QED real corrections in the Sherpa event generator

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QED parton shower

- Splitting functions have the same form as for a QCD shower [Catani & Seymour, 1997]

$$\langle V \rangle_{f\gamma}(z, y) \propto \frac{2}{1 - z(1 - y)} - (1 + z)$$
$$\langle V \rangle_{\gamma f}(z, y) \propto z^2 + (1 - z)^2$$

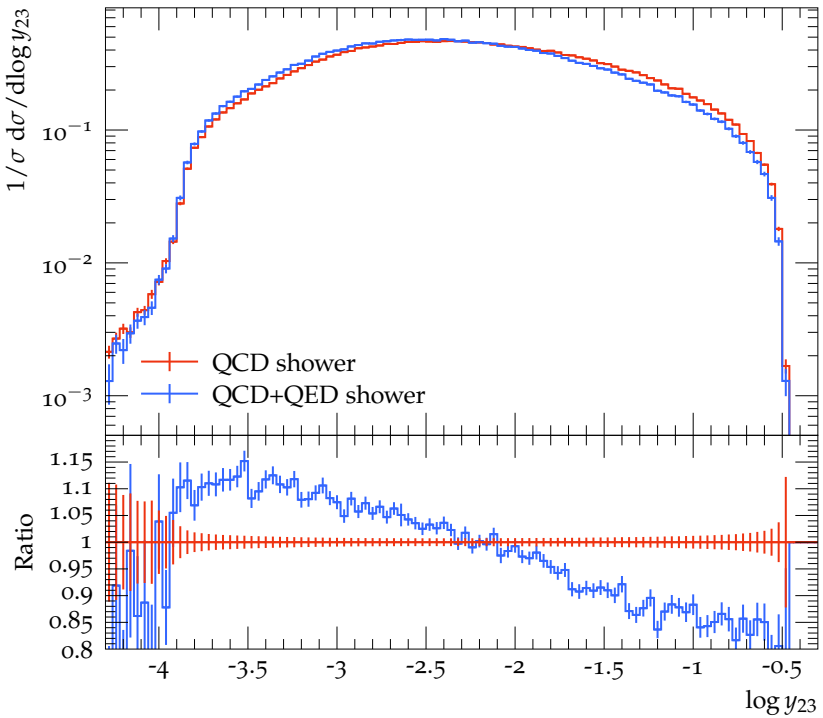
- Colour correlator $\mathbf{T}_{\tilde{ij}}\mathbf{T}_{\tilde{k}}$ replaced by charge correlator [Dittmaier, 2000]

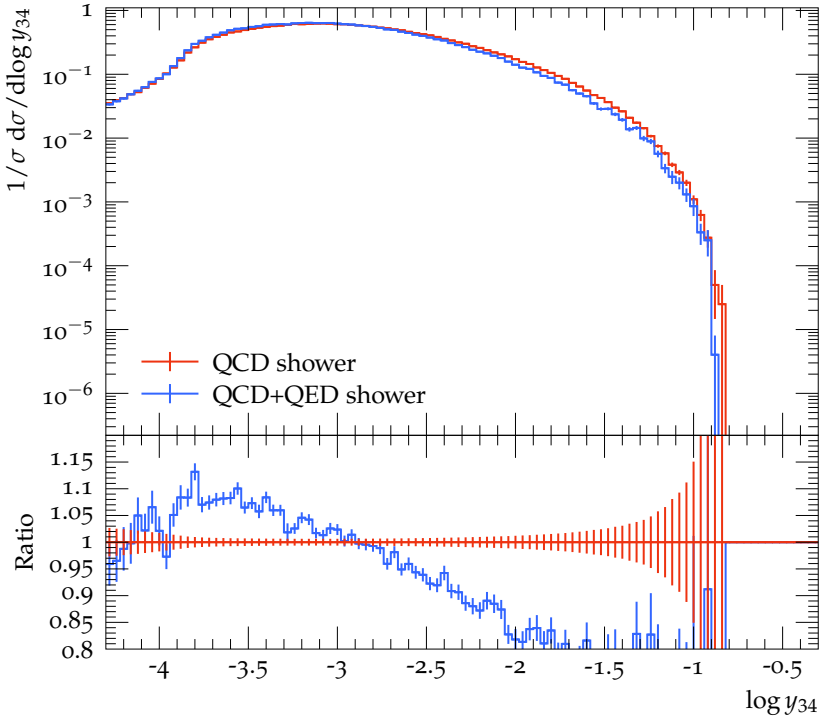
$$\mathbf{Q}^2_{\tilde{ij}\tilde{k}} = \begin{cases} -\frac{Q_{\tilde{ij}} Q_{\tilde{k}} \theta_{\tilde{ij}} \theta_{\tilde{k}}}{Q^2_{\tilde{ij}}}, & \text{for } \tilde{ij} \neq \gamma \\ -\kappa_{\tilde{ij}\tilde{k}}, & \text{for } \tilde{ij} = \gamma \end{cases}$$

QED parton shower

- Requires treatment of negative weights for same-sign dipoles
- Use modified analytic weights method [Höche, Schumann & Siegert (2009)]
- Allow fermions to radiate photons with $\alpha(0)$, since most photons will be long-distance
- Photons split into fermion pairs with $\alpha(t)$
- Interleaved QCD+QED shower is then easy

Differential Durham jet rates in $e^+e^- \to q\bar{q}$





Problems to resolve

- Catani-Seymour shower in SHERPA assumes at most two spectators
- QED: any number of spectators!
- Not all spectators contribute equally yet so some cancellations are incomplete

The PhotonSplitter module

- PHOTONS++ in SHERPA adds soft photons to a charged final state [Schönherr & Krauss, 2008]
- Uses YFS resummation [Yennie, Frautschi & Suura, 1961]
- $\gamma \to f\bar{f}$ occurs at NNLO but is logarithmically enhanced with the fermion mass
- Motivation: a better description of $\mathcal{O}(\alpha^2)$ corrections to $Z \to e^+e^-$
- PHOTOS [Barberio & Zbigniew, 1994] estimated per mille effect
- As a result, reduced systematic uncertainties in correction to Born leptons

Dilepton invariant mass in $Z \longrightarrow e^+e^-$

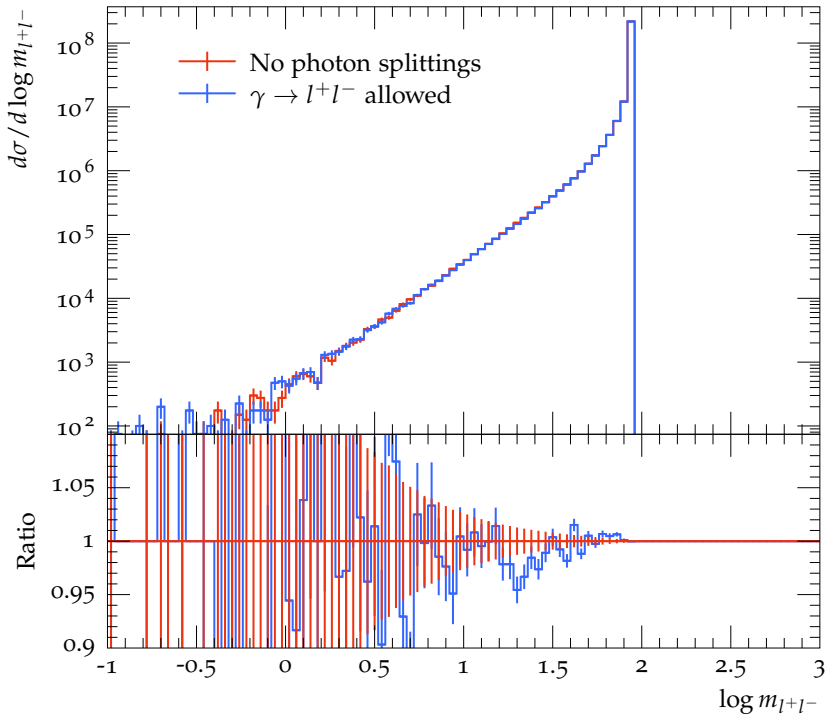


Figure: Bare leptons

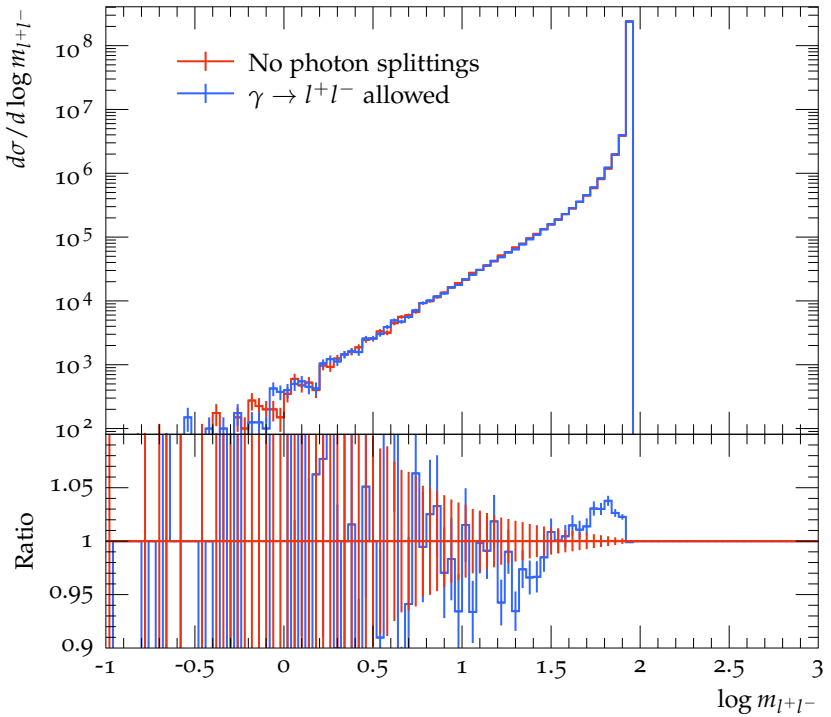


Figure: Dressed leptons

Dilepton invariant mass in $Z \to e^+e^-$

Photon splitting function multiplied by 5 to aid visualisation

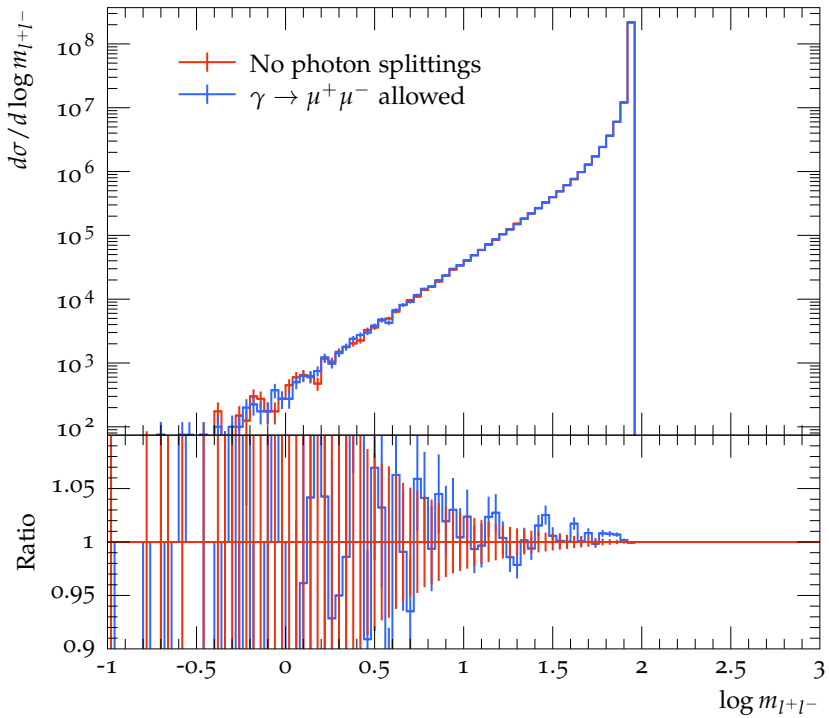


Figure: Bare leptons

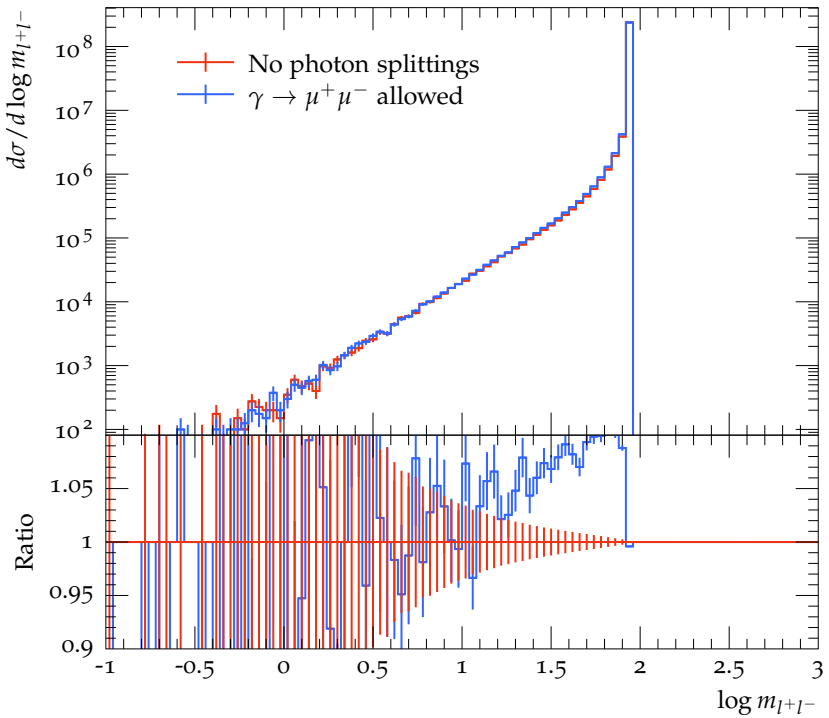


Figure: Dressed leptons

Next steps

- Include soft/collinear leptons in the dressing of primary electrons
- Look into $\mathcal{O}(\alpha^2)$ observables directly
- Option for virtuality-ordering
- As with parton shower, choice of spectator scheme

Thank you for listening