The Fröhlich-Morchio-Strocchi mechanism in Multi-boson processes

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Polarized Perspectives
Vienna
Austria

Österreichischer Wissenschaftsfonds

What’s up?

Review: 1712.04721
Update: 2305.01960

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See review for background!

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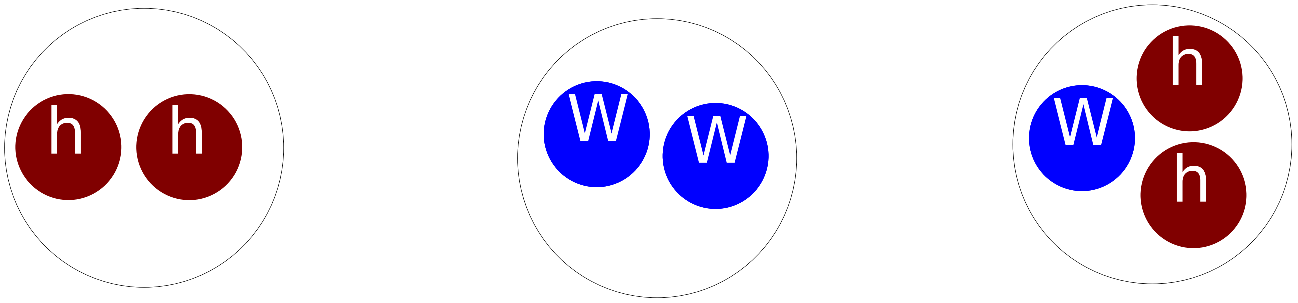
  - Higgs-Higgs, W-W, Higgs-Higgs-W etc.



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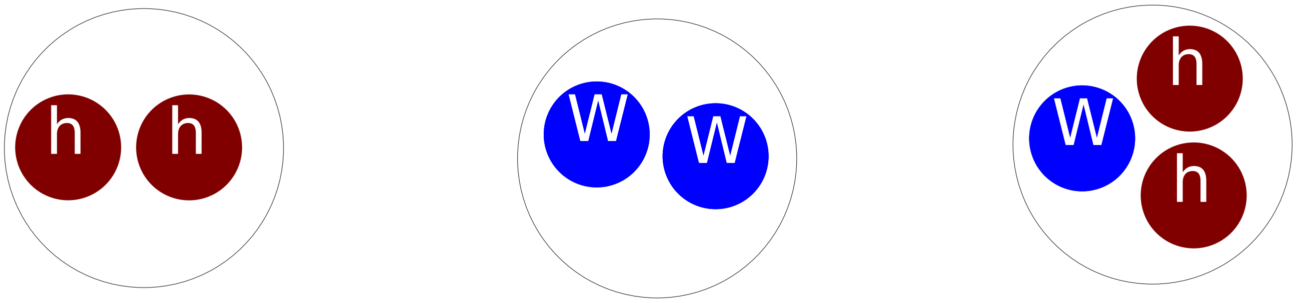

- Why does perturbation theory work?
  - Fröhlich-Morchio-Strocchi mechanism

Fröhlich-Morchio-Strocchi Mechanism

[Fröhlich et al.’80,’81
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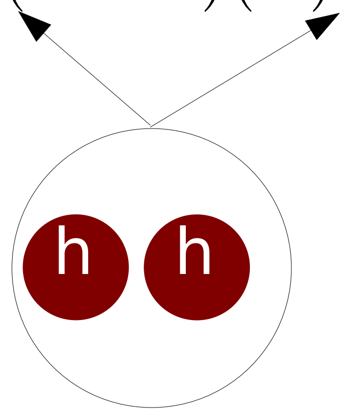

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Augmented perturbation theory

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Trivial two-particle state

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What about this?

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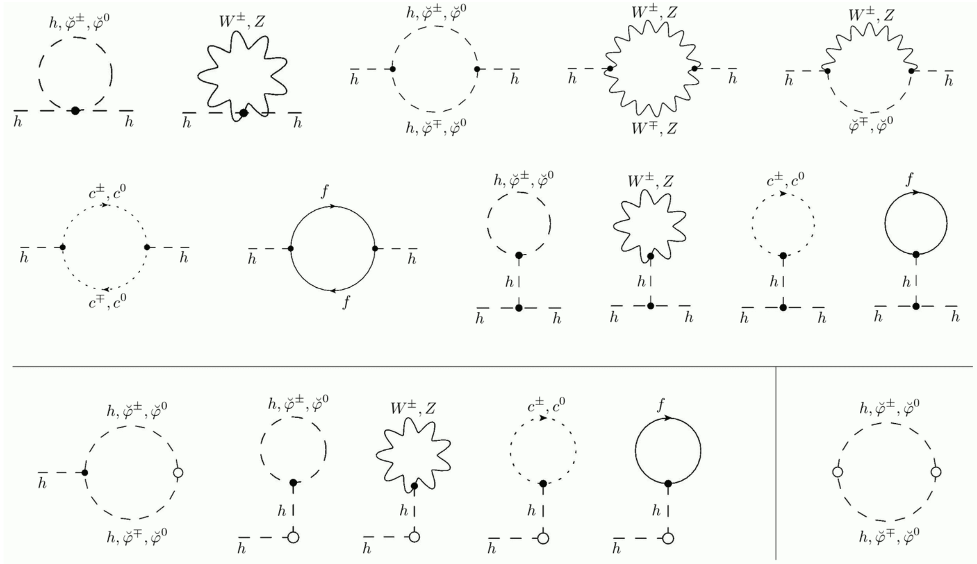

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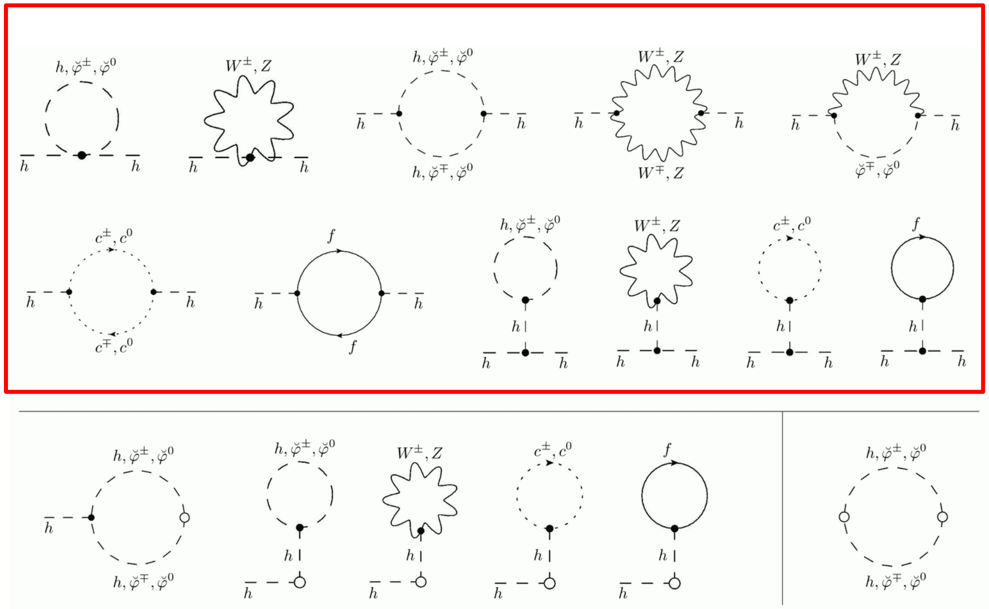

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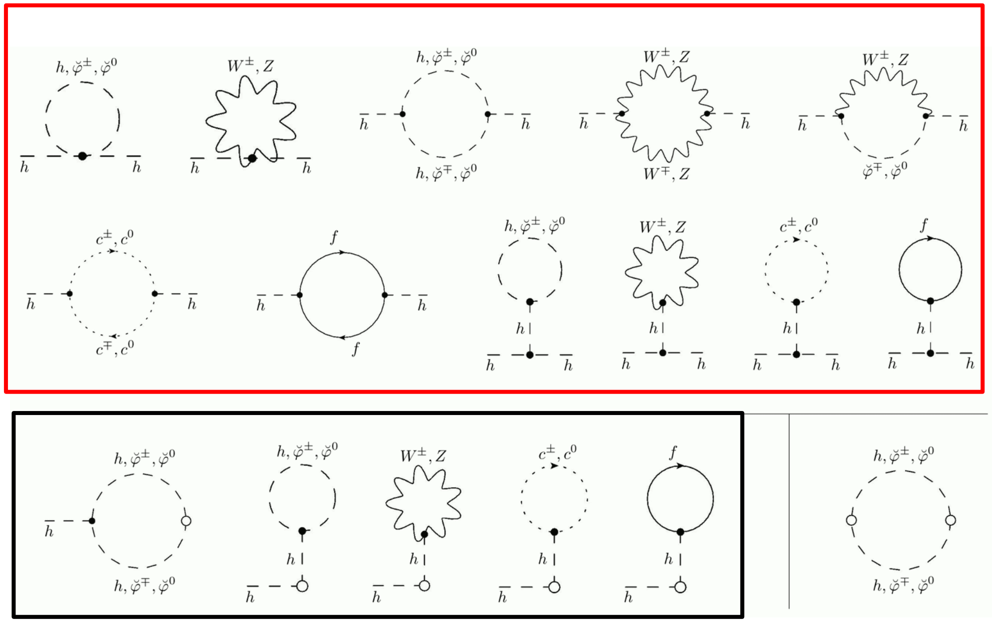

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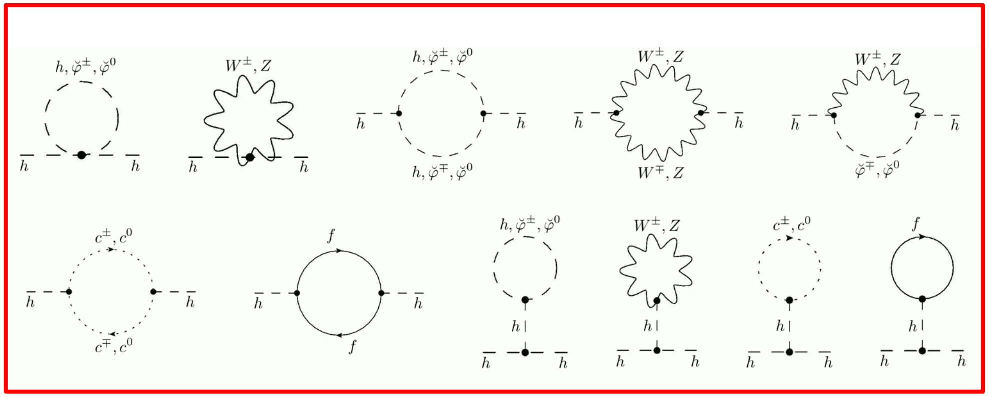

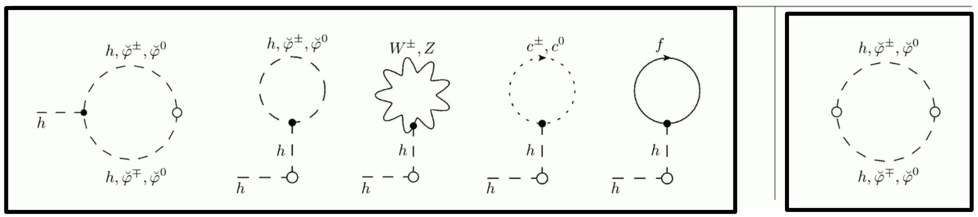

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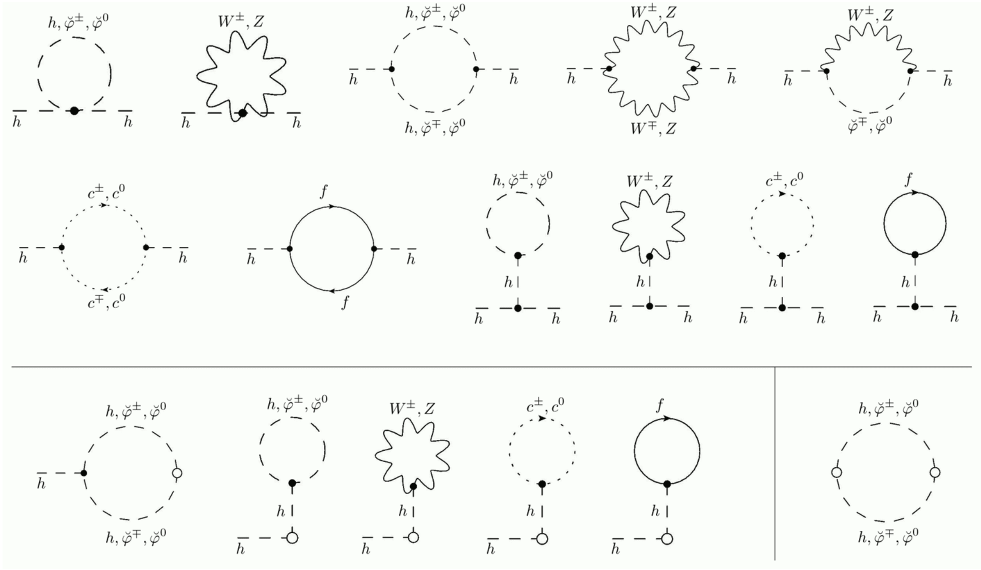

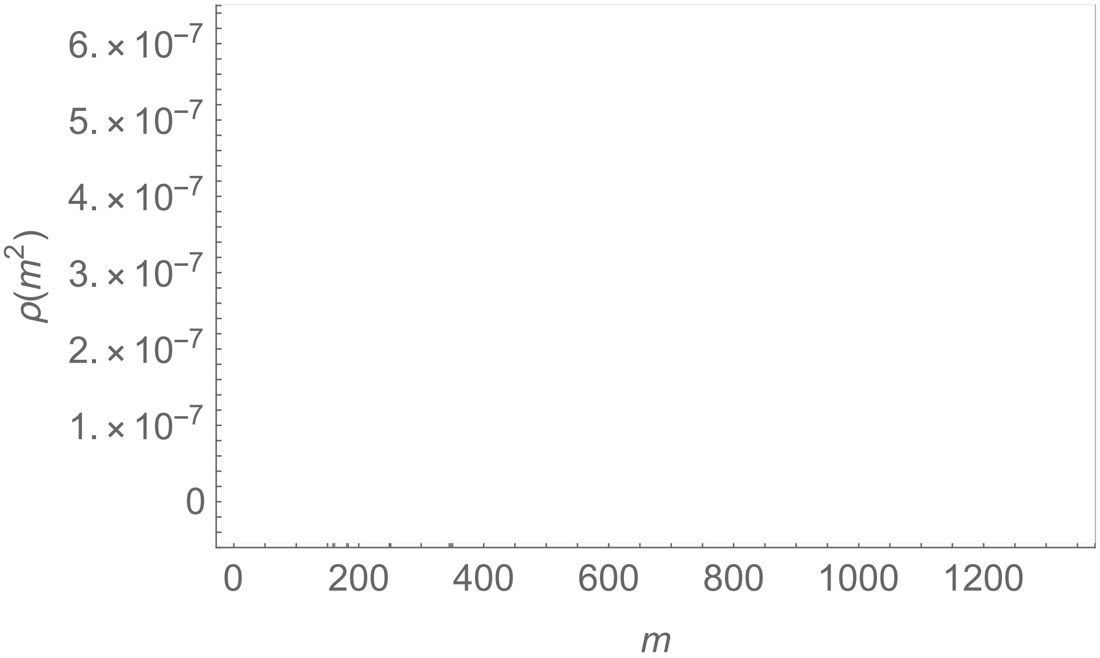

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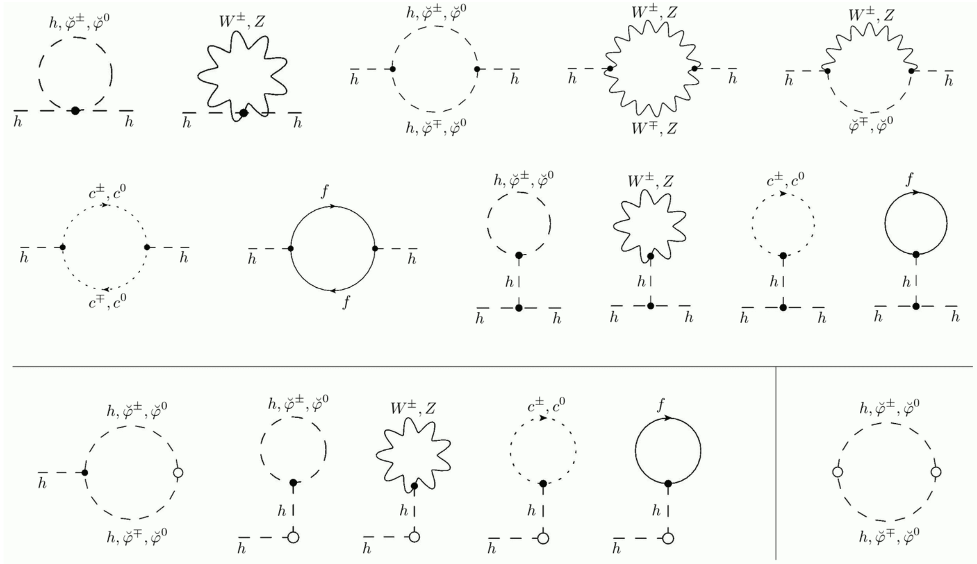

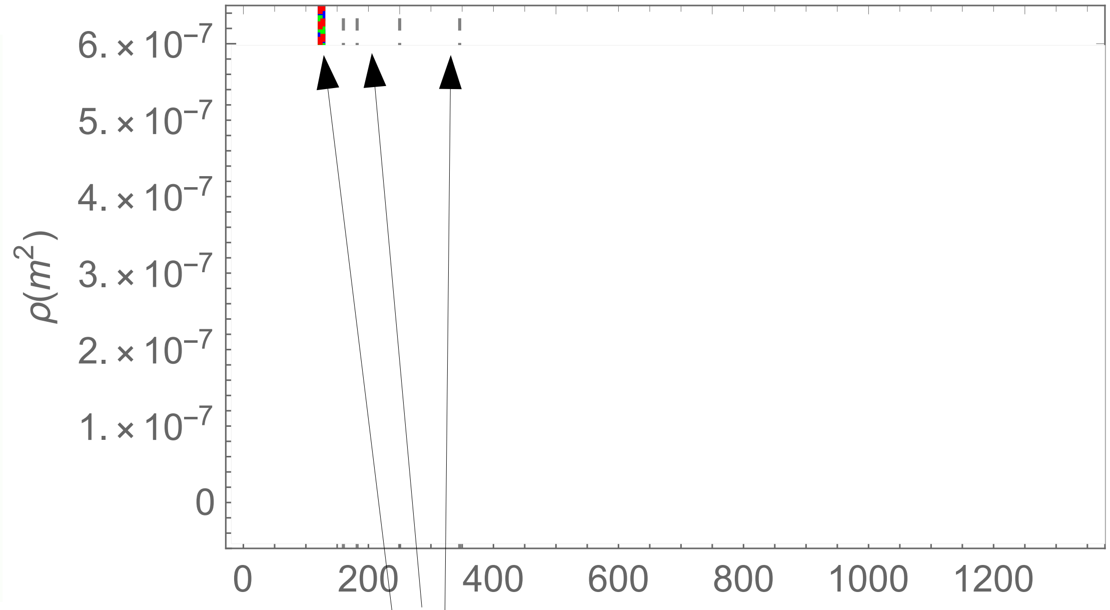

Physical thresholds

[Maas'12,’17
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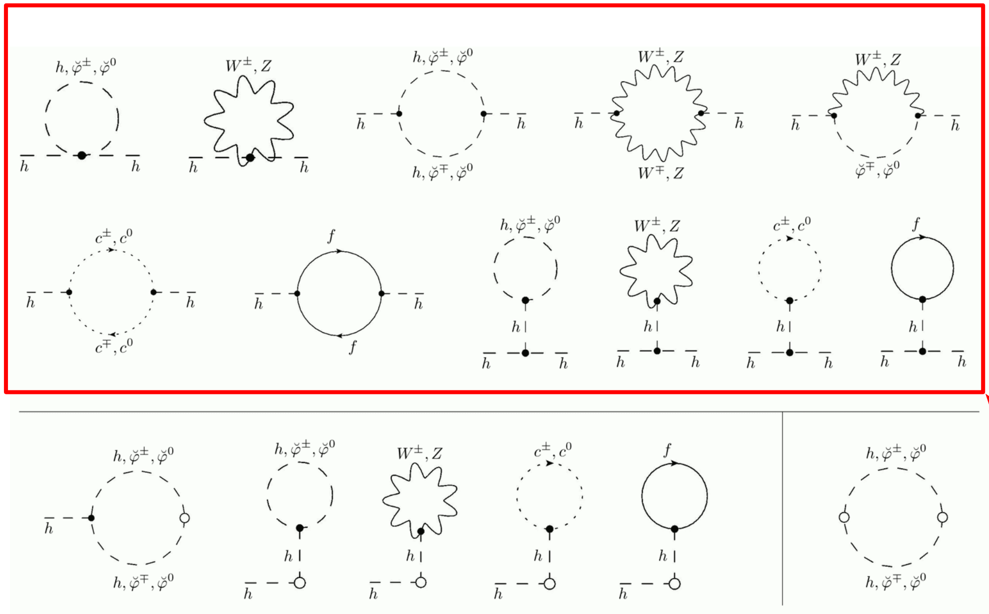

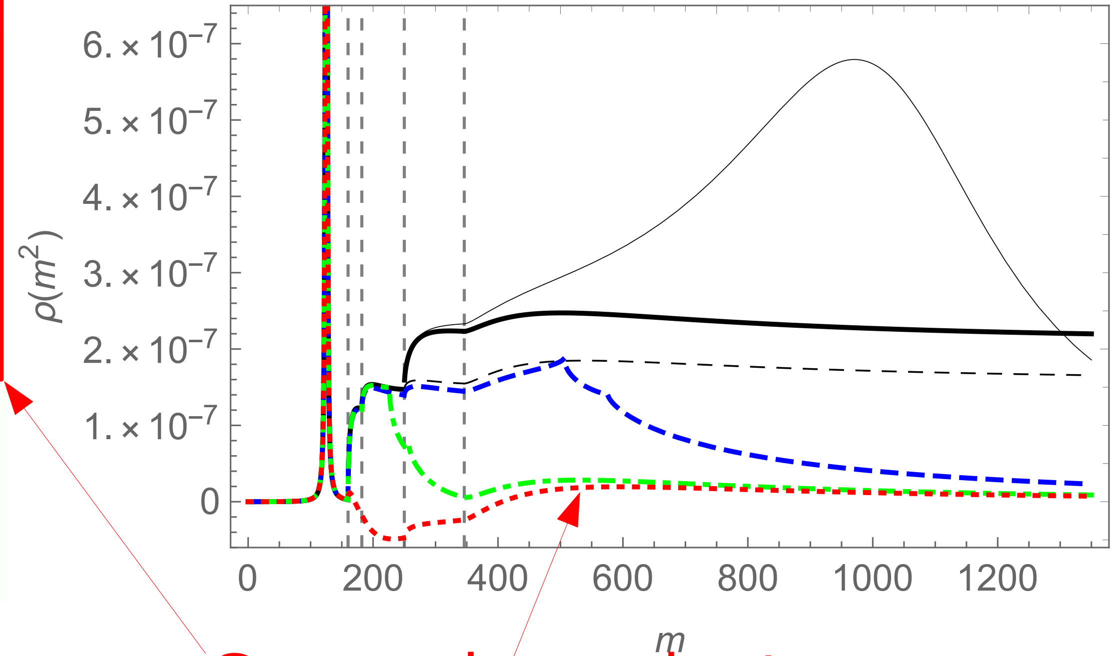

Gauge-dependent

[Maas'12,'17
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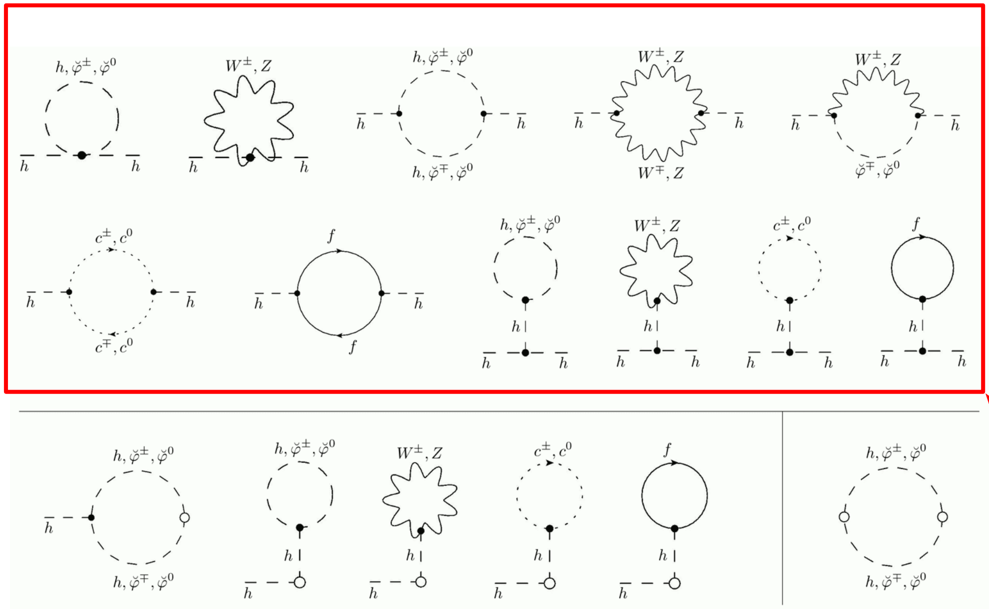

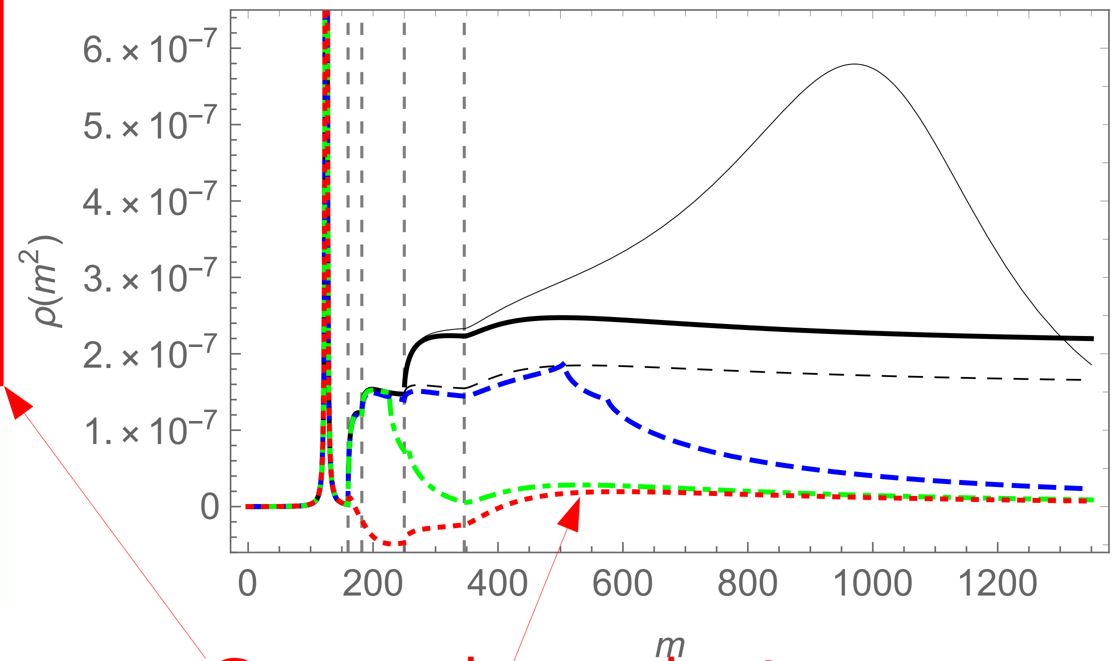

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Unphysical features:

Positivity violation

Additional thresholds

[Maas'12,'17
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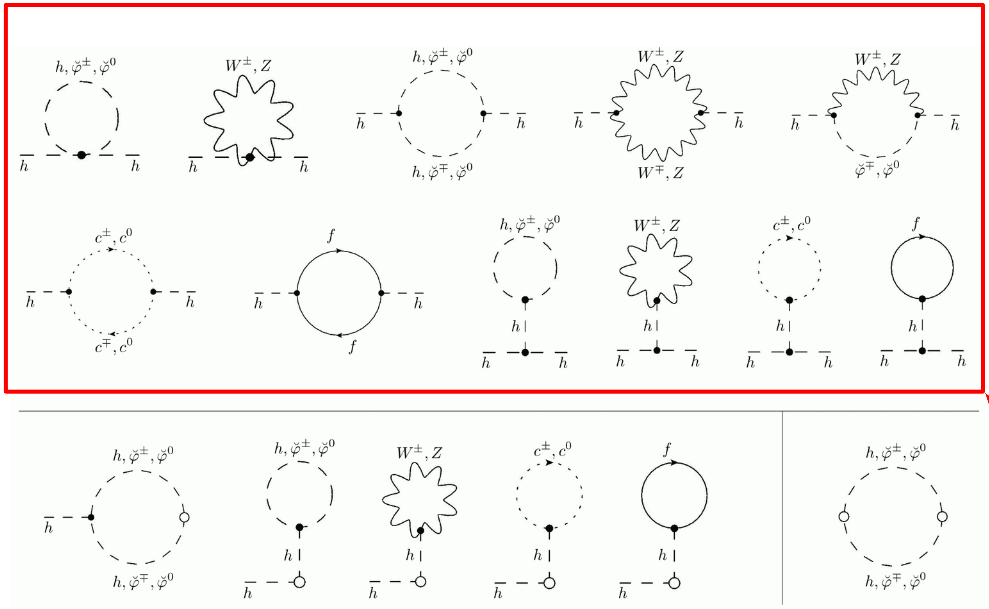

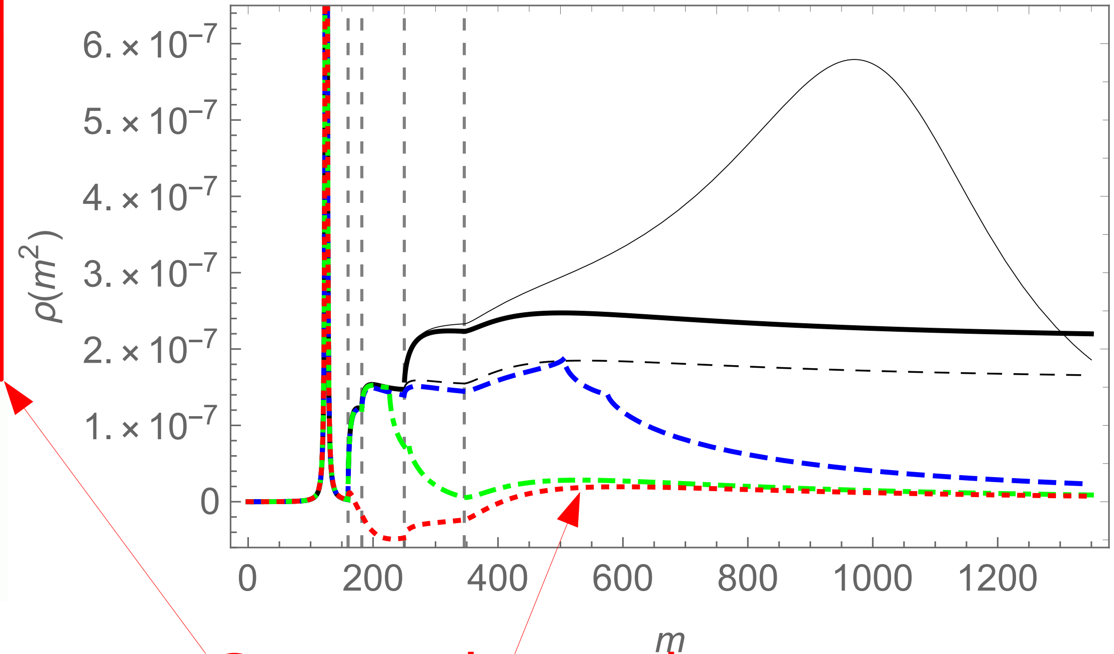

Gauge-dependent
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Not a consequence of instability: Occurs even for an asymptotically stable Higgs in a toy theory

[Maas'12,'17
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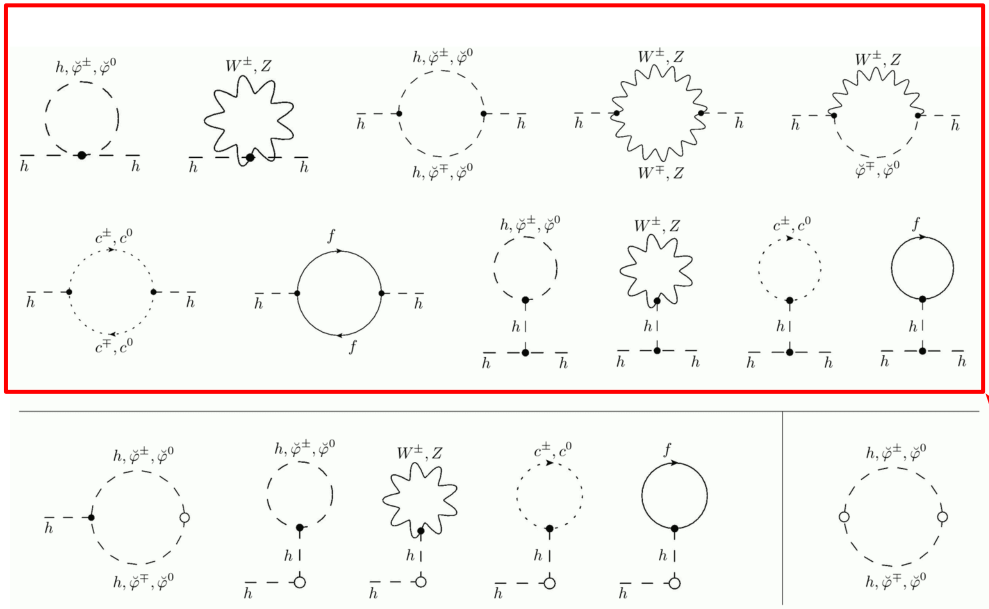

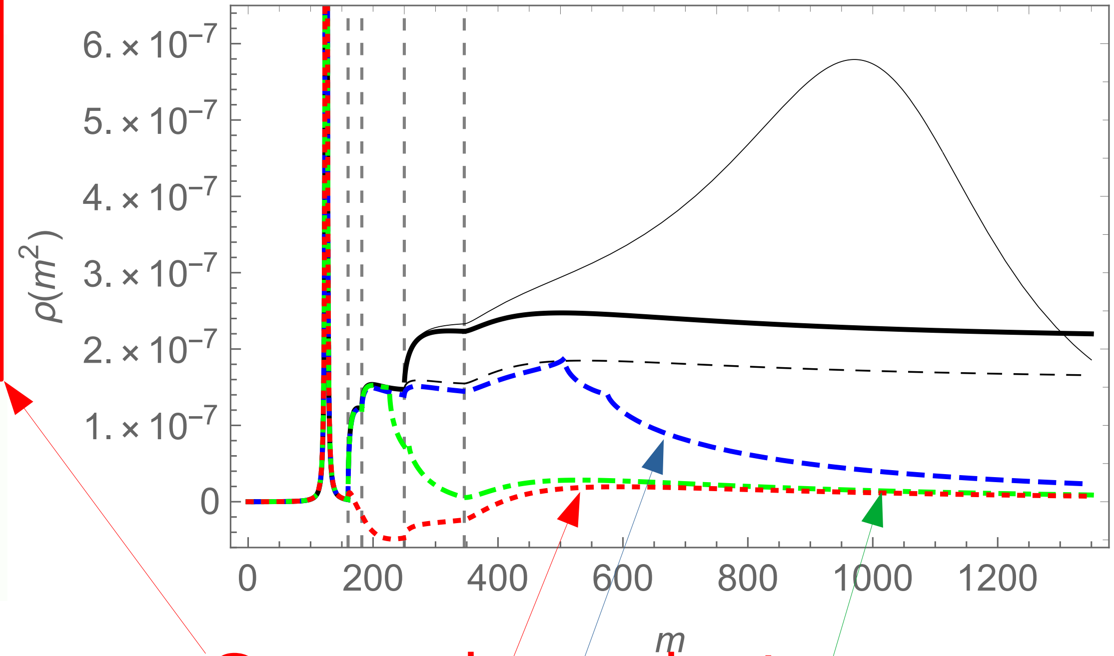

Gauge-dependent

Other gauge choices

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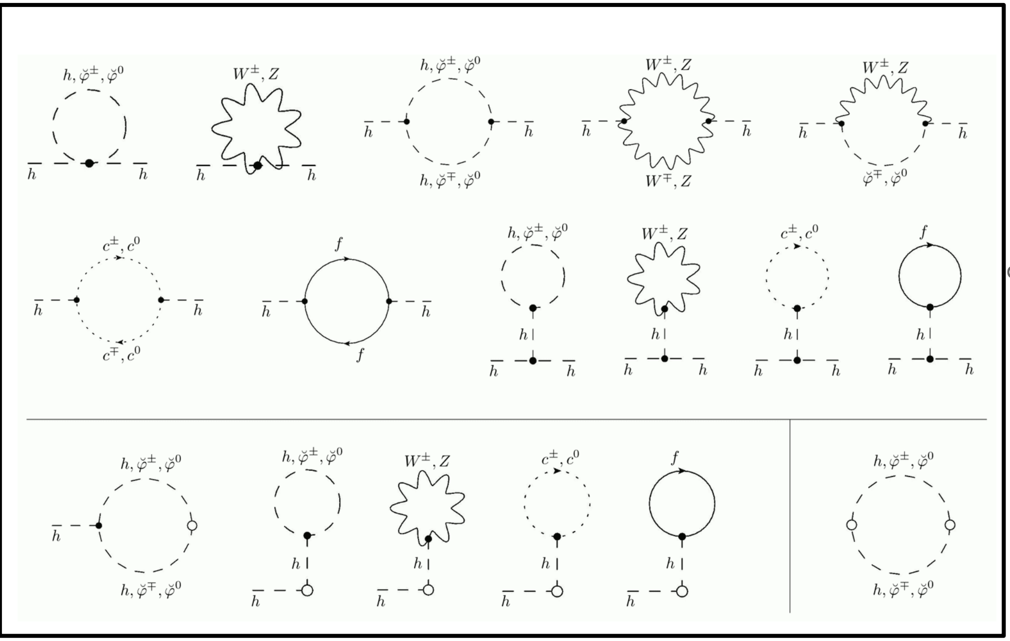

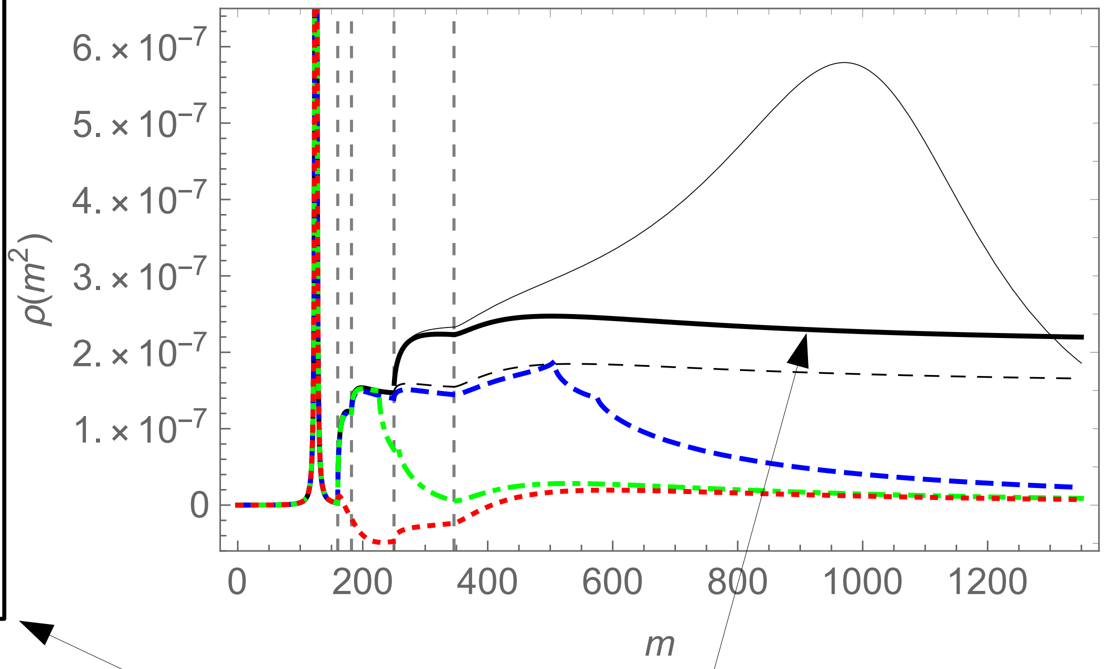

Physical – same for all gauge choices

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Flavor

[Fröhlich et al.'80,
Egger, Maas, Sondenheimer'17]

- Flavor has two components
  - Global SU(3) generation
  - Local SU(2) weak gauge (up/down distinction)

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  - Different masses for doublet members

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- Can this be true? Lattice test

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[Afferrante,Maas,Sondenheimer,Törek'20]

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  - Degenerate leptons and neutrinos
  - Dirac fermions: left/right-handed non-degenerate
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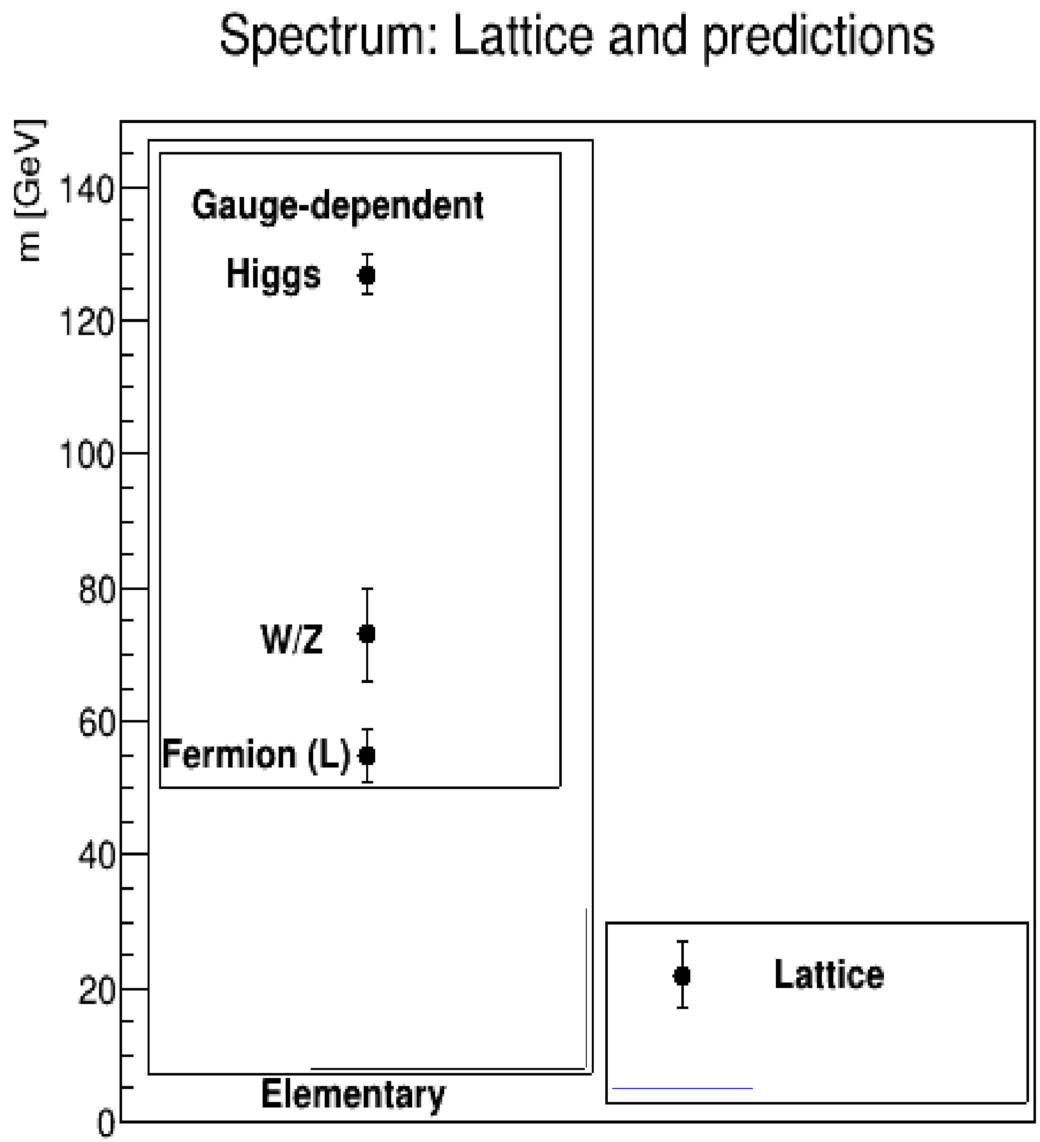

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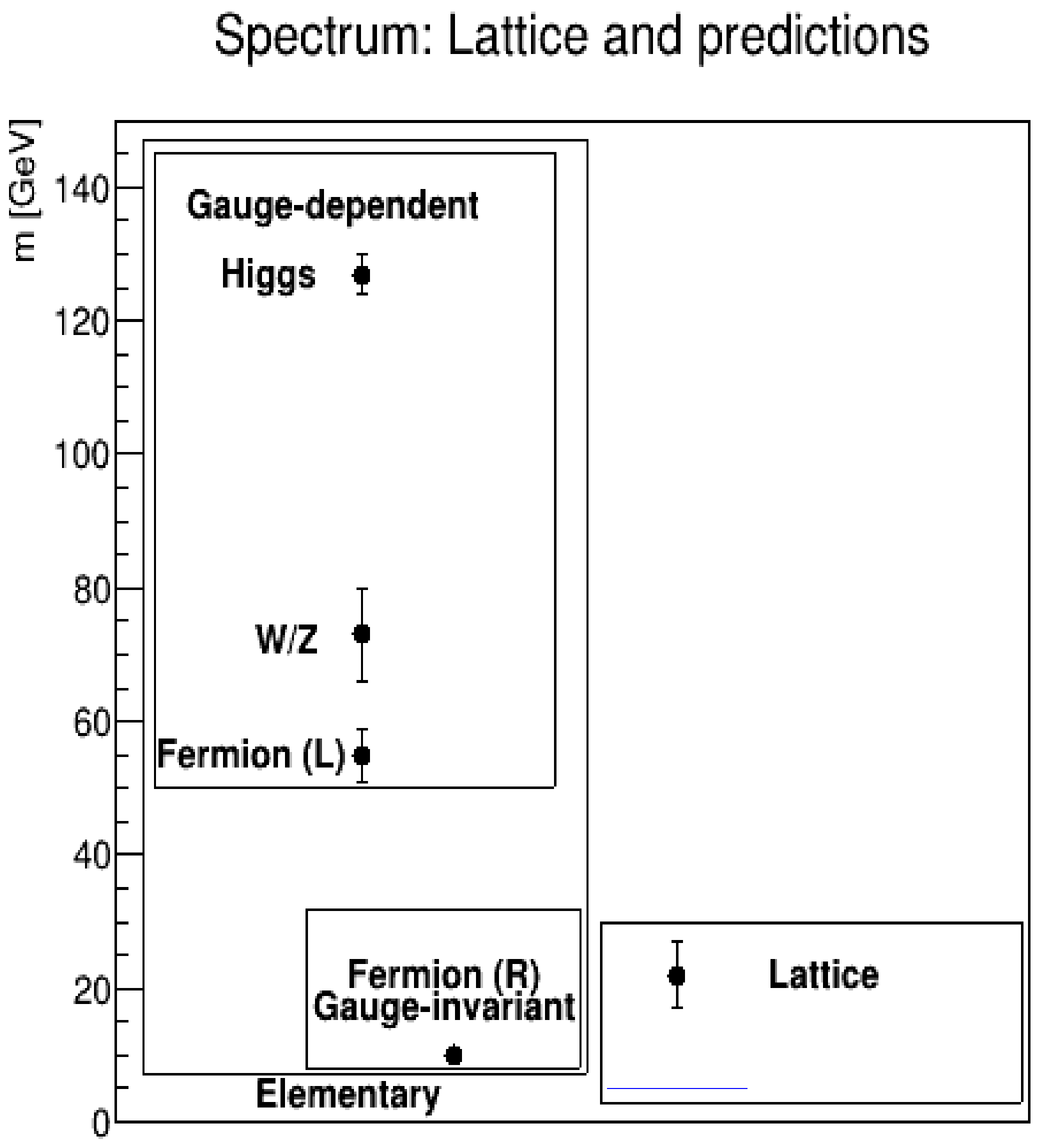

Flavor on the lattice

[Afferrante,Maas,Sondenheimer,Törek'20]

- Only mock-up standard model
  - Compressed mass scales
  - One generation
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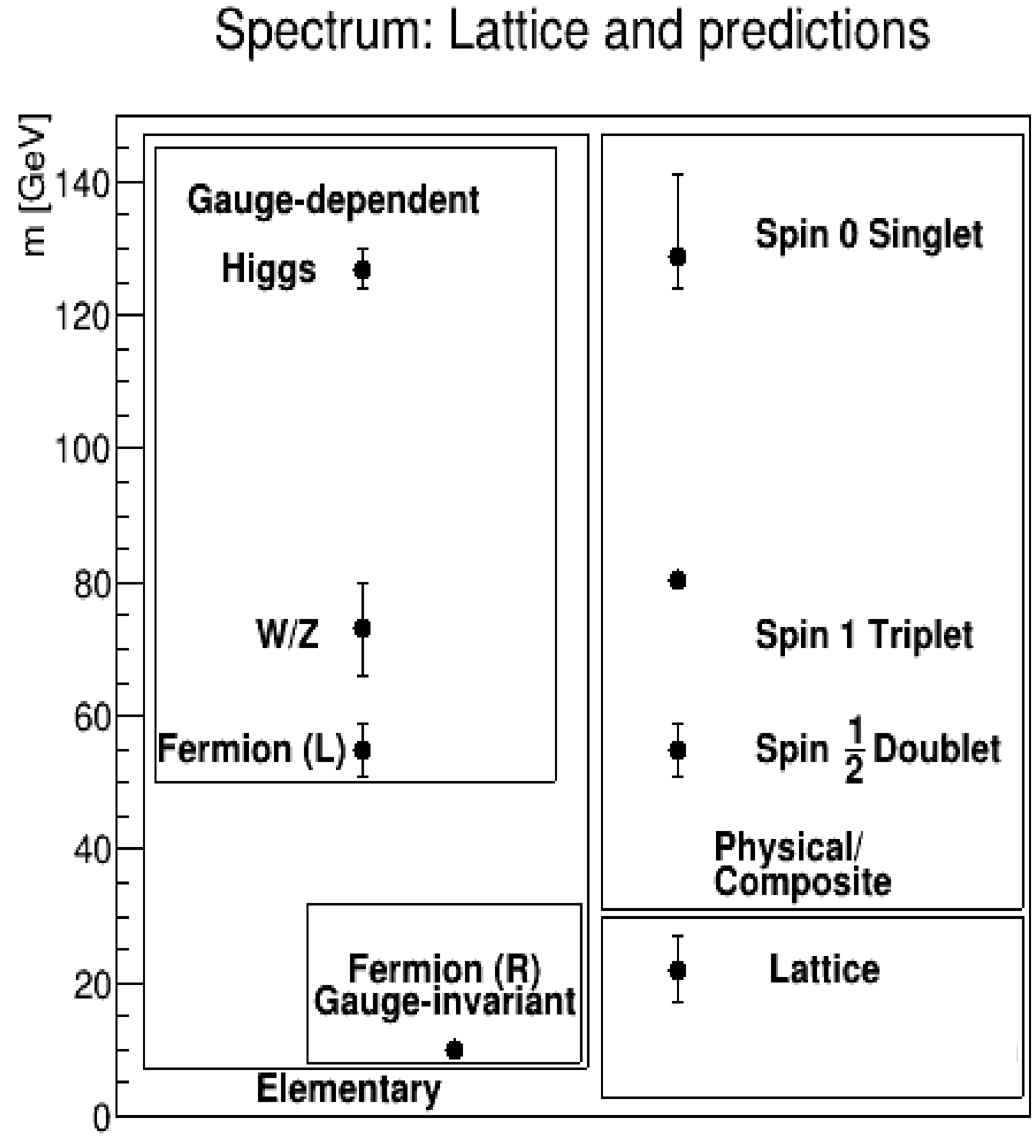

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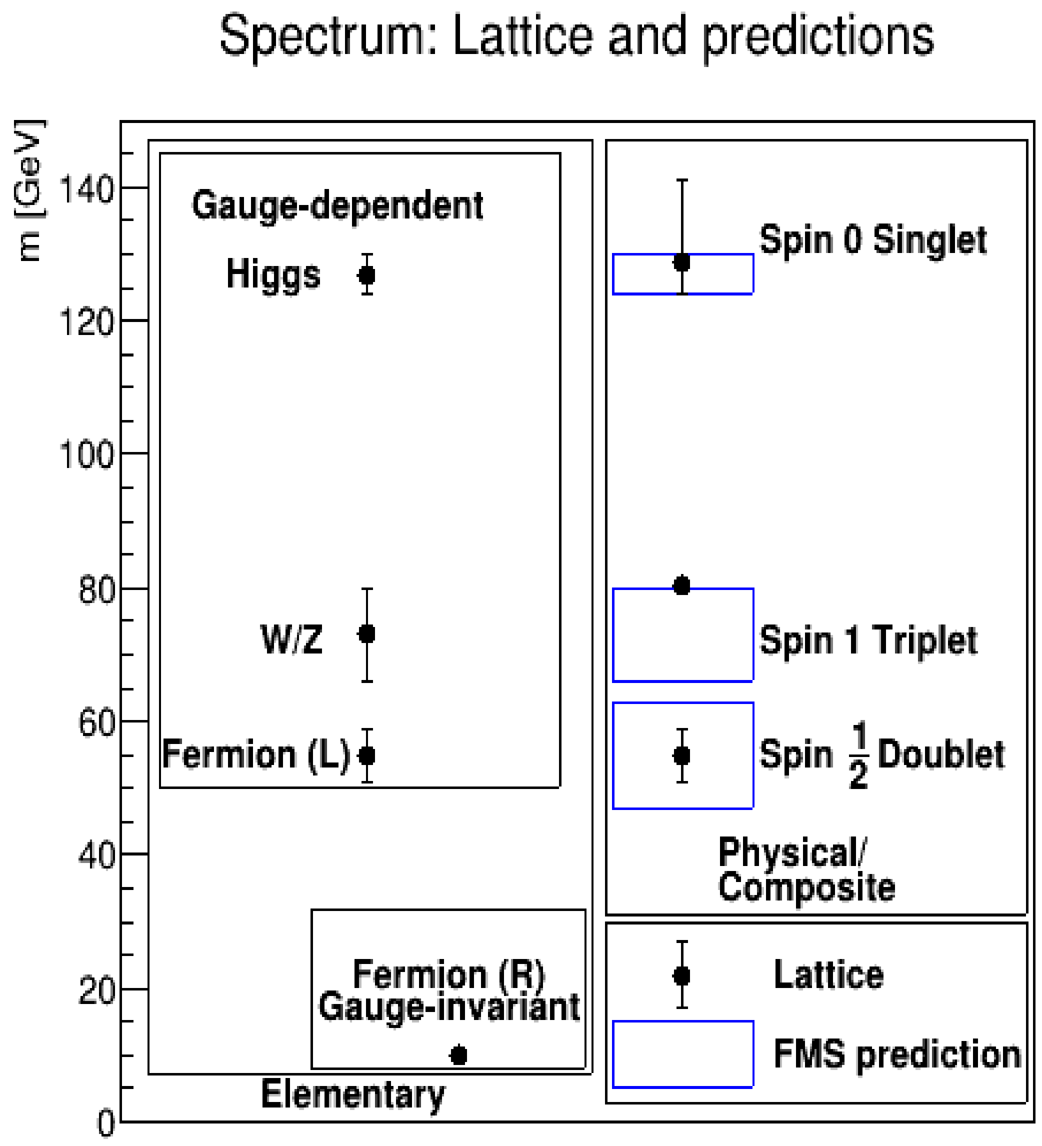

Multi-boson process as a probe

- Bound states have an extension
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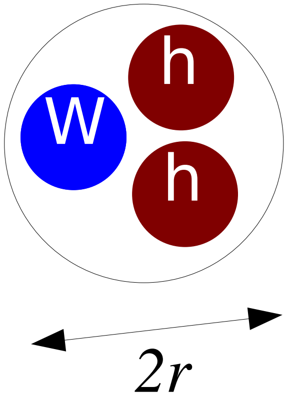

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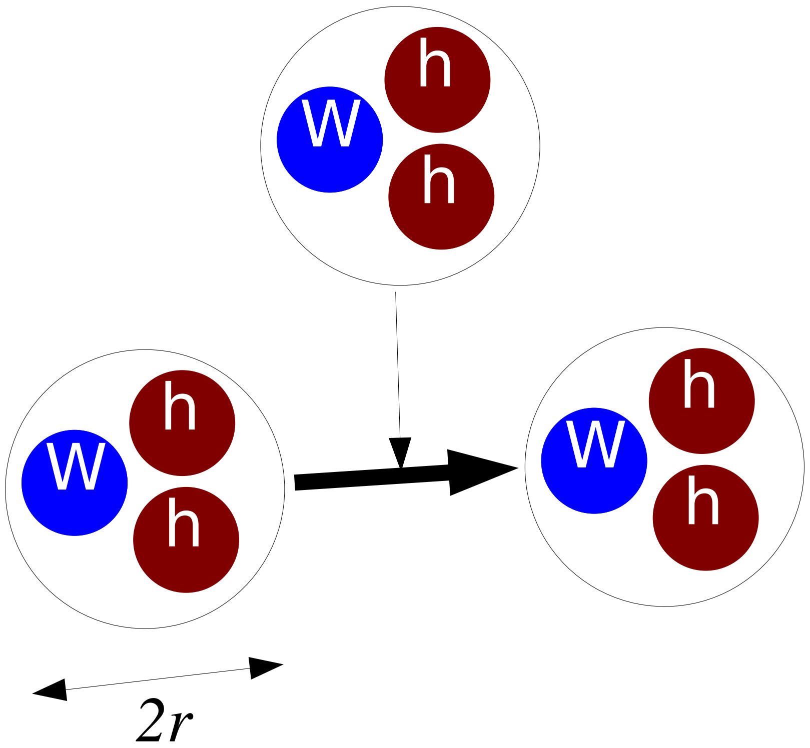

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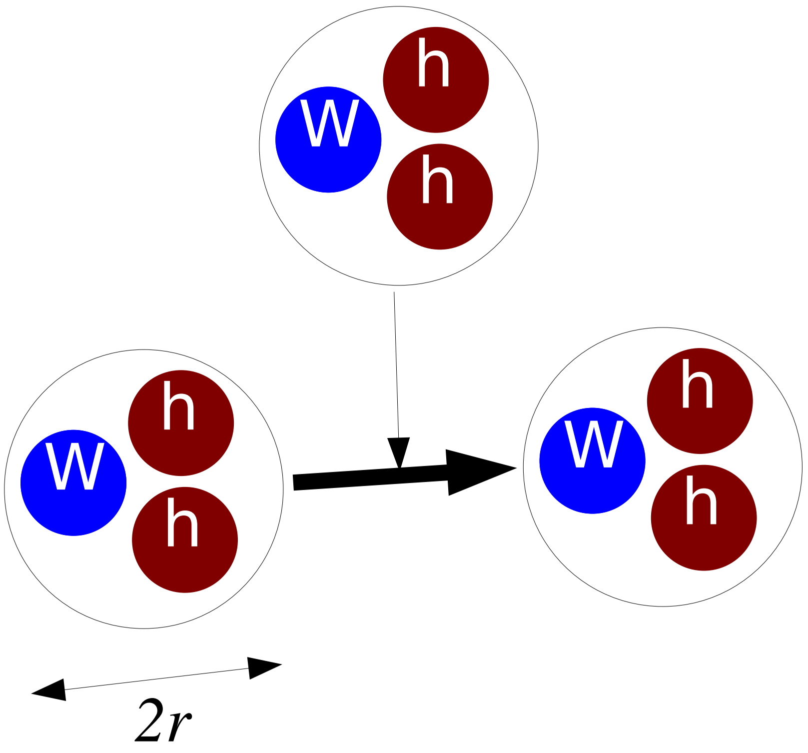

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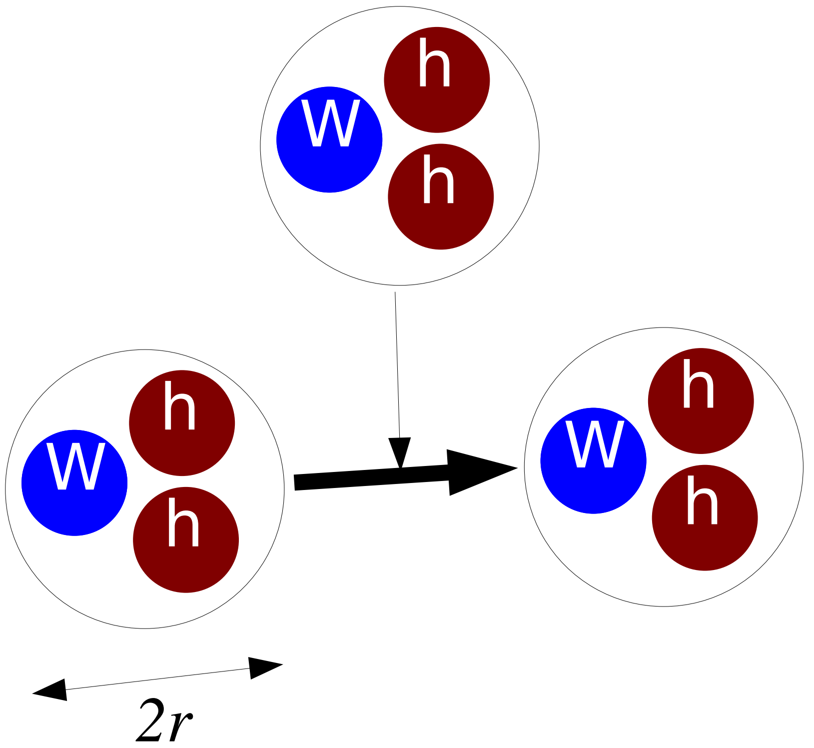

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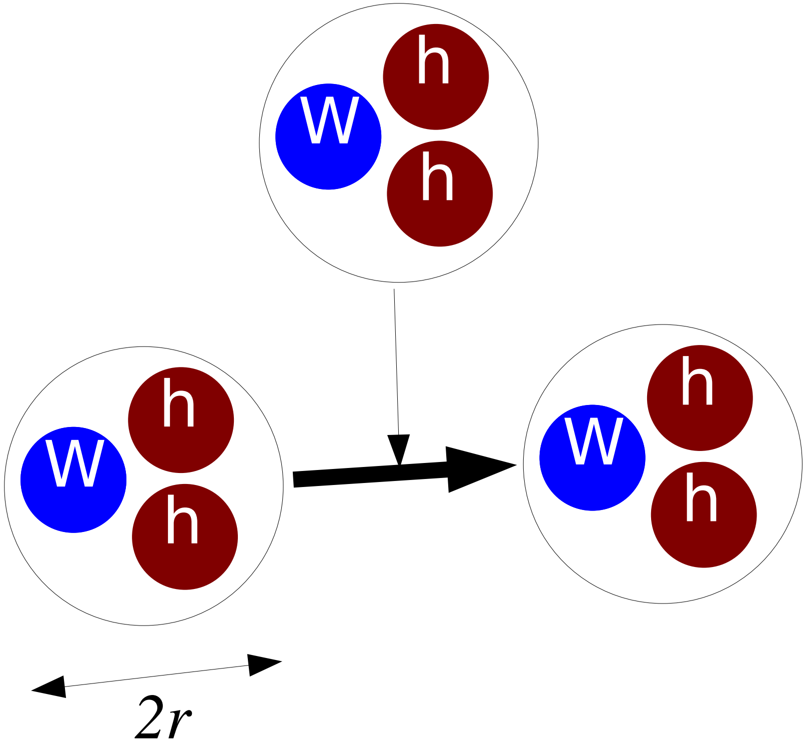

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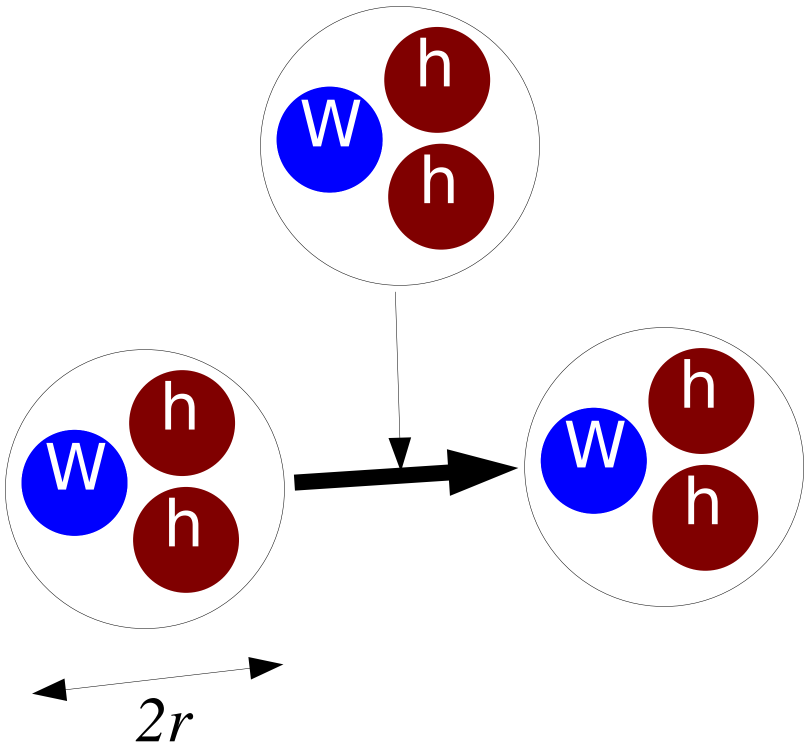

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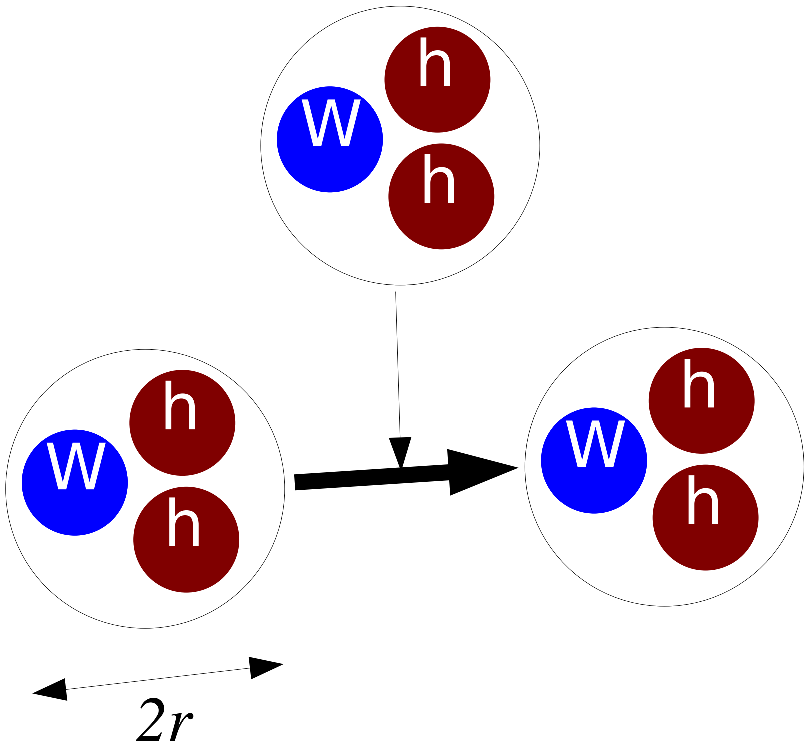

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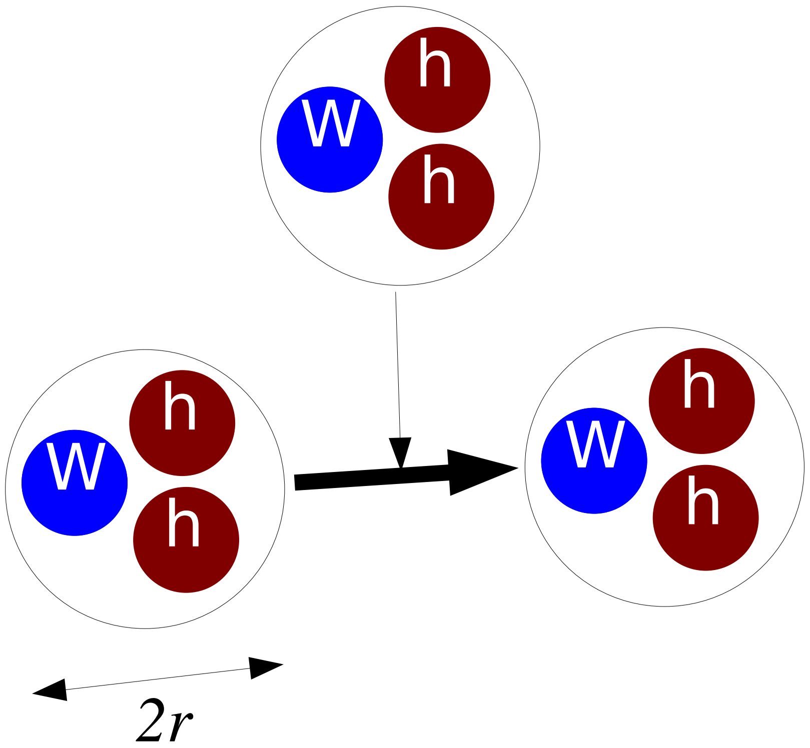

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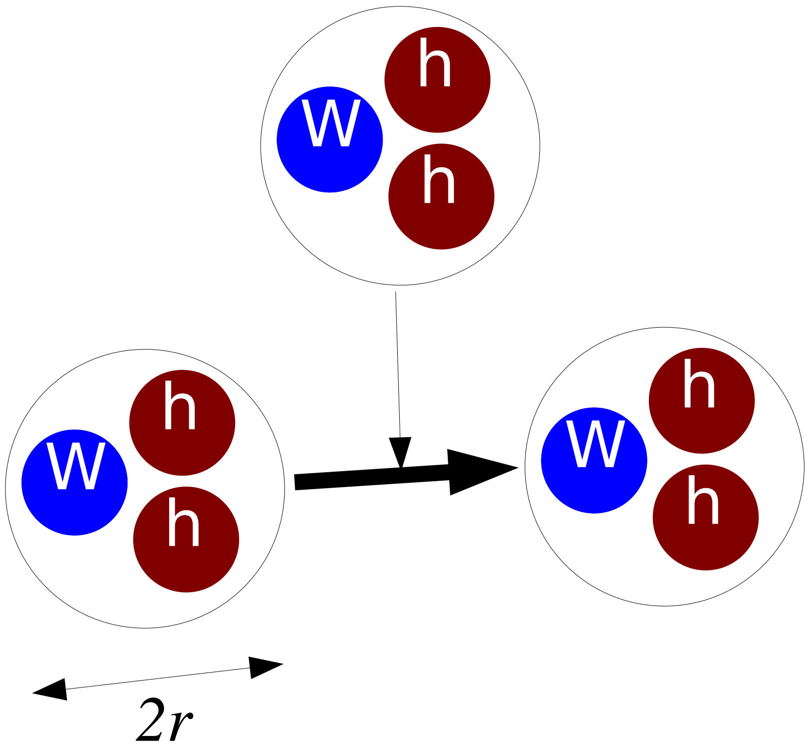

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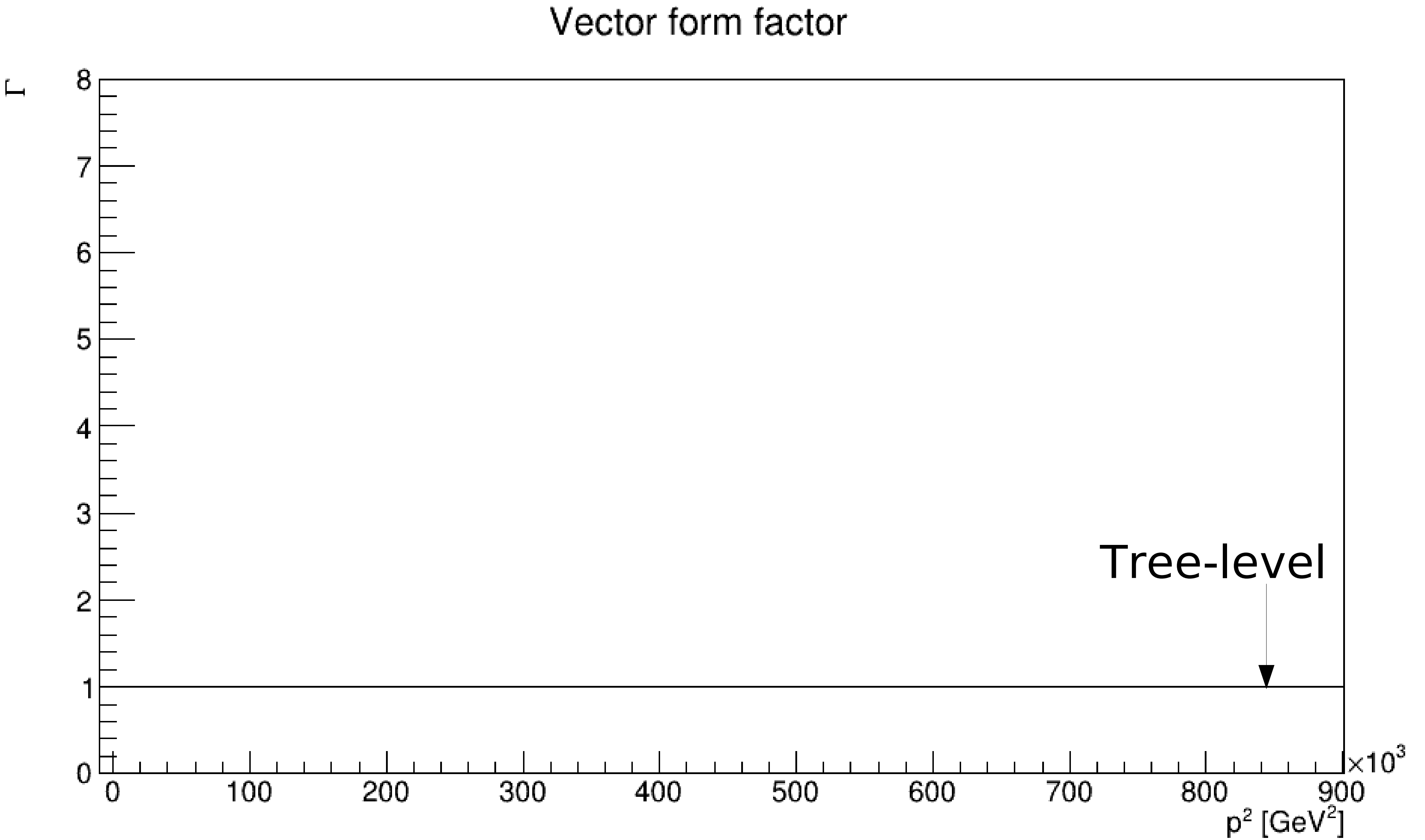
Bound states as extended objects

[Maas,Raubitzke,Törek'18]



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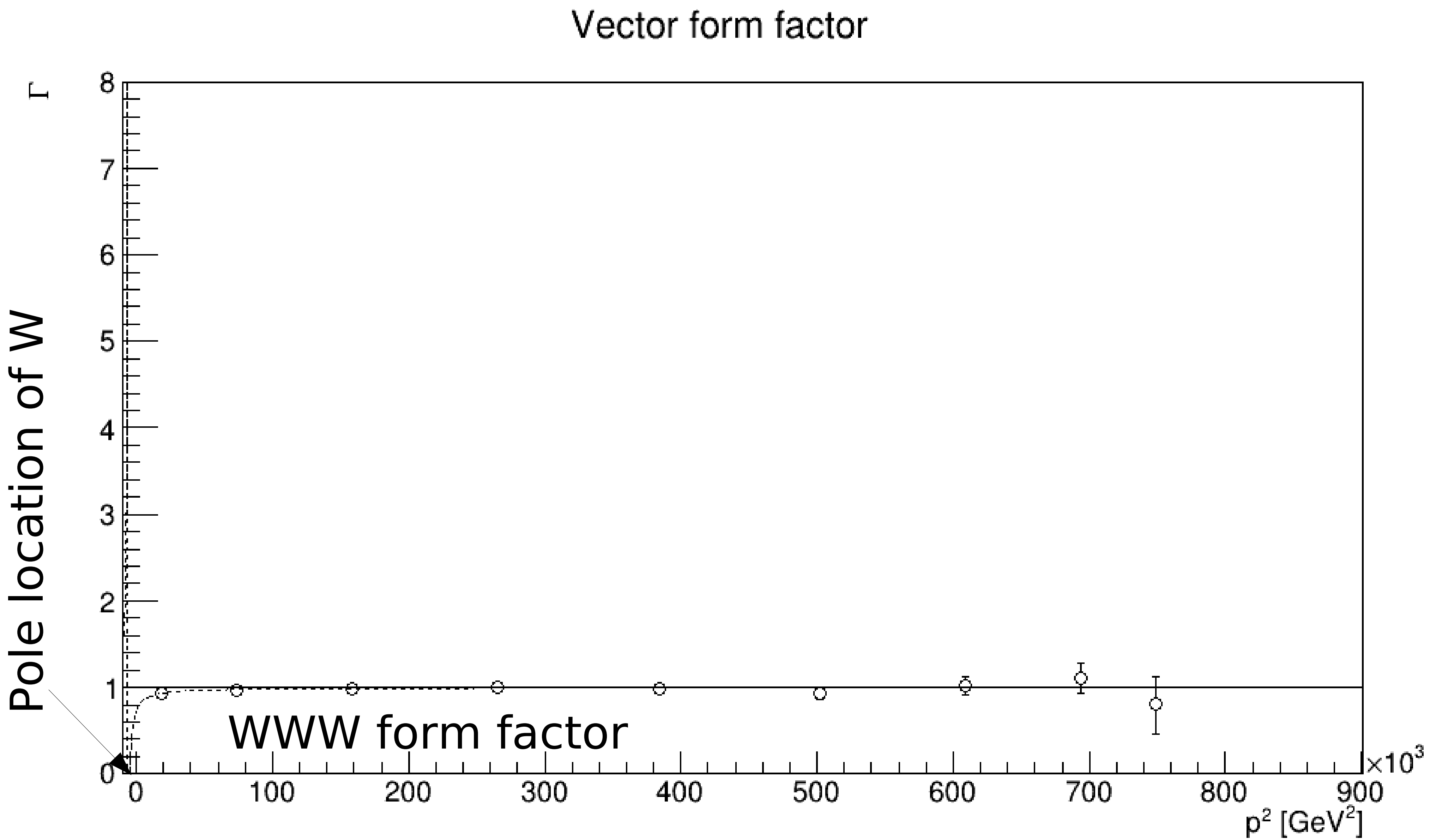

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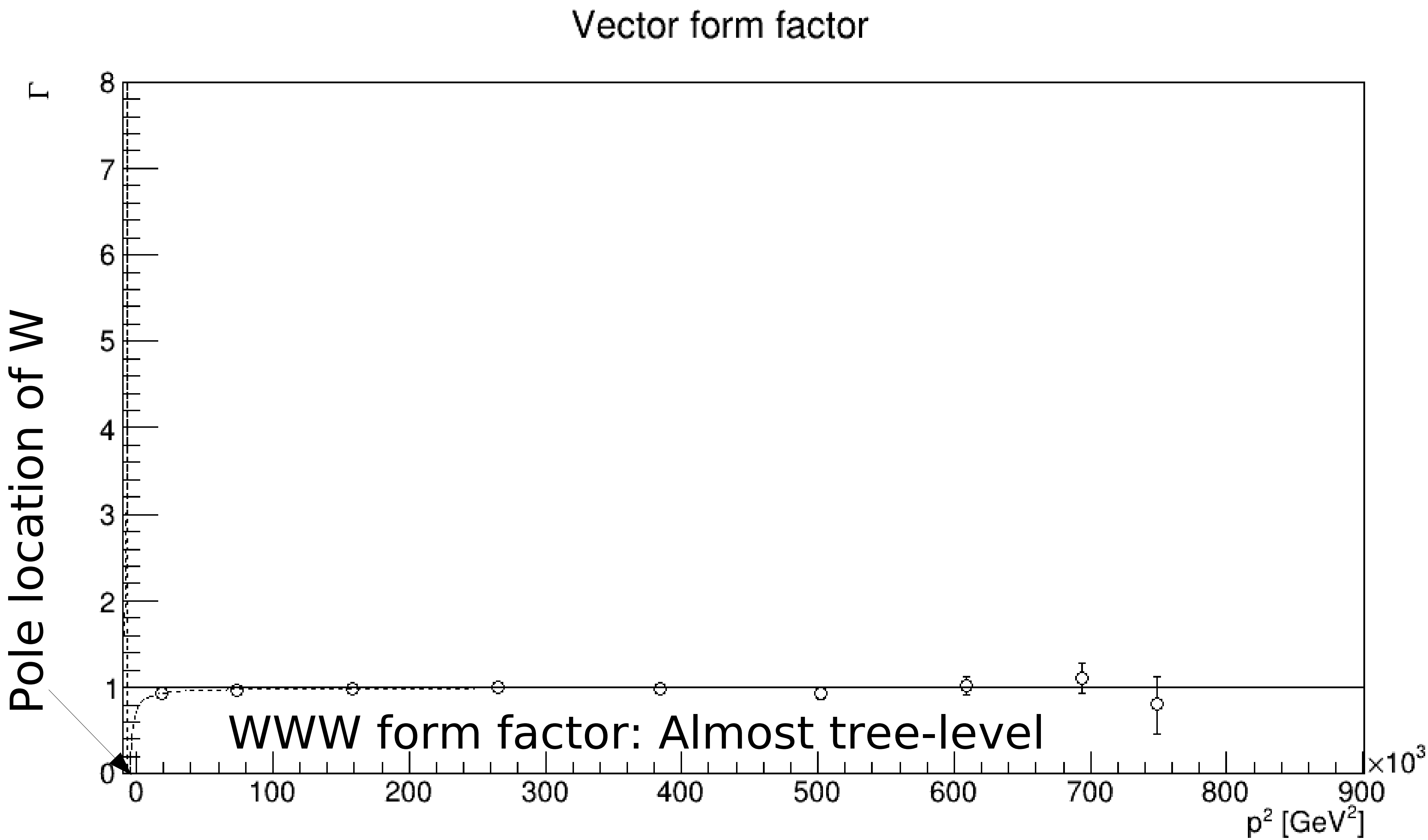

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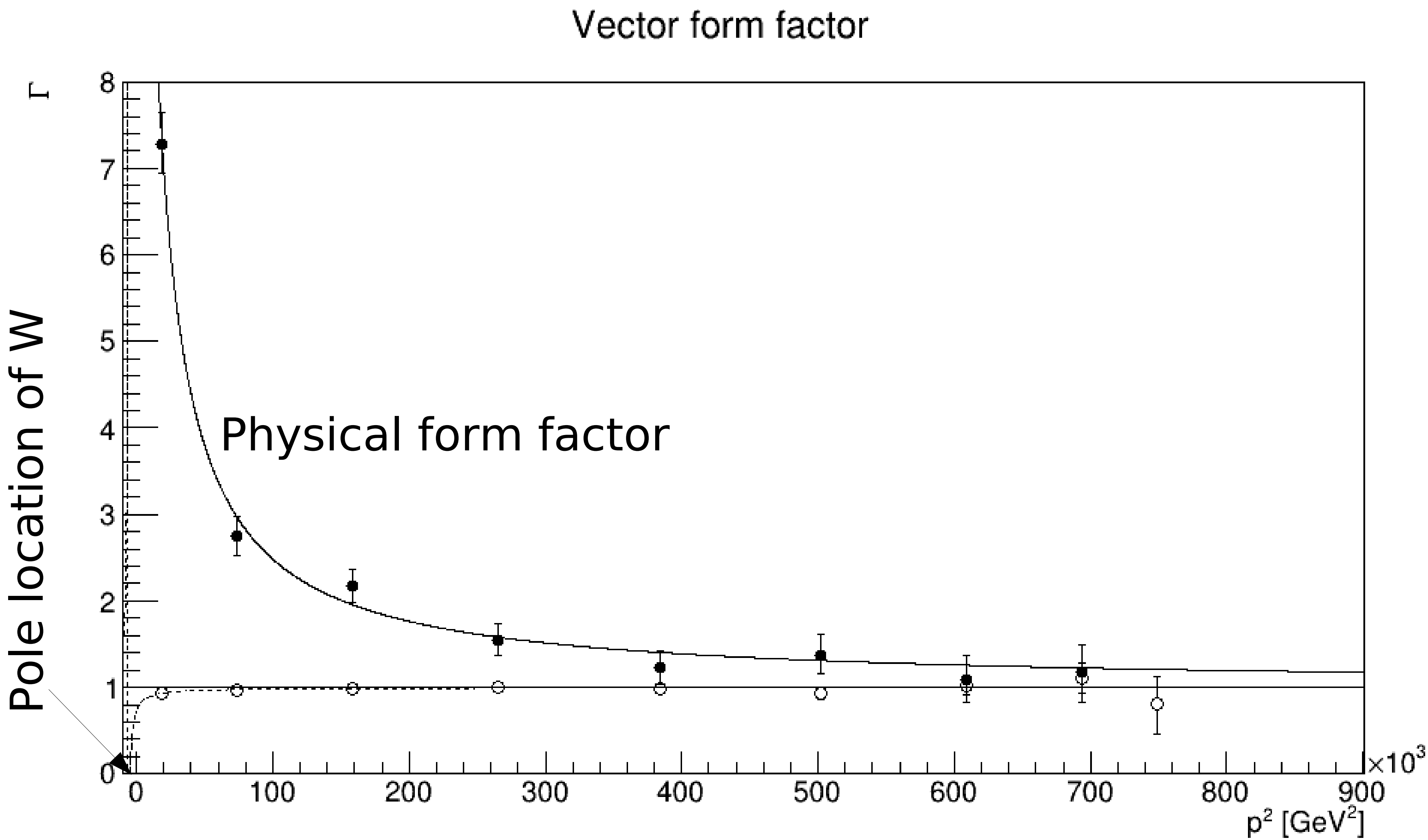

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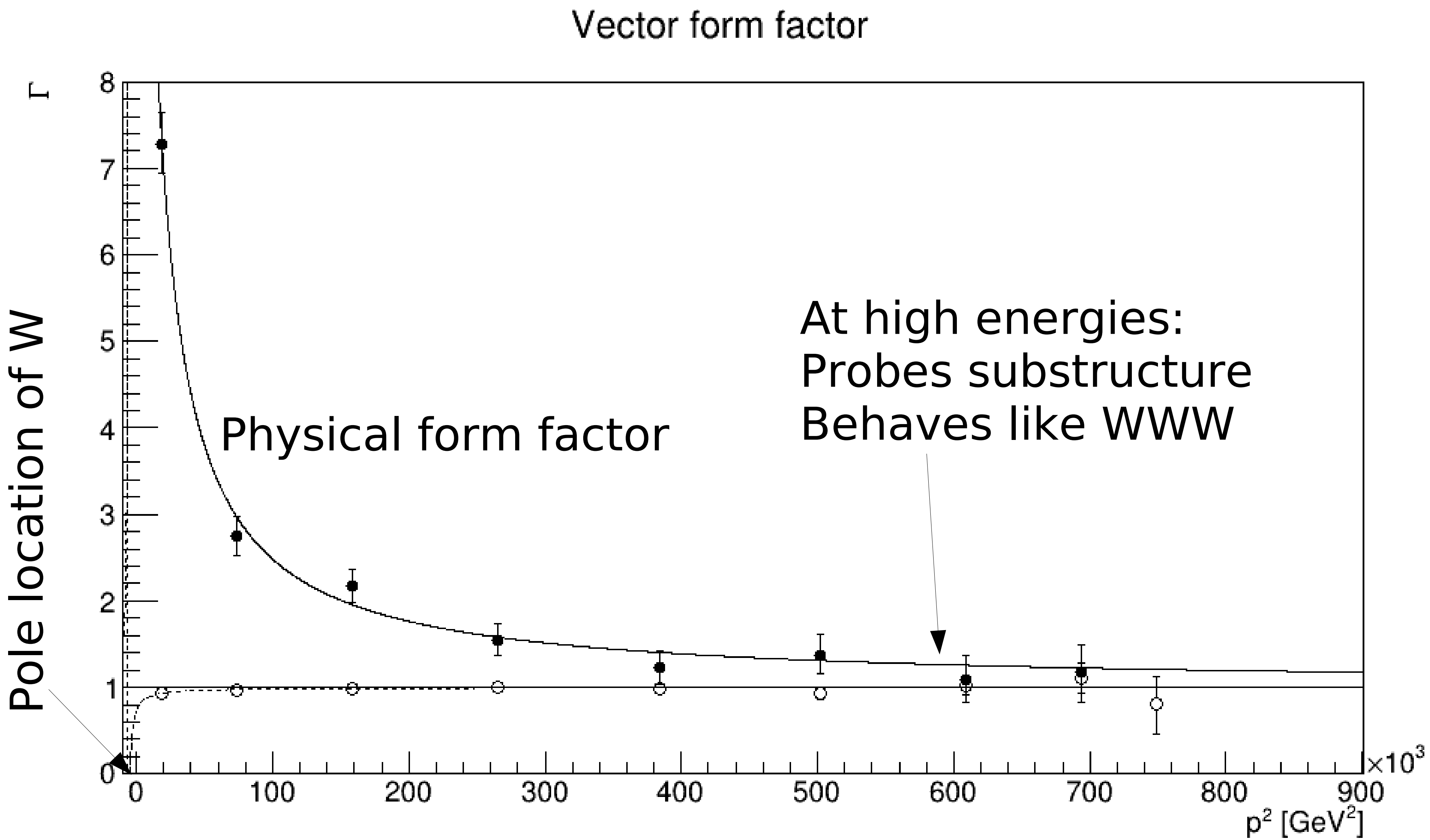

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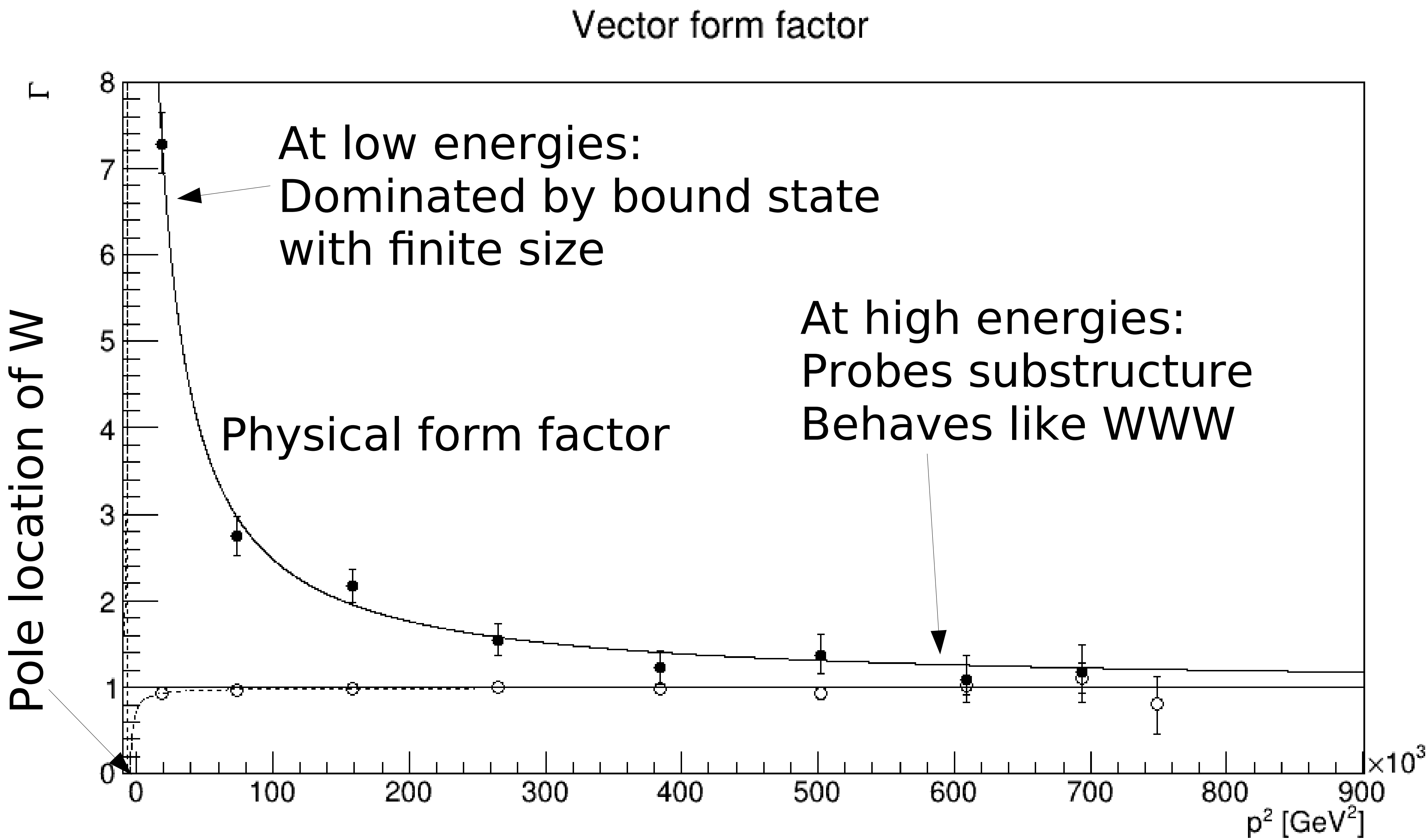

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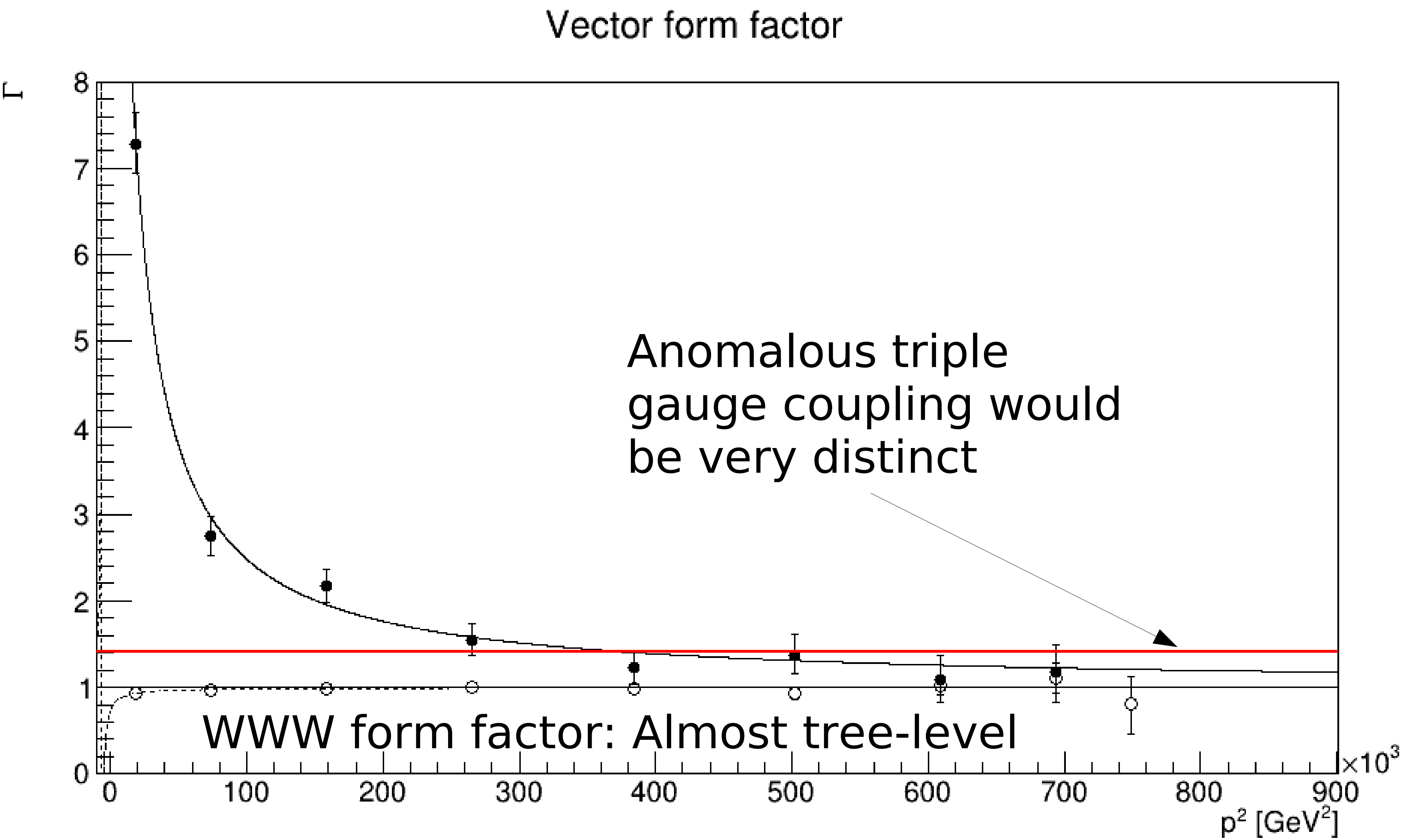

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Scattering

[Maas et al.'17
Maas & Reiner '22
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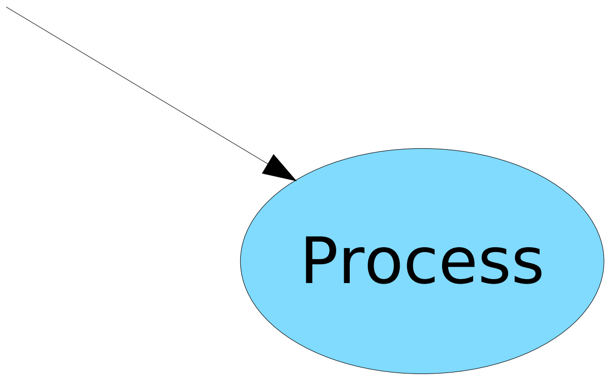
Incoming (asymptotic) particle
Standard LSZ: Elementary particle



$$\left\langle f\left(p\right)\ldots\right\rangle$$

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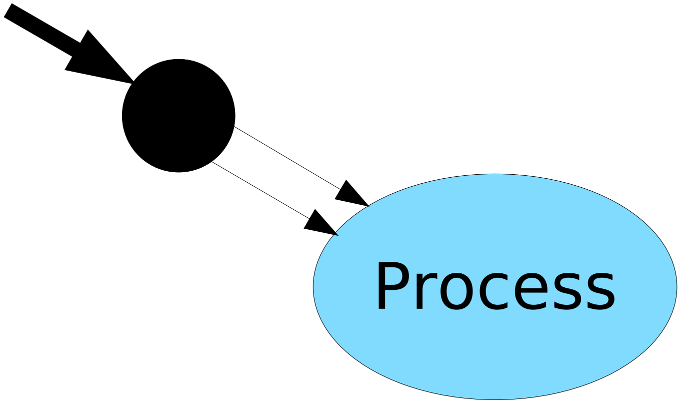

$$\langle (Hf)(p)\ldots \rangle$$

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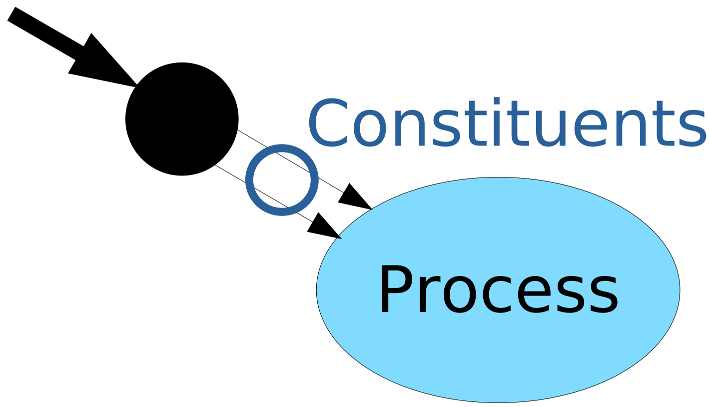

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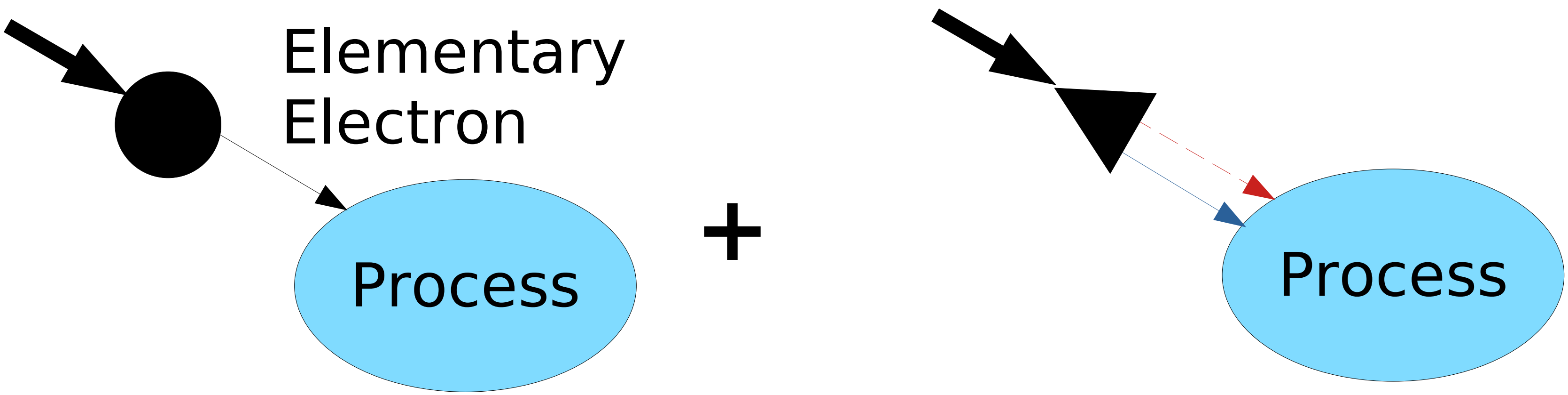

$$v\langle f(p)\dots\rangle + \int dq\,\Gamma(P,q)\,D_f(p-q)\,D_h(q)\langle h(q)\,f(P-q)\dots\rangle$$

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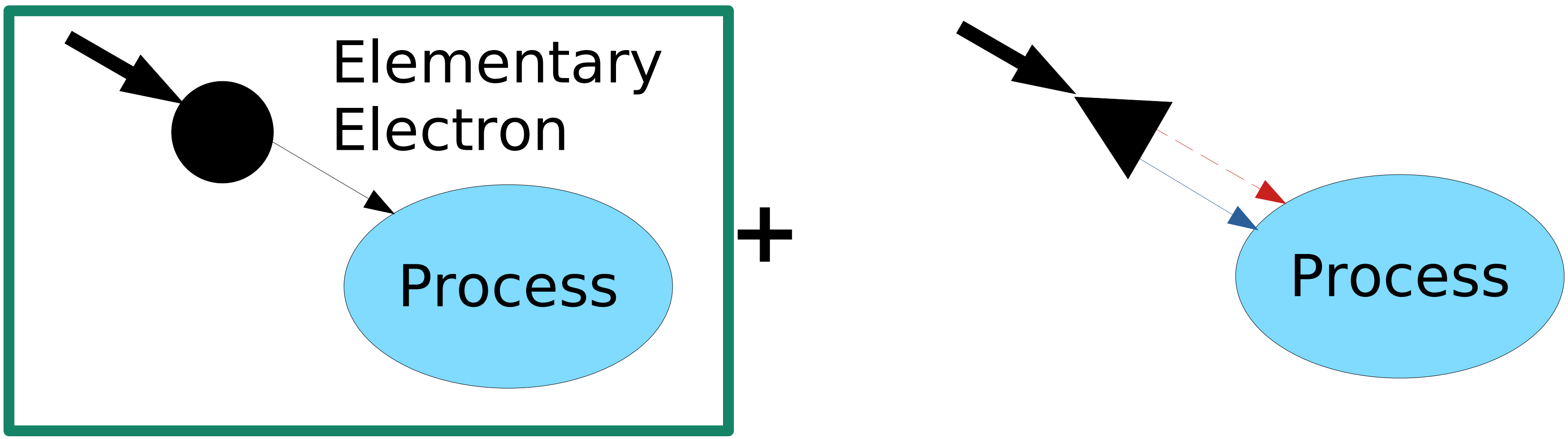

Standard perturbation theory

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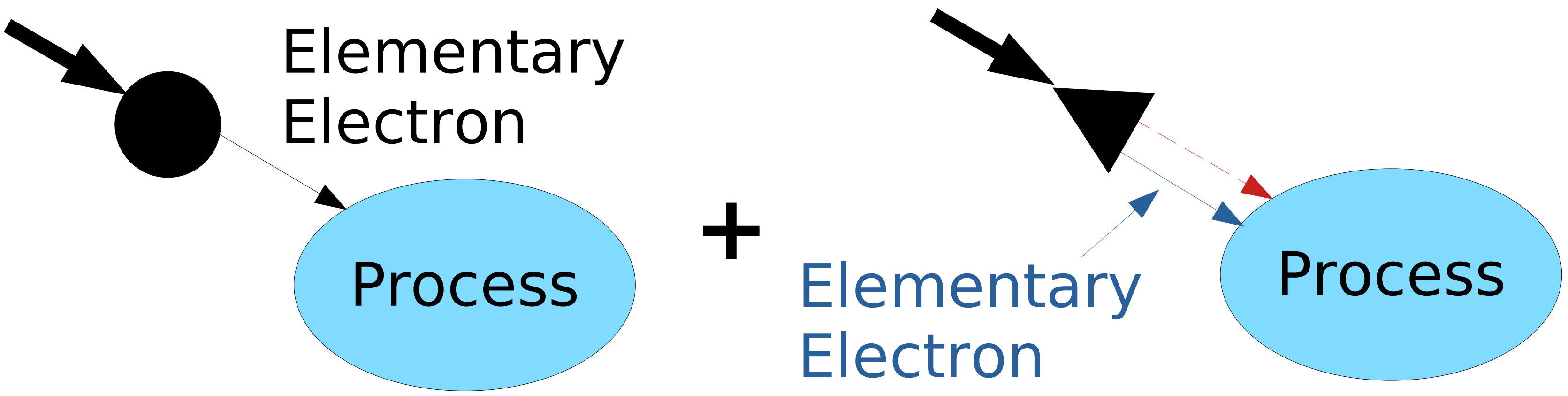

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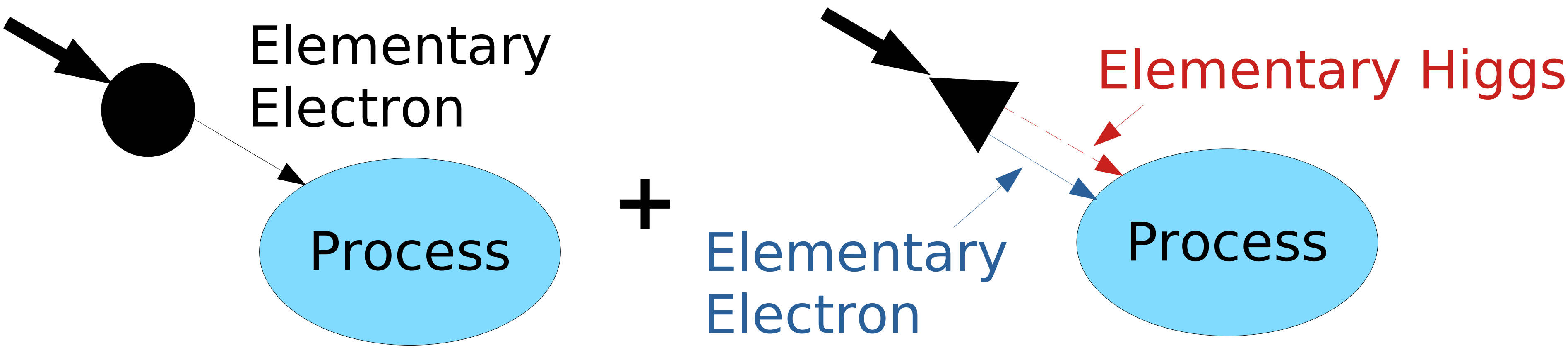

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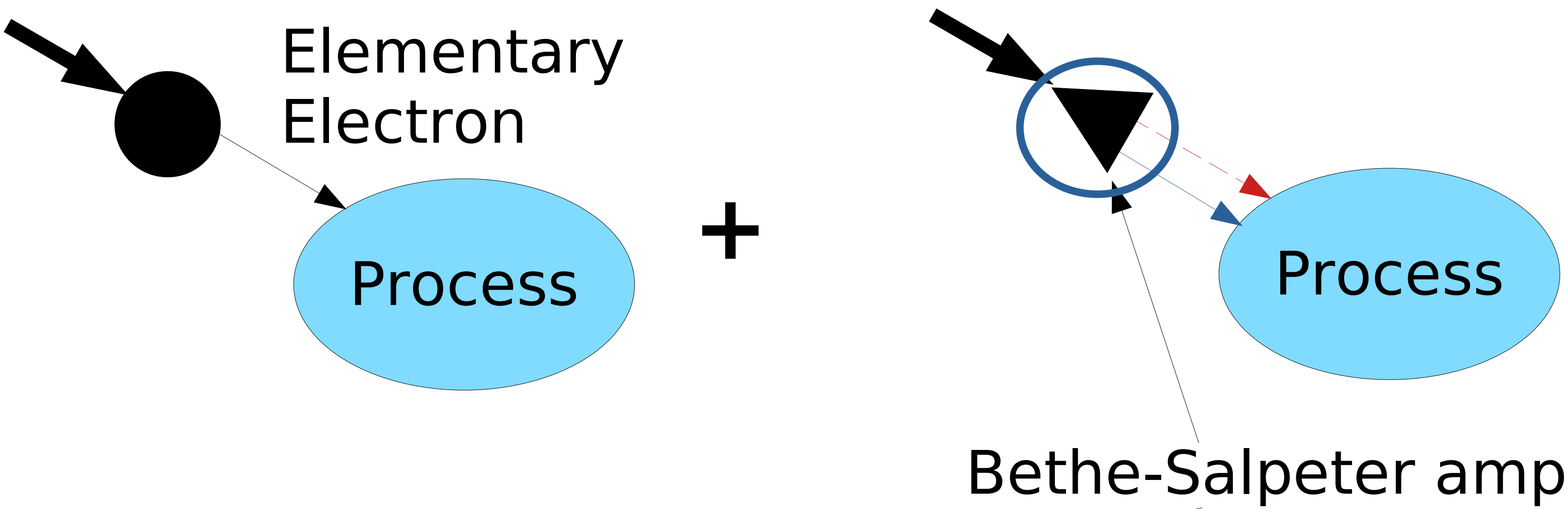

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Bethe-Salpeter Amplitude

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Calculable itself in augmented perturbation theory

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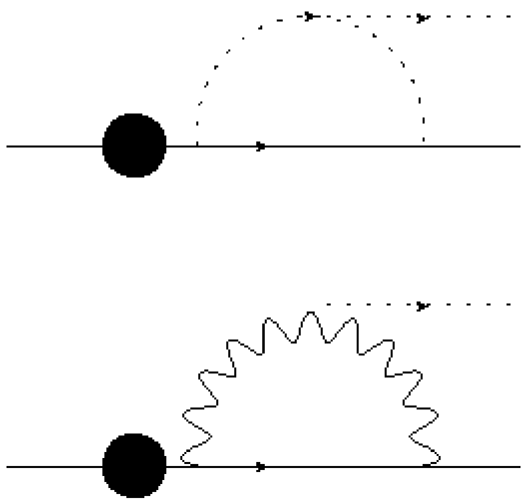

$$v_i \Gamma^{ffh}_{ijk}(P, P-q, q)$$

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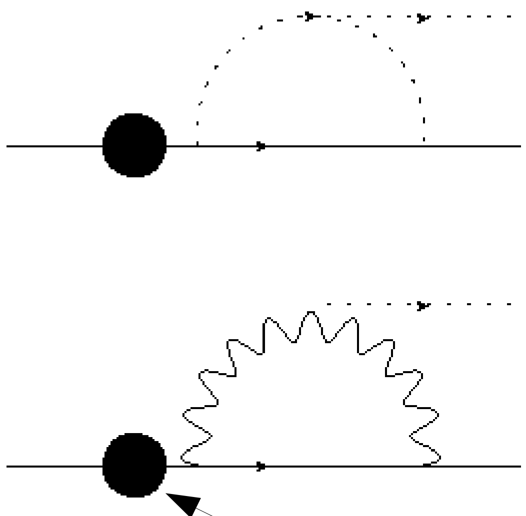

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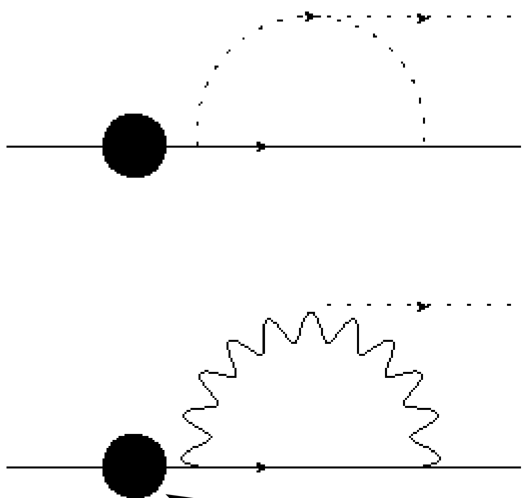

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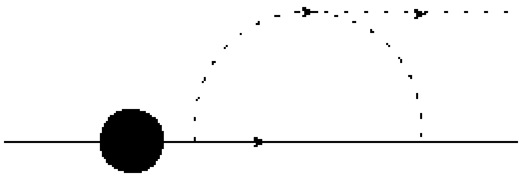

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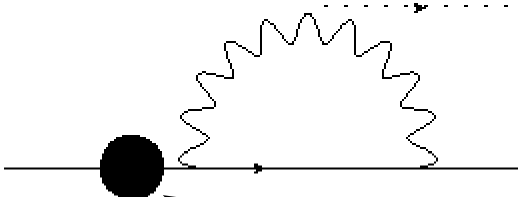

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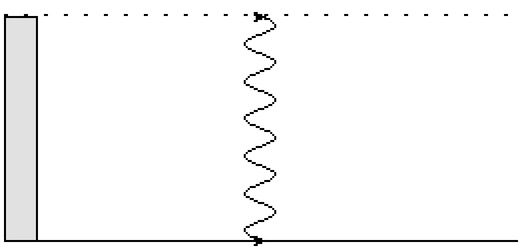

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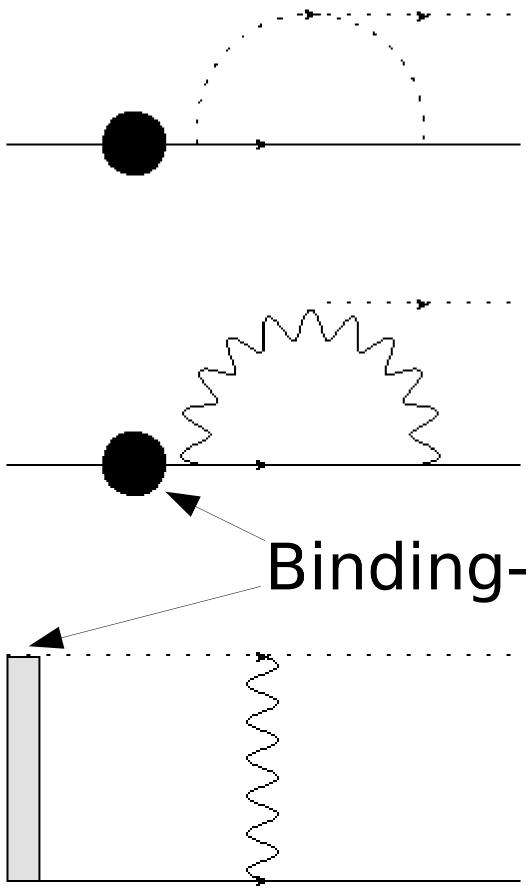

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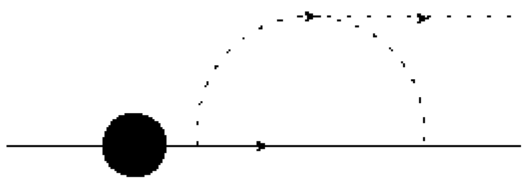

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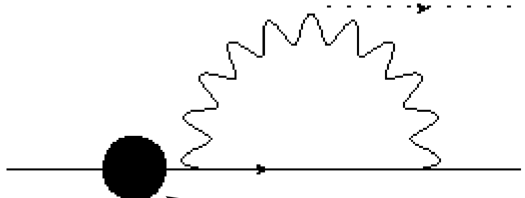

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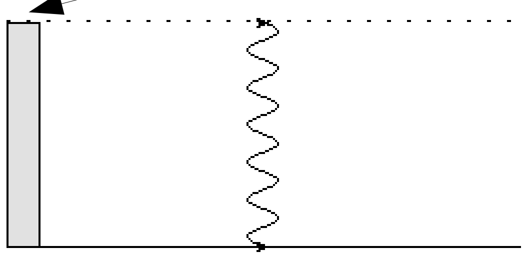

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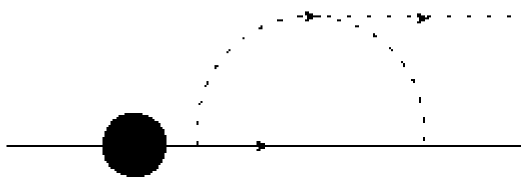

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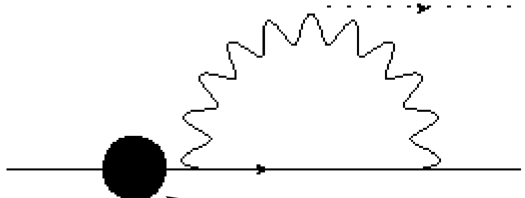

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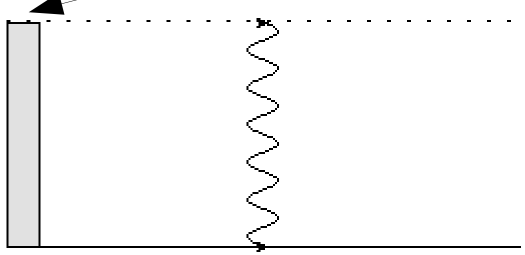

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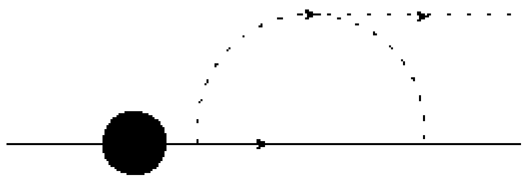

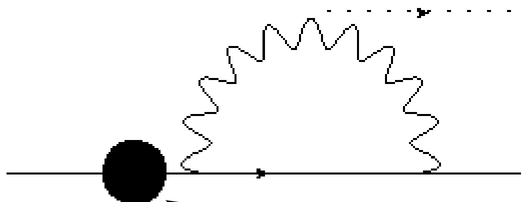

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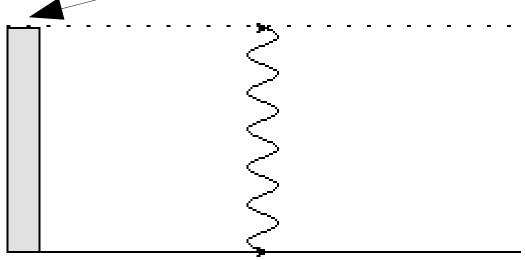

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But neither are Yukawa suppressed

Impact in VBS/VBF

- Elastic region: $160/180\,GeV \leqslant \sqrt{s} \leqslant 250\,GeV$
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Cross section

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Matrix element

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Partial wave amplitude

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Legendre polynom

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Scattering length~"size"

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→ **Lattice Lüscher analysis**

Phase shifts in VBS/VBF

- Reduced SM: Only W/Z and the Higgs
  - Parameters slightly different
    - Higgs 145 GeV and weak coupling larger

[Jenny, Maas, Riederer’22]

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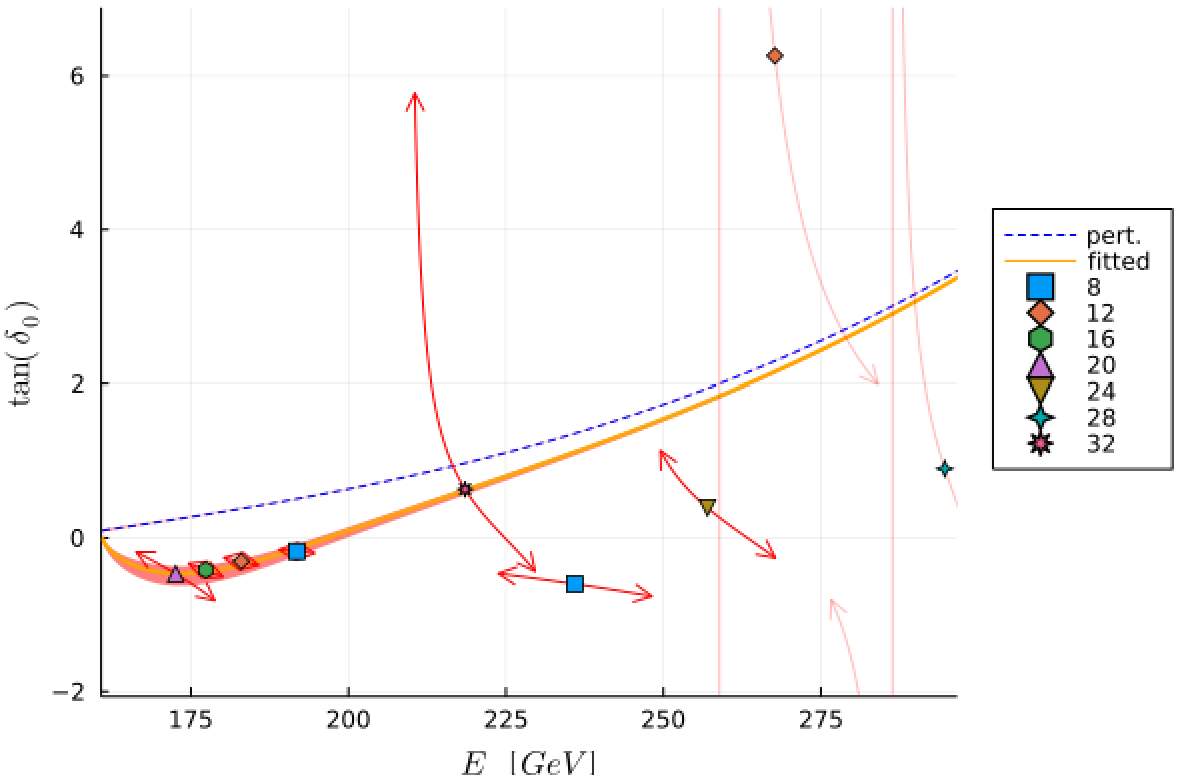

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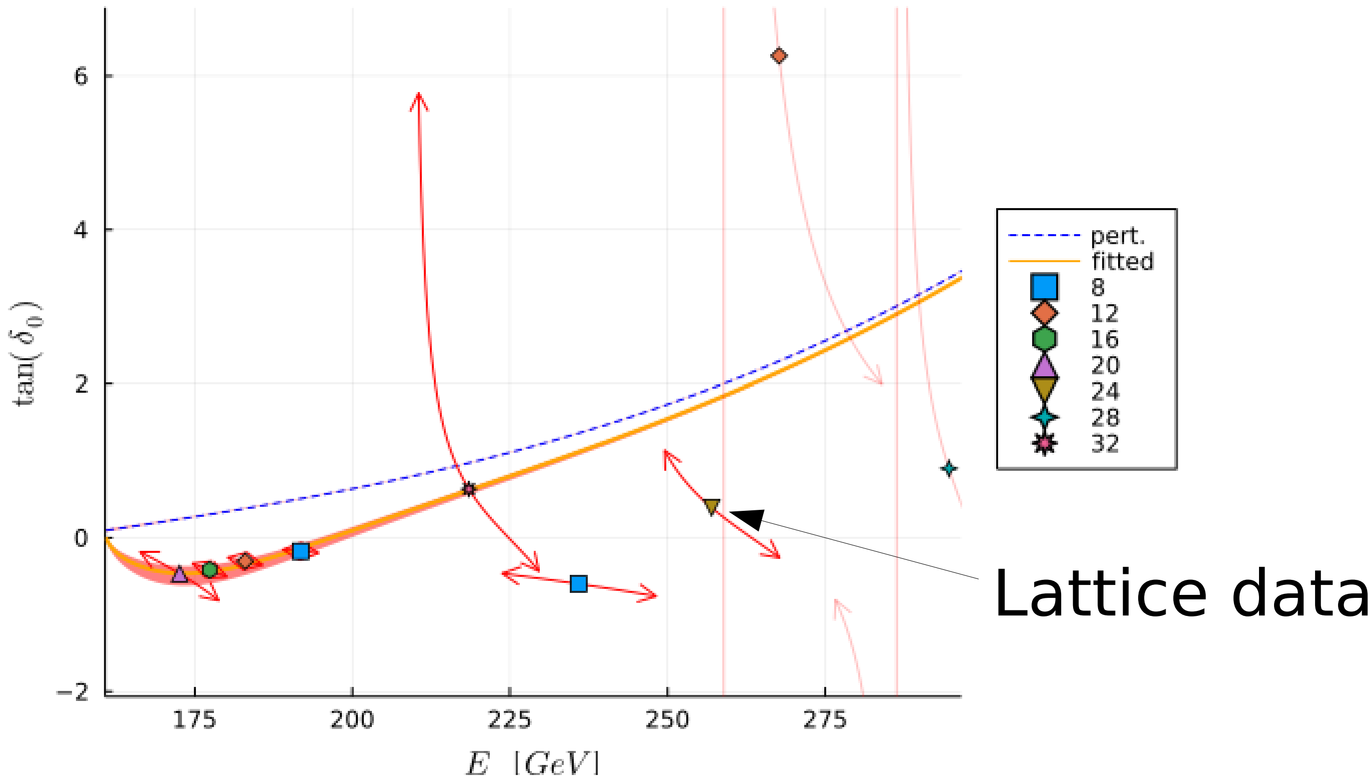

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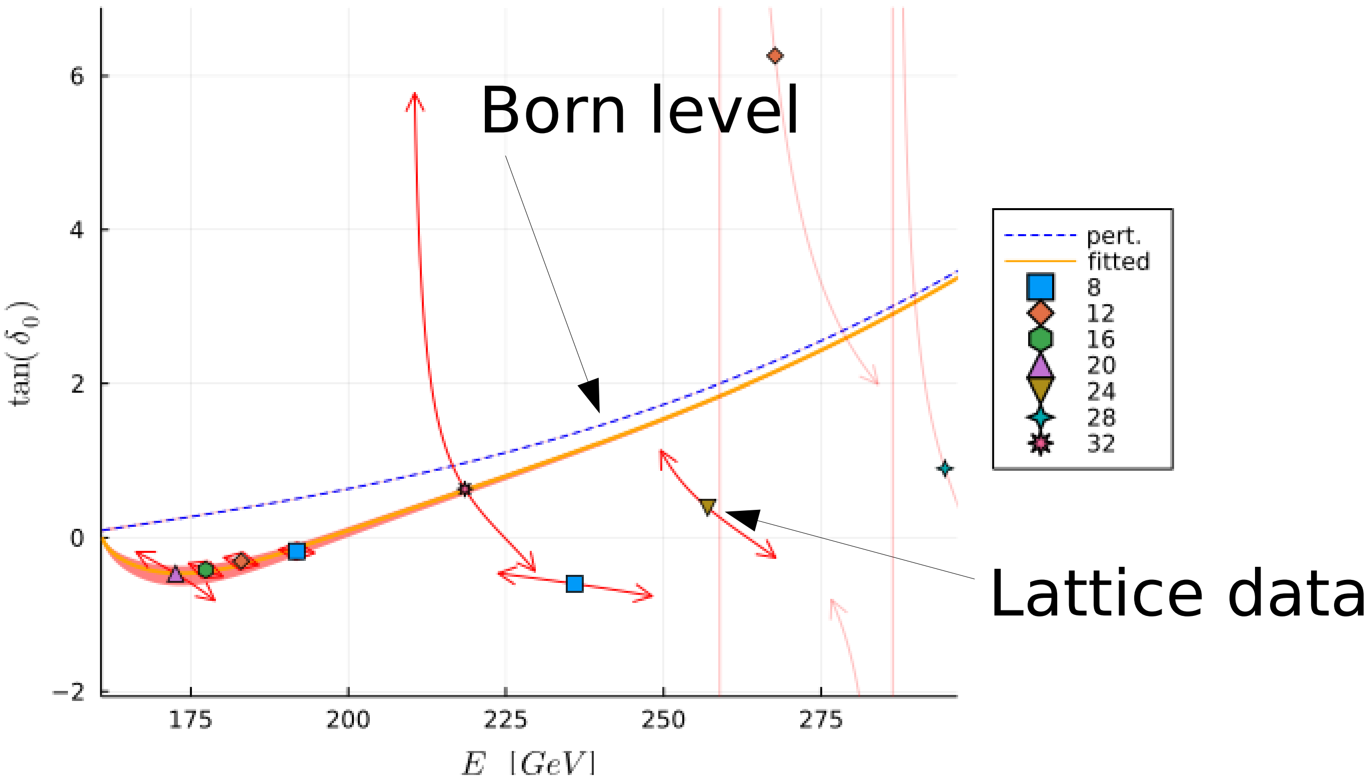

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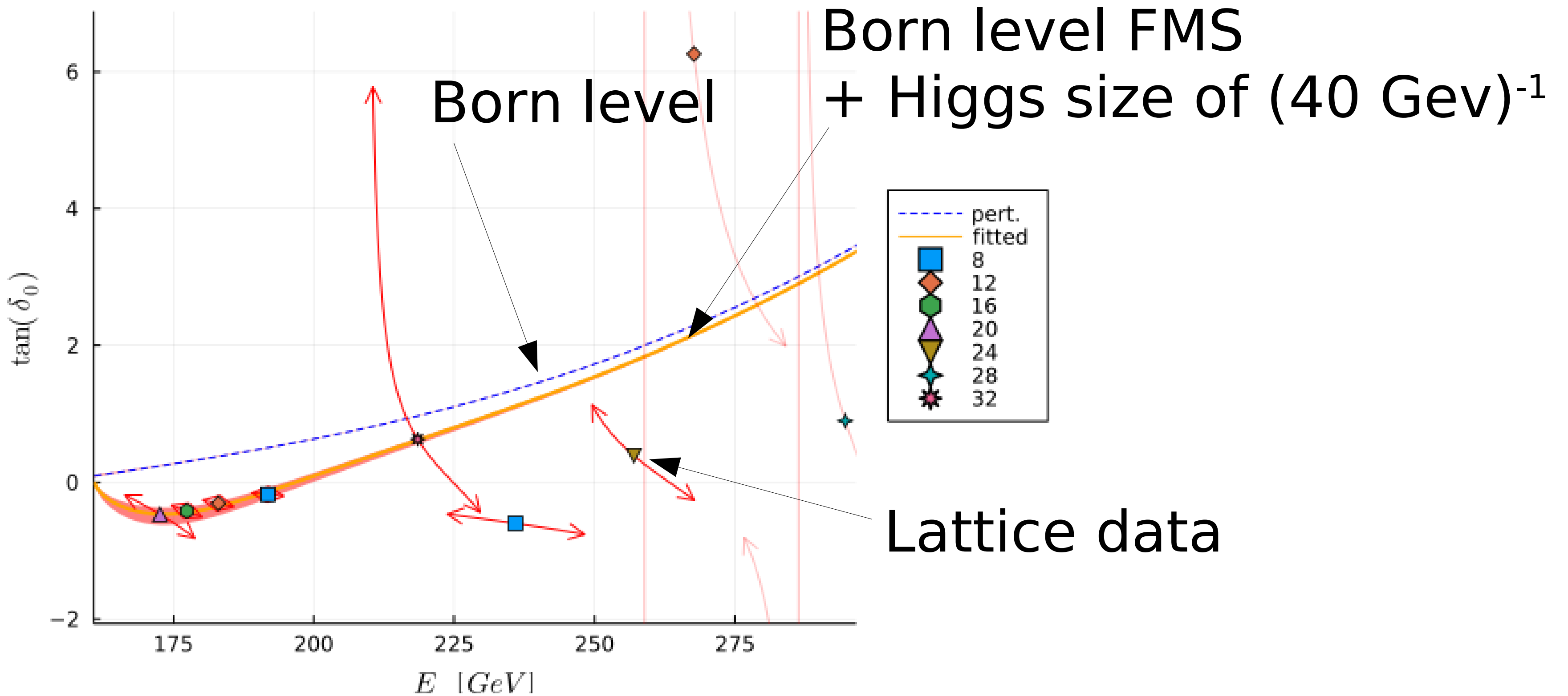

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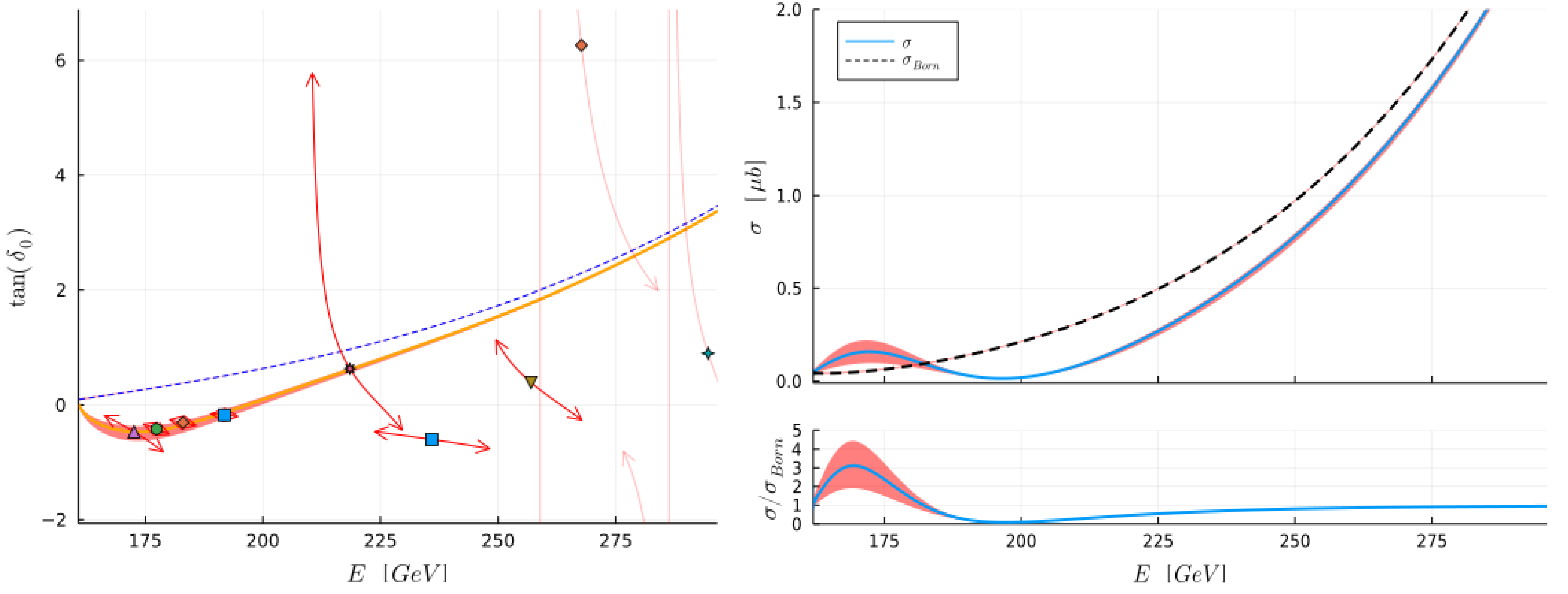

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Resummation effects

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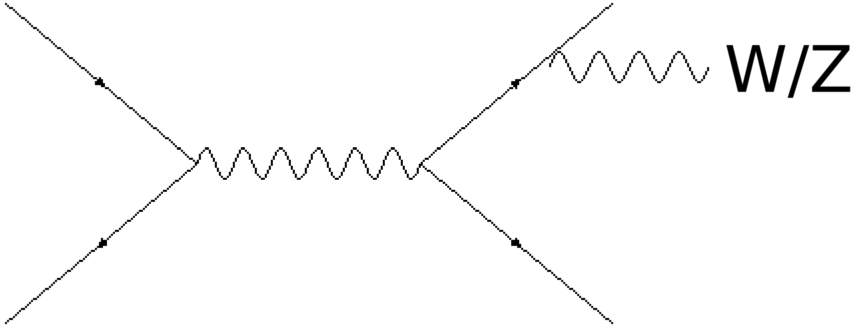

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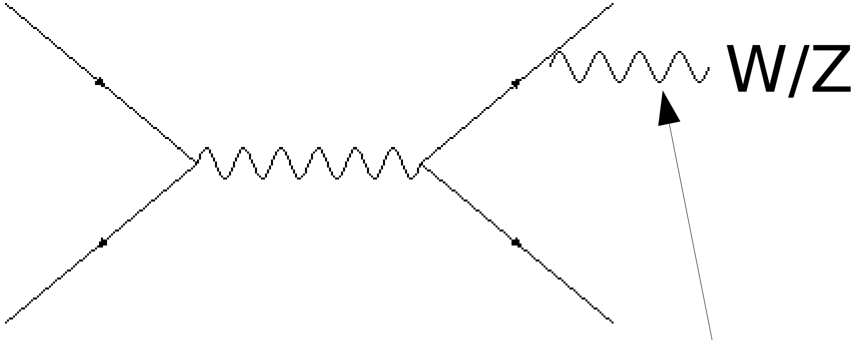

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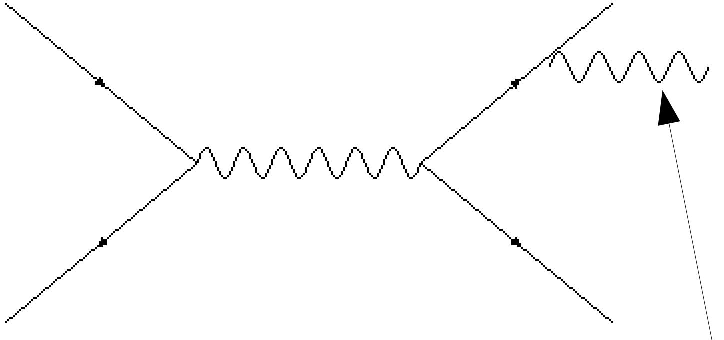

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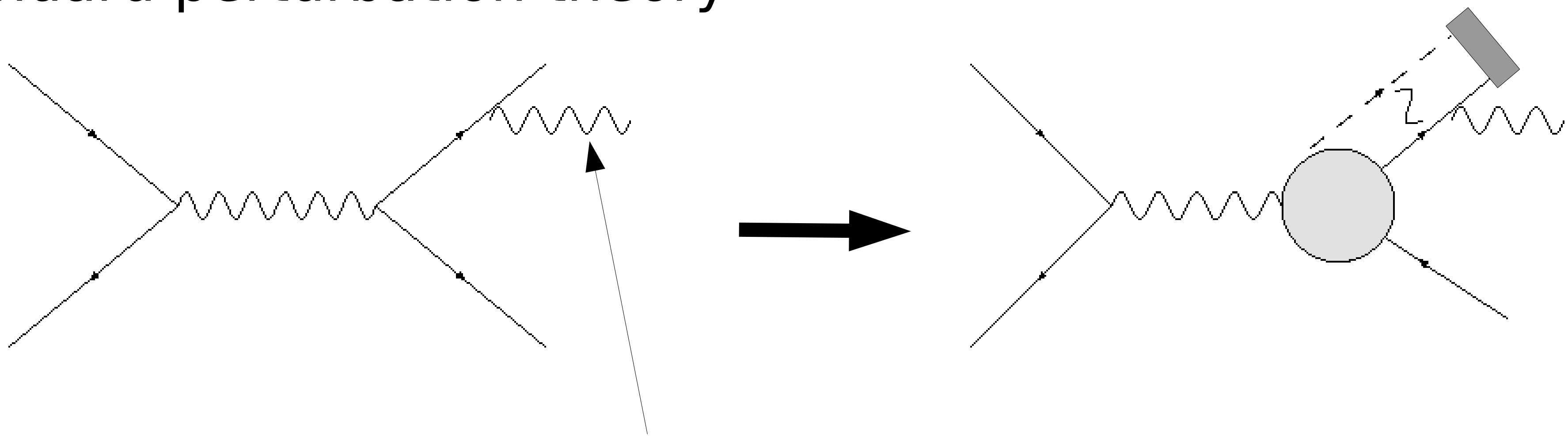

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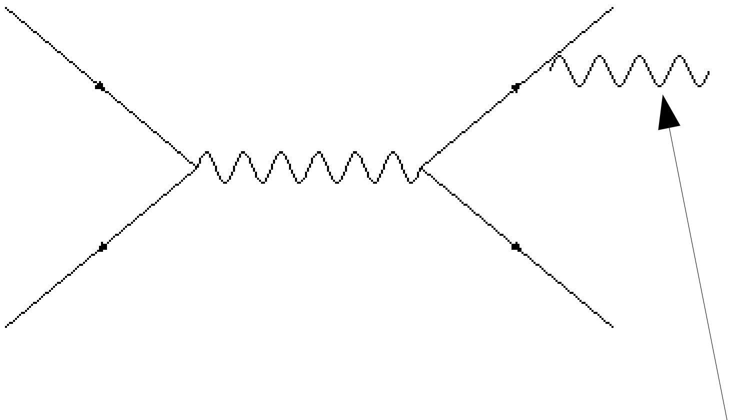

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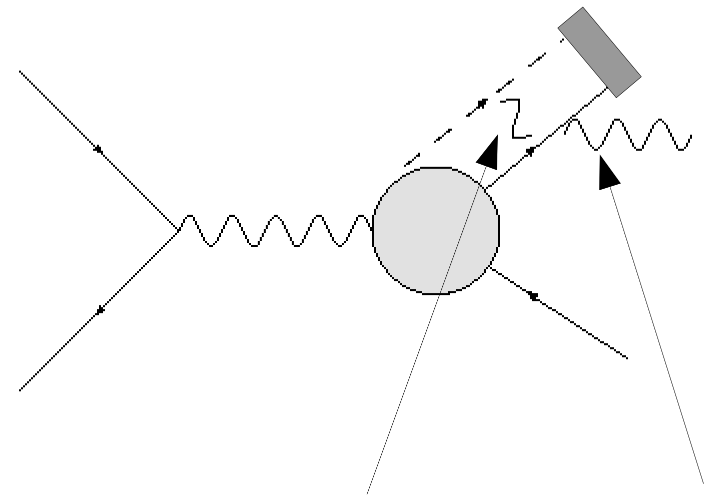

Virtual and real
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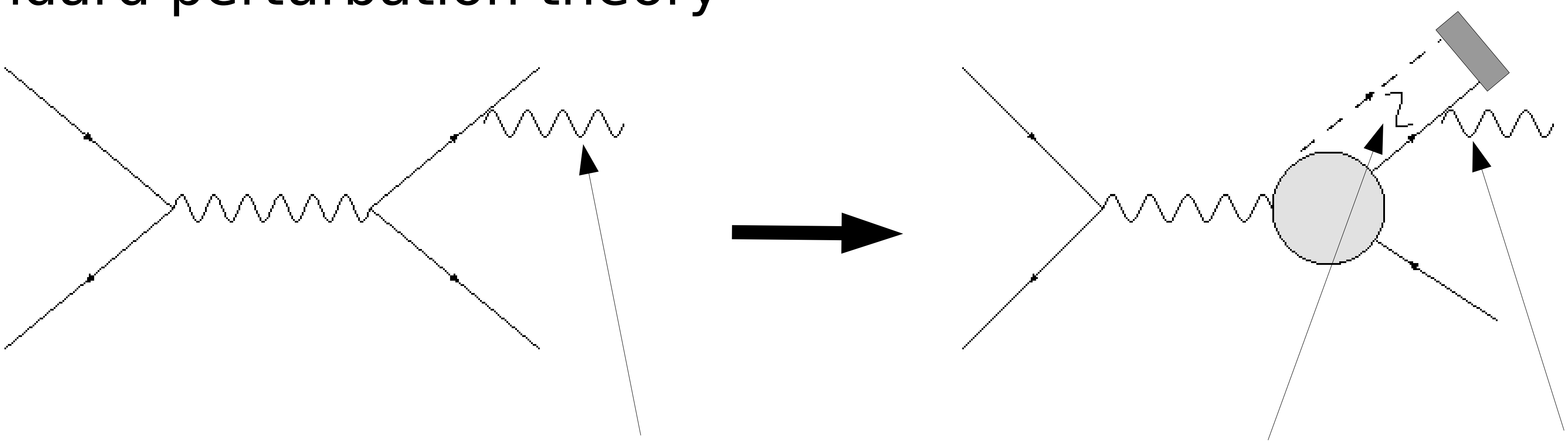

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Virtual and real emissions compensate (BN/KLN theorems)
- substantial change: Cancel this effect

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Review: 1712.04721
Update: 2305.01960

- Field theory requires change of asymptotic states
  - Can be treated using FMS-augmented perturbation theory
  - Changes in the SM at one or two loop orders

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