Thrust distribution in Higgs decays at the next-to-leading order and beyond

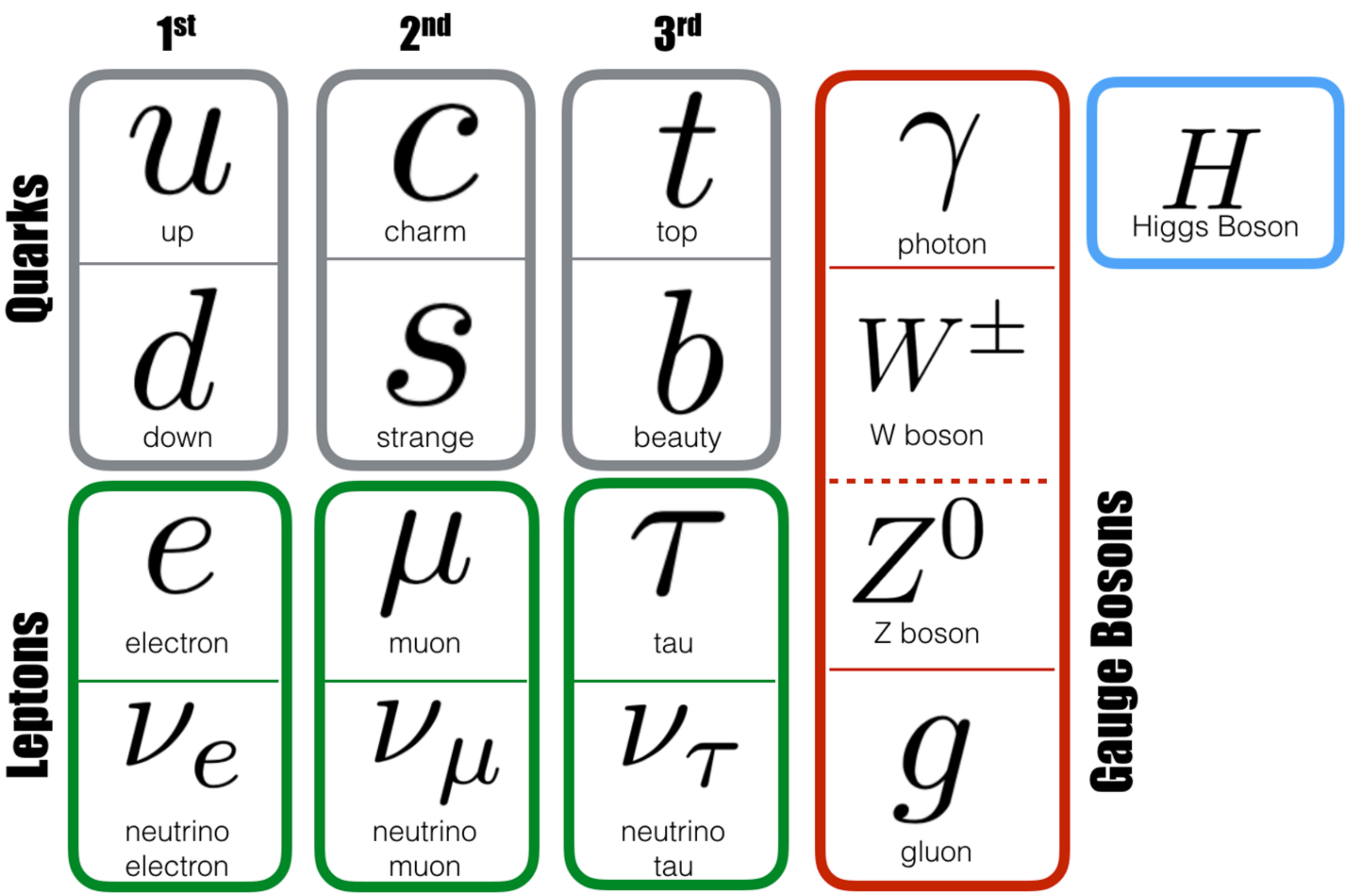
Yin-Qiang Gong
Peking University

2018 International Workshop on the High Energy Circular Electron Positron Collider

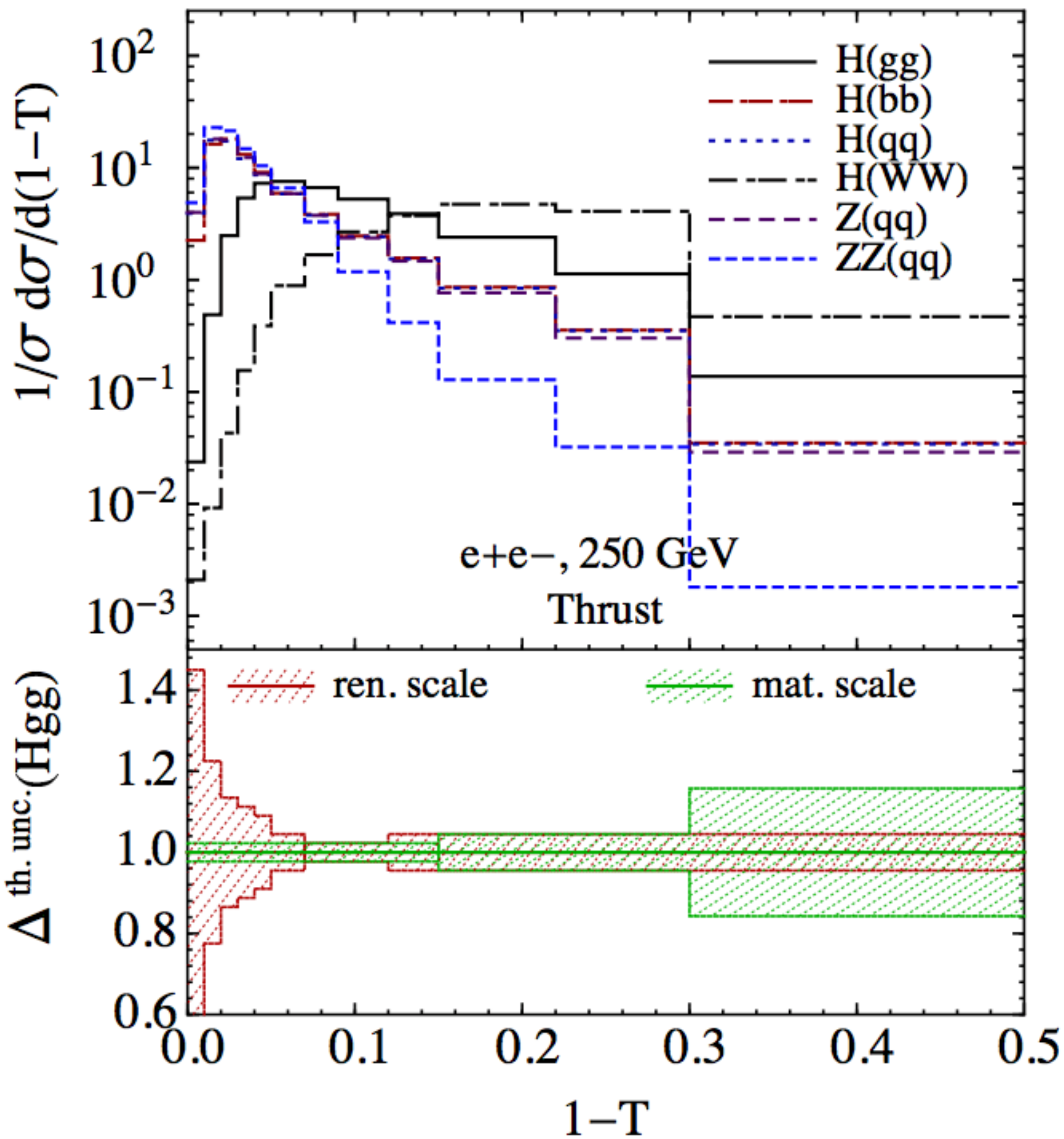
Outline

- Introduction
- Fix Order
- Factorization and NNLO-S
- Summary and Outlook

Motivation: Precision Measurements of Higgs Boson



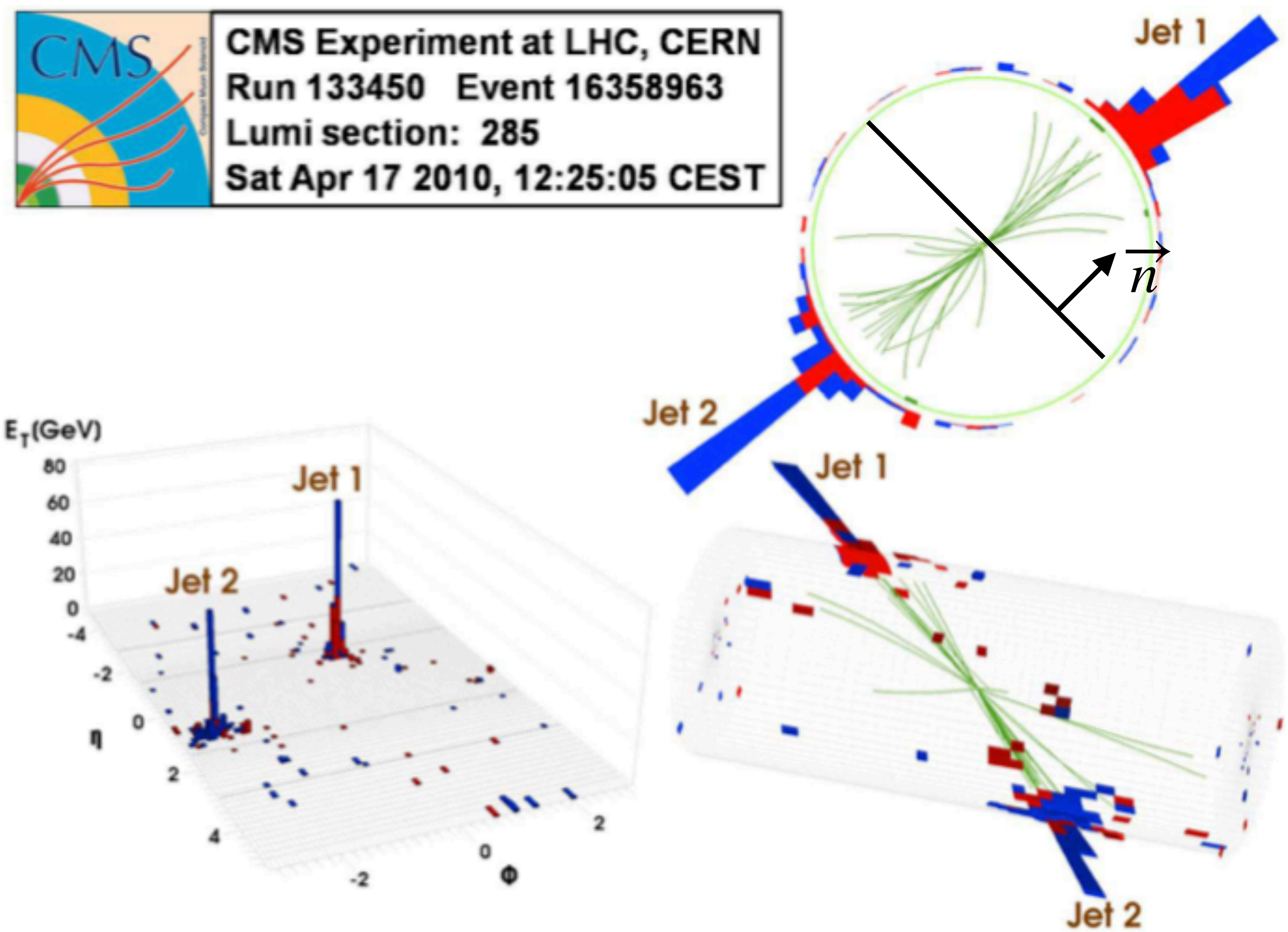
Motivation: Constrains to Light Quark Yukawa Coupling



Jun Gao arXiv:1608.0174

- The quark signal and The gluon signal has different peak position.
- Helpful to select the signal and improve constrain to the light quark Yukawa coupling.
- Requires high precision theoretical prediction.

Introduction:Thrust

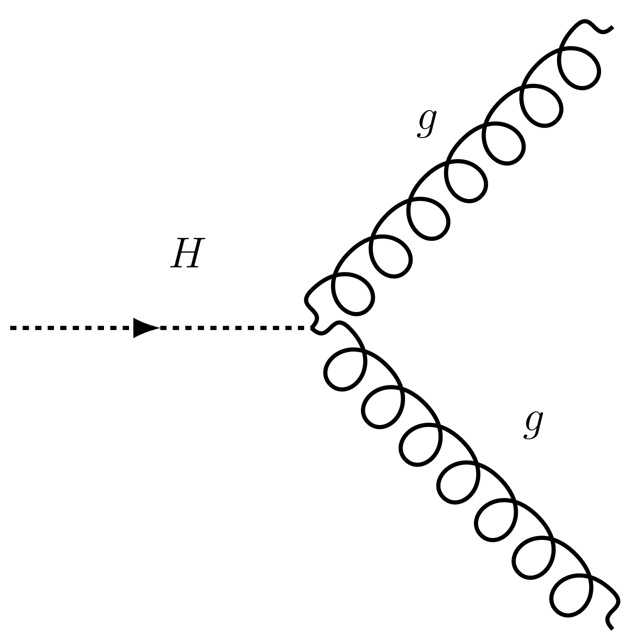


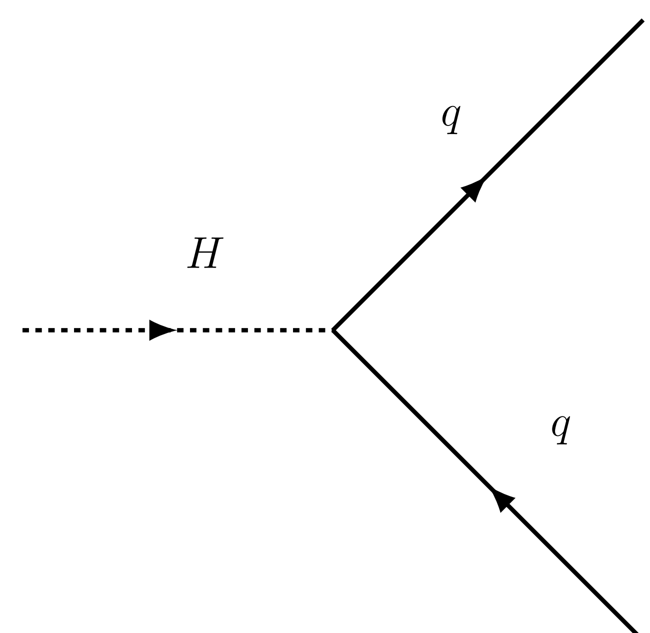
$$\tau = 1 - \max_{\vec{n}} \frac{\Sigma_i |\vec{q_i} \cdot \vec{n}|}{\Sigma_i |\vec{q_i}|},$$

Fix Order

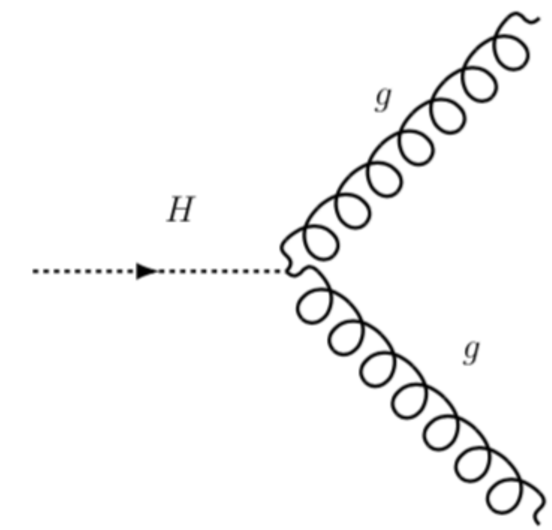
Fix Order: Effective Lagrangian

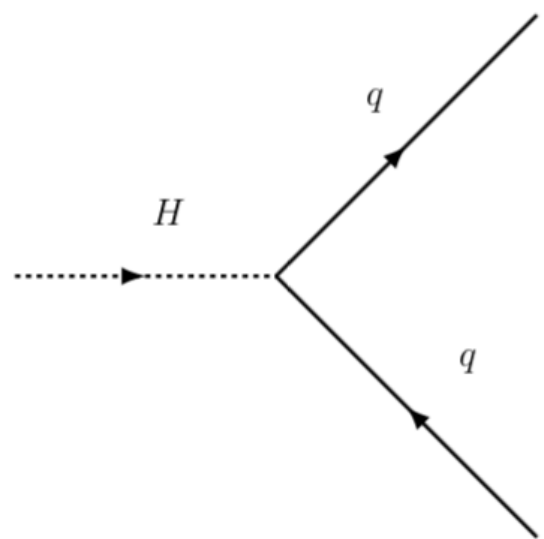
$$\mathcal{L}_{\text{eff}} = \frac{\alpha_s(\mu)C_t(m_t,\mu)}{12\pi v} H G^{\mu\nu,\alpha} G^{\alpha}_{\mu\nu} + \sum_q \frac{y_q(\mu)}{\sqrt{2}} H \bar{\psi}_q \psi_q,$$



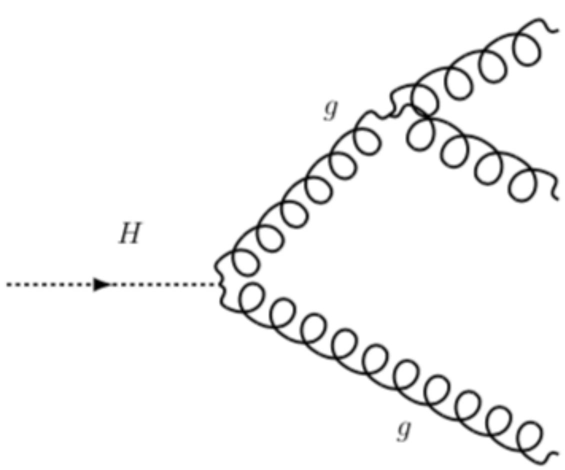


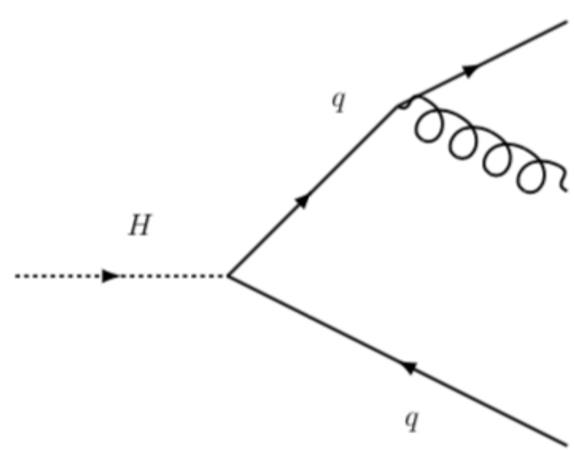
Fix Order: Leading Order





$$\delta(\tau)$$

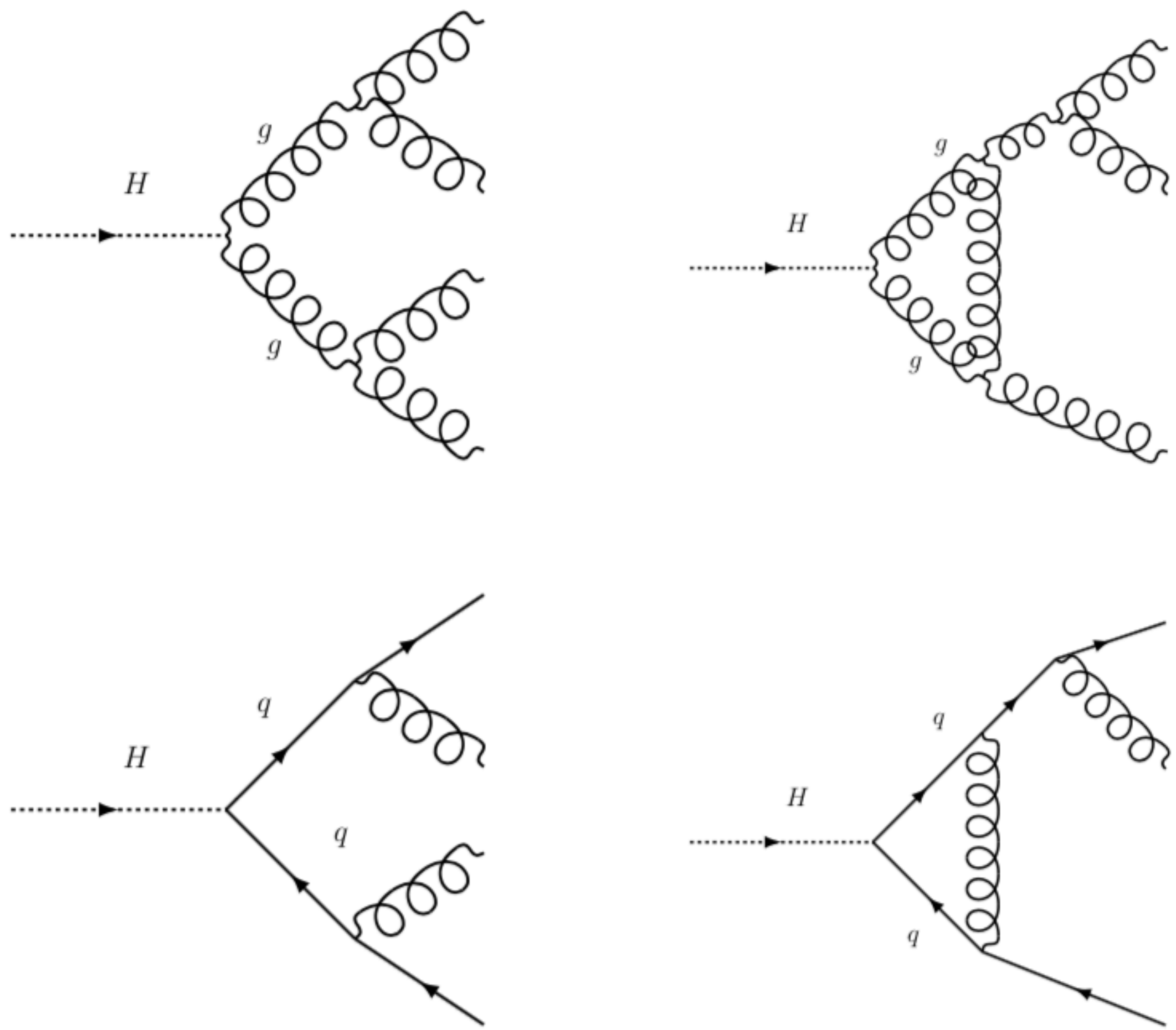




Non-trivial Leading Order

$$\tau = 1 - \max_{\vec{n}} \frac{\Sigma_i |\vec{q_i} \cdot \vec{n}|}{\Sigma_i |\vec{q_i}|},$$

Fix Order: NLO and IR Subtraction



Double Real (RR)

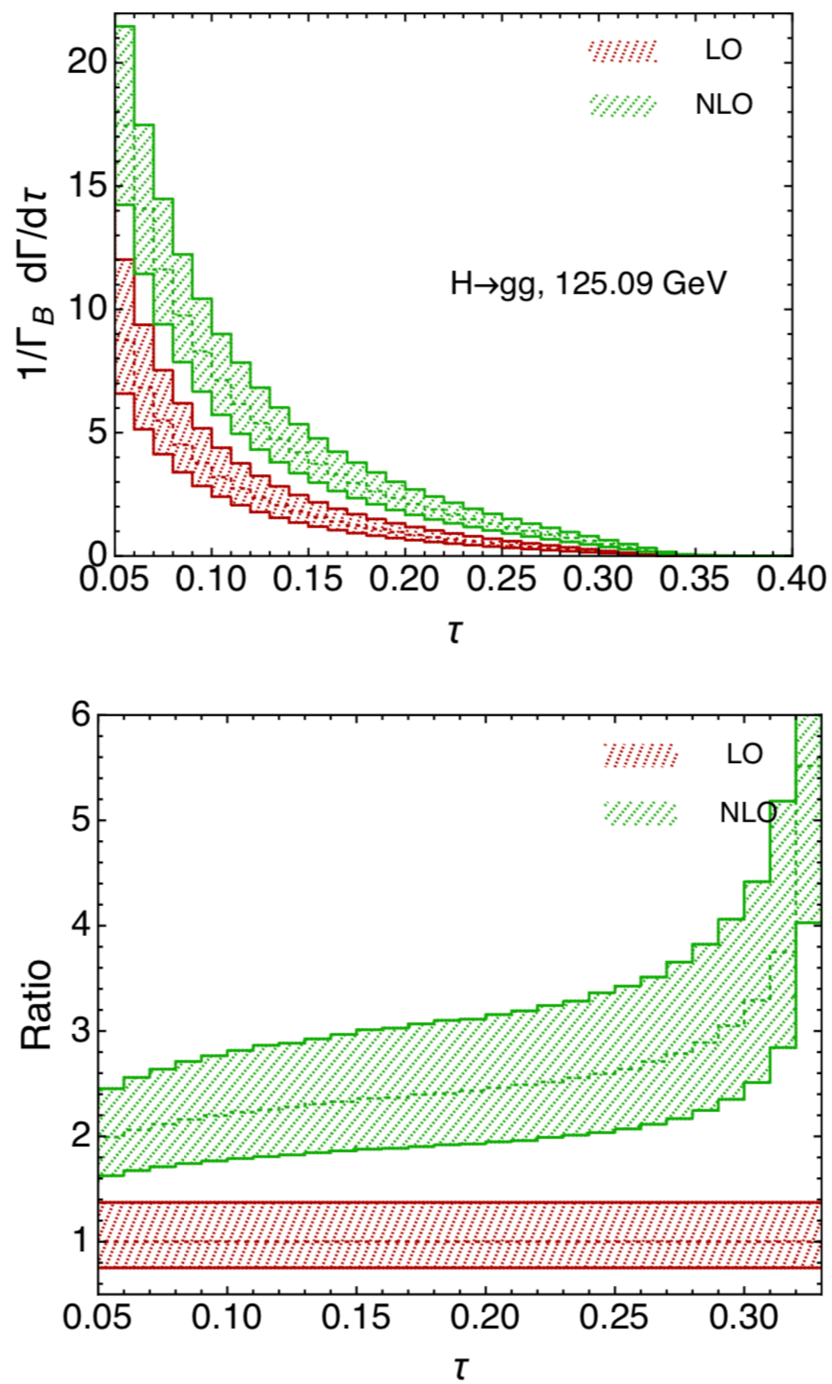
Real Virtual (RV)

$$\sigma_{NLO} = \int_{n+1} \mathrm{d}\sigma_{real} + \int_n \mathrm{d}\sigma_{virt} = \int_{n+1} (\mathrm{d}\sigma_{real} - \mathrm{d}\sigma_A) + \int_n \left(\mathrm{d}\sigma_{virt} + \int_1 \mathrm{d}\sigma_A \right)$$

Fix Order: NLO and Numerical Implementations

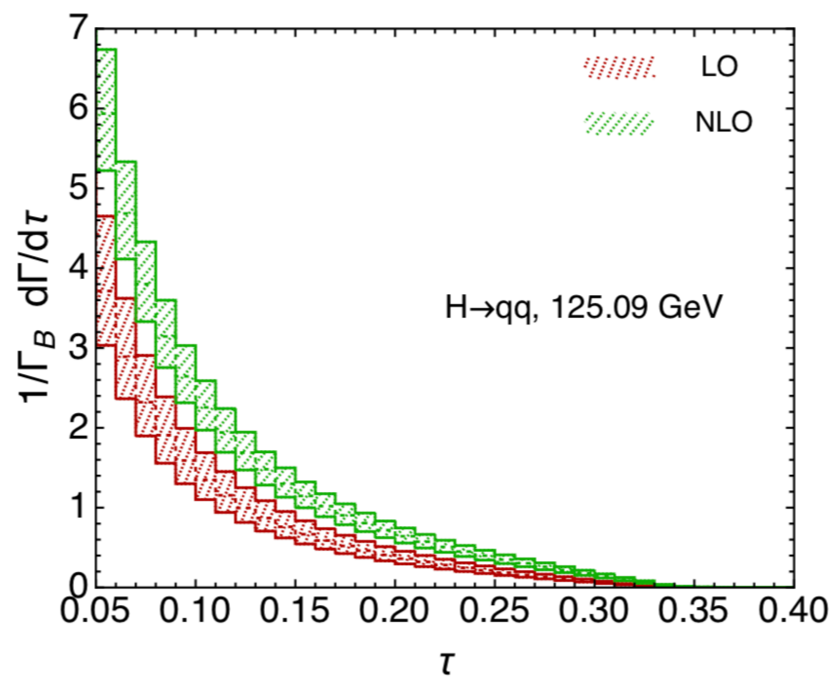
- Tree level matrix elements: HELAS
- One-loop matrix elements: OpenLoops
- IR subtraction: dipole formalism

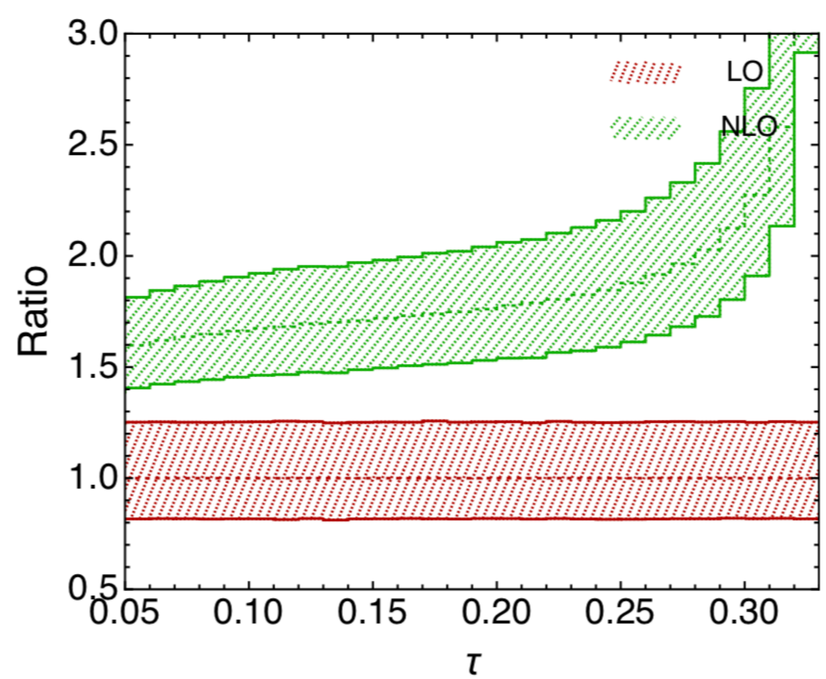
Fix Order: Numeric Result
Gluon channel



- the NLO correction is relatively large
- The scale dependence is not improved by the next to leading order correction.
- The scale dependence at leading order underestimate the higher order correction

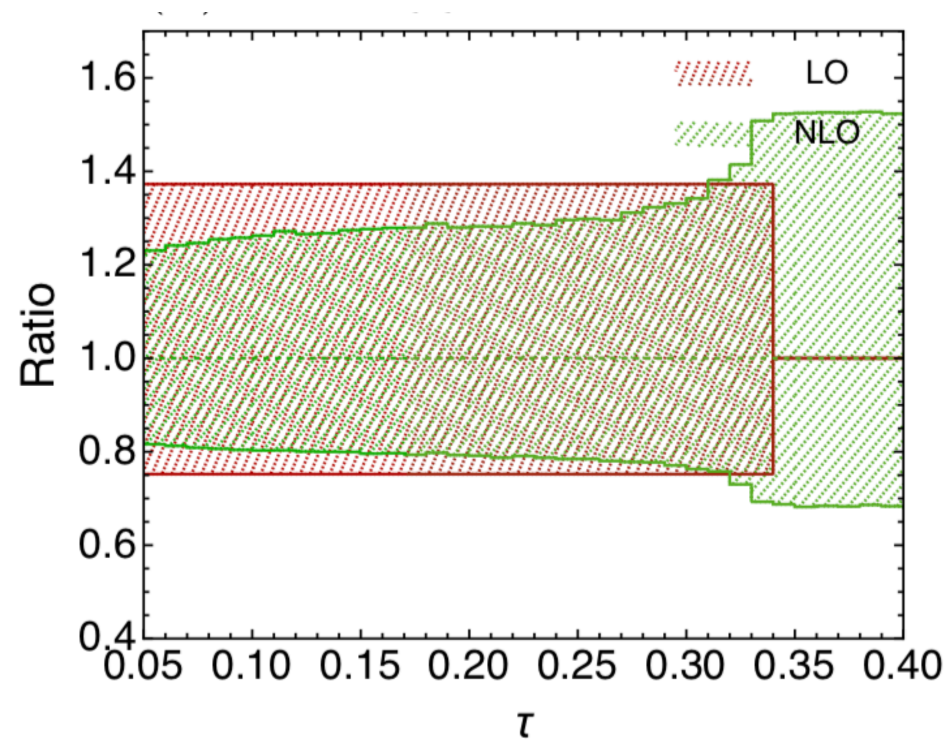
Fix Order: Numeric Result
Quark channel

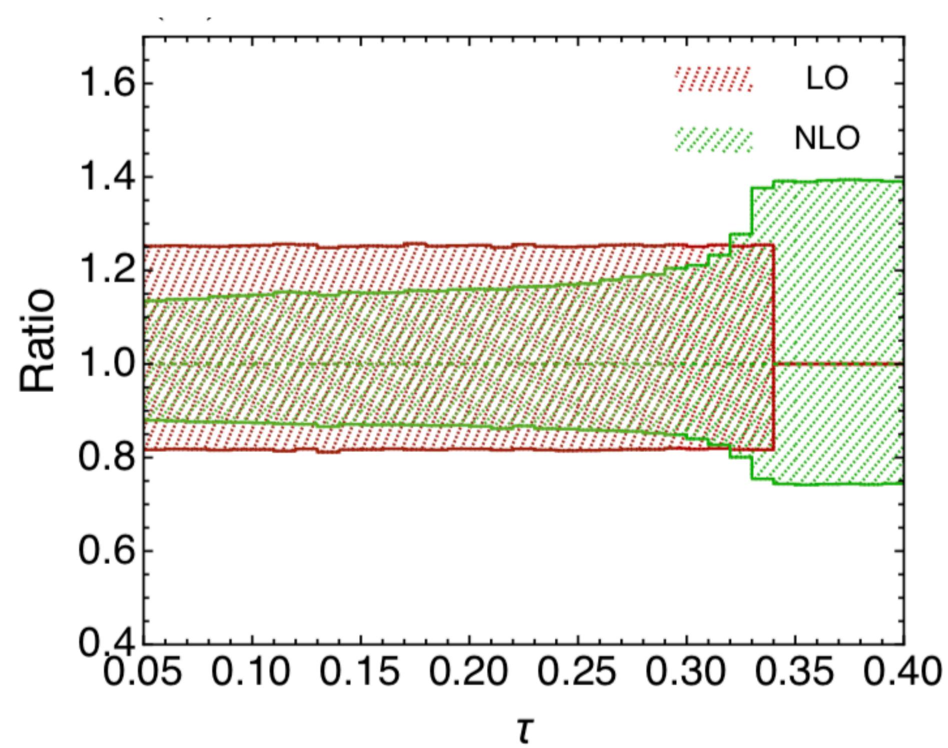




- the NLO correction is relatively large
- The scale dependence is not improved by the next to leading order correction.
- The scale dependence at leading order underestimate the higher order correction

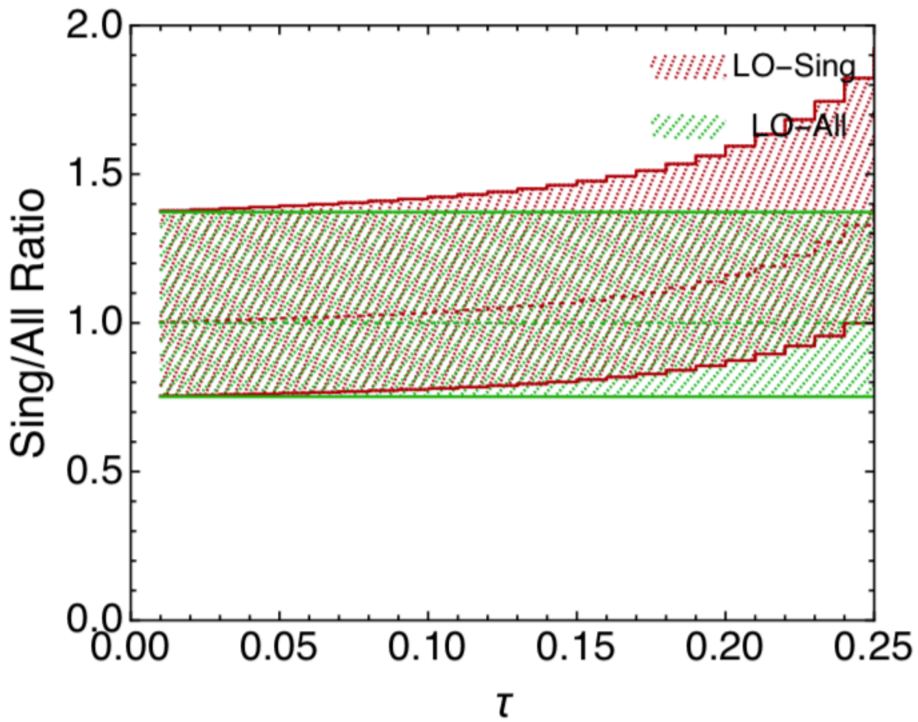
Fix Order: Numeric Result
Ratio to central value



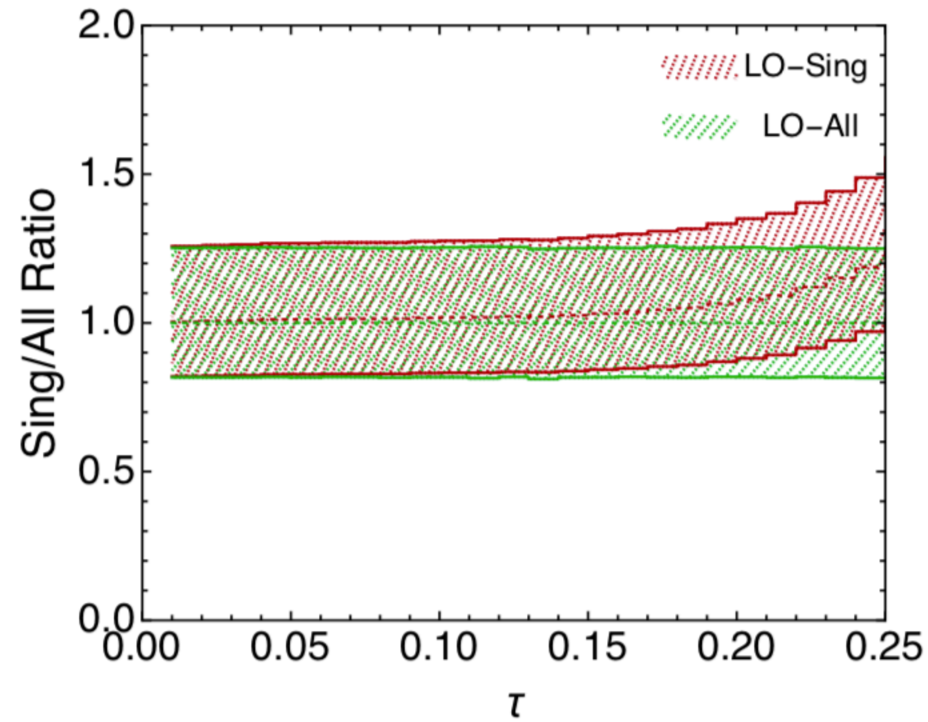


- The leading order distribution vanished at tau greater than one third
- The next to leading order correction is the leading contribution.
- The scale dependence is thus larger than the small tau region

Fix Order: Singular Part



(a) $H \to gg$



(b) $H \to q\bar{q}$

$$\frac{1}{\Gamma_B^{(q,g)}}\frac{\mathrm{d}\Gamma^{(q,g)}}{\mathrm{d}\tau} = \sum_{n=1}^{\infty}\left(\frac{\alpha_s}{4\pi}\right)^n\left(\sum_{i=0}^{n-1}A_{n,i}\frac{\ln^i\tau}{\tau} + R_n\right)$$

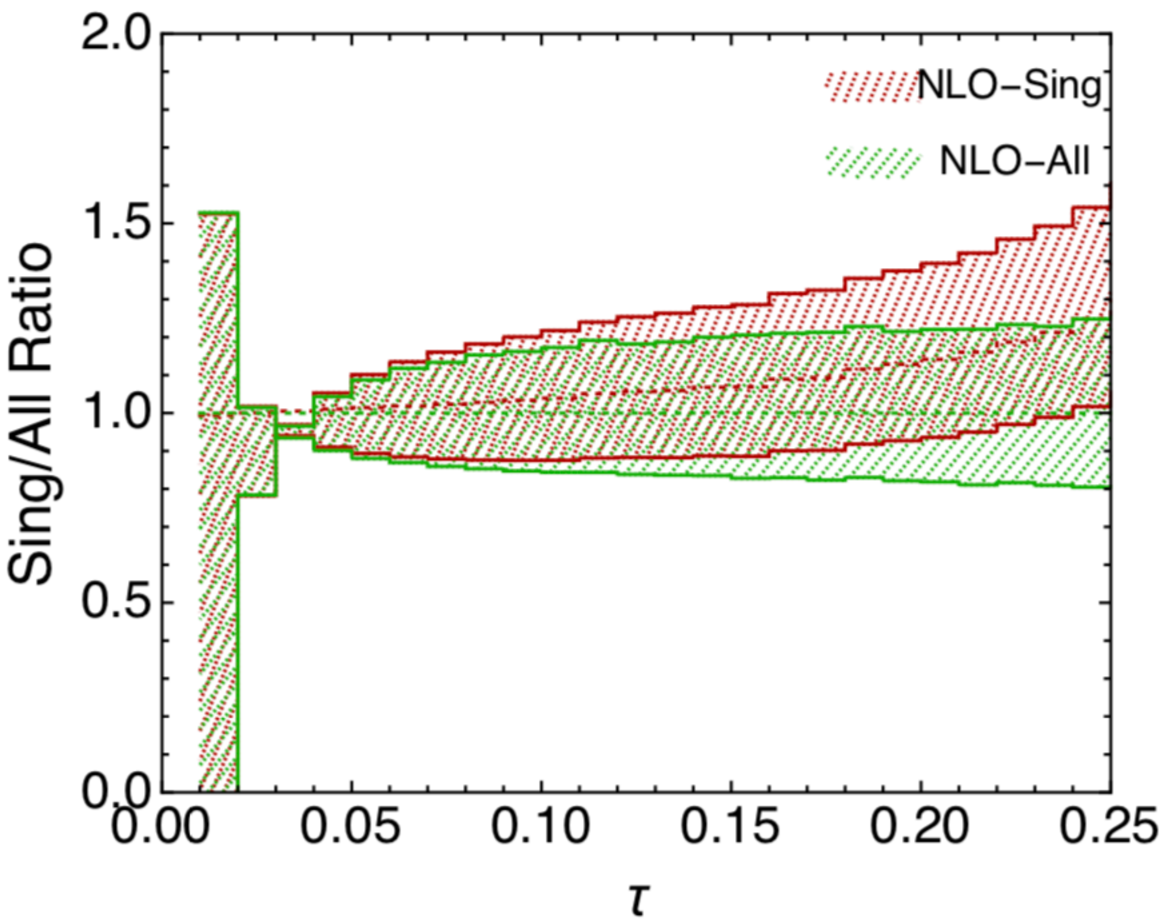
Factorization and NNLO-S

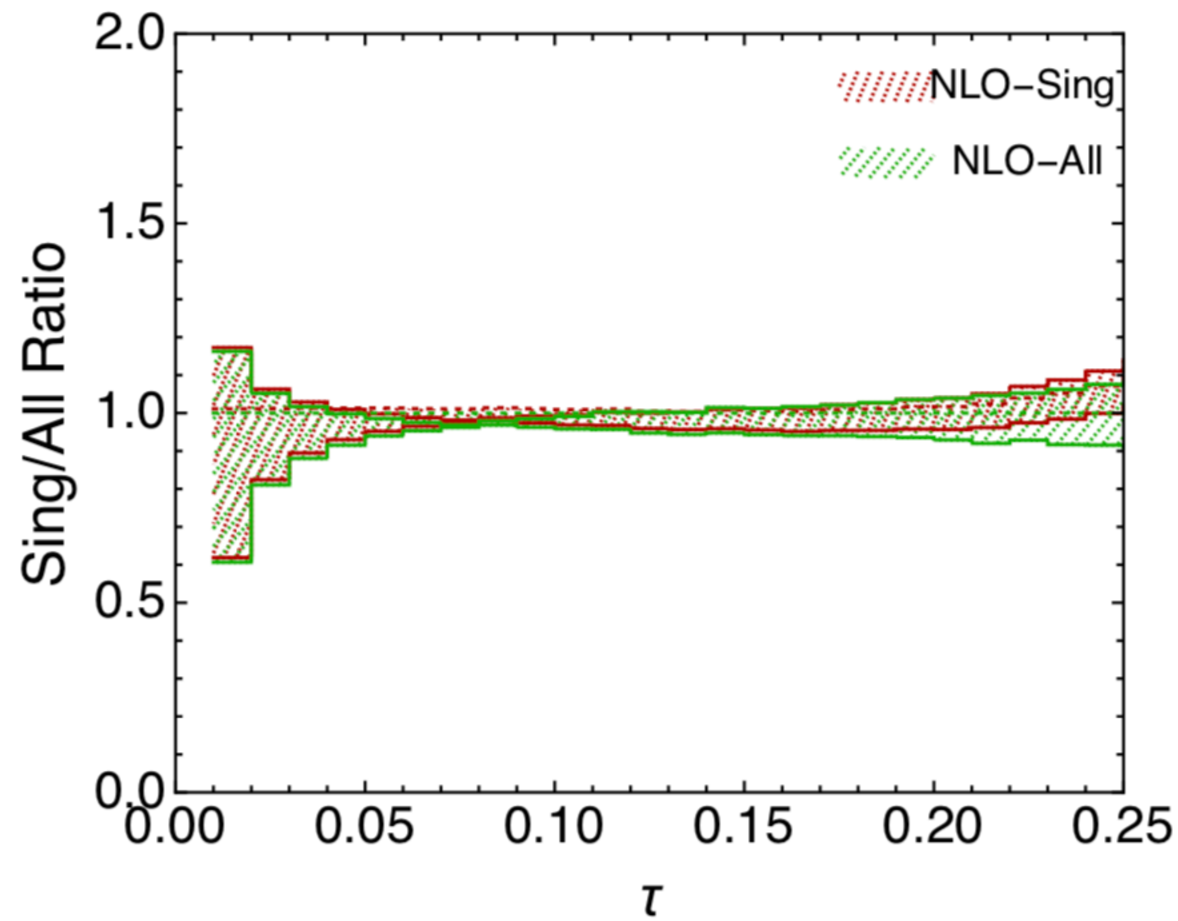
Factorization

$$\mathcal{L}_{\text{SCET}} = \frac{\alpha_s C_t C_S^g}{12\pi v} H \mathcal{A}_{\perp\bar{n}}^{\mu\nu,\alpha} \mathcal{A}_{\perp n,\mu\nu,\alpha} + \frac{y_q}{\sqrt{2}} C_S^q H \bar{\chi}_{\bar{n}} \chi_n,$$

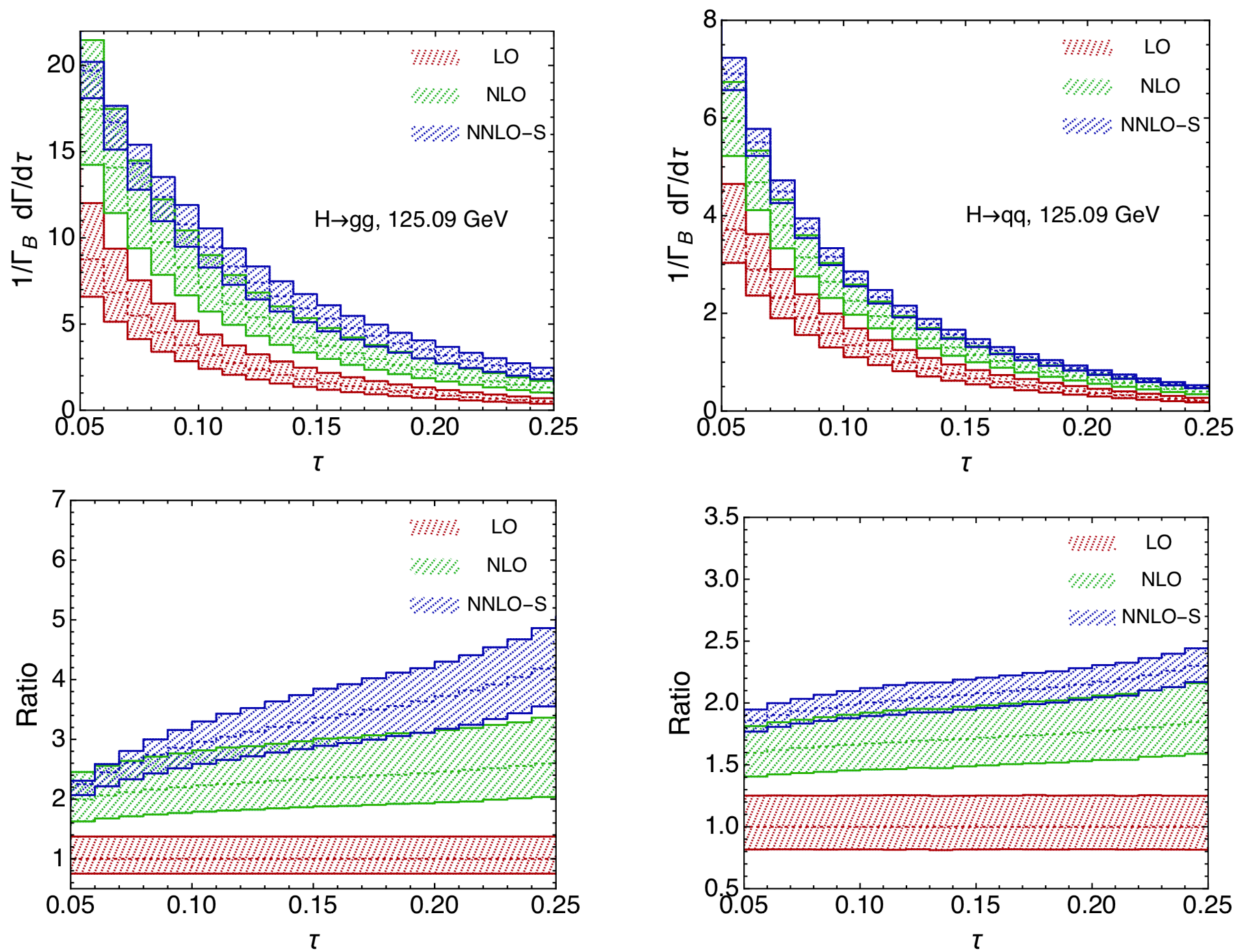
$$\begin{aligned}\frac{\mathrm{d}\Gamma_q}{\mathrm{d}\tau} =& \Gamma_B^q |C_S^q(M_h,\mu)|^2 \int \mathrm{d}M_n^2 \mathrm{d}M_{\bar{n}}^2 \mathrm{d}k \; \delta\left(\tau - \frac{M_n^2 + M_{\bar{n}}^2}{M_h^2} - \frac{k}{M_h}\right) J_n^q(M_n^2,\mu) J_{\bar{n}}^q(M_{\bar{n}}^2,\mu) \\ & \times S^q(k,\mu), \\ \frac{\mathrm{d}\Gamma_g}{\mathrm{d}\tau} =& \Gamma_B^g |C_t(m_t,\mu)|^2 |C_S^q(M_h,\mu)|^2 \int \mathrm{d}M_n^2 \mathrm{d}M_{\bar{n}}^2 \mathrm{d}k \; \delta\left(\tau - \frac{M_n^2 + M_{\bar{n}}^2}{M_h^2} - \frac{k}{M_h}\right) J_n^g(M_n^2,\mu) \\ & \times J_{\bar{n}}^g(M_{\bar{n}}^2,\mu) \; S^g(k,\mu),\end{aligned}$$

Singular Part at NLO

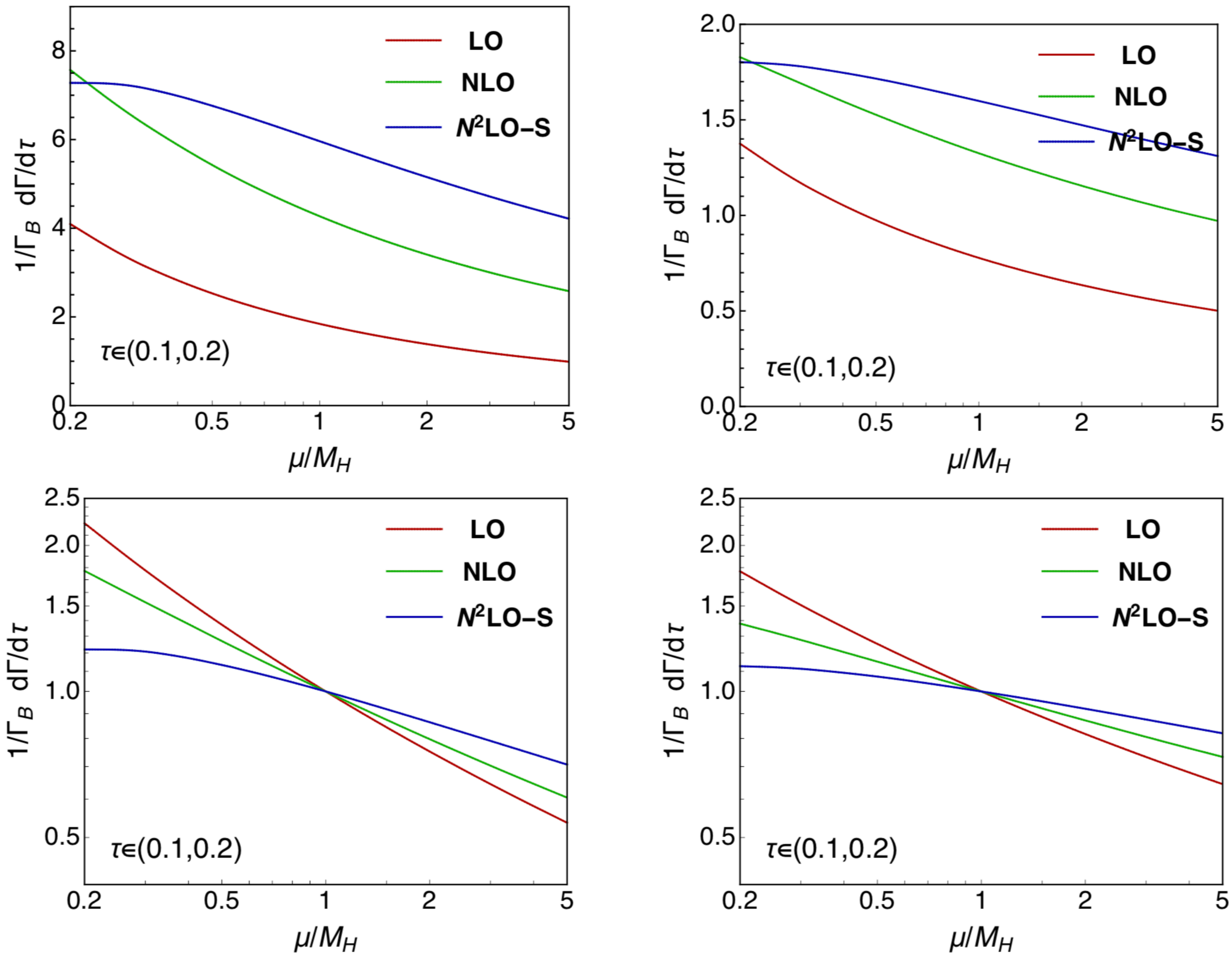




Numeric Result at NNLO-S



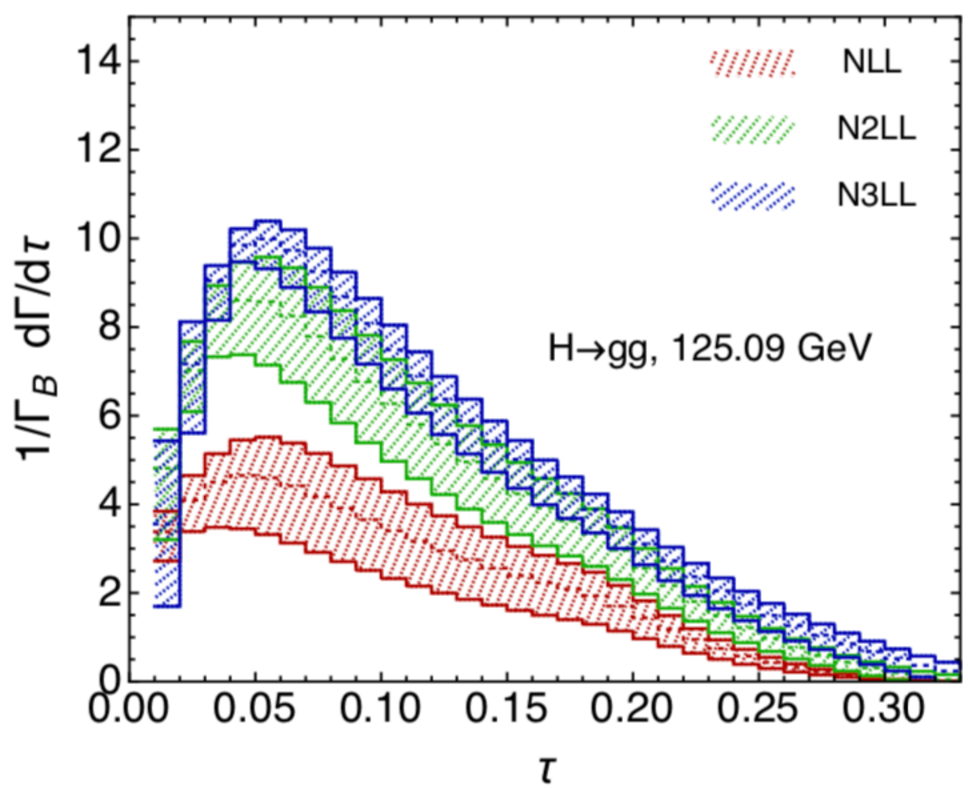
Scale dependence at NNLO-S

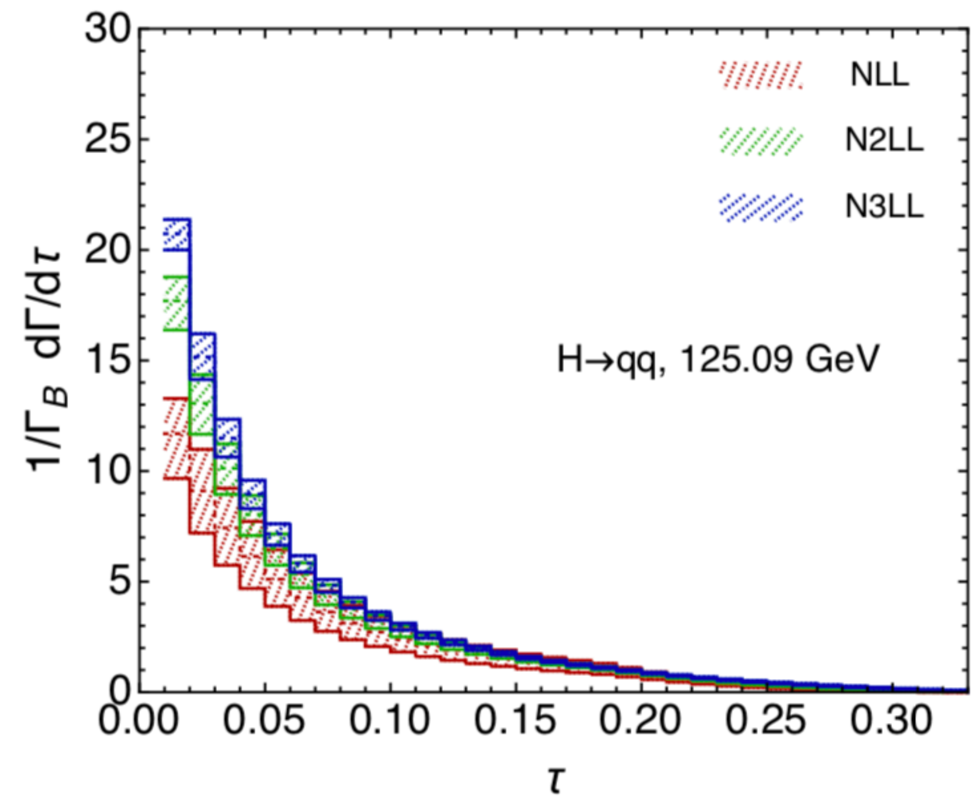


Summary and Outlook

- The NLO correction and the NNLO-S correction based on the factorization theorem.
- The perturbative expansion is badly converged and we may need higher order corrections.
- The scale dependence at LO and NLO respectively underestimate the higher order correction.
- To improve our result:
    - Small τ region: N3LL resummation
    - Large τ region: Regular terms of NNLO correction
    - Medium area: Higher order correction

Preliminary Result at N3LL+NLO





Thanks