

(Bottom fragmentation) **issues in top mass determination**

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- ▶ How accurately can we measure the top mass?
 - ▶ Concentrate here on uncertainties stemming from bottom quark fragmentation
 - ▶ See e.g. G. Corcella, talk at TOPLHCWG Nov. 2013, <https://indico.cern.ch/getFile.py/access?contribId=14&sessionId=5&resId=0&materialId=slides&confId=280522>
- ▶ In fact, what are we measuring?
 - ▶ Relevant question because “precision” use of top mass requires precise definition
 - ▶ See e.g. A. Hoang, talk at Top2014, or S. Weinzierl, talk at Moriond EW 2015 and 1505.00630

Tens of methods for measuring the top mass.
What are they measuring?

If they use a Monte Carlo, they are most likely
measuring a “MC mass”

Such an MC mass (which is not the “pole mass”,
which has itself an ambiguity $O(\Lambda_{\text{QCD}})$) depends
on details of MC, including soft physics

MC top mass or “masses”?

Slide from G. Corcella's talk

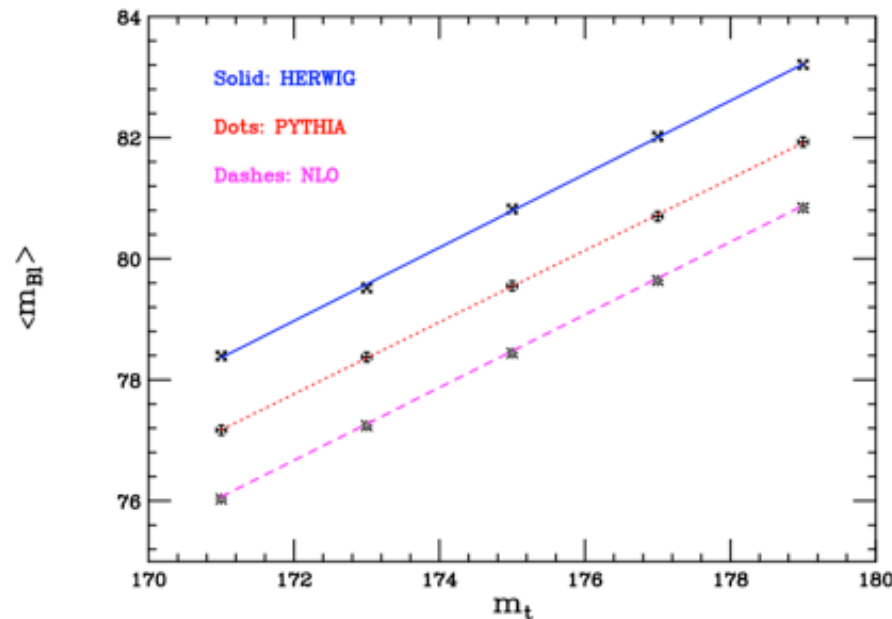
Linear fits to extract m_t from $m_{B\ell}$

HERWIG: $\langle m_{B\ell} \rangle_H \simeq -25.31 \text{ GeV} + 0.61 m_t$; $\delta = 0.043 \text{ GeV}$

PYTHIA: $\langle m_{B\ell} \rangle_P \simeq -24.11 \text{ GeV} + 0.59 m_t$; $\delta = 0.022 \text{ GeV}$

NLO: $\langle m_{B\ell} \rangle_{\text{NLO}} \simeq -26.7 \text{ GeV} + 0.60 m_t$; $\delta = 0.004 \text{ GeV}$

Biswas, Melnikov,
Shulze, 1006.0910



$\Delta \langle m_{B\ell} \rangle_{H,P} \simeq 1.2 \text{ GeV}$; $\Delta \langle m_{B\ell} \rangle_{H,\text{NLO}} \simeq 2.2 \text{ GeV}$; $\Delta \langle m_{B\ell} \rangle_{P,\text{NLO}} \simeq 1.1 \text{ GeV}$

NLO+showers for top decays or C++ codes may shed light on this discrepancy

Lessons on the MC top mass (for a perfect MC)

The interpretation (and value) of the top mass parameter in each MC generator is unique and should be observable-independent.

The value measured for the top mass depends on details of the MC, so in principle different MC have different top mass values.

The MC top mass parameter has features similar to a Top meson mass, and the way how to extract a field theoretical mass (in a suitable scheme) is analogous to methods in B physics

Without further knowledge there is an uncertainty of order $\lesssim 1\text{GeV}$ one has to add when translating the MC top mass to a suitable suitable field theoretical top mass ($m_t^{\text{MSR}}(R=1 - 3 \text{ GeV})$)

Can one do better?

Likely yes, but it takes some care

One has to define observables in terms of a “short distance mass”, unaffected by soft physics by construction

The connection between perturbative calculations and the measured observable quantity will most likely include “soft” contributions that have to be factored out and determined elsewhere

Fleming, Hoang, Mantry, Stewart, '07

Scale	Matrix elements	Effective theory	Affects	Remarks
$Q \dots m_t$	hard function	QCD	norm of the distribution	depends on m_t
$m_t \dots \Gamma_t$	jet function	SCET	shape and position	depends on m_t
$\Gamma_t \dots \Lambda_{QCD}$	soft function	top-HQET	shape and position	independent of m_t

Analogy of factorisation:

Effective theory: Hard function / jet function / soft function

Monte Carlo: Hard matrix element / parton shower / hadronisation

Parton shower has a lower cut-off.

⇒ Monte Carlo mass is something like a short-distance mass.

From MC to field-theoretic mass

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Alternatively (or complementarily) one may develop a brand new MC based on effective theories (SCET?) where all factorisations and resummations are properly accounted for from the start

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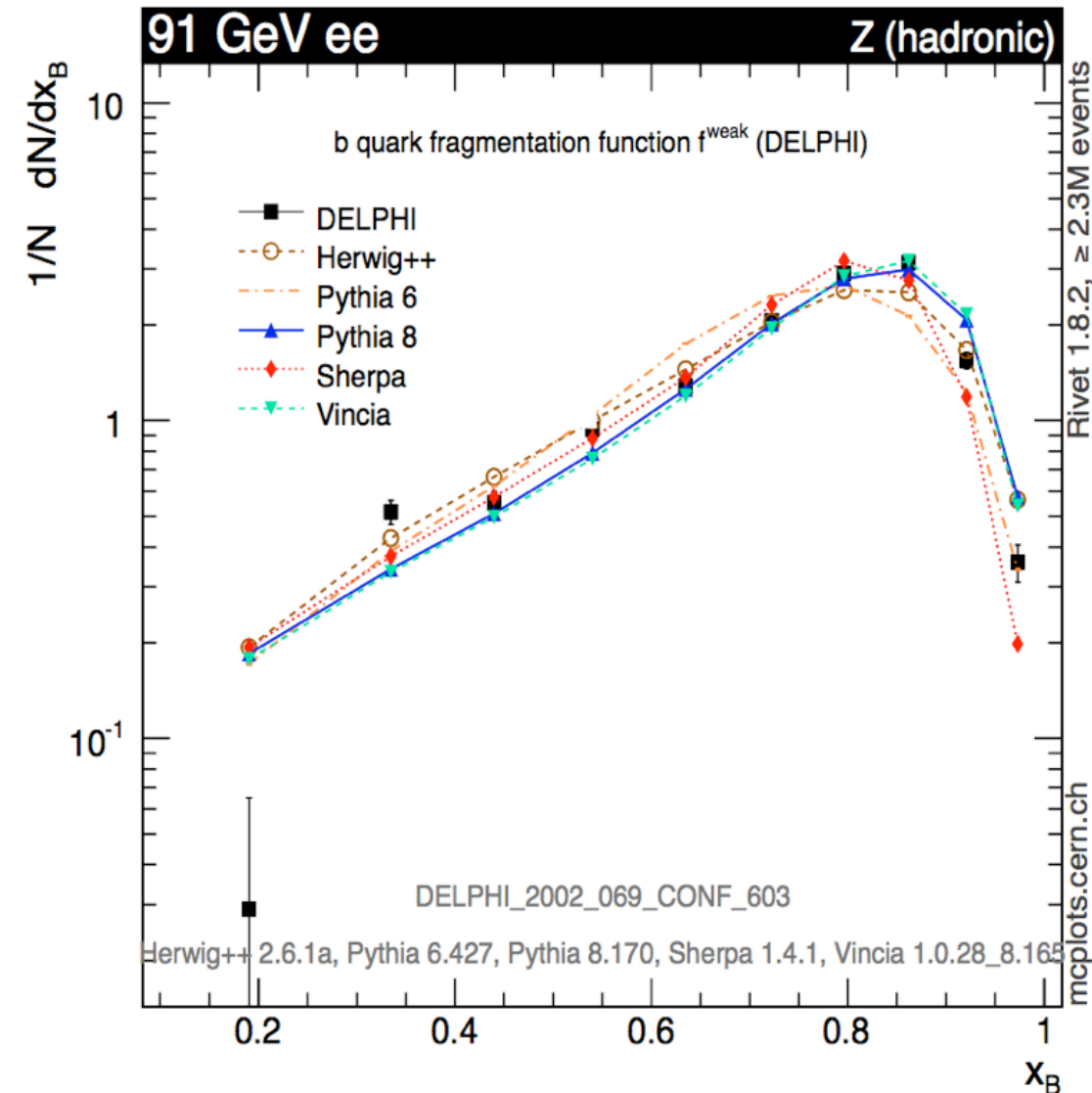
Note that, if different MCs give different masses, at some point experimental uncertainty may perhaps be small enough to tell, e.g., $m^{\text{MC}}_{\text{HERWIG}}$ from $m^{\text{MC}}_{\text{PYTHIA}}$

What I’d certainly not do (at least not forever), is averaging blindly top masses measured with different MCs from different observables by different experiments

b fragmentation in MCs

Bottom fragmentation is one of the biggest systematics in many top mass analyses

Plot from G. Corcella's talk

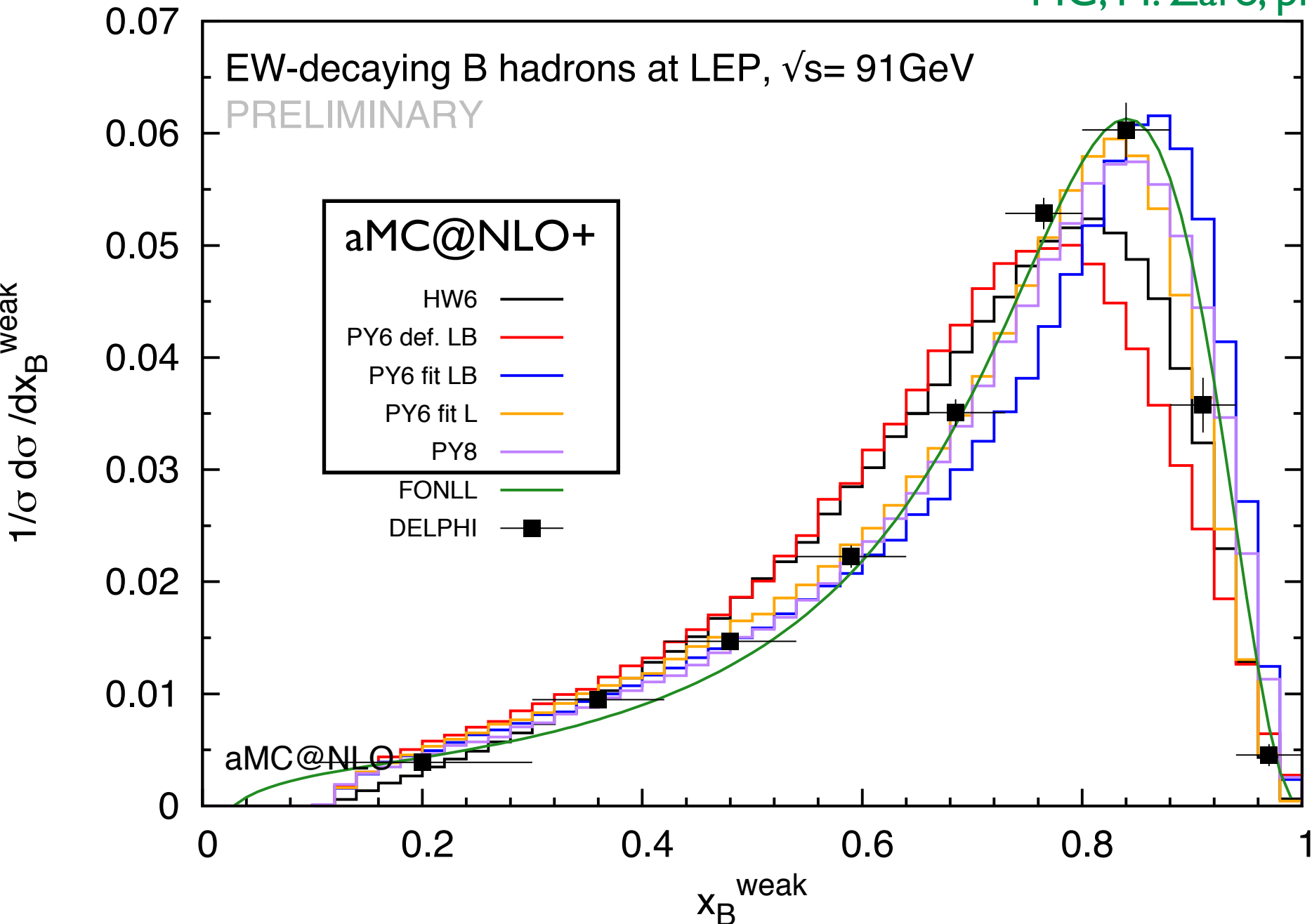


Significant discrepancies between default tunes of MCs and with data

**Are modern MCs, based on matching of
NLO and PS, doing better?**

b frag in aMC@NLO

MC, M. Zaro, preliminary



b frag in NLO+PS Monte Carlos

Even modern tools (C++ MCs, NLO+PS Monte Carlos) seem to do a bad job at describing bottom fragmentation using their default settings

It is somewhat surprising (to me, at least) that better public “default” tunes have not appeared yet. Some work has been done, e.g. I404.5630 for Pythia 8. I do not see any obvious obstacle to generalise this.

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NB. Even after tuning, a possible residual top mass difference between two MCs will not necessarily give the full uncertainty on a “MC mass”

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- ▶ Estimate of relative size of uncertainties can tell if progress in either of these two steps is useless