The fundamental constants and the need for a self-consistent, global approach

John Martens
work done in collaboration with John Ralston

arXiv:1810.XXXXX
www.constantfinder.org (soon!)

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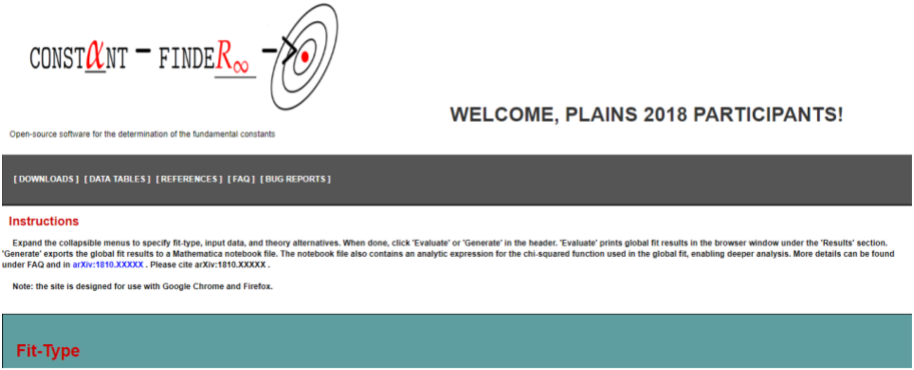
University of Kansas

October 17, 2018

CONSTαNT – FINDER_∞

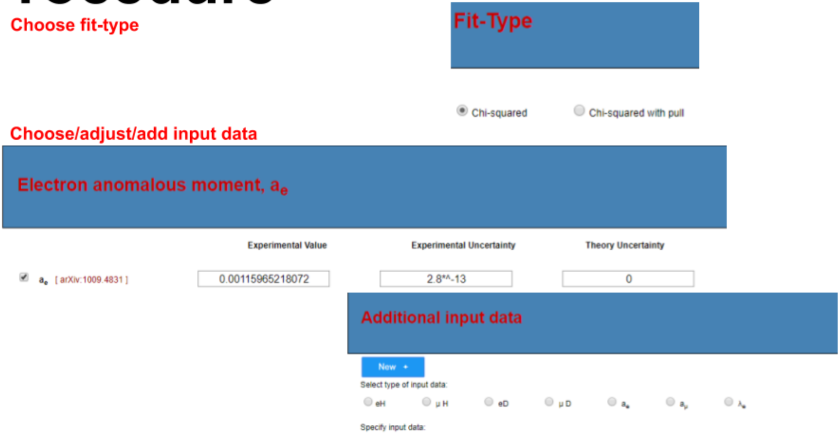
www.constantfinder.org on loading ...



Procedure

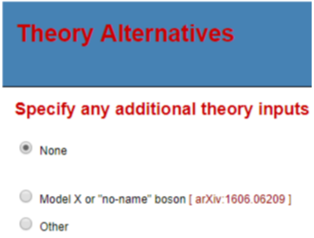
1. Choose fit-type

2. Choose/adjust/add input data

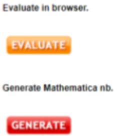


Procedure(cont'd)

3. **Add any new physics; Other = [your model here]**



4. **Evaluate in-browser or generate Mathematica nb for in-depth analysis**



EX:

Analysis 1 assuming SM physics: proton size puzzle gone! Muon g-2 anomaly remains

Global Fit Results

Evaluate in browser.

EVALUATE

Generate Mathematica nb.

GENERATE

Fitted values:

dalp	-0.0735618 ± 0.02198
rr	0.840881 ± 0.000261597
rrD	2.12647 ± 0.00547901

Chi-squared:

Sector	Chi-squared
eH	7.1949
eD	4.2455
muH	0.000754973
ae	0.197676
amu	15.6748
emass	0.0000143215
total	27.3137
dof	16

Theory Alternatives

Specify any additional theory inputs

- (•) None
- ( ) Model X or "no-name" boson [arXiv:1606.06209]
- ( ) Other

Analysis 2 assuming SM + 'no-name' boson: proton size puzzle AND muon g-2 anomaly gone!

Global Fit Results

Evaluate in browser.

EVALUATE

Generate Mathematica nb.

GENERATE

Fitted values:

dalp	-0.0692326 ± 0.0220082
rr	0.841154 ± 0.000270757
rrD	2.12655 ± 0.00547884
alpx	$3.81687 \times 10^{-8} \pm 9.80602 \times 10^{-9}$

Chi-squared:

Sector	Chi-squared
eH	6.803
eD	4.20616
muH	0.000680496
ae	1.13934
amu	0.013997
emass	0.0000143215
total	12.1632
dof	15

Theory Alternatives

Specify any additional theory inputs to global chi-squa

- ( ) None
- (•) Model X or "no-name" boson [arXiv:1606.06209]

Specify value of m_X in MeV.

m_X : 50

- ( ) Other

How are the fundamental constants determined?

Fundamental constants α, R_∞, r_p, r_d, λ_e
are determined by ML fit to experimental data.

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Most basic incarnation* corresponds to minz of a χ^2 function.

$$\chi^2 = \sum_j \frac{(d_j - t_j(\theta_\ell))^2}{\sigma_j^2}$$

d_j and t_j are the jth data and theory values,
where t_j is a function of the fundamental constants θ_ℓ.
θ_ℓ are free parameters, fixed by minz.
σ_j is the jth experimental uncertainty.

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**Correlations, pull parameters are higher order effects, safely ignored for present purposes*

How are the fundamental constants determined?

$\chi^2 = \sum_j \frac{(d_j - t_j(\theta_\ell))^2}{\sigma_j^2}$ can be broken out into 'data sectors'

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Sectors: a_e, a_μ, eH, eD, μH, μD, λ_e (neglecting scattering data)

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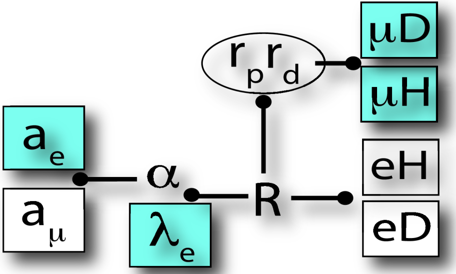
Global picture



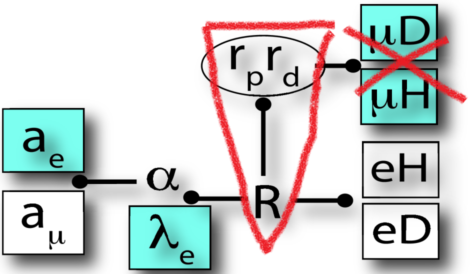
Values of constants sensitive to which sectors (and which data in which sectors) are included in fit.

How are the fundamental constants determined?

NIST standardizes values of constants

NIST fits constants using only *electronic* data; does not confront muon expt'l anomalies

Rationale: STANDARDIZATION

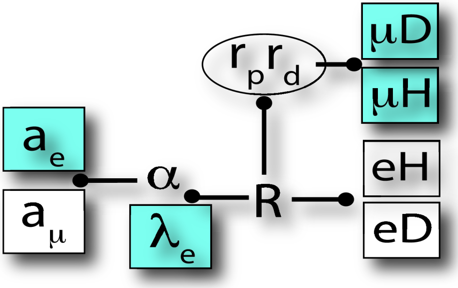


"We own the fundamental constants!"
-Bill Phillips

NIST = NO MUONS

piecemeal fit

NIST sectors: *eH*, *eD*, λ_e (α det'd upstream from fit to a_e)



SELF-CONSISTENCY REQUIRES A GLOBAL FIT

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If you:

add data, remove data, change data, change theory, add BSM physics to QED-verse ... *re-do global fit to constants.*

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www.constantfinder.org makes it easy.

Ex: No-name model 1606.06209 Ralston, JM $\Longleftarrow$ 'bottom-up' pheno

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Particle X: mass m_X, coupling $\alpha_X = |g_\ell g_p|/4\pi = g_\ell^2/4\pi$ ℓ X

Moments: a_e, a_μ

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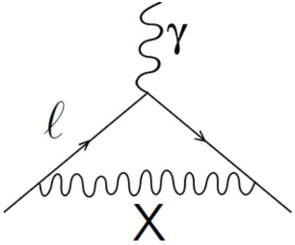

Spectroscopy: eH, μH

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Yukawa:

$V_X = \pm\alpha_X \cdot e^{-m_X r}/4\pi r$

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$\Delta E_X \sim \pm(m_e\alpha/n)^3 \cdot \alpha_X \cdot (1/m_X^2)$

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First-order PT ok if α_X/m_X^2 small enough.

Collected results: Part I ($m_X = 50 MeV$)

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Line 1 fit solves muon $g-2$ and proton size,
with χ^2 for each sector under control.
Note: α^*, R^*_∞, r^*_p, r^*_d all shifted by multiple σ compared to NIST values.

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χ^2 budget

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line	omit	χ^2	*dof*	R_B	$\Delta\chi^2$	$\chi^2_{\lambda_c}$	$\chi^2_{\mu H}$	$\chi^2_{\mu D}$	$\chi^2_{a_e}$	$\chi^2_{a_\mu}$	χ^2_{eH}	χ^2_{eD}
1	*none*	12.5	15	.91(10)	15.0	1.0	0.0011	0.000096	0.24	0.019	7.0	3.3
9	$\mu H, \mu D, a_\mu$	6.9	13	.73(11)	0.23	0	–	–	0	–	3.3	3.0

Fitted values

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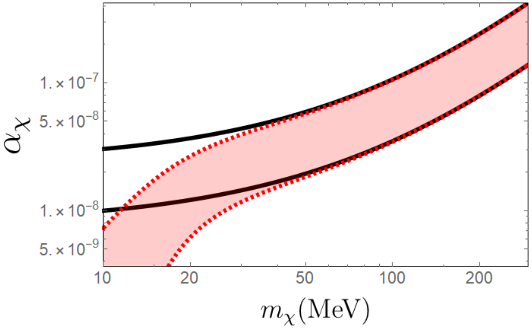
line	omit	$(\delta R_\infty / R^*_\infty)/10^{-12}$	$(\delta\alpha/\alpha^*)/10^{-10}$	r_p fm	r_d fm	ξ MeV$^{-2}/10^{-11}$
1	*none*	$-12.5(2.9)$	$-5.1(2.3)$	0.84115(27)	2.12879(13)	1.52(39)
9	$\mu H, \mu D, a_\mu$	2.5(9.6)	0.0(5.0)	0.883(20)	2.1428(97)	$-1.1(2.3)$

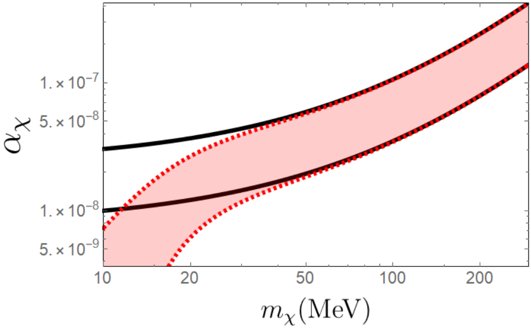
Collected results: Part II

m_χ MeV	$\Delta\chi^2$	$(\delta R_\infty/R^*_\infty)/10^{-12}$	$(\delta\alpha/\alpha^*)/10^{-10}$	r_p fm	r_d fm	ξ MeV$^{-2}/10^{-11}$
15	6.6	−10.9(3.1)	−10.6(3.9)	0.84157(37)	2.12894(16)	4.3(1.7)
25	12.4	−11.4(3.0)	−8.9(2.9)	0.84147(31)	2.12890(14)	3.45(98)
50	15.0	−12.5(2.9)	−5.1(2.3)	0.84115(27)	2.12879(13)	1.52(39)
100	15.5	−13.0(2.9)	−3.6(2.2)	0.84101(26)	2.12875(13)	0.70(18)
150	15.6	−13.1(2.9)	−3.1(2.2)	0.84097(26)	2.12873(13)	0.49(12)
200	15.6	−13.1(2.9)	−3.0(2.2)	0.84096(26)	2.12873(13)	0.40(10)
300	15.6	−13.2(2.9)	−2.8(2.2)	0.84094(26)	2.12872(13)	0.320(81)



Red band is region in the (m_X, α_X) plane favored by the no-name analysis. Solid **black** lines define a piecemeal solution region that solves muon $g-2$ anomaly with α, R_∞, r_p, and r_d fixed at NIST values. **Piecemeal = falsely restrictive !**

Conclusions



Piecemeal fits = falsely restrictive
Global fits = necessary (for self-consistency)
For all your global fit needs: www.constantfinder.org

THANKS