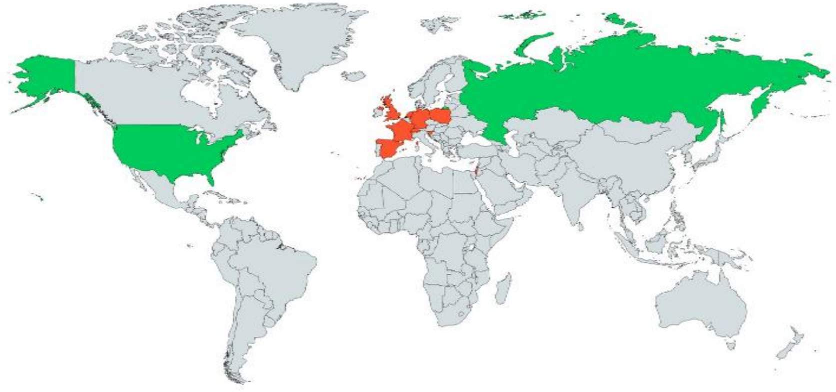
STRONG-2020 ANNUAL MEETING (2022)

Proton Radius European Network (PREN, NA4, WP15)

Dominique Marchand (IJCLab, France)
Randolf Pohl (J.G. Mainz University, Germany)

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

PROTON CHARGE RADIUS EUROPEAN NETWORK



Theory and Experiment
from
Atomic Physics and Lepton Scattering

Experimental determination:

- Lepton scattering off protons, nuclear physics
- Atomic spectroscopy, atomic physics
  - Hydrogen atoms, hydrogen molecular ions
  - Muonic hydrogen, muonic atoms/ions

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 persistent discrepancies and to come to a statement on the **value of the proton charge radius**.

- **52** participants (**in person**)
- 4 full days (45' reviews, 30' presentations, discussions)
- « Transverse » conference: « On the meaning of measurement uncertainties in metrology and precision physics », Fabien Grégis (*SPHere - Sciences, Philosophy, History ; Univ. Paris Cité)*
- Social events: welcome reception, PREN dinner

https://indico.mitp.uni-mainz.de/e/pren2022

Organizing committee:

Jean-Philippe Karr (LKB, Paris), Dominique Marchand (IJCLab Orsay), Randolf Pohl (JG University Mainz), Eric Voutier (IJCLab)

Administrative / technical support : Sylvie Teulet (IJCLab Orsay), Michaël Roynel (LPNHE, Paris) and LKB team

Financial support: IJCLab STRONG-2020/PREN budget

« Proton Radius Activities and Related Topics »

*Reviews and updates on **experimental** and **theoretical** efforts concerning **nucleons**, **nuclei**, **molecular ions radii***

(Very) Lively discussions, constructive remarks, and stimulation for collaborative (home)works:

Only a a few hints

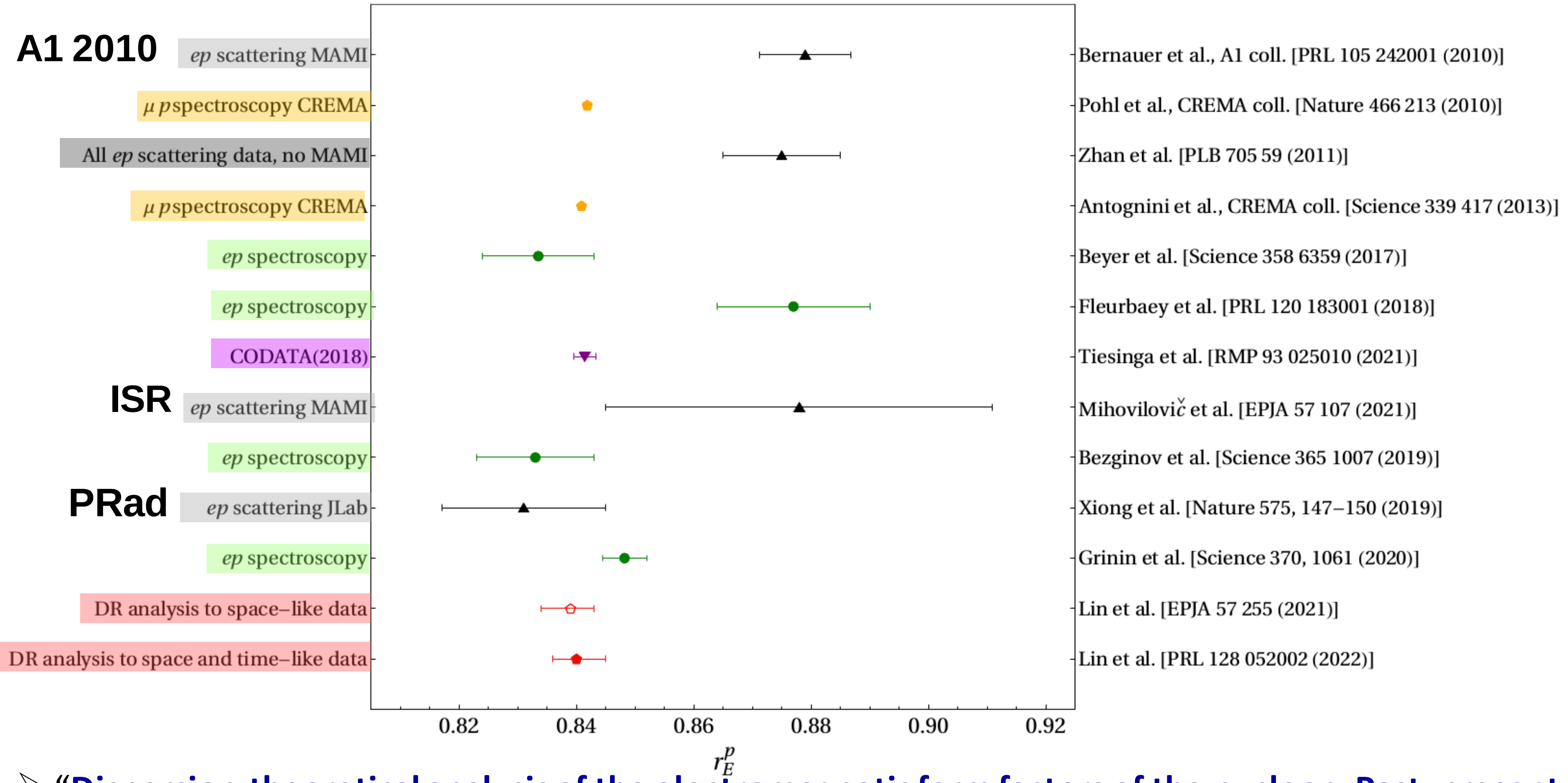
- **Ulf Meissner's review: "Dispersive analysis of the nucleon electromagnetic form factors"**
  - Mainz A1 2010 data at large scattering angles not described very well by dispersion fits: investigation required.
  - Recent neutron data not yet included in current analysis. Data have been shared during the PREN2022 meeting.
  - Working detailed discussion between K. Pachucki and U. Meissner about the language mismatch between atomic and nuclear physics. An agreement seemed to be found that terms on the nuclear physics side haven't been calculated, which are very important for atomic physics nuclear structure calculations.
- **From Jan Bernauer's review:** project to build an **open database on nucleon form factors** including parametrization functions. Discussion with IJCLab team which has started such a project several years ago (C3F2: Collect, Classify, Compute Form Factors).
- Arguments for **inverse kinematics** (hadron scattering off atomic electrons) **at AMBER** to measure **p, π and kaons** form factors to determine their radii.
- New opportunities in Japan using the SCRIT (Self-Confining Radioactive-isotope Ion Target) device (RIKEN) for **low Q^2 electron scattering on heavy (radioactive) ion**s to determine the **neutron radius** (neutron skin) from the evaluation of **the 4th moment of the charge density distribution.**
- Pressure to also focus on **magnetic form factor** entering the Zemach radius connected to atomic physics.
- Suggestion to perform **blinded analysis** of lepton scattering data while optimizing the extraction strategy relying only on fit quality.
- Lively discussion about the way **CODATA** includes obviously discrepant data. The CODATA Members (K. Pachucki, F. Nez, R. Pohl) explained the procedure (increasing the uncertainties by multiplying all of them with the same value>1 until the reduced χ^2 is satisfactory), but not all participants liked this procedure and alternative solutions were suggested, like additive uncertainties, or straight removal of some data. No consensus was reached.

Mainz, Germany

Next PREN workshop foreseen in June 2023 at J.G.University Mainz

PREN: PROTON CHARGE RADIUS STATUS

Fig. from U.G. Meissner 's review, PREN2022.



- "**Dispersion-theoretical analysis of the electromagnetic form factors of the nucleon: Past, present and future**", H.Y. Lin, H.W. Hammer, U.G. Meissner, Eur. Phys. J. A (2021) 57:255.
- « **New insights into the Nucleon's electromagnetic Sturcture** », Y.H. Lin, H.W. Hammer, U.G. Meissner, Phys. Rev. Letters 128 (2022) 052002.
- « **Proton radius from a dispersive analysis of the latest space-like e-p scattering data** », Y.H Lin (2022), https://arxiv.org/pdf/2202.08622.pdf

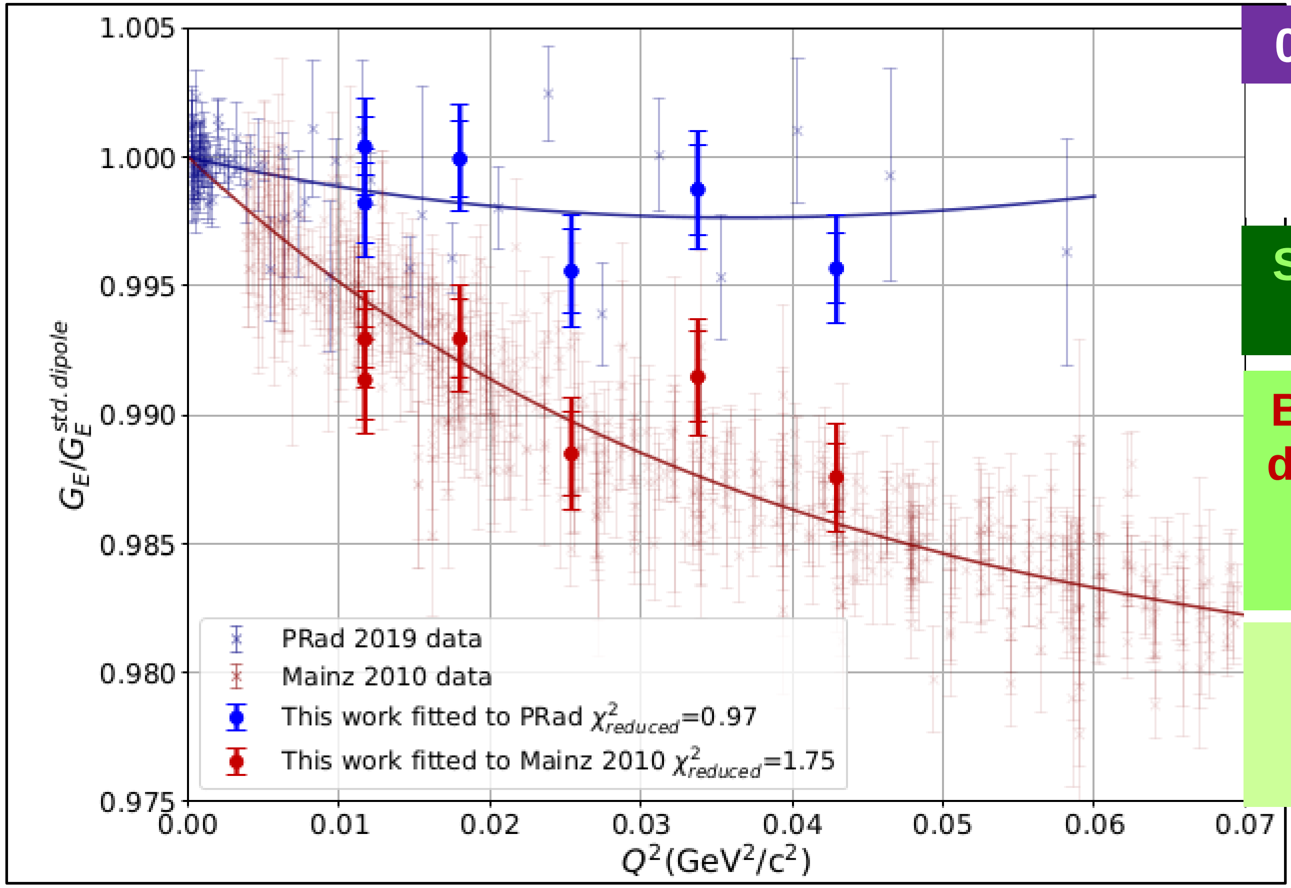
PREN FY22 ACTIVITIES: LEPTON SCATTERING

Update on MaMi "new" A1 experiment

« Low Q^2 electron-proton elastic scattering experiment using a gas jet target», Y. Wang et al., August 2022, https://arxiv.org/pdf/2208.13689.pdf, submitted to PRC.

MAGIX gas jet target (windowless) at A1

Successful demonstration!



$0.01 \leq Q^2 \leq 0.045\ (\mathrm{GeV}/c)^2$

Data takings: 03/20, 09/21, 12/21

Successful measurements of elastic ep scattering!

But too limited statistics to discriminate between PRad rational (1:1) and Mainz polynomila fits

Looking forward to high intensity MAGIX@MESA Experiment (GE and GM)

First beam for exp.: 2025

PREN FY22 ACTIVITIES: LEPTON SCATTERING

Current status and future plans

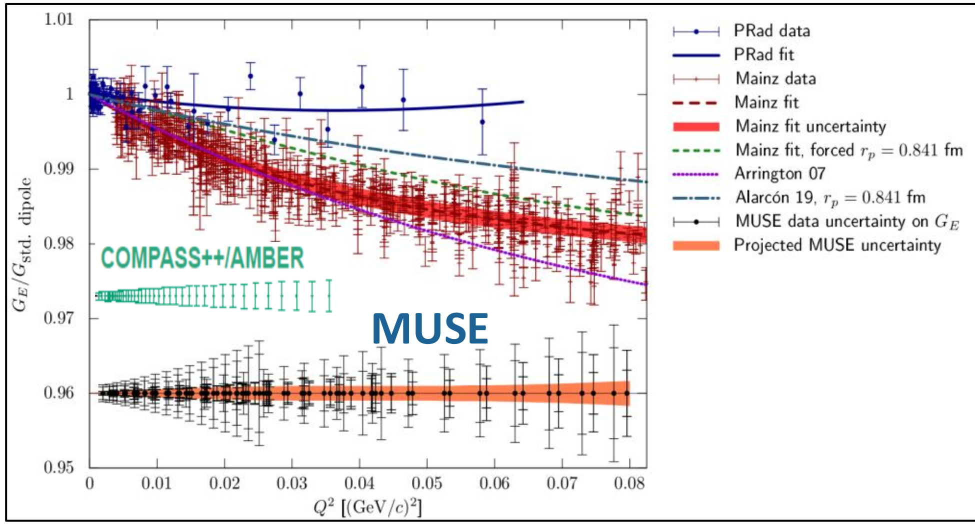
From J.C. Bernauer

Experiment	Beam	Laboratory	Q^2 $(\mathrm{GeV}/c)^2$	δr_p (fm)	Data taking	
MUSE	$e^{\pm}, \mu^{\pm}$	PSI	0.0015 - 0.08	0.01	2022-2024	**6 months/year**
PRM Compass++/AMBER	$\mu^{\pm}$	CERN	0.001 - 0.04	0.01	2023 (2024)	TPC issue (IKAR?)
PRad-II	e^-	Jefferson Lab	4×10^{-5} - 6×10^{-2}	0.0036	2024 -	Upgrade in progress
PRES @ A2	e^-	Mainz	0.001 - 0.04	0.6% (rel.)	Delayed 2023?	TPC issue
A1@MAMI (jet target)	e^-	Mainz	0.004 - 0.085		Published	
MAGIX@MESA	e^-	Mainz	$\geq 10^{-4} - 0.085$		2025 -	
ULQ^2	e^-	Tohoku University	3×10^{-4} - 8×10^{-3}	$\sim 1\%$ (rel.)	2022-2023	**in production**

PRES@A2 Mainz (Proton Radius from Electron Scattering): High pressure active TPC target (detection of recoil proton + scattered electron)

PRM (Proton Radius Measurement with Muons) featuring a high pressure active TPC target (detection of recoil proton). Production: 2023 (2024).
Also project at AMBER of **inverse kinematics** experiments dedicated to hadron radii (p, π, K)

MuSE (Muon Scattering Experiment):
successful commisionning,
Data production on-going (6 months/yr, 22-24)



(Table from H. Gao, PANIC 2021, updated)

PREN FY22 ACTIVITIES: LEPTON SCATTERING

IJCLab Irène Joliot-Curie Laboratoire de Physique des 2 Infinis

STRONG 2020

Marilou MEDAWAR (Master thesis, 2022), *supervised by Mostafa Hoballah (IJCLab)*

Attempts to extract the proton charge radius from Mainz 2010 cross section data sets based on simultaneous fits and blinded data

Number of Mainz 2010 cross section data sets: **18** (6 beam energies x 3 spectrometers)

Simultaneous fit: performing a fit of each data set considering the same functional form over the whole Q2 range, keeping the luminosity normalisation factor independent from one set to the other

1) Polynomial functional forms for G_E AND G_M, idem J.C. Bernauer *et al.*, « as a check » **Not blinded**

38 parameters: 10 (GE) + 10 GM (GM) + 18 (luminosity normalisation)

✓ $r_p = 0.87557 \pm (0.00084)_{stat.}$ fm, $\chi^2_{red} = 0.55$ compatible with $r_p = 0.879 \pm (0.005)_{stat+syst}$ [J.C. Bernauer *et al.*]

2) G_E (ratio of polynoms*) and G_M (polynomial function) **Blinded**

22 parameters:
4 (GE) + 18 (normalisation)

$r_p = 0.880839 \pm (0.006682)_{stat.}$ fm, $\chi^2_{red} = 0.078$

Normalisation parameters all found close to 1

3) G_E (ratio of polynoms*) and G_M (ratio of polynoms*) **Blinded**

26 parameters:
4 (GE) + 4 (GM) + 18 (normalisation)

! $r_p = 0.840828 \pm (0.008443)_{stat.}$ fm, $\chi^2_{red} = 0.08$

Normalisation parameters all found close to 1

*J.J. Kelly, Phys. Rev. C 70 (2004) 068202

$\chi^2_{red} << 1$: over fitting

Data blinding ⇨ focusing only on fit quality
Essential to prevent against analyzer subjectivity

PREN FY22 ACTIVITIES: LEPTON SCATTERING

Determination of spatial moments (r^λ) of the charge density

Mostafa Hoballah et al.

Integral method* relying on integral forms of the inverse Fourier transform of the charge distribution
⇒ determination of both **odd** and **even**, **positive** and **negative**, spatial moments of the distribution.
⇒ method not limited to low Q^2, overcomes the limitations of the derivative method.

Post-doc (8 months): procedure on-going

Author (Year)	k^2 range (fm^{-2})	nb. of data points
Xiong (2019)	0.005-14.9	71
Bernauer (2014)	0.39-14.15	77
Lehmann (1961)	1.05-2.98	1
Frerejacque (1966)	0.975-1.76	4
Janssens (1966)	4-30	20
Borkowski (1975)	0.35-3.15	10
Walker (1994)	25.65-77	4
Andivahis (1994)	44.85-226	8
Christy (2004)	16.65-133	7
Mihovilovic (2019)	0.0256 - 0.436	25

(Cut-off Q_c^2 [(GeV/c)^2] ~ 2)

λ	$\langle r^\lambda \rangle_{Qc}$ [fm^λ]	± (stat.)	± (syst)	± (model)	± (choice of model)	r^n
-2	7.671	8.047×10^{-5}	0.0013	0.0029	2.306	8.699
-1	2.050	3.146×10^{-5}	0.0002	0.0004	0.172	2.088
0	1.000					1.000
1	0.718	0.0019	0.0002	0.0002	0.0134	0.718
2	0.693	0.0090	0.0012	0.0006	0.0276	0.693
3	0.865	0.0610	0.0066	0.0018	0.1035	0.865
4	1.444	0.3580	0.0285	0.0063	0.2062	1.444
5	3.641	2.1030	0.0131	0.0203	0.4018	3.641
6	15.25	14.660	1.1000	0.0634	0.7285	15.253
7	95.95	114.40	9.1080	0.2206	20.9622	95.948

- Functional: ratio of polynoms (Kelly)
- Silmutaneous fit of data sets
- Stat. & Syst.: from exp. data
- Error propagation: Monte Carlo

Preliminary

$r_p = 0.8326 \pm (0.0054)_{stat.} \pm (0.0007)_{syst.} \pm (0.0003)_{model} \pm (0.0166)_{param.}$

Statistically in agreement within errors with « small » and « large » radius value

"Extraction of spatial density moments using integral method", M. Hoballah et al., in preparation

* Based on « Connecting spatial moments and momentum densities », M. Hoballah et al, Phys. Lett. B 808 (2020) 135669

STRONG 2020

Triton charge radius from Tritium 1S-2S

	^{3}He 1.9687* (13) ~~1.9730 (160)~~	^{4}He 1.6778* (7) ~~1.6810 (40)~~
^{1}H 0.8409 (4) ~~0.8751 (61)~~	^{2}D 2.1277 (2) ~~2.1413 (25)~~	^{3}T **1.7xxx (2)** 1.7550 (860)

*** Preliminary**

Triton-Radius EXperiment Mainz

Cold Atomic Hydrogen Source (trap)

400x better radius with 1 kHz measurement

(vs. 0.01 kHz for H, D)

PREN FY22 ACTIVITIES: ATOMIC SPECTROSCOPY

Laboratoire Kastler Brossel
Physique quantique et applications

STRONG 2020

- **Measurement of vibrational transition in the H_2^+** (Trapped ion team)

  ⇨ complementary information w.r.t HD+ isotope for determination of fundamental constants and New Physics (NP) searches

  Relies on measurement of absolute frequencies in the mid-infrared with sufficient precision

  ✓ spectroscopy laser successfully locked to a frequency comb, itself locked to an ultra-stable signal referenced to a cesium clock, sent to LKB from the French metrology institute via a fiber link

  Performance characterization of the frequency measurement setup underway

- **1S-3S Deuterium / Hydrogen Spectroscopy: hunt for systematics (H ⇔ LKB-2018 & MPQ 2020)**

  ✓ Background reduction improvement

  ✓ New H atomic beam (dry pumps instead of oil pumps, suspected as a source of contamination)

- **Sensitivity of HD^+/H_2^+ spectroscopy to fundamental constants (including Rp)**

  Development of a numerical method to solve the Dirac Equation at the 10^{-20} level, 7-8 orders of magnitude improvement

  ⇨ Non perturbative calculations of QED corrections (one-loop self-energy correction)

  • *H.D. Nogueira, V.I. Korobov, J.-Ph. Karr, High-precision solution of the Dirac equation for the hydrogen molecular ion by an iterative method, Phys. Rev. A* ***105****, L060801 (2022).*

- **Improvement in hyperfine structure theory**

  ⇔ Extraction of spin-averaged rovibrational transition frequencies from hyperfine components measured in experiments.

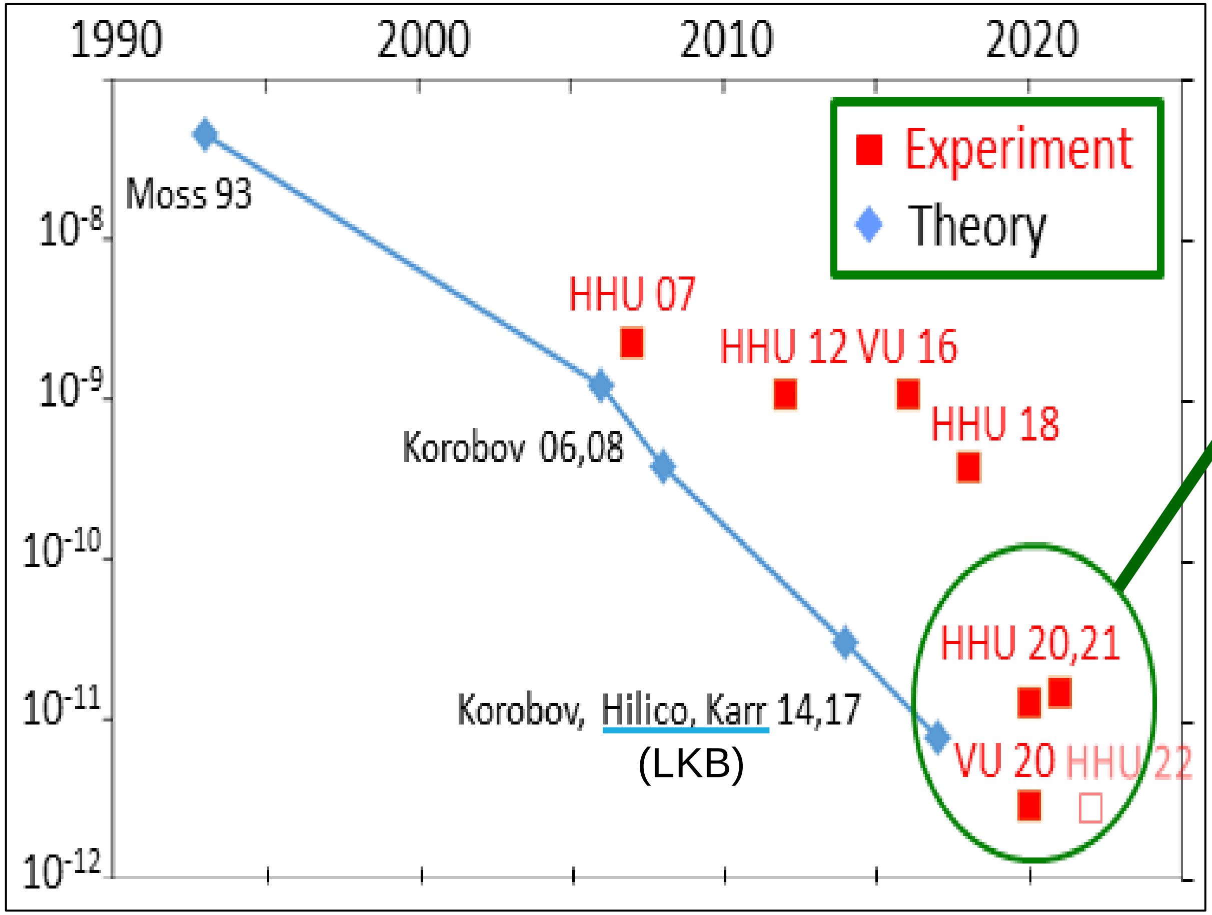
  • *M. Haidar, V.I. Korobov, L. Hilico, J.-Ph. Karr, Higher-order corrections to spin-orbit and spin-spin tensor interactions in hydrogen molecular ions: Theory and application to H_2^+, Phys. Rev. A* ***106****, 022816 (2022).*

  • *M. Haidar, V.I. Korobov, L. Hilico, J.-Ph. Karr, Higher-order corrections to spin-orbit and spin-spin tensor interactions in HD^+, arXiv:2209.02382, to appear in Phys. Rev. A.*

PREN FY22 ACTIVITIES: ATOMIC SPECTROSCOPY

Spectroscopy of H molecular ions: a competitive method of determining m_p/m_e

Progress in experimental and theoretical precision of rovibrational transition frequencies in the HD^+ molecular ion.



4 measurements to be included in the next CODATA adjustment of fundamental constants.

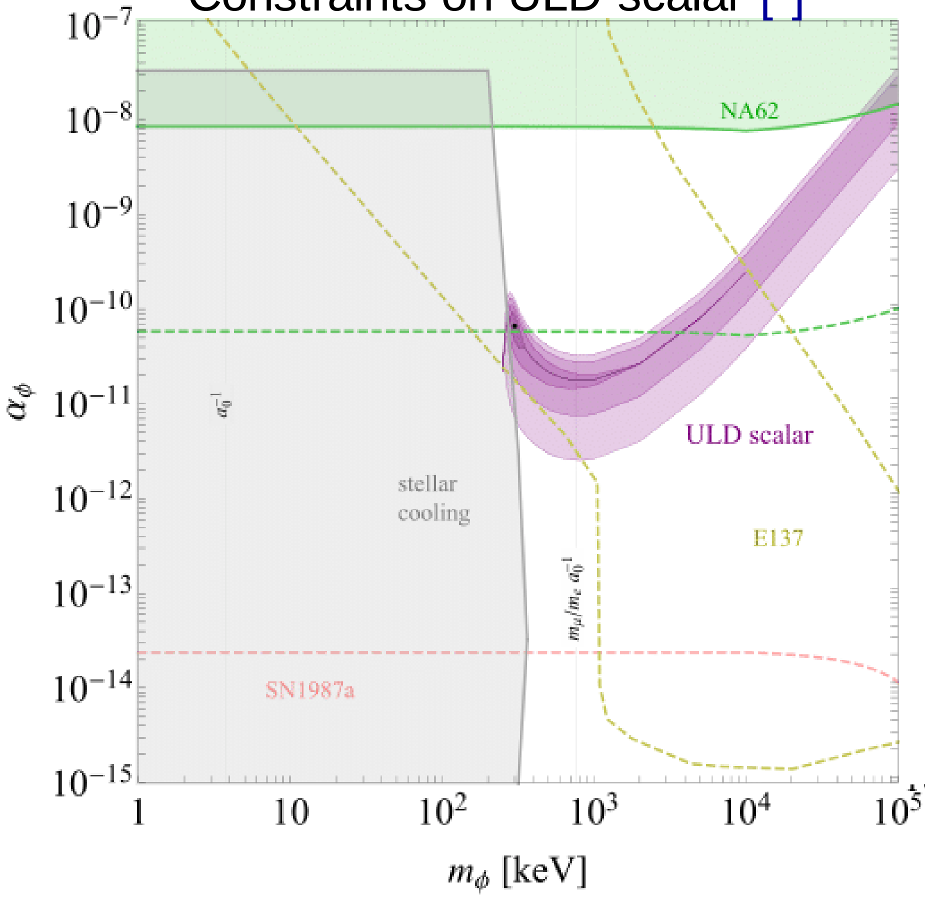
The LKB theory team will collaborate with the CODATA Task Group on Fundamental Constants in the next few months for the practical implementation of this decision.

HHU: Heinrich Heine Universität (Düsseldorf)
VU: Vreije Universiteit (Amsterdam).

PREN FY22 ACTIVITIES: ATOMIC SPECTROSCOPY / PARTICLE PHYSICS

Development of a self-consistent method to constrain “new physics” from high-precision spectroscopic data

Constraints on ULD scalar [*]



m_ϕ: mass of hypothetic scalar mediator

α_ϕ: « New Physics » coupling constant

Simultaneous adjustment of fundamental constants and NP parameters, circumventing the problem of possible “contamination” of fundamental constant values by NP

Several benchmark models were tested

⇨ Tensions related to the **proton charge radius determination** can be ameliorated at a statistically significant level by a single light scalar particle: **Up-Lepto-Darko** (ULD) **scalar**

NOT a claim of a NP discovery (tensions may also be explained by underestimated experimental uncertainties), **BUT** an interesting indication and an illustration of the power of the method.

The purple-shaded regions are the 1, 2, 3, 4 confidence level regions favored by the least-squares adjustment,
Black dot [m_ϕ ~300 keV, α_ϕ ~7x10-11]: best fit point.
Other existing constraints taken from [*]

[*]***“Self-consistent extraction of spectroscopic bounds on light new physics”***, C. Delaunay (LAPTH), J.-Ph. Karr (LKB), , T. Kitahara (Nagoya University), J.C.J. Koelemeij (Amsterdam VU), Y. Soreq (Technion, Israël Inst. of Technology), J. Zupan (Univ. Cincinnati), to appear in arXiv in October 2022

PREN FY22 SUMMARY

- **PREN2022 Convention, June 20-23, Paris**

PREN 2022

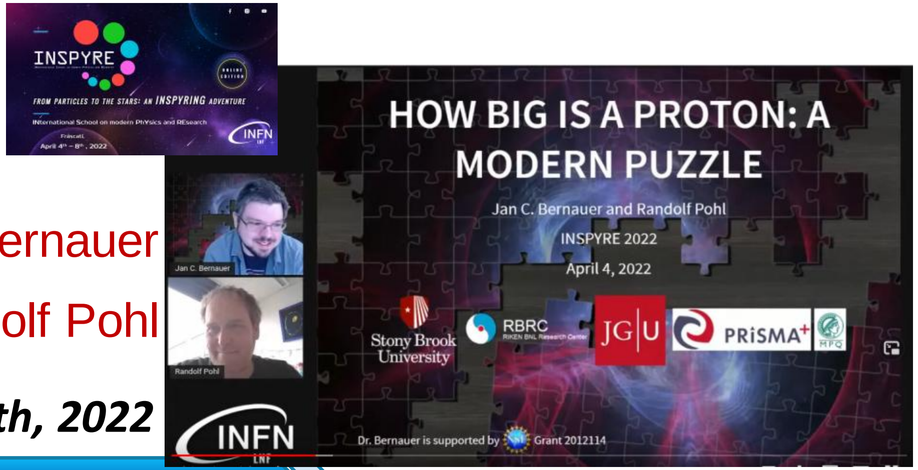
- **Lepton scattering:**
  - **« New » Mainz A1: proof of reliable experimental setup, requires higher statistics (⇨ MAGIX@MESA)**
  - **MUSE and ULQ2 experiments: on-going**
  - **AMBER: PRM + inverse kinematics reactions (p,π, K radii)**
  - **Benefit of blinded analysis**
  - **Postdoctoral fellow hiring procedure on track at IJCLab: spatial moments of the charge density**
    (01/12/22-30/07/23; 8 month duration contract)
- **Atomic Spectroscopy:**
  - **Preparation/optimization of experiments (H_2 , 1S-3S « new atomic H beam », T-REX, HyperMu@PSI, …)**
  - **Huge precision improvements in QED correction calculation, hyperfine structure theory**
  - **New physics constraints from high-precision spectroscopic data**
- **Outreach:**

Magnetic radius
⇕
Zemach radius

Jan Bernauer

Randolf Pohl

April 4th, 2022



PREN FY23 PLANS & PERSPECTIVES

STRONG 2020

- **Lepton scattering:**
  - **MUSE (preliminary) results**
  - **ULQ2 (preliminary) results**
  - **Collaboration IJCLab – J. Bernauer for the development of FF database**
  - **AMBER follow-up: PRM (2023?)+ inverse kinematics reactions (p,π, K radii)**
  - **PRES@A2 (Mainz) follow-up on TPC**
  - **Next future: PRad (2024), MAGIX@MESA (2025)**

Magnetic radius ⇕ Zemach radius

- **Atomic Spectroscopy:**
  - **H_2^+,1S-3S transition on D and H (LKB), further future 1S-4S (LKB), T-REX (JGU Mainz)**
  - **HyperMu@PSI (CREMA, 2024), further future: 5x better Lamb shift in μH (CREMA)**

- **Follow-up PREN2022 Convention, June 20-23, Paris**

  ⇨ **Looking forward to PREN2023 in Mainz**

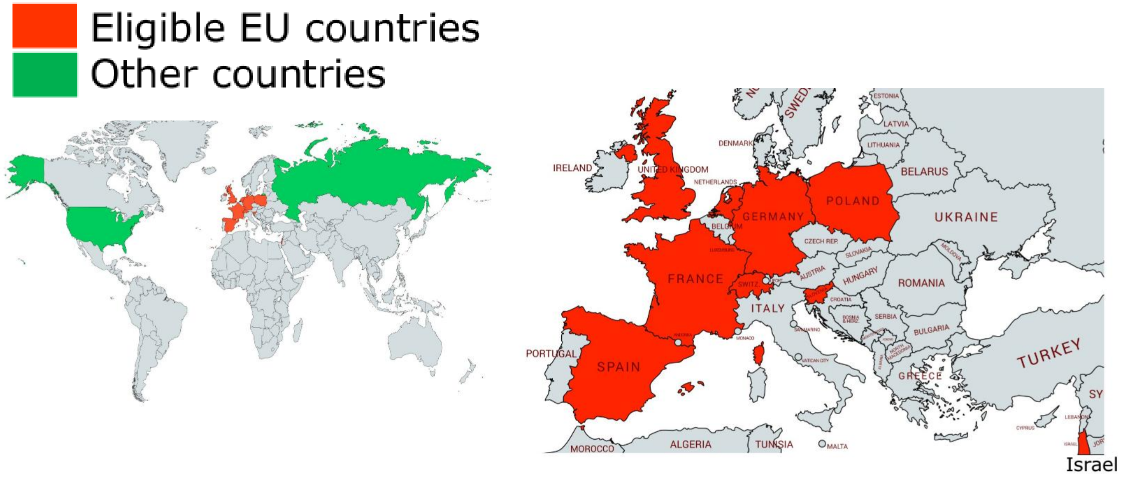
0 [fm] 1 PREN 2023

STRONG-2020 Extension beyond Nov. 2023?

⇨ **Catching-up for the time lost by the CoViD** for « **in person** » **collaborative works**:
Form factor database, Zemach radius /Magnetic radius, …

⇨ **possibility to extend the contract duration of the postdoc fellow who should start a contract at IJCLab on Dec. 1st, 2022, for a 8 month duration.**

PREN: 22 INSTITUTIONS / 11 COUNTRIES



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

Theorists and **Experimentalists**
from
Atomic and **Lepton Scattering Physics**

- **Bogoliubov Laboratory of Theoretical Physics**, JINR Dubna, Russia; V. Korobov,
- **George Washington University**, Washington DC, USA; A. Afanasev,
- **CFNS, Stony Brook University & RIKEN BNL Research Center**, USA; J. Bernauer,
- **North Carolina A&T State University**, Greensboro, NC, USA; A. Gasparian,
- **Rutgers**, The State University of New Jersey, Piscataway, NJ, USA; R. Gilman,
- **Petersburg Nuclear Physics Institute** (PNPI), Gatchina, Russia; A. Vorobyov

Thank you!

BACK-UP

PREN FY22 ACTIVITIES: LEPTON SCATTERING

Update on MaMi A1 High-resolution HIGH Q^2 experiment

« *High Q^2 electron-proton elastic scattering experiment using a gas jet target*», PhD Julian Mueller

Analysis on-going

High Precision measurements of Proton Magnetic FF (LH2 target)

~0.5 ≤ Q^2 ≤ ~1.9 $(GeV/c)^2$

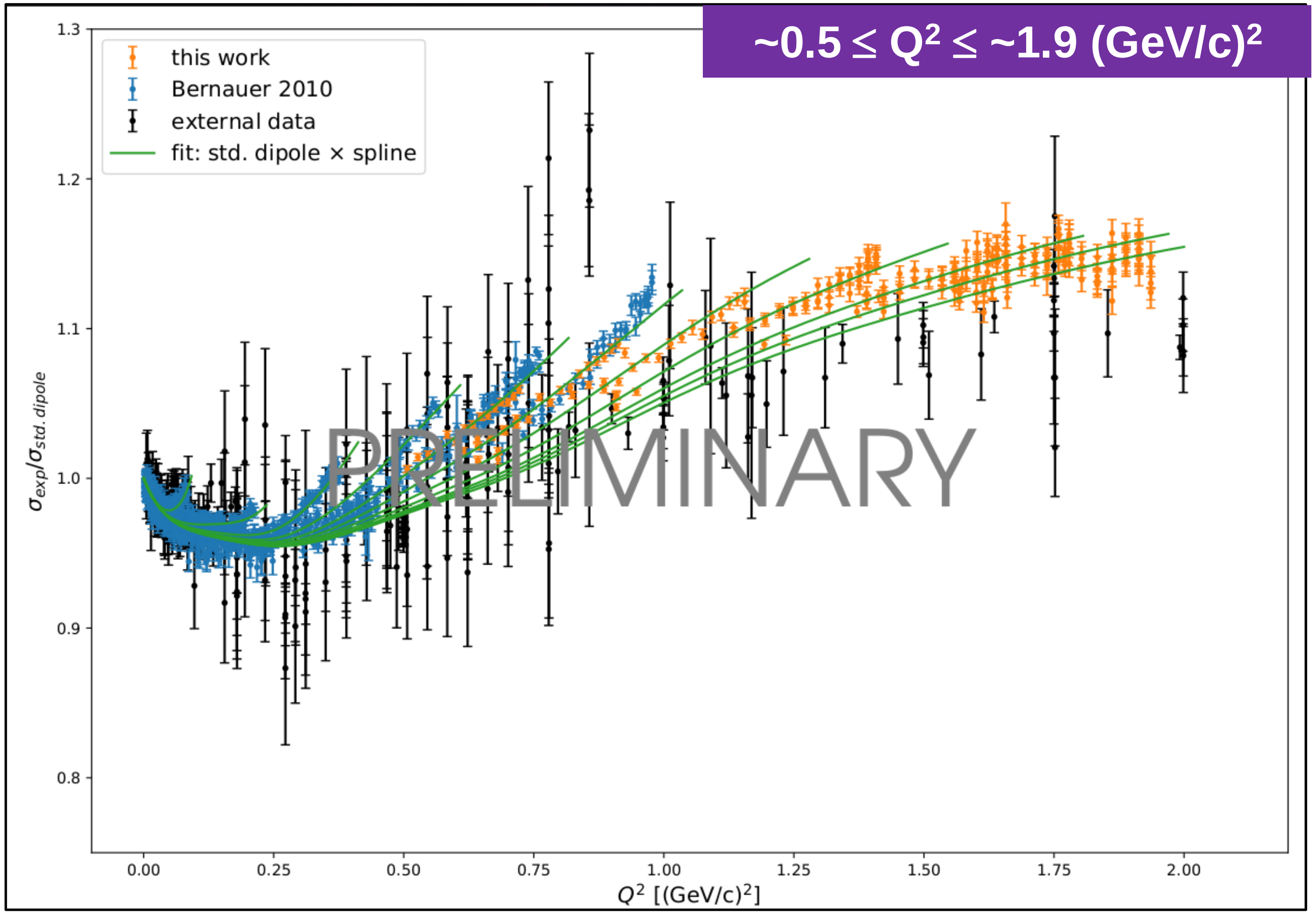


Fig. from J.C. Bernauer's From J.C. Bernauer 's Review, PREN2022.

PREN FY22 ACTIVITIES: LEPTON SCATTERING

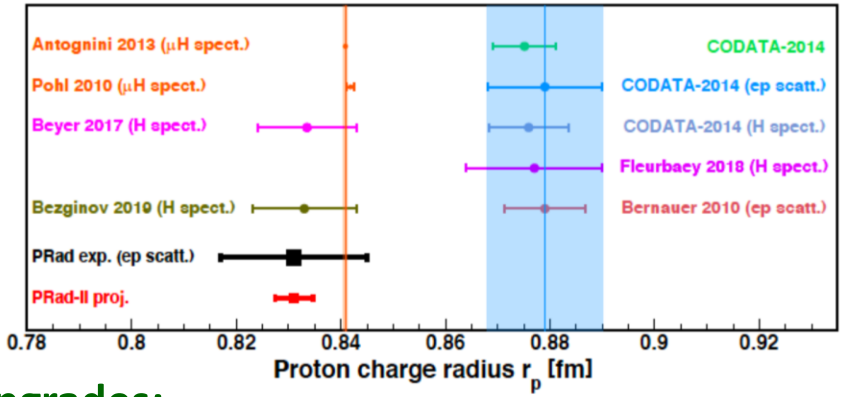
PRoton Radius-II (2024)

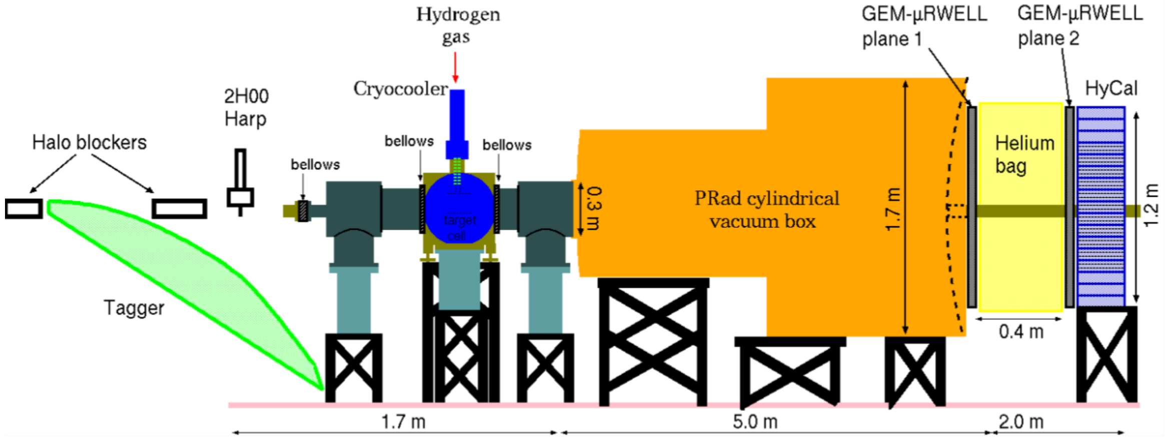
Update on Jefferson Lab./Hall B/PRad II

From A. Gasparian

"PRad-II: A New Upgraded High Precision Measurement of the Proton Charge Radius", A. Gasparian et al., Jan. 2022, https://arxiv.org/abs/2009.10510 [nucl-ex]

Goal: ✸a factor **3.8** improvement in the total of incertainties on Rp w.r.t. PRad-I, targetting ~0.4% total uncertainty.
✸~10^{-5} $(GeV/c)^2 \leq Q^2 \leq 6 \times 10^{-2}$ $(GeV/c)^2$.
✸Entire range covered in a **single fixed experimental setup**, just as in PRad
✸Ee = 0.7, 1.4 and 2.1 GeV.





Set-up main upgrades:

- **HyCal** (all $PbWO_4$), + **GEM** (tracking), + **scintillators** (lower scatt. angles, 0.5° – 0.7°, e-p / Moller),
- Possibly **a liquid-droplet hydrogen target** + adequate laser based gating, instead PRad gas flow target

"Differential cross section predictions for PRad-II from dispersion theory", Y.H. Lin et al., Phys. Lett. B 827 (2022) 136981. Sensitivity to TPE.

Other opportunities with PRad setup: DRad, Prad+, X17 anomaly (PAC« A »), …

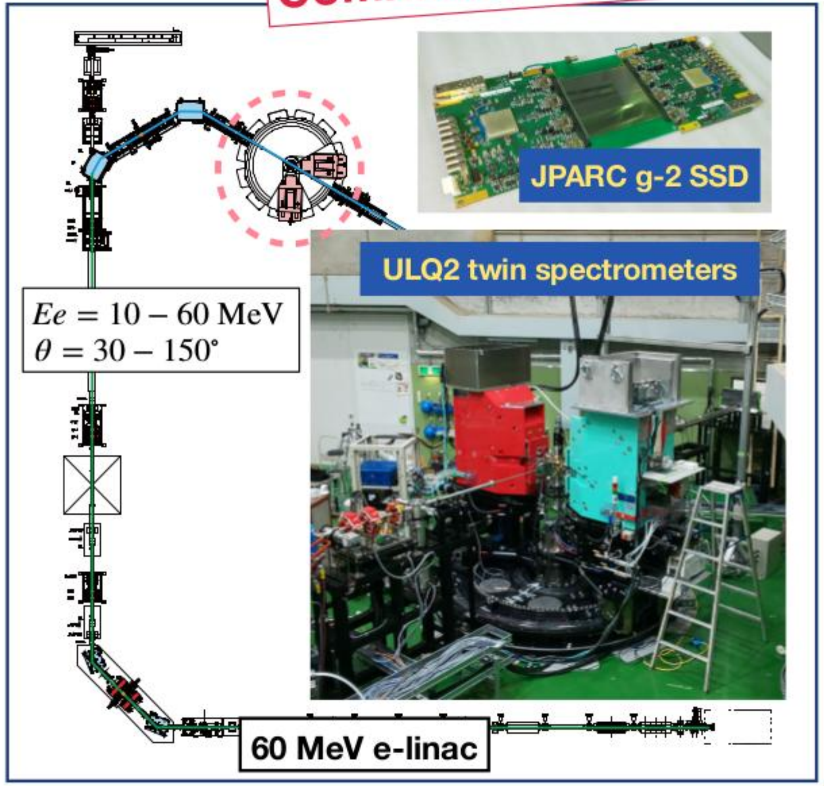
PREN FY22 ACTIVITIES: LEPTON SCATTERING

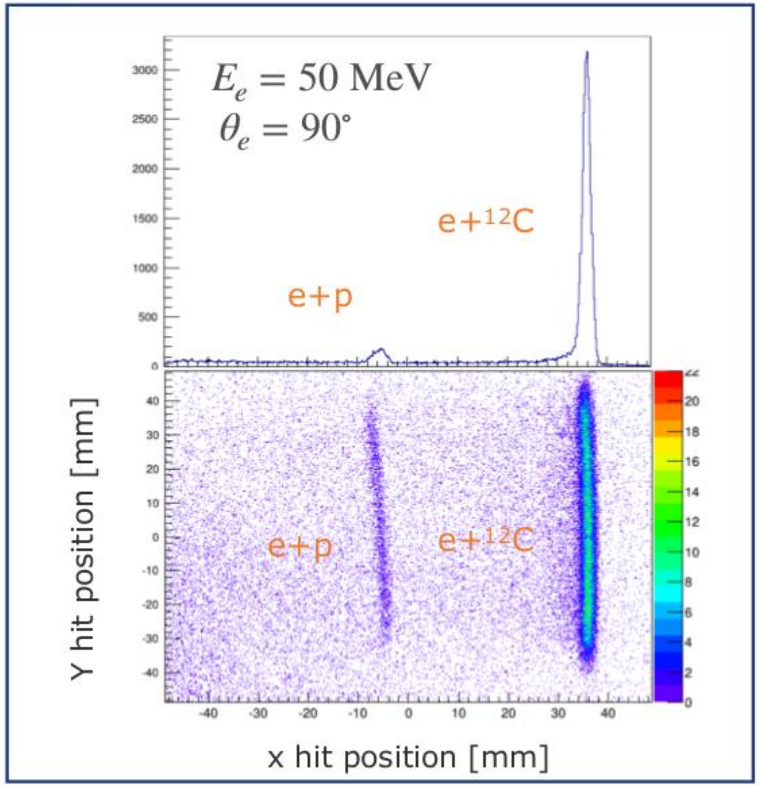
Update on ULQ2 (Ultra-Low Q^2) experiment (Tohoku Univ., Japan)

① Extreme low Q^2 : $0.0003 \leq Q^2 \leq 0.008$ $(\text{GeV}/c)^2$.
② e+p absolute cross section with $\sim 10^{-3}$ accuracy.
=> relative measurement of e+C and e+H with CH_2 target
③ Rosenbluth separated $G_E(Q^2)$ and $G_M(Q^2)$.

From T. Suda and Y. Honda

Commissioning completed, and physics run started!





PREN FY22 ACTIVITIES: ATOMIC SPECTROSCOPY

STRONG 2020

Measurement of the ground state (1S) HyperFine Splitting (HFS) in Muonic Hydrogen with a pulsed laser: HyperMu Experiment (A. Antognini, R. Pohl *et al.)*

PAUL SCHERRER INSTITUT PSI

Exp. R-16-02

« A cross over experiment between particle, atomic and nuclear physics »

https://www.psi.ch/en/ltp/hypermu

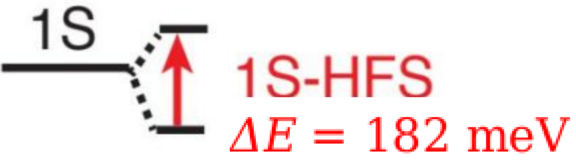
European Research Council erc

CREMA-3 Collaboration

Goal: 1ppm relative accuracy measurement

⇨ TPE (Zemach radius + polarisabilities) with 3×10^{-4} relative accuracy

HFS in μp ⇨ information about the **magnetic structure of the proton**, sensitive to **Zemach radius (r_Z)**



- Potential evidence of lepton flavor violation
- Benchmark for proton modeling: Lattice QCD, chiral perturbation theories, dispersion-based theories

$$r_Z = -\frac{4}{\pi}\int_0^\infty \frac{dQ}{Q^2}\left[\frac{G_E(Q^2)G_M(Q^2)}{1+\kappa_N}-1\right]$$

STRONG 2020 **Financial support contribution to 2 PhDs supervised by R. Pohl**

Related proposals: FAMU @ RIKEN/RAL, μp at J-PARC

"The Proton Structure in and out of Muonic Hydrogen", A. Antognini, F. Hagelstein, V. Pascalutsa, Annual Review Nuclear and Particle Science (2022) 72:389–418.

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Postdoctoral position (M/F) Euristic analysis of data from electron-proton elastic scattering

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Application deadline: 13 October 2022 (published 22/09/2022)

Candidate selected
Employment procedure on-going

Irène Joliot-Curie
Laboratoire de Physique des 2 Infinis

Contract period: 8 months (fully covered by IJClab PREN personal budget, 39 k€)
Expected date of employment: December 1st, 2022

The research activity of the postdoctoral fellow will be performed within the framework of the "Proton Radius European Network" (PREN) which is part of the STRONG-2020 European project (, http://www.strong-2020.eu/) . It will be carried out within the hadronic physics team of the "high energy physics" pole of the laboratoire de physique des 2 infinis Irène Joliot-Curie (IJCLab).

The work will consist in performing an objective and exhaustive analysis of the ep elastic scattering data with the aim of extracting the moments of the charge and magnetization densities, among which the proton charge and magnetic radii.

The person recruited will study the application of recent theoretical developments of the group to ep elastic scattering data, and will extend this approach to Zemarch moments, by applying them to experimental elastic electron-proton scattering data. The postdoctoral fellow will conduct these studies until their publication and their dissemination in conferences.