Talk for Discovery PhD-day

Loop-corrections in Gauge Theories

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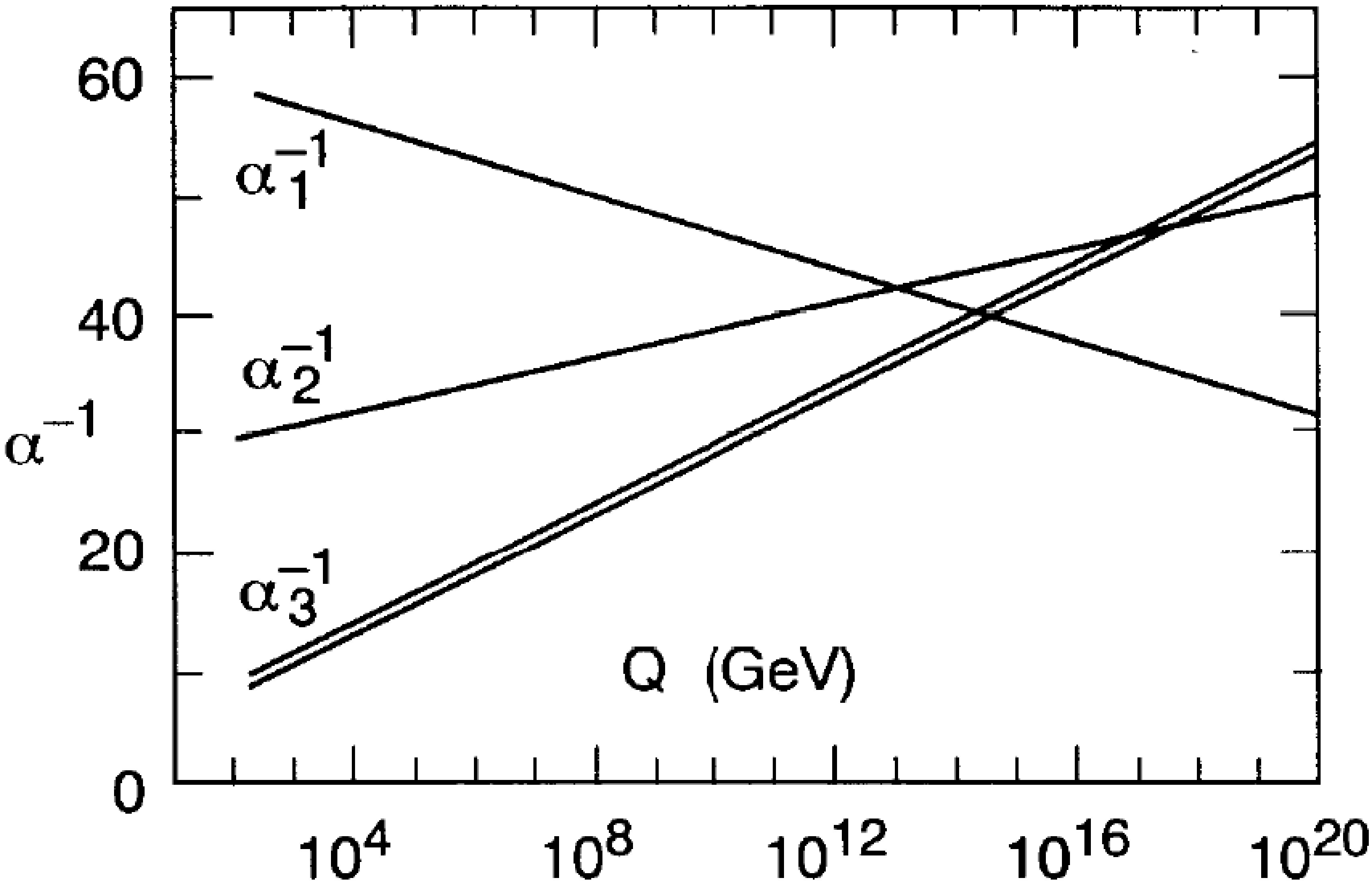
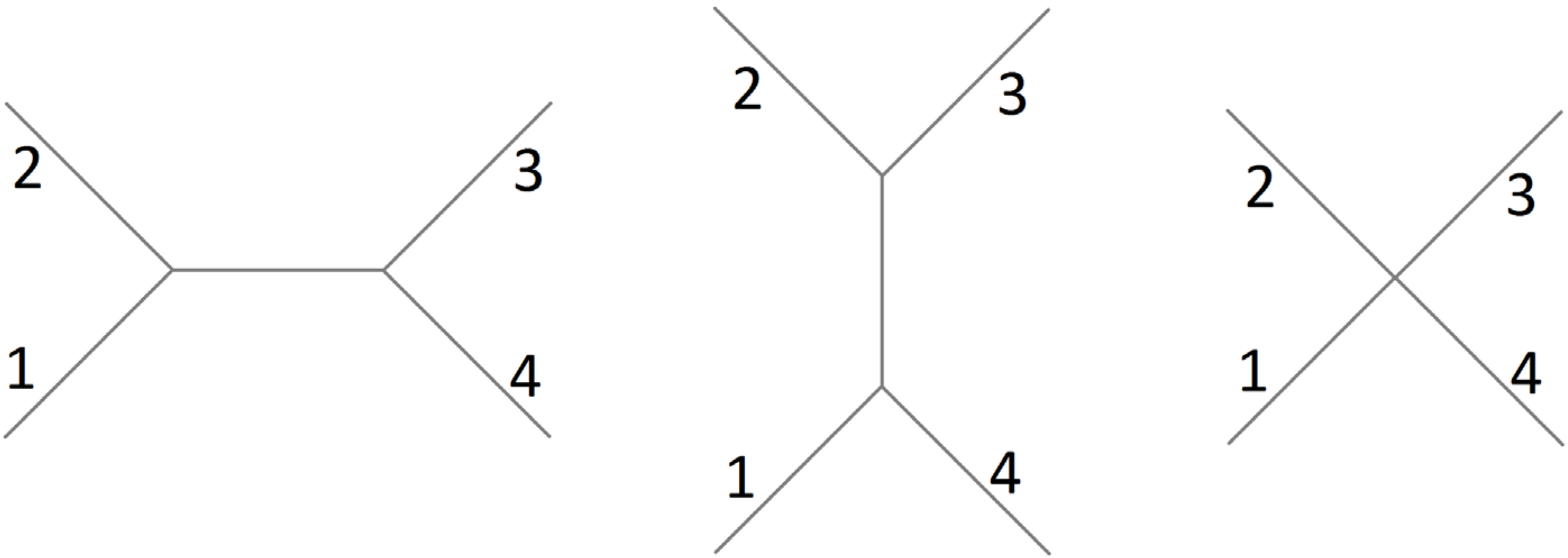


60
40
20
0
α^{-1}
α_1^{-1}
α_2^{-1}
α_3^{-1}
Q (GeV)
10^4
10^8
10^{12}
10^{16}
10^{20}

$$g_1 + g_2 \to g_3 + g_4$$

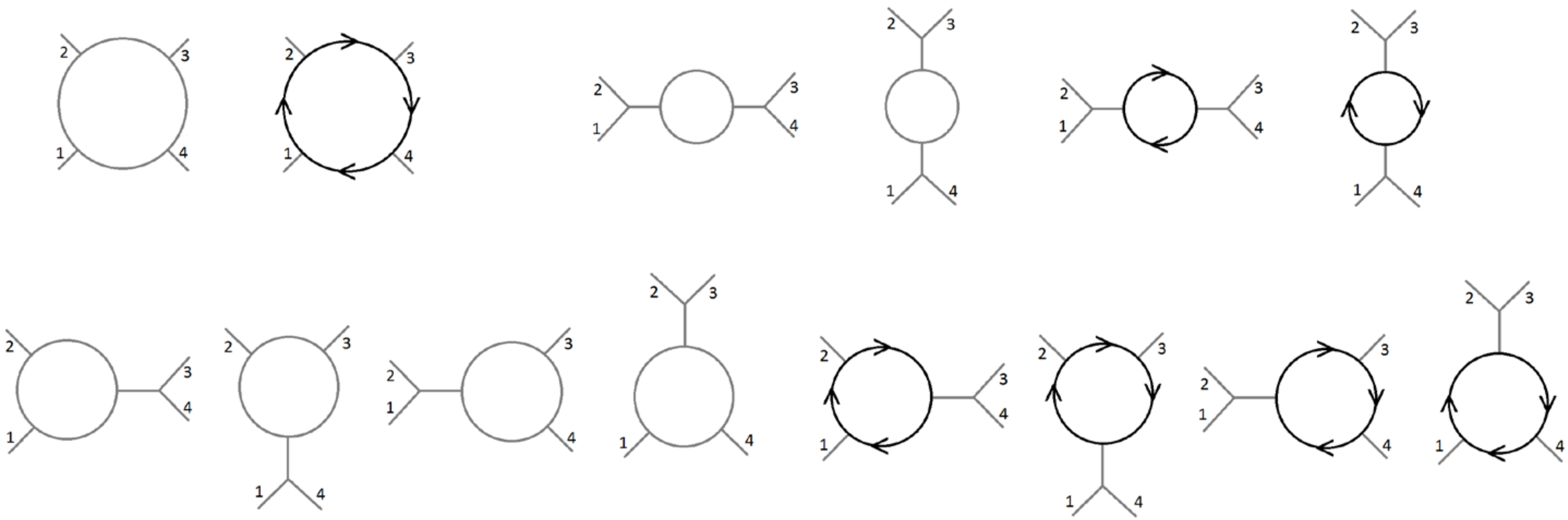
Tree-level:



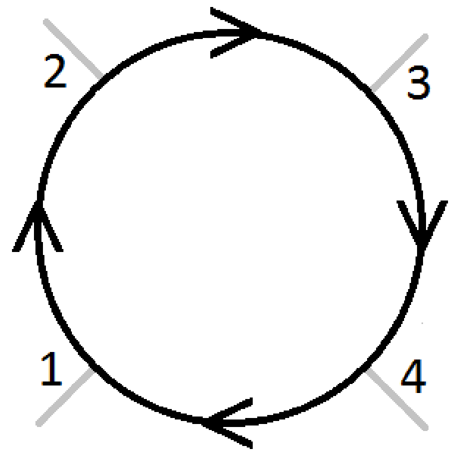
colour-ordered.

$$g_1 + g_2 \to g_3 + g_4$$

1-loop-level:



in the m=0 limit.



means

$$\int \frac{\mathrm{d}^d k}{(4\pi)^{d/2}} \frac{\mathrm{Tr}\Big(\not{k}\gamma^\sigma(\not{k}+\not{p}_4)\gamma^\tau(\not{k}+\not{p}_1+\not{p}_2)\gamma^\nu(\not{k}+\not{p}_1)\gamma^\mu\Big)}{k^2(k+p_4)^2(k+p_1+p_2)^2(k+p_1)^2}\epsilon_\mu(p_1)\epsilon_\nu(p_2)\epsilon^*_\tau(p_3)\epsilon^*_\sigma(p_4)$$

in the m=0 limit.

At loop-order there are

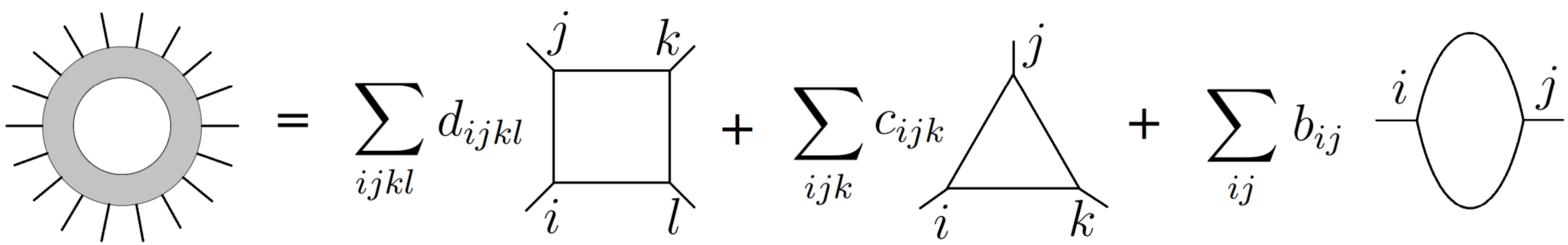
Many diagrams

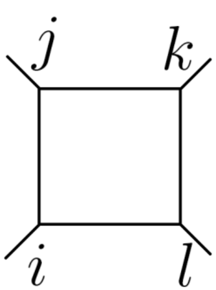
With complicated expressions

Conclusion: Don’t do the calculation using Feynman diagrams!

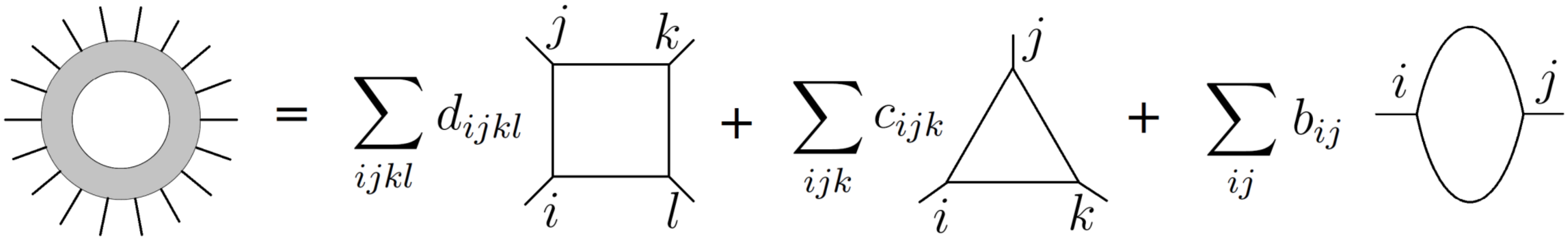
Trick: “Generalized Unitarity”.

Write the amplitude as a sum of “boxes”, “triangles”, and “bubbles”.



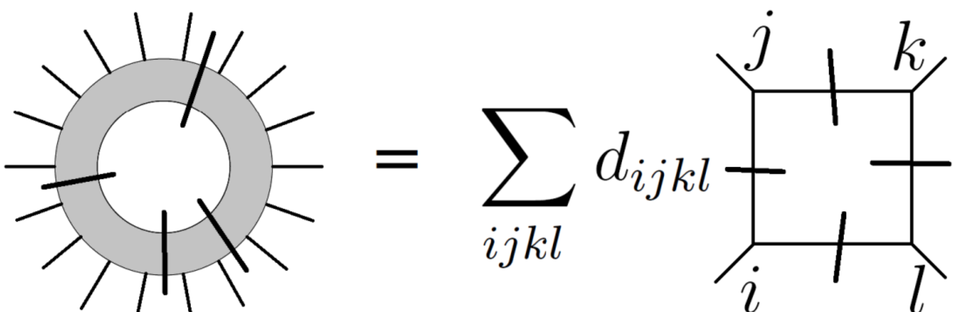


$$\equiv \int \frac{\mathrm{d}^d k}{(4\pi)^{d/2}} \frac{1}{(k-P_i)^2(k-P_j)^2(k-P_k)^2(k-P_l)^2}$$



Apply "Quaduple-cut"

cut: $$\frac{1}{\left(k-P_i\right)^2} \rightarrow \delta\left(k-P_i\right)$$



$$\Rightarrow d_{ijkl} = \mathcal{A}_i \mathcal{A}_j \mathcal{A}_k \mathcal{A}_l$$

The one-loop case was completed long ago (2009)
Recent research is on two and more loops.

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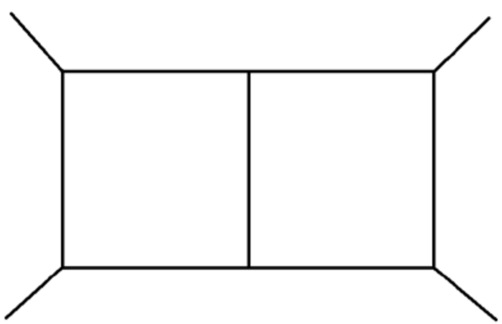
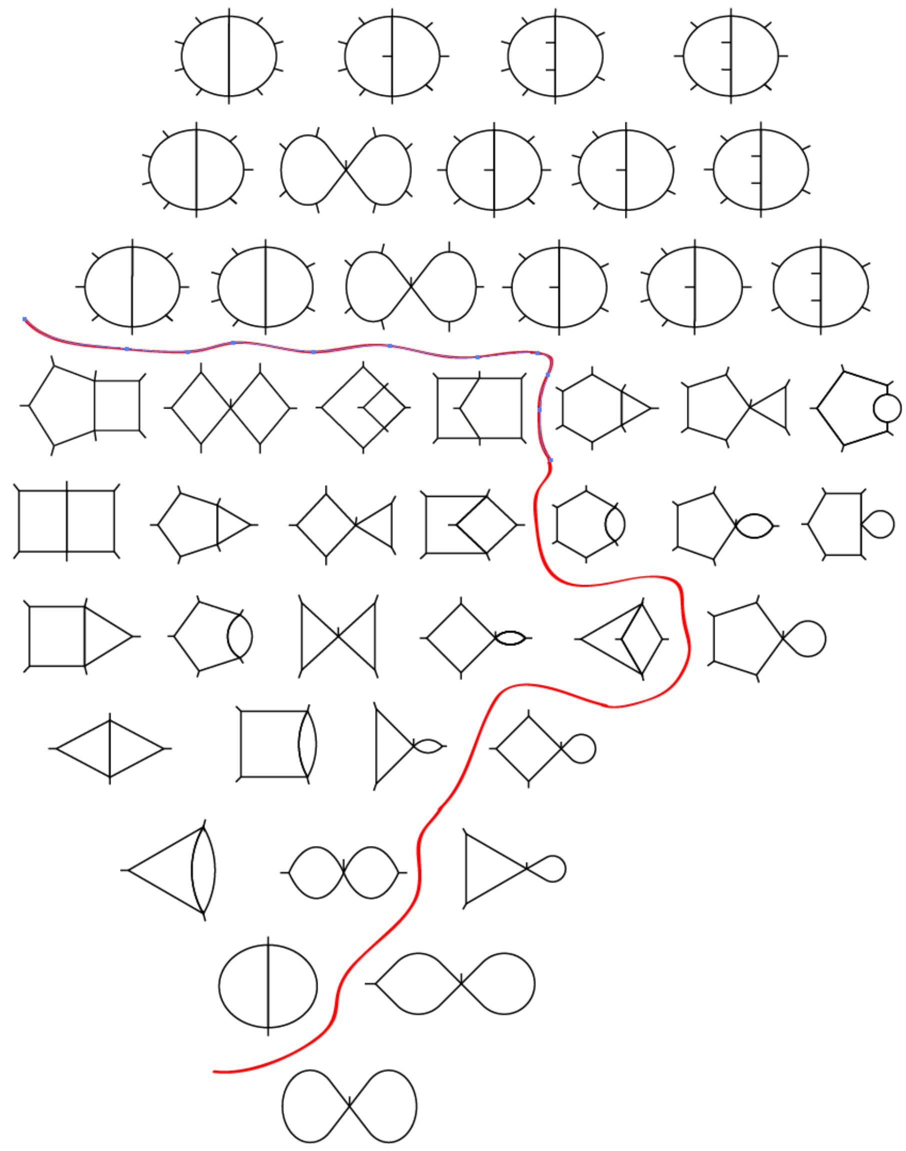


$$\int\!\!\int \frac{\mathrm{d}^d k \; \mathrm{d}^d q}{(4\pi)^{d/2}} \; \frac{(k \cdot p_4)^2 (q \cdot p_1)}{D_1 D_2 \cdots D_7}$$

For higher loop order not everything is scalar, i.e. the double box has 32 terms (arXiv: 1202.2019).

45 uber-topologies at two-loop.
Each with various mass-subtypes,
various extra legs,
various tensor-powers,
and various dimensions.



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There is plenty to do in this field!