NLO QCD corrections to the production of a weak boson pair with a jet

Grégory Sanguinetti

LAPTH - Annecy

sangui@lapp.in2p3.fr

in collaboration with J.-P. Guillet, T. Binoth, S. Karg, N. Kauer

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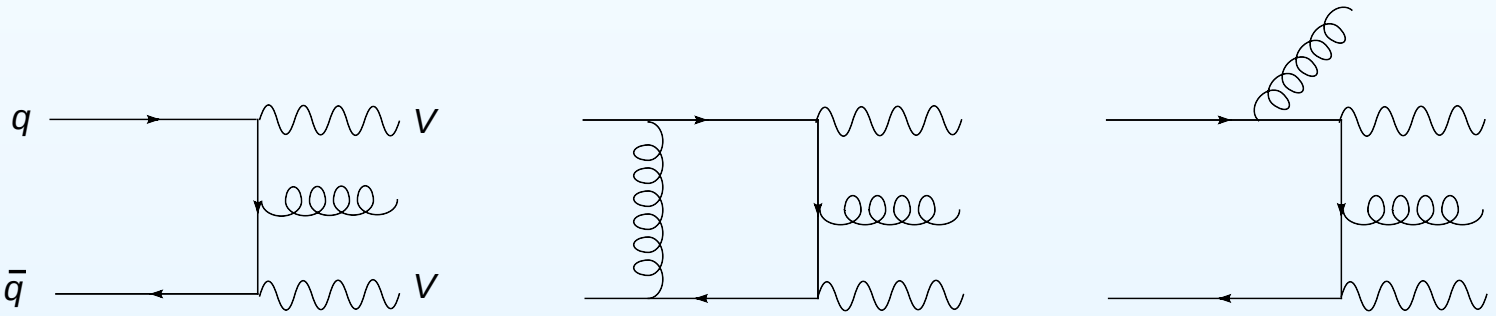
Motivations for $pp \longrightarrow VV + jet$

- on top of "Les Houches wishlist 2005" for important missing NLO predictions
- important background for the production of $H + jet$, $t\bar{t}\,H$, and new physics
- important test before approaching more complicated many particle processes at NLO

Outline of $pp \to VV + jet$

- inclusive cross section: $pp \to VV + jet + X$
- 3 parts: tree level, virtual correction, real emission



Preliminaries

- $VV \in \{ZZ, W^-W^+, \gamma\gamma\}$ and massless quarks
- $qg \to VVq, \quad \bar{q}g \to VV\bar{q} \Leftarrow$ by momentum crossing
- Algebraic Feynman diagrams approach
- Helicity amplitudes formalism:

  $\Rightarrow$ 36 helicities but 6 independent!
  ($\mathcal{B}$ose, $\mathcal{C}$harge, $\mathcal{P}$arity transformations)

Computation: Semi-numerical method

- using FORM
  $\longrightarrow$ Algebraic tensor reduction
- using the General One-Loop Evaluator for Matrix elements library

  T.Binoth, J.-P.Guillet, G.Heinrich, E.Pilon, C.Schubert - JHEP 0510 (2005) 015
- using MAPLE
  $\longrightarrow$ Automated simplification for the large FORM expressions
- using BASES/SPRING
  $\longrightarrow$ Phase space integration

Difficulties

- NLO calculation with 5 legs, 2 external masses

  $\Rightarrow$ huge complexity / number of terms:
  `FORM` output around 100 Mbytes for a 5-points diagram!

- Gram determinants $\rightarrow$ numerical instabilities?

Numerical check

- $ZZ + jet$ and $W^+W^- + jet$ virtual corrections performed
- Comparison of 2 independent codes
  $\rightarrow$ Successful check of the tree level and virtual corrections
- Comparison of numerical results for $W^+W^- + jet$

  S. Dittmaier, S. Kallweit, P. Uwer arXiv:0710.1577v1 [hep-ph]

  J. Campbell, R.K. Ellis, G. Zanderighi arXiv:0710.1832v2 [hep-ph]

  $\rightarrow$ in Les Houches 2007 summary report:
  The NLO multileg working group: arXiv: 0803.0494 [hep-ph]

Work in progress

- IR divergences already extracted from the real emission, using the Catani-Seymour dipole subtraction
- Evaluating the finite terms of the real emission
- to get the final cross section soon

Thank You!

Gram determinants

- spurious instability $\rightarrow$ disappear for physical quantities
- Dilemma: slow numerical evaluation or reduction with instabilities?

$$I_5^{n,\,\mu_1,\mu_2,\mu_3,\mu_4}(a_1,a_2,a_3,a_4;S) = \int d\tilde{k}\,\frac{q_{a_1}^{\mu_1}\ldots q_{a_5}^{\mu_5}}{\prod\limits_{i=1,\ldots,5}(q_i^2-m_i^2+i\delta)}$$

$$\rightarrow I_4^n(S), I_3^n(S), I_2^n(S)???$$

- Faith in "compact" analytical result...

- Origin: from the reduction

$$I_4^{n+2}(l;S) = (b_l\, I_4^{n+2}(S) + \frac{1}{2}\sum_{j\in S} S_{jl}^{-1}\, I_3^n(S\backslash\{j\}) - \frac{1}{2}\sum_{j\in S\backslash\{l\}} b_j\, S_{jl}^{-1}\, I_3^n(l, S\backslash\{j\}))$$

  det G : polynomial in $s_{ij} = (p_i + p_j)^2$
  $\to 0$ in the phase space?

- depend on a good choice of the function basis

- Origin: from the reduction

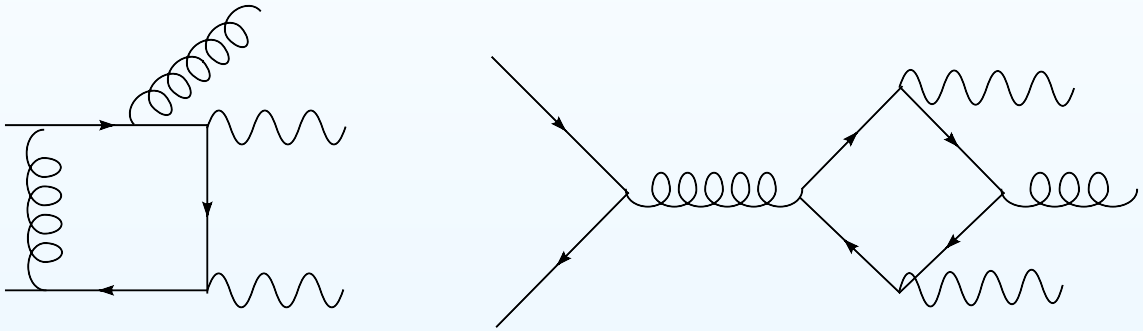
$$I_4^{n+2}(l;S) = -\frac{\det S}{\det G}(b_l\, I_4^{n+2}(S) + \frac{1}{2}\sum_{j\in S} S_{jl}^{-1}\, I_3^n(S\backslash\{j\}) - \frac{1}{2}\sum_{j\in S\backslash\{l\}} b_j\, S_{jl}^{-1}\, I_3^n(l, S\backslash\{j\}))$$

  det G : polynomial in $s_{ij} = (p_i + p_j)^2$
  $\rightarrow 0$ in the phase space?

- depend on a good choice of the function basis

Differences between ZZ and W^+W^-

- ZZ case: 80 diagrams ← Z bosons crossing



- W^+W^- case: 51 diagrams ← additional diagrams with WWV vertex