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Charged Higgs boson production in the intermediate mass region

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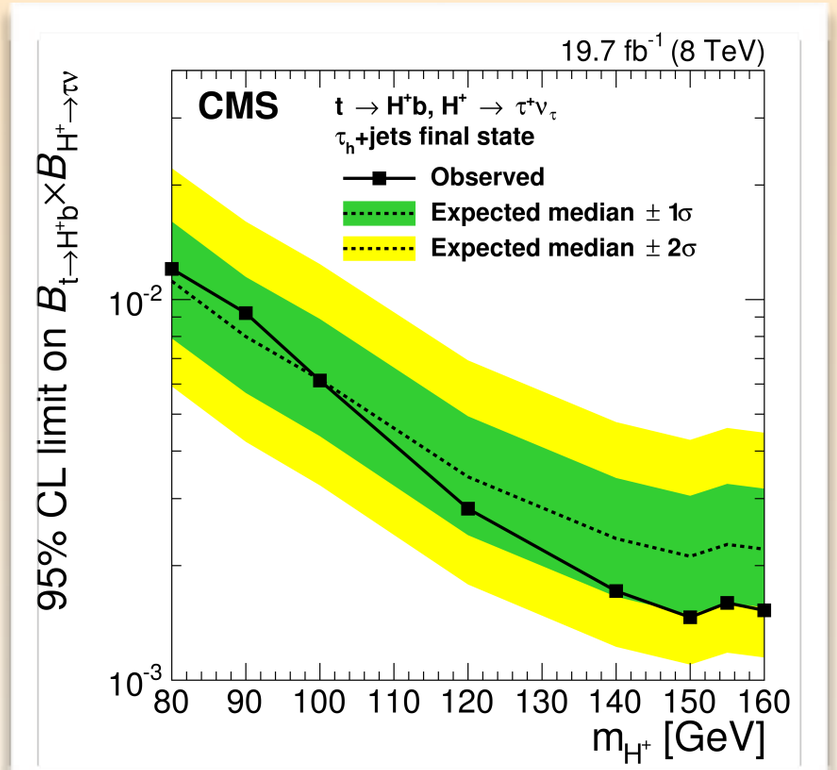
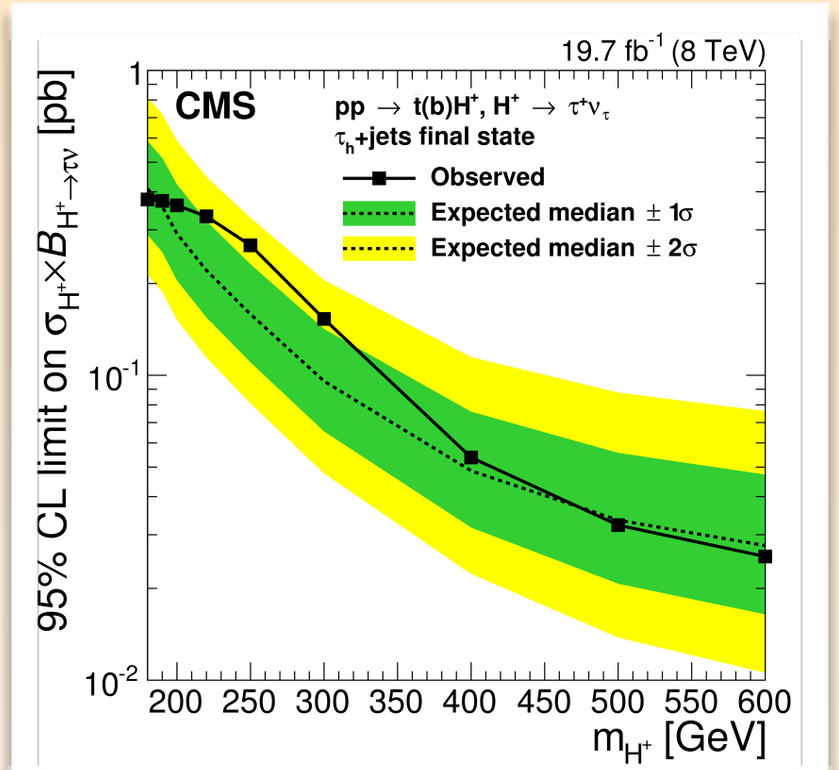
Charged Higgs production

- Many extensions of the SM contain charged Higgs boson
- Most commonly studied in a 2 Higgs Doublet Model
  - For example MSSM contains a (special case of) type-II 2HDM
- But also possible via Triplets Models
  - Introduces tree-level interaction between $H^{\pm}WZ$
  - Very different phenomenology w.r.t. 2HDM (or nHDM)
  - Not covered in the rest of this talk

Limits on charged Higgs production



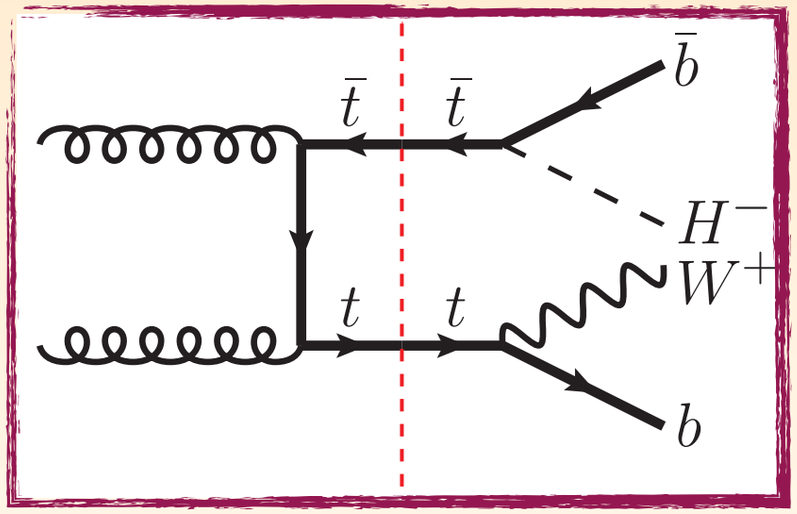


- Similar results available from ATLAS
- What about the mass range 160—180 GeV?
  - No accurate theory predictions!

Production for small and large masses

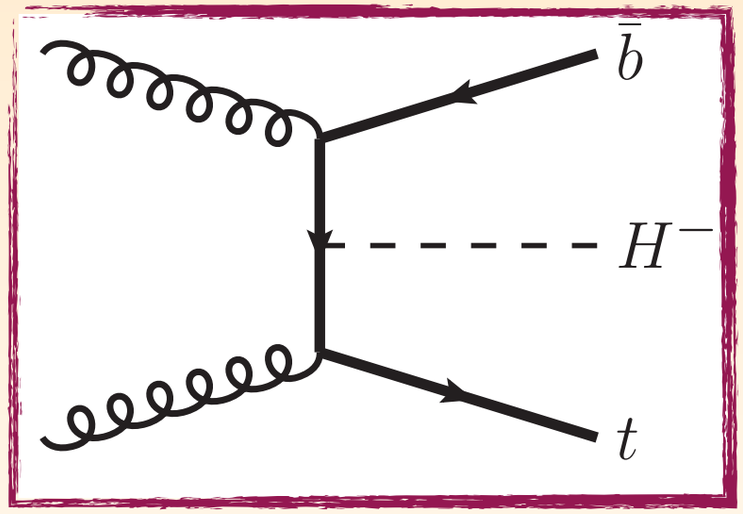
- In a 2HDM, charged Higgs bosons couple predominantly to top and b quarks
- Hence, largest cross section in the low and high mass ranges are computed from:

$m_{H^+} << m_{top}$



- Essentially top quark pair production, with (at least) one top decaying to a charged Higgs

$m_{H^+} >> m_{top}$

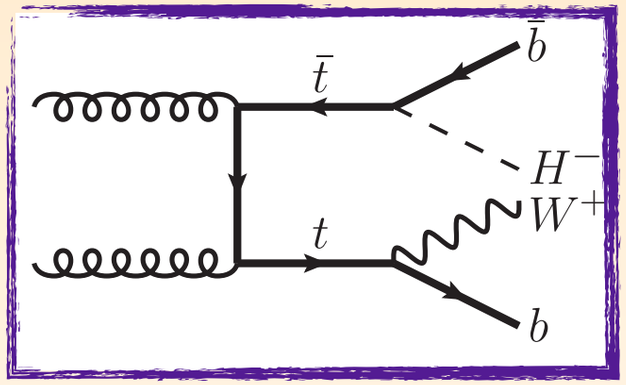


- Charged Higgs plus single top production. Also possible to describe using a 5 flavour scheme

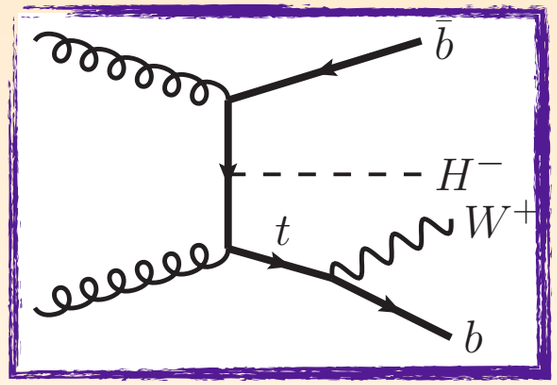
- Both calculation are known to NLO accuracy or better
- Characterised by the possibility of using a **zero top quark width**

Consistent description

- In the intermediate mass range, $m_{H+} \sim m_{top}$, one has to include the top quark width
- Hence, the complete process pp> HWbb needs to be considered. This process contains the following topologies/contributions at LO



- Double resonant
- Dominant for $m_{H+} << m_{top}$



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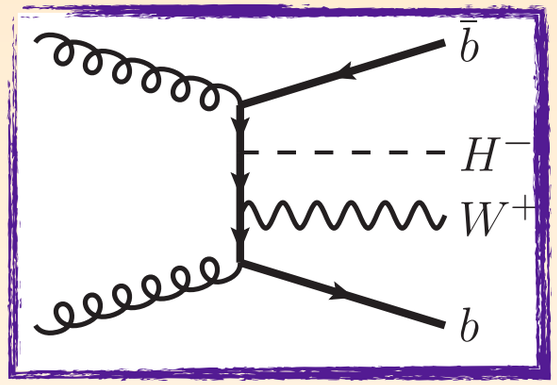
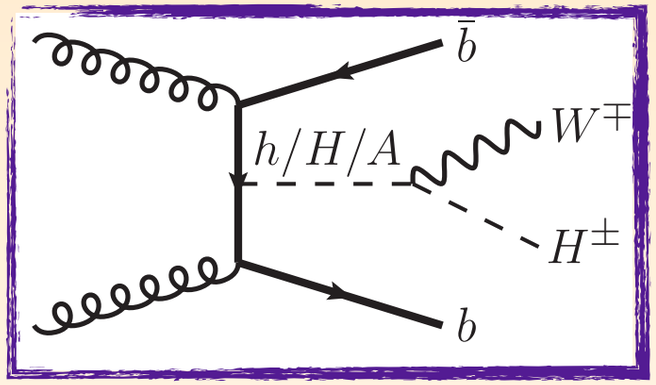


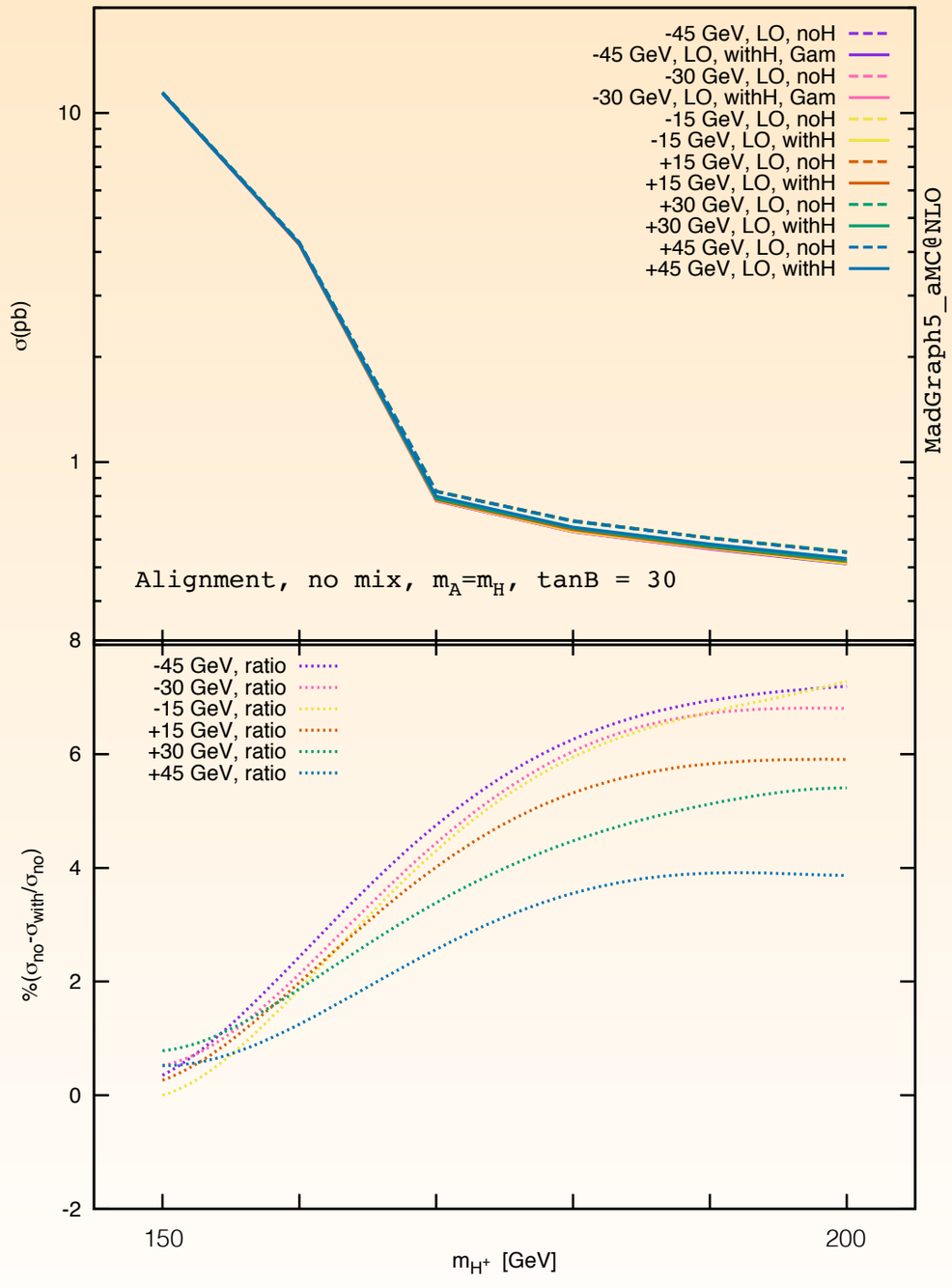
- Non-resonant
- Needed for gauge invariance



- Neutral scalar contributions
- Induce additional model dependence

- **For accurate predictions, need at least NLO accuracy**

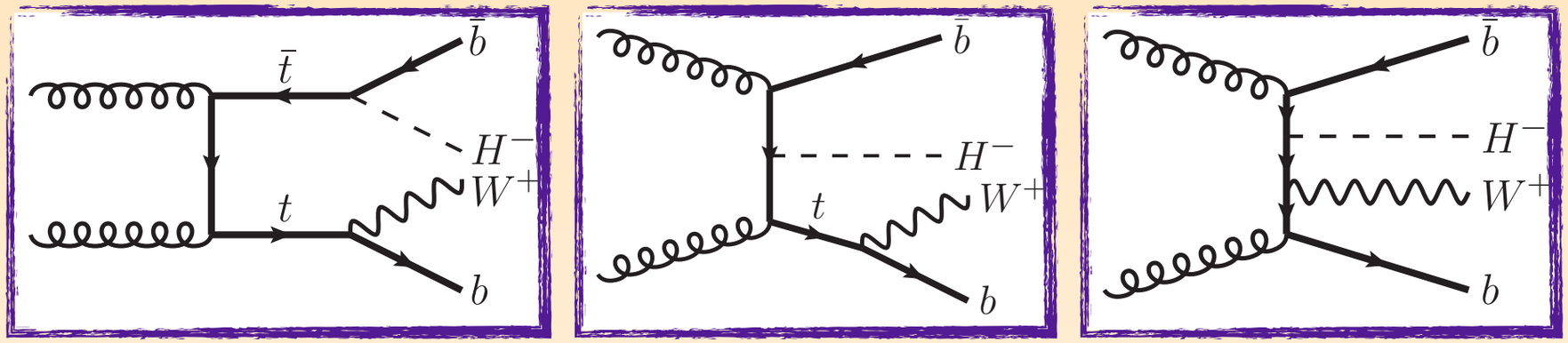
Contributions with Neutral Scalars



- A model scan at LO in the region allowed by EW precision fits shows that the contributions with **neutral scalars are small*** (at most 7% (they are largest in the alignment region, with $m_{H^+} > 180$ GeV and $m_H = m_A = m_{H^+} - 45$ GeV)), and we do **not include them in the computation**
  - They can be included at LO only, without hampering the NLO accuracy of the results
  - **Only 2 new parameters: the charged Higgs mass and tanβ**, just like in the low and high mass regions

* As long as they cannot go on-shell

Setup



- Complete NLO in QCD corrections
- 4 flavour scheme (massive b quark, no initial state b quarks)
- Focus on type-II 2HDM; considering tanβ=1, 8 and 30; others can be obtained from inter/extrapolation
  (bottom Yukawa: $y_b \sim \tan\beta$, top Yukawa: $y_{top} \sim 1/\tan\beta$)
- Complex mass scheme to include the top quark width in a gauge invariant way
- Renormalisation and factorisation scales are set to 125 GeV
  - Matches default scale for small mass and large mass 4FS calculations
  - Varied independently up and down by a factor 2 to approximate scale uncertainty
- NLO 4-flavour PDF4LHC15 α_S and parton distributions (also for the LO results)
- top and b mass parameters (and Yukawa) following the HXSWG recommendations

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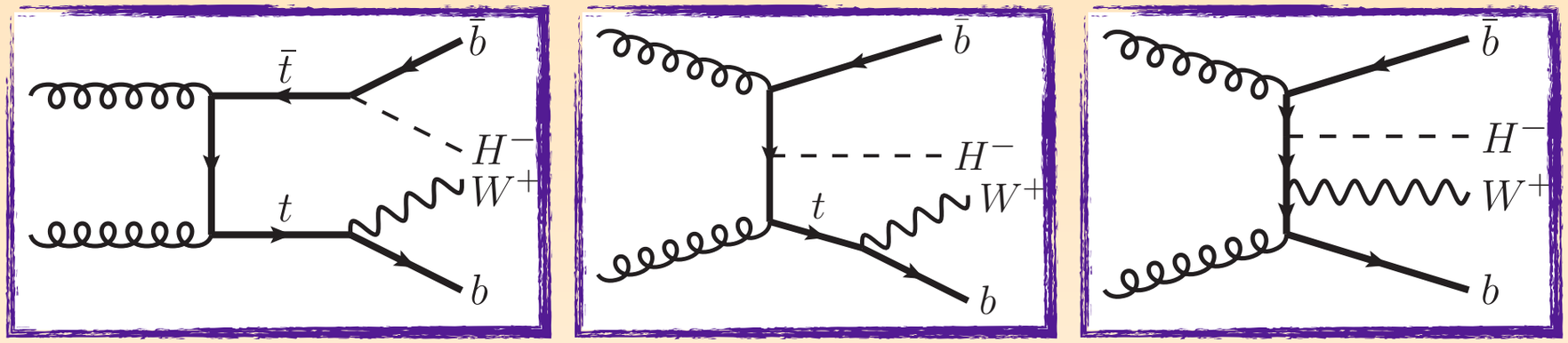

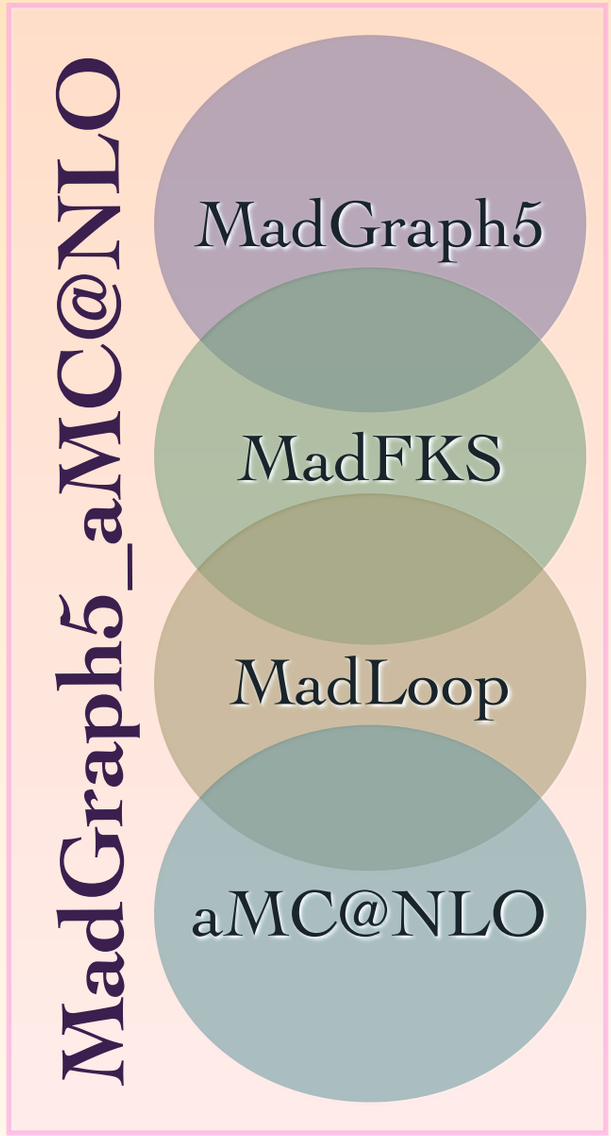

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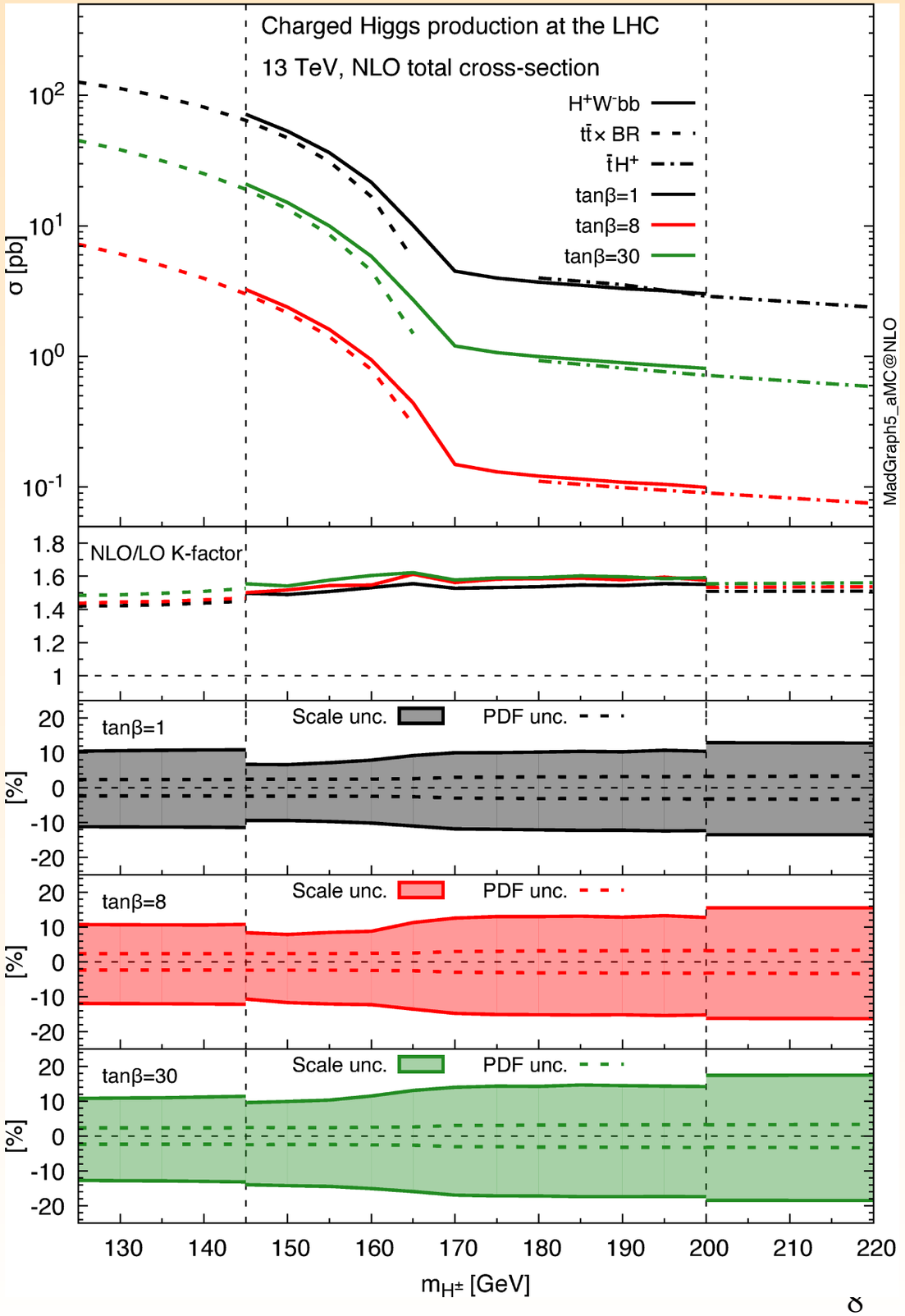
Results

- K-factor about 1.5-1.6 *, with very mild dependence on the charged Higgs mass and tanβ
- NLO scale dependence 8-17%; larger for large tanβ due to extra scale dependence in bottom Yukawa
- Smooth interpolation between dedicated low and high mass calculations with the new results
  - Dedicated high/low mass calculations using same setup/inputs as intermediate results
- O(10%) steps due to missing single (non) resonant contributions in the low- (high-) mass dedicated calculations



* usual precaution: large dependence on scales and other inputs

Other tan-beta values

- We extended the MadGraph5_aMC@NLO framework to give you separate results for each coupling order, i.e. $\sigma(y_b^2)$, $\sigma(y_b y_{top})$, $\sigma(y_{top}^2)$
- This allows for easy inter/extrapolation to other tanβ values using

$$\sigma(\tan\beta') = \left[\left(\frac{\tan\beta'}{\tan\beta}\right)^2 \sigma_{y_b^2}(\tan\beta) + \sigma_{y_b y_t}(\tan\beta) + \left(\frac{\tan\beta}{\tan\beta'}\right)^2 \sigma_{y_t^2}(\tan\beta)\right] \times \left(\frac{\Gamma_t(\tan\beta)}{\Gamma_t(\tan\beta')}\right)^2$$

- Cross checked that using this formula, the cross sections for tanβ=1 and tanβ=30 can be obtained from the tanβ=8 results within about 1% (which is the MC integration uncertainty for each of the results)
- Also cross sections for other scenarios, e.g. a type-I 2HDM, can be obtained in this way
- Cross sections available at: https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCHXSWGMSSMCharged#Intermediate_mass_145_200_GeV_ch

Conclusions

- The long standing problem of charged Higgs production in the intermediate mass range has now been solved
- This allows one to set meaning full limits on charged Higgs cross sections, which **can be compared to accurate theoretical predictions**
- New Results match rather will with dedicated, simpler low and high mass calculation (which are based on neglecting the top quark width)
- Our central NLO value is about 1.5-1.6 times larger than our LO value, with only a very mild dependence on the charged Higgs mass and tanβ value
  - Outlook: would be interesting to see if this factorisation is also valid for more exclusive observables or differential distributions