The higher twist method

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thanks to Guang-you

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Outline

Fragmentation functions, why the HT needs them

The physics of scale, why virtuality is important

Calculating with virtuality, what are the different cuts

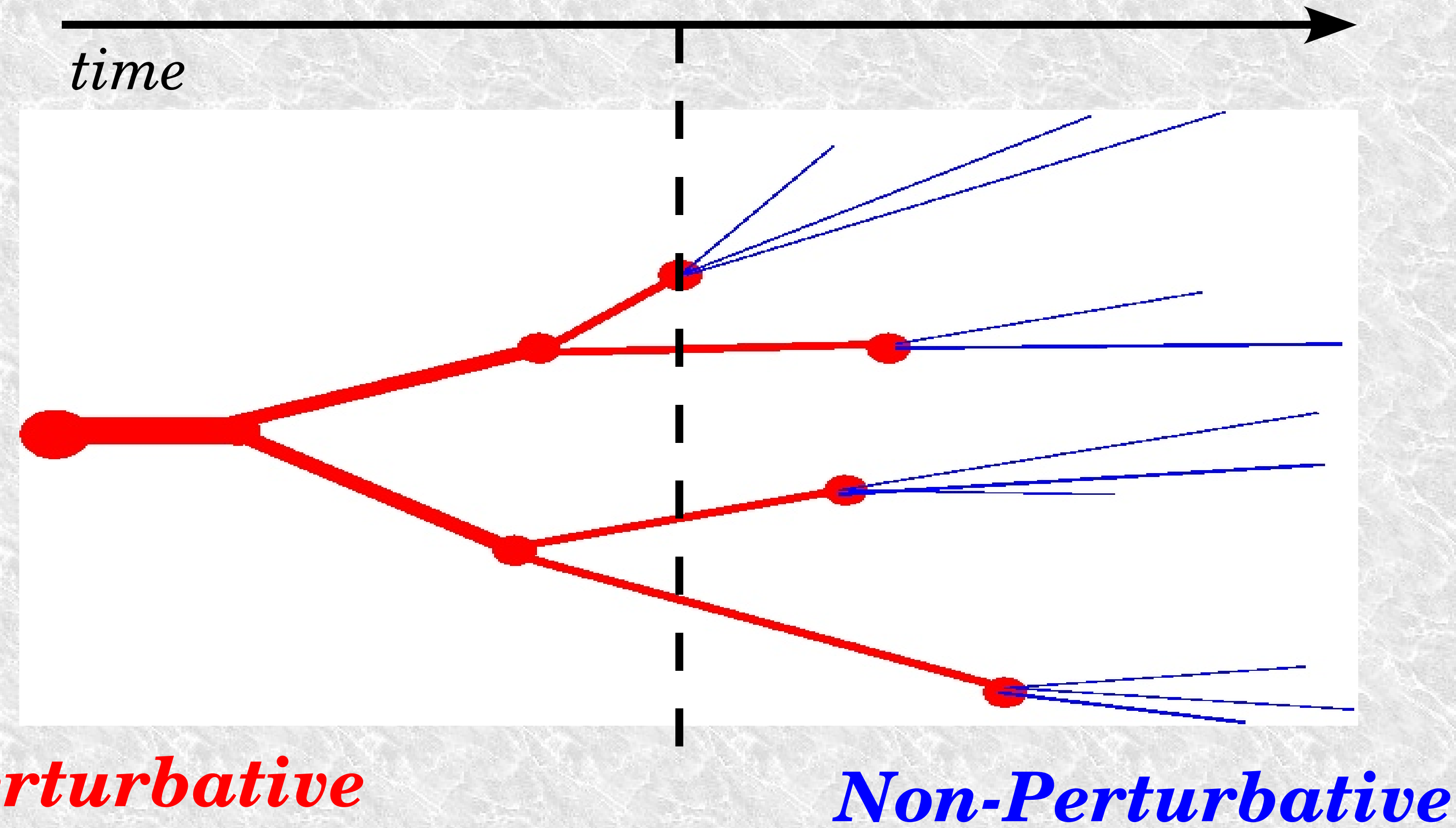
What are we measuring in the medium

Trying to take out the fragmentation function,
(uncoupling the hadronic distribution)

Some new ideas of what else we can do.

Note: all plots preliminary!!

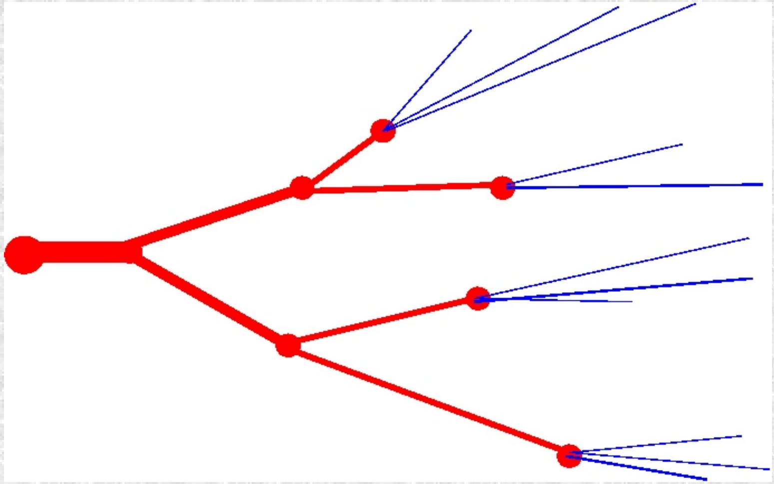
What is everybody's picture (except AMY)

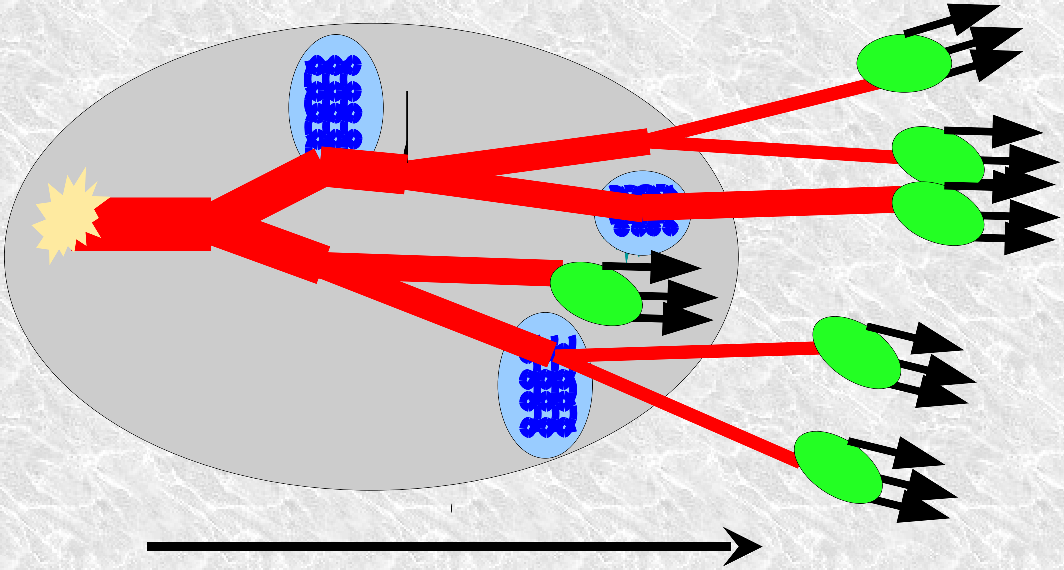


This is captured in DGLAP

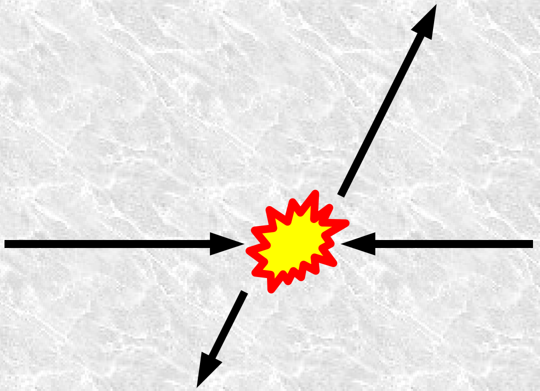
Factorization of hard CS at Q^2

At leading order all the processes with $\mu_F < Q$ live in the fragmentation or medium modified fragmentation function.



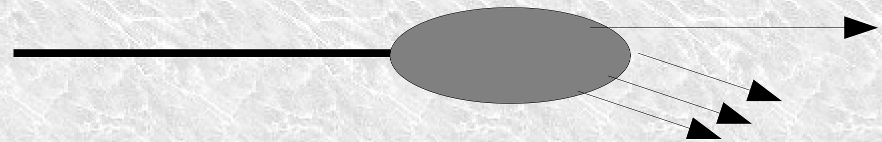


The hard CS lives at the scale Q^2.

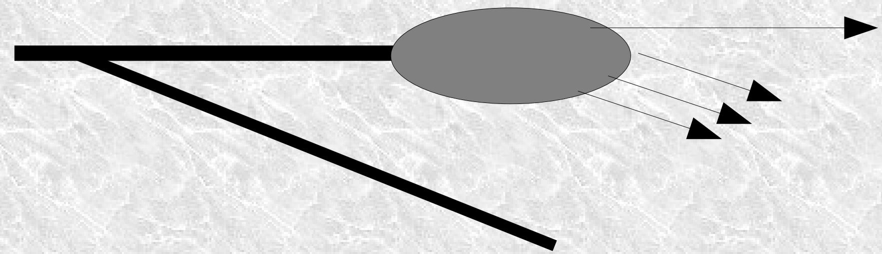


Building it up step by step (in vac)

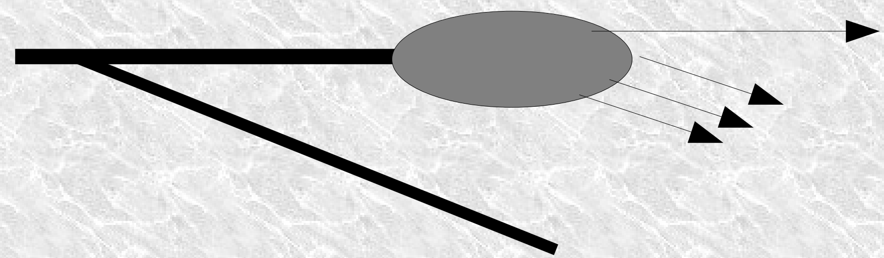
$D(z,\mu^2)$ with $\mu^2 > 1$ GeV^2



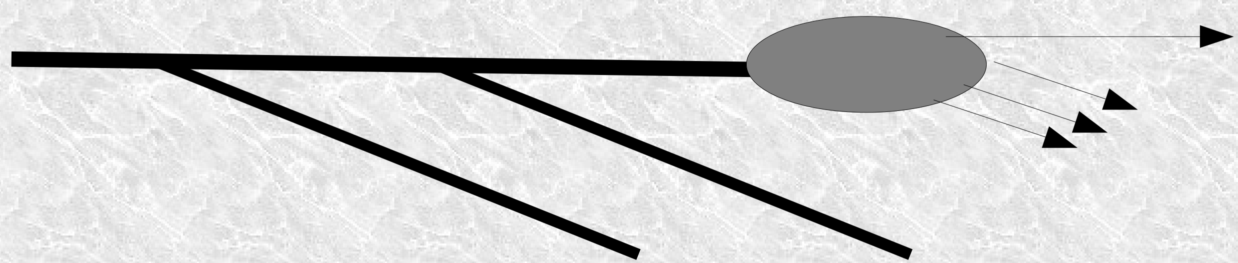
$D(z,\mu^2 + \Delta\mu^2) = D(z,\mu^2) +$



$D(z,\mu^2 + \Delta\mu^2 + \Delta\mu^2) = D(z,\mu^2) +$



+

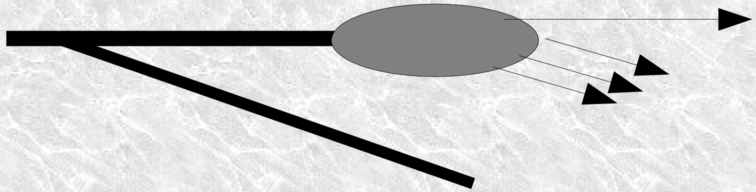


Raising the scale is building the partonic shower

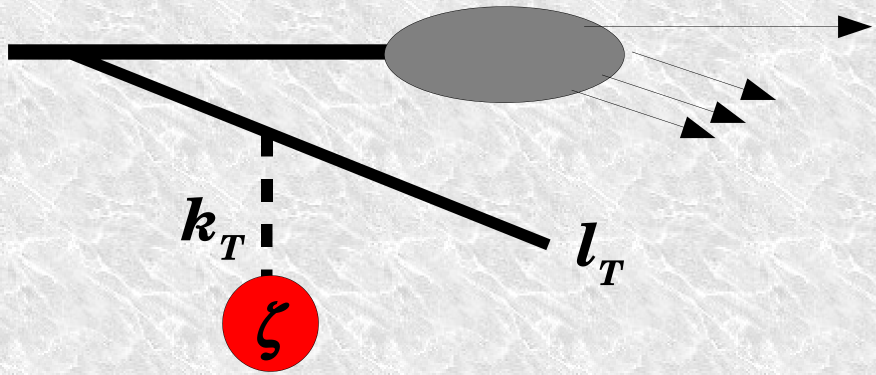
$$\frac{\partial D(z,Q^2)}{\partial \ln(Q^2)} = \frac{\alpha_s(Q^2)}{2\pi}\int_z^1 \frac{dy}{y} P(y) D(z/y, Q^2)$$

Medium gives scattering corrections to this process

D(z, ζ_i, L ,E,$\mu^2 + \Delta\mu^2$) = D(z,μ^2) +



$$\int d\zeta$$



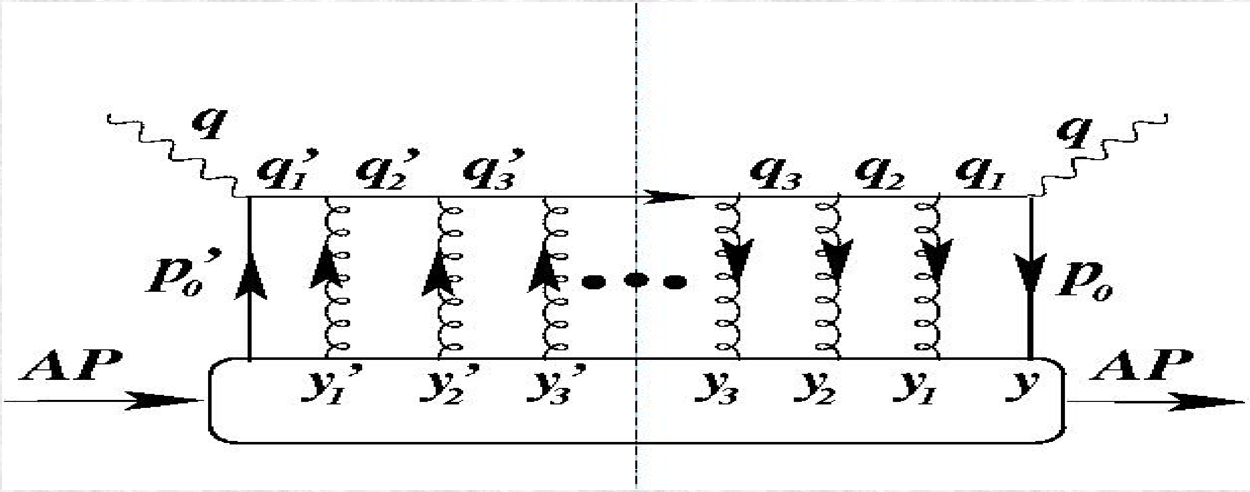
In the limit: $l_T \gg k_T$

$$\frac{\partial D\left(z, Q^2, q^-\right)_{\zeta_i}^{L}}{\partial \ln\left(Q^2\right)} = \frac{\alpha_s\left(Q^2\right)}{2\pi}\int_z^1 \frac{dy}{y} P(y) \int_{\zeta_i}^{\zeta_f} d\zeta\, 2\pi \alpha_s\left(Q^2\right) \rho_g(\zeta) \times \frac{2 - 2\cos\left[Q^2 \zeta^- / \left\{2q^- y(1-y)\right\}\right]}{Q^2} \times D\left(z/y, Q^2, q^-\right)_{\zeta}^{L}$$

+ vacuum evolution

What are we measuring in the medium

The partons traverse a soft gluon field undergoing diffusion

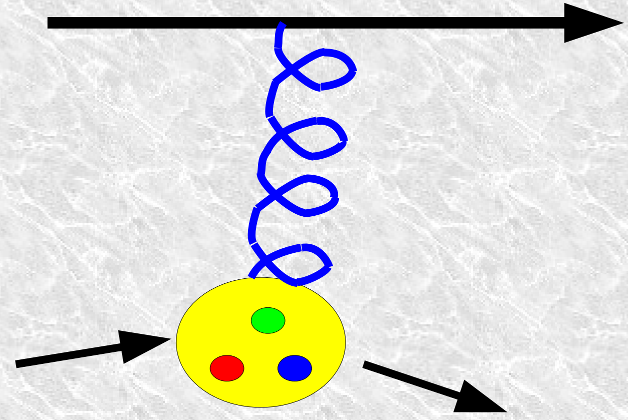


$$\frac{\partial f(l_\perp, L^-)}{\partial L^-} = \nabla_{l_\perp} \cdot D \cdot \nabla_{l_\perp} f(l_\perp, L^-) \qquad l_\perp^2 = 4\,D\,L^- = 4\sqrt{2}\,Dt$$

$$\hat{q} = \frac{l_\perp^2}{t} = \frac{8\pi^2 \alpha_s C_R}{N_c^2 - 1} \frac{\int dy^-}{2\pi} \left\langle N \middle| F^{\mu\alpha}(t)\, v_\alpha F_\mu^{\beta}(0)\, v_\beta \middle| N \right\rangle$$

Can be evaluated in a well defined medium: HTL plasma, heavy static scattering centers

More transport coeffs: Elastic energy loss



Every interaction induces not only transverse but also longitudinal momentum

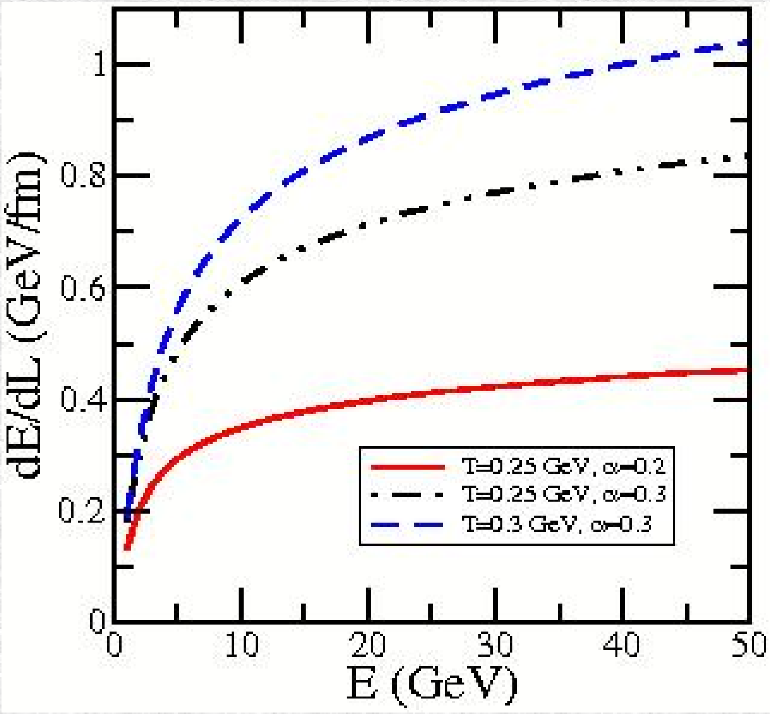
$$f(\vec{l}) \equiv \delta^2(\vec{l}_{perp}) \Rightarrow \delta^2(\vec{l}_{perp})\,\delta(l^- - q^- + k^-)$$

This k^- is tiny and usually ignored

$$\frac{\partial f(l^-, L^-)}{\partial L^-} = c_1 \frac{\partial f}{\partial l^-} + c_2 \frac{\partial^2 f}{\partial^2 l^-}$$

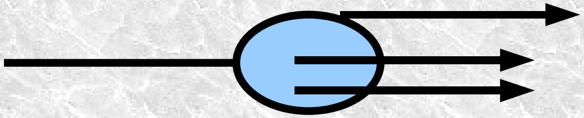
Keeping these contributions and resumming leads to drag and diff

Evaluating c_1 in a thermal medium

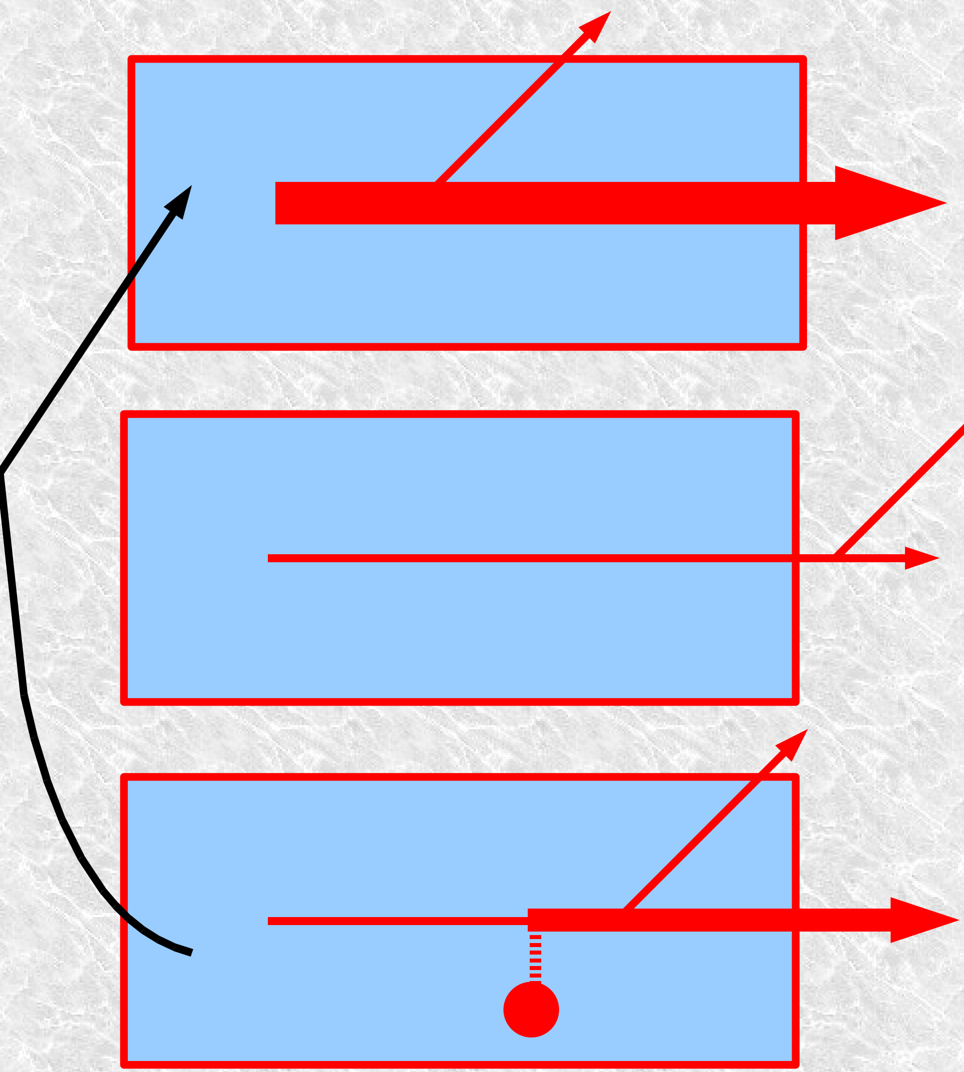


A.M. arXiv:0810.4967 [nucl-th]

Cutting off the in-medium evolution



$D(z,Q^2)$ contains all partons up to Q^2



Large virtuality partons radiate inside the medium

Low virtuality partons radiate outside, cut off medium part at $Q^2 < E/L$

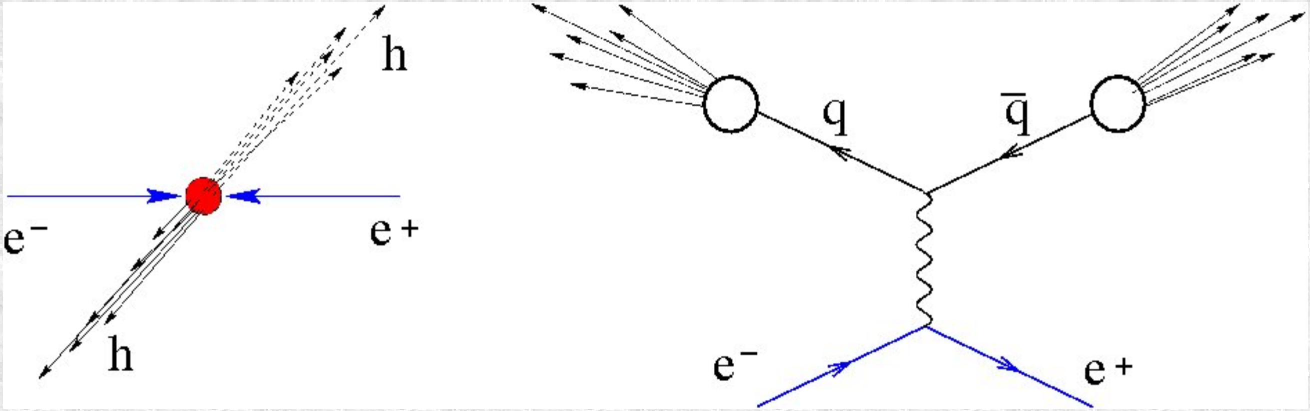
Cases where virtuality raised by collision included with the first type of term

The meaning of fragmentation functions

What is the upper scale to use: process dependent!

In e^+e^-, at LO, use the invariant mass, M

All off-shellness-es of the quark prop. upto M^2 are in the fragmentation function

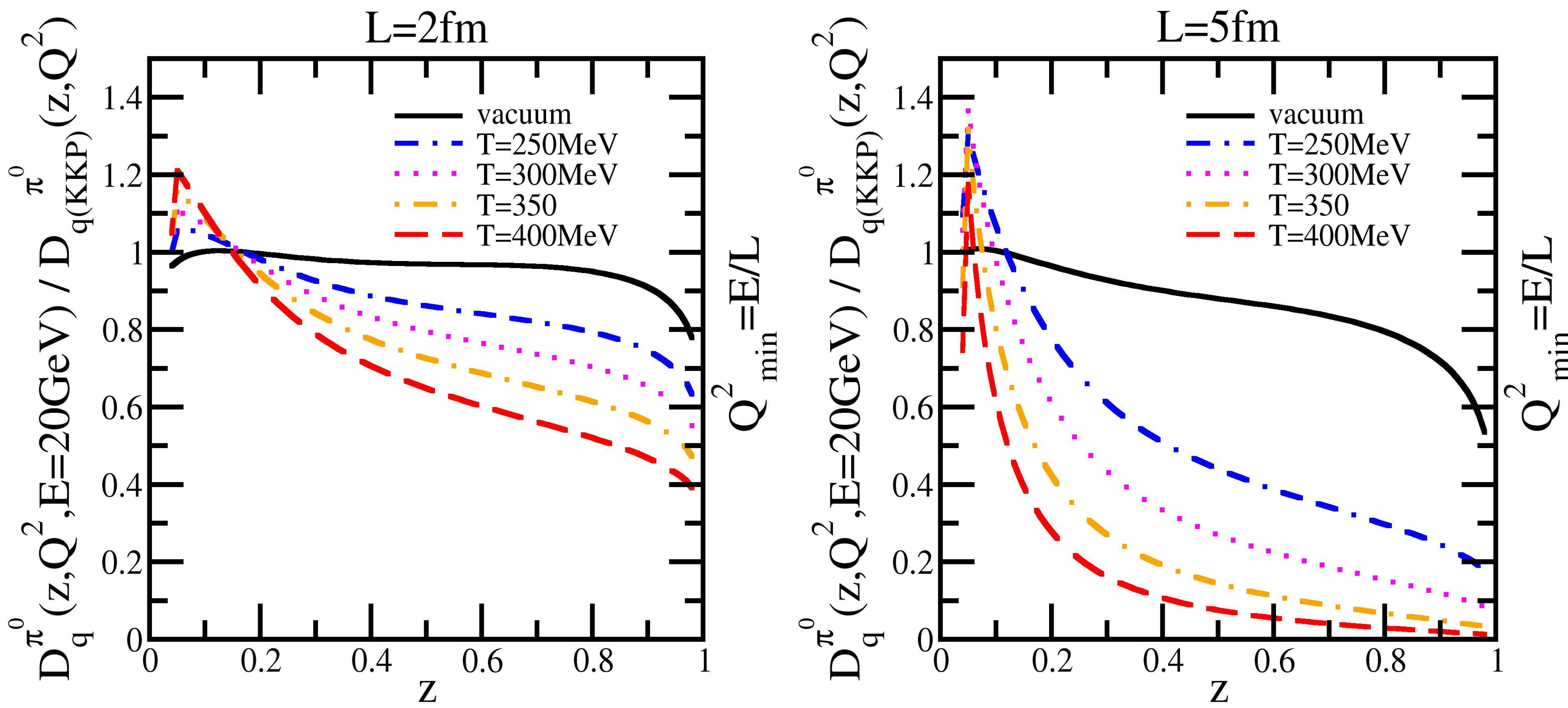


Virtualities are logarithmically distributed upto M^2.

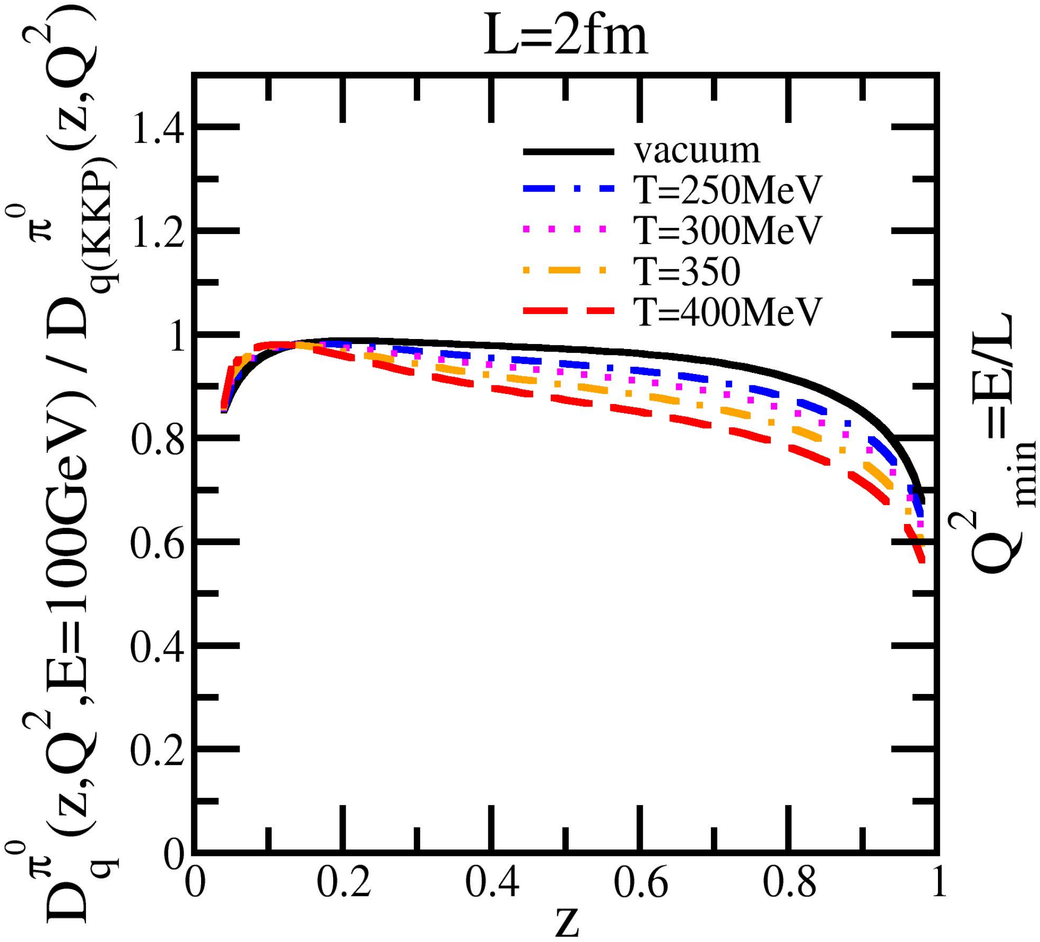
For jets one usually uses $Q = p_{hadron} \sim E/2$
so we will use $Q^2 = E^2/4$

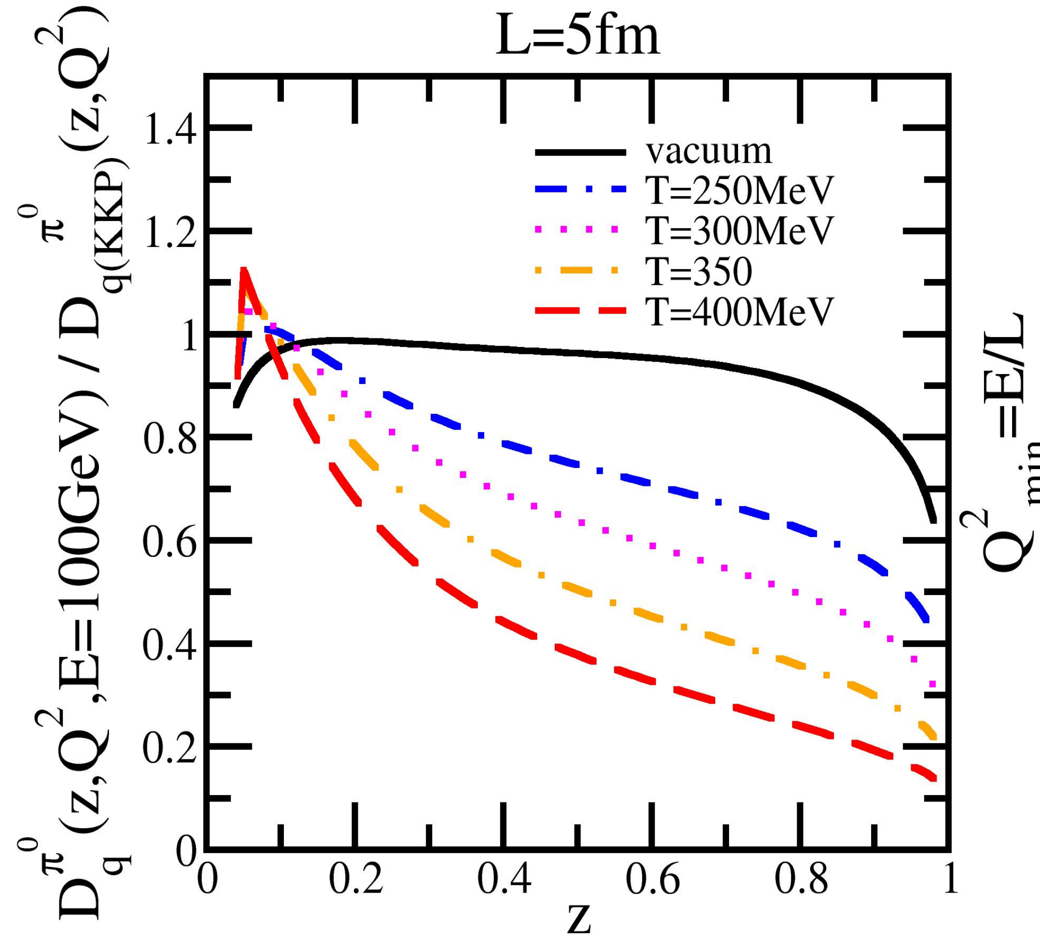
Jets at $E = 20$ GeV, $Q^2 = 100$ GeV^2

We also evolve the vacuum distribution from E/L to Q^2



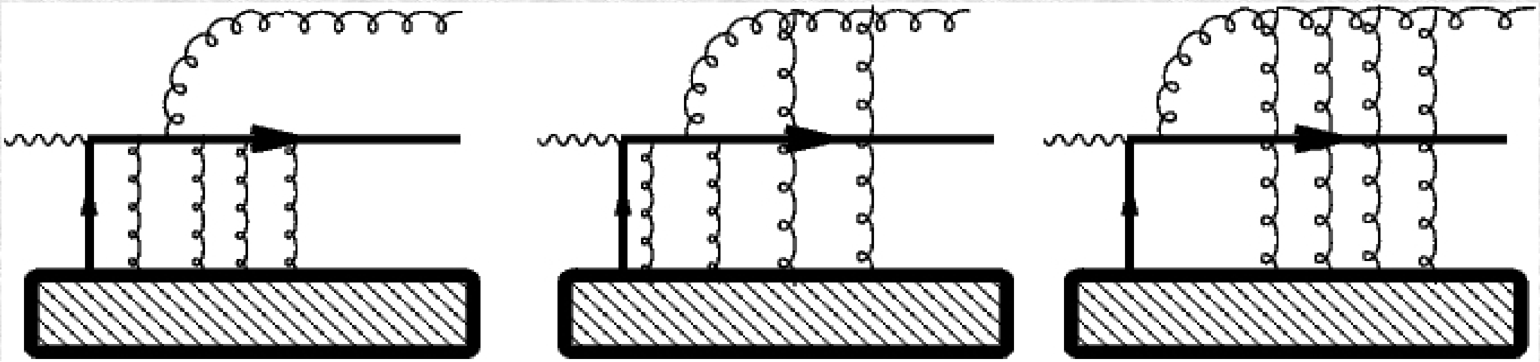
Jets at E = 100 GeV, Q^2 = 2500 GeV^2





Q^2_{min} = E/L, just an Ansatz, Need a more detailed theory or MC

Note all these plots will change a bit as new all-twist kernel introduced



In the large Nc limit, similar to the single scattering kernel

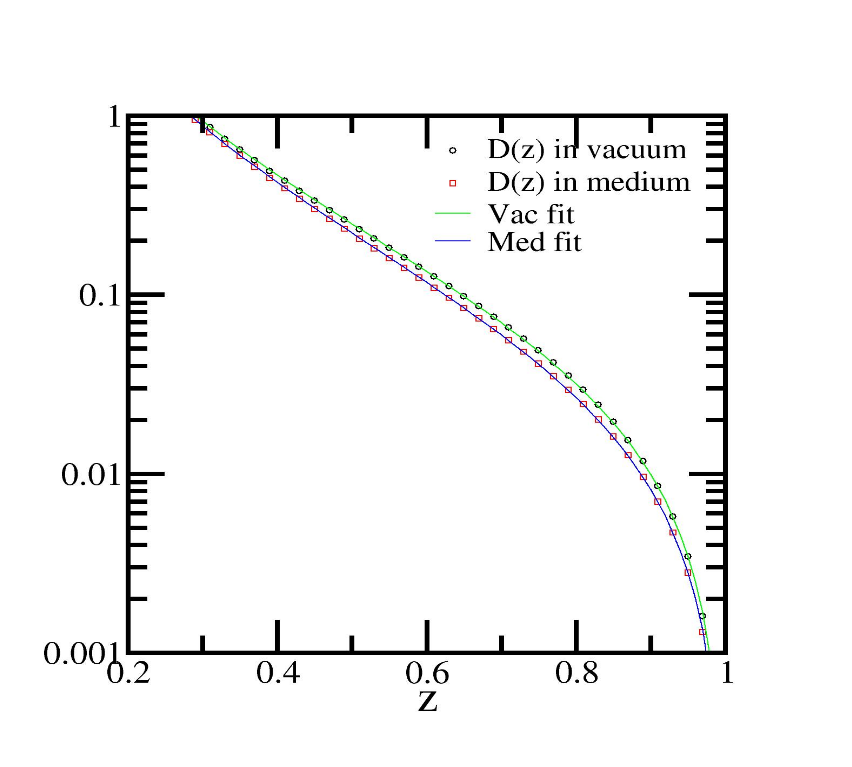
except that initial and produced partons undergo diffusion in medium

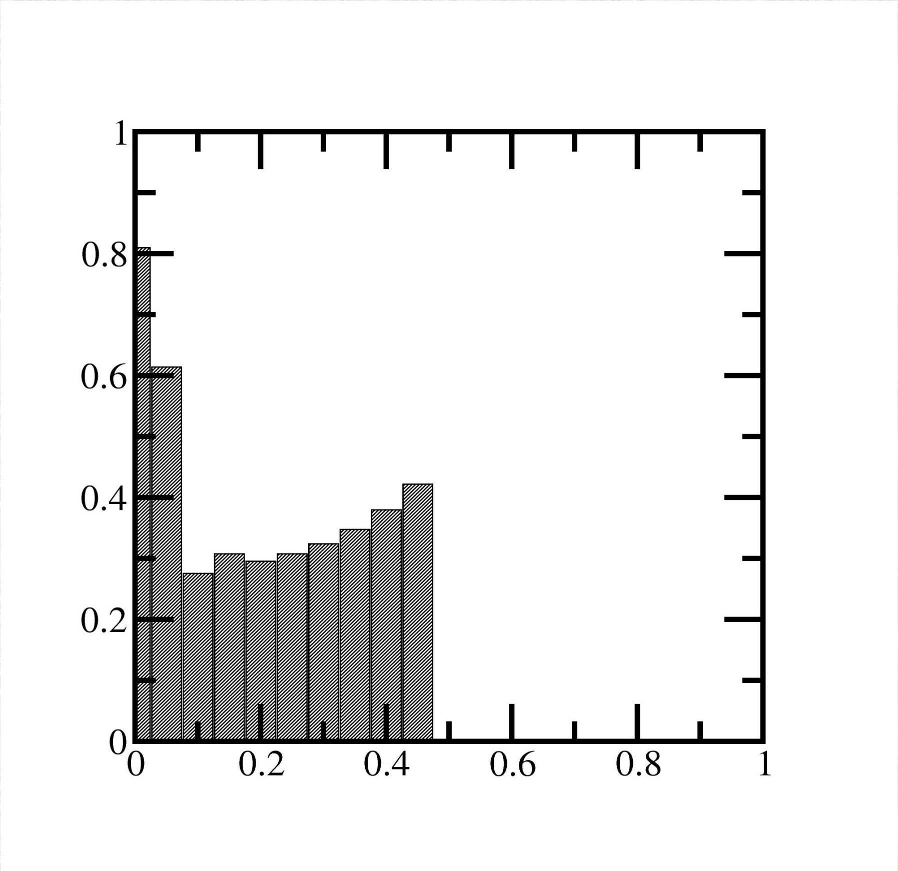
Connecting with GLV and ASW

How to take out the fragmentation function to get to the energy loss distribution

$$\tilde{D}(z,Q^2,E)=\int_0^{1-z}\frac{d\epsilon}{1-\epsilon}P(\epsilon)D(z/(1-\epsilon)) \quad - \quad P(0)D(z)$$

$P(\epsilon)$ = splitting function (probability density) to lose E fraction ϵ.
P(0) = probability to lose no energy

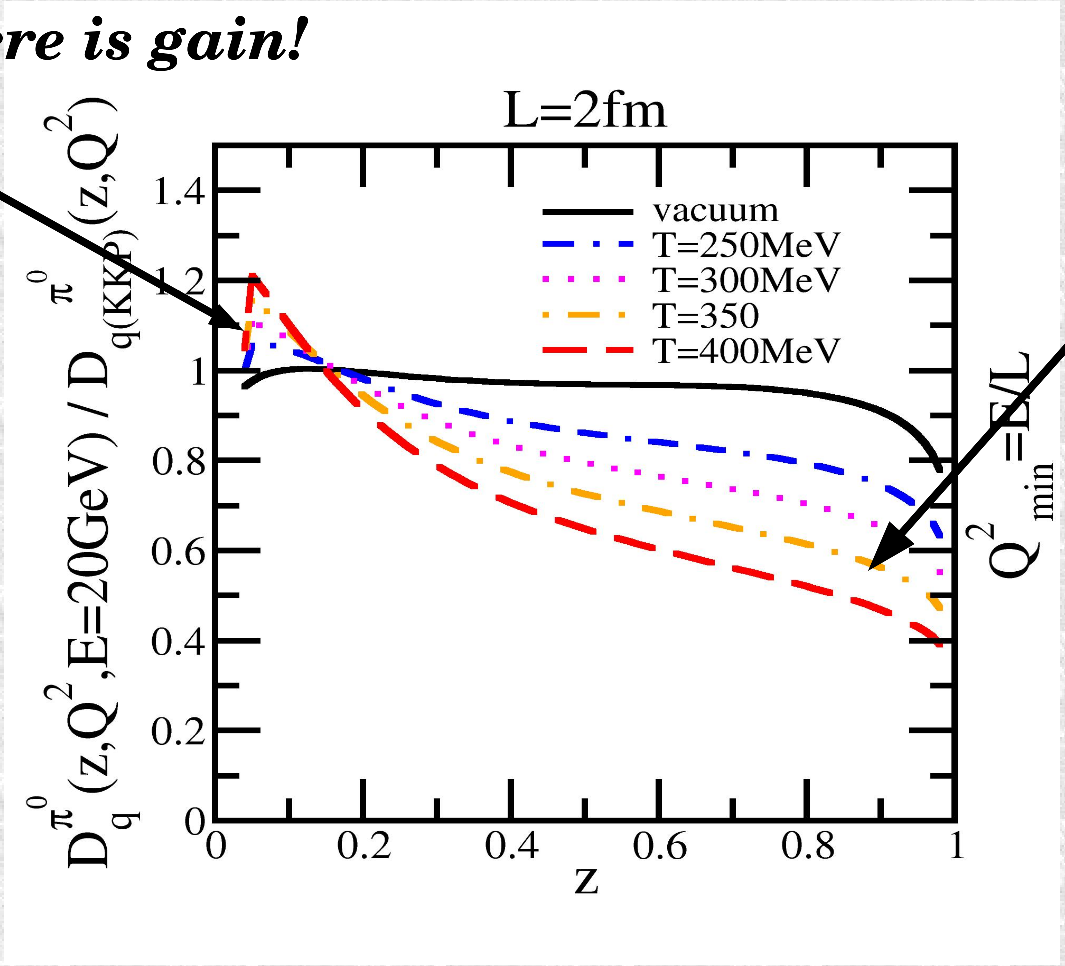




The probability distributions tend to rise at large e-Loss!!

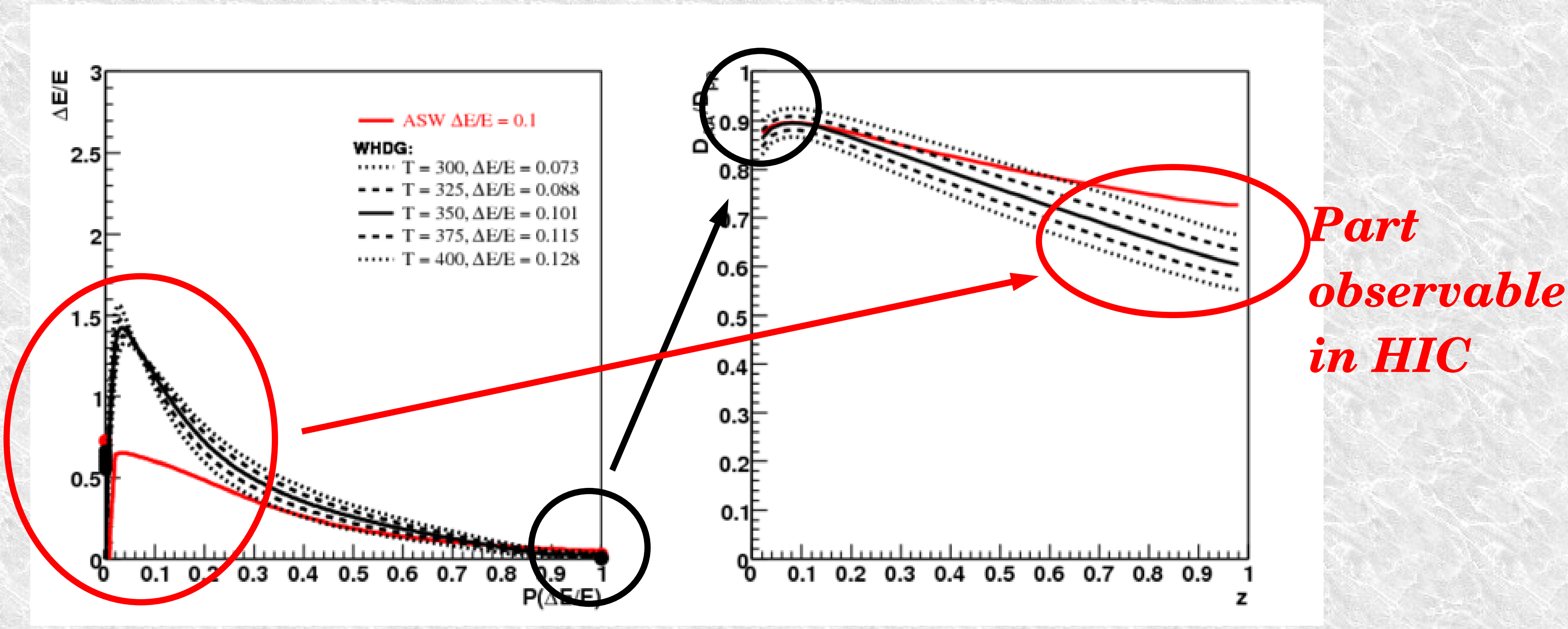
At small z there is gain!

At large z, there is loss



P(e) interpolates from a loss distribution to a gain distribution
Preliminary result: cannot get a P_loss dist. at large E-loss

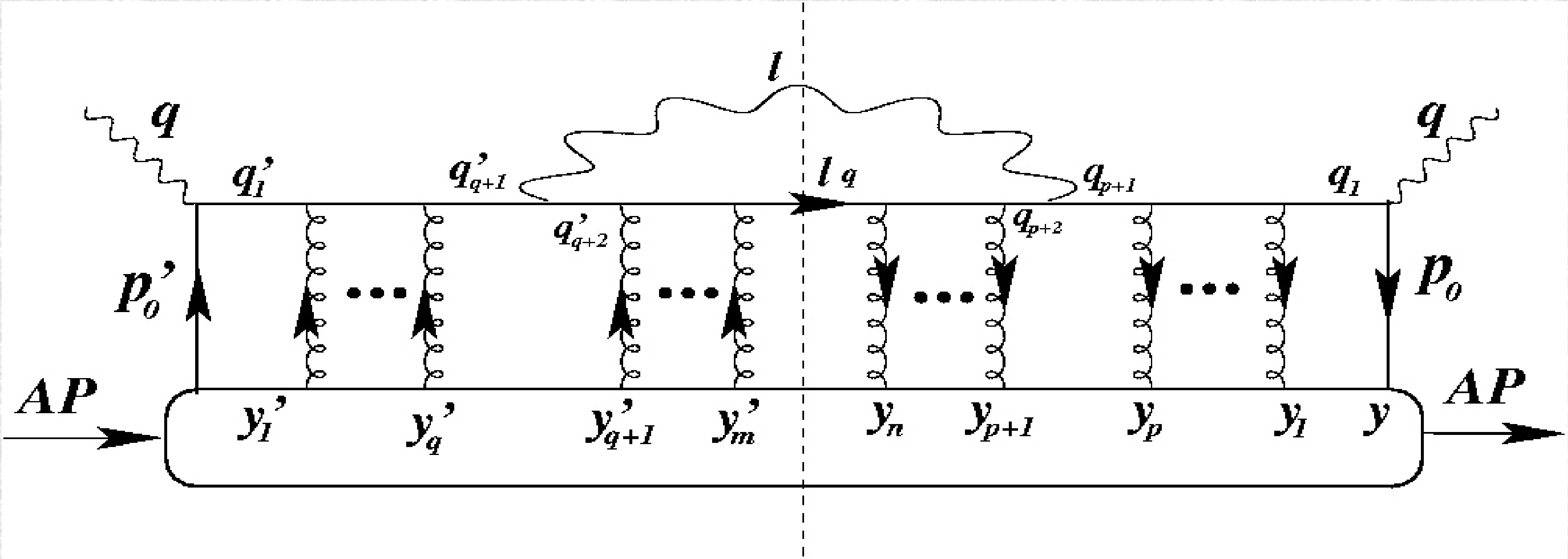
Note: most of the issues related to P(e) at large E_loss



The continous drop in the P(e) means that the medium modified fragmentation function will never rise above the vacuum at low z
Unitarity ??

A suggestion for an unambiguous comparison

Triggered Photon production !



Very similar to E-loss, except photon does not scatter

QED LPM effect

No fragmentation function!

If we dont agree on this, we will not agree on gluon radiation

Experimentalists can settle the issue by actually measuring this

Conclusions

1) Detailed comparisons emerging between E-loss schemes

2) Preliminary result, it may not be possible to extract a P(e) distribution from the higher twist

3) The fragmentation function ``re-weights'' the importance of the P(e) distribution

4) The differences at large (e) will be hard to see in Expt.

5) Not clear if a formalism with out the pile effect gets the right physics

6) (Experimentalists) If the parton distribution is what you want, then we should do what AMY does,

7) Photons, anyone !