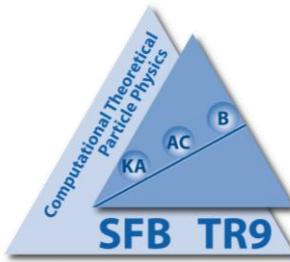
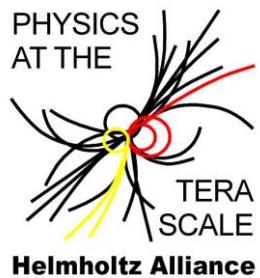
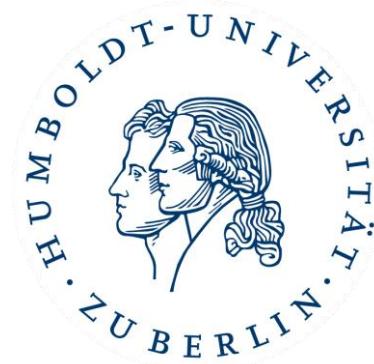


New techniques to determine the top-quark mass

Peter Uwer



GK1504





Motivation

Measure the top-quark mass as precise as possible

- Fundamental parameter of the SM interesting per se
- Important for precise tests of the Standard Model
- Test of New Physics scenarios i.e. GUT scenarios

Possible applications

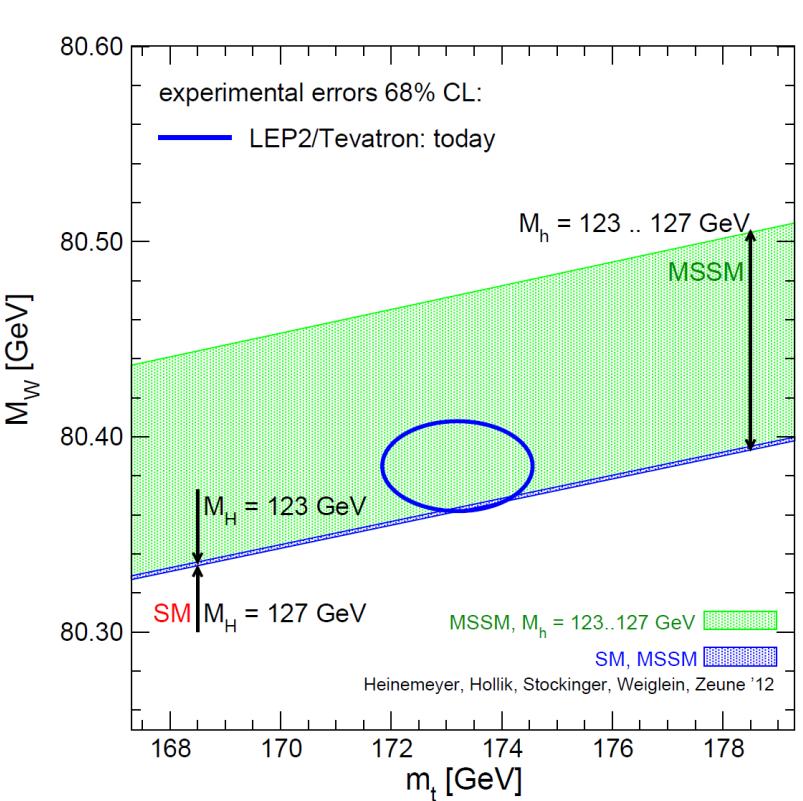
a) Parameter determination

Hadronic tt cross section

$$\frac{\Delta\sigma}{\sigma} \approx 5 \times \frac{\Delta m_t}{m_t}$$

→ important for SM tests,
“parameter” extraction, i.e
gluon luminosity \mathcal{L}_{gg}

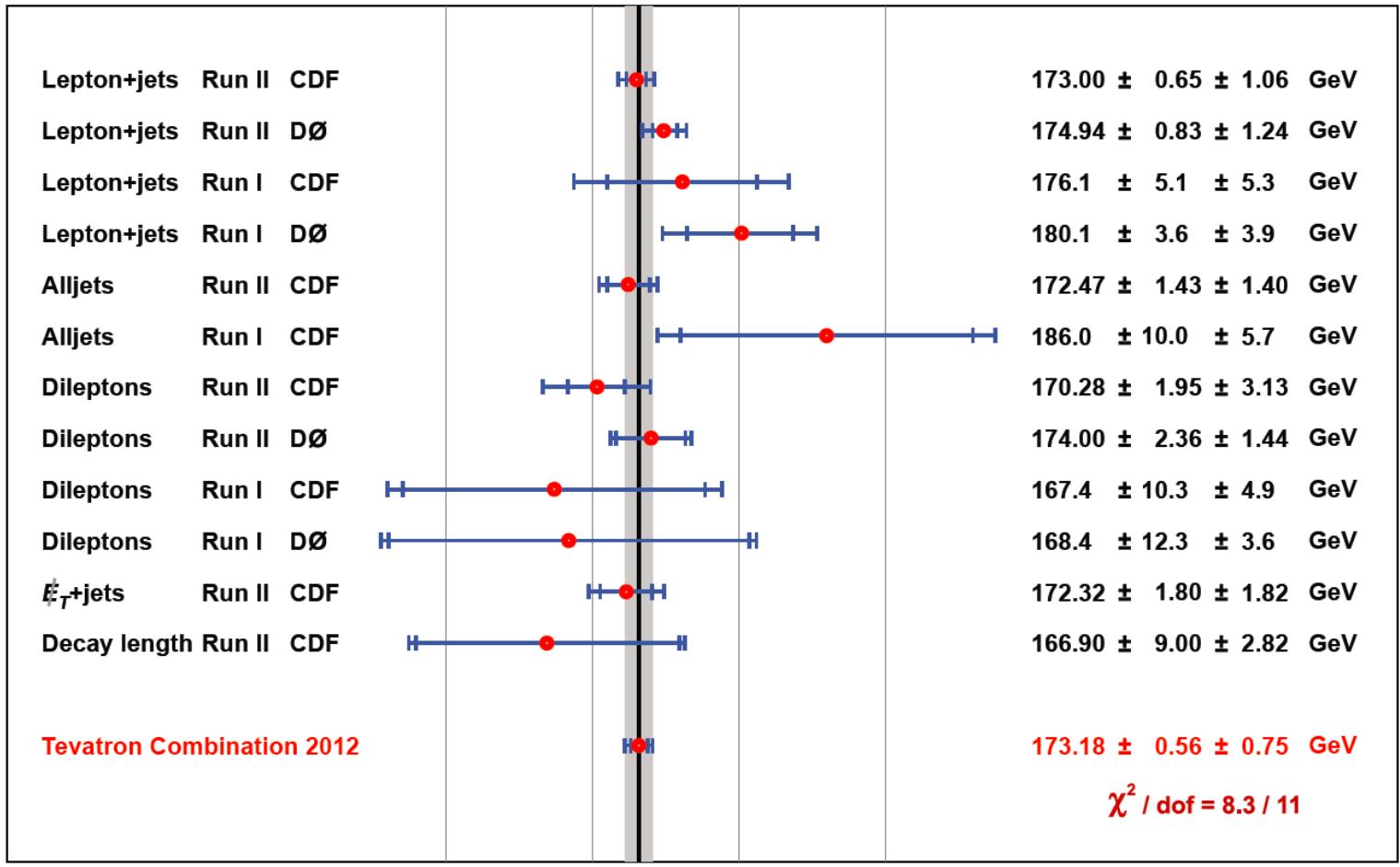
b) Consistency of the SM



[www.ifca.unican.es/users/heinemey/uni/plots]

Top-quark mass measurements: Tevatron

[arXiv:1207.1069]

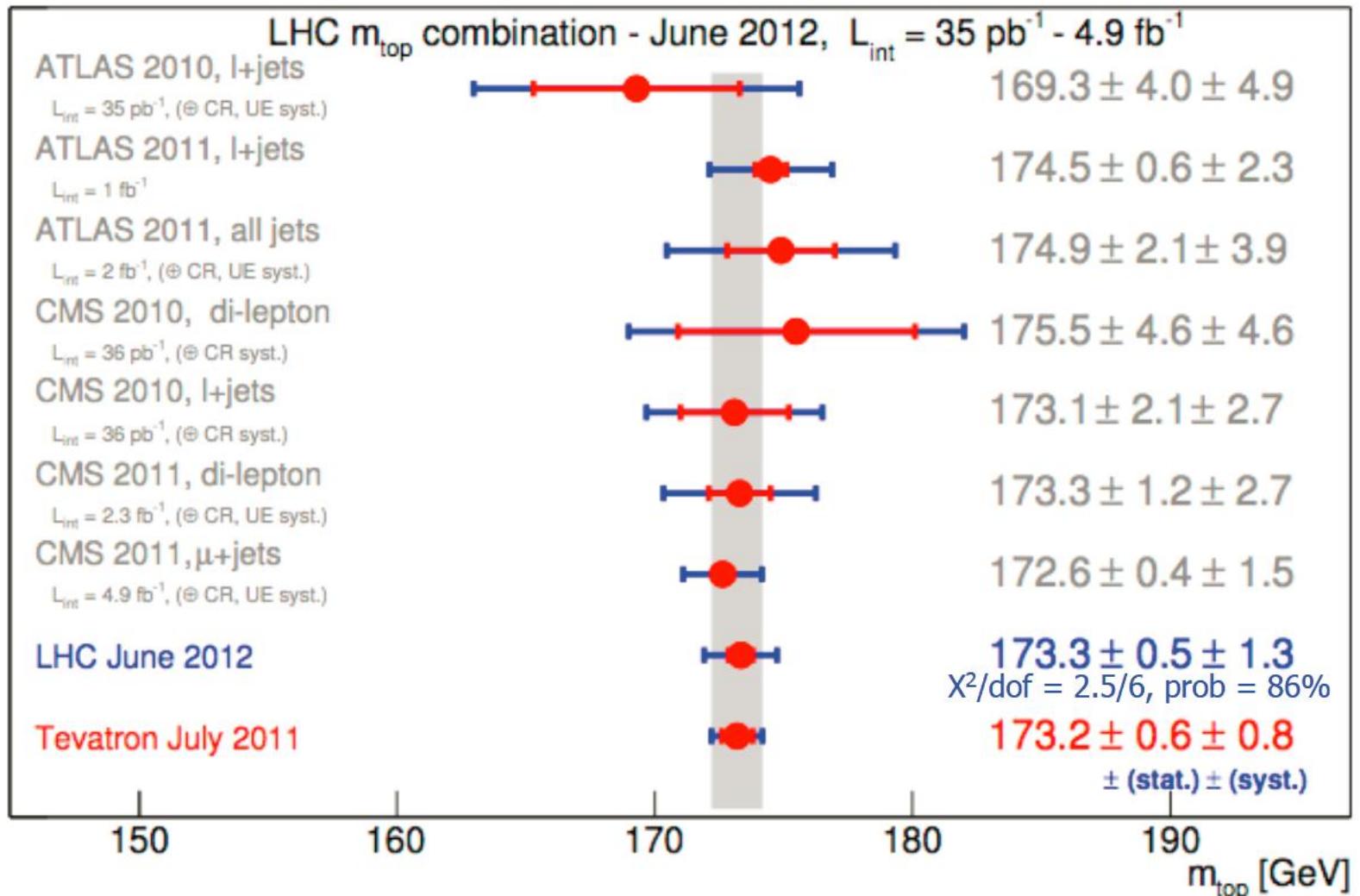


Mass of the Top Quark [GeV]

$\Delta m < 1$ GeV

Top-quark mass measurements: LHC

[Frédéric Déliot, ICHEP2012]



Top-quark mass measurements

Most precise known quark mass

!

How well do we understand the measurement

?

Can we do even better

?

Current measurements

1. Template method
2. Matrix element method
3. Ideogram method

Issues:

- Reconstruction of top momentum from color neutral hadrons / color reconnection
- Precise relation
$$m_{\text{MC}} = m_{\text{Pole}} (1 \pm \Delta)$$
- Intrinsic limitations of pole mass ($\sim \Lambda_{\text{QCD}}$)

Not independent

How important ?

Impact on current measurements

Different channels and different experiments
give consistent results



Large effects unlikely

Difficult to quantify

Impact on current measurements

Color reconnection:

$$\Delta m = 500 MeV$$

[Skands,Wicke '08]

?

Relation measured mass \leftrightarrow pole mass:

$$m_{\text{MC}} = m_{\text{Pole}} (1 \pm \Delta)$$

$$\Delta = \left\{ \begin{array}{l} \frac{\Lambda}{m} \approx 0.13\% \\ \frac{\Gamma}{m} \approx 0.8\% \\ \frac{\alpha_s}{\pi} \approx 3.7\% \end{array} \right.$$

Possible improvements of current measurements

Template method:

- Study additional distributions / observables
- Compare with NLO templates

Matrix element method

- Matrix element method at NLO

Alternative measurements ?

Top-quark mass from jet rates

Top-quark mass from jet-rates (ttj)

[Work in progress S. Alioli, J.Fuster, A. Irles, S. Moch, PU, M. Vos]

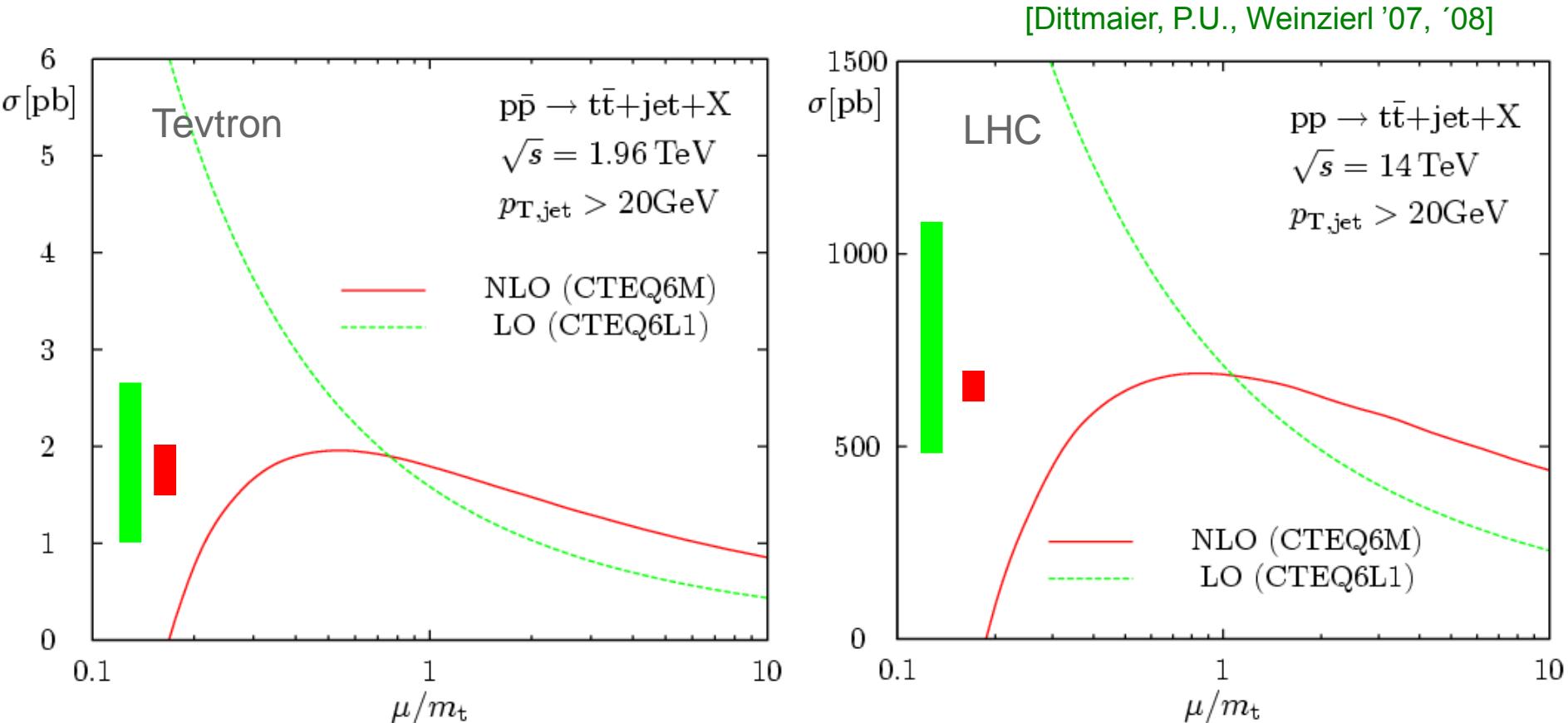
Use tt+1-jet events

- Large event rates (~30 % of inclusive tt events)
- NLO corrections available [Dittmaier, Uwer, Weinzierl '07, '08, Melnikov, Schulze '10, Melnikov, Scharf, Schulze '12]
- NLO+shower available [Alioli, Moch, PU '11, Kardos, Papadopoulos, Trocsanyi '11]

Similar to b-quark mass measurement at LEP
using 3-jet rates

[Bilenky, Fuster, Rodrigo, Santarmaria]

Top-quark pair + 1-Jet Production at NLO



- Improved scale dependence
- Small corrections

Top-quark mass from jet rates

[Work in progress S. Alioli, J.Fuster, A. Irles, S. Moch, PU, M. Vos]

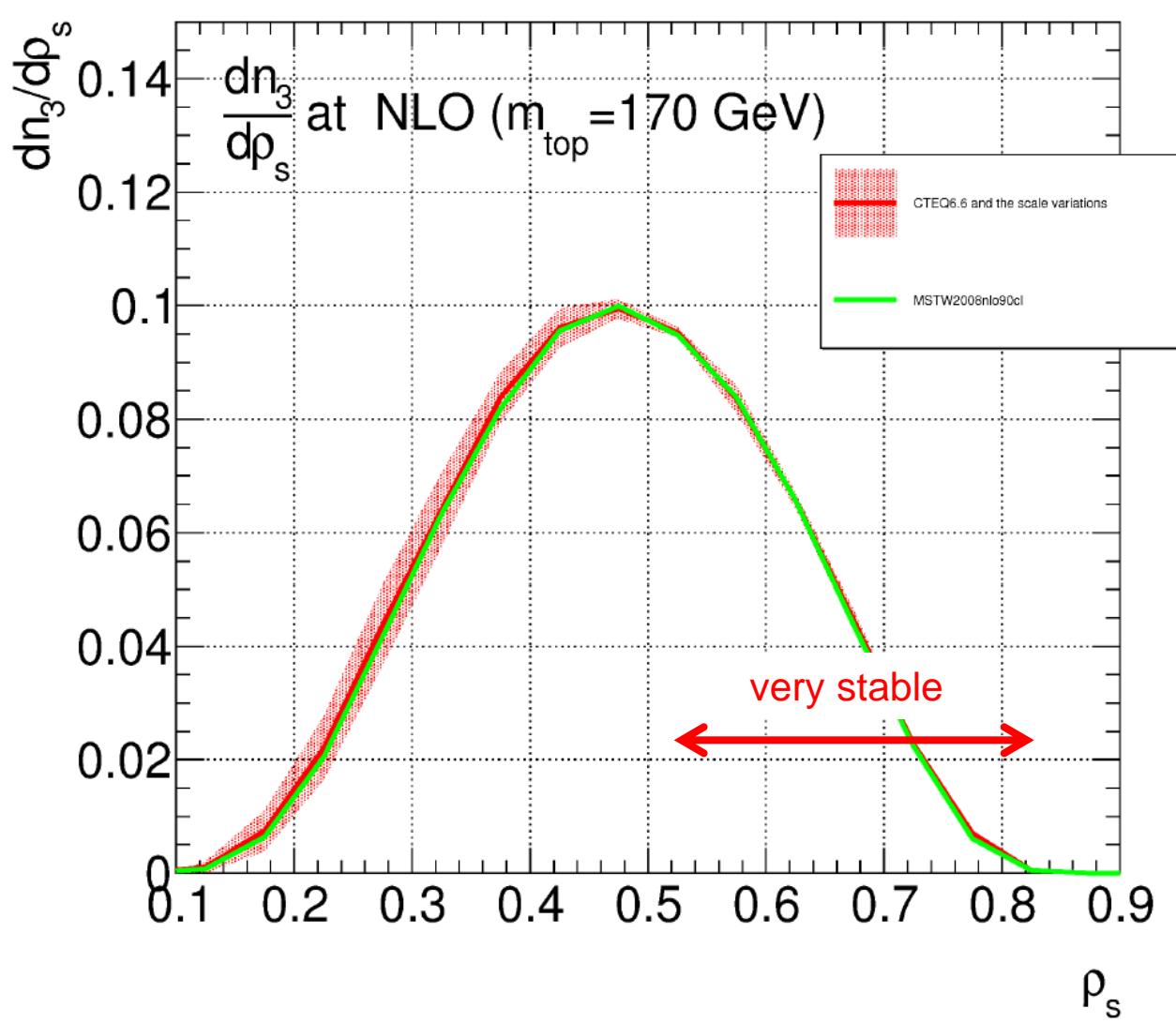
To enhance mass sensitivity study:

$$\frac{dn_3}{d\rho_s}(m_{\text{Pole}}) = \frac{1}{\sigma_{t\bar{t}+1\text{Jet}}} \frac{d\sigma_{t\bar{t}+1\text{Jet}}}{d\rho_s}(m_{\text{Pole}})$$

with $\rho_s = \frac{2m_0}{\sqrt{S_{t\bar{t}+1\text{Jet}}}}$, $m_0 = O(m)$ “1 - Distance from threshold”
i.e. $m_0 = 170 \text{ GeV}$

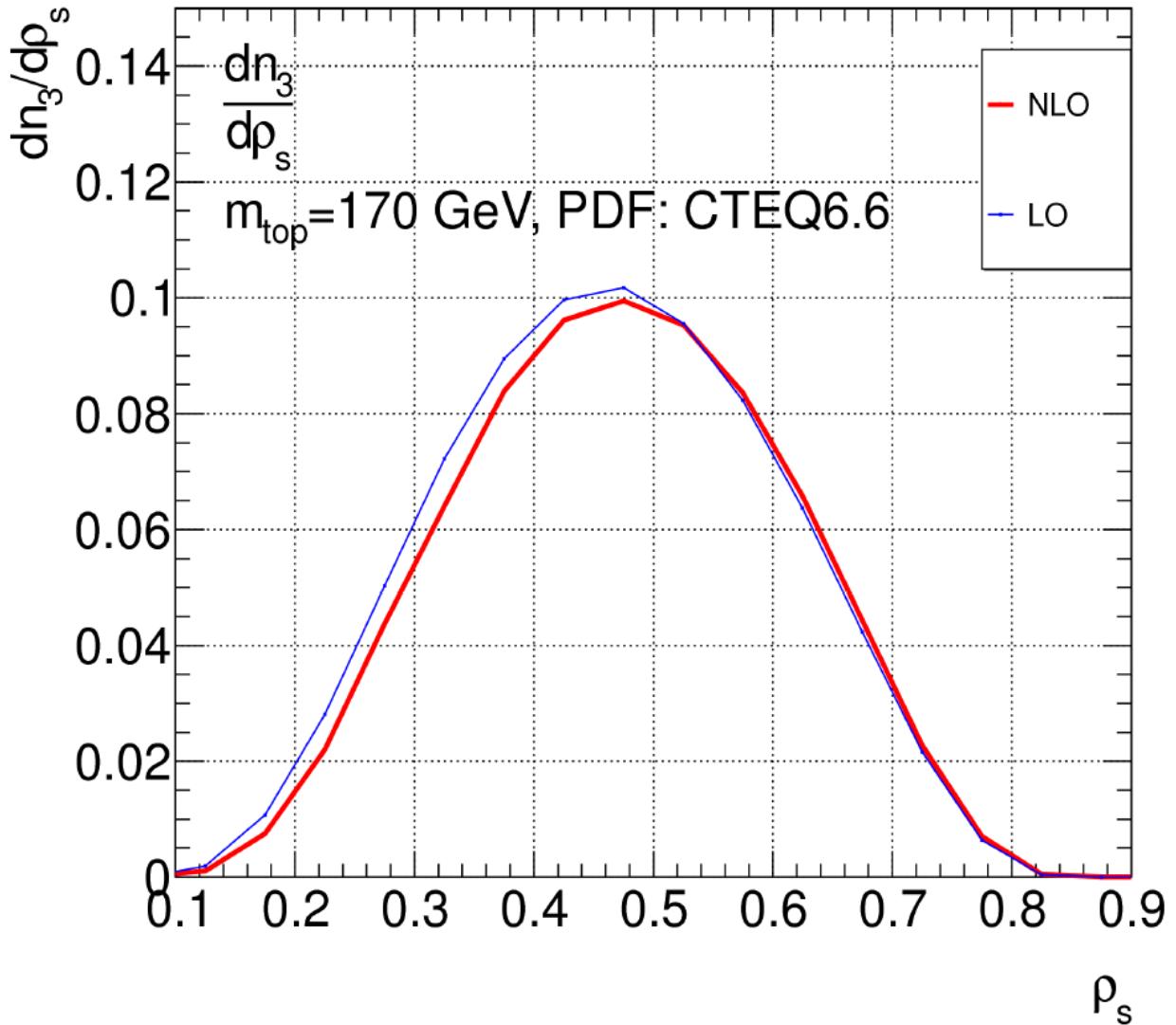
Scale and PDF uncertainties

[Work in progress S. Alioli, J.Fuster, A. Irles, S. Moch, PU, M. Vos]



Impact of higher order corrections

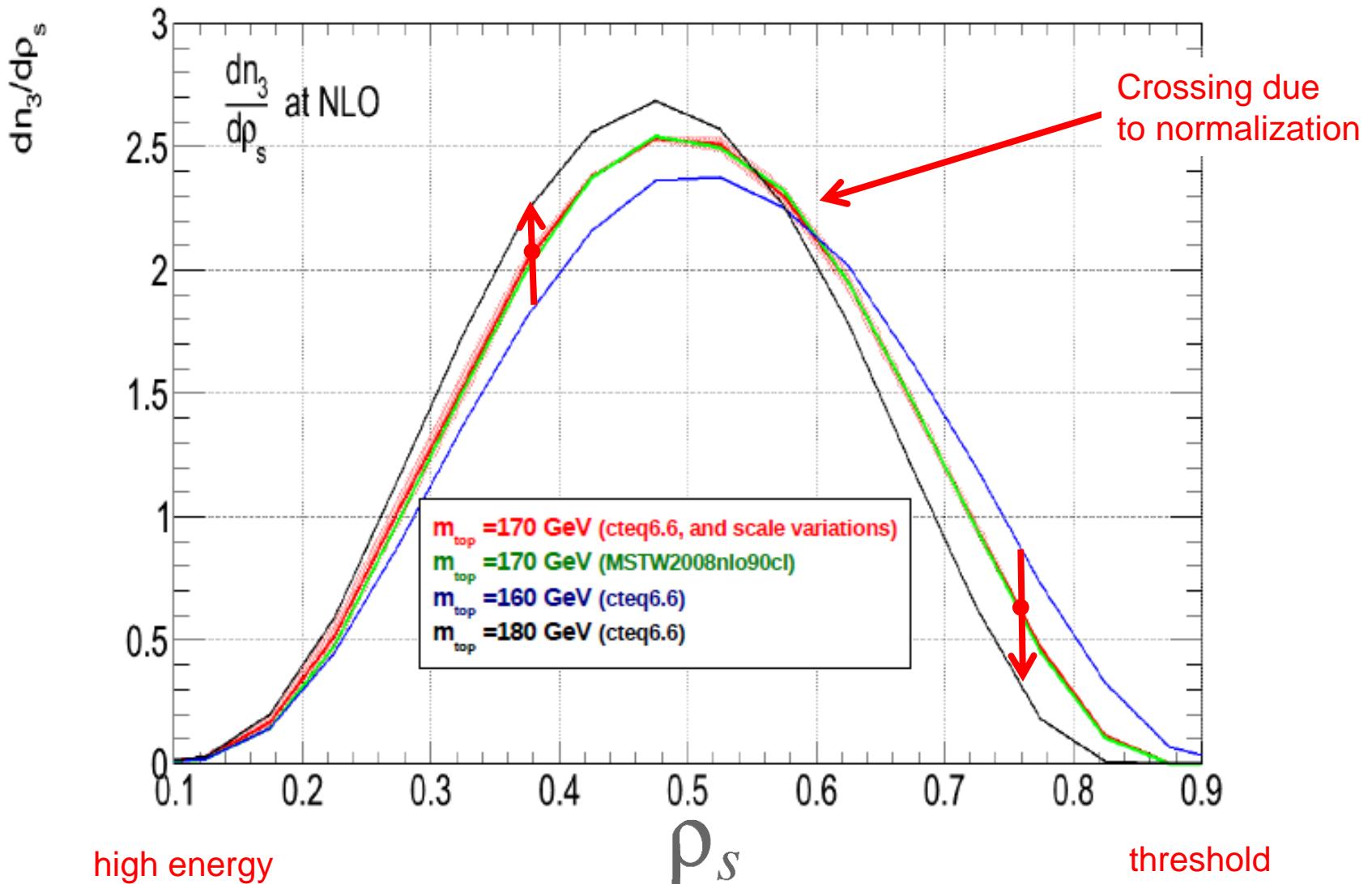
[Work in progress S. Alioli, J.Fuster, A. Irles, S. Moch, PU, M. Vos]



- Consistent with scale variation
- ttj: Corrections in general moderate
- Hard corrections → small ρ

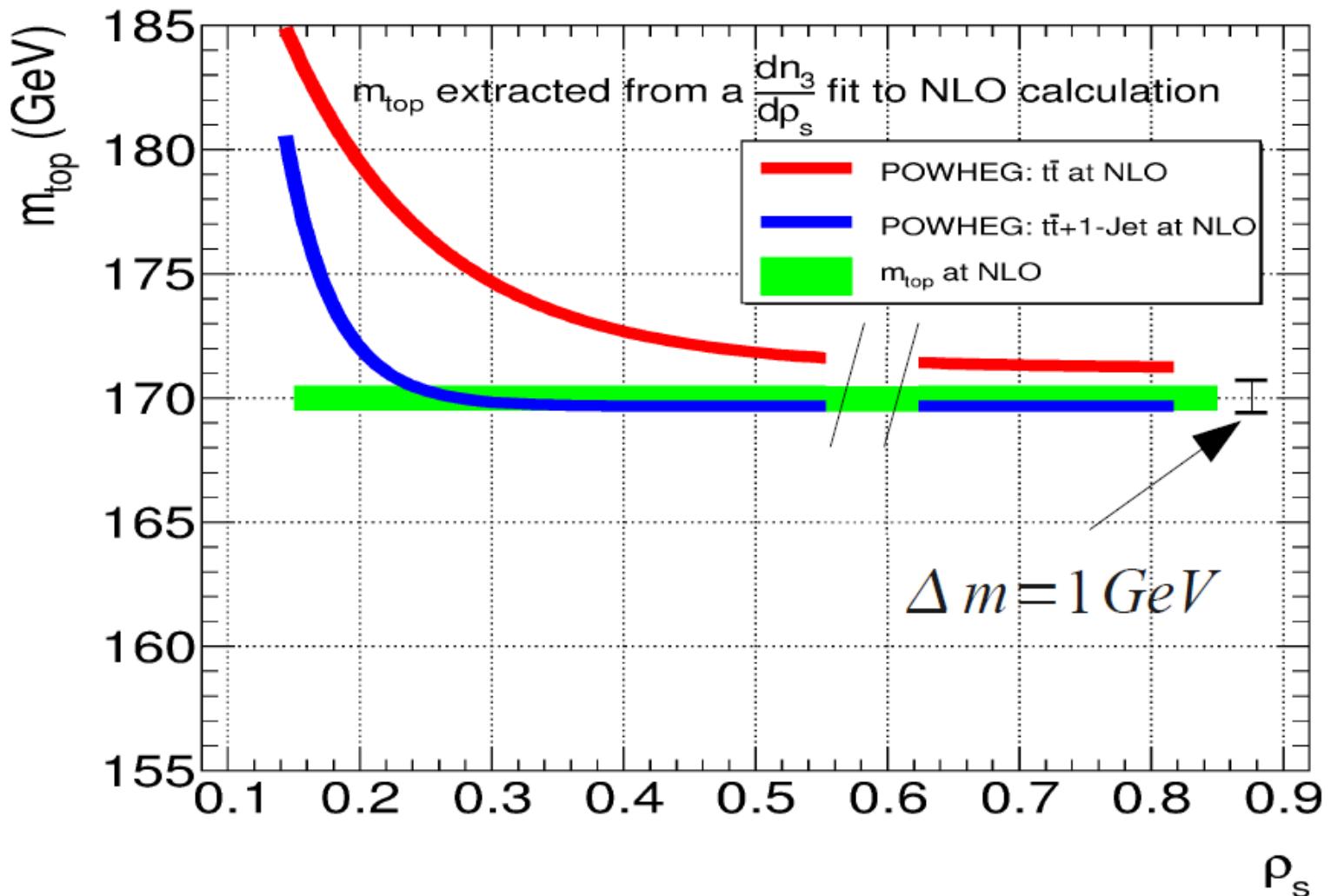
Mass dependence

[Work in progress S. Alioli, J.Fuster, A. Irles, S. Moch, PU, M. Vos]



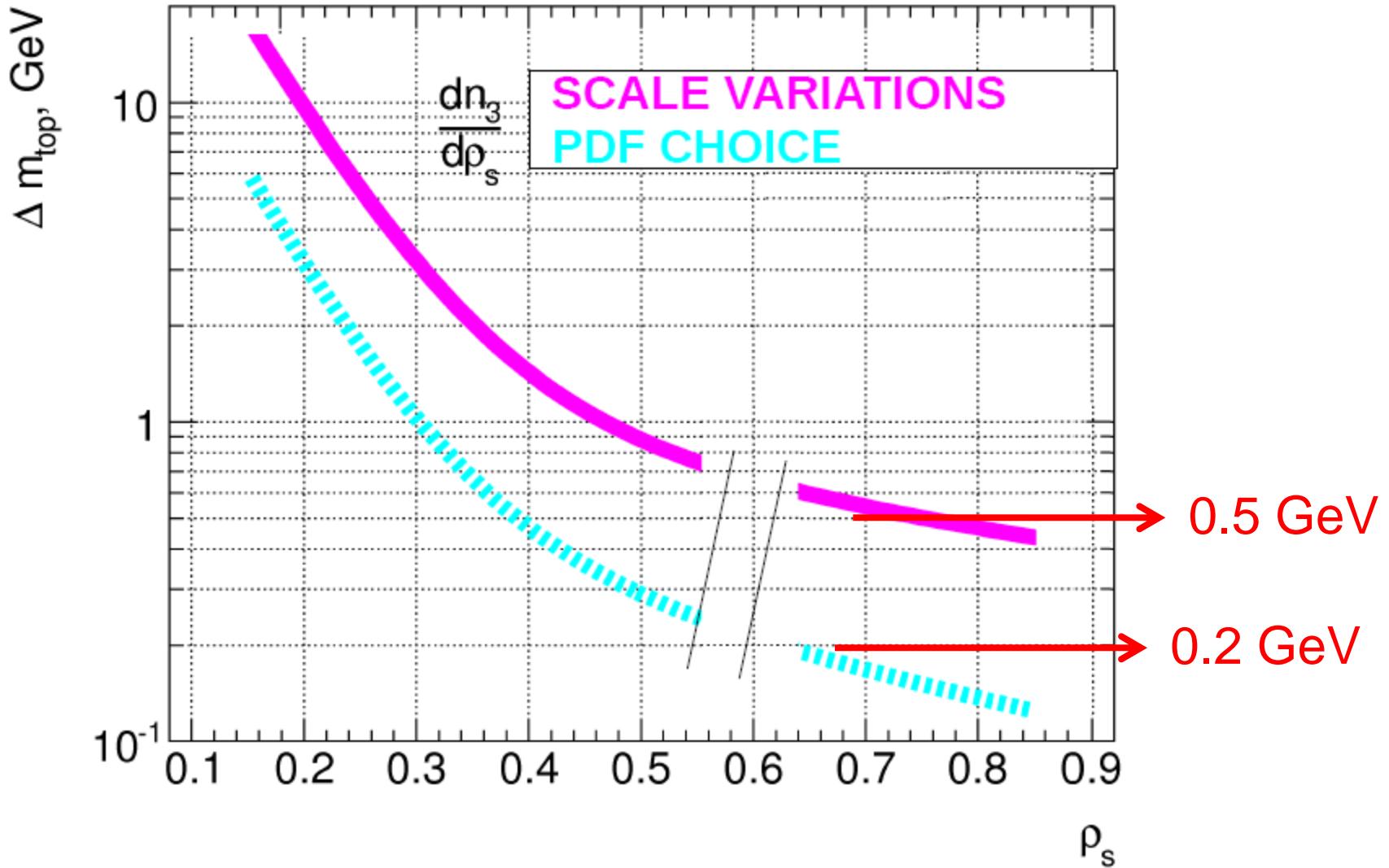
Toy experiment

[Work in progress S. Alioli, J.Fuster, A. Irles, S. Moch, PU, M. Vos]



Scale and PDF uncertainties

[Work in progress S. Alioli, J.Fuster, A. Irles, S. Moch, PU, M. Vos]



Estimate of uncertainties

[Work in progress S. Alioli, J.Fuster, A. Irles, S. Moch, PU, M. Vos]

	Source of uncertainty	Impact on the top quark mass	
Theoretical uncertainties	μ variations	$\sim 0.5 \text{ GeV}$	1 GeV
	PDF choice	$\sim 0.2 \text{ GeV}$	
Experimental uncertainties	MC comparison	$\sim 0.4 \pm 0.3 \text{ GeV}$	
	JES	$\sim 0.8 \text{ GeV}$	
	Statistics (5 fb-1)	$\sim 1.2 \text{ GeV}$	

$$\Delta JES = \pm 3\%$$

Summary

- Top-quarks physics becomes precision physics
- Aiming for $\Delta m \approx 1\text{GeV}$ requires solid understanding
- Open questions of current measurements
- Important to study alternative methods for top-quark mass determination
- Top-quark mass from jet rates looks promising
- Direct determination of running mass possible

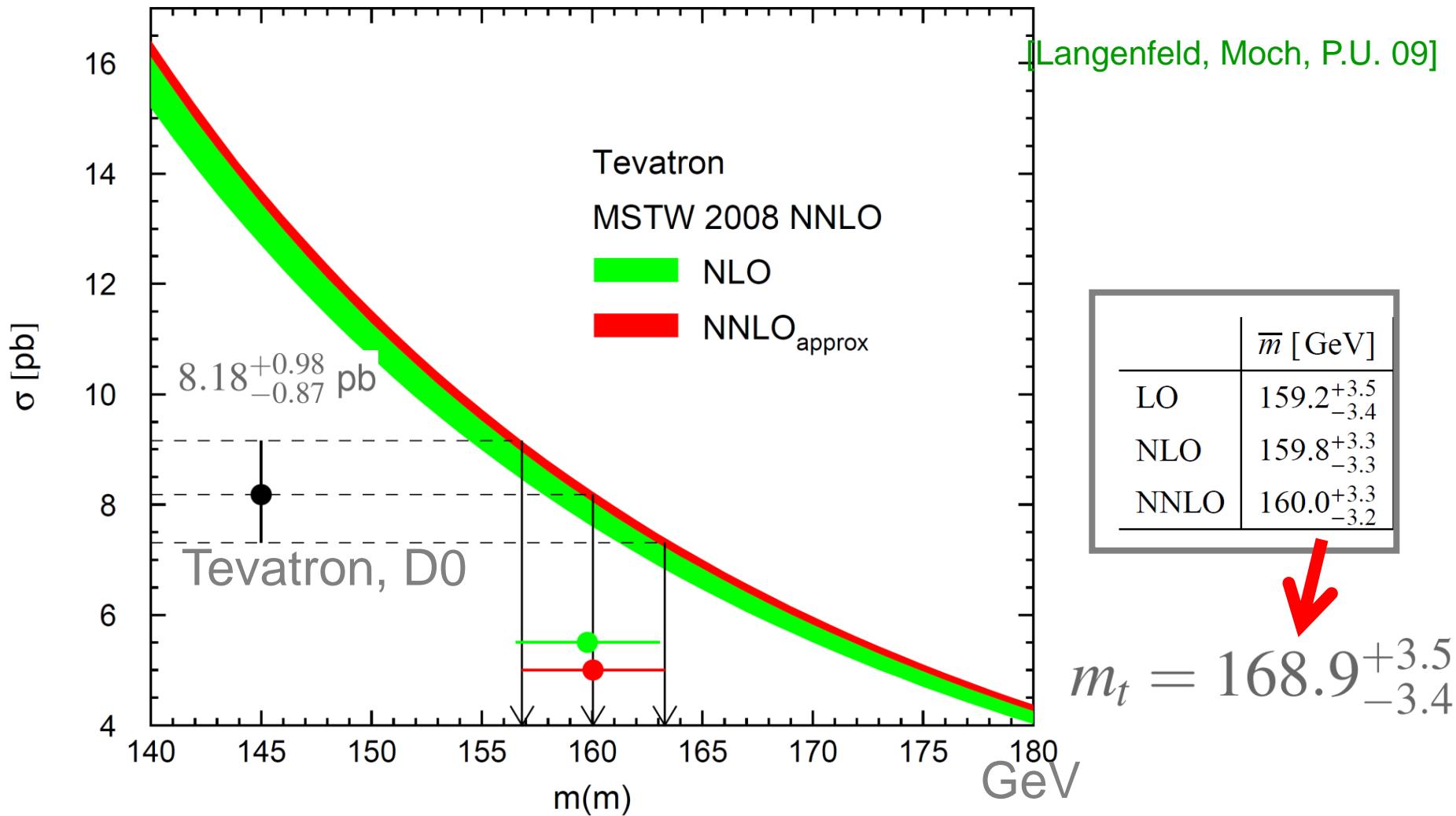
Final remark

- Top-quark mass is not an observable
→ we need to rely on theory for a meaningful measurement
- Need NLO to fix renormalization scheme
- Good understanding of measured quantity is crucial for later applications
- Difficult to assess theoretical uncertainties,
important to use **independent** methods

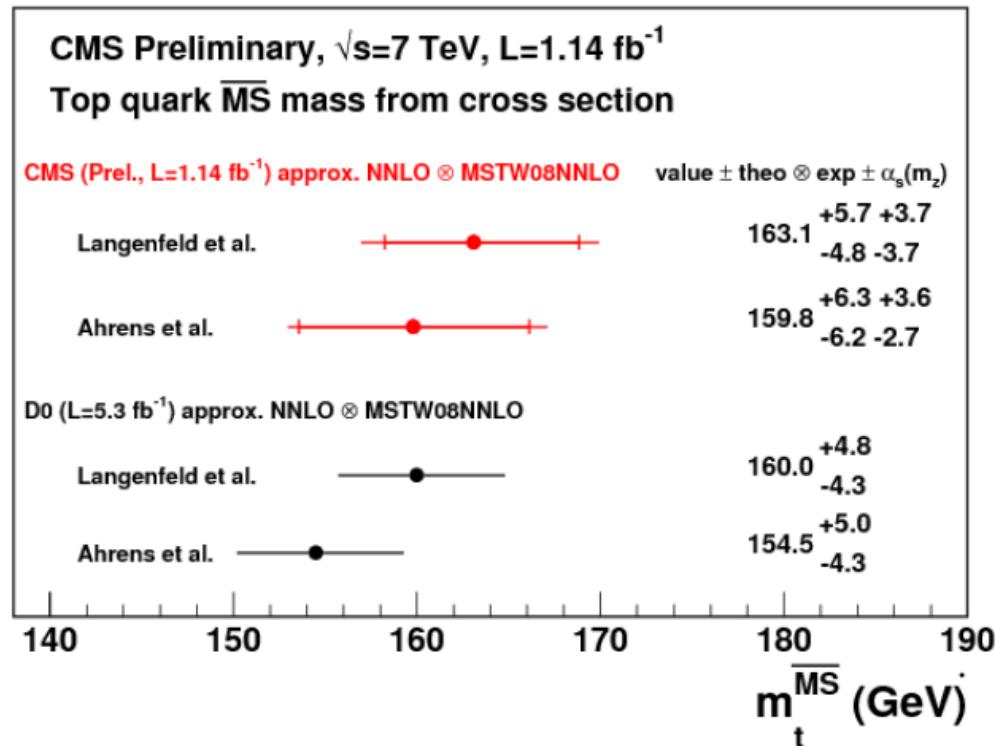
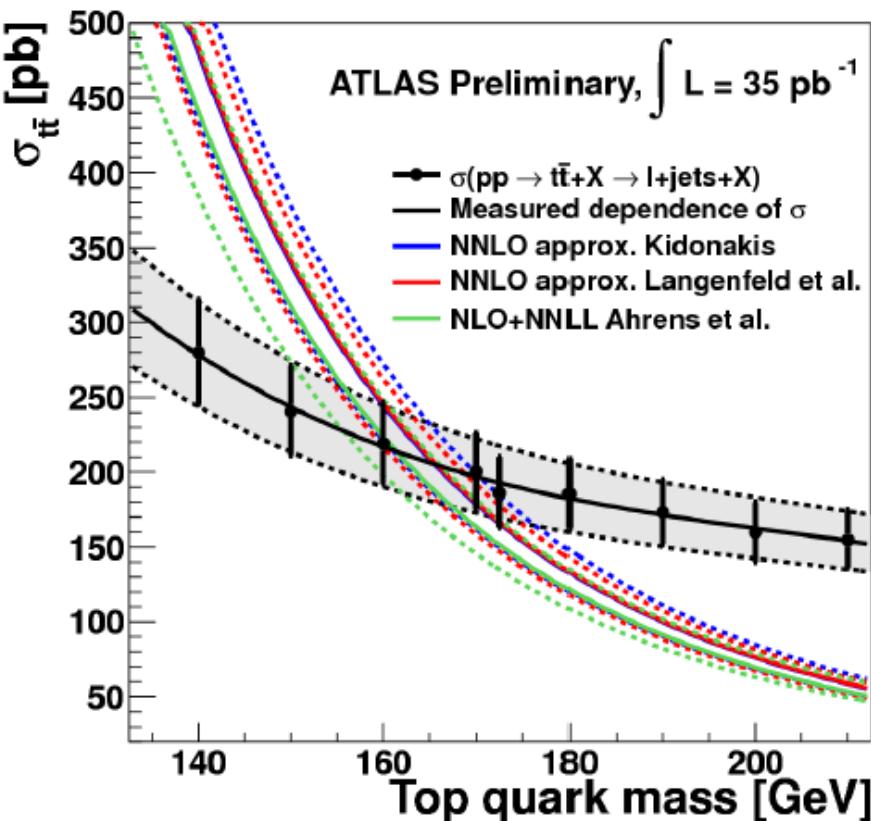


First direct determination of the running mass

Total cross section as function of the $\overline{\text{MS}}$ Masse



Top quark mass from cross section

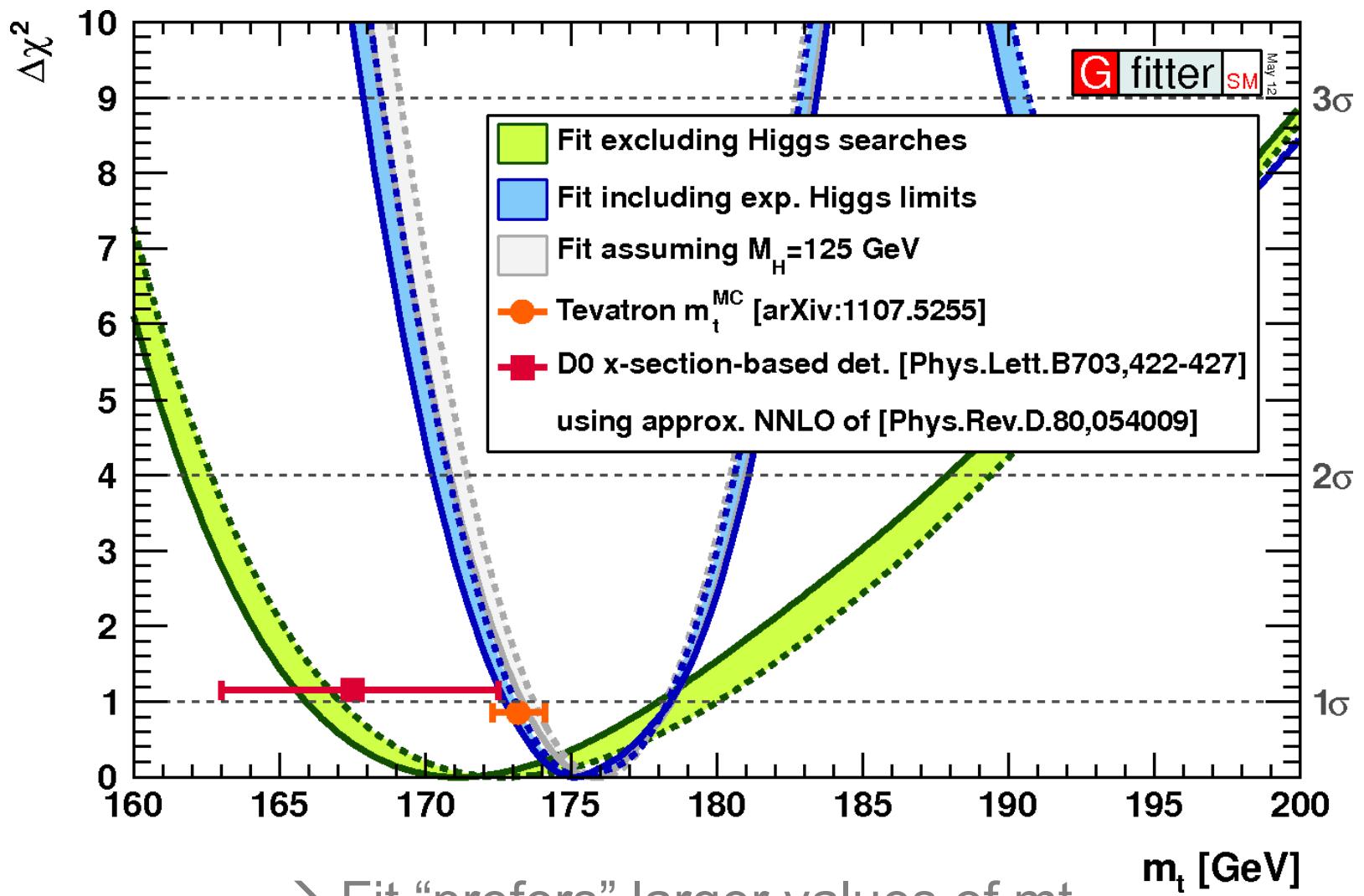


Mass scheme well defined, higher orders can be included

Drawback: Limited sensitivity to m_t

$$\frac{\Delta \sigma_{t\bar{t}}}{\sigma_{t\bar{t}}} \approx 5 \frac{\Delta m_t}{m_t}$$

EW precision fit

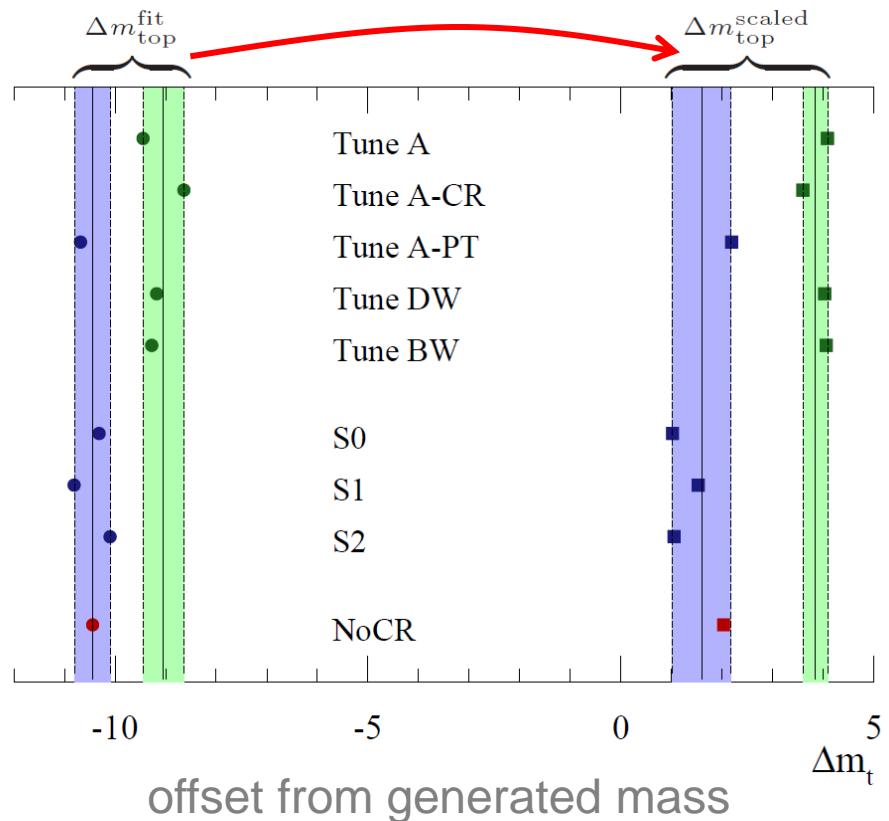


Non-perturbative effects

Non-perturbative effects at the LHC

[Skands,Wicke '08]

Simulate top mass measurement using different models/tunes
for non-perturbative physics / colour reconnection



different offset for
different tunes!

Non-perturbative
effects result in uncertainty
of the order of 500 MeV

blue: pt-ordered PS
green: virtuality ordered PS

Jetmass in e+e-

Study high energetic tops in different hemispheres [Hoang 07,08]
 factorisation in hard scattering and soft functions

Double differential invariant mass distribution:

$$Q = 5 \times 172 \text{ GeV}$$

$$\Gamma = 1.43 \text{ GeV}$$

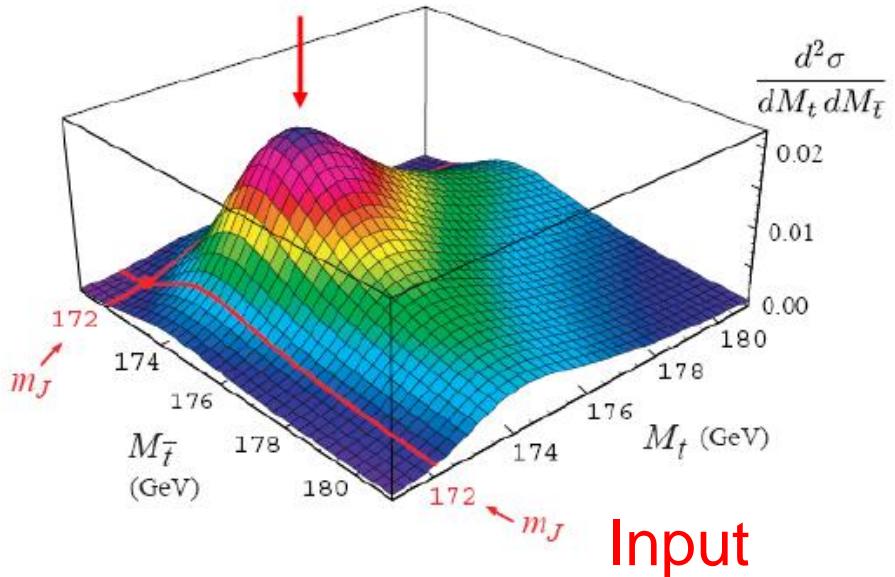
$$m_J(2 \text{ GeV}) = 172 \text{ GeV}$$

$$\mu_\Gamma = 5 \text{ GeV}$$

$$\mu_\Lambda = 1 \text{ GeV}$$

$$a = 2.5, \quad b = -0.4$$

$$\Lambda = 0.55 \text{ GeV}$$



Non-perturbative corrections shift peak by ~ 2.4 GeV
 and broaden the distribution