Towards H+2j at NNLO

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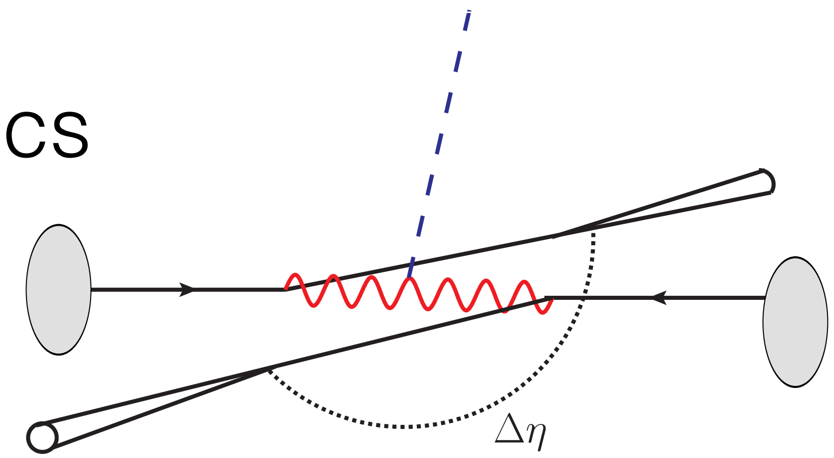
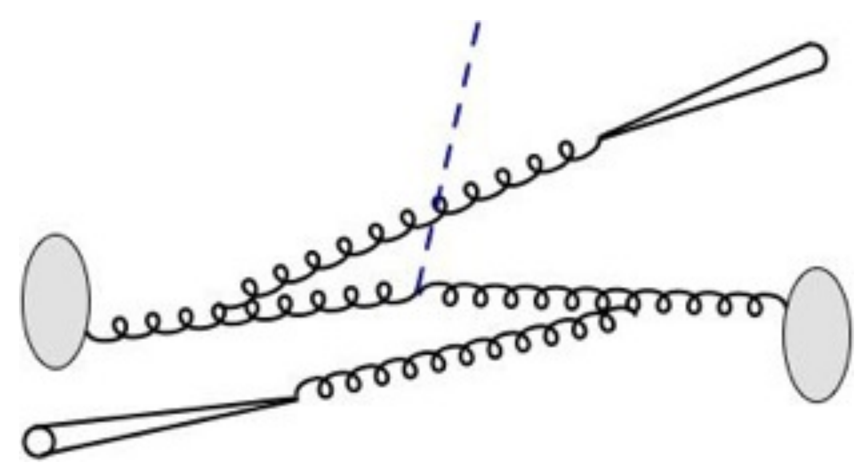
H+2j Motivation

VBF channel very important for Higgs physics



- ~10% of gluon fusion H production
- sensitive to HWW & HZZ couplings, CP
- clear experimental signature (separated jets etc)

Gluon fusion H+2j contaminates signal



- ~25% contamination after VBF cuts
- only known at NLO

NNLO Subtraction

Unphysical intermediate quantities are divergent

- need to regulate with RR, RV and VV subtraction terms

$$
\begin{aligned}
\mathrm{d}\sigma_{ab,NNLO} = &\int_{\Phi_{m+2}} \mathrm{d}\sigma^{RR}_{ab,NNLO} \\
&+ \int_{\Phi_{m+1}} \mathrm{d}\sigma^{RV}_{ab,NNLO} + \mathrm{d}\sigma^{MF,1}_{ab,NNLO} \\
&+ \int_{\Phi_{m}} \mathrm{d}\sigma^{VV}_{ab,NNLO} + \mathrm{d}\sigma^{MF,2}_{ab,NNLO}
\end{aligned}
$$

NNLO Subtraction

Unphysical intermediate quantities are divergent,

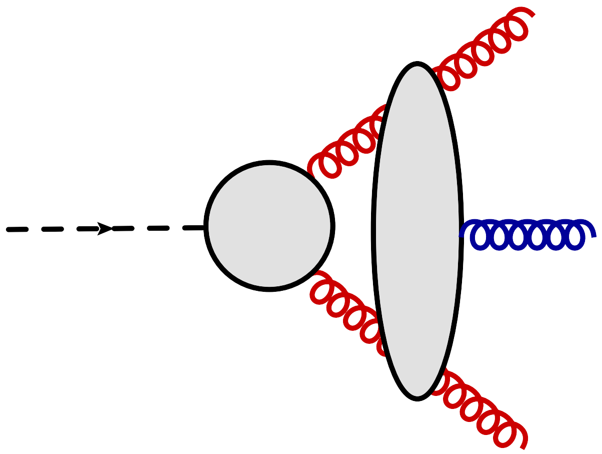
- need to regulate with RR, RV and VV subtraction terms

$$
\begin{aligned}
\mathrm{d}\sigma_{ab,NNLO} = & \int_{\Phi_{m+2}} \left[\mathrm{d}\sigma^{RR}_{ab,NNLO} - \mathrm{d}\sigma^{S}_{ab,NNLO}\right] \\
& + \int_{\Phi_{m+1}} \left[\mathrm{d}\sigma^{RV}_{ab,NNLO} - \mathrm{d}\sigma^{T}_{ab,NNLO}\right] \\
& + \int_{\Phi_{m}} \left[\mathrm{d}\sigma^{VV}_{ab,NNLO} - \mathrm{d}\sigma^{U}_{ab,NNLO}\right]
\end{aligned}
$$

IR subtracted cross section is numerically integrable in 4-D

Antenna Subtraction

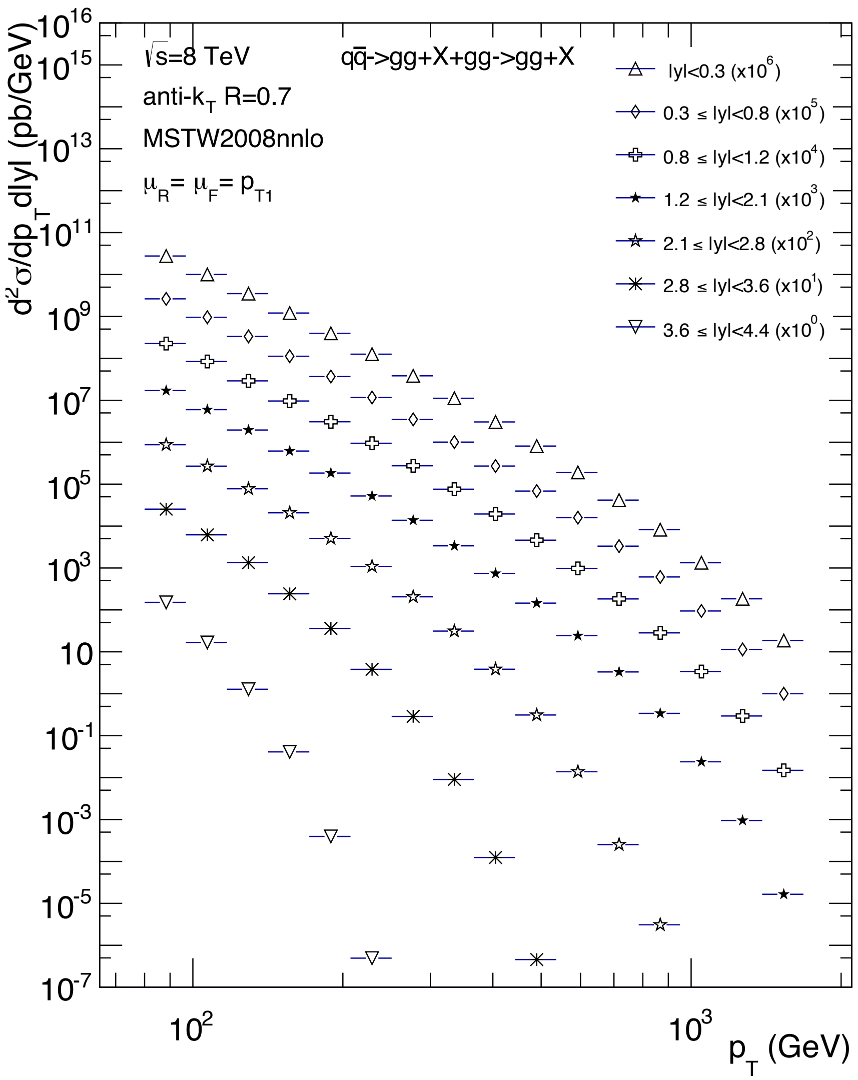
Construct subtraction term from *antennae*

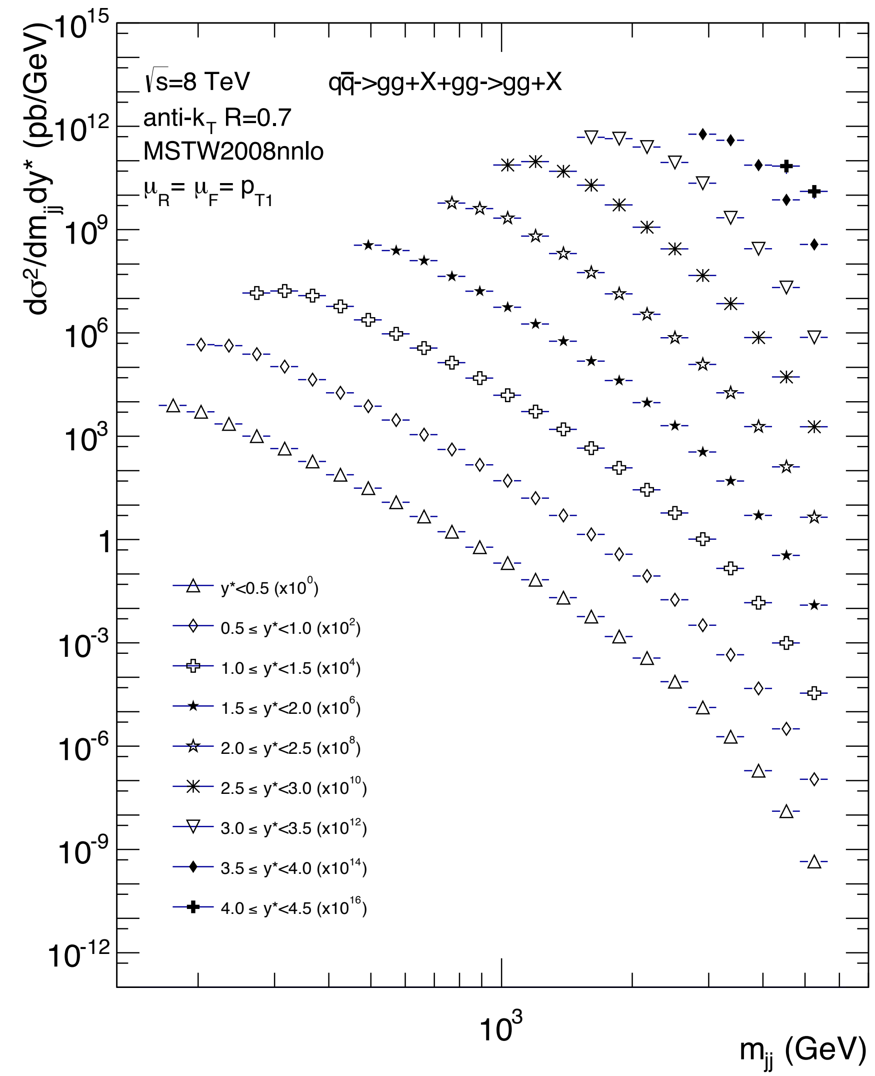


- built from matrix elements
- regulate multiple unresolved limits
- integrated antennae cancel virtual poles *analytically*
- can deal with initial-state colour and many (>1) jets
- already used for $e^+e^- \to 3j$, $pp \to 2j$, $pp \to H+j$

Dijet production

“Gluons only” channel complete at NNLO





Process Independence

Adding in a Higgs… from 2j to H+2j

- infrared singularity/divergence structure the same
- process dependence in reduced matrix elements
- helicity summed amplitudes share symmetry properties (DWI, cyclicity, reflection)

$$f_3^0(i,j,k)A_5^0(1,2,(\widetilde{ij}),(\widetilde{jk}),l) \to f_3^0(i,j,k)A_5^0(1,2,(\widetilde{ij}),(\widetilde{jk}),l;H)$$

What We Can Do

Tree-level amplitudes known for arbitrary legs [Dixon, Glover, Khoze 2004]

- H+6g needed for RR matrix elements
- RR subtraction term known from dijets

One-loop H+4g known analytically [Badger, Glover, Mastrolia, Williams 2009]

- needed for 1-loop reduced matrix elements in RV
- RV subtraction term known from dijets

Two-loop singularity structure known [Catani 1998]

- VV subtraction term known, cancels known pole structure

What We Need

One-loop H+5g amplitudes

- used recently for H+3j NLO [Cullen et al 2013]
- one-loop provider or full analytic results?

Two-loop H+4g amplitudes

- much recent progress in 2-loop amplitudes
- two-loop provider? Speed issues
- challenge shifted back to multi-loop computation

Summary

- H+2j signal phenomenologically interesting
- antenna subtraction method versatile and general
- can reuse known dijet subtraction terms at no cost
- all gluons-only H+2j subtraction terms known
- focus shifting back to 2-loop integrals