Prediction for M_W in non-minimal SUSY

In collaboration with G. Weiglein [arxiv:1808:xxxxx]

Philip Diessner

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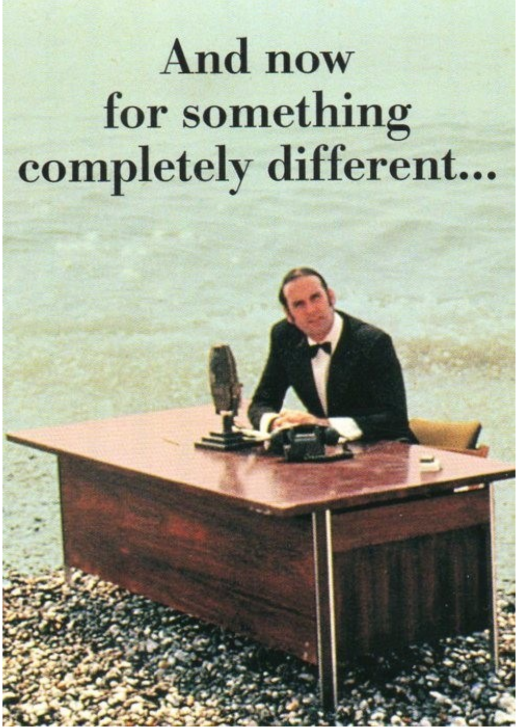
And now
for something
completely different...

Introduction

- No clear direct sign of BSM at LHC
- Use precision observables to separate SM from new physics
- M_W, $(g-2)_\mu$, M_h, flavour observables

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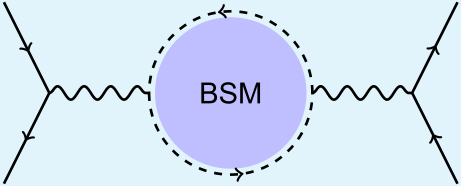
Loops matter



Requires precise theory prediction and experimental measurements

$$M_W^{\text{SM, on-shell}} = 80.360 \pm 0.008 \text{ GeV}$$
$$M_W^{\text{exp., LEP+Tevatron}} = 80.385 \pm 0.015 \text{ GeV}, \; M_W^{\text{ATLAS}} = 80.370 \pm 0.019 \text{ GeV}$$

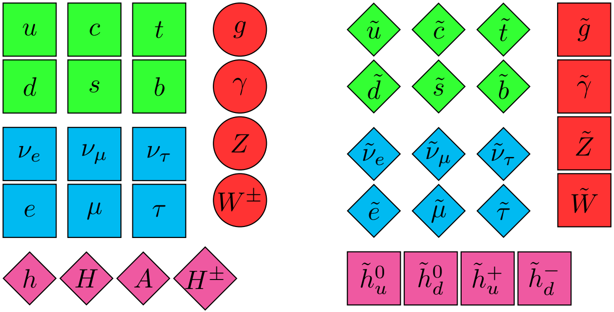
Outline

R-Symmetric SUSY

Prediction for M_W in the MRSSM

Results

Minimal Supersymmetry



Going beyond the MSSM

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- DM candidate
- Solves Hierarchy problem
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- LHC Run 2 on-going
- Look into non-minimal models for wide spectrum of alternative predictions

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Motivation

- LHC Run 2 on-going
- Look into non-minimal models for wide spectrum of alternative predictions
- Here: **R-Symmetry**
  - Includes solution to flavor problem of the MSSM
  - Dirac gauginos (esp. gluino) might explain SUSY non-discovery
  - Extended Higgs sector, different predictions than (N)MSSM

R-symmetry

- Additional symmetry allowed by SUSY algebra: $[Q_\alpha, R] = Q_\alpha \ , \quad [\overline{Q}_{\dot\alpha}, R] = -\overline{Q}_{\dot\alpha}$
- For $N = 1$ SUSY it is a global $U(1)_\mathrm{R}$ symmetry
  $\rightarrow$ Different charges for Superpartners
- SM fields have $Q_\mathrm{R} = 0$
- SUSY partners carry charge
- Lagrangian has to be invariant (MRSSM Kribs et.al. (Phys.Rev. D78 (2008) 055010))
- Forbids Majorana mass terms and A terms

Assume R-symmetry to be unbroken.

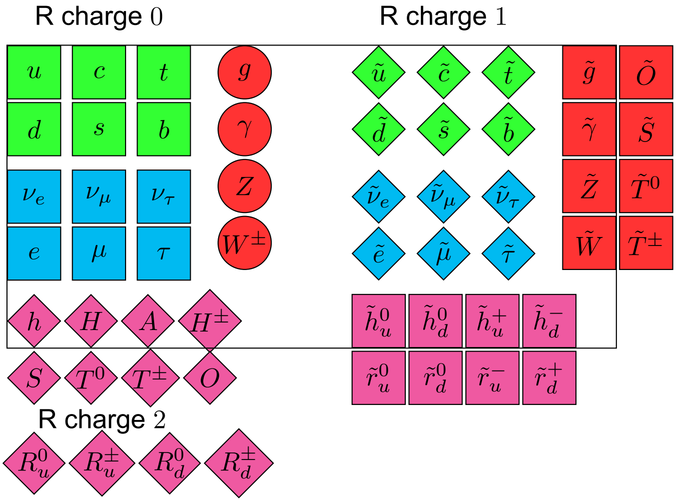
Particles of the MRSSM

Adding to the MSSM

		$SU(3)_C$	$SU(2)_L$	$U(1)_Y$	$U(1)_\mathrm{R}$
Singlet	$\hat{S}$	1	1	0	0
Triplet	$\hat{T}$	1	3	0	0
Octet	$\hat{O}$	8	1	0	0
R-Higgses	$\hat{R}_u$	1	2	$-1/2$	2
	$\hat{R}_d$	1	2	$1/2$	2

$$\mathcal{W} = -\,Y_d\,\overline{D}\,(QH_d)\;-Y_e\,\overline{E}\,(LH_d)\;+Y_u\,(\overline{U}\,QH_u)$$
$$+\,\Lambda_d\,(\hat{R}_d\hat{T})\,H_d\;+\Lambda_u\,(\hat{R}_u\hat{T})\,H_u\;+\lambda_d\,\hat{S}\,(\hat{R}_dH_d)\;+\lambda_u\,\hat{S}\,(\hat{R}_uH_u)$$
$$\mu_d\,(\hat{R}_dH_d)\;+\mu_u\,(\hat{R}_uH_u)\,.$$

Particles of the MRSSM



Muon decay

$$\frac{G_\mu}{\sqrt{2}} = \frac{e^2}{8M_W^2 s_W^2}(1+\Delta r)$$

Precisely known: α, M_Z, G_μ, can solve for M_W

$$M_W^2 = M_Z^2\left(\frac{1}{2}+\sqrt{\frac{1}{4}-\frac{\alpha\pi}{\sqrt{2}G_\mu M_Z^2}(1+\Delta r)}\right)$$

(assuming no triplet vev for now)

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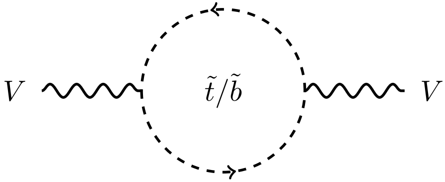
One-loop Δr in the SM

$$\Delta r = \Delta\alpha(\propto \log\frac{M_Z}{m_f}, \approx 6\%) - \frac{c_W^2}{s_W^2}\Delta\rho(\propto M_t^2, \approx -3\%) + \Delta r_{\text{rem}}(\propto \frac{M_h}{M_Z}, \approx 1\%)$$

BSM contributions to Δr

$\Delta\rho$

- Quantifies difference between charged and neutral current interactions
- $\Delta\rho = \frac{\Sigma_T^{ZZ}(0)}{M_Z^2} - \frac{\Sigma_T^{WW}(0)}{M_W^2}$ (same as T parameter)
- In MSSM mainly stop/sbottom (Driven by top-Yukawa)



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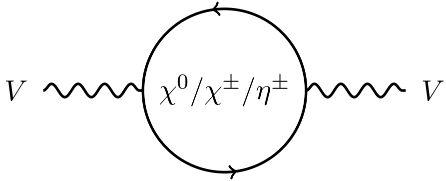
- In MRSSM additional effects from λ/Λ via charginos/neutralinos
- Generally, $\Delta\rho_{\text{MRSSM}} > 0$ and $\delta M_W^2 = M_W^2 \frac{c_W^2}{c_W^2 - s_W^2} \Delta\rho > 0$



Effects of a triplet vev

- Triplet with zero hyper-charge leads to tree-level contribution: $M_W^2 = \frac{g_2^2}{4}v^2 + g_2^2 v_T^2$
- Disturbs on-shell relation breaking custodial symmetry

$$\hat{c}_W^2 \equiv \cos^2(\hat{\theta}_W) = \frac{g_2^2}{g_1^2 + g_2^2}\,, \qquad \frac{m_W^2}{m_Z^2} = \hat{c}_W^2 + \frac{e^2 v_T^2}{(1-\hat{c}_W^2)m_Z^2}.$$

- v_T depends on SUSY parameters via EWSB conditions
- Calculation of M_W from G_μ, α, M_Z, v_T

$$M_W^2 = M_Z^2\left(\frac{1}{2} + \sqrt{\frac{1}{4} - \frac{\alpha\pi}{\sqrt{2}G_\mu M_Z^2}(1 + \Delta\hat{r} - 4\sqrt{2}G_\mu v_T^2)}\right)\cdot\left(\frac{1}{1 - \frac{4\sqrt{2}G_\mu v_T^2}{1+\Delta\hat{r}}}\right).$$

- Needs to be renormalized

Precision with more than one loop

SM prediction for M_W

- full one-loop
- full two-loop
- leading three- and four-loop contributions to $\Delta\rho$

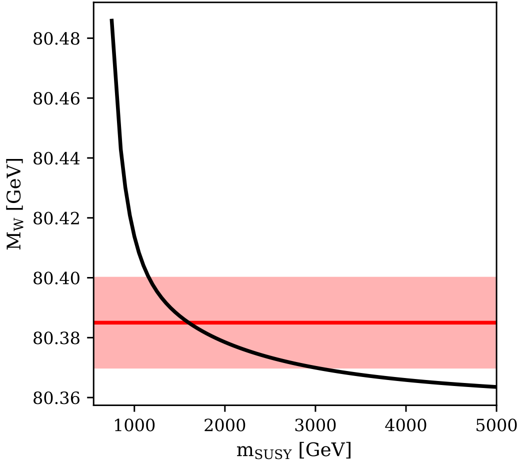
MRSSM prediction for M_W

- all known SM contributions
- full MRSSM one-loop contributions
- Available MSSM two-loop results not applicable because Dirac nature of gluino

Precision

- intrinsic theory uncertainty: SM 4-6 MeV, MRSSM 9-12 MeV
- parametric uncertainty: from δM_t 6 MeV, $\delta\Delta\alpha_{\text{had}}$, δM_Z each 2.5 MeV
- experimental uncertainty: with LEP and Tevatron 15 MeV, +LHC 10 MeV
- ILC would reduce experimental and parametric unc.

General result



- SUSY effects decouple
- M_W prediction generally larger than in MSSM for similar scale
- Caused by enlarged matter sector and new couplings

$M_W^{\text{SM}} = 80.360$ GeV

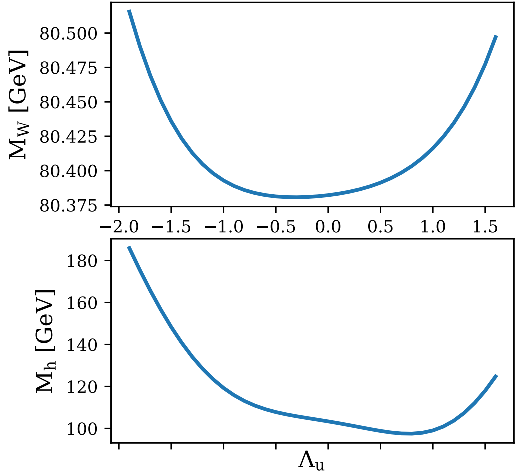
Influence of new parameters

Λ is Yukawa-like coupling

$$\mathcal{W} \supset \Lambda_d\,(\hat{R}_d \hat{T})\,H_d + \Lambda_u\,(\hat{R}_u \hat{T})\,H_u$$

contributes similarly to ρ

$$\Delta\rho_\Lambda = \frac{1}{16\pi M_W^2 \hat{s}_W^2}\frac{13\left(\Lambda_u^2 v_u^2 - \Lambda_d^2 v_d^2\right)^2}{96 M_{\text{wino}}^2}.$$



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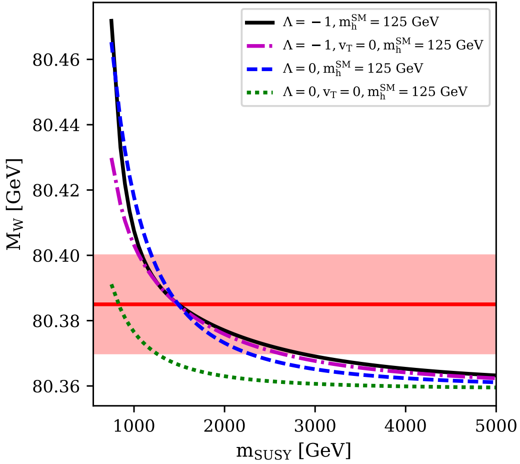
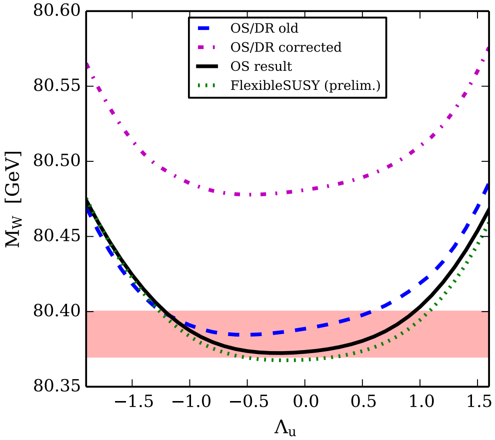
Triplet vev related via EWSB conditions

$$v_T = \frac{(\Lambda_u \mu_u + g_2 M_{\text{wino}}) v_u^2 - (\Lambda_d \mu_d + g_2 M_{\text{wino}})}{2\left(m_{\text{Triplet}}^2 + 4 M_{\text{wino}}^2\right)}$$



Comparison to other calculations



- Previous results in MRSSM from `SARAH/SPheno`
- Bug found adding 100 MeV to M_W
- Interestingly, OS result in line with old one
- Investigation underway
- fixed `FlexibleSUSY` OS/DR in development
  (points kindly provided by M. Bach)

Conclusions

- MRSSM as example of non-minimal SUSY accessible by LHC
- Relevant to also study precision observables
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Thanks for the attention!