The PARTONS Framework: Integrating GPD Models into Event Generators for Exclusive Processes

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NATIONAL CENTRE FOR NUCLEAR RESEARCH ŚWIERK

EMMI RRTF “Impact of Vector Mesons on the Studies of the 3D Structure of the Nucleon

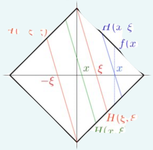
CERN, June 15th, 2026

Outline

- General GPD calculation scheme
- Software environment
  - PARTONS
  - EpIC
  - OpenDatabase
- Summary

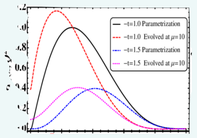
General calculation scheme

double distribution at μ_{ref}



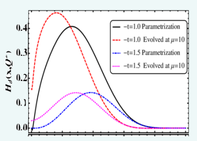
Radon transform

GPD at μ_{ref}



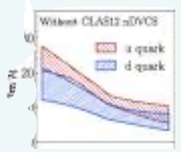
evolution

GPD at μ

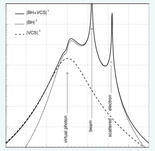


convolution

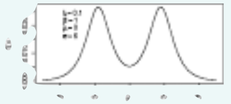
amplitude



cross section

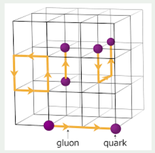


observable

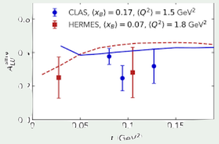


General calculation scheme

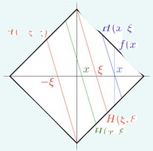
lattice QCD



experimental data

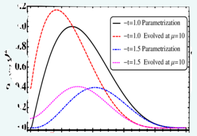


double distribution at μ_{ref}



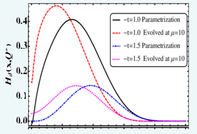
Radon transform

GPD at μ_{ref}



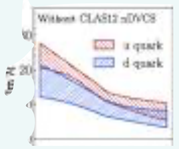
evolution

GPD at μ

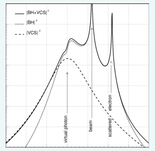


convolution

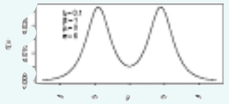
amplitude



cross section

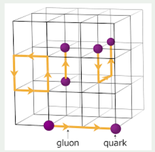


observable

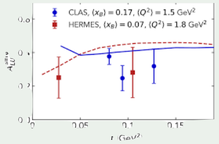


General calculation scheme

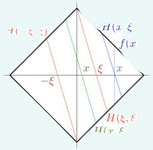
lattice QCD



experimental data

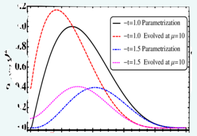


double distribution at μ_{ref}



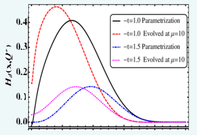
Radon transform

GPD at μ_{ref}



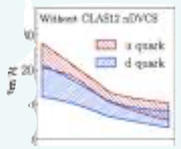
evolution

GPD at μ

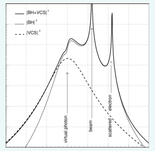


convolution

amplitude



cross section



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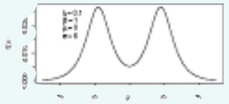
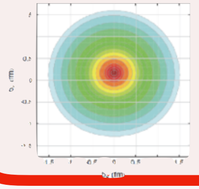
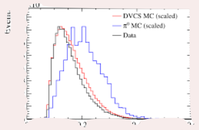


tomography, OAM, GFFs

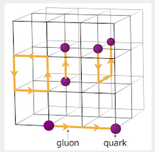


MC generator



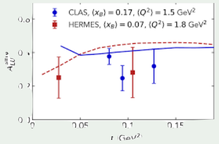
SOFTWARE ENVIRONMENT

lattice QCD



Open Database

experimental data



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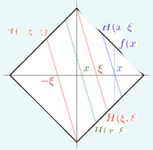

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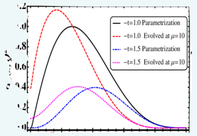
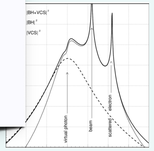
GPD at μ_{ref}

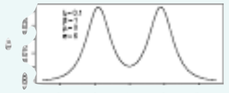


PARTONS framework

cross section



observable



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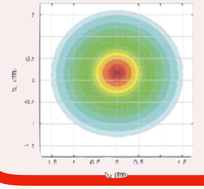
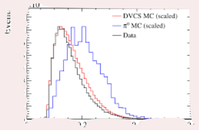


MC generator

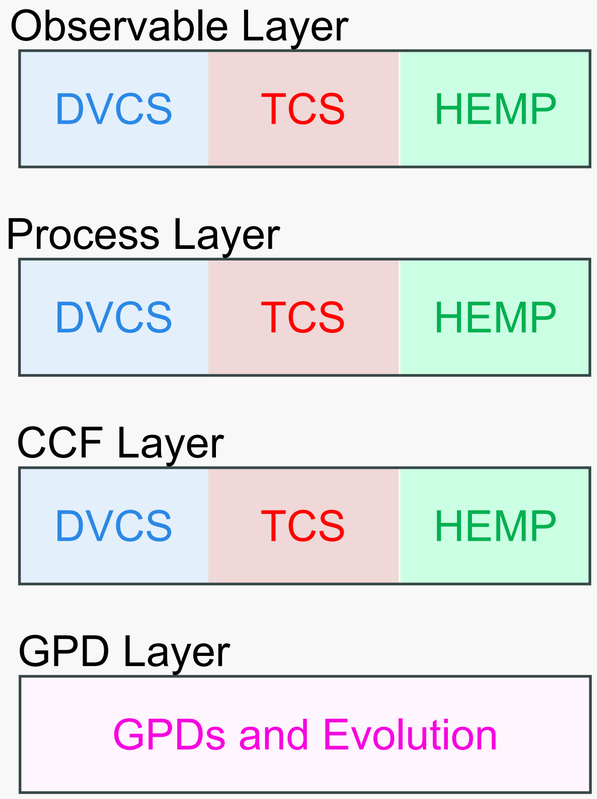


EpIC generator

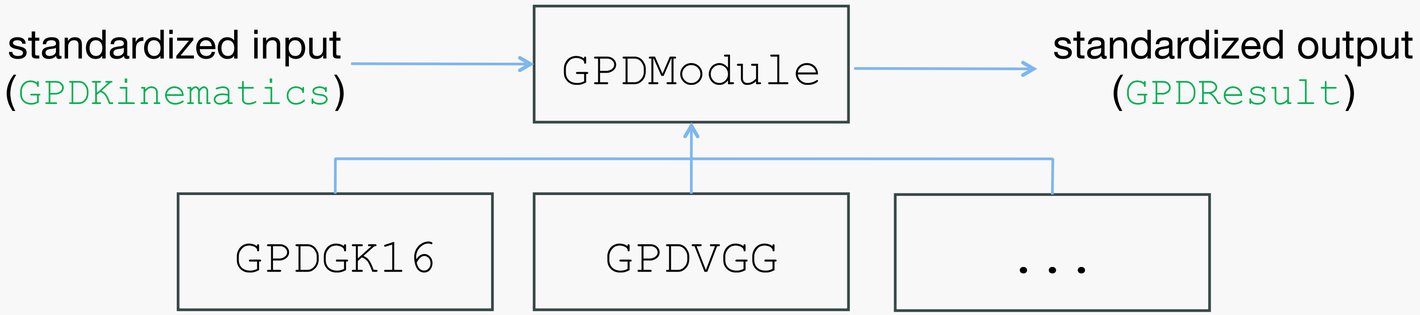
PARTONS FRAMEWORK

PARTONS - a platform to study GPDs

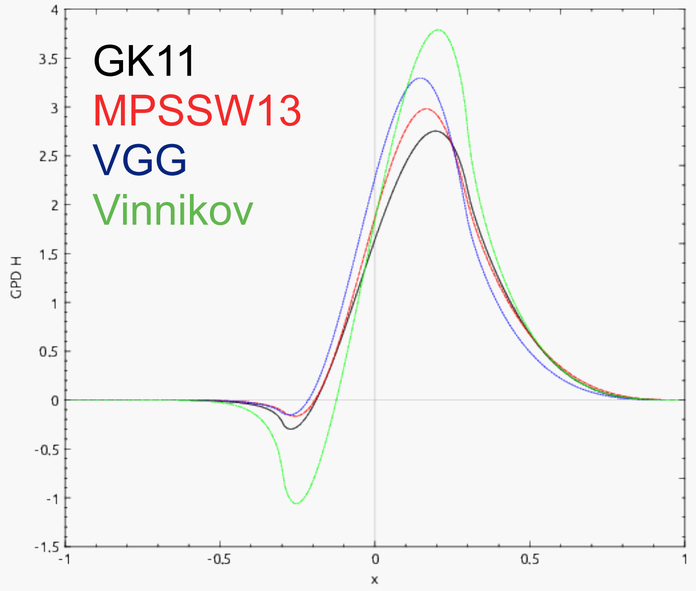
- includes a variety of utility tools and built-in physics developments
- written in C++ to ensure high performance (requires some technical expertise)
- functions either as a library within custom programs or
  as a standalone executable using XML input files
- groups evaluations into computational layers
- features a highly modular structure, making it easy to integrate new developments
- integrates with external physics-oriented libraries:
  - Apfel++ for GPD evolution
  - LHAPDF for PDFs
- note another project of this type
  GeParD: https://gepard.phy.hr/



PARTONS FRAMEWORK



- benefits from C++ inheritance and polymorphism mechanisms
- enables the easy addition of new modules
  by simply filling class "templates" with code
- operates as part of a registry-factory mechanism



H^u @ $xi = 0.2$, $t = -0.1$ GeV^2, $\mu_F^2 = 2$ GeV^2

PARTONS FRAMEWORK

- Licensing:
  distributed as an open-source project, with specific licenses varying by subproject
- Main Website & Source Code:
  http://partons.cea.fr
  https://github.com/3d-partons (note: source code repository recently relocated)
- Available as a Docker image:
  https://hub.docker.com/repository/docker/partons/partons
- Reference publication:
  Eur. Phys. J. C 78 (2018) 6, 478
- Version 5 available
  optimized to be “lighter”
- Processes included:
  DVCS, TCS, DDVCS, DVMP, and GAM2

PARTONS: PARtonic Tomography Of Nucleon Software

A computing framework for the phenomenology of Generalized Parton Distributions

B. Berthou[1], D. Binosi[2], N. Chouika[1], L. Colaneri[3,4], M. Guidal[3], C. Mezrag[5], H. Moutarde[1,a], J. Rodríguez-Quintero[7,8], F. Sabatié[1], P. Sznajder[3,6], J. Wagner[6]

[1] IRFU, CEA, Université Paris-Saclay, 91191 Gif-sur-Yvette, France
[2] ECT*/Fondazione Bruno Kessler, Villa Tambosi, Strada delle Tabarelle 286, 38123 Villazzano, TN, Italy
[3] Institut de Physique Nucléaire d’Orsay, CNRS-IN2P3, Université Paris-Sud, Université Paris-Saclay, 91406 Orsay, France
[4] University of Connecticut, Storrs, CT 06269, USA
[5] Istituto Nazionale di Fisica Nucleare, Sezione di Roma, P. le A. Moro 2, 00185 Roma, Italy
[6] National Centre for Nuclear Research (NCBJ), 00-681 Warsaw, Poland
[7] Dpto. Ciencias Integradas, Centro de Estudios Avanzados en Fis., Mat. y Comp., Fac. Ciencias Experimentales, Universidad de Huelva, 21071 Huelva, Spain
[8] CAFPE, Universidad de Granada, 18071 Granada, Spain

Received: 3 April 2018 / Accepted: 29 May 2018 / Published online: 11 June 2018

EPIC MC GENERATOR

- universal (generic):

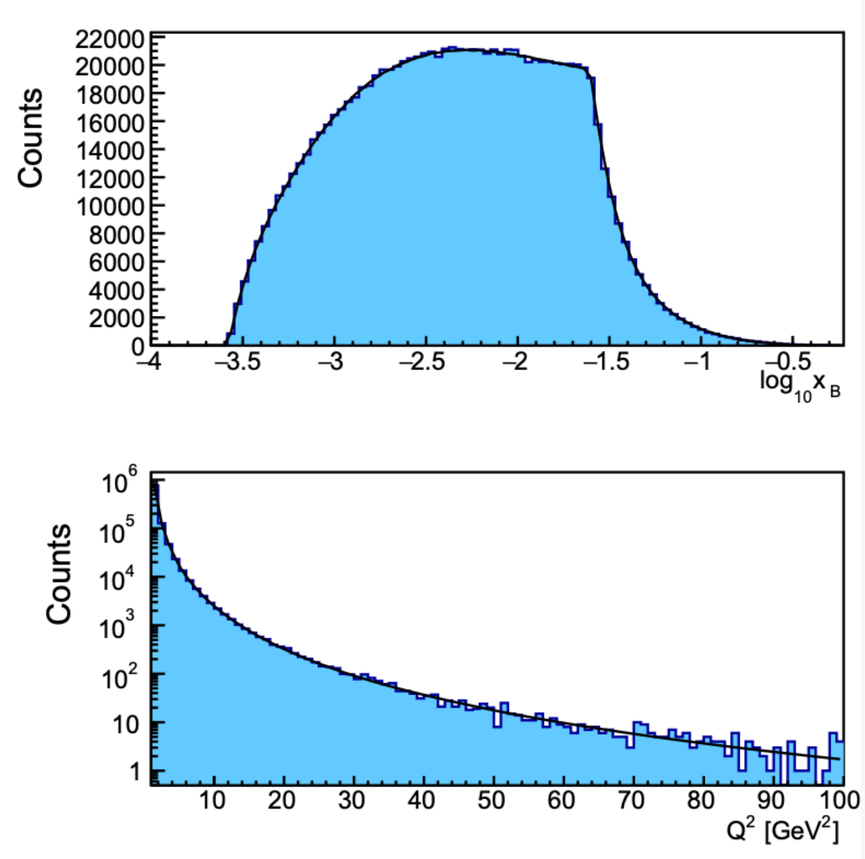
  standardized for CERN, JLab, and the EIC, …

  replaces "home-made" generators
- multichannel:

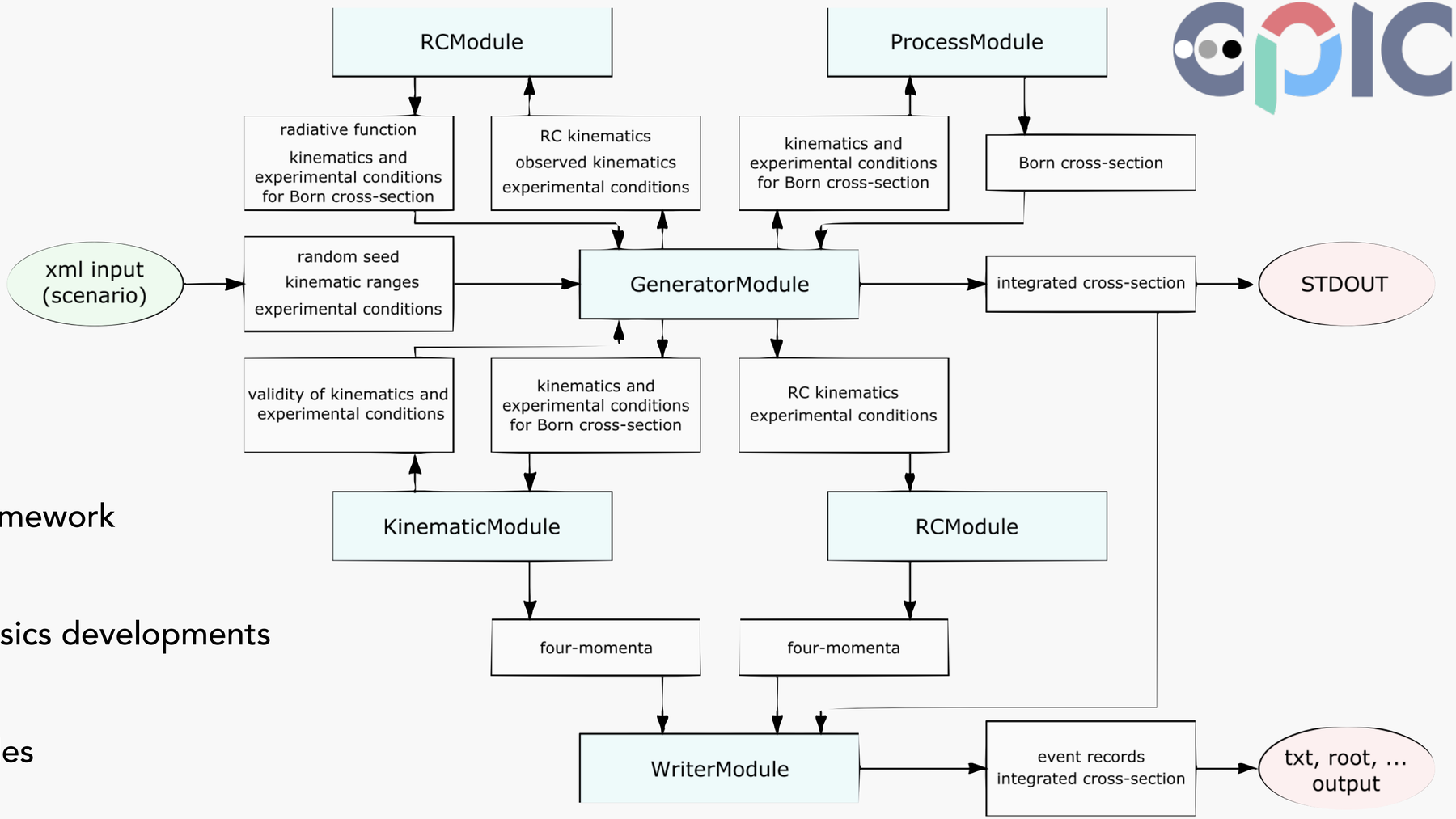
  brings all processes (DVCS, TCS, DVMP, etc.) implemented in PARTONS
- modular:

  built for maximum flexibility and simplicity.
- uses rigorous coding practices and modern C++ paradigms
- highly maintainable

  engineered for a 20+ year lifespan with comprehensive documentation



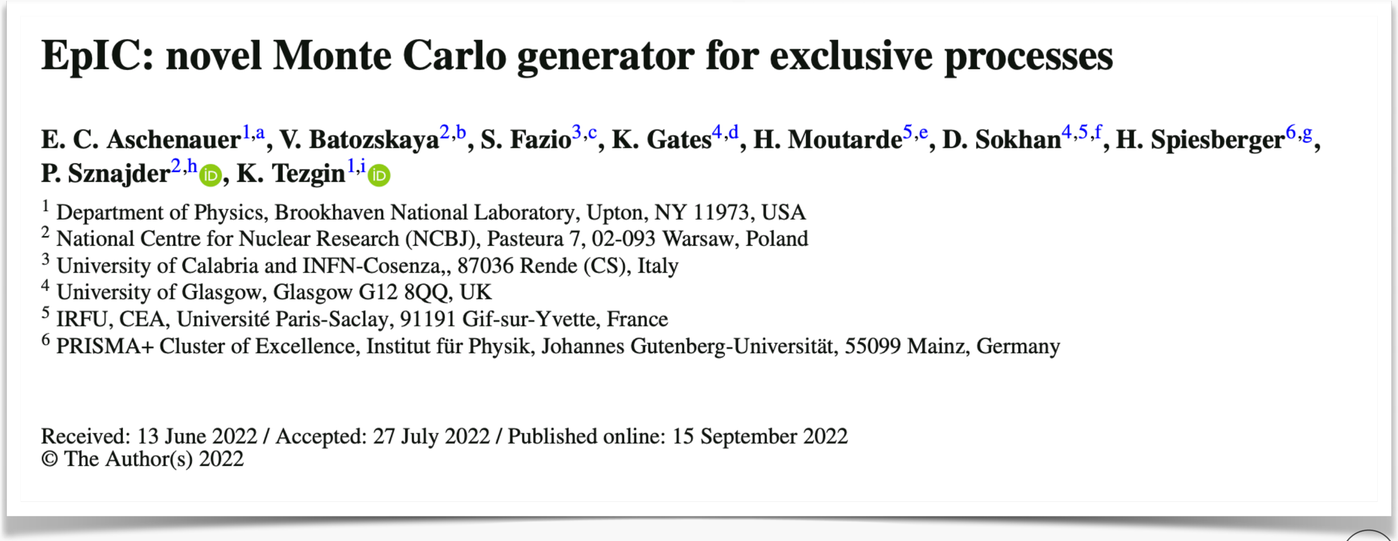
EpIC MC generator



- PARTONS foundation:
  built directly on the PARTONS framework
- modular architecture:
  simplifies the addition of new physics developments
- radiative corrections:
  includes dedicated, built-in modules
- FOAM integration:
  for the random probing of cross-sections
- flexible output
  supports HepMC3 and Pythia formats (with easy extension to new formats)

EpIC MC generator

- Licensing:
  distributed as an open-source project
- Main Website & Source Code:
  https://pawelsznajder.github.io/epic
  https://github.com/pawelsznajder/epic
- Available as a Docker image:
  https://hub.docker.com/repository/docker/partons/epic
- Reference publication:
  Eur. Phys. J. C 82 (2022) 9, 819
- Version 1.1.8 available
  a few bugs corrected, some minor improvements
- Processes included:
  DVCS, TCS, DDVCS, DVMP, and GAM2



EpIC: novel Monte Carlo generator for exclusive processes

E. C. Aschenauer[1,a], V. Batozskaya[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]

[1] Department of Physics, Brookhaven National Laboratory, Upton, NY 11973, USA
[2] National Centre for Nuclear Research (NCBJ), Pasteura 7, 02-093 Warsaw, Poland
[3] University of Calabria and INFN-Cosenza,, 87036 Rende (CS), Italy
[4] University of Glasgow, Glasgow G12 8QQ, UK
[5] IRFU, CEA, Université Paris-Saclay, 91191 Gif-sur-Yvette, France
[6] PRISMA+ Cluster of Excellence, Institut für Physik, Johannes Gutenberg-Universität, 55099 Mainz, Germany

Received: 13 June 2022 / Accepted: 27 July 2022 / Published online: 15 September 2022

OPEN DATABASE

- comprehensive data storage:

  accommodates experimental, lattice QCD, and theoretical data

  a clear distinction between actual and pseudo-data
- tailored YAML format:

  uses human-readable YAML with predefined types for units and observables,

  optimized specifically for GPD physics
- dual-language interfaces:

  features native Python and C++ interfaces
- GitHub-backed ecosystem:

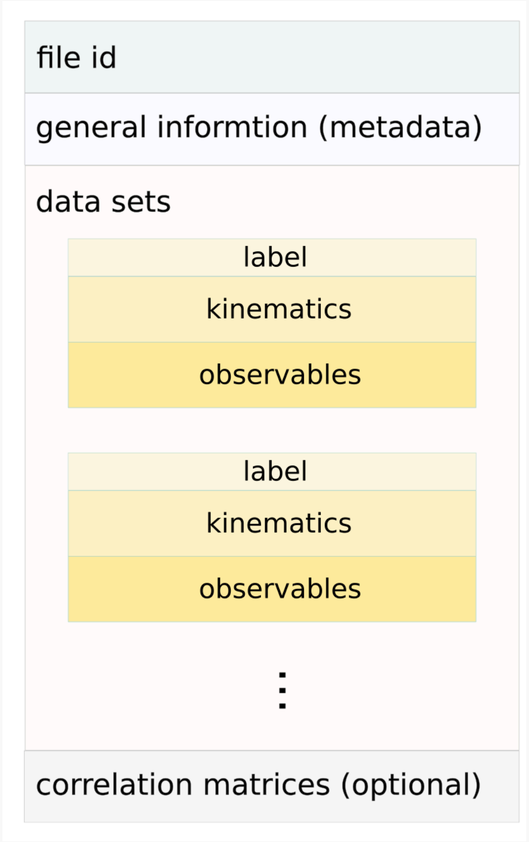
  leverages GitHub for version control, CI/CD pipelines, user communication, and team management
- scalable architecture:

  built to allow seamless future transfer to external databases (e.g., MySQL) to bypass hosting storage limits.

Open database

```yaml
---
uuid: 6pDJMSey

general_info:
    date: 2024-07-25
    data_type: DVCS
    collaboration: CLAS
    reference: https://arxiv.org/pdf/hep-ex/0107043.pdf
    conditions:
        lepton_beam_type: e-
        lepton_beam_energy: 4.25
        hadron_beam_type: p

data:

    - data_set:

        label: "none_dep"

        kinematics:
            name: [xB, t, Q2]
            unit: [none, GeV2, GeV2]
            value:
                - [0.19, -0.19, 1.25]
        observable:
            name: [ALUSin1Phi, ALUSin2Phi]
            unit: [none, none]
            value:
                    - [0.202, -0.024]
            stat_unc:
                    - [0.028, 0.021]
            sys_unc:
                    - [0.013, 0.009]
```

- general structure of data files:



- many more features available, including:
  - kinematic bins
  - unsymmetrical uncertainties
  - scale uncertainties
  - partial systematic uncertainties and correlations between them

Open database

- Licensing:
  distributed as an open-source project
- Main Website & Source Code:
  https://github.com/opengpd/gpddatabase
  https://opengpd.github.io/gpddatabase
- Available as a Python module:
  https://pypi.org/project/gpddatabase
- Reference publication:
  Eur. Phys. J. C 85 (2025) 8, 838
- Version 1.1.3 available
  a few bugs corrected, some minor improvements
- Data included:
  all DVCS data on proton
  some DVCS EIC pseudo-data
  lattice-QCD data by Hadstruc Coll.

Open database for GPD analyses

V. D. Burkert[1], A. Camsonne[1], P. Chatagnon[1,2], K. Cichy[3], M. Constantinou[4], H. Dutrieux[5], I. M. Higuera-Angulo[1,a], C. Mezrag[2], D. Richards[1], P. Sznajder[6]

[1] Thomas Jefferson National Accelerator Facility, 12000 Jefferson Avenue, 23606 Newport News, VA, USA
[2] Irfu, CEA, Université Paris-Saclay, F-91191 Gif-sur-Yvette, France
[3] Faculty of Physics and Astronomy, Adam Mickiewicz University, ul. Uniwersytetu Poznańskiego 2, 61-614 Poznań, Poland
[4] Department of Physics, Temple University, Philadelphia 19122-1801, USA
[5] Physics Department, William & Mary, Williamsburg 23187, USA
[6] National Centre for Nuclear Research, 02-093 Warsaw, Poland

Received: 11 April 2025 / Accepted: 9 July 2025

Summary

- Standardizing GPD research

  transitioning the community from isolated tools to a unified, open-source framework
- PARTONS

  core modular framework for robust GPD modeling and evaluation
- EpIC

  universal, long-term event generator for next-generation facilities (EIC, JLab)
- Open Database

  flexible, YAML-based data storage seamlessly bridging theory and experiment
- Access & Collaboration

  standards of open-source and open-science promoted