Revisiting Higgs Photoproduction in MadGraph5_aMC@NLO

Laboni Manna

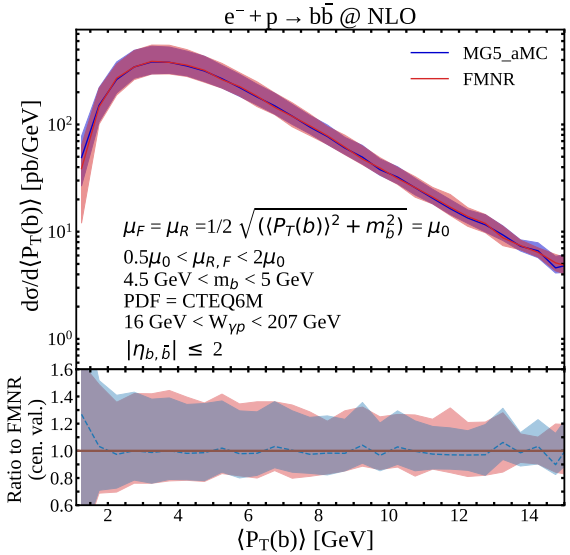
Warsaw University of Technology

work done in collaboration with
J.P Lansberg, O. Mattelaer

Higgs Hunting 2024

Context

- Photoproduction up to NLO in MG5 has been validated **[see talk by L. Manna, EPS-HEP 2023]**
- Verified the results for heavy quark pair production

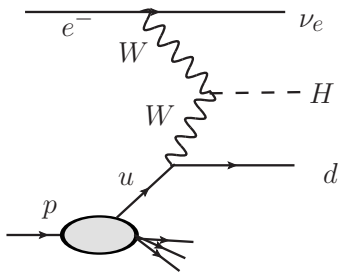


- Predicted the production of $\gamma p \to b\bar{b}c\bar{c} \to$ non-prompt $J/\psi + c + X$ and compared with prompt J/ψ + c production for EIC
- In MG5 we can study both `loop_induced` (loop at LO) and `HEFT` model for Higgs production

Higgs photoproduction

Higgs photoproduction, we have different channels [Li et. al, Nuclear Physics B, 115134]

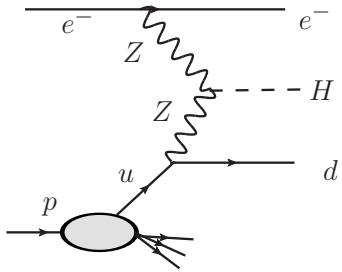
1. $e^- p \to H \nu_e q X$



$\sim \mathcal{O}(100)$ fb

$\sim \mathcal{O}(5)$ fb with cut $|\eta_q| \leq 5$

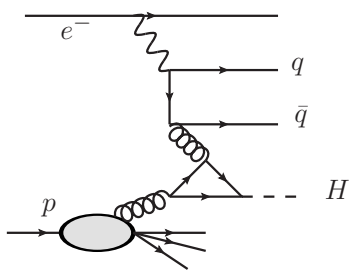
2. $e^- p \to H e^- q X$



$\sim \mathcal{O}(10)$ fb

< 1 fb with cut $|\eta_q| \leq 5$

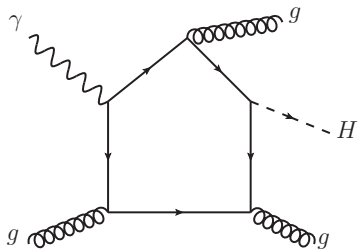
3. $\gamma p \to H q \bar{q} X$



Best described as a resolved-photon contribution. Possible to study with asymmetric-collision developments in MG5
[See talk by A. Safronov, ICHEP 2022]

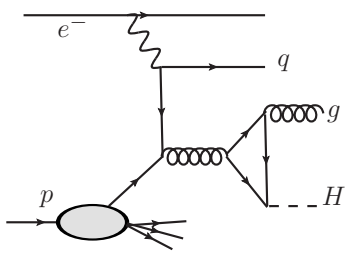
Higgs photoproduction

4. $\gamma p \to HggX$



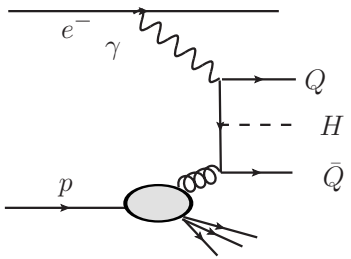
$\sim 10^{-4}$ fb (negligible)

5. $\gamma p \to HgqX$



$g - g - h$ coupling can be studied in `HEFT` & `loop_induced` model

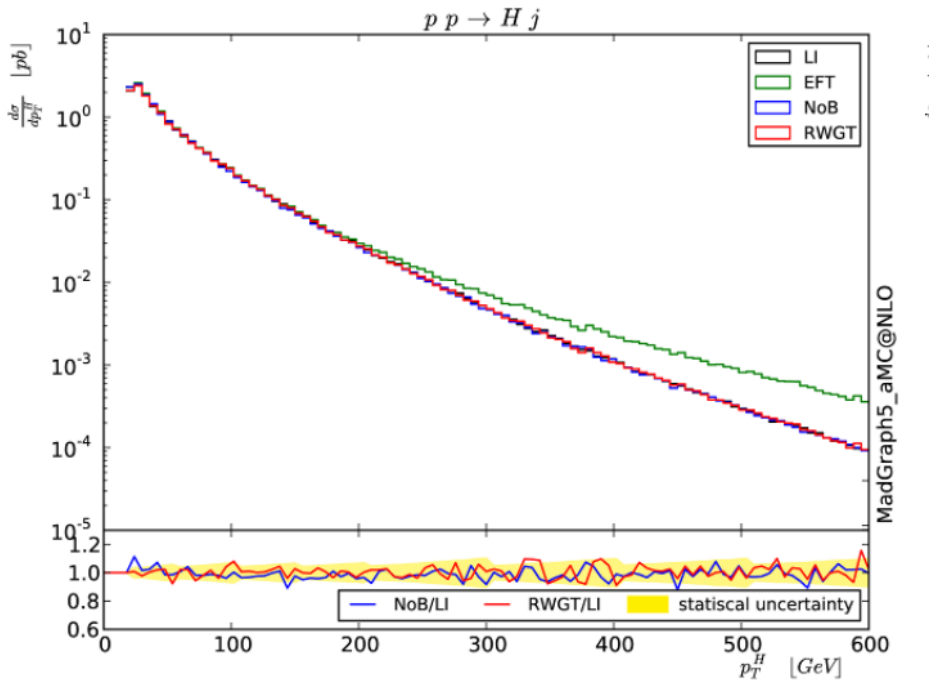
6. $\gamma p \to HQ\bar{Q}X$ [new channel, not considered by Li et al.]



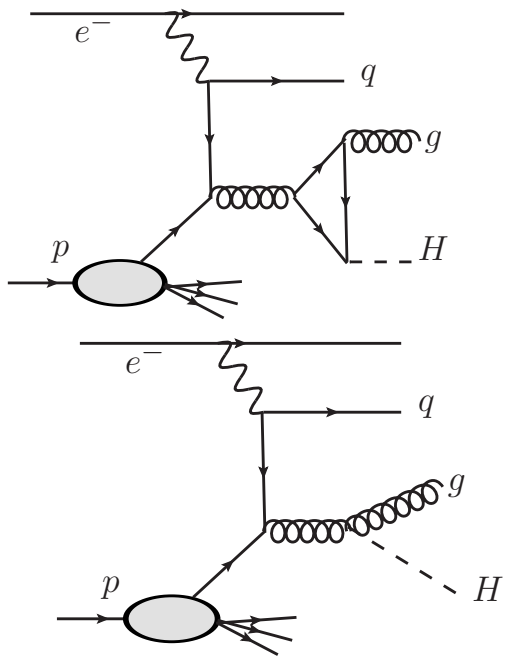
Higgs photoproduction [loop_induced vs. HEFT]

- $\gamma p \to HgqX$ features a g-g-H triangular loop
- In principle, it can be calculated both from loop_induced & HEFT model
- One should be careful with the applicability of HEFT model
- Indeed, for $pp \to Hj$ at larger P_T, HEFT breaks down

[V. Hirschi, O. Mattelaer,JHEP10(2015)146]



- Process $\gamma p \to HgqX$ fails to explain by `HEFT`

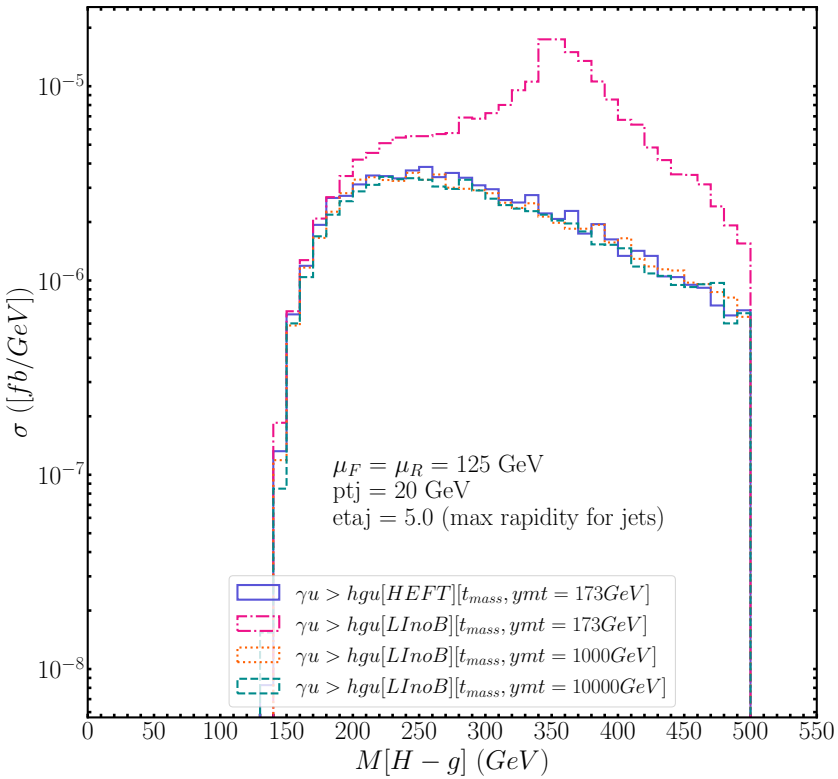


$\sim 3 \times 10^{-4}$fb

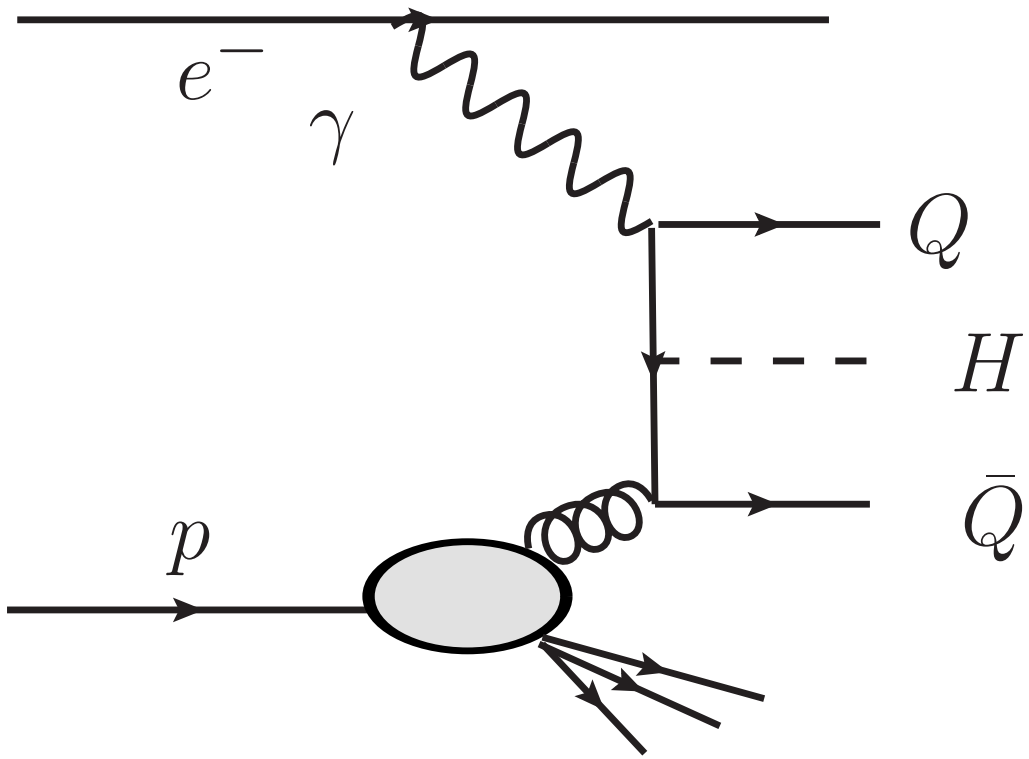
$\sim 1 \times 10^{-4}$fb

- (Exact) `loop_induced` result is 3 times higher than `HEFT`
- Excess from the region of $H - g$ invariant-mass near the top threshold.
- Specific of g-to-H fragmentation
- Note that the scale in the WWA flux is not m_H or something similar, but a few GeV (exp. cut) [Fixed now in MG5]

- Illustration below for u-quark channel [largest contribution]
- Infinite top mass limit for `loop_induced` corresponds to the `HEFT` result (peak shifted to higher $H-g$ values with smaller x-section)
- Note: inclusion of b-loop amplitudes in the `loop_induced` computation with t-loop reduce the cross section by $\sim 3\%$



Higgs + Heavy quark photoproduction @ NLO



New: Higgs + Heavy quark photoproduction @ NLO

$E_e(GeV)$	$E_p(GeV)$	Mass of Higgs (GeV)	Scale (GeV)	PDF used
60	7000 / 50000	125	125	CT18NLO

Partonic process	LO (ab)	NLO (ab)	
a p $\to h b\bar{b}$	9.2	10	LHeC @ 1.3 TeV
a p $\to h t\bar{t}$	5.7	6.1	
a p $\to h c\bar{c}$	1.1	2.2	

Partonic process	LO (ab)	NLO (ab)	
a p $\to h t\bar{t}$	490	470	FCC-eh @ 3.4 TeV
a p $\to h b\bar{b}$	81	90	
a p $\to h c\bar{c}$	10	25	

- K_{NLO} close to 1 for $H + t$ and $H + b$, but close to 2 for $H + c$
- For LHeC, $H + b$ largest
- For FCC-eh, $H + t$ largest
- Might be measurable for itself

Conclusion

- We have validated photoproduction in MG5 up to NLO with several checks (bottom and charm photoproduction cases)
- We have studied Higgs photoproduction and recovered some results from the paper by **Li et. al** [Specific scale for WWA flux important]
- We have studies $H + Q + \bar{Q}$ photoproduction up to NLO which has low cross section compared to WBF case though it is possible to study this channel .
- MG5 in fully functional for both `HEFT` and `loop_induced` model for photoproduction but be careful with the applicability of `HEFT`