Initial State Parton Evolution beyond the Leading Logarithmic Order of QCD

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Minami-Tateya QCD meeting

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H. Tanaka, PTP **110** (2003) 963.

✓Introduction

- LL Parton Shower Evolution
  1. Parton number evolution

     non-singlet parton

  2. Parton momentum evolution

     singlet parton

  (H. Tanaka, T. Munehisa, Mod. Phys. Lett. A13(1998)1085)

⬇

NLL parton evolution

✓Splitting function

$$P_{ij}(\alpha_s, z) = \frac{\alpha_s}{2\pi} P_{ij}^{(0)}(z) + \left(\frac{\alpha_s}{2\pi}\right)^2 P_{ij}^{(1)}(z)$$

i,j : quark or gluon

LL order

NLL order

$$P_q(\alpha_s, z) = P_{qq}(\alpha_s, z) + P_{gq}(\alpha_s, z),$$

$$P_g(\alpha_s, z) = 2N_f P_{qg}(\alpha_s, z) + P_{gg}(\alpha_s, z)$$

✓Parton momentum evolution

Sudakov (non branching) formactor

$$\Pi_{NB}^{(i)}(K_2^2, K_1^2) = \exp[-\int_{K_1^2}^{K_2^2} \frac{dK^2}{K^2} \int_0^{1-\varepsilon} dz z P_i(\alpha_s, z)]$$

real emission term

$$\int_0^1 dx x[\Sigma(x, K^2) + G(x, K^2)] = 1$$

number distribtion

: momentum conservation

$$\int_0^1 dz z[P_i(\alpha_s, z)]_+ = 0$$

: normalization

✓Three body branch

Let's consider following 3-body braching

$$a(p) \longrightarrow g(k_1) + g(k_2) + a(k_3)$$

quark or gluon

p, k_1, k_2, k_3 : momentum

$p^2 = k_1{}^2 = k_2{}^2 = 0$, $k_3{}^2 = s < 0$

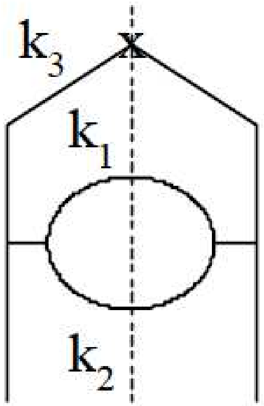
3-body decay function

$$V^{(3)} = \left(\frac{\alpha_s}{2\pi}\right)^2 \delta(1 - x_1 - x_2 - x_3) dx_1 dx_2 dx_3 \sum_{j=A}^{D} J^{[j]} \frac{d(-s)}{-s}$$

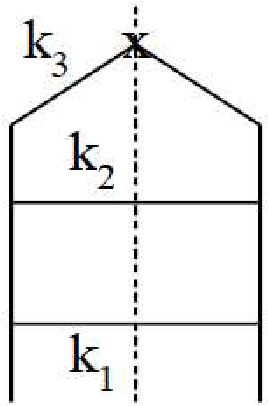
x_i : momentum fraction

$j=A,B,C,D$: type of matrix elements

✓Diagrams for the squared ME



[A]



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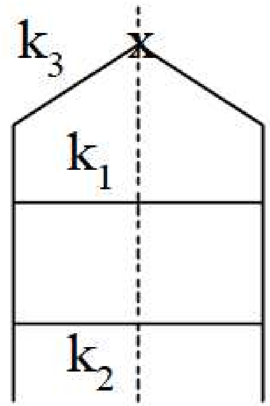

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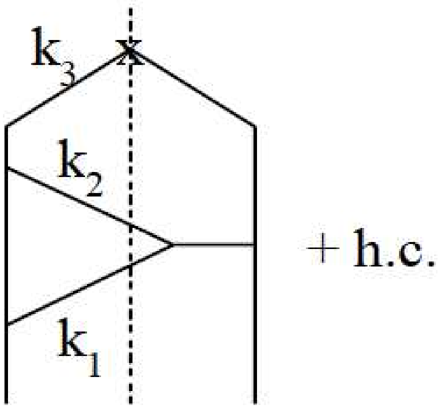

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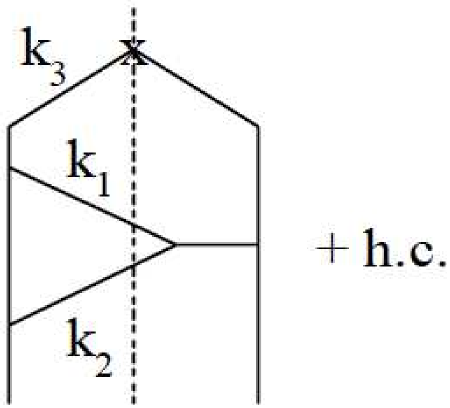

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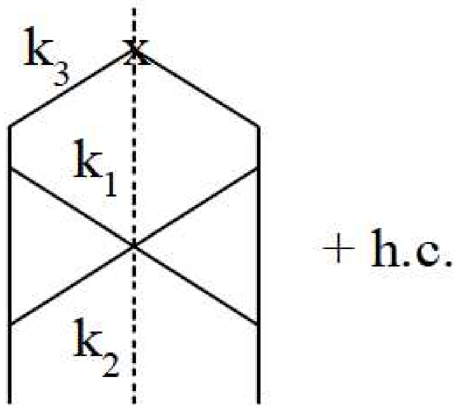


[D]

For ***j=A,B1,B2*** :

$$J^{[j]} = \int_{M_0^2}^{(-s)} L^{[j]} \log \frac{dK_j^2}{K_j^2} + L^{[j]} \log W^{[j]} + N^{[j]}$$

↑

O($\alpha_s^{\,2}$) term of LL contribution

↑

They must be subtracted from $V^{(3)}$

For ***j=C1,C2,D*** :

$$J^{[j]} = L^{[j]} \log W^{[j]} + N^{[j]}$$

✓Subtraction of the LL order terms

$$J_M = J_0 - \int_{M_0^2}^{(-s)f_A} L^{[A]} \frac{dK_A^2}{K_A^2} - \int_{M_0^2}^{(-s)f_{B1}} L^{[B1]} \frac{dK_{B1}^2}{K_{B1}^2} - \int_{M_0^2}^{(-s)f_{B2}} L^{[B2]} \frac{dK_{B2}^2}{K_{B2}^2}$$

$$J_0 = \sum_{j=A}^{D} J^{[j]}$$

Our choice

$$f_{B1}=f_{B2}=1 \quad (K^2_{B1}, K^2_{B2}<-s)$$

$$f_A = exp(\overline{J}_0 / L^{[A]})$$

$$\tilde{J}_0 = J_0 - (L^{[A]} + L^{[B1]} + L^{[B2]}) \ln(-s/M_0^2)$$

$$J_M=0$$

✓Where is the NLL contribution ?

Only 2-body brancing!

For small $x_1 \ll x_2, x_3$,

$f_A \approx x_1$

↓

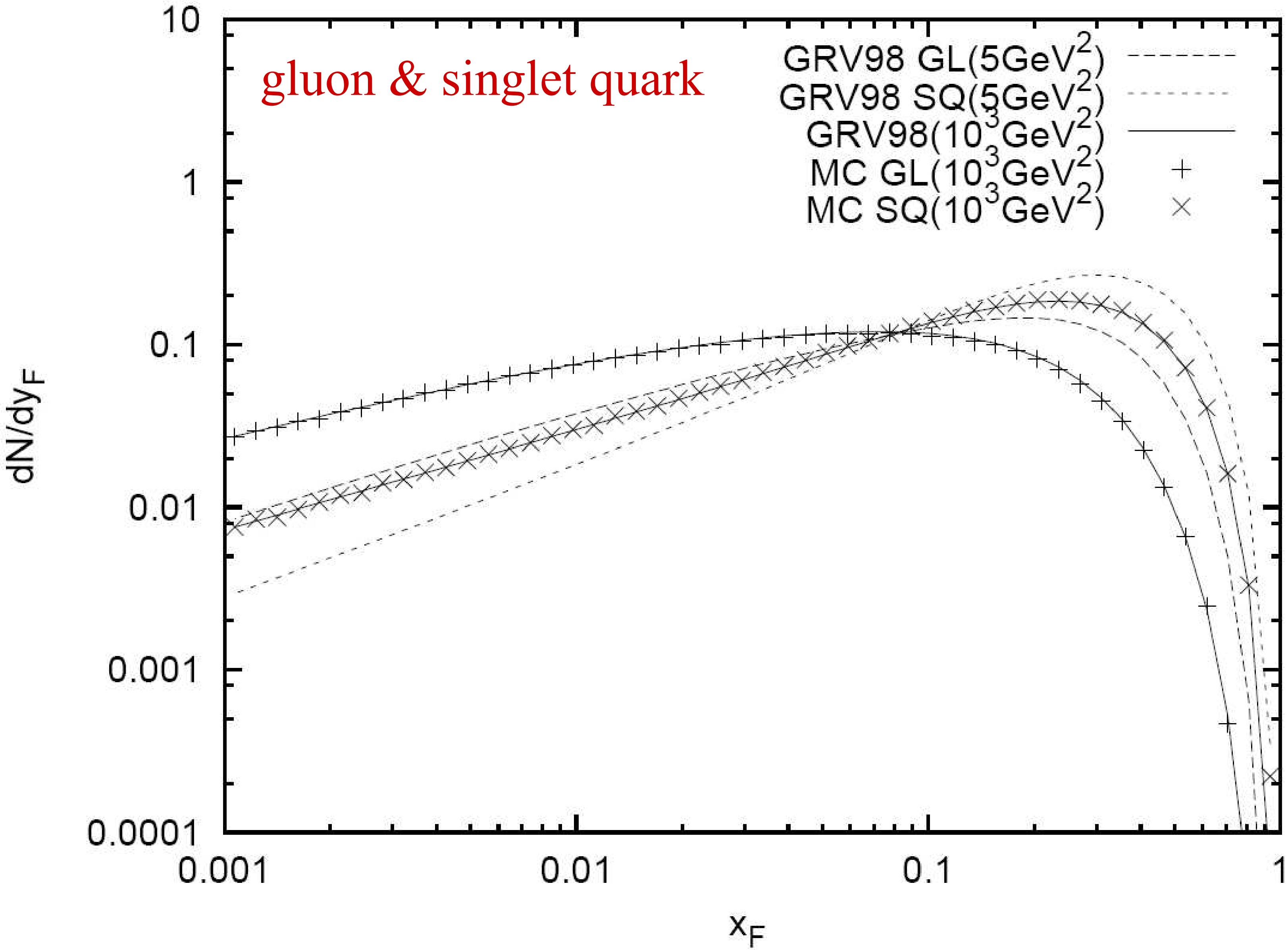
$\theta_{k1k2} < \theta_{pk2}$

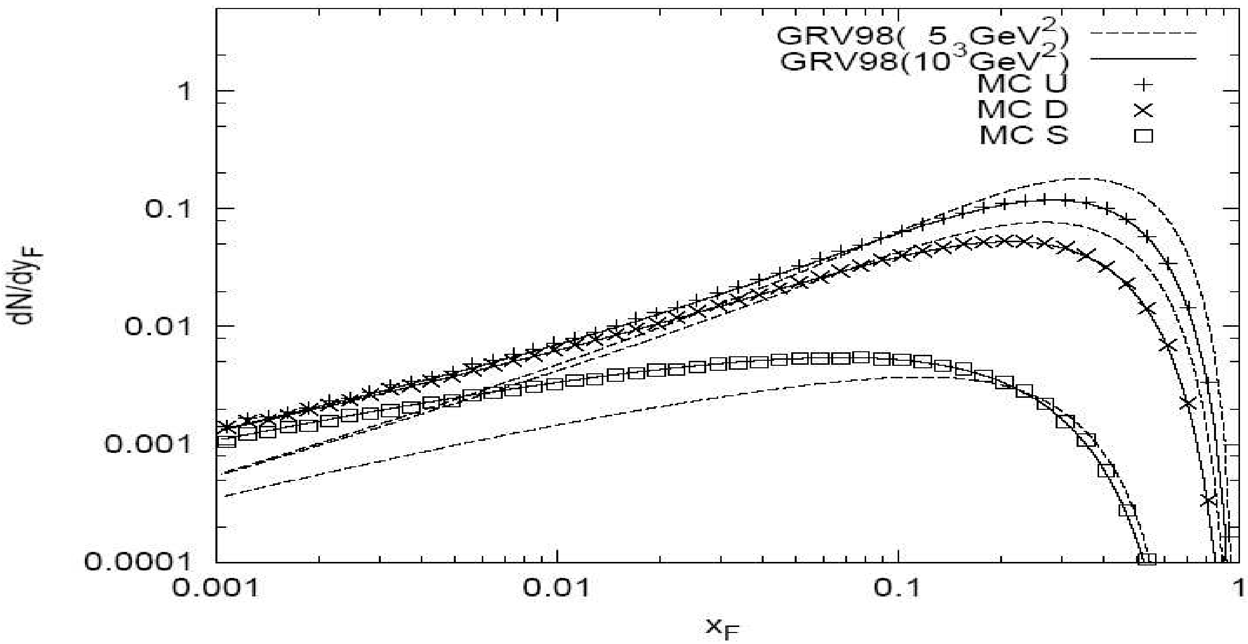
↓

Angular ordering !!

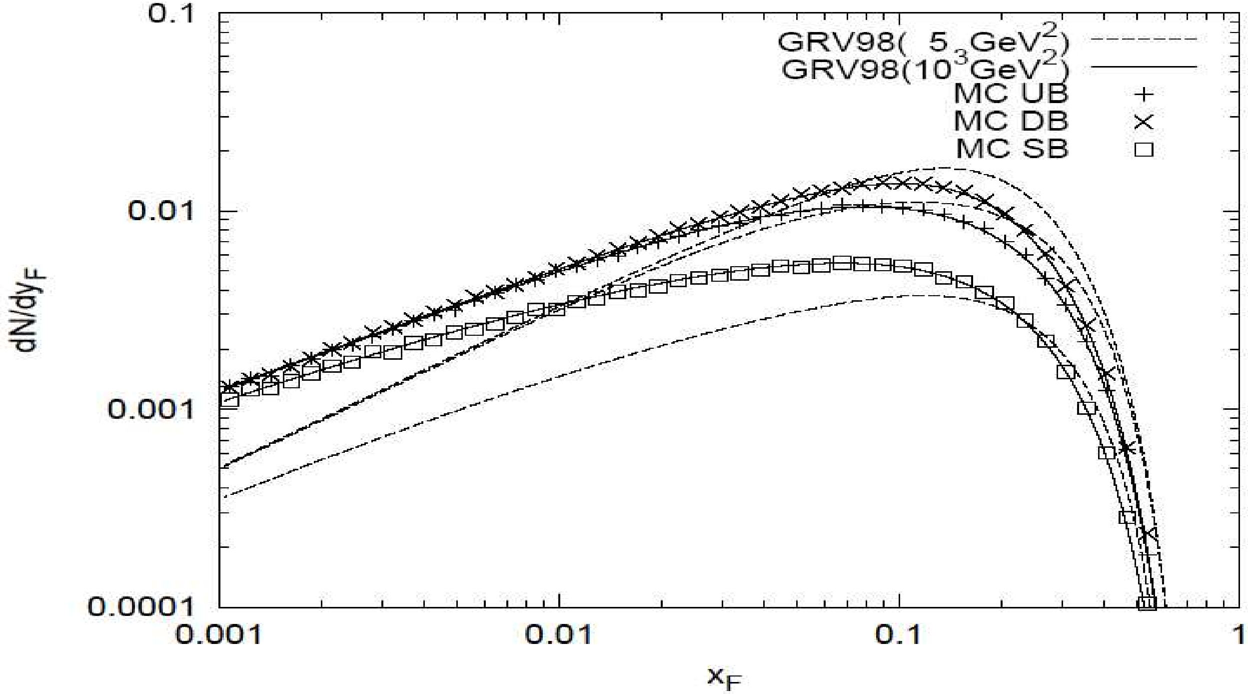
NLL effect is in the kinematical boundary

✓Numerical results



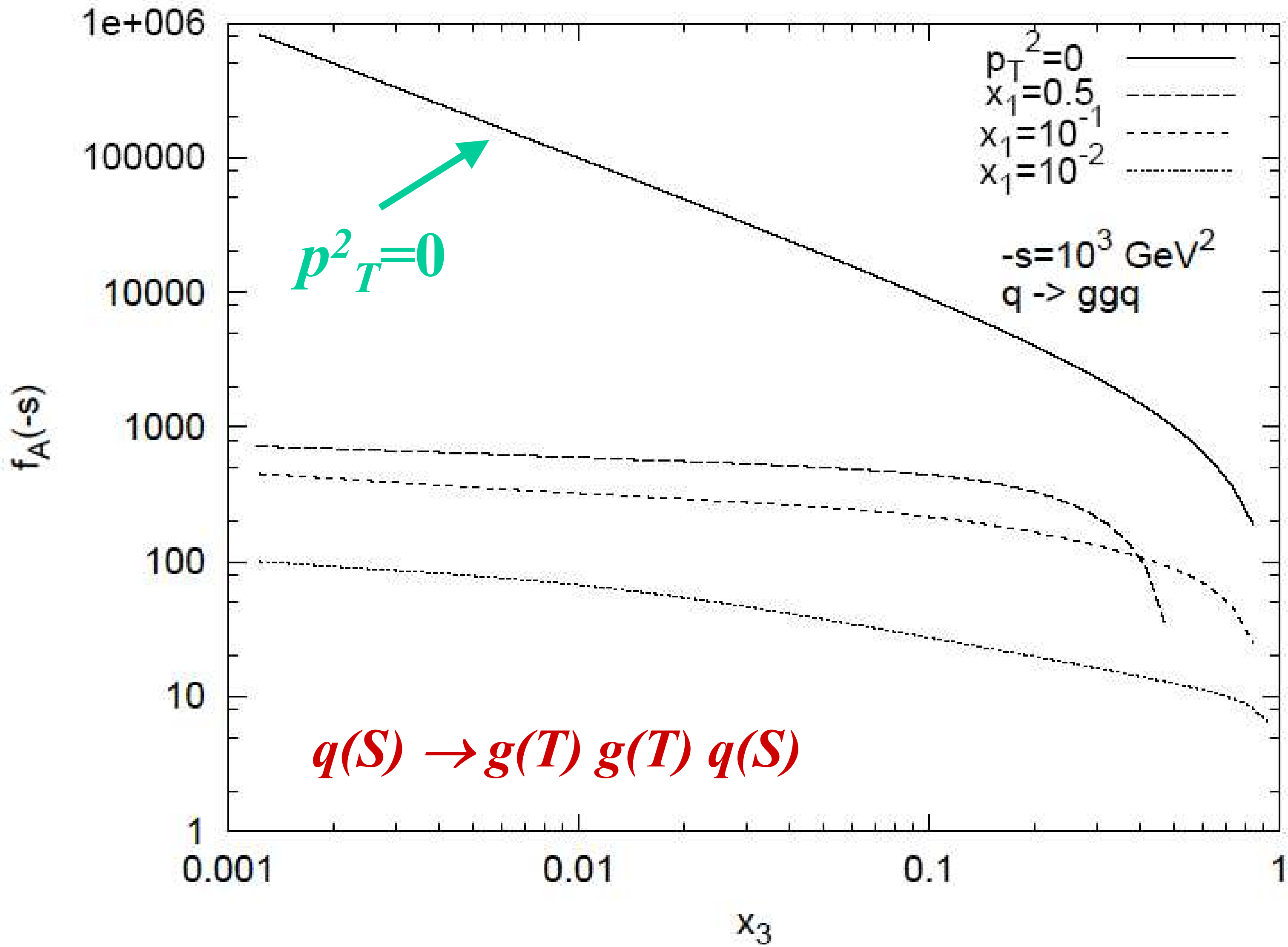


each quark flavor

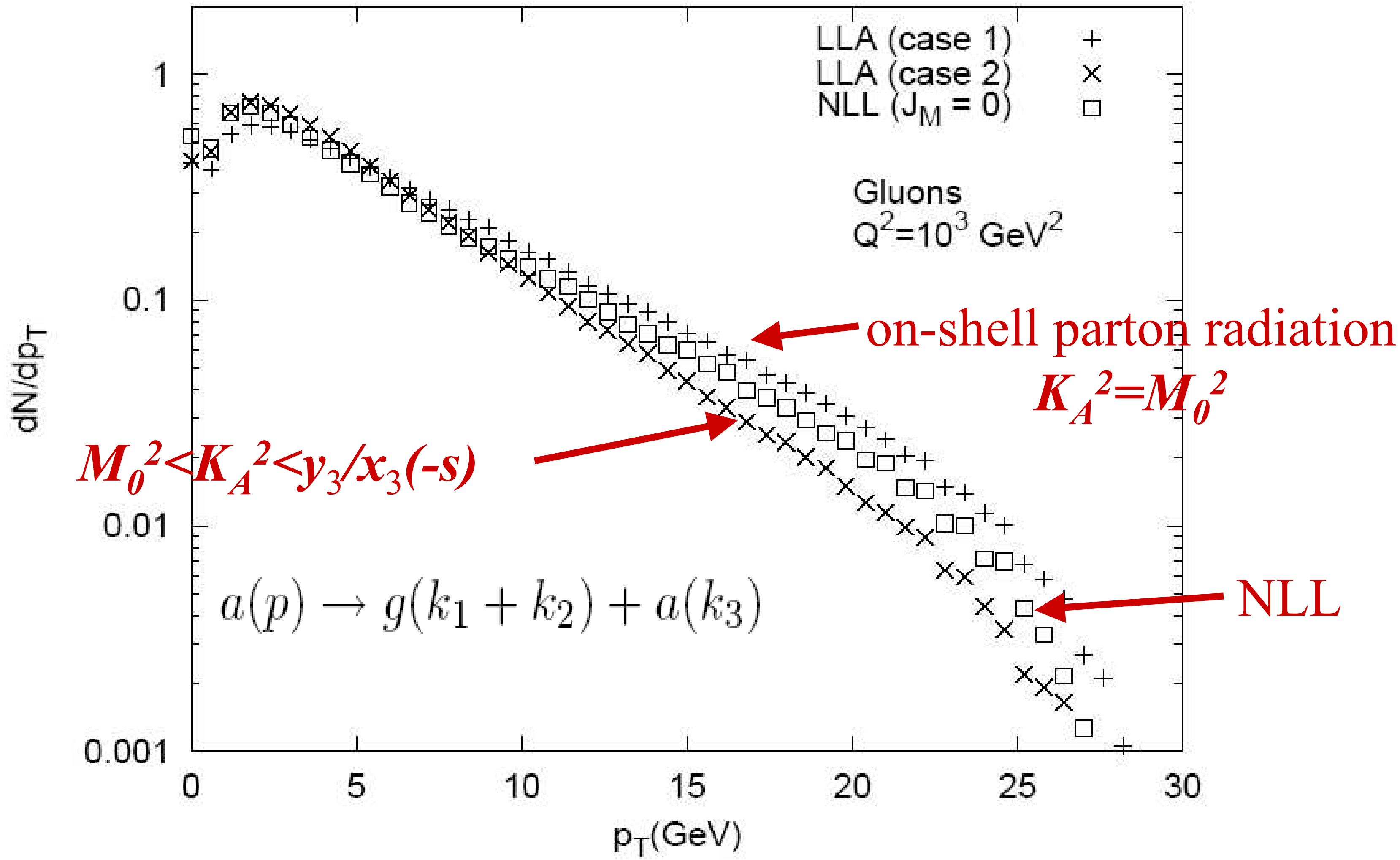


anti-quark

upper limits of K^2_A



p_T distribution Gluon

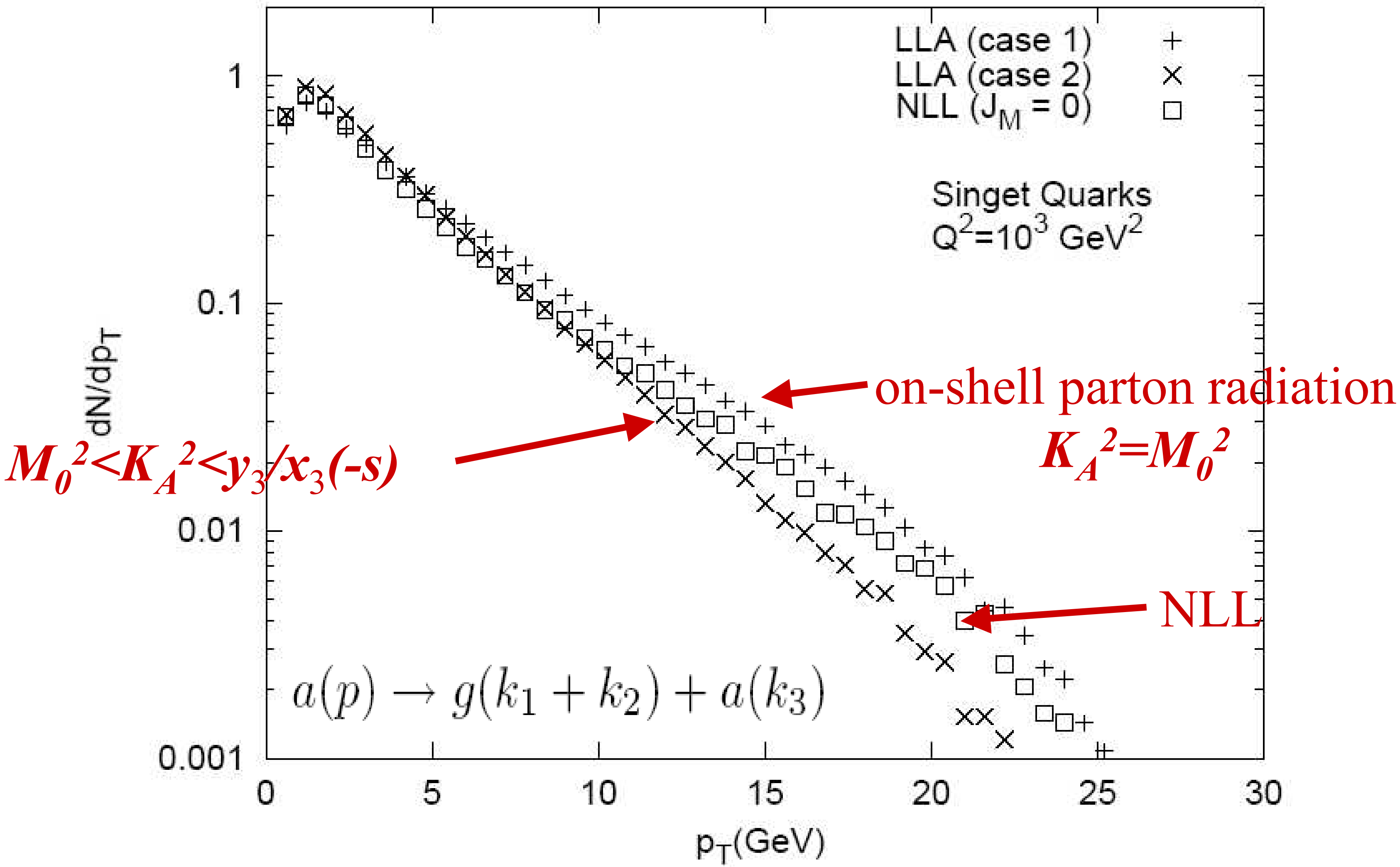


$$p_T^2 = x_3 y_3 \left[p^2 + \frac{-s}{x_3} - \frac{K_A^2}{y_3} \right]$$

$K_A^2 = (k_1+k_2)^2$, $s = k_3^2$ and $p_T^2 = \vec{k}_{3T}^2$

$y_3 = 1 - x_3$

p_T distribution : singlet quarks



✓Future plan

1. Apply x-deterministic method

2. Imprement into generators

3. Detailed comparison with HERWIG