CCEM 2017 Report
CODATA Task Group for Fundamental Constants

Barry Wood

BIPM
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Outline

- **CODATA TGFC**
- **TGFC's Role in SI Redefinition**
- **The special LSA**
- **Data for the Planck, Avogadro & Boltzmann constants**
- **Fine structure & Rydberg - Why these?**
- **Timeline**
- **Present Status**
- **The 2018 LSA.**

CODATA

- Committee on Data for Science and Technology (CODATA) – was established in 1966 - is an interdisciplinary Scientific Committee of the International Council for Science (ICSU), which works to improve the quality, reliability, management, and accessibility of data of importance to all fields of science and technology.

- CODATA Task Group on Fundamental Constants - established in 1969 - “to periodically provide the scientific and technological communities with a self-consistent set of internationally recommended values of the basic constants and conversion factors of physics and chemistry based on all of the relevant data available at a given point in time.”

- The Task Group sanctions the data selection and methodology of the adjustment of the recommended values of the constants.

TGFC Members

- D. B. Newell, NIST, USA (Chair)
- F. Cabiati, Istituto Nazionale di Ricerca Metrologica, Italy
- E. de Mirandés, BIPM, France
- J. Fischer ,PTB, Germany
- K. Fujii, National Metrology Institute of Japan, Japan
- S. G. Karshenboim, D. I. Mendeleyev Institute of Metrology, Russia
- K. Pachucki, University of Warsaw. Poland
- H. Margolis, NPL, UK
- P. J. Mohr, NIST, USA
- F. Nez, Laboratoire Kastler-Brossel, France
- T. J. Quinn, CBE FRS, France
- B. N. Taylor, NIST, USA
- M. Wang, IMP, China
- B. M. Wood, National Research Council, Canada (ViceChair)
- Z. Zhonghua, National Institute of Metrology, China

How to get the values

The NIST Reference on Constants, Units, and Uncertainty

Information at the foundation of modern science and technology from the Physical Measurement Laboratory of NIST

URL: physics.nist.gov/constants

CODATA Internationally recommended 2014 values of the Fundamental Physical Constants

Constants Topics:
Values
Energy Equivalents
Searchable Bibliography
Background
Constants Bibliography
Constants, Units & Uncertainty home page

Version history and disclaimer

(e.g., **electron mass**, most misspellings okay)

Search by name [ ] Search

Display ◉ alphabetical list, ○ table (image), or ○ table (pdf)

by clicking a category below

Universal | Electromagnetic | Atomic and nuclear | Physico-chemical

Adopted values | Non-SI units | Conversion factors for energy equivalents | X-ray values

Frequently used constants | Extensive listings | **All values** (ascii)

Find the correlation coefficient between any pair of constants

See also

Article on the 2014 adjustment of the values of the constants
Wall Chart and Wallet Card of the 2014 constants
Background information related to the constants
Links to selected scientific data
Previous Values (2010) (2006) (2002) (1998) (1986) (1973) (1969)

DEADLINE NOTICES (UPDATED)!

There will be an adjustment of the constants to provide the values for a revision of the International System of Units (SI) expected to take place in 2018. To be considered for use in this adjustment, new results must be **accepted for publication by 1 July 2017**.

The 2018 CODATA adjustment of the fundamental constants will be based on the revised SI, which will significantly affect the uncertainties of many constants. For data to be considered for use in this adjustment, they must be **discussed in a publication preprint or a publication by 31 December 2018**.

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SI Redefinition

In essence, the change involves *exactly fixing the values* of 7 constants that set the scale of the SI units :

c	– speed of light	$E = m c^2$
$\Delta\nu$	– ground state hyperfine splitting frequency of ^{133}Cs	
h	– Planck constant	$E = h\upsilon$
e	– the elementary charge	*charge on a proton*
k	– Boltzmann constant	$E = k\,T$
N_A	– Avogadro constant	*number of entities in a mole*
K_{cd}	– luminous efficacy of 540×10^{12} Hz radiation	

c, h, e, k, N_A are fundamental physical constants

Formal Notice of the Change

CGPM 2011: Resolution A

- **takes note** of the *intention* of the International Committee for Weights and Measures to propose a *revision to the SI* as follows:
- the *International System of Units*, the SI, will be the system of units in which:

  - the ground state hyperfine splitting frequency of the caesium 133 atom $\Delta\nu(^{133}Cs)_{hfs}$ is exactly 9 192 631 770 hertz
  - the speed of light in vacuum c is exactly 299 792 458 metre per second,
  - the Planck constant h is exactly 6.626 06X × 10^{-34} joule second,
  - the elementary charge e is exactly 1.602 17X × 10^{-19} coulomb,
  - the Boltzmann constant k is exactly 1.380 6X × 10^{-23} joule per kelvin,
  - the Avogadro constant N_A is exactly 6.022 14X × 10^{23} reciprocal mole,
  - the luminous efficacy K_{cd} of monochromatic radiation of frequency 540 × 10^{12} Hz is exactly 683 lumen per watt,

X represents digits to be determined at redefinition.

CODATA TGFC's Role

CODATA TGFC has been recommending self-consistent values of the fundamental constants since 1973.

The CCU has decided that the TGFC will prepare the values for redefinition. The CCU and CIPM will approve those numbers.

The task group has committed to preparing a Special LSA just for the SI redefinition.

This will be quickly followed by a full LSA using the revised SI and its uncertainties

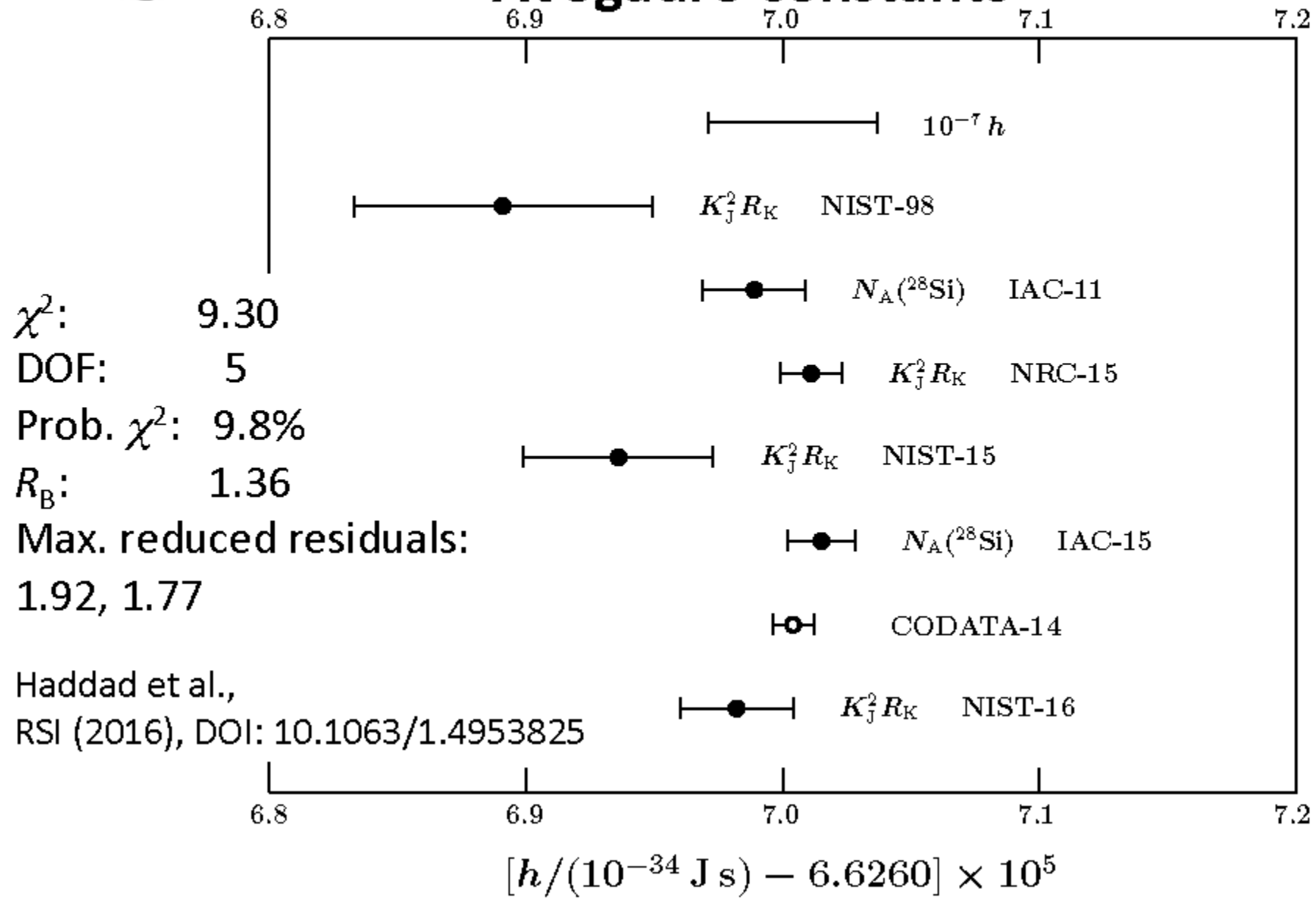
CODATA Recommended Values of the Fundamental Physical Constants: 2014

- 141 input data, 74 variables, 67 degrees of freedom
- $\chi^2 = 50.4$ with $p(50.4|67) = 0.93$; $R_B = 0.87$

  - $u_r(h) = 1.2 \times 10^{-8}$
  - $u_r(e) = 0.61 \times 10^{-8}$
  - $u_r(k) = 57 \times 10^{-8}$
  - $u_r(N_A) = 1.2 \times 10^{-8}$

The relative uncertainties of the four constants in 2014

2014 Input data related to the Planck and Avogadro constants



χ^2: 9.30

DOF: 5

Prob. χ^2: 9.8%

R_B: 1.36

Max. reduced residuals:

1.92, 1.77

Haddad et al.,
RSI (2016), DOI: 10.1063/1.4953825

2014 Input data related to the Boltzmann constant

χ^2: 4.07

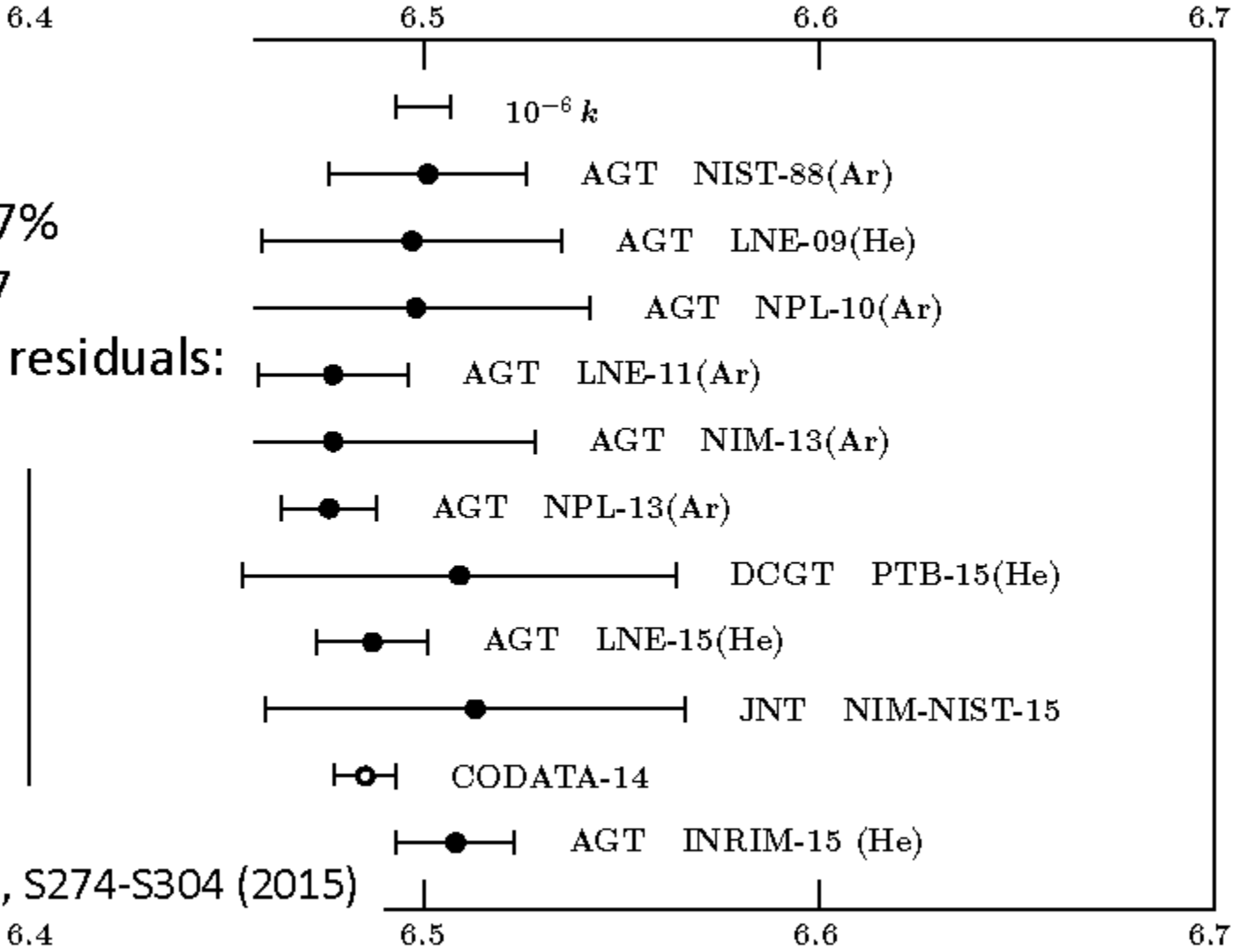
DOF: 9

Prob. χ^2: 90.7%

R_B: 0.67

Max. reduced residuals:

-1.16, 1.27



Gavioso et al.,
Metrologia **52**(5), S274-S304 (2015)

Why the Rydberg ?

The Special LSA will generate new values for the Planck, Avogadro, and Boltzmann constants.

But why must it also include the Rydberg and fine structure constants?

This is because the Rydberg and fine structure constant are the two best known constants and in combination with h and N_A provide the best link to the elementary charge, e.

The Rydberg

For different elements there is a different ‘Rydberg’.

$R_M = R_\infty (1+m_e/M)$, M is the mass of the protons

$R_\infty = m_e e^4/((4\pi\varepsilon_0)^2 h^3 4\pi c) = m_e e^4/(8\varepsilon_0^2 h^3 c)$

$= 10973731.568525\ (73)\ \ m^{-1}$

And

$R_\infty = \alpha^2\, m_e\, c/(4\pi h) = \alpha^2\, e\, \lambda_e$

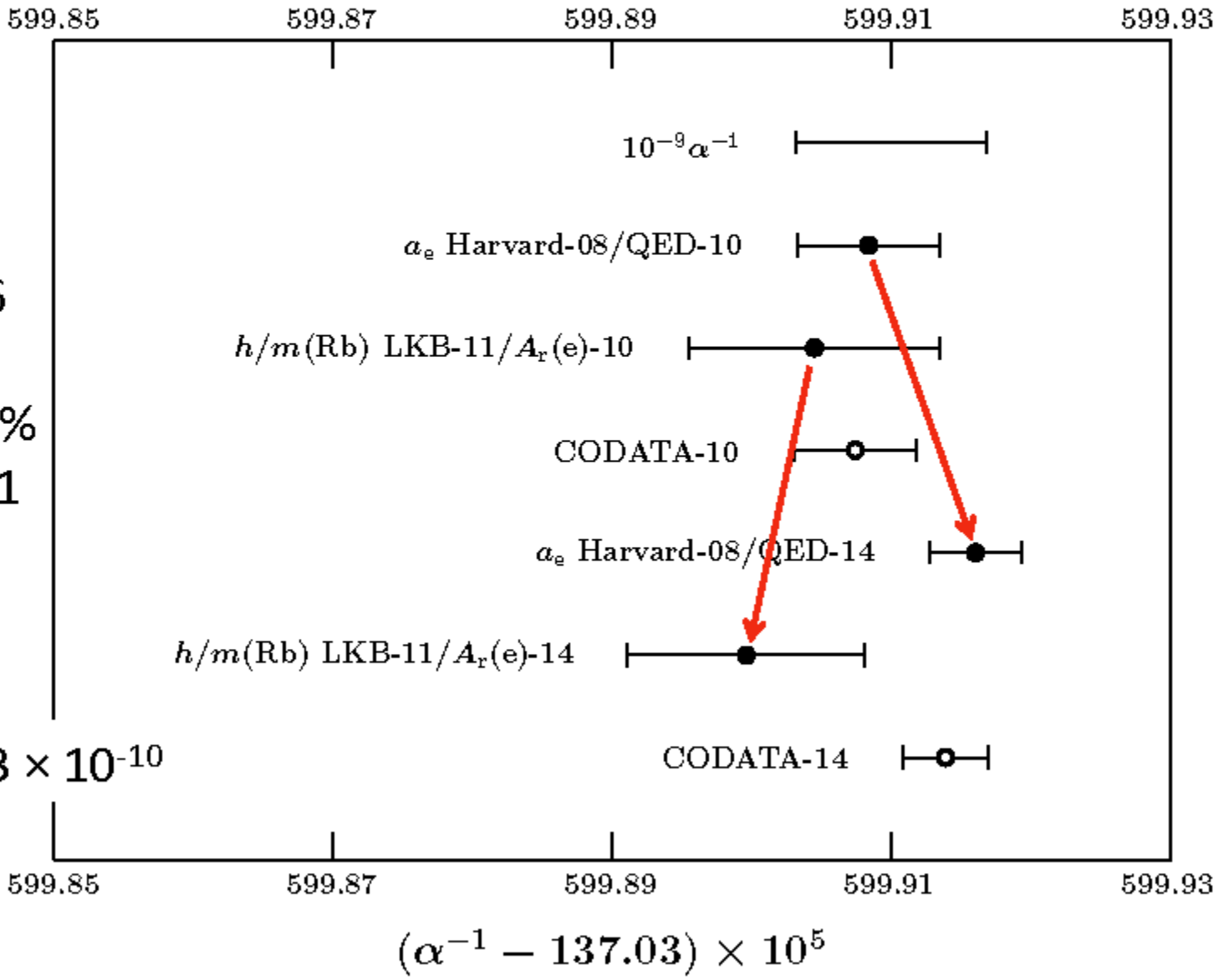
Fine Structure Constant

α is also the ratio of the impedance of vacuum and the universal conductance and is related to several other constants.

Thus, α appears in all models that incorporate quantum and relativistic properties of charged particles. For this reason it is related to many other fundamental constants and often found in theory.

$$\alpha = \frac{e^2}{\hbar c\ 4\pi\epsilon_0} = 7.297\,352\,5376(50) \times 10^{-3} = \frac{1}{137.035\,999\,679(94)}$$

2014 Input data related to the Fine-structure constant



χ^2: 3.26
DOF: 1
Prob. χ^2: 7.1%
R_B: 1.81
Residuals:
1.68, -0.65

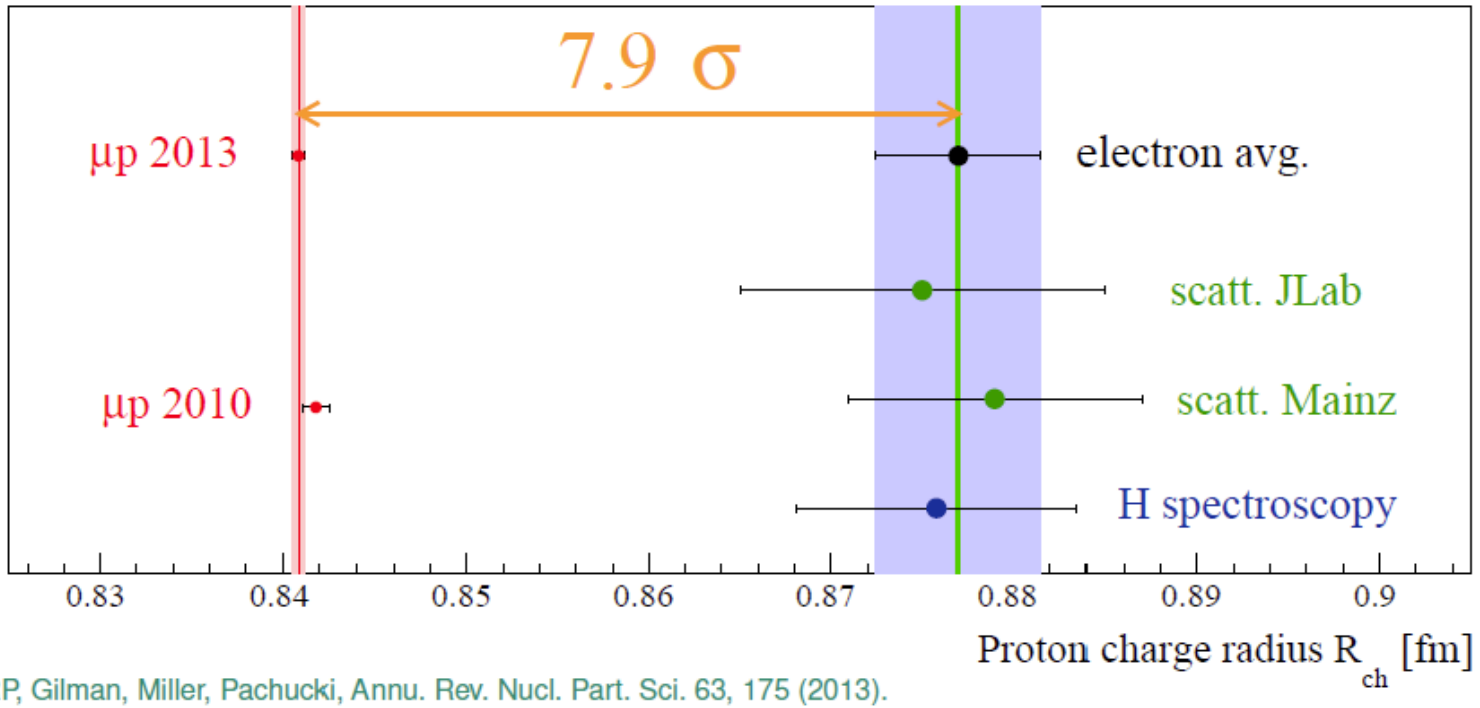
$u_r(\alpha) = 2.3 \times 10^{-10}$

The proton charge radius controversy: a significant correction for the Rydberg

The proton rms charge radius measured with

electrons: 0.8770 ± 0.0045 fm

muons: 0.8409 ± 0.0004 fm



RP, Gilman, Miller, Pachucki, Annu. Rev. Nucl. Part. Sci. 63, 175 (2013).

Present Status

- **Software ported to a second ‘new’ computer and tested.**
- **Full and subset LSAs are running with present data sets.**
- **Concise Special LSA manuscript has been drafted and is ready for new numbers.**
- **Longer Special LSA manuscript is in preparation.**
- **Decisions about proton radius controversy have already been decided.**

Timeline

July 1, 2017	**To be considered for use in this 'Special' adjustment, new results must be accepted for publication by 1 July 2017.**
Sept 4	**CODATA TGFC meeting** **Special LSA manuscript accepted and publically available online.**
Sept 5-6	**CCU reviews values, recommends digits etc.**
Oct 16-20	**CIPM meeting – recommendation to the CGPM**
Nov 13-24(2018)	**CGPM approves the 'Revised SI'**
Dec 31(2018)	**Data to be published by 31 December 2018. The 2018 CODATA adjustment of the fundamental constants will be based on the revised SI, which will significantly affect the uncertainties of many constants.**

Conclusions

New data available in the next three months.
No present knowledge of any great discrepancies.
CCM guidelines - OK (?)
CCT guidelines - OK (?)
Rydberg and fine structure data sets are essentially unchanged from 2014.

At the present time, I do not know of any ‘show stoppers’.