NLOAccess for Horizon Europe

A Virtual Access to automated computations of hard-scattering observables in hadronic, particle and nuclear physics

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with the support of

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NLOAccess is a Virtual Access (VA) for the automated computation of hard-scattering observables up to NLO in perturbative QCD accessible online at https://nloaccess.in2p3.fr. It has been consolidated during the previous EU program, STRONG-2020 with IJCLab Orsay and UCLouvain as core members of the Consortium. NLOAccess gathered a large community[1] (currently 789 users from all over the world) with a wide range of interests, from high energy to hadron and nuclear physics, and expertise, from students to researchers and professors in Universities and Research Centers. It gives access to the online usage of widely-used codes such as HELAC-Onia and MadGraph5_aMC@NLO (MG) with simple automated procedures. For the first time, the full NLO version of MG was made accessible online. MG was further developed with features of interest for the hadron-physics community like the inclusion of asymmetric hadronic collisions. This effort was supported by EU by hiring colleagues holding a PhD in physics working as research engineers in IJCLab and UCLouvain. Despite not being funded by STRONG-2020, INFN Cagliari and WUT Warsaw were considerably involved in NLOAccess, and it is natural to include them now as beneficiaries for the current call to sustain our effort towards a reliable service to a wide community of users. NLOAccess was heavily used for dissemination actions: more than 60 talks, tutorials and hands-on sessions using NLOAccess were held, and 17 scientific papers and 5 proceedings were published to advertise its feature. 2 PhD theses were partly supported by NLOAccess and 5 other PhD students have worked or currently work on its development in WUT and IJCLab.

1. Research objectives

For Horizon Europe, our EU funding request, mainly for human resources for research engineers, for the VA NLOAccess is justified by five work packages (WP):

1. **WP1: maintenance of the e-infrastructure**: hardware, software for codes and cloud, the portal and its security, and the database. Given the large size of the user community, a specific effort is needed for a reliable service.
2. **WP2: extension of the e-infrastructure**: access to new technologies (GPUs), upgrade of MG to version 7 featuring optimised resource usage, inclusion of AI-based phase-space integrators (MadNIS, https://madnis.ai/), and exploration of credential transfer of the NLOAccess users for online access to remote HPC resources (IN2P3, INFN, CERN GRID, ...) for intensive computations for e.g. NNLO codes.
3. **WP3: online access to 5 new codes complementary to the existing codes**: (i) STARlight (https://github.com/STARlightsim/STARlight), (ii) SuperCHIC (https://superchic.hepforge.org/) to reach a new community of researchers on photon-induced relativistic-ion collisions, (iii-iv) 2 NLO codes for exclusive production of quarkonia with possible interface to the VA GPD-Portal, (v) 1 NLO code (INCNLO) for high-p_T hadrons in *pp* collisions using collinear fragmentation functions (FFs) at NLL with possible interface to the VA TMD-Portal and with an interface to a library of computed quarkonium FFs.
4. **WP4: 3 extensions of MG to new hadronic processes for online usage**: (i) *ep* and *eA* collisions via DIS for EIC, LHeC and FCC-eh communities, (ii) quarkonium production for the LHC, RHIC, EIC, FCC and fixed-target experiment communities and (iii) processes involving transverse-momentum dependent (TMD) distributions, also for the LHC, RHIC, EIC, FCC and fixed-target experiment communities;
5. **WP5: development of 5 new online tools for the hadronic and nuclear physics community** for an automated usage of diffractive PDFs, of resolved-photon PDFs through LHAPDF and of the centrality dependence of nuclear PDFs (or other cold nuclear effects on hard probes), for automated and transparent inclusion of photon-induced reactions in HEP MC codes with gamma-UPC (https://hshao.web.cern.ch/hshao/gammaupc.html) and for the production of reliable data-driven quarkonium samples in Pythia for the LHC, RHIC and the EIC. All these tools will be interfaced to MG and HO and will also be usable as standalone for third party codes.

Transversal objectives can be individuated for the WPs:

- While each WP will have its dissemination actions, there will be a global dissemination action for the entire VA.

[1] Starting from 60 users at the end of the Reporting Period 1 to 662 users at the end of the Reporting Period 5.

- Using the proposed NLOAccess tools, we wish to improve the reach to the ALICE, LHCb and EIC Communities, currently less involved in the usage of the four main codes mentioned (MG, HELAC-Onia, STARlight and SuperCHIC) although hard-scattering are usually used as baselines.
- We will also analyse the usage of NLOAccess in order to improve the VA, better meet the needs of the Community and tune the computer resources behind the VA. Indeed, some actions will optimise the usage of computing resources (GPU, AI, ...) while some extension will imply more resources.

2. Connection to Transnational Access infrastructures (TAs) and/or Virtual Access projects (VAs)

By essence, NLOAccess is of interest for any colleague in hadronic, particle and nuclear physics who is interested to obtain computations of hard scattering in perturbative QCD. This spanned an extremely wide range of actions within STRONG2020. As such, dedicated collaborative actions are already identified with:

- the **CERN TNA** where we had several meetings and where many colleagues are already using the codes accessible via NLOAccess. In addition, our GPU related task will be performed with a team at CERN.
- the **VA GPD Portal** & **TMD Portal** (ex-Partons) which are meant to give access to non-perturbative inputs which are those needed to compute observables via NLOAccess. We aim at 3 specific activities investigating interface between the VAs, as described above.
- the **ECT* TNA** where we organised a workshop in 2024 during STRONG2020. We envision to contribute to one of the yearly training program to enlarge the user community of NLOAccess in particular towards the experimental community from LHC, RHIC and EIC looking for reliable MC simulation and theoretical predictions for their measurements.

3. Estimated budget request

In the table in appendix, we have detailed our anticipated actions for each of the WP along with the need of HR and the list of key people involved complementing the HR requested to the EU. While the content of actions may be modified over the course of the 4 years, we do not expect the objectives to be changed and the corresponding need in term of resources to change[2] much.

In short, we anticipate the needs for 56 h.m. for WP1, 48 h.m. for WP2, 33h.m. for WP3, 39 h.m. for WP4, 49 h.m. for WP5, of which 192 h.m. would be for research engineers (50k€/year) following the profile hired during STRONG2020 and 36 h.m. for a postdoctoral researcher (60k€/year) needed for coordination of the scientific objectives for the developments of new codes or tools. All the hired personnel will work in close collaboration with the 20+ participating laboratories and will welcome inputs from the entire consortium of the research-infrastructure project.

NLOAccess is relying on a 320-core cluster at IJCLab hosted by the Virtual Data platform[3]. We anticipate the replacement of the oldest part of them for a cost of 20 k€. For the GPU-related task, we anticipate the need for 20k€ for hardware. Finally, for the communication and training actions, we anticipate the need of 40k€.

Overall, the requested budget is 1 060 000€, and including 25% of overhead: 1 325 000€, distributed as follows

- CNRS-IJCLab Orsay : 465 625 €
- UC Louvain : 303 125 €
- INFN Cagliari : 278 125 €
- Warsaw University of Technology: 278 125 €

4. Participating and partner institutions

Participating beneficiary institutions:

- IJCLab Orsay (represented by J.P. Lansberg)
- UC Louvain (represented by O. Mattelaer)
- INFN Cagliari (represented by C. Pisano)
- Warsaw University of Technology (represented by D. Kikoła)

Partner institutions:

AGH Krakow (rep. by P. Kotko)	INFN Perugia (rep. by M. Rinaldi)	RIKEN (rep. by N. Yamanaka)
Bergen U. (rep. by J. Nystrand)	Jagellonian U. (rep. by L. Motyka)	RUG Groningen (rep. by D. Boer)
CERN (rep. by D. d'Enterria)	Jyvaskyla U. (rep. by I. Helenius)	Santiago de Compostela U, (rep. by N. Armesto)
Heidelberg U. (rep. by T. Plehn)	Lancaster U. (rep. by V. Kartvelishishvili)	Tubingen U. (rep. by M. Schlegel)
IFJ-PAN Krakow (rep. by A. Kusina)	LPTHE Jussieu (rep. by H.S. Shao)	UC Dublin (rep. by R. McNulty)
IIHE Brussels (rep. by C. Van Hulse)	Lund U. (rep. by R. Frederix)	UC London (rep. by L. Harland-Lang)
INFN Bologna (rep. by D. Pagani)	Munster U. (rep. by A. Kulesza)	
INFN Milan and Milan U. (rep. by M. Zaro)	Penn State U. (rep. by A. Stasto)	

[2] From our experience from STRONG2020, the HR needs are as follows: 3 h.m single-purpose code with file upload interface; 6 h.m: single-purpose code with dedicated user interface; 9 h.m: multi-purpose code with user interface; 12 h.m: multi-purpose code with user interface and dedicate output.

[3] : https://virtualdata.fr/

			Total h.m	IJCLAB (h.m)	IJCLab people	Partner	WUT (h.m)	WUT people	Partner	UCLouvain (h.m)	UCLouvain people	Partner	CA (h.m)	CA people	Partner
WP1	**NLOAccess maintenance and consolidation**	Maintenance of the database, of the cluster, of the security of the portal and of the cloud + software upgrade if hardware upgrade.	*44*	12	L.A. Couturier	CC IN2P3	16	D. Kikola		4	O.Mattelaer		12	C. Puggioni	
56	**Training, dissemination, communication and helpdesk activities**	Helpdesk with ticket systems. Documentation on a wiki-like page. Training using the VA at Schools via off/online Master Classes. Note that dissemination actions are also understood for each activities.	*12*	3	J.P. Lansberg		3	D. Kikola		3	F. Maltoni		3	C. Pisano	
WP2	**Online access to MG7 + MG7NLO**	Installation of MG7(NLO) on the NLOAccess cluster, verification of the performances, update of the user interface, upgrade of the user interface with new options offered compared to MG5.	*12*			LPTHE (H.S. Shao)				3	O.Mattelaer		9	C. Flore	INFN-Bologna (D. Pagani) Lund (R. Frederix)
48	**Credential transfer**	Investigation of a protocol to use e.g. the GRID/HPC credentials of NLOAccess users. Upgrade of the database and of the login page with higher security level. Implementation for a selected subset of users (e.g. IN2P3, INFN, CERN, ...).	*6*	2	S. Lion		2	J. Oleniacz		2	O.Mattelaer				
	Software adaptation if credential transfer	Recompilation and possible adaptation of a selection of computing-intensive codes on NLOAccess to run on the GRID or other HPC facilities. Test with NNLO heavy-quark production codes.	*3*	3	V. Lafage										
	MadNIS (neural network integrator) [https://madnis.ai/]	Implementation of the usage of the MadNIS (neural network sampling MC integrator) for quarkonium production in Madgraph at NLO	*9*							9	O.Mattelaer	INFN-Milan (R.Winterhalder). HD (T. Plehn)			
	Online access to GPU (MG7 + TMD evolution)	Interface to GPU facilities to run the GPU compliant version of MG5 online with optimised evolution code for TMD using FFT and PDF reweighting, Check of the code; Upgrade of the online interface. Investigation to port other codes.	*18*	3	V. Lafage	UCD (T. Kechadi)	6	G. Wlazlowski		7	O.Mattelaer	CERN (S. Roiser)	2	C. Puggioni	
WP3	**Starlight [https://github.com/STARlightsim/STARlight]**	Inclusion of the Starlight MC code (ultra-peripheral collisions of relativistic ions). Online interface to launch runs and dedicated output generation.	*9*	2	L. Massacrier	UCD (R. McNulty)						IIHE (C. Van Hulse)	7	C. Pisano	Bergen U. (J. Nystrand)
33	**Exclusive lepto- and photo-production of quarkonia at NLO for EIC**	Interface to two codes for exclusive production of quarkonia via resp. virtual and real photons at NLO using HEF. Code documentation. Test of a transparent interface to load GPD grids from the VA GPD Portal (ex Partons)	*6*	4	J.P. Lansberg					2	C. Flett	IIHE (C. Van Hulse)			
	SuperChic [https://superchic.hepforge.org/]	Inclusion of the SuperCHIC MC code (exclusive and photon-initiated production in proton and heavy ion collisions). Online interface to launch runs and dedicated output generation.	*9*	2	L. Massacrier	UCD (R. McNulty)						IIHE (C. Van Hulse)	7	C. Pisano	UCL London (L. Harland-Lang)
	NLO code for high pt hadron & quarkonium production with colinear fragmentation functions	Online interface for INCNLO (a NLO code using NLL FF). Computation of quarkonium FF up to NLO in alpha_s and v^2. Document. Test of a transparent interface to FF from APFEL++ and input FF from the VA TMD Portal. Investigation of quarkonium FF studies at FCC-ee.	*9*	9	J.P. Lansberg	Lancaster (V.Kartvelishishvili), N. Yamanaka (RIKEN)									
WP4	**DIS in MG7 for EIC, LHeC & FCC-eh**	Extension of MG7 to DIS processes at NLO (implementation, validation, tests, upgrade of the user interface, documentation)	*12*				3	D. Kikola + PhD student	IFJ Krakow (R. Ruiz)	9	F. Maltoni	UniMi (M. Zaro). USC (N. Armesto)			
39	**Quarkonium in MG7 at NLO**	Extension of MG7 to quarkonium production at NLO in NRQCD (currently achieved at LO). Creation of a library for virtual corrections to be used by other codes. Upgrade of the user interface to the quarkonium parameters	*15*	6	J.P. Lansberg + PhD student	LPTHE (H.S. Shao)				6	F. Maltoni, C. Flett		3	C. Pisano	Lund (R. Frederix)
	TMD hard scatterings using helicity-dependent amplitudes up to NLO in MG7	Extension of MG7 to use helicity-dependent amplitudes with NLO virtual corrections to generate hard scatterings at NLO in TMD factorisation with realistic TMD inputs to generate MC events (+ coupling to GPU computation of TMD evolution). Upgrade of the user interface. Documentation. Test of a transparent interface to load intial conditions for TMD evolution from the VA TMD Portal.	*12*	3	J.P. Lansberg	Groningen U. (D. Boer)				3	F. Maltoni		6	C. Pisano	Tübingen (M. Schlegel)
WP5	**Tool for automated online usage of diffractive PDFs via LHAPDF FOR LHC & EIC**	Creation of an online tool to generate LHAPDF grids for diffractive PDFs and interface with MG7 and HO. Test, validation and documentation.	*3*	3	J.P. Lansberg	Jyvaskyla (V. Guzey)			IFJ Krakow (A. Kusina), Penn State (A.Stasto)						Münster (M. Klasen)
49	**Tool for automated online usage of resolved-photon PDFs for inclusive UPCs at LHC and *ep* collisions at LHEC & FCC-eh via LHAPDF**	Creation of an online tool to generate LHAPDF grids for resolved-photon PDFs and interface with MG7 and HO for inclusive UPC computation up to NLO. Test, validation and documentation.	*3*	3	J.P. Lansberg	Jyvaskyla (V. Guzey)			IFJ Krakow (A. Kusina), Penn State (A.Stasto)						INFN-Perugia (M. Rinaldi)
	Online tool for Pythia, Double Parton Scatterings and quarkonium production LHC, EIC & RHIC: tunes and colour reconnection effects	Interface to use online Pythia tunes of NRQCD LDMEs on LHC and HERA quarkonium data to allow one to generate reliable MC quarkonium samples at the LHC, EIC & RHIC, including double parton scatterings. Interface via Pythia between LHE files and color reconnection effects in quarkonium production. Documentation.	*16*	7	Z. Conesa del Valle, S. Barsuk	Jyvaskyla (I. Helenius), CERN (D. d'Enterria); LPTHE (H.S. Shao)	9	D. Kikola	AGH (P. Kotko), JU (L. Motyka), Penn State (A.Stasto), Münster (A. Kulesza)	3	O.Mattelaer	IIHE (C. Van Hulse)			INFN-Perugia (M. Rinaldi)
	Online interface to gamma-UPC (+ extension to single photon production) [https://hshao.web.cern.ch/hshao/gammaupc.html]	Online user interface to gamma-UPC in MG and HELAC-Onia. Extension to single-photon fluxes for UPCs with neutron emission (implementation, test and documentation)	*9*	9	J.P. Lansberg	LPTHE (H.S. Shao), CERN (D. d'enterria) , UCD (R. McNulty & PhD student)									
	Code and online interface for centrality-dependent cold nuclear matter effects in a Glauber MC for pA, AA and eA collisions	Interface between the asymmetric version of MG and a MC Glauber code reproducing the centrality selection of RHIC and LHC experiments to provide nuclear modfications factors for any hard probe in MG up to NLO (including parton shower and hadronisation at LO). A selection of the criteria used for the experimental centrality classes will be used and matched to an impact parameter distribution.	*18*	4	C. Hadjidakis	CERN (D. d'Enterria); LPTHE (H.S. Shao)	12	D. Kikola	IFJ Krakow (A. Kusina + PhD student)				2	C. Flore	
			228	*75*			*51*			*51*			*51*		

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LHCb	R. Mc Nulty (UCD)	PHENIX	C. Da Silva (LANL)

VA GPDPortal: V. Bertone (CEA)

LHeC and FCC-eh: J.P. Lansberg (IJCLab)

FCC-ee and FCC-hh: D. d'Enterria (CERN)