Letter of Intent H2020
HORIZON-INFRA-2025-01-SERV-03
LHCTuneAndCombine: Common LHC tuning parameters with input from combined measurements.

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1 Research objectives

1.1. Introduction and methodology: With the LHC entering Run III, the need to strengthen collaboration between experiments is becoming more crucial than ever. This is especially true in the field of heavy ions, where the level of involvement remains marginal in three of the four main LHC experiments. During Run II, ALICE, ATLAS, CMS, and LHCb worked together on a project to combine results from selected areas, aiming to expand the reach of each individual collaboration and improve communication between experiments. This project, called HonexComb (HC), was very successful, with research output including several publications [6, 12] and contributions at international conferences [2]. Equally important, it promoted exchange and networking of young postdocs. One concrete outcome of the networking efforts, was the creation of the LHC Heavy Ion group, which is now established within the LHC Physics community. While working on HC, we identified several areas where comparisons between experiments were suboptimal and where further work was clearly needed. The most significant issue was the lack of reliable theoretical predictions that were consistent across experiments. This is especially important when presenting results that rely on stable predictions, particularly in cases where variables dependent on the underlying event, such as track multiplicity, are crucial for evaluating the strength of the results. In this project we propose to set up a team of experimentalists from different LHC experiments to work together with the authors of the two general purpose Monte Carlo event generators Pythia 8.3 [5] and Herwig 7 [4]. The expected outcome of this collaboration would be three-fold:
1) Identify observables where the different kinematic coverage of experiments could provide complementary information to reproduce data in other regions or collision systems.
2) Use the selected observables to develop tuning techniques and contribute to infrastructure, such as e.g. Rivet [8], to be openly shared between experiments and theorists without reservations.
3) Employ the developed combined observables, techniques and infrastructure to provide tuning updates.
The implementation of the tasks above would be undertaken by the young postdocs and PhD students hired under this project; they will be a combination of experimental collaboration members from the different participating experiments, and from phenomenology. The interaction among the different postdocs from different experiments and theory would result in a discussion forum for the young physicists involved. In particular for the experimental members the resulting publications with only a few authors would be welcome in an area where many papers have over a thousand collaborators. The applicants for these positions will be selected by a committee with at least one representative of each experiment and a theorist, and will mainly be based at CERN in order to maximise the interaction among them. No collaboration rule will be violated in the process, as only previously published results will be included and analysed. Discussion with the managements of the four experiments have already happened and they are very supportive of the effort.
1.2 Selected subjects In this project we propose to work in two main areas, the area of Monte Carlo generators and the area of analysis and combination of data published from the LHC experiments. The main themes we would like to pursue in each area are listed below, with the possibility to expand or reduce according to the interests of the young physicists involved and hired on the project.

- Combination of results from the different experiments in the field of quarkonia and D-meson production, in several collision systems and at different centre-of-mass energies, including the results from the unique fixed target system at LHCb[10]. All experiments have results in this area, but there are tensions in some measurements, for instance in the coherent J/ψ production in the most central regions, where ATLAS and ALICE seem to disagree [3]. LHCb [1] and CMS [11] have also results in this area and could contribute to a deep understanding of this challenging production.

- Combination of Drell-Yan production measurements, with new possibilities as di-tau final states and the recent involvement of LHCb could open the route to a cross-experimental combination which would dig deep also in the theory behind this challenging production.

- A thorough study of different B-meson production in different kinematic ranges using Monte Carlo to cover the uninstrumented regions in order to exctract with high precision the $b\bar{b}$ total cross-section, still known with large uncertainties.
- A common tuning scenario for both Pythia and Herwig meant to reproduce the underlying event across several collision systems, where the use of machine learning techniques [9, 7] could add speed and precision to the prediction, then easily tested by the four collaborations.
- Addressing the long-standing discrepancies in baryon production observed between e^+e^- and pp collisions. The opportunity to combine data across the full LHC coverage, along with enhanced collaboration between event generator groups, will represent a significant contribution to resolving these issues.

More subjects can be explored if timely for the project.

2 Connection to Transnational Access infrastructures (TAs)

This project is structured around the collaboration of the four major LHC experiments at CERN, the European Laboratory of Particle Physics. CERN and its LHC collaborations are a pillar of the European hadron physics landscape. The LHC experiments support a broad user community by enabling access to cutting-edge experimental data, fostering scientific excellence and innovation. This project will build upon the CERN strategy ensuring sustained and enhanced availability of key infrastructure capabilities to the European research community in full alignment with Horizon Europe's strategic objectives.

3 Estimated budget request

The project requires funds for two years of four postdoctoral Research Associate (RA) and four years of PhD student salaries for two PhD students, with the post-docs being one per experiment and the PhD students dedicated to the Monte Carlo generators. A co-supervision of the PhD students or a shared postdoc between the theorists and the experiment could be foreseen. The total funds requested are detailed in Table 1. Possibility of co-funding by the host institutions will be explored.

Year of contract	1st	2nd	3rd	4th	Total
Postdoc salary UniCA	53	53	-	-	106
Postdoc salaries IFJPAN and AGH	45	45	-	-	180
Postdoc salary EP	53	53	-	-	106
PhD salary UJ	28	28	30	-	78
PhD salary LU	85	85	85	85	340
Total	810 k€.				

Table 1: Funds requested in k€.

4 Participating and partner institutions

The team will be composed of: (please specify the full name of your institute and your title).

- University of Cagliari (UniCA) and INFN: Prof. Giulia Manca (LHCb), Prof. Rudolf G.C. Oldeman (LHCb), Dr. Camilla De Angelis (LHCb).
- Institute of Nuclear Physics PAN (IFJ PAN): Prof. Jacek Otwinowski (ALICE);
- AGH University of Krakow (AGH): Prof. Iwona Grabowska-Bołd (ATLAS);
- Jagiellonian University (UJ): Assoc. Prof. Andrzej Siódmok (Herwig)
- Lund University (LU): Department of Physics: Docent Christian Bierlich (Pythia)
- Ecole Polytechnique and CNRS (EP): Dr. Matthew Nguyen (CMS)

References

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