SUBA-Jet, a new coherent jet energy loss model

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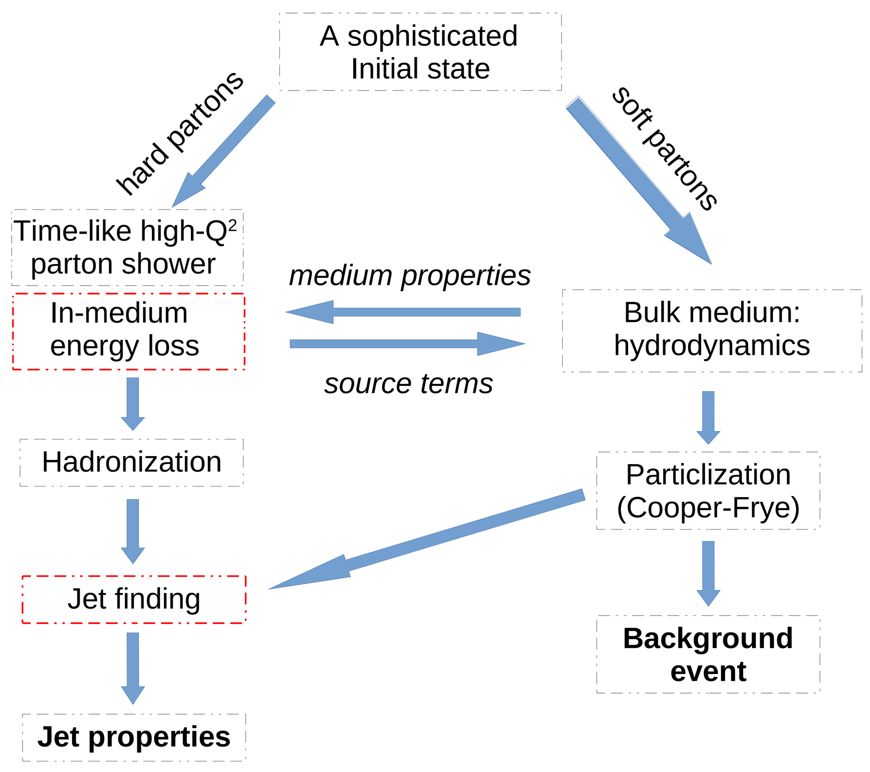
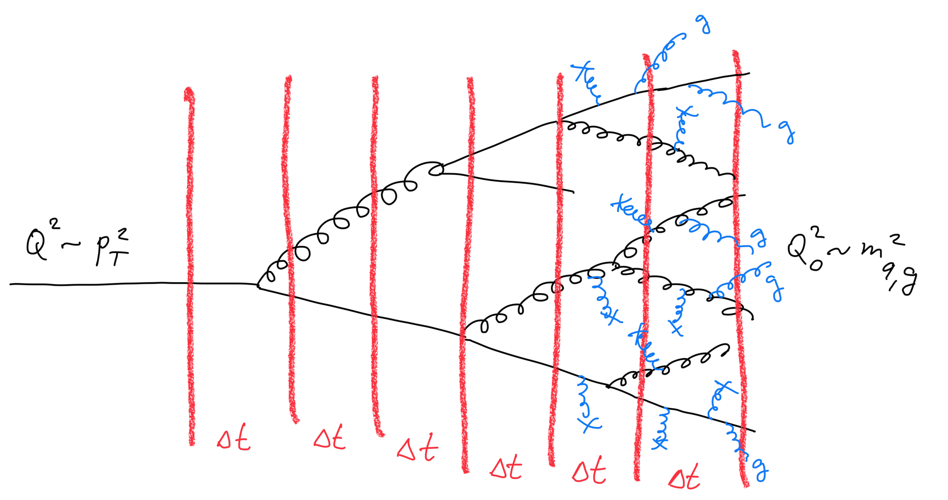
Our project

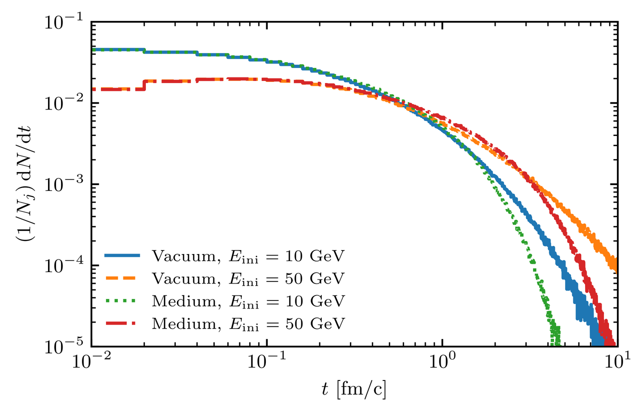
To get both hydrodynamic IS and initial hard partons from preferrably the same initial state, make hydrodynamic and jet parts talk to each other, add hadronization scheme and jet finding.



Time-like parton shower + spacetime picture

- Monte Carlo simulation of DGLAP equations for a parton shower between virtuality scales $Q_{\uparrow}$ (from Born process in hard scattering) and $Q_{\downarrow} = 0.6$ GeV.

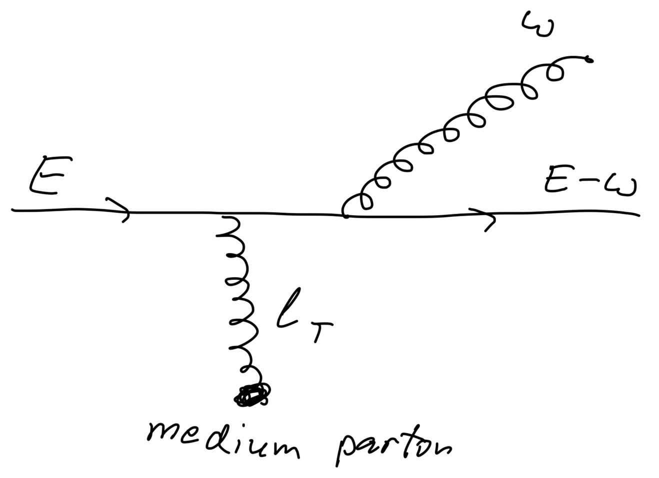




On top of that:

- The *time* evolution is split into timesteps (ideal for merging with hydrodynamic medium evolution)
- Parton splitting (for high-Q^2 partons) happens with a probability according to mean life times between the splittings $\Delta t = E/Q^2$.

Medium-induced radiation: single (incoherent) radiation process



Basic idea: Gunion, Bertsch '82

Extension for heavy quark projectile and dynamical light quarks:
Aichelin, Gossiaux, Gousset, Phys. Rev. D**89**, 074018 (2014):

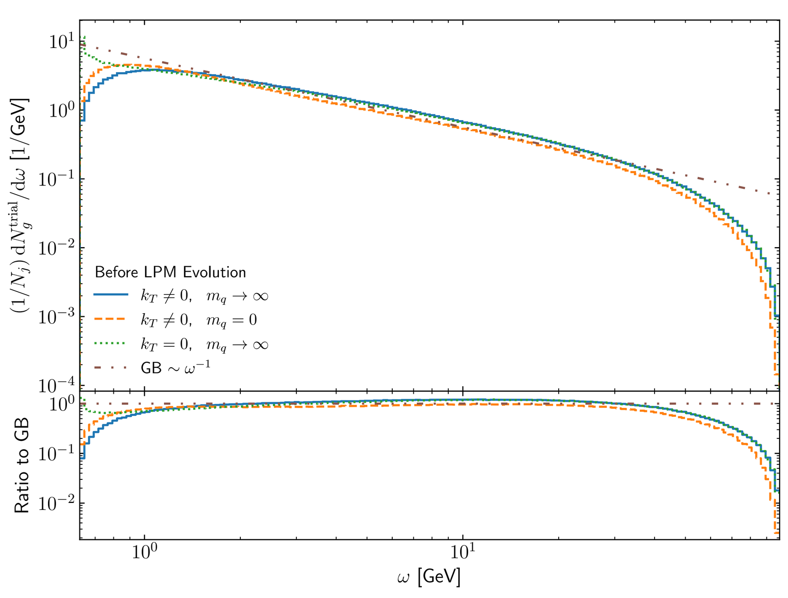
In the region of small x, the matrix elements from QCD can be approximated by so-called *scalar* QCDwhich at high energy leads to a factorized formula for the total cross section of the radiation process:

$$\frac{d\sigma^{Qq\to Qqg}}{dx d^2k_T d^2l_T} = \frac{d\sigma_{\rm el}}{d^2 l_T} P_g(x, k_T, l_T)\theta(\Delta), \quad \text{where}$$

$$P_g(x, \vec{k_T}, \vec{l_T}; M) = \frac{C_A \alpha_s}{\pi^2} \frac{1-x}{x} \left(\frac{\vec{k_T}}{\vec{k_T}^2 + x^2M^2} - \frac{\vec{k_T} - \vec{l_T}}{(\vec{k_T} - \vec{l_T})^2 + x^2M^2} \right)^2,$$

Allows for finite quark/gluon masses → heavy quark jets

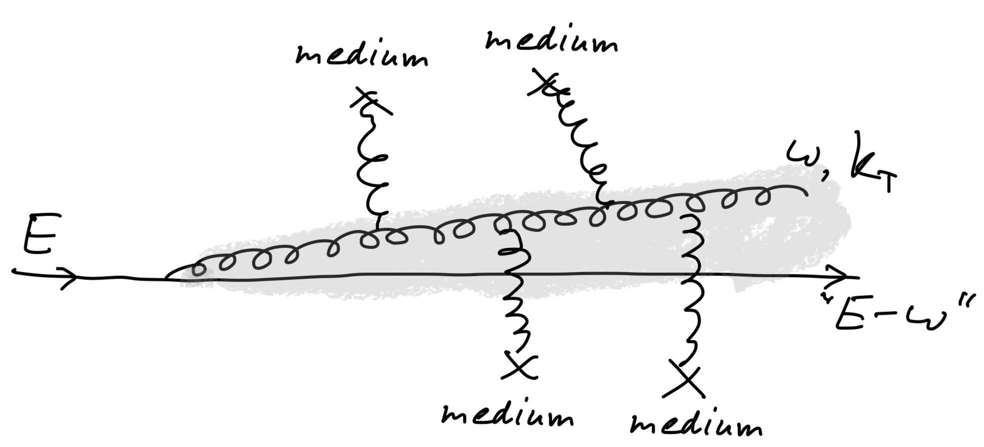
Medium-induced radiation: single (incoherent) radiation process



Setup:

- Medium: $T = 400$ MeV, length $L = 4$ fm, $\alpha_s = 0.3$
- projectile: $E = 100$ GeV, low virtuality
- At most energies, the radiation spectrum behaves as ω^{-1}.

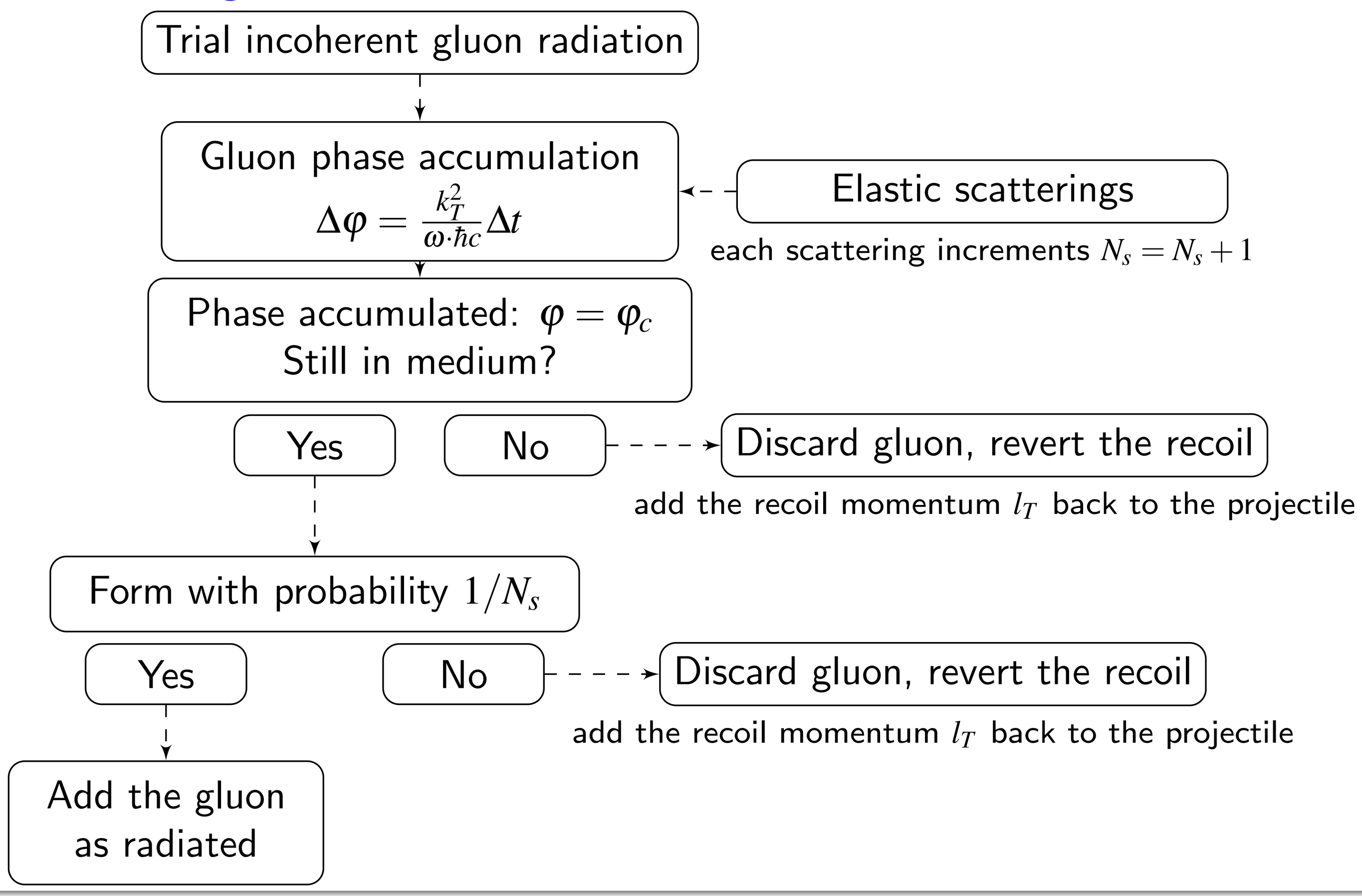
Coherent radiation



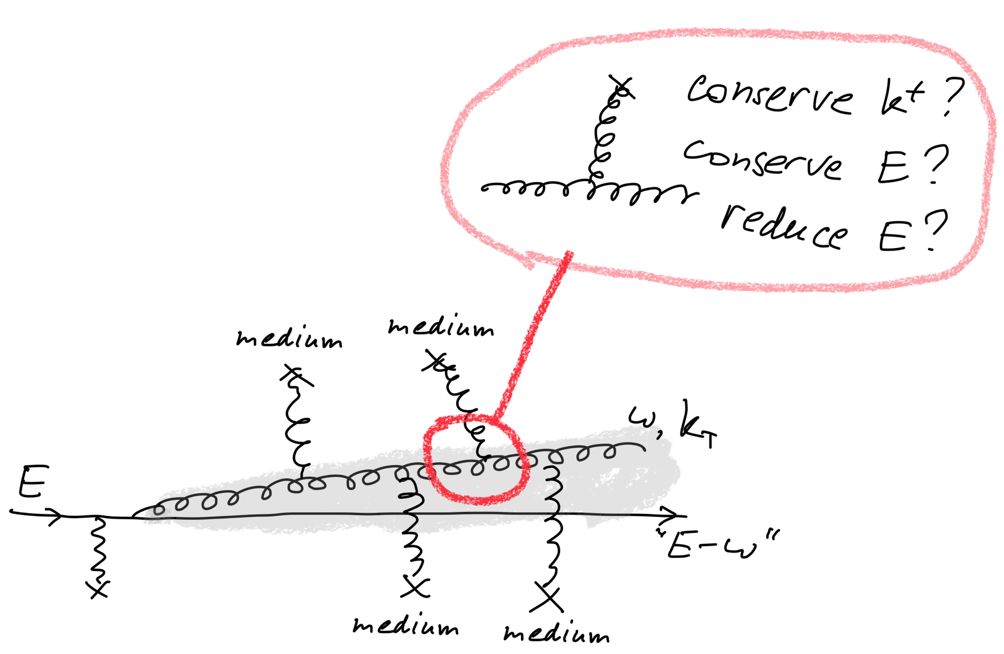
For the multiple scatterings in medium, one has to take into account coherence effects: Landau-Pomeranchuk-Migdal (LPM) effect in QED, or BDMPS-Z in QCD.

- For low-Q^2 partons: at each timestep, an elastic scattering and/or a radiation of pre-formed gluon happens with a probability $R_{\rm el}\Delta t$, $R_{\rm inel}\Delta t$ respectively.
- Each parton can generate arbitrary number of pre-formed gluons (∝blob).
- We adopted a faithful implementation of the BDMPS-Z by Zapp, Stachel, Wiedemann, JHEP **07** (2011), 118

The Monte Carlo algorithm for coherent radiation block

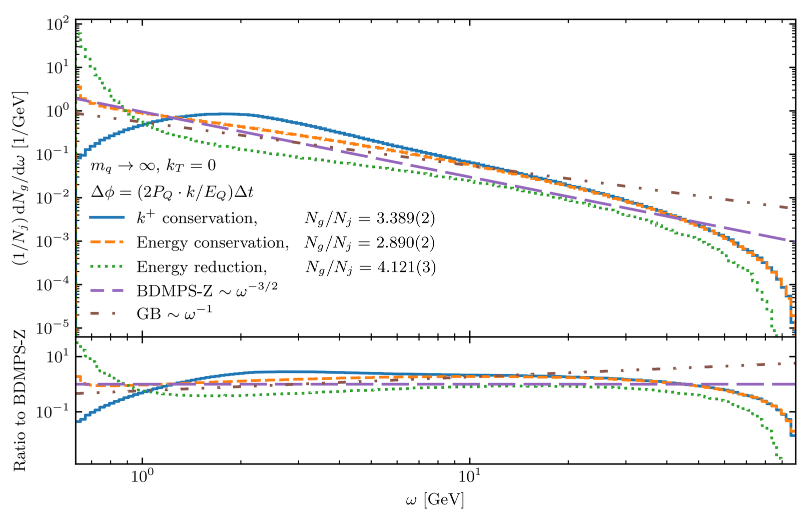


Reproducing BDMS limit *with full GB seed*



$$\frac{d\sigma_{\rm el}}{d^2 l_T} \to \frac{8\alpha_s^2}{9(\vec{l_T}^2 + \mu^2)^2}$$

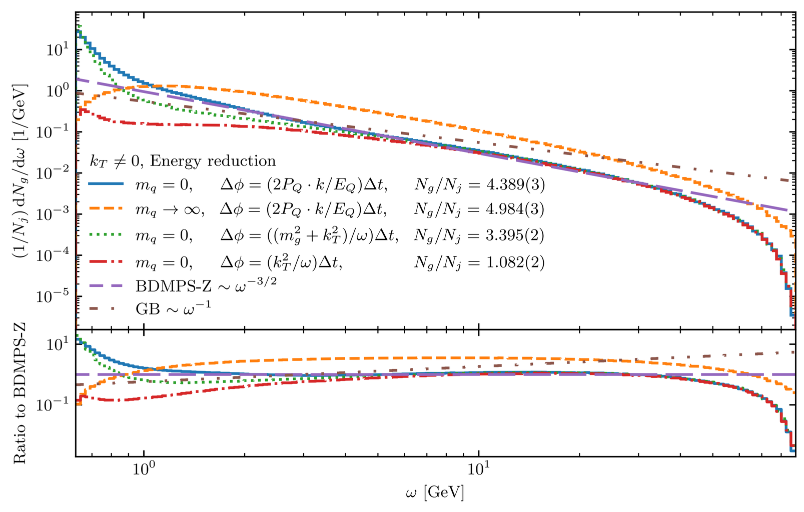
- k^+ conservation is used in BDMS calculation,
- we explore two other choices:
- energy conservation
- energy reduction (energy gain by the medium parton is subtracted from the projectile gluon)



Setup:

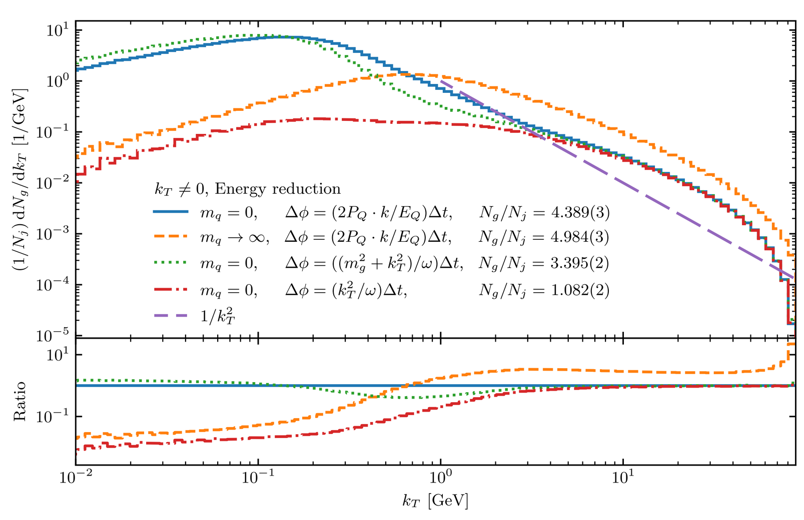
- Medium: $T = 400$ MeV, length $L = 4$ fm, $\alpha_s = 0.3$
- projectile: $E = 100$ GeV, low virtuality
- scattering centers with infinite mass, initial $k_T = 0$, eikonal limit: P_Q does not change
- phase accumulation: $\Delta\phi = (2P_Q \cdot k/E_Q)\Delta t/\hbar c$
- BDMS curve: $dN_g/d\omega \propto \alpha_s \sqrt{\frac{Lm_D^2}{\hbar c}\frac{1}{\omega^{3/2}}}$

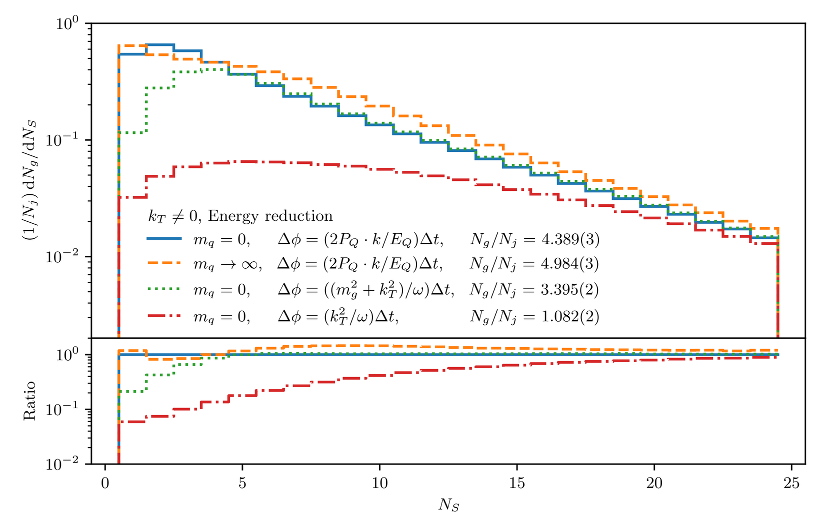
A more realistic case: scattering off maseless medium partons



- The blue curve corresponds to the most realistic scenario (or at least we think so), and it exhibits a nice $\omega^{-3/2}$ behaviour but it is a non-trivial interplay of different features plugged in!

... and corresponding dN/dk_T and dN/dN_s distributions





Summary

- We've constructed a Monte Carlo implementation of the coherent radiative energy loss in BDMPS-Z formalism, based on an extension of the Gunion-Bertsch model to massive quarks/gluons.
- In a BDMS-mimicking setup, we reproduce the $\omega^{-3/2}$ behaviour.
- In the transition towards more realistic setup, details and choices made in the algorithm seem to be important
- *I guess* the reason is that there is no clear separation of scales: $E \gg \omega \gg k_T$ in theory, but in practice they may and do overlap.

Outlook:
Run the jet energy loss model over a realistic medium background (vHLLE, already in progress), compute basic observables, look at the effects of medium response.

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