bbH part (II)
(experiment)

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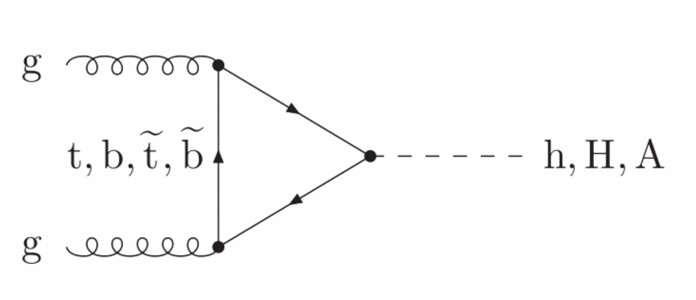
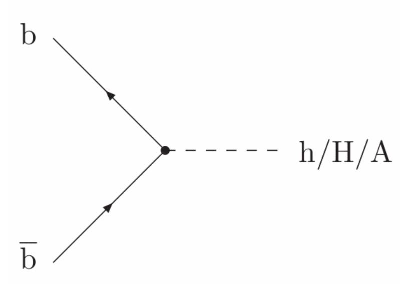
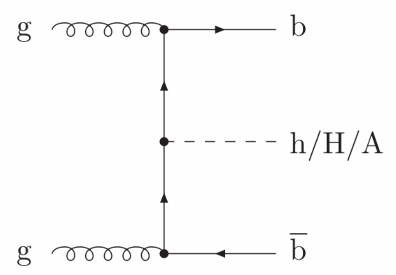
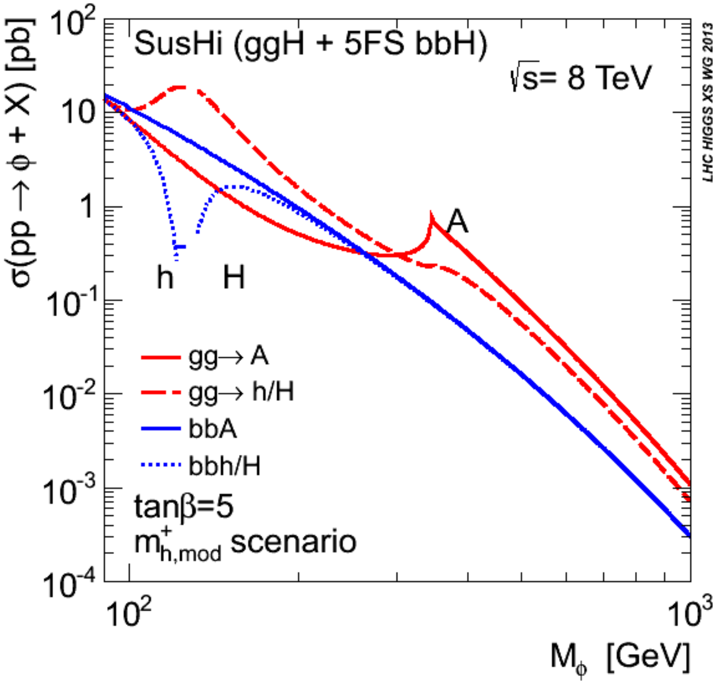
8th LHCHXSWG meeting
CERN, 22-24th Jan. 2014

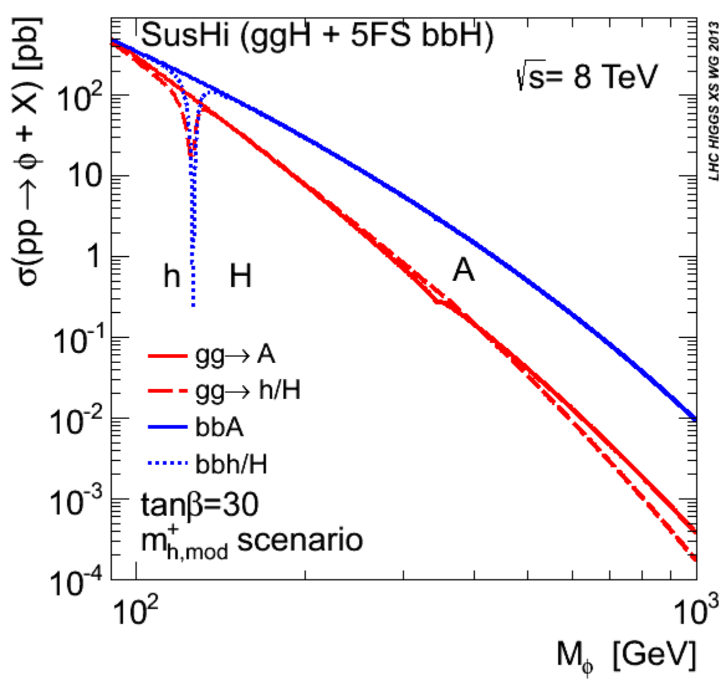
MSSM neutral $\phi \to \tau\tau$ analysis





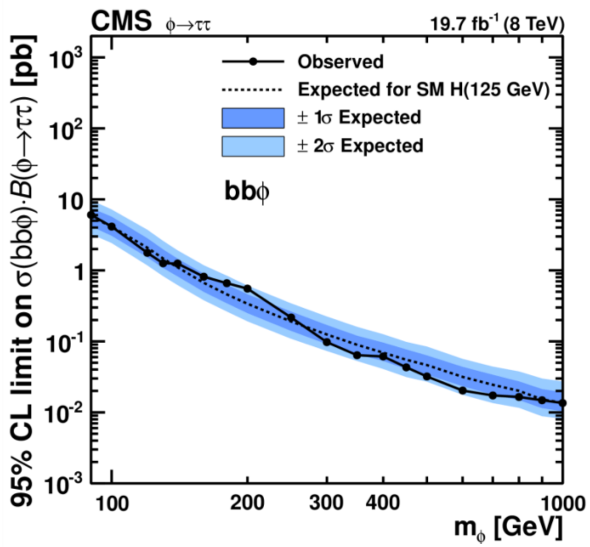


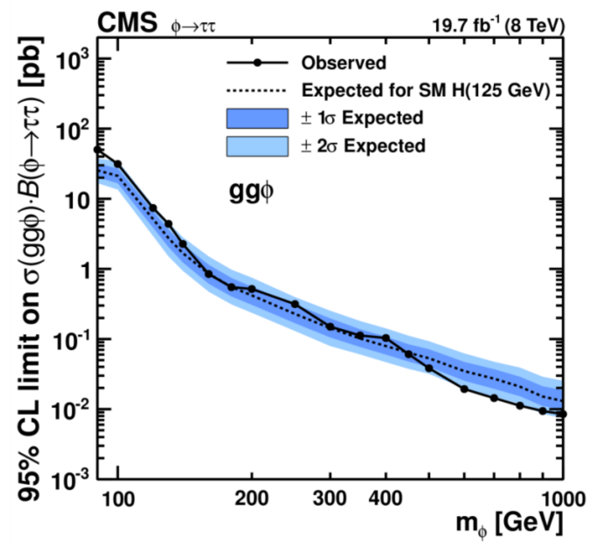


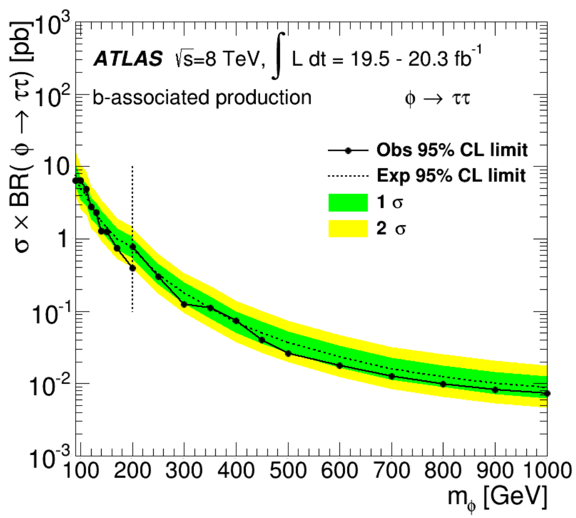


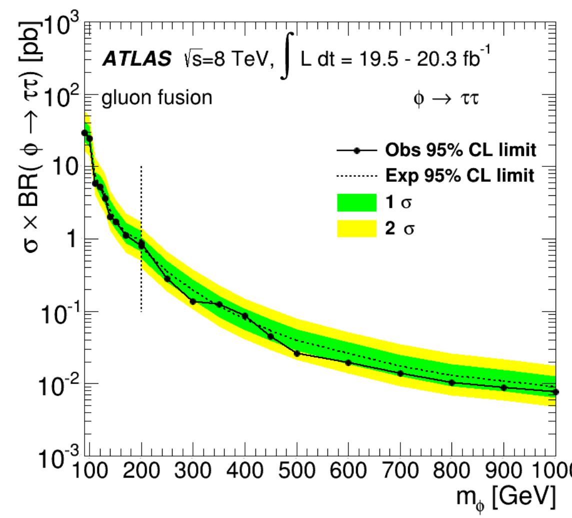
- **split events into b-tag and no-b-tag categories**
- **consider $\tau_\mu\tau_h$, $\tau_e\tau_h$, $\tau_h\tau_h$, $\tau_e\tau_\mu$, $\tau_\mu\tau_\mu$ final states**

ϕ->ττ : “model independent” limits





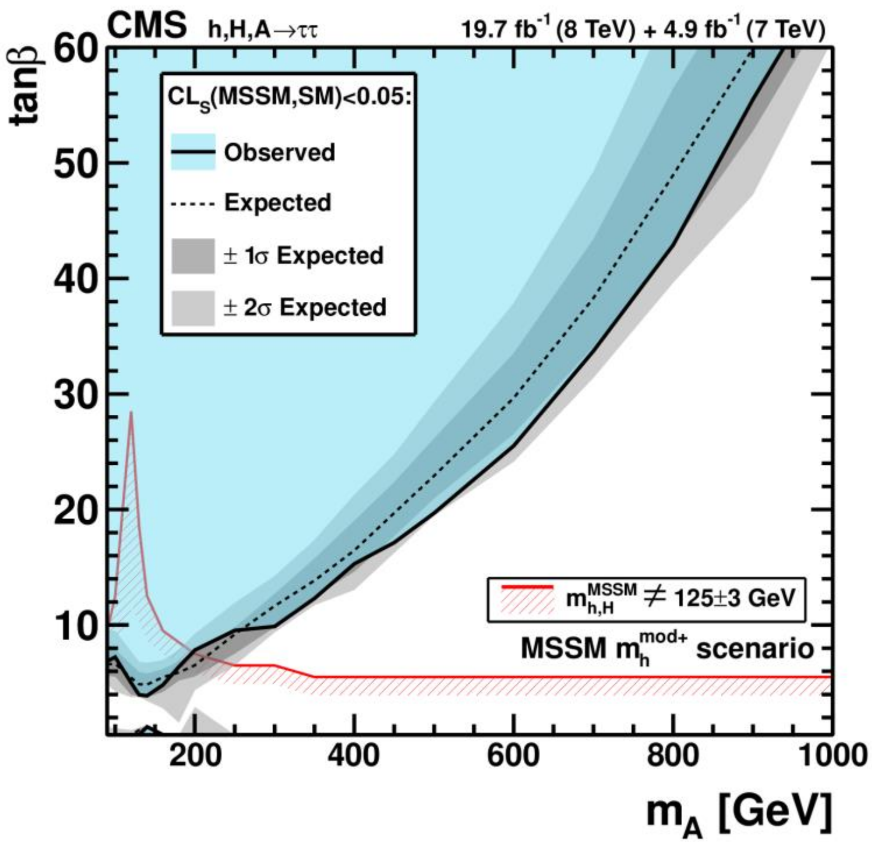


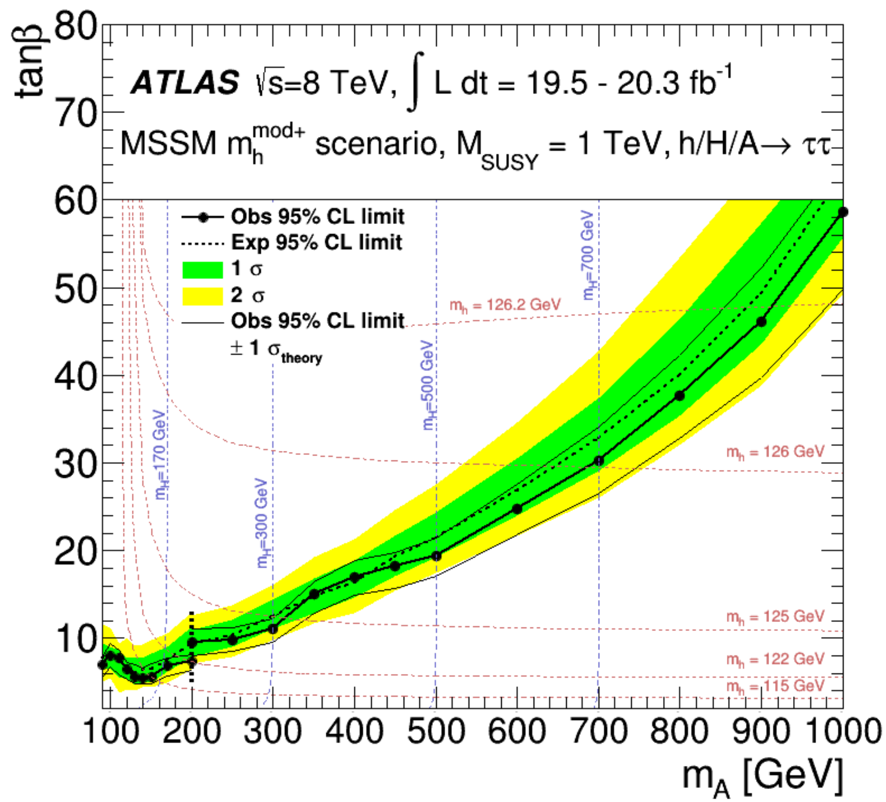


- **Go to MSSM interpretation using inclusive cross section and uncertainties provided by LHCHXSWG**

$\phi \to \tau\tau$: interpretation in MSSM benchmark scenarios

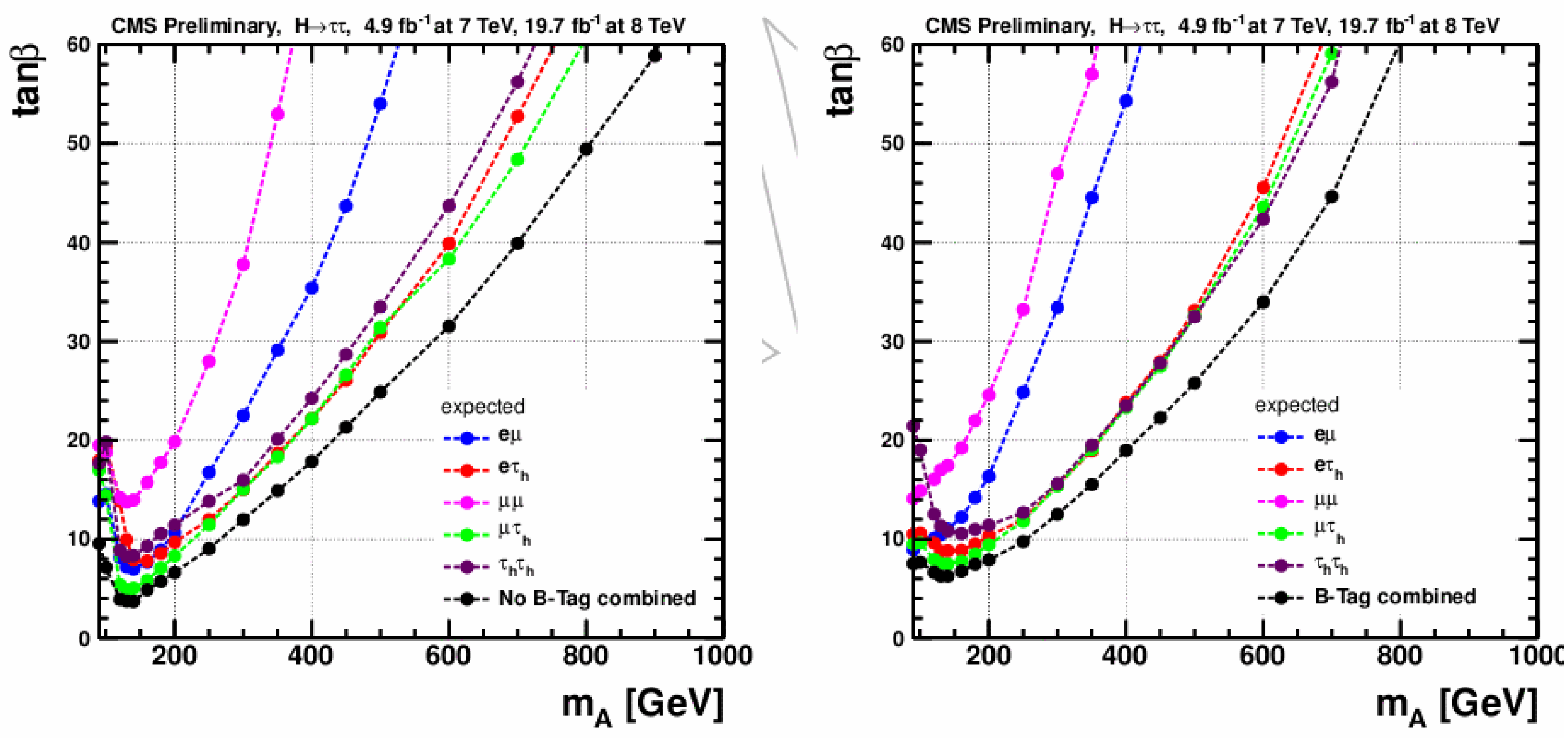
- **Example: m_h^{mod+} scenario from M.Carena at al. arXiv:1302.7033**





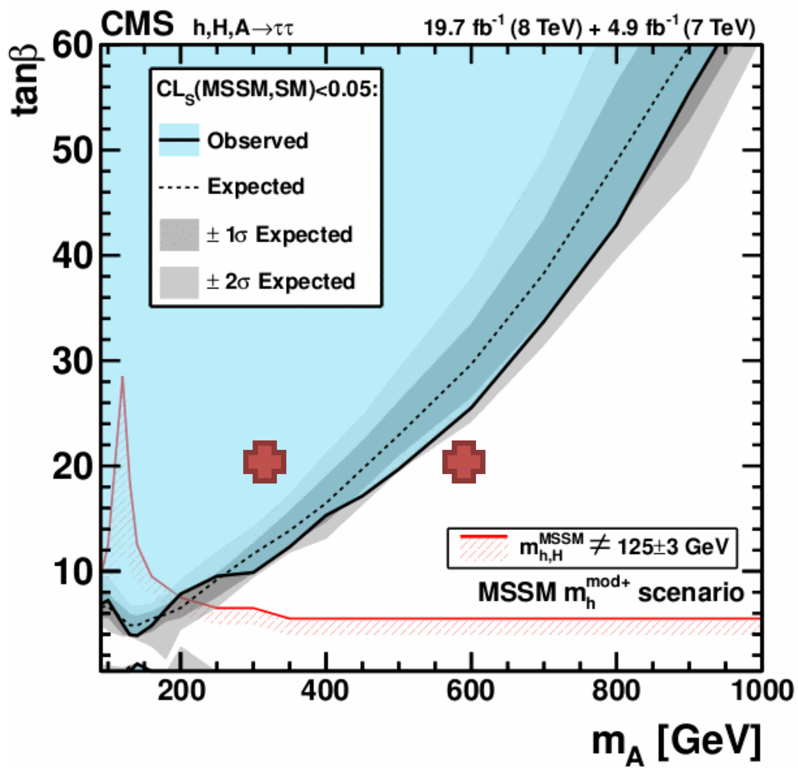
How big is bbH contribution in this analysis ?

- **b-tag and non-b-tag categories have the similar sensitivity**



- **Obviously b-tag category is dominated by bbH**

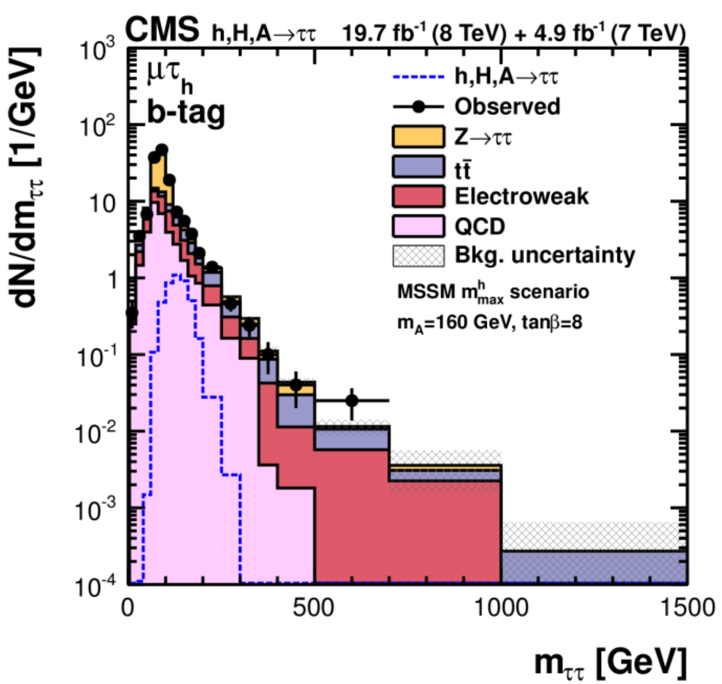
- **Non b-tag category is also dominated by bbH at large m_A**

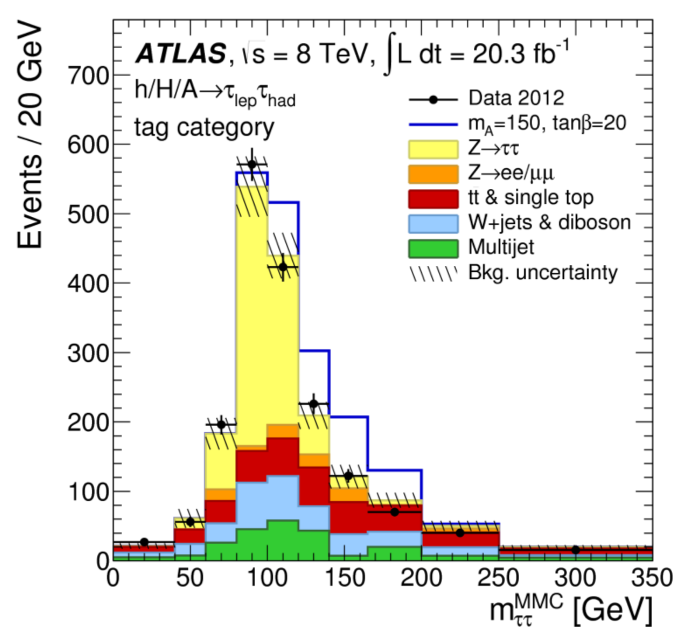


	m_A=300 GeV tanβ = 20	m_A=600 GeV tanβ=20
σ(gg->A+H)/σ(bb->A+H)	0.16	0.08
σ(gg->A+H)/σ(bb->A+H) x $(\varepsilon_{gg\to H}/\varepsilon_{bb\to H})^{exp}$	0.20	0.27

In what m_ϕ region we are searching for the $bb\phi$ process ?

- for both low and high Higgs boson masses
  - new: 20 GeV < m_A < 70 GeV, 2HDM pp->bbA, A->μμ,ττ
    - Motivated by Gunion et al. arXiv:1412.3385, arXiv:1405.3584
    - Run new analysis with 8 TeV data, will continue with 13 TeV data
  - m_A > 200 GeV, continue MSSM, 2HDM analysis with 13 TeV





- Heavily relay in the analysis on the signal acceptance calculation from bbH Monte Carlo
- Used so far in the public MSSM analyses:
  - CMS PY6 2->3, pp->bbH
  - ATLAS LO Sherpa 1.4.1

- bbH process implemented recently in aMC@NLO_MG5 in 4FS
  - M. Wiesemann at al, “Higgs production in association with bottom quarks”, arXiv:1409.5301, 18^{th} September 2014
- Questions we have just started to address
  - how the acceptance efficiency is different between LO and NLO ?
  - what is uncertainty of the kinematical acceptance due to
    - Shower matching Q_{sh}
    - Renormalization and factorization scales μ_R, μ_F
  - what is uncertainty in the kinematical distribution ?

A few first results

1. Difference in the acceptance between the old (LO) and new (NLO) generation;

a parton level analysis

Signal selection efficiencies MG5_aMC@NLO+PY8 vs PY6 for pp->bbA, A->$\tau\tau$, m_A=400 GeV

	Selection on τ_h p_T and h for both τ_h used in CMS MSSM H->$\tau_h\tau_h$ analysis (still need to apply on τ_h but not to τ)	
	aMC@NLO_MG5+PY8	PY6
p_T^{τ} >45 GeV, $\lvert\eta^{\tau}\rvert$ < 2.4	0.895	0.860
>= 1 b-jet p_T >30 GeV, $\lvert\eta\rvert$<2.4	0.383	0.346
1 b-jet no other jets $\lvert\eta\rvert$< 4.7	0.379	0.579

- ~ 30 % difference in the jet veto efficiency

Signal selection efficiencies MG5_aMC@NLO+PY8 vs PY6 for pp->bbA, A->$\mu\mu$, m_a=30 GeV

	Selection on muon p_T, GeV $\|\eta\|$ < 2.1 for both muons					
	10		15		20	
	NLO+PY8	PY6	NLO+PY8	PY6	NLO+PY8	PY6
Muon selections	0.368	0.379	0.059	0.057	0.013	0.014
>= 1 b-jet after μ's sel. p_T >30 GeV, $\|\eta\|$<2.4	0.114	0.106	0.307	0.379	0.613	0.731
1 b-jet no other jets $\|\eta\|$< 4.7	0.402	0.751	0.298	0.722	0.171	0.640

- **Huge difference in additional jet veto**
  - decided to change a search strategy dropping the jet veto from the selections

uncertainties in the acceptance due to the shower matching scale; a first look

A parton level analysis

We are talking about parameters α, f_1,f_2 in eq.(3.5) of arXiv:1409.5301 defining the range of shower scale Q_{sh}

mally of NNLO and beyond can still contribute to the cross section. In order to assess this higher-order systematics of MC origin (which in MC@NLO is tantamount to the matching systematics), in MadGraph5_aMC@NLO one is given the possibility of setting the value[3] of $Q_{\rm sh}$; this value is actually picked up at random in a user-defined range:

$$\alpha f_1 \sqrt{s_0} \leq Q_{\rm sh} \leq \alpha f_2 \sqrt{s_0}\,, \tag{3.5}$$

so as to avoid possible numerical inaccuracies due to the presence of sharp thresholds; more details can be found in sect. 2.4.4 of ref. [27] (see in particular eq. (2.113) and the related discussion). In eq. (3.5), s_0 is the Born-level partonic c.m. energy squared, and α, f_1, and f_2 are numerical constants whose defaults are 1, 0.1, and 1 respectively. The

As in the paper, I keep

f_1=0.1, f_2=1,

take

α = ¼ and 1

and see how kinematical acceptance is changing

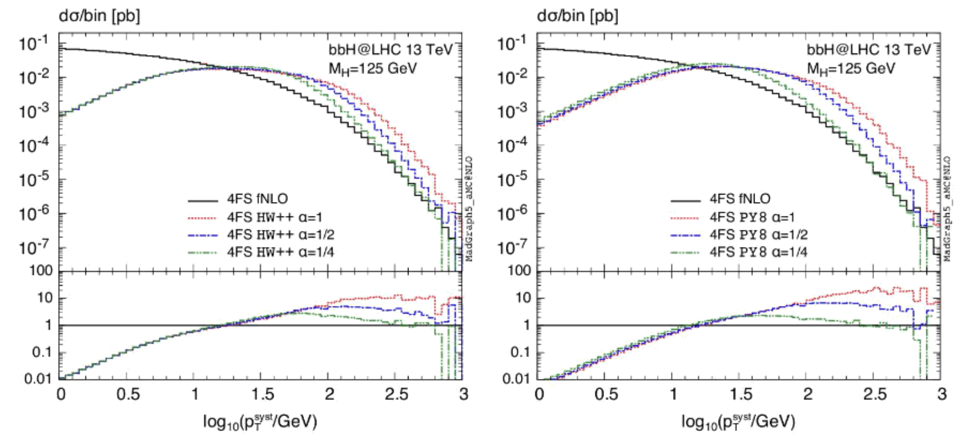
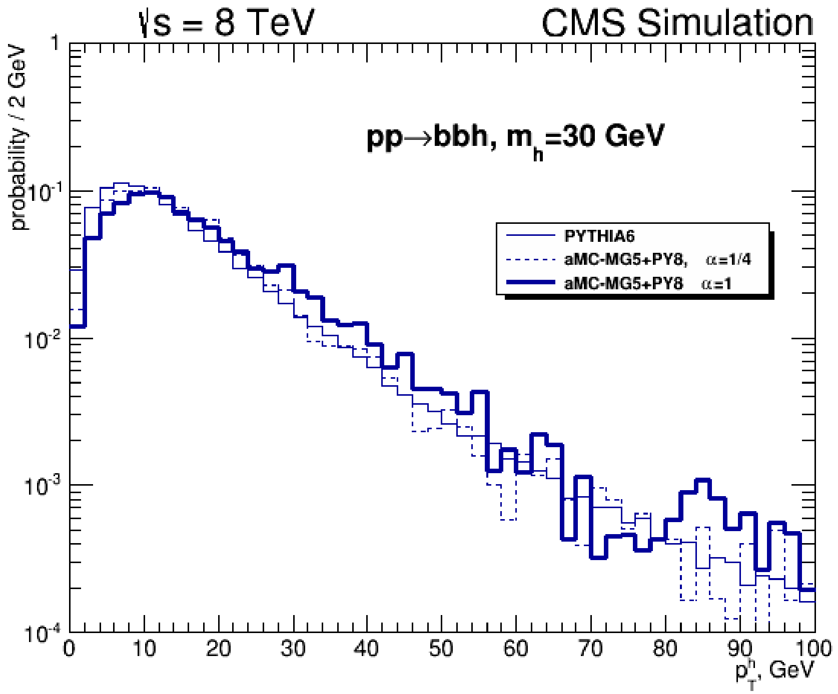


Figure 5: Transverse momentum of the $b\bar{b}H$ or BBH system, in the 4FS at fNLO (black solid), and at NLO+PS with $\alpha = 1$ (red dotted), $\alpha = 1/2$ (blue dot-dashed), and $\alpha = 1/4$ (green dash-double-dotted). Left panel: Herwig++; right panel: Pythia8.

- Consider two values of m_H with selections similar to ones used in the CMS analyses:
  - m_A=30 GeV, 2HDM pp->bbA, A->$\mu\mu$ analysis
    - $p_T^{\mu1,2}$ > 25, 5 GeV, $|\eta^{\mu1,2}|$<2.1, 2.4
    - >=1 b-jet, p_T > 30 GeV,* $|\eta|$<2.4
  - m_A=400 GeV, MSSM pp->bbA, A->$\tau_h\tau_h$ analysis
    - p_T^{τ} > 45 GeV, $|\eta^{\tau}|$ < 2.4**
    - >=1 b-jet p_T>30 GeV*, $|\eta|$<2.4
    - no other jets p_T > 30 GeV, $|\eta|$<4.7

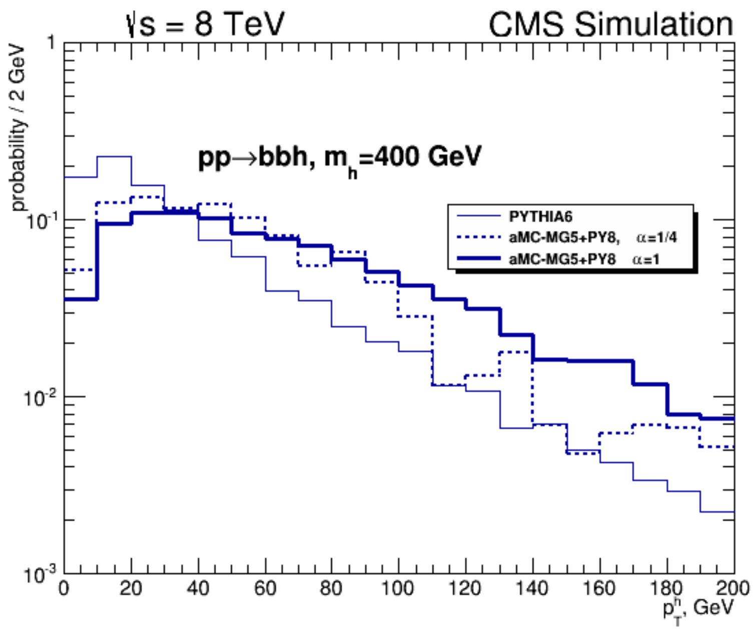
- * in CMS actual cut used is 20 GeV
- ** in CMS we cut on p_T/η of τ_h

m_A=30 GeV



MC generator	PY6	aMC@NLO_MG5 + PY8	
Parton level selections		Shape parameters: Eq 3.5 arXiv:1409.5301	
		0.025-0.25 (α=1/4)	0.1-1.0 (α=1)
$p_T^{\mu1,2}$> 25, 5 GeV $\|\eta^{\mu1,2}\|$ < 2.1, 2.4 $\Delta R(\mu\text{-}j)$>0.5	0.102	0.106	0.147
>=1 b-jet p_T^b > 30 GeV, $\|\eta^b\|$ < 2.4	0.400	0.283	0.356

m_A=400 GeV



MC generator	PY6	aMC@NLO_MG5 + PY8	
Parton level selections		Shape parameters: Eq 3.5 arXiv:1409.5301	
		0.025-0.25 (α=1/4)	0.1-1.0 (α=1)
$p_T^\tau > 45$, $\lvert\eta^\tau\rvert < 2.4$ $\Delta R(\tau\text{-}j)>0.5$	0.860	0.895	0.894
>= 1b-jet $p_T^b > 30$ GeV, $\lvert\eta^b\rvert < 2.4$	0.346	0.383	0.468
1 b-jet, no other jets $p_T > 30$ GeV, $\lvert\eta\rvert<4.7$	0.579	0.379	0.296

- **A first look at acceptance uncertainty due to the shower scale parameters in pp->bbA process modelling with aMC@NLO_MG5+PY8:**
  - considerable change of Higgs p_T is observed with the variation of the shower scale parameters
  - for low mass Higgs 30 GeV the change in the acceptance
    - ~ 50 % with lepton p_T selections
    - ~ 20 % with b-jet p_T selections
  - for high mass Higgs 400 GeV the change in the acceptance
    - negligible for τ p_T selection (since cuts on $p_T << m_A$)
    - ~ 20 % with b-jet p_T selection
    - ~ 20 % with additional jet veto requirement

Repeat with the recommended central value α=0.25 and varying it by factor two up and down

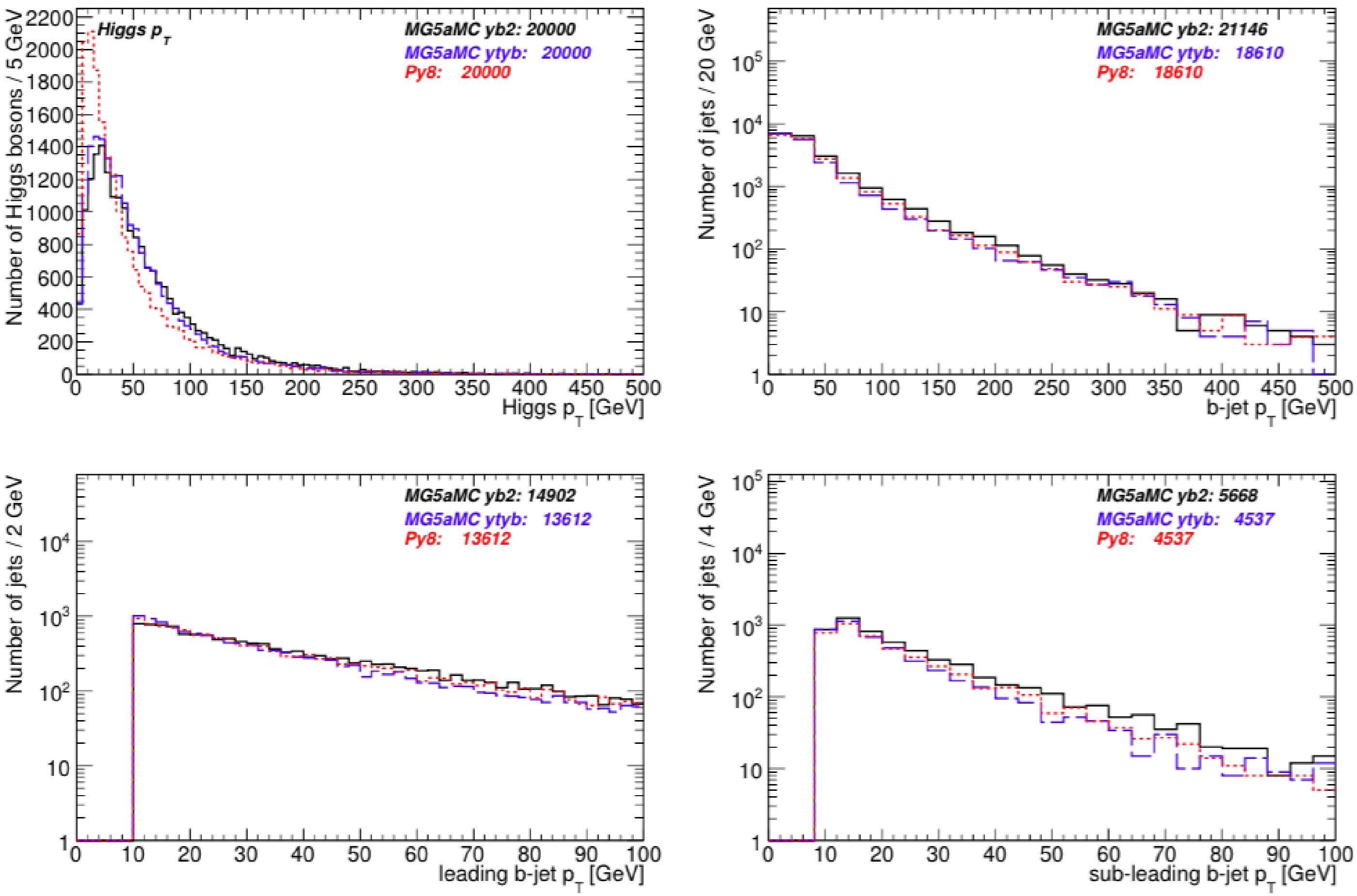
ATLAS bbH Studies (I)

- Comparison of MG5_aMC@NLO and PYTHIA8 (LO) for bbH(→ττ) at 13 TeV in ATL-PHYS-PUB-2014-022
  - MG5_aMC@NLO hadronisation using HERWIG++
  - Terms proportional to y_b^2 and $y_b y_t$ compared separately
  - b-jets defined as b-quark truth matched anti-k_T R=0.4 jets

	bbH, $\sqrt{s}$=13 TeV	
ME gen.	MadGraph5_aMC@NLO	Pythia8
	v2.1.2	v8.175
PS/UE gen.	Herwig++	Pythia8
	v2.7.0a	v8.175
Ren./Fac. scale	$H_T/4$	*default*
ME & PS/UE PDF	CT10	CTEQ6L1
Tune	UE-EE-4	AU2
m_H	500 GeV	500 GeV

Table 13: Summary of the settings used for the simulation of b-associated Higgs boson samples.

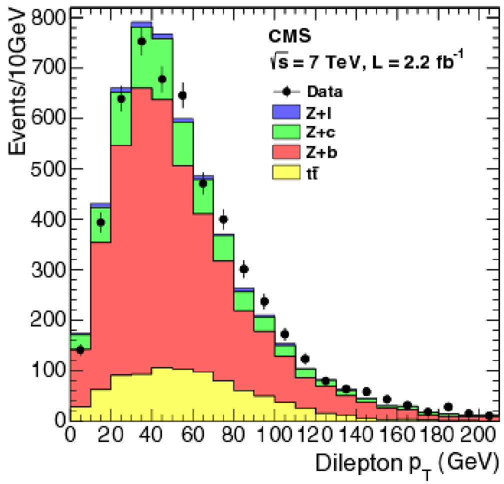
ATLAS bbH Studies (II)



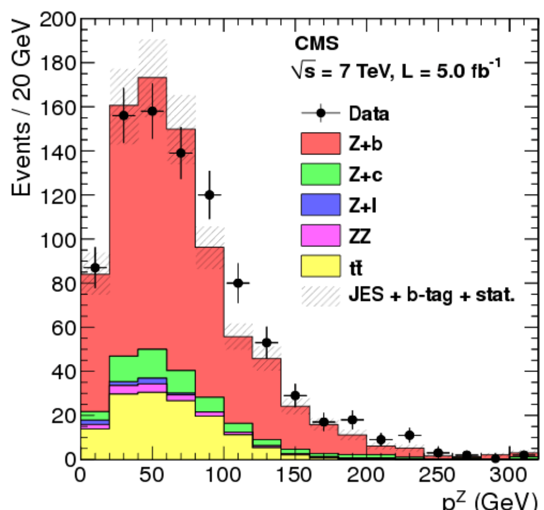
- **Harder Higgs p_T spectrum in MG5_aMC@NLO wrt. PYTHIA8**

Need to use Z+b(b) data to cross-check MC

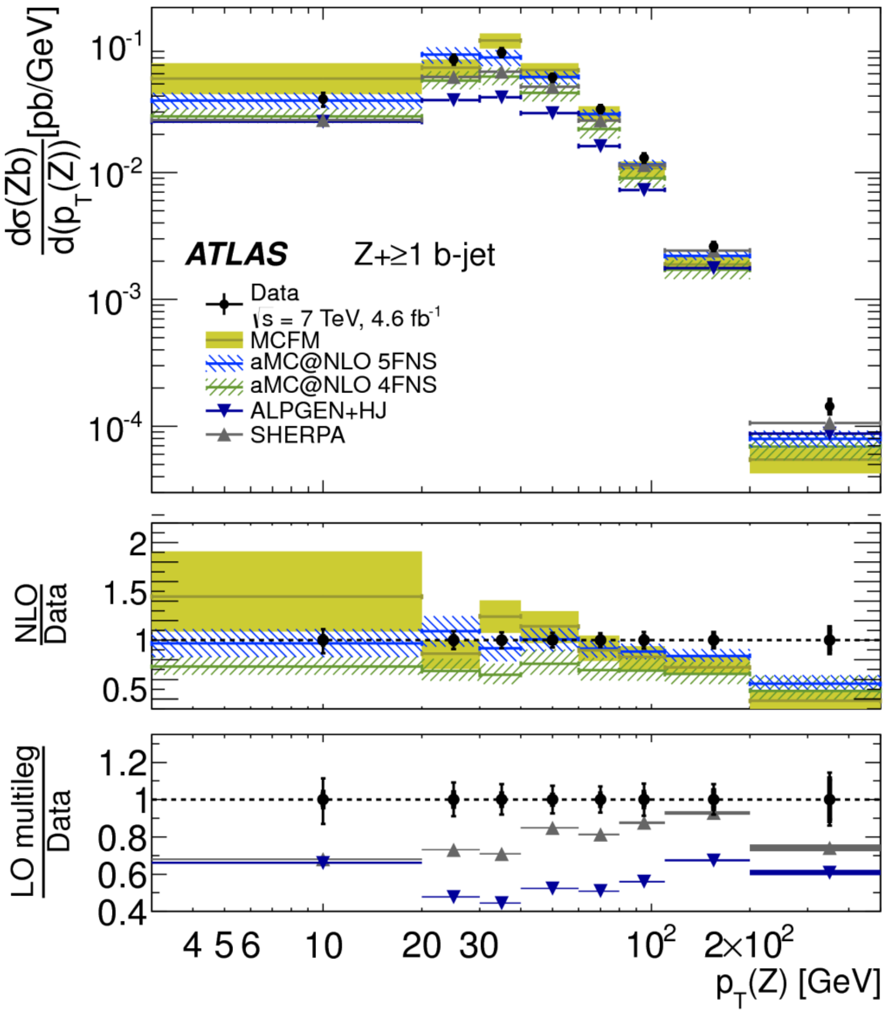
JHEP 06 (2012) 126, Z+b



JHEP 06 (2014) 120 Z+bb



JHEP 10 (2014) 141, Z+>=1b



Plans

- **Detailed analysis of the acceptance uncertainties and distribution uncertainties**
  - **aMC@NLO_MG5 4FS**
  - **Sherpa 4FS/5FS**
- **The current 13 TeV Higgs signal request (CMS) already incudes bbH process to be generated with MG5_aMC@NLO+PY8**

123	HIG (Yuta Takahashi) tautau group	SUSY : ggH + H->tautau	Pythia
124	HIG (Yuta Takahashi) tautau group	SUSY : ggH + H->tautau	Powheg
125	HIG (Yuta Takahashi) tautau group	SUSY : bbH + H->tautau	Pythia
126	HIG (Yuta Takahashi) tautau group	SUSY : bbH + H->tautau	Madgraph5_aMCatNLO (NLO)
127	HIG (Yuta Takahashi) tautau group	SUSY : ggH (H->hh->2tau2b)	Pythia
128	HIG (Yuta Takahashi) tautau group	SUSY : bbH (H->hh->2tau2b)	Pythia
129	HIG (Yuta Takahashi) tautau group	SUSY : A->Zh (Z->ll, h->tautau)	Madgraph5
130	HIG (Yuta Takahashi) tautau group	SUSY : A->Zh (Z->ll, h->bb)	Pythia
131	HIG (Yuta Takahashi) tautau group	nMSSM bba1 + a1->tautau	Pythia
132	HIG (Yuta Takahashi) tautau group	nMSSM bba1 + a1->tautau	Madgraph5_aMCatNLO (NLO)

- **ATLAS is planning to use aMC@NLO_MG5+HERWIG++ for the signal generation**

By when we should be ready with it ?

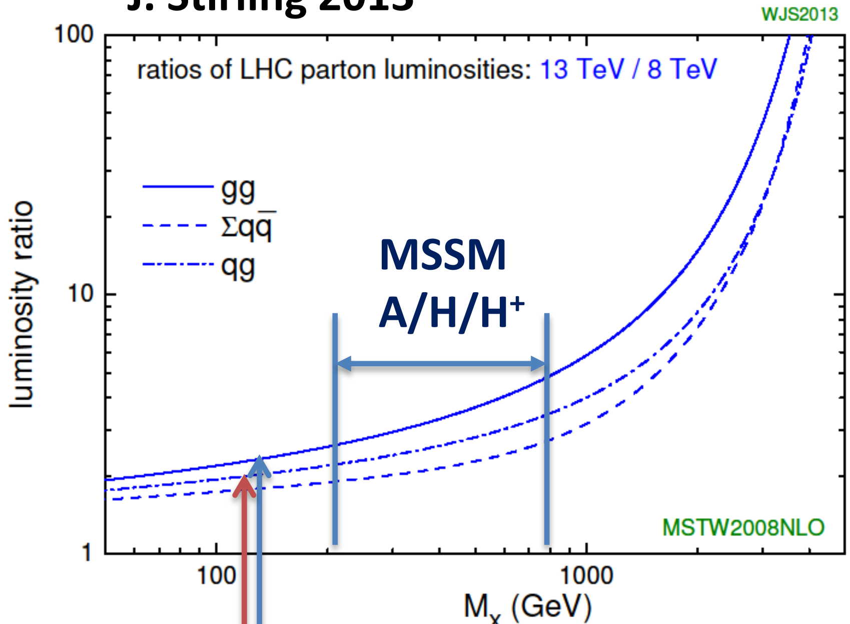
Prospects for 2015-2016:

- **No immediate discovery for Higgs-Exotics channels with first 5-10 fb^{-1} is expected so far:**

  rare processes, need luminosity

  – with ~ 5-10 fb^{-1} at 13 TeV expect to reach 8 TeV/20 fb^{-1} sensitivity of current 8 TeV analyses and start to explore a new territory

J. Stirling 2013



NMSSM H2(125)->H1H1

h(125)->DM

A. Djouadi et.al. arXiv:1307.5205