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MadGraph and NLOAccess

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**IRN Terascale
LPSC Grenoble
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NLOAccess - the framework

The STRONG-2020 WP **VA1-NLOAccess**:

- a **virtual access** for automated perturbative calculation for collider physics, with emphasis on heavy ions and quarkonia
- an online code library
- any code that could be compiled and launched via bash could be added
- ✓ **HELAC-Onia** and **MadGraph5** are included

C. Flore, EPJ A 59 (2023) 46

NLOAccess - facts and figures

Some facts and figures about NLOAccess:

- general information at <https://nloaccess.in2p3.fr>
- HELAC-Onia: <https://nloaccess.in2p3.fr/H0/>
- MG5: <https://nloaccess.in2p3.fr/MG5/>
- **over 400 users** from all over the world; **over 4000 runs** performed by the users
- features:
 - **secure two-step registration** process
 - **protected OwnCloud storage** is given
 - **file input** as first way to submit a run
 - **live user run status** and **run history**
 - almost **zero computational cost** for the users

NLOAccess - the tools

- HELAC-Onia

H.-S. Shao, CPC 184 (2013) 2562-2570 & CPC 198 (2016) 238-259

- **LO(+PS)** automated event generator for **quarkonia** in the SM
- based on the **NRQCD** framework, relies on **off-shell recursion relations**
- approximate NLO calculation (e.g. NLO*, aNLO) feasible

C. Flore et al., Phys. Lett. B 811 (2020) 135926; H.-S. Shao, JHEP 01 (2019) 112

- MG5

http://amcatnlo.web.cern.ch/amcatnlo/list_refs.htm

- **full NLO(+PS)** matrix element and event generator in the SM and for BSM phenomenology
- **LO for any user-defined Lagrangian**, and at the **NLO** for models supporting such a calculation
- onium feasible within **(I)CEM**

J.-P. Lansberg et al., Phys. Lett. B 807 (2020) 135559

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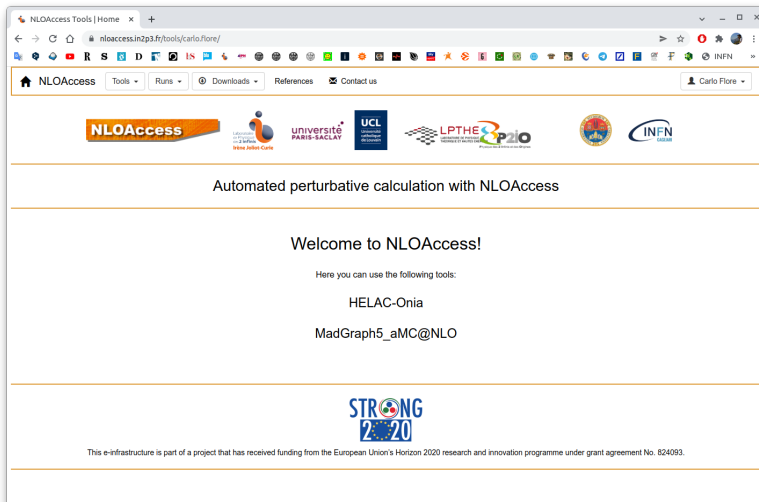
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⇒ **Les Houches Events** available for both codes

NLOAccess Tools - homepage

(<https://nloaccess.in2p3.fr/tools/>)



The screenshot shows a web browser window with the address bar displaying `nloaccess.in2p3.fr/tools/carlo.flore/`. The page features a navigation bar with a home icon, the text "NLOAccess", and dropdown menus for "Tools", "Runs", "Downloads", "References", and "Contact us". A user profile "Carlo Flore" is visible in the top right. Below the navigation bar is a row of logos for NLOAccess, Université Paris-Saclay, UCL, LPTHE, and INFN. The main content area has a heading "Automated perturbative calculation with NLOAccess" followed by "Welcome to NLOAccess!". Below this, it lists available tools: "HELAC-Onia" and "MadGraph5_aMC@NLO". At the bottom, there is a "STRONG 2020" logo and a note: "This e-infrastructure is part of a project that has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 824093."

- MadGraph5 online version was only limited to LO calculation
- NLOAccess offers access for the first time to full NLO SM online calculation with MG5_aMC@NLO!



The screenshot shows a web browser window with the URL `nloaccess.in2p3.fr/tools/mg5/carlo.flore/`. The page features a navigation bar with a home icon, the text "MG5_aMC@NLO", and menu items for "Tools", "Rais", "Downloads", "References", and "Contact us". Below the navigation bar is a row of logos for NLOAccess, universit  Paris-Saclay, UCL, LPTHE SP20, and INFN. The main content area is titled "Automated perturbative calculation with NLOAccess" and "MG5_aMC@NLO". A paragraph of text describes the framework's capabilities, and a section titled "Here is what you can do:" lists "Generate a new code" and "Check your code database". At the bottom, there is a logo for "STRONG 2020".

NLOAccess

universit  Paris-Saclay

UCL

LPTHE SP20

INFN

Automated perturbative calculation with NLOAccess

MG5_aMC@NLO

MadGraph5_aMC@NLO is a framework that aims at providing all the elements necessary for SM and BSM phenomenology, such as the computations of cross sections, the generation of hard events and their matching with event generators, and the use of a variety of tools relevant to event manipulation and analysis. Processes can be simulated to LO accuracy for any user-defined Lagrangian, or the NLO accuracy in the case of models that support this kind of calculations – prominent among these are QCD and EW corrections to SM processes. Matrix elements at the tree- and one-loop-level can also be obtained.

Here is what you can do:

- Generate a new code
- Check your code database

STRONG 2020

MG5 - code generation

The screenshot shows a web browser window with the URL `nloaccess.in2p3.fr/tools/MG5/carlo.flore/generate-process/`. The page header includes the NLOAccess logo and logos for partner institutions: universit  PARIS-SACLAY, UCL, LPTHE SP2O, and INFN. The main heading is "MG5_aMC@NLO - Generate process".

The main content area is titled "MG5_aMC code generation" and contains the following instructions and form:

Submit here your process and, if desired, the name of your output folder.

import model
generate
output

Or, if you want to upload your input file, do it here:

Choose your file: Nessun file selezionato

• Input file syntax example (e.g.: proton proton \rightarrow t t-):

```
generate p p > t t-  
output _myoutputfolder
```


MG5 - code database

NLOAccess Tools | Home | NLOAccess Tools | HELAC | MG5_aMC@NLO | Database

nioaccess.in2p3.fr/tools/MG5/carlo.flore/run-database/

NLOAccess Tools | Runs | Downloads | References | Contact us

Carlo Fiore

NLOAccess Université Paris-Saclay UCL LPTHE INFN

MG5_aMC@NLO - Carlo's database

Process Database

Folder name	Creation date (dd/mm/yyyy)	Creation time	Process	
test-ag2bbbar-10-11-21	10/11/2021	11:12:52	a g > b b-	Run
PROCNLO_loop_sm_20	24/09/2021	14:10:16	p p > t t- [QCD]	Run
PROC_loop_sm_1	30/09/2021	16:44:07	p p > H [QCD]	Run
PROC_loop_sm_0	29/09/2021	23:10:21	p p > h [QCD]	Run
PROCNLO_loop_sm_19	24/09/2021	13:04:48	p p > t t- [QCD]	Run
PROCNLO_loop_sm_18	24/09/2021	13:04:48	p p > t t- [QCD]	Run

Your personal OwnCloud folder

CTP@NLO

MG5 - code running

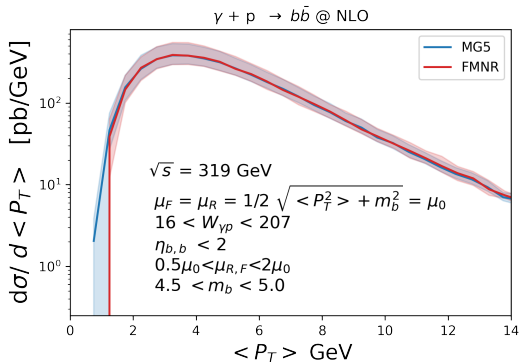
The screenshot shows a web browser window with the URL `nloaccess.in2p3.fr/tools/carlo.flore/MG5/PROCNLO_loop_sm_20/run/`. The page header includes the NLOAccess logo and navigation menus for Tools, Runs, Downloads, and References. Below the header are logos for NLOAccess, universit  PARIS-SACLAY, UCL, LPTHE, and INFN. The main content area is titled "MG5_aMC@NLO - PROCNLO_loop_sm_20" and contains a "Run the process" form. The form includes a text input for "Upload cards" with a "Scegli file" button and the text "Nessun file selezionato". Below this are six dropdown menus arranged in two columns: "Order" (set to "NLO"), "Fixed Order" (set to "OFF"), "Shower" (set to "No shower"), "Madspin" (set to "OFF"), "Reweight" (set to "OFF"), and "MadAnalysis" (set to "OFF"). A green "Submit run" button is located at the bottom of the form.

MG5 and NLOAccess - where are we?

- NLOAccess members highly involved in MG5 development
- MG5 designed and validated at NLO for **symmetric collisions**, *i.e.* mostly LHC physics
- lepton-hadron collisions were not yet validated at NLO at fixed-order
- need for extending MG5 to **asymmetric collisions**:
 - ℓh collisions (including photoproduction) \Rightarrow EIC, EicC, LHeC, FCC-eh ...
 - pA , AB , πp , πA collisions

MG5 - photoproduction (I)

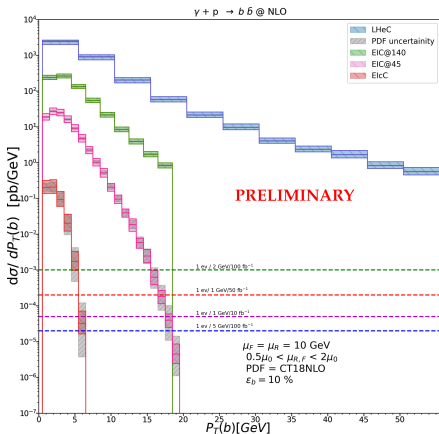
- **Photoproduction processes** will be important at the **future lepton-hadron colliders**
- what was done: fixed photon flux Q_{max}^2 , fixed boost routines, validated LO and NLO code at fixed order



FMNR code from private communication w/ S. Frixione; courtesy of L. Manna (WUT)

MG5 - photoproduction (II)

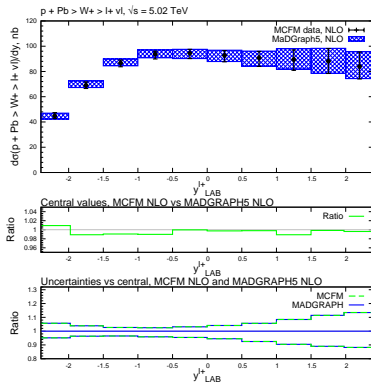
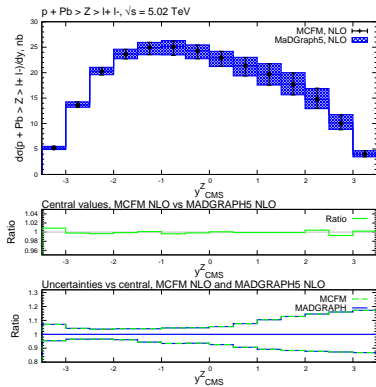
- Predictions for heavy-quark pair photoproduction for future experiments



courtesy of L. Manna (WUT)

MG5 - hA collisions (I)

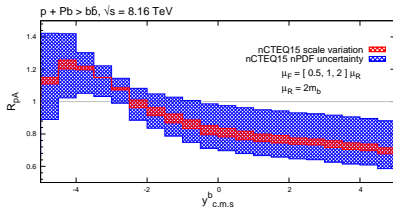
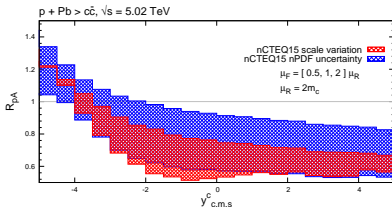
- MG5 integration of LHAPDF already allowed to compute AA collisions
- what was done: modification of parton luminosities functions and plotting routines to **automatically compute nuclear modification factors R_{pA}**



A. Safronov *et al.*, PoS ICHEP2022 (2022) 494

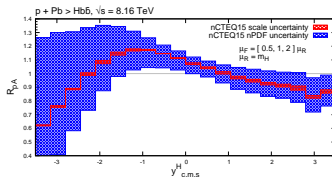
MG5 - hA collisions (II): R_{hA}

- only needed to specify the proton and ion LHAPDF id in the run card
- Predictions for R_{pPb} at the LHC



A. Safronov *et al.*, PoS ICHEP2022 (2022) 494

- A fancier prediction: Higgs + $b\bar{b}$ at the LHC



Courtesy of A. Safronov (WUT)

Conclusions and outlook

- **NLOAccess**: an online platform for automated perturbative calculation for collider physics
- **MG5** now available online in its **full NLO version on NLOAccess**
- validated and developed MG5 for **asymmetric collisions**
 - **photoproduction** in lh collisions
 - **nuclear modification factors** in pA and AB collisions

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- next:
 - extension to pion beams and to (N)LO+PS
 - automation of onium production computations at (N)LO in MG5
[A. Abdul-Hameed, LPTHE Paris, C. Flett, IJCLab Orsay]
 - automation of spin and transverse momentum effects for quarkonium production

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Thank you

Backup

Quarkonium Production Model

Phys.Rept. 889 (2020) 1-106 & EPJC (2016) 76:107 for reviews

- No agreement on which mechanism is dominant
- Differences in the **treatment of the hadronization**
- **3 common models:**
 1. COLOR SINGLET MODEL:
hadronization **w/o gluon emission**; colour and spin are preserved during the hadronization
 2. NRQCD AND COLOR OCTET MECHANISM:
higher Fock states of the mesons taken into account; $Q\bar{Q}$ can be produced in octet states with different quantum number as the meson;
 3. COLOR EVAPORATION MODEL:
based on **quark-hadron duality**;
only the invariant mass matters; semi-soft gluons emissions;
color-wise decorrelated $c\bar{c}$ prod. and hadr.

HELAC-Onia is an automatic matrix element and event generator for quarkonium physics

- based on **NRQCD** framework
- based on **off-shell recursion relations**

NRQCD factorisation:

$$\sigma(pp \rightarrow Q + X) = \sum_{i,j,n} \int dx_1 dx_2 f_{i/p}(x_1) f_{j/p}(x_2) \hat{\sigma}(ij \rightarrow Q\bar{Q}[n] + X) \langle \mathcal{O}_n^Q \rangle$$

- $f_{i/p}(x_1), f_{j/p}(x_2)$ are the **PDFs**
- $\hat{\sigma}(ij \rightarrow Q\bar{Q}[n] + X)$ is the **partonic cross section** for producing a heavy quark pair in the Fock state n
- $n = {}^{2S+1}L_J^c$, with $c = 1, 8$ (color singlet or color octet)
- $\langle \mathcal{O}_n^Q \rangle$ are the **LDMEs**

Code vs metacode

What is the main difference between HELAC-Onia and MG5_aMC@NLO?

HELAC-Onia is a **code**

MG5_aMC@NLO is a **metacode**, *i.e.* a code generating another code

	HELAC-Onia	MG5_aMC@NLO
compilation	once	once for each generate command
running	run single executable each time	(re-)run the generated code for the requested process
code re-usage	✘	✔

NLOAccess - homepage

(<https://nloaccess.in2p3.fr>)

NLOAccess
Virtual Access: Automated perturbative NLO calculations for heavy ions and quarkonia (NLOAccess)

Home - The project - Communication - Tools - Account - Downloads - Request registration

GENERAL DESCRIPTION

Objectives:

NLOAccess will give access to automated tools generating scientific codes allowing anyone to evaluate observables - such as production rates or kinematical properties - of scatterings involving hadrons. The automation and the versatility of these tools are such that these scatterings need not to be pre-coded. In other terms, it is possible that a random user may request for the first time the generation of a code to compute characteristics of a reaction which nobody thought of before. NLOAccess will allow the user to test the code and then to download to run it on its own computer. It essentially gives access to a dynamical library.

The automated tools on which NLOAccess is based are (i) the MADGRAPH ensemble heavily used by the high-energy physics (HEP) community, but extended to deal with meson and heavy-ion beams and (ii) the HELAC-ONIA code allowing the computation of cross section for heavy-quark bound states, the quarkonia.

The portal NLOAccess will allow one to access additional automated tools. I will extend the portal of MADGRAPH@UCLouvain with the necessary additions to deal with heavy-ion collisions and quarkonium production.

As of today, in contrast to HEP, no such place exists for hadronic physics where interested colleagues can go test their ideas and turn them into concrete realisation with automated Monte Carlo tools. In addition, the available tools are limited to a reduced class of applications. For each, one needs to install them one by one, sometimes along with dedicated libraries and one needs to get familiar with their syntax. A single portal for hadron physics will not only ease the task of the

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STRONG 2020

The e-infrastructure is part of a project that has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 624093.

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© Jean-Philippe Lansberg gives a talk at

7 TeV LHC Color Singlet $2 < \chi_{\text{min}} < 4.5$ $\frac{m_{\text{H}}}{m_{\text{Z}}} = 4$

dN/dP_T (mb/CsV)

10^1
 10^0
 10^{-1}
 10^{-2}
 10^{-3}
 10^{-4}
 10^{-5}
 10^{-6}
 10^{-7}
 10^{-8}
 10^{-9}
 10^{-10}

10 20 30

10 20 30

<https://nloaccess.in2p3.fr>

NLOAccess - run status

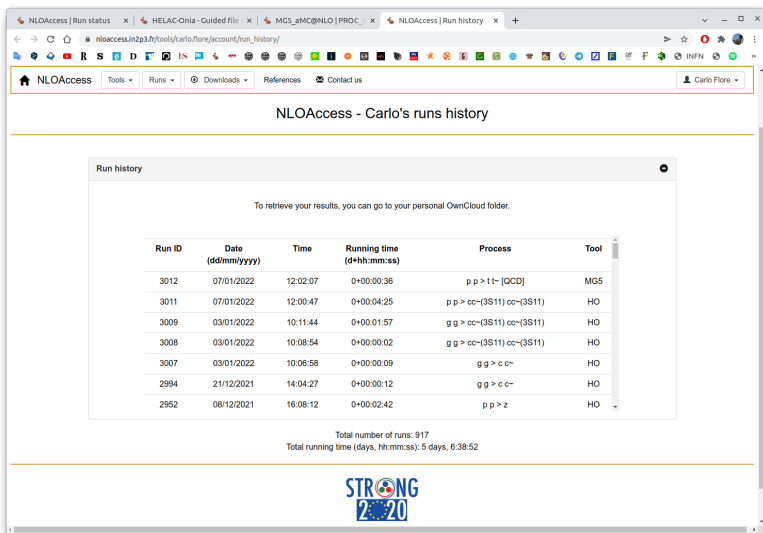
The screenshot shows a web browser window with the URL `nloaccess.in2p3.fr/tools/carlo.flore/account/run_status/`. The page header includes the NLOAccess logo and logos for partner institutions: Université Paris-Saclay, UCL, LPTHE, CP2O, and INFN. The main heading is "NLOAccess - Carlo's runs".

The "Run status" section contains a search bar for "Run id(s)" with a "Remove run(s)" button. Below this is a table of active runs:

Run ID	Date (dd/mm/yyyy)	Time (d+hh:mm:ss)	Idle	Running	Completed	Process	Tool
3012	07/01/2022	12:02:07	5	0	0	$p p > t t^-$ [QCD]	MG5
3011	07/01/2022	12:00:47	0	1	6	$p p > c c^-$ (3S11) $c c^-$ (3S11)	HO

Below the table, a message states: "This page will automatically refresh every 30 seconds. If you want to refresh now the page, click on the button below." with a "Refresh" button.

NLOAccess - run history



The screenshot shows a web browser window with the URL `nloaccess.in2p3.fr/tools/carlo.flore/account/run_history/`. The page title is "NLOAccess - Carlo's runs history". Below the title, there is a "Run history" section with a message: "To retrieve your results, you can go to your personal OwnCloud folder." Below this message is a table with the following data:

Run ID	Date (dd/mm/yyyy)	Time	Running time (d+hh:mm:ss)	Process	Tool
3012	07/01/2022	12:02:07	0+00:00:36	p p > t1- [QCD]	MG5
3011	07/01/2022	12:00:47	0+00:04:25	p p > cc-(3S11) cc-(3S11)	HO
3009	03/01/2022	10:11:44	0+00:01:57	g g > cc-(3S11) cc-(3S11)	HO
3008	03/01/2022	10:08:54	0+00:00:02	g g > cc-(3S11) cc-(3S11)	HO
3007	03/01/2022	10:06:58	0+00:00:09	g g > c c~	HO
2994	21/12/2021	14:04:27	0+00:00:12	g g > c c~	HO
2952	08/12/2021	16:08:12	0+00:02:42	p p > z	HO

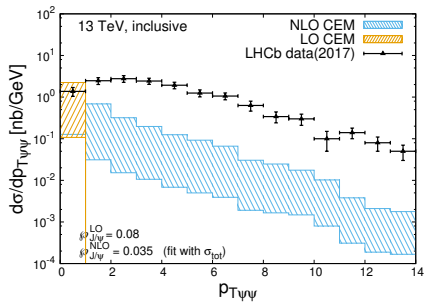
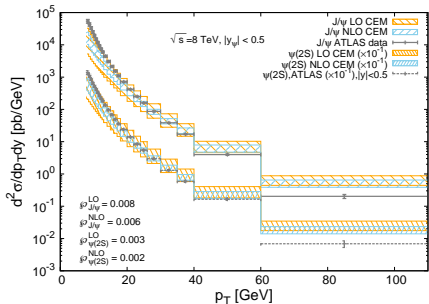
Below the table, the following summary information is displayed:

Total number of runs: 917
Total running time (days, hh:mm:ss): 5 days, 6:38:52

At the bottom of the page, there is a logo for "STRONG 2020" featuring the European Union flag.

Bonus - NLO (di-)onium production in MG5

J.-P. Lansberg, H.-S. Shao, N. Yamanaka, Y.-J. Zhang, C. Noûs, PLB 807 (2020) 135559



All the computations were done with [MG5_AMC@NLO](#) [J. Alwall et al., JHEP 07 (2014) 079].

- Good description of the P_T spectrum for single J/ψ (still some issues at large P_T)
- di- J/ψ production cannot be described by NLO CEM

The Color Evaporation Model

- In the CEM, an onium production cross section is obtained from the one for $Q\bar{Q}$ production, with a cut on the invariant mass of the pair:

$$d\sigma_Q^{(N)\text{LO}} = \mathcal{P}_Q^{(N)\text{LO}} \int_{2m_Q}^{2m_H} dm_{Q\bar{Q}} \frac{d\sigma_{Q\bar{Q}}^{(N)\text{LO}}}{dm_{Q\bar{Q}}}$$

- its Improved version (ICEM), momenta are rescaled:

$$d\sigma_Q^{(N)\text{LO}} = \mathcal{P}_Q^{(N)\text{LO}} \int_{2m_Q}^{2m_H} dm_{Q\bar{Q}} \frac{d\sigma_{Q\bar{Q}}^{(N)\text{LO}}}{dm_{Q\bar{Q}}} \Big|_{p_{Q\bar{Q}} = \frac{m}{M_Q} p_Q}$$