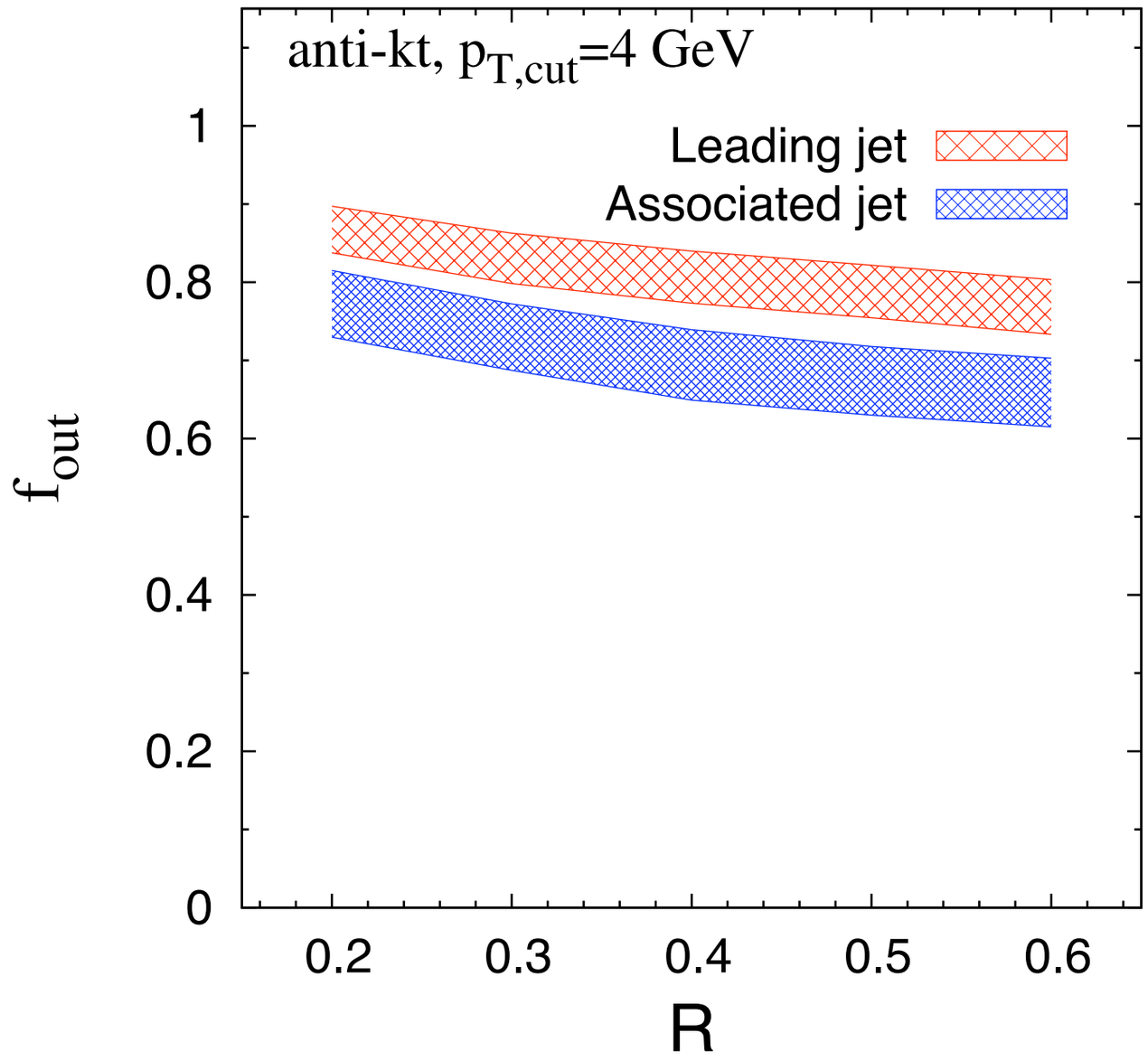
$$L = 2\frac{\int_0^\infty d\tau\tau\rho(\mathbf{x}+\hat{n}\tau,\tau}{\int_0^\infty d\tau\rho(\mathbf{x}+\hat{n}\tau,\tau)}$$

- Simple absorption model to discriminate leading and associated jets: Probability of jet absorption:

$$A(L) = e^{-L^2/L_c^2}$$

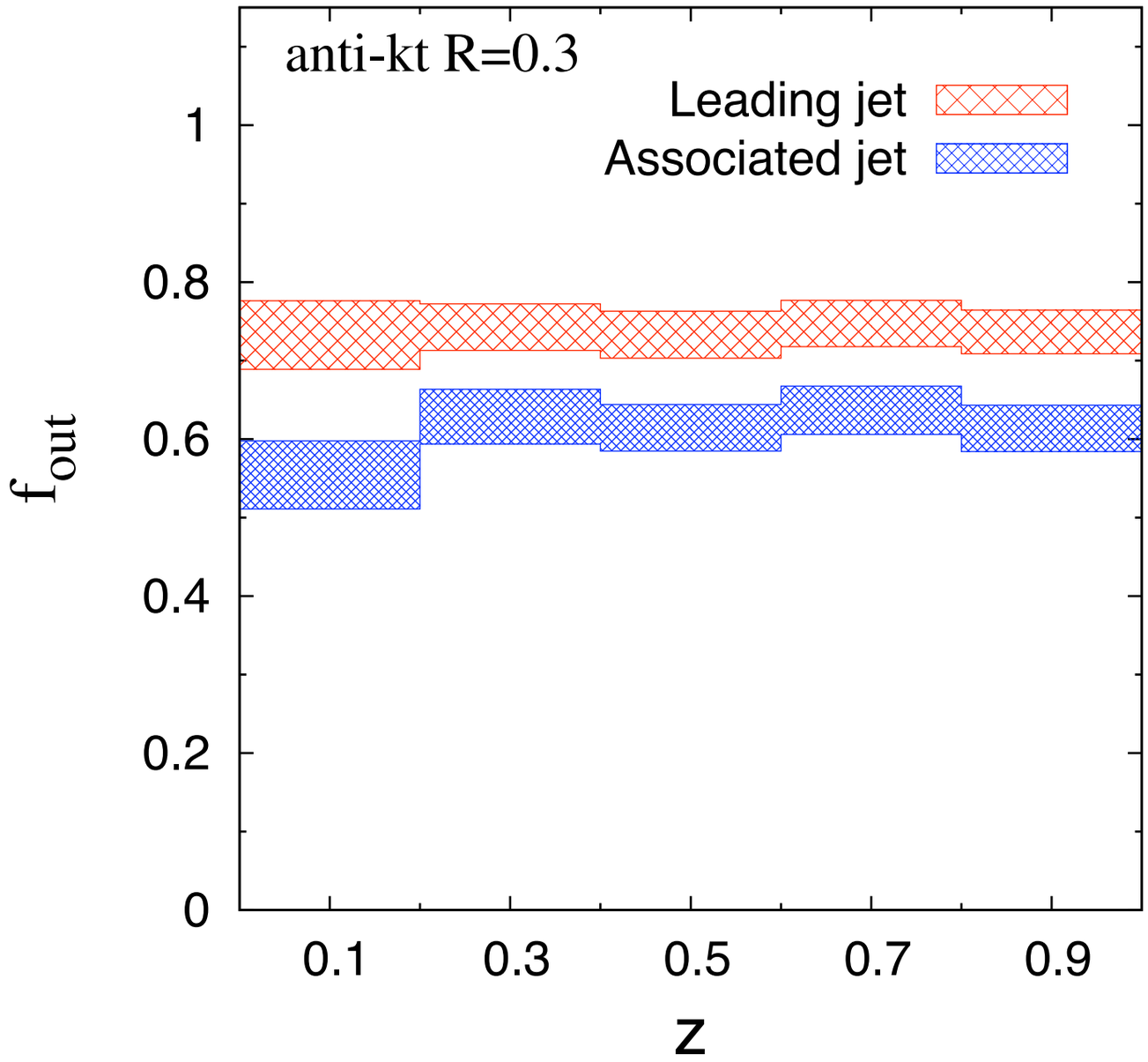
(L_c=3.3 fm fixed from R_{AA}=0.5)

Out-of-Medium Emissions



- A large fraction of fragments are emitted outside of the medium both for leading and associated jet

Out-of-Medium Emissions



- Mild dependence on the energy of the fragment (at least for those within the jet cone)

Conclusions

- If in-medium jet evolution proceeds like in vacuum:

  More than $\begin{matrix}80\%\text{ of leading}\\70\%\text{ of associated}\end{matrix}$ jet fragments occur outside

- Unless a conspiracy of effects occurs, unmodified FF imply

  In-medium evolution cannot alter Q^2 evolution significantly

  Additional in-medium radiation must be:

  -Emitted at large angles (outside of the cone)

  and/or

  -Dominated by soft fragments