Structure Functions of Heavy Quarks

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CMS-Note: 2001/002: M.Dittmar (ETH, Zurich), K.M.

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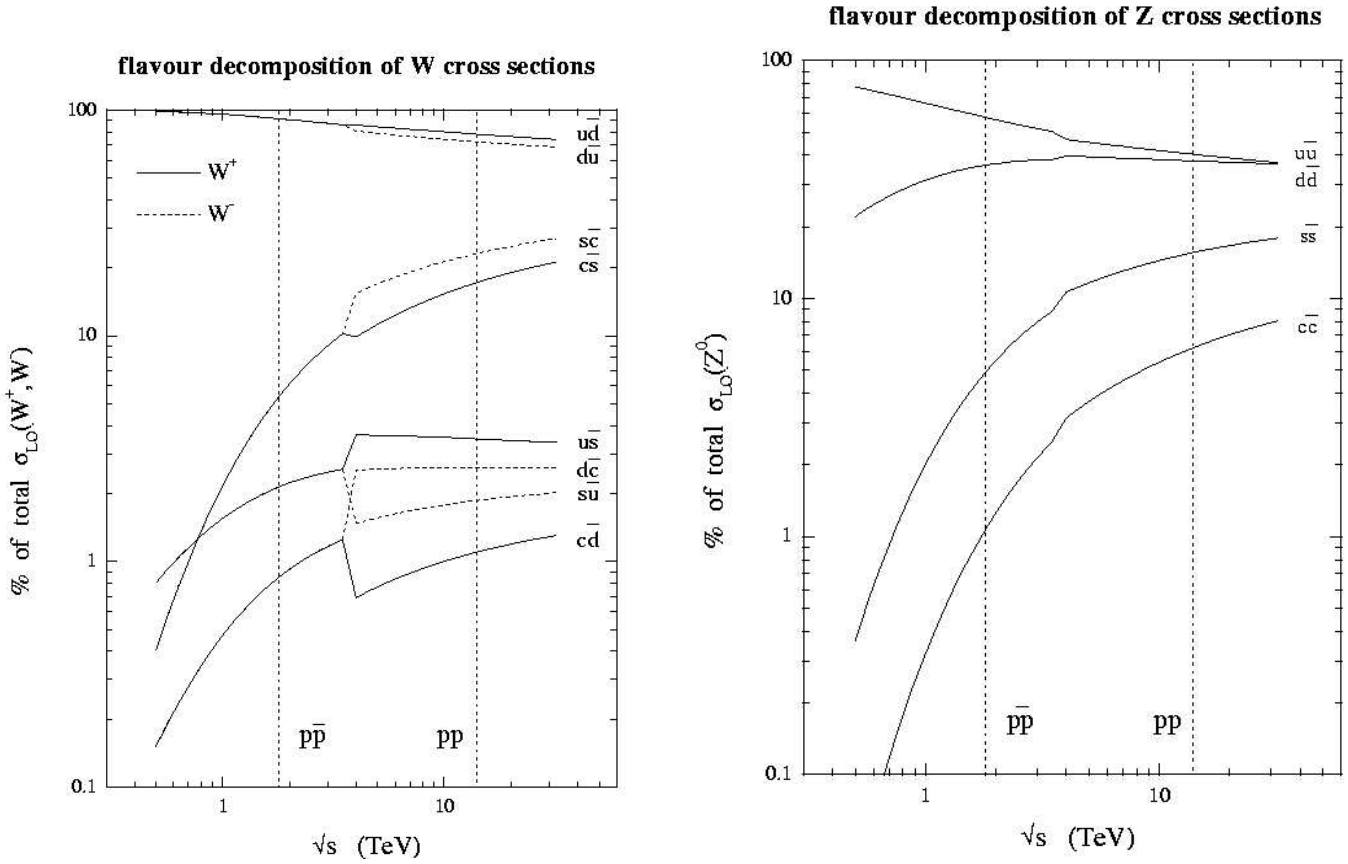
Constraining PDFs at LHC



$\sim$ 25 (15)% of W (Z) events at LHC are due to heavy quark content of the proton.

Determination of PDFs at LHC

- Assuming theoretical values for 'standard' processes at LHC can be calculated to a good accuracy, including higher order contributions, determination of structure functions at LHC will be an iterative process using 'well' understood SM reactions.

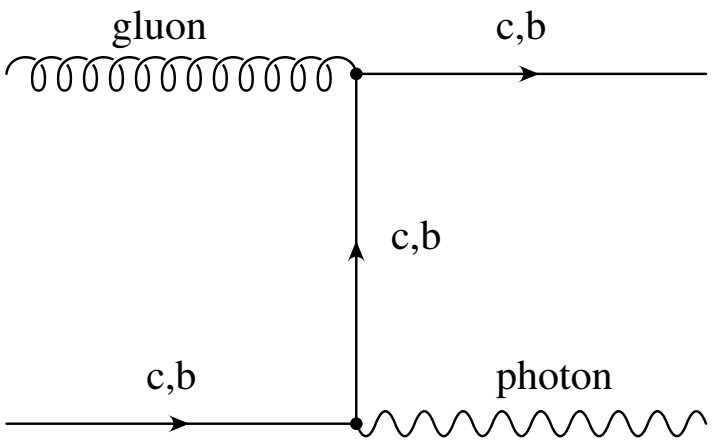
- Need events with well-measured kinematics as well (rapidity and Q^2).

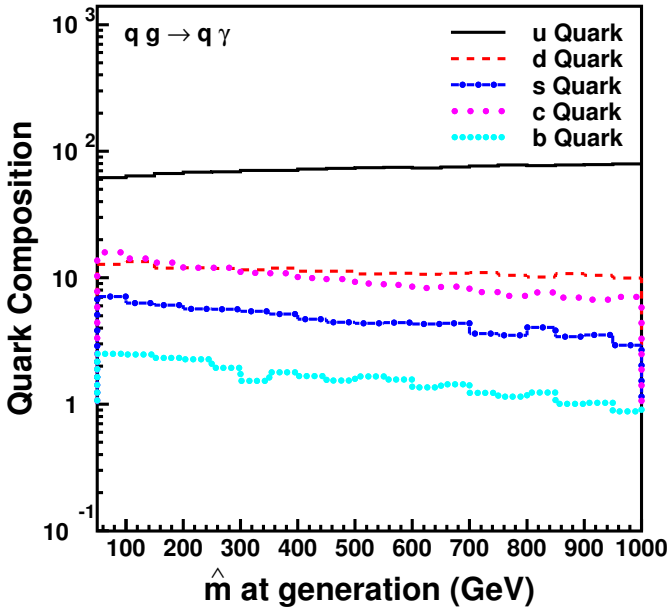
- *e.g.,* density of valence quark and sea anti-quarks constrained from pseudo-rapidity distributions of leptons from W,Z decays: $\Longrightarrow$ x range $\sim$ 0.0003 to 0.1
(Dittmar et. al., hep-ex/9705004).

- Gluon pdf from $gq(\bar{q}) \rightarrow \gamma q(\bar{q}),\ \ gq(\bar{q}) \rightarrow Zq(\bar{q})$
$\Longrightarrow$ isolated jet balanced by a photon or, leptons from Z.
Probed x range: 0.0005 to 0.2 . Note, these events has irreducible background of $\sim$ 20% due to $q\bar{q} \rightarrow \gamma q(\bar{q})$.

- Good knowledge of $u,\ \bar{u},\ d,\ \bar{d},\ g$ (expected accuracy of $\sim 1\%$ or better?) will subsequently allow the estimation of other densities.

Charm and Bottom initiated events



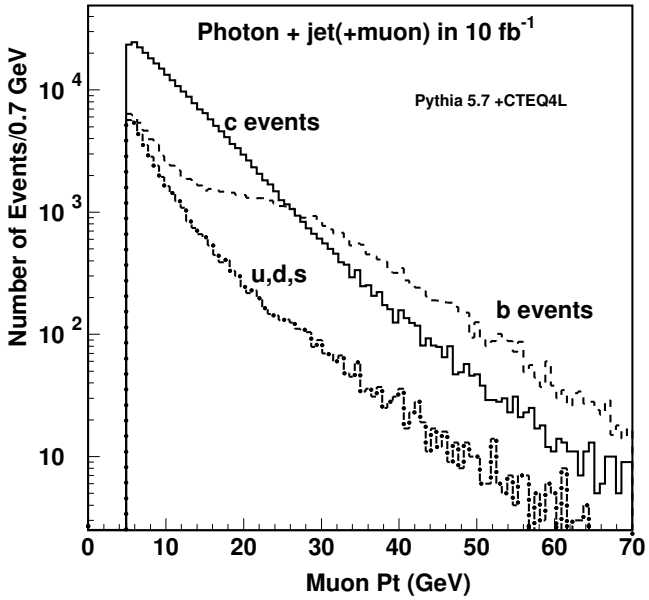


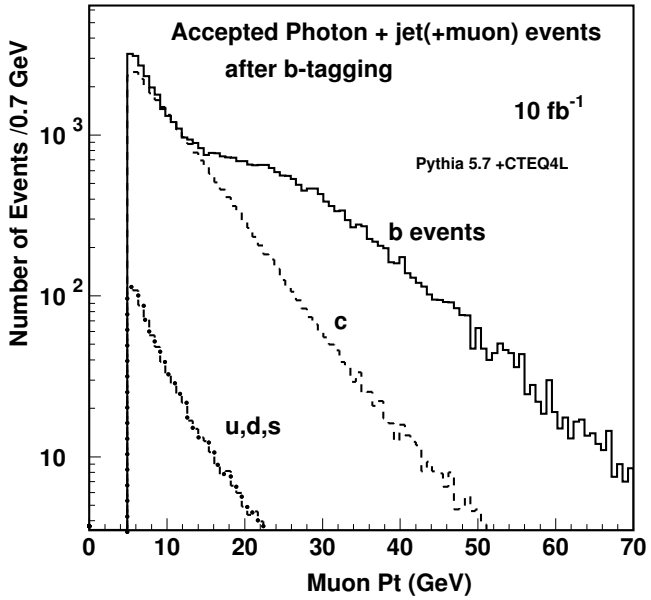
- $\sim 20\%$ of these γ+jet events are from $gc/b \to \gamma c/b$.
- Select semileptonic decays of heavy mesons in γ+jet events

Discriminating Charm vs. Bottom events

- Choose jets with inclusive muons ($p_T^{\mu} > 5/10$ GeV/c)
- Further selection through b-tagging (eff.: ~ 50 %, $p_T^{b-jet} > 40$ GeV)

mistag: c-quarks ~ 10 %, others $\sim 2\%$.

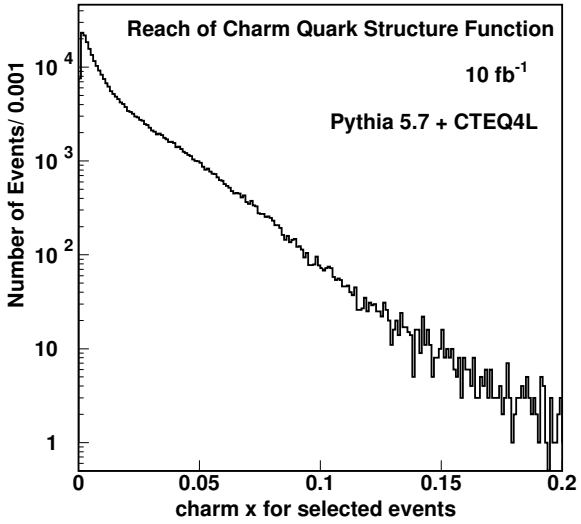


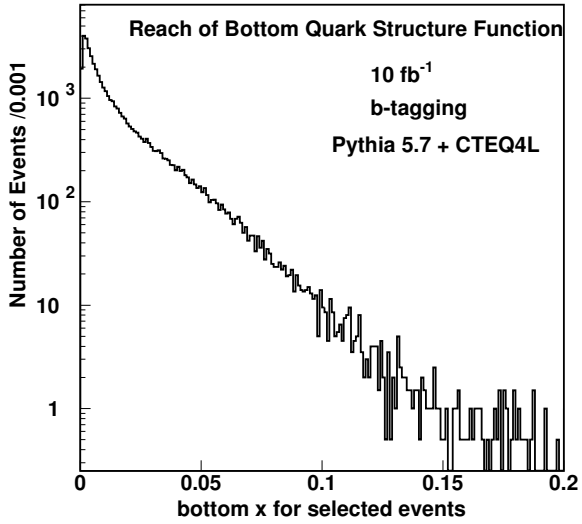


Reach in 10 fb^{-1}

- 10^5 charm + bottom events in 10 fb^{-1}.

$\Longrightarrow$ x_c, x_b range probed upto 0.1 and 0.05 respectively, with statistical accuracy of 10%.

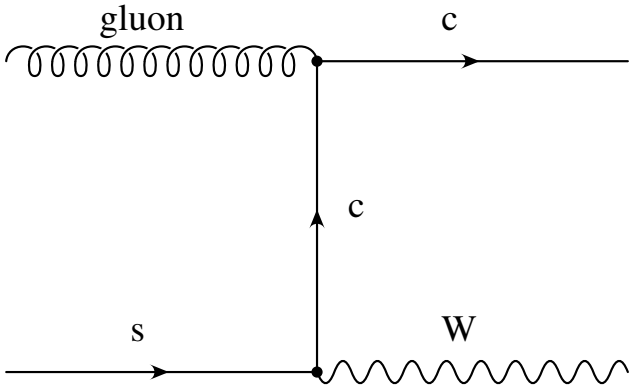


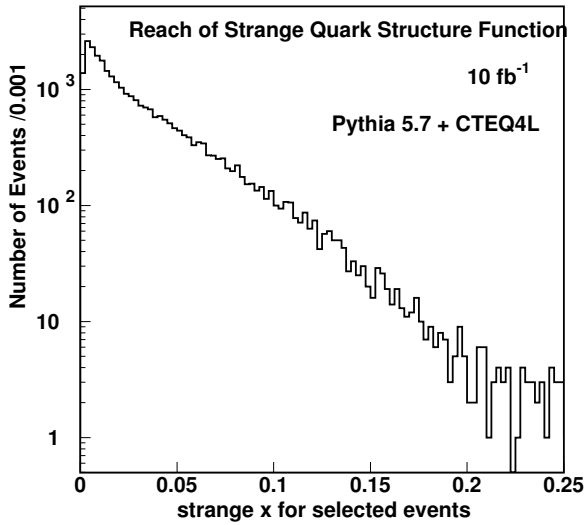


Strange Density through $sg \to Wc$ channel

- Rather unusual final state: high p_T, isolated lepton from W decay + μ-tagged charm jet (experimental identification to be studied).
  Additional criteria: tagged lepton from charm decay is in opposite hemisphere to isolated μ from W.

- x reach ~ 0.1 in 10 fb^{-1} with statistical accuracy of 10%.





Present situation

- Assuming $\Delta\sigma^{\rm th}_{W,Z} \sim 2\%$ including NNLO calculations, the expected error on luminosity measurement $\sim 5\%$ based on data of 1 fb^{-1}.
  Systematic uncertainties are $\sim$ 2 - 3 % for muonic decay channels.
  (CMS Note 2006-082)

- Systematic uncertainties in rate calculation (CMS numbers for $\mathcal{L} > 10$ fb^{-1}):
  - jet energy scale ($\sim 5\%$), jet energy resolution ($\sim 5\%$),
  - lepton momentum scale ($\sim 1\%$), lepton momentum resolution ($\sim 1\%$)
  - The uncertainties in lepton identification and isolation ($\sim$ 0.5 - 1%).
  - b-tagging efficiency $\sim 50\%$
  - mistagging rate for c-jet $\sim 10\%$, u,d,s :$\leq 0.1\%$

What is needed to be evaluated

- The exepcted reach and uncertainties on $x_u,\ x_d$ densities from W, Z events.
- What will be the reach and uncertainties on x_g from $qg \to q\gamma/Z$ events.
- The above uncertainty to be folded in to get the reach for heavy quark densities.
- What we need to put in: uncertainties in fragmentation functions, semileptonic branching fraction of heavy mesons.
  These could be limiting factors for achievable accuracy.
- Experimental study needed for strange, charm-jet tagging or exclusive reconstruction.
- Event rates affected by ISR and FSR to be considered as systematics.
- Trigger should not be an issue if we consider limited pseudorapidity range.

Conclusion

- It is extremely important to extract the pdf information with minimum uncertainty.
- A method is proposed to determine the parton densities as well as heavy quark contents of the proton, using only LHC data.
- More realistic study needed for judging the feasibility of the scheme.

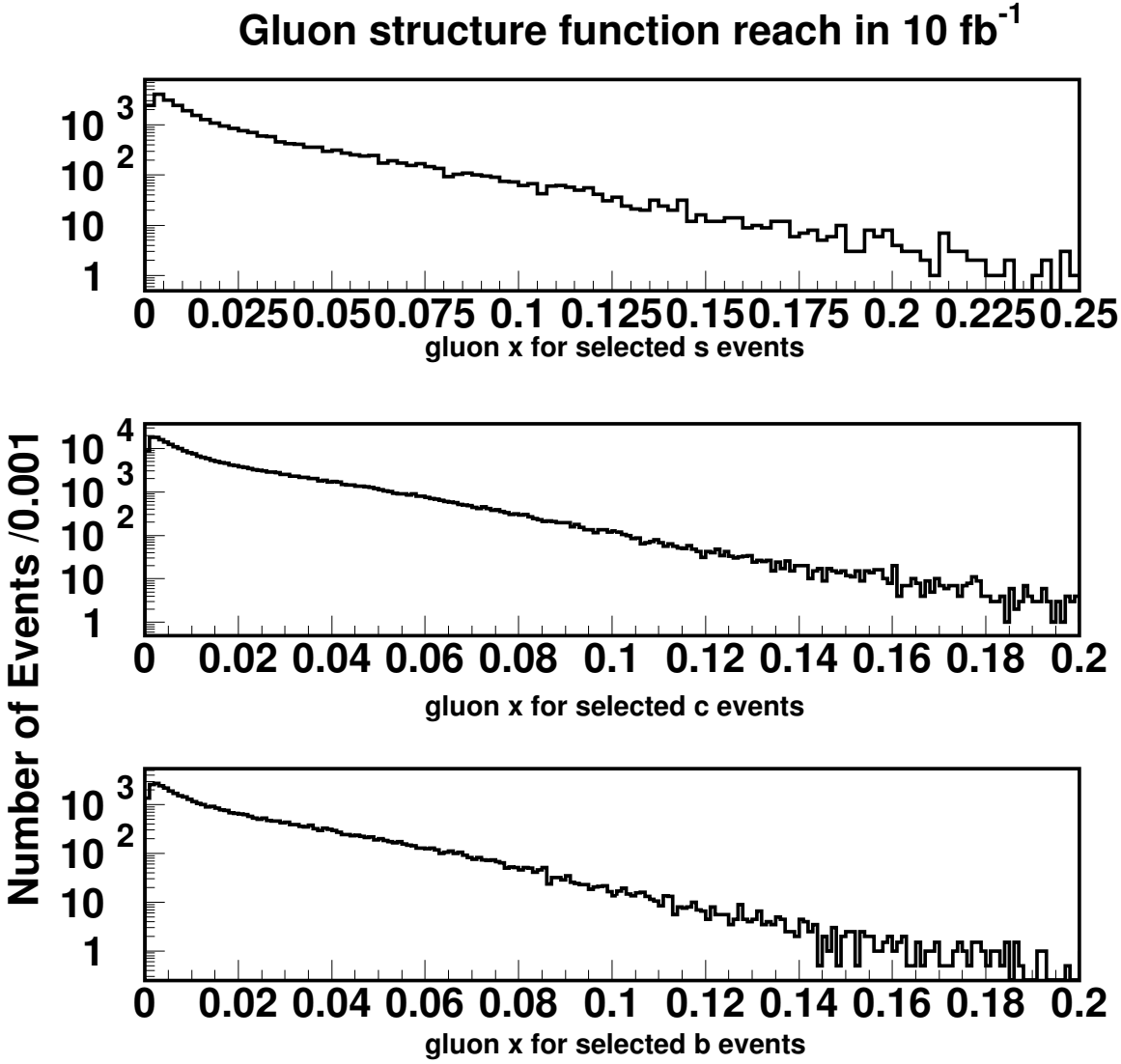
Backup

- γ-jet events: irreducible background $\sim 15\%$ from $q(\bar{q}) \to \gamma/Z/W + g$
  $\Longrightarrow$ need strict selection criteria.
  Still huge cross-section, $\mathcal{O}$(nb)!

- The rapidity asymmetry between the leptons from vector bosons and the jet may discriminate the signal from the background.

- Events with high p_T (≥ 40 GeV), isolated photon balanced by a jet ($E_T \geq 30$ GeV).

- Several million γ-jet events in 10 fb^{-1}.
  Demand jet to be back-to-back with γ within 20^0


Gluon structure function reach in 10 fb-1
Number of Events /0.001
gluon x for selected s events
gluon x for selected c events
gluon x for selected b events