Ingredients for the Tevatron Higgs Search Limits

Marc Buehler
University of Virginia

On behalf of the
Tevatron New Phenomena and Higgs Working Group

http://tevnphwg.fnal.gov

Introduction

- In a conference talk it is not possible to discuss our analysis in depth. This talk is meant to clarify some of the details that feed into the calculation of the Tevatron Higgs limits.
- The Tevatron Higgs mass exclusion range is by its nature a probabilistic statement. All uncertainties must be treated properly, accounting for correlations, in order to obtain an accurate result.
- We choose theoretical inputs for our Higgs search limits that represent the consensus of the theoretical community. Picking extreme choices for these inputs would be biased and lead to over-coverage.

Scale Variations (μ_R & μ_F)

- Is our treatment of assessing cross section uncertainties due to scale variations reasonable?
- We obtain our gluon fusion production cross sections from:

  D. de Florian, M. Grazzini, Phys. Lett. **B674**, 291-294 (2009). [arXiv:0901.2427 [hep-ph]].

  C. Anastasiou, R. Boughezal, F. Petriello, JHEP **0904**, 003 (2009). [arXiv:0811.3458 [hep-ph]].

- We use a scale variation of a factor of 2 from the central value ($\mu=m_H/2$) to estimate the magnitude of potential contributions from higher-order processes
- The authors confirmed that higher order corrections to these cross sections are small and that the standard $\kappa=2$ scale variations are perfectly reasonable for assigning uncertainties
- Another recent, independent publication argues for even smaller scale uncertainties than those being currently assigned in our searches:

  V. Ahrens, T. Becher, M. Neubert *et al.*, Eur. Phys. J. **C62**, 333-353 (2009). [arXiv:0809.4283 [hep-ph]];

  V. Ahrens, T. Becher, M. Neubert *et al.*, [arXiv:1008.3162 [hep-ph]].

- **Yes, our treatment is sufficient and supported by the theoretical community**

Additional Theoretical Uncertainties

- Should there be an additional theoretical uncertainty assigned to our gluon fusion cross sections coming from the effective field theory (EFT) approach used to integrate electroweak contributions from heavy and light loop particles?
- Such an uncertainty is already included:

> C. Anastasiou, R. Boughezal, F. Petriello, JHEP **0904**, 003 (2009). [arXiv:0811.3458 [hep-ph]].

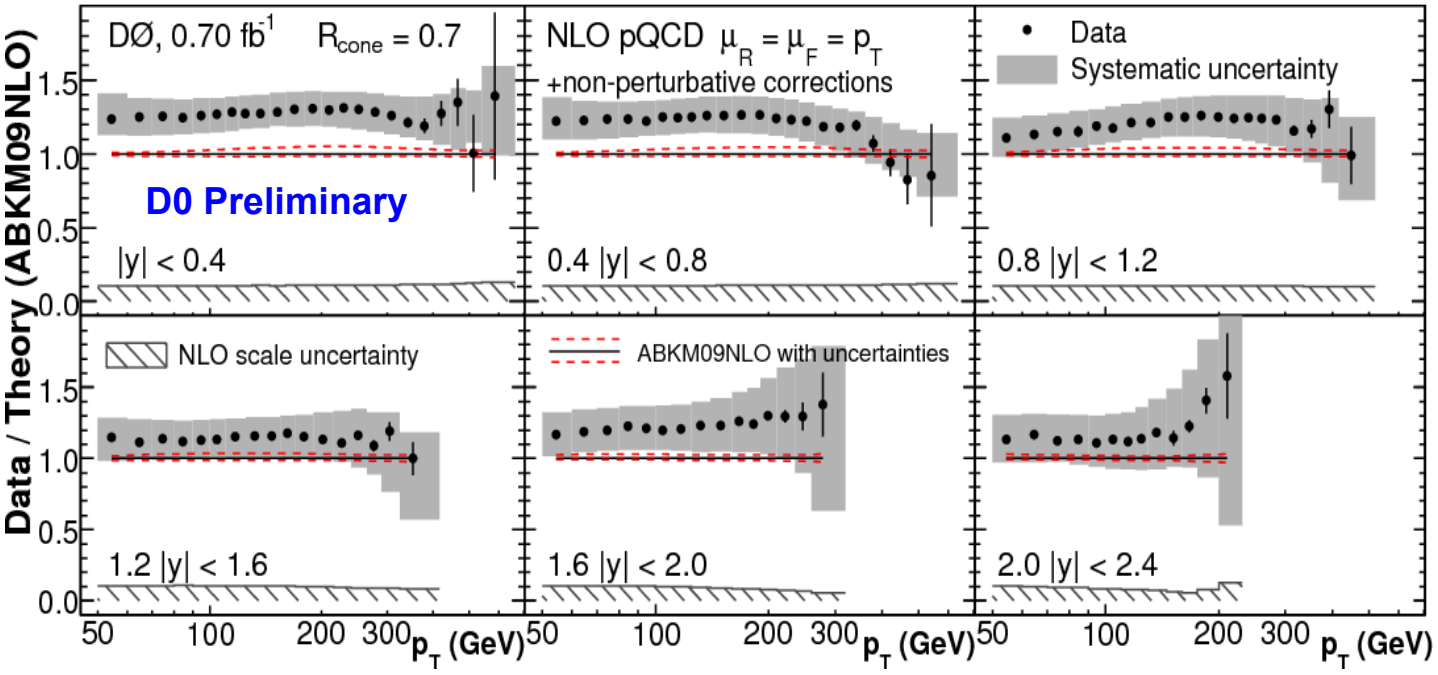
- Uncertainties on the gluon fusion cross section used in Tevatron Higgs searches incorporate a ~2% level component to account for this effect
- The same authors find that when they entirely remove corrections from light quark diagrams (clearly too conservative), the total cross section changes by less than 4%
- **Our current treatment of EFT effects is on solid ground**

PDF Uncertainties

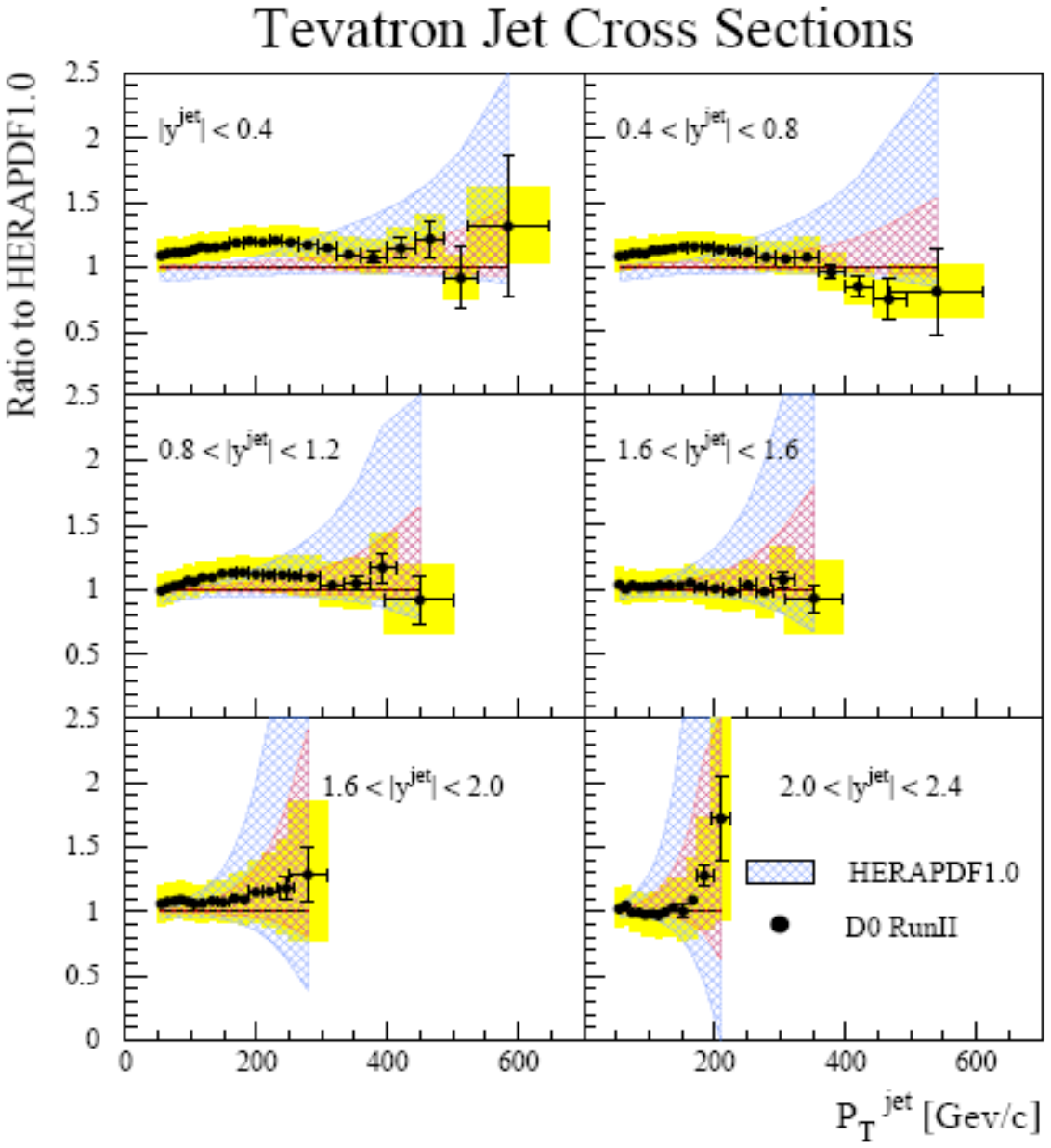
- Should our PDF uncertainties account for observed differences in cross sections obtained using our default MSTW model and ABKM/HERAPDF models?
- See Juan Rojo's talk on “Recent Developments and Open Problems in Parton Distributions” in the Tuesday afternoon session
- ABKM09 & HERAPDFs do not include Tevatron data, which provide the best constraints on the relevant high-x gluon distributions at Tevatron energies
- A comparison of high E_T Tevatron data with ABKM09 & HERAPDF shows large disagreement:

ABKM09 at the Tevatron:
Ratio of D0 High-ET jet cross-section to ABKM09 prediction (Data vs central PDF value)

(→ Uncertainty on ABKM Prediction)



PDF Sets



HERAPDF1.0 at the Tevatron:
Ratio of D0 High-ET jet cross section to HERAPDF1.0 prediction (Data vs central PDF value)

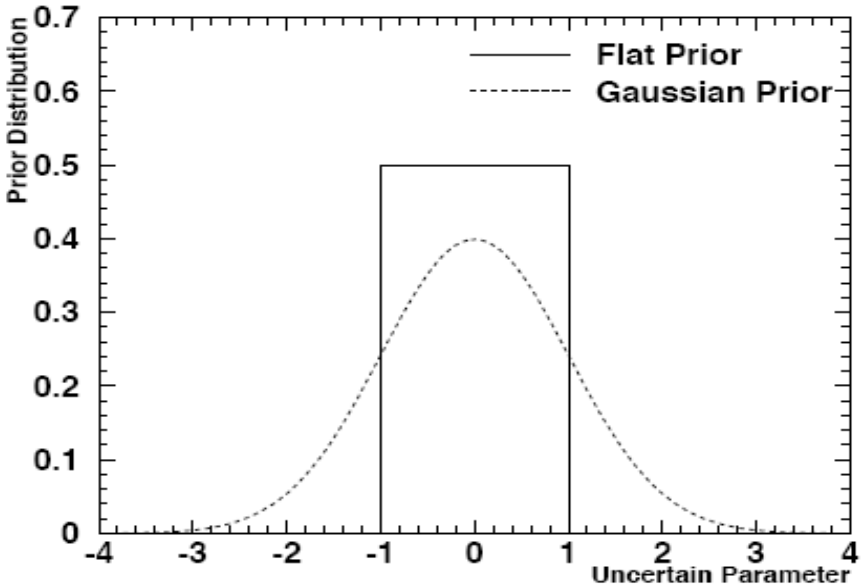
→ Total PDF uncertainty
→ Experimental PDF uncertainty
→ Systematic experimental error

- Our choice is also consistent with recommendations by the PDF4LHC working group, which is charged to provide guidance to experiments with respect to the use of PDF sets: http://www.hep.ucl.ac.uk/pdf4lhc/
- **Our PDF uncertainties are appropriate**

H1 & Zeus collaborations:
https://www.desy.de/h1zeus/combined_results/benchmark/tev.html

Treatment of Theoretical Uncertainties

- Most theoretical uncertainties are rather loosely stated. They are interpreted in terms of a maximum range of variations (*flat prior*)
- We treat theoretical uncertainties as gaussian (*gaussian prior*)
- Are we underestimating our uncertainties?
- We use the maximum bound as 1σ. This means we allow even larger variations than the given bounds. (See figure)
- We also tested the flat prior approach and found no significant change in our limits
- **We are not underestimating our uncertainties**



Emulation of Tevatron Limit Calculation

- Care needs to be taken when trying to emulate Tevatron limits
- Correlations between different input channels need to be properly taken into account:
  - Our limit calculation uses these correlations to constrain the backgrounds
  - Our backgrounds are better constrained by the data, as compared to the theory. This can be viewed as a measurement of the true rate and the a posteriori uncertainty is an experimental determination of the true error.
- An estimation of the sensitivity increase due to MVA is not straightforward:
  - Our pre-selection cuts are kept as loose as possible to maximize signal acceptance and cannot be interpreted as an optimized cut-based analysis
  - MVAs are used to separate signal from background
  - To estimate MVA sensitivity gains: compare fully optimized cut-based results with MVA results
  - MVAs typically improve limits by ~30% over optimized cut-based
- Impact of theoretical uncertainties:
  - Theoretical uncertainties are statistically accounted for together with other systematics
  - Increasing theoretical cross section uncertainties is not equivalent to decreasing the central prediction

Emulation of Tevatron Limit Calculation

- Care needs to be taken when trying to emulate Tevatron limits
- Correlations between different input channels need to be properly taken into account:
  - Our limit calculation uses these correlations to constrain the backgrounds
  - Our backgrounds are better constrained by the data, as compared to the theory. This can be viewed as a measurement of the true rate and the a posteriori uncertainty is an experimental determination of the true error.
- An estimation of the sensitivity increase due to MVA is not straightforward:
  - Our pre-selection cuts are kept as loose as possible to maximize signal acceptance and cannot be interpreted as an optimized cut-based analysis
  - MVAs are used to separate signal from background
  - To estimate MVA sensitivity gains: compare fully optimized cut-based results with MVA results
  - MVAs typically improve limits by ~30% over optimized cut-based
- Impact of theoretical uncertainties:
  - Theoretical uncertainties are statistically accounted for together with other systematics
  - Increasing theoretical cross section uncertainties is not equivalent to decreasing the central prediction

"Don't try this at home!"

Conclusion

- Our Higgs limits are based on standard practices of the HEP community and the base assumptions that meet a consensus

Conclusion

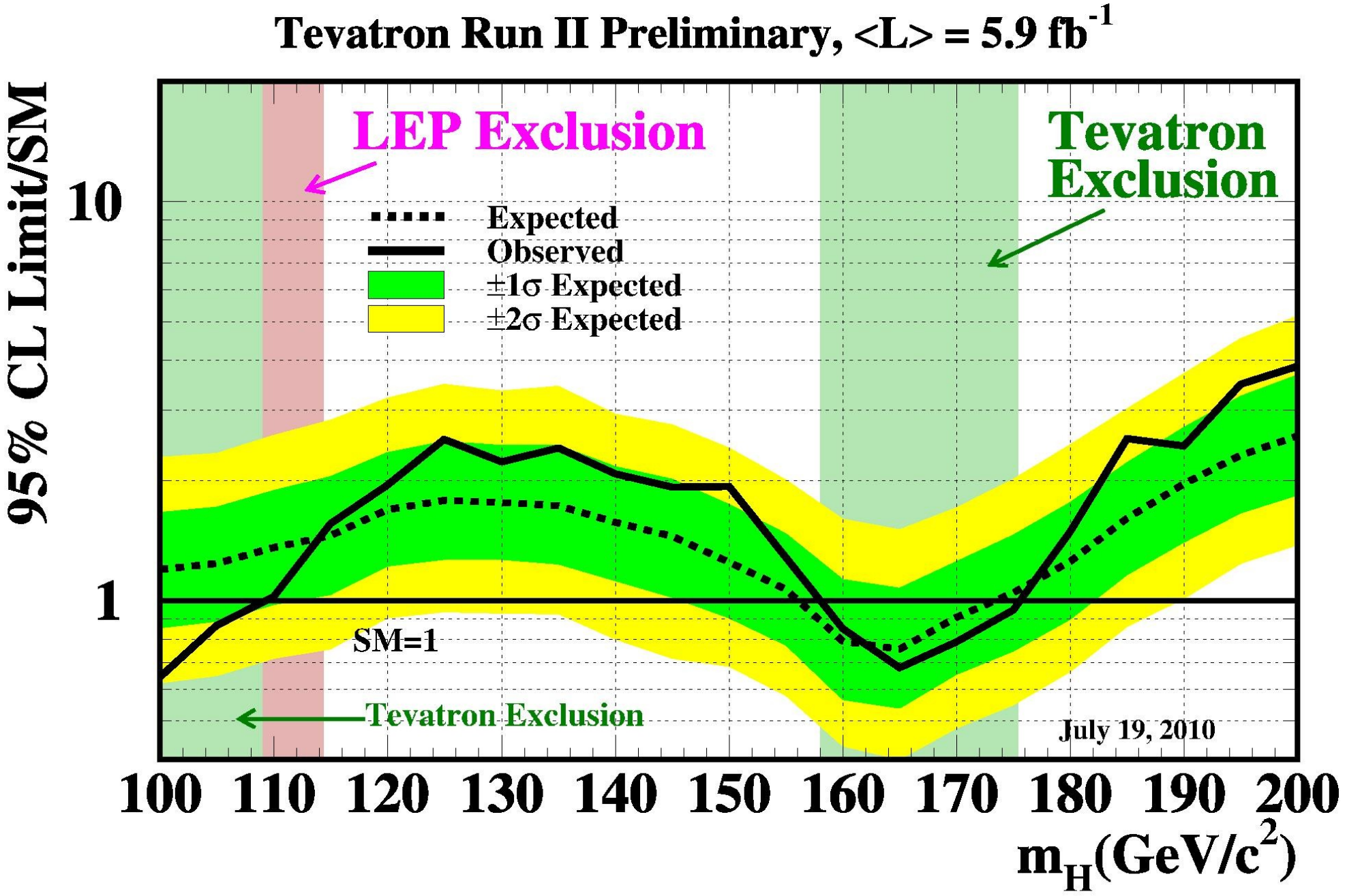
- Our Higgs limits are based on standard practices of the HEP community and the base assumptions that meet a consensus
- We are happy that our results on Higgs boson searches have captured the interest of the HEP theory community

Conclusion

- Our Higgs limits are based on standard practices of the HEP community and the base assumptions that meet a consensus
- We are happy that our results on Higgs boson searches have captured the interest of the HEP theory community
- We welcome the scrutiny that comes with producing such important results

Conclusion

- Our Higgs limits are based on standard practices of the HEP community and the base assumptions that meet a consensus
- We are happy that our results on Higgs boson searches have captured the interest of the HEP theory community
- We welcome the scrutiny that comes with producing such important results
- **The Higgs limits obtained by the Tevatron are sound and indicate exclusion of the Higgs boson with masses between 158 and 175 GeV at the 95% CL**


Tevatron Run II Preliminary, <L> = 5.9 fb-1
95% CL Limit/SM
10
1
LEP Exclusion
Tevatron Exclusion
Expected
Observed
±1σ Expected
±2σ Expected
SM=1
Tevatron Exclusion
July 19, 2010
100 110 120 130 140 150 160 170 180 190 200
mH(GeV/c2)