Exploring k_T broadening in expanding medium induced cascades

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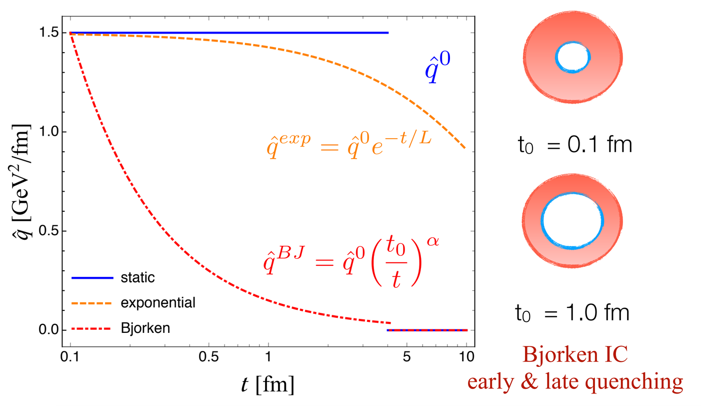
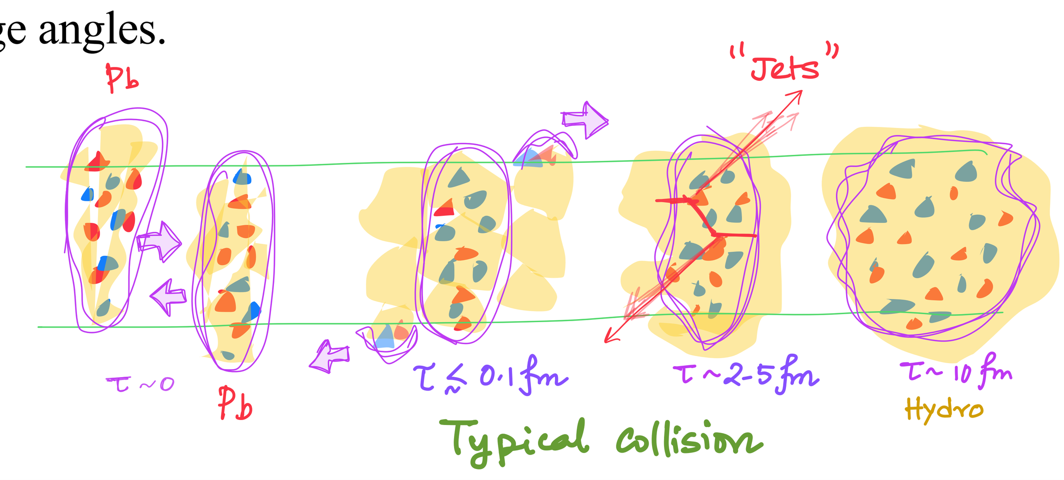
- A Jet is an energetic and collimated bunch of particles produced in a high-energy collision.
- Jets are extended objects, ideal to study *space time evolution*.
- *Energy is lost* in soft particles at large angles.





- The gluon evolution inside a medium is described by the BDIM[a] equation.
- Describes the interplay between *collinear splittings* and *diffusion in momentum* space in the development of the in-medium parton cascade.

$$\frac{\partial}{\partial t}D(x,\mathrm{k},t)=\frac{1}{t^*}\int_0^1 dz\,\tilde{K}(z,t)\left[\frac{1}{z^2}\sqrt{\frac{z}{x}}D\left(\frac{x}{z},\frac{\mathrm{k}}{z},t\right)\theta(z-x)-\frac{z}{\sqrt{x}}D(x,\mathrm{k},t)\right]+\int\frac{d^2l}{(2\pi)^2}C(\mathrm{l},t)D(x,\mathrm{k}-\mathrm{l},t)$$

$$\frac{1}{t^*}=\frac{\alpha_s}{\pi}\sqrt{\frac{\hat{q}}{E}}\qquad C(\mathrm{l},t)\sim\frac{4\pi\hat{q}}{\mathrm{l}^2(\mathrm{l}^2+m_D^2)}$$

Medium evolved gluon spectra; Splitting Kernel; gain term; loss term; elastic collision term

[a]Blaizot, Dominguez, Iancu, Mehtar-Tani, 2014.

Why we need it ?

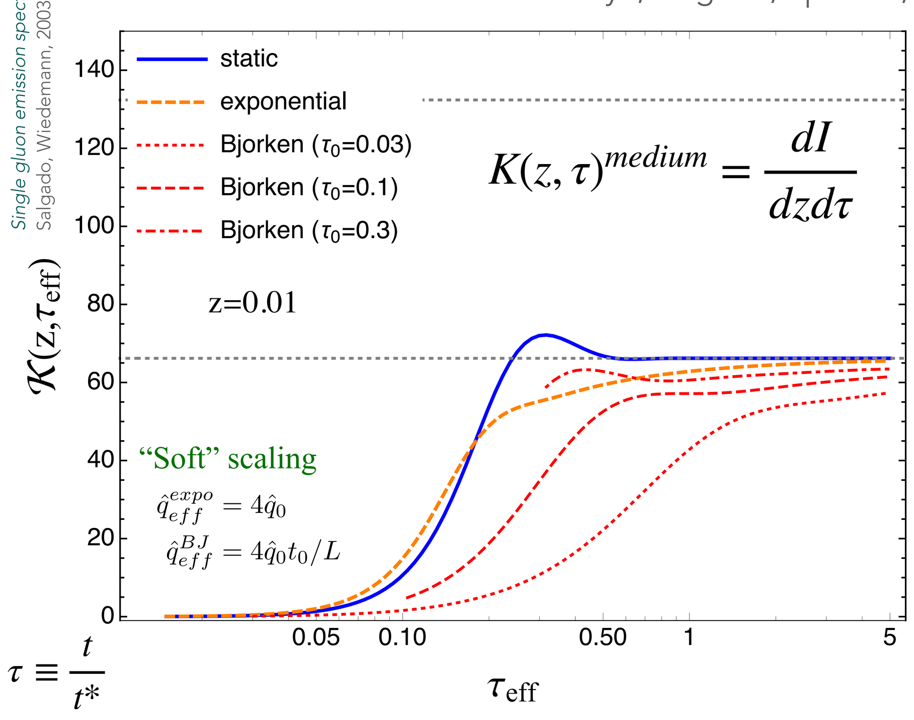
- Inclusion of finite medium size effects with the BDMPS-Z rates.
- Expanding medium with varying time for the onset of the quenching.
- Scaling relations in effective lengths between expanding and static medium profiles, successful in describing R_{AA} *and* v_2 *of jets* with *sensitivity* to medium expansions recently[b].
- Exploratory study of *hard and soft jets in angular regions*.

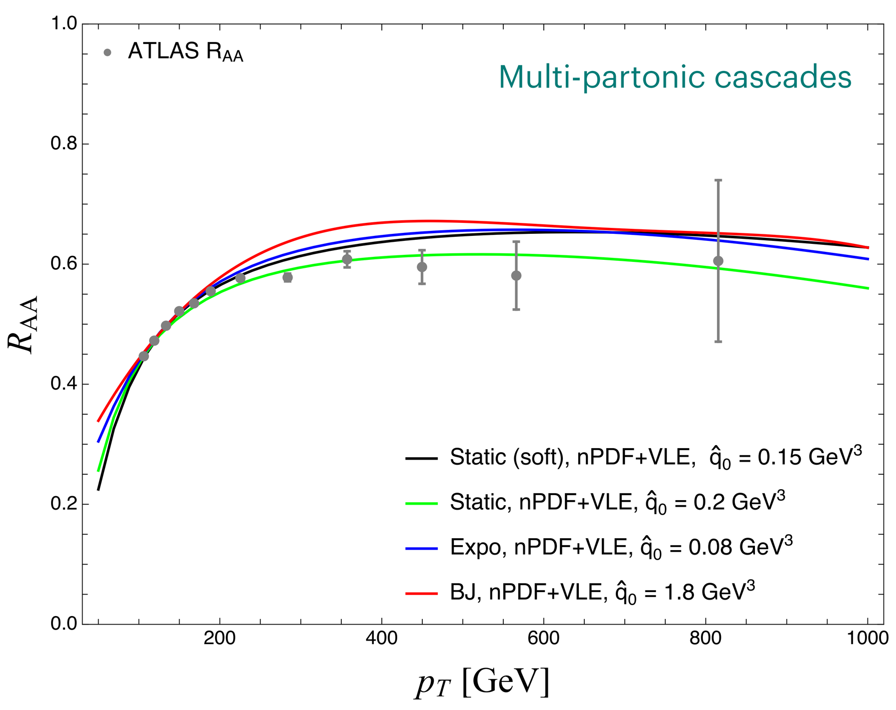
Baier, Dokshitzer, Mueller, Peigné, Schiff, Zakharov 1996, 97.

$$K(z,\tau)^{static}\sim\frac{\alpha_s}{\pi}P(z)\kappa(z)\;\Rightarrow\;K(z,\tau)^{BJ}=\frac{\alpha_s}{\pi}P(z)\kappa(z)\sqrt{\frac{\tau_0}{\tau_0+\tau}}Re\left[(1-i)\frac{J_1(z_L)Y_1(z_0)-J_1(z_0)Y_1(z_L)}{J_1(z_0)Y_0(z_L)-J_0(z_L)Y_1(z_0)}\right]$$

[b]Adhya, Salgado, Spousta, Tywoniuk 2020, 2021, 2022.

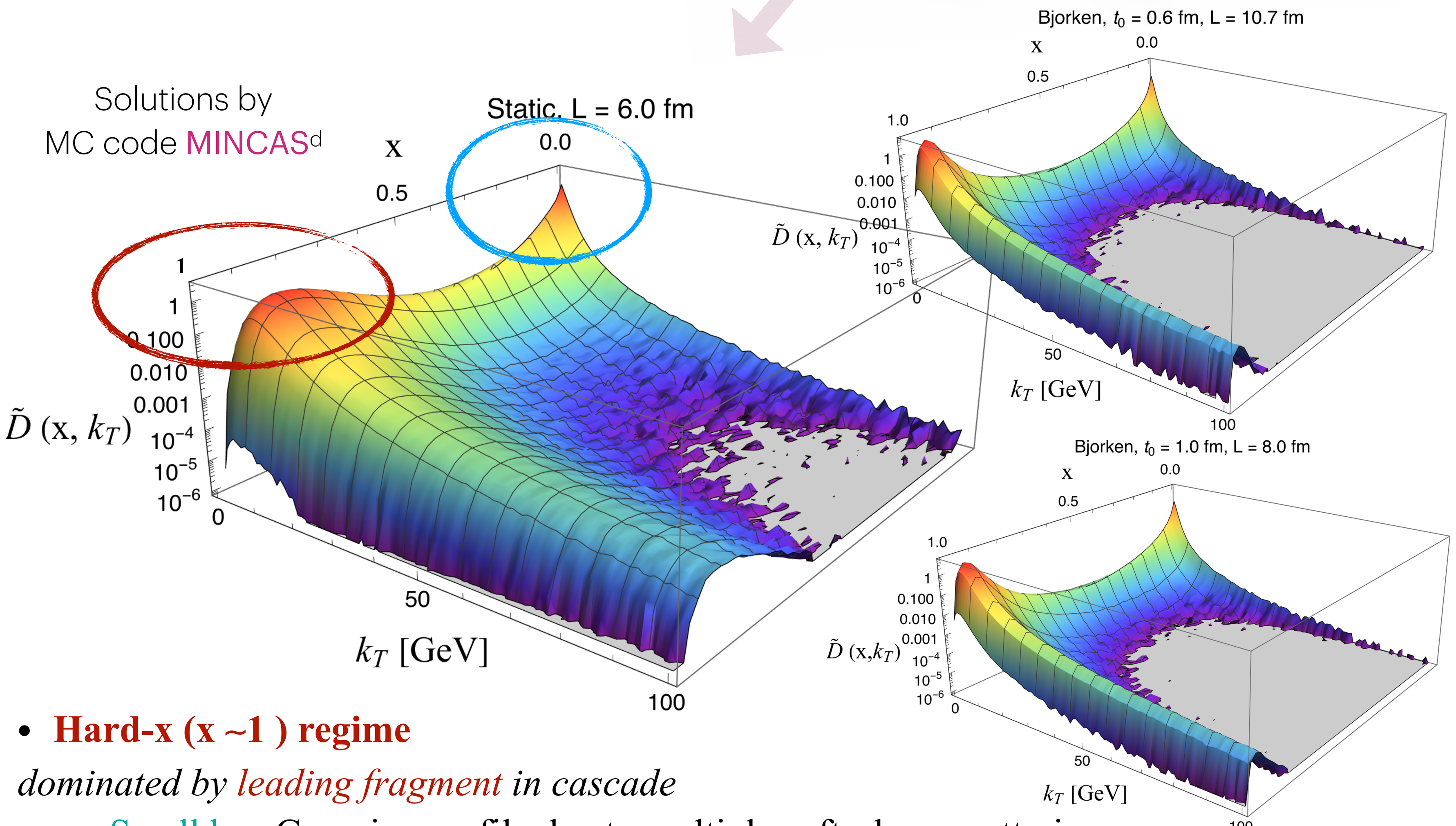
Single gluon emission spectrum: Arnold, Salgado, Wiedemann, 2003, 09.





How we solve it ?

Solutions by MC code MINCAS[d]



- **Hard-x (x ~1) regime**

dominated by leading fragment in cascade
- Small k_T : Gaussian profile due to multiple soft-gluon scatterings.
- Large k_T : Power law suppression due to rare hard medium interactions.

- **Soft-x (x << 1) regime**

accumulation of soft gluons towards the medium scale
- Small k_T : Distribution is narrower and approx. Gaussian.
- Large k_T : No distinct transition to a power-law behavior.

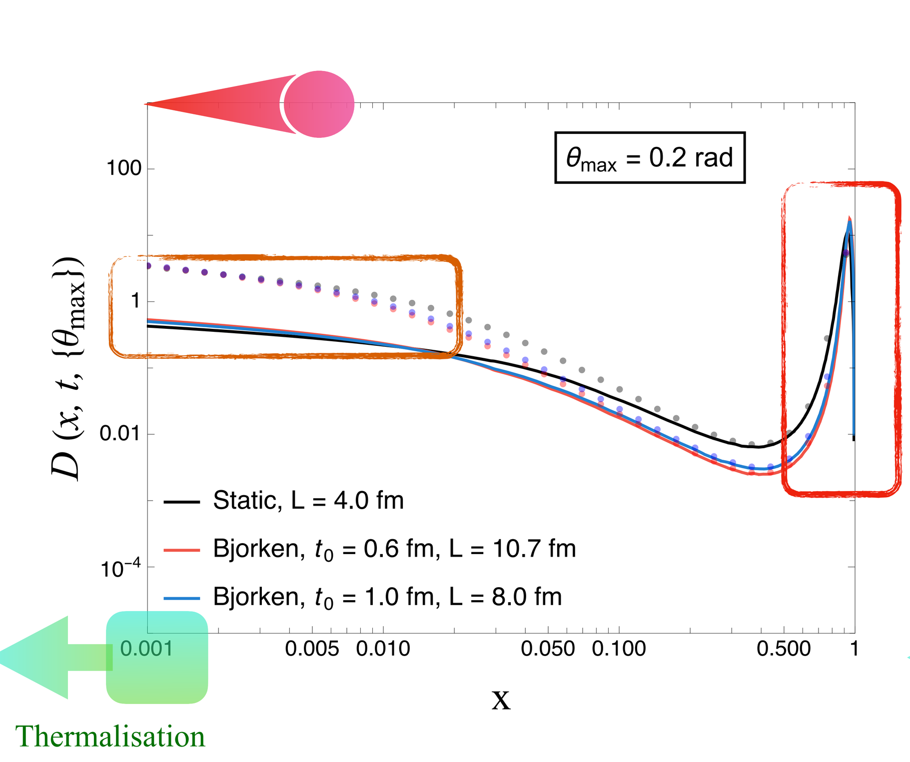
Adhya, Kutak, Placzek, Rohrmoser, Tywoniuk, 2022.

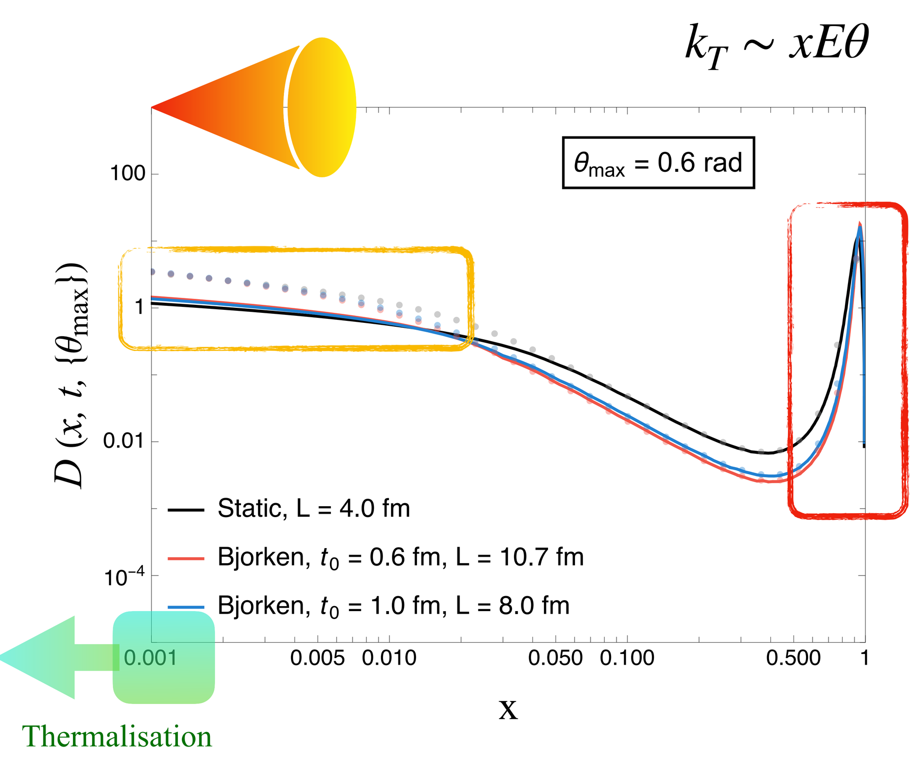
[d]Kutak, Placzek, Straka, 2019.

What we find ?

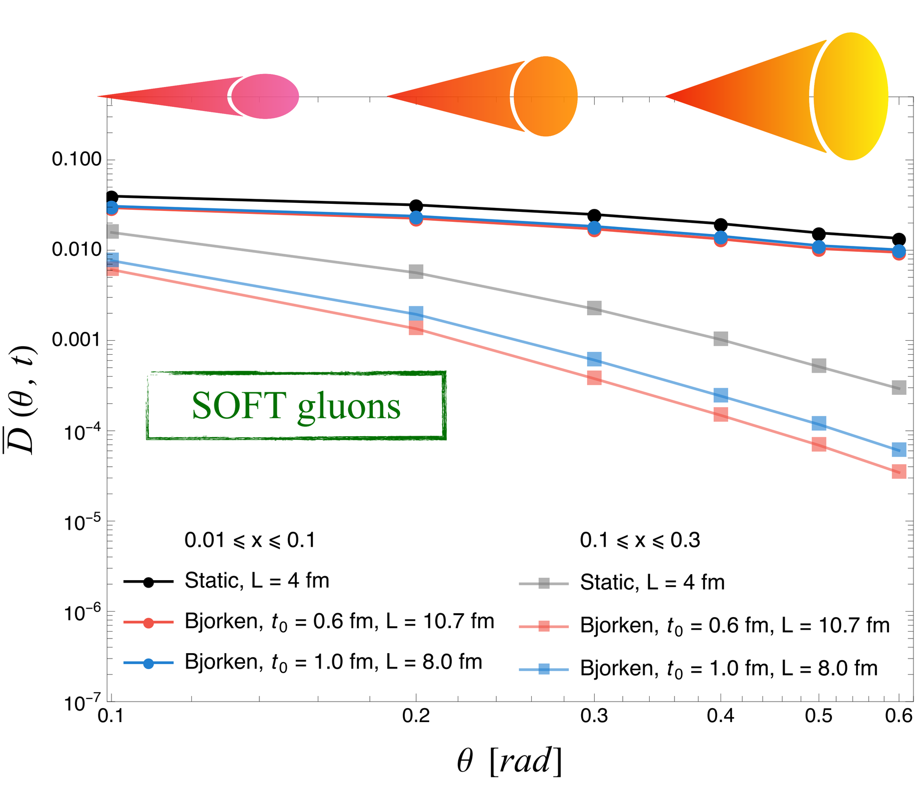
Scaling in the spectrum ..

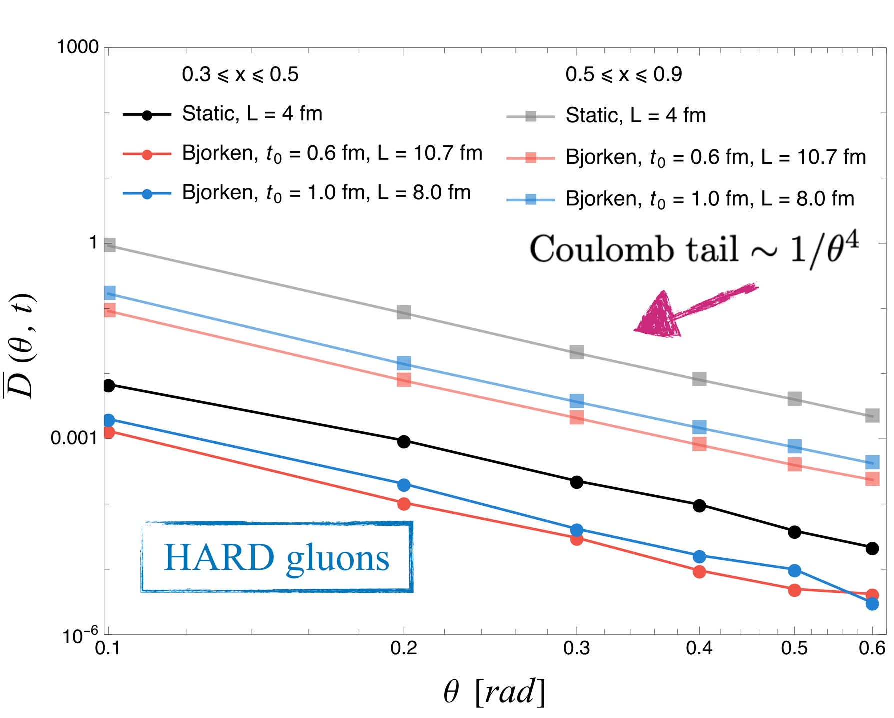
$k_T\sim xE\theta$





- As one opens up the angle, recovery of more softer gluons.
- No change of harder gluons as they primarily remain collimated.
- Hard jet fragments are *sensitive* to medium expansion, softer ones are not.



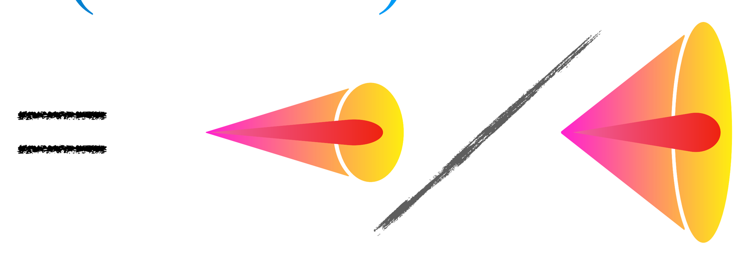


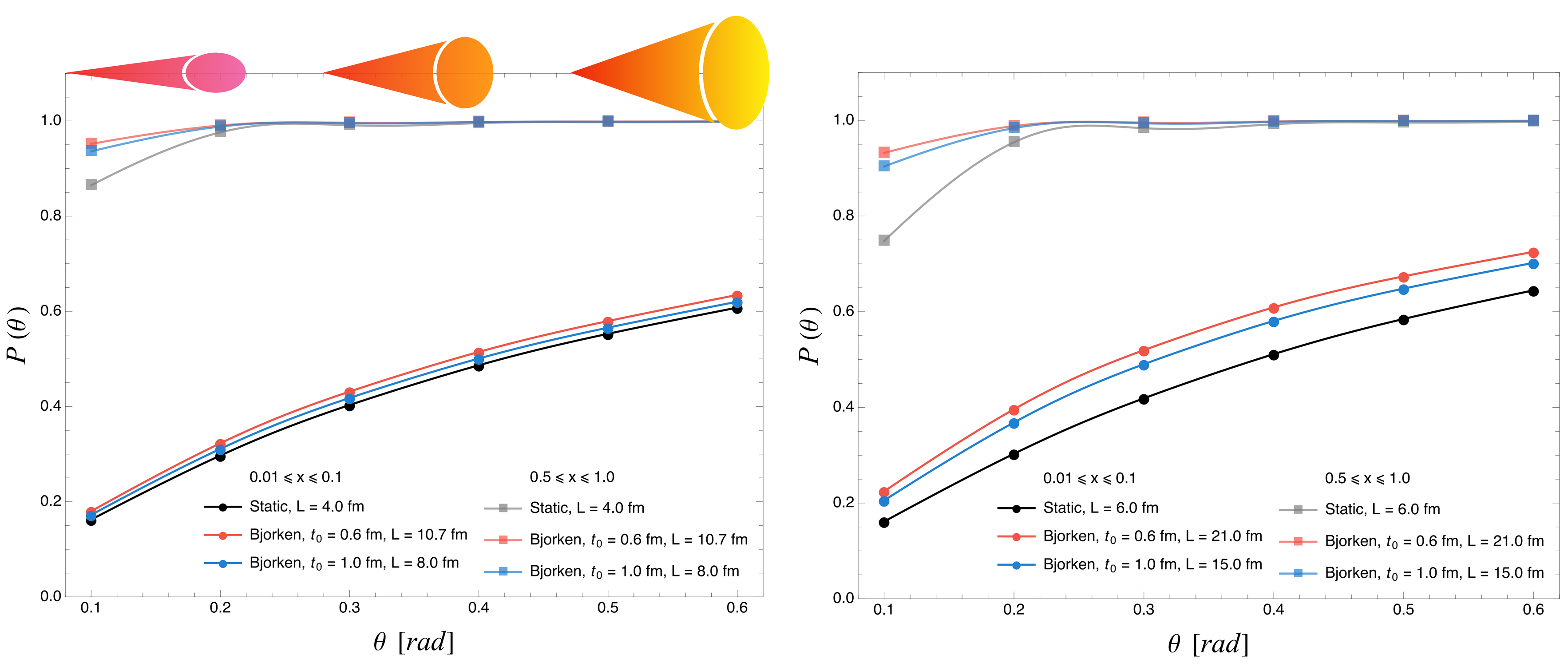
- Energy is re-distributed to larger angles for softer gluons.
- Collinear radiation with insignificant transverse momentum broadening for hard gluons.

What we interpret ?

Which gluons we capture (in- cone) ..

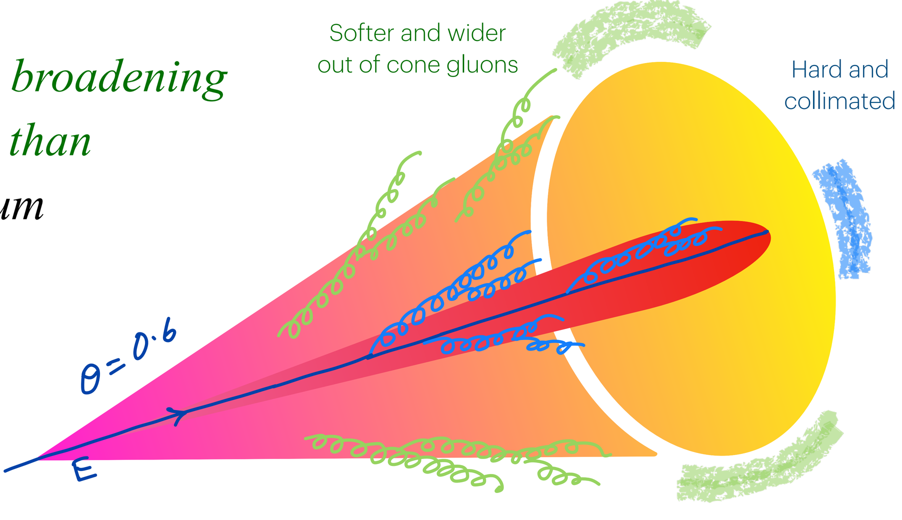
$$P(\theta,t;\{x_{\min},x_{\max}\})=\frac{\int_{x_{min}}^{x_{max}}\mathrm{d}x\int_0^{\theta}\mathrm{d}\theta'\,\bar{D}(x,\theta',t)}{\int_{x_{min}}^{x_{max}}\mathrm{d}x\int_0^{\pi}\mathrm{d}\theta'\,\bar{D}(x,\theta',t)}$$





- Hard sector: Medium recovers most of the energy already at θ = 0.2; insensitive to medium expansion.
- Soft sector: Gluon cascade is narrower in the expanding medium than static medium.

- *Hard partons remain collinear, momentum broadening pre-dominantly caused by splittings rather than medium collisions and transverse momentum exchanges.*
- *In soft sector, broadening by subsequent gluon splittings contributes to out of cone energy loss at large angles.*



- *Harder and softer jet fragments within a cone are sensitive to details of medium expansion.*
- *Cascades in expanding media more collimated than static media.*

Adhya, Kutak, Placzek, Rohrmoser, Tywoniuk, 2022

References:

Fellowship Agreement No: PAN.BFD.S.BDN.612.022.2021, PASIFIC Program, Horizon 2020 within the Marie Sklodowska Curie Actions.