RTG 2575:
Rethinking
Quantum Field Theory

Loop Tree Duality

explained to my grandma*

* supposing she were a PhD student in Physics

05.01.2021

STUDENT SEMINAR BY DANIELE ARTICO

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Numerical Integration: WHY?

- More precise experiments need BETTER calculations
- Actual scattering processes: at least NNLO QCD, many mass scales

↓

NUMERICAL INTEGRATION

some issues: D-dimensions, singular integrands ...

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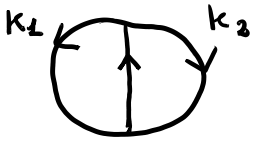
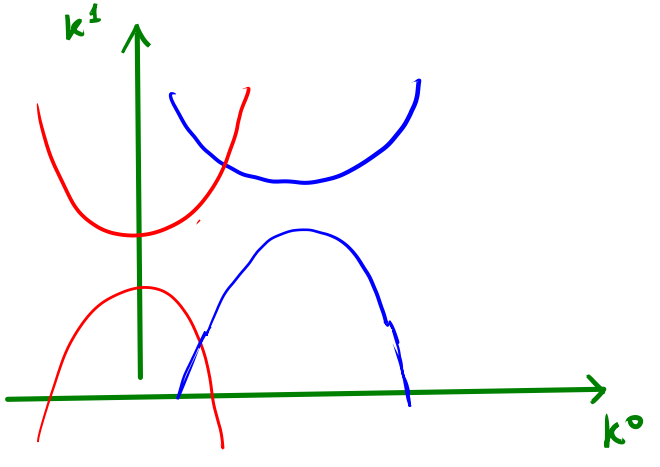
Let's start !



$$\sim \int d^D k_1 d^D k_2 \; \frac{1}{(k_1^2 - m^2 + i\varepsilon)(k_2^2 - m^2 + i\varepsilon)\left[(k_1+k_2)^2 - m^2 + i\varepsilon\right]}$$

for numerical: D integer, $\varepsilon = 0$



to avoid singularities we use contour deformation → simulates $+i\varepsilon$

- non compact surfaces
- intersections
- one loop ✓ multi loop ✗

$$k' = k + i\tilde{k} \longrightarrow (k'^2 - m^2) = (k^2 - m^2 + 2i\tilde{k}\cdot k)$$

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We can use the RESIDUE THEOREM (with $+i\varepsilon$) on the energy components

$$\int dk_0 \frac{1}{(k_0^2 - E^2)} = -2\pi i \, \delta^+(k_0^2 - E^2)$$

This means we are considering integration ON MASS SHELLS

We get PHASE SPACE integrals → IR divergencies can cancel at integrand level!

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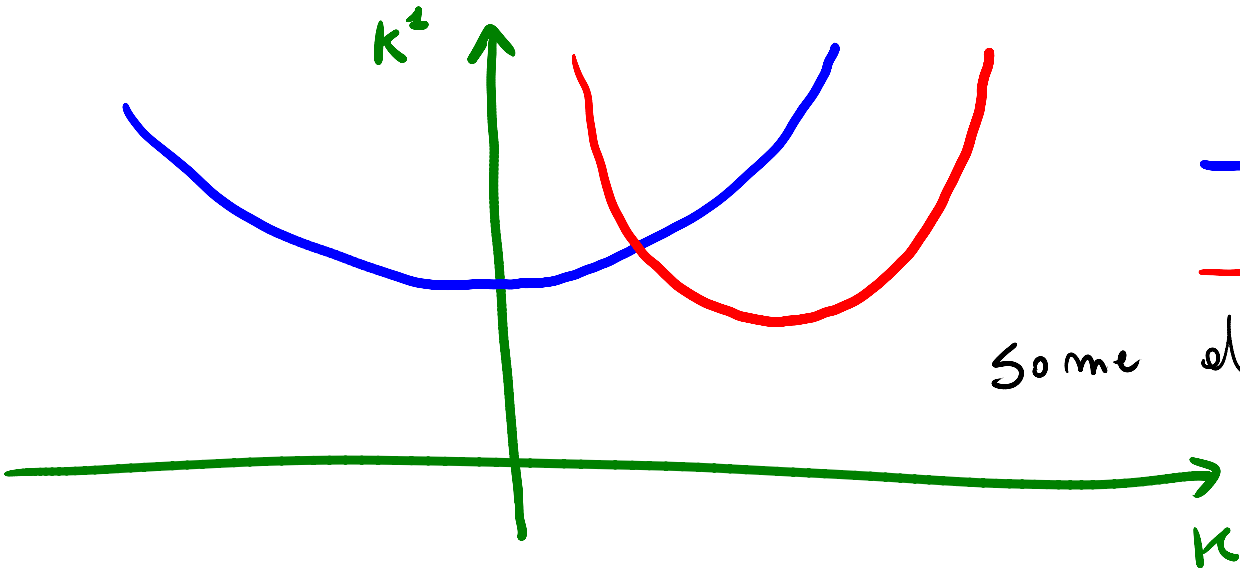
The importance of living on a shell



— OUT to IN

— IN to OUT

Some divergencies will cancel ...

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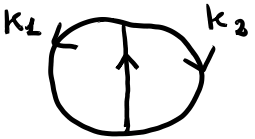
Mested Residues

Let's go back to



$$\sim \int d^D k_1 d^D k_2 \; \frac{1}{(k_1^2 - m^2 + i\varepsilon)(k_2^2 - m^2 + i\varepsilon)\left[(k_1+k_2)^2 - m^2 + i\varepsilon\right]}$$

D_1 D_2 D_3

we have to cut 2 ordered legs

- 1, 2 ✓
- 3, 2
- 1, 3
- 3, 1

} they combine eliminating uncertain residues coming after $\int dk_i^0$

→ one term each SPANNING TREE (1906.06138 hep-ph)

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To do List

- understand the singularities } next time
- build contour deformation
- treat UV and IR divergencies } long term goals
- some phenomenology : $e^+e^- \longrightarrow t\bar{t}H$

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