Photons with POWHEG in Herwig++

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Summary

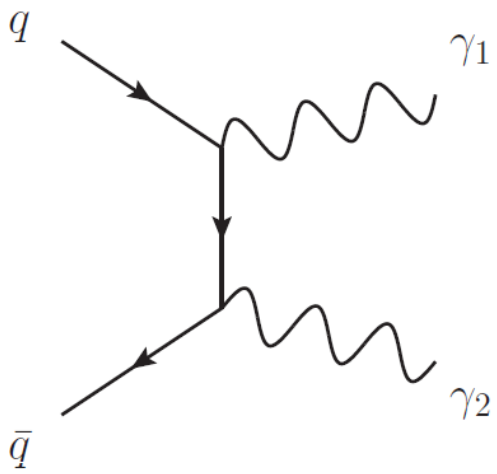
- Introduction
- Method
- Di-Photon Production
- Drell-Yan
- Conclusions

Introduction

- There are many important processes in which either we are interested:
  - in observing photon production, for example $pp \rightarrow \gamma\gamma + X$ for the Higgs signal;
  - in measuring something which such accuracy that we need to take higher order QED and EW effects into account, e.g. Drell-Yan production of W and Z.
- Both of these can be simulated using POWHEG based approaches.

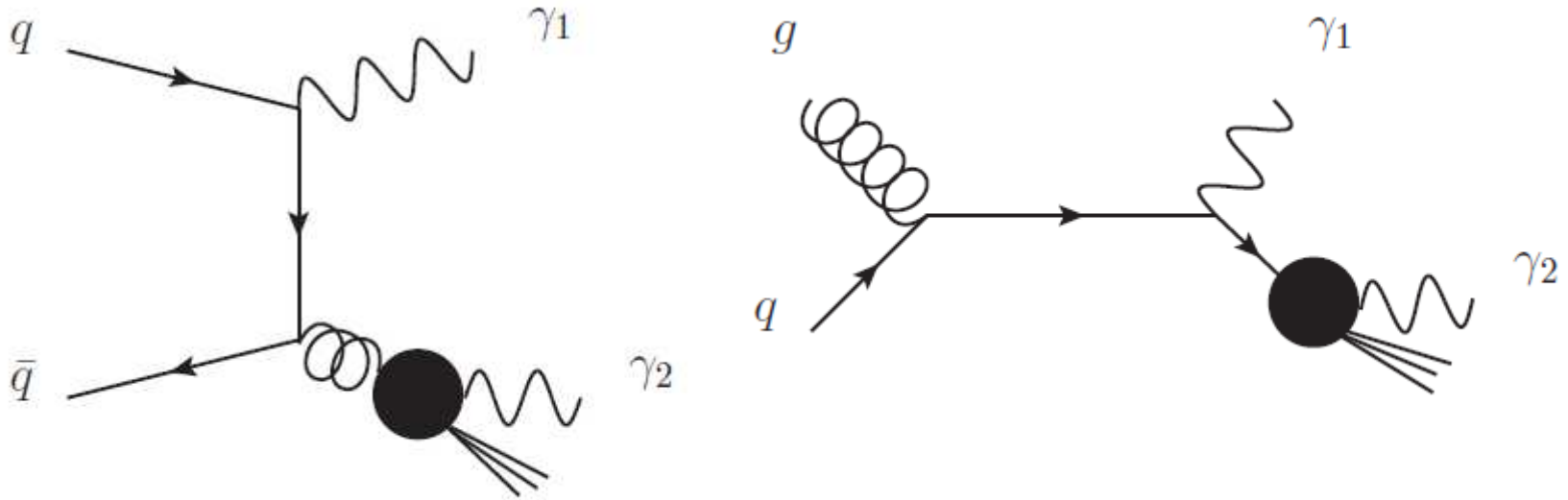
Direct Photon Production

- In any process involving photon production at leading order we need to include both:
  - prompt photon production in the hard process;



Direct Photon Production

– production of photons as part of the fragmentation process;

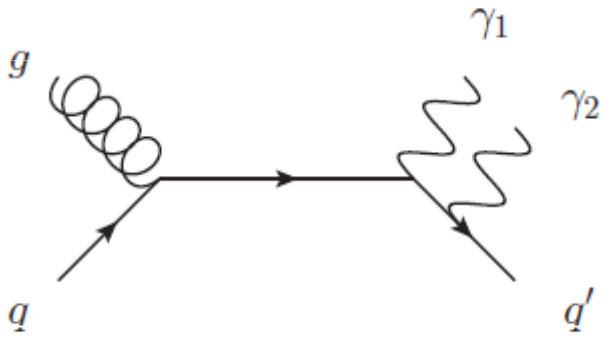


Direct Photon Production

- In an analytic calculation the fragmentation contribution is included using the measured photon fragmentation function $D^{\gamma}(z)$ for the photon to carry a fraction z of the parton's momentum.
- In a Monte Carlo simulation the combination of allowing perturbative QED radiation in the parton shower and the production of photons in hadronic decays models this contribution.

Direct Photon Production

- At NLO there is an additional problem.
- The real emission corrections include singularities when one of the photons is collinear with a final-state quark.



- Formally this has to be absorbed into the fragmentation function.
- Not clear how to proceed in an NLO simulation.

Direct Photon Production

- Separate the real emission processes into:
  - a piece which is a QCD correction to diphoton production, contributes to both $\overline{B}$ and the Sudakov for hard emission;
  - a separate QED correction to photon+jet production, just contributes to a Sudakov for hard QED emission.
- Allows NLO simulation with the shower still generating the photon fragmentation contribution.

Direct Photon Production

- So the real contribution

$$R(\Phi_B, \Phi_R) = R_{\mathrm{QED}}(\Phi_B, \Phi_R) + R_{\mathrm{QCD}}(\Phi_B, \Phi_R),$$

is split into two pieces

$$R_{\mathrm{QED}}(\Phi_B, \Phi_R) = \frac{\sum_i D^i_{\mathrm{QED}}}{\sum_j D^j_{\mathrm{QED}} + \sum_j D^j_{\mathrm{QCD}}} R(\Phi_B, \Phi_R)$$

$$R_{\mathrm{QCD}}(\Phi_B, \Phi_R) = \frac{\sum_i D^i_{\mathrm{QCD}}}{\sum_j D^j_{\mathrm{QED}} + \sum_j D^j_{\mathrm{QCD}}} R(\Phi_B, \Phi_R)$$

Direct Photon Production

- Giving

$$\begin{aligned} \mathrm{d}\sigma = \quad & \bar{B}(\Phi_B)\mathrm{d}\Phi_B \left[\Delta_{\mathrm{QCD}}(0) + \frac{R_{\mathrm{QCD}}(\Phi_B,\Phi_R)}{B(\Phi_B)}\Delta_{\mathrm{QCD}}(k_T(\Phi_B,\Phi_R))\mathrm{d}\Phi_R\right] \\ & + B'(\Phi'_B)\mathrm{d}\Phi'_B \left[\Delta_{\mathrm{QED}}(0) + \frac{R_{\mathrm{QED}}(\Phi'_B,\Phi'_R)}{B'(\Phi'_B)}\Delta_{\mathrm{QED}}(k_T(\Phi'_B,\Phi'_R))\mathrm{d}\Phi'_R\right], \end{aligned}$$

where

$$\bar{B}(\Phi_B) = \left\{ B(\Phi_B) + V(\Phi_B) + \int \left[R_{\mathrm{QCD}}(\Phi_B,\Phi_R) - \sum_i D^i_{\mathrm{QCD}}(\Phi_B,\Phi_R)\right] \mathrm{d}\Phi_R \right\} \mathrm{d}\Phi_{\mathrm{B}}$$

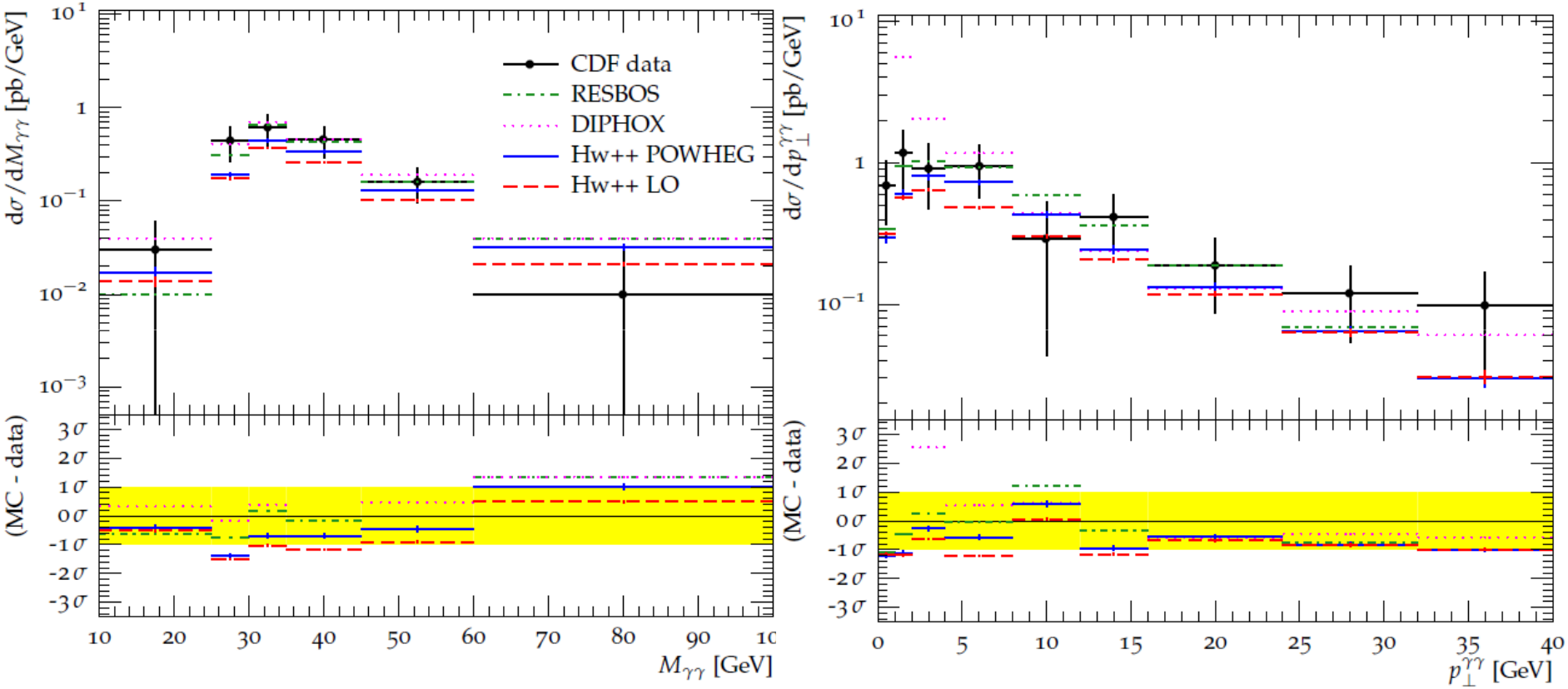
$$\Delta_{\mathrm{QCD}}(p_T) = \exp\left[- \int \mathrm{d}\Phi_R \frac{R_{\mathrm{QCD}}(\Phi_B,\Phi_R)}{B(\Phi_B)} \theta(k_T(\Phi_B,\Phi_R) - p_T)\right]$$

$$\Delta_{\mathrm{QED}}(p_T) = \exp\left[- \int \mathrm{d}\Phi'_R \frac{R_{\mathrm{QED}}(\Phi'_B,\Phi'_R)}{B'(\Phi'_B)} \theta(k_T(\Phi'_B,\Phi'_R) - p_T)\right]$$

Direct Photon Production

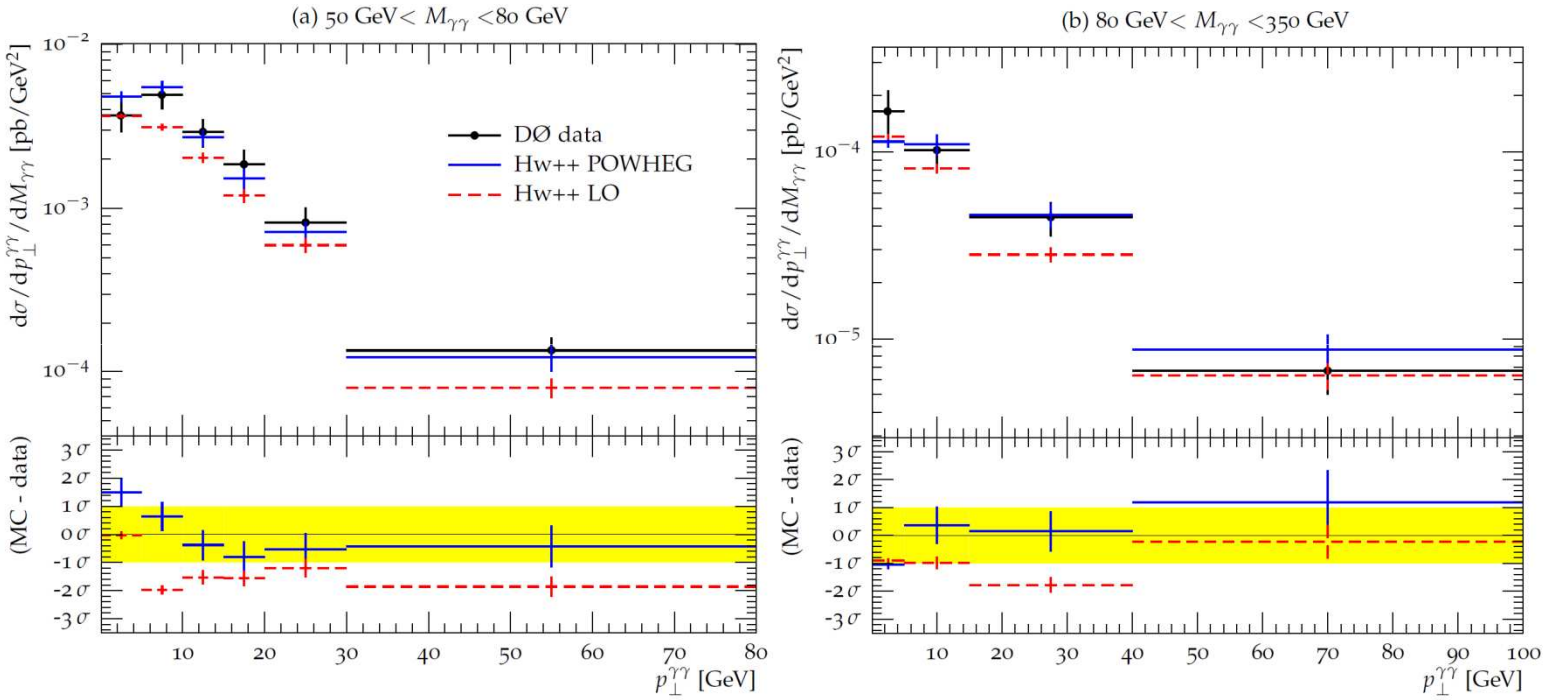
- This allows us to construct a simulation where the fragmentation contribution is still simulated by the shower, including hard corrections from the matrix element.
- Unfortunately the fragmentation contribution retains its leading-order normalization.

Diphoton Production



PR and L d'Errico arXiv:1106.2983 Herwig++ compared to CDF data Phys. Rev. Lett. 95 022003, 2005.

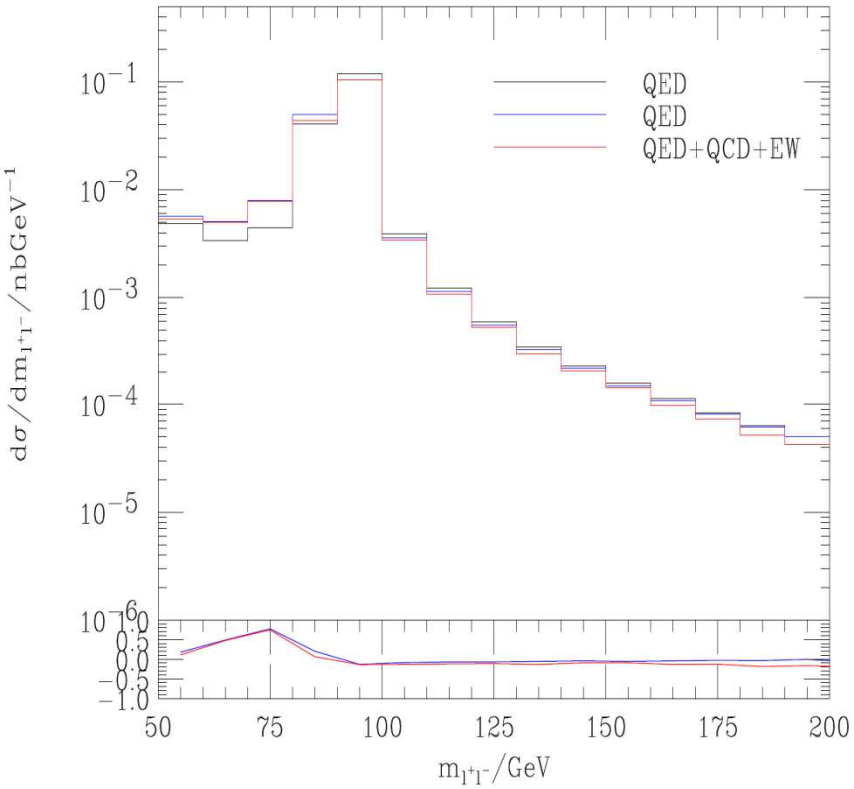
Diphoton Production



PR and L d'Errico arXiv:1106.2983 Herwig++ compared to D0 data Phys. Rev. Lett. 102 231801, 2009.

QED+QCD Radiation

- Another area where we need to include photon radiation is in processes where we need NLO accuracy in both QCD and QED/EW.
- In this case the QED and QCD radiation can both be simulated using the POWHEG method and competition.



Z Drell-Yan
PR and Emanuele Re, in preparation

Summary

- Simulating of QED radiation while in general less important than QCD radiation is important in some cases.
- These can be simulated using POWHEG based approaches.
- Will be available in a future version of Herwig++.