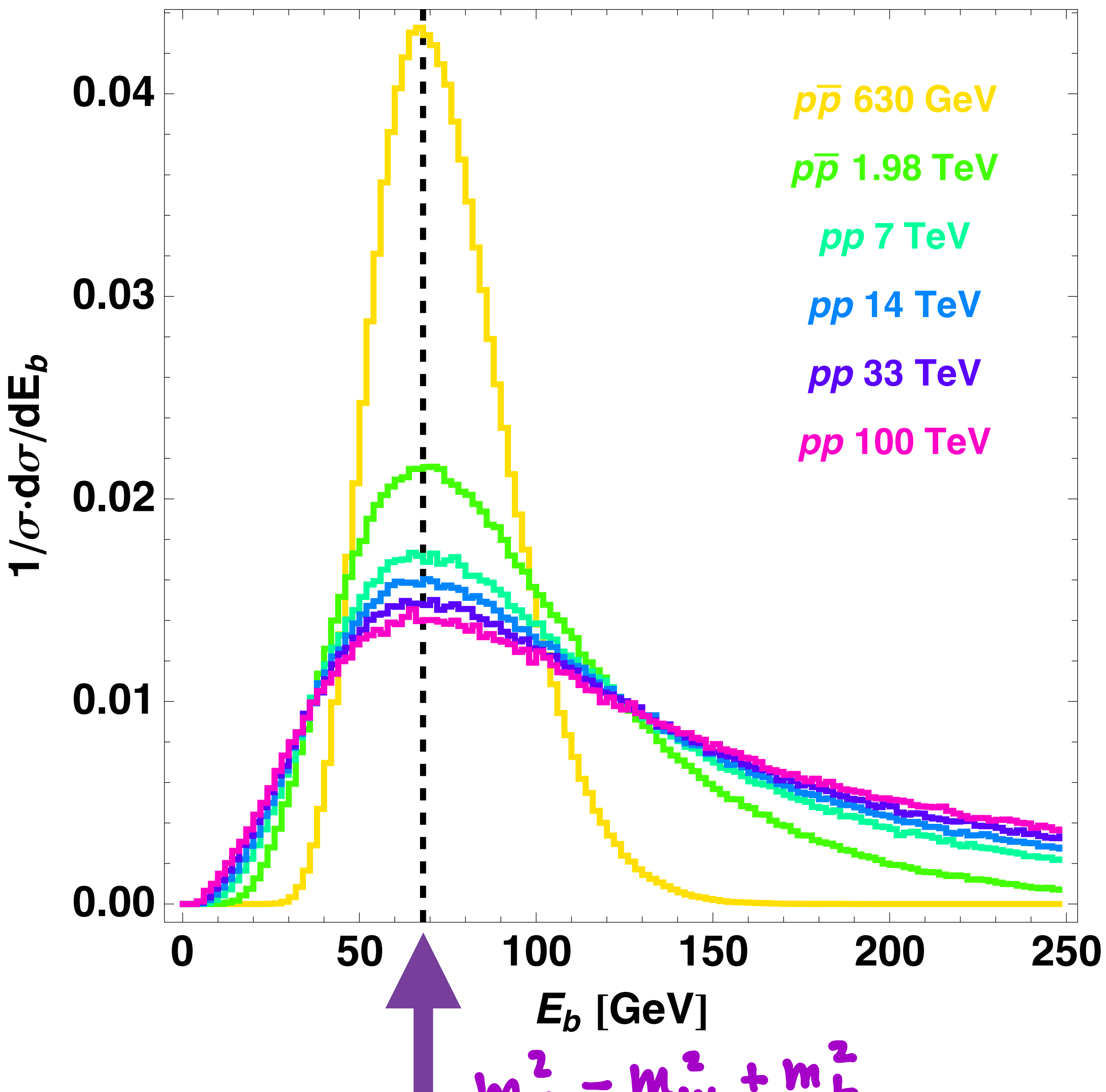
B-hadrons: peaks and other observables

Roberto Franceschini (CERN)
with Agashe, Kim and Schulze - 1603.03445
plus
work in progress with G. Corcella

The invariance of energy

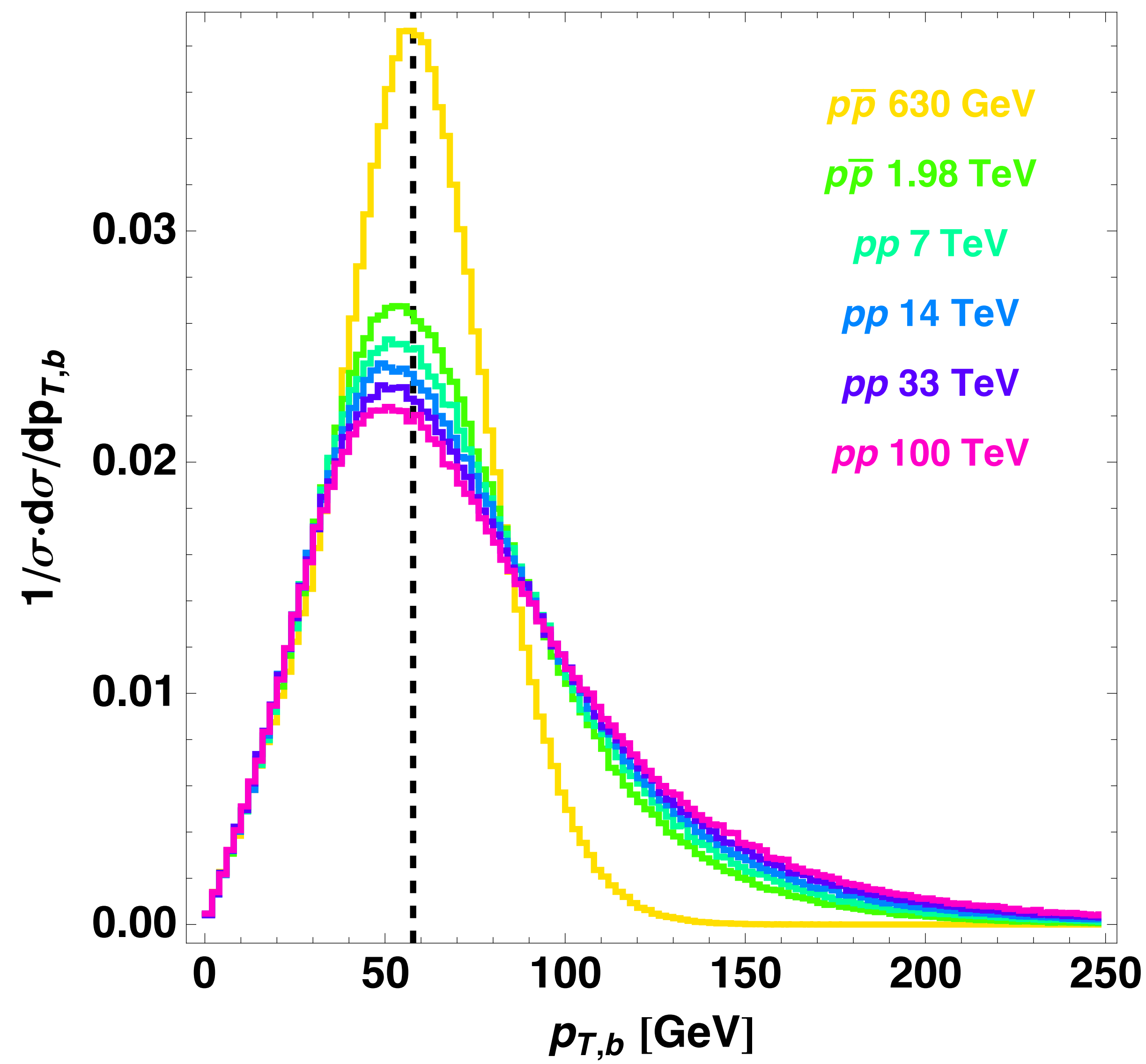
1209.0772 - Agashe, RF and Kim

Shape changes, peak doesn't!



$$E_b^* = \frac{m_t^2 - m_W^2 + m_b^2}{2 m_t}$$

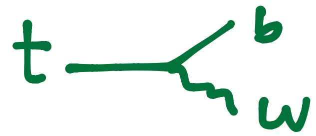
Shape changes, peak does too

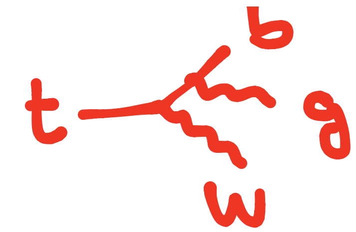


NLO: production & decay

(MCFM)

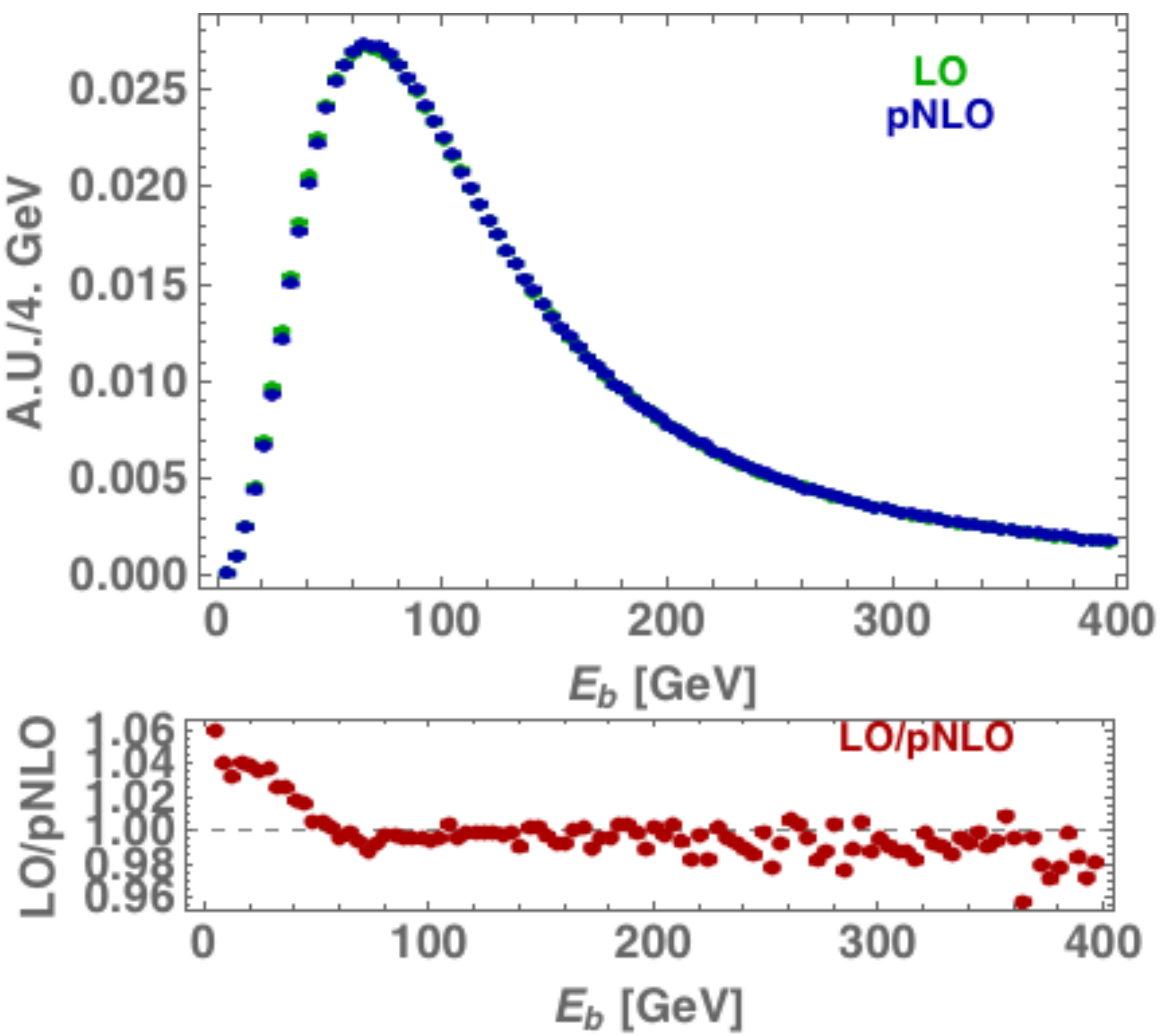
Energy of b-jet

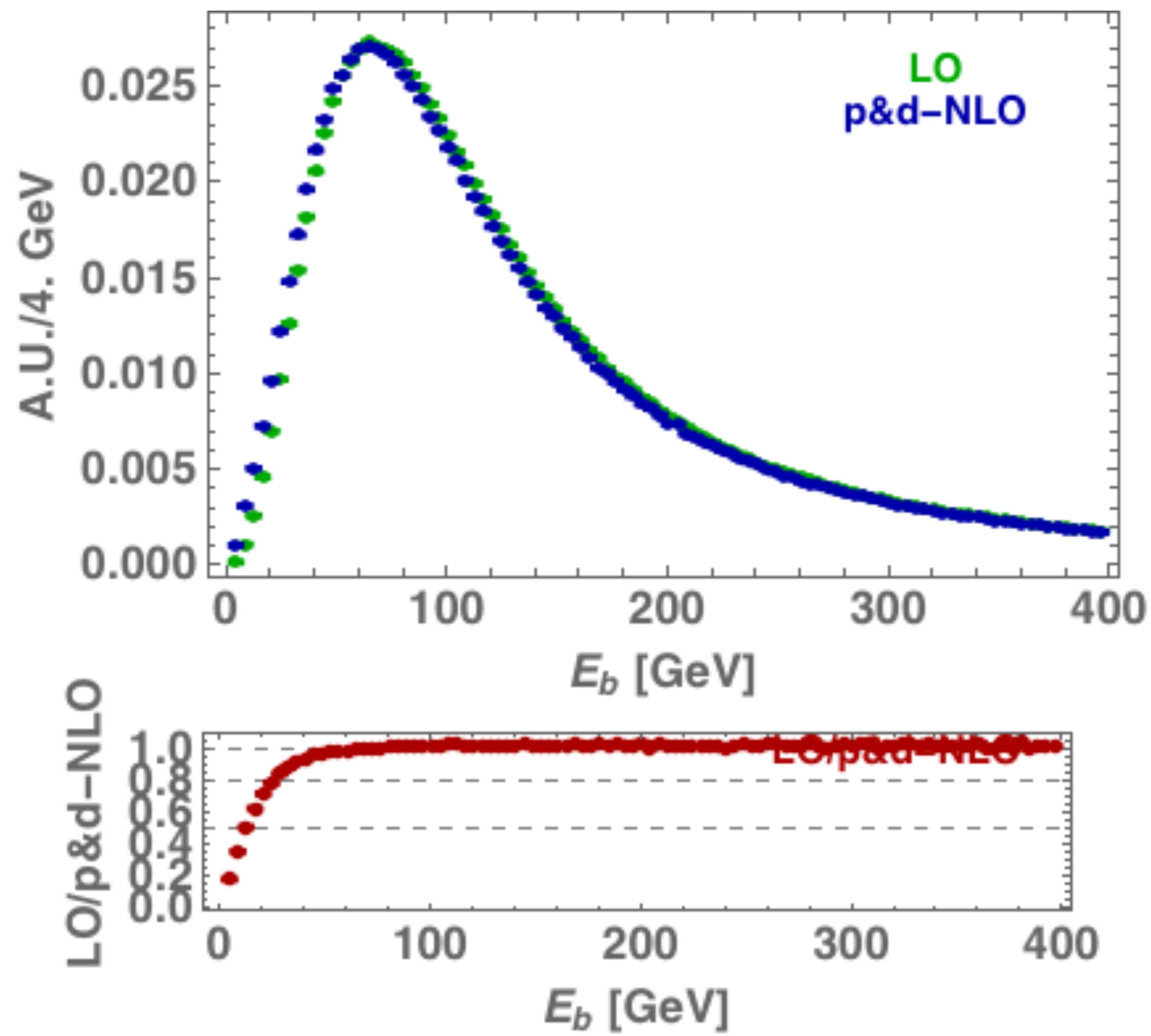




decay at LO

decay at NLO

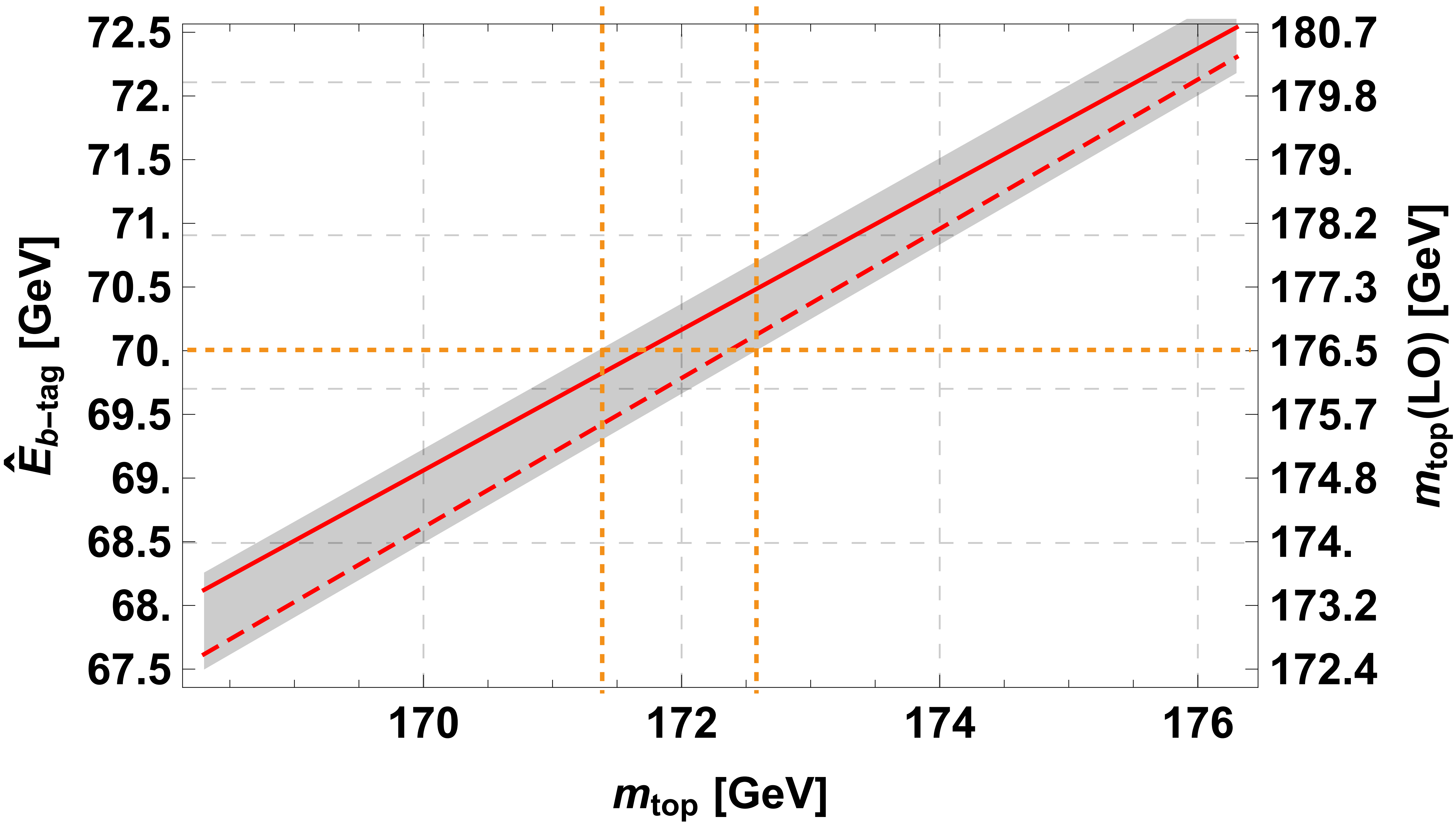




The result

Agashe, RF, Kim, Schulze - 1603.06536

Δ(th)=±0.6 GeV



- **b-jet energy peaks "invariance" holds** when only **NLO production** corrections are considered

- full NLO gives **$\delta m_{top} \simeq \pm 0.6$ GeV scale sensitivity** mostly arising from **description of decay**

- **NNLO <u>decay</u>** description of jets would probably be enough to make a solid prediction at **$\delta m_{top} \simeq \Lambda_{QCD}$**

NLO $E^*(m_{top})$

Agashe, RF, Kim, Schulze - 1603.06536

$pT_j > 30$ GeV, $\eta_j < 2.4$, $pT_\ell > 20$ GeV, $\eta_\ell < 2.4$

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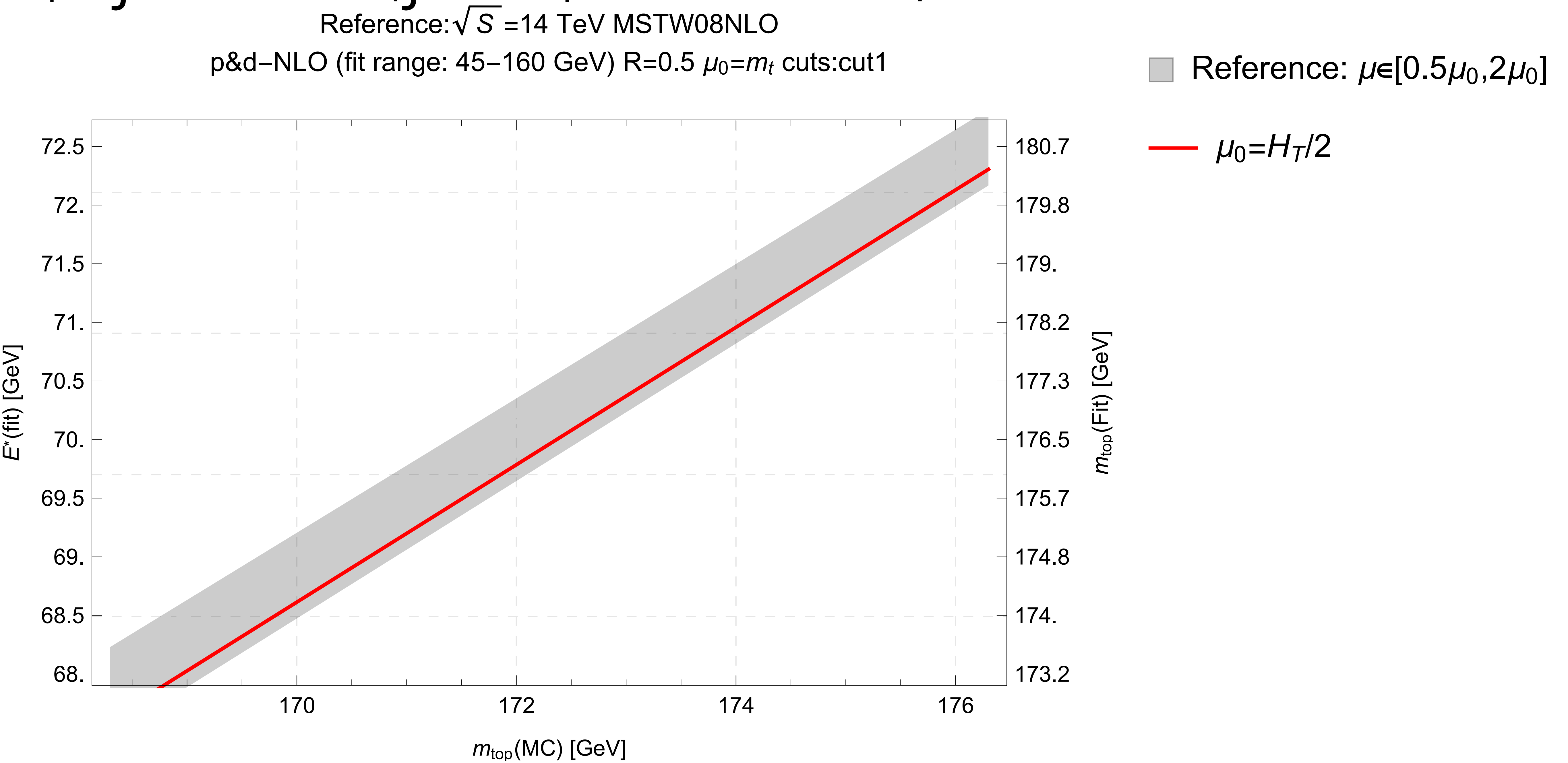

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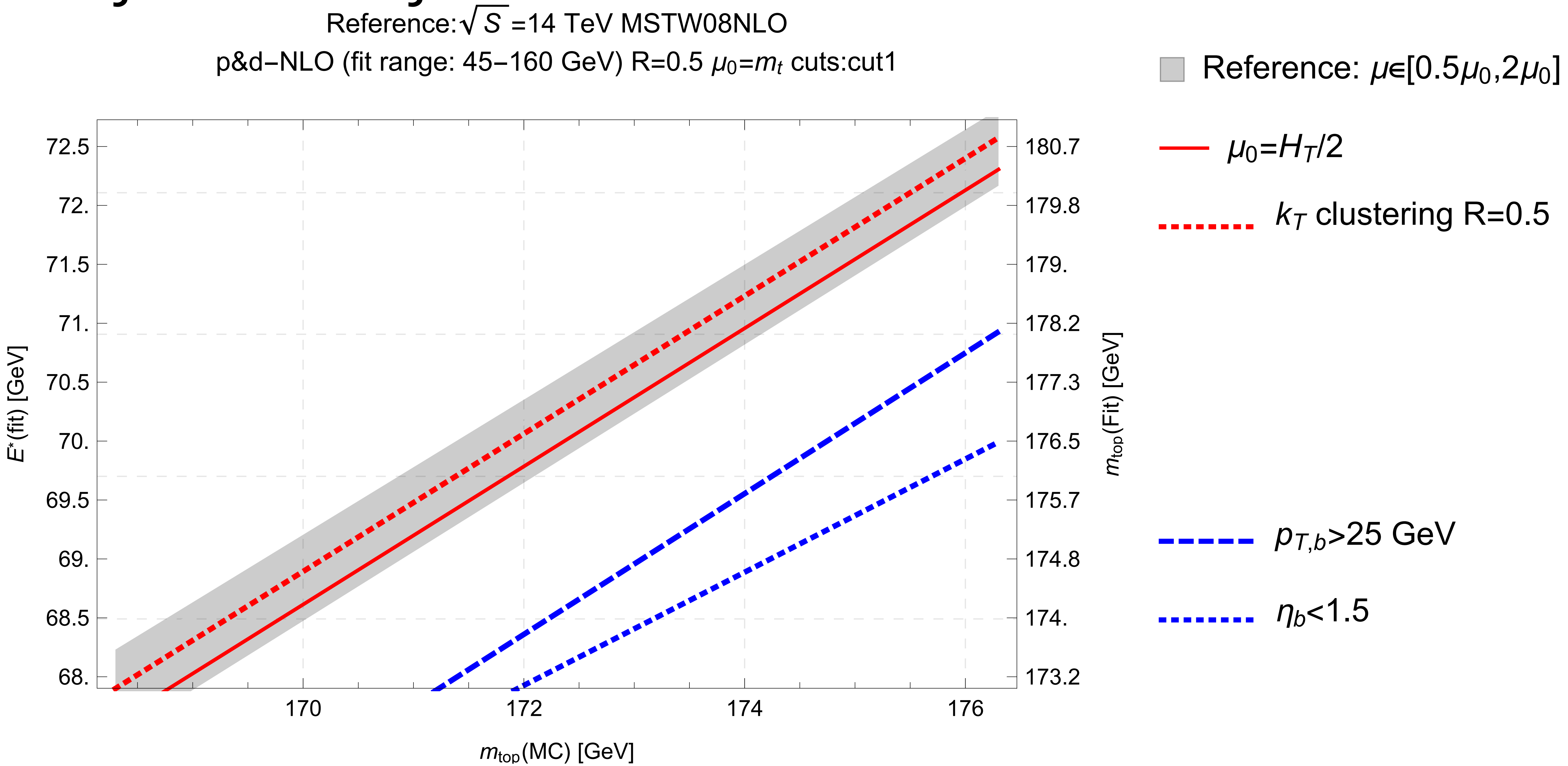

NLO E*(m_{top})

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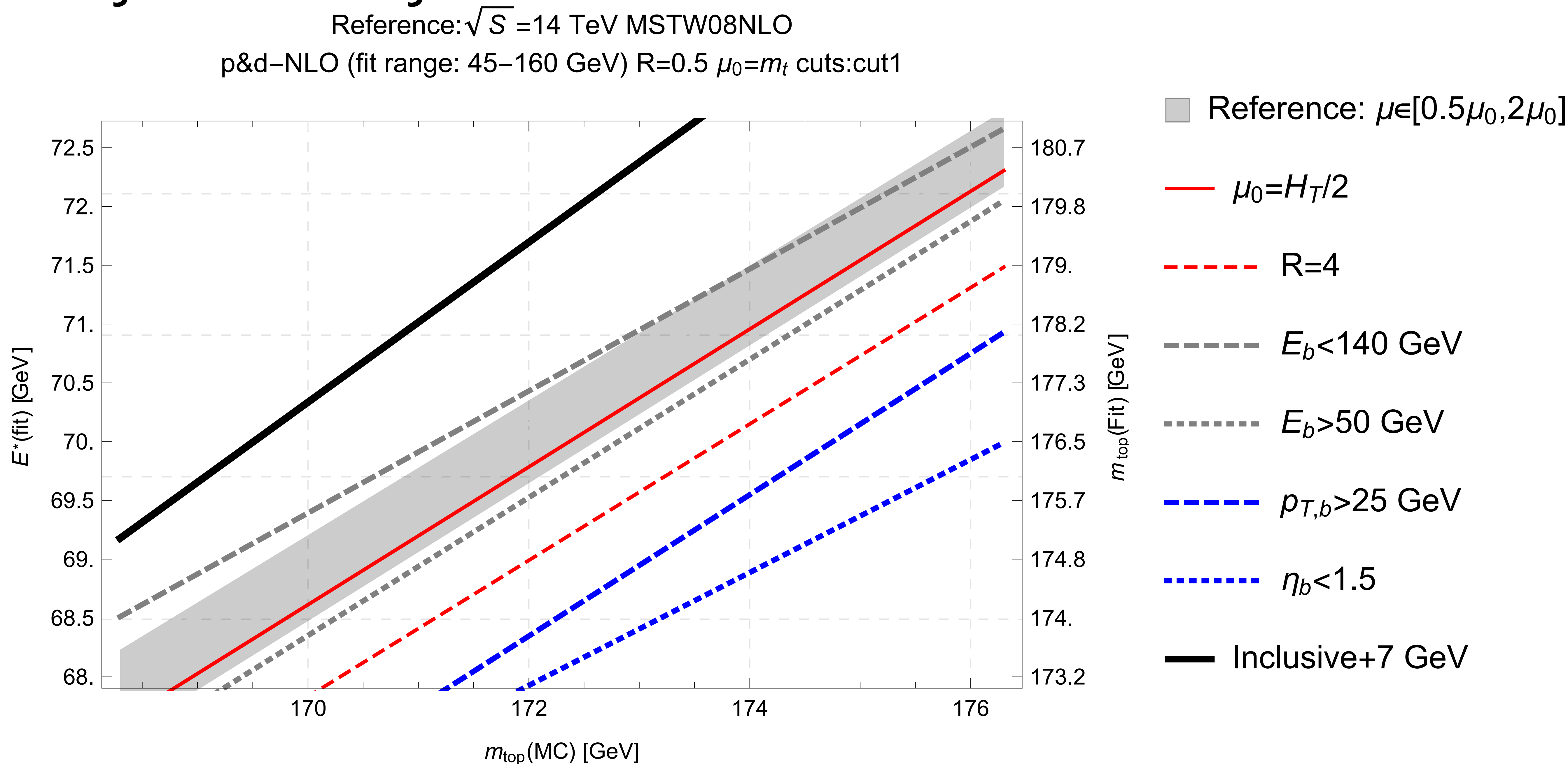
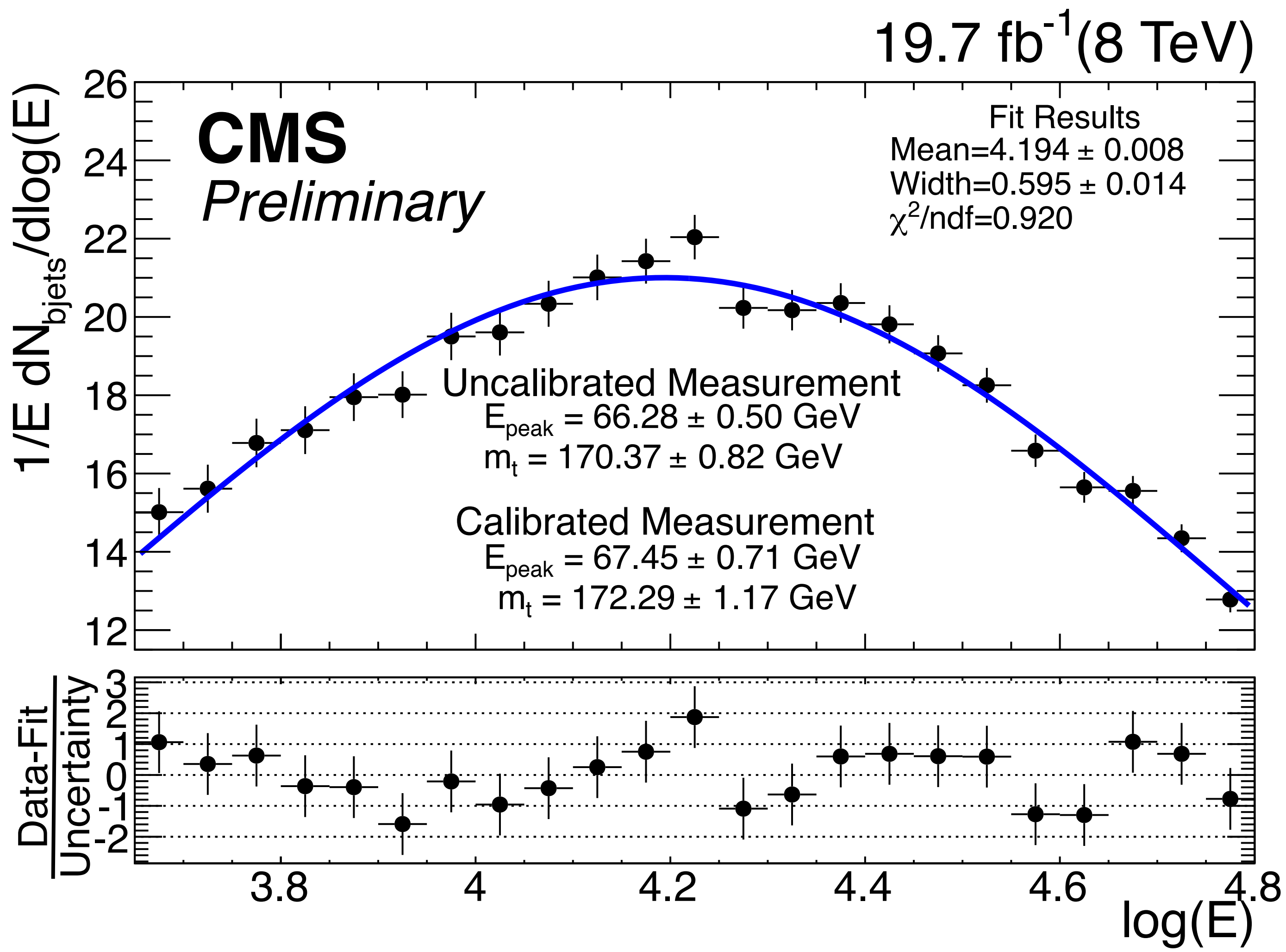


CMS PAS TOP-15-002

$m_t = 172.29 \pm 1.17\ (\text{stat.}) \pm 2.66\ (\text{syst.})\ \text{GeV}$



Source of uncertainty	δE_{peak} (GeV)	δm_t (GeV)
Experimental uncertainties		
Jet energy scale	0.74	1.23
b jet energy scale	0.14	0.22
Jet energy resolution	0.18	0.30
Pile-up	0.01	0.02
b-tagging efficiency	0.12	0.20
Lepton efficiency	0.02	0.03
Fit calibration	0.14	0.24
Backgrounds	0.21	0.34
Modeling of hard scattering process		
Generator modeling	0.91	1.50
Renormalization and factorization scales	0.13	0.22
ME-PS matching threshold	0.24	0.39
Top p_T reweighting	0.90	1.49
PDFs	0.13	0.22
Modeling of non-perturbative QCD		
Underlying event	0.22	0.35
Color reconnection	0.38	0.62
Total	1.62	2.66

leading uncertainty from theory can be reduced

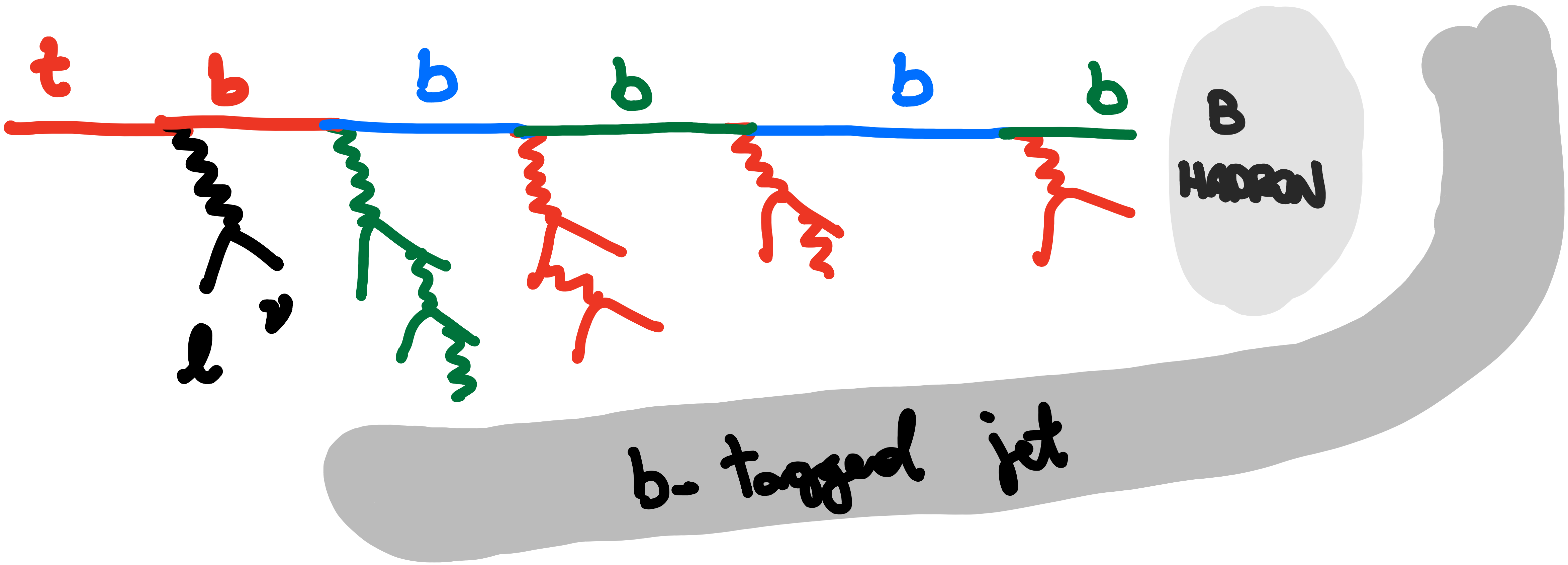
pT(top) reweighting smaller than other methods (Lxy, pTℓ …)

beyond jets

… and their intrinsic uncertainties

B hadron (peak) observables

The strength of the future LHC top mass measurement will build on the **diversity of methods**
⇒ not very useful to talk about "*single best measurement*"



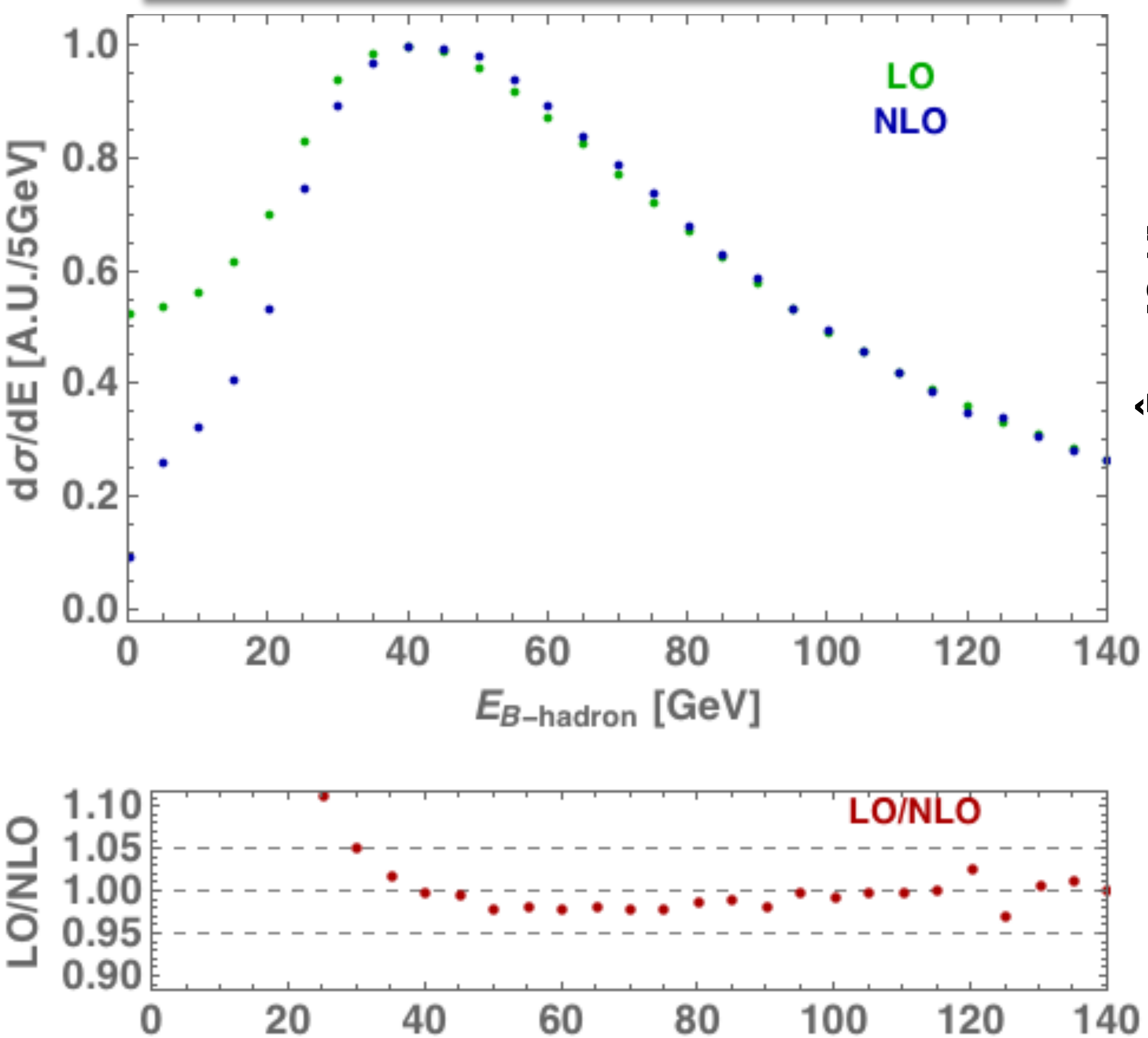
B hadron is a well defined, in principle fully reconstructible, subset of the b-jet

1603.06536

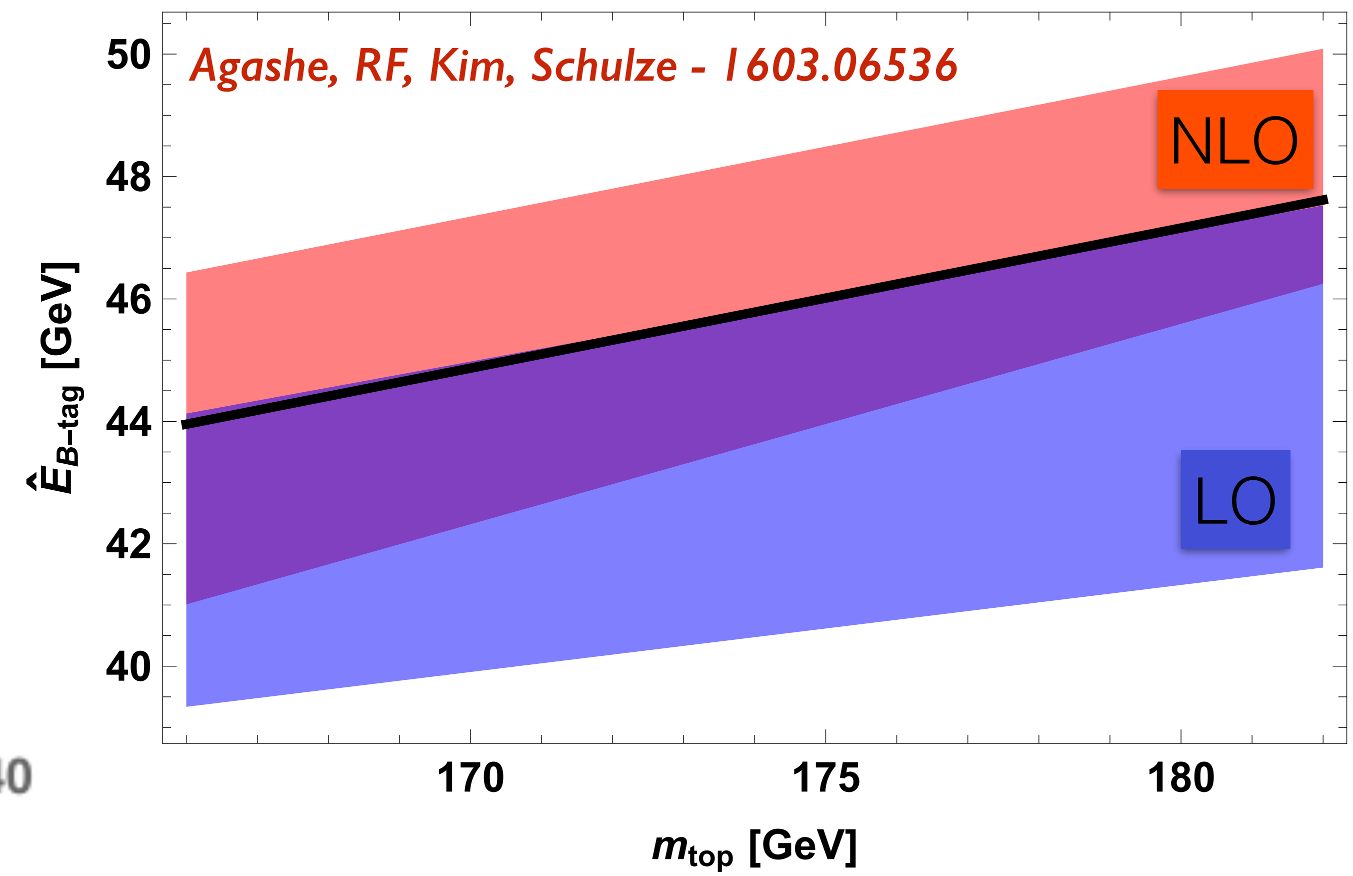
CMS-PAS-TOP-15-014

Hadron Spectrum

pp → $t\bar{t}$ ⊗ NLO fragmentation function



dominated by fragmentation scale



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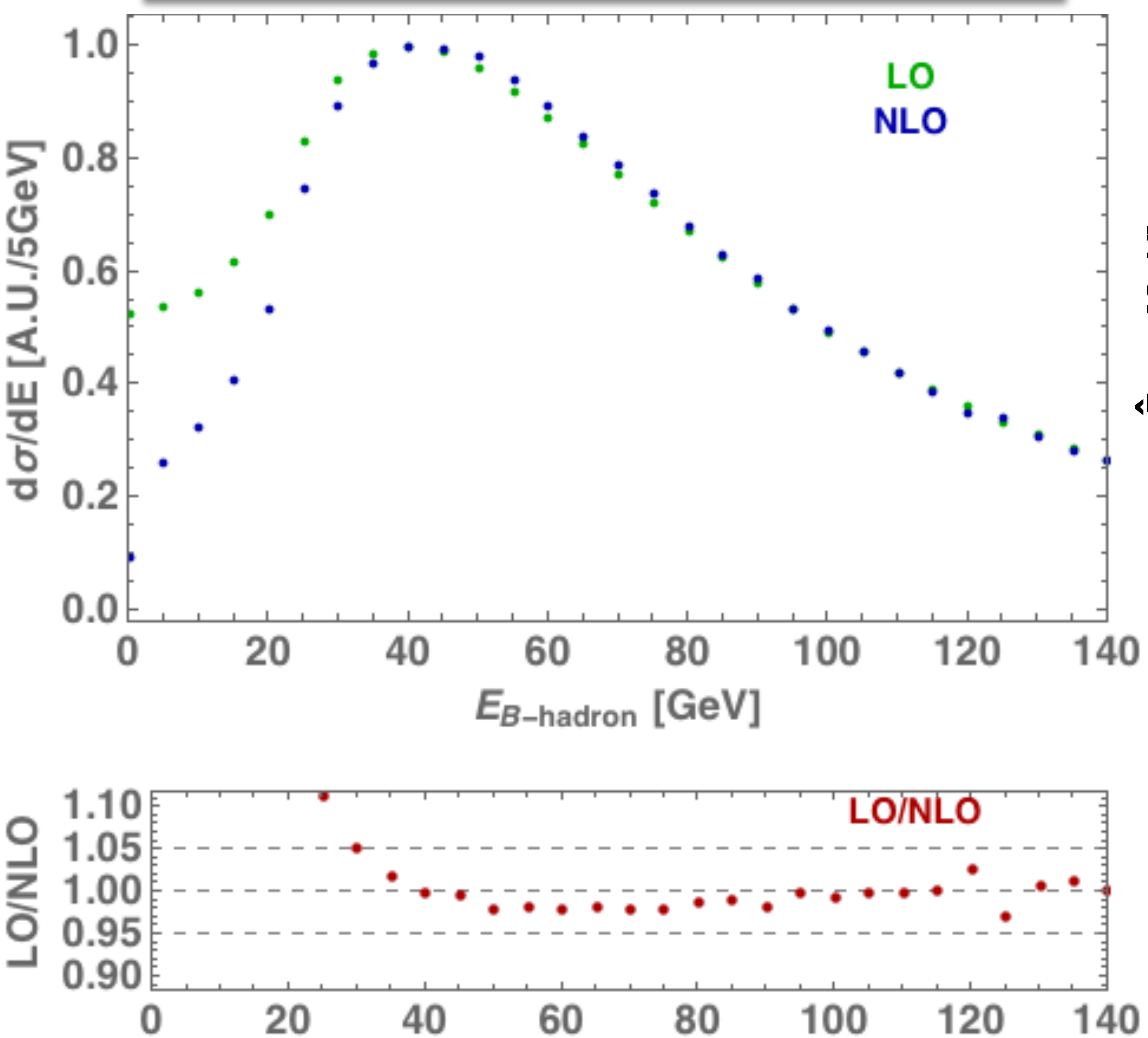

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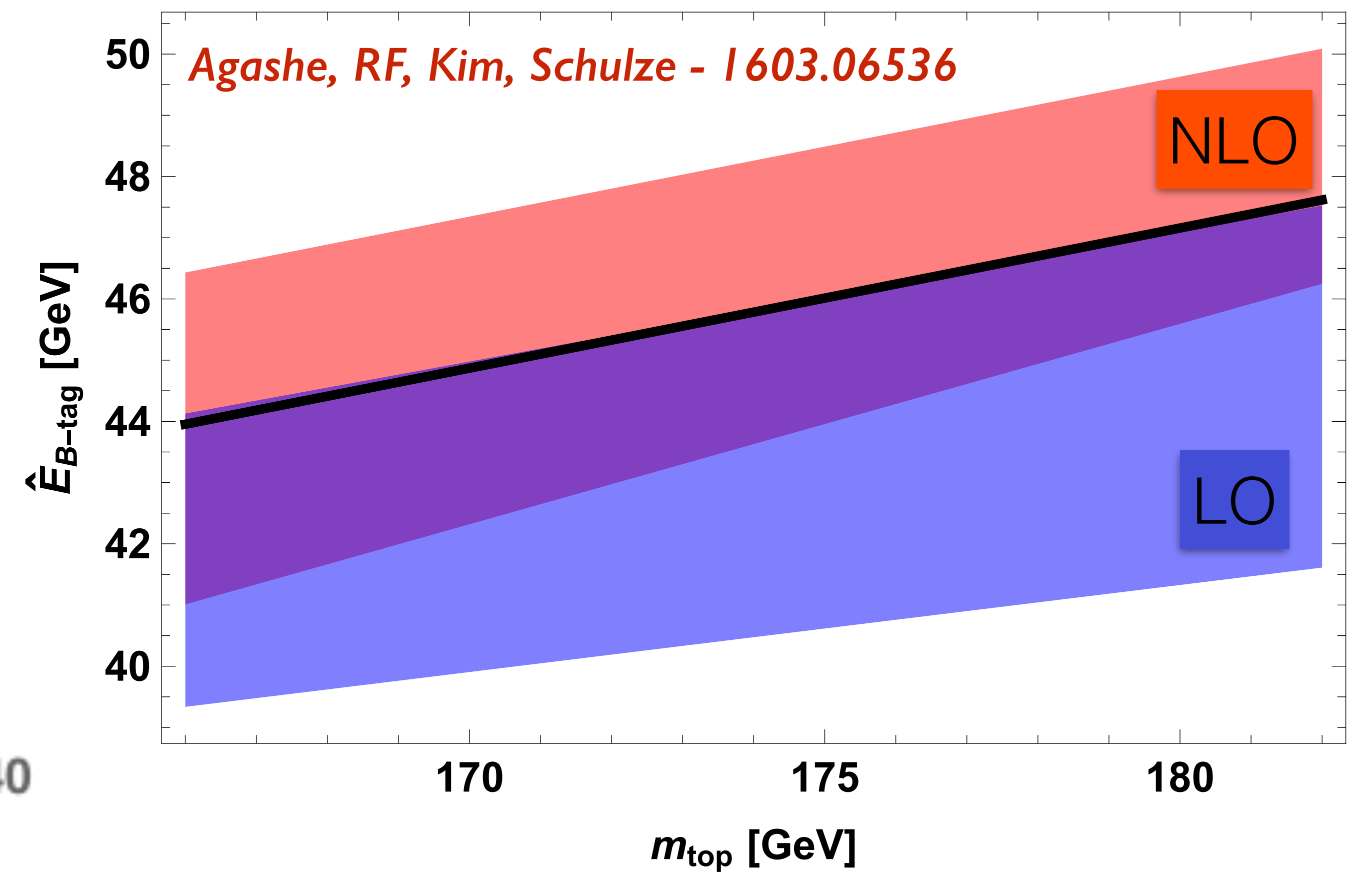


NLO sensitive to the scale choice: ±3.5 GeV on m_{top}

insisting on hadrons

For each observables used in top quark mass measurement with b-jets a derived observable can be defined using the B-hadron instead of the b-jet (and JES ↔ Hadronization)

E(b-jet) ⇒ E(B-hadron)

p_T(b-jet) ⇒ p_T(B-hadron)

E(b-jet)+ E(b-jet) ⇒ E(B-hadron)+ E(B-hadron)

m(b-jet,lepton) ⇒ m(B-hadron,lepton)

What is the current uncertainty from hadronization modeling?

How precisely we need to tune the models on (top quark specific) data?

insisting on hadrons

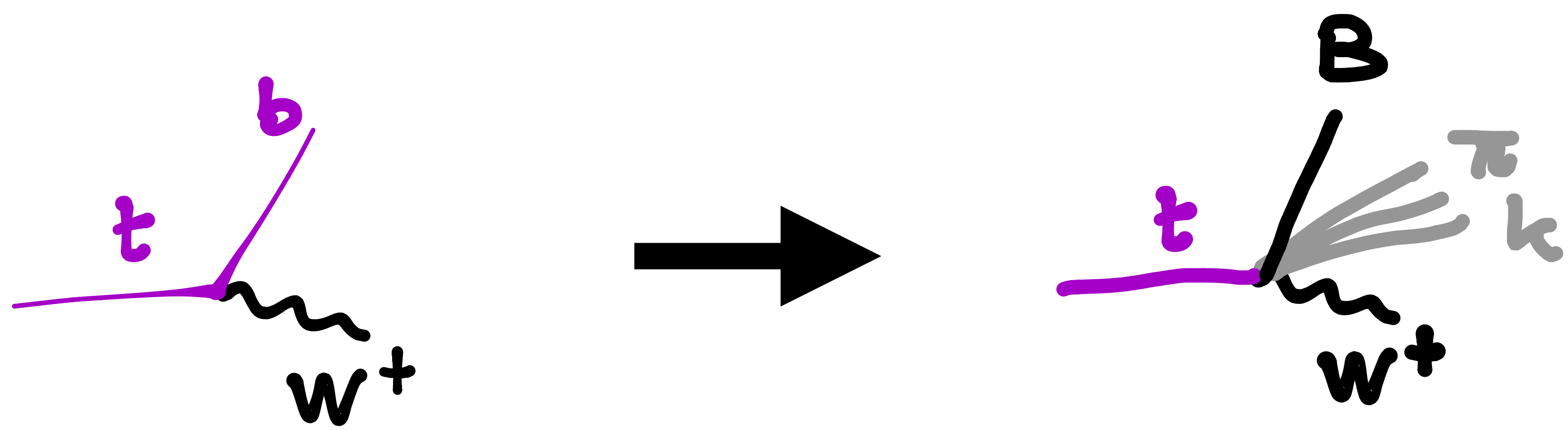
For each observables used in top quark mass measurement with b-jets a derived observable can be defined using the B-hadron instead of the b-jet (and JES ↔ Hadronization)

	FWHM Mellin-1	Peak-fit	End-fit
E(b-jet) ⇒ E(B-hadron)	★	★	
p_T(b-jet) ⇒ p_T(B-hadron)	★		
E(b-jet)+ E(b-jet) ⇒ E(B-hadron)+ E(B-hadron)	★		
m(b-jet,lepton) ⇒ m(B-hadron,lepton)	★		★

What is the current uncertainty from hadronization modeling?

How precisely we need to tune the models on (top quark specific) data?

B hadron energy peak



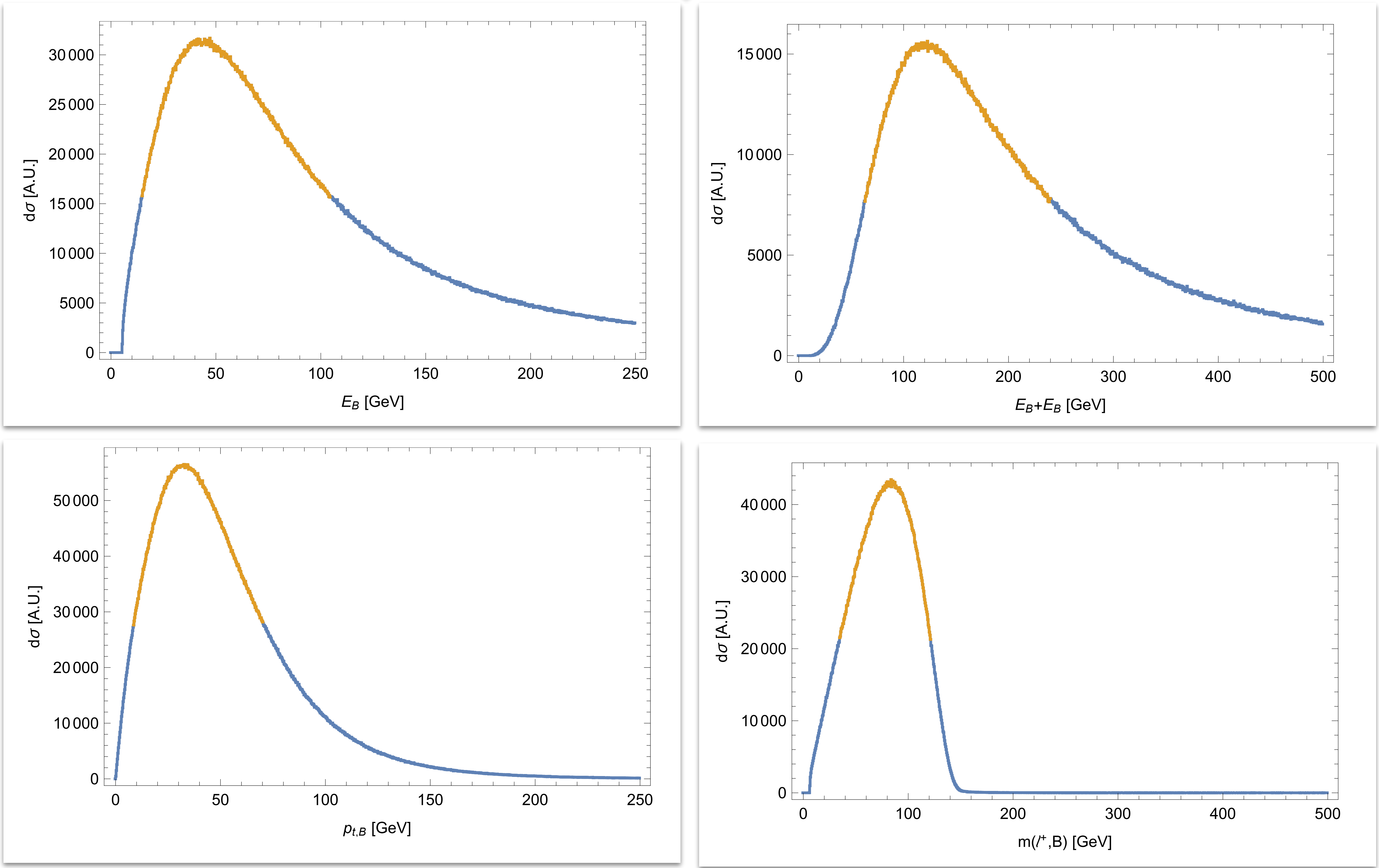
intrinsically a multi-body decay

less protected by the "invariance"

Pythia 8.2

pp@√s=13 TeV

hadron sensitivity to Lund-Bowler r_b



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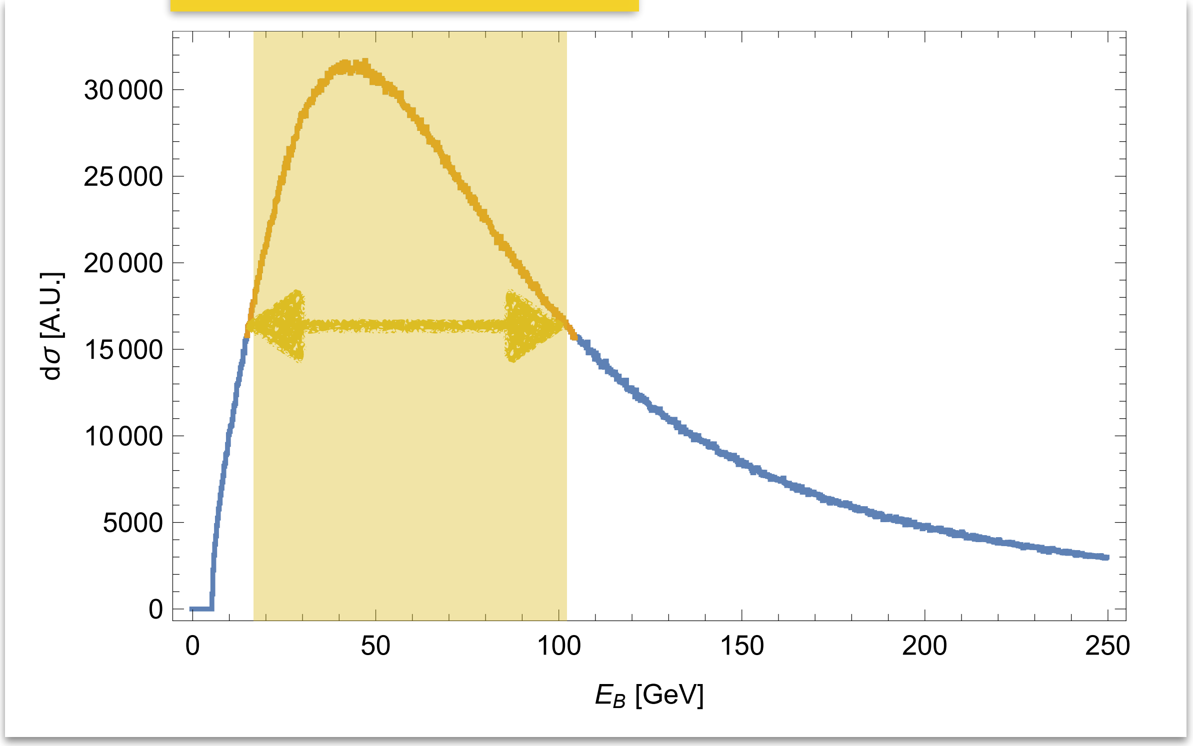
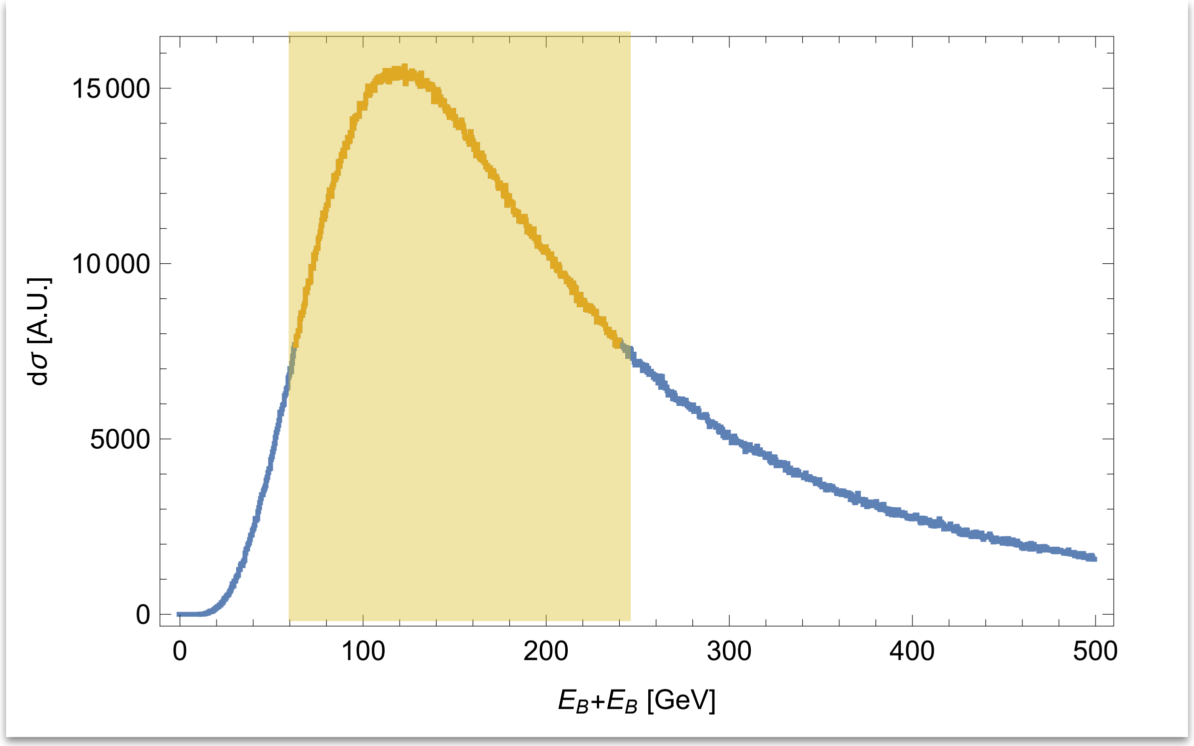
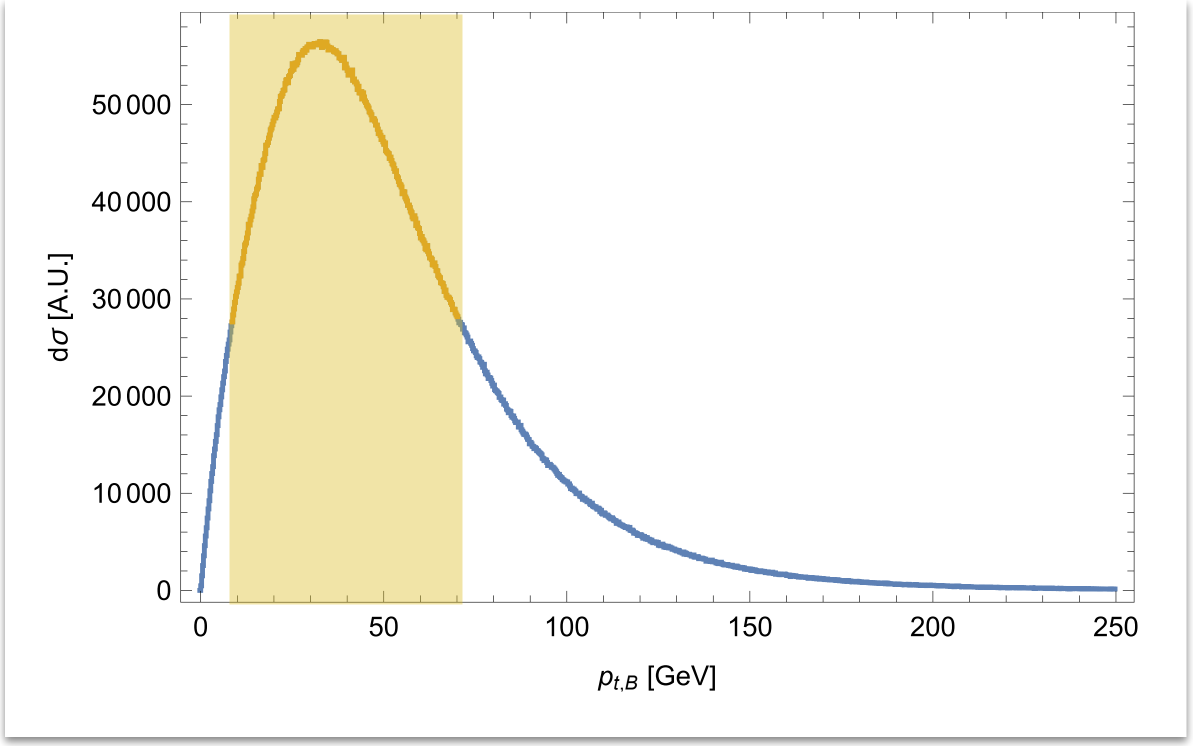
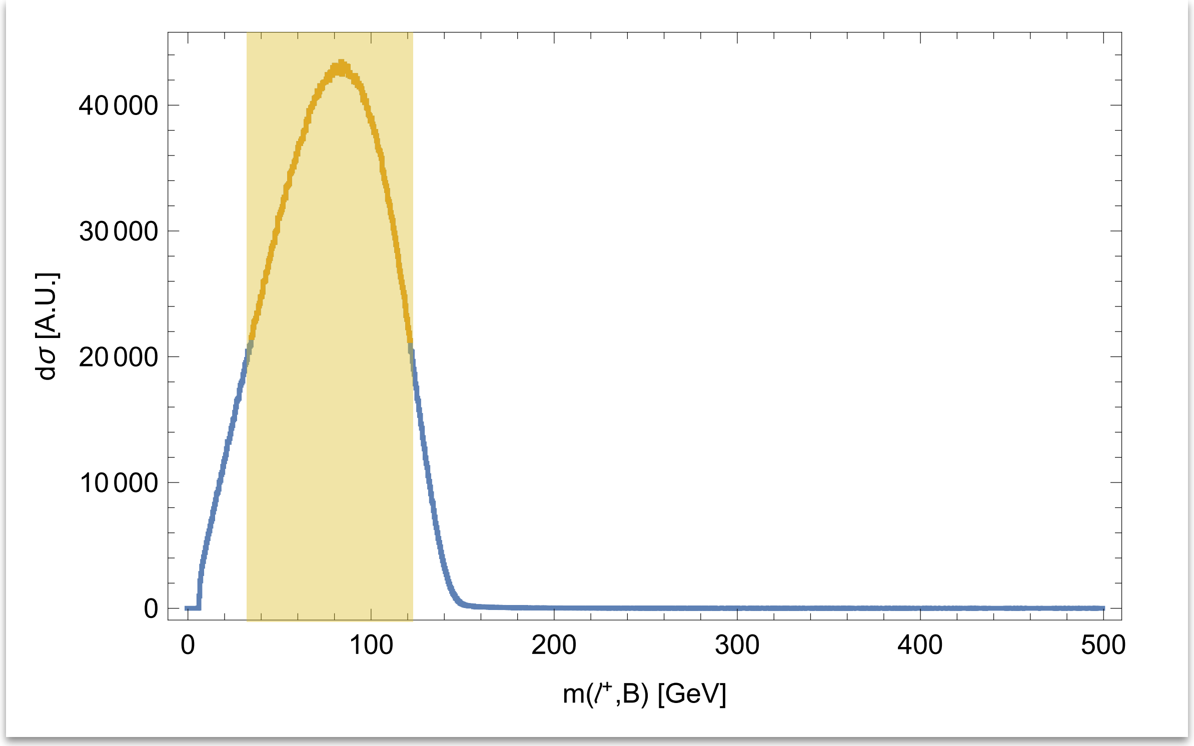
FWHM
used to compute
Mellin-1









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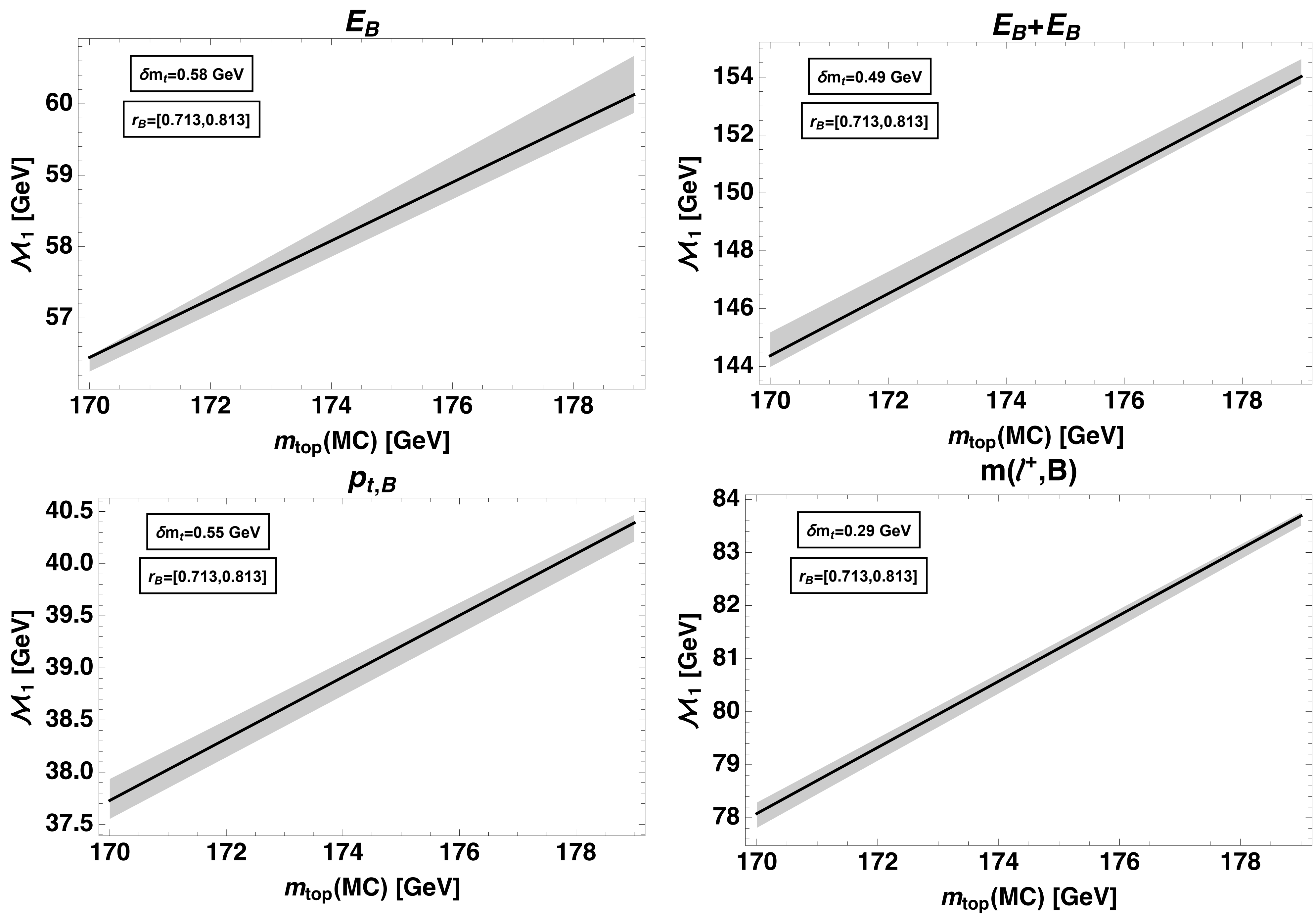
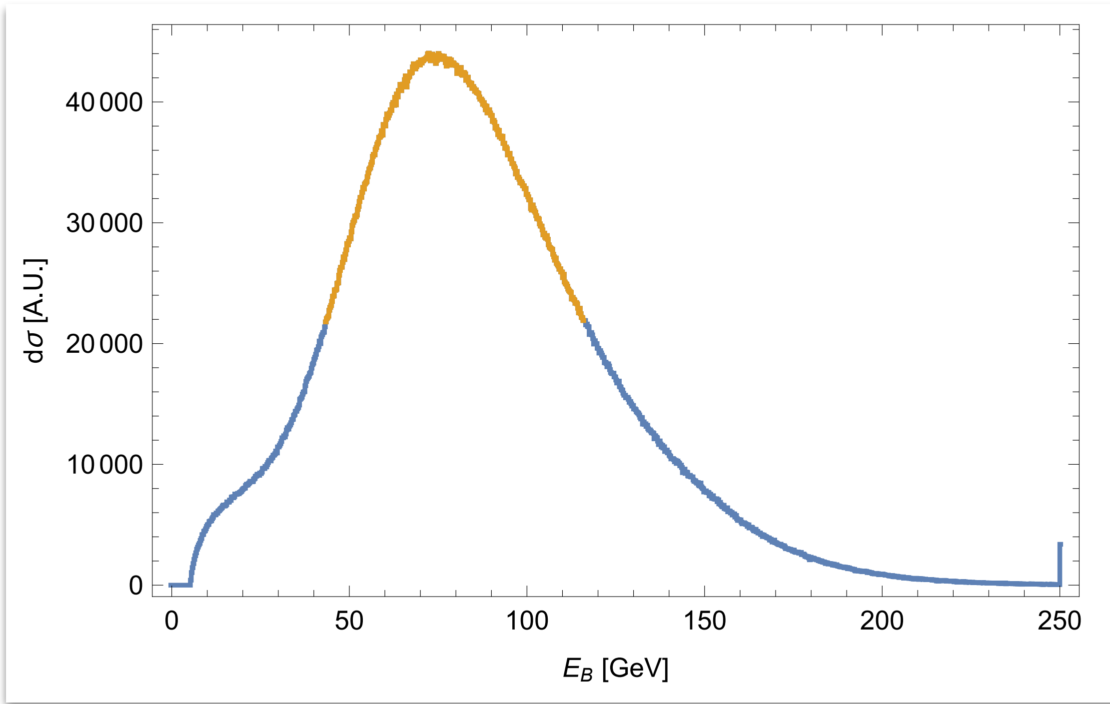


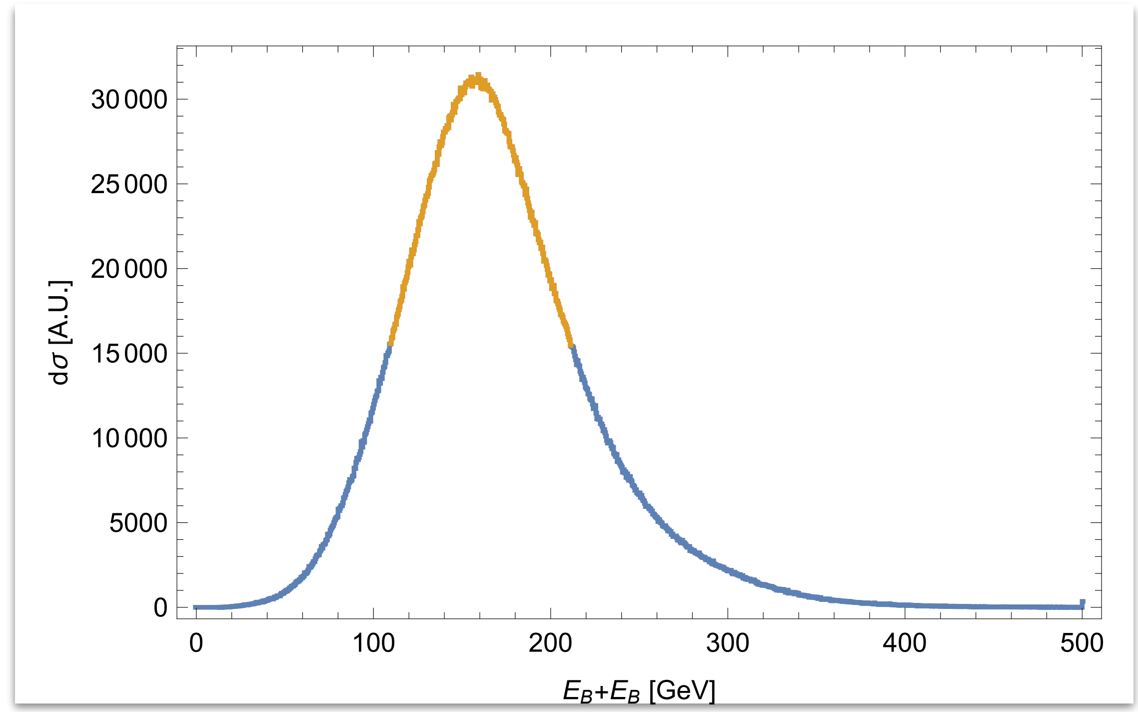
FYI: Pythia 8.1 → 8.2: r_b 0.67 → 0.855

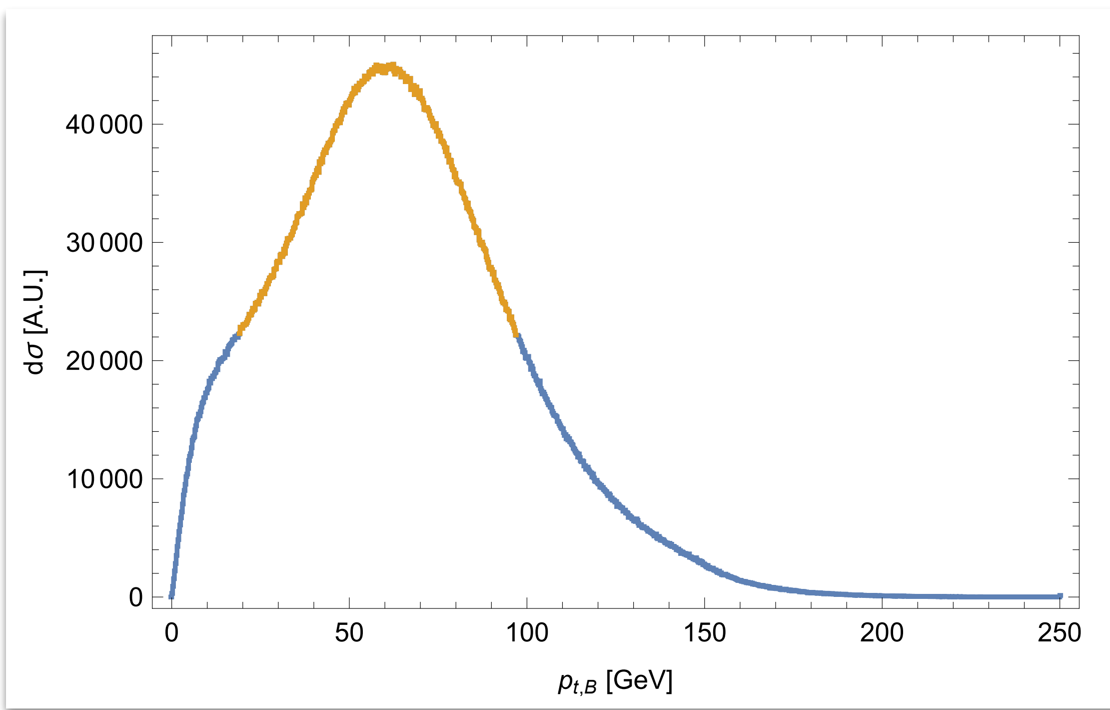
pp̄@√s=1 TeV

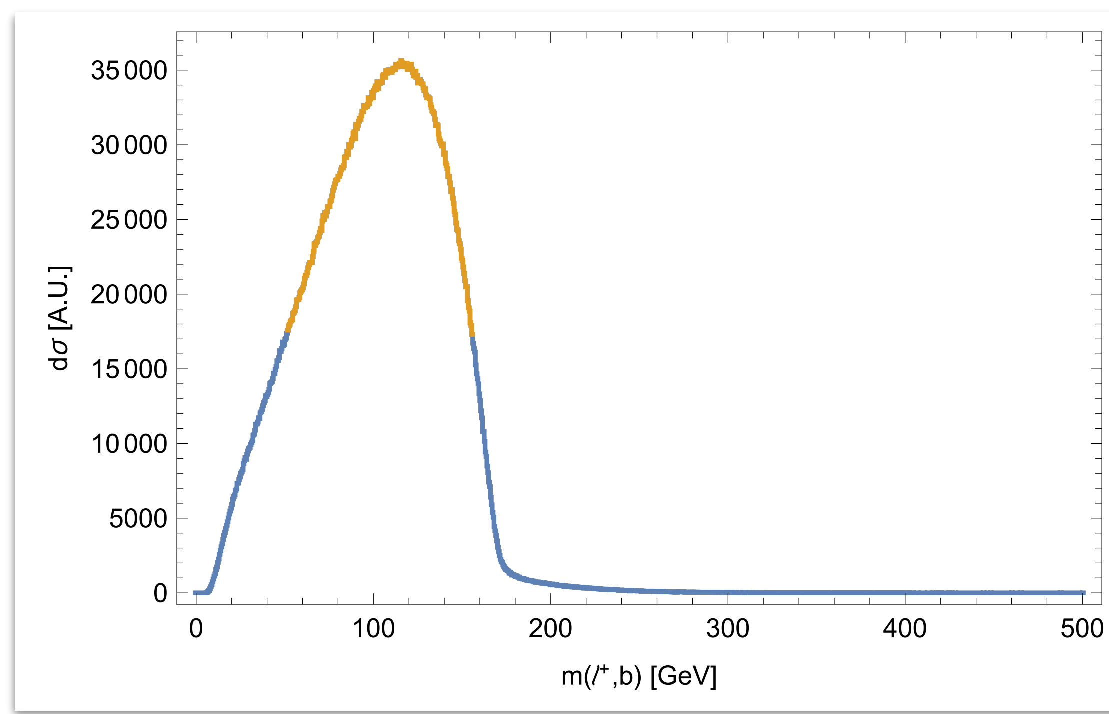
Pythia 8.2

hadron sensitivity to Lund-Bowler r_b





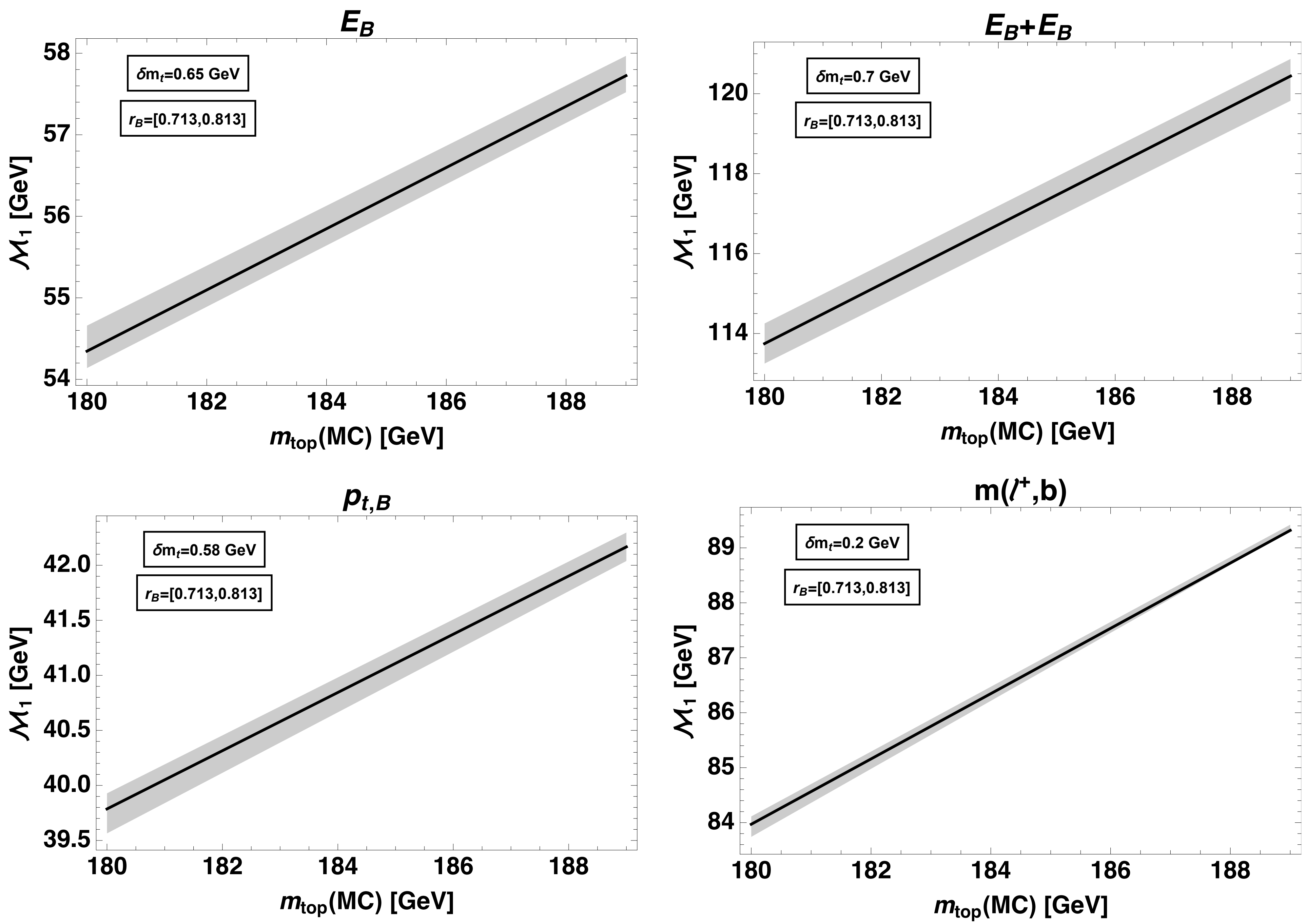




$p\bar{p}$@$\sqrt{s}$=1 TeV

Pythia 8.2

hadron sensitivity to Lund-Bowler r_b



FYI: Pythia 8.1 → 8.2: r_b 0.67 → 0.855

Herwig 7.0.1

will do

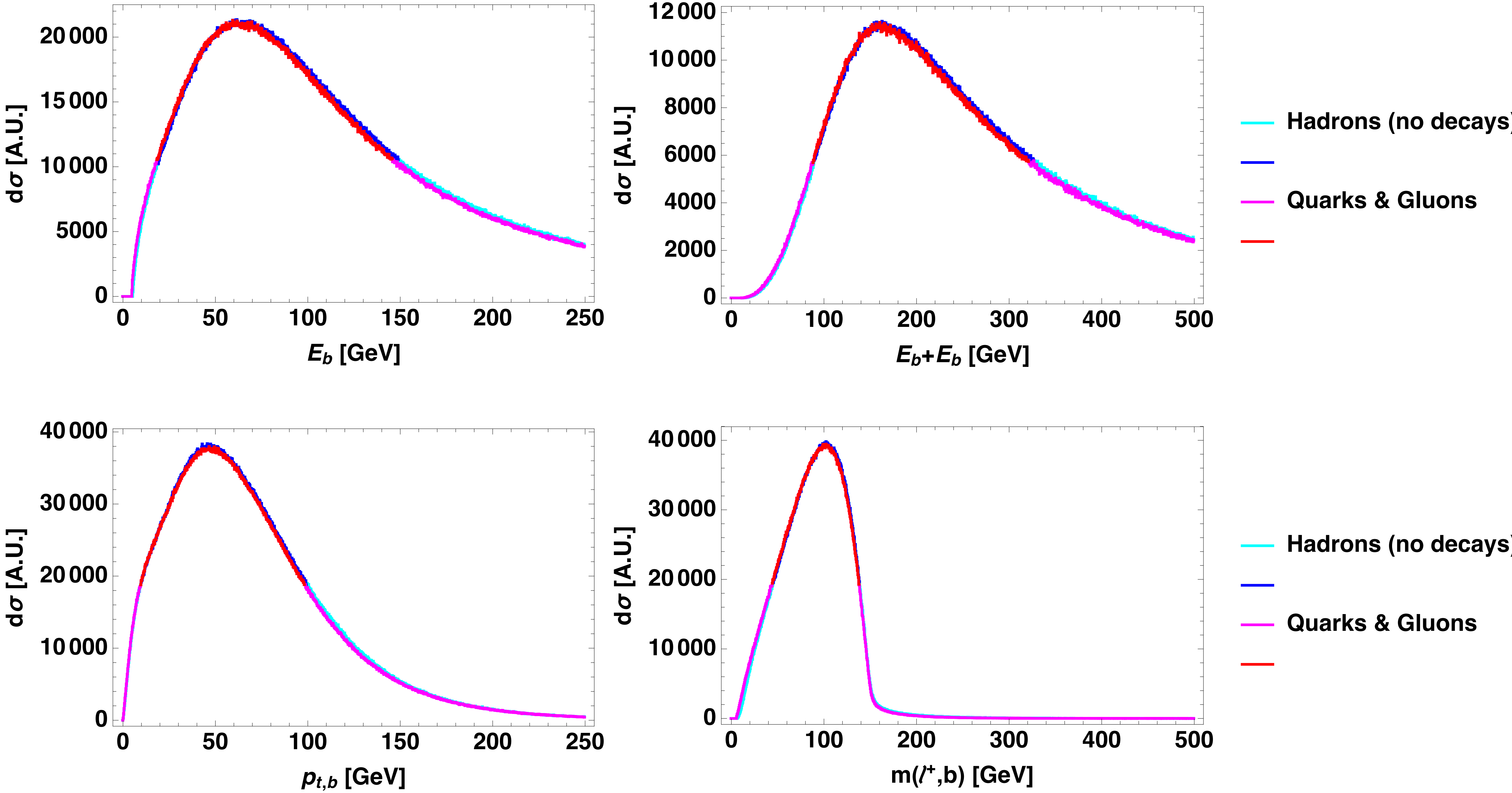
back to jets

… and their intrinsic uncertainties

Pythia 8.2

pp@√s=13 TeV

jet sensitivity to hadronization



pp@√s=13 TeV

Pythia 8.2

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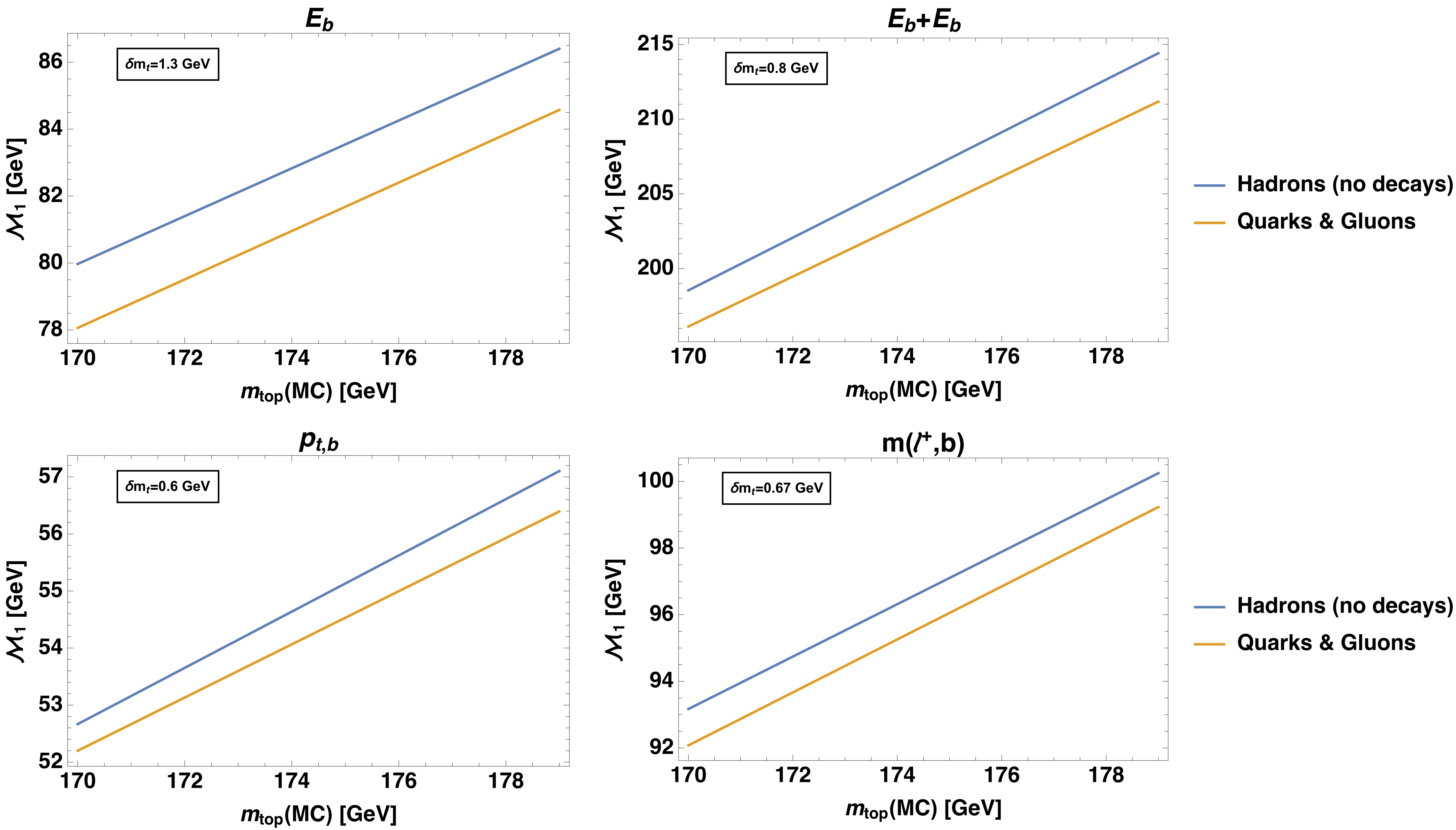

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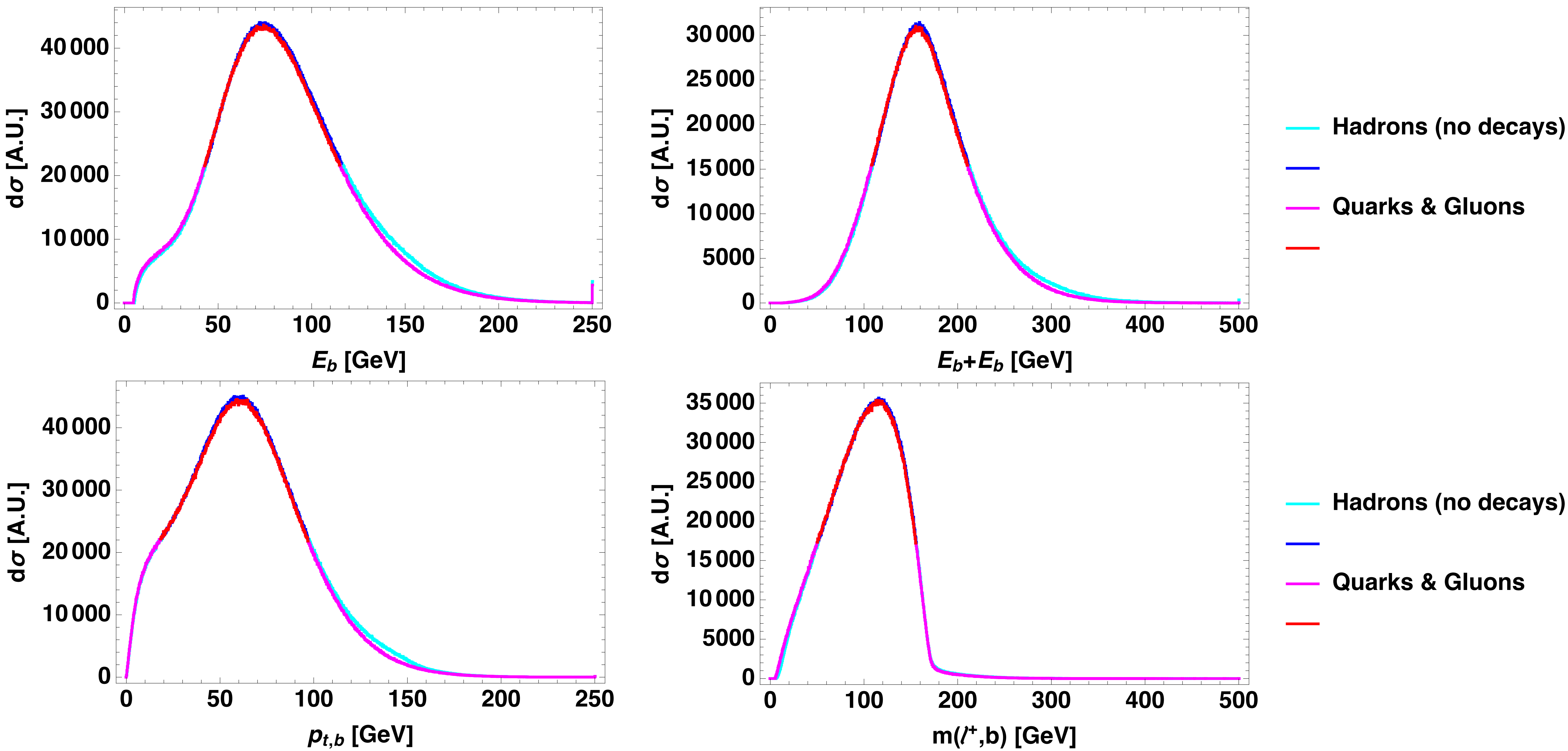
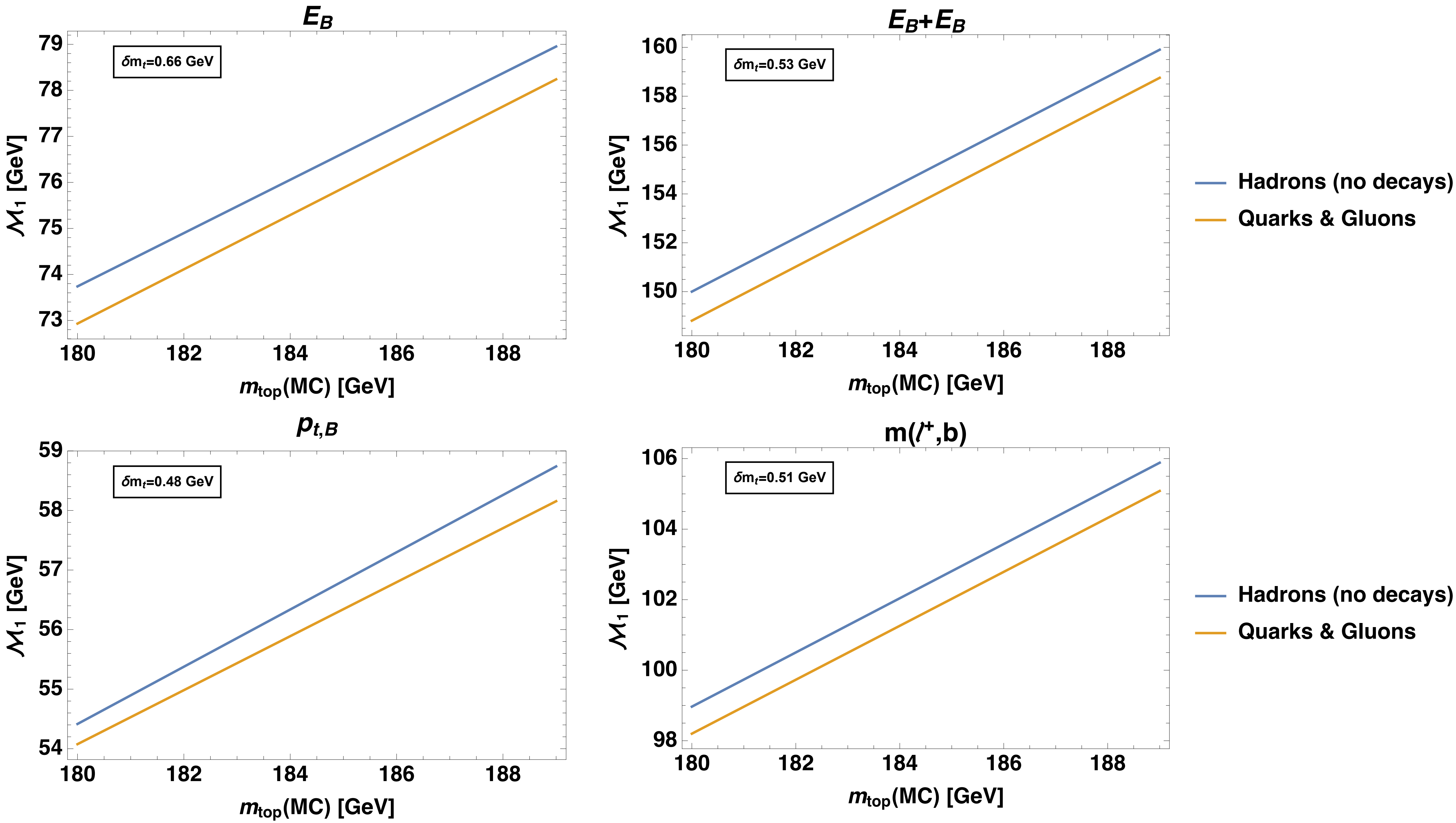


Pythia 8.2

pp̄@√s=1 TeV

jet sensitivity to hadronization

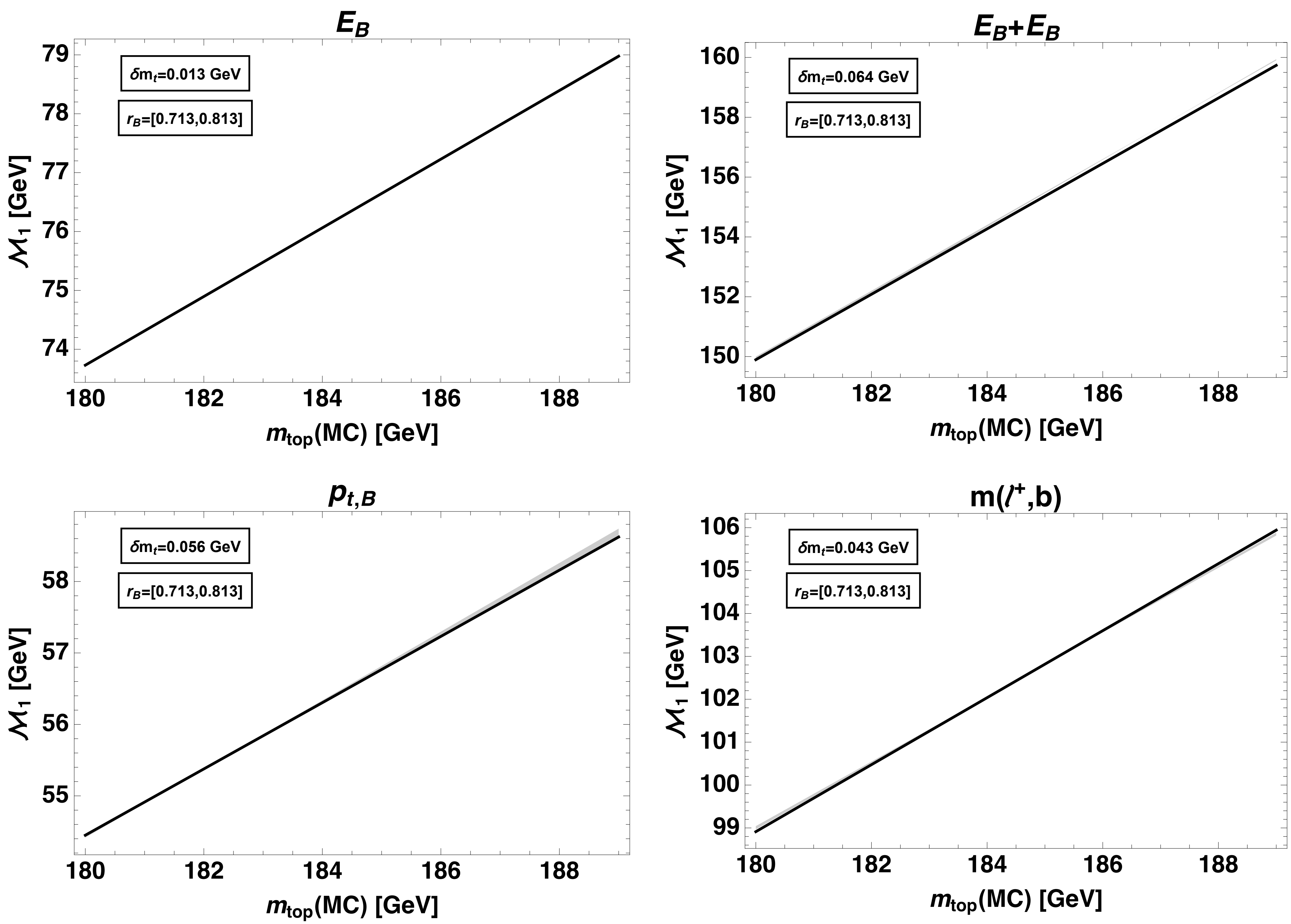


Pythia 8.2

pp̄@√s=1 TeV

pp@√s=13 TeV

jet (in)sensitivity to Lund-Bowler r_b



Summary

b-jets

- **b-jet energy peaks "invariance" holds** when only **NLO production** corrections are considered

- full NLO gives **$\delta m_{top} \simeq \pm 0.6$ GeV scale sensitivity** mostly arising from **description of decay**

- **NNLO <u>decay</u>** description of jets would probably be enough to make a solid prediction at **$\delta m_{top} \simeq \Lambda_{QCD}$**

Summary

B-hadrons

- **Transform jet observables into B-hadron observables** (JES ↔ Hadronization)

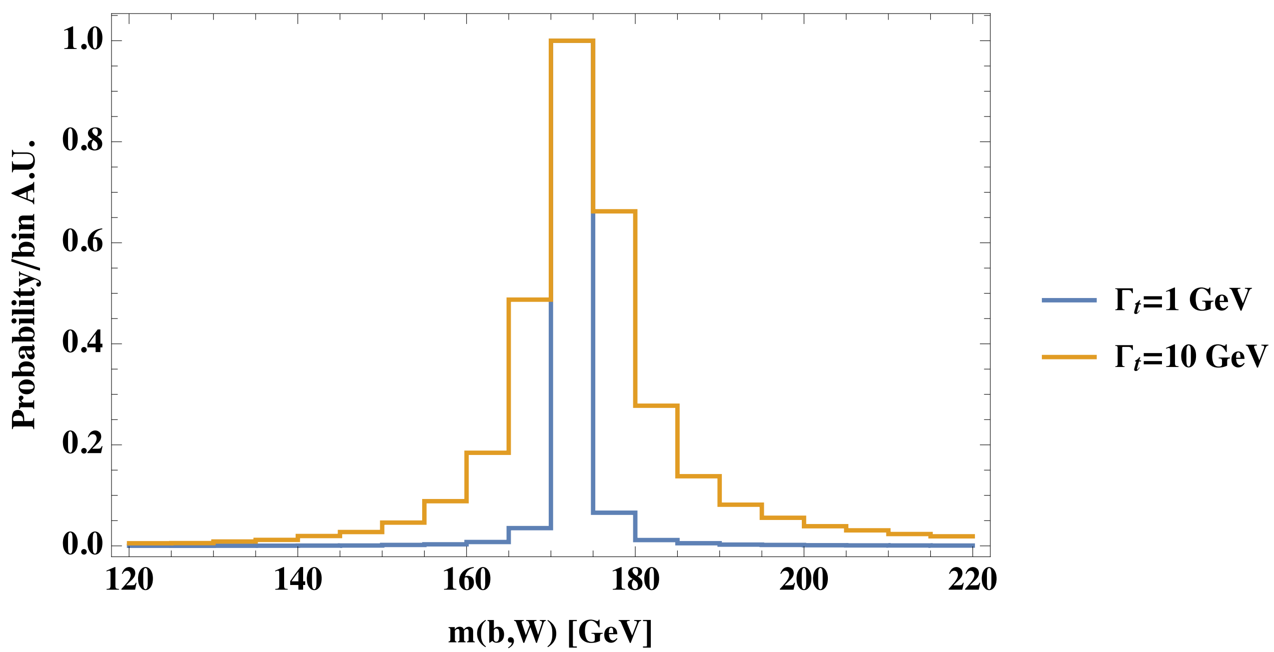
- B-hadron **fragmentation scale sensitivity** dominates Energy spectrum prediction from fragmentation function

- Fragmentation models in MCs need **tuning in top quark specific data** for other observables

Thank you!

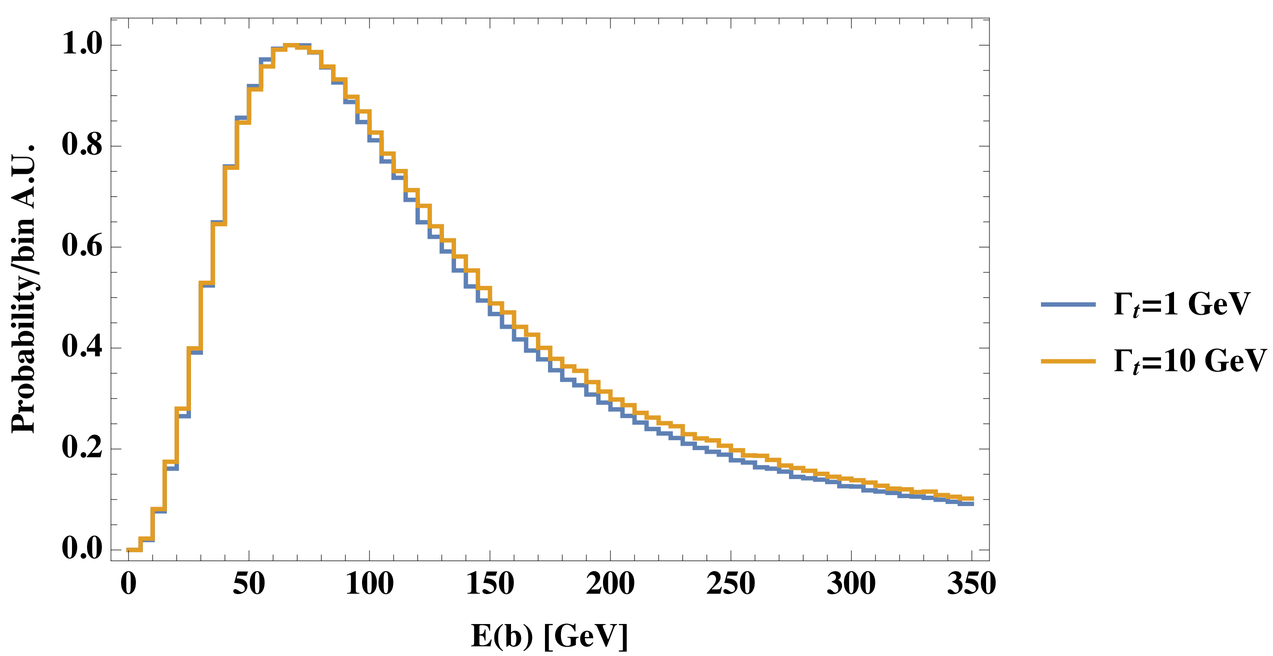
$\log(1+x) \simeq x$

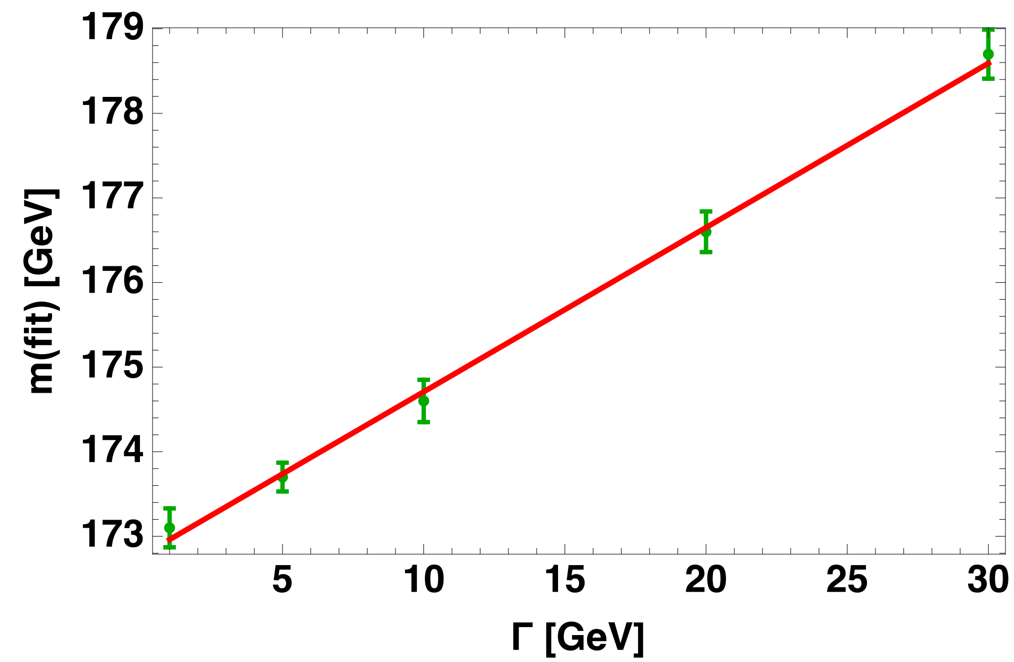
Width effect

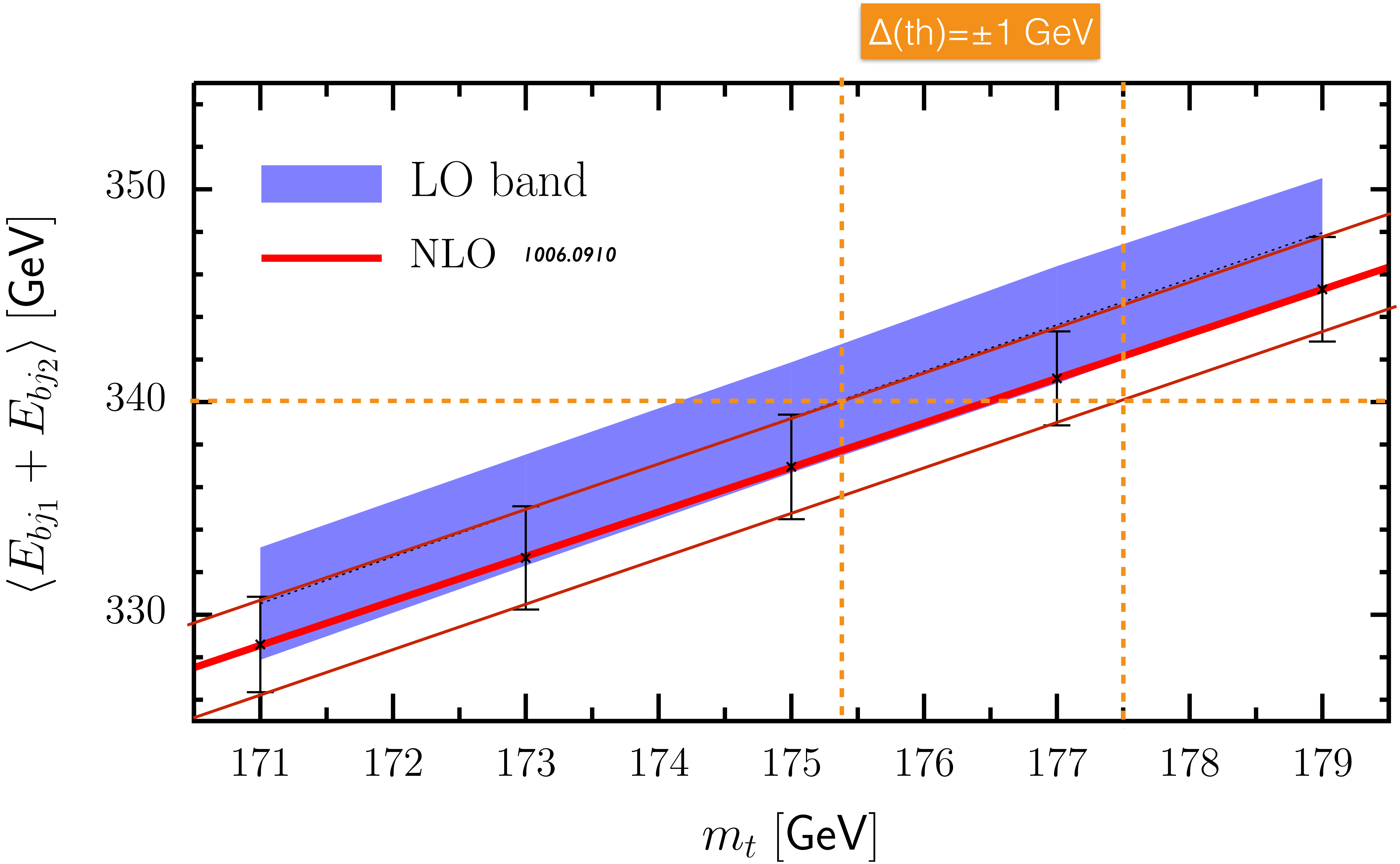


Small effects from the top width
$\delta m \sim 0.2\,\Gamma$

	Estimate	Error estimate
const	172.767	0.077694
lin	0.194153	0.00544191







Δ(th)=±1 GeV
LO band
NLO
1006.0910
350
340
330
171
172
173
174
175
176
177
178
179
$\langle E_{bj_1} + E_{bj_2} \rangle$ [GeV]
m_t [GeV]