UNICA UNIVERSITÀ DEGLI STUDI DI CAGLIARI

INFN CAGLIARI

Asymmetric collisions in MadGraph5_aMC@NLO & NLOAccess

Carlo Flore

Università di Cagliari & INFN - Sezione di Cagliari

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Work done in collaboration with
L. Manna, A. Safronov, D. Kikoła, A. Kusina, J.-P. Lansberg, O. Mattelaer, H.-S. Shao

arXiv:2501.14487 [hep-ph]

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- we extended MG5 to accomodate for asymmetric reactions (pA, AB, πA, ep, eA ...) at NLO in α_S

Symmetric hadronic collisions in MG5 at NLO

CF, D. Kikoła, A. Kusina, J.-P. Lansberg, O. Mattelaer, A. Safronov, arXiv:2501.14487 [hep-ph]

$$d\sigma_{hh\to\ell^+\ell^- X} = \sum_{a,b} \int dx_a dx_b \, f_{a/h}(x_a, \mu_F; \texttt{LHAID_h}) \, f_{b/h}(x_b, \mu_F; \texttt{LHAID_h})$$
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How to extend to asymmetric collisions?

- modify parton luminosity
- adapt enforcement of kinematical cuts (hadronic c.m.s. no longer the natural frame)

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  5. in general $N^{\text{asym}}_{\text{entr}} > N^{\text{symm}}_{\text{entr}}$, may also be $N^{\text{asym}}_{\text{entr}} \gg N^{\text{symm}}_{\text{entr}}$

Example - *pA* collision

CF, D. Kikoła, A. Kusina, J.-P. Lansberg, O. Mattelaer, A. Safronov, arXiv:2501.14487 [hep-ph]

- To trigger the asymmetric computation one should select:

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#*********************************************************************
 True = asymm_choice ! choice of the collision system
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proton baseline — nPDF list

Validation - *pA*

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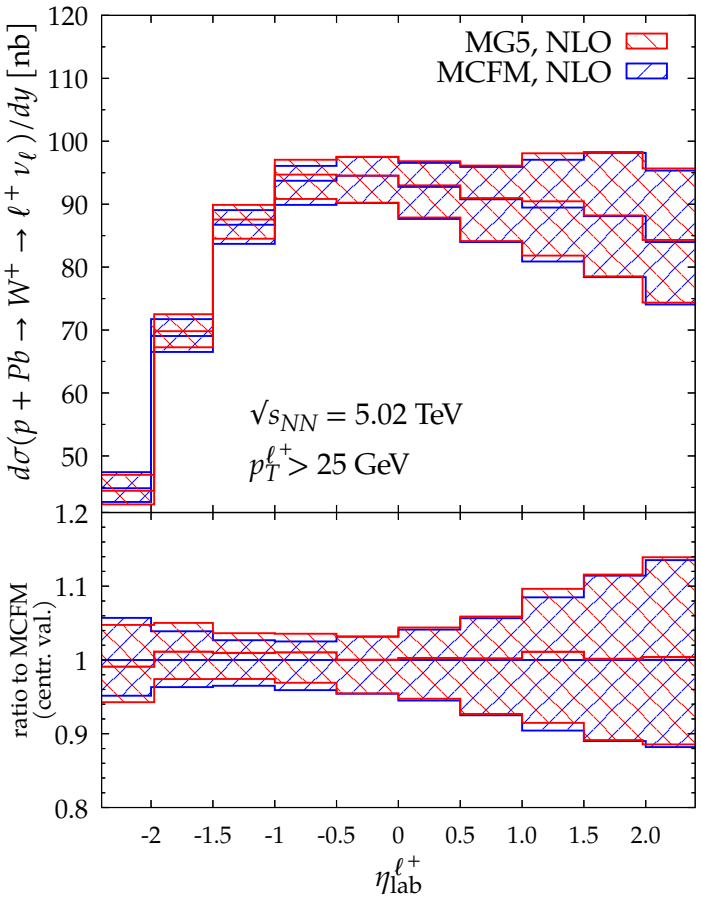

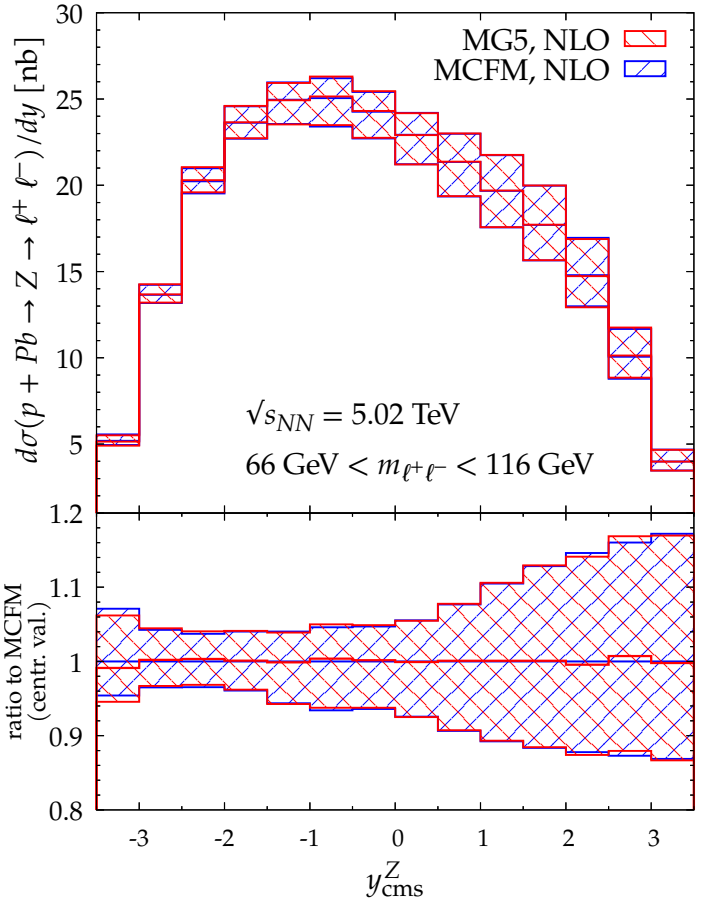

- only nPDF uncertainty (nCTEQ15) shown
- excellent agreement with MCFM

Validation - πA

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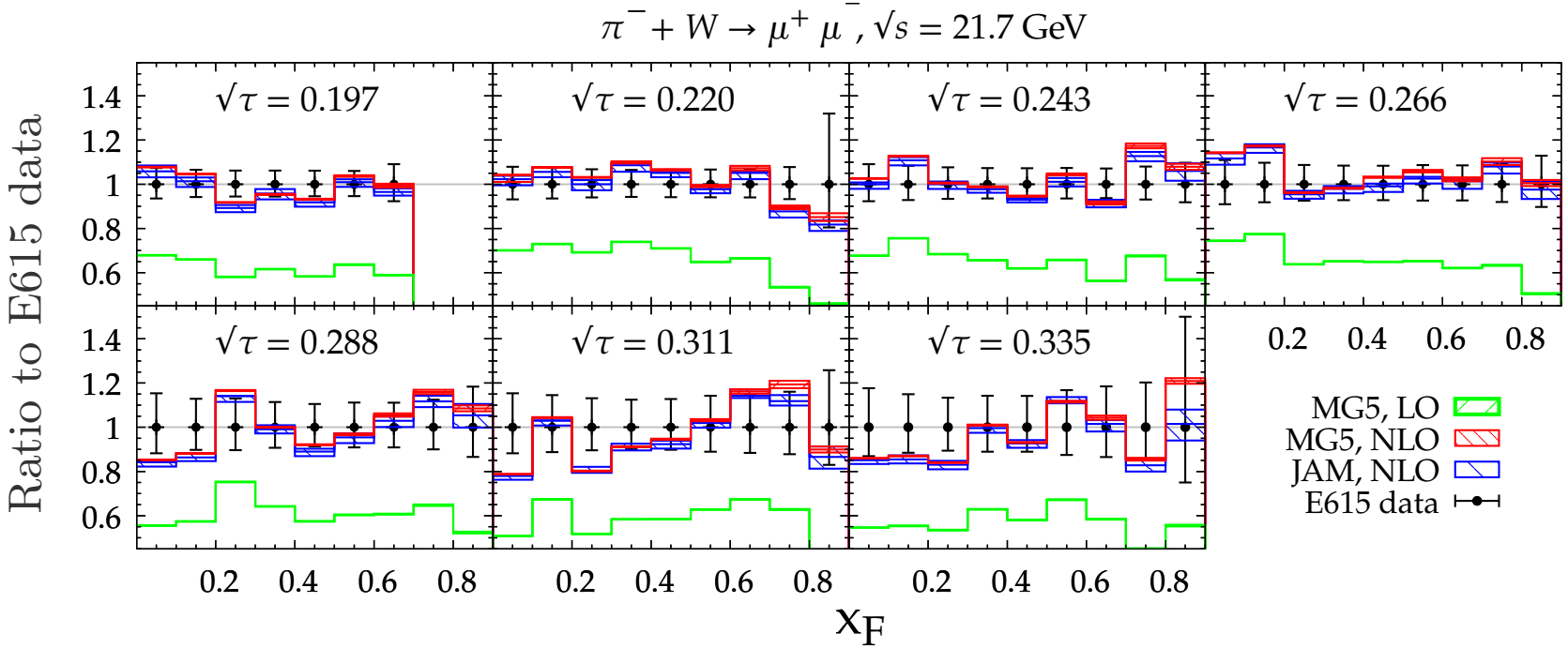

- MG5 and JAM MC statistical uncertainties tend to grow in the most forward region
- MG5 and JAM results essentially identical and compatible with experimental data

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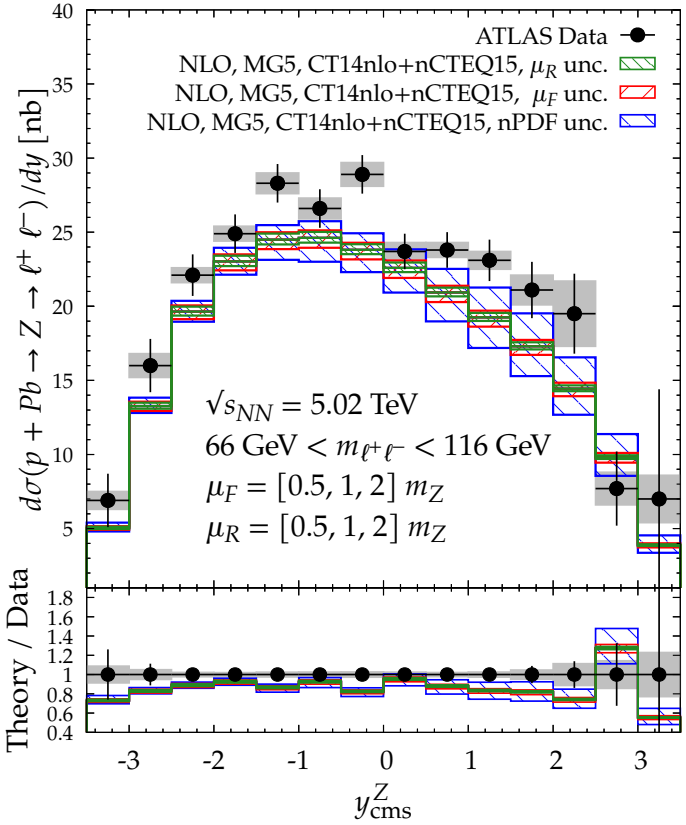

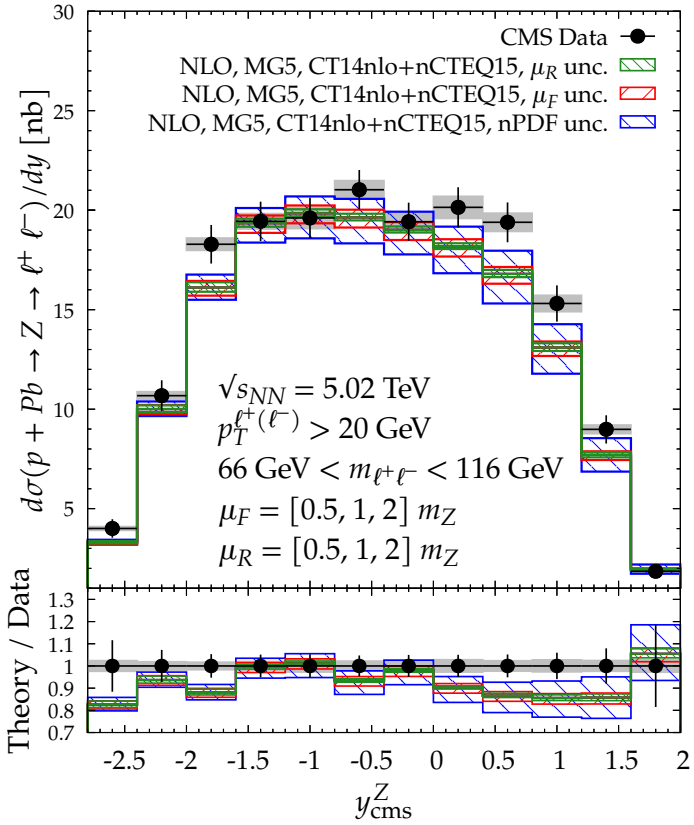

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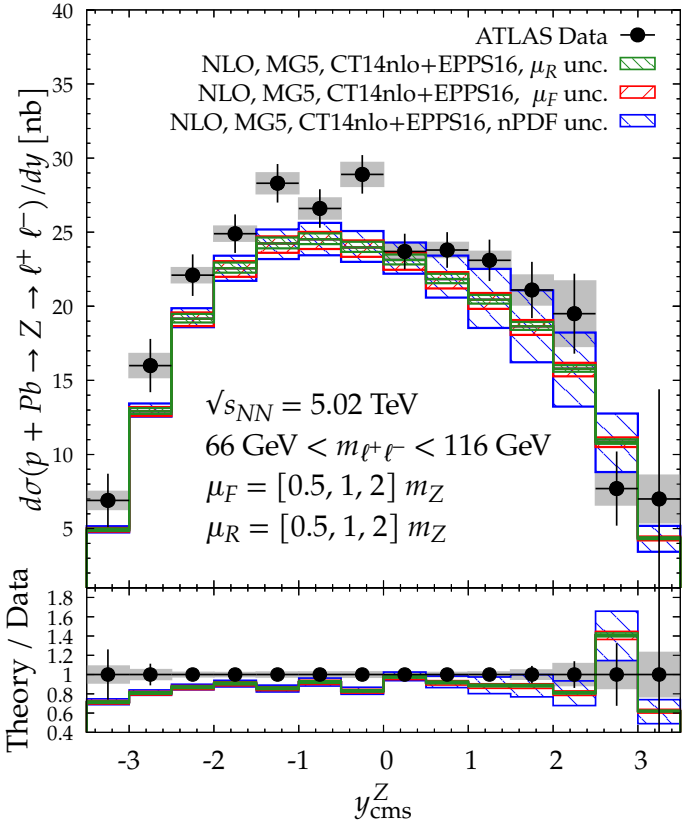

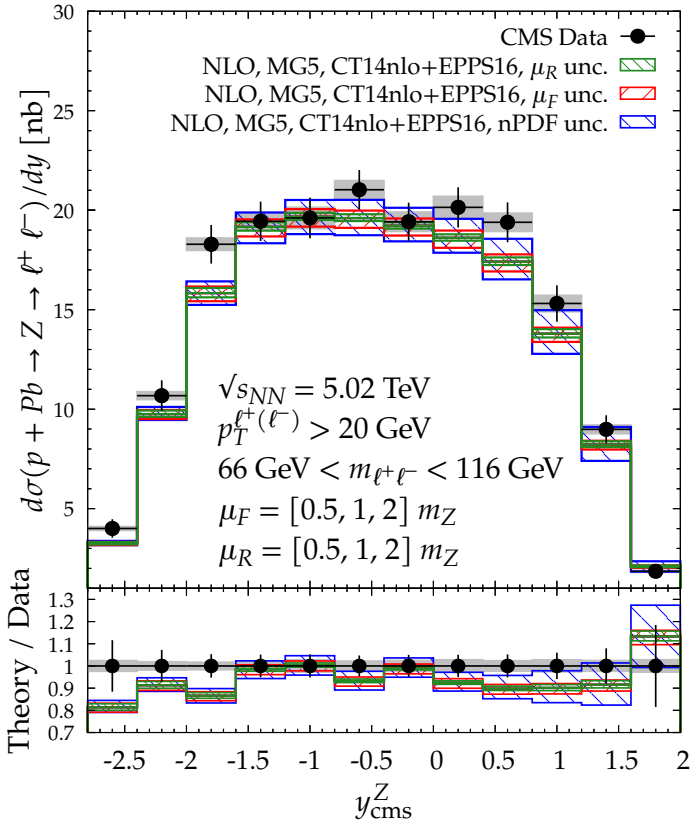

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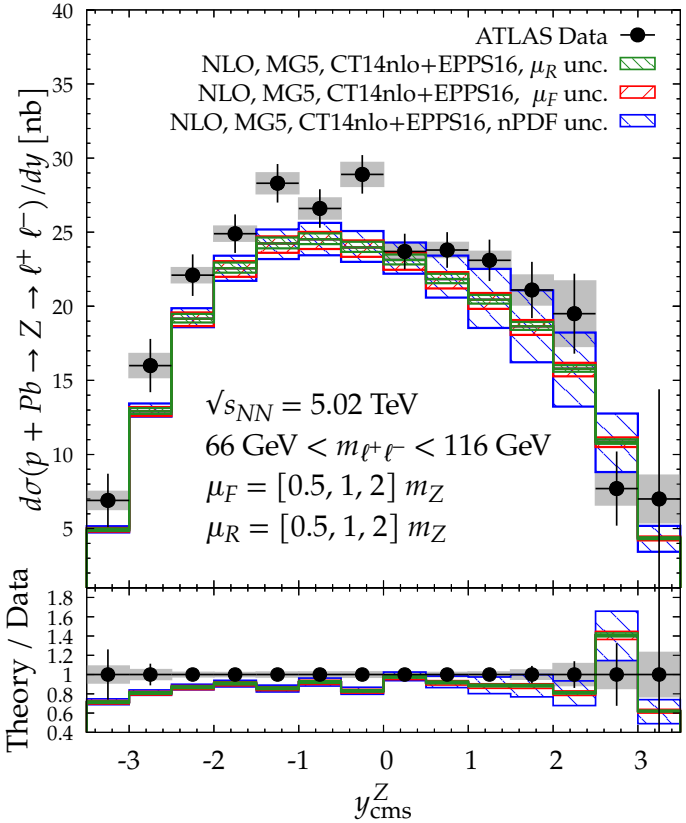

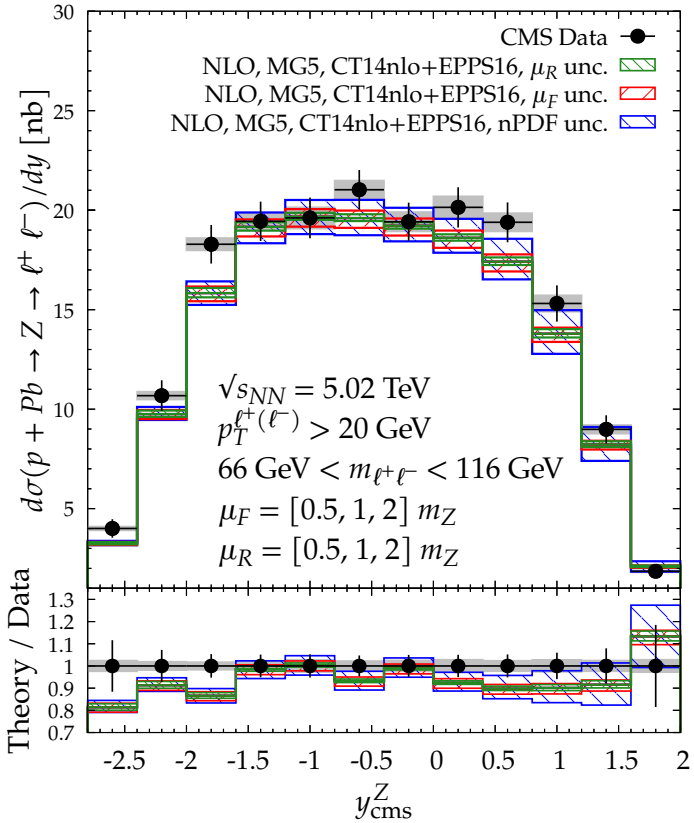

- such predictions can be now obtained in a single run by indicating three `LHAIDs` in the run_card

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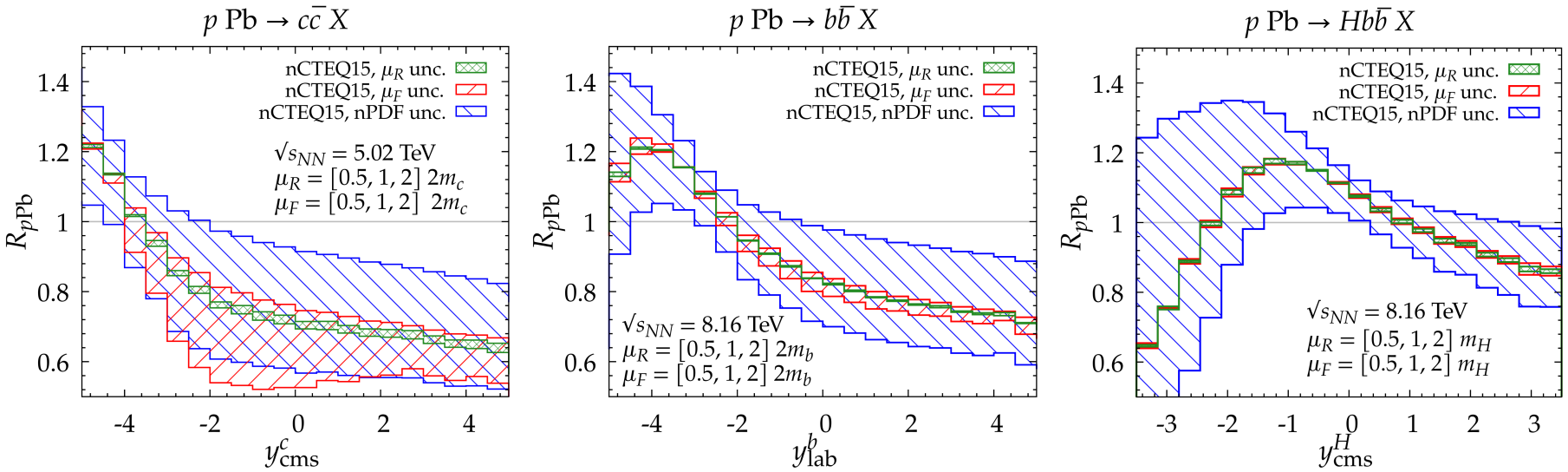

- nuclear modification factor: $R_{p\mathrm{Pb}} = \frac{1}{A_{\mathrm{Pb}}} \frac{d\sigma_{p\mathrm{Pb}}}{d\sigma_{pp}}$
- approximation for computing uncertainty:

$$\delta(R_{AB}) = \frac{1}{A_A A_B} \frac{\delta(d\sigma_{AB})}{d\sigma_{pp}^{\mathrm{central}}}$$

- $R_{p\mathrm{Pb}}$ automatically computed in a single run

ep and *eA* collisions

L. Manna et al., in preparation; L. Manna, A. Safronov et al., PoS EPS-HEP2023 (2024) 274; L. Manna, A. Safronov et al. PoS DIS2024 (2024)

We now focus on photoproduction:

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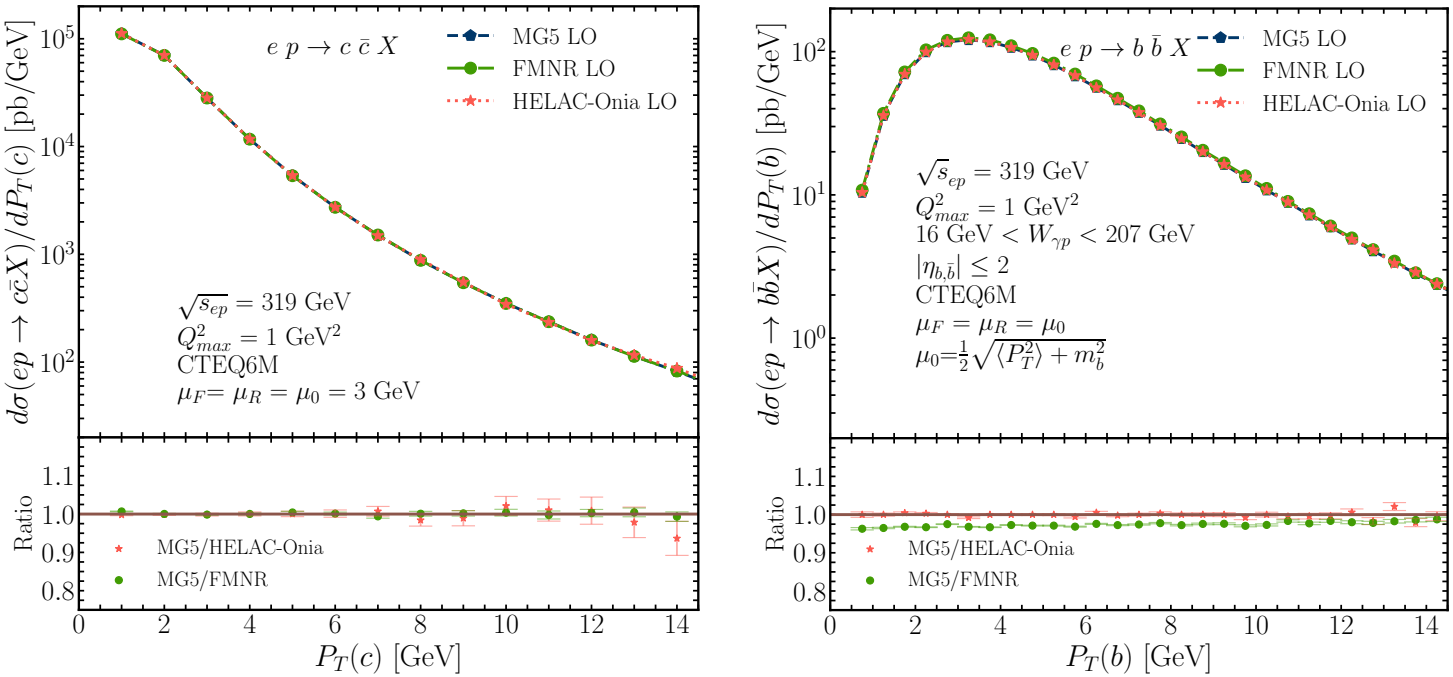
- lab frame now default

Inclusive photoproduction - validation at LO

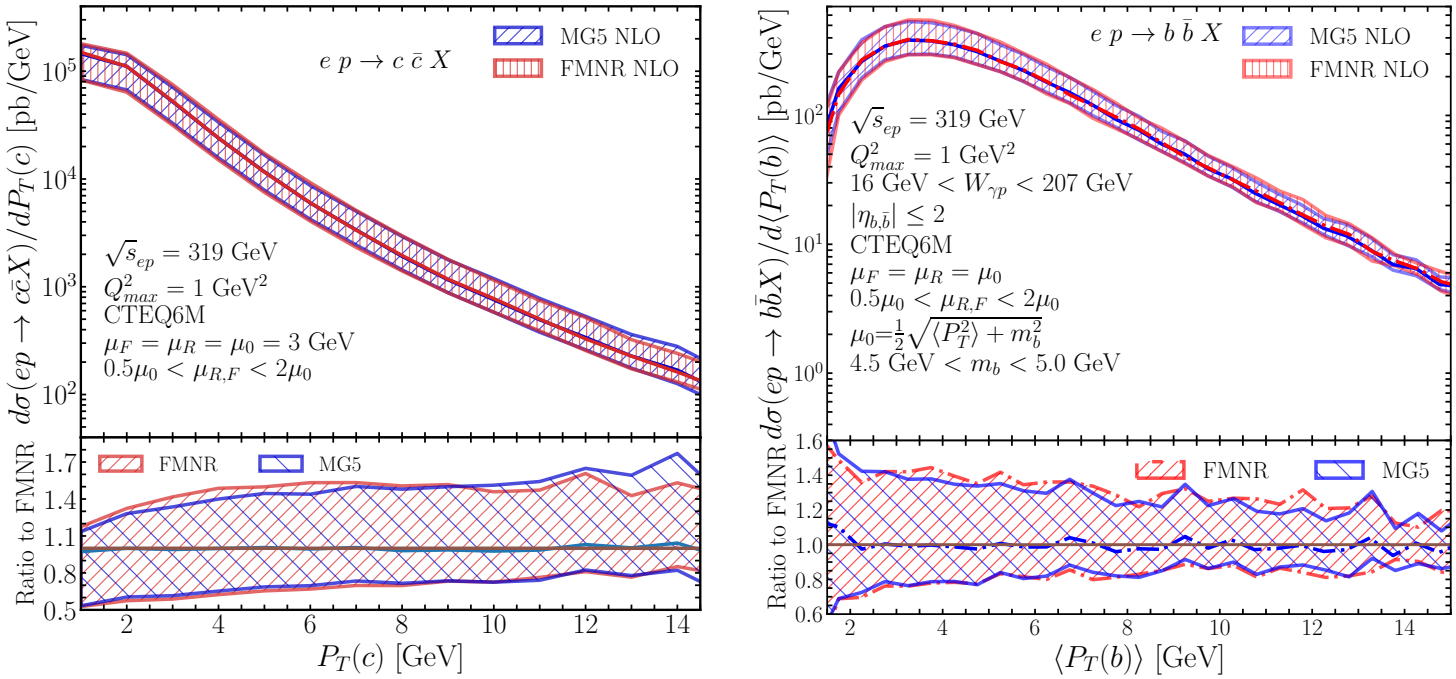
L. Manna et al., in preparation; L. Manna, A. Safronov et al., PoS EPS-HEP2023 (2024) 274; L. Manna, A. Safronov et al. PoS DIS2024 (2024)



- validation for $c\bar{c}$ (left) and $b\bar{b}$ photoproduction (HERA kinematics) at LO
- agreement $\mathcal{O}(1\%)$ with HELAC-Onia and $\sim 4\%$ with FMNR

Inclusive photoproduction - validation at NLO

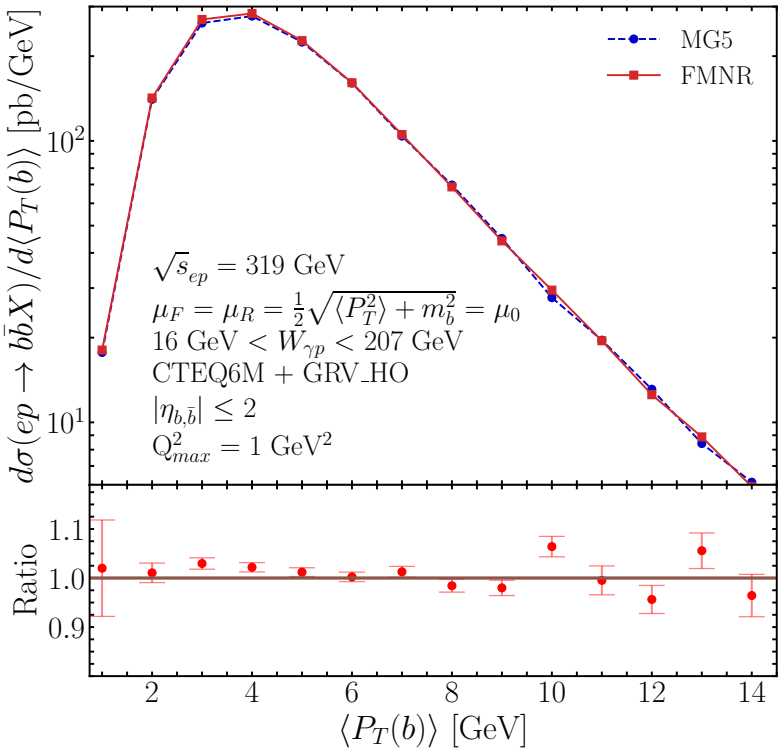
L. Manna et al., in preparation; L. Manna, A. Safronov et al., PoS EPS-HEP2023 (2024) 274; L. Manna, A. Safronov et al. PoS DIS2024 (2024)



- validation for $c\bar{c}$ (left) and $b\bar{b}$ photoproduction (HERA kinematics) at NLO
- very satisfactory agreement ($\mathcal{O}(1\%)$) with FMNR

Resolved contribution - validation at NLO

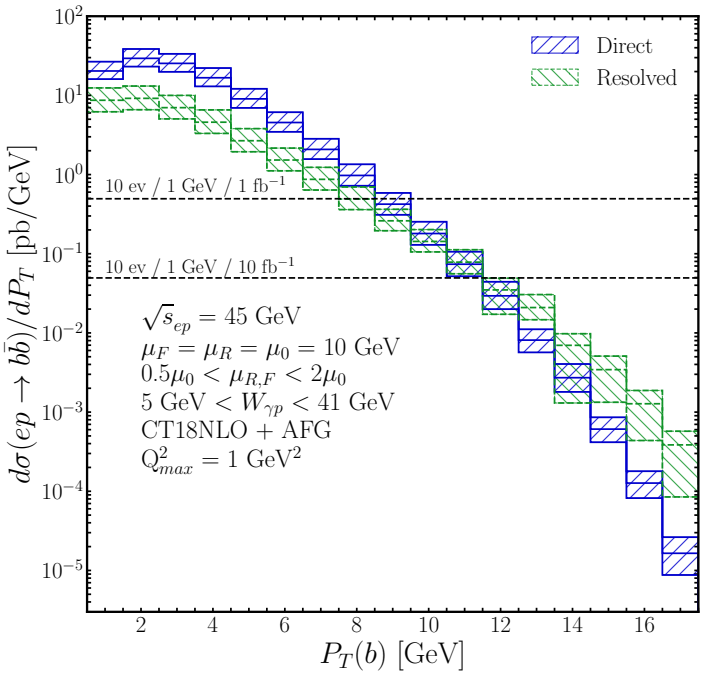
L. Manna et al. in preparation; L. Manna, A. Safronov et al., PoS EPS-HEP2023 (2024) 274; L. Manna, A. Safronov et al. PoS DIS2024 (2024)

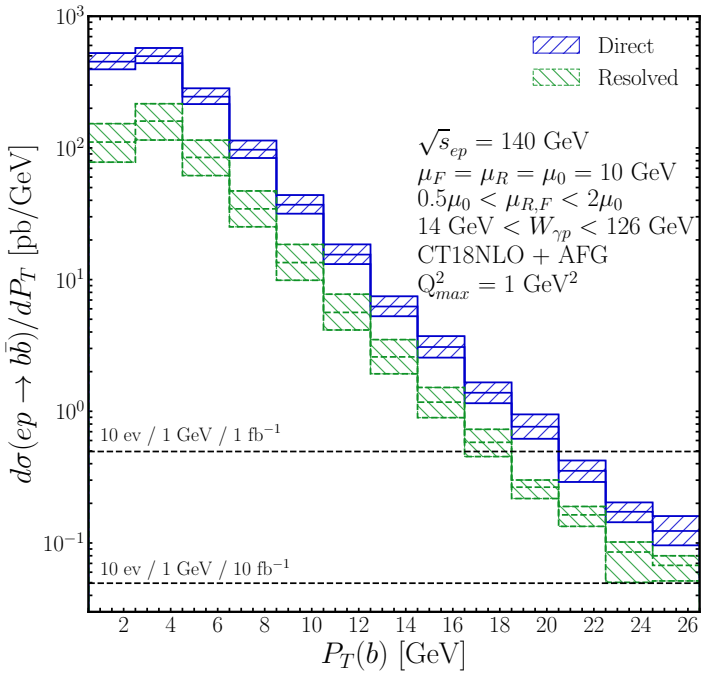


- ratio FMNR to MG5 with combined Monte Carlo uncertainties
- $\sim \mathcal{O}(2\%)$ agreement with FMNR

Example - $b\bar{b}$ photoproduction at the EIC

L. Manna et al. in preparation; L. Manna, A. Safronov et al., PoS EPS-HEP2023 (2024) 274; L. Manna, A. Safronov et al. PoS DIS2024 (2024)



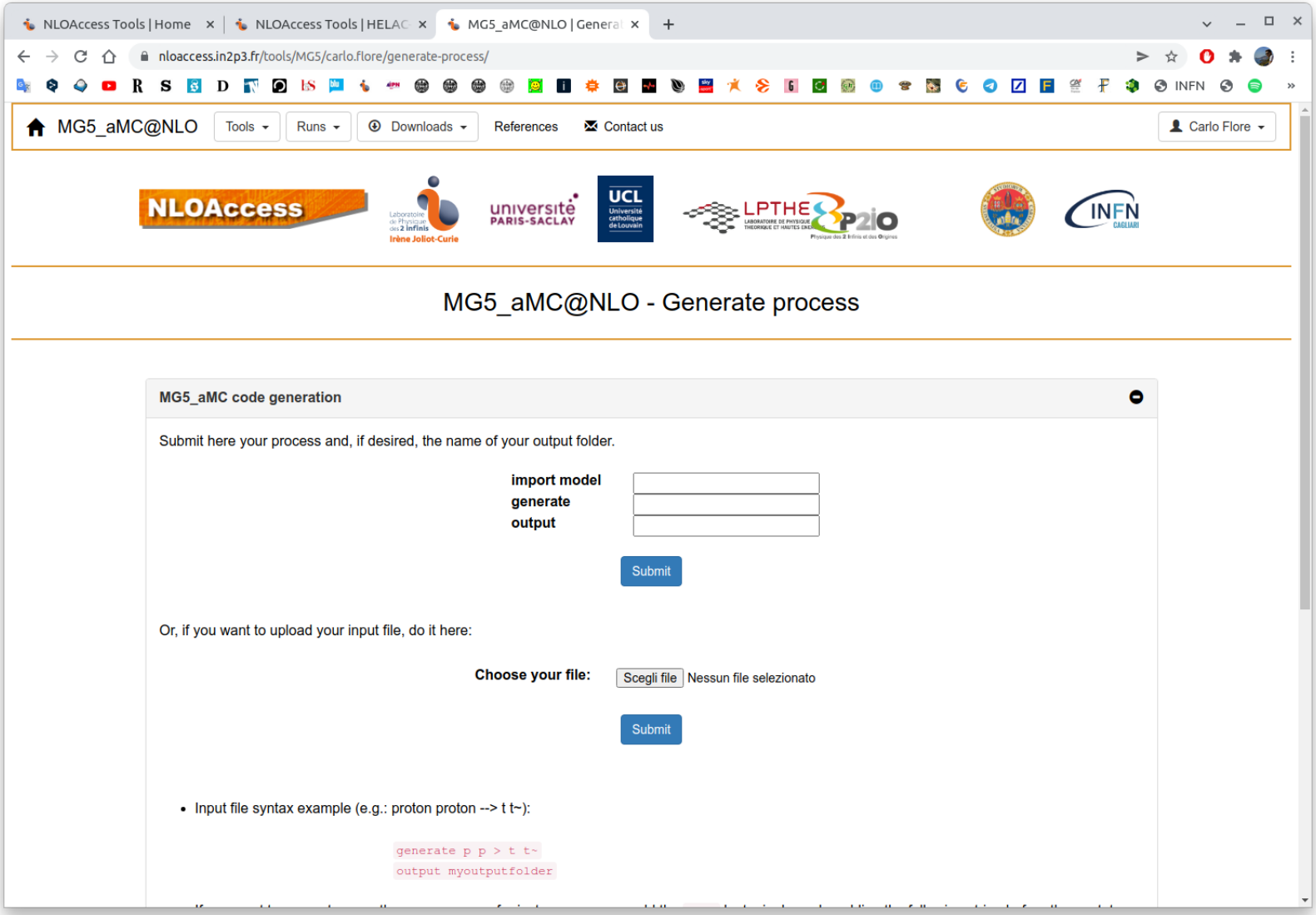


- predictions for the EIC at $\sqrt{s_{ep}} = 45$ GeV (left) and $\sqrt{s_{ep}} = 140$ GeV (right)
- resolved contribution comparable with direct one around $P_T \sim 9 - 10$ GeV at $\sqrt{s_{ep}} = 45$ GeV
- direct contribution dominant but resolved one not negligible at $\sqrt{s_{ep}} = 140$ GeV

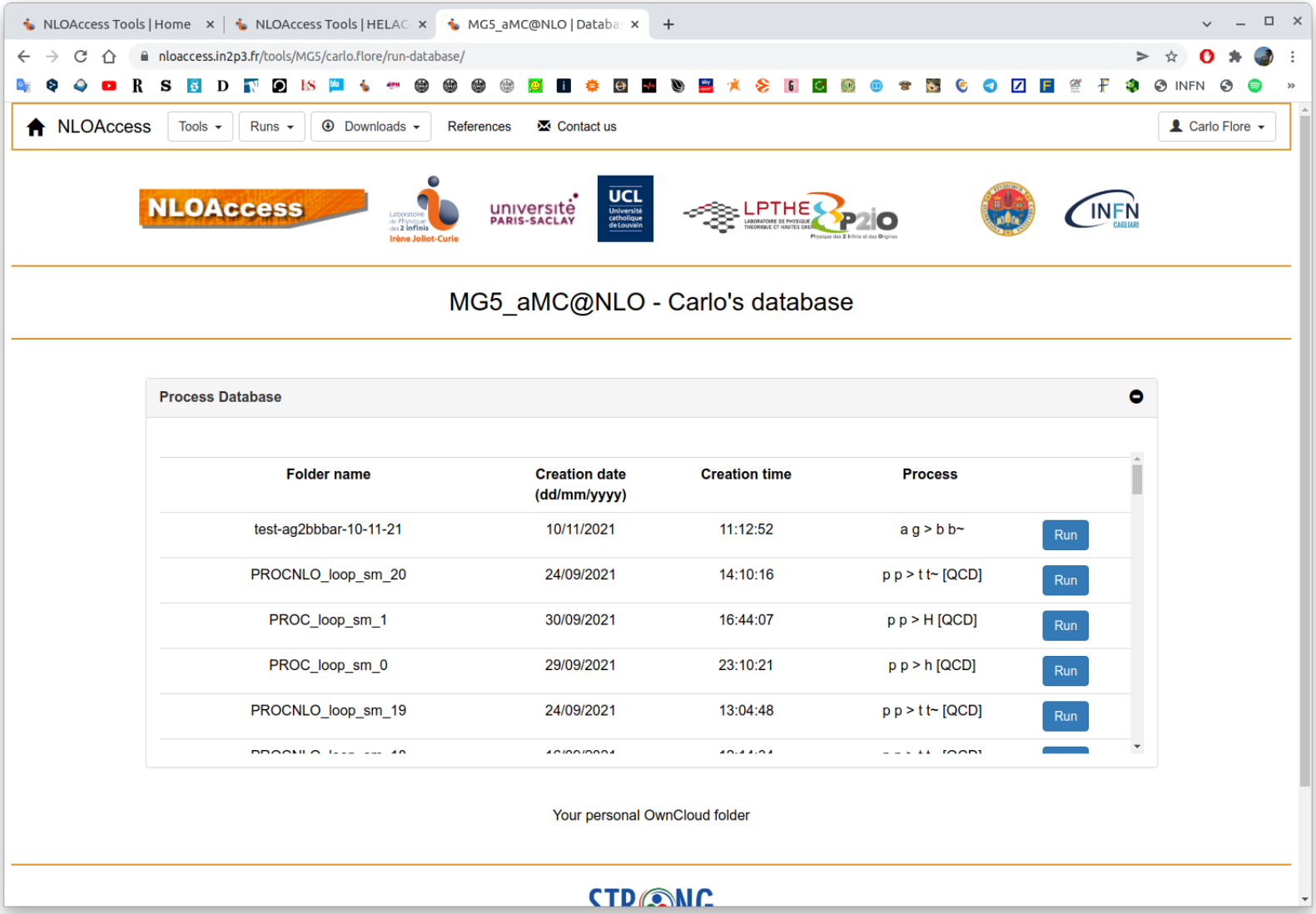
MG5 & NLOAccess (https://nloaccess.in2p3.fr/MG5/)

- NLOAccess: WP 10 - VA1 of STRONG-2020: (https://nloaccess.in2p3.fr/)
- it offers access for the first time to full NLO SM online calculation with MG5_aMC@NLO

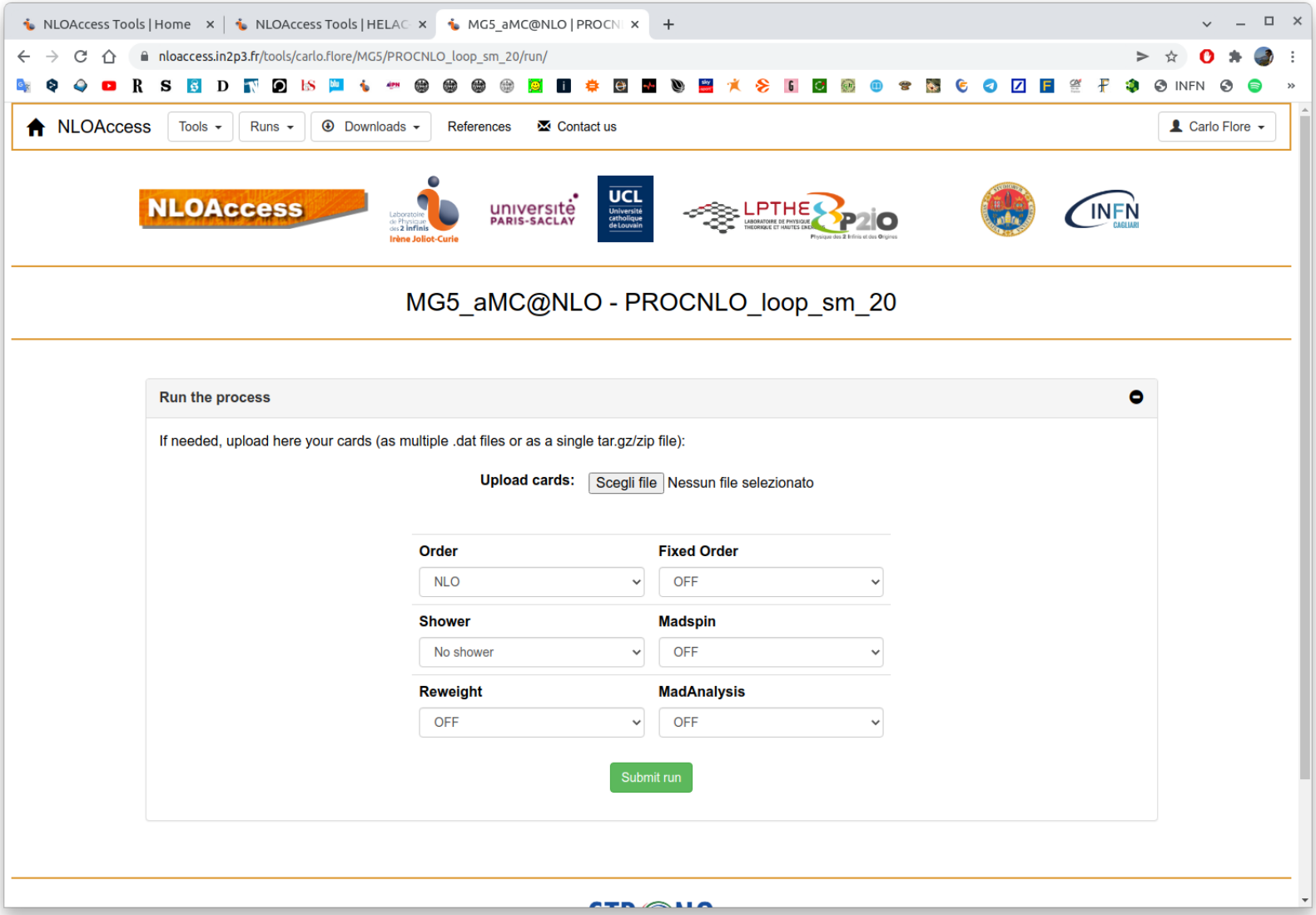
MG5 & NLOAccess - code generation



MG5 & NLOAccess - code database



MG5 & NLOAccess - code running



Conclusions and outlook

- MG5 now available online in its full NLO version on NLOAccess
- validated and developed MG5 for asymmetric collisions
  - photoproduction in ℓh collisions
  - cross-sections and nuclear modification factors in pA, πA and AB collisions

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Thank you

Backup

MG5 HwU output for asymmetric collisions

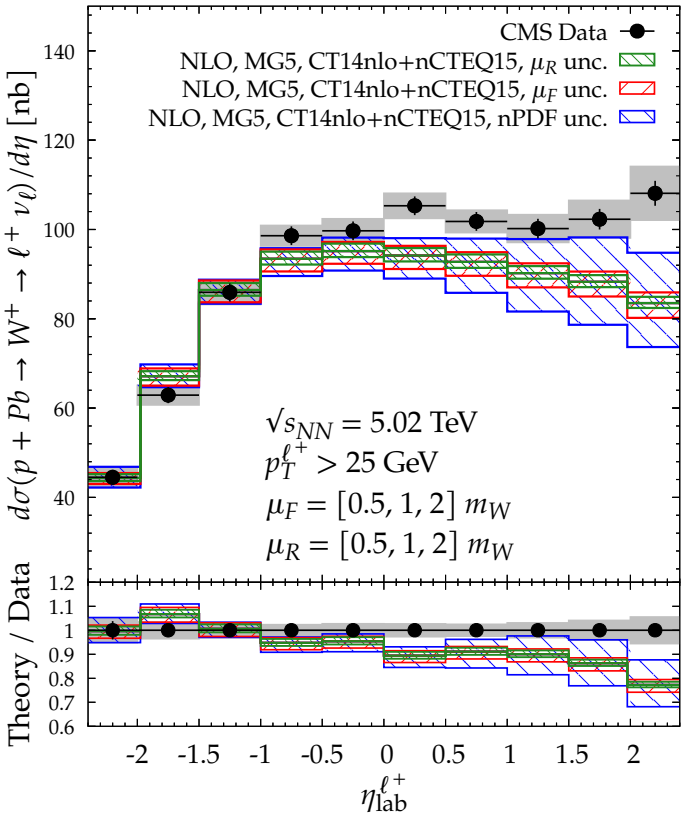
CF, D. Kikoła, A. Kusina, J.-P. Lansberg, O. Mattelaer, A. Safronov, arXiv:2501.14487 [hep-ph]

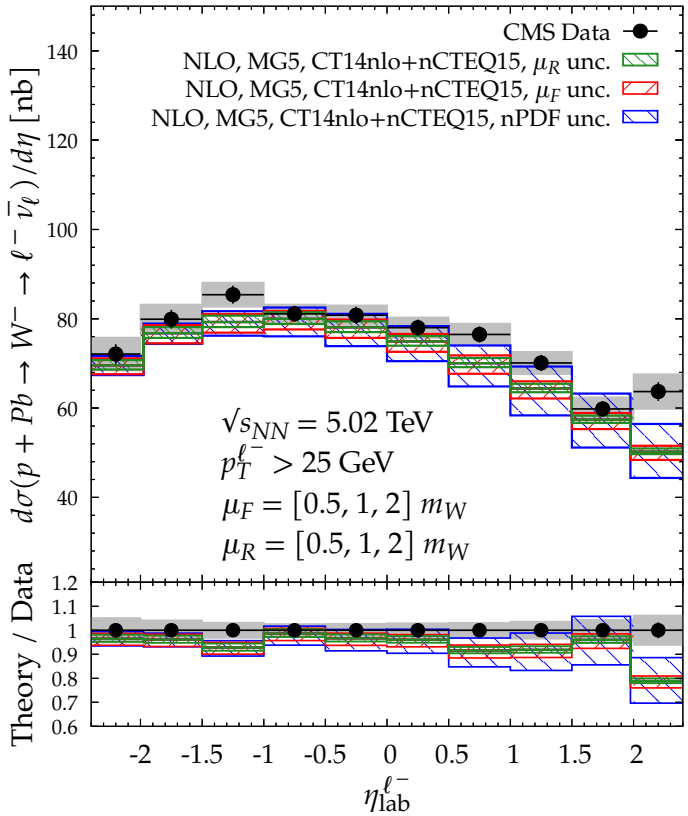
reweight_scale	reweight_PDF	No. of entries (symmetric): $N^{\text{sym}}_{\text{entr}}$	No. of entries (asymmetric): $N^{\text{asym}}_{\text{entr}}$
True	True	$4 + N_{\text{LHAID}}\left(3 + N_\mu\right) + \sum_{i=1}^{N_{\text{LHAID}}}\left(3 + N^i_{\text{mem}}\right)$	$N^{\text{sym}}_{\text{entr}} + 2(N_{\text{LHAID}} - 1)\left(3 + N_\mu\right) + 2\sum_{i=2}^{N_{\text{LHAID}}}\left(3 + N^i_{\text{mem}}\right)$
True	False	$4 + N_{\text{LHAID}}\left(3 + N_\mu\right) + N_{\text{LHAID}}\left(3 + 1\right)$	$N^{\text{sym}}_{\text{entr}} + 2(N_{\text{LHAID}} - 1)\left(3 + N_\mu\right) + 2(N_{\text{LHAID}} - 1)\left(3 + 1\right)$
False	True	$4 + \sum_{i=1}^{N_{\text{LHAID}}}\left(3 + N^i_{\text{mem}}\right)$	$N^{\text{sym}}_{\text{entr}} + 2\sum_{i=2}^{N_{\text{LHAID}}}\left(3 + N^i_{\text{mem}}\right)$
False	False	$4 + N_{\text{LHAID}}\left(3 + 1\right)$	$N^{\text{sym}}_{\text{entr}} + 2(N_{\text{LHAID}} - 1)\left(3 + 1\right)$

- N_μ: no. of scale combinations
- N_{LHAID}: no. of LHAIDs listed in the run_card
- N^i_{mem}: no. of PDF members

Illustrative asymmetric computations

CF, D. Kikoła, A. Kusina, J.-P. Lansberg, O. Mattelaer, A. Safronov, arXiv:2501.14487 [hep-ph]





- such predictions can be now obtained in a single run by indicating three `LHAIDs` in the run_card

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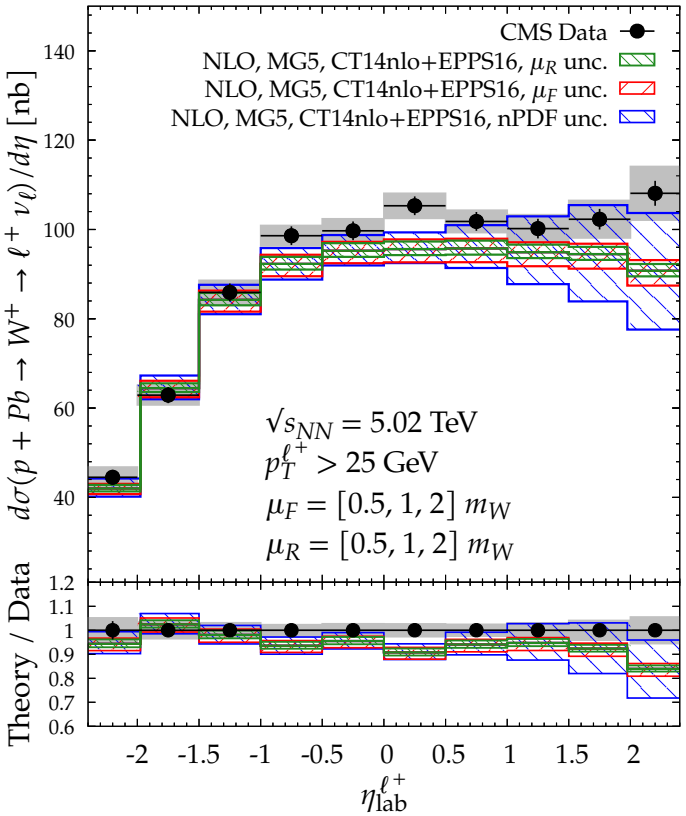

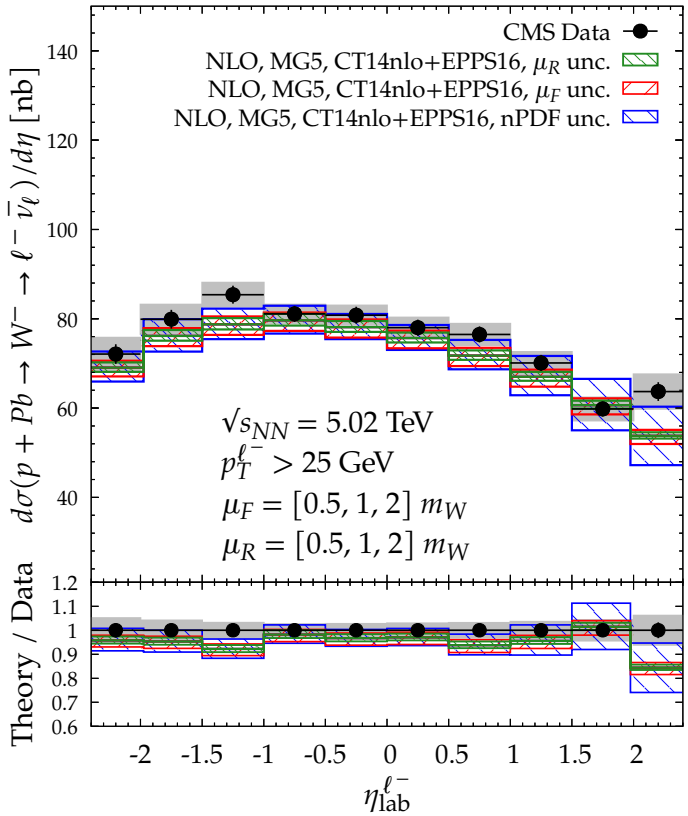

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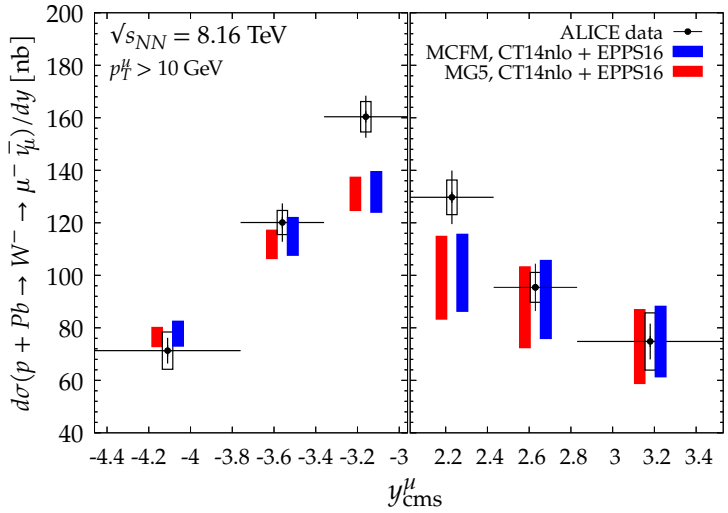
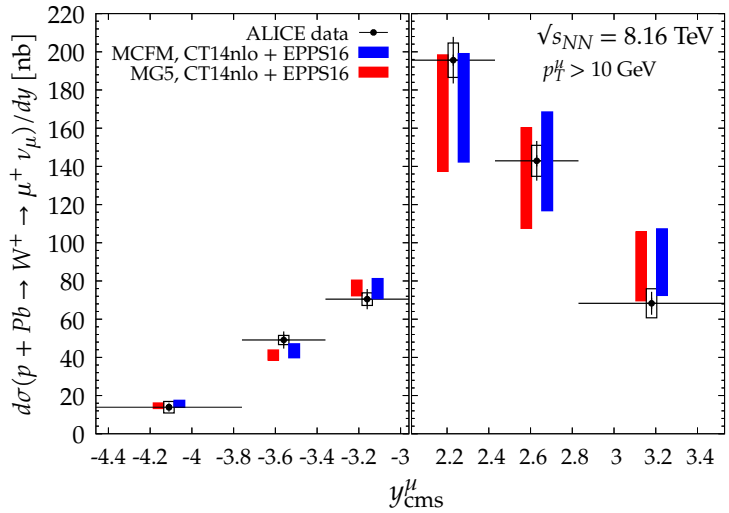
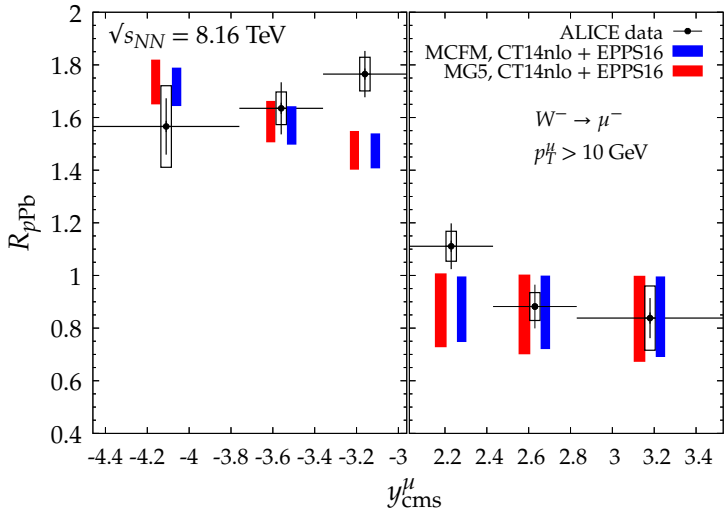
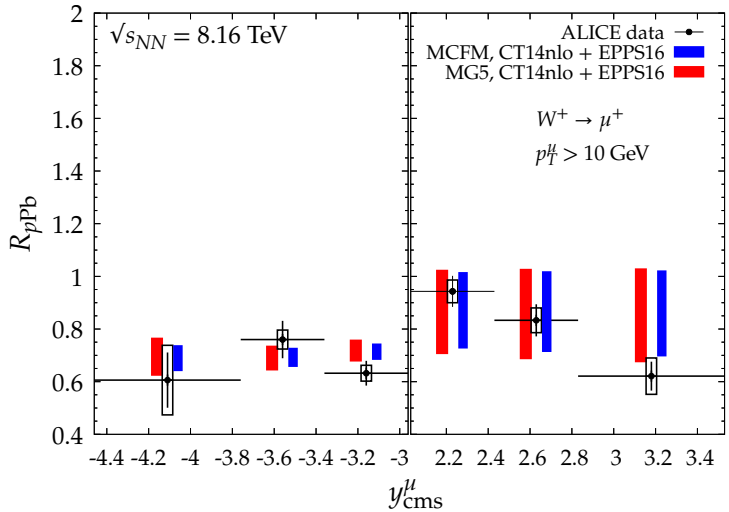


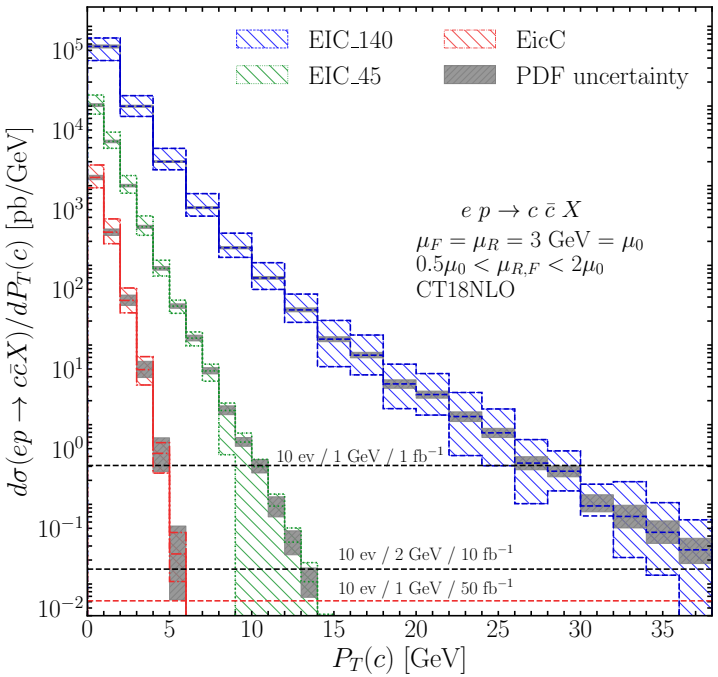


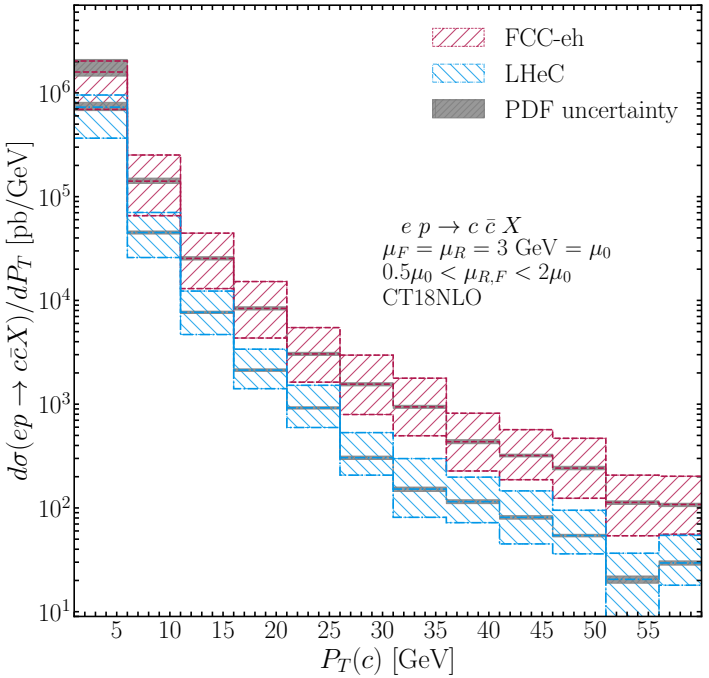




Inclusive $c\bar{c}$ photoproduction - predictions

L. Manna et al., in preparation





- NLO predictions for future *ep* colliders
- limited P_T range at EIcC
- P_T spectrum extend to $P_T \sim 60$ GeV at LHeC and FCC-eh

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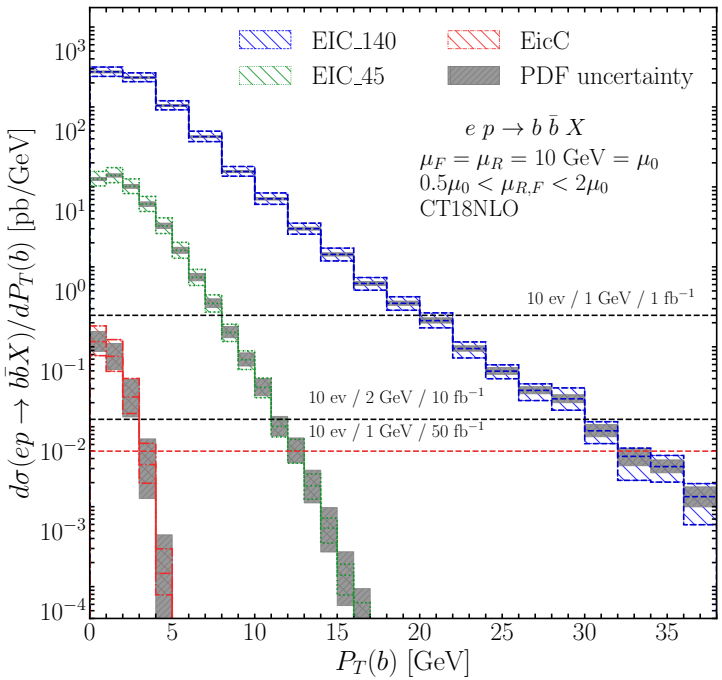

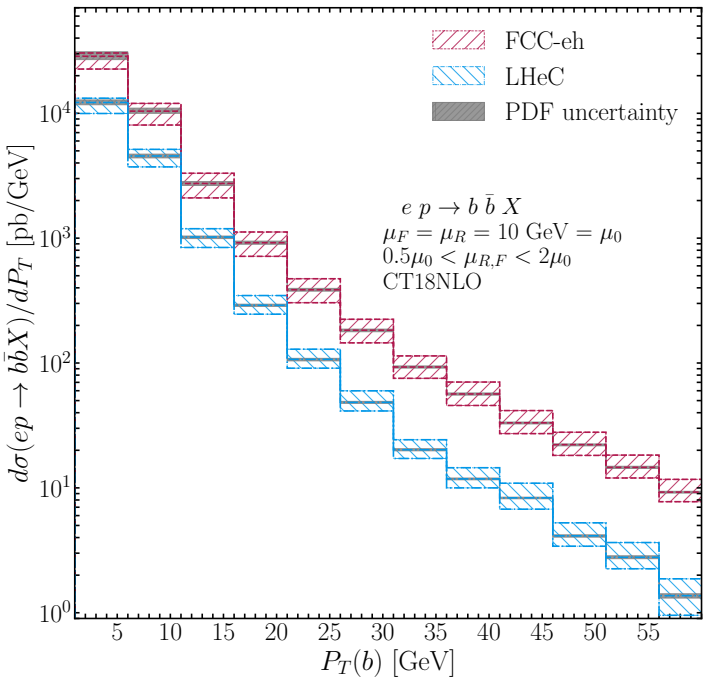

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