

Kunst or Kunst? — Both!

Workshop in honour of Zoltan's 80 Birthday

Zurich, May 24, 2024

Gudrun Heinrich

Institute for Theoretical Physics, Karlsruhe Institute of Technology

Zoltan mastered the Art (Kunst) of

- conveying enthusiasm for particle physics
- contributing significantly to many important research fields
- being always up to date about recent developments in particle physics
- keeping close contact to experimentalists
- having a large network of collaborators and friends
- being always welcoming and open-minded

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- conveying enthusiasm for particle physics
- contributing significantly to many important research fields
- being always up to date about recent developments in particle physics
- keeping close contact to experimentalists
- having a large network of collaborators and friends
- being always welcoming and open-minded
- asking questions also at talks where everybody else was lost or had fallen asleep ...

The art of broadness

- Electroweak physics
- Jet physics, FKS-subtraction
- Higgs physics
- Supersymmetry
- Helicity amplitudes
- Quantum field theory
- Numerical methods
- Unitarity methods
- Extra dimensions
- Lattice gauge theory



Hungarian Academy of Sciences, 2022



30 years ago ...

I first met Zoltan here:



- I had applied for a PhD position in and Zoltan had invited me for an interview
- In my Diploma Thesis I had worked on technicolor theories with Jochum van der Bij, but technicolor was basically ruled out by 1994
- Time to do something more sustainable!
- I found a very welcoming atmosphere during the interview
(and of course Zoltan's enthusiasm about his projects was contagious, so I turned down an offer from John Bagger)

ETH Hönggerberg

of course what also attracted me was the mountains, visible already on my first trip to Hönggerberg



Work places



Work places



“Home office” ?

Work places



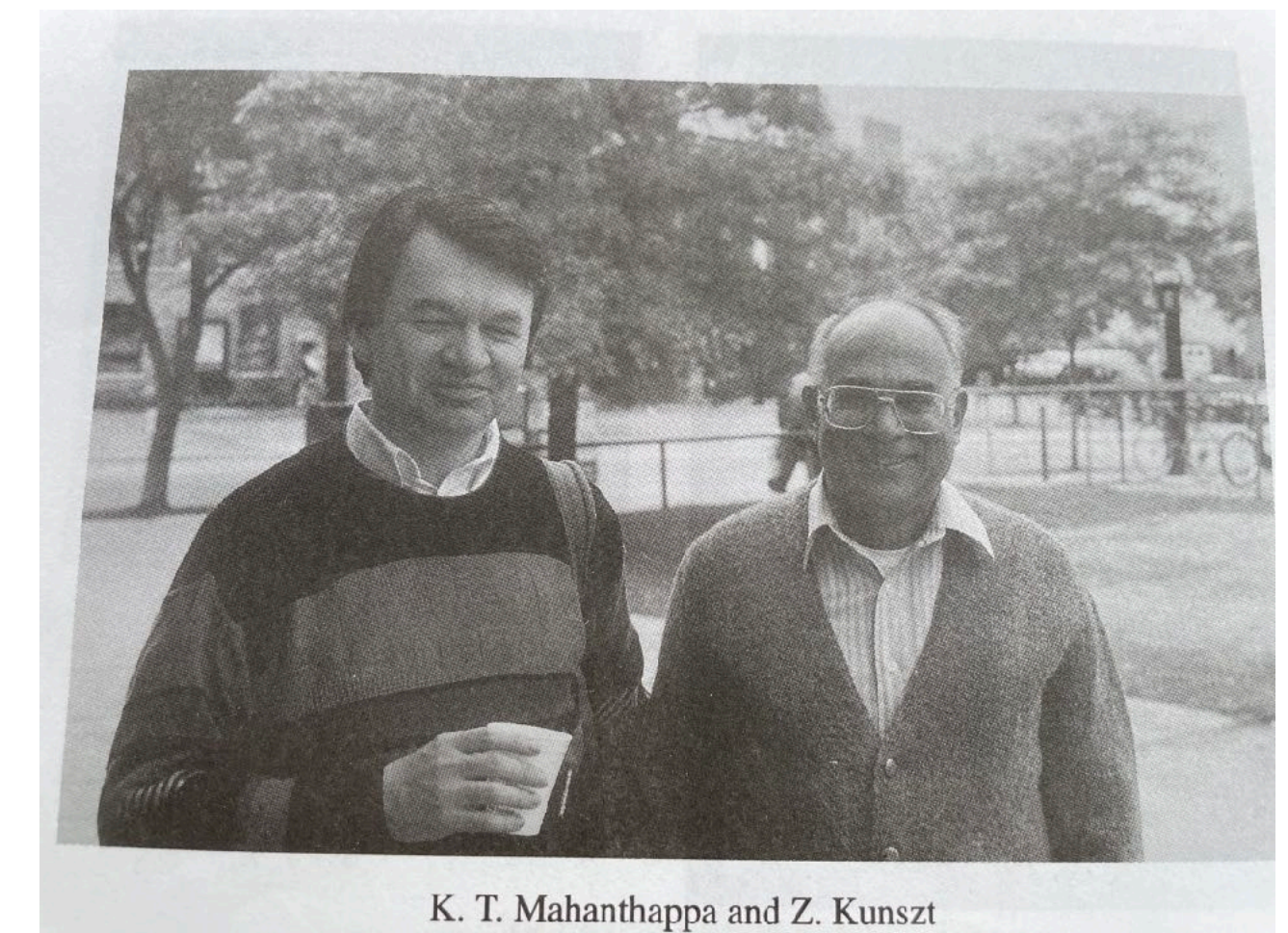
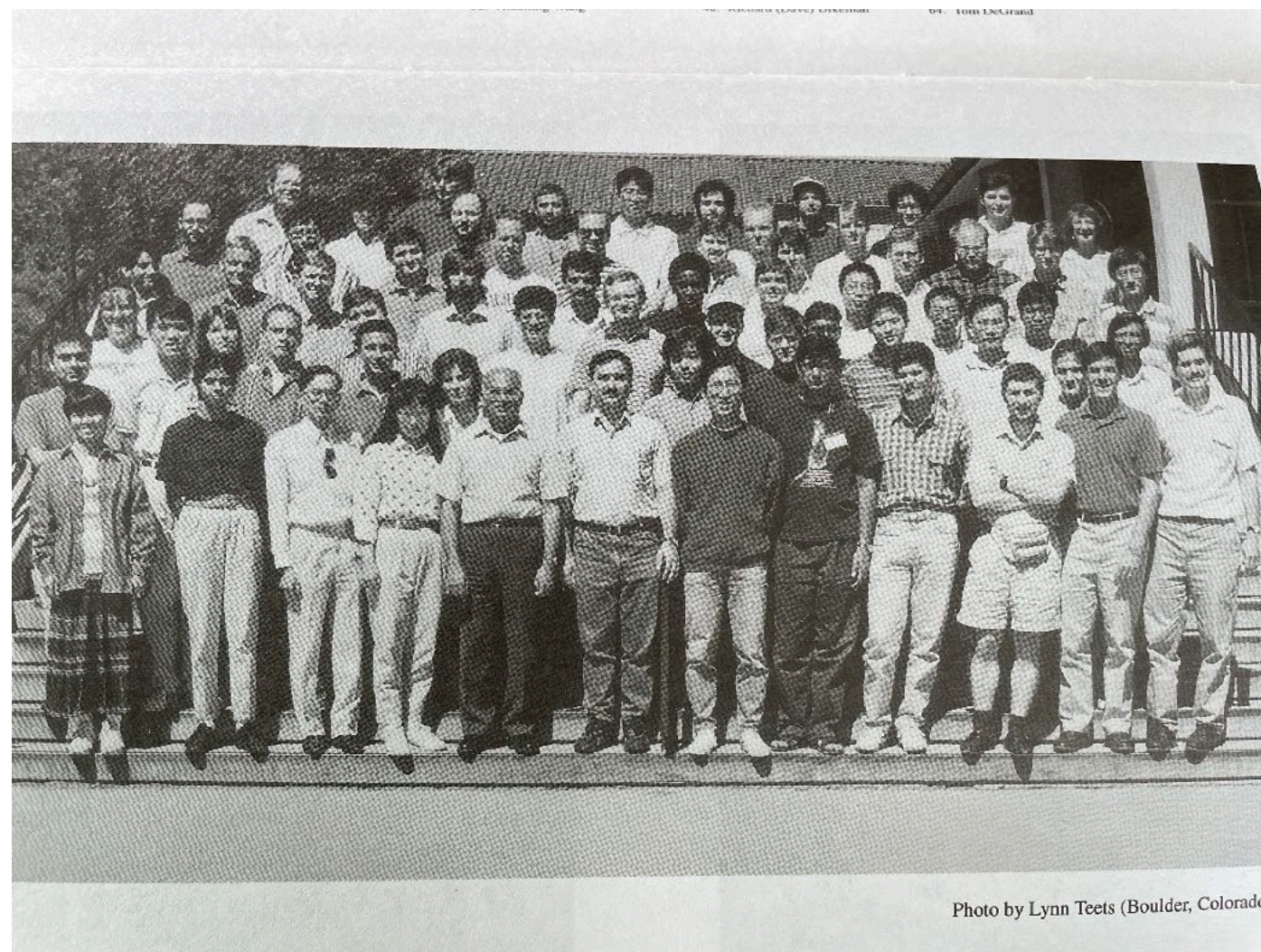
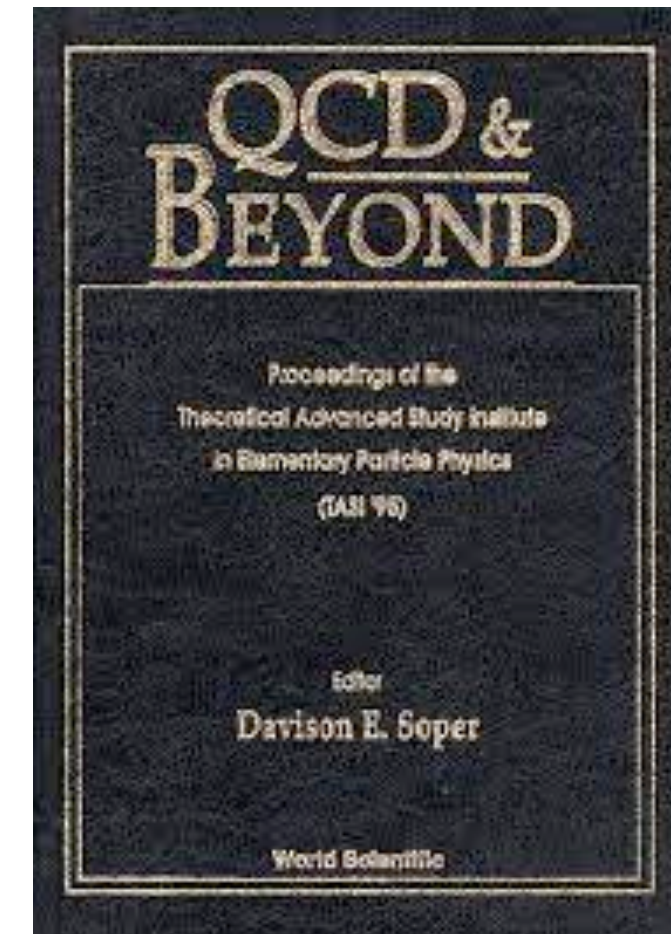
“Home office” ?

TASI 95

Thanks to Zoltan I had the great opportunity to attend the TASI Summer School in Boulder in 1995

Amazing lectures: John Collins, Lance Dixon, Zoltan, George Sterman, James Stirling, Nathan Seiberg, ...

Many participants still in Academia: Aude, Thomas, Gino Isidori, Csaba Csaki, Martin Schmaltz, Francesco Sannino, ...



The nineties: jet physics

Zoltan has done pioneering work on jet physics and IR subtraction at NLO

JUNE 10

PHYSICAL REVIEW LETTERS

7

Two-Jet Production in Hadron Collisions at Order α_s^3 in QCD

Stephen D. Ellis

Department of Physics, University of Washington, Seattle, Washington 98195

Zoltan Kunszt

Eidgenössische Technische Hochschule, CH-8093 Zürich, Switzerland

Davison E. Soper

Institute of Theoretical Science, University of Oregon, Eugene, Oregon 97403

(Received 9 July 1992)



OITS 475
January 1992

Calculation of Jet Cross Sections in Hadron Collisions
at Order α_s^3

Zoltan Kunszt

Institute for Theoretical Physics, Eidg. Technische Hochschule, Zurich, Switzerland

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30 years to upgrade 2j in full colour to NNLO!

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Three-jet cross sections to next-to-leading order

S. Frixione^{a,1}, Z. Kunszt^a, A. Signer^{b,1}

^a Theoretical Physics, ETH, Zurich, Switzerland

^b SLAC, P.O. Box 4349, Stanford, CA 94309, USA

Received 20 December 1995; accepted 23 February 1996

the famous FKS method



OITS 475
January 1992

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(Received 9 July 1992)

30 years to upgrade 2j in full colour to NNLO!

25 years to upgrade 3j to NNLO!

Three-jet cross sections to next-to-leading order

S. Frixione^{a,1}, Z. Kunszt^a, A. Signer^{b,1}
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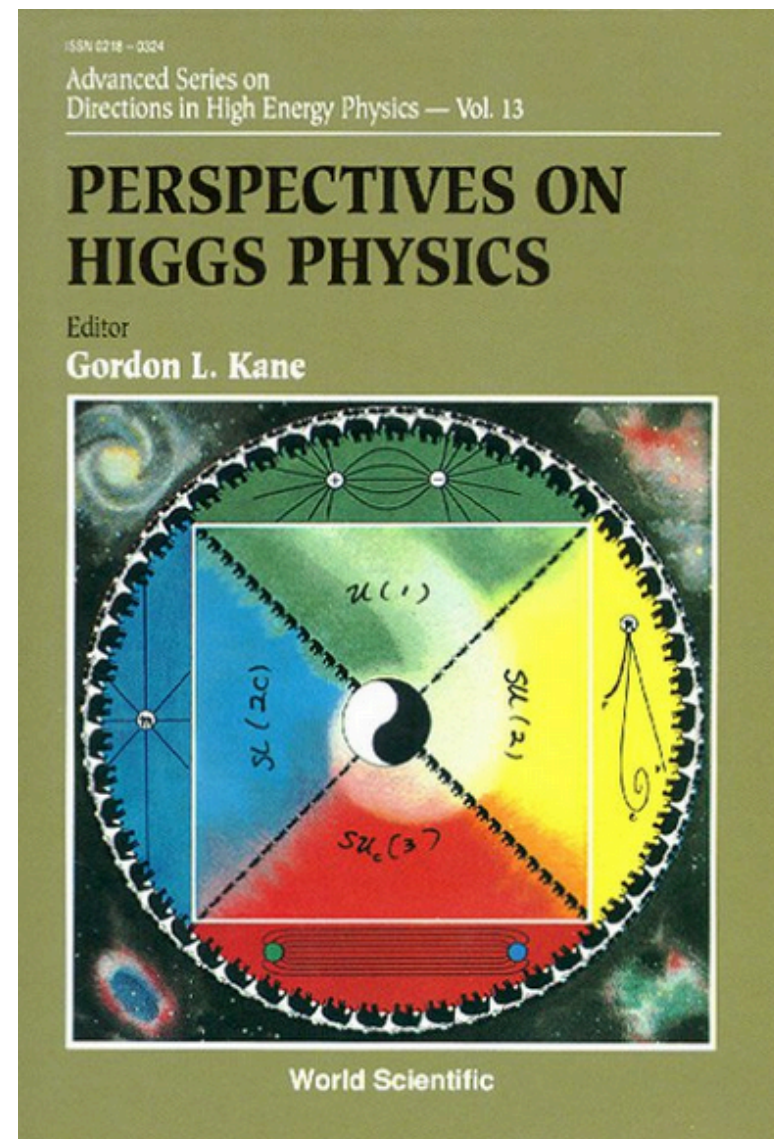
The nineties: Higgs physics

Advanced Series on Directions in High Energy Physics

| Perspectives on Higgs Physics, pp. 156-178 (1993)

Search for Higgs Bosons with Isolated Photons at Large Hadron Colliders

Z. Kunszt



Higgs production at the LHC: an update on cross sections and branching ratios^{*}

Z. Kunszt¹, S. Moretti^{2,3}, W.J. Stirling^{4,5}

¹ Theoretical Physics, ETH, CH-8093 Zürich, Switzerland

² Dipartimento di Fisica Teorica, Università di Torino, and I.N.F.N., Sezione di Torino, Via Pietro Giuria 1, I-10125 Torino, Italy

³ Cavendish Laboratory, University of Cambridge, Madingley Road, Cambridge, CB3 0HE, United Kingdom

⁴ Department of Physics, University of Durham, South Road, Durham DH1 3LE, United Kingdom

⁵ Department of Mathematical Sciences, University of Durham, South Road, Durham DH1 3LE, United Kingdom

Received: 25 November 1996

VOLUME 82, NUMBER 26

PHYSICAL REVIEW LETTERS

28 JUN

Higgs Production with Large Transverse Momentum in Hadronic Collisions at Next-to-Leading Order

D. de Florian, M. Grazzini, and Z. Kunszt

Institute of Theoretical Physics, ETH, CH-8093 Zürich, Switzerland

(Received 26 February 1999)

The nineties: helicity amplitudes

One-loop helicity amplitudes for all $2 \rightarrow 2$ processes in QCD and $N = 1$ supersymmetric Yang–Mills theory*

Zoltan Kunszt, Adrian Signer and Zoltán Trócsányi

Theoretical Physics, ETH, Zürich, Switzerland

Received 12 May 1993

Accepted for publication 3 August 1993

Helicity amplitudes for $O(\alpha_s)$ production of W^+W^- , $W^\pm Z$, ZZ , $W^\pm\gamma$, or $Z\gamma$ pairs at hadron colliders

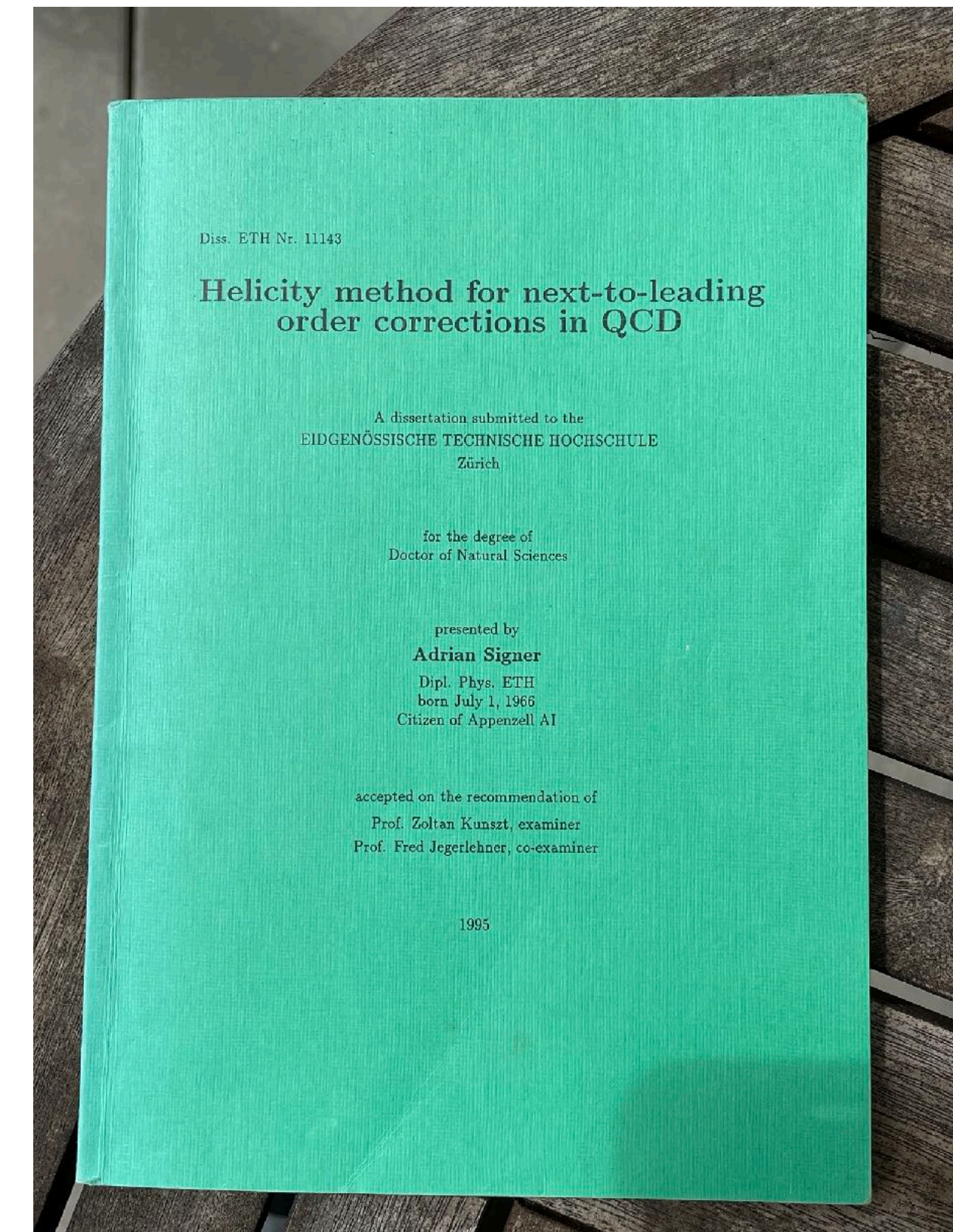
L. Dixon^a, Z. Kunszt^b, A. Signer^c

^a *Stanford Linear Accelerator Center, Stanford University, Stanford, CA 94309, USA*

^b *Theoretical Physics, ETH, Zürich, Switzerland*

^c *Theory Division, CERN, CH-1211 Geneva 23, Switzerland*

Received 24 March 1998; accepted 19 May 1998



Adrian Signer's PhD Thesis

Beyond the Standard Model

Testing the Higgs sector of the minimal supersymmetric standard model at large hadron colliders

Z. Kunszt

Institute of Theoretical Physics, ETH, Zurich, Switzerland

F. Zwirner *

Theory Division, CERN, Geneva, Switzerland

Received 31 March 1992

Accepted for publication 8 July 1992

QCD corrections and the Leptoquark interpretation of the HERA high- Q^2 events*

Z. Kunszt¹, W. J. Stirling^{2,3}

¹ Institute of Theoretical Physics, ETH, CH-8093 Zürich, Switzerland

² Department of Physics, University of Durham, South Road, Durham DH1 3LE, United Kingdom

³ Department of Mathematical Sciences, University of Durham, South Road, Durham DH1 3LE, United Kingdom

Received: 2 May 1997

Radiative corrections with 5D mixed position-/momentum-space propagators

Martin Puchwein* and Zoltan Kunszt

Institute for Theoretical Physics, ETH, CH-8093 Zurich, Switzerland

Received 19 September 2003

1994/95

Zoltan also worked on parton distribution functions!

The evolution of parton distributions at small x

R.K. Ellis^a, Z. Kunszt^b, E.M. Levin^{a,1}

^a Fermi National Accelerator Laboratory, P.O. Box 500, Batavia, IL 60510, USA

^b Theoretical Physics, ETH, Hönggerberg, 8093 Zurich, Switzerland

Received 7 December 1993; accepted 11 January 1994

- My task was to calculate the spin-dependent two-loop splitting functions using the light-cone gauge
- To learn the method first the spin-independent calculation had to be reproduced
- However, things turned out differently ...

19 OCTOBER 1994

PHYSICAL REVIEW LETTERS

581, NUMBER 16

Diffractive Deeply Inelastic Scattering of Hadronic States with Small Transverse Size

F. Hautmann,¹ Z. Kunszt,² and D.E. Soper¹
¹Institute of Theoretical Science, University of Oregon, Eugene, Oregon 97403
²Institute of Theoretical Physics, ETH, CH-8093 Zürich, Switzerland
(Received 8 June 1998)

1995/96



The calculation of the two-loop spin splitting functions $P_{ij}^{(1)}(x)$

R. Mertig¹, W.L. van Neerven²

¹NIKHEF-H, P.O. Box 41882, 1009 DB Amsterdam, The Netherlands

²Instituut-Lorentz, University of Leiden, P.O. Box 9506, 2300 RA Leiden, The Netherlands

Received: 30 June 1995

The spin-dependent two-loop splitting function

W. Vogelsang

Rutherford Appleton Laboratory, Chilton, Didcot, Oxon OX11 0QX, UK

Received 25 March 1996; accepted 29 May 1996

The evolution of parton distributions beyond
leading order:
the singlet case

R. K. Ellis

Fermi National Accelerator Laboratory,
P. O. Box 500,
Batavia, IL 60510, USA.

and

Division TH,
CERN,
1211 Geneva 23, Switzerland.

W. Vogelsang

Rutherford Appleton Laboratory,
Chilton, DIDCOT,
Oxon OX11 0QX, England.

1996-1998

Zoltan offered me two alternatives to go ahead:

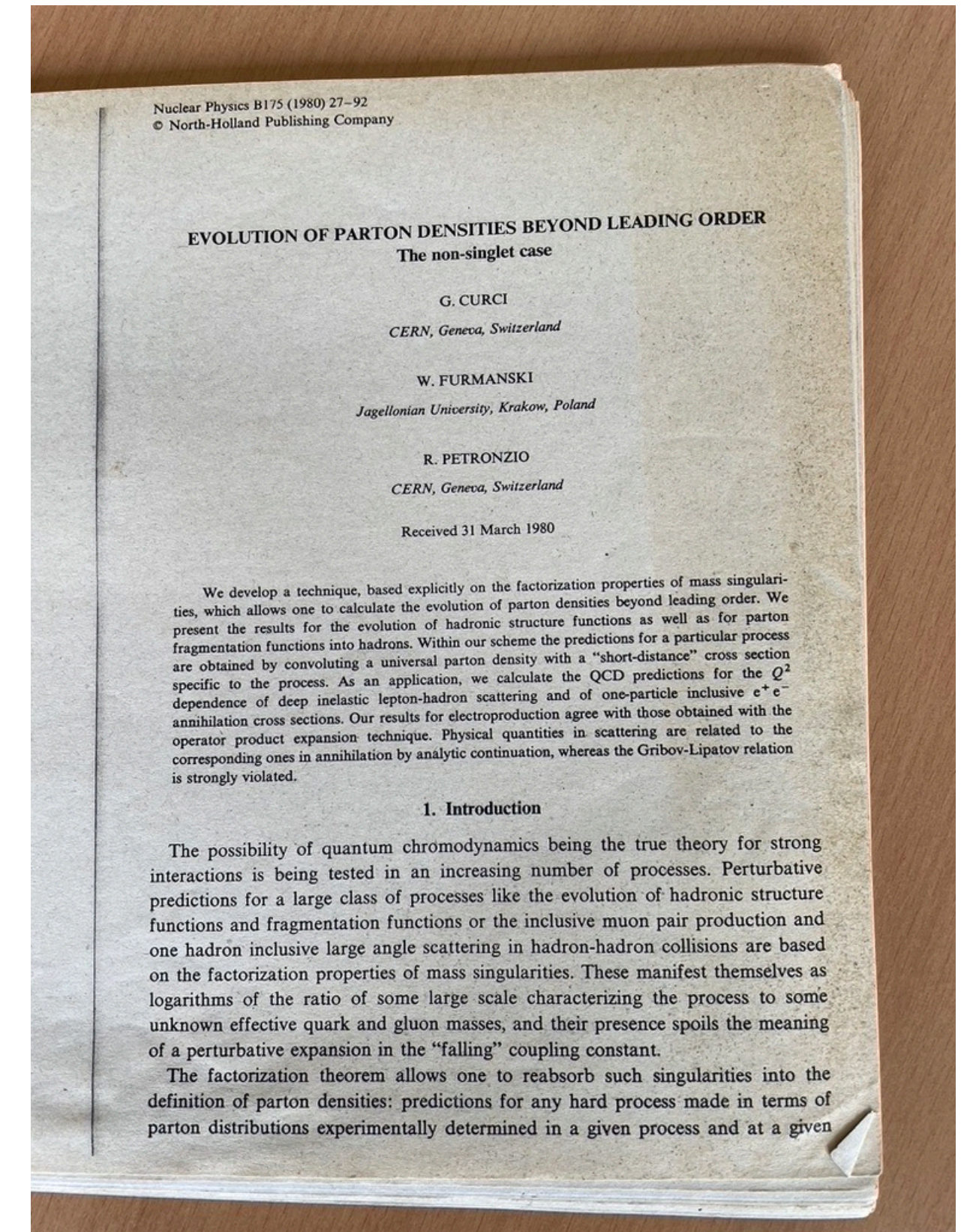
- a more phenomenological subject or
- investigate whether the light-cone gauge could be suitable to calculate the 3-loop splitting functions

Evolution of Parton Densities Beyond Leading Order: The Nonsinglet Case

G. Curci (CERN), W. Furmanski (Jagiellonian U.), R. Petronzio (CERN) (Feb, 1980)

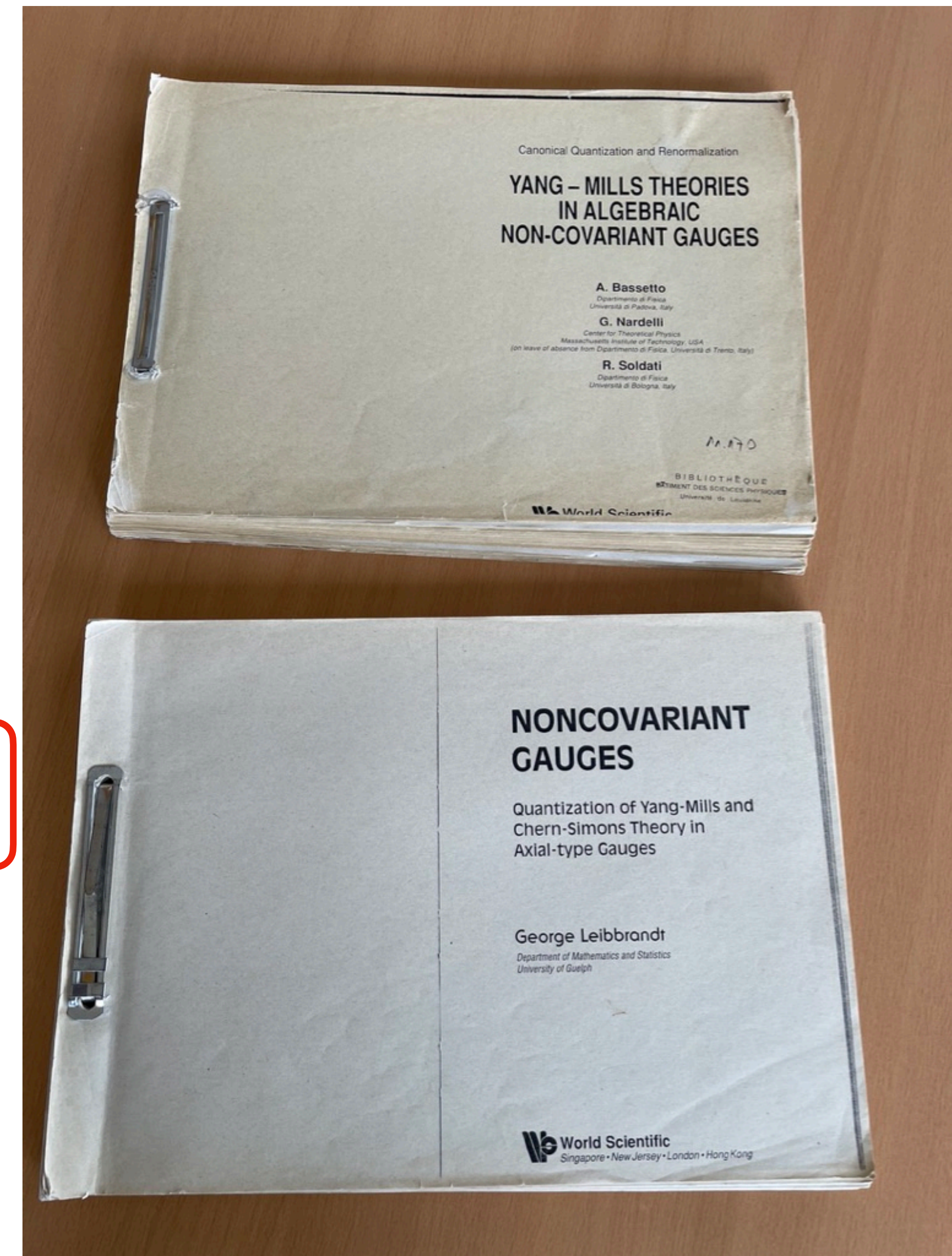
Published in: *Nucl.Phys.B* 175 (1980) 27-92

There were some open Quantum Field Theory questions related to spurious poles appearing in the light-cone gauge



Non-covariant gauges

gauge) from Z_F cancel with those from the photon vertex. This means that the factorizability in the light-like gauge would be broken without local subtractions of spurious poles. (On the other hand, once we *do* subtract them, the scheme works: our space-like two-loop anomalous dimensions coincide with the OPE result and, hopefully, it will be a challenge for field theory experts to provide a more formal support for our “phenomenological” rules.)



Non-covariant gauges

Two-loop anomalous dimension in light-cone gauge with Mandelstam–Leibbrandt prescription

Gudrun Heinrich¹, Zoltan Kunszt

Institute of Theoretical Physics, ETH, Zürich, Switzerland

Received 12 September 1997; accepted 21 January 1998

PHYSICAL REVIEW D, VOLUME 58, 094020

Light-cone gauge and the calculation of the two-loop splitting functions

A. Bassetto,¹ G. Heinrich,² Z. Kunszt,² and W. Vogelsang³

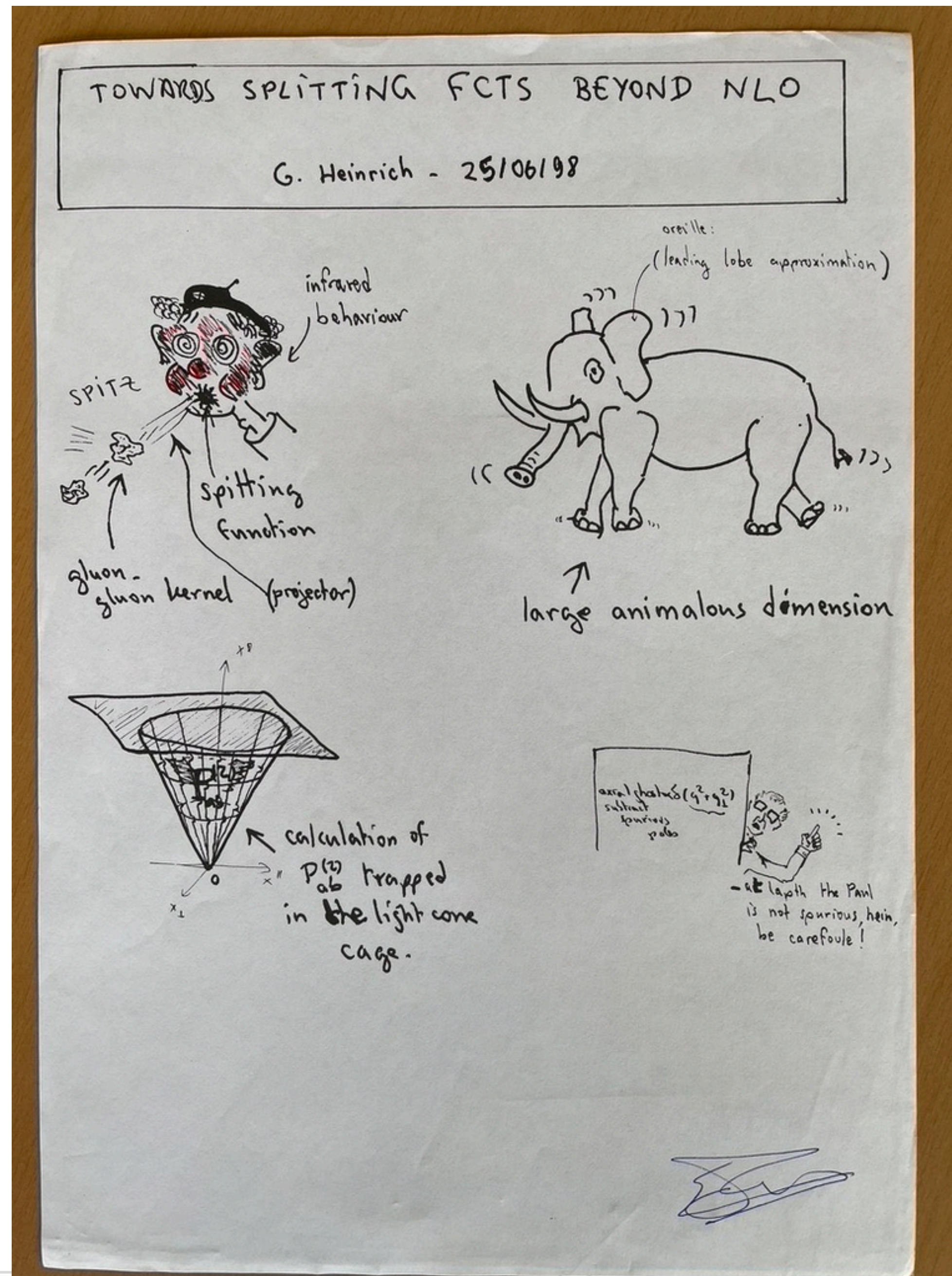
¹*Dipartimento di Fisica “G. Galilei,” via Marzolo 8, I-35131 Padova, Italy
and INFN, Sezione di Padova, Padova, Italy*

²*Institute of Theoretical Physics, ETH Zürich, Switzerland*

³*Theoretical Physics Division, CERN, CH-1211 Geneva 23, Switzerland*

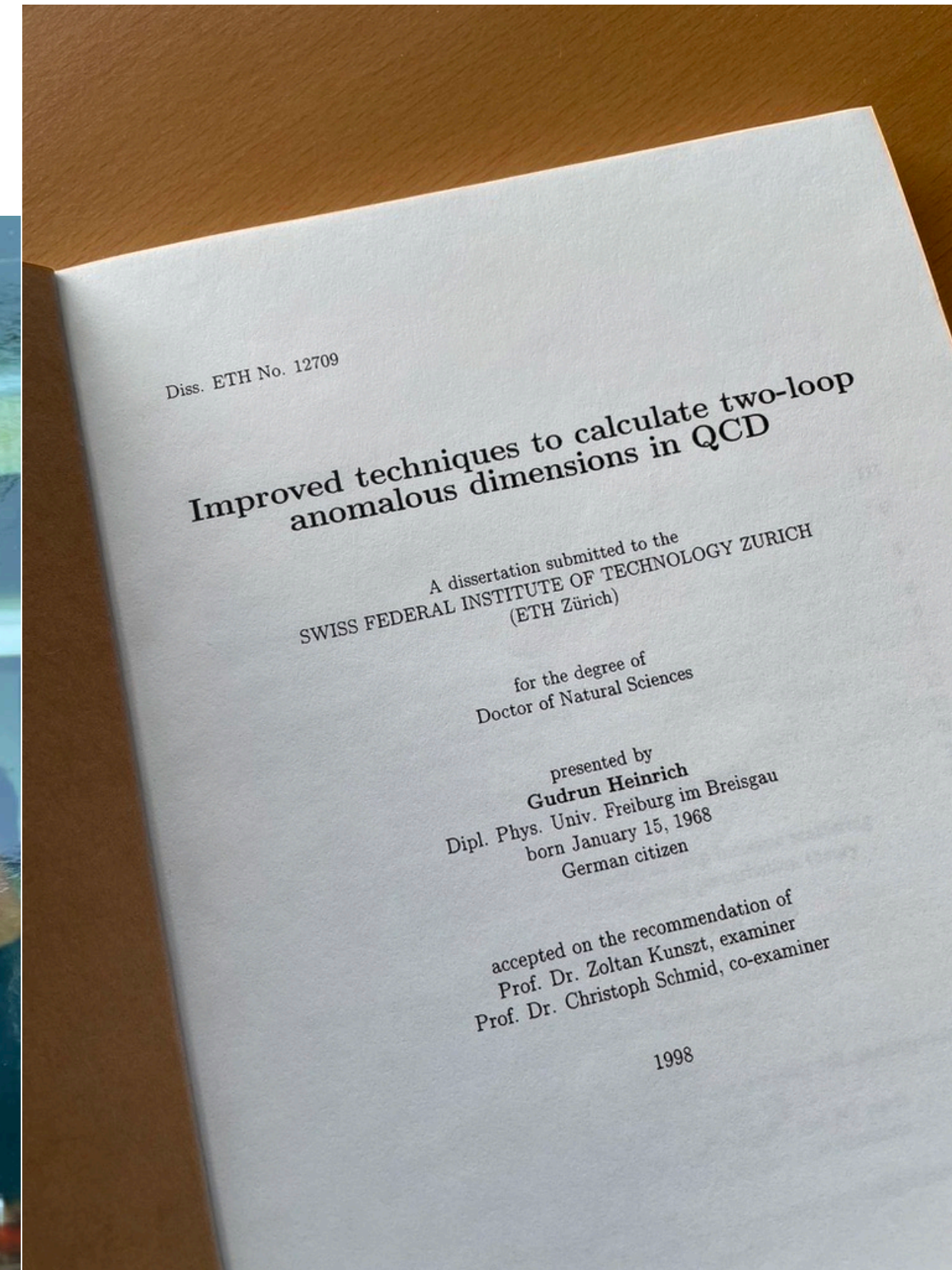
(Received 12 May 1998; published 1 October 1998)

talk in Annecy



artwork: Eric Pilon

PhD



PhD



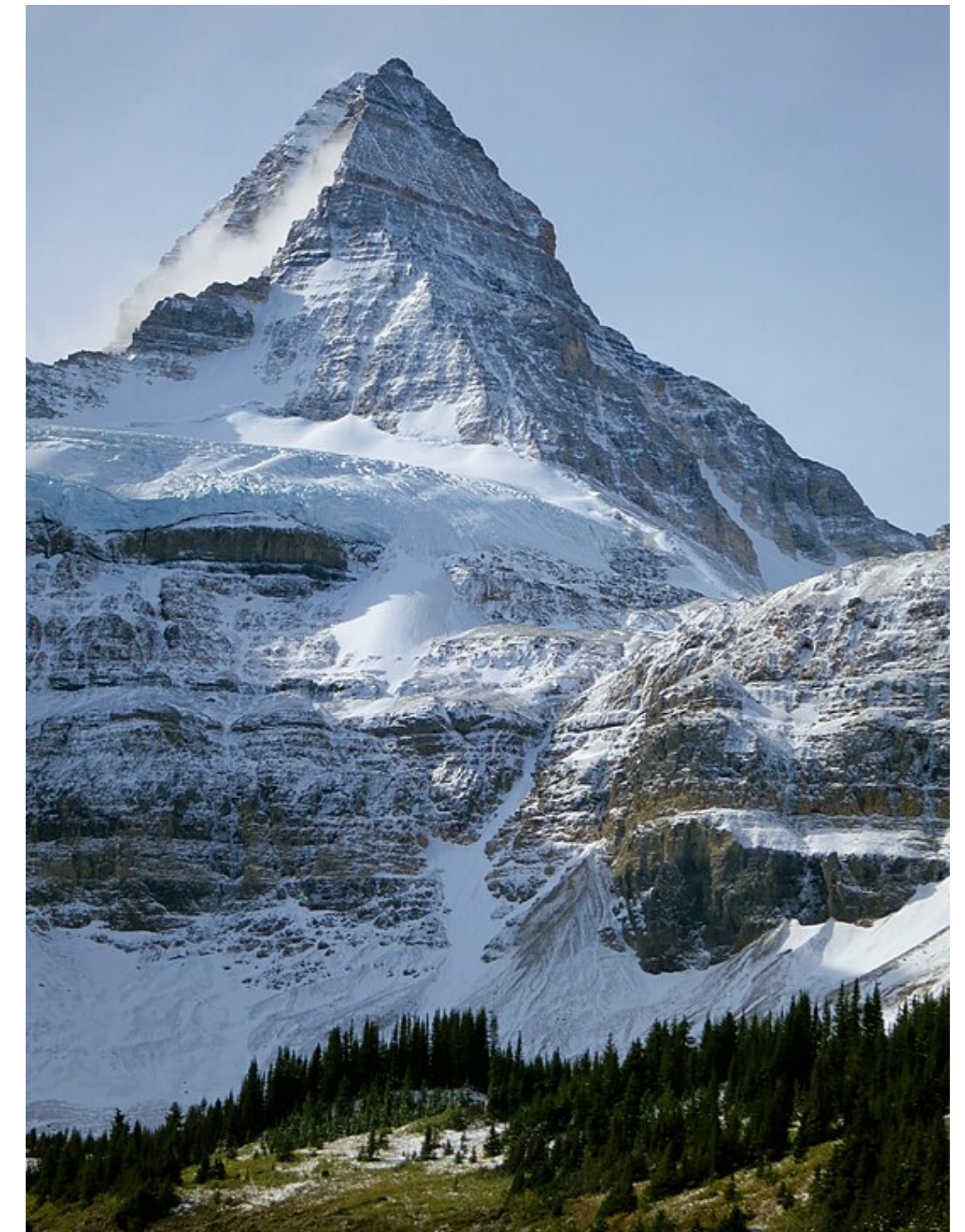
fellow PhD students, postdocs ... friends for a lifetime!



First postdoc



at University of Guelph, Ontario, Canada
with George Leibbrandt, whom I had met
at a conference in Montpellier



A “side-product” of my time at ETH

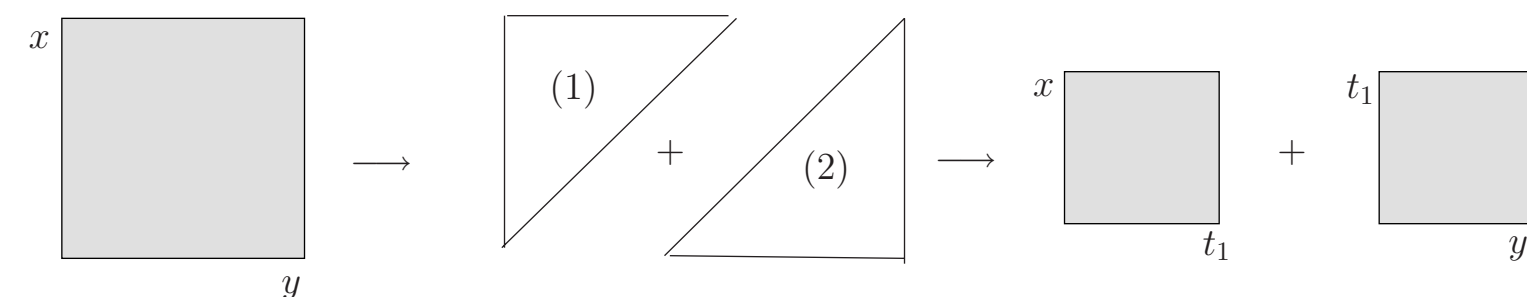
some of the 2-loop integrals in the light-cone gauge
were really nasty (overlapping singularities)



inspired by a “trick” used by Klaus Hepp for overlapping
UV singularities and discussions within the group



→ decompose into sectors!



A “side-product” of my time at ETH

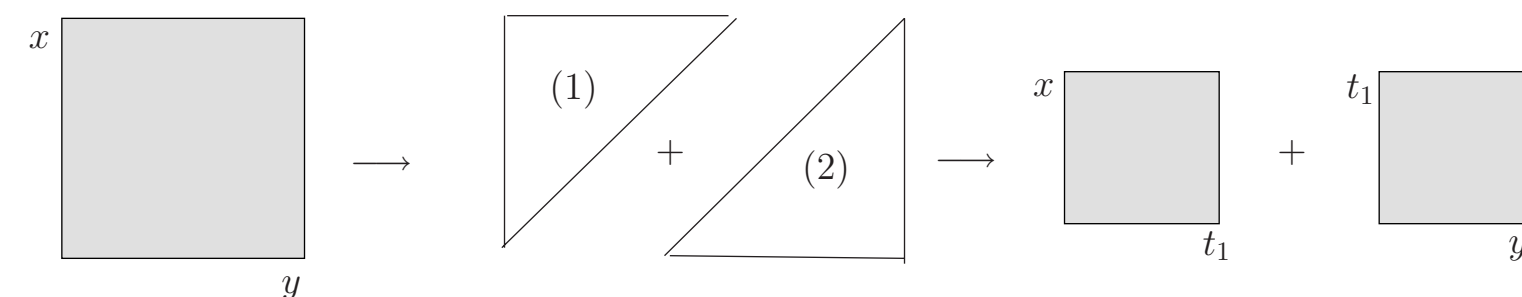
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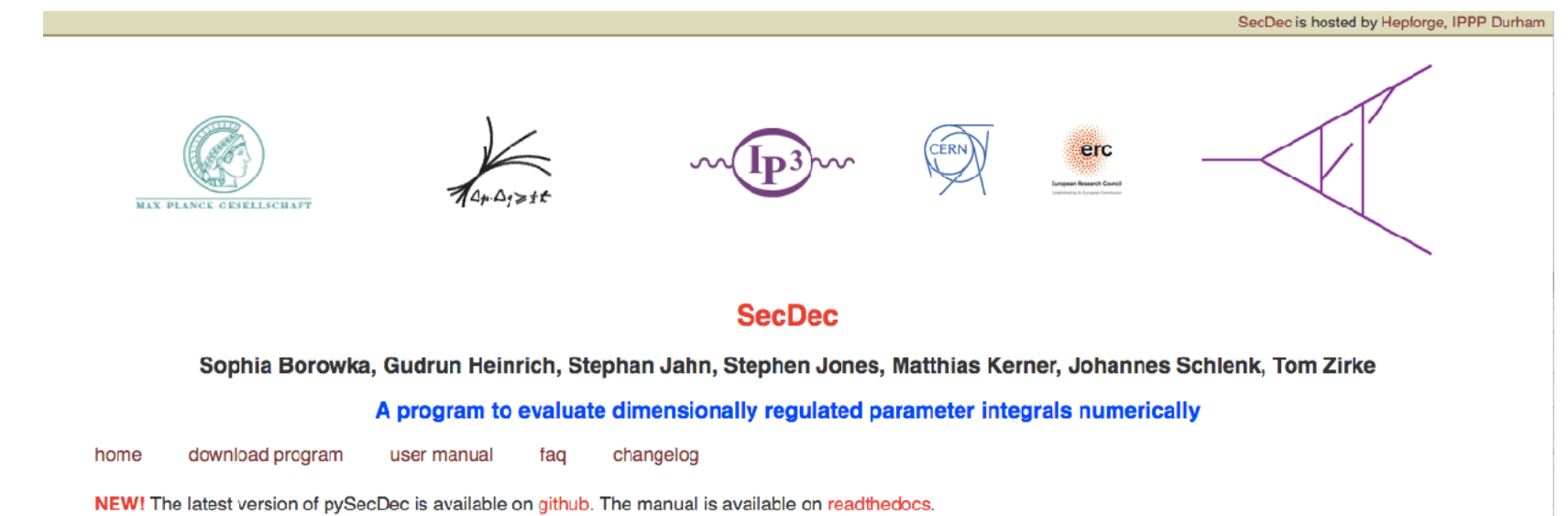


An automatized algorithm to compute infrared divergent multi-loop integrals

T. Binoth^a and G. Heinrich^b

^aLaboratoire d'Annecy-Le-Vieux de Physique Théorique¹ LAPTH, Chemin de Bellevue, B.P. 110, F-74941 Annecy-le-Vieux, France

^bLaboratoire de Physique Théorique² LPT, Université de Paris XI, Bâtiment 210, F-91405 Orsay, France



pySecDec 1.6.3

```
pip install pySecDec
```

today: formulation in terms of algebraic geometry

© Copyright 2024, the SecDec collaboration: Sophia Borowka, Gudrun Heinrich, Stephan Jahn, Stephen Jones, Matthias Kerner, Florian Langer, Vitaly Magerya, Anton Olsson, Andres Poldaru, Johannes Schlenk, Emilio Villa, Tom Zirke.

Following Zoltan's footsteps

Comment on the $O(\alpha_s^2)$ corrections to
jet-production in e^+e^- annihilation

Zoltán Kunszt^{a b}

^a Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany

^b L. Eötvös University, Budapest, Hungary

NLO corrections to the thrust distribution

1981

Following Zoltan's footsteps

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Second-order QCD corrections to the thrust distribution

[A. Gehrmann-De Ridder \(Zurich, ETH\)](#), [T. Gehrmann \(Zurich U.\)](#), [E.W.N. Glover \(Durham U.\)](#), [G. Heinrich \(Edinburgh U.\)](#) (Jul, 2007)

Published in: *Phys.Rev.Lett.* 99 (2007) 132002 • e-Print: [0707.1285](#) [hep-ph]

NLO corrections to the thrust distribution

1981

NNLO corrections to the thrust distribution

2007

Scientific (grand)-children

ttH

Associated Production of Heavy Higgs Boson with Top Quarks

Z. Kunszt (Bern U.) (May, 1984)

Published in: *Nucl.Phys.B* 247 (1984) 339-359

[DOI](#) [cite](#) [claim](#)

[reference search](#) [305 citations](#)

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ttH

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[Z. Kunszt \(Bern U.\)](#) (May, 1984)

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Two-loop amplitudes for $t\bar{t}H$ production: the quark-initiated N_f -part

[Bakul Agarwal \(KIT, Karlsruhe, TP\)](#), [Gudrun Heinrich \(KIT, Karlsruhe, TP\)](#), [Stephen P. Jones \(Durham U.\)](#), [Matthias Kerner \(KIT, Karlsruhe, TP\)](#), [Sven Yannick Klein \(RWTH Aachen U.\)](#) et al. (Feb 5, 2024)

Published in: *JHEP* 05 (2024) 013 • e-Print: [2402.03301 \[hep-ph\]](#)

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diphoton+jet(s)

Two photons plus jet at LHC: The NNLO contribution from the g g initiated process

[D. de Florian \(Zurich, ETH\)](#), [Z. Kunszt \(Zurich, ETH\)](#) (May, 1999)

Published in: *Phys.Lett.B* 460 (1999) 184-188 • e-Print: [hep-ph/9905283](#) [hep-ph]

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Photon isolation effects at NLO in $\gamma\gamma$ + jet final states in hadronic collisions

[T. Gehrmann \(Zurich U.\)](#), [N. Greiner \(Munich, Max Planck Inst.\)](#), [G. Heinrich \(Munich, Max Planck Inst.\)](#) (Mar 4, 2013)

Precise QCD predictions for the production of a photon pair in association with two jets

[Thomas Gehrmann \(Zurich U.\)](#), [Nicolas Greiner \(Munich, Max Planck Inst.\)](#), [Gudrun Heinrich \(Munich, Max Planck Inst.\)](#) (Aug 16, 2013)

Published in: *Phys.Rev.Lett.* 111 (2013) 222002 • e-Print: [1308.3660](#) [hep-ph]

Much more!



Nuclear Physics B

Volume 822, Issues 1–2, 21 November 2009, Pages 270-282



Masses, fermions and generalized D -dimensional unitarity

R. Keith Ellis^a ✉, Walter T. Giele^a ✉, Zoltan Kunszt^b 👤 ✉, Kirill Melnikov^c ✉



Physics Reports

Volume 518, Issues 4–5, September 2012, Pages 141-250



One-loop calculations in quantum field theory: From Feynman diagrams to unitarity cuts

R. Keith Ellis^a ✉, Zoltan Kunszt^b ✉, Kirill Melnikov^c 👤 ✉, Giulia Zanderighi^d ✉

^a Fermilab, Batavia, IL 60510, USA

^b Institute for Theoretical Physics, ETH, Zurich, CH-8093 Zurich, Switzerland

^c Department of Physics, John Hopkins University, Baltimore, USA

^d Rudolf Peierls Centre for Theoretical Physics, 1 Keble Road, University of Oxford, UK

→ “The NLO revolution”

- development of tools like CutTools, Samurai, Ninja, ...
- vital for the automation of one-loop calculations

Tensorial Reconstruction at the Integrand Level

G. Heinrich (Durham U., IPPP and Durham U.), G. Ossola (New York City Coll. Tech.), T. Reiter (NIKHEF Amsterdam), F. Tramontano (CERN) (Aug, 2010)

Published in: *JHEP* 10 (2010) 105 • e-Print: [1008.2441](#) [hep-ph]

Automated One-Loop Calculations with GoSam

GoSam Collaboration • Gavin Cullen (DESY, Zeuthen and Edinburgh U.) et al. (Nov, 2011)

Published in: *Eur.Phys.J.C* 72 (2012) 1889 • e-Print: [1111.2034](#) [hep-ph]

- many more (and more important) one-loop tools!
- two-loop automation also in the making

Towards two-loop automation in OpenLoops

Max Frederik Zoller (PSI, Villigen), Stefano Pozzorini (Zurich U.), Natalie Schaer (PSI, Villigen) (Jul 2022)

Thank you so much for the great time at ETH Zürich and for your support!

Happy Birthday again and all the best to you and to Marika!

