Standard Model couplings from IR fixed points in the MSSM with a vector-like family

Navin McGinnis w/
Radovan Dermiśek
based on: 1812.05240

Pheno 2019

VL fermions and pheno

- *Higgs mass in SUSY models*
- *g -2*
- *flavor anomalies*
- *top partners*
- *etc.*

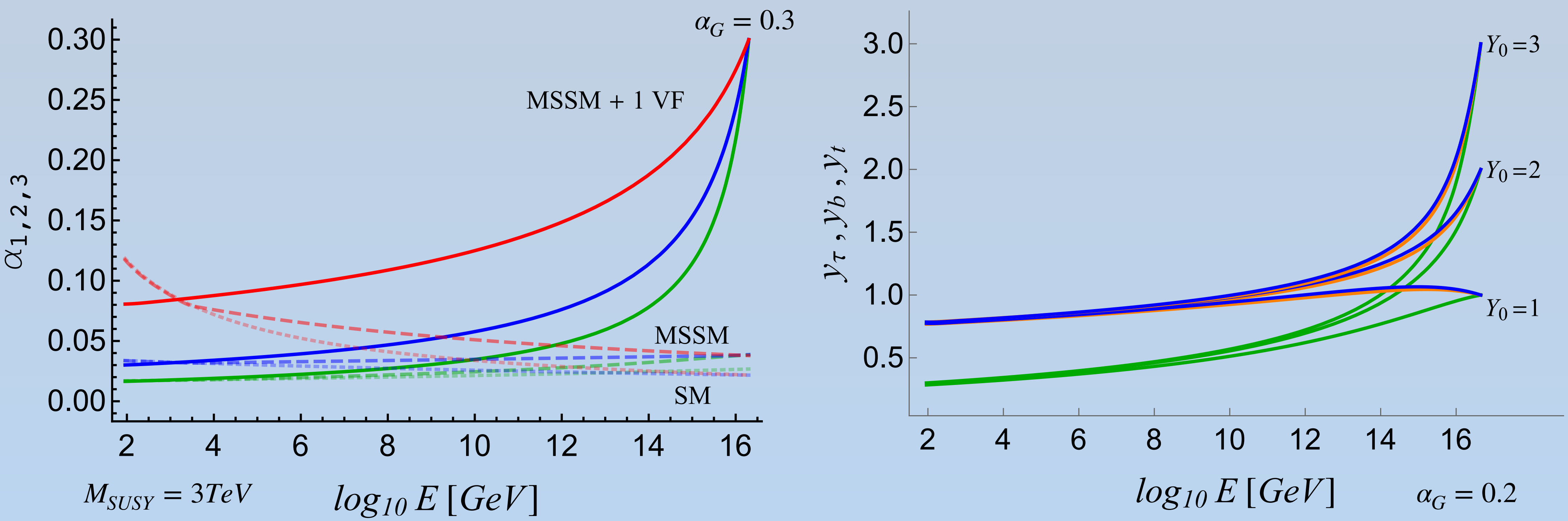
★ **Extending models with VL fermions offers scenarios where low energy parameters can be understood from particle content**

★ **In MSSM + 1VF, the seven largest couplings of the SM**

$$\alpha_{1,2,3}, y_{t,b,\tau}, \lambda_H$$

can be understood from IR fixed points of the model

Understanding weak scale parameters from IR fixed points in unified models



$$W \supset Y_0 16_3 10_H 16_3 + Y_V 16 10_H 16 + \bar{Y}_V \bar{16} 10_H \bar{16} + M_V 16 \bar{16}$$

- **Solid line: full spectrum all the way to EW scale**
  - **SM singlets remain at MG**
  - $Y_0 = Y_V = \bar{Y}_V$

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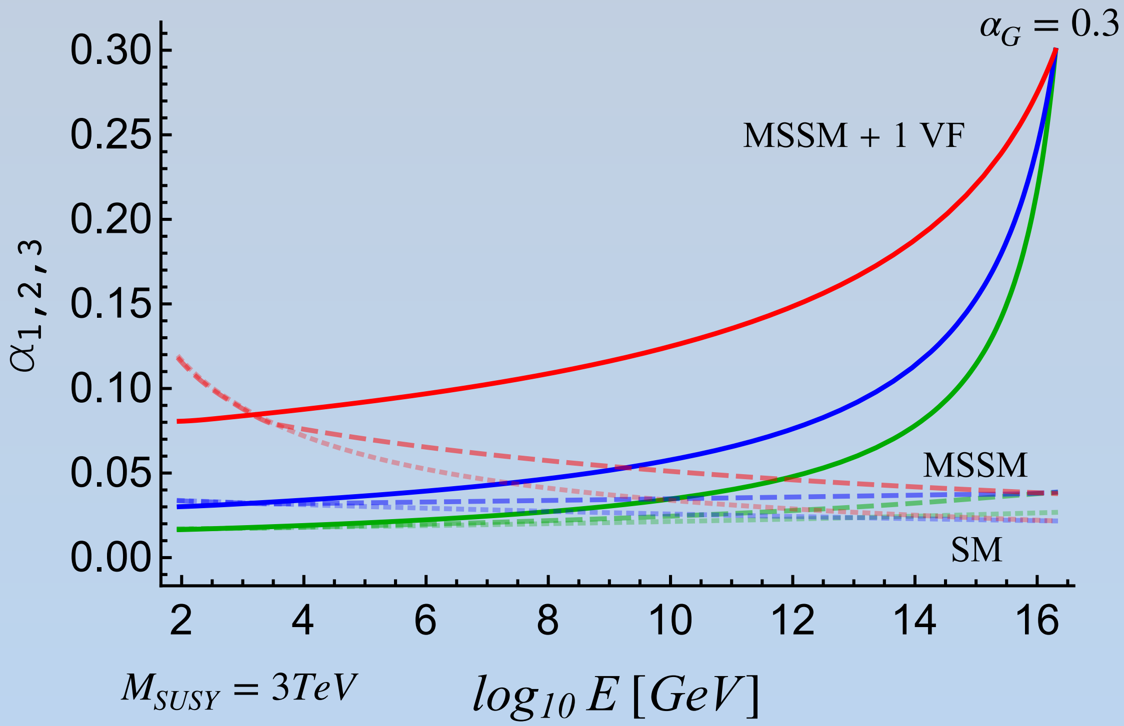

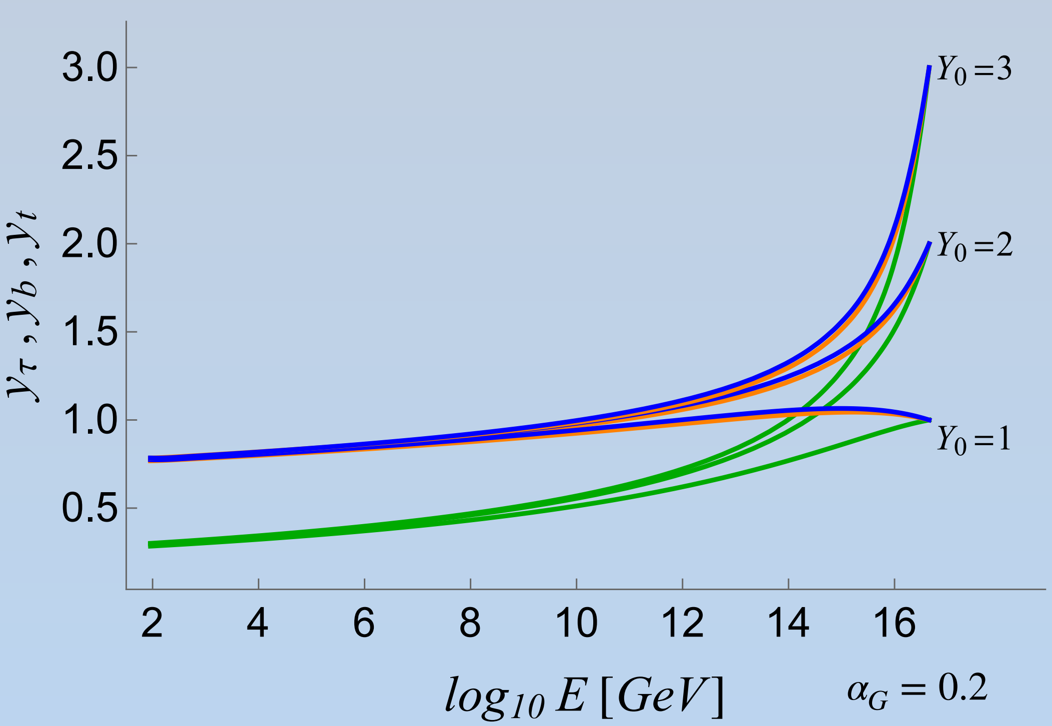

$$\alpha_i^{-1}(M_Z) = \frac{b_i}{2\pi} \ln \frac{M_G}{M_Z} + \alpha^{-1}(M_G)$$

$$b_i > 0$$

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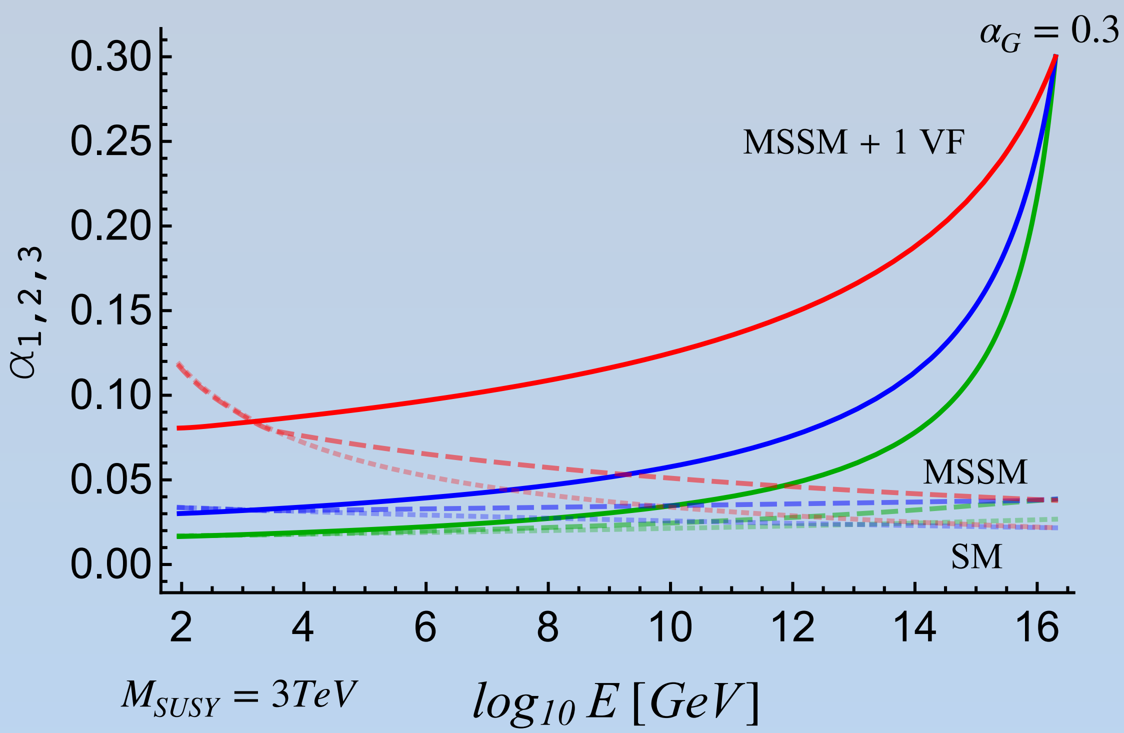

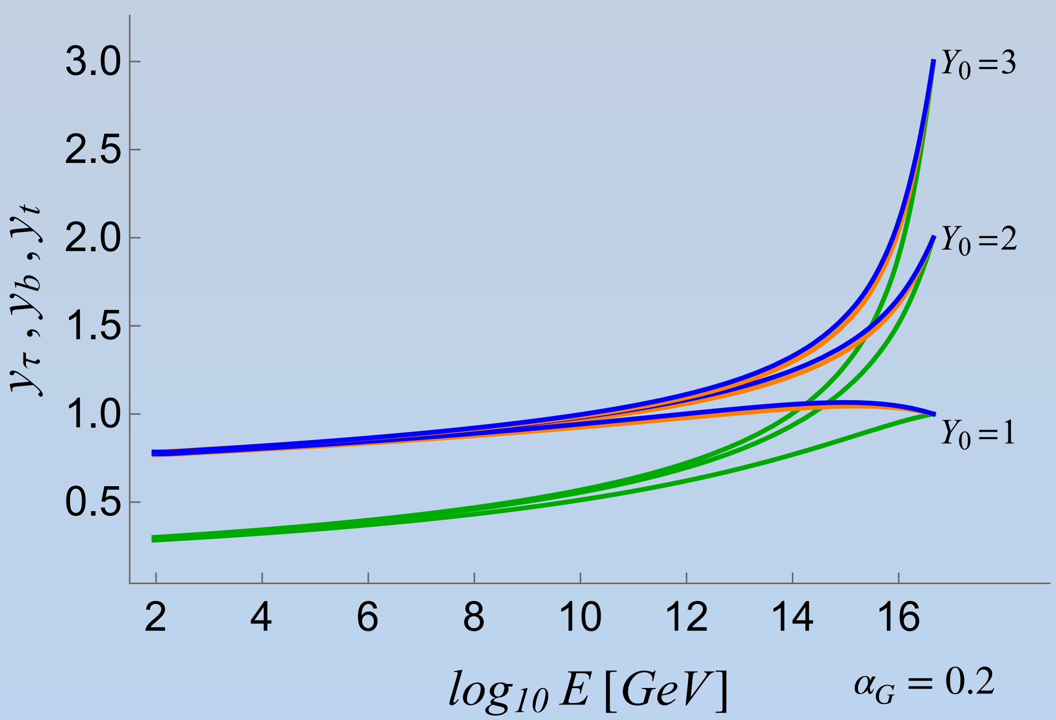

$$\alpha_i^{-1}(M_Z) = \frac{b_i}{2\pi}\ln\frac{M_G}{M_Z} + \alpha^{-1}(M_G) \quad (\alpha^{-1}(M_G) \sim 0)$$

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$$\sin^2\theta_W \equiv \frac{\alpha'}{\alpha_2+\alpha'} \simeq \frac{b_2}{b_2+b'} = 0.2205$$

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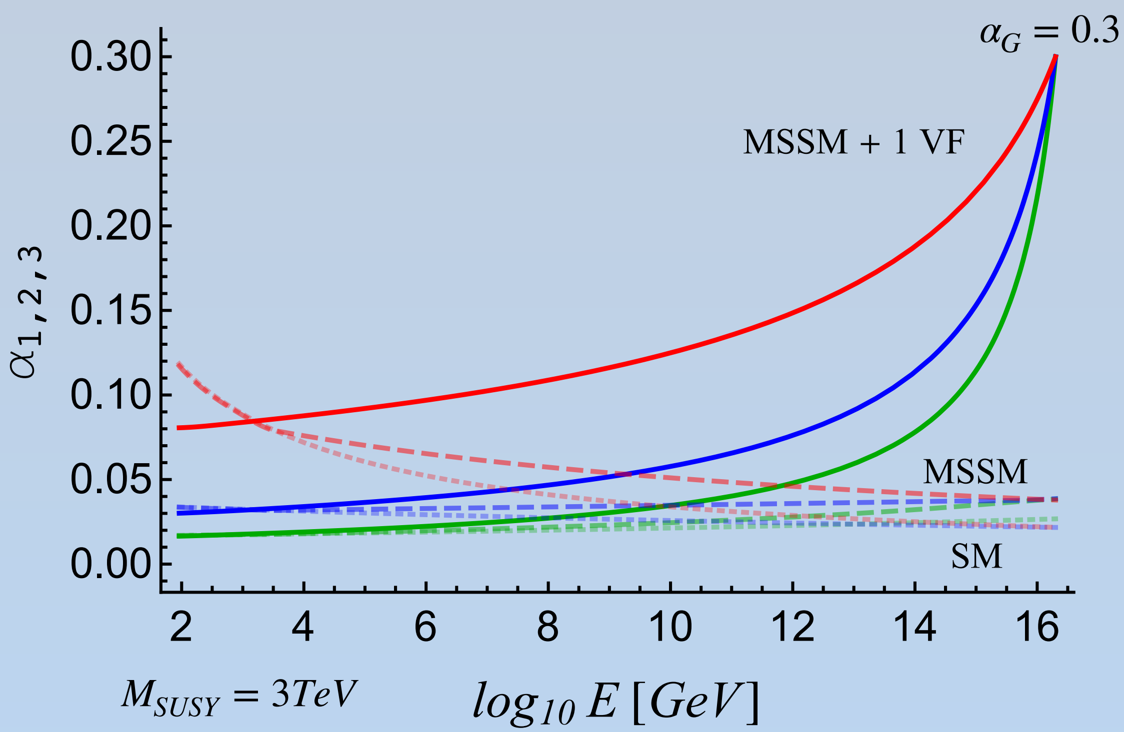

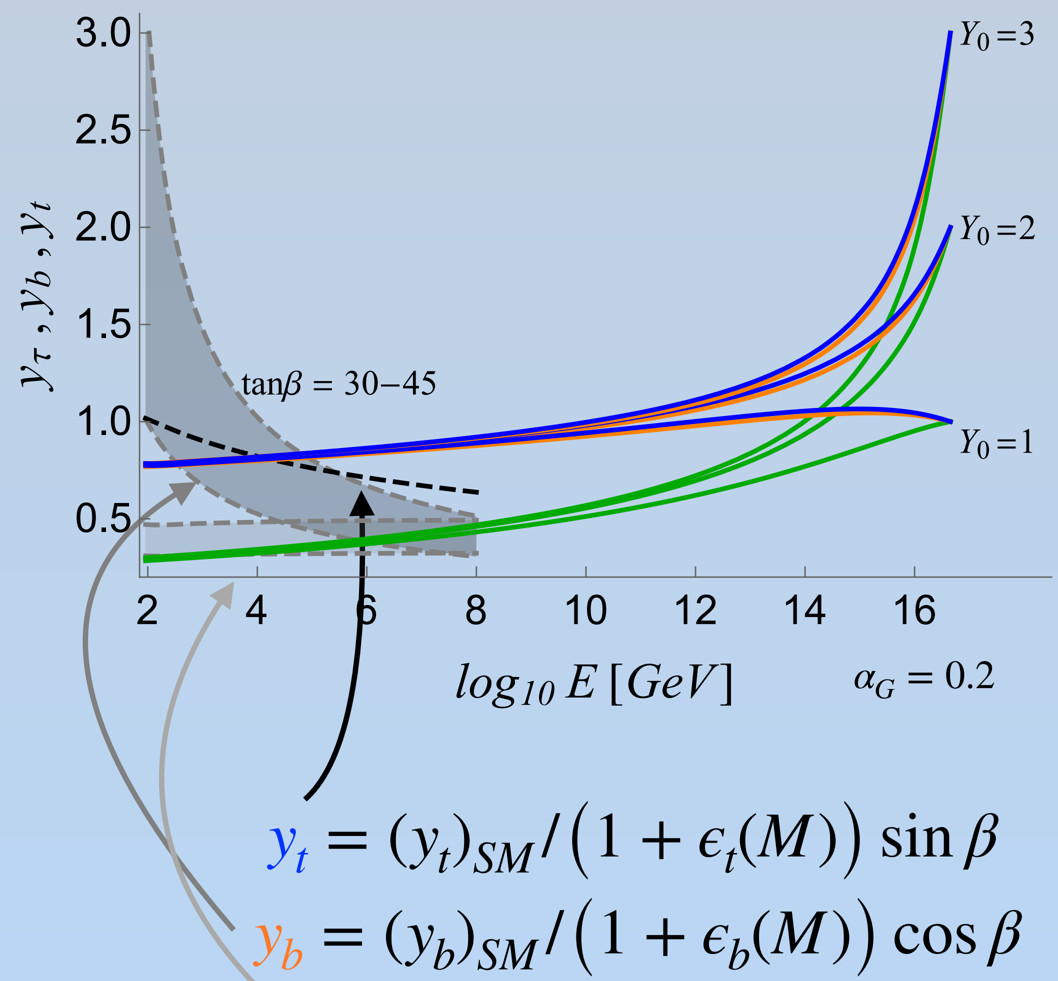

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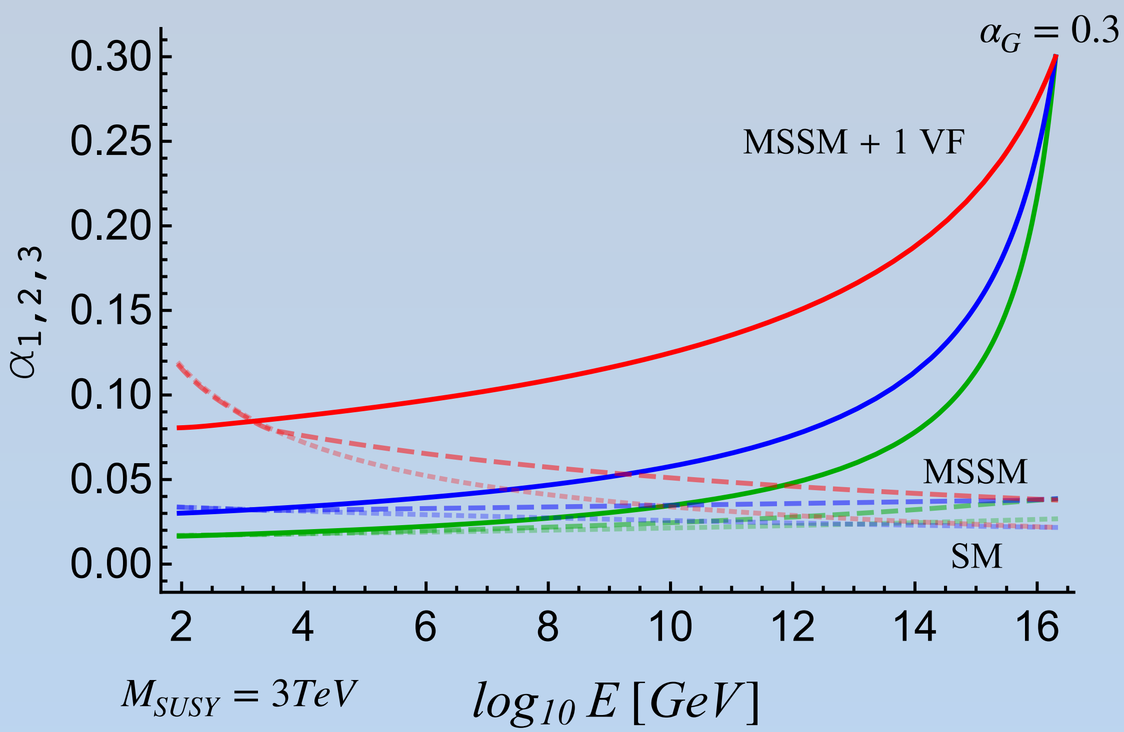

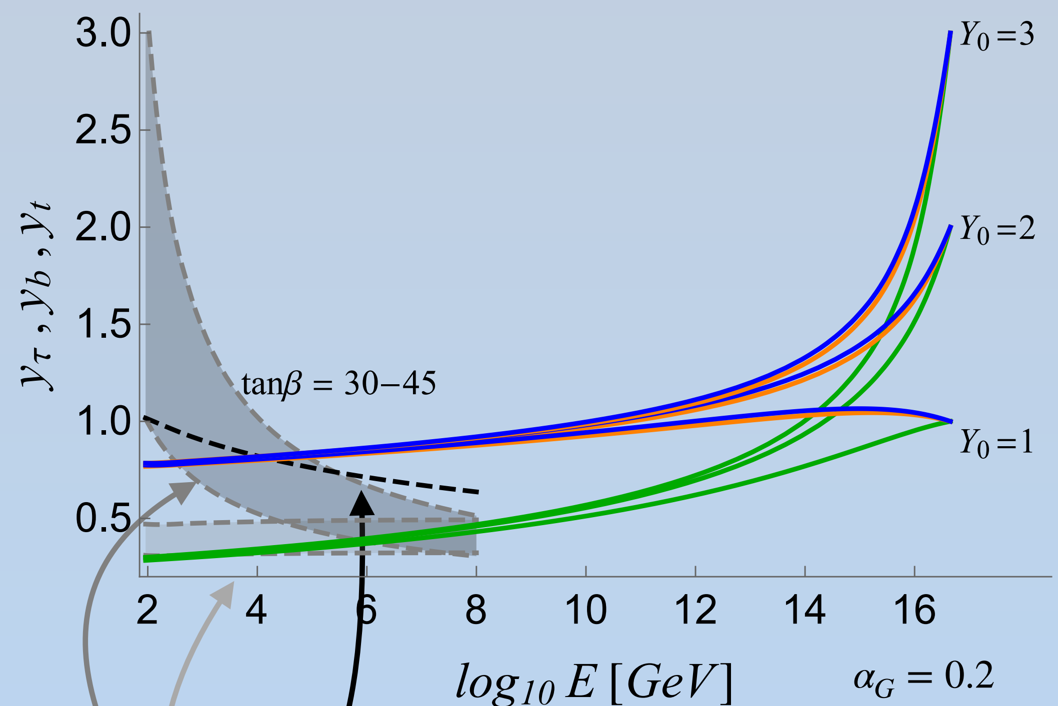

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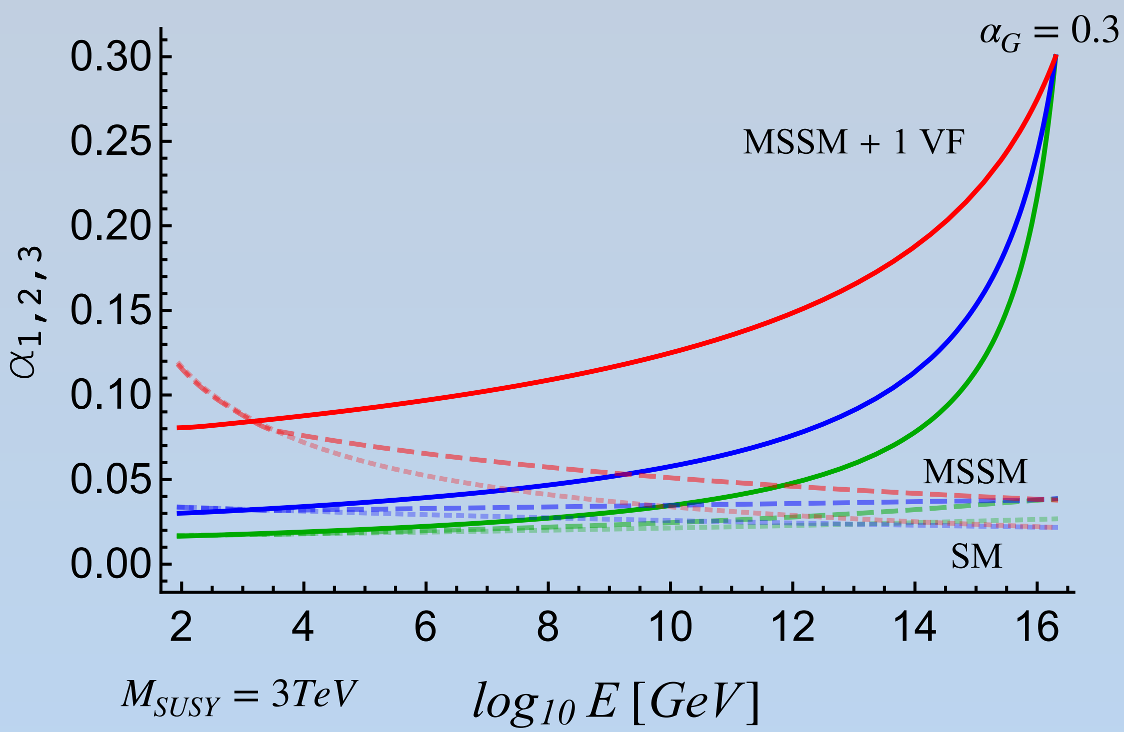

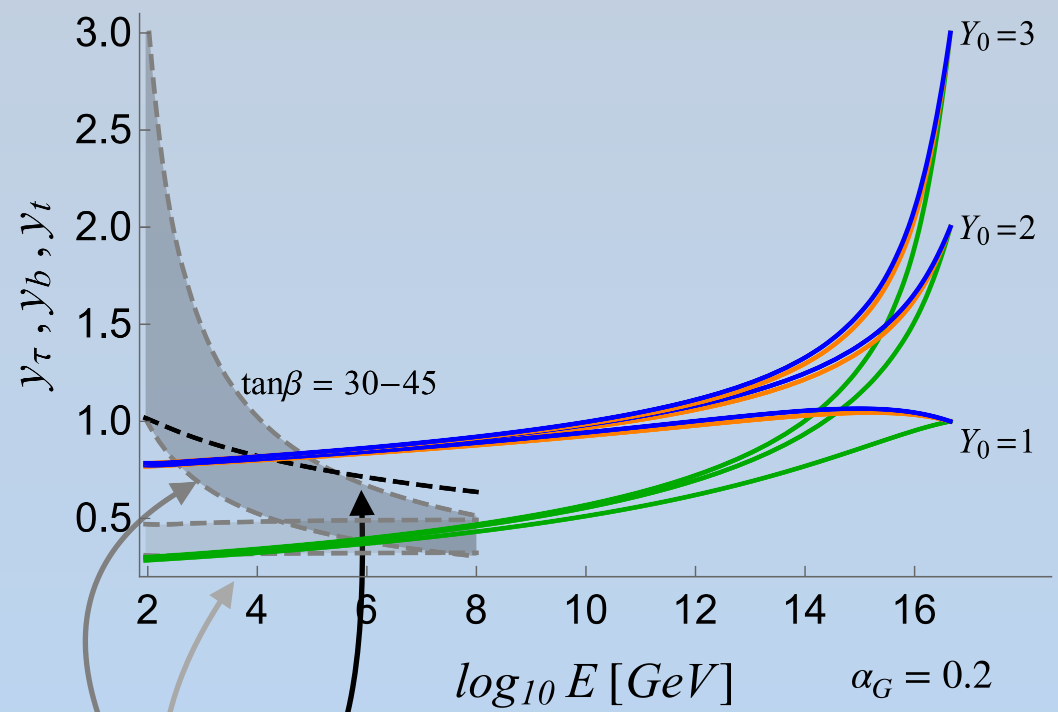

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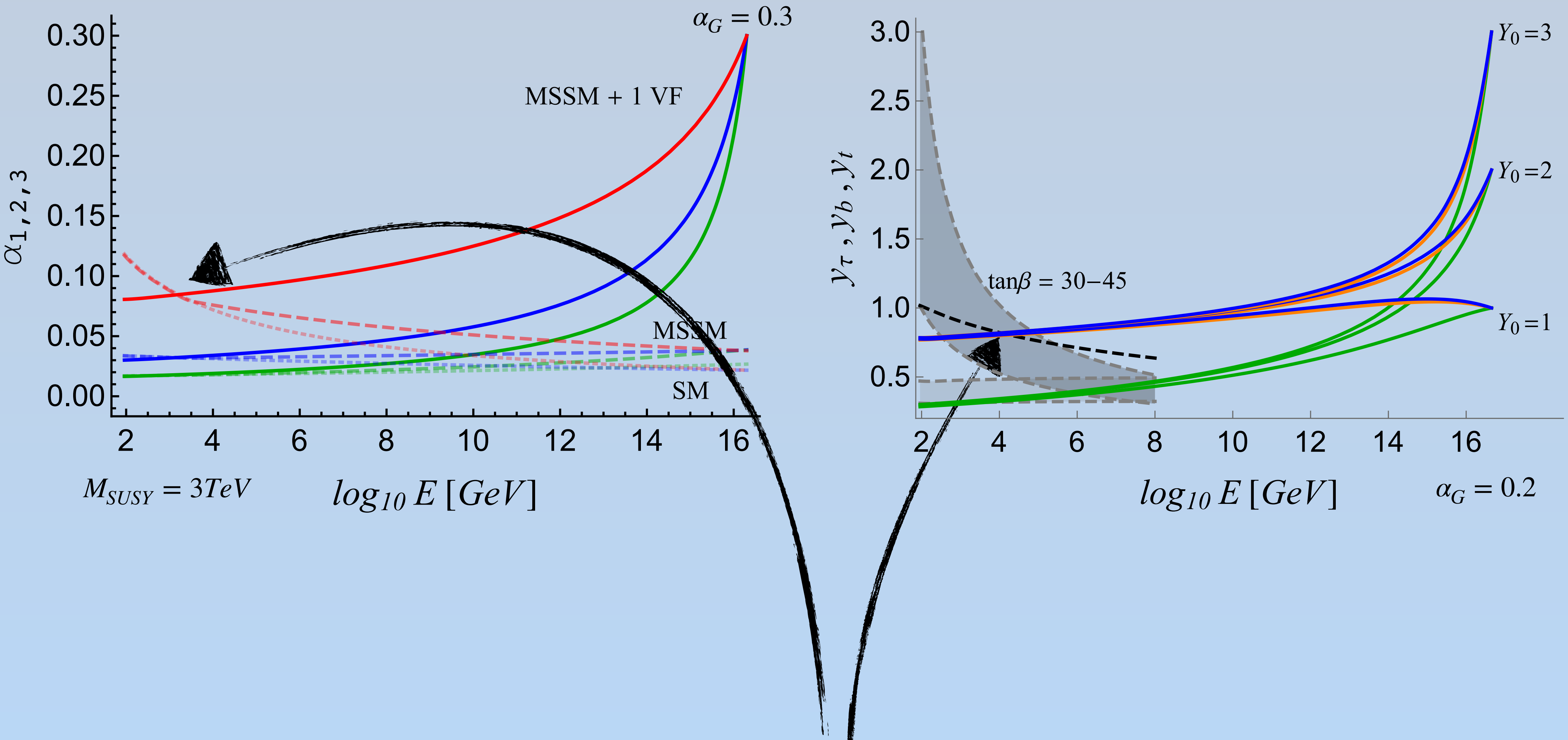
$$\left(\frac{y_{t,IR}^2}{g_3^2}\right) = \frac{16 + 3b_3}{3N_{Y_q}}$$

Understanding weak scale parameters from IR fixed points in unified models



$M_{SUSY} \sim M_{VF}$~ **multi-TeV**

couplings run to trivial fixed points and ratios run to constant values

R.Dermišek & N.M.: 1712.03527

R.Dermišek & N.M.: 1810.12474

Alternative viewpoint to unification

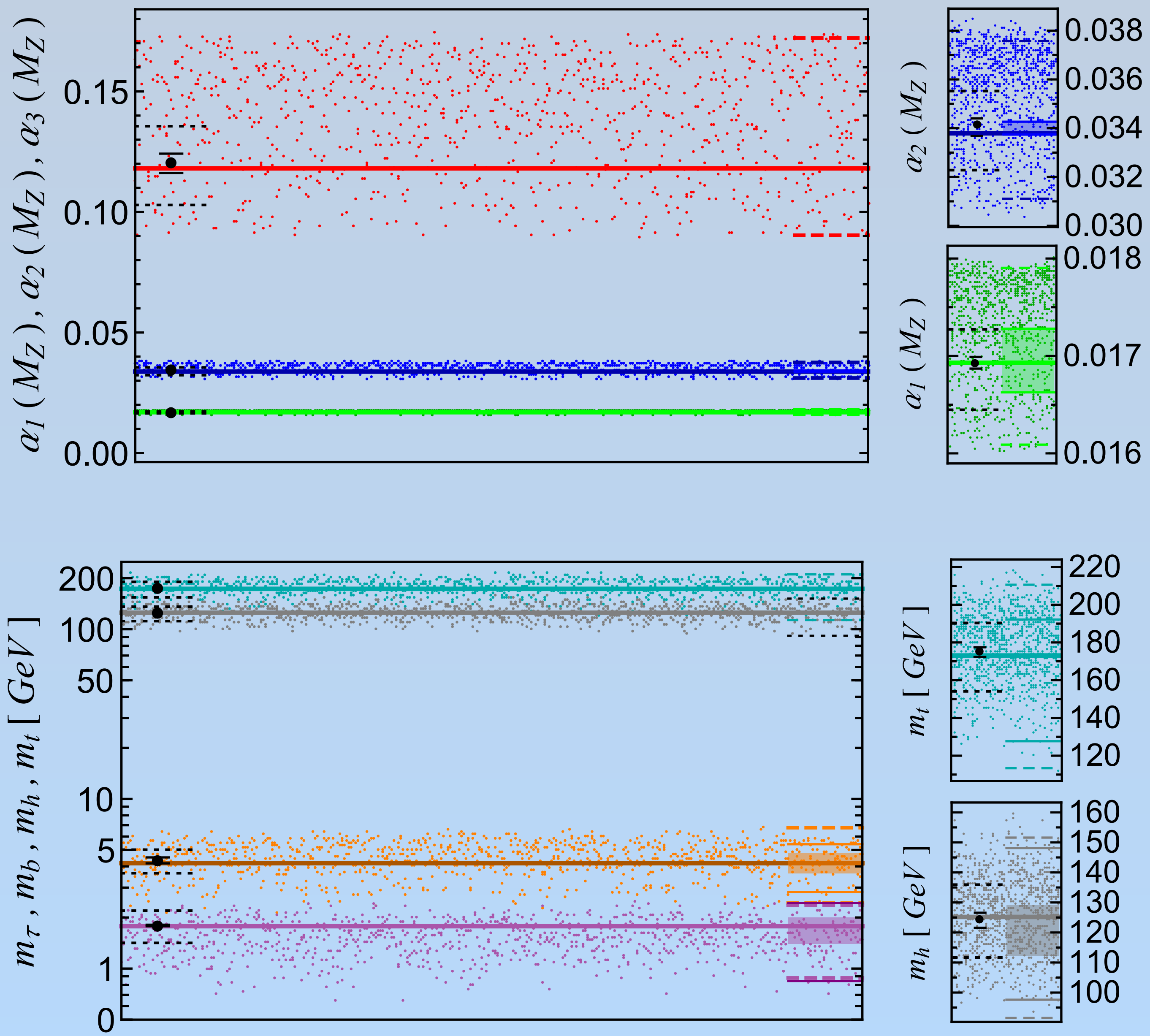
- Pattern of low energy couplings emerges from the structure of RG flow, depending very little on BC's from high scale physics
  - Maiani, Parisi, Petronzio (1978) ~ gauge couplings in EW
  - Pendleton-Ross/Hill fixed point (1981) ~ fermion masses in SM/2HDM
  - Bardeen, Carena, Pokorski, Wagner (1994) ~ top mass in MSSM

★In MSSM+1VF, low energy pattern of the seven largest couplings in the SM emerges from RG flow from completely <u>random</u> BC's ★

Low energy predictions of IR fixed points

$\alpha_{1,2,3}(M_G) \in [0.1, 0.3] \qquad M_G = 3.5 \times 10^{16} GeV$

$y_t, y_b, y_\tau, Y_V(M_G) \in [1,3] \quad M = 7TeV \quad \tan\beta = 40$



Correct hierarchical pattern of low energy couplings emerges from RG flow and <u>single</u> scale of NP

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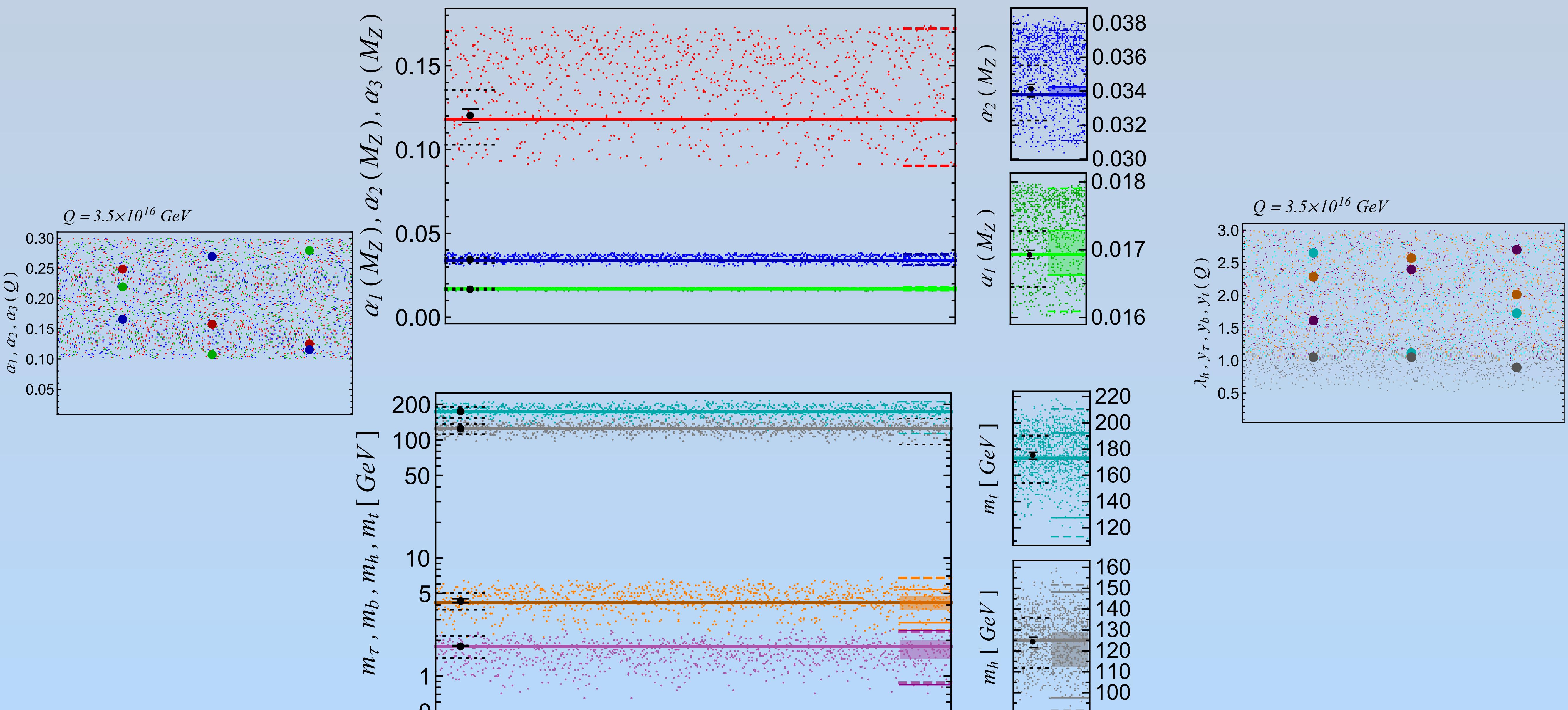

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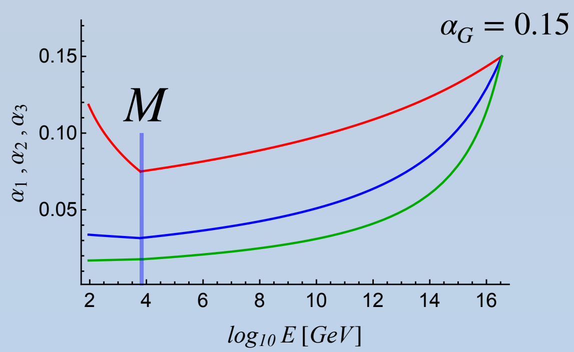
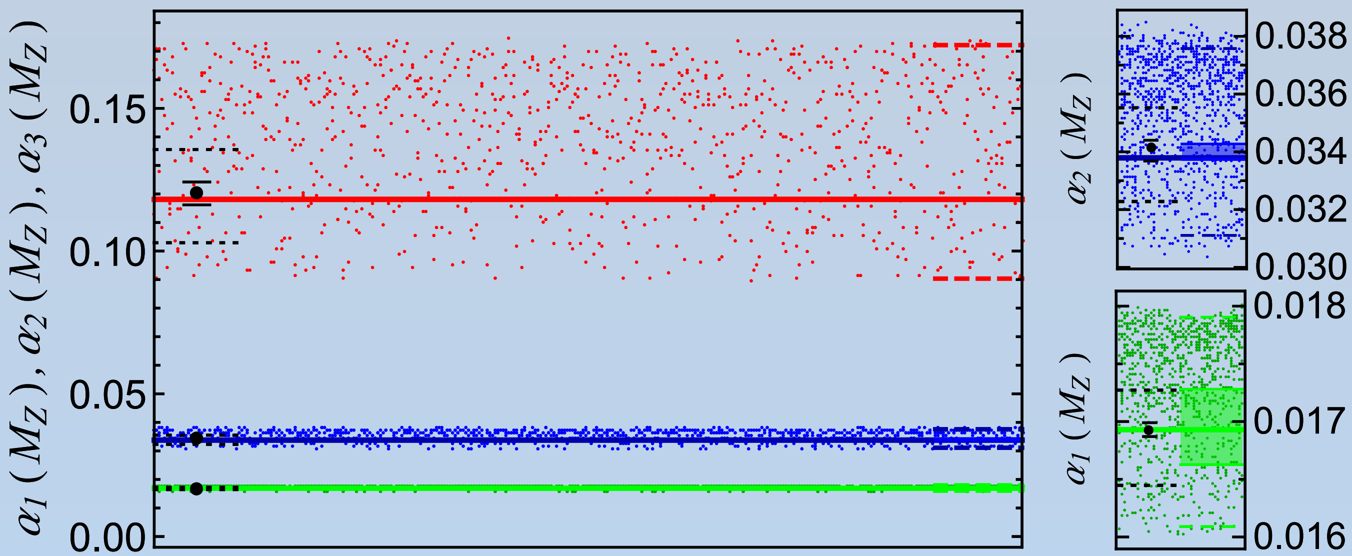
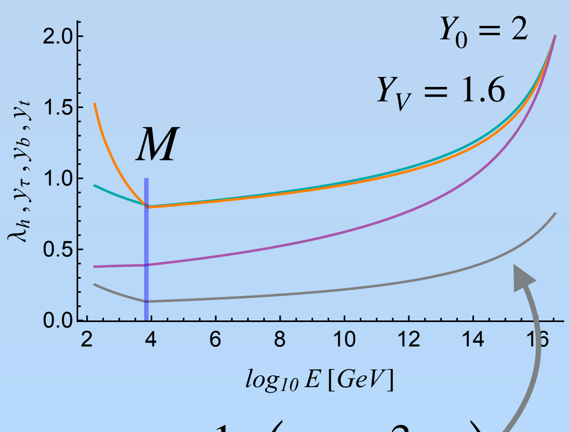
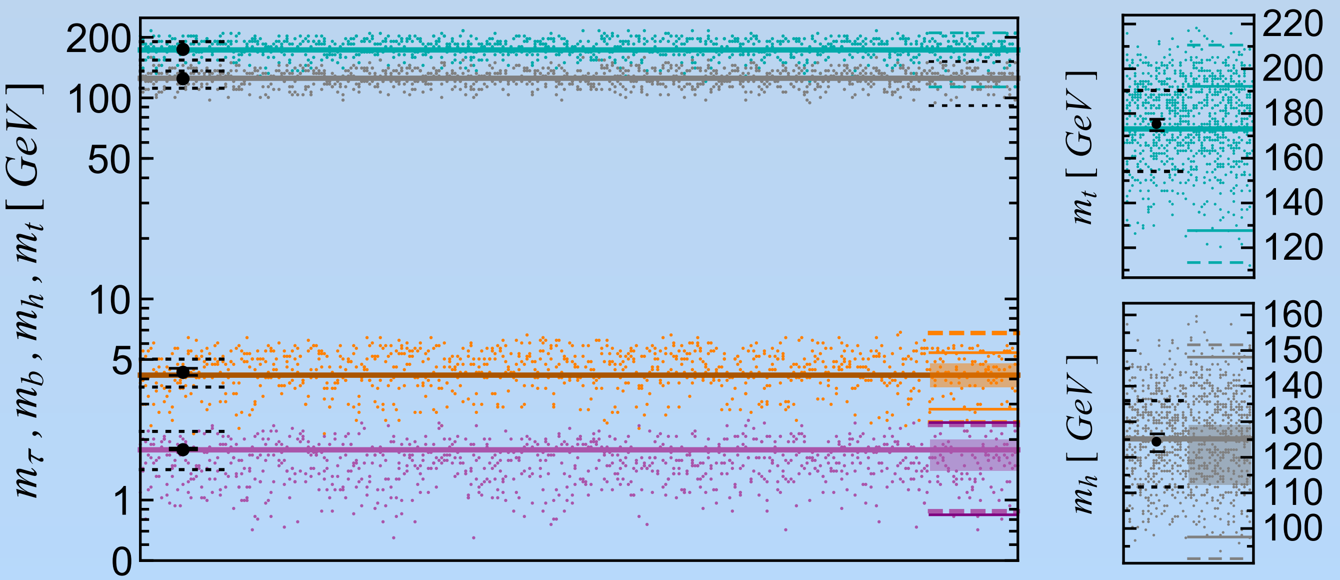




SM





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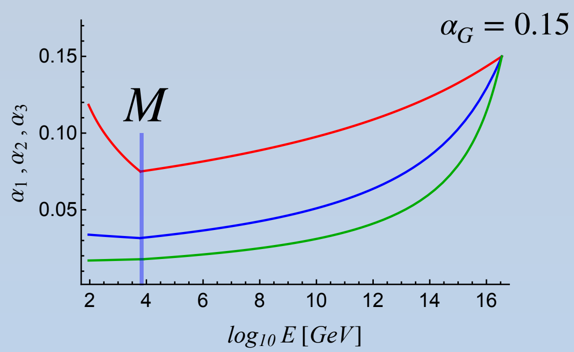

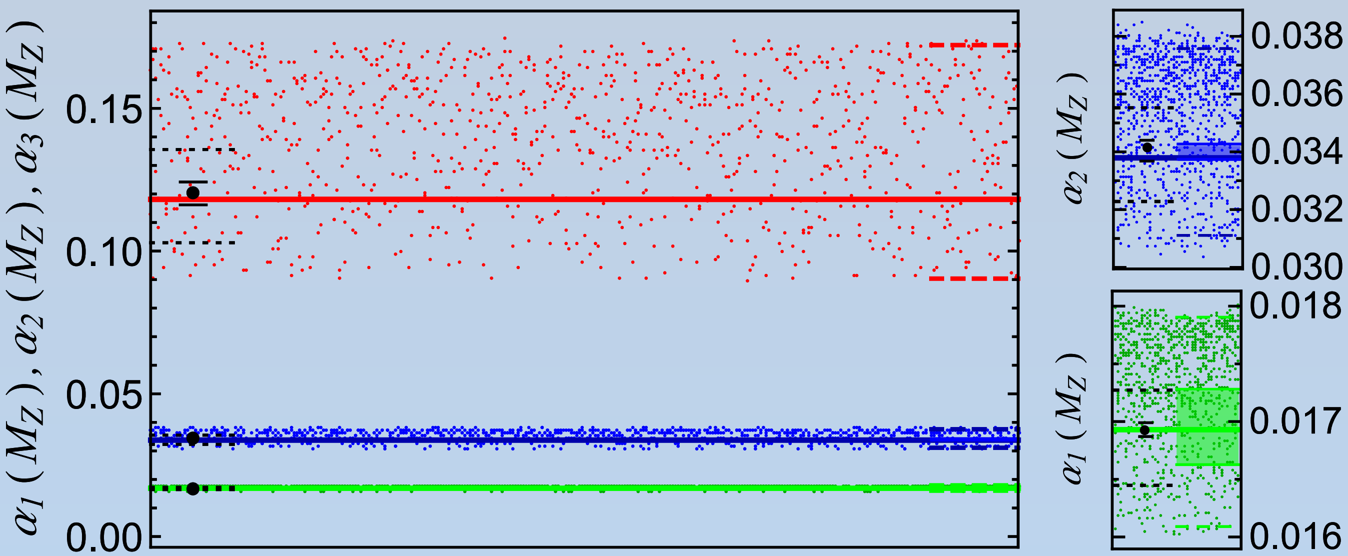

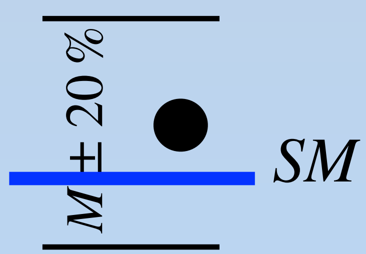

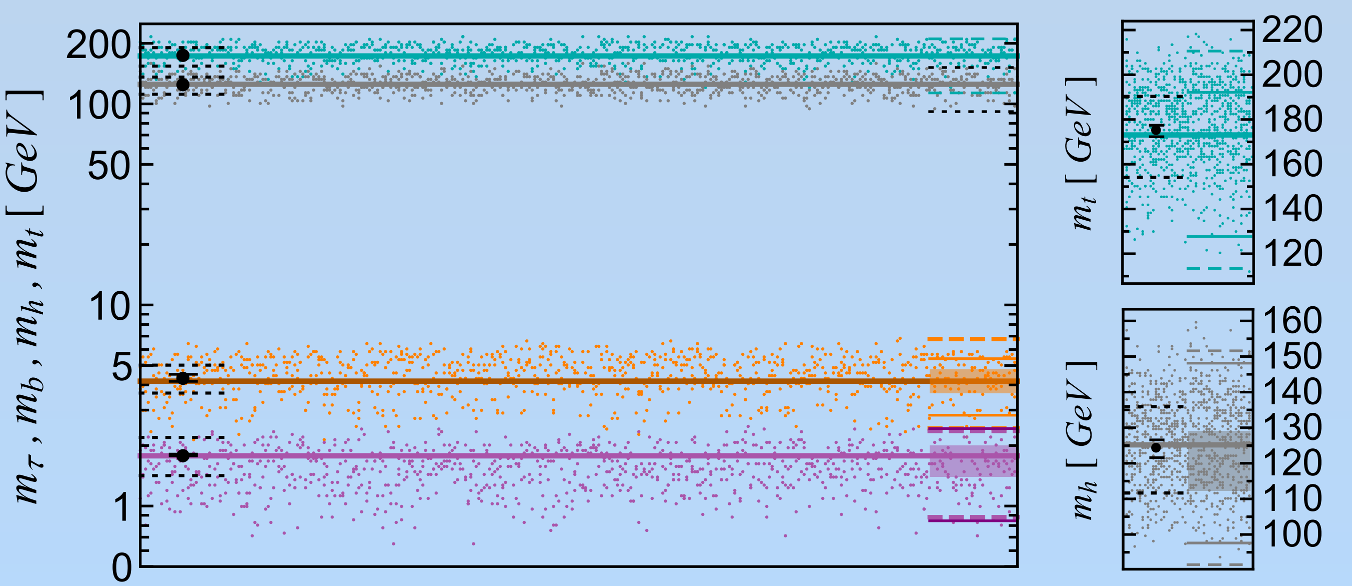

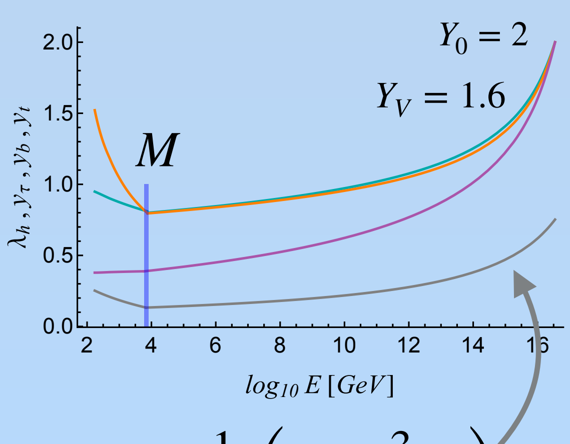

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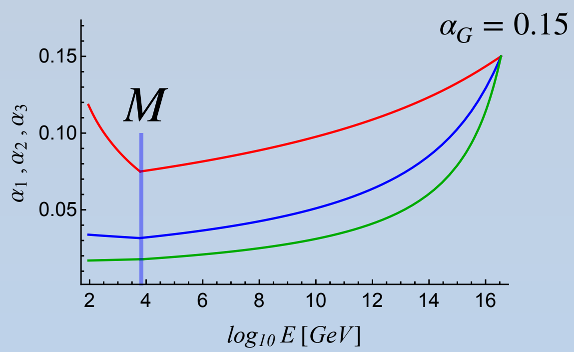

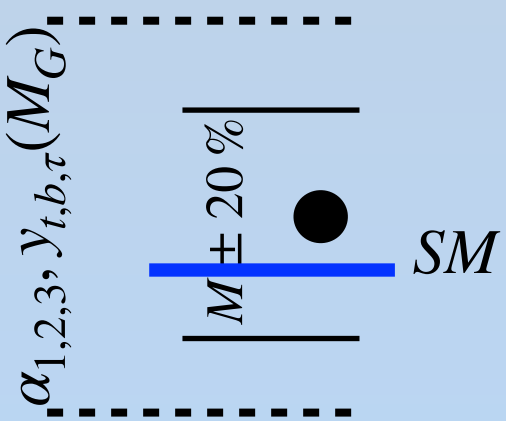

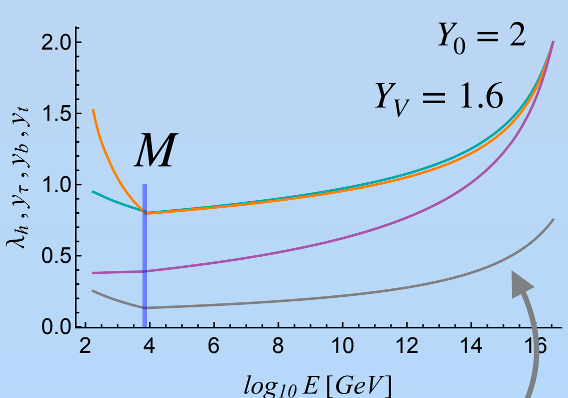

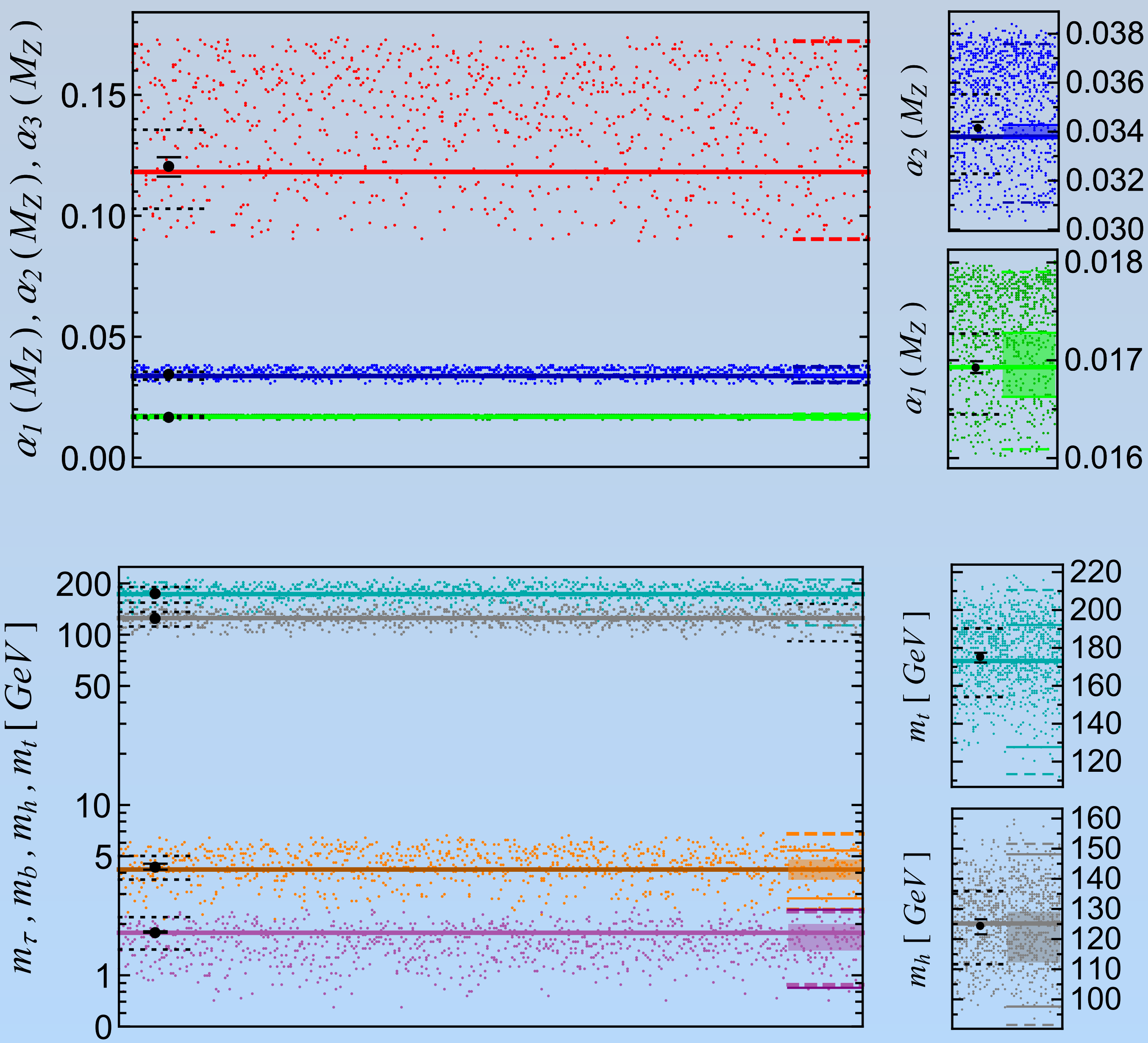

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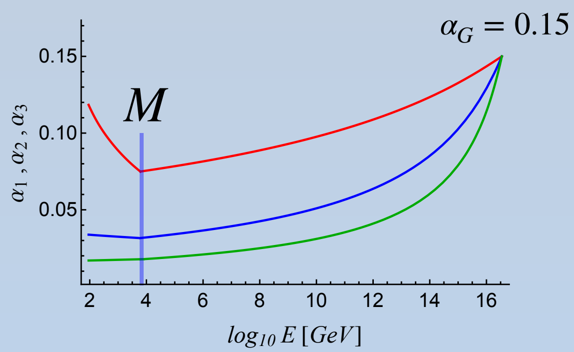

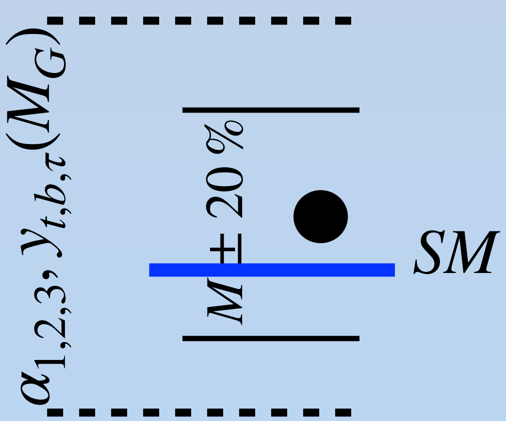

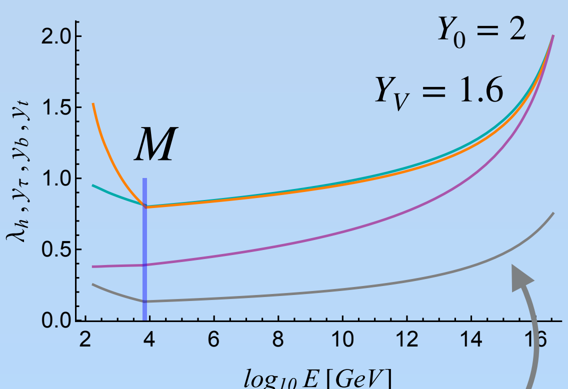

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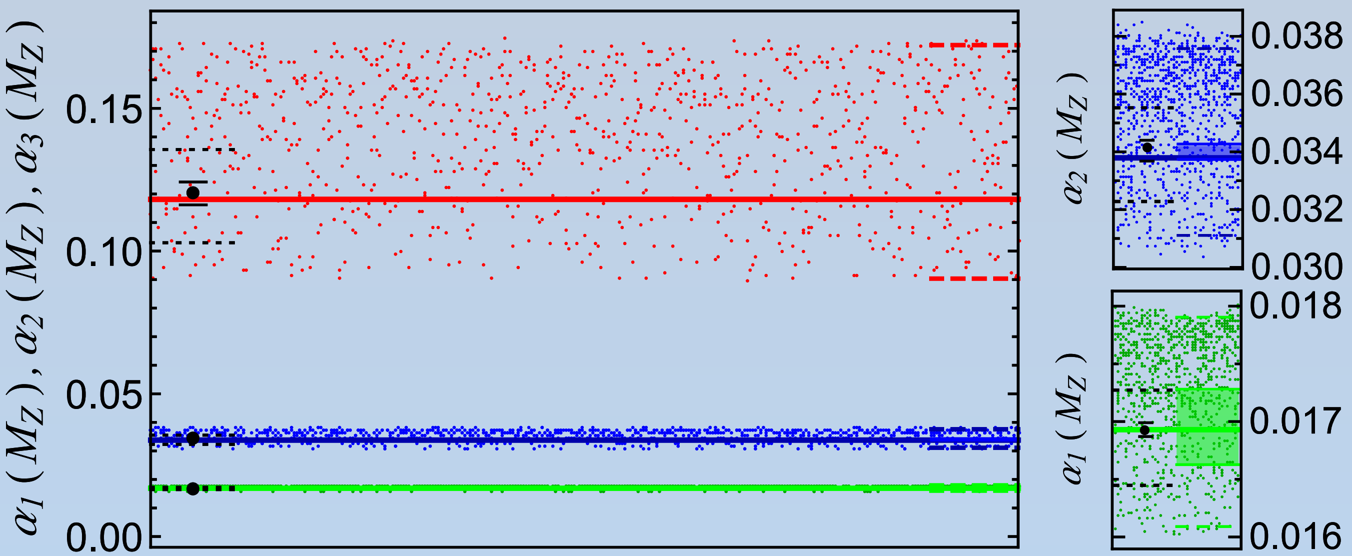

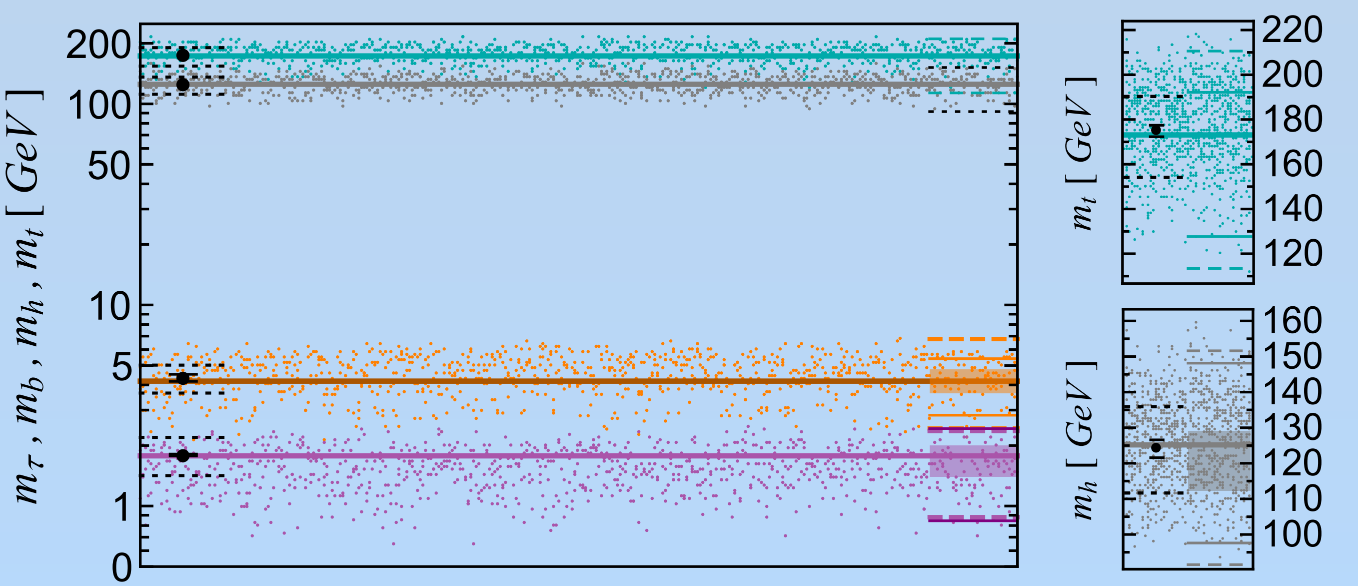

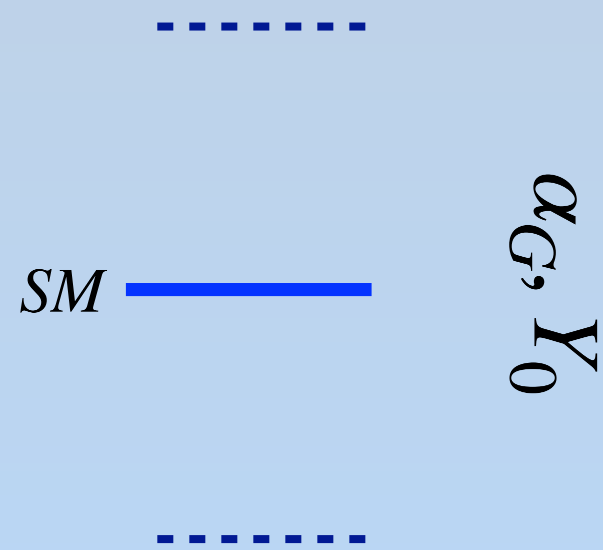

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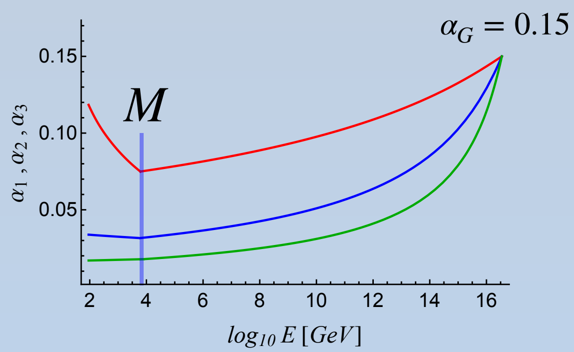

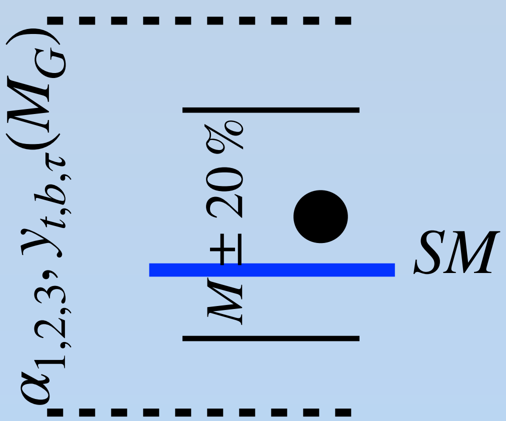

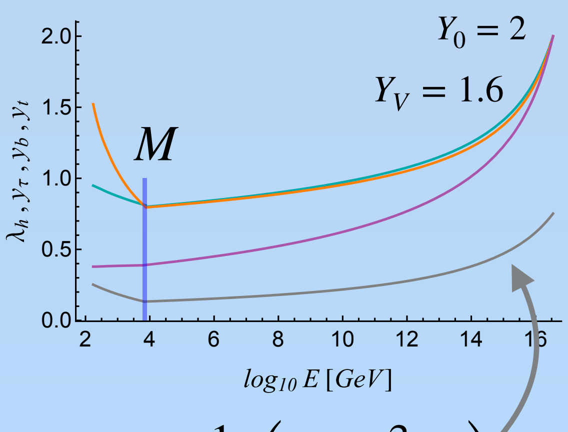

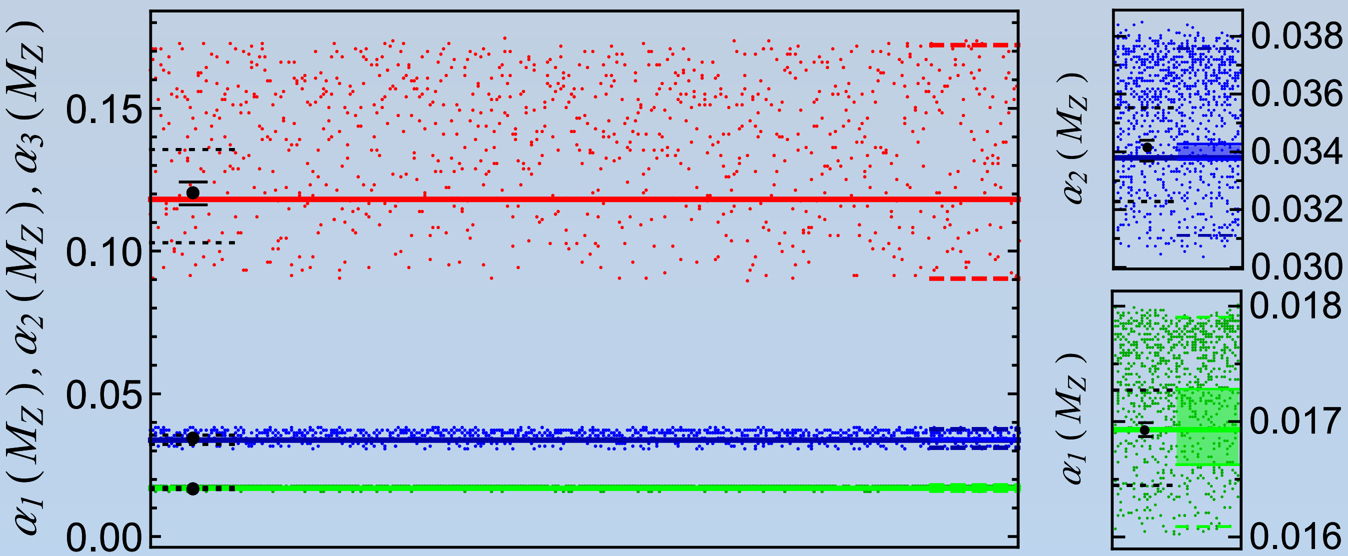

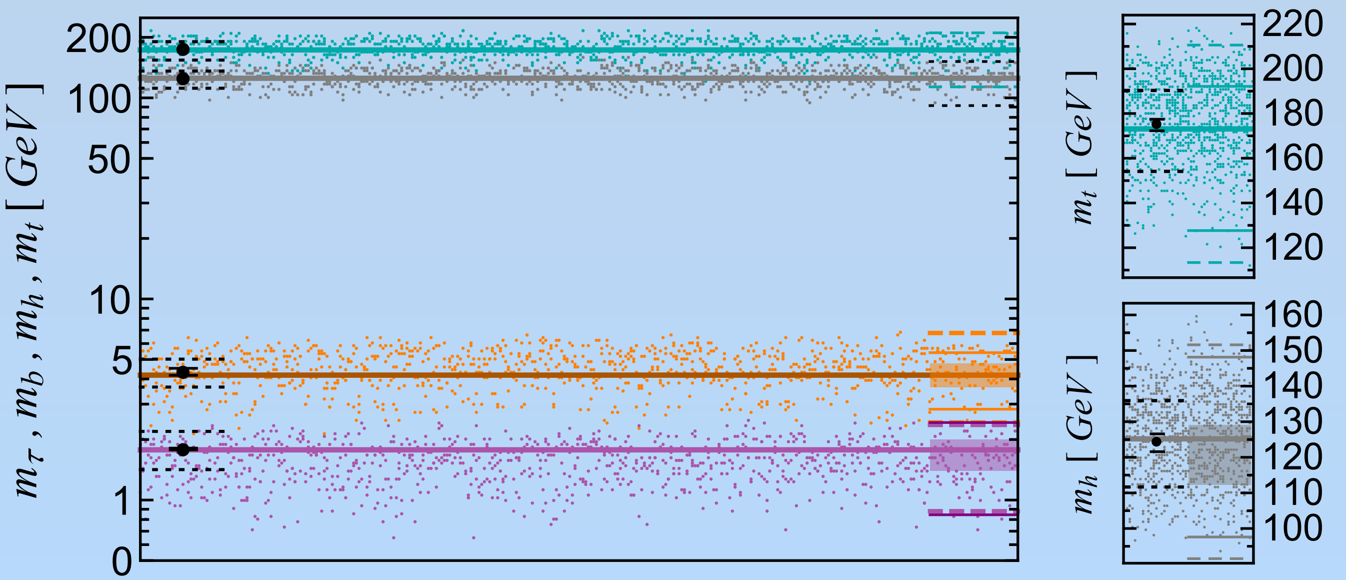

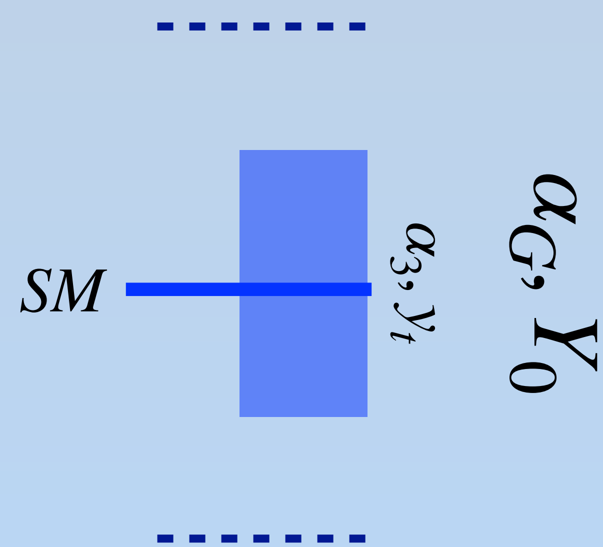

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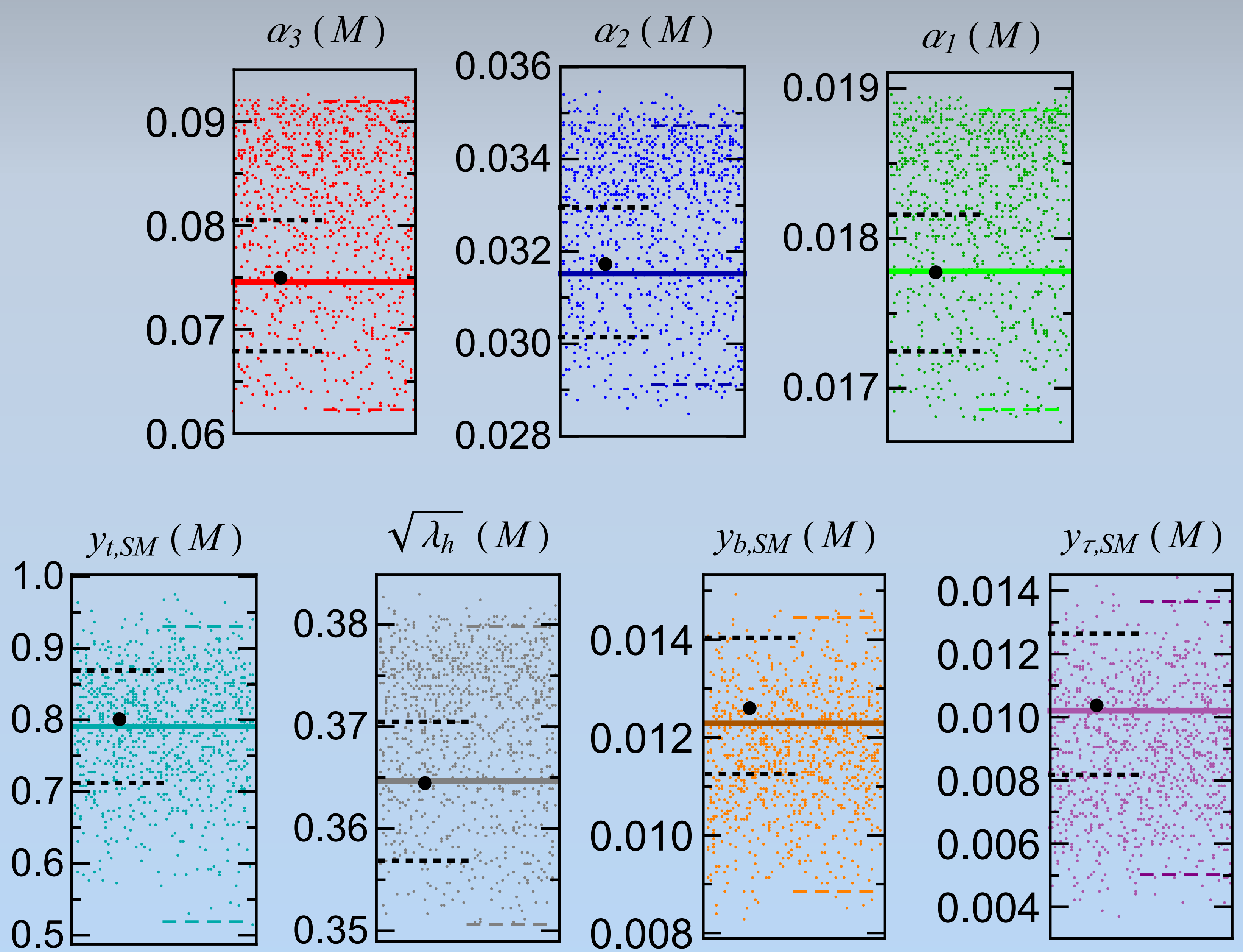
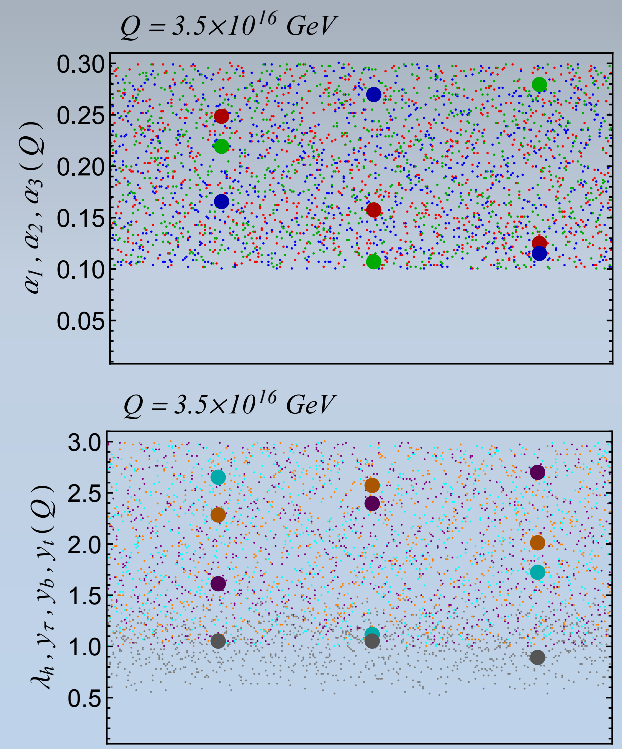
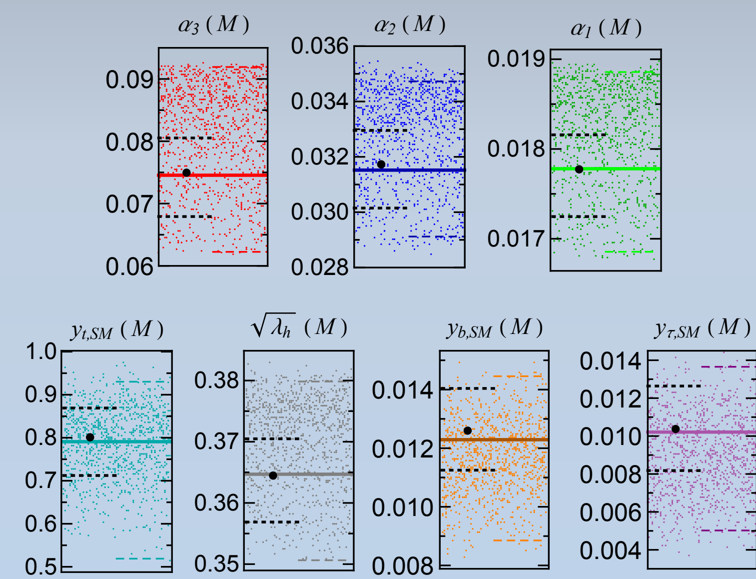
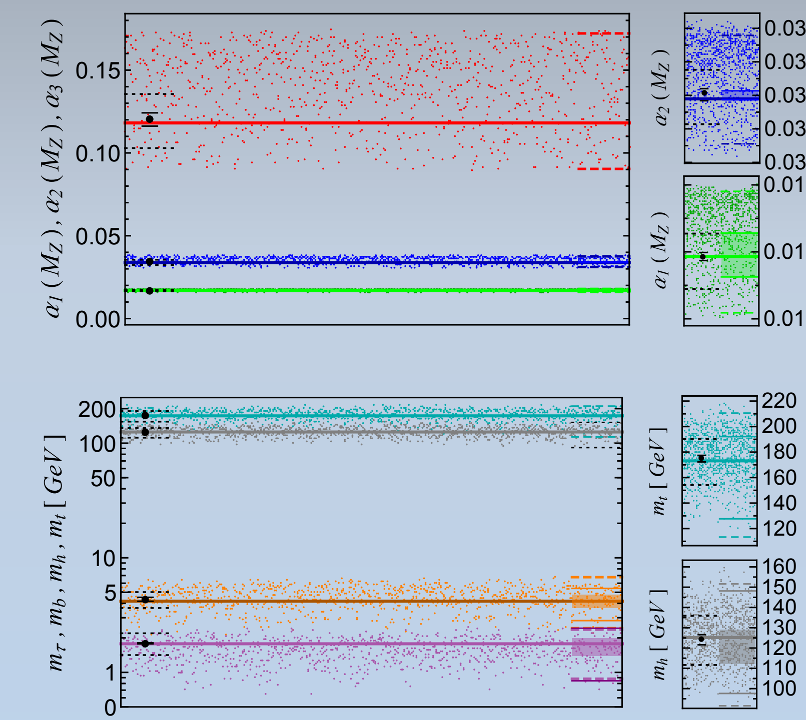
Predictions at M



- **Predictions for couplings are sharper at the fixed point**
- **Most of the spread in RG flow appears below M**







- Optimizing dimensionfull couplings, M_G, M, $\tan\beta$, no parameter more than:
  - 25% from measured value for completely random
  - 15% from measured value for GUT

- Further optimizing Y_V, all couplings within 11% (7.5%) for completely random (GUT)

Fin

- Extending the MSSM w/ 1VF offers a scenario where the dominant features of the SM can be understood from the scale of new physics
  - pattern of low energy couplings emerges from RG flow
  - Robust wrt details of parameters at M_G, GUT BC's look very similar as completely random
- Number of couplings, GUT embedding (flipped SU(5), Pati-Salam, etc), or whether couplings unify at all lead to very similar results
- Interesting models to explore, details of spectrum, corrections, etc. offer rich opportunities for phenomenology

Thanks!