**Template VA**

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| --- | --- | --- | --- |
| **Work package number** | WP11 | **Start date** | 01/06/2019 |
| **Activity Type** | Virtual Access | | |
| **Work package acronym** | VA2-3DPartons | | |
| **Work package title** | Virtual Access to 3DPartons | | |
| **Lead beneficiary** | 24 - CEA | | |

1. Description of access facilities
   1. **Modalities and opportunities for access**

The 3DParton main website (<http://partons.cea.fr>), also referenced to on the STRONG-2020 webpage devoted to this work package (<http://www.strong-2020.eu/virtual-access/va2-3dpartons.html>), has undergone maintenance and it has been recently updated to advertise the release of version 4 of PARTONS and its dependencies. PARTONS v4, amongst other improvements, provides a wider set of physical observables and models for generalized parton distributions (GPDs). Alongside, a virtual machine Docker image with PARTONS v4 has been released. This virtual machine allows users to run PARTONS out of the box on any machine without the burden of having to compile and install locally the software.

The PARTONS website, not only provides information about this specific code that is mostly devoted to GPDs, but also makes reference to other software of the 3DPartons family, such as APFEL, xFitter, NangaParbat, MontBlanc, TMDlib. These codes are devoted to the study of collinear parton distribution functions (PDFs) and fragmentation functions (FFs) as well as of transverse-momentum-dependent distributions (TMDs) and generalized TMDs (GTMDs).

A link to the webpage of the new multipurpose Monte Carlo generator software EpIC for exclusive process based on PARTONS (<https://github.com/pawelsznajder/epic>) has been added to the PARTONS webpage.

In view of the constantly growing popularity of the Python, a user friendly language that comes with a very large number of tools for, *e.g.*, statistical analysis and plotting, a wrapper of PARTONS in this language has finally been released. This wrapper allows the user to access most of the main functionalities of PARTONS through a Python interface, giving one the possibility to make it interoperable with other tools such as NumPy, Pandas, and Matplotlib.

Finally, a workshop on the virtual access 3DPartons and related physics projects has been held in October 2022 in the Paris area. The corresponding Indico page can be consulted from here: https://indico.cern.ch/event/1175276/overview.

# 2. International Assessment Board

## 2.1 Organization of International Assessment Board

This board consist of eight experts in relevant fields. It is composed of two theoretical physicists and two experimental physicists covering GPD and TMD domains, one physicist experienced in PDF fits and computing codes, and one expert experienced in Monte Carlo event generators. This panel of physicists is completed by two researchers specialized in software development and statistical data analysis.

## 2.2 International Assessment Board Members

In alphabetical order, the members of the International Assessment Board (IAB) are:

* BOBIN, Jérôme (IRFU, CEA, Université Paris-Saclay)
* BRESSAN, Andrea (INFN, Trieste)
* CHAPON, Damien (IRFU, CEA, Université Paris-Saclay)
* DIEHL, Markus (DESY)
* GLAZOV, Alexander (DESY)
* HAUTMANN, Francesco (Rutherford Appleton Laboratory, University of Oxford and Elementaire Deeltjes Fysica, Universiteit Antwerpen)
* PASQUINI, Barbara (INFN, Università Di Pavia)
* SOKHAN, Daria (IRFU, CEA, Université Paris-Saclay and University of Glasgow)

## 2.2 International Assessment Board Meetings

One IAB meeting took place in the reference period, specifically on February the 2nd 2023. The spokesperson of VA2 gave a detailed overview of the work package presenting the latest achievements both in terms of physical results and code developments. The experts provided feedback in the form of comments and suggestions that were recorded in a set of minutes. The meeting was also video recoded for future reference.

# Virtual Access activity during the reporting period

## 3.1 Detailed description of the activity

In the GPD domain, PARTONS v4 was released on July 2024. It contains new observables and new GPD models. The Monte Carlo general purpose event generator for exclusive processes EpIC was developed in order to be fully compatible with PARTONS: each exclusive channel provided by PARTONS can potentially be used for event generation in EpIC, along with the selection of various computing assumptions (GPD models, higher-order corrections, etc.). EpIC has been publicly released and is available from: <https://github.com/pawelsznajder/epic>.

In the collinear distribution domain, the Denali code was publicly released (<https://github.com/MapCollaboration/Denali>). This code is devoted to the extraction of longitudinally polarized PDFs and has been used for a determination of these quantities that was made available through the LHAPDF interface.

The TMD fitting framework NangaParbat was updated to include the possibility of determining the flavor dependence of TMDs. This resulted in a publication and the resulting TMDs are released in the TMDlib2 format.

The family of codes belonging to the 3DPartons family proved its capacity to interoperate in a recent study of GTMDs. Indeed, these objects are generalizations of both GPDs and TMDs, which are in turn generalizations of PDFs. In this context, a first model-independent determination of GTMDs including radiative corrections has been achieved using a compound of codes that includes PARTONS, NangaParbat, APFEL++, and LHAPDF.

As mentioned above, an in-person workshop devoted to 3DPartons has been held in the Paris area in October 2022 (https://indico.cern.ch/event/1175276/overview). This workshop gathered many experts from different fields of QCD and hadronic structure with the purpose of advancing our understanding of the 3D structure of hadrons. The participants shared their knowledge and know-how about scientific and technical problems related to GPDs and TMDs. The 3DPartons framework was central in many discussions but many other implications were also discussed.

Google Analytics has been replaced by the GDPR[[1]](#footnote-1)-compliant alternative Piwik PRO, a web analytics service with a consent manager, a tag manager and analytics. The tool is one of the analysis platforms approved by the French National Commission on Informatics and Liberty (CNIL). It offers a free version, with limited features, suited for sites with relatively low traffic, which should be suitable for a website hosting specialized 3D hadron structure computing software. Piwik Pro has a shared history with Matomo (formerly Piwik) which is the basis of Europa Analytics, the corporate service monitoring the European Commission’s websites.

## 3.2 Access to the facility during the reporting period supported by the project

The transition to Piwik Analytics became effective starting from July 1st 2023. Data prior to this date collected through Google Analytics is thus no longer accessible. This caused a gap of 13 months between the 1st of June 2022, end date of the last report, and 31st of June 2023. To fill this gap, the estimates provided below are obtained through a linear extrapolation based on the period 07/2023-07/2024 (13 months) to the full period 06/2022-07/2024 (26 months). The reliability of these estimates is supported by their similarity with previous estimates given in past reports.

Between June 1st 2022 and July 31st 2023, there have been more than 4000 views of the PARTONS website. These views correspond to around 1400 users worldwide. With a bounce rate of about 64%, the website still engages visitors to go deeper into its structure. It received around 10% returning visitors and 90% new visitors. Interestingly, around 1100 users out of 1400 accessed the website directly without passing through a search engine. This indicates that most of the visitors are assiduous users.

Similarly to what was observed during the first and second periods, visitors connected mostly from: the United States (320), France (240), Russia (210), Poland (85), and China (60). The general interpretation of these numbers is presumably as follows: many of the current and forthcoming experimental facilities conducting GPD programs are located in the United States (*e.g.* the Jefferson Laboratory and the Electron-Ion Collider (EIC)). Moreover, there are many developers and users of PARTONS in France and Poland, which explains the large number of visits from these countries. The future electron-ion collider in China (EIcC) explains why there have been a considerable number of visits from this country. More surprising are instead the large number of accesses from Russia. It is conjectured that NICA (Nuclotron-based Ion Collider fAсility), an accelerator complex designed at the Joint Institute for Nuclear Research (Dubna) to study properties of dense baryonic matter, has catalyzed the number of visits from Russia.

## 3.3 Scientific output of the users at the facility

A large number of physics and technical results have been achieved during the reference period using the tools provided by the VA2 work package, many of which are still on going. Amongst the main results already published or under review in peer-revied journals, we mention:

* An extraction of unpolarized TMD PDFs of the pion from a fit to experimental data accurate to N3LL.[[2]](#footnote-2)
* A determination of the GTMDs of the proton exploiting our current knowledge of GPDs and TMDs and including one-loop radiative corrections.[[3]](#footnote-3)
* A phenomenological study of the implication of the perturbative calculation the PDFs of the electron at current and future *e+e-* high-energy colliders.[[4]](#footnote-4)
* An extraction of unpolarized TMD PDFs of the proton and of the TMD FFs of pion and kaon from a global fit to experimental data at N3LL accuracy.[[5]](#footnote-5)
* A method to established a connection between GPDs and PDFs and gauge its accuracy.[[6]](#footnote-6)
* A re-computation and implementation of the one-loop evolution kernels for all of the twist-2 quark and gluon GPDs.[[7]](#footnote-7)
* An extraction of helicity-dependent PDFs at NNLO accuracy from inclusive and semi-inclusive deep-inelastic scattering data.[[8]](#footnote-8)
* A benchmark of deep-inelastic-scattering structure functions at N3LO accuracy.[[9]](#footnote-9)
* A determination of the flavor dependence of unpolarized quark TMDs PDFs and FFs from a global fit.[[10]](#footnote-10)
* A study of perturbative renormalization-group-equation systematics in precision observables at high-energy colliders.[[11]](#footnote-11)
* A combination of lattice QCD and phenomenological inputs to constrain GPDs at moderate skewness.[[12]](#footnote-12)
* A study of the implications of Lorentz symmetry and partial DGLAP knowledge on our knowledge of GPDs.[[13]](#footnote-13)
* An extraction of the distribution amplitude of the *ηc*-meson at leading twist from lattice QCD.[[14]](#footnote-14)
* A study of exclusive vector-quarkonium photoproduction at NLO in *αs* in collinear factorization including evolution effects of the GPDs and high-energy resummation.[[15]](#footnote-15)
* A systematic description of hadron’s response to nonlocal QCD probes by means of Froissart-Gribov projections in an analysis of deeply virtual Compton scattering.[[16]](#footnote-16)
* A phenomenology study of double deeply virtual Compton scattering in the era of new experiments.[[17]](#footnote-17)
* A paper describing the EpIC Monte Carlo generator for exclusive processes.[[18]](#footnote-18)
* A phenomenological study of diphoton photoproduction at NLO accuracy.[[19]](#footnote-19)
* A study of the evolution of PDFs in the short-distance factorization scheme.[[20]](#footnote-20)

Almost all of these publications have been presented at international conferences, workshops, or schools. However, we do not attempt to list all oral contributions here.

While collecting the physics output of VA2 users, we observed that some of them merely cite the original paper describing the PARTONS framework,[[21]](#footnote-21) and do not include in the acknowledgments the sentence: *“The virtual access infrastructure 3DPartons has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 824093.”* To contrast this phenomenon, an explicit statement in the section “License and reference” of the main page of the PARTONS website (<http://partons.cea.fr>) has been added. In this respect, it is worth stressing that the work carried out within VA2 is likely to have a farther-reaching impact on the hadron structure community than that conveyed by the list of papers given above.

# 4. Tables to be filled in the IT tool in Part A of the Periodic Report

***4.1 Researchers who have access to research e-infrastructures through Union support***

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **e-infrastructure name** | **e-infrastructure service** | **Activity Domain (Discipline)** | **Maximum possible number of users** | **Nr of actual users by max possible number in P3 (%)** |
| 3DPartons | Collaborative services enabling the sharing of open-source software, applications, and other research objects | Physics | 300 | 470%  (709 users in the period 07/2023-07/2024  extrapolated to ~1400 users in the period 06/2022-07/2024) |

Since the 1st July 2023, following a directive from the STRONG-2020 Governing Board, the tracking platform has been changed from Google Analytics to Piwik Analytics (see above). Unfortunately, data prior to this change has been lost. Therefore, there is a gap between June 2022 and June 2023 for which we have no data. In the table above, we provide a linear extrapolation based on the period 07/2023-07/2024 to the entire reference period 06/2022-07/2024.

The counting criteria of Piwik Analytics are such that a user is counted once no matter the number of actual visits of the website.

# 5. Resources used to provide access to Research Infrastructures

*[Explain how many PM have been used to provide access and explain for which task (e.g. scientific support to users, etc.)].*

***5.1 Resources used to provide access***

|  |  |  |  |
| --- | --- | --- | --- |
| **Beneficiary/Linked Third Party short name** | **Installation(s)** | **P/m** | **Explanations of tasks** |
| CEA | VA 3DPartons |  | Aggregation and improvement of  existing codes from the GPD and PDF/FF, TMD, and GTMD communities.  Integration,  maintenance, release, testing, documentation and technical assistance to users. |

1. General data protection regulation <https://gdpr-info.eu>. [↑](#footnote-ref-1)
2. MAP Collaboration, Phys.Rev.D 107 (2023) 1, 014014. [↑](#footnote-ref-2)
3. V. Bertone, Eur.Phys.J.C 82 (2022) 10, 941. [↑](#footnote-ref-3)
4. V. Bertone *et al.*, JHEP 10 (2022) 089. [↑](#footnote-ref-4)
5. MAP Collaboration, JHEP 10 (2022) 127. [↑](#footnote-ref-5)
6. H. Dutrieux *et al.*, Phys.Rev.D 107. [↑](#footnote-ref-6)
7. V. Bertone *et al.*, Phys.Rev.D 109 (2024) 3, 034023. [↑](#footnote-ref-7)
8. MAP Collaboration, e-Print: 2404.04712. [↑](#footnote-ref-8)
9. V. Bertone, A. Karlberg, Eur.Phys.J.C 84 (2024) 8, 774. [↑](#footnote-ref-9)
10. MAP Collaboration, JHEP 08 (2024) 232. [↑](#footnote-ref-10)
11. V. Bertone, G. Bozzi, F. Hautmann, e-Print: 2407.20842. [↑](#footnote-ref-11)
12. M. Reberdy *et al.*, Eur.Phys.J.C 84 (2024) 2, 201. [↑](#footnote-ref-12)
13. P. Dall’Olio *et al.*, Phys.Rev.D 109 (2024) 9, 096013. [↑](#footnote-ref-13)
14. B. Blossier *et al.*, JHEP 09 (2024) 079. [↑](#footnote-ref-14)
15. C. Flett *et al.*, e-Print: 2409.05738. [↑](#footnote-ref-15)
16. K. M. Semenov-Tian-Shansky *et al.*, Phys.Rev.D 109 (2024) 5, 054010. [↑](#footnote-ref-16)
17. K. Deja *et al.*, Phys.Rev.D 107 (2023) 9, 094035, Phys.Rev.D 107 (2023) 9. [↑](#footnote-ref-17)
18. E.C. Aschenauer *et al.*, Eur.Phys.J.C 82 (2022) 9, 819. [↑](#footnote-ref-18)
19. O, Grocholski *et al.*, Phys.Rev.D 105 (2022) 9, 094025. [↑](#footnote-ref-19)
20. H. Dutrieux *et al.*, JHEP 04 (2024) 061.. [↑](#footnote-ref-20)
21. B. Berthou *et al.*, Eur. Phys. J. **C78** (2018) 478. [↑](#footnote-ref-21)