

STRONG-2020

HORIZON 2020

Annual Meeting 2024

VA2 – 3DPartons

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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 with support also for PDFs and FFs.

It consists of **several libraries organised in a modular way**, which allows for continuous improvements and addition of new models, channels, and theoretical refinements.

Computing codes that contribute to 3DPartons

As of today, **3DPartons** is based on parts of, or offers interfaces to, various existing codes:

- **PDFs/FFs:** LHAPDF, APFEL/APFEL++, xFitter, MontBlanc, Denali,
- **GPDs:** PARTONS, EpIC, GeParD,
- **TMDs:** NangaParbat, arTeMiDe, TMDlib, CASCADE.



Progress during the last year



- **Maintenance and support**
- **Development of new codes**
- **Several spin-offs**
- **Plenty of physics result already published and in the pipeline both internal to 3DPartons and by external users.**

Public GPD analysis frameworks



PARTONS Partonic Tomography Of Nucleon Software

Main Page Download Tutorials Reference documentation About

Main Page

What is PARTONS?

PARTONS is a software framework dedicated to the phenomenology of 3D hadron structure, in particular Generalized Parton Distributions (GPDs) and Transverse Momentum Dependent (TMDs) parton distribution functions.

The experimental program devoted to study GPDs and TMDs has been carrying out by experiments in several facilities, like CERN, DESY, Fermilab, Jefferson Lab and BNL. The 3D structure of hadrons will be also a key component of the physics case for the future US electron ion collider (EIC) and Chinese electron ion collider (EIC). PARTONS is useful to theorists to develop new models, phenomenologists to interpret existing measurements and to experimentalists to design new experiments.

PARTONS provides a necessary bridge between GPD models and experimental data measured in various channels, like for example deeply virtual Compton scattering (DVCS), timelike Compton scattering (TCS) and hard exclusive meson production (HEMP).

What is 3DPartons?

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.

<https://partons.cea.fr/partons/doc/html/index.html>

gepard

Tool for studying the 3D quark and gluon distributions in the nucleon

GeparD Tool for studying the 3D quark and gluon distributions in the nucleon

GeparD is software for analysis of three-dimensional distribution of quarks and gluons in hadrons, encoded in terms of the so-called Generalized Parton Distributions (GPDs).

This web site has manifold purpose:

- Documentation of the software
- Examples of the use of software
- Interface to various representations of results: numerical and graphical
- Interface to datasets used in analyses: numerical and graphical

Contents:

- [Software documentation](#)
 - [Installation](#)
 - [Quickstart](#)
 - [Tutorial](#)
 - [Data points, sets and files](#)

<https://gepard.phy.hr/>

Public TMD analysis frameworks



arTeMiDe

News

- 12 Dec 2019:** Version 2.02 released (+manual update).
- 23 Feb 2019:** Version 1.4 released (+manual update).

Articles, presentations & supplementary materials

Extra pictures for the paper arXiv:1902.08474

<https://teorica.fis.ucm.es/artemide/>

Nanga Parbat:
a TMD fitting framework

Nanga Parbat is a fitting framework aimed at the determination of the non-perturbative component of TMD distributions.

Download

Suggested Workflows
Based on your tech stack

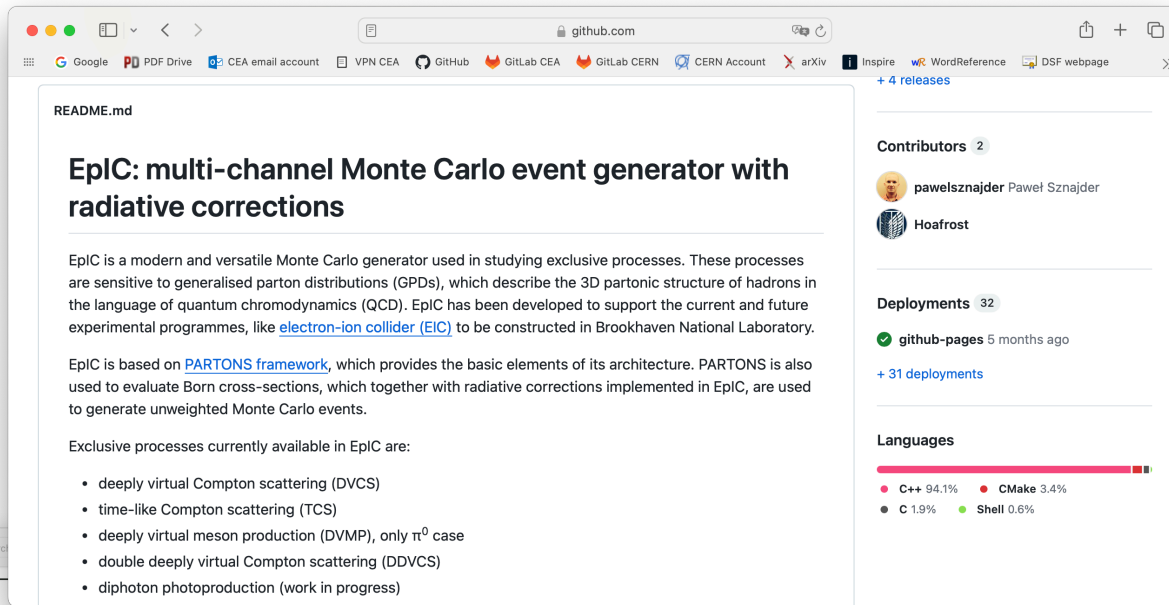
- Jekyll using Docker image** - Configure
- SLSA Generic generator** - Configure
- Pylint** - Configure

[More workflows](#) [Dismiss suggestions](#)

<https://github.com/MapCollaboration/NangaParbat>

Highlights: EpIC Monte Carlo Event Generator

- **Based on PARTONS:** can use all provided exclusive channels in a transparent way.
- Includes treatment of radiative corrections.
- **Already used by** the EIC community and run at BNL.
- **Publicly available through GitHub.**
- Paper publish in EPJC.



The screenshot shows the GitHub repository page for 'EpIC: multi-channel Monte Carlo event generator with radiative corrections'. The main content is the README.md file, which describes the generator's capabilities and its foundation on the PARTONS framework. The repository has 2 contributors (pawelsznajder and Hoafrost), 32 deployments (including github-pages), and a language distribution of 94.1% C++, 3.4% CMake, 1.9% C, and 0.6% Shell.

README.md

EpIC: multi-channel Monte Carlo event generator with radiative corrections

EpIC is a modern and versatile Monte Carlo generator used in studying exclusive processes. These processes are sensitive to generalised parton distributions (GPDs), which describe the 3D partonic structure of hadrons in the language of quantum chromodynamics (QCD). EpIC has been developed to support the current and future experimental programmes, like [electron-ion collider \(EIC\)](#) to be constructed in Brookhaven National Laboratory.

EpIC is based on [PARTONS framework](#), which provides the basic elements of its architecture. PARTONS is also used to evaluate Born cross-sections, which together with radiative corrections implemented in EpIC, are used to generate unweighted Monte Carlo events.

Exclusive processes currently available in EpIC are:

- deeply virtual Compton scattering (DVCS)
- time-like Compton scattering (TCS)
- deeply virtual meson production (DVMP), only π^0 case
- double deeply virtual Compton scattering (DDVCS)
- diphoton photoproduction (work in progress)

Eur. Phys. J. C (2022) 82:819
<https://doi.org/10.1140/epjc/s10052-022-10651-z>

THE EUROPEAN
PHYSICAL JOURNAL C

Special Article - Tools for Experiment and Theory

EpIC: novel Monte Carlo generator for exclusive processes

E. C. Aschenauer^{1,a}, V. Batzskaya^{2,b}, S. Fazio^{3,c}, K. Gates^{4,d}, H. Moutarde^{5,e}, D. Sokhan^{4,5,f}, H. Spiesberger^{6,g}, P. Sznajder^{2,h}, K. Tezgin^{1,i}



Highlights: PyPARTONS



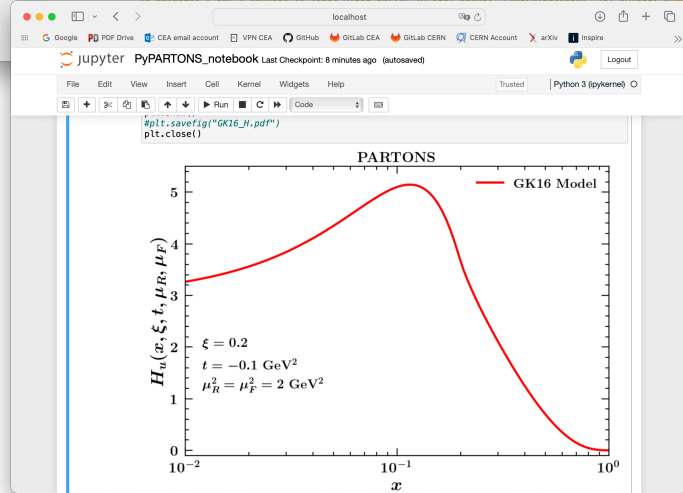
- Simplify interoperability with **popular libraries** on *e.g.*
 - machine learning (e.g. TensorFlow),
 - plotting (e.g. Matplotlib),
 - statistical data analysis (e.g. Pandas).
- Convenient for a **wide community of new (young) users.**
- **Facilitates dissemination of research** through e.g. Jupyter notebooks.
- Still working documentation.

```
In [1]: import numpy as np
import matplotlib.pyplot as plt
import MatplotlibSettings
import pypartons

In [2]: # Initialise PARTONS and get instance
p = pypartons.PARTONS
p.PARTONS.init()
inst = p.PARTONS.getInstance()

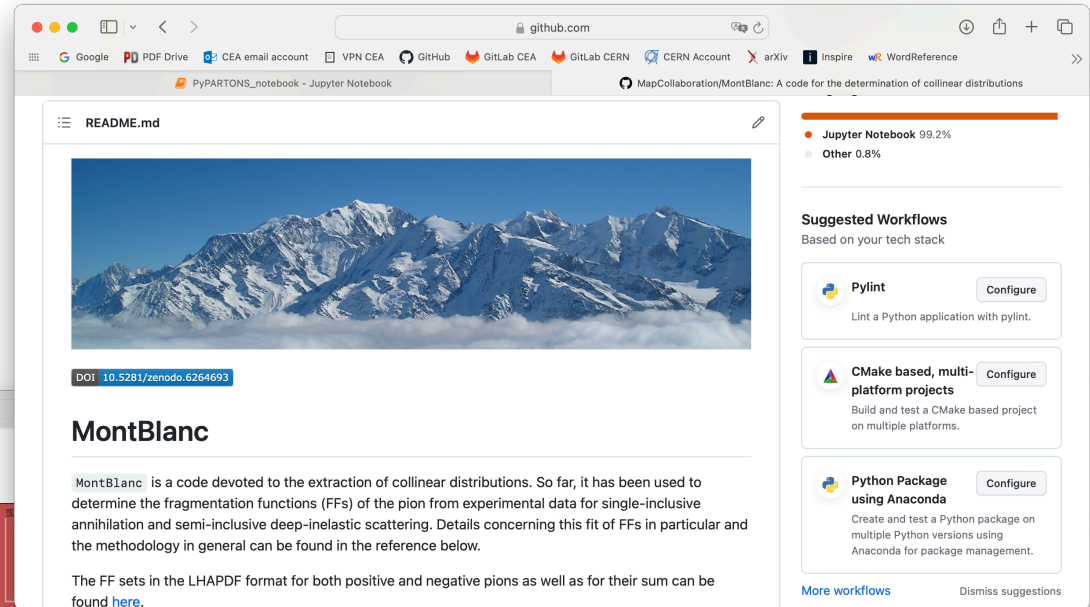
In [3]: # Initialise GPD service and GPD model
gpdService = inst.getServiceRegistry().getGPDService()
gpdModel = inst.getModuleObjectFactory().newGPDModule("GPDGK16")

21-09-2022 05:50:02 [INFO] (Partons::printVersion) PARTONS 3.0.0 (http://partons.cea.fr) distributed under GNU Public License
21-09-2022 05:50:02 [INFO] (Partons::printVersion) Git branch and revision of this version is python_interface/5864fad98ba3841f066222b7475157186b33eaf9
21-09-2022 05:50:02 [INFO] (Partons::printVersion) Built using Elementary-Utils 3.0.0 (master/ceb0ecb0eab58698f982261863f68599e85c062e) and Num++ 3.0.0 (master/d84c72cb2af5ad69bc67330b97de8b1798eb34a)
21-09-2022 05:50:02 [Warning] (DatabaseManager::init) MySQL database is currently not available ; Check your connection properties in partons.properties ; Or check if MySQL server is installed -> (DatabaseManager::init) Can't connect to database : Can't connect to local MySQL server through socket '/tmp/mysql.sock' (2)
MySQL: Unable to connect
```



Highlights: MontBlanc and FFs at NNLO

- First extraction of pion and kaon FFs at **NNLO** accuracy.
- **Code made publicly available:**
 - fully documented,
 - many spin-offs.
- FFs available through **LHAPDF**.
- Paper published in **PLB**.



The screenshot shows a GitHub repository for 'MontBlanc'. The main content is the README.md file, which features a large image of a snow-capped mountain range. Below the image, the DOI is listed as 10.5281/zenodo.6264693. The title 'MontBlanc' is prominently displayed. The text describes the code's purpose: 'MontBlanc is a code devoted to the extraction of collinear distributions. So far, it has been used to determine the fragmentation functions (FFs) of the pion from experimental data for single-inclusive annihilation and semi-inclusive deep-inelastic scattering. Details concerning this fit of FFs in particular and the methodology in general can be found in the reference below.' It also mentions that the FF sets are available in the LHAPDF format for both positive and negative pions and their sum, with a link to 'here'.

On the right side of the repository page, there is a 'Suggested Workflows' section based on the tech stack. It includes three workflow cards: 'Pylint' (Lint a Python application with pylint), 'CMake based, multi-platform projects' (Build and test a CMake based project on multiple platforms), and 'Python Package using Anaconda' (Create and test a Python package on multiple Python versions using Anaconda for package management).

Physics Letters B 834 (2022) 137456

Contents lists available at [ScienceDirect](#)



Physics Letters B

www.elsevier.com/locate/physletb

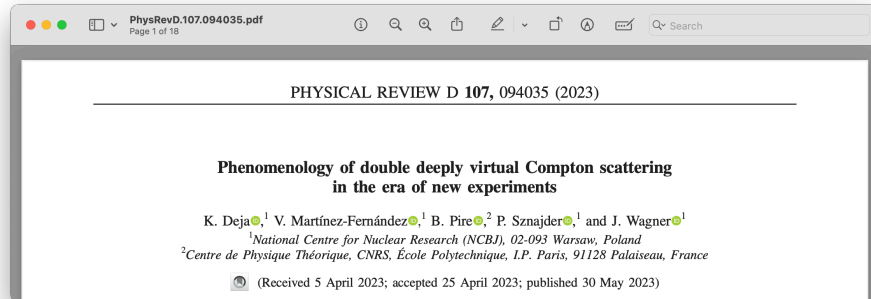
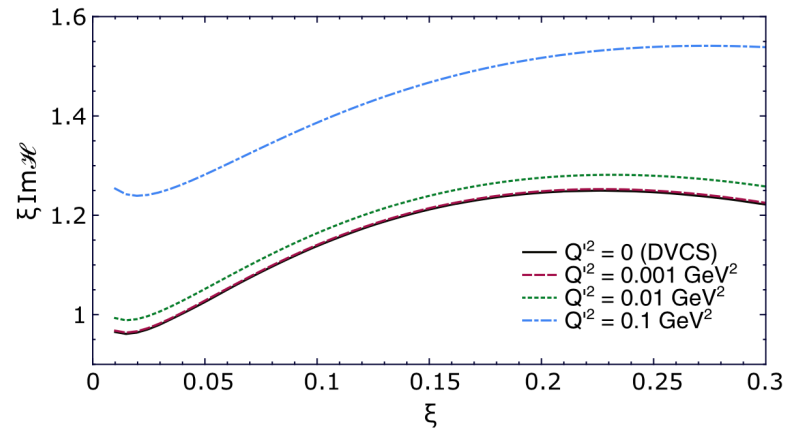
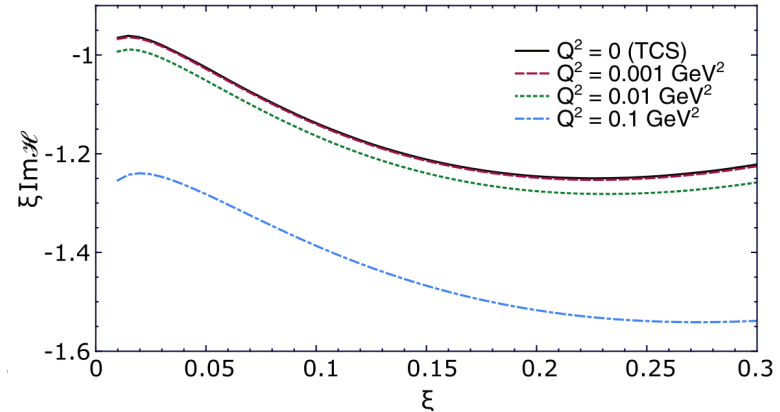
Pion and kaon fragmentation functions at next-to-next-to-leading order

Rabah Abdul Khalek^a, Valerio Bertone^b, Alice Khoudli^b, Emanuele R. Nocera^{c,*}



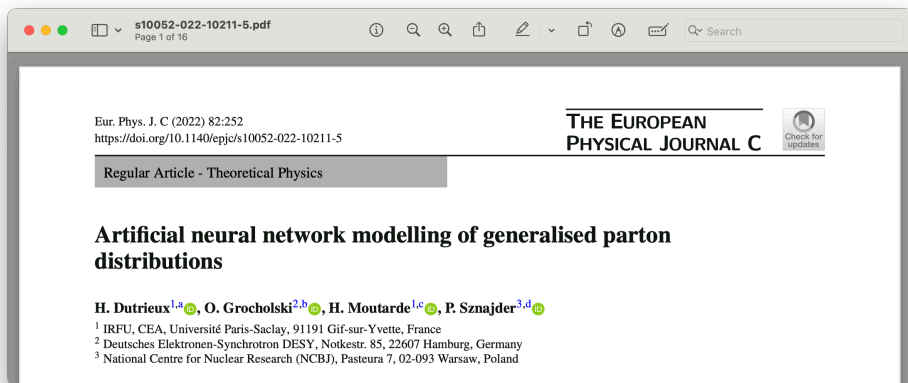
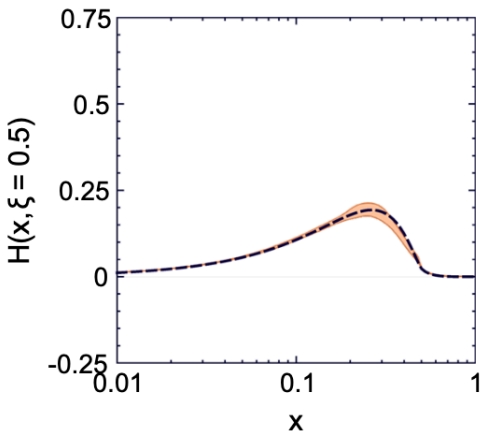
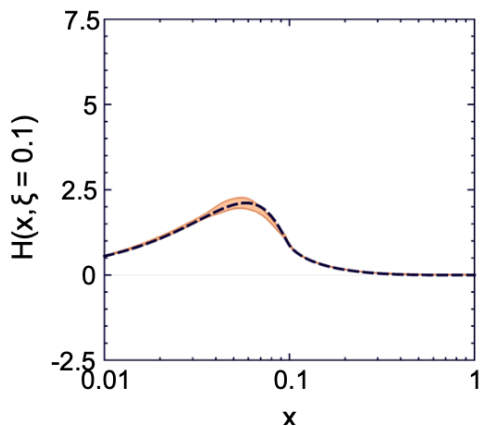
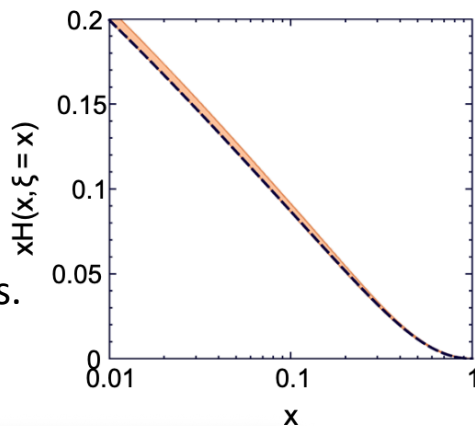
Highlights: DDVCS in PARTONS/EpIC

- Revisitation of DDVCS at leading order:
 - reformulation suitable for efficient numerical computation.
- **Code available through PARTONS:**
 - also available in EpIC
- Paper published in PRD.



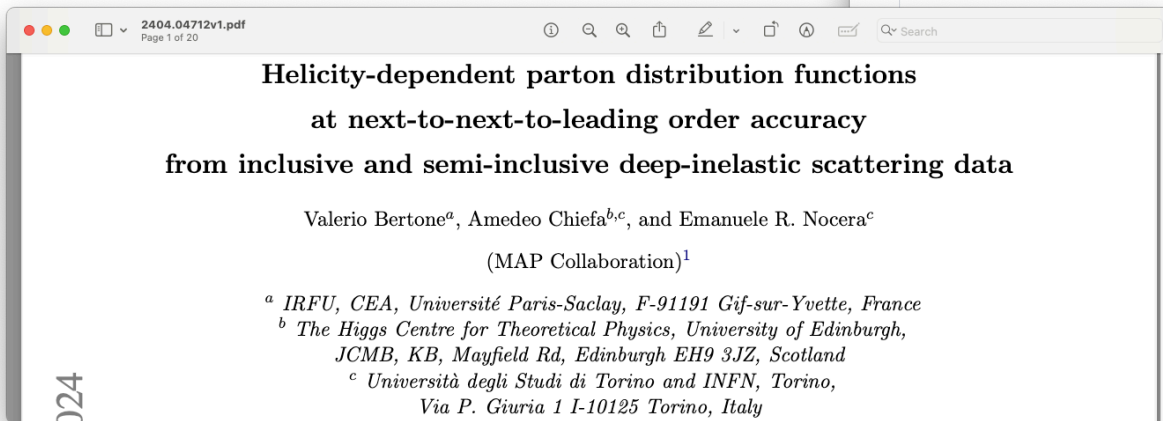
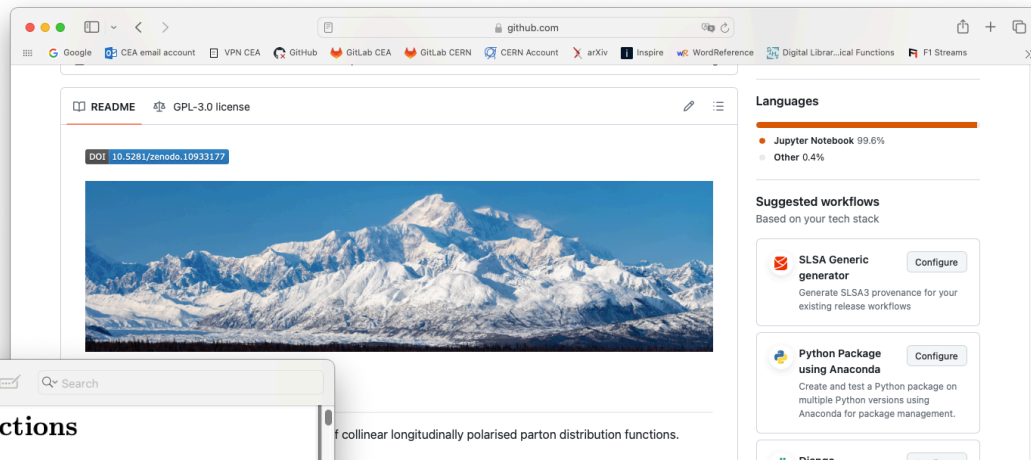
Highlights: ANN modelling of GPDs

- Study of the parameterisation of GPDs:
 - in direct (momentum) space
 - in double-distribution space.
- All relevant symmetries satisfied.
- Exploitation of machine learning techniques.
- Paper published in EPJC.



Highlights: Denali and polarised PDFs at NNLO

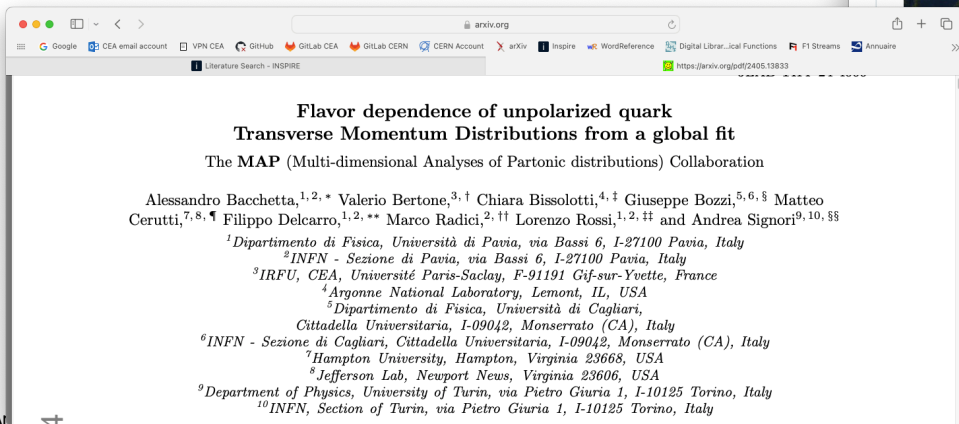
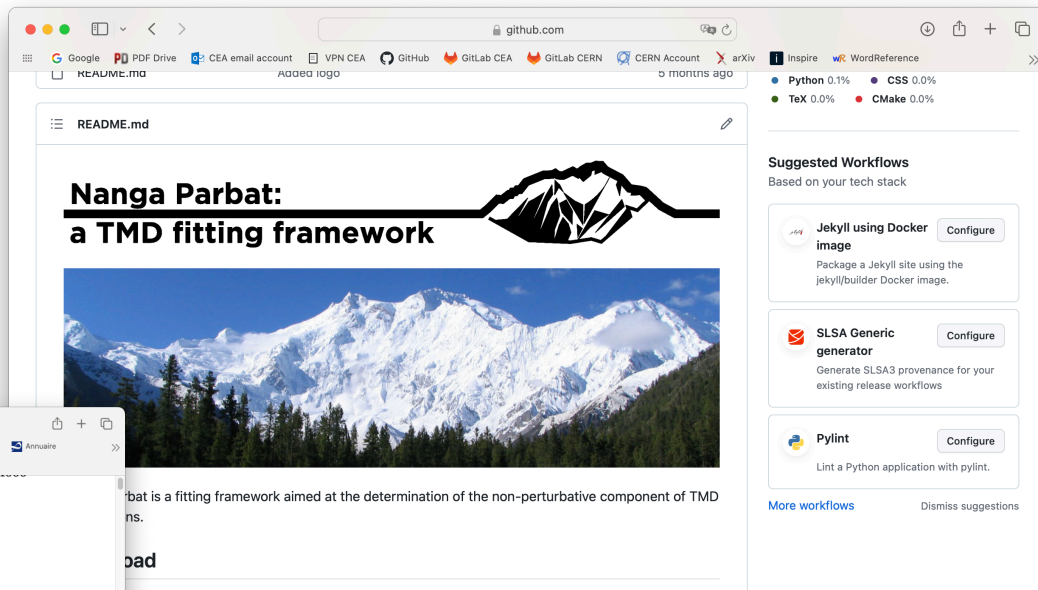
- First extraction of polarised proton PDFs at **NNLO** accuracy.
- **Code publicly available:**
 - fully documented,
- PDFs will be made available through **LHAPDF**.
- Paper soon on the arXiv.



[e-Print: 2404.04712]
Paper under review

Highlights: NangaParbat and global TMDs

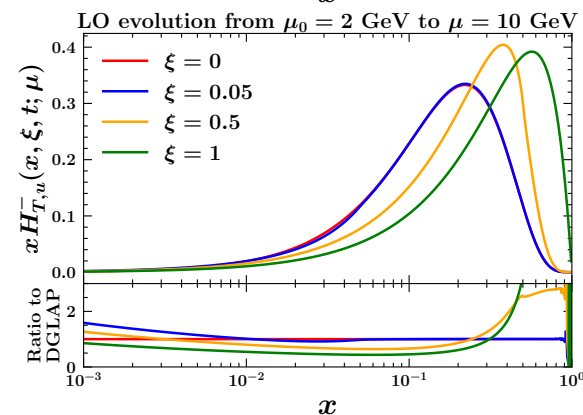
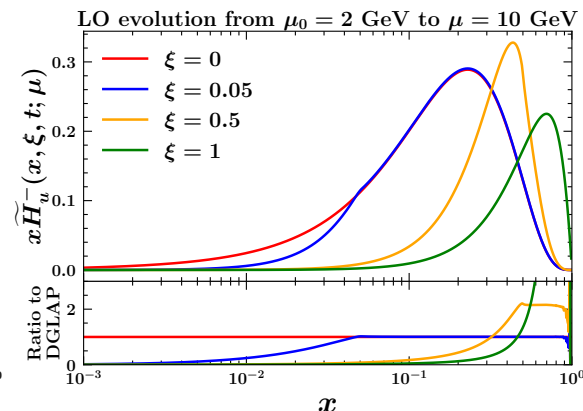
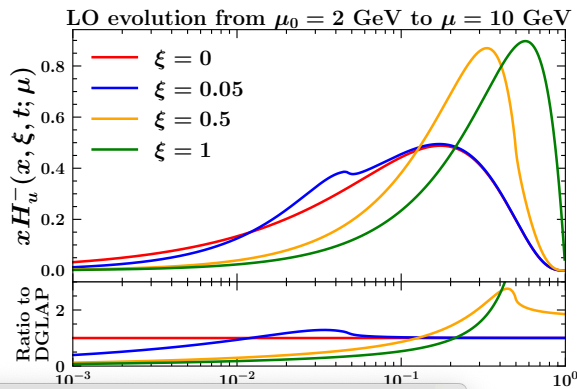
- Global extraction TMD PDFs and FFs at N3LL accuracy and with **flavour dependence**.
- **Code publicly available:**
 - fully documented.
- **TMDs available through TMDlib.**



[e-Print: 2405.13833]
Paper under review

Highlights: GPD evolution in APFEL++/PARTONS

- Revisit and implement GPD evolution for all twist-2 polarisations
- **Code publicly available within PARTONS.**
- One paper already published in EPJC.
- Paper published in PRD.



PHYSICAL REVIEW D **109**, 034023 (2024)

One-loop evolution of twist-2 generalized parton distributions

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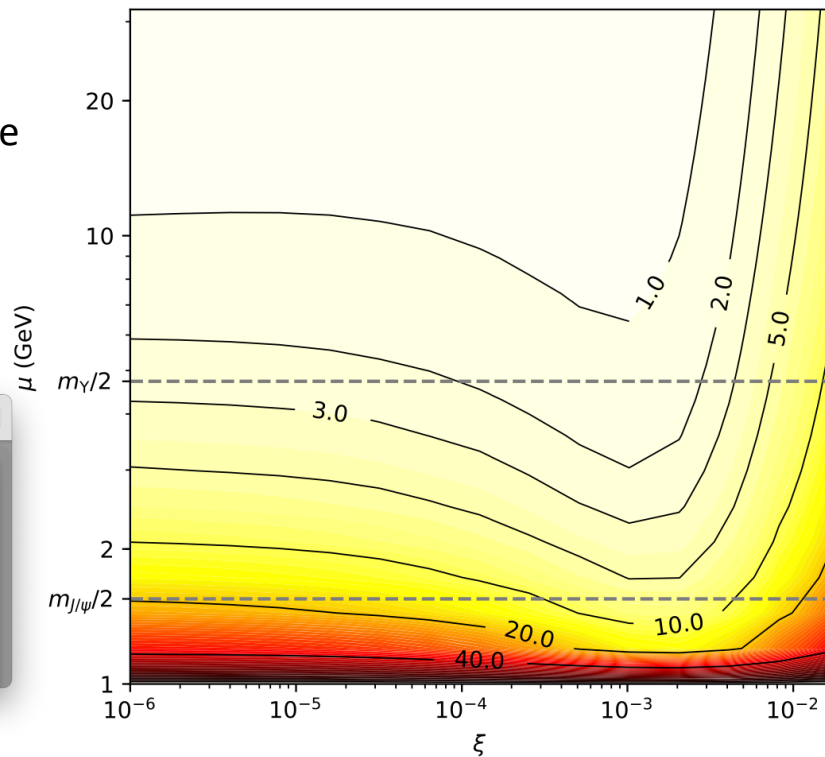
⁵Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22607 Hamburg, Germany

⁶CPHT, CNRS, Ecole polytechnique, Institut Polytechnique de Paris, 91120 Palaiseau, France

(Received 29 November 2023; accepted 29 January 2024; published 23 February 2024)

Highlights: Connecting PDFs and GPDs

- Investigate the **connection between GPDs and PDFs**.
- A method to establish the connection and gauge its accuracy is put forward.
- It made use of **PARTONS**.
- Published in PRD.



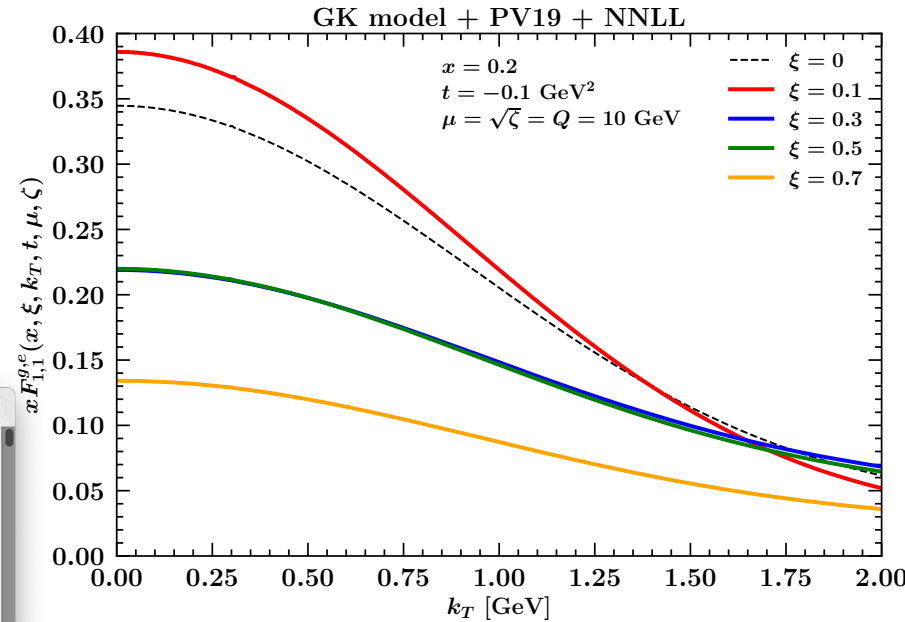
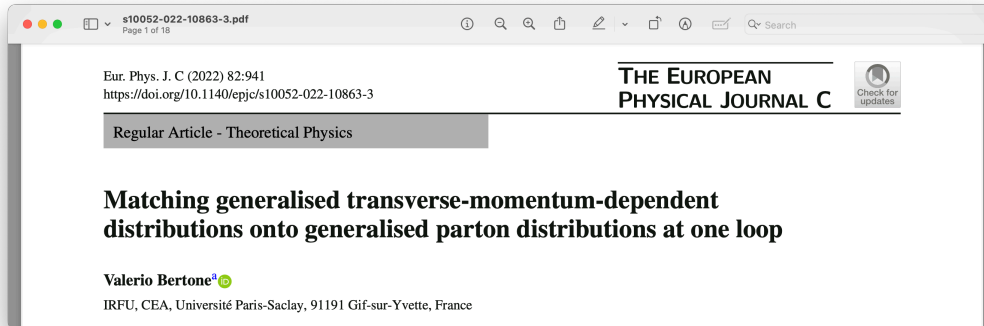
PHYSICAL REVIEW D **107**, 114019 (2023)

Exclusive meets inclusive particle production at small Bjorken x_B : How to relate exclusive measurements to PDFs based on evolution equations

Hervé Dutrieux[✉], Michael Winn[✉], and Valerio Bertone[✉]
IRFU, CEA, Université Paris-Saclay, 91191 Gif-sur-Yvette, France

An example of interoperability: reconstructing GTMDs

- Interoperability of codes belonging to 3DPartons allowed us to reconstruct GTMDs:
 - **PARTONS** (GPD model)
 - **NangaParbat** (TMD model)
 - **APFEL++** (perturbative input)
- **Code publicly available through GitHub.**
- Paper published in EPJC.





Summary

- **3DPartons** delivered **impactful results** in many areas of **hadronic structure**, in some respects **beyond the original plans**.
- It is built upon a **solid code infrastructure** that consistently incorporates the resulting developments making them **publicly available**.
- 3DPartons in a unique position to exploit **present and future opportunities**:
 - current and future experimental facilities,
 - theoretical developments,
 - technological advances.