On the way to photoproduction events in Sherpa

Student talk for the 23rd MCnet Meeting, Manchester
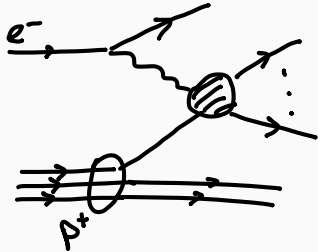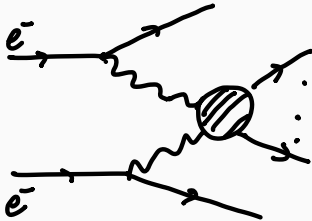
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What is photoproduction?

Consider electromagnetic interaction in lepton-lepton and lepton-hadron collisions

Discern two types of electromagnetic interaction:

Electroproduction $\Rightarrow$ high virtuality ($\rightarrow$ e.g. DIS)
Photoproduction $\Rightarrow$ low virtuality $\Rightarrow$ "quasi-real photons"

The Weizsäcker-Williams formula

The Weizsäcker-Williams formula approximates an electron beam by a photon beam spectrum

First formulated in 1934 [1, 2], see [3] for review

Observe that

- for photon virtuality $P^2 < \Lambda_{\text{cut}}^2$, the photo-absorption cross-section can be approximated by its mass-shell value
- the same domain gives the dominant contribution in photoproduction

$\Rightarrow$ estimate the cross-section by $d\sigma_{eX} = \sigma_{\gamma X}(P^2 = 0)dn$, with dn the photon spectrum

Part of Equivalent Photon Approximation interface in Sherpa

Photon PDFs

(Quasi-)real photons need parton distribution functions!

The following photon PDF libraries have been included in Sherpa:
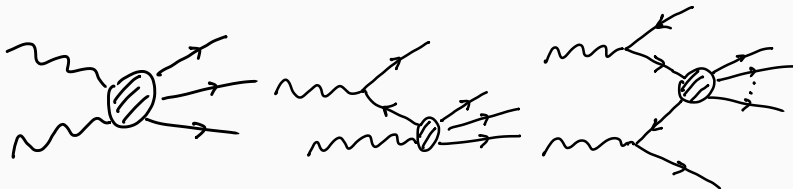
Glück-Reya-Vogt [4], Glück-Reya-Schienbein [5],
Slominski-Abramowicz-Levy [6], Cornet-Jankowski-Krawczyk [7–10],
Schuler-Sjöstrand [11, 12]

All these libraries provide PDFs for the real photon, in LO and some
in NLO.

GRS and SaS additionally cover PDFs for the virtual photon.

Photoproduction at LEP

Three different hard processes: direct, single-resolved and double-resolved:

In Sherpa:

Emission of real collinear photons, approximated by Weizsäcker-Williams formula
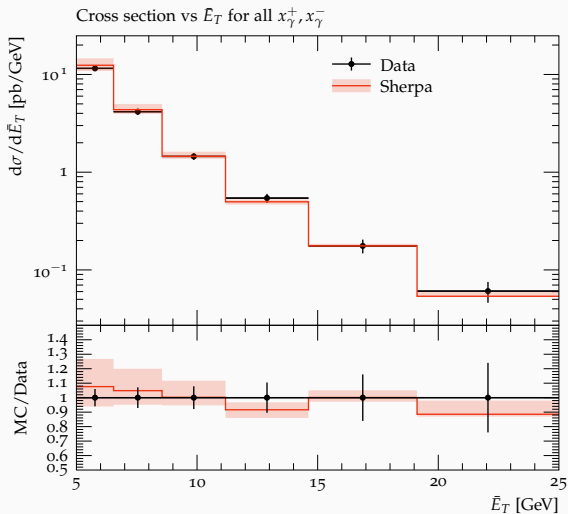+ Interfacing of photon PDFs
+ LO calculation

Figure 1: Simulation of the LEP1 photoproduction data in Sherpa using Weizsäcker-Williams formula and the CJKLLO photon PDF.
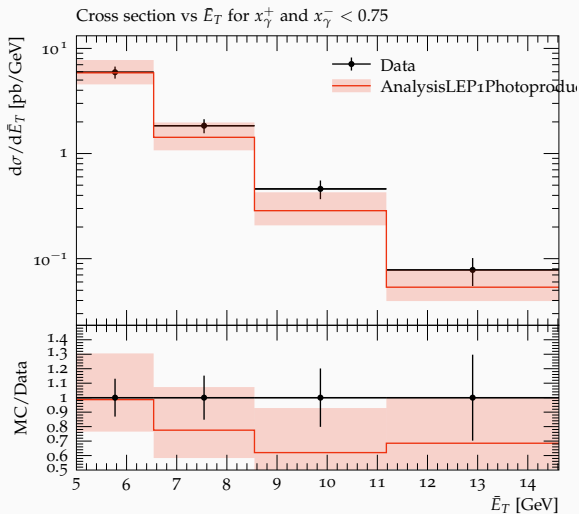
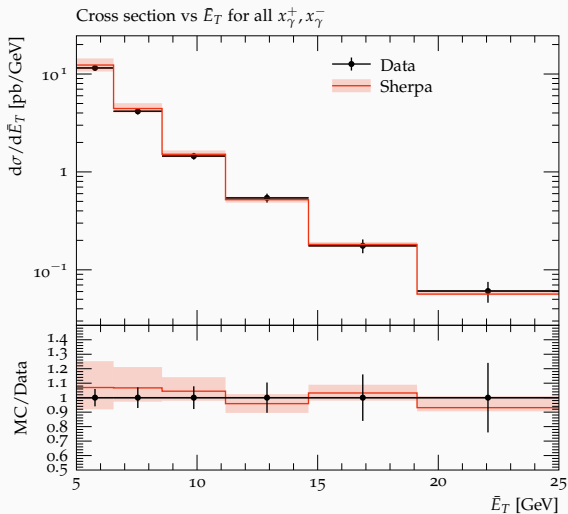**Figure 2:** Simulation of the LEP1 data for 'double-resolved photon' events in Sherpa using Weizsäcker-Williams formula and the CJKLLO photon PDF.

Figure 3: Simulation of the LEP1 photoproduction data in Sherpa using Weizsäcker-Williams formula and the SAS2D photon PDF.

- Only two different hard processes: direct and single-resolved
- Strongly asymmetric kinematics
- Adapt the Weizsäcker-Williams formula to *ep* collisions, cf. [15]

Vector-Meson Dominance model – needed for stringent description of event characteristics

Photonic interaction can be either **bare** or through fermionic fluctuations:

- leptonic $\rightarrow$ negligible for jet production
- 'hard' quarks $\rightarrow$ $p_\perp^2 \sim Q^2 > 0$ $\rightarrow$ short-lived and perturbatively calculable
- 'soft' quarks $\rightarrow$ $p_\perp^2 \sim Q^2 \approx 0$ $\rightarrow$ long-lived and non-perturbative $\rightarrow$ hadron-hadron physics

$(Q^2$ – virtuality$)$

Some remarks:

- Pure state is dominant, but QCD fluctuations have larger cross-section
- VMD-type state dominated by ρ^0
- Two cut-off scales in transverse-momentum needed to parametrise the decomposition
- All three event types have different remnants and $p_\perp$ structures, i.e. are experimentally distinguishable!

Tasks for the extension and application of the simulation:

- validation against HERA
- extend the kinematics to virtual photons
- extend PDFs for virtual photons ($\rightarrow$ VMD)
- LHC photon physics
- implement coherent transition between electro- and photoproduction

References

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