Progress Towards b Fragmentation at NNLO

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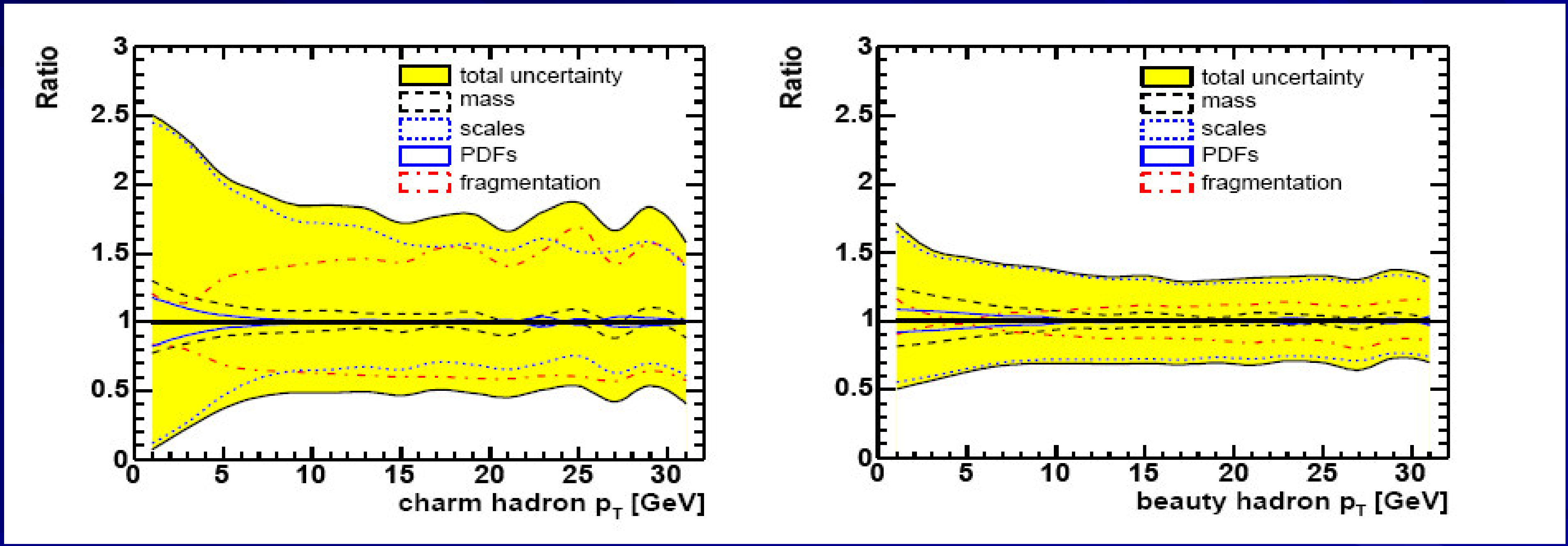
DESY

Work in progress with M. Cacciari and S-O. Moch

Also based on: hep-ph/0604160 (with Sven Moch)
hep-ph/0604053 (with Sven Moch and Andres Vogt)
hep-ph/0410205
hep-ph/0404143 (with Kirill Melnikov)

Fragmentation at NNLO?

From the previous HERA-LHC workshop hep-ph/0601164 …



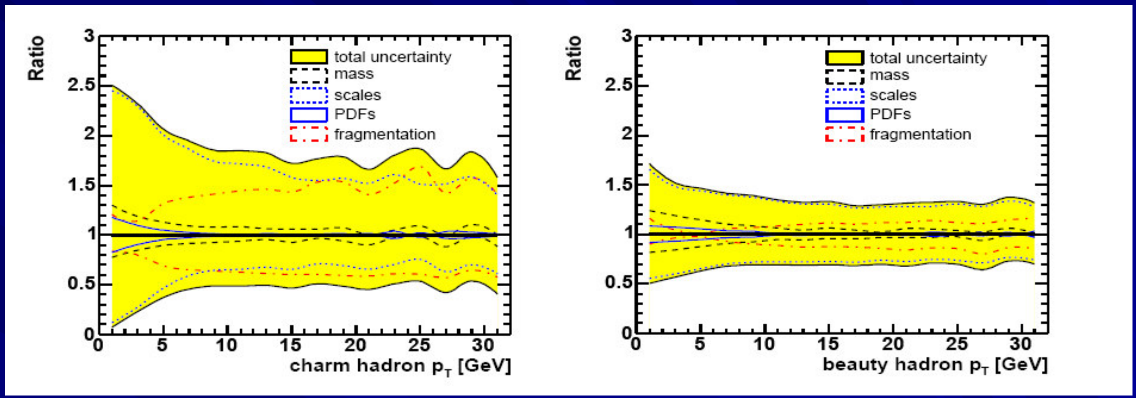
QCD predictions from NLO QCD (fixed order only)

Mangano, Nason, Ridolfi (1992)

Fragmentation at NNLO?

The leading uncertainties are:

- perturbative,
- fragmentation.



Note: there are also hidden perturbative uncertainties in the fragmentation component!

Can these two leading uncertainties be reduced?

- perturbative corrections known to NLO. NNLO is hard but feasible! (There is ongoing work in this direction).
- Fragmentation is presently “refined” at NLL accuracy.

Current status of b-fragmentation

The fragmentation b →B is:
- purely non-perturbative transition,
- it is process independent.

We can't describe it from first principles, but can extract it from data (e^+e^-).

Fragmentation is the key to a large class of collinearly sensitive processes!

Examples are single particle distributions, sensitive to the b →B transition:

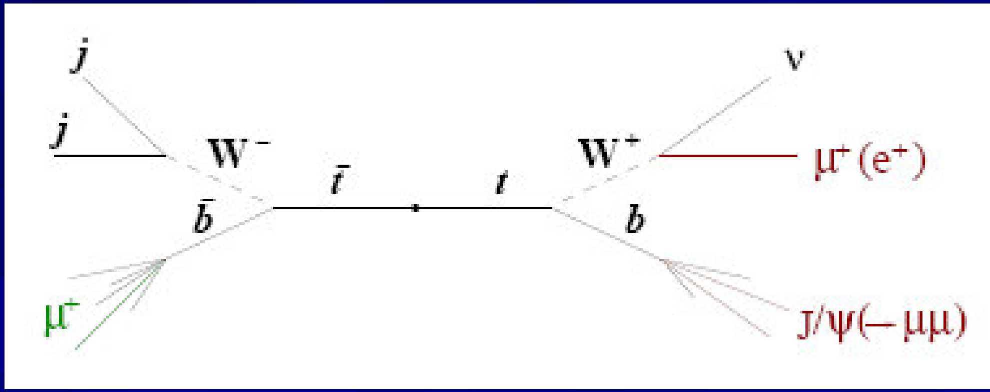
- transverse momentum distribution (hadron colliders),
- energy spectra (e^+e^-),
- particle spectra in decays of heavy particles (Higgs, top),
- top-mass measurement at LHC (from b-lepton invariant mass).

Relevance for the LHC (and HERA)

1) P_T - spectra of b-mesons,

2) Precise top mass measurement at the LHC from the invariant mass distribution of B-meson and a lepton:

$\Delta m_{top} \leq 1\text{GeV}$



- Method proposed by A. Kharchilava, hep-ph/9912320.
- Further studies with MC's:
  Corcella, Mangano and Seymour: hep-ph/0004179
- Based on HERWIG 6.0 and 6.1

On the theory side: NLO – easy; NNLO – feasible. How about the experiment?

Back to Fragmentation

How does it work?

Measured at LHC → $$\frac{d\sigma_B}{dp_T} = \frac{d\sigma_b}{dp_T} \otimes D^{DGLAP} \otimes D^{ini} \otimes D^{\rm n.p.}_{b\to B}$$

Measured at e^+e^- → $$\frac{d\sigma_B}{dE} = \frac{d\sigma_b}{dE} \otimes D^{DGLAP} \otimes D^{ini} \otimes D^{\rm n.p.}_{b\to B}$$

Important point: $D^{n.p.}$ is not an "absolute" object, but just the leftover between data and pQCD.

Therefore, the non-perturbative function is highly sensitive to the treatment of the perturbative part!

Clearly, extraction of fragmentation functions must be synchronized with their applications!

Fragmentation at NNLO : recent progress

During the last couple of years there have been important developments towards NNLO fragmentation.

All required perturbative components for the extraction from e^+e^- data are now available:

$$\frac{d\sigma_B}{dE} = \frac{d\sigma_b}{dE} \otimes D^{DGLAP} \otimes D^{ini} \otimes D^{\mathrm{n.p.}}_{b\to B}$$

1) All coefficient functions in e^+e^- known to two loops:

Rijken and van Neerven (1996)
A.M. and Sven Moch (2006)

2) NLO and NNLO (ns) time-like splitting functions now known:

Curci, Furmanski, Petronzio (1980),
A.M., Sven Moch and Andreas Vogt (2006)

The singlet NNLO time-like splitting functions will be known too.
They are not very important in e^+e^- (since no gluons at LO …).

Fragmentation at NNLO : recent progress

The previous components are common for both heavy and light flavors.

The perturbative calculations were done in Mellin space with a method not relying on OPE.

A.M. (2005)

$$\frac{d\sigma_B}{dE} = \frac{d\sigma_b}{dE} \otimes D^{DGLAP} \otimes D^{ini} \otimes D^{\text{n.p.}}_{b\to B}$$

3) The perturbative heavy quark FF: Mele, Nason (1991).

Mele, Nason (1991)
A.M., Kirill Melnikov (2004),
A.M. (2004).

All components of the PFF are known. They were derived at NNLO using dedicated, process-independent approach:

Keller, Laenen (1999),
Cacciari, Catani (2001)

Partial results in the large-nf limit were known:

Cacciari, Gardi (2003)

Current activity

Extraction of $D^{n.p.}$ from e^+e^- data with NNLO accuracy.

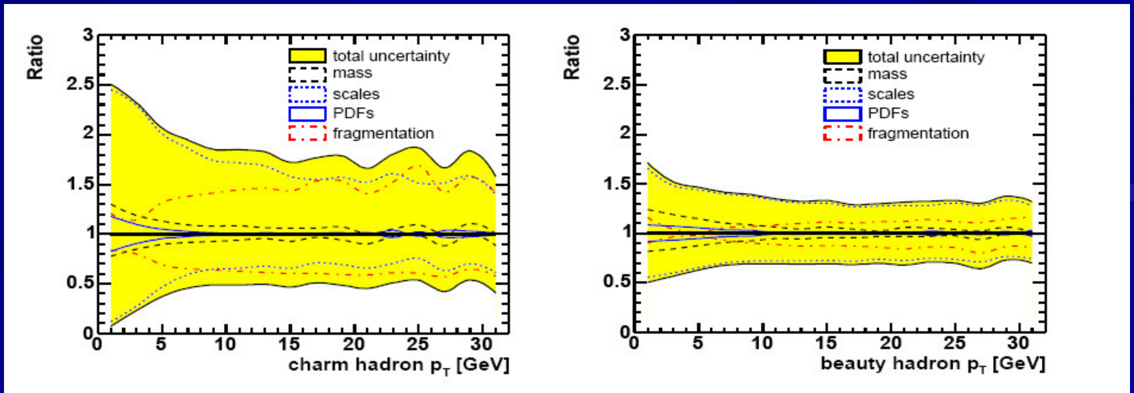
1) We are in a position to study full resummation of both collinear and soft logs. With that accuracy ➔ stability of the result.

2) From a comparison to numerical results on b-spectra at NNLO,

Nason, Oleari (1996; 1999)

we can systematically study mass-suppressed corrections at two loops.

This has never been studied before at that level. It has implications for the stability of the predictions at low scales.



Summary

- There have been exciting developments towards b-fragmentation at NNLO
- Two-loop coefficient functions in electron positron annihilation,
- 3-loop non-singlet time-like splitting functions,
- The perturbative heavy quark Fragmentation Function at two loops.

- Expect in the following months results on extracted b-fragmentation function at NNLO!

Applications (especially LHC)

- P_T - distribution of b-quarks,
- Extension to charm is also possible.
- Precise top mass measurement from J/Ψ in top decay.

Looking forward to discussions with experimentalists about implementations and other suggestions!