# Probing QCD media with projected energy correlators

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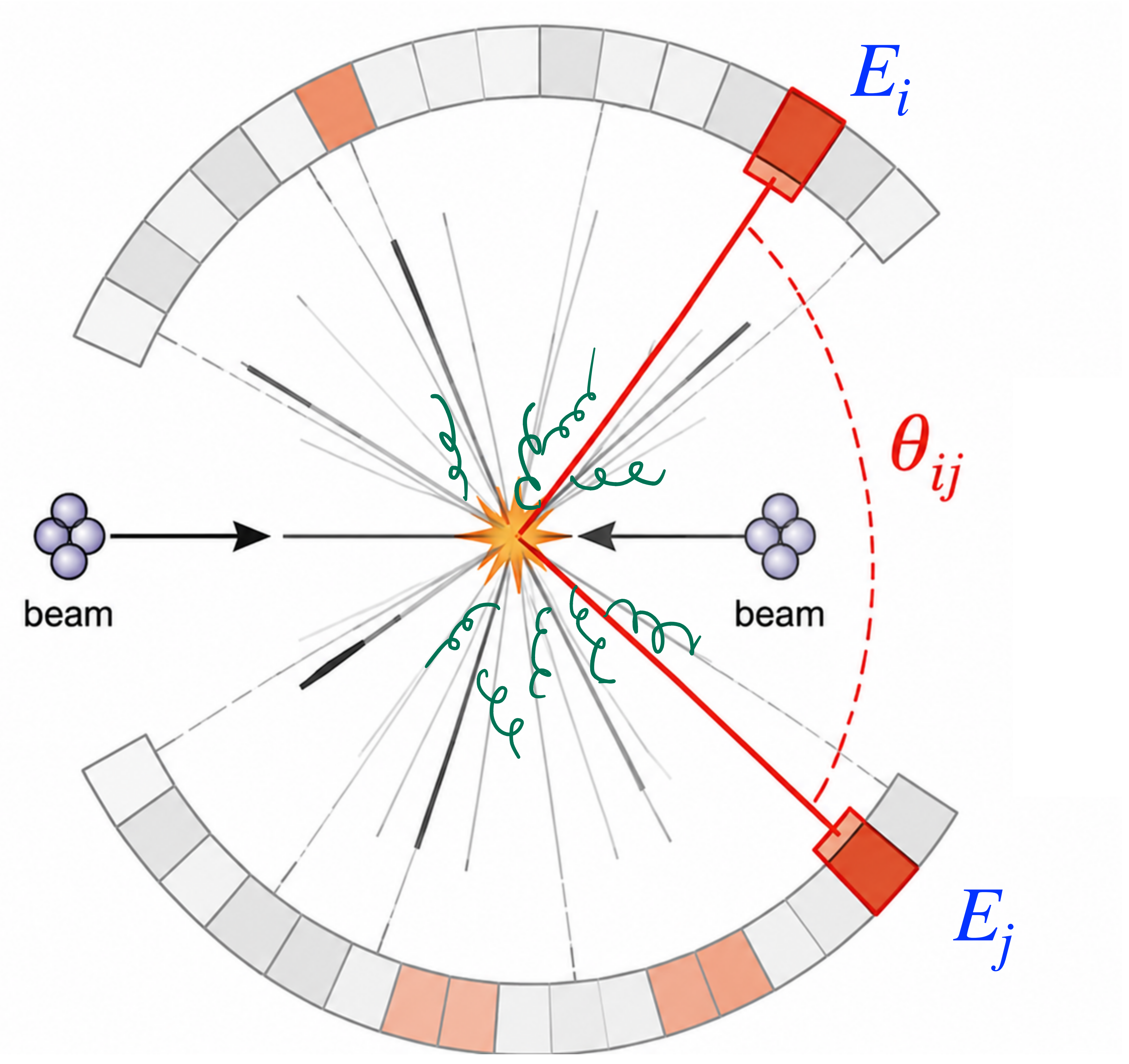
EMMI Workshop: Probing the early stages with jets, July 13-17, 2026

# Energy-energy correlator

Measure correlations of energy flow as a function of angular separation between particles

Two point energy correlator, EEC




$$\frac{d\Sigma_{\text{EEC}}}{d\chi} \simeq \sum_{ij} \int \frac{d\sigma}{Q^2} \underbrace{E_i E_j}_{\text{Energy weights}} \underbrace{\delta(\chi - \theta_{ij})}_{\text{Angular measurement}}$$

$\theta_{ij} \longrightarrow$ angular separation between particles

Probe evolution of QCD radiation, DGLAP

IRC safe, well defined in QFT

Perturbatively calculable

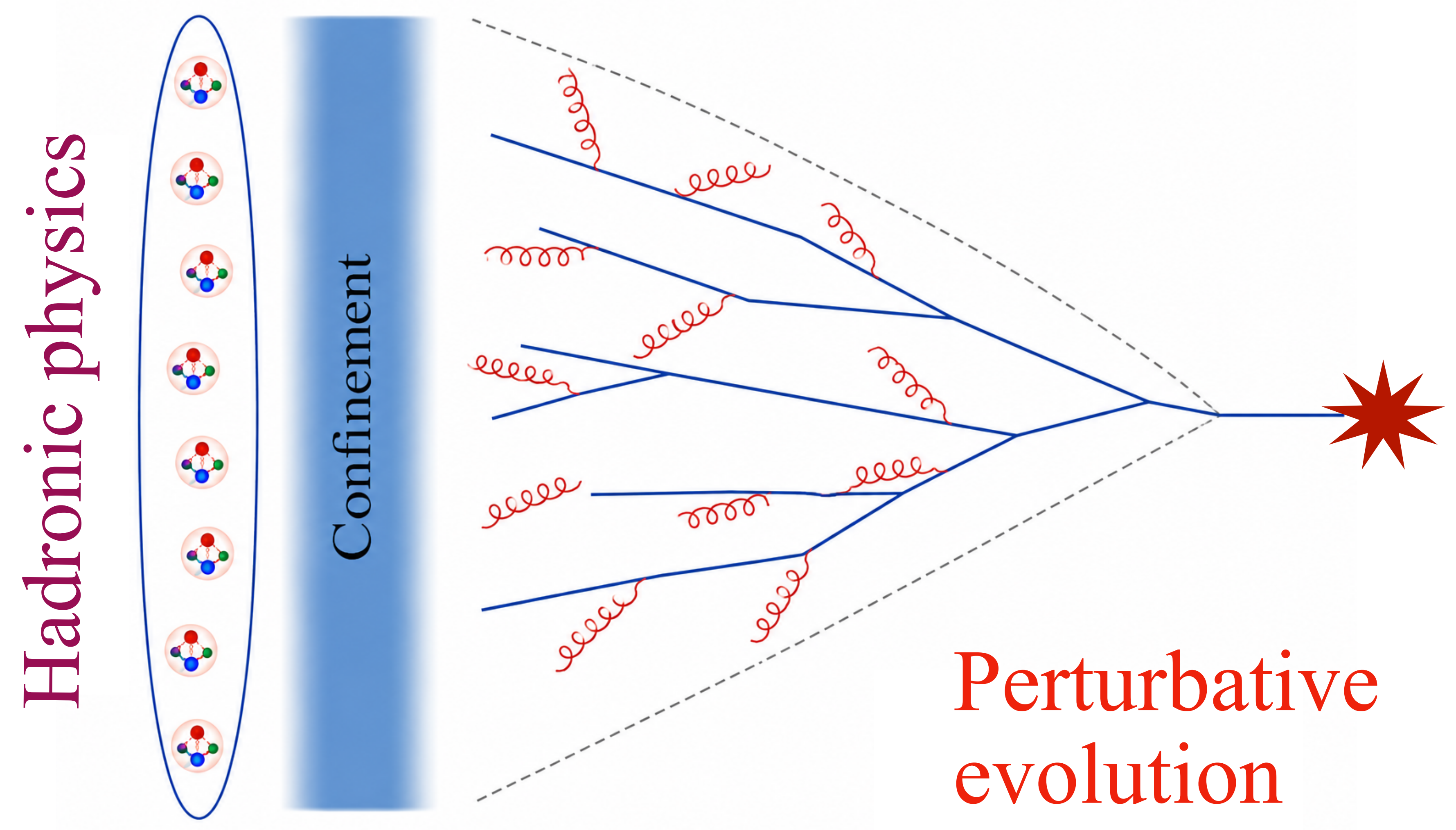
Sensitive to confinement and medium modifications in HICs

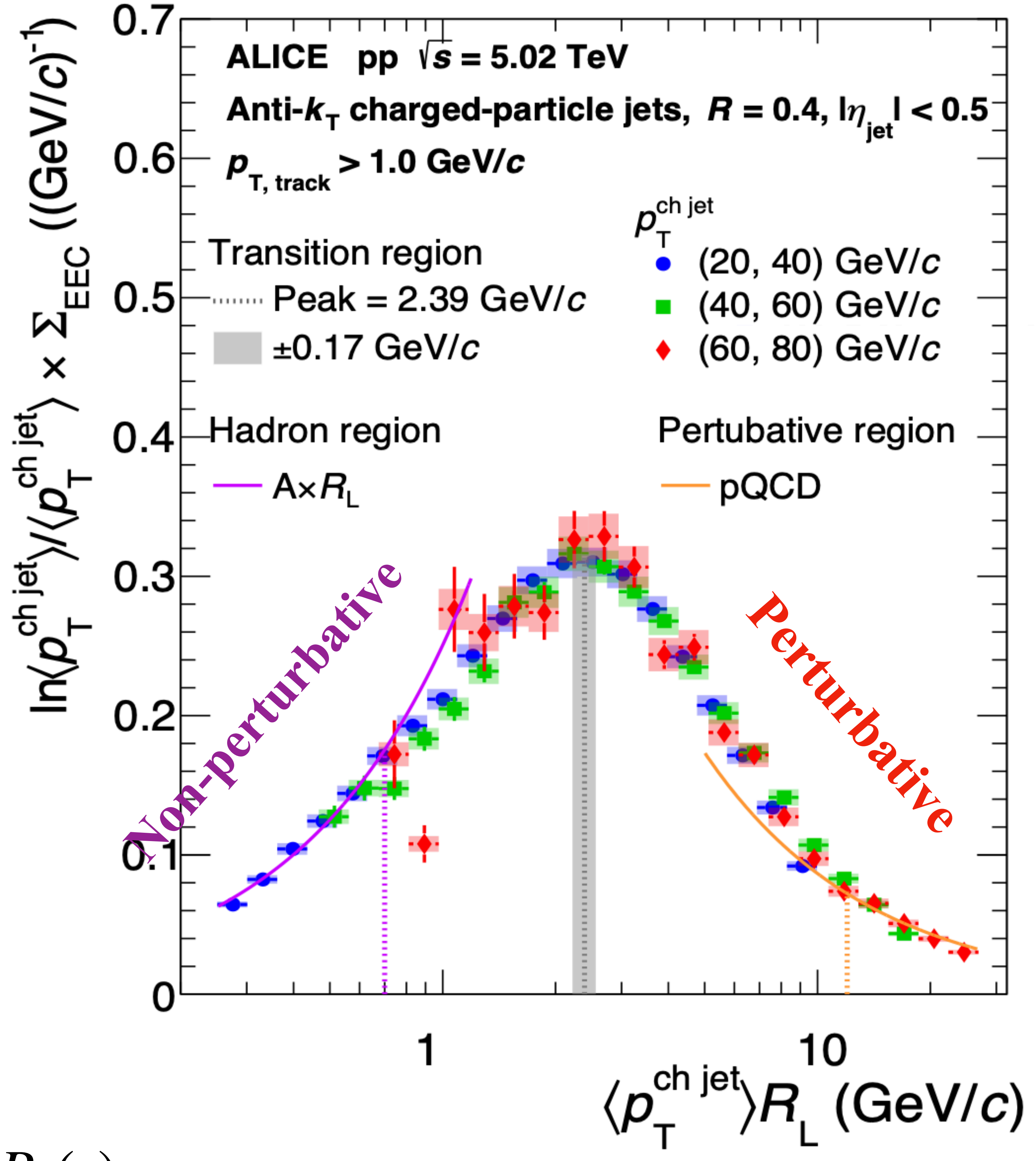
**For jets**: $i, j$ are particles inside the jet

**Notations**: $\chi, \theta, R_L$ are same variable

# Why Energy correlators

Single measurement images the entire evolution from perturbative production to non-perturbative hadronization




Two distinct scaling behaviors

Access to anomalous dimension

Collinear limit $\dfrac{d\Sigma_{\mathrm{EEC}}^{\mathrm{pert}}}{d\chi} \sim \chi^{-1+\gamma(3)}$

$$\gamma(3) = -\int_0^1 dz\, z^2 P_{ij}(z)$$

2209.11236

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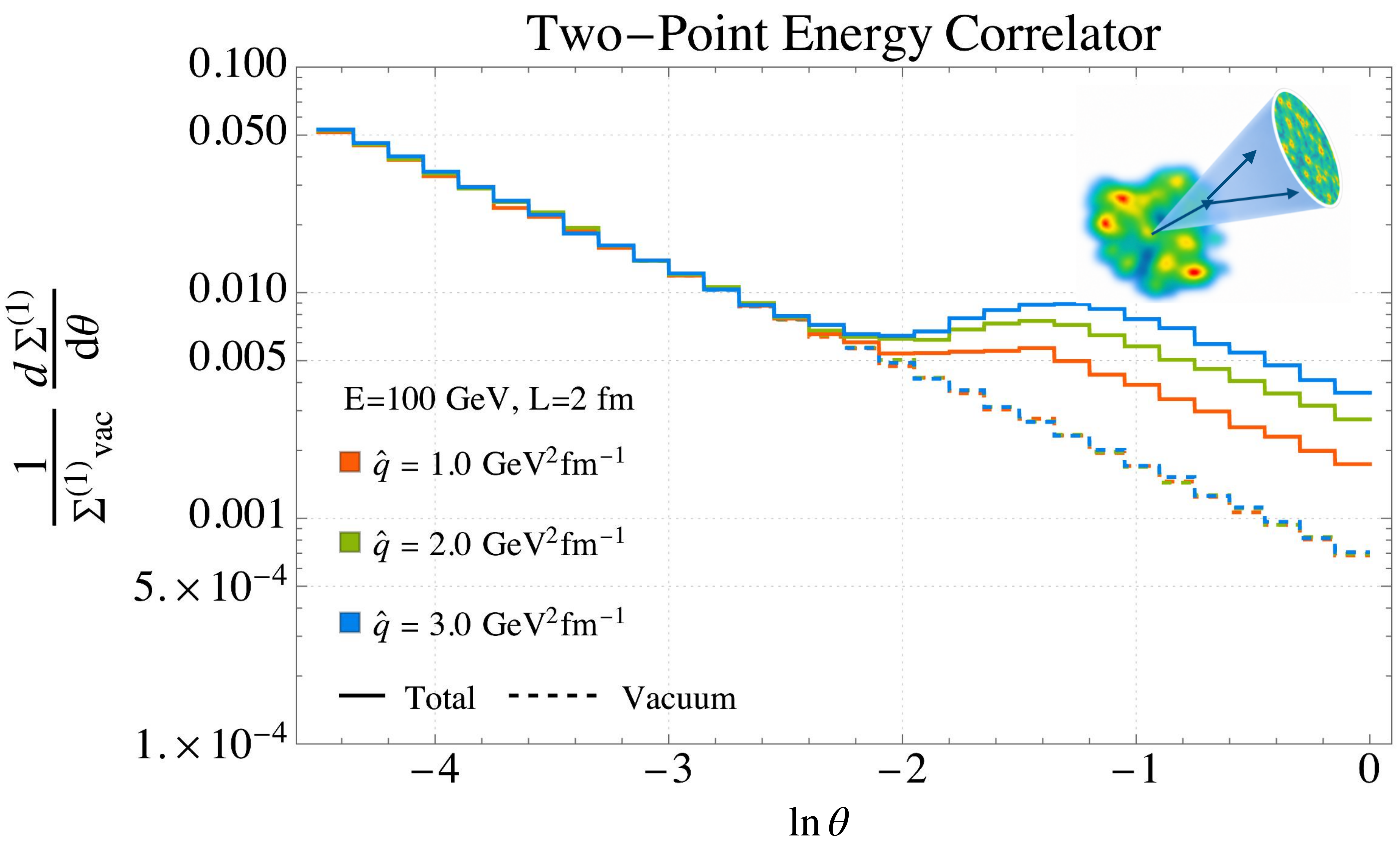
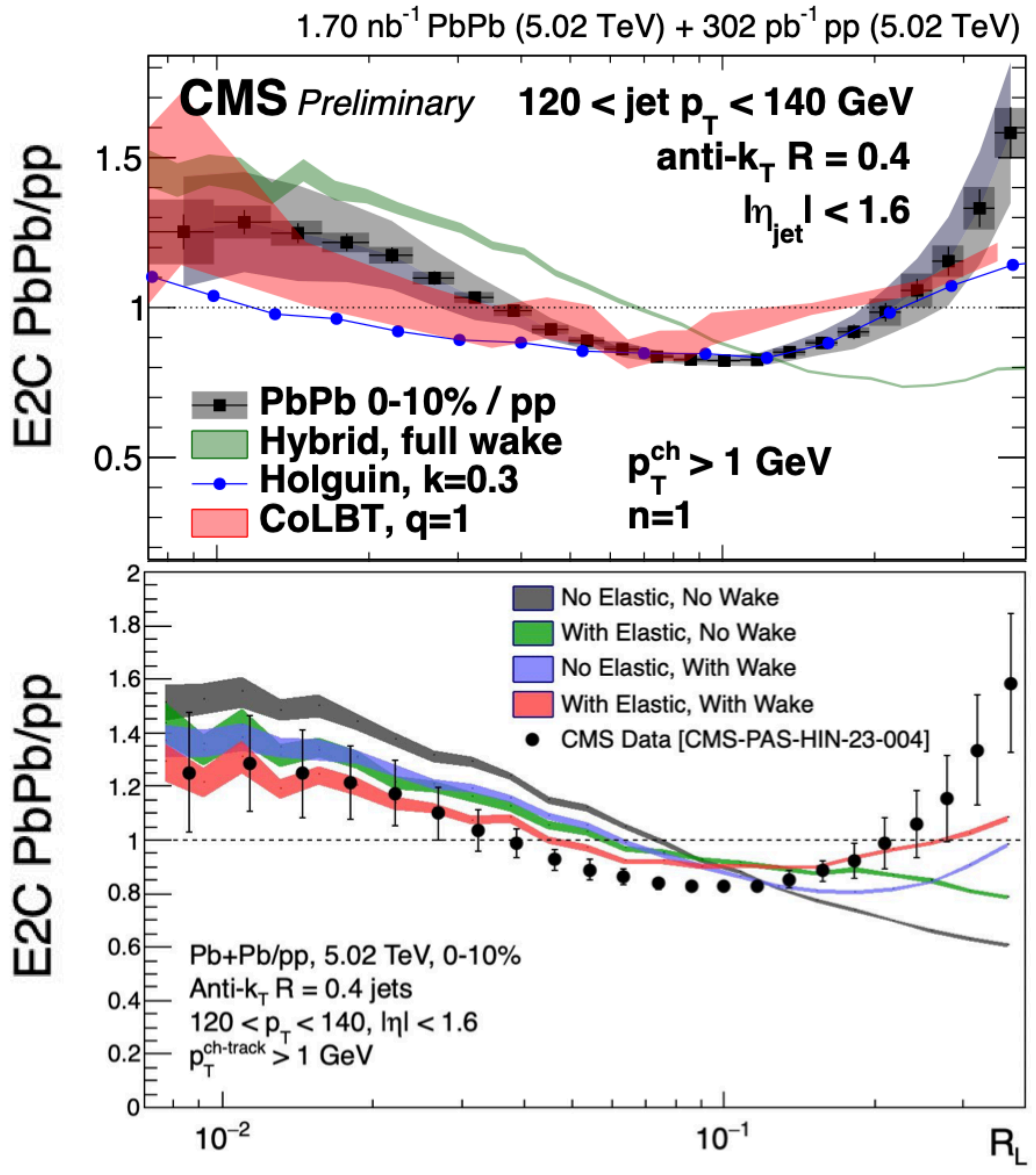
# Energy correlators in HICs

Medium induced dynamics is imprinted on final state distributions

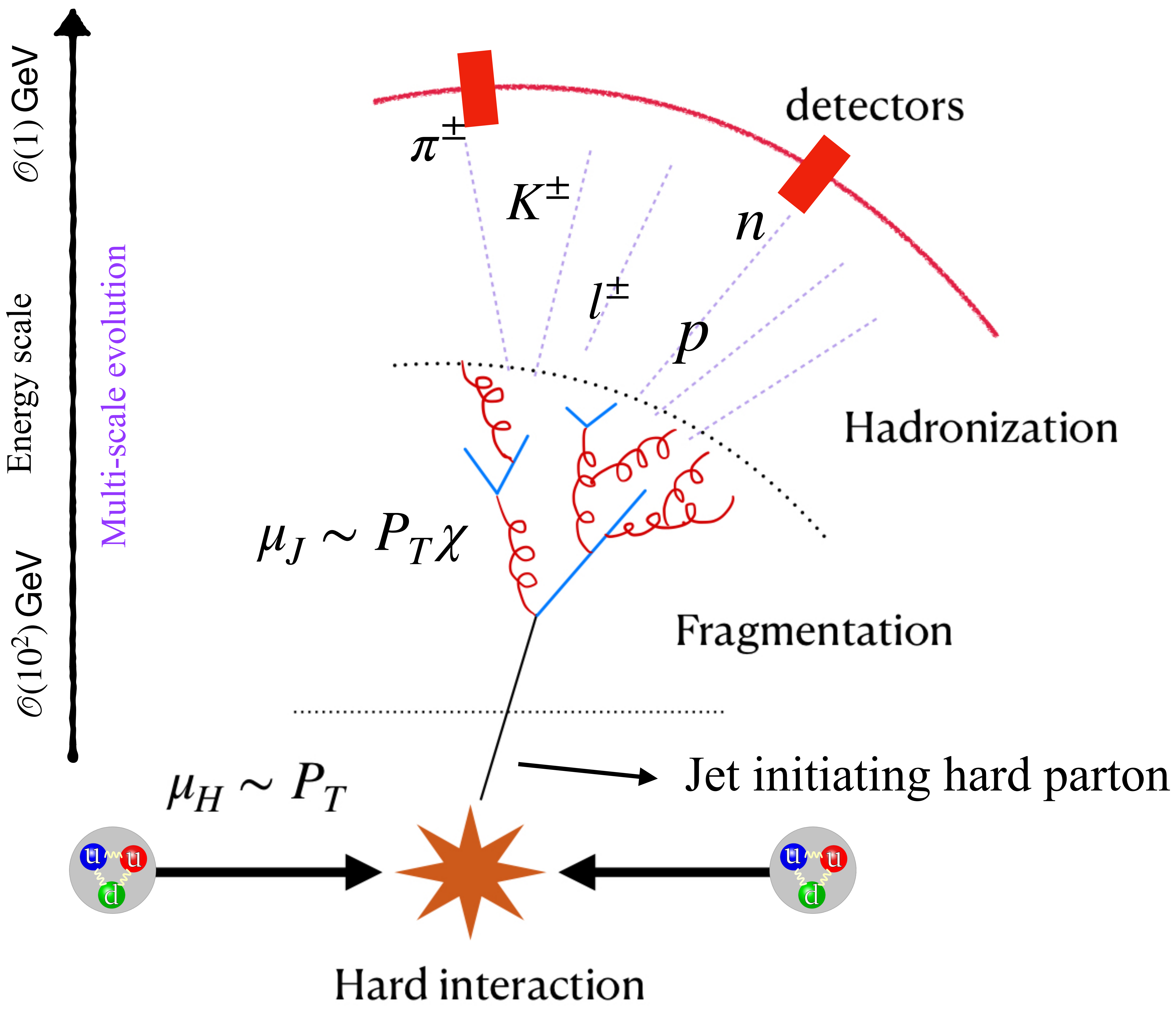
**Large angle:** medium induced + medium response



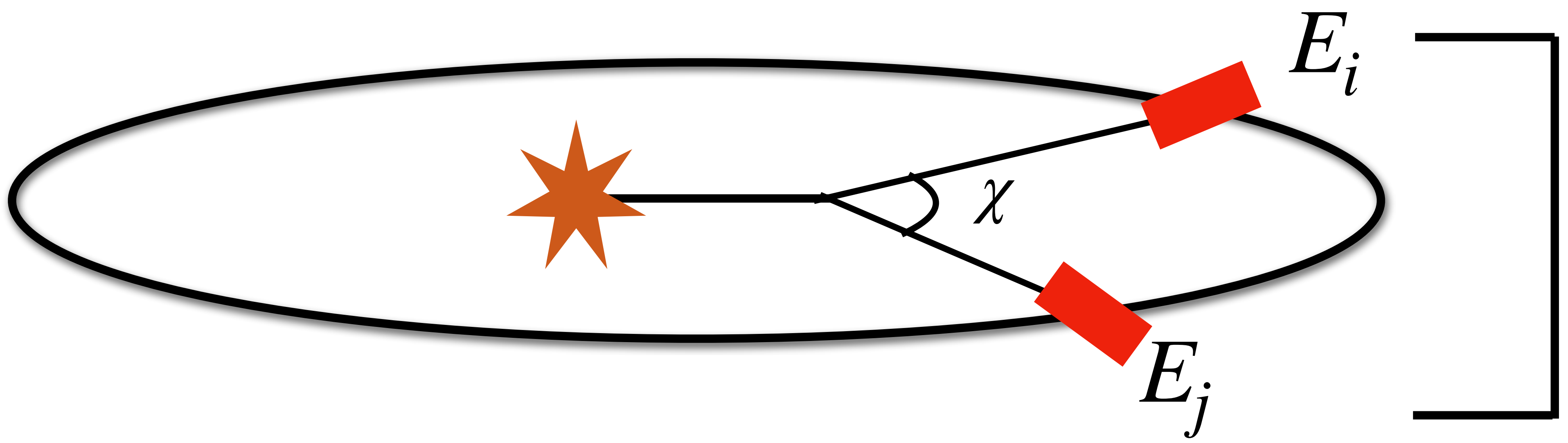




I will focus on factorization approach for a general class of energy correlators

# Factorization approach in pp collision




proton-proton collision




measurement

- ➡ $E_i$ and $E_j$ are energies of two particles
- ➡ In pp collision only two scales

$$\mu_H \sim p_T \qquad \mu_J \sim p_T\chi$$

- ➡ For $\chi \ll 1$ two scales are widely separated

$$\mu_H \gg \mu_J$$

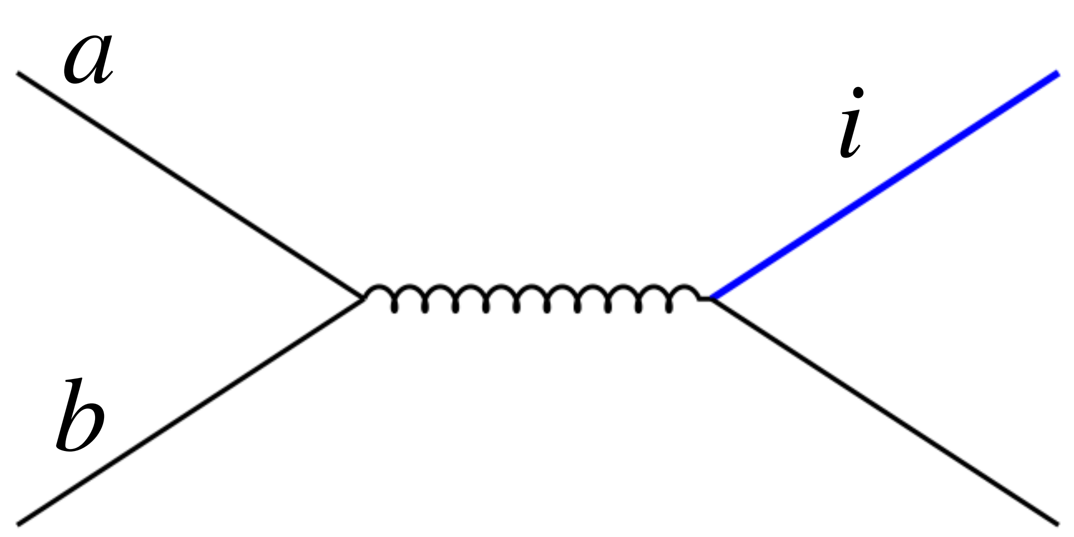
# Factorization approach in pp collision

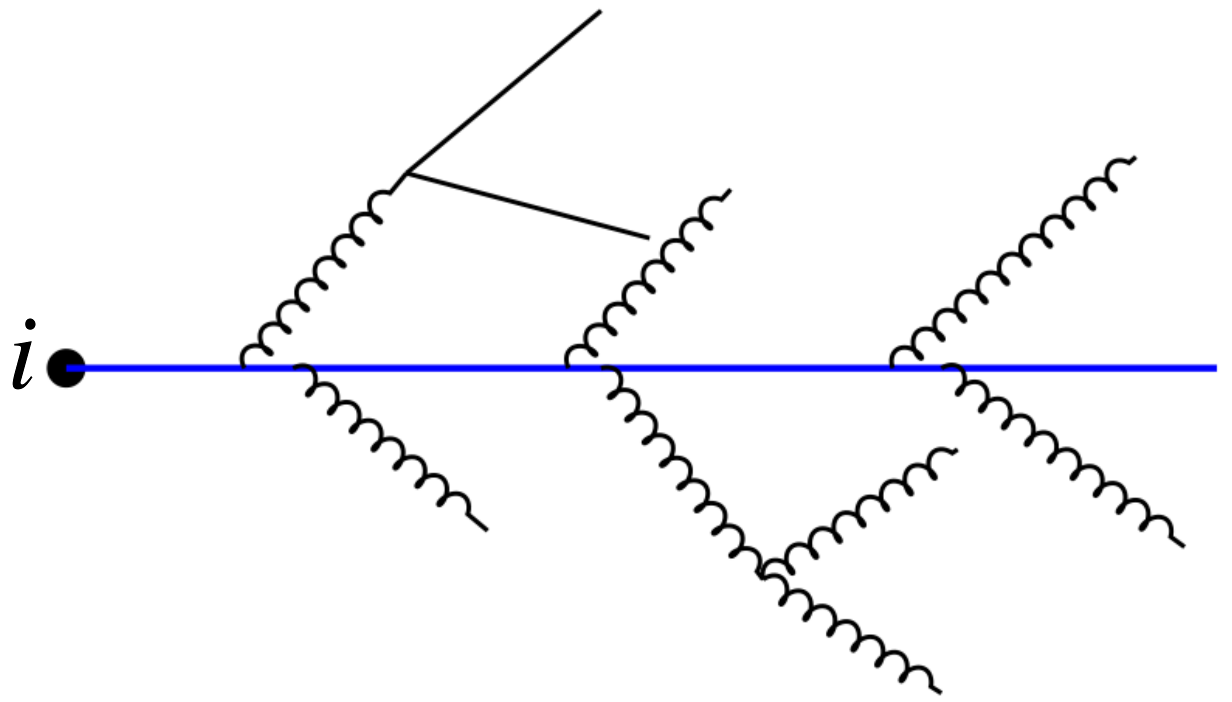
Differential cross section can be factorized; collinear limit $\chi \ll 1$

$$\frac{d\Sigma}{d\chi} = \sum_{a,b,i} \int dx\, x^2\, H_{a\,b\to i}(Q,\mu)\; J_i(Q,\chi,\mu)$$

hard function

Jet function




Production mechanism

Subsequent evolution of jet

**Hard function:**

production of jet initiating parton, does not depend on final state measurements

**Jet function:**

subsequent evolution, depends on measurement on final state particles

DGLAP evolution

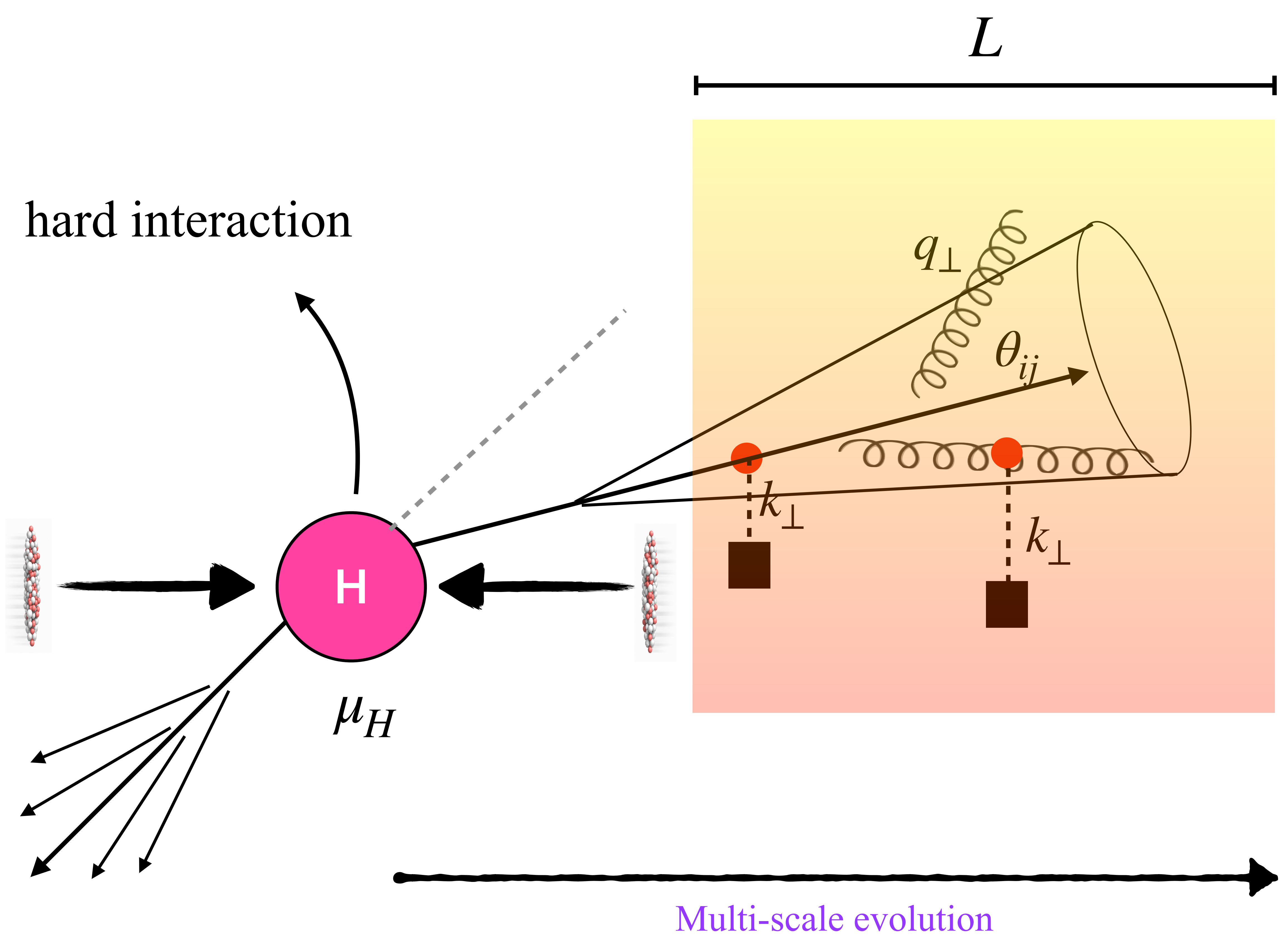
$$\frac{dJ_i(\mu)}{d\ln\mu} = 2\,\gamma(3,\alpha_s(\mu))\,J_i(\mu)$$

$$J(\chi) \sim \chi^{-1+\gamma(3)}$$

leading log accuracy

# Jet in a medium

Jet encounters various direct and indirect scales introduced by the medium




$l_{\mathrm{mfp}}$ → mean free path

$T \sim m_D$ → medium temperature

$\tau_f \sim \dfrac{E_g}{q_\perp^2}$ → formation time

Direct scales

$\hat{q}$ → jet quenching parameter

$\theta_c \sim \dfrac{1}{\sqrt{\hat{q}L^3}}$ → critical angle

emergent scales

Scale hierarchy: $\mu_H \gg \mu_J, T \sim m_D \geq \Lambda_{QCD}$

We will use these scales as a guide for the EFT

$g \sim \mathcal{O}(1)$, so $T$ and $m_D$ are not separate scales

# Soft Collinear Effective Theory (SCET)

SCET 1410.1892

EFT of QCD designed to study collinear and soft radiations

Collinear: boosted along jet direction

$$A^\mu = A_n^\mu + A_s^\mu \qquad \psi = \xi_n + \psi_s$$

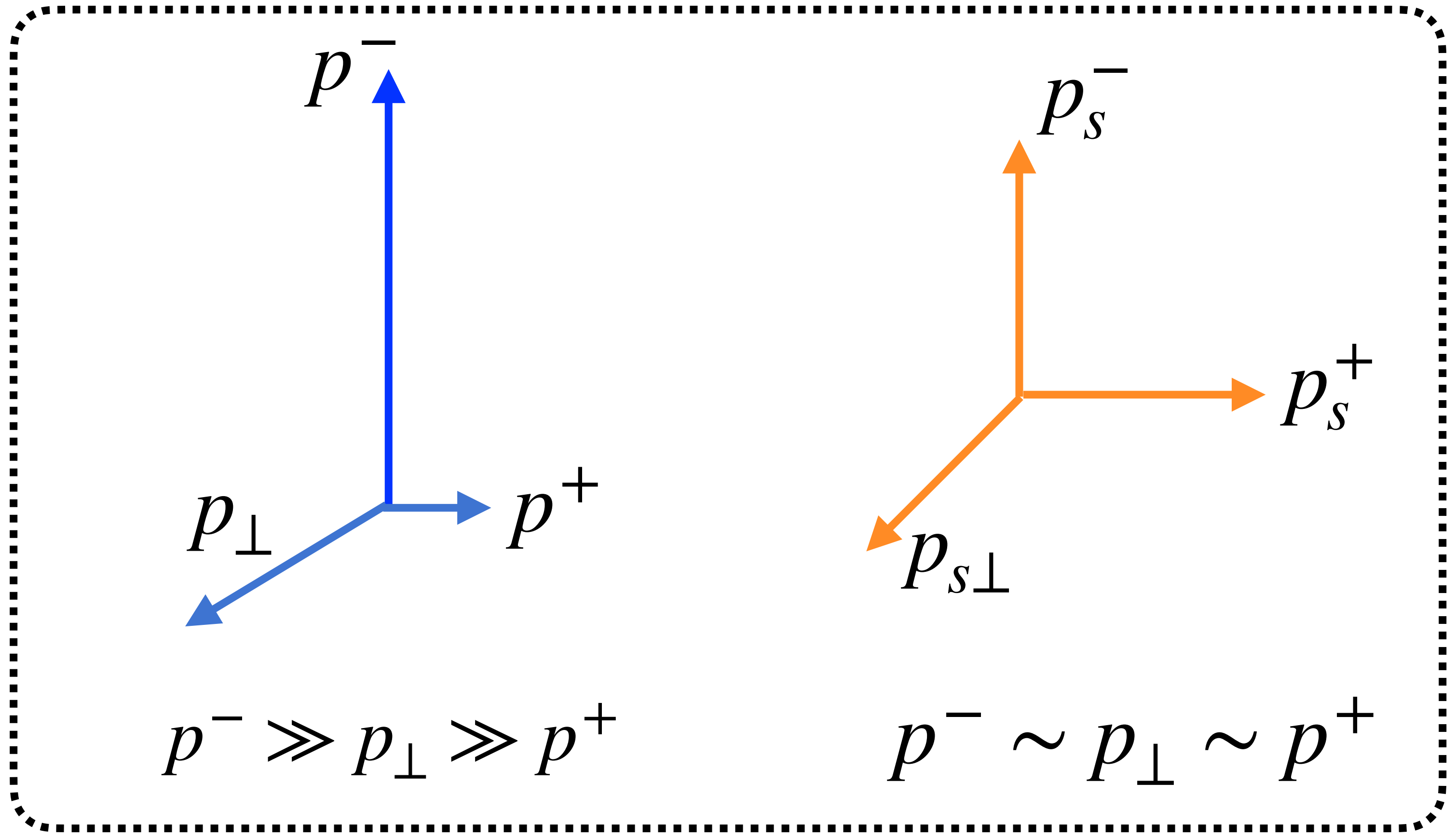
$$\mathscr{L}_n^0 = \bar{\xi}_n \left( in\cdot D + iD_\perp \frac{1}{i\bar{n}\cdot D} iD_\perp \right) \frac{\bar{n}}{2} \xi_n$$

Soft : no preferred direction

$$\mathscr{L}^0_{\mathrm{SCET}} = \mathscr{L}_s(\psi_s, A_s) + \sum_{n_i} \mathscr{L}^0_{n_i}(\xi_{n_i}, A_{n_i}) + \mathscr{L}_G(\xi_{n_i}, A_{n_i}, \psi_s, A_s)$$

SCET building blocks

- All collinear emission $\mathscr{L}_n^0$
- Medium interactions $\mathscr{L}_s$ (same as full QCD Lagrangian)
- Jet and medium interactions $\mathscr{L}_G$



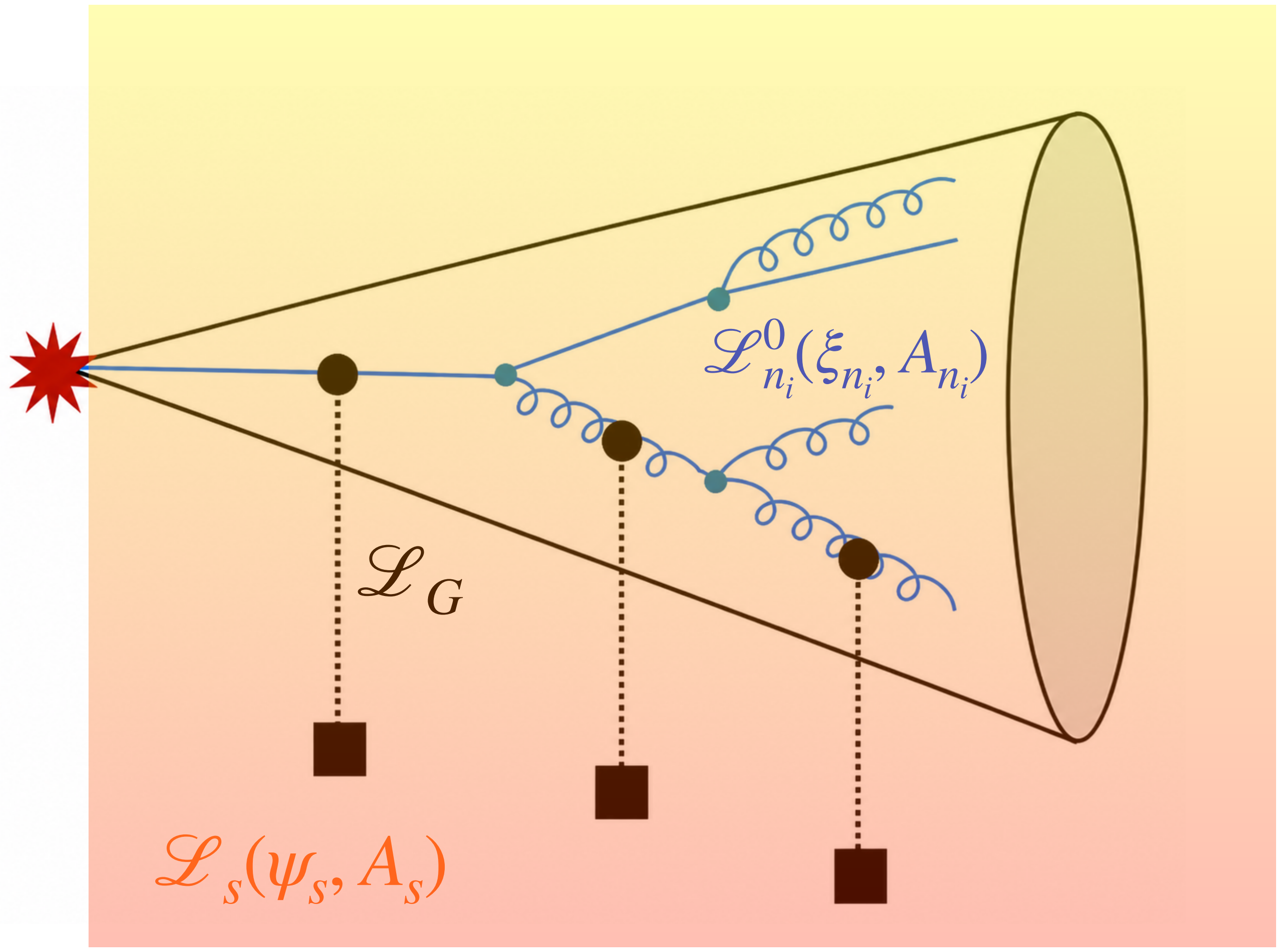

$n^\mu = (1,0,0,1)$

$\bar{n}^\mu = (1,0,0,-1)$

$p^\mu = (p^-, p^+, \vec{p}_\perp)$

$p^+ = n\cdot p$

$p^- = \bar{n}\cdot p$




Jet-medium interaction

# Glauber operators in EFT

Glauber operators are made up of bilinears in each sector and are Gauge invariant

$$\boxed{\mathscr{L}_G(x) = \sum_{ij=q,g} C_{ij} O_{ns}^{ij}(x)}$$

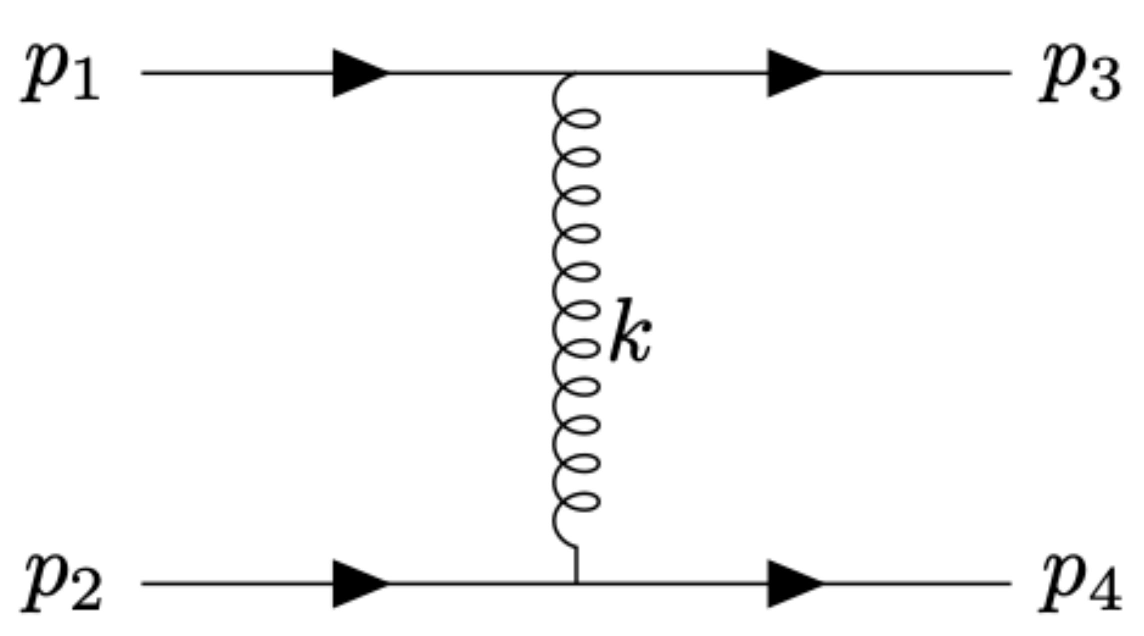
$$\mathcal{O}_{ns}^{qg} = O_n^{qA} \frac{1}{\mathbb{P}_\perp^2} O_s^{gA} \qquad \mathcal{O}_{ns}^{qq} = O_n^{qA} \frac{1}{\mathbb{P}_\perp^2} O_s^{qA}$$

$$\mathcal{O}_n^{qA} = \bar{\chi}_n T^A \frac{\bar{n}}{2} \chi_n \qquad \chi_n = W_n \xi_n$$

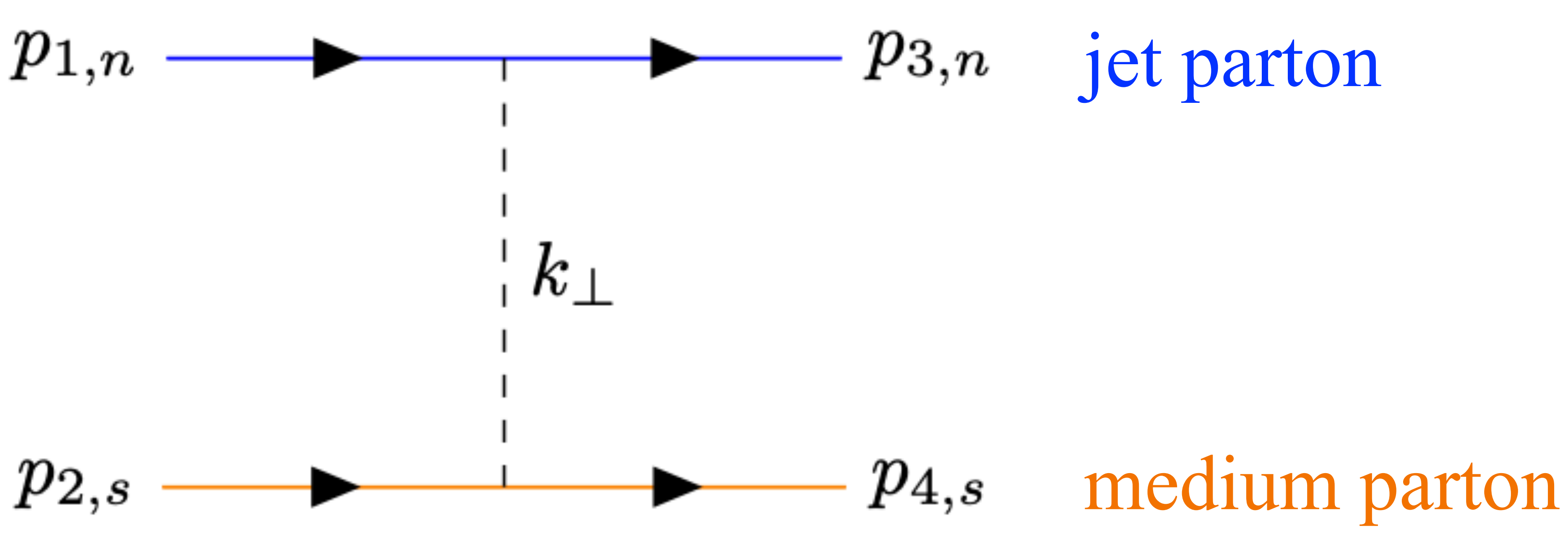
$$\mathcal{O}_s^{qA} = \bar{\psi}_s T^A \frac{n}{2} \psi_s \qquad W_n(x) = \mathrm{P}\exp\left[ ig \int_{-\infty}^{0} ds\, \bar{n} \cdot A_n(x + s\bar{n}) \right]$$

$\mathbb{P}_\perp$ is transverse momentum operators that pulls out Glauber gluon momentum from medium operators

$C_{ij}$ is Glauber Wilson coefficient fixed by the matching between full QCD and EFT




Full QCD diagram



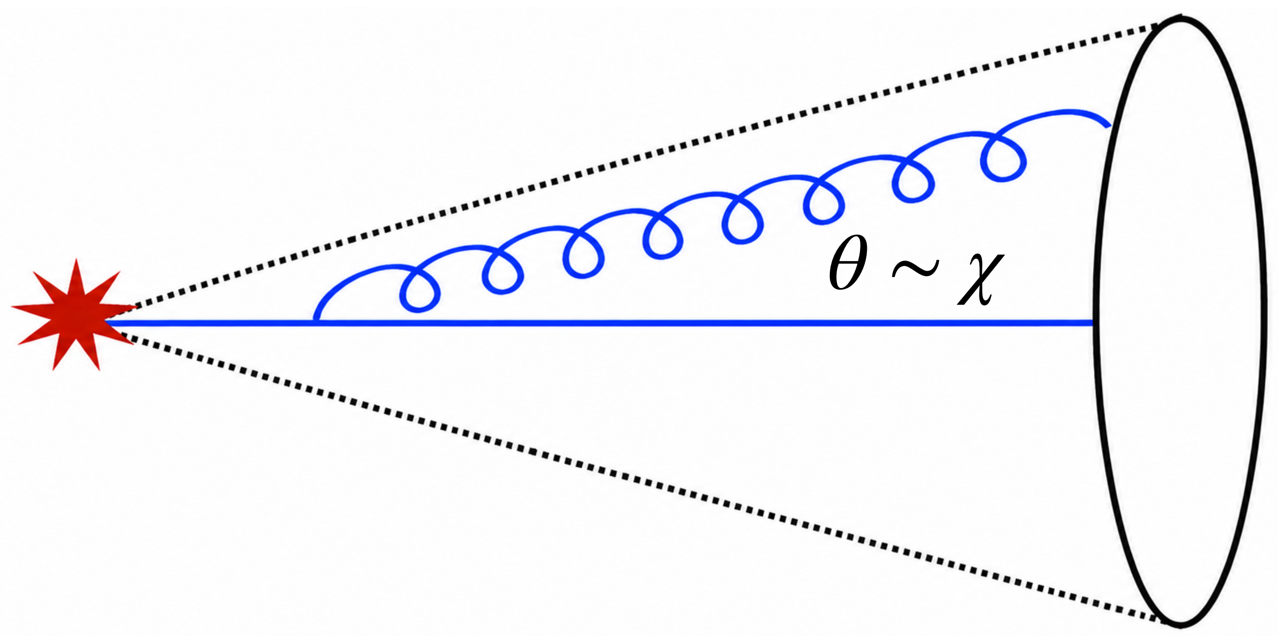

EFT diagram

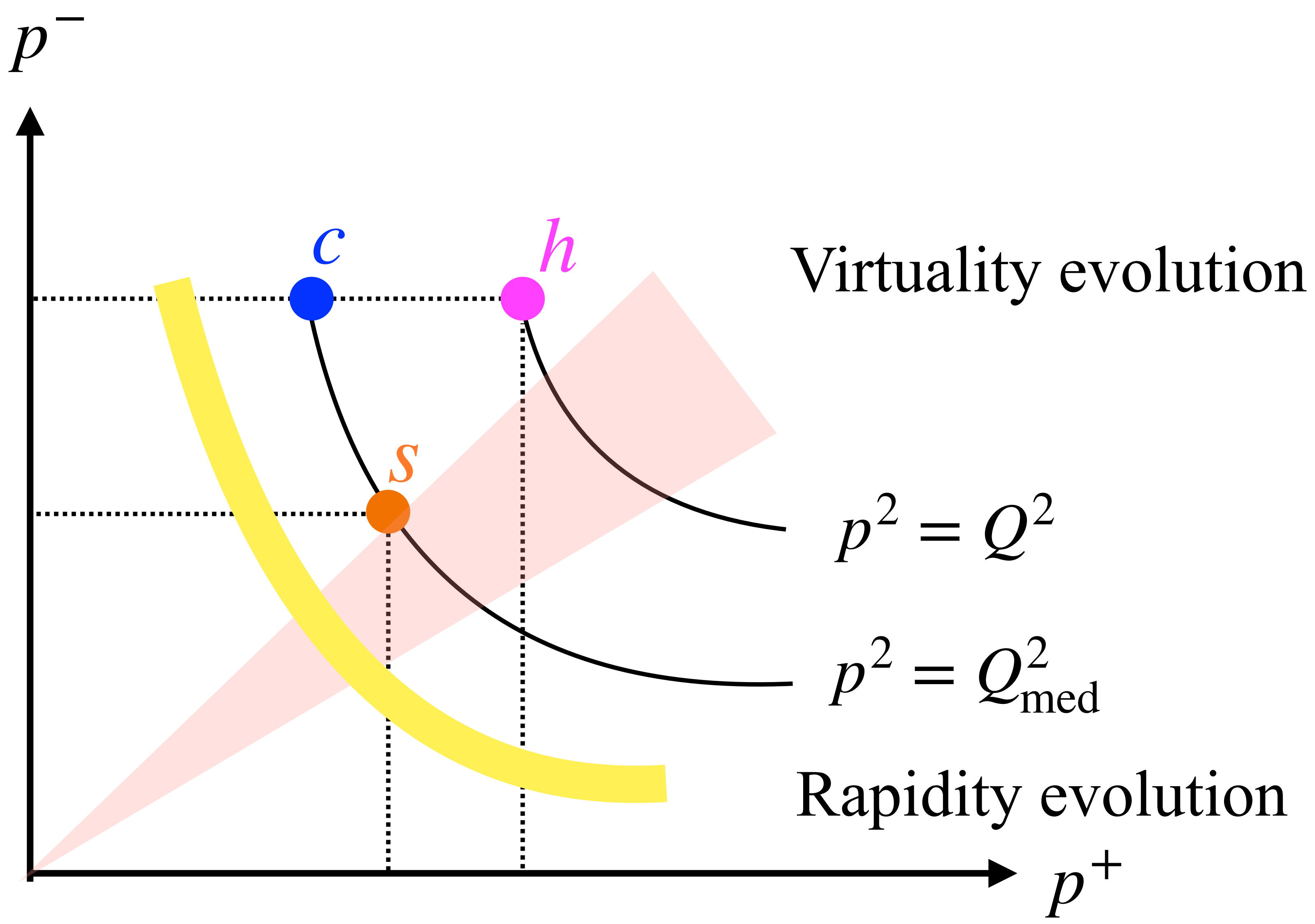
# EFT landscape

At least four momentum modes to describe jet evolution in a medium

| **Mode** | **Momentum scaling** $p = (p^-, p^+, p_\perp)$ | **Describes** | **Scale** |
|---|---|---|---|
| Hard | $p_h \sim Q(1,1,1)$ | hard production | $Q \sim \mathcal{O}(p_T)$ production scale |
| Collinear | $p_c \sim Q(1,\lambda^2,\lambda)$ | jet evolution | $p_{c\perp} = Q\lambda = Q\chi$ |
| Soft | $p_s \sim Q(\lambda,\lambda,\lambda)$ | medium dynamics | $Q\lambda = T \approx Q_{\rm med}$ |
| Glauber | $p_G \sim Q(\lambda,\lambda^2,\lambda)$ | jet-medium interaction | off-shell modes |

Scaling of c mode is fixed by the measurement $p_{c\perp} = Q\lambda = Q\chi$



# Jet as open quantum system

Jet propagating is non-equilibrium evolution in a thermal bath

treat jet as open quantum system

1. Factorized initial density matrix; decoupled

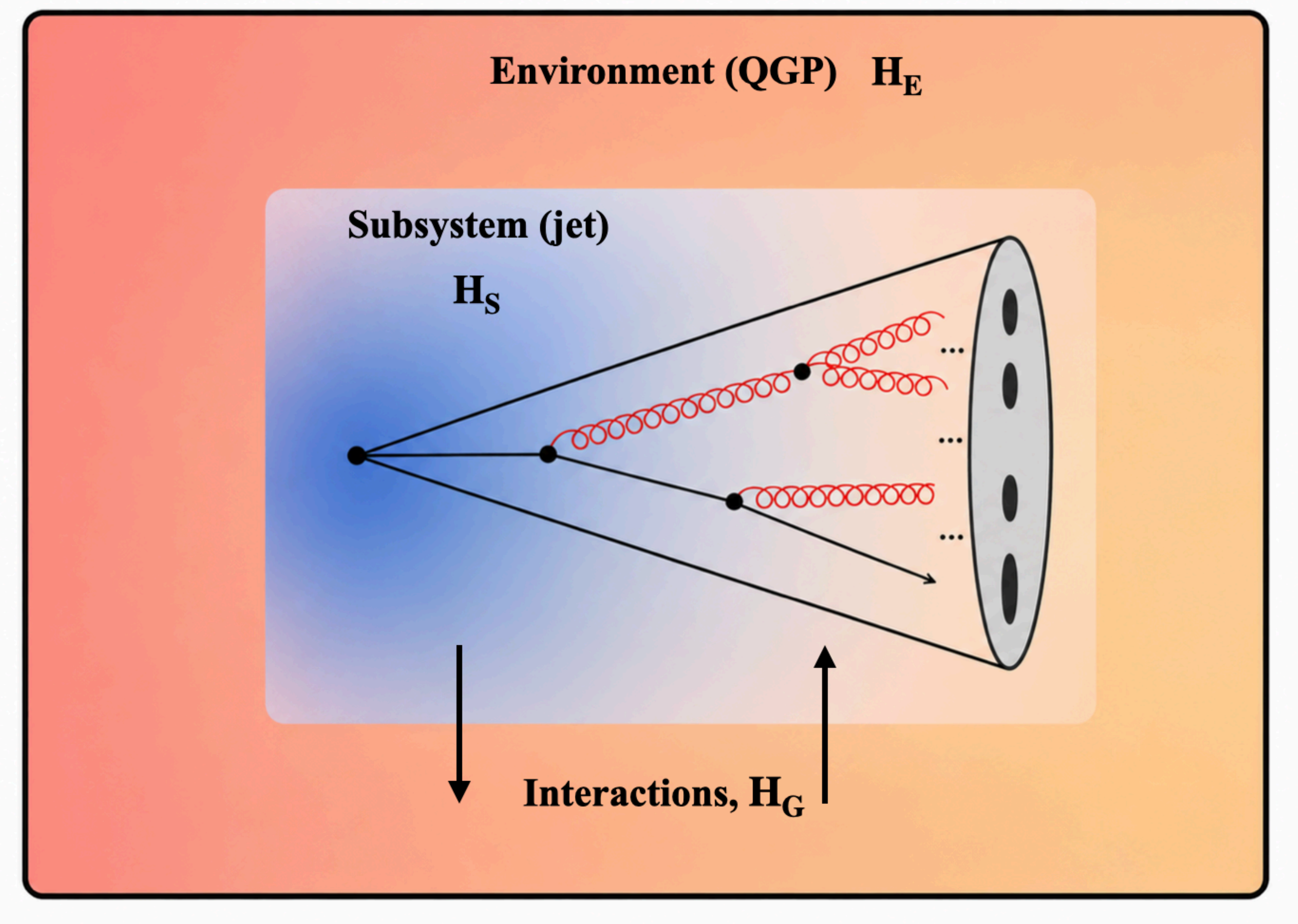
$$\rho(0) = |e^+e^-\rangle\langle e^+e^-| \otimes \rho_E(0) \qquad \rho_E = \frac{e^{-\beta H_E}}{\mathrm{Tr}[e^{-\beta H_E}]}$$

2. Time evolution of the jet is defined through system density matrix evolution

$$\rho(t) = e^{-iHt}\rho(0)e^{iHt}$$

3. Compute the jet observable ($\mathscr{M}$- Two point Energy correlator)

$$\frac{d\sigma}{d\chi} = \lim_{t\to\infty} \mathrm{Tr}_{\mathrm{E}}[\rho(t)\mathscr{M}] \longrightarrow$$ Trace out the bath



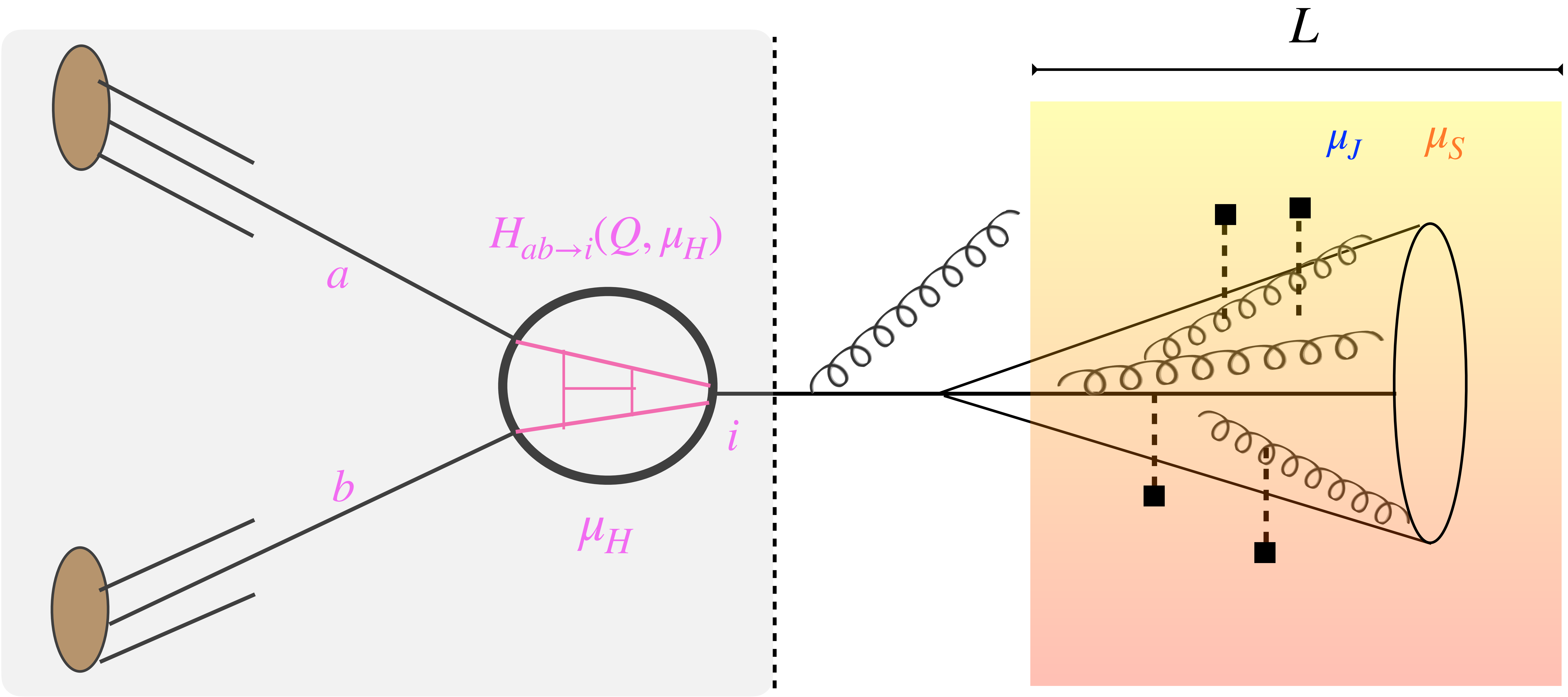

$$H = H_S + H_E + H_G + C(Q)l^\mu j_\mu \equiv H_0 + \mathcal{O}_H$$

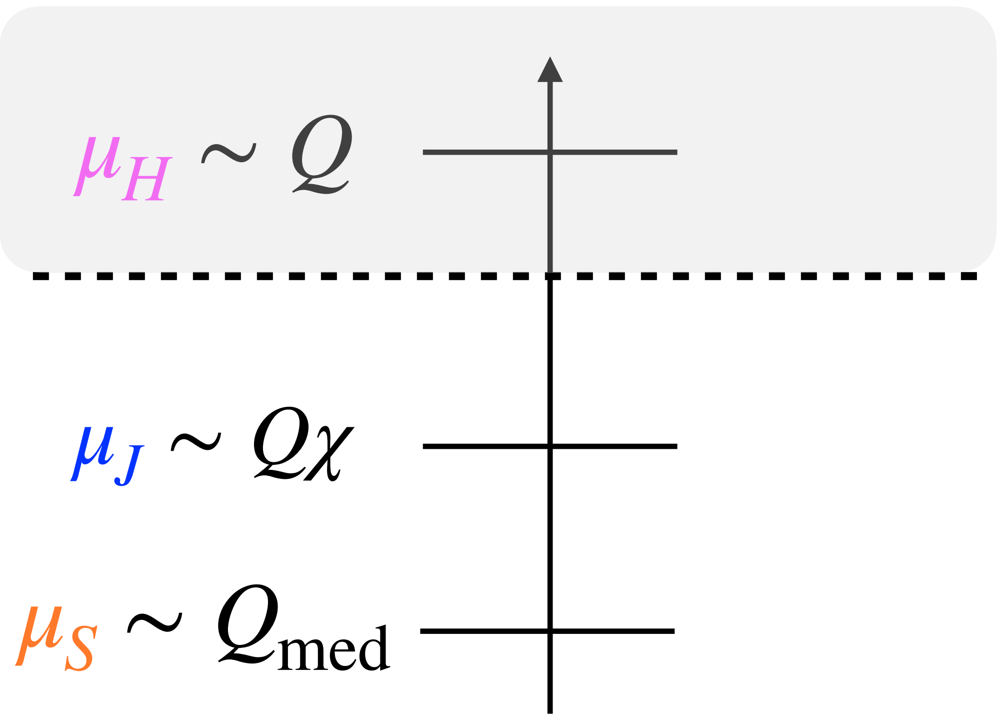
Hard interaction

$$j^\mu = \bar{\chi}_n \gamma^\mu \chi_n$$

# Factorizing hard function

OPE factorizes hard production of the jet




Scale separation

$$\frac{d\sigma}{d\chi} = \sum_{i\in\{q,\bar{q},g\}} \int dx\, x^2 H_{ab\to i}(Q,\mu) J_i(L,\chi\,;\mu_J,\mu_s)$$

Hard function is universal

# Measurement factorization

$$J_q(\chi) = \frac{1}{2N_c}\sum_X \mathrm{Tr}\Big[\rho_E(0)\frac{\bar{n}}{2}e^{iH_{ns}t}\,\underbrace{\bar{\mathbf{T}}\Big\{e^{-i\int_0^t dt' H_{G,I}(t')}\chi_{n,I}(0)\Big\}}_{\text{Glauber interaction}}\mathscr{M}\,|X\rangle\langle X|\,\underbrace{\mathbf{T}\Big\{e^{-i\int_0^t dt' H_{G,I}(t')}\bar{\chi}_{n,I}(0)\Big\}}_{\text{Glauber interaction}}\,e^{-iH_{ns}t}\Big]$$

Measurement function acts on state $|X\rangle$ which composed of both collinear and soft Fock spaces

$$|X\rangle = |X_n\rangle \otimes |X_s\rangle$$

$$\mathscr{M} = \hat{E}(\chi)|X\rangle = \frac{1}{Q}\sum_{i\in\{X_n,X_s\}}\Big(E_{i,n}\delta(\chi-\theta_{n,i}) + E_{i,s}\delta(\chi-\theta_{s,i})\Big)|X_n\rangle|X_s\rangle$$

Power suppressed contributions in the EFT

$$E_{i,n} \gg E_{i,s}$$

- Soft contributions to the measurement are power suppressed
- Glaubers being off-shell modes do not contribute to the measurement
- Only collinear modes contribute to the measurement at the final state

# Separating vacuum jet dynamics

Expanding the jet function in Glauber Hamiltonian gives vacuum jet function at leading order

$$J_q(\chi,\mu) = J_q^{(0)} + J_q^{(2)} + J_q^{(4)} + \ldots = \sum_{i=0}^{\infty} J_q^{(i)}(\chi,\mu)$$

$$J_q^{(0)}(\chi,\mu) = \frac{1}{2N_c}\sum_{X_n} \mathrm{Tr}\left[\frac{\bar{n}}{2}\langle 0|\chi_n(0)\mathscr{M}\,|X_n\rangle\langle X_n|\bar{\chi}_n(0)|0\rangle\right]$$

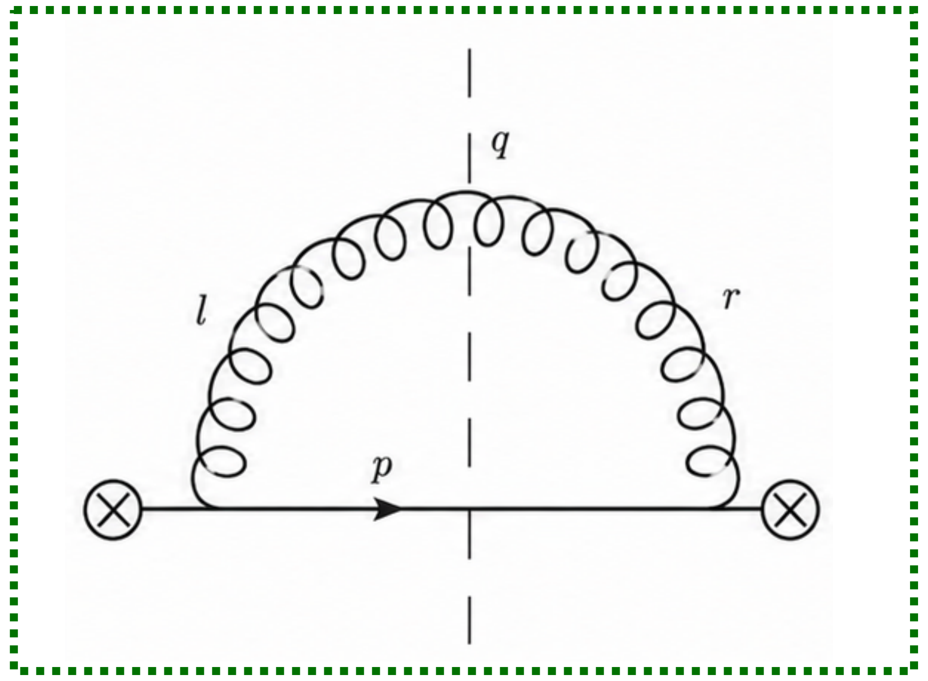
$i=0$, vacuum, no Glauber insertions

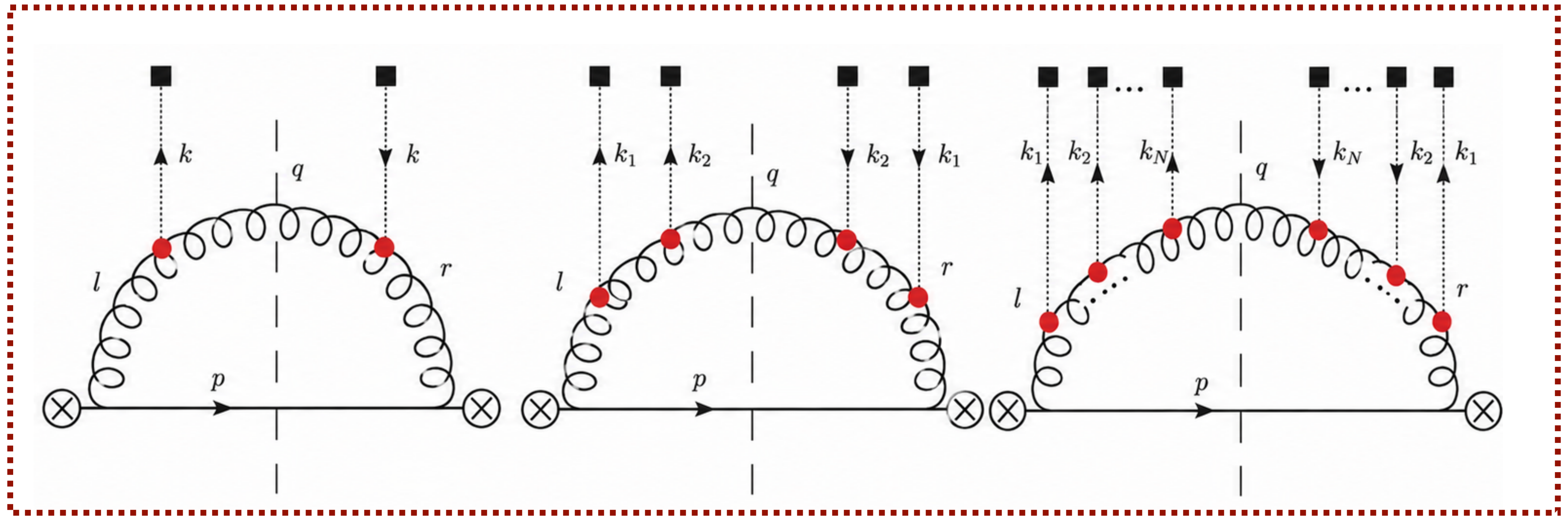
$i=2$, single scattering, dilute medium

$i\geq 4$, multiple scattering, dense medium

For $J_q^{(0)}$ soft function becomes identity; no medium $\quad \mathrm{Tr}[\rho(0)_E X_s\rangle\langle X_s|\,] = 1$

$$J_q^{(N)} \equiv \int \prod_{i=1}^{a} d^4x_i \prod_{j=1}^{b} d^4y_j Tr\Big[\rho_B \frac{\bar{n}}{2}\,\mathbf{T}\{O_{ns}^{qq}(x_1)\cdots O_{ns}^{qq}(x_a)\}\,\chi_{n,I}(0)\,|X\rangle\langle X|\,\bar{\mathbf{T}}\{O_{ns}^{qq}(y_1)\cdots O_{ns}^{qq}(y_b)\}\,\bar{\chi}_{n,I}(0)\Big]$$



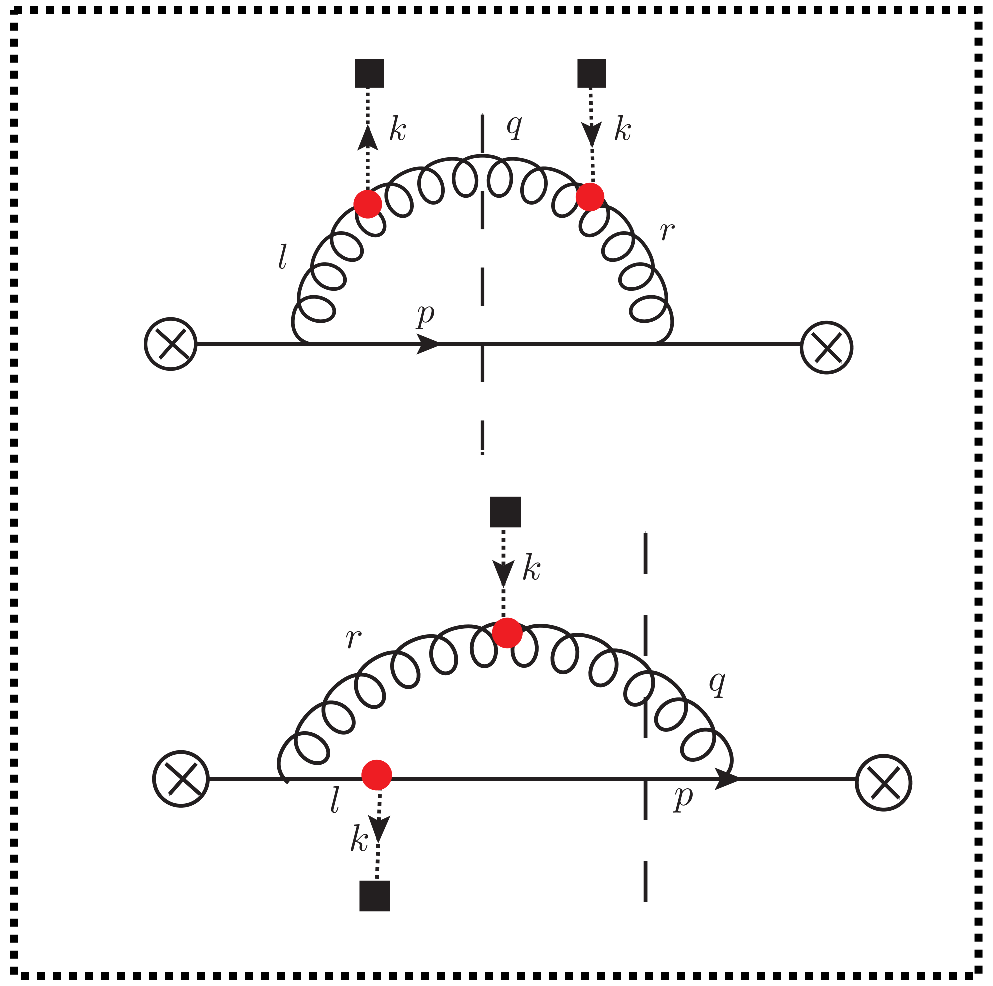
Nucl. Phys. B 594 (2001) 371–419

# Medium induced jet dynamics

In the dilute limit, EFT recovers GLV results

$$J_q^{(2)}(\chi, L) = L \int \frac{d^2 k_\perp}{(2\pi)^2} \left[ \mathbf{J}_{q,R}^{(2)}(\chi, k_\perp, L) - \mathbf{J}_{q,V}^{(2)}(\chi, k_\perp, L) \right] \mathbf{B}(k_\perp) + \mathcal{O}(H_G^4)$$

$$\mathbf{J}_q^{(2)}(\chi, \omega, k_\perp) \simeq g^2 L \int \frac{dz}{z} \int \frac{d^2 q_\perp}{(2\pi)^2} \underbrace{\frac{\vec{q}_\perp \cdot \vec{k}_\perp}{\vec{q}_\perp^{\,2} \vec{\kappa}_\perp^{\,2}}}_{\vec{\kappa} = \vec{q}_\perp - \vec{k}_\perp} \Bigg( 1 - \underbrace{\frac{z\omega}{\vec{\kappa}_\perp^{\,2} L} \sin\left[ \frac{L \vec{\kappa}^2}{z\omega} \right]}_{\text{LPM}} \Bigg) 2z\, \delta\!\left( \chi^2 - \frac{q_\perp^2}{z^2 \omega^2} \right)$$



Medium function ($\mathbf{B}(k_\perp)$ is thermal correlators of soft bilinear operators

$$B_E(K) = \int_0^{\frac{1}{T}} d\tau \int d^3x\, e^{iK\cdot X} \langle \hat{O}^{qA}(X)\, \hat{O}^{qB}(0) \rangle$$

For multiple scatterings medium function becomes correlations of Wilson lines

$$\hat{O}^{qA}(x) = \frac{1}{\mathbb{P}_\perp^2} O_s^{qA}(x)$$

$$B(x_\perp) = \langle W^\dagger(0) \rho(0)_E W(x_\perp) \rangle \qquad W(x) = \mathbf{P} \exp\left[ -ig \int_0^L d(\bar{n}\cdot r)\, \hat{O}_s^{qA}(x + \bar{n}\cdot r) \right]$$

Can be computed on lattice?

In progress

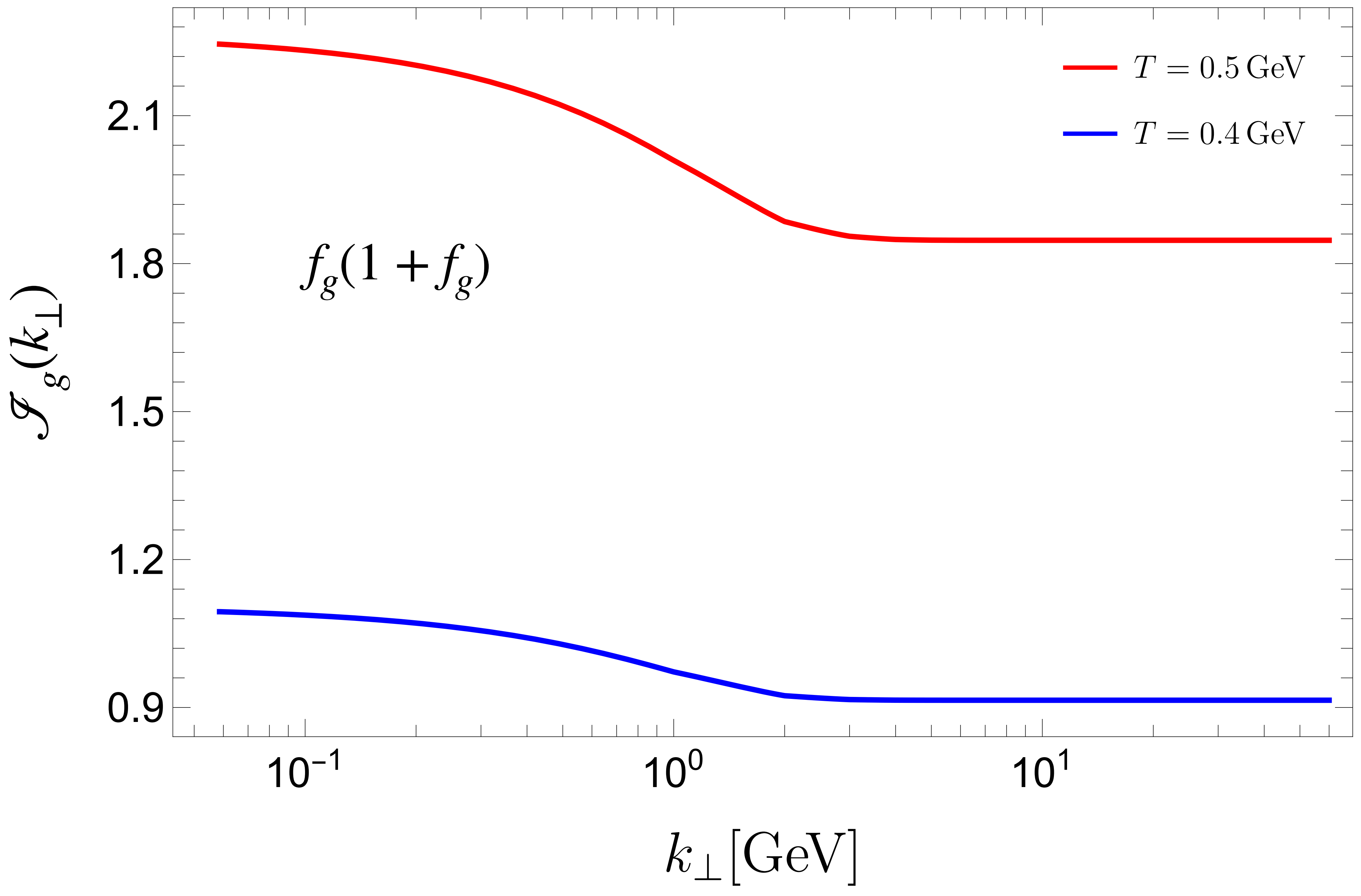
Budhraja, Yong and **BS**

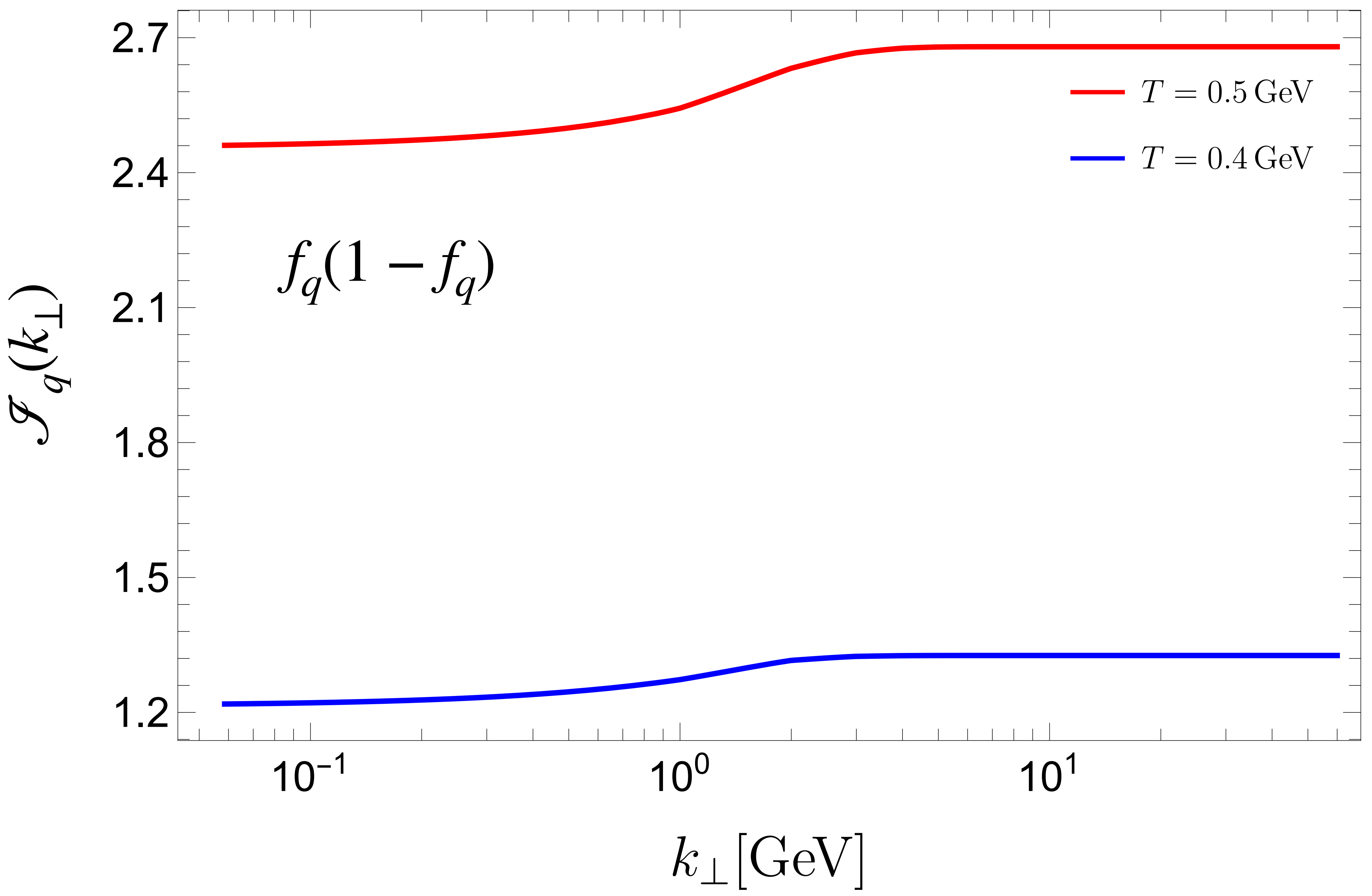
# LO medium function

At leading order small $k_\perp$ dependence in the numerator term

$$\mathbf{B}_{\mathrm{LO}}(k_\perp) \approx \frac{\mathcal{I}(k_\perp)}{k_\perp^4} \equiv \frac{\mathcal{I}(k_\perp)}{(k_\perp^2 + m_D^2)^2}$$

$$\mathcal{I}(k_\perp) = \mathcal{I}_g(k_\perp) + \mathcal{I}_q(k_\perp)$$




In progress

Budhraja, Yong and **BS**

Higher order effects in medium correlator?

# Resummed EEC jet function

Medium induced DGLAP 2109.11568 2512.11952

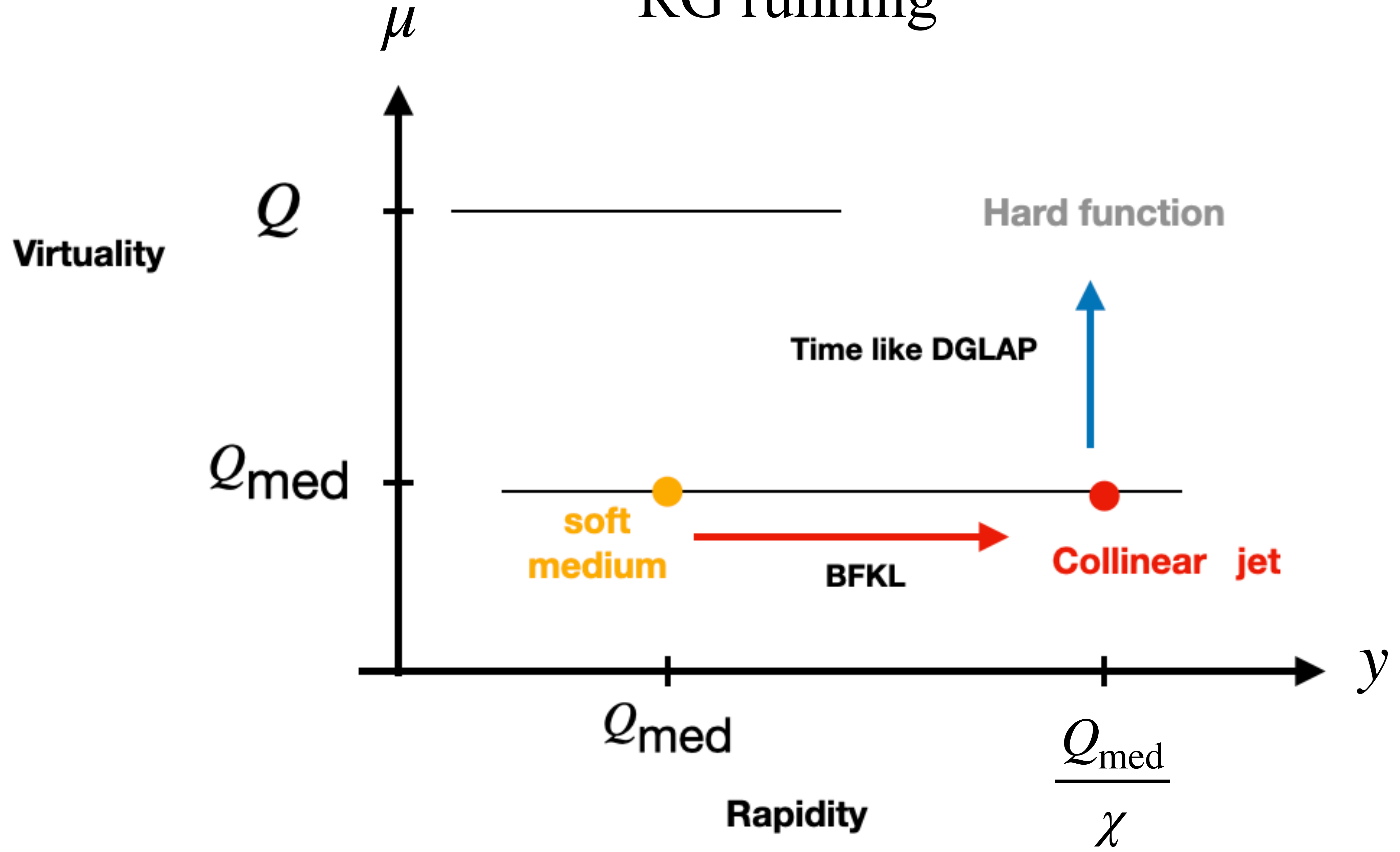
Medium and jet function obey BFKL evolution equation

$$\frac{d\Sigma}{d\chi} \sim H \otimes \left( J^0(\chi) + J_q^{(2)}(\chi) \otimes \mathbf{B} \right) \qquad \gamma_{J_q^{(2)}} = -\gamma_B$$

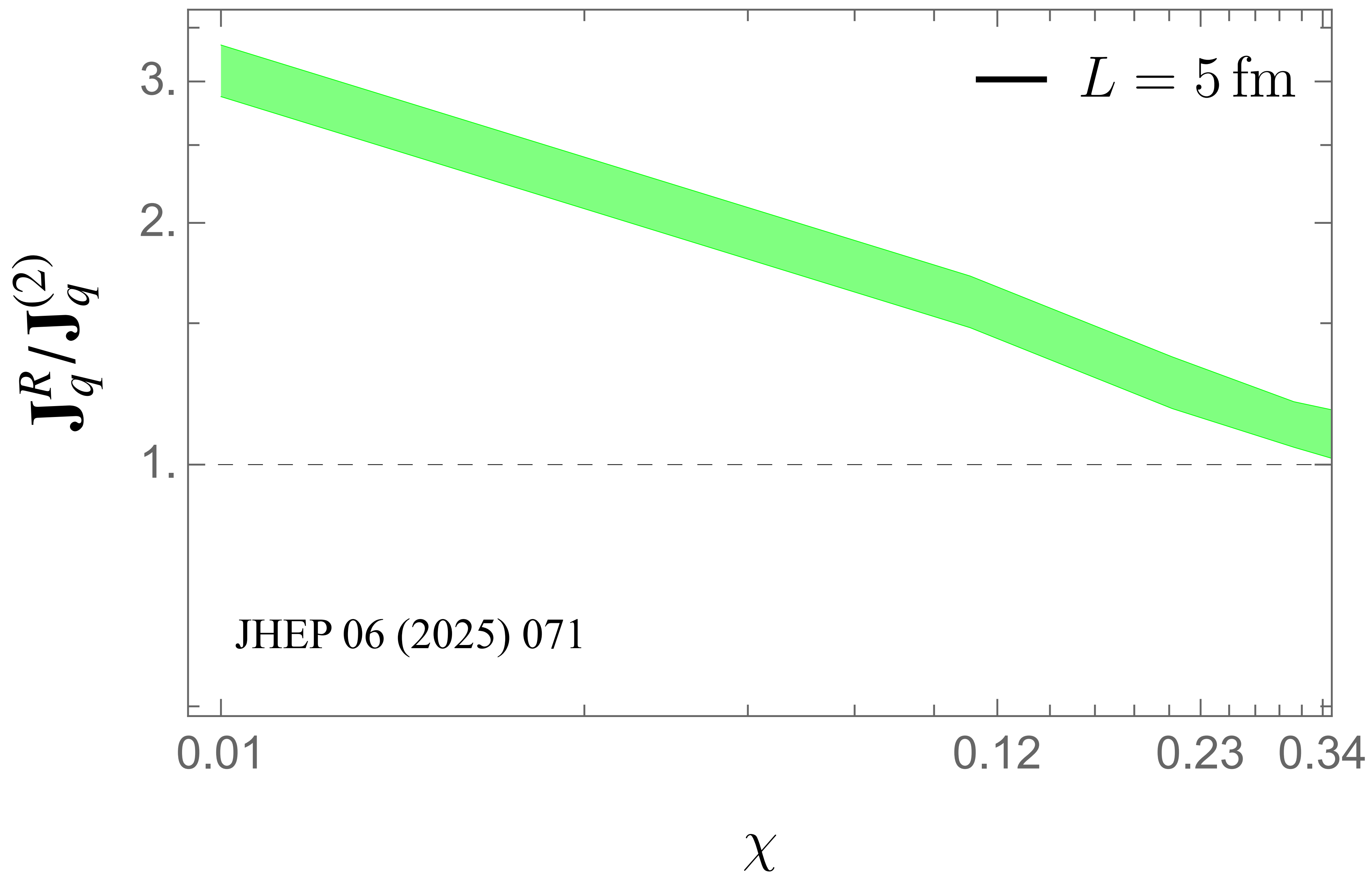
$$\mathbf{J}_q^R(k_\perp, \mu, y_f) = \int d^2 l_\perp \mathbf{J}_q^{(2)}(l_\perp, \mu, y_0) \int \frac{d\xi}{2\pi} k_\perp^{-1+2i\xi} l_\perp^{-1-2i\xi} e^{in(\phi_k - \phi_l)} e^{-\frac{\alpha_s(\mu) N_c}{\pi} \Phi(n,r) \log \frac{y_f}{y_0}} \qquad y_0 \sim \frac{Q_{\rm med}}{\chi} \qquad y_f \sim Q_{\rm med}$$

Resums $\sim \alpha_s \log \chi$ terms which are relevant in small $\chi$ limit

RG running

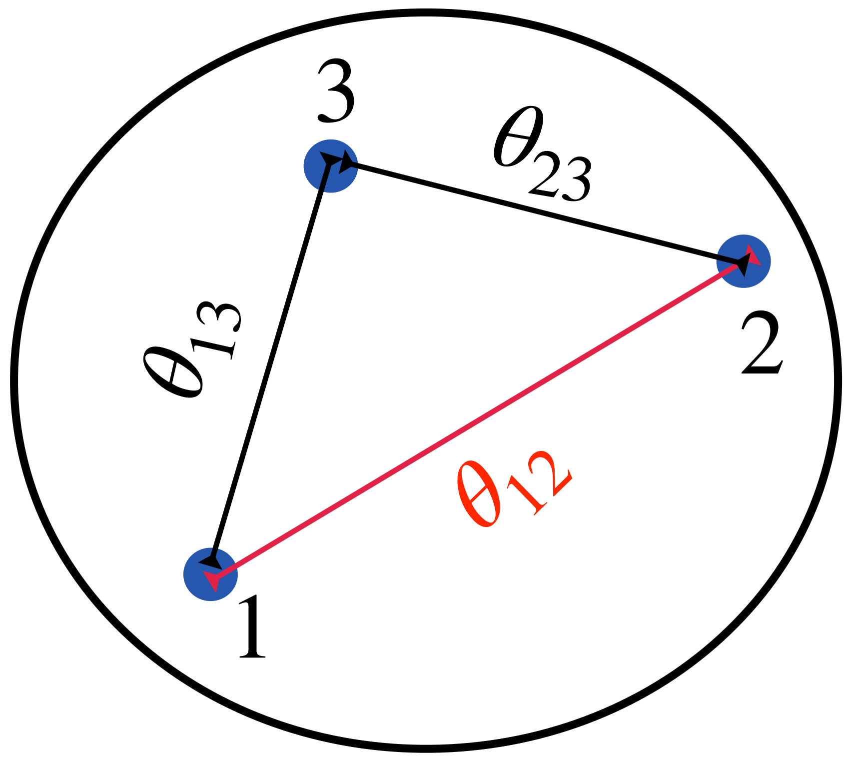



Resummed and NLO ratio, BFKL only



# Generalizing energy correlators

N-point projected energy correlators are defined by tracking particles with maximum angular separation




$$\frac{d\Sigma^{[N]}}{d\chi} = \sum_M \int d\sigma_M \sum_{i_1,\ldots,i_N=1}^{M} \frac{E_{i_1}\cdots E_{i_N}}{Q^N}\,\delta\big(\chi - \theta_{\max}(i_1,\ldots,i_N)\big) \qquad \theta_{\max}(i_1,\ldots,i_N) \equiv \max_{a<b}\,\theta_{i_a i_b}$$

Energy weights of correlators

| Single particle | Two particles |
|---|---|
| $\frac{E_{i_1}^N}{Q^N}\delta(\chi)$ | $\left[\frac{(E_{i_1}+E_{i_2})^N}{Q^N} - \frac{E_{i_1}^N}{Q^N} - \frac{E_{i_2}^N}{Q^N}\right]\delta(\chi-\theta_{i_1 i_2})$ |

These are binomial expansions and can be analytically continued to non-integer values $N \to \nu$

- For IRC safe $\nu > 0$

$$\frac{\mathrm{d}\Sigma^{[\nu]}}{\mathrm{d}\chi} = \int \mathrm{d}\sigma_X \left[\sum_{a=1,2} W_1^{[\nu]}(i_a)\,\delta(\chi) + \sum_{i_1<i_2} W_2^{[\nu]}(i_1,i_2)\delta(\chi-\theta_{12})\right]$$

$\nu = 2$ gives standard energy-energy correlator (EEC)

Energy weights

$$W_1^{[\nu]}(i_a) = \frac{E_{i_a}^\nu}{Q^\nu}$$

$$W_2^{[\nu]}(i_1,i_2) = \frac{(E_{i_1}+E_{i_2})^\nu}{Q^\nu} - \sum_{a=1,2} W_1^{[\nu]}(i_a)$$

# Factorization for $\nu$-correlators

Analytic continuation does not change the power counting of the modes

Factorization structure

$$\frac{d\Sigma^{[\nu]}}{d\chi} = \sum_{i\in\{q,\bar{q},g\}} \int dx x^{\nu} H_{ab\to i}(Q,\mu)\, J_i^{[\nu]}(Q,\chi,\mu)$$

Measurement function

$$\mathscr{M}^{[\nu]} = \sum_{a=1,2} W_1^{[\nu]}(i_a)\delta(\chi) + W_2^{[\nu]}(i_1,i_2)\delta(\chi-\theta_{12})$$

weights hard and soft particles differently

Soft limit simplifications of measurement function

For $\nu = 2$ $\qquad \mathscr{M}^{[2]} = -2z\,[\delta(\chi) - \delta(\chi-\theta)]$

For $\nu < 1$ $\qquad \mathscr{M}^{[\nu]} = z^{\nu}\,[\delta(\chi) - \delta(\chi-\theta)]$

Jet function contains medium correlator and captures both vacuum and medium induced jet dynamics

$$J_q^{[\nu]}(\chi) = \frac{1}{2N_c}\sum_X \mathrm{Tr}\Big[\rho_E(0)\frac{\bar{n}}{2}e^{iH_{ns}t}\,\underbrace{\bar{\mathbf{T}}\Big\{e^{-i\int_0^t dt' H_{G,I}(t')}\chi_{n,I}(0)\Big\}}_{\text{Glauber interaction}}\,\mathscr{M}^{[\nu]}\,|X\rangle\langle X|\,\underbrace{\mathbf{T}\Big\{e^{-i\int_0^t dt' H_{G,I}(t')}\bar{\chi}_{n,I}(0)\Big\}}_{\text{Glauber interaction}}\,e^{-iH_{ns}t}\Big]$$

# $\nu$-correlators in dilute medium

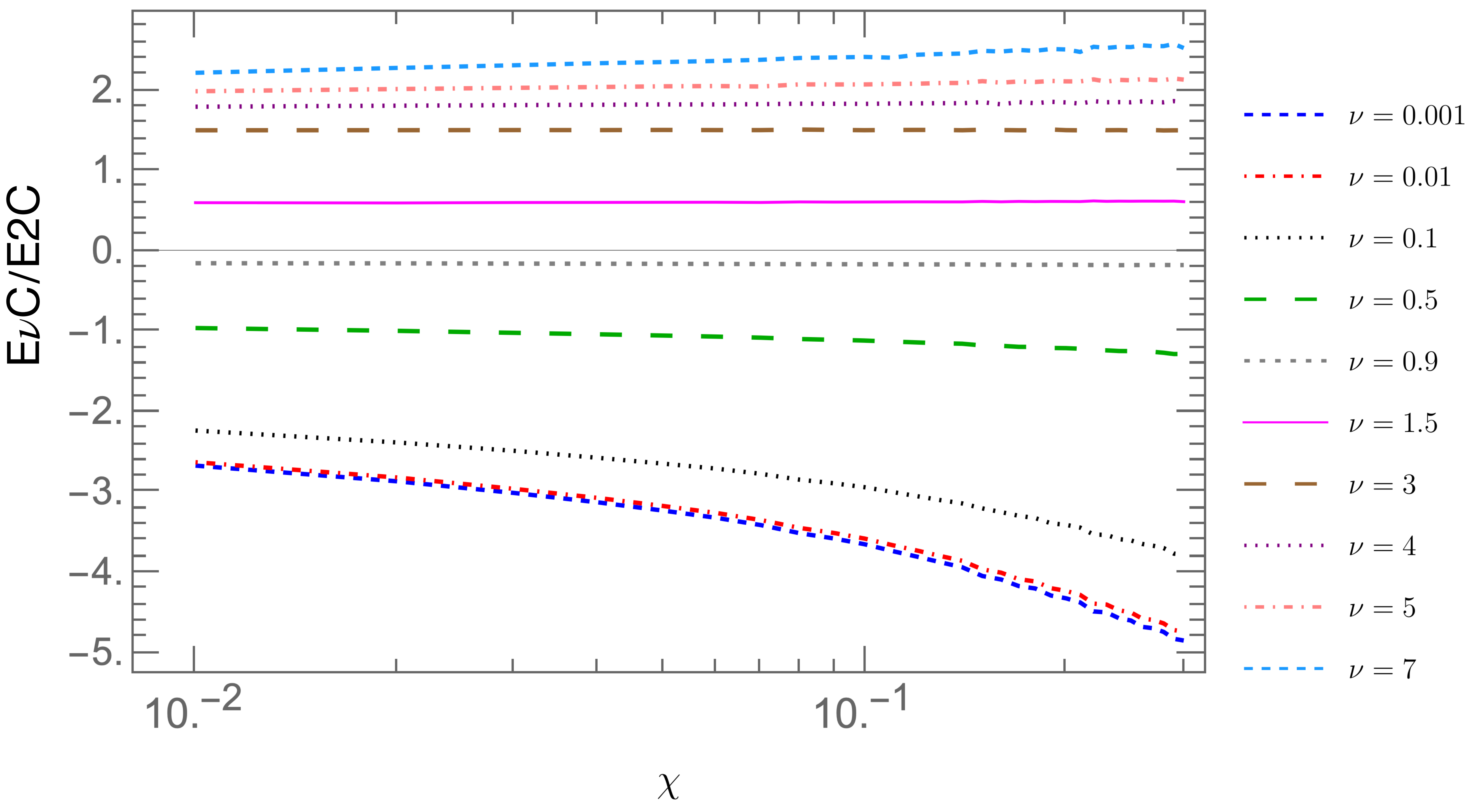
For small $\nu$ values correlators saturate at small $\nu$ values

BFKL resummation does not include $\nu$ dependent anomalous dimensions

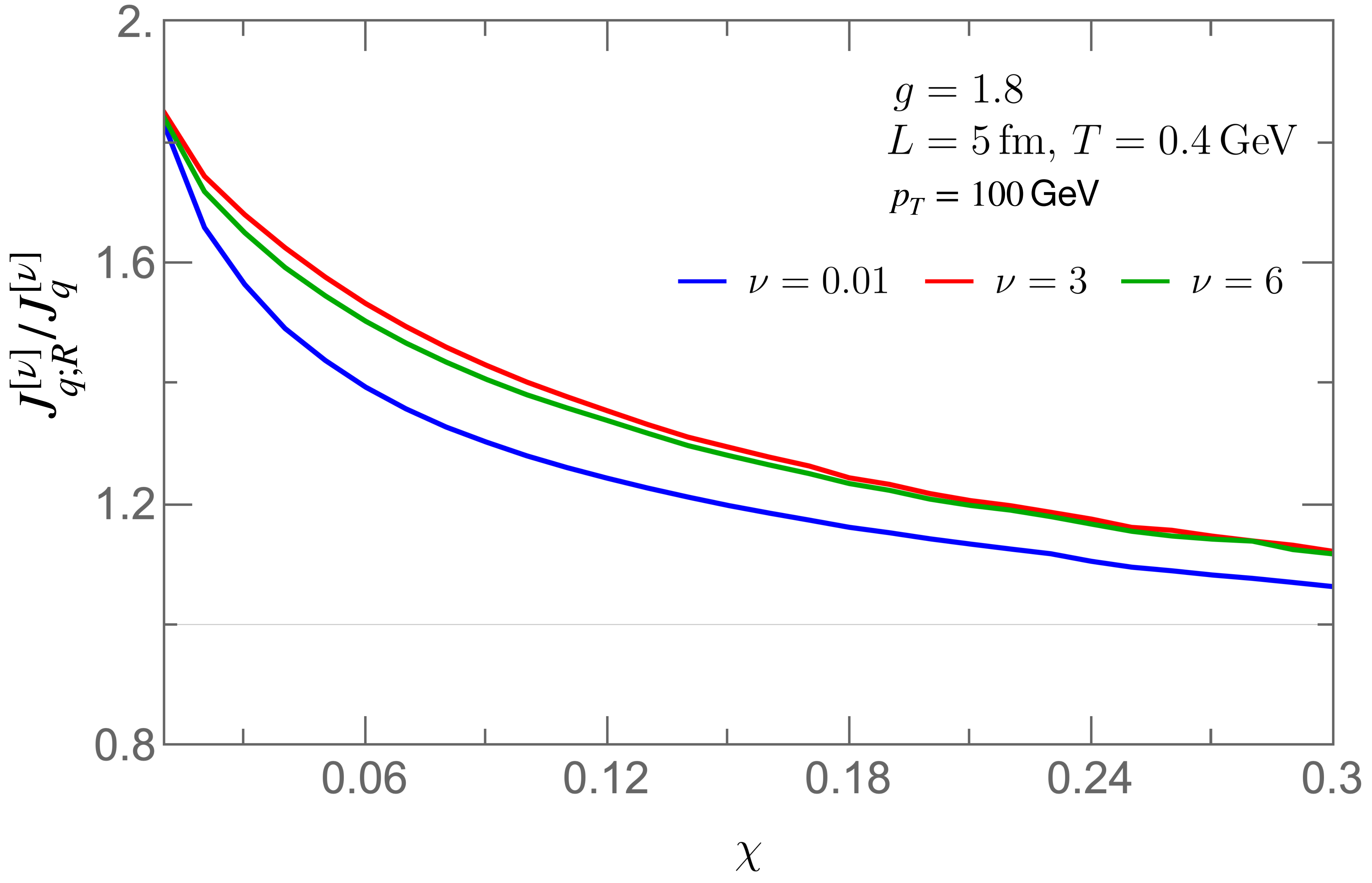
Parameters

$L = 5\,\mathrm{fm} \quad T = 0.4\,\mathrm{GeV} \quad \alpha_s = 0.3$

Ratio with two point EC




Ratio of resummed and fixed order, BFKL only

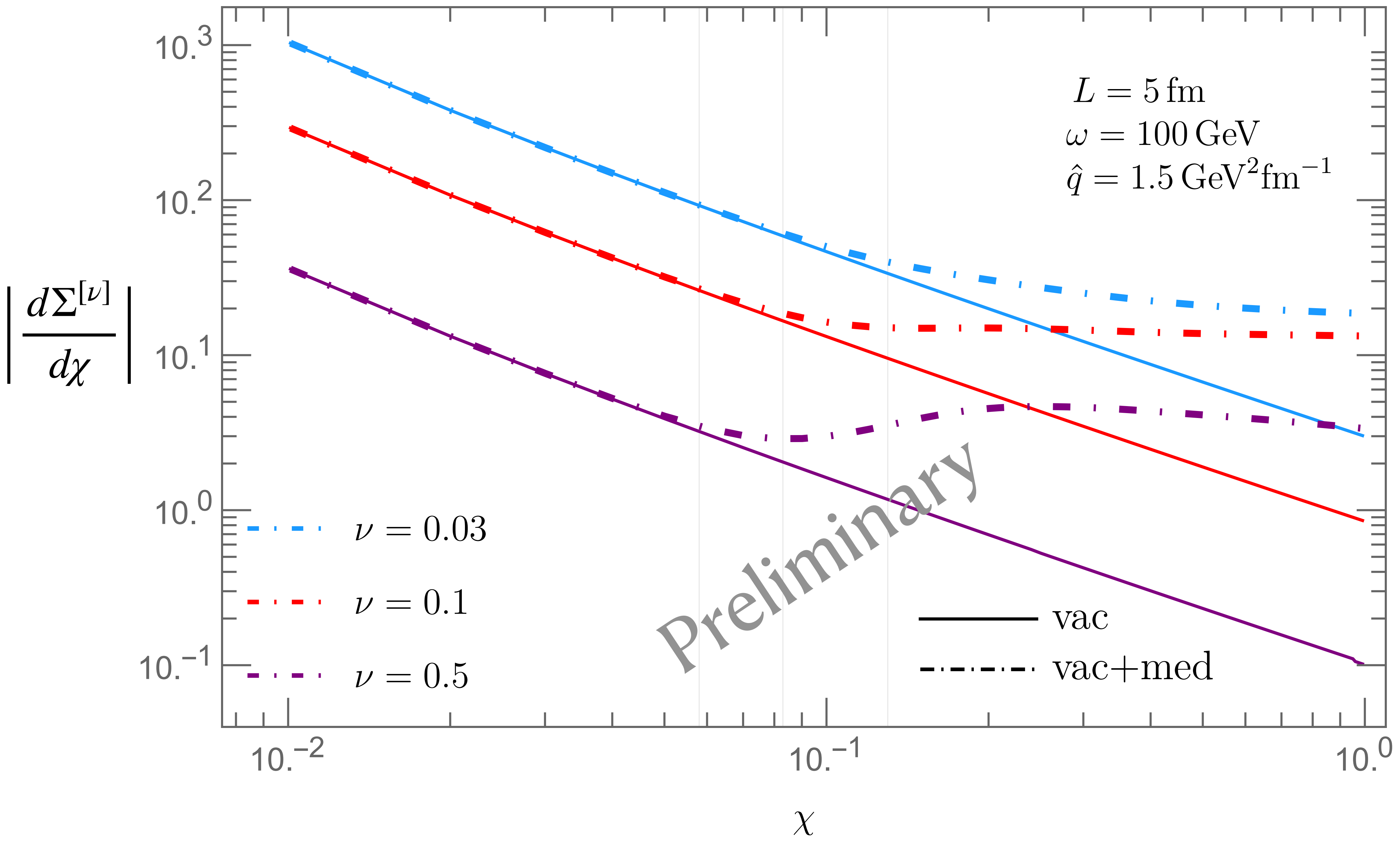


# $\nu$-correlators in dense medium

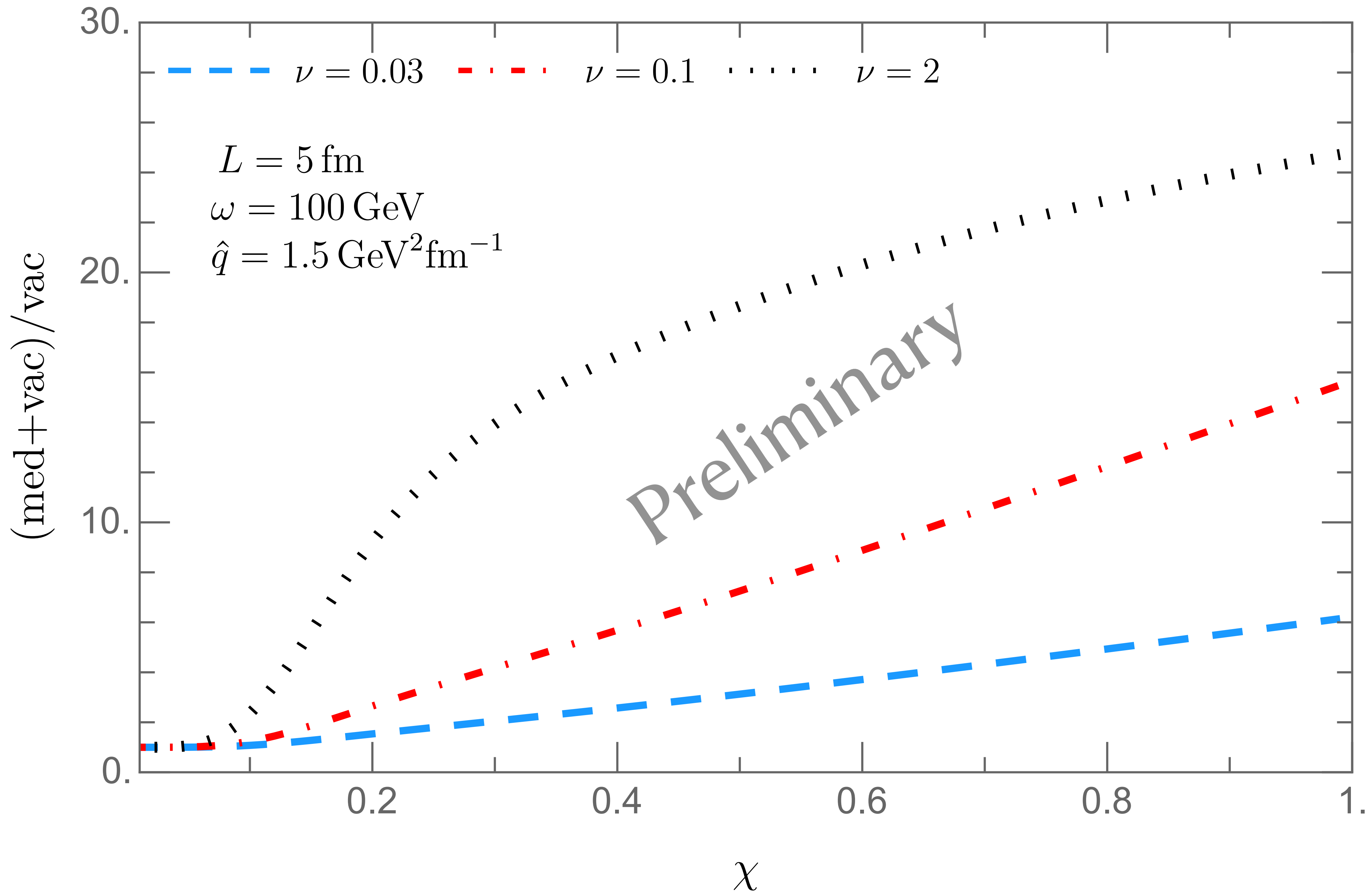
In progress

Andrey, Liliana and **BS**

Medium-induced emission contribution is suppressed for smaller $\nu$ valued correlators




Model: semi-classical approximation




$$\frac{d\Sigma^{[\nu]}_{\mathrm{vac}}}{d\chi} \sim \frac{\hat{\gamma}(1+\nu)}{\chi^{1-\gamma(1+\nu)}} \qquad \hat{\gamma}_{gq} \sim \frac{1}{\nu}$$

$$\frac{d\Sigma^{[\nu]}_{\mathrm{med}}}{d\chi} \sim \mathsf{c}(\chi) + \mathcal{O}(\nu)$$

Consistent behavior in EFT, BDMPS-Z, harmonic oscillator approximation

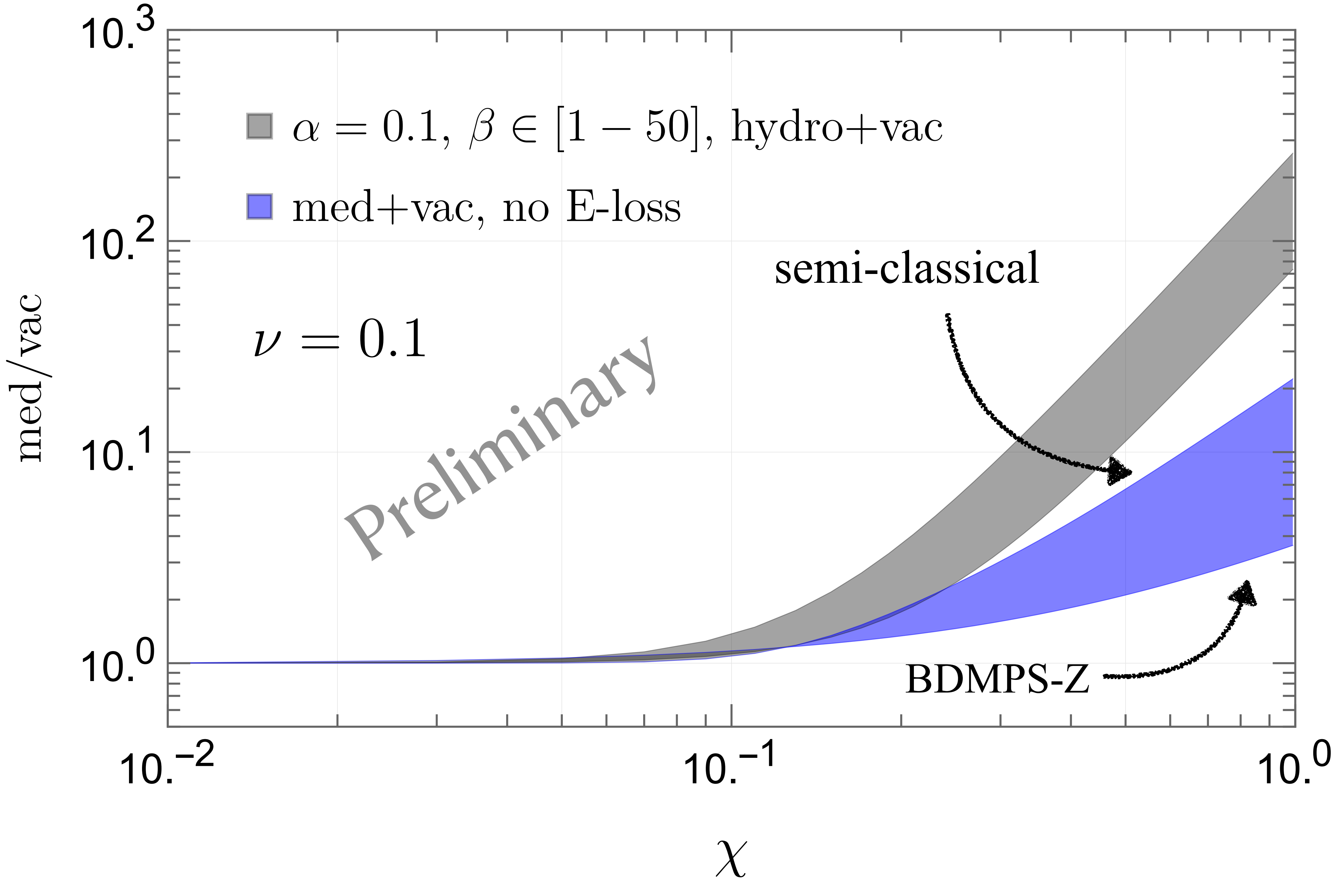
# Medium response to $\nu$-correlators

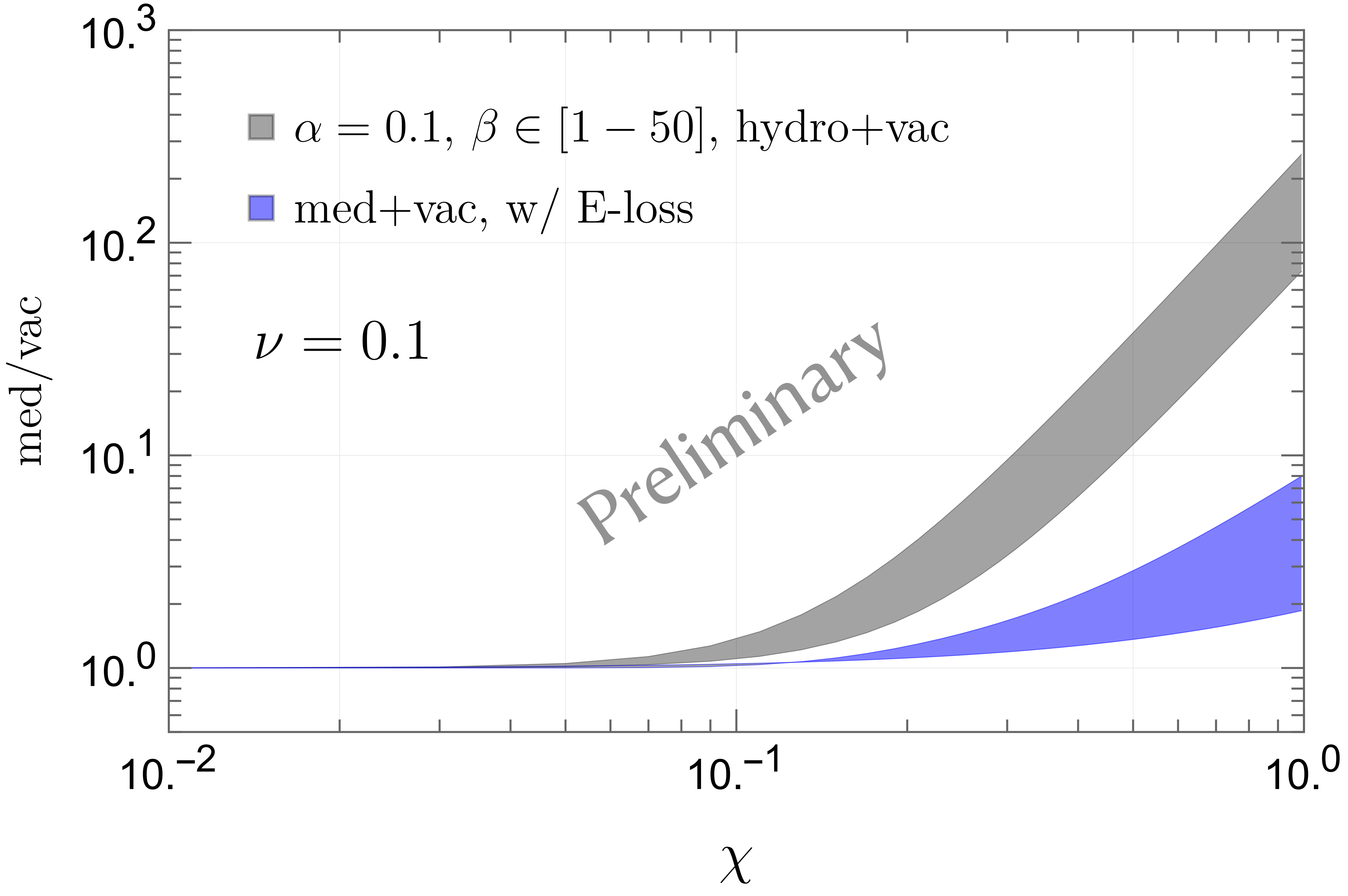
In progress

Andrey, Liliana and **BS**

For medium response, we define the final differential distribution of $\nu$-correlators through $f(\mathbf{p})$

$$\frac{1}{\sin\chi}\frac{d\Sigma^{(\nu)}}{d\chi} = \int_{\mathbf{p}_1,\mathbf{p}_2} f(\mathbf{p}_1)f(\mathbf{p}_2)\frac{(E_1+E_2)^\nu - E_1^\nu - E_2^\nu}{p_T^\nu}\,\delta\left(\hat{\mathbf{p}}_1\cdot\hat{\mathbf{p}}_2 - \cos\chi\right)\Theta(\chi>0)$$




$$f(p,\cos\theta) = \frac{(2\pi)^3}{p^2}\left[\alpha\, e^{-\frac{(p-p_{ch})^2}{e_h^2}}\, e^{-\frac{\theta^2}{R^2}}\,\Theta(p-p_{\text{min}}) + \beta\, e^{-\frac{p}{T}}\right]\Theta(R-|\theta|)$$

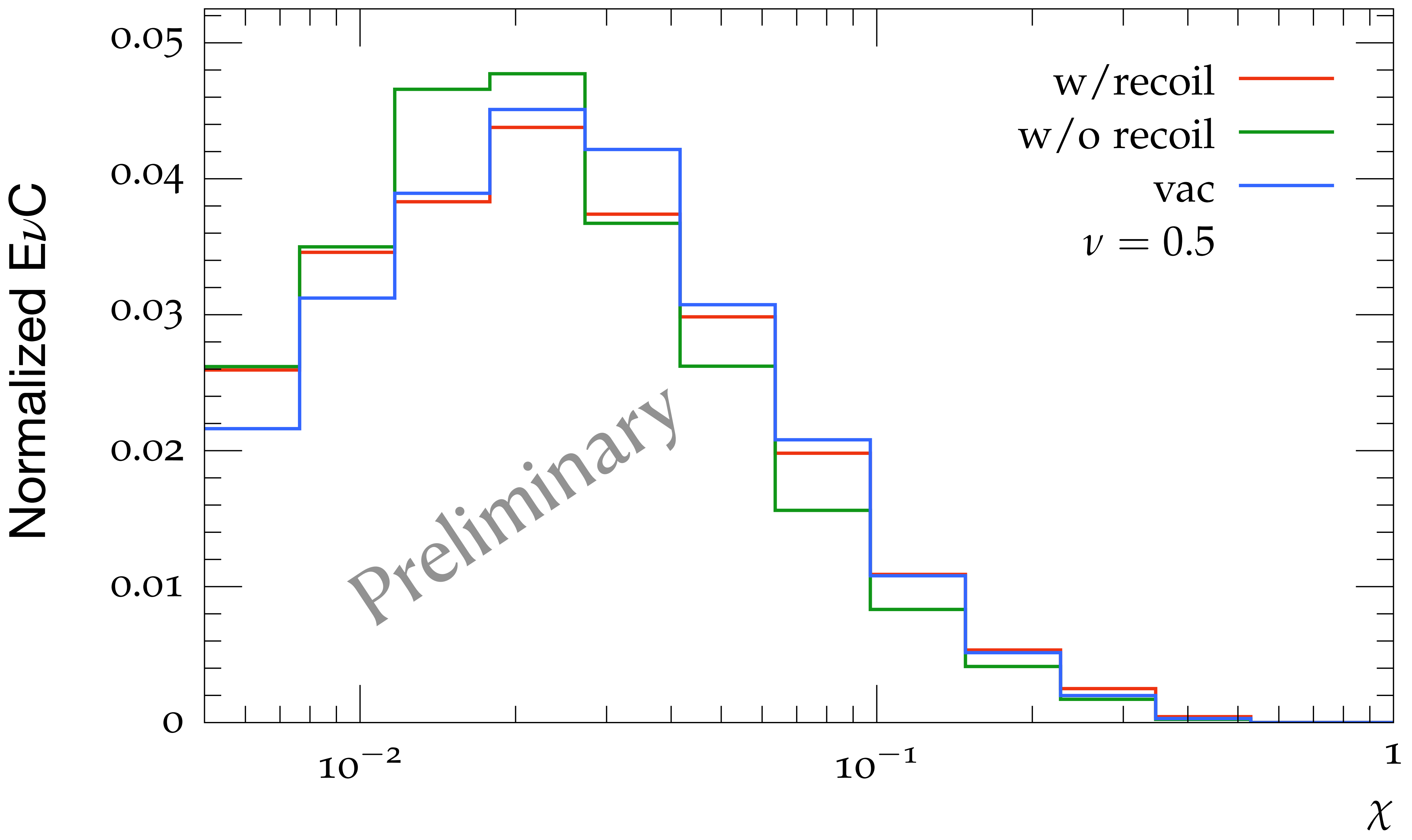
$$\int \frac{d^3p}{(2\pi)^3} f(\theta) = N \quad \text{(Number of particles)}$$

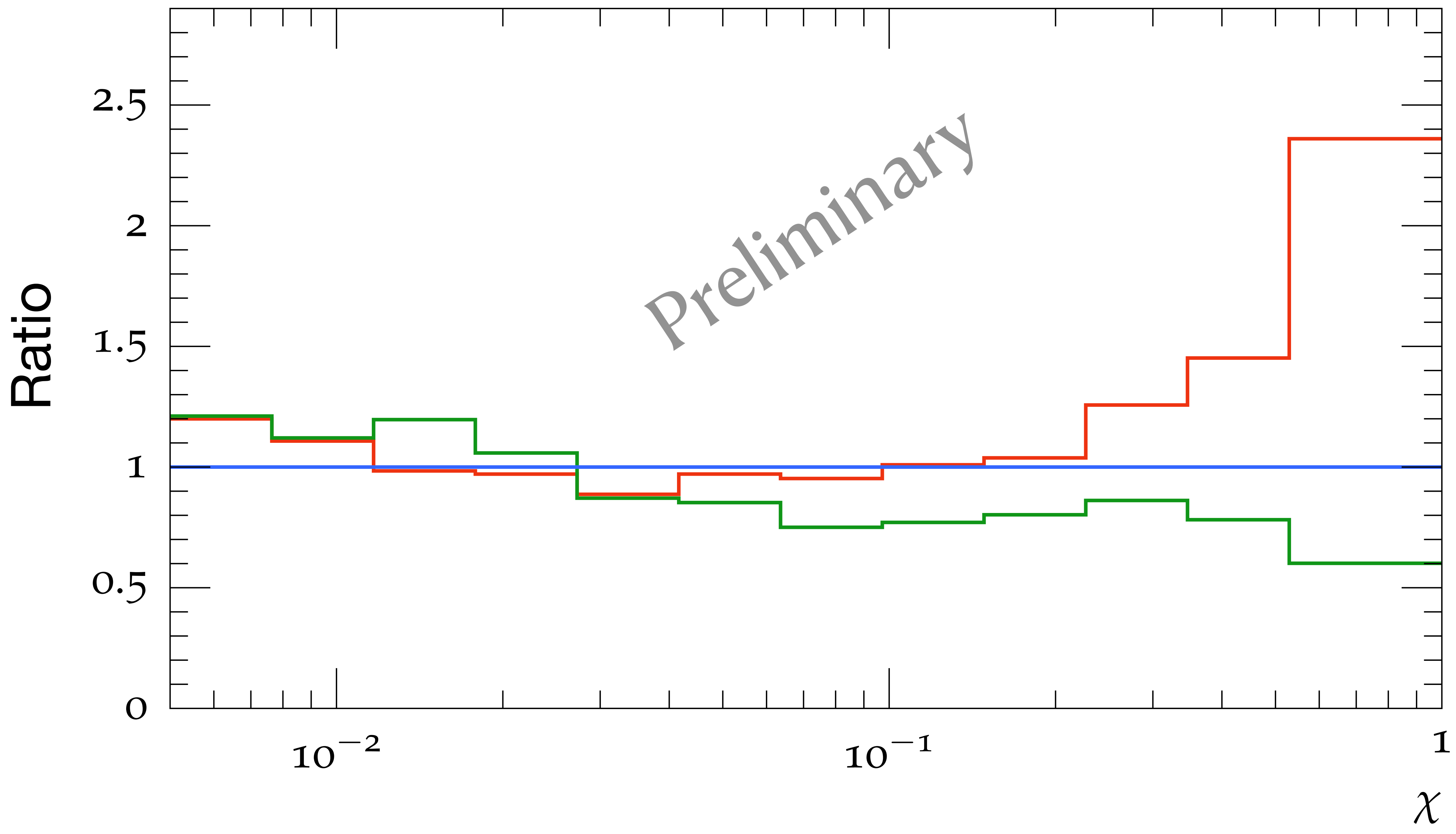
# JEWEL simulations

In progress

Andrey, Liliana and **BS**

$p_T^J \in [100 - 120]$ GeV   $|\eta|^J < 2$   $R = 0.4$   $T_i = 0.45$ GeV   Centrality = $[0 - 10]$ %




$\nu$ correlators seem to be interesting, can it used to quantify various medium-induced effects?

# Summary and outlook

Ongoing work

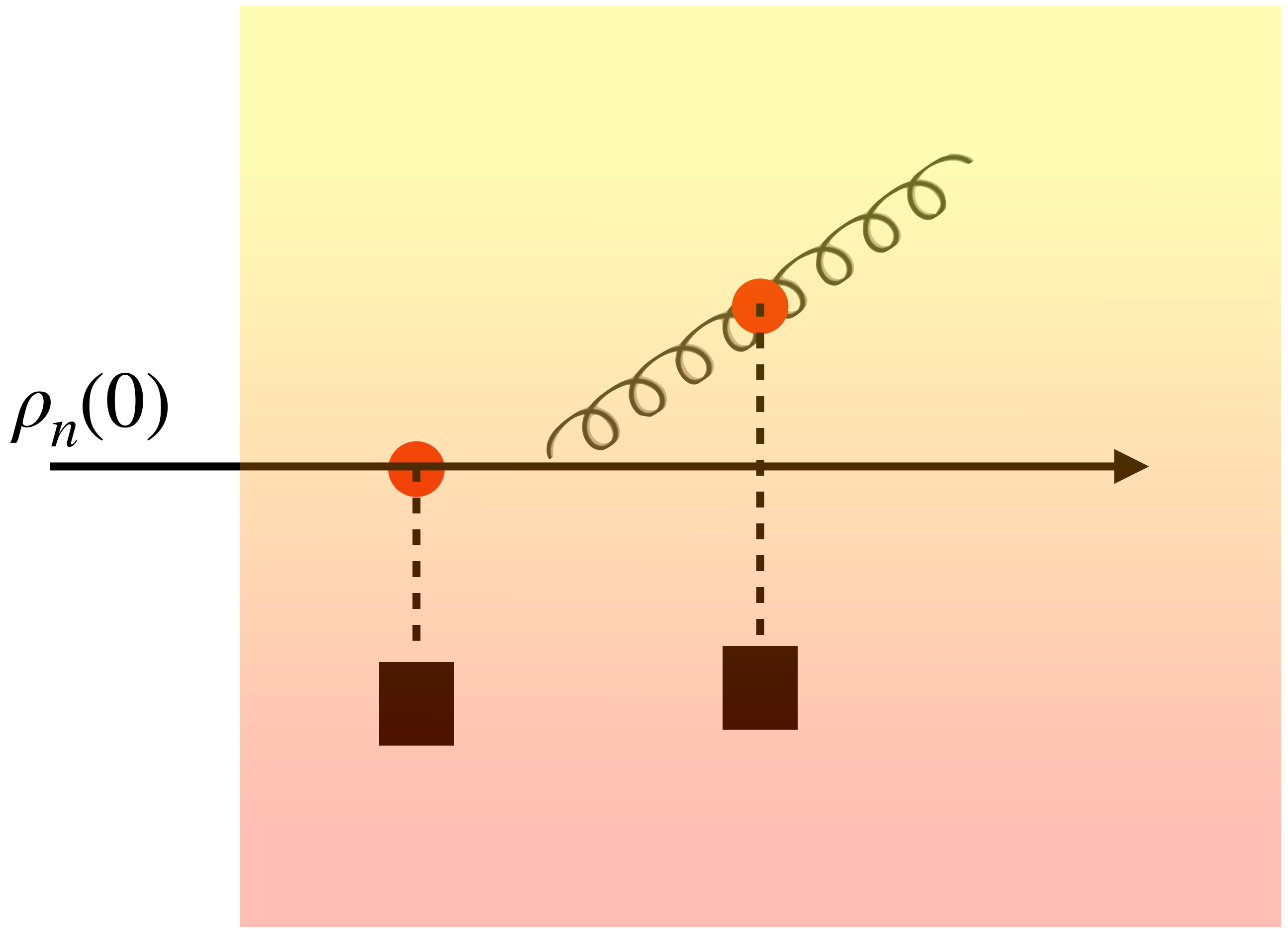
Liliana and **BS**

1. EFT provides a systematically improvable framework and enables resummations of large logarithms

2. Higher order calculations of medium-induced jet function will provide better accuracy

3. $\nu$-correlators could be useful in identifying various medium-induced effects in jets

4. EFT + open quantum system $\longrightarrow$ time evolution of jets




$$H = H_n + H_s + H_G, \qquad \rho(0) = \rho_n(0) \otimes \rho_E, \qquad \rho_n(0) = |X_n\rangle\langle X_n|$$

Markovian limit $\tau_{\mathrm{E}} \ll \tau_{\mathrm{f}} < L$, Lindbladian evolution

$$\boxed{\dot{\rho}_n(t) = -i\left[H_n + H_{LS}, \rho_n(t)\right] + \sum_i \left(L_i\,\rho_n(t)\,L_i^\dagger - \frac{1}{2}\left\{L_i^\dagger L_i, \rho_n(t)\right\}\right)}$$

$$L_i \equiv \sqrt{\gamma^A}\ A^A(\omega)$$

Medium correlator

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LIP

TÉCNICO UNIVERSIDADE DE LISBOA

# Medium model

Semi-classical approximation

$$\frac{d\Sigma_q^{[\nu]}}{d\chi} = \sum_{i,j\in J} \int dz\, d\theta_{ij} \left( 1 + \frac{\alpha_{s,\mathrm{med}}}{\alpha_s(\mu)} F_{\mathrm{med}}(z,\theta) \right) \frac{dP_{\mathrm{vac}}}{dz\, d\theta} \mathscr{M}^{[\nu]}(z, \theta_{ij}, \chi)$$

$$F_{\mathrm{med}}(z,\theta) = \frac{2}{\tau_f} \int_0^L dt \left[ \frac{4}{f_1 \hat{q} \tau_f \theta^2 t^2} \left\{ 1 - e^{-\frac{f_1 \hat{q}(L-t)\theta^2 t^2}{4}} \right\} \cos\left(\frac{t}{\tau_f}\right) - \sin\left(\frac{t}{\tau_f}\right) \right] e^{-\frac{1}{12}\hat{q} f_2 \theta^2 t^3}$$

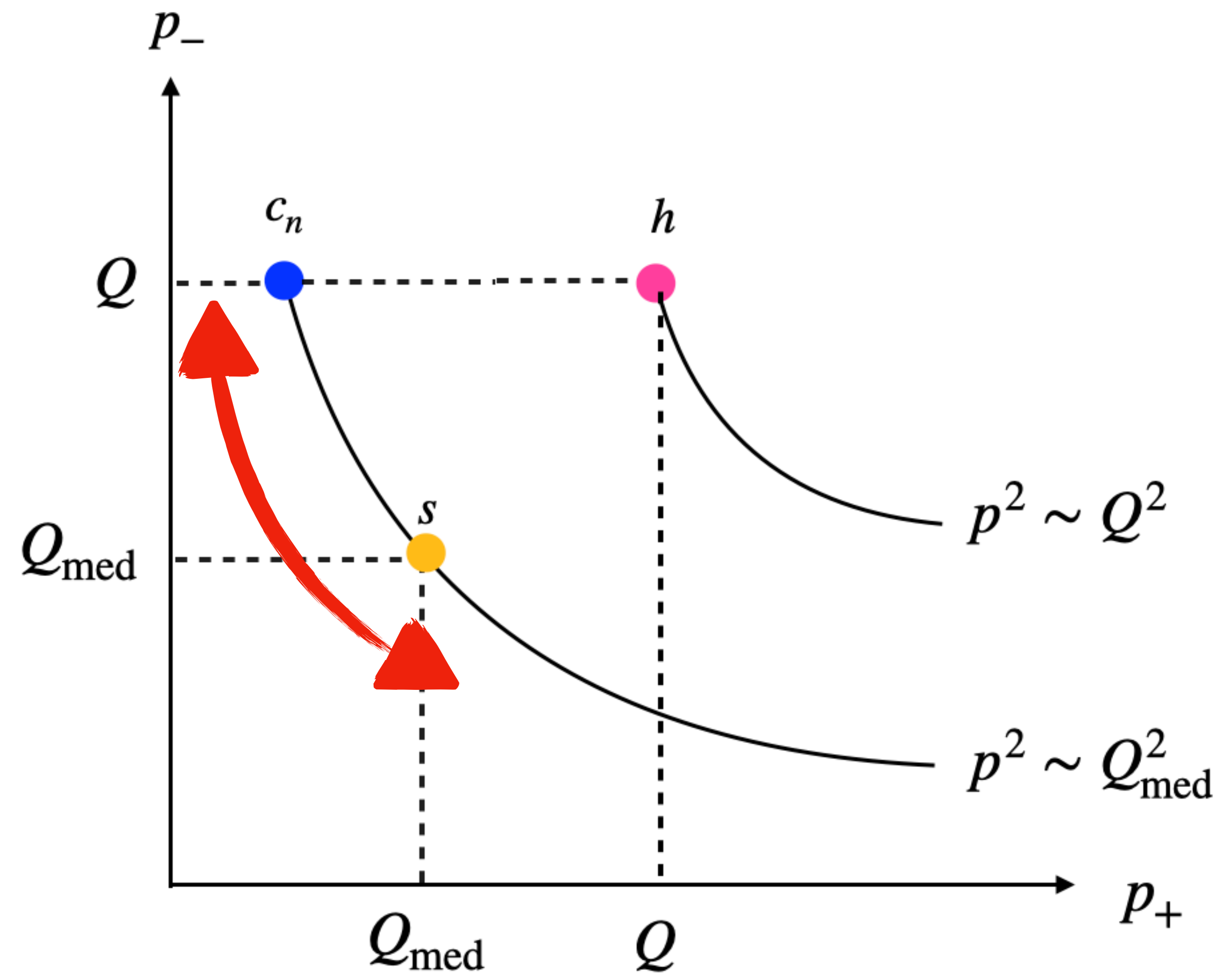
BDMPS-Z limit

$$\frac{d\mathscr{P}}{dzd\theta} = \frac{\alpha_{s,med}}{L} \sqrt{\frac{8\omega_c}{z^3\omega}} \Theta(\omega_c - z\omega)(z^2\omega^2\theta) \int_0^L \frac{dt\, e^{-\frac{z^2\omega^2\theta^2}{\hat{q}(L-t)}}}{\hat{q}(L-t)}$$

# BFKL evolution

- Medium function has BFKL anomalous dimension

$$y\frac{d\mathbf{J}_q^{(2)}(k_\perp,\nu)}{dy} = -\frac{\alpha_s(\mu)N_c}{\pi^2}\int d^2l_\perp\left[\frac{\mathbf{J}_q^{(2)}(l_\perp,y)}{(\vec{l}_\perp-\vec{k}_\perp)^2} - \frac{k_\perp^2\mathbf{J}_q^{(2)}(k_\perp,y)}{2l_\perp^2(\vec{l}_\perp-\vec{k}_\perp)^2}\right]$$




$y$ is rapidity scale which appears at NNLO for energy correlators

Scales are fixed by the corresponding jet and medium functions in perturbation theory