
Strong2020 WorkStop/ThinkStart

Introduction & Organisation

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ZÜRICH / 05 JUNE 2023

what do we want?

UZH 13–16 Sep 2016 [1705.01827]

Eur. Phys. J. C (2017) 77:471
DOI 10.1140/epjc/s10052-017-5023-2

THE EUROPEAN
PHYSICAL JOURNAL C



Regular Article - Theoretical Physics

To d , or not to d : recent developments and comparisons of regularization schemes

C. Gnendiger^{1,8}, A. Signer^{1,2}, D. Stöckinger³, A. Broggio⁴, A. L. Cherchiglia⁵, F. Driencourt-Mangin⁶, A. R. Fazio⁷, B. Hiller⁸, P. Mastrolia^{9,10}, T. Peraro¹¹, R. Pittau¹², G. M. Pruna¹, G. Rodrigo⁹, M. Sampaio¹³, G. Sborlini^{6,14,15}, W. J. Torres Bobadilla^{6,9,10}, F. Tramontano^{16,17}, Y. Ulrich^{1,2}, A. Visconti^{1,2}

Florence 4–6 Nov 2019 [2012.02567]

Eur. Phys. J. C (2021) 81:250
https://doi.org/10.1140/epjc/s10052-021-08996-y

THE EUROPEAN
PHYSICAL JOURNAL C



Review

May the four be with you: novel IR-subtraction methods to tackle NNLO calculations

W. J. Torres Bobadilla^{1,2,8}, G. F. R. Sborlini³, P. Banerjee⁴, S. Catani⁵, A. L. Cherchiglia⁶, L. Cieri⁵, P. K. Dhani^{5,7}, F. Driencourt-Mangin², T. Engel^{4,8}, G. Ferrera⁹, C. Gnendiger⁴, R. J. Hernández-Pinto¹⁰, B. Hiller¹¹, G. Pelliccioli¹², J. Pires¹³, R. Pittau¹⁴, M. Rocco¹⁵, G. Rodrigo⁹, M. Sampaio⁶, A. Signer^{4,8}, C. Signorile-Signorile^{16,17}, D. Stöckinger¹⁸, F. Tramontano¹⁹, Y. Ulrich^{4,8,20}

UZH 4–7 Feb 2019 [2004.13663]

Eur. Phys. J. C (2020) 80:591
https://doi.org/10.1140/epjc/s10052-020-8138-9

THE EUROPEAN
PHYSICAL JOURNAL C



Review

Theory for muon-electron scattering @ 10 ppm

A report of the MUonE theory initiative

P. Banerjee¹, C. M. Carloni Calame², M. Chiesa³, S. Di Vita⁴, T. Engel^{1,5}, M. Fael⁶, S. Laporta^{7,8}, P. Mastrolia^{7,8}, G. Montagna^{2,9}, O. Nicrosini², G. Ossola¹⁰, M. Passera⁸, F. Piccinini², A. Primo⁵, J. Ronca¹¹, A. Signer^{1,5,8}, W. J. Torres Bobadilla¹¹, L. Trentadue^{12,13}, Y. Ulrich^{1,5}, G. Venanzoni¹⁴

Durham 3–5 Aug 2022

N³LO kick-off WorkStop/ThinkStart

<https://conference.ippp.dur.ac.uk/event/1104/>

- idea: make a next step in

Radiative corrections and Monte Carlo tools for low-energy hadronic cross sections in e^+e^- collisions

Eur. Phys. J. C (2010) 66: 585–686
 DOI 10.1140/epjcs/10052-010-1251-4

THE EUROPEAN
 PHYSICAL JOURNAL C

Review

- inspired by [\[0912.0749\]](#)

Quest for precision in hadronic cross sections at low energy: Monte Carlo tools vs. experimental data

Working Group on Radiative Corrections and Monte Carlo Generators for Low Energies

S. Actis³⁸, A. Arbuzov^{9,e}, G. Balossini^{32,33}, P. Beltrame¹³, C. Bignamini^{32,33}, R. Bonciani¹⁵, C.M. Carloni Calame³⁵, V. Cherepanov^{25,26}, M. Czakon¹, H. Czyż^{19,a,f,j}, A. Denig²², S. Eidelman^{25,26,g}, G.V. Fedotovich^{25,26,e}, A. Ferroglia²³, J. Gluza¹⁹, A. Grzebińska⁸, M. Guina¹⁹, A. Hafner²², F. Ignatov²⁵, S. Jadach⁶, F. Jegerlehner^{1,19,41}, A. Kalinowski²⁹, W. Kluge¹⁷, A. Korchin²⁰, J.H. Kühn¹⁸, E.A. Kuraev⁹, P. Lukin²⁵, P. Mastrolia¹⁴, G. Montagna^{32,33,h,d}, S.E. Müller^{22,f}, F. Nguyen^{14,d}, O. Nicrosini³³, D. Nomura^{26,h}, G. Pakhlova²⁴, G. Pancheri¹¹, M. Passera²⁸, A. Penin⁴⁰, F. Piccinini³³, W. Placzek⁷, T. Przedzinski⁶, E. Remiddi^{4,5}, T. Riemann⁴¹, G. Rodrigo³⁷, P. Roig²⁷, O. Shekhovtsova¹¹, C.P. Shen¹⁶, A.L. Sibidanov²⁵, T. Teubner^{21,h}, L. Trentadue^{30,31}, G. Venanzoni^{11,i,j}, J.J. van der Bij², P. Wang², B.F.L. Ward³⁹, Z. Was^{8,g}, M. Worek^{40,19}, C.Z. Yuan²

- consolidate and implement the progress since 2010

Team: P. Beltrame, E. Budassi, C. Carloni Calame, G. Colangelo, M. Cottini, A. Driutti, T. Engel, L. Flower, A. Gurgone, M. Hoferichter, F. Ignatov, S. Kollatzsch, B. Kubis, A. Kupsc, F. Lange, D. Moreno, F. Piccinini, M. Rocco, K. Schönwald, A. Signer, G. Stagnitto, D. Stöckinger, P. Stoffer, T. Teubner, W. Torres Bobadilla, Y. Ulrich, G. Venanzoni

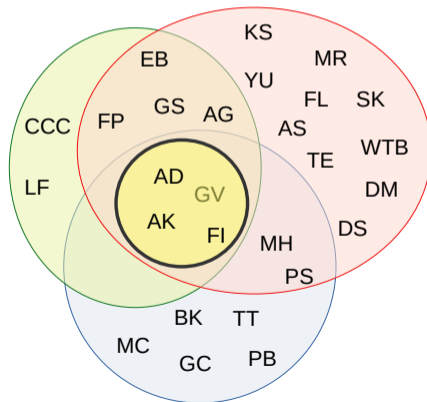
-
- WP1:** QED for leptons at NNLO

 - WP2:** Form factor contributions at N³LO

 - WP3:** Processes with hadrons

 - WP4:** Parton showers

 - WP5:** Experimental input



This is NOT a workshop, it's a WorkStop/ThinkStart

- **stop** working, **start** thinking only about $e^+ e^- \rightarrow \text{hadrons}$
- in this room: expertise in fixed-order, parton shower, dispersive approach, **and** experimental guidance where progress is most urgently needed
- scheduled talks are only “get going” triggers, hopefully they fizzle out into discussions in smaller groups
- learn from each other, ask questions (preferably stupid ones), explain to each other within small groups
- communicate outcomes to everyone through [Excalidraw](#)

Connection WP – processes

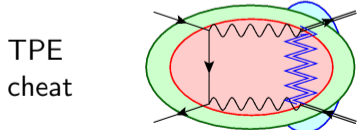
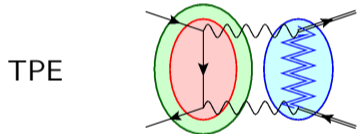
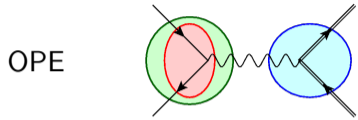
- in the WorkStop, we 'just' want to **take stock** what is available and **improve** the theoretical description for $e^+ e^- \rightarrow$ hadrons
- **main** processes (input from **WP5**)

$$e^+ e^- \rightarrow \pi^+ \pi^- \quad \gamma\{+\gamma\}$$

$$e^+ e^- \rightarrow \mu^+ \mu^- \quad \gamma\{+\gamma\}$$

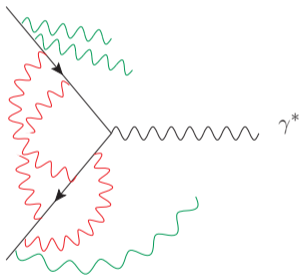
$$e^+ e^- \rightarrow e^+ e^- \quad \gamma\{+\gamma\}$$

- there are more processes and $(e^+ e^-)$ in final state
- cross links with $\mu e^- \rightarrow \mu e^-$ and $\ell p \rightarrow \ell p$
- here: link **WP1/2** – **WP3** – **WP4**



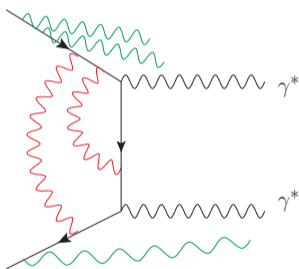
- clearly separated worlds
- combine WP1/2 and WP4
- can use any form factor in WP3
- do we need to combine WP3 and WP4?
- combine WP1/2 + WP4 with WP3
- dispersive approach
- additional radiation from pions !!?
- FsQED with 'implementable advice' from WP3 ?
- expand rule of WP1/2 + WP4 ??
(partly available from $e^+ e^- \rightarrow l^+ l^-$)
- additional radiation from pions ok

Buliding block $e^+ e^- \rightarrow \gamma^*$



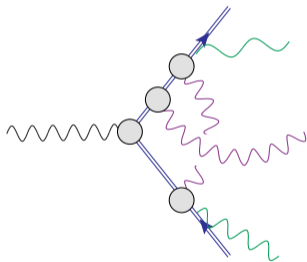
- **NNLO** available (used for $e\mu \rightarrow e\mu$ and $lp \rightarrow lp$) including real and virtual
- moving towards **NNNLO**, \exists open questions in particular NNLO for $e^+ e^- \rightarrow \gamma^* \gamma$
- playground for combination with **parton showers**
- **YFS vs collinear** are parton showers LL or NLL ??
- can we use next-to-soft LBK to improve YFS ??

Buliding block $e^+ e^- \rightarrow \gamma^* \gamma^*$



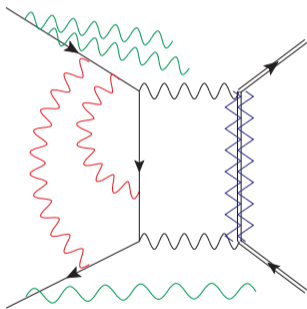
- doubly virtual Compton scattering (gauge invariant)
- **NLO** doable, including real and virtual
- **NNLO** painful, would it be useful ?
if one $\gamma^* \rightarrow \gamma$ it is desperately wanted
- dispersive approach to combine with $\pi^+ \pi^-$ final state
- playground for combination with **parton showers**

Buliding block $\gamma^* \rightarrow \pi^+ \pi^-$



- at LO, any grey blob ok (from computational p.o.v) but what is a 'good' form factor?
- beyond LO: need implementable advice
- (N)NLO with FsQED useful ?
- 'good' form factor s.t. the loop integrals are doable?
- quantify systematically contributions beyond FsQED?
- do we need additional radiation off pions?

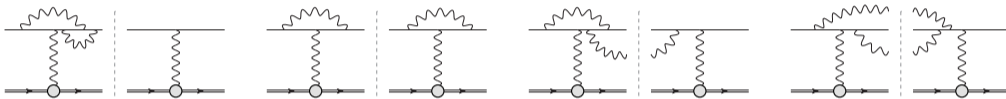
sewing together building blocks $e^+ e^- \rightarrow l^+ l^-$ and $e^+ e^- \rightarrow \pi^+ \pi^-$



- $e^+ e^- \rightarrow l^+ l^-$
 - \sim known at NNLO, generator ?!
 - combine with parton shower (MUonE !!)
 - NNLO for $e^+ e^- \rightarrow l^+ l^- \gamma$, ouch
-
- $e^+ e^- \rightarrow \pi^+ \pi^-$
 - can we proceed as for TPE in $lp \rightarrow lp$?
 - use QED as much as possible, model beyond

Copying from TPE in $\ell p \rightarrow \ell p$??

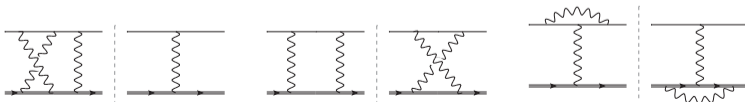
NNLO leptonic correction: QED with arbitrary form factors (FF)



NLO TPE with form factors and resonance contribution, (split pointlike (IR!) + rest)



beyond this: pointlike proton (not too bad, error $\sim 30\% \times (\alpha/\pi)^2$)



←!! in FF or not

- many questions, ideas, possibilities
- more processes and questions → Andrzej
- many experts (hopefully) with some answers
- many things to be computed
- how to go about this ?

→ The grand plan

- collect questions/answers/suggestions during Mon, Tue, Wed on [Excalidraw](#)
- reprocess and digest Thu morning (also overflow from previous days)
- convert to and assign homework on Fri morning

light yellow is negotiable (e.g. Tue 30 minutes shift scheduled)
 coffee in Y36-K-08 'continuous'
 rest is fix (Swiss timing!)

	Mon 05 June	Tue 06 June	Wed 07 June	Thu 08 June	Fri 09 June	
09:00		WP1	WP4	take stock		Y36-K-08
10:00					fix homework	KOL-F-101
11:00						coffee
12:00						
13:00						
14:00			conference	conference	conference	
15:00	WP3	WP2				
16:00					goodbye/beer	
17:00						
18:00						
				WorkStop dinner		