Impact of LHC search results on the W mass prediction in SUSY models

Lisa Zeune

Cargese Summer School

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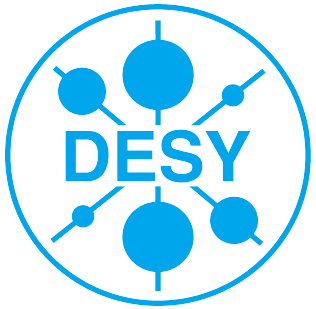


W-boson mass

- How to find new physics?
  - Direct search for new particles
  - Search for virtual effects of new particles
- Electroweak precision observables

$$M_W, \Gamma_Z, \sin\Theta_W^{\text{eff}} \ldots$$

- Highly sensitive to quantum effects of 'New physics'
- New experimental value from Tevatron

$$M_W^{\text{exp}} = 80.385 \pm 0.015 \text{ GeV}$$

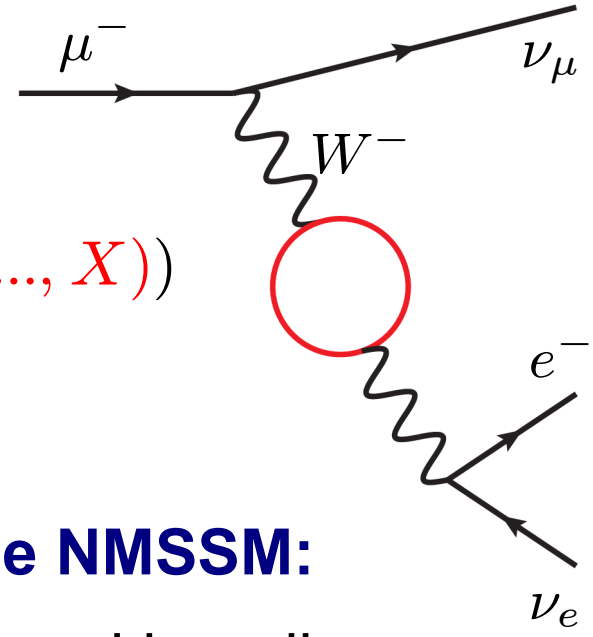
Tevatron Electroweak Working Group, April '12

- Precise theoretical calculation for the W-boson mass needed
  - Test models
  - Constrain model parameters

Determination of the W-boson mass

- Comparison of muon decay in SM and Fermi model gives:

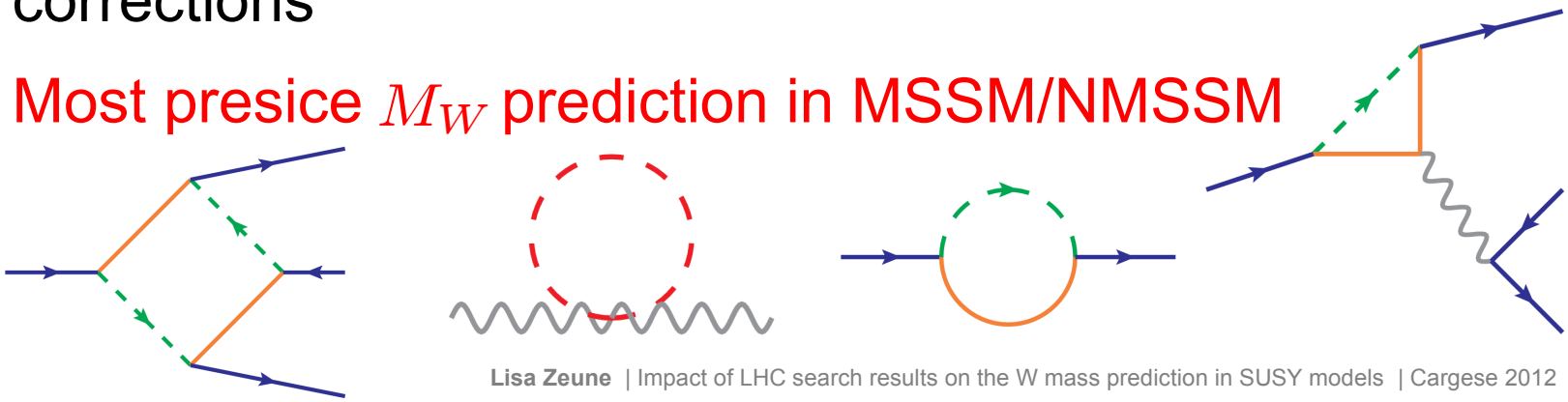
$$\frac{G_F}{\sqrt{2}} = \frac{e^2}{8 s_W^2 M_W^2} \left(1 + \Delta r(M_W, M_Z, m_t, ..., X)\right)$$



- X model dependent!

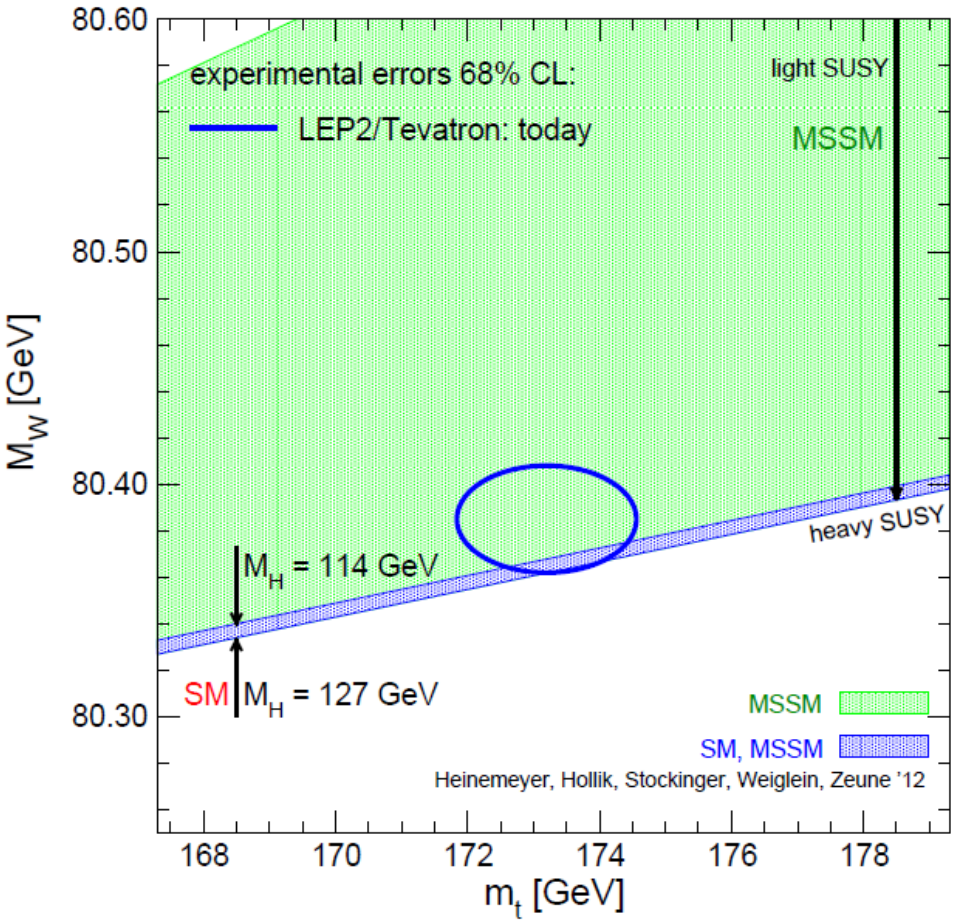
Δr – Calculation in the MSSM and the NMSSM:

- Calculation of >100 self-energy, vertex and box diagrams
- Incorporation of all known SM and SUSY higher order corrections
- Most presice M_W prediction in MSSM/NMSSM



W-boson mass prediction in the MSSM

- Scan over the MSSM parameter space
- Allowed range for SM-like Higgs: 114 - 127 GeV



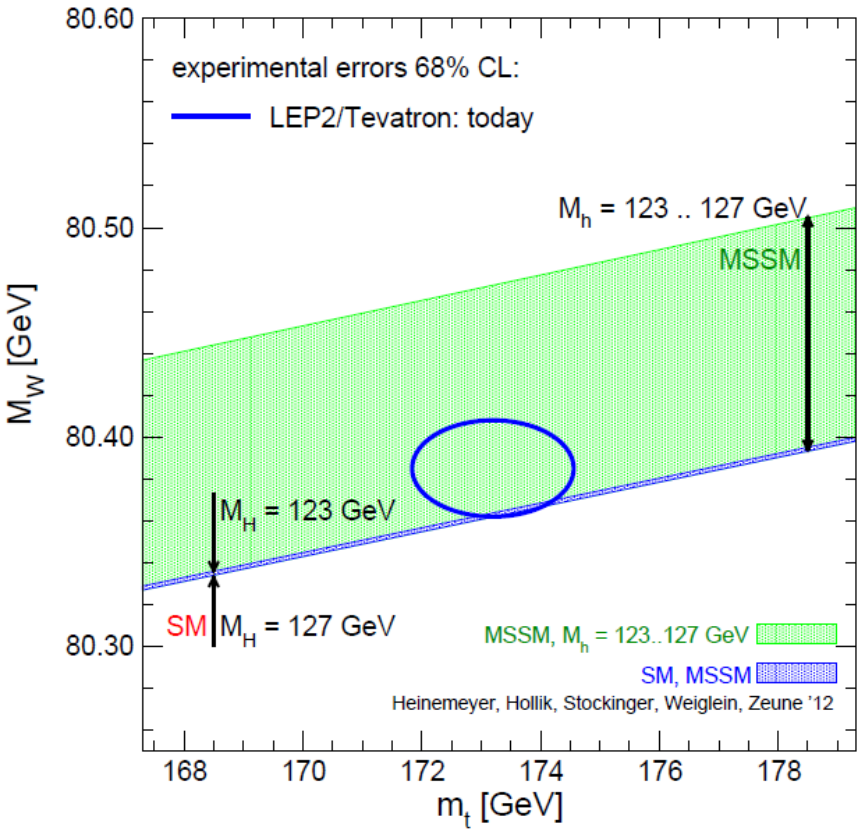
Green: MSSM
Blue: MSSM and SM

- Large SUSY contributions possible
- Main SUSY contributions from:
  - Stops and sbottoms
- Experimental data favors non-zero SUSY contribution

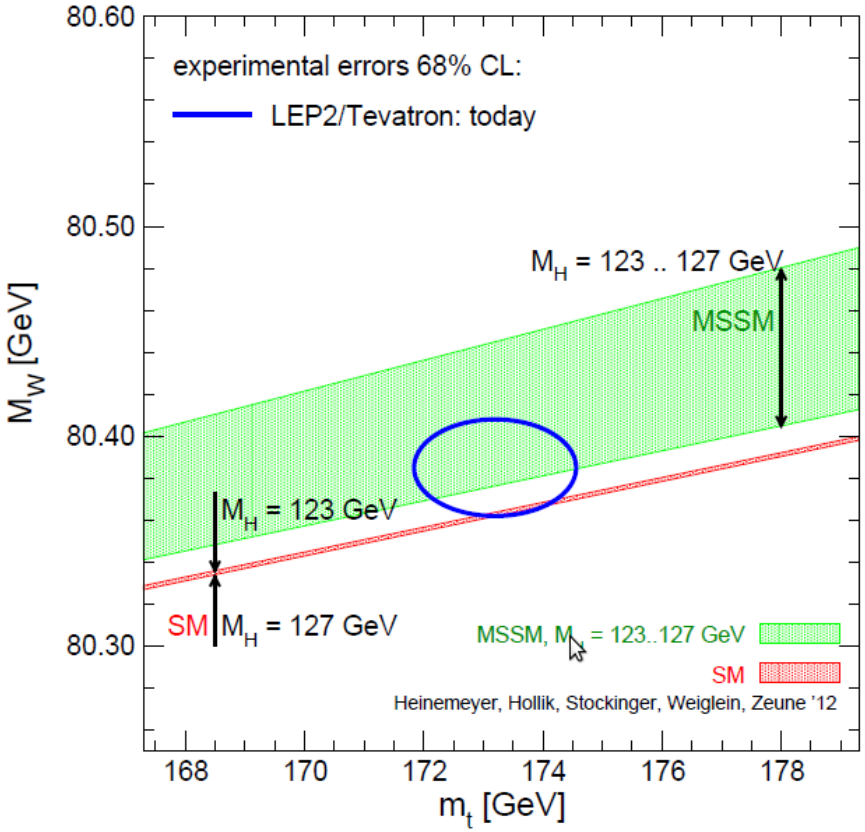
Impact of a Higgs at 125 GeV

- LHC discovered Higgs at 125 GeV

  → Strong impact on M_W prediction



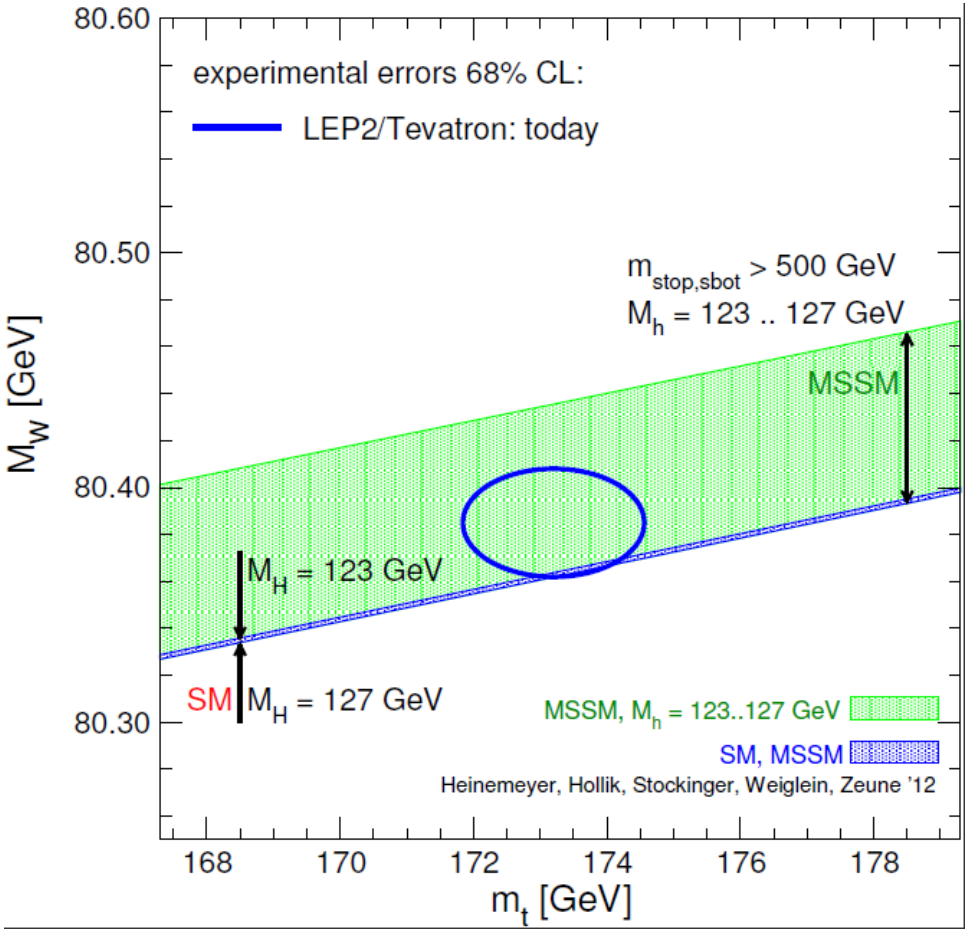
Assuming light CP-even MSSM Higgs at 125 GeV



Assuming heavy CP-even MSSM Higgs at 125 GeV

Impact of squark mass limits

- LHC limit on 1st and 2nd generation squarks: $m_{\tilde{q}} \gtrsim 1000\ \mathrm{GeV}$
- First LHC limits on stops and sbottoms

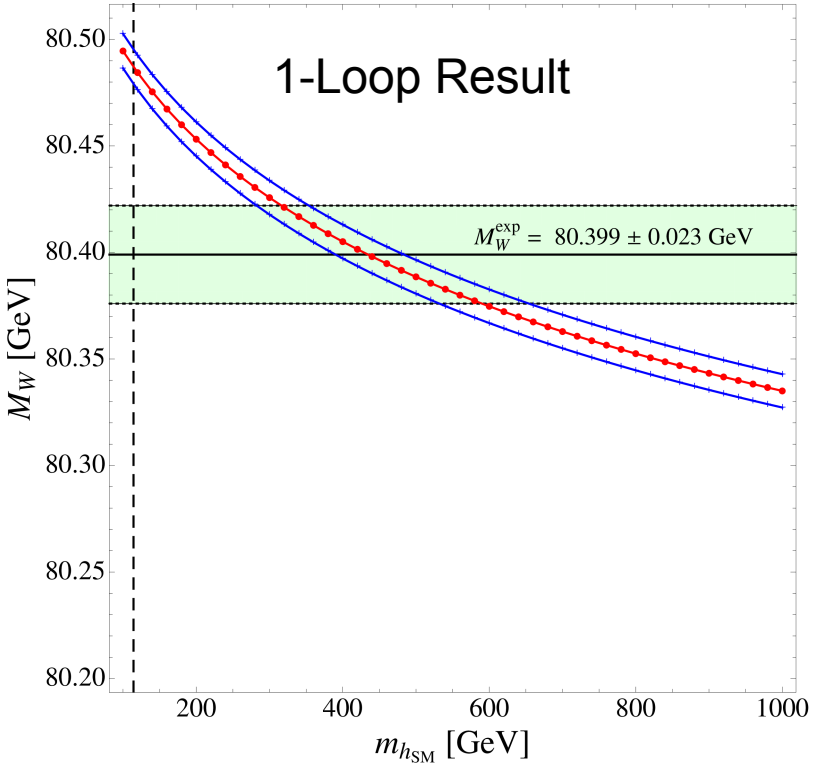


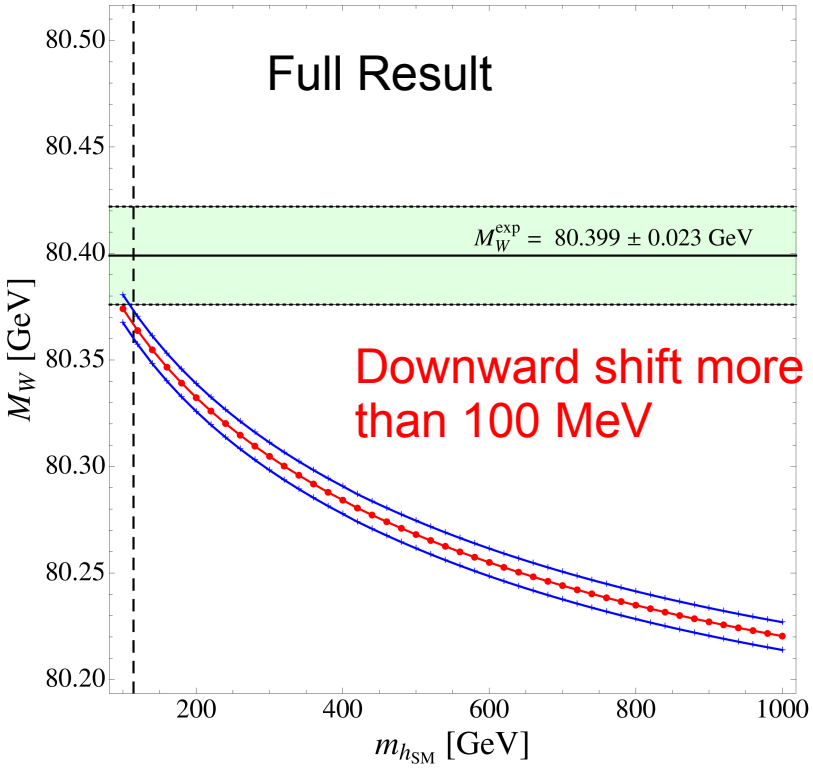
- Assume
  $m_{\tilde{t},\tilde{b}} > 500\ \mathrm{GeV}$
- Main SUSY contributions from:
  - Sleptons
  - Charginos and neutralinos
- MSSM W-boson mass prediction in good agreement with experimental value

Backup

MW in the SM

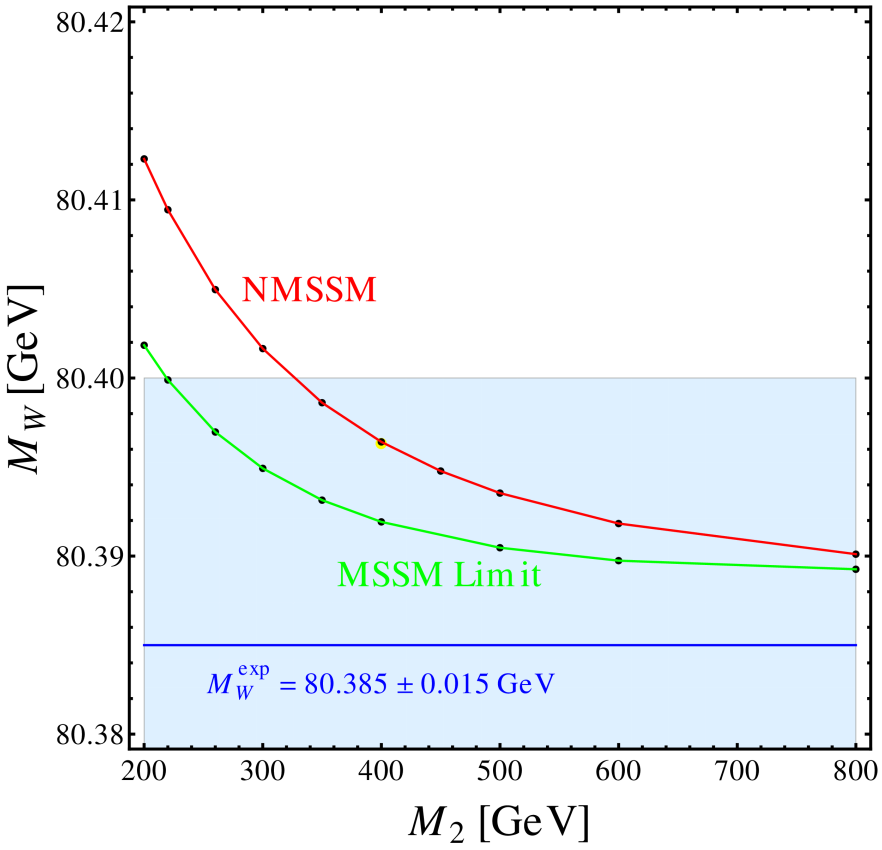
$$\Delta r^{SM} = \Delta r^{(\alpha)} + \Delta r^{(\alpha\alpha_s)} + \Delta r^{(\alpha\alpha_s^2)} + \Delta r^{(\alpha^2)}_{ferm} + \Delta r^{(\alpha^2)}_{bos} + \Delta r^{(G_\mu^2\alpha_s m_t^4)} + \Delta r^{(G_\mu^3 m_t^6)} + \Delta r^{(G_\mu m_t^2 \alpha_s^3)}$$





NMSSM contribution

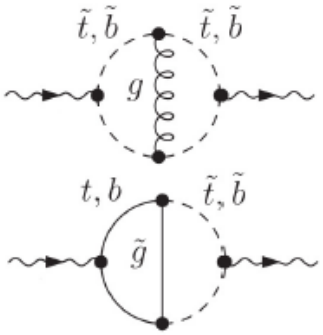
- Comparison to MSSM limit
- Higgs sector:
  - Light Higgs could give large contributions
  - But strongly constrained by Higgs searches
  - In allowed region Higgs contributions only few MeV
- Neutralino sector:
  - Contributions can be sizable



SUSY higher order corrections

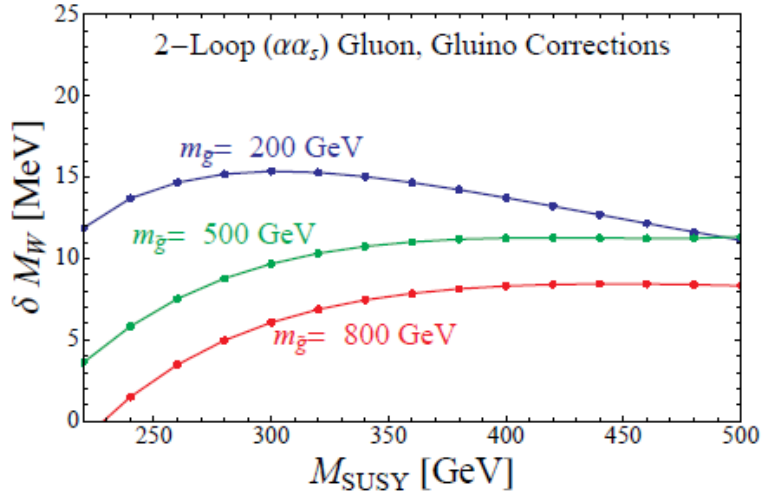
Supersymmetric two-loop contributions

- Irreducible supersymmetric two-loop contributions
  - SUSY QCD corrections of $\mathcal{O}(\alpha\alpha_s)$:
    (S)quark loops with gluon and gluino exchange [Djouadi et. al '98]
  - Two-loop Yukawa contributions $\mathcal{O}(\alpha_t^2), \mathcal{O}(\alpha_t\alpha_b), \mathcal{O}(\alpha_b^2)$:
    (S)quark loops with Higgs and Higgsino exchange
    [Haestier, Heinemeyer, Stoeckinger, Weiglein '05]



- Leading reducible two-loop corrections [Consoli, Hollik, Jegenlehner '89]
- Complete Δr^{MSSM} agrees with previous result [Heinemeyer, Hollik,Stöckiger, Weber, Weiglein '06]

Sfermion sector



- $\mathcal{O}(\alpha\alpha_s)$ contributions up to 15 MeV
  ($\gtrsim$ exp. accuracy at LHC and ILC)
- Can enter with both signs
- Important for a precise M_W prediction!