Valence quarks and k_T factorisation

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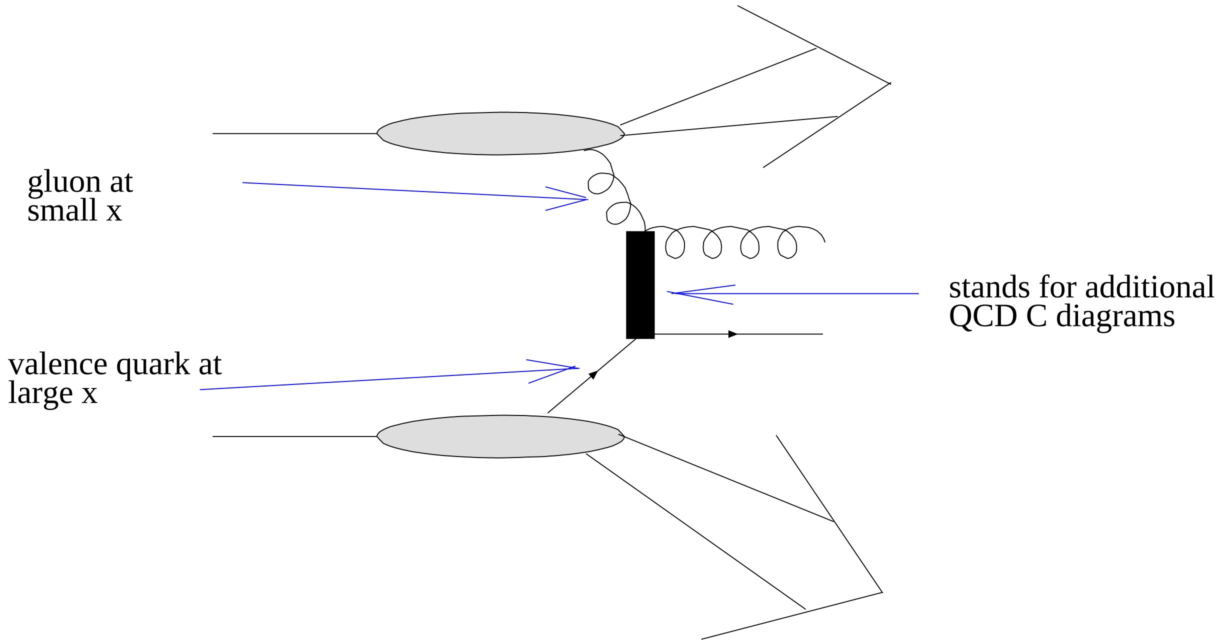
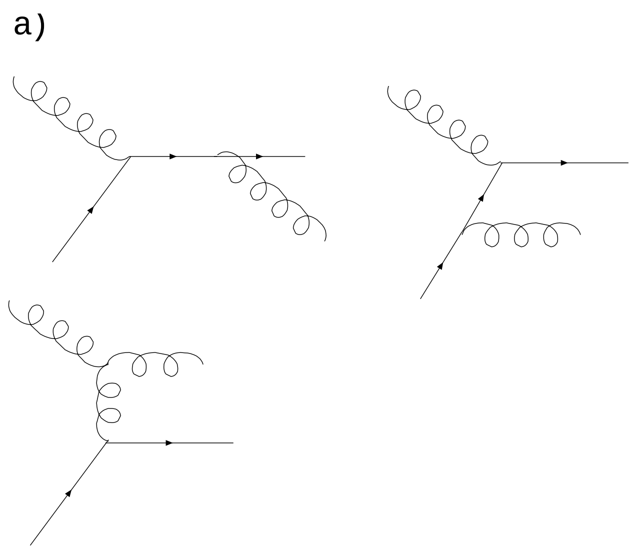
Motivation

- HERA $\longrightarrow$ hints that at rapidities $y > 3$ there can be new kind of dynamics $\longrightarrow$ BFKL, CCFM, BK. However, at HERA we cannot go to the more forward region.
- LHC will allow for this study. The interesting region can be studied if we consider QCD Compton scattering:



Jets at LHC - collinear approach

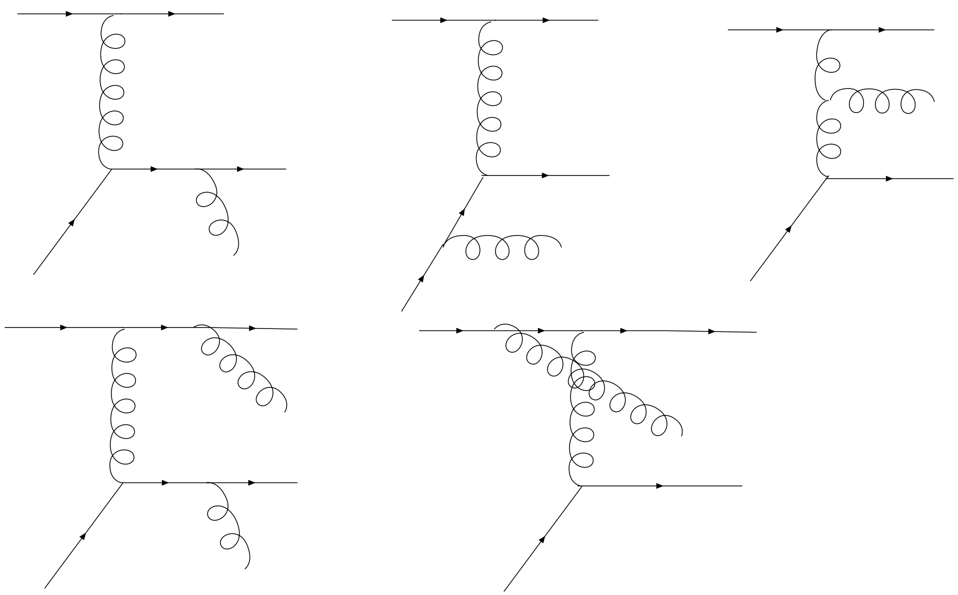
Jets are initiated by hard subprocesses QCD Compton. It is the relevant hard process if we want to study low x_g effects where x_g is a longitudinal momentum fraction carried by gluon.



To go to low x_g safely we need to consider off-shell gluon...

QCD Compton in k_T factorisation

Incoming gluon is not collinear to the proton it is off-shell. Valence quark is collinear to the proton. The upper quark line $\longrightarrow$ replaced by gluon distribution after matrix element is calculated



All five diagrams are required by gauge invariance.

Details of kinematics

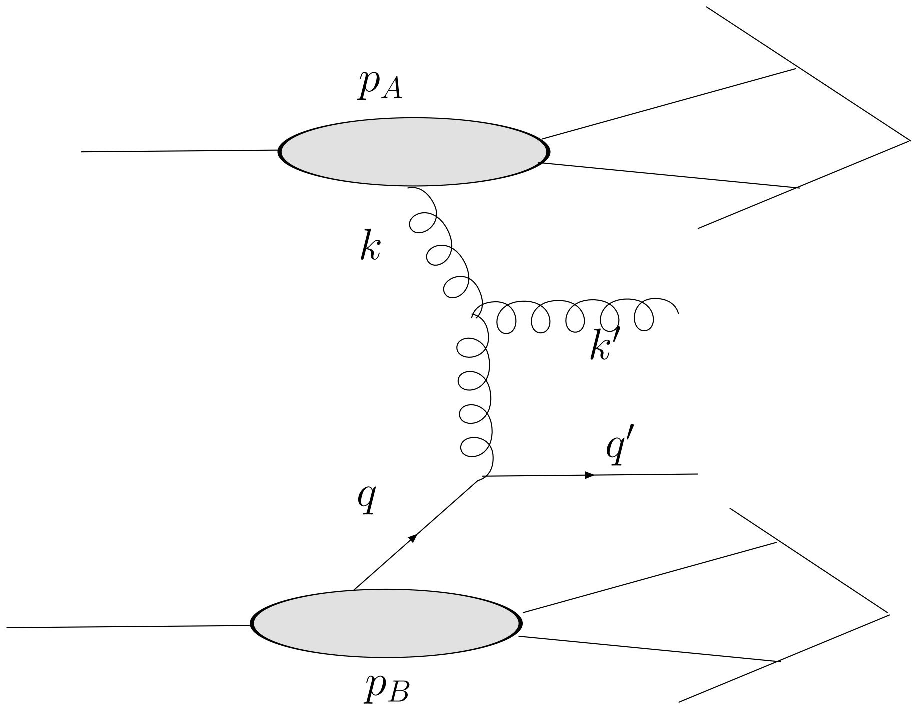
The Sudakov decomposition is:

$k = x_g p_A + z_g p_B + k_T$

$q = x_q$

$k' = x_{g'} p_A + z_{g'} p_B + k'_T$

$q' = z_{q'} p_A + x_{q'} p_B + q'_T$



Mandelstam variables are:

$s = (p_1 + p_2)^2$

$\hat{s} = (k + q)^2$

$\hat{u} = (k - q')^2$

$\hat{t} = (k - k')^2$

We are interested in configuration where:

$\hat{s},\ \hat{t},\ \hat{u} \ll s$

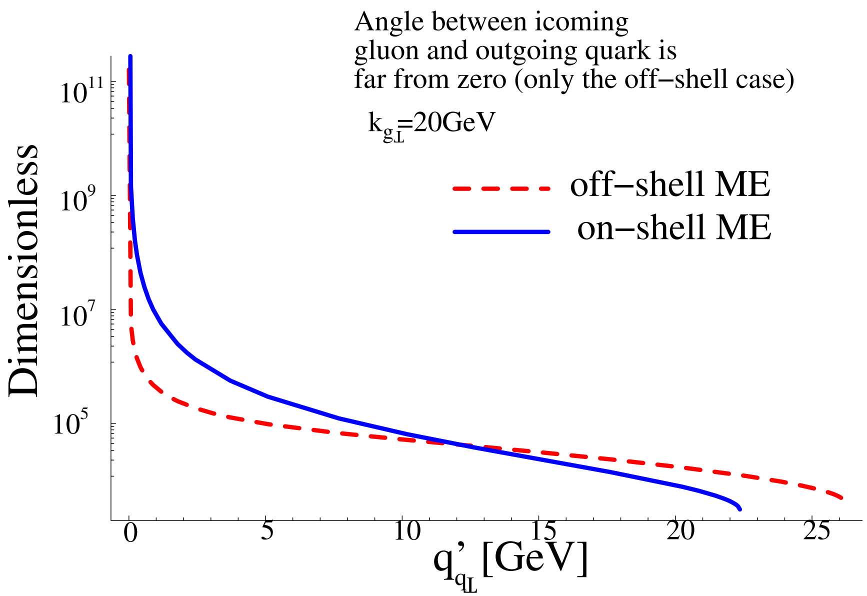
Hard matrix element

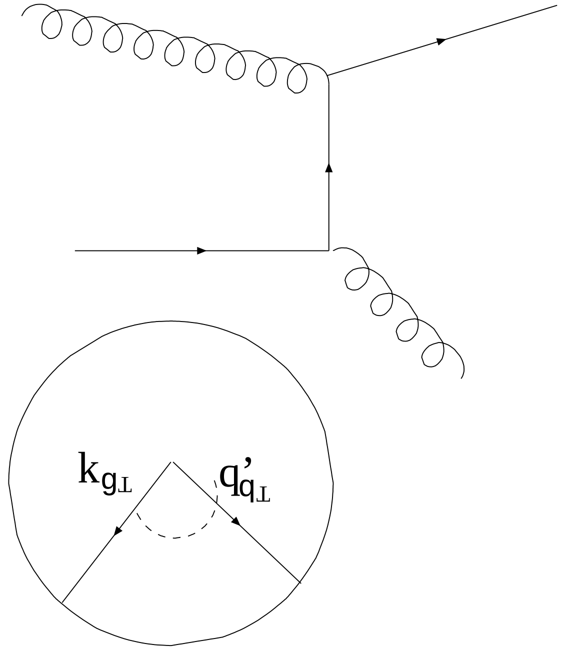
After squaring amplitude we obtain:

$$|M|^2 = -(4\pi)^2 \alpha_s^2 \frac{x_g^2 s^2 (x_q^2 + x_{q'}^2)}{18 \hat{s}\hat{u}\hat{t}} \left(\frac{\hat{s}(8x_q + x_{q'}) - \hat{u}(8x_{q'} + x_q)}{x_q - x_{q'}} + k^2 \right)$$

- In collinear limit $k^2 \longrightarrow 0$ one obtains QCD Compton
- Symmetry $\hat{s} \longrightarrow -\hat{u}$, $x_{q'} \longrightarrow x_q$
- This matrix element was calculated by M. Ciafaloni (Phys. Lett. B 429 (1998) 363-368) in different form and in different context

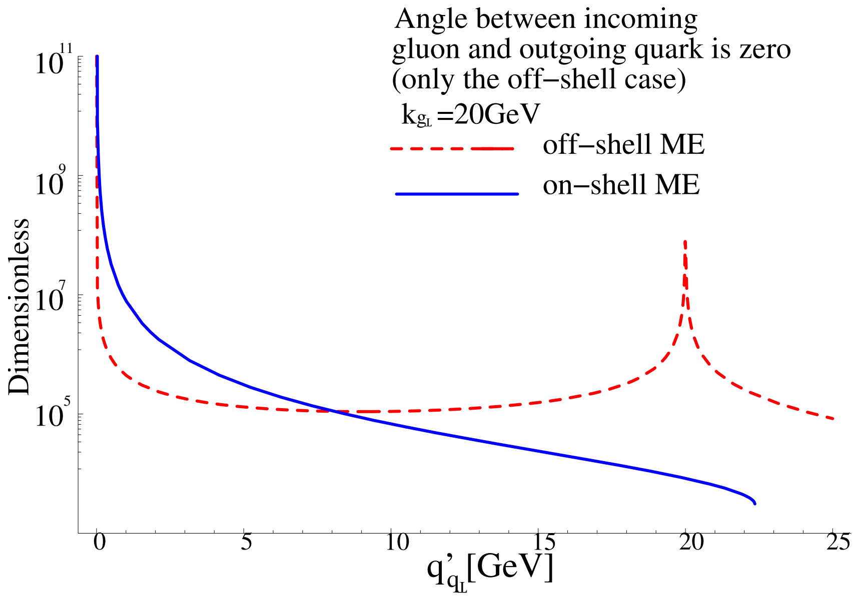
Some properties of the off-shell ME

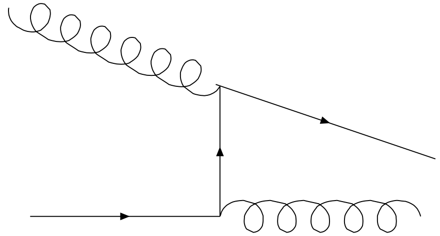


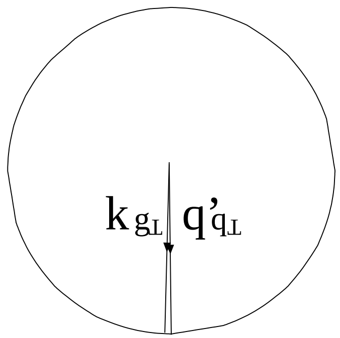


- off-shell ME allows for larger q'_q

Some properties of the off-shell ME







- at 0 angle there is a singularity at $k'_q = k_g$

Cross-section for 2 jets

Cross-section for 2-jet production:

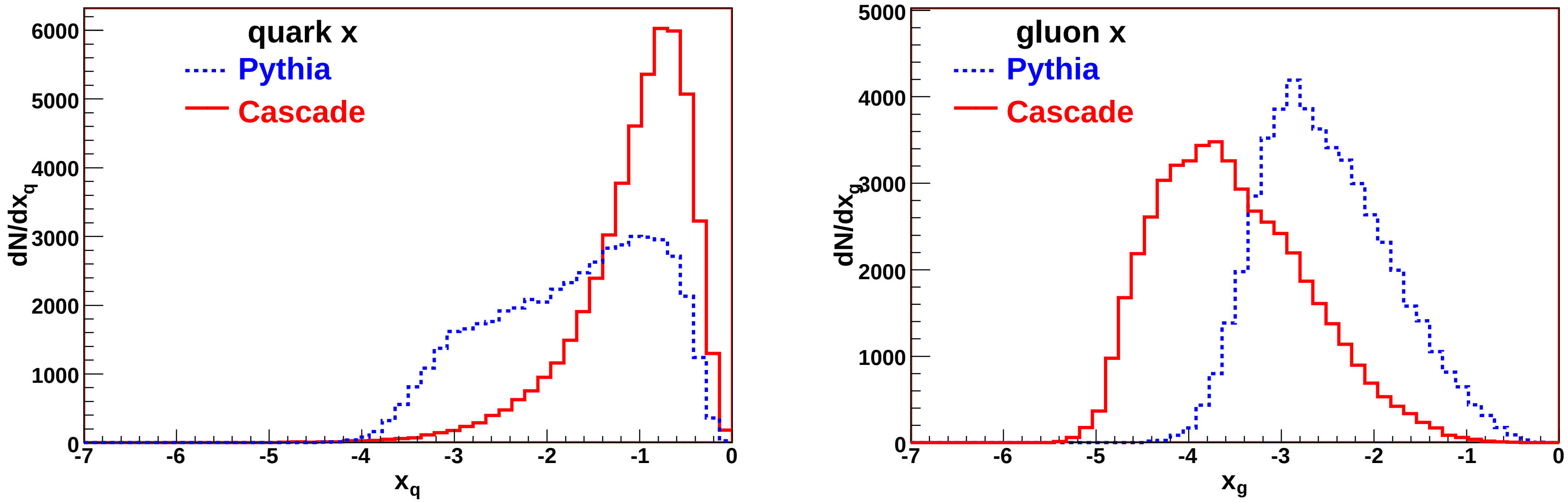
$$\sigma \sim f_g(x_g, k_T^2, \mu) \otimes |M|^2 \otimes \; f_q(x_q, k_{T\,2}^2, \mu)$$

- $f_g(x_g, k_T^2, \mu)$ unintegrated gluon density $\longleftarrow$ CCFM
- $f_q(x_q, k_T^2, \mu)$ unintegrated valence quark density (needed for technical reasons) $\longleftarrow$ CCFM-like. Initial valence quark distribution is provided by CTEQ 6.1
- $\alpha_s \longrightarrow \alpha_s(k_T^2)$
- cut on momenta of outgoing jets $\longrightarrow$ $p_T{>}10GeV$

The result for the total x-section is roughly: $0.17mb$

For comparison total pp x-section at LHC energies is roughly 80 mb

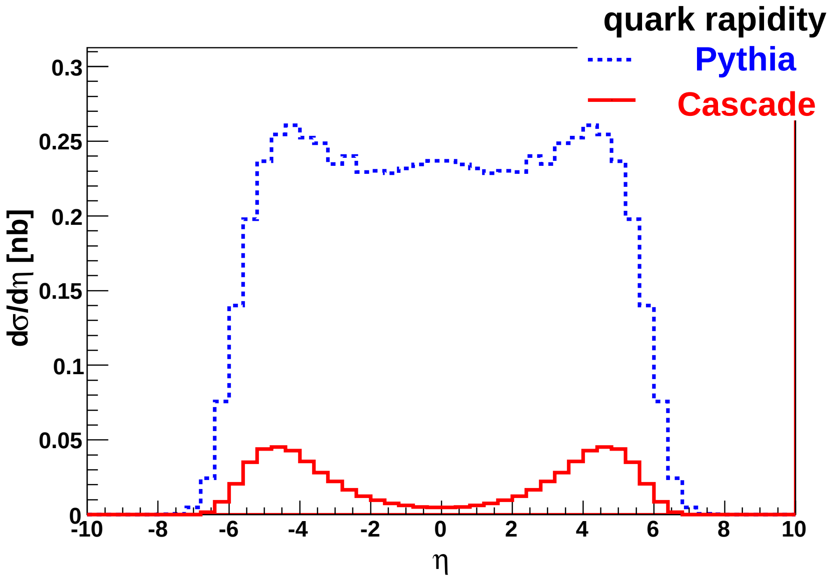
Results - x distribution before collision

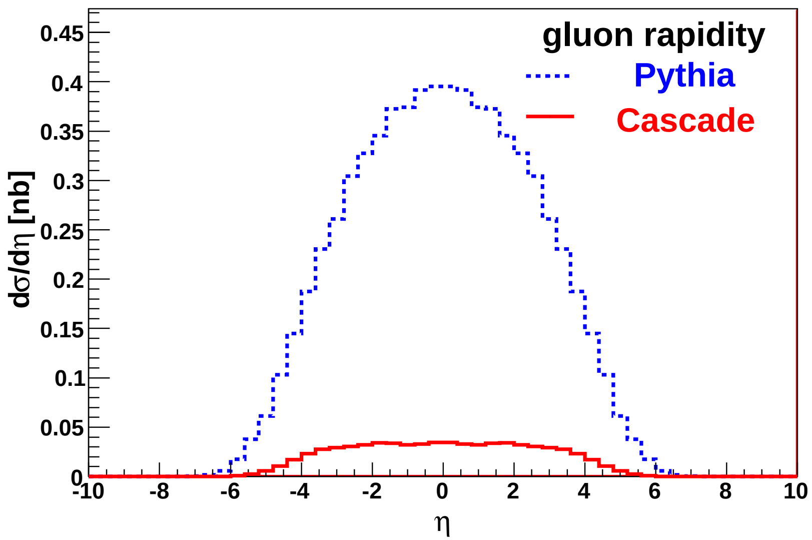


- difference in the distribution of gluon x because of k_T of gluon and quark

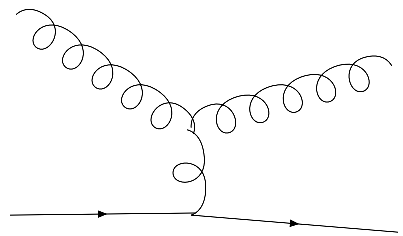
- difference in the distribution of quark x because of sea quarks

Results - pseudo-rapidity distribution of produced jets

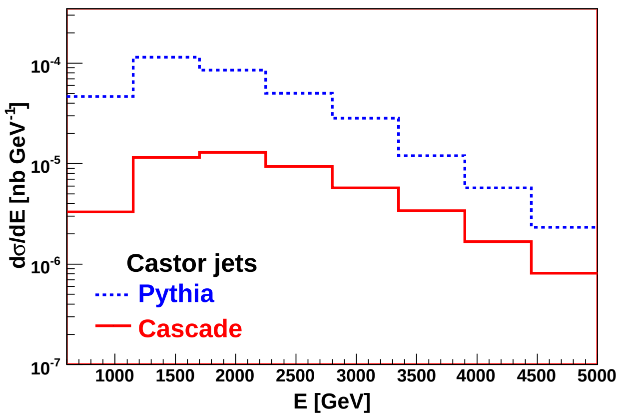


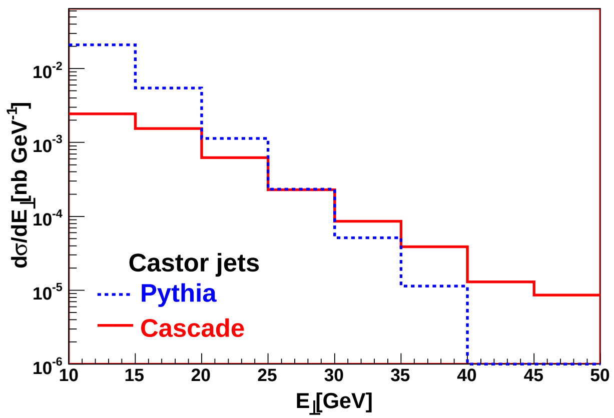


- valence quark $(m_q = 0)$ is slightly deflected
- produced jets are well separated in rapidity

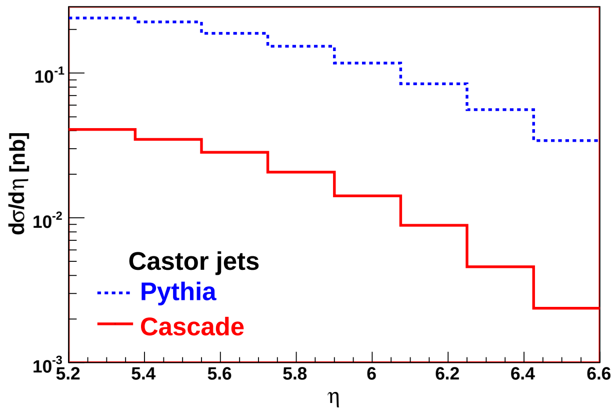


Energy, transversal energy and η of jets in Castor calorimeter

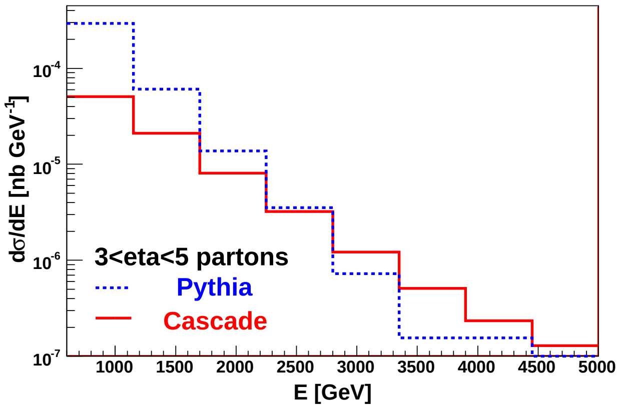


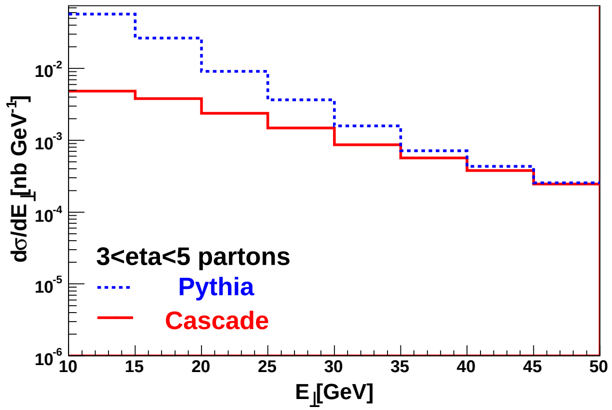


- Castor – pseudo-rapidity region $5.2 < \eta < 6.6$

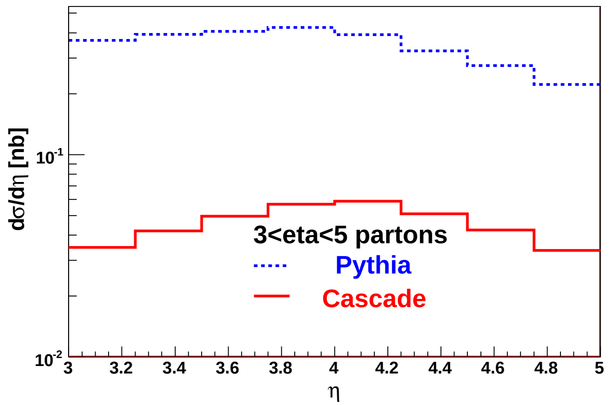


Energy, transversal energy and η of jets in $3 < \eta < 5$ region





- A detector in pseudo-rapidity region $3 < \eta < 5$
- Difference could come from sea-quarks

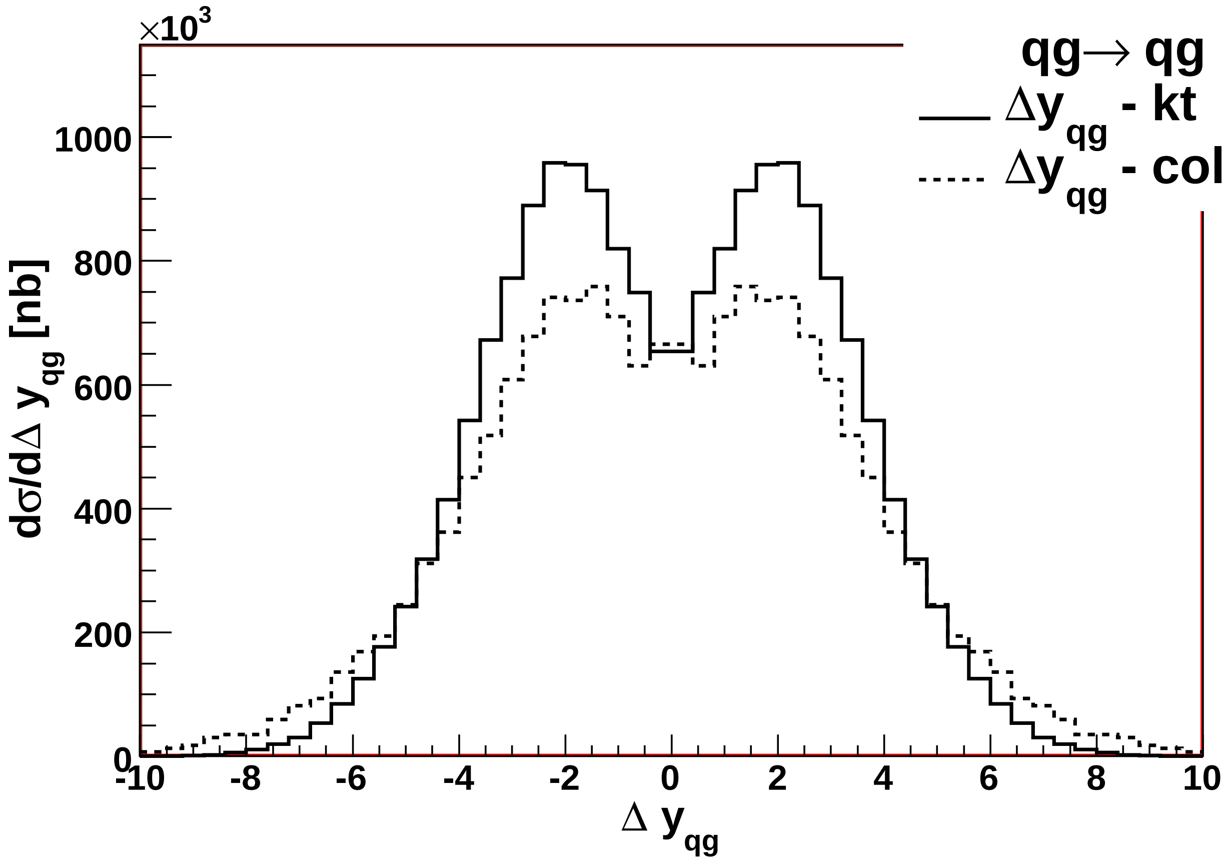


Conclusions and outlook

- We obtained matrix element in k_T factorisation which allow for studies of low x_g effects at the LHC
- CCFM-like equation for unintegrated quark distribution has been incorporated in Monte Carlo framework $\longrightarrow$ CASCADE
- p_T and rapidity spectra of produced jets have been calculated

- Next step: inluding parton showers
- Step towards including multiple interactions for MC generator in k_T factorisation framework
- Since gluon is probed at low momentum fraction we are going to include nonlinear evolution equation to parametrize unintegrated gluon distribution
- Incusion of sea-quarks initiated process

Back up slides



- Rapidity difference between produced jets