# Finite Heavy Quark Mass Effects in Gluon Fusion Higgs Production

## Effects on the Transverse Momentum Spectrum

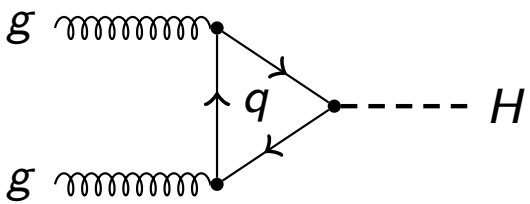
Silvan Kuttimalai

Institute for Particle Physics Phenomenology, Durham

April 1, 2014

# Gluon Fusion Higgs Production at the LHC

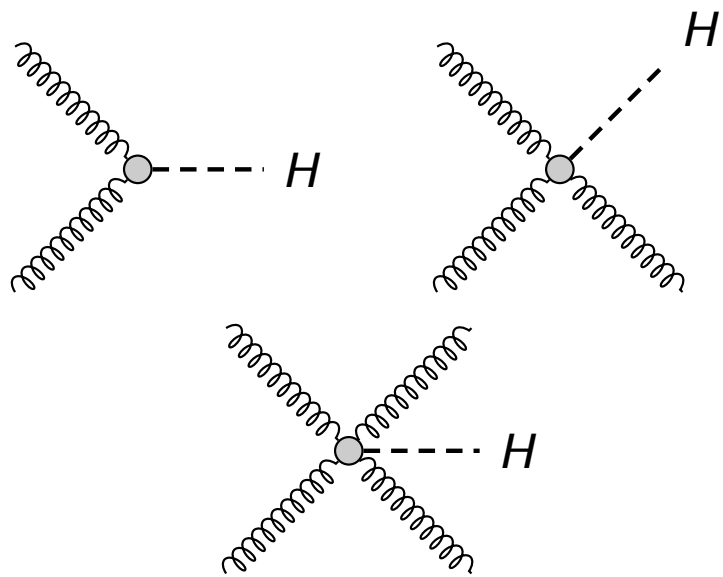
## Dominant Prod. Channel at the LHC




- Large corrections to total cross section beyond leading order $\mathcal{O}\left(100\,\%\right)$
- At leading order: $p_\perp = 0$
- $p_\perp$ distribution driven by QCD corrections
- Rapidity distribution driven by PDFs

## Effective Lagrangian

$$\mathcal{L}_{ggh} \propto G^{\mu\nu} G_{\mu\nu} H$$



# Beyond the Effective Interaction Approach

## Finite Quark Mass Effects

- Top mass effect on total inclusive cross section: 5% at leading order
- Top-bottom interference contributions of similar magnitude expected $\frac{y_t y_b}{y_t y_t} \approx 3\%$
- Effect on $p_\perp$ distribution can be larger for $p_\perp \approx m_q$
- Neglect bottom-squared contribution for now, suppressed by additional small Yukawa coupling

## Difficulties in Exact Mass Dependence Treatment

- Adds one loop to each matrix element
- Bottom quark adds third scale to resummation problem ($m_b << m_H \approx m_t$)
  - MC showers resum large logarithms $\ln^m(m_H/p_\perp)$ to all orders
  - Based on factorization of real emission matrix elements for $p_\perp < \mu_F$
  - Bottom contributions factorize below $m_b$
  - Top contributions factorize below $m_t \approx m_H$

# Beyond the Effective Interaction Approach

## Available Calculations

- HNNLO/HRes: NNLO plus analytic NNLL resummation, exact top and bottom mass treatment up to NLO Grazzini, Sargsyan: Heavy-Quark Mass Effects in Higgs Boson Production at the LHC, arXiv:1306.4581
- NLO MC with finite top and bottom mass matched to parton showers
  - MC@NLO v4.10
  - POWHEG

## Our Approach

- Multijet merging of three MC@NLO samples (MEPS@NLO)
  - $g\ g \to H$
  - $g\ g \to H\ j$
  - $g\ g \to H\ j\ j$
- Correct matrix elements by reweighting with $m_q$-exact one-loop matrix elements (OpenLoops)
- Generate top-top and top-bottom interference samples separately (OpenLoops)
- Use bottom mass as shower starting scale for top-bottom interference

Grazzini, Sargsyan: Heavy-Quark Mass Effects in Higgs Boson Production at the LHC, arXiv:1306.4581

# Correcting for Finite Masses by Reweighting

## $\mathbb{S}$-events

$$\overline{B}(\phi_B) = B(\phi_B) + V(\phi_B) + I^S(\phi_B) + \int \left[ D^A(\phi_B, \phi_1) - D^S(\phi_B, \phi_1) \right] \mathrm{d}\phi_1$$

- Unintegrated Catani-Seymour dipole terms $D^{A/S} = \sum B \otimes V$
- Integrated Catani-Seymour dipole terms $I^S = \sum B \otimes I$
- Virtual contribution $V$ contains two-loop matrix for finite quark masses, approximation: assume factorization of mass correction
- Reweight all contributions by ratios of matrix elements with born kinematics

$$\frac{|\mathcal{M}^B_{m_q}(\phi_B)|^2}{|\mathcal{M}^B_{m_q \to \infty}(\phi_B)|^2}$$

# Correcting for Finite Masses by Reweighting

## $\mathbb{H}$-events (MC@NLO)

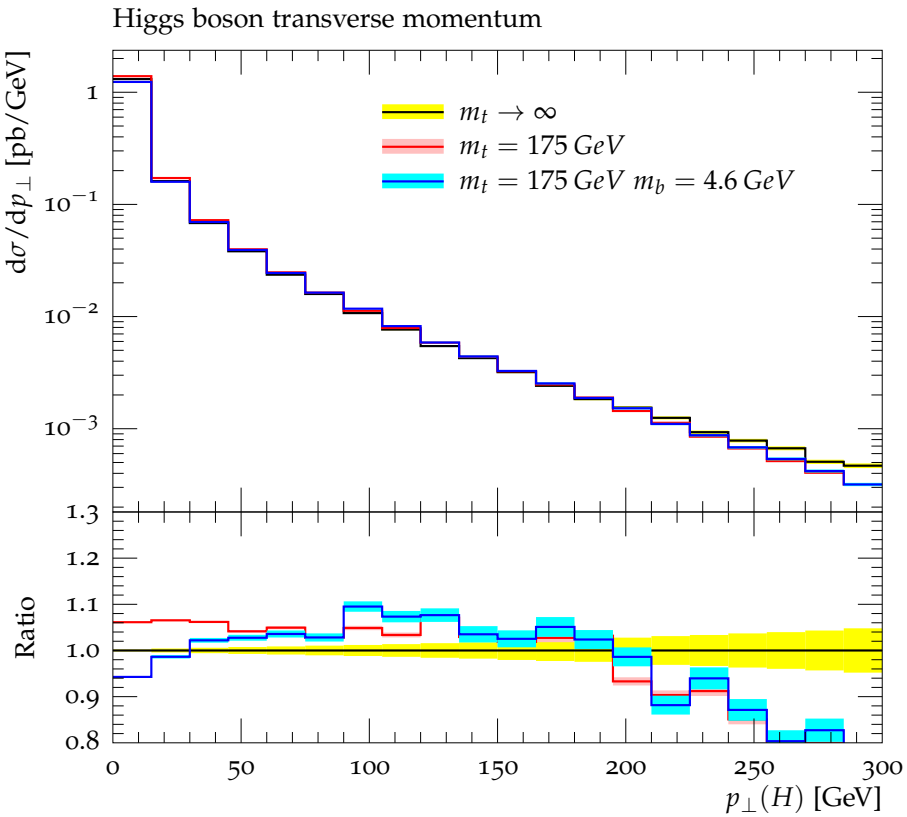
$$H(\phi_R) = R(\phi_R) - D^A(\phi_B, \phi_1)$$

- Reweight real emission term $R$ with real emission matrix elements

$$\frac{|\mathcal{M}^R_{m_q}(\phi_R)|^2}{|\mathcal{M}^R_{m_q \to \infty}(\phi_R)|^2}$$

- Reweight subtraction terms $D^A$ with born-ratios as in the case of $\mathbb{S}$-events

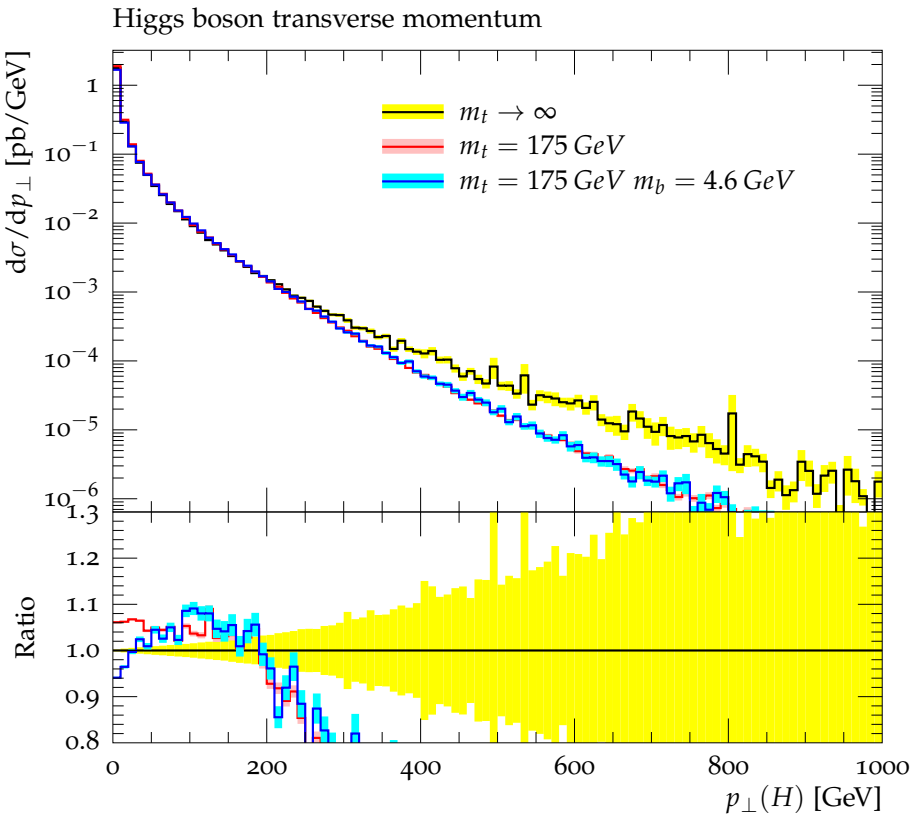
# Preliminary Results




## Fixed Order

- No shower, top-top and top-bottom contributions in one run
- $j\ j \to H$ (NLO)
- $\sqrt{s} = 8$ TeV

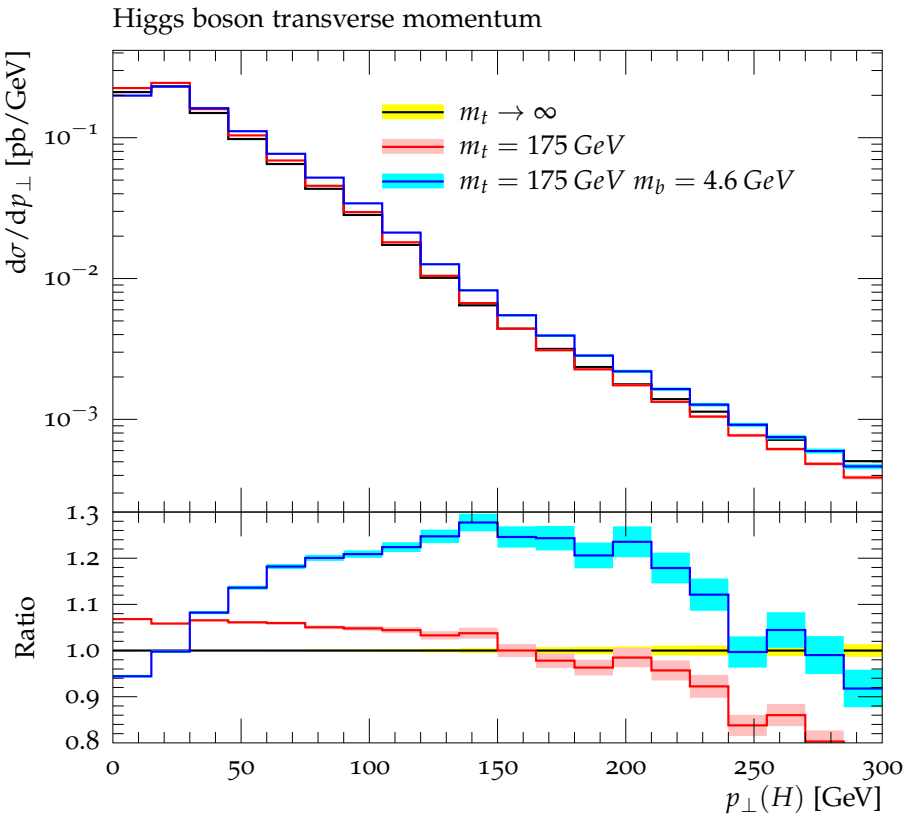
# Preliminary Results




## Fixed Order

- No shower, top-top and top-bottom contributions in one run
- $j\ j \to H$ (NLO)
- $\sqrt{s} = 8$ TeV

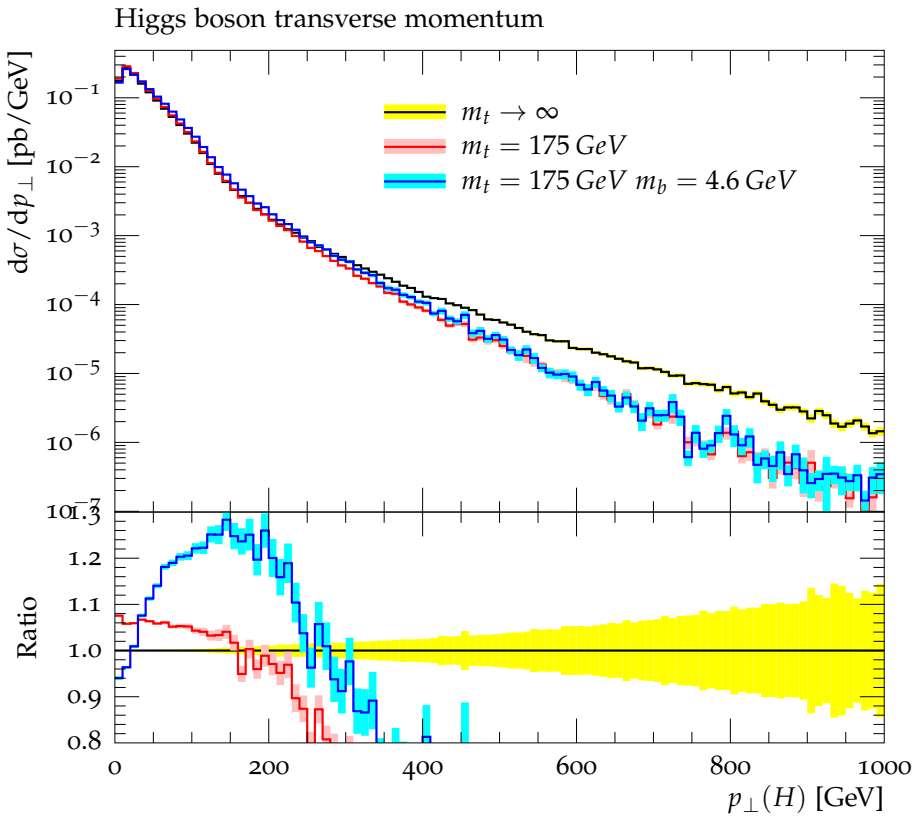
# Preliminary Results




## MC@NLO

- Top-top contribution:
  - $g\ g \to H$ (MC@NLO)
- Top-bottom contribution (MEPS):
  - $g\ g \to H$ (LO)
  - $g\ g \to H\ j$ (LO)
  - $Q_{\text{cut}} = m_b$

# Preliminary Results




## MC@NLO

- Top-top contribution:
  - $g\ g \to H$ (MC@NLO)
- Top-bottom contribution (MEPS):
  - $g\ g \to H$ (LO)
  - $g\ g \to H\ j$ (LO)
  - $Q_{\text{cut}} = m_b$

# References


M. Grazzini and H. Sargsyan. "Heavy-quark Mass Effects in Higgs Boson Production at the LHC". In: *Journal of High Energy Physics* 1309 (2013), p. 129. DOI: 10.1007/JHEP09(2013)129. arXiv: 1306.4581 [hep-ph].