

MITP workshop

The Evaluation of the Leading Hadronic Contribution to the Muon $g-2$: Toward the MUonE Experiment

Introduction to McMULE

Yannick Ulrich

IPPP, University of Durham

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McMULE

Monte Carlo for MUons and other LEptons
<https://mule-tools.gitlab.io>

- fixed-order QED corrections: some NLO, most NNLO, playing with N^3LO , some EW
- fully-differential Monte Carlo integrator, **not** an event generator (yet)
- playing with parton shower (not ready yet)
- whenever possible, steal QCD@LHC technology
 - dimensional regularisation
 - IBP reduction, integral calculations
 - subtraction schemes

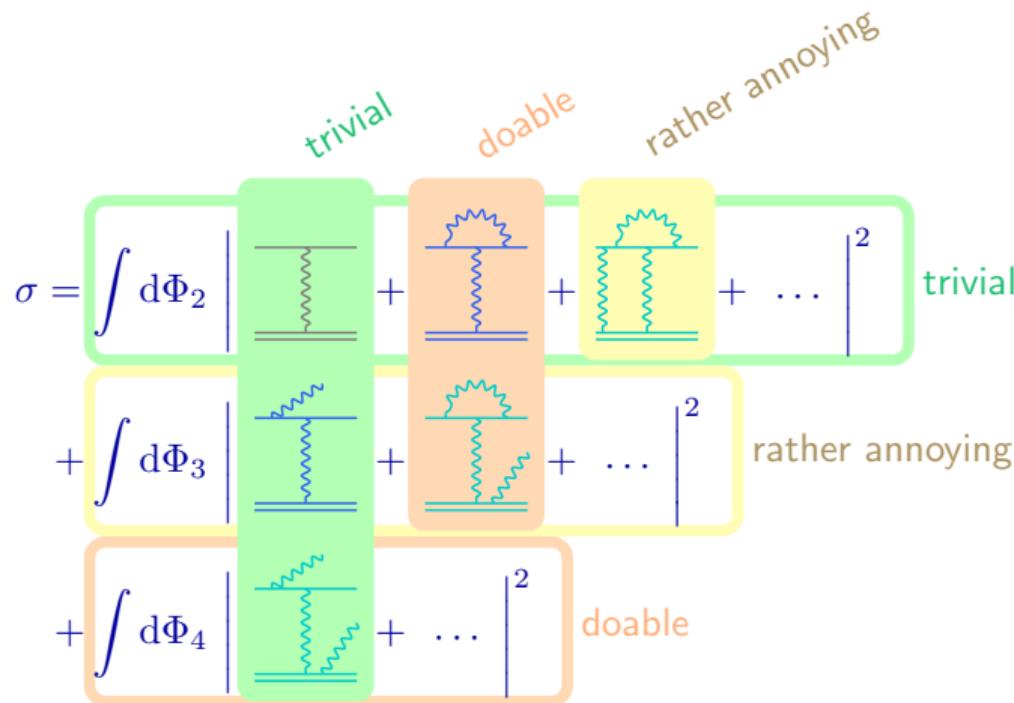
process	precision	experiment	physics motivation
$e\mu \rightarrow e\mu$	NNLO* ⊕ NLO-EW	MUonE	HVP to $(g - 2)_\mu$
$\ell p \rightarrow \ell p$	NNLO#	P2, Muse, Prad, ...	proton radius
$e^-e^- \rightarrow e^-e^-$	NNLO*	Prad 2 MOLLER, ...	normalisation $\sin \theta_W^2$ at low Q^2
$e^+e^- \rightarrow e^+e^-$	NNLO*,#	any e^+e^- collider	luminosity measurement
$ee \rightarrow \ell\ell$	NNLO† ⊕ NLO-EW	VEPP, BES, Daphne, ... Belle	R -ratio τ properties
$ee \rightarrow \gamma\gamma$	NNLO*,#	Daphne any e^+e^- collider	dark searches luminosity measurement
$\mu \rightarrow \nu\bar{\nu}e$	NNLO ⊕ resum	MEG DUNE	ALP searches beam-line profiling

*: massification (cf. Tim's talk)

#: some hadronic effects missing

†: only dominant corrections

physical $2 \rightarrow 2$ cross section



- two-loop w/ full m -dependence: **really** difficult (cf. Tim's talk)
- VP diagrams for $e/\mu/\tau/\text{had}/\dots$ numerically with full mass dependence (Matteo's method)
- real-virtual: really unstable for soft/collinear emission
- phase space integration: divergent



[Signer 22]



f.l.t.r.: F.Hagelstein (Mainz), A.Coutinho (PSI), N.Schalch (Bern), L.Naterop (Zurich & PSI), S.Kollatzsch (Zurich & PSI), A.Signer (Zurich & PSI), M.Rocco (PSI), T.Engel (→ Freiburg), V.Sharkovska (Zurich & PSI), Y.Ulrich (Durham), A.Gurgone (Pavia)



McMULE
mule-tools.gitlab.io

for experimentalists

- event generator
- which observables / cuts should we use for tuning
- what can we share already now (i.e. $d\sigma/d\theta_e$)
- running with μ^+ or μ^- to check calculations
- ...

for theorists

- which observables have the hierarchy electr. \gg mixd. \gg muonic
- what can we resum up to NLL?
- N^3 LO \rightarrow see later
- how good is the massification \rightarrow Pavia calculation w/o approximation ongoing
- ...