Template NA

Work package number	WP15	**Start date**	01/06/2019
Activity Type	Networking activity		
Work package acronym	NA4-PREN		
Work package title	Proton Radius European Network		

1. Work carried out and overview of progress

1.1 Project objectives

[Please give an overview of the project objectives for the third reporting period (June 2022 – July 2024), with regard to the overall objectives as described in the Annex 1 of the Grant Agreement and summarized below.]

This network represents a reinforced world-wide effort, both experimental and theoretical to solve the so-called proton radius puzzle". It combines atomic spectroscopy and lepton scattering, each involving both electrons and muons. The international effort on this matter concerns several leading groups in Europe. The network proposed here constitutes the critically missing forum between atomic spectroscopy and lepton scattering communities. It will provide the ideal framework to develop synergies, to draw common strategies and to enhance constructive collaborative theoretical and experimental research activities in order to converge together in attempting to solve the proton charge radius puzzle.

1.2 Progress made during the reporting period towards the objectives

[Please describe the progress made during the third reporting period in line with your Gantt chart and the project overall tasks as described in the Annex 1 of the Grant Agreement and summarized below.]

Table 1.2 Progress made during the reporting period for each task

Task 1.1: PREN-Collaboration: Enhance collaboration between groups working in similar fields ("competing" groups), by funding exchanges of scientists, e.g. for participation in beam times / measurements, or joint analyses or publications. To allow outstanding Postdoctoral fellows and PhD students to spend several months at a "competing" group. The aim is to migrate knowledge between different groups and provide new input to established procedures in these groups
- 17/09 - 06/10/2024: active contribution from D. Marchand and E. Voutier (IJCLab, France) to a 2 weeks data taking campaign of ULQ2 (UltraLow Q^2) experiment at Tohoku University / ELPH (Sendaï, Japan). The ULQ2 experiment aims to determine the proton and the deuteron charge radius from measurements at very low Q2 ([$3x10^{-5}$; 0.013] $(GeV/c)^2$) relying on relative cross section measurements (elastic electron proton / electron Carbon scattering). Apart from daily 8 hour shifts, D. Marchand and E. Voutier have taken part to analysis meetings. This close collaboration took its origin within the Proton Radius European Network.

Task 1.2: PREN-Study: help fund extra studies (experimental and theoretical), e.g. for supporting systematics studies of experiments or comprehensive theory studies, e.g. in two-photon physics
Task 2.1: PREN-Conventions: a kick-off meeting to identify the most pressing questions. Two more workshops will be organized where all PREN groups will present results. Detailed discussions and targeted sessions will scrutinize the results in great detail, and provide guidance for more in-depth studies
- PREN2022 Convention: International STRONG-2020 workshop on the proton charge radius and related topics, 20 – 23/06/2022, Paris, France. - PREN2023 + μASTI (Muonic Atom Spectroscopy Theory Initiative), 26 - 30/06/2023, Mainz, Germany. - NREC (Nuclear Radius Extraction Collaboration) Kick-off meeting, 6 – 10/05/2024, Stony Brook, USA. This new collaboration was created to extend the STRONG-2020 Proton Radius European Network.
Task 2.2: PREN-Meetings: organization of working meetings or targeted workshops dedicated to specific sub-topics relevant for the proton radius puzzle

1.3 Highlights of significant results

[Include an overview of the project results towards the objectives in line with the structure of the Annex 1 to the Grant Agreement.]

- "Determination of the moments of the proton charge density", M. Atoui, M.B. Barbaro, M. Hoballah, C. Keyrouz, M. Lassaut, D. Marchand, G. Quémèner, E. Voutier, *Phys.Rev.C*, 2024, 110 (1), pp.01520. ⟨10.1103/PhysRevC.110.015207⟩. ⟨hal-04093642⟩ https://arxiv.org/pdf/2304.13521

- "Determination of the moments of the proton charge density: is there a proton radius puzzle?", M. Atoui, M.B. Barbaro, M. Hoballah, C. Keyrouz, R. Kunne, M. Lassaut, D. Marchand, G. Quémèner, E. Voutier, J. van de Wiele, NUCLEAR THEORY, Vol. 40 (2023), eds. M. Gaidarov, N. Minkov, Heron

Press, Sofia. Proceedings of the 40th International Workshop on Nuclear Theory (IWNT), Rila Mountains, July 2023.

2.1 Risk materialization

[Provide the information on the project risks described in Annex 1 to the Grant Agreement.]

1) Proton Radius Puzzle solve before 2019 (low)

Whether the risk has materialized? **No**

Late 2019 new results from lepton scattering experiment and from atomic physics (hydrogen) confirmed within errors bars the results obtained with muonic hydrogen. Even though the pressure on the proton charge value is less pregnant, the understanding of the origin of the discrepancies between earlier lepton scattering and from hydrogen atom measurements remain a search activity.

2.2 Risk-mitigation measures applied

[Please indicate whether the risk-mitigation plan described in Annex 1 to the Grant Agreement and corresponding to the risk number was applied in the reporting period.]

1) One experiment alone can not “solve” the puzzle. We would still have to understand the issues with other techniques, and learn from the discrepancy.

Whether the risk-mitigation plan was applied? **No**

2.3 Comments/new risk-mitigation measures proposed

[Provide any significant comments on the risks encountered and the mitigation plan applied. Give any unforeseen risks encountered during the reporting period and not mentioned above.]

3. Deviations from Annex 1 (Description of Action) and Annex 2 (Estimated budget for Action) (if applicable)

3.1 Deviations from planned objectives and tasks, and their impact on the progress of the work package

[Explain the reasons for deviations, the consequences and the proposed corrective actions.]

We took advantage of the CoViD acute period (2020) to write a report entitled "The proton size" (Jean-Philippe Karr, Dominique Marchand, Eric Voutier. Nature Rev.Phys., 2020, 2 (11), pp.601-614. 10.1038/s42254-020-0229-x, hal-03011020, acting as the PREN White paper deliverable (D15.2)

CoViD acute period implied to shift the organization of meetings in person (vital for our network gathering 2 physics communities). The 2 PREN conventions have been held in 2022 and 2023.

3.2 Deviations between actual and planned person months

[Explain deviations between actual and planned person-months. If applicable, propose corrective actions.]

4. Deliverables and milestones tables

4.1 Deliverables

[Please list all the deliverables due in this reporting period, as indicated in Annex I.
Deliverables must also be accompanied by a short report (deliverable description and technical documentation, such as photo, list of publications, etc.), so that the European Commission has a record of their existence.]

Table 4.1 List of deliverables

Deliverable No.	Deliverable name	Lead Beneficiary	Nature	Dissemination level[1]	Delivery month from Annex I	Delivered (yes/no)	Actual delivery month	Comments
D15.2	PREN-WP	1 - CNRS	Report	PU	54			

In case a deliverable has been delivered in the reporting period and a report exists in the Participant Portal, you can indicate "uploaded report" in correspondence of a deliverable

We took advantage of the CoViD acute period (2020) to write a report entitled "The proton size" (Jean-Philippe Karr, Dominique Marchand, Eric Voutier. Nature Rev.Phys., 2020, 2 (11), pp.601-614. 10.1038/s42254-020-0229-x, hal-03011020, acting as the PREN White paper deliverable (D15.2)

4.2 Milestones

[Please complete the table if milestones are specified in Annex I.
Milestones will be assessed against specific criteria and performance indicators as defined in Annex I.]

[1] PU = Public
PP = Restricted to other programme participants (including the Commission Services).
RE = Restricted to a group specified by the consortium (including the Commission Services).
CO = Confidential, only for members of the consortium (including the Commission Services).

Table 4.2 List of milestones

Milestone number	Milestone name	Lead beneficiary	Delivery month from Annex I	Delivered (yes/no)	Actual delivery month	Comments
MS18	Conventions	1 - CNRS	53			
MS19	Meetings	1 - CNRS	50			

- PREN2022 Convention: International STRONG-2020 workshop on the proton charge radius and related topics, 20 – 23/06/2022, Paris, France.

- PREN2023 + μASTI (Muonic Atom Spectroscopy Theory Initiative), 26 - 30/06/2023, Mainz, Germany.

4.3 Deliverable Reports

[Please provide, per each deliverable listed in Table 4.1, a brief description, including if possible some technical documentation (photos, list of publications, etc.). Use as many pages as needed per each report.]

We took advantage of the CoViD acute period (2020) to write a report entitled "The proton size" (Jean-Philippe Karr, Dominique Marchand, Eric Voutier. Nature Rev.Phys., 2020, 2 (11), pp.601-614. 10.1038/s42254-020-0229-x, hal-03011020, acting as the PREN White paper deliverable (D15.2)

Abstract:

The proton charge radius has been measured since the 1950s using elastic electron–proton scattering and ordinary hydrogen atomic spectroscopy. In 2010, a highly accurate measurement of the proton charge radius using, for the first time, muonic hydrogen spectroscopy unexpectedly led to controversy, as the value disagreed with the previously accepted one. Since then, atomic and nuclear physicists have been trying to understand this discrepancy by checking theories, questioning experimental methods and performing new experiments. Recently, two measurements from electron scattering and ordinary hydrogen spectroscopy were found to agree with results from muonic atom spectroscopy. Is the 'proton-radius puzzle' now resolved? In this Review, we scrutinize the experimental studies of the proton radius to gain insight on this issue. We provide a brief history of the proton before describing the techniques used to measure its radius and the current status of the field. We assess the precision and reliability of available experimental data, with particular focus on the most recent results. Finally, we discuss the forthcoming new generation of refined experiments and theoretical calculations that aim to definitely end the debate on the proton.