Heavy Higgs Bosons at 14 and 100 TeV

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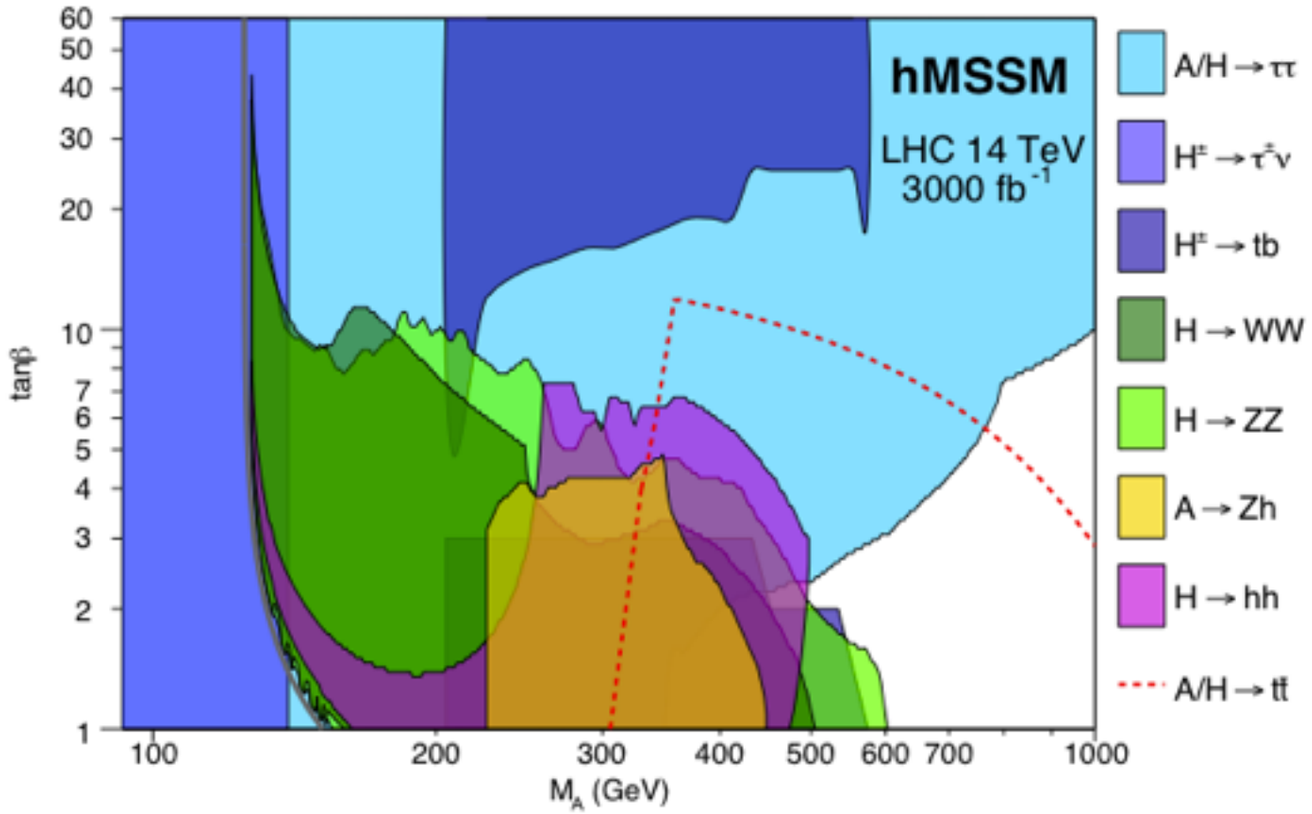
BSM Higgs Bosons

An extended Higgs sector extensively exists in NP

- We focus on the MSSM Higgs bosons (no CP-violation): H, A, Hc
- Higgs mass spectrum and couplings only depend on two parameters (in additional to the SM ones) at tree-level: tan_beta, mA/mHc
- We can make a sensitivity projection on a plane expanded by these two parameters: mA/mHc - tan_beta

MSSM Higgs Bosons at 14 TeV



	Couplings	MSSM
H	g_{HVV}	$\cos(\beta-\alpha)$
	$g_{Ht\bar{t}}$	$\sin\alpha/\sin\beta$
	$g_{Hb\bar{b}}$	$\cos\alpha/\cos\beta$
	$g_{H\tau\bar{\tau}}$	$\cos\alpha/\cos\beta$
A	g_{AVV}	0
	$g_{At\bar{t}}$	$\cot\beta$
	$g_{Ab\bar{b}}$	$\tan\beta$
	$g_{A\tau\bar{\tau}}$	$\tan\beta$
$H^\pm$	$g_{H^+\bar{u}d}$	$\frac{1}{\sqrt{2}v}V^*_{ud}[m_d\tan\beta(1+\gamma_5)+m_u\cot\beta(1-\gamma_5)]$
	$g_{H^-u\bar{d}}$	$\frac{1}{\sqrt{2}v}V_{ud}[m_d\tan\beta(1-\gamma_5)+m_u\cot\beta(1+\gamma_5)]$
	$g_{H^+\nu\bar{l}}$	$\frac{1}{\sqrt{2}v}m_l\tan\beta(1+\gamma_5)$
	$g_{H^-\nu\bar{l}}$	$\frac{1}{\sqrt{2}v}m_l\tan\beta(1-\gamma_5)$

[A. Djouadi et. al.'15]

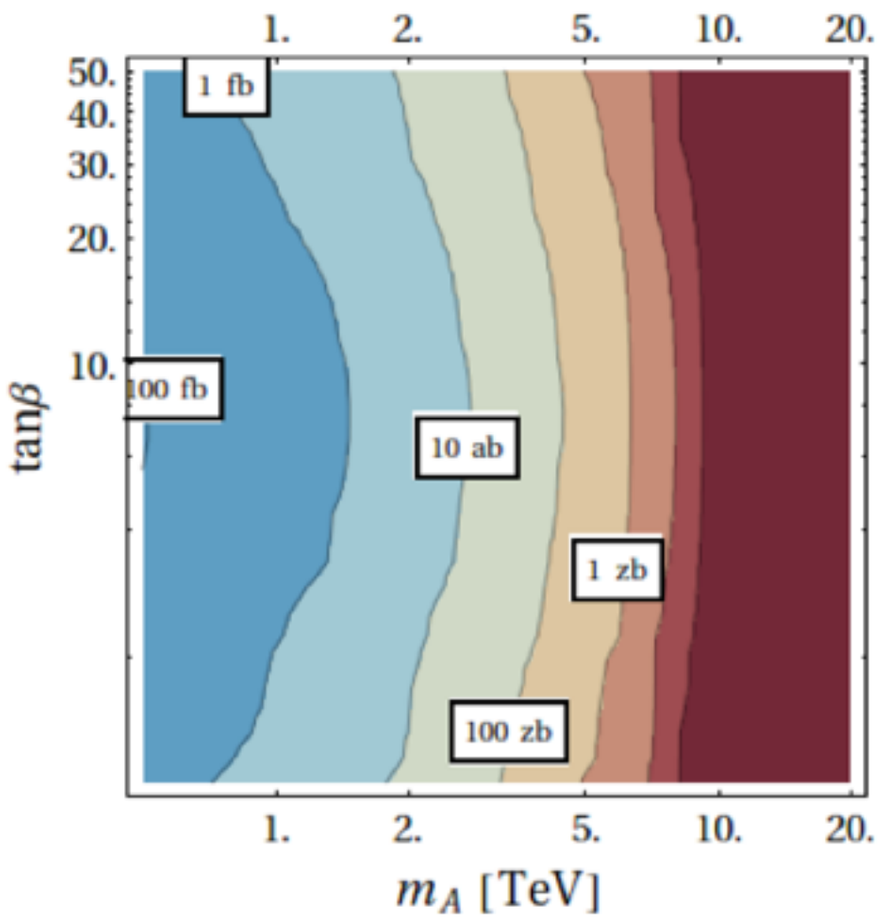
- Rescaling the 7 and 8 TeV results to 14 TeV
- Neutral Higgs: excluded up to ~ O(1) TeV, except a wedge region
- Charged Higgs: excluded up to ~600 GeV, via pp -> tb Hc -> tbtb

Questions to Address

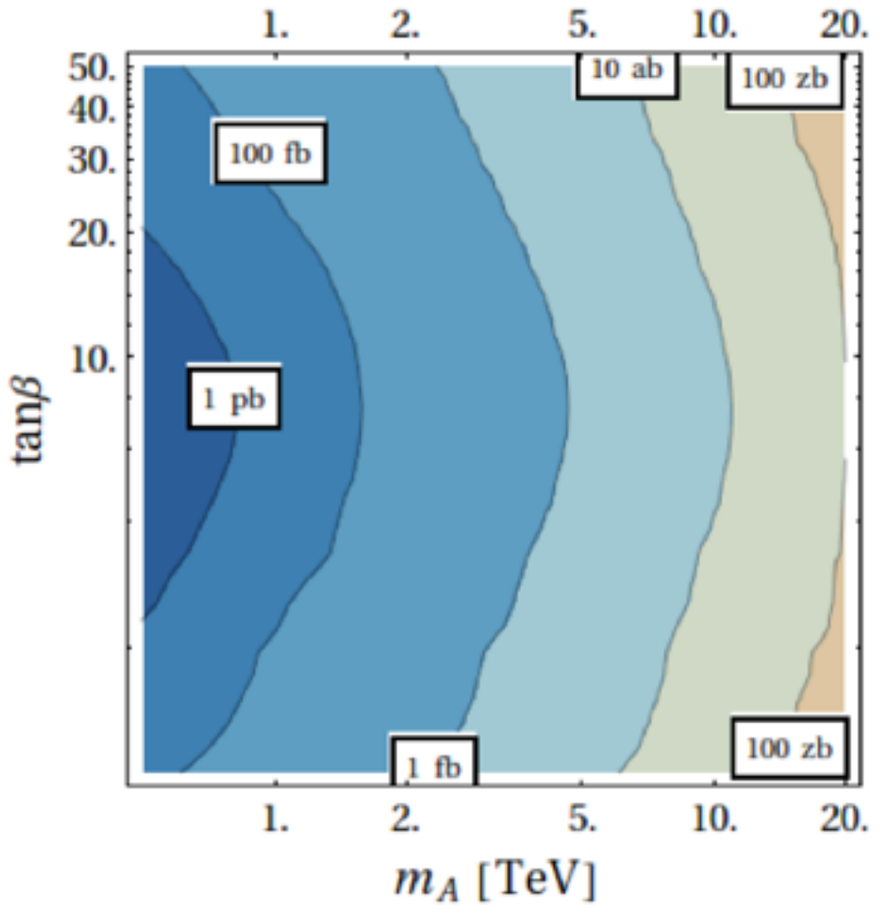
- For neutral Higgs search, how to probe the uncovered wedge region?
- What are the main contributing channels for charged Higgs?
- What is the related collider kinematics?
- What are the sensitivity reaches that might be achieved at 100TeV pp collider?

Neutral Higgs

$$g_{HVV} = g_{hZA} = g_{hW^{\mp}H^{\pm}} \propto \cos(\beta - \alpha) \to 0$$



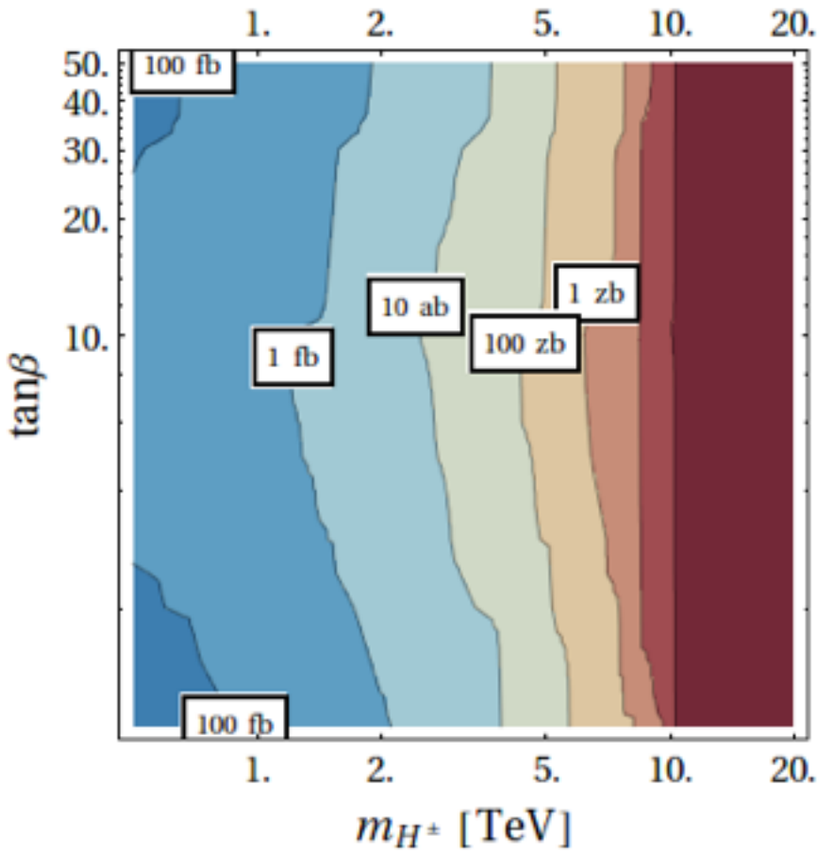
$\sigma(pp \to b\bar{b}H/A)\mathrm{Br}(H/A \to t\bar{t})$



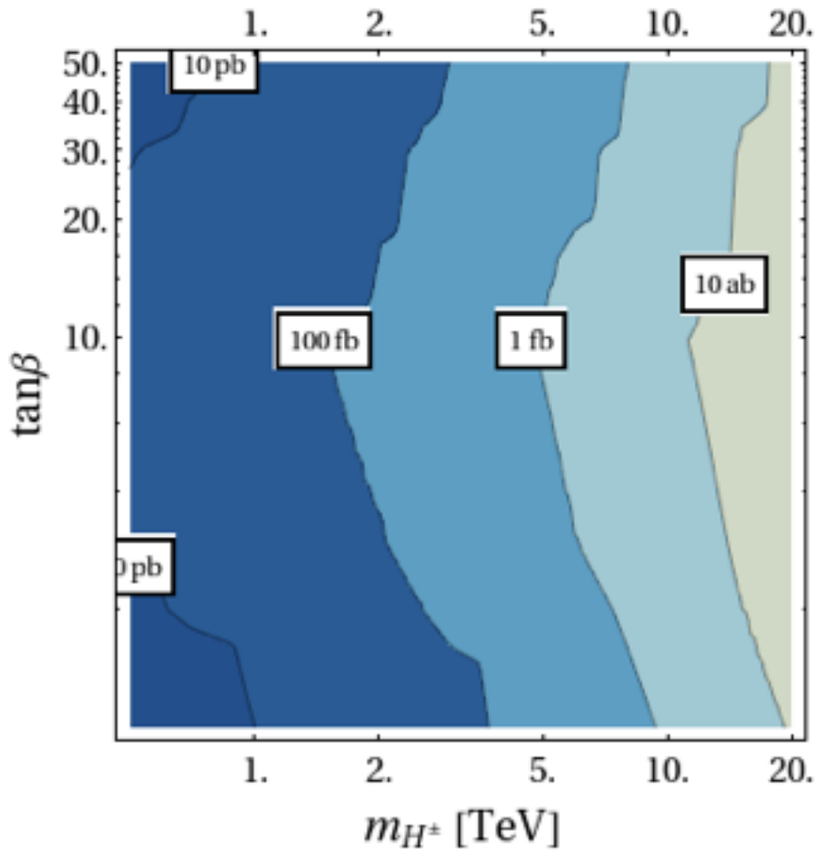
$\sigma(pp \to b\bar{b}H/A)\mathrm{Br}(H/A \to t\bar{t})$

- moderate tan_beta enhanced
- expected to yield a larger sensitivity for probing moderate tan_beta => the wedge region might be covered !

Charged Higgs



$\sigma(pp \to tbH^\pm)\,\mathrm{Br}(H^\pm \to tb)$



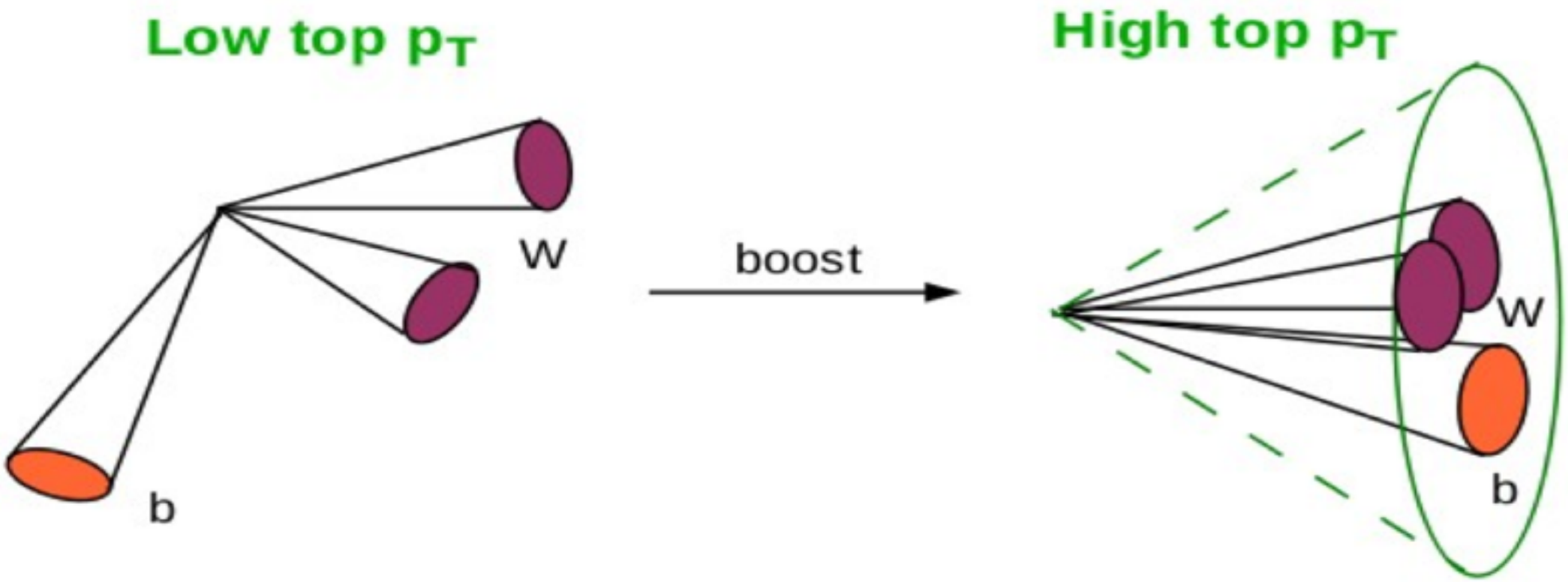
$\sigma(pp \to tbH^\pm)\,\mathrm{Br}(H^\pm \to tb)$

- Production: tb Hc is dominant, enhanced by both low and high tan_beta
- Decay: dominated by Hc -> bt (particularly for low tan_beta)

  can not neglect Hc -> tau+vt for high tan_beta region

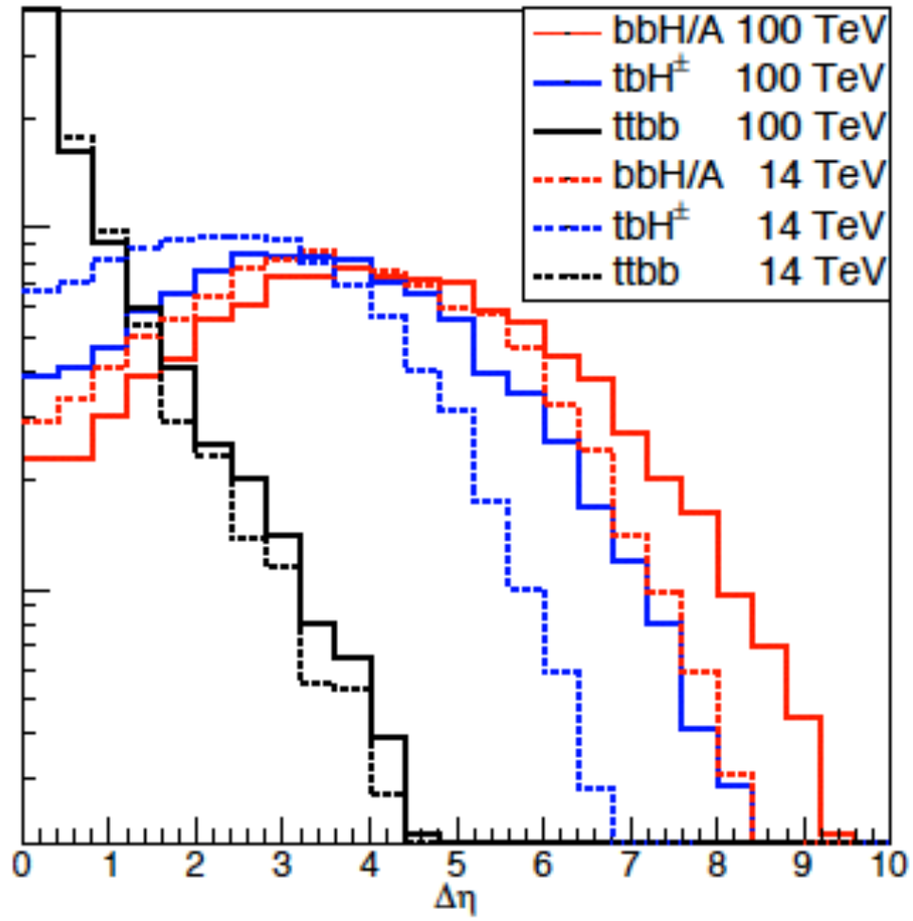
$$g_{H^+\bar{u}d} = \frac{1}{\sqrt{2}v} V_{ud}^* [m_d \tan\beta(1+\gamma_5) + m_u \cot\beta(1-\gamma_5)]$$

Kinematics - Heavy Higgs Resonance



- Boosted top quarks from heavy resonance decay
- Boostness techniques should be applied

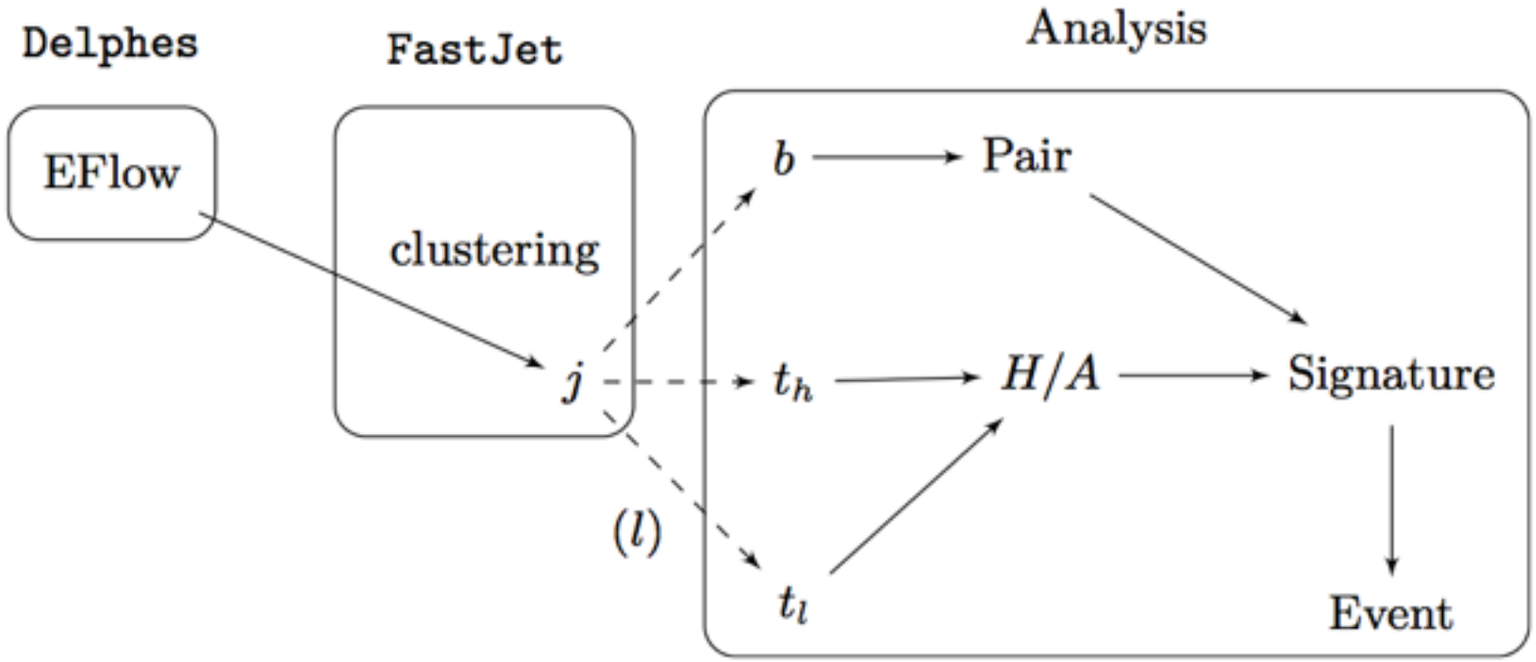
Kinematics - Particles Accompanying Higgs Production



$\Delta\eta$ between the two accompanying b-quarks

- All b quarks are required to have pt > 40 GeV for 100TeV, and pt > 20GeV for 14TeV.
- The b-quarks accompanying Higgs production tend to be forward and backward => large delta eta

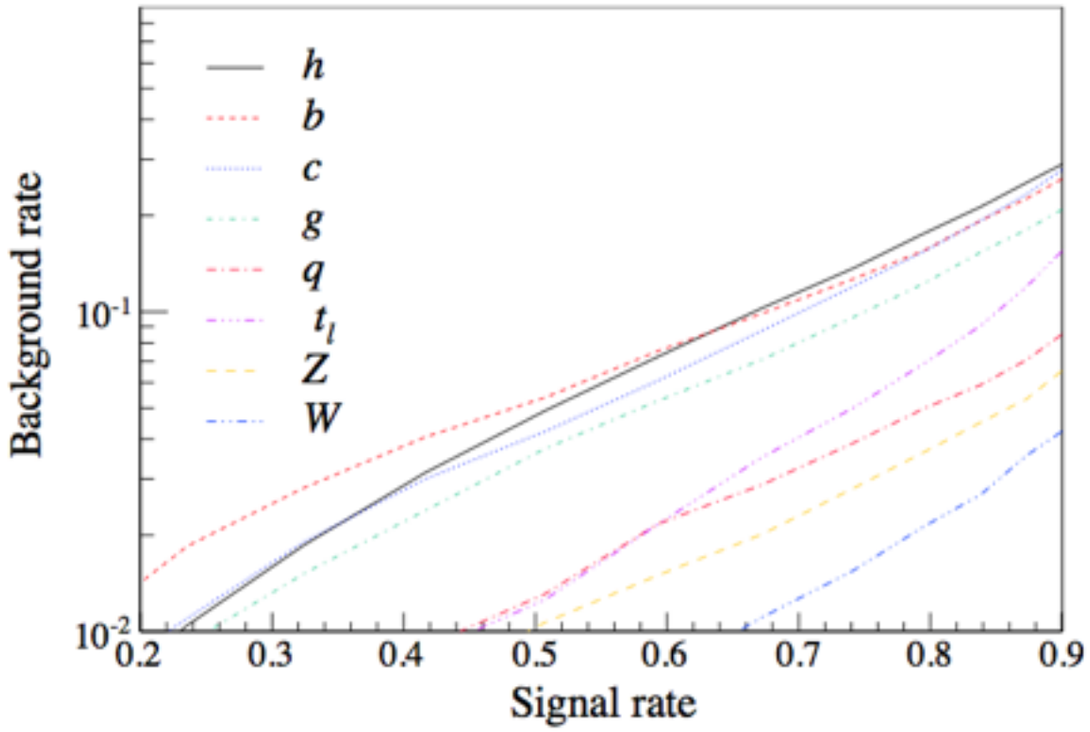
Overall Strategies



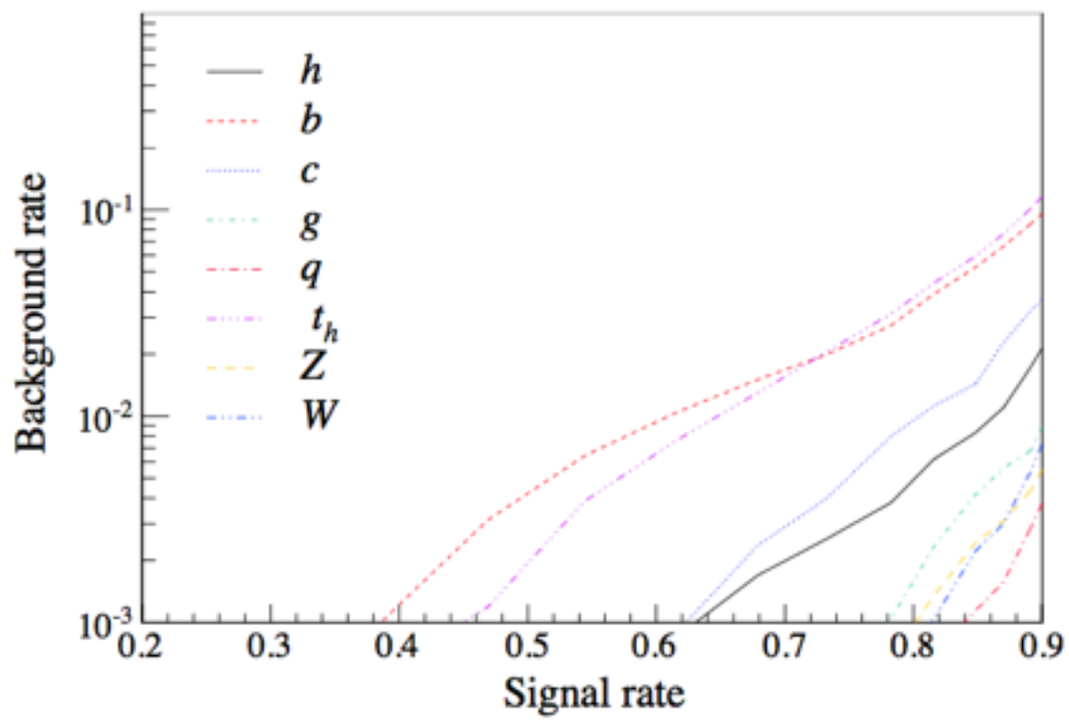
(a) BDT-based event reconstruction in the case of boosted tops.

- Detector simulation: CMS detector resolution with detector eta coverage 3.5 and 2.5 for 100TeV collider and 14TeV collider, respectively.
- Kinematic features of (the resonance + the accompanying products, if any)
  - bbH/A -> bbtt: two hard top jets (one hadronic, one leptonic) with Higgs reconstruction + two b jets with large delta eta
  - bt Hc -> btbt: one hard leptonic top jet and one hard b jet with Higgs reconstruction + two additional b jets with large delta eta

Top Tagger BDT



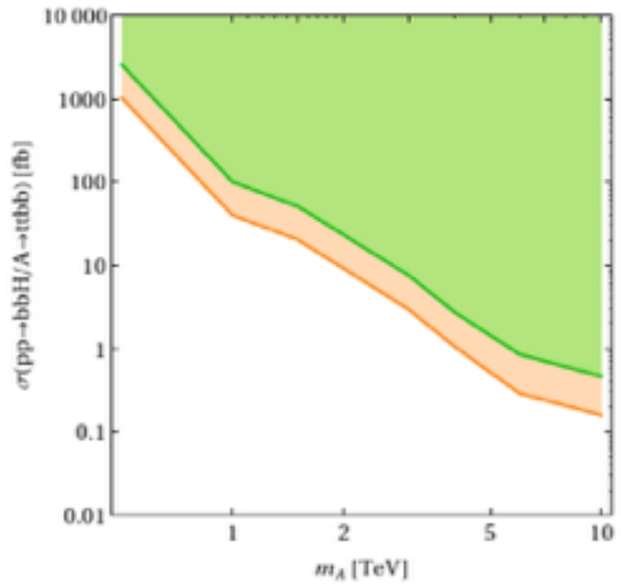
$1000\,\mathrm{GeV} < p_T^j(\mathrm{hadronic}) < 1500\,\mathrm{GeV}$



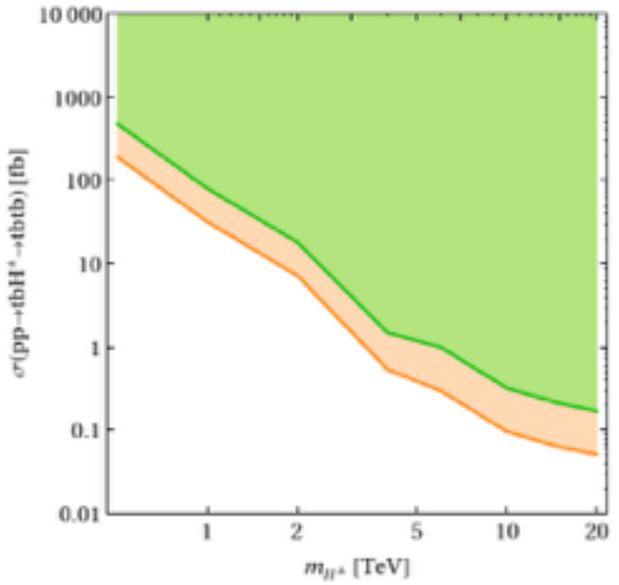
$1000\,\mathrm{GeV} < p_T^j(\mathrm{leptonic}) < 1500\,\mathrm{GeV}$

- hadronic top tagger: b secondary vertex and jet mass information, also veto hard lepton.
- leptonic top tagger: b secondary vertex and lepton information, as well as jet mass requirement.

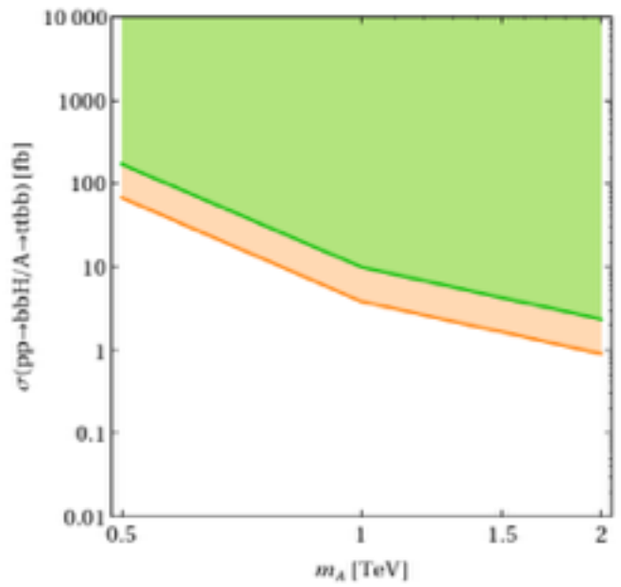
Model-independent Exclusion limit



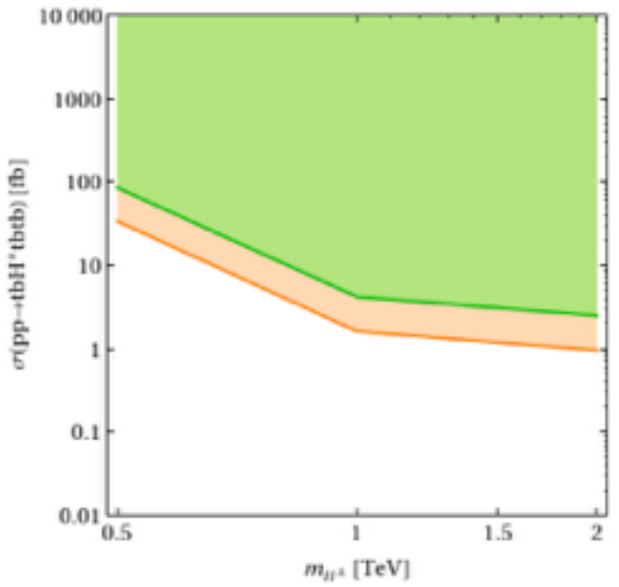
(a) Neutral Higgs at 100 TeV



(b) Charged Higgs at 100 TeV



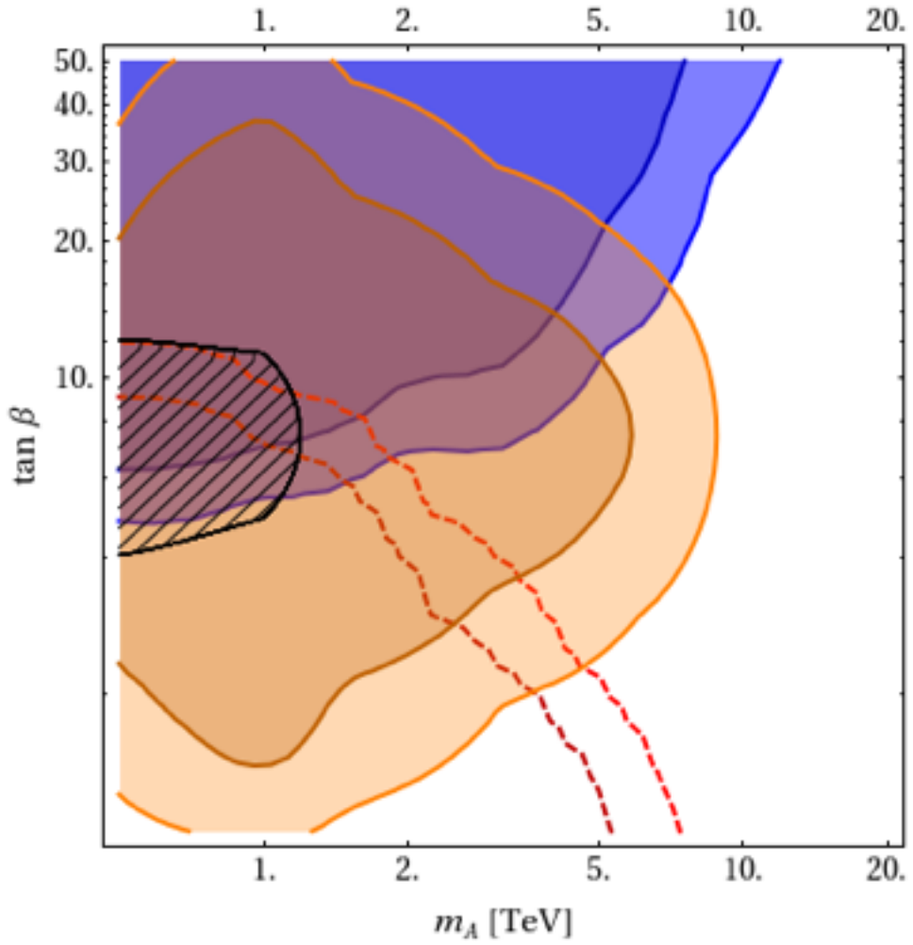
(c) Neutral Higgs at 14 TeV

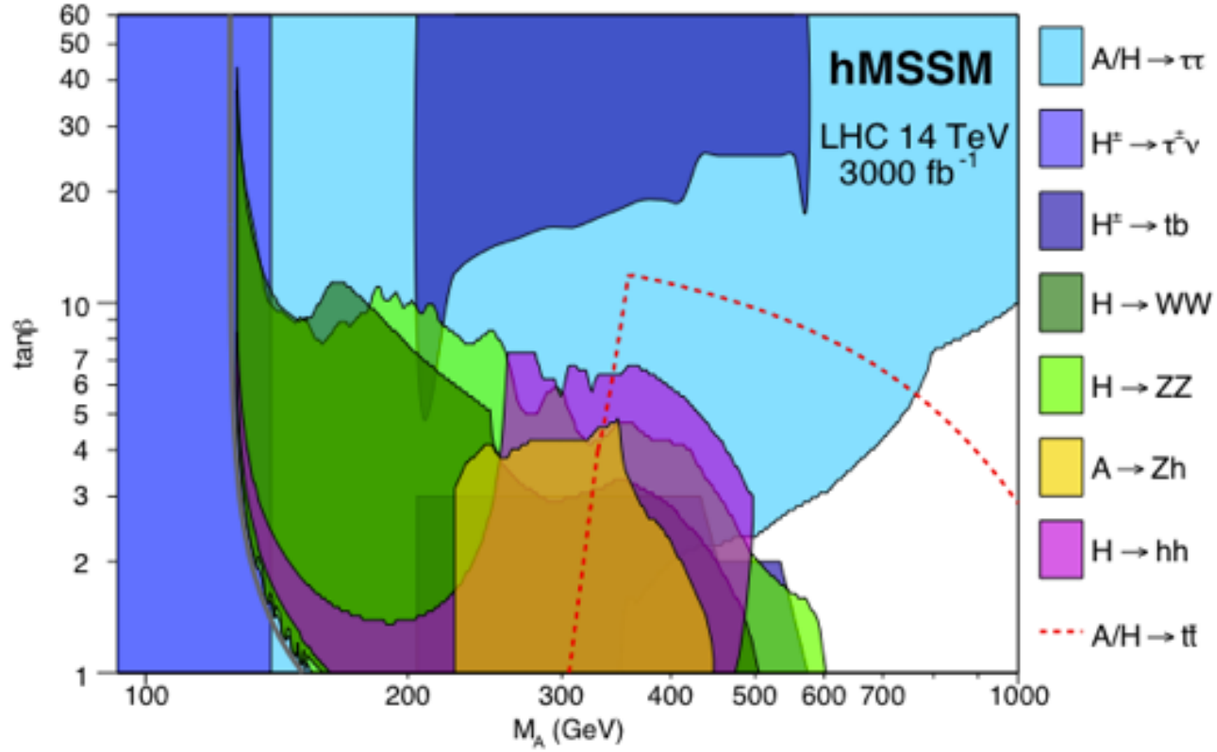


(d) Charged Higgs at 14 TeV

- As mass increases, the constraints become stronger.
- Constraints are weaker at 100TeV compared with that at 14TeV

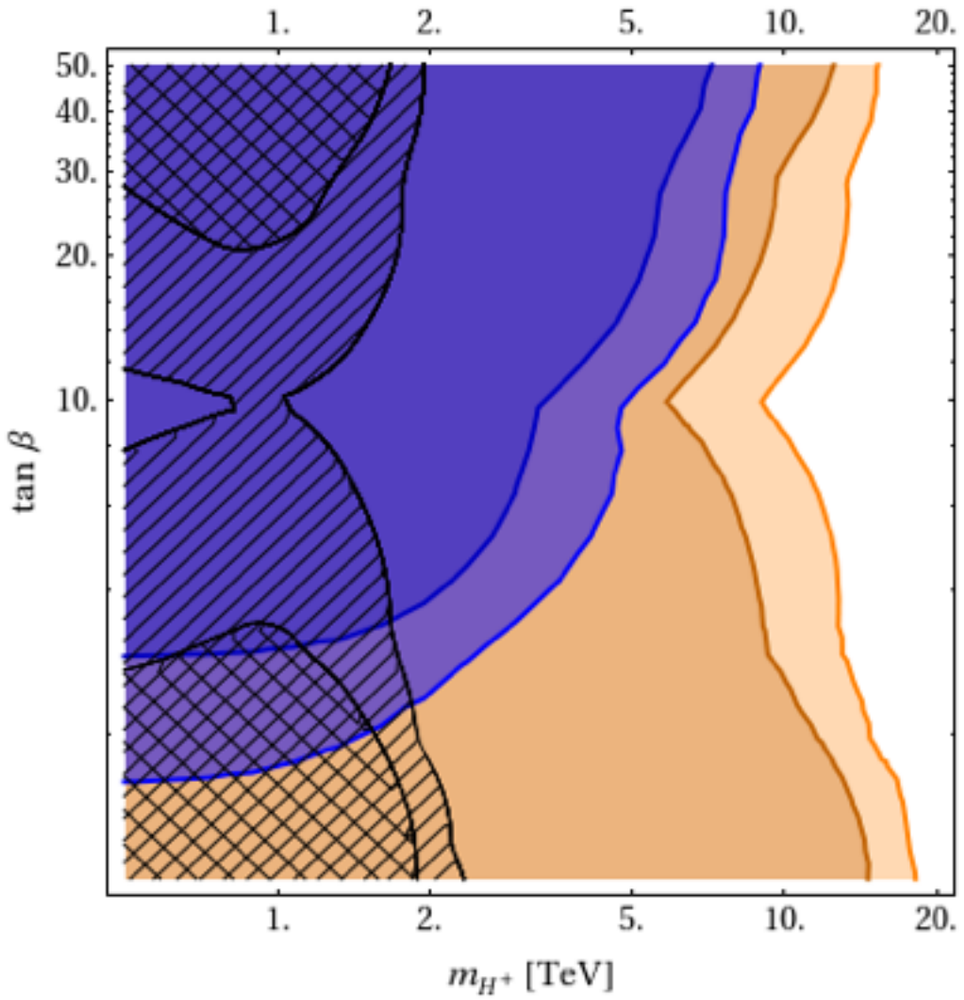
Sensitivities for Neutral Higgs Search





- The wedge region centered on moderate tan_beta can be covered via bbH/A -> bbtt, up to ~1TeV at the LHC (3/ab).
- A potential to push the limit up to 10TeV at 100 TeV collider (30/ab)

Sensitivities for Charged Higgs Search



- Combining with the bbH/A channel, the limit for the MSSM Higgs search can be pushed up to ~1TeV for the whole tan_beta region, at the LHC
- A 100 TeV collider can push the limit up to 10 TeV, and additionally probes for high and low tan beta regions with even greater sensitivity.

Thank you !