

COLLABORATION AGREEMENT

IN2P3 - COPIN

I. Identification of the laboratories

Partner	COPIN
IN2P3 laboratories	IJCLab
Partner laboratories	Cracovie (SIP)

II. Identification of the collaboration

Title of the collaboration	Leptons in p pion-induced reactions with HADES
Number of the collaboration	04-111
IN2P3 spokesperson	B. RAMSTEIN
COPIN spokesperson	P. SALABURA
Scientific Domain	Nuclear Physics

Status of the collaboration

Status	The renewal of the collaboration is requested for the period January 1st - December 31st, 2023
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III. Status report for the period January 1st to December 31st, 2022

III.1 IN2P3 scientists in COPIN

Total time approved for 2022	18
Total time used for 2022	16
List of scientists	1. B. Ramstein (2 days) 2. F. Hojeij (7 days) 3. R. Abou Yassine (7 days)

III.2 COPIN scientists in France

Total time approved for 2022	25
Total time used for 2022	25
List of scientists	1. P. Salabura (2 days) 2. R. Lalik (5 days) 3. I. Ciepal (18 days)

III.3 Scientific results of the above-mentioned collaboration

Description	
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The aim of the HADES experiment at GSI/Darmstadt is to investigate the nuclear matter at high densities and moderate temperatures where baryonic resonances play a significant role. The experimental program also comprises measurements in elementary reactions (nucleon-nucleon or pion-nucleon) to provide references for medium effects studies and study specific processes, with a particular interest on baryonic resonances production and decay, which is the main focus of the COPIN collaboration.

This year, the joint activities included the data taking in February ($pp@4.5$ GeV), data analysis of several experiments and the preparation of future pion beam experiments. An extended visit of I. Ciepal was organized (26 September-16 October) to work on the data analysis. P. Salabura came October 13-15, jointly with a visit of the FFN/GSI physicists within the IN2P3-GSI collaboration agreement. This will be followed by a visit of R. Lalik in November to work on the analysis and simulation software. The French physicists came to Poland for the HADES analysis meeting in July in Warsaw and the two students also went to Cracow to work on the data analysis. The two teams also met at the Hades collaboration meetings in GSI in March and in Coimbra in September.

The paper on the analysis of the quasi-free $\pi^-p \rightarrow e^+e^-n$ reaction, measured on CH₂ target at an incident pion momentum of 685 MeV/c was submitted [arXiv [2205.15914](https://arxiv.org/abs/2205.15914) [nucl-ex]]. These data provide a very sensitive test of models describing baryon electromagnetic transitions in the time-like region. They are compared (i) to a Vector Dominance Model (ii) to a microscopic Lagrangian model and (iii) to a time-like electromagnetic transition form factor model (collaboration B. Ramstein (IJCLab), T. Galatyuk (GSI) and P. Salabura (UJ-Cracow)). We are now preparing the publication of the inclusive quasi-free $\pi^-p \rightarrow e^+e^-X$ reaction, which includes a description of the π^0 and eta Dalitz decay processes. The results have been presented at the QNP conference (B. Ramstein, invited talk) and at the NSTAR conference (I. Ciepal).

Two PhDs were defended this year in UJ Cracow this year. The first one, by N. Rathod, deals with the exclusive $\pi^-p \rightarrow \pi^-p e^+e^-$ data, which are produced via the πN Bremsstrahlung process. The second one, by K. Nowakowski was devoted to the analysis of the $\Lambda(1520)$ production in the $p+p$ and $p+Nb$ reaction at 3.5 GeV. Two papers on these analysis are in preparation. The UJ team is also involved in the analysis of the Inclusive $\Sigma(1385)$ production in $p+p@3.5$ GeV. This analysis and its extension also to $\Lambda(1520)$ production in $pp@4.5$ GeV is the subject of K. Sumara PhD.

As a result of the GPAC meeting in 2020, one month of beam time was allocated in February 2022 to the HADES collaboration for the study of the pp reaction at 4.5 GeV, which is the highest proton beam energy at SIS18. This experiment exploited, for the first time, the newly installed forward tracking system, which was constructed as a collaboration between Orsay, Jülich and Cracow. The experiment was successful and the early stages of the data analysis are on-going. It will enable the study of hyperon production and decay, hence paving the way for similar studies foreseen in future with the PANDA experiments in the antiproton-proton reaction. This topic is strongly promoted by the UJ team. Another important outcome of this experiment will be the measurement of e^+e^- spectra, which will provide a reference for future experiments studying medium effects at high incident energies, either in the $p+A$ reaction at SIS18 or in the $A+A$ reaction at SIS100. This energy range is particularly interesting to test models as production mechanisms are expected to evolve in this energy range from baryon resonance excitation to string fragmentation. Such studies, using both inclusive and exclusive e^+e^- production channels are the subject of the PhD work of Rayane Abou Yassine, in the framework of a Paris-Saclay/TU-Darmstadt cotutelle. A lot of activities this year has been focused on the first steps of the data analysis of this experiment. The Polish team is deeply involved in calibration and tracking developments activities related with the new Forward Detector while the Orsay team focused on dilepton reconstruction.

The HADES team at IJCLab will be reinforced in November 2022 by a postdoctoral fellow (Suman Deb). He will analyze the ϕ production in the $K+K^-$ channel. This analysis will be complementary to the study by R. Abou Yassine in the e^+e^- channel and will allow for a detailed study of the production mechanism. A study of the non resonant $K+k^-$ production is also foreseen.

The thesis of F. Hojeij at IJCLab, cosupervised by I. Ciepal (INP Cracow) is devoted to the analysis of hadronic channels in the π^-+C reaction. Proton and pion distributions and correlations are studied in various exit channels (pp^- , pp^-p^+ , ppp ,...), allowing for a selective study of the pion production and rescattering steps in the carbon nucleus. The objective is to test transport models (RQMD, GIBUU, SMASH) and the INCL++ hadronic model included in GEANT4. The visit of I. Ciepal in fall 2022 was very beneficial for the progress of the PhD work. We took advantage of this visit to organize discussions with J.-C. David from IRFU, Saclay, who develops the INCL++ cascade. The results have been presented and discussed in the HADES collaboration and analysis meetings. F. Hojeij gave a talk at the FAIRNESS conference in May, at the QNP conference in September and will soon present the results at the NSTAR conference.

publications:

"First measurement of massive virtual photon emission from N^* baryon resonances" , (HADES collab), arXiv [2205.15914](https://arxiv.org/abs/2205.15914) [nucl-ex]

"Impact of the Coulomb field on charged-pion spectra in few-GeV heavy-ion collisions", (HADES collab), *Eur.Phys.J.A* 58 (2022) 9, 166.

talks:

HYP2022 conference:

R. Lalik (UJ), "Review of strangeness physics programme at HADES – past and future perspectives"

FAIRNESS conference Thessaloniki, May 2022

F. Hojeij (IJCLab) "Investigation of hadronic exit channels of the $\pi^- + ^{12}\text{C}$ reaction at an incident momentum of 0.7 GeV/c

QNP conference, on line, 5-9 Sept. 2022:

R. Lalik (UJ) "Hyperons electromagnetic form factors with HADES"

B. Ramstein (IJCLab) "Time like baryon transition studies with HADES" , invited talk,

F. Hojeij (IJCLab) "proton and pion emission channels in $\pi^- + \text{C}$ at an incident momentum of 0.7 GeV/c.

NSTAR conference, Santa Margherita Ligure, 17-24 Oct. 2022 ,

F. Hojeij, "Investigation of proton and pion production in the $\pi^- + \text{C}$ reaction at an incident momentum of 0.7 GeV/c with HADES"

I. Ciepal (INP) "Studies of Two-Pion Production and Time-like Electromagnetic Structure of Baryons in Pion-Induced Reactions"

K. Sumara (UJ) "Elastic scattering reconstruction"

Hades collaboration meeting, on-line, 21-25 March 2022:

R. Lalik(UJ) "STS+fRPC overview"

I. Ciepal (INP) "Trigger performance during pp@4.5 GeV run "

P. Salabura (UJ) "Lambda(1520) production in pp and pNb"

R. Abou Yassine (IJCLab) , "Preliminary results of e+e- analysis "

F. Hojeij (IJCLab)"Hadronic channels studies in $\pi^- + \text{C}$ reaction at 690 MeV/c "

Hades analysis meeting, Warsaw, 11-13 July 2022:

I. Ciepal (INP) "TOF status and updates "

K. Sumara (UJ) " fRPC calibration"

K. Sumara (UJ) "Overview of pp elastic scattering analysis - Konrad Sumara

K. ProÅciÅski (UJ) "Count estimates for meson decays in pp@4.5 GeV -"

R. Abou Yassine (IJCLab) "First studies on dileptons emission in pp @ 4,5 GeV"

F. Hojeij (IJCLab) "Investigation of exclusive hadronic exit channels in π^+C reaction @ 0.69 GeV/c"

Hades collaboration meeting, Coimbra, 19-23 September 2022:

K. Sumara (UJ) "Update on fRPC detector calibration"

R. Lalik (UJ) "Forward detector status and tracking "

I. Ciepal (INP) "rare meson decays in $pp@4.5\text{GeV}$ "

F. Hojeij (IJCLab) investigation of pion and proton emission in the π^+C reaction at an incident momentum of 0.7 GeV/c with HADES

Symposium: baryons from the lab to neutron stars, Coimbra 24 Sept. 2022

B. Ramstein (IJCLab) "Time-like baryon transition studies with HADES"

IV. Renewal of the collaboration for 2023

IV.1 Proposed scientific program

Description

Next year, the joint activities will be focused on:

data analysis : As mentioned above, two PhDs have been defended in JU this year, by N. Rathod on the π^+N bremsstrahlung in the $\pi^+ + CH_2$ experiment and by K. Nowakowski on $\Lambda(1520)$ production in pp and pNb reactions. We will finalize the publication of these analysis. Both teams will also strongly collaborate in analysis of dilepton and strangeness production in proton-proton collisions. In both cases new aspects, not addressed before, will be addressed with high statistics data measured in the pp reaction at 4.5 GeV. This includes production of the higher mass hyperon Ξ , $\Lambda(1405)$ line shape in all isospin decay channels, multi-differential distributions of $\Lambda(1520)$ in $\Lambda\pi\pi$ decay channel, dilepton production in the intermediate mass region (above 1 GeV) and rare η decays. The study of the e^+e^- production channels in the pp reaction at 4.5 GeV (R. Abou Yassine's PhD) will continue at IJCLab and GSI. An analysis of the K^+K^- channel (including the ϕ production) will also start, with the arrival of a new post-doctoral fellow. Jagellonian University is involved in tracking and strangeness production in hyperon channels. Two new PhD students A. Włodarczyk and K. Prokociński joined this year UJ team. Their activity will concentrate on the hyperon $\Lambda(1405)$, on the Ξ - cascade and rare dilepton decays of light mesons (η, ω). Visits in Orsay and Cracow will be organized to discuss these complementary aspects. We will also continue to prepare the physics program of the future pion beam experiment, in collaboration with the FFN/GSI group.

F. Hojeij's PhD: The PhD of F. Hojeij, which is focused on the analysis of hadronic channels in the $\pi+C$ reaction, and comparison with predictions of transport models and of the INCL++ cascade, will be finalized next year. We plan visits in Orsay of I. Ciepal, who is cosupervising the PhD with B. Ramstein to discuss the final results. I. Ciepal will also be invited to participate to the defense in Orsay.

Workshop on tests of the INCL++ cascade code in Orsay: This one-day workshop already foreseen last year will eventually take place early July with the help of a small P2IO budget. We plan to attach the workshop to the HADES analysis meeting (see below). The goal is to discuss on-going activities related to the comparison of HADES data with the INCL++ cascade code (including the PhD thesis of F. Hojeij). In addition to HADES members and INCL++ developers, we will also invite physicists using the INCL++ as an hadronic model in GEANT4 (neutrino physics, response of electronic or hadronic calorimeters, ...) to understand what can be the impact of our studies in other domains. As the implementation of Short Range Correlations in INCL++ is in progress, this topic will also be included in the workshop.

Hades analysis meeting: We plan to organize it early July at IJCLab, attached to the INCL++ workshop, as explained above. 3 Polish physicists (P. Salabura, I. Ciepal, R. Lalik) and two students (K. Sumara, K. Proscinski) will participate to the analysis meeting and the workshop.

Meson conference: The MESON conference will be organized in Cracow in June 2023. P. Salabura is a chairman of the conference, R. Lalik one of the scientific secretaries and B. Ramstein a member of the international advisory committee. Part of the collaboration days will therefore be used for the participation of the French physicists to this conference.

IV.2 Estimated duration for IN2P3 scientists in COPIN	
Total time requested for 2023	25
List of scientists	1. B. Ramstein (10 days) 2. F. Hojeij (5 days) 3. S. Deb (10 days)
IV.3 Estimated duration for COPIN scientists in France	
Total time requested for 2023	31
List of scientists	1. P. Salabura (8 days) 2. R. Lalik (10 days) 3. I. Ciepal (10 days) 4. K. Proscinski (3 days)

Comment Validation	
Unity Director	Fadi IBRAHIM (IJCLab) - 2022-10-14 09:10:41