Jet propagation within a Linearized Boltzmann Transport Model

LuoTan

Central China Normal University
Institute of Particle Physics

In collaboration with Yayun He, Xin-Nian Wang and Yan Zhu

Outline

- Introduction
- The Linearized Boltzmann Transport (LBT) model with the complete set of elastic processes
- Results
- Summary and Outlook

Introduction

- The energy loss (radiative and elastic) of high energy partons propagating through the QGP has long been studied to gain information on the medium properties.

- The jet propagation and the induced medium excitation have been investigated via the Linearized Boltzmann Transport Model.

Hanlin Li, Fuming Liu, Guo-liang Ma, Xin-Nian Wang, Yan Zhu **Phys.Rev.Lett. 106, 012301**

Xin-Nian Wang, Yan Zhu **Phys.Rev.Lett. 111, 062301**

- We need to treat the elastic process in a more detailed manner to study further.

Boltzmann Equation:

$$p_1 \cdot \partial f_1(p_1) = -\int dp_2 dp_3 dp_4 (f_1 f_2 - f_3 f_4)|M_{12\to 34}|^2 \times (2\pi)^4 \delta^4(P_1 + P_2 - P_3 - P_4)$$

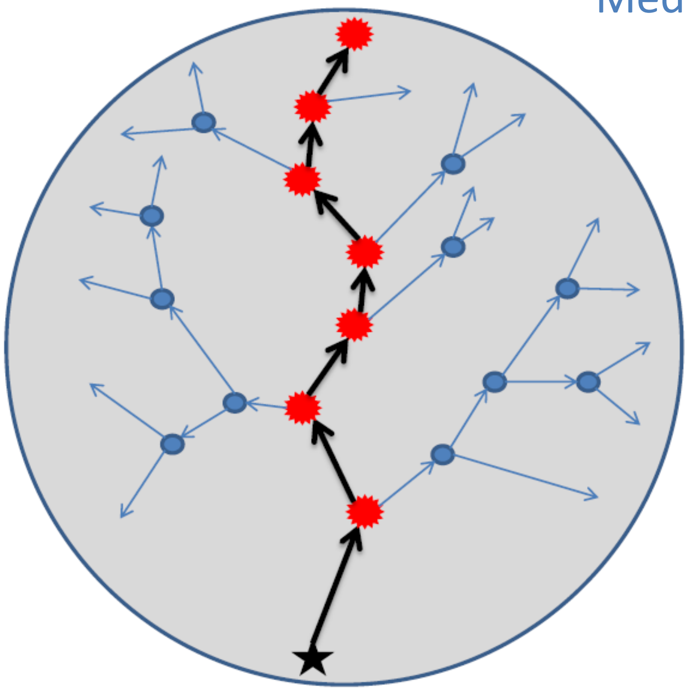
$$dp_i \equiv \frac{d^3 p_i}{2E_i (2\pi)^3}, \; |M_{12\to 34}|^2 = C g^2 (s^2 + u^2)/(t + \underline{\mu}^2)^2$$

$$f_i = 1/(e_i^{p.u/T} \pm 1)(i = 2, 4), \; f_i = (2\pi)^3 \delta^3(\vec{p} - \vec{p}_i)\delta^3(\vec{x} - \vec{x}_i)(i = 1, 3)$$

Leading parton-----thermal parton scattering

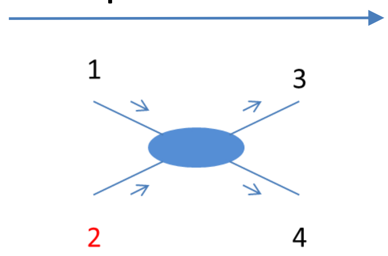
recoiled parton-----thermal parton scattering

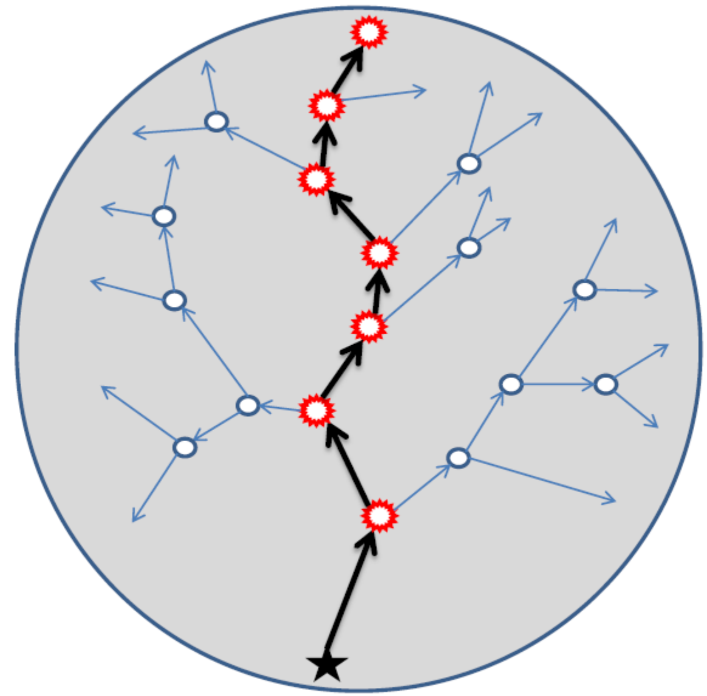
Medium Excitation



Negative particle

the particle hole





Linearized Boltzmann jet transport

neglect scatterings between recoiled medium partons.

It's a good approximation when the jet induced medium excitation δf<<f.

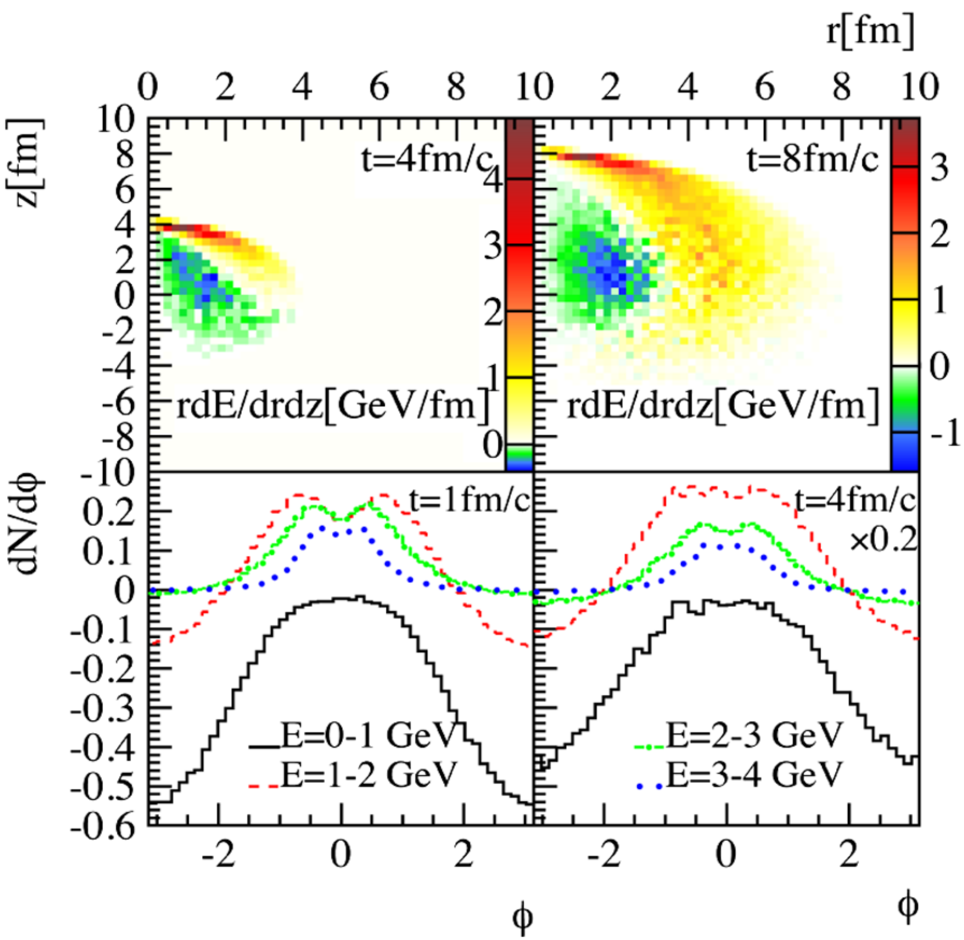
Deflection of different phase space.

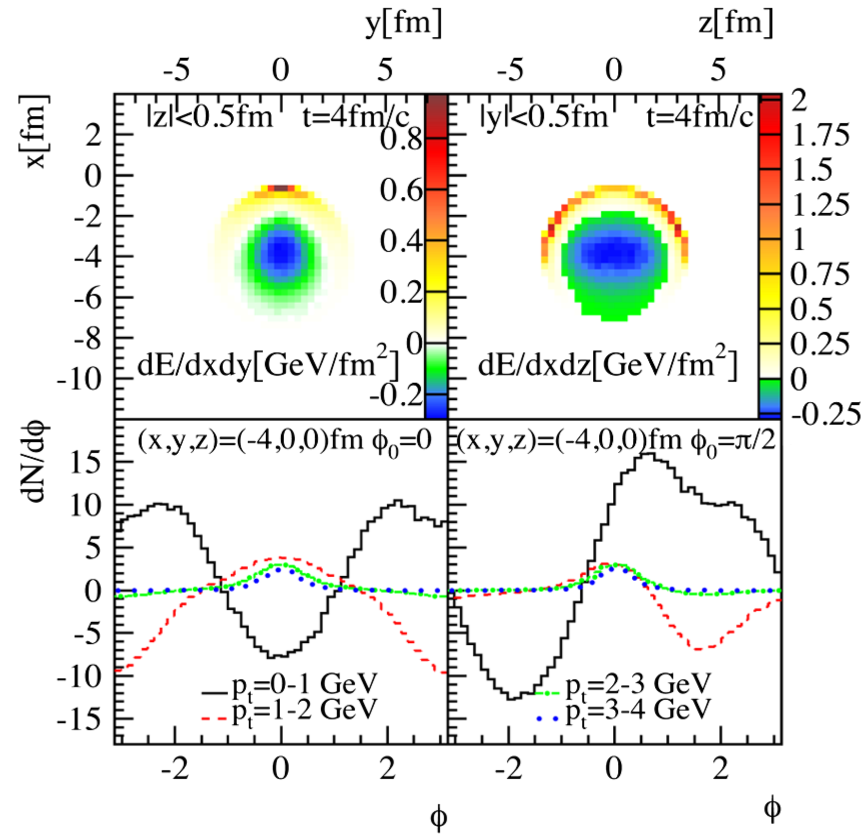
One has to subtract the 4-momentum of negative particle when combine it to jet.

Jet induced Mach Cone in HIC

I. No conic distribution of the final partons in an uniform medium.

II. Double-peak correlation of the final partons in 3+1D medium .

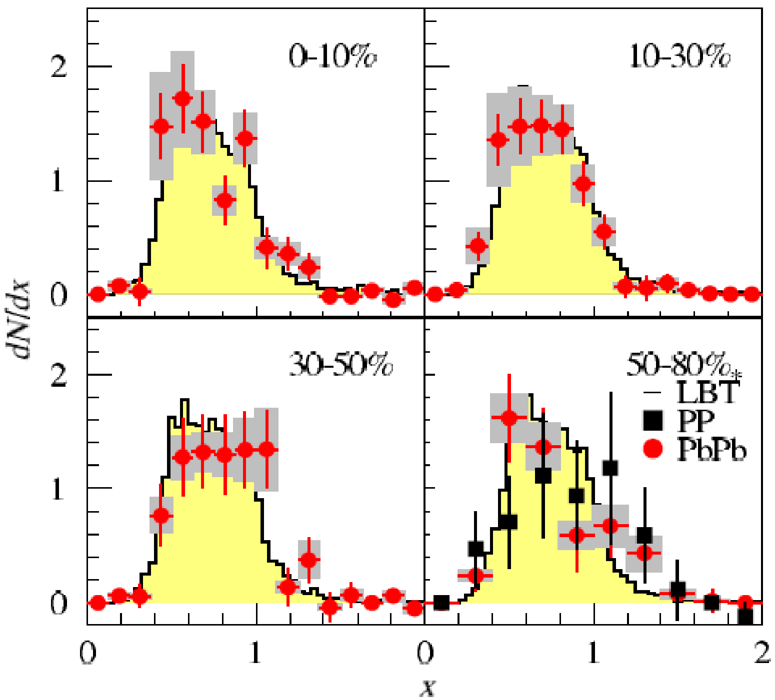




Hanlin Li, Fuming Liu, Guo-liang Ma, Xin-Nian Wang, Yan Zhu

Phys. Rev. Lett. 106, 012301

Medium Modification of Jets in HIC



Radiation process is included

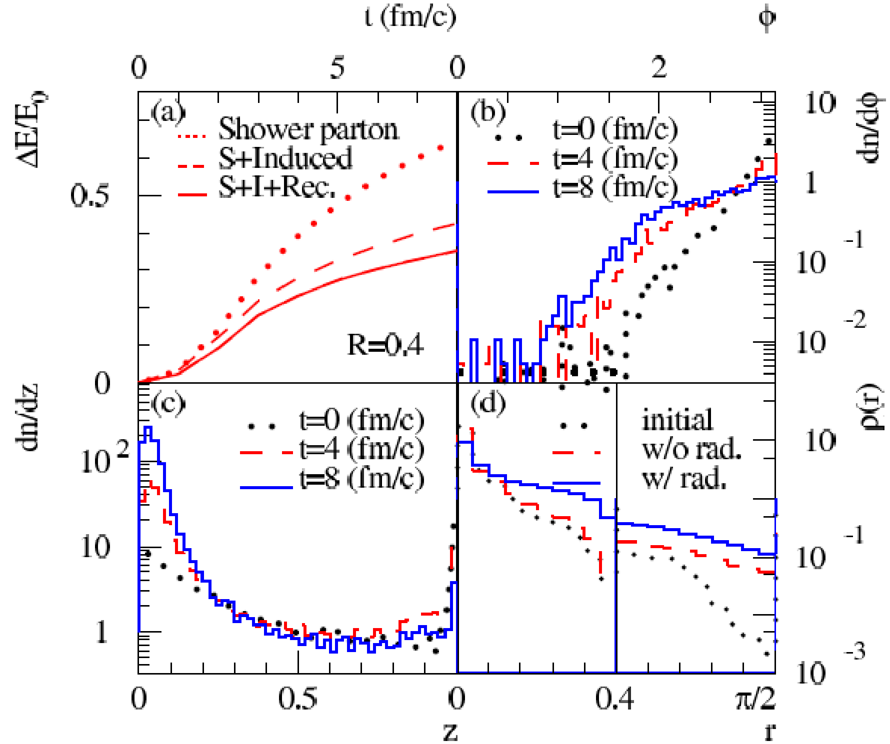
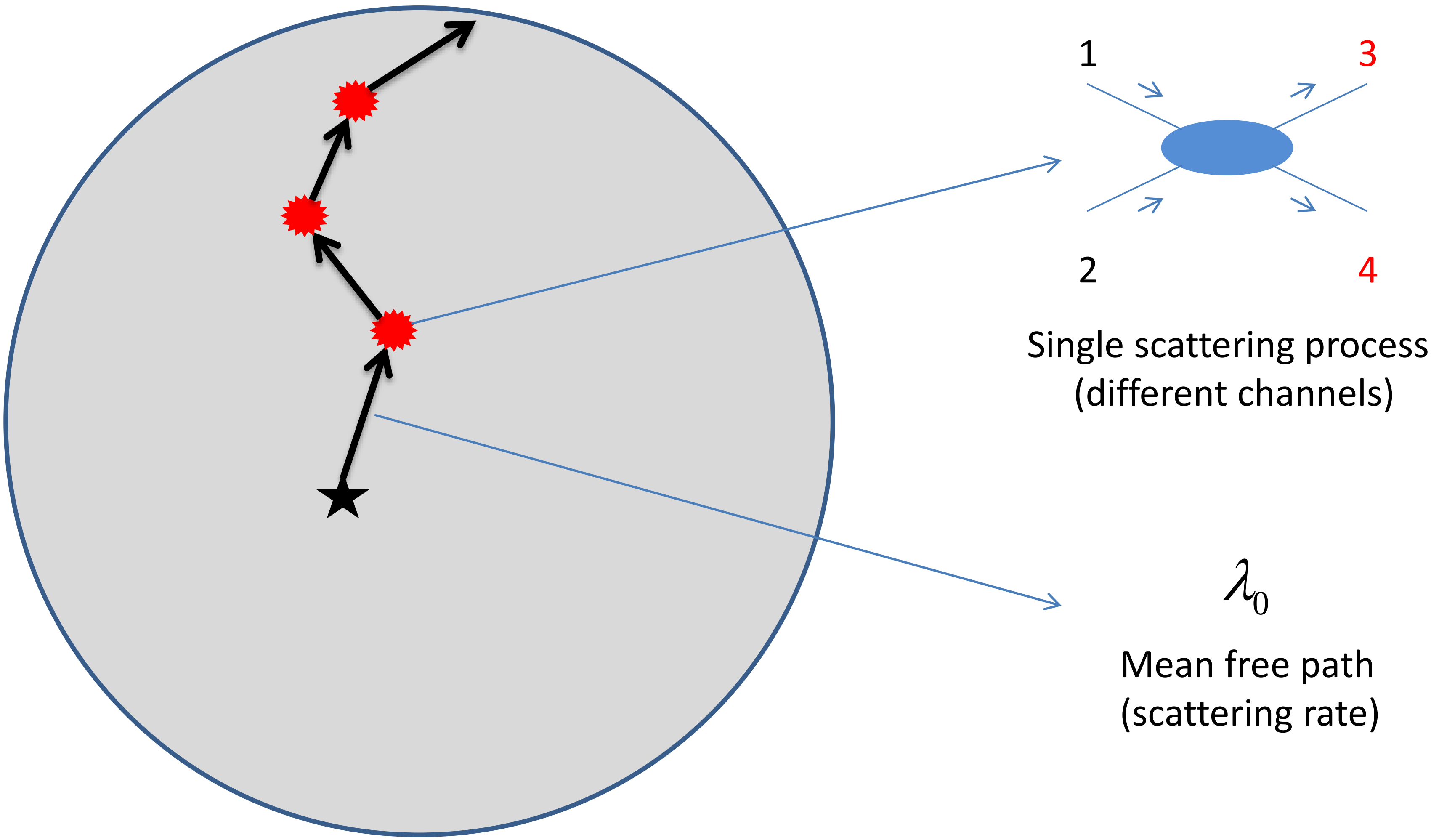


FIG. 1: (a) Energy loss as a function of time; (b) azimuthal distribution relative to the γ-direction, (c) reconstructed jet fragmentation function (parton) at different times, (d) initial (dotted) and final jet transverse profile with (solid) and without (dashed) induced radiation for γ-tagged jets in a uniform gluonic medium. See text for more detailed descriptions.

Simulation results for gamma-jet correlation describe the experiment data successfully.

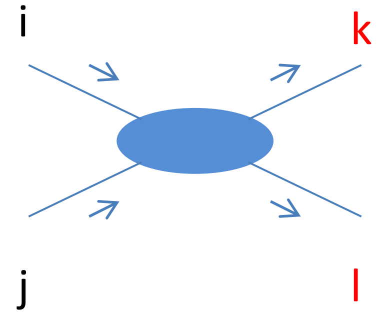
Yan Zhu Thursday 4:00pm

The Monte-Carlo Simulation : a hard parton traversing an uniform medium



a static, homogeneous and infinite QGP

Single scattering



$$i, j = g, u, d, s, \bar{u}, \bar{d}, \bar{s}$$

Jussi Auvinen, Kari J. Eskola, Thorsten Renk

Phys.Rev. C82 024906

- Scattering rate for a process $ij \to kl$ in the local rest frame of the fluid

$$\Gamma_{ij\to kl} = \frac{1}{2E_1}\int \frac{d^3p_2}{(2\pi)^3 2E_2}\int \frac{d^3p_3}{(2\pi)^3 2E_3}\int \frac{d^3p_4}{(2\pi)^3 2E_4} \times f_j(p_2\cdot u, T)$$
$$\times |M|^2_{ij\to kl}(s,t,u)\times S_2(s,t,u)\times(2\pi)^4\delta^4(P_1+P_2-P_3-P_4)$$

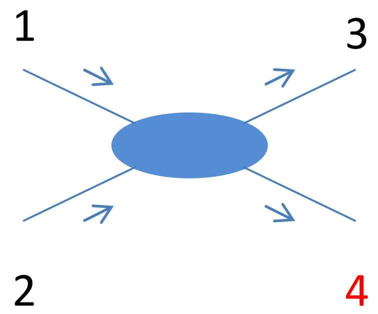
- The regularization

$$S_2(s,t,u) = \theta(s \geq 2\mu_D^2)\theta(-s+\mu_D^2 \leq t \leq -\mu_D^2) \qquad \mu_D^2 = (\frac{3}{2})4\pi\alpha_s T^2$$

- The mean free path

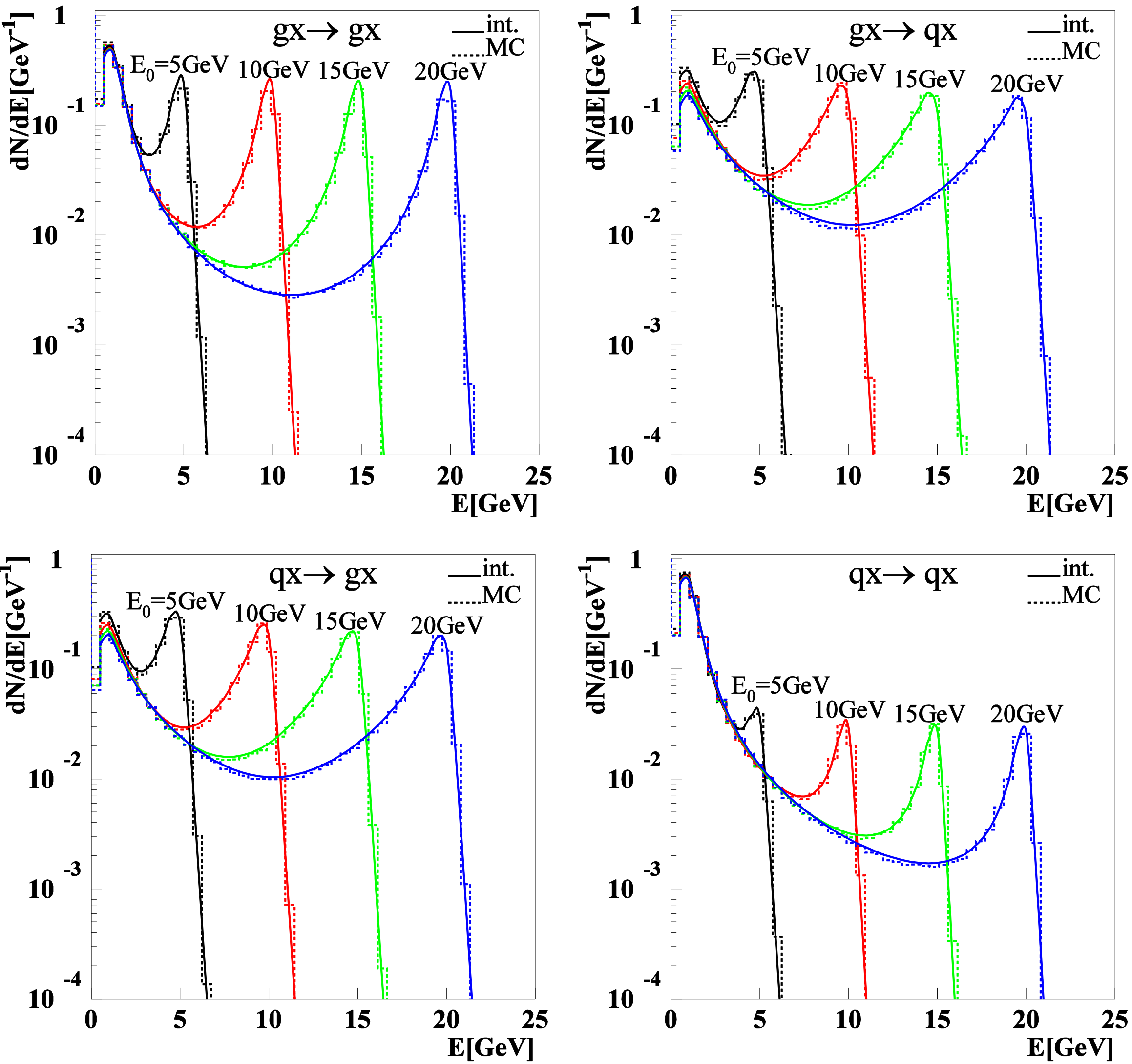
$$\Gamma_i = \sum_{j,(kl)} \Gamma_{ij\to kl} = 1/\lambda_0 \qquad P(\Delta t) = 1 - e^{-\Gamma_i \Delta t} \qquad P(ij\to kl) = \frac{\Gamma_{ij\to kl}}{\Gamma_i}$$

Single scattering



the selection of the jet parton

T=0.2GeV



$$gg \to gg$$

$$gg \to q\bar{q}$$

$$gq \to gq + g\bar{q} \to g\bar{q}$$

$$q_i g \to q_i g$$

$$q_i q_j \to q_i q_j$$

$$q_i q_i \to q_i q_i$$

$$q_i \bar{q}_i \to q_j \bar{q}_j$$

$$q_i \bar{q}_i \to q_i \bar{q}_i$$

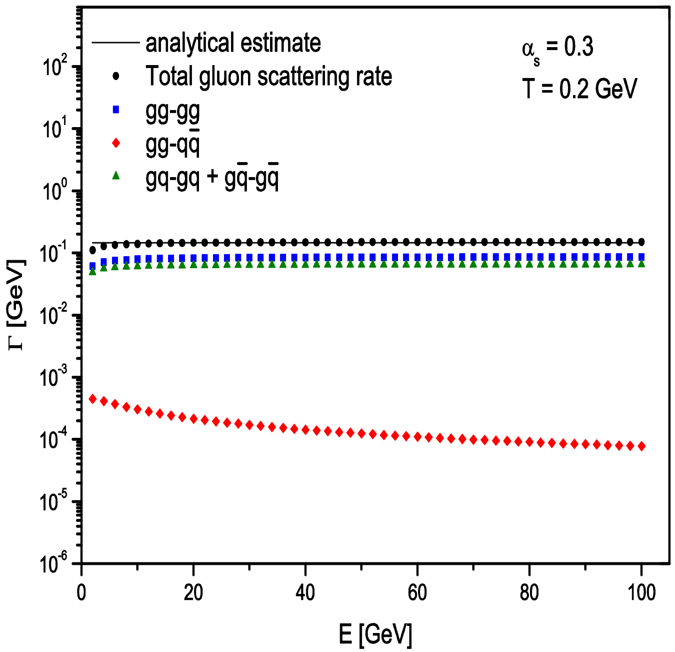
$$q_i \bar{q}_i \to gg$$

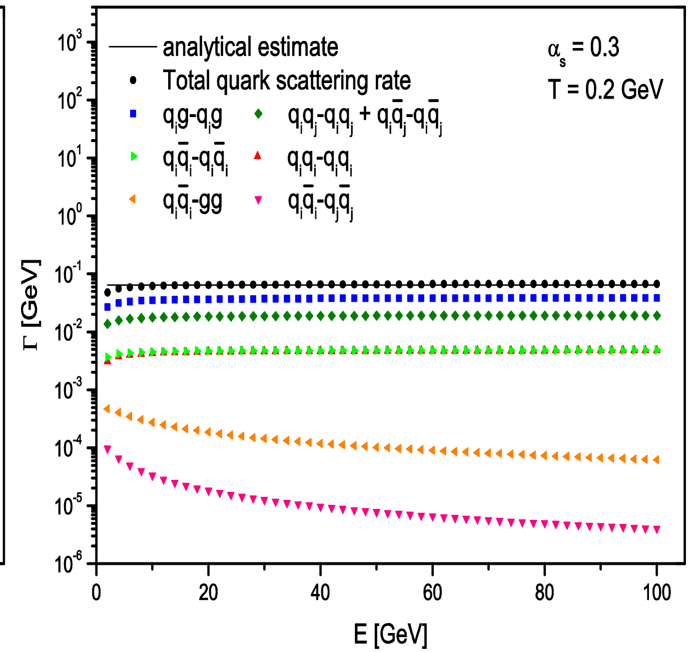
Scattering rate

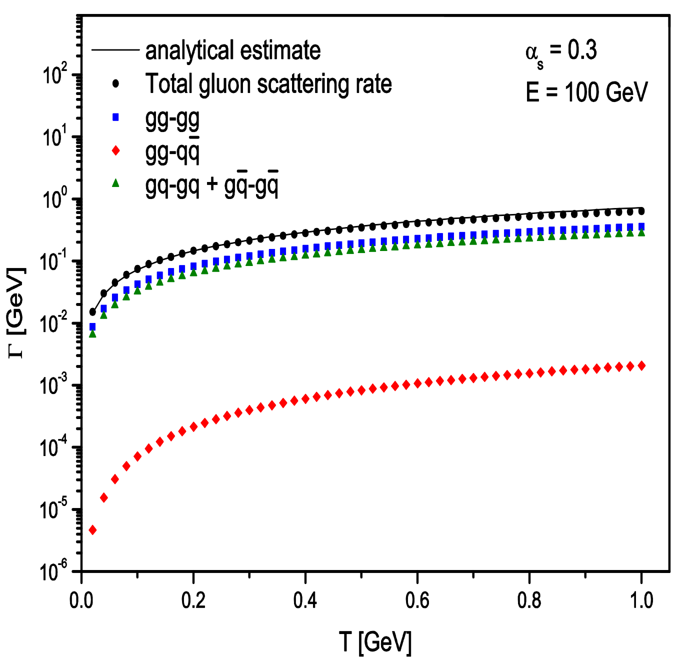
Contribution of different processes on scattering rate as functions of energy and temperature

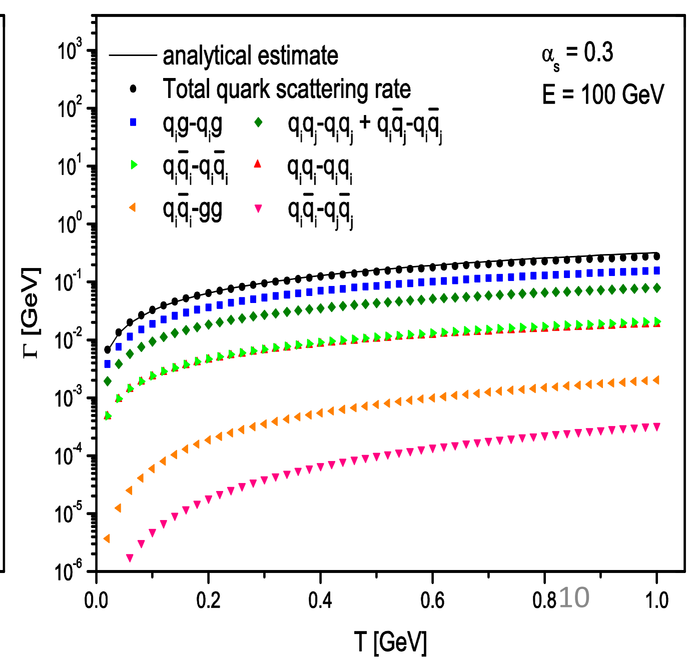
gluon

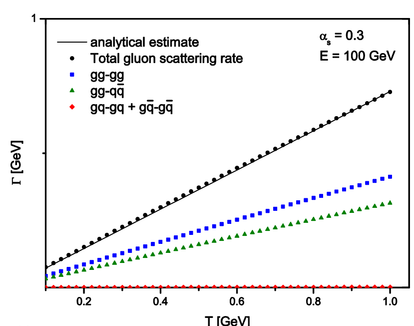
quark

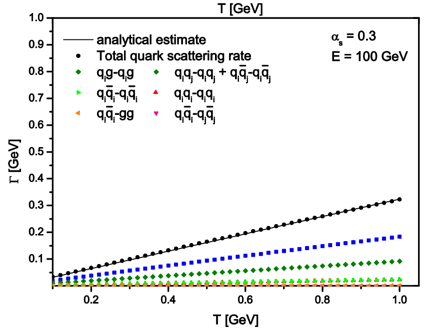






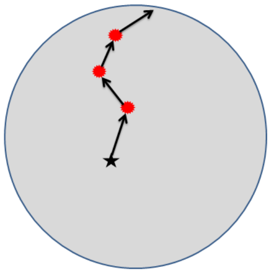






Multiple scattering

Leading parton only



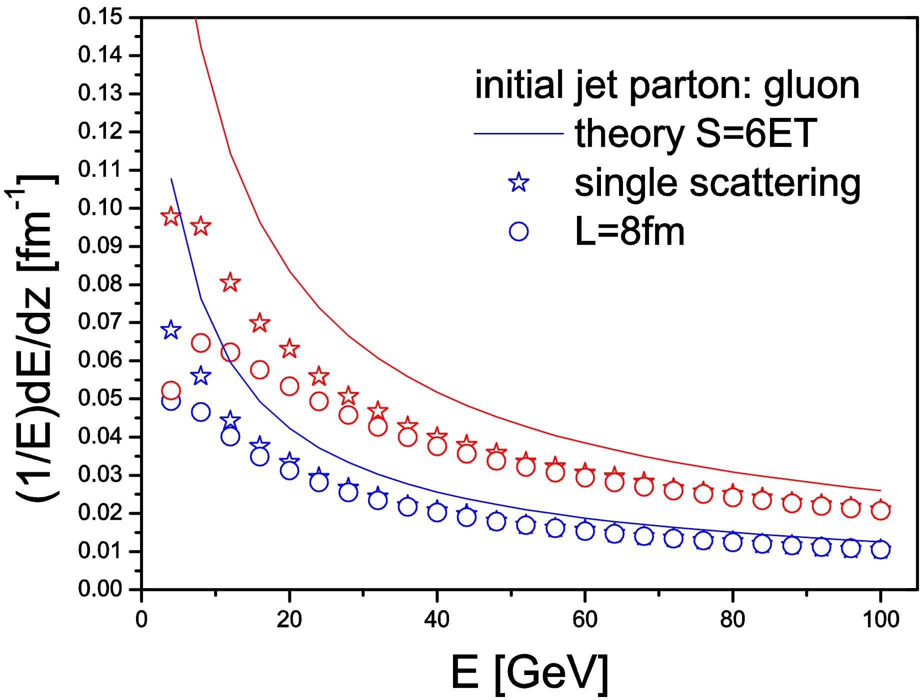
$$\frac{dE_{el}}{dz} = C\frac{3\pi\alpha_s^2}{2\mu_D^2}T^2\left\langle q_\perp^2\right\rangle$$

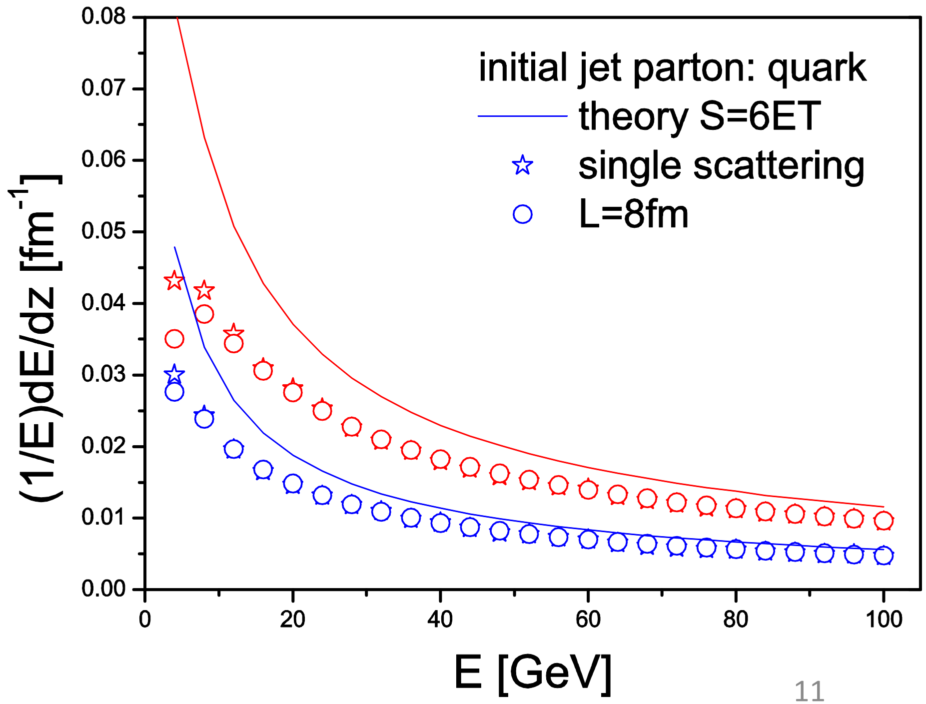
$$\left\langle q_\perp^2\right\rangle = \mu_D^2 \ln\frac{S}{4\mu_D^2}$$

C = 4/3 for quark

C = 3 for gluon

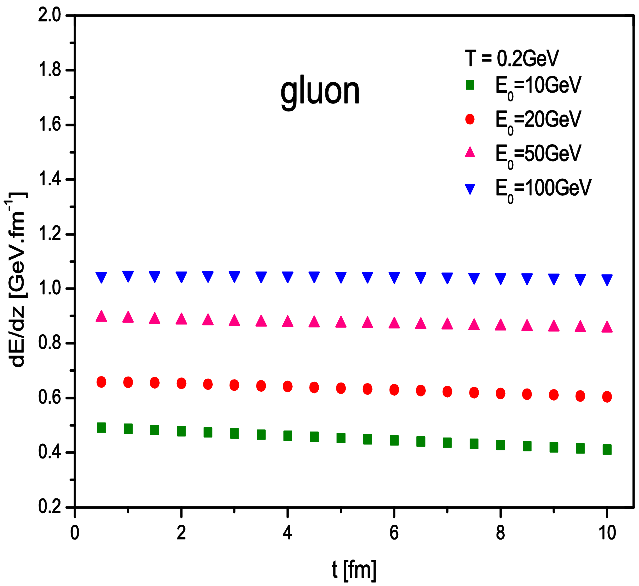
Energy loss as a function of initial energy

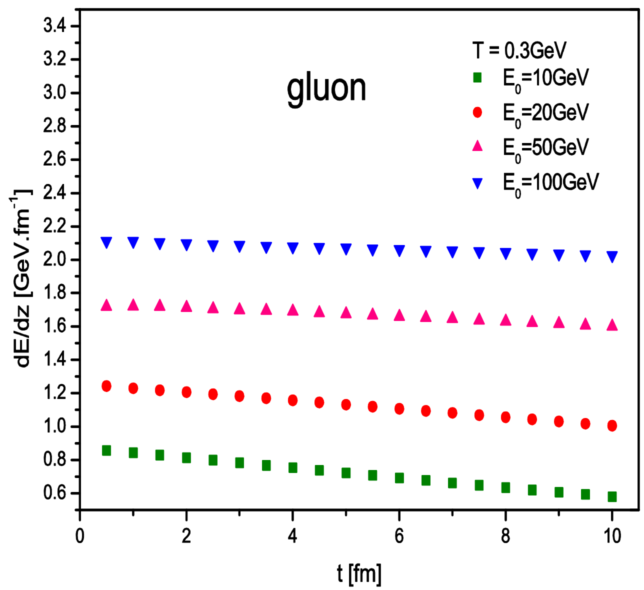


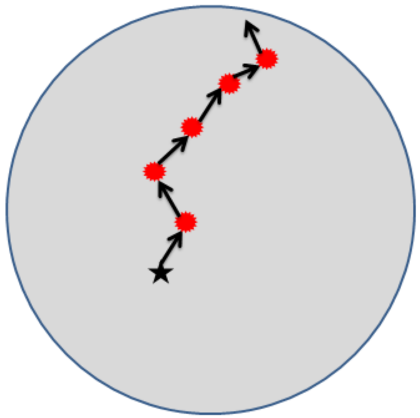


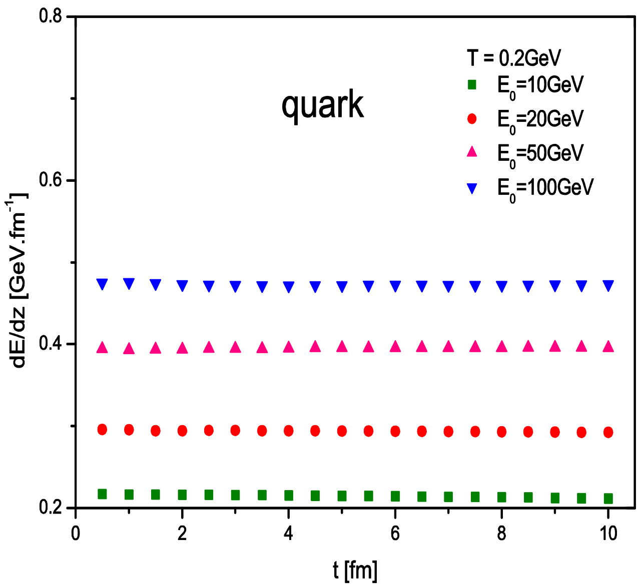
Multiple scattering

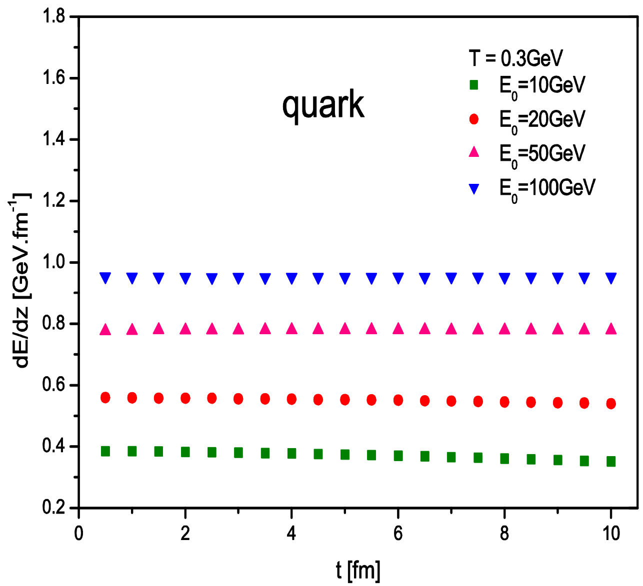
Energy loss as a function of time

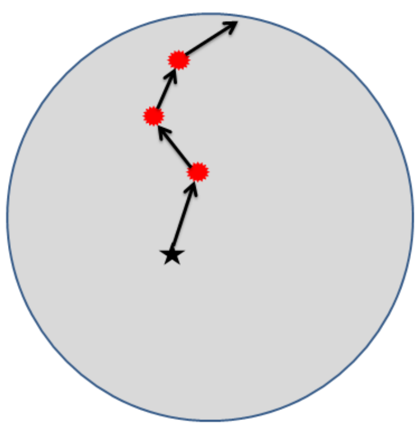












Multiple scattering

dn/dpt as a function of time

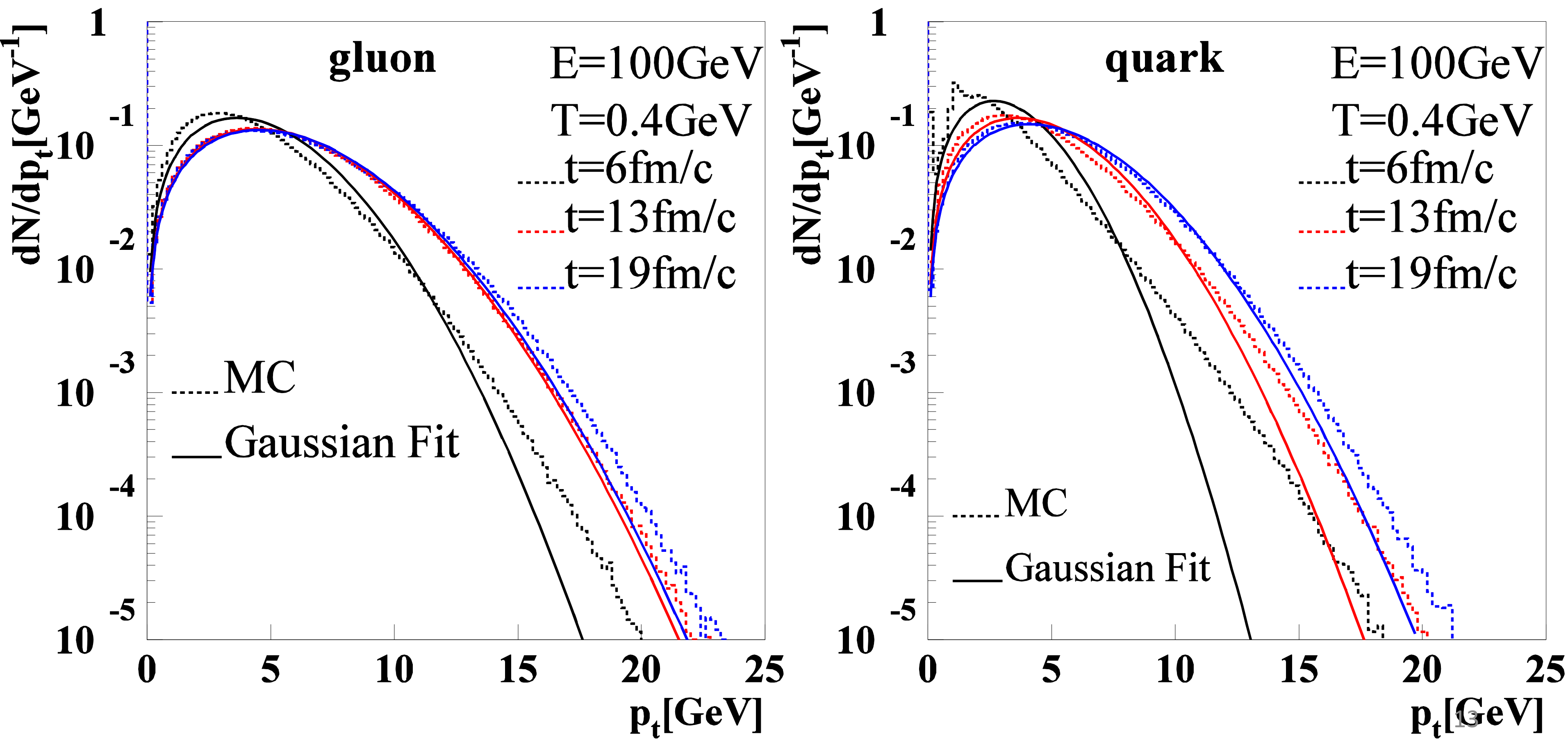
F. D'Eramo, M. Lekaveckas, Hong Liu and K. Rajagopal

arXiv:1211.1922

Gaussian fit $$\frac{dn}{dp_t} = \frac{2p_t}{\langle p_t^2 \rangle} e^{-\frac{p_t^2}{\langle p_t^2 \rangle}}$$

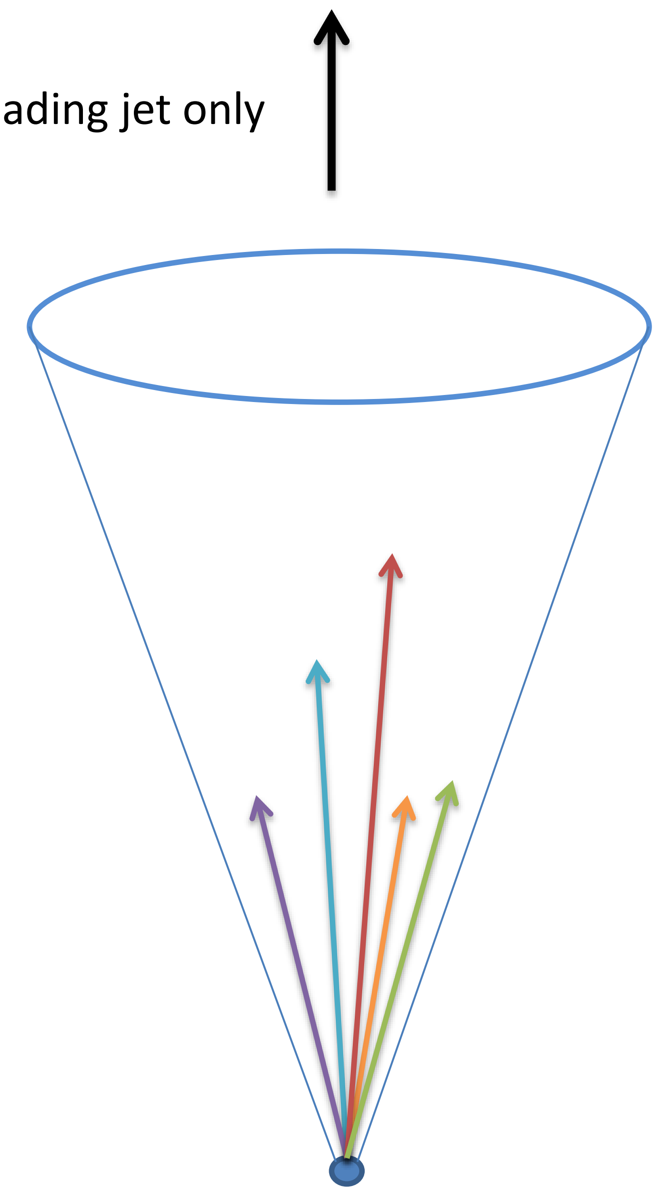
Pt broadening

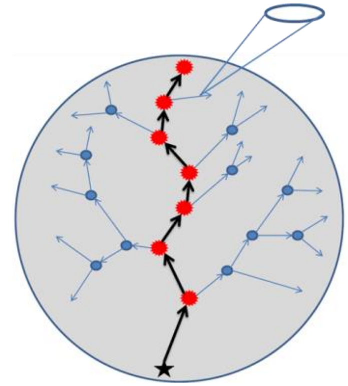
The <pt^2> comes from the MC simulation



Reconstructed jet

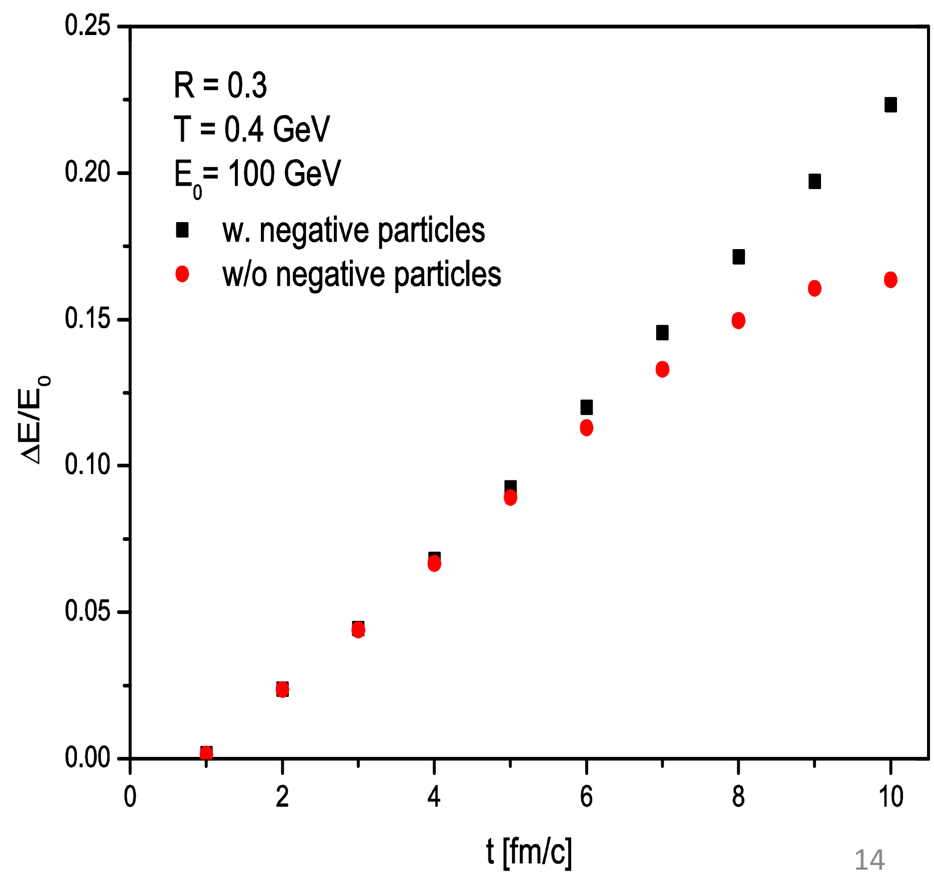
Leading jet only





Anti-Kt algorithm in FASTJET is used to reconstruct jets

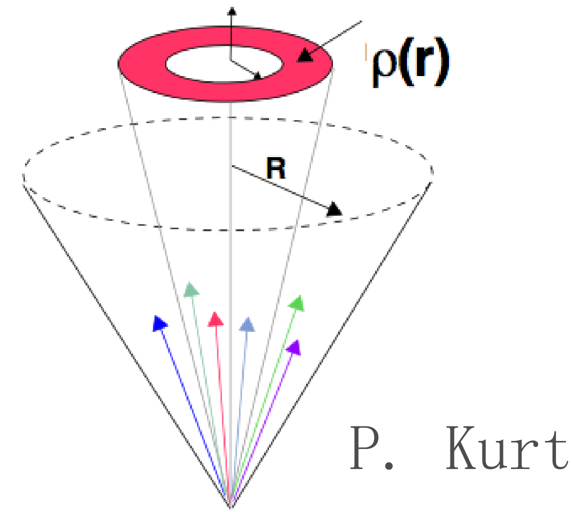
Energy loss



Reconstructed jet

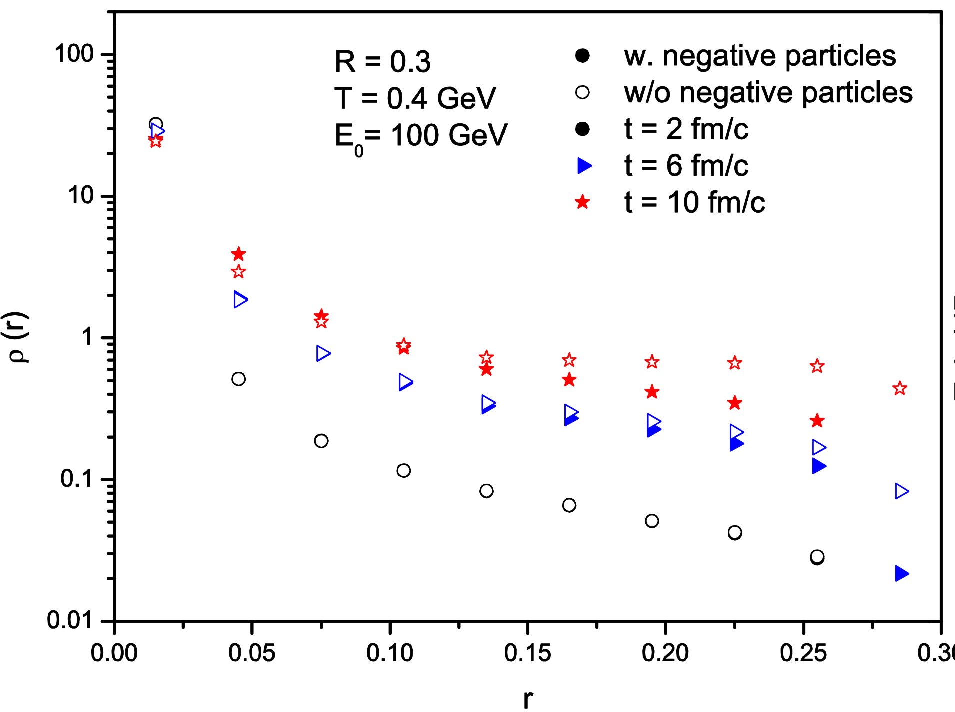
$$\rho(r) = \frac{1}{\Delta r}\frac{1}{N_{jet}}\sum_{jets}\frac{p_t(r-\frac{\Delta r}{2}, r+\frac{\Delta r}{2})}{p_t(0,R)}$$

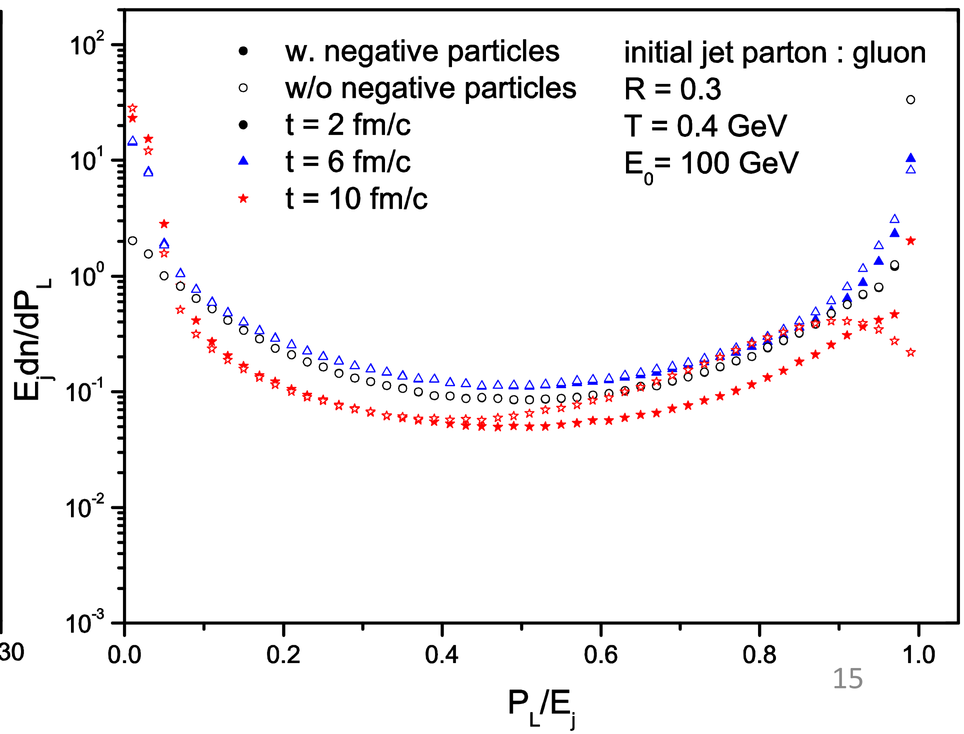
$$Z_{jet} = P_L / E_{jet}$$



transverse profile

longitudinal profile





Summary

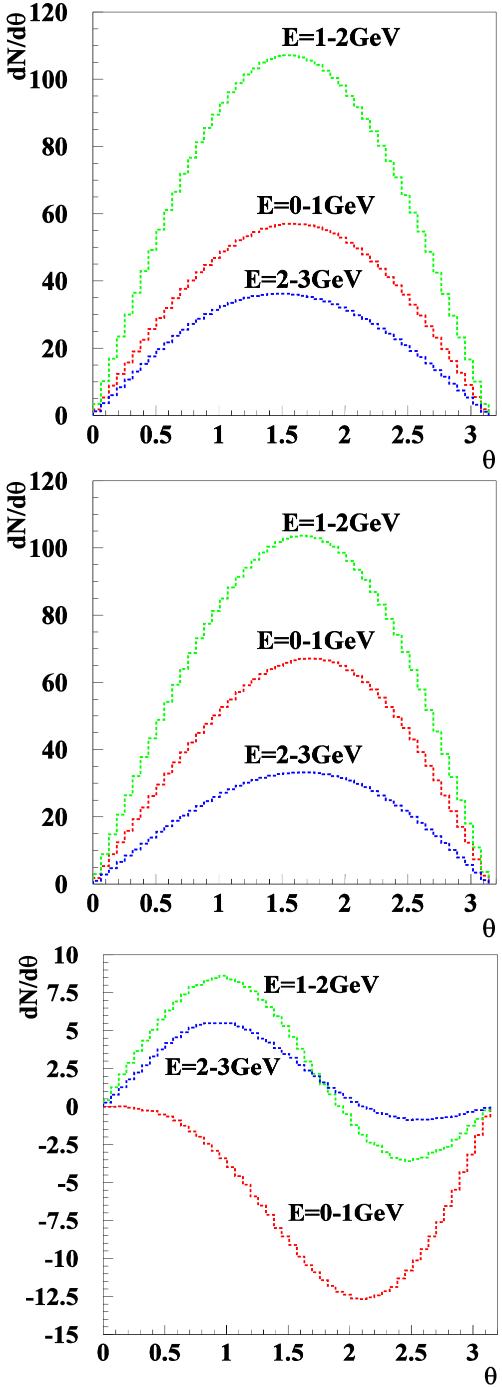
- We present a computation of elastic energy loss of the leading parton traversing the uniform medium.
- The FASTJET program is used to reconstruct jets, the leading jet structure is distorted by the interaction with thermal partons.

Outlook

- Radiative energy loss. Xin-Nian Wang, Yan Zhu **Phys.Rev.Lett. 111, 062301**
- LBT+Hydro.
- Heavy quark energy loss.

Thanks

t=9fm



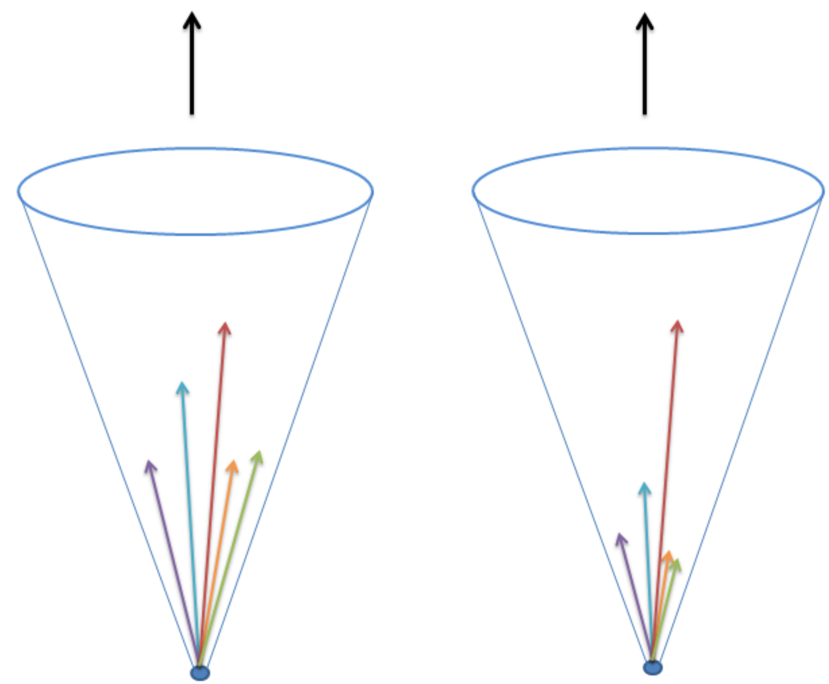
positive

negative

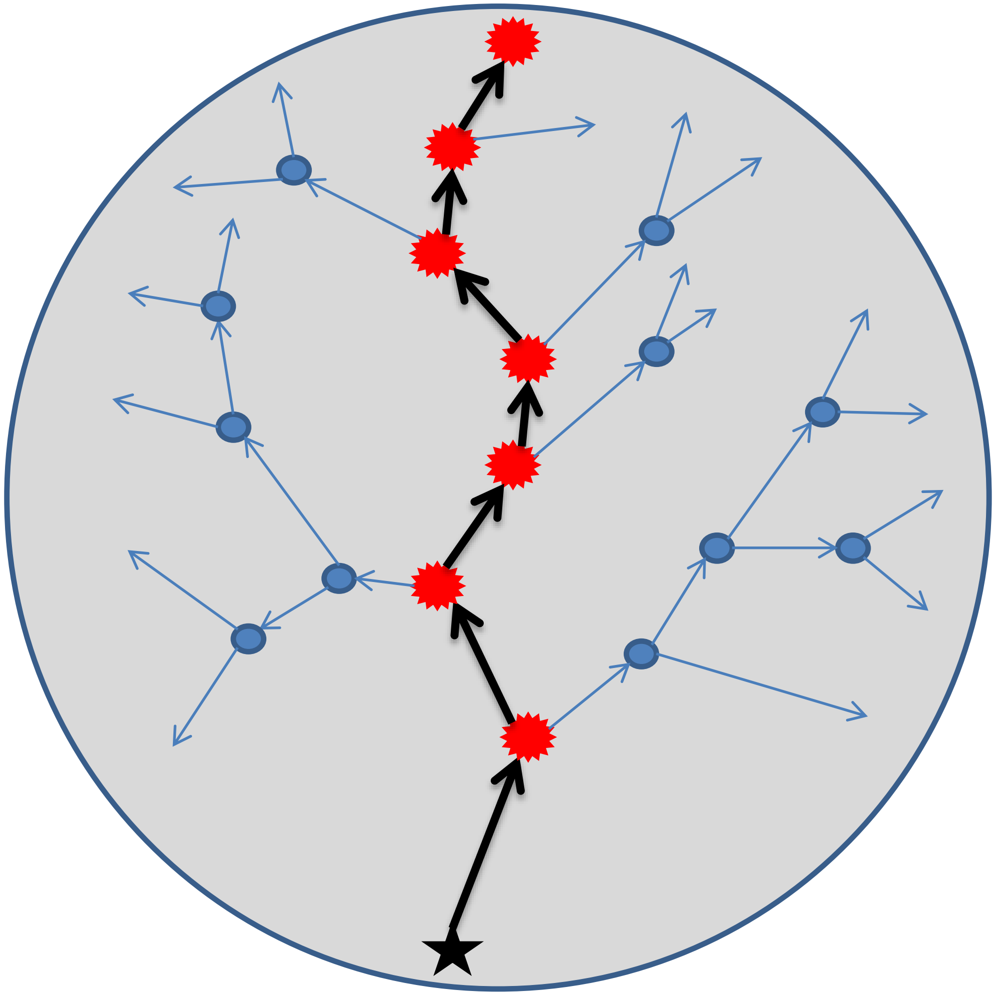
combine

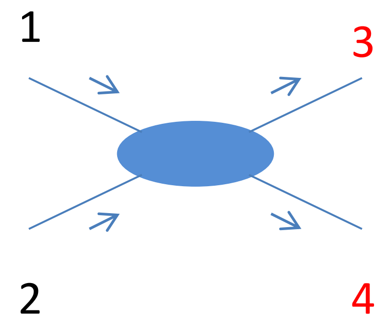
w/o negative

w. negative



Positive particles : Medium Excitation





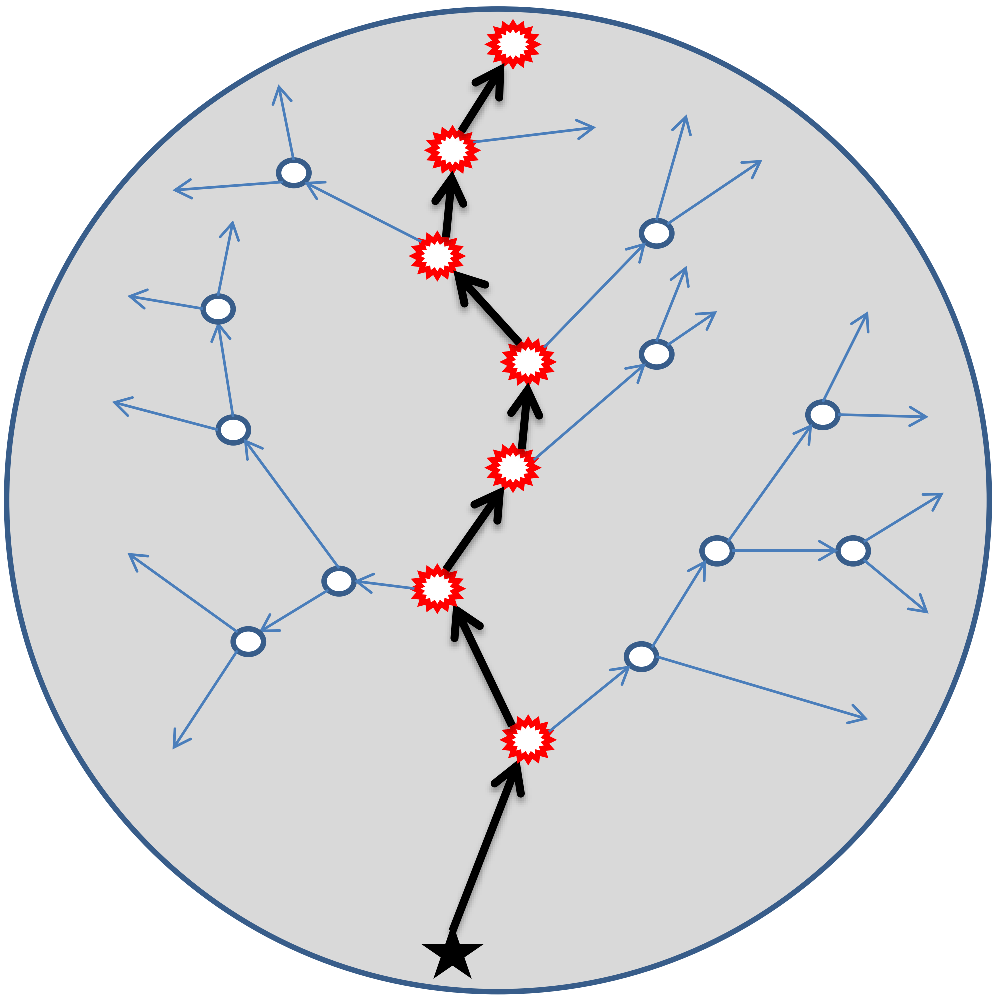
Leading parton-----thermal parton scattering

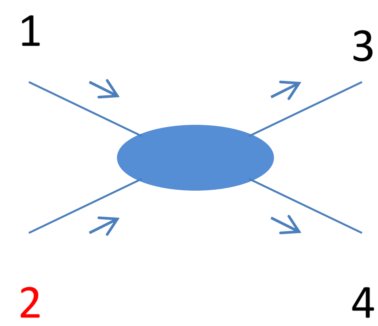
recoiled parton-----thermal parton scattering

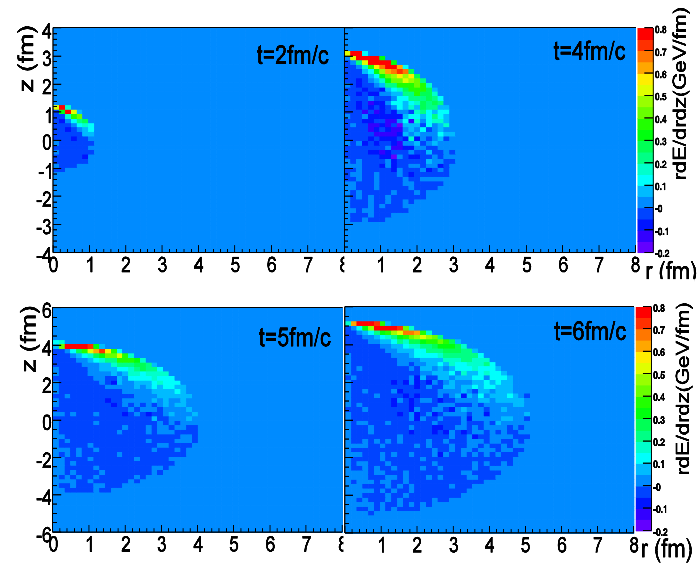
Linearized Boltzmann jet transport
neglect scatterings between recoiled medium partons.

It’s a good approximation when the jet induced medium excitation δf<<f.

Negative particles : the particle hole

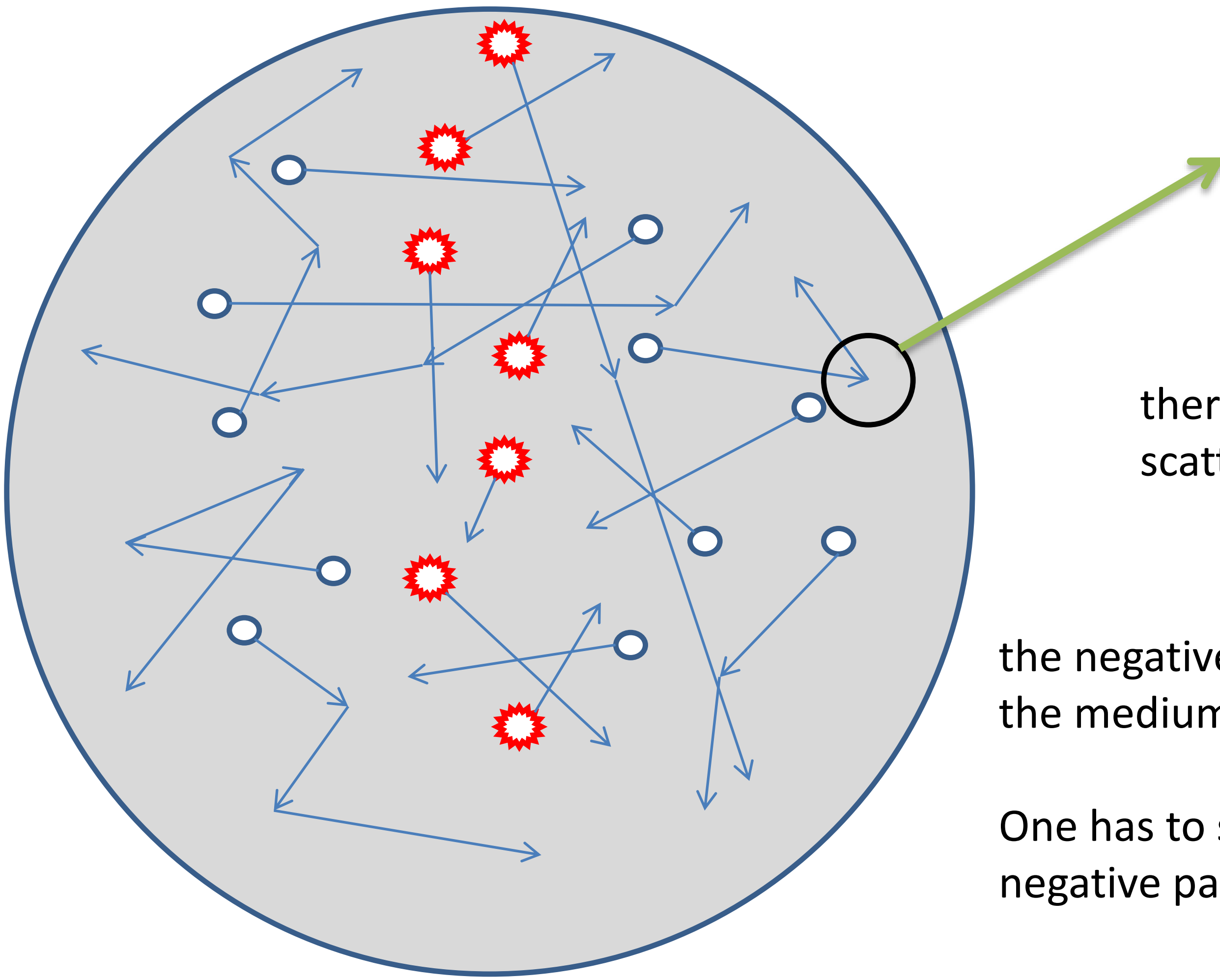


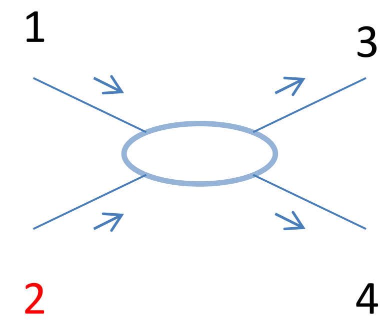




One has to subtract the 4-momentum of negative particle when combine it to jet

Negative particles : how do we deal with them?



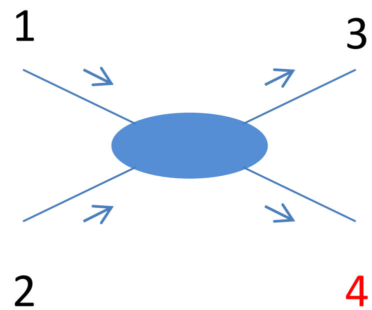


thermal parton-----thermal parton scattering

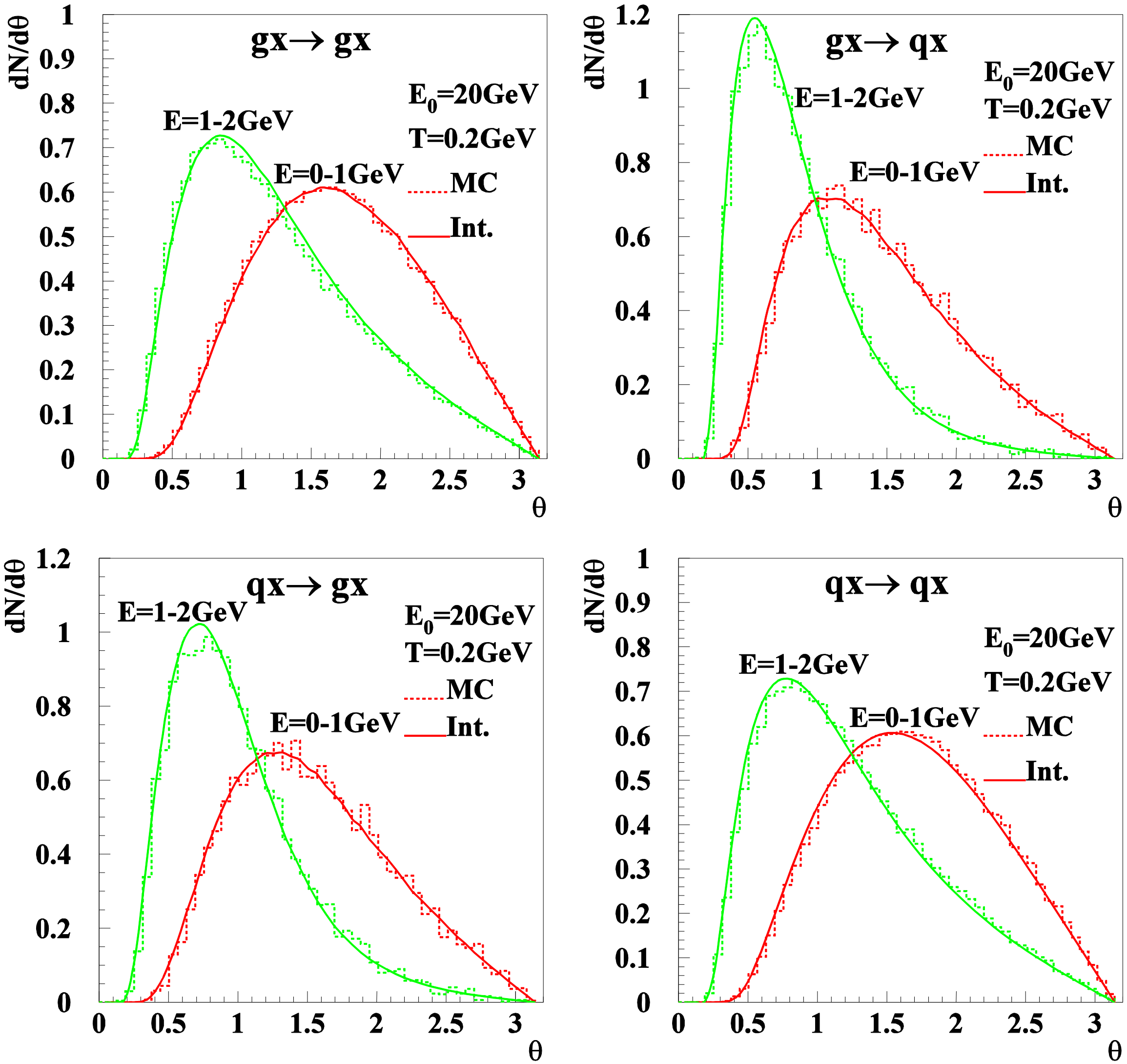
the negative particle is also traveling in the medium

One has to subtract the 4-momentum of negative particle when combine it to jet

Single scattering



the direction of the recoiled partons are more likely to be closer to the incoming jets'



$$gg \to gg$$

$$gg \to q\bar{q}$$

$$gq \to gq + g\bar{q} \to g\bar{q}$$

$$q_i g \to q_i g$$

$$q_i q_j \to q_i q_j$$

$$q_i q_i \to q_i q_i$$

$$q_i \bar{q}_i \to q_j \bar{q}_j$$

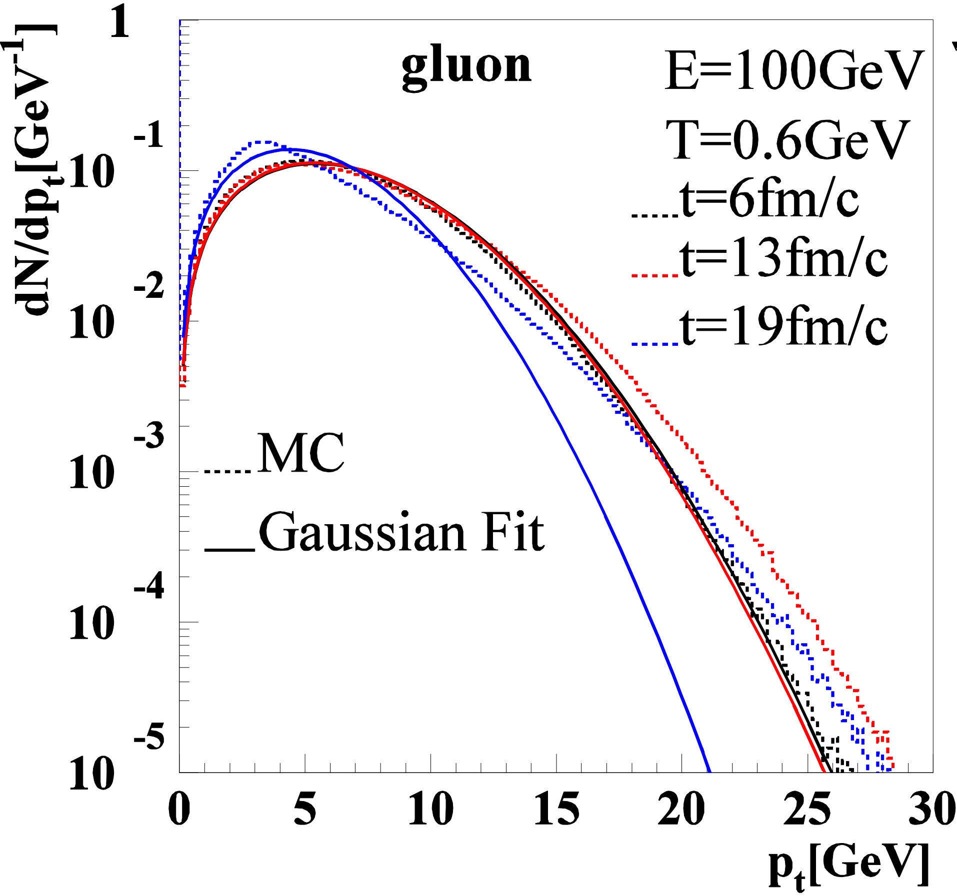
$$q_i \bar{q}_i \to q_i \bar{q}_i$$

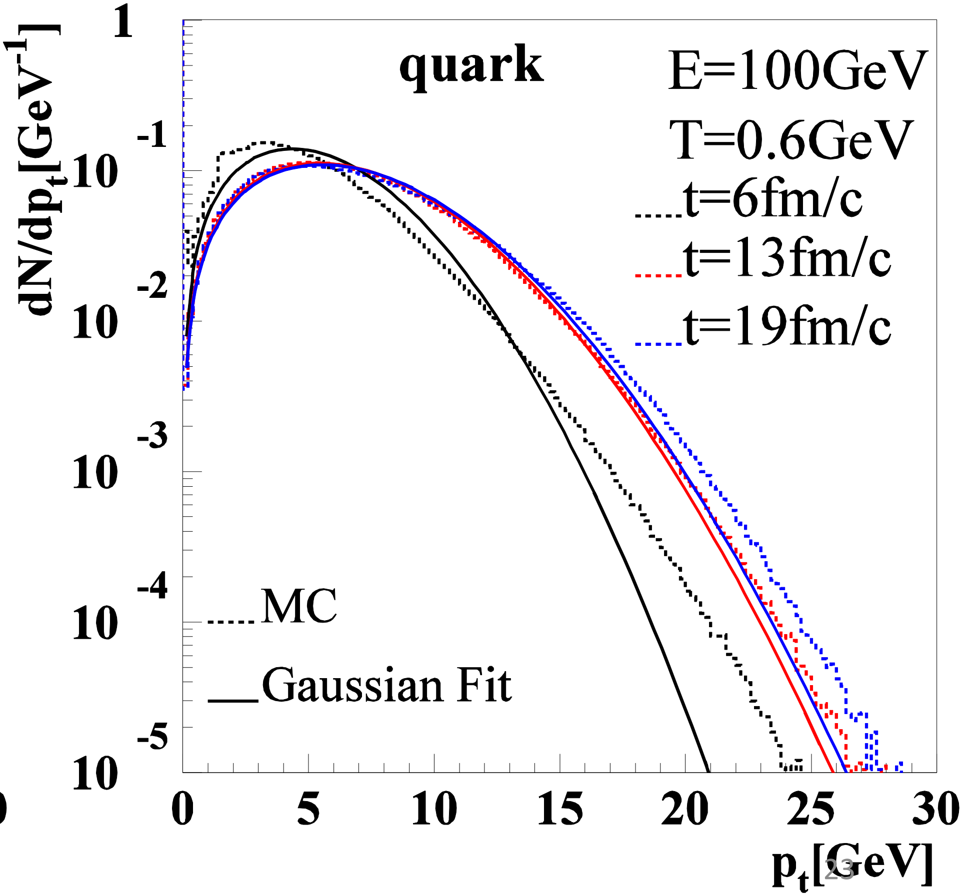
$$q_i \bar{q}_i \to gg$$

Multiple scattering

dn/dpt as a function of time

Gaussian fit $$\frac{dn}{dp_t} = \frac{2p_t}{\langle p_t^2 \rangle} e^{-\frac{p_t^2}{\langle p_t^2 \rangle}}$$





Scattering rate

- The total scattering rate for a hard parton i is defined as

$$\Gamma_i = \sum_{j,(kl)} \Gamma_{ij\to kl} = 1/\lambda_0 \qquad P(\Delta t) = 1 - e^{-\Gamma_i \Delta t} \qquad P(ij \to kl) = \frac{\Gamma_{ij\to kl}}{\Gamma_i}$$

- The total scattering rate for a gluon

$$\Gamma_g = \Gamma_{gg\to gg} + \Gamma_{gg\to q\bar{q}} + \Gamma_{gq\to gq + g\bar{q}\to g\bar{q}}$$

- The total scattering rate for a quark

$$\Gamma_{q_i} = \Gamma_{q_i g\to q_i g} + \Gamma_{q_i q_j\to q_i q_j} + \Gamma_{q_i q_i\to q_i q_i} + \Gamma_{q_i \bar{q}_i\to q_j \bar{q}_j} + \Gamma_{q_i \bar{q}_i\to q_i \bar{q}_i} + \Gamma_{q_i \bar{q}_i\to gg}$$