



“The strong interaction at the frontier of knowledge: fundamental research and applications”

PREN (Proton Radius European Network)

NA4 / WP15

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Université Paris-Sud / Paris-Saclay, France

STRONG-2020 Kick-off meeting

October 23-25, 2019



Led by

Randolf Pohl (**atomic spectroscopy physicist**, *J.G. Univ. Mainz, Germany*)

and

D. M. (**nuclear physicist**, *IPN Orsay, France*)

Goal

To **stimulate** and **support**
a **real synergy**

between all the physicists involved

in the world-wide **experimental** and **theoretical** effort

from **atomic spectroscopy** and **lepton scattering**

in order to **fully understand** the persistant discrepancies and
to come to a statement on **the value of the proton charge radius**



Gathering participants from 22 institutions representing 11 countries

- **CEA** Saclay/DRF/Irfu/Département de Physique Nucléaire, France; contact person: N. D'Hose,
- **CNRS**: France; contact persons: D. Marchand (IPN Orsay) and J.-Ph. Karr (LKB, Paris), G. Quémener (LPC Caen), H. Fonvielle (LPC Clermont-Ferrand),
- **ETH Zurich**, Switzerland; contact person: P. Crivelli,
- **Hebrew University**, Jerusalem, Israel; contact person: G. Ron,
- **JG University Mainz**, Germany; contact persons: M. Ostrick, R. Pohl, M. Vanderhaeghen,
- **JWG University** Frankfurt, Germany; contact person: R. Grisenti,
- **Jožef Stefan Institute**, Ljubljana, Slovenia; contact persons: M. Mihovilovič, S. Sirca,
- **LaserLaB**, Vrije Universiteit, Amsterdam, Netherlands; contact persons: W. Vassen, K. Eikema,
- **MPQ Garching**, Germany; contact persons: T.W. Hänsch, Th. Udem, S. Karshenboim,
- **Paul-Scherrer-Institut (PSI)**, Villigen, Switzerland; contact person: A. Antognini,
- **Technische University München**, Garching, Germany; contact person: S. Paul,
- **Universitat Autònoma de Barcelona** / IFAE, Spain; contact person: A. Pineda,
- **University College of London**, London, UK; contact person: D. Cassidy,
- **University of Warsaw**, Warszawa, Polska; contact person: Krzysztof Pachucki.



(9 eligible countries)



+ Key participants from other parts of the World



- **Bogoliubov Laboratory of Theoretical Physics**, JINR Dubna, Russia; contact person: V. Korobov,
- **George Washington University**, Washington DC, USA; contact person: A. Afanasev,
- **Massachusetts Institute of Technology**, Cambridge, MA, USA; contact person: J. Bernauer,
- **North Carolina A&T State University**, Greensboro, NC, USA; contact person: A. Gasparian,
- **Rutgers**, The State University of New Jersey, Piscataway, NJ, USA; contact person: R. Gilman,
- **Petersburg Nuclear Physics Institute** (PNPI), Gatchina, Russia; contact person: A. Vorobyov

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



Eligible EU countries
Other countries

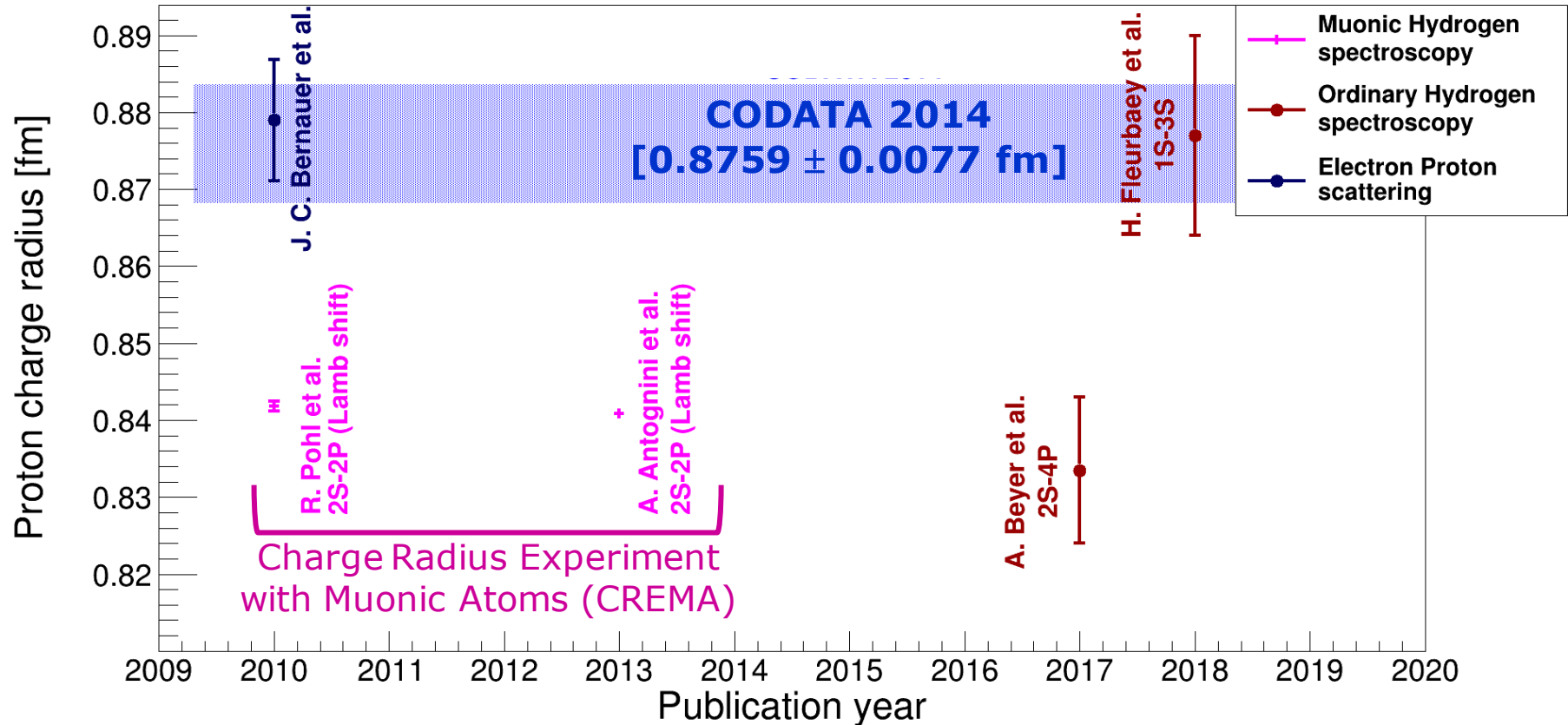
PREN mapping



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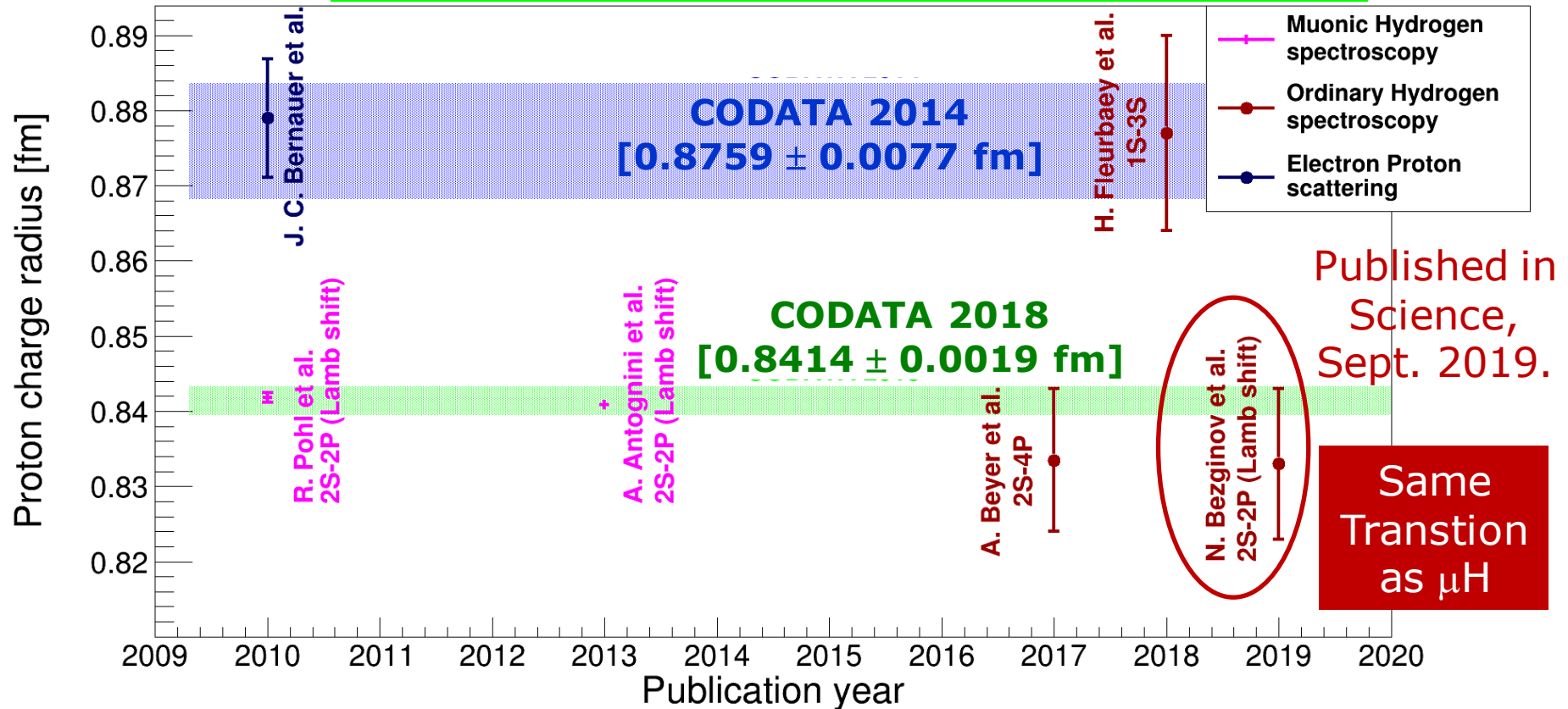
**Proton charge radius results
[2010,2018]**



- **Beyer et al. (2S-4P) result on ordinary H in agreement with μH**
- **Discrepancy between 2 most recent results from spectroscopy ...**



**Proton charge radius results
[2010,2019] (1)**



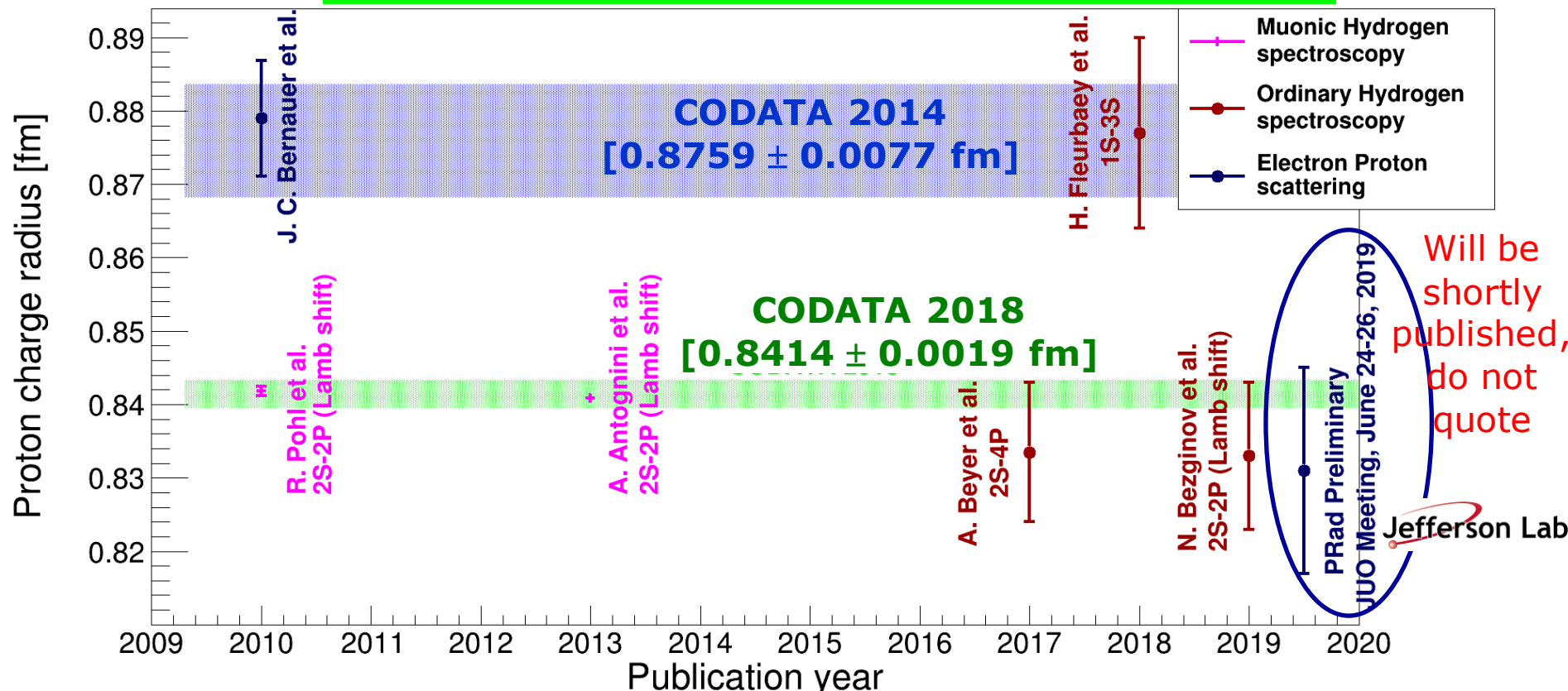
➤ **CODATA adjustment on μH results**

➤ **Discrepancy between 3 most recent results from spectroscopy ...**

➤ **Focus on LKB result by H. Fleurbaey et al.**



**Proton charge radius results
[2010,2019] (2)**



- **First agreement between ep scattering and spectroscopy**
- **More focus on LKB result by H. Fleurbaey et al.**
- **Stay tuned for upcoming ep and μp scattering results**

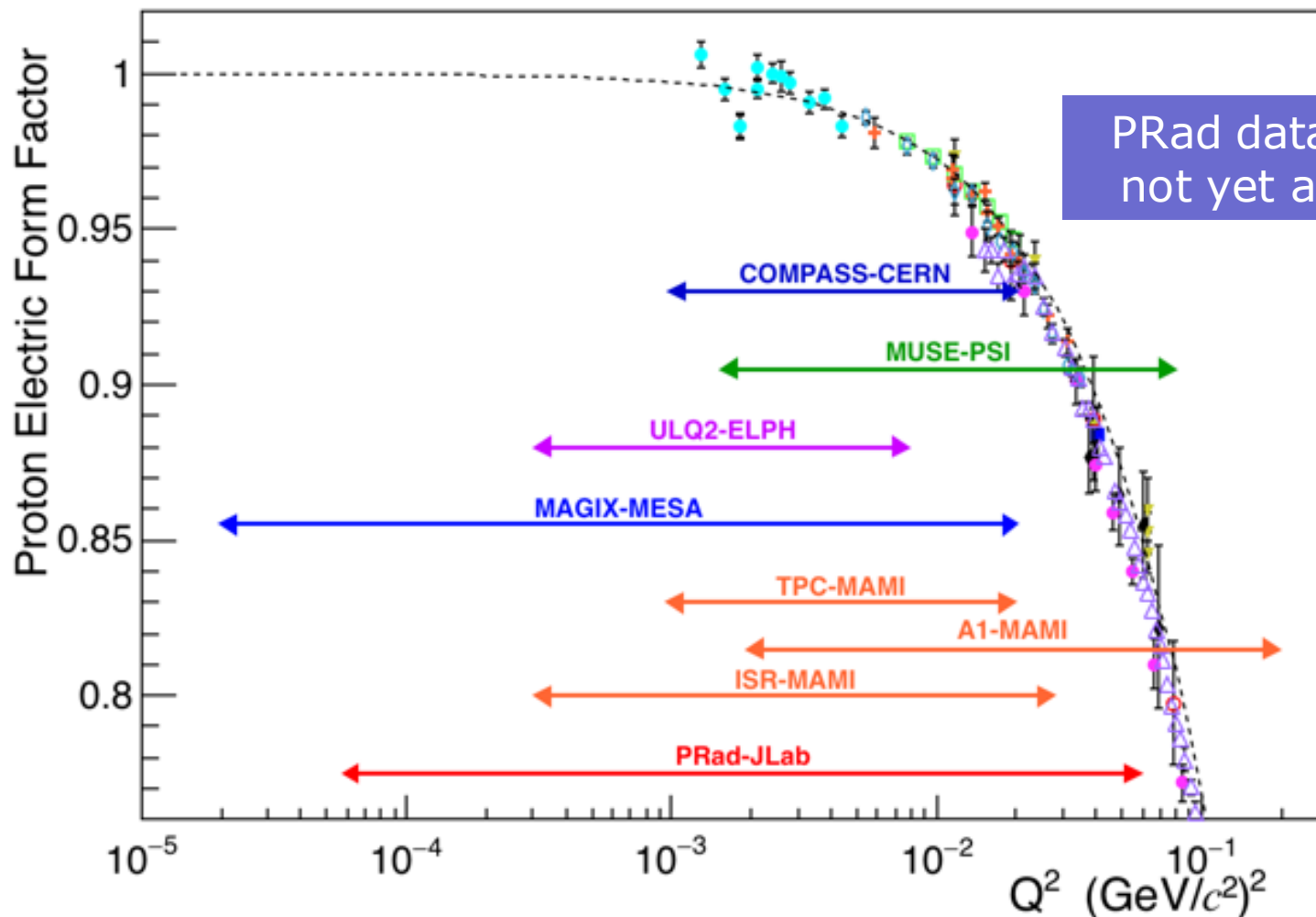
[Link to Prad presentation at JLUO 2019 : \(index 9:18\)](https://www.youtube.com/watch?v=BdZ1y1xbeOk&feature=youtu.be)

<https://www.youtube.com/watch?v=BdZ1y1xbeOk&feature=youtu.be>



From lepton scattering side

Experiment	Place	Projectile	Momentum [MeV/c]	Target	Q^2_{\min} [(GeV/c) ²]	Q^2_{\max} [(GeV/c) ²]	Comments
MUSE@PSI	Swiss.	$e^{+/-}$; $\mu^{+/-}$	115,153,210	LH ₂	1.6×10^{-3}	8×10^{-2}	Lepton U., TPE
ISR@MAMI	Germany	e^-	195, 330, 495	Gas H ₂	2×10^{-4}	2×10^{-2}	Extension, recoil p
New MAMI A1	Germany	e^-	180, 240, 300	Gas H ₂	2×10^{-3}	2×10^{-1}	Abs. σ , G_E, G_M Spectros
MAMI TPC	Germany	e^-		Active gas H ₂ TPC	8×10^{-4}	2×10^{-2}	G_E, G_M Recoil p and e^- detected
ULQ2 Tohoku Sendai	Japan	e^-	20-60	CH ₂	3×10^{-4}	8×10^{-3}	Abs. σ , G_E/G_M sep., 2019
MAGIX@MESA	Germany	e^- polar.	100	H ₂ Polar.	4×10^{-3}	4×10^{-2}	Polarized, R_E, R_M , ≥ 2019
COMPASS @CERN	Swiss.	$\mu^{+/-}$	100×10^3	Active H ₂ TPC	1×10^{-4}	1×10^{-1}	Less Rad. Corr., recoil p





Common topic in atomic physics: **Rydberg constant** (99% correlated with R_p)

- **Hydrogen-like**
 - Experiments in H, D, T: LKB Paris, Garching, JGU Mainz
 - He+: LaserLab Amsterdam, MPQ Garching
- **“Hydrogen without finite size“**
 - Muonium: PSI, ETH Zürich → μ -specific forces?
 - Positronium: ETH Zürich, UC London
- **2-electron atoms and ions**
 - He: LaserLab Amsterdam, MPQ Garching
 - Li+: MPQ Garching
- **Molecules and molecular ions**
 - H₂, HD⁺, etc.: Amsterdam
- **Muonic Li, Be:** JGU Mainz, PSI
- **Zemach (magnetic) radius:**
 - muonic H: PSI, JGU Mainz
- **Theory**
 - Atomic/molecular structure: Warsaw, Barcelona
 - Nucleon/atomic polarizabilities: Barcelona, JGU Mainz



Attendance to Topical Proton Radius meetings:

➤ **Precision Measurements and Fundamental Physics:**



The Proton Radius Puzzle and Beyond

July 23-27, 2018 – Mainz (Germany)

(~30 participants: atomic and nuclear physicists)

JOHANNES GUTENBERG
UNIVERSITÄT MAINZ

Mainz Institute
for
Theoretical Physics

➤ **XIX International Conference on Science, Arts and Culture:** **The Proton Radius**



September 15 - 20, 2019 – Veli Lošinj (Croatia)

(~30 participants: mostly nuclear physicists)

PREN money financed few travels

Collaboration:

➤ The writing of an article to be submitted in Nature Review Physics has been initiated between IPN Orsay and LKB teams thanks of PREN.

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- D15.1 Development of a **dedicated PREN website**
 - (a) to advertise PREN collaborators and to announce events publicly,
 - (b) to share information between all PREN participants with specific pages according to topics, to keep track of convent and workshop materials

Deliverable Number ¹⁴	Deliverable Title	Lead beneficiary	Type ¹⁵	Dissemination level ¹⁶	Due Date (in months) ¹⁷
D15.1	PREN website	1 - CNRS	Websites, patents filling, etc.	Public	6

- **Advancement:** specifications and website design under discussion at IPN Orsay
Will rely on the STRONG-2020 chart materials (logo, ...)
- **Expected delivery date:** **December 2019**

D15.2	PREN-WP (White Paper)	1 - CNRS + Mainz U.	Report	Public	48
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- MS17 corresponding to D15.1 has to be achieved M6

Milestone number ¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS17	Development of a dedicated website	1 - CNRS	6	Access availability

- **Advancement:** specifications and website design under discussion at IPN Orsay
- **Expected delivery date:** December 2019

MS18	Conventions	1 - CNRS + Mainz Univ.	x 1 x 2	45	Convention, due dates (in months): 3, 24, 45
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First PREN Convention to be organized in Paris, Spring 2020.

MS19	Meetings	1 - CNRS	x 2	33	Targeted workshop organization, due dates (in months) : 15, 33
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Total budget: **200k€** (overheads included)

Submitted PREN budgetary table:

REQUESTED EC CONTRIBUTION PER BUDGETARY ITEM AND PER BENEFICIARY

Contr. No	Contractor Acronym		Personnel (EUR)	Other costs (durables, consumables, travel, workshops) (EUR)	Total direct costs (EUR)	Indirect costs (EUR)	Requested EC contribution (EUR)	
1	CEA Saclay/Irfu DPhN, France			4 000	4 000	1 000	5 000	
2	CNRS, France	IPN Orsay	39 000	22 000	61 000	15 250	76 250	88 750
		LPC Caen		4 000	4 000	1 000	5 000	
		LKB Paris		6 000	6 000	1 500	7 500	
3	J.G. Mainz, Germany		56 000	24 000	80 000	20 000	100 000	
4	TUM, Germany			5 000	5 000	1 250	6 250	
TOTAL			95 000	65 000	160 000	40 000	200 000	

Staff effort:

➤ at J.G. Univ. Mainz: **56 k€**

Hiring procedure has not yet been initiated

➤ at IPN Orsay (phenomenology activities): **39 k€**

CNRS salary grid → 8 months post-doctorant, looking for additional funds to extend to 12 months.

Hiring procedure has not yet been initiated

PREN: Funding (2)

Remarks



- From original proposal (Oct. 2017), to better meet European requirements the ***number of beneficiary institutions needed to be reduced:***
 - ⇒ Within **J.G Univ. Mainz**, PREN travel allocated budget (24 k€) will benefit to participants from the **Institute of Nuclear Physics** (Experimental and theoretical groups) and from the **Institute of Physics** **and** will benefit to PREN atomic physics participants from non-beneficiary institutions (MPQ Garching, Netherlands, Poland, Spain, Switzerland, UK, ...).
 - ⇒ **IPN Orsay** will benefit to PREN nuclear physics participants from non-beneficiary institutions (Israel, Slovenia, USA).



- Concomitant and consistent results by Bezginov et al. and PRad, BOTH in agreement with the very accurate muonic hydrogen value represent a real breakthrough towards a possible end to the proton radius.
- Persistent discrepancies between results in spectroscopy and proton radius value extracted from previous ep scattering HAVE TO BE UNDERSTOOD.
- Looking forward to all upcoming results from ep (Japan, Mainz) and μp (COMPASS) scattering experiments. PRad result HAS TO BE CONFIRMED.
- Lepton (non)universality is being investigated by MUSE at PSI.

The PREN advantageously helps keeping the link between all participants to closely follow-up world-wide activities dedicated to proton charge radius measurements.

Looking forward to the first PREN meeting in Paris, Spring 2020.



Thank you

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Back up slides

Work package number	15															
Work package acronym	PREN															
Work package title	NA4-Proton Radius European Network															
TASKS/Subtasks	Year 1				Year 2				Year 3				Year 4			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1. PREN-Collaboration																
1.1 Development of a dedicated website			1													
2. PREN-Meetings																
2.1 Conventions		2						2							2	
2.2 Targeted workshops					3						3					

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