Virtual QCD Corrections to gg->ZH via a Transverse-Momentum Expansion

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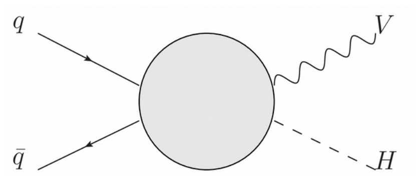
1. Introduction

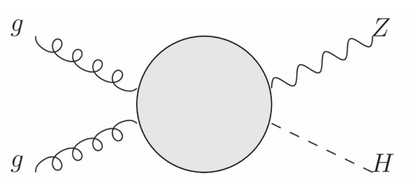
Associated VH production (V=W,Z) is the most sensitive channel for the measurement of H→bb̄ decay at the LHC

Two partonic channels contribute to this process:

1) **$q\bar{q}$-channel**: both WH and ZH
Main contribution to the total cross section



2) **gg-channel**: only ZH
About 6% of the total cross section



Larger theoretical uncertainties in ZH production, as the gluon-initiated channel is known only at leading order (LO)
→ It is important to study gg→ZH at NLO in QCD

Th. Unc. for (WH, W→lv) [1]

$\sqrt{s}$[GeV]	σ[fb]	$\Delta_{\text{scale}}[\%]$	$\Delta_{\text{PDF}/\alpha_s/\text{PDF}\oplus\alpha_s}[\%]$
7	23.04	$^{+0.6}_{-0.8}$	$\pm2.2/\pm0.6/\pm2.3$
8	28.62	$^{+0.6}_{-0.8}$	$\pm2.1/\pm0.6/\pm2.1$
13	59.83	$^{+0.4}_{-0.7}$	$\pm1.8/\pm0.8/\pm2.0$
14	66.49	$^{+0.5}_{-0.6}$	$\pm1.7/\pm0.9/\pm1.9$

Th. Unc. for (ZH, Z→ ll) [1]

$\sqrt{s}$[GeV]	σ[fb]	$\Delta_{\text{scale}}[\%]$	$\Delta_{\text{PDF}/\alpha_s/\text{PDF}\oplus\alpha_s}[\%]$
7	11.43	$^{+2.6}_{-2.4}$	$\pm1.6/\pm0.7/\pm1.7$
8	14.18	$^{+2.9}_{-2.4}$	$\pm1.5/\pm0.8/\pm1.7$
13	29.82	$^{+3.8}_{-3.1}$	$\pm1.3/\pm0.9/\pm1.6$
14	33.27	$^{+3.8}_{-3.3}$	$\pm1.3/\pm1.0/\pm1.6$

2. The gg→ZH process

- **LO contribution**: one-loop diagrams (mainly top loops)

- **NLO virtual QCD corrections**: two-loop diagrams, some of them known fully analytically

- **Main challenge at NLO**: calculation of two-loop box integrals

Box integrals depend on five energy scales:

$$I(\hat{s}, \hat{t}, m_Z^2, m_H^2, m_t^2)$$

No analytic result currently available → Use approximation

3. The pT Expansion

1) Amplitude expressed using 6 form factors

2) In the limit pT→0, form factors are Taylor-expanded in the parameters

$$\frac{m_H^2}{\hat{s}}, \frac{m_Z^2}{\hat{s}}, \frac{p_T^2}{\hat{s}} \ll 1 \qquad \frac{p_T^2}{4m_t^2} \ll 1$$

3) After integration-by-parts reduction
the structure of the resulting integrals is simplified

$$I(\hat{s}, \hat{t}, m_Z^2, m_H^2, m_t^2) \longrightarrow I(\hat{s}/m_t^2)$$

- Final result depends on 52 master integrals
- NLO checked with exact numerical evaluation [2]
- Accuracy below 1% for pT ≲ 350 GeV
- Allows to cover ~ 98% of hadronic cross section
- Inaccurate results for the high-energy tail

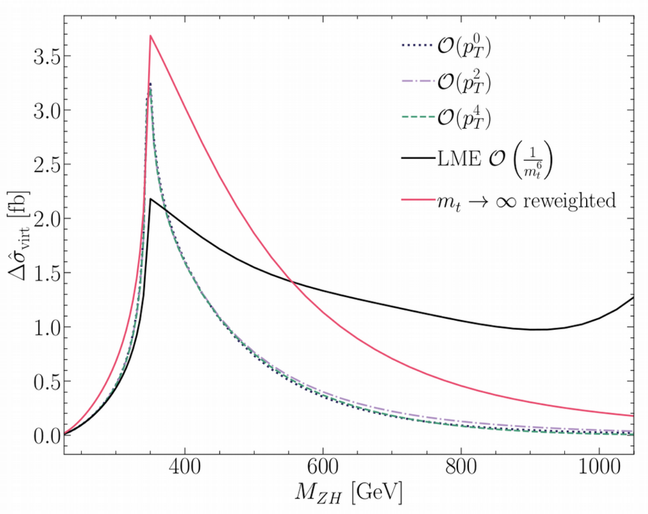


Fig.1: NLO QCD virtual corrections for various orders of the pT expansion. Other analytic approximations shown for comparison. See [3]

4. Combination with High-Energy Expansion

- Approximation accurate in high-energy tail available in literature [4]
- The pT and HE expansion are accurate in almost complementary phase-space regions

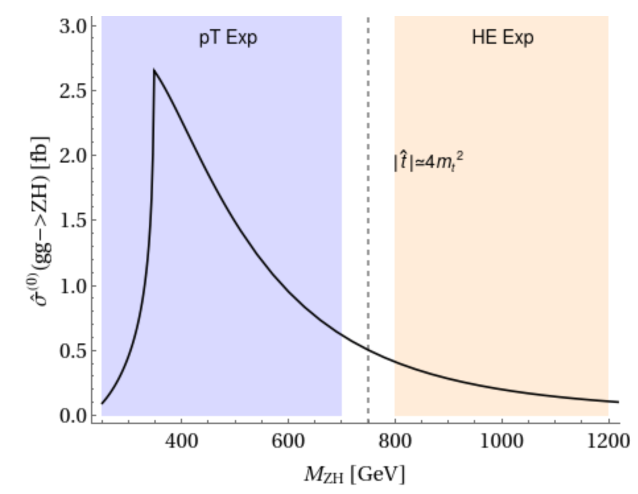


Fig.2: Validity regions for the pT and HE expansions vs. LO partonic cross section

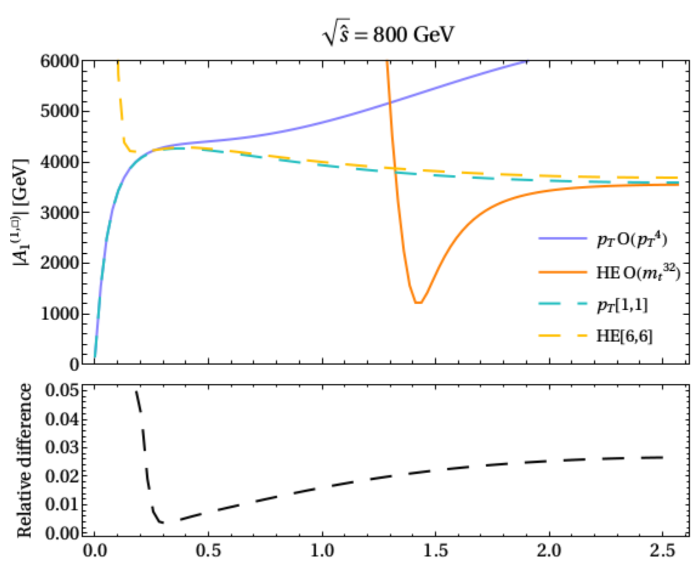


Fig.3: Comparison of pT and HE expansions (solid lines) vs. Padé-improved results (dashed lines)

- Padé approximants used to improve convergence of both expansions
- Padé-improved results merged in single prediction [5]
- Complete phase-space coverage

5. Conclusions

- Fast and flexible analytic approximation of virtual corrections
- Accuracy below 1% over whole phase space
- Results recently used for the calculation of the complete (virtual+real) NLO corrections to gg→ZH [6]

References

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