Studies of b-associated production of neutral MSSM Higgs bosons

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PHYSICS AT THE TERA SCALE

Helmholtz Alliance

BMBF-Forschungsschwerpunkt
ATLAS Experiment

Physics on the TeV-scale at the Large Hadron Collider

FSP 101

ATLAS

Outline

Main emphasis: Not discuss discovery potential, but list possible areas of cooperation between the different experiments and theorists.

For example: Which MC generator to use ?
How to normalize (consistently) to higher orders ?
How to get a proper estimate of the uncertainty of this normalization ?

- short introduction to the MSSM
- b-Quark associated Higgsboson production
  - Generator comparisons
  - Normalization
- ATLAS result on discovery potential in muonic decay mode

MSSM Higgs-Sector

- 2 Higgs doublets → 5 Higgsbosons
  - h^0, H^0 (CP=+1) A^0 (CP=-1) $H^{\pm}$
- In leading order determined by $\tan\beta = v_2/v_1$ und M_{A^0}

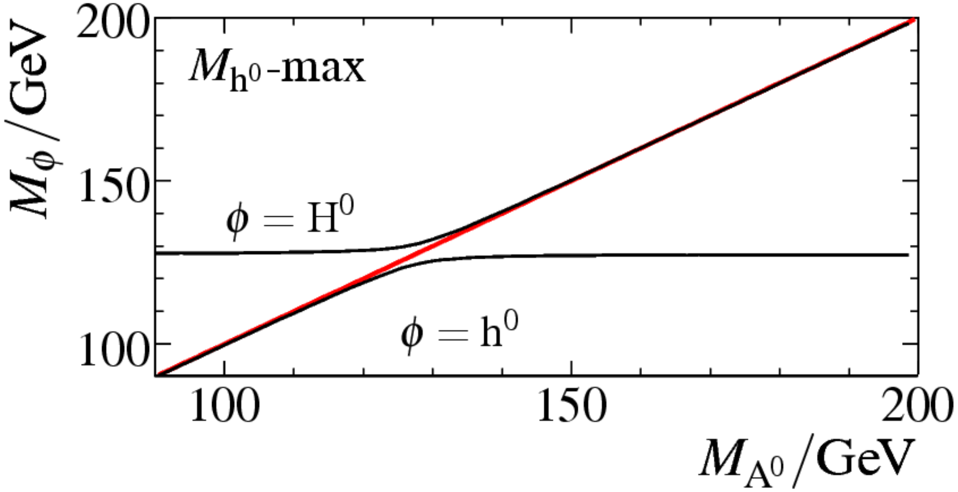
g_{MSSM}/g_{SM}	u,c,t	d,s,b e,μ,τ	W/Z
h^0	$\cos\alpha/\sin\beta$	$-\sin\alpha/\cos\beta$	$\sin(\alpha-\beta)$
H^0	$\sin\alpha/\sin\beta$	$\cos\alpha/\cos\beta$	$\cos(\alpha-\beta)$
A^0	$\cot\beta$	$\tan\beta$	-----

α = Mixing between h^0,H^0

- large tanβ: Enhanced couplings to b,τ,μ
- Higher-order corrections: additional 5 parameters: X_t, M_0, M_2, M_{gluino}, μ
- Benchmarkscenarios: All parameters except tanβ and M_{A^0} fixed, e.g.: **M_h^{max}-scenario**

Higgs sector for large tanβ

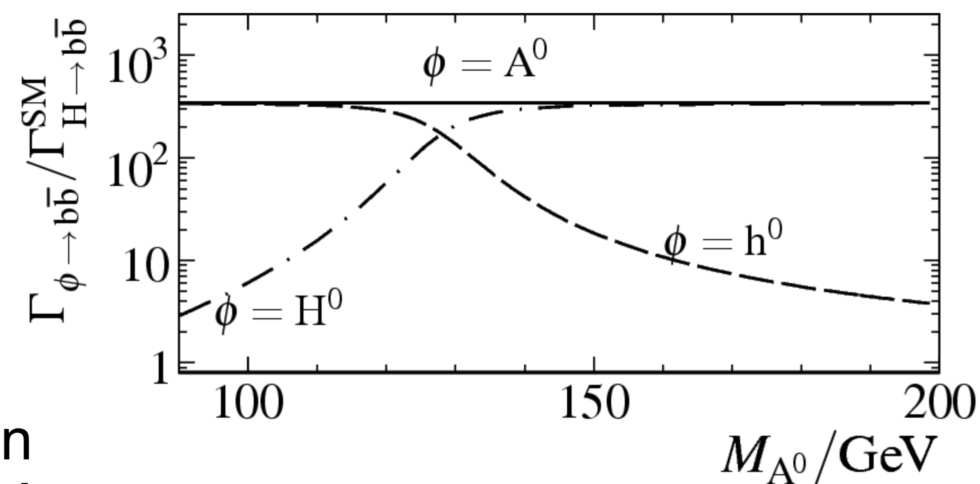
Masses of h^0 and H^0
either of them almost mass degenerate with A^0



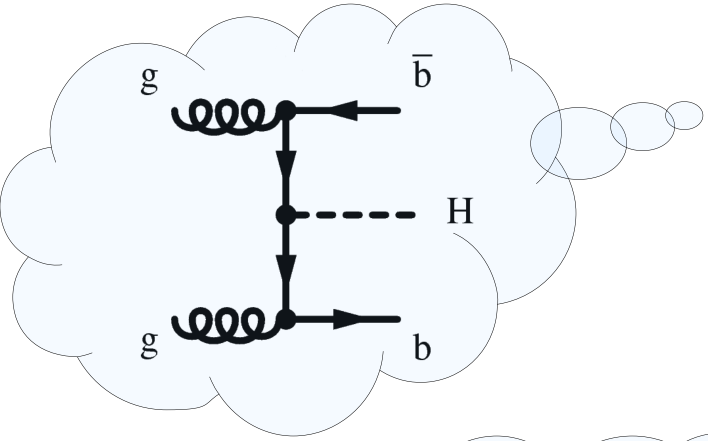
Coupling to down-type fermions

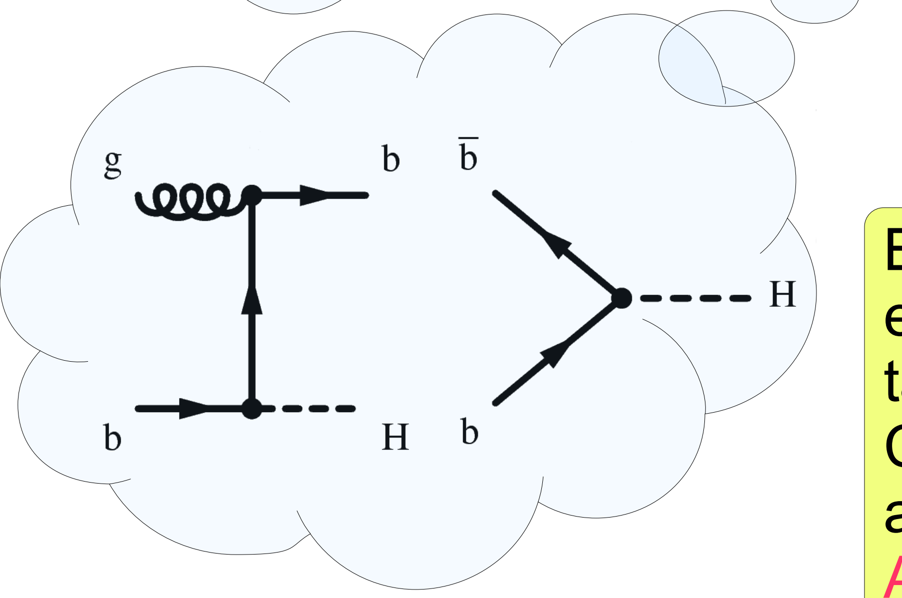
- enhanced for degenerate states
- b-associated production ($\sigma \propto \tan^2\beta$)
- most important decays:
  bb ~90%
  ττ ~10%
  μμ ~10^{-4}

BUT: good mass resolution in muonic final state!



b-associated Higgsboson production





b's at low pt: large collinear logarithms

- most reliable for both b's at high p_t

move one or both gluon-splittings into a b-pdf

- best for exactly one or zero b's at high p_t

BUT: Typical analysis splits into exactly zero and at least one b-tagged jet !
Cannot simply add the three approaches to simulate samples.
Avoid double-counting by using SHERPA (CKKW-matching) !

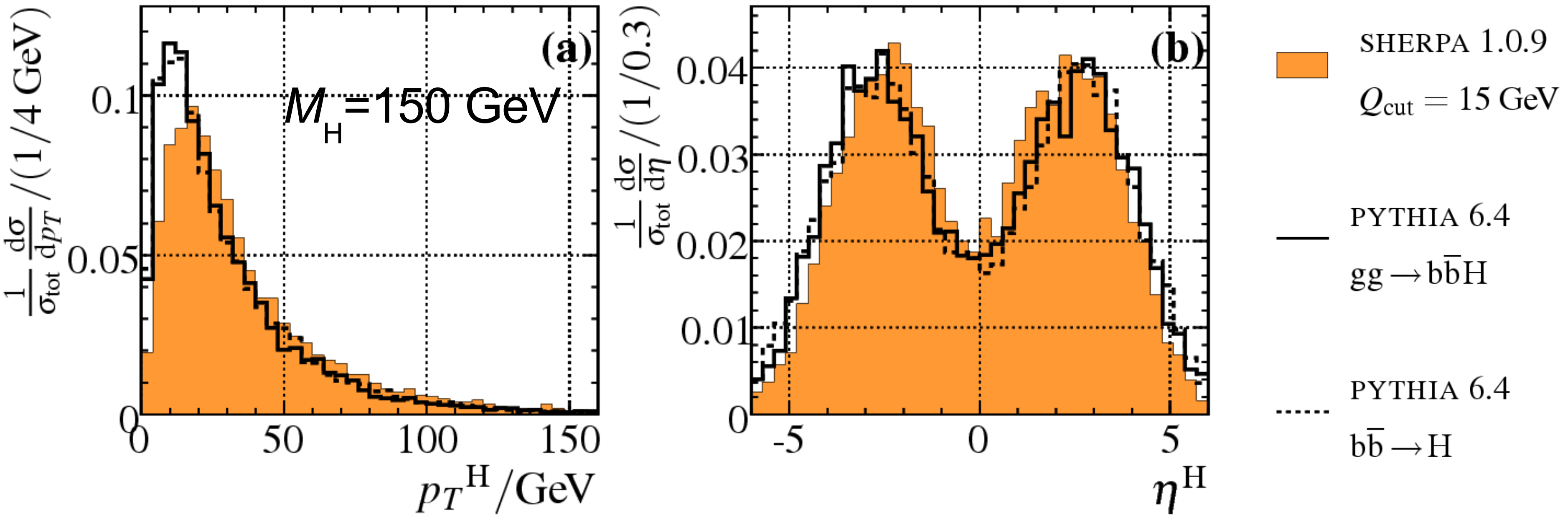
Generator comparisons

So far: used mainly Pythia gg→bbH as signal process

compare to SHERPA and Pythia bb→H

$\sqrt{s}$=14 TeV

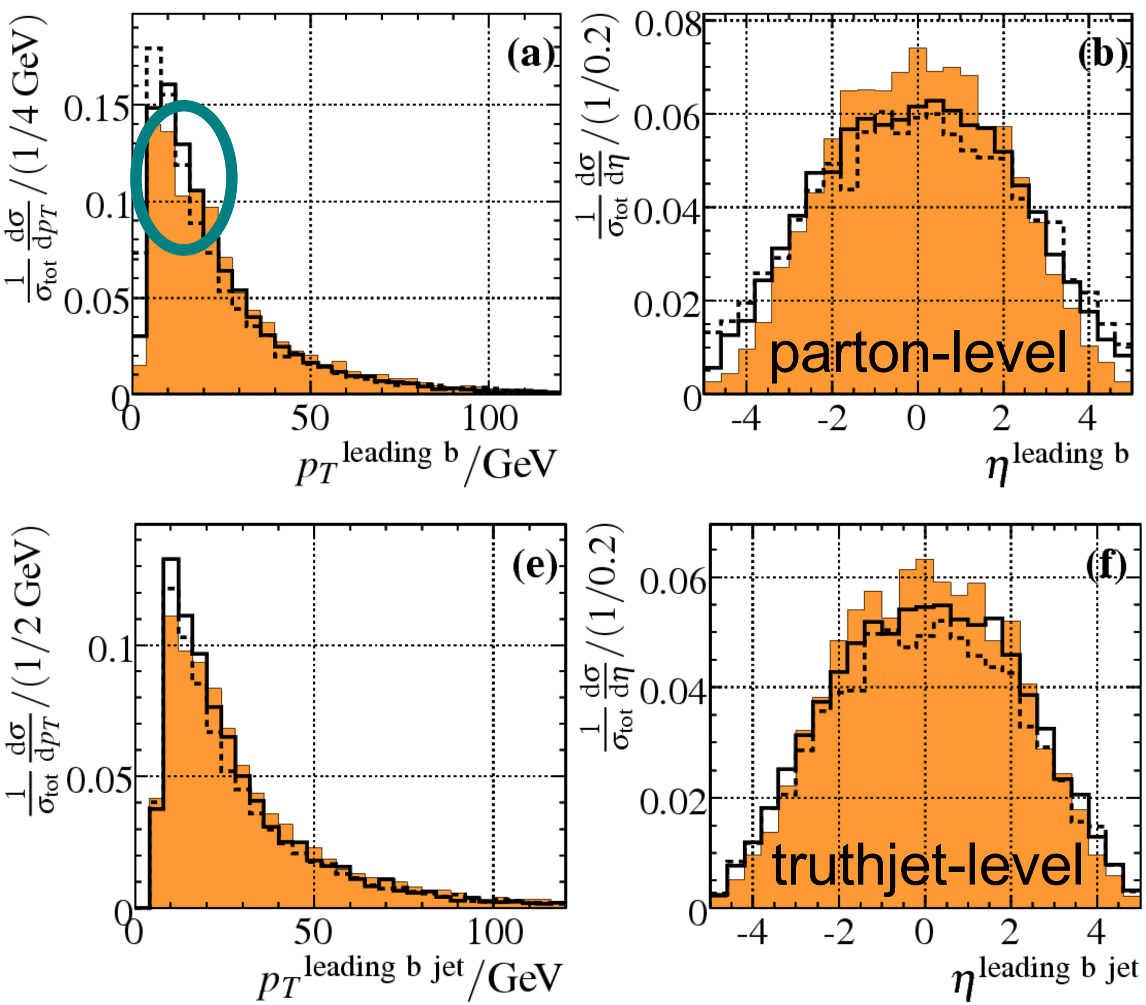
Distributions for the Higgs boson



SHERPA slightly harder, more central
gg→bbH and bb→H remarkably similar

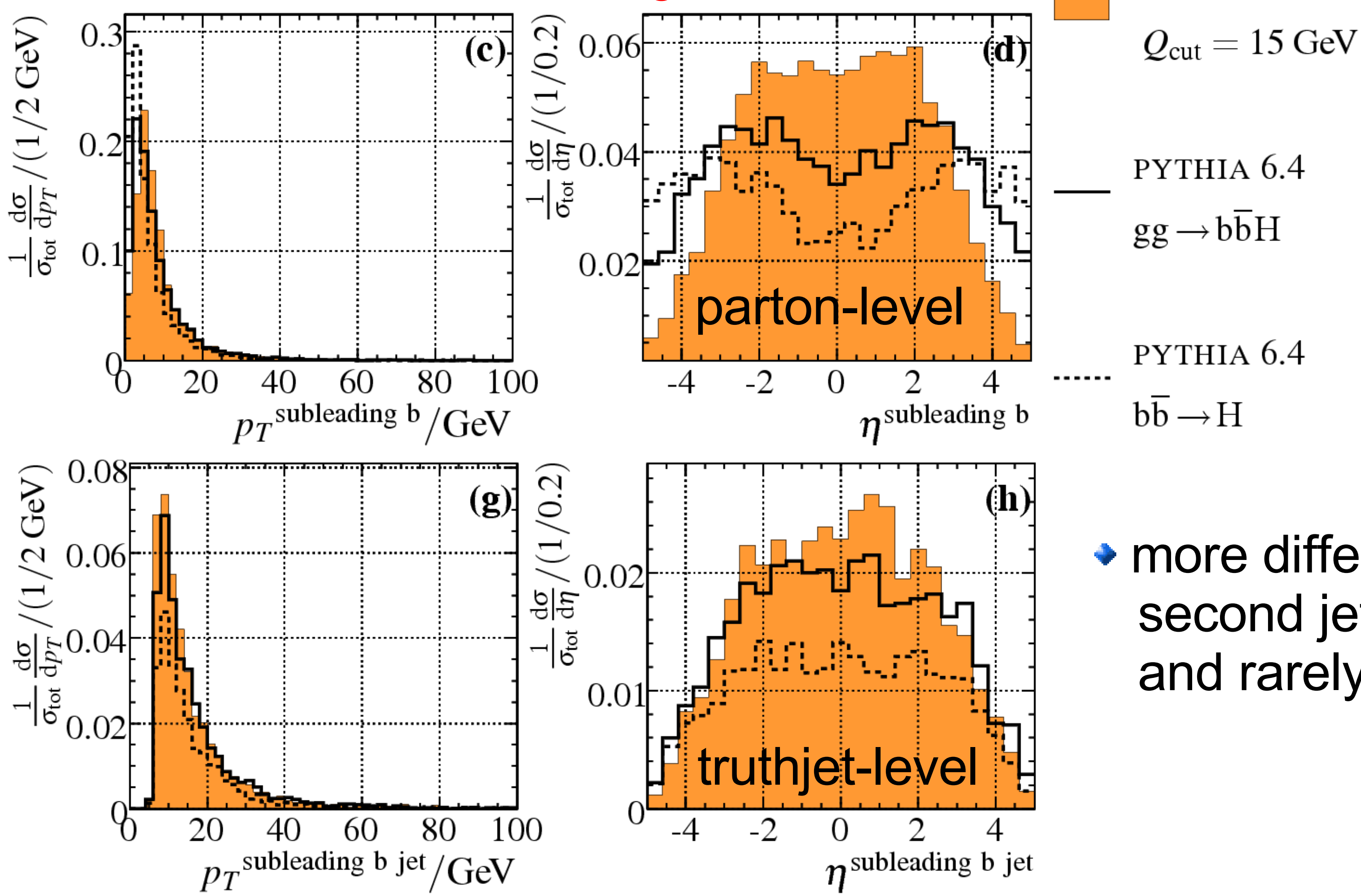
Generator comparisons

leading b



- slightly harder/more central in SHERPA
- slight depression in SHERPA around the matching scale
- less pronounced out on truthjet-level

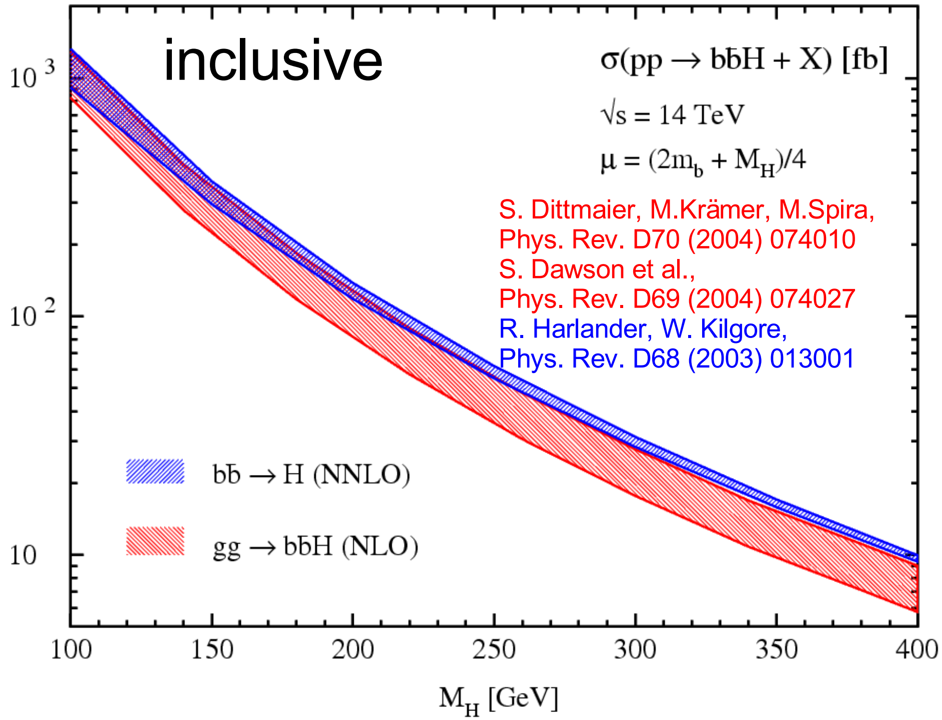
subleading b

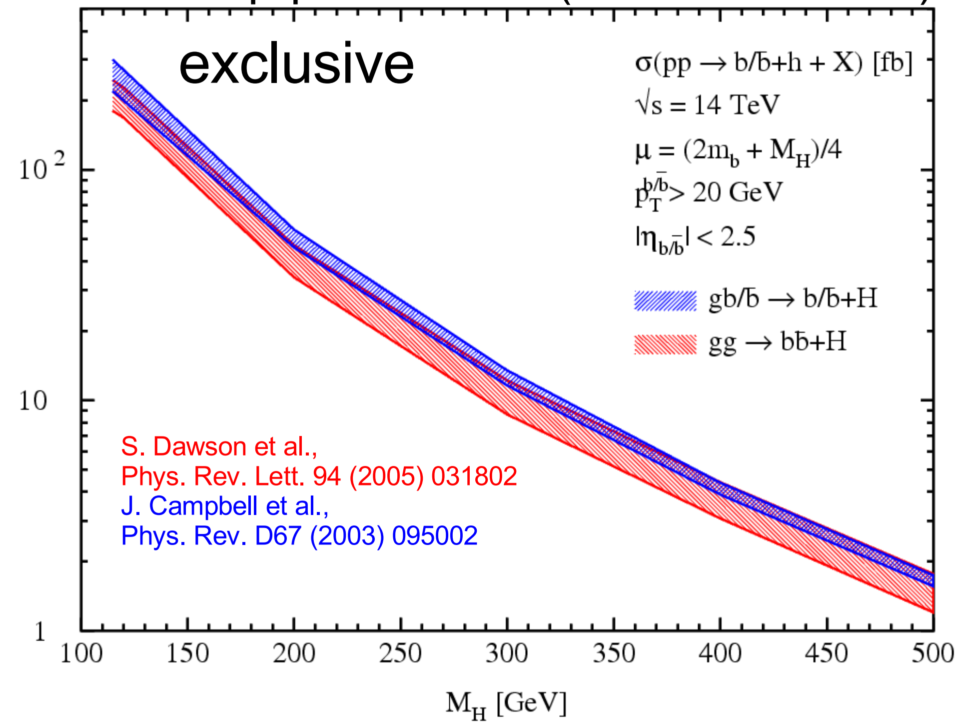


- more differences, but second jet is very soft and rarely observable

Comparison to theory predictions

from hep-ph/0406152 (Les Houches 03)





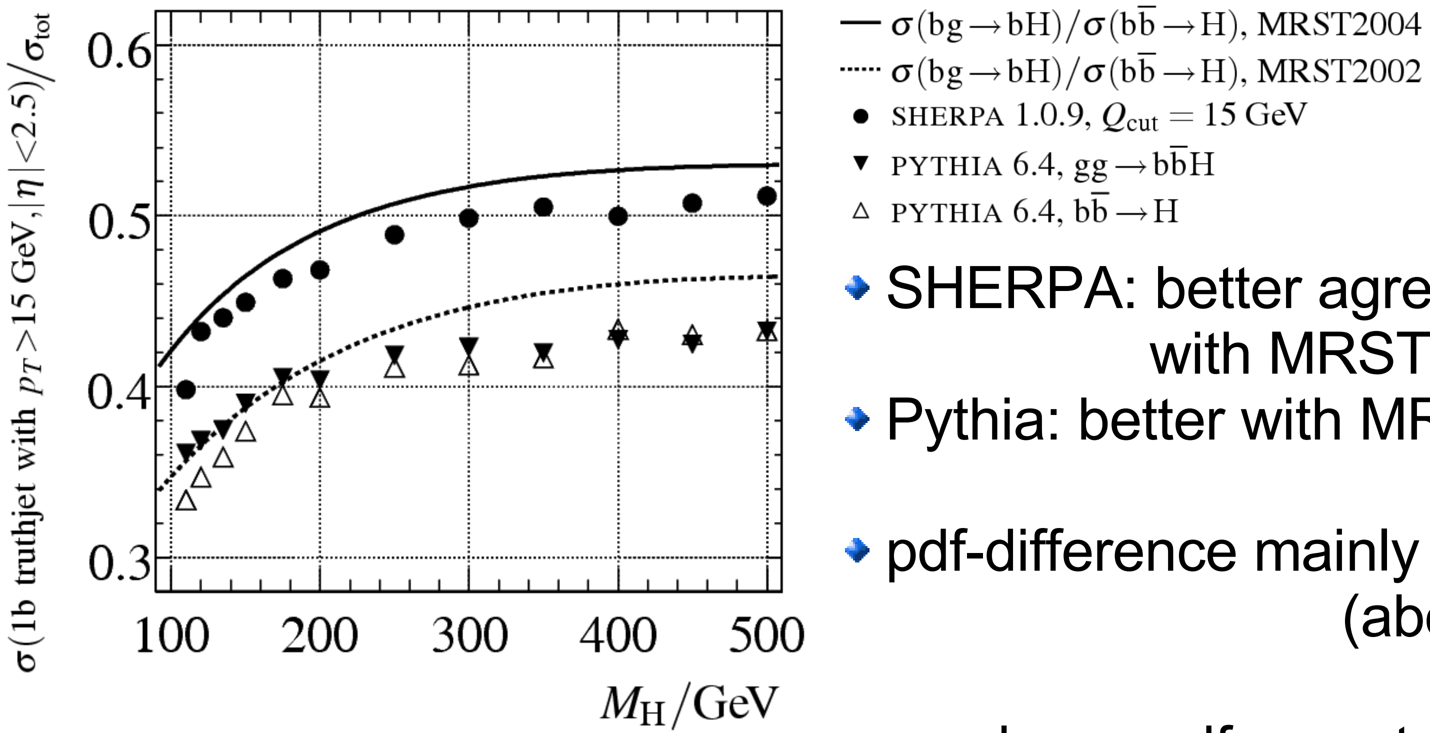
blue line: numerical values supplied by Robert Harlander

(two PDF sets: MRST2004 and MRST2002)

blue line: implemented into MCFM, so easy to calculate

compare ratio of exclusive to inclusive cross section to the one-jet-rate in the Monte Carlo

Exclusive one-b-jet rate



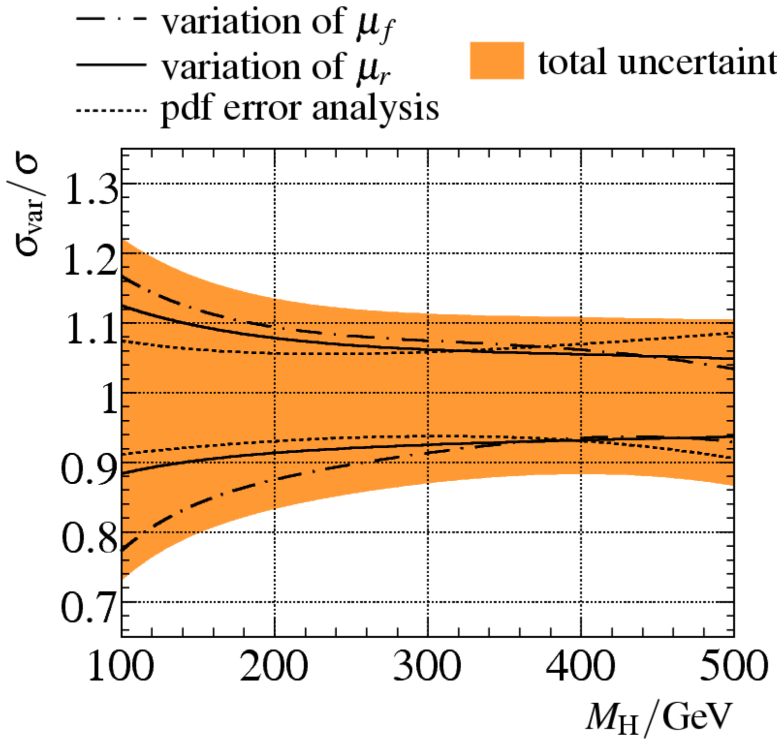
- SHERPA: better agreement with MRST2004
- Pythia: better with MRST2002
- pdf-difference mainly in σ(bb→H) (about 15%)
- used as a pdf-uncertainty on the total cross section

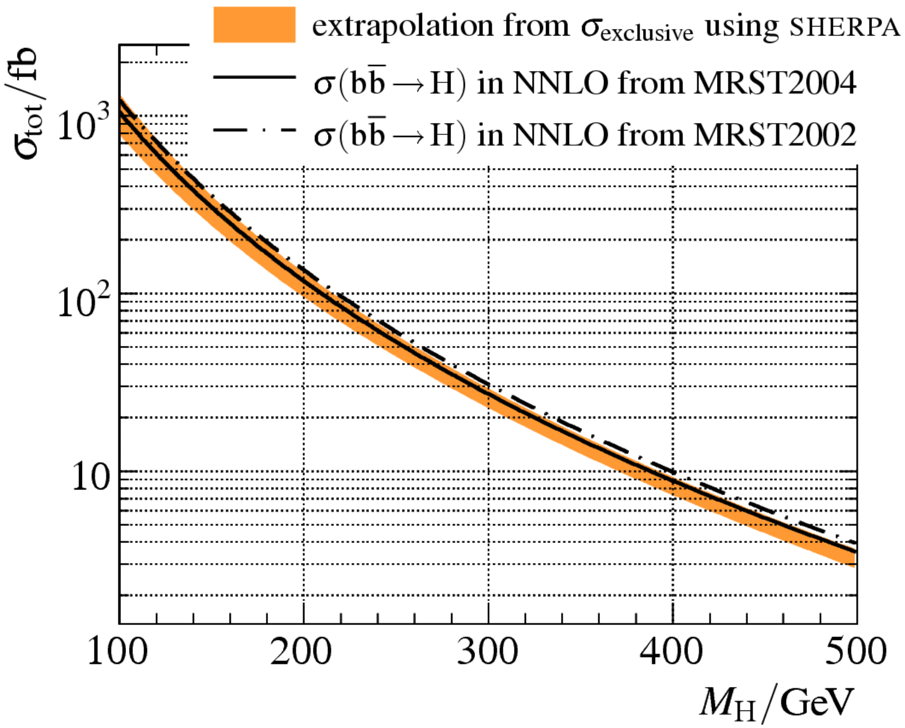
Within uncertainties good agreement for both generators !

Normalization

1. Use inclusive cross section σ(bb→H), use difference between PDF-sets as uncertainty. **Used in recent ATLAS analyses!**

2. Normalize to the σ(bg-->bH), extrapolate to full phasespace by MC one-truthjet rate.
   Pro: can do scale and pdf-variation in MCFM (CTEQ6M error sets)





Reweighting to MSSM

- Cross sections only for SM Higgs bosons
- Reweight to MSSM by ratio of partial widths

$$\sigma^{\mathrm{MSSM}}_{\mathrm{b\bar{b}}\phi}(M_{\mathrm{A}^0}, \tan\beta) = \sigma^{\mathrm{SM}}_{\mathrm{b\bar{b}H}}(M_\phi) \cdot \frac{\Gamma^{MSSM}_{\phi\to\mathrm{b\bar{b}}}(M_{\mathrm{A}^0}, \tan\beta)}{\Gamma^{\mathrm{SM}}_{\mathrm{H}\to\mathrm{b\bar{b}}}(M_\phi)}, \ \phi \in \{h^0, H^0, A^0\}$$

- This is exactly the way it is done in FEYNHIGGS to print out production cross sections. The SM cross sections come from a look-up table, and are not really calculated !
- Better way to do it ? - Sure, but is it as easy ?
- Remember: We need these cross sections basically arbitrary MSSM parameters in order to do a scan of the (M_A, tanβ)-plane !

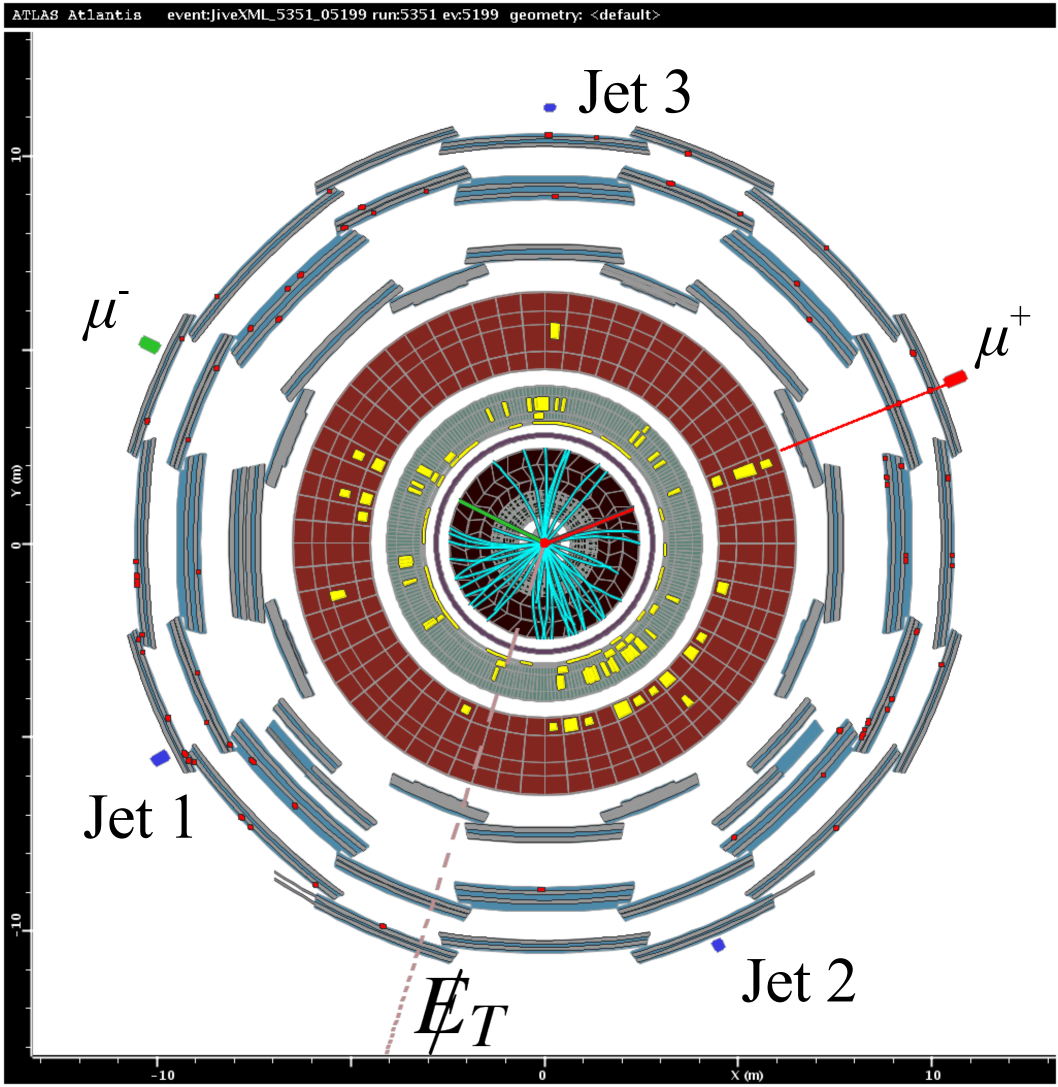
Analysis

Signal characteristics:

- $\mu^+\mu^-$ pair
- no significant missing transverse energy
- soft b-jets

Main backgrounds:

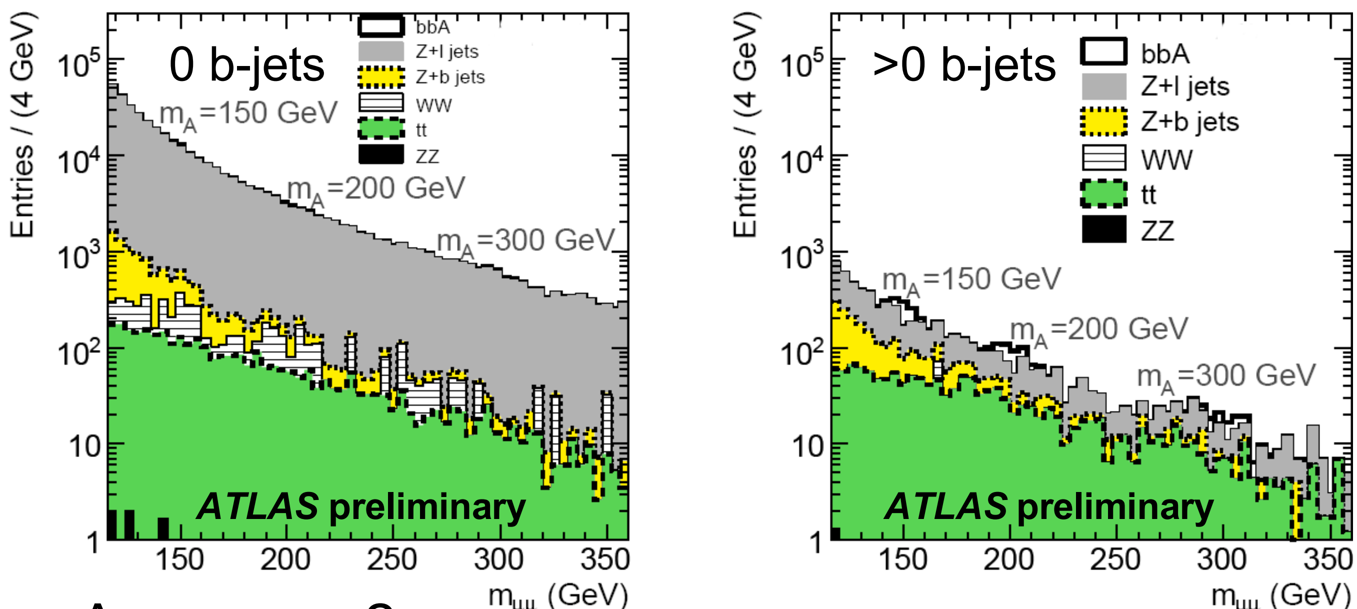
- Z^0+jets
  - Z^0+b irreducible
  - Z^0+udsgc reducible by b-tagging
- ttbar
  - real b-jets
  - missing transverse energy
  - more jet activity



Analysis

- Muon preselection: 2 muons, p_T>20 GeV, $|\eta|$<2.7
- E_t^{miss}<40 GeV
- split analysis:
  - b-tag: further cuts against ttbar: Acoplanarity $|\sin\varphi_{\mu\mu}|$<0.75, $\sum p_t$(jets)<90 GeV
  - b-tag-veto

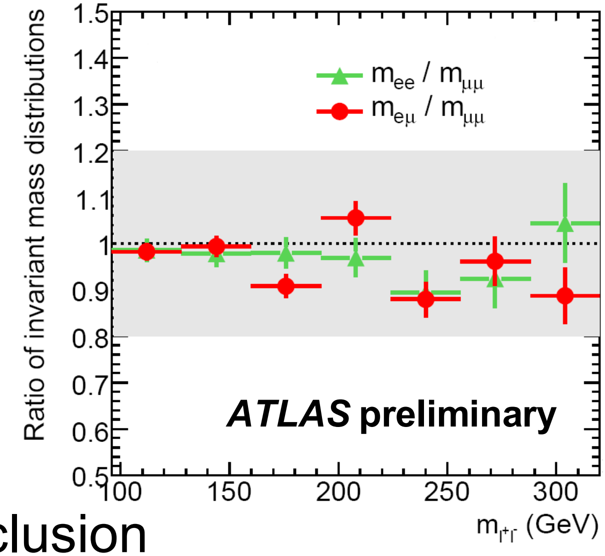
L=30fb^{-1}, 14 TeV



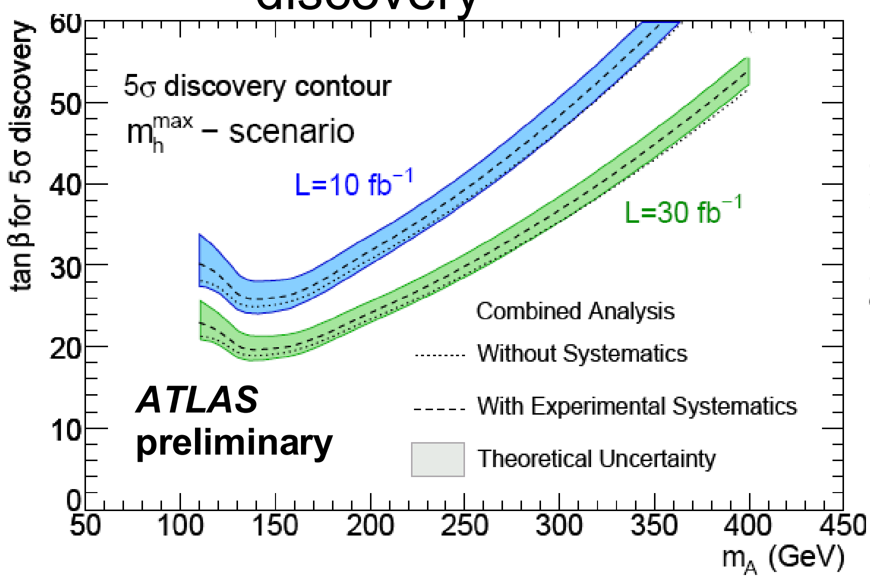
Last: Mass Window $\Delta m = m_A \pm 2\sigma$

Discovery potential

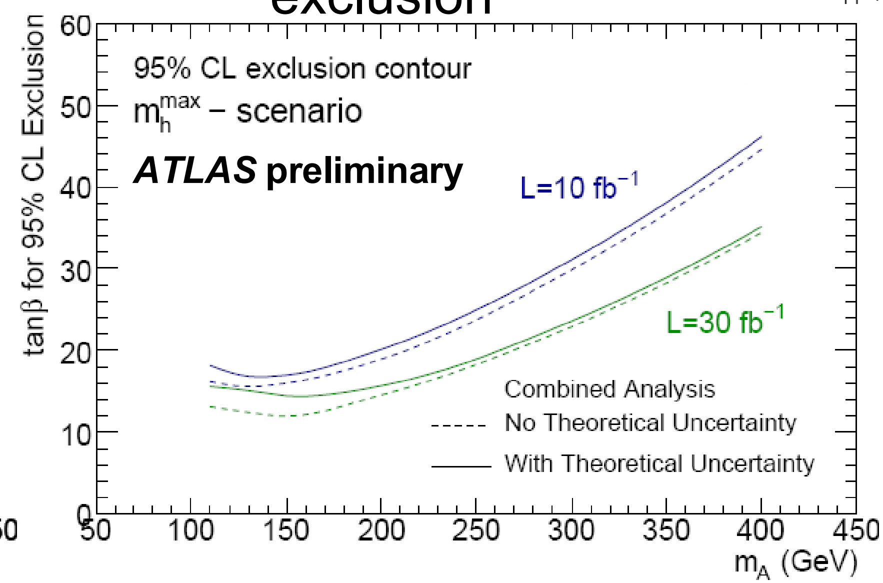
- Large systematic uncertainties on background rates
- Studies to extract the background from data:
  - Z→μμ from Z→ee (ATLAS-PHYS-PUB-2006-019)
  - ttbar from eμ final state



discovery



exclusion



Summary

- b-quark-associated Higgs boson production in the MSSM
  - generator comparisons
  - normalization

    Uncertainty due to different pdf-sets warrants closer investigation.
  - Reweighting from SM to MSSM cross sections.
- (generators and normalization for background processes)
- Preliminary ATLAS analysis of discovery potential:
  - crucial to estimate the background from data
  - good discovery potential for small masses and large tanβ

ATLAS Collaboration, Expected Performance of the ATLAS Experiment, Detector, Trigger and Physics, CERN-OPEN-2008-020, Geneva, 2008, to appear.