High E_T parton jets in hard QCD processes at LHC

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MOTIVATION

- High Q^2 final states at LHC will be dominated by inclusive jet production. QCD hard scattering-large momentum transfers - production of jets, photons, W-and Z-bosons and heavy flavors etc. - One essential "bread and butter" physics measurements at the LHC.
- Within QCD the only fundamental quantity that needs to be measured with utmost accuracy is α_s, the coupling constant. No one so

far came up with a bright idea on how to improve the knowledge of α_s at the LHC.

- Structure of proton at short distances is crucial to predict the xsections for processes with (hadronic)initial states. The complex dynamics involved is obvious and needs to be investigated in detail in order to measure and interpret evenually the physics at highest possible jet E_T corresponding to $\sim 10^{-17}$ cm, distance scale, much smaller than any other LHC process.
- Some results from Tevatron

jets up to 450 GeV show excess at large E_T and that the results agree with theory at the level of 30 %. Also there is some dependence on PDF chosen.

- **Obvoius that LHC-experiments will allow accurate consistency checks with QCD predictions for the E_T dependent jet xsections extending from today's E_T values from $\sim$ 450 GeV upto roughly a factor of ten xsections extending into the multi-TeV domain.**
- **The use of high E_T data, sensitive to a variety of exotic new phenomena will be limited**

by these potential uncertainties.

- Direct implications on the prediction of cross-sections for processes which produce potential background in the search for new phenomena.
- Testing connections between jet algorithms at the parton level and at the detector level, ME Monte Carlo matching at LO and NLO and extrapolation to LHC energy provide a potential source of information. Important for MC tunes at start of LHC data.

- All sources of experimental information will add to our understanding of QCD, the fundamental physics.
- More fashionable (?) physics, HIGGS Very few efforts on the basic issues. New Physics at hadron colliders is likerly to come from QCD ("wishfully" !!) and at the same time the background to these new processes is likely to be from QCD.

Jet Production Rates

- **Jet production dominates by far all hard processes.**

- **Depending on the potential accuracy the rapidity and the E_T distributions depend on the parton distribution function $f_{q,g}(x, Q^2)$.**

- **Relative contributions from qq, qg,$q\bar{q}$ scattering vary strongly as a function of E_T and η (y).**

- **Interesting to study different partonic components of proton.**

- **Simulated**
- **15 million events at 14 TeV (LHC)**
- **10 million events at 1.8 TeV(CDF/D0)**
- **10 million events at 0.63 TeV (UA1/UA2)**
- **PYTHIA6205**
- **CTEQ5M1 (Not really relevant at the moment; needs to be investigated in future)**
- **Parton Jets in $2 \rightarrow 2$ hard QCD processes**

Inclusive jet x-sections

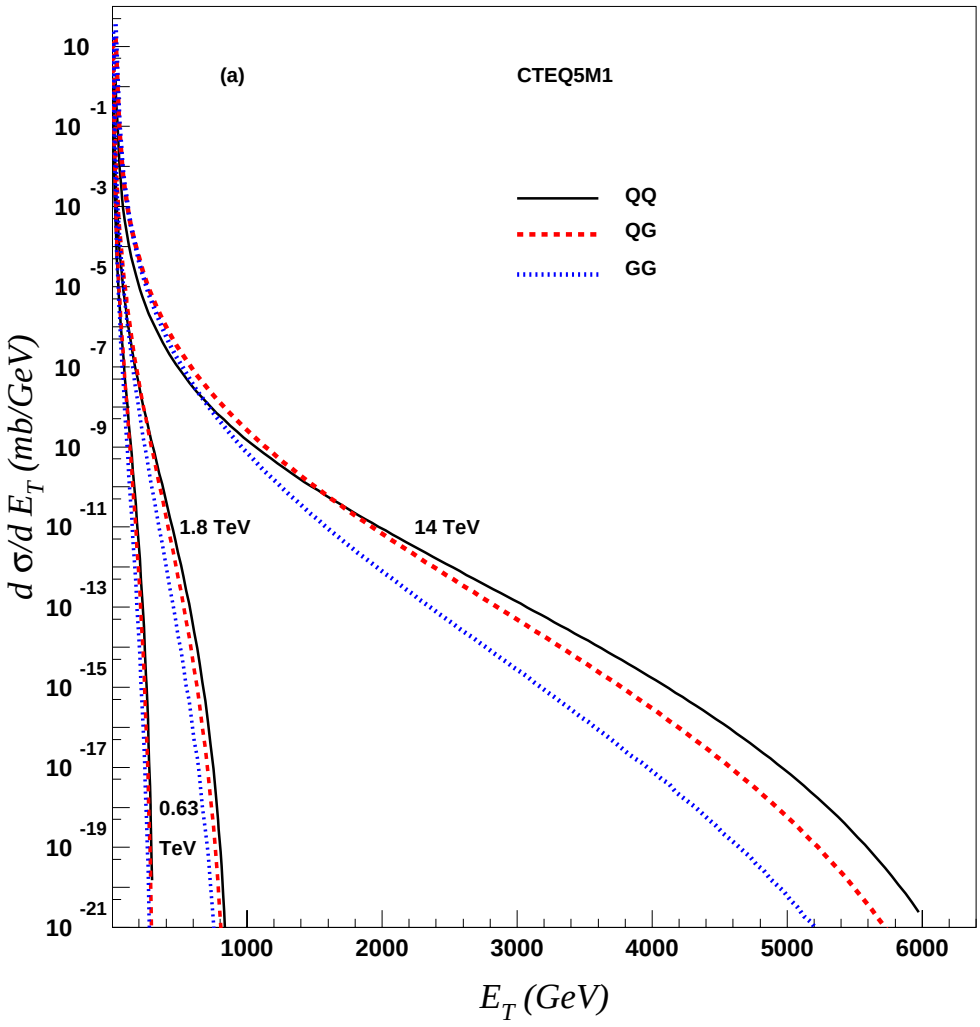

Figure 1: Inclusive jet-xsection of qq, qg,gg scatterings at different c.m.energies

Inclusive jet x-sections(log)

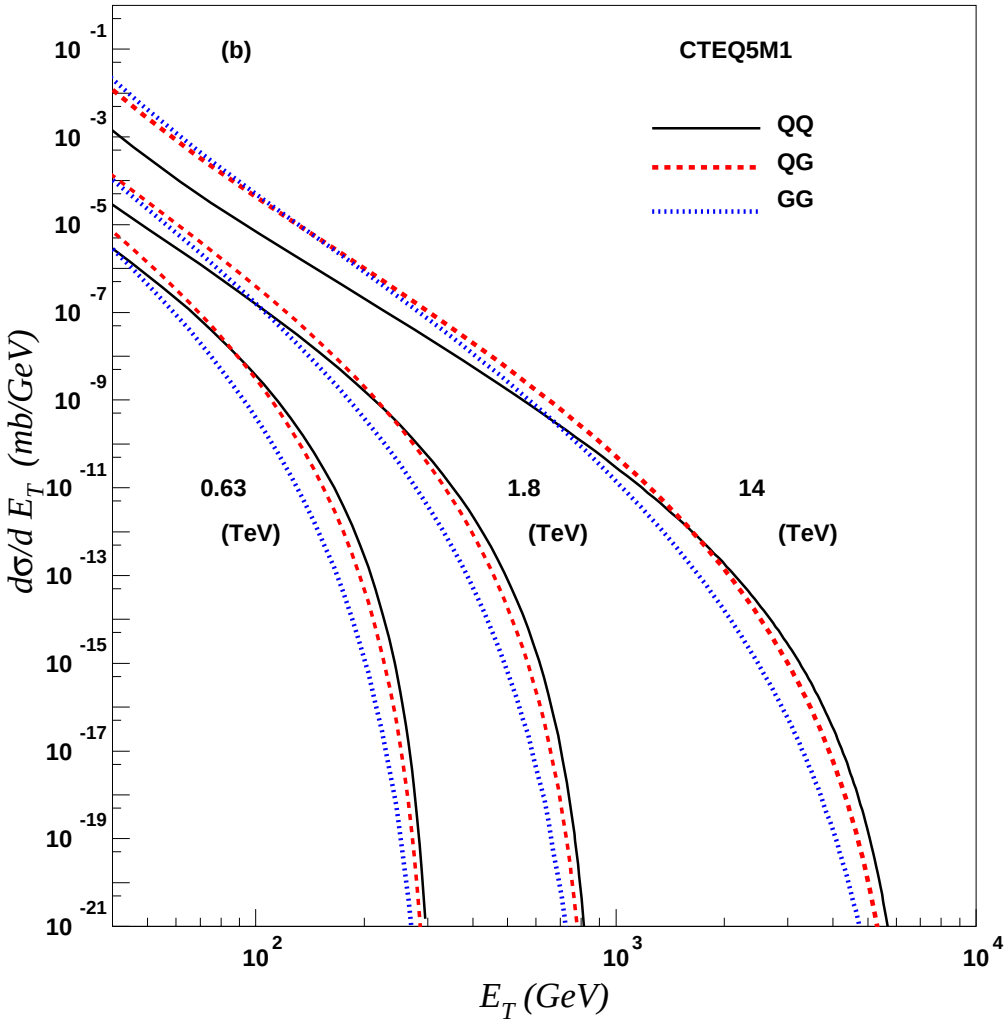

Figure 2: Inclusive jet-xsection (log-scale) of qq, qg,gg scatterings at different c.m.energies

Quark/Gluon Contributions

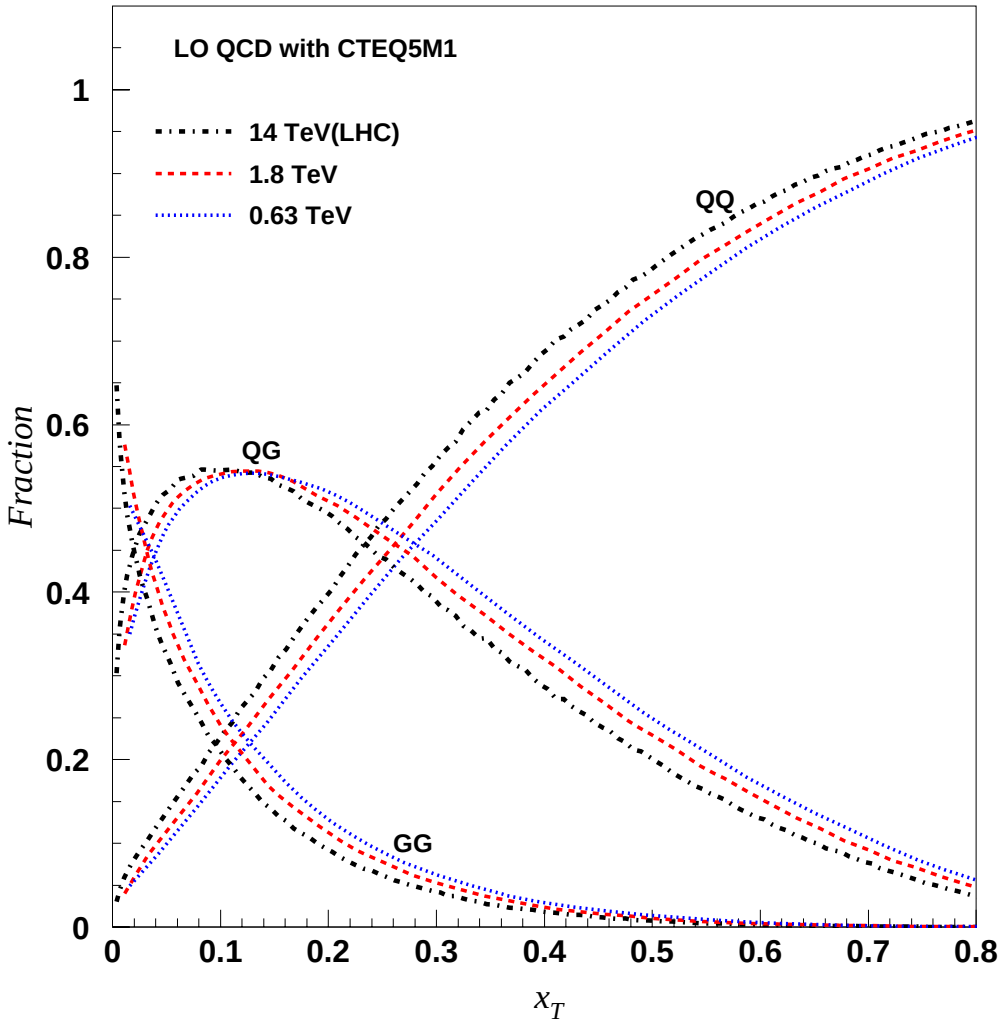

Figure 3: contribution to jet cross sections from different quark and gluon scatterings

Table 1: Fraction of Quark/Gluon contributions to the jet xsection with $X_T > 0.5$

Energy (TeV)	qq	qg	gg
14 (LHC)	$\sim 79\%$	$\sim 20\%$	$\sim 0.8\%$
1.8 (Tevatron)	$\sim 75.5\%$	$\sim 23\%$	$\sim 1.0\%$
0.63 (CERN)	$\sim 75\%$	$\sim 23\%$	$\sim 1.1\%$

Observations

- **Fraction of qq collisions increases with $\sqrt{s}$ and that of gg decreases.**
- **Results at Tevatron and CERN $p\bar{p}$ show $\sim$ 20 % uncertainty on high E_T jet rates comes from gluon-induced processes. Our simulations indicate that these**

uncertainties will decrease at high E_T due to smaller fraction of these scatterings.

- **Figs.4-5 Expected number of events for L=100 fb^{-1}(one year of LHC); different η intervals. Super high E_T (> 1.5 TeV) jets will be produced only in the central part of the detector ; $-2 < \eta < 2$**

- **Figures 6-8 Flavor dependent jet x-sections. For $E_T >$ a few hundred GeV $\sim 2\%$ of all jets are beauty flavored and $\sim 3\%$ are charm flavored ; fractions essentailly E_T independent up to 1–2 TeV.**

Expected No. of events with $E_T < 1000$ GeV for one year of LHC

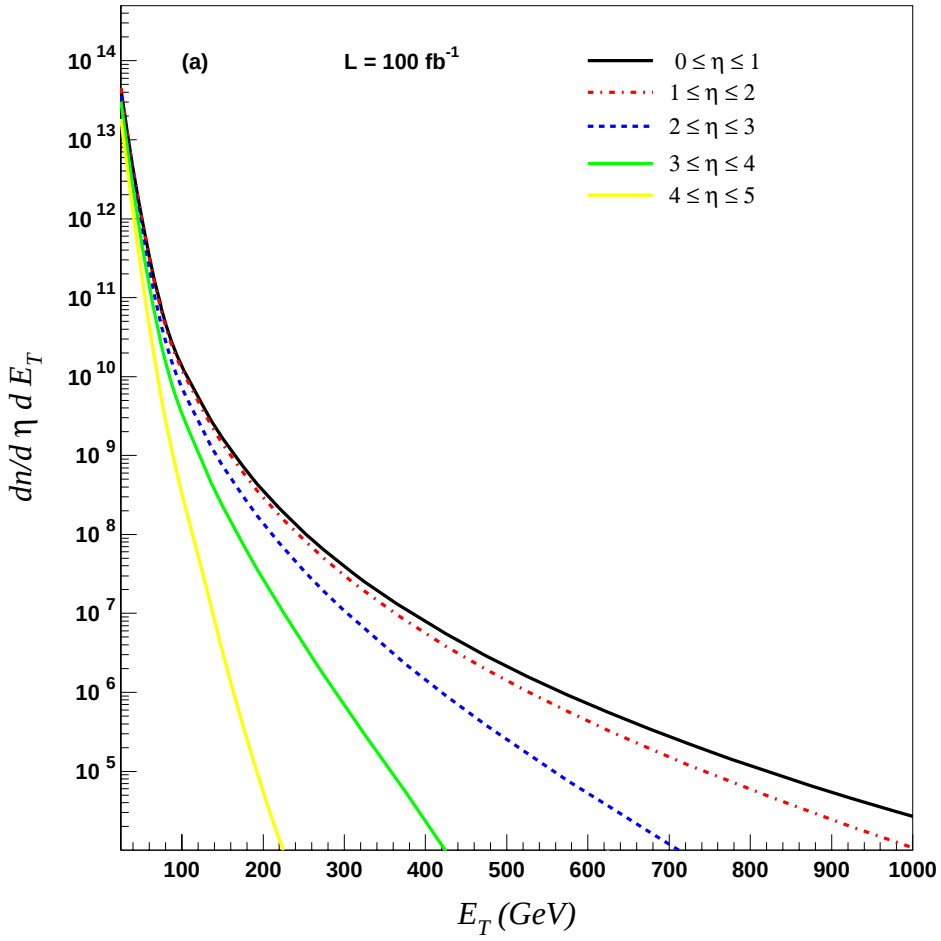

Figure 4: Jet x-sections for different rapidity intervals

Expected No. of events with $E_T > 1000$ GeV for one year of LHC

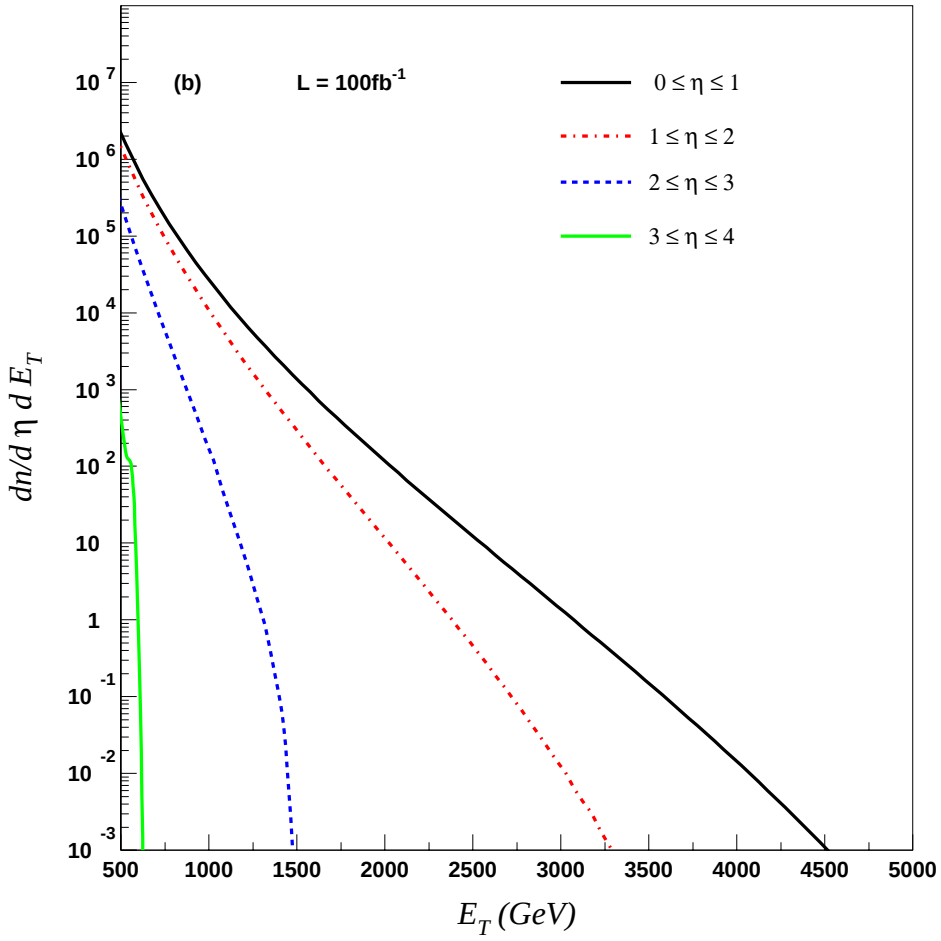

Figure 5: Jet x-sections for different rapidity intervals

Expected No. of events for 100 fb^{-1} (one year of LHC

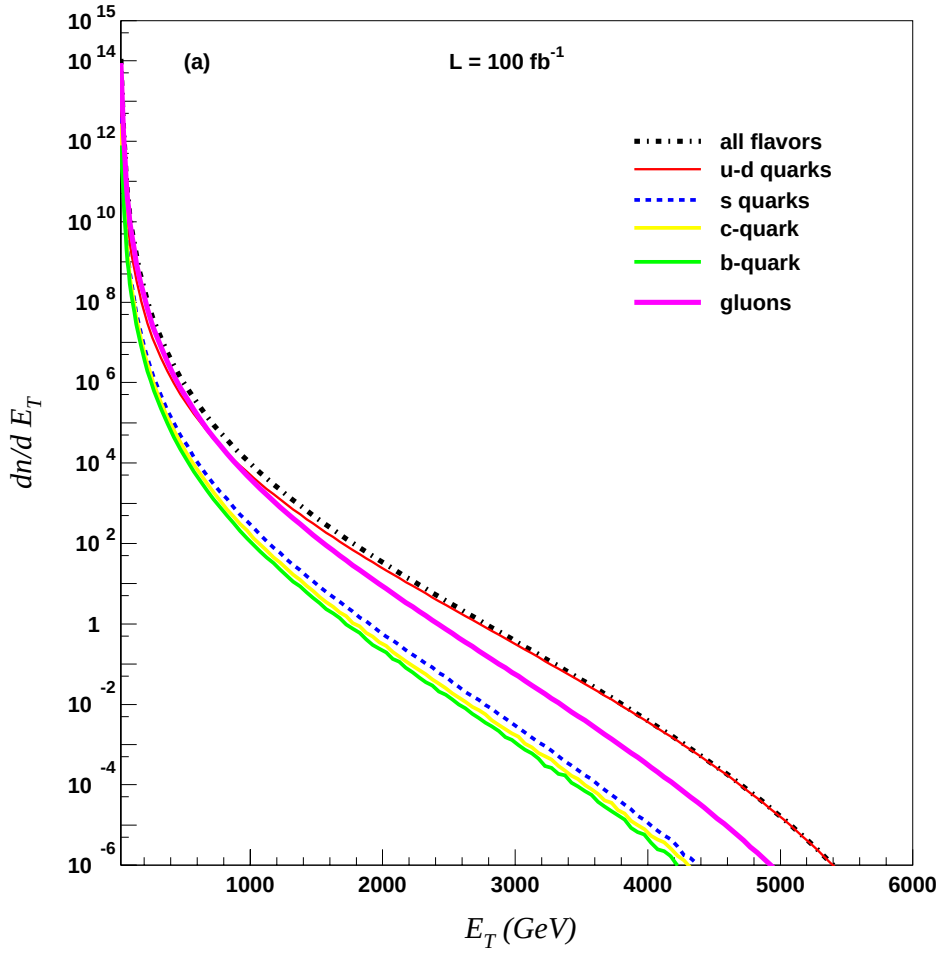

Figure 6: x-sections for different jet flavors

Expected No. of events for 100 fb^{-1} (one year of LHC

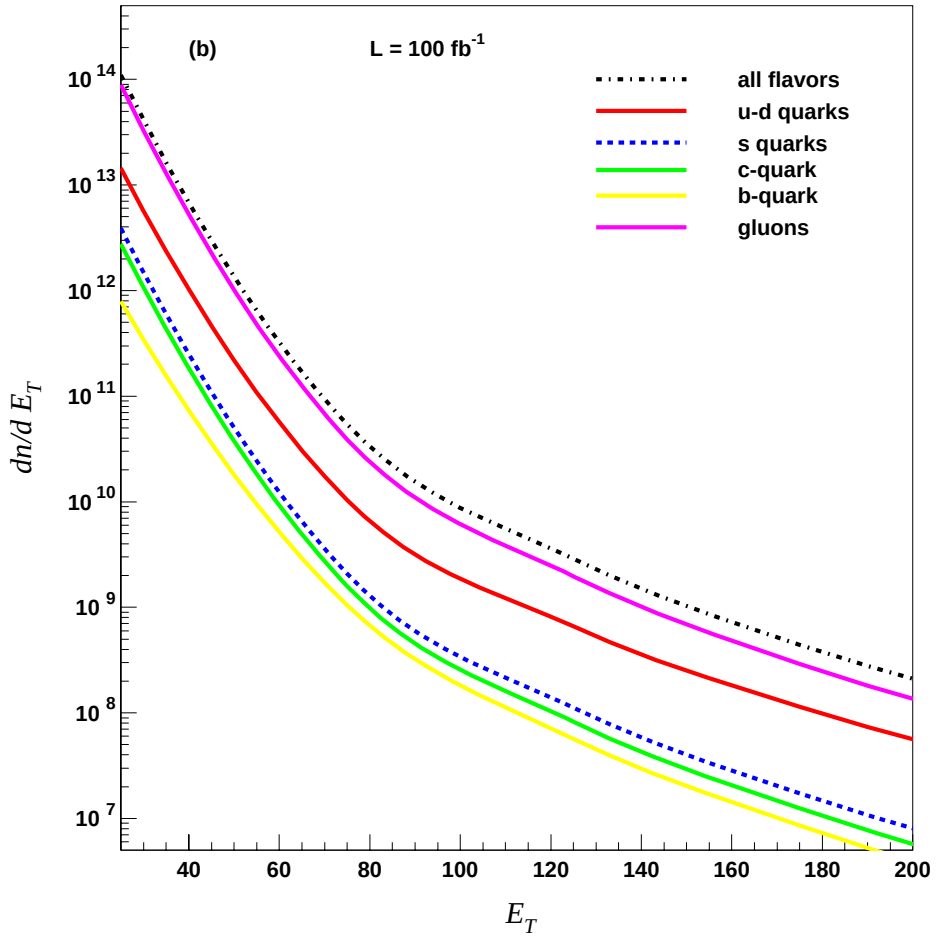

Figure 7: x-sections for different jet flavors

Flavor fractions at LHC parton-parton scatterings

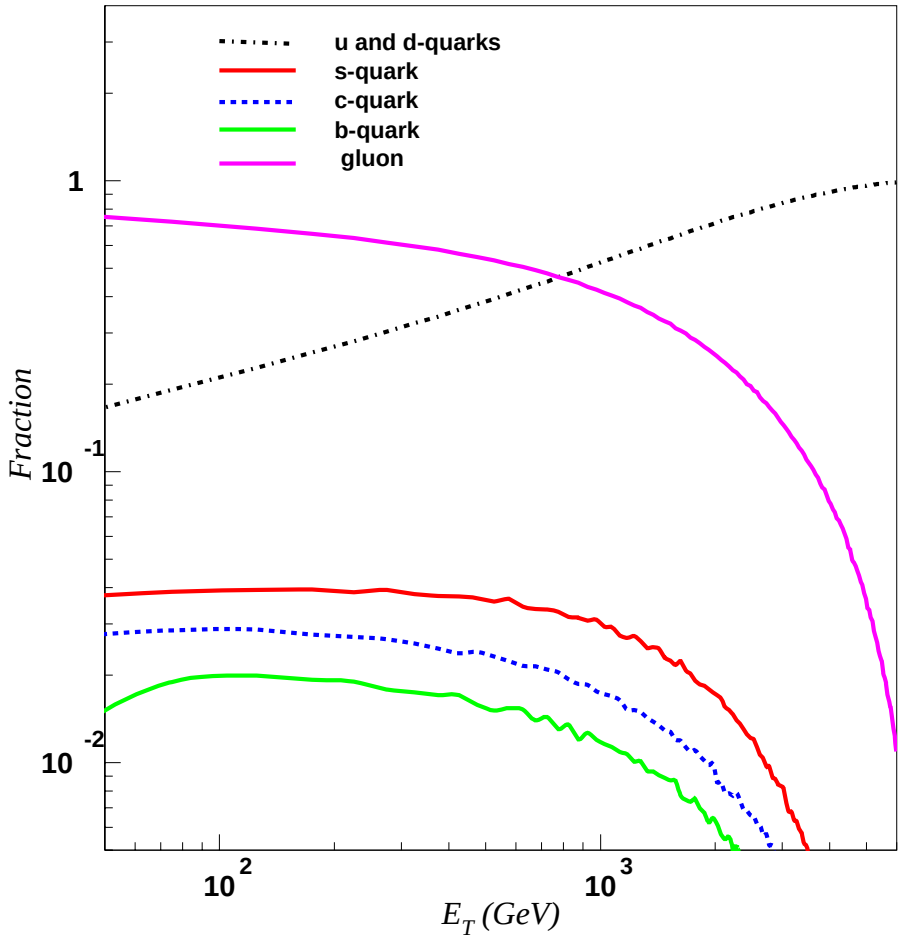

Figure 8: x-sections fractions for different jet flavors

Results

- Contributions from quark-gluon and gluon-gluon scatterings decrease at high c.m. energies, indicating the possibility to improve upon the uncertainties of high E_T jet rates.
- Measurement of b-jets should be possible up to a few TeV.
- combining large cross-sections and the expected b-tagging capabilities of CMS tracking detectors and the possibilty to measure inclusive muon production from charm and beauty, it might eventually be

possible to measure the flavor dependent x-sections with CMS

- Also one might reach (optimistic !) efficiencies of 50 % for b–jets. Thus potential b-signal to background ratio should not be too different from 1 : 1.
- It might thus be interesting in the near future to investigate this possibilty in a complete CMS simulation.

Outlook

- The results presented are intended to give an up-to-date picture of high E_T jet x-sections at LHC and can only be considered as a beginning of QCD studies within CMS.
- Both ATLAS and CMS aim to achieve jet energy resolution of ~ 2 %. x-section measurements at very high E_T have in principle "sensitivity" to observe new physics like "quark compositeness" up to 30-40 TeV assuming that QCD calculations can be done with sufficient accuracy. This needs

to be quantified during the coming years.

- The next step should include effects of higher order QCD corrections and various detailed experimental studies. For this one needs to include systematics from jet reconstruction and resolution with CMS, including fragmentation effects, jet algorithms and uncertainties from PDF's.
- This currently almost "grey" area will be hopefully understood in detail before the data taking will start.