MSSM Higgs Mass

(The Effective Field Theory approach)

Javier Pardo Vega
(SISSA / ICTP)

based on: JP and Giovanni Villadoro [arXiv:1504.05200]

SusyHD

Higgs Hunting
Orsay, France, July 30-August 01, 2015

Higgs mass constraint on SUSY

$$m_h^2 \approx m_Z^2 \cos^2 2\beta + \frac{3}{2\pi^2}\frac{m_t^4}{v^2}\left[\ln\frac{m_{\tilde{t}}^2}{m_t^2} + \frac{X_t^2}{m_{\tilde{t}}^2} - \frac{X_t^4}{12 m_{\tilde{t}}^4}\right] + \dots$$

tree-level

RG logarithm

stop mixing contribution

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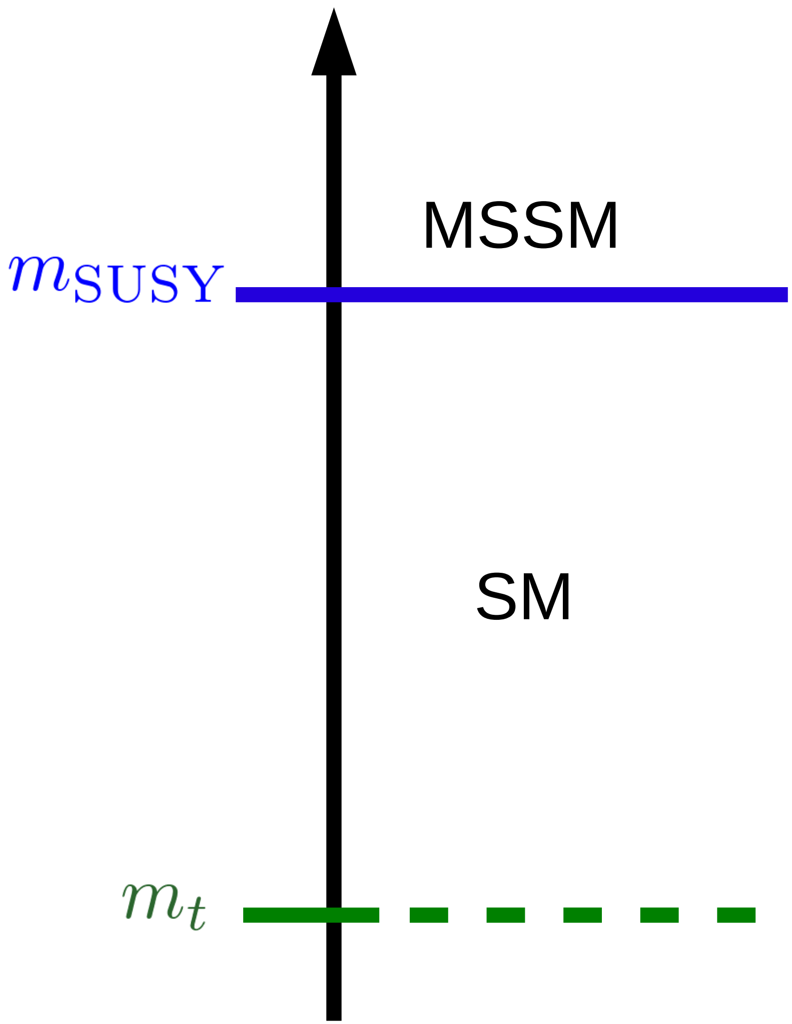
tree-level

RG logarithm

stop mixing contribution

It is important to calculate the Higgs mass with high precision.

Effective Field Theory calculation



SM couplings at $m_{\rm SUSY}$
as function of the SUSY parameters

running
SM (NNNLO) + $o(m_t^2/m_{\rm SUSY}^2)$

SM couplings at m_t

Mathematica Package SusyHD

http://www.ictp.it/~susyhd

- $\mathrm{SetSMparameters}[M_t, \alpha_s]$
- $\mathrm{MHiggs}\,[\{\tan\beta, M_1, M_2, M_3, \mu, A_t, m_{Q_3}, m_{U_3}, m_{D_3}, m_{Q_2}, m_{U_2}, m_{D_2}, m_{Q_1}, m_{U_1}, m_{D_1}, m_{L_3}, m_{E_3}, m_{L_2}, m_{E_2}, m_{L_1}, m_{E_1}, m_A\}]$
- $\Delta\mathrm{MHiggs}[\{...\}]$

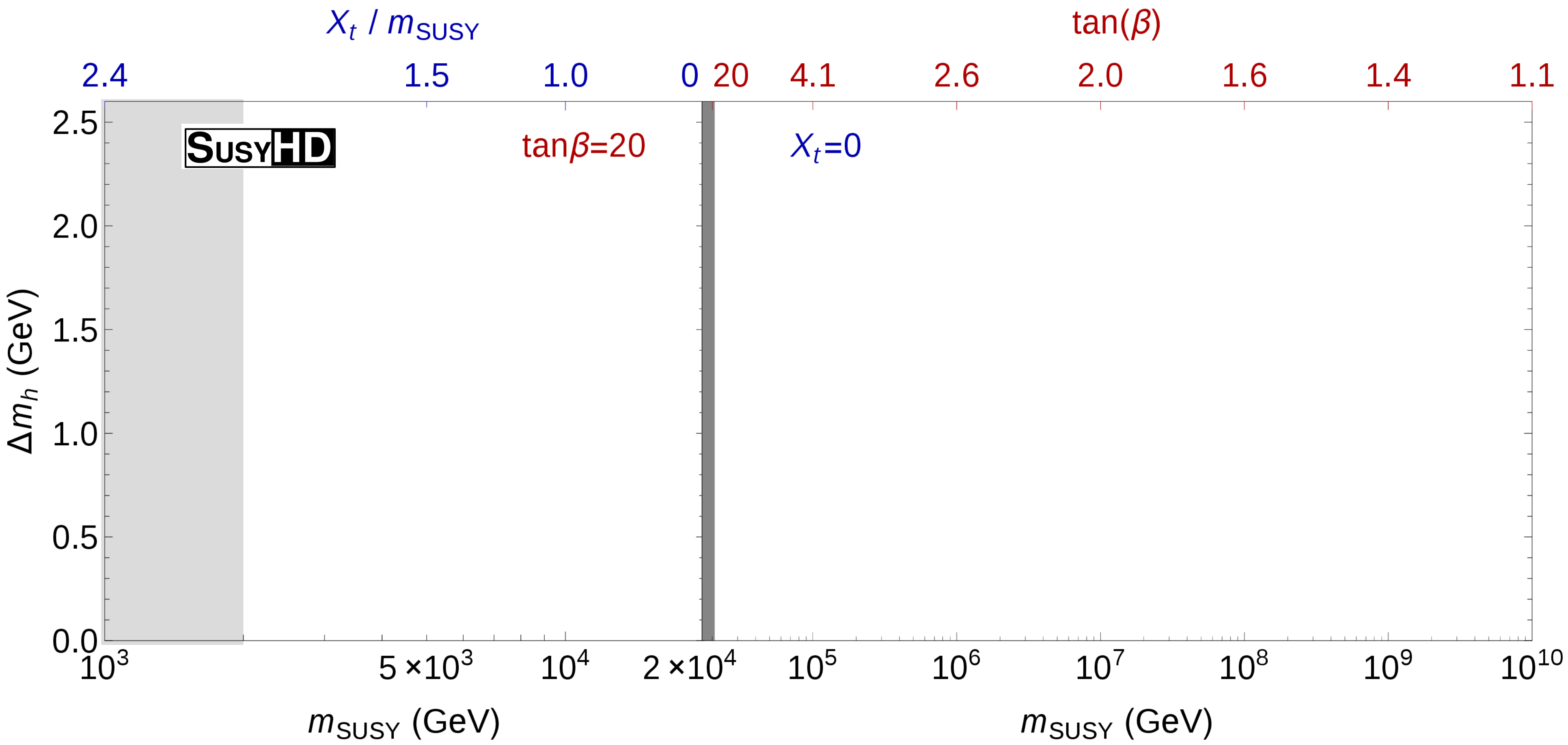
```
In[1]:= << SUSYHD`

        ----------------------------------
        SUSYHD v1.0.2 (2015)
        Javier Pardo Vega and Giovanni Villadoro
        http://www.ictp.it/~susyhd
        ----------------------------------

In[2]:= Mh := MHiggs[{tb, m0, At}]
        ΔMh := ΔMHiggs[{tb, m0, At}]

In[4]:= tb := 20; m0 := 2000; At := √6 m0;
        {Mh, ΔMh}

Out[5]= {125.467, 1.23442}

In[6]:= Timing[Mh]

Out[6]= {0.008000, 125.467}

In[7]:= SetSMparameters[173.34 + 0.76 × 2, 0.1184];
        {Mh, ΔMh}

Out[8]= {126.767, 1.2656}
```

- Interpolated solution of the SM RGEs

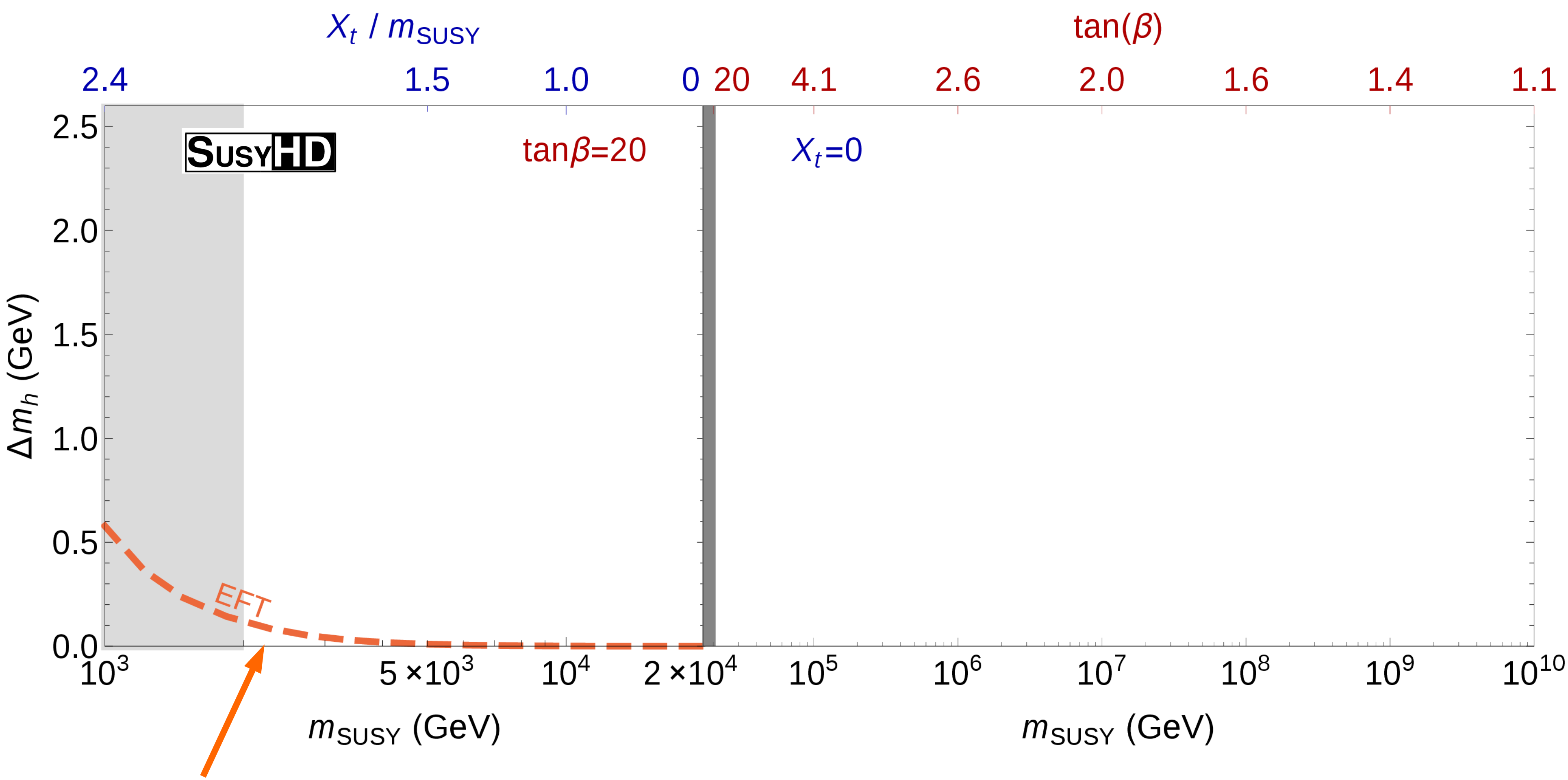
$$\lambda(m_t) = F\left(\lambda(Q), \ln\frac{Q}{m_t}\right)$$

- Fast program, Higgs mass can be used as a constraint.

Estimate of uncertainties

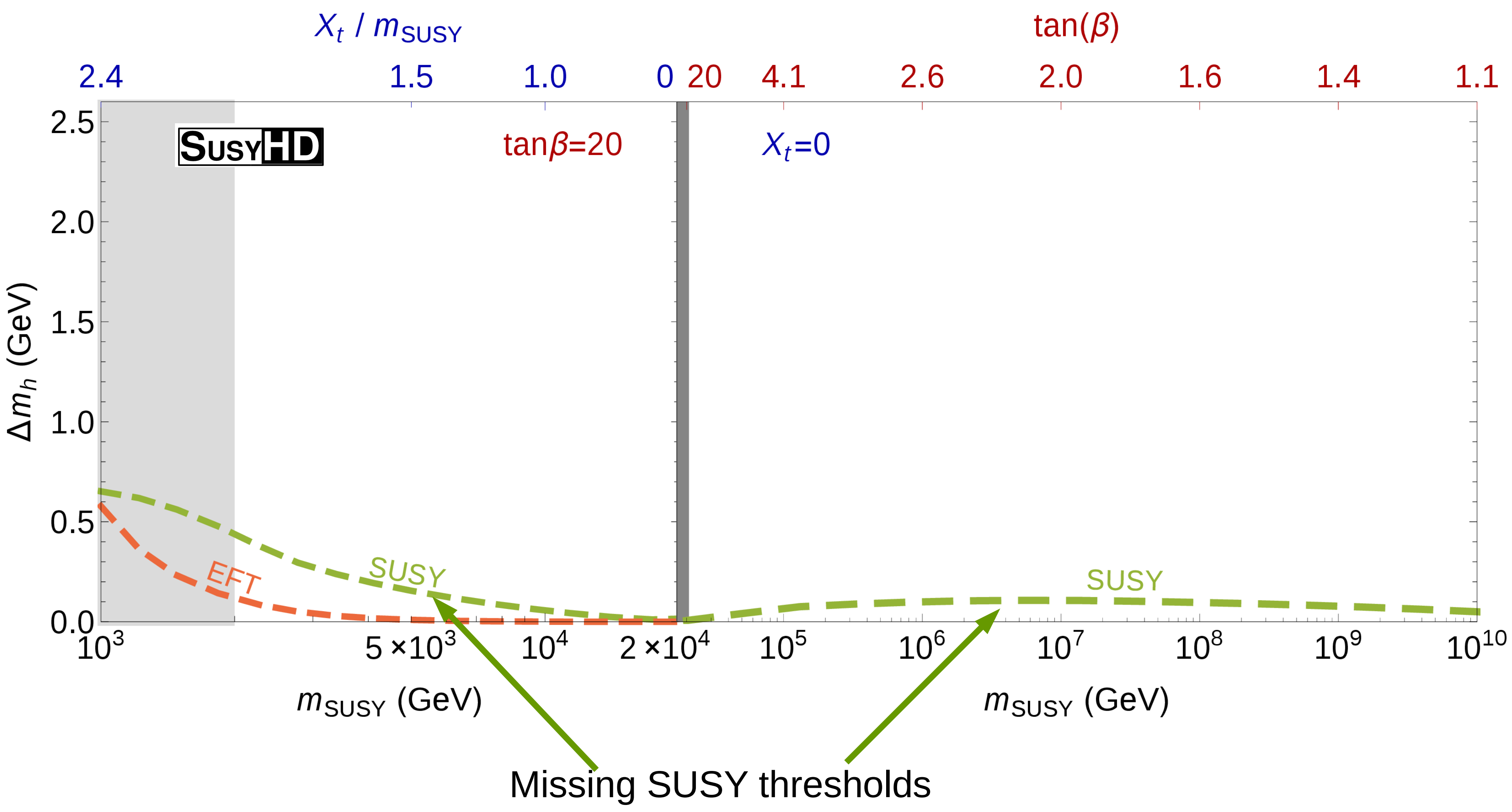


Estimate of uncertainties

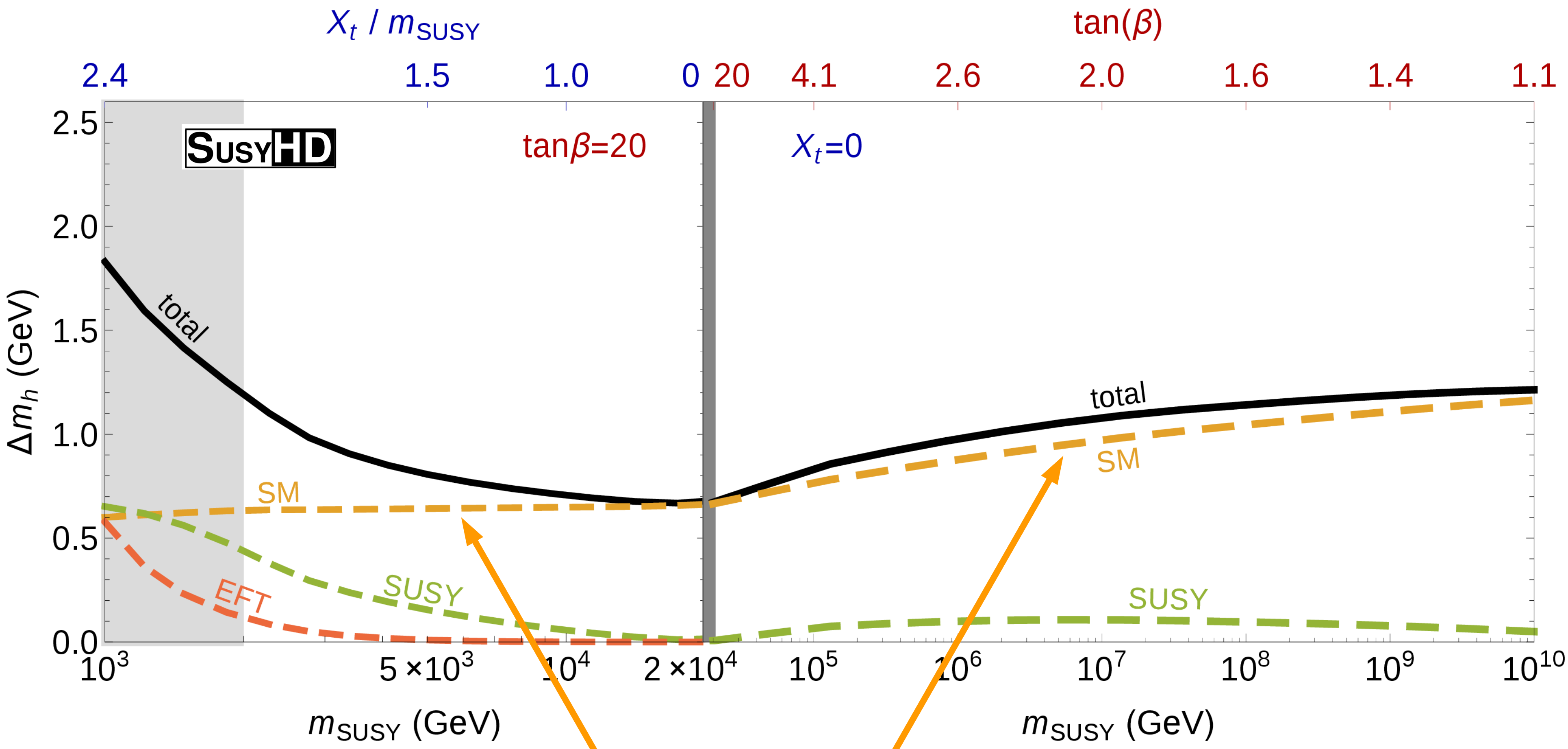


EW suppressed corrections $\mathcal{O}(v^2/m^2_{\rm SUSY})$

Estimate of uncertainties

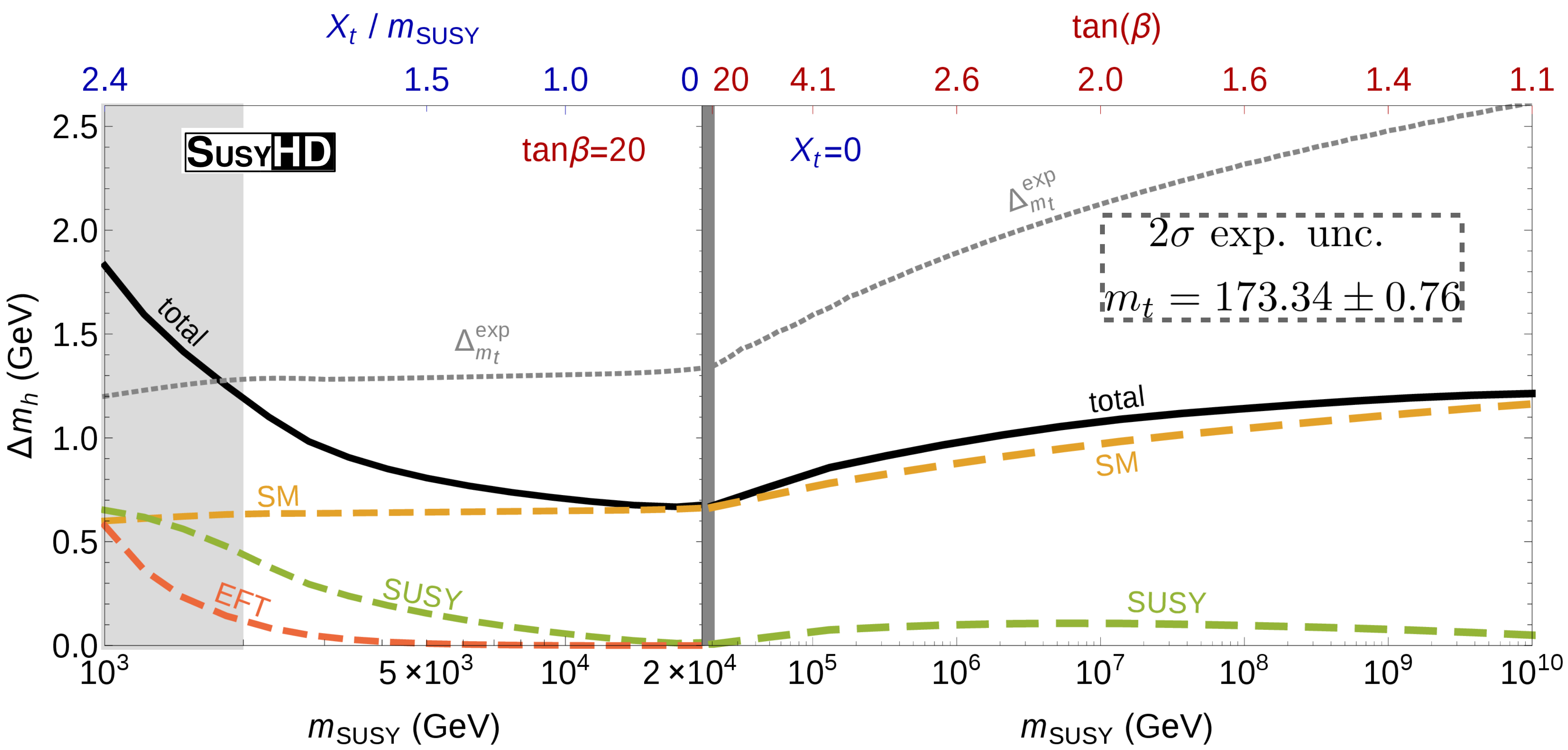


Estimate of uncertainties

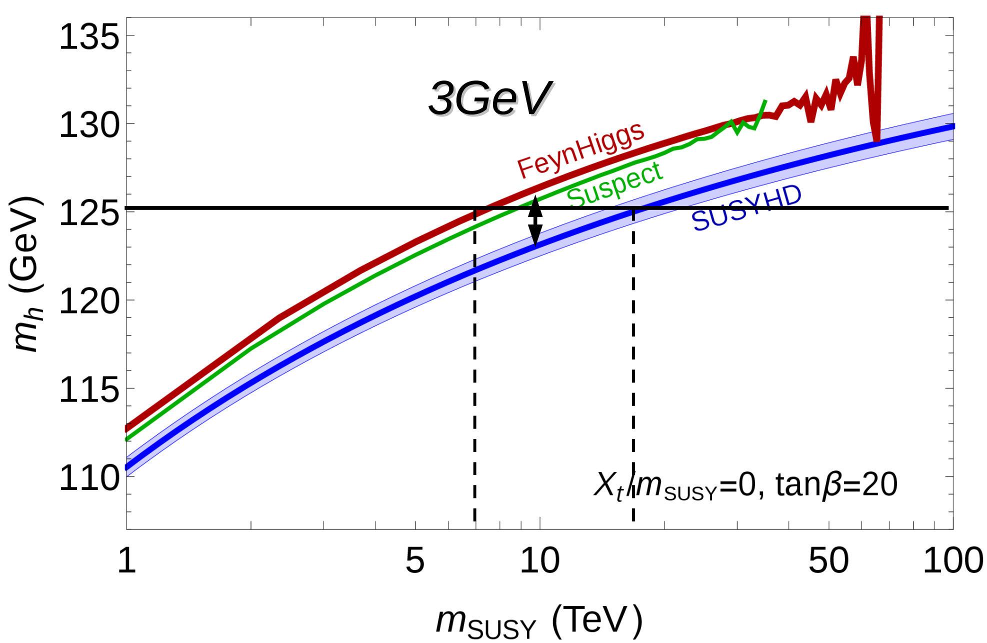


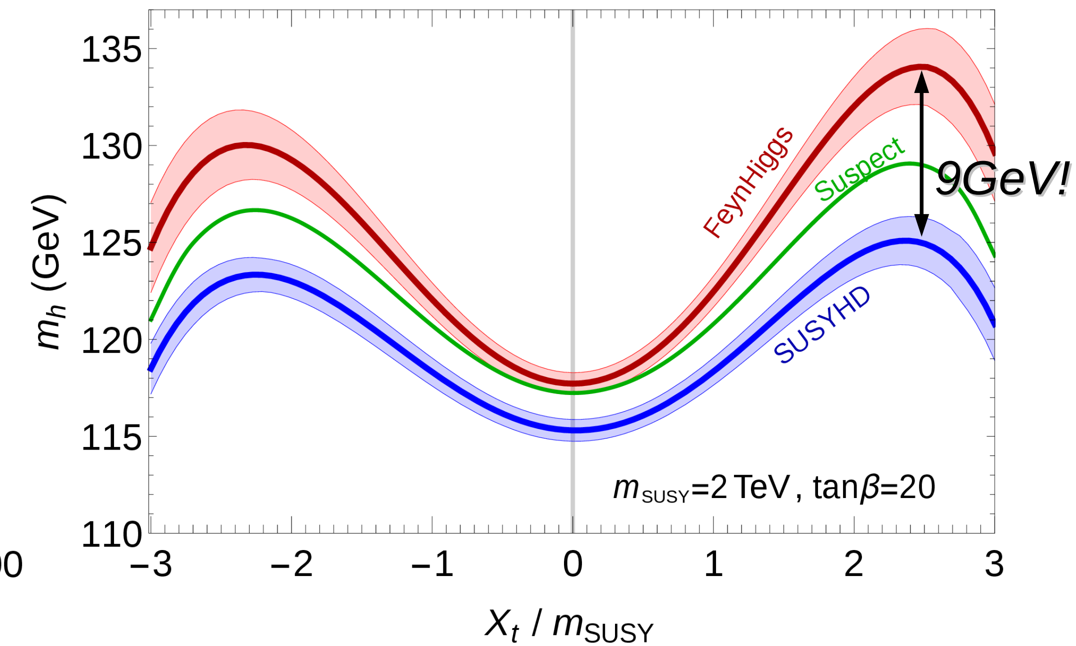
Matching of the SM couplings at the EW scale and their running (SM RGEs)

Estimate of uncertainties



Comparison with existing computations





High sensitivity to the determination of the running top Yukawa

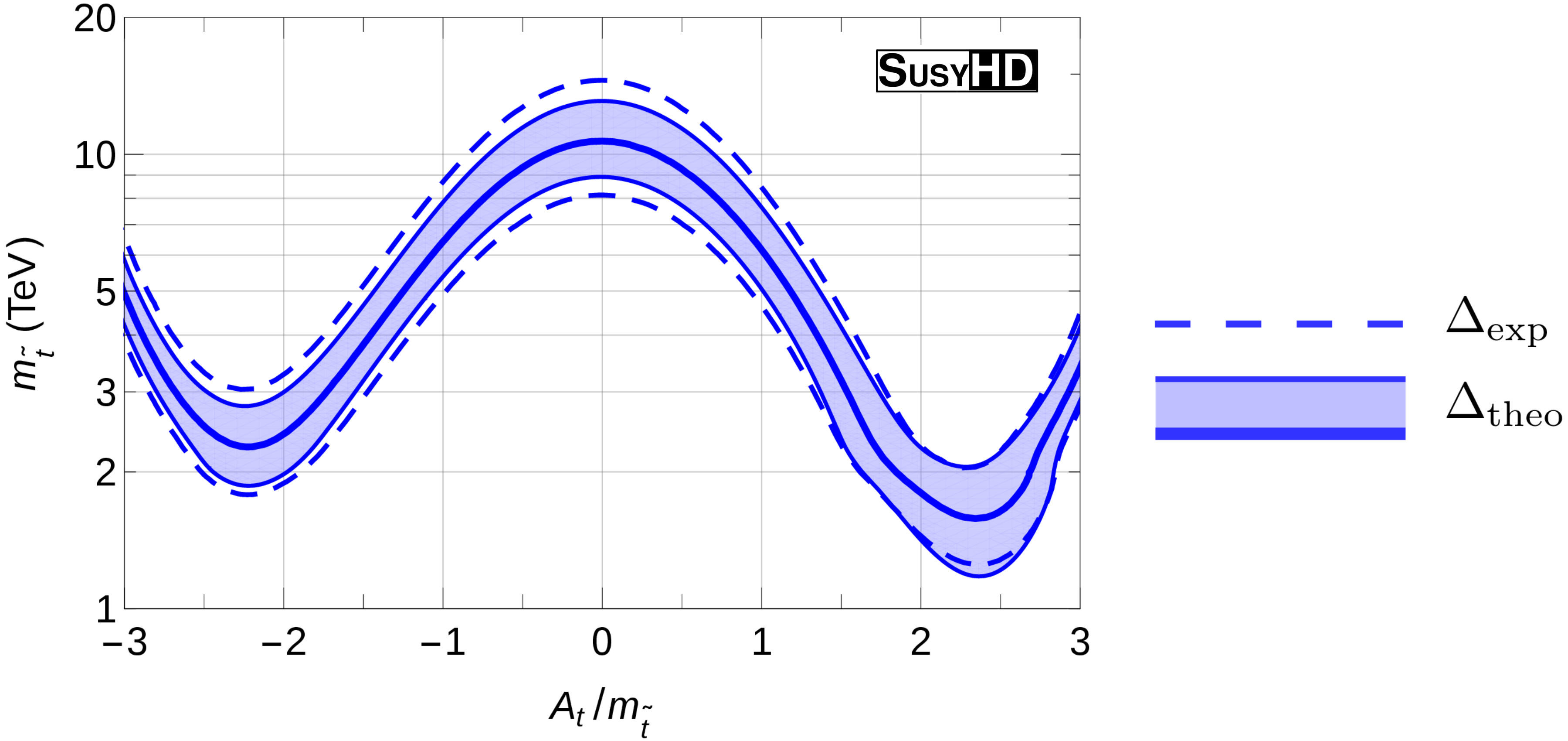
$$m_t^{\overline{\text{MS}}}(M_t) = 173.34 - 8.00 - 1.90 - 0.59 - 0.21\ \text{GeV}$$

1 loop *2 loop* *3 loop* *4 loop*

[P. Marquarad, A. V. Smirnov, V. A. Smirnov, M. Steinhauser '2015]

Where is SUSY?

$$\tan\beta = 20, \mu = 300\ \text{GeV}, \qquad \text{other sparticles } m = 2\ \text{TeV}$$



Minimal Gauge Mediation (MGM)

[Dine, Nir and Shirman '96]
[Rattazzi and Sarid '96]

$$\mu\,, \qquad \Lambda = \frac{F}{M}\,, \qquad M\,, \qquad N$$

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fixed by m_Z

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$\text{fixed by } m_Z$ $\quad$ $\text{fixed by } m_h$

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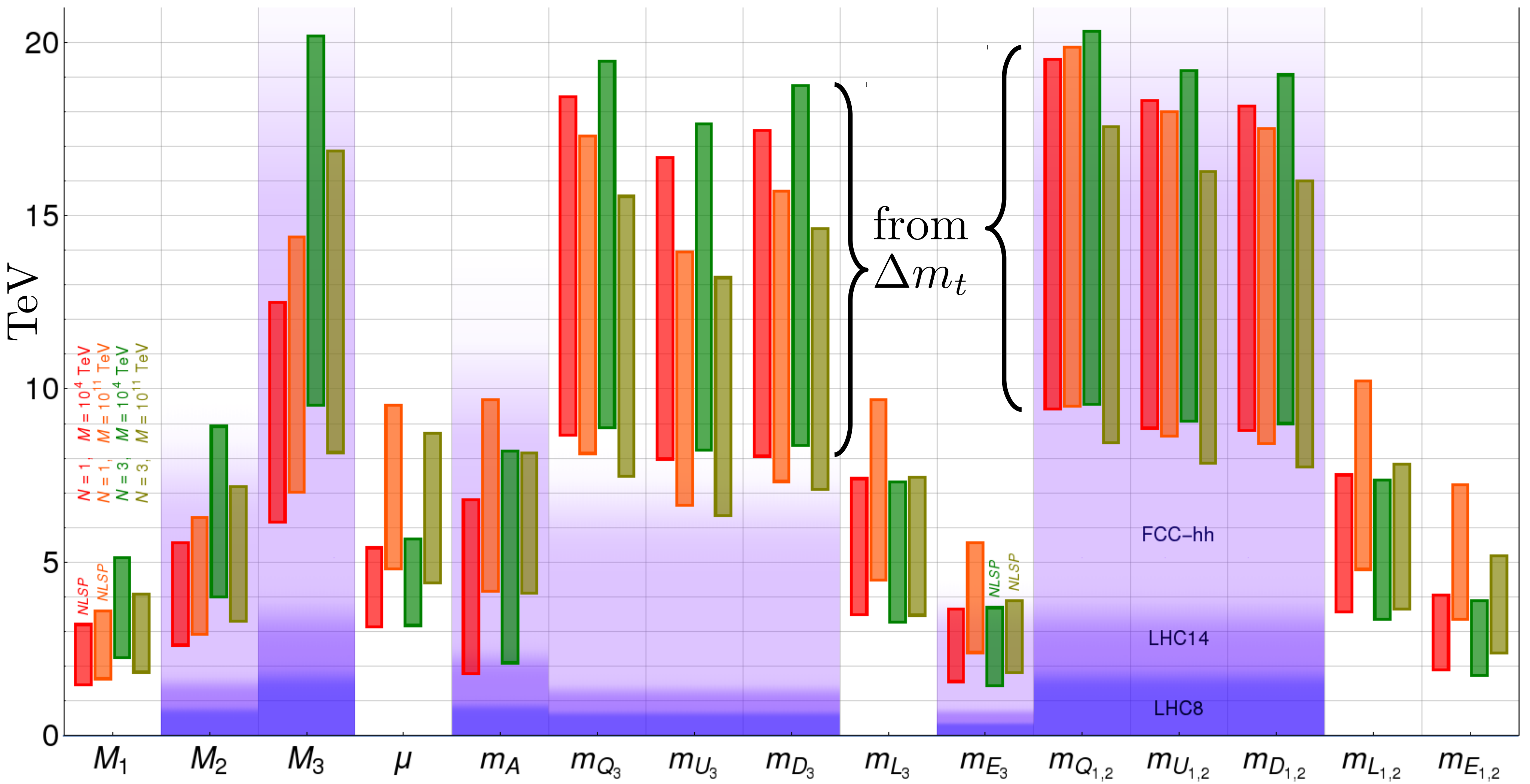
$$\mu\,, \qquad \Lambda = \frac{F}{M}\,, \qquad M\,, \qquad N$$

fixed by m_Z fixed by m_h

- No FCNC
- $B\mu$, A – loop suppressed → large $\tan\beta \sim 50$
- No EDM
- Gauge coupling unification

Predicting the spectrum of MGM



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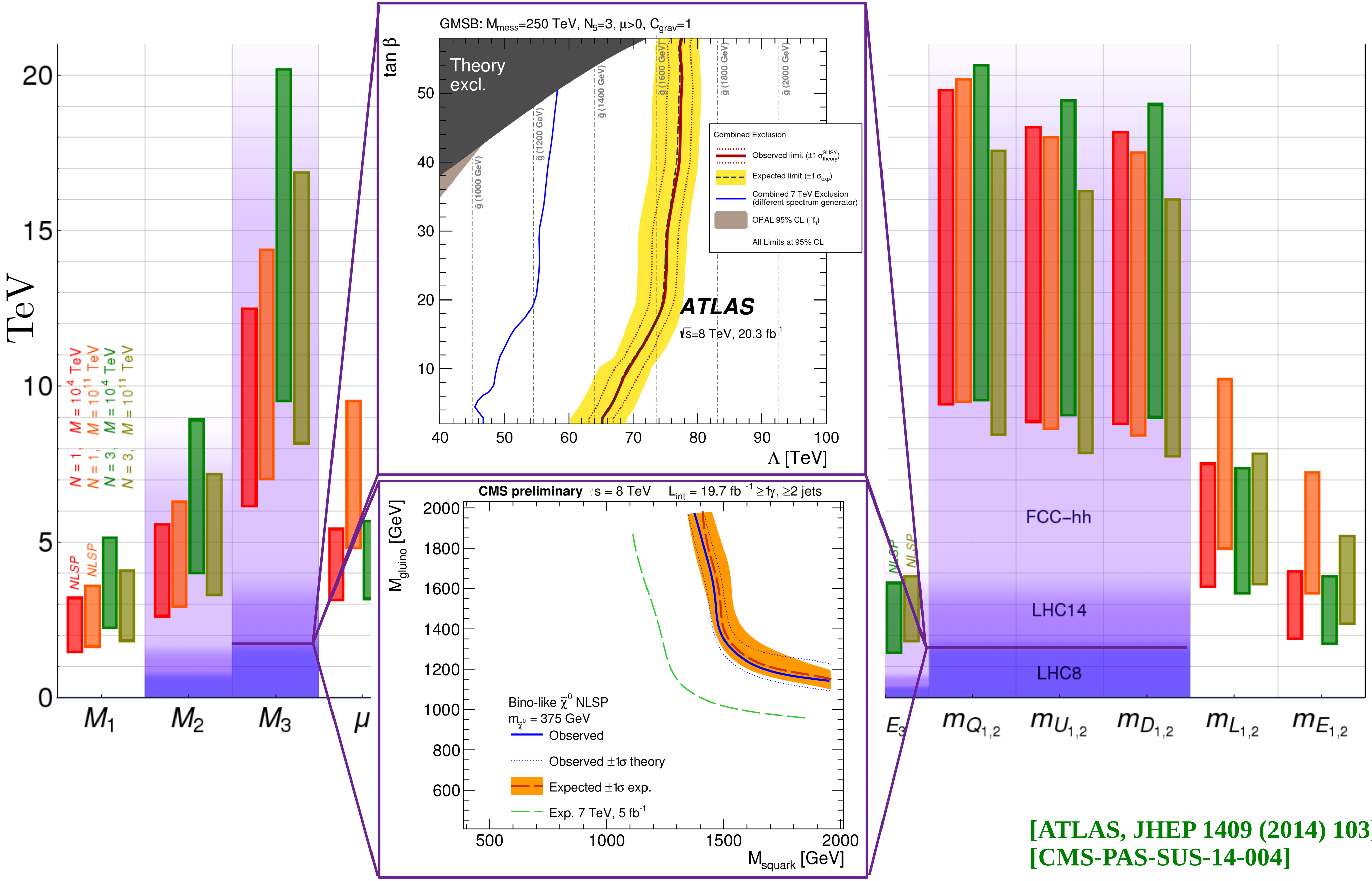

[ATLAS, JHEP 1409 (2014) 103]
[CMS-PAS-SUS-14-004]

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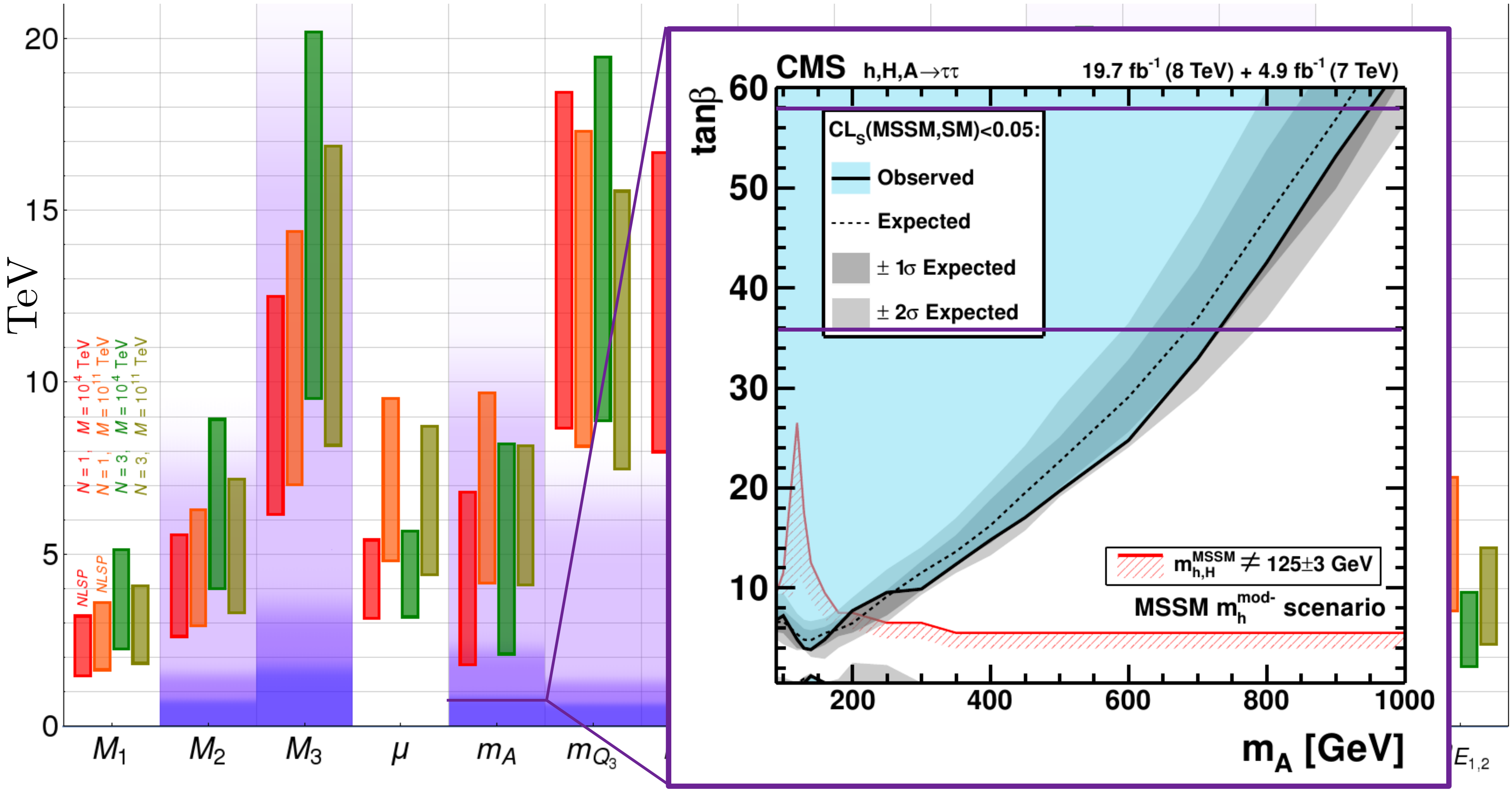
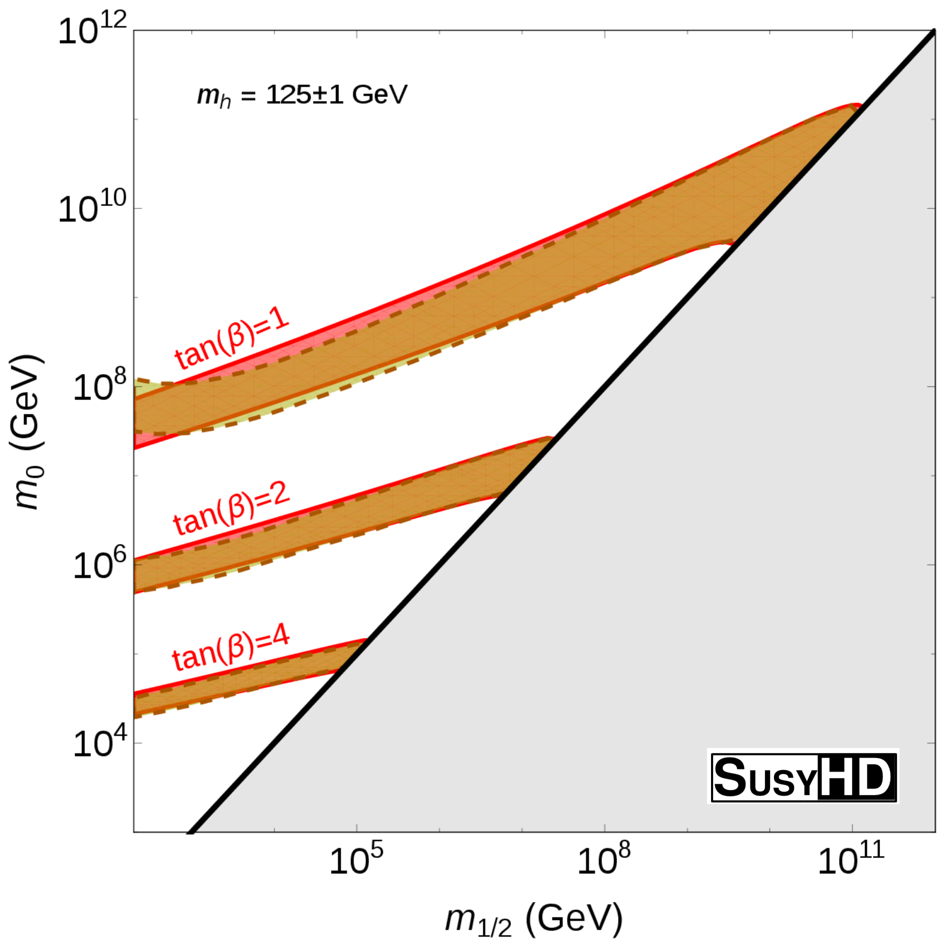


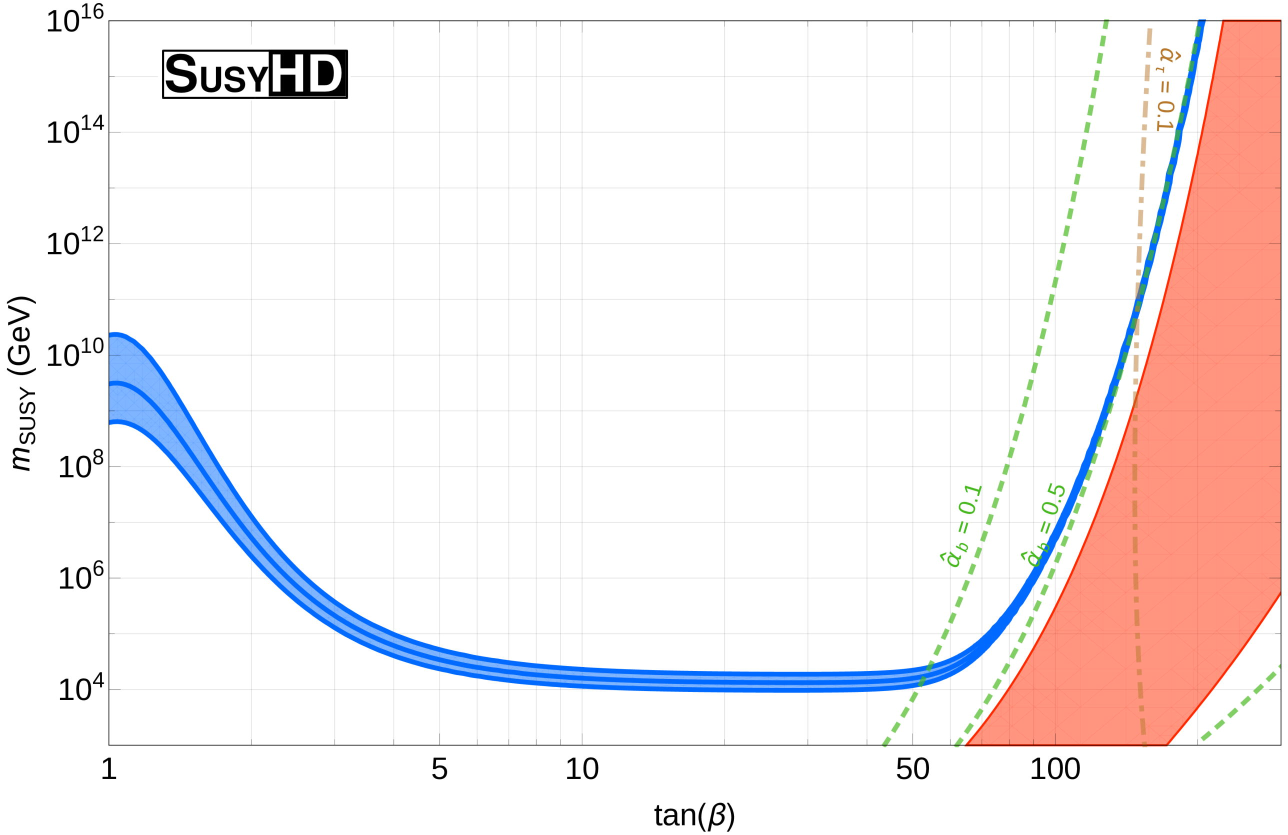
[CMS, JHEP 1410 (2014) 160]

Thanks for your attention!

High-Scale and Split EFT calculations

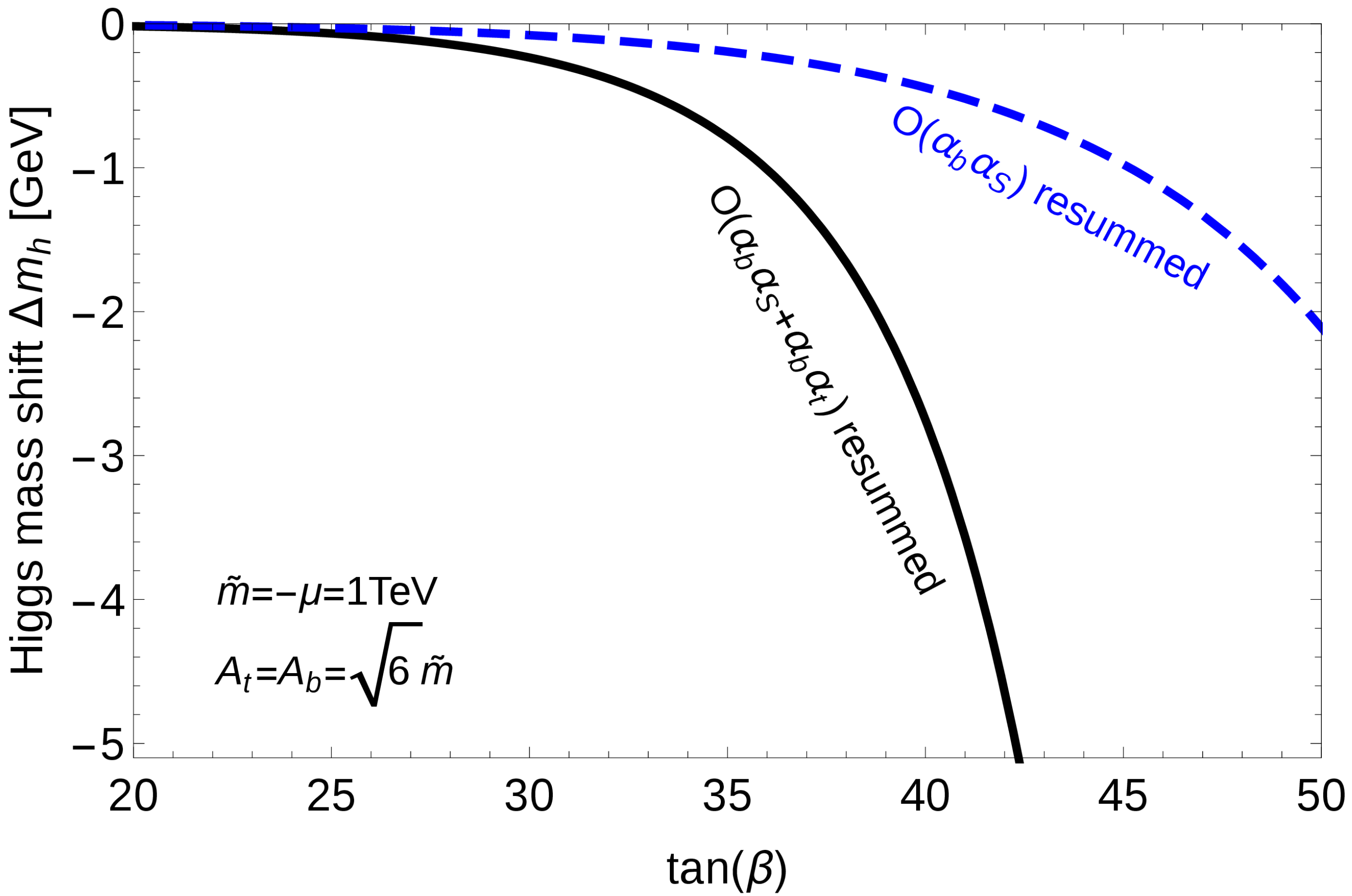


$\tan\beta$ − enhanced corrections



$$\Delta\lambda^{(\alpha_b)} = -\frac{\hat{y}_b^4}{2(4\pi)^2}\frac{\mu^4}{m_{\tilde{b}}^4}$$

$\tan\beta$ – enhanced corrections (sbottom sector)



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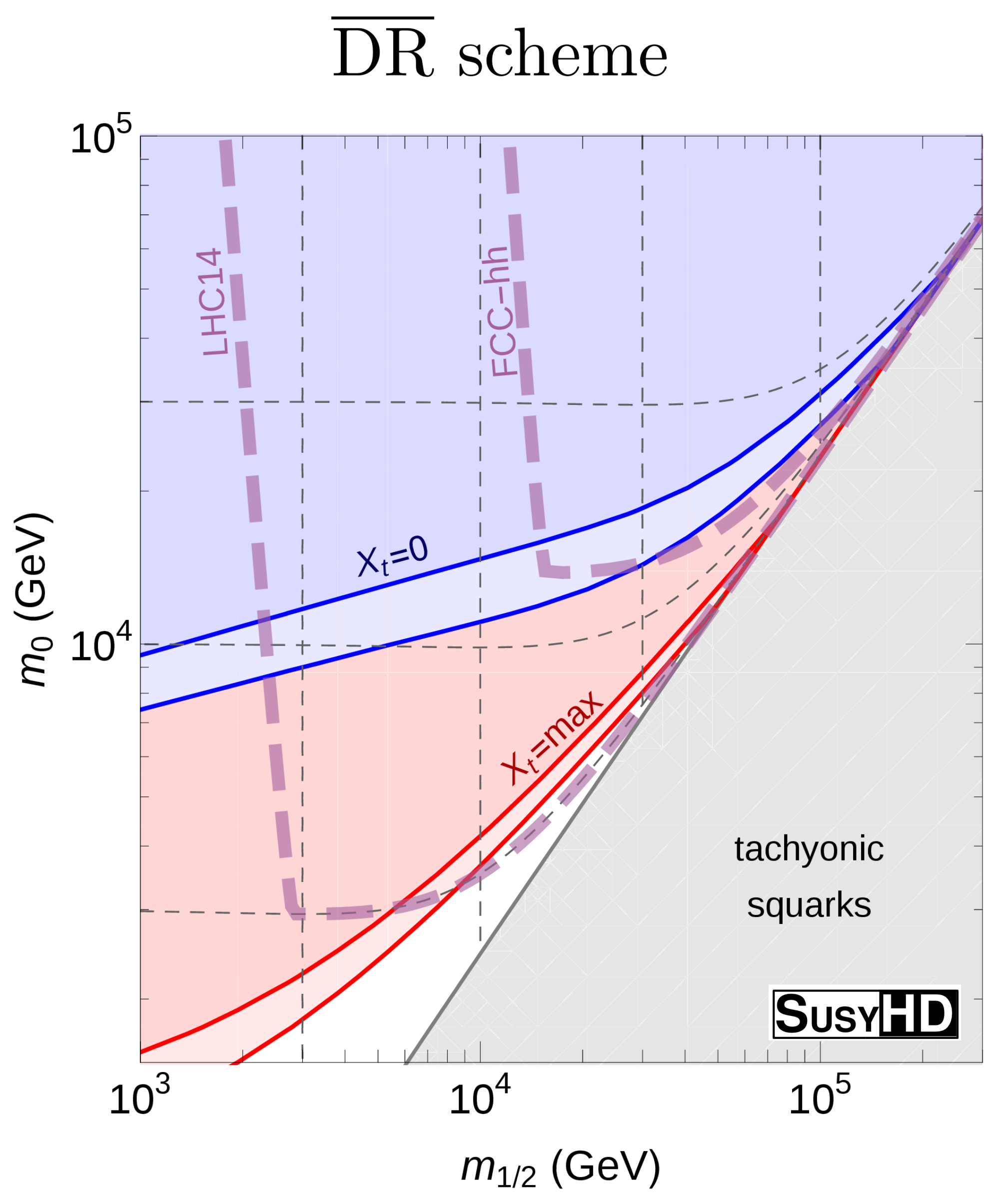
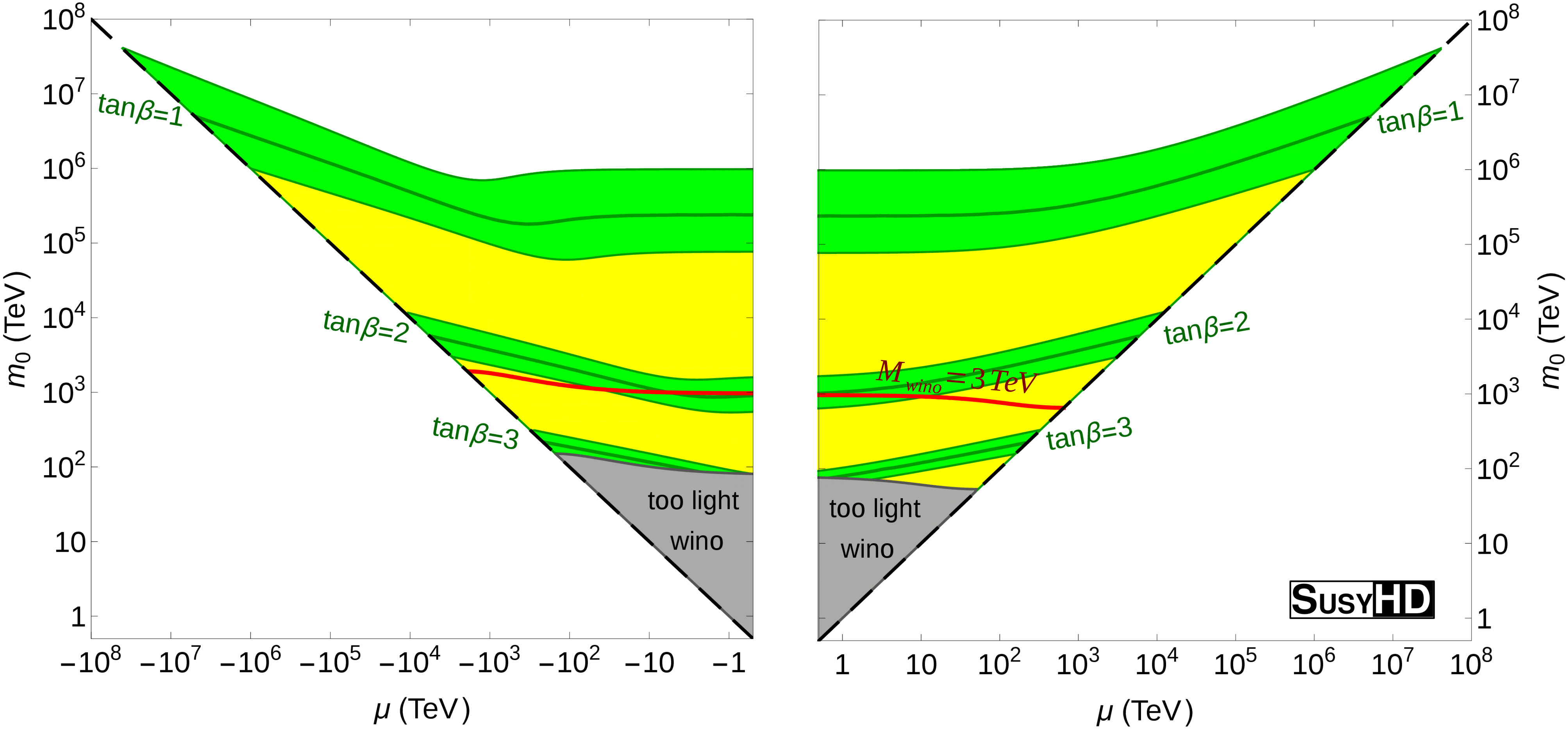


Parameter Space of Anomaly Mediation

[Giudice et. al., hep-ph/9810442, 9901378]

Independent parameters: $m_0 = m_{3/2},\ \mu,\ \tan\beta$



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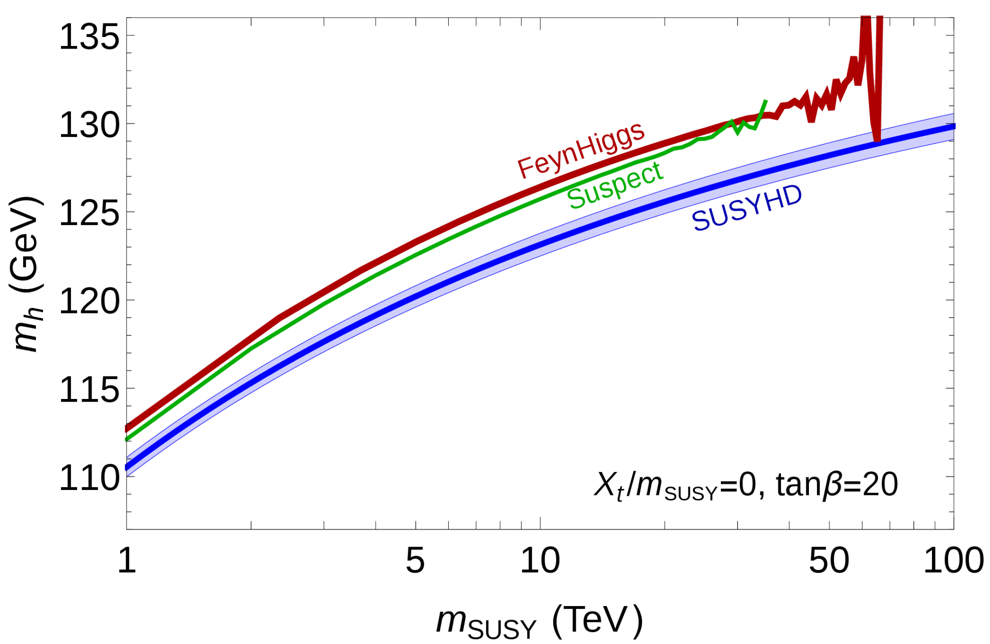

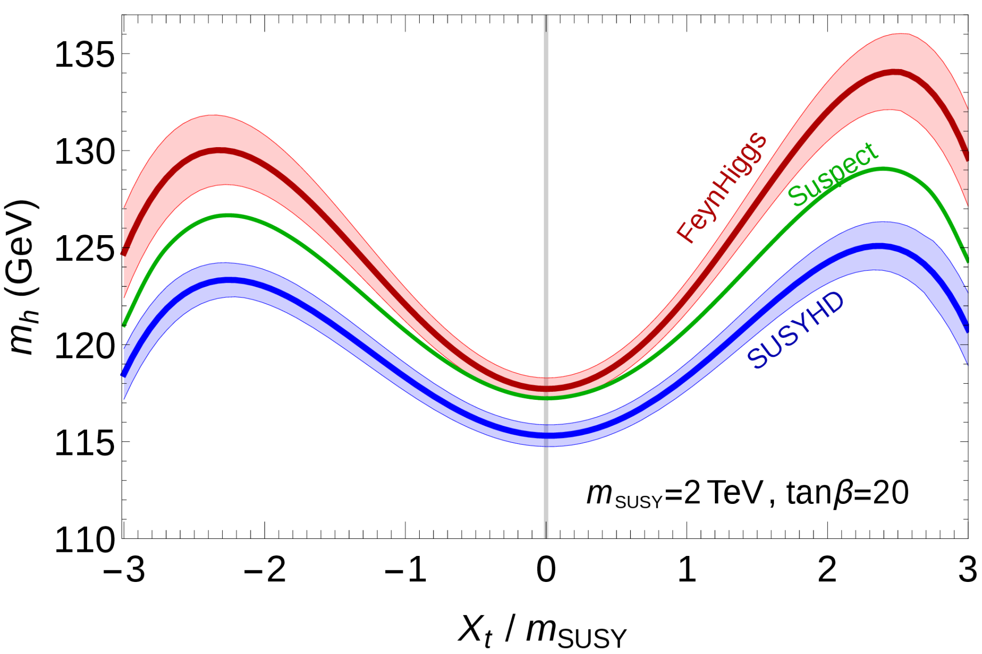

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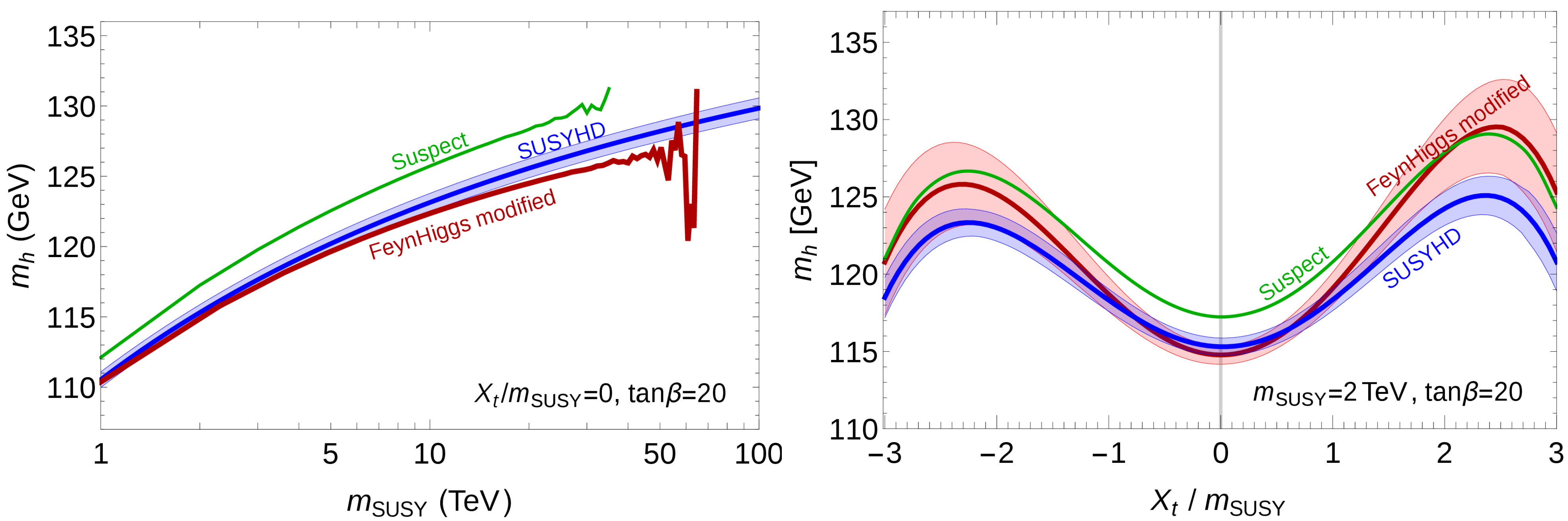
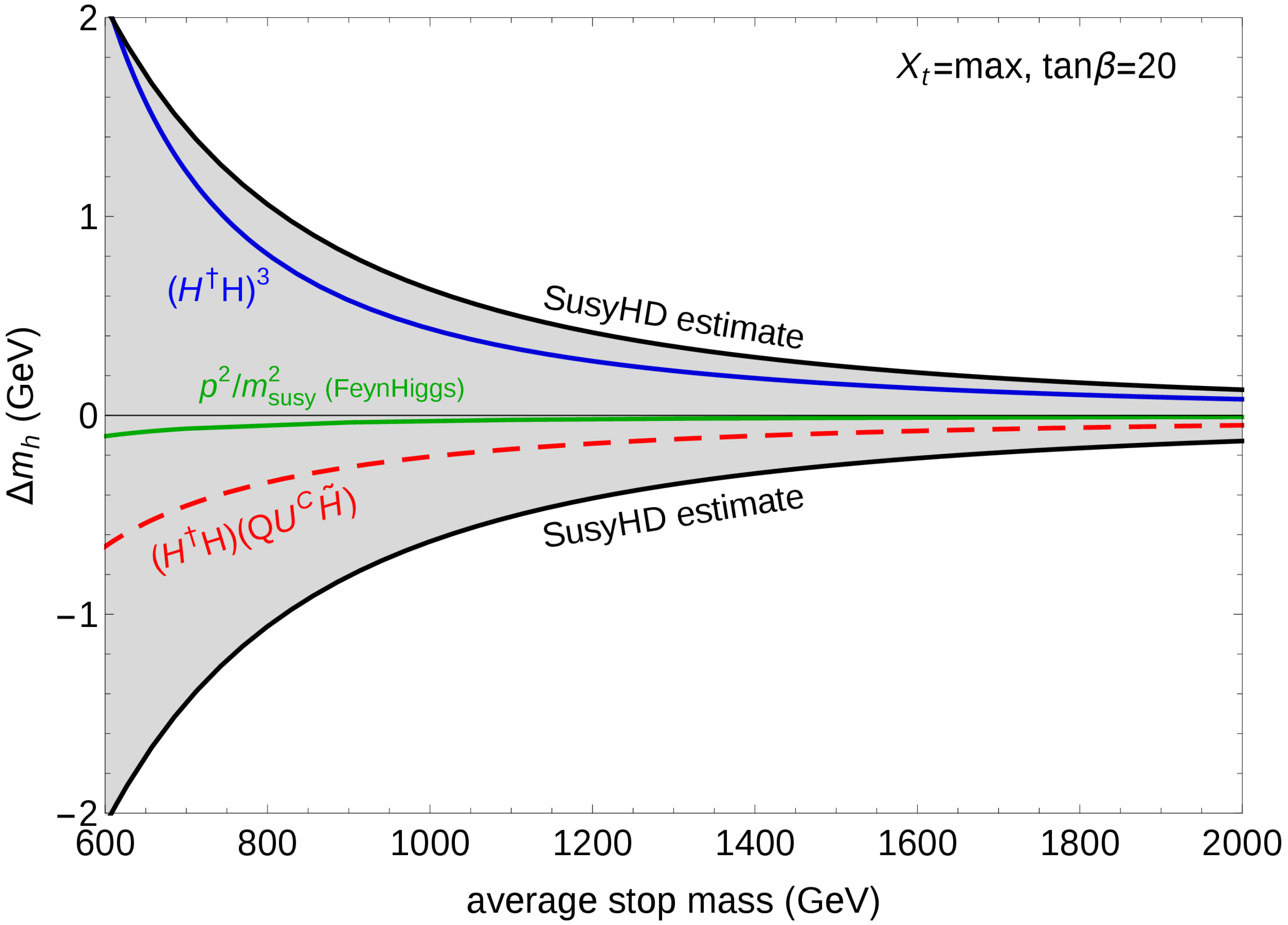


Changing the value of the running top Yukawa

Estimating the EFT uncertainty



We focus on the contribution from the stops (at maximal mixing)

Small contributions to a longstanding effort

[Pierce, Pokorski, Rosiek, Dabelstein, Zhang, Espinosa, Quiros, Hempfling, Hoang, Hahn, Heinemeyer, Hollik, Weiglein, Brignole, Slavich, Zwirner, Degrassi, Martin, Giuice, Strumia, Wagner, Carena, and many many others]

In particular, we use the results from:
hep-ph/9912516 (matching bottom Yukawa MSSM)
hep-ph/0003246, hep-ph/0105096 (two loop EP contribution to m_h^2)
1108.6077 (2-loop Split RGEs)
1307.3536 (3-loop SM RGEs, matching EW scale)
1407.4081 (SUSY thresholds in the EFT approach)
and many others...

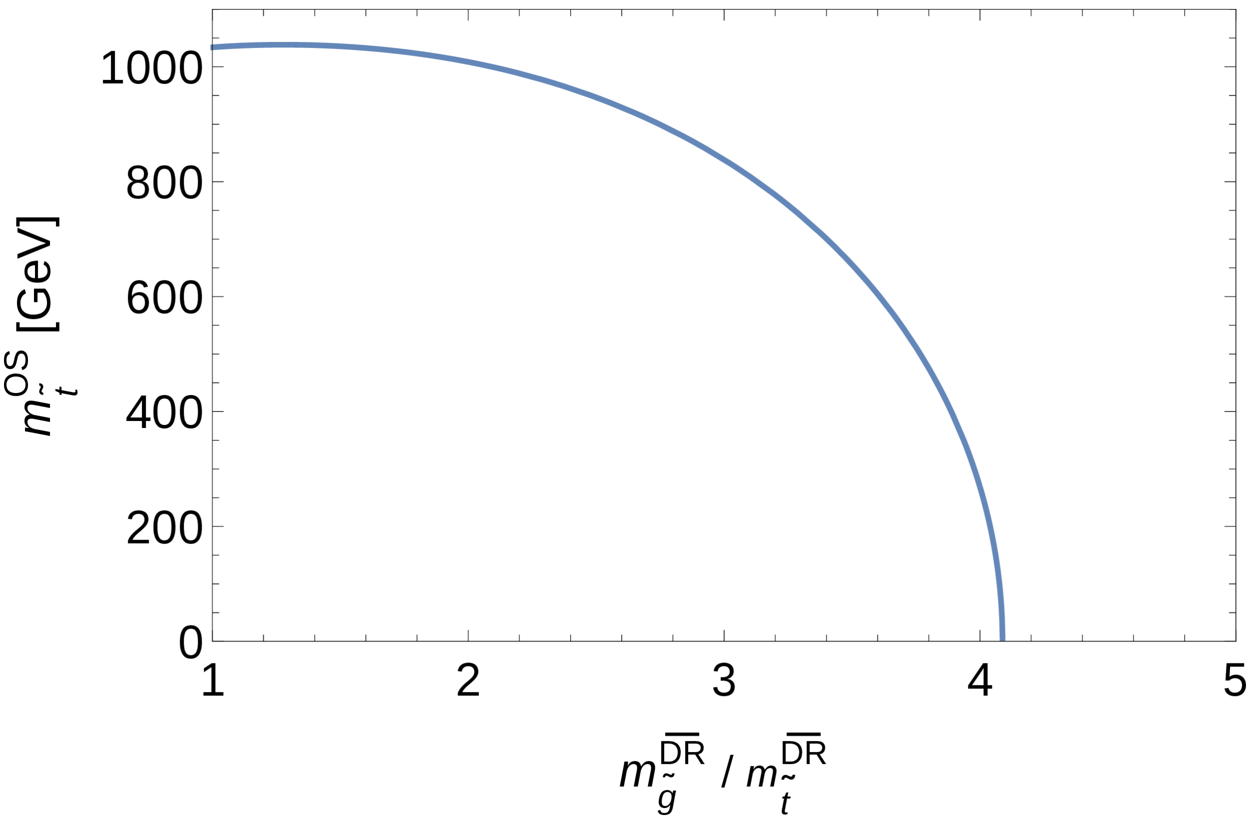
- Re-computation $\mathcal{O}(\alpha_t \alpha_s)$ SUSY threshold to λ
- Obtain $\mathcal{O}\left(\alpha_t^2\right)$ correction for degenerate scalars
- Include $\tan\beta-$enhanced corrections (sbottom and stau sectors)
- Estimate of theoretical uncertainties in the EFT calculation
- Computation in both $\overline{\mathrm{DR}}$ and OS schemes
- Mathematica Package SusyHD

Conversion $\overline{\text{DR}}$ – OS squark masses

$$\delta m^2 = (m^2)^{\overline{\text{DR}}} - (m^2)^{\text{OS}} = \text{Re}\,\hat{\Pi}\,(m^2)$$

$\hat{\Pi}\,(m^2)$: self-energy of the particle

[Degrassi, Slavich, Zwirner, arXiv: 0105096]



Possible Improvements

- Reduce experimental uncertainty of the top mass

- Calculation of missing SM thresholds and RGEs

$$\Delta\lambda^{(\alpha_t \alpha_s^2)}, \quad \beta(\lambda)^{(\alpha_t \alpha_s^3)}, \quad \beta(y_t)^{(\alpha_s^4)}$$

- Include $\mathcal{O}(v^2/m_{\text{SUSY}}^2)$ corrections in the EFT expansion

- Calculation of SUSY thresholds

$$\mathcal{O}(\alpha_t^2) \text{ general}, \mathcal{O}(\alpha_t\alpha, \alpha_s\alpha), \mathcal{O}(\alpha_b\alpha_s, \alpha_b\alpha_t, \alpha_b^2), \mathcal{O}(\alpha_t\alpha_s^2)$$

- In the code:
  - run the MSSM parameters or integrate with spectrum calculators
  - further optimization

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: July 2015

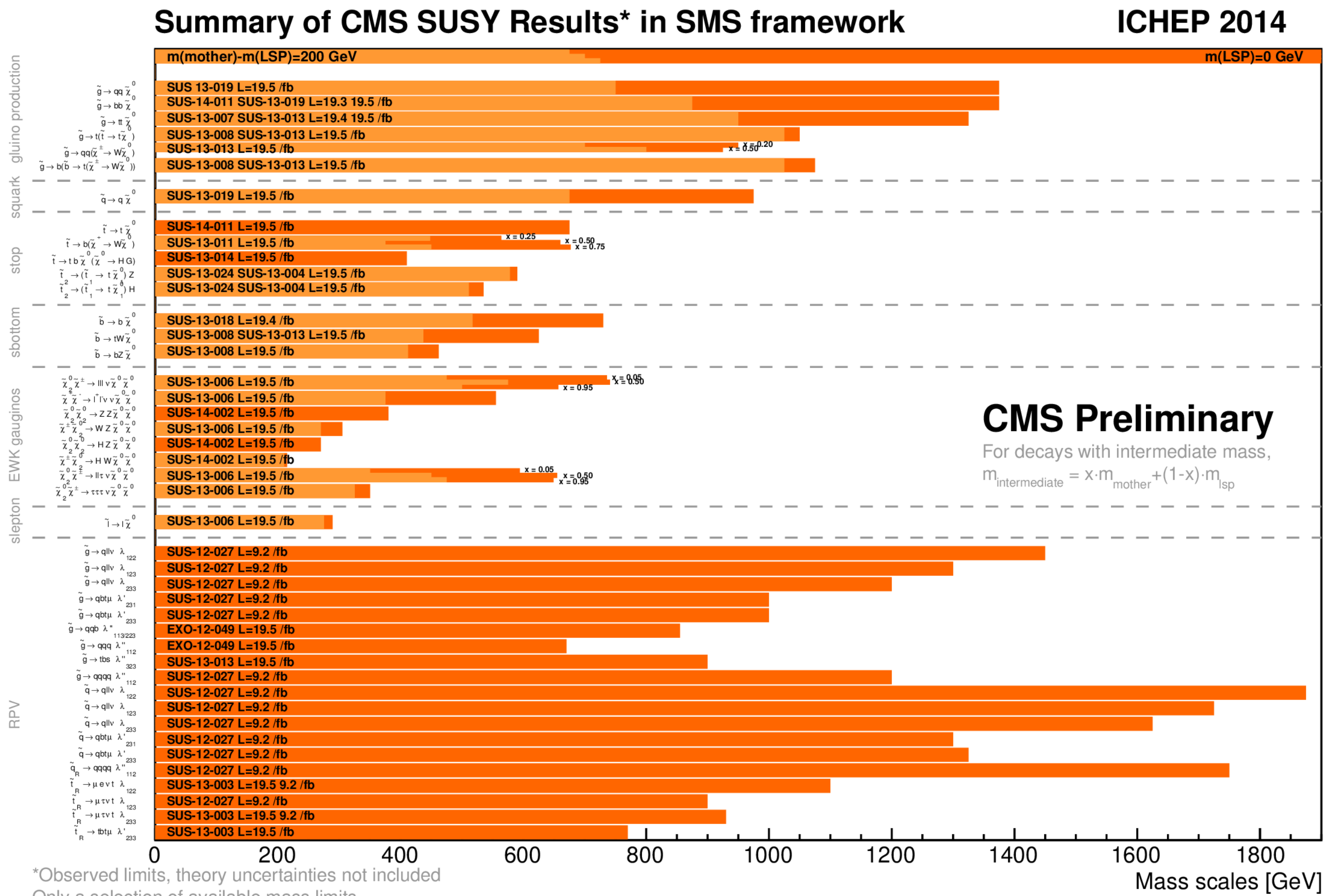
ATLAS Preliminary

$\sqrt{s}$ = 7, 8 TeV

	Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\, dt [fb^{-1}]$		Mass limit ($\sqrt{s}$ = 7 TeV / $\sqrt{s}$ = 8 TeV)		Reference
Inclusive Searches	MSUGRA/CMSSM	0-3 e,μ /1-2 τ	2-10 jets/3 b	Yes	20.3	$\tilde{q}, \tilde{g}$	1.8 TeV	$m(\tilde{q})=m(\tilde{g})$	1507.05525
	$\tilde{q}\tilde{q}, \tilde{q}\to q\tilde{\chi}^0_1$	0	2-6 jets	Yes	20.3	$\tilde{q}$	850 GeV	$m(\tilde{\chi}^0_1)$=0 GeV, m(1st gen. $\tilde{q}$)=m(2nd gen. $\tilde{q}$)	1405.7875
	$\tilde{q}\tilde{q}, \tilde{q}\to q\tilde{\chi}^0_1$ (compressed)	mono-jet	1-3 jets	Yes	20.3	$\tilde{q}$	100-440 GeV	$m(\tilde{q})-m(\tilde{\chi}^0_1)$<10 GeV	1507.05525
	$\tilde{q}\tilde{q}, \tilde{q}\to q(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}^0_1$	2 e,μ (off-Z)	2 jets	Yes	20.3	$\tilde{q}$	780 GeV	$m(\tilde{\chi}^0_1)$=0 GeV	1503.03290
	$\tilde{g}\tilde{g}, \tilde{g}\to q\bar{q}\tilde{\chi}^0_1$	0	2-6 jets	Yes	20.3	$\tilde{g}$	1.33 TeV	$m(\tilde{\chi}^0_1)$=0 GeV	1405.7875
	$\tilde{g}\tilde{g}, \tilde{g}\to qq\tilde{\chi}^\pm_1\to qqW^\pm\tilde{\chi}^0_1$	0-1 e,μ	2-6 jets	Yes	20	$\tilde{g}$	1.26 TeV	$m(\tilde{\chi}^0_1)$<300 GeV, $m(\tilde{\chi}^\pm)=0.5(m(\tilde{\chi}^0_1)+m(\tilde{g}))$	1507.05525
	$\tilde{g}\tilde{g}, \tilde{g}\to qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}^0_1$	2 e,μ	0-3 jets	-	20	$\tilde{g}$	1.32 TeV	$m(\tilde{\chi}^0_1)$=0 GeV	1501.03555
	GMSB ($\tilde{\ell}$ NLSP)	1-2 τ + 0-1 ℓ	0-2 jets	Yes	20.3	$\tilde{g}$	1.6 TeV	$\tan\beta$ >20	1407.0603
	GGM (bino NLSP)	2 γ	-	Yes	20.3	$\tilde{g}$	1.29 TeV	$c\tau$(NLSP)<0.1 mm	1507.05493
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	20.3	$\tilde{g}$	1.3 TeV	$m(\tilde{\chi}^0_1)$<900 GeV, $c\tau$(NLSP)<0.1 mm, μ<0	1507.05493
	GGM (higgsino-bino NLSP)	γ	2 jets	Yes	20.3	$\tilde{g}$	1.25 TeV	$m(\tilde{\chi}^0_1)$<850 GeV, $c\tau$(NLSP)<0.1 mm, μ>0	1507.05493
	GGM (higgsino NLSP)	2 e,μ (Z)	2 jets	Yes	20.3	$\tilde{g}$	850 GeV	m(NLSP)>430 GeV	1503.03290
	Gravitino LSP	0	mono-jet	Yes	20.3	$F^{1/2}$ scale	865 GeV	$m(\tilde{G})>1.8\times10^{-4}$ eV, $m(\tilde{g})=m(\tilde{q})$=1.5 TeV	1502.01518
3rd gen. $\tilde{g}$ med.	$\tilde{g}\tilde{g}, \tilde{g}\to b\bar{b}\tilde{\chi}^0_1$	0	3 b	Yes	20.1	$\tilde{g}$	1.25 TeV	$m(\tilde{\chi}^0_1)$<400 GeV	1407.0600
	$\tilde{g}\tilde{g}, \tilde{g}\to t\bar{t}\tilde{\chi}^0_1$	0	7-10 jets	Yes	20.3	$\tilde{g}$	1.1 TeV	$m(\tilde{\chi}^0_1)$ <350 GeV	1308.1841
	$\tilde{g}\tilde{g}, \tilde{g}\to t\bar{t}\tilde{\chi}^0_1$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$	1.34 TeV	$m(\tilde{\chi}^0_1)$<400 GeV	1407.0600
	$\tilde{g}\tilde{g}, \tilde{g}\to b\bar{t}\tilde{\chi}^+_1$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$	1.3 TeV	$m(\tilde{\chi}^0_1)$<300 GeV	1407.0600
3rd gen. squarks direct production	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to b\tilde{\chi}^0_1$	0	2 b	Yes	20.1	$\tilde{b}_1$	100-620 GeV	$m(\tilde{\chi}^0_1)$<90 GeV	1308.2631
	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to t\tilde{\chi}^\pm_1$	2 e,μ (SS)	0-3 b	Yes	20.3	$\tilde{b}_1$	275-440 GeV	$m(\tilde{\chi}^\pm_1)$=2 $m(\tilde{\chi}^0_1)$	1404.2500
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to b\tilde{\chi}^\pm_1$	1-2 e,μ	1-2 b	Yes	4.7/20.3	$\tilde{t}_1$	110-167 GeV (7 TeV); 230-460 GeV	$m(\tilde{\chi}^\pm_1)$ = 2$m(\tilde{\chi}^0_1)$, $m(\tilde{\chi}^0_1)$=55 GeV	1209.2102, 1407.0583
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to Wb\tilde{\chi}^0_1$ or $t\tilde{\chi}^0_1$	0-2 e,μ	0-2 jets/1-2 b	Yes	20.3	$\tilde{t}_1$	90-191 GeV; 210-700 GeV	$m(\tilde{\chi}^0_1)$=1 GeV	1506.08616
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to c\tilde{\chi}^0_1$	0	mono-jet/c-tag	Yes	20.3	$\tilde{t}_1$	90-240 GeV	$m(\tilde{t}_1)-m(\tilde{\chi}^0_1)$<85 GeV	1407.0608
	$\tilde{t}_1\tilde{t}_1$ (natural GMSB)	2 e,μ (Z)	1 b	Yes	20.3	$\tilde{t}_1$	150-580 GeV	$m(\tilde{\chi}^0_1)$>150 GeV	1403.5222
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2\to\tilde{t}_1 + Z$	3 e,μ (Z)	1 b	Yes	20.3	$\tilde{t}_2$	290-600 GeV	$m(\tilde{\chi}^0_1)$<200 GeV	1403.5222
EW direct	$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}, \tilde{\ell}\to\ell\tilde{\chi}^0_1$	2 e,μ	0	Yes	20.3	$\tilde{\ell}$	90-325 GeV	$m(\tilde{\chi}^0_1)$=0 GeV	1403.5294
	$\tilde{\chi}^+_1\tilde{\chi}^-_1, \tilde{\chi}^+_1\to\tilde{\ell}\nu(\ell\tilde{\nu})$	2 e,μ	0	Yes	20.3	$\tilde{\chi}^\pm_1$	140-465 GeV	$m(\tilde{\chi}^0_1)$=0 GeV, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}^\pm_1)+m(\tilde{\chi}^0_1))$	1403.5294
	$\tilde{\chi}^+_1\tilde{\chi}^-_1, \tilde{\chi}^+_1\to\tilde{\tau}\nu(\tau\tilde{\nu})$	2 τ	-	Yes	20.3	$\tilde{\chi}^\pm_1$	100-350 GeV	$m(\tilde{\chi}^0_1)$=0 GeV, $m(\tilde{\tau},\tilde{\nu})=0.5(m(\tilde{\chi}^\pm_1)+m(\tilde{\chi}^0_1))$	1407.0350
	$\tilde{\chi}^\pm_1\tilde{\chi}^0_2\to\tilde{\ell}_L\nu\tilde{\ell}_L\ell(\tilde{\nu}\nu), \ell\tilde{\nu}\tilde{\ell}_L\ell(\tilde{\nu}\nu)$	3 e,μ	0	Yes	20.3	$\tilde{\chi}^\pm_1, \tilde{\chi}^0_2$	700 GeV	$m(\tilde{\chi}^\pm_1)=m(\tilde{\chi}^0_2)$, $m(\tilde{\chi}^0_1)$=0, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}^\pm_1)+m(\tilde{\chi}^0_1))$	1402.7029
	$\tilde{\chi}^\pm_1\tilde{\chi}^0_2\to W\tilde{\chi}^0_1 Z\tilde{\chi}^0_1$	2-3 e,μ	0-2 jets	Yes	20.3	$\tilde{\chi}^\pm_1, \tilde{\chi}^0_2$	420 GeV	$m(\tilde{\chi}^\pm_1)=m(\tilde{\chi}^0_2)$, $m(\tilde{\chi}^0_1)$=0, sleptons decoupled	1403.5294, 1402.7029
	$\tilde{\chi}^\pm_1\tilde{\chi}^0_2\to W\tilde{\chi}^0_1 h\tilde{\chi}^0_1, h\to b\bar{b}/WW/\tau\tau/\gamma\gamma$	e,μ,γ	0-2 b	Yes	20.3	$\tilde{\chi}^\pm_1, \tilde{\chi}^0_2$	250 GeV	$m(\tilde{\chi}^\pm_1)=m(\tilde{\chi}^0_2)$, $m(\tilde{\chi}^0_1)$=0, sleptons decoupled	1501.07110
	$\tilde{\chi}^0_2\tilde{\chi}^0_3, \tilde{\chi}^0_{2,3}\to\tilde{\ell}_R\ell$	4 e,μ	0	Yes	20.3	$\tilde{\chi}^0_{2,3}$	620 GeV	$m(\tilde{\chi}^0_2)=m(\tilde{\chi}^0_3)$, $m(\tilde{\chi}^0_1)$=0, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}^0_2)+m(\tilde{\chi}^0_1))$	1405.5086
	GGM (wino NLSP) weak prod.	1 e,μ + γ	-	Yes	20.3	$\tilde{W}$	124-361 GeV	$c\tau$<1 mm	1507.05493
Long-lived particles	Direct $\tilde{\chi}^+_1\tilde{\chi}^-_1$ prod., long-lived $\tilde{\chi}^\pm_1$	Disapp. trk	1 jet	Yes	20.3	$\tilde{\chi}^\pm_1$	270 GeV	$m(\tilde{\chi}^\pm_1)-m(\tilde{\chi}^0_1)$~160 MeV, $\tau(\tilde{\chi}^\pm_1)$=0.2 ns	1310.3675
	Direct $\tilde{\chi}^+_1\tilde{\chi}^-_1$ prod., long-lived $\tilde{\chi}^\pm_1$	dE/dx trk	-	Yes	18.4	$\tilde{\chi}^\pm_1$	482 GeV	$m(\tilde{\chi}^\pm_1)-m(\tilde{\chi}^0_1)$~160 MeV, $\tau(\tilde{\chi}^\pm_1)$<15 ns	1506.05332
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	27.9	$\tilde{g}$	832 GeV	$m(\tilde{\chi}^0_1)$=100 GeV, 10 μs<$\tau(\tilde{g})$<1000 s	1310.6584
	Stable $\tilde{g}$ R-hadron	trk	-	-	19.1	$\tilde{g}$	1.27 TeV		1411.6795
	GMSB, stable $\tilde{\tau}$, $\tilde{\chi}^0_1\to\tilde{\tau}(\tilde{e},\tilde{\mu})+\tau(e,\mu)$	1-2 μ	-	-	19.1	$\tilde{\chi}^0_1$	537 GeV	10<$\tan\beta$<50	1411.6795
	GMSB, $\tilde{\chi}^0_1\to\gamma\tilde{G}$, long-lived $\tilde{\chi}^0_1$	2 γ	-	Yes	20.3	$\tilde{\chi}^0_1$	435 GeV	2<$\tau(\tilde{\chi}^0_1)$<3 ns, SPS8 model	1409.5542
	$\tilde{g}\tilde{g}, \tilde{\chi}^0_1\to ee\nu/e\mu\nu/\mu\mu\nu$	displ. $ee/e\mu/\mu\mu$	-	-	20.3	$\tilde{\chi}^0_1$	1.0 TeV	7 <$c\tau(\tilde{\chi}^0_1)$< 740 mm, $m(\tilde{g})$=1.3 TeV	1504.05162
	GGM $\tilde{g}\tilde{g}, \tilde{\chi}^0_1\to Z\tilde{G}$	displ. vtx + jets	-	-	20.3	$\tilde{\chi}^0_1$	1.0 TeV	6 <$c\tau(\tilde{\chi}^0_1)$< 480 mm, $m(\tilde{g})$=1.1 TeV	1504.05162
RPV	LFV $pp\to\tilde{\nu}_\tau + X, \tilde{\nu}_\tau\to e\mu/e\tau/\mu\tau$	$e\mu,e\tau,\mu\tau$	-	-	20.3	$\tilde{\nu}_\tau$	1.7 TeV	λ'_{311}=0.11, $\lambda_{132/133/233}$=0.07	1503.04430
	Bilinear RPV CMSSM	2 e,μ (SS)	0-3 b	Yes	20.3	$\tilde{q}, \tilde{g}$	1.35 TeV	$m(\tilde{q})=m(\tilde{g})$, $c\tau_{LSP}$<1 mm	1404.2500
	$\tilde{\chi}^+_1\tilde{\chi}^-_1, \tilde{\chi}^+_1\to W\tilde{\chi}^0_1, \tilde{\chi}^0_1\to ee\tilde{\nu}_\mu, e\mu\tilde{\nu}_e$	4 e,μ	-	Yes	20.3	$\tilde{\chi}^\pm_1$	750 GeV	$m(\tilde{\chi}^0_1)>0.2\times m(\tilde{\chi}^\pm_1)$, $\lambda_{121}\neq0$	1405.5086
	$\tilde{\chi}^+_1\tilde{\chi}^-_1, \tilde{\chi}^+_1\to W\tilde{\chi}^0_1, \tilde{\chi}^0_1\to\tau\tau\tilde{\nu}_e, e\tau\tilde{\nu}_\tau$	3 e,μ + τ	-	Yes	20.3	$\tilde{\chi}^\pm_1$	450 GeV	$m(\tilde{\chi}^0_1)>0.2\times m(\tilde{\chi}^\pm_1)$, $\lambda_{133}\neq0$	1405.5086
	$\tilde{g}\tilde{g}, \tilde{g}\to qqq$	0	6-7 jets	-	20.3	$\tilde{g}$	917 GeV	BR(t)=BR(b)=BR(c)=0%	1502.05686
	$\tilde{g}\tilde{g}, \tilde{g}\to qq\tilde{\chi}^0_1, \tilde{\chi}^0_1\to qqq$	0	6-7 jets	-	20.3	$\tilde{g}$	870 GeV	$m(\tilde{\chi}^0_1)$=600 GeV	1502.05686
	$\tilde{g}\tilde{g}, \tilde{g}\to\tilde{t}_1 t, \tilde{t}_1\to bs$	2 e,μ (SS)	0-3 b	Yes	20.3	$\tilde{g}$	850 GeV		1404.250
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to bs$	0	2 jets + 2 b	-	20.3	$\tilde{t}_1$	100-308 GeV		ATLAS-CONF-2015-026
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to b\ell$	2 e,μ	2 b	-	20.3	$\tilde{t}_1$	0.4-1.0 TeV	BR($\tilde{t}_1\to be/\mu$)>20%	ATLAS-CONF-2015-015
Other	Scalar charm, $\tilde{c}\to c\tilde{\chi}^0_1$	0	2 c	Yes	20.3	$\tilde{c}$	490 GeV	$m(\tilde{\chi}^0_1)$<200 GeV	1501.01325

10^{-1} 1 **Mass scale [TeV]**

*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.



*Observed limits, theory uncertainties not included
Only a selection of available mass limits
Probe *up to* the quoted mass limit