Automated sgluon pair production to NLO

Pheno 2012 symposium

May 8th 2012 Pittsburgh

Dorival Gonçalves Netto

in collaboration with D. Lopez-Val, T. Plehn (Heildelberg U.)

K. Mawatari (Vrije U. Brussel) & I. Wigmore (U. Edinburgh)

arXiv:1203.6358

ITP - Universität Heidelberg

Institut für Theoretische Physik

Ruprecht-Karls Universität Heidelberg

Outline

- Introduction
- MadGOLEM: NLO tool for BSM physics
- NLO corrections to slguon pair production
- Comparison with MLM matching
- Summary

Introduction

Scalar gluons (sgluons) are color octet scalars without electroweak charges

- Appear in various extensions to SM as composite or fundamental degrees of freedom:

➡ **Extra Dimensions**: color octet scalars emerge as low-lying KK modes of the bulk gluon field

Burdman, Dobrescu, Ponton, Phys. Rev. D 74, 075008 (2006)

➡ **SUSY**: sgluons emerge as scalar partners of a Dirac gluino

T. Plehn, T. Tait, J. Phys. G 36, 075001 (2009)

- At the LHC sgluon pairs will be copiously produced by their coupling to gluons

- The most generic pheno signature is $pp \to GG^* \to 4jets$

- Absence of direct sgluon couplings to matter in SUSY (loop induced couplings been naturally small)

➡ Sgluon mass is not constrained by bounds from dijet resonance searches. So it can be relatively light

Introduction

- Since we are only interested in analyze the **sgluon pair production** we can decouple all SUSY partners except for the sgluon, retaining all benefits of a renormalizable theory

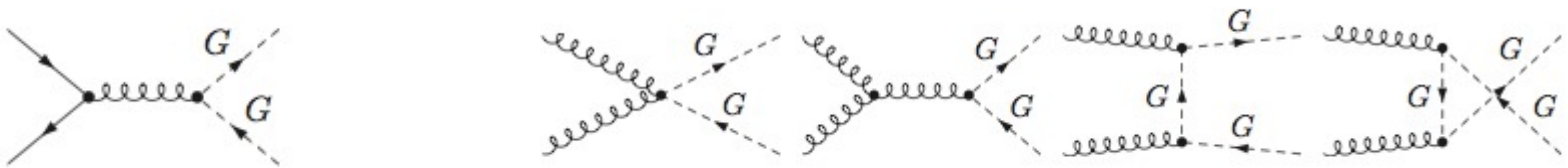
➡ The gluonic QCD corrections to sgluon pair production are well defined

➡ Can be interpreted as the relevant QCD part of an effective strongly interacting theory

- To compute NLO corrections for sgluon pair production we minimally extend the SM by one additional <u>color octet</u>, <u>weak singlet</u>, <u>electrically neutral</u>, and <u>complex scalar field G</u>

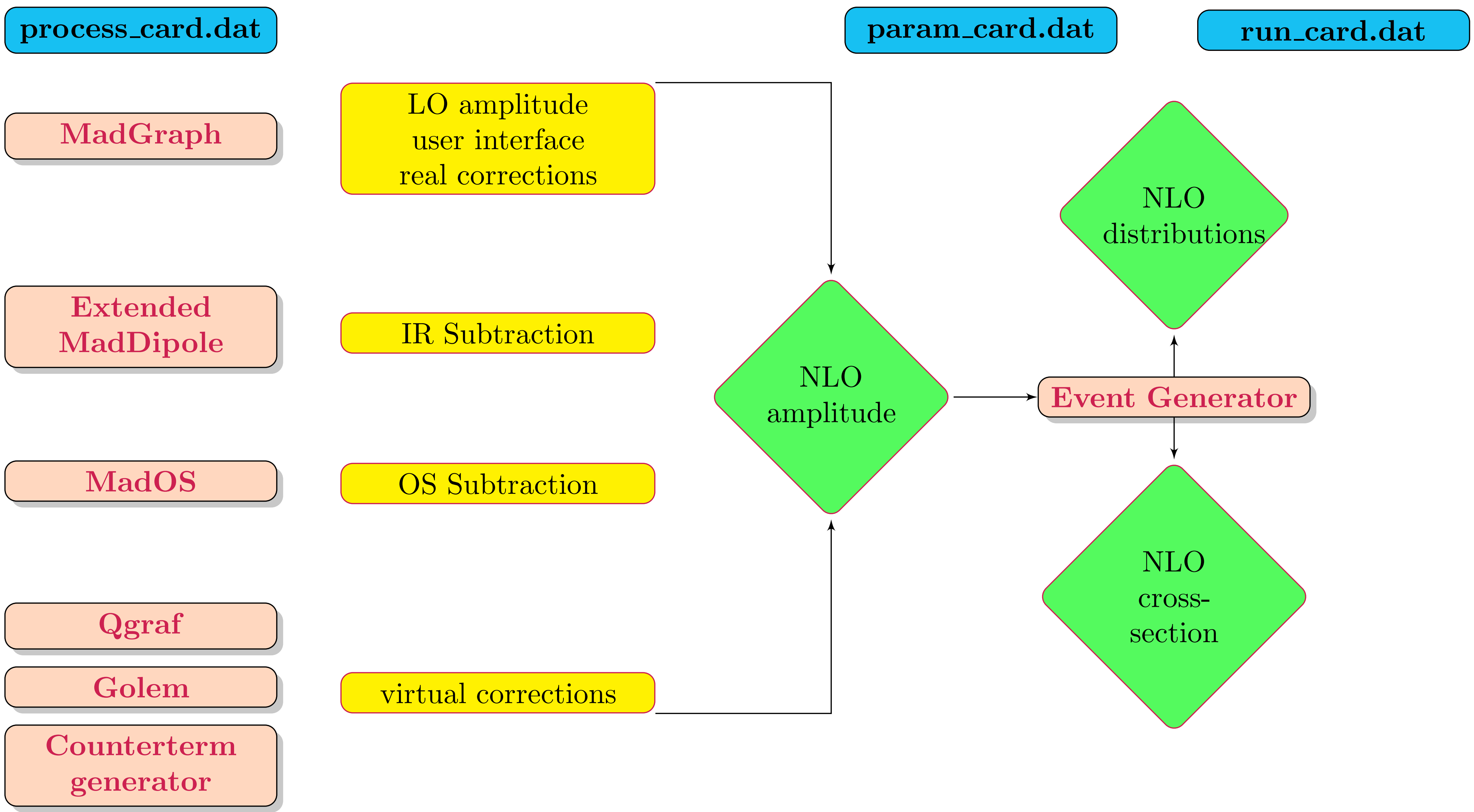
$$\mathcal{L} \supset D_\mu G^* D^\mu G - m_G^2 G G^*$$
$$\supset -g_s f^{ABC} \left[G^{A*}(\partial^\mu G^B) - (\partial^\mu G^{A*}) G^B\right] A^C_\mu + g_s^2 \left[f^{ACE} f^{BDE} + f^{ADE} f^{BCE}\right] G^{C*} G^D A^A_\mu A^{B\mu}$$

- LO diagrams for sgluon pair production:



MadGOLEM

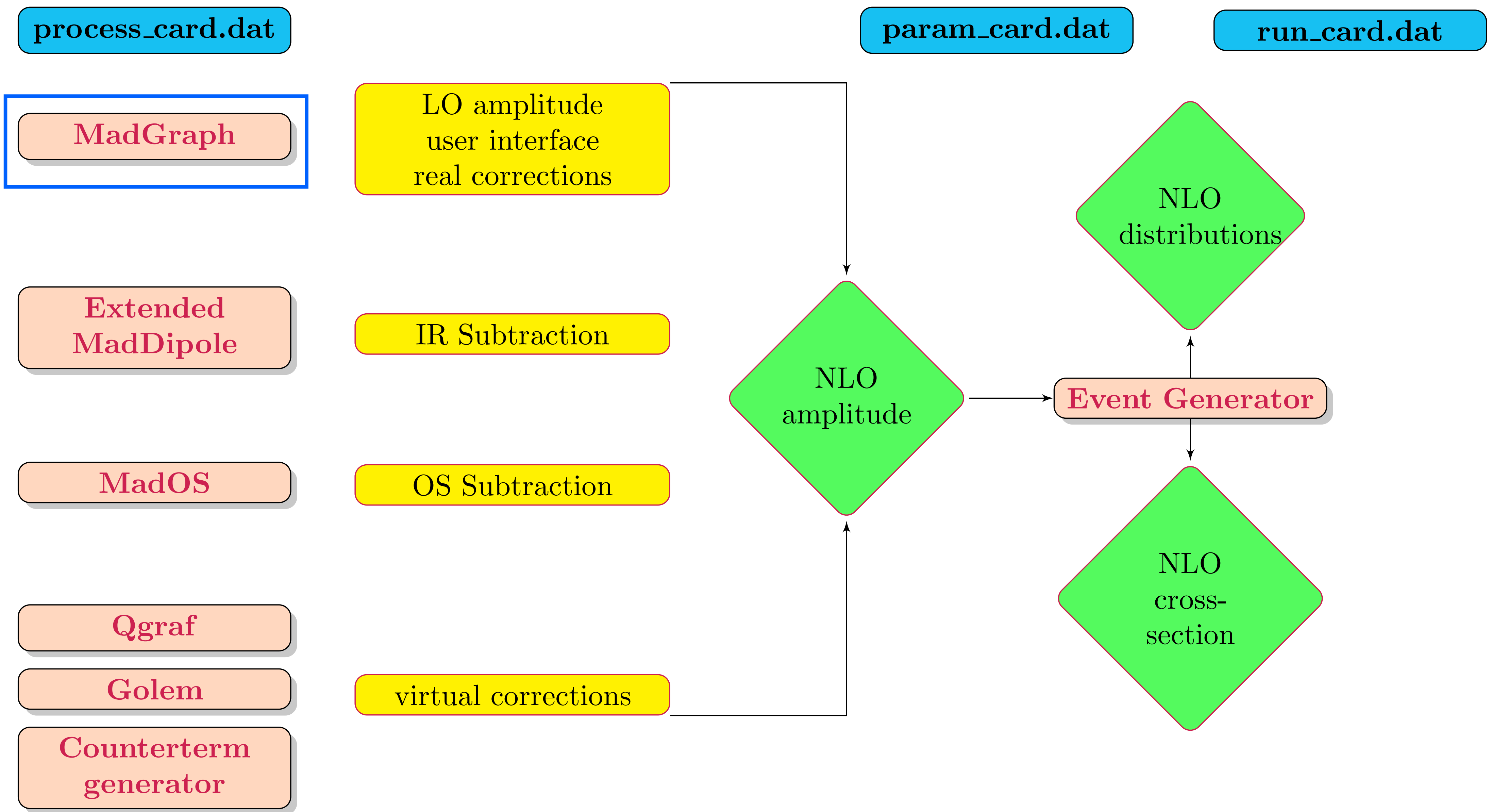
Phys. Rev. D 84, 075005 (2011)



$$\sigma^{NLO} = \int_n d\sigma^{LO} + \int_{n+1} \left(d\sigma^{Real}_{\varepsilon=0} - d\sigma^{A}_{\varepsilon=0} - d\sigma^{OS}_{\varepsilon=0} \right) + \int_n \left(d\sigma^{Virtual} + \int_1 d\sigma^{A} \right)_{\varepsilon=0}$$

MadGOLEM

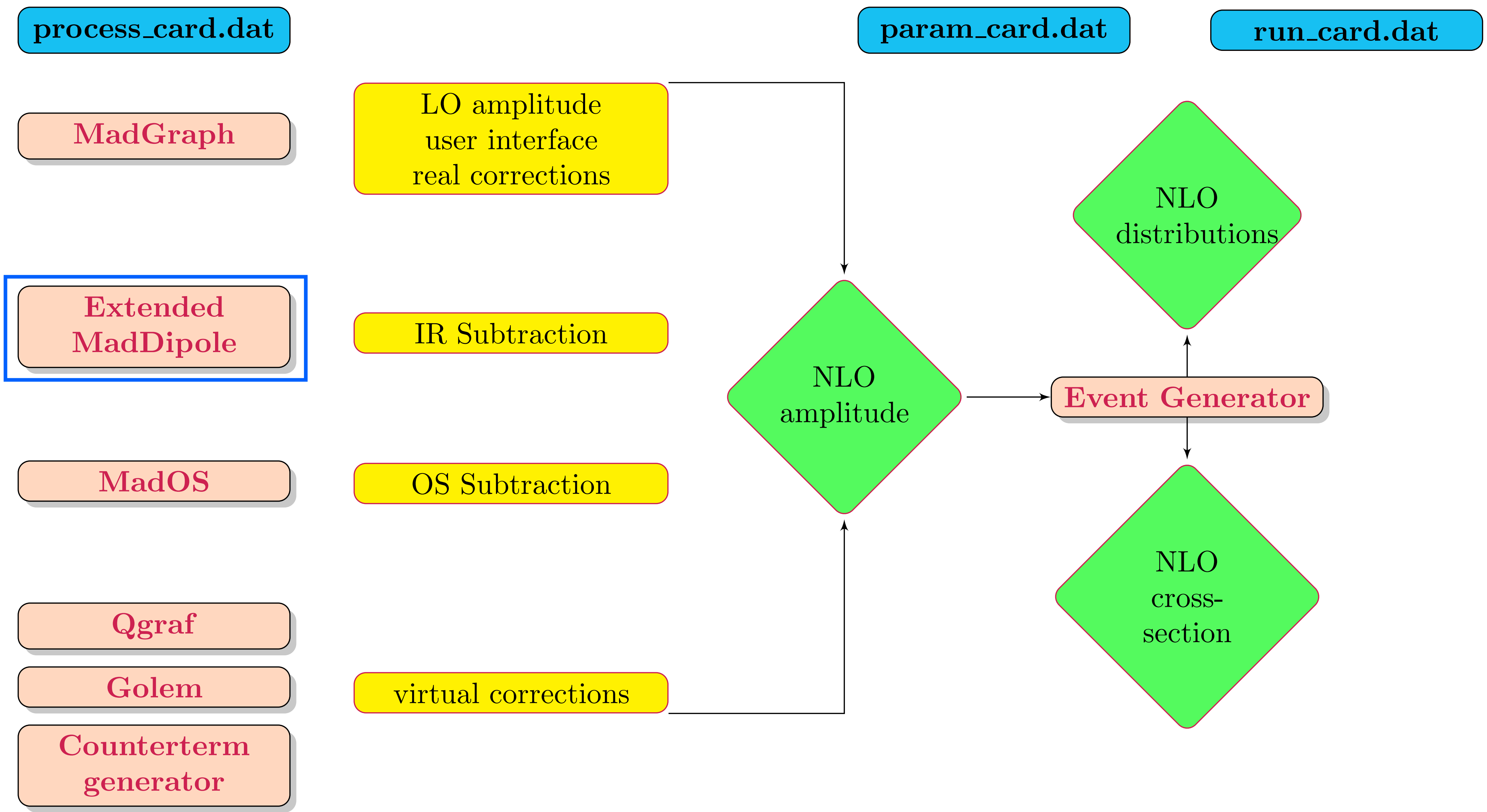
Phys. Rev. D 84, 075005 (2011)



$$\sigma^{NLO} = \int_n d\sigma^{LO} + \int_{n+1} \left(d\sigma^{Real}_{\varepsilon=0} - d\sigma^{A}_{\varepsilon=0} - d\sigma^{OS}_{\varepsilon=0} \right) + \int_n \left(d\sigma^{Virtual} + \int_1 d\sigma^{A} \right)_{\varepsilon=0}$$

MadGOLEM

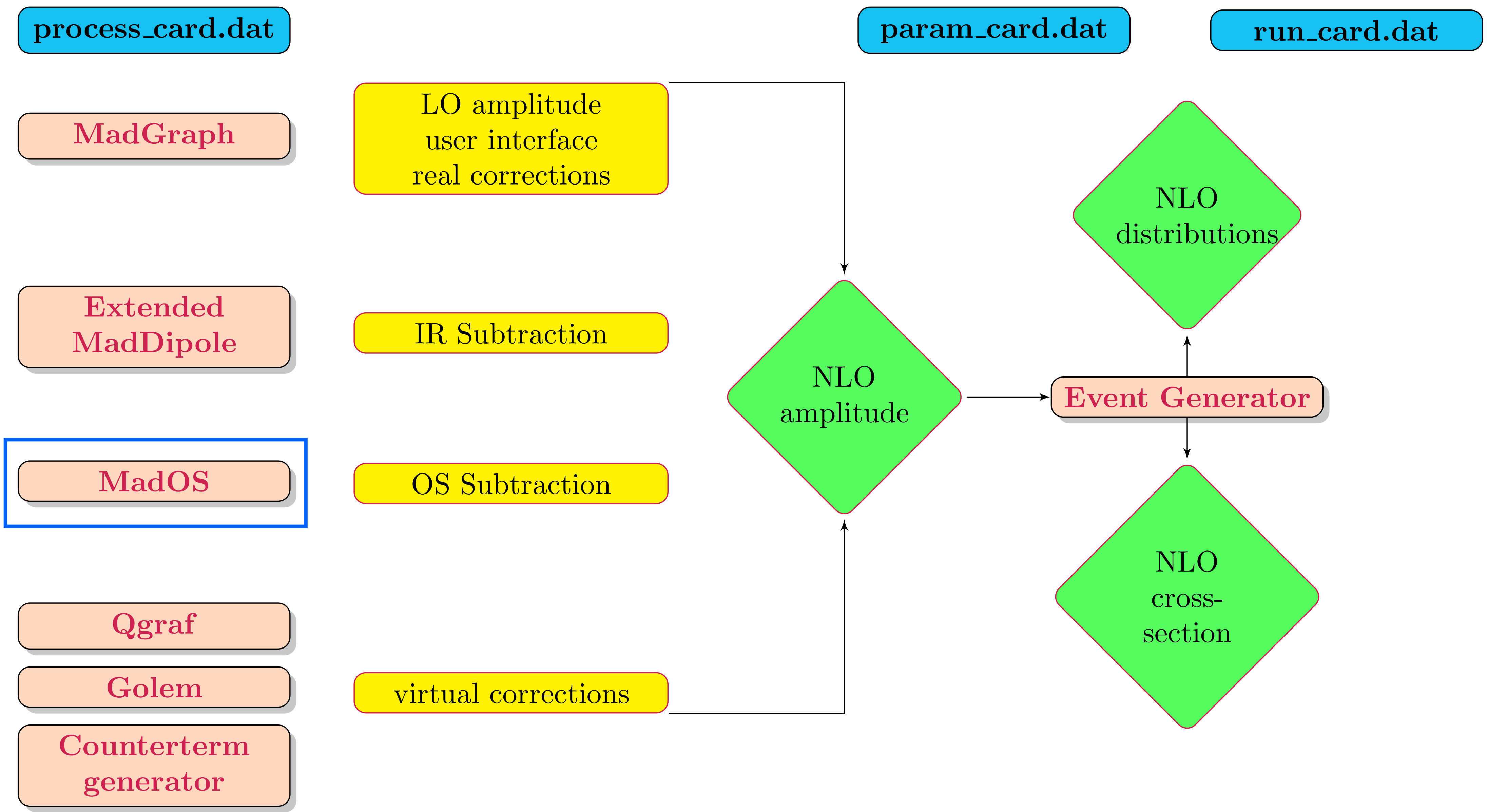
Phys. Rev. D 84, 075005 (2011)



$$\sigma^{NLO} = \int_n d\sigma^{LO} + \int_{n+1} \left(d\sigma^{Real}_{\varepsilon=0} - \boxed{d\sigma^{A}_{\varepsilon=0}} - d\sigma^{OS}_{\varepsilon=0}\right) + \int_n \left(d\sigma^{Virtual} + \boxed{\int_1 d\sigma^{A}}\right)_{\varepsilon=0}$$

MadGOLEM

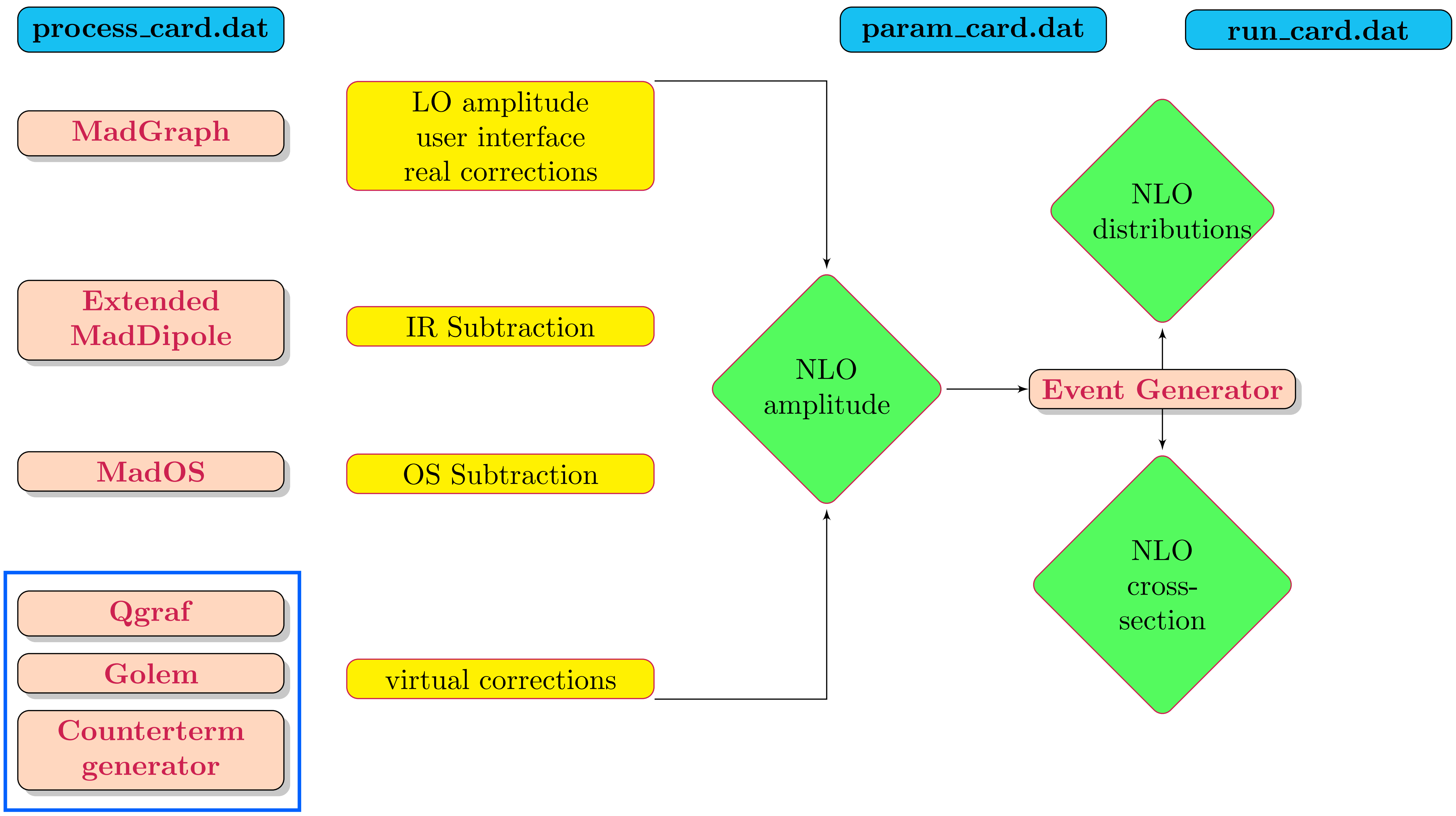
Phys. Rev. D 84, 075005 (2011)



$$\sigma^{NLO} = \int_n d\sigma^{LO} + \int_{n+1} \left(d\sigma^{Real}_{\varepsilon=0} - d\sigma^{A}_{\varepsilon=0} - \boxed{d\sigma^{OS}_{\varepsilon=0}} \right) + \int_n \left(d\sigma^{Virtual} + \int_1 d\sigma^{A} \right)_{\varepsilon=0}$$

MadGOLEM

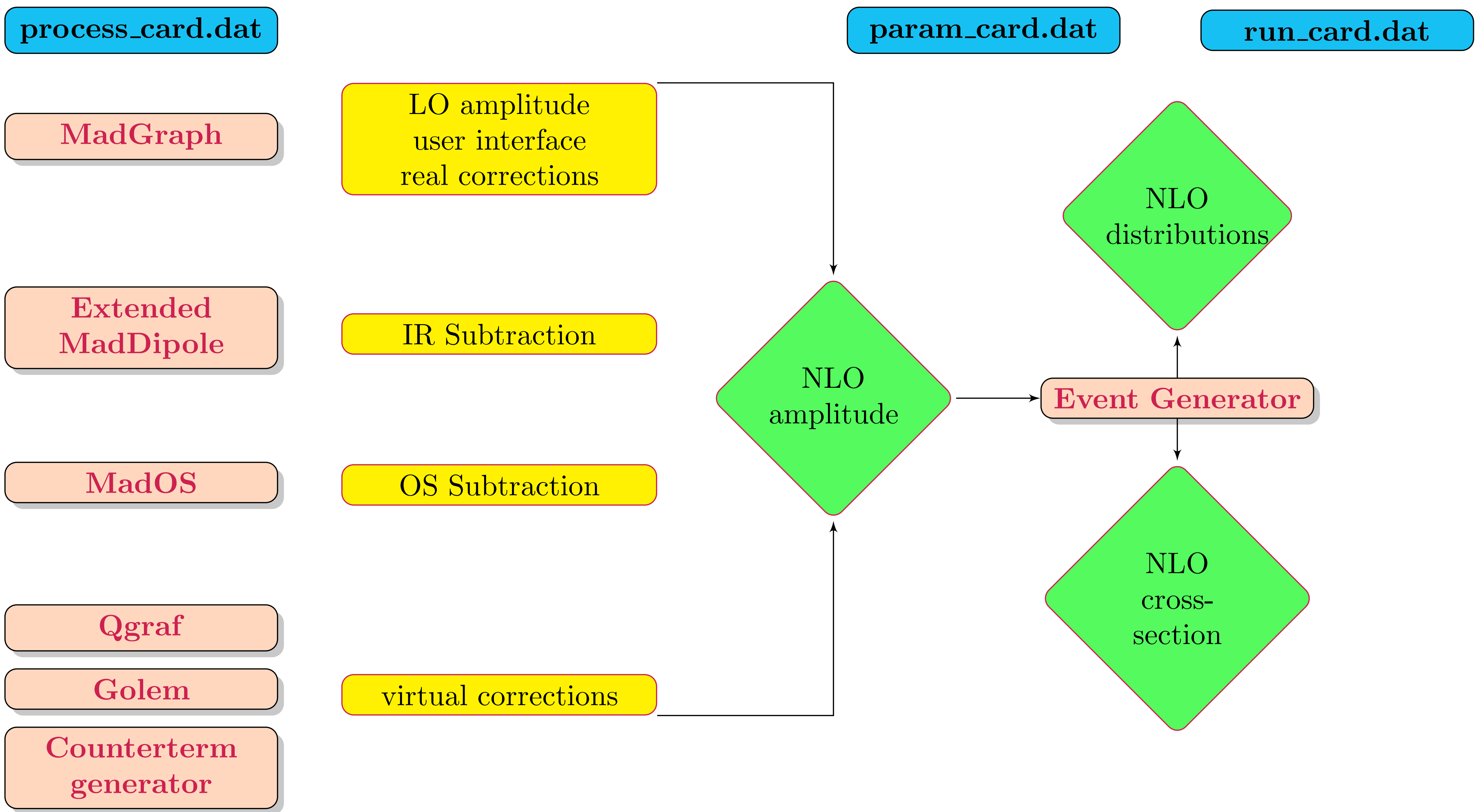
Phys. Rev. D 84, 075005 (2011)



$$\sigma^{NLO} = \int_n d\sigma^{LO} + \int_{n+1} \left(d\sigma^{Real}_{\varepsilon=0} - d\sigma^{A}_{\varepsilon=0} - d\sigma^{OS}_{\varepsilon=0}\right) + \int_n \left(d\sigma^{Virtual} + \int_1 d\sigma^{A}\right)_{\varepsilon=0}$$

MadGOLEM

Phys. Rev. D 84, 075005 (2011)

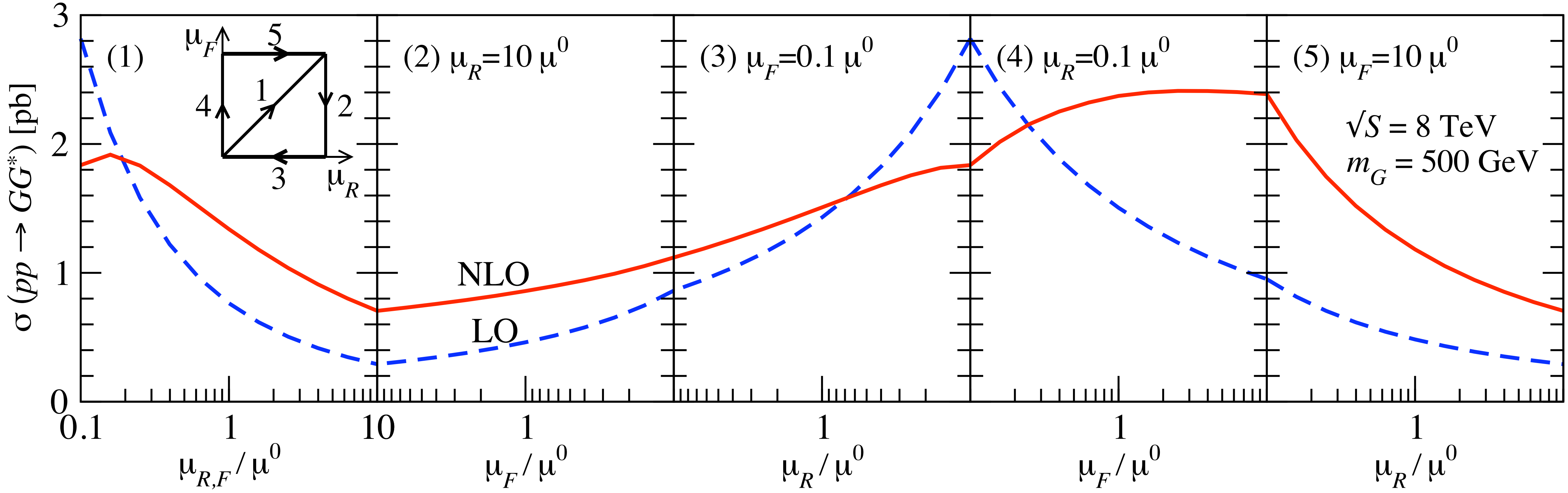


$$\sigma^{NLO} = \int_n d\sigma^{LO} + \int_{n+1} \left(d\sigma^{Real}_{\varepsilon=0} - d\sigma^{A}_{\varepsilon=0} - d\sigma^{OS}_{\varepsilon=0}\right) + \int_n \left(d\sigma^{Virtual} + \int_1 d\sigma^{A}\right)_{\varepsilon=0}$$

For more details: D. Lopez-Val talk!

Scale Dependence

- Stabilization of the scale dependence on the unphysical μ_R & μ_F

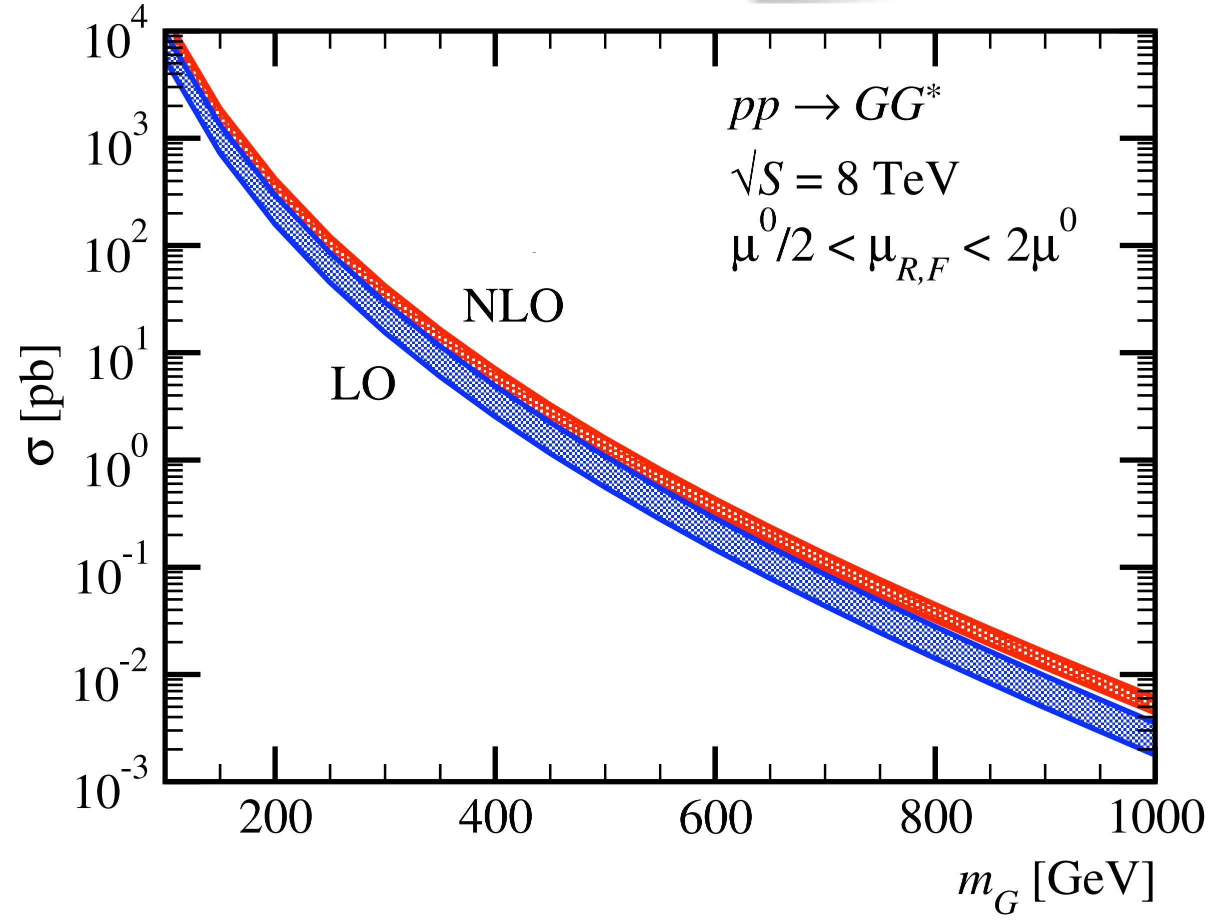


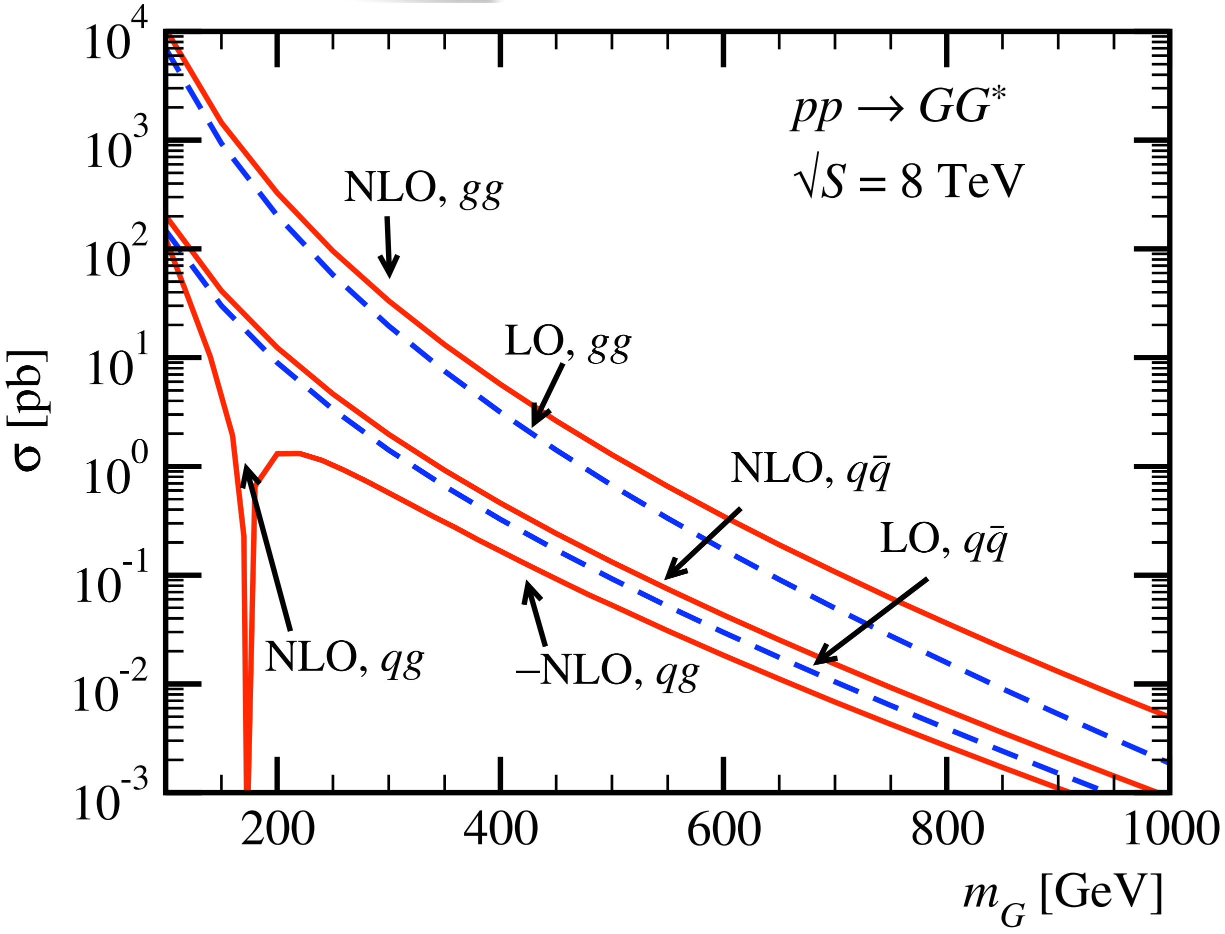
$\Delta\sigma^{\rm NLO}/\sigma^{\rm NLO} \sim \mathcal{O}(30\%)$, down from up to $\Delta\sigma^{\rm LO}/\sigma^{\rm LO} \sim \mathcal{O}(80\%)$

- Unlike Drell-Yan-type channels there is μ_R dependence at LO: $\sigma^{LO} \sim \alpha_s^2$

➡ The bulk of the scale dependence comes from μ_R

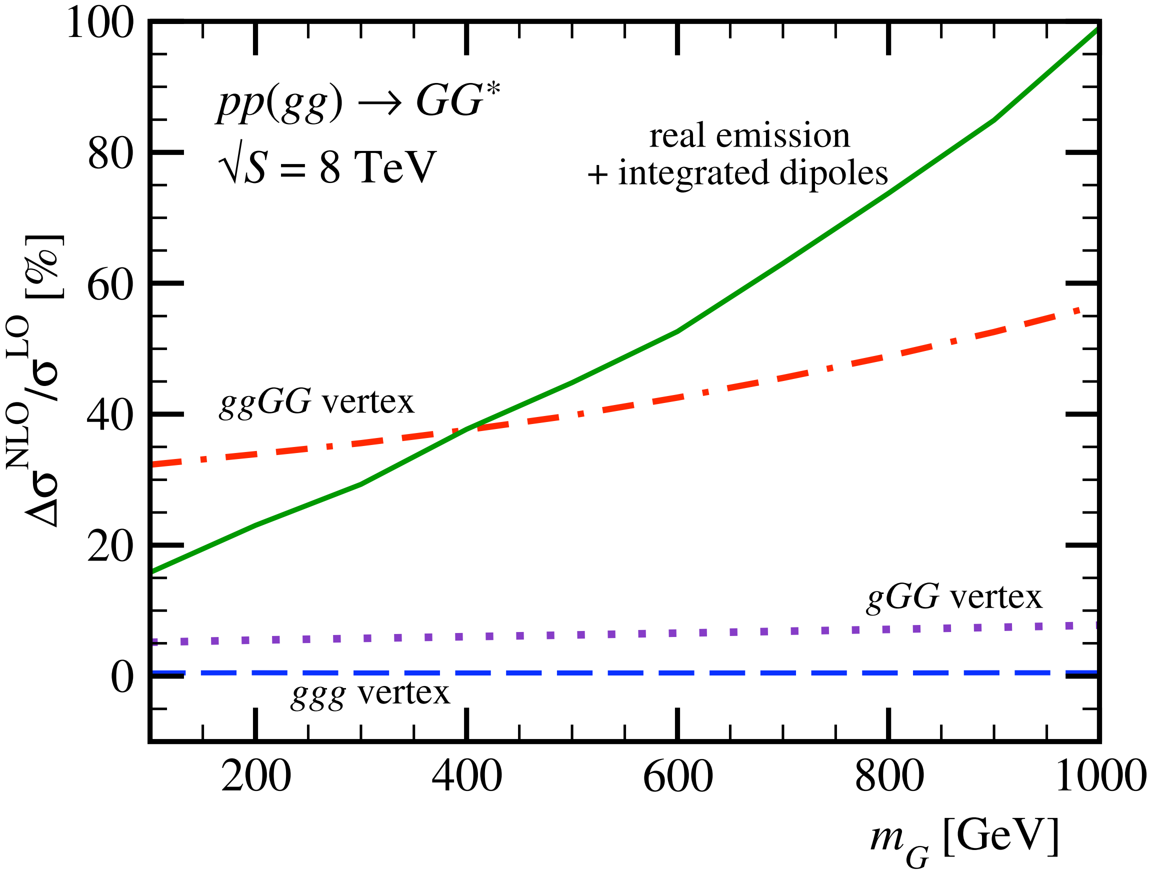
NLO corrections

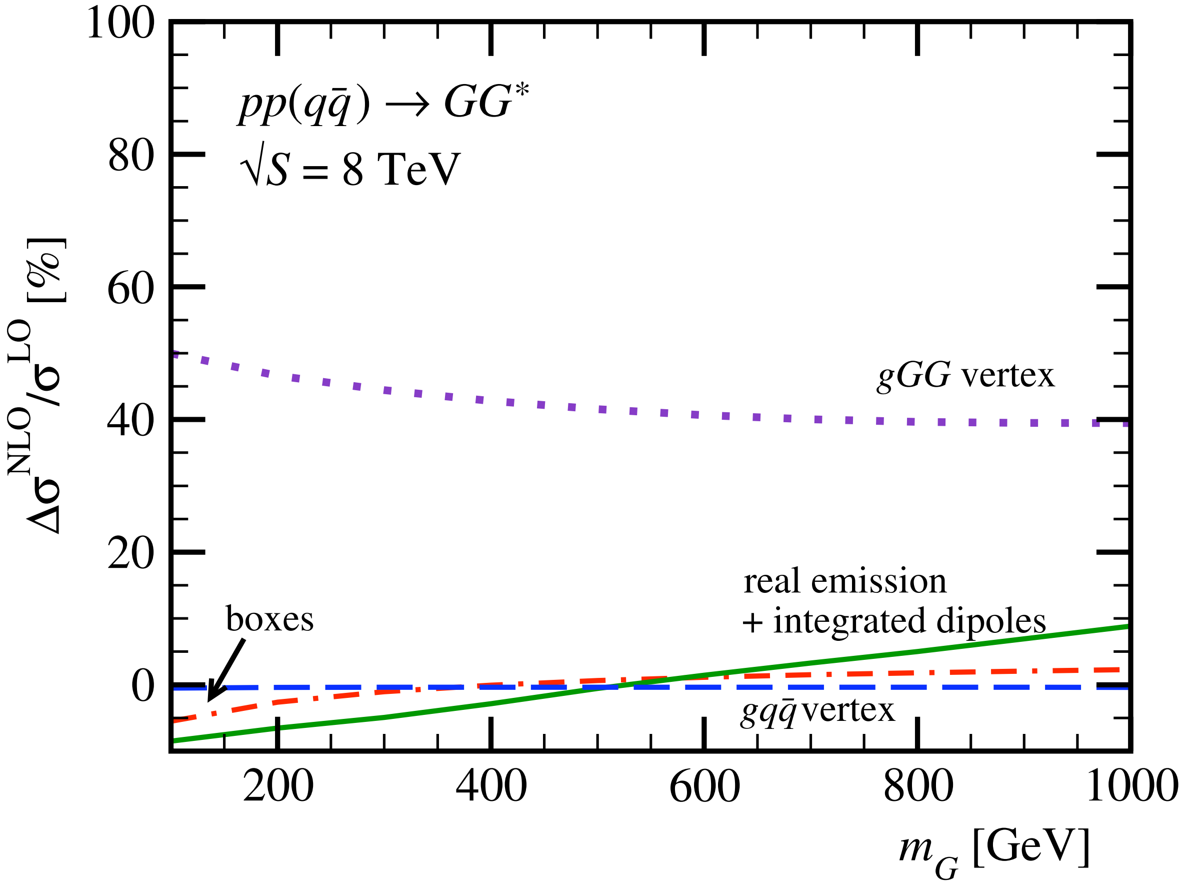




- NLO corrections increase for increasing m_G
- Dominance of $gg \to GG^*$
  - ➡ color charge
  - ➡ threshold effects: $\begin{cases} \sigma_{gg} \sim \beta, & \text{s-wave component of } \sigma_{gg} \\ \sigma_{q\bar{q}} \sim \beta^3, & \text{p-wave component of } \sigma_{q\bar{q}} \end{cases}, \quad \beta = \sqrt{1 - 4m_G^2/s}$

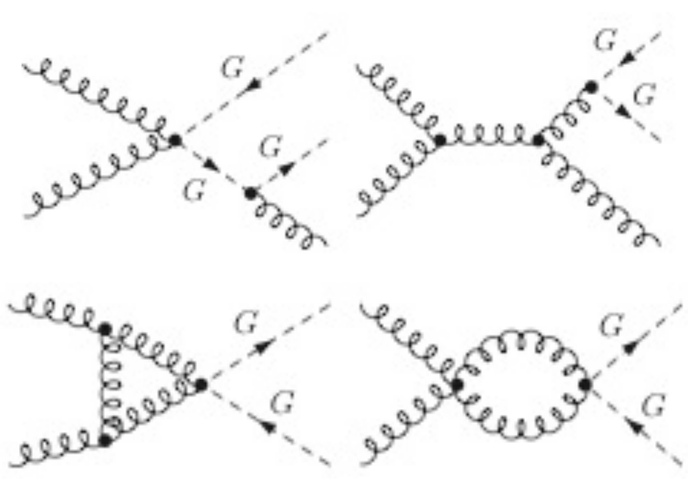
NLO corrections

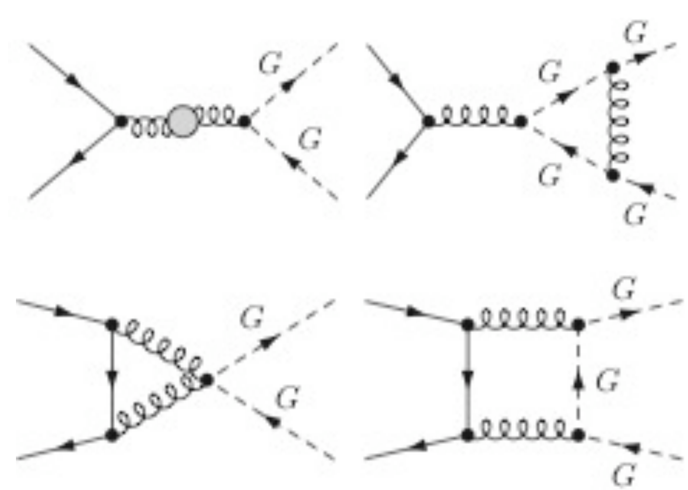




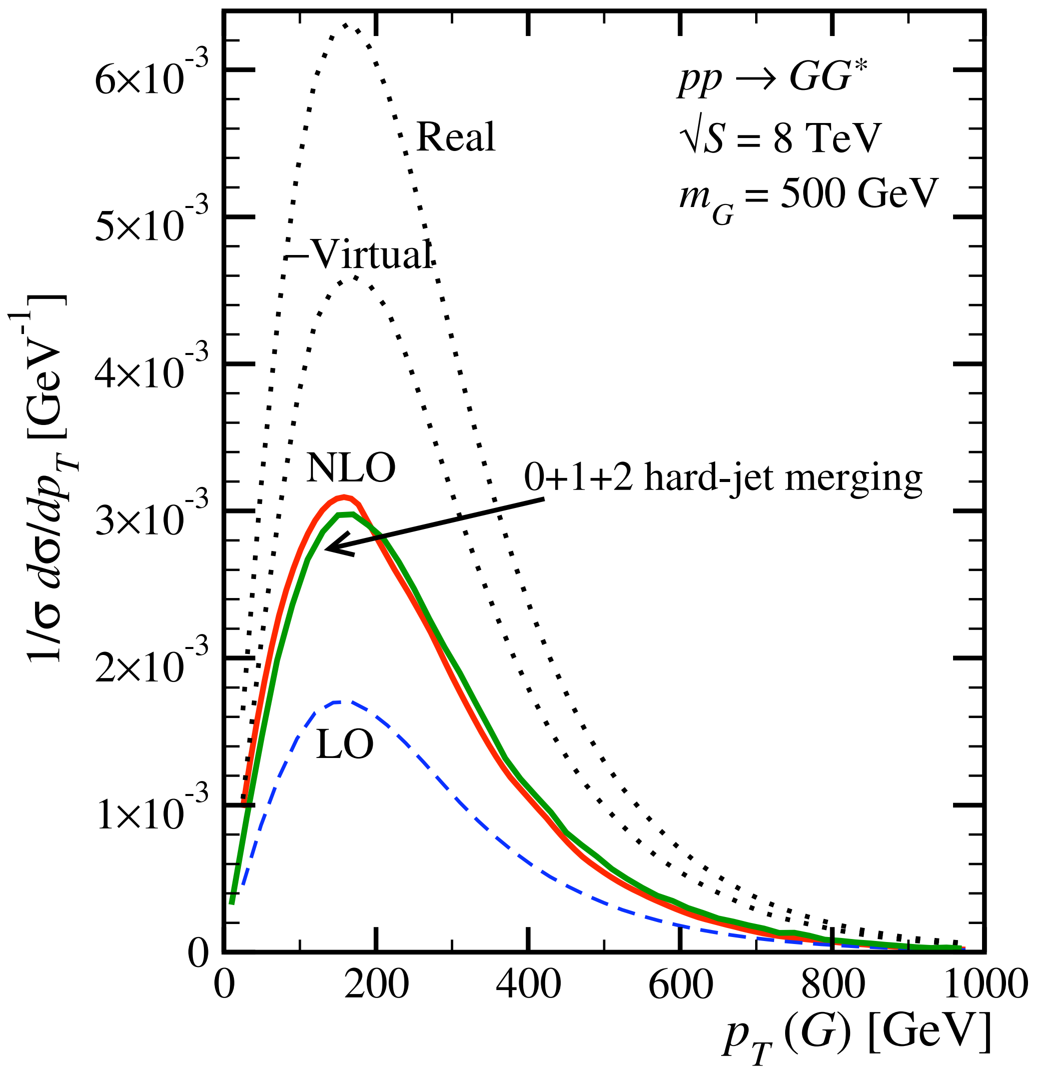
- real emission and virtual box diagrams contributes to the bulk of the NLO quantum effects for σ_{gg}

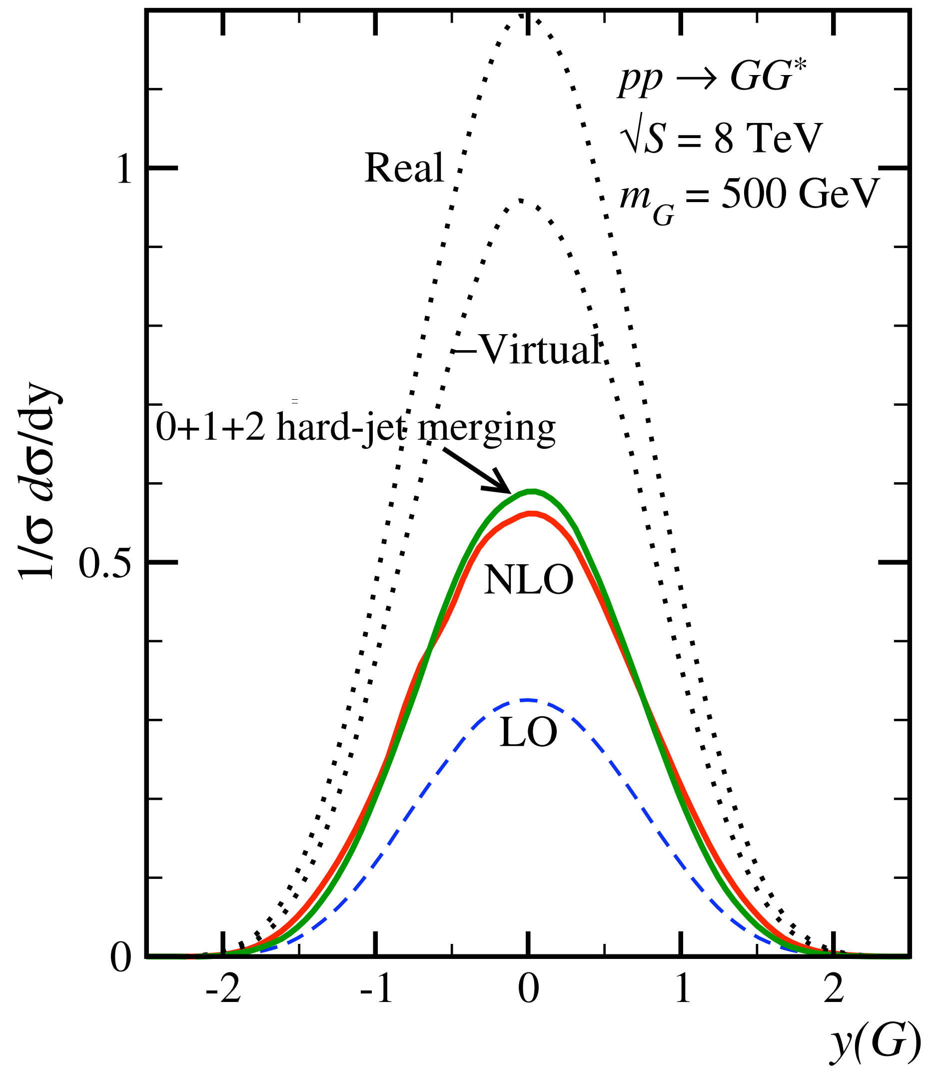
➡ their size and increase with m_G come from the threshold behavior of the NLO corrections $\sigma_{gg} \sim \beta$





Comparison with Multi-jet Merging





- Jet merging: combine ME + Parton Shower without double counting

  ME ↙ Partons are hard and well separated ↘

  Parton Shower ↘ Partons are soft/collinear (resums large logs) ↙

  Complementary

- NLO distributions for the heavy final states in good agreement with multi-jet merged calculation via MLM matching with MadGraph

Summary

- First complete calculation of sgluon pair production to NLO
  - High production rates $\sigma \sim \mathcal{O}(1\ pb)$ for ($m_G \sim 500$ GeV and $\sqrt{S} = 8\,TeV$)
  - Scale uncertainty largely reduced from 80% @LO down to 30% @NLO and high K factor $K \sim 1.7$
- NLO distributions in agreement with MLM matching
- Besides its pheno impact it ilustrates the fully automized NLO package, MadGOLEM

Backup slide

- Sgluon dipoles: