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NLOAccess: A hitchhikers guide to the (online computation) galaxy

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Synergies EIC-LHC for quarkonium physics
ECT* Trento
July 12th, 2024

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

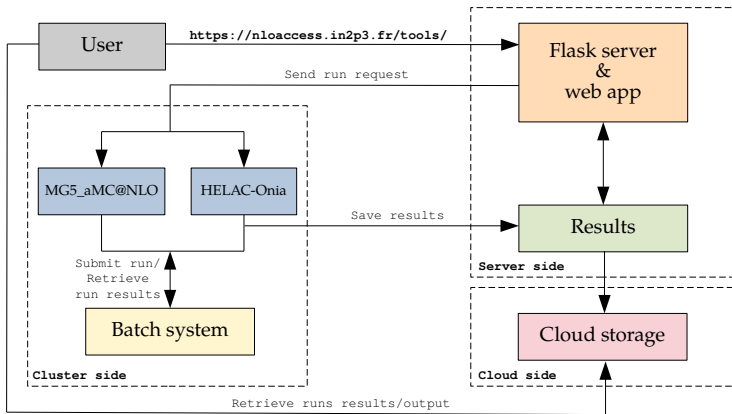
C. Flore, EPJ A 59 (2023) 46

NLOAccess - facts and figures

Some facts and figures about NLOAccess:

- general information at <https://nloaccess.in2p3.fr>
- tools homepage: <https://nloaccess.in2p3.fr/tools/>
- **over 650 users** from all over the world; over **5000 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 - behind the scenes



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 so far feasible within **(I)CEM**

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

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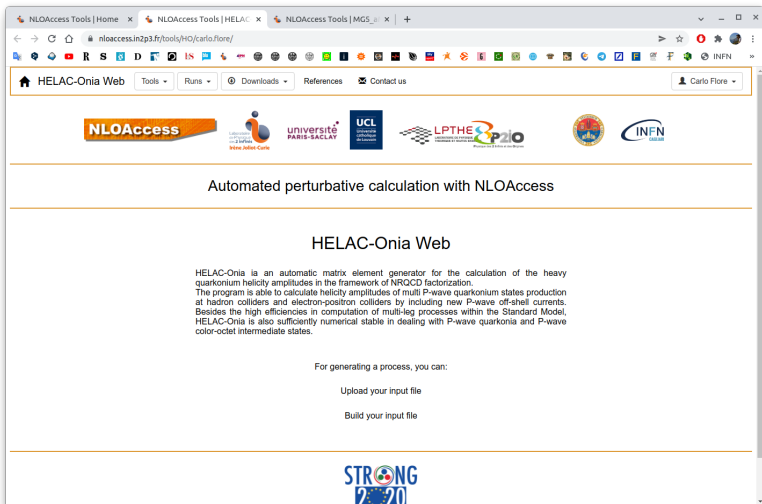
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⇒ **Les Houches Events** available for both codes

The screenshot shows a web browser window with the URL `nloaccess.in2p3.fr/tools/carlo.flore/`. The page features a navigation bar with 'NLOAccess', 'Tools', 'Runs', 'Downloads', 'References', and 'Contact us'. A user profile for 'Carlo Flore' is visible in the top right. Below the navigation bar is a row of logos for partner institutions: NLOAccess, Laboratoire de Physique des Hautes Energies (LPHES) at Université Paris-Saclay, UCL, LPTHE at Université de Clermont-Ferrand, INFN, and INFN CNAF. The main content area is titled 'Automated perturbative calculation with NLOAccess' and includes a 'Welcome to NLOAccess!' message. It lists available tools: 'HELAC-Onia' and 'MadGraph5_aMC@NLO'. At the bottom, there is a 'STRONG 2020' logo and a note that the e-infrastructure is part of a project funded by the European Union's Horizon 2020 research and innovation programme under grant agreement No. 824093.



The screenshot shows a web browser window with the URL `nloaccess.in2p3.fr/tools/H0/carlo.flore/`. The page features a navigation bar with "HELAC-Onia Web", "Tools", "Runs", "Downloads", "References", and "Contact us". Below the navigation bar are logos for NLOAccess, Université Paris-Saclay, UCL, LPTHE Saclay, INFN, and others. The main content area is titled "Automated perturbative calculation with NLOAccess" and "HELAC-Onia Web". It contains a paragraph describing the tool's capabilities: "HELAC-Onia is an automatic matrix element generator for the calculation of the heavy quarkonium helicity amplitudes in the framework of NRQCD factorization. The program is able to calculate helicity amplitudes of multi P-wave quarkonium states production at hadron colliders and electron-positron colliders by including new P-wave off-shell currents. Besides the high efficiencies in computation of multi-leg processes within the Standard Model, HELAC-Onia is also sufficiently numerical stable in dealing with P-wave quarkonia and P-wave color-octet intermediate states." Below this text, it says "For generating a process, you can:" followed by two options: "Upload your input file" and "Build your input file". At the bottom of the page is the "STRONG 2020" logo.

HELAC-Onia - run submission

The screenshot shows a web browser window with the URL `nloaccess.in2p3.fr/tools/HO/Carlo.Fiore/guided-file-submission/`. The page title is "HELAC-Onia - Guided input file submission". The interface includes a navigation bar with "Tools", "Runs", "Downloads", "References", and "Contact us" menus, and a user profile for "Carlo Fiore".

The main content area is titled "Create your input file" and contains the following elements:

- A text input field labeled "Input next command(s):" with a large empty box below it.
- A blue button labeled "Add command(s)".
- A label "Remove line(s) containing:" followed by a text input field.
- Two buttons: "Remove line(s)" and "Clear file".
- A green button labeled "Submit job".
- A section titled "Your input file:" containing a code block with the following text:

```
generate p > cc-(3S11) cc-(3S11)
set colpar = 1
set energy_beam1 = 7000
set energy_beam2 = 7000
set qcd = 2
decay cc-(3S11) > m+ m- @ 0.06
launch
```
- A text prompt: "Please, remember to follow this structure for your input file:"
- A code block showing the required structure:

```
generate { process }
set { parameter } = { value }
:
:
launch
```
- A note: "For more examples: see this reference or take a look to the [User Guide](#)."

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The main content area is titled "HELAC-Onia - Guided input file submission". It features a large text input field with the following pre-filled text:

```
generate p p > cc~(3S11) cc~(3S11)
set colpar = 1
set energy_beam1 = 7000
set energy_beam2 = 7000
set qcd = 2
decay cc~(3S11) > m+ m- @ 0.06
launch
```

Below the input field, there is an "Add command(s)" button. To the left, there is a "Remove line(s) containing:" label followed by an empty text input field. Below this are "Remove line(s)" and "Clear file" buttons. At the bottom of the input area is a green "Submit job" button.

To the right of the input field, there is a note: "Please, remember to follow this structure for your input file:" followed by a box containing the following structure:

```
generate { process }
set { parameter } = { value }
:
launch
```

Below this structure, there is a reference: "For more examples: see this reference or take a look to the [User Guide](#)."

HELAC-Onia - input file

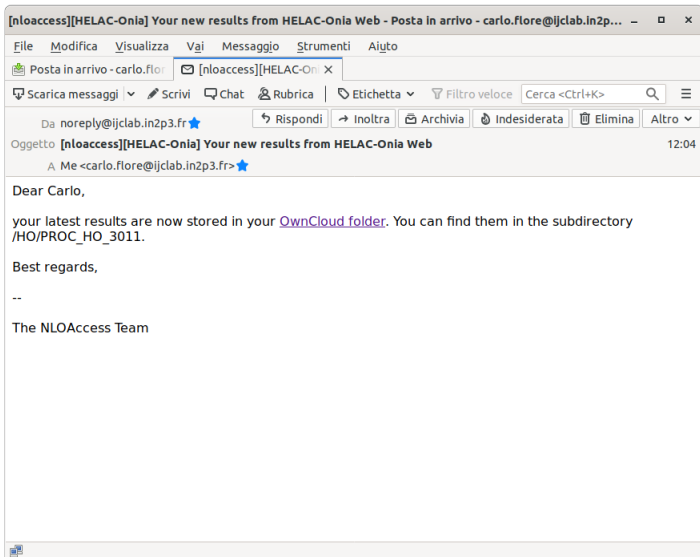
The input file should be in the following form:

```
generate { process }  
set { parameter }={ value }  
  
:  
launch
```

Users can have control on several kind of parameters via the set command:

- collisions parameters;
- theory parameters;
- MC setup variables;
- PDFs parameters;
- kinematical cuts;
- quarkonium specific parameters (e.g. the values of different LDMEs);
- physical constants (both EW and QCD sectors, e.g. M_Z or M_W , or m_q , or couplings).
- kind of output (ROOT, Gnuplot, TopDrawer or LHE)

HELAC-Onia - results



[nloaccess][HELAC-Onia] Your new results from HELAC-Onia Web - Posta in arrivo - carlo.flore@ijclab.in2p3...

File Modifica Visualizza Vai Messaggio Strumenti Aiuto

Posta in arrivo - carlo.flor [nloaccess][HELAC-Oni X

Scarica messaggi Scrivi Chat Rubrica Etichetta Filtro veloce Cerca <Ctrl+K>

Da noreply@ijclab.in2p3.fr Rispondi Inoltra Archivia Indesiderata Elimina Altro

Oggetto [nloaccess][HELAC-Onia] Your new results from HELAC-Onia Web 12:04

A Me <carlo.flore@ijclab.in2p3.fr>

Dear Carlo,

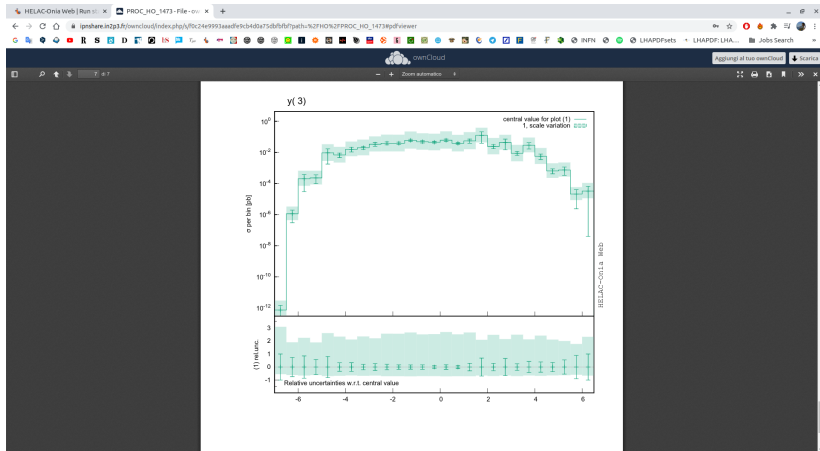
your latest results are now stored in your [OwnCloud folder](#). You can find them in the subdirectory /HO/PROC_HO_3011.

Best regards,

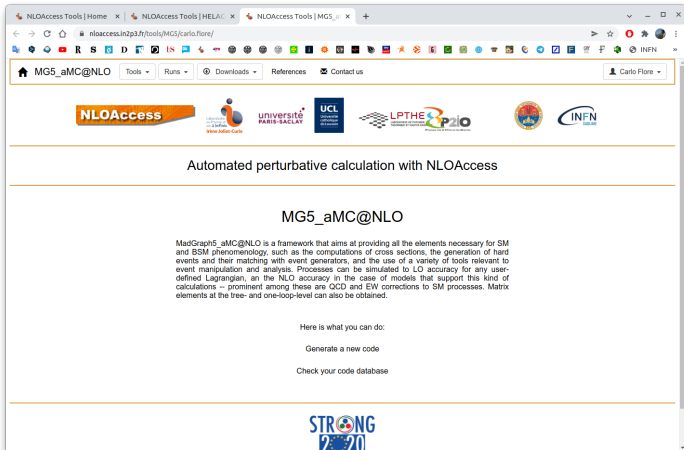
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The NLOAccess Team

HELAC-Onia - results



- 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 the text "MG5_aMC@NLO" and a user profile "Carlo Flore". Below the navigation bar is a row of logos for NLOAccess, Université Paris-Saclay, UCL, LPTHE SP20, and INFN. The main content area is titled "Automated perturbative calculation with NLOAccess" and "MG5_aMC@NLO". A paragraph describes the MadGraph5_aMC@NLO framework, highlighting its capabilities in providing all elements necessary for SM and BSM phenomenology, including cross-section calculations, event generation, and matching with event generators. Below the text, there are two buttons: "Generate a new code" and "Check your code database". At the bottom of the page, there is a logo for "STRONG 2020".

MG5 - code generation

The screenshot shows a web browser window with the URL `nloaccess.in2p3.fr/tools/MG5/carlo.fiore/generate-process/`. The page title is "MG5_aMC@NLO - Generate process". The header includes logos for NLOAccess, universit  PARIS-SACLAY, UCL, LPTHE, and INFN. The main content area is titled "MG5_aMC code generation" and contains the following text and form elements:

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 Flore

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	ag > b b-
PROCNLO_loop_sm_20	24/09/2021	14:10:16	pp > tt [QCD]
PROC_loop_sm_1	30/09/2021	16:44:07	pp > H [QCD]
PROC_loop_sm_0	29/09/2021	23:10:21	pp > h [QCD]
PROCNLO_loop_sm_19	24/09/2021	13:04:48	pp > tt [QCD]

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, References, and Contact us. Below the header are logos for NLOAccess, universitè PARIS-SACLAY, UCL, LPTHE, and INFN. The main content area is titled "MG5_aMC@NLO - PROCNLO_loop_sm_20". A "Run the process" dialog box is open, containing the following configuration options:

Run the process

If needed, upload here your cards (as multiple .dat files or as a single tar.gz/zip file):

Upload cards: Nessun file selezionato

Order	<input type="text" value="NLO"/>	Fixed Order	<input type="text" value="OFF"/>
Shower	<input type="text" value="No shower"/>	Madspin	<input type="text" value="OFF"/>
Reweight	<input type="text" value="OFF"/>	MadAnalysis	<input type="text" value="OFF"/>

HELAC-Onia vs MG5

	HELAC-Onia	MG5
code compilation	once	once for every generate/output or launch commands
running	run single executable for each run	re-run the generated code for the requested process
code re-usage	X	✓

NLOAccess - synergies

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 - J/ψ photoproduction
 - estimates for DPS contribution to $di-J/\psi$
 - baseline for first triple J/ψ measurement at CMS
 - single and double quarkonium production in the I(CEM)

Liza's talk

Matteo's talk

Maria Elena's talk

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 - ℓh collisions (including photoproduction) \Rightarrow EIC, EicC, LHeC, FCC-eh . . . Laboni's talk
 - $pA, AB, \pi p, \pi A$ collisions Anton's talk

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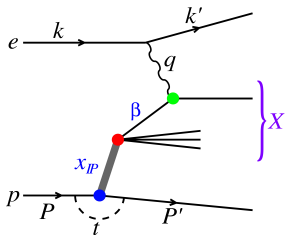
Anton's talk

what's next?

Incl. diffractive vs inclusive photoproduction

Diffractive PDFs extracted from $ep \rightarrow epX$ measurements at HERA

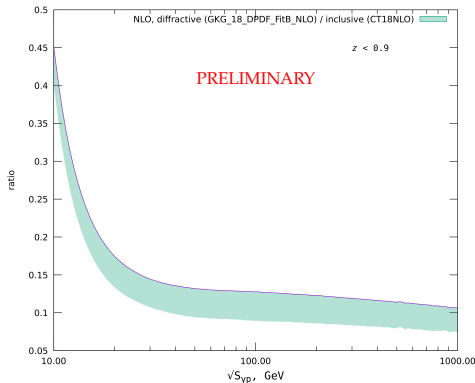
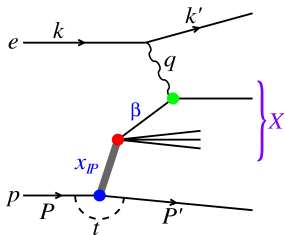
Goharipour, Khanpou, Guzey, EPJC (2018) 78:309



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- **Preliminary estimates** using $\hat{\mu}_F$ -prescription for inclusive (diffractive) J/ψ photoproduction; pomeron flux still missing, take the plot with a grain of salt

⇒ Code by M. Nefedov & Y. Yedelkina, to be made available on NLOAccess

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
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Thank you

Backup

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**

NLOAccess - run status

NLOAccess | Run status

HELAC-Onia - Guided File | MGS_aMC@NLO | PROC_ |

nloaccess.in2p3.fr/tools/carlo.fiore/account/run_status/

NLOAccess Tools Runs Downloads References Contact us

Carlo Fiore

NLOAccess Université Paris-Saclay UCL LPTHE INFN

NLOAccess - Carlo's runs

Run status

Run id(s) Remove run(s)

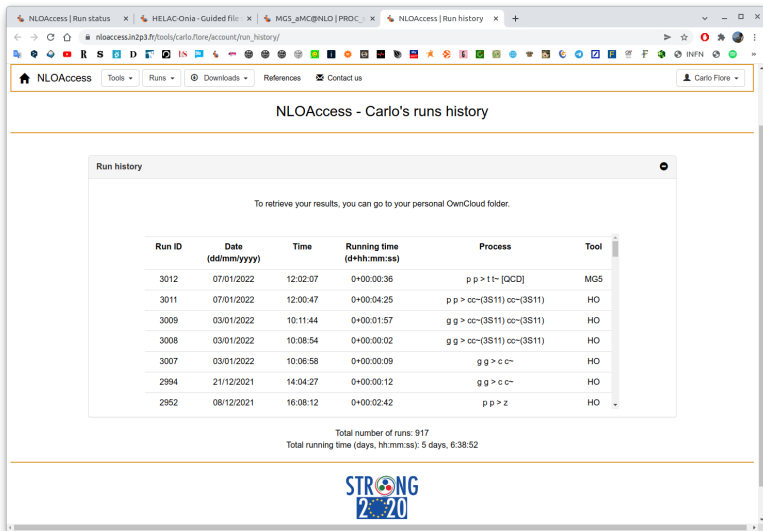
For removing multiple runs, separate the IDs with a comma or a semicolon.

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]	MGS
3011	07/01/2022	12:00:47	0	1	6	p p > cc-(3S11) cc-(3S11)	HO

This page will automatically refresh every 30 seconds. If you want to refresh now the page, click on the button below.

Refresh

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	$p p > t t^-$ [QCD]	MG5
3011	07/01/2022	12:00:47	0+00:04:25	$p p > c c^-$ (3S11) $c c^-$ (3S11)	HO
3009	03/01/2022	10:11:44	0+00:01:57	$g g > c c^-$ (3S11) $c c^-$ (3S11)	HO
3008	03/01/2022	10:08:54	0+00:00:02	$g g > c c^-$ (3S11) $c c^-$ (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

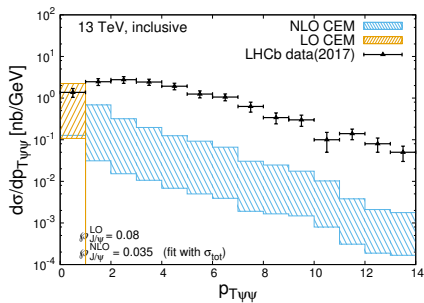
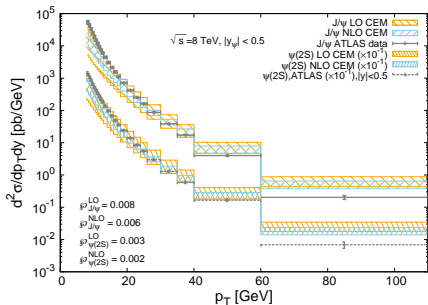
Below the table, the following summary statistics are displayed:

- 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:

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