QCD corrections to Higgs plus jets production with GoSam

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NLO QCD corrections to the production of Higgs plus two jets at the LHC, e-Print: arXiv:1301.0493, accepted by Physics Letters B

[HvD, Greiner, Luisoni, Mastrolia, Mirabella, Ossola, Peraro, von Soden-Fraunhofen, Tramontano, 2013]

Outline

Motivation

Scattering amplitudes at one-loop

Determining the parametric form of the numerator

Extended rank numerator

Higgs plus two jets

Higgs plus three jets

Summary

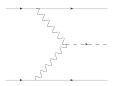
► Boson discovered by Atlas and CMS → Higgs?

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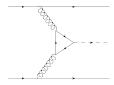
Need to determine properties: spin, CP properties, couplings

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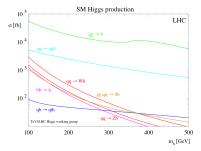


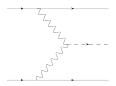
Vector Boson Fusion



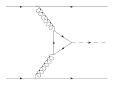
Gluon Fusion via top loop

- ▶ Boson discovered by Atlas and CMS → Higgs?
- Need to determine properties: spin, CP properties, couplings

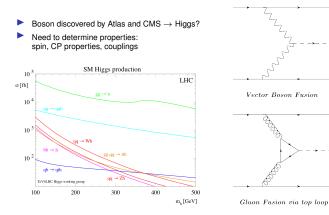




Vector Boson Fusion

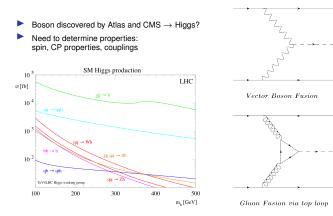


Gluon Fusion via top loop



Leading order too strong dependence on renormalization and factorization scale

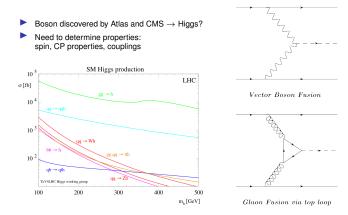
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Leading order too strong dependence on renormalization and factorization scale

Development of more general framework for NLO automation

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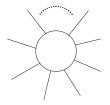


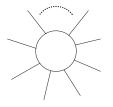
Leading order too strong dependence on renormalization and factorization scale

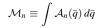
Development of more general framework for NLO automation

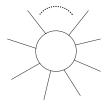
$$\sigma^{NLO} = \int_{m+1} \left[d^{(4)} \sigma^R - d^{(4)} \sigma^A \right] + \int_m \left[d^{(4)} \sigma^B + \int_{loop} d^{(d)} \sigma^V + \int_1 d^{(d)} \sigma^A \right]$$

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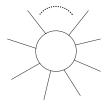






$$\mathcal{M}_n \equiv \int \mathcal{A}_n(\bar{q}) d\bar{q} \equiv \int d^{-2\epsilon} \mu \int d^4q \frac{N(q,\mu^2)}{\bar{D}_0 \dots \bar{D}_{n-1}}$$

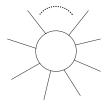
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$$\mathcal{M}_n \equiv \int \mathcal{A}_n(\bar{q}) \, d\bar{q} \equiv \int d^{-2\epsilon} \mu \int d^4q \frac{N(q,\mu^2)}{\bar{D}_0 \dots \bar{D}_{n-1}}$$

Decompose:



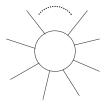


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Decompose:

$$\mathcal{A}_{n}^{\text{one-loop}} = c_{5,0} + c_{4,0} + c_{4,4} + c_{4,4} + c_{3,0} + c_{3,7} + c_{2,0} - c_{4,2} + c_{2,0} + c_{2,0} + c_{2,0} + c_{2,0} + c_{1,0} +$$

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$$\mathcal{M}_n \equiv \int \mathcal{A}_n(\bar{q}) \, d\bar{q} \equiv \int d^{-2\epsilon} \mu \int d^4q \frac{N(q,\mu^2)}{\bar{D}_0 \dots \bar{D}_{n-1}}$$

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$$\int d^{-2\epsilon} \mu^2 d^4 q \mathcal{A}_n(q) = \int d\bar{q} \frac{c_{5,0}}{D_0 D_1 D_2 D_3 D_4} + \int d\bar{q} \frac{c_{4,0} + c_{4,4} \mu^4}{D_0 D_1 D_2 D_3} + \int d\bar{q} \frac{c_{3,0} + c_{3,7} \mu^2}{D_0 D_1 D_2} + \int d\bar{q} \frac{c_{2,0} + c_{2,9} \mu^2}{D_0 D_1} + \int d\bar{q} \frac{c_{1,0}}{D_0}$$

• computation of $\mathcal{M}_n \rightarrow$ computation of coefficients

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$$\mathcal{A}_{n}^{\text{one-loop}} = c_{5,0} + c_{4,0} + c_{4,4} + c_{3,0} + c_{3,7} + c_{3,7} + c_{2,0} + c_{2,9} + c_{2,9} + c_{1,0}$$

$$\int d^{-2\epsilon} \mu^{2} d^{4} q \mathcal{A}_{n}(q) = \int d\bar{q} \frac{c_{5,0}}{D_{0} D_{1} D_{2} D_{3} D_{4}} + \int d\bar{q} \frac{c_{4,0} + c_{4,4} \mu^{4}}{D_{0} D_{1} D_{2} D_{3}} + \int d\bar{q} \frac{c_{3,0} + c_{3,7} \mu^{2}}{D_{0} D_{1} D_{2}} + \int d\bar{q} \frac{c_{2,0} + c_{2,9} \mu^{2}}{D_{0} D_{1}} + \int d\bar{q} \frac{c_{1,0}}{D_{0}}$$

• integral \rightarrow integrand:

$$\begin{aligned} \mathcal{A}_{n}^{\text{one-loop}} &= c_{5,0} & + c_{4,0} & + c_{4,4} & + c_{4,4} & + c_{3,0} & + c_{3,7} & + c_{2,0} - - + c_{2,0} - + c_{1,0} \\ & \int d^{-2\epsilon} \mu^2 d^4 q \mathcal{A}_n(q) = \int d\bar{q} \frac{c_{5,0}}{D_0 D_1 D_2 D_3 D_4} + \int d\bar{q} \frac{c_{4,0} + c_{4,4} \mu^4}{D_0 D_1 D_2 D_3} \\ & + \int d\bar{q} \frac{c_{3,0} + c_{3,7} \mu^2}{D_0 D_1 D_2} + \int d\bar{q} \frac{c_{2,0} + c_{2,9} \mu^2}{D_0 D_1} + \int d\bar{q} \frac{c_{1,0}}{D_0} \end{aligned}$$

► integral → integrand:

$$A_n(q) = \frac{c_{5,0} + f_{01234}(q, \mu^2)}{D_0 D_1 D_2 D_3 D_4} + \frac{c_{4,0} + c_{4,4} \mu^4 + f_{0123}(q, \mu^2)}{D_0 D_1 D_2 D_3} + \frac{c_{3,0} + c_{3,7} \mu^2 + f_{012}(q, \mu^2)}{D_0 D_1 D_2} + \frac{c_{2,0} + c_{2,9} \mu^2 + f_{01}(q, \mu^2)}{D_0 D_1} + \frac{c_{1,0} + f_0(q, \mu^2)}{D_0}$$

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$$\begin{aligned} \mathcal{A}_{n}^{\text{one-loop}} &= c_{5,0} & + c_{4,0} & + c_{4,4} & + c_{4,4} & + c_{3,0} & + c_{3,7} & + c_{2,0} & - + c_{2,0} & - + c_{2,0} & - + c_{1,0} & - \\ & \int d^{-2\epsilon} \mu^2 d^4 q \mathcal{A}_n(q) = \int d\bar{q} \frac{c_{5,0}}{D_0 D_1 D_2 D_3 D_4} + \int d\bar{q} \frac{c_{4,0} + c_{4,4} \mu^4}{D_0 D_1 D_2 D_3} \\ & + \int d\bar{q} \frac{c_{3,0} + c_{3,7} \mu^2}{D_0 D_1 D_2} + \int d\bar{q} \frac{c_{2,0} + c_{2,9} \mu^2}{D_0 D_1} + \int d\bar{q} \frac{c_{1,0}}{D_0} \end{aligned}$$

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$$\int d^{-2\epsilon} \mu^2 \int d^4 q \quad \frac{f_{ij\dots}(q,\mu^2)}{D_i D_j\dots} = 0$$

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$$\begin{aligned} \mathcal{A}_{n}^{\text{one-loop}} &= c_{5,0} & + c_{4,0} & + c_{4,4} & + c_{4,4} & + c_{3,0} & + c_{3,7} & + c_{2,0} & - + c_{2,0} & - + c_{2,0} & - + c_{1,0} & - \\ & \int d^{-2\epsilon} \mu^2 d^4 q \mathcal{A}_n(q) = \int d\bar{q} \frac{c_{5,0}}{D_0 D_1 D_2 D_3 D_4} + \int d\bar{q} \frac{c_{4,0} + c_{4,4} \mu^4}{D_0 D_1 D_2 D_3} \\ & + \int d\bar{q} \frac{c_{3,0} + c_{3,7} \mu^2}{D_0 D_1 D_2} + \int d\bar{q} \frac{c_{2,0} + c_{2,9} \mu^2}{D_0 D_1} + \int d\bar{q} \frac{c_{1,0}}{D_0} \end{aligned}$$

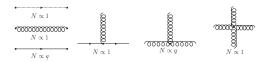
► integral → integrand:

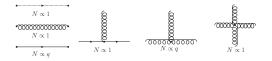
$$A_n(q) = \frac{c_{5,0} + f_{01234}(q, \mu^2)}{D_0 D_1 D_2 D_3 D_4} + \frac{c_{4,0} + c_{4,4} \mu^4 + f_{0123}(q, \mu^2)}{D_0 D_1 D_2 D_3} + \frac{c_{3,0} + c_{3,7} \mu^2 + f_{012}(q, \mu^2)}{D_0 D_1 D_2} + \frac{c_{2,0} + c_{2,9} \mu^2 + f_{01}(q, \mu^2)}{D_0 D_1} + \frac{c_{1,0} + f_0(q, \mu^2)}{D_0}$$

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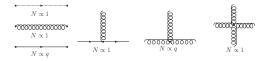
$$\mathcal{A}_n = \sum_{ijkl} \frac{\Delta_{ijkl}(q,\mu^2)}{D_i D_j D_k D_l} + \sum_{ijk} \frac{\Delta_{ijk}(q,\mu^2)}{D_i D_j D_k} + \sum_{ij} \frac{\Delta_{ij}(q,\mu^2)}{D_i D_j} + \sum_i \frac{\Delta_i(q,\mu^2)}{D_i}$$

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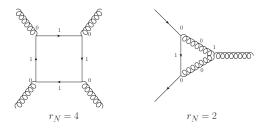


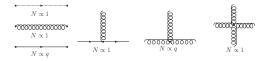


 Only q propagators and 3-gluon-vertices contribute one power of q to numerator

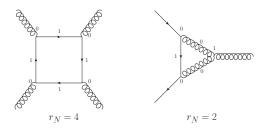


 Only q propagators and 3-gluon-vertices contribute one power of q to numerator



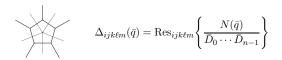


 Only q propagators and 3-gluon-vertices contribute one power of q to numerator



▶ $r_N \leq \#D$

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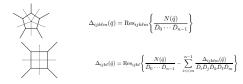
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$$\Delta_{ijk\ell m}(\bar{q}) = \operatorname{Res}_{ijk\ell m} \left\{ \frac{N(\bar{q})}{\bar{D}_0 \cdots \bar{D}_{n-1}} \right\}$$

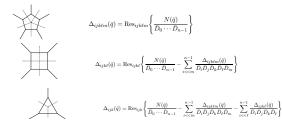
$$\Delta_{ijk\ell}(\bar{q}) = \operatorname{Res}_{ijk\ell} \left\{ \frac{N(\bar{q})}{\bar{D}_0 \cdots \bar{D}_{n-1}} - \sum_{i < < m}^{n-1} \frac{\Delta_{ijk\ell m}(\bar{q})}{\bar{D}_i \bar{D}_j \bar{D}_k \bar{D}_\ell \bar{D}_m} \right\}$$

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$$\Delta_{ijk}(\bar{q}) = \operatorname{Res}_{ijk} \left\{ \frac{N(\bar{q})}{\bar{D}_0 \cdots \bar{D}_{n-1}} - \sum_{i < < m}^{n-1} \frac{\Delta_{ijk\ell m}(\bar{q})}{\bar{D}_i \bar{D}_j \bar{D}_k \bar{D}_\ell} - \sum_{i < \ell}^{n-1} \frac{\Delta_{ijk\ell}(\bar{q})}{\bar{D}_i \bar{D}_j \bar{D}_k \bar{D}_\ell} \right\}$$

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$$\Delta_{ij}(\bar{q}) = \operatorname{Res}_{ij} \left\{ \frac{N(\bar{q})}{\bar{D}_0 \cdots \bar{D}_{n-1}} - \sum_{i < < m}^{n-1} \frac{\Delta_{ijk\ell m}(\bar{q})}{\bar{D}_i \bar{D}_j \bar{D}_k \bar{D}_\ell \bar{D}_m} - \sum_{i < < k}^{n-1} \frac{\Delta_{ijk\ell}(\bar{q})}{\bar{D}_i \bar{D}_j \bar{D}_k \bar{D}_\ell} - \sum_{i < < k}^{n-1} \frac{\Delta_{ijk}(\bar{q})}{\bar{D}_i \bar{D}_j \bar{D}_k} \right\}$$

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$$\Delta_{ijk\ell m}(\vec{q}) = \operatorname{Res}_{ijk\ell m} \left\{ \frac{N(\vec{q})}{D_0 \cdots D_{n-1}} \right\}$$

$$\Delta_{ijk\ell}(\vec{q}) = \operatorname{Res}_{ijk\ell} \left\{ \frac{N(\vec{q})}{D_0 \cdots D_{n-1}} - \sum_{i < m}^{n-1} \frac{\Delta_{ijk\ell m}(\vec{q})}{D_i D_j D_k D_l D_m} \right\}$$

$$\Delta_{ijk}(\vec{q}) = \operatorname{Res}_{ijk} \left\{ \frac{N(\vec{q})}{D_0 \cdots D_{n-1}} - \sum_{i < m}^{n-1} \frac{\Delta_{ijk\ell m}(\vec{q})}{D_i D_j D_k D_l D_m} - \sum_{i < m}^{n-1} \frac{\Delta_{ijk\ell m}(\vec{q})}{D_i D_j D_k D_k D_m} \right\}$$

$$\Delta_{ij}(\vec{q}) = \operatorname{Res}_{ijk} \left\{ \frac{N(\vec{q})}{D_0 \cdots D_{n-1}} - \sum_{i < m}^{n-1} \frac{\Delta_{ijk\ell m}(\vec{q})}{D_i D_j D_k D_k D_m} - \sum_{i < m}^{n-1} \frac{\Delta_{ijk\ell m}(\vec{q})}{D_i D_j D_k D_k D_\ell} \right\}$$

$$\Delta_{ij}(\vec{q}) = \operatorname{Res}_{i} \left\{ \frac{N(\vec{q})}{D_0 \cdots D_{n-1}} - \sum_{i < m}^{n-1} \frac{\Delta_{ijk\ell m}(\vec{q})}{D_i D_j D_k D_k D_\ell} - \sum_{i < \ell}^{n-1} \frac{\Delta_{ijk\ell m}(\vec{q})}{D_i D_j D_k D_\ell D_m} - \sum_{i < \ell}^{n-1} \frac{\Delta_{ijk\ell m}(\vec{q})}{D_i D_j D_k D_\ell D_m} + \sum_{i < \ell}^{n-1} \frac{\Delta_{ijk\ell}(\vec{q})}{D_i D_j D_k} - \sum_{i < \ell}^{n-1} \frac{\Delta_{ijk\ell m}(\vec{q})}{D_i D_j D_k} \right\}$$

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$$\begin{split} \Delta_{ijk\ell m}(q,\mu^2) &= c_{5,0}^{(ijk\ell m)} \ \mu^2 \ , \\ \Delta_{ijk\ell}(q,\mu^2) &= \Delta_{ijk\ell}^R(q,\mu^2) + c_{4,0}^{(ijk\ell)} + c_{4,2}^{(ijk\ell)} \mu^2 + c_{4,4}^{(ijk\ell)} \mu^4 \ , \\ \Delta_{ijk}(q,\mu^2) &= \Delta_{ijk}^R(q,\mu^2) + c_{3,0}^{(ijk)} + c_{3,7}^{(ijk)} \mu^2 \ , \\ \Delta_{ij}(q,\mu^2) &= \Delta_{ij}^R(q,\mu^2) + c_{2,0}^{(ij)} + c_{2,9}^{(ij)} \mu^2 \ , \\ \Delta_{i}(q,\mu^2) &= c_{1,0}^{(i)} + c_{1,1}^{(i)}((q+p_i) \cdot e_1) + c_{1,2}^{(i)}((q+p_i) \cdot e_2) \\ &\quad + c_{1,3}^{(i)}((q+p_i) \cdot e_3) + c_{1,4}^{(i)}((q+p_i) \cdot e_4) \ . \end{split}$$

$$\begin{split} \Delta^R_{ijk\ell}(q,\mu^2) &= \left(c^{(ijk\ell)}_{4,1} + c^{(ijk\ell)}_{4,3} \ \mu^2\right)(q+p_i) \cdot v_{\perp} \ , \\ \Delta^R_{ijk}(q,\mu^2) &= \left(c^{(ijk)}_{3,1} + c^{(ijk)}_{3,8} \ \mu^2\right)(q+p_i) \cdot e_3 + \left(c^{(ijk)}_{3,4} + c^{(ijk)}_{3,9} \ \mu^2\right)(q+p_i) \cdot e_4 \\ &\quad + c^{(ijk)}_{3,3}((q+p_i) \cdot e_3)^2 + c^{(ijk)}_{3,6}((q+p_i) \cdot e_4)^2 \\ &\quad + c^{(ijk)}_{3,3}((q+p_i) \cdot e_3)^3 + c^{(ijk)}_{3,6}((q+p_i) \cdot e_4)^3 \ , \\ \Delta^R_{ij}(q,\mu^2) &= c^{(i)}_{2,1}(q+p_i) \cdot e_2 + c^{(ij)}_{2,2}((q+p_i) \cdot e_2)^2 \\ &\quad + c^{(ij)}_{2,3}(q+p_i) \cdot e_3 + c^{(ij)}_{2,4}((q+p_i) \cdot e_3)^2 \\ &\quad + c^{(ij)}_{2,5}(q+p_i) \cdot e_4 + c^{(ij)}_{2,6}((q+p_i) \cdot e_4)^2 \\ &\quad + c^{(ij)}_{2,7}((q+p_i) \cdot e_2)((q+p_i) \cdot e_3) + c^{(ij)}_{2,6}((q+p_i) \cdot e_2)((q+p_i) \cdot e_4) \,. \end{split}$$

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$$\begin{split} &\Delta_{ijk\ell m}(q,\mu^2) = c_{i,0}^{(ijk\ell m)} \mu^2 \ , \\ &\Delta_{ijk\ell}(q,\mu^2) = \Delta_{ijk\ell}^{q}(q,\mu^2) + c_{4,0}^{(ijk\ell)} + c_{4,2}^{(ijk\ell)} \mu^2 + c_{4,4}^{(ijk\ell)} \mu^4 \ , \\ &\Delta_{ijk}(q,\mu^2) = \Delta_{ijk}^{q}(q,\mu^2) + c_{3,0}^{(ij)} + c_{3,0}^{(ij)} \mu^2 \ , \\ &\Delta_{ij}(q,\mu^2) = \Delta_{ij}^{q}(q,\mu^2) + c_{2,0}^{(ij)} + c_{2,0}^{(ij)} \mu^2 \ , \\ &\Delta_{ij}(q,\mu^2) = c_{1,0}^{(i)} + c_{1,1}^{(i)}(q+p_i) \cdot e_1) + c_{1,2}^{(i)}((q+p_i) \cdot e_2) \\ &+ c_{1,3}^{(i)}((q+p_i) \cdot e_3) + c_{1,4}^{(i)}((q+p_i) \cdot e_4) \ . \end{split}$$

$$\begin{split} \Delta^{0}_{ijk\ell}(q,\mu^2) &= \left(c_{41}^{(1k0)} + c_{43}^{(1k0)}(\mu^2)(q+p_i) \cdot v_{\perp} \ , \\ \Delta^{0}_{ijk}(q,\mu^2) &= \left(c_{51}^{(1k)} + c_{53}^{(1k)}(\mu^2)(q+p_i) \cdot e_{4} + \left(c_{54}^{(1k)} + c_{53}^{(1k)}(\mu^2)(q+p_i) \cdot e_{4} + c_{53}^{(1k)}((q+p_i) \cdot e_{3})^2 + c_{53}^{(1k)}((q+p_i) \cdot e_{4})^2 \right. \\ &+ c_{53}^{(1k)}((q+p_i) \cdot e_{3})^2 + c_{53}^{(1k)}((q+p_i) \cdot e_{4})^2 \\ &+ c_{53}^{(1k)}(q+p_i) \cdot e_{3})^2 + c_{53}^{(1k)}((q+p_i) \cdot e_{3})^2 \\ &+ c_{53}^{(1k)}(q+p_i) \cdot e_{3} + c_{54}^{(1k)}((q+p_i) \cdot e_{3})^2 \\ &+ c_{53}^{(1k)}(q+p_i) \cdot e_{3} + c_{54}^{(1k)}((q+p_i) \cdot e_{3})^2 \\ &+ c_{53}^{(1k)}(q+p_i) \cdot e_{4} + c_{54}^{(1k)}((q+p_i) \cdot e_{3})^2 \\ &+ c_{53}^{(2k)}(q+p_i) \cdot e_{4} + c_{54}^{(1k)}((q+p_i) \cdot e_{3}) + c_{53}^{(1k)}((q+p_i) \cdot e_{3}) + c_{53}^{(1k)}((q+$$

coefficients:

- 5ple cut: 1 coefficient
- 4ple cut: 5 coefficients
- Sple cut: 10 coefficients
- 2ple cut: 10 coefficients
- 1 ple cut: 5 coefficients

$$\begin{split} & \Delta_{ijk\ell m}(q,\mu^2) = c_{i,0}^{(ijk\ell m)} \mu^2 \;, \\ & \Delta_{ijk\ell}(q,\mu^2) = \Delta_{ijk\ell}^R(q,\mu^2) + c_{4,0}^{(ijk\ell)} + c_{4,2}^{(ijk\ell)} \mu^2 + c_{4,4}^{(ijk\ell)} \mu^4 \;, \\ & \Delta_{ijk}(q,\mu^2) = \Delta_{ijk}^R(q,\mu^2) + c_{3,0}^{(ijk)} + c_{3,1}^{(ij\ell)} \mu^2 \;, \\ & \Delta_{ij}(q,\mu^2) = \Delta_{ij}^R(q,\mu^2) + c_{2,0}^{(ij)} + c_{2,0}^{(ij)} \mu^2 \;, \\ & \Delta_{ij}(q,\mu^2) = c_{1,0}^{(i)} + c_{1,1}^{(i)}(q+p_i) \cdot e_1) + c_{1,2}^{(i)}((q+p_i) \cdot e_2) \\ & \quad + c_{1,3}^{(i)}((q+p_i) \cdot e_3) + c_{1,4}^{(i)}((q+p_i) \cdot e_4) \;. \end{split}$$

$$\begin{split} & \Delta^{B}_{ijk\ell}(q,\mu^2) = \left(c^{\ell_1(kb)}_{4} + c^{\ell_1(kb)}_{4}(\mu^2)(q+p_i) \cdot v_{\perp} \ , \\ & \Delta^{B}_{ijk}(q,\mu^2) = \left(c^{\ell_1(kb)}_{4} + c^{\ell_2(kb)}_{4}(\mu^2)(q+p_i) \cdot e_{3} + \left(c^{\ell_1(k)}_{4,4} + c^{\ell_2(kb)}_{4}(\mu^2)(q+p_i) \cdot e_{4} \right. \\ & + c^{\ell_1(kb)}_{4,3}((q+p_i) \cdot e_{3})^2 + c^{\ell_1(kb)}_{4,3}((q+p_i) \cdot e_{4})^2 \\ & + c^{\ell_1(kb)}_{4,3}((q+p_i) \cdot e_{3})^3 + c^{\ell_1(kb)}_{4,3}((q+p_i) \cdot e_{4})^3 \ , \\ & \Delta^{B}_{ij}(q,\mu^2) = c^{\ell_1(k)}_{4,3}(q+p_i) \cdot e_{3} + c^{\ell_2(k)}_{4,3}((q+p_i) \cdot e_{3})^2 \\ & + c^{\ell_2(k)}_{4,3}(q+p_i) \cdot e_{3} + c^{\ell_2(k)}_{4,3}((q+p_i) \cdot e_{3})^2 \\ & + c^{\ell_2(k)}_{4,3}(q+p_i) \cdot e_{4} + c^{\ell_2(k)}_{4,3}((q+p_i) \cdot e_{3})^2 \\ & + c^{\ell_2(k)}_{4,3}(q+p_i) \cdot e_{4} + c^{\ell_2(k)}_{4,3}((q+p_i) \cdot e_{3})^2 \\ & + c^{\ell_2(k)}_{4,3}((q+p_i) \cdot e_{3}) (q+p_i) \cdot e_{3}) \right) \end{split}$$

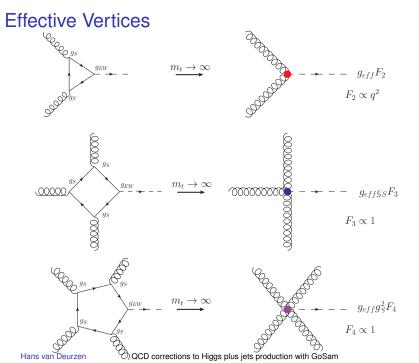
- coefficients:
 - 5ple cut: 1 coefficient
 - 4ple cut: 5 coefficients
 - Sple cut: 10 coefficients
 - 2ple cut: 10 coefficients
 - 1ple cut: 5 coefficients
- form residues process independent
- values of coefficients process dependent

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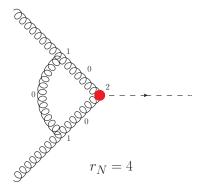
$$\begin{split} & \Delta_{ijk\ell m}(q,\mu^2) = c_{i,0}^{(ijk\ell m)} \mu^2 \;, \\ & \Delta_{ijk\ell}(q,\mu^2) = \Delta_{ijk\ell}^R(q,\mu^2) + c_{4,0}^{(ijk\ell)} + c_{4,2}^{(ijk\ell)} \mu^2 + c_{4,4}^{(ijk\ell)} \mu^4 \;, \\ & \Delta_{ijk}(q,\mu^2) = \Delta_{ijk}^R(q,\mu^2) + c_{3,0}^{(ijk)} + c_{3,1}^{(ij\ell)} \mu^2 \;, \\ & \Delta_{ij}(q,\mu^2) = \Delta_{ij}^R(q,\mu^2) + c_{2,0}^{(ij)} + c_{2,0}^{(ij)} \mu^2 \;, \\ & \Delta_{ij}(q,\mu^2) = c_{1,0}^{(i)} + c_{1,1}^{(i)}(q+p_i) \cdot e_1) + c_{1,2}^{(i)}((q+p_i) \cdot e_2) \\ & \quad + c_{1,3}^{(i)}((q+p_i) \cdot e_3) + c_{1,4}^{(i)}((q+p_i) \cdot e_4) \;. \end{split}$$

$$\begin{split} \Delta^{A}_{ijk\ell}(q,\mu^2) &= \left(e^{i_1(jk)}_{k} + e^{i_1(jk)}_{k} + e$$

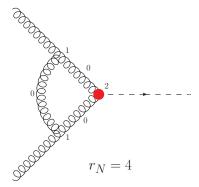
- coefficients:
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- form residues process independent
- values of coefficients process dependent
- Implemented in Samurai [Ossola, Reiter, Tramontano, Mastrolia, 2010]



Rankcounting, higher rank



Rankcounting, higher rank



• One effective vertex: $r_N \leq \#D + 1$

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Extended rank residues

$$\begin{split} \Delta_{ijjk\ell m}(q,\mu^2) &= \binom{i_{ijk\ell m}}{s_{,0}}\mu^2 \ , \\ \Delta_{ijjk\ell}(q,\mu^2) &= \Delta^R_{ijk\ell}(q,\mu^2) + c^{(ijk\ell)}_{4,0} + c^{(ijk\ell)}_{4,2}\mu^2 + c^{(ijk\ell)}_{4,4}\mu^4 \ , \\ \Delta_{ijk}(q,\mu^2) &= \Delta^R_{ij}(q,\mu^2) + c^{(ijk)}_{3,0} + c^{(ijk)}_{3,2}\mu^2 \ , \\ \Delta_{ij}(q,\mu^2) &= \Delta^R_{ij}(q,\mu^2) + c^{(ij)}_{2,0} + c^{(ij)}_{2,0}\mu^2 \ , \\ \Delta_{i}(q,\mu^2) &= c^{(i)}_{1,0} + c^{(i)}_{1,1}((q+p_i) \cdot e_1) + c^{(i)}_{1,2}((q+p_i) \cdot e_2) \\ &\quad + c^{(i)}_{1,3}((q+p_i) \cdot e_3) + c^{(i)}_{1,4}((q+p_i) \cdot e_4) \ . \end{split}$$

$$\begin{split} \Delta^{B}_{1jkl}(q,\mu^2) &= \left(c^{(ijk)}_{1,1} + c^{(ijk)}_{3,1} \mu^2\right)(q+p_l) \cdot v_{\perp} \ , \\ \Delta^{R}_{1jk}(q,\mu^2) &= \left(c^{(ijk)}_{3,1} + c^{(ijk)}_{3,k} \mu^2\right)(q+p_l) \cdot e_3 + \left(c^{(ijk)}_{3,k} + c^{(ijk)}_{3,j} \mu^2\right)(q+p_l) \cdot e_4 \\ &+ \frac{c^{(ijk)}_{3,2}}{(q+p_l) \cdot e_3)^2} + c^{(ijk)}_{3,k}(q+p_l) \cdot e_4)^2 \\ &+ \frac{c^{(ijk)}_{3,k}}{(q+p_l) \cdot e_3)^2} + c^{(ijk)}_{3,k}(q+p_l) \cdot e_4)^3 \ , \\ \Delta^{R}_{0j}(q,\mu^2) &= c^{(ijk)}_{3,1}(q+p_l) \cdot e_2 + c^{(ijk)}_{2,2}(q+p_l) \cdot e_3)^2 \\ &+ c^{(ijk)}_{2,2}(q+p_l) \cdot e_2 + c^{(ijk)}_{2,2}(q+p_l) \cdot e_3)^2 \\ &+ c^{(ijk)}_{2,2}(q+p_l) \cdot e_3 + c^{(ijk)}_{2,k}(q+p_l) \cdot e_3)^2 \\ &+ c^{(ijk)}_{2,2}(q+p_l) \cdot e_2(q+p_l) \cdot e_3)^2 \\ &+ c^{(ijk)}_{2,2}((q+p_l) \cdot e_2)(q+p_l) \cdot e_3)^2 \\ &+ c^{(ijk)}_{2,2}((q+p_l) \cdot e_2)(q+p_l) \cdot e_3)^2 \\ &+ c^{(ijk)}_{2,2}((q+p_l) \cdot e_2)(q+p_l) \cdot e_3)^2 \\ &+ c^{(ijk)}_{2,2}((q+p_l) \cdot e_3)(q+p_l) \cdot e_3)^2 \\ &+ c^{(ijk)}_{2,2}(q+p_l) \cdot e_3) + c^{(ijk)}_{2,3}(q+p_l) \cdot e_3)^2 \\ &+ c^{(ijk)}_{2,2}(q+p_l) \cdot e_3)(q+p_l) \cdot e_3)^2 \\ &+ c^{(ijk)}_{2,2}(q+p_l) \cdot e_3) + c^{(ijk)}_{2,3}(q+p_l) \cdot e_3) \\ &+ c^{(ijk)}_{2,3}(q+p_l) \cdot e_3 + c^{(ijk)}_{2,3}(q+p_l) \cdot e_3)^2 \\ &+ c^{(ijk)}_{2,3}(q+p_l) \cdot e_3) + c^{(ijk)}_{2,3}(q+p_l) \cdot e_3) \\ &+ c^{(ijk)}_{2,3}(q+p_l) \cdot e_3 + c^{(ijk)}_{2,3}(q+p_l) \cdot e_3) \\ &+ c^{(ijk)}_{2,3}(q+p_l) \cdot e_3 + c^{(ijk)}_{2,3}(q+p_l) \cdot e_3) \\ &+ c^{(ijk)}_{2,3}(q+p_l) \cdot e_3 + c^{(ijk)}_{2,3}(q+p_l) \cdot e_3) \\ &+ c^{(ijk)}_{2,3}(q+p_l) \cdot e_3 + c^{(ijk)}_{2,3}(q+p_l) \cdot e_3) \\ &+ c^{(ijk)}_{2,3}(q+p_l) \cdot e_3 + c^{(ijk)}_{2,3}(q+p_l) \cdot e_3) \\ &+ c^{(ijk)}_{2,3}(q+p_l) \cdot e_3 + c^{(ijk)}_{2,3}(q+p_l) \cdot e_3) \\ &+ c^{(ijk)}_{2,3}(q+p_l) \cdot e_3 + c^{(ijk)}_{2,3}(q+p_l) \cdot e_3 + c^{(ijk)}_{2,3}(q+p_l) \cdot e_3) \\ &+ c^{(ijk)}_{2,3}(q+p_l) \cdot e_3 + c^{(ijk)}_{2,3}(q+p_l) \cdot$$

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QCD corrections to Higgs plus jets production with GoSam

Extended rank residues

$$\begin{split} &\Delta_{ijk\ell m}(q,\mu^2) = C_{5,0}^{(ijkm)} \; \mu^2 \;, \\ &\Delta_{ijk\ell}(q,\mu^2) = \Delta_{ijk\ell}^R(q,\mu^2) + c_{4,0}^{(ijk\ell)} + c_{4,2}^{(ijk\ell)} \mu^2 + c_{4,4}^{(ijk\ell)} \mu^4 \;, \\ &\Delta_{ijk}(q,\mu^2) = \Delta_{ijk}^R(q,\mu^2) + c_{3,0}^{(ijk)} + c_{3,7}^{(ijk)} \mu^2 \;, \\ &\Delta_{ij}(q,\mu^2) = \Delta_{ij}^R(q,\mu^2) + c_{2,9}^{(ij)} + c_{2,9}^{(ij)} \mu^2 \;, \\ &\Delta_{il}(q,\mu^2) = c_{1,0}^{(i)} + c_{1,1}^{(i)}((q+p_i) \cdot e_1) + c_{1,2}^{(i)}((q+p_i) \cdot e_2) \\ &+ c_{1,3}^{(i)}((q+p_i) \cdot e_3) + c_{i,4}^{(i)}((q+p_i) \cdot e_4) \;. \end{split}$$

$$\begin{split} \Delta^{0}_{ijk\ell}(q,\mu^2) &= \left(c^{(ijkl)}_{\lambda} + c^{(ijkl)}_{\lambda} + c^{(ijkl)}_{\lambda} - p^2_{\lambda}(q+p_{\lambda}) \cdot c_{\lambda} + \\ \Delta^{R}_{ijk\ell}(q,\mu^2) &= \left(c^{(ijk)}_{\lambda} + c^{(ijk)}_{\lambda} + c^{(ijk)}_{\lambda} + c^{(ijk)}_{\lambda} + c^{(ijk)}_{\lambda} - c^{(ijk)}_{\lambda} - c^{(ijk)}_{\lambda} + c^{(ijk)}_{\lambda} - c^{(ijk)}_{\lambda} + c^{(ijk)}_{\lambda} - c^{(ijk)$$

$$\begin{split} \Lambda_{ijk\ell m}(q,\mu^2) &= \Delta_{ijk\ell m}(q,\mu^2) \,, \\ \Lambda_{ijk\ell}(q,\mu^2) &= \Delta_{ijk\ell}(q,\mu^2) + c_{1,3}^{(ijkh)} \, \mu^4 \, (q+p_i) \cdot v_{\perp} \,, \\ \Lambda_{ijk}(q,\mu^2) &= \Delta_{ijk}(q,\mu^2) + c_{1,3}^{(ijk)} \, \mu^4 + c_{3,12}^{(ijk)} \, \mu^2 \, ((q+p_i) \cdot c_3)^2 \\ &+ c_{3,12}^{(ijk)} \, \mu^2 \, ((q+p_i) \cdot c_4)^2 + c_{3,12}^{(ijk)} \, ((q+p_i) \cdot c_3)^4 \\ &+ c_{3,12}^{(ijk)} \, ((q+p_i) \cdot c_4)^4 \,, \\ \Lambda_{ij}(q,\mu^2) &= \Delta_{ij}(q,\mu^2) + \mu^2 \left(c_{2,10}^{(ij} \, (q+p_i) \cdot c_2 + c_{2,11}^{(ij)} \, ((q+p_i) \cdot c_3) \\ &+ c_{3,12}^{(ijk)} \, ((q+p_i) \cdot c_4)^4 \,, \\ (\Lambda_{ij}(q,\mu^2) &= \Delta_{ij}(q,\mu) + c_4) + c_{3,13}^{(ijk)} \, ((q+p_i) \cdot c_3) + c_{3,14}^{(ijk)} \, ((q+p_i) \cdot c_4)^3 \\ &+ c_{3,12}^{(ijk)} \, ((q+p_i) \cdot c_4)^4 + c_{3,14}^{(ijk)} \, ((q+p_i) \cdot c_3)^2 + c_{3,14}^{(ij)} \, ((q+p_i) \cdot c_2)^2 \, ((q+p_i) \cdot c_4) \\ &+ c_{3,11}^{(ij)} \, ((q+p_i) \cdot c_2)^2 \, ((q+p_i) \cdot c_4)^2 \,, \\ &+ c_{3,11}^{(ij)} \, ((q+p_i) \cdot c_2)^2 \, ((q+p_i) \cdot c_4)^2 \,, \\ \Lambda_i(q,\mu^2) &= \Delta_i(q,\mu^2) + c_{1,3}^{(i)} \, ((q+p_i) \cdot c_2)^2 \, + c_{1,4}^{(ij)} \, ((q+p_i) \cdot c_4)^2 \,, \\ &+ c_{1,11}^{(ij)} \, ((q+p_i) \cdot c_3)^2 \, + c_{1,3}^{(i)} \, ((q+p_i) \cdot c_4)^2 \,, \\ &+ c_{1,12}^{(ij)} \, ((q+p_i) \cdot c_3)^2 \, + c_{1,3}^{(i)} \, ((q+p_i) \cdot c_4)^2 \,, \\ &+ c_{1,12}^{(ij)} \, ((q+p_i) \cdot c_3)^2 \, + c_{1,3}^{(i)} \, ((q+p_i) \cdot c_4)^2 \,, \\ &+ c_{1,12}^{(ij)} \, ((q+p_i) \cdot c_3)^2 \, + c_{1,3}^{(i)} \, ((q+p_i) \cdot c_4)^2 \,, \\ &+ c_{1,12}^{(ij)} \, ((q+p_i) \cdot c_3)^2 \, + c_{1,3}^{(i)} \, ((q+p_i) \cdot c_4)^2 \,, \\ &+ c_{1,12}^{(ij)} \, ((q+p_i) \cdot c_3)^2 \, + c_{1,3}^{(i)} \, ((q+p_i) \cdot c_4)^2 \,, \\ &+ c_{1,12}^{(ij)} \, ((q+p_i) \cdot c_3)^2 \, + c_{1,3}^{(i)} \, ((q+p_i) \cdot c_4)^2 \,, \\ &+ c_{1,12}^{(ij)} \, ((q+p_i) \cdot c_3)^2 \, + c_{1,3}^{(i)} \, ((q+p_i) \cdot c_4)^2 \,, \\ &+ c_{1,13}^{(ij)} \, ((q+p_i) \cdot c_3)^2 \, + c_{1,3}^{(i)} \, ((q+p_i) \cdot c_4)^2 \,, \\ &+ c_{1,14}^{(ij)} \, + c_{1,13}^{(ij)} \, ((q+p_i) \cdot c_3)^2 \,, \\ &+ c_{1,14}^{(ij)} \, + c_{1,13}^{(ij)} \, ((q+p_i) \cdot c_3)^2 \,, \\ &+ c_{1,14}^{(ij)} \, + c_{1,13}^{(ij)} \, ((q+p_i) \cdot c_3)^2 \,, \\ &+ c_{1,14}^{(ij)} \, + c_{1,15}^{(ij)} \, ((q+p_i) \cdot c_3)^2 \,, \\ &+ c_{1,14}^{(ij)} \, + c_{1,15}^{(ij)} \, ((q+p$$

[Mastrolia, Mirabella, Peraro, 2012]

Extended rank residues

```
\begin{split} &\Delta_{ijk\ell m}(q,\mu^2) = c_{3,0}^{(ijkm)} \mu^2 \ , \\ &\Delta_{ijk\ell}(q,\mu^2) = \Delta_{ijk\ell}^{R}(q,\mu^2) + c_{4,0}^{(ijk)} + c_{4,2}^{(ijkk)} \mu^2 + c_{4,4}^{(ijk)} \mu^4 \ , \\ &\Delta_{ijk}(q,\mu^2) = \Delta_{ijk}^{R}(q,\mu^2) + c_{3,0}^{(ijk)} + c_{3,7}^{(ijk)} + c_{4,7}^{(ijk)} \mu^2 \ , \\ &\Delta_{ij}(q,\mu^2) = \Delta_{ij}^{R}(q,\mu^2) + c_{2,0}^{(ij)} + c_{2,2}^{(ij)} \mu^2 \ , \\ &\Delta_{i}(q,\mu^2) = c_{1,0}^{R} + c_{1,4}^{(i)}((q+p_i) \cdot e_i) + c_{1,2}^{(i)}((q+p_i) \cdot e_i) \ , \\ &+ c_{1,3}^{(i)}((q+p_i) \cdot e_i) + c_{1,4}^{(i)}((q+p_i) \cdot e_i) \ . \end{split}
```

$$\begin{split} &\Delta^B_{ijk\ell}(q,p^2) = \begin{pmatrix} c_{k1}^{(i)k\ell} + c_{k3}^{(i)k\ell} \, p^2 \end{pmatrix} (q+p_i) \cdot v_{\perp} \,, \\ &\Delta^B_{ijk\ell}(q,p^2) = \begin{pmatrix} c_{k1}^{(i)k} + c_{k3}^{(i)k} \, p^2 \end{pmatrix} (q+p_i) \cdot c_i + \begin{pmatrix} c_{k1}^{(i)k} + c_{k3}^{(i)k} \, p^2 \end{pmatrix} (q+p_i) \cdot c_i \\ &+ c_{k3}^{(i)k} \end{pmatrix} ((q+p_i) \cdot c_j)^2 + c_{k3}^{(i)k} ((q+p_i) \cdot c_i)^2 \\ &+ c_{k3}^{(i)k} \end{pmatrix} ((q+p_i) \cdot c_j)^2 + c_{k3}^{(i)k} ((q+p_i) \cdot c_i)^3 \,, \end{split}$$

 $\Delta^R_{ij}(q,\mu^2) = c^{(ij)}_{2,1}(q+p_i) \cdot e_2 + c^{(ij)}_{2,2}((q+p_i) \cdot e_2)^2$

$$+ c_{2,3}^{(ij)}(q + p_i) \cdot e_3 + c_{2,4}^{(ij)}((q + p_i) \cdot e_3)^2$$

$$+ c_{2,5}^{(ij)}(q + p_i) \cdot e_4 + c_{2,6}^{(ij)}((q + p_i) \cdot e_4)^2$$

$$+ \ c_{2,7}^{(ij)}((q+p_i) \cdot e_2)((q+p_i) \cdot e_3) + c_{2,8}^{(ij)}((q+p_i) \cdot e_2)((q+p_i) \cdot e_4) \, .$$

 $\Lambda_{ijk\ell m}(q,\mu^2) = \Delta_{ijk\ell m}(q,\mu^2) \ ,$

 $\Lambda_{ijk\ell}(q,\mu^2) = \Delta_{ijk\ell}(q,\mu^2) + c_{4,5}^{(ijk\ell)} \ \mu^4 \ (q+p_i) \cdot v_\perp \ ,$

 $\Lambda_{ijk}(q, \mu^2) = \Delta_{ijk}(q, \mu^2) + c_{3,14}^{(ijk)} \mu^4 + c_{3,10}^{(ijk)} \mu^2 ((q + p_i) \cdot e_3)^2 \\ + c_{3,11}^{(ijk)} \mu^2 ((q + p_i) \cdot e_4)^2 + c_{3,10}^{(ijk)} ((q + p_i) \cdot e_3)^4$

 $+ c_{3,13}^{(ijk)} ((q + p_i) \cdot e_4)^4$,

 $\Lambda_{ij}(q, \mu^2) = \Delta_{ij}(q, \mu^2) + \mu^2 (c_{2,10}^{(ij)}(q + p_i) \cdot e_2 + c_{2,11}^{(ij)}(q + p_i) \cdot e_3$

```
+ c_{2,12}^{(ij)}(q + p_i) \cdot e_4 \Big) + c_{2,13}^{(ij)} ((q + p_i) \cdot e_2)^3 + c_{2,14}^{(ij)} ((q + p_i) \cdot e_3)^3
```

```
+ c_{2,15}^{(ij)}((q+p_i) \cdot e_4)^3 + c_{2,16}^{(ij)}((q+p_i) \cdot e_2)^2((q+p_i) \cdot e_3)
```

 $+ \, c_{2,17}^{(ij)}((q+p_i) \cdot e_2)^2((q+p_i) \cdot e_4)$

 $+ \, c_{2,18}^{(ij)} ((q+p_i) \cdot e_2) ((q+p_i) \cdot e_3)^2$

 $+ c_{2,19}^{(ij)}((q + p_i) \cdot c_2)((q + p_i) \cdot c_4)^2$,

```
\Lambda_i(q,\mu^2) = \Delta_i(q,\mu^2) + c_{1,5}^{(i)}((q+p_i)\cdot e_1)^2 + c_{1,6}^{(i)}((q+p_i)\cdot e_2)^2
```

```
+ c_{1,7}^{(i)} ((q + p_i) \cdot e_3)^2 + c_{1,8}^{(i)} ((q + p_i) \cdot e_4)^2
```

```
+ \, c_{1,10}^{(i)}((q+p_i) \cdot e_1)((q+p_i) \cdot e_3) + c_{1,11}^{(i)}((q+p_i) \cdot e_1)((q+p_i) \cdot e_4)
```

```
+ c_{1,12}^{(i)}((q+p_i) \cdot e_2)((q+p_i) \cdot e_3) + c_{1,13}^{(i)}((q+p_i) \cdot e_2)((q+p_i) \cdot e_4)
```

```
+ \, c_{1,14}^{(i)} \ \mu^2 + c_{1,15}^{(i)}((q+p_i) \cdot e_3)((q+p_i) \cdot e_4) \ ,
```

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QCD corrections to Higgs plus jets production with GoSam

coefficients:

- ► 5ple cut: 1→1 coefficient
- Aple cut: 5→6 coefficients
- Sple cut: 10→15 coefficients
- P 2ple cut: 10→20 coefficients
- Iple cut: 5→15 coefficients

► Samurai → XSamurai

 $\blacktriangleright \ \Delta(q,\mu^2)$ multivariate polynomial in q and μ^2

- $\blacktriangleright \ \Delta(q,\mu^2)$ multivariate polynomial in q and μ^2
- Systematic sampling: DFT

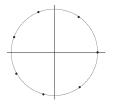
- $\blacktriangleright \ \Delta(q,\mu^2)$ multivariate polynomial in q and μ^2
- Systematic sampling: DFT

$$P(x) = c_0 + c_1 x + c_2 x^2 + \dots + c_n x^n$$

- $\blacktriangleright \ \Delta(q,\mu^2)$ multivariate polynomial in q and μ^2
- Systematic sampling: DFT

$$P(x) = c_0 + c_1 x + c_2 x^2 + \dots + c_n x^n$$

$$x_k = \rho \exp\left[-2\pi i \frac{k}{n+1}\right]$$



- $\Delta(q,\mu^2)$ multivariate polynomial in q and μ^2
- Systematic sampling: DFT

$$P(x) = c_0 + c_1 x + c_2 x^2 + \dots + c_n x^n$$
$$x_k = \rho \exp\left[-2\pi i \frac{k}{n+1}\right]$$
$$P_k = P(x_k) = \sum_{l=0}^n c_l \rho^l \exp\left[-2\pi i \frac{k}{(n+1)}l\right]$$

- $\Delta(q,\mu^2)$ multivariate polynomial in q and μ^2
- Systematic sampling: DFT

$$P(x) = c_0 + c_1 x + c_2 x^2 + \dots + c_n x^n$$

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$$\sum_{n=0}^{N-1} \exp\left[2\pi i \frac{k}{N}n\right] \exp\left[-2\pi i \frac{k'}{N}n\right] = N\delta_{kk'}$$

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- $\Delta(q,\mu^2)$ multivariate polynomial in q and μ^2
- Systematic sampling: DFT

$$P(x) = c_0 + c_1 x + c_2 x^2 + \dots + c_n x^n$$

$$x_k = \rho \exp\left[-2\pi i \frac{k}{n+1}\right]$$

$$P_k = P(x_k) = \sum_{l=0}^n c_l \rho^l \exp\left[-2\pi i \frac{k}{(n+1)}l\right]$$

$$\sum_{n=0}^{N-1} \exp\left[2\pi i \frac{k}{N}n\right] \exp\left[-2\pi i \frac{k'}{N}n\right] = N\delta_{kk'}$$

$$c_l = \frac{\rho^{-l}}{n+1} \sum_{k=0}^n P_k \exp\left[2\pi i \frac{k}{n+1}l\right]$$

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QCD corrections to Higgs plus jets production with GoSam

•
$$q = \sum_{i=1}^{4} x_i e_i \Rightarrow$$
 Cuts constrain DOFs

- $q = \sum_{i=1}^{4} x_i e_i \Rightarrow$ Cuts constrain DOFs
- At quintuple cut: Everything constrained

- $q = \sum_{i=1}^{4} x_i e_i \Rightarrow$ Cuts constrain DOFs
- At quintuple cut: Everything constrained
- At quadruple cut: μ^2 free

- $q = \sum_{i=1}^{4} x_i e_i \Rightarrow$ Cuts constrain DOFs
- At quintuple cut: Everything constrained
- At quadruple cut: μ^2 free
- At triple cut: $\Delta = \Delta(x_3, x_4)$ Condition: $x_3x_4 = C(x_1, x_2) = C \Rightarrow \Delta(x_3, C/x_3)$

- $q = \sum_{i=1}^{4} x_i e_i \Rightarrow$ Cuts constrain DOFs
- At quintuple cut: Everything constrained
- At quadruple cut: μ^2 free
- At triple cut: $\Delta = \Delta(x_3, x_4)$ Condition: $x_3x_4 = C(x_1, x_2) = C \Rightarrow \Delta(x_3, C/x_3)$
 - Use DFT: solutions $\propto \frac{1}{C}$, problem if C = 0

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 - ► Use DFT twice, $\Delta(x3, C/x3)$ and $\Delta(C/x_4, x_4)$ solutions $\propto \frac{1}{1-C}$, problem if C = 1

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 - ► Use DFT twice, $\Delta(x3, C/x3)$ and $\Delta(C/x_4, x_4)$ solutions $\propto \frac{1}{1-C}$, problem if C = 1
 - Branching:

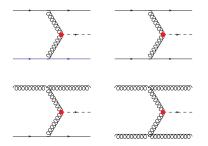
if(C=0): Use $\Delta(x_3, C/x_3)$ and $\Delta(C/x_4, x_4)$ else: Use $\Delta(x_3, C/x_3)$

• At double cut: $\Delta(x_1, x_3, x_4)$ with $x_3x_4 = F(x_1) = Ax_1^2 + Bx_1 + C$ lot of branchings:

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 - ... think carefully
- At single cut: Δ(x₁, x₂, x₃, x₄) with x₃x₄ x₁x₂ = G similar to the triple cut

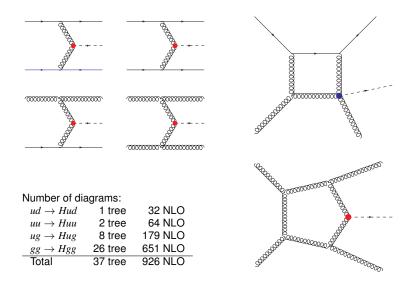
Higgs plus two jets



Number of diagrams:

$ud \rightarrow Hud$	1 tree	32 NLO
$uu \rightarrow Huu$	2 tree	64 NLO
$ug \rightarrow Hug$	8 tree	179 NLO
$gg \rightarrow Hgg$	26 tree	651 NLO
Total	37 tree	926 NLO

Higgs plus two jets



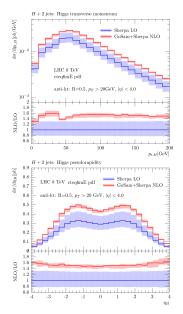
Results Higgs plus two jets

- Interface GoSam + Sherpa (talk Gionata Luisoni)
- Pole cancellation
- Agreement with MCFM(v6.4) and R. K. Ellis, W. Giele, and G. Zanderighi

	gg ightarrow Hgg	
c_0	$0.1507218951429643 \cdot 10^{-3}$	
a_0	59.8657965614009	
a_{-1}	-26.4694115468536	-26.46941154671207
a_{-2}	-12.00000000000001	-12.000000000000000000000000000000000000
	gg ightarrow Hq ar q	
c_0	$0.5677813961826772\cdot 10^{-6}$	
a_0	66.6635142370683	
a_{-1}	-16.5816633315627	-16.58166333155405
a_{-2}	-8.666666666666669	-8.666666666666666666666666666666666666
	$q\bar{q} \rightarrow Hq\bar{q}$	
	99 / 1199	
c_0	$0.1099527895267439 \cdot 10^{-5}$	
c_0 a_0		
	$0.1099527895267439 \cdot 10^{-5}$	-10.96737553134440
a_0	$\begin{array}{c} 0.1099527895267439 \cdot 10^{-5} \\ 88.2959834057198 \end{array}$	-10.96737553134440 -5.3333333333333333334
$a_0 \\ a_{-1}$	$\begin{array}{r} 0.1099527895267439 \cdot 10^{-5} \\ 88.2959834057198 \\ -10.9673755313443 \end{array}$	
$a_0 \\ a_{-1}$	$\begin{array}{r} 0.1099527895267439\cdot 10^{-5}\\ 88.2959834057198\\ -10.9673755313443\\ -5.333333333333332\end{array}$	
$a_0 \\ a_{-1} \\ a_{-2}$	$\begin{array}{c} 0.1099527895267439\cdot 10^{-5}\\ 88:2959834057198\\ -10.9673755313443\\ -5.3333333333333333\\ q\bar{q} \rightarrow Hq'\bar{q}' \end{array}$	
$a_0 \\ a_{-1} \\ a_{-2} \\ c_0$	$\begin{array}{c} 0.1099527895267439\cdot 10^{-5}\\ 88:2959834057198\\ -10.9673755313443\\ -5.333333333333322\\ \hline q\bar{q}\rightarrow Hq'\bar{q}'\\ 0.1011096724203529\cdot 10^{-6} \end{array}$	

$$\frac{2\Re \left\{ \mathcal{M}^{\text{tree-level}} \mathcal{M}^{\text{one-loop}} \right\}}{\left(4\pi\alpha_s\right) \left| \mathcal{M}^{\text{tree-level}} \right|^2} \equiv \frac{a_{-2}}{\epsilon^2} + \frac{a_{-1}}{\epsilon} + a_0$$

Results Higgs plus two jets

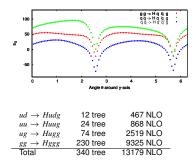


LHC 8 TeV PDF: cteq6mE anti-kt: R = 0.5 $p_T > 20 \text{ GeV}$ $|\eta| < 4.0$ $M_H = 125 \text{ GeV}$ $\mu_R = \mu_F = M_H$

Hans van Deurzen

QCD corrections to Higgs plus jets production with GoSam

Results Higgs plus three jets



$$\frac{2\mathfrak{Re}\left\{\mathcal{M}^{\text{tree-level}*}\mathcal{M}^{\text{one-loop}}\right\}}{\left(4\pi\alpha_{s}\right)\left|\mathcal{M}^{\text{tree-level}}\right|^{2}} \equiv \frac{a_{-2}}{\epsilon^{2}} + \frac{a_{-1}}{\epsilon} + a_{0}$$

	$gg \rightarrow Hq\bar{q}g$	
b_0	$0.6309159660038877 \cdot 10^{-4}$	
a_0	48.68424097859422	
a_{-1}	-36.08277727147958	-36.08277728199094
a_{-2}	-11.666666666667209	-11.66666666666666666666666666666666666
	$q\bar{q} \rightarrow Hq\bar{q}g$	
b_0	$0.3609139855530763\cdot 10^{-4}$	
a_0	69.32351140490162	
a_{-1}	-29.98862932963380	-29.98862932963629
a_{-2}	-8.333333333333333333333333	-8.333333333333333333334
	$q\bar{q} \rightarrow Hq'\bar{q}'g$	
b_0	$0.2687990772405433\cdot 10^{-5}$	
a_0	15.79262767177915	
a_{-1}	-32.35320587070861	-32.35320587073038
a_{-2}	-8.333333333333333398	-8.333333333333333333333333333333333333

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QCD corrections to Higgs plus jets production with GoSam

Summary



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