GDR Terascale
Lyon 2011

Effective couplings for Relic Density in Susy

Guillaume Drieu La Rochelle
LAPTh, Annecy

Dark Matter & Constraints on Beyond Standard Model

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- SUSY framework

$\sigma_{\tilde{\chi}\tilde{\chi} \mapsto SM}$ at the few percent level $\longrightarrow$ one-loop level

Dark Matter & Constraints on Beyond Standard Model

- Comple
  - EWSB
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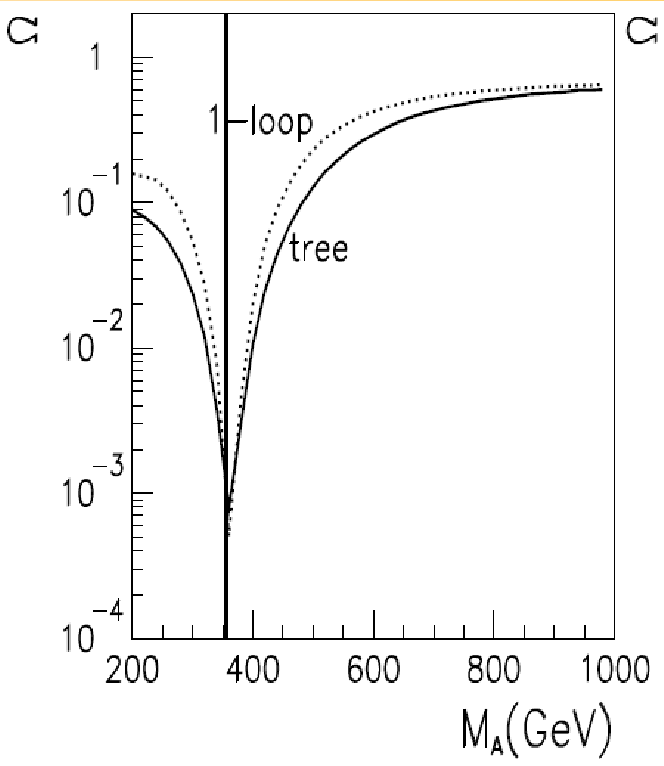
Playing with WMAP exclusions : the one-loop gap



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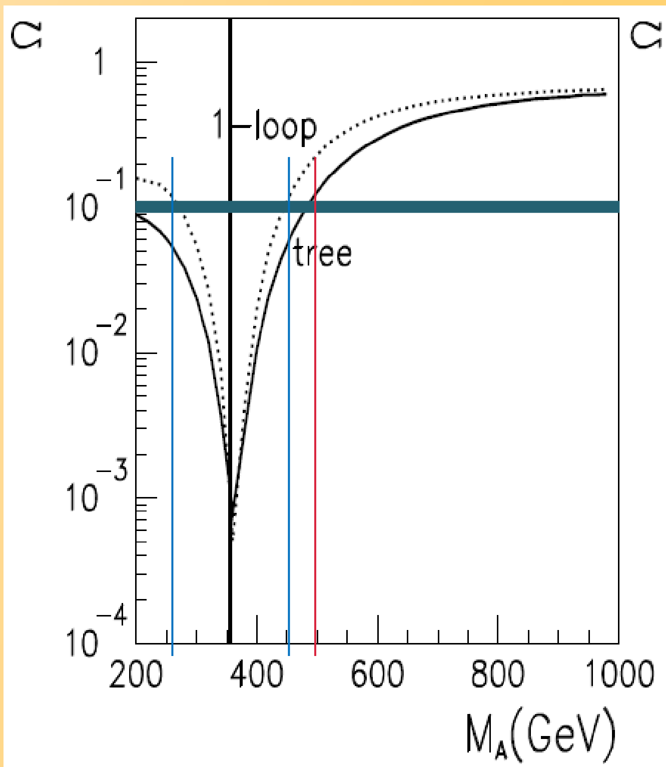

Points allowed :

One-Loop

- 260 & 450 GeV

Tree-level

- 500 GeV

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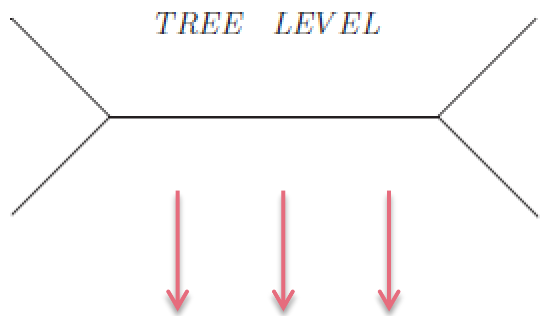

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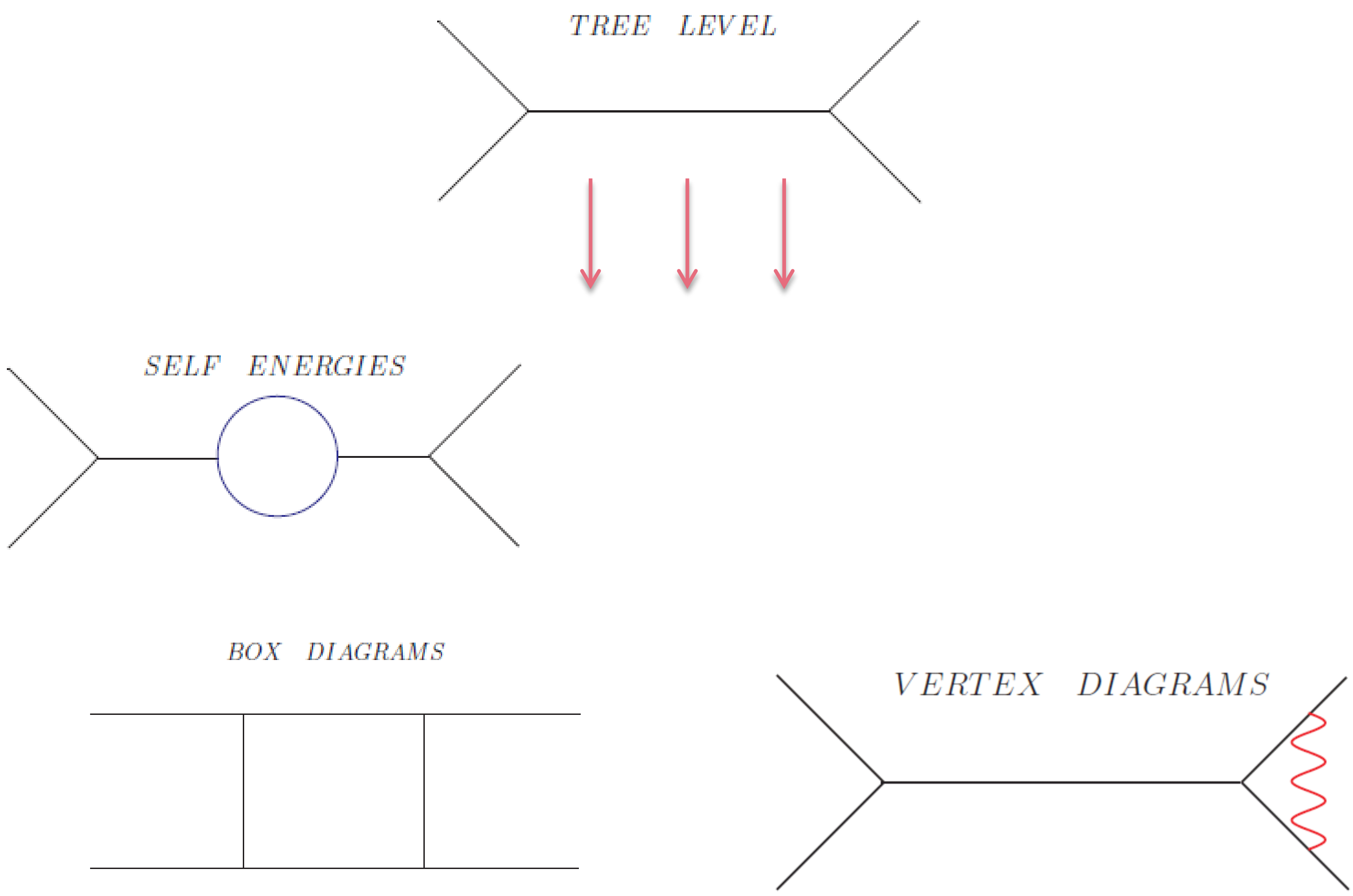

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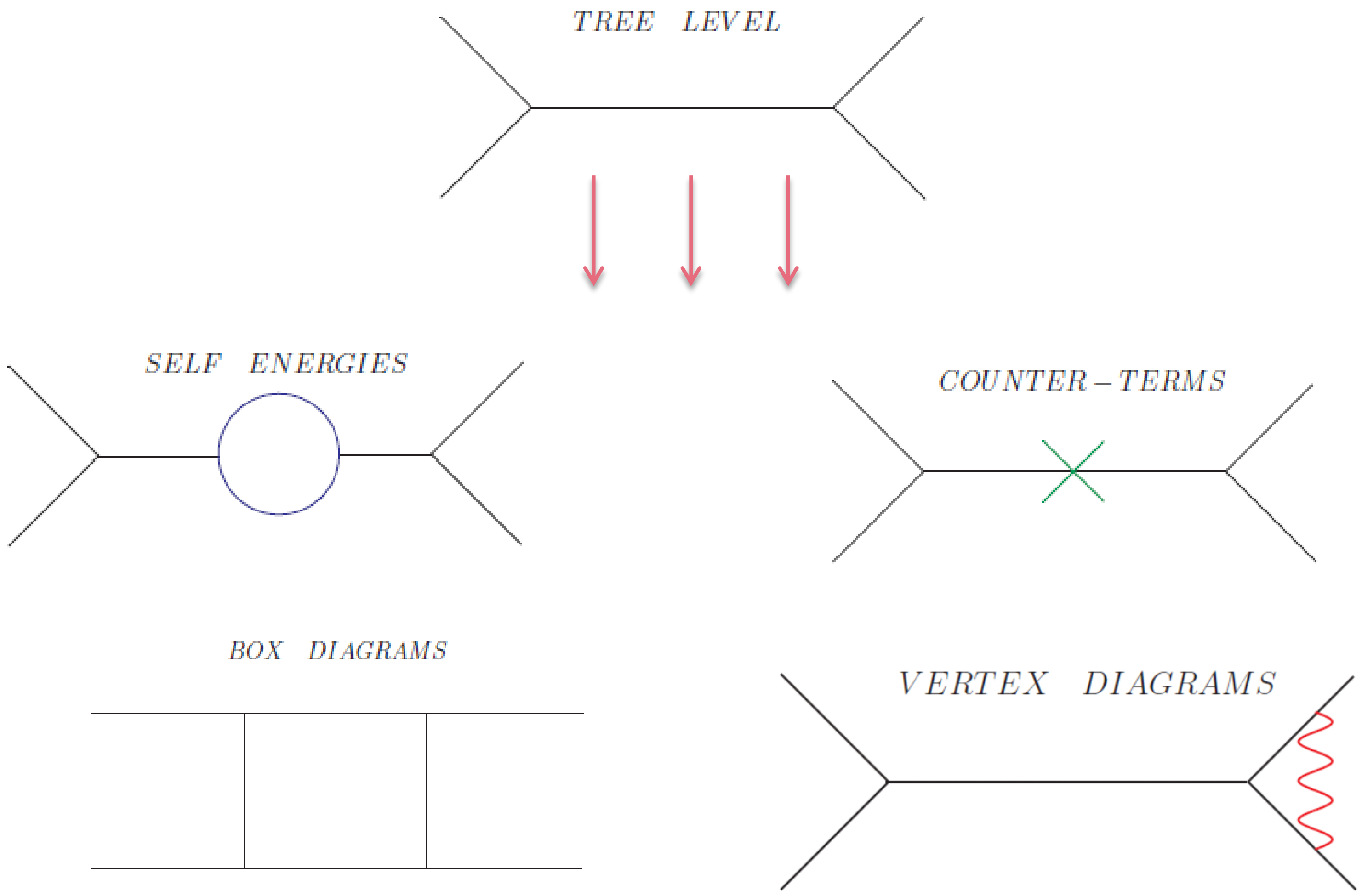

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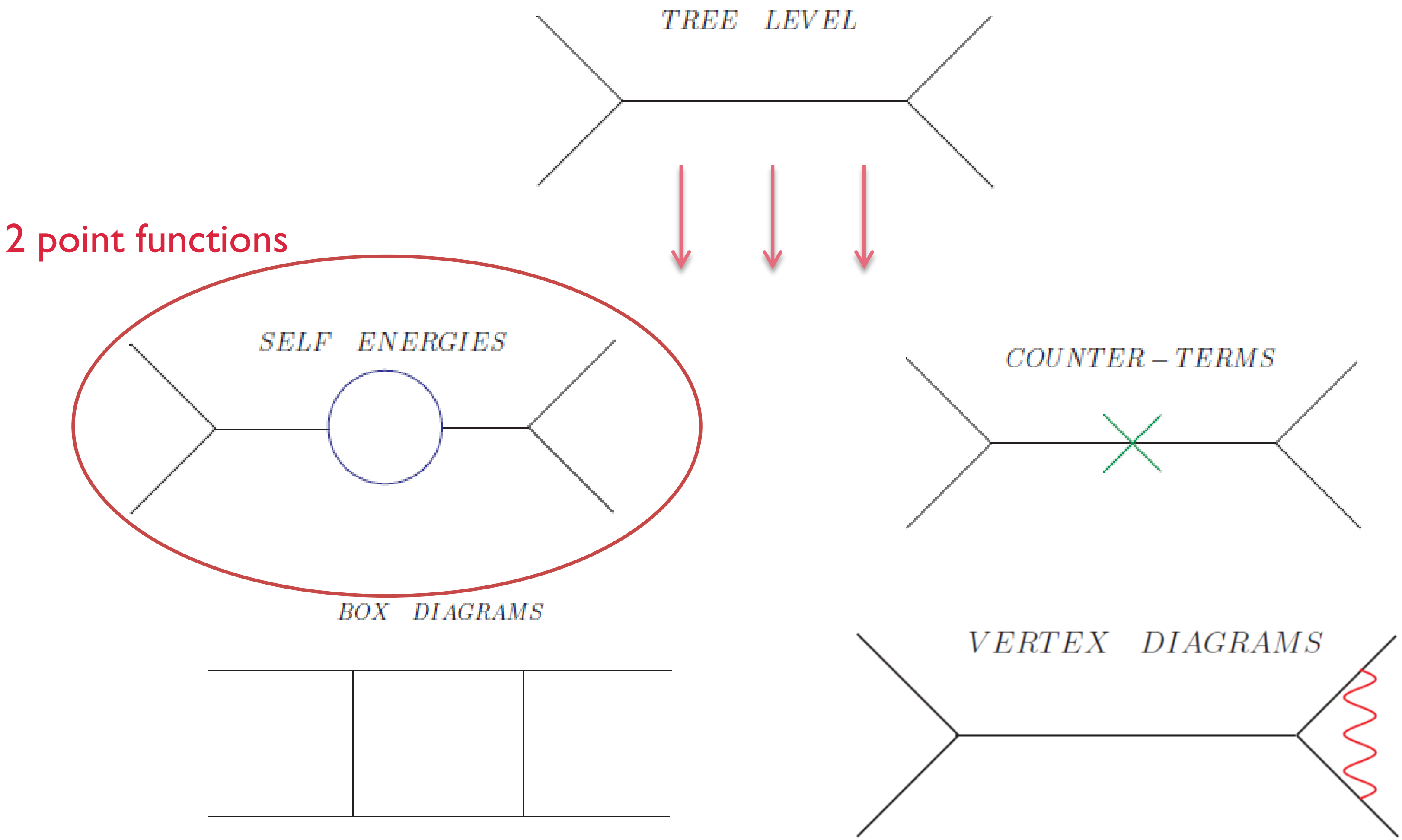

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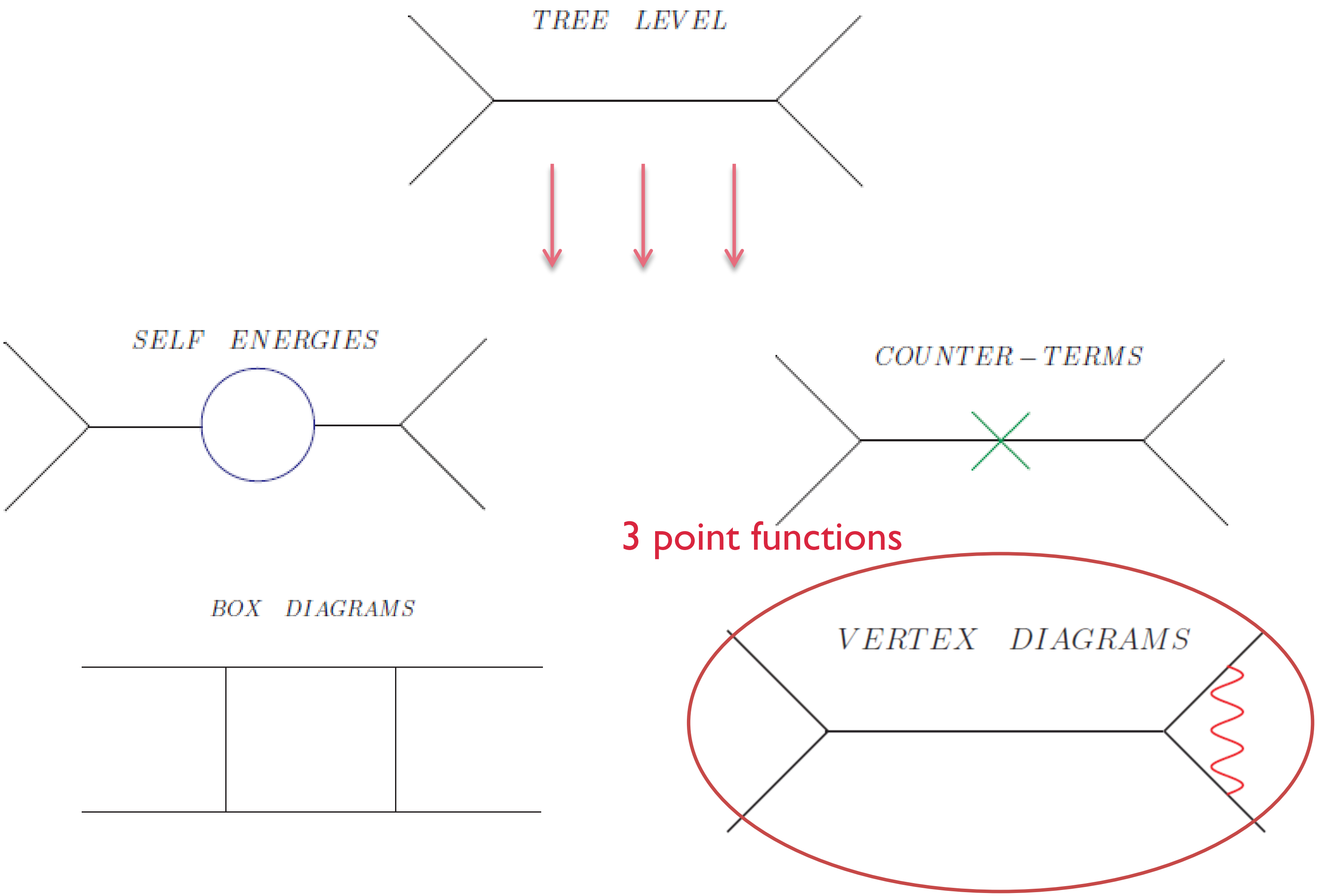

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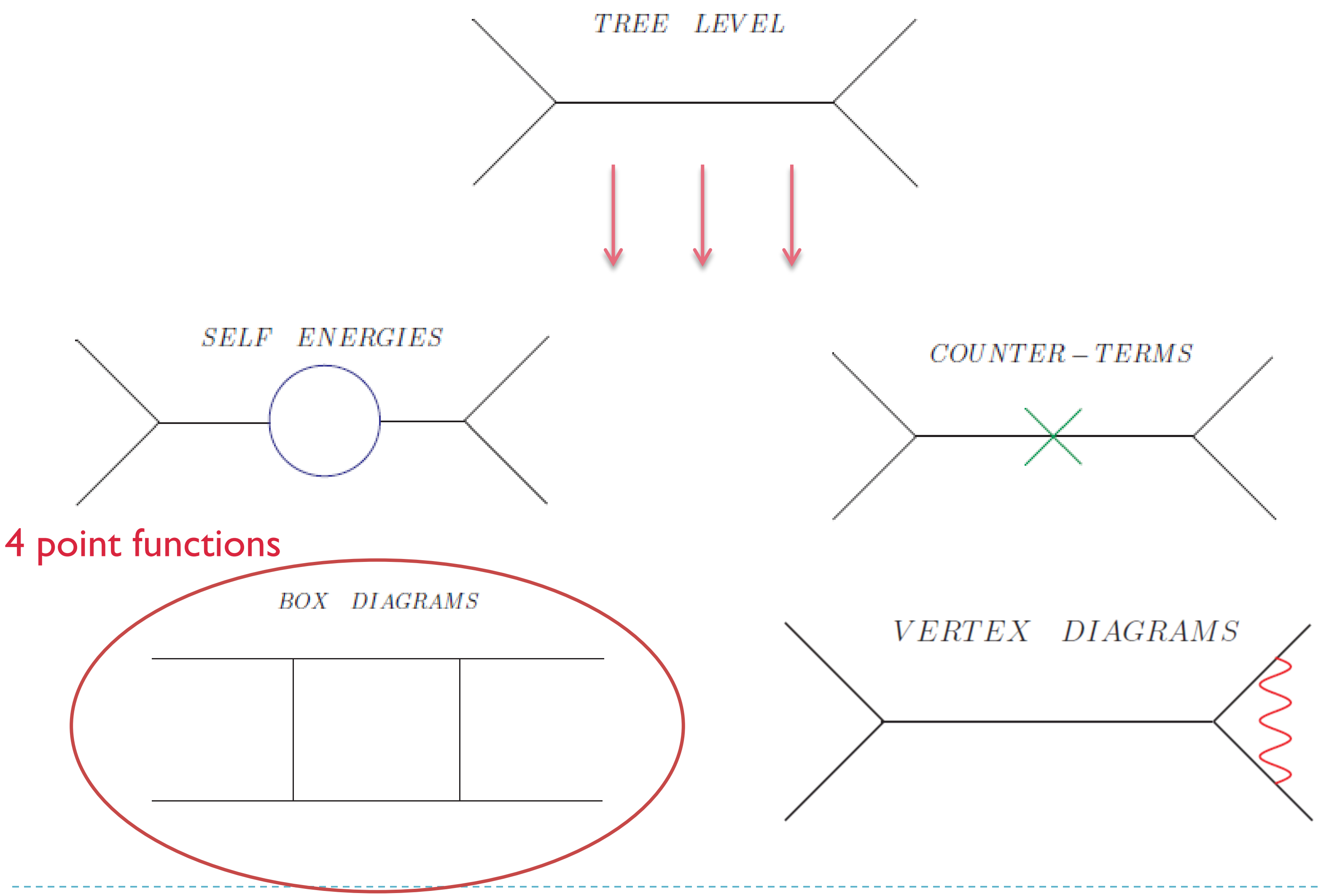

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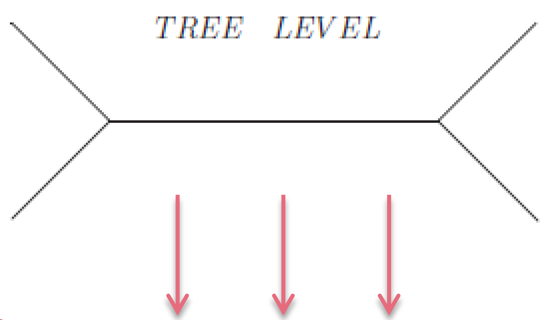

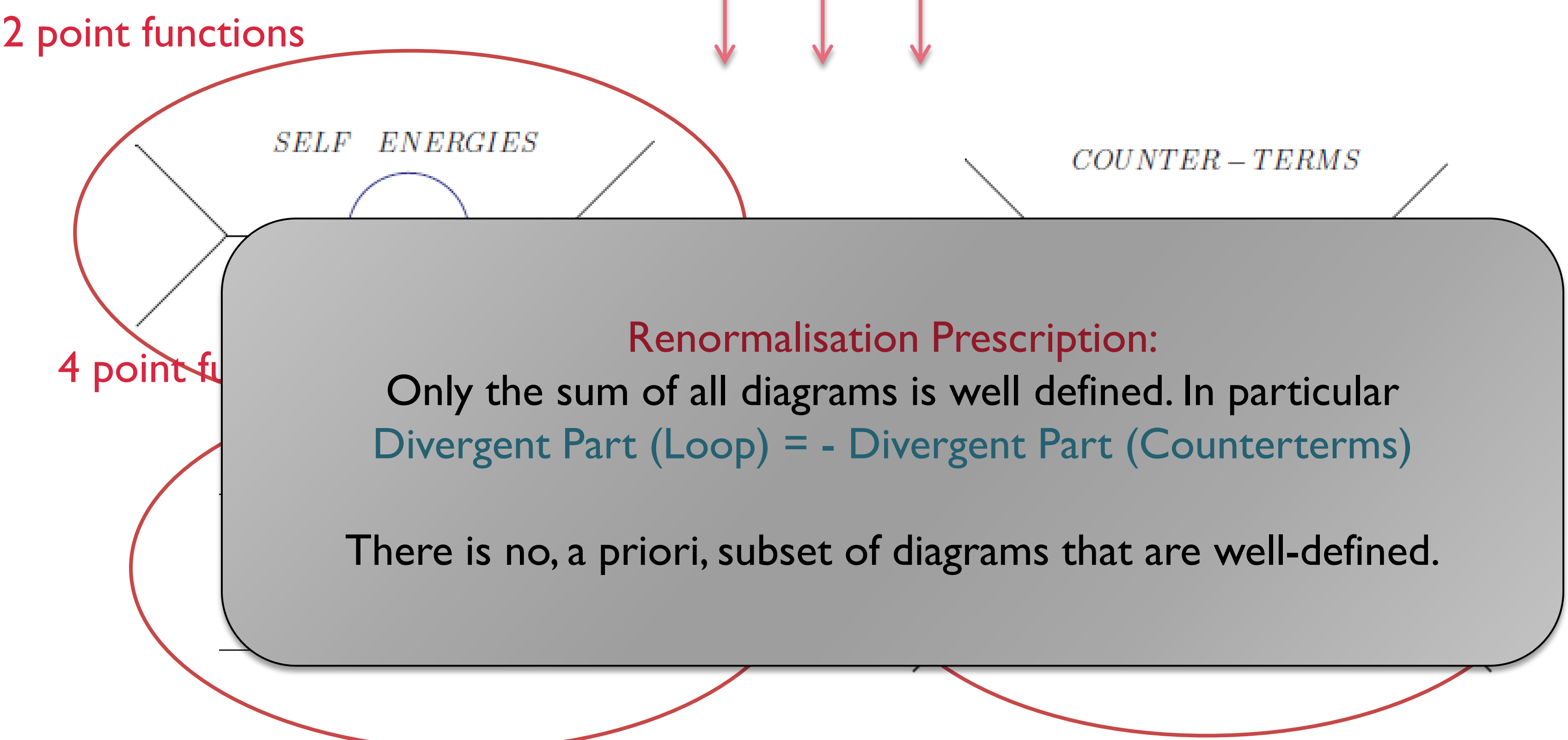

Renormalisation Prescription:

Only the sum of all diagrams is well defined. In particular

Divergent Part (Loop) = - Divergent Part (Counterterms)

There is no, a priori, subset of diagrams that are well-defined.

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- … but still thorny
  - Still a process by process method (many of them being likely to contribute significantly to Ω), whereas tree-level is not.
  - Opens widely the parameter space (through sfermions loop contribution, M_q, M_l, A_f … jump in the game)
  - Enhances drastically the number of amplitudes to be computed.
    - From 6 at tree-level to more than 1000 at the loop level.

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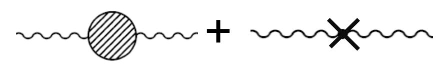
    - e.g. in the SM, δM_Z fixed by requiring 

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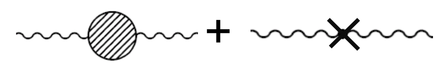
    - e.g. in the SM, δM_Z fixed by requiring  = 0

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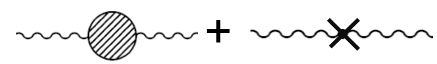
    - e.g. in the SM, δM_Z fixed by requiring  = 0

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$$\left.\begin{matrix} M_H \\ A_0 \mapsto \tau^- \tau^+ \end{matrix}\right\} \text{OS schemes}$$

- Neutralino/Chargino sector :
  - 6 masses for 3 parameters (M_1, M_2, μ)

$$M_{\tilde{\chi}_1^+}, M_{\tilde{\chi}_2^+}, M_{\tilde{\chi}_1^0}$$

Going for an effective potential

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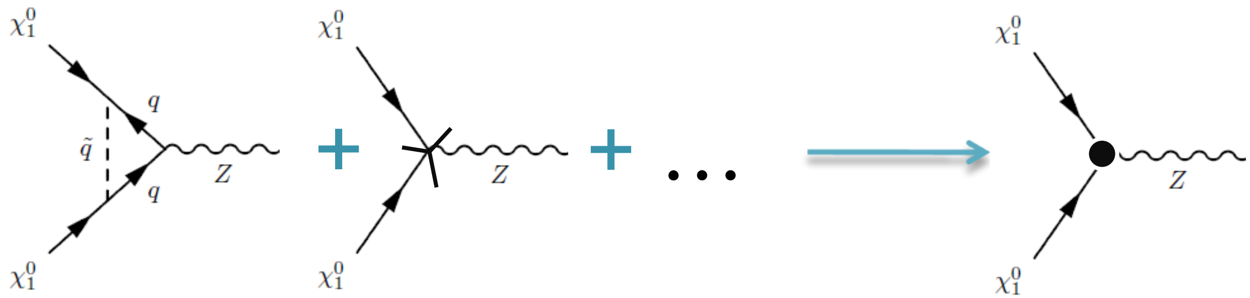

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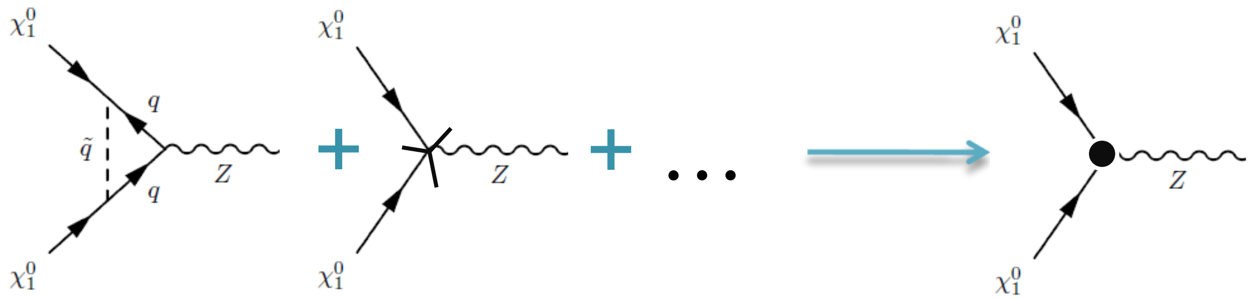

- L at one-loop $\longrightarrow$ L_{eff}
  - Counterterms such as δZ easy to include (include δZ for each leg)
  - Possible for triangles

  Those corrections are universal, they can be used in any process

  - More complicated for boxes

Mixing matrices & External Legs corrections

- Ω is mainly driven by the nature of $\tilde{\chi}_1^0$

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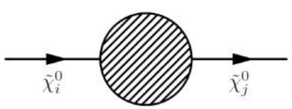
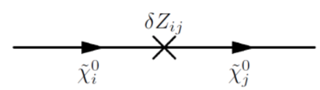
- But some of the loops play a nature-changing role





  - Hence we expect δZ corrections to give contributions to Ω

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- Effective running $\alpha_{QED}(Q)$ Yields a universal correction δ_α

Numerical Study

- Model : pMSSM (19 parameters)
  - @ one-loop order (Renormalisation Scheme as described)
  - M_1, M_2, μ taken as input instead of $M_{\tilde{\chi}_1^+}, M_{\tilde{\chi}_2^+}, M_{\tilde{\chi}_1^0}$
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- Parameter space
  - Generically heavy sfermions (l~500, q~800), idem for A0 (~1 TeV)
  - t_β has moderate values (~4)
  - Neutralino parameter (M_1, M_2, μ) vary, to span the different cases, but overall yield a light $\tilde{\chi}_1^0$ (~100 GeV)
- Process $\tilde{\chi}_1^0 \tilde{\chi}_1^0 \to \mu^- \mu^+$ Focus on EW corrections

Bino Case

- $M_1 = 90 \quad M_2, \mu >> M_1$
  - Bino-like 99%

$$\delta_{\text{One-loop}} = 19.58\% \quad \delta_{eff} = 18.06\%$$

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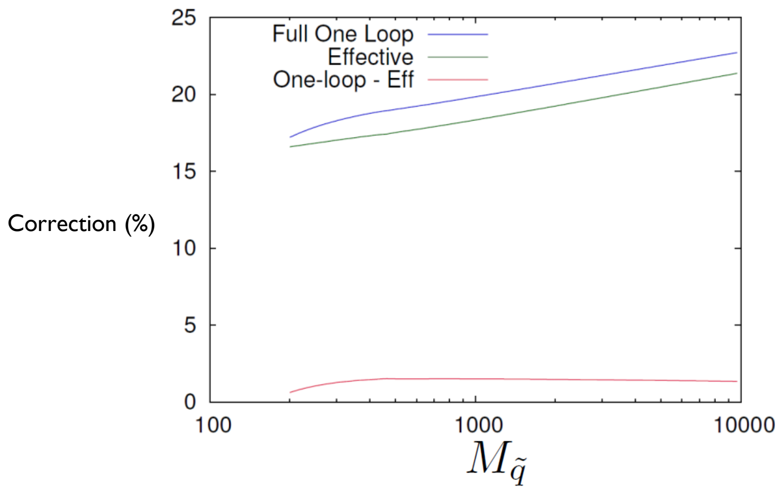
- Evolution with squarks masses



No decoupling of squarks

  - Non-effective part stays flat and small!

Higgsino Case

- $\mu = -100 \quad M_1, M_2 >> \mu$
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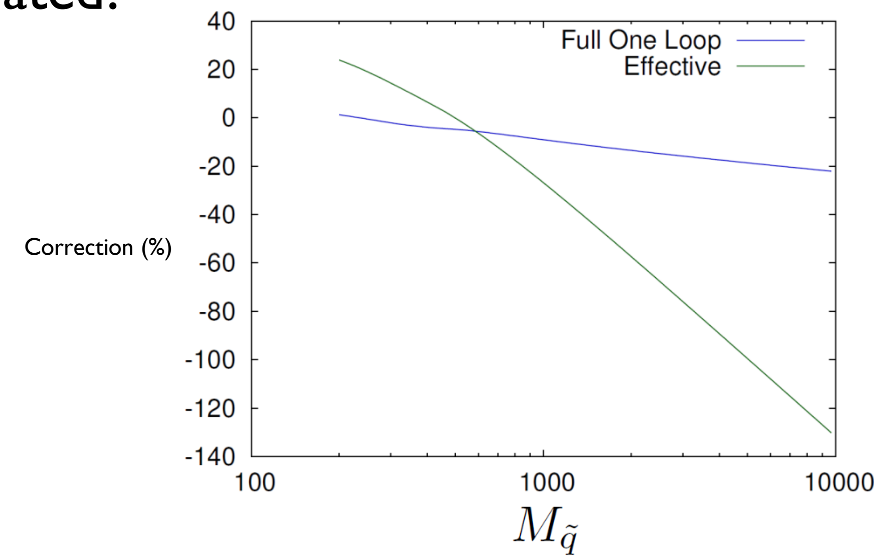

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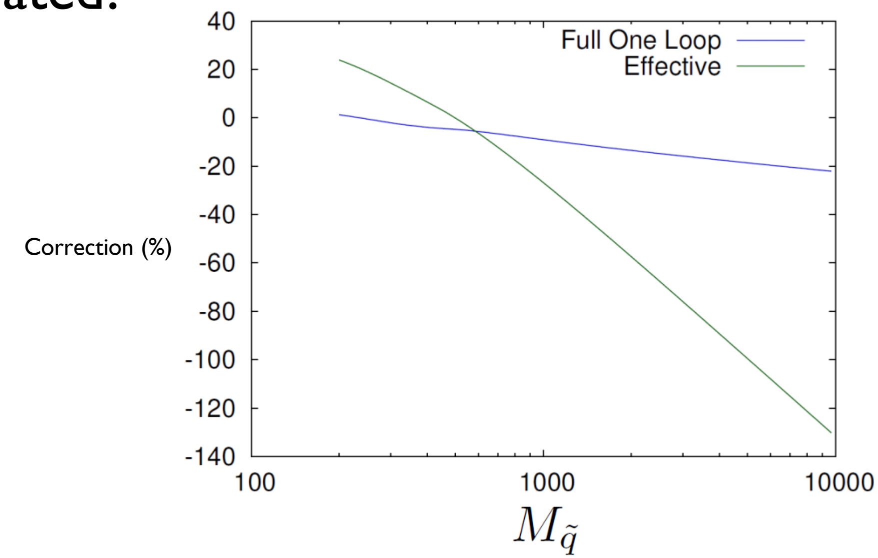

- Boxes non negligible ?

  $$\delta_{boxes} = -14.6\%$$
- How can we improve it?

Analysing discrepancies

- Do the discrepancies …
  - Stem from 2-point functions with other particles
  - Stem from 3-point functions

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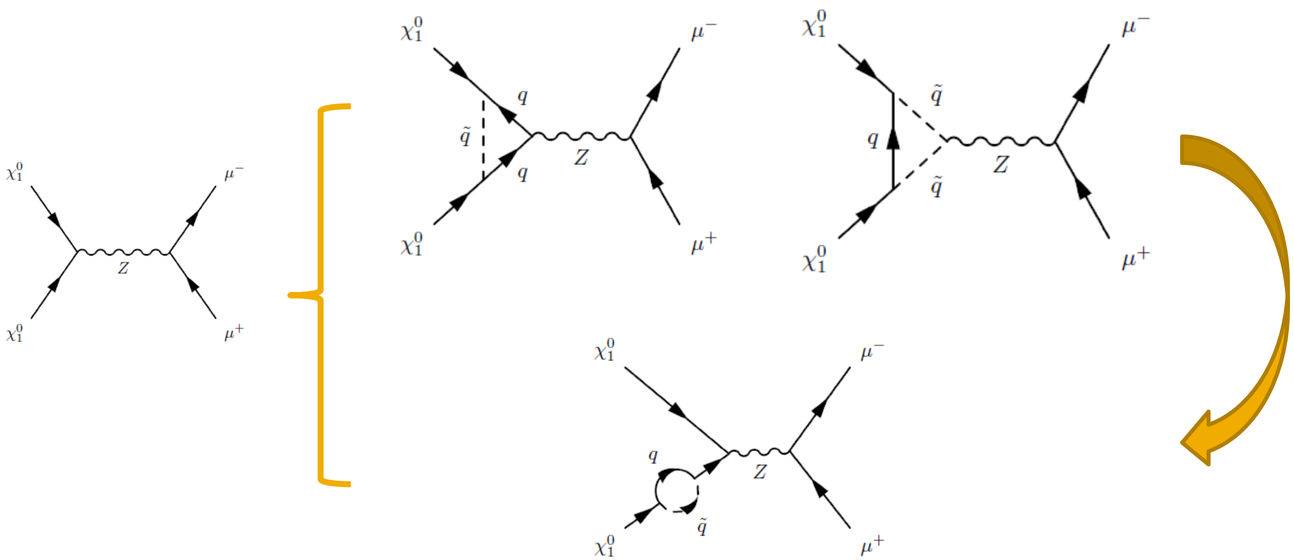

Cancelation

Discrepancies … The Yukawa correction

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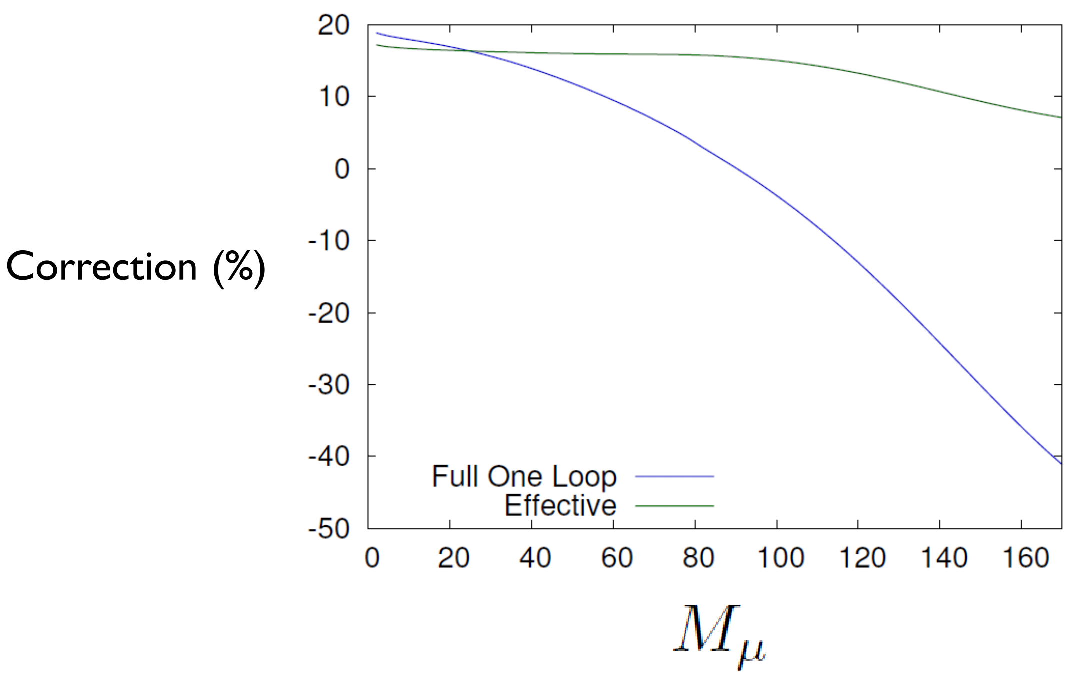

Conclusion & Outlook

- Relying on such an effective approach is tricky
  - There are cases where the effective contribution is a real improvement.
  - There is a lot more to do for a more universal correction.

- How can we improve it
  - Include the effect of triangles in effective operators such as

$$Z\tilde{\chi}_1^0\tilde{\chi}_1^0$$
$$\tilde{\chi}_1^0\tilde{f}f$$

  - How do we account for gauge particles loop contribution?

QUESTIONS?

Wino Case

- No expectations
- $M_2 = 100 \quad M_1, \mu >> M_2$

$$\delta_{\text{One-loop}} = 46.8\% \quad \delta_{eff} = 15.11\% \quad \delta_{\alpha} = 14.83\%$$

$$\delta_{boxes} = 34.7\%$$

Titre

- Truc