

Towards precise predictions for Higgs-boson production in the MSSM

E. Bagnaschi¹, R.V. Harlander², S. Liebler¹, H. Mantler³, P. Slavich^{4,5} and A. Vicini⁶



¹DESY, Notkestraße 85, D-22607 Hamburg, Germany

²Fachbereich C, Bergische Universität Wuppertal, Gaußstraße 20, D-42119 Wuppertal, Germany

³CERN, Theory Division, CH-1211 Geneva 23, Switzerland

⁴LPthe, UPMC Univ. Paris 06, Sorbonne Universités, 4 Place Jussieu, F-75252 Paris, France

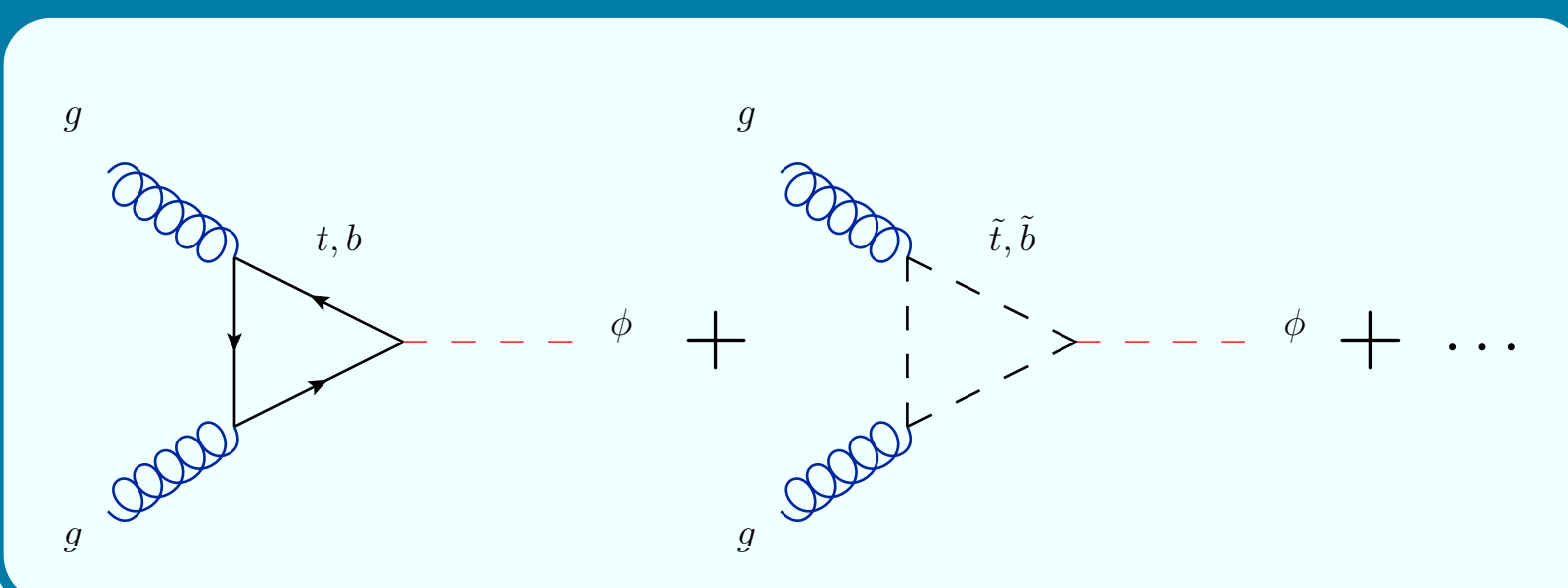
⁵LPthe, CNRS, 4 Place Jussieu, F-75252 Paris, France

⁶Dipartimento di Fisica, Università di Milano and INFN Milano, Via Celoria 16, I-20133 Milano, Italy

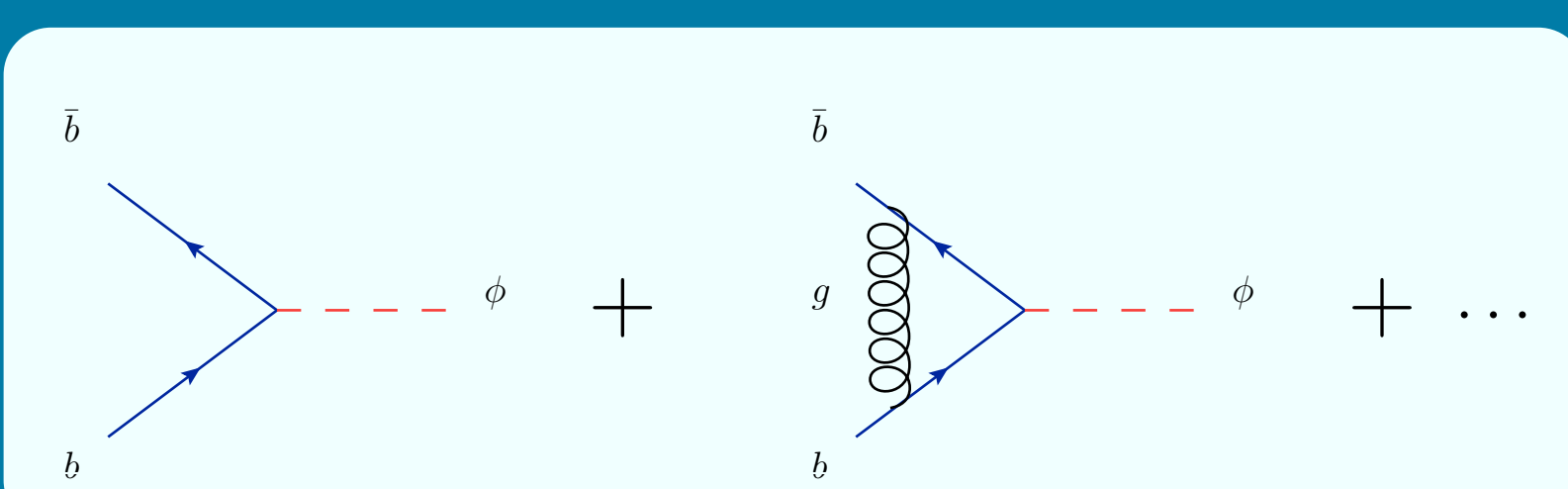
Aim of the study

Now that we are entering the era of **precision physics at the LHC**, it is important to have a **thorough understanding of the theoretical uncertainties that affect our predictions**. Our work follows this line of research and focuses on the case of the **production of the neutral Higgs bosons of the MSSM in gluon fusion and bottom annihilation**[1].

Gluon fusion



Bottom annihilation (5FS)

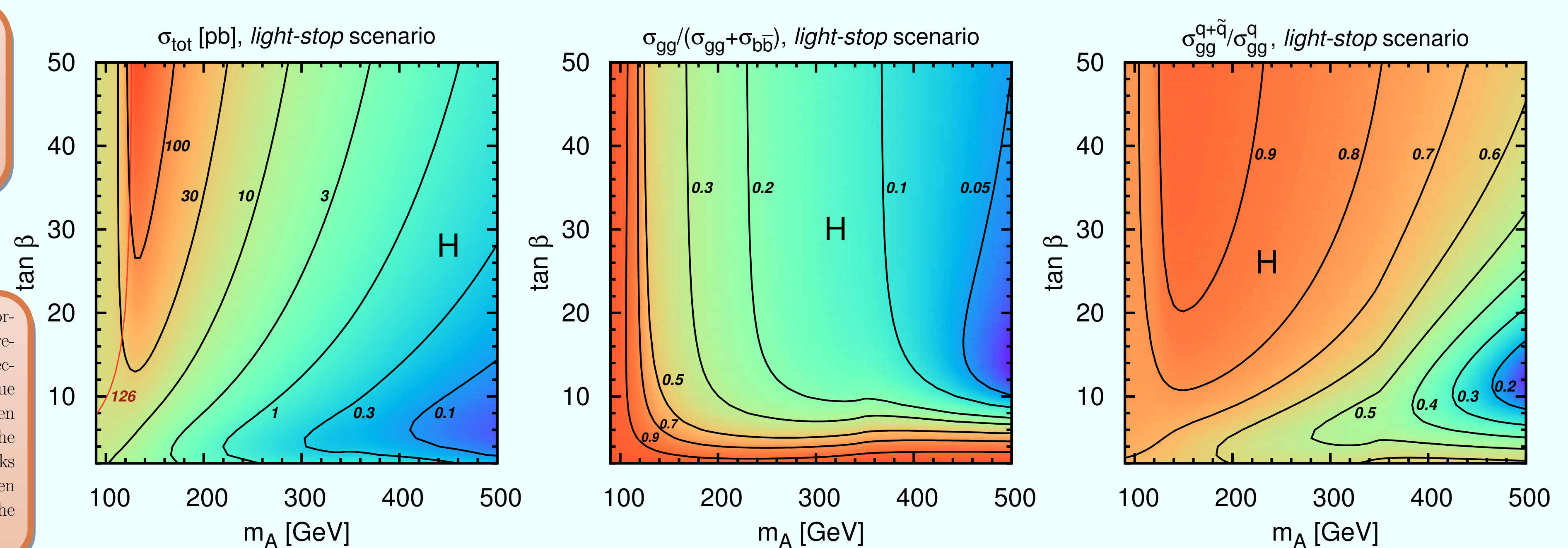


Outline of the analysis

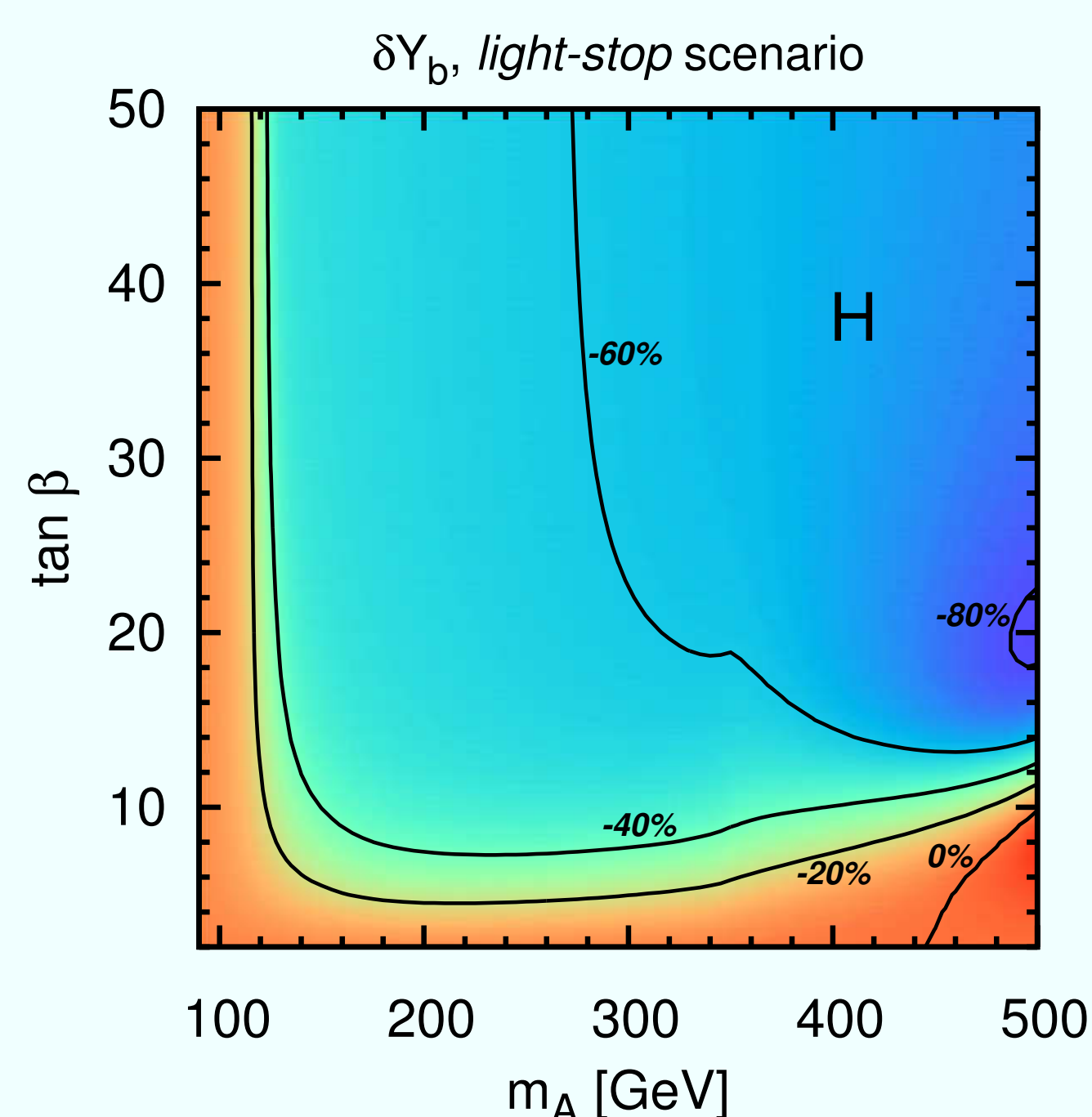
We have studied the production of $\phi = h, H, A$ using the code **SusHi** in the MSSM benchmark scenarios proposed by Carena et al (2013). Gluon fusion in **SusHi** includes: the exact top and bottom contribution up to NLO, the top results in the Heavy Quark Effective Field Theory (HQEFT) at NNLO, SUSY-QCD corrections from the stops and sbottom sectors at NLO and the available stops contribution at NNLO. EW contributions are included in a factorized form at NLO. The bottom Yukawa is rescaled to include $\tan\beta$ -enhanced corrections (Δ_b). Bottom annihilation is included at NNLO in the 5FS (SUSY-QCD corrections are included in a rescaled bottom Yukawa coupling). The results shown in the poster are for **H production** in the so called **light stop scenario** ($m_{\tilde{t}_1} = 324$ GeV, $m_{\tilde{t}_2} = 672$ GeV). In this box, **from left to right, we show the total cross section, the relative importance of the gluon fusion process and the impact of the SUSY-QCD corrections in the $\tan\beta - m_A$ plane**. In the rest of the poster we present the main uncertainties that affect this prediction for the total rate of H production.

The light stop scenario was slightly modified from its original form to evade more recent results from ATLAS and CMS.

In the bottom-right corner lies a *gluophobic* region where the cross section is very small due to a cancellation between the contributions of the quarks and the squarks (as it can be also seen from the last plot on the right).



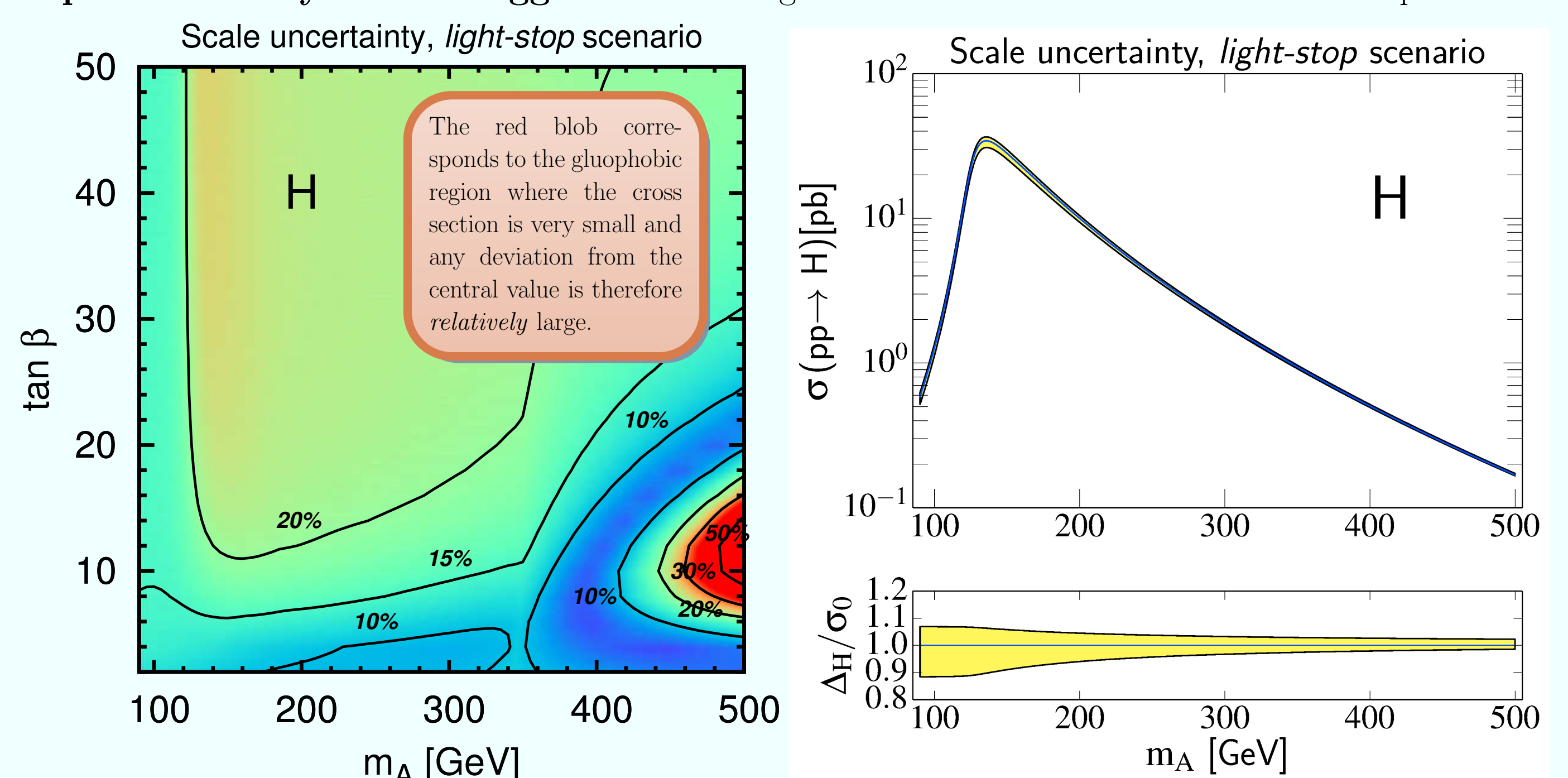
Bottom Yukawa renormalization scheme in gluon fusion



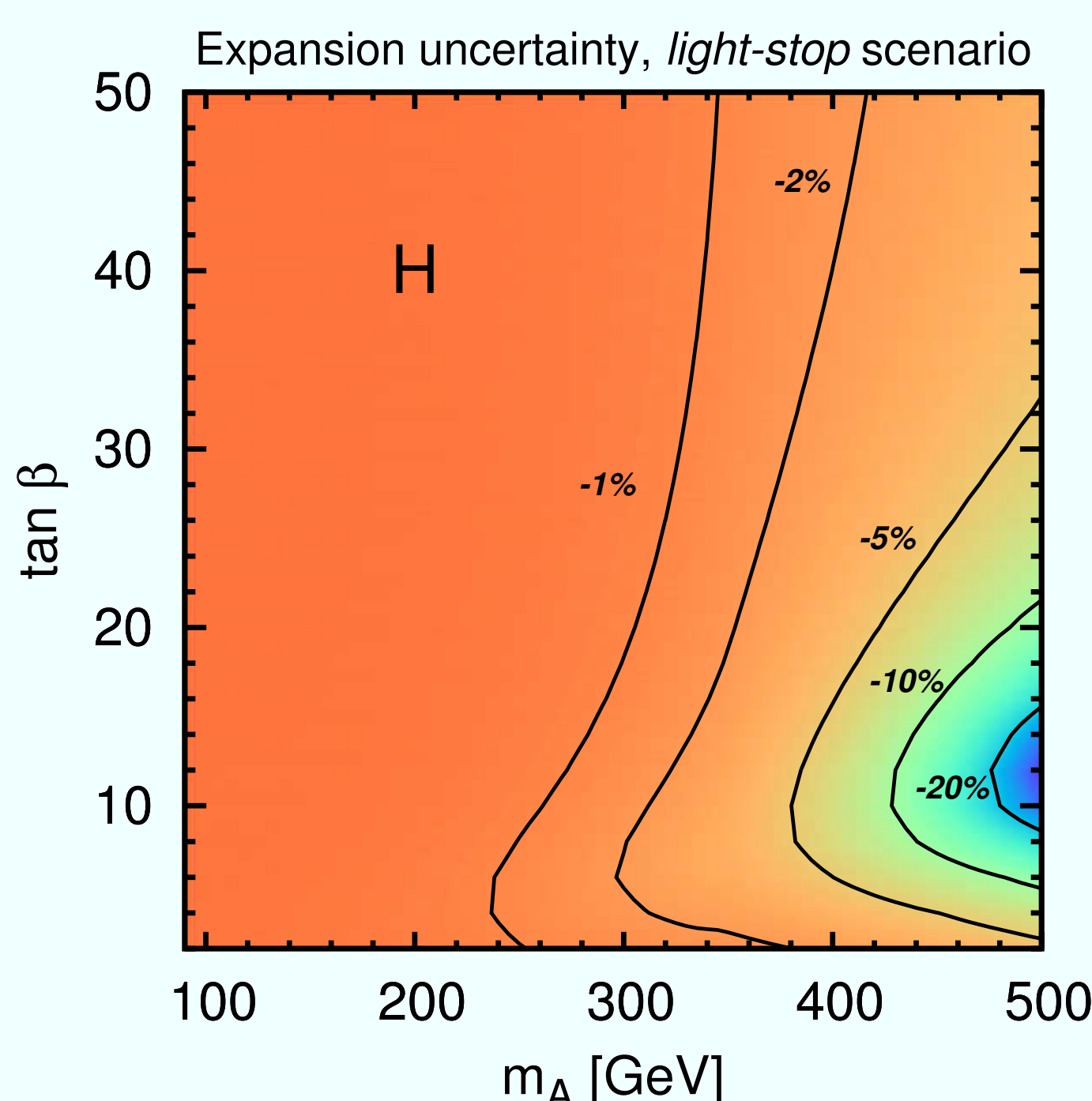
The bottom quark contribution to the gluon fusion process is subleading in the SM. In the MSSM, on the other hand, it **can be the dominant one**. Traditionally the bottom Yukawa has been extracted from the pole mass M_b . However **there are no theoretical justifications to prefer this choice over the one of extracting the Yukawa from the \overline{MS} mass, $m_b(\mu_r)$** . On the left we show the relative difference of the cross section for H when $Y_b \sim m_b(m_H/2)$ with respect to the canonical one obtained with $Y_b \sim M_b$. We see that when the bottom contribution is the dominant one we have deviations up to 60%–80%. While such a large uncertainty could appear as worrisome, **we should remember that in these regions the dominant production process is bottom annihilation**, as it can be seen from the middle plot of the top-right box. Analogous considerations are valid for the other Higgses.

Scale uncertainty

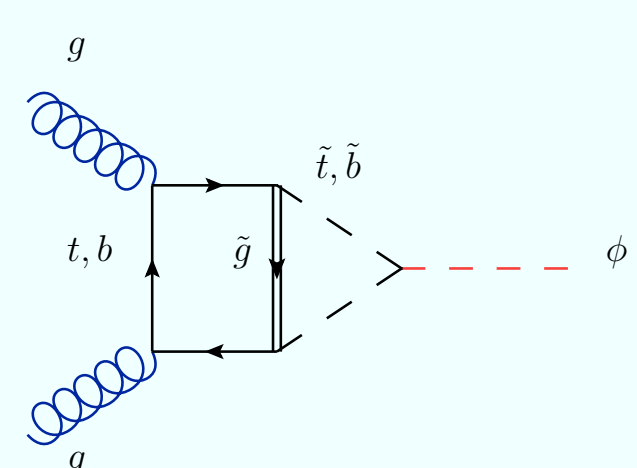
The **scale variation uncertainty** is evaluated with the **standard prescription** (a rescaling factor $r = 2$ is used and we opt not to include μ_r and μ_f combinations that could introduce potentially large logarithmic deviation from the central value). Here we show the **relative scale-uncertainty band width for H production in gluon fusion (left) and bottom annihilation (right)**. In the case of **gluon fusion**, we observe that **the uncertainty follows the pattern determined by the available accuracy of the dominant contribution** (e.g. where the bottom, known only at NLO, is dominant, the uncertainty is larger with respect to where the top contribution is dominant). In the case of **bottom annihilation**, being the SUSY-QCD corrections only in the rescaled bottom Yukawa, we see a **dependence only on the Higgs mass**. Analogous considerations are valid for h and A production.



SUSY-QCD expansion uncertainty



Not all SUSY-QCD corrections are available at NLO in an exact form. For example, NLO 2-loop diagrams with quarks, squarks and a gluino are included in **SusHi** in the form of an expansion in the inverse powers of the SUSY-particle masses. We **estimate the error** due to this approximation by **rescaling the NLO result for stops and sbottoms by the test factor $t \equiv \mathcal{A}_{\tilde{q}}^{1l} / \mathcal{A}_{\tilde{q}}^{1l,exp}$** . In the plot we show the relative difference of the cross section for H when computed with the test factor with respect to its canonical value. **We see that, aside from the gluophobic region, the impact in the $\tan\beta - m_A$ plane is rather modest**. For the pseudoscalar uncertainties have a similar pattern but they are smaller in magnitude due to the fact that the squarks appear at NLO and not at LO.



Other sources of uncertainty

There are also other sources of uncertainty that we have considered in our study:

- The bottom mass dependence in the PDF.
- PDF+ α_s uncertainty.
- Uncertainty due to our incomplete knowledge of NNLO SUSY-QCD corrections.
- Estimation of the theoretical uncertainties coming from the Δ_b corrections.

Acknowledgments

This work was supported in part by the Research Executive Agency (REA) of the European Commission under the Grant Agreements PITN-GA-2010-264564 (LHCPhenoNet), PITN-GA-2012-315877 (MCnet) and PITN-GA-2012-316704 (HiggsTools), and by the European Research Council (ERC) under the Advanced Grant ERC-2012-ADG_20120216-321133 (Higgs@LHC). The work of E. B. and P. S. at LPthe was supported in part by French state funds managed by the ANR (ANR-11-IDEX-0004-02) in the context of the ILP LABEX (ANR-10-LABX-63). S. L. acknowledges support by the DFG (SFB 676 “Particles, Strings and the Early Universe”). S. L., H. M. and R. H. were also supported by the DFG grant HA 2990/5-1. A. V. was supported in part by an Italian PRIN2009 grant and a European Investment Bank EIBURS grant.

References

- [1] E. Bagnaschi, et al. “Towards precise predictions for Higgs-boson production in the MSSM.” *JHEP*, 06:167, 2014. doi:10.1007/JHEP06(2014)167.

Contacts

emanuele.bagnaschi@desy.de
robert.harlander@uni-wuppertal.de
stefan.liebler@desy.de
hendrik.mantler@cern.ch
slavich@lpthe.jussieu.fr
alessandro.vicini@mi.infn.it