

# Parton distributions and lattice QCD calculations II: A community white paper—2019 update

A. Author<sup>1,2</sup>,

*\* WE'LL FIX THIS AT THE END*

<sup>1</sup>Department of Physics and Astronomy, Michigan State University, East Lansing, MI 48824, USA

<sup>2</sup>Department of Computational Mathematics, Science and Engineering,  
Michigan State University, East Lansing, MI 48824, USA

<sup>3</sup>Rudolf Peierls Centre for Theoretical Physics, 1 Keble Road,  
University of Oxford, OX1 3NP Oxford, United Kingdom

<sup>4</sup>Higgs Centre for Theoretical Physics, School of Physics and Astronomy,  
University of Edinburgh, EH9 3FD, UK

<sup>5</sup>Department of Physics, Southern Methodist University, Dallas, TX 75275, USA

<sup>6</sup>Physics Department, College of William and Mary, Williamsburg, VA 23187, USA

<sup>7</sup>Thomas Jefferson National Accelerator Facility, Newport News, VA 23606, USA

<sup>8</sup>Department of Physics and Astronomy, VU University Amsterdam,  
De Boelelaan 1081, NL-1081, HV Amsterdam, The Netherlands

<sup>9</sup>Nikhef, Science Park 105, NL-1098 XG Amsterdam, The Netherlands

<sup>10</sup>Hampton University, Hampton, VA 23668, USA

<sup>11</sup>Department of Physics, University of Cyprus, P.O. Box 20537, 1678 Nicosia, Cyprus

<sup>12</sup>Computation-based Science and Technology Research Research,  
The Cyprus Institute, 20 Kavafi Str., Nicosia 2121, Cyprus

<sup>13</sup>Dipartimento di Fisica, Università degli Studi di Pavia, and INFN, Sezione di Pavia, 27100 Pavia, Italy

<sup>14</sup>Department of Physics, Center for Theoretical Sciences, and Leung Center for Cosmology and Particle Astrophysics, National  
Taiwan University, Taipei, Taiwan 106

<sup>15</sup>Institute for Theoretical Physics, Universität Regensburg, D-93040 Regensburg, Germany

<sup>16</sup>Department of Physics, University of Oxford,  
Denys Wilkinson Building, 1 Keble Road, OX1 3RH Oxford, United Kingdom

<sup>17</sup>Department of Physics, Temple University, Philadelphia, PA 19122, USA

<sup>18</sup>Department of Physics, New Mexico State University, Las Cruces, NM 88003-8001, USA

<sup>19</sup>NIC, Deutsches Elektronen-Synchrotron, 15738 Zeuthen, Germany

<sup>20</sup>Los Alamos National Laboratory, Theoretical Division, T-2, Los Alamos, NM 87545, USA

<sup>21</sup>Department of Physics and Astronomy, University College London, WC1E 6BT, United Kingdom

<sup>22</sup>T. D. Lee Institute, Shanghai Jiao Tong University, Shanghai, 200240, P. R. China

<sup>23</sup>Laboratoire de Physique Subatomique et de Cosmologie, Université Grenoble-Alpes,  
CNRS/IN2P3, 53 avenue des Martyrs, 38026 Grenoble, France.

<sup>24</sup>Institute of Nuclear Physics Polish Academy of Sciences, PL-31342 Krakow, Poland

<sup>25</sup>Department of Physics and Astronomy, University of Kentucky, Lexington, KY 40506, USA

<sup>26</sup>Physics Department, University of Virginia, 382 McCormick Road, Charlottesville, VA 22904, USA

<sup>27</sup>Laboratori Nazionali di Frascati, INFN, Frascati, Italy

<sup>28</sup>Institute for Nuclear Theory, University of Washington, Seattle, WA 98195, USA

<sup>29</sup>Deutsches Elektronen-Synchrotron DESY, 22603 Hamburg, Germany

<sup>30</sup>Institute for Theoretical Physics, Tübingen University, D-72076 Tübingen, Germany

<sup>31</sup>PRISMA Cluster of Excellence and Institute for Nuclear Physics Johannes Gutenberg University of Mainz,  
Johann-Joachim-Becher-Weg 45, 55128 Mainz, Germany

<sup>32</sup>CSSM, Department of Physics, The University of Adelaide, Adelaide, SA, Australia 5005

*Preprint numbers:*

DESY MSUHEP-19-\*\*\*, SMU-HEP-19-\*\*\*.

**Abstract** **OLD FROM PAPER 1** In the framework of quantum chromodynamics (QCD), parton distribution functions (PDFs) quantify how the momentum and spin of a hadron are divided among its quark and gluon constituents. Two main approaches exist to determine PDFs. The first approach, based on QCD factorization theorems, realizes a QCD analysis of a suitable set of hard-scattering measurements, often using a variety of hadronic observables. The second approach, based on first-principle operator definitions of PDFs, uses lattice QCD to compute directly some PDF-related quantities, such as their moments. Motivated by re-

cent progress in both approaches, in this document we present an overview of lattice-QCD and global-analysis techniques used to determine unpolarized and polarized proton PDFs and their moments. We provide benchmark numbers to validate present and future lattice-QCD calculations and we illustrate how they could be used to reduce the PDF uncertainties in current unpolarized and polarized global analyses. This document represents a first step towards establishing a common language between the two communities, to foster dialogue and to further improve our knowledge of PDFs.

CONTENTS

I. Introduction and motivation	2
II. Chapter # 2: Parton Distribution Functions (PDFs)	3
II.1. Global PDFs: Updates	3
II.2. Universal Fits	3
II.3. Intersection of Lattice and Global PDF Fits	3
II.4. Intersection of Lattice and Global PDF Fits	3
II.5. Strange PDFs	3
II.6. Small x	3
II.7. Nuclear PDFs	3
III. Chapter # 3: Generalized PDFs (GPD)	4
III.1. Intro to GPD	4
III.2. Landscape of current GPDs	4
III.3. Lattice moments and x-dep. GPDs	4
III.4. Machine Learning for GPDs	4
III.5. Toward global GPD fits: to do/wanted list	4
IV. Chapter # 4 : Transverse Momentum Dependent PDFs (TMD)	4
IV.1. Intro to TMDs	4
IV.2. Quasi TMD-PDFs	4
IV.3. Toward global TMD fits in the next decade	4
V. Outlook and Conclusions	5
V.1. Outlook	5
V.2. Conclusions	5
Acknowledgments	5
A. Appendix 1	5
B. Appendix 2	5
C. Appendix 3	5
D. References	6
References	6

General notes: We'll use bibtex for references. The file main.bib will be auto-generated. If you have "custom" references, place these in extra.bib.

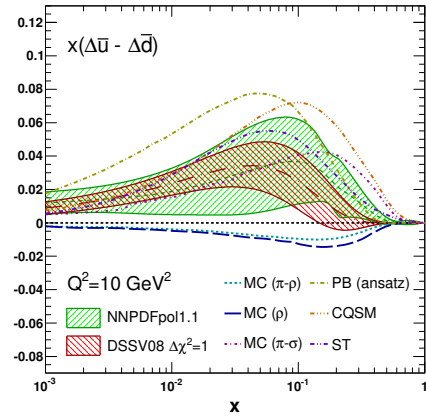


FIG. 1 Sample figures. xxxxxx xxxxxx xxxxxx xxxxxx xxxxxx  
xxxxxx xxxxxx xxxxxx xxxxxx xxxxxx xxxxxx

I. INTRODUCTION AND MOTIVATION

*Editors: Fred, ...*

- Intro: (2-3 pages) *Fred*

- Introduce the "cast"
- Relation between Collinear PDFs, GPD, TMD
- Impact for SM and BSM

The detailed understanding of the inner structure of nucleons is an active research field with phenomenological implications in high-energy, hadron, nuclear and astroparticle physics. ...

The first paper is in Ref. (Lin *et al.*, 2018)  
: Introduction (2-3 pages) (Fred) Introduce the "cast"  
Relation between GPD, TMD, Collinear PDFs BSM  
SAMPLE FIGURE  
SAMPLE WIDE FIGURE



### III. CHAPTER # 3: GENERALIZED PDFS (GPD)

*Editors: Martha, ...*

Chapter # 3: GPDs (20??? pages)

- Intro to GPDs *Jianwei, ...*
- Landscape of current GPDs *Jianwei, ...*
- Lattice moments and x-dep. GPDs *Martha, Anatoly, Simonetta, Abha, Jianjui,*
- ML for GPDs *Simonetta*
- Toward global GPD fits: to do/wanted list *Jianwei, Simonetta, ...*

#### III.1. Intro to GPD

*Jianwei, ...*

Sub-Chapter 1 of Chapter 3  
Chapter-topics GPDs

#### III.2. Landscape of current GPDs

*Jianwei, ...*

Sub-Chapter 2 of Chapter 3  
Chapter-topics GPDs

#### III.3. Lattice moments and x-dep. GPDs

*Martha, Anatoly, Simonetta, Abha, Jianjui, ...*

Sub-Chapter 3 of Chapter 3  
Chapter-topics GPDs

#### III.4. Machine Learning for GPDs

*Simonetta*

Sub-Chapter 4 of Chapter 3  
Chapter-topics GPDs

#### III.5. Toward global GPD fits: to do/wanted list

*Jianwei, Simonetta, ...*

Sub-Chapter 5 of Chapter 3  
Chapter-topics GPDs

### IV. CHAPTER # 4 : TRANSVERSE MOMENTUM DEPENDENT PDFS (TMD)

*Michael E., Huey-Wen*

Chapter # 4: TMDs (20??? pages)

- Intro to TMDs *Ted, Markus,...*
- Quasi TMD-PDFs *Markus, Mike E, ...*
- Toward global TMD fits in the next decade *Jianwei, ...*
  1. What can LQCD do ?
  2. What can others do

#### IV.1. Intro to TMDs

*Ted, Markus, ...*

Sub-Chapter 1 of Chapter 4 TMD sub-Chapter

#### IV.2. Quasi TMD-PDFs

*Markus, Mike E, ...*

Sub-Chapter 2 of Chapter 4 TMD sub-Chapter

#### IV.3. Toward global TMD fits in the next decade

*Jianwei, ...*

Sub-Chapter 3 of Chapter 4 TMD sub-Chapter

## V. OUTLOOK AND CONCLUSIONS

*Editor: Pavel*

- Outlook:
  - Rethinking PDFs for the next decade
  - what measurements do we need
- Conclusions:
- Acknowledgments

The study of the PDFs of the proton is an active interdisciplinary research field lying at the crossroads of high-energy, hadronic and nuclear physics, with important applications in astroparticle physics. In this white paper,

### V.1. Outlook

### V.2. Conclusions

### Acknowledgments

We are grateful to \*\*\*\*\* for their help in the organization of the workshop. We thank

### Appendix A: Appendix 1

In this appendix # 1

### Appendix B: Appendix 2

In this appendix # 2

### Appendix C: Appendix 3

In this appendix # 3

**Appendix D: References****REFERENCES**

H.-W. Lin *et al.*, *Prog. Part. Nucl. Phys.* **100**, 107 (2018),  
[arXiv:1711.07916 \[hep-ph\]](#).