Ingredients for describing production and decay of massive short-lived particles with non-trivial decay chains

Setup: - production and decay of heavy short-lived particles
(top → b+l+nu, T`/stop → top+χ_0 → b+l+nu+χ_0 , ...)

- narrow-width approximation is applicable
→ separation into "production" and "decay"

Assumption: - NLO QCD corrections to the production process are known/automated

- we want to describe decay kinematics exact through NLO QCD

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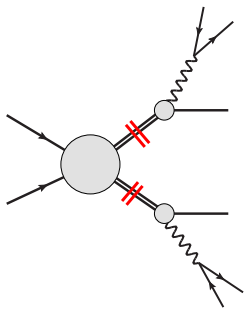
Physics: - spin correlations and acceptances

Description: - density matrix $|\mathcal{M}|^2 \sim \mathrm{Tr}[DP\bar{D}] = D_{\lambda\lambda'}\, P_{\lambda,\lambda',\sigma,\sigma'}\, \bar{D}_{\sigma,\sigma'}$



- decay wave function $\bar{\tilde{u}}(p_t) = \mathcal{M}(t \to b\ell^+\nu)\frac{\mathrm{i}(\not{p}_t + m_t)}{\sqrt{2m_t\Gamma_t}}$

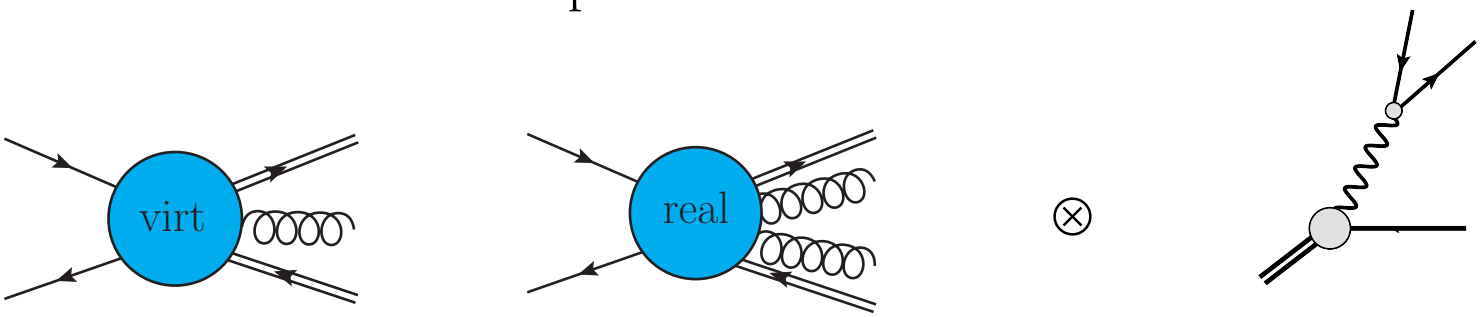
$$|\mathcal{M}|^2 = |\bar{\tilde{u}}(p_t)\,\tilde{\mathcal{M}}(gg \to \bar{t}tg)\,\tilde{v}(p_{\bar{t}})|^2 \quad + \mathcal{O}(\tfrac{\Gamma_t}{m_t})$$

(similar to HELAS/MG)

NLO QCD: example $t\bar{t}$ + jet

(represents a larger class of processes with jets,leptons + missing E_T)

production contribution

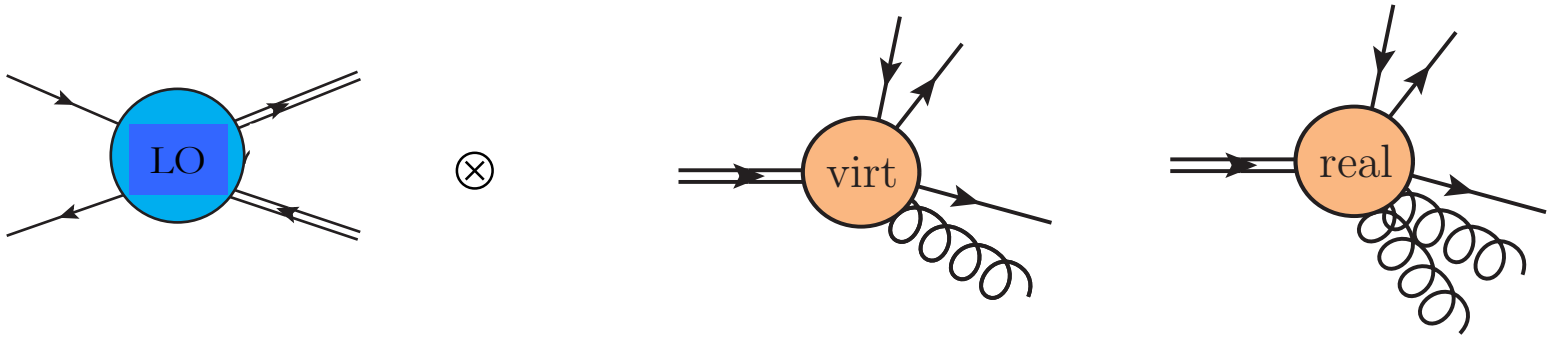


not covered in this talk: assume to be automated

note: since chirality of top decay current is fixed by LH W-coupling,
no sum over top helicities is necessary
→ speed-up by factor of four (wrt. to density matrix calculation)

NLO QCD: example $t\bar{t}$ + jet

decay contribution



NLO QCD: example $t\bar{t}$ + jet

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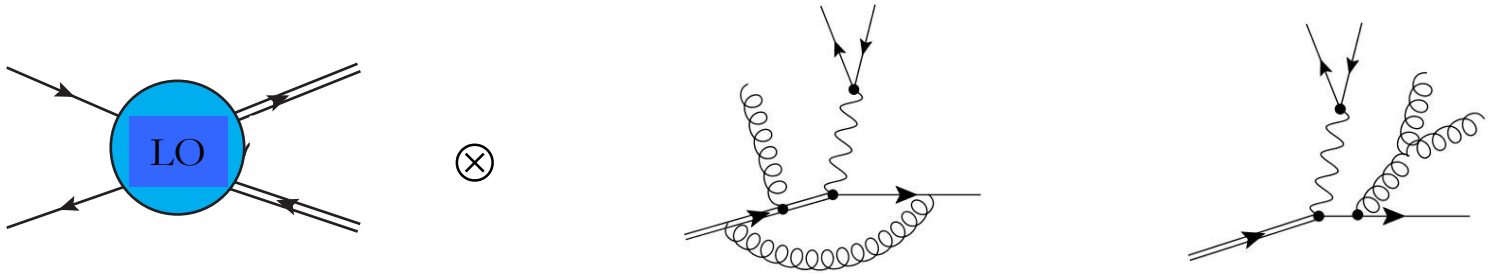


- virtual corrections: straight forward

- real emission requires regularization: dipoles

  original dipole papers are formulated for 2→N scattering processes

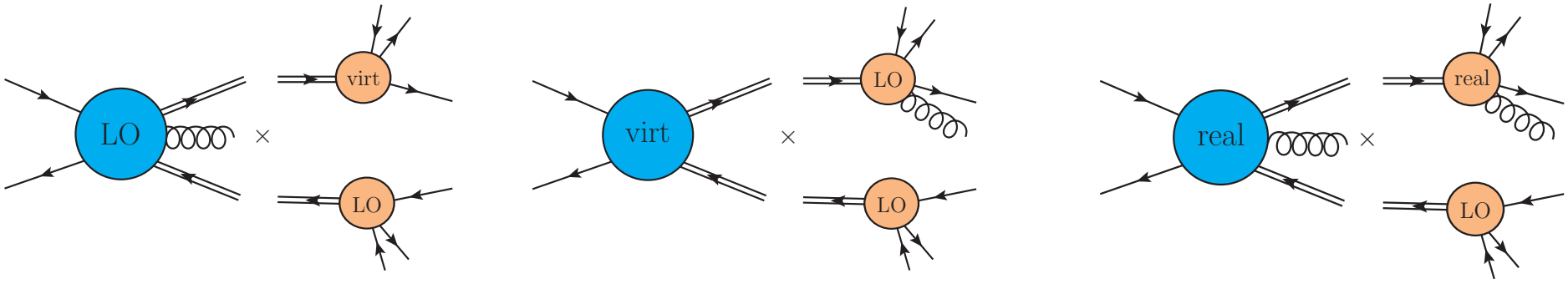
  decay kinematics requires modifications (only final-final, final-initial dipoles required)

  a complete list of dipoles is now available [Campbell,Ellis,Tramontano;Melnikov,Scharf,M.S.]

  note: two gluon helicities in decay current cancel the speed-up (wrt. density matrix)

NLO QCD: example $t\bar{t}$ + jet

"mixed" contribution



- real correction requires subtraction terms for production *and* decay
  which cannot be treated separately

- not necessarily positive-definite
  we found that their size is significant
  LHC (7TeV): sigma(ttb+jet) = 323(Pr) + 41(decay) – 76(mixed) = 288 fb

- not clear if this contribution is covered by any parton shower approximation