Radiative mass splittings

Pitfalls of an iterative pole mass calculation

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based on arXiv:1710.01511 – J. McKay, P. Scott, P. Athron

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Electroweak multiplet dark matter

Electroweak multiplets appear in several places

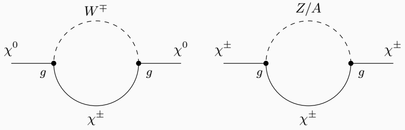
- The wino limit of the MSSM (effectively SM + triplet), $M \sim 3$ TeV
- Minimal dark matter
  - SM + fermionic $SU(2)_L$ quintuplet, $M \sim 9$ TeV
- Vector dark matter, an $SU(2)_L$ vector multiplet, $M \sim$ TeV

Electroweak mass splittings

Extend the SM by an electroweak multiplet, $\chi = (\chi^-, \chi^0, \chi^+)$

$$\mathcal{L} = \mathcal{L}_{\mathsf{SM}} + \frac{1}{2}\overline{\chi}\,(i\not{D} - \hat{M})\,\chi$$

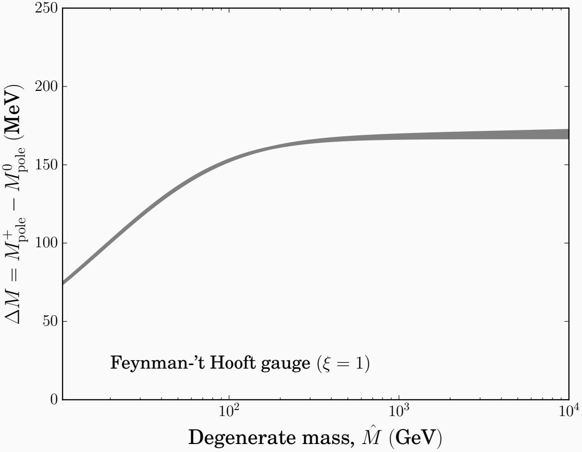
- Degenerate mass parameter – $\hat{M} \sim \mathcal{O}(\mathrm{TeV})$
- Simple one-loop radiative corrections



- results a slightly heavier χ^+

The electroweak multiplet self energy

- The resultant difference has a finite limit



- Essential to be $\neq 0$, exact value important for collider constraints

A potential pitfall

- Set up your multiplet model in a spectrum generator
- In FlexibleSUSY you can choose pole mass calculated with:
  - *High precision*
  - *Medium precision*
  - *Low precision*
- For your study, only "*High precision*" will do!
- You pass the spectrum onto other routines and assume your getting the best result

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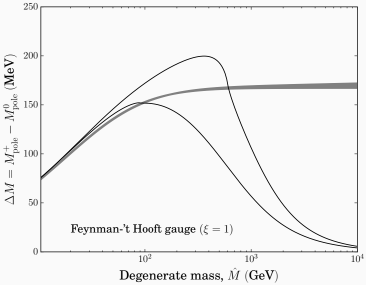


High precision?!

- The *pole mass* is the pole of the two point propagator, $\not{p}$ such that

$$\not{p} - \hat{M} + \Sigma_K(p^2)\not{p} + \Sigma_M(p^2) = 0$$

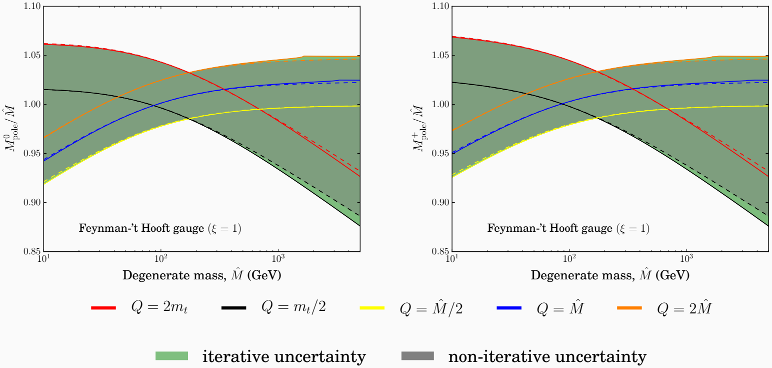
- High precision *The iterative pole mass*

$$M_{\mathrm{pole}} = \hat{M} - \Sigma_M(M^2_{\mathrm{pole}}) - M_{\mathrm{pole}}\Sigma_K(M^2_{\mathrm{pole}})$$

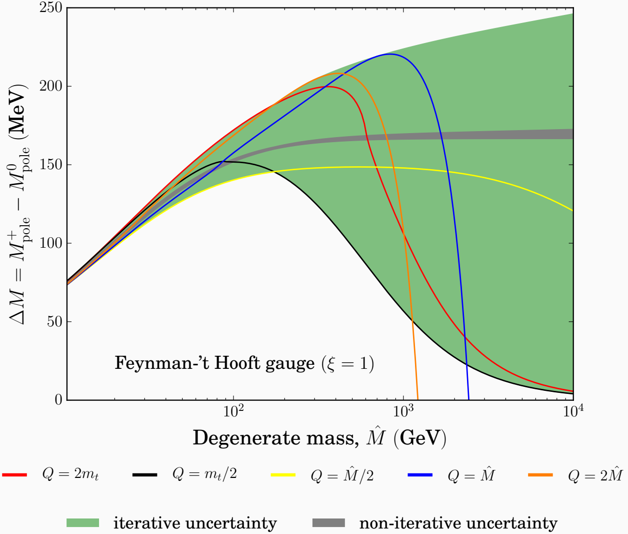
- Low precision *The explicit pole mass*

$$M_{\mathrm{pole}} = \hat{M} - \Sigma^{(1)}_M(\hat{M}^2) - \hat{M}\,\Sigma^{(1)}_K(\hat{M}^2) + \mathcal{O}\left(\alpha^2\right)$$

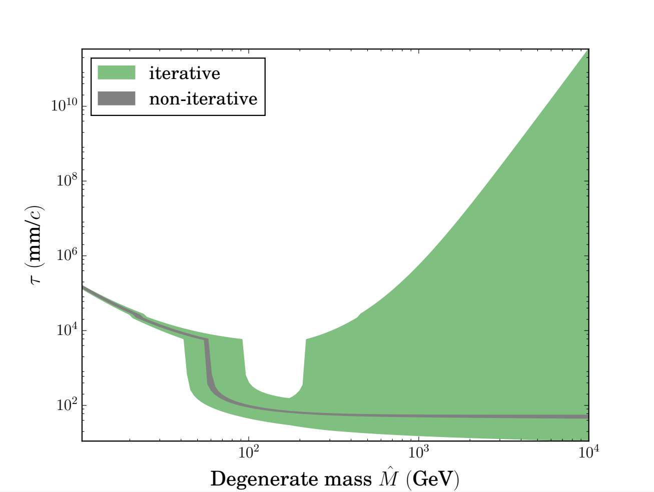
The one-loop pole masses



The iterative uncertainty



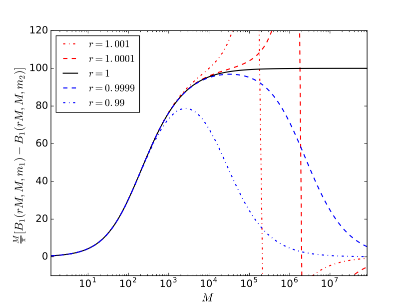
Does this even matter?



So what is going on?

- Pole masses have scale dependent logarithms of the form $\log(m/Q)$
- These result in erroneously large corrections to M_{pole} when there is a large hierarchy of scales

  $\to r = M_{\text{pole}}/\hat{M} \neq 1$



One-loop self-energy functions are extremely sensitive to r for

$$\Delta M \sim \frac{M}{\pi}\left[B_0(rM, M, m_1) - B_0(rM, M, m_2)\right]$$

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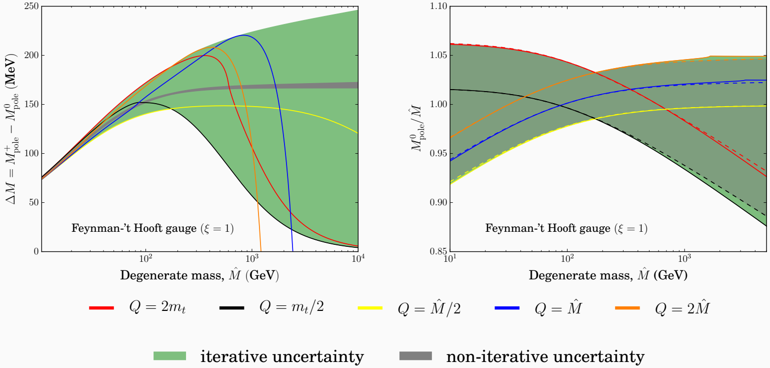
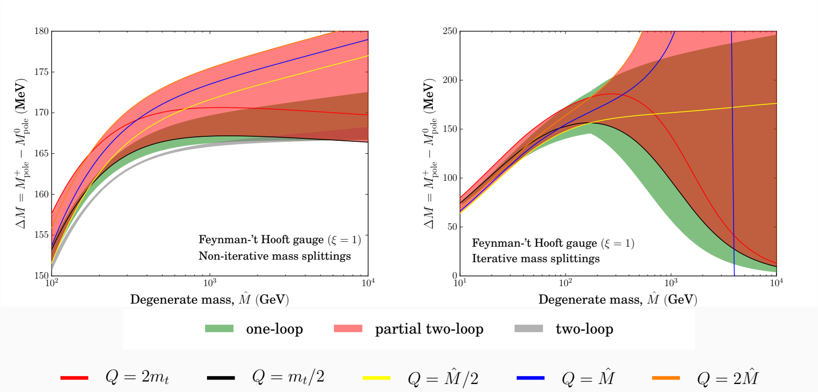


Considering higher-order corrections



So do we need to consider this uncertainty?

No – but only after this thorough investigation are we confident that this uncertainty comes from unphysical scale dependent terms.

This is reaffirmed by the fact that a finite mass splitting is predicated classically by the a simple coulomb energy argument.

Summary

- Don't compute mass splitting using an iterative pole mass!
- check out arXiv:1710.01511 for more details
- Look out for upcoming two-loop mass splitting results
- New tool will eventually be available for automating the final step in the chain of two-loop self-energy calculations