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Heavy Scalar Search with Associated Production at 14 and 100 TeV

Ying-Ying Li

arXiv:1605.08744 N. Craig, J.Hajer, T.Liu and H. Zhang

Hong Kong Univ of Science and Technology

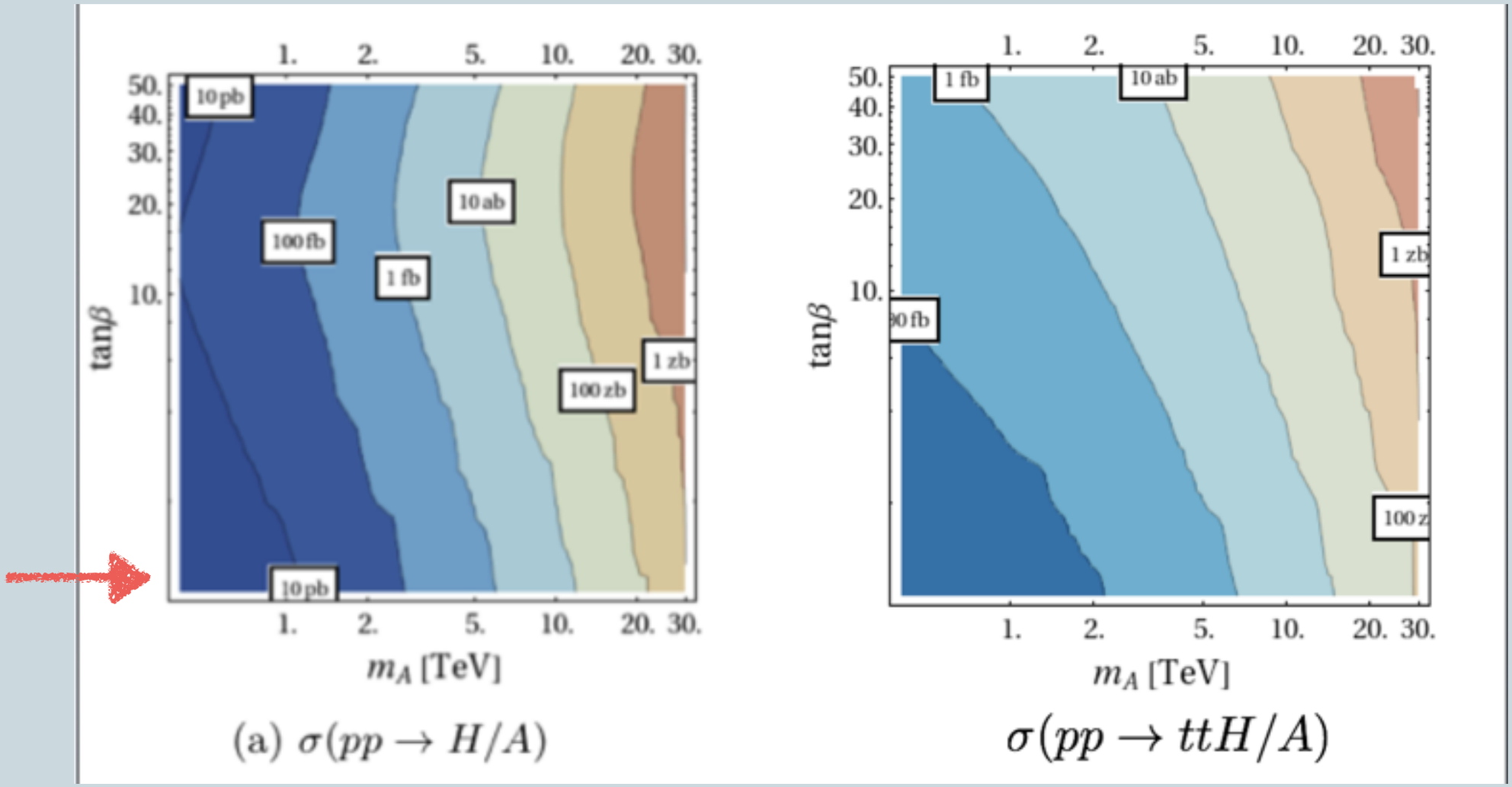
Motivation

- Heavy Scalar and Pseudoscalar mostly couple to top quark.
  - MSSM: low tan_beta region
  - Composite Higgs
  - ...

gluon fusion production
dominant decay channel into ttbar.

- interesting but deconstructive Interference with tt background
- works on total rate: S.Jung, etc; Line shape: R. Barcelo etc.
- We try to use associated production to probe.

Neutral Scalar Comparison at 100TeV

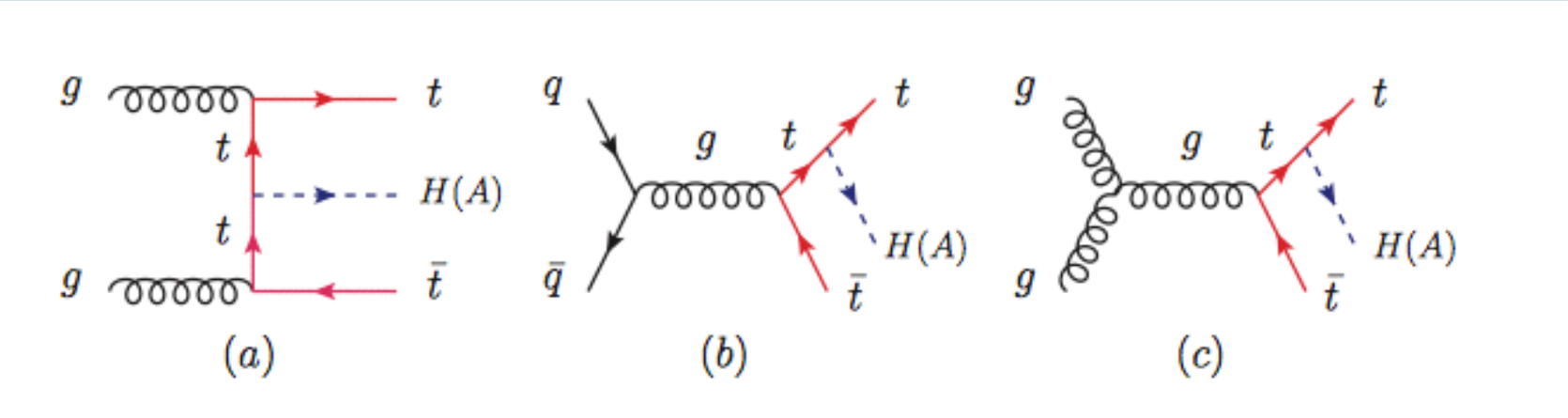


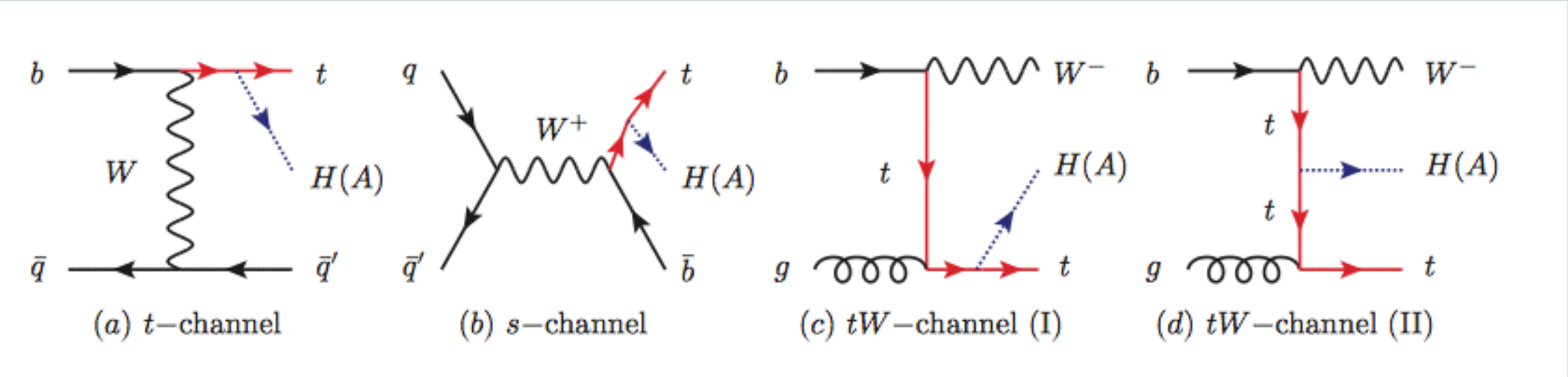
(a) $\sigma(pp \to H/A)$

$\sigma(pp \to ttH/A)$

$$\mathcal{L} = -y_t(c_H H\bar{t}t + ic_A A\bar{t}\gamma_5 t)$$

Neutral (Pseudo)Scalar Associated Production

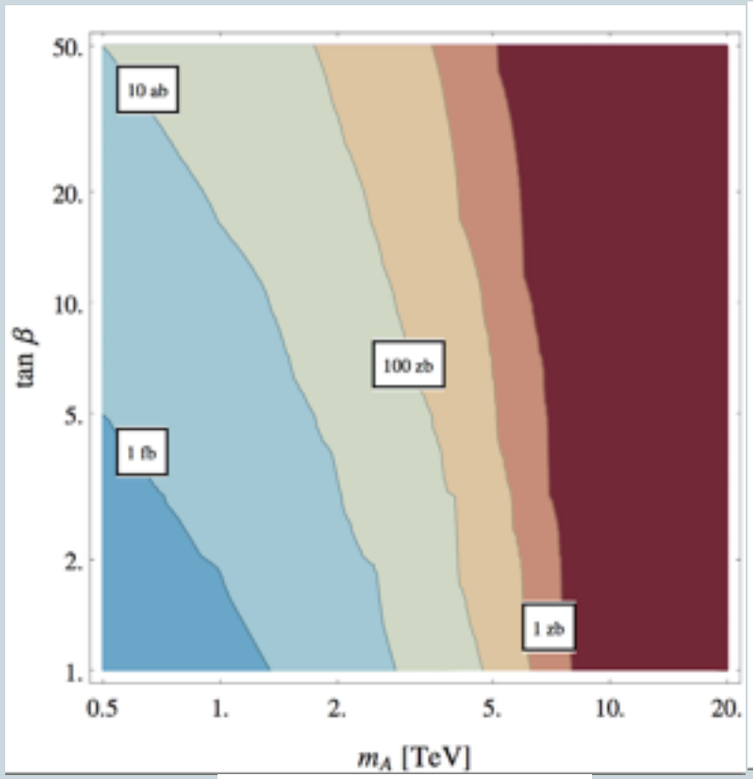




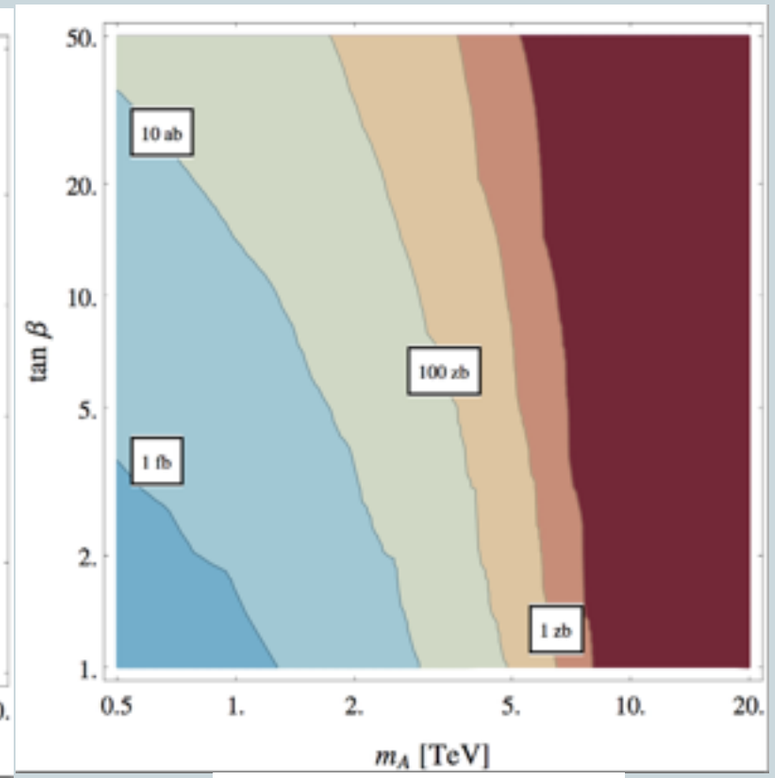
a) subdominant by requiring SSDL

b) s-channel process suppressed by the 1/s^2

Neutral (Pseudo)Scalar-14TeV



$\sigma(pp \to H/Att)$

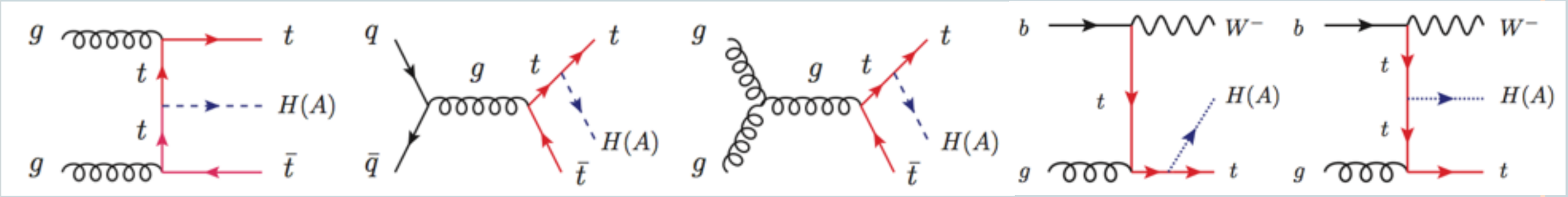


$\sigma(pp \to H/AtW)$

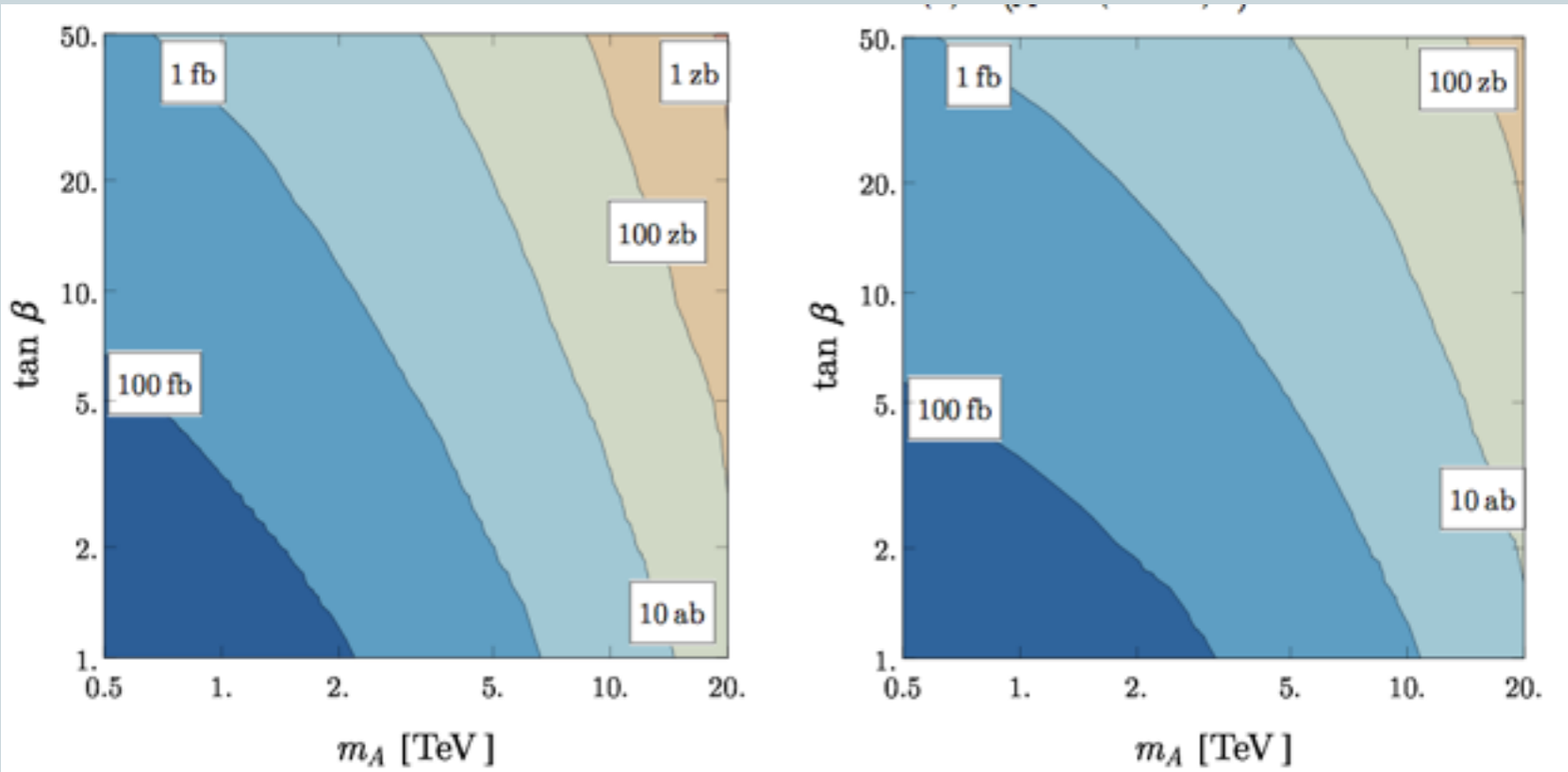
a) Low mass region: $\sigma(pp \to H/Att)$ larger, strong coupling and gluon PDF

b) High mass region: $\sigma(pp \to H/AtW)$ larger

Asymptotic freedom and faster fall off of gluon PDF



Neutral (Pseudo)Scalar-100TeV



$\sigma(pp \to H/Att)$ $\sigma(pp \to H/AtW)$

a) Low mass region: $\sigma(pp \to H/Att)$ larger, strong coupling and gluon PDF

b) High mass region: $\sigma(pp \to H/AtW)$ larger

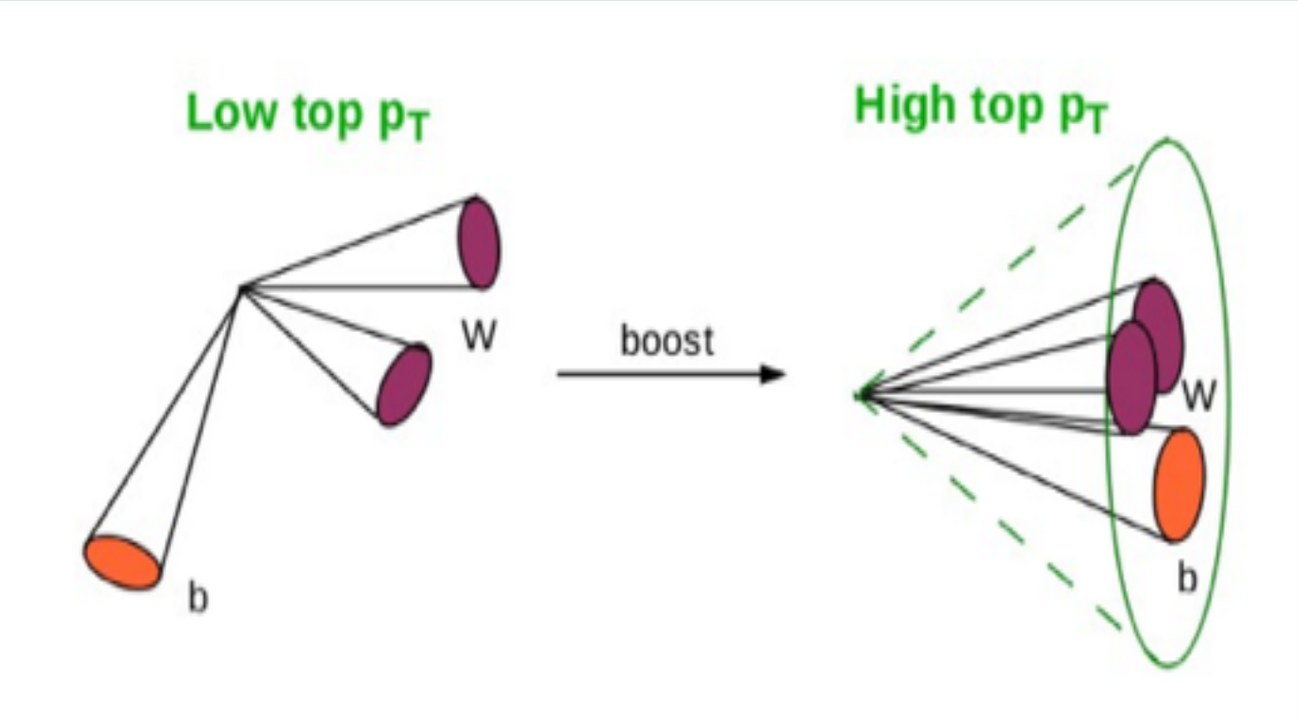
Asymptotic freedom and faster fall off of gluon PDF

Compared to 14TeV, the cross section is increased by a factor of around 100!

Kinematics

- Heavy (Pseudo) scalar resonance

  related to the heaviness of (Pseudo) scalar.



$$P_T^t \sim \frac{m_S}{2}$$

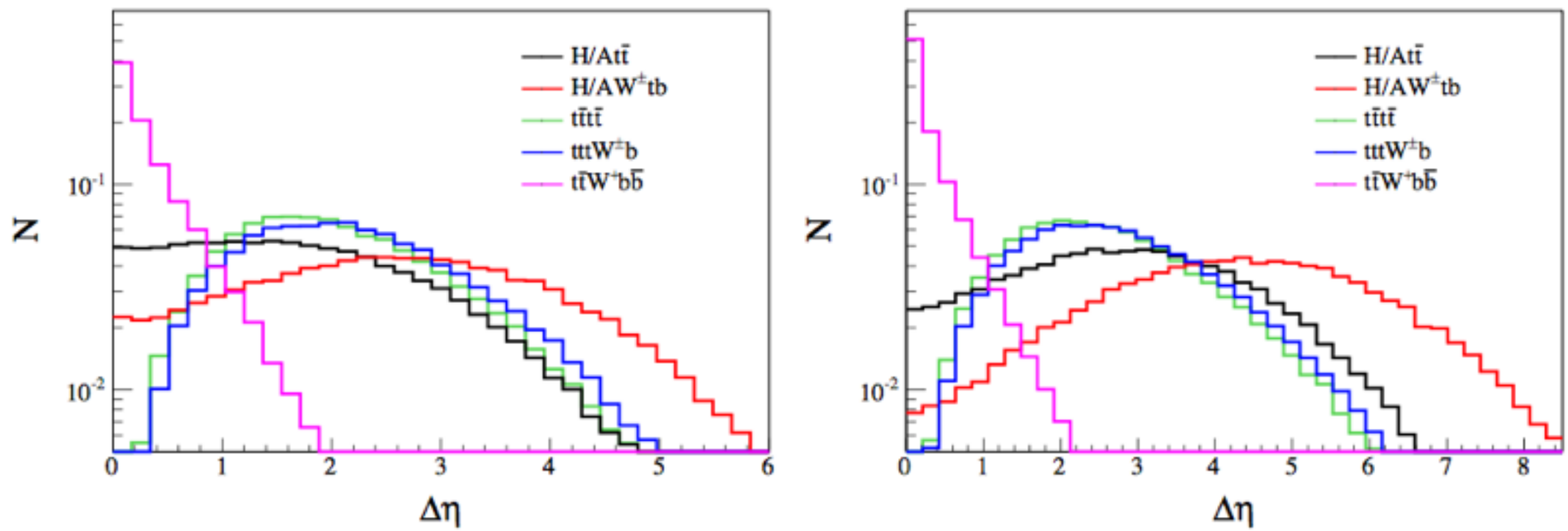
$$R \sim \frac{2m_t}{P_T^t} \sim 0.5$$

- We have take both boosted regime and unboosted regime into consideration. For boosted regime, jet substructure is used.

Kinematics

- Forwardness/Backwardness of accompanying particles

  the accompanying particles are less boosted, but tend to have a large rapidity.

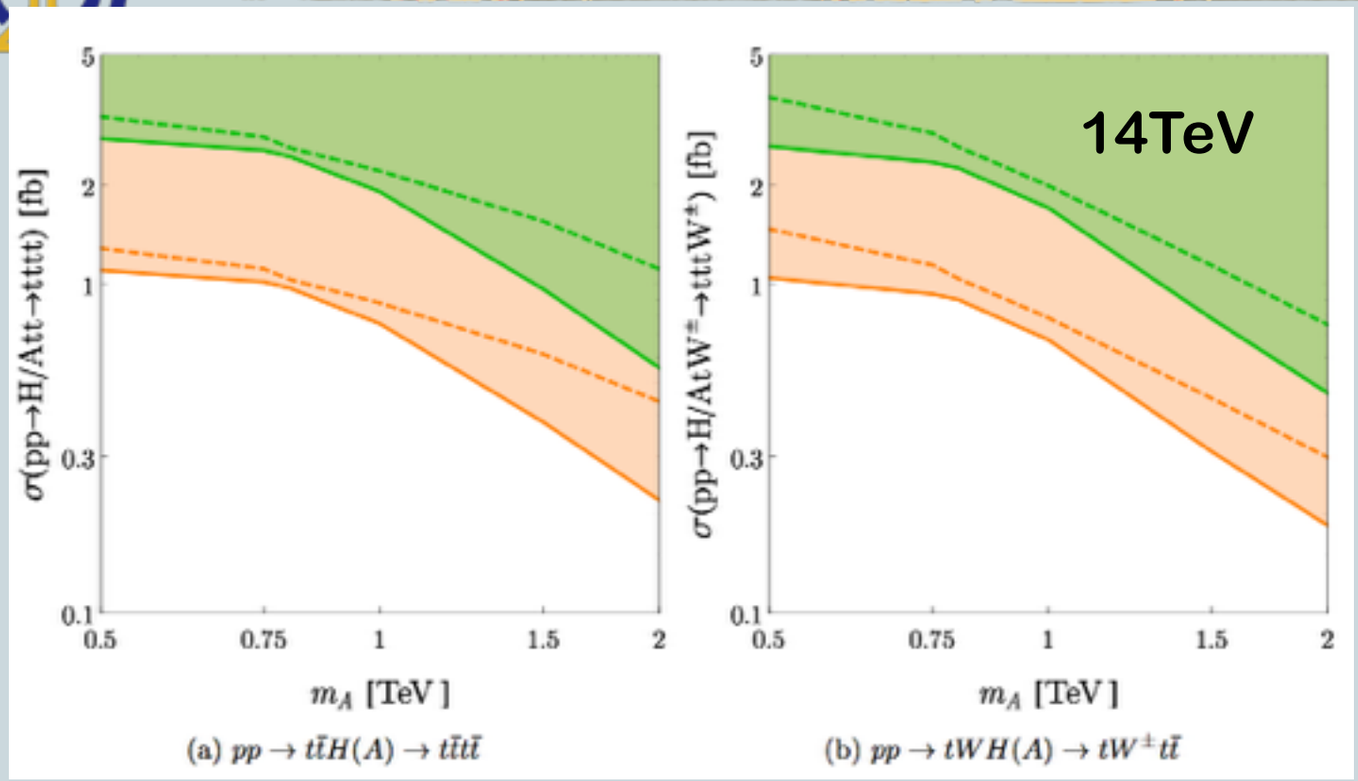


(a) 500 GeV heavy Higgs at 14 TeV (b) 5 TeV heavy Higgs at 100 TeV

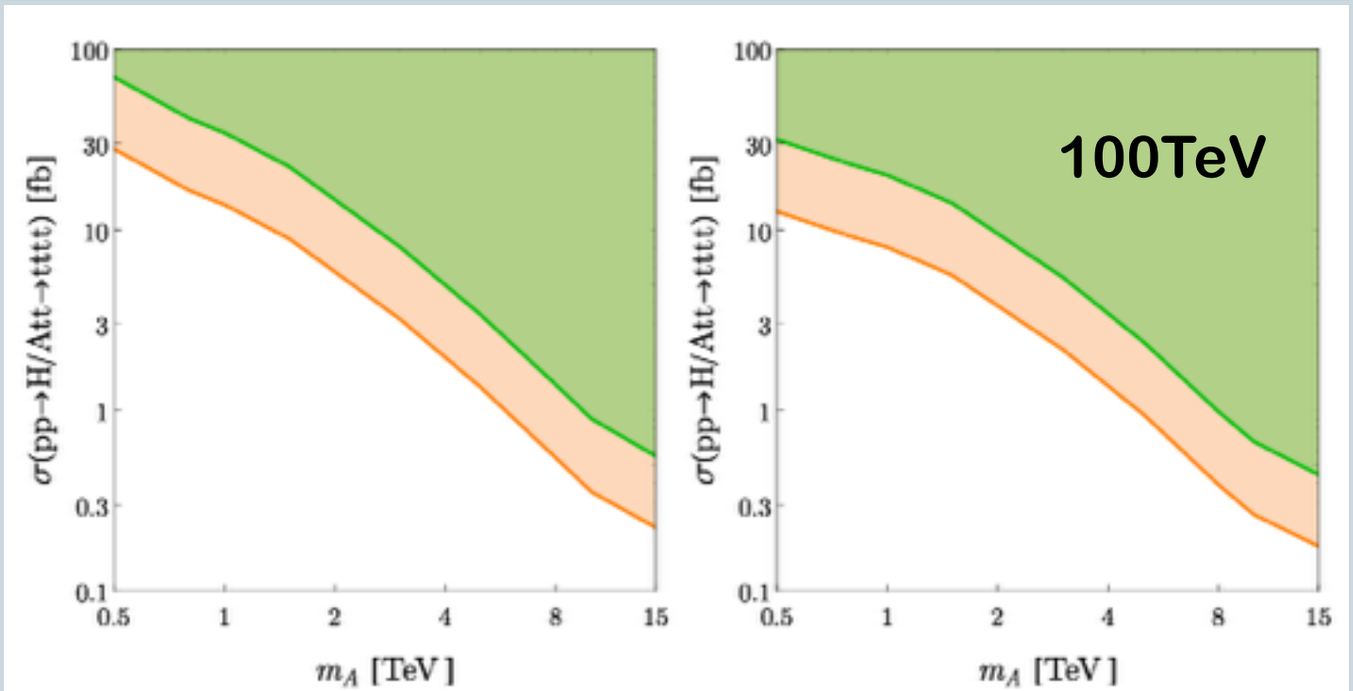
- Require pt(b) > 20 GeV at LHC and pt(b) > 40 GeV at 100 TeV collider.

More details see our paper

Exclusion limit for (Pseudo) Scalar



(a) $pp \to t\bar{t}H(A) \to t\bar{t}t\bar{t}$ (b) $pp \to tWH(A) \to tW^{\pm}t\bar{t}$

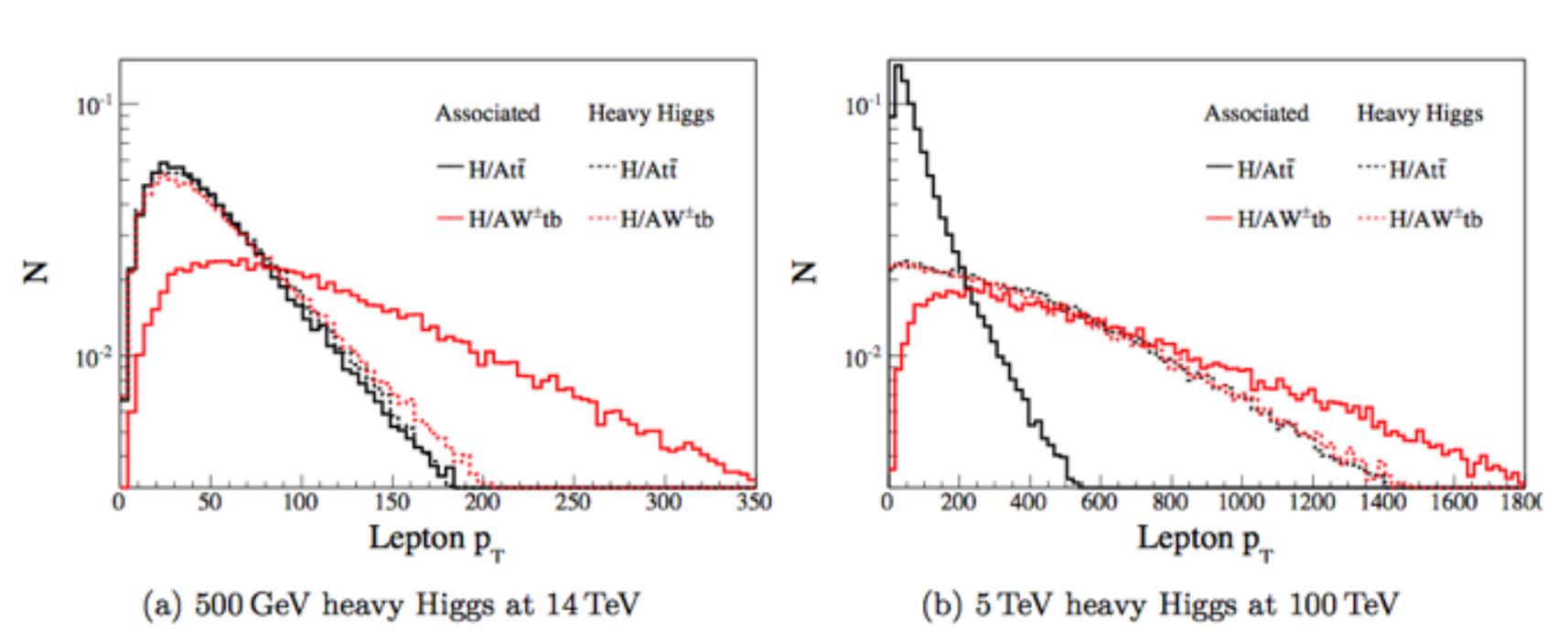


(a) $pp \to t\bar{t}H(A) \to t\bar{t}t\bar{t}$ (b) $pp \to tW^{\pm}H(A) \to tW^{\pm}t\bar{t}$

- As mass increases, the constraints becomes stronger: Background decrease.
- Constraints are weaker at 100TeV: Background is large compared to 14TeV collider.
- The dominance of three top channel over four top channel. Can be explained by the kinematics.

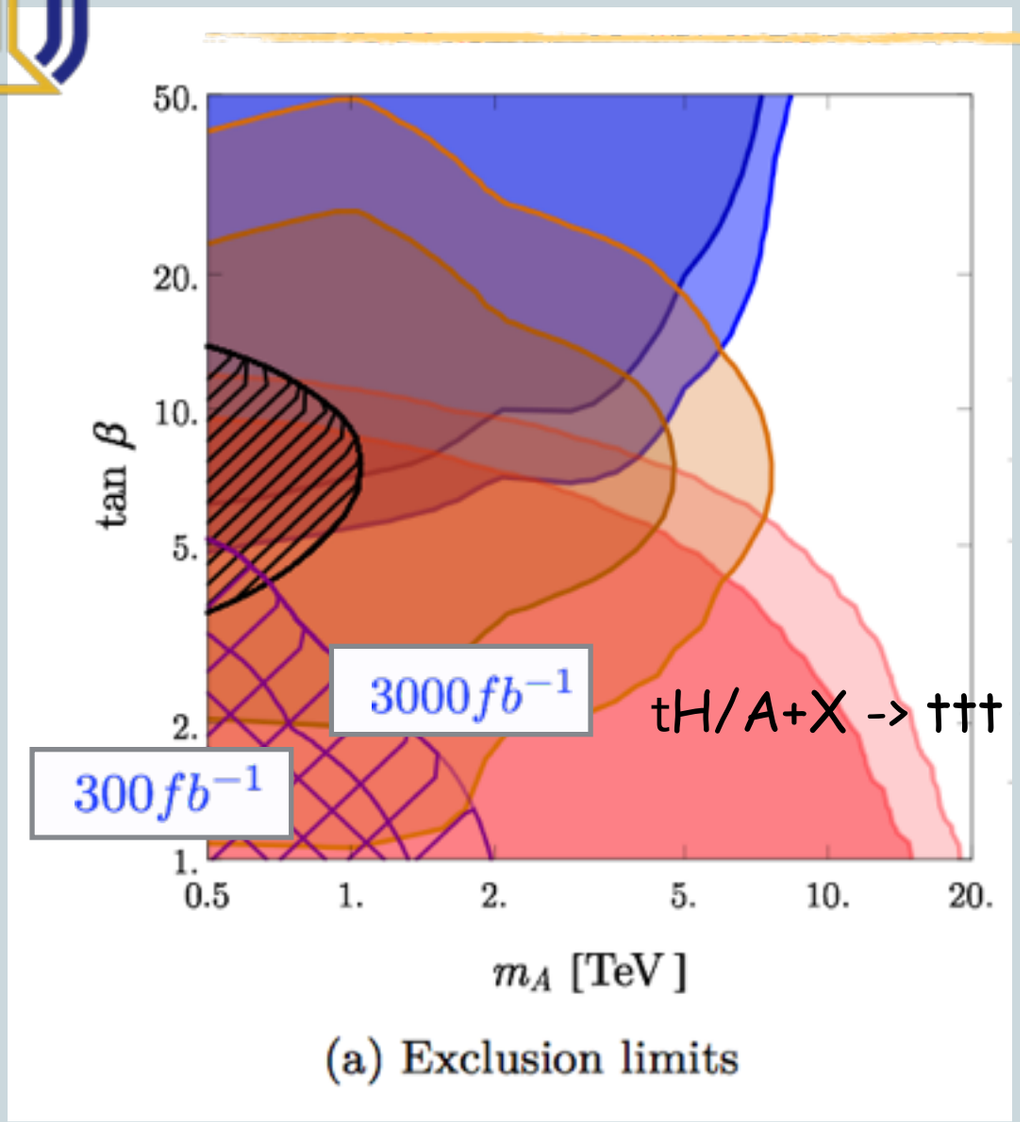
Kinematics

- The more forward associated bottom jet.

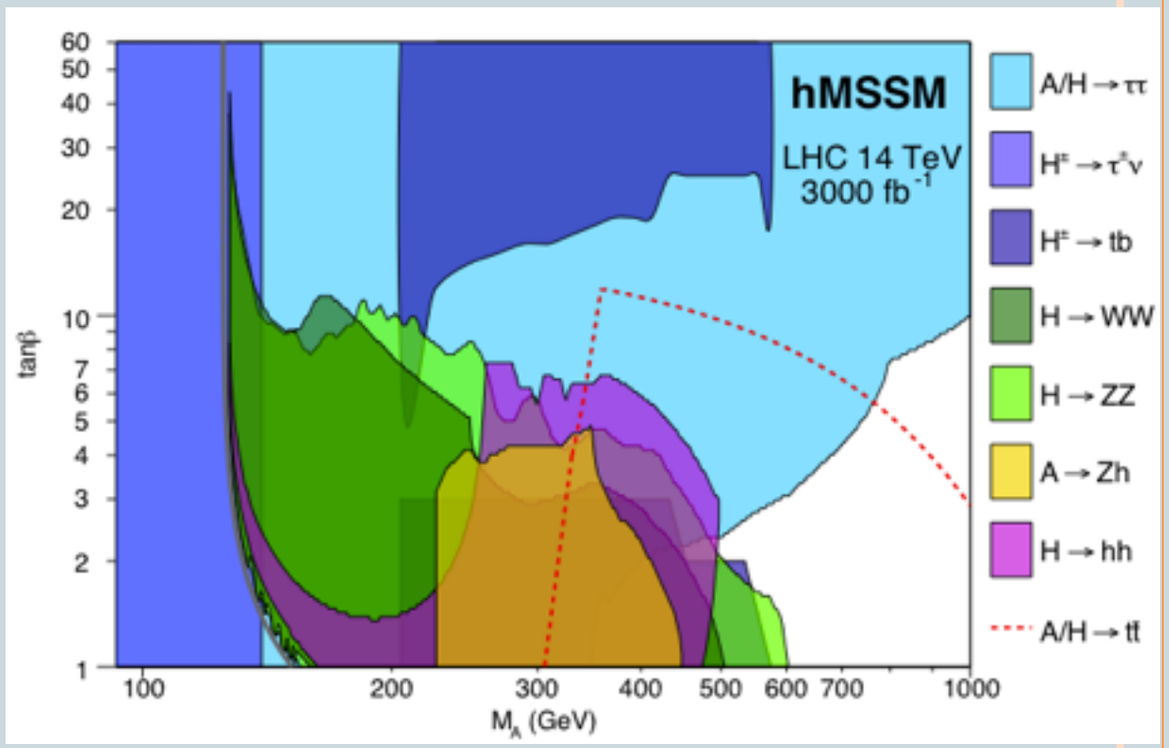


- Harder leptons from associated W boson.

Exclusion Limit for MSSM



(a) Exclusion limits



[A. Djouadi et. al.'15]

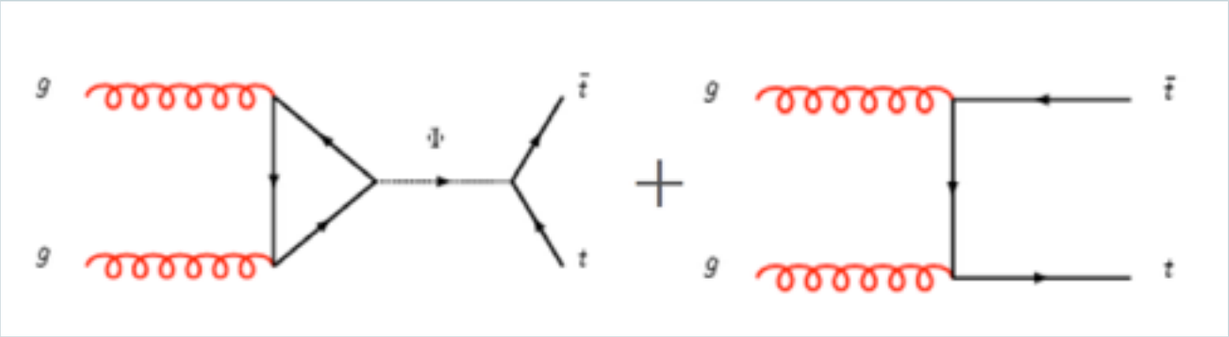
- The red dotted line for low tan_beta region is covered to ~1 TeV for (0.3/ab) and to ~1.5TeV for (3/ab).
- Associated production help to probe the low tan_beta region.

GRConference on particle physics: June 25-30

GRSeminar: June 24-25

Welcome

Neutral Higgs-14TeV

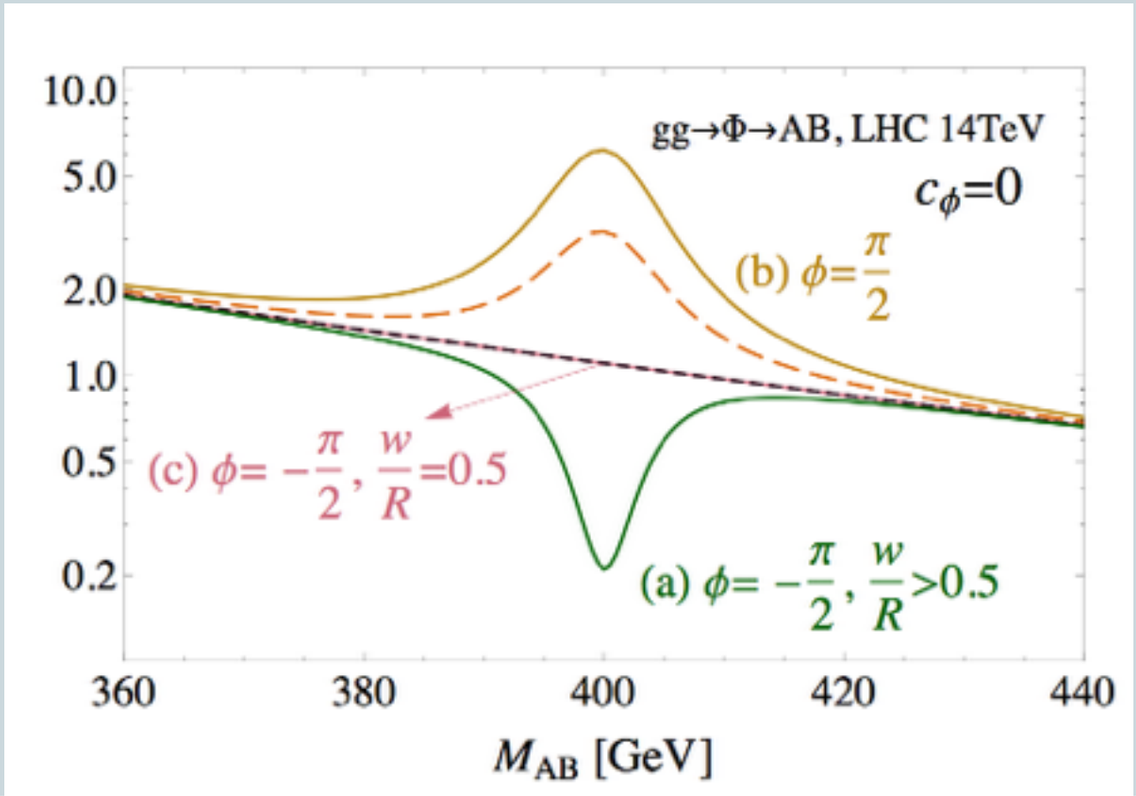


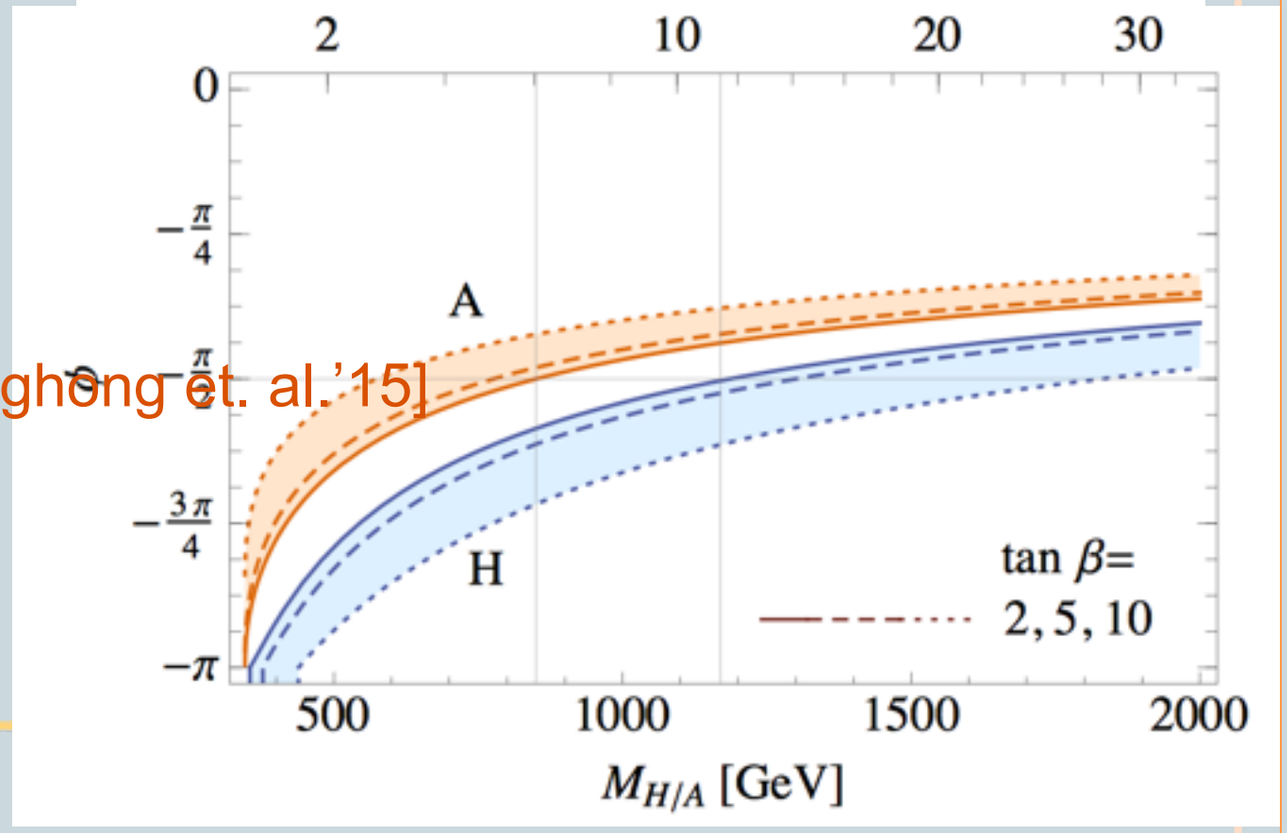
$$\hat{\sigma} = \hat{\sigma}_{\rm bg} + \frac{M^4}{(\hat{s}-M^2)^2 + M^4 w^2} \times \left[\frac{2(\hat{s}-M^2)}{M^2}\,\hat{\sigma}_{\rm int} c_\phi + \hat{\sigma}_{\rm res}\left(1 + \frac{2w}{R} s_\phi\right)\right]$$

$$\hat{\sigma}_{\rm bg,res} = \frac{1}{32\pi\hat{s}} \int dz \sum \mathcal{A}^2_{\rm bg,res},$$

$$\hat{\sigma}_{\rm int} e^{i\phi} = \frac{1}{32\pi\hat{s}} \int dz \sum \mathcal{A}_{\rm bg}\mathcal{A}_{\rm res} e^{i(\phi_{\rm res}-\phi_{\rm bg})}$$

$$R = \frac{\hat{\sigma}_{\rm res}}{\hat{\sigma}_{\rm int}}, \quad w \equiv \frac{\Gamma}{M}.$$





[J. Sunghong et. al.'15]

Neutral Higgs-14TeV

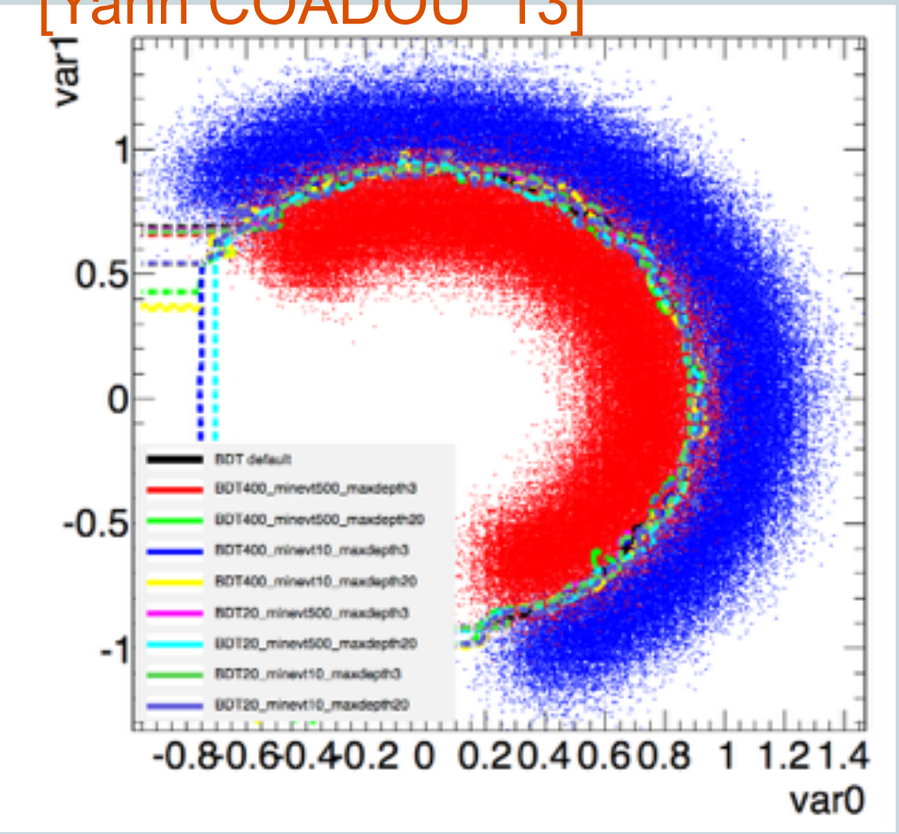
Background	14 TeV		100 TeV	
	σ [fb]	$\mathcal{L}_{\text{gen}}$ [ab^{-1}]	σ [fb]	$\mathcal{L}_{\text{gen}}$ [ab^{-1}]
$t\bar{t}t\bar{t}$	0.4851	103	122.7	1.63
$tttW^{\pm}b$	0.06016	831	14.86	6.73
$t\bar{t}W^{+}b\bar{b}$	0.03284	1520	0.3822	262

BDT

BDT: Non-linear combination of variables.

optimise the analysis.

[Yann COADOU '13]



(a) Circular correlation example

- Construct top BDT: one is hadronic, another one is leptonic.
- Construct Bottom Fusion BDT: demand two b-like jets with large delta eta