STRONG-2020 ANNUAL MEETING (2022)

VA2-3DPartons/WP11: virtual access to 3DPartons

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824093

PLAN OF PRESENTATION

1) Scientific results obtained since the last year
2) Modifications of the scientific Work Plan (as compared to the initial plan in the Grant Agreement)
3) **Possibilities**/needs of another request for the extension of the project (beyond 30 November 2023)

Fruitful developments with important results in physics and code design.

How to think about and be prepared for the post-STRONG-2020 era?

INTEROPERATING CODES, COMMON TOOLS AND COMMON SOLUTIONS

Reminder

3DPartons gives access to ***open-source code*** *necessary for high precision phenomenology in the field of 3D hadron structure, with a specific emphasis on GPDs and TMDs.*

It consists of ***several libraries organized within a fully modular and open architecture****, which allows the possibility of permanent improvement by the addition of new models, channels or theoretical refinements.*

Galaxy of existing computing codes

As it stands, 3DPartons will be based on parts of, or offer interfaces to, various existing codes:

- *PDF (LHAPDF, APFEL, xFitter),*
- *GPD (PARTONS, Gepard web interface),*
- *TMD (arTeMiDe, Nanga Parbat, TMDlib, CASCADE),*
- *Fragmentation functions (xFitter, Mont Blanc).*

WHAT IS THE 3D STRUCTURE OF THE PION?

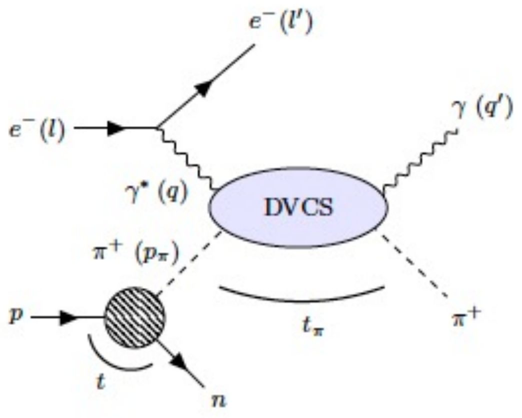
Not so much is know (neither 1D nor 3D)…

Specific role of the pion in QCD.

Realistic DVCS prediction for EIC needs:

- Implementation of known phenomenological limits: PDFs and elastic form factors
- Fulfilling of theory constraints
- Handling higher order corrections

The whole PARTONS framework has been used for this study



arXiv:2110.09462v1 [hep-ph] 18 Oct 2021

Accessing the pion 3D structure at US and China Electron-Ion Colliders

José Manuel Morgado Chávez,[1,*] Valerio Bertone,[2,†] Feliciano De Soto Borrero,[3,‡] Maxime Defurne,[2,§] Cédric Mezrag,[2,¶] Hervé Moutarde,[2,**] José Rodríguez-Quintero,[1,††] and Jorge Segovia[3,‡‡]

[1] *Department of Integrated Sciences and Center for Advanced Studies in Physics, Mathematics and Computation, University of Huelva, E-21071 Huelva, Spain*
[2] *Irfu, CEA, Université Paris-Saclay, 91191, Gif-sur-Yvette, France*
[3] *Dpto. Sistemas Fìsicos, Quìmicos y Naturales, Universidad Pablo de Olavide, E-41013 Sevilla, Spain*

(Dated: October 19, 2021)

We present in this letter the first systematic feasibility study of accessing generalised parton distributions of the pion at an electron-ion collider through deeply virtual Compton scattering at next-to-leading order. It relies on a state-of-the-art model, able to fulfil by construction all the theoretical constraints imposed on generalised parton distributions. Strikingly, our analysis shows that quarks and gluons interfere destructively and that gluon dominance could be spotted by a sign change of the DVCS beam spin asymmetry.

INTRODUCTION

Due to its double role of being both a Goldstone boson of the chiral symmetry breaking and a QCD bound state, the pion has been widely investigated since its discovery in 1947. In the 1980s and after, many efforts have been done to extract experimental information about its internal structure, from its electromagnetic form factor (EFF) through pion-electron scattering [1] to its parton distribution functions (PDFs) through the Drell-Yan process [2-4]. The latter has in fact triggered a controversy on the PDF large-x behaviour which remains not completely solved today, despite modern phenomenological and theoretical progresses [5-8]. However, using the available pion sources, EFF measurements are limited to low momentum transfer, precluding the possibility to test perturbative-QCD (pQCD) predictions [9, 10]. Exploiting the ideas of Sullivan [11], consisting of interacting with the meson cloud of the proton, EFF data at significantly larger values of the momentum transfer between the virtual and real pion have been obtained [12]. This same principle is being seriously considered both for improving the knowledge on the pion EFF and to extract the PDFs of the pion in the context of the forthcoming US and Chinese Electron Ion Collider (EIC and EicC) [13-15]. The question has raised sufficient interest so that the EIC Yellow Report [16] mentions the study of the 3D structure of the pion through the Sullivan process. The present paper is a quantitative assessment of the latter.

The 3D structure [17] of the pion can be gained through Generalised Parton Distributions (GPDs) [18-22]. Throughout the years, many models for pion's GPDs have been developed [23-35], including in the crossed channel [36]. They rely on various physics assumptions and if feasible, Deep Virtual Compton Scattering (DVCS) [19] off the pion would provide key constraints on these models [37-39].

In this paper, relying on the implementation of the state-of-the-art model for pion's GPD presented in section 2, we compute in section 3 the Sullivan amplitude at Next-to-Leading Order (NLO), the minimal order required to treat the EIC kinematical region. In section 4, we evaluate the associated counting rate and assess the asymmetries, concluding that, providing that the one-pion exchange is the dominant process, DVCS off a virtual pion will be measurable and will provide a clear signal for a glue-dominated regime ideal to "understand the glue that binds us all".

MODELLING GPDS

Among all available pion's GPD models, we chose the one presented in Ref. [39], a kinematical completion of that featured in [35] owing to a long effort developed over the last decade [24-27, 30, 31]. In a nutshell, this model is built on the state-of-the-art Continuum Schwinger Methods (CSM) investigations [40-46] which have already provided the community with Parton Distributions Functions (PDFs) in agreement with the large-x behaviour extracted from experimental data including soft-gluon (threshold) resummation [7, 8]; and are confirmed both in the quark and gluon sectors [47, 48] by lattice QCD computations.

The leap from quark PDFs q_π to quark GPDs H_π^q is however made difficult because their dependences on x, the average momentum fraction of the active parton in the pion, ξ, half of the exchanged longitudinal momentum fraction, and t_π the square of the total momentum transfer are constrained by a set of properties [49, 50]. To ensure that all properties are satisfied by construction, we turn to the lightfront wave function formalism [51] (see also [52-56] for details of the connection between CSM and lightfront physics) supplemented by the so-called GPD covariant extension [30, 31]. Our quark

J.M. Morgado Chavez *et al.*, Phys. Rev. Lett. **128** (2022) 20

FLEXIBLE MODELING OF GPDS

Key problem since the early days which slowed down global fitting.

Interplay of deep theoretical constraints requiring different fitting parameterizations.

First published attempt to model GPD with neural networks.

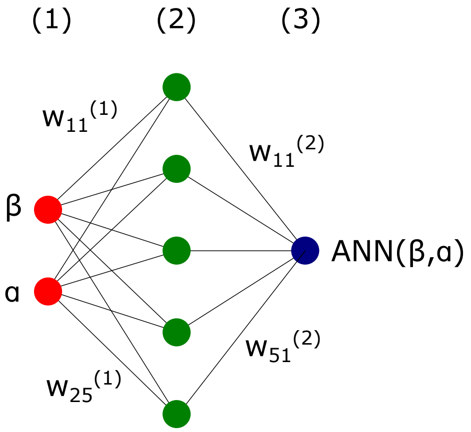
Opens a path for global GPD fits

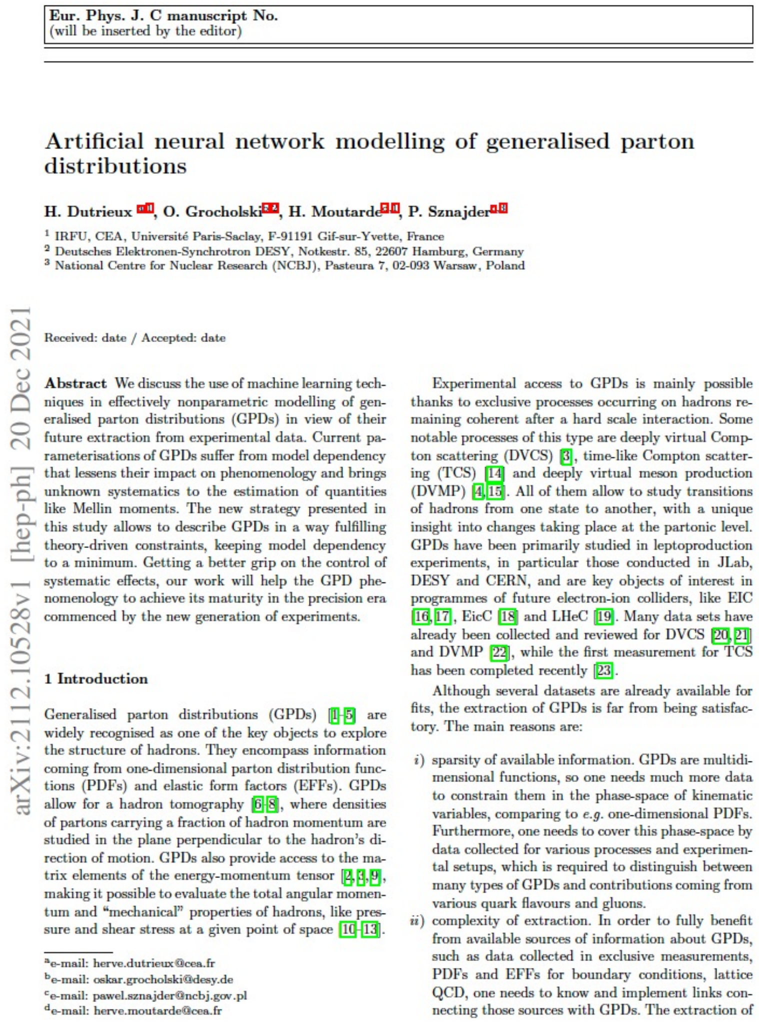
with PARTONS

using experimental

data, pQCD, and

nonperturbative objects.





Eur. Phys. J. C manuscript No.
(will be inserted by the editor)

Artificial neural network modelling of generalised parton distributions

H. Dutrieux [a,1], **O. Grocholski** [b,2], **H. Moutarde** [c,1], **P. Sznajder** [d,3]

[1] IRFU, CEA, Université Paris-Saclay, F-91191 Gif-sur-Yvette, France
[2] Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22607 Hamburg, Germany
[3] National Centre for Nuclear Research (NCBJ), Pasteura 7, 02-093 Warsaw, Poland

Received: date / Accepted: date

Abstract We discuss the use of machine learning techniques in effectively nonparametric modelling of generalised parton distributions (GPDs) in view of their future extraction from experimental data. Current parameterisations of GPDs suffer from model dependency that lessens their impact on phenomenology and brings unknown systematics to the estimation of quantities like Mellin moments. The new strategy presented in this study allows to describe GPDs in a way fulfilling theory-driven constraints, keeping model dependency to a minimum. Getting a better grip on the control of systematic effects, our work will help the GPD phenomenology to achieve its maturity in the precision era commenced by the new generation of experiments.

1 Introduction

Generalised parton distributions (GPDs) [1–5] are widely recognised as one of the key objects to explore the structure of hadrons. They encompass information coming from one-dimensional parton distribution functions (PDFs) and elastic form factors (EFFs). GPDs allow for a hadron tomography [6–8], where densities of partons carrying a fraction of hadron momentum are studied in the plane perpendicular to the hadron's direction of motion. GPDs also provide access to the matrix elements of the energy-momentum tensor [2,3,9], making it possible to evaluate the total angular momentum and "mechanical" properties of hadrons, like pressure and shear stress at a given point of space [10–13].

Experimental access to GPDs is mainly possible thanks to exclusive processes occurring on hadrons remaining coherent after a hard scale interaction. Some notable processes of this type are deeply virtual Compton scattering (DVCS) [3], time-like Compton scattering (TCS) [14] and deeply virtual meson production (DVMP) [4,15]. All of them allow to study transitions of hadrons from one state to another, with a unique insight into changes taking place at the partonic level. GPDs have been primarily studied in leptoproduction experiments, in particular those conducted in JLab, DESY and CERN, and are key objects of interest in programmes of future electron-ion colliders, like EIC [16,17], EicC [18] and LHeC [19]. Many data sets have already been collected and reviewed for DVCS [20,21] and DVMP [22], while the first measurement for TCS has been completed recently [23].

Although several datasets are already available for fits, the extraction of GPDs is far from being satisfactory. The main reasons are:

i) sparsity of available information. GPDs are multidimensional functions, so one needs much more data to constrain them in the phase-space of kinematic variables, comparing to *e.g.* one-dimensional PDFs. Furthermore, one needs to cover this phase-space by data collected for various processes and experimental setups, which is required to distinguish between many types of GPDs and contributions coming from various quark flavours and gluons.

ii) complexity of extraction. In order to fully benefit from available sources of information about GPDs, such as data collected in exclusive measurements, PDFs and EFFs for boundary conditions, lattice QCD, one needs to know and implement links connecting those sources with GPDs. The extraction of

[a] e-mail: herve.dutrieux@cea.fr
[b] e-mail: oskar.grocholski@desy.de
[c] e-mail: pawel.sznajder@ncbj.gov.pl
[d] e-mail: herve.moutarde@cea.fr

H. Dutrieux *et al.*, Eur. Phys. J. **C82** (2022) 3, 252

PREPARING THE GROUND FOR FUTURE MEASUREMENTS

Generic exclusive event generators.

Can integrate radiative corrections.

Fully compatible with PARTONS for systematic studies.

Asked by experimentalists for a long time.

Already used e.g. in BNL.

On-going impact study to evaluate what EIC can bring to DVCS studies.

Other exclusive processes to

be interfaced soon.

Eur. Phys. J. C manuscript No.
(will be inserted by the editor)

arXiv:2205.01762v1 [hep-ph] 3 May 2022

EpIC: novel Monte Carlo generator for exclusive processes

E. C. Aschenauer, V. Batozskaya, S. Fazio, K. Gates, H. Moutarde, D. Sokhan, H. Spiesberger, P. Sznajder, K. Tezgin

[1] Department of Physics, Brookhaven National Laboratory, Upton, New York 11973
[2] National Centre for Nuclear Research (NCBJ), Pasteura 7, 02-093 Warsaw, Poland
[3] University of Calabria & INFN-Cosenza, Italy
[4] University of Glasgow, Glasgow G12 8QQ, United Kingdom
[5] IRFU, CEA, Université Paris-Saclay, F-91191 Gif-sur-Yvette, France
[6] PRISMA$^+$ Cluster of Excellence, Institut für Physik, Johannes Gutenberg-Universität, D-55099 Mainz, Germany

Received: date / Accepted: date

Abstract We present the EpIC Monte Carlo event generator for exclusive processes sensitive to generalised parton distributions. EpIC utilises the PARTONS framework, which provides a flexible software architecture and a variety of modelling options for the partonic description of the nucleon. The generator offers a comprehensive set of features, including multichannel capabilities and radiative corrections. It may be used both in analyses of experimental data, as well as in impact studies, especially for future electron-ion colliders.

1 Introduction

The objective of this study is to develop a Monte Carlo event generator for exclusive processes involving hadrons remaining coherent during interactions with high-energy leptons. The factorisation theorems developed in the framework of quantum chromodynamics (QCD) allow one to describe such processes in terms of non-perturbative generalised parton distribution functions (GPDs) [1–5] convoluted with perturbatively calculable hard scattering subprocesses.

GPDs are universal, process-independent functions that parametrise the off-forward nucleon matrix elements of quark and gluon bilinear operators with light-like separations. In case there is no momentum transfer to the nucleon, *i.e.* in the forward limit, certain GPDs become equivalent to PDFs. Additionally, the first Mellin moments of GPDs are related to elastic form factors. In this regard, GPDs may be viewed as a unified concept of elastic form factors studied via elastic scattering processes and one-dimensional parton distribution functions studied via (semi-) inclusive scattering processes. Another key aspect of GPDs is their relation to nucleon tomography. The Fourier transform of GPDs are related to the impact parameter space distributions when there is no collinear, but finite transverse momentum transfer to the nucleon [6–8]. This relation enables nucleon tomography, which involves the correlation between impact space distribution functions, parton polarization, and the longitudinal momentum fractions carried by partons. GPDs also exhibit a unique relationship with energy-momentum tensor (EMT) form factors, which encode fundamental properties of the nucleon, such as mass and spin decomposition of the nucleon into its constituent parts (including orbital angular momentum) [2,3,9] as well as its internal structure based on the so-called "mechanical" forces [10–12]. For more information on GPDs, we refer to the available reviews on the subject, like Ref. [13].

The extraction of GPDs from data on exclusive processes is not an easy task, mainly due to the difficulty of the inverse problem one must solve. Namely, typically many types of GPDs contribute to a given process, and it is necessary to deconvolute them all from the process amplitude. In order to accomplish this, measurements of many different types of processes are needed in a wide range of kinematic domains. Therefore, measurements of exclusive processes have been performed in several facilities, such as DESY, JLAB, and CERN. In addi-

[a] e-mail: elke@bnl.gov
[b] e-mail: varvara.batozskaya@ncbj.gov.pl
[c] e-mail: salvatore.fazio@unical.it
[d] e-mail: k.gates.1@research.gla.ac.uk
[e] e-mail: herve.moutarde@cea.fr
[f] e-mail: daria.sokhan@cea.fr
[g] e-mail: spiesber@uni-mainz.de
[h] e-mail: pawel.sznajder@ncbj.gov.pl
[i] e-mail: ktezgin@bnl.gov

E. Aschenaeur *et al.*, Eur. Phys. J. **C82** (2022) 9, 819

GPD EVOLUTION FOR ALL

No generic documented publicly available code before.

Difficult theoretical literature in the field…

Bottleneck for many physics studies.

Timely and particularly relevant for future collider studies.

APFEL++

Revisiting evolution equations for generalised parton distributions

Valerio Bertone[1], Hervé Dutrieux[1], Cédric Mezrag[1], José M. Morgado[2], Hervé Moutarde[1]

[1] IRFU, CEA, Université Paris-Saclay, F-91191 Gif-sur-Yvette, France.
[2] Department of Integrated Sciences and Center for Advanced Studies in Physics, Mathematics and Computation, University of Huelva, E-21071 Huelva, Spain.

Abstract

We revisit the evolution of generalised parton distributions (GPDs) in momentum space. We formulate the evolution kernels at one-loop in perturbative Quantum Chromodynamics (pQCD) in a form suitable for numerical implementation and that allows for an accurate study of their properties. This leads to the first open-source implementation of GPD evolution equations able to cover the entire kinematic region and allowing for heavy-quark-threshold crossings. The numerical implementation of the GPD evolution equations is publicly accessible through the APFEL++ evolution library and is available within the PARTONS framework.

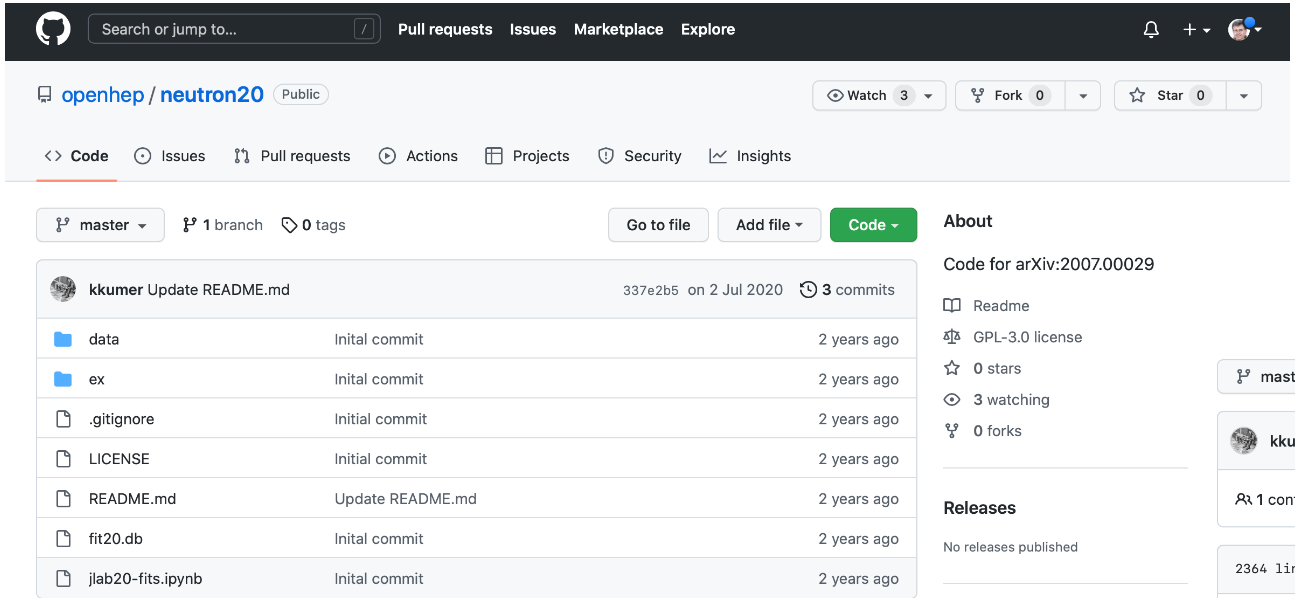
Our formulation makes use of the operator definition of GPDs in light-cone gauge renormalised in the $\overline{\mathrm{MS}}$ scheme. For the sake of clarity, we recompute the evolution kernels at one-loop in pQCD, confirming previous calculations. We obtain general conditions on the evolution kernels deriving from the GPD sum rules and show that our formulation obeys these conditions. We analytically show that our calculation reproduces the DGLAP and the ERBL equations in the appropriate limits and that it guarantees the continuity of GPDs. We numerically check that the evolved GPDs fulfil DGLAP and ERBL limits, continuity, and polynomiality. We benchmark our numerical implementation against analytical evolution in conformal space. Finally, we perform a numerical comparison to an existing implementation of GPD evolution finding a general good agreement on the kinematic region accessible to the latter.

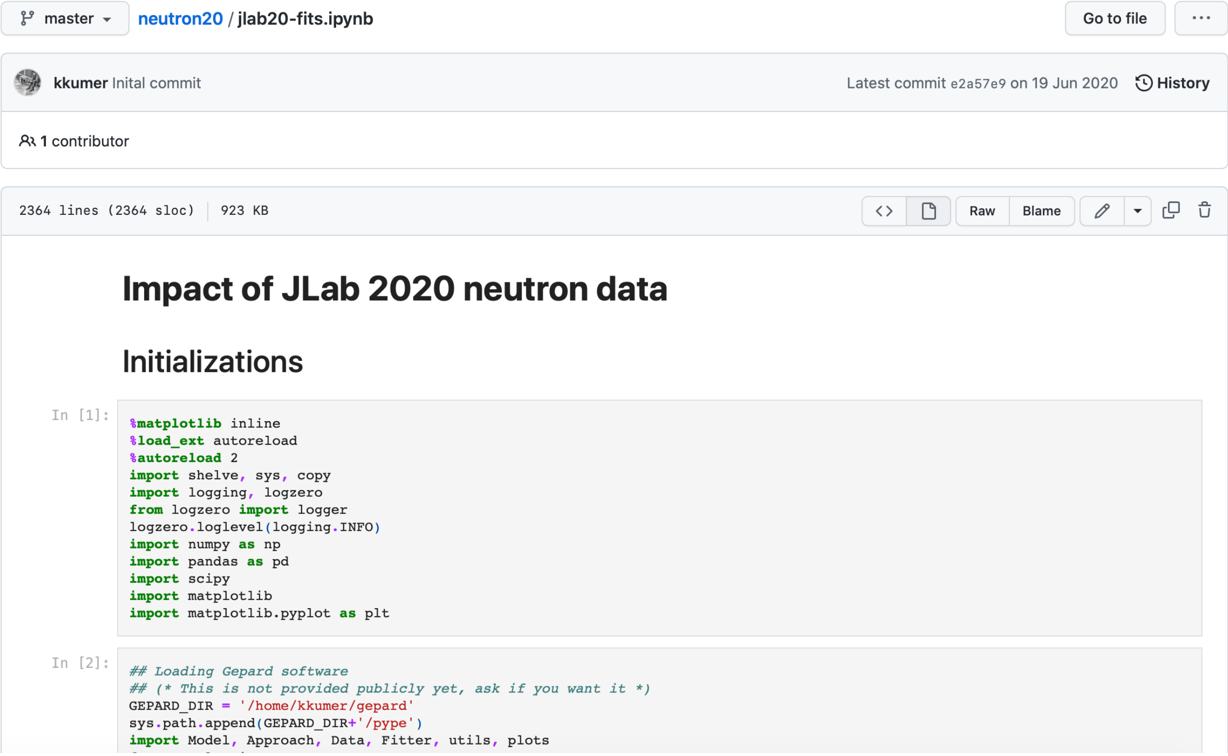
This work provides a pedagogical description of GPD evolution equations which benefits from a renewed interest as future colliders, such as the electron-ion colliders in the US and in China, are being designed. It also paves the way to the extension of GPD evolution codes to higher accuracies in pQCD desirable for precision phenomenology at these facilities.

1

V. Bertone *et al.*, Eur. Phys. J. **C82** (2022) 10, 888

PYTHON WRAPPING AND JUPYTER NOTEBOOKS





Increase community of users and developpers.

Natural way to disseminate and facilitate reproducible science.

3DPARTONS WEEK

Europe/Paris | Français | S'authentifier

3DPartons week

26–28 oct. 2022
Fuseau horaire Europe/Paris

Entrer le texte à rechercher

- Accueil
- Ordre du jour
- Liste des contributions
- Inscription
- Organisation Committee
- Liste des participants
- Accomodation
- Getting to Institut Pascal

3DPartons is a virtual access infrastructure supported by the European project STRONG-2020. 3DPartons gives access to open-source computing codes necessary for high precision phenomenology in the field of 3D hadron structure. Benefiting from the experience of decades of parton distribution function (PDF) studies, the GPD and TMD communities can find in 3DPartons a forum where they can mutualize knowledge and know-how about scientific and technical problems related to the complexity of the GPD and TMD computing chains.

Commence le 26 oct. 2022, 09:15
Finit le 28 oct. 2022, 22:15
Europe/Paris

The workshop is supported by Gluodynamics and STRONG-2020

Fonctionne avec Indico v3.2.1-pre

Aide | Contact | Conditions générales | Raccourcisseur d'URL