B→$D^*\tau\nu$ with SuperIso

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New Physics at Belle II Workshop

@ KIT

Global Fit

- Sensitivity would be improved by combining measurements. → **Global fit**
  - Derive allowed/excluded parameter space
  - Check compatibility of models

$A = 0.813^{+0.015}_{-0.027}$
$\lambda = 0.2255^{+0.0007}_{-0.0003}$
$\bar{\rho} = 0.149^{+0.016}_{-0.008}$
$\bar{\eta} = 0.342^{+0.013}_{-0.011}$
(68% CL)

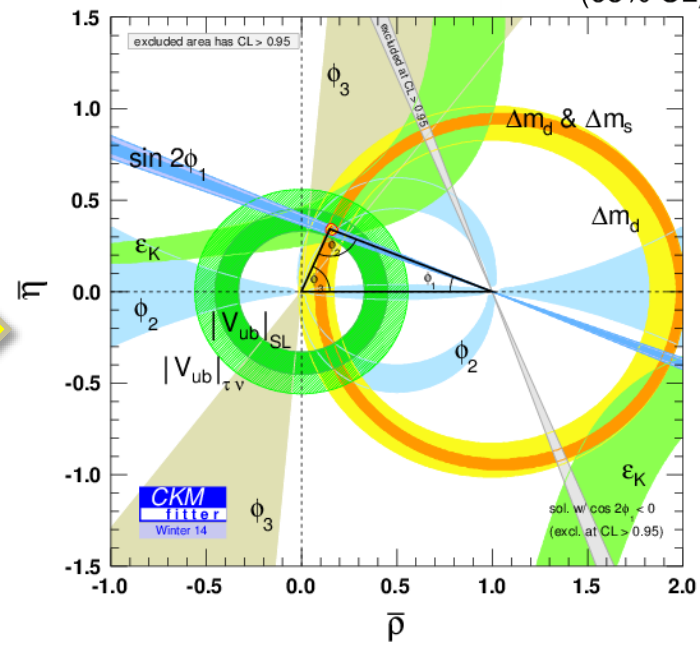
Winter 2014

Experimental results (+QCD cal.)

$|V_{ud}|,\ |V_{us}|$
$|V_{cb}|,\ |V_{ub}|_{SL}$
$B \to \tau\nu$
$\Delta m_d,\ \Delta m_s$
$\epsilon_K,\ \sin 2\phi_1$
$\phi_2,\ \phi_3$

SM

→ **CKM fitter** / **UT fit** →



- There are several public codes to calculate observables.
  - "SusyFlavour", "SuperIso", "SusyFit", and "GammaCombo" are introduced at last B2TiP meeting (Nov.2014).

→ Global analysis for Belle II using public code.

Calculation codes

In my study, public code "SuperIso" is used.

SuperIso

- Dedicated to the flavor physics observable calculation
  - **Observables**
    - $b \to s\gamma$, $b \to sll$, $B \to \tau\nu$, $B \to D\tau\nu$, $B_{s/d} \to \mu\mu$, $D_s \to l\nu$, $K \to \mu\nu/\pi \to \mu\nu$, muon g-2 …
    - $B \to D^*\tau\nu$ is not implemented in SuperIso.
      - Calculation code for $\mathcal{B}(B \to D^*\tau\nu)$ in Type-II 2HDM are made, communicating with Y. Sakaki, R. Watanabe, and M. Tanaka.
      - It is combined with SuperIso. *[PRD87, 034028 (2013)].*
  - **Models**
    - SM
    - 2HDM (type-I, II, lepton specific, flipped)
    - MSSM (CMSSM, NUHM, AMSB, HCAMSB, MMAMSB, GMSB)
    - NMSSM (CNMSSM, NGMSB, NNUHM)
    - …

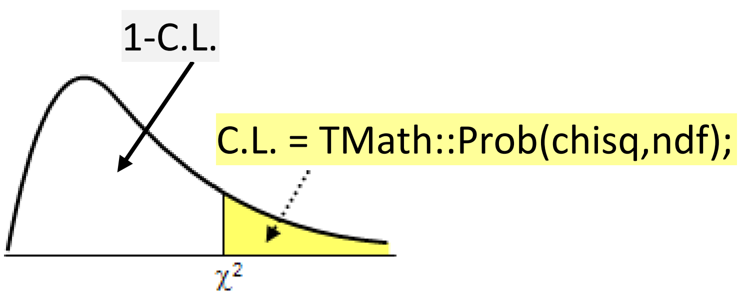
Statistical method

- Chi-squared approach.

$$\chi^2 = \sum_i \chi_i^2, \quad \chi_i^2 = \frac{\left|x_i^{\mathrm{exp}} - x_i^{\mathrm{theory}}\right|^2}{\left(\sigma_i^{\mathrm{exp}}\right)^2 + \left(\sigma_i^{\mathrm{theory}}\right)^2} = \frac{|\Delta x_i|^2}{\sigma_i^2}$$

(x_i : i$^{\mathrm{th}}$ observable)

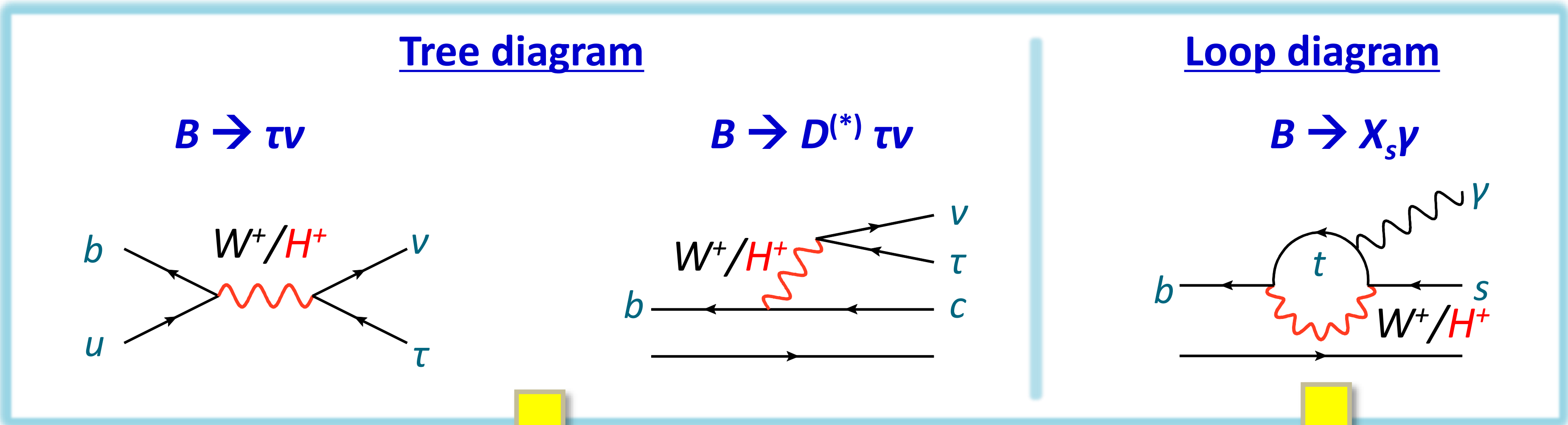
  - Correlation between observables is not considered.
  - For the estimation of theoretical error, relative accuracy at SM prediction is assumed.
- χ^2 is translated to confidence level (C.L.), and allowed/excluded region is estimated.



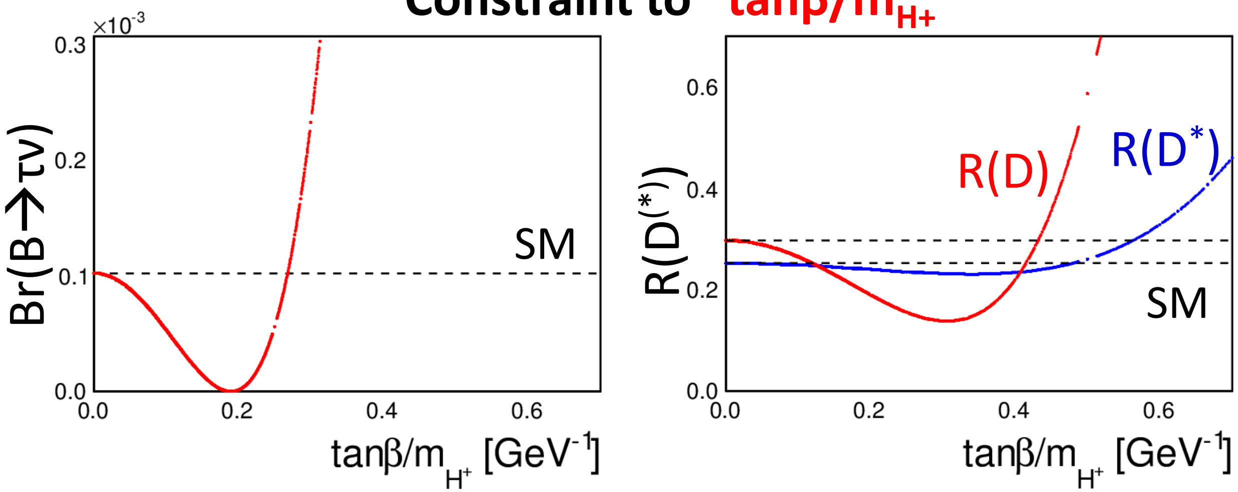
* In this talk, I will show “combined constraint plots” which are made based on the above conditions (NOT official plots).

Observables sensitive to charged Higgs

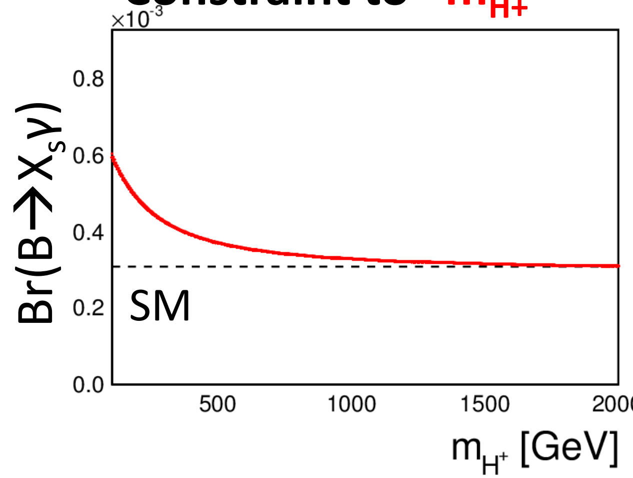
- Type-II 2HDM



Constraint to "$\tan\beta/m_{H+}$"



Constraint to "m_{H+}"



$R(D^{(*)}) = Br(D^{(*)}\tau\nu)/Br(D^{(*)}l\nu)$

Observables used in global analysis

Theoretical prediction | **Experimental results**

$B \to D^{(*)}\tau\nu$

$$R(D^*) = 0.252 \pm 0.004$$
$$R(D) = 0.305 \pm 0.012$$

@PRD87,032028,2013

*Naïve **Belle** average (A. Bozek's average @KEK-FF0213)*

$$R(D^*) = 0.405 \pm 0.047$$
$$R(D) = 0.430 \pm 0.091$$

- **Inclusive tag**, 535MBB, PRL 99, 191807 (2007)
- **Inclusive tag**, 657MBB, PRD 82, 072005 (2010)
- **Hadronic tag**, 657MBB, arXiv:0910.4301

$B \to D^{(*)}\tau\nu$ with full Belle data is still ongoing.

$B \to \tau\nu$

$$\mathcal{B}(\mathrm{B} \to \tau\nu) = (75.3^{+10}_{-5}) \times 10^{-6}$$

@CKM fitter winter 2014

*Naïve **Belle** average (my hand calculation)*

$$\mathcal{B}(B \to \tau\nu) = (0.91 \pm 0.23) \times 10^{-4}$$

- **Semileptonic tag**, 772MBB, CKM2014, arXiv:1409.5269
- **Hadronic tag**, 772MBB, PRL 110, 131801 (2013)

New Belle result for $B \to \tau\nu$ with semilept. tag is included.

$b \to s\gamma$

$$\mathcal{B}(B \to s\gamma) = (3.15 \pm 0.23) \times 10^{-4}$$

@PRD 98, 022002 (2007)

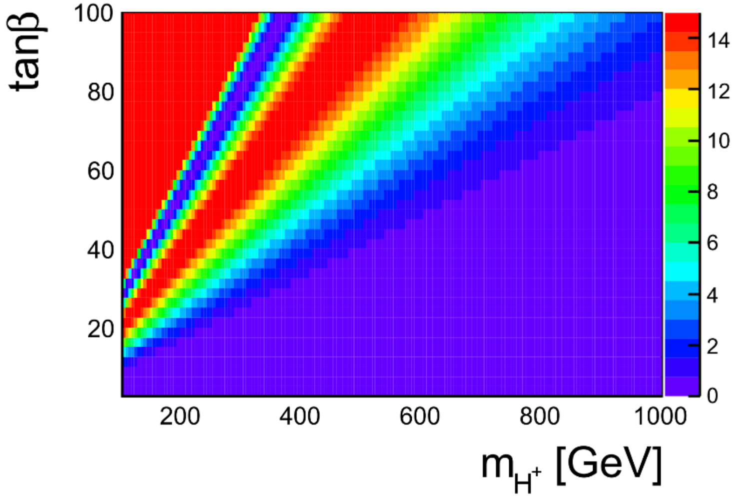
HFAG average 2013

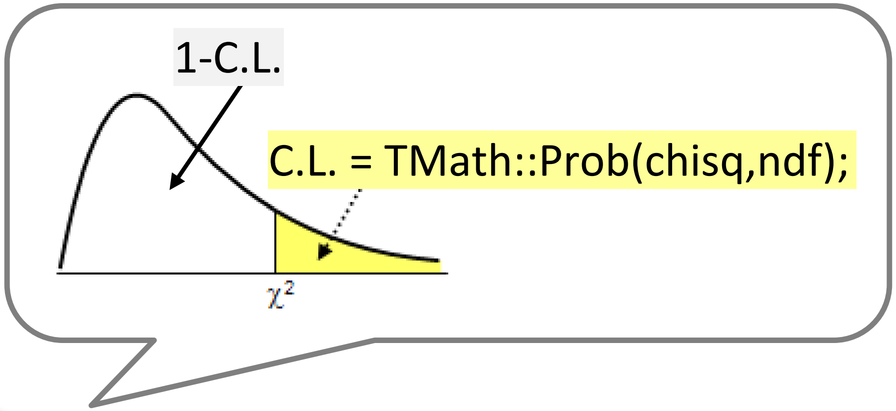
$$\mathcal{B}(B \to s\gamma) = (3.43 \pm 0.22) \times 10^{-4}$$

Derivation of constraint plots

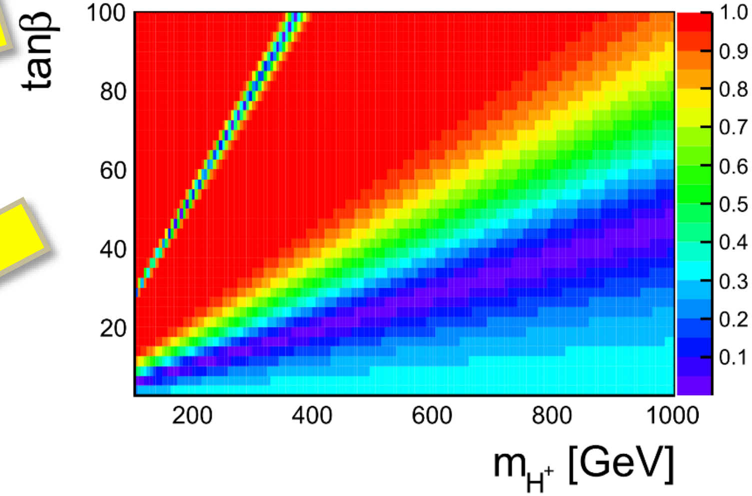
- e.g. $B \to \tau\nu$

χ^2 distribution

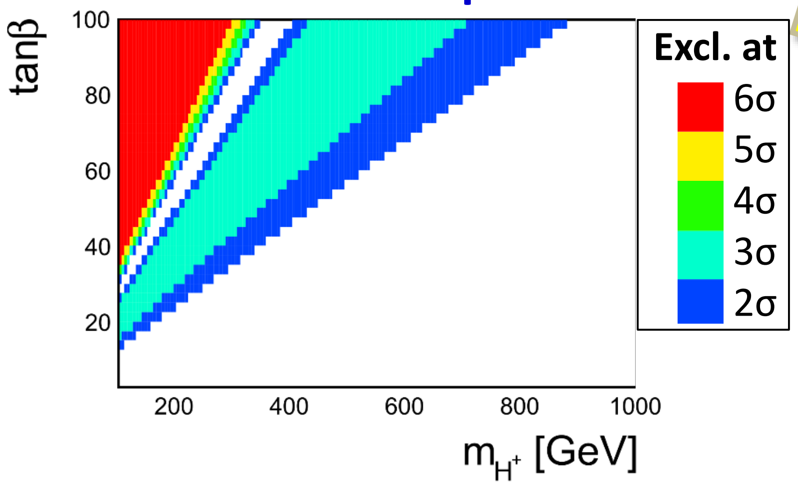




1- C.L. distribution

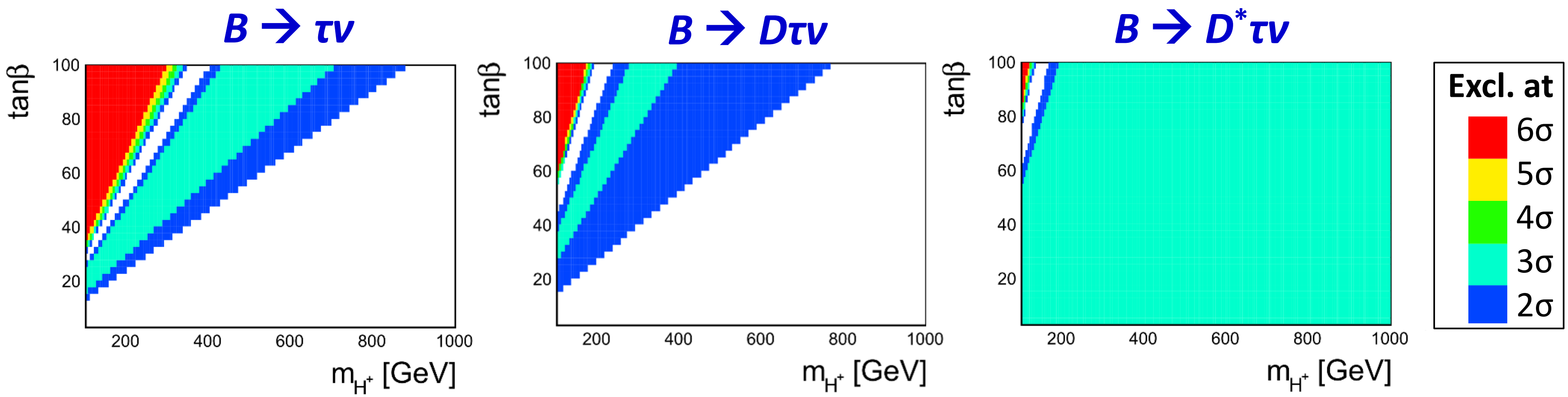


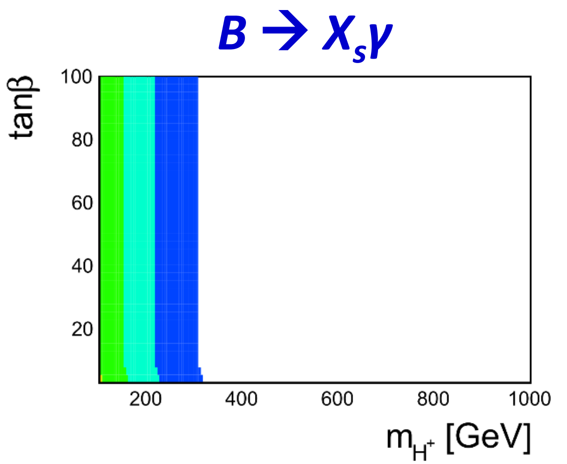
Constraint plots



Constraint on type-II 2HDM

- Only Belle results described in previous page.





- HFAG2013 value is used.

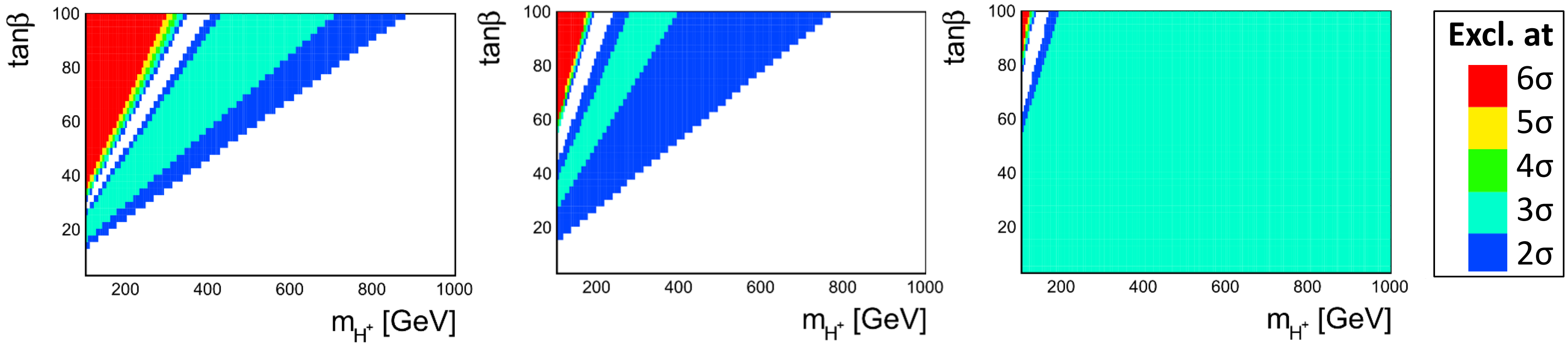
Different value of tanβ/m_{H+} is favored.

Exclude m_{H+} < 310 GeV with 95% C.L. for any value of tanβ.

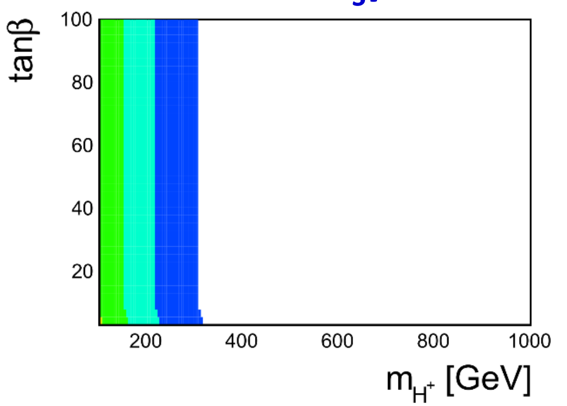
Combined constraint on type-II 2HDM

- Only Belle results described in previous page.

B → τν ***B → Dτν*** ***B → D*τν***

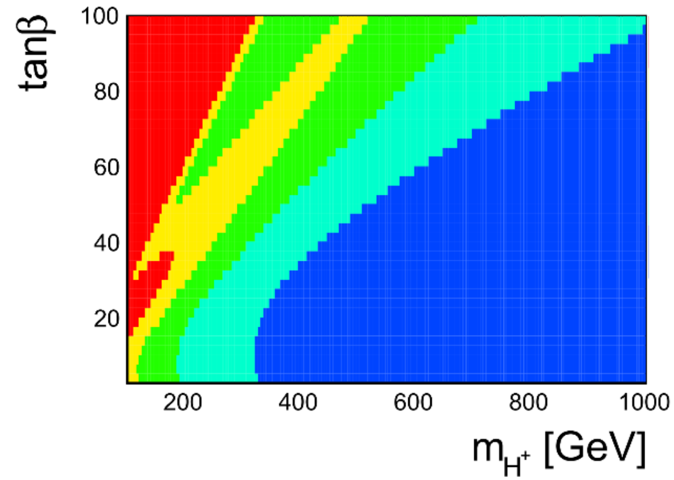


B → X_sγ



- HFAG2013 value is used.

Constraints from **four** observables.



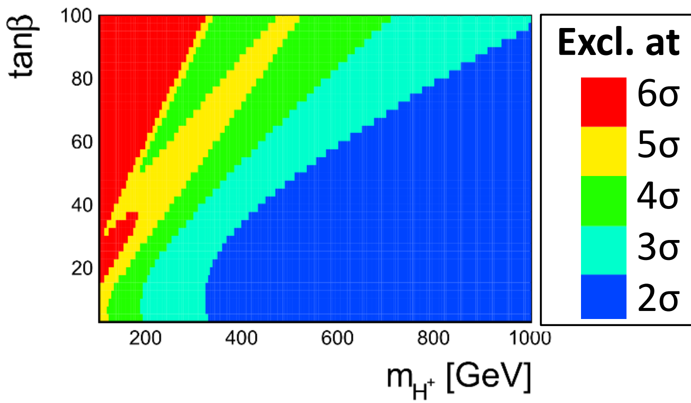
Exclude with 98.7% C.L. for any value of $\tan\beta/m_{H+}$.

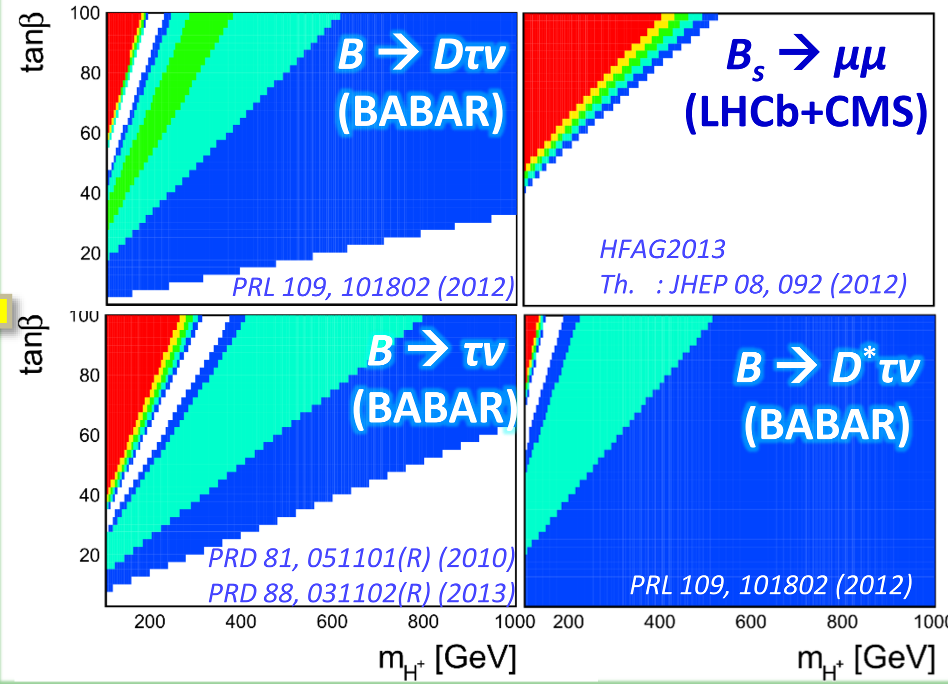
Combined constraint on type-II 2HDM

- More combination with other experimental results.

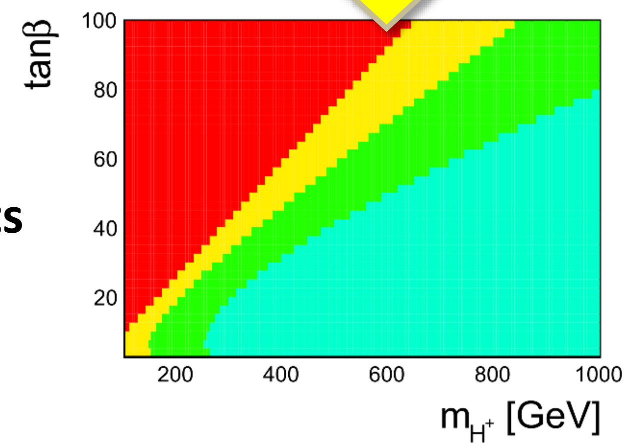
Constraint from four exp. results

- $B \to \tau\nu$, $D\tau\nu$, $D^*\tau\nu$ by Belle
- $B \to X_s\,\gamma$ (HFAG2013)





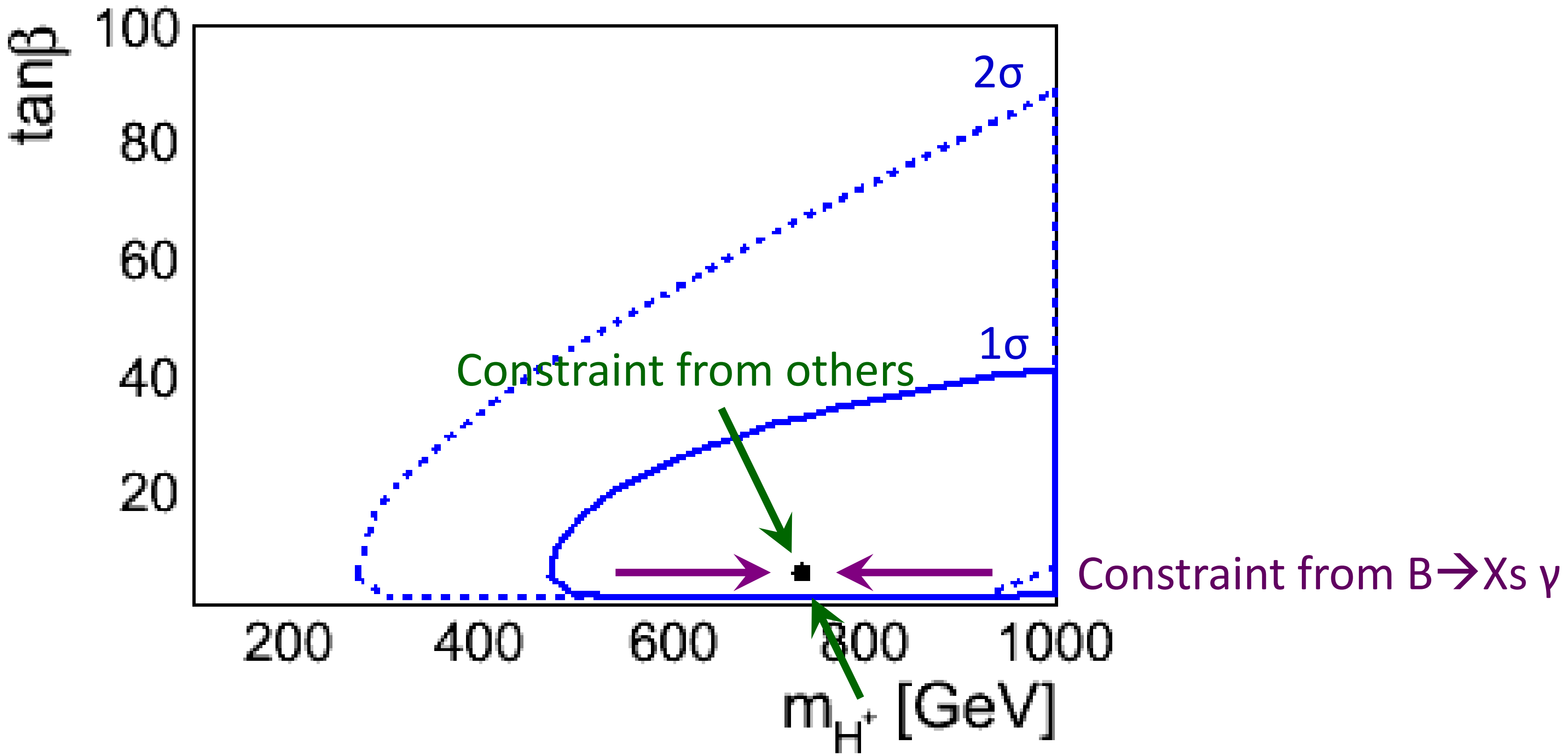
Constraint from eight exp. results



- More stringent constraint on large $\tan\beta/m_{H+}$ region.
- Exclude with 99.98% C.L. for any value of $\tan\beta/m_{H+}$.

Global fit on type-II 2HDM

- Global fit also can be possible using 8 experimental results.
  - Optimal points can be found, although type-II 2HDM is disfavored (χ^2/ndf =26.1/8).



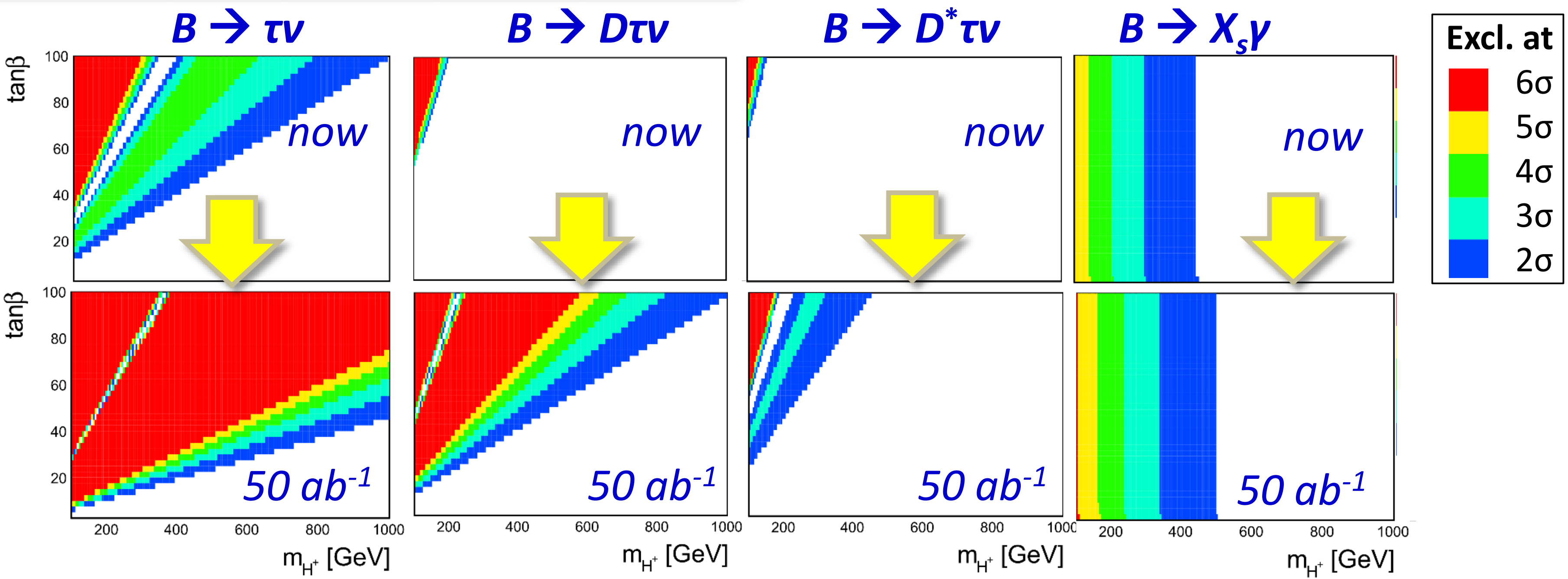
Prospect of constraint on type-II 2HDM@ Belle II

- Constraint from **four** observables at Belle II.
  - All experimental inputs are assumed to be SM values.
  - Experimental uncertainties are estimated based on Belle II TDR.
  - Improvement of theory side is not included except for $B \to \tau\nu$.

	Exp.			Th.
	Now	5 ab^{-1}	50 ab^{-1}	Now
B → τν	25%	10%	3%	-7+14%
B → Dτν	30%	11%	4%	4%
B → D*τν	19%	7%	2%	2%
B → X_sγ	7%	5%	4%	7%

Will be improved by precise V_{ub} measurements.
My naive estimation assuming σ_{fB} ~1% :
~5% @Belle II era

My naive estimation



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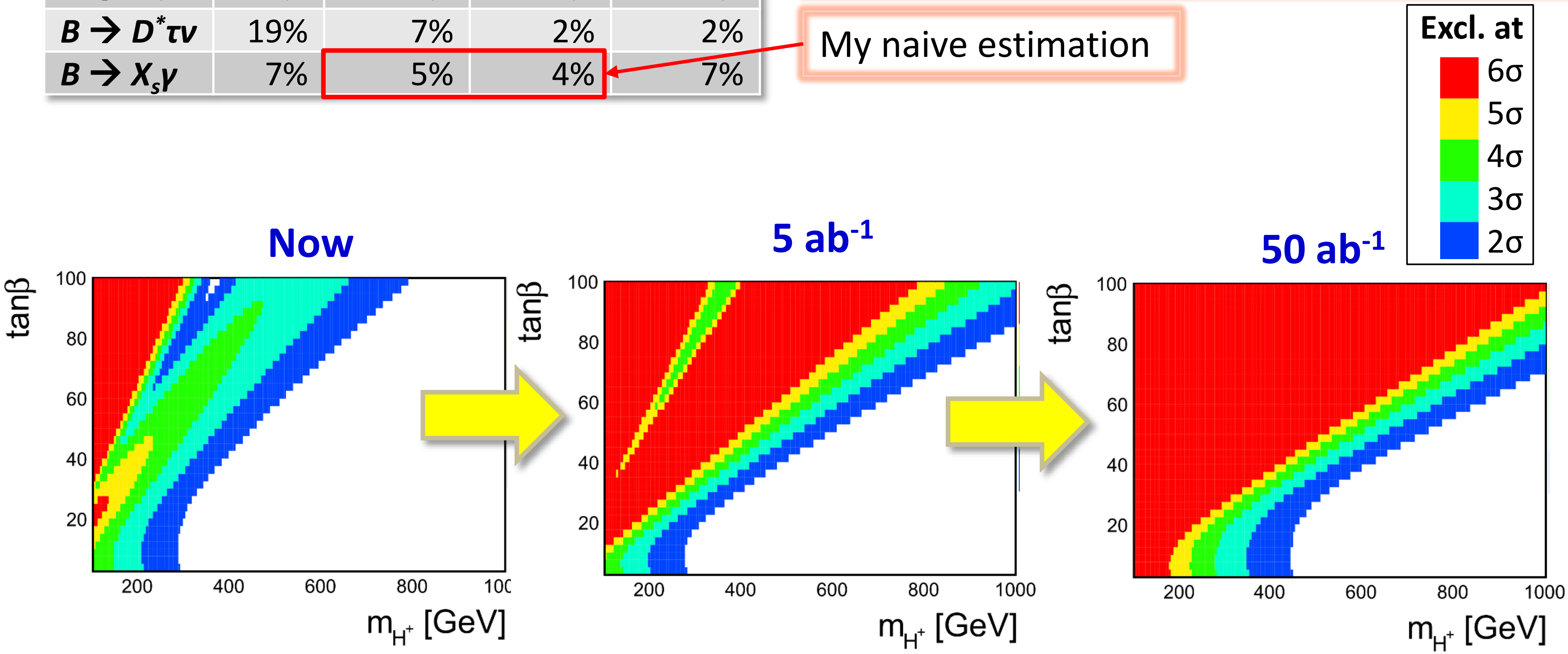
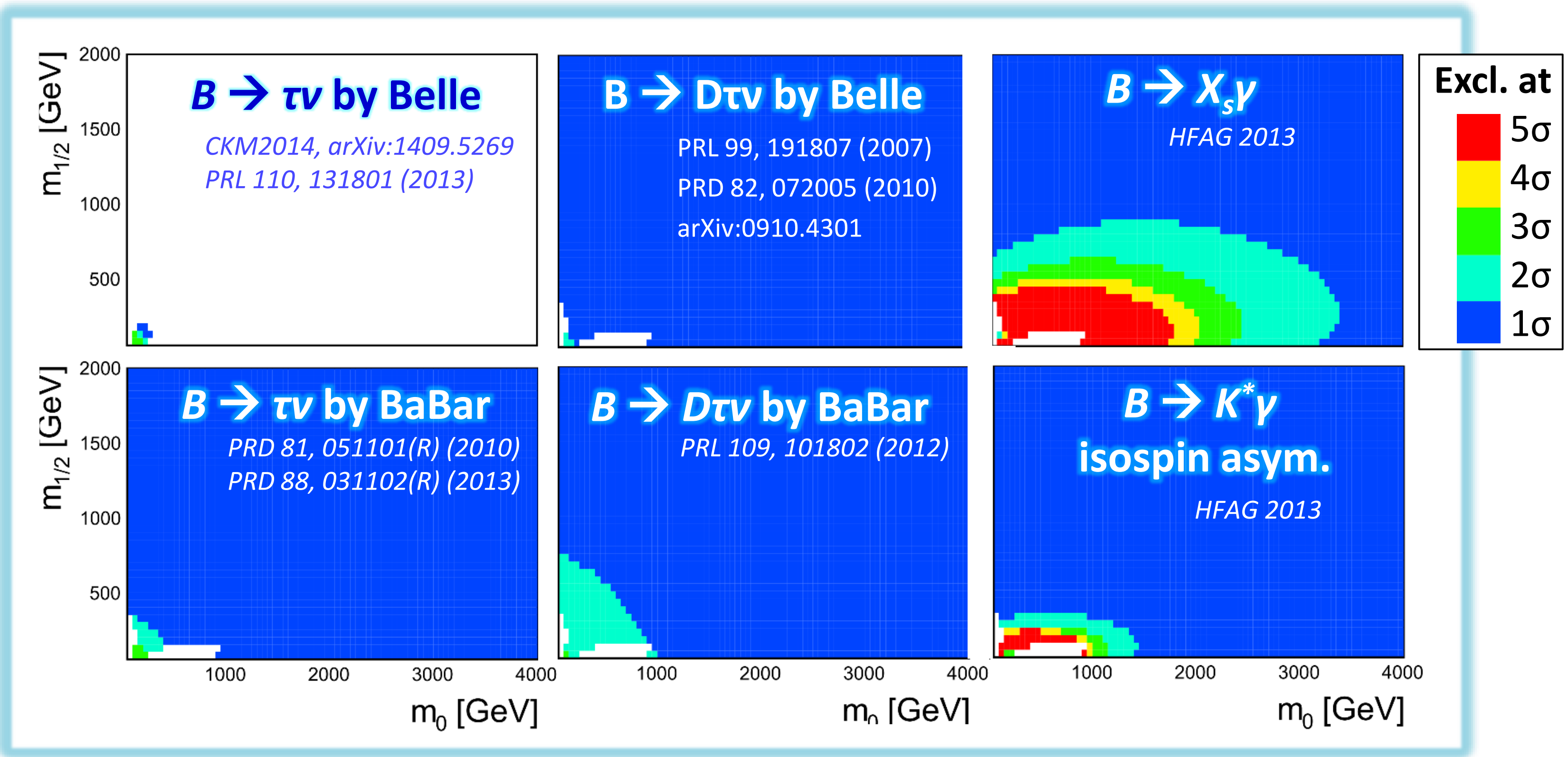


Constraint on CMSSM

- $B \rightarrow D^{*}\tau\nu$ is not implemented in SuperIso.
- Isospin asymmetry in $B \rightarrow K^{*}\gamma$ is added.
  - **[Th.]** 0.026 ± 0.008 @PRD72, 014013 (2015), [**Exp.]** 0.052 ±0.026 @HFAG2013
- There are five parameters (m_0, $m_{1/2}$, $\tan\beta$, A_0, $sgn(\mu)$) in CMSSM.

$\tan\beta = 30$, $A_0 = -2m_0$, $sgn(\mu)>0$

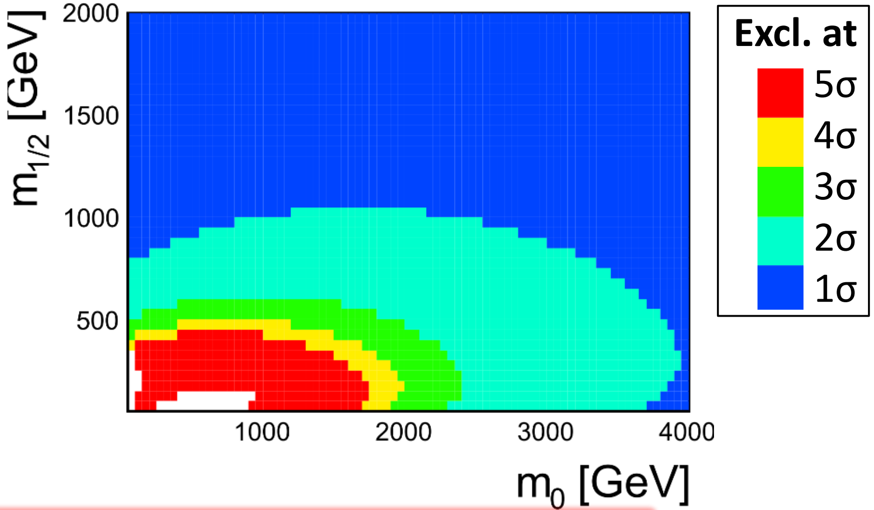


Combined constraint on CMSSM

Constraint from **six** experimental results by **Belle/BaBar**

- $\tan\beta = 30$, $A_0 = -2m_0$, $\mathrm{sgn}(\mu)>0$

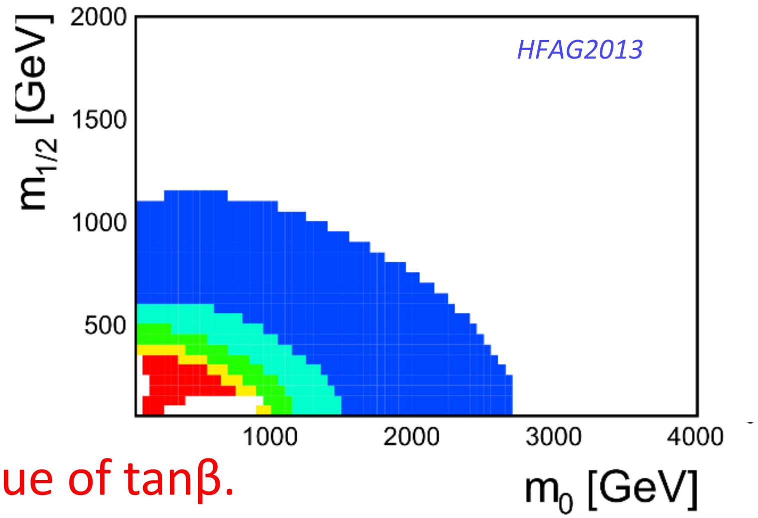
- $B \to \tau\nu$, $D\tau\nu$ by Belle
- $B \to \tau\nu$, $D\tau\nu$ by BaBar
- $B \to X_s\gamma$, $K^*\gamma$ (HFAG2013)



Exclude $m_{1/2}$ < ~1 TeV and m_0 < ~4 TeV with 2σ level.

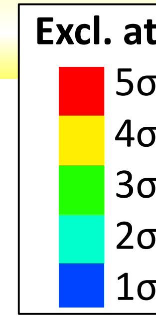
Comparison with LHCb/CMS

Constraint from $B_s \to \mu\mu$ by **LHCb/CMS**



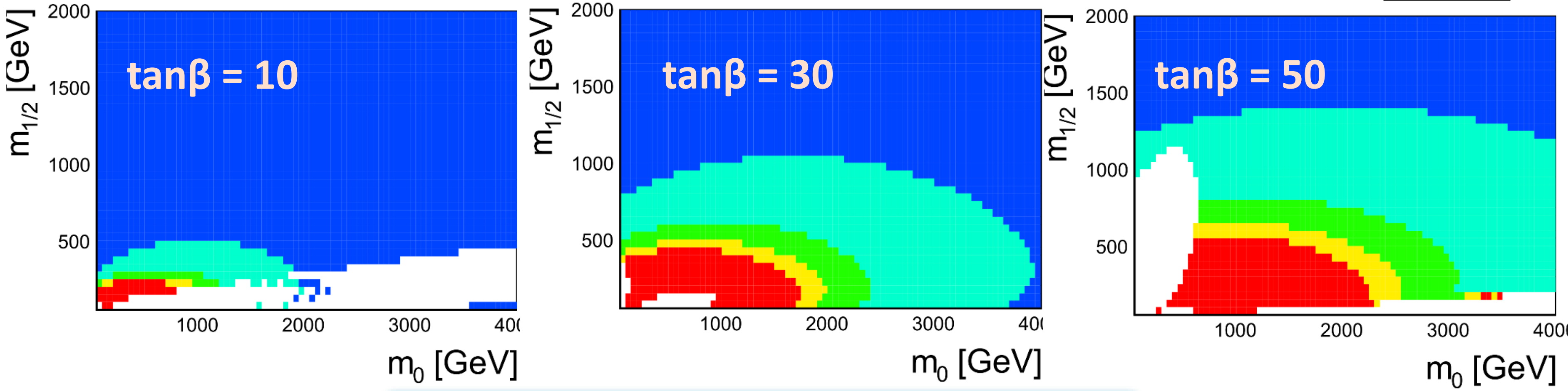
The situation highly depends on the value of tanβ.
If tanβ is large, $B_s \to \mu\mu$ gives stronger constraints.

tanβ dependence on CMSSM

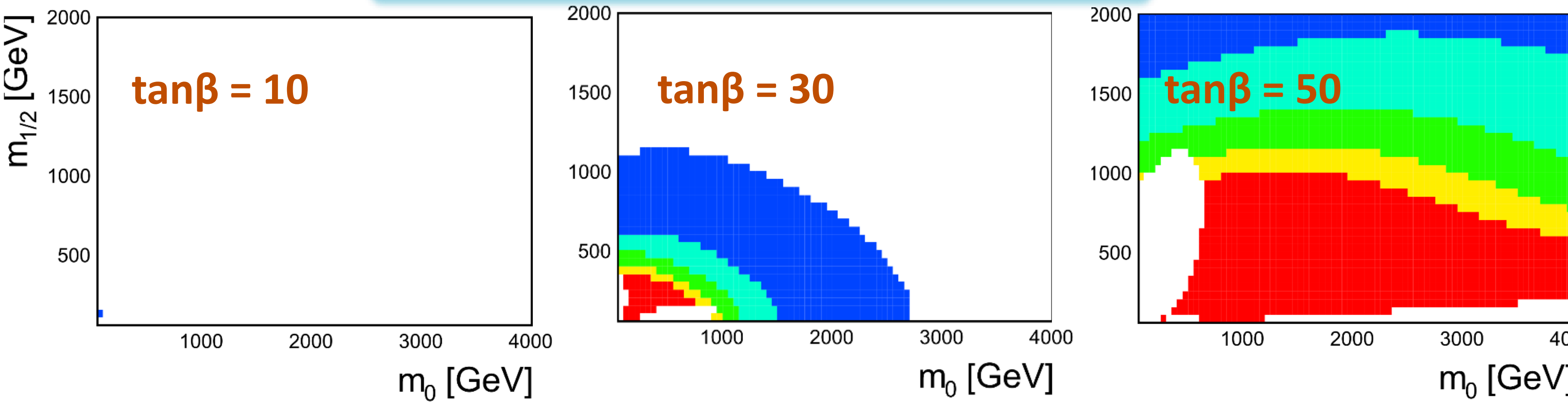


Constraint from **six** experimental results by Belle/BaBar

- $B \rightarrow \tau\nu$, $D\tau\nu$ by Belle/BaBar and $B \rightarrow X_s\gamma$, $K^*\gamma$ (HFAG2013)



Constraint from $B_s \rightarrow \mu\mu$ by LHCb/CMS



Prospect of constraint on CMSSM@ Belle II

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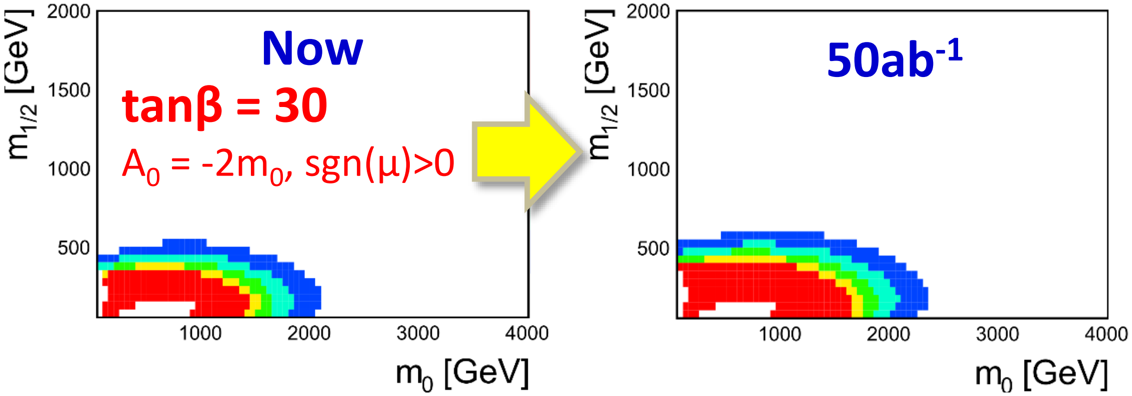

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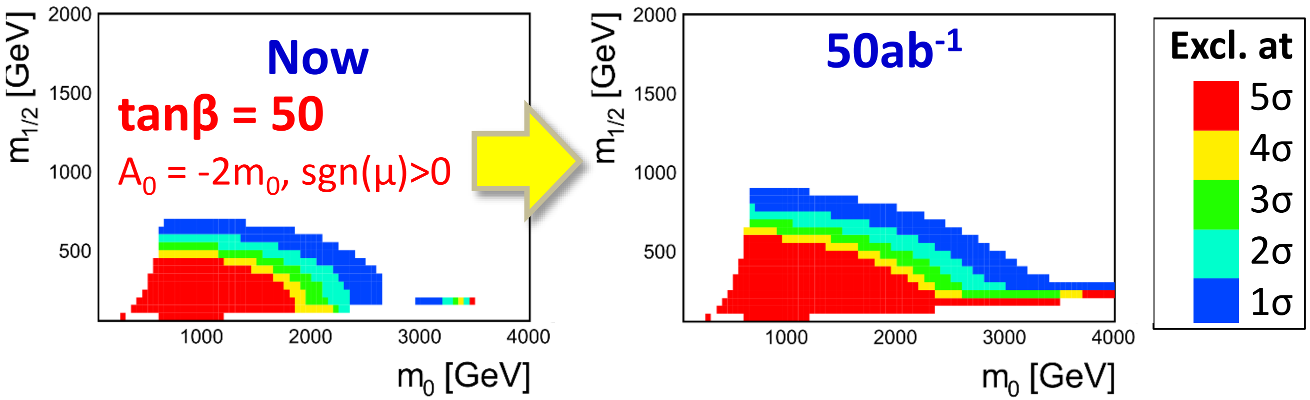
$B \rightarrow K^*\gamma$	±0.026	±0.010	±0.005	±0.008



Constraint region can be expanded in CMSSM using Belle II data.
We need benchmark theoretical model which has a rich flavor structure, because Belle II is more sensitive to the flavor structure in NP.

Summary

- Global fit analysis for Belle II are performed using
  - existing public code "SuperIso"
  - code for $B \rightarrow D^* \tau \nu$ in type-II 2HDM
    - which is made, communicating with Y. Sakaki, R. Watanabe, and M. Tanaka *[PRD87, 034028 (2013)].*
- Observables : $B \rightarrow \tau\nu$, $B \rightarrow D\tau\nu$, $B \rightarrow D^*\tau\nu$, $B \rightarrow X_s\gamma$, $\Delta_{0-}(B \rightarrow K^*\gamma)$
- Models : Type-II 2HDM, CMSSM

Benchmark theoretical model

Need benchmark theoretical model which has a rich flavor structure, because Belle II is sensitive to the flavor structure in NP.

Theoretical calculation codes

Not covered all observables, which are important for Belle II.
We can also combine multiple calculation tools.

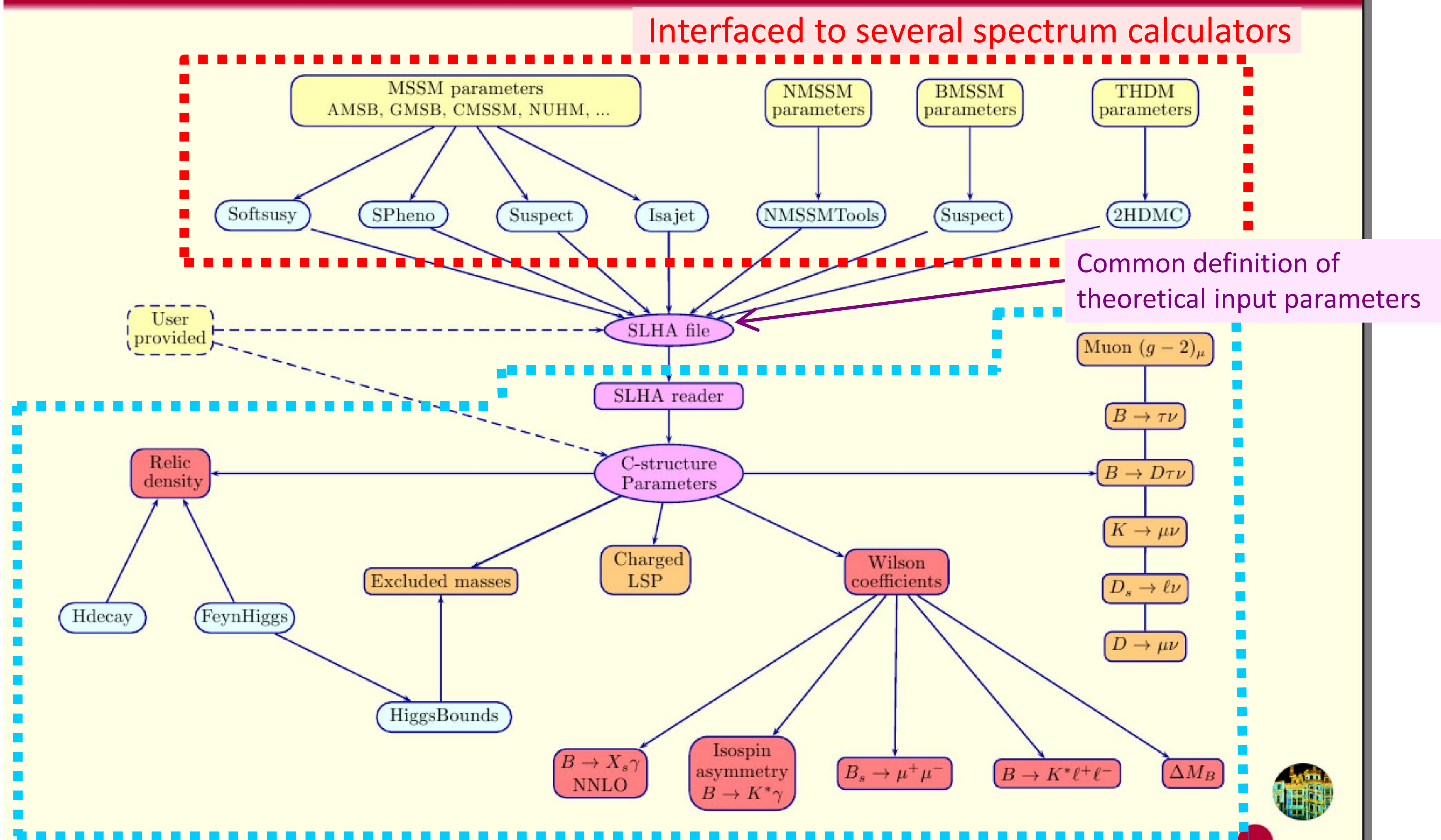
Fitter code

Simplest method (chi-square) is used so far.
The treatment of error should be cared.

Backup

SuperIso framework

SuperIso



Itoh-san's slide

Br prediction by 2HDM consistent for both Dτν and D*τν

BR(B→Dτν) and BR(B→Dlν) from Y. Sakaki, R. Watanabe, and M. Tanaka

(Phys. Rev. D87, 034028 (2013) + private comm.)

$$\mathrm{Br}(\bar{B} \to D\tau\bar{\nu}_\tau) = \tau_{\bar{B}}\Gamma(\bar{B} \to D\tau\bar{\nu}_\tau)$$

$$\equiv \tau_{\bar{B}} G_F^2 |V_{cb}|^2 V_1(1)^2 \times \Bigg[\Gamma_1 + \Gamma_2\rho_1^2 + \Gamma_3\rho_1^4 + (\Gamma_4 + \Gamma_5\rho_1^2 + \Gamma_6\rho_1^4)\left(\frac{4.91\mathrm{GeV} - 1.77\mathrm{GeV}}{m_b - m_c}\right)\mathrm{Re}(C_{S_1} + C_{S_2}) + (\Gamma_7 + \Gamma_8\rho_1^2 + \Gamma_9\rho_1^4)\left(\frac{4.91\mathrm{GeV} - 1.77\mathrm{GeV}}{m_b - m_c}\right)^2 |C_{S_1} + C_{S_2}|^2\Bigg]$$

$$\Gamma_1 = +(1.868 \;\; - 2.321 \times 10^{-2}a \;\; + 1.373 \times 10^{-4}a^2)\, 10^{-2}$$
$$\Gamma_2 = -(6.829 \;\; - 7.181 \times 10^{-2}a \;\; + 3.708 \times 10^{-4}a^2)\, 10^{-3}$$
$$\Gamma_3 = +(7.005 \;\; - 6.645 \times 10^{-2}a \;\; + 3.121 \times 10^{-4}a^2)\, 10^{-4}$$

$$\Gamma_4 = +(2.804 \;\; - 6.543 \times 10^{-2}a \;\; + 4.140 \times 10^{-4}a^2)\, 10^{-2}$$
$$\Gamma_5 = -(8.864 \;\; - 18.08 \times 10^{-2}a \;\; + 9.985 \times 10^{-4}a^2)\, 10^{-3}$$
$$\Gamma_6 = +(8.317 \;\; - 15.45 \times 10^{-2}a \;\; + 7.735 \times 10^{-4}a^2)\, 10^{-4}$$

$$\Gamma_7 = +(1.953 \;\; - 4.881 \times 10^{-2}a \;\; + 3.265 \times 10^{-4}a^2)\, 10^{-2}$$
$$\Gamma_8 = -(5.518 \;\; - 12.05 \times 10^{-2}a \;\; + 7.065 \times 10^{-4}a^2)\, 10^{-3}$$
$$\Gamma_9 = +(4.787 \;\; - 9.484 \times 10^{-2}a \;\; + 5.039 \times 10^{-4}a^2)\, 10^{-4}$$

$$\mathrm{Br}(\bar{B} \to D\ell\bar{\nu}_\ell) = \tau_{\bar{B}}\Gamma(\bar{B} \to D\ell\bar{\nu}_\ell)$$

$$\equiv \tau_{\bar{B}} G_F^2 |V_{cb}|^2 V_1(1)^2 \times [\Gamma_1 + \Gamma_2\rho_1^2 + \Gamma_3\rho_1^4]$$

$$\Gamma_1 = +8.788 \times 10^{-2}$$
$$\Gamma_2 = -5.230 \times 10^{-2}$$
$$\Gamma_3 = +0.8190 \times 10^{-2}$$

Assume Type II 2HDM.

$\rho_1^2 = 1.186 \pm 0.036 \pm 0.041$ (HFAG).

$a = 1 \pm 1$
(M. Tanaka and R. Watanabe).

$m_b = 4.20 \pm 0.07$ GeV and
$m_c = 0.901^{+0.111}_{-0.113}$ GeV
(MSbar, PRD77, 113016 (2008)).

Gaussian assumption for the errors.

$$C_{S_1} = -\frac{m_\tau m_b}{m_{H_\pm^2}} \tan^2\beta$$

$$C_{S_2} = -\frac{m_\tau m_c}{m_{H_\pm^2}}$$

Itoh-san's slide

BR(B→D*τν) and BR(B→D*lν) from Y. Sakaki, R. Watanabe, and M. Tanaka

$$\begin{aligned}\mathrm{Br}(\bar{B}\to D^*\tau\bar{\nu}_\tau) &= \tau_B\Gamma(\bar{B}\to D^*\tau\bar{\nu}_\tau)\\ &= \tau_B G_F^2|V_{cb}|^2A_1(1)^2\times\Big[\Gamma_1+\Gamma_2\rho_{A_1}^2+\Gamma_3\rho_{A_1}^4\\ &\quad+(\Gamma_4+\Gamma_5\rho_{A_1}^2+\Gamma_6\rho_{A_1}^4)\left(\frac{4.91\mathrm{GeV}+1.77\mathrm{GeV}}{m_b+m_c}\right)\mathrm{Re}(C_{S_1}-C_{S_2})\\ &\quad+(\Gamma_7+\Gamma_8\rho_{A_1}^2+\Gamma_9\rho_{A_1}^4)\left(\frac{4.91\mathrm{GeV}+1.77\mathrm{GeV}}{m_b+m_c}\right)^2|C_{S_1}-C_{S_2}|^2\Big]\end{aligned}$$

$$\Gamma_1=+\left(5.538-0.005388R_1(1)+0.1344R_1(1)^2-2.027R_2(1)+0.3519R_2(1)^2+5.400\times10^{-2}a_3+7.117\times10^{-4}a_3^2-2.444\times10^{-2}R_2(1)a_3\right)10^{-2}$$

$$\Gamma_2=-\left(15.64-0.01815R_1(1)+0.4034R_1(1)^2-6.847R_2(1)+1.226R_2(1)^2+17.11\times10^{-2}a_3+20.83\times10^{-4}a_3^2-7.749\times10^{-2}R_2(1)a_3\right)10^{-3}$$

$$\Gamma_3=+\left(12.97-0.01635R_1(1)+0.3373R_1(1)^2-6.254R_2(1)+1.144R_2(1)^2+14.90\times10^{-2}a_3+17.09\times10^{-4}a_3^2-6.756\times10^{-2}R_2(1)a_3\right)10^{-4}$$

$$\Gamma_4=+\left(1.136-1.028R_2(1)+0.2327R_2(1)^2+5.972\times10^{-2}a_3+8.307\times10^{-4}a_3^2-2.701\times10^{-2}R_2(1)a_3\right)10^{-2}$$

$$\Gamma_5=-\left(3.611-3.272R_2(1)+0.7412R_2(1)^2+17.55\times10^{-2}a_3+22.48\times10^{-4}a_3^2-7.946\times10^{-2}R_2(1)a_3\right)10^{-3}$$

$$\Gamma_6=+\left(3.154-2.859R_2(1)+0.6481R_2(1)^2+14.44\times10^{-2}a_3+17.35\times10^{-4}a_3^2-6.541\times10^{-2}R_2(1)a_3\right)10^{-4}$$

$$\Gamma_7=+\left(0.3132-0.2834R_2(1)+0.06409R_2(1)^2+1.738\times10^{-2}a_3+2.538\times10^{-4}a_3^2-0.7857\times10^{-2}R_2(1)a_3\right)10^{-2}$$

$$\Gamma_8=-\left(0.9240-0.8368R_2(1)+0.1895R_2(1)^2+4.724\times10^{-2}a_3+6.346\times10^{-4}a_3^2-2.138\times10^{-2}R_2(1)a_3\right)10^{-3}$$

$$\Gamma_9=+\left(0.7623-0.6908R_2(1)+0.1565R_2(1)^2+3.658\times10^{-2}a_3+4.600\times10^{-4}a_3^2-1.657\times10^{-2}R_2(1)a_3\right)10^{-4}$$

$$\begin{aligned}\mathrm{Br}(\bar{B}\to D^*\ell\bar{\nu}_\ell) &= \tau_B\Gamma(\bar{B}\to D^*\ell\bar{\nu}_\ell)\\ &\equiv \tau_B G_F^2|V_{cb}|^2A_1(1)^2\times[\Gamma_1+\Gamma_2\rho_{A_1}^2+\Gamma_3\rho_{A_1}^4]\end{aligned}$$

$$\Gamma_1=+\left(32.87-0.04784R_1(1)+0.8060R_1(1)^2-17.68R_2(1)+3.351R_2(1)^2\right)\times10^{-2}$$

$$\Gamma_2=-\left(15.34-0.02262R_1(1)+0.3460R_1(1)^2-9.521R_2(1)+1.875R_2(1)^2\right)\times10^{-2}$$

$$\Gamma_3=+\left(1.993-0.002827R_1(1)+0.04062R_1(1)^2-1.337R_2(1)+0.2699R_2(1)^2\right)\times10^{-2}$$

Assume Type II 2HDM.

ρ_{A1}^2 = 1.207±0.015±0.021 (HFAG).

$R_1(1)$ = 1.403±0.033 (HFAG).

$R_2(1)$ = 0.854±0.020 (HFAG).

a_3 = 1±1
(M. Tanaka and R. Watanabe).

m_b = 4.20±0.07 GeV and
$m_c = 0.901^{+0.111}_{-0.113}$ GeV
(MSbar, PRD77, 113016 (2008)).

Gaussian assumption for the errors.

$$C_{S_1}=-\frac{m_\tau m_b}{m_{H^2_\pm}}\tan^2\beta$$

$$C_{S_2}=-\frac{m_\tau m_c}{m_{H^2_\pm}}$$

Experimental values : $R(D^{(*)})$

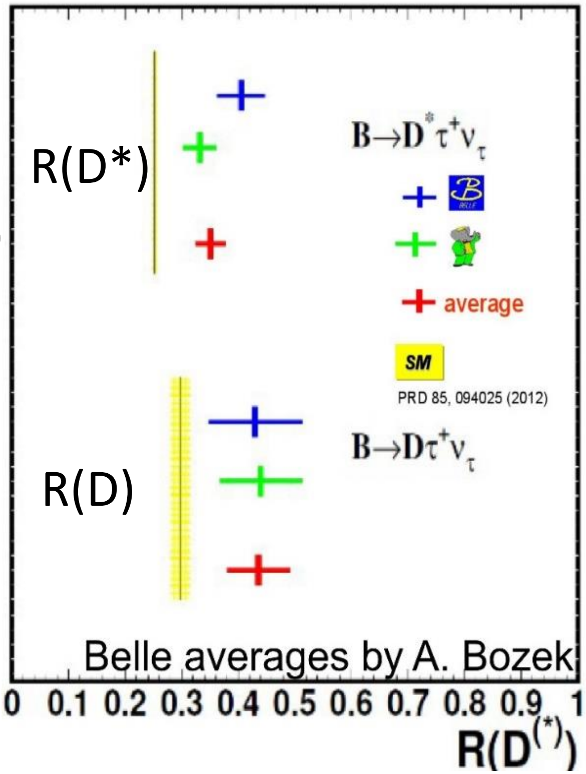
Belle average

- Naïve average for inclusive and exclusive hadronic tags (A. Bozek's average @KEK-FF0213)
  - $R(D^*) = 0.405 \pm 0.047$
  - $R(D) \;\; = 0.430 \pm 0.091$
    - Inclusive tag, 535MBB (69%), PRL 99, 191807 (2007)
    - Inclusive tag, 657MBB (85%), PRD 82, 072005 (2010)
    - Hadronic tag, 657MBB (85%), arXiv:0910.4301

BaBar results

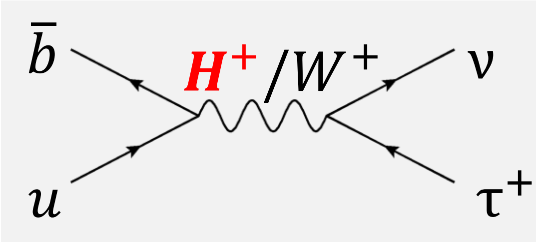
- $R(D^*) = 0.332 \pm 0.024 \pm 0.018$
- $R(D) \;\; = 0.440 \pm 0.058 \pm 0.042$
  - Hadronic tag, 471MBB (100%), PRL 109, 101802 (2012)

Bozek's slide @KEK-FF2013



Purely leptonic *B* decay "*B* → τν"

Branching fraction in SM



$$\mathcal{B}(B \to \tau\nu)_{\rm SM} = \frac{G_F^2 \tau_B}{8\pi} f_B^2 |V_{\rm ub}|^2 m_B^3 \left(1 - \frac{m_\tau^2}{m_B^2}\right)^2 \left(\frac{m_\tau}{m_B}\right)^2$$

- f_B : decay constant calculate on the Lattice
- $V_{\rm ub}$: CKM matrix element

Branching fraction in NP

$$\mathcal{B}(B \to \tau\nu) = r_H \cdot \mathcal{B}(B \to \tau\nu)_{\rm SM}$$

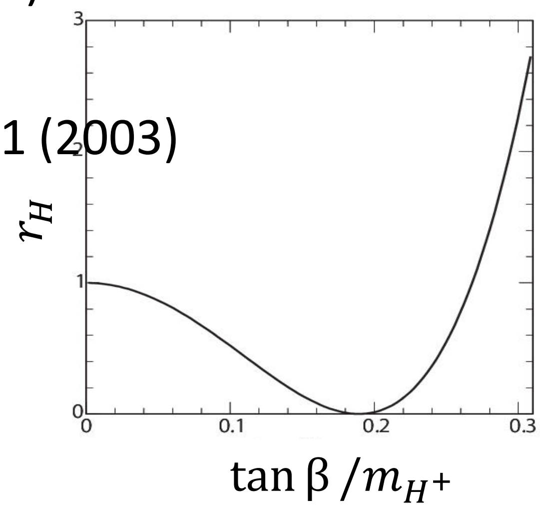
$$r_H = \left(1 - m_B^2 \frac{\tan^2\beta}{m_{H^+}^2}\right)^2$$

Type –II 2HDM
@ PRD 48, 2342 (1993)

$$r_H = \left(1 - \frac{m_B^2}{1 + \tilde{\epsilon}_0 \tan\beta} \frac{\tan^2\beta}{m_{H^+}^2}\right)^2$$

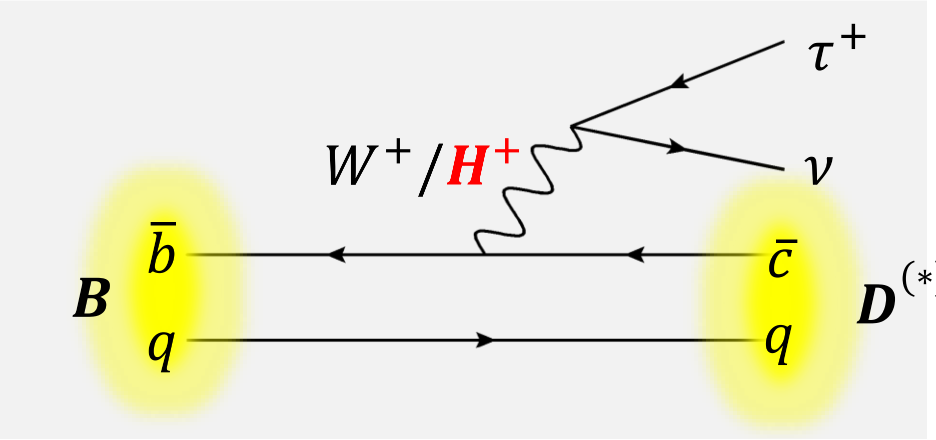
SUSY
@ J. Phys. G29, 2311 (2003)

Destructive interference between *W* and H^+.

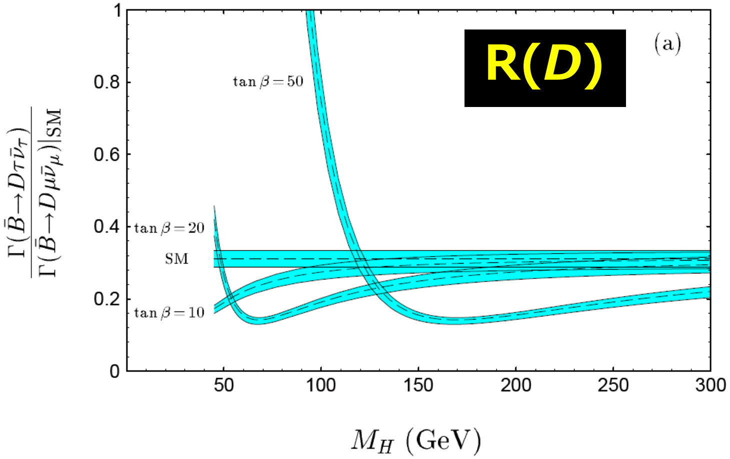


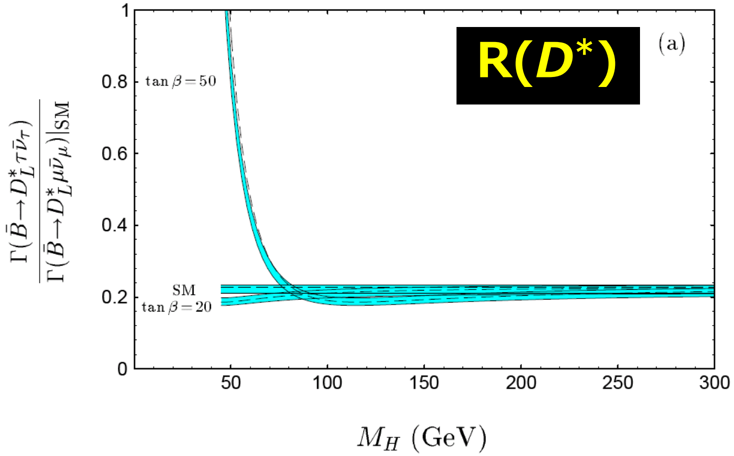
→ **Constraint on "$\tan\beta / m_{H^+}$"**

Semi-tauonic *B* decay "$B \to D^{(*)}\tau\nu$"



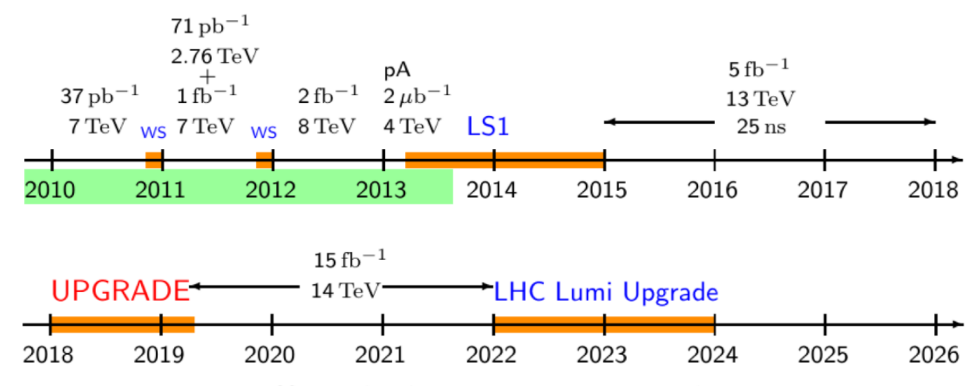
- Different vertex contribution
  - $B \to \tau\nu$: $H - b - u$
  - $B \to D^{(*)}\tau\nu$: $H - b - c$
- $R(D^{(*)}) = \frac{BF\,(B \to D^{(*)}\tau\nu)}{BF(B \to D^{(*)}l\nu)}$ $(l = e, \mu)$
  - Suppress theoretical(form factor, V_{cb}) and experimental (efficiency) uncertainties.

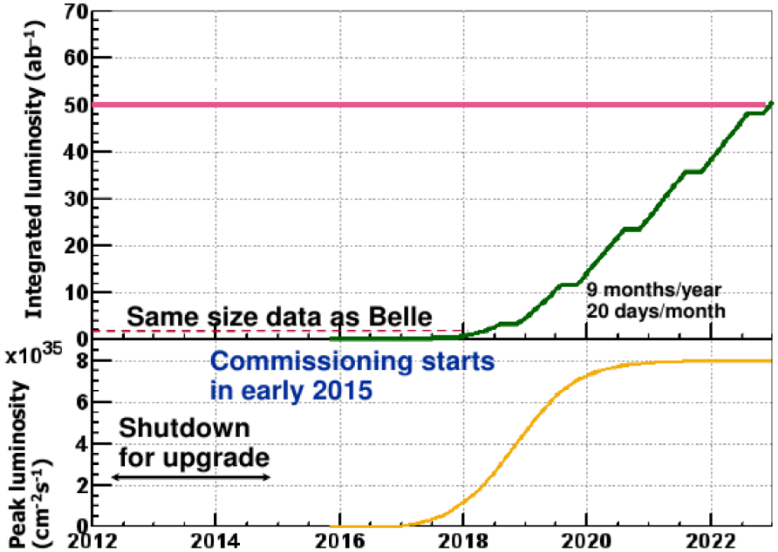




LHCb/Belle II schedules

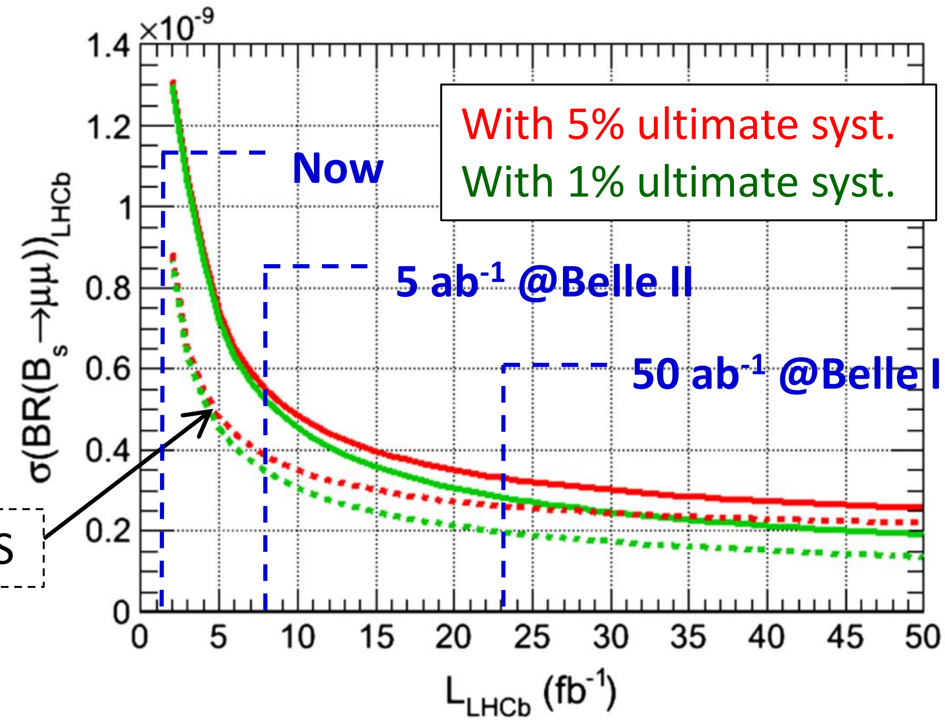
- LHCb (A. Contu, Charm 2013)
  - expect $\sim 8\ \text{fb}^{-1}$ by 2018
  - 2018 - mid 2019 upgrade (3 - 4$\times$increase in D meson yields)
  - then additional 15 fb^{-1} by 2022
- Belle II
  - 2017: start to increase luminosity
  - collect $\sim 10\ \text{ab}^{-1}$ by mid 2019
  - collect 50 ab^{-1} by 2023

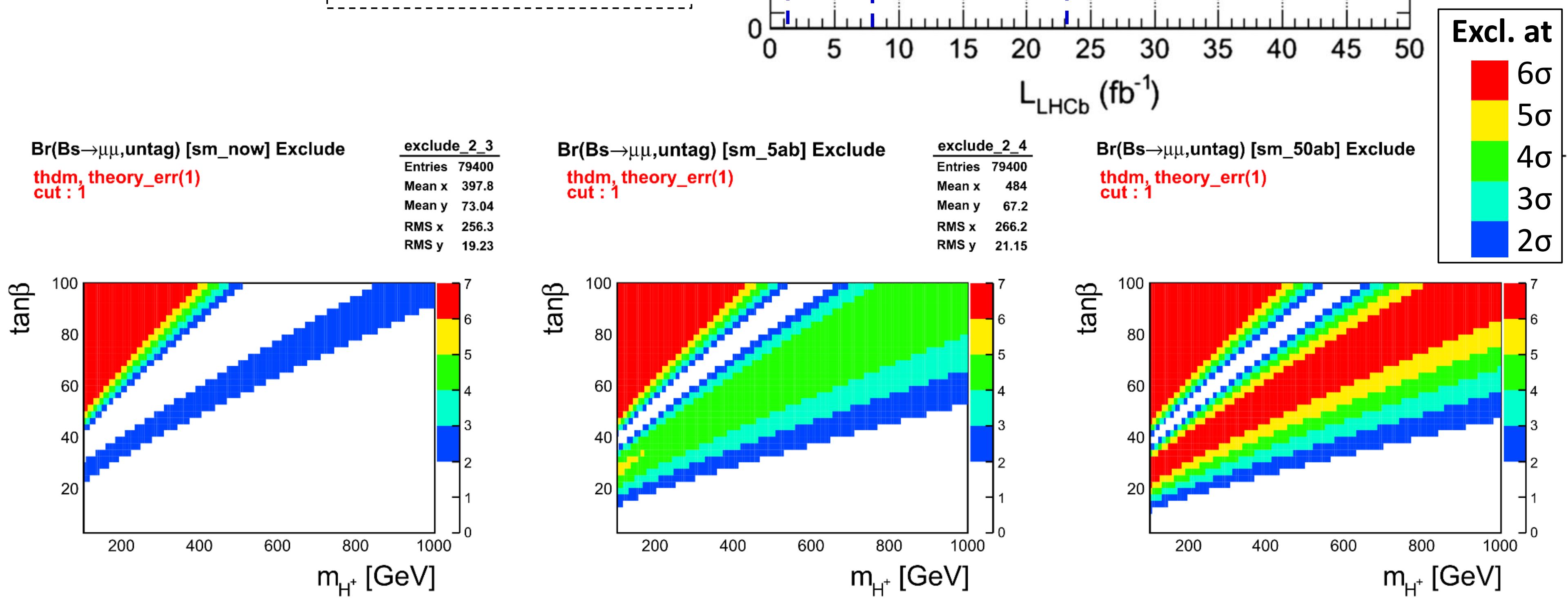




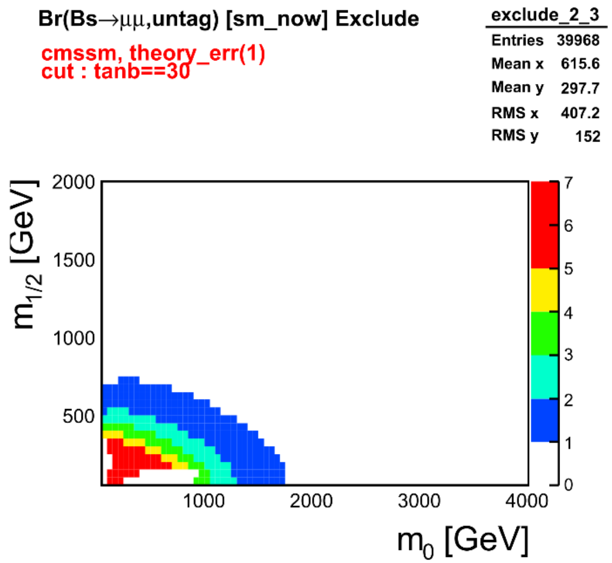
Prospect of Br($B_s \to \mu\mu$) on type-II 2DHM

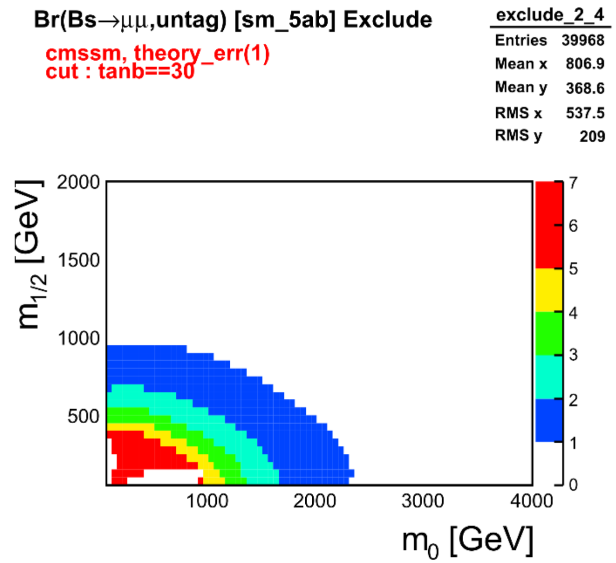
- PRD 87, 035026
- Same period with Belle II
  - 5 ab^{-1} @2018
  - 50 ab^{-1} @2023
- 5% ultimate syst. and combination with CMS are assumed.

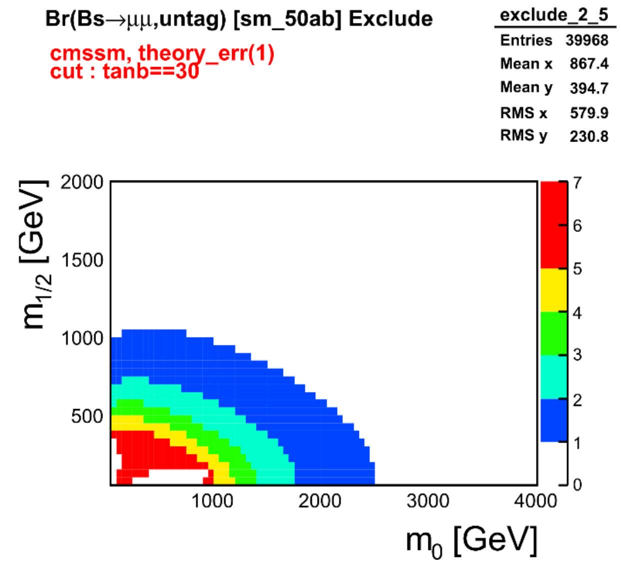


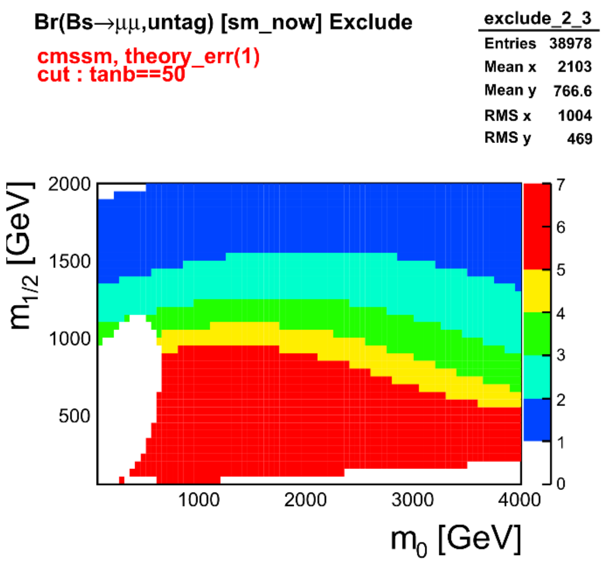


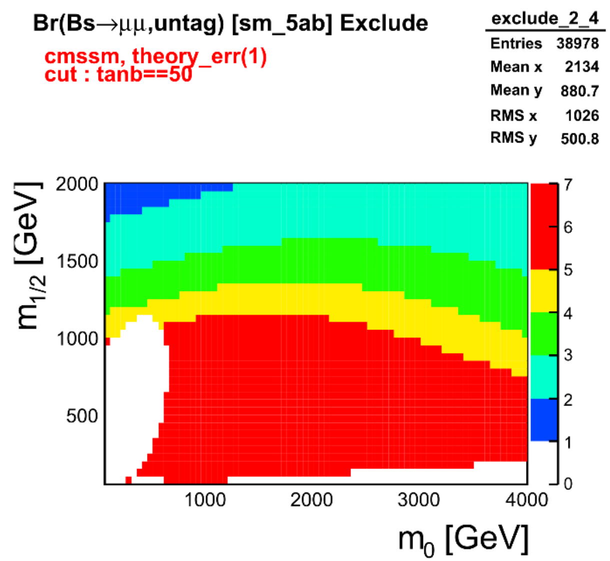
Prospect of Br($B_s \to \mu\mu$) on CMSSM

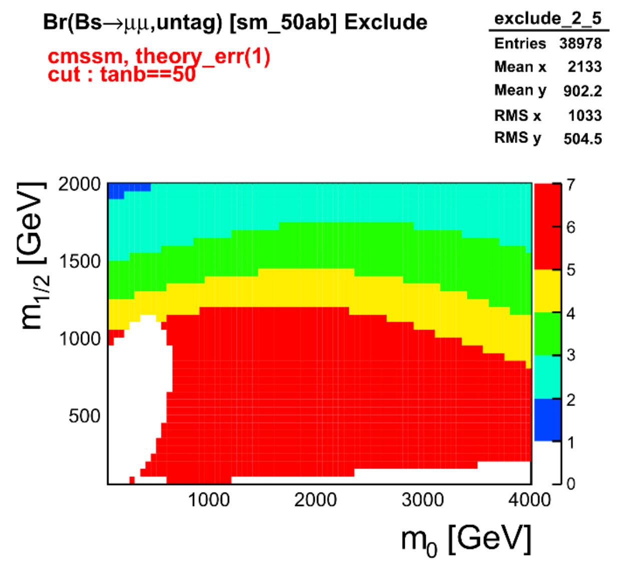












Experimental values : Br(B→τν)

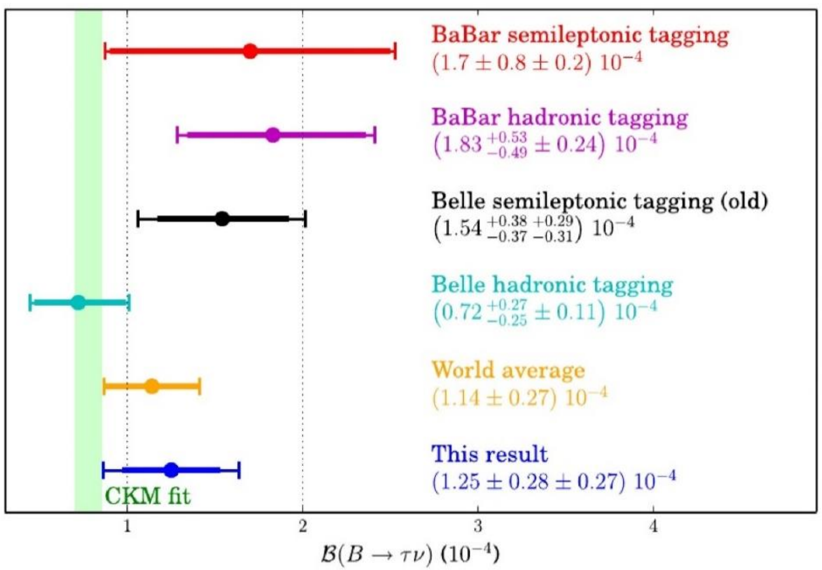
Belle average

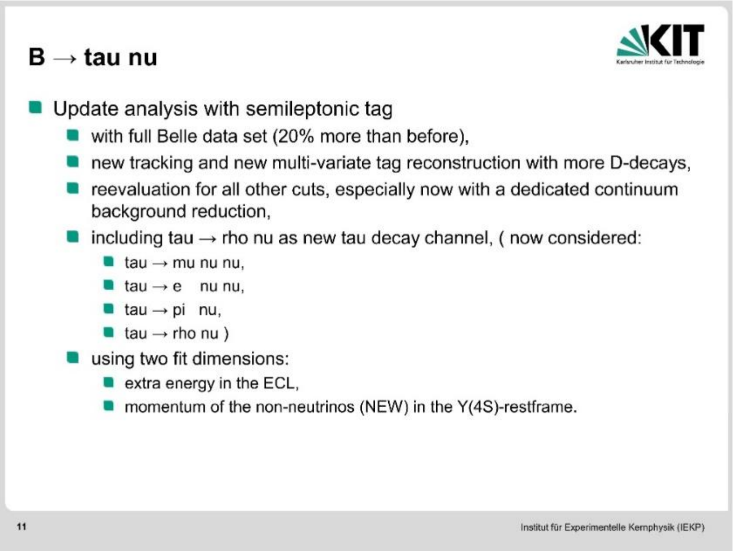
- Naïve private average for semileptonic and hadronic tags
- $\mathbf{Br(B \to \tau\nu) = (0.91 \pm 0.23) \times 10^{-4}}$
  - $(1.25 \pm 0.28 \pm 0.27) \times 10^{-4}$: semileptonic tag, 772MBB (100%), CKM2014
  - $(0.72^{+0.27}_{-0.25} \pm 0.11) \times 10^{-4}$: hadronic tag, 772MBB (100%), PRL 110, 131801 (2013)

BaBar average

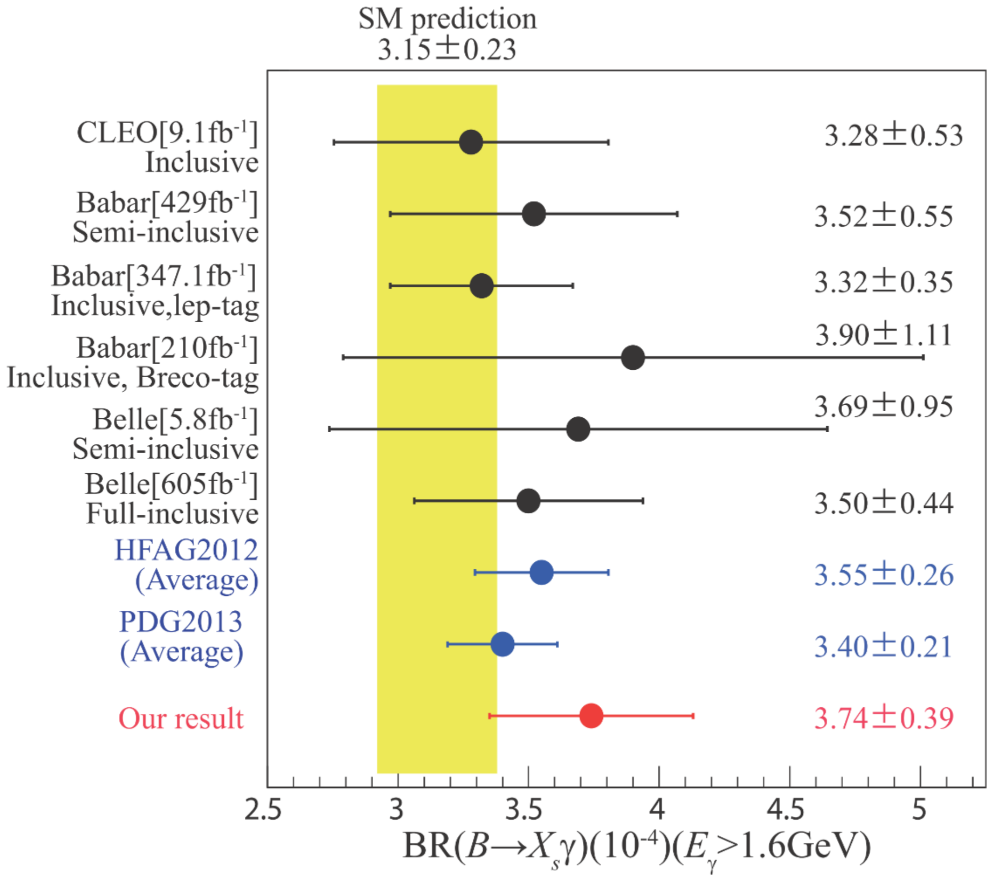
- $\mathbf{Br(B \to \tau\nu) = (1.79 \pm 0.48) \times 10^{-4}}$
  - $(1.7 \pm 0.8 \pm 0.2) \times 10^{-4}$: semileptonic tag, 468MBB (100%), PRD 81, 051101(R) (2010)
  - $(1.83^{+0.53}_{-0.49} \pm 0.24) \times 10^{-4}$: hadronic tag, 468MBB (100%), PRD 88, 031102(R) (2013)

Martin's slide @ CKM2014





$B \to X_s\gamma$


SM prediction
3.15±0.23
CLEO[9.1fb-1]
Inclusive
3.28±0.53
Babar[429fb-1]
Semi-inclusive
3.52±0.55
Babar[347.1fb-1]
Inclusive,lep-tag
3.32±0.35
Babar[210fb-1]
Inclusive, Breco-tag
3.90±1.11
Belle[5.8fb-1]
Semi-inclusive
3.69±0.95
Belle[605fb-1]
Full-inclusive
3.50±0.44
HFAG2012
(Average)
3.55±0.26
PDG2013
(Average)
3.40±0.21
Our result
3.74±0.39
2.5
3
3.5
4
4.5
5
BR(B→Xsγ)(10-4)(Eγ>1.6GeV)

$B \to X_s\gamma$

Slide by Misiak @FPCP2013

Update of the SM prediction (preliminary)

$$\mathcal{B}(\bar{B} \to X_s\gamma)^{\rm SM}_{E_\gamma > 1.6\ {\rm GeV}} = (3.14 \pm 0.22) \times 10^{-4}$$

Hardly any change w.r.t $(3.15 \pm 0.23) \times 10^4$ in 2006. (several $\sim 1 \div 2\%$ corrections cancel by chance).

Contributions to the total TH uncertainty (summed in quadrature):

5% non-perturbative, **3%** from the unknown $U(r, E_0)$

3% higher order $\mathcal{O}(\alpha_s^3)$, **2.2%** parametric

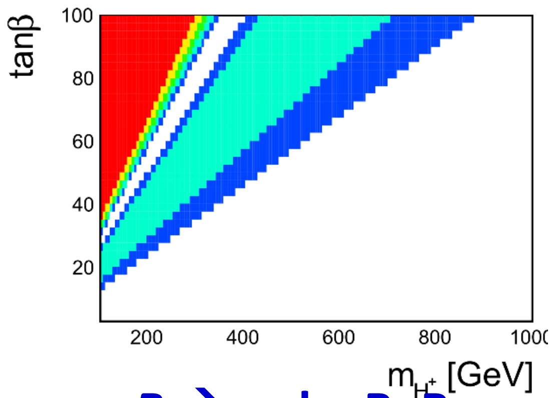
Experimental world average (HFAG, 2.08.2012):

$$\mathcal{B}(\bar{B} \to X_s\gamma)^{\rm EXP}_{E_\gamma > 1.6\ {\rm GeV}} = (3.43 \pm 0.21 \pm 0.07) \times 10^{-4}$$

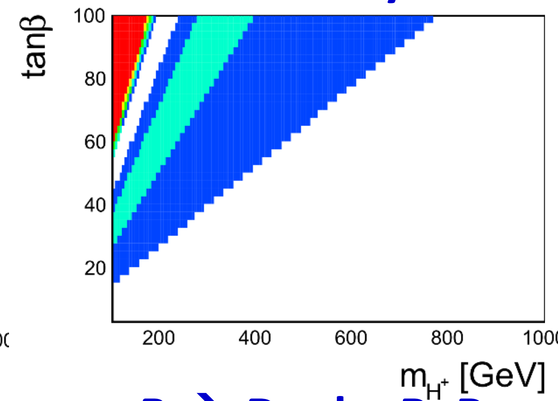
Experiment agrees with the SM at better than $\sim 1\sigma$ level. Uncertainties: TH $\sim 7\%$, EXP $\sim 6.5\%$.

Constraints on Type-II 2HDM

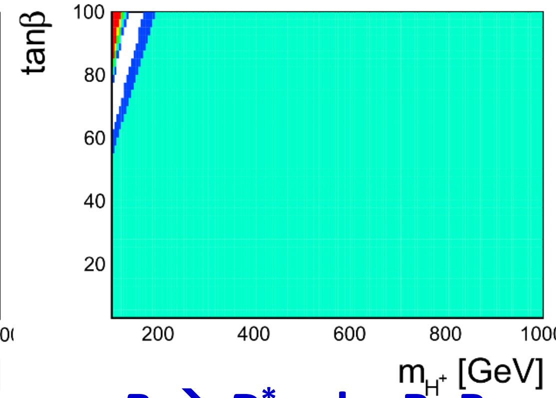
$B \rightarrow \tau\nu$ by Belle



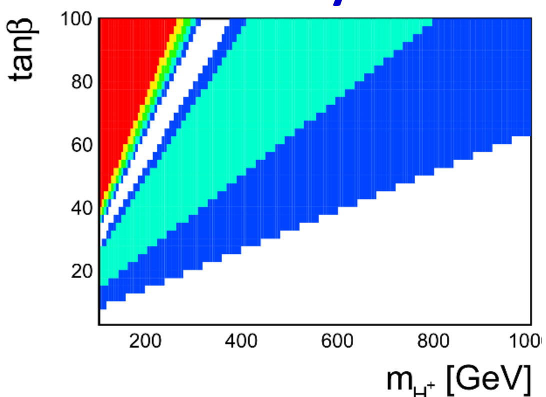
$B \rightarrow D\tau\nu$ by Belle



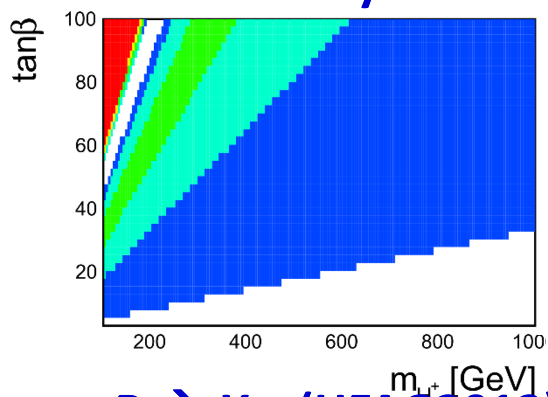
$B \rightarrow D^*\tau\nu$ by Belle



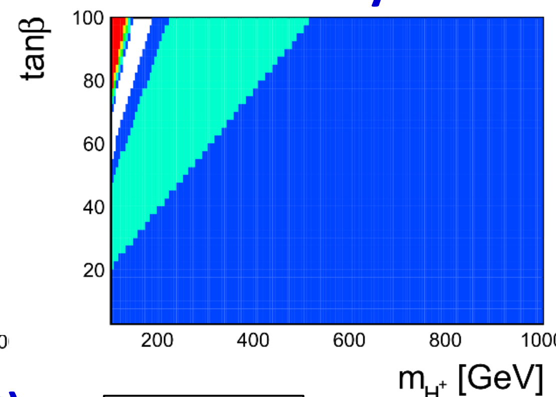
$B \rightarrow \tau\nu$ by BaBar



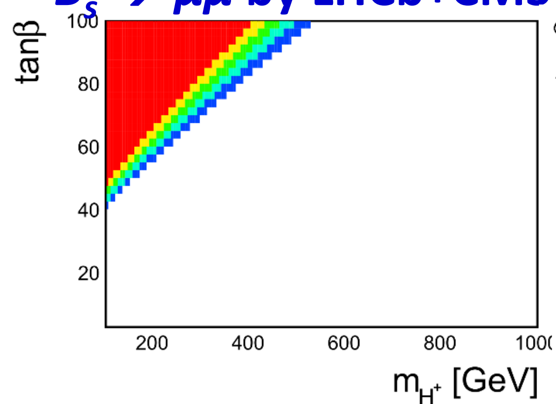
$B \rightarrow D\tau\nu$ by BaBar



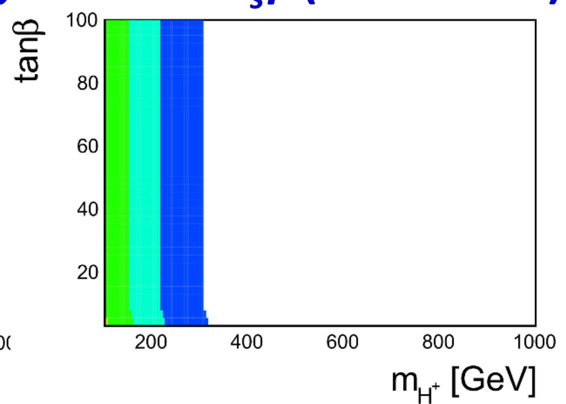
$B \rightarrow D^*\tau\nu$ by BaBar



$B_s \rightarrow \mu\mu$ by LHCb+CMS



$B \rightarrow X_s\gamma$ (HFAG2013)

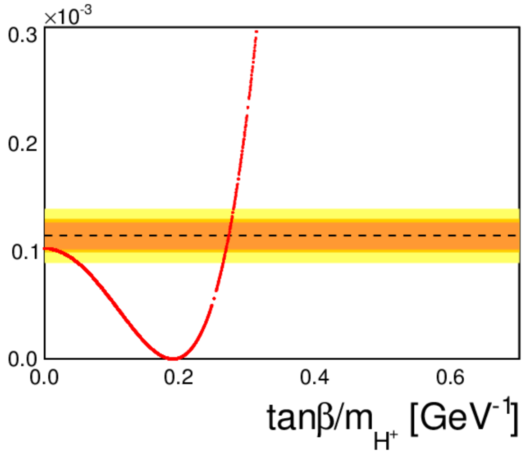


Excl. at

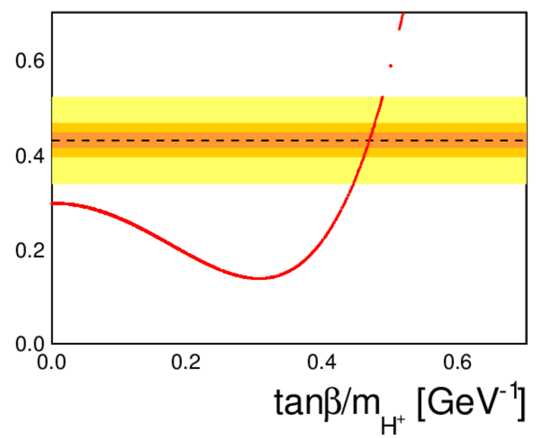
- 6σ
- 5σ
- 4σ
- 3σ
- 2σ

Type-II 2HDM

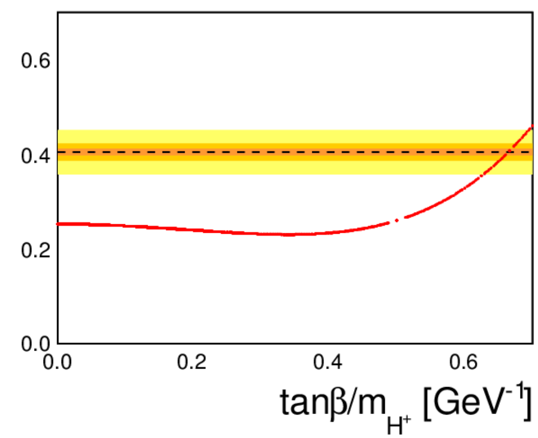
Br(B→τν)



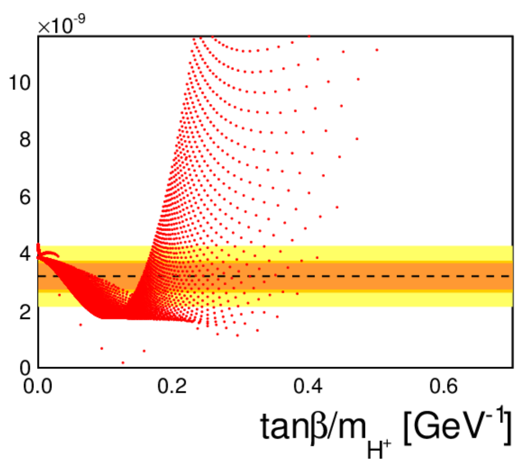
R(D)



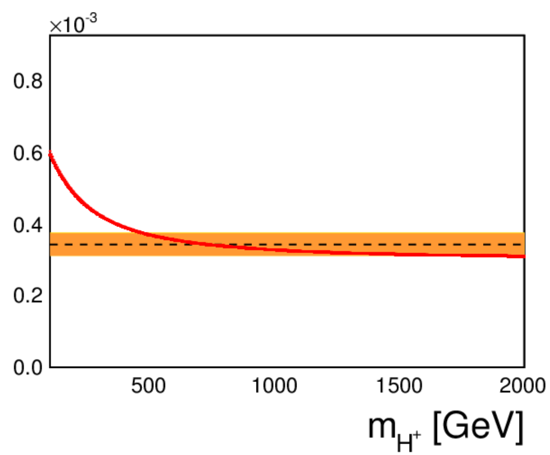
R(D*)



Br(Bs→μμ)



Br(B→sγ)



Charged Higgs constraint from ATLAS