Institut national de physique nucléaire et de physique des particules

COLLABORATION AGREEMENT

IN2P3 - COPIN

I. Identification of the laboratories	
Partner	COPIN
IN2P3 laboratories	**LPNHE**
Partner laboratories	Cracovie (IFJ PAN)

II. Identification of the collaboration	
Title of the collaboration	ATLAS-LPNHEIFJ-ELECINJET: Use of electrons in jets with Atlas data
Number of the collaboration	10-140
IN2P3 spokesperson	F. DERUE
COPIN spokesperson	A. KACZMARSKA
Scientific Domain	Hadronic and Particle Physics

Status of the collaboration	
Status	The renewal of the collaboration is requested for the period January 1st - December 31st, 2023

III. Status report for the period January 1st to December 31st, 2022	
III.1 IN2P3 scientists in COPIN	
Total time approved for 2022	15
Total time used for 2022	15
List of scientists	1. F. DERUE (15 days)
III.2 COPIN scientists in France	
Total time approved for 2022	15
Total time used for 2022	15
List of scientists	1. A. KACZMARSKA (8 days) 2. B. ZABINSKI (7 days)
III.3 Scientific results of the above-mentioned collaboration	
Description	

The aim of the proposal is to analyze ATLAS data, in particular with the use of leptons (electrons, muons and taus) or tracks in jets. These studies rely on good understanding of the inner detector and the calorimeters. Our studies mix detector performance and physics analyses of the LHC Run-2 data. Results were shown in dedicated ATLAS working groups (the top WG, the tau combined performance WG and the higgs WGs) and are published or on the way to be.

The LPNHE group participates to the measurement of the top quark mass using ttbar events with $J/\psi \to \mu\mu$ and D mesons embedded in a b-jet. Such events allow for measurements of the top quark mass using its strong sensitivity to the invariant mass from the lepton+meson system. A PhD has been defended in the group in September 2020, based on full Run-2 data, with a value of the top quark mass measured to be m_{top}=173.50±0.56 (stat) ±1.51 (syst) GeV [1]. Two ingredients of the reconstruction of such events are directly linked to the subject of this proposal. The first is the estimation of the level of background from fake isolated leptons, jets mis-identified as electrons/muons, electrons or muons in jets or electrons from conversions. This background is estimated with a data driven method which implies to measure the real and fake identification efficiency, so including the identification of electrons in jets. These estimates are constantly ameliorated. Even if this background is small (~3% of events), it leads to an important uncertainty of the top quark mass: it was estimated to be ~0.30 GeV last year; thanks to the work done this year it has been reduced to ~0.10 GeV. The second is the reconstruction of the soft muons embedded in b jets. The effect on the mass is smaller, of the order of 0.05 GeV. In the current year there is work continued on legacy Run-2 publication, in particular fighting against low MC statistics and some ttbar modelling issues, delaying publication. Perspectives of the accuracy of this measurement (down to 0.5 GeV) for the end of the HL-LHC period are published in Ref. [2]. No work has started yet using Run 3 data analysis.

The Cracow group has been continuing studies on searches of heavy charged Higgs boson, decaying to a tau lepton and its neutrino in tau+jets channel (top quark decays hadronically) based on full Run-2 data. Such a boson is foreseen by many models beyond the Standard Model, in particular by the Minimal Supersymmetric Standard Model. The observation of a charged Higgs boson would clearly indicate new phenomena beyond the Standard Model. The main background in those studies consists of the top-anti top pairs production, process studied in detail by the LPNHE group. The tau polarization information has been used to remove this overwhelming background. It increased analysis sensitivity particularly for low masses of charged Higgs. To improve signal background separation MVA techniques are used. The group is also developing estimation of background coming from jets mis-identified as hadronically decaying tau leptons, using data driven method (so called "fake factors method"). In the current year there is work continued on legacy Run-2 publication. It should be finished in next months.

The Cracow group has started to be also involved in searches of di-higgs production in multilepton final state. In the Standard Model destructive interference between the two production processes, significantly reduces the cross section, making such measurements very challenging. On the other hand, physics beyond the SM could enhance the di-Higgs production rate, either through resonant or non-resonant production. The main backgrounds for that analysis are also processes studied by the LPNHE group. This analysis has been never done by the ATLAS Collaboration and results should be published next year.

It should be noted that, besides the IN2P3-COPIN collaboration, this collaborative effort has benefited from the invitation of A. Kaczmarska as guest researcher by Université de Paris for two weeks in May 2022 at LPNHE in the ATLAS group.

[1] J. Zahreddine, Mesure de la masse du quark top dans des événements ttbar avec des mésons J/ψ et D dans l’état final avec les données du Run 2 de l’expérience ATLAS auprès du LHC, PhD, 23 september 2020, Sorbonne Université, To be published

[2] ATLAS and CMS Collaborations, Report on the Physics at the HL-LHC and Perspectives for the HE-LHC, arXiv:1902.10229, CERN-LPCC-2019-01

IV. Renewal of the collaboration for 2023

IV.1 Proposed scientific program

Description

The ATLAS groups of IFJ and LPNHE are participating in ATLAS physics analyses like precision measurement of the Standard Model of particle physics using W, Z and top quark production as well as studies of the Standard Model Higgs boson, measurement of its parameters and search for physics beyond the Standard Model. In most cases, the precision of these analyses is limited by our knowledge of some ATLAS detector performances, such as the precision to which the particle energies are measured, or the efficiency with which we can identify these particles.

Physics processes of prime interest at the LHC are expected to produce leptons from a few GeV to several TeV. Both groups, IFJ-PAN Cracow and LPNHE Paris, are involved in analyses with such leptons in final states. The IFJ-PAN Cracow is interested in study of Z and W decays to tau leptons (polarization studies, backgrounds to searches for New Physics), and in searches for New Physics signatures with tau leptons in final states (charged

Higgs, diHiggs). The LPNHE Paris members of this proposal are interested in top quark studies, mainly its mass measurement. One of the common background in all these studies are low density jets which can mimic signal isolated leptons, which include electrons/muons from heavy flavors, electrons from Dalitz decays, muons from kaons decays, or photon conversions originating from neutral pion decays and jets in general. Leptons or charged tracks produced in b jets can be used also to reconstruct some signal final state, in particular for the top quark physics. Our proposal is to focus on the study of such leptons embedded in jets which are a common from our analyses.

In year 2022, both groups were actively working on the analysis legacy of the data taken during the Run-2 and will continue in 2023. Besides, the Run-3 of the LHC having started in summer 2022, this lead to the need for new estimates of the all chain procedure with these new data.

The LPNHE group participates to the measurement of the top quark mass using ttbar events with J/ψ and D mesons embedded in a b-jet. The analysis of the Run-2 data is ongoing to get measurements and to improve the understanding of the systematic uncertainties. In particular, the same events can be used to study the fragmentation of b quarks. The relevant part of these studies to this collaborative effort is the estimate and mostly the related uncertainties of the fake leptons background events for top analyses, which is one of the largest detector related uncertainties, but also the identification of leptons and charged tracks close to jets which is more complicated in Run-2 due to the boost of the particles in final states. Analysis of Run-3 may start, as increase of statistics will help this analysis, but it may not be the priority.This study will benefit from the expertise of the Cracow group with tau channels which represent large similarities.

The Cracow group plans to continue searches of the New Physics with tau leptons in the final states and to continue with di-higgs process analysis for multilepton finals state. In both cases overwhelming background coming from top quark pairs production has to be under control. For that reason, evolved methods of separation of that background from signal have to be developed with help of the LPHNE group (an expert on the top quark production). In addition the group will be involved in development of tau identification algorithms for the HL-LHC conditions.

Both groups have developed similar expertise on leptons (in particular electrons) in jets, seen either as background or signal depending on the physics analyses. Tau leptons have a very different way to be reconstructed, but physics done with them suffer, in part, from similar backgrounds like low density jets. The proposal consists in the application of this common knowledge on the ATLAS data to obtain a better understanding of the backgrounds and also for LPNHE to add tau leptons in their studies, with the help of IFJ-PAN members.

The total time requested in the proposal should help the two groups to meet personally and enhance contacts done all along the year.

It should be noted that, besides the IN2P3-COPIN collaboration, this collaborative effort will benefit from the invitation of F. Derue as guest researcher by IFJ-PAN in Cracow for two weeks in January 2023 in part to give lectures to doctoral school on particle detectors.

IV.2 Estimated duration for IN2P3 scientists in COPIN

Total time requested for 2023	15
List of scientists	1. F. DERUE (15 days)

IV.3 Estimated duration for COPIN scientists in France

Total time requested for 2023	15
List of scientists	1. M. WOLTER (5 days) 2. B. ZABINSKI (5 days) 3. P. BRUCKMAN de RENSTROM (5 days)

Comment Validation	
Unity Director	Marco ZITO (LPNHE) - 2022-10-04 09:57:03