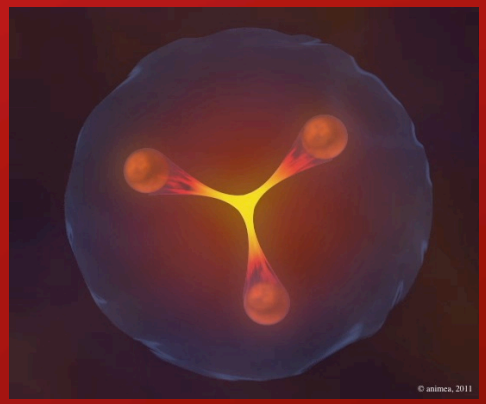
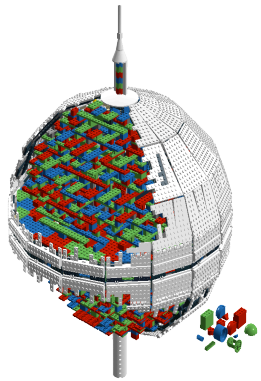
DE LA RECHERCHE À L'INDUSTRIE

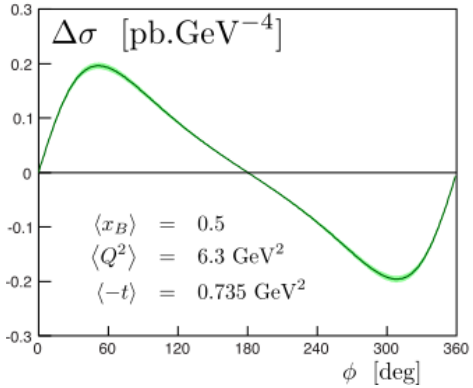
cea

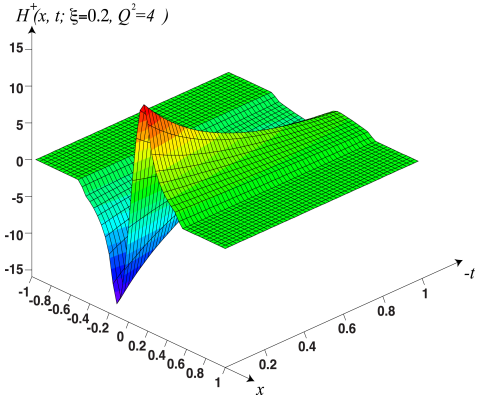


www.cea.fr

Status of PARTONS







3DPartons Week | Hervé MOUTARDE

université PARIS-SACLAY

Oct. 26, 2022

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

Virtual access infrastructure (2019-23).

From independent research initiatives to common tools.

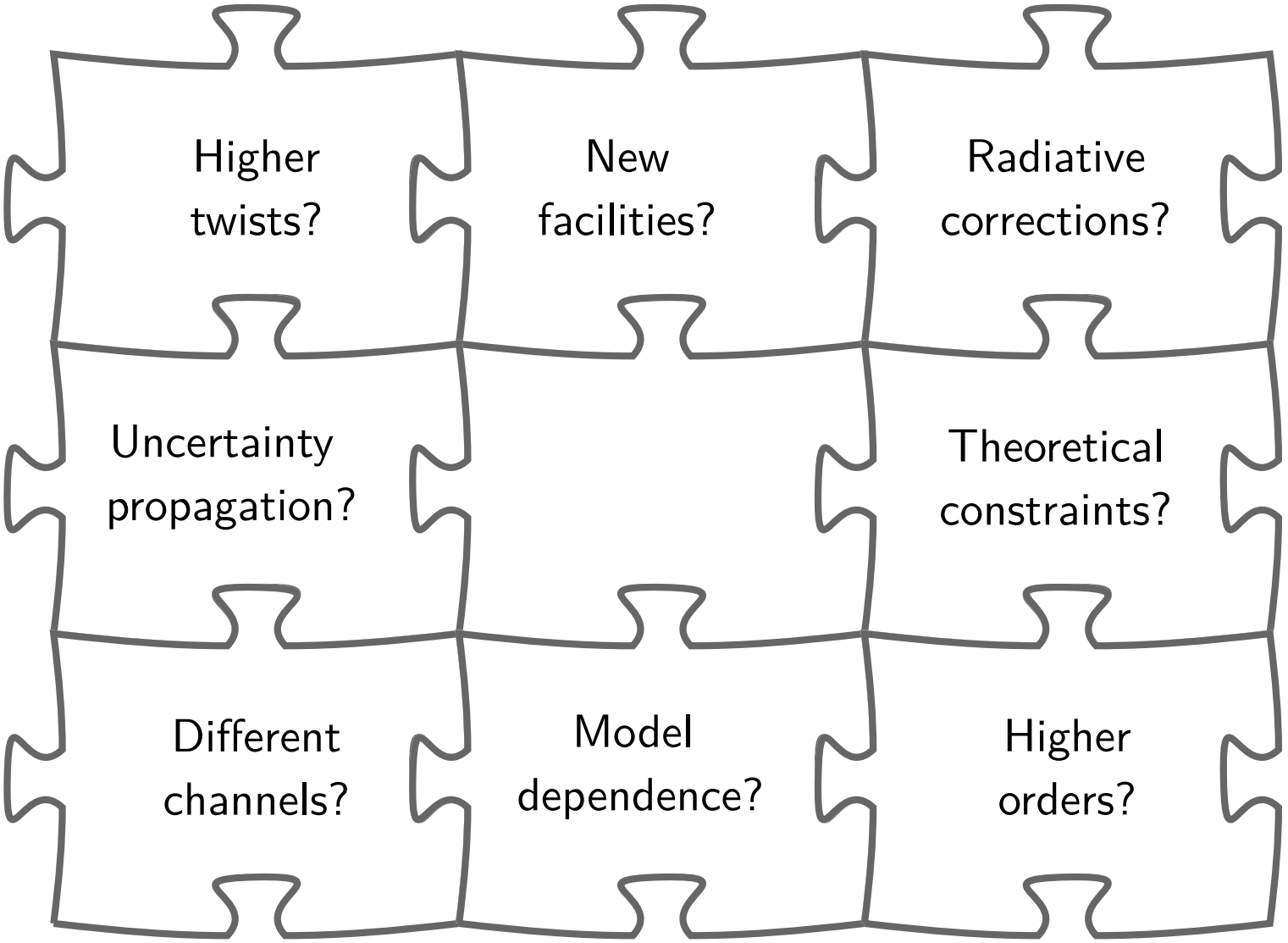
- 3DPartons gives access to **open-source code** necessary for high precision phenomenology in the field of 3D hadron structure, with a specific emphasis on GPDs and TMDs.
- It consists of **several libraries organized within a fully modular and open architecture**, which allows the possibility of permanent improvement by the addition of new models, channels or theoretical refinements.

Aims

1. Make sure we can use existing codes **together**.
2. **Mutualize** common tools.
3. **Save time** for future developments by building on existing tools or solutions.
4. **Devise common solutions** for similar problems from **different subfields**.

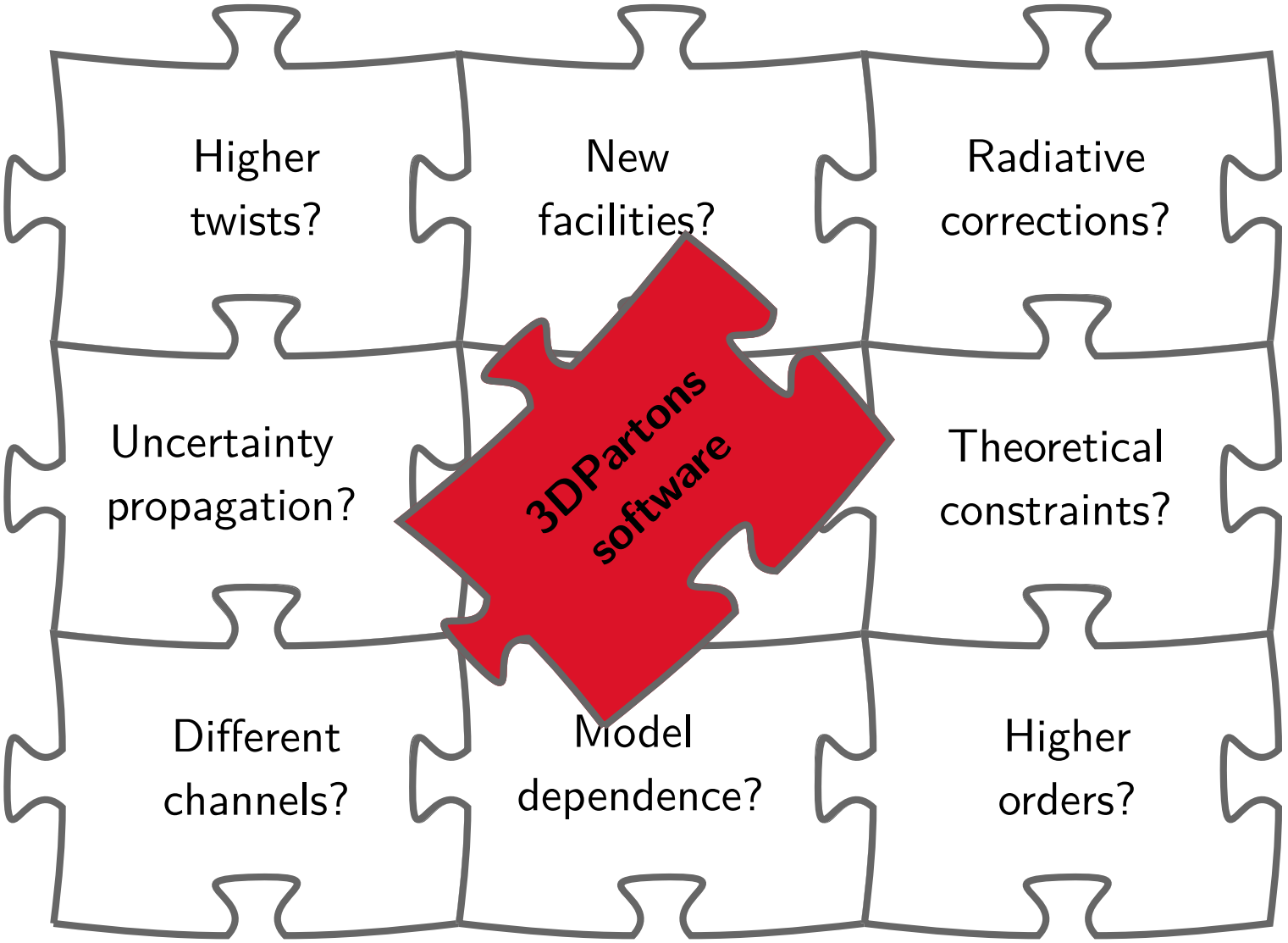
Software for 3D hadron structure.

Different questions to be answered with the same tools.



Software for 3D hadron structure.

Different questions to be answered with the same tools.

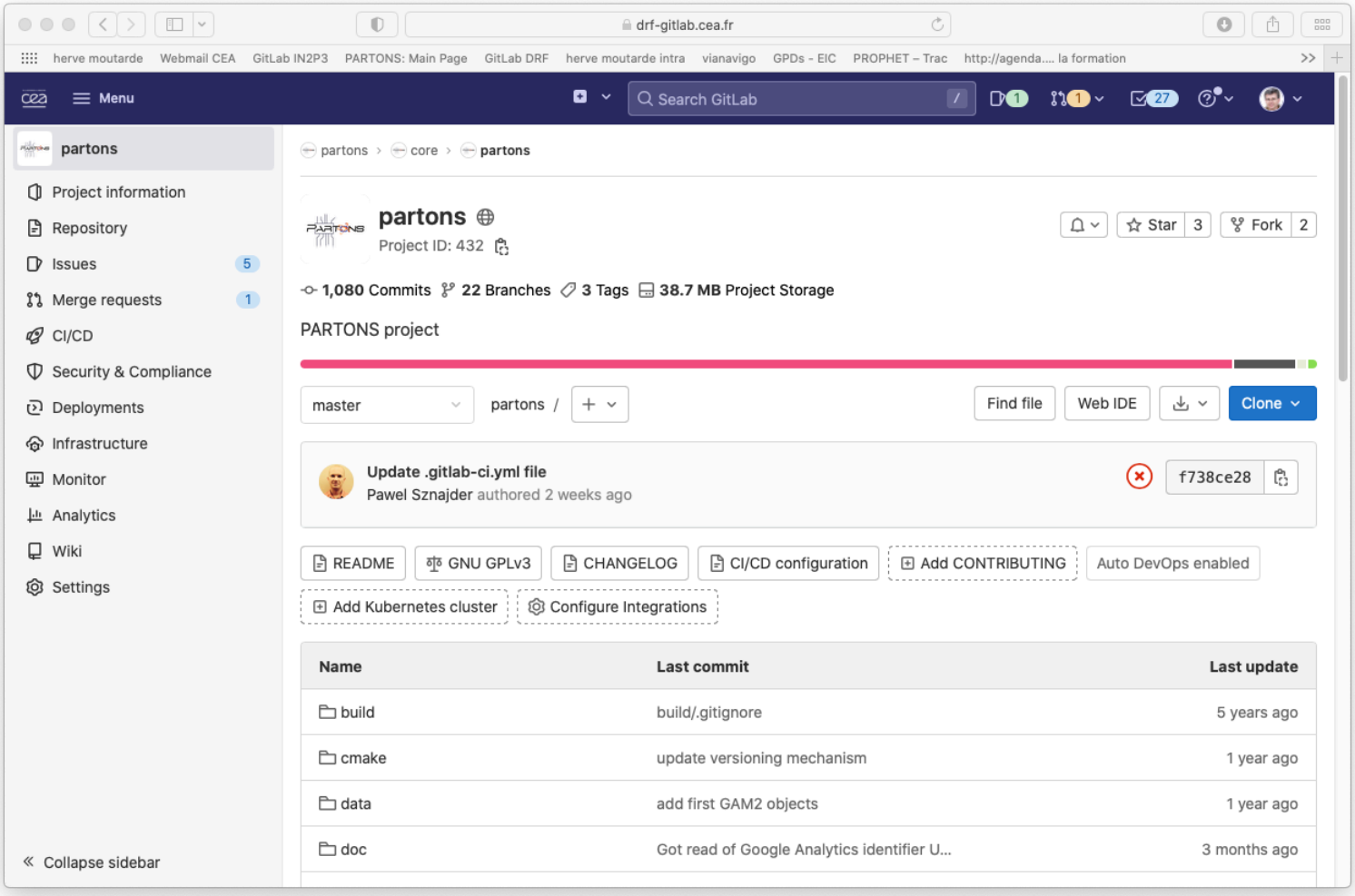


PROPHET.

Platform for **R**epresenting the **O**rganization of **P**artons inside **H**adrons and **E**xperimental **T**omographies.

1. Comprehensive **database of experimental results**.
2. Comprehensive **database of theoretical predictions**.
3. **Fitting engine**.
4. **Propagation** of statistic and systematic **uncertainties**.
5. **Visualizing software** to compare experimental results and model expectations.
6. Connection to **experimental set-up descriptions** to design new experiments.
7. **Interactive website** providing free access to model and experimental values.

A 10-year perspective.
From the original idea to the current strategy.



Development and dissemination

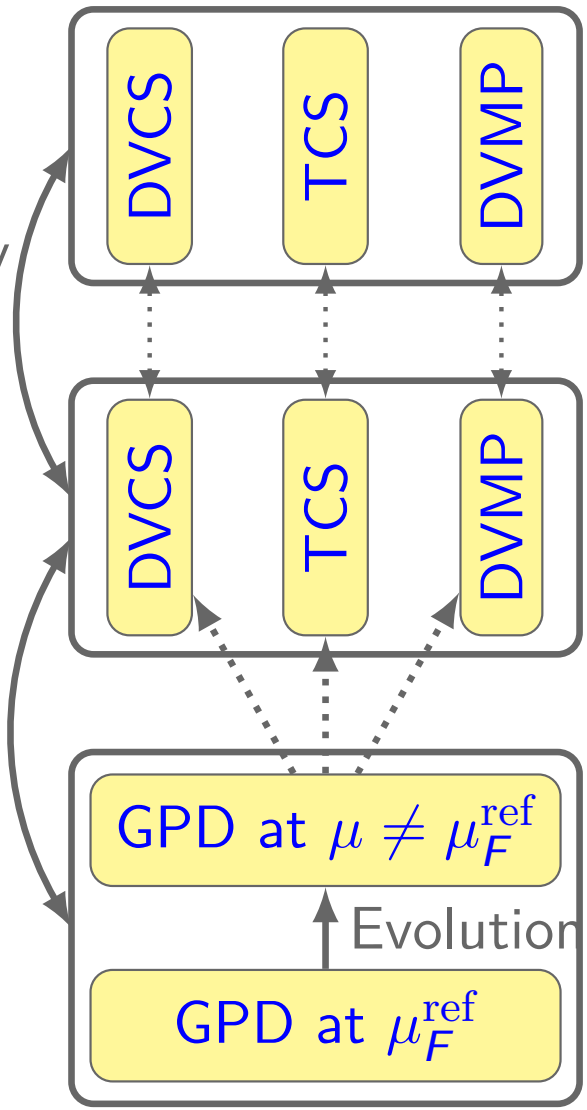
Computing chain design.

EIC perspective considered at the time of design.

Full processes
Experimental data and phenomenology

Small distance
Computation of amplitudes

Large distance
First principles and fundamental parameters



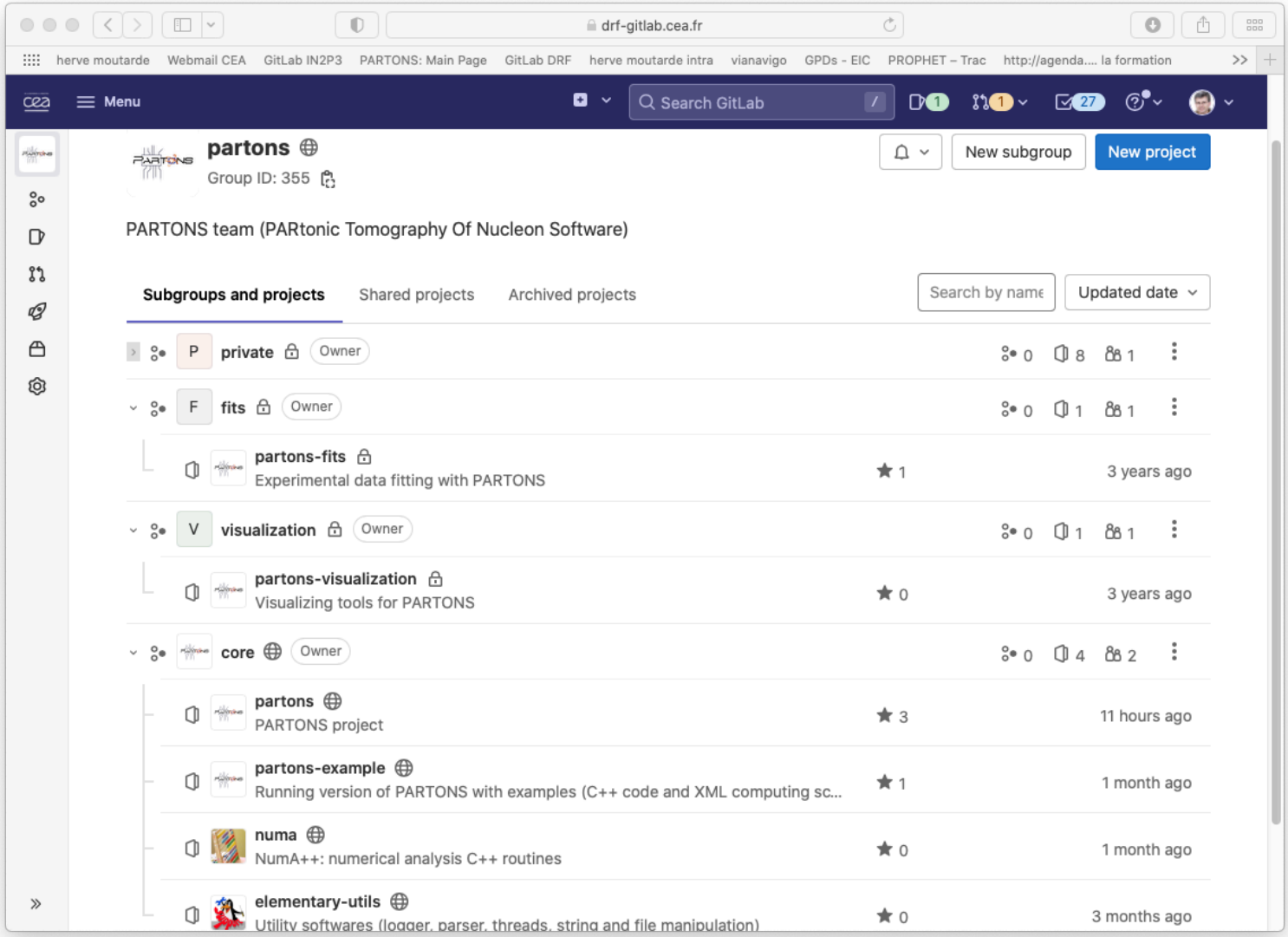
PARtonic **T**omography **O**f **N**ucleon **S**oftware

- Perturbative approximations.
- Physical models.
- Fits.
- Numerical methods.
- Accuracy and speed.

Berthou *et al.* (2015)

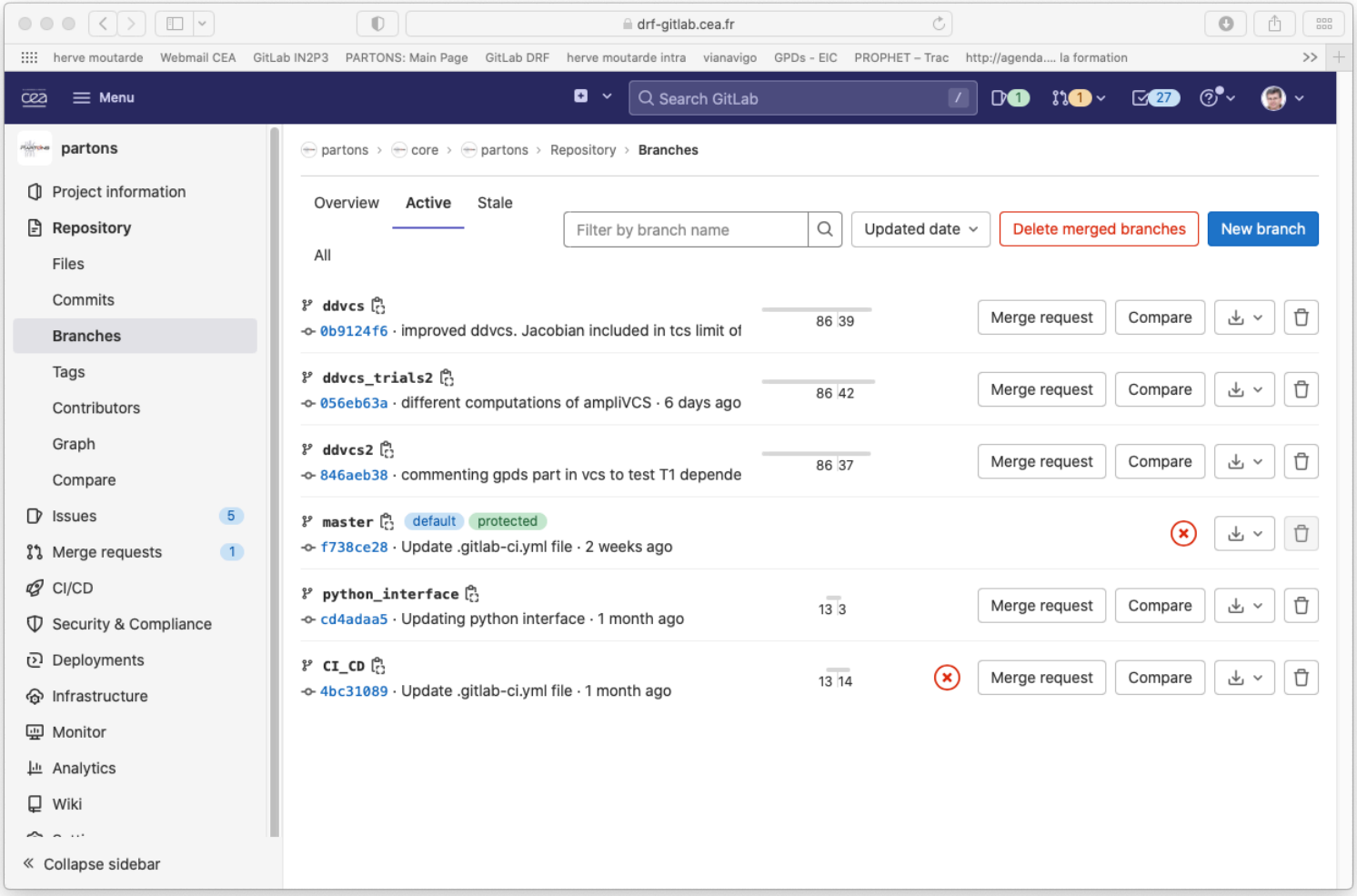
A collection of tools.

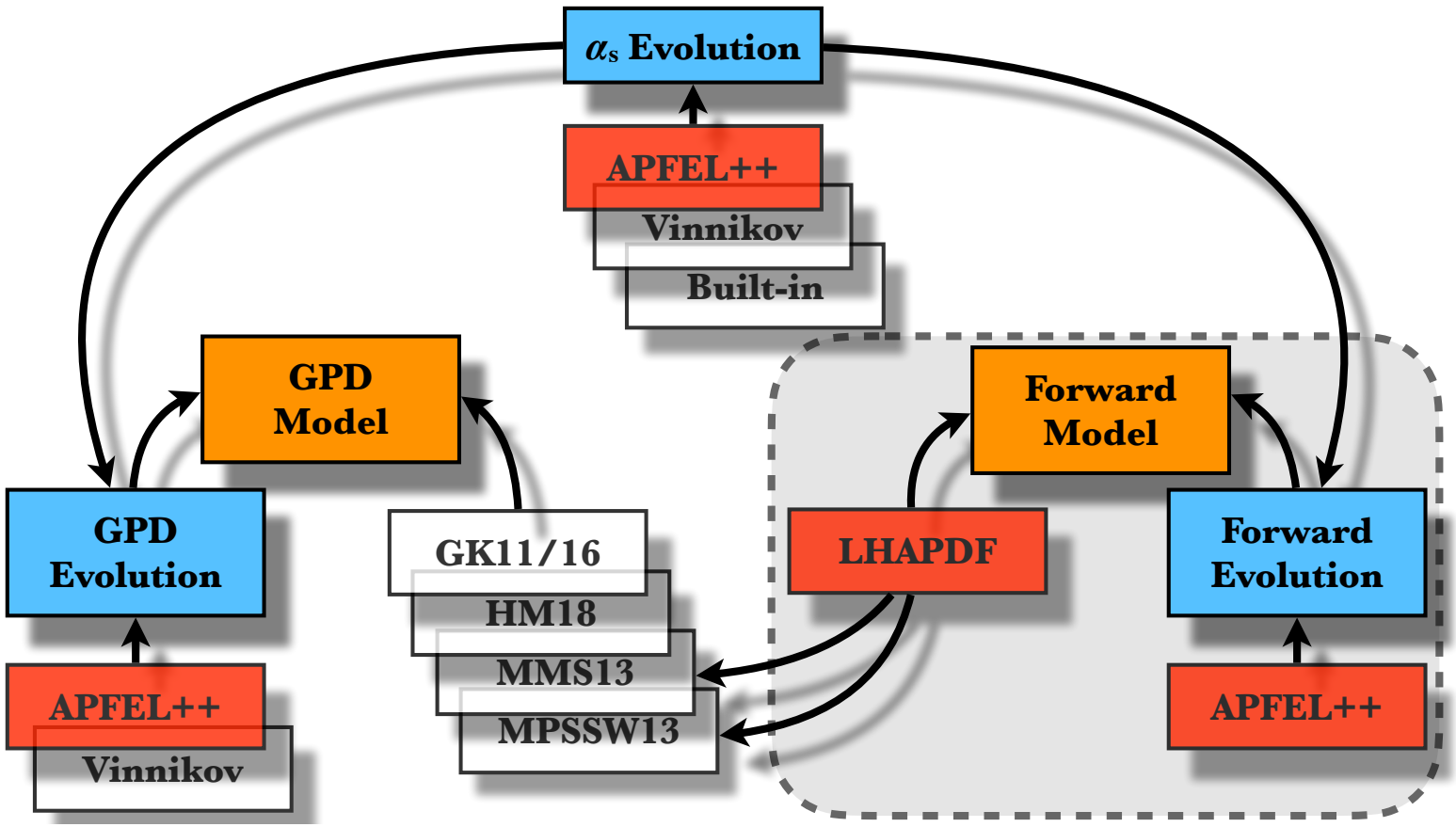
PARTONS is not just a GPD model but a complete framework.



Current active branches.

Physics and new functionalities for users and developpers.





Interfaces to external libraries.

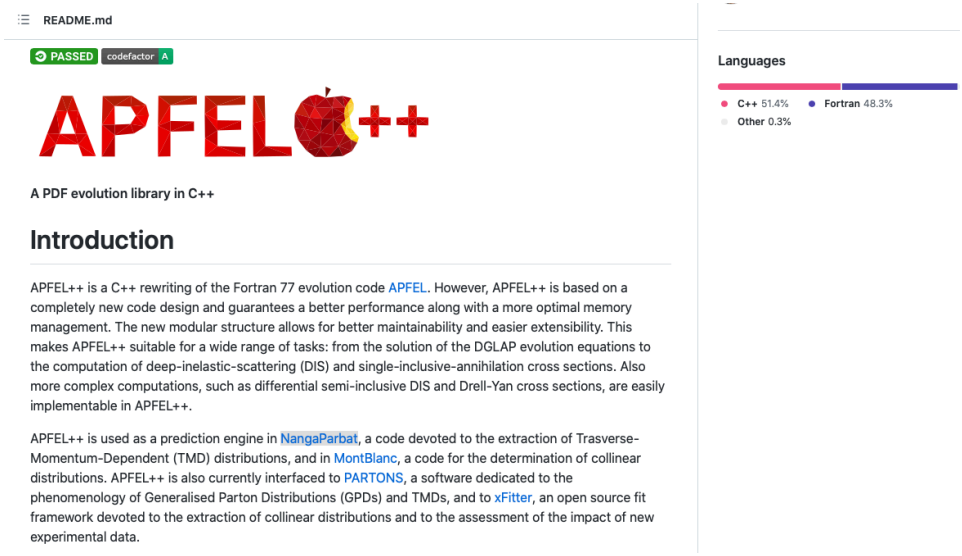
Benefiting of existing state-of-the-art libraries.


```
18  <!-- Define physics assumptions -->
19  <computation_configuration>
20
21    <!-- Select collinear distribution model -->
22    <module type="CollinearDistributionModule" name="CollinearDistributionLHAPDF">
23
24      <!-- Indicate name of the LHAPDF set, member, and type -->
25      <param name="setName" value="CT14nnlo" />
26      <param name="member" value="0" />
27      <param name="collinear_distribution_type" value="UnpolPDF"/>
28
29      <!-- Select collinear distribution evolution model and its parameters -->
30      <module type="CollinearDistributionEvolutionModule" name="CollinearDistributionEvolutionApfel">
31        <param name="muF2Ref" value="1.677025" />
32        <param name="qcd_order_type" value="NNLO" />
33        <param name="collinear_distribution_type" value="UnpolPDF" />
34        <param name="thresholds" value="0 0 0 1.3 4.75 172" />
35        <param name="masses" value="0 0 0 1.3 4.75 172" />
36        <param name="subgridNodes" value="100 60 50 50" />
37        <param name="subgridLowerBounds" value="0.0001 0.1 0.6 0.8" />
38        <param name="subgridInterDegrees" value="3 3 3 3" />
39        <param name="tabNodes" value="100" />
40        <param name="tabLowerBound" value="1" />
41        <param name="tabUpperBound" value="1000" />
42        <param name="tabInterDegree" value="3" />
43
44        <!-- Select alpha_s model -->
45        <module type="RunningAlphaStrongModule" name="RunningAlphaStrongVinnikov">
46        </module>
47      </module>
48    </module>
49  </computation_configuration>
```

Towards GPD evolution with APFEL++.

x-space evolution publicly available (and documented).

- Evolution code for PDFs, GPDs and TMDs.
- APFEL++ numerically solves evolution equations in x-space.
- Fully modular.
- Heavy quark threshold crossing.


README.md

PASSED codefactor A

APFEL++

A PDF evolution library in C++

Introduction

APFEL++ is a C++ rewriting of the Fortran 77 evolution code APFEL. However, APFEL++ is based on a completely new code design and guarantees a better performance along with a more optimal memory management. The new modular structure allows for better maintainability and easier extensibility. This makes APFEL++ suitable for a wide range of tasks: from the solution of the DGLAP evolution equations to the computation of deep-inelastic-scattering (DIS) and single-inclusive-annihilation cross sections. Also more complex computations, such as differential semi-inclusive DIS and Drell-Yan cross sections, are easily implementable in APFEL++.

APFEL++ is used as a prediction engine in NangaParbat, a code devoted to the extraction of Trasverse-Momentum-Dependent (TMD) distributions, and in MontBlanc, a code for the determination of collinear distributions. APFEL++ is also currently interfaced to PARTONS, a software dedicated to the phenomenology of Generalised Parton Distributions (GPDs) and TMDs, and to xFitter, an open source fit framework devoted to the extraction of collinear distributions and to the assessment of the impact of new experimental data.

Languages

C++ 51.4% Fortran 48.3%

Other 0.3%

✍ Bertone *et al.* (2022)

ℹ See Valerio's talk on Friday and Hervé's talk on Wednesday

Enlarging the ecosystem.

EpIC: novel MC generator for exclusive processes.

EpIC: Monte Carlo generator for exclusive processes

This page:
about
instalation
usage
license
acknowledgements
contact

View project on GitHub:
link

View Doxygen documentation:
link

View reference article:
arXiv inspire

Hosted on GitHub Pages
Theme based on minimal
2022-05-05 13:20 UTC

About

What is EpIC?

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

We refer to PARTONS documentation of modules for information on theory developments (like GPD models) available for the evaluation of Born cross-sections.

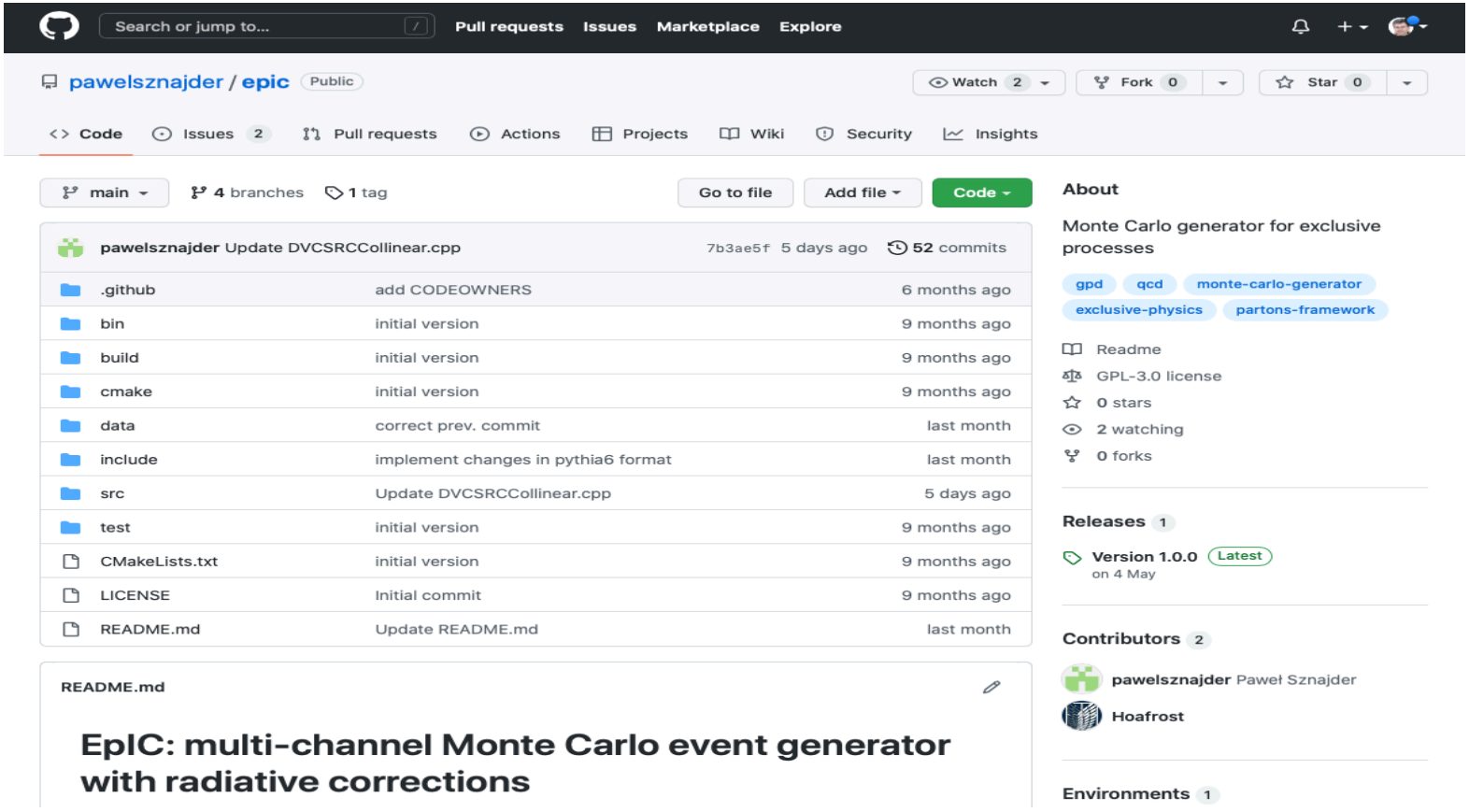
EpIC is written in C++. It utilities paradigms of the modular programming. Each step of the generation of Monte Carlo events is well distinguished from the others, allowing for the encapsulation of specific pieces of the code into easy-to-develop modules. The flow of data between the modules is supervised by services.

✍ Aschenauer *et al.* (2022)

ℹ See Kemal's, Daria's and Salvatore's talks on Wednesday

Enlarging the ecosystem.

EpIC: novel MC generator for exclusive processes.



Enlarging the ecosystem beyond GPDs.
A common framework for TMD and GPD studies.

.gitignore	test SIDIS	7 months ago
CMakeLists.txt	Fixed typo	5 months ago
LICENSE	Adding LICENSE	2 years ago
README.md	Update README.md	6 months ago

Languages

HTML 98.4% C++ 1.4%
Python 0.2% CSS 0.0%
CMake 0.0% Shell 0.0%

README.md

Nanga Parbat: a TMD fitting framework

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

See Valerio's talk on Wednesday

Enlarging the ecosystem beyond GPDs.
A common framework for TMD and GPD studies.

CMakeLists.txt	Uploading the code	6 months ago
README.md	Update README.md	6 months ago

README.md

MontBlanc

`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.

The FF sets in the LHAPDF format for both positive and negative pions as well as for their sum can be found here.

Languages

Jupyter Notebook 99.4% Other 0.6%

See Valerio's talk on Wednesday

PROGRAM SUMMARY

Computer for which the program is designed and others on which it is operable: any with standard C++, tested on Linux and Mac OS systems

Programming Language used: C++

High-speed storage required: No

Separate documentation available: No

Keywords: QCD, TMD factorization, high-energy factorization, TMD PDFs, TMD FFs, unintegrated PDFs, small-x physics.

Other programs used: LHAPDF (version 6) for access to collinear parton distributions, ROOT (any version $>$ 5.30) for plotting the results

Download of the program: `http://tmdlib.hepforge.org`

Unusual features of the program: None

Contacts: H. Jung (hannes.jung@desy.de), A. Bermudez Martinez (armando.bermudez.martinez@desy.de)

Citation policy: please cite the current version of the manual and the paper(s) related to the parameterization(s).

See Valerio's talk on Wednesday

GPD channels in PARTONS.

Contributions provided by (at least part of) the framework (1/2).

- Exclusive diphoton photoproduction $\gamma p \to \gamma\gamma p$
  - Implementation at LO and NLO.
  - Direct treatment of $i\epsilon$-prescription and MC multi-dimensional integrations.
  - Demanding: heavy use of a computing farm.

ℹ See Lech's talk on Wednesday

✍ Grocholski *et al.* (2021)

- DDVCS $\gamma^* p \to \gamma^* p$
  - Preliminary integration of cross-sections and LO CFFs.
  - Possible mismatch in original papers and recalculation of analytic expressions partially done.

ℹ See Victor's talk on Friday

GPD channels in PARTONS.

Contributions provided by (at least part of) the framework (2/2).

- DVCS off a pion target $\gamma^*\pi \to \gamma\pi$
  - NLO CFFs + LO evolution + various GPD models.
  - Ready for phenomenology with EIC/EIcC-focused papers.

✍ Morgado Chavez *et al.* (long) (2021)

✍ Morgado Chavez *et al.* (short) (2021)

- Ultra-peripheral collisions and GPDs

ℹ See Jakub's talk on Wednesday

- GPD modeling with neural networks

ℹ See Pawel's talk on Thursday

- GPD modeling from double distributions

ℹ See Pietro's talk on Friday

Python interface.

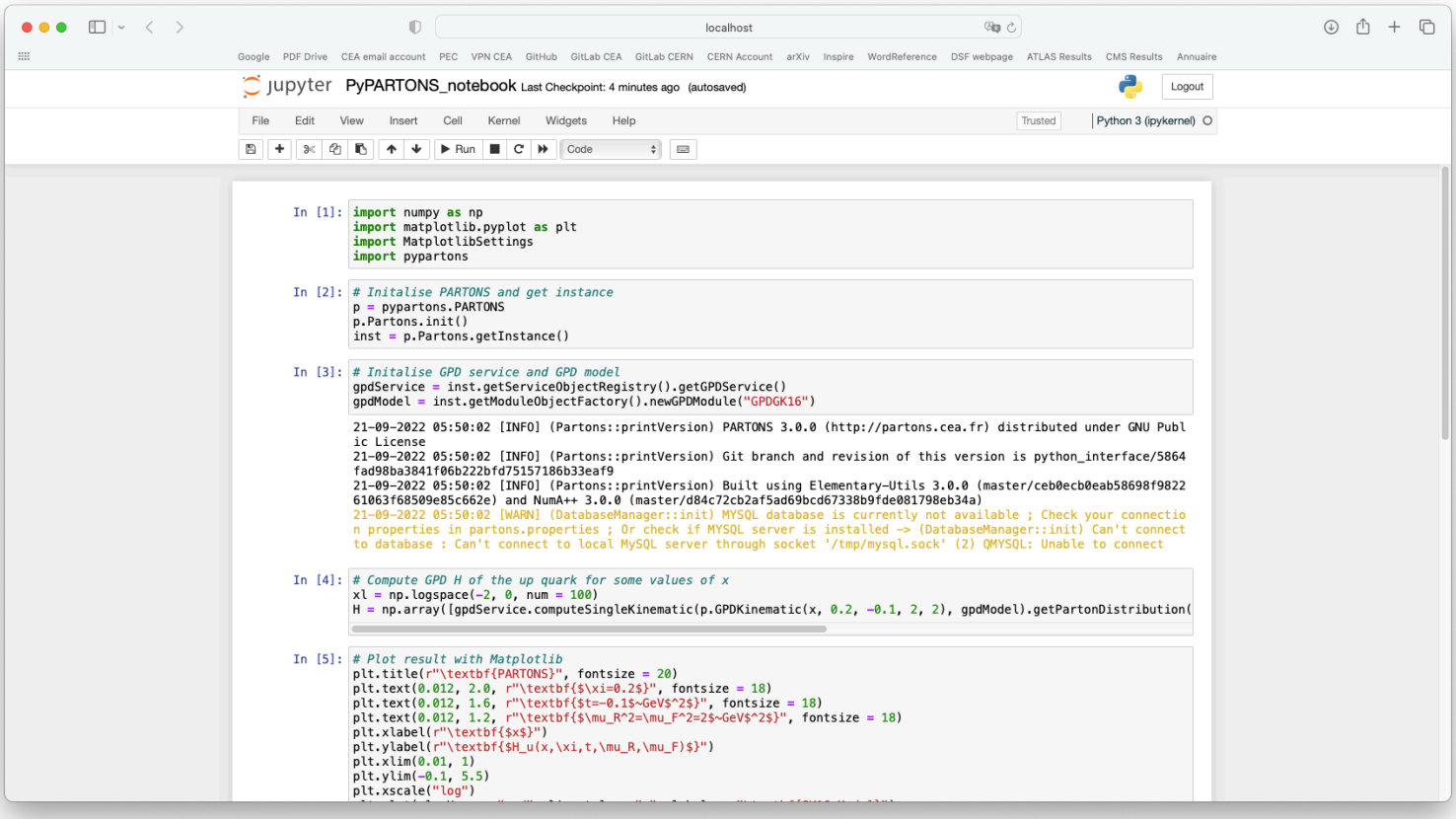
Python wrapper for PARTONS.

- Simplify connection to **popular libraries** on *e.g.*
  - machine learning
  - plotting
  - statistical data analysis
- Convenient for a **wide community of new users**, in particular PhD students of postdocs.
- **Facilitates dissemination of research** through *e.g.* Jupyter notebooks.
- Remaining work on documentation and dissemination before public release

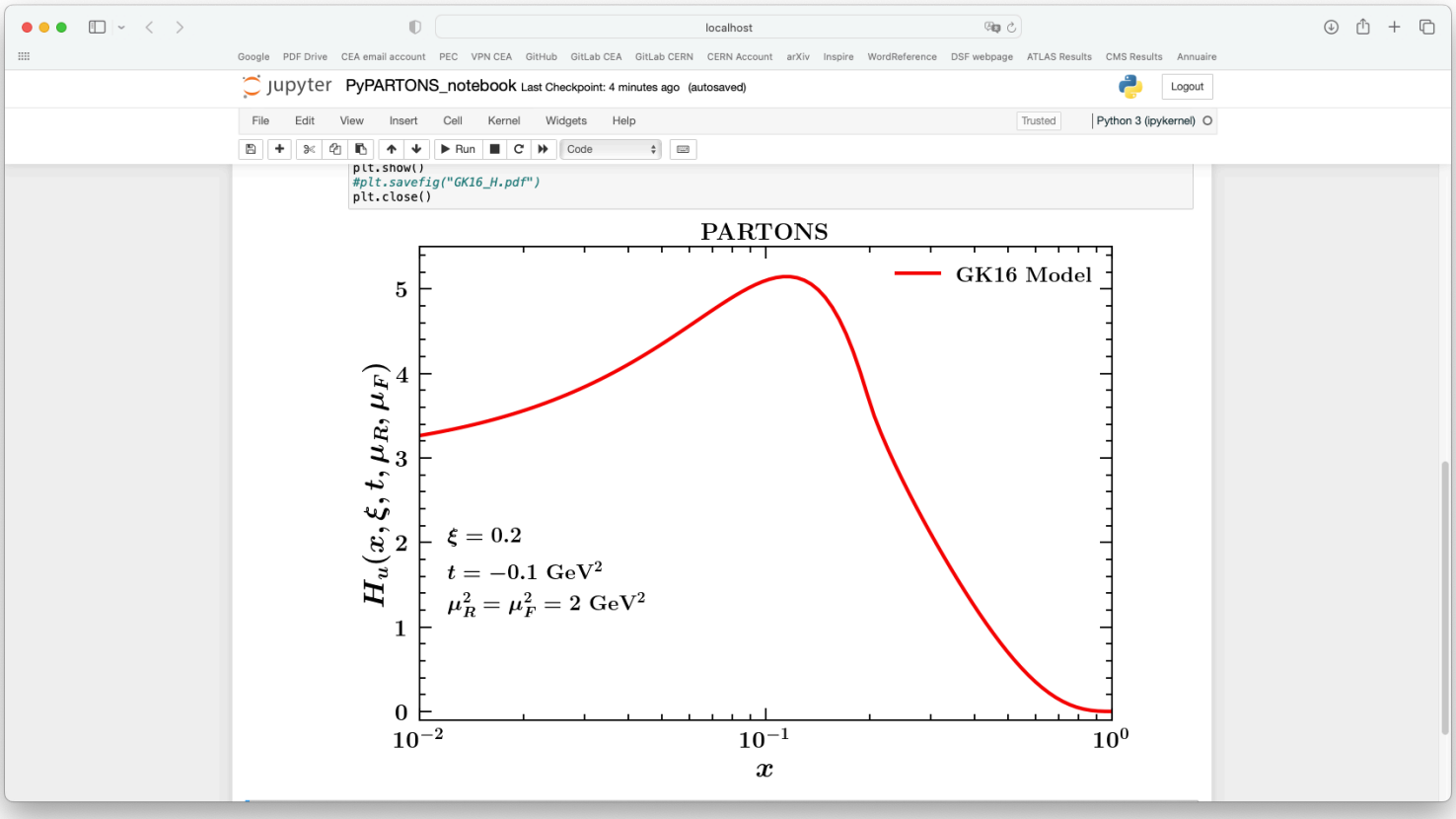
Python interface.

Python wrapper for PARTONS.

Status of PARTONS



Python interface.
Python wrapper for PARTONS.



What is PARTONS?

PARTONS is a software framework dedicated to the phenomenology of 3D hadron structure, in particular Generalized Parton Distributions (GPDs) and Tranverse 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 (EIcC). 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.

The virtual access infrastructure 3DPartons has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824093.

NangaParbat is a fitting framework for the determination of TMDs from experimental data, like for example Drell-Yan measurements. The corresponding fitted TMDs can also be accessed through TMDlib. MontBlanc is a fitting framework for the determination of FFs from experimental data for single inclusive annihilation (SIA) and semi inclusive deep inelastic scattering (SIDIS). xFitter is a fitting framework for the determination of collinear distributions from a vast body of experimental channels. PARTONS, NangaParbat, MontBlanc and xFitter share the common feature of being interfaced to APFEL++ which solves QCD evolution equations for various parton distributions, and to LHAPDF which provides access to modern PDF sets.

EpIC is a generic Monte Carlo event generator for exclusive processes. It is fully compatible with PARTONS: it can be used to generate events for all exclusive processes and all models provided by PARTONS.

Official release of PARTONSv3.

Simultaneous releases of EpIC and PARTONS.

CHANGELOG.md 1.92 KB

3.0

Updates:

- improve configuration with CMake
  - Qt is version either Qt 4 or 5 can be used
  - printing of versions improved
  - automatic population of environment_configuration.dat file
- add new GPD types, namelly for transversity nad higher-twist GPDs
- add Docker configuration file with description
- remove MSTW files (now one can chose PDF with LHAPDF)

Physics:

- addition of new exclusive production channel - DVMP
- addition of objects for collinear distributions, including services, DB connection, evolution
- addition of APFEL interface
- addition of LHAPDF interface
- addition of subtraction constant module related to Eur.Phys.J.C 81 (2021) 4, 300
- addition of GPD module related to Phys.Rev.D 103 (2021) 11, 114019
- addtion of GPD model used in Phys. Lett. B 805 (2020) 135454
- addition of few observable modules, like for the evaluation of backward-forward asymmetry for TCS, or total cross-section for DVCS
- addition to new runnung coupling and threshold modules, mostly related to APFEL

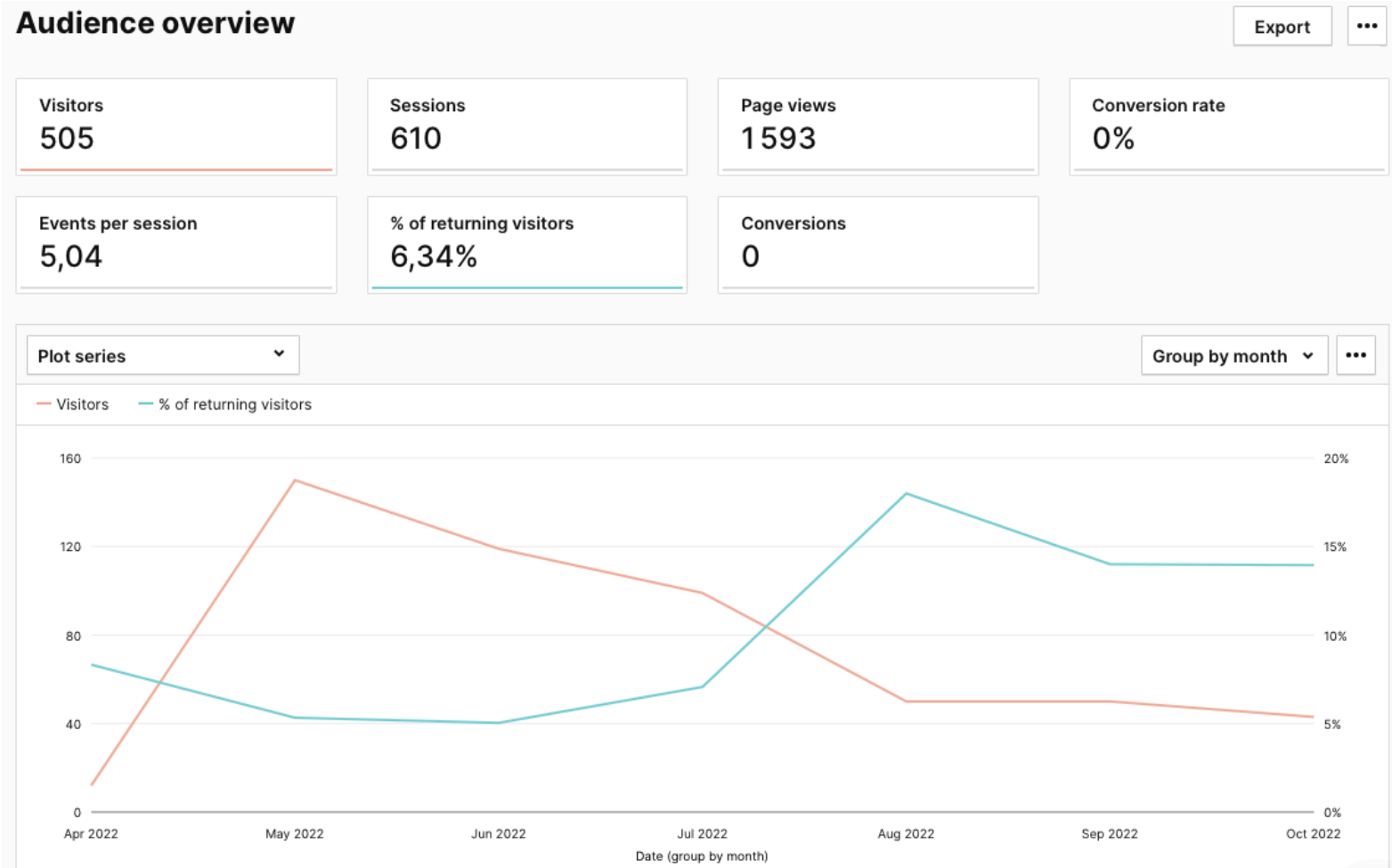
Geographical repartition of users

Continent	Visitors	Sessions	Bounce rate	Goal conversions	Goal conversion rate	Sum of goal revenue
	505	**610**	**63,11%**	**0**	**0%**	
Europe	322 (63,76%)	367 (60,16%)	60,22%	0	0%	No data
North America	105 (20,79%)	146 (23,93%)	71,92%	0	0%	No data
Asia	74 (14,65%)	91 (14,92%)	60,44%	0	0%	No data
Africa	4 (0,79%)	4 (0,66%)	75%	0	0%	No data
South America	2 (0,4%)	2 (0,33%)	50%	0	0%	No data

Most interested countries

	Country	Visitors	Sessions	Bounce rate	Goal conversions	Goal conversion rate	Sum of goal revenue
		505	**610**	**63,11%**	**0**	**0%**	
☐	France	175 34,65%	175 28,69%	71,43%	0	0%	No data
☐	United States	102 20,2%	142 23,28%	72,54%	0	0%	No data
☐	Germany	50 9,9%	60 9,84%	21,67%	0	0%	No data
☐	Spain	31 6,14%	31 5,08%	38,71%	0	0%	No data
☐	Russia	24 4,75%	24 3,93%	100%	0	0%	No data
☐	China	23 4,55%	27 4,43%	59,26%	0	0%	No data
☐	Poland	20 3,96%	49 8,03%	51,02%	0	0%	No data
☐	South Korea	13 2,57%	18 2,95%	44,44%	0	0%	No data
☐	India	9 1,78%	9 1,48%	88,89%	0	0%	No data
☐	Italy	7 1,39%	9 1,48%	77,78%	0	0%	No data

Analytics



Access to the website

	Page title	Page views	Unique page views	Entries	Page bounce rate	Average time on page	Exit rate
		1 593	**1 119**	**606**	**63,53%**	**2m 51s**	**100%**
☐	PARTONS: Main Page	528 33,15%	377 33,69%	344 56,77%	63,08%	1m 54s	75,2%
☐	PARTONS: Download PARTONS	344 21,59%	220 19,66%	129 21,29%	67,44%	6m 21s	74,29%
☐	PARTONS: Quick quide	63 3,95%	46 4,11%	9 1,49%	55,56%	5m 26s	43,48%
☐	PARTONS: Using PARTONS	60 3,77%	37 3,31%	15 2,48%	86,67%	3m 22s	50%
☐	PARTONS: User's guide	56 3,52%	35 3,13%	6 0,99%	33,33%	3s	8,57%
☐	PARTONS: Tutorials	48 3,01%	32 2,86%	1 0,17%	0%	9s	3,13%
☐	PARTONS: PARTONS with our provided virtual machine	47 2,95%	25 2,23%	6 0,99%	66,67%	2m 58s	52%
☐	PARTONS: Contact and support	39 2,45%	32 2,86%	2 0,33%	50%	2m 0s	15,63%
☐	PARTONS: PARTONS Namespace Reference	32 2,01%	20 1,79%	0 0%	0%	1m 14s	25%
☐	PARTONS: PARTONS on GNU/Linux	30 1,88%	27 2,41%	8 1,32%	50%	4m 34s	55,56%

Conclusion

Conclusion and prospects.

Better physics with better tools.

- Wide set of computing tools publicly available.
- Some unique physics studies made possible.
- Possible connections to lattice QCD and TMDs.
- Need for **multi-channel** analysis **beyond LO** on a **wide kinematic coverage**. EIC and EIcC much needed!
- The GPD deconvolution problem is **ill-posed**. **Huge sensitivity** to numerical noise or experimental uncertainties.

- Development of the **software ecosystem** PARTONS for 3D hadron structure studies.
- Need for **coordinated effort** involving fits, computing chains, continuum and lattice QCD to make the best from experiments.

Abbreviations

Abbreviations used in this presentation.

ANN	artificial neural network
APFEL	a PDF evolution library
DDVCS	double deeply virtual Compton scattering
DVCS	deeply virtual Compton scattering
DVMP	deeply virtual meson production
EIC	electron-ion collider
EIcC	electron-ion collider in China
FF	fragmentation function
GPD	generalized parton distribution
LO	leading order
NLO	next-to-leading order
PDF	parton distribution function
TCS	timelike Compton scattering
TMD	transverse momentum dependent PDF

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