The gluon-fusion cross section with a jet veto

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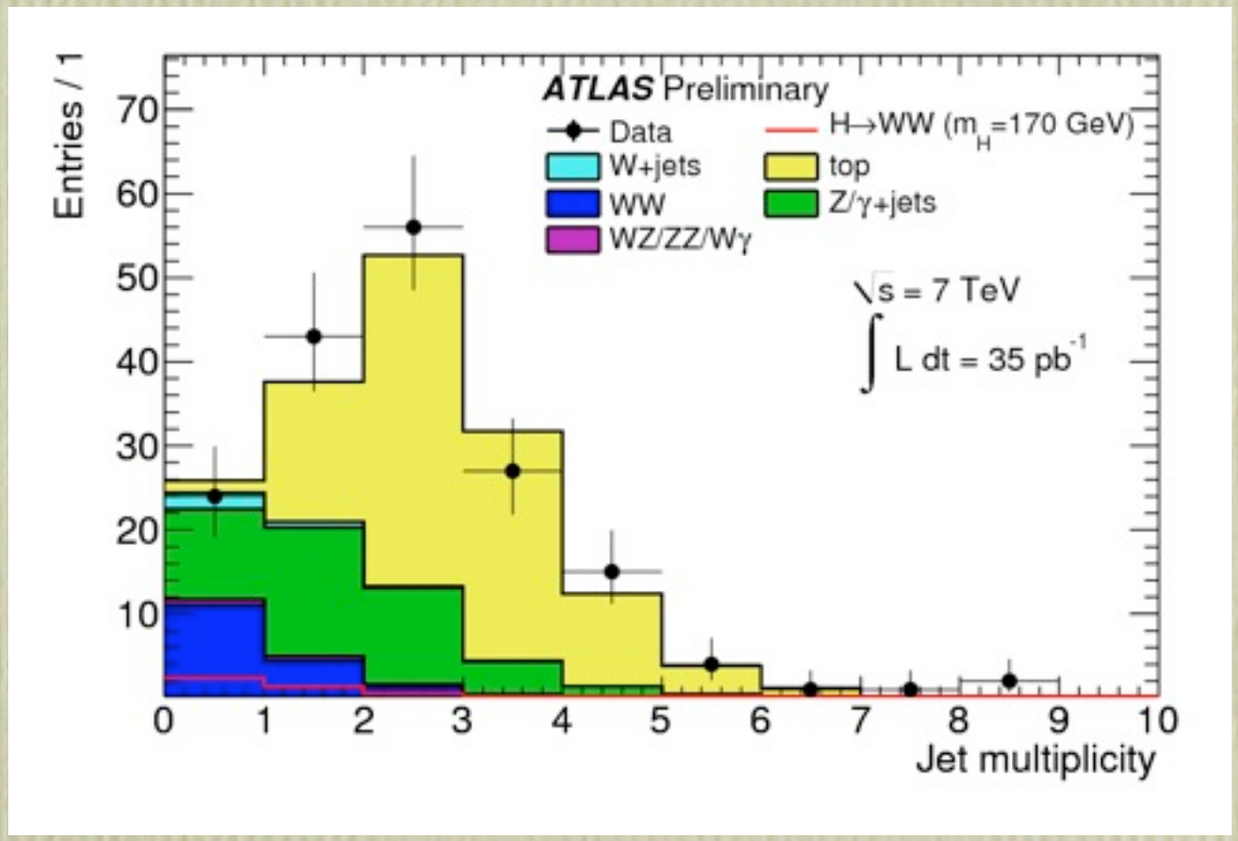
Reporting on work by Massimiliano Grazzini, Jianming Qian,
Iain Stewart, Fabian Stoeckli, Frank Tackmann and others

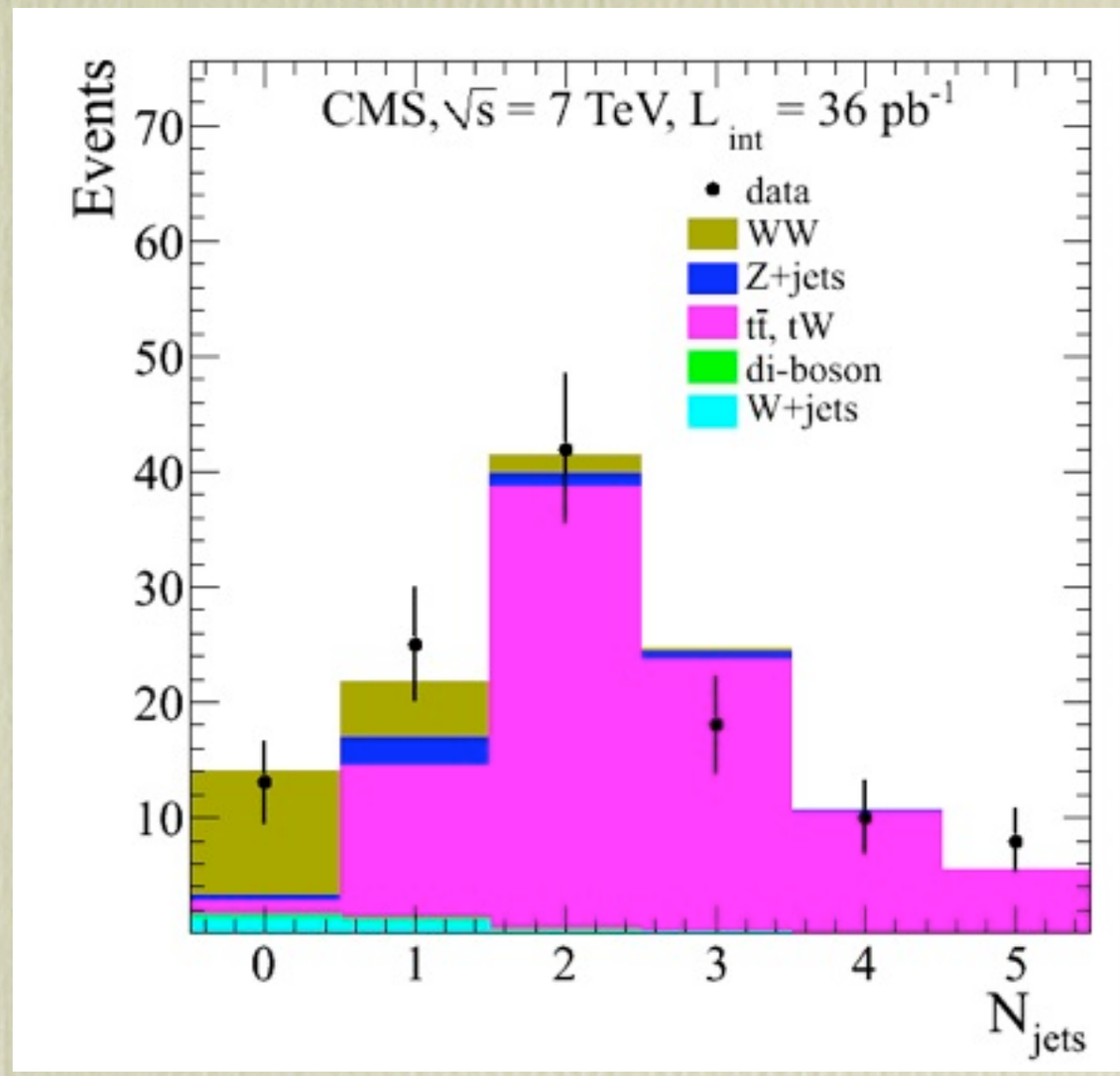
Higgs cross sections for the LHC
May 5, 2011

Issues for discussion

- What are the uncertainties for the 0,1,2 jet bins; should they be taken from fixed-order NNLO, or from elsewhere?
- Given a set of uncertainties (say, from fixed-order) how do we treat correlations between the jet bins?

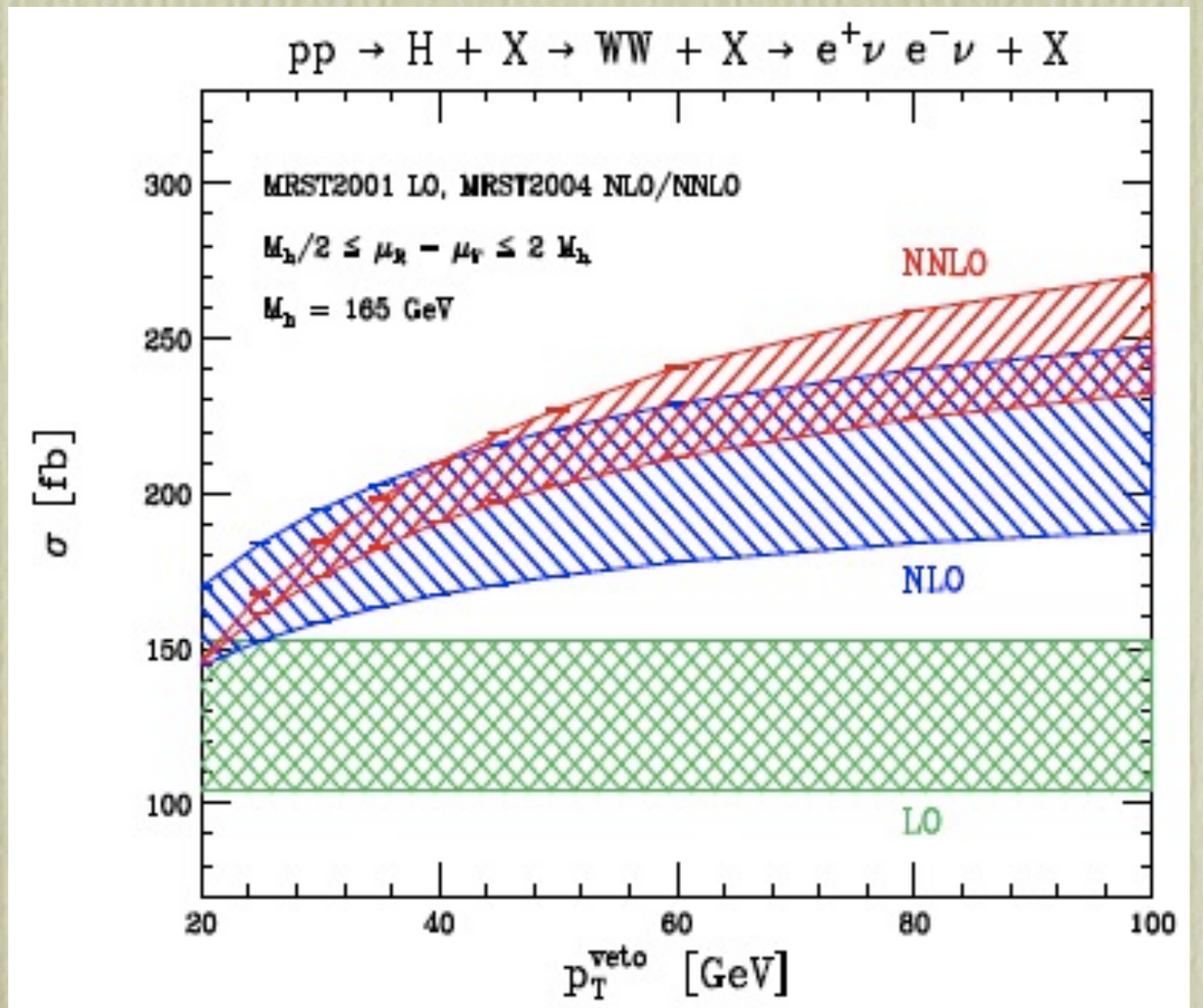
The need for the jet veto





- Large ttbar background forces binning via jet multiplicity; 25 GeV cut envisioned

Large logarithms



Anastasiou, Dissertori, Stoeckli 2007

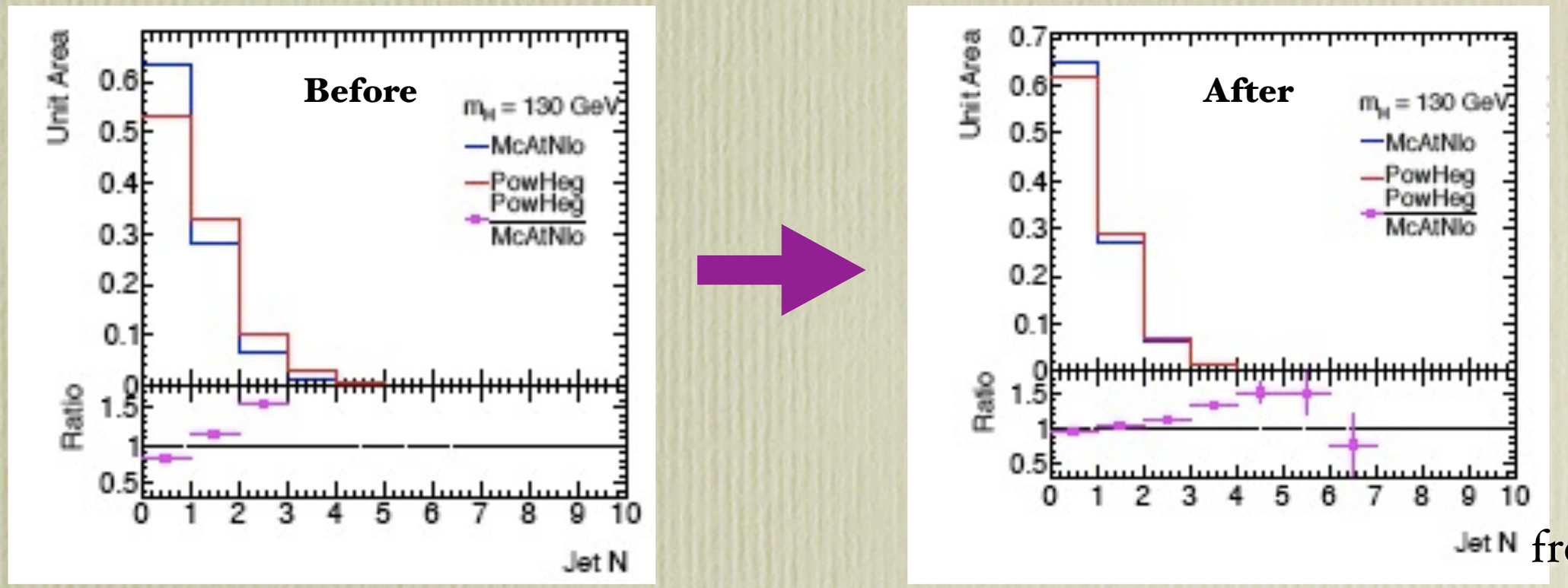
- Fixed-order expansion shows evidence of large logarithms

$$2C_A \frac{\alpha_s}{\pi} \ln^2\left(\frac{m_h}{p_T^{cut}}\right) \approx 0.6$$

- Large for LHC cuts (25 GeV)
- Scale variation for this cut indicates 5-6% uncertainty

Higgs p_T reweighting

- Unfortunately can't resum jet veto directly; forced to rely upon other variables for insight



from J. Qian

- Reweight Monte Carlo to Higgs p_T at NNLL using HqT Grazzini et al.
- But p_T differs from the jet veto at $O(\alpha_s^2)$ due to multiple gluon emission

Higgs p_T reweighting

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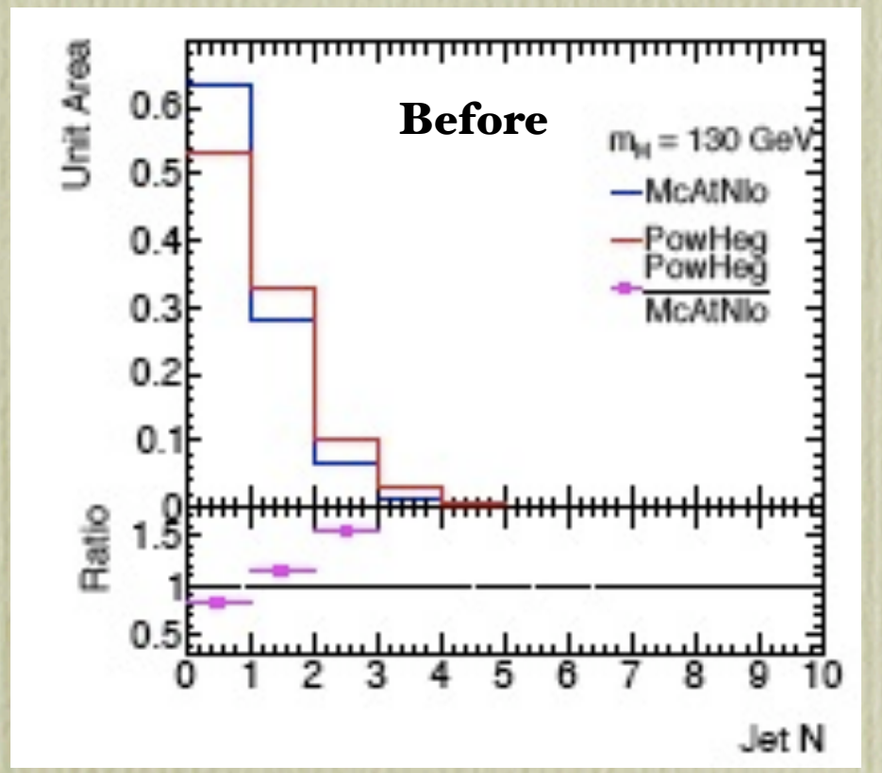
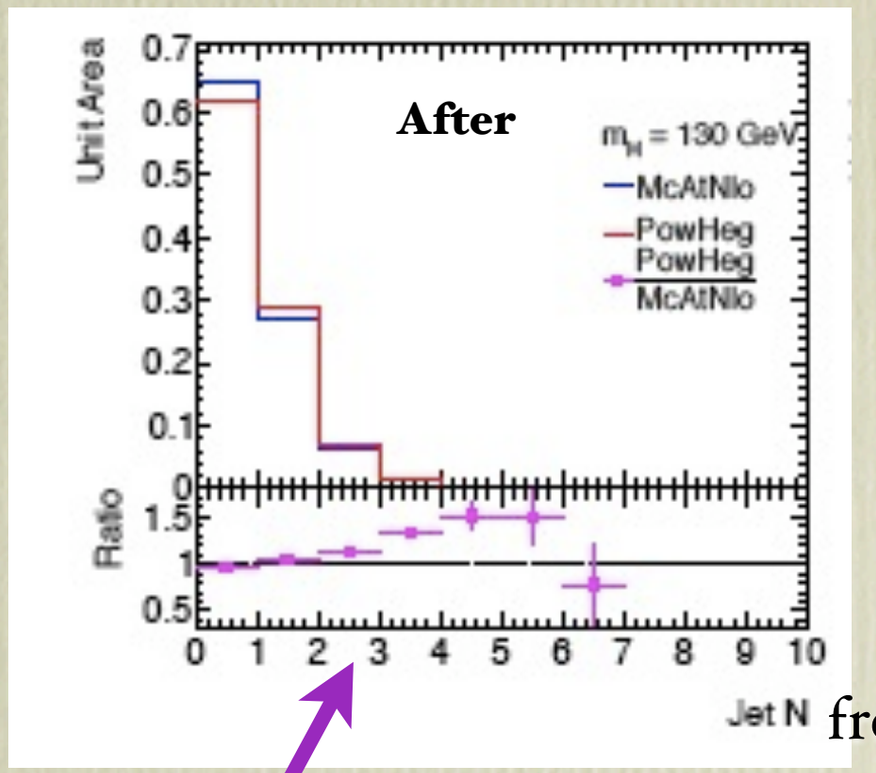




from J. Qian

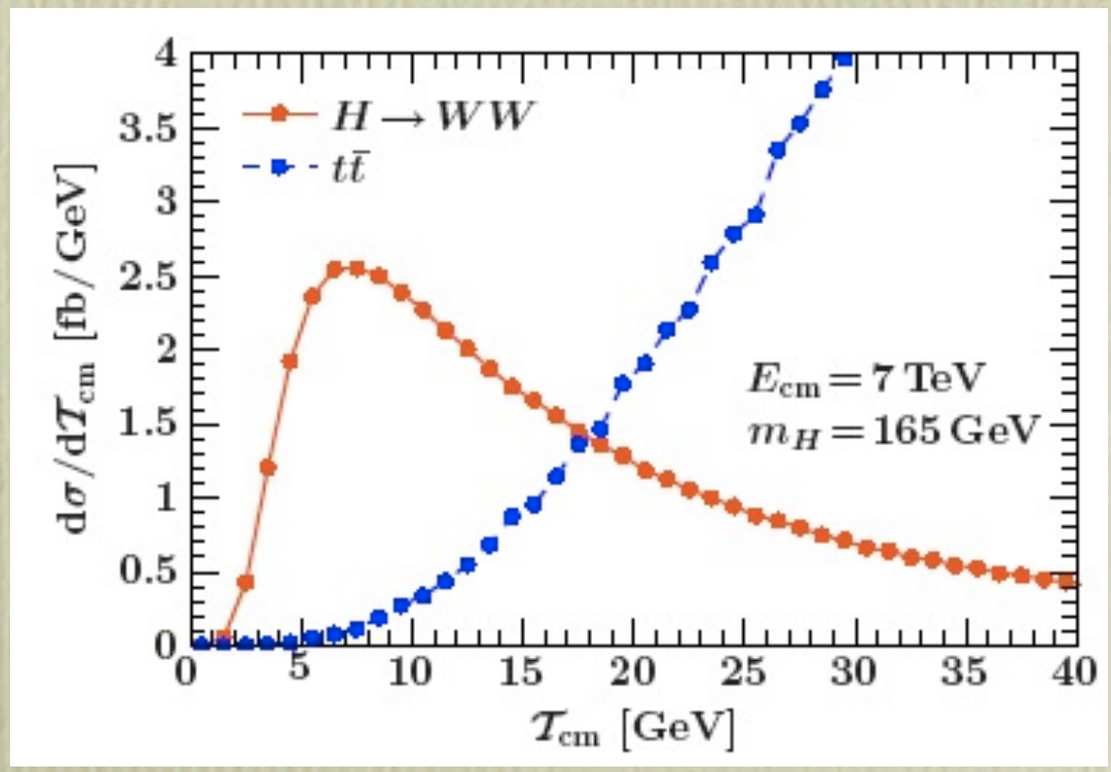
Note MC@NLO/POWHEG agreement after reweighting

Beam thrust

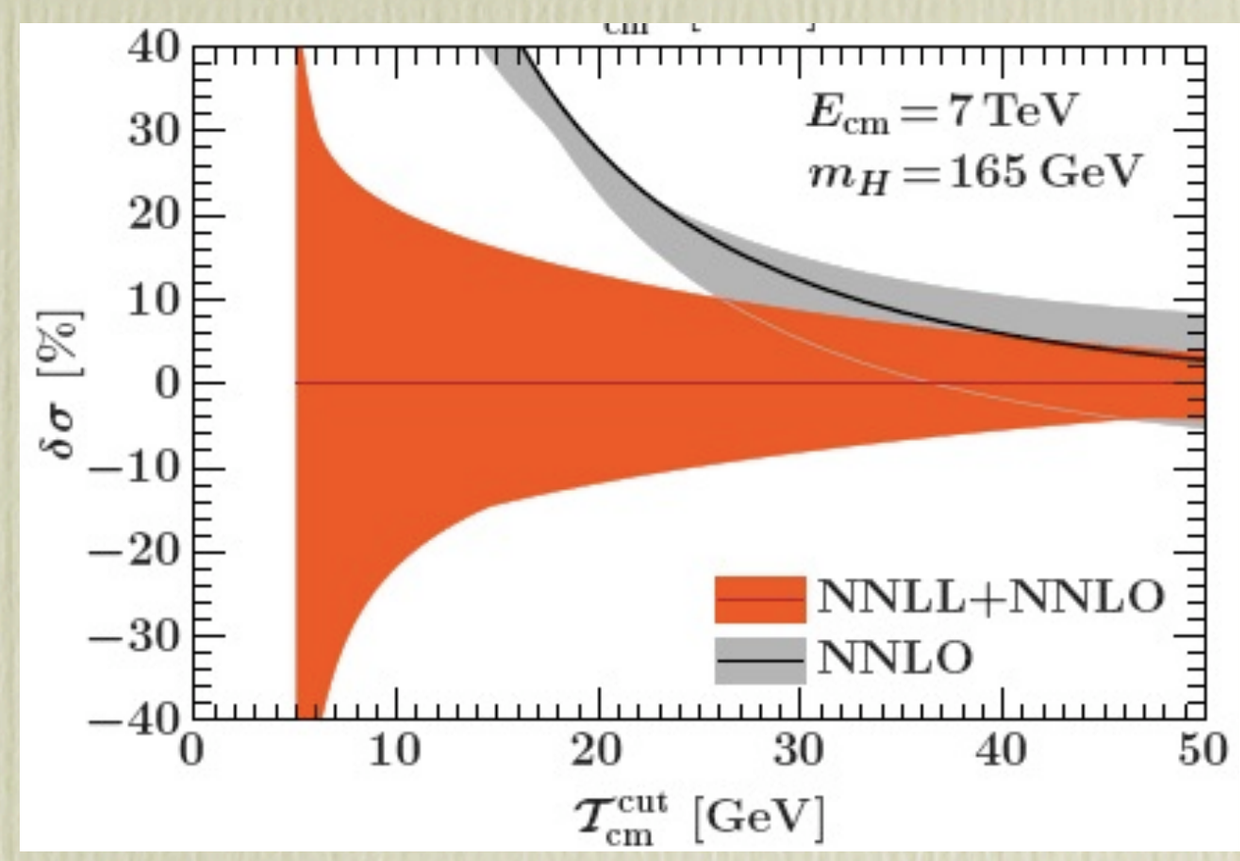
$$\tau = \frac{\mathcal{T}_{\rm cm}}{m_H}\,, \qquad \mathcal{T}_{\rm cm} = \sum_k |\vec{p}_{kT}|\, e^{-|\eta_k|} = \sum_k (E_k - |p_k^z|)\,.$$

$$\mathcal{T}_{\rm cm}^{\rm cut} \simeq m_H \left(\frac{p_T^{\rm cut}}{m_H}\right)^{\sqrt{2}}$$

$$\sigma(\mathcal{T}_{\rm cm}^{\rm cut}) \propto \left(1 - \frac{\alpha_s C_A}{\pi} \ln^2 \frac{\mathcal{T}_{\rm cm}^{\rm cut}}{m_H} + \cdots\right), \qquad \sigma(p_T^{\rm cut}) \propto \left(1 - \frac{2\alpha_s C_A}{\pi} \ln^2 \frac{p_T^{\rm cut}}{m_H} + \cdots\right)$$



Berger, Marcantonini, Stewart, Tackmann, Waalewijn 2010



Most importantly, a much larger uncertainty

Beam thrust

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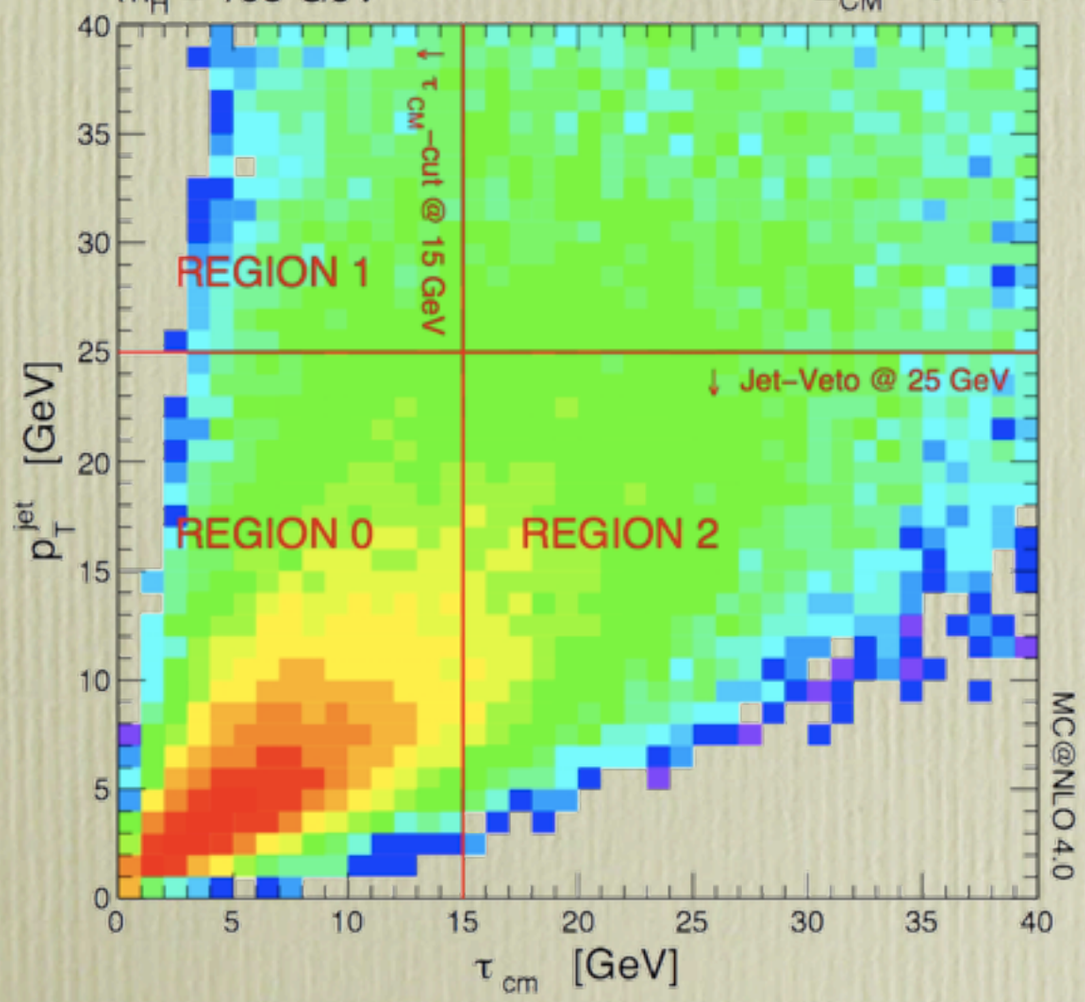
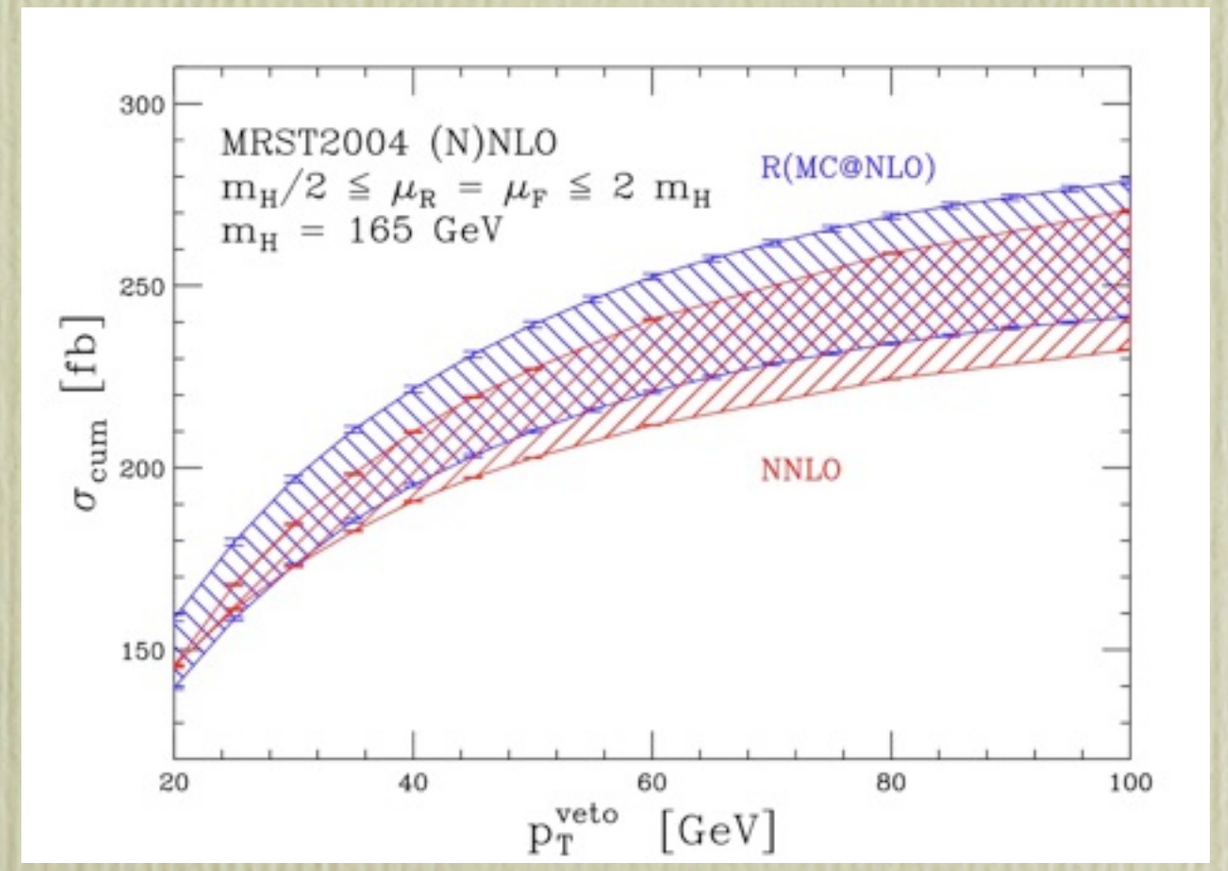


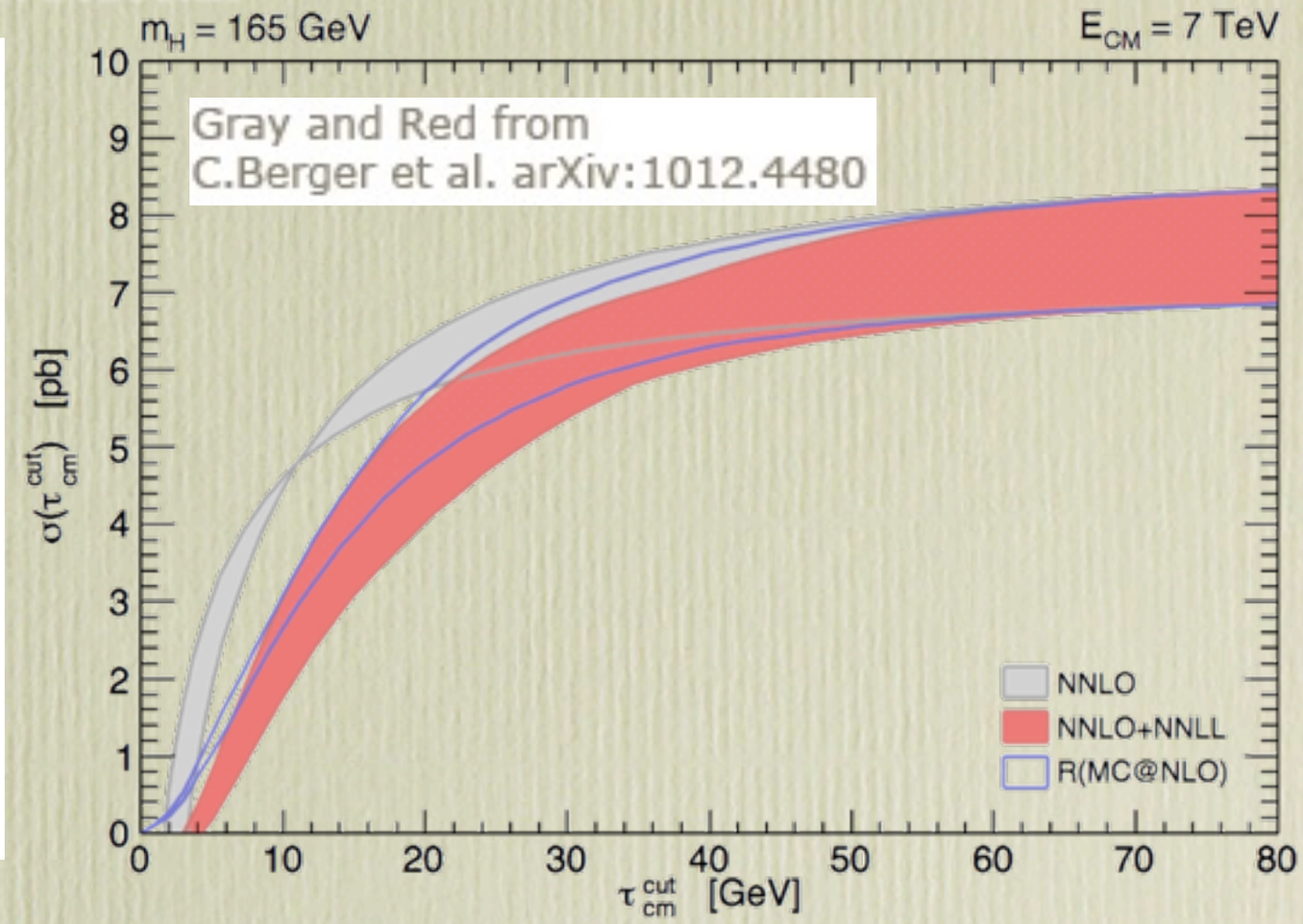
from F. Stoeckli

- Unfortunately this isn't quite the jet veto either

Reweighting

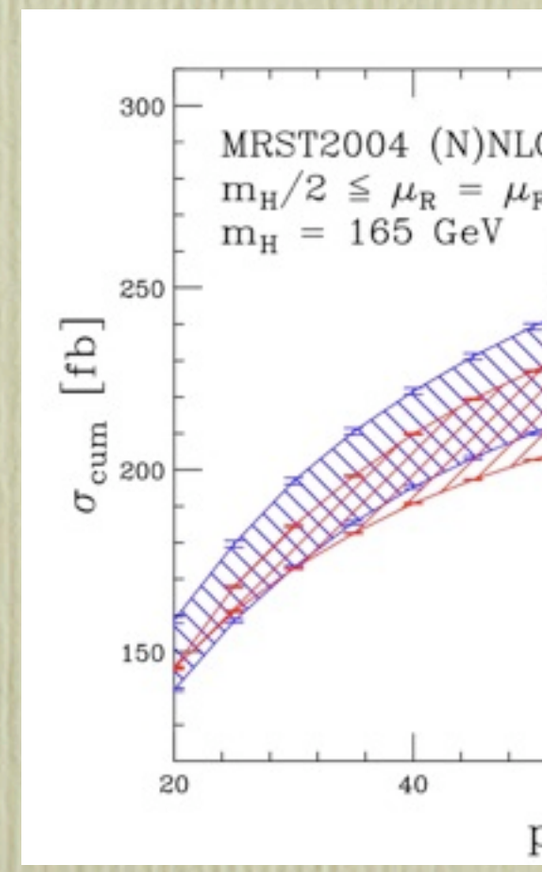
from F. Stoeckli

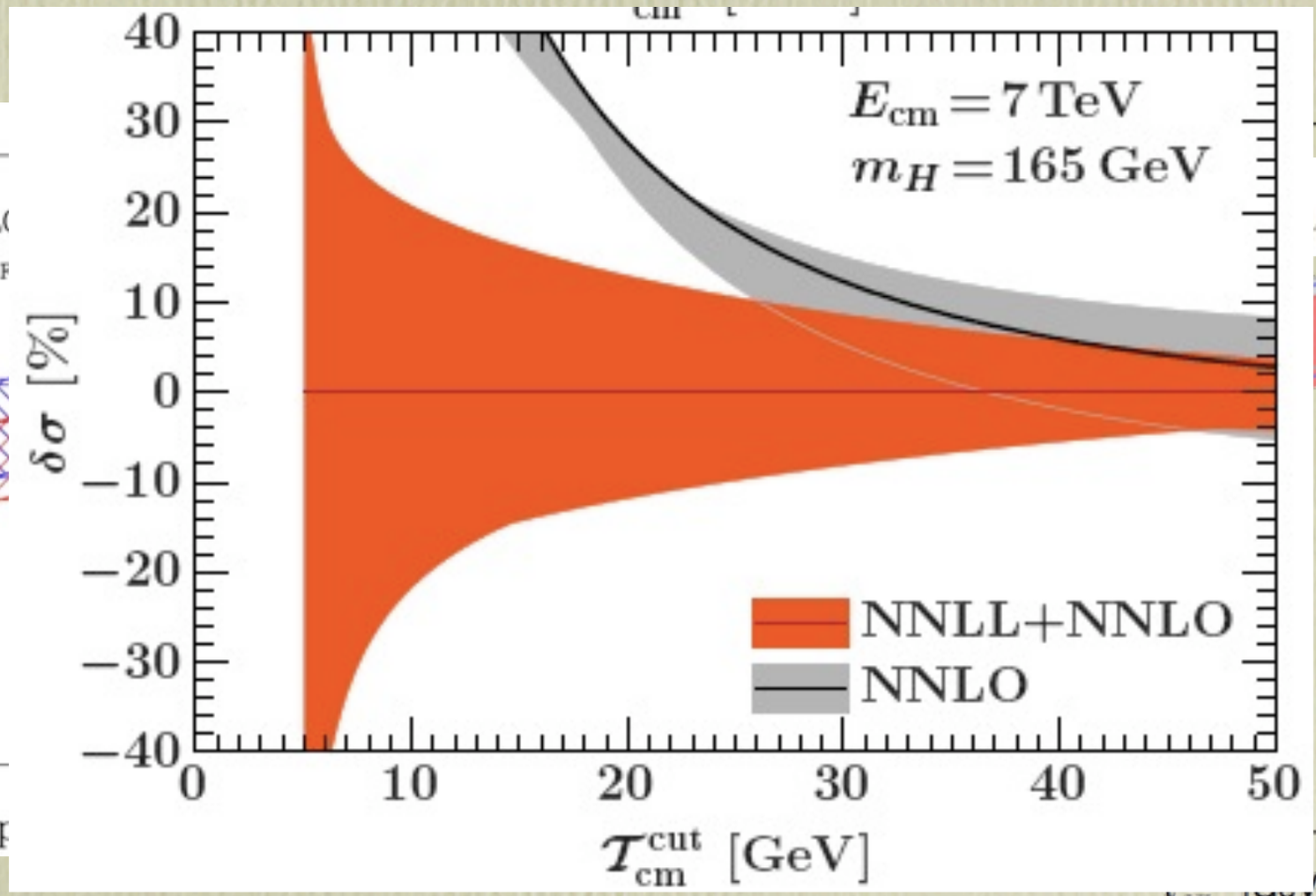


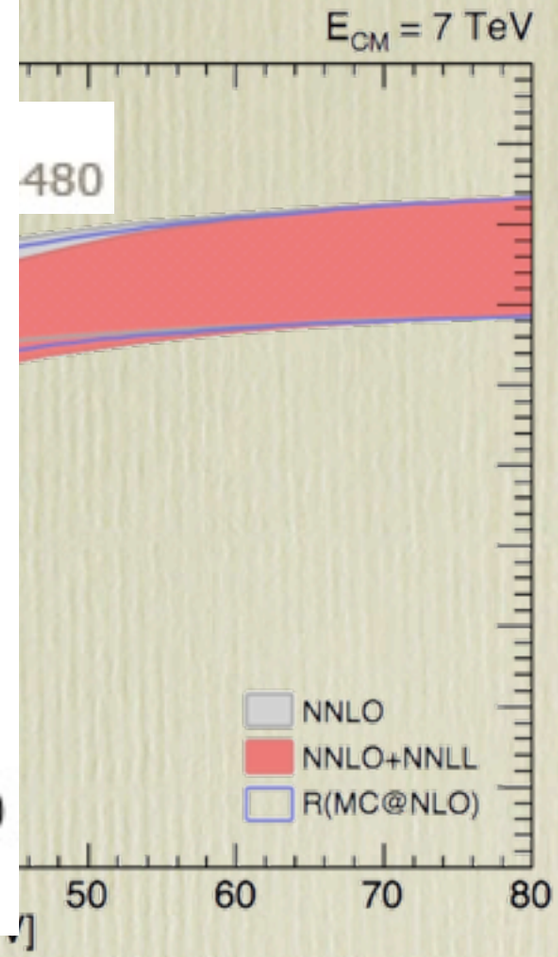


- It appears that reweighting MC@NLO/POWHEG to p_T spectrum gives a description of all kinematic variables consistent with best guess

Reweighting







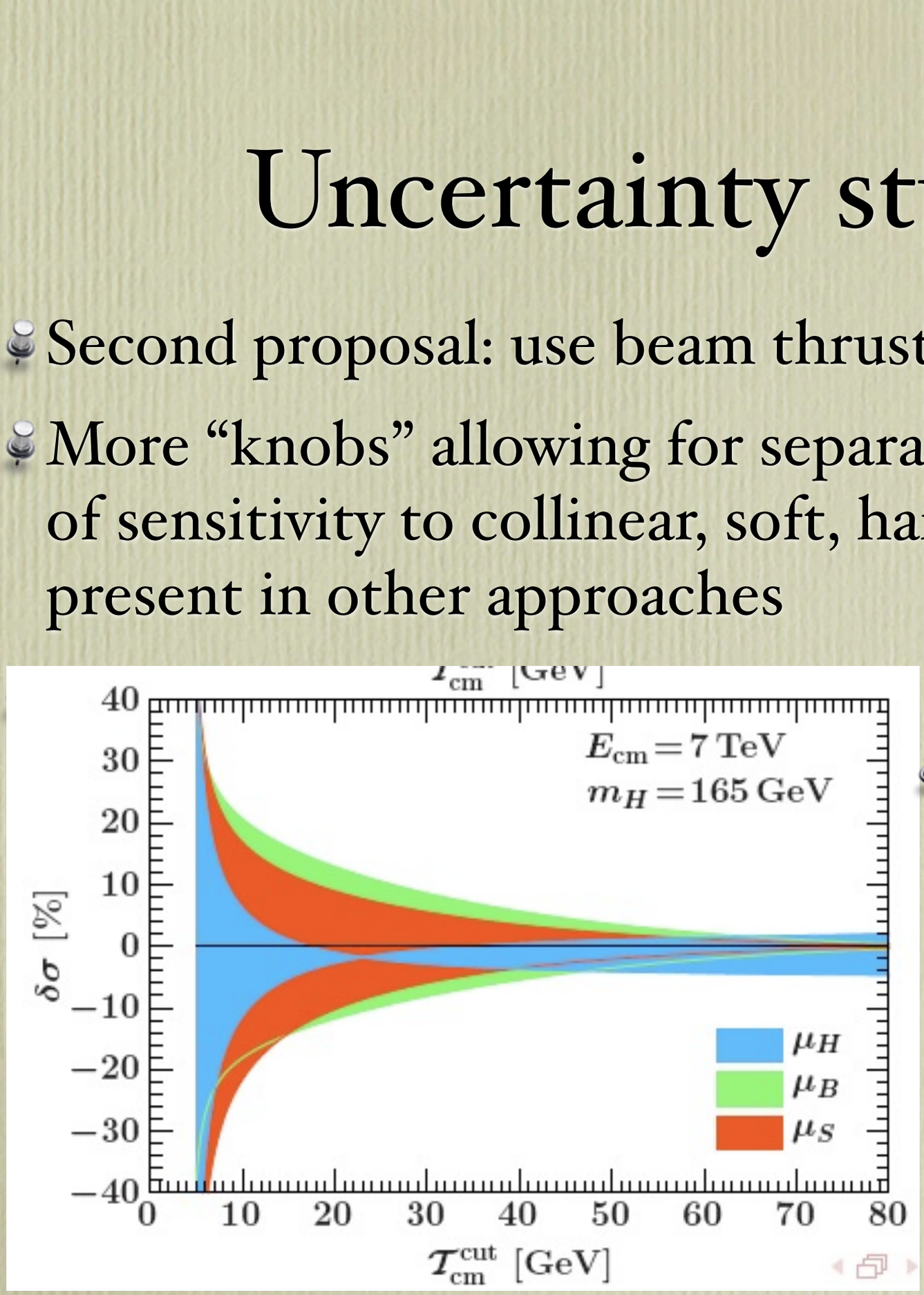
- But given this we should be conservative with the error

Uncertainty studies

- 5-6% for the 0-jet bin, less than for the simpler inclusive cross section, is too small…
- First proposal: new verson of HqT Grazzini et al. will allow for separate variation of μ_R, μ_F, resummation scale, and non-perturbative parameters (next talk). Vary all and take envelope, use max/min to reweight MC@NLO/POWHEG and MC@NLO. Find uncertainty after cuts. Is it larger than fixed-order (5-6%) in 0-jet bin?

Uncertainty studies

- Second proposal: use beam thrust to reweight
- More “knobs” allowing for separate determination of sensitivity to collinear, soft, hard radiation, not present in other approaches



- If not a study for the short-term (summer conferences), then should be done in the long-term

Correlations

- Given uncertainties we have now (fixed-order for total cross section, 0,1,2 jet bins), how best to use them and treat correlations?

Correlations: proposal 1

$$\sigma_{\text{vis}} = \sigma_{\text{tot}} \times A \times f$$

Fractions in each jet bin

- Take the total cross sections and their uncertainties from the CERN Yellow Report;
- Estimate jet veto/bin (scale) uncertainties separately and take into account potential correlations with those on the total cross sections

f_j correlation matrix

$$\begin{pmatrix} 1.00 & -0.95 & -0.98 \\ -0.95 & 1.00 & 0.88 \\ -0.98 & 0.88 & 1.00 \end{pmatrix}$$

σ_{tot} and f_j correlation:

0-jet=-0.99, 1-jet=0.96, 2-jet=0.95

from J. Qian

Reproduces the following uncertainties for the 0, 1 jet-bin cross sections, m_H = 165 GeV, p_T < 30 GeV veto:

- 5-6% in 0-jet bin
- 14-16% in 1-jet bin

Correlations: proposal 2

from F. Tackmann

First consider *inclusive* jet cross sections

$$\sigma_{\text{total}},\ \sigma_{\geq 1},\ \sigma_{\geq 2} \quad \Rightarrow \quad C = \begin{pmatrix} \Delta^2_{\text{total}} & 0 & 0 \\ 0 & \Delta^2_{\geq 1} & 0 \\ 0 & 0 & \Delta^2_{\geq 2} \end{pmatrix}$$

- Logic: logarithms of $\ln(m_H/p_T^{\text{cut}})$ appear in ≥1 cross section, but not the total; assume these terms dominate error

Correlations: proposal 2

from F. Tackmann

First consider *inclusive* jet cross sections

$$\sigma_{\text{total}},\ \sigma_{\geq 1},\ \sigma_{\geq 2} \quad \Rightarrow \quad C = \begin{pmatrix} \Delta^2_{\text{total}} & 0 & 0 \\ 0 & \Delta^2_{\geq 1} & 0 \\ 0 & 0 & \Delta^2_{\geq 2} \end{pmatrix}$$

Transform to *exclusive* jet cross sections

$$\sigma_0 = \sigma_{\text{total}} - \sigma_{\geq 1}\,, \qquad \sigma_1 = \sigma_{\geq 1} - \sigma_{\geq 2}\,, \qquad \sigma_{\geq 2}$$

$$\Rightarrow \quad C = \begin{pmatrix} \Delta^2_{\text{total}} + \Delta^2_{\geq 1} & -\Delta^2_{\geq 1} & 0 \\ -\Delta^2_{\geq 1} & \Delta^2_{\geq 1} + \Delta^2_{\geq 2} & -\Delta^2_{\geq 2} \\ 0 & -\Delta^2_{\geq 1} & \Delta^2_{\geq 2} \end{pmatrix}$$

- Note the larger uncertainty in the 0-jet bin

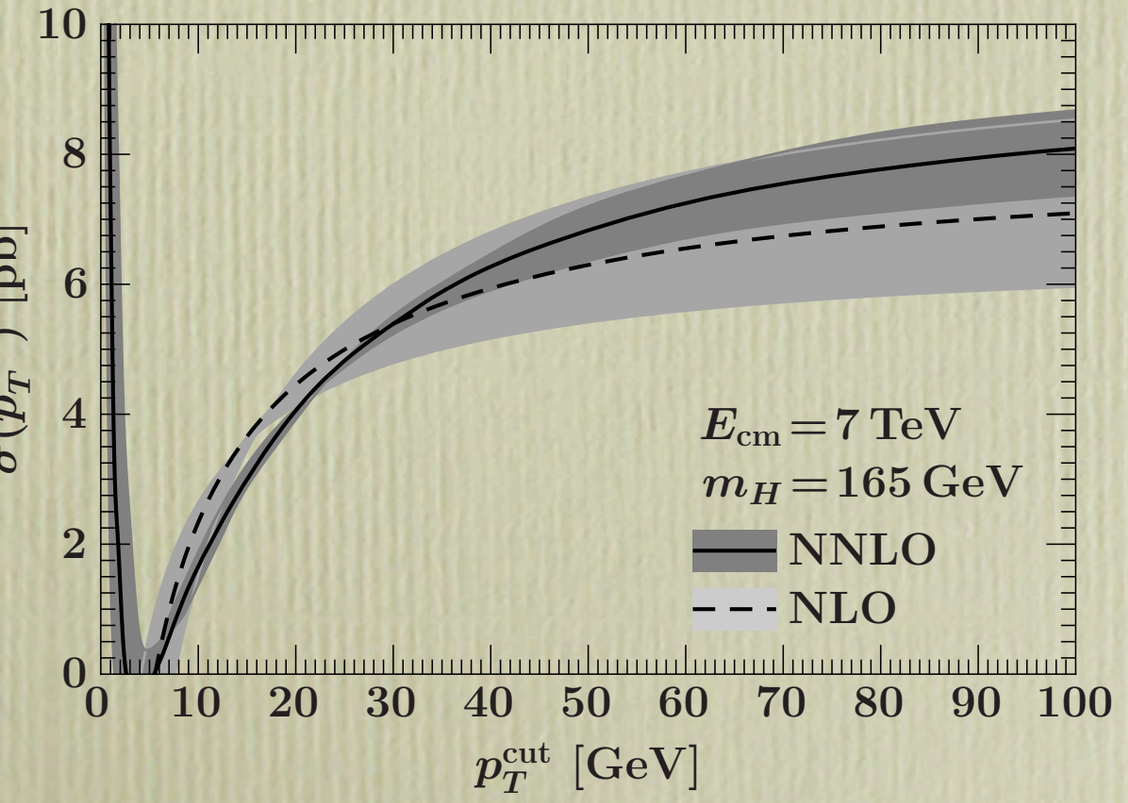
Correlations: proposal 2

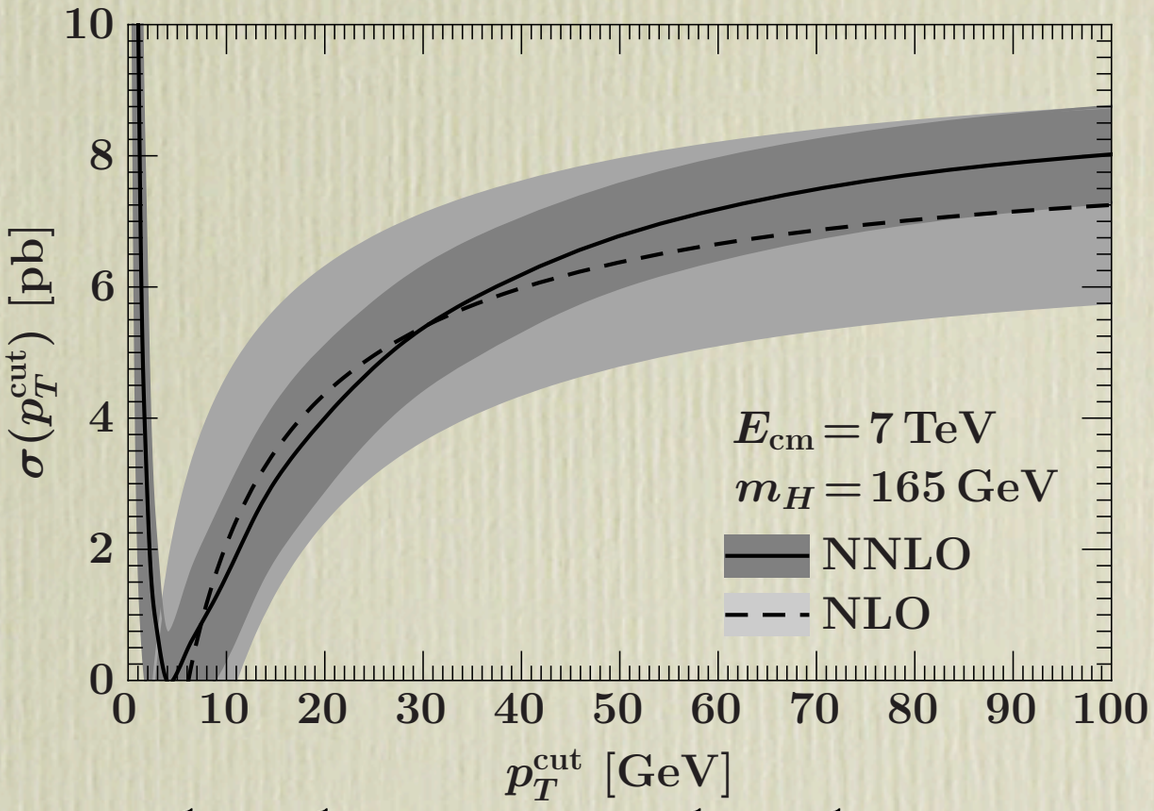
from F. Tackmann

same test case:

cut	$\frac{\Delta\sigma_{\text{total}}}{\sigma_{\text{total}}}$	$\frac{\Delta\sigma_{\geq 1}}{\sigma_{\geq 1}}$	$\frac{\Delta\sigma_{\geq 2}}{\sigma_{\geq 2}}$	$\frac{\Delta\sigma_{0}}{\sigma_{0}}$	$\frac{\Delta\sigma_{1}}{\sigma_{1}}$
$p_T^{\text{cut}} = 30\,\text{GeV},\ \eta^{\text{cut}} = 3$	10%	21%	45%	17%	29%

More conservative error





- Overlap between NNLO, resummed scale variation bands

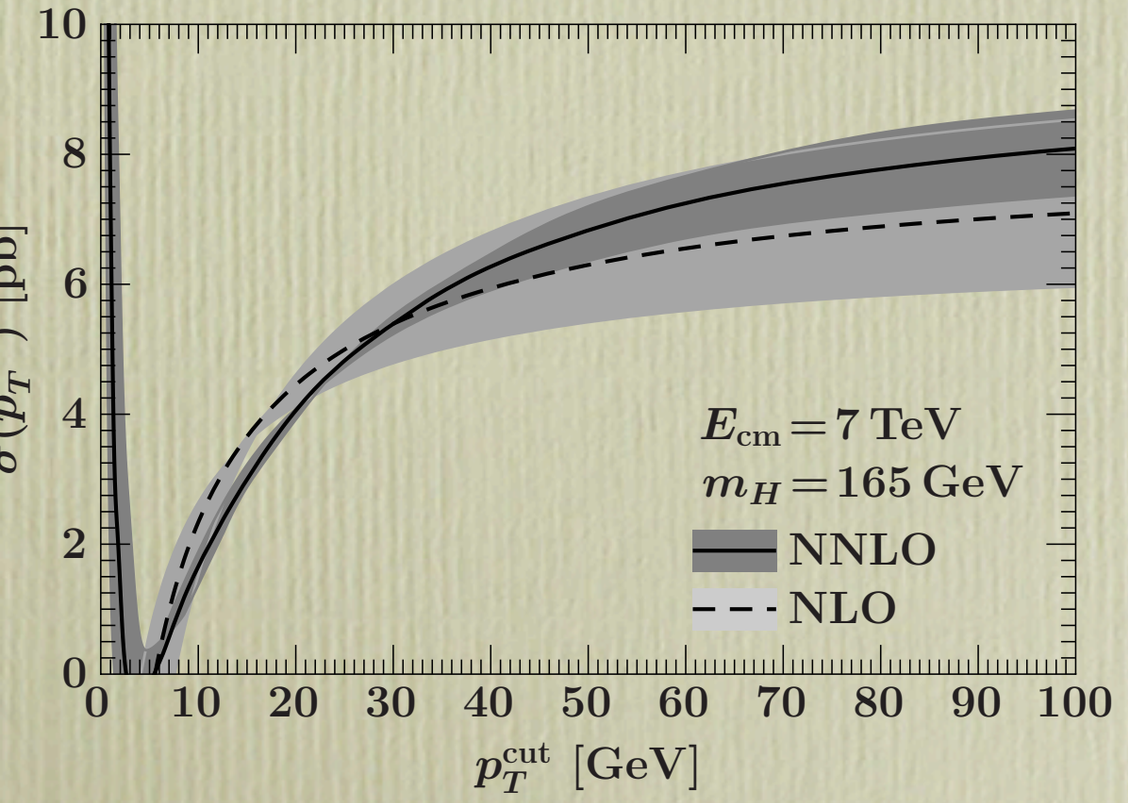
Correlations: proposal 2

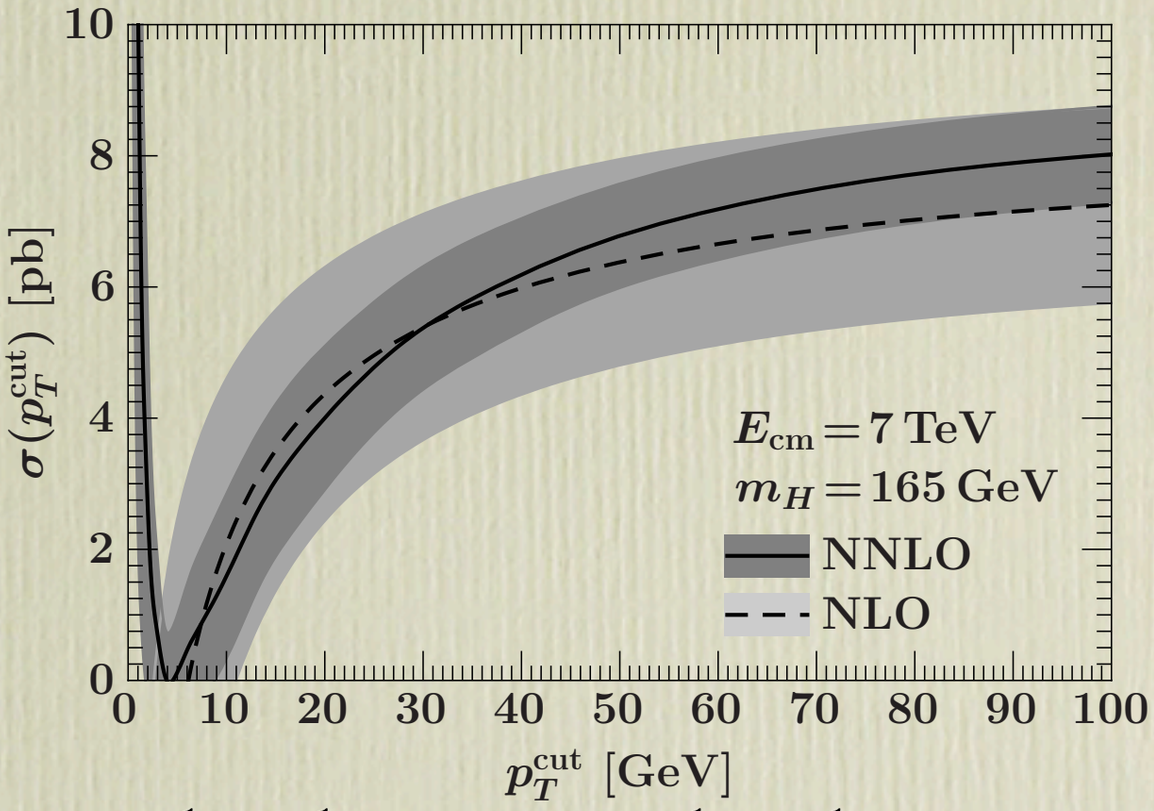
from F. Tackmann

Correlations for $\{\sigma_{\text{total}}, f_0, f_1, f_2\}$

$$\begin{pmatrix} 1 & 0.44 & -0.33 & -0.22 \\ 0.44 & 1 & -0.92 & -0.10 \\ -0.33 & -0.92 & 1 & -0.31 \\ -0.22 & -0.10 & -0.31 & 1 \end{pmatrix}$$

Can be translated into an error matrix for the event fractions





- Overlap between NNLO, resummed scale variation bands

Another proposal for errors

- Determine central values of jet bin fractions f_i from MC by each experiment for its selection;
- Calculate binned cross sections as

$$\sigma_i = f_i \times \sigma_{tot}$$

- Calculate uncertainties as

$$\Delta\sigma_i = \sqrt{(\Delta f_i)^2 \sigma_{tot}^2 + f_i^2 (\Delta\sigma_{tot})^2}$$

i.e. ignore the correlations between jet fraction and total cross section, it's simpler !

- take the uncertainty on the total cross section from CERN Yellow Report;
- estimate the uncertainty on the faction using fixed order program such as HNNLO

Gives 11-12% uncertainty in the 0-jet bin for the test study

from J. Qian

Conclusions

- Some worry that current uncertainties for cross sections in jet bins (5-6% in 0-jet bin) are too small
- Several studies suggested (HqT, beam-thrust reweightings) to test robustness of uncertainty estimate from fixed-order scale variation
- Different correlation technique that can, right now, increase the uncertainties to the 10-15% level for 0-jet bin
- How to best combine efforts with NLO-MC uncertainty project?