

NA4- Proton Radius European Network (PREN)

presented by Randolph Pohl, JGU Mainz, Germany

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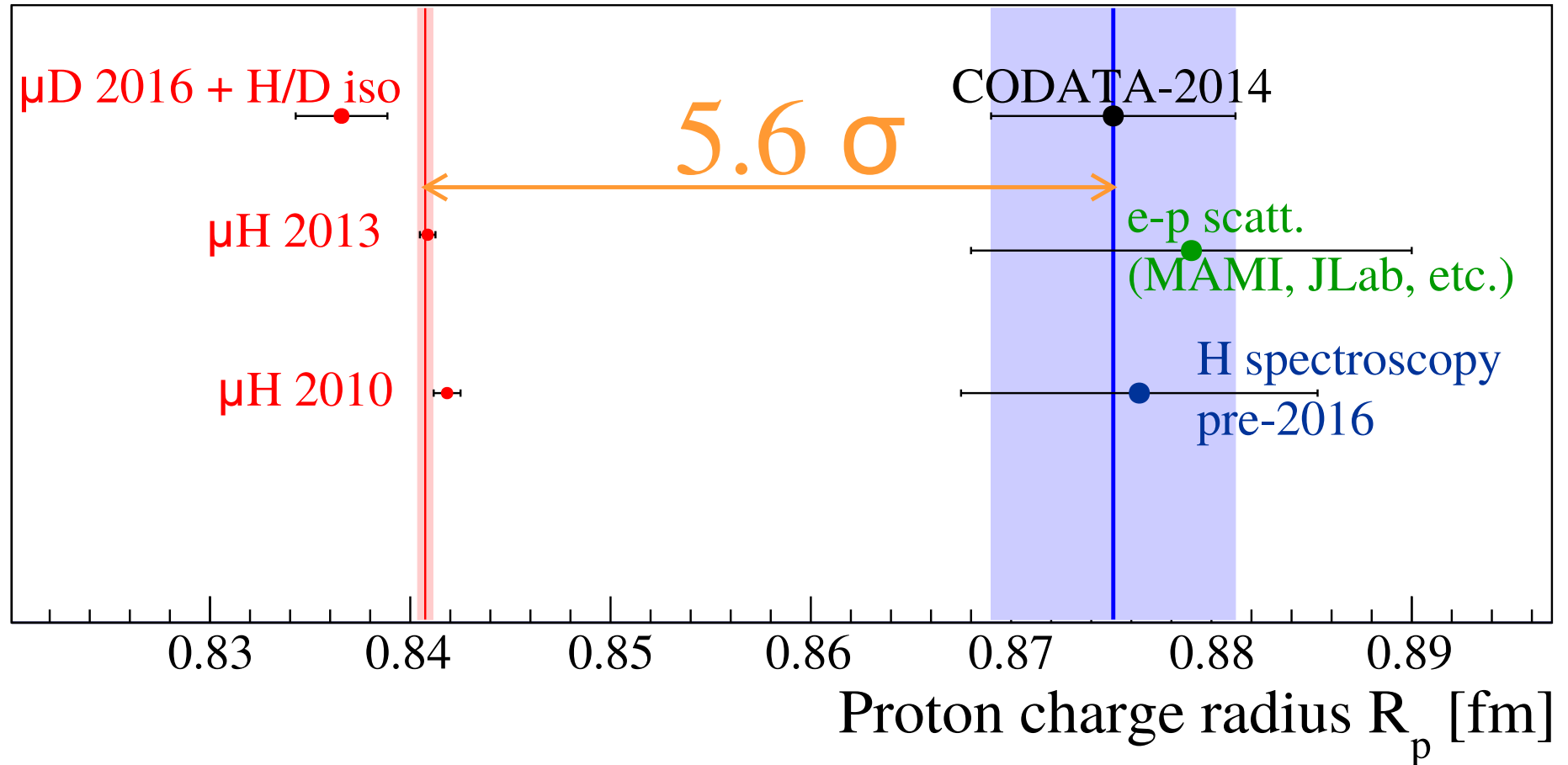
1 To **stimulate** and support a real **synergy** between all the physicists involved in the world-wide **experimental** and **theoretical** effort from **atomic spectroscopy** and **lepton scattering** in order to fully understand the persistent discrepancies and to come to a statement on the **value of the proton charge radius**.

Plan : How large is the proton, really ?



muons

electrons

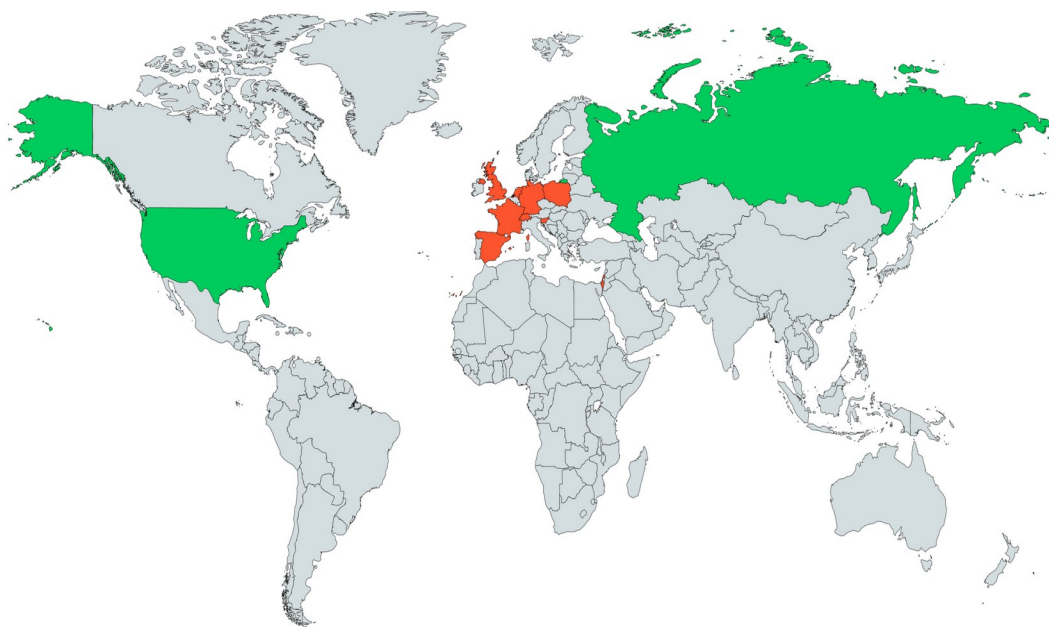


Situation before
2018

Participants from 22 institutions / 11 countries



- Eligible EU countries
- Other countries



Theory and Experiment
from
Atomic Physics and Lepton Scattering



Israel



1 PREN Website: <https://indico.in2p3.fr/e/PREN>

2 Workshop Travel Support

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



September 15 - 20, 2019 – Veli Lošinj (Croatia)
(~30 participants: mostly nuclear physicists)

3 Targeted Workshops / Conventions:

planned for Spring 2020, but Covid-19

new plan: spring 2021



4 Review paper: J.-Ph. Karr, D. Marchand, E. Voutier, **“The proton size”**,
Nature Review Physics Sept. 2020
<https://www.nature.com/articles/s42254-020-0229-x>

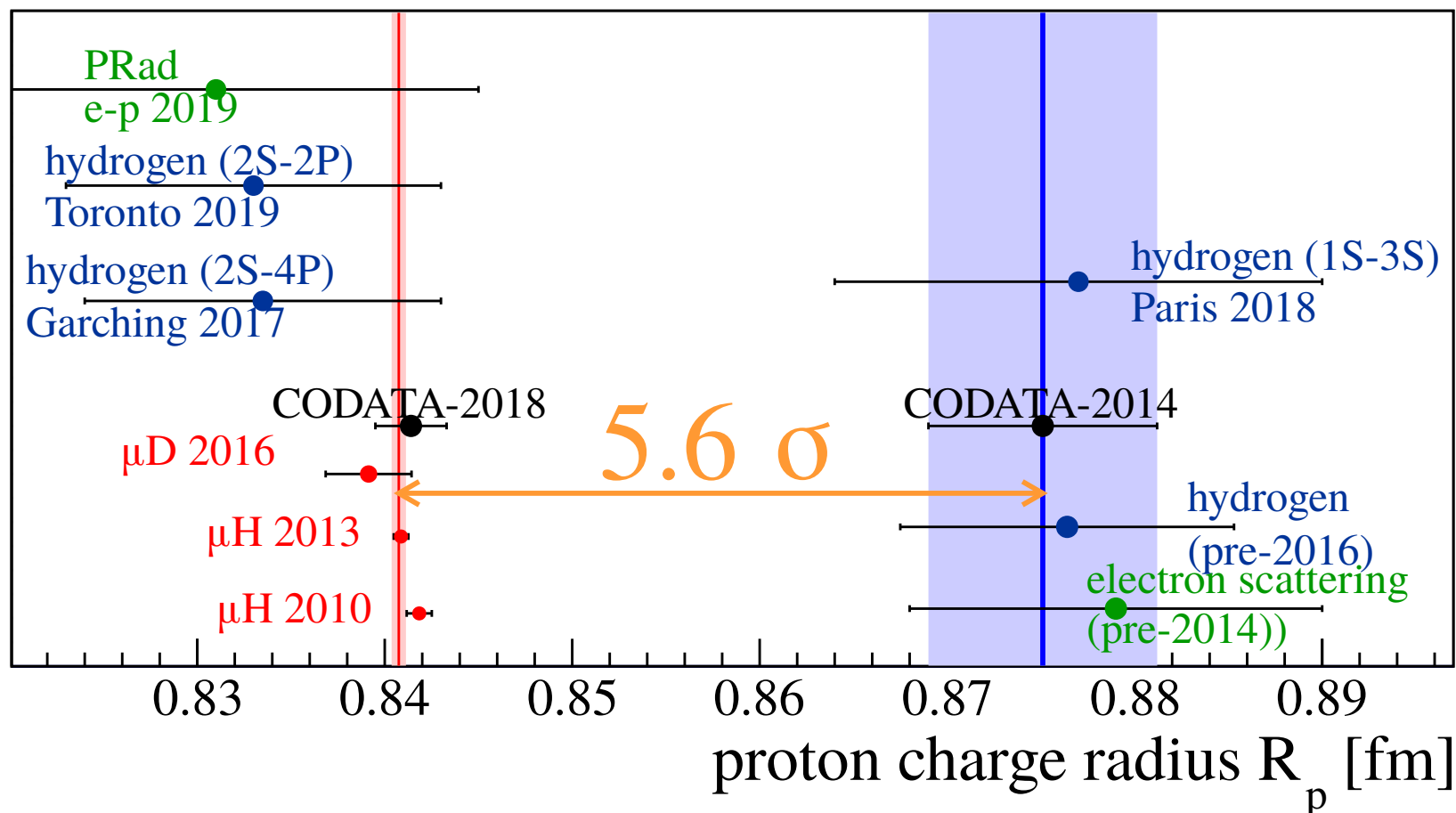
5 Collaboration on systematic effects in hydrogen spectroscopy (MPQ -LKB)

6 ...

Many new results since 2017

Muons

Old value



PRad : low- Q^2 e-p scattering (JLab)

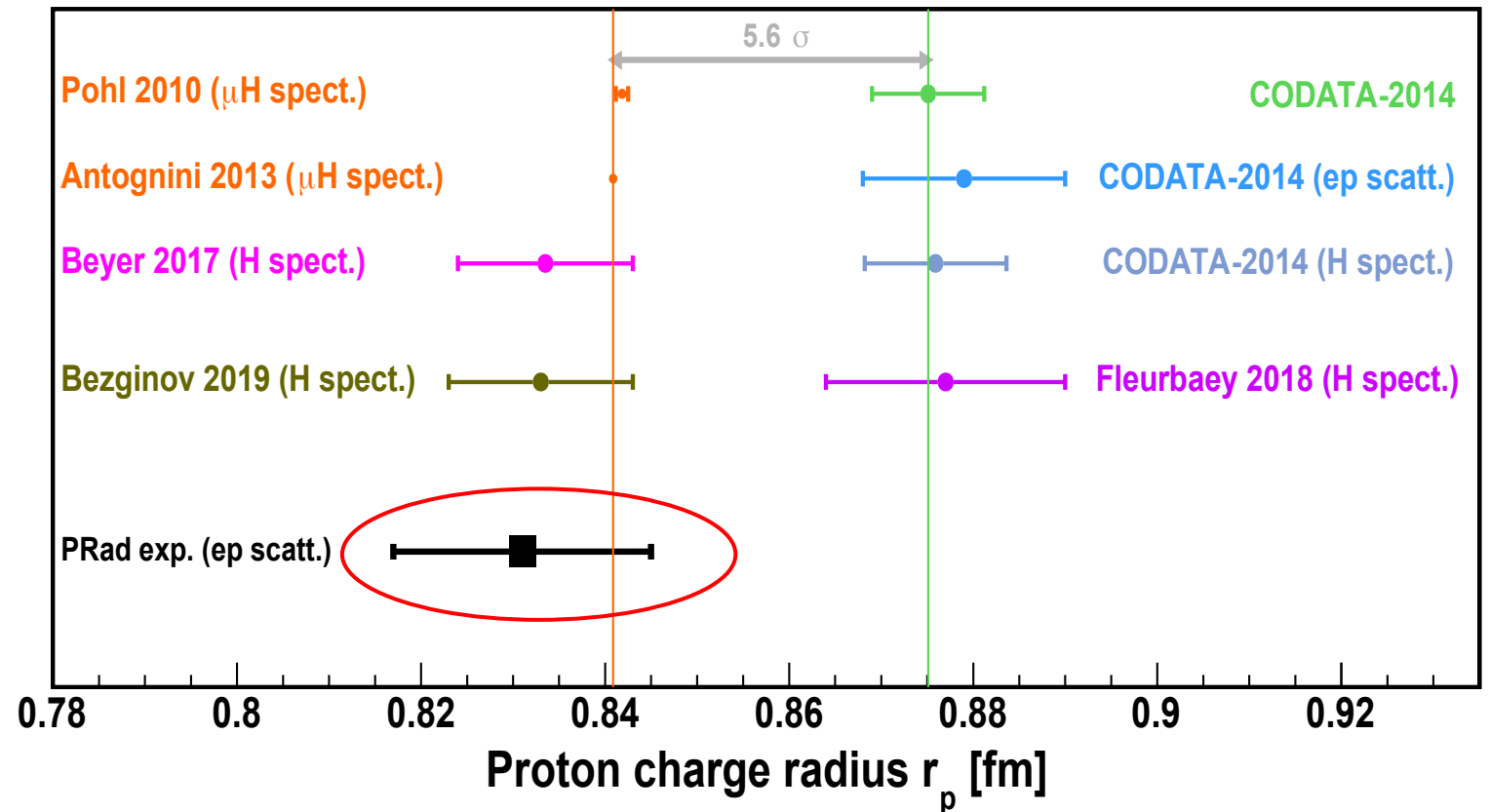
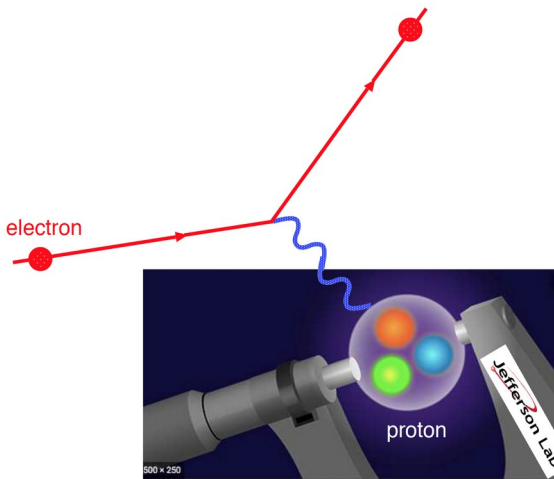


- Precision measurement of the Proton charge radius (PRad):

- ✓ Performed in 2016 in Hall B at JLab;
- ✓ Published in Nov. 2019 in Nature journal:
Nature 575, 145 – 150 (2019).

$$r_p = 0.831 \pm 0.007 \text{ (stat.)} \pm 0.012 \text{ (syst.) fm}$$

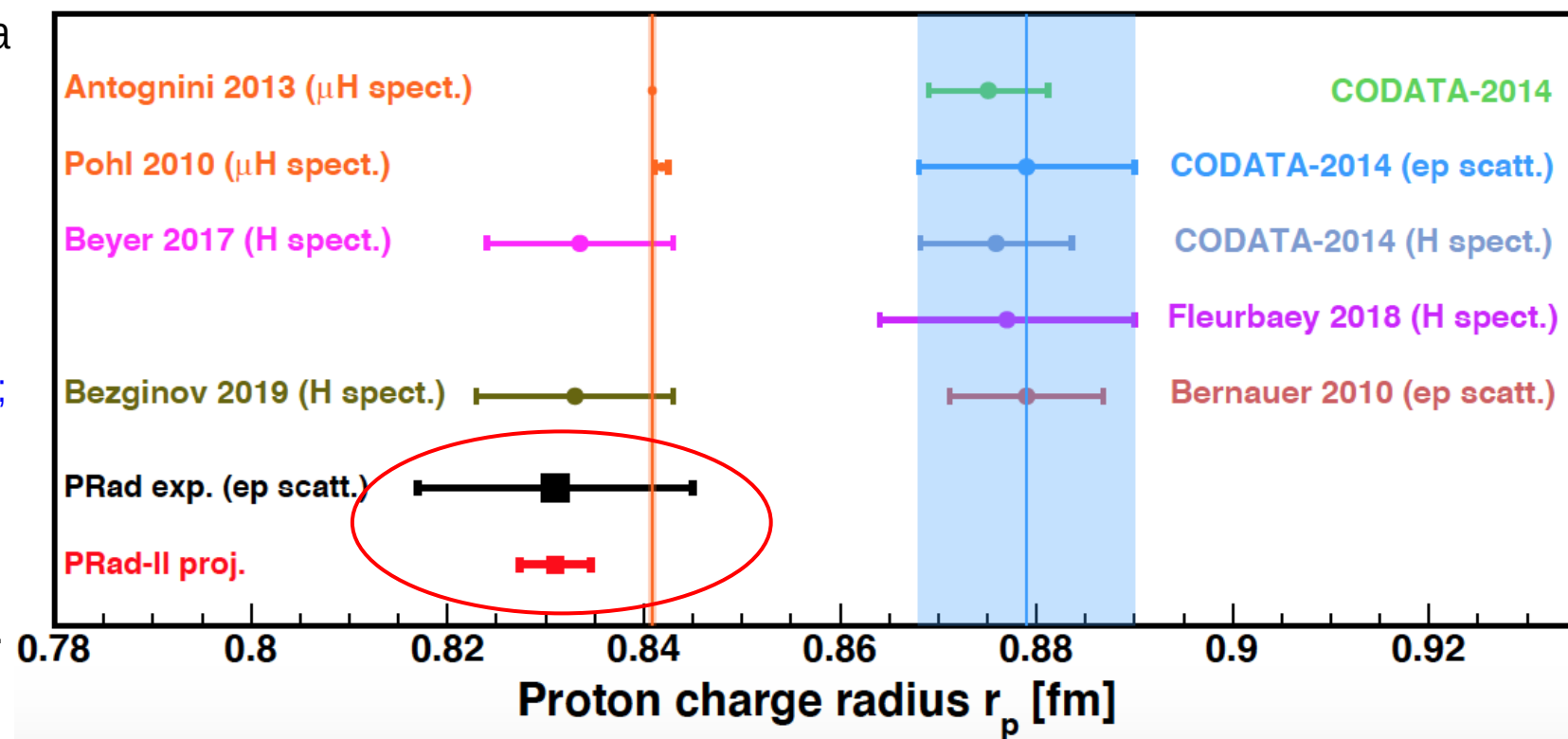
supports a smaller radius.



from A. Gasparian

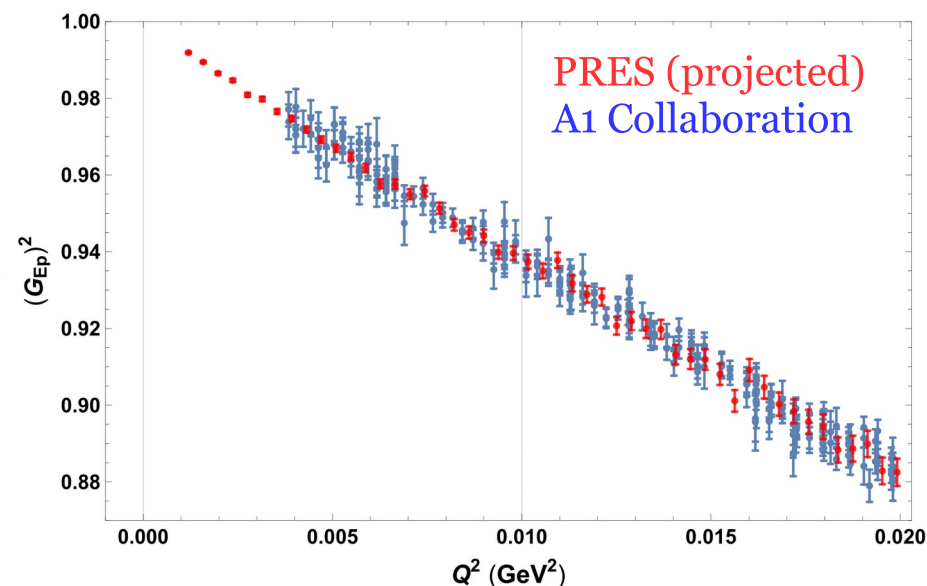
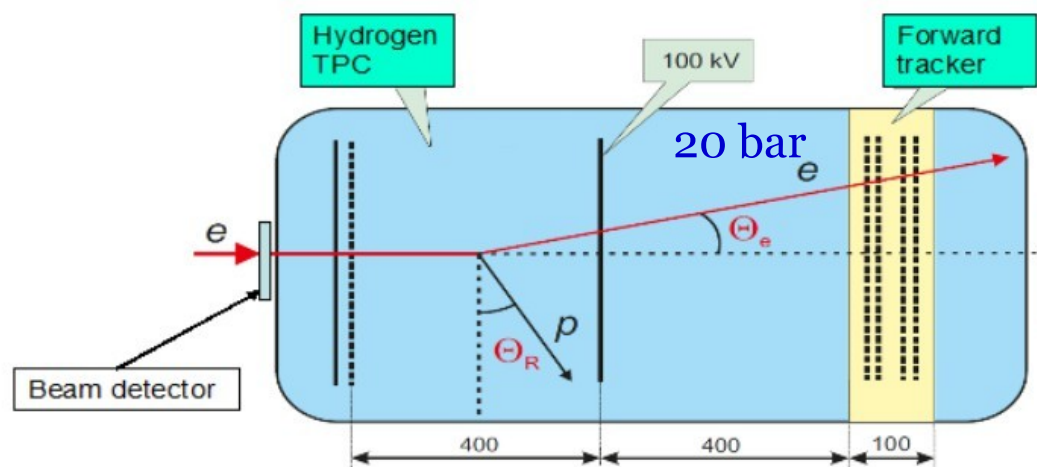
PRad : low- Q^2 e-p scattering (JLab)

- New proposal recently approved by the JLab's PAC48 with an "A" scientific rating to perform new experiment (PRad-II) to improve the measurement accuracy by a factor of 4.
- ✓ add tracking detectors (two GEMs or microRwells);
- ✓ upgrade HyCal calorimeter to all PbWO_4 crystals;
- ✓ reach $Q^2 = 10^{-5} \text{ GeV}/c^2$ range for the first time;
- ✓ improved beamline conditions for less background at very small angles;
- ✓ add new scintillator detectors to veto Moller events at very low scattering angles;
- ✓ implement new liquid drop target (if possible).
- ✓ Work started on the preparation of this experiment.



from A. Gasparian

PRES : Active TPC at MAMI

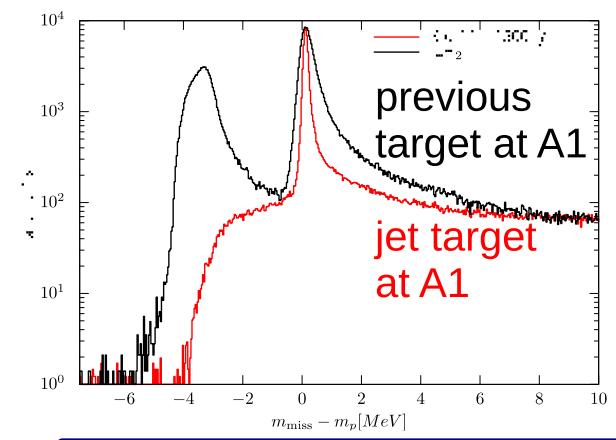
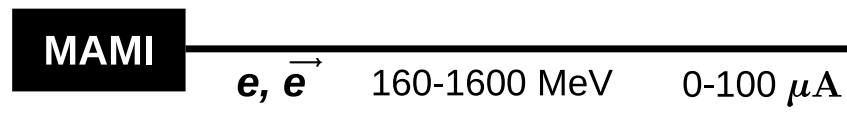


Detect scattered electron and recoil proton

- Hydrogen TPC to be used as an active target
- Measurements at low momentum transfer: 0.001 – 0.02 (0.04) GeV^2
- Absolute measurements of $d\sigma/dt$ with an accuracy on a level of $\sim 0.2\%$
- Lower radiative corrections compared to measurements with detection of the scattered electron only
- Further opportunities for form factor measurements for the deuteron and helium isotopes

from V. Sokoyan

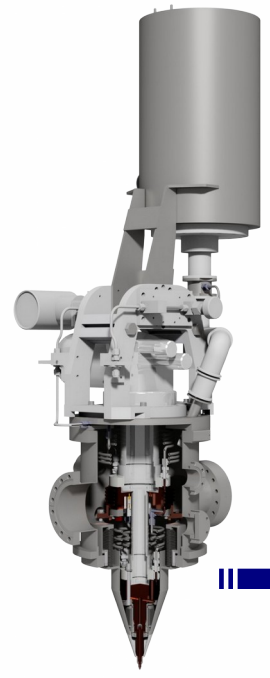
world's largest microtron



remeasure
selected kinematics of
Bernauer *et al.* - data set
with improved systematics

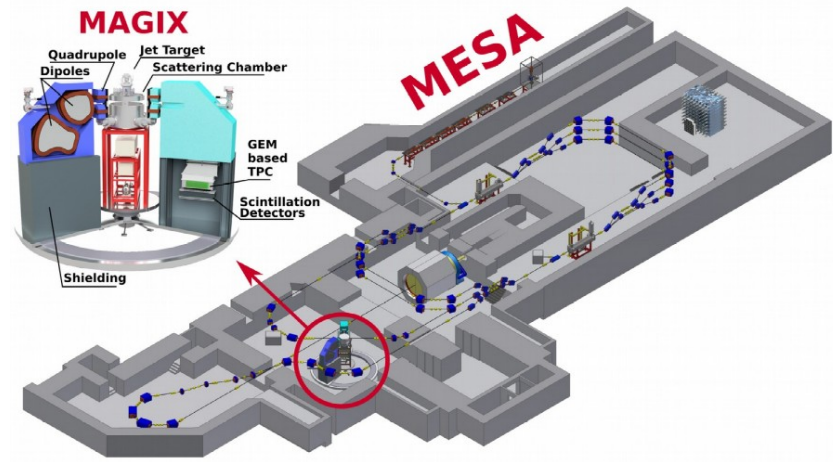
started with 315 MeV in 2020
(Y. Wang *et al.*)

measurement of proton form factors in $H(e,e')p \Rightarrow r_p$

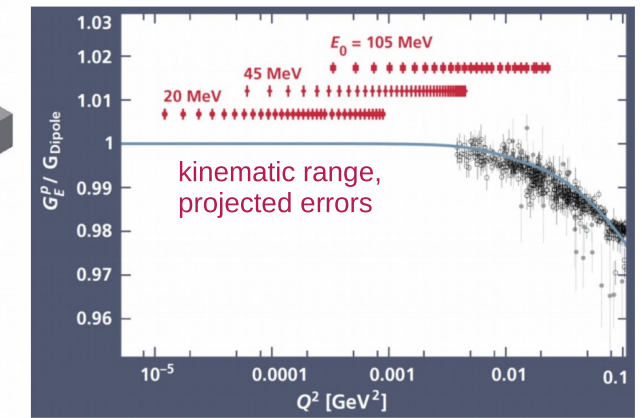


point-like
gas jet
target

AG Khoukaz,
Münster



energy recovering linac
 e, e^- ~20-105 MeV 0-1000 μA



access to very low momentum
transfers at the MAGIX
experiment, 2022+

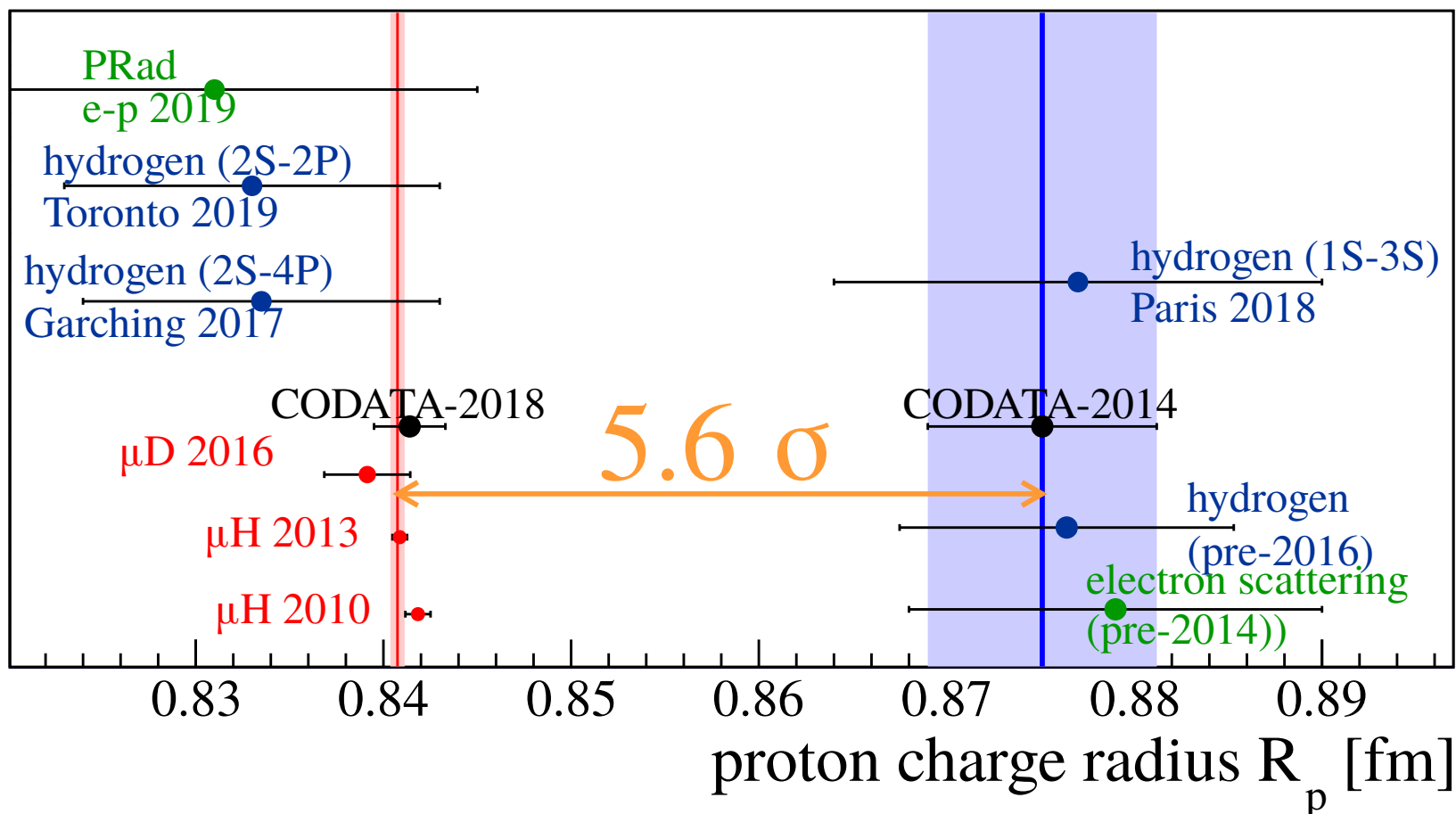


from
S. Schlimme

Atomic Spectroscopy

Muons

Old value



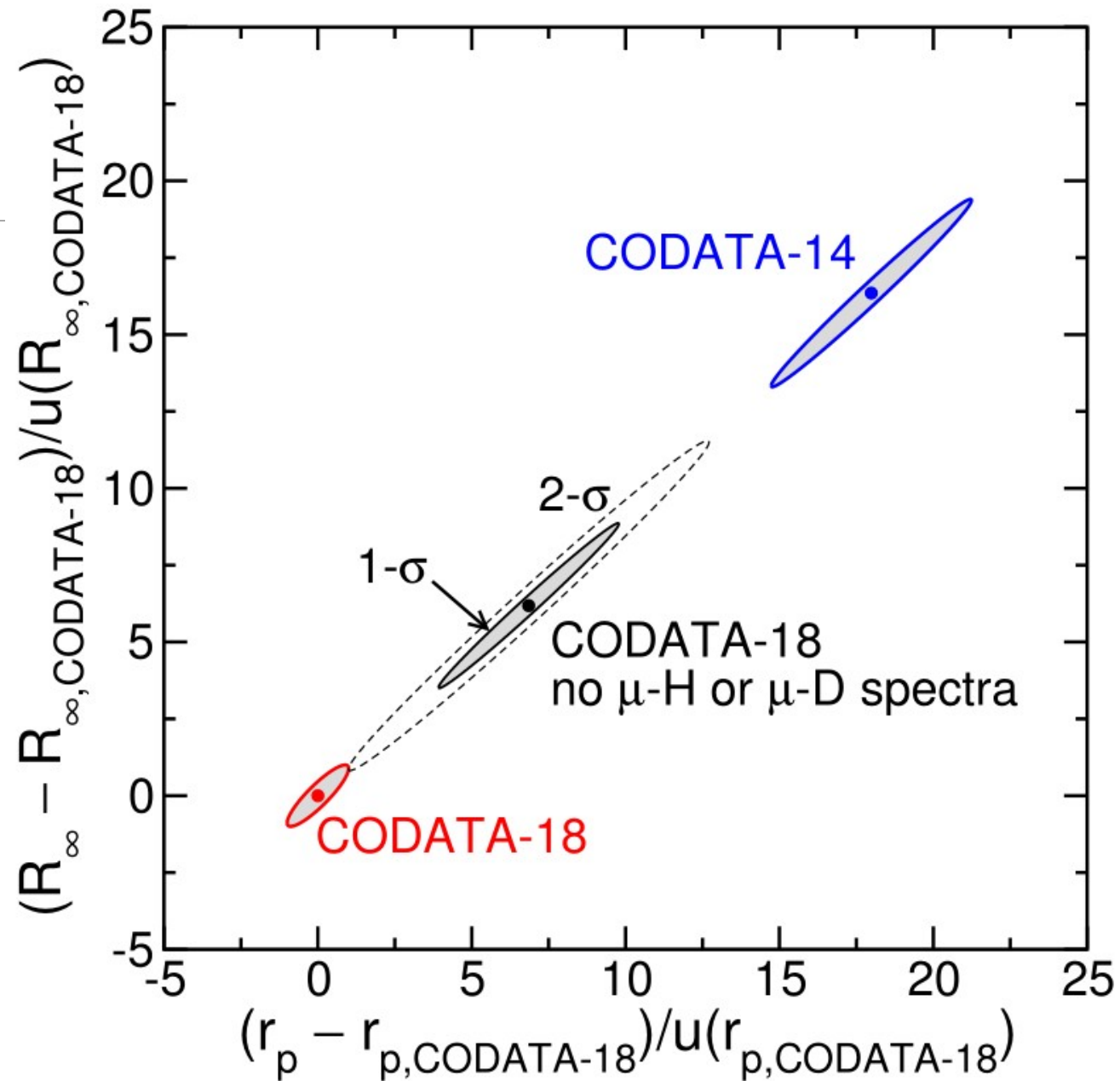
adopting smaller proton radius

$$R_p (\text{CODATA-18}) = 0.84140 (190) \text{ fm}$$

$$R_p (\text{muonic}) = 0.84087 (39) \text{ fm}$$

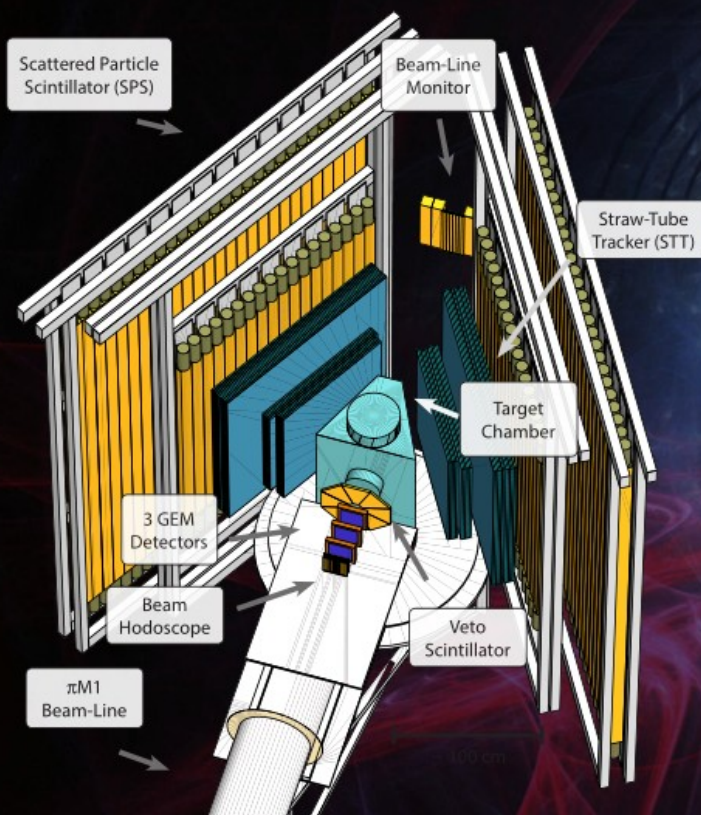
correspondingly smaller Rydberg constant

from K. Pachucki

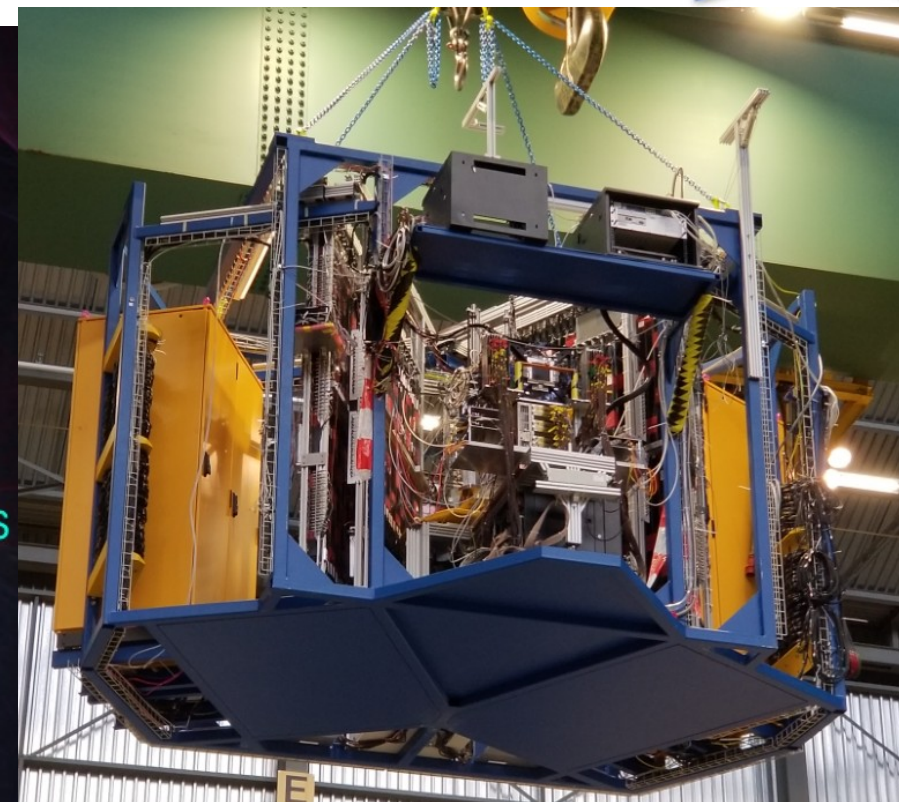


Muon Scattering : MUSE, COMPASS

Experiment layout



- » Secondary beam
⇒ track beam particles
- » Low flux (3.5 MHz)
⇒ large acceptance
- » Mixed beam
⇒ PID in trigger



MUSE @ PSI
Data taking 2021/22















from J. Bernauer

R. Gilman et al., arXiv:1303.2160 (nucl-ex)



- 1 Many more results to come:
 - muonic 4He paper: accepted
 - H(1S-3S) Paper (MPQ): accepted
 - Deuterium, muonic Helium-3
 - 2-photon exchange
 -
- 2 PREN Workshop: Spring 2021
- 3 Better understanding of the proton size from all perspectives

Thank You!

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