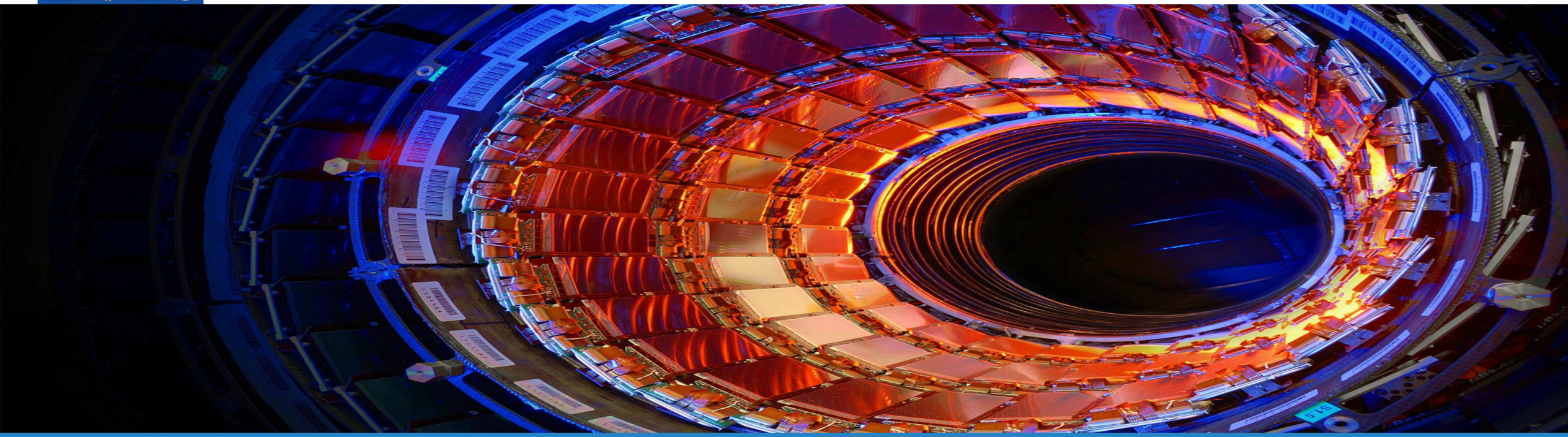


WP13 (NA2-Small-x): *Small-x Physics at the LHC and future DIS experiments*

N. Armesto
IGFAE, Universidade de Santiago de Compostela

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

Plan:

1 Work performed from the beginning of the project to the end of the period covered by the report and main results achieved so far

2 List of the Deliverables and Milestones achieved

3 Progress beyond the state of the art, expected results until the end of the project and potential impact

Introduction:

- 15 institutions; recently 2 contacts (B. Blok - Technion and G. Chachamis - LIP).
- Meeting this year to be held at ECT* in July, delayed to next year:

SATURATION AND DIFFRACTION AT THE LHC AND THE EIC

28 June 2021 — 02 July 2021

ECT* - Villa Tambosi

- Online meeting on 15/09/2020.

Participant institutions:

- **BGU**: Ben-Gurion University of the Negev, Beer Sheva, Israel (M. Lublinsky).
- **CNRS**: École Polytechnique, Université Paris-Saclay, Palaiseau, France (C. Marquet, S. Munier) + IPhT, Commissariat à l'énergie atomique, Saclay, France (F. Gelis, E. Iancu, G. Soyez) + Laboratoire de Physique Théorique, Université Paris-Saclay, Orsay, France (S. Wallon).
- **Consenza**: Università della Calabria, Cosenza, Italia (A. Papa).
- **CTU**: Czech Technical University, Prague, Czech Republic (J. Cepila, G. Contreras).
- **ECT***, Trento, Italy (D. Triantafyllopoulos).
- **Firenze**: Università de Firenze, Italia (D. Colferai).
- **Granada**: Universidad de Granada, Spain (J. L. Albacete).
- **Groningen**: University of Groningen, The Netherlands (D. Boer).
- **Jyväskylä**: University of Jyväskylä, Finland (T. Lappi, H. Paukkunen, K. J. Eskola).
- **Krakow INP**: Henryk Niewodniczański Institute of Nuclear Physics, Krakow, Poland (K. Golec-Biernat, K. Kutak, S. Sapeta).
- **Krakow JU**: Jagiellonian University, Krakow, Poland (Leszek Motyka, Michal Praszalowicz)
- **Madrid**: Universidad Autónoma de Madrid, Spain (A. Sabio Vera).
- **Regensburg**: University of Regensburg, Germany (G. Chirilli).
- **Santiago**: Universidade de Santiago de Compostela, Spain (N. Armesto).
- **Warsaw**: National Centre for Nuclear Research, Warsaw, Poland (T. Altinoluk, L. Szymanowski).

Work performed in the period:

Task 1: Nuclear PDFs.

- Work ongoing to include new LHC run 2 data in nuclear PDF fits. In particular, studies have focused on the impact of the inclusion of data on the production of D-mesons in pPb (JYU).

- Study of the impact of high-x CLAS data on nPDFs (JYU).

- Studies of the prospects for determination of nPDFs at future DIS experiments: LHeC and FCC-eh (USC-JYU).

Work performed in the period:

Task 2: New NLO-based precision phenomenology in CGC and BFKL.

- First fit of HERA inclusive DIS data in dipole picture with full NLO impact factor (JYU).
- Finite N_c corrections to the NLO BK equation (JYU).
- Systematic NRQCD light cone wave functions needed for exclusive vector meson production at small x (JYU).
- Calculation at partial NLO accuracy in BFKL of Higgs-jet, heavy quark pair, Λ pair and Λ-jet hadroproduction, and of Φ meson electroproduction (Calabria).
- Study of the basic limitations of the JIMWLK Hamiltonian presently available for small-x evolution (BGU).
- Studies of the effect of collinear improvements to the BK equation on fits to HERA data, and on nuclear structure functions including the impact parameter dependence (ECT*-CNRS and CTU).
- Studies of properties of the BFKL equation (UAM).

Work performed in the period:

Task 3: TMDs at small x.

- Study of the comparison of the TMD and HEF formalisms at small x in 2 to 3 processes: three jets in photoproduction and hadroproduction (CNRS and IFJ PAN).

- Study of the comparison between the iTMD and the CGC formalisms at small x for 2 to 2 processes: forward quark jets (CNRS).

- Access to the spin content of the proton in DIS on unpolarised targets through odderon exchange (CNRS-NCBJ).

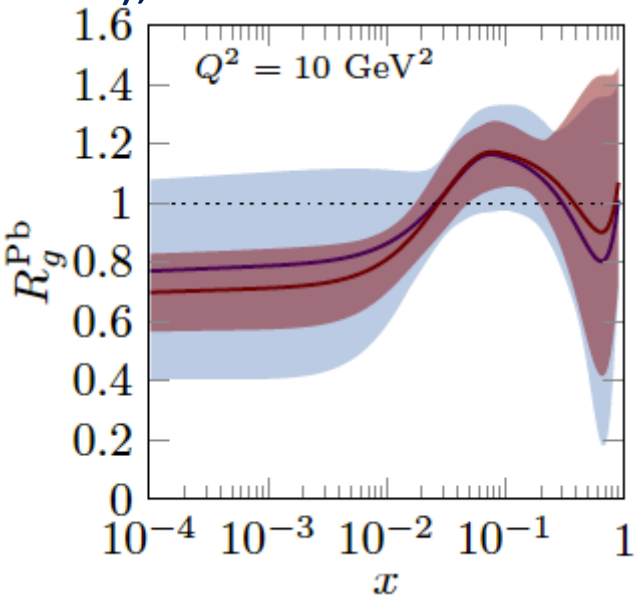
Work performed in the period:

Task 4: Multi-particle correlations & Thermalization.

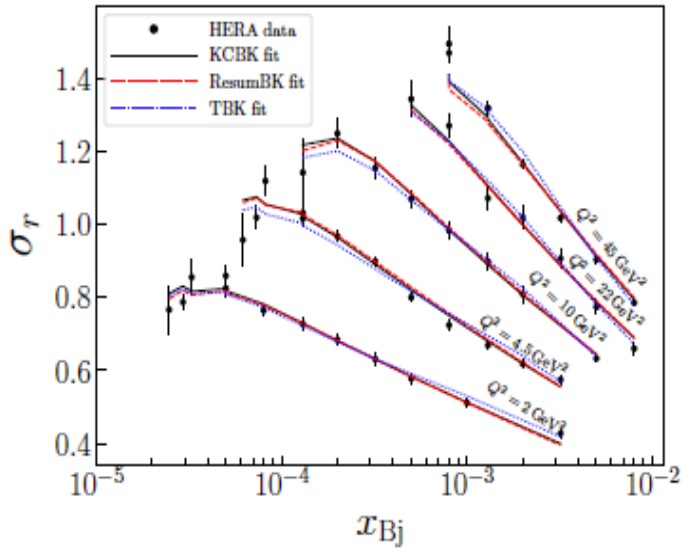
- Heavy ion phenomenology: building a realistic impact parameter distribution of matter created in heavy ion collision, with models constrained by DIS data (JYU).
- Understanding the universal behaviour and the transport coefficients in an overoccupied gluon plasma, such as present in the thermalization stage of a heavy ion collision (JYU).
- Study of the effect of non-eikonal corrections to the CGC on azimuthal asymmetries in pp collisions (USC-NCBJ).
- Calculation of gluon production in the fragmentation region in nucleus-nucleus collisions (JU).

Highlights:

Task 1: impact of the inclusion of data on D-meson production in pPb at the LHC on nPDFs, previous to its eventual inclusion in a global nPDF fit. K. J. Eskola, I. Helenius, P. Paakkinen, H. Paukkunen, JHEP 05 (2020), 037.



Task 2: 1st dipole model fit to HERA data using the most recent theoretical ingredients: full NLO impact factor, resummed NLO evolution kernel. G. Beuf, H. Hanninen, T. Lappi, H. Mäntysaari, arXiv:2007.01645 [hep-ph], sent to Phys. Rev. D.



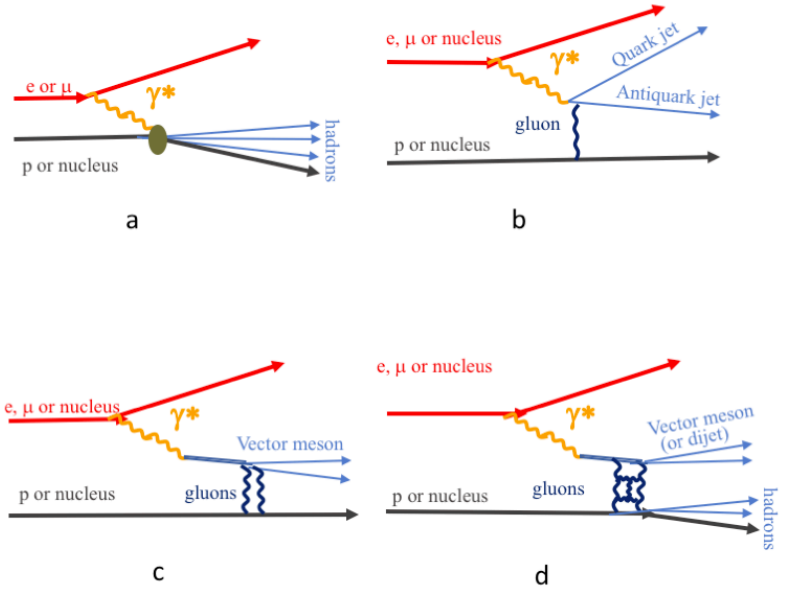
Highlights:

Task 3: 3-jet production in γ-A: first piece (real corrections) for understanding the relation among CGC and TMD and HEF - central milestone in the study of TMDs at small x. T. Altinoluk, R. Boussarie, C. Marquet, P. Taels, JHEP 07 (2020) 143.

$$(2\pi)^9 \frac{\mathrm{d}\sigma^{\gamma A\to q\bar{q}g+X}}{\mathrm{d}^3\vec{k}_1\mathrm{d}^3\vec{k}_2\mathrm{d}^3\vec{k}_3}\bigg|_{\text{corr. limit}} = 2\pi\delta\big(p^+ - \sum_{i=1}^{3} k_i^+\big)\,[\mathrm{H}]_{ij}^{\text{total}} \times\left[\frac{1}{2}\delta^{ij}\mathcal{F}_{gg}^{(3)}(x_A,\mathbf{q}_T) + \frac{1}{2}\Big(2\frac{\mathbf{q}_T^i\mathbf{q}_T^j}{\mathbf{q}_T^2} - \delta^{ij}\Big)\mathcal{H}_{gg}^{(3)}(x_A,\mathbf{q}_T)\right]$$

unpolarized gluon TMD — linearly-polarized gluon TMD

Task 4: considerable progress in building realistic impact parameter distributions of matter created in a heavy ion collision, with models constrained by DIS data. S. R. Klein and H. Mantysaari, Nature Rev. Phys. 1 (2019) no.11, 662-674.



Deliverables and milestones:

No Deliverables or Milestones in the RP1 (months 1-18).

22 publications and 34 talks sent for uploading in the participant portal.

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D13.1	NPDFs	23 - JYU	Report	Public	48
D13.2	Resummed NLO cross sections	1 - CNRS	Report	Public	36
D13.3	TMD factorization	37 - IFJ PAN	Report	Public	48
D13.4	Initial vs final state correlations	20 - USC	Report	Public	36

MS11	Reweighting of nPDFs including new LHC data	WP13	20 - USC	24	Publications and presentations in conferences, and software released and validated by a user group
MS12	Dipole cross section from resummed JIMWLK evolution	WP13	20 - USC	24	Publications and presentations in conferences, and software released and validated by a user group
MS13	TMD factorization at small x for 3 final-state particles	WP13	20 - USC	24	Publications and presentations in conferences
MS14	Completion of the calculation of multi-particle correlations in the dilute limit of the CGC	WP13	20 - USC	24	Publications and presentations in conferences

Use of financial resources:

- Some travel costs for research collaboration between institutes participating in the network. However, less than foreseen, first because reimbursing them through USC and JYU as originally planned became impossible, leading to a grant agreement modification procedure, and subsequently by the COVID outburst in February-March 2020.

- The two joint postdocs planned in the activity (USC-JYU: Florian Cougoulic; CNRS-IFJ PAN: Victor Vila) start their contracts in October and November this year, but their salaries will be covered initially by other grants that have to be employed to complement the STRONG 2020 contribution.

Institution	Original	Final
CNRS (Polytechnique, LPT Orsay, Saclay)	0	12000
ECT*	0	2000
Firenze	0	2000
Jyvaskyla	32000	16000
Krakow INP	0	6000
Krakow JU	0	4000
Regensburg	0	2000
Santiago de Compostela	32000	16000
NCBJ Warsaw	0	4000
Total	**64000**	**64000**

Beneficiary number	Organization legal name (in italics the Research Units)	Short name	Human effort from Annex I (person-months for 18 months)	Actual human effort in the reporting period (person-months)
1	Centre National de la Recherche Scientifique	CNRS	4,50	0
20	Universidad de Santiago de Compostela	USC	2,25	0
23	Jyvaskylan Yliopisto	JYU	2,40	0
37	The Henryk Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences	IFJ PAN	4,50	0

Progress, expected results and impact:

Task 1, D13.1: New global nPDF fit including LHC data, expected to have a large impact (e.g. EPPS16 has 300 citations in INSPIRE in less than 4 years), of central use for hard probes in heavy ion collisions and as cold nuclear matter effects (small systems).

Task 2, D13.2: dipole cross sections using resumed JIMWLK, central for the phenomenology at small x (e.g. AAMQS has 218 citations in INSPIRE in less than 9 years).

Task 3, D13.3: TMD factorisation at small x beyond LO, crucial for clarifying the relation between different factorisation schemes at small x.

Task 4, D13.4: multiparticle correlations in the CGC, needed for QCD based initial conditions for thermalisation and hydrodynamics, understanding of emergence in small systems.

Summary:

- Progress of the programmed activities goes well in all tasks.
- Milestones and deliverables not yet due but very likely to be achieved.
- Negligible use of financial resources until now: Grant Agreement modification, COVID situation, and usual timing in calls/contracts for postdocs.
- Workshops and travel activities to be restarted as soon as the COVID situation allows.